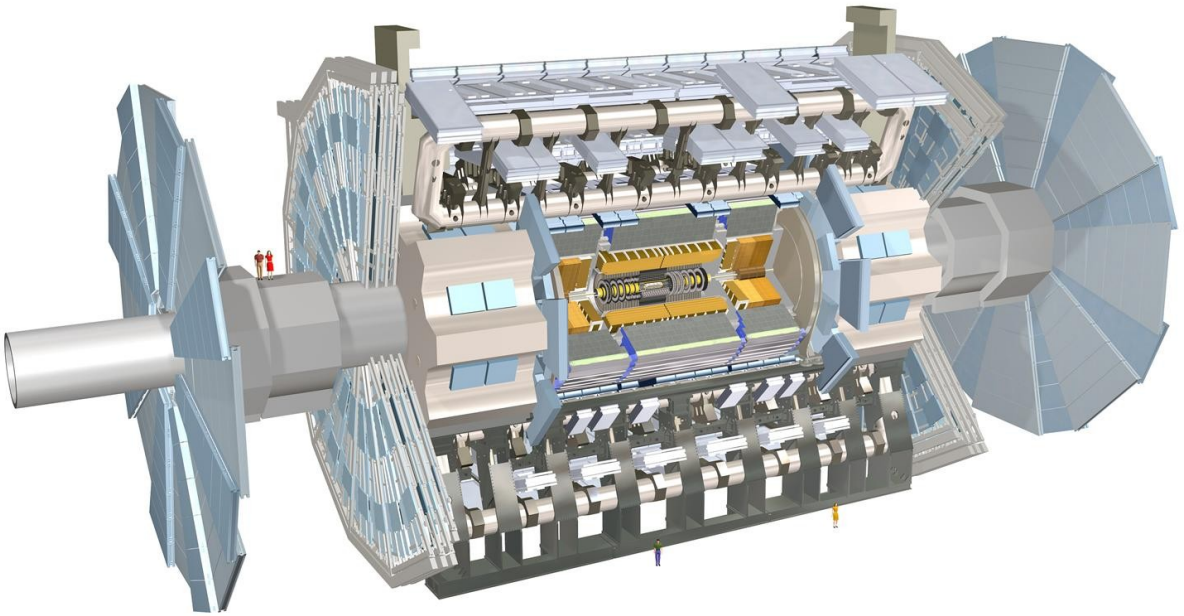
Heavy Ions Studies in ATLAS



Martin Rybář

for the ATLAS collaboration

Heavy Ions at the LHC

- opportunity to study QCD in many particle regime

RHIC - $\sqrt{s_{NN}} = 200$ **GeV**

- evidence for new state of matter and new phenomena

LHC - $\sqrt{s_{NN}} = 5.5$ **TeV** (2.75 TeV expected in 2010)

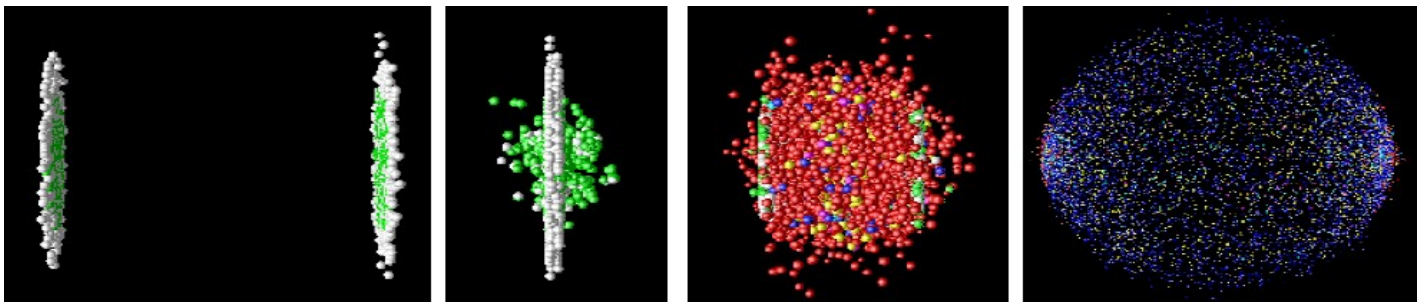
- thirty times larger energy ➡ a new regime in HI physics
- a hotter, denser and longer living QGP

➡ hope for unexpected discoveries

Pb+Pb nominal conditions:

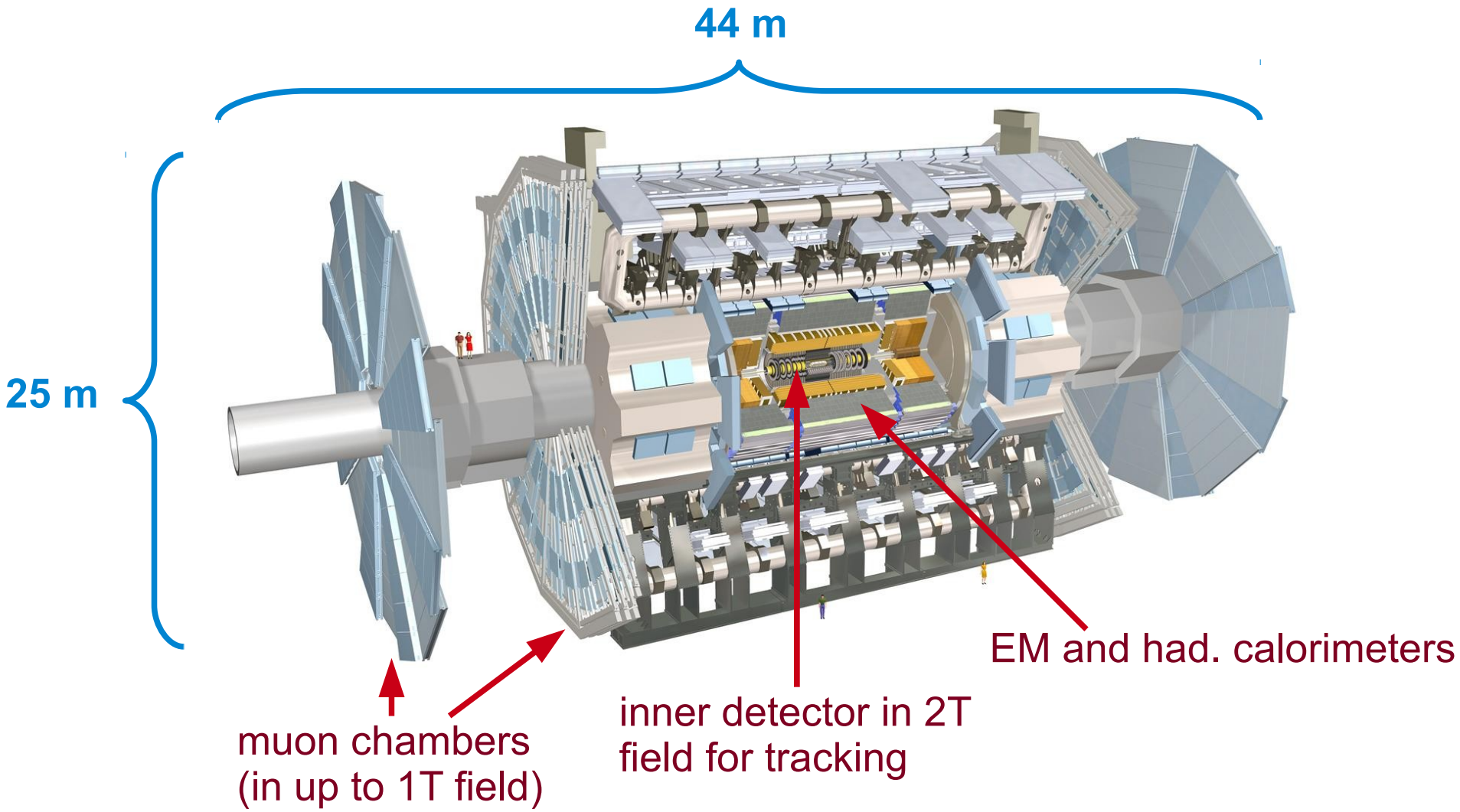
- luminosity 10^{27} $cm^{-2}s^{-1}$
- event rate: 7.7 kHz

➡ LHC experiments with HI programme: ALICE, ATLAS, CMS



The ATLAS Detector

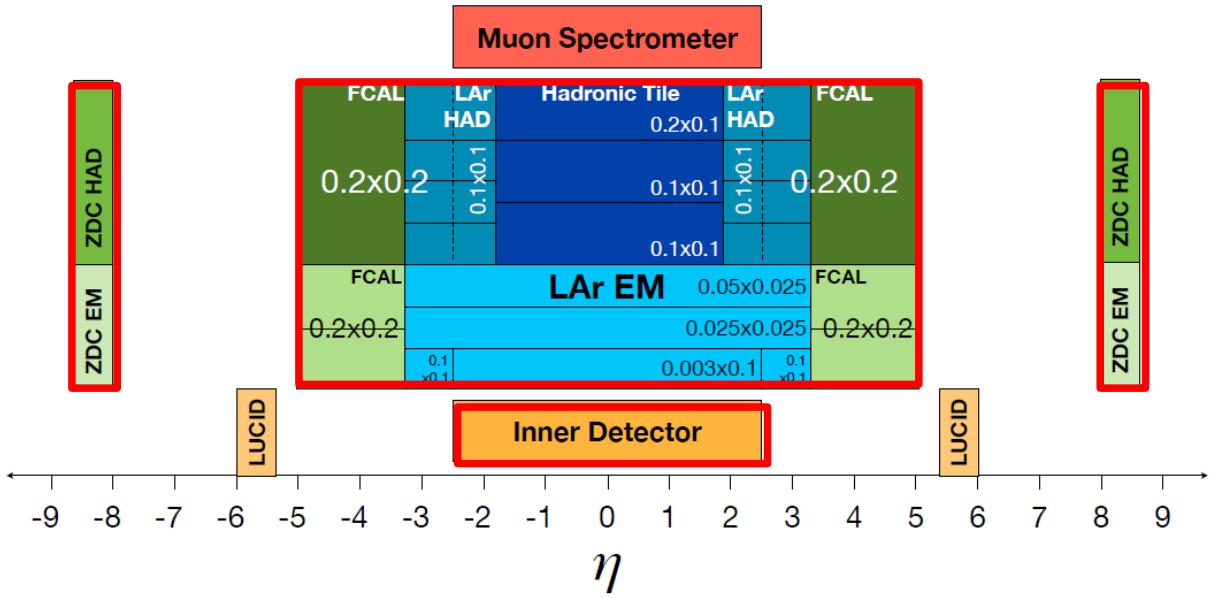
- ATLAS is a general-purpose p+p experiment, but most features developed for p+p can also be used for heavy ion physics!

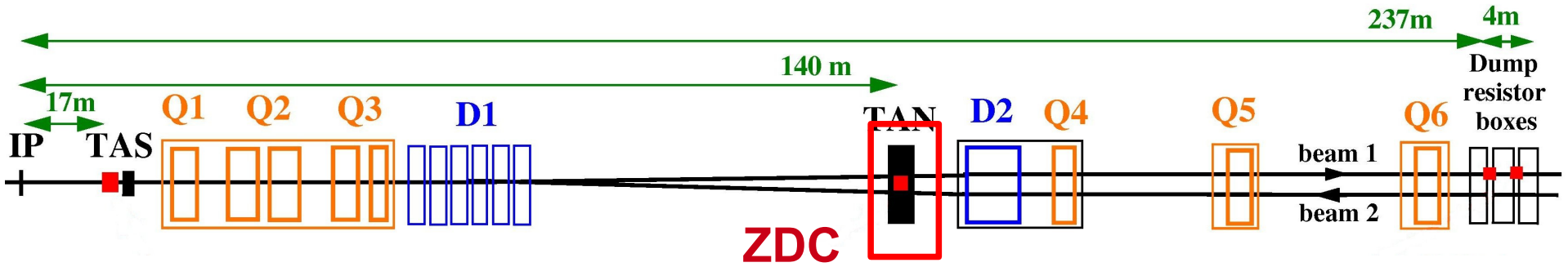


Heavy Ion Programme

- the ATLAS detector has excellent capabilities for heavy ion physics

➡ precise inner detector and calorimeter for measurements of global observables (multiplicity, transverse energy, flow)



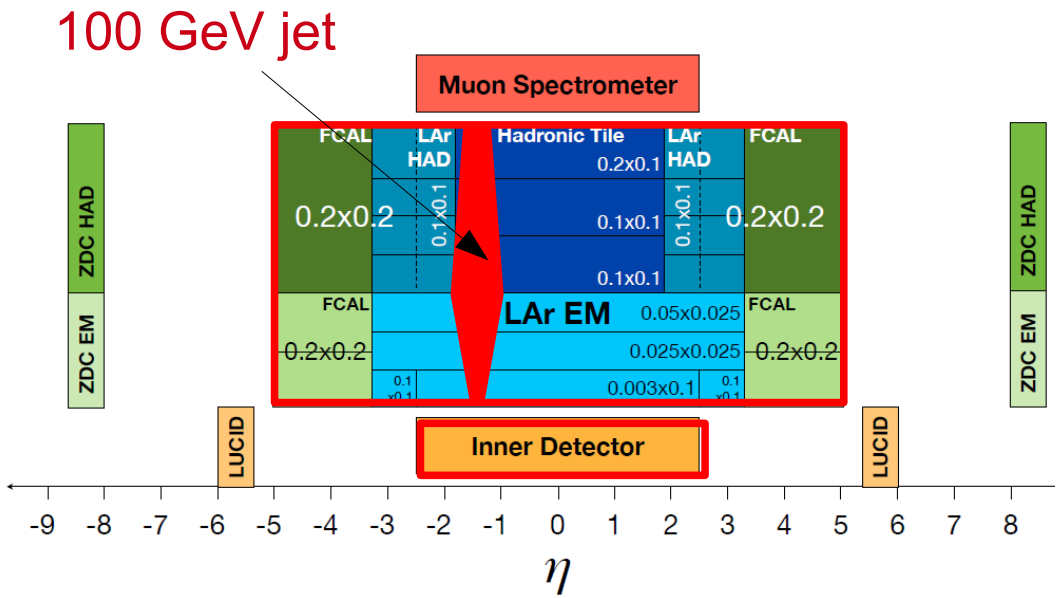


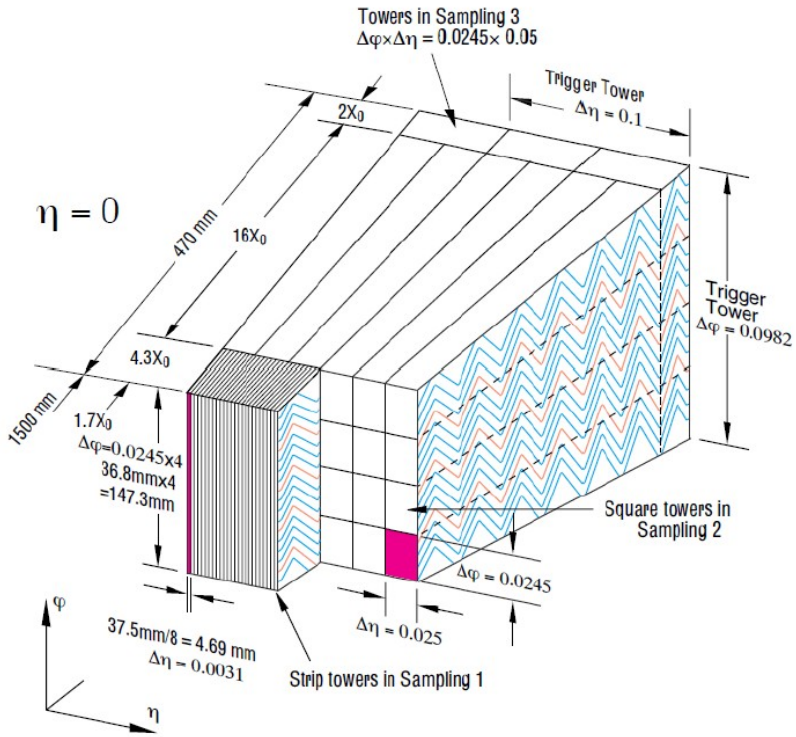
Heavy Ion Programme

- the ATLAS detector has excellent capabilities for heavy ion physics

➡ fine segmented calorimeter for jet and photon measurements

➡ inner detector for jet fragmentation studies

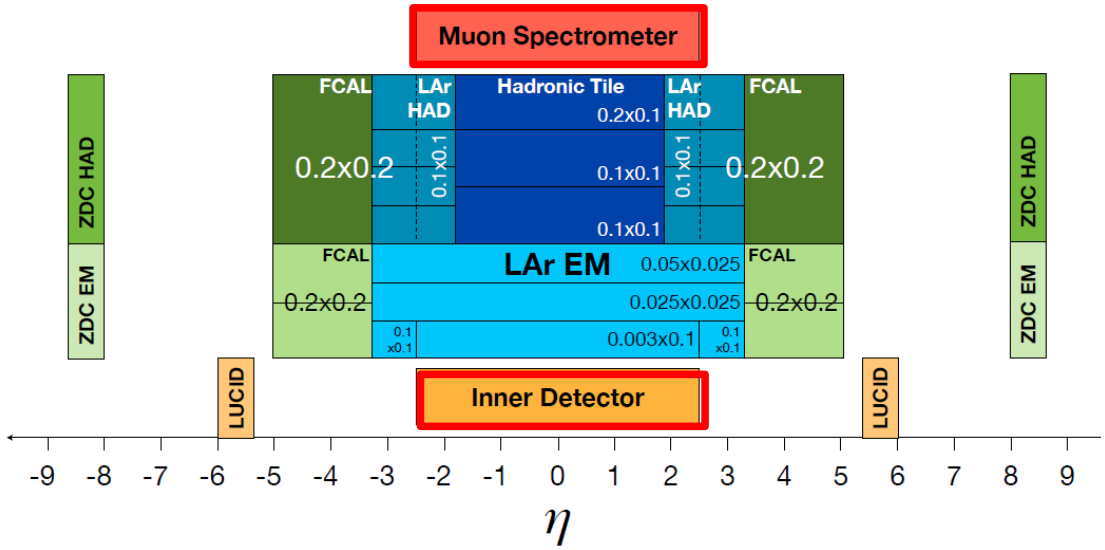


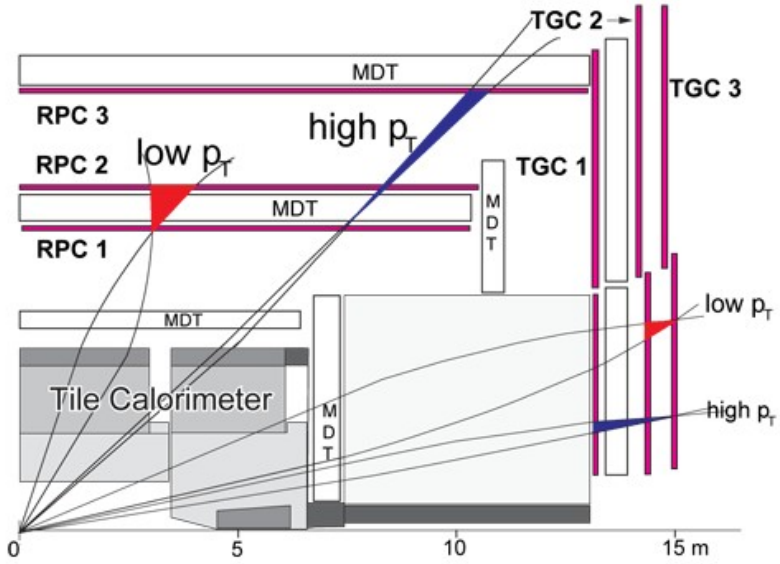


Heavy Ion Programme

- the ATLAS detector has excellent capabilities for heavy ion physics

→ muon system and inner detector for quarkonia and Z's measurement

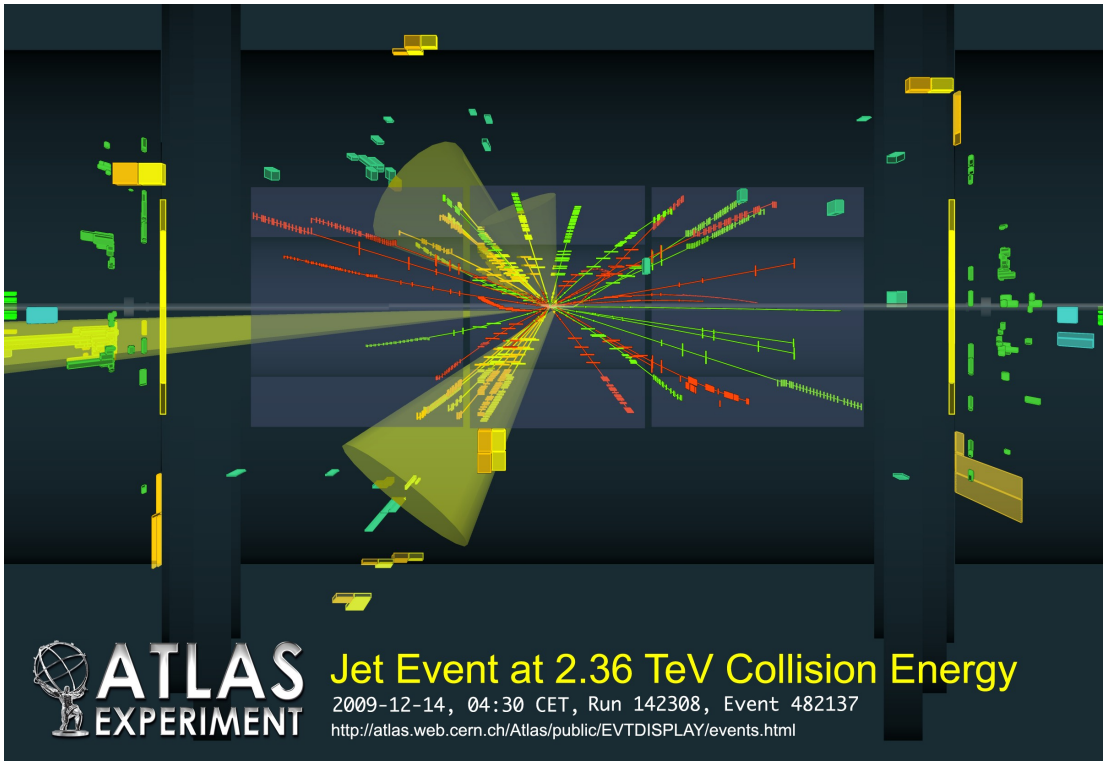




ATLAS Detector Status and Performance

- ATLAS detector is fully operational
- 2008-2009: millions of cosmic events were recorded
- end of 2009: first p+p events at 900 GeV, top energy 2.36 TeV

Subdetector	# Channels	Operation Fraction *
Pixels	80 M	97.9%
SCT Silicon Strips	6.3 M	99.3%
TRT Transition Radiation Tracker	350 k	98.2%
LAr EM	170 k	98.8%
Tile calorimeter	9800	99.2%
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	98.5%
TGC Endcap Muon Trigger	320 k	99.4%
LVL1 Calo trigger	7160	99.8%



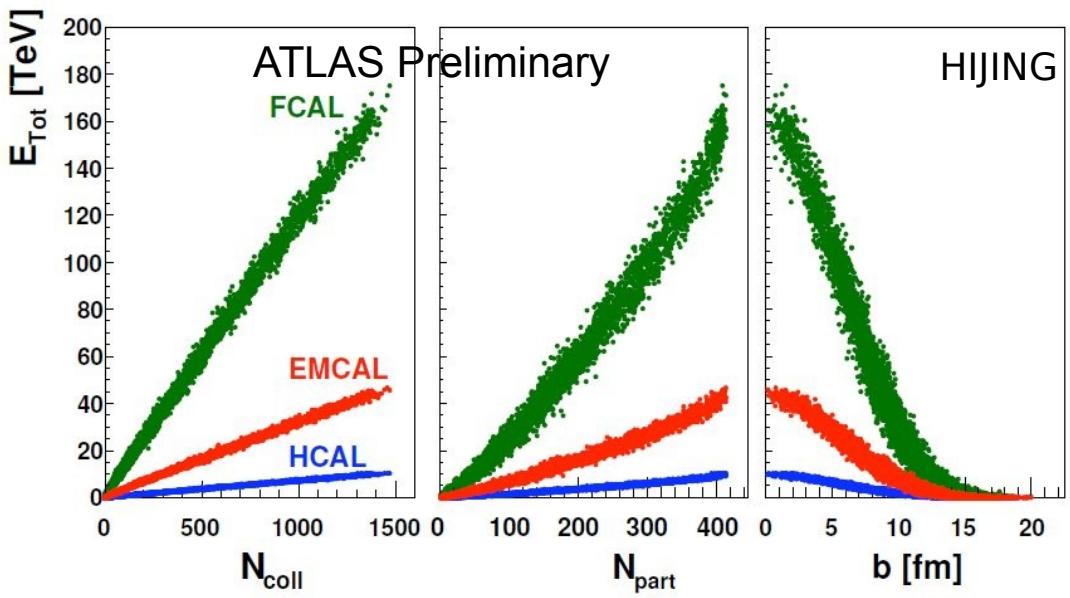
➡ Excellent results during first physics runs!

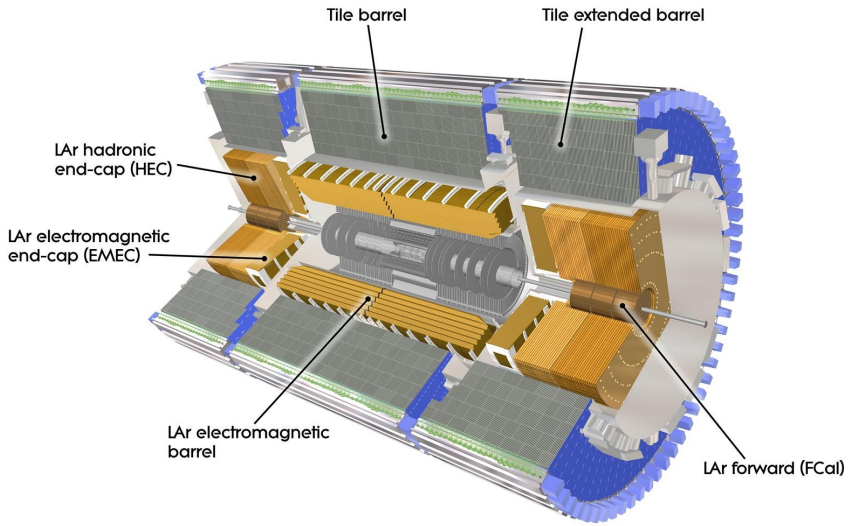
*10-12-2009

Global Observables I

- properties of initial state, collective motion
- primary „day 1” measurement
- global observables are correlated with event geometry
- event by event measurement

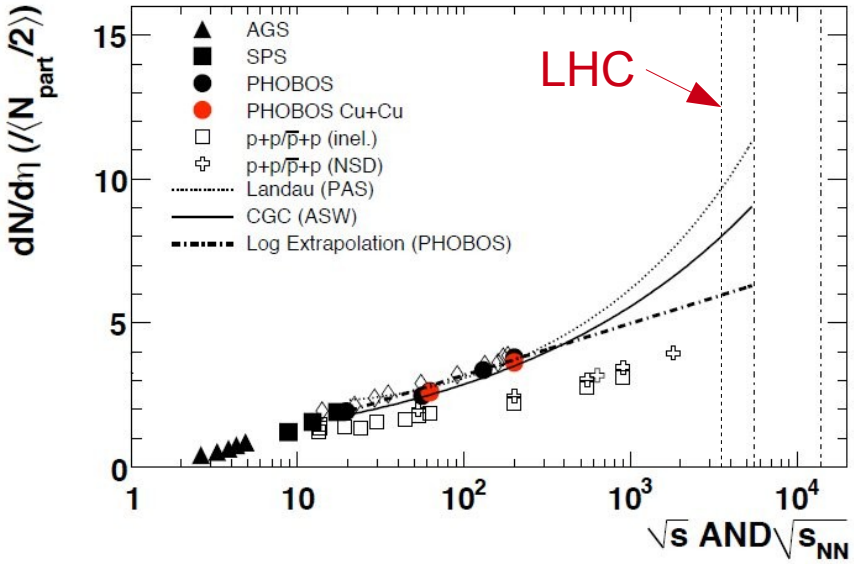
Total E_T measurement ➡ impact parameter number of collisions and participants

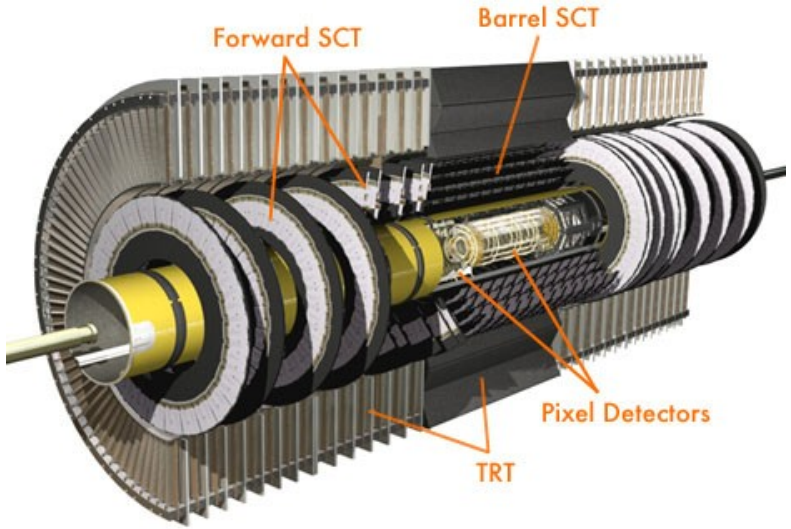




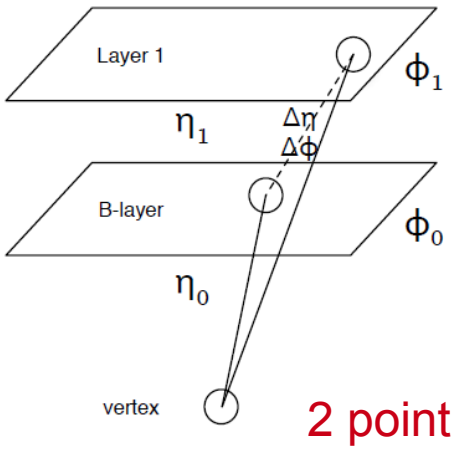
Global Observables II

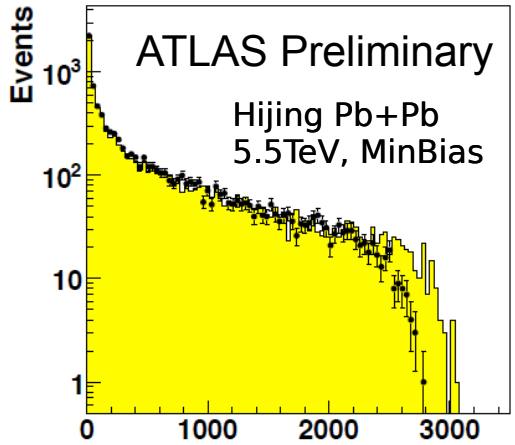
Charged particle multiplicity ➡ testing predictions of theoretical models



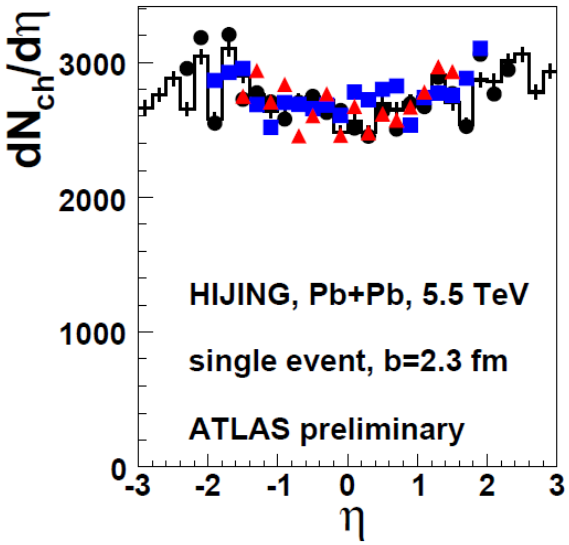


- two methods for N_{ch} estimation:





2 point pixel tracklets



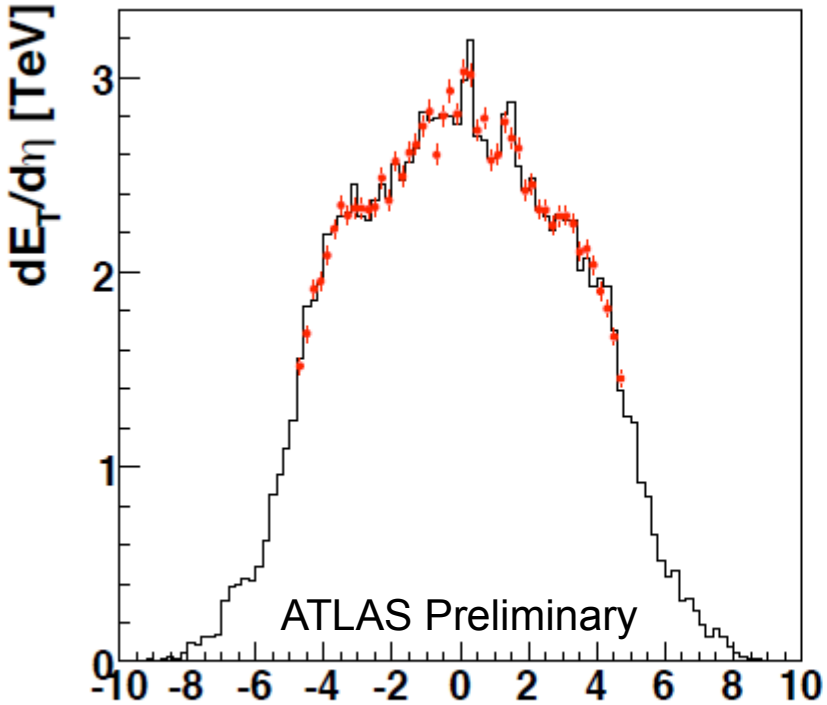
hit counting method:
N_{ch} is proportional to the # of hit clusters in different barrel pixel layers (colour marks)

Global Observables III

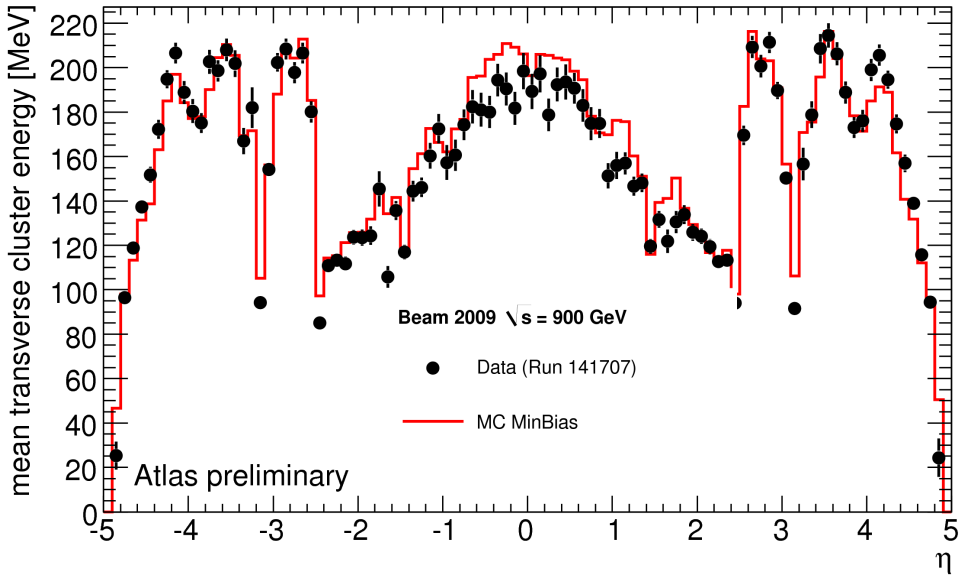
Transverse energy as an example of reconstruction performance

Two approaches:

- calorimeter (em+had) clusters + muons + correction for dead material
- η-dependent correction from MC simulation and measured E_T



A+A MC & reconstruction
a single b=2.3 fm Pb+Pb HIJING event!



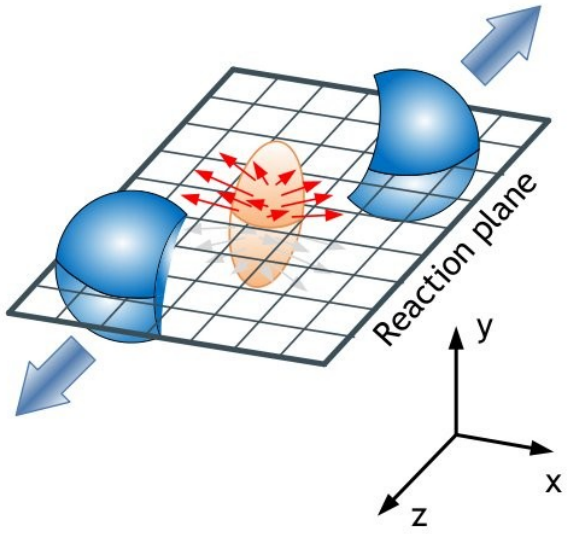
p+p DATA and MC
performance of the calorimeter

Global Observables IV

Elliptic flow

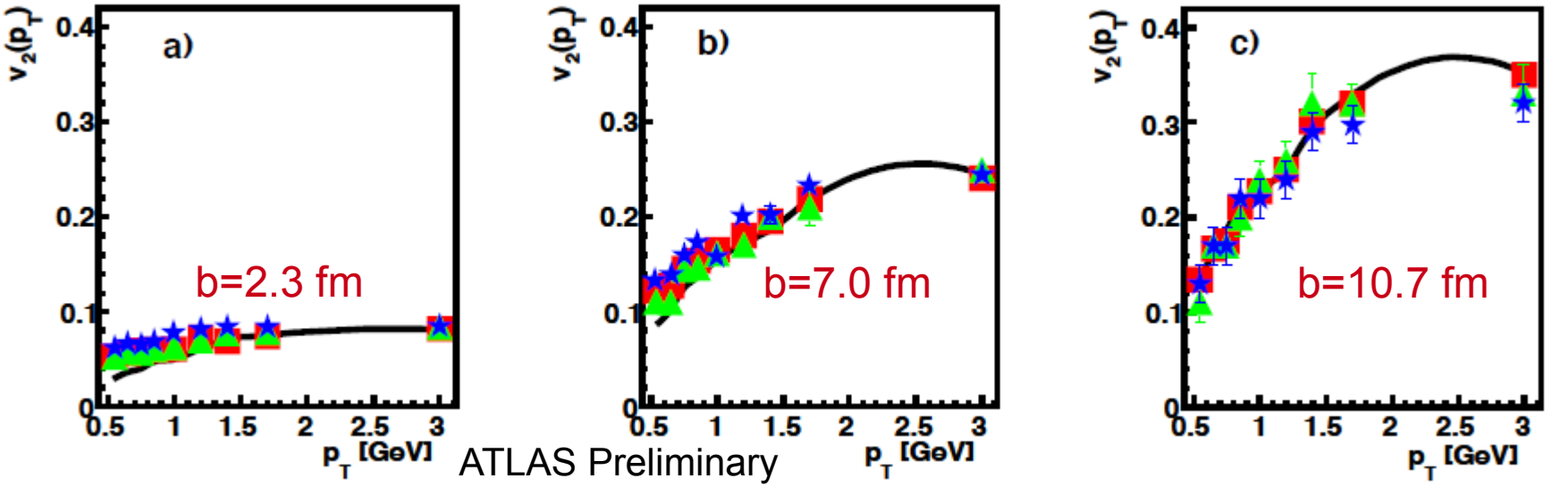
- particle emission asymmetry due to the initial pressure gradient
- various methods for azimuthal anisotropies measurement are developed (non-flow effects)

$$E\frac{\mathrm{d}^3N}{\mathrm{d}p^3} = \frac{1}{2\pi}\frac{\mathrm{d}^2N}{p_T\mathrm{d}p_T\mathrm{d}y}\left(1+\sum_{n=1}^{\infty}2v_n\cos[n(\phi-\Psi_r)]\right)$$



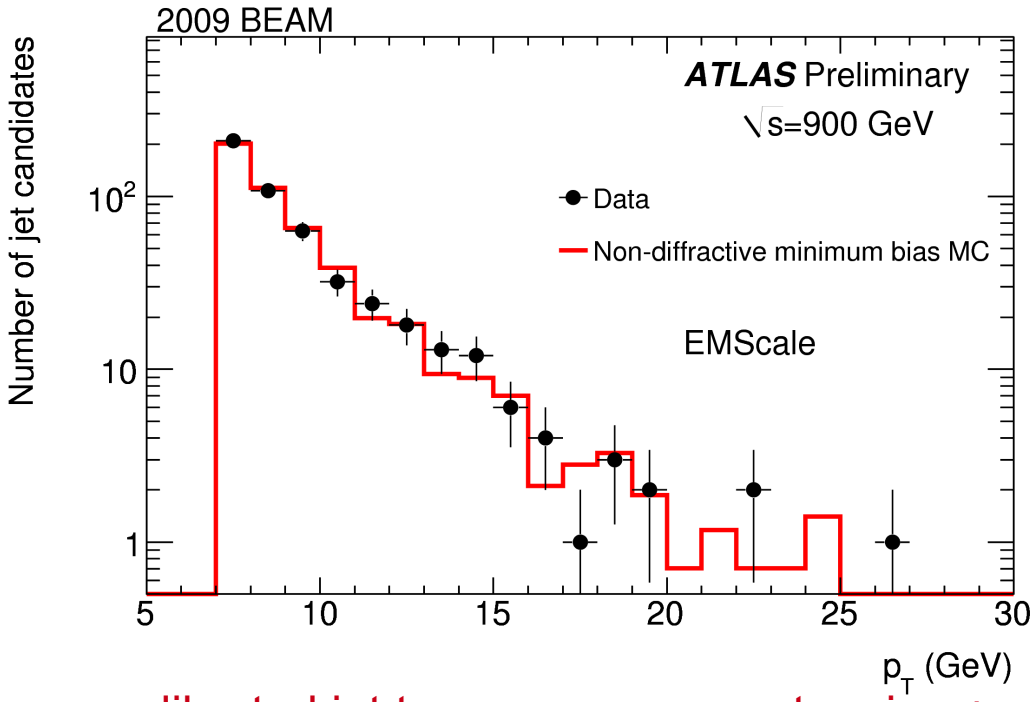
v_2 - elliptic flow

▲ Lee -Yang zeros method ■ event plane method ★ two-particle correlations



Jets in HI Collisions

- jet rates can be calculated with pQCD
- we expects ~20 million jets with E_T>50GeV during one month of A+A at nominal luminosity (integrated luminosity of 0.5nb^{-1})
- ATLAS is already measuring jets in p+p

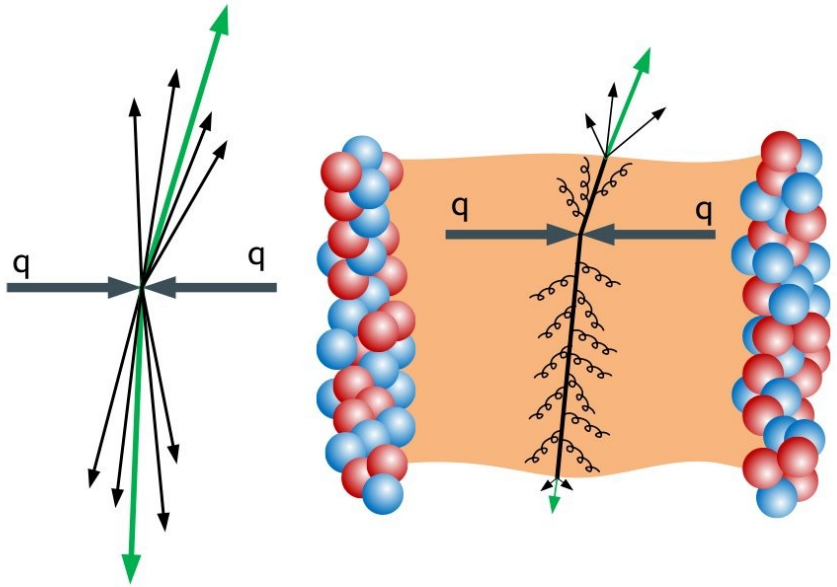


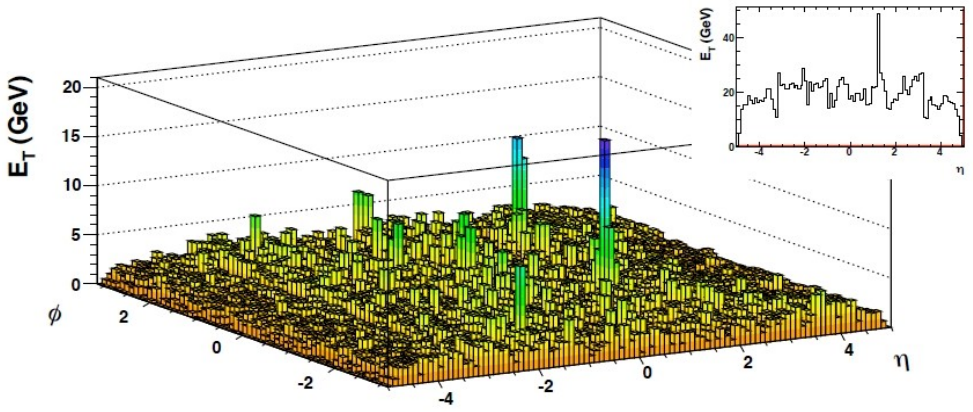
Distribution of the uncalibrated jet transverse momentum in p+p collisions at 900GeV

➡ jets are ideal for tomography of medium

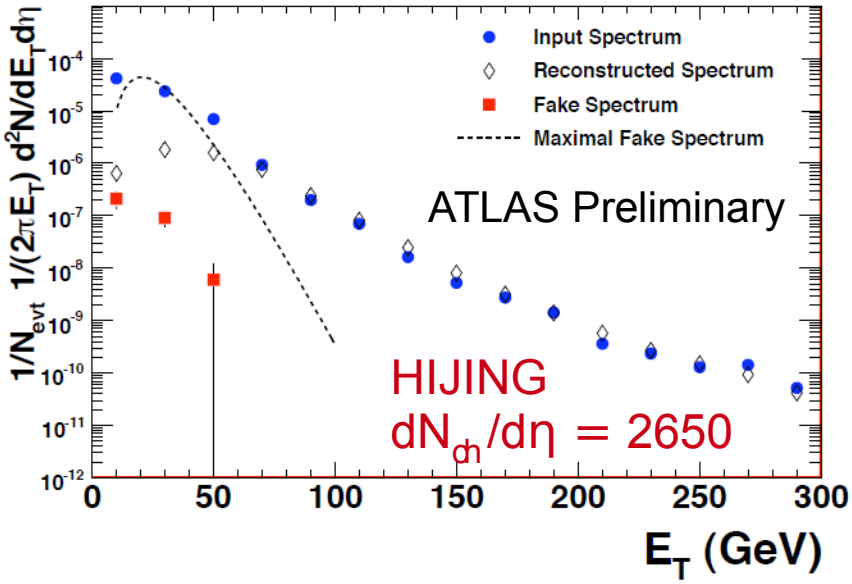
Jet Measurement

- partons are expected to lose energy in dense coloured medium
- ➡ jet quenching
- ➡ medium properties
- capabilities and performance for full jet reconstruction
- two reconstruction strategies: cone and anti-kT algorithm
- event-by-event background subtraction





Tower energies for a PYTHIA di-jet event embedded into a HIJING event



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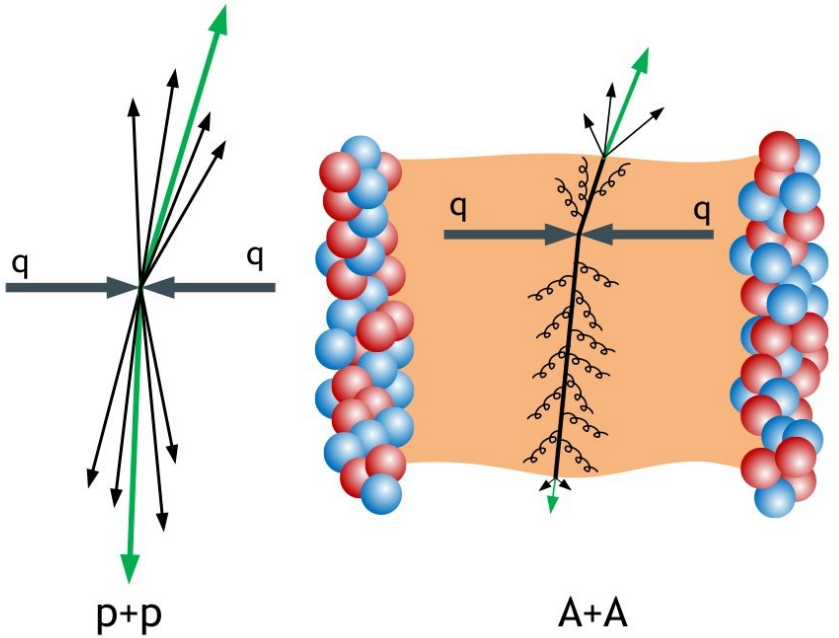
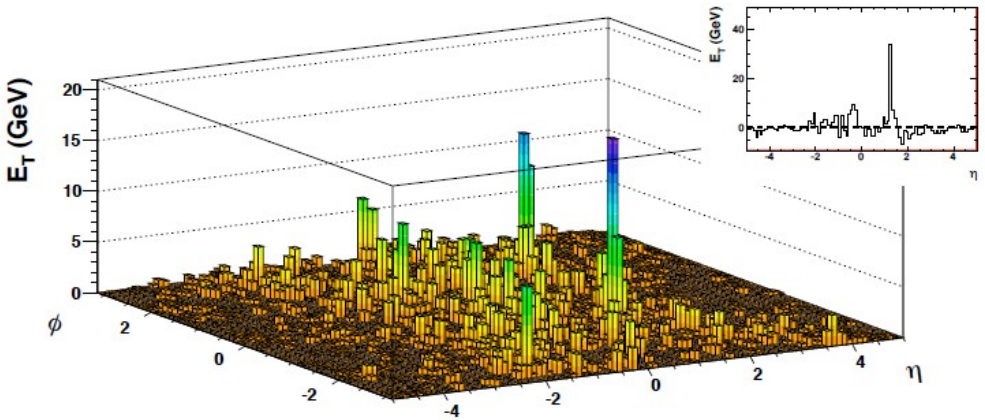
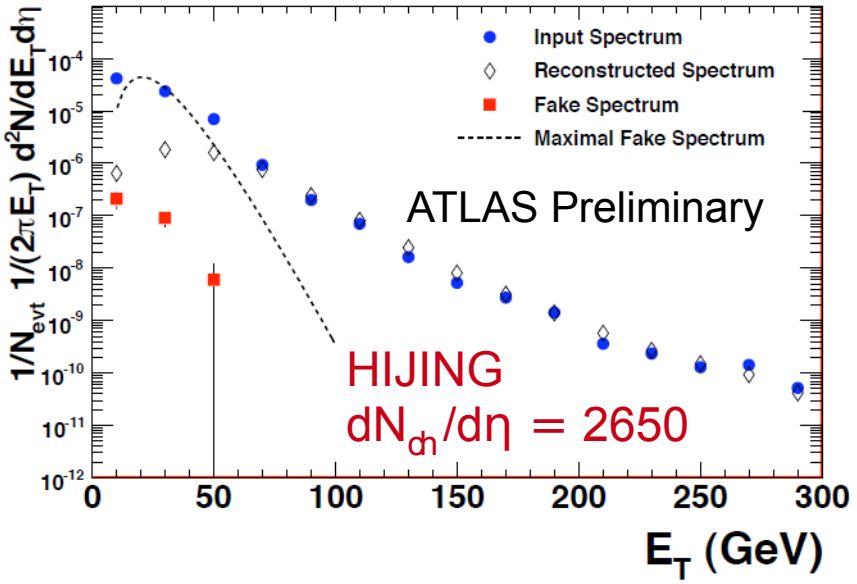




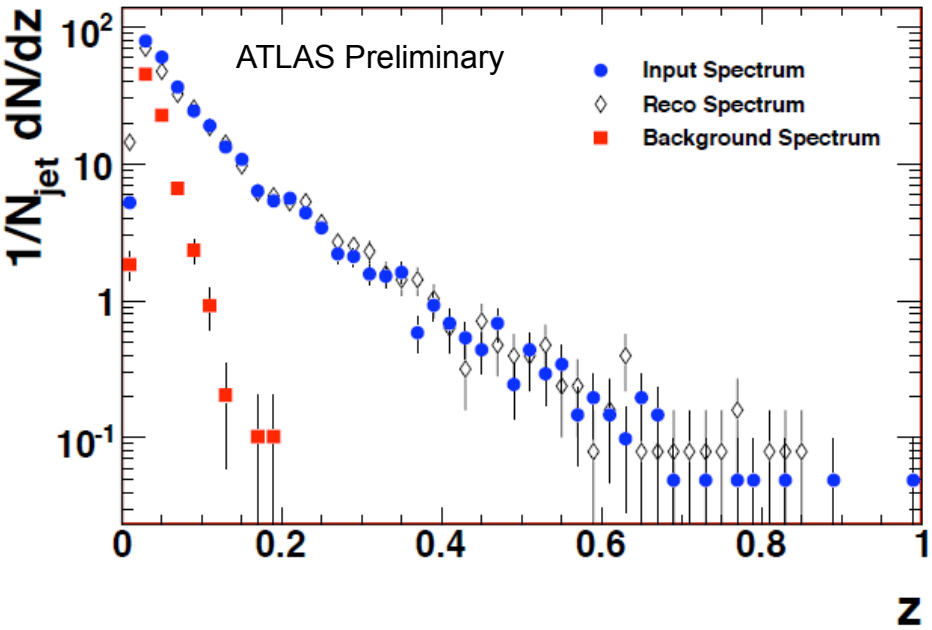
Tower energies in the same event after layer- and η-dependent subtraction



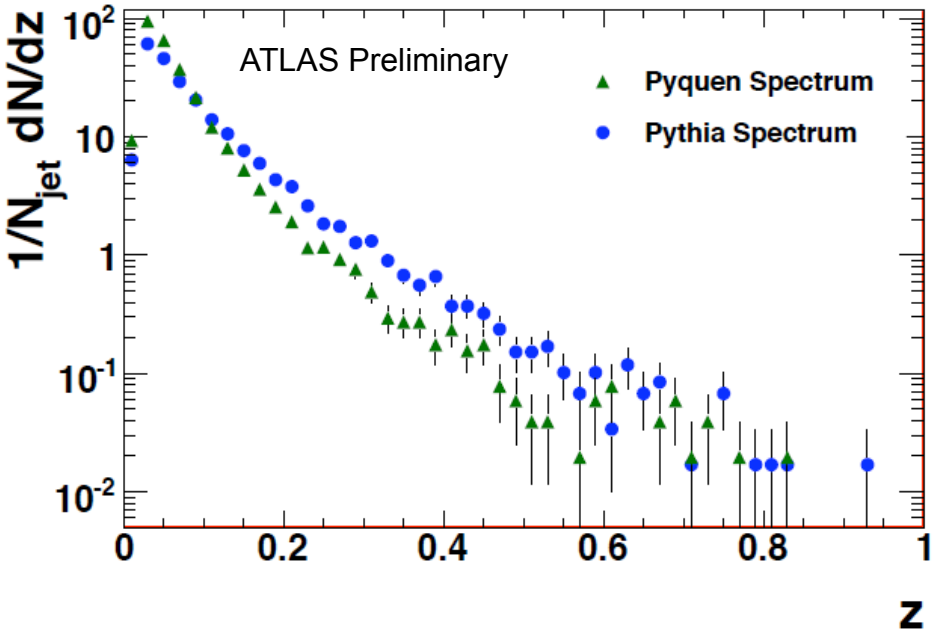
Jet Internal Structure

- sensitive to in-medium energy loss mechanisms
- fragmentation functions, D(z) and j_T distribution
- integral and differential jet shapes

$$z = \frac{\hat{p}_{jet} \cdot \vec{p}_{frag}}{|\vec{p}_{jet}|}$$



$dN_{ch}/d\eta$ = 2650 HIJING events with embedded PYTHIA jets

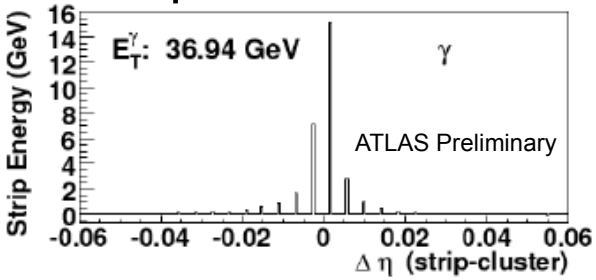


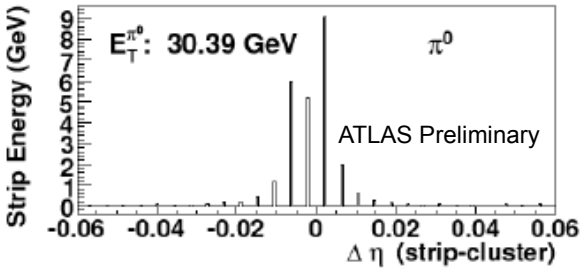
PYTHIA and PYQUEN jets not embedded in HI events

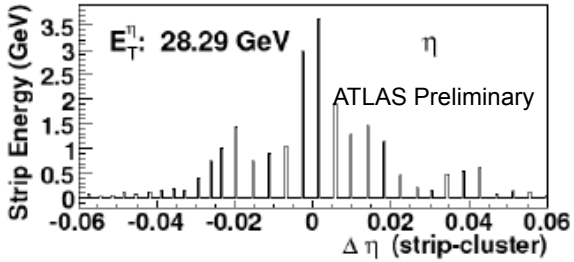
➡ ATLAS is sensitive to quenching effect if it is of the PYQUEN size

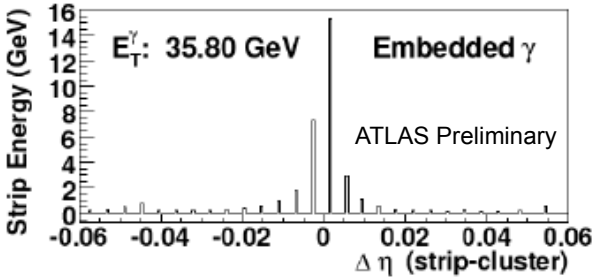
Photon Measurement

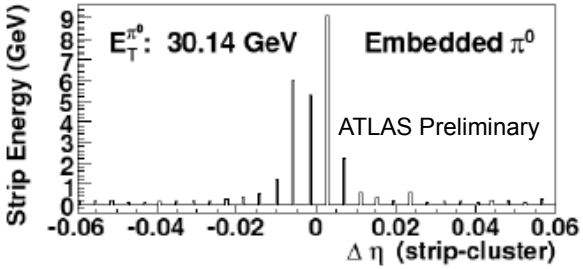
- unique resolution of ATLAS calorimetry for γ

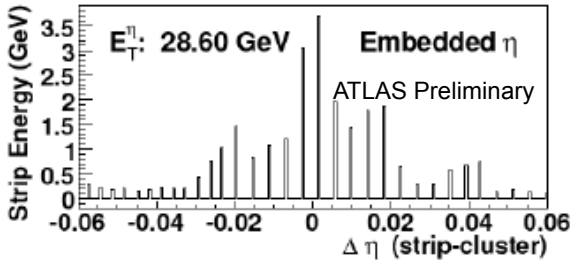


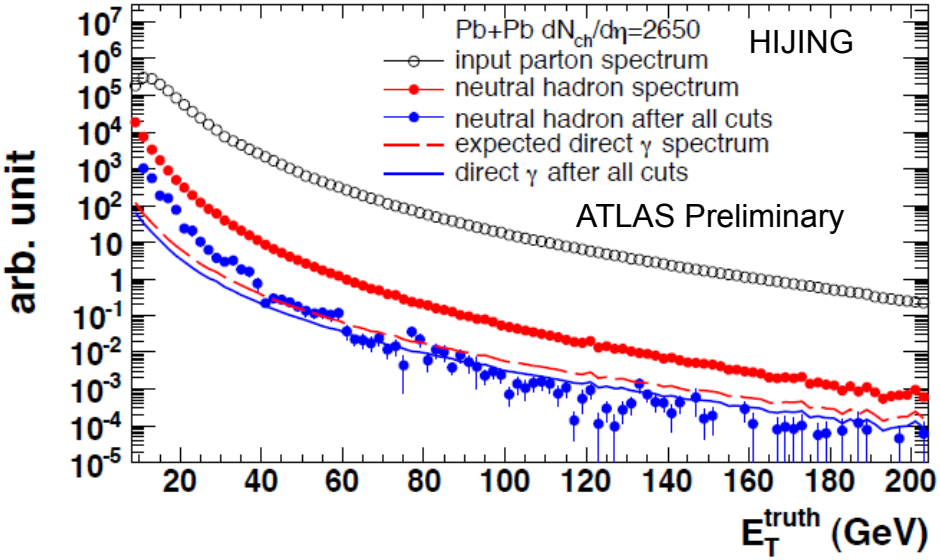








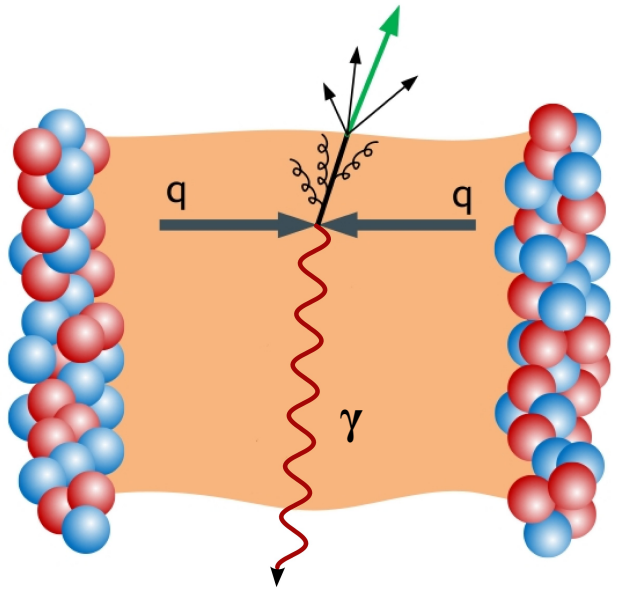


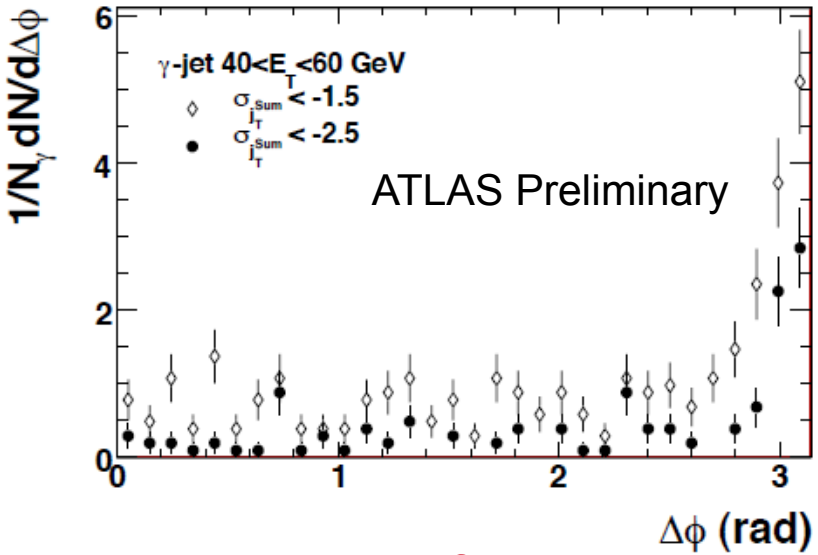


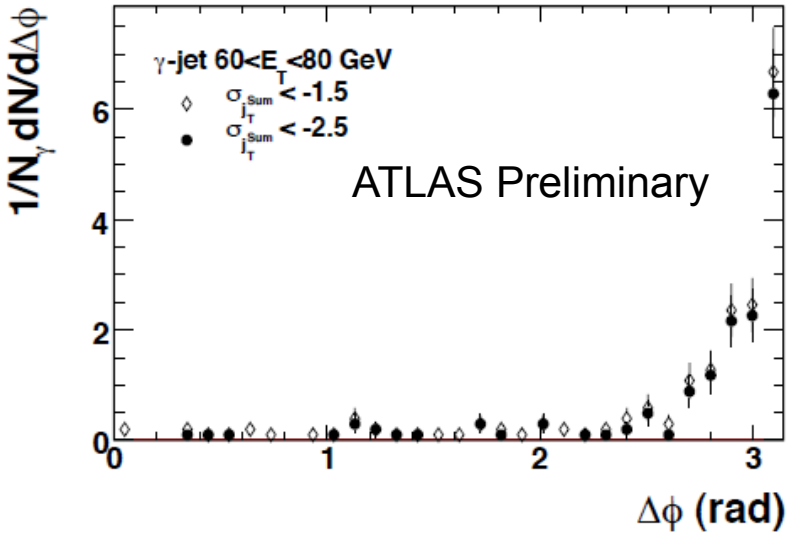
➡ photons well reconstructed after applying isolation cuts and shower pattern recognition also in HI collisions

γ-Jet Correlations

- medium is transparent for photons
- → photons are direct handle on jet energy loss process
- ~200k photons E_T> 30GeV in standard Pb+Pb run (0.5 nb^{-1})
- angular correlation enables fake rejection





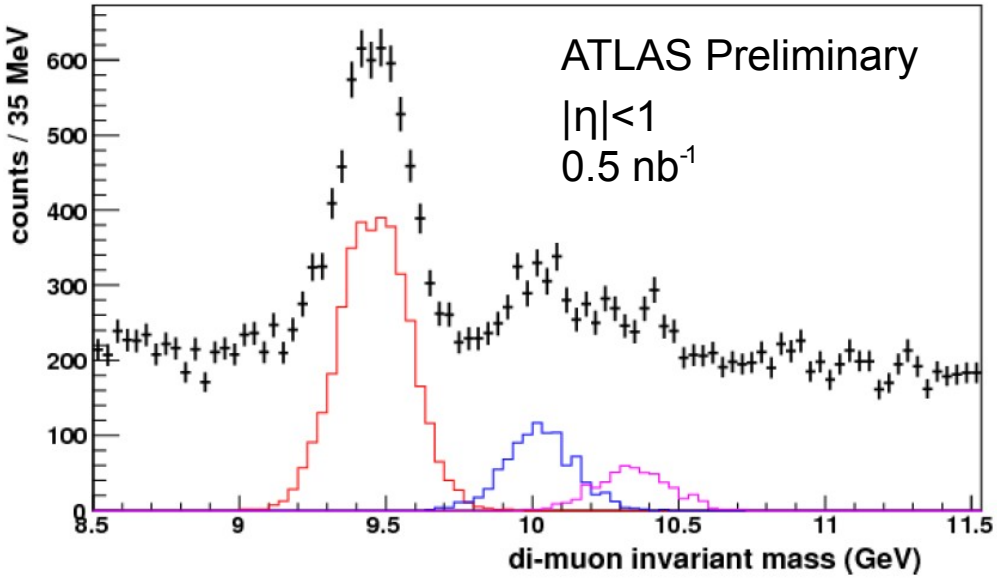


correlations of γ-jet pairs embedded into central HIJING Pb+Pb events

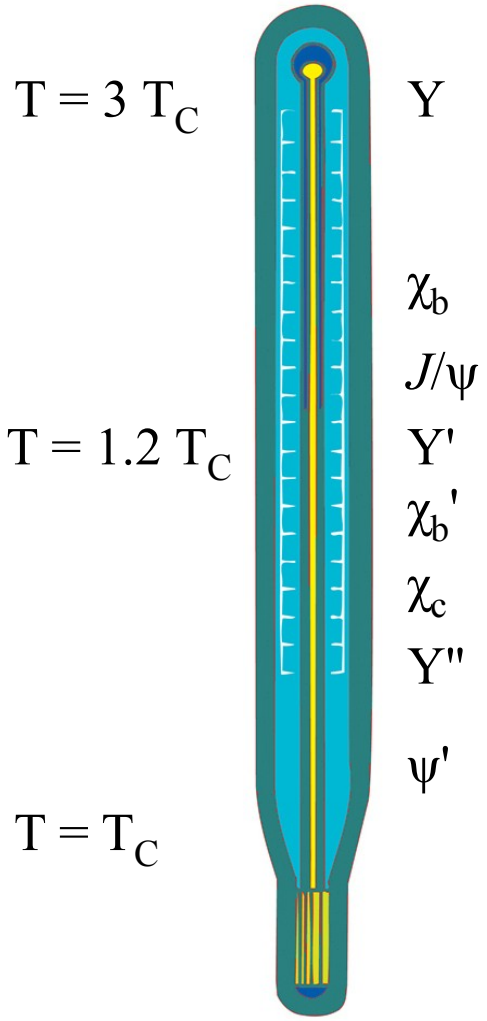
Quarkonia

- quarkonia test deconfinement of medium
- size of quarkonia > colour screening length
- dependence of colour screening length on T

➡ different quarkonium states disassociate at different plasma temperatures ➡ quarkonia suppression



- mass resolution ~120 MeV
- 100k J/ψ, 25k Y, 7k Y', 4k Y" for standard Pb+Pb run



Quarkonia as
a thermometer for QGP

Conclusions

- ATLAS has excellent capability to study HI physics especially due to the fine granularity of calorimeter and large coverage of all the subsystem
- detector will be calibrated and commissioned thanks to the p+p
- real data are in a good agreement with MC simulations from p+p collisions
- ATLAS has developed comprehensive physics program for HI collisions to measure many HI observables:
  - global observables
  - jets and photons
  - quarkonia
  - Z's
- we expect some results early in running, but have a multi-year program for hard probes