Jet Quenching Measurements with ATLAS at LHC

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for the ATLAS Collaboration

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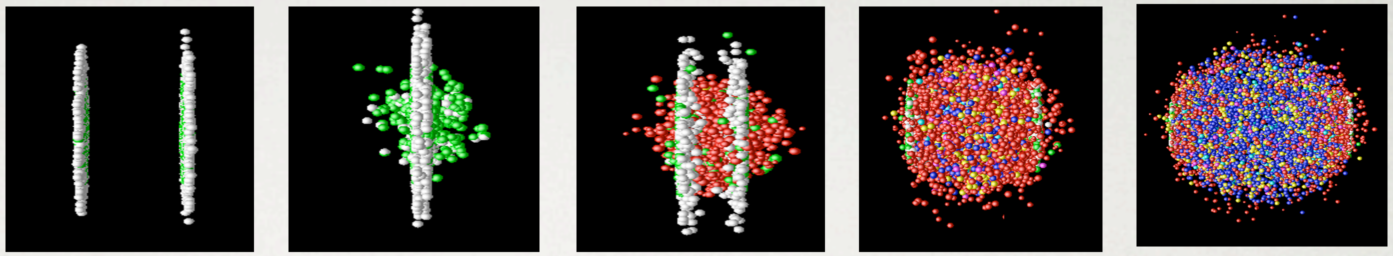
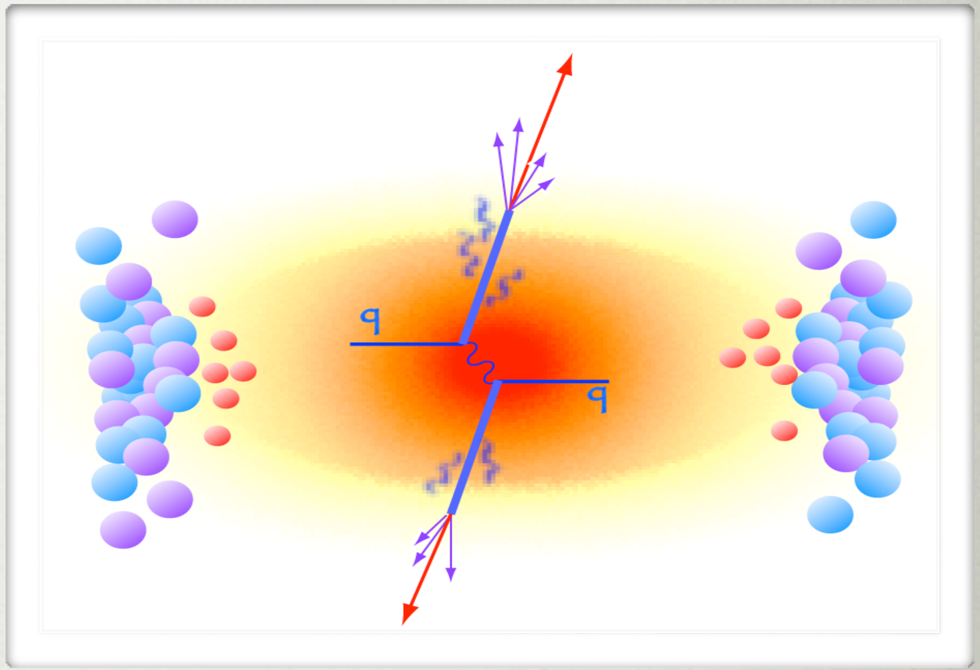
Nuclear Physics and Applications
Santiago de Chile, December 2009

Outline

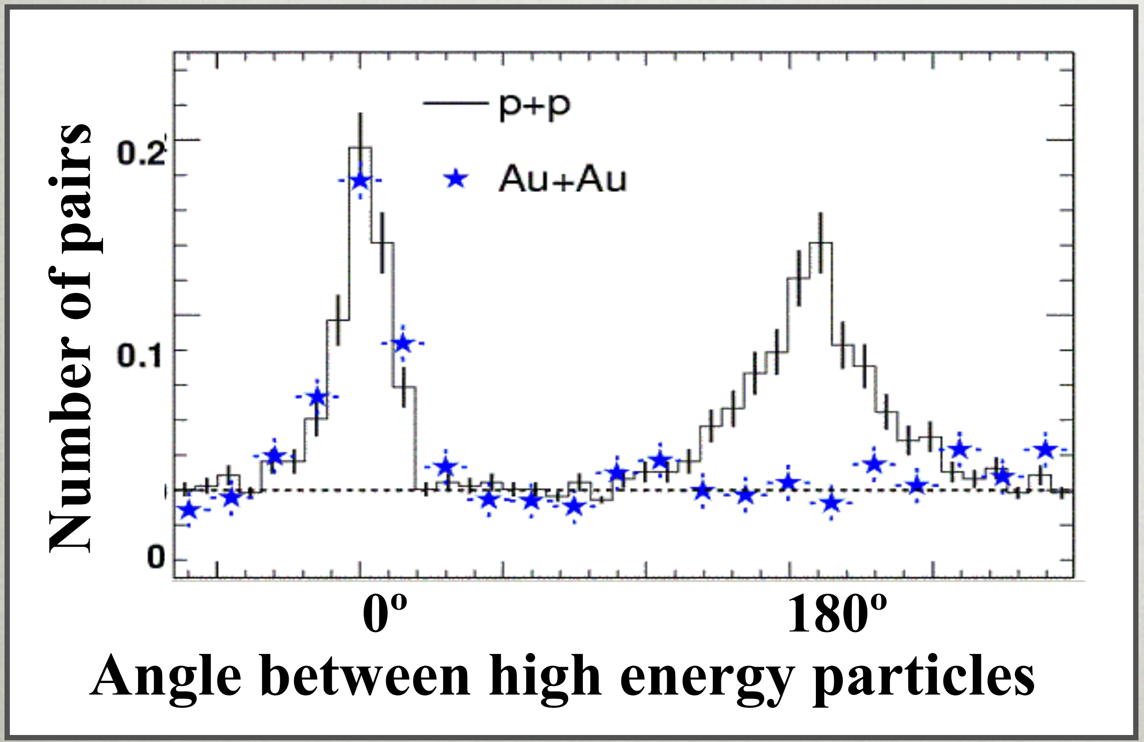
- Jet quenching: context
- Introduction to ATLAS
- Survey of ATLAS heavy-ion program
- Jet suppression physics
- Conclusion

Context



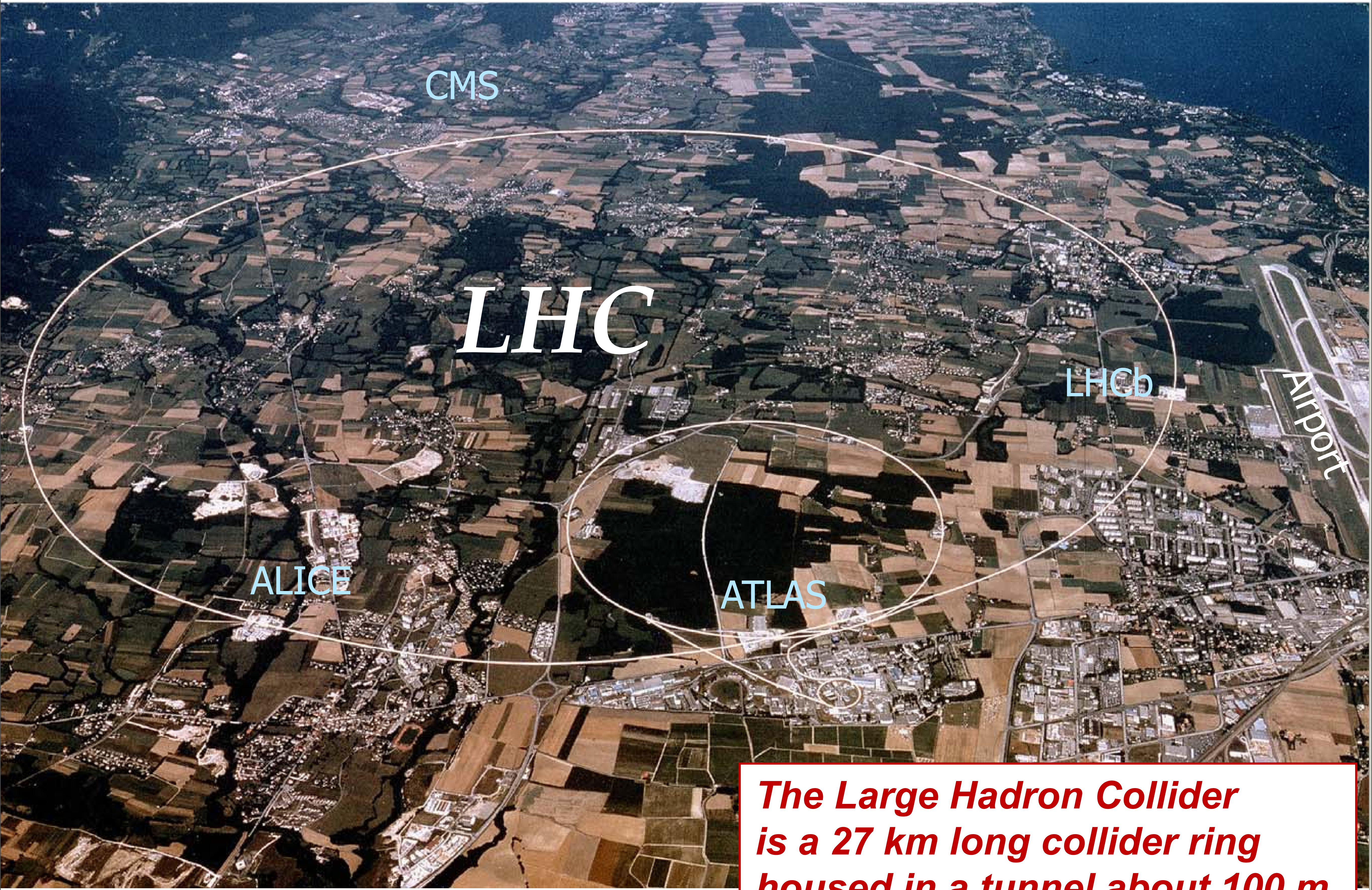


- The Relativistic Heavy Ion Collider (RHIC/BNL) has discovered a *new state of matter* in heavy ion collisions
- Experimental evidence indicates it is a hot, dense, strongly interacting system that behaves as a liquid with ultra-low viscosity
- The most compelling evidence that a super-dense medium is formed is ***jet quenching*** - *the disappearance of one of the jets in high-p_T two-jet events:*

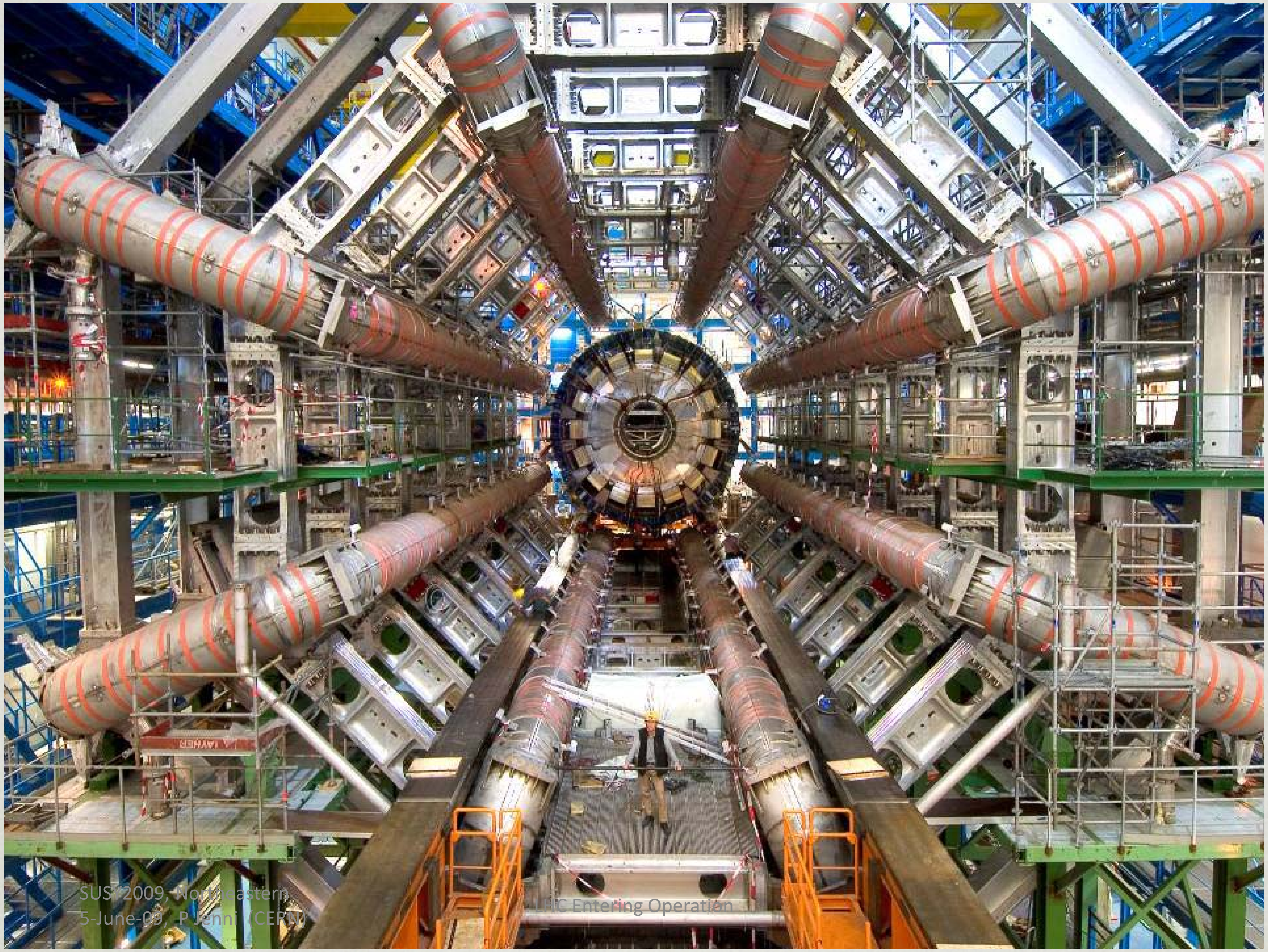


- The phenomenon is qualitatively understood, but a number of puzzles remain
- The study of jet quenching in heavy ion collisions at LHC offers many new possibilities:
    - Much wider kinematic range and larger cross sections
    - Well-defined jets
    - Heavy quark jets

Introduction to the ATLAS Experiment



The Large Hadron Collider is a 27 km long collider ring housed in a tunnel about 100 m underground near Geneva



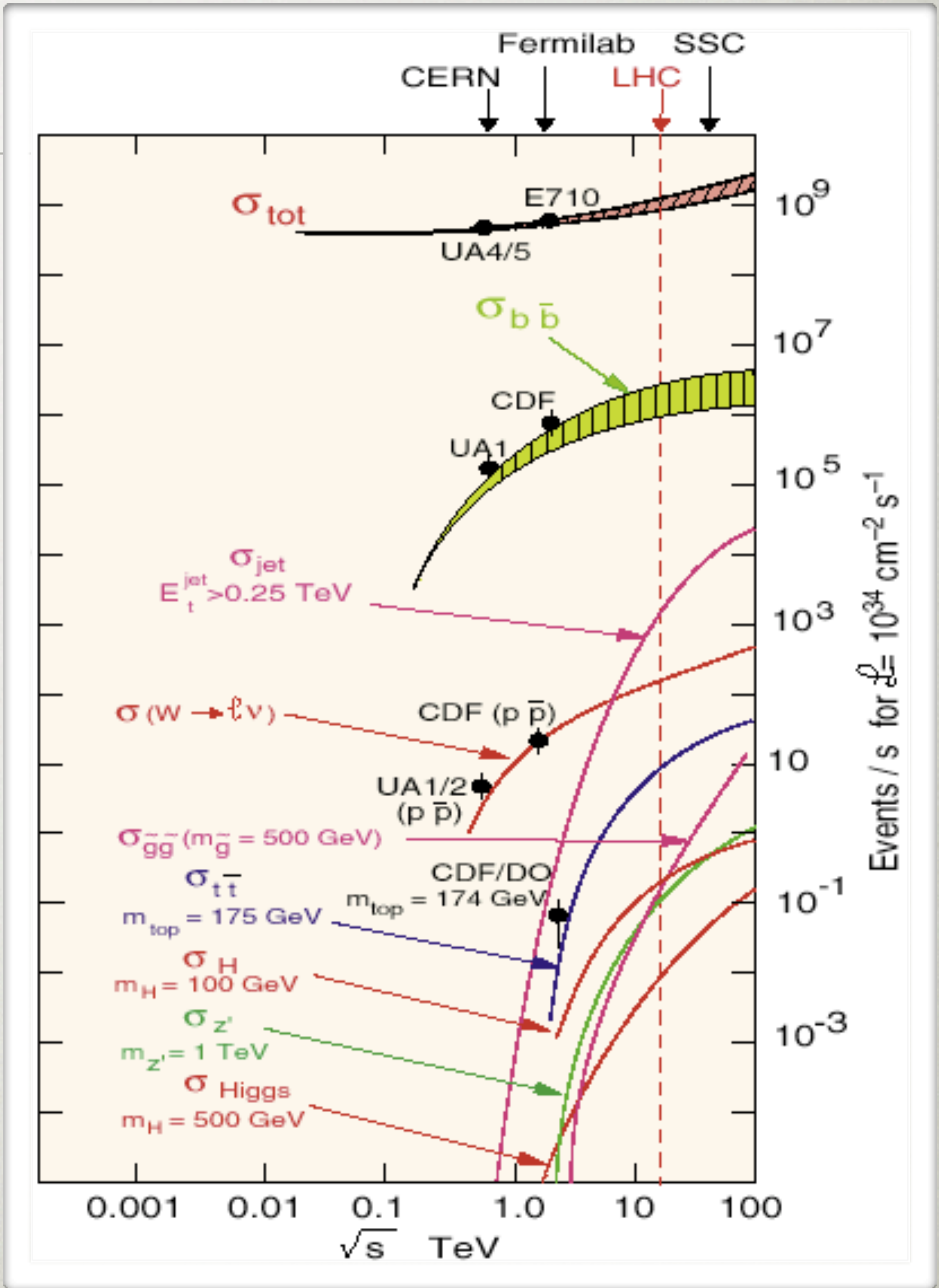
The ATLAS Experiment

The ATLAS Collaboration and G Aad et al 2008 JINST 3 S08003

2700 collaborators (700 students)
7000 tons, 22 m diameter, 46 m long
Superconducting solenoid and toroid magnets
88 million detector channels
550 M CF

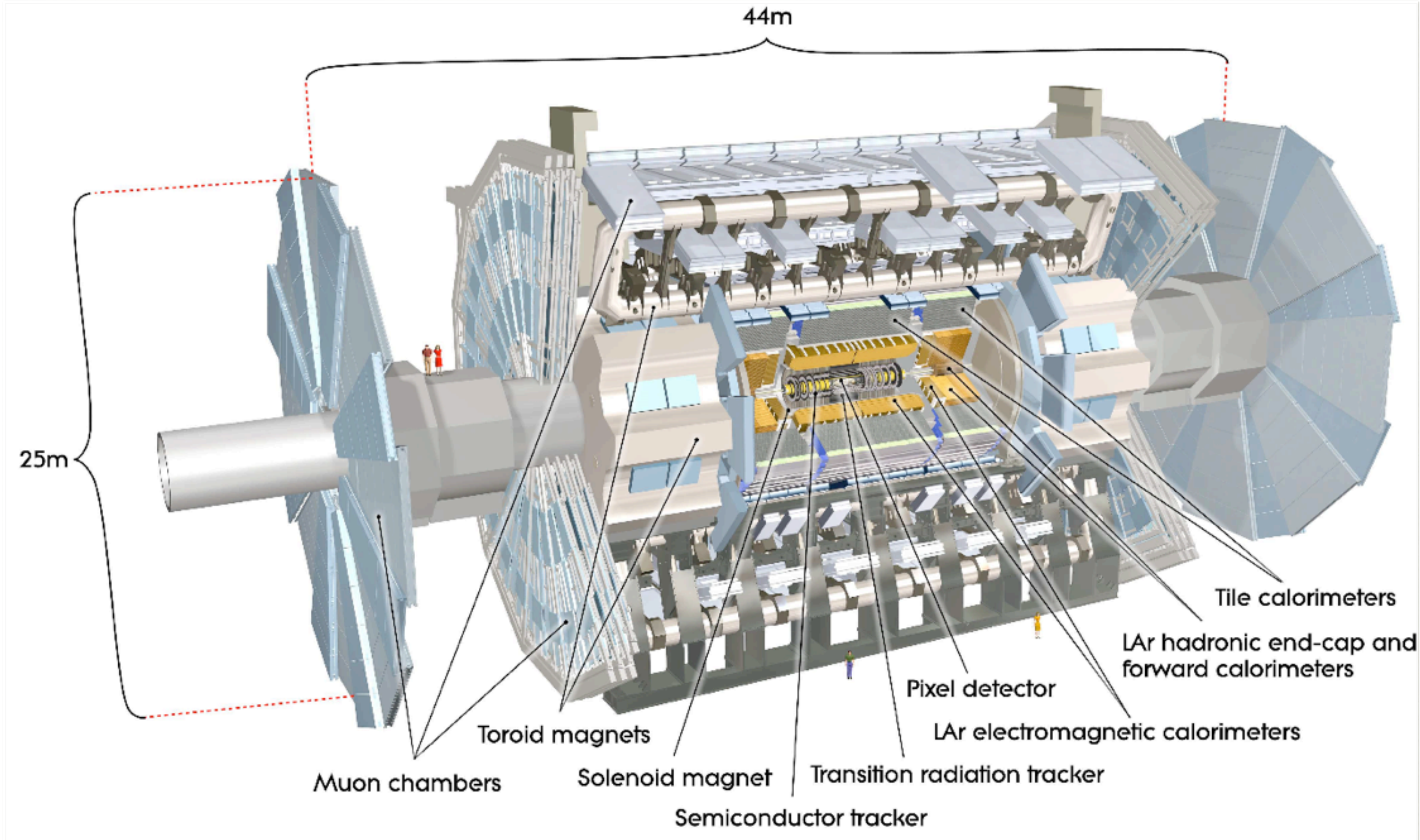
ATLAS Physics Programme

- B Physics
- Exotics
- Heavy Ions
- Higgs
- Standard Model
- SUSY
- Top Quark Physics

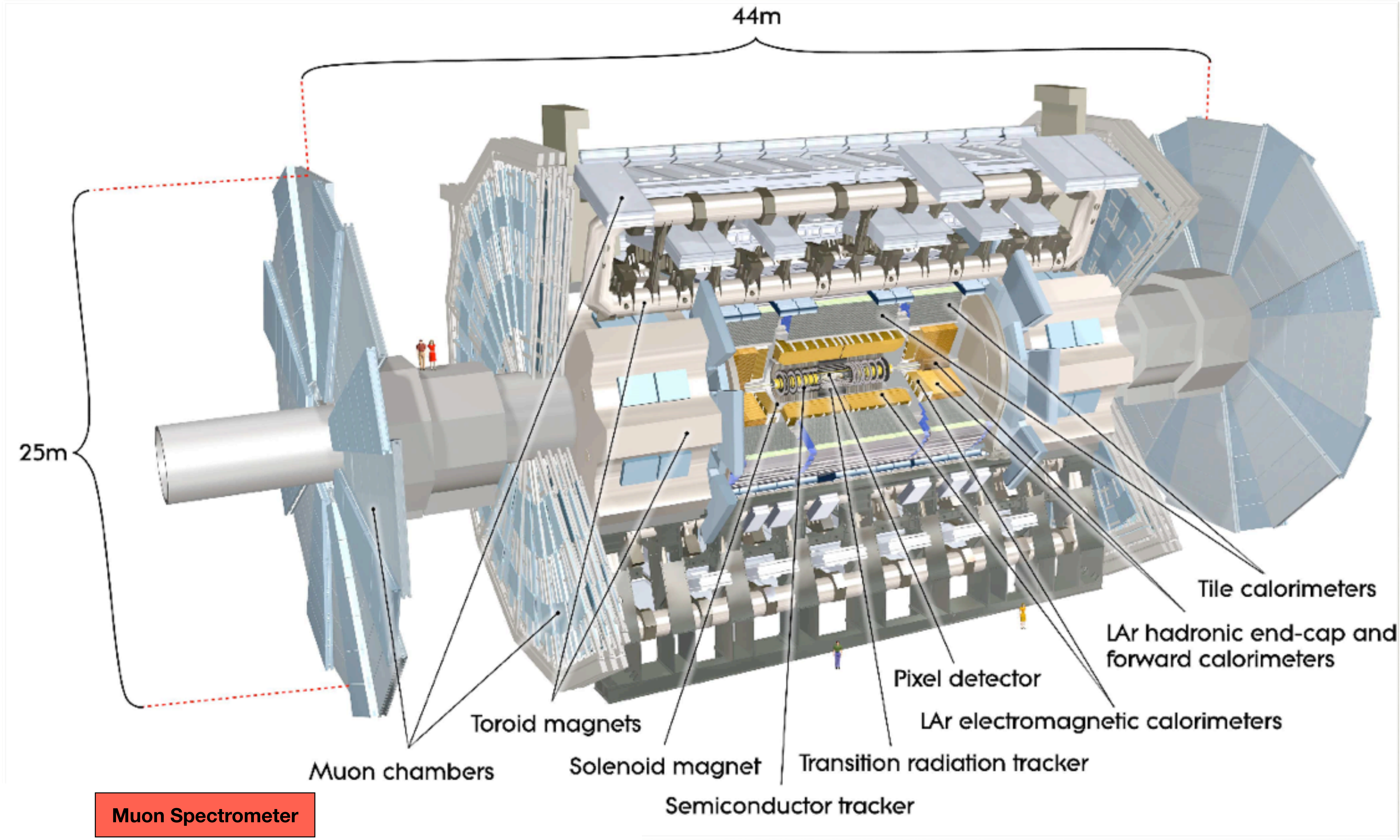


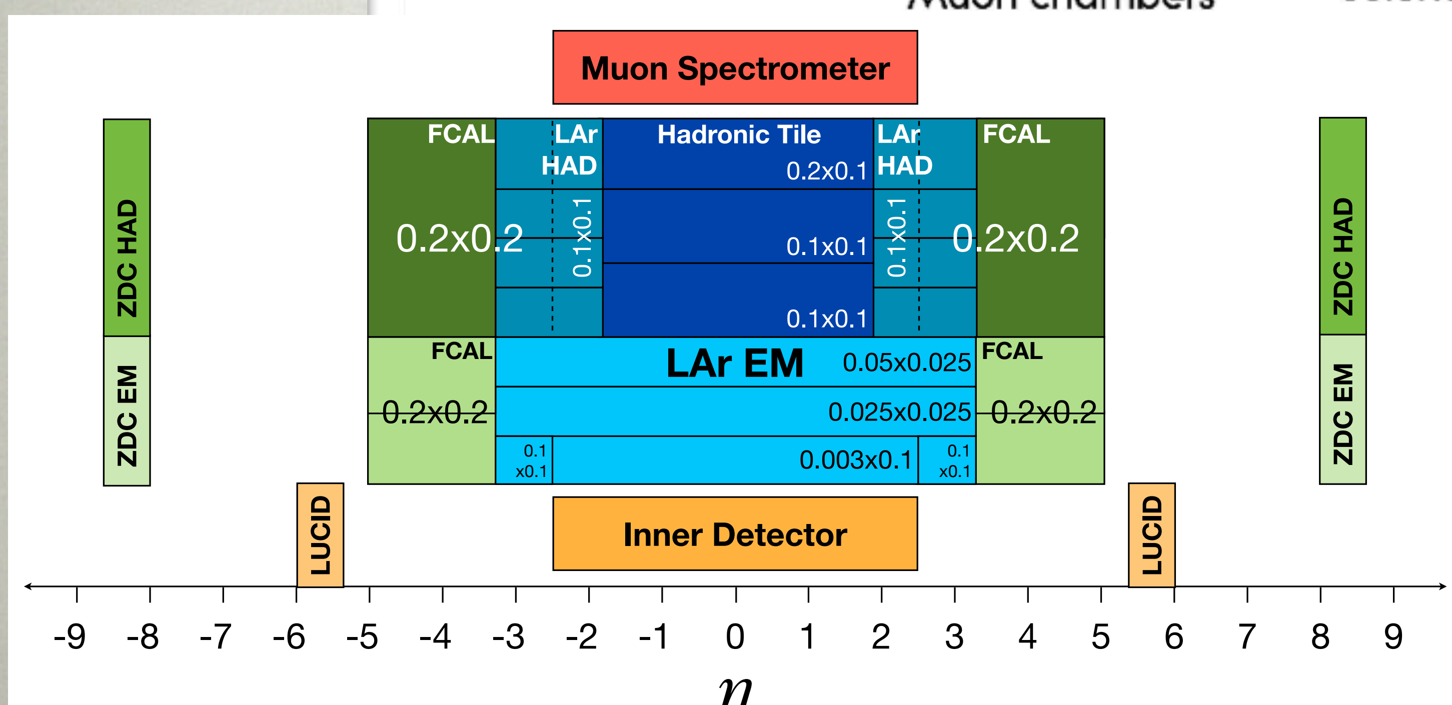
ATLAS Collaboration,
Expected Performance of the ATLAS Experiment, Detector, Trigger and Physics,
CERN-OPEN-2008-020, ISBN978-92-9083-321-5, Geneva, 2008

ATLAS Detector Systems

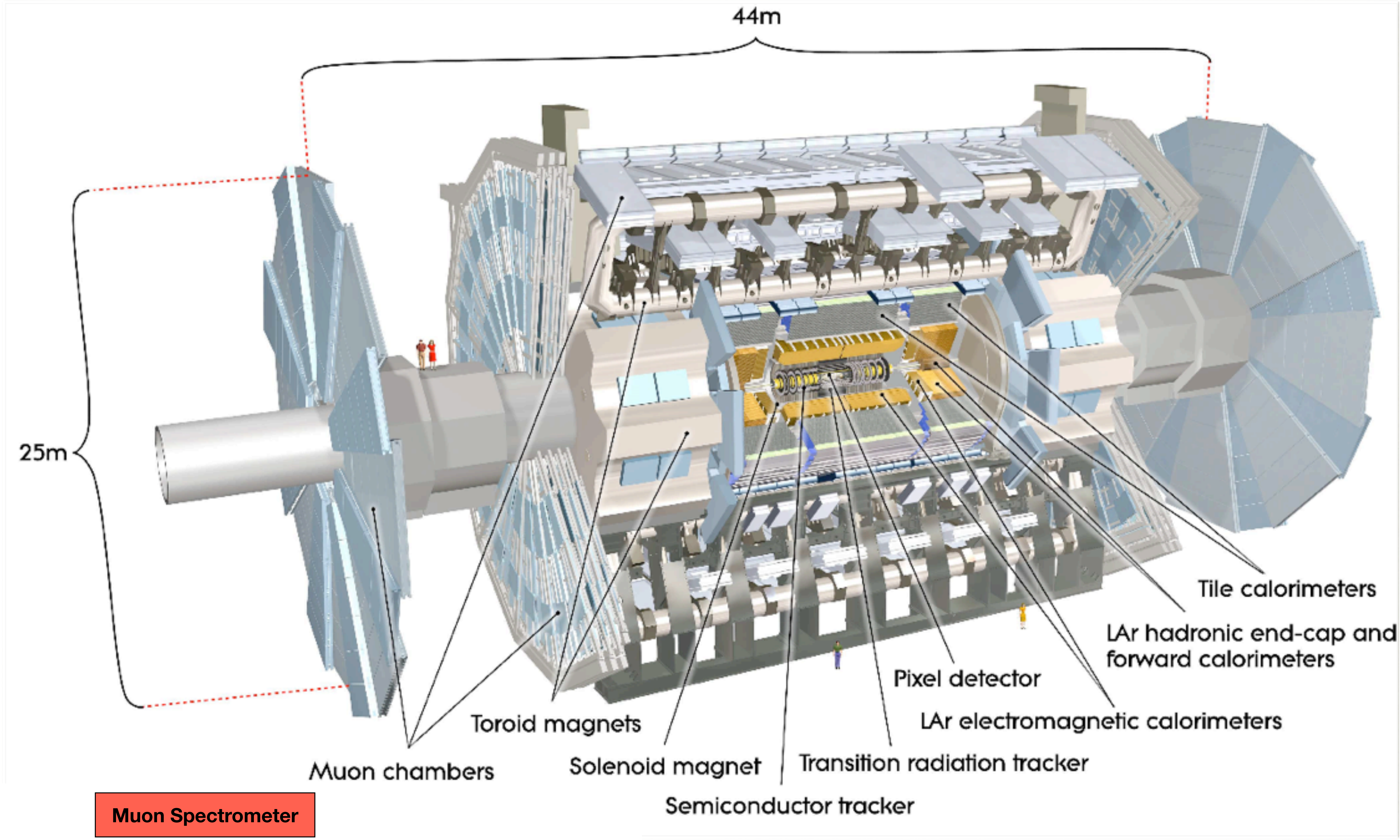


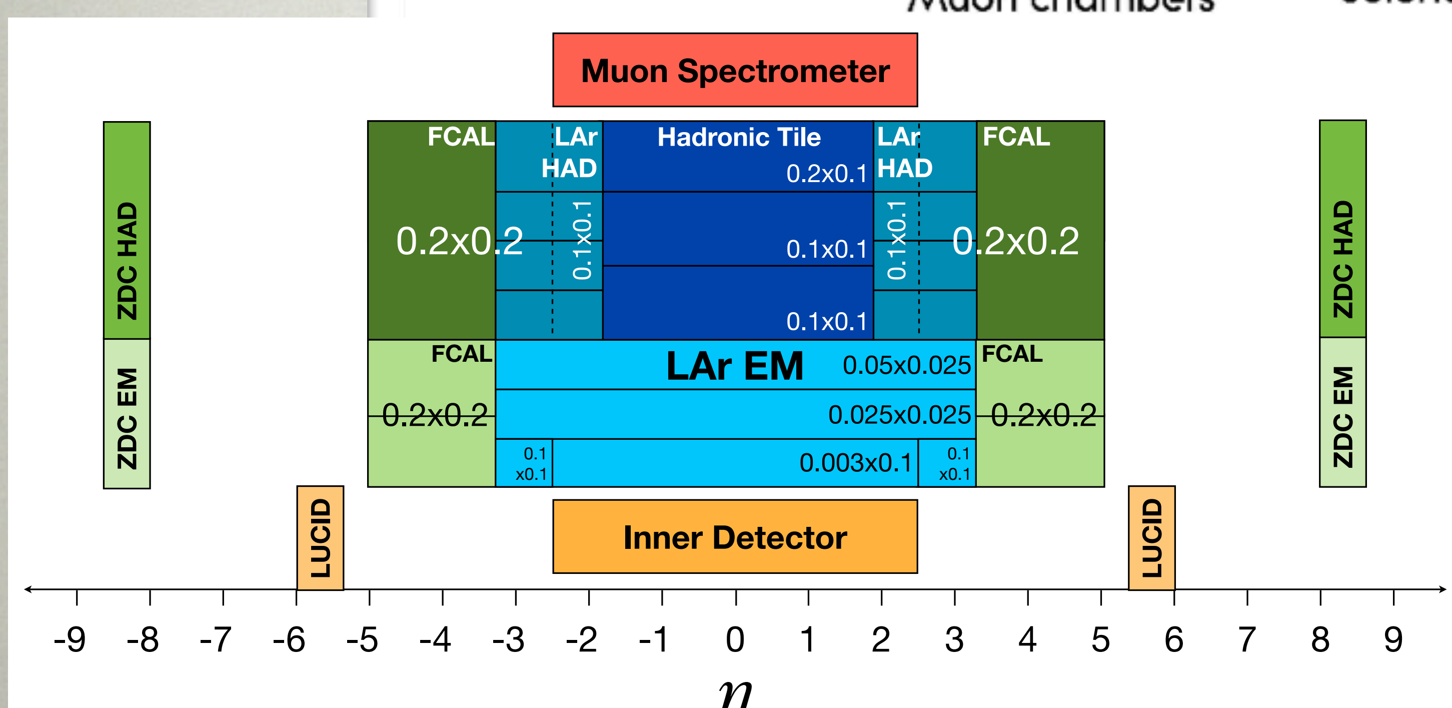
ATLAS Detector Systems





ATLAS Detector Systems





Reminder:

$\eta=3 \Leftrightarrow \theta \sim 0.1°$

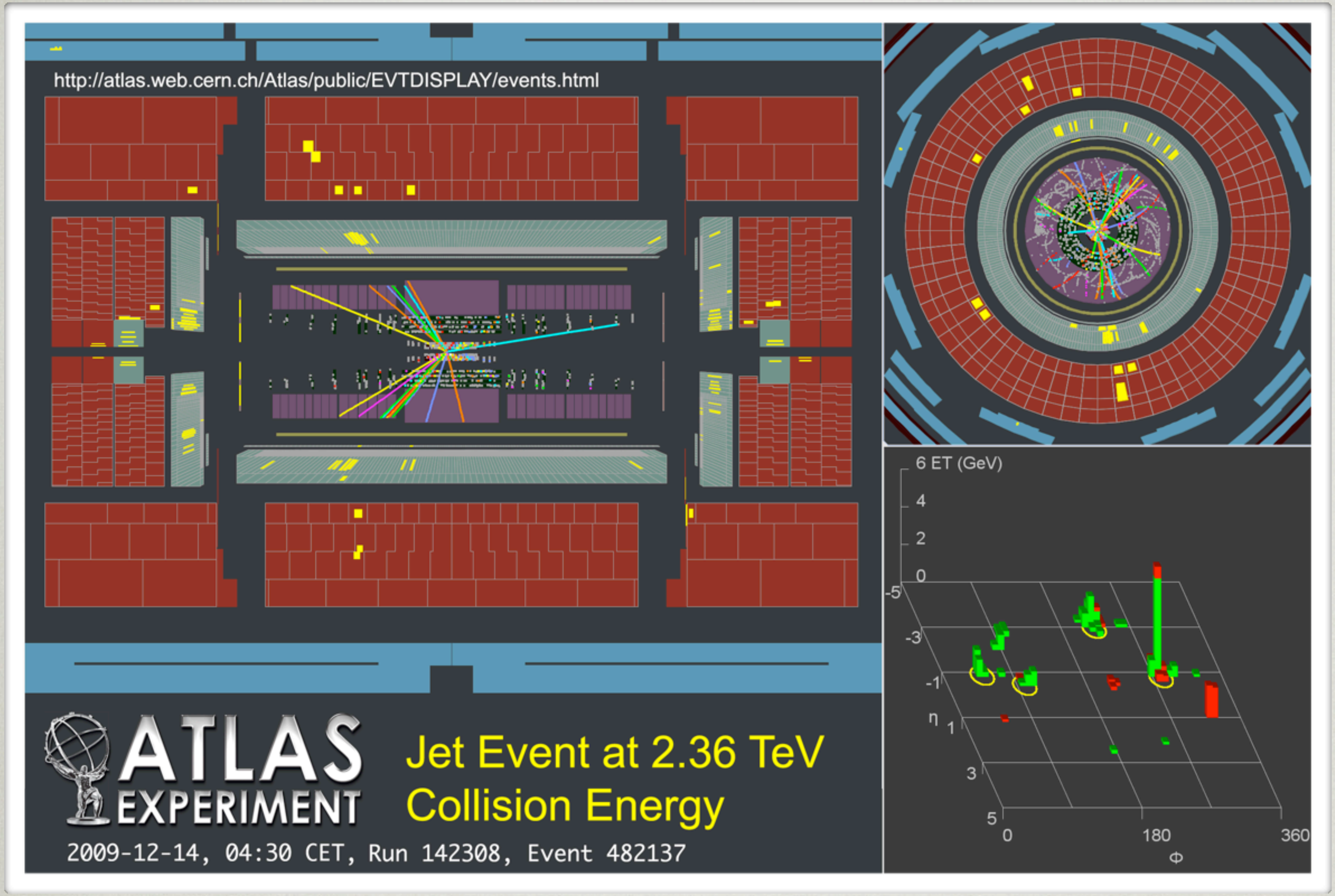
$\eta=5 \Leftrightarrow \theta \sim 0.001°$

ATLAS Detector Status

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	98.0%
SCT Silicon Strips	6.3 M	99.3%
TRT Transition Radiation Tracker	350 k	98.2%
LAr EM Calorimeter	170 k	98.8%
Tile calorimeter	9800	99.5%
Hadronic endcap LAr calorimeter	5600	99.9%
Forward LAr calorimeter	3500	100%
MDT Muon Drift Tubes	350 k	99.7%
CSC Cathode Strip Chambers	31 k	98.4%
RPC Barrel Muon Trigger	370 k	>97%
TGC Endcap Muon Trigger	320 k	99.8%
LVL1 Calo trigger	7160	99.8%

Operational fraction as of 28 September 2009

ATLAS:
CHANNEL COUNT, READINESS



A jet event in ATLAS from this week!

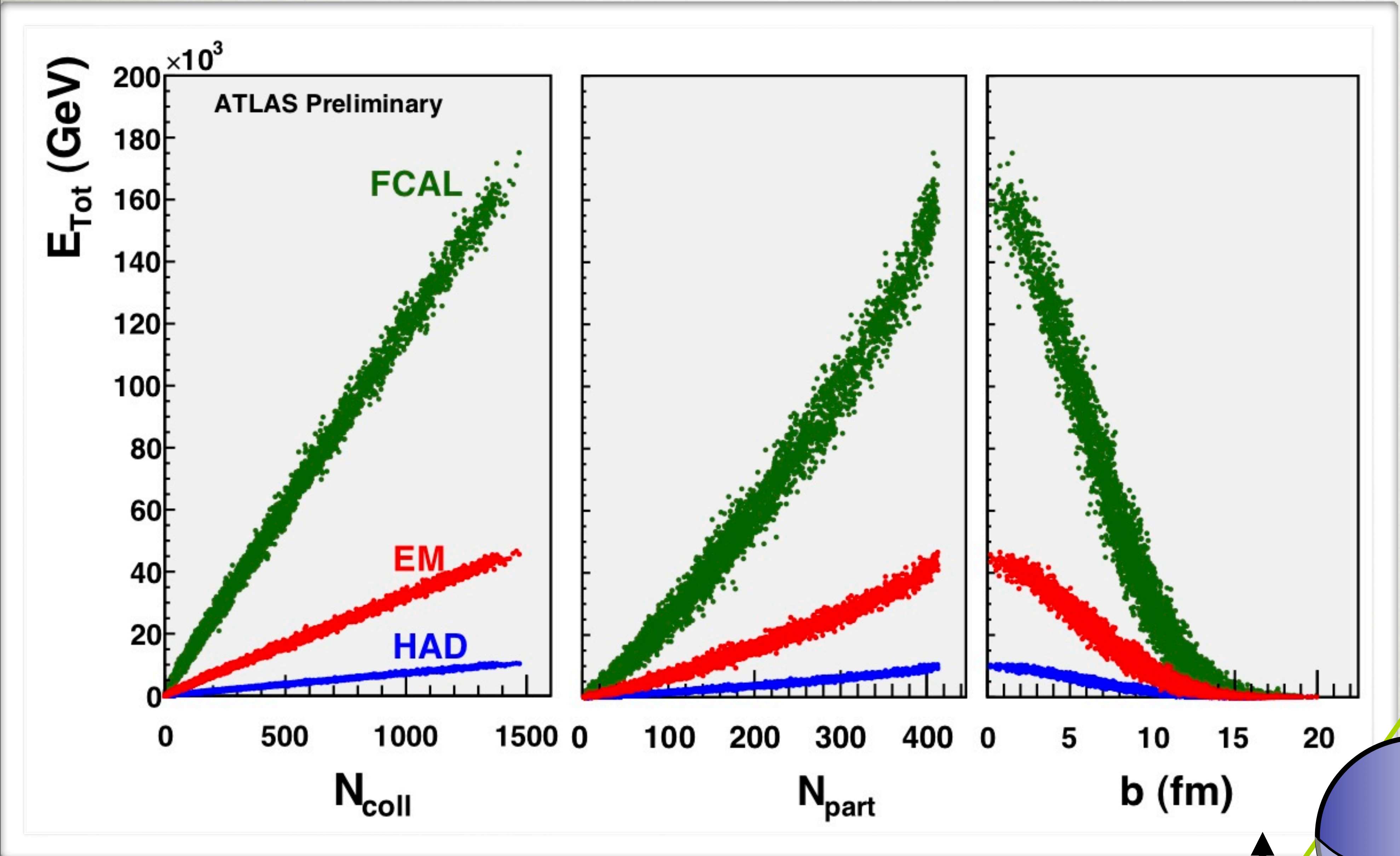
The ATLAS Heavy-ion Program

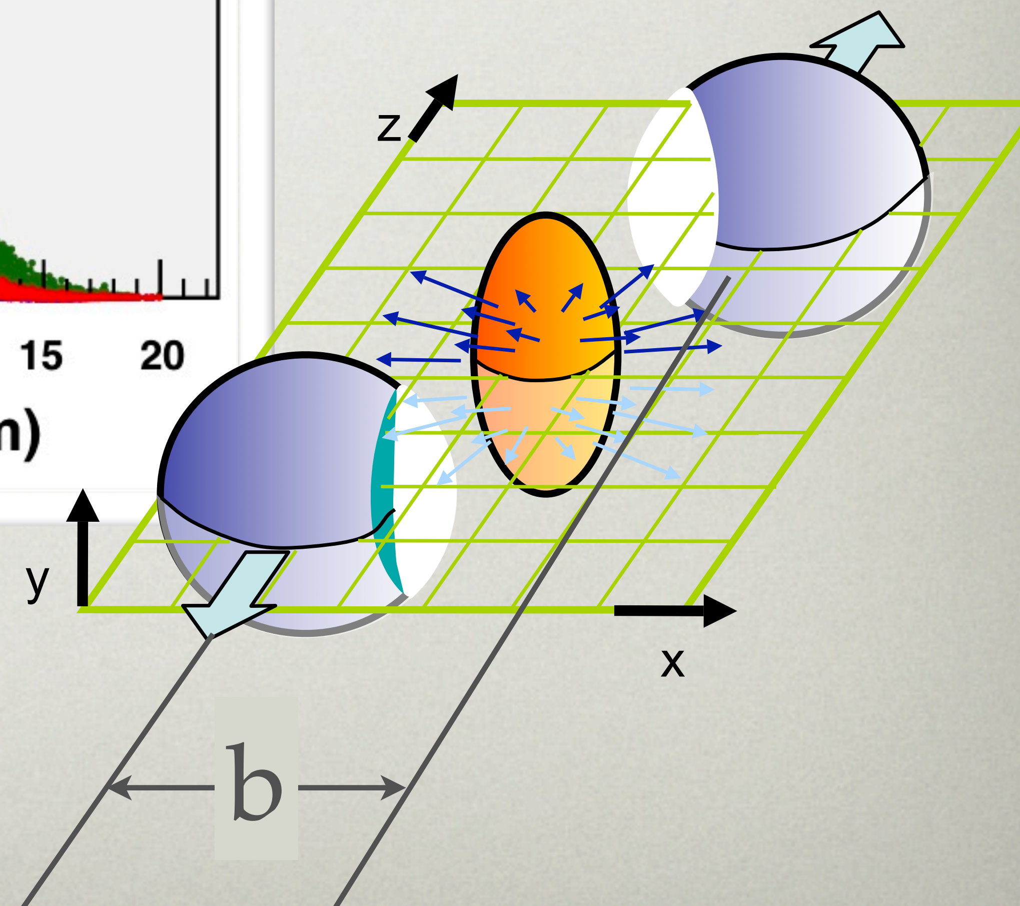
First Year´s Pb-Pb Collision Data

- Baseline measurements for 2010 HI run:
  - RHIC data at E_{CM} = 200 GeV
  - ATLAS p-p data (E_{CM} = 7 TeV➛➛ 14 TeV)
- For HI, E_{CM} = 2.75 TeV➛➛ 5.5 TeV (per nucleon)
- Factor of up to 30 increase in energy means basic features are unknown; focus on:
  - Global properties of collisions
  - Quarkonia
  - Hard probes

B. Wosiek, Acta Phys. Pol. B 38 (2007) 1047-1056
P. Steinberg, J. Phys. G 35 (2008) 104151

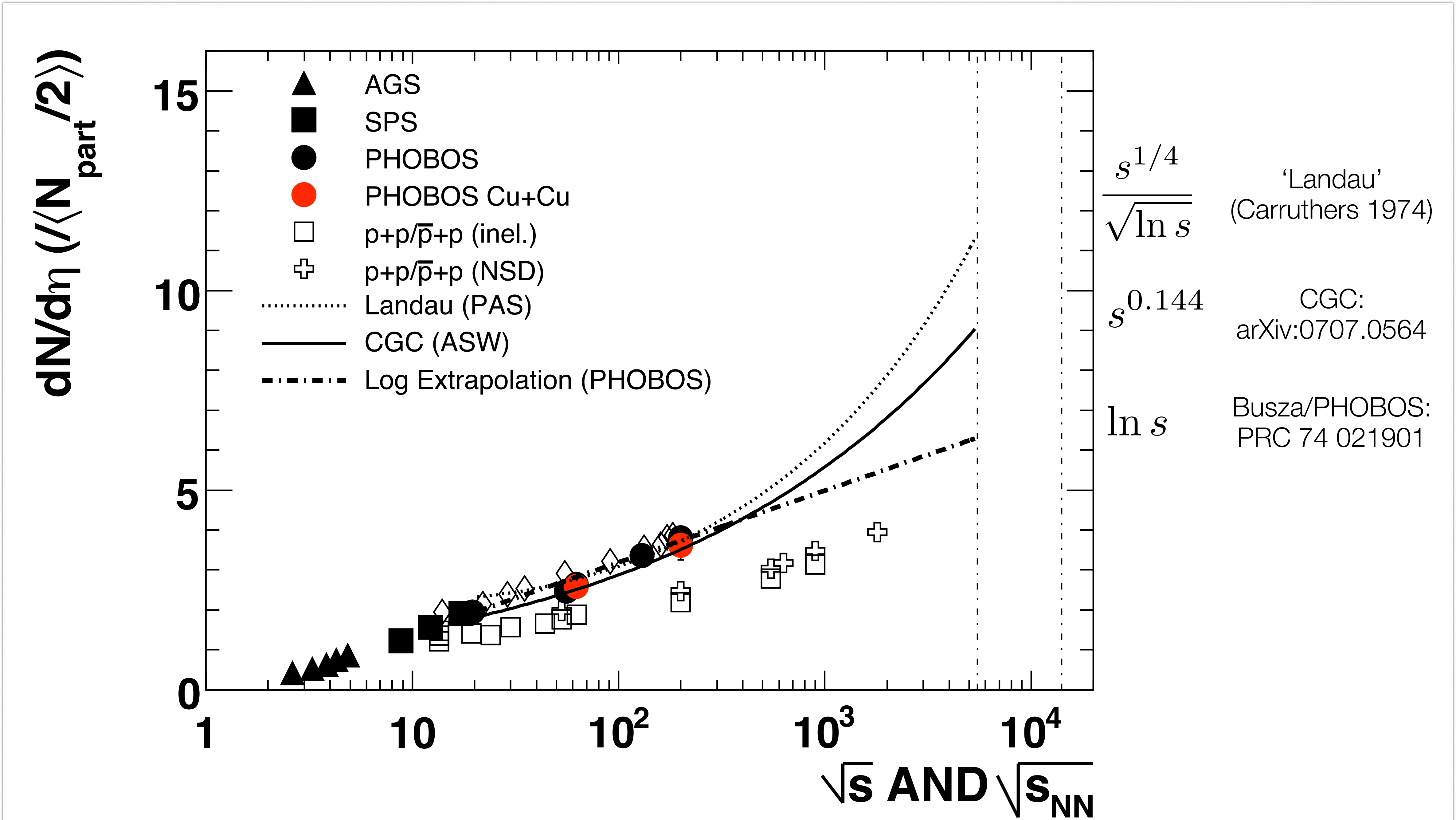
Measurement of impact parameter





Estimate impact parameter, number of collision participants, number of collisions via total energy in calorimeters

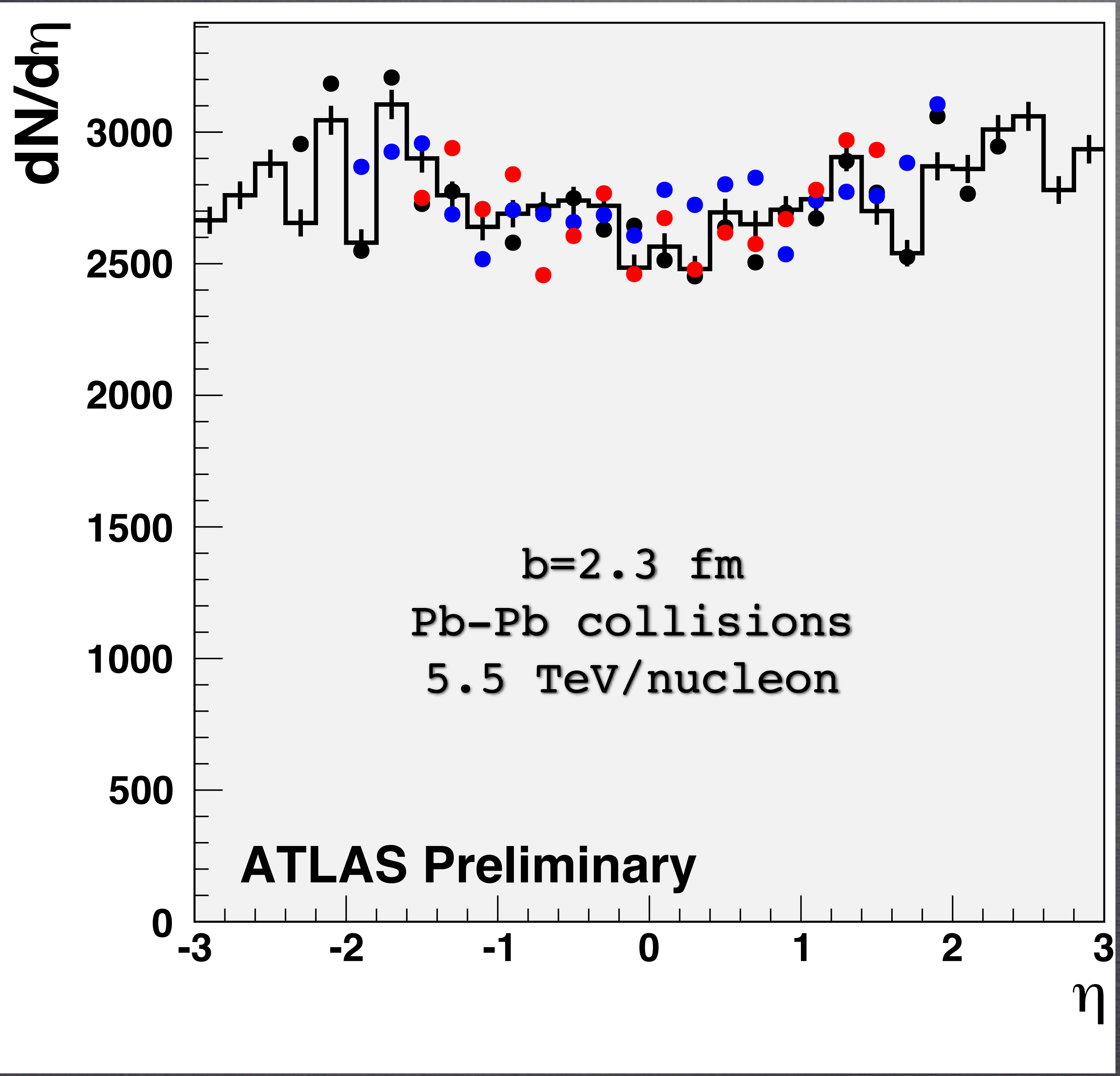
Global Event Properties



Extrapolations of energy dependence of multiplicity

P. Steinberg, Nuclear Physics A 827 (2009) 128c–136c

Global Event Properties



Pixel hits in first, second, and third layers independently determine $dN_{charged}/d\eta$

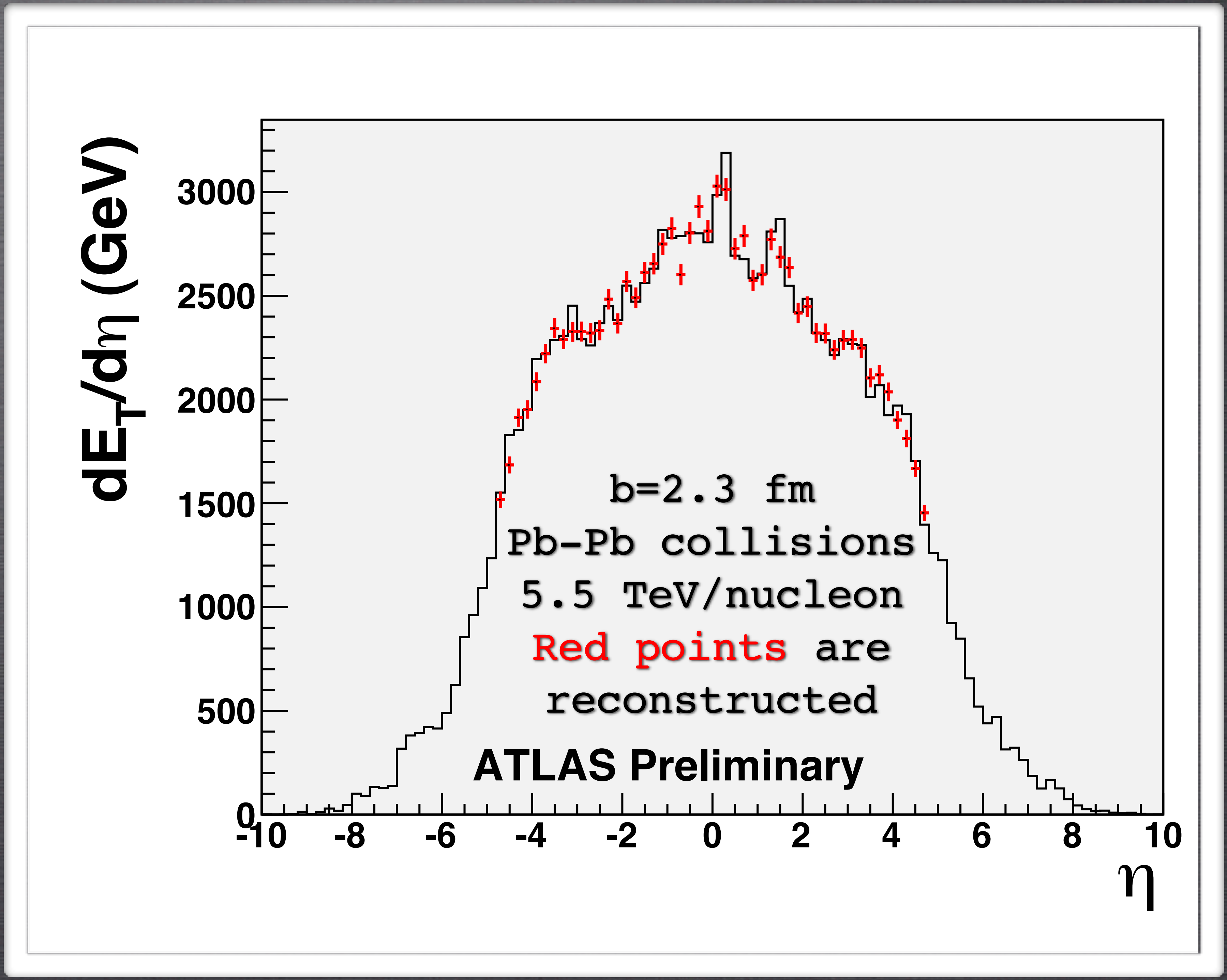
A. Truzpek, ATL-PHYS-PROC-2009-090

multiplicity reconstruction from pixel cluster for a single HIJING event

Global Event Properties

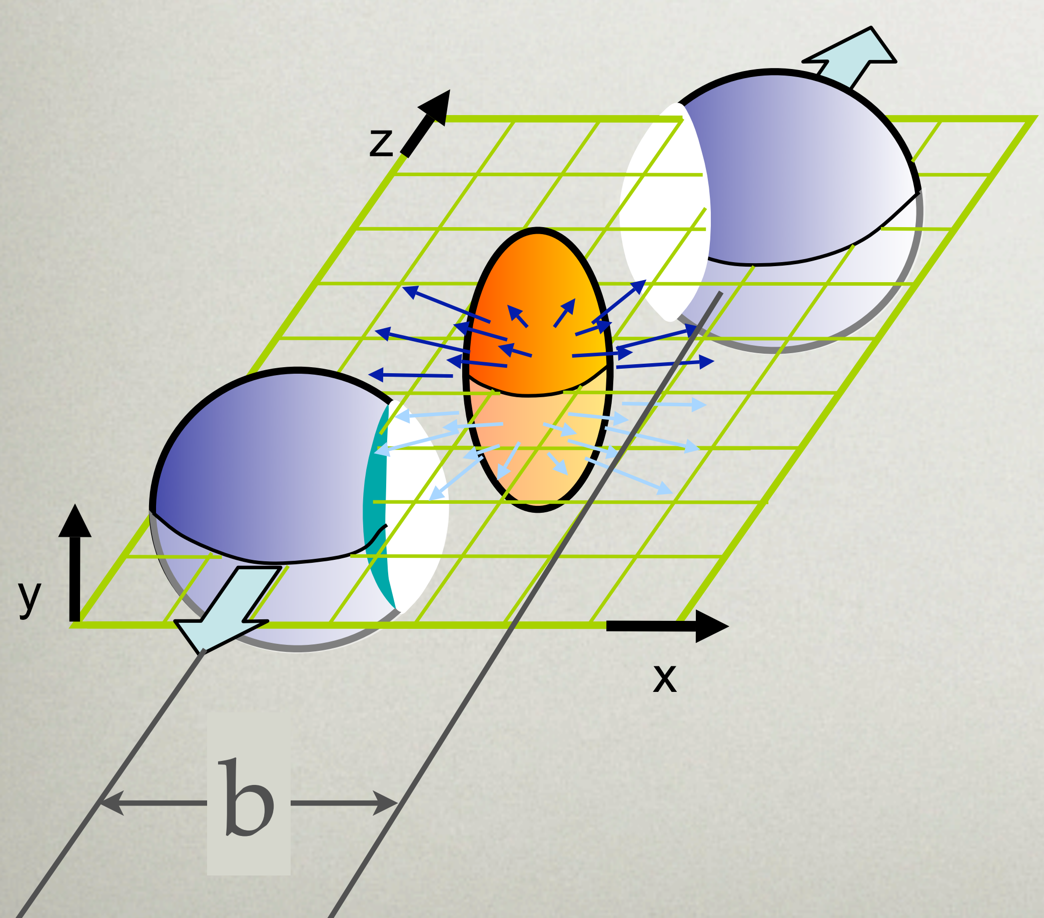
Sum over EM and hadronic calorimeter cells

Good event-by-event measure of E_T

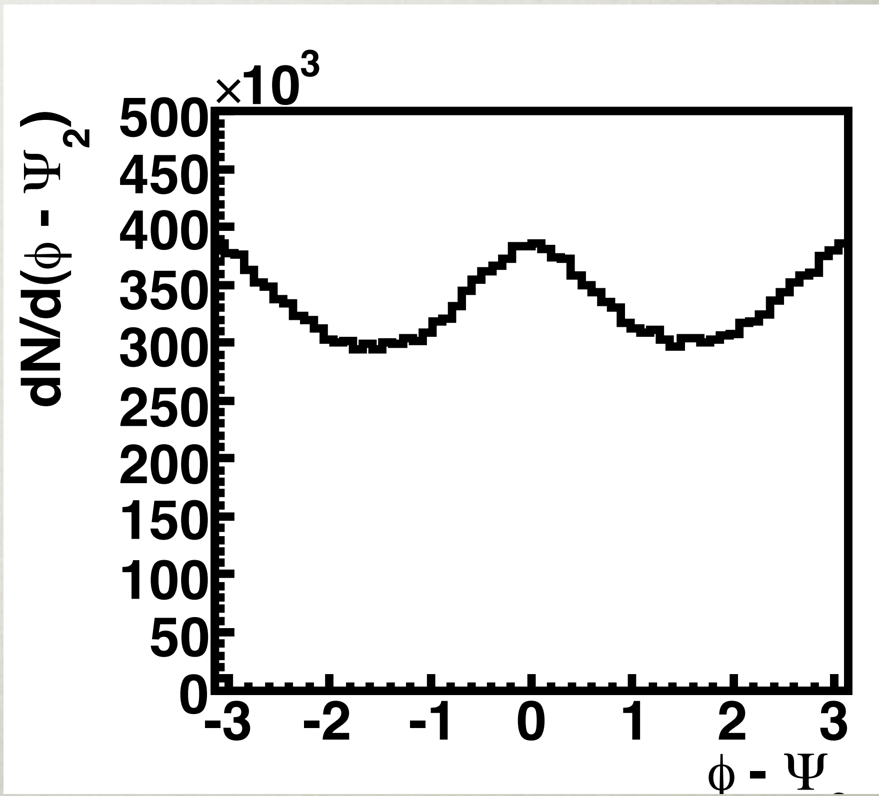


Single event reconstruction of Transverse energy vs pseudorapidity

Elliptic Flow



Asymmetry of particle emission relative to the event plane



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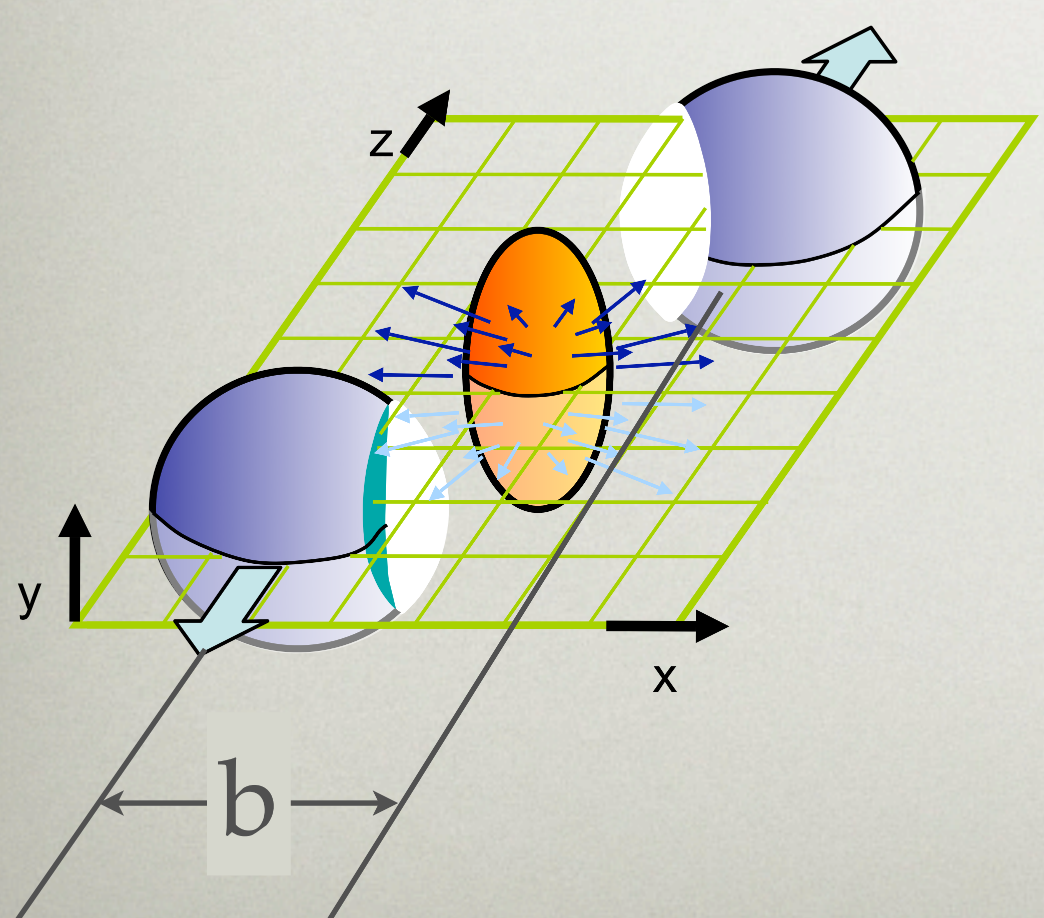

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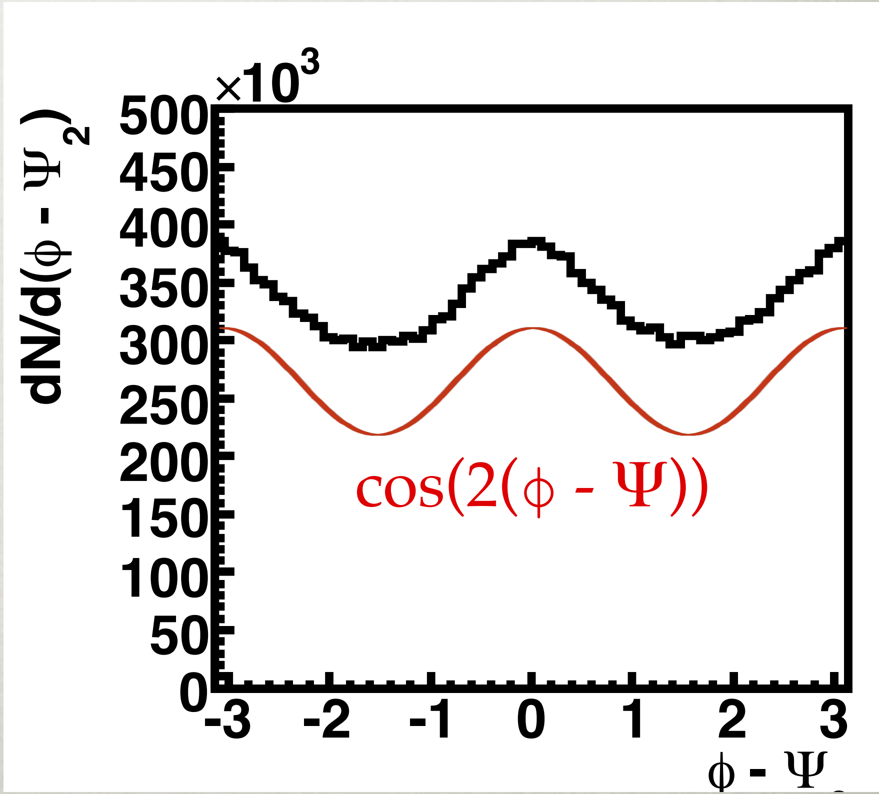

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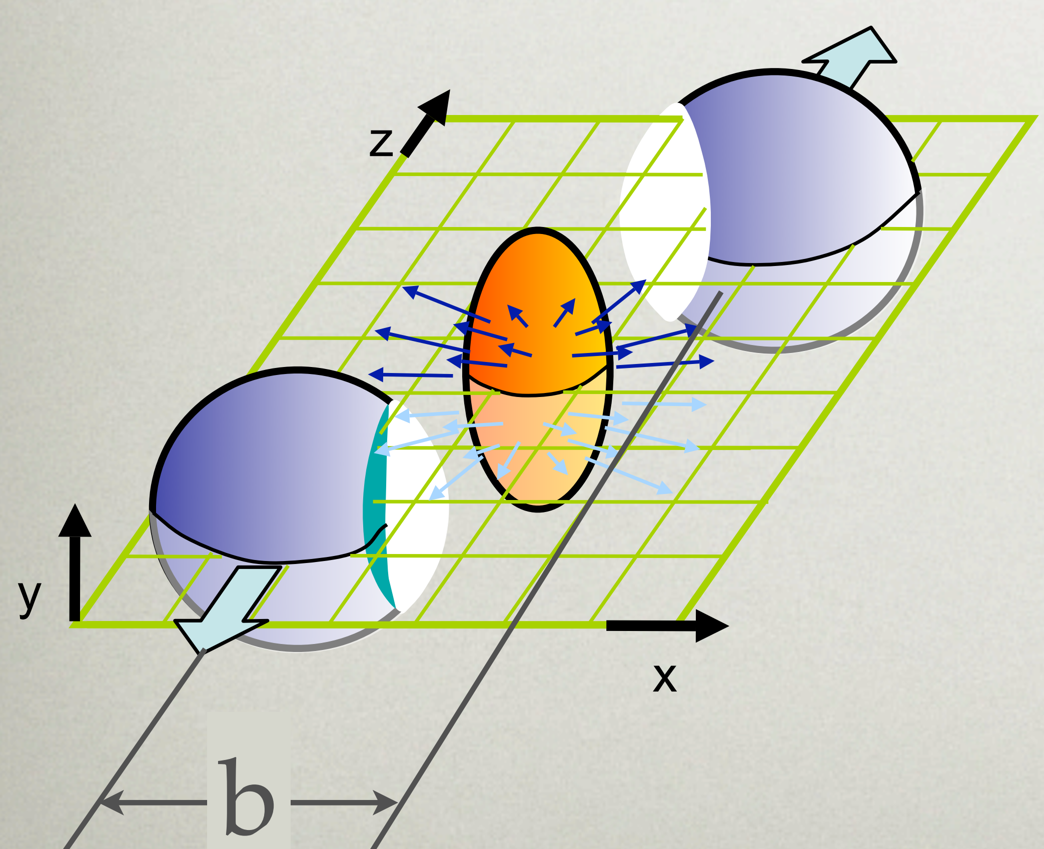

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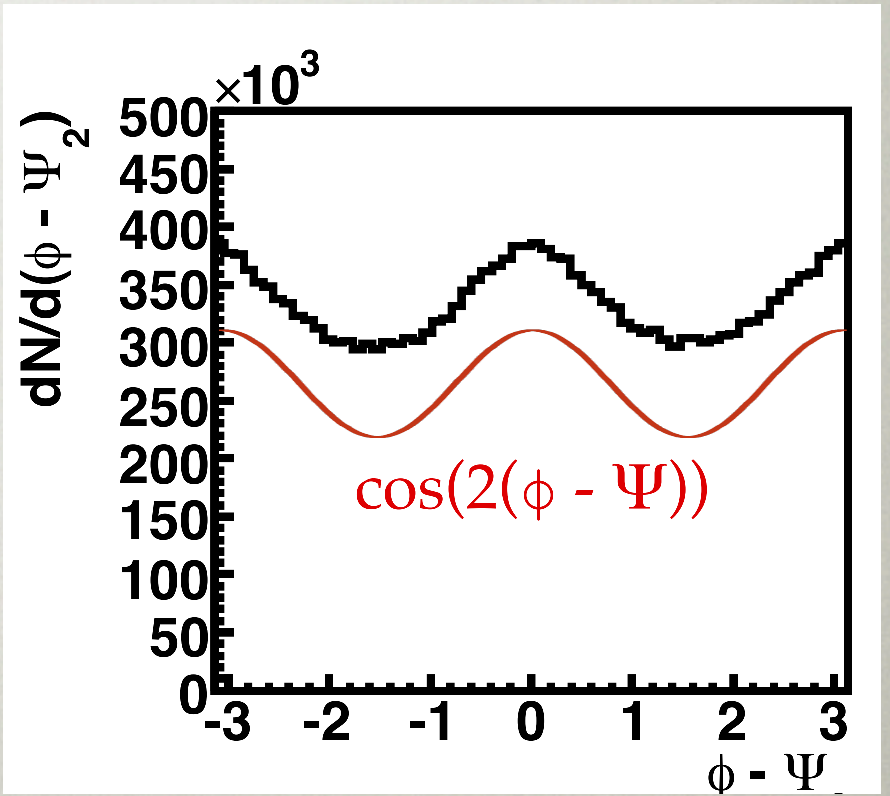
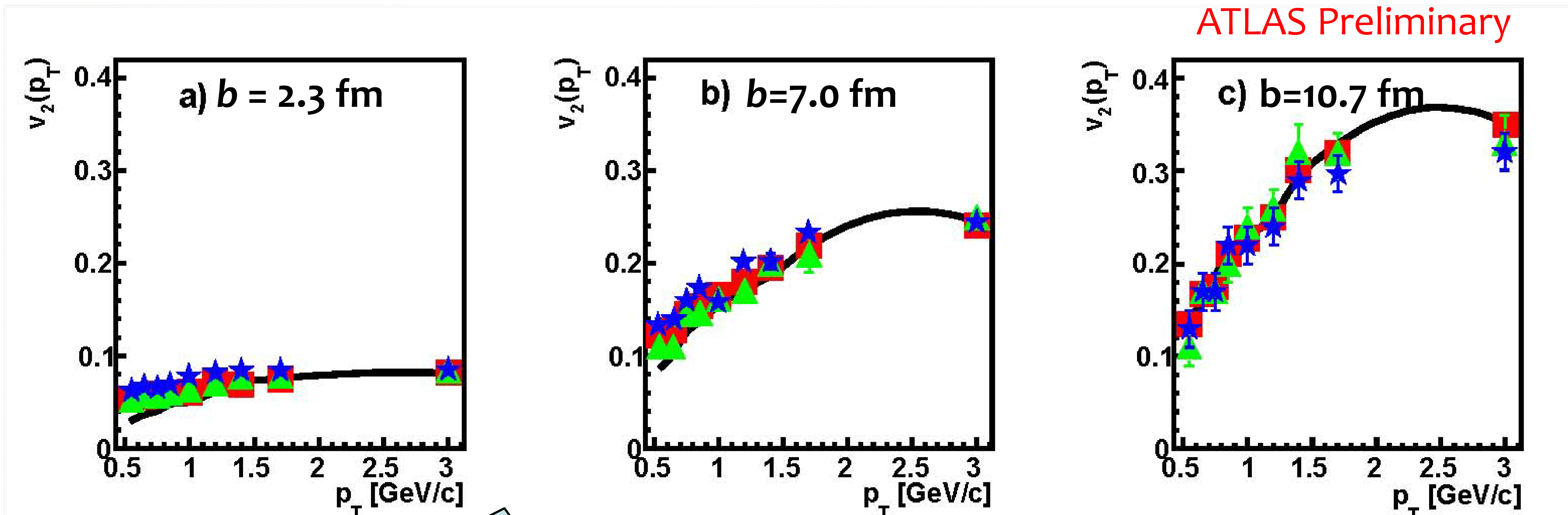
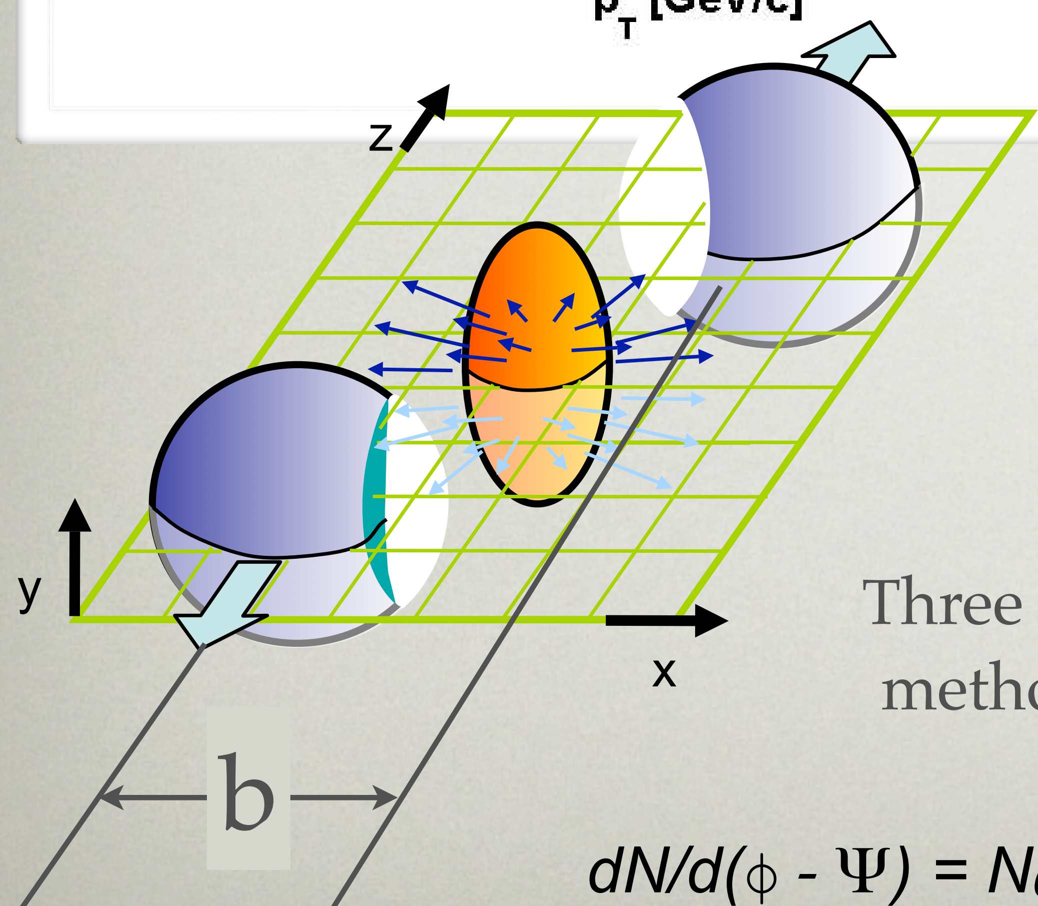


$$dN/d(\phi - \Psi) = N_0\,(1 + 2v_1 \cos(\phi - \Psi) + 2\mathbf{v_2} \cos(2(\phi - \Psi)) + \ldots)$$

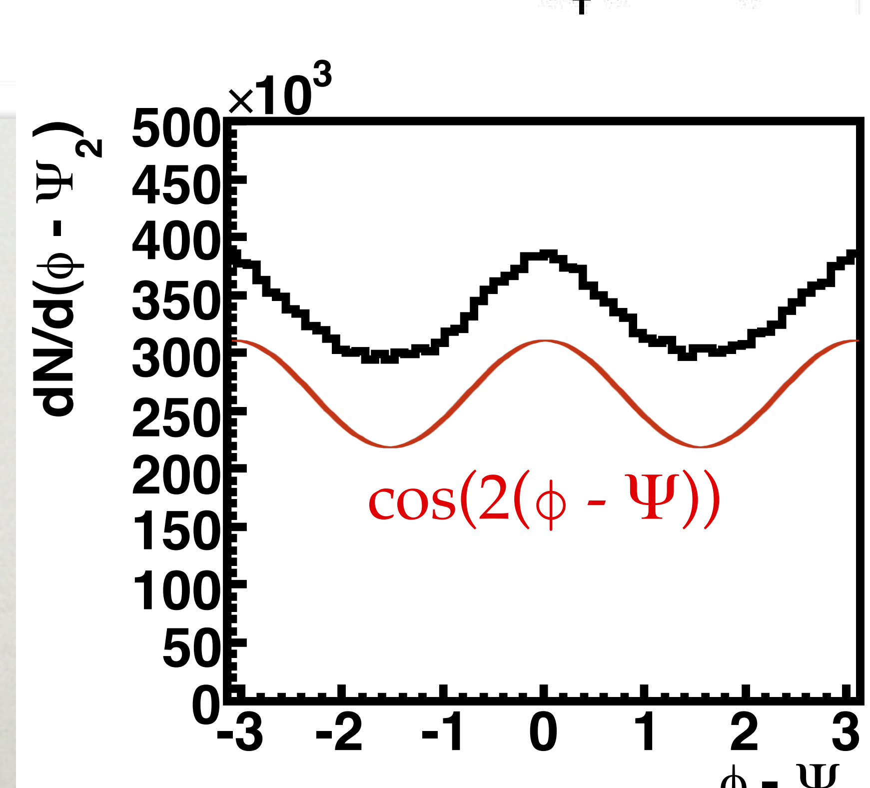
Elliptic Flow





Asymmetry of particle emission relative to the event plane

Three separate reconstruction methods give similar results



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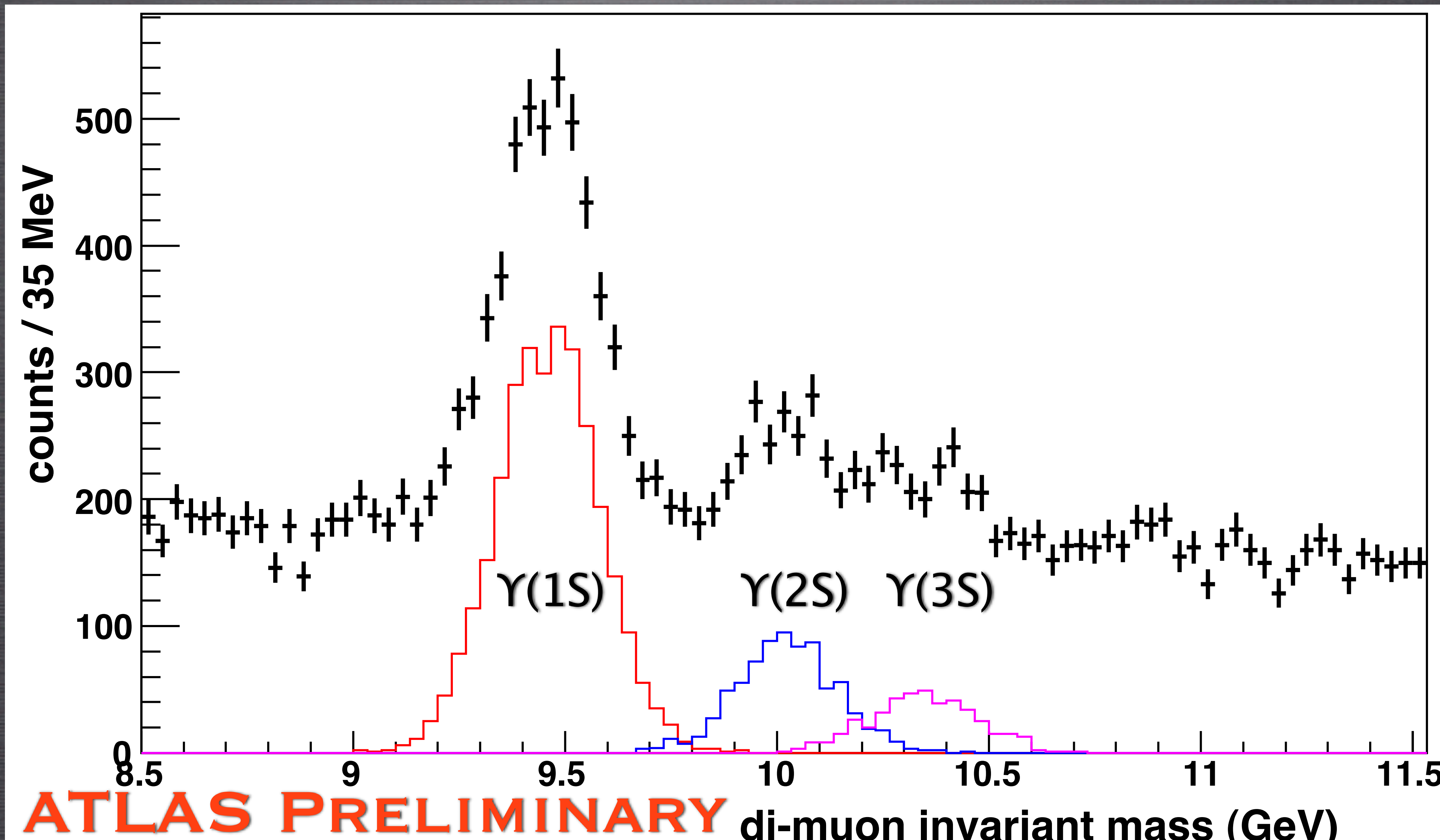
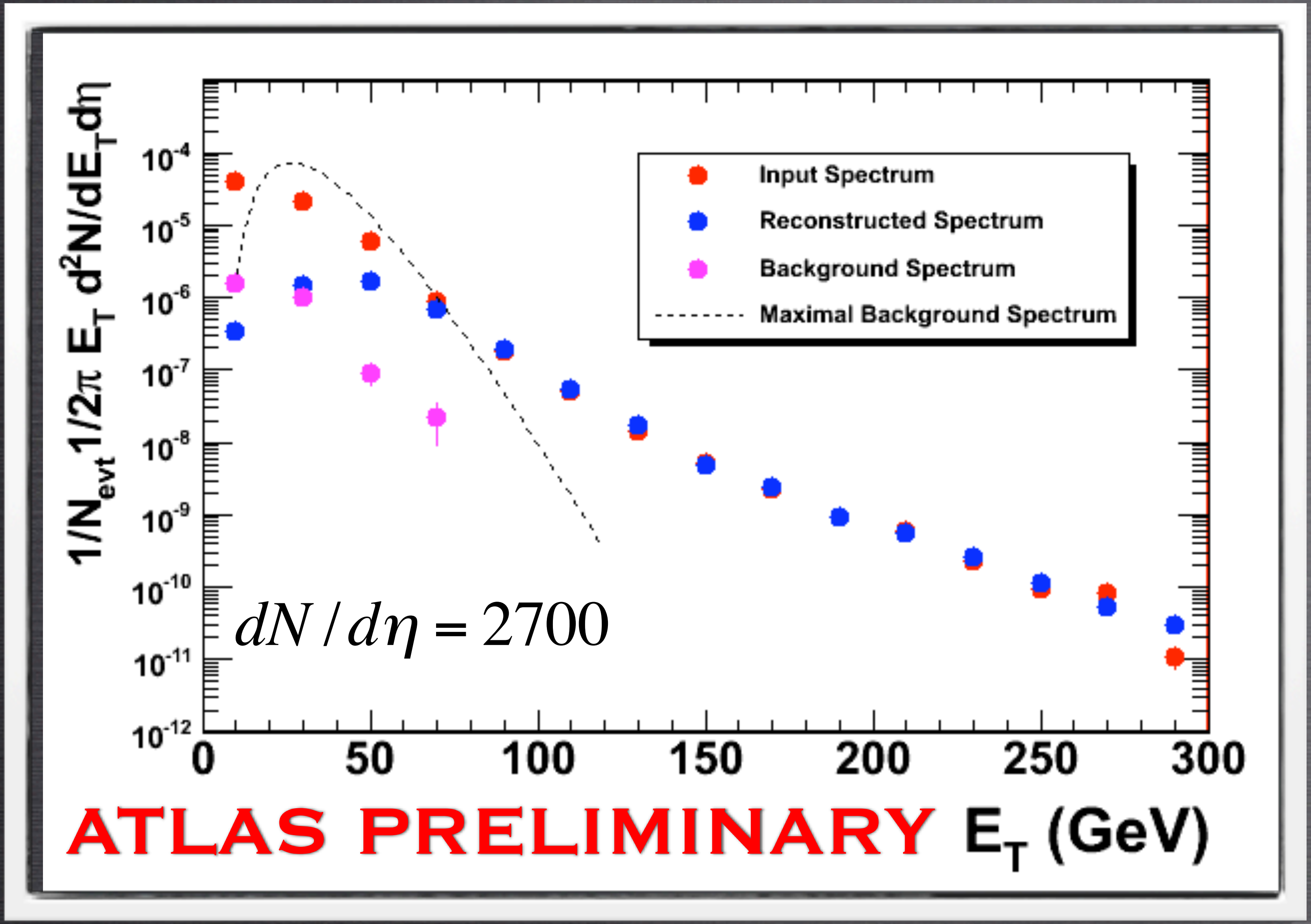
Heavy Quarkonia - $c\bar{c}$, $b\bar{b}$



Test predictions that different quarkonium states disassociate at different plasma temperatures

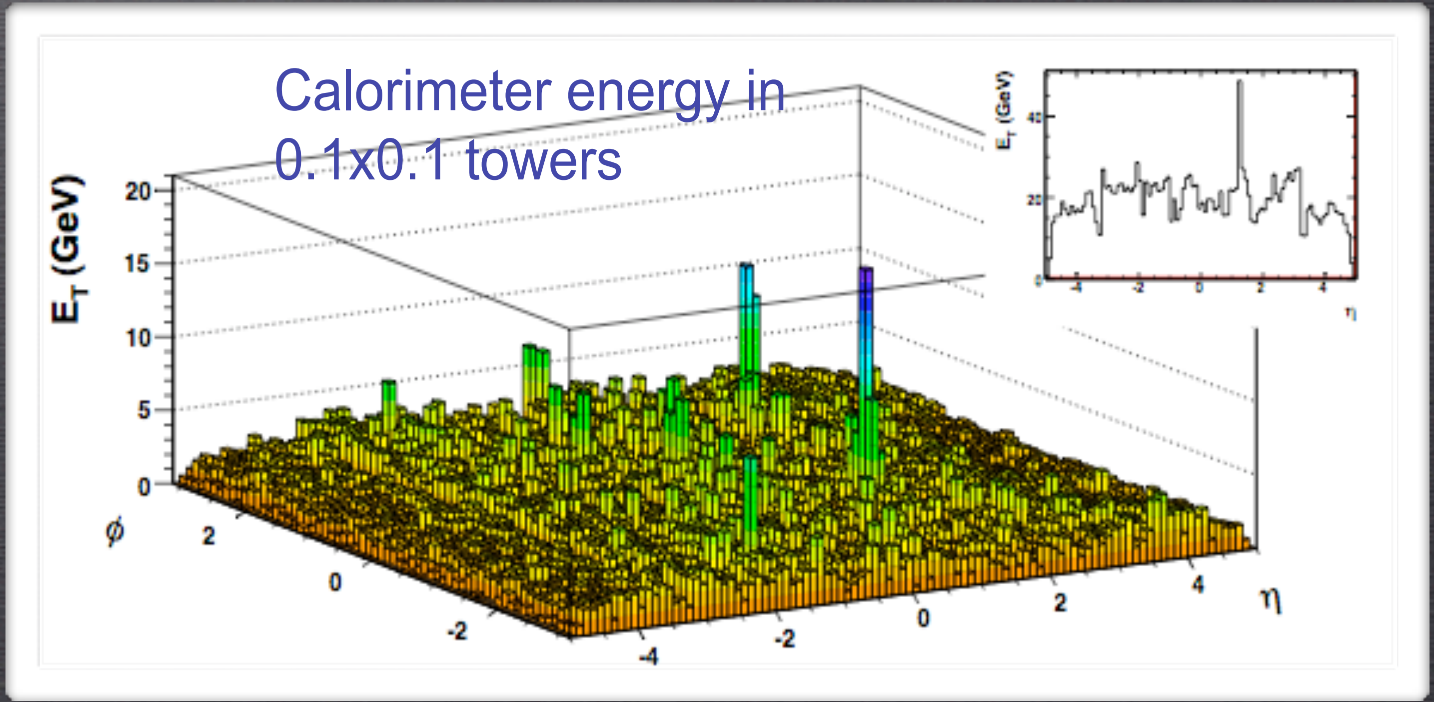
good rate, good mass resolution - can study color screening through Upsilon and J/Ψ suppression

J. Dolejší, Nucl. Phys, A 830 (2009) 89c

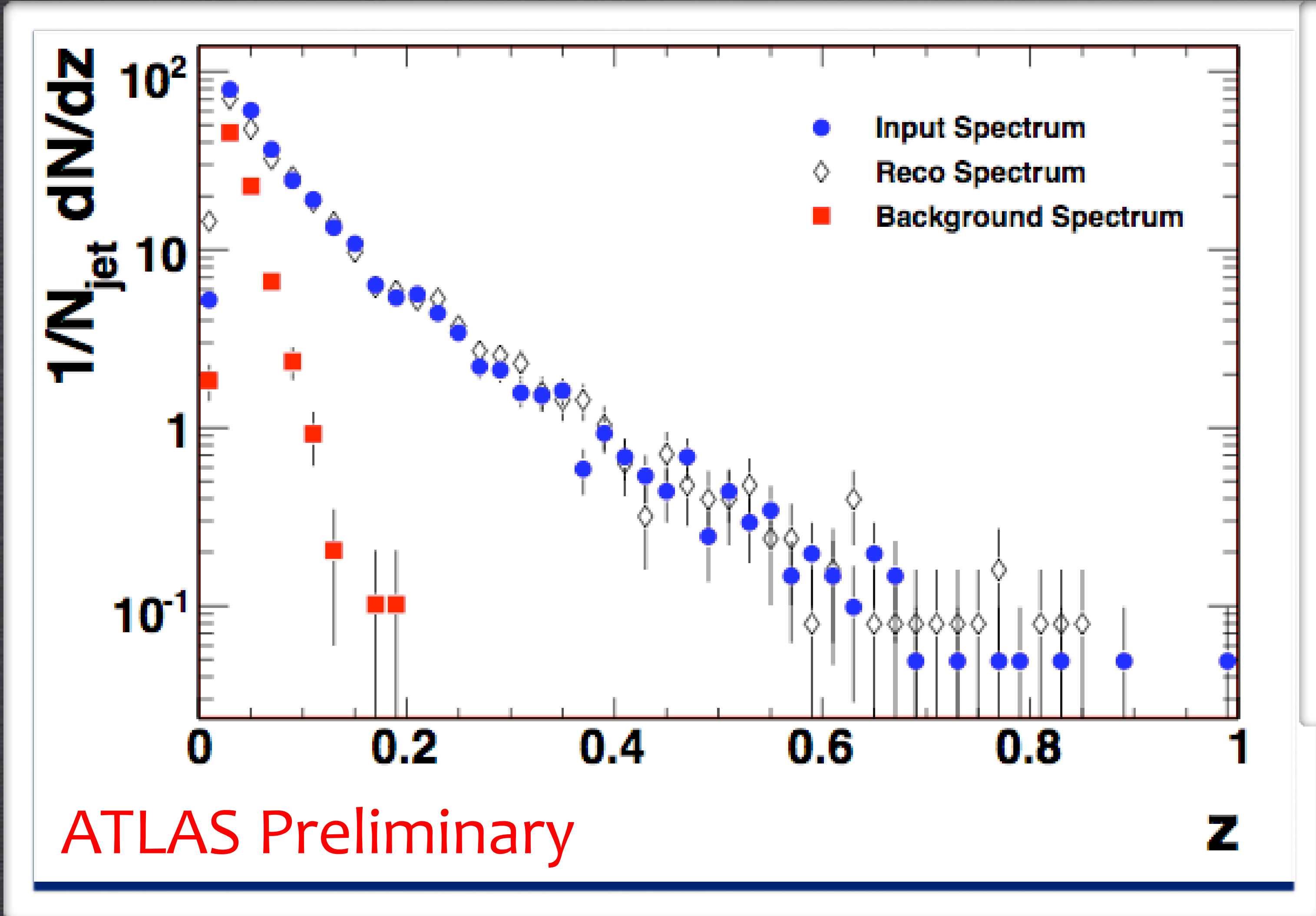


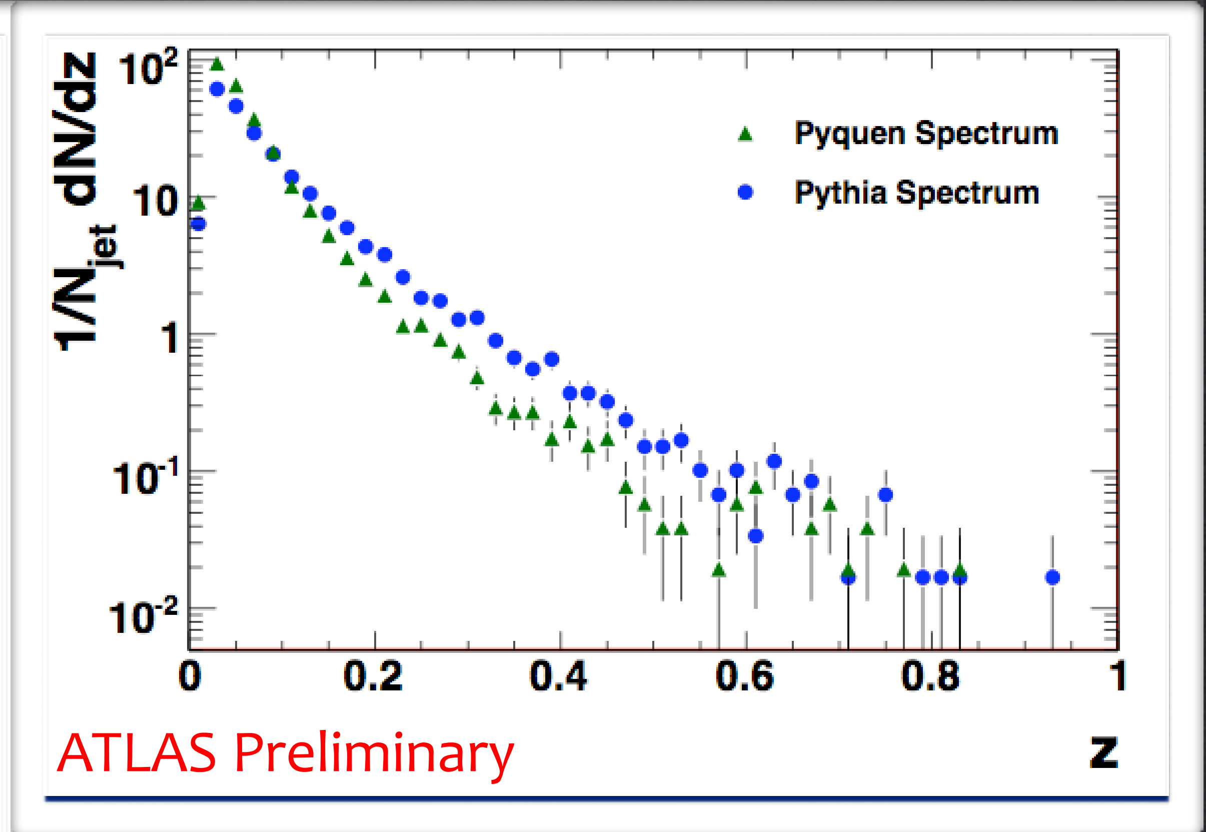
METHOD REQUIRES SUBTRACTION OF BACKGROUND FROM UNDERLYING HEAVY ION EVENT

INCLUSIVE JET RECONSTRUCTION



M. Spousta, ATL-PHYS-PROC-2009-002.pdf



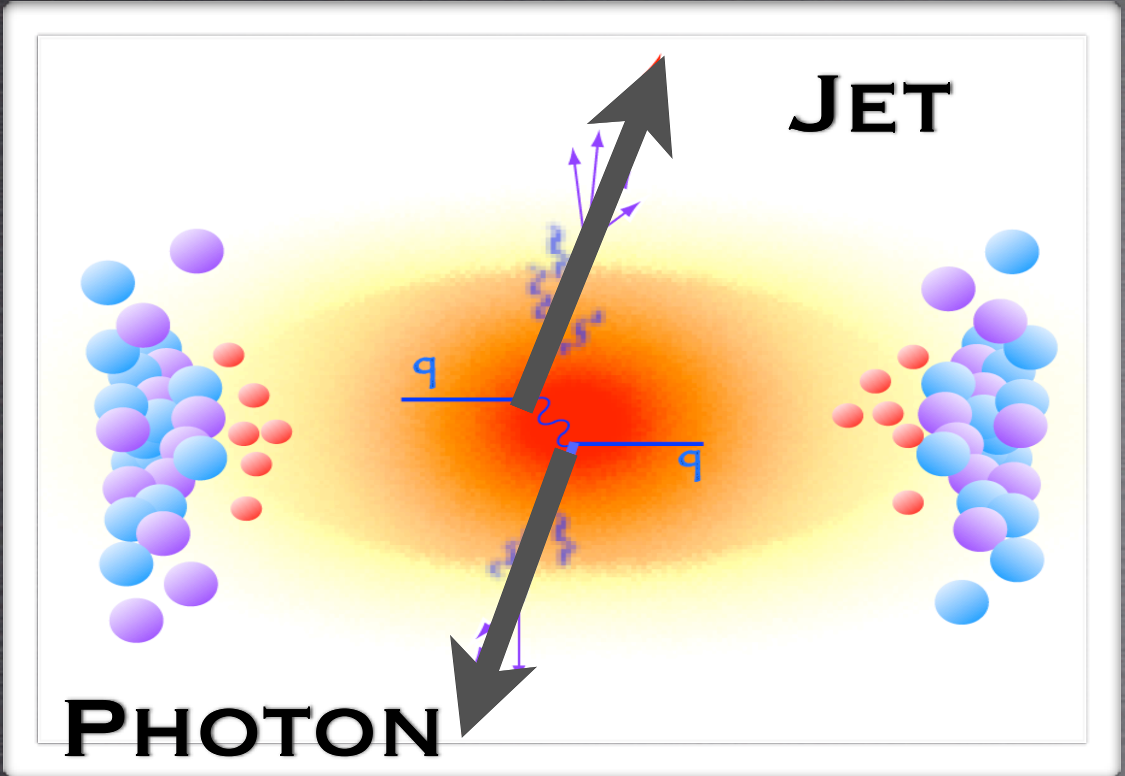


Jet Fragmentation

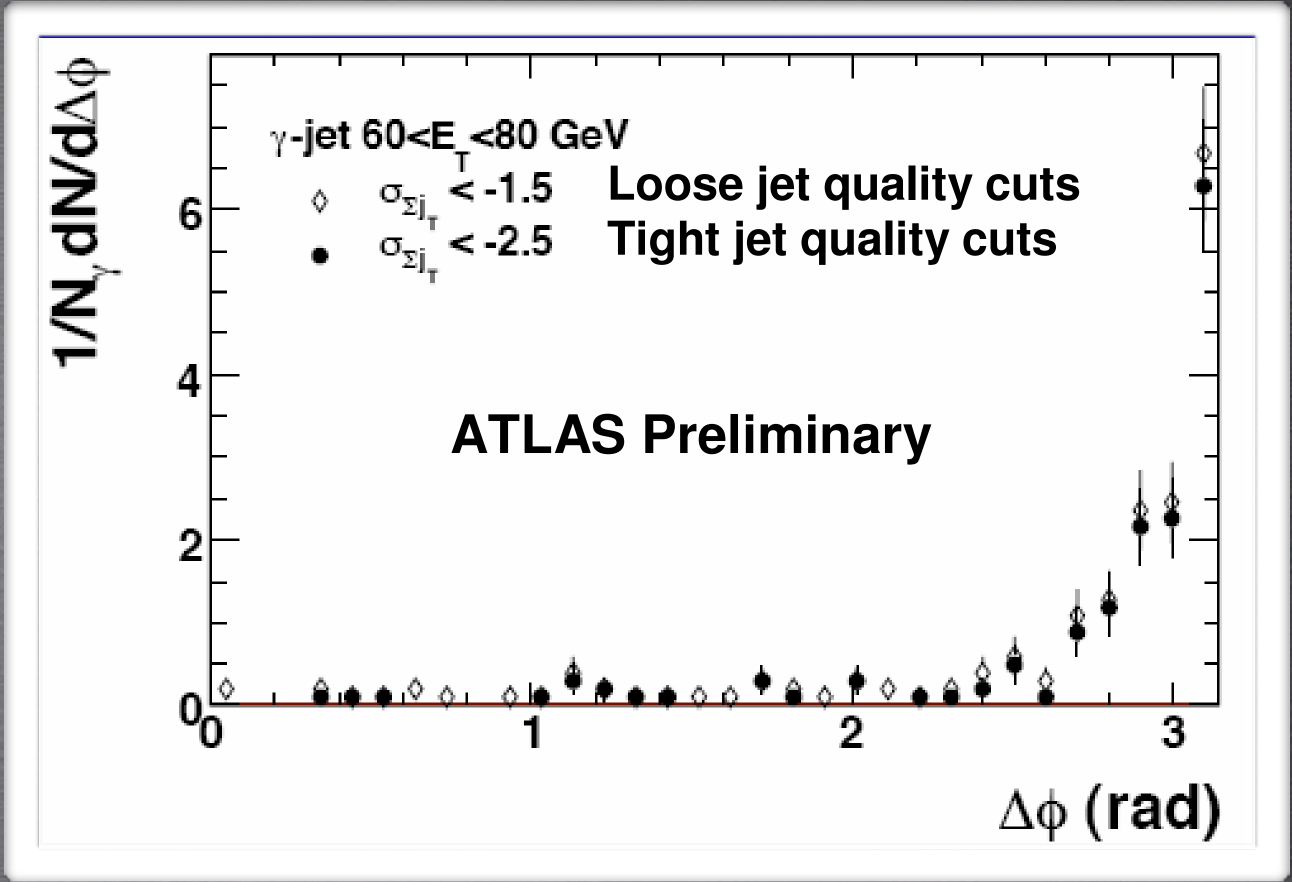
Feasible to extract accurate fragmentation functions

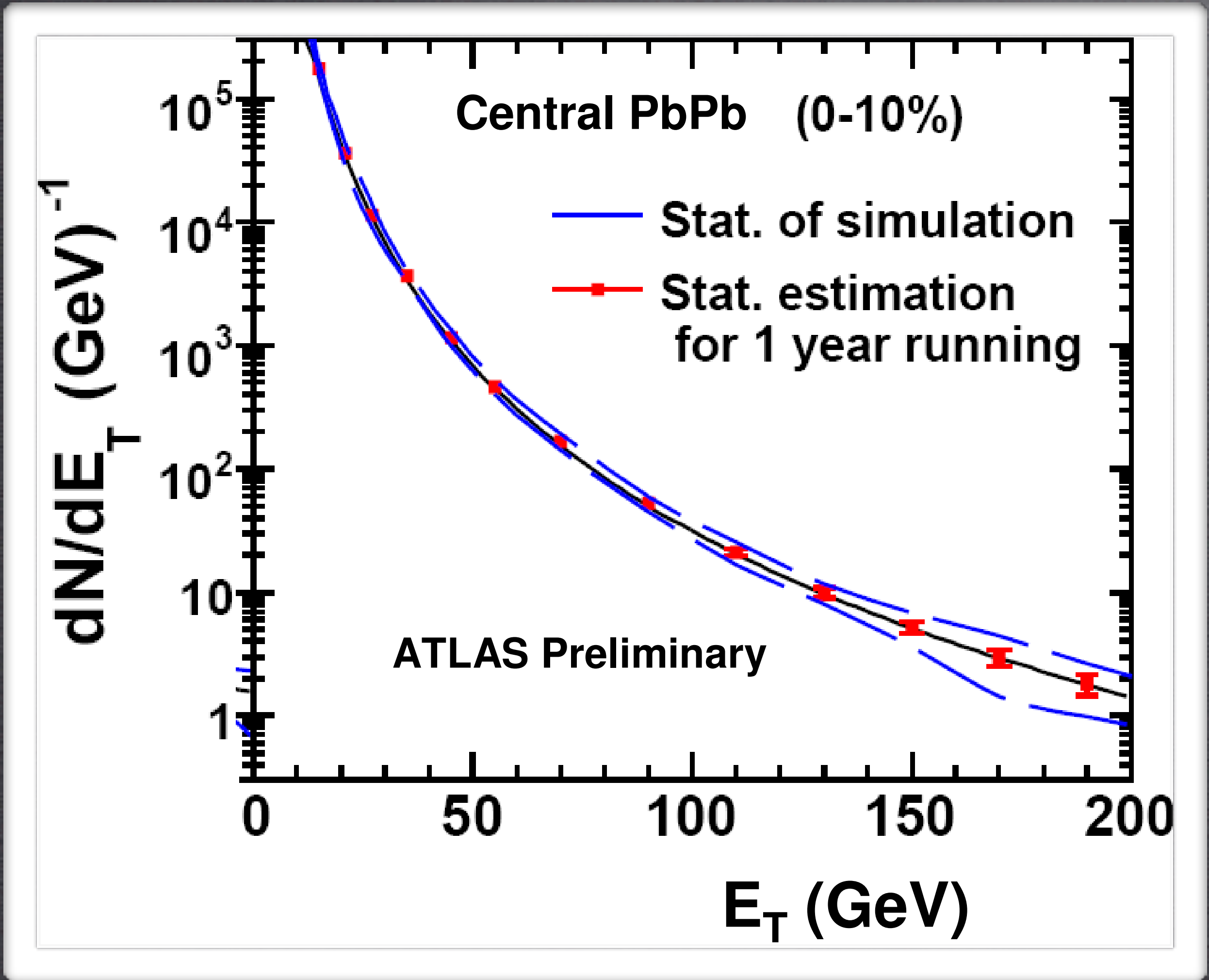
Can extract jet quenching if it is of the size given by Pyquen

M. Spousta, ATL-PHYS-PROC-2009-002.pdf
N. Grau, ATL-PHYS-PROC-2009-046.pdf



Photon is ~unaffected by the medium





Direct photons, Gamma-Jet Correlations

The excellent ATLAS calorimetry permits good neutral hadron rejection

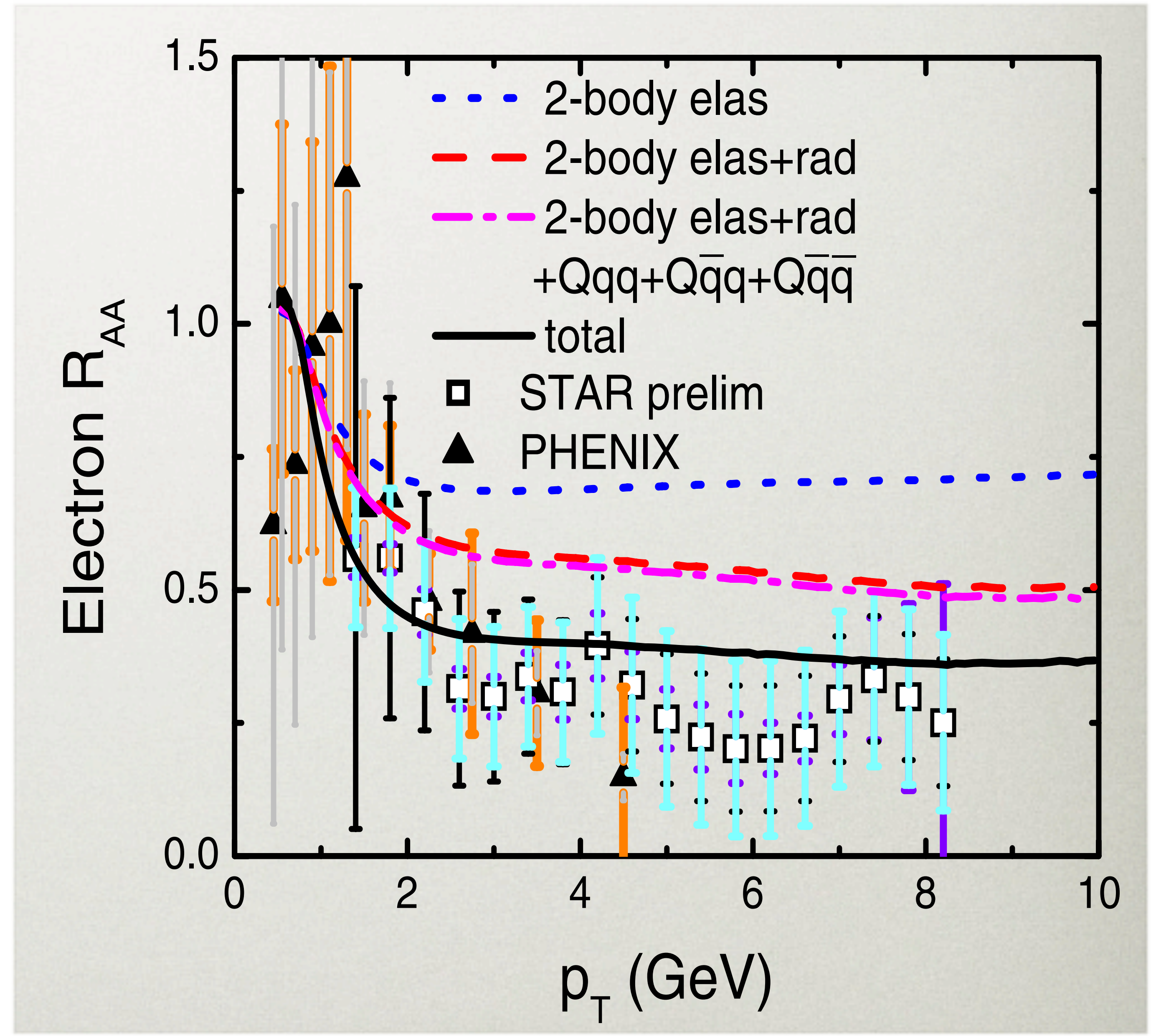
Clean γ-jet signal ideal for jet suppression studies

M. Baker, Nucl. Phys. A830:499c-502c, 2009

Heavy Quark Jet Suppression

$$R_{AA} = \frac{1}{N_{coll}} \frac{\frac{dN}{dp_T}|_{AA}}{\frac{dN}{dp_T}|_{pp}}$$

- Naive radiative energy loss picture predicts minimal suppression of heavy quarks
- Radiation and collisional losses in 2 and 3-body interactions provide only partial explanation
- This puzzle can be probed at LHC with much higher p_T, better statistics, and potentially with directly identified heavy mesons



"**KPS**" = B. Z. Kopeliovich, I. K. Potashnikova, I. Schmidt, J. Phys. G35:054001, 2008

Ko and Liu, Nuclear Physics A 783 (2007) 233c–240c

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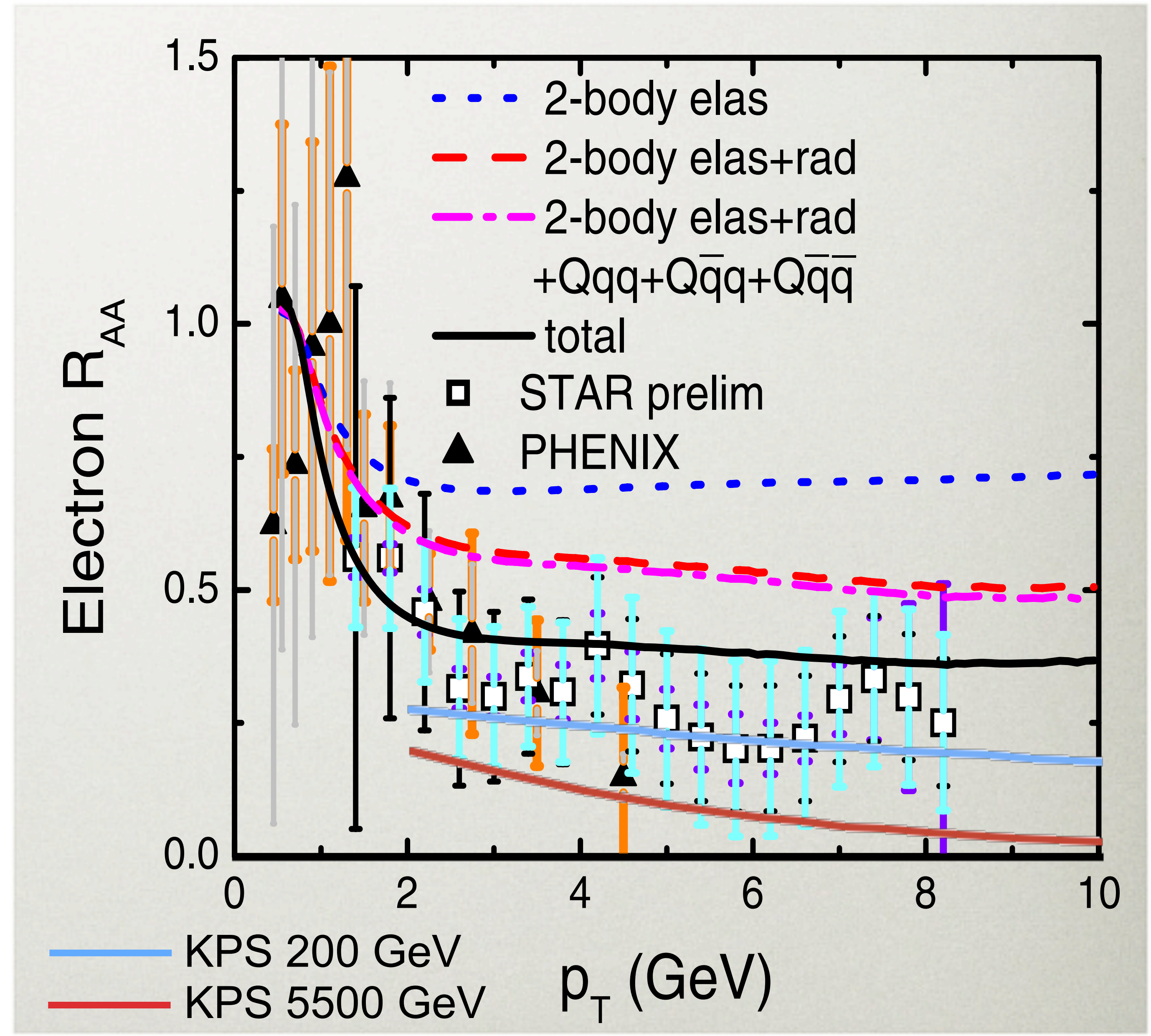

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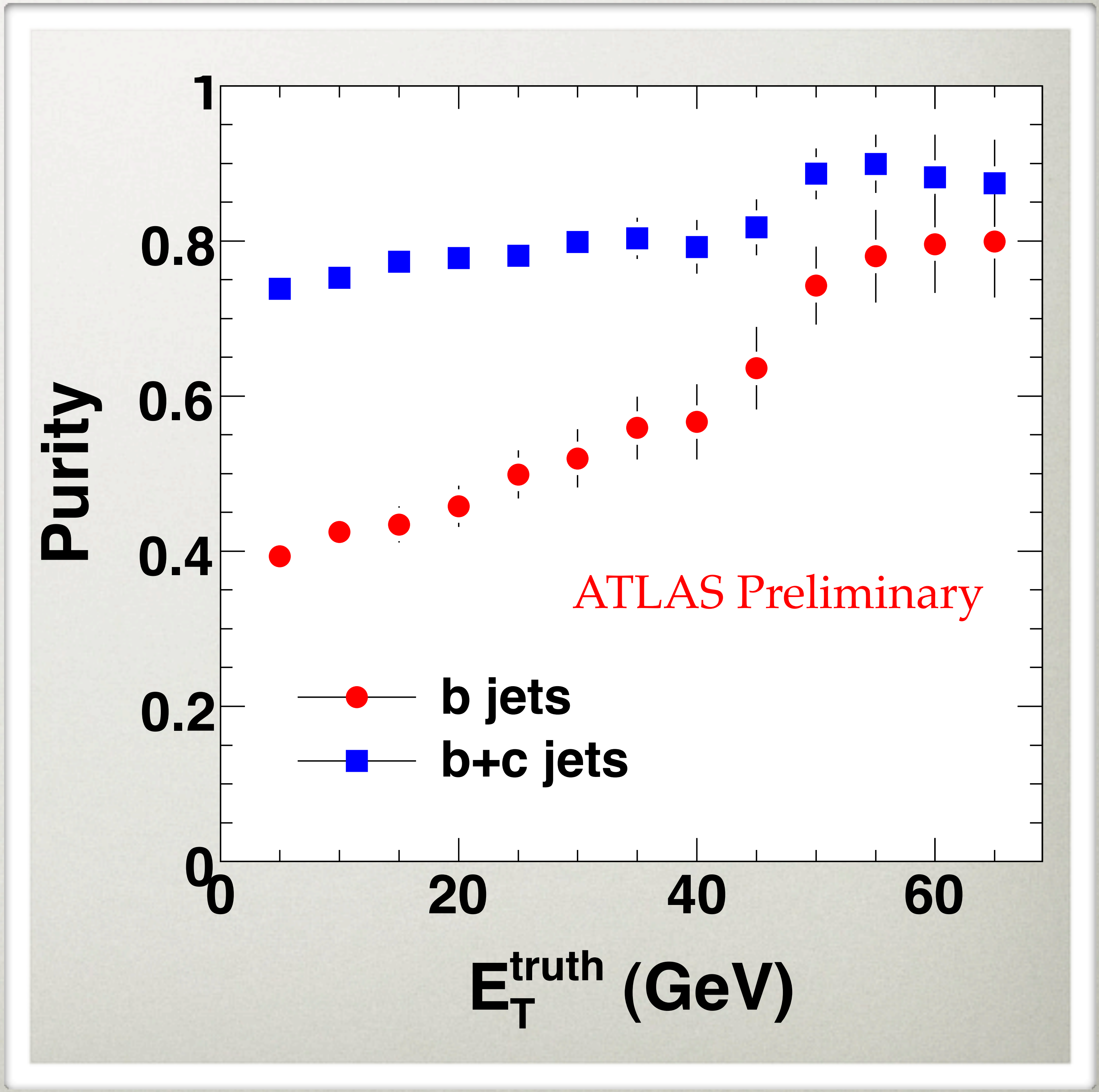
Ko and Liu, Nuclear Physics A 783 (2007) 233c–240c

Heavy Quark Jets via Muon-Tagging in ATLAS

- Semi-leptonic decay of heavy quarks can be tagged by muons
- Clean environment in standalone muon system, trigger by single/double tracks
- High purity for muon E_T above ~50 GeV



Conclusions

- Exciting physics program for heavy ions with ATLAS
- ATLAS instrumentation is ideal for measuring jet quenching
- Methods of global event characterization are understood; ready for first data
- Heavy-quark jet quenching may yield new insights