Preparations for the ATLAS Heavy Ion Physics Program at the LHC

Deepak Kar

IKTP, TU Dresden

On behalf of the ATLAS Collaboration

QCD

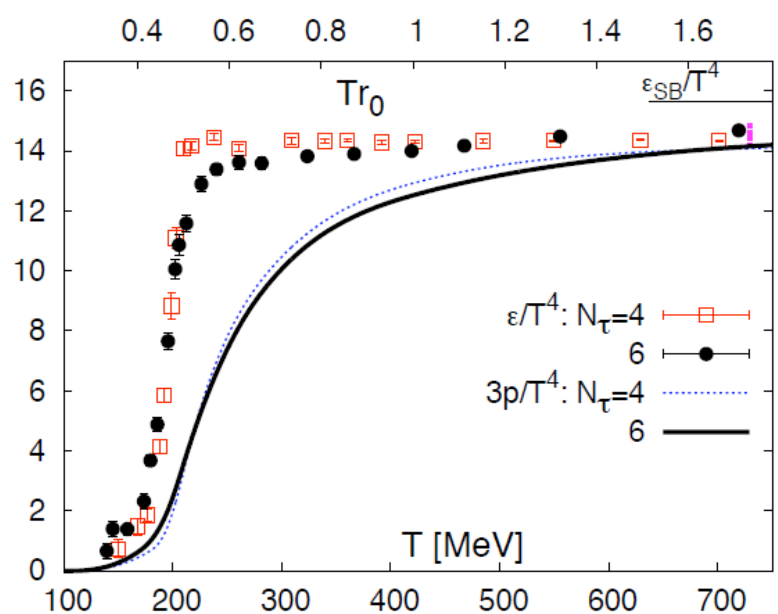
Hadronic phase: Bound states of quark and gluon

pp collisions

Partonic phase: Asymptotically free quark s

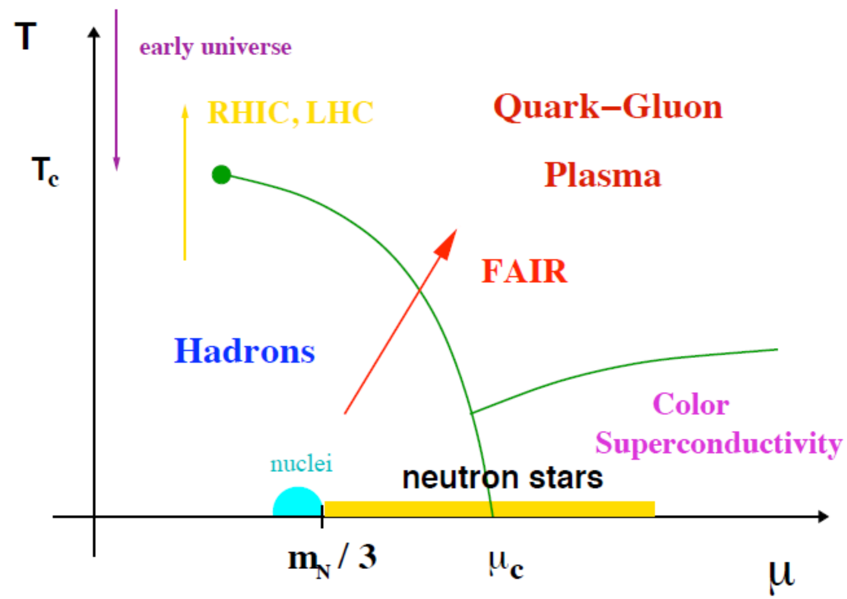
Heavy ion collisions

Deconfined QGP: distinct change in the number of degrees of freedom



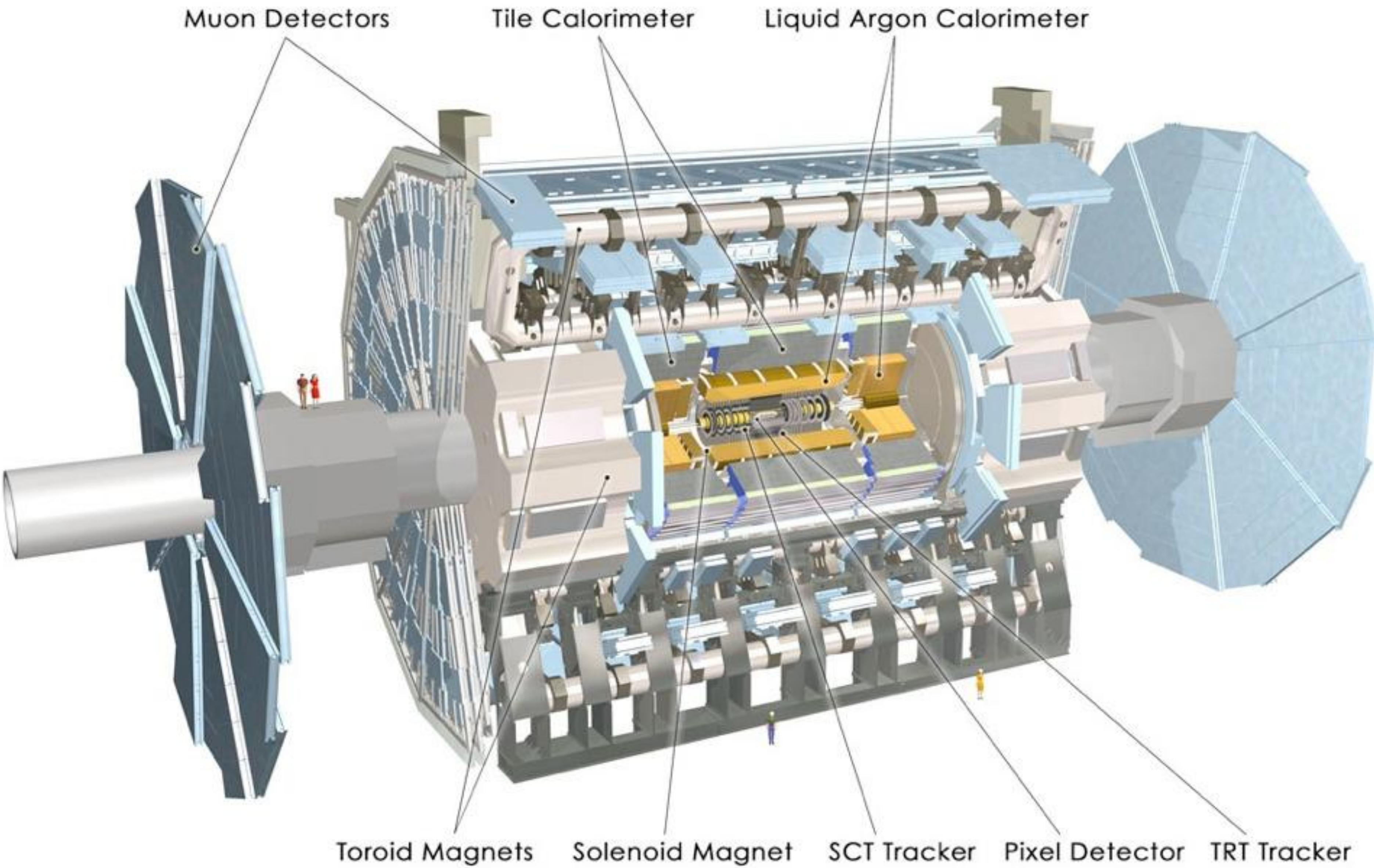
Why Important

- ➢ Probe of QCD
- ➢ Identify QGP
- ➢ Insight into early universe after big bang
- ➢ Novel phenomenon like CCG, jet quenching.

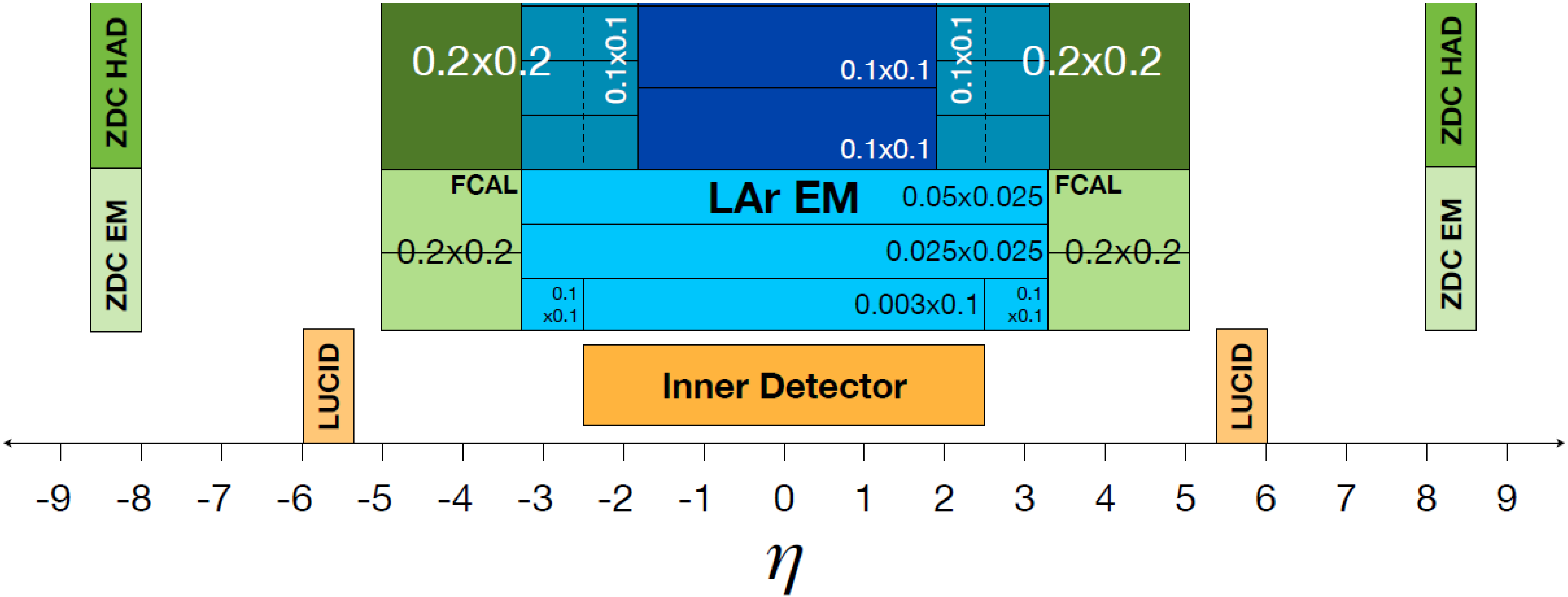


AGS 5 GeV	SPS 17 GeV	RHIC 200 GeV	LHC 5500 GeV
hadrons	hadrons J/Ψ γ,e,μ Excess in low mass dilelectron	hadrons J/Ψ γ,e,μ light jets	hadrons J/Ψ, Υ γ,e,μ,Z,W Light&heavy jets

Beyond RHIC: LHC will create a different QGP medium, more importantly higher rate and p_T for hard-probes.



ATLAS Detector at the LHC

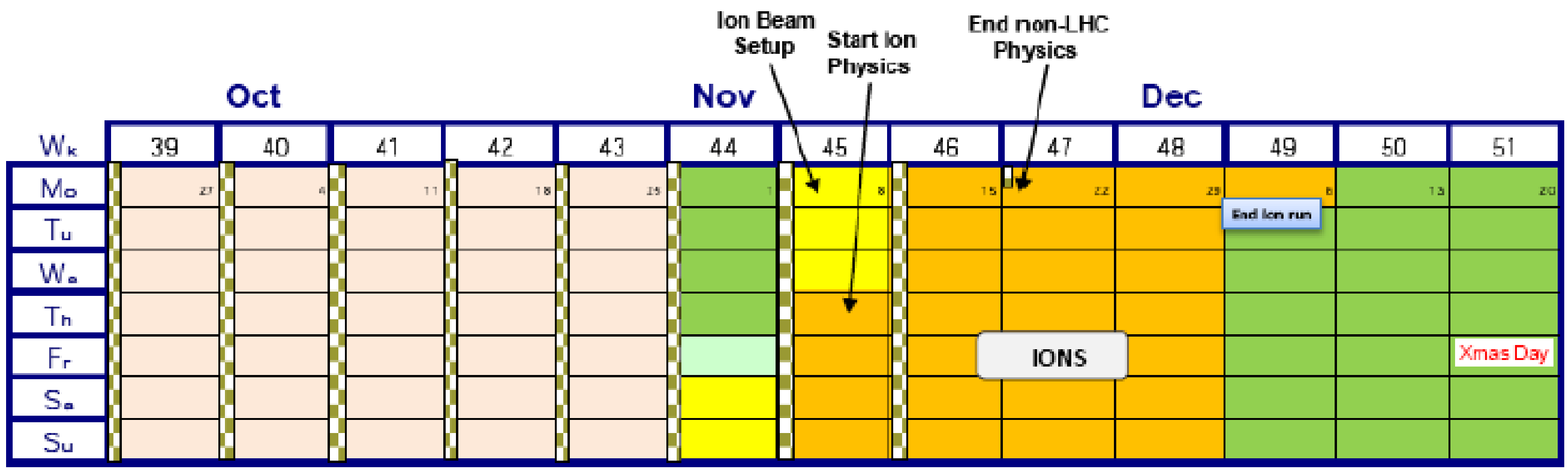


Acceptance far beyond RHIC detectors in particular with EM & hadronic calorimetry.

Two ZDCs are installed and currently running in p+p

ZDC: high-efficiency, low-background trigger for Pb+Pb events, as a means to characterize the centrality and determine the orientation of the reaction plane in nuclear collisions, and potentially to measure the absolute luminosity via coincidence measurements. 3

Schedule 15/8/2010:



Technical Stop
Recommissoning with beam
SPS et al - physics
Ion run
Ion setup

Setup: Nov. 6 – 4.5 + (1) days
Physics: Nov.11 – 4 weeks
End: Dec.6

LHC: Pb + Pb at $\sqrt{s_{NN}}$= 2.76 TeV

Expect to collect ~3 μb^{-1} of integrated luminosity (~20 Mevents)

November 15th to December 7th

Machine parameters: Ion Beam at 3.5 Z·TeV

$^{208}Pb^{82+} \Rightarrow \quad \Leftarrow {}^{208}Pb^{82+}$

		Early (2010/11)	Nominal
$\sqrt{s_{NN}}$ (per colliding nucleon pair)	TeV	2.76	5.5
Number of bunches		62	592
Bunch spacing	ns	1350	99.8
β^*	m	$2 \rightarrow 3.5$	0.5
Pb ions/bunch		7×10^7	7×10^7
Transverse norm. emittance	μm	1.5	1.5
Initial Luminosity (L_0)	$cm^{-2}s^{-1}$	$(1.25 \rightarrow 0.7) \times 10^{25}$	10^{27}
Stored energy (W)	MJ	0.2	3.8
Luminosity half life (1,2,3 expts.)	h	τ_{IBS}=7-30	8, 4.5, 3

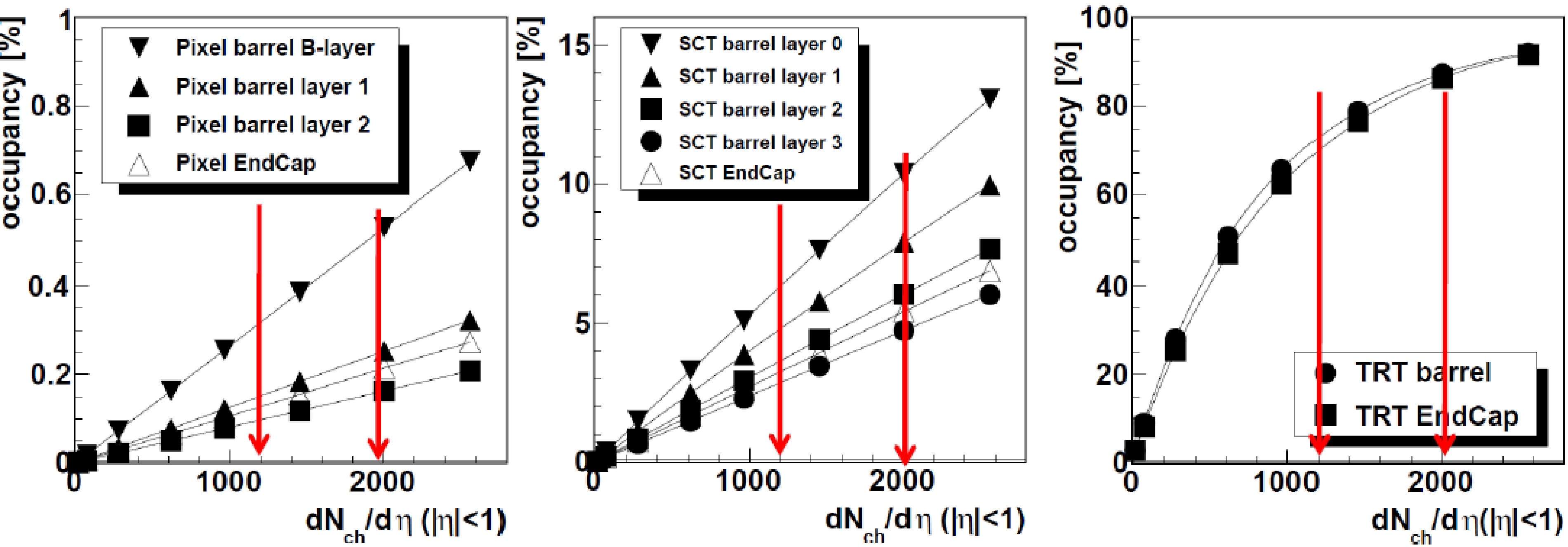
J. Jowett, 6/09/2010

Interaction rate: 50 – 100 Hz

2010 integrated luminosity: 1 – 3 μb^{-1}

~10^7 - 10^8 collision events/month

ATLAS Detector Condition

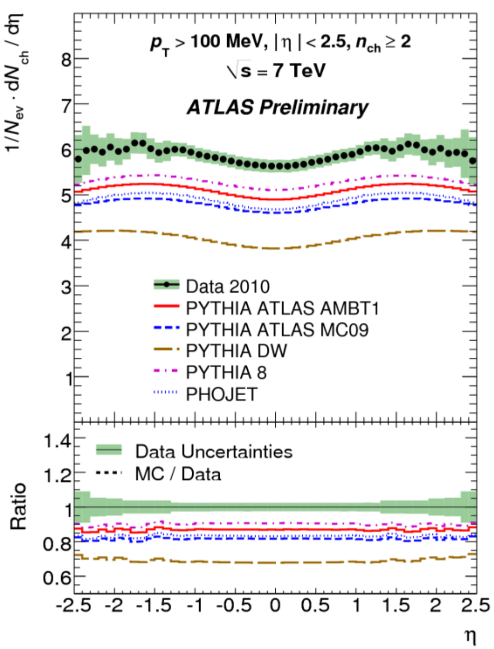


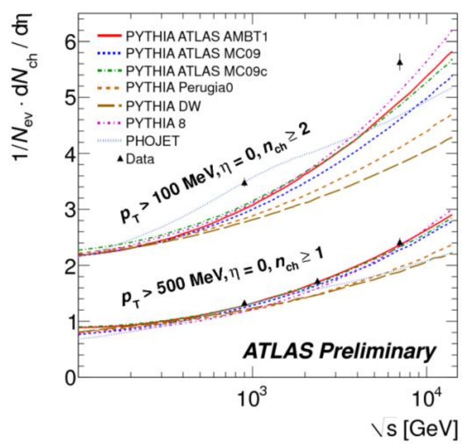
Arrows indicate expected range in mid-rapidity multiplicities for central Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV .
(right arrows – HIJING simulations; left arrows – extrapolation of lower energy data).

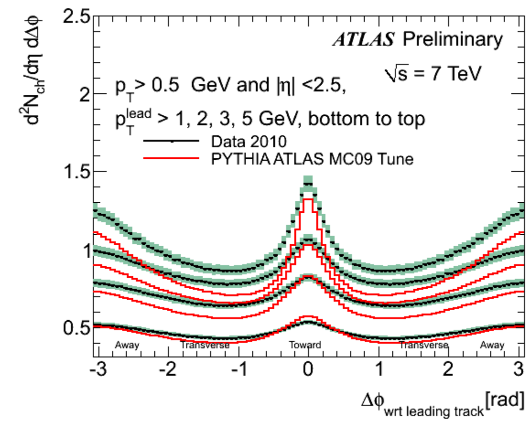
Pixel and SCT occupancies manageable even in central Pb+Pb collisions.

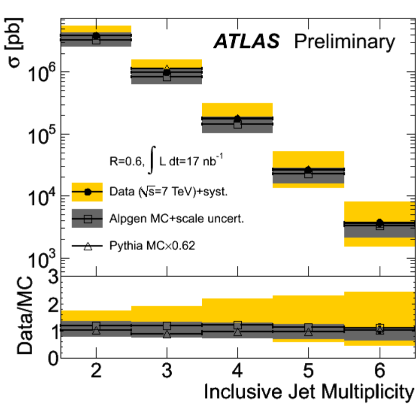
Early Measurements

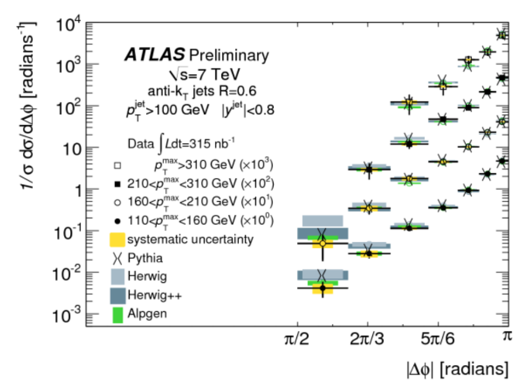
Most of these techniques have already been applied to p+p MC and data.





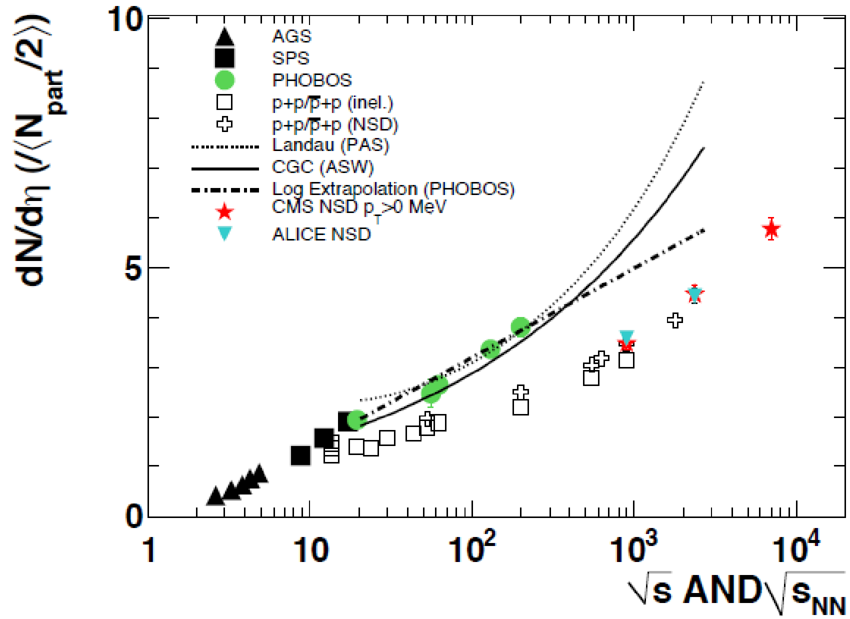






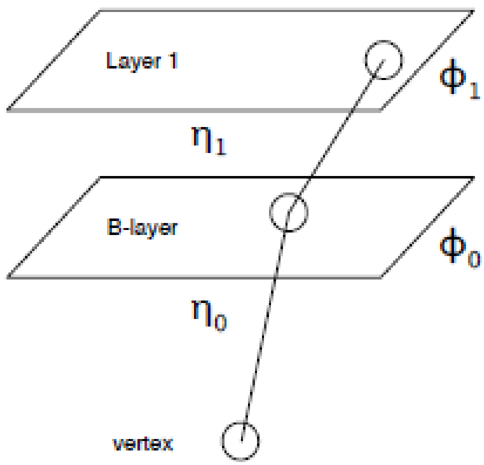
Multiplicity: $dN_{ch}/d\eta$

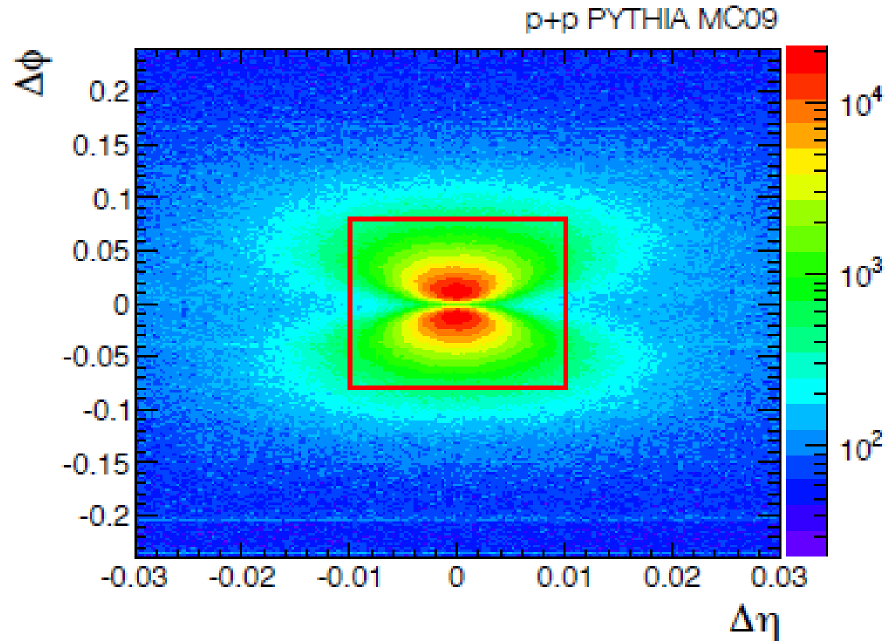
- From pixel two point tracklets
- From tracks (pixel/SCT) with $p_T > 1$ GeV
- From hit counting



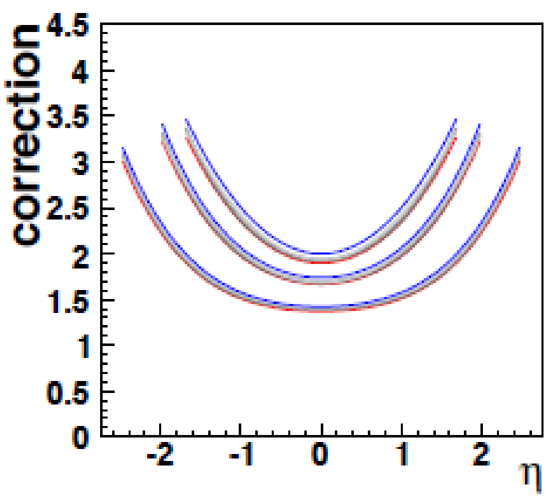
•Multiplicity program coming into focus with release of measurements from all three LHC experiments.
•Important information on initial conditions.
•Allows us to consider both the role of models and empirical scaling “rules” (e.g. factor of 1.5 and log scaling): both suggest densities of $dN_{ch}/d\eta$~1200 @ 2.76 TeV.

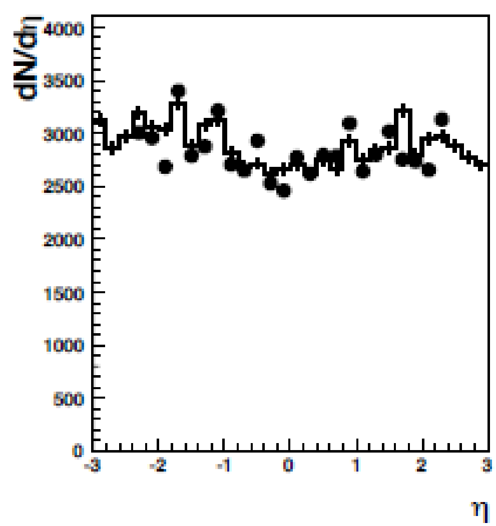
Tracklet counting in pixels

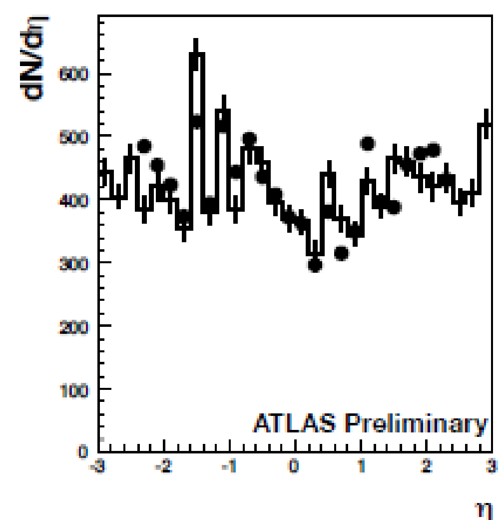




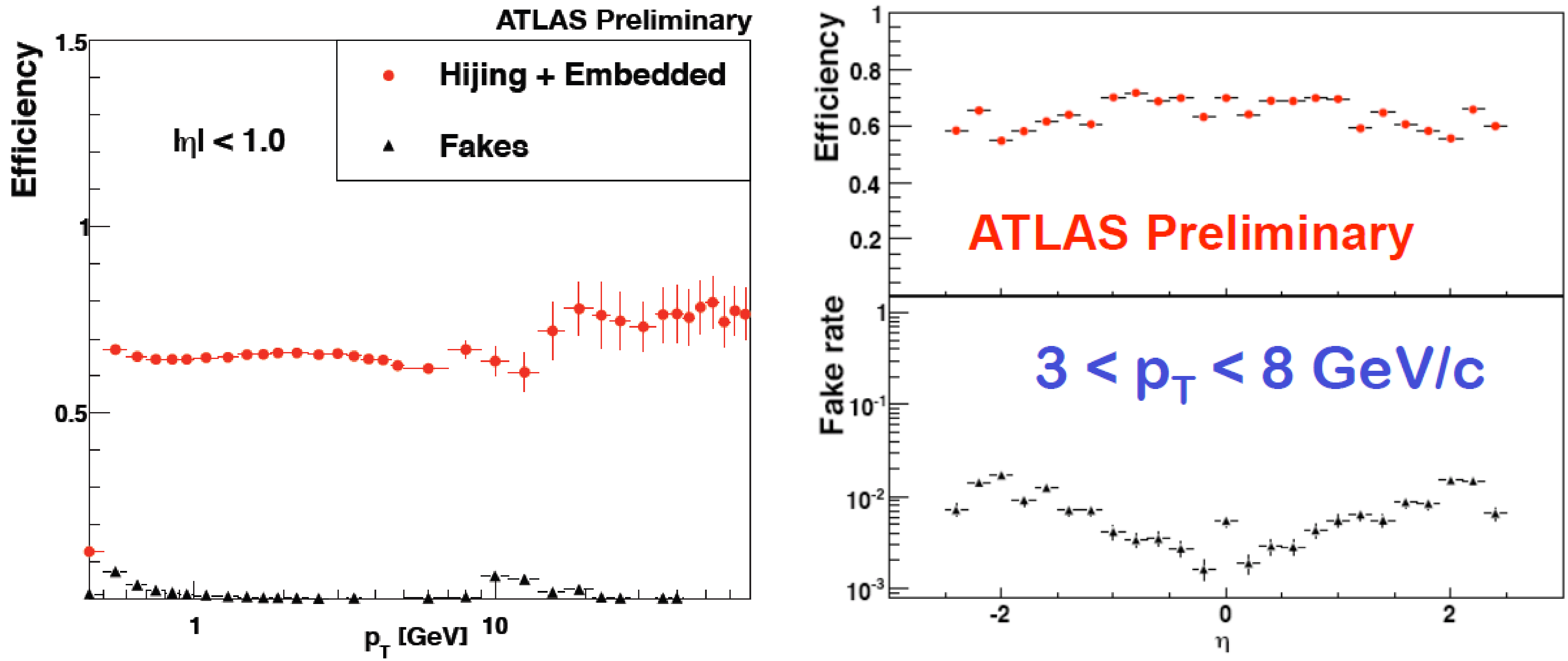
Hit counting in pixels







Tracking Performance



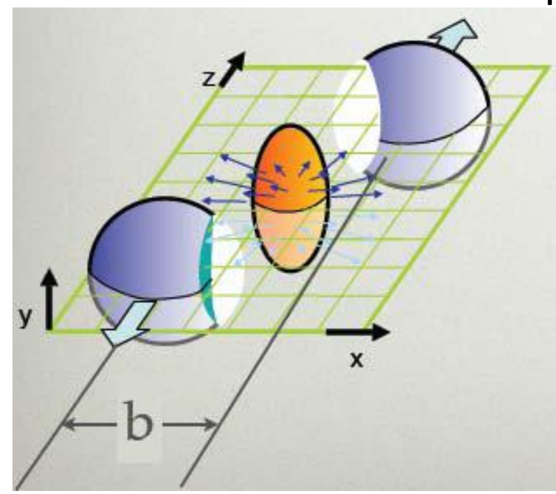
- Use matching to calorimeter to control fake rates at very high p_T.
- Uniform tracking efficiency vs p_T, η , crucial for controlling systematics on jet fragmentation measurements.

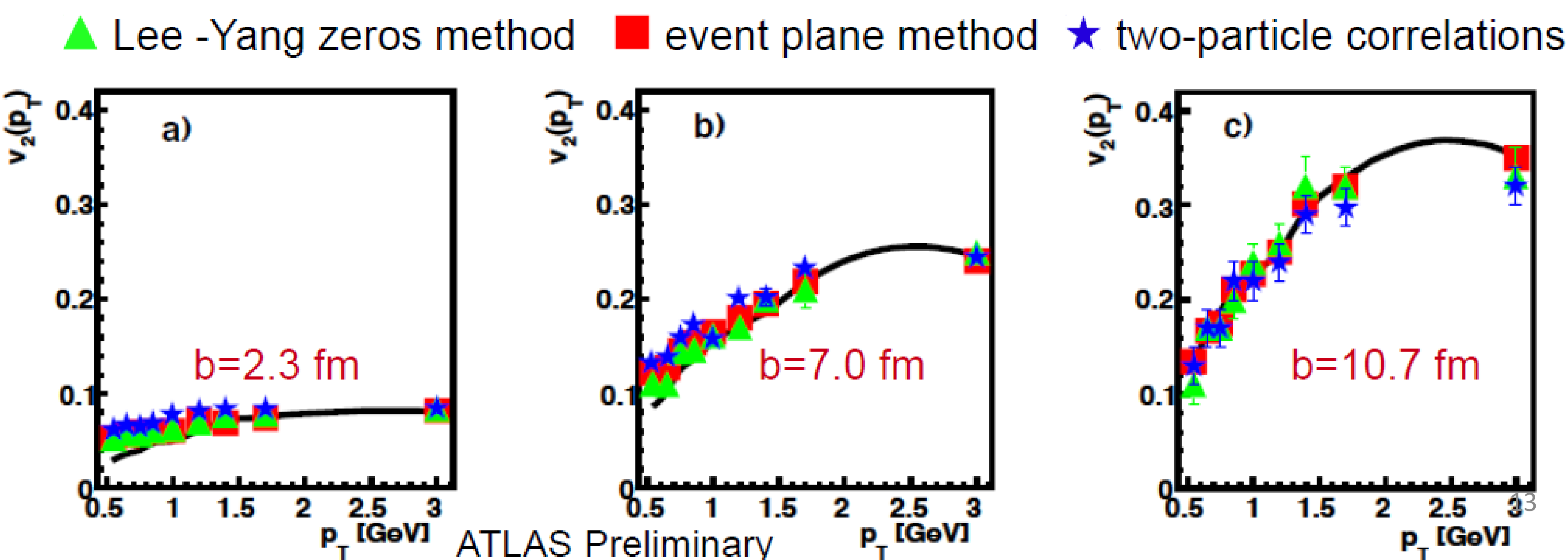
Elliptic Flow Measurements

Reaction plane from tracks, EMCal, HCAL, FCAL

Collective motion of the system driven by pressure gradients converts initial spatial anisotropy into final azimuthal anisotropy

$$\frac{dN}{d\varphi} = \frac{1}{2\pi}(1 + 2v_1 \cos\varphi + 2v_2 \cos 2\varphi + \ldots)$$





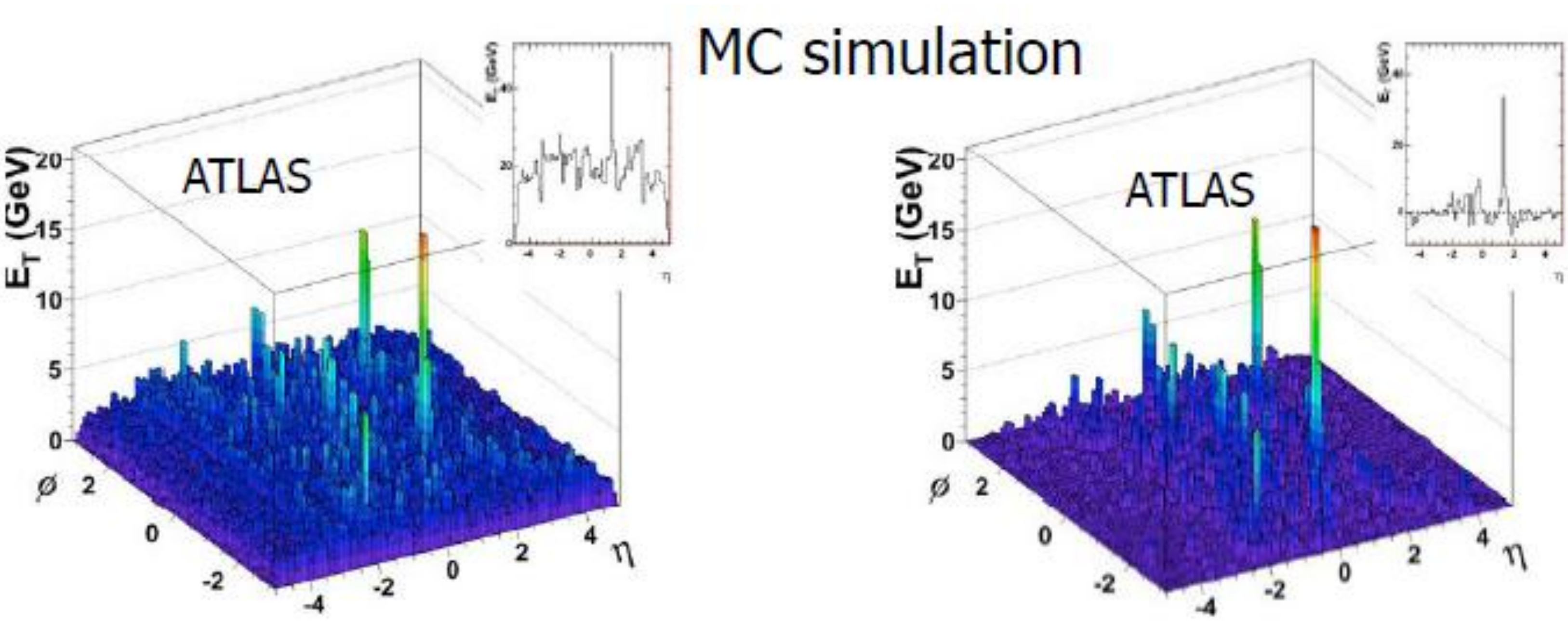
Initial Jet Studies

About 10k jets with E_T> 100 GeV can be expected

High-p_T partons probe the dense colored medium:

- Partons are expected to lose energy in dense coloured medium
- Jet quenching observed at RHIC.
- Medium properties (in-medium jet modifications are expected)

Jet Reconstruction

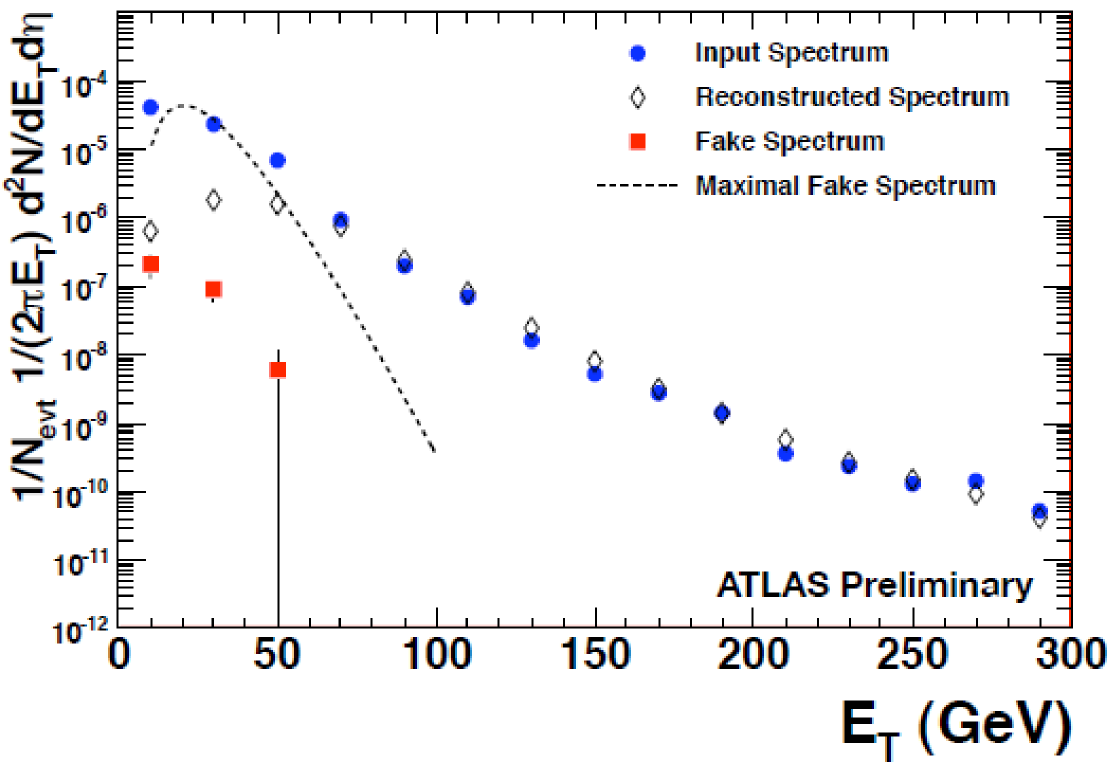


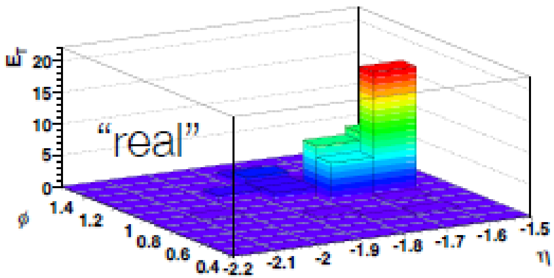
Full HIJING event with embedded PYTHIA jets

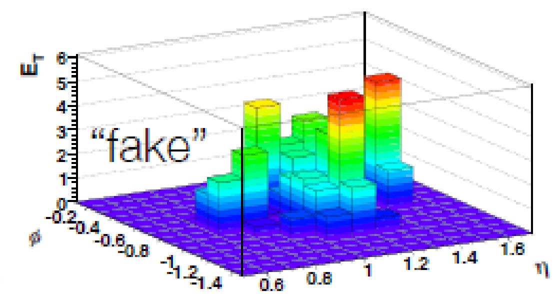
After layer-by-layer removal of background in η bins, excluding jet regions

Then apply "standard" jet reconstruction algorithms (cone, k_T, anti-k_T) in R=0.4,0.6 and reject fake jets.

Jet Reconstruction



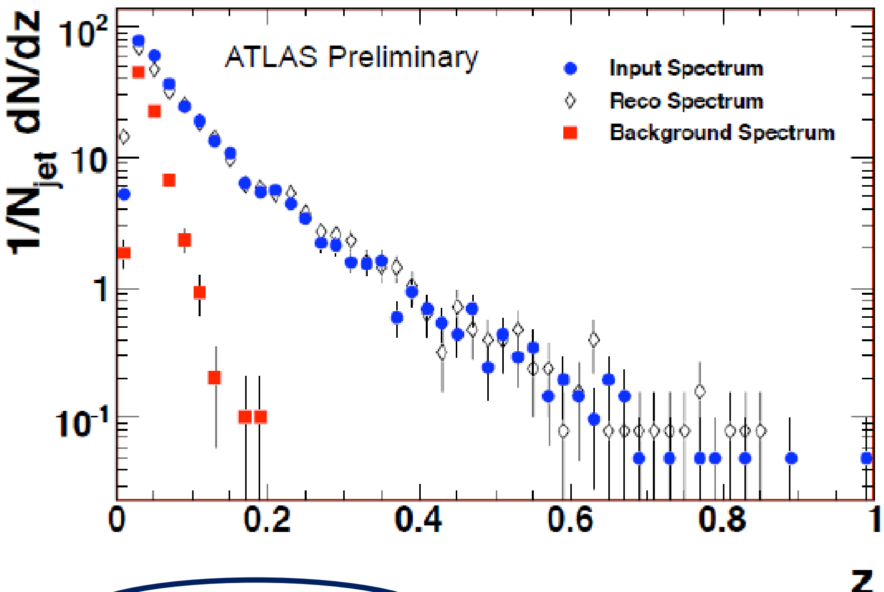


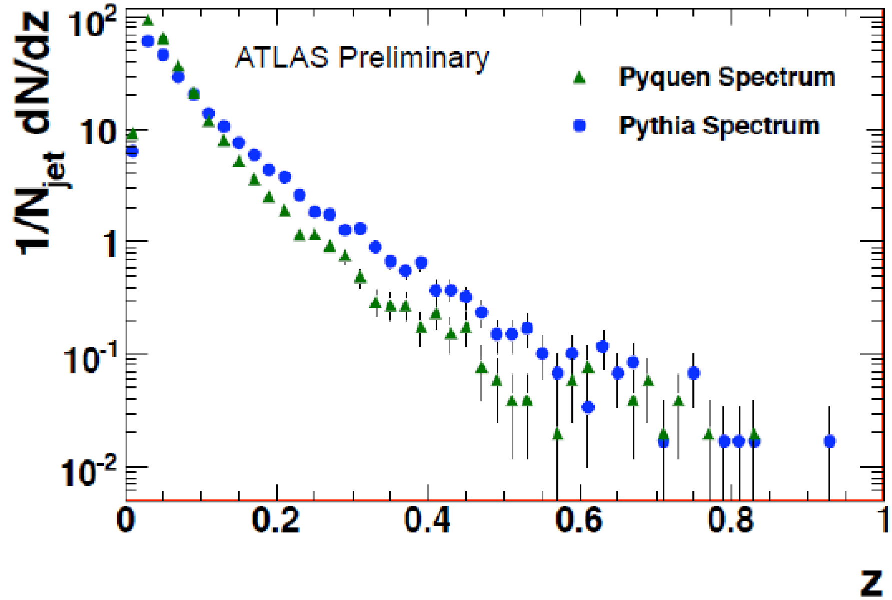


- Reconstruction of jet energy spectrum (before unfolding)
- Clearly some efficiency loss below 80 GeV
- Fake jets (in HIJING) are non trivial until $E_T \approx 80$-100 GeV

Jet Properties

Fragmentation Function





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

PYTHIA and PYQUEN jets not embedded in HI events

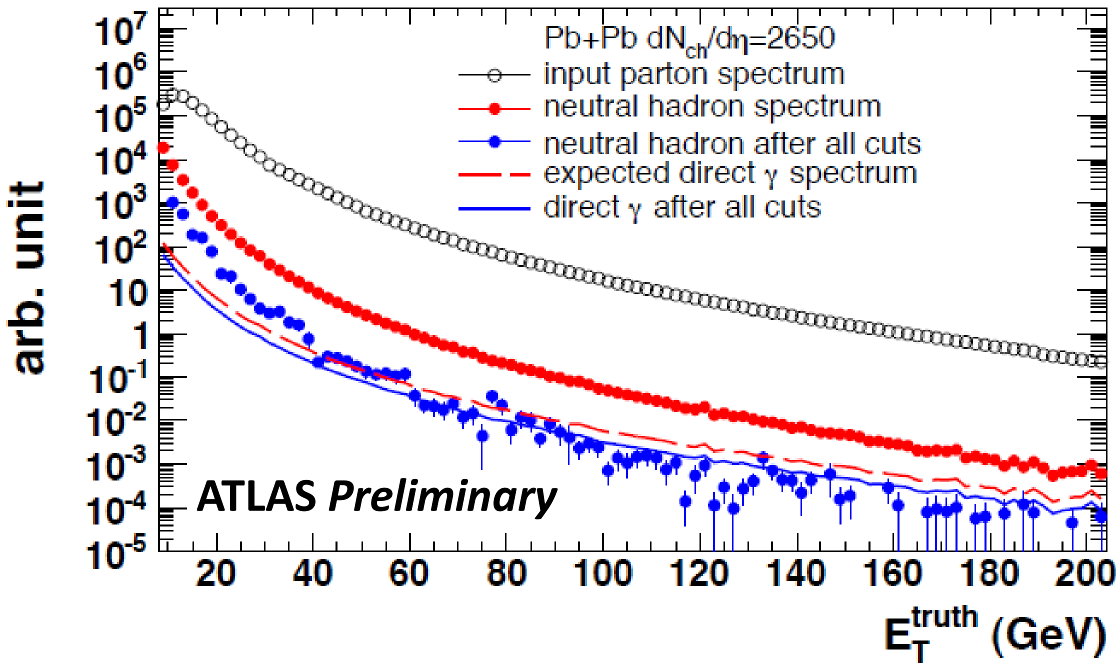
ATLAS is sensitive to quenching effect if it is of the PYQUEN size.

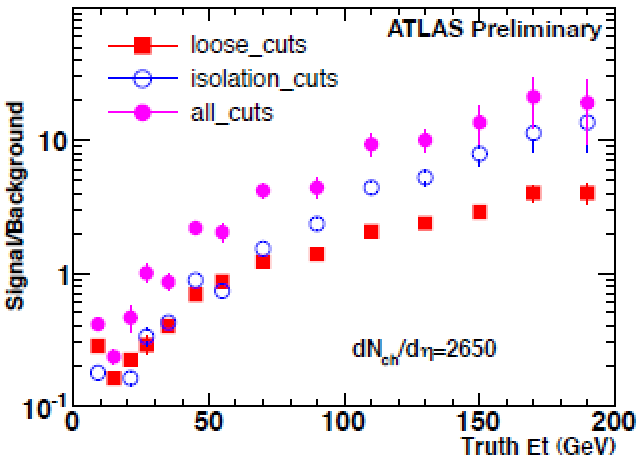
Also studies of integral and differential jet shapes.

Longer Term Plans

Post-shutdown, hard probes will become the primary focus, Quarkonia, Z, and photon physics will be used to probe the microscopic properties of the medium.

Photon Measurement





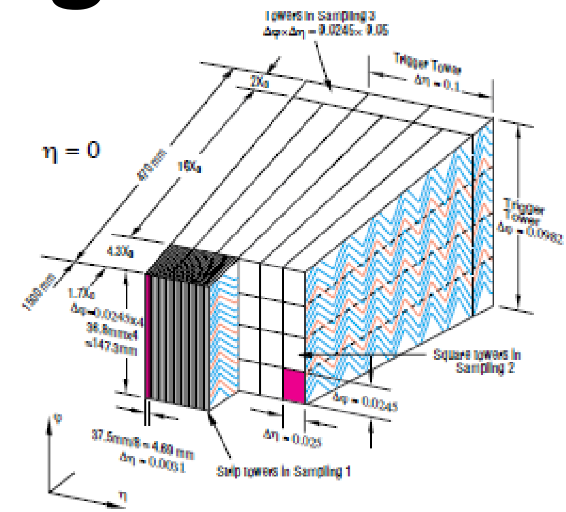
$R_{AA}=1/5$

•Unique resolution of ATLAS calorimetry for γ.

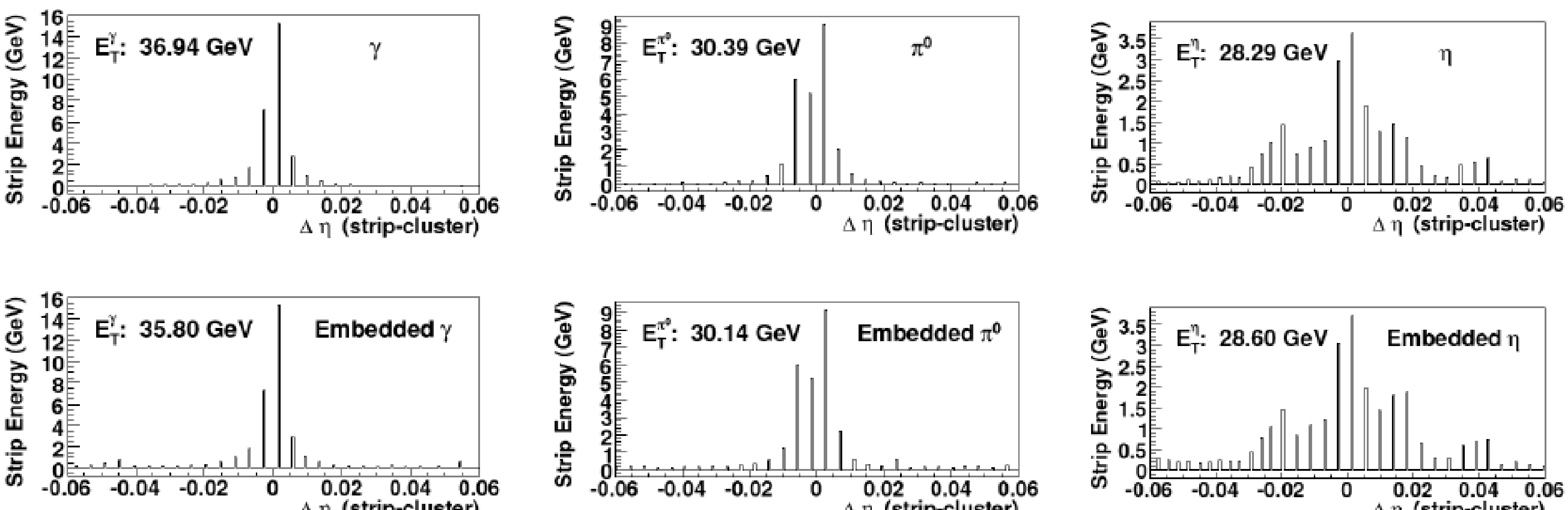
•Detailed study performed on shower shape and isolation cuts to optimize efficiency and purity - photons well reconstructed after applying isolation cuts and shower pattern recognition. (S/B > 1 for E_{gamma}=30 GeV assuming a factor of 5 suppression for hadrons).

Photon Tagging

Fine segmentation of 1st EM layer allows detailed study of shower shape

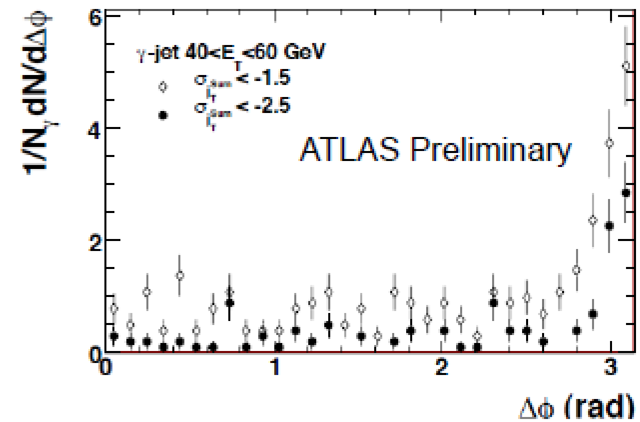


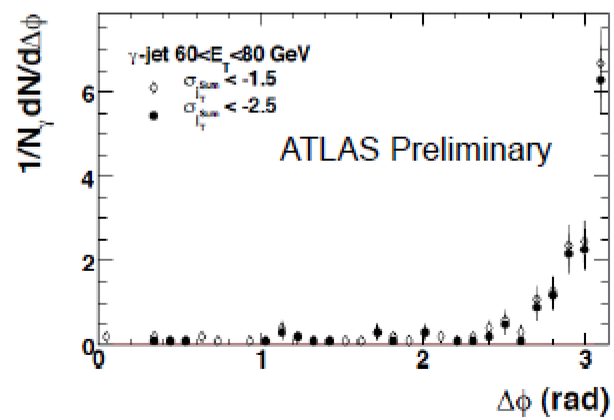
Clear differences between γ,π^0,η not affected by embedding into Pb+Pb (full energy in these simulations)



γ-Jet Correlations

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

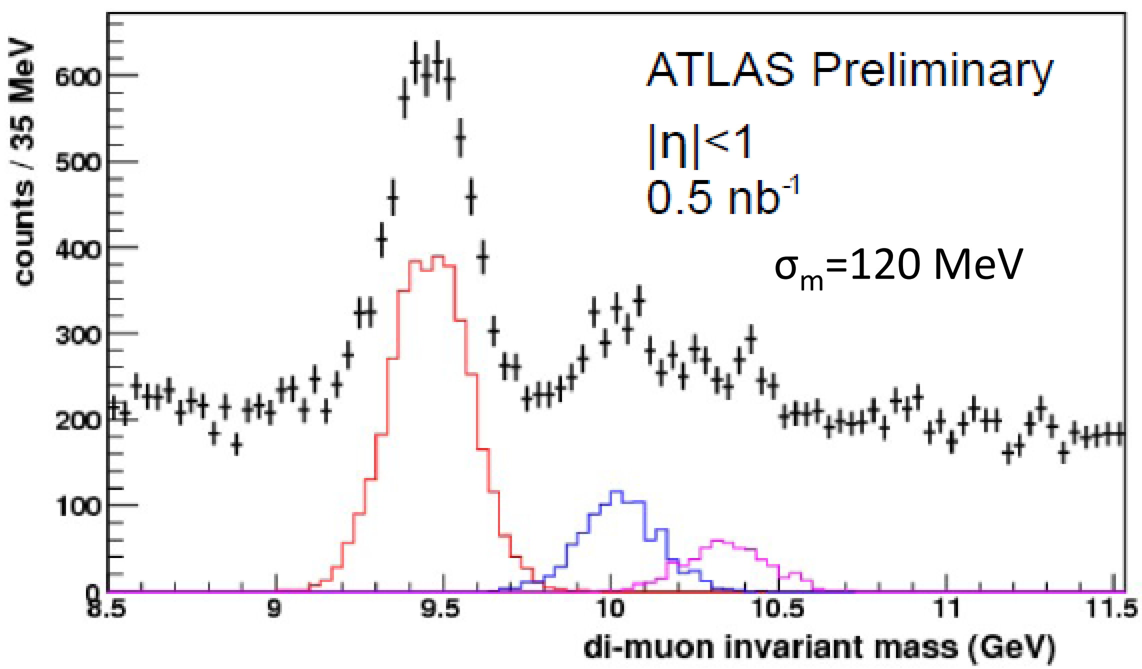


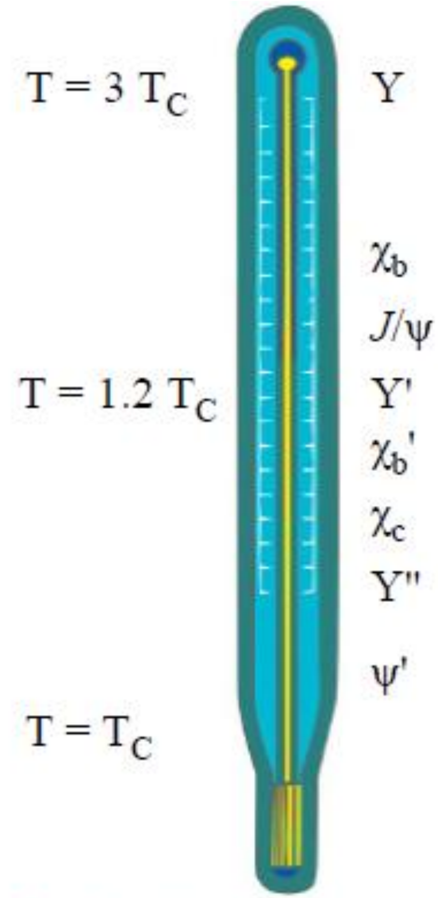


correlations of γ-jet pairs embedded into central HIJING Pb+Pb events

Quarkonia

• Test of deconfinement of medium.
• Different quarkonium states disassociate at different plasma temperatures (quarkonia suppression)



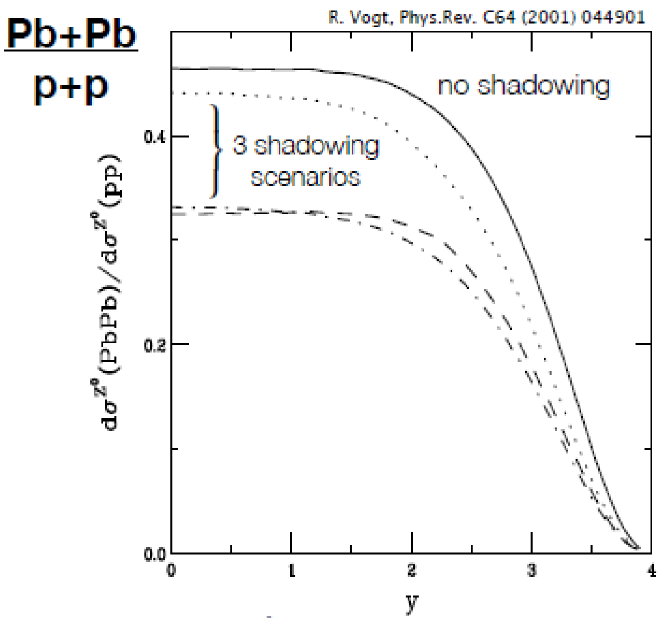


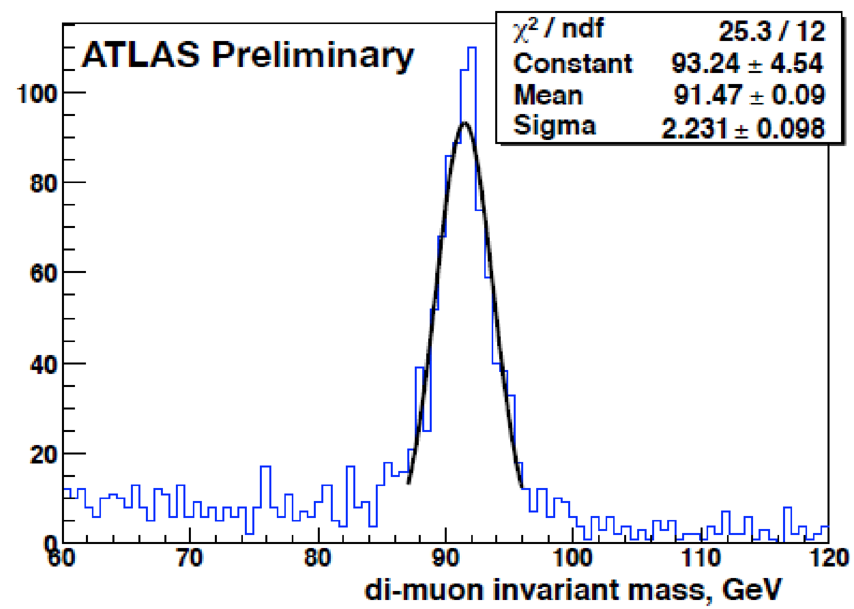
Quarkonia as a thermometer for QGP

In one month at nominal luminosity & energy, expect to measure all three upsilon states

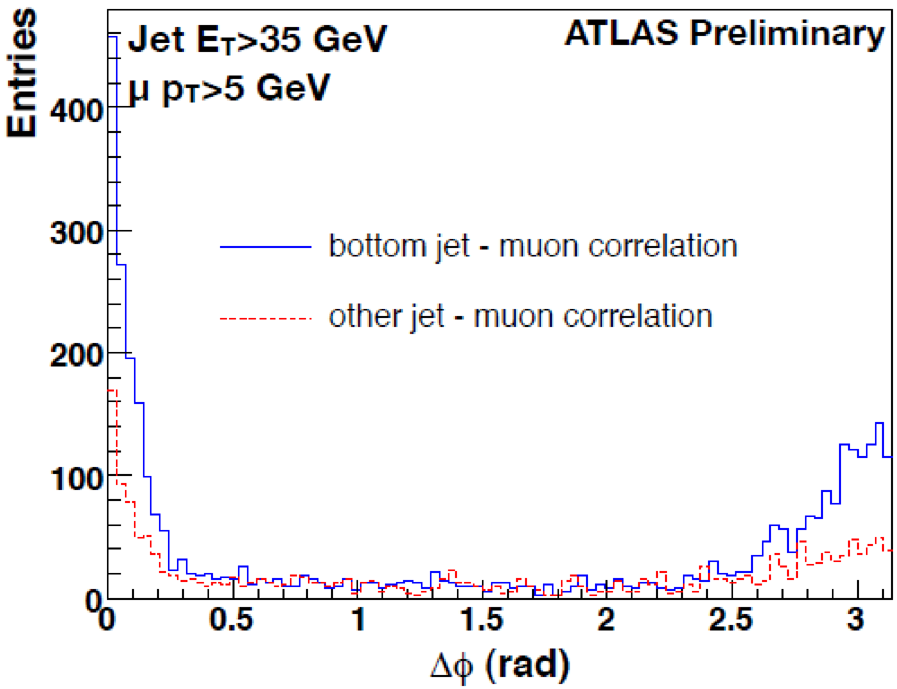
Z Reconstruction

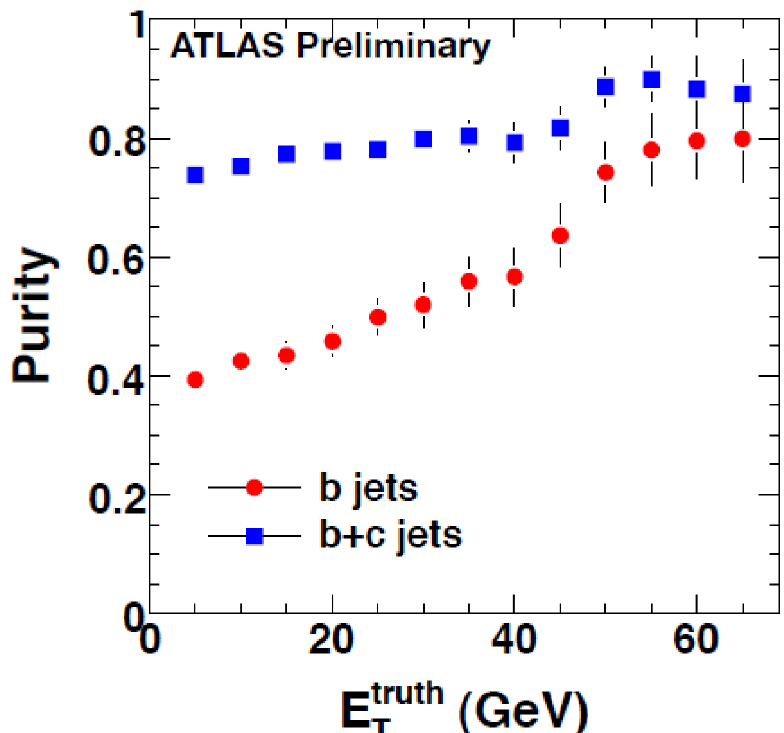
- Z bosons provide a nearly background-free measurement of nuclear PDFs, e.g. shadowing.
- Mass resolution of reconstructed Z similar to p+p .
- Minimal effect from embedding into HIJING background .
- *Expect ~8k Zs in 0.5nb^{-1} at 5.5.*





Heavy flavor jets: jet-μ correlation





- Clear jet-muon correlation
- Purity increases with jet E_T

Conclusions and Outlook

- ATLAS detector is calibrated and commissioned thanks to the p+p. Early ATLAS results show excellent performance of detector.
- Simulations with Pb+Pb find ATLAS to be a powerful tool for measuring jets, muons, and particularly photons.
- ATLAS is ready for global and jet physics with the early Pb+Pb data at the LHC …

Some results expected early in running, but we have a multi-year program for hard probes:

- This year: Measurements to probe bulk properties –multiplicity, flow, spectra.
- High p_T jets and correlations to probe dynamic properties of QGP.
- Upsilon and J/psi to probe Debye screening.
- Low x physics to probe the initial conditions.