Final Report to Office of High Energy Physics, U.S. Dept. of Energy

1. DOE Award number DE-FG02-91ER40662 to Regents of the University of California (Campus: University of California, Los Angeles)

2. Experimental and Theoretical High Energy Physics Research at UCLA
P.I. Robert Cousins, cousins@physics.ucla.edu
Phone 310-825-1928, 310-825-3441, cell +41-76-487-2767

4. Description of Accomplishments of Task Co-PIs Arisaka, Bern, Cline, Cousins, Ferrara, Gelmini, Hauser, Kusenko, Saltzberg, Wallny, Wang

Contents: Page

Task B Final report: Co-leaders: David Cline and Hanguo Wang
B1: Dark Matter Searches with Noble Liquids
B2: Large Liquid Argon TPC (LBNE and ICARUS)

Task B1: The search for dark matter using liquid noble gas detectors, XENON 100, 1 ton, and Darkside

Task B1 is devoted to the search for dark matter particles and the development of new concepts for dark matter detection. This science effort started in the late 1980s while working on ICARUS. We studied both liquid Argon and liquid Xenon properties at CERN while on ICARUS. We built the first 2 kg single phase liquid xenon detector at CERN using the first demonstrated background rejection techniques by us and installed it at the Montblanc underground laboratory in Italy in mid 90s. After the fire there we decided to form the ZEPLIN collaboration with the UKDMC group and constructed the first two-phase dark matter detector, a 30kg ZEPLIN II and successfully operated at Boulby Mine, UK and published the first limit on direct dark matter search using liquid Xenon two phase detector [5]. Since then we are actively participating in the direct dark matter search in the XENON collaboration and the DarkSide collaboration. The DarkSide experiment uses liquid Argon from underground sources with similar two-phase techniques as XENON with a high efficiency neutron veto developed by the Princeton Group.

David Cline has always been the PI on the DOE support throughout the years and has been closely collaborating with Dr. Hanguo Wang (PI of NSF support) at UCLA. We ran the tenth bi-annual major dark matter conference at UCLA. This work led to the direction of the US dark matter search programs using liquid (such as XENON and the LUX).

We are an important member of the XENON collaboration. The current best limits on the search for dark matter come from XENON 100. Figure 5 and 6 show these results.

XENON100

2011 was a hugely important one for the XENON100 collaboration. Following the publication of a world-leading limit on the WIMP-nucleon spin-independent cross-section using 10 live days of data, XENON100 ran between the months of January and June, yielding 100.9 live days of data.

The active volume of XENON100 contains 68kg of xenon but fiducial cuts where applied to restrict this to a 48kg volume which exploits the self shielding capabilities of liquid xenon and reduces the level of background from detector components and interactions at the liquid surface.

A WIMP search region was defined using the characterization of elastic nuclear recoil events from a dedicated AmBe neutron calibration. Analysis of this and of dedicated electron recoil calibrations led to an expected electron recoil rejection of 99.75% with a nuclear recoil acceptance of 50%. Over the course of 100.9 live days, (1.8±0.6) events due to electron recoil background were expected below the 50% neutron acceptance line.

Once the acquired data was unblinded, three events were found to fall in the WIMP search region.

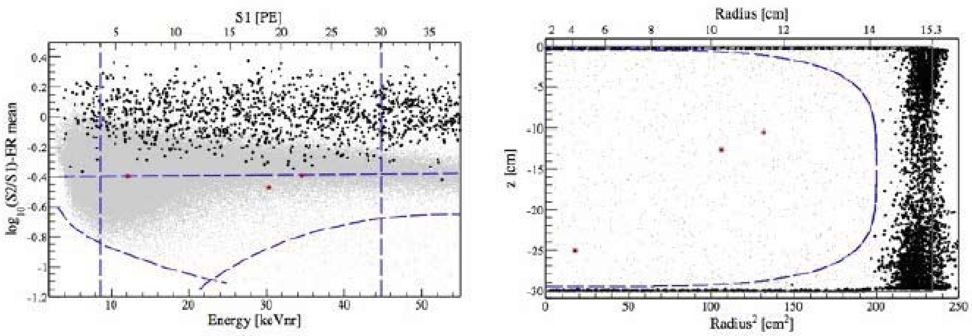

Figure 1. (*left)* The three events that fall within the WIMP search region (bounded by the dashed blue line) are shown in red. The black markers denote events within the 48 kg fiducial volume and the grey markers denote elastic nuclear recoils from the AmBe calibration run. *(right)* The position of the three events within the fiducial volume.

Given the expected background level, this is consistent with a null observation of WIMP recoil events. This null observation allowed the calculation of the most stringent WIMP-nucleon spin-independent cross-section of 7.0x10-45 cm2 for a WIMP mass of 50 GeV/c2 at a confidence level of 90%.[1]

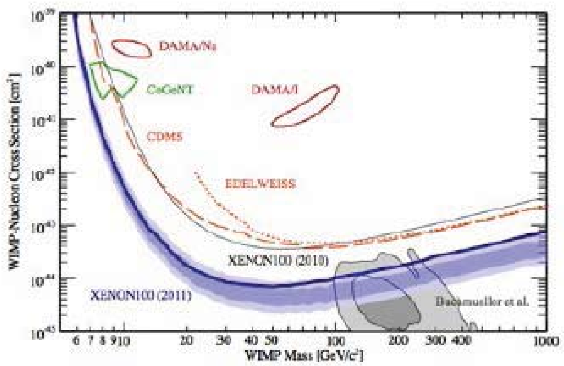

Figure 2. Limits set by XENON100 in comparison with the result from 10 days of data and with other experimental limits and regions where potential signals have been seen by competing experiments.

We are currently working on the construction of XENON1T while operating the XENON100 detector, which is currently the leading experiment in the field with the best limit [4]. We are also a key member of the DarkSide50, a 50kg underground argon two-phase detector, which will start operation early next year. We are also participating in the DarkSide G2 design study.

The DarkSide Program – a FNAL Experiment at the LGNS approved by both NSF and DOE

The use of liquid Argon for a dark matter detector was first proposed by David Cline in 1989. The current DarkSide detector utilizes the following five key concepts: 1. The two-phase discrimination technology, 2. Use of underground argon with ^{39}Ar depleted by at least a factor of 150 compared to the atmospheric argon, 3. 99.5% High efficiency neutron veto using a 4pi Borated liquid scintillator, 4. S1 pulse shape discrimination which provides additional powerful n-gamma separation by a factor of 10^8, and 5. a large 10m water tank for shielding to reduce lab

[1] E. Aprile *et al.* (XENON100) (2011) arXiv:1104.2549.

background. The unique combination of background rejection techniques coming from Argon technology and the extremely powerful veto system leads to expected background lower than 0.1 events in 0.1 ton-year. The projected sensitivity with a threshold of ~20KeV is in the order of ~1 x 10^{-45} cm^2 for a 100 GeV WIMP. 3 years of background free exposure, Figure 10.

We are operating a test detector, DarkSide10, at LNGS and have achieved so far the highest light yield of 9-photo-electron per keV at null field. The Darkside50 construction is fully approved by DOE (lead by FNAL) and NSF (lead by Princeton) as well as INFN, Italy, and the detector construction is well underway using the existing Boraxino counting test facility (CTF) water tank. The veto vessel is fully installed and the detector is being fabricated.

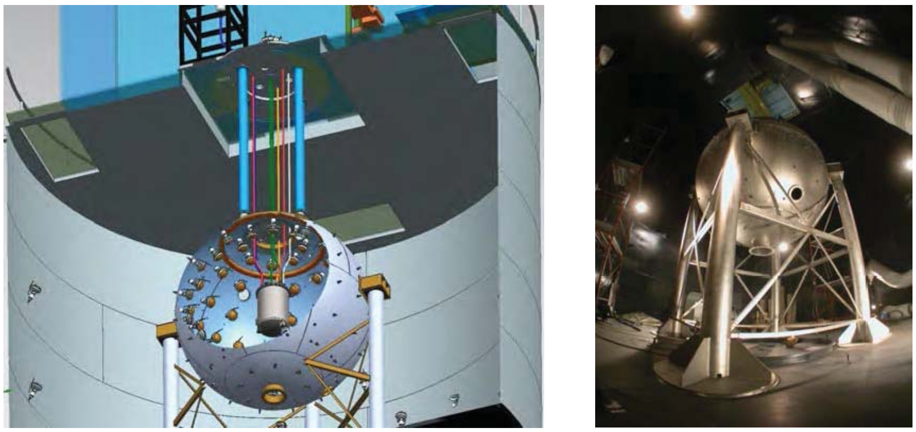

FIG. 3: Left: Assembly drawing showing the DarkSide-50 cryostat at the center of the LSV, installed in CTF and the process lines connecting the DarkSide-50 TPC to the clean room CRH. Right: the 4m diameter LSV, upon completion, April 27, 2012.

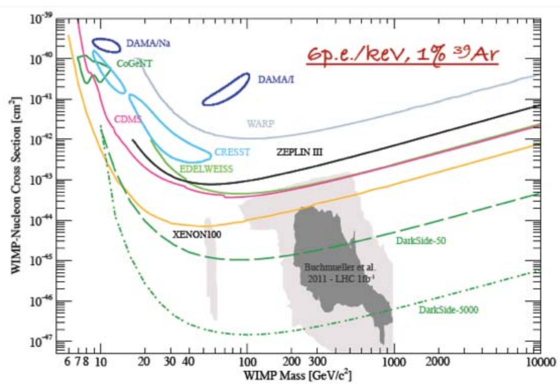

Figure 4. The sensitivity of the 5-ton DarkSide detector (5-years background free exposure) and the sensitivity of the 50kg detector (3-years background free exposure).

UCLA has a Dark Matter laboratory and has contributed to many of the original ideas used in today's liquid noble gas experiments and some of the hardware for XENON1T.

Task B2: ICARUS, LBNE work on a far LAr detector and near detector, and the 5m test detector at CERN

The focus of this scientific effort is to develop a very large liquid Argon (LAr) time project chamber (TPC) for proton decay and long baseline neutrino physics. We started with the

ICARUS concept around late 1980s. The first ICARUS R&D demonstration module was a 3-ton LAr-TPC, built in 1989-1992 at CERN with Prof. C. Rubbia and Prof. Pio Picchi. Two UCLA students received PhDs on this work. In the late 1990s, after the successful run of the 3-ton LAr-TPC, a 300-ton LAr-TPC half module was built and tested in Pavia. After many delays at LNGS, the full 600-ton detector (2x300-ton modules) was assembled at the LNGS and recently started taking neutrino beam data from CERN in 2010. It is still taking data [1][2].

Members of UCLA team (Prof. Cline and Dr. Wang) participated since the beginning of the ICARUS program and made significant contribution during the 3-ton R&D activities starting in 1989. On the ICARUS 600-ton LAr-TPC, UCLA has been responsible for the high voltage system including HV feedthrough fabrication and testing. This HV FT concept has been the key to the later XENON1T, DarkSide and the LBNE programs. D. Cline, K. MacDonald, John Learned, and F. Sergiampietri were the first to propose a 100k-ton LAr-TPC called LANNDD [3]. We helped the LBNE LAr program since the beginning for both the near and far LAr-TPC. The current plan is to send a neutrino beam from FNAL to the 10k-ton LAr-TPC at the Homestake mine in South Dakota. The original NSF proposed DUSEL program is being supported by DOE and the LBNE CD1 review is planned in Oct. 2012. UCLA is responsible for the HV FT design, construction and integration to the 10kt TPC. A full demonstration of an -185kV FT is planned early 2013. We are very interested in supernova neutrino physics and are working with Prof. George Fuller (UCSD) on the flavor swap physics for a detected supernova burst.

ICARUS

During FY 2011 we made great progress on the operation of the 600 ton ICARUS detector at the LNGS. This detector can be considered as a proof of principle for the 20kt LAr detector for LBNE. During this period the UCLA team found 35 neutrino events out of the 130 total now collected by ICARUS from the CNGS beam. UCLA is one of the five “scanning teams” in ICARUS. The electron lifetime in the LAr detector is now more than 5 milliseconds. This would allow a seven meter drift. The LBNE LAr detector will use a 3.65-meter drift. During the coming year we hope to collect 500 to 1000 neutrino events and search for sterile neutrinos and exotic forms of proton decay on n-bar oscillations. Plans are also being made to move the ICARUS 600 ton detector to CERN in the PS neutrino beam to make a more careful search for sterile neutrinos than mini-Boone or MicroBooNE. David Cline gave an invited talk on ICARUS at the Brown University DPF meeting.

Neutrino Speed Measurement using the 785km away CERN CNGS beam

The UCLA team members currently working on ICARUS are David Cline (physics analysis), Hanguo Wang (HV system and feedthrough), Xiaofeng Yang (engineer, HV system operation and shift-taking). Kevin Lee (studies ICARUS data to learn how to simulate credible LBNE events), and Natalia Makrouchina (data scanning and analysis).

Figure 5 shows an ICARUS neutrino event where most of the particles have been identified [2]. We know of no other detector with this proven particle identification capability, a true three-D electronics bubble chamber with mm special resolution. Natalia Makrouchina of the UCLA team found this event during the event scan. Currently UCLA does most of the event scanning. Events found are sent to Padova for further processing.

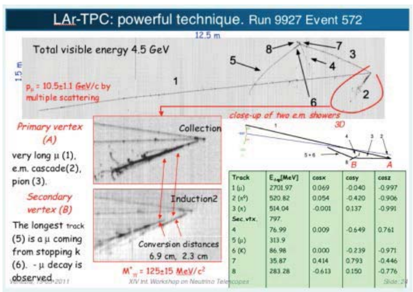

Figure 5. An unusual ICARUS event observed at the LGNS from the CNGS beam from CERN. Note that most of the tracks in this event are identified showing the powerful particle ID of the LAr-TPC.

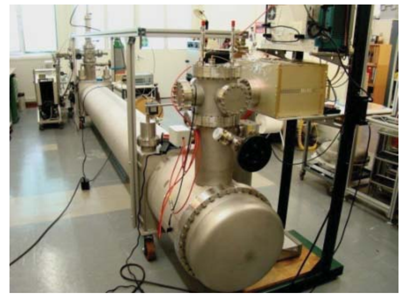

Figure 6. The 5-meter electron drift test detector now constructed at CERN and ready to take data, A UCLA/Pisa/ETH project.

LBNE LAr-TPC

UCLA and the proof of principle test yields a satisfactory result of the new feedthrough design. This preliminary design and tests of the HV feedthrough work was supported by FNAL. Dr. Artin Teymourian joins Hanguo Wang in this design and construction effort. UCLA has also been assigned the task to design and build the HV feedthroughs and other parts of the HV system in close collaboration with BNL LAr-TPC team. The current members of the UCLA team on LBNE are Dr. Hanguo Wang (HV and feedthrough for the 10kt detector), Dr. Artin Teymourian (working with H. Wang), Dr. K. Lee and D. Cline (physics simulation including supernova neutrino simulation for the detector). We show in Figure 7 the new LBNE configuration. LBNE is in CD0 phase with the CD1 review planned for this design in Oct. 2012.

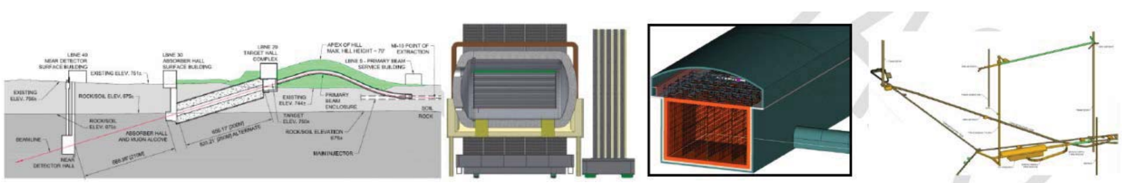

Figure 7. The latest scheme for LBNE from a June FNAL report that has DOE approval: from left to right, a less expensive neutrino beam at FNAL, a magnetized near detector, a 10kT LAr detector on the surface at Homestake, and the Homestake underground site.

In summary, our long-time and unique work on the ICARUS detector provides us with crucial expertise on LBNE including: (a) The HV system; (b) Event reconstruction; (c) Physics studies such as supernova neutrino burst detection and analysis. We are pleased to help LBNE become a reality for the USA.

Activities for LBNE

The long baseline neutrino experiment (LBNE) proposes the use a 33kT liquid argon (LAr) time projection chambers (TPC) as far detectors sited at shallow 800' or the 8450' deep site at Homestake mine, in South Dakota. We propose here to continue the follow up study of the modular option for the 33kT LAr detector, basing on the experience made with ICARUS-T600, the first detector based on this technique and operating at the underground laboratory of INFN at Gran Sasso, Italy.

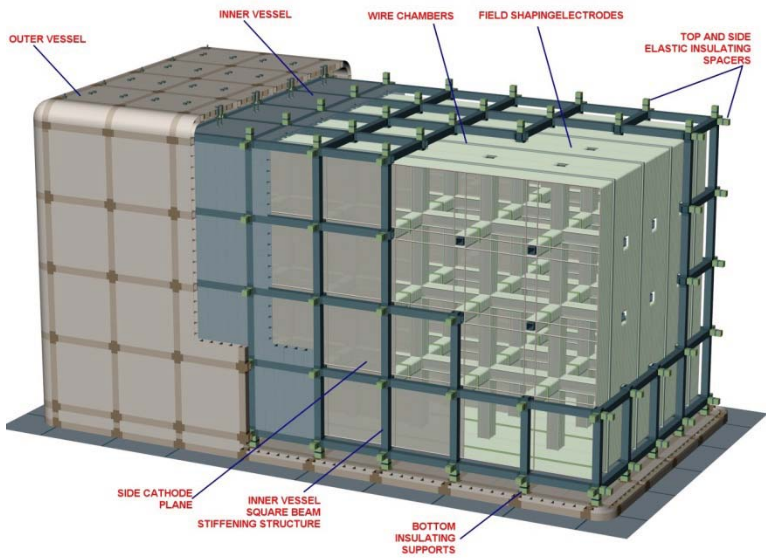

Figure 8. The 20 kton version of vacuum insulated Liquid Argon TPC for LBNE.

The main characteristic of the present modular proposal relies on the vacuum thermal insulation of the cryostat. This means to have an inner vessel (~20m wide, ~20m high and 55m long) surrounded by an outer vessel with vacuum in between. The gap between inner and outer walls is of the order of 0.8m wide, allowing for man pass for inspection and tightness verification and for wrapping the inner vessel by superinsulation layers.

The vacuum evacuated with super insulation is the most efficient for operating this large mass at an underground sited. This allows the LAr TPC to operate in ultra-quite conditions for safety and for minimizing microphonic noise that can be induced on the readout wires by updrafts of gas bubbles in LAr. The good insulation implies reduced operation costs (typically of 1/10÷1/40 compared to passive insulation) during the full experiment duration (10-20 years).

Bibliography and References

1. S. Amerio, et al., "Design, construction, and tests of the ICARUS T600 detector," Nucl. Instrum. Meth. **A527** (2004) 329-410.
2. C. Rubbia, et al., "Underground operation of the ICARUS T600 LAr-TPC: first results," JINST **6** (2011) P07011.
3. D.B. Cline, J.G. Learned, K. McDonald, F. Sergiampietri, "LANNDD: A massive liquid Argon detector for proton decay, supernova and solar neutrino studies, and a neutrino factory detector," Proc. of the 3rd International Workshop on Neutrino Factory Based on Muon Storage Rings (NuFact '01), Tsukuba, Japan, May 24-30, 2001, Nucl. Instrum. Meth. **A503** (2003), 136-140.
4. E. Aprile, et al., "Dark matter results from 225 live days of XENON100 data," arXiv:1207.5988v1 [astro-ph.CO], submitted 25 Jul 2012.
5. G. J. Alner, et al., "First limits on WIMP nuclear recoil signals in ZEPLIN II: A two phase Xenon detector for dark matter detection," Astropart. Phys. **28** (2007) 164-167.

Task C: Theoretical Particle and Astroparticle Physics

1 Overview of Theoretical Physics at UCLA

This is final report on behalf of Zvi Bern, Sergio Ferrara, Graciela Gelmini and Alexander Kusenko. It covers the period January 2010 to April 2013. The topics covered by this progress report range from astroparticle physics, cosmology, LHC physics, supergravity and aspects of string theory.

Overview of Research.

The physics interests of the proponents span a wide spectrum, ranging from rather phenomenological issues to deep questions of principle. Thus, not surprisingly, the research program proposed here is rather broad, including astroparticles, dark matter, collider physics, QCD, supergravity and aspects of string theory. The strong overlap of our theoretical work with the interests of our experimental colleagues both in astroparticle physics and collider physics is noteworthy. Even the more theoretical aspects of the research of Zvi Bern and Sergio Ferrara are also driven by the desire to understand important physical issues in quantum gravity and string theory. The individual detailed research programs of the faculty members over the past three years are described in the following pages.

Postdocs who were on our DOE grant during the previous funding period are Yu-tin Huang, Harald Ita, Kemal Ozeren, Gerban Stavenga, Ji-Haeng Huh and Eugenio Del Nobile. Harald Ita is now a faculty member at Freiburg, Yu-tin Huang for a postdoc position at Michigan and Kemal Ozeren obtained an LHC Fellowship and was taken off the grant. In the final year we had three postdocs Gerban Stavenga, Ji-Haeng Huh and Eugenio Del Nobile. Gerban Stevenga works on collider physics and the other two work in the area of astroparticle physics and cosmology, replacing ones that worked on QCD and formal scattering amplitudes.

Graduate students who have been partly supported in past three years by the DOE are Nassim Bozorgnia, Scott Davies, Tristan Dennen, Warren Essey, Ian Shoemaker, Lauren Pearce. Warren Essey left for LBL, Ian Shoemaker for Los Alamos National Laboratory, Tristan Dennen for the Neils Bohr Institute and Nassim Bozorgnia the Max Planck Institute in Heidelberg. Dennen and Davies won DOE graduate fellowships and were taken off the grant at that point. Since there were insufficient funds in the grant to support all our students, we rotated support amongst them, as best as we could.

2 Report for Zvi Bern

Research

Over the past 20 years I have been working on different aspects scattering amplitudes, contributing to both theoretical and phenomenological aspects. My research ranges from providing direct theoretical support to CMS and ATLAS to fundamental issues in quantum gravity and supersymmetric gauge theories. A summary of activities in the past three years is:

Scattering Amplitudes in $N = 4$ super-Yang-Mills theory: In 2004, together with Lance Dixon and Volodya Smirnov, I formulated a conjecture [1]— now known as the "BDS ansatz"—for planar scattering in maximally supersymmetric gauge theory to *all* quantum loop orders and for *all* values of the couplings. This was spectacularly confirmed by Luis Alday and Juan Maldacena [2] for four-gluon amplitudes, using Maldacena's AdS/CFT duality to string theory. Although our initial proposal fails at six points [3, 4], it opened up the field of scattering amplitudes in $\mathcal{N} = 4$ super-Yang-Mills theory. Since our initial paper hundreds of papers have been written on this topic, including our recent studies of nonplanar amplitudes [5, 6, 7].

A duality between color and kinematics: Together with former UCLA graduate students, John Joseph Carrasco (currently at Stanford) and Henrik Johansson (currently at CERN) we uncovered a surprising duality between color and kinematics, commonly called "BCJ duality" in the literature. Our duality conjecture states that to all loop orders one can find a representation of scattering amplitudes such that kinematic numerators of diagrams satisfy the same algebraic properties as color factors [8]. This put highly nontrivial constraints on gauge theory scattering amplitudes. Whenever such representations are found a simple "double-copy formula" gives us corresponding (super)gravity amplitudes. This observation gives us the most powerful means available today for obtaining multiloop gravity amplitudes. We recently confirmed that the duality holds through four loops in $\mathcal{N} = 4$ super-Yang-Mills theory [6] and to one-loop in nonsupersymmetric pure Yang-Mills theory [9], among many other studies that have been performed.

Supergravity: For over 25 years people have believed that it is impossible to construct a point-like ultraviolet-finite theory of quantum gravity in four dimensions. If it were possible, it would be of profound significance because it would imply a new symmetry or dynamical mechanism in gravity theories. My work with Lance Dixon, Radu Roiban and others [10, 11], reopened the question. Our work demonstrates the existence of novel ultraviolet cancellations in $\mathcal{N} = 8$ supergravity to *all* loop orders. We still have much more to do before we have a proper understanding of the ultraviolet properties, but a rather significant recent step has been our recent calculation of the four-loop four-point amplitude in $\mathcal{N} = 8$ supergravity [11, 5, 6]. More recently, together with UCLA students and postdocs in $\mathcal{N} = 4$ supergravity [12] we demonstrated the vanishing of a potential three-loop counterterm which respects all known symmetries [13]. We also demonstrated nontrivial examples of ultraviolet cancellations in a two-loop example in $D = 5$ [14]. These results cast substantial doubt on the potential existence of a seven-loop divergence in $D = 4$ $\mathcal{N} = 8$ supergravity suggested by recent studies [15, 13]. I expect there will be much more activity in the coming years to understand the consequences of our results.

State of the Art QCD for the LHC: A difficult theoretical problem people had been struggling with for a long time is obtaining accurate theoretical predictions for events with large numbers of final state objects including jets at the LHC. Together with Lance Dixon (SLAC) I founded the BlackHat Collaboration to take advantage of out theoretical advances to provide state-of-the-art predictions of scattering processes at the LHC. The fundamental advance that allowed us to carry to make progress on these problems was our 1994 paper paper developing and on-shell formalism for computing amplitudes [16]. Besides our flagship work on vector bosons in association with multiple jets, we directly assisted the CMS collaboration in understanding theoretical uncertainties in the search for supersym-

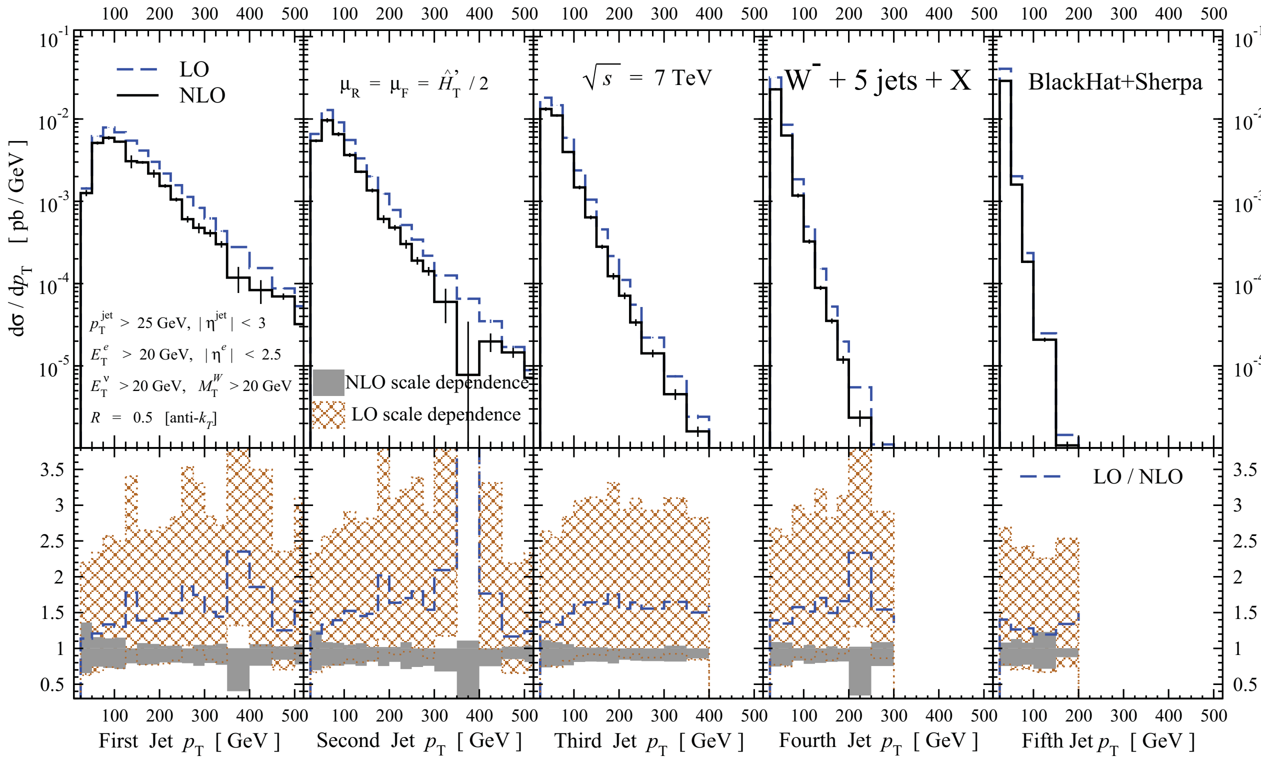

Figure 1: The p_T distributions of the leading five jets in W^- + 5-jet production at the LHC at $\sqrt{s} = 7$ TeV. In the upper panels, the NLO predictions are shown as solid (black) lines, while the LO predictions are shown as dashed (blue) lines. The lower panels show the predictions for the LO distribution and scale-dependence bands normalized to the NLO prediction. The LO distribution is the dashed (blue) line, and the scale-dependence bands are shaded (gray) for NLO and cross-hatched (brown) for LO. From Ref. [22].

metry [17]. (This has nicely acknowledged by CMS spokesperson Joe Incandela, whom the referees should feel free to contact.) In addition we uncovered a new Standard Model polarization effect with vector bosons at large transverse momenta [18, 19]. This has subsequently been been measured by both CMS and ATLAS [20]. Results from the BlackHat collaboration were highlighted recently in Riccardo Barbieri's ICHEP 2012 conference summary talk[21].

Over the past few years I have put considerable effort into theoretical support for the LHC experiments via the BlackHat Collaboration. Some important milestone results are:

1. The first NLO QCD computation of W+3 jet production at hadron colliders [23]. Our results for the W case were later confirmed by R.K. Ellis and his collaborators [24].
2. The only available NLO computations of $W + 4$ jets [18]. These are currently the only NLO QCD computations with five final state objects, including jets. Our predictions have been compared against ATLAS data in ref. [25] showing very good agreement. It is certainly satisfying to see that NLO agrees well with the data "out of the box" without tuning, as sometimes done with other approaches. In search regions of new physics this should provide important theoretical guidance.
3. The completion of the long-awaited NLO computation of $Z + 4$ jets at the LHC [26].

This process is a primary background to searches of new physics via missing transverse energy. In ref. [27] ATLAS compared their measurement against our theoretical prediction, again showing very good agreement. We have also recently presented NLO results results for four-jet production in pure QCD [28].

4. The completion of $W + 5$ jets at the LHC [22]. This process sets a new level for state-of-the-art NLO QCD computations of LHC physics. The p_T spectra of the five leading jets is given in Fig. 1

5. The identification of a new Standard Model polarization effect for vector bosons [19]. We demonstrated that at the LHC, vector bosons at high transverse momentum carry a strong left-handed polarization in the *transverse* direction to the beams. Both CMS and ATLAS measured the effect confirming our prediction [29]. The interest in the effect stems from the fact it may be helpful for separating prompt W's from those coming from top quark decay or sources of new physics.

6. Our direct assistance to the CMS collaboration in their determination of the Standard Model background to the missing transverse momentum of supersymmetry [30], acknowledged in their paper [31]. Our NLO QCD study was used to determine the theoretical uncertainty when using measurements of photons plus jets to estimate the irreducible background to missing transverse energy plus jets coming from Standard Model processes where a Z boson decays to neutrinos. Our work had a major impact final constraints obtained by CMS on supersymmetry. We recently completed a new paper studying the uncertainties for more aggressive cuts and for the case of $Z + 3$ jets [32], continuing our assistance to CMS. We have also been working closely with David Saltzberg and his students and postdoc on understanding Z boson production in association with multiple jets at large transverse energies. In addition the the ATLAS collaboration uses `BlackHat` results for comparing the best available theoretical predictions of vector bosons plus jets to experimental data [25, 27].

The above work has garnered significant attention in the past several years, and I have been invited to give a large number of seminars, colloquia and lectures at advanced schools and conferences. I have been summary speaker at conferences such as Amplitudes 2011 (Michigan) and LoopFest 2012 (Pittsburgh). I have given recent review talks on hard QCD at the LHC at five conferences: April 2011 Meeting of the APS (Anaheim), 2011 Workshop on Supersymmetry Searches (LBL), SLAC Summer Institute 2012 topical conference (Stanford), Pheno 2012 (Pittsburgh) and Physics at the LHC 2012 (Vancouver). In the past three years, I lectured multiple times at advanced schools around the world. This includes twice at Antonio Ziccichi's school in Erice, twice at Cargese, once at the Jerusalem Winter School and once at Parma. Together with my long-time collaborators Lance Dixon and David Kosower, I wrote the cover story in the May 2012 issue of *Scientific American*, explaining the unitarity method and the associated advances in collider physics and gravity.

Service and outreach

Over the past few years I have performed a variety of community service and public outreach tasks:

- Together with my long-time collaborators Lance Dixon and David Kosower, we wrote

May 2012 *Scientific American* cover article explaining our work on scattering amplitudes and their applications to collider physics and quantum gravity [33].

- Spoke at the TEDxCaltech Richard Feynman celebration held January 14, 2011. (The video can be viewed on by googling "TEDxCaltech" and clicking on my name.)
- In recent years, I lectured multiple times at advanced schools around the world. This includes four times at Antonio Zicchichi's school in Erice, twice at Cargese, once at the Jerusalem Winter School and once at Parma.
- Served two years on the Sakurai Prize Committee for the American Physical Society (2011-2012).
- Editor for the Journal of High Energy Physics (JHEP) since 2009.
- Served on various workshop organizing committees and in particular chaired the organizing committee of a three month program on *The Harmony of Scattering Amplitudes* at the Kavli Institute for Theoretical Physics (KITP) at UC Santa Barbara in 2011. The committee consisted of Thomas Gehrmann, Anastasia Volovich, Zoltan Kunszt and myself, with Nima Arkani-Hamed acting as an adviser.

References for Zvi Bern

[1] Z. Bern, L. J. Dixon and V. A. Smirnov, "Iteration of planar amplitudes in maximally supersymmetric Yang-Mills theory at three loops and beyond," Phys. Rev. D **72**, 085001 (2005) [hep-th/0505205].

[2] L. F. Alday and J. M. Maldacena, "Gluon scattering amplitudes at strong coupling," JHEP **0706**, 064 (2007) [arXiv:0705.0303 [hep-th]].

[3] L. F. Alday and J. Maldacena, "Comments on gluon scattering amplitudes via AdS/CFT," JHEP **0711**, 068 (2007) [0710.1060 [hep-th]].

[4] Z. Bern, L. J. Dixon, D. A. Kosower, R. Roiban, M. Spradlin, C. Vergu and A. Volovich, "The Two-Loop Six-Gluon MHV Amplitude in Maximally Supersymmetric Yang-Mills Theory," Phys. Rev. D **78**, 045007 (2008) [0803.1465 [hep-th]].

[5] Z. Bern, J. J. M. Carrasco, L. J. Dixon, H. Johansson and R. Roiban, "The Complete Four-Loop Four-Point Amplitude in N=4 Super-Yang-Mills Theory," Phys. Rev. D **82**, 125040 (2010) [arXiv:1008.3327 [hep-th]].

[6] Z. Bern, J. J. M. Carrasco, L. J. Dixon, H. Johansson and R. Roiban, "Simplifying Multiloop Integrands and Ultraviolet Divergences of Gauge Theory and Gravity Amplitudes," Phys. Rev. D **85**, 105014 (2012) [arXiv:1201.5366 [hep-th]].

[7] Z. Bern, J. J. M. Carrasco, H. Johansson and R. Roiban, arXiv:1207.6666 [hep-th].

[8] Z. Bern, J. J. M. Carrasco and H. Johansson, "New Relations for Gauge-Theory Amplitudes," Phys. Rev. D **78**, 085011 (2008) [arXiv:0805.3993 [hep-ph]];
Z. Bern, J. J. M. Carrasco, H. Johansson, "Perturbative Quantum Gravity as a Double Copy of Gauge Theory," Phys. Rev. Lett. **105**, 061602 (2010). [arXiv:1004.0476 [hep-th]].

[9] Z. Bern, S. Davies, T. Dennen, Y.-t. Huang and J. Nohle, "Color-Kinematics Duality for Pure Yang-Mills and Gravity at One and Two Loops," arXiv:1303.6605 [hep-th].

[10] Z. Bern, L. J. Dixon and R. Roiban, "Is N = 8 supergravity ultraviolet finite?," Phys. Lett. B **644**, 265 (2007) [arXiv:hep-th/0611086];
Z. Bern, J. J. Carrasco, L. J. Dixon, H. Johansson, D. A. Kosower and R. Roiban, "Three-Loop Superfiniteness of $\mathcal{N} = 8$ Supergravity," Phys. Rev. Lett. **98**, 161303 (2007) [hep-th/0702112].

[11] Z. Bern, J. J. Carrasco, L. J. Dixon, H. Johansson and R. Roiban, "The Ultraviolet Behavior of N=8 Supergravity at Four Loops," Phys. Rev. Lett. **103**, 081301 (2009) [arXiv:0905.2326 [hep-th]].

[12] Z. Bern, S. Davies, T. Dennen and Y. -t. Huang, "Absence of Three-Loop Four-Point Ultraviolet Divergences in N=4 Supergravity," arXiv:1202.3423 [hep-th].

[13] G. Bossard, P. S. Howe, K. S. Stelle and P. Vanhove, "The vanishing volume of D=4 superspace," Class. Quant. Grav. **28**, 215005 (2011) [arXiv:1105.6087 [hep-th]].

[14] Z. Bern, S. Davies, T. Dennen and Y. -t. Huang, "Ultraviolet Cancellations in Half-Maximal Supergravity as a Consequence of the Double-Copy Structure," Phys. Rev. D **86**, 105014 (2012) [arXiv:1209.2472 [hep-th]];
Z. Bern, S. Davies and T. Dennen, "The Ultraviolet Structure of Half-Maximal Supergravity with Matter Multiplets at Two and Three Loops," arXiv:1305.4876 [hep-th].

[15] J. Bjornsson and M. B. Green, "5 loops in 24/5 dimensions," JHEP **1008**, 132 (2010). [arXiv:1004.2692 [hep-th]];
N. Beisert, H. Elvang, D. Z. Freedman, M. Kiermaier, A. Morales, S. Stieberger, "E7(7) constraints on counterterms in N=8 supergravity," Phys. Lett. **B694**, 265-271 (2010)

[16] Z. Bern, L. J. Dixon, D. C. Dunbar and D. A. Kosower, "One loop n-point gauge theory amplitudes, unitarity and collinear limits," Nucl. Phys. B **425**, 217 (1994) [hep-ph/9403226];
Z. Bern, L. J. Dixon, D. C. Dunbar and D. A. Kosower, "Fusing gauge theory tree amplitudes into loop amplitudes," Nucl. Phys. B **435**, 59 (1995) [hep-ph/9409265].

[17] Z. Bern, G. Diana, L. J. Dixon, F. Febres Cordero, S. Hoche, H. Ita, D. A. Kosower, D. Maitre and K. Ozeren , "Driving Missing Data at Next-to-Leading Order," Phys. Rev. D **84**, 114002 (2011) [arXiv:1106.1423 [hep-ph]];
S. Chatrchyan *et al.* [CMS Collaboration], "Search for New Physics with Jets and Missing Transverse Momentum in pp collisions at sqrt(s) = 7 TeV," 1106.4503 [hep-ex];
Z. Bern, G. Diana, L. J. Dixon, F. Febres Cordero, S. Hoeche, H. Ita, D. A. Kosower and D. Maitre, K. Ozeren, "Missing Energy and Jets for Supersymmetry Searches," arXiv:1206.6064 [hep-ph];
S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1207.1898 [hep-ex].

[18] C. F. Berger, Z. Bern, L. J.Dixon, F. Febres Cordero, D. Forde, T. Gleisberg, H. Ita, D.A. Kosower, D. Maitre, "Precise Predictions for W + 4 Jet Production at the Large Hadron Collider," Phys. Rev. Lett. **106**, 092001 (2011) [arXiv:1009.2338 [hep-ph]].

[19] Z. Bern, G. Diana, L. J. Dixon, F. Febres Cordero, D. Forde, T. Gleisberg, S. Hoeche, H. Ita and D. Maitre, "Left-Handed W Bosons at the LHC," Phys. Rev. **D84**, 034008 (2011) [arXiv:1103.5445 [hep-ph]].

[20] S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the Polarization of W Bosons with Large Transverse Momenta in W+Jets Events at the LHC," 1104.3829 [hep-ex];
G. Aad *et al.* [ATLAS Collaboration], "Measurement of the polarisation of W bosons produced with large transverse momentum in pp collisions at sqrt(s) = 7 TeV with the ATLAS experiment," Eur. Phys. J. C **72**, 2001 (2012) [arXiv:1203.2165 [hep-ex]].

[21] R. Barbieri, pages 4-6
https://indico.cern.ch/conferenceTimeTable.py?confId=181298#20120711.detailed

[22] Z. Bern, L. J. Dixon, F. F. Cordero, S. Hoeche, H. Ita, D. A. Kosower, D. Maitre and K. J. Ozeren, arXiv:1304.1253 [hep-ph], to appear in Phys. Rev. D.

[23] C. F. Berger, Z. Bern, L. J.Dixon, F. Febres Cordero, D. Forde, T. Gleisberg, H. Ita, D.A. Kosower, D. Maitre, "Precise Predictions for W + 3 Jet Production at Hadron Colliders," Phys. Rev. Lett. **102**, 222001 (2009) [arXiv:0902.2760 [hep-ph]].

[24] R. K. Ellis, K. Melnikov and G. Zanderighi, "$W + 3$ jet production at the Tevatron," Phys. Rev. D **80**, 094002 (2009) [arXiv:0906.1445 [hep-ph]].

[25] G. Aad *et al.* [ATLAS Collaboration], "Study of jets produced in association with a W boson in pp collisions at sqrt(s) = 7 TeV with the ATLAS detector," Phys. Rev. D **85**, 092002 (2012) [arXiv:1201.1276 [hep-ex]].

[26] H. Ita, Z. Bern, L. J. Dixon, F. F. Cordero, D. A. Kosower and D. Maitre, "Precise Predictions for Z + 4 Jets at Hadron Colliders," arXiv:1108.2229 [hep-ph].

[27] G. Aad *et al.* [ATLAS Collaboration], "Measurement of the production cross section for Z/γ^* in association with jets in pp collisions at sqrt(s) = 7 TeV with the ATLAS detector," Phys. Rev. D **85**, 032009 (2012) [arXiv:1111.2690 [hep-ex]].

[28] Z. Bern, G. Diana, L. J. Dixon, F. Febres Cordero, S. Hoeche, D. A. Kosower, H. Ita and D. Maitre *et al.*, "Four-Jet Production at the Large Hadron Collider at Next-to-Leading Order in QCD," Phys. Rev. Lett. **109**, 042001 (2012) [arXiv:1112.3940 [hep-ph]].

[29] S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the Polarization of W Bosons with Large Transverse Momenta in W+Jets Events at the LHC," 1104.3829 [hep-ex];
G. Aad *et al.* [ATLAS Collaboration], "Measurement of the polarisation of W bosons produced with large transverse momentum in pp collisions at sqrt(s) = 7 TeV with the ATLAS experiment," Eur. Phys. J. C **72**, 2001 (2012) [arXiv:1203.2165 [hep-ex]].

[30] Z. Bern, G. Diana, L. J. Dixon, F. Febres Cordero, S. Hoche, H. Ita, D. A. Kosower, D. Maitre and K. Ozeren, "Driving Missing Data at Next-to-Leading Order," Phys. Rev. D **84**, 114002 (2011) [arXiv:1106.1423 [hep-ph]].

[31] S. Chatrchyan *et al.* [CMS Collaboration], "Search for New Physics with Jets and Missing Transverse Momentum in pp collisions at sqrt(s) = 7 TeV," JHEP **1108**, 155 (2011) [arXiv:1106.4503 [hep-ex]].

[32] Z. Bern, G. Diana, L. J. Dixon, F. F. Cordero, S. Hoeche, H. Ita, D. A. Kosower, D. Maitre and K. Ozeren, "Missing Energy and Jets for Supersymmetry Searches," arXiv:1206.6064 [hep-ph].

[33] Z. Bern, L. J. Dixon and D. A. Kosower, "Loops, trees and the search for new physics," Sci. Am. **306N5**, 20 (2012).

3 Report for Sergio Ferrara

The research activity of Sergio Ferrara supported by the DOE grant at UCLA over the last three years involves collaborations on different projects with major US institutes (Berkeley, Stanford, NYU and Pennsylvania university), as well as European Institutes (INFN Frascati, CERN, University and Politecnico of Turin, Imperial College London, LAPTH Annecy (France), Leuven (Belgium)).

The main topics and outcome of recent and ongoing research cover different aspects of theoretical high energy physics,in the area of Unified Theories of Particle Forces and their implication for early cosmology. Main aspects covered are:

1. Properties and Classification of Extremal Black Holes in Supergravity and String Theory;
2. First Order Flow and Attractors for Single and Multi-centered extremal Black Holes;
3. Supersymmetric Higgs Model Inflation;
4. Generalized Mirror-Symmetry in M Theory and String-Theory compactification .Trace anomalies and their relation to Quantum Black Hole Entropy;
5. Invariants for one center and two center BH orbits and the Theory of Invariant Polynomials;
6. Groups of Type E_7 and application to Matter Creation after Inflation;
7. Electric-Magnetic duality in non linear Maxwell theories:beyond Born-Infeld action;
8. Some holografic aspects of higher spin field theories.

Different aspects of the physical and mathematical properties of black holes and the exploitation of electric-magnetic duality to uncover many of their attributes have been investigated. Major progress has been made in the classification of one center (Refs. 3,4,15,18,19,20,22) extremal BH solutions, both small (singular and horizonless at the classical level) and large (satisfying the Bekenstein-Hawking Entropy-Area formula) and their properties under U duality. This analysis has been extended to double-centered extremal balck holes. The role of a horizontal symmetry $SL(2, \mathbf{R})$ was investigated in connection to their classification (Refs. 5,6,7,8). The major outcome of this investigation is that, while one-center BH solutions are classified by a unique duality invariant, two-centered solutions are classified by four (duality and horizontal) invariants, one of these being the Schwinger-Dirac bilinear symplectic product of two dyonic charge vectors. Split attractor flow in the $N = 2$ minimally coupled supergravity, the simplest non-trivial examples of attractor solutions, has been carefully studied (Ref. 10) and it has been shown that its physics properties such as marginal stability, do depend on the multicenter duality invariant combinations of charge vectors.

Another fundamental aspect of extreme Black Holes is the existence of a real function of scalar fields and electric and magnetic BH charges, called “fake Superpotential” which allows one to study the BH evolution toward the Horizon,through a “first order flow” (Refs. 21,24,25,26,27) Such function reduce to the (modulus of) central charge in the supersymmetric (BPS) case. Such function interpolates,along the flow, between the ADM mass (at infinity) and the Bekenstein-Hawking entropy at the Horizon. In particular in a collaboration with INFN Padua, Turin and Frascati, it was found a universal expression for such function for arbitrary (symmetric) $N = 2$ special Geometry and for higher N-extended Supergravity.

Attractor equations, with scalar super potentials corresponding to internal rather than space-time fluxes, were also studied to find supersymmetric and non-supersymmetric vacua with AdS geometry (Ref. 23).

In two projects with Imperial College London (M. Duff and others, Refs. 9,11), we introduced a generalized concept of mirror symmetry for seven-manifolds in M theory. We used the fact that different field representations may give different quantum corrections. Undualized theories with more than eight supercharges appear to be mirror symmetric and consequently exhibit vanishing gravitational on-shell trace anomaly. Recently an intriguing connection between trace anomalies and logarithmic corrections to the BH entropy recently computed by A. Sen has been observed (Ref. 1).

In a collaboration with Stanford University (Kallosh and others, Refs. 12,13) we have investigated the role played by superconformal symmetry in the Higgs induced inflation, opening the way for supersymmetric model building describing the Physics beyond the Standard model and inflationary cosmology. In another project with R. Kallosh (Refs.14,16), we obtain restrictions on the supergravity couplings for inflaton decay into matter, allowing consistent cosmological models for creation of matter in the Universe.

Recently, in collaboration with M. Porrati (NYU), we elucidated some aspects of 4D localization in Randall-Sundrum brane scenarios and we have studied the holographic properties of higher-spin Vasiliev theories (Ref. 2).

We have studied, in collaboration with R. Kallosh and some postdocs at Stanford (Ref.17), a class of deformations of the so called twisted self-duality condition for the Maxwell field was lowest order solution is just Maxwell theory while its most popular deformation is non-linear Born Infeld electric-magnetic self dual theory. We have shown that the latter is just a particular case of more general non linear theories, including their $N = 1$ and $N = 2$ supersymmetric extension. This analysis was done in attempts to clarify the role that electromagnetic duality could play in quantum corrections to $N = 8$ supergravity, whose electric magnetic symmetry is encoded in the exceptional group $E_{7,7}$.

Recent research covers further aspects of extremal black hole physics and the role which supersymmetry and E_7 could play in the finiteness conjecture of Bern et al. of perturbative $N = 8$ Supergravity in four dimensions. In a work with Renata Kallosh from Stanford we study quantum aspects of $N = 4$ supergravity in an attempt to explain the absence of three loop divergences discovered by Bern and his students as a consequence of some hidden symmetry of pure $N = 4$ supergravity (Ref. 28).

In collaboration with CERN and INFN we have been studying first order flows of multi-center extremal black holes, after recent progress due to Bossard (Paris) and Yeranyan (LNF,INFN).

The open problem of constructing Born Infeld Supergravity is also underway. Constraints given by N extended Supersymmetry on non linear higher order derivative theories of Maxwell and Einstein lagrangians,and their implications for candidate counterterms, is also under investigation. Collaborations on these subjects involve Stanford (R. Kallosh et al) and Italian Universities. A recent paper on this topic is Ref. 29.

Recent service

- International Advisory Committee STRINGS 09 (Rome, Italy), STRINGS 10 (College Station, Texas, USA), STRINGS 11 (Uppsala, Sweden), STRINGS 12 (Munich, Germany)
- Scientific Advisory Board (co-President) Round Table Italia-Russia on Black-holes in Mathematics and Physics, Dubna 2011
- International Advisory Committee Black Objects in Supergravity School, BOSS 2011

(LNF Frascati, Italy)

- Organization Committee of School and workshop on D-brane instantons, wall crossing and microstate counting 2010 (ICTP, Trieste)
- Editorial Board of Advances in Theoretical and Mathematical Physics journal, International Press.
- Co-editor (with R. Varadarajan and R. Fioresi) of the proceedings of the UCLA conference on "Supersymmetry Mathematics and Physics", Springer-Verlag Lecture Notes Math. Vol. 2027 (2011)

References for Sergio Ferrara

1. S. Ferrara and A. Marrani, "Generalized Mirror Symmetry and Quantum Black Hole Entropy," Phys. Lett. B **707** (2012) 173 [arXiv:1109.0444 [hep-th]].
2. S. Ferrara and M. Porrati, "4D Localization in Randall-Sundrum 2 Supergravity and in Vasiliev Theories," Phys. Lett. B **704** (2011) 249 [arXiv:1108.1993 [hep-th]].
3. L. Borsten, M. J. Duff, S. Ferrara, A. Marrani and W. Rubens, "Explicit Orbit Classification of Reducible Jordan Algebras and Freudenthal Triple Systems," arXiv:1108.0908 [math.RA].
4. L. Borsten, M. J. Duff, S. Ferrara, A. Marrani and W. Rubens, "Small Orbits," Phys. Rev. D **85** (2012) 086002 [arXiv:1108.0424 [hep-th]].
5. A. Ceresole, S. Ferrara, A. Marrani and A. Yeranyan, "Small Black Hole Constituents and Horizontal Symmetry," JHEP **1106** (2011) 078 [arXiv:1104.4652 [hep-th]].
6. L. Andrianopoli, R. D'Auria, S. Ferrara, A. Marrani and M. Trigiante, "Two-Centered Magical Charge Orbits," JHEP **1104** (2011) 041 [arXiv:1101.3496 [hep-th]].
7. S. Ferrara, A. Marrani, E. Orazi, R. Stora and A. Yeranyan, "Two-Center Black Holes Duality-Invariants for stu Model and its lower-rank Descendants," J. Math. Phys. **52** (2011) 062302 [arXiv:1011.5864 [hep-th]].
8. S. Bellucci, S. Ferrara, A. Shcherbakov and A. Yeranyan, "Attractors and first order formalism in five dimensions revisited," Phys. Rev. D **83** (2011) 065003 [arXiv:1010.3516 [hep-th]].
9. M. J. Duff and S. Ferrara, "Four curious supergravities," Phys. Rev. D **83** (2011) 046007 [arXiv:1010.3173 [hep-th]].
10. S. Ferrara, A. Marrani and E. Orazi, "Split Attractor Flow in N=2 Minimally Coupled Supergravity," Nucl. Phys. B **846** (2011) 512 [arXiv:1010.2280 [hep-th]].
11. M. J. Duff and S. Ferrara, "Generalized mirror symmetry and trace anomalies," Class. Quant. Grav. **28**, 065005 (2011) [arXiv:1009.4439 [hep-th]].
12. S. Ferrara, R. Kallosh, A. Linde, A. Marrani and A. Van Proeyen, "Superconformal Symmetry, NMSSM, and Inflation," Phys. Rev. D **83** (2011) 025008 [arXiv:1008.2942 [hep-th]].
13. S. Ferrara, R. Kallosh, A. Linde, A. Marrani and A. Van Proeyen, "Jordan Frame Supergravity and Inflation in NMSSM," Phys. Rev. D **82** (2010) 045003 [arXiv:1004.0712 [hep-th]].
14. S. Ferrara and R. Kallosh, "Creation of Matter in the Universe and Groups of Type E_7," JHEP **1112** (2011) 096 [arXiv:1110.4048 [hep-th]].
15. S. Ferrara, A. Marrani and A. Yeranyan, "On Invariant Structures of Black Hole Charges," JHEP **1202** (2012) 071 [arXiv:1110.4004 [hep-th]].

16. S. Ferrara, R. Kallosh and A. Marrani, "Degeneration of Groups of Type E7 and Minimal Coupling in Supergravity," arXiv:1202.1290 [hep-th].
17. J. Broedel, J. J. M. Carrasco, S. Ferrara, R. Kallosh and R. Roiban, "$N = 2$ Supersymmetry and $U(1)$-Duality," arXiv:1202.0014 [hep-th].
18. B.L. Cerchiai, S. Ferrara , A. Marrani and B. Zumino, "Charge Orbits of Extremal Black Holes in Five Dimensional Supergravity," Phys.Rev. D82 (2010) 085010 arXiv:1006.3101 [hep-th].
19. A. Ceresole, S. Ferrara, and A. Marrani, Small N=2 Extremal Black Holes in Special Geometry. Jun 2010. 14 pp. Note: 14 pages Phys.Lett. B693 (2010) 366-372 arXiv:1006.2007 [hep-th]
20. L. Borsten, D. Dahanayake, M.J. Duff, S. Ferrara , A. Marrani and W. Rubens, "Observations on Integral and Continuous U-duality Orbits in N=8 Supergravity.", Class.Quant.Grav. 27 (2010) 185003 arXiv:1002.4223 [hep-th]
21. M. Bianchi, S. Ferrara and R. Kallosh "Observations on Arithmetic Invariants and U-Duality Orbits in N =8 Supergravity", JHEP 1003 (2010) 081 arXiv:0912.0057 [hep-th].
22. L. Andrianopoli, R. D'Auria, S. Ferrara and M. Trigiante, "Fake Superpotential for Large and Small Extremal Black Holes", JHEP 1008 (2010) 126 arXiv:1002.4340 [hep-th].
23. D. Cassani, S. Ferrara, A. Marrani, J. F. Morales and H. Samtleben, "A Special road to AdS vacua", JHEP 1002 (2010) 027 arXiv:0911.2708 [hep-th].
24. S.Ferrara, A. Marrani, and E. Orazi, "Maurer-Cartan Equations and Black Hole Superpotentials in N = 8 Supergravity", Phys.Rev. D81 (2010) 085013 arXiv:0911.0135 [hep-th]
25. M. Bianchi , S. Ferrara and R. Kallosh , "Perturbative and Non-perturbative N =8 Supergravity", Phys.Lett. B690 (2010) 328-331 arXiv:0910.3674 [hep-th].
26. A. Ceresole, G. Dall'Agata , S. Ferrara and A. Yeranyan, "Universality of the superpotential for d = 4 extremal black holes", Nucl.Phys. B832 (2010) 358-381 arXiv:0910.2697 [hep-th]
27. A. Ceresole, G. Dall'Agata, S. Ferrara and A. Yeranyan "First order flows for N=2 extremal black holes and duality invariants", Nucl.Phys. B824 (2010) 239-253 arXiv:0908.1110 [hep-th]
28. S. Ferrara, R. Kallosh and A. Van Proeyen, "Conjecture on Hidden Superconformal Symmetry of N=4 Supergravity," Phys. Rev. D **87**, 025004 (2013) [arXiv:1209.0418 [hep-th]].
29. W. Chemissany, S. Ferrara, R. Kallosh and C. S. Shahbazi, "N=2 Supergravity Counterterms, Off and On Shell," arXiv:1208.4801 [hep-th].

4 Report for Graciela Gelmini

I have continued working on several problems at the interface between elementary particles and cosmology-astrophysics, in particular dark matter (DM) abundance and detection, neutrino astrophysics and cosmology and ultrahigh energy cosmic rays and neutrinos.

Research

New DM candidates: "Inert-Sterile" neutrinos as warm and cold dark matter

In usual particle models sterile neutrinos can account for the DM of the Universe only if they have masses in the keV range and are warm DM. However, small variation of the simplest neutrino models can produce sterile neutrinos which could be the DM for different ranges of masses and coupling. S. Palomares-Ruiz (CFTP, Lisboa, Portugal), E. Osoba and I studied one of these variations [1] within the "inert doublet model"(E. Ma 2006). The lightest sterile neutrino in the model we studied can account for the DM in the Universe, can be either cold or warm DM, according to details of the model, could have mass in the range of MeV and above and would be stable, thus not subjected to bounds derived from X-ray observations. This candidate would not be detectable in DM direct or indirect searches.

Astrophysics done with neutrinos:

A. Erkoca (Arizona U.), M. H. Reno (Iowa State U.), I. Sarcevic (Arizona U.) and I [2] evaluated the rate of contained events, upward muon events and contained shower event rates from the interactions of neutrinos produced from DM annihilation in the Galactic Center, of relevance to Ice Cube and future neutrino detectors such as the KM3NeT.

T. Weiler (Vanderbilt U.), A. Kusenko and I wrote a Scientific American article [3] in the May 2010 issue, about the astrophysics and cosmology that will be done in the future using neutrinos as messengers. The article was also published in German in the July 2010 issue of the "Spektrum der Wissenschaft" magazine

Relevance of ion-channeling in direct DM detection:

Channeling fractions:

"Channeling" occurs when ions propagate inside a crystal along symmetry axes and planes. Channeled ions give 100% of their energy to electrons, producing more scintillation and ionization than they would produce otherwise. In direct DM searches, channeling occurs when the nuclei that recoil after being hit by DM particles move off in a direction close to a symmetry axis or symmetry plane of the crystal. The potential importance of this effect for direct DM detection was first pointed out for NaI(Tl) by Drobyshevski in 2007 and soon after by the DAMA collaboration [4].

P. Gondolo, N. Bozorgnia and I used analytical models of channeling developed since the 1960's to evaluate upper bounds to the fraction of channeled recoils as function of the energy for NaI, Si and Ge, CsI, and solid Xe, Ar and Ne [5]. We found that channeling fractions are much smaller than those in the estimates of the DAMA coll. The reason is that the recoiling ions start from lattice sites, thus the "blocking" effect, neglected in the DAMA calculation, is very important. "Blocking" is the reduction along symmetry axes and planes of the flux of ions originating in lattice sites due to the shadowing effect of the lattice atoms directly in front of the emitting lattice site.

Light WIMPs:

There is intense interest at present on the possibility of "light WIMPs". Already in 2004-2005 P. Gondolo and I pointed out that, in spite of many claims to the contrary, the annual modulation signal observed by the DAMA/NaI collaboration, interpreted as a signal of DM WIMPs, was still compatible with the negative results of all other DM searches, for light WIMPs in the mass range 5–9 GeV [6]. Now also data from CoGeNT, CRESST and CDMS-II (Si) point to light WIMPs too.

The incorrect estimate given by the DAMA coll. [4] of the channeling fraction of recoiling ions implied that the region of light WIMPs shifted considerably to lower cross sections, by about one order of magnitude, putting the region in agreement with the region implied by other data. In Ref. [7] Savage, Gondolo, Freese and I (besides studying the limits imposed by XENON10 and 100) showed that with the new evaluation of channeling [5], this effect is not important at less than 5σ level.

Daily modulation due to channeling:

The channeling fraction depends on the velocity distribution of WIMPs in the dark halo of our galaxy, and could lead to a daily modulation of the signal in direct DM crystalline detectors, an idea first suggested by Avignone, Creswick and Nussinov in 2008 and 2010 [8]. N. Bozorgnia, P. Gondolo and I computed in Ref. [9] the expected amplitude of the daily modulation due to channeling in particular, in the data already collected by the DAMA/NaI and DAMA/LIBRA experiments. We found that the modulation amplitudes are not observable at the 3σ level for a standard halo in the 13 years of data taken by the DAMA coll.

Novel Features in Directional DM Detection

Directional detectors can measure the direction on the nuclear recoil due to WIMP collisions and not only the recoil energy. The same techniques Bozorgnia, Gondolo and I developed to carry out the calculations described in Section 3.3 allowed us to understand features that will characterize the observation of DM in directional detectors [10]. One of these features is a ring of maximal rate around the average recoil direction which in principle could be used as an additional indication of the WIMP mass range. Others are "aberration" features, due to the motion of the Earth around the Sun, in particular the Galactic Hemisphere Annual Modulations (GHAM) with amplitudes larger than the usual non-directional annual modulation.

Ultra-High Energy Neutrinos and Cosmic Rays

O. Kalashev (INR, Moscow), D. Semikoz (APC, Paris) and I collaborated between 2004 and 2007 in several papers [11] devoted to photons as Ultra-High Energy Cosmic rays (UHECR), and used by the Pierre Auger collaboration papers on the subject. Recently we studied neutrinos with the same, although upgraded, code we used earlier. In Ref.[12] we presented the maximum cosmogenic neutrino fluxes which can be expected in neutrino telescopes (such as IceCube, ANITA, LM3NeT, ARA and JEM-EUSO). These correspond to models in which the UHECR are mostly protons. One such model, consistent with the spectrum and composition measurements of HiRes, the so called "dip" model, which assumes that the UHECRs above 10^{18} eV consist exclusively of protons. We showed that the largest fluxes predicted in the dip model would be detectable by IceCube in about 10 years of observation and are within the reach of a few years of observation with the ARA project.

As member of the Auger collaboration I signed several papers in the last three years. I am no longer a member of that collaboration since the beginning of 2011.

Dark Halo Model independent comparisons of direct DM detection data

The recoil rate of all direct DM detectors depends on the local dark halo properties only through in the same product $\rho\eta(v_{min}, t)$, where ρ is the local WIMP density and $\eta(v_{\rm min}, t)$ is a function of $v_{\rm min}$, the minimum WIMP speed necessary to produce a particular recoil energy. This allows all rate measurements or upper bounds to be mapped into the $v_{\rm min}$, $\rho\eta(v_{min}, t)$ space to compare them without making any assumption about the halo model, as first proposed by Fox, Liu, and Weiner in 2010 and then employed by Frandsen et al. in

2011.

In Ref. [13] P. Gondolo and I extended this method by including energy resolution, efficiency, and form factors with arbitrary energy dependence. We compared the results of all direct detection experiments relevant for "Light WIMPs" with spin independent interactions. In Ref. [14] a recent potential signal of Light WIMPs in CDMS-II Si data was included.

Asymmetric DM in non-standard pre BBN cosmologies

The earliest episode in the history of the Universe from which we have data is Big Bang Nucleosynthesis but the relic abundance of DM particles is determined before. In Ref.[15] J-H. Huh and T.Rehagen and I explored the potential changes in the relic abundance of the minority component of asymmetric DM and showed that, contrary to what happens with the standard cosmological assumptions, in non-standard pre BBN cosmologies the present annihilation rate of asymmetric DM can be non-negligible and in some instances even larger than for symmetric DM with the same annihilation cross section in the standard cosmology.

Service and outreach:

In the past three years I have served as a member of the High Energy Physics Advisory Panel (HEPAP), as member of NSF HEP Theory and Cosmology Advisory Panels in Feb. 2011 and March 2012 and March 2013, as member of the Aspen Center for Physics (where I belonged to several committees and was chair of the 2011 Winter Program Committee and of the Diversity Committee in 2012). During my last year at HEPAP (2011) I was chair of the Demography Committee. I regularly review proposals for NSF and DOE and act as referee for several scientific journals. I am co-organizing a workshop on Dark Matter at the Aspen Center for Physics in August 2013 and a three month workshop on neutrino physics at KITP Santa Barbara in the Fall of 2014.

With respect to outreach, with T. Weiler and Kusenko I wrote a Scientific American article "Through neutrino eyes," in 2010 (as I mentioned above) and recently I gave a seminar for general public, in italian, about cosmology.

References for Graciela Gelmini

[1] G. B. Gelmini, E. Osoba and S. Palomares-Ruiz, Phys. Rev. D **81**, 063529 (2010) [arXiv:0912.2478 [hep-ph]].

[2] A. E. Erkoca, G. Gelmini, M. H. Reno and I. Sarcevic, Phys. Rev. D **81**, 096007 (2010) [arXiv:1002.2220 [hep-ph]].

[3] G. B. Gelmini, A. Kusenko and T. J. Weiler, "Through neutrino eyes," Sci. Am. **302N5**, 20-27, May issue (2010).

[4] R. Bernabei *et al.*, Eur. Phys. J. C **53**, 205 (2008) [arXiv:0710.0288 [astro-ph]]

[5] N. Bozorgnia, G. B. Gelmini, P. Gondolo, JCAP **1011**, 019 (2010) [arXiv: 1006.3110];

[6] G. Gelmini, P. Gondolo, [hep-ph/0405278];

[7] C. Savage, G. Gelmini, P. Gondolo, K. Freese, Phys. Rev. **D83**, 055002 (2011). [arXiv:1006.0972 [astro-ph.CO]].

[8] F. Avignone, R. Creswick, S. Nussinov, [arXiv:0807.3758 [hep-ph]];

[9] N. Bozorgnia, G. B. Gelmini, P. Gondolo, Phys. Rev. **D84**, 023516 (2011). [arXiv:1101.2876 [astro-ph.CO]].

[10] N. Bozorgnia, G. B. Gelmini and P. Gondolo, JCAP **1206**, 037 (2012) [arXiv:1111.6361]

[11] G. Gelmini, O. Kalashev and D. V. Semikoz, JETP **106**, 1061-1082 (2008);

[12] G. B. Gelmini, O. Kalashev and D. V. Semikoz, JCAP **1201**, 044 (2012) [arXiv:1107.1672 [astro-ph.CO]]

[13] P. Gondolo and G. B. Gelmini, JCAP **1212**, 015 (2012) [arXiv:1202.6359 [hep-ph]].

[14] E. Del Nobile, G. B. Gelmini, P. Gondolo and J. -H. Huh, arXiv:1304.6183 [hep-ph].

[15] G. B. Gelmini, J. -H. Huh and T. Rehagen, arXiv:1304.3679 [hep-ph].

5 Report for Alexander Kusenko

Research

Learning from the highest-energy natural accelerators

DOE-funded *Pierre Auger Observatory* has reported new puzzling data regarding the composition of ultrahigh-energy cosmic rays. In a recent Phys. Rev. Letter [5] which I co-authored with my Ph.D. student A. Calvez and with S. Nagataki (U. of Kyoto), we pointed out a likely connection between the data reported by *Pierre Auger Observatory* and past supernova, hypernova, or gamma-ray bursts in our own Milky Way galaxy. This connection opens a way for a new kind of “astro-archeology”, and it will help separate extragalactic sources from those in the past of our own galaxy.

Gamma-ray telescopes, including DOE-funded Fermi and VERITAS, provide important information about the particle interactions at high energies. These telescopes have reported some surprising observations of multi-TeV photons from distant active galactic nuclei (AGN). The data were surprising because the spectra showed no significant attenuation due to pair production in interactions with extragalactic background light (EBL). These observations have led to a debate as to whether one should reconsider the calculations of EBL. However, even if EBL is thinner and softer, the observations are difficult to reconcile with the expected absorption. The unusual transparency of the universe to TeV gamma rays from distant blazars has given rise to explanations involving new physics, such as hypothetical axion-like particles or violation of Lorentz invariance. Of course, “extraordinary claims require extraordinary evidence”. In this particular case, we have found a standard explanation based on Standard Model physics. Our new understanding has opened some new opportunities for learning about the universe.

In a series of recent papers co-authored with my student W. Essey and several other collaborators, I showed that no new physics is, in fact, required to explain the data [1, 3, 7, 8, 10, 12, 14]. Powered by supermassive black holes, blazars are expected to produce both gamma rays and cosmic rays. Therefore, observed high-energy gamma rays from distant blazars may contain a significant contribution from secondary gamma rays produced along the line of sight by the interactions of cosmic-ray protons with background photons. This explains the surprisingly low attenuation observed for distant blazars, because the observed secondary gamma rays are produced, on average, much closer to Earth than the distance to the source.

This explanation is confirmed by a growing number of blazar spectra as shown by us, as well as several other authors, who have joined the investigation of the mechanism Essey and Kusenko have proposed. A recent (2013) measurement of blazar PKS 1424+240 redshift $z \geq 0.6$, combined with the VERITAS observations of very high energy gamma rays with a hard spectrum provide a strong additional piece of evidence in favor of our mechanism, because the implied optical depth to primary photons is greater than 5.

Our new interpretation of blazar spectra opens a way for measuring intergalactic magnetic fields deep in the voids [8]. These magnetic fields are the closest measure of the seed magnetic fields created in the Big Bang from inflation, a phase transition, or some other process involving physics beyond the standard model. Our measurements of magnetic fields in the femtogauss range have inspired several new models of primordial magnetogenesis.

Dark matter

Identifying the nature of cosmological dark matter is recognized as one of the most important scientific problems. Although we know that most of the matter in the universe is not made of ordinary atoms, the identity of dark matter remains a mystery. Since the interactions of dark-matter particles, except for their gravitational interactions are unknown, one must pursue different candidates motivated by theory and experiment, such as axions, weakly interacting massive particles (WIMP), supersymmetric Q-balls (which originated from my earlier work), sterile neutrinos, gravitinos, moduli, etc. My recent work addressed five of the dark-matter candidates listed above.

Together with my collaborators at Kavli IPMU, I have pointed out the possibility of a PeV dark matter, whose decay may explain the PeV neutrinos recently discovered by IceCube [16].

Dark matter emergence from the neutrino sector

Theoretical motivation for sterile neutrinos comes from the need for additional, non-interacting "right-handed" neutrinos to explain the masses of ordinary ("active") neutrinos. The most compelling explanation is based on the *seesaw* mechanism, according to which at least two sterile states should exist at a very high mass scale. In a recent paper [6] which I co-authored with F. Takahashi and T. Yanagida, we showed that it is natural for the third sterile neutrino to have a much lower mass, in which case it plays the role of cosmological dark matter. The model hypothesizes the existence of the fifth dimension. For a fermion localized on a distant brane, both the Yukawa coupling and the Majorana mass are exponentially suppressed by the smallness of the wave function overlap with the standard model brane. However, the suppression is such that the ratio of the Yukawa coupling squared to the Majorana mass is not affected. So, the successful seesaw formula still applies, but both the mass and the mixing angle in the low-energy 4-dimensional effective theory can be much smaller than the Planck scale. The resulting democracy of scales implies that the seesaw mechanism can naturally explain the smallness of neutrino masses for an arbitrarily small right-handed neutrino mass. If the scales of the seesaw parameters are split, with two right-handed neutrinos at a high scale and one at a keV scale, one can explain the matter-antimatter asymmetry of the universe, as well as dark matter in this simple model.

A dedicated dark matter search using X-ray telescopes in space

I initiated the first dedicated dark matter search using X-ray telescopes in space. Although archival data were used by particle physicists in the past to set constraints on dark matter, no one scheduled dedicated observations of optimized targets with X-ray telescopes and analyzed the data with the purpose to search for dark matter. I teamed up with an X-ray astronomer Michael Loewenstein (NASA), and we applied for observing time and conducted observations on all three X-ray telescopes in space, namely *Suzaku*, *Chandra*, and *XMM-Newton*, for more than 400 kiloseconds. Deep, long-exposure observations of dark-matter-dominated systems are optimized to search for dark matter. The targeted dark-matter candidates include sterile neutrinos, string moduli, and weakly interacting massive particles (WIMP). We published our first results in Refs. [2, 13].

String moduli as dark matter

The X-ray data can also be useful to search for dark matter in the form of string-theory moduli. String theory and global supersymmetry (whether emerging from string theory or unrelated to strings) predict the existence of light scalar fields that are abundantly produced in the early universe. In most models, the overproduction of moduli is problematic. However, T.T. Yanagida (Kavli IPMU, Japan) and I are exploring an exciting possibility that this generic class of particles can be dark matter with just the right abundance to agree with the data. Our preliminary findings indicate that, as long as the Higgs boson mass is close to 126 GeV, the dark moduli masses should be in the range (1–100) keV. This is ideal for a search using the X-ray telescopes, building on our experience with sterile neutrinos.

In collaboration with M. Loewenstein (NASA) and T.T. Yanagida (Kavli IPMU, Japan), I will pursue both the theoretical understanding of this possibility and the limits that can be obtained with the help of existing X-ray telescopes, as well as the new X-ray telescope, *Astro–H*, which will become operational during the time period covered by this proposal. My contribution will be theory, while the data collection and analysis will be done by M. Loewenstein (NASA).

A new signature of cosmic nuclear accelerators

In a recent paper, M. Voloshin (U. Minnesota) and I described a new signature which can be used to identify astrophysical sources of high-energy nuclei using a characteristic feature in their gamma-ray spectrum [9]. Astrophysical sources of nuclei are expected to produce a broad spectrum of isotopes, many of which are unstable. An unstable nucleus can beta-decay outside the source into a single-electron ion. Heavy one-electron ions, thus formed, can be excited in their interactions with cosmic microwave background photons, in which case they relax to the ground state with the emission of a gamma ray. Repetitive cycles of excitation and gamma-ray emission can produce an observable feature in the gamma-ray spectrum with a maximum around 5 GeV (for iron). We find that the observed spectrum of Centaurus A is consistent with a substantial flux of nuclei accelerated to 0.1 EeV and higher energies, and that the effect they described can explain the spectral shape around 8 GeV. A characteristic 8 GeV (iron) shoulder in the gamma-ray spectra of other sources can help identify astrophysical accelerators of nuclei or set upper limits on nuclear acceleration.

Inflation and the primordial seeds of supermassive black holes

Supermassive black holes exist in the centers of galaxies, including Milky Way, but there is no compelling theory of their formation. Furthermore, observations of quasars imply that supermassive black holes have already existed at some very high redshifts, suggesting the possibility of their primordial origin.

Together with Kawasaki and Yanagida (Kavli IPMU, Japan), I proposed a viable cosmological scenario that can explain the formation of these remarkable objects [11]. In a class of well-motivated models, inflationary epoch could include two or more periods of inflation dominated by different scalar fields. The transition between such periods of inflation could enhance the spectrum of density perturbations on some specific scale, which could lead to formation of primordial black holes with a very narrow range of masses of the order of 10^5 solar masses. These primordial black holes could have provided the requisite seeds for the observed population of supermassive black holes. We will explore the implications of this scenario for theories of the early universe.

Particle physics and collider phenomenology

Together with a UCLA student L. Pearce, and UCLA faculty members J. Cornwall and R. Peccei, I studied a strongly-coupled phase of the minimal supersymmetric standard model (MSSM) [15]. This project arose from my earlier work, which has received additional strong motivation by the evidence of a 125 GeV Higgs boson from LHC. The Higgs boson mass of 125 GeV is difficult to reconcile with supersymmetry, because the lightest Higgs boson mass should be lower in the MSSM. Large tri-linear supersymmetry breaking couplings have been invoked to increase the Higgs boson mass in the MSSM. However, as my collaborators and I have shown some time ago, large tri-linear couplings can lead to a formation of bound states of squarks (due to the Higgs boson exchange), which can have the quantum numbers of the Higgs bosons and which can have a non-zero VEV. As a result, MSSM can be realized at low energy as an effective theory with fewer squarks and with some extra *composite* Higgs bosons. Furthermore, the 125 GeV Higgs mass is no longer problematic in this case, thanks to the way supersymmetry breaking triggers electroweak symmetry breaking [15].

Service and outreach

August 3, 2011	Public lecture at *Family BBQ, Aspen Center for Physics*, shown on local TV and available at http://www.grassrootstv.org
March 24, 2011	Public lecture, Bigfoot Studios, Cebu, Philippines
August 28, 2010	Public lecture, Mt. Wilson Observatory Association, Pasadena, CA

I co-authored a Scientific American article with G. Gelmini and T. Weiler [4]. My research results were highlighted in *Nature* (2010), *Science* (2010), *Scientific American* (2010 and 2011), UCLA News (2010), IPMU News (2010).

- Served on the organizing committee for *Snowbird Particle Astrophysics and Cosmology (SnowPAC) conferences in 2010, 2011, 2012, 2013*, Snowbird, Utah.
- Chaired the organizing committee for *Particle Astrophysics and Cosmology, Including Fundamental InteraCtions (PACIFIC)* conference, 2011 and 2012.

- Co-organized a focus week *Astrophysics of dark matter* at IPMU, Japan, May 30 – June 3, 2011.
- Chaired and served on a number of committees for Aspen Center for Physics
- Served as a convener for a subsection of Snowmass-2013 community study.

My work of the last few years has received a lot of attention in the scientific community. I was invited to speak at a number of international conferences. I was also invited to give the following departmental colloquia:

April 4, 2011	Colloquium, LNS, MIT, Cambridge, MA
November 9, 2010	Colloquium, Carnegie Observatories, Pasadena, CA
October 7, 2010	Physics Colloquium, University of Toronto, Canada
September 8, 2010	Cockroft Colloquium, Daresbury Laboratory, Warrington, UK

In 2012 I was awarded an *Outstanding Referee* award by American Physical Society (of which I am also a *Fellow*).

References for Alexander Kusenko

[1] W. Essey and A. Kusenko, Astropart. Phys. **33**, 81 (2010) [arXiv:0905.1162 [astro-ph.HE]].

[2] M. Loewenstein and A. Kusenko, Astrophys. J. **714**, 652 (2010) [arXiv:0912.0552 [astro-ph.HE]].

[3] W. Essey, O. E. Kalashev, A. Kusenko and J. F. Beacom, Phys. Rev. Lett. **104**, 141102 (2010) [arXiv:0912.3976 [astro-ph.HE]].

[4] G. B. Gelmini, A. Kusenko and T. J. Weiler, Sci. Am. **302N5**, 20 (2010).

[5] A. Calvez, A. Kusenko and S. Nagataki, Phys. Rev. Lett. **105**, 091101 (2010) [arXiv:1004.2535 [astro-ph.HE]].

[6] A. Kusenko, F. Takahashi and T. T. Yanagida, Phys. Lett. B **693**, 144 (2010) [arXiv:1006.1731 [hep-ph]].

[7] W. Essey, O. Kalashev, A. Kusenko and J. F. Beacom, Astrophys. J. **731**, 51 (2011) [arXiv:1011.6340 [astro-ph.HE]].

[8] W. Essey, S. Ando and A. Kusenko, Astropart. Phys. **35**, 135 (2011) [arXiv:1012.5313 [astro-ph.HE]].

[9] A. Kusenko and M. B. Voloshin, Phys. Lett. B **707**, 255 (2012) [arXiv:1109.0565 [astro-ph.HE]].

[10] W. Essey and A. Kusenko, Astrophys. J. **751**, L11 (2012) [arXiv:1111.0815 [astro-ph.HE]].

[11] M. Kawasaki, A. Kusenko and T. T. Yanagida, Phys. Lett. B **711**, 1 (2012) [arXiv:1202.3848 [astro-ph.CO]].

[12] A. Prosekin, W. Essey, A. Kusenko and F. Aharonian, Astrophys. J. **757**, 183 (2012) [arXiv:1203.3787 [astro-ph.HE]].

[13] M. Loewenstein and A. Kusenko, Astrophys. J. **751**, 82 (2012) [arXiv:1203.5229 [astro-ph.CO]].

[14] F. Aharonian, W. Essey, A. Kusenko and A. Prosekin, Phys. Rev. D **87**, 063002 (2013) [arXiv:1206.6715 [astro-ph.HE]].

[15] J. M. Cornwall, A. Kusenko, L. Pearce and R. D. Peccei, Phys. Lett. B **718**, 951 (2013) [arXiv:1210.6433 [hep-ph]].

[16] B. Feldstein, A. Kusenko, S. Matsumoto and T. T. Yanagida, arXiv:1303.7320 [hep-ph].

UCLA Task E Final Report, June 2013
Hadron Collider Physics

Robert Cousins, Jay Hauser, David Saltzberg, and Rainer Wallny

1 Task E Overview

In this final report, we focus on the progress in the last project period of the grant (1/15/2010 – 1/14/2013, extended to 4/30/2013), with some historical information for context. During this period our group has been devoted entirely to CMS operations, management, hardware improvements, event reconstruction, and of course physics analysis. Most members of the group are either resident at CERN or spend a large fraction of time there, so that we are embedded into a number of key efforts in CMS. With Robert Cousins having rotated out of the CMS Deputy Spokesperson position into influential physics data analysis roles, UCLA still retains two seats on the CMS Executive and Management Boards with Jay Hauser continuing as Muon CSC Project Manager and Greg Rakness taking on a new role as Deputy Run Coordinator. Meanwhile David Saltzberg has taken on major responsibilities in the new CSC chamber construction. Slava Valuev served a two-year term as CMS Muon Physics Object Group Co-convener (with a seat in Physics Coordination) and is now co-convener of Exotica analyses focusing on leptonic signatures of resonances.

Our team has a broad range of commitments that form a coherent whole around the unifying theme of muons in CMS. Muons are a key to much of the physics potential of CMS, whether it be the Higgs boson, supersymmetry, Z′ and W′ bosons, top and bottom quark physics, or other new physics involving leptons. Our group is deeply involved in muon detection, triggering, simulation, reconstruction, and physics analysis. In first CMS physics analyses, we focused our efforts on Z′ and W′ bosons and on top quark physics. Since then, while continuing with Z′ analyses, we have put new emphasis on signatures associated with supersymmetry (SUSY) or other new physics, notably multi-lepton searches and long-lived heavy stable charged particles. We also are working closely with UCLA theorist Zvi Bern and his BlackHat colleagues on the physics of events with vector bosons plus jets, a key background to understand for a convincing discovery of new physics. Finally, while we have not been directly performing the search for Higgs decays, our underlying work on muons is crucial to the discovery, and one of us has been deeply involved in the internal review of the results for both the discovery of the new boson and its characterization. Rainer Wallny was an active faculty member in the group during the first year covered by this report, but left UCLA in October 2010 after accepting a high-level position at ETH Zurich. In addition to his other activities on CMS, Rainer was a world leader in developing diamond detector technology that is used by CMS for beam-condition monitoring, and which is a possibility for luminosity measurements and for future high-luminosity detector upgrades.

1.1 Personnel working on Task E efforts

The members of Task E during the three-year project period (with those who left before April 30, 2013 noted as “departed”) are as follows:

- **Faculty**: Robert Cousins, Jay Hauser, David Saltzberg, and Rainer Wallny (departed).

- **Faculty "Affiliate Member" of CMS** Zvi Bern (funded under Task C)
- **Postdoctoral/short-term staff physicists**: Amanda Deisher (departed), Chad Jarvis (departed), Charles Plager 50% (departed), Gregory Rakness, Viatcheslav Valuev, Matthias Weber, Peter Everaerts, Piotr Traczyk (departed).
- **Graduate students**: Joe Duris (departed), Chris Farrell, Eric Takasugi, Jordan Tucker (departed).
- **Undergraduates**: Taylor Barrella (departed), Jacob Beres (departed), Andrew Peck, Alan Tran.
- **Engineer**: Jonathan Kubic (supported by US-CMS M&O Project and this Task).
- **Administrative Assistant**: Cassandra Gonzalez (support shared with other Tasks and with UCLA Dept. of Physics and Astronomy).
- **Science Administrator**: James Kolonko; most of his support for partial retirement recall is from UCLA Dept. of Physics and Astronomy. Juleen Moon is starting to replace Kolonko, also supported by the department.

1.2 Summary of Task E work in the project period

The items below very briefly summarize the achievements of Task E personnel from the last project period (1/15/2010 – 4/30/2013); more complete descriptions are then provided in the sections that follow.

Section 2 Leadership roles in CMS: members of our group taking on high-level leadership roles within the collaboration include Hauser as Muon CSC Project Manager; Rakness previously as CSC Operations Manager and now Deputy Run Coordinator for all of CMS; Valuev as previous co-convener of the Muon Physics Object Group is now co-convener of Exotica analyses focusing on leptonic signatures of resonances; and Cousins as past Chair (2010 and 2011) and an intellectual leader of the CMS Statistics Committee, which gives (often urgent) advice on CMS papers.

Section 3 CMS muon CSC electronics: Hauser's team, especially engineer Kubic, built a large number of sophisticated trigger and readout electronics boards, and continues to maintain them and their associated firmware using test facilities at UCLA.

Section 4 CMS data analysis tools development: Our UCLA group wrote and maintains the CSC trigger emulation code (Jarvis and Valuev). Likewise, we created and maintain the CSC online timing procedures and offline timing reconstruction (Deisher, Farrell, Everaerts), and gas gain calibrations for CSC dE/dX reconstruction (Rakness). We also developed common tools for high-mass dilepton analysis (Tucker). The CSC upgrades now require substantial modification to both the trigger emulation and the CSC timing software.

Section 5 CMS physics analysis: Cousins, Tucker, and Valuev played key leadership roles in the preparation and first CMS published Letter on the search for high-mass dilepton resonances; UCLA continues to have to have a major impact. Jarvis, with Hauser, were active members of the team performing the published 2011 W′ search. Farrell was the lead analyzer in the published 2011 search for heavy stable charged particles

(HSCP) in CMS using muon time-of-flight and tracker dE/dX, and is now solely responsible for extension of the analysis to neutral-in-tracker particles in the 2012 HSCP data analysis. Saltzberg, Weber, and Takasugi are working closely with Zvi Bern to compare their full NLO calculation of the kinematics of Z+jets to CMS data. Plager and Deisher simultaneously measured the top quark and W+jets production cross sections. Everaerts spear-headed UCLA's entry into analyses of multi-lepton searches for supersymmetry, for which Cousins was the editor of CMS's paper using 2011 data. Cousins has served since 2011 as a member of the internal review team for the CMS combined Higgs-search results.

Section 6 The UCLA group is deeply involved in preparing the CSC muon system upgrades for first LHC long shutdown (LS1 in 2013-2015). These upgrades are needed in order to maintain excellent triggering capabilities, high efficiency, and excellent position and time resolution in the face of increased background levels at luminosities well above the LHC design value of 10^{34} cm^{-2} s^{-1}. The need for new electronics is to recuperate the pseudorapidity range $2.1 \leq |\eta| \leq 2.4$, which has been hampered by front-end ganging of cathode strips. Hauser, with Kubic are building new, improved electronics and their associated firmware for the highest-rate ME1/1 muon station. Saltzberg, with Takasugi and Weber, has taken on major responsibilities for the construction and testing of 72 new muon chambers (station ME4/2) to improve high-luminosity muon trigger and reconstruction in the pseudorapidity range $1.2 \leq |\eta| \leq 1.8$.

Section 7 Diamond detector R&D: In 2010, Duris, Barrella, and Wallny participated in test beam studies at CERN within the RD42 collaboration in order to study radiation hardness of diamond detectors. Wallny was a proponent of a CMS wide-initiative to use diamond as a radiation hard material for distant future upgrades of the CMS pixel detector.

Section 8 CMS Service: As senior U.S. physicists with a large presence at CERN, Cousins and Hauser help out in various contexts, including significant time spent on internal reviews of CMS results. Our group members serve on a wide variety of online and offline shifts, assuring the quality of the data.

Section 9 Outside service and outreach: Cousins has served on two DOE laboratory review panels in the last three years, and has given two well-attended public lectures at UCLA on LHC physics. Saltzberg served on APS and IUPAP committees and aids the National Academy of Sciences as a consultant to their "Science and Entertainment Exchange". He is the physics consultant for the popular CBS program 'The Big Bang Theory' which features physicists as its main characters.

2 CMS Leadership Roles

2.1 Muon CSC Project Manager - Hauser

Since 2010, Hauser has been the Project Manager for the CSC muon subdetector and is thereby a member of the CMS Management Board and the Extended Executive Board, where the central issues facing CMS are brought up and discussed on a weekly basis. Hauser oversees CSC activities in three main areas: detector operations, detector performance assessment, and detector upgrades. The CSC group consists of about 150 scientists, engineers, and graduate students from numerous institutions. Clear communication with top CMS management is an important function of the job, and in part that is accomplished through weekly meetings of the CMS Extended Executive Board, as well as monthly meetings of the larger CMS Management Board. In order to be most effective at the task, Hauser moved to the Geneva area in summer 2010.

The CSC detector community consists mostly of U.S. Collaborators, but there are important international CMS contributions from JINR Dubna, PNPI St. Petersburg, and IHEP Beijing laboratories. There is an important financial relationship with the U.S. CMS Project office, and close contact is kept with the Level 2 CSC manager, Dick Loveless, as well as top U.S. CMS project management (Joel Butler, Cathy Newman-Holmes) on relevant financial and strategic matters. (The CSC muon system had an initial construction cost of more than $40 million, and has a yearly maintenance cost of several million dollars.)

Actual day-to-day activities as Project Manager vary considerably. Specific areas of oversight include alignment, trigger, data acquisition, reconstruction software, upgrades, detector services, and finances. Important connections to other groups include the Muon Physics Object Group (POG) (co-led for two years by Valuev) and the Level 1 and high-level trigger groups. In this role, it is important to connect regularly with each of the CSC scientists and engineers that are stationed in Geneva, and to optimize their work.

Numerous operational challenges were overcome in short order during the first run of the LHC as the luminosity climbed more than six orders of magnitude. The CSC subdetector now typically contributes a negligible amount of downtime to the CMS operations. Greg Rakness and Misha Ignatenko (the latter from Task H) were instrumental in the immediate success of the CSC system as a running detector. Various capabilities have been added that were not foreseen in the Technical Design Report, including much better timing (due mainly to Deisher and Farrell), and triggering capability in the high-pseudorapidity ($|\eta| > 2.1$) region (largely a U. Florida contribution).

At present, with LS1 underway in 2013 and 2014, planning for upgrades has become a major focus of the Project Manager job. In order to handle the higher signal and background rates of the High Luminosity LHC (HL-LHC), not only are 72 new ME4/2 chambers to be built and installed, but a complex series of operations needs to be performed in order to remove the 72 existing ME1/1 chambers, refurbish them with new electronics, and reinstall them.

2.2 CSC Muon Operations and CMS Run Coordination - Rakness

Rakness led the entire CSC commissioning effort from 2007 through 2011, coordinating the work of around 50 scientists, engineers, and technicians from many different institutions, including Carnegie Mellon, UC Davis, Dubna, Fermilab, Florida, IHEP Beijing, Ohio State, St. Petersburg, Rice, UC Riverside, Wisconsin, and others. In 2009-2011, Rakness had the official title of CSC Operations Manager (the position now held by Misha Ignatenko). Rakness was appointed as the new Deputy Run Coordinator for all of CMS for the 2012-2013 period. In this new role, Rakness is deeply involved in all aspects of CMS detector operation.

The 2010 run saw Rakness overseeing (or personally implementing) numerous changes to cope with the luminosity, which climbed six orders of magnitude, as well as substantial improvements in timing, readout efficiency, and trigger configuration. Even though the CSC system is large and complex, the reliability was very good, due in large part to Rakness' tireless efforts.

During 2011, the luminosity continued to increase by more than one order of magnitude, and additional challenges were seen such as neutron-induced backgrounds and higher current levels in the chambers. Rakness supervised a streamlining of CSC operations that puts more responsibilities on the central shift personnel of CMS, and automation of the high voltage reset procedure for chambers that trip off during current spikes.

Now, as Deputy Run Coordinator of all of CMS, Rakness maintains tight coordination between CMS detector operations, the LHC conditions and planning, and CMS upper management. Rakness has played a large part in reducing CMS detector downtimes, which were considerably reduced in 2012 from those in 2011 (now only a few percent), despite higher luminosity, equipment that has not been serviced for a long time, and diversion of critical personnel to data analysis on high-priority topics such as the search for the Higgs boson. He was also the key link person responsible for coordination of CMS detector activities with the LHC accelerator on a daily basis.

2.3 CMS Muon Physics Object Group Management - Valuev

CMS Muon Physics Object Group management and follow-up: In calendar years 2010 and 2011, Valuev served as co-convener of the Muon Physics Object Group (Muon POG), one of six Physics Object groups in CMS. In this leadership position, Valuev was responsible for all aspects of reconstruction of the muons that are central to many CMS discovery analyses, and was part of the central CMS Physics Coordination team reporting directly to the CMS Physics Coordinator. He continues to be deeply involved in muon-related issues, and was the lead editor on the official (63-page) CMS Muon Performance paper [1] published in JINST.

Valuev's appointment as Muon POG co-convener followed from the extensive work done by the UCLA group on muon reconstruction, including work that pioneered the use of muon chambers to improve TeV muon momentum measurement. The primary charge of the Muon POG is to develop and maintain various muon reconstruction, identification, and high-level trigger algorithms, and to measure their performance (efficiencies, resolutions, fake rates, etc.) In addition, the mandate of the group includes a wide range of more technical tasks, such as developing muon data quality monitoring (DQM), certifying quality of muons in collision runs, and managing the storage space on the Tier-2 computing centers assigned to the group. The two conveners are responsible for all activities of the group and report to the CMS Physics Coordinator.

In 2011, the top priority for the group was to study the muon reconstruction performance with 7 TeV collision data. This wealth of data provided a solid ground for detailed studies of muons in a wide range of transverse momentum p_{T}, carried out under Valuev's guidance. For example, the efficiencies of various muon reconstruction, selection, and trigger algorithms could be measured with high precision both at low p_{T} (using muons from J/ψ decays) and in the p_{T} range from 20 to about 100 GeV/c (using muons from Z^0). Other important results include measurements of probabilities for various types of hadrons to be misidentified as muons, and of muon momentum scale and resolution. Measurements of these and other muon-related quantities based on 2010 data are documented in a 63-page paper [1] in JINST.

As the instantaneous luminosity of the LHC continued to grow, muon trigger algorithms and paths needed to be re-optimized to keep the trigger rate under control while maintaining the efficiency for interesting physics processes high. This work had a direct impact on our group's discovery-physics searches (Sec. 5) in which Valuev has been deeply involved again since his Muon POG term ended.

2.4 CMS Statistics Committee - Cousins

Since 1983, Cousins has been teaching a graduate seminar on data analysis, which over the years has led to a significant impact on statistical practice in HEP. His papers with Virgil Highland [2] and with Gary Feldman [3] are two of the most widely cited statistics papers in HEP, with 398 and 1586 citations, respectively, in the INSPIRE database. Cousins has been an active member of the CMS Statistics Committee since its inception while he was co-spokesperson, and he served as chair in 2010 and 2011. The Statistics Committee advises the collaboration on a wide range of issues, both conceptual and practical, which over time has led to a convergence on default methods for many problems, while emphasizing the usefulness of trying more than one method. As CMS began putting out dozens of physics papers with colliding proton-proton beam data, statistics issues were often at the forefront. As the only member of the committee based at CERN most of the year, Cousins is able to respond personally and quickly to many requests for ad hoc meetings to help sort out issues which range from complex unfolding algorithms for jet physics, to search methods for new dijet resonances, and since 2011 to the reviews of CMS's search for the Higgs boson.

3 CMS Muon CSC Electronics Maintenance

UCLA designed and built 1700 high-speed electronics boards that handle trigger and data acquisition functions for the CSC muon detector of CMS. These boards come in three general types: ALCT boards that handle trigger and readout for anode wire groups, TMB boards that handle trigger and trigger-readout for cathode strips, and RAT interface boards. As these are programmable boards, UCLA provides occasional firmware updates, especially for the TMB boards, and continues to maintain and repair all of the boards as necessary.

The CSC trigger hardware is highly configurable and requires a large amount of firmware for optimal running. For example, the TMB board alone has more than one hundred configuration registers. Engineer Jonathan Kubic maintains the CSC trigger electronics firmware modifications that are needed from time to time. The firmware improvements are supported by analysis and emulation code from Slava Valuev.

Kubic not only maintains the electronics boards and firmware, but also supplies well-commented testing software that is ported by Rakness for use in the CERN environment, and writes well-detailed specifications documentation.

4 CMS Data Analysis Tools

The UCLA group has developed a number of important tools needed to check and monitor raw data, and to turn raw data into data that is directly useful for physics analysis. The following sections describe some of these tools.

4.1 CSC Muon Timing

The UCLA group has taken full responsibility for the CSC muon timing ever since the cosmic ray data runs of 2008. The original goals for CSC timing were to trigger on the correct bunch crossing with more than 99% efficiency. Our UCLA group has gone well beyond that by careful improvements to the timing algorithms and calibration, now attaining bunch crossing identification better than 99.9%, and timing of 3 ns (RMS) per station and 1.8 ns per muon track. This precision in timing has in turn enabled searches for slow-moving heavy stable particles using the CSC muon system (Sec. 5.3), and is useful in rejecting muon backgrounds from beam halo and albedo particles.

The improvements have required numerous changes to firmware (Kubic), online timing procedures and constants (Rakness), development of offline timing reconstruction algorithms for both cathode (Deisher) and anode (Farrell) data, and careful timing calibration (Farrell). The timing of the CSC system has been stable, requiring only occasional monitoring to track sub-ns timing shifts.

Farrell took the lead on the CSC timing in the course of collecting the data for his thesis analysis on heavy stable charged particles. Farrell has improved the Monte Carlo timing simulation, has accounted for run-to-run timing variations, and has made special corrections (about 10 ns) for the small inner parts of the ME1/1 chambers. As a result of this work, Farrell won a prestigious CMS Achievement Award in 2011.

4.2 Emulation of the CSC Muon Trigger

The UCLA team continues to be responsible for the digital bit-for-bit emulation of UCLA-built Level-1 trigger hardware, as well as of the Muon Port Card (MPC) trigger boards built by Rice University. For many years the trigger emulator developed by UCLA has been used for optimization and testing of algorithms realized in the trigger electronics, and for evaluations of the trigger performance in the Monte Carlo based physics studies in CMS.

The emulation has proved to be capable of catching subtle mistakes in the CSC trigger decisions that no other tool could find.

5 CMS Physics Data Analysis

5.1 Overview

The year 2010 brought the first physics publications from collisions in CMS. In one of the highlights, UCLA's long-standing leadership in the search for high-mass dimuon resonances (Sec. 5.2) continued with the publication of CMS's search for high-mass dileptons using the 2010 data set (40 pb^{-1}) [4]. Already these data excluded Z' bosons with Standard Model couplings and masses up to about 1 TeV, beyond Tevatron limits. At the same time, Hauser and Jarvis contributed to CMS's search for W' bosons. As luminosity increased by orders of magnitude and the beam energy increased in 2012, substantial updates followed. The paper on the full statistics of 2011 (about 5 fb^{-1}) [5] was published in Physics Letters B, followed by another PLB paper with mid-year results from 2012 [6]. Preliminary results from the full 2012 data set [7] were presented in the winter 2013 conferences and extended the 95% U.L. lower limit on the Z' mass to 2960 GeV for a Z' with standard-model-like couplings. This is just one example in which the UCLA CMS group's deep involvement in the physics is symbiotic with our carrying out major technical accomplishments,

Our experimental work is a natural fit with UCLA theoretical work through the BlackHat project [8, 9, 10] of our theory colleague Zvi Bern and his collaborators. Blackhat is the only full NLO calculation of W/Z+jets production with up to 5 jets. (See Sec. 5.4.) Saltzberg, Takasugi and Weber are working with Bern and UCLA theory postdoc Kemal Ozeren to compare collider physics data with the predictions.

With the long tradition of UCLA's CDF group searching for SUSY in multi-lepton channels, and with the redirection of that activity to CMS, we are now pursuing our long-held plan of participating in multi-leptons searches for new physics in CMS (Sec. 5.5). This naturally included the study of top, both as a signal and a background (Sec. 5.6); UCLA's expertise in CDF top physics was also "ported" to CMS, with ideas that have advanced the state of the art.

Finally, although our postdocs and students have not had a direct analysis involvement in the search for the Higgs boson, Cousins has been deeply involved in the review of CMS's combined Higgs results (Sec. 5.7).

5.2 High Mass Muon Pairs

The small UCLA subgroup of Cousins, Valuev, and two successive Ph.D. students (Jason Mumford and Jordan Tucker) has been the driving force within CMS on the search for $Z' \to \mu^+\mu^-$ beginning with simulation studies in 2003. With this history (and our group's history in developing tools for TeV muon reconstruction), our group was of course central to the Z' search effort when LHC physics data came in 2010, and Cousins was co-editor of the first Z' search physics paper on 2010 data [4]. A welcome development with that paper was the complete integration of our dimuon analysis with the dielectron analysis of our CMS colleagues from other institutions.

Tucker has now moved on to a postdoc at Cornell, and Valuev performed the bulk of the dimuon analysis for the ICHEP conference in mid-2012, with some redundancy and value added provided by a student from Florida, a researcher at Dubna, and others. The fits themselves are done by postdoc Gena Kukartsev from Brown.

To keep our Z' search effort at full strength though the remainder of the acquisition and analysis based on 2012 data, we hired an experienced postdoc, Piotr Traczyk for the 11 months ending in April 2013. He was a key part of the CMS dimuon rapid-response team as data rolled in, chasing down anomalies and pursuing studies of muon resolution that become feasible as more high-mass continuum events are accumulated. As noted above, Preliminary results from the full 2012 data set [7] were presented in the winter 2013 conferences and extended the 95% U.L. lower limit on the Z' mass to 2960 GeV for a Z' with standard-model-like couplings.

5.3 Heavy Stable Charged Particle (HSCP) Search

As his main PhD thesis analysis topic, Farrell has been searching for heavy stable charged particles (HSCP, or sometimes called CHAMPs). These come in several varieties in theories of physics beyond the standard model. One variety, such as the stau of SUSY theory, is a high-mass charged particle which is not strongly interacting and happens to be a metastable object. These particles do not shower significantly in the calorimetry and pass through the muon system leaving trails of ionization just as a muon particle. Because of high mass, however, they travel with a speed significantly slower than the speed of light. Farrell also searched for strongly interacting R-hadrons that produce anomalously high dE/dx in the central tracking chamber but do not necessarily make it through the calorimeters to the muon system.

During the first LHC collisions in 2010, Farrell greatly refined the timing of the CSC chambers in order to make a time-of-flight measurement useful for the HSCP searches. In 2011, Farrell was the lead analyst for the published CMS paper (published in Physics Letters B [11]) that describes the HSCP search results based on 5 fb^{-1} of 7 TeV data. Now, in 2012, Farrell is the sole analyst in an ambitious extension of the HSCP search to particles that are produced as neutral and acquire a charge via the strong interaction in passing through the calorimeter and muon system; this search relies on muon-only tracking without confirmation from the inner silicon tracking, as well as missing energy.

In 2011, Farrell made several improvements to the previous analysis. First, his greatly improved CSC timing resulted in better capability to separate the hypothetical slow particles from the much larger flux of muons of a similar momentum. Also, Farrell took on his own initiative to add a slow particle trigger based on the RPC muon system that allows particles that travel slowly enough to span two bunch crossings to be associated with the correct bunch crossing for efficient readout of the central tracking information. Farrell also found that the previous event skimming code was inadvertently removing particles with momentum greater than 1 TeV, which could be the most interesting of all.

In order to confirm such events if they were found, Rakness has created CSC dE/dx calibration and reconstruction software, so that the CSC muon system would have two largely independent handles on such particles, namely late timing and high dE/dx. This may enable an acceptable S/N ratio for this additional type of HSCP search. Rakness has found that the gains vary within chambers by as much as a factor of 3, but that the variations with position as well as time-dependent variations (due mainly to atmospheric pressure) can be taken out with proper calibration. He has now incorporated these calibrations into the standard CMS software package.

5.4 Vector Boson Plus Jets Production: BlackHat vs CMS data

The production of W and Z bosons plus jets is an important channel at the LHC, both for intrinsic physics interest and as a background for Higgs Boson studies and searches for physics beyond the Standard Model. At UCLA, we are in the fortunate position to be able to make detailed comparisons of theoretical calculations and experimental results: our theory colleague Zvi Bern and his collaborators including postdoc Kemal Ozeren are working on the BlackHat calculation program [8, 9, 10] that provides the only exact NLO predictions for a variety of processes, including vector boson + multi-jet production. Weber, Takasugi and Saltzberg are working closely with the BlackHat collaboration to make a full NLO comparison to the data. Graduate student Eric Takasugi has been comparing 7 TeV and 8 TeV data to the theoretical ntuples with a goal of publication of the 8 TeV comparisons. In consultation with Zvi Bern, he has developed variables specifically suited to probe BlackHat's suspected problem areas, but is finding excellent agreement, nonetheless.

As a CMS Affiliate Member, Bern now has access to all internal documents. We are able to show him our interim plots for rapid feedback. As a side benefit, he has already corrected errors in CMS papers before publication.

In Figure 1, we show an example plot made by Matthias Weber and the W/Z+jets group comparing an event-shape variable $\tau_\perp$ ("transverse thrust", a measure of the isotropy of the jet configuration) for data and simulation. This is one of the plots shown at ICHEP-2012 [13]. The simulation has been unfolded so it can be correctly matched to data. As a graduate student Matthias Weber became an unfolding expert under the tutelage of Bob Cousins.

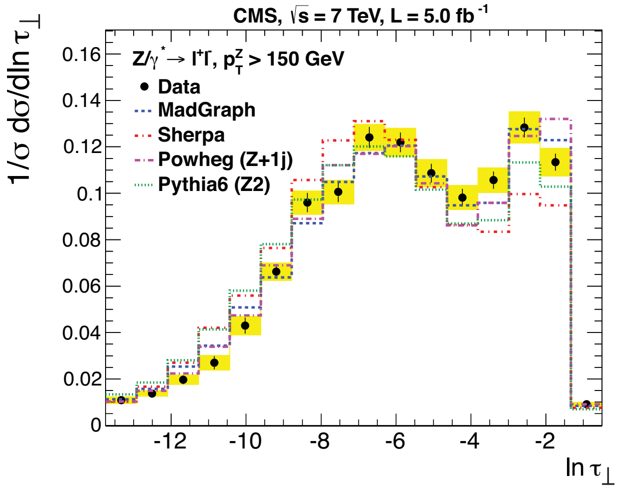

Figure 1: Comparison of an event shape variable ($\tau_\perp$) in Z+jets data to leading-order simulations. The data are unfolded so can be directly compared to the simulation. Weber produced this plot for publication [13]. Weber, Takasugi, and Saltzberg are now adding a comprehensive comparison to a full Next-to-leading-order (NLO) QCD prediction by working closely with BlackHat theorists.

5.5 Supersymmetry and Exotica Studies in Multi-Leptons

Since September 2011 our group's expertise in leptons has been supplemented by the expertise of postdoc Pieter Everaerts, who did his thesis at MIT on the measurement of W boson production in CMS with the W decaying to electron plus neutrino (missing energy). He joined the study of events with three or more leptons in CMS, which is still in a stage in which improvements could be made.

In his first year, Pieter worked closely with a Florida subgroup that has extensive prior experience on CMS dilepton searches. This work is already incorporated into the published paper [14] that describes several searches in electroweak production scenarios. In these "electroweak-ino" production scenarios, (somewhat motivated by the failure to find strong production of colored SUSY particles at the LHC thus far thus far), the lowest-lying SUSY states are not colored, and charginos and neutralinos are pair-produced via electroweak production, followed by decays resulting in multi-leptons and two lightest-supersymmetric particles (LSP). After various selection criteria to select three-lepton events and suppress top and Drell-Yan background, Everaerts focused on the the invariant mass $M_{\ell\ell}$ of two opposite-sign leptons, and the transverse mass M_{T} formed from one lepton and the missing transverse energy $\not{E}_T$. No excess emerged. These results are included in this first major CMS paper targeting electroweak pair production, "Search for electroweak production of charginos and neutralinos using leptonic final states in pp collisions at $\sqrt{s} = 7$ TeV," based on the 5 fb^{-1} 2011 data set. The paper combines Everaerts's work with a variety of (mostly pre-existing) efforts within CMS at Rutgers, Karlsruhe, ETH Zurich, UCSD, UCSB, Fermilab, and Florida. The CMS SUSY conveners, after consulting all the analyzers, asked Cousins to write the paper that brought together these disparate results into a coherent narrative published in JHEP [14]. With the data obtained in 2011, already there was enough sensitivity to probe or exclude electroweak production for chargino and neutralino masses in the range from 200 to 500 GeV for favorable branching fractions [14]. Everaerts was chosen by the CMS Collaboration to present these results at a Moriond conference.

Meanwhile, we are of course went forward analyzing 2012 data and making a number of improvements, both in the analysis and the sociology. The CMS electroweak-ino analyses were re-designed more coherently from the beginning, taking the best ideas old and new. Further, as the CMS detector continued to be understood better and better, we are cautiously moving from cut-based analyses to more shape-based analyses that are more powerful if the systematics can be kept under control. The preliminary results from 2012 have recently been approved by the CMS Collaboration and made public [15].

5.6 Top Quark Studies in ℓ + b + n jets

Deisher and Plager analyzed the early top physics data in a working group that includes collaborators from ETH Zurich, Kansas State, Johns Hopkins, and Vanderbilt. The technique, invented by Plager for CDF, simultaneously measures the top pair cross section as well as that of W + jets by using a sample of a single identified lepton and multiple jets This is called 'SHyFT' (*S*imultaneous *H*eav*y* *F*lavor and *T*op Cross Section Measurement) SHyFT uses a shape fitting technique to determine background and signal simultaneously. This approach has been unique in the CMS top group, and its effectiveness is the reason SHyFT was chosen as the CMS Reference Analysis of the 36 pb^{-1} 2010 data from five tagged $t\bar{t}$ to lepton+jets cross section measurements [16] and the 1 fb^{-1} top-pair production cross section [17] . Deisher increased her involvement in the SHyFT group, taking sole responsibility for fitter development/running and a greater leadership role in the group. In summer 2012, the SHyFT effort pioneered at UCLA moved with Deisher to ETH Zurich, with Plager having earlier departed for a position in industry.

5.7 Internal review of CMS Higgs Combination result

The search for the Higgs boson in CMS is performed in many final-state channels that are then combined into one overall result. Each final-state channel has an internal "Analysis Review Committee" (ARC) assigned to scrutinize it, and there is in addition an ARC that scrutinizes the combination of all of the results, and thus to a certain extent the inputs to the combination as well. This four-person Higgs combination ARC includes Bob Cousins, who has thus had the privilege to be in the "inner circle" scrutinizing these results and helping to shape the interpretation of them and the carefully chosen words in the collaboration's publications. As these discussions in the end cannot avoid some issues of philosophy of science, statistical inference, and decision theory, Cousins tries to inform those discussions as well. Highlights of the several publications included the refereed discovery paper [18], the refereed paper disfavoring the zero-spin negative-parity hypothesis in comparison to the (Higgs-like) zero-spin positive-parity hypothesis [19], and a recent conference paper [20] using the full 2012 data set to make further measurements of the properties of the new boson.

6 Muon Upgrades for CSC Electronics and Chambers

The CSC chambers in CMS are expected to survive the increased radiation levels from the LHC luminosity upgrades. However, the CSC muon triggering and readout require specific improvements in order to maintain excellent triggering capabilities, high efficiency, and excellent position and time resolution in the face of increased background levels. The plan during LS1 is to recover triggering capability over the pseudorapidity range $1.2 \le |\eta| \le 1.8$ by adding 72 CSC chambers to a new ME4/2 station, and over the pseudorapidity range $2.1 \le |\eta| \le 2.4$ by upgrading ME1/1 chambers with new "digital" cathode front-end boards (DCFEBs) and their readout Trigger Mother Boards (TMBs) and Data acquisition Mother Boards (DMBs). It is also planned to replace the small mezzanine cards on some of the Anode Local Charged Track (ALCT) boards for better trigger data flow and improved spatial and time resolution.

6.1 CMS Upgrade Muon Electronics for ME1/1 and ME4/2

The 72 new ME4/2 CSC chambers require additional electronics for trigger and readout. Kubic has built 80 large ALCT base boards to be installed at the chamber factory, using the existing design from 2001. All of the large "base" boards were built in early 2012 and most are now working perfectly, with a small number that remain to be debugged and fixed.

On each large ALCT board there is mounted a small mezzanine board that contains the central FPGA device to handle triggering and readout functions. Kubic has created a new design that uses a modern FPGA (Spartan-6) that contains 10 times as much logic and is twice as fast. Ten Spartan-6 prototype boards were produced and all worked perfectly. Hauser performed radiation tests at the UC Davis cyclotron in July 2012 on three of them. The results of the tests showed that the devices will withstand three times the dose expected for any CSC chamber under the highest luminosity LHC upgrade conditions (3000 pb^{-1}). The 72 ME1/1 chambers are being outfitted during LS1 with new cathode front-end cards (DCFEB, built by Ohio State) for greatly improved triggering and readout.

Associated to the new DCFEB boards in ME1/1 will be new mezzanine boards for the TMB that contain optical links and modern FPGAs. Kubic has already ported the existing TMB firmware from the present (Virtex-2) TMB mezzanine card to the new (Virtex-6) card. Two generations of prototype Virtex-6 mezzanine boards were build by Texas A&M, and testing at UCLA by Kubic has yielded lists of suggested improvements.

6.2 CMS Upgrade Muon Chamber Construction (ME4/2)

Saltzberg, with group members Weber and Takasugi is playing a major role in the construction of new muon chambers for high-luminosity running. In addition undergraduates Beres and Peck have gone to CERN for three and six months, respectively, to work at the chamber production facility.

Construction of the new ME4/2 CSCs is well underway. The chambers are constructed from $5' \times 12'$ "skins" of copper-clad fiberglass (FR4). These were made by the aircraft industry in Los Angeles County. Saltzberg has become familiar with the detailed specifications of the materials in order to oversee the skins production. He and UCLA graduate student Takasugi took responsibility for overseeing factory production in person and performing quality control of the skins.

Our group is also deeply involved in overall chamber construction at the CSC factory at CERN. Eric Takasugi spent his first summer (2011) on CMS at the CERN Prévessin site full-time gluing, soldering, and winding panels for chambers as well as measuring their tension and pitch. Takasugi was a quick study and soon became the person who trained new people on much of the equipment. At the end of the summer Takasugi was chosen to give the important status report at the muon Detector Performance Group (DPG) meeting. For summer 2012, undergraduate Jacob Beres moved to the Prévessin factory to similarly aid in the construction effort. Graduated undergraduate Andrew Peck arrived in January 2013 and will work on chamber construction through July. Along the way he fixed many dozens of CFEB (Cathode Front-End) boards necessary to keep the production line running. Takasugi also returned to the factory and to be at CERN full time in a new role described below.

In addition to contributions to skin quality assurance and chamber construction at CERN, UCLA's main responsibility is for the Final Assembly and Testing (FAST) site at the CERN Prévessin site, Bldg. 904. Matthias Weber started this project in October 2011 with a basic electronics crate; he wrote and determined the quality-assurance software, and organized the activity into shift work. After full-time work for 7 months he constructed a full chamber test stand and software, often with key consultation from Misha Ignatenko. Weber has finished testing the first few of the approximately 70 chambers he will test. Graduate student Eric Takasugi moved out to CERN (Summer 2012) indefinitely and is supporting this chamber testing effort.

Saltzberg's involvement in ME4/2 is substantial–not simply assigning personnel for others to manage. He pays attention to vendor and production issues. He follows closely the activity of the ME4/2 construction facility including attending its weekly meetings via video and staying in twice-weekly contact with Takasugi and Weber. He also stays in close contact with the ME4/2 project management (Dick Loveless, Armando Lanaro) to discuss technical issues as they arise. For example, when the sense wires kept breaking during winding, he was one of the few people asked to join the CERN phone call with the vendor. He spends a week at CERN every 6-8 weeks to keep a close eye on UCLA's responsibilities as well as to keep contact with the overall construction operations.

We completed the quality assurance of skin production for the second endcap at M. C. Gill Corp. in Los Angeles in November 2012. For the FAST site our milestones are the weekly validation and final repair of chambers; we have approximately 30 chambers to go from now through March 2014, which will complete both end caps. Takasugi and Weber are eager to participate in the installation of the chambers on the disks of the experiment and their knowledge of CSC construction and testing will be essential for that activity. In 2014, Takasugi and Weber will be providing validation of these new chambers.

7 Diamond Detector Research

Wallny and students worked on developing diamonds as a radiation hard detector for radiation monitoring and ultimately for tracking applications. Prior to 2010 they installed Beam Condition Monitors based on diamonds successfully into the CDF detector. In 2010 he and two students went to CERN to participate in the RD42 test beam campaigns in June and August testing single-crystal diamond irradiated with protons at lower energies (70 MeV at Cyric, Japan and 800 MeV in Los Alamos) The goal of these studies was to map out the non-ionizing energy loss (NIEL) curve for diamond. Most of this work was funded separately from the base program, and ended when Wallny left UCLA in fall 2010.

8 CMS Service

CMS Physics Analysis Reviews:
Hauser, Cousins, and Valuev have all served as internal referees on various CMS papers, in some cases having a large and public impact. Since late 2010, Cousins has chaired two internal paper reviews leading to publications, while Hauser has chaired five reviews and served as member of six additional reviews leading to eight publications including two "fast-track" PRL publications (plus two PLB and four JHEP articles).

CMS Shifts:
Cousins, Deisher, Everaerts, Farrell, Hauser, Jarvis, Rakness, Saltzberg, Takasugi, Tucker, Weber, and Valuev have run numerous shifts for the CSC muon detector and continue to do so. Valuev and Saltzberg have also taken 'global' CMS shifts. Weber is one of only five people on CMS who perform the offline "Jet-MET" shifts, which is a front-line effort to guarantee the performance of the calorimeters for physics.

Support and Advice for Physicists at the LPC:
Until he departed, Plager assisted in user support at the LHC Physics Center (LPC) at Fermilab. In this broad role, he provided support to physicists from many different institutions, ranging from ROOT and basic CMS software framework questions to statistical questions from physics analyses.

9 Service outside CMS and Outreach

DOE reviews:
In addition to the usual proposal peer review by all professors, Cousins served as an ad hoc reviewer at two multi-day U.S. DOE reviews, the "Review of Laboratory Non-Accelerator Research Program", Sept 27 - Oct 1, 2010; and the "SLAC S&T Review", June 18-20, 2012.

Committee Work for APS, IUPAP, NAS, etc.:
Saltzberg completed his three-year term as an elected member of the executive committee of the APS's Division of Particles and Fields (DPF). He serves on the APS's "Committee on Informing the Public". This is the official advisory board for, and provides oversight of, the society's public outreach and media relations activities. He serves as member-at-large on the IUPAP's United States Liaison Committee (US-LC). He served as a member of the international advisory committee for the 2011 Lepton-Photon conference. He also contributes to the Science and Entertainment Exchange [21], a program run by the National Academy of Sciences to connect scientists to the film and television industry, and has provided approximately a dozen consults to major productions.

Public Outreach:
Cousins gave public lectures attended by about 500 people as the LHC physics program began [22] in 2010 and after the Higgs-like boson discovery in 2012. On the weekend of the new boson discovery announcement, Saltzberg authored and narrated a public event where the LA Derby Dolls recreated LHC collisions with roller skaters playing the role of particles [23].

The Big Bang Theory
Saltzberg is the "physics consultant" for the Emmy-nominated sitcom on CBS called "The Big Bang Theory", created and written by a highly accomplished television team which features physicists as its main characters. He corrects the scripts for physics accuracy,

suggests story elements, and advises the set designers and the property master. The show has received positive reviews from Science and Nature Physics magazines for its accurate science and human portrayal of physicists. And according to *The Guardian* (Nov 5, 2011):

> A cult US sitcom has emerged as the latest factor behind a remarkable resurgence of physics among A-level and university students...Experts at the Institute for Physics (IoP) also believe the sitcom is playing a role in increasing the number of physics students. Its spokesman, Joe Winters, said: "The rise in popularity in physics appears to be due to a number of factors, including [Brian Greene, the LHC], and we're sure, the popularity of shows like *The Big Bang Theory*.

References for Task E

[1] CMS Collaboration, "Performance of CMS muon reconstruction in pp collisions at $\sqrt{s}$ = 7 TeV," JINST 7 (2012) P10002. [arXiv:1206.4071].

[2] Robert D. Cousins and Virgil L. Highland, "Incorporating Systematic Uncertainties into an Upper Limit," Nucl. Instr. Meth. **A320** 331-335 (1992).

[3] G.J. Feldman and R.D. Cousins, "Unified approach to the classical statistical analysis of small signals," Phys. Rev. **D57**, 3873-3889 (1998).

[4] CMS Collaboration, "Search for Resonances in the Dilepton Mass Distribution in *pp* Collisions at $\sqrt{s} = 7$ TeV," JHEP **1105**, 093 (2011). [arXiv:1103.0981 [hep-ex]].

[5] CMS Collaboration, "Search for narrow resonances in dilepton mass spectra in *pp* collisions at $\sqrt{s} = 7$ TeV," Phys. Lett. B **714** (2012) 158 [arXiv:1206.1849 [hep-ex]].

[6] CMS Collaboration, "Search for heavy narrow dilepton resonances in *pp* collisions at $\sqrt{s} = 7$ TeV and $\sqrt{s} = 8$ TeV," Phys. Lett. B **720** (2013) 63 [arXiv:1212.6175 [hep-ex]].

[7] CMS Collaboration, "Search for Resonances in the Dilepton Mass Distribution in pp Collisions at $\sqrt{s} = 8$ TeV," CMS-PAS-EXO-12-061, `http://cds.cern.ch/record/1519132`.

[8] C. F. Berger, et al., [BlackHat Collaboration], "Precise Predictions for $W + 3$ Jet Production at Hadron Colliders," Phys. Rev. Lett. **102**, 222001 (2009);

[9] C. F. Berger, et al., [BlackHat Collaboration], "Precise Predictions for W + 4 Jet Production at the Large Hadron Collider," Phys. Rev. Lett. **106**, 092001 (2011) [arXiv:1009.2338 [hep-ph]].

[10] H. Ita, et al., [BlackHat Collaboration], "Precise Predictions for $Z + 4$ Jets at Hadron Colliders," Phys. Rev. D **85**, 031501 (2012) [arXiv:1108.2229 [hep-ph]];

[11] CMS Collaboration, "Search for heavy long-lived charged particles in pp collisions at $\sqrt{s} = 7$ TeV," Phys. Lett. B713, 408 (2012).

[12] CMS Collaboration, "CMS Physics Technical Design Report Volume II: Physics Performance", CERN/LHCC 2006-021, 26 June 2006, `http://cmsdoc.cern.ch/cms/cpt/tdr/ptdr2_final.pdf`, also in: J. Phys. G: Nucl. Part. Phys. 34 995-1579.

[13] Plot provided by M. Weber for the CMS Collaboration. Shown at ICHEP-2012. For more information see the public webpage authored by M. Weber for the CMS Collaboration, https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEWK11021

[14] CMS Collaboration, "Search for electroweak production of charginos and neutralinos using leptonic final states in pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1211**, 147 (2012) [arXiv:1209.6620 [hep-ex]].

[15] CMS Collaboration, "Search for electroweak production of charginos, neutralinos, and sleptons using leptonic final states in pp collisions at $\sqrt{s} = 8$ TeV," CMS-PAS-SUS-12-022, http://cds.cern.ch/record/1546777.

[16] CMS Collaboration, "Measurement of the $t\bar{t}$ Production Cross Section in pp Collisions at 7 TeV in Lepton + Jets Events Using b-quark Jet Identification," Phys. Rev. D **84**, 092004 (2011) [arXiv:1108.3773 [hep-ex]].

[17] CMS Collaboration, "Measurement of $t\bar{t}$ Pair Production Cross Section at $\sqrt{s} = 7$ TeV using b-quark Jet Identification Techniques in Lepton + Jet Events," CMS-PAS-TOP-11-003. http://cdsweb.cern.ch/record/1386709

[18] CMS Collaboration, "Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC," Phys. Lett. B **716**, 30 (2012) [arXiv:1207.7235 [hep-ex]].

[19] CMS Collaboration, "On the mass and spin-parity of the Higgs boson candidate via its decays to Z boson pairs," Phys. Rev. Lett. **110**, 081803 (2013) [arXiv:1212.6639 [hep-ex]].

[20] CMS Collaboration, "Measurement of the properties of the new boson with a mass near 125 GeV," CMS-PAS-HIG-13-005. (April 17, 2013) http://cds.cern.ch/record/1542387

[21] http://www.scienceandentertainmentexchange.org/

[22] Bob Cousins, public lecture at UCLA, March 31, 2010. http://newsroom.ucla.edu/portal/ucla/robert-cousins-speaks-about-the-156948.aspx and UCLA Science Faculty Annual Research Colloquium, Nov. 8, 2012, http://www.physicalsciences.ucla.edu/index.php/component/content/article/14-events/upcoming-events/92-annual-science-faculty-research-colloquium.html

[23] Los Angeles Times, July 5, 2012, http://articles.latimes.com/2012/jul/05/entertainment/la-et-guidefeature-20120705

UCLA Task F Final Report, June 2013 Dark Matter Physics

Katsushi Arisaka

1 Task F Overview

This final report summarizes the progress in the last project period of the grant from 1/15/2010-1/14/2013 (extended to 4/30/2013). The Task F group has been focused on the search for WIMP dark matter using noble liquids for direct detection in the Xenon collaboration and on photodetector research and development. As part of the Xenon100 experiment, we have produced the world's best limits on the WIMP mass and spin-independent cross section while beginning to probe the SUSY (MSSM) favored phase space. In analysis, we have focused primarily on improvement of the limits at low masses by modifying the existing statistical method and producing a more accurate simulation of nuclear recoil events. Additionally, the group has been active in general efforts for next generation detectors through the invention of a low-radioactive novel photosensor called the Qupid and development and characterization of a larger conventional vacuum photomultiplier tube.

For the next generation detector from the Xenon collaboration, Xenon1Ton, the group is responsible for the characterization and performance validation, base design and manufacture, and support structure design for the photomultiplier tubes. The PMT characterization is especially important as it provides a feedback loop for improvements in collaboration with Hamamatsu. A large effort has also gone into detector background and light yield simulations and a dedicated screening campaign using a variety of techniques.

2 2010-2013 Personnel

The Task F personnel working during project period of the past three years are as follows:

- **Faculty**: Katsushi Arisaka
- **Researchers and Associated Professors**: Peter Smith, Hanguo Wang
- **Postdoctoral Researchers**: Paolo Beltrame, Chamkaur Ghag, Alexey Lyashenko
- **Graduate Students**: Ethan Brown, Chi Wai Lam, Kevin Lung, Artin Teymourian
- **Undergraduate Students**: Andri Bargetzi, Dante Gordon, Justin Kaidi, Tae Lim, Sean Nizawa, Eylene Pirez, Ziqi Yan, Ke Ye, Jason Zadwick
- **Chief Machinist**: Harry Lockhart
- **Administrative Assistant**: Cassandra Gonzalez

3 Results from Xenon100

The Xenon100 experiment has been operating almost continuously over the past three years and all graduate student and postdoc group members have contributed extensively towards detector operation, calibration, and monitoring at the Gran Sasso Laboratory (LNGS) in Italy. Ethan Brown, who now has a postdoctoral position at the University of Ḿunster, has spent a substantial amount of his student career overseeing the proper commissioning and operation of the detector. The collaboration released the most recent results in 2012 after a 225 day run culminated in the improvement over our previous best 90% CL limit [1] by over a factor of five to 2×10^{-45} cm^2 at 55 GeV/c^2 [2]. Brown, Kevin Lung, and Artin Teymourian have been a part of the core analysis team specializing in modeling of the electromagnetic background through simulations as well as modeling waveforms from both the primary and secondary scintillation signals.

Lung and Paolo Beltrame have dedicated a large portion of their efforts to improve the limit at low masses using an ionization signal based approach. In particular, Lung's PhD thesis focuses on the improvements that can be made by such a method using a statistical model for the signal events and a resulting profile likelihood analysis incorporating uncertainties from this model. This analysis method developed within this group provided improved energy resolution by over a factor of two for energy deposits below 10 keV$_r$ and improved background and signal discrimination [3]. Beltrame has aided in provided improved two dimensional detector acceptances and a comprehensive analysis coding package. The result of this analysis was a factor of ten improvement at WIMP masses below 10 GeV/c^2.

Other physics analyses of interest carried out by this team were the search for inelastic dark matter, headed by Chi Wai Lam, and axion-like particles called superWIMPs. Inelastic dark matter is predicted to scatter of baryonic matter as it transitions to an excited state at energy δ above the ground state such that the spectrum may now be peaked at non-zero energies because the low energy component becomes suppressed. This was developed to help explain the presence of a signal in the sodium iodide crystals of DAMA/LIBRA. Lam and Lung were the main contributors to this analysis, which resulted in ruling out the possibility of a DAMA/LIBRA signal originating from inelastic dark matter [4].

Undergraduate students Justin Kaidi and Ke Ye were involved in modeling the solar axion and superWIMP signal of liquid xenon detectors. This model was used to impose upper limits on both solar axion and superWIMP couplings to normal matter for experiments on the order of the size Xenon100 as well as future generation detectors. The analysis projects competitive results with dedicated axion search experiments and further reduces the available phase space for bosonic superWIMPs [5].

4 Future Detector R&D

Future dark matter detectors, such as Xenon1Ton require photosensors with both lower radioactivity and improved performance to increase their discovery potential. Katsushi Arisaka and Hanguo Wang in concert with Hamamatsu have developed a new quartz photosensor called the Qupid which has extremely low radioactivity and exceptional performance in low photon environments. Teymourian dedicated a large portion of his PhD thesis to the detailed characterization of the Qupid including customized support design to hold the device as well as low temperature gaseous testing environments. The low radioactivity, high performance, and low noise characteristics were measured at UCLA and by Hamamatsu [6].

Another candidate photodetector tested was the 3-inch Hamamatsu R11410 photomultiplier tube, which is slightly easier to operate than the Qupid, but has much worse performance. It was characterized in the same environments as the QUPID by Lung and Andri Bargetzi exposing some of the imperfections regarding excess noise and large transit time spread [7].

For XENON1Ton, the successor to the XENON100 detector, the R11410 was ultimately selected as the detector device due to its ease of operation. Alexey Lyashenko and the group have been assigned to design a proper support for the detector and have provided several options regarding its orientations. Lyashenko and Dante Gordon have also contributed various detailed technical drawings of the detector to the collaboration in different iterations. Their efforts in PMT support design were in the process of being tested at a smaller scale in a 7 PMT array, only a fraction the total hundred PMTs in the final array. Beltrame has used the Hoffman2 cluster at UCLA (funded by the DOE) to perform large scale background and light yield simulations to advise the technical hardware committee on the design of the time projection chamber and cryostat.

Beyond XENON1Ton, the group has been active in promoting the development of multi-ton rare event search detectors using both argon and xenon as target materials. Such detectors would be capable of becoming both a dark matter and neutrino observatory. Lam and Beltrame have simulated ten and hundred ton detectors to guide the future of the noble liquid community in a promising direction [8].

Chamkaur Ghag has been the leading organizing force behind all these efforts. He has also spearheaded an extensive screening program using solid state germanium detectors, ICP-MS, and ICP-OES, to cross calibrate between each of the methods and obtain a comprehensive understanding of all the materials that will be used in the construction of the XENON1Ton detector.

5 Summary

The Task F group has been involved in key analyses of XENON100 data, photodetector characterization for future noble liquid detectors, and hardware development and simulations for the XENON1Ton detector. Numerous undergraduates have been trained in photodetector characterization and simulation studies for potential experiments as well. The group has had a large influence on the next generation XENON1Ton detector and will continue to do so in the future.

References

[1] E. Aprile *et al.*, “Dark Matter Results from 100 Live Days of XENON100 Data,” *Phys.Rev.Lett.*, vol. 107, p. 131302, 2011.

[2] E. Aprile *et al.*, “Dark Matter Results from 225 Live Days of XENON100 Data,” *Phys.Rev.Lett.*, vol. 109, p. 181301, 2012.

[3] K. Arisaka, P. Beltrame, C. Ghag, K. Lung, and P. R. Scovell, “A New Analysis Method for WIMP searches with Dual-Phase Liquid Xe TPCs,” *Astropart.Phys.*, vol. 37, pp. 1–88, 2012.

[4] E. Aprile *et al.*, “Implications on Inelastic Dark Matter from 100 Live Days of XENON100 Data,” *Phys.Rev.*, vol. D84, p. 061101, 2011.

[5] K. Arisaka, P. Beltrame, C. Ghag, J. Kaidi, K. Lung, *et al.*, "Expected Sensitivity to Galactic/Solar Axions and Bosonic Super-WIMPs based on the Axio-electric Effect in Liquid Xenon Dark Matter Detectors," *Astropart.Phys.*, vol. 44, pp. 59–67, 2013.

[6] A. Teymourian, D. Aharoni, L. Baudis, P. Beltrame, E. Brown, *et al.*, "Characterization of the QUartz Photon Intensifying Detector (QUPID) for Noble Liquid Detectors," *Nucl.Instrum.Meth.*, vol. A654, pp. 184–195, 2011.

[7] K. Lung, K. Arisaka, A. Bargetzi, P. Beltrame, A. Cahill, *et al.*, "Characterization of the Hamamatsu R11410-10 3-Inch Photomultiplier Tube for Liquid Xenon Dark Matter Direct Detection Experiments," *Nucl.Instrum.Meth.*, vol. A696, pp. 32–39, 2012.

[8] K. Arisaka, C. Lam, P. Smith, P. Beltrame, C. Ghag, *et al.*, "Studies of a three-stage dark matter and neutrino observatory based on multi-ton combinations of liquid xenon and liquid argon detectors," *Astropart.Phys.*, vol. 36, pp. 93–122, 2012.

Task H Final Report: Co-PIs David Cline and Katsushi Arisaka
The LHC CMS detector EMU-CSC system and Multi-B physics analysis

The team is very integrated with the team of Cousins, Hauser, and Saltzberg. Since our team was the first UCLA group in CMS and since we helped construct and operate the CSC EMU system in the data taking runs we have a different role in CMS which involve two areas:

A. Physics studies (V. Andreev, D. Cline, S. Otwinowski)

(1) Analysis of b physics related scenes
We were a key member of the CMS b physics production team and helped prepare the published paper "Inclusive b jet production in pp collisions at $\sqrt{s}$ = 7 TeV," published in JHEP 04, 2012:084. We continue to work on this subject.

(2) The search for new physics in 3b final states (V. Andreev, D. Cline, S. Otwinowski). Using our knowledge of b identification (including double tags) we have started a program to study 3b final states to search for the process g + b $\rightarrow$ new particle decays with $b\bar{b}$ + b.
At the end of 2011 we have studied 20,000 3b-events. In the 2012 run we expect over 100,000 events.

B. CSC operation and maintenance (D. Cline, M. Ignatenko, K. Arisaka)

Since we constructed many of the large CSC chambers at UCLA and our team received every CSC chamber sent from the whole collaboration, it is natural for us to be deeply involved in the operation of the EMU system at the CMS/LHC. Mikhail Ignatenko is key to the operation of the whole system and has worked in our group since the construction phase of the CSC chambers.

New CSC Chamber Construction

Our team is involved in the construction of new CSC chambers in Building 904 at CERN. There will be 72 new large CSC chambers constructed. X. Yang is helping to build the chamber and is responsible for the gas system and HV system parts. Two chambers have been constructed and tested so far. Mikhail Ignatenko will help with the installation of 31 chambers in CMS in 2013. The whole project will be finished between 2014 and 2015. This will add valuable information for muon detection and the construction of the EMU system.

Our preliminary results for the search in 3b final state are illustrated in Figure 1. The data sample corresponds to ~ 5.0 fb^{-1} integrated luminosity collected by CMS in 2011 and to the first 2.5 fb^{-1} of prompt data collected in 2012. The invariant mass distribution of di-b-jets is shown for the data 2011 on the left plot and for the data 2012 on the right plot. Our experience in b tags is key here. Further details follow in the next section.

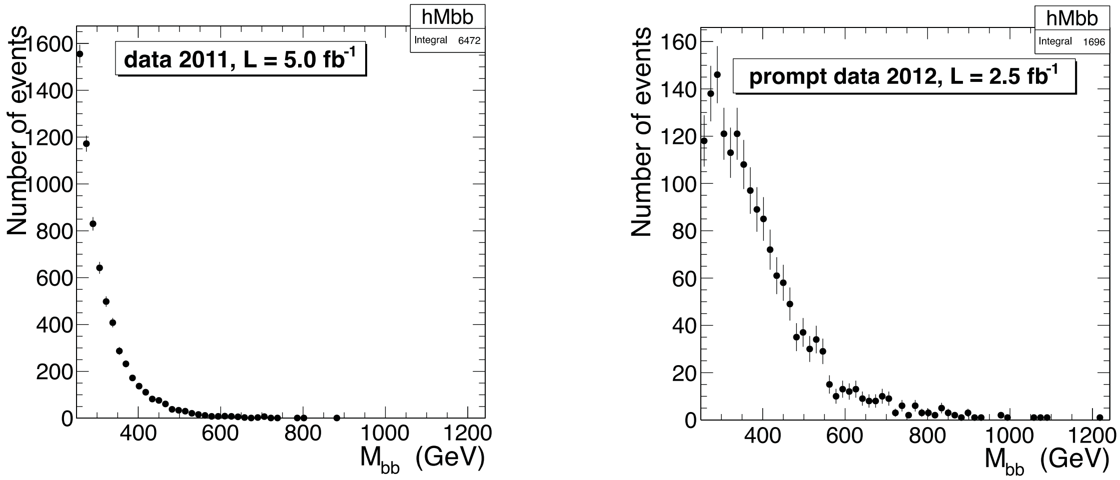

Figure 1. Invariant mass (in GeV) distribution for the b-jet pair in 3 b-tagged jets events data collected by CMS in 2011 (left plot, 5.0 fb^{-1}) and for the first 2.5 fb^{-1} of data collected in 2012 (right plot).

1. Analysis of 7 TeV data: b Production and Search in multi-b-jets events

The physics program of the UCLA group consists of a search for the new phenomena at the LHC in channels with muons and *b* quarks in the final state.

The first signature we are looking for is a peak in the $b\bar{b}$ invariant mass spectrum in events containing more than two b-jets. Such events could originate from many new physics processes expected at LHC, namely, associative Standard model Higgs production (HZ, HW), $Z' \to b\bar{b}$, SUSY (MSSM) neutral Higgs bosons (collectively denoted as ϕ): h, H and A decays.

b quarks and muons in the final state are key objects to enhance a new physics signal contribution with respect to the Standard Model processes. The effective background suppression relies on excellent performance of the muon track measurements and *b* tagging. The Standard Model processes with similar event topology are $b\bar{b}$ - and $t\bar{t}$ -events. The prediction for the $t\bar{t}$ inclusive production cross section is rather precise, while the observed at Tevatron $b\bar{b}$ cross section has some deviations from QCD prediction. For this reason we would like to measure first the inclusive *b*-quark production at the LHC energies.

One UCLA group (V. Andreev, D.B. Cline, S. Otwinowski) has performed the first study for inclusive *b*-quark production with CMS published in the CMS Physics Technical Design Report [J.Phys.G34:995-1579, 2007], high p_T *b*-quark analysis.

Search for New Physics in 3b final states

Due to the tan β enhancement, the main decay for the three neutral Higgs bosons is $\varphi \to b\bar{b}$ with branching ratios near 90% (the remainder being mostly $\varphi \to \tau\tau$). Since a direct search for $\varphi \to b\bar{b}$ is difficult due to large multijet backgrounds, searches rely on the case where φ is produced in association with one b quark. The final state with three b quarks represents a powerful search channel, with the third b-jet providing additional suppression of the large multijet background at a hadron collider. The φ is identified with the A Higgs boson in the SUSY, and may be easier to discover than the low mass Higgs (120 GeV).

Our first preliminary results for the search in 3b final state are illustrated in Figure 2. The data sample corresponds to ~ 1.0 fb^{-1} integrated luminosity collected by CMS before the EPS2011 conference. The invariant mass distribution of di-b-jets is shown for the low mass (left plot) and for the high-mass region (right plot). Our experience in b tags is key here.

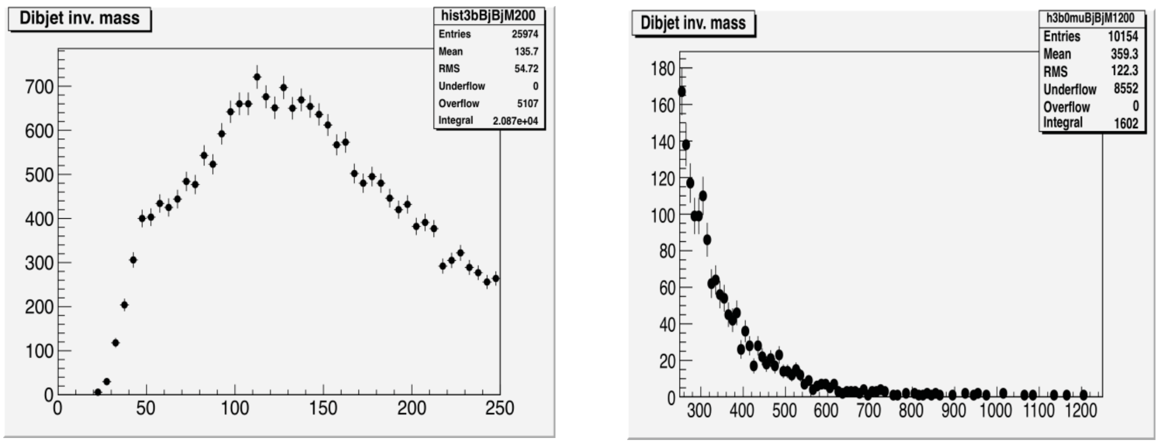

Figure 2. Invariant mass (in GeV) distribution for the b-jet pair in 3 b-tagged jets events for the first 1.0 fb^{-1} of data collected by CMS in 2011.

Figure 3 shows new data on a possible 1 TeV resonance. Investigation of the nature of this apparent excess (fluctuation, instrumental effects, or New Physics) is severely hampered by the fact that support for Cline and Andreev was eliminated at the end April and this effort is not supported in the new grant.

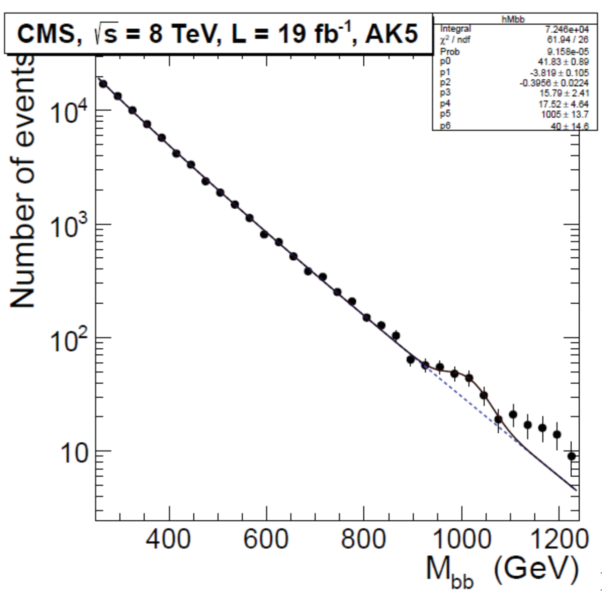

Figure 3.

Task J Final Report

David Saltzberg, Task P.I.
June 2013

1 Science overview

Task J is dedicated to the detection of ultra-high energy neutrinos and cosmic rays, using radio detection. In addition to astrophysical interest, these neutrinos would allow probing the weak interaction at an energy ten times higher than the LHC. We and collaborators established this technique with a series of experiments at SLAC, now known as the Askaryan effect. Now, nearly a dozen experiments world-wide employ this technique to search for ultra-high energy neutrinos.

We produced the best limits on the ultra-high energy flux of neutrinos. Our first search was conducted using the Moon as a target, viewed from the Goldstone radio telescopes (in close collaboration with JPL and Univ. of Hawaii). Subsequently, we built and flew a balloon-borne interferometer called ANITA (Antarctic Impulsive Transient Antenna.

Recently we discovered a new technique for detecting the highest energy cosmic rays ($> 10^{18}$ eV) with ANITA. We are optimizing ANITA-III to record hundreds of these cosmic-ray events. This discovery was the subject of an article in Physics Today [1].

For neutrinos, our aperture was limited by the ANITA trigger, not by analysis-level reconstruction. We will improve the neutrino sensitivity of ANITA-III, our final flight with upgrades: An entire new ring of drop-down antennas will lower our energy threshold and improve pointing. A new trigger will perform basic interferometry, also greatly improving our energy threshold and recording events more consistent with neutrinos.

2 2010-13 Personnel

- *Faculty P.I.*: David Saltzberg
- *Postdoctoral Researchers*: Konstantin Belov, Stephanie Wissel
- *Graduate student*: Stephen Hoover, Abigail (Goodhue) Vieregg
- *Undergraduates*: Kyle Borch, Andy Huang, Joe Lam, Andrew Peck, David Sandoval-Urdaneta
- *Chief Machinist*: Harry Lockart

3 Results

- NASA approved our proposal for a hybrid neutrino and UHECR detector, ANITA-III. Preparations for construction are underway for a 2014 flight. Postdoc Stephanie Wissel is helping construct the payload and took the lead on the ground calibration system.

- Graduate student Stephen Hoover won the 2011 Tanaka Prize from the American Physical Society (APS) Division of Particles and Fields (DPF). This award is given annually to the best dissertation in experimental particle physics. Hoover's thesis established that ANITA could detect ultra-high energy cosmic rays with an aperture as large as the Auger experiment and was published in Physical Review Letters. [2] Stephen Hoover is now a McCormick Fellow at the University of Chicago.

- Graduate student Stephen Hoover completed the most sensitive search for neutrinos in the ANITA-1 dataset. His results were published as the updated curve in the ANITA-2 publication. [3]

- Graduate student Abigail Vieregg performed the ANITA-II search for neutrinos. Her analysis on the ANITA-II data were four times as sensitive as the

ANITA-I result. [3] Her limit is the nominal collaboration value and was published in the Physical Review. Abigail is now an NSF Fellow at the Harvard Center for Astrophysics. She has been offered several tenure-track faculty jobs.

- Abigail Vieregg also completed a search for neutrino bursts in coincidence with known Gamma-ray bursts (GRBs) during our flight. Using the temporal information of the GRB's we reduced the number of expected background events to 0.0044, so that the observation of even one event would be interesting. No coincident events were observed. She published the result in the Astrophysical Journal. [4]

- Postdoc Konstantin Belov has nearly completed the very hard problem of determining the energy scale of our cosmic-ray events. He uses Corsika for shower development, coREAS for the radio emission and his own simulation of the ANITA trigger. His preliminary results show that the events are consistent with the ultra-high energy cosmic rays with a threshold of 10^{18} eV and mean energy in the 10^{19} eV range. We have an internal paper draft we will soon submit to the collaboration. He supervises the work of undergraduates Joe Lam and David Urdaneta on this project.

- Belov discovered a major improvement to our previous energy estimate which would only set a lower limit on cosmic-ray event energies, event-by-event. [5] He showed after much simulation on our Saxon cluster (funded by the DOE) that the frequency spectrum could be use to constrain the viewing angle of the shower to within tenths of degrees, thereby allowing an event-by-event estimate of particle shower energies. The technique has been shown at international conferences and is part of a paper in progress.

- Undergraduate Taylor Barrella won the prestigious Goldwater Scholarship. In part, this was for his analysis of the data and publication in the Journal of Glaciology of Ross Ice shelf attenuation data taken by Saltzberg and Barwick. [6] This is the only *in situ* measurement at our frequencies of an ice shelf. Barella is now a graduate student at Stanford University.

- Konstantin Belov supports the Saxon Cluster a ∼260 AMD-core, 55 TB, cluster used by about a dozen ANITA collaborators (Hawaii, Ohio State, Kansas and JPL).

- Graduate student Alden Fan (temporarily with our group) worked for a half year in our group. Along the way he worked closely with Andres Romero-Wolff (Hawaii, then JPL) to determine the polarity response of several antennas and thus the calibration of testbeam we had taken earlier. He resolved an ambiguity of the orientation of the antennas and thereby confirmed the published pulse shape. This work will ultimately lead to reducing our backgrounds from man-made sources by using the pulse polarity.

- Barella, Saltzberg and Vieregg realized that an increased neutrino aperture is possible for ground-based detectors due to tau lepton penetration from subglacial rock. We estimated this will double the existing aperture of detectors such as RICE, Arianna, and the Askaryan Radio Array. Barella and Saltzberg completed the analysis and presented it at the American Physical Society.

- ANITA relies on a good knowledge of the propagation of radio waves through ice. This had led us to several measurements of ice properties in our frequency bands. In addition to being useful for ANITA, these have become part of the radioglaciology literature as well. A recent example is our results from the Ross Ice Shelf. [6]

- We have been granted beam time SLAC for a new experiment T-510. We will direct the new ESA 13 GeV electron beam on an alumina and polyethylene target placed in a magnetic field. This will test the emission mechanism of the ultra-high energy cosmic rays and bound the simulations. Belov is the collaboration's principle organizer of this experiment.

- Abigail Vieregg worked closely with the authors of our magnetic monopole search and she performed the final candidate event analysis using her algorithms for filtering, payload noise evaluation, and pointing to avoid locations of human activity. [7]

- Remote ground pulser stations will run autonomously on the ice sheet surface using solar power during the flight from quiet locations in Antarctica. For ANITA-III we have built eight "drop-and-go" stations. The six "simple" boxes have been completed. The firmware for the two "advanced" boxes is nearly complete. This has been the work of undergraduates Andrew Peck, Kyle Borch, and Andy Huang working under the supervision of postdoc Stephanie Wissel as well as the UCLA machine shop.

4 Summary

The UCLA group is a key part of ANITA and related accelerator-based experiments. Major publications have been produced by our group. Our graduate students have won prestigious awards, and moved on to excellent post-doctoral positions. Numerous undergraduates are given hardware experience. ANITA-III is being built with major improvements and will probe deep into the region of neutrino fluxes predicted by the GZK process. In addition, its ten times larger dataset of ultra-high energy cosmic rays holds the possibility of finally pointing back to their sources.

References

[1] "Balloon Experiment Reveals a New Way of Finding Ultrahigh-Energy Cosmic Rays," Physics Today, December 2010, pp.22-25.

[2] S. Hoover *et al.* "Observation of Ultra-high energy Cosmic Rays with the ANITA Balloon-borne Radio Interferometer," Physical Review Letters **105**, 151101 (2010).

[3] P. Gorham *et al.* "Observational Constraints on the Ultra-high Energy Cosmic Neutrino Flux from the Second Flight of the ANITA Experiment," Physical Review **D82**, 022004 (2010).

[4] A. Vieregg *et al.*, "The first Limits on the Ultra-high Energy Neutrino Fluence from Gamma-ray Bursts," The Astrophysical Journal **736**, 50 (2011).

[5] K. Belov, ARENA 2012, "Towards Determining the energy of the UHECRs observed by the ANITA detector." `https://indico.cern.ch/getFile.py/access?contribId=21&sessionId=10&resId=0&materialId=slides&confId=159364`.

[6] T. Barella, S. Barwick and D. Saltzberg, "Ross Ice Shelf *in situ* Radio-Frequency Ice Attenuation," Journal of Glaciology **57**, 61 (2011).

[7] M. Detrixhe *et al.* "Ultra-Relativistic Magnetic Monopole Search with the ANITA-II Balloon-borne Radio Interferometer," Phys. Rev. D, 02513 (2011).

5. List of Papers

Final Report Item 5: Publications

All of our papers include work (including that by collaborators) that at least partially involves sources of funding beyond this DOE grant. In all papers, part of the work is partially supported by other funding agencies. Thus we list no publications under Item 5a. For Item 5b, we list the publications by Task below: First Tasks B and F are grouped together (since both include XENON100 papers), followed by Task C, followed by Tasks E and H grouped together (since both include CMS papers), followed by Task J.

Item 5b: Tasks B and F Publications

1. J. Abraham *et al.* [Pierre Auger Collaboration], "Atmospheric effects on extensive air showers observed with the Surface Detector of the Pierre Auger Observatory," Astropart. Phys. **32** (2009) 89 [Erratum-ibid. **33** (2010) 65] [arXiv:0906.5497 [astro-ph.IM]].

2. J. Abraham *et al.* [Pierre Auger Collaboration], "The Fluorescence Detector of the Pierre Auger Observatory," Nucl. Instrum. Meth. A **620** (2010) 227 [arXiv:0907.4282 [astro-ph.IM]].

3. J. Abraham *et al.* [Pierre Auger Collaboration], "Trigger and aperture of the surface detector array of the Pierre Auger Observatory," Nucl. Instrum. Meth. A **613** (2010) 29 [arXiv:1111.6764 [astro-ph.IM]].

4. A. Fukasawa, K. Arisaka, H. Wang and M. Suyama, "QUPID, a single photon sensor for extremely low radioactivity," Nucl. Instrum. Meth. A **623** (2010) 270.

5. J. Abraham *et al.* [Pierre Auger Collaboration], "A Study of the Effect of Molecular and Aerosol Conditions in the Atmosphere on Air Fluorescence Measurements at the Pierre Auger Observatory," Astropart. Phys. **33** (2010) 108 [arXiv:1002.0366 [astro-ph.IM]].

6. J. Abraham *et al.* [Pierre Auger Collaboration], "Measurement of the Depth of Maximum of Extensive Air Showers above 10^{18} eV," Phys. Rev. Lett. **104** (2010) 091101 [arXiv:1002.0699 [astro-ph.HE]].

7. J. Abraham *et al.* [Pierre Auger Collaboration], "Measurement of the energy spectrum of cosmic rays above 10^{18} eV using the Pierre Auger Observatory," Phys. Lett. B **685** (2010) 239 [arXiv:1002.1975 [astro-ph.HE]].

8. E. Aprile *et al.* [XENON100 Collaboration], "First Dark Matter Results from the XENON100 Experiment," Phys. Rev. Lett. **105** (2010) 131302 [arXiv:1005.0380 [astro-ph.CO]].

9. P. Abreu *et al.* [Pierre Auger Collaboration], "Update on the correlation of the highest energy cosmic rays with nearby extragalactic matter," Astropart. Phys. **34** (2010) 314 [arXiv:1009.1855 [astro-ph.HE]].

10. P. Abreu *et al.* [Pierre Auger Collaboration], "The exposure of the hybrid detector of the Pierre Auger Observatory," Astropart. Phys. **34** (2011) 368 [arXiv:1010.6162 [astro-ph.HE]].

11. P. Abreu *et al.* [Pierre Auger Collaboration], "The Pierre Auger Observatory scaler mode for the study of solar activity modulation of galactic cosmic rays," JINST **6** (2011) P01003.

12. E. Aprile *et al.* [XENON100 Collaboration], "Study of the electromagnetic background in the XENON100 experiment," Phys. Rev. D **83** (2011) 082001 [Erratum-ibid. D **85** (2012) 029904] [arXiv:1101.3866 [astro-ph.IM]].

13. E. Aprile *et al.* [XENON100 Collaboration], "Likelihood Approach to the First Dark Matter Results from XENON100," Phys. Rev. D **84** (2011) 052003 [arXiv:1103.0303 [hep-ex]].

14. A. Teymourian, D. Aharoni, L. Baudis, P. Beltrame, E. Brown, D. Cline, A. D. Ferella and A. Fukasawa *et al.*, "Characterization of the QUartz Photon Intensifying Detector (QUPID) for Noble Liquid Detectors," Nucl. Instrum. Meth. A **654** (2011) 184 [arXiv:1103.3689 [physics.ins-det]].

15. E. Aprile, K. Arisaka, F. Arneodo, A. Askin, L. Baudis, A. Behrens, K. Bokeloh and E. Brown *et al.*, "Material screening and selection for XENON100," Astropart. Phys. **35** (2011) 43 [arXiv:1103.5831 [physics.ins-det]].

16. E. Aprile *et al.* [XENON100 Collaboration], "Dark Matter Results from 100 Live Days of XENON100 Data," Phys. Rev. Lett. **107** (2011) 131302 [arXiv:1104.2549 [astro-ph.CO]].

17. E. Aprile *et al.* [XENON100 Collaboration], "Implications on Inelastic Dark Matter from 100 Live Days of XENON100 Data," Phys. Rev. D **84** (2011) 061101 [arXiv:1104.3121 [astro-ph.CO]].

18. K. Arisaka, C. W. Lam, P. F. Smith, P. Beltrame, C. Ghag, K. Lung, A. Teymourian and H. Wang *et al.*, "Studies of a three-stage dark matter and neutrino observatory based on multi-ton combinations of liquid xenon and liquid argon detectors," Astropart. Phys. **36** (2012) 93 [arXiv:1107.1295 [astro-ph.IM]].

19. E. Aprile *et al.* [XENON100 Collaboration], "The XENON100 Dark Matter Experiment," Astropart. Phys. **35** (2012) 573 [arXiv:1107.2155 [astro-ph.IM]].

20. T. Akiri *et al.* [LBNE Collaboration], "The 2010 Interim Report of the Long-Baseline Neutrino Experiment Collaboration Physics Working Groups," arXiv:1110.6249 [hep-ex].

21. E. Pantic, D. Aharoni, K. Arisaka, P. Beltrame, E. Brown, D. Cline, A. Fukasawa and C. Ghag *et al.*, "Status of QUPID, a novel photosensor for noble liquid detectors," Nucl. Instrum. Meth. A **695** (2012) 121.

22. K. Arisaka, P. Beltrame, C. Ghag, K. Lung and P. R. Scovell, "A New Analysis Method for WIMP searches with Dual-Phase Liquid Xe TPCs," Astropart. Phys. **37** (2012) 1 [arXiv:1202.1924 [astro-ph.IM]].

23. K. Lung, K. Arisaka, A. Bargetzi, P. Beltrame, A. Cahill, T. Genma, C. Ghag and D. Gordon *et al.*, "Characterization of the Hamamatsu R11410-10 3-Inch Photomultiplier Tube for Liquid Xenon Dark Matter Direct Detection Experiments," Nucl. Instrum. Meth. A **696** (2012) 32 [arXiv:1202.2628 [physics.ins-det]].

24. D. Akimov *et al.* [DarkSide Collaboration], "Light Yield in DarkSide-10: a Prototype Two-phase Liquid Argon TPC for Dark Matter Searches," arXiv:1204.6218 [astro-ph.IM].

25. E. Aprile *et al.* [XENON100 Collaboration], "Analysis of the XENON100 Dark Matter Search Data," arXiv:1207.3458 [astro-ph.IM].

26. E. Aprile *et al.* [XENON100 Collaboration], "Dark Matter Results from 225 Live Days of XENON100 Data," Phys. Rev. Lett. **109** (2012) 181301 [arXiv:1207.5988 [astro-ph.CO]].

27. E. Aprile *et al.* [XENON Collaboration], "Comment on 'On the subtleties of searching for dark matter with liquid xenon detectors'," arXiv:1208.5762 [astro-ph.CO].

28. K. Arisaka, P. Beltrame, C. Ghag, J. Kaidi, K. Lung, A. Lyashenko, R. D. Peccei and P. Smith *et al.*, "Expected Sensitivity to Galactic/Solar Axions and Bosonic Super-WIMPs based on the Axio-electric Effect in Liquid Xenon Dark Matter Detectors," Astropart. Phys. **44** (2013) 59 [arXiv:1209.3810 [astro-ph.CO]].

29. E. Aprile, M. Alfonsi, K. Arisaka, F. Arneodo, C. Balan, L. Baudis, A. Behrens and P. Beltrame *et al.*, "The distributed Slow Control System of the XENON100 Experiment," JINST **7** (2012) T12001 [arXiv:1211.0836 [astro-ph.IM]].

30. E. Aprile *et al.* [XENON100 Collaboration], "Limits on spin-dependent WIMP-nucleon cross sections from 225 live days of XENON100 data," arXiv:1301.6620 [astro-ph.CO].

31. E. Aprile *et al.* [XENON100 Collaboration], "Response of the XENON100 Dark Matter Detector to Nuclear Recoils," arXiv:1304.1427 [astro-ph.IM].

32. A. Ankowski *et al.* [ICARUS Collaboration], "Energy reconstruction of electromagnetic showers from pi0 decays with the ICARUS T600 Liquid Argon TPC," Acta Phys. Polon. B **41** (2010) 103 [arXiv:0812.2373 [hep-ex]].

33. D. B. Cline, "The Search for Dark Matter (WIMPS): At low mass and with new methods," Mod. Phys. Lett. A **26** (2011) 925 [arXiv:1010.0636 [astro-ph.HE]].

34. C. Rubbia, M. Antonello, P. Aprili, B. Baibussinov, M. B. Ceolin, L. Barze, P. Benetti and E. Calligarich *et al.*, "Underground operation of the ICARUS T600 LAr-TPC: first results," JINST **6** (2011) P07011 [arXiv:1106.0975 [hep-ex]].

35. M. Antonello *et al.* [ICARUS Collaboration], "A Search for the analogue to Cherenkov radiation by high energy neutrinos at superluminal speeds in ICARUS," Phys. Lett. B **711** (2012) 270 [arXiv:1110.3763 [hep-ex]].

36. M. Antonello, D. Bagliani, B. Baibussinov, H. Bilokon, F. Boffelli, M. Bonesini, E. Calligarich and N. Canci *et al.*, “Search for ’anomalies’ from neutrino and anti-neutrino oscillations at $\Delta m^2 \sim 1$ eV^2 with muon spectrometers and large LAr-TPC imaging detectors,” arXiv:1203.3432 [physics.ins-det].

37. M. Antonello *et al.* [ICARUS Collaboration], “Measurement of the neutrino velocity with the ICARUS detector at the CNGS beam,” Phys. Lett. B **713** (2012) 17 [arXiv:1203.3433 [hep-ex]].

38. A. Antonello, D. Bagliani, B. Baibussinov, H. Bilokon, F. Boffelli, M. Bonesini, E. Calligarich and N. Canci *et al.*, “Search for anomalies in the neutrino sector with muon spectrometers and large LArTPC imaging detectors at CERN,” arXiv:1208.0862 [physics.ins-det].

39. M. Antonello, B. Baibussinov, P. Benetti, F. Boffelli, E. Calligarich, N. Canci, S. Centro and A. Cesana *et al.*, “Precision measurement of the neutrino velocity with the ICARUS detector in the CNGS beam,” JHEP **1211** (2012) 049 [arXiv:1208.2629 [hep-ex]].

40. M. Antonello, *et al.*, “Experimental search for the “LSND anomaly” with the ICARUS detector in the CNGS neutrino beam,” Eur. Phys. J. C **73** (2013) 2345 [arXiv:1209.0122 [hep-ex]].

41. M. Antonello, B. Baibussinov, P. Benetti, E. Calligarich, N. Canci, S. Centro, A. Cesana and K. Cieslik *et al.*, “Precise 3D track reconstruction algorithm for the ICARUS T600 liquid argon time projection chamber detector,” Adv. High Energy Phys. **2013** (2013) 260820 [AHEP Volume **2013** (2013) , Article ID 260820] [Adv. High Energy Phys. **2013** (2013) 260820] [arXiv:1210.5089 [physics.ins-det]].

Item 5b (cont): Task C Publications

The UCLA theory group played a central role in all publications and conference proceedings listed here.

Publications Partly Funded by DOE for Zvi Bern after January 2010

1. Z. Bern, J. J. M. Carrasco and H. Johansson, "Perturbative Quantum Gravity as a Double Copy of Gauge Theory," Phys. Rev. Lett. **105**, 061602 (2010) [arXiv:1004.0476 [hep-th]].

2. Z. Bern, T. Dennen, Y. -t. Huang and M. Kiermaier, "Gravity as the Square of Gauge Theory," Phys. Rev. D **82**, 065003 (2010) [arXiv:1004.0693 [hep-th]].

3. C. F. Berger, Z. Bern, L. J. Dixon, F. Febres Cordero, D. Forde, T. Gleisberg, H. Ita and D. A. Kosower *et al.*, "Next-to-Leading Order QCD Predictions for Z,gamma*+3-Jet Distributions at the Tevatron," Phys. Rev. D **82**, 074002 (2010) [arXiv:1004.1659 [hep-ph]].

4. C. F. Berger, Z. Bern, L. J. Dixon, F. Febres Cordero, D. Forde, T. Gleisberg, H. Ita and D. A. Kosower *et al.*, "Vector Boson + Jets with BlackHat and Sherpa," Nucl. Phys. Proc. Suppl. **205-206**, 92 (2010) [arXiv:1005.3728 [hep-ph]].

5. Z. Bern, J. J. M. Carrasco and H. Johansson, "The Structure of Multiloop Amplitudes in Gauge and Gravity Theories," Nucl. Phys. Proc. Suppl. **205-206**, 54 (2010) [arXiv:1007.4297 [hep-th]].

6. Z. Bern, J. J. M. Carrasco, L. J. Dixon, H. Johansson and R. Roiban, "The Complete Four-Loop Four-Point Amplitude in N=4 Super-Yang-Mills Theory," Phys. Rev. D **82**, 125040 (2010) [arXiv:1008.3327 [hep-th]].

7. C. F. Berger, Z. Bern, L. J. Dixon, F. Febres Cordero, D. Forde, T. Gleisberg, H. Ita and D. A. Kosower *et al.*, "Precise Predictions for W + 4 Jet Production at the Large Hadron Collider," Phys. Rev. Lett. **106**, 092001 (2011) [arXiv:1009.2338 [hep-ph]].

8. Z. Bern, J. J. Carrasco, T. Dennen, Y. -t. Huang and H. Ita, "Generalized Unitarity and Six-Dimensional Helicity," Phys. Rev. D **83**, 085022 (2011) [arXiv:1010.0494 [hep-th]].

9. Z. Bern and T. Dennen, "A Color Dual Form for Gauge-Theory Amplitudes," Phys. Rev. Lett. **107**, 081601 (2011) [arXiv:1103.0312 [hep-th]].

10. Z. Bern and Y. -t. Huang, "Basics of Generalized Unitarity," J. Phys. A A **44**, 454003 (2011) [arXiv:1103.1869 [hep-th]].

11. Z. Bern, J. J. Carrasco, L. J. Dixon, H. Johansson and R. Roiban, "Amplitudes and Ultraviolet Behavior of N = 8 Supergravity," Fortsch. Phys. **59**, 561 (2011) [arXiv:1103.1848 [hep-th]].

12. Z. Bern, G. Diana, L. J. Dixon, F. Febres Cordero, D. Forde, T. Gleisberg, S. Hoeche and H. Ita *et al.*, "Left-Handed W Bosons at the LHC," Phys. Rev. D **84**, 034008 (2011) [arXiv:1103.5445 [hep-ph]].

13. Z. Bern, G. Diana, L. J. Dixon, F. Febres Cordero, S. Hoche, H. Ita, D. A. Kosower and D. Maitre *et al.*, "Driving Missing Data at Next-to-Leading Order," Phys. Rev. D **84**, 114002 (2011) [arXiv:1106.1423 [hep-ph]].

14. Z. Bern, C. Boucher-Veronneau and H. Johansson, "N ¿= 4 Supergravity Amplitudes from Gauge Theory at One Loop," Phys. Rev. D **84**, 105035 (2011) [arXiv:1107.1935 [hep-th]].

15. Z. Bern and H. Ita, "Harmony of scattering amplitudes: From QCD to gravity," Nucl. Phys. Proc. Suppl. **216**, 2 (2011).

16. H. Ita, Z. Bern, L. J. Dixon, F. Febres Cordero, D. A. Kosower and D. Maitre, "Precise Predictions for Z + 4 Jets at Hadron Colliders," Phys. Rev. D **85**, 031501 (2012) [arXiv:1108.2229 [hep-ph]].

17. Z. Bern, G. Diana, L. J. Dixon, F. Febres Cordero, S. Hoeche, D. A. Kosower, H. Ita and D. Maitre *et al.*, "Four-Jet Production at the Large Hadron Collider at Next-to-Leading Order in QCD," arXiv:1112.3940 [hep-ph].

18. Z. Bern, G. Diana, L. J. Dixon, F. Febres Cordero, D. Forde, T. Gleisberg, S. Hoeche and H. Ita *et al.*, "NLO vector boson production with light jets," arXiv:1201.5288 [hep-ph].

19. Z. Bern, J. J. M. Carrasco, L. J. Dixon, H. Johansson and R. Roiban, "Simplifying Multiloop Integrands and Ultraviolet Divergences of Gauge Theory and Gravity Amplitudes," Phys. Rev. D **85**, 105014 (2012) [arXiv:1201.5366 [hep-th]].

20. Z. Bern, S. Davies, T. Dennen and Y. -t. Huang, "Absence of Three-Loop Four-Point Divergences in N=4 Supergravity," Phys. Rev. Lett. **108**, 201301 (2012) [arXiv:1202.3423 [hep-th]].

21. Z. Bern, L. J. Dixon and D. A. Kosower, "Loops, trees and the search for new physics," Sci. Am. **306N5**, 20 (2012).

22. Z. Bern, G. Diana, L. J. Dixon, F. Febres Cordero, S. Hoeche, H. Ita, D. A. Kosower and D. Maitre *et al.*, "Missing Energy and Jets for Supersymmetry Searches," arXiv:1206.6064 [hep-ph].

23. Z. Bern, J. J. M. Carrasco, H. Johansson and R. Roiban, Phys. Rev. Lett. **109**, 241602 (2012) [arXiv:1207.6666 [hep-th]].

24. Z. Bern, S. Davies, T. Dennen and Y. -t. Huang, Phys. Rev. D **86**, 105014 (2012) [arXiv:1209.2472 [hep-th]].

25. Z. Bern, K. Ozeren, L. J. Dixon, S. Hoeche, F. F. Cordero, H. Ita, D. Kosower and D. Maitre, PoS LL **2012**, 018 (2012) [arXiv:1210.6684 [hep-ph]].

26. Z. Bern, J. J. Carrasco, L. J. Dixon, M. R. Douglas, M. von Hippel and H. Johansson, Phys. Rev. D **87**, 025018 (2013) [arXiv:1210.7709 [hep-th]].

Publications Partly Funded by DOE for Sergio Ferrara after January 2010

1. L. Borsten, D. Dahanayake, M.J. Duff, S. Ferrara , A. Marrani and W. Rubens, "Observations on Integral and Continuous U-duality Orbits in N=8 Supergravity", Class.Quant.Grav. 27 (2010) 185003 arXiv:1002.4223 [hep-th]

2. A. Ceresole, S. Ferrara, and A. Marrani, "Small N=2 Extremal Black Holes in Special Geometry", Jun 2010. 14 pp. Note: 14 pages Phys.Lett. B693 (2010) 366-372 arXiv:1006.2007 [hep-th]

3. B.L. Cerchiai, S. Ferrara , A. Marrani and B. Zumino, "Charge Orbits of Extremal Black Holes in Five Dimensional Supergravity," Phys.Rev. D82 (2010) 085010 arXiv:1006.3101 [hep-th].

4. L. Andrianopoli, R. D'Auria, S. Ferrara and M. Trigiante, "Fake Superpotential for Large and Small Extremal Black Holes", JHEP 1008 (2010) 126 arXiv:1002.4340 [hep-th].

5. S. Ferrara, R. Kallosh, A. Linde, A. Marrani and A. Van Proeyen, "Superconformal Symmetry, NMSSM, and Inflation," Phys. Rev. D **83** (2011) 025008 [arXiv:1008.2942 [hep-th]].

6. S. Bellucci, S. Ferrara, A. Shcherbakov and A. Yeranyan, "Attractors and first order formalism in five dimensions revisited," Phys. Rev. D **83** (2011) 065003 [arXiv:1010.3516 [hep-th]].

7. M. J. Duff and S. Ferrara, "Four curious supergravities," Phys. Rev. D **83** (2011) 046007 [arXiv:1010.3173 [hep-th]].

8. S. Ferrara, A. Marrani and E. Orazi, "Split Attractor Flow in N=2 Minimally Coupled Supergravity," Nucl. Phys. B **846** (2011) 512 [arXiv:1010.2280 [hep-th]].

9. S. Ferrara, A. Marrani, E. Orazi, R. Stora and A. Yeranyan, "Two-Center Black Holes Duality-Invariants for stu Model and its lower-rank Descendants," J. Math. Phys. **52** (2011) 062302 [arXiv:1011.5864 [hep-th]].

10. M. J. Duff and S. Ferrara, "Generalized mirror symmetry and trace anomalies," Class. Quant. Grav. **28**, 065005 (2011) [arXiv:1009.4439 [hep-th]].

11. S. Ferrara, R. Kallosh, A. Linde, A. Marrani and A. Van Proeyen, "Jordan Frame Supergravity and Inflation in NMSSM," Phys. Rev. D **82** (2010) 045003 [arXiv:1004.0712 [hep-th]].

12. L. Andrianopoli, R. D'Auria, S. Ferrara, A. Marrani and M. Trigiante, "Two-Centered Magical Charge Orbits," JHEP **1104** (2011) 041 [arXiv:1101.3496 [hep-th]].

13. A. Ceresole, S. Ferrara, A. Marrani and A. Yeranyan, "Small Black Hole Constituents and Horizontal Symmetry," JHEP **1106** (2011) 078 [arXiv:1104.4652 [hep-th]].

14. S. Ferrara and M. Porrati, "4D Localization in Randall-Sundrum 2 Supergravity and in Vasiliev Theories," Phys. Lett. B **704** (2011) 249 [arXiv:1108.1993 [hep-th]].

15. L. Borsten, M. J. Duff, S. Ferrara, A. Marrani and W. Rubens, "Explicit Orbit Classification of Reducible Jordan Algebras and Freudenthal Triple Systems," arXiv:1108.0908 [math.RA].

16. L. Borsten, M. J. Duff, S. Ferrara, A. Marrani and W. Rubens, "Small Orbits," Phys. Rev. D **85** (2012) 086002 [arXiv:1108.0424 [hep-th]].

17. S. Ferrara and A. Marrani, "Generalized Mirror Symmetry and Quantum Black Hole Entropy," Phys. Lett. B **707** (2012) 173 [arXiv:1109.0444 [hep-th]].

18. S. Ferrara, A. Marrani and A. Yeranyan, "On Invariant Structures of Black Hole Charges," JHEP **1202** (2012) 071 [arXiv:1110.4004 [hep-th]].

19. S. Ferrara and R. Kallosh, "Creation of Matter in the Universe and Groups of Type E_7," JHEP **1112** (2011) 096 [arXiv:1110.4048 [hep-th]].

20. J. Broedel, J. J. M. Carrasco, S. Ferrara, R. Kallosh and R. Roiban, "N=2 Supersymmetry and U(1)-Duality," Phys. Rev. D **85**, 125036 (2012) [arXiv:1202.0014 [hep-th]].

21. S. Ferrara, A. Marrani, M. Trigiante, A. Marrani and M. Trigiante, "Super-Ehlers in Any Dimension," JHEP **1211**, 068 (2012) [arXiv:1206.1255 [hep-th]].

Publications Partly Funded by DOE for Graciela Gelmini after January 2010

1. A. E. Erkoca, G. Gelmini, M. H. Reno and I. Sarcevic, "Muon Fluxes and Showers from Dark Matter Annihilation in the Galactic Center," Phys. Rev. D **81**, 096007 (2010) [arXiv:1002.2220 [hep-ph]].

2. C. Savage, G. Gelmini, P. Gondolo, K. Freese, "XENON10/100 dark matter constraints in comparison with CoGeNT and DAMA: examining the Leff dependence," Phys. Rev. **D83**, 055002 (2011). [arXiv:1006.0972 [astro-ph.CO]].

3. N. Bozorgnia, G. B. Gelmini and P. Gondolo, "Channeling in direct dark matter detection I: channeling fraction in NaI(Tl) crystals," JCAP **1011**, 019 (2010). [arXiv:1006.3110 [astro-ph.CO]].

4. N. Bozorgnia, G. B. Gelmini and P. Gondolo, "Channeling in direct dark matter detection II: channeling fraction in Si and Ge crystals," JCAP **1011**, 028 (2010). [arXiv:1008.3676 [astro-ph.CO]].

5. N. Bozorgnia, G. B. Gelmini and P. Gondolo, “Channeling in direct dark matter detection III: channeling fraction in CsI crystals,” JCAP **1011**, 029 (2010). [arXiv:1009.3325 [astro-ph.CO]].

6. N. Bozorgnia, G. B. Gelmini, P. Gondolo, “Channeling in solid Xe, Ar and Ne direct dark matter detectors,” Nucl. Ins. and Meth. in Phys. (NIM) A **654**, 162 (2011). [arXiv:1011.6006 [astro-ph.CO]].

7. N. Bozorgnia, G. B. Gelmini, P. Gondolo, “Daily modulation due to channeling in direct dark matter crystalline detectors,” Phys. Rev. **D84**, 023516 (2011). [arXiv:1101.2876 [astro-ph.CO]].

8. G. B. Gelmini, O. Kalashev and D. V. Semikoz, “Gamma-Ray Constraints on Maximum Cosmogenic Neutrino Fluxes and UHECR Source Evolution Models,” JCAP **1201**, 044 (2012) [arXiv:1107.1672 [astro-ph.CO]].

9. N. Bozorgnia, G. B. Gelmini and P. Gondolo, “Ring-like features in directional dark matter detection,” JCAP **1206**, 037 (2012) [arXiv:1111.6361 [astro-ph.CO]].

10. P. Gondolo and G. B. Gelmini, “Halo independent comparison of direct dark matter detection data,” JCAP **1212**, 015 (2012) [arXiv:1202.6359 [hep-ph]].

11. N. Bozorgnia, G. B. Gelmini and P. Gondolo, “Aberration features in directional dark matter detection,” JCAP **1208**, 011 (2012) [arXiv:1205.2333 [astro-ph.CO]].

Conference Proceedings, Divulgation Articles and Book Chapter

12. G. B. Gelmini, A. Kusenko and T. J. Weiler, “Through neutrino eyes,” Sci. Am. **302N5**, 20 (2010).

13. G. B. Gelmini, A. Kusenko and T. J. Weiler, “Neutrinos as messengers from faraway worlds,” Spektrum Wiss. **2010N7**, 24 (2010).

14. G. B. Gelmini, “Ion-Channeling in Direct Dark Matter Crystalline Detectors,” PoS IDM **2010**, 016 (2011) [arXiv:1012.3807 [hep-ph]].

15. G. B. Gelmini, “Recoiling Ion-Channeling in Direct Dark Matter Detectors,” J. Phys. Conf. Ser. **384**, 012007 (2012) [arXiv:1201.4560 [astro-ph.CO]].

16. G. B. Gelmini, O. Kalashev and D. V. Semikoz, “Restrictions on cosmogenic neutrinos and UHECR from Fermi 3 years data,” Talk presented at 12th International Conference of Topic in AstroParticle and Underground Physics (TAUP 2011), J. Phys. Conf. Ser. **375**, 052012 (2012).

Publications as member of the Pierre Auger Collaboration
(I was a member until 12/31/2010)

17. J. Abraham *et al.* [Pierre Auger Collaboration], “A Study of the Effect of Molecular and Aerosol Conditions in the Atmosphere on Air Fluorescence Measurements at the Pierre Auger Observatory,” Astropart. Phys. **33** (2010) 108 [arXiv:1002.0366 [astro-ph.IM]].

18. J. Abraham *et al.* [Pierre Auger Observatory Collaboration], "Measurement of the Depth of Maximum of Extensive Air Showers above $10^1$8 eV," Phys. Rev. Lett. **104**, 091101 (2010) [arXiv:1002.0699 [astro-ph.HE]].

19. J. Abraham *et al.* [Pierre Auger Collaboration], "Measurement of the energy spectrum of cosmic rays above 10^{18} eV using the Pierre Auger Observatory," Phys. Lett. B **685**, 239 (2010) [arXiv:1002.1975 [astro-ph.HE]].

20. P. Abreu *et al.* [Pierre Auger Observatory Collaboration], "Update on the correlation of the highest energy cosmic rays with nearby extragalactic matter," Astropart. Phys. **34**, 314-326 (2010). [arXiv:1009.1855 [astro-ph.HE]].

21. P. Abreu *et al.* [Pierre Auger Observatory Collaboration], "The exposure of the hybrid detector of the Pierre Auger Observatory," Astropart. Phys. **34**, 368-381 (2011). [arXiv:1010.6162 [astro-ph.HE]].

22. P. Abreu *et al.* [Pierre Auger Collaboration], "The Pierre Auger Observatory scaler mode for the study of solar activity modulation of galactic cosmic rays," JINST **6**, P01003 (2011).

23. J. Abraham *et al.* [Pierre Auger Observatory Collaoration Collaboration], "Trigger and aperture of the surface detector array of the Pierre Auger Observatory," Nucl. Instrum. Meth. A **613**, 29 (2010) [arXiv:1111.6764 [astro-ph.IM]].

Publications Partly Funded by DOE for Alexander Kusenko after January 2010

1. S. 'i. Ando and A. Kusenko, "Interactions of keV sterile neutrinos with matter," Phys. Rev. D **81**, 113006 (2010) [arXiv:1001.5273 [hep-ph]].

2. J. Abraham *et al.* [Pierre Auger Collaboration], "A Study of the Effect of Molecular and Aerosol Conditions in the Atmosphere on Air Fluorescence Measurements at the Pierre Auger Observatory," Astropart. Phys. **33**, 108 (2010) [arXiv:1002.0366 [astro-ph.IM]].

3. J. Abraham *et al.* [Pierre Auger Observatory Collaboration], "Measurement of the Depth of Maximum of Extensive Air Showers above 10^{18} eV," Phys. Rev. Lett. **104**, 091101 (2010) [arXiv:1002.0699 [astro-ph.HE]].

4. J. Abraham *et al.* [Pierre Auger Collaboration], "Measurement of the energy spectrum of cosmic rays above 10^{18} eV using the Pierre Auger Observatory," Phys. Lett. B **685**, 239 (2010) [arXiv:1002.1975 [astro-ph.HE]].

5. A. Calvez and A. Kusenko, "Can past gamma-ray bursts explain both INTEGRAL and ATIC/PAMELA/Fermi anomalies simultaneously?," Phys. Rev. D **82**, 063005 (2010) [arXiv:1003.0045 [astro-ph.HE]].

6. A. Calvez, W. Essey, M. Fairbairn, A. Kusenko and M. Loewenstein, 'On the use of X-ray and gamma-ray telescopes for identifying the origin of electrons and positrons observed by ATIC, Fermi, and PAMELA," Astropart. Phys. **35**, 185 (2011) [arXiv:1003.1113 [astro-ph.HE]].

7. J. Abraham *et al.* [Pierre Auger Observatory Collaoration Collaboration], "Trigger and aperture of the surface detector array of the Pierre Auger Observatory," Nucl. Instrum. Meth. A **613**, 29 (2010) [arXiv:1111.6764 [astro-ph.IM]].

8. A. Calvez, A. Kusenko and S. Nagataki, "The role of Galactic sources and magnetic fields in forming the observed energy-dependent composition of ultrahigh-energy cosmic rays," Phys. Rev. Lett. **105**, 091101 (2010) [arXiv:1004.2535 [astro-ph.HE]].

9. S. 'i. Ando and A. Kusenko, "Evidence for Gamma-Ray Halos Around Active Galactic Nuclei and the First Measurement of Intergalactic Magnetic Fields," Astrophys. J. **722**, L39 (2010) [arXiv:1005.1924 [astro-ph.HE]].

10. A. Kusenko, F. Takahashi and T. T. Yanagida, "Dark Matter from Split Seesaw," Phys. Lett. B **693**, 144 (2010) [arXiv:1006.1731 [hep-ph]].

11. G. B. Gelmini, A. Kusenko and T. J. Weiler, "Through neutrino eyes," Sci. Am. **302N5**, 20 (2010).

12. I. M. Shoemaker, K. Petraki and A. Kusenko, "Collider signatures of sterile neutrinos in models with a gauge-singlet Higgs," JHEP **1009**, 060 (2010) [arXiv:1006.5458 [hep-ph]].

13. A. Kusenko, "Past Galactic GRBs, and the origin and composition of ultrahigh-energy cosmic rays," AIP Conf. Proc. **1279**, 242 (2010) [arXiv:1007.0961 [astro-ph.HE]].

14. G. B. Gelmini, A. Kusenko and T. J. Weiler, "Neutrinos as messengers from faraway worlds," Spektrum Wiss. **2010N7**, 24 (2010).

15. A. Kusenko, "Ultrahigh-energy nuclei, photons, and magnetic fields," Nucl. Phys. Proc. Suppl. **212-213**, 194 (2011) [arXiv:1010.4836 [astro-ph.HE]].

16. W. Essey, O. Kalashev, A. Kusenko and J. F. Beacom, "Role of line-of-sight cosmic ray interactions in forming the spectra of distant blazars in TeV gamma rays and high-energy neutrinos," Astrophys. J. **731**, 51 (2011) [arXiv:1011.6340 [astro-ph.HE]].

17. W. Essey, S. 'i. Ando and A. Kusenko, "Determination of intergalactic magnetic fields from gamma ray data," Astropart. Phys. **35**, 135 (2011) [arXiv:1012.5313 [astro-ph.HE]].

18. J. W. d. Herder, L. Piro, T. Ohashi, C. Kouveliotou, D. H. Hartmann, J. S. Kaastra, L. Amati and M. Andersen *et al.*, "ORIGIN: Metal Creation and Evolution from the Cosmic Dawn," arXiv:1104.2048 [astro-ph.IM].

19. A. Kusenko and M. B. Voloshin, "A gamma-ray signature of energetic sources of cosmic-ray nuclei," Phys. Lett. B **707**, 255 (2012) [arXiv:1109.0565 [astro-ph.HE]].

20. G. M. Fuller, C. T. Kishimoto and A. Kusenko, “Heavy sterile neutrinos, entropy and relativistic energy production, and the relic neutrino background,” arXiv:1110.6479 [astro-ph.CO].

21. W. Essey and A. Kusenko, “On weak redshift dependence of gamma-ray spectra of distant blazars,” Astrophys. J. **751**, L11 (2012) [arXiv:1111.0815 [astro-ph.HE]].

22. M. Kawasaki, A. Kusenko and T. T. Yanagida, “Primordial seeds of supermassive black holes,” Phys. Lett. B **711**, 1 (2012) [arXiv:1202.3848 [astro-ph.CO]].

23. A. Prosekin, W. Essey, A. Kusenko and F. Aharonian, “Time structure of gamma-ray signals generated in line-of-sight interactions of cosmic rays from distant blazars,” arXiv:1203.3787 [astro-ph.HE].

24. M. Loewenstein and A. Kusenko, “Dark Matter Search Using XMM-Newton Observations of Willman 1,” Astrophys. J. **751**, 82 (2012) [arXiv:1203.5229 [astro-ph.CO]].

25. K. N. Abazajian, M. A. Acero, S. K. Agarwalla, A. A. Aguilar-Arevalo, C. H. Albright, S. Antusch, C. A. Arguelles and A. B. Balantekin *et al.*, “Light Sterile Neutrinos: A White Paper,” arXiv:1204.5379 [hep-ph].

26. F. Aharonian, W. Essey, A. Kusenko and A. Prosekin, “TeV gamma rays from blazars beyond z=1?,” Phys. Rev. D **87**, 063002 (2013) [arXiv:1206.6715 [astro-ph.HE]].

27. A. Kusenko, “Cosmic connections: from cosmic rays to gamma rays, to cosmic backgrounds and magnetic fields,” arXiv:1207.3579 [astro-ph.HE].

28. A. Kusenko, M. Loewenstein and T. T. Yanagida, “Moduli dark matter and the search for its decay line using Suzaku X-ray telescope,” Phys. Rev. D **87**, 043508 (2013) [arXiv:1209.6403 [hep-ph]].

29. J. M. Cornwall, A. Kusenko, L. Pearce and R. D. Peccei, “Can supersymmetry breaking lead to electroweak symmetry breaking via formation of scalar bound states?,” Phys. Lett. B **718**, 951 (2013) [arXiv:1210.6433 [hep-ph]].

Item 5b (cont.): Task E and H Publications

DOE is one of a number of agencies providing funding. The UCLA funding is mainly DOE (base grant and through Fermilab) with some additional funds from the NSF through the U.S. CMS Program Office (though April 2012).

All publications by CMS collaboration include the UCLA CMS Group members from Tasks E and H. As a member of CMS for almost 20 years, UCLA has a role in the success of the experiment and all papers. Papers in which UCLA directly worked, either on the analysis presented in the paper or in writing, editing, or extensively reviewing the paper, are marked with an asterisk (*).

1. S. Chatrchyan *et al.* [CMS Collaboration], "Search for gluino mediated bottom- and top-squark production in multijet final states in pp collisions at 8 TeV," arXiv:1305.2390 [hep-ex].

2. S. Chatrchyan *et al.* [CMS Collaboration], "Multiplicity and transverse-momentum dependence of two- and four-particle correlations in pPb and PbPb collisions," arXiv:1305.0609 [nucl-ex].

3. S. Chatrchyan *et al.* [CMS Collaboration], "Searches for long-lived charged particles in pp collisions at $\sqrt{s}$=7 and 8 TeV," arXiv:1305.0491 [hep-ex].

4. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the ratio of the inclusive 3-jet cross section to the inclusive 2-jet cross section in pp collisions at $\sqrt{s} = 7$ TeV and first determination of the strong coupling constant in the TeV range," arXiv:1304.7498 [hep-ex].

5. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the Lambda(b)0 lifetime in pp collisions at sqrt(s) = 7 TeV," arXiv:1304.7495 [hep-ex].

6. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of masses in the $t\bar{t}$ system by kinematic endpoints in pp collisions at $\sqrt{s}$=7 TeV," arXiv:1304.5783 [hep-ex].

7. S. Chatrchyan *et al.* [CMS Collaboration], "Search for a standard-model-like Higgs boson with a mass of up to 1 TeV at the LHC,"

8. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the Y(1S), Y(2S), and Y(3S) cross sections in pp collisions at $\sqrt{s} = 7$ TeV," arXiv:1303.5900 [hep-ex].

9. S. Chatrchyan *et al.* [CMS Collaboration], "Search for microscopic black holes in pp collisions at sqrt(s) = 8 TeV," arXiv:1303.5338 [hep-ex].

10. S. Chatrchyan *et al.* [CMS Collaboration], "Studies of jet mass in dijet and W/Z+jet events," arXiv:1303.4811 [hep-ex].

11. S. Chatrchyan *et al.* [CMS Collaboration], "Observation of a new boson with mass near 125 GeV in pp collisions at sqrt(s) = 7 and 8 TeV," arXiv:1303.4571 [hep-ex].

12. S. Chatrchyan *et al.* [CMS Collaboration], "A new boson with a mass of 125-GeV observed with the CMS experiment at the Large Hadron Collider," Science **338**, 1569 (2012).

13. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of associated production of vector bosons and top quark-antiquark pairs at sqrt(s) = 7 TeV," Phys. Rev. Lett. **110**, 172002 (2013) [arXiv:1303.3239 [hep-ex]].

14. S. Chatrchyan *et al.* [CMS Collaboration], "Search for supersymmetry in hadronic final states with missing transverse energy using the variables α_T and b-quark multiplicity in pp collisions at $\sqrt{s} = 8$ TeV," arXiv:1303.2985 [hep-ex].

15. S. Chatrchyan *et al.* [CMS Collaboration], "Search for the standard model Higgs boson produced in association with a top-quark pair in pp collisions at the LHC," arXiv:1303.0763 [hep-ex].

16. S. Chatrchyan *et al.* [CMS Collaboration], "Search for narrow resonances using the dijet mass spectrum in pp collisions at sqrt(s) = 8 TeV," arXiv:1302.4794 [hep-ex].

17. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the X(3872) production cross section via decays to J/psi pi pi in pp collisions at sqrt(s) = 7 TeV," JHEP **1304**, 154 (2013) [arXiv:1302.3968 [hep-ex]].

18. S. Chatrchyan *et al.* [CMS Collaboration], "Search for a Higgs boson decaying into a b-quark pair and produced in association with b quarks in proton-proton collisions at 7 TeV," Phys. Lett. B **722**, 207 (2013) [arXiv:1302.2892 [hep-ex]].

19. S. Chatrchyan *et al.* [CMS Collaboration], "Search for new physics in final states with a lepton and missing transverse energy in pp collisions at the LHC," Phys. Rev. D **87**, 072005 (2013) [arXiv:1302.2812 [hep-ex]].

20. S. Chatrchyan *et al.* [CMS Collaboration], "Study of the underlying event at forward rapidity in pp collisions at $\sqrt{s} = 0.9$, 2.76, and 7 TeV," JHEP **1304**, 072 (2013) [arXiv:1302.2394 [hep-ex]].

21. S. Chatrchyan *et al.* [CMS Collaboration], "Searches for Higgs bosons in pp collisions at sqrt(s) = 7 and 8 TeV in the context of four-generation and fermiophobic models," arXiv:1302.1764 [hep-ex].

22. S. Chatrchyan *et al.* [CMS Collaboration], "Search for pair-produced dijet resonances in four-jet final states in pp collisions at sqrt(s) = 7 TeV," Phys. Rev. Lett. **110**, 141802 (2013) [arXiv:1302.0531 [hep-ex]].

23. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the ttbar production cross section in the all-jet final state in pp collisions at sqrt(s) = 7 TeV," arXiv:1302.0508 [hep-ex].

24. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the top-antitop production cross section in the tau+jets channel in pp collisions at sqrt(s) = 7 TeV," Eur. Phys. J. C **73**, 2386 (2013) [arXiv:1301.5755 [hep-ex]].

25. S. Chatrchyan *et al.* [CMS Collaboration], "Search for contact interactions using the inclusive jet pT spectrum in pp collisions at sqrt(s) = 7 TeV," Phys. Rev. D **87**, 052017 (2013) [arXiv:1301.5023 [hep-ex]].

26. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of W+W- and ZZ production cross sections in pp collisions at sqrt(s) = 8 TeV," Phys. Lett. B **721**, 190 (2013) [arXiv:1301.4698 [hep-ex]].

27. S. Chatrchyan *et al.* [CMS Collaboration], "Search for physics beyond the standard model in events with tau leptons, jets, and large transverse momentum imbalance in pp collisions at sqrt(s) = 7 TeV," arXiv:1301.3792 [hep-ex].

28. S. Chatrchyan *et al.* [CMS Collaboration], "Interpretation of searches for supersymmetry with simplified models," arXiv:1301.2175 [hep-ex].

29. S. Chatrchyan *et al.* [CMS Collaboration], "Event shapes and azimuthal correlations in Z + jets events in pp collisions at $\sqrt{s}$ = 7 TeV," Phys. Lett. B **722**, 238 (2013) [arXiv:1301.1646 [hep-ex]].

30. S. Chatrchyan *et al.* [CMS Collaboration], "Search for supersymmetry in events with opposite-sign dileptons and missing transverse energy using an artificial neural network," Phys. Rev. D **87**, 072001 (2013) [arXiv:1301.0916 [hep-ex]].

31. S. Chatrchyan *et al.* [CMS Collaboration], "Search for supersymmetry in pp collisions at $\sqrt{s}$ = 7 TeV in events with a single lepton, jets, and missing transverse momentum," Eur. Phys. J. C **73**, 2404 (2013) [arXiv:1212.6428 [hep-ex]].

32. S. Chatrchyan *et al.* [CMS Collaboration], "On the mass and spin-parity of the Higgs boson candidate via its decays to Z boson pairs," Phys. Rev. Lett. **110**, 081803 (2013) [arXiv:1212.6639 [hep-ex]].

33. S. Chatrchyan *et al.* [CMS Collaboration], "Measurements of differential jet cross sections in proton-proton collisions at $\sqrt{s}$ = 7 TeV with the CMS detector," arXiv:1212.6660 [hep-ex].

34. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the $t\bar{t}$ production cross section in pp collisions at $\sqrt{s}$ = 7 TeV with lepton + jets final states," Phys. Lett. B **720**, 83 (2013) [arXiv:1212.6682 [hep-ex]].

35. S. Chatrchyan *et al.* [CMS Collaboration], "Inclusive search for supersymmetry using the razor variables in pp collisions at $\sqrt{s}$ = 7 TeV," arXiv:1212.6961 [hep-ex].

36. S. Chatrchyan *et al.* [CMS Collaboration], "Search for new physics in events with same-sign dileptons and b jets in pp collisions at $\sqrt{s}$ = 8 TeV," JHEP **1303**, 037 (2013) [arXiv:1212.6194 [hep-ex]].

37. S. Chatrchyan *et al.* [CMS Collaboration], "Search for heavy narrow dilepton resonances in pp collisions at $\sqrt{s}$ = 7 TeV and $\sqrt{s}$ = 8 TeV," Phys. Lett. B **720**, 63 (2013) [arXiv:1212.6175 [hep-ex]].

38. S. Chatrchyan *et al.* [CMS Collaboration], "Search for contact interactions in opposite-sign dimuon events in pp collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. D **87**, 032001 (2013) [arXiv:1212.4563 [hep-ex]].

39. S. Chatrchyan *et al.* [CMS Collaboration], "Search for heavy resonances in the W/Z-tagged dijet mass spectrum in pp collisions at 7 TeV," arXiv:1212.1910 [hep-ex].

40. S. Chatrchyan *et al.* [CMS Collaboration], "Search for long-lived particles decaying to photons and missing energy in proton-proton collisions at sqrt(s) = 7 TeV," arXiv:1212.1838 [hep-ex].

41. S. Chatrchyan *et al.* [CMS Collaboration], "Search for exotic resonances decaying into WZ/ZZ in pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1302**, 036 (2013) [arXiv:1211.5779 [hep-ex]].

42. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the ZZ production cross section and search for anomalous couplings in 2 l2l ' final states in pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1301**, 063 (2013) [arXiv:1211.4890 [hep-ex]].

43. S. Chatrchyan *et al.* [CMS Collaboration], "Search for new physics in events with photons, jets, and missing transverse energy in pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1303**, 111 (2013) [arXiv:1211.4784 [hep-ex]].

44. S. Chatrchyan *et al.* [CMS Collaboration], "Identification of b-quark jets with the CMS experiment," JINST **8**, P04013 (2013) [arXiv:1211.4462 [hep-ex]].

45. S. Chatrchyan *et al.* [CMS Collaboration], "Search for Z ' resonances decaying to $t\bar{t}$ in dilepton+jets final states in pp collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. D **87**, 072002 (2013) [arXiv:1211.3338 [hep-ex]].

46. S. Chatrchyan *et al.* [CMS Collaboration], "Search for supersymmetry in final states with a single lepton, b-quark jets, and missing transverse energy in proton-proton collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. D **87**, 052006 (2013) [arXiv:1211.3143 [hep-ex]].

47. S. Chatrchyan *et al.* [CMS Collaboration], "Search in leptonic channels for heavy resonances decaying to long-lived neutral particles," JHEP **1302**, 085 (2013) [arXiv:1211.2472 [hep-ex]].

48. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of differential top-quark pair production cross sections in pp colisions at $\sqrt{s} = 7$ TeV," Eur. Phys. J. C **73**, 2339 (2013) [arXiv:1211.2220 [hep-ex]].

49. S. Chatrchyan *et al.* [CMS Collaboration], "Search for supersymmetry in final states with missing transverse energy and 0, 1, 2, or at least 3 b-quark jets in 7 TeV pp collisions using the variable alphaT," JHEP **1301**, 077 (2013) [arXiv:1210.8115 [hep-ex]].

50. S. Chatrchyan *et al.* [CMS Collaboration], "Search for a non-standard-model Higgs boson decaying to a pair of new light bosons in four-muon final states," arXiv:1210.7619 [hep-ex].

51. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the sum of WW and WZ production with W+dijet events in pp collisions at $\sqrt{s} = 7$ TeV," Eur. Phys. J. C **73**, 2283 (2013) [arXiv:1210.7544 [hep-ex]].

52. S. Chatrchyan *et al.* [CMS Collaboration], "Search for heavy quarks decaying into a top quark and a W or Z boson using lepton + jets events in pp collisions at $\sqrt{s} = 7$ TeV," JHEP **01**, 154 (2013) [arXiv:1210.7471 [hep-ex]].

53. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the inelastic proton-proton cross section at $\sqrt{s} = 7$ TeV," Phys. Lett. B **722**, 5 (2013) [arXiv:1210.6718 [hep-ex]].

54. S. Chatrchyan *et al.* [CMS Collaboration], "Search for pair production of third-generation leptoquarks and top squarks in pp collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. Lett. **110**, 081801 (2013) [arXiv:1210.5629 [hep-ex]].

55. S. Chatrchyan *et al.* [CMS Collaboration], "Search for third-generation leptoquarks and scalar bottom quarks in pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1212**, 055 (2012) [arXiv:1210.5627 [hep-ex]].

56. S. Chatrchyan *et al.* [CMS Collaboration], "Observation of long-range near-side angular correlations in proton-lead collisions at the LHC," Phys. Lett. B **718**, 795 (2013) [arXiv:1210.5482 [nucl-ex]].

57. S. Chatrchyan *et al.* [CMS Collaboration], "Observation of Z decays to four leptons with the CMS detector at the LHC," JHEP **1212**, 034 (2012) [arXiv:1210.3844 [hep-ex]].

58. S. Chatrchyan *et al.* [CMS Collaboration], "Search for excited leptons in pp collisions at $\sqrt{s} = 7$ TeV," Phys. Lett. B **720**, 309 (2013) [arXiv:1210.2422 [hep-ex]].

59. S. Chatrchyan *et al.* [CMS Collaboration], "Search for heavy neutrinos and W[R] bosons with right-handed couplings in a left-right symmetric model in pp collisions at sqrt(s) = 7 TeV," Phys. Rev. Lett. **109**, 261802 (2012) [arXiv:1210.2402 [hep-ex]].

60. S. Chatrchyan *et al.* [CMS Collaboration], "Search for narrow resonances and quantum black holes in inclusive and b-tagged dijet mass spectra from pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1301**, 013 (2013) [arXiv:1210.2387 [hep-ex]].

61. S. Chatrchyan *et al.* [CMS Collaboration], "Search for fractionally charged particles in pp collisions at $\sqrt{s} = 7$ TeV,"

62. S. Chatrchyan *et al.* [CMS Collaboration], "Search for supersymmetry in events with photons and low missing transverse energy in pp collisions at $\sqrt{s} = 7$ TeV," Phys. Lett. B **719**, 42 (2013) [arXiv:1210.2052 [hep-ex]].

63. S. Chatrchyan *et al.* [CMS Collaboration], "Search for heavy lepton partners of neutrinos in proton-proton collisions in the context of the type III seesaw mechanism," Phys. Lett. B **718**, 348 (2012) [arXiv:1210.1797 [hep-ex]].

64. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the relative prompt production rate of chi(c2) and chi(c1) in pp collisions at $\sqrt{s} = 7$ TeV," Eur. Phys. J. C **72**, 2251 (2012) [arXiv:1210.0875 [hep-ex]].

65. S. Chatrchyan *et al.* [CMS Collaboration], "Search for anomalous production of highly boosted Z bosons decaying to dimuons in pp collisions at $\sqrt{s} = 7$ TeV," Phys. Lett. B **722**, 28 (2013) [arXiv:1210.0867 [hep-ex]].

66. S. Chatrchyan *et al.* [CMS Collaboration], "Search for electroweak production of charginos and neutralinos using leptonic final states in pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1211**, 147 (2012) [arXiv:1209.6620 [hep-ex]].

67. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the single-top-quark t-channel cross section in pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1212**, 035 (2012) [arXiv:1209.4533 [hep-ex]].

68. S. Chatrchyan *et al.* [CMS Collaboration], "Search for resonant $t\bar{t}$ production in lepton+jets events in pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1212**, 015 (2012) [arXiv:1209.4397 [hep-ex]].

69. S. Chatrchyan *et al.* [CMS Collaboration], "Search for the standard model Higgs boson produced in association with W and Z bosons in pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1211**, 088 (2012) [arXiv:1209.3937 [hep-ex]].

70. S. Chatrchyan *et al.* [CMS Collaboration], "Search for a narrow spin-2 resonance decaying to a pair of Z vector bosons in the semileptonic final state," Phys. Lett. B **718**, 1208 (2013) [arXiv:1209.3807 [hep-ex]].

71. S. Chatrchyan *et al.* [CMS Collaboration], "Evidence for associated production of a single top quark and W boson in pp collisions at 7 TeV," Phys. Rev. Lett. [arXiv:1209.3489 [hep-ex]].

72. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the Y1S, Y2S and Y3S polarizations in pp collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. Lett. [arXiv:1209.2922 [hep-ex]].

73. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the top-quark mass in $t\bar{t}$ events with dilepton final states in pp collisions at $\sqrt{s} = 7$ TeV," Eur. Phys. J. C **72**, 2202 (2012) [arXiv:1209.2393 [hep-ex]].

74. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the top-quark mass in $t\bar{t}$ events with lepton+jets final states in pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1212**, 105 (2012) [arXiv:1209.2319 [hep-ex]].

75. S. Chatrchyan *et al.* [CMS Collaboration], "Observation of a diffractive contribution to dijet production in proton-proton collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. D **87**, 012006 (2013) [arXiv:1209.1805 [hep-ex]].

76. S. Chatrchyan *et al.* [CMS Collaboration], “Search for exclusive or semi-exclusive photon pair production and observation of exclusive and semi-exclusive electron pair production in pp collisions at $\sqrt{s} = 7$ TeV,” JHEP **1211**, 080 (2012) [arXiv:1209.1666 [hep-ex]].

77. S. Chatrchyan *et al.* [CMS Collaboration], “Combined search for the quarks of a sequential fourth generation,” Phys. Rev. D **86**, 112003 (2012) [arXiv:1209.1062 [hep-ex]].

78. S. Chatrchyan *et al.* [CMS Collaboration], “Search for pair produced fourth-generation up-type quarks in pp collisions at $\sqrt{s} = 7$ TeV with a lepton in the final state,” Phys. Lett. B **718**, 307 (2012) [arXiv:1209.0471 [hep-ex]].

79. S. Chatrchyan *et al.* [CMS Collaboration], “Search for supersymmetry in events with b-quark jets and missing transverse energy in pp collisions at 7 TeV,” Phys. Rev. D **86**, 072010 (2012) [arXiv:1208.4859 [hep-ex]].

80. S. Chatrchyan *et al.* [CMS Collaboration], “Study of the dijet mass spectrum in $pp \to W+$ jets events at $\sqrt{s} = 7$ TeV,” Phys. Rev. Lett. **109**, 251801 (2012) [arXiv:1208.3477 [hep-ex]].

81. S. Chatrchyan *et al.* [CMS Collaboration], “Search for three-jet resonances in pp collisions at $\sqrt{s} = 7$ TeV,” Phys. Lett. B **718**, 329 (2012) [arXiv:1208.2931 [hep-ex]].

82. S. Chatrchyan *et al.* [CMS Collaboration], “Observation of sequential Upsilon suppression in PbPb collisions,” Phys. Rev. Lett. **109**, 222301 (2012) [arXiv:1208.2826 [nucl-ex]].

83. S. Chatrchyan *et al.* [CMS Collaboration], “Measurement of the $t\bar{t}$ production cross section in the dilepton channel in pp collisions at $\sqrt{s} = 7$ TeV,” JHEP **1211**, 067 (2012) [arXiv:1208.2671 [hep-ex]].

84. S. Chatrchyan *et al.* [CMS Collaboration], “Measurement of the azimuthal anisotropy of neutral pions in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV,”

85. S. Chatrchyan *et al.* [CMS Collaboration], “Search for flavor changing neutral currents in top quark decays in pp collisions at 7 TeV,” Phys. Lett. B **718**, 1252 (2013) [arXiv:1208.0957 [hep-ex]].

86. S. Chatrchyan *et al.* [CMS Collaboration], “Search for a W ’ boson decaying to a bottom quark and a top quark in pp collisions at $\sqrt{s} = 7$ TeV,” Phys. Lett. B **718**, 1229 (2013) [arXiv:1208.0956 [hep-ex]].

87. S. Chatrchyan *et al.* [CMS Collaboration], “Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC,” Phys. Lett. B **716**, 30 (2012) [arXiv:1207.7235 [hep-ex]].

88. S. Chatrchyan *et al.* [CMS Collaboration], “Search for heavy Majorana neutrinos in $\mu^+\mu^+[\mu^-\mu^-]$ and $e^+e^+[e^-e^-]$ events in pp collisions at $\sqrt{s} = 7$ TeV,” Phys. Lett. B **717**, 109 (2012) [arXiv:1207.6079 [hep-ex]].

89. S. Chatrchyan *et al.* [CMS Collaboration], "Search for pair production of first- and second-generation scalar leptoquarks in pp collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. D **86**, 052013 (2012) [arXiv:1207.5406 [hep-ex]].

90. S. Chatrchyan *et al.* [CMS Collaboration], "Study of the inclusive production of charged pions, kaons, and protons in pp collisions at $\sqrt{s} = 0.9$, 2.76, and 7 TeV," Eur. Phys. J. C **72**, 2164 (2012) [arXiv:1207.4724 [hep-ex]].

91. S. Chatrchyan *et al.* [CMS Collaboration], "Forward-backward asymmetry of Drell-Yan lepton pairs in pp collisions at $\sqrt{s} = 7$ TeV," Phys. Lett. B **718**, 752 (2013) [arXiv:1207.3973 [hep-ex]].

92. S. Chatrchyan *et al.* [CMS Collaboration], "A search for a doubly-charged Higgs boson in pp collisions at $\sqrt{s} = 7$ TeV," Eur. Phys. J. C **72**, 2189 (2012) [arXiv:1207.2666 [hep-ex]].

93. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the underlying event activity in pp collisions at $\sqrt{s} = 0.9$ and 7 TeV with the novel jet-area/median approach," JHEP **1208**, 130 (2012) [arXiv:1207.2392 [hep-ex]].

94. S. Chatrchyan *et al.* [CMS Collaboration], "Search for new physics in the multijet and missing transverse momentum final state in proton-proton collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. Lett. **109**, 171803 (2012) [arXiv:1207.1898 [hep-ex]].

95. S. Chatrchyan *et al.* [CMS Collaboration], "Search for supersymmetry in hadronic final states using MT2 in pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1210**, 018 (2012) [arXiv:1207.1798 [hep-ex]].

96. S. Chatrchyan *et al.* [CMS Collaboration], "Search for a fermiophobic Higgs boson in pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1209**, 111 (2012) [arXiv:1207.1130 [hep-ex]].

97. S. Chatrchyan *et al.* [CMS Collaboration], "Search for new physics with long-lived particles decaying to photons and missing energy in pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1211**, 172 (2012) [arXiv:1207.0627 [hep-ex]].

98. S. Chatrchyan *et al.* [CMS Collaboration], "Search for stopped long-lived particles produced in pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1208**, 026 (2012) [arXiv:1207.0106 [hep-ex]].

99. S. Chatrchyan *et al.* [CMS Collaboration], "Inclusive and differential measurements of the $t\bar{t}$ charge asymmetry in proton-proton collisions at 7 TeV," Phys. Lett. B **717**, 129 (2012) [arXiv:1207.0065 [hep-ex]].

100. S. Chatrchyan *et al.* [CMS Collaboration], "Search for a light pseudoscalar Higgs boson in the dimuon decay channel in pp collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. Lett. **109**, 121801 (2012) [arXiv:1206.6326 [hep-ex]].

101. S. Chatrchyan *et al.* [CMS Collaboration], "Search for dark matter and large extra dimensions in monojet events in pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1209**, 094 (2012) [arXiv:1206.5663 [hep-ex]].

102. S. Chatrchyan *et al.* [CMS Collaboration], "Performance of CMS muon reconstruction in *pp* collision events at $\sqrt{s} = 7$ TeV," JINST **7**, P10002 (2012) [arXiv:1206.4071 [physics.ins-det]].

103. S. Chatrchyan *et al.* [CMS Collaboration], "Search for new physics in events with opposite-sign leptons, jets, and missing transverse energy in *pp* collisions at $\sqrt{s} = 7$ TeV," Phys. Lett. B **718**, 815 (2013) [arXiv:1206.3949 [hep-ex]].

104. S. Chatrchyan *et al.* [CMS Collaboration], "Search for charge-asymmetric production of W ' bosons in top pair + jet events from *pp* collisions at $\sqrt{s} = 7$ TeV," Phys. Lett. B **717**, 351 (2012) [arXiv:1206.3921 [hep-ex]].

105. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the electron charge asymmetry in inclusive W production in *pp* collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. Lett. **109**, 111806 (2012) [arXiv:1206.2598 [hep-ex]].

106. * S. Chatrchyan *et al.* [CMS Collaboration], "Search for narrow resonances in dilepton mass spectra in *pp* collisions at $\sqrt{s} = 7$ TeV," Phys. Lett. B **714**, 158 (2012) [arXiv:1206.1849 [hep-ex]].

107. S. Chatrchyan *et al.* [CMS Collaboration], "Search for high mass resonances decaying into τ^- lepton pairs in *pp* collisions at $\sqrt{s} = 7$ TeV," Phys. Lett. B **716**, 82 (2012) [arXiv:1206.1725 [hep-ex]].

108. S. Chatrchyan *et al.* [CMS Collaboration], "Search for a W' or Techni-ρ Decaying into WZ in *pp* Collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. Lett. **109**, 141801 (2012) [arXiv:1206.0433 [hep-ex]].

109. S. Chatrchyan *et al.* [CMS Collaboration], "Search for new physics with same-sign isolated dilepton events with jets and missing transverse energy," Phys. Rev. Lett. **109**, 071803 (2012) [arXiv:1205.6615 [hep-ex]].

110. S. Chatrchyan *et al.* [CMS Collaboration], "Study of W boson production in PbPb and *pp* collisions at $\sqrt{s_{NN}} = 2.76$ TeV," Phys. Lett. B **715**, 66 (2012) [arXiv:1205.6334 [nucl-ex]].

111. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of jet fragmentation into charged particles in *pp* and PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV," JHEP **1210**, 087 (2012) [arXiv:1205.5872 [nucl-ex]].

112. S. Chatrchyan *et al.* [CMS Collaboration], "Search for a light charged Higgs boson in top quark decays in *pp* collisions at $\sqrt{s} = 7$ TeV," JHEP **1207**, 143 (2012) [arXiv:1205.5736 [hep-ex]].

113. S. Chatrchyan *et al.* [CMS Collaboration], "Search for new physics in events with same-sign dileptons and b-tagged jets in *pp* collisions at $\sqrt{s} = 7$ TeV," JHEP **1208**, 110 (2012) [arXiv:1205.3933 [hep-ex]].

114. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the pseudorapidity and centrality dependence of the transverse energy density in PbPb collisions at $\sqrt{s_{NN}} =$ 2.76 TeV," Phys. Rev. Lett. **109**, 152303 (2012) [arXiv:1205.2488 [nucl-ex]].

115. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the $Lambda_b$ cross section and the $\bar{\Lambda}($ $b^)$ to $Lambda_b$ ratio with $Lambda_b$ to J/Psi Λ decays in pp collisions at $\sqrt{s} = 7$ TeV," Phys. Lett. B **714**, 136 (2012) [arXiv:1205.0594 [hep-ex]].

116. S. Chatrchyan *et al.* [CMS Collaboration], "Search for heavy long-lived charged particles in pp collisions at $\sqrt{s} = 7$ TeV," Phys. Lett. B **713**, 408 (2012) [arXiv:1205.0272 [hep-ex]].

117. S. Chatrchyan *et al.* [CMS Collaboration], "Studies of jet quenching using isolated-photon+jet correlations in PbPb and pp collisions at $\sqrt{s_{NN}} = 2.76$ TeV," Phys. Lett. B **718**, 773 (2013) [arXiv:1205.0206 [nucl-ex]].

118. S. Chatrchyan *et al.* [CMS Collaboration], "Observation of a new Xi(b) baryon," Phys. Rev. Lett. **108**, 252002 (2012) [arXiv:1204.5955 [hep-ex]].

119. S. Chatrchyan *et al.* [CMS Collaboration], "Search for anomalous production of multi-lepton events in pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1206**, 169 (2012) [arXiv:1204.5341 [hep-ex]].

120. S. Chatrchyan *et al.* [CMS Collaboration], "Search for leptonic decays of W ' bosons in pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1208**, 023 (2012) [arXiv:1204.4764 [hep-ex]].

121. S. Chatrchyan *et al.* [CMS Collaboration], "Search for physics beyond the standard model in events with a Z boson, jets, and missing transverse energy in pp collisions at $\sqrt{s} = 7$ TeV," Phys. Lett. B **716**, 260 (2012) [arXiv:1204.3774 [hep-ex]].

122. S. Chatrchyan *et al.* [CMS Collaboration], "Shape, transverse size, and charged hadron multiplicity of jets in pp collisions at 7 TeV," JHEP **1206**, 160 (2012) [arXiv:1204.3170 [hep-ex]].

123. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the mass difference between top and antitop quarks," JHEP **1206**, 109 (2012) [arXiv:1204.2807 [hep-ex]].

124. S. Chatrchyan *et al.* [CMS Collaboration], "Search for anomalous t t-bar production in the highly-boosted all-hadronic final state," JHEP **1209**, 029 (2012) [arXiv:1204.2488 [hep-ex]].

125. S. Chatrchyan *et al.* [CMS Collaboration], "Azimuthal anisotropy of charged particles at high transverse momenta in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV," Phys. Rev. Lett. **109**, 022301 (2012) [arXiv:1204.1850 [nucl-ex]].

126. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the Z/gamma*+b-jet cross section in pp collisions at 7 TeV," JHEP **1206**, 126 (2012) [arXiv:1204.1643 [hep-ex]].

127. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the elliptic anisotropy of charged particles produced in PbPb collisions at nucleon-nucleon center-of-mass energy = 2.76 TeV," Phys. Rev. C **87**, 014902 (2013) [arXiv:1204.1409 [nucl-ex]].

128. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the underlying event in the Drell-Yan process in proton-proton collisions at $\sqrt{s} = 7$ TeV," Eur. Phys. J. C **72**, 2080 (2012) [arXiv:1204.1411 [hep-ex]].

129. S. Chatrchyan *et al.* [CMS Collaboration], "Search for heavy bottom-like quarks in 4.9 inverse femtobarns of pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1205**, 123 (2012) [arXiv:1204.1088 [hep-ex]].

130. S. Chatrchyan *et al.* [CMS Collaboration], "Search for Dark Matter and Large Extra Dimensions in pp Collisions Yielding a Photon and Missing Transverse Energy," Phys. Rev. Lett. **108**, 261803 (2012) [arXiv:1204.0821 [hep-ex]].

131. * S. Chatrchyan *et al.* [CMS Collaboration], "Ratios of dijet production cross sections as a function of the absolute difference in rapidity between jets in proton-proton collisions at $\sqrt{s} = 7$ TeV," Eur. Phys. J. C **72**, 2216 (2012) [arXiv:1204.0696 [hep-ex]].

132. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the top quark pair production cross section in pp collisions at $\sqrt{s} = 7$ TeV in dilepton final states containing a τ," Phys. Rev. D **85**, 112007 (2012) [arXiv:1203.6810 [hep-ex]].

133. S. Chatrchyan *et al.* [CMS Collaboration], "Search for heavy, top-like quark pair production in the dilepton final state in pp collisions at $\sqrt{s} = 7$ TeV," Phys. Lett. B **716**, 103 (2012) [arXiv:1203.5410 [hep-ex]].

134. S. Chatrchyan *et al.* [CMS Collaboration], "Search for $B^0_s to \mu^+\mu^-$ and $B^0 to \mu^+\mu^-$ decays," JHEP **1204**, 033 (2012) [arXiv:1203.3976 [hep-ex]].

135. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the cross section for production of bb^- bar X, decaying to muons in pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1206**, 110 (2012) [arXiv:1203.3458 [hep-ex]].

136. S. Chatrchyan *et al.* [CMS Collaboration], "Search for microscopic black holes in pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1204**, 061 (2012) [arXiv:1202.6396 [hep-ex]].

137. * S. Chatrchyan *et al.* [CMS Collaboration], "Search for quark compositeness in dijet angular distributions from pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1205**, 055 (2012) [arXiv:1202.5535 [hep-ex]].

138. S. Chatrchyan *et al.* [CMS Collaboration], "Jet momentum dependence of jet quenching in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV," Phys. Lett. B **712**, 176 (2012) [arXiv:1202.5022 [nucl-ex]].

139. S. Chatrchyan *et al.* [CMS Collaboration], "Inclusive b-jet production in pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1204**, 084 (2012) [arXiv:1202.4617 [hep-ex]].

140. S. Chatrchyan *et al.* [CMS Collaboration], "Search for the standard model Higgs boson decaying to bottom quarks in *pp* collisions at $\sqrt{s} = 7$ TeV," Phys. Lett. B **710**, 284 (2012) [arXiv:1202.4195 [hep-ex]].

141. S. Chatrchyan *et al.* [CMS Collaboration], "Search for neutral Higgs bosons decaying to τ pairs in *pp* collisions at $\sqrt{s} = 7$ TeV," Phys. Lett. B **713**, 68 (2012) [arXiv:1202.4083 [hep-ex]].

142. S. Chatrchyan *et al.* [CMS Collaboration], "Search for large extra dimensions in dimuon and dielectron events in pp collisions at $\sqrt{s} = 7$ TeV," Phys. Lett. B **711**, 15 (2012) [arXiv:1202.3827 [hep-ex]].

143. S. Chatrchyan *et al.* [CMS Collaboration], "Search for the standard model Higgs boson in the H to ZZ to 2 $\ell 2\nu$ channel in *pp* collisions at $\sqrt{s} = 7$ TeV," JHEP **1203**, 040 (2012) [arXiv:1202.3478 [hep-ex]].

144. S. Chatrchyan *et al.* [CMS Collaboration], "Search for the standard model Higgs boson in the H to ZZ to $\ell\ell\tau\tau$ decay channel in *pp* collisions at $\sqrt{s} = 7$ TeV," JHEP **1203**, 081 (2012) [arXiv:1202.3617 [hep-ex]].

145. S. Chatrchyan *et al.* [CMS Collaboration], "Study of high-pT charged particle suppression in PbPb compared to *pp* collisions at $\sqrt{s_{NN}} = 2.76$ TeV," Eur. Phys. J. C **72**, 1945 (2012) [arXiv:1202.2554 [nucl-ex]].

146. S. Chatrchyan *et al.* [CMS Collaboration], "Search for the standard model Higgs boson in the decay channel H to ZZ to 4 leptons in *pp* collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. Lett. **108**, 111804 (2012) [arXiv:1202.1997 [hep-ex]].

147. S. Chatrchyan *et al.* [CMS Collaboration], "Search for the standard model Higgs boson decaying to a W pair in the fully leptonic final state in *pp* collisions at $\sqrt{s} = 7$ TeV," Phys. Lett. B **710**, 91 (2012) [arXiv:1202.1489 [hep-ex]].

148. S. Chatrchyan *et al.* [CMS Collaboration], "Combined results of searches for the standard model Higgs boson in *pp* collisions at $\sqrt{s} = 7$ TeV," Phys. Lett. B **710**, 26 (2012) [arXiv:1202.1488 [hep-ex]].

149. S. Chatrchyan *et al.* [CMS Collaboration], "Search for the standard model Higgs boson decaying into two photons in *pp* collisions at $\sqrt{s} = 7$ TeV," Phys. Lett. B **710**, 403 (2012) [arXiv:1202.1487 [hep-ex]].

150. S. Chatrchyan *et al.* [CMS Collaboration], "Search for a Higgs boson in the decay channel H to ZZ(*) to q qbar ℓ^- l+ in *pp* collisions at $\sqrt{s} = 7$ TeV," JHEP **1204**, 036 (2012) [arXiv:1202.1416 [hep-ex]].

151. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the inclusive production cross sections for forward jets and for dijet events with one forward and one central jet in *pp* collisions at $\sqrt{s} = 7$ TeV," JHEP **1206**, 036 (2012) [arXiv:1202.0704 [hep-ex]].

152. S. Chatrchyan *et al.* [CMS Collaboration], "Suppression of non-prompt J/ψ, prompt J/ψ, and Y(1S) in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV," JHEP **1205**, 063 (2012) [arXiv:1201.5069 [nucl-ex]].

153. S. Chatrchyan *et al.* [CMS Collaboration], "Centrality dependence of dihadron correlations and azimuthal anisotropy harmonics in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV," Eur. Phys. J. C **72**, 2012 (2012) [arXiv:1201.3158 [nucl-ex]].

154. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of isolated photon production in pp and PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV," Phys. Lett. B **710**, 256 (2012) [arXiv:1201.3093 [nucl-ex]].

155. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the charge asymmetry in top-quark pair production in proton-proton collisions at $\sqrt{s} = 7$ TeV," Phys. Lett. B **709**, 28 (2012) [arXiv:1112.5100 [hep-ex]].

156. S. Chatrchyan *et al.* [CMS Collaboration], "Search for signatures of extra dimensions in the diphoton mass spectrum at the Large Hadron Collider," Phys. Rev. Lett. **108**, 111801 (2012) [arXiv:1112.0688 [hep-ex]].

157. S. Chatrchyan *et al.* [CMS Collaboration], "Exclusive photon-photon production of muon pairs in proton-proton collisions at $\sqrt{s} = 7$ TeV," JHEP **1201**, 052 (2012) [arXiv:1111.5536 [hep-ex]].

158. C. T. Kullenberg *et al.* [NOMAD Collaboration], "A Search for Single Photon Events in Neutrino Interactions in NOMAD," Phys. Lett. B **706**, 268 (2012) [arXiv:1111.3713 [hep-ex]].

159. S. Chatrchyan *et al.* [CMS Collaboration], "J/ψ and ψ_{2S} production in pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1202**, 011 (2012) [arXiv:1111.1557 [hep-ex]].

160. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the Production Cross Section for Pairs of Isolated Photons in pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1201**, 133 (2012) [arXiv:1110.6461 [hep-ex]].

161. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the Rapidity and Transverse Momentum Distributions of Z Bosons in pp Collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. D **85**, 032002 (2012) [arXiv:1110.4973 [hep-ex]].

162. S. Chatrchyan *et al.* [CMS Collaboration], "Jet Production Rates in Association with W and Z Bosons in pp Collisions at $\sqrt{s} = 7$ TeV," JHEP **1201**, 010 (2012) [arXiv:1110.3226 [hep-ex]].

163. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the weak mixing angle with the Drell-Yan process in proton-proton collisions at the LHC," Phys. Rev. D **84**, 112002 (2011) [arXiv:1110.2682 [hep-ex]].

164. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of energy flow at large pseudorapidities in pp collisions at $\sqrt{s} = 0.9$ and 7 TeV," JHEP **1111**, 148 (2011) [Erratum-ibid. **1202**, 055 (2012)] [arXiv:1110.0211 [hep-ex]].

165. S. Chatrchyan *et al.* [CMS Collaboration], "Forward Energy Flow, Central Charged-Particle Multiplicities, and Pseudorapidity Gaps in W and Z Boson Events from pp Collisions at 7 TeV," Eur. Phys. J. C **72**, 1839 (2012) [arXiv:1110.0181 [hep-ex]].

166. C. Collaboration *et al.* [CMS Collaboration], "Performance of tau-lepton reconstruction and identification in CMS," JINST **7**, P01001 (2012) [arXiv:1109.6034 [physics.ins-det]].

167. S. Chatrchyan *et al.* [CMS Collaboration], "Search for a Vector-like Quark with Charge 2/3 in $t + Z$ Events from pp Collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. Lett. **107**, 271802 (2011) [arXiv:1109.4985 [hep-ex]].

168. S. Chatrchyan *et al.* [CMS Collaboration], "Search for Supersymmetry at the LHC in Events with Jets and Missing Transverse Energy," Phys. Rev. Lett. **107**, 221804 (2011) [arXiv:1109.2352 [hep-ex]].

169. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the $t\bar{t}$ Production Cross Section in pp Collisions at 7 TeV in Lepton + Jets Events Using b-quark Jet Identification," Phys. Rev. D **84**, 092004 (2011) [arXiv:1108.3773 [hep-ex]].

170. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the Differential Cross Section for Isolated Prompt Photon Production in pp Collisions at 7 TeV," Phys. Rev. D **84**, 052011 (2011) [arXiv:1108.2044 [hep-ex]].

171. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the Drell-Yan Cross Section in pp Collisions at $\sqrt{s} = 7$ TeV," JHEP **1110**, 007 (2011) [arXiv:1108.0566 [hep-ex]].

172. * S. Chatrchyan *et al.* [CMS Collaboration], "Search for B(s) and B to dimuon decays in pp collisions at 7 TeV," Phys. Rev. Lett. **107**, 191802 (2011) [arXiv:1107.5834 [hep-ex]].

173. * S. Chatrchyan *et al.* [CMS Collaboration], "Search for Resonances in the Dijet Mass Spectrum from 7 TeV pp Collisions at CMS," Phys. Lett. B **704**, 123 (2011) [arXiv:1107.4771 [hep-ex]].

174. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the Inclusive W and Z Production Cross Sections in pp Collisions at $\sqrt{s} = 7$ TeV," JHEP **1110**, 132 (2011) [arXiv:1107.4789 [hep-ex]].

175. S. Chatrchyan *et al.* [CMS Collaboration], "Dependence on pseudorapidity and centrality of charged hadron production in PbPb collisions at a nucleon-nucleon centre-of-mass energy of 2.76 TeV," JHEP **1108**, 141 (2011) [arXiv:1107.4800 [nucl-ex]].

176. S. Chatrchyan *et al.* [CMS Collaboration], "Determination of Jet Energy Calibration and Transverse Momentum Resolution in CMS," JINST **6**, P11002 (2011) [arXiv:1107.4277 [physics.ins-det]].

177. S. Chatrchyan *et al.* [CMS Collaboration], "Search for Three-Jet Resonances in pp Collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. Lett. **107**, 101801 (2011) [arXiv:1107.3084 [hep-ex]].

178. S. Chatrchyan *et al.* [CMS Collaboration], "Search for supersymmetry in pp collisions at $\sqrt{s} = 7$ TeV in events with a single lepton, jets, and missing transverse momentum," JHEP **1108**, 156 (2011) [arXiv:1107.1870 [hep-ex]].

179. S. Chatrchyan *et al.* [CMS Collaboration], "A search for excited leptons in pp Collisions at $\sqrt{s} = 7$ TeV," Phys. Lett. B **704**, 143 (2011) [arXiv:1107.1773 [hep-ex]].

180. S. Chatrchyan *et al.* [CMS Collaboration], "Inclusive search for squarks and gluinos in pp collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. D **85**, 012004 (2012) [arXiv:1107.1279 [hep-ex]].

181. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the Underlying Event Activity at the LHC with $\sqrt{s} = 7$ TeV and Comparison with $\sqrt{s} = 0.9$ TeV," JHEP **1109**, 109 (2011) [arXiv:1107.0330 [hep-ex]].

182. S. Chatrchyan *et al.* [CMS Collaboration], "Missing transverse energy performance of the CMS detector," JINST **6**, P09001 (2011) [arXiv:1106.5048 [physics.ins-det]].

183. S. Chatrchyan *et al.* [CMS Collaboration], "Search for New Physics with a Mono-Jet and Missing Transverse Energy in pp Collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. Lett. **107**, 201804 (2011) [arXiv:1106.4775 [hep-ex]].

184. S. Chatrchyan *et al.* [CMS Collaboration], "Search for New Physics with Jets and Missing Transverse Momentum in pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1108**, 155 (2011) [arXiv:1106.4503 [hep-ex]].

185. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the Strange B Meson Production Cross Section with J/Psi ϕ Decays in pp Collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. D **84**, 052008 (2011) [arXiv:1106.4048 [hep-ex]].

186. S. Chatrchyan *et al.* [CMS Collaboration], "Search for Supersymmetry in Events with b Jets and Missing Transverse Momentum at the LHC," JHEP **1107**, 113 (2011) [arXiv:1106.3272 [hep-ex]].

187. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the t-channel single top quark production cross section in pp collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. Lett. **107**, 091802 (2011) [arXiv:1106.3052 [hep-ex]].

188. S. Chatrchyan *et al.* [CMS Collaboration], "Search for Light Resonances Decaying into Pairs of Muons as a Signal of New Physics," JHEP **1107**, 098 (2011) [arXiv:1106.2375 [hep-ex]].

189. * S. Chatrchyan *et al.* [CMS Collaboration], "Search for Same-Sign Top-Quark Pair Production at $\sqrt{s} = 7$ TeV and Limits on Flavour Changing Neutral Currents in the Top Sector," JHEP **1108**, 005 (2011) [arXiv:1106.2142 [hep-ex]].

190. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the Top-antitop Production Cross Section in pp Collisions at $\sqrt{s} = 7$ TeV using the Kinematic Properties of Events with Leptons and Jets," Eur. Phys. J. C **71**, 1721 (2011) [arXiv:1106.0902 [hep-ex]].

191. S. Chatrchyan *et al.* [CMS Collaboration], "Search for Physics Beyond the Standard Model Using Multilepton Signatures in *pp* Collisions at $\sqrt{s}$ = 7 TeV," Phys. Lett. B **704**, 411 (2011) [arXiv:1106.0933 [hep-ex]].

192. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the Ratio of the 3-jet to 2-jet Cross Sections in *pp* Collisions at $\sqrt{s}$ = 7 TeV," Phys. Lett. B **702**, 336 (2011) [arXiv:1106.0647 [hep-ex]].

193. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the Inclusive Jet Cross Section in *pp* Collisions at $\sqrt{s}$ = 7 TeV," Phys. Rev. Lett. **107**, 132001 (2011) [arXiv:1106.0208 [hep-ex]].

194. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the $t\bar{t}$ production cross section and the top quark mass in the dilepton channel in *pp* collisions at $\sqrt{s}$ = 7 TeV," JHEP **1107**, 049 (2011) [arXiv:1105.5661 [hep-ex]].

195. S. Chatrchyan *et al.* [CMS Collaboration], "Search for First Generation Scalar Leptoquarks in the evjj channel in *pp* collisions at $\sqrt{s}$ = 7 TeV," Phys. Lett. B **703**, 246 (2011) [arXiv:1105.5237 [hep-ex]].

196. * S. Chatrchyan *et al.* [CMS Collaboration], "Indications of suppression of excited Υ states in PbPb collisions at $\sqrt{S_{NN}}$ = 2.76 TeV," Phys. Rev. Lett. **107**, 052302 (2011) [arXiv:1105.4894 [nucl-ex]].

197. S. Chatrchyan *et al.* [CMS Collaboration], "Search for supersymmetry in events with a lepton, a photon, and large missing transverse energy in *pp* collisions at $\sqrt{s}$ = 7 TeV," JHEP **1106**, 093 (2011) [arXiv:1105.3152 [hep-ex]].

198. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of $W\gamma$ and $Z\gamma$ production in *pp* collisions at $\sqrt{s}$ = 7 TeV," Phys. Lett. B **701**, 535 (2011) [arXiv:1105.2758 [hep-ex]].

199. S. Chatrchyan *et al.* [CMS Collaboration], "Long-range and short-range dihadron angular correlations in central PbPb collisions at a nucleon-nucleon center of mass energy of 2.76 TeV," JHEP **1107**, 076 (2011) [arXiv:1105.2438 [nucl-ex]].

200. S. Chatrchyan *et al.* [CMS Collaboration], "Charged particle transverse momentum spectra in *pp* collisions at $\sqrt{s}$ = 0.9 and 7 TeV," JHEP **1108**, 086 (2011) [arXiv:1104.3547 [hep-ex]].

201. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the Polarization of W Bosons with Large Transverse Momenta in W+Jets Events at the LHC," Phys. Rev. Lett. **107**, 021802 (2011) [arXiv:1104.3829 [hep-ex]].

202. * S. Chatrchyan *et al.* [CMS Collaboration], "Search for new physics with same-sign isolated dilepton events with jets and missing transverse energy at the LHC," JHEP **1106**, 077 (2011) [arXiv:1104.3168 [hep-ex]].

203. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the B^0 production cross section in *pp* Collisions at $\sqrt{s}$ = 7 TeV," Phys. Rev. Lett. **106**, 252001 (2011) [arXiv:1104.2892 [hep-ex]].

204. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the differential dijet production cross section in proton-proton collisions at $\sqrt{s} = 7$ TeV," Phys. Lett. B **700**, 187 (2011) [arXiv:1104.1693 [hep-ex]].

205. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the Inclusive Z Cross Section via Decays to Tau Pairs in pp Collisions at $\sqrt{s} = 7$ TeV," JHEP **1108**, 117 (2011) [arXiv:1104.1617 [hep-ex]].

206. S. Chatrchyan *et al.* [CMS Collaboration], "Search for Neutral MSSM Higgs Bosons Decaying to Tau Pairs in pp Collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. Lett. **106**, 231801 (2011) [arXiv:1104.1619 [hep-ex]].

207. R. Cousins [CMS Collaboration], "Status of the CMS experiment," Conf. Proc. C **0908171**, 23 (2009).

208. S. Chatrchyan *et al.* [CMS Collaboration], "Search for Large Extra Dimensions in the Diphoton Final State at the Large Hadron Collider," JHEP **1105**, 085 (2011) [arXiv:1103.4279 [hep-ex]].

209. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the lepton charge asymmetry in inclusive W production in pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1104**, 050 (2011) [arXiv:1103.3470 [hep-ex]].

210. S. Chatrchyan *et al.* [CMS Collaboration], "Search for Physics Beyond the Standard Model in Opposite-Sign Dilepton Events at $\sqrt{s} = 7$ TeV," JHEP **1106**, 026 (2011) [arXiv:1103.1348 [hep-ex]].

211. S. Chatrchyan *et al.* [CMS Collaboration], "Search for Supersymmetry in pp Collisions at $\sqrt{s} = 7$ TeV in Events with Two Photons and Missing Transverse Energy," Phys. Rev. Lett. **106**, 211802 (2011) [arXiv:1103.0953 [hep-ex]].

212. * S. Chatrchyan *et al.* [CMS Collaboration], "Search for Resonances in the Dilepton Mass Distribution in pp Collisions at $\sqrt{s} = 7$ TeV," JHEP **1105**, 093 (2011) [arXiv:1103.0981 [hep-ex]].

213. * S. Chatrchyan *et al.* [CMS Collaboration], "Search for a W' boson decaying to a muon and a neutrino in pp collisions at $\sqrt{s} = 7$ TeV," Phys. Lett. B **701**, 160 (2011) [arXiv:1103.0030 [hep-ex]].

214. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of W^+W^- Production and Search for the Higgs Boson in pp Collisions at $\sqrt{s} = 7$ TeV," Phys. Lett. B **699**, 25 (2011) [arXiv:1102.5429 [hep-ex]].

215. * S. Chatrchyan *et al.* [CMS Collaboration], "Study of Z boson production in PbPb collisions at nucleon-nucleon centre of mass energy = 2.76 TeV," Phys. Rev. Lett. **106**, 212301 (2011) [arXiv:1102.5435 [nucl-ex]].

216. S. Chatrchyan *et al.* [CMS Collaboration], "Search for a Heavy Bottom-like Quark in pp Collisions at $\sqrt{s} = 7$ TeV," Phys. Lett. B **701**, 204 (2011) [arXiv:1102.4746 [hep-ex]].

217. V. Khachatryan *et al.* [CMS Collaboration], "Strange Particle Production in pp Collisions at $\sqrt{s} = 0.9$ and 7 TeV," JHEP **1105**, 064 (2011) [arXiv:1102.4282 [hep-ex]].

218. V. Khachatryan *et al.* [CMS Collaboration], "Measurement of $B\bar{B}$ Angular Correlations based on Secondary Vertex Reconstruction at $\sqrt{s} = 7$ TeV," JHEP **1103**, 136 (2011) [arXiv:1102.3194 [hep-ex]].

219. * V. Khachatryan *et al.* [CMS Collaboration], "Measurement of Dijet Angular Distributions and Search for Quark Compositeness in pp Collisions at $sqrts = 7$ TeV," Phys. Rev. Lett. **106**, 201804 (2011) [arXiv:1102.2020 [hep-ex]].

220. S. Chatrchyan *et al.* [CMS Collaboration], "Observation and studies of jet quenching in PbPb collisions at nucleon-nucleon center-of-mass energy = 2.76 TeV," Phys. Rev. C **84**, 024906 (2011) [arXiv:1102.1957 [nucl-ex]].

221. V. Khachatryan *et al.* [CMS Collaboration], "First Measurement of Hadronic Event Shapes in pp Collisions at $\sqrt(s) = 7$ TeV," Phys. Lett. B **699**, 48 (2011) [arXiv:1102.0068 [hep-ex]].

222. V. Khachatryan *et al.* [CMS Collaboration], "Dijet Azimuthal Decorrelations in pp Collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. Lett. **106**, 122003 (2011) [arXiv:1101.5029 [hep-ex]].

223. V. Khachatryan *et al.* [CMS Collaboration], "Inclusive b-hadron production cross section with muons in pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1103**, 090 (2011) [arXiv:1101.3512 [hep-ex]].

224. V. Khachatryan *et al.* [CMS Collaboration], "Measurement of Bose-Einstein Correlations in pp Collisions at $\sqrt{s} = 0.9$ and 7 TeV," JHEP **1105**, 029 (2011) [arXiv:1101.3518 [hep-ex]].

225. V. Khachatryan *et al.* [CMS Collaboration], "Search for Supersymmetry in pp Collisions at 7 TeV in Events with Jets and Missing Transverse Energy," Phys. Lett. B **698**, 196 (2011) [arXiv:1101.1628 [hep-ex]].

226. V. Khachatryan *et al.* [CMS Collaboration], "Search for Heavy Stable Charged Particles in pp collisions at $\sqrt{s} = 7$ TeV," JHEP **1103**, 024 (2011) [arXiv:1101.1645 [hep-ex]].

227. V. Khachatryan *et al.* [CMS Collaboration], "Measurement of the B^+ Production Cross Section in pp Collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. Lett. **106**, 112001 (2011) [arXiv:1101.0131 [hep-ex]].

228. V. Khachatryan *et al.* [CMS Collaboration], "Search for a heavy gauge boson W ' in the final state with an electron and large missing transverse energy in pp collisions at $\sqrt{s} = 7$ TeV," Phys. Lett. B **698**, 21 (2011) [arXiv:1012.5945 [hep-ex]].

229. V. Khachatryan *et al.* [CMS Collaboration], "Measurement of the Inclusive υ production cross section in pp collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. D **83**, 112004 (2011) [arXiv:1012.5545 [hep-ex]].

230. V. Khachatryan *et al.* [CMS Collaboration], "Search for Pair Production of First-Generation Scalar Leptoquarks in *pp* Collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. Lett. **106**, 201802 (2011) [arXiv:1012.4031 [hep-ex]].

231. V. Khachatryan *et al.* [CMS Collaboration], "Search for Pair Production of Second-Generation Scalar Leptoquarks in *pp* Collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. Lett. **106**, 201803 (2011) [arXiv:1012.4033 [hep-ex]].

232. V. Khachatryan *et al.* [CMS Collaboration], "Search for Microscopic Black Hole Signatures at the Large Hadron Collider," Phys. Lett. B **697**, 434 (2011) [arXiv:1012.3375 [hep-ex]].

233. V. Khachatryan *et al.* [CMS Collaboration], "Measurements of Inclusive W and Z Cross Sections in *pp* Collisions at $\sqrt{s} = 7$ TeV," JHEP **1101**, 080 (2011) [arXiv:1012.2466 [hep-ex]].

234. V. Khachatryan *et al.* [CMS Collaboration], "Measurement of the Isolated Prompt Photon Production Cross Section in *pp* Collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. Lett. **106**, 082001 (2011) [arXiv:1012.0799 [hep-ex]].

235. V. Khachatryan *et al.* [CMS Collaboration], "Charged particle multiplicities in *pp* interactions at $\sqrt{s} = 0.9$, 2.36, and 7 TeV," JHEP **1101**, 079 (2011) [arXiv:1011.5531 [hep-ex]].

236. V. Khachatryan *et al.* [CMS Collaboration], "Search for Stopped Gluinos in *pp* collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. Lett. **106**, 011801 (2011) [arXiv:1011.5861 [hep-ex]].

237. V. Khachatryan *et al.* [CMS Collaboration], "Prompt and non-prompt J/ψ production in *pp* collisions at $\sqrt{s} = 7$ TeV," Eur. Phys. J. C **71**, 1575 (2011) [arXiv:1011.4193 [hep-ex]].

238. V. Khachatryan *et al.* [CMS Collaboration], "First Measurement of the Cross Section for Top-Quark Pair Production in Proton-Proton Collisions at $\sqrt{s} = 7$ TeV," Phys. Lett. B **695**, 424 (2011) [arXiv:1010.5994 [hep-ex]].

239. * V. Khachatryan *et al.* [CMS Collaboration], "Search for Quark Compositeness with the Dijet Centrality Ratio in *pp* Collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. Lett. **105**, 262001 (2010) [arXiv:1010.4439 [hep-ex]].

240. * V. Khachatryan *et al.* [CMS Collaboration], "Search for Dijet Resonances in 7 TeV pp Collisions at CMS," Phys. Rev. Lett. **105**, 211801 (2010) [arXiv:1010.0203 [hep-ex]].

241. * V. Khachatryan *et al.* [CMS Collaboration], "Observation of Long-Range Near-Side Angular Correlations in Proton-Proton Collisions at the LHC," JHEP **1009**, 091 (2010) [arXiv:1009.4122 [hep-ex]].

242. V. Khachatryan *et al.* [CMS Collaboration], "CMS Tracking Performance Results from early LHC Operation," Eur. Phys. J. C **70**, 1165 (2010) [arXiv:1007.1988 [physics.ins-det]].

243. V. Khachatryan *et al.* [CMS Collaboration], "First Measurement of the Underlying Event Activity at the LHC with $\sqrt{s} = 0.9$ TeV," Eur. Phys. J. C **70**, 555 (2010) [arXiv:1006.2083 [hep-ex]].

244. V. Khachatryan *et al.* [CMS Collaboration], "Measurement of the charge ratio of atmospheric muons with the CMS detector," Phys. Lett. B **692**, 83 (2010) [arXiv:1005.5332 [hep-ex]].

245. V. Khachatryan *et al.* [CMS Collaboration], "Measurement of Bose-Einstein correlations with first CMS data," Phys. Rev. Lett. **105**, 032001 (2010) [arXiv:1005.3294 [hep-ex]].

246. V. Khachatryan *et al.* [CMS Collaboration], "Transverse-momentum and pseudorapidity distributions of charged hadrons in pp collisions at $\sqrt{s} = 7$ TeV," Phys. Rev. Lett. **105**, 022002 (2010) [arXiv:1005.3299 [hep-ex]].

247. R. D. Cousins, K. E. Hymes and J. Tucker, "Frequentist evaluation of intervals estimated for a binomial parameter and for the ratio of Poisson means," Nucl. Instrum. Meth. A **612**, 388 (2010).

248. V. Khachatryan *et al.* [CMS Collaboration], "Transverse momentum and pseudorapidity distributions of charged hadrons in pp collisions at $\sqrt{(s)} = 0.9$ and 2.36 TeV," JHEP **1002**, 041 (2010) [arXiv:1002.0621 [hep-ex]].

249. S. Chatrchyan *et al.* [CMS Collaboration], "Commissioning and Performance of the CMS Pixel Tracker with Cosmic Ray Muons," JINST **5**, T03007 (2010) [arXiv:0911.5434 [physics.ins-det]].

250. * S. Chatrchyan *et al.* [CMS Collaboration], "Performance of the CMS Level-1 Trigger during Commissioning with Cosmic Ray Muons," JINST **5**, T03002 (2010) [arXiv:0911.5422 [physics.ins-det]].

251. S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the Muon Stopping Power in Lead Tungstate," JINST **5**, P03007 (2010) [arXiv:0911.5397 [physics.ins-det]].

252. S. Chatrchyan *et al.* [CMS Collaboration], "Commissioning and Performance of the CMS Silicon Strip Tracker with Cosmic Ray Muons," JINST **5**, T03008 (2010) [arXiv:0911.4996 [physics.ins-det]].

253. * S. Chatrchyan *et al.* [CMS Collaboration], "Performance of CMS Muon Reconstruction in Cosmic-Ray Events," JINST **5**, T03022 (2010) [arXiv:0911.4994 [physics.ins-det]].

254. * S. Chatrchyan *et al.* [CMS Collaboration], "Performance of the CMS Cathode Strip Chambers with Cosmic Rays," JINST **5**, T03018 (2010) [arXiv:0911.4992 [physics.ins-det]].

255. S. Chatrchyan *et al.* [CMS Collaboration], "Performance of the CMS Hadron Calorimeter with Cosmic Ray Muons and LHC Beam Data," JINST **5**, T03012 (2010) [arXiv:0911.4991 [physics.ins-det]].

256. S. Chatrchyan *et al.* [CMS Collaboration], "Fine Synchronization of the CMS Muon Drift-Tube Local Trigger using Cosmic Rays," JINST **5**, T03004 (2010) [arXiv:0911.4904 [physics.ins-det]].

257. S. Chatrchyan *et al.* [CMS Collaboration], "Calibration of the CMS Drift Tube Chambers and Measurement of the Drift Velocity with Cosmic Rays," JINST **5**, T03016 (2010) [arXiv:0911.4895 [physics.ins-det]].

258. S. Chatrchyan *et al.* [CMS Collaboration], "Performance of the CMS Drift-Tube Local Trigger with Cosmic Rays," JINST **5**, T03003 (2010) [arXiv:0911.4893 [physics.ins-det]].

259. * S. Chatrchyan *et al.* [CMS Collaboration], "Commissioning of the CMS High-Level Trigger with Cosmic Rays," JINST **5**, T03005 (2010) [arXiv:0911.4889 [physics.ins-det]].

260. S. Chatrchyan *et al.* [CMS Collaboration], "Identification and Filtering of Uncharacteristic Noise in the CMS Hadron Calorimeter," JINST **5**, T03014 (2010) [arXiv:0911.4881 [physics.ins-det]].

261. S. Chatrchyan *et al.* [CMS Collaboration], "Performance of CMS Hadron Calorimeter Timing and Synchronization using Test Beam, Cosmic Ray, and LHC Beam Data," JINST **5**, T03013 (2010) [arXiv:0911.4877 [physics.ins-det]].

262. S. Chatrchyan *et al.* [CMS Collaboration], "Performance of the CMS Drift Tube Chambers with Cosmic Rays," JINST **5**, T03015 (2010) [arXiv:0911.4855 [physics.ins-det]].

263. * S. Chatrchyan *et al.* [CMS Collaboration], "Commissioning of the CMS Experiment and the Cosmic Run at Four Tesla," JINST **5**, T03001 (2010) [arXiv:0911.4845 [physics.ins-det]].

264. S. Chatrchyan *et al.* [CMS Collaboration], "CMS Data Processing Workflows during an Extended Cosmic Ray Run," JINST **5**, T03006 (2010) [arXiv:0911.4842 [physics.ins-det]].

265. S. Chatrchyan *et al.* [CMS Collaboration], "Aligning the CMS Muon Chambers with the Muon Alignment System during an Extended Cosmic Ray Run," JINST **5**, T03019 (2010) [arXiv:0911.4770 [physics.ins-det]].

266. S. Chatrchyan *et al.* [CMS Collaboration], "Performance Study of the CMS Barrel Resistive Plate Chambers with Cosmic Rays," JINST **5**, T03017 (2010) [arXiv:0911.4045 [physics.ins-det]].

267. S. Chatrchyan *et al.* [CMS Collaboration], "Time Reconstruction and Performance of the CMS Electromagnetic Calorimeter," JINST **5**, T03011 (2010) [arXiv:0911.4044 [physics.ins-det]].

268. S. Chatrchyan *et al.* [CMS Collaboration], "Alignment of the CMS Muon System with Cosmic-Ray and Beam-Halo Muons," JINST **5**, T03020 (2010) [arXiv:0911.4022 [physics.ins-det]].

269. S. Chatrchyan *et al.* [CMS Collaboration], "Precise Mapping of the Magnetic Field in the CMS Barrel Yoke using Cosmic Rays," JINST **5**, T03021 (2010) [arXiv:0910.5530 [physics.ins-det]].

270. S. Chatrchyan *et al.* [CMS Collaboration], "Performance and Operation of the CMS Electromagnetic Calorimeter," JINST **5**, T03010 (2010) [arXiv:0910.3423 [physics.ins-det]].

271. S. Chatrchyan *et al.* [CMS Collaboration], "Alignment of the CMS Silicon Tracker during Commissioning with Cosmic Rays," JINST **5**, T03009 (2010) [arXiv:0910.2505 [physics.ins-det]].

Item 5b (cont): Task J Publications

Task J is funded approximately 50% by DOE. The primary other agency contributiong to these papers is NASA's suborbital program. All the publications from Task J for ANITA and related work include members from collaborating institutions.

1. E. R. Hudson and D. Saltzberg, "Antiprotons Reflect a Magnetic Symmetry," Physics **6**, 36 (2013).

2. D. Z. Besson, J. Stockham, M. Sullivan, P. Allison, S. W. Barwick, B. M. Baughman, J. J. Beatty and K. Belov *et al.*, "Antarctic Radio Frequency Albedo and Implications for Cosmic Ray Reconstruction," arXiv:1301.4423 [astro-ph.IM].

3. P. W. Gorham, A. Connolly, P. Allison, J. J. Beatty, K. Belov, D. Z. Besson, W. R. Binns and P. Chen *et al.*, "Implications of ultra-high energy neutrino flux constraints for Lorentz-invariance violating cosmogenic neutrinos," Phys. Rev. D **86**, 103006 (2012) [arXiv:1207.6425 [astro-ph.HE]].

4. A. G. Vieregg, K. Palladino, P. Allison, B. M. Baughman, J. J. Beatty, K. Belov, D. Z. Besson and S. Bevan *et al.*, "The First Limits on the Ultra-high Energy Neutrino Fluence from Gamma-ray Bursts," Astrophys. J. **736**, 50 (2011) [arXiv:1102.3206 [astro-ph.HE]].

5. T. Barrella, S. Barwick and D. Saltzberg, "Ross Ice Shelf in situ radio-frequency ice attenuation," J. Glaciology **57**, 61 (2011) [arXiv:1011.0477 [astro-ph.IM]].

6. M. Detrixhe *et al.* [ANITA-II Collaboration], "Ultra-Relativistic Magnetic Monopole Search with the ANITA-II Balloon-borne Radio Interferometer," Phys. Rev. D **83**, 023513 (2011) [arXiv:1008.1282 [astro-ph.HE]].

7. S. Hoover *et al.* [ANITA Collaboration], "Observation of Ultra-high-energy Cosmic Rays with the ANITA Balloon-borne Radio Interferometer," Phys. Rev. Lett. **105**, 151101 (2010) [arXiv:1005.0035 [astro-ph.HE]].

8. P. W. Gorham *et al.* [ANITA Collaboration], "Erratum: Observational Constraints on the Ultra-high Energy Cosmic Neutrino Flux from the Second Flight of the ANITA Experiment," Phys. Rev. D **85**, 049901 (2012) [arXiv:1011.5004 [astro-ph.HE], arXiv:1003.2961 [astro-ph.HE]].

9. P. W. Gorham *et al.* [ANITA Collaboration], "Observational Constraints on the Ultra-high Energy Cosmic Neutrino Flux from the Second Flight of the ANITA Experiment" Phys. Rev. D **82**, 022004 (2010) [arXiv:1003.2961 [astro-ph.HE]]

6. List of People

The pages for this item give the lists of people for each of the three years of the last project period.

2010 - List of People on this DOE Project

Name (AA = Admin; PD = *postdoc/equiv; Eng = engineer; GS = grad student; SR = senior researcher)*	FULL PARTIAL support?	# of mo. of DOE support	Remainder of Support *(P&A = UCLA Dept of Physics and Astronomy)*
KA11			
Cassandra Gonzalez	partial	4.8	Dept of Physics & Astronomy
Charles Plager	partial	6	50% US CMS Operations
Chris Farrell	Full		
D. Cline	partial	0.5 sum	
D. Saltzberg	partial	1.0 sum	
J. Hauser	partial	2.0 sum	
Jonathan Kubic	Partial	0.5	US CMS Operations
Jordan Tucker	Full		
Joseph Duris	Full		
Misha Ignatenko	full		
R. Cousins	partial	2.0 sum	
Valeri Andreev	full		
Yunfeng Xi	Full		
KA13			
Artin Teymourian	Full		
Cassandra Gonzalez	partial	2.4	
Chi Wai Lam	Full		
D. Saltzberg	partial	1.0 sum	
David Cline	Partial	.5 sum	DOE Accelerator grant
DL MacLaughlan-Dumas	partial	6	department supported 50%
Ethan Brown	Full		
Franco Sergiampietri	partial	2	Fermilab LBNE project funds
Grad Student - New	Full		2010 Grad students (A. Vieregg
Grad Student - New	Full		and S. Hoover graduated)
K. Arisaka	partial	2.0 sum	
Kevin Lee	Partial	3	DOE Accelerator + teaching
Kevin Lung	Full		
Konstantin Belov	partial	6	performing research on cosmic ray energy scale and maintaining the saxon cluster.

N. Ng	partial	6	
Natalia Makrouchina	partial	4.8	Fermilab LBNE project funds
Yixiong Meng	partial	4.25	NSF Dark Matter Grant

<u>KA14</u>

A. Kusenko	partial	2.0 sum mo	
Antione Calvez	partial	3	Dept paid - teaching
G. Gelmini	partial	2.0 sum mo	
Nassim Bozorgnia	partial	3	Dept paid - teaching
Tristin Dennen	partial	3	Dept paid - teaching
Warren Essay	partial	3	Dept paid - teaching
Z. Bern	partial	2.0 sum mo	

2011 - List of People on this DOE Project

Name (AA = Admin; PD = *postdoc/equiv; Eng = engineer; GS = grad student; SR = senior researcher)*	FULL PARTIAL support?	# of mo. of DOE support	Remainder of Support *(P&A = UCLA Dept of Physics and Astronomy)*
KA11			
Cassandra Gonzalez, AA	partial	4.8	KA13, P&A
Chris Farrell, GS	Full		
D. Cline	partial	0.5 sum	KA13, DOE accel, P&A faculty
D. Saltzberg	partial	1.0 sum	KA13, P&A faculty
J. Hauser	partial	2.0 sum	P&A faculty
Jonathan Kubic, Eng.	partial	0.5	US CMS Operations
Eric Takasugi, GS	Full		
Joseph Duris replacement, GS	Full		
Misha Ignatenko, SR	Full		
R. Cousins	partial	2.0 sum	P&A faculty
Valeri Andreev, SR	Full		
Yunfeng Xi, GS	Full		
Viatcheslav Valuev, PD	Full		
Gregory Rakness, PD	Full		
Kevin Lee, PD	partial	3	DOE Accelerator + teaching
Franco Sergiampietri, PD	partial	2	Fermilab LBNE project funds
Stan Otwinowski	partial	3	
Natalia Makrouchina, Eng.	partial	4.8	Fermilab LBNE project funds
N. Ng, AA	partial	3	P&A
DL MacLaughlan-Dumas, AA	partial	3	P&A
David Cline	partial	.25 sum	KA13, DOE accel, P&A faculty
Pieter Evaerts	Full		
Matthias Weber	Full		
KA13			
Alex Cahill, GS	Full		
Cassandra Gonzalez, AA	partial	2.4	KA11; P&A
D. Saltzberg	partial	1.0 sum	KA11, P&A faculty
David Cline	partial	.25 sum	KA11, DOE accel, P&A faculty
DL MacLaughlan-Dumas, AA	partial	3	P&A
K. Arisaka	partial	2.0 sum	P&A faculty

Kevin Lung, GS	Full		
Konstantin Belov, PD	partial	6	NASA
N. Ng, AA	partial	3	P&A
Yixiong Meng, GS	partial	4.25	NSF Dark Matter Grant
Hanguo Wang	partial	0.5	P&A research faculty
Paolo Beltrame	Full		
Chamkaur Ghag	Full		
Alden Fan, GS	partial	4.5	P&A teaching asst.

KA14

A. Kusenko	partial	2.0 sum	P&A faculty
Antione Calvez, GS	partial	3	P&A Teaching Asst.
G. Gelmini	partial	2.0 sum	P&A faculty
Nassim Bozorgnia, GS	partial	3	P&A Teaching Asst.
Tristin Dennen, GS	Full		
Warren Essey, GS	partial	3	P&A Teaching Asst.
Z. Bern	partial	2.0 sum	P&A faculty
Yu-tin Huang, PD	Full		
Kemal Ozeran, PD	Full		
Harald Ita	Full		

2012 - List of People on this DOE Project

Name *(AA = Admin; PD = postdoc/equiv; Eng = engineer; GS = grad student; SR = senior researcher)*	FULL PARTIAL support?	# of mo. of DOE support	Remainder of Support *(P&A = UCLA Dept of Physics and Astronomy)*
KA11			
Valery Andreev, SR	Full		
David Cline		0.60	KA13, DOE accel, P&A faculty
Robert Cousins		2.00	P&A faculty
Pieter Everaerts	Full		
Christopher Farrell, GS		Full	
Joyce Frechette		2.50	KA13, P&A
Cassandra Gonzalez, AA		4.10	KA13, P&A
Jay Hauser		2.00	P&S faculty
Mikhail Ignatenko, SR	Full		
Zaniah Jordan		0.23	
Lanora Moon, AA		0.64	P&A
Maksim Nikiforov		0.75	
Andrew Peck		0.75	
Gregory Rakness, PD		9.00	
David Saltzberg		1 sum	KA13, P&A faculty
Eric Takasugi, GS		Full	
Piotr Traczyk		8.00	
Jordan Tucker		4.00	
Viatcheslav Valouev, PD	Full		
Matthias Weber	Full		
Pui Yu		2.00	
KA13			
Katsushi Arisaka		2 sum	P&A faculty
Malcolm Bellman, AA		4.75	
Konstantin Belov, PD	Full		
Paolo Beltrame, GS		Full	
Kyle Borch		0.03	
Alexander Cahill, GS		1.32	
David Cline		0.40	KA11, DOE accel, P&A faculty
Joyce Frechette		2.50	KA11, P&A
Chamkaur Ghag		1.50	

Cassandra Gonzalez, AA	4.10	KA11, P&A
Dante Gordon	2.50	
Zaniah Jordan	0.55	
Joe Lam	0.04	
Kevin Lee	8.00	
Kevin Lung, GS	Full	
Alexey Lyashenko, SR	3.00	
Debra Maclaughlan-dumes, AA	1.60	P&A
Natalia Makrouchina	5.40	
Yixiong Meng, GS	4.20	NSF Dark Matter Grant
Nickie Ng, AA	6.80	P&A
Maksim Nikiforov	0.75	
Andrew Peck	0.75	
Linda Reyes	1.15	
David Saltzberg	1 sum	KA11, P&A faculty
Peter Smith	1.80	
Artin Teymourian	1.50	
David Urdaneta Sandoval, US	3.18	
Tyler Willms	0.90	
Stephanie Wissel	2.90	
Ziqi Yan	1.89	

KA14

Zvi Bern	2 sum	P&A
Nassim Bozorgnia	3.60	
Scott Davies, GS	2.20	DOE Fellowship
Eugenio Del Nobile	3.80	
Tristan Dennen, GS	3.50	DOE Fellowship
Graciela Gelmini	2.00	P&A
Yu tin Huang, PD	5.00	Johns Hopkins
Ji-haeng Huh	3.85	
Harald Ita	Full	
Alexander Kusenko	2 sum mo	P&A
Kemal Ozeren, PD	Full	
Gerben Stavenga	6.75	

7. Unexpended funds

We had no unexpended funds left at the end of the grant period.

8. Budgets

Not applicable for final report.