Recent heavy ion results from ATLAS experiment

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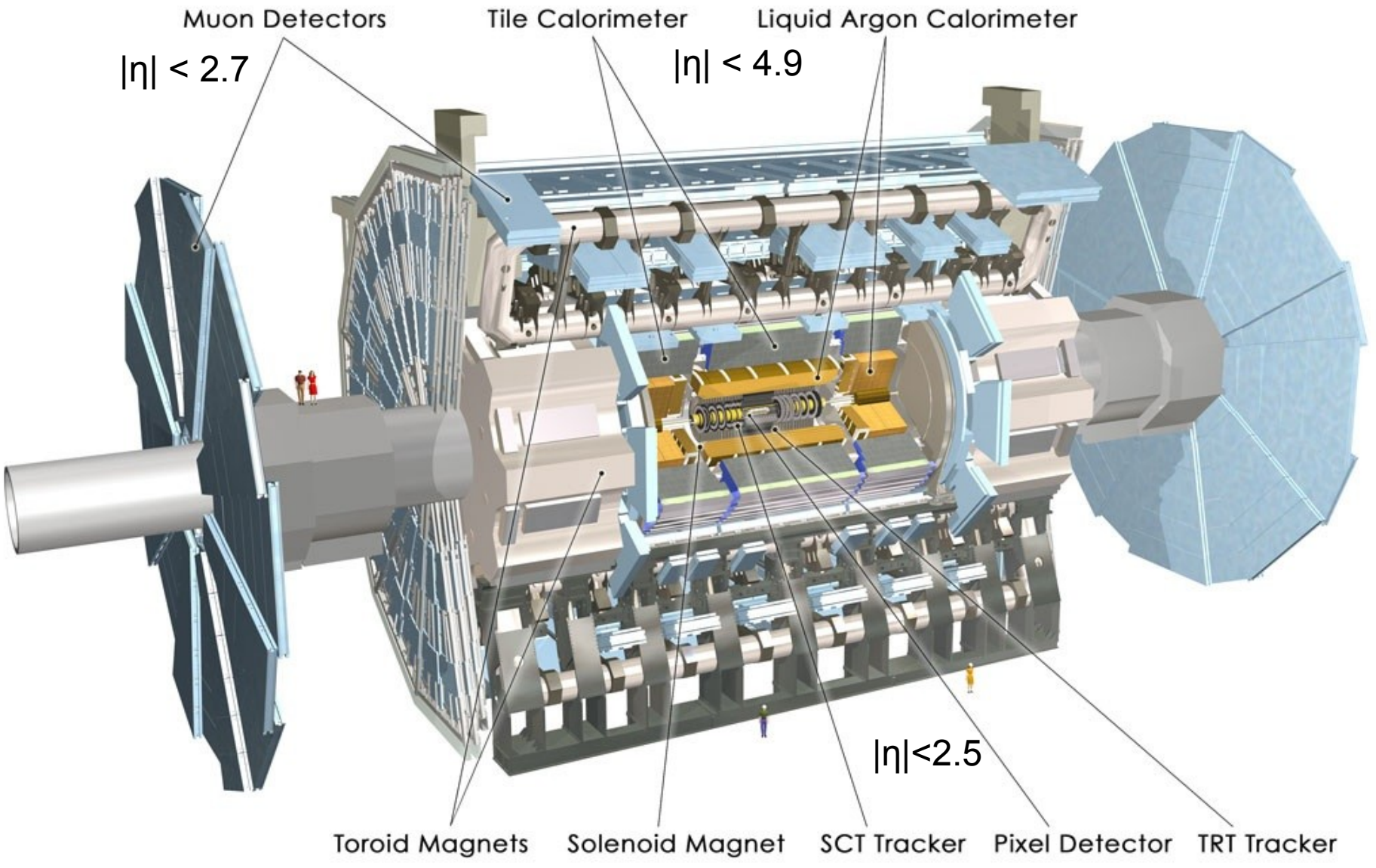
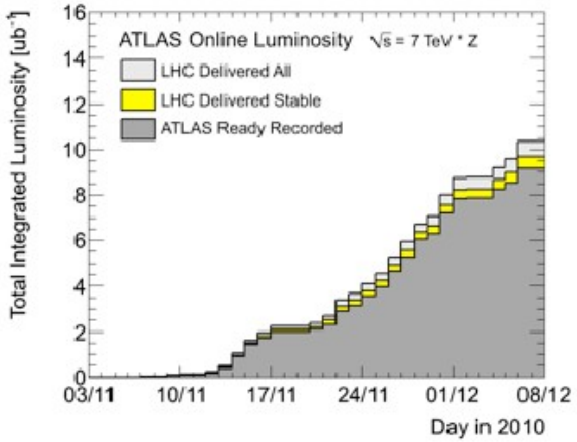
on behalf of the ATLAS experiment


Muon Detectors
|η| < 2.7
Tile Calorimeter
|η| < 4.9
Liquid Argon Calorimeter
|η|<2.5
Toroid Magnets
Solenoid Magnet
SCT Tracker
Pixel Detector
TRT Tracker

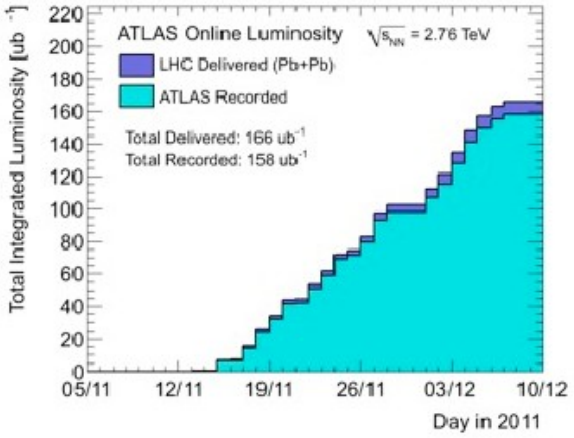
Heavy ions at the LHC

- RHIC established the basic context for the heavy ion program at the LHC
  - Observation of a “near perfect fluid”, described by hydrodynamics
  - Fluctuations of initial state already manifest in flow measurements
  - Large suppression of strongly-interacting high p_T probes observed
- LHC program immediately added enormously to this
  - Strong energy imbalance between dijets observed, with no broadening of the dijet opening angle
  - Measurements of higher-order flow coefficients well described by event wise 3D viscous hydrodynamics
- What have we learned recently from ATLAS?

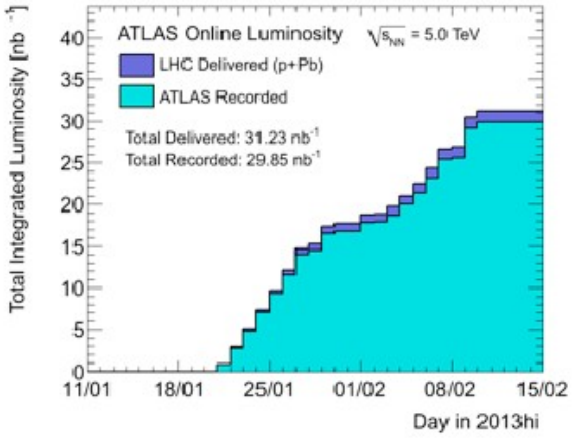
Integrated luminosity for LHC-HI Run 1



$8 \mu b^{-1}$ Pb+Pb in 2010
$300\ nb^{-1}$ p+p in 2011



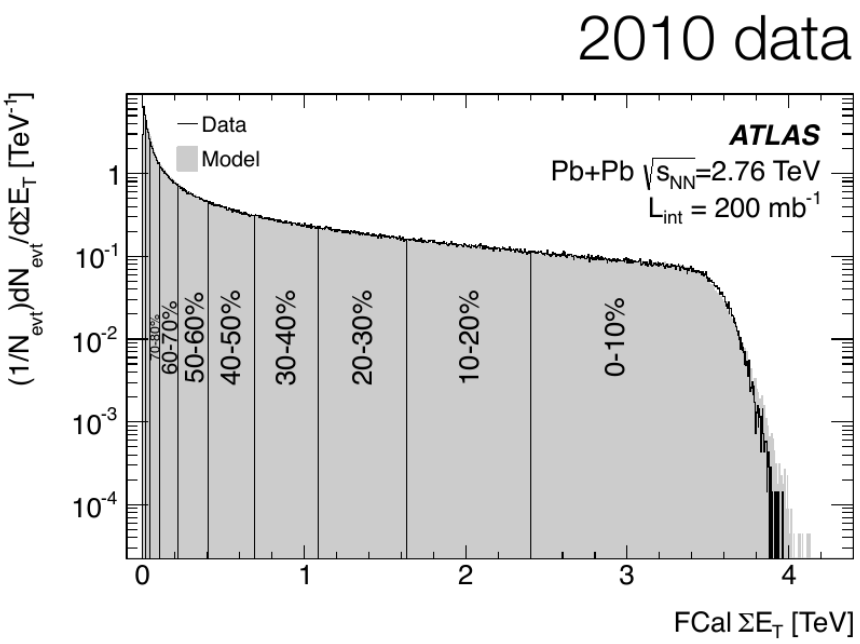
$140\ \mu b^{-1}$ Pb+Pb in 2011



$1\ \mu b^{-1}$ p+Pb in 2012
$30\ nb^{-1}$ p+Pb in 2013

- Three very successful runs with ATLAS performing well

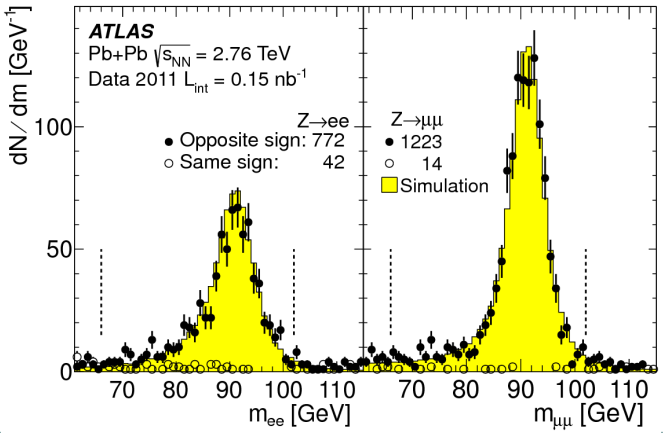
Centrality definition

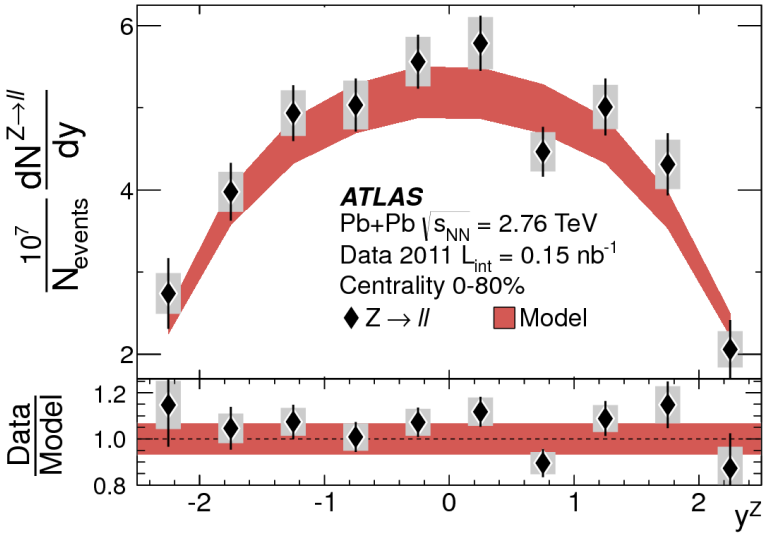


- Centrality defined by ΣE_T in ATLAS forward calorimeter (FCal)
  - $3.2<|\eta|<4.9$
- FCal ΣE_T shape established to be identical to 2010 (after known 4.1% rescaling), where efficiency relative to total cross section estimated to be 98±2%

EW bosons in nuclear collisions

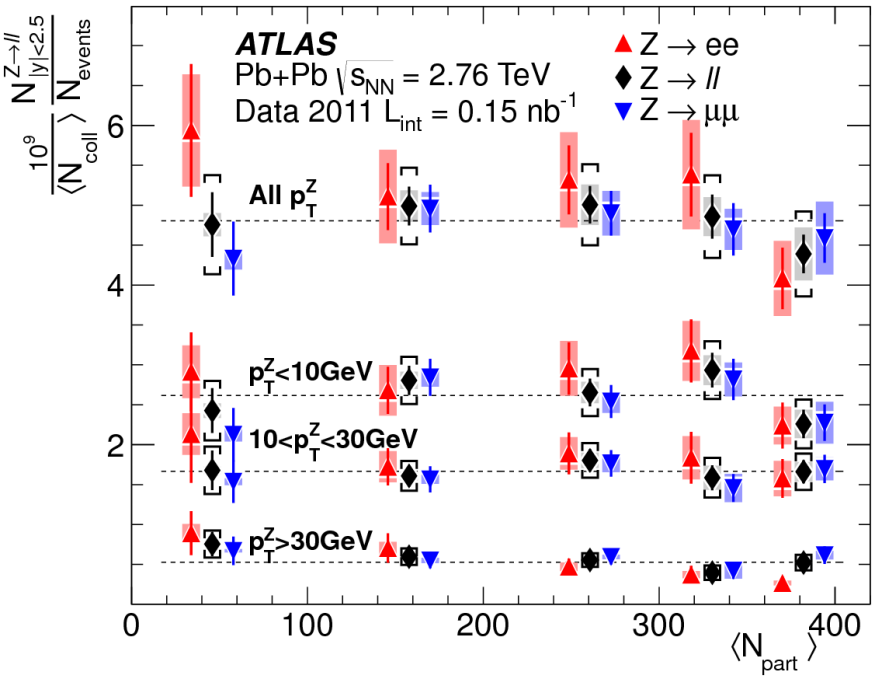
- Electroweak bosons are penetrating probes of the hot, dense medium
- *Z* reconstruction in 2011 Pb+Pb data:
  - Electrons require match of track with EM cluster, along with shower shape cuts
  - Muons reconstructed using combination of Muon Spectrometer and/or Inner Detector: optimized for Z efficiency, high quality muons p_T>10 GeV lower quality p_T>20 GeV
  - We observe 772 opposite sign e^+e^- pairs and 1223 opposite sign $\mu^+\mu^-$ pairs, from which 42 (14) same sign electron (muon) pairs were subtracted as background





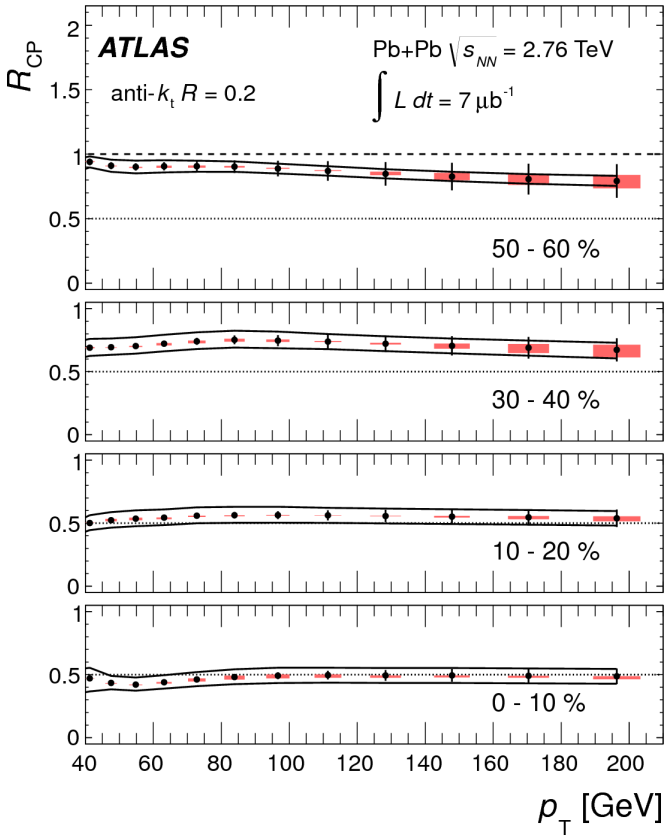
- *Z* yield shown for 0-80% centrality, normalized to the number of events and compared to the PYTHIA rapidity shape normalized to σ_{NNLO} <T_{AA}> (average nuclear thickness)

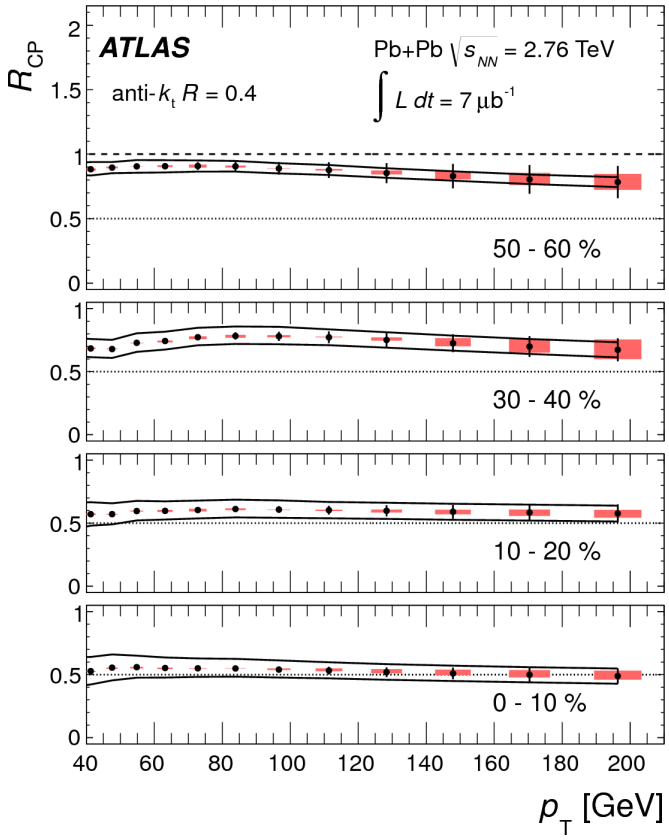
Scaling of $Z/W/\gamma$ with collision centrality



- Integrated yields show a clear scaling with number of binary collisions
  - *Z* bosons do not interact with the medium, as expected
- Same dependence observed for three momentum ranges
  - p_T<10, 10<p_T<30, p_T>30 GeV
- Similar scaling with binary collisions in Pb+Pb collisions was also observed by ATLAS from $W \to \mu\nu$ and high p_T photons

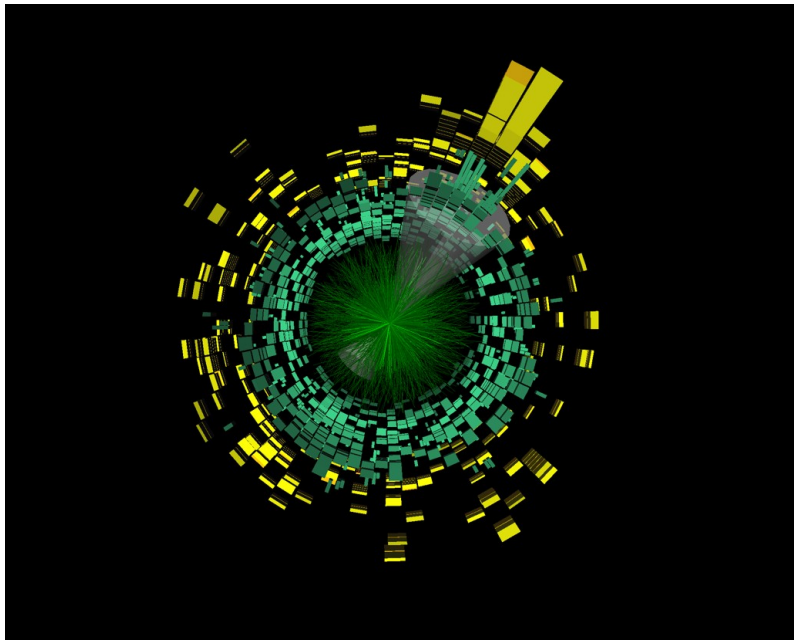
Jet suppression

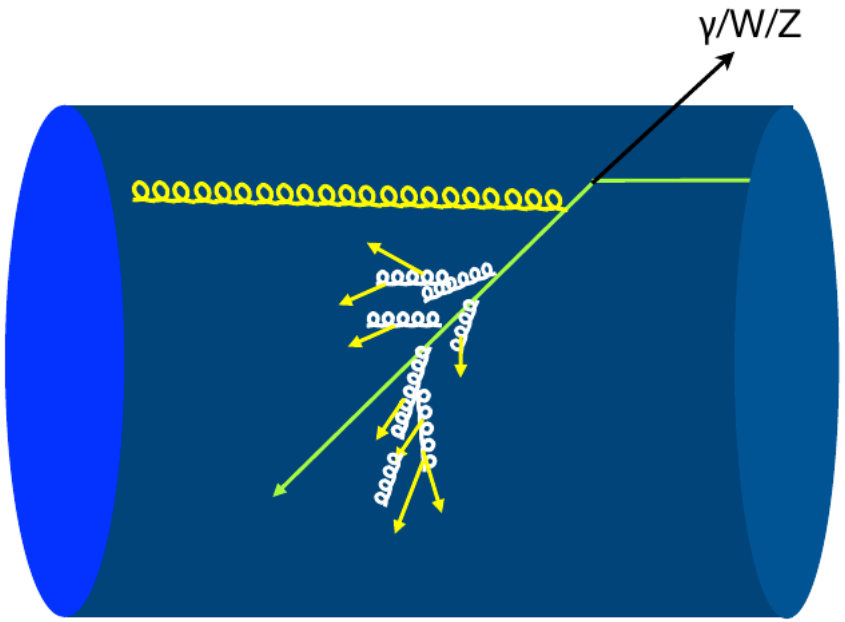




- ATLAS has already measured the centrality dependence of full jet suppression (relative to peripheral events) unfolding detector response
  - The observed suppression is only weakly dependent on jet radius and transverse momentum.

Photon+jet and *Z*+jet production

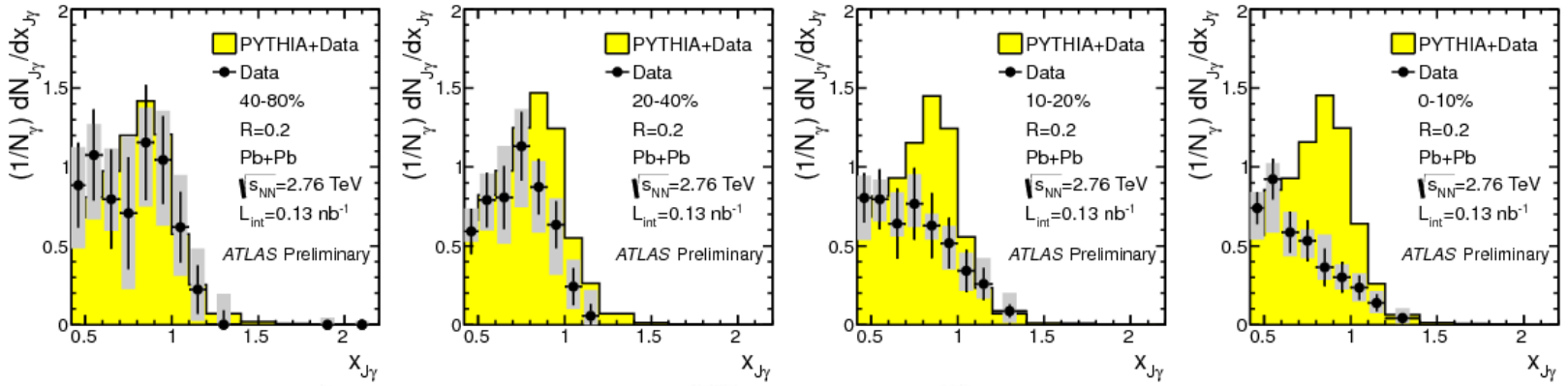




- In dijet events, both jets are potentially modified by the hot, dense medium
- Electroweak bosons are unaffected by the medium, allow us to calibrate scale of hard process and directly probe jet energy loss

Jet suppression in γ+jet events

$x_{J\gamma}=E_{Tj} / E_{T\gamma}$

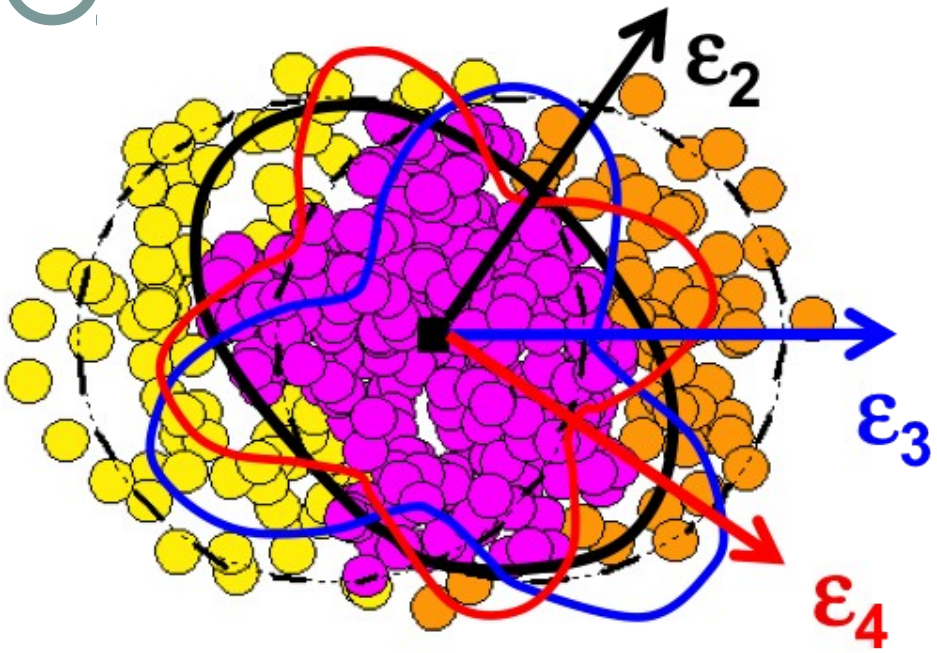


$60 < p_T^{\gamma} < 90$ GeV, $|\eta_\gamma| < 1.3$, $p_T^{jet} > 25$ GeV, $|\eta^{jet}| < 2.1$ and $|\Delta\phi_{J\gamma}| > 7\pi/8$.

- Suppression of jets at central collisions are observed wrt to simulation in γ+jet events
  - See also suppression of Z+jets in E. M. Lobonzinska's talk tomorrow
- These results are qualitatively consistent with the expectation of energy loss in jets as they traverse the hot dense medium created in HI collisions
  - Consistent with previous ATLAS measurements and also with CMS observations

Flow fluctuations

- Elliptic flow at RHIC showed that spatial deformations in the initial overlap region closely correlated with momentum anisotropies
- ATLAS extended our understanding with wider η and p_T than available at RHIC
- With the high multiplicities & large acceptance of ATLAS, we have also studied higher order components of the transverse flow, now event-by-event

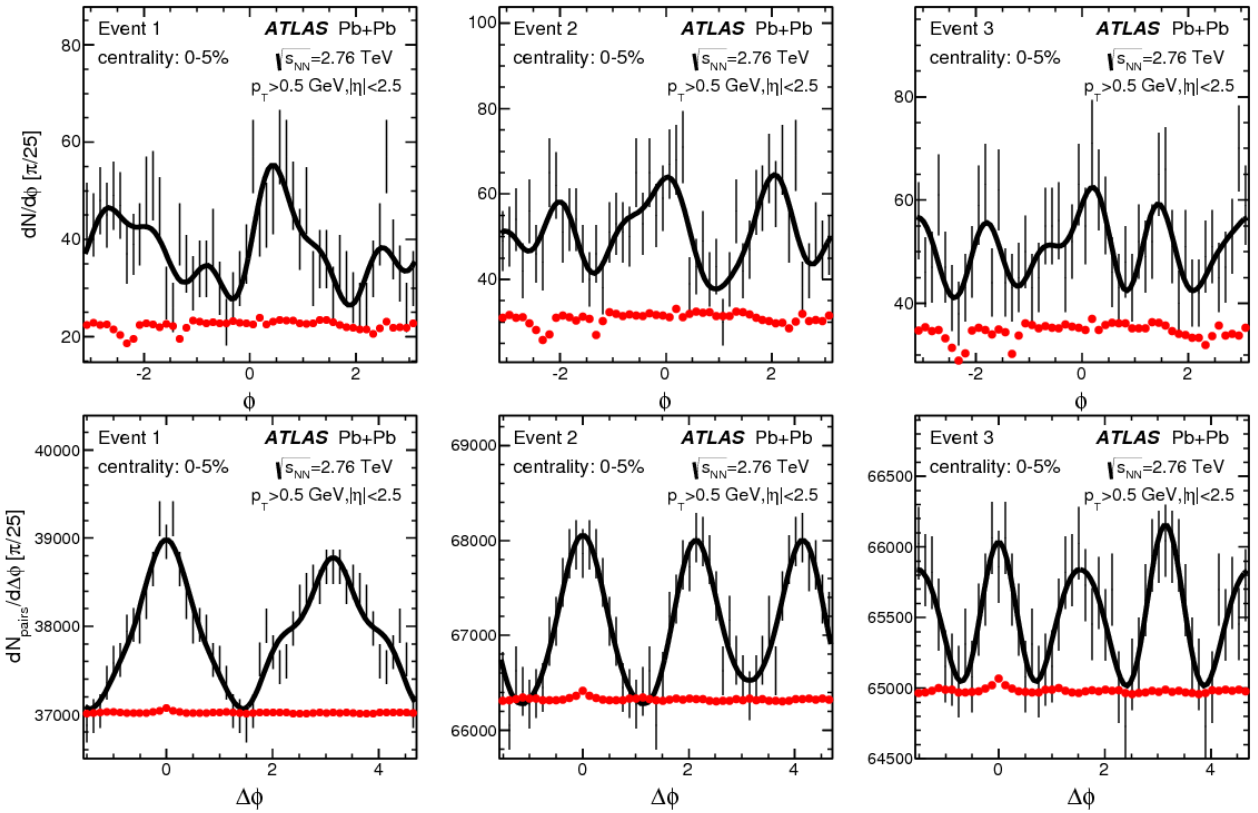


Do v_n directly reflect higher order deformations in initial state?

$$\frac{dN}{d\phi} \propto 1 + 2\sum_{n=1}^{\infty} v_n \cos n(\phi - \Phi_n)$$

Higher modes should be more sensitive to viscous effects

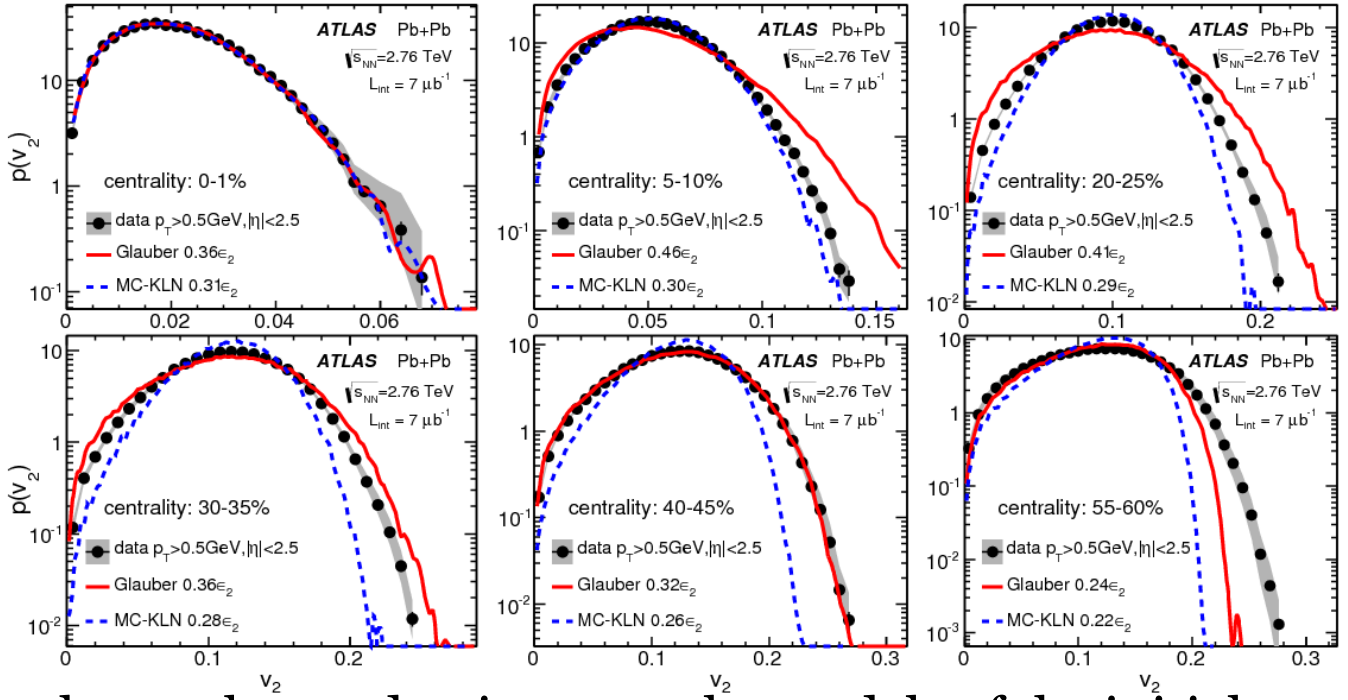
Measuring flow fluctuations



- We can decompose both φ distribution and and $\Delta\varphi$ distribution event by event
  - Finite number of particles and track resolution implies that we must unfold to recover original distribution

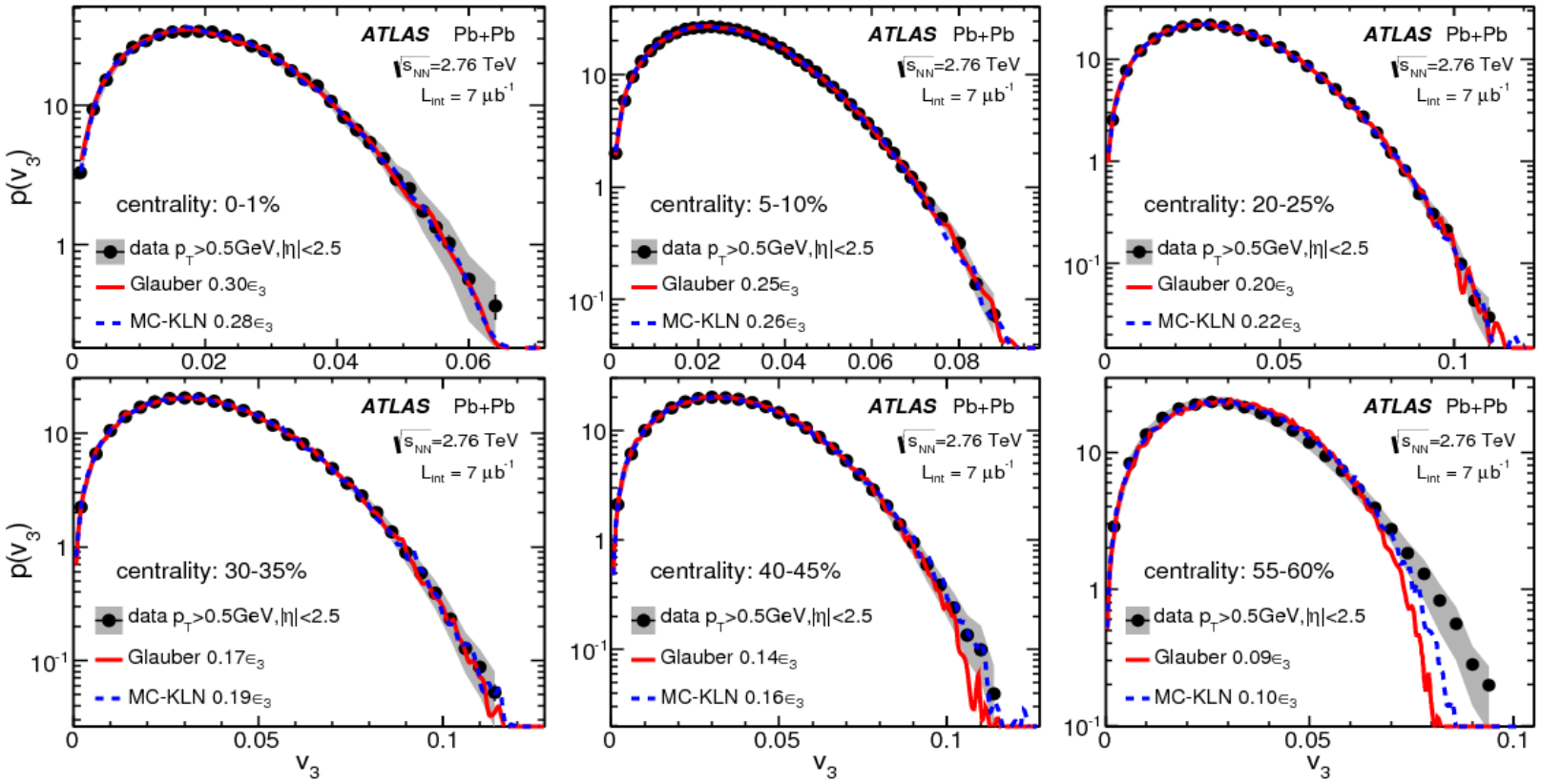
Comparison of v_2 with initial state models

- Glauber model and MC-KLN predictions were compared to observations
  - MC-KLN is based on Glauber but also takes into account corrections to initial geometry due to gluon saturation effects



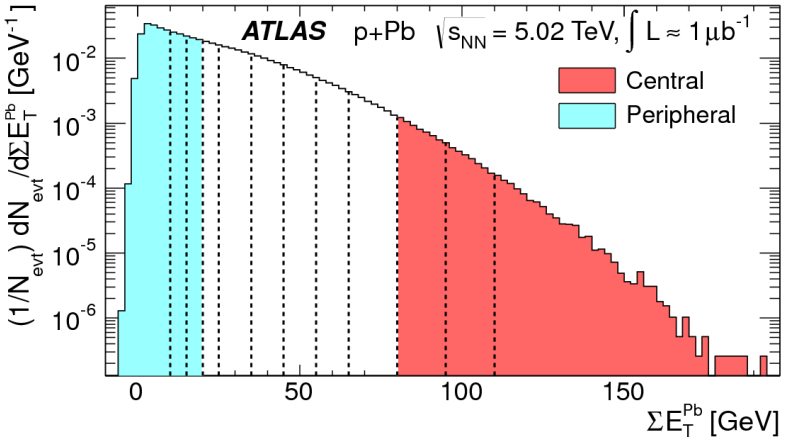
- The results can be used to improve the models of the initial geometry
  - Glauber model gives better agreement for v_2 in peripheral collisions
  - MC-KLN agrees better for v_2 in central collisions, and has generally requires smaller scale factor

Comparison of v_3 with initial state models

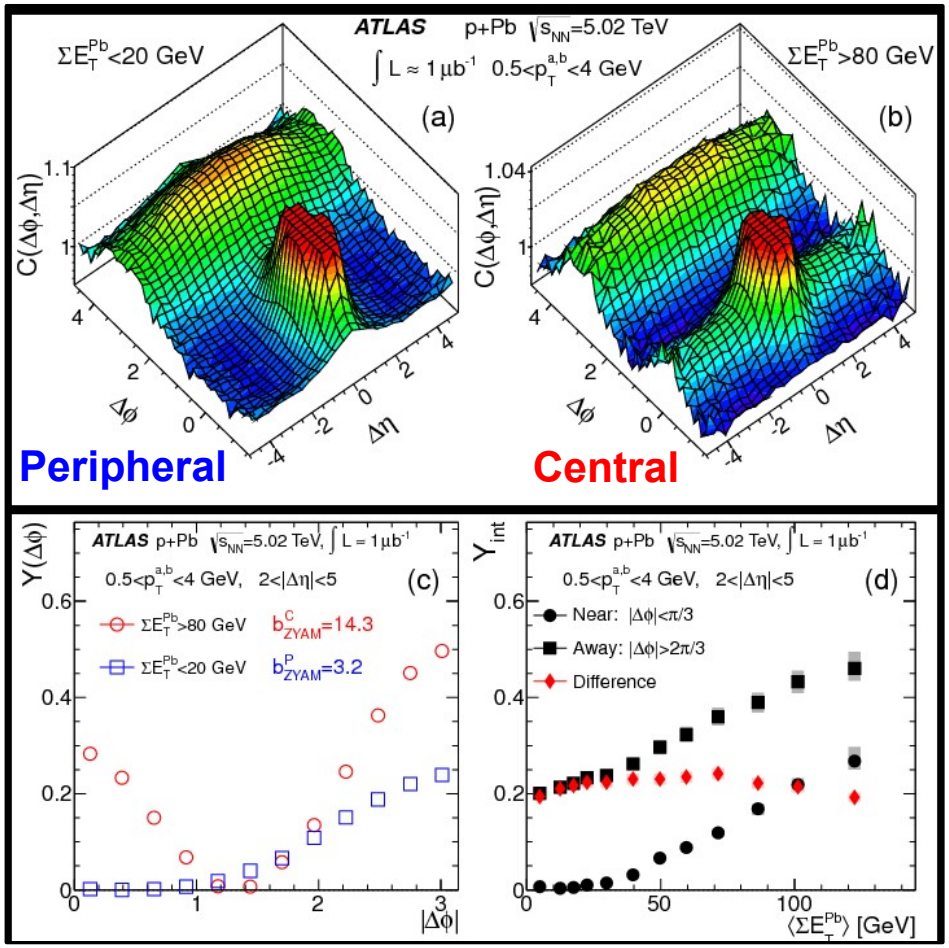


- Both models agree better with observations for v_3 than for v_2
  - Higher harmonics are more dominated by fluctuations than v_2 which has a large component from the collision geometry

Ridge effect in p+Pb collisions



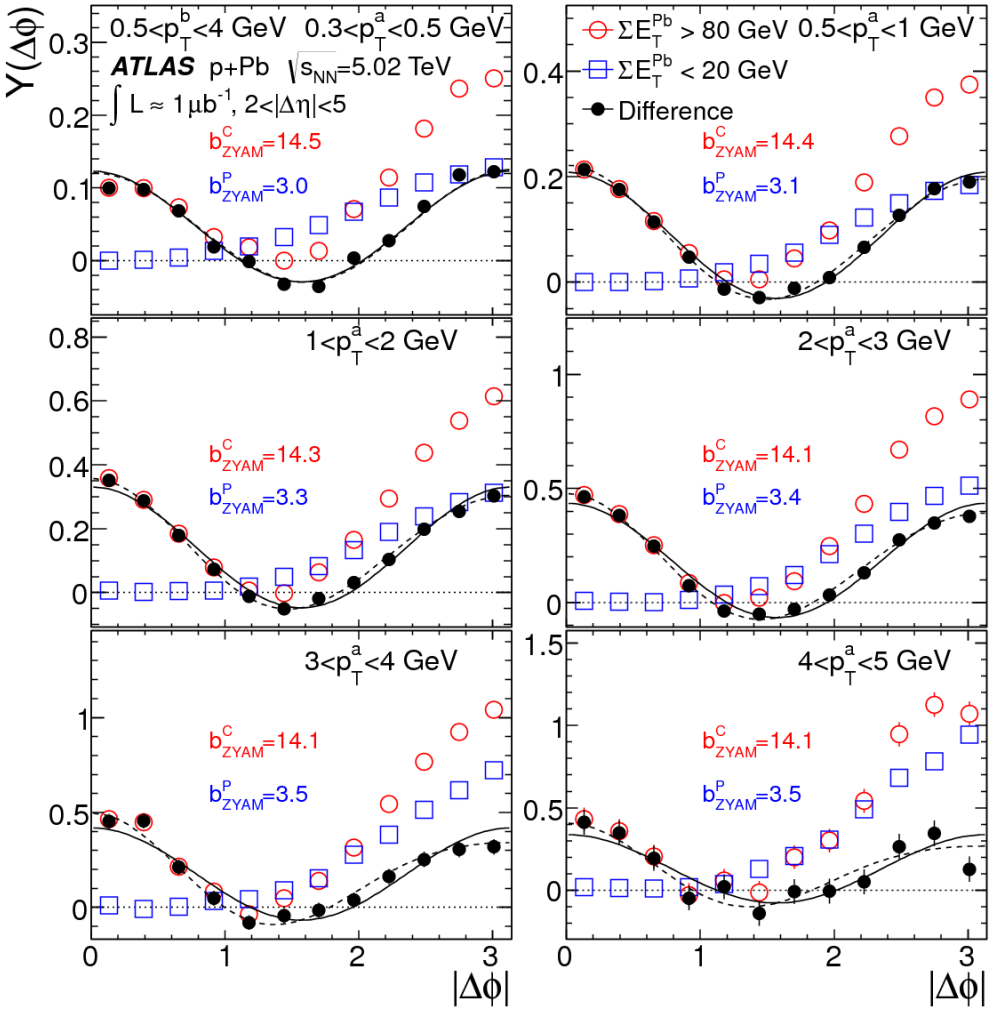
- Centrality selected using FCal on Pb-going side
- Near and away side in azimuthal angle increase in a correlated fashion vs event activity
- The difference between near and away side is independent of activity → Recoil!



Corrected yields are a cos(2φ) modulation

- Recoil contribution was subtracted
- The yield per trigger for all p_T intervals was found to be proportional to cos(2|$\Delta\varphi$|)
  - With a smaller cos(3|$\Delta\varphi$|) componen

More details and interpretation M. Villa's talk this morning!



Summary

- ATLAS has analyzed data from a full range of collision systems
  - Pb+Pb and p+p at 2.76 TeV (0.14 nb^{-1} and 5 pb^{-1} respectively)
    - Continued work on flow, spectra, jets, photons, electroweak
  - p+Pb at 5.02 GeV (30 nb^{-1})
    - Many new results expected on flow, spectra, jets, photons, electroweak
- Newly submitted results on flow fluctuations in Pb+Pb
  - Powerful constraints on initial state models and hydro calculations
- Recent results on correlations in p+Pb
  - Discovery of correlated near and away side ridge, suggestive of flow
  - Intense debates as to source of this signal