Particle Physics in the Czech Republic

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**on behalf of the CZ HEP Community*

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Selected chapters from history on few slides (1/3)

- *Roots of the Czech(oslovak) experimental particle physics are in 1950's connected with the analysis of cosmic rays interactions registered with nuclear emulsions; some of them irradiated on Gerlach peak, High Tatra, Slovakia*
- *Bubble chamber era:*
  - *2m CERN hydrogen bubble chamber: antiproton-proton @ 5.7 GeV/c (late 1960's)*
  - *2m JINR Dubna hydrogen bubble chamber Ludmila in early 1970's: antiproton-proton @ 22.4 GeV/c and later on antideuteron-deuteron @ 12.0 GeV/c*
- *"Electronic" experiments with JINR Dubna in late 1970's, among others:*
  - *BIS spectrometer: 40–70 GeV neutrons on carbon, production of Lambda(c)*
  - *RISK spectrometer: π beams @ 40 GeV/c, different nuclear targets*

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Selected chapters from history on few slides (2/3)

- *In 1980's more vivid contacts with CERN, mostly via JINR Dubna:*
  - *NA4 Collaboration (from late 1970's)*
  - *In 1983 our physicists started collaborate with **DELPHI** (this had very influence 10 years later on the membership procedure to became a member state of CERN)*
- *In 1986 Czechoslovak laboratories became members of H1 experiment @ DESY – first institutional membership in "western" experiment*

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Selected chapters from history on few slides (3/3)

- *Czech republic is a CERN member state from 1993 (from 1992 as Czechoslovakia)*
- *The status of particle physics research in CERN member states is regularly reviewed by ECFA; last review of our research took place on March 9-10, 2007*

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Institutes and human resources (1/2)

Particle physics is cultivated in the following 15 institutions:

- AS CR, Prague **(1773-) 6700 employees**
  - Astronomical Institute
  - Institute of Physics
  - Institute of Information Theory and Automation
  - Nuclear Physics Institute
  - Inst. of Scientific Instruments
- Czech TU in Prague **(1707-) 2000 employees, 24000 students**
  - Faculty of Nuclear Sciences and Physical Engineering
  - Faculty of Mechanical Engineering
  - Computing and Information Centre
  - Institute of Experimental and Applied Physics
- Masaryk U Brno **(1919-) ~ 2000 employees, 36000 students**
  - Faculty of Natural Sciences

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Institutes and human r

- Silesian U Opava **(1991-) ~2000 students**
  - Faculty of Philosophy and Natural Science
- Charles U, Prague **(1348-) 5500 employees, 48000 students**
  - Faculty of Mathematics and Physics
- Palacky U, Olomouc **(1573-) 1300 employees, 17600 students**
  - Faculty of Natural Sciences
- TU Liberec **(1953-) ~1400 employees, 7500 students**
  - Faculty of Mechanical Engineering
- U West Bohemia, Pilsen **(1991-) 1600 employees, 17000 students**
  - Faculty of Electrical Engineering

Number of research employees collaborating in particle physics: 400 + 100 students

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Czech particle physics - experiments

I will speak here practically exclusively about our participation in experiments.

This can be split in several blocks – participation in:

- *Neutrino experiments*
- *Astro-particle experiments*
- *Non-CERN accelerator experiments*
- *Running CERN experiments*
- *CERN experiments under preparation (@LHC)*
- *R&D project*

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Neutrino experiments

Czech contribution to neutrino experiments

Czech neutrino groups <
in a good shape <
and well motivated <
to accept responsibilities <
in highly challenging <
great experiments <

> NEMO 3
> TGV II
> PICASSO
> Daya Bay
> KATRIN

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Neutrino experiments (1/3)

Charles University Prague <
R. Leitner, V. Vorobel, Z. Dolezal
V. Pec (dip. st.), P. Nevidansky (bc.)

reactor oscillation experiment <
optimized for Θ_{13} measurement <
sensitivity of 0.01 @ 90% c.l.
located at Daya Bay, China <
4 reactor cores, 2 more in 2011 <
17.4 GW in total
starting in 2010 with a full detector <

Daya Bay

Czech group responsible for <
Monte Carlo of background <
R&D veto detector <

> trasparency by R. Leitner, Ch. Uni.

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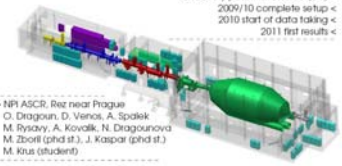
Neutrino experiments (2/3)

beta decay experiment <
to measure neutrino mass
in model independent way

KATRIN

the next generation tritium exp. <
sensitivity 0.2 eV (90%c.l.) (no signal) <
discovery potential 0.35 eV (5 σ) <
2009/10 complete setup <
2010 start of data taking <
2011 first results <



> NPI ASCR, Rez near Prague
O. Dragoun, D. Venos, A. Spalek
M. Rysavy, A. Kovalik, N. Dragounova
M. Zboril (phd st.), J. Kaspar (phd st.)
M. Krus (student)

Czech group responsible for <
calibration & monitoring task <
1 – 3 ppm for 5 years
R&D of nuclear standards of
monoenergetic electrons
Am/Co, Rb/Kr (NPI Rez)
CKrS (Uni Muenster)

and contributing by <
optimized distrib. of meas. time <
MC simulations of el. scattering <
gamma spectroscopy <

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Neutrino experiments (3/3)

NEMO 3 & TGV II & PICASSO

NEMO 3	TGV II	PICASSO
0νββ and 2νββ experiment located at Frejeus Underg. Lab. several isotopes ^{100}Mo, ^{82}Se, ^{130}Te, ^{116}Cd, ^{96}Zr, ^{48}Ca, ^{150}Nd operated all 2004 from Oct. 2004 with radon free air	multi-detector telesc. spectrometer < ββ process in ^{106}Cd (EC/EC), ^{48}Ca < located at Modane Underg. Lab. < 32 HPGe detectors < in a common cryostat	dark matter experiment neutralino detection located at SNO superheated droplets detectors elastic nuclear scattering
IEAP CTU Prague I. Stekl, L.Vala, J. Jerie (phd) P. Benes (phd), F. Mamedov (phd) V. Bocanov (phd) Charles University Prague V. Vorobel	IEAP CTU Prague I. Stekl, P. Cermak, P. Benes (phd)	IEAP CTU Prague S. Pospisil, I. Stekl, J. Sodomka

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Pierre Auger Observatory (1/3)

Detection of Ultra High Energy Cosmic Rays

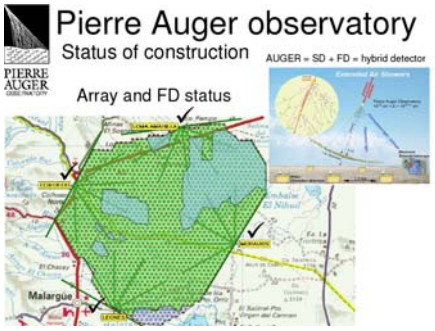
Spectrum (GZK?), Sources, Composition, etc.

participating institutions in the Czech Republic (3):
a) Institute of Physics AS CR
b) Joint Laboratory of Optics of Palacky University and Institute of Physics ASCR
c) Institute of Particle and Nuclear Physics, Faculty of Mathematics and Physics, Charles University

senior scientists (8): M. Bohacova, J. Grygar, M. Prouza, J. Ridky, P. Travnicek, D. Nosek, M. Hrabovsky, M. Palatka, P.Schovanek
phd students (6): D. Mandat, L. Nozka, M. Pech, T. Karova, P. Necesal, R. Smida
8 technicians

12 orders of magnitude!

Pierre Auger Observatory (2/3)



12 orders of magnitude!

Pierre Auger Observatory (3/3)

Pierre Auger observatory

activities of Czech group

Hardware (HW), Performance studies & data quality (PS), Physics Analysis (PA)

optical system design for fluorescence telescopes (spot analysis, corrector rings, ... , actual design and production of ½ of all the telescope mirrors)

December 2006 - last FD observatory completed
February 2007 - first data

HW

12 orders of magnitude!

Other astro-particle physics projects

VHE Gamma Ray Astronomy
High Energy Stereoscopic System

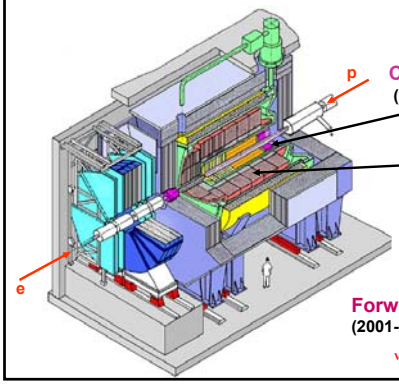
- Galactic sources
- Galactic plane survey
- Supernova remnants
- Pulsar wind nebulae
- Binaries
- The Galactic Center
- Extragalactic sources

participating institutions in the Czech Republic (1): Institute of Particle and Nuclear Physics, Faculty of Mathematics and Physics, Charles University
senior scientists (1): , no.: phd students (1): , no.:

CZELTA

- CZEch Large-area Time coincidence Array.
- Collaboration with University of Alberta (project ALTA in Canada)
- Project for the detection of high energy cosmic rays (> 10^{14} eV).
- Stations are installed at roofs of high schools -> educational impact of the project.

H1 experiment (1/2)



Prague contribution:

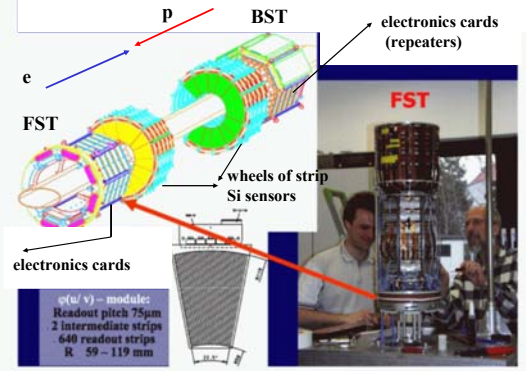
Calorimeter SPACAL
(1994-1995)

Liquid argon Calorimeter
(1987-1990)

Backward silicon tracker
(1996-1997)

Forward silicon tracker
(2001-2005)

Forward and backward silicon detectors



D0 Experiment

Our contribution

- Run II Upgrade
  - HV distribution boxes for muon detectors built here in Prague
  - calibration system for muon trigger (Light Mixing Boxes)
  - 1 year of silicon detector tests
  - contribution to the building of Forward Proton Detectors (Roman Pots)
- Software: code for accessing luminosity information and for normalization of the data

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Experiment Dirac

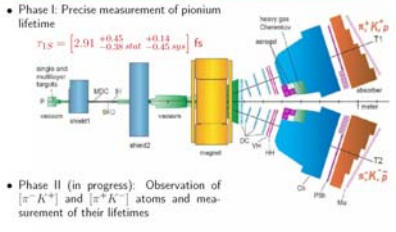
- Czech group lead by prof. Čechák (6 physicists + 1 engineer + 1 PhD student + 1 undergrad. student)
  - Faculty of Nuclear Sciences and Physical Engineering, CTU
  - Institute of Physics ASCR
  - Nuclear Physics Institute ASCR

DIRAC experiment

- Phase I: Precise measurement of pionium lifetime

$$\tau_{1S} = \left[2.91\ ^{+0.45}_{-0.38\ stat}\ ^{+0.14}_{-0.45\ syst}\right]\ fs$$

- Phase II (in progress): Observation of $[\pi^- K^+]$ and $[\pi^+ K^-]$ atoms and measurement of their lifetimes



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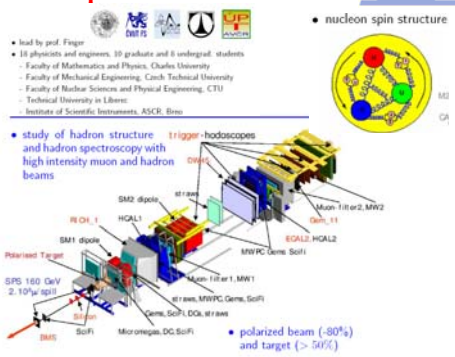
Experiment COMPASS

- nucleon spin structure
- lead by prof. Finger
- 18 physicists and engineers, 10 graduate and 8 undergrad. students
  - Faculty of Mathematics and Physics, Charles University
  - Faculty of Mechanical Engineering, Czech Technical University
  - Faculty of Nuclear Sciences and Physical Engineering, CTU
  - Technical University in Liberec
  - Institute of Scientific Instruments, ASCR, Brno
- study of hadron structure and hadron spectroscopy with high intensity muon and hadron beams



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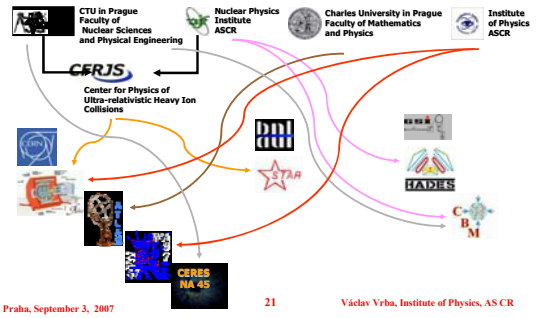
Structure of activities in Heavy Ion Physics



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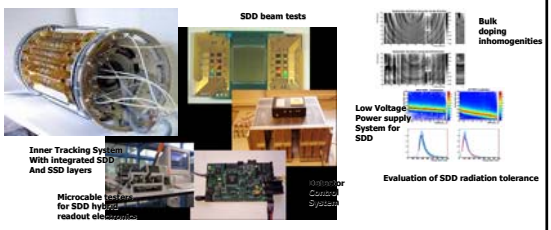
ALICE ITS



- Local detector calibration
- Detector Control System of SDD
- Tests of Silicon drift detectors, detector selection for assembly

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TOTEM Experiment (1/2)

Physics goals:

- measurement of σ_{tot} for scattering up to energies of 14 TeV
- measurement of pp elastic scattering in the range $10^{-3} < -t < 10$ GeV^2
- forward physics with TOTEM – soft diffraction:
  - single diffraction, central exclusive production (DPE)
  - particle flow in the forward direction
- forward physics CMS/TOTEM – hard diffraction:
  - production of jets, W, Z, … in SD and DPE
  - central exclusive production (Higgs etc.)
  - low – x physics

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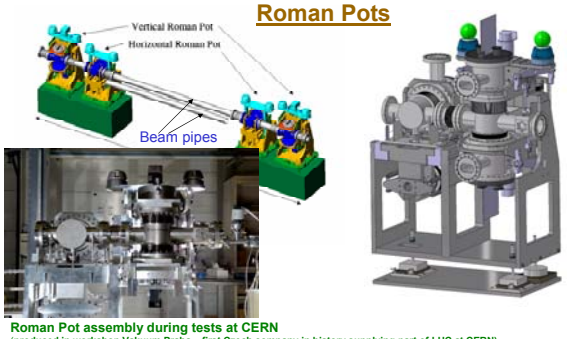
TOTEM Experiment (2/2)

Roman Pots



Roman Pot assembly during tests at CERN
(produced in workshop Vakuum Praha – first Czech company in history supplying part of LHC at CERN)

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CZ participation in Atlas experiment

- Institute of Physics of the Academy of Sciences of the Czech Republic, group is lead by Vaclav Vrba; (IP ASCR)
- Faculty of Mathematics and Physics of the Charles University in Prague, lead by Rupert Leitner; (IPNP FMF CU)
- Faculty of Nuclear Sciences and Physical Engineering, Faculty of Mechanical Engineering, Institute of Experimental and Applied Physics of the Czech Technical University in Prague, lead by Stanislav Pospisil; (FNSPE, FME, IEAP TU)

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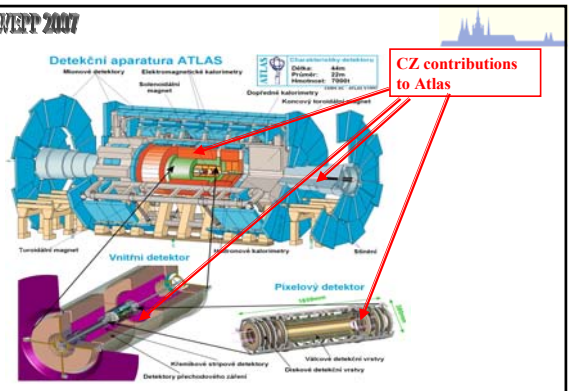

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Pixel sensors testing at Prague (IP ASCR)

Sensor produced at *ON Semiconductor , Czech Rep.*

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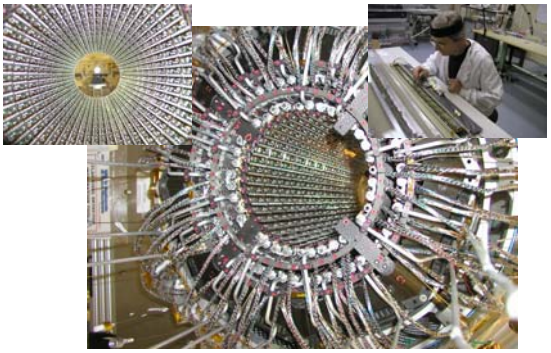
Assembly of Pixel Detector layers @ CERN



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Inner Detector services (cables and pipes) installation in the inner bore of the barrel cryostat

Coordination of Pixel Detector services installation

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SCT Endcap Tracker (IPNP FMF CU)

Module design
Special test methods (laser, source)

QA: 210 modules (10% endcap)
Installation at CERN

Clean room class 10000

Environmental control system

Laser test setup

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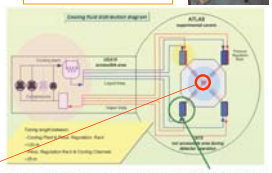
ATLAS Inner detector cooling system (FME TU)

Overall status of the ID cooling system for SCT and Pixels:

- Main parts of the external cooling system installed, commissioned and in operation:
  - Cooling plant with all infrastructure
  - Tubes and distributing racks

All main hardware in a reasonably good shape and under control



Compressor-condenser station&Storage vesel

BUT – serious problems inside the cryostat with heaters&HEXes&their control. Now being solved

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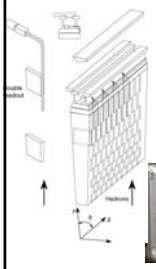
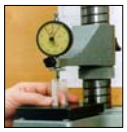
TILECAL construction

(IP ASCR, CU Prague)





- TILE Hadronic calorimeter
  Produced in 8 laboratories, Czech contribution to the submodule production 1999 – 2003
  - 3 000 tons of rolled steel delivered from CR for the whole calorimeter
  - 309 submodules (1/4 of TILE barrel) constructed
  - Few tons of anticorrosive black paint DISKOR
- lightmixer production 1999 - 2001
  - 10 000 light mixers, 800 special pieces produced
- HV and LV power supply system 2000 - 2007
  - HV power supplies, 256 channels, 16 units, designed and produced
  - LV power supply system for the TILE, substantial contribution to design and production

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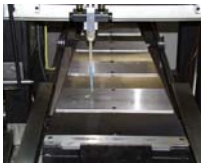

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ATLAS TileCal @ CERN

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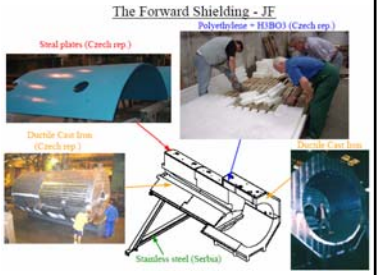
ATLAS Neutron Shielding (IEAP TU, IPNP FMF CU)

ATLAS JF shielding:
- JF cast iron blocks (high content of C)
- Borated polyethylene (BPE) bricks for JF
- Steel JF cladding production
- Facing of BPE and iron cladding on JF cast iron blocks
- Production of transport beds for JF parts
- Transport of JF parts from Czech Republic to CERN.
JM shielding of ATLAS ID
ATLAS JTT shielding
JN shielding for LHC – in ATLAS Hall - „Washers"



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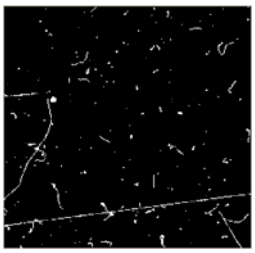
Medipix2-USB Device for ATLAS (IEAP TU, IPNP FMF CU)

The project is proposed by ATLAS Institutions in cooperation with the CERN MEDIPIX2 Collaboration (see https://edms.cern.ch/document/815615/1).
1) Czech Technical University in Prague, Institute of Experimental and Applied Physics, Czech Republic
2) Charles University in Prague, Institute of Particle and Nuclear Physics, Czech Republic
3) CERN –ATLAS
4) University of Montreal, Canada
5) Glasgow University, Scotland
6) NIKHEF, The Netherlands

- **The MEDIPIX2-USB device connected to the portable PC. Up to 5 frames per second (USB 1 option). One PC can effectively run up to 50 MEDIPIX-USB devices (each in individual regime), or simultaneously.**
- **View of the MEDIPIX2-USB device (http://www.utef.cvut.cz/MEDIPIX). The Medipix2 motherboard (left PCB, 80x46mm2) is assembled to the USB interface board which is placed in a duralumin box (64x50x20mm3) for shielding and mechanical purposes. The motherboard can also be placed in a duralumin box with an appropriate entrance window.**

TWEPP 2007 Medipix2-USB Device for ATLAS (IEAP TU, IPNP FMF CU)

Natural background radiation



Clearly recognizable tracks and traces of X-rays, electrons generated mostly by gamma rays, alpha particles, muon, …

Examples of response of MEDIPIX-USB device to fast monochromatic neutrons (17MeV neutrons, flux about 10^4 n/(s.cm2)

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R&D projects which supported our participation in LHC experiments

During 1990's the Czech groups participated in R&D projects, which in most of cases in the participation in development of particular sub-system of LHC detector (s). In our case it was ATLAS or ALICE.

RD8 Development of GaAs Detectors for Physics at the LHC *(St.Pospíšil)*

RD18 New Fast and Radiation Hard Scintillators for Calorimetry at LHC *(J.A.Mareš)*

RD19 Development of hybrid and monolithic silicon micropattern detectors *(V.Vrba)*

RD28 Development of gas micro-strip chambers for high radiation-rate detection and tracking, *(J.Bohm), later on continuing with* RD-20 – Development of high resolution Si strip detectors for experiments at high luminosity at the LHC

RD34 Developments for a scintillator tile sampling hadron calorimeter with "longitudinal" tile configuration – TileCal project *(R.Leitner)*

RD48 Further work on radiation hardening of silicon detectors, *which continues with …*

RD50 Development of Radiation Hard Semiconductor Devices for Very High Luminosity Colliders *(B.Sopko, V.Vrba)*

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R&D projects for future linear e+e- collider

SILK Collaboration – development of the Silicon tracking for Linear Collider (Charles University)

CALICE Collaboration – development of calorimetry for future linear e+e- collider (Academy of Sciences, Charles University)

➔ *Participants of the EUDET Project*

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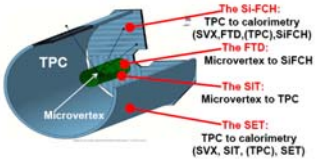
ILC Tracker

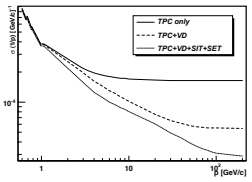
SiLC: Silicon Tracking for the ILC

Charles University, Faculty of Math&Phys, IPNP

Additional silicon envelope to the TPC



Momentum resolution: TPC only vs. TPC+Si



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ILC Tracker

SiLC: Silicon Tracking for the ILC

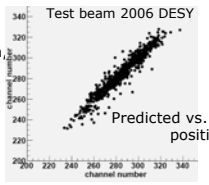
Charles University, Faculty of Math&Phys, IPNP

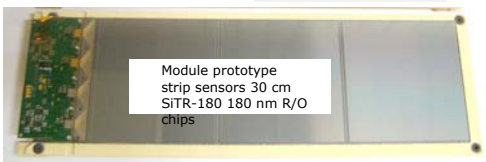
Prague activities:

Testing module prototypes (beam, source, laser)

Simulations of the ILC detector (digitization, MERLIN/MOKKA)

Members of EUDET (EU project)





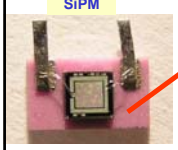
The HCAL prototype comprises 38 planes of scintillating detectors with 216 tiles in first 30 planes and 145 tiles in 8 last ones.

Our contribution to the TileHcal:

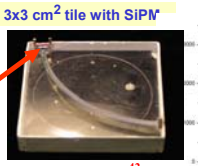
1. Study of geometry (WLS fibre, groove) scintillator producer (Bicron, Russian)
2. Construction of the preprototype frame – minical, APD properties
3. Preamplifier for APDs
4. Design and construction of LED calibration system for prototype

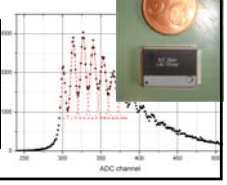
Light from a tile is read out via WLS fiber and SiPM

SiPM



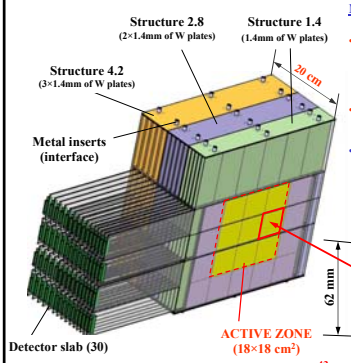
3x3 cm^2 tile with SiPM





LAL 18 ch. SiPM FE chip

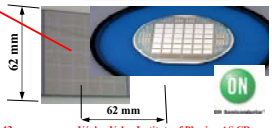
ECal physics prototype



Multi-layer (30) W-Si Prototype :

- 3 independent C-W alveolar structures , 10 layer each, with thickness of tungsten plates (1.4, 2.8 and 4.2 mm)
- 30 detector slabs which are slid into central and bottom cells of each structure
- Active layers : 3×3 pad matrices in 30 layers

9720 pads



Physics prototype - sensors

Two Si sensor vendors : ON Semiconductor, Czech Rep., and Elma, Russia

Si wafer specifications:

Wafer diameter: 4"

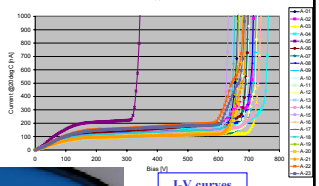
Thickness: 525 μm

N-type, resistivity ≥ 5 kΩ·cm

Sensor array:

36 pads of 1x1 cm²

Guard ring area + scribe line area: 1 mm



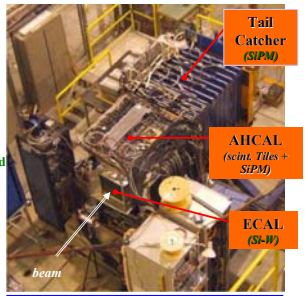
I-V curves

Very successful test beam @ CERN in 2006

Irradiations from August to October 2006 at H6B SPS test beam area

For ECal the most important data have been obtained in October in the *combined ECal+ AnalogHCal + TailCatcher&Muon Tracker run*

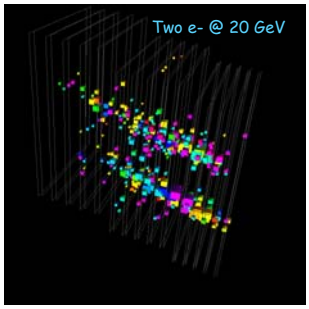
- ECal : 70% equipped Si-W prototype: 30 layers (10 with 1.4 mm W, 10 with 2.8 mm W and 10 with 4.2 mm W) interleaved by 18x12 cm² of Si 1x1 cm² pad arrays ➔ 6480 channels
- Positron beam energy scan: 10, 15, 16, 18, 20, 30 and 50 GeV; about 300k events, each energy
- Electron beam energy scan: 6, 10, 15, 20 GeV; several 100k events, each
- more than 30M muons for calibration



Setup for the combined ECal+ AnalogHCal + TailCatcher&MuonTracker run at CERN

Test Beam Data Analysis

Example of ECal separability power for close el.mag. showers:



Conclusions

- *Czech physicist participate in all major projects in leading HEP laboratories: CERN, Fermilab, DESY, BNL and present biggest astrophysics experiment Pierre Auger.*
- *Participation in large and multi-purpose projects is "laced" by participation in "small" (but also important) dedicated projects.*
- *Czech laboratories have sufficient potential visibly contribute to experiment instrumentation. Such tasks are supported by our participation in relevant R&Ds.*

ATLAS SCT Detector