Physics Capabilities of the ATLAS Experiment in Pb+Pb Collisions at the LHC

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on behalf of ATLAS Collaboration

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Heavy Ion Physics

SPS	RHIC	LHC
Pb+Pb	Au+Au	Pb+Pb
$\sqrt{s_{NN}} = 17.3GeV$	$\sqrt{s_{NN}} = 200GeV$	$\sqrt{s_{NN}} = 5.5TeV$

In HI collisions a new form of matter is formed - Quark Gluon Plasma (QGP)

Observables used in HI program:

ï Global observables (**N_{ch}, E_T, elliptic flow**)

Å Initial state and dynamics of colliding system

Å Test of theoretical models

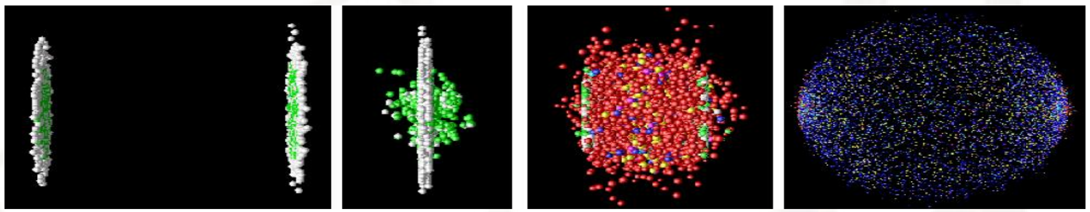
ï Jets & photons

Å Parton energy loss

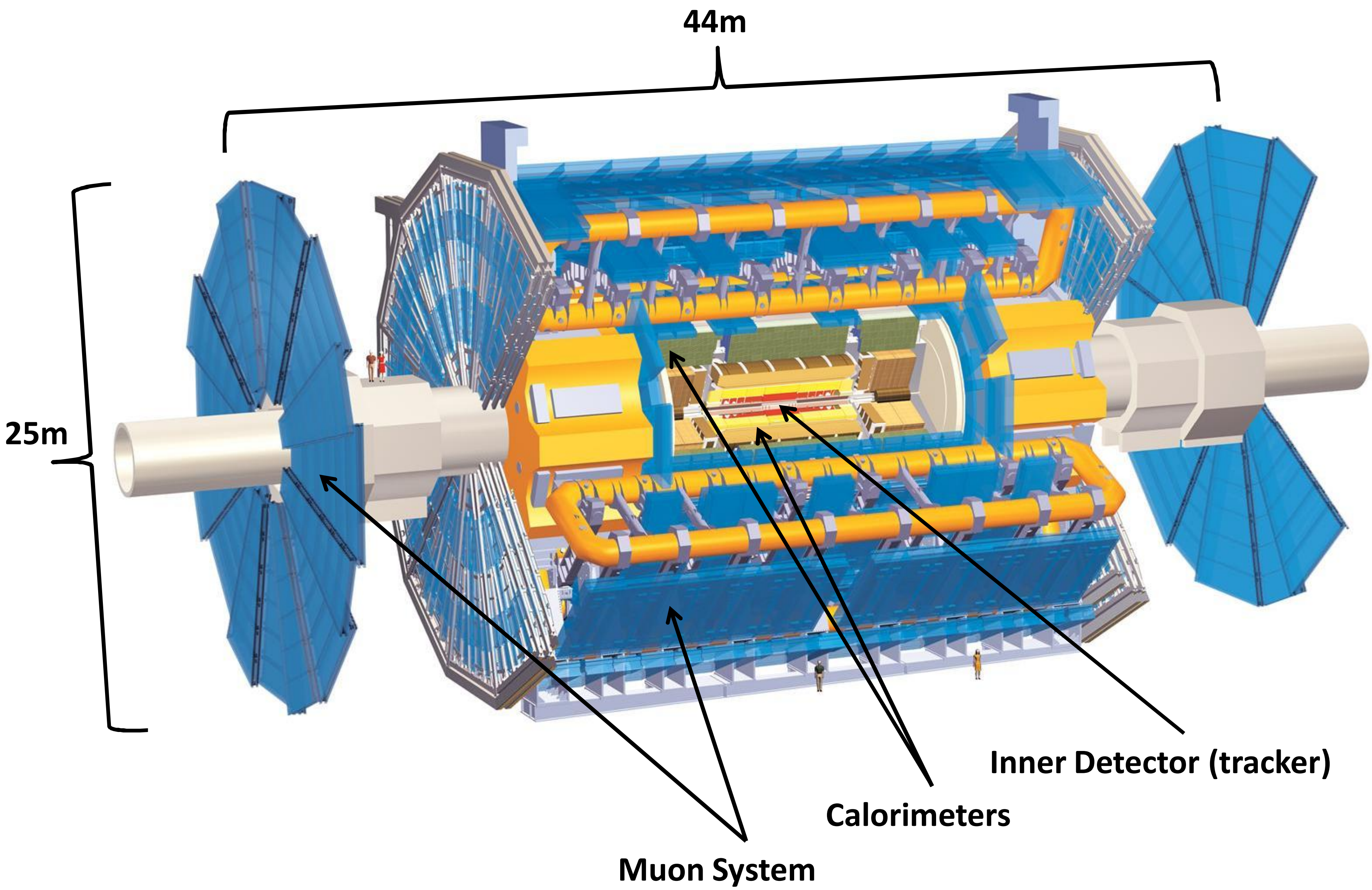
ï Quarkonia suppression

Å Deconfinement

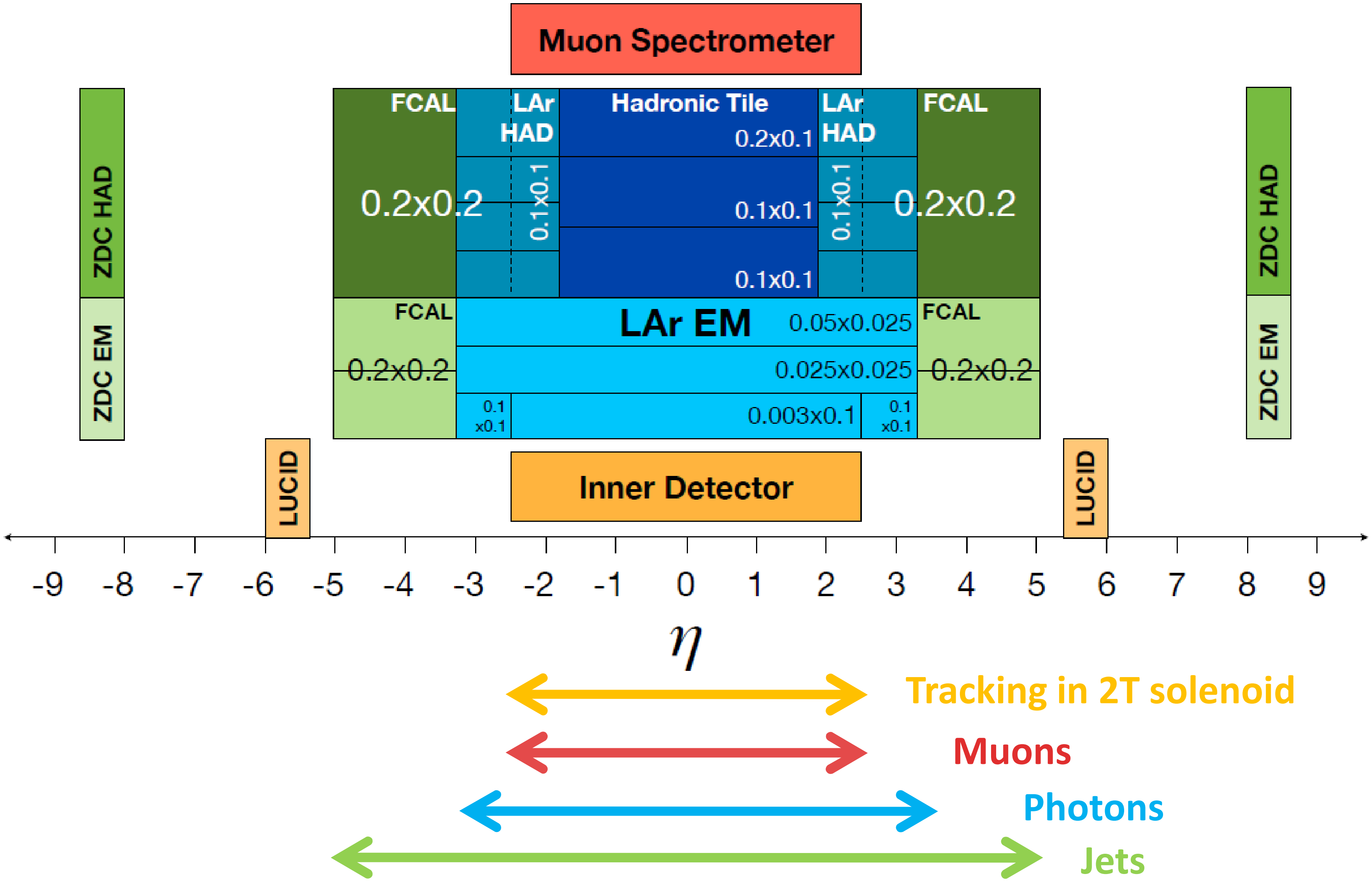
Space-time evolution of AA collision



ATLAS Overview

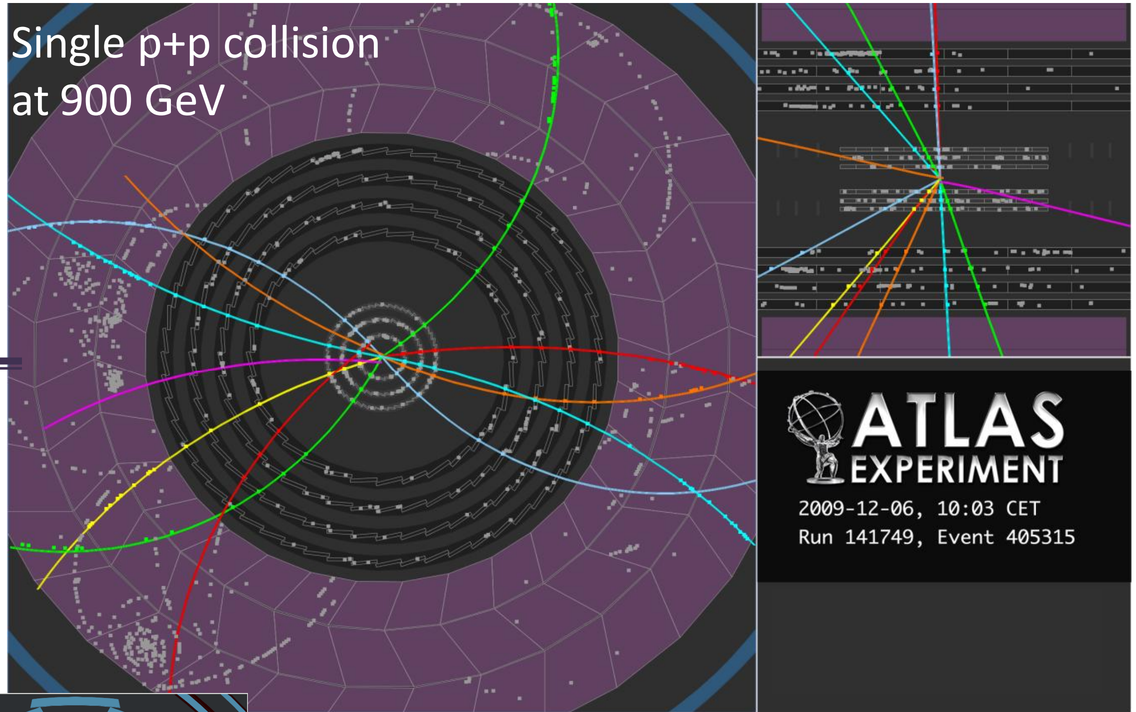


ATLAS Acceptance

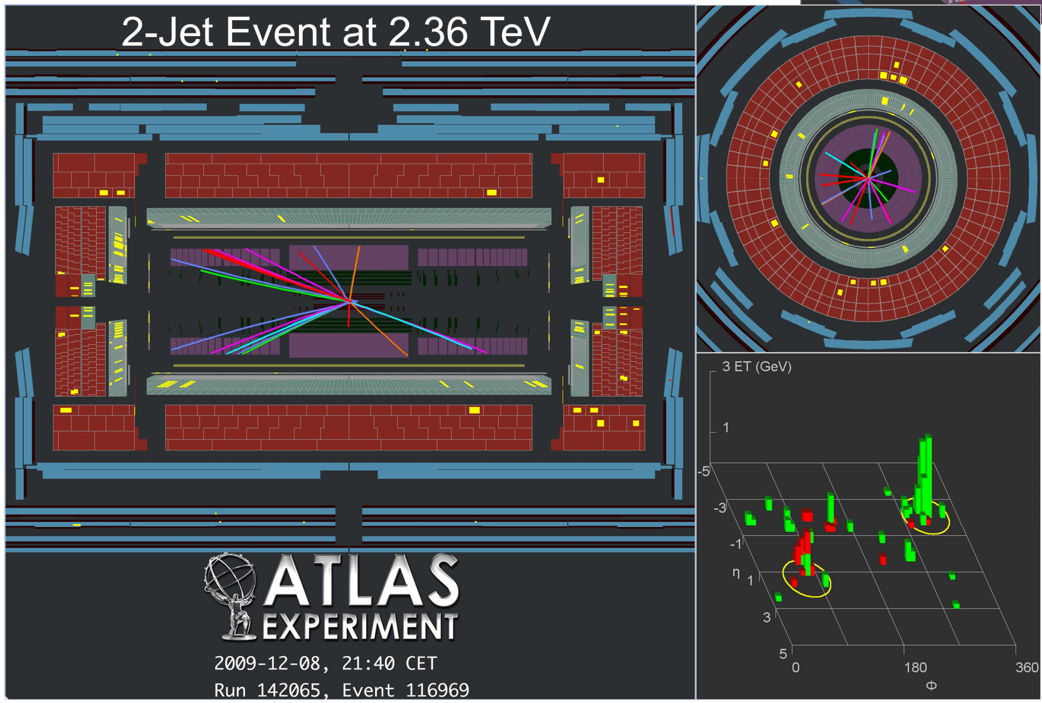


First p+p Collisions in ATLAS in 2009

Åpp(900GeV) 23 November
Åpp(2.36TeV) 8 December

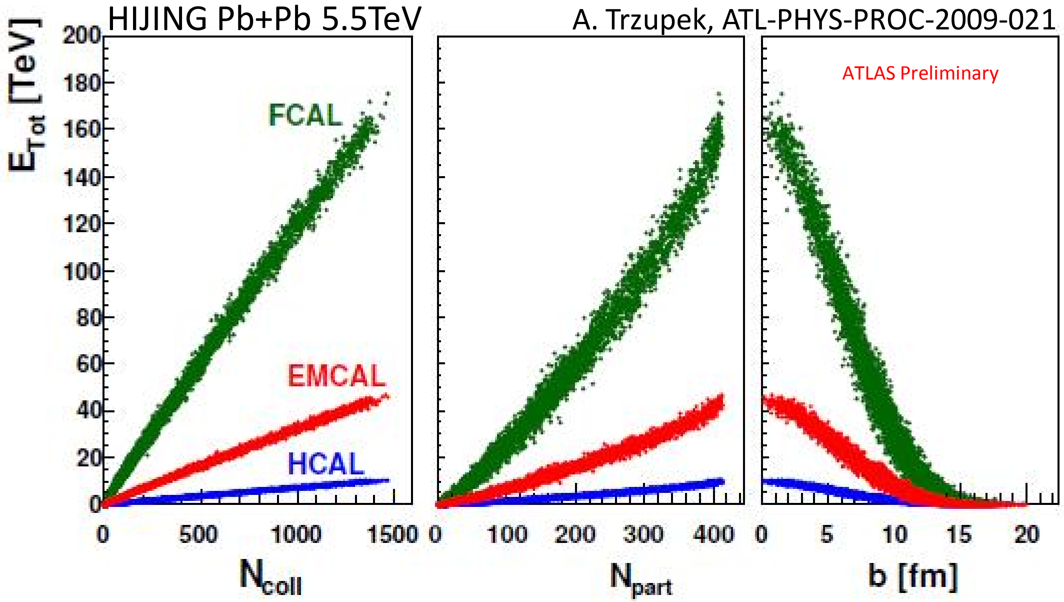


http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html

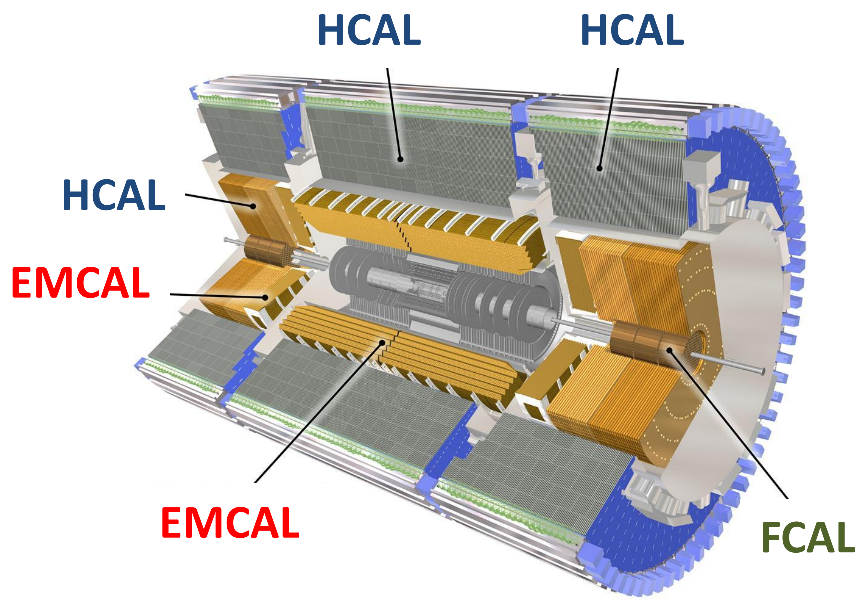


Excellent performance of ATLAS during first physics runs

Collision Centrality



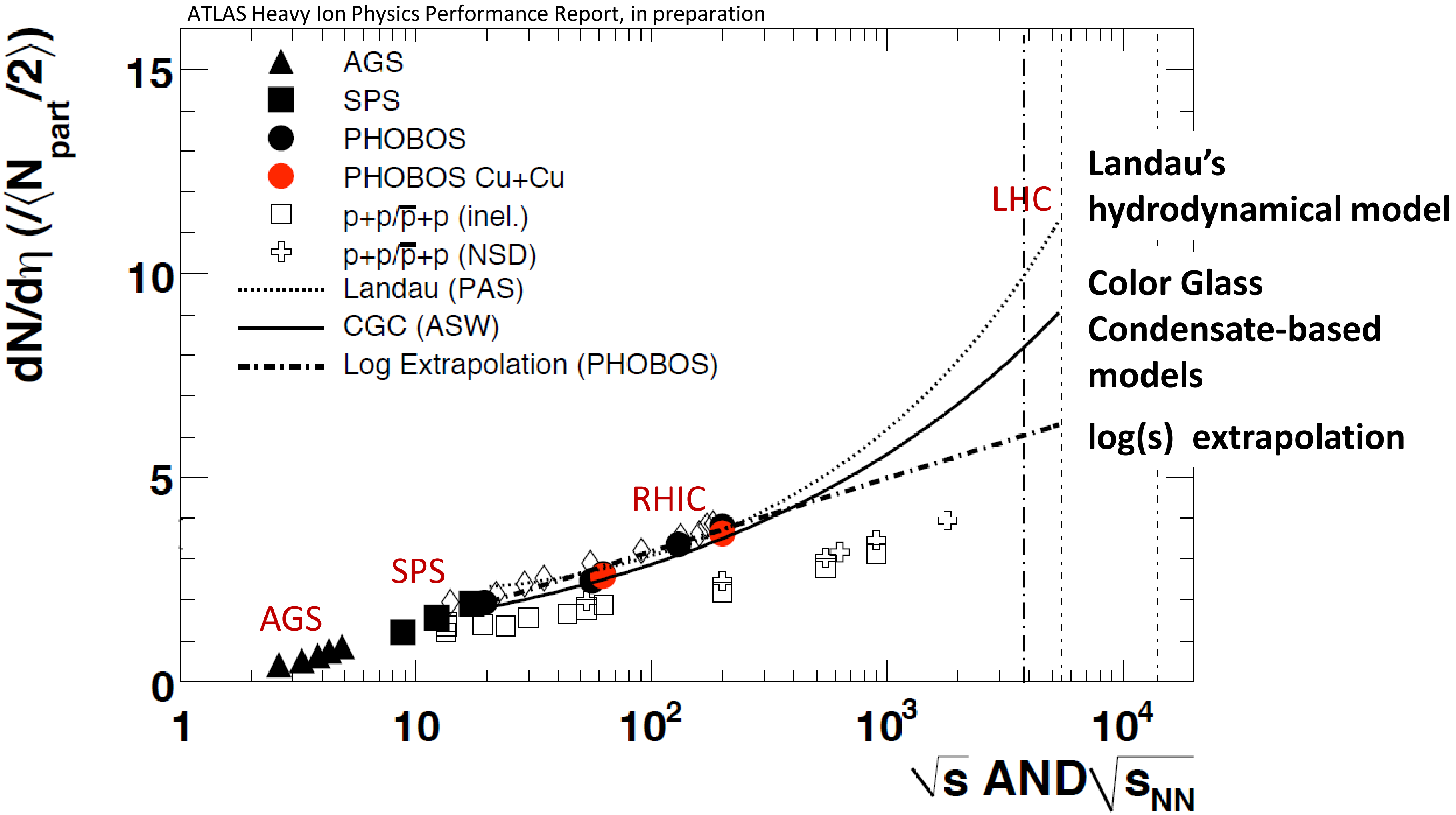
$$E_{Tot} = \sum_{cells} E_{cell}$$



N_{part} – number of participant nucleons
N_{coll} – number of binary nucleon-nucleon collisions
b – impact parameter

Correlation between the total energy and event centrality parameters (N_{part}, N_{coll}, b)

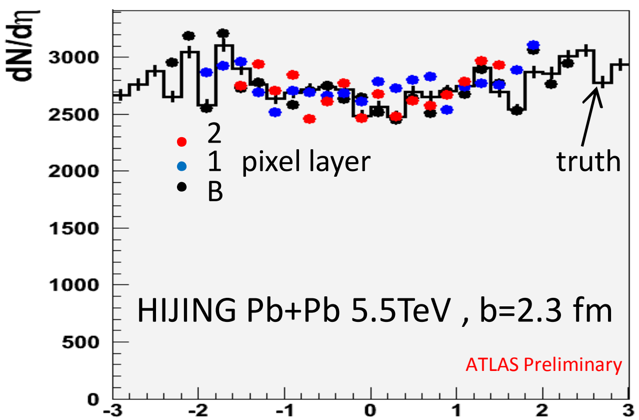
Charged Particle Multiplicity



Measurement of charged particle multiplicity is crucial to test predictions of different theoretical models.

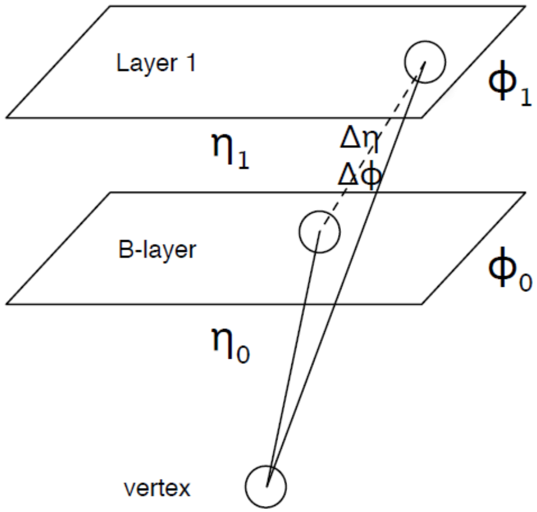
Charged Particle Multiplicity

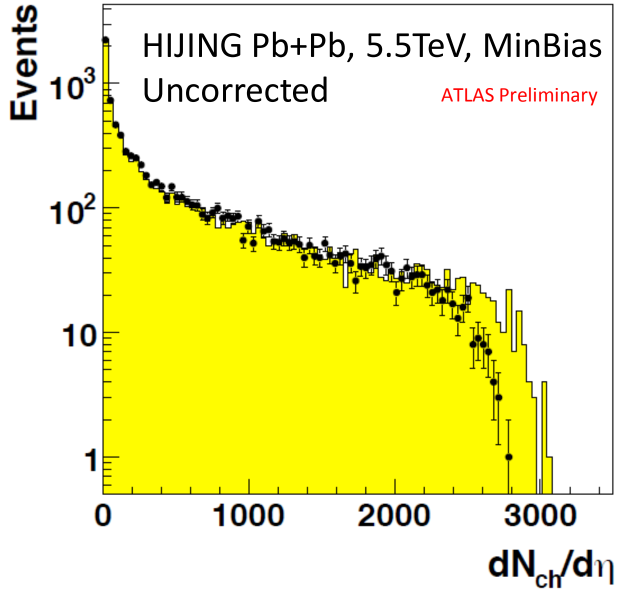
Å Hit counting method



Pixel detector
Number of readout channels: ~80M
Acceptance: -2.5 < η < 2.5

Å Tracklet method





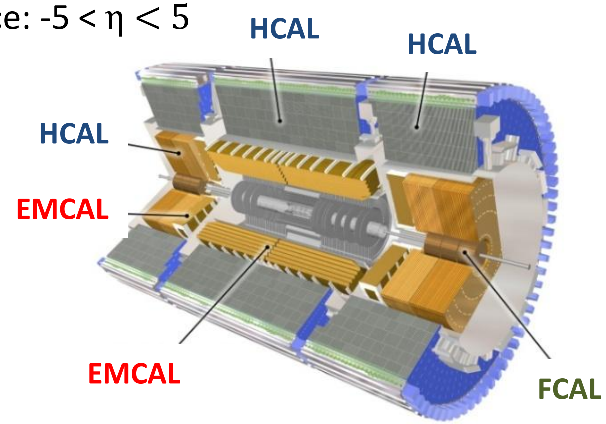
Very good accuracy for both techniques

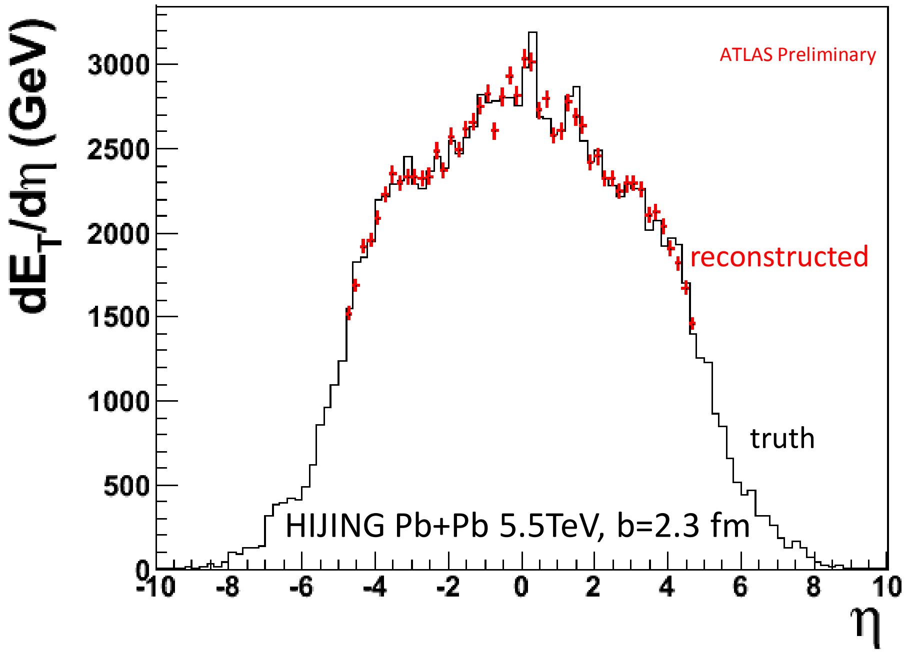
Transverse Energy

- **Transverse energy measurement allows to study medium energy density (e.g. via Bjorken formula)**
- **$dE_T/d\eta$ is calculated directly from cell energies measured in electromagnetic and hadronic calorimeter corrected for dead material and detector effects:**

$$C(\eta) = \frac{\left\langle \frac{dE_T^{MC\_Truth}}{d\eta} \right\rangle}{\left\langle \frac{dE_T^{reconstructed}}{d\eta} \right\rangle}$$

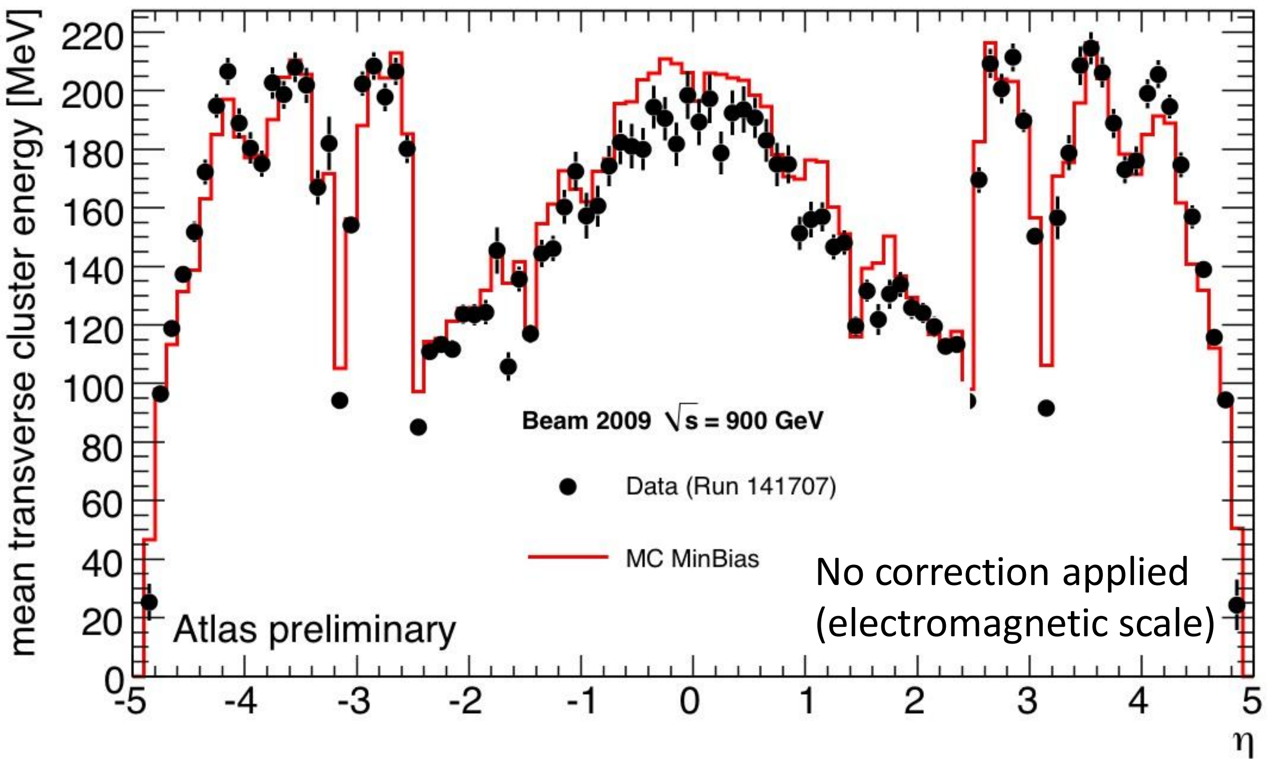
Number of readout channels: ~180k
Acceptance: $-5 < \eta < 5$





Very good performance for $dE_T/d\eta$ measurement

Transverse energy in ATLAS calorimeter in p+p (900GeV) data



https://twiki.cern.ch/twiki/bin/view/Atlas/JetEtMissPublicCollisionResults

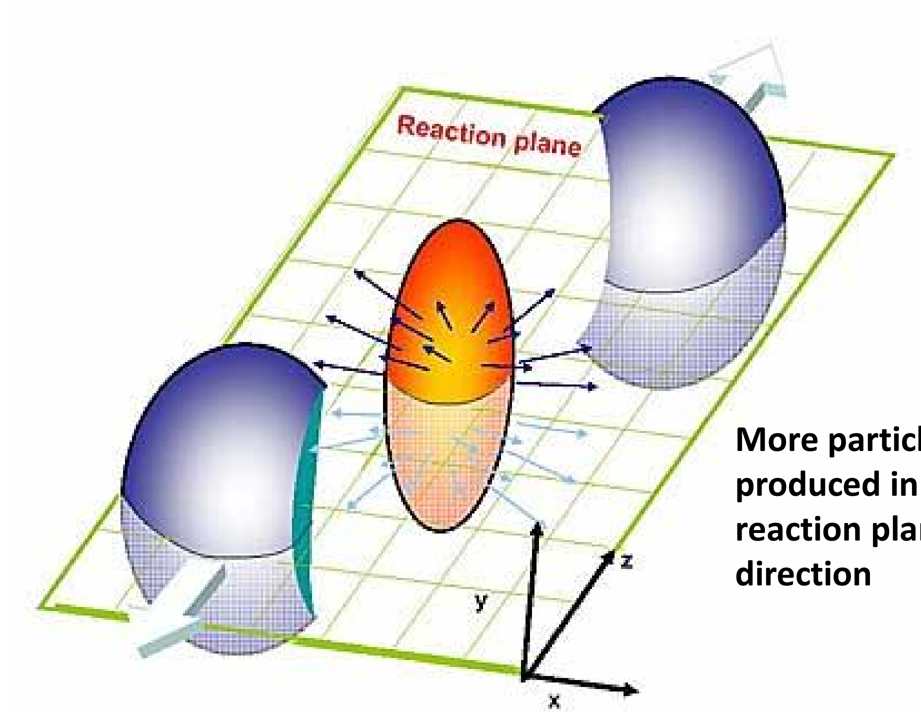
Performance of the calorimeter during p+p (900GeV) run shows good understanding of detector condition and description in MC simulation

Elliptic Flow

Å In HI collisions there is observed azimuthal anisotropy
Å Final state anisotropy can be quantified by studying the Fourier decomposition of particles' azimuthal angle distribution

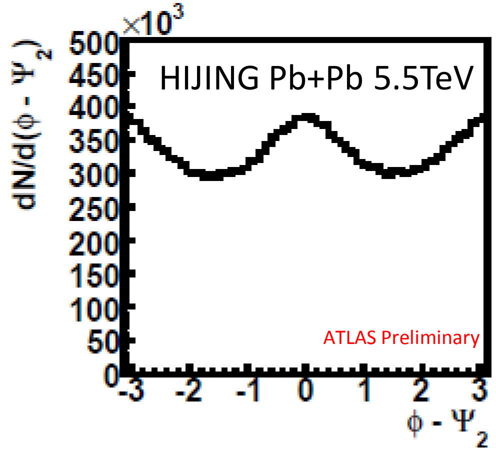
$$\frac{dN}{d(\phi-\psi_{RP})} = N_0(1+2v_1\cos(\phi-\psi_{RP})+2v_2\cos(2(\phi-\psi_{RP}))+\ldots)$$

v_1 - directed flow **v_2 - elliptic flow**



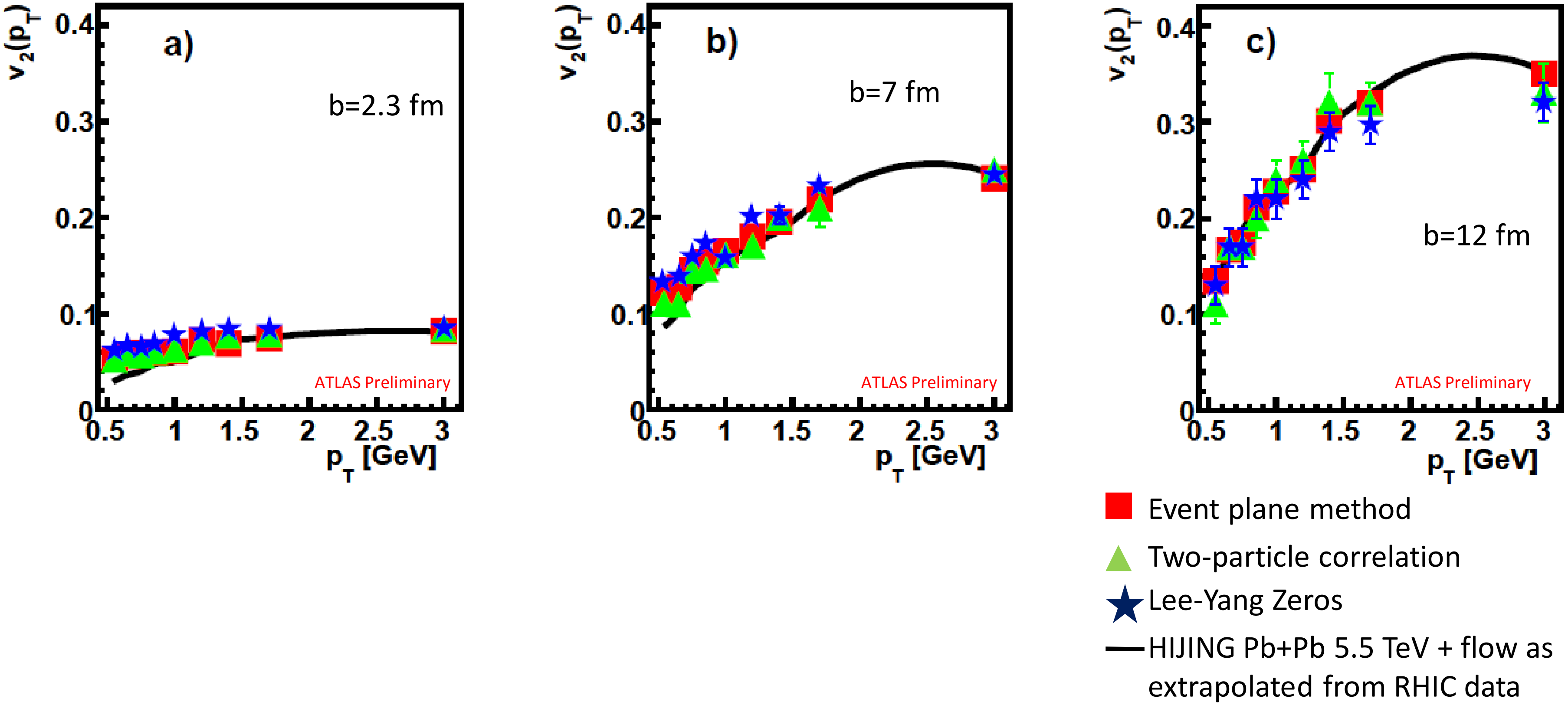
More particles produced in reaction plane direction

Flow azimuthal distribution relative to reaction plane



Elliptic Flow

ÅTransverse momentum dependence of the v2 from several methods



ÅAzimuthal anisotropy of produced particle is well reconstructed

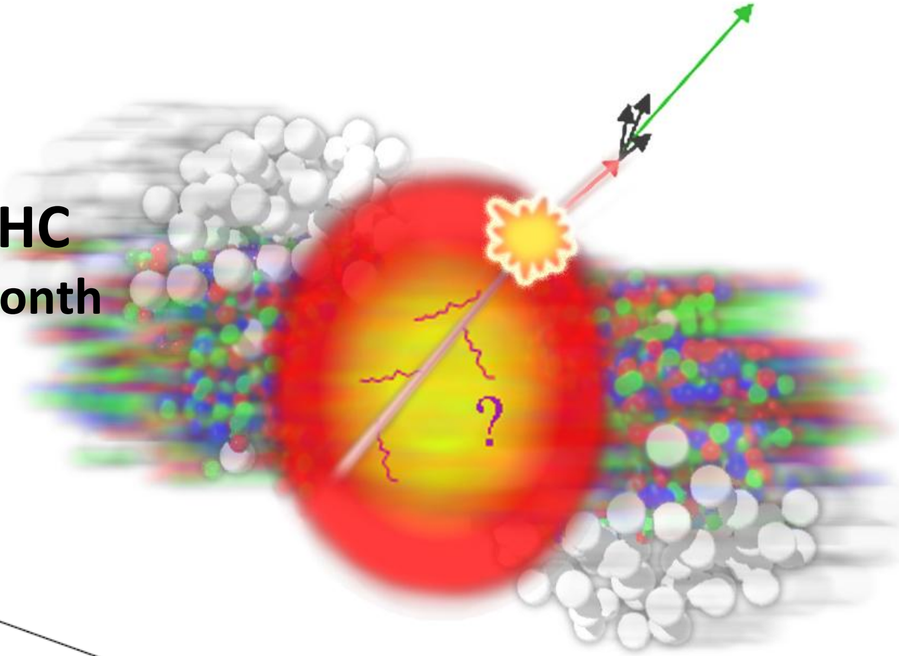
ÅSeveral analysis method using different detector sub-systems

Jets in Pb+Pb Collisions at LHC

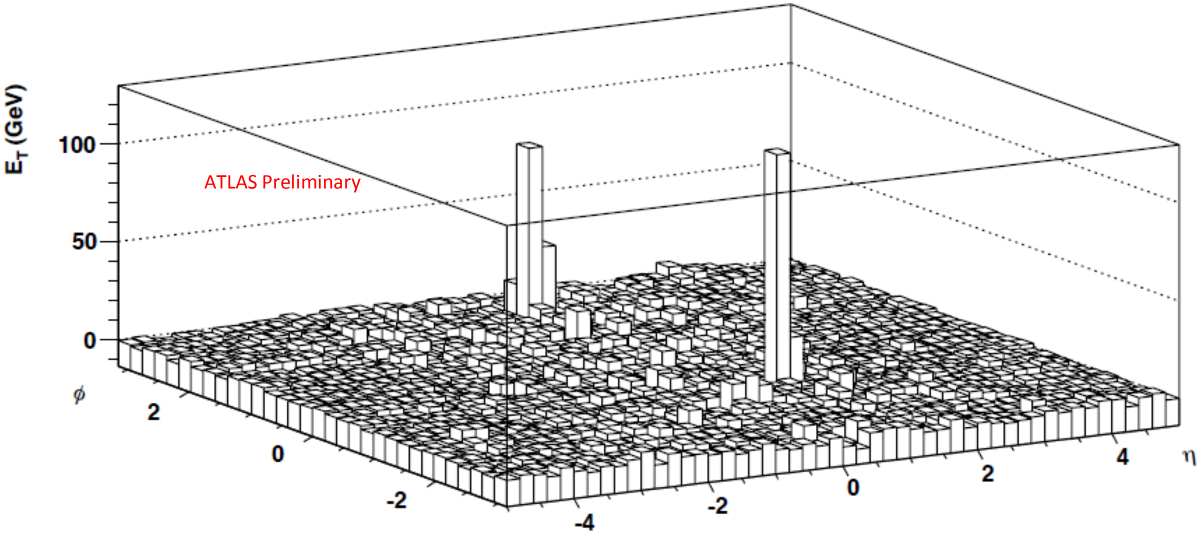
ÅAt LHC jets will be ideal probe to study parton energy loss effects

ÅHigh rates of jets are expected at LHC

- ~20 million jets of E_T>50 GeV in one month of Pb+Pb (5.5 TeV) run at nominal luminosity (0.5 nb^{-1})



M. Spousta, ATL-PHYS-PROC-2009-022

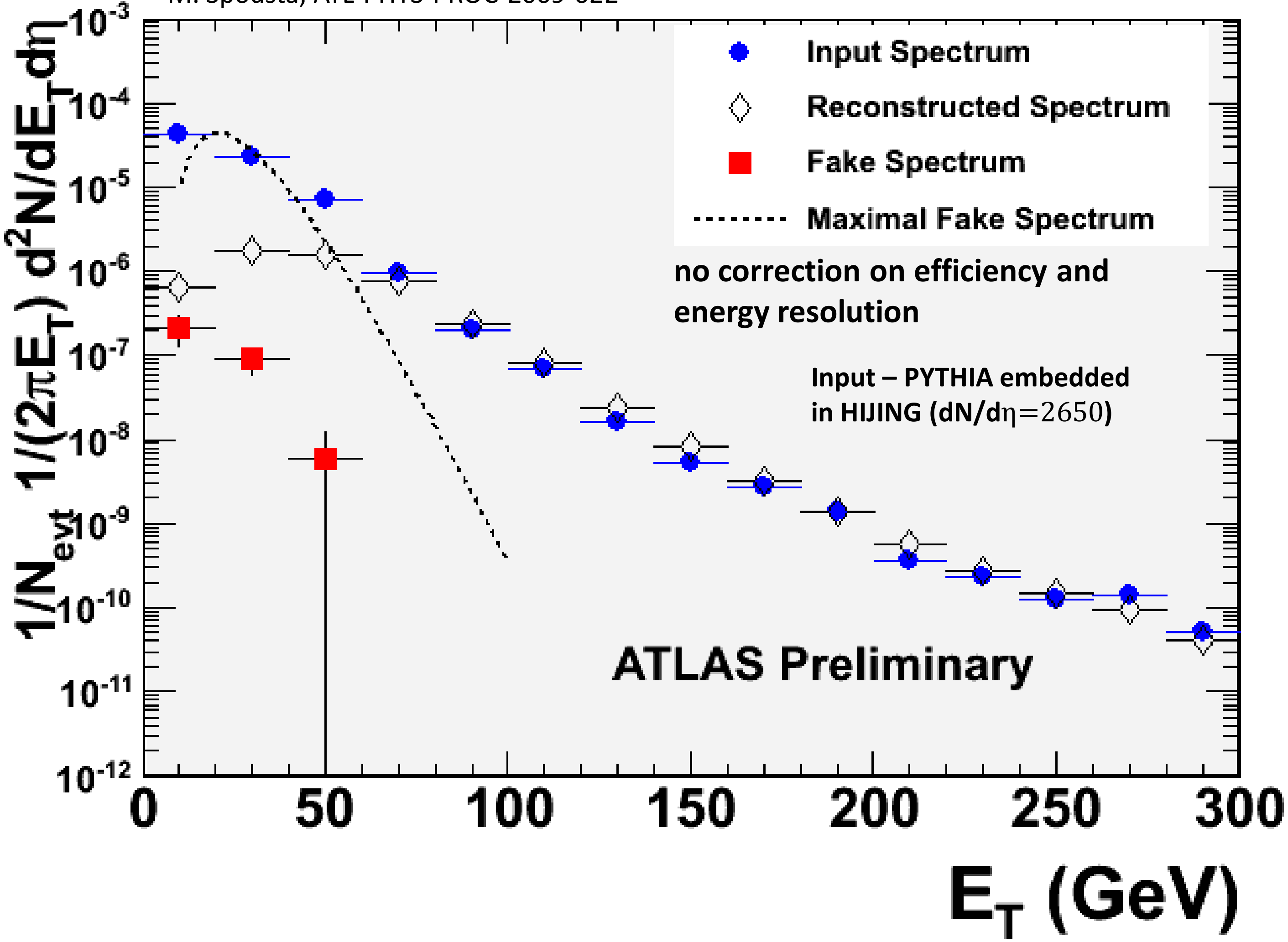


PYTHIA di-jet event embedded in HIJING with dN/dη=2650

Jets well visible in ATLAS detector

Jet Reconstruction

M. Spousta, ATL-PHYS-PROC-2009-022

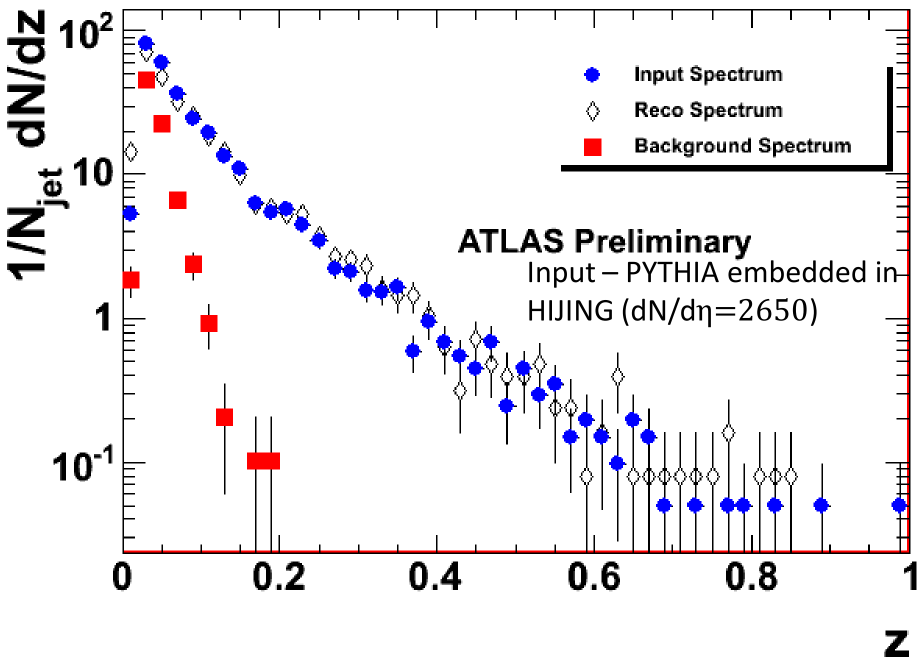


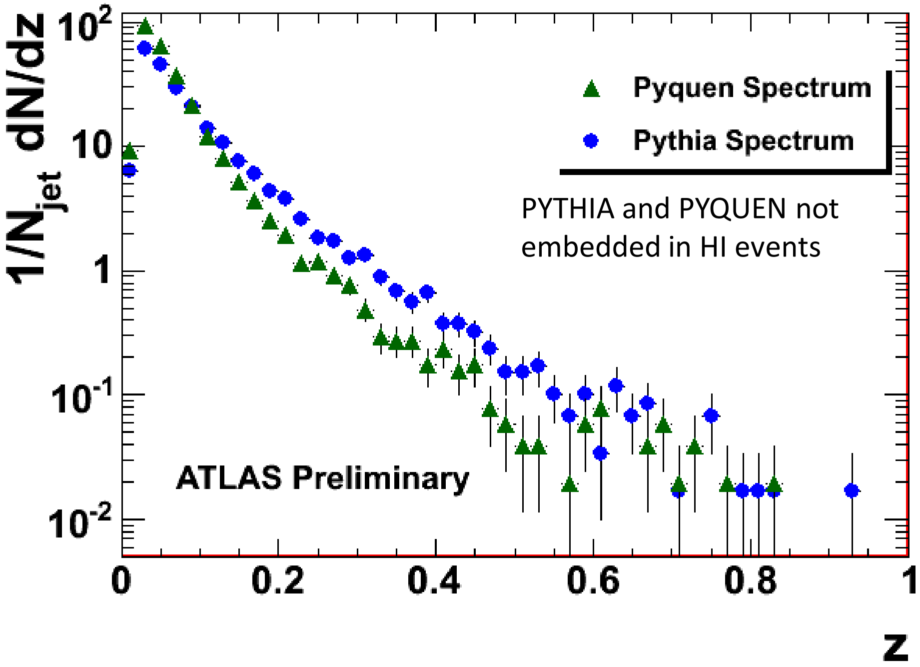
Above 80 GeV nearly 100% efficiency for cone (R=0.4) algorithm

Jet Fragmentation Function

- Jet fragmentation function D(z) is sensitive to in-medium energy loss
- D(z) is obtained using reconstructed tracks from inner detector and jets from calorimeter

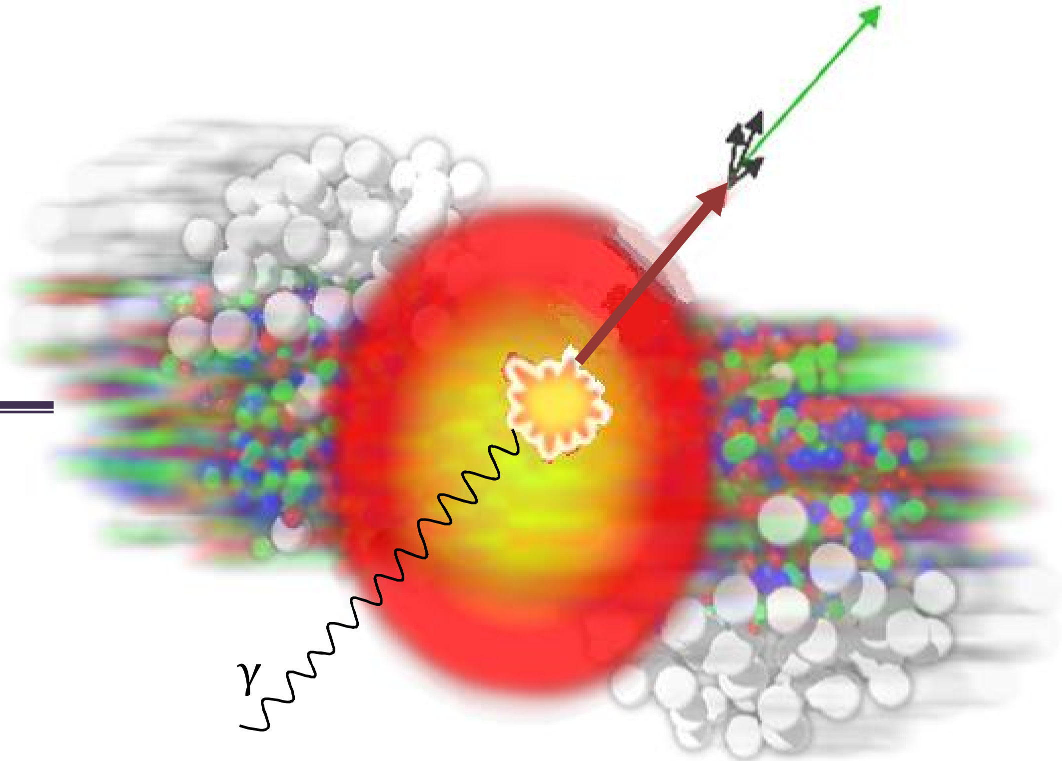
$$z = \frac{\vec{p}_{jet} \cdot \vec{p}_{frag}}{\left|\vec{p}_{jet}\right|}$$ - fraction of jet momentum carried by the fragment





ATLAS has good capabilities to measure modifications of D(z) due to energy loss effects

Direct photons and photon-Jet

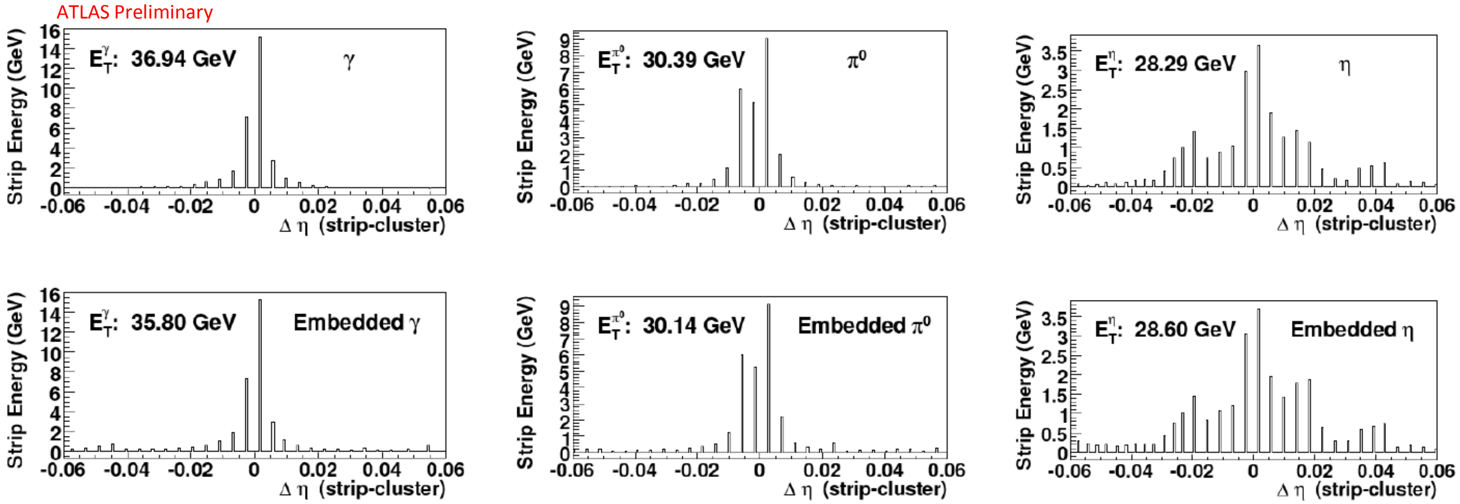


Åɔ - tagged jets at LHC (5.5 TeV, Pb+Pb) are a direct handle on jet energy loss process in QGP because the medium is nearly transparent to photons

Åɔ-jet events will also serve as a calibration tool for jet reconstruction

Direct photons Reconstruction

The energy depositions in calorimeter strip layer of single photon, ´ ^{0} and d



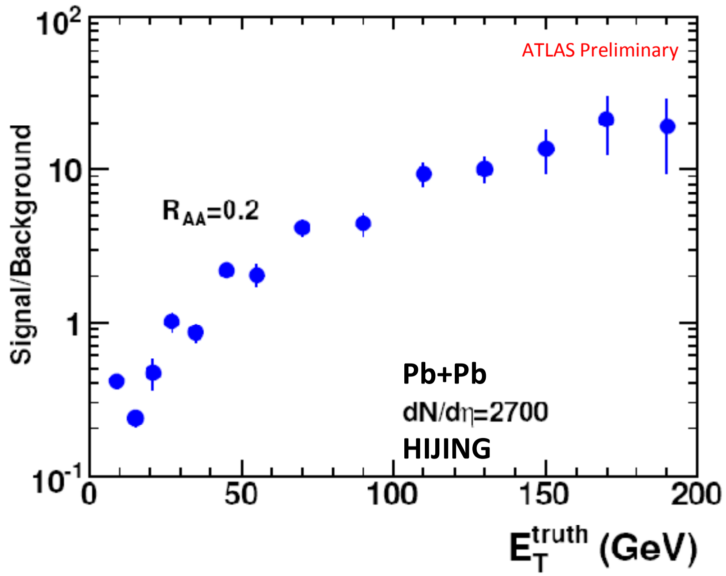
Without HI background

With HI background (HIJING Pb+Pb b=2fm)

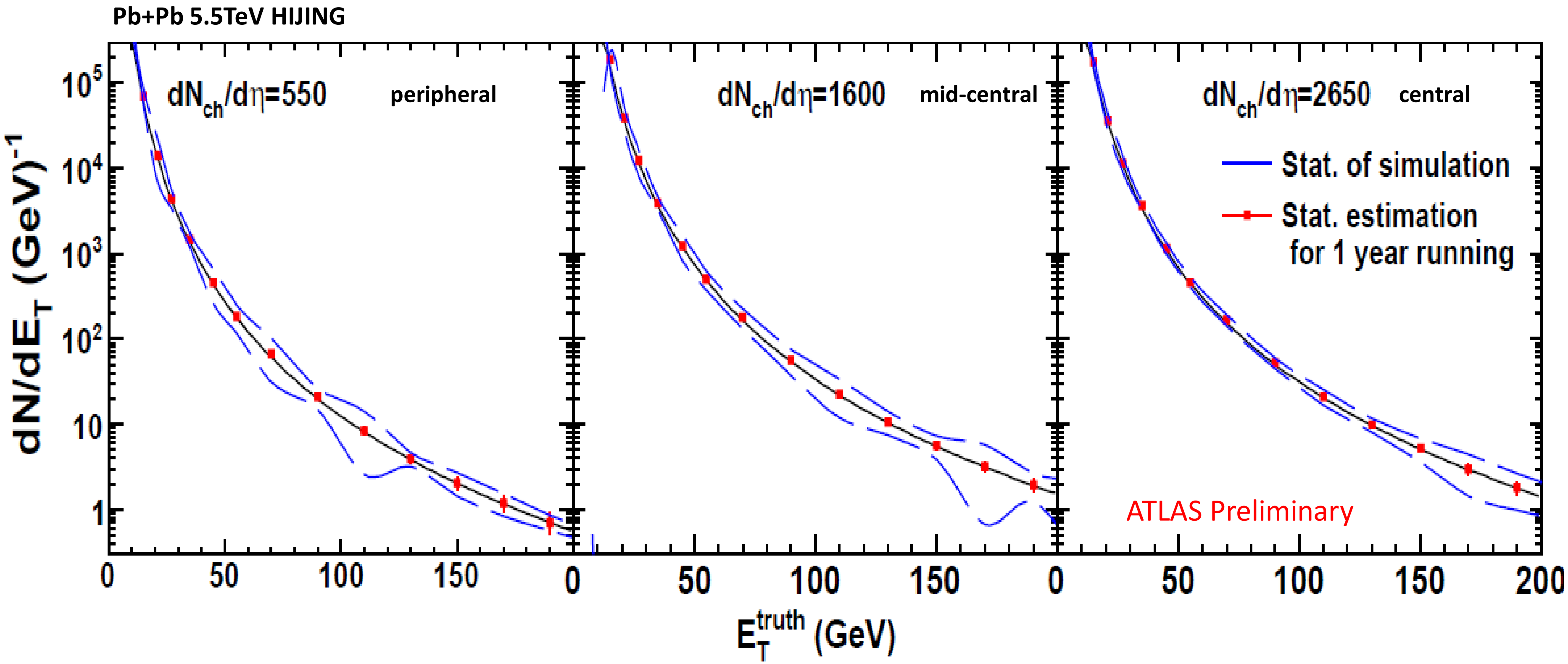
M.D. Baker, Nucl. Phys. A, *830* (2009) 499c;

ÅMinimal effect on shower profile from HI background

ÅA set of cuts based on shower shape allows to distinguish direct photons from neutral hadron background



Direct photons Spectrum in Pb+Pb (5.5TeV) Collisions

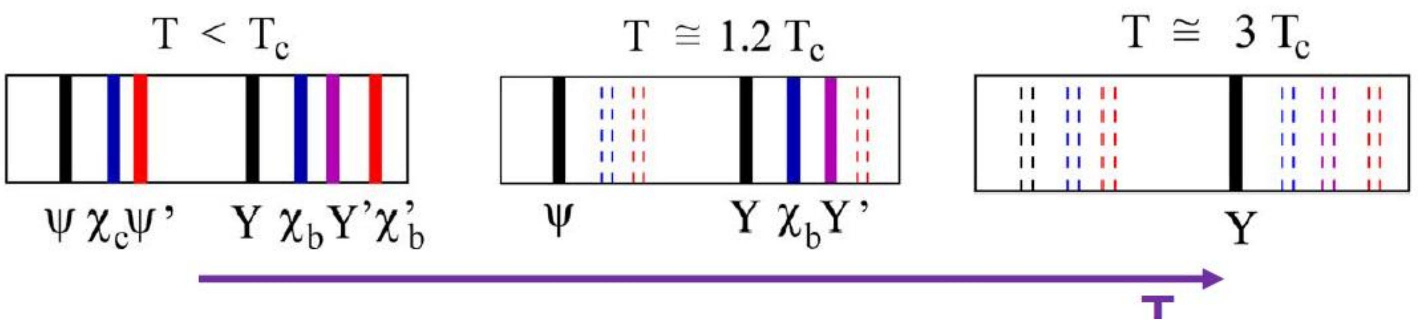


- ÅExpected direct photon spectrum after 1 month at nominal luminosity
- ÅExpected rate of direct photons in 0.5nb-1 for Pb+Pb collisions:
  - Å200k ɔ above 30 GeV with S/B>1
  - Å10k ɔ above 70 GeV with S/B>4

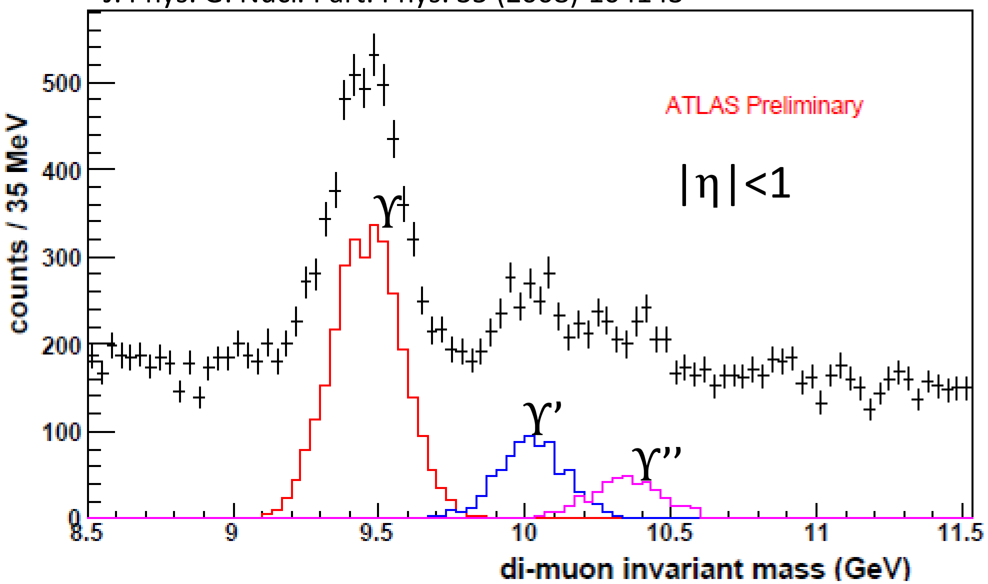
Quarkonia suppression

Color screening prevents various quarkonia states from being formed.

Nucl.Phys.A783,p.249,2007



J. Phys. G: Nucl. Part. Phys. 35 (2008) 104143



Mass resolution ~120MeV is sufficient to separate Υ from Υ'/Υ'' **states but is not sufficient to distinguish between** Υ' and Υ''**.**

Summary

- Excellent performance of the ATLAS detector during p+p (900GeV) run
- Early analyses of p+p data prove good understanding of detector description and simulation
- ATLAS will be excellent detector for heavy ion physics due to:
  - hermetic construction
  - fine granularity of tracking and calorimeter systems
- Heavy ion program of ATLAS is focusing on:
  - Global variables
  - High energy jets and photons
  - Quarkonia suppression
- Analysis of p+p data will be used for preparation to Pb+Pb run and will serve as a baseline for Pb+Pb measurements