ATLAS Heavy Ion Physics Program

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FCPPL Workshop
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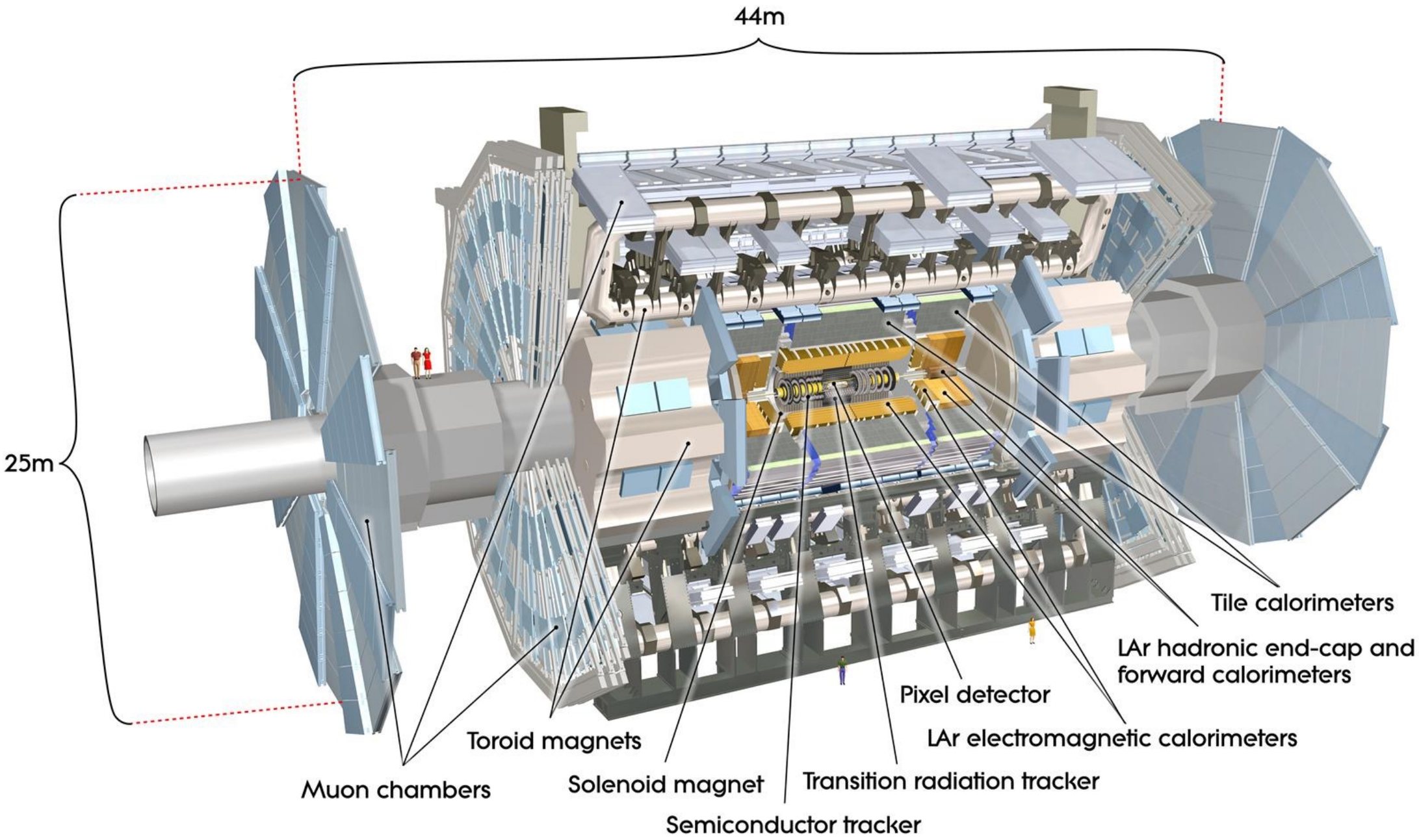
University of Science and Technology of China

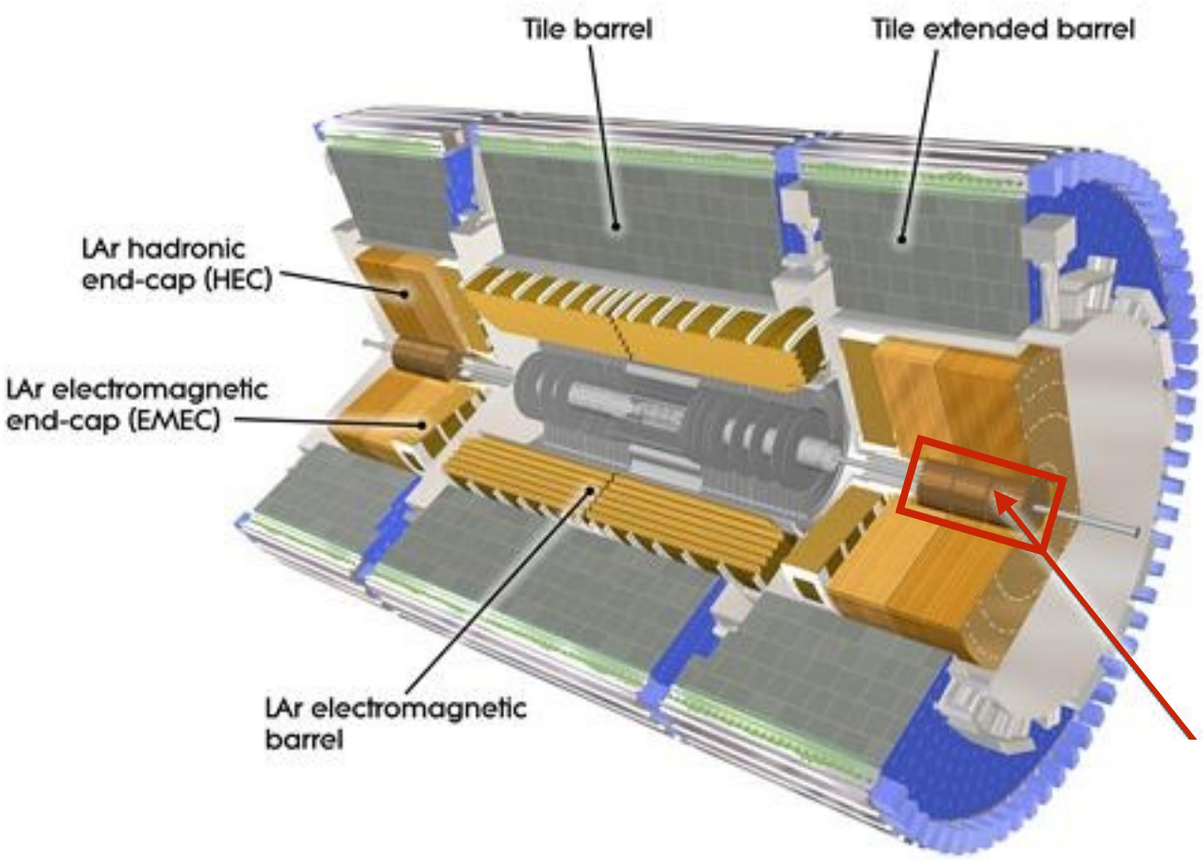
Outline

- Experiment setup
- Soft probes: collective dynamics
- Hard probes: jets, EW bosons
- Summary

The ATLAS Detector



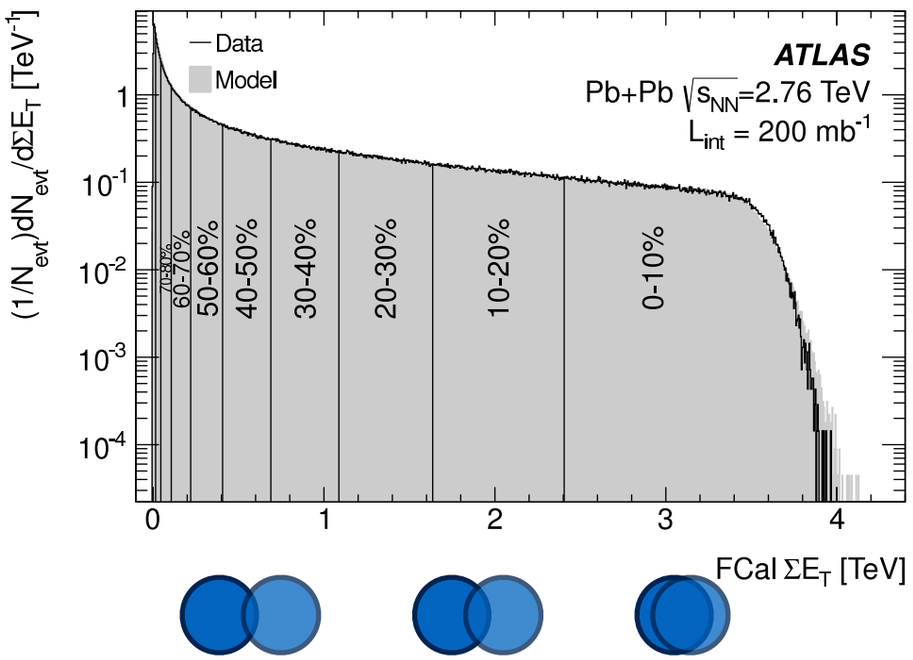
The ATLAS Detector



Liquid Argon Forward Calorimeter (FCal) $3.2 < |\eta| < 4.9$

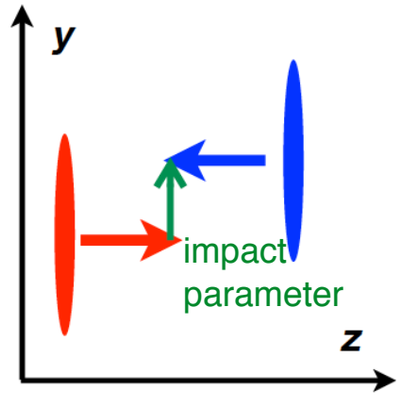
Total E_T in FCal used to classify event centrality

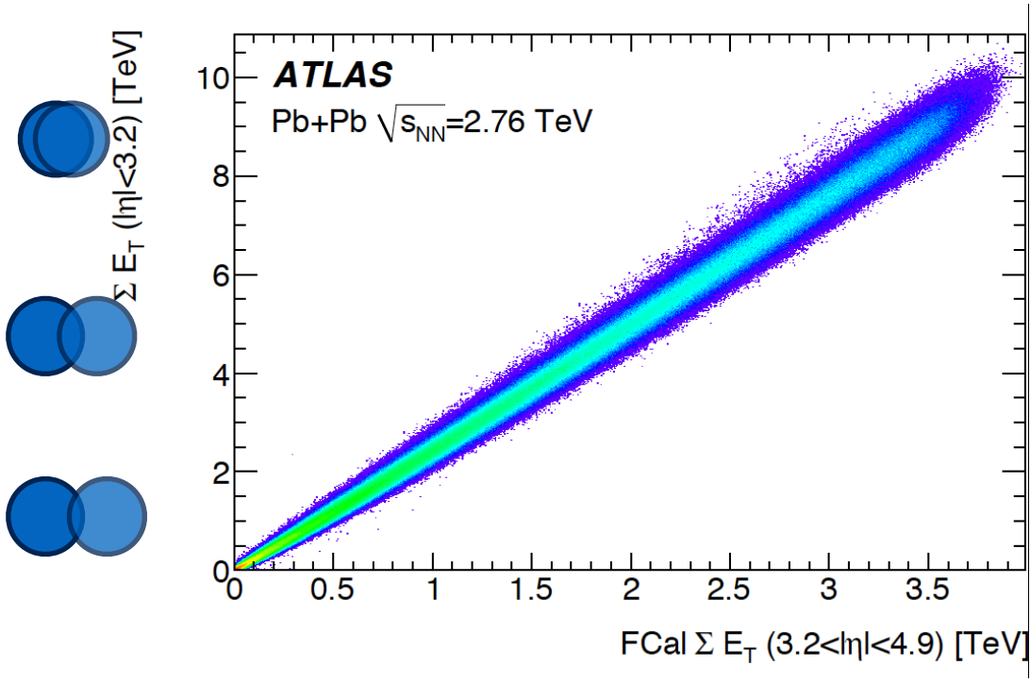
Centrality in Pb+Pb and p+Pb

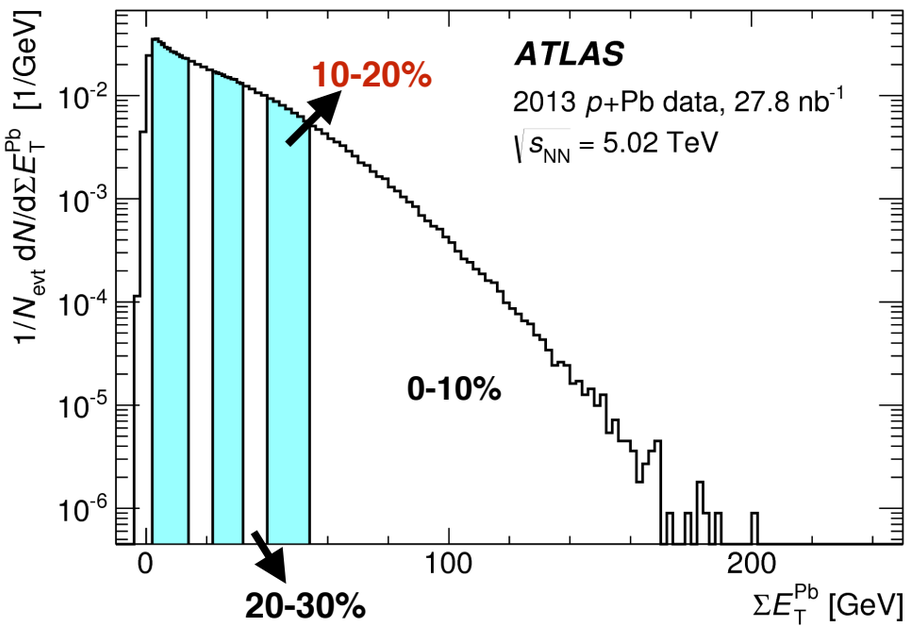


Partition FCal E_T distribution into ranges corresponding to fixed percentiles of the total.

Glauber Model is used to determine impact parameter, N_{coll} and N_{part} in the same percentile.







ATLAS also defined centrality for p+Pb based on Pb-going side FCal E_T.

Both Glauber and Glauber-Gribov are used.

Soft probes

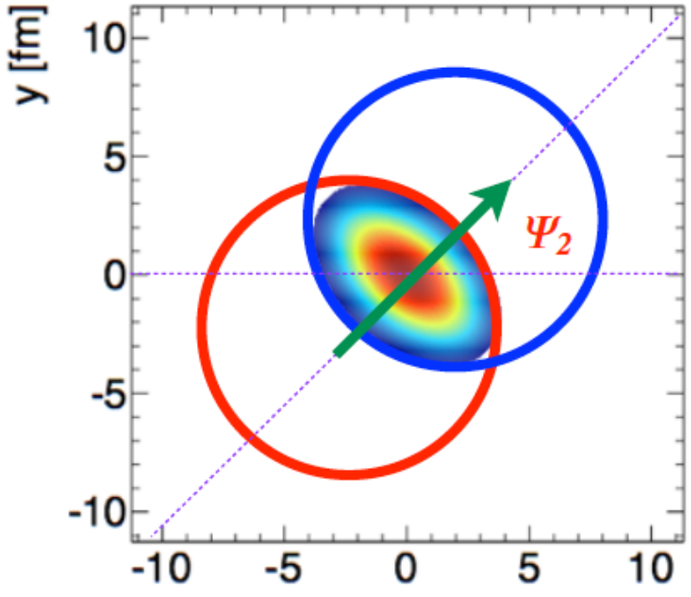
Collective flow phenomena

In transverse plane, overlap region is anisotropic.

- Higher density gradients in direction of “reaction plane” angle (Ψ_2) result in higher pressure gradients.

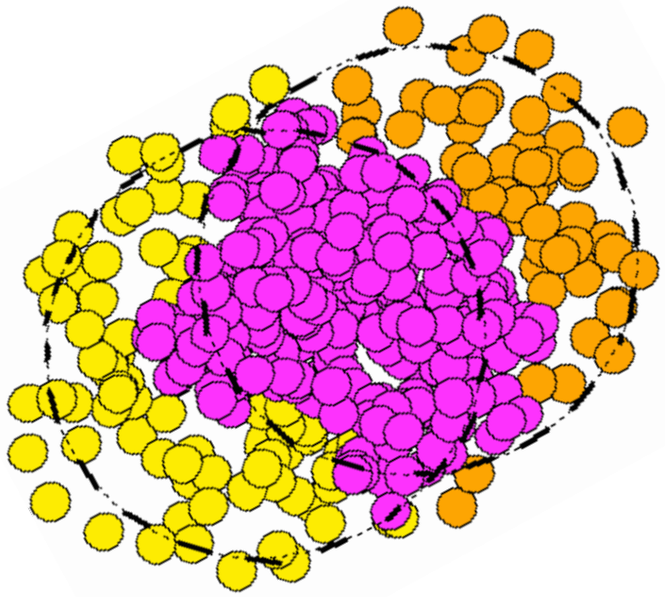
$$\frac{\mathrm{d}N}{\mathrm{d}\phi} \propto 1 + 2\sum_n v_n \cos n(\phi - \Psi_n)$$

The magnitude of anisotropy can be quantified by Fourier expansion coefficients v_n.



x [fm]

Event average vs.
Event-by-event fluctuation

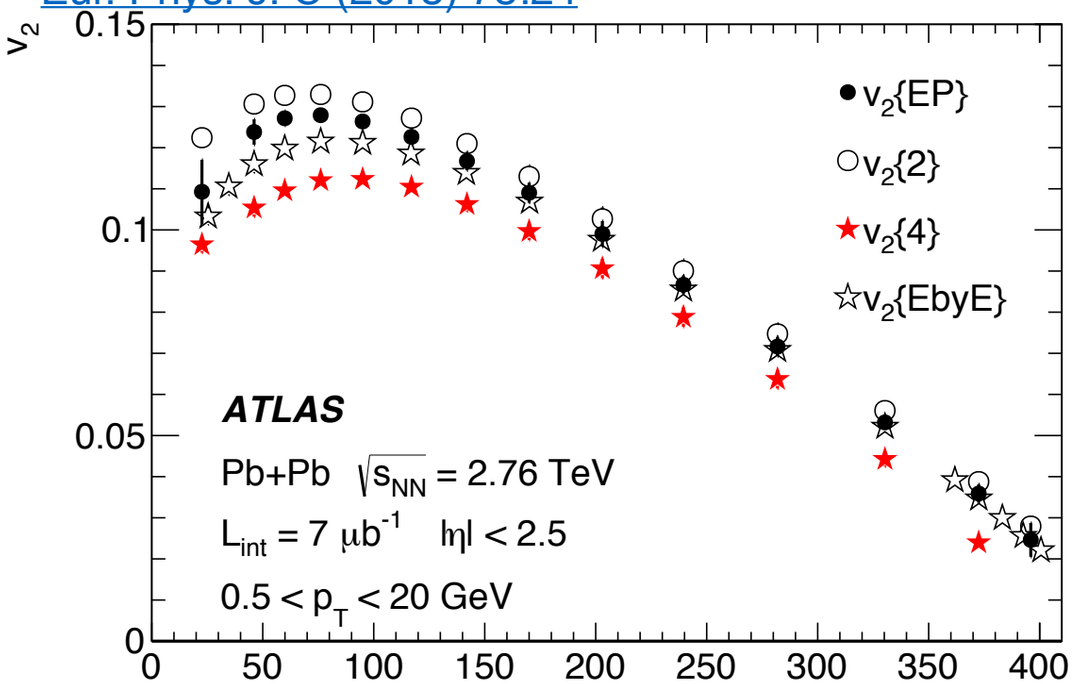


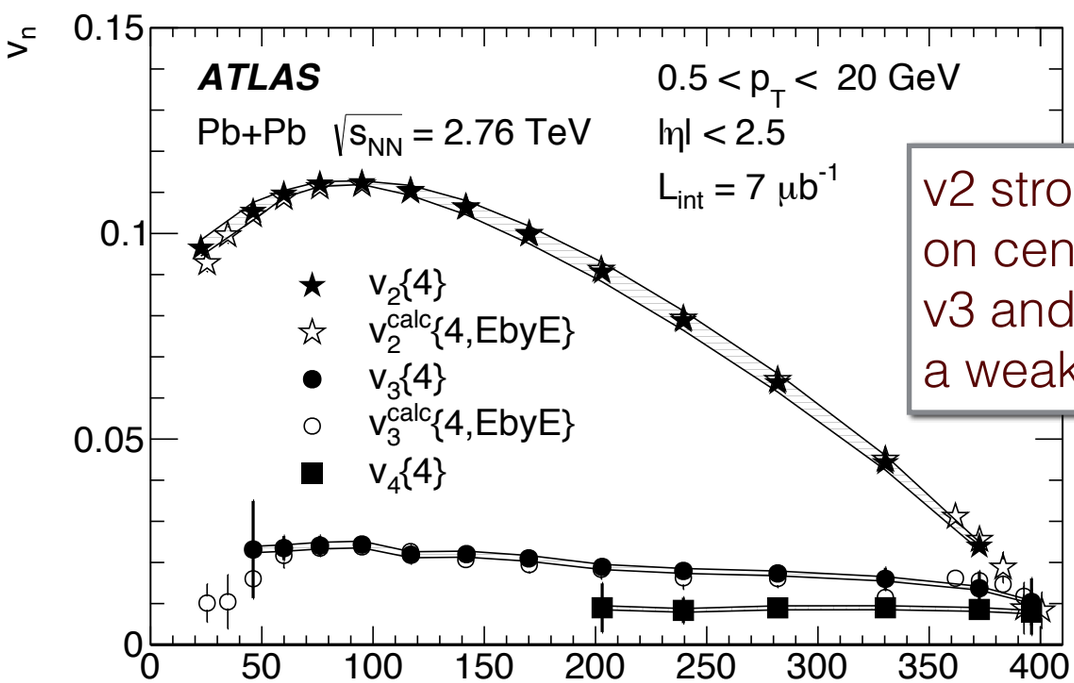
Methods for determining v_n:

- Two-particle correlations method (2PC)
- Event Plane method (EP)
- Event-by-event fluctuation method (EbyE)
- Cumulant method

Flow in Pb+Pb — Cumulants

Eur. Phys. J. C (2015) 75:24

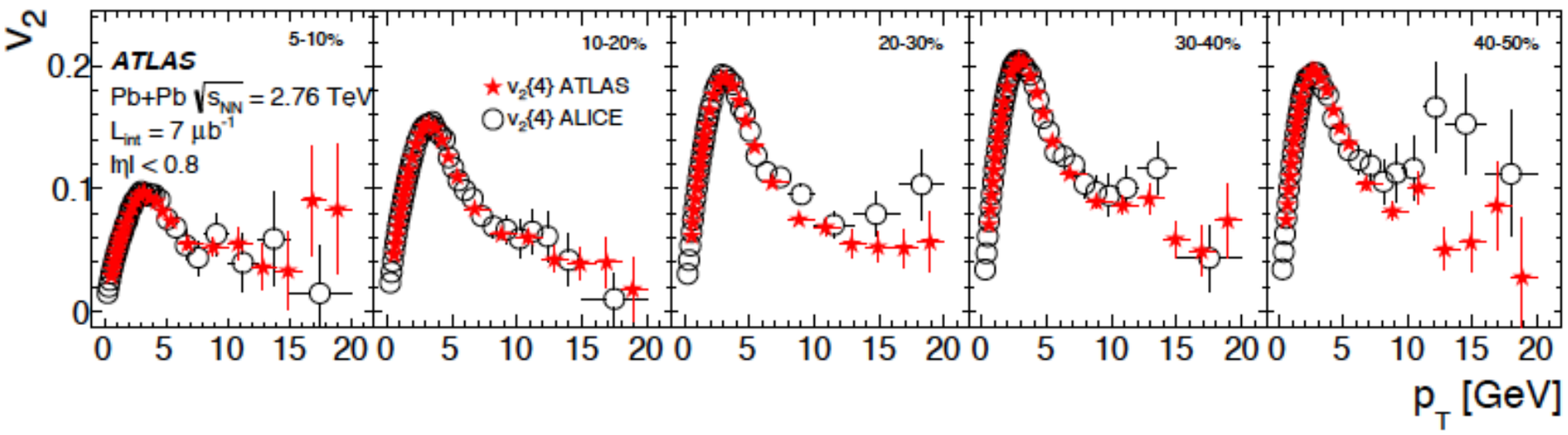




v2 strongly depends on centrality.
v3 and v4 only show a weak dependence.

Generating function formalism (GFC method) is used to calculate cumulants

$v_2\{2\}$: significant non-flow contributions.
$v_2\{4\}$: efficiently suppress non-flow correlations.

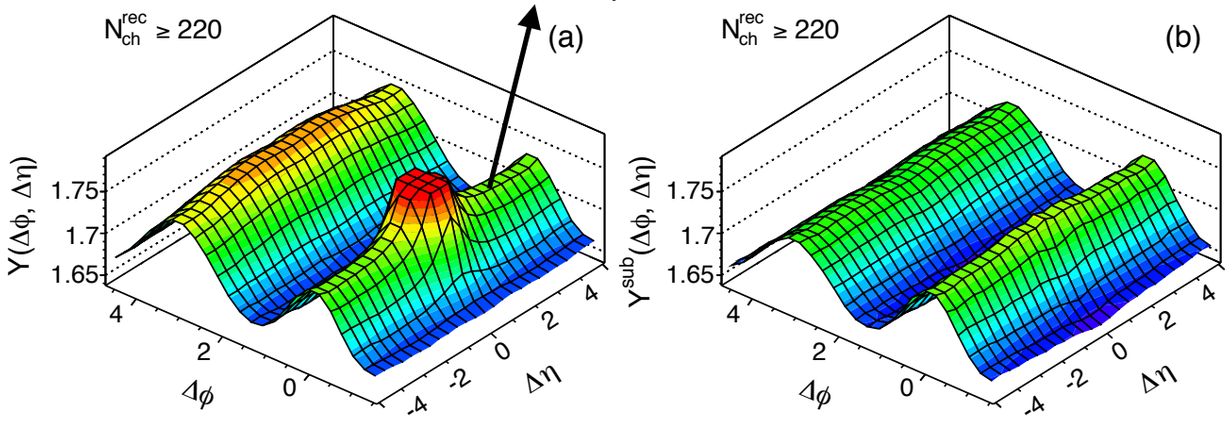


Good agreement between cumulants and event-by-event measurement

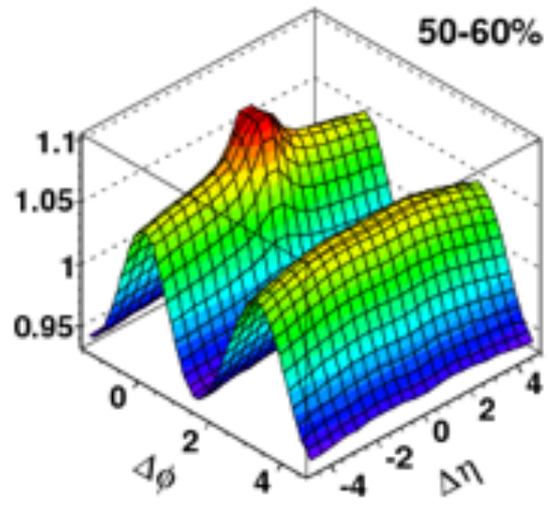
Good agreement between ATLAS and ALICE.

Ridge in p+Pb Collisions

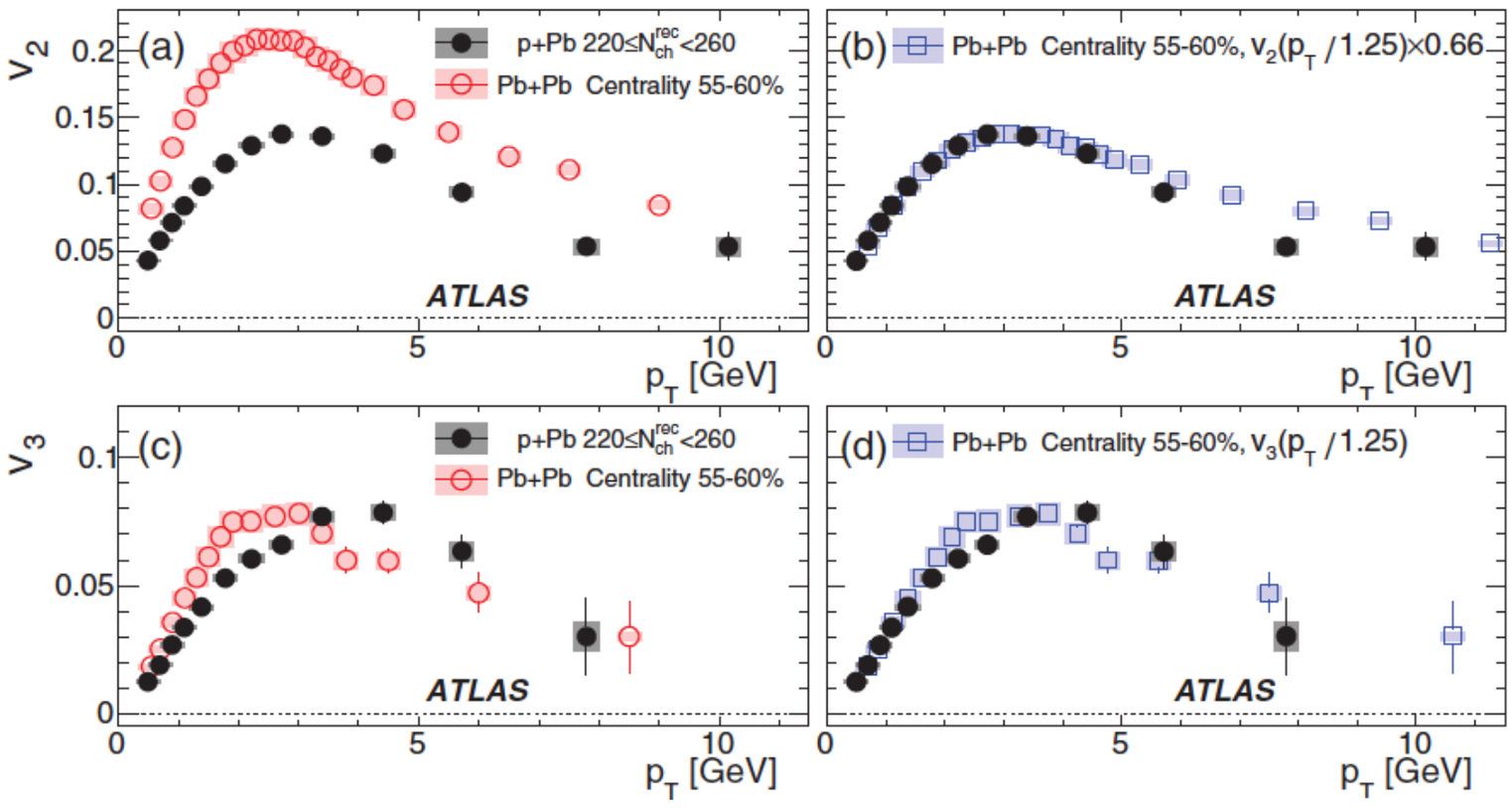
Near side “ridge”
in central p+Pb events.



Short range correlation subtraction at near side and recoil subtraction at away side.



[Phys. Rev. C 90.044906]



ATLAS

Pb-Pb $\sqrt{s_{NN}}$=2.76 TeV

Good agreement between p+Pb and Pb+Pb after p_T rescaling.

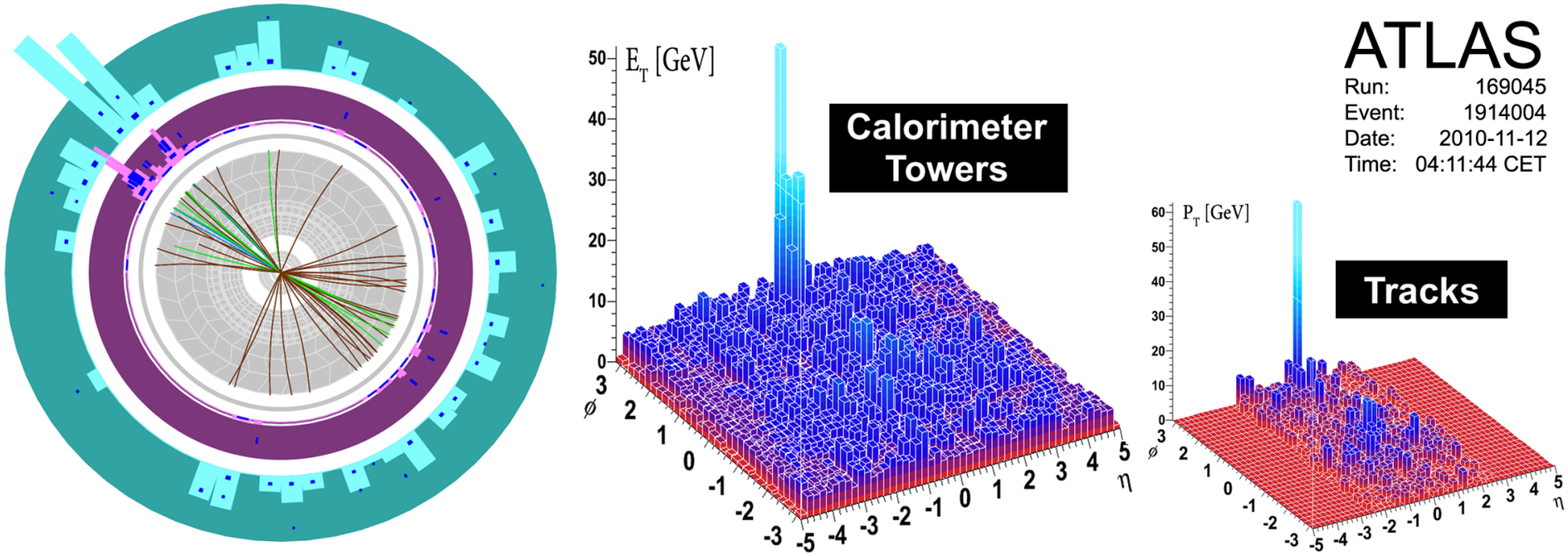
Long-range ridge correlations in central p+Pb collisions and peripheral Pb+Pb collisions are driven by similar dynamics.

Hard probes

Hard Probes in Medium

- Jet quenching: modification of high p_T particle production rates due to partonic energy loss in the medium

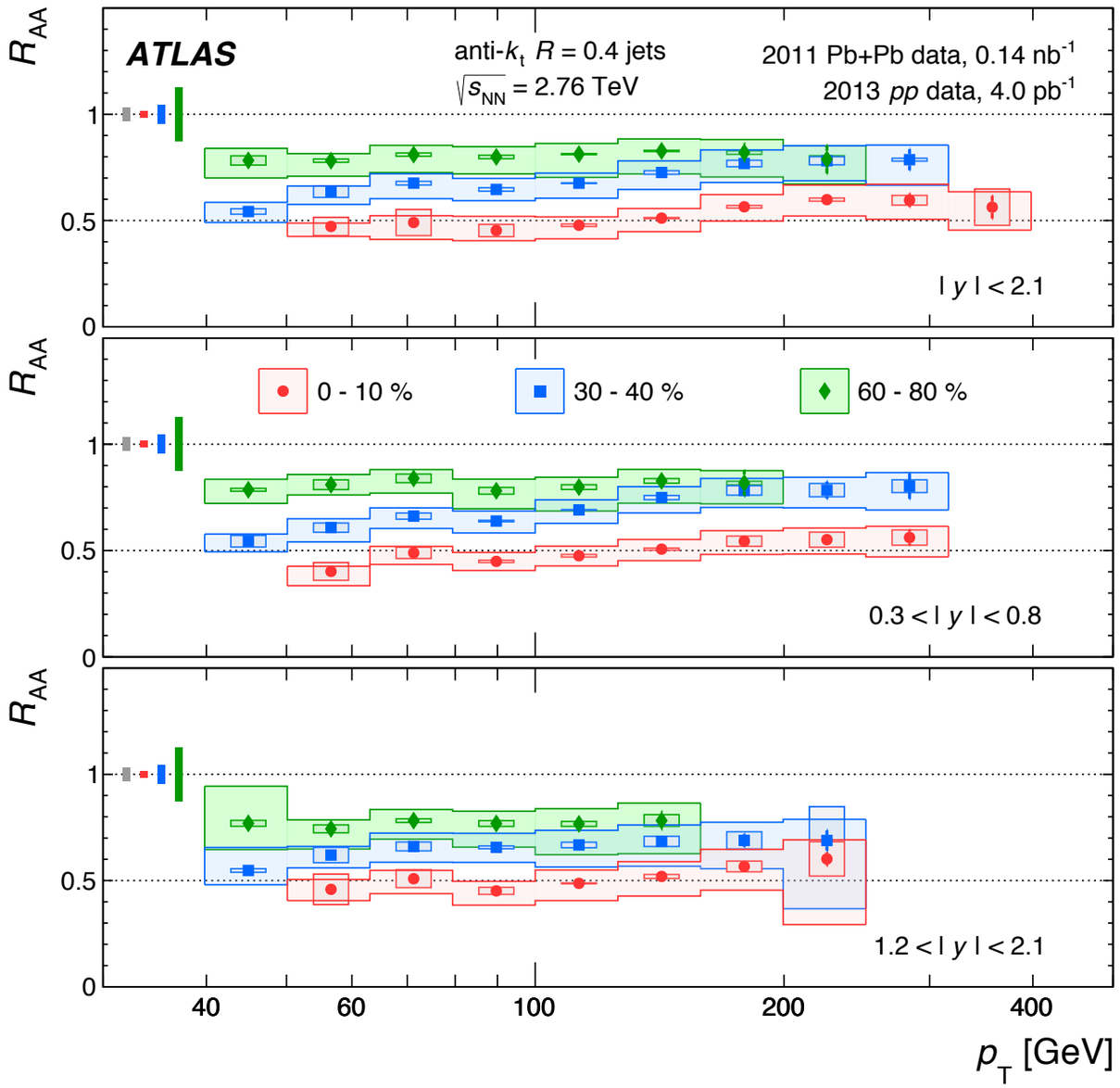
- EW bosons are the baseline of medium induced modification to hard probes.



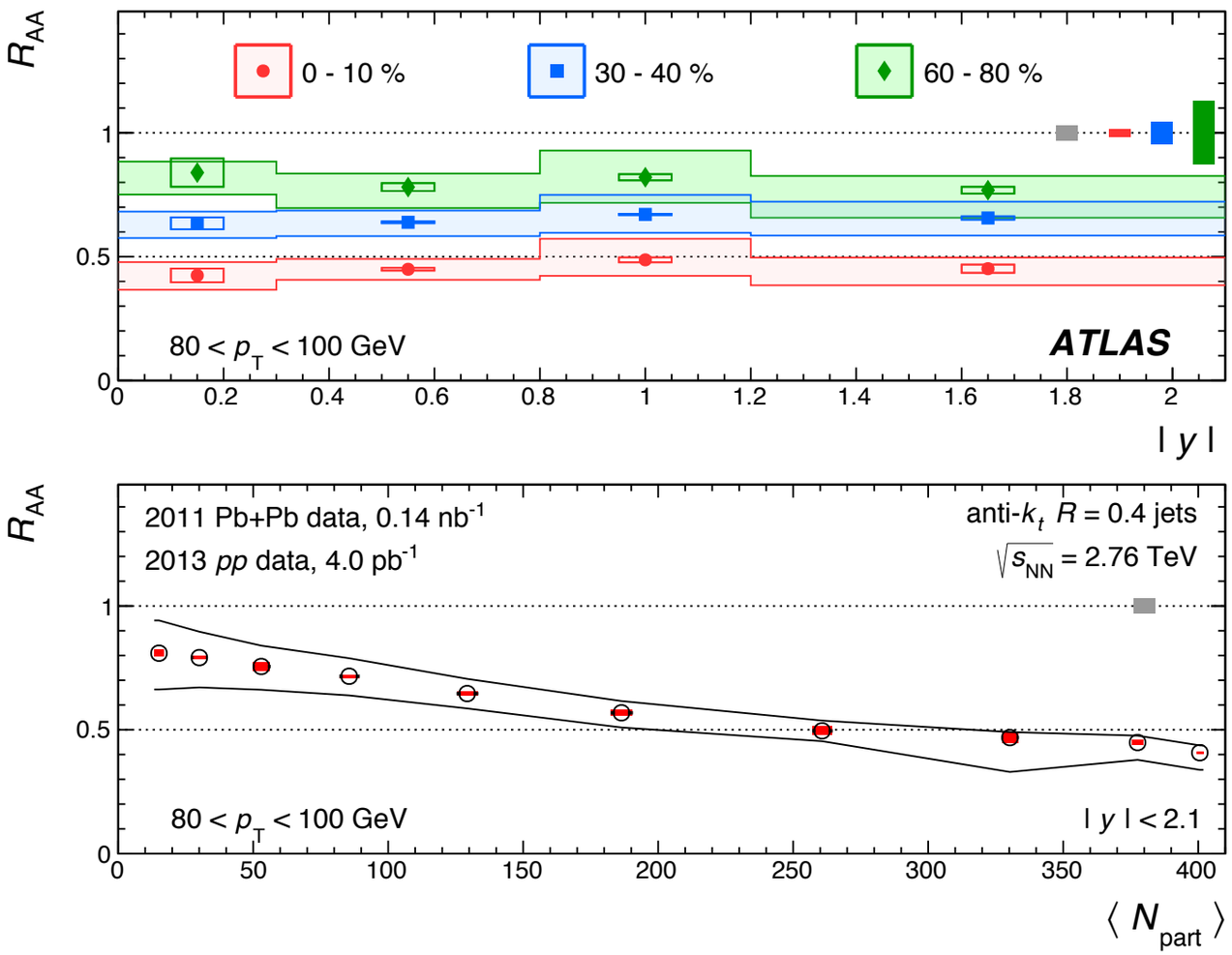
Highly asymmetric dijet event.

Jets in Pb+Pb Collisions

Phys. Rev. Lett. 114, 072302

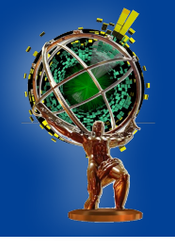


Strong suppression up p_T of 400 GeV.
A weak rise with p_T. Slops vary with centrality.



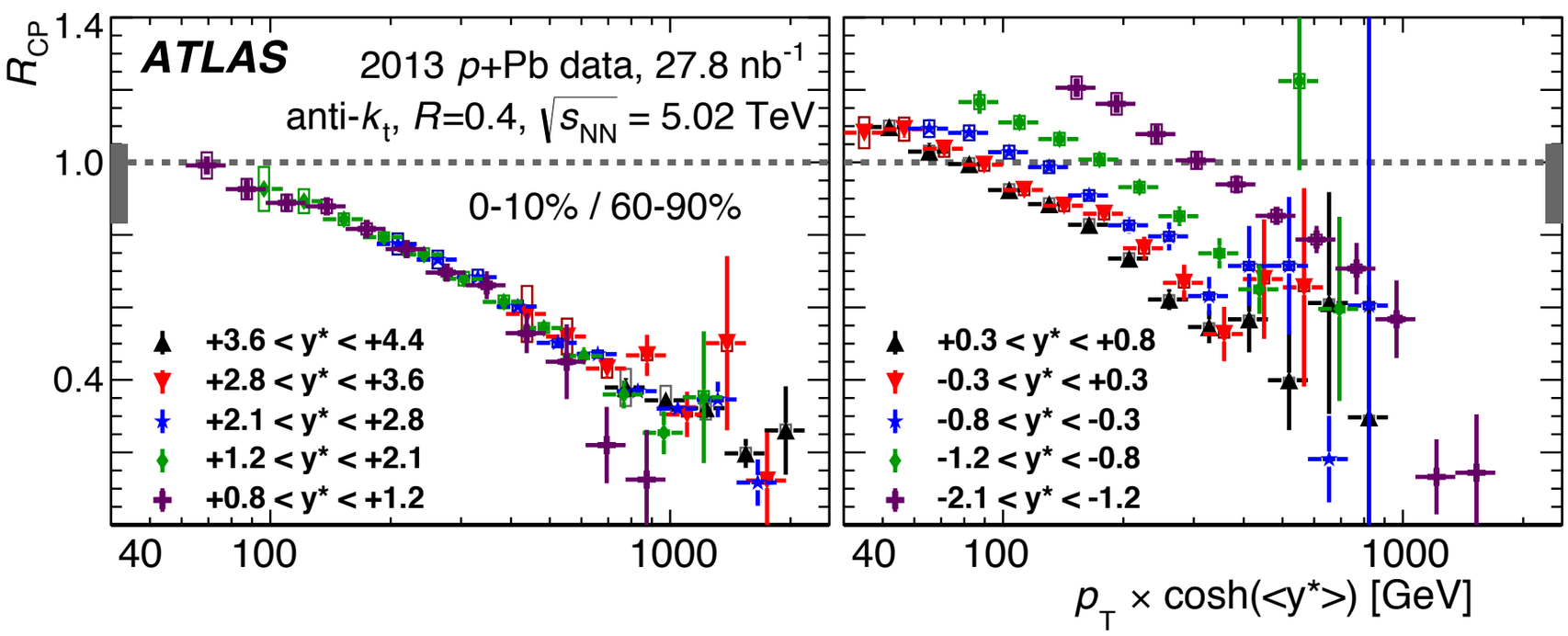
The R_{AA} decreases gradually with increasing $<N_{part}>$ while no significant dependence on rapidity.

Jets in p+Pb Collisions



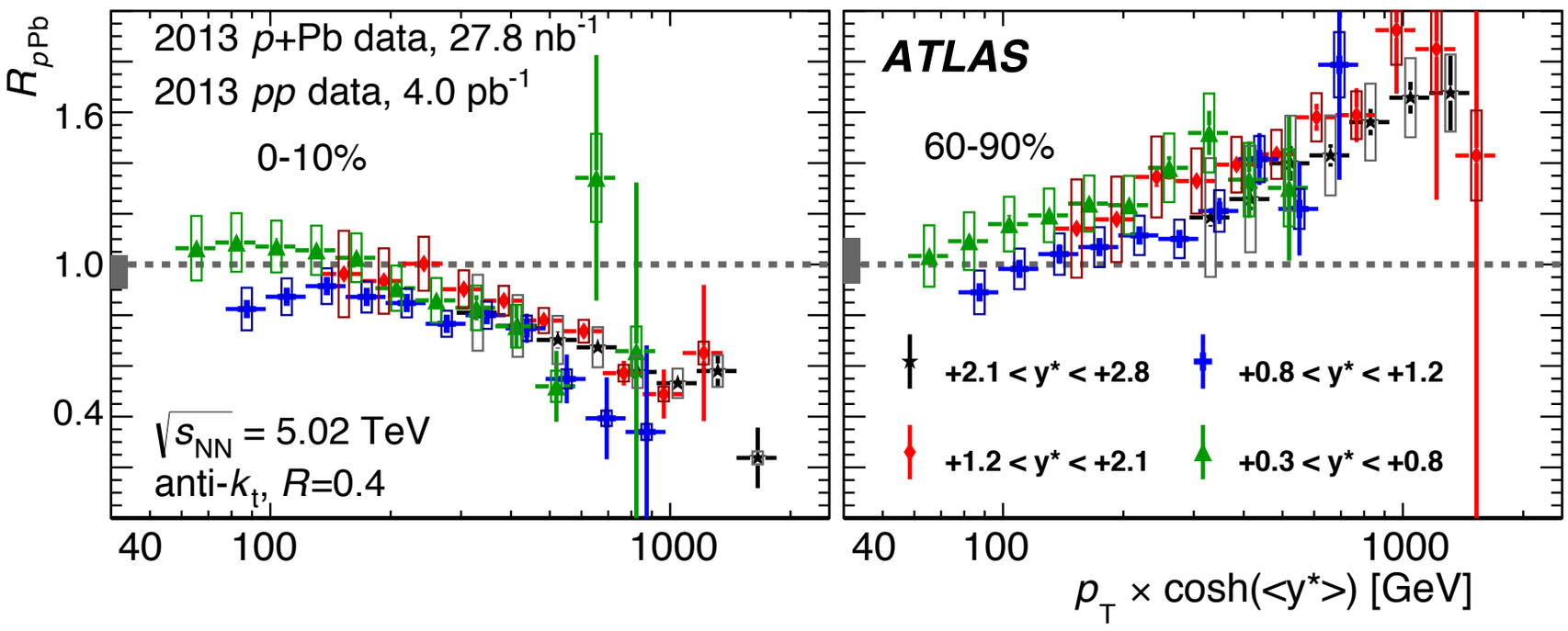
arXiv:1412.4092

$$R_{\rm CP} = \frac{< N_{\rm coll}^{peripheral} >}{< N_{\rm coll}^{central} >} \frac{{\rm d}^2 N^{central}/{\rm d}y{\rm d}p_{\rm T}}{{\rm d}^2 N^{peripheral}/{\rm d}y{\rm d}p_{\rm T}}$$



Strong variation in jet yield with centrality.

$$p_{\rm T} \times \cosh(< y^* >) \approx p$$

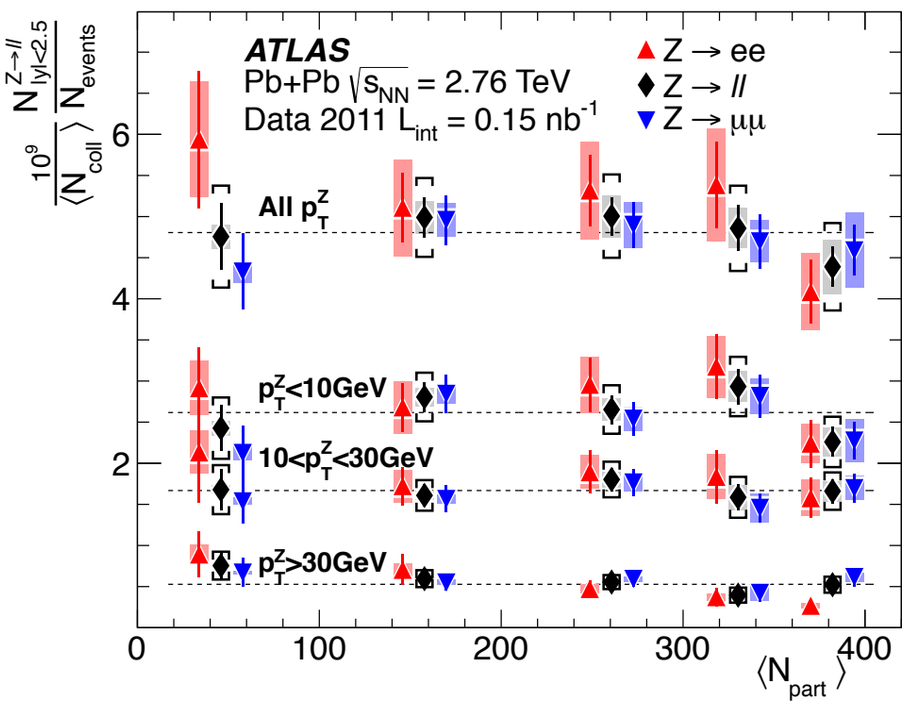


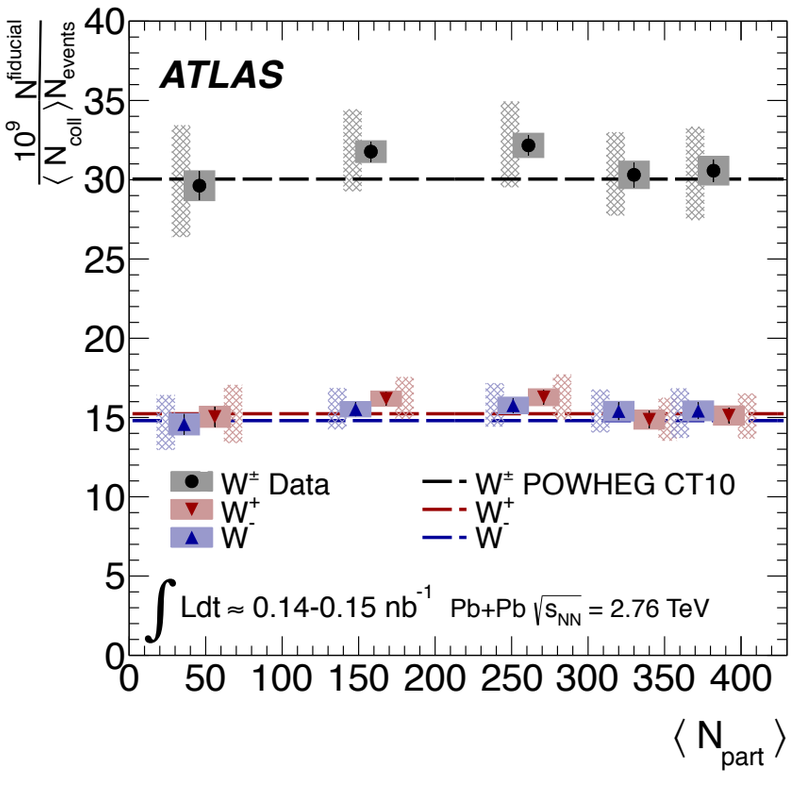
Suppression in central collisions

enhancement in peripheral collisions

Z and W in Pb+Pb Collisions

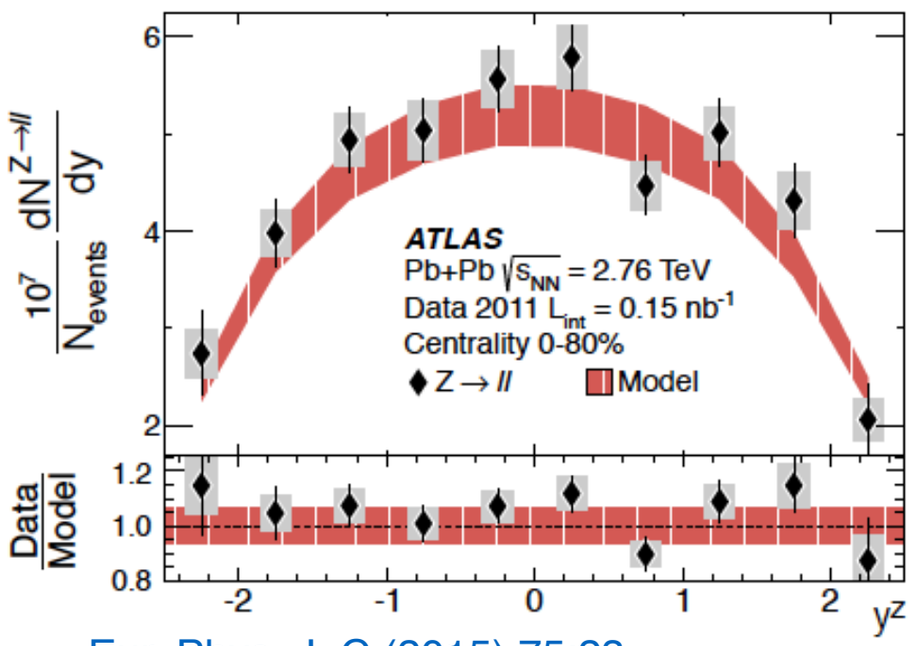
Phys. Rev. Lett. 100, 022301





Experimental control over geometric and nPDF effects.

Z and W yields increase proportional to N_{coll}. Obey binary collision scaling.



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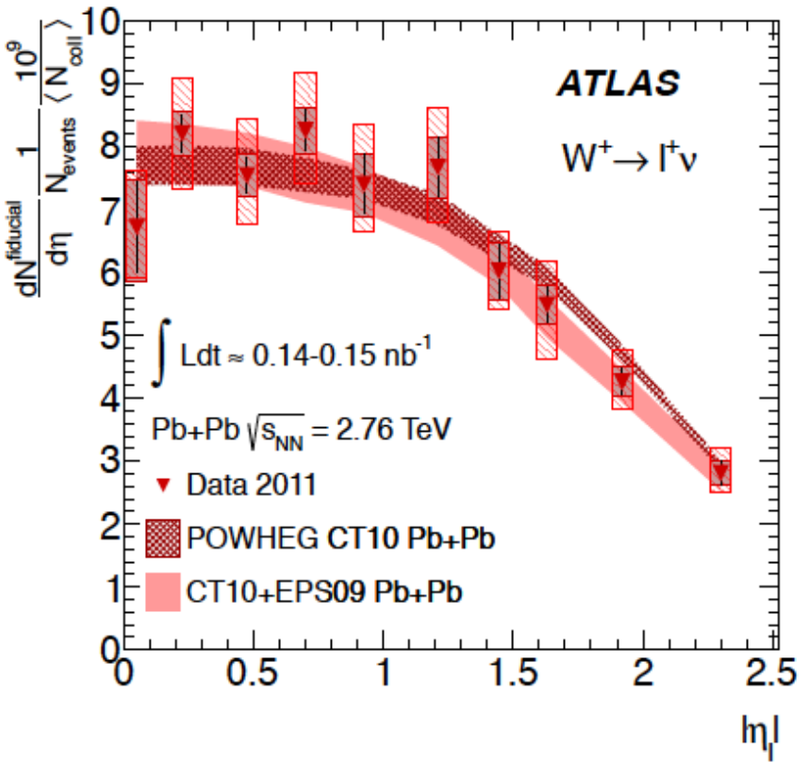
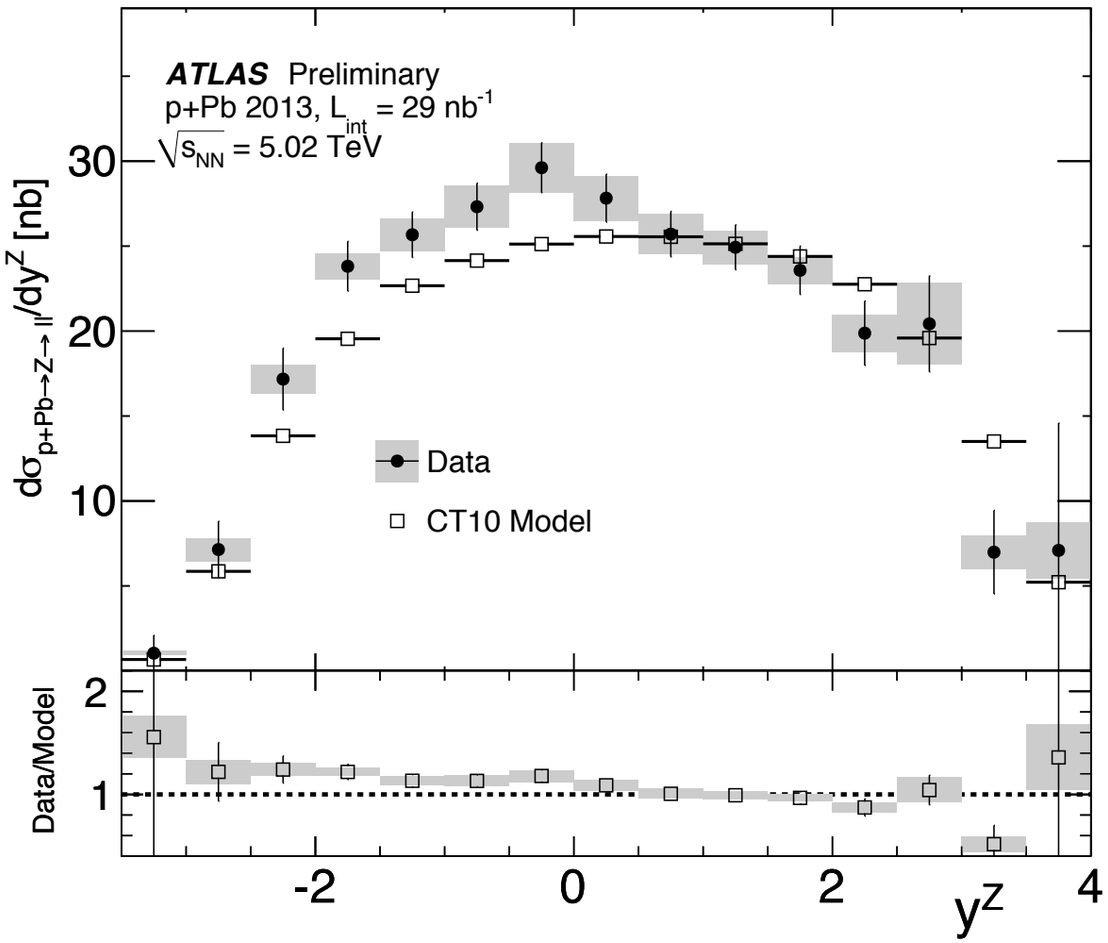


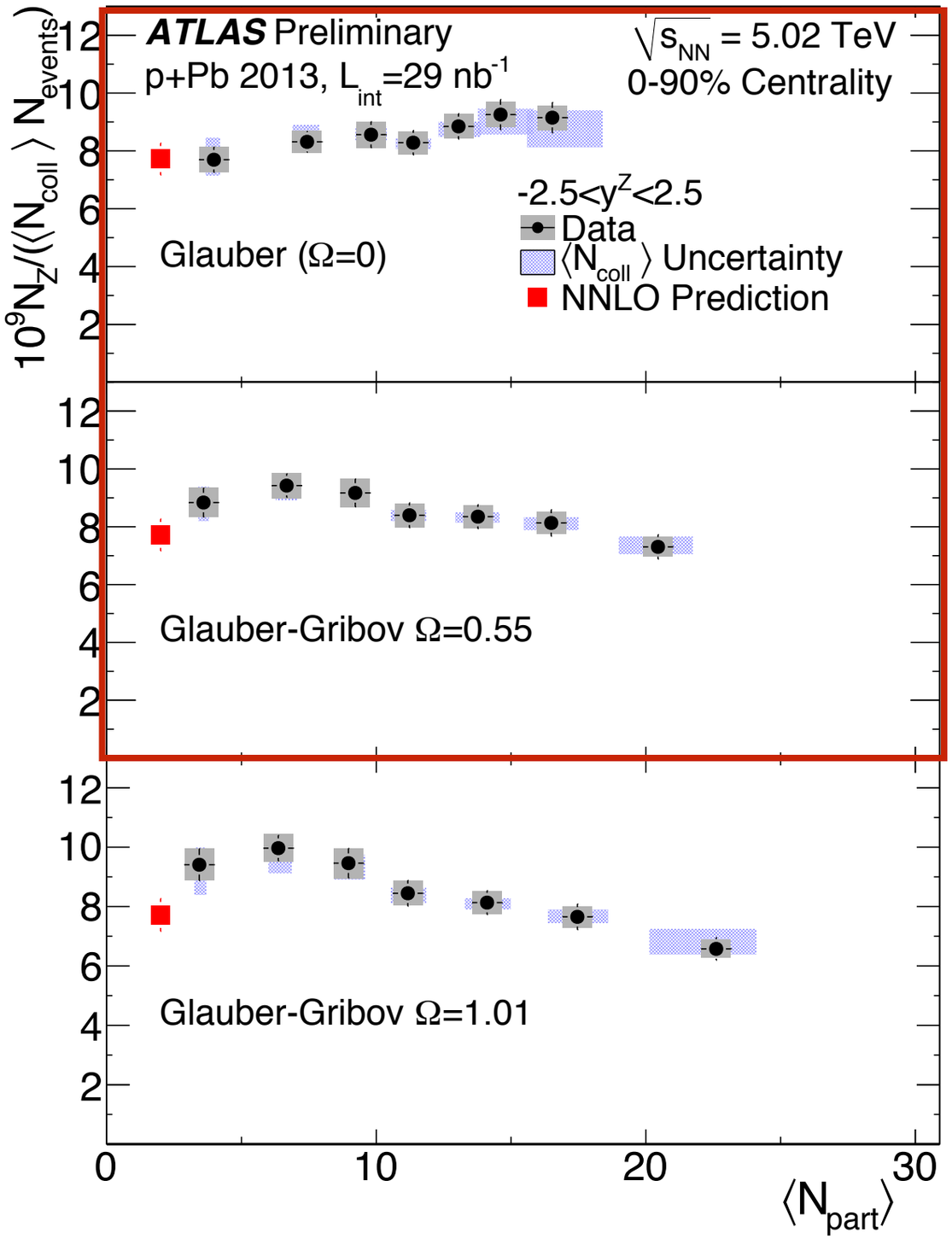
Need more data to test nPDF effects.

Z in p+Pb Collisions

Sensible results for
Glauber and GG Ω = 0.55.



A slight backward enhancement



Summary

- Soft probes

  Pb+Pb: v_n from cumulants method and compared to other methods.

  p+Pb: ridges in central p+Pb and peripheral Pb+Pb are driven by similar dynamics.

- Hard probes:

  - Jets

    Pb+Pb: R_{AA} shows strong dependence on centrality and weak dependence on p_T

    p+Pb: jet production is suppressed in central and enhanced in peripheral collisions.

  - W/Z Bosons

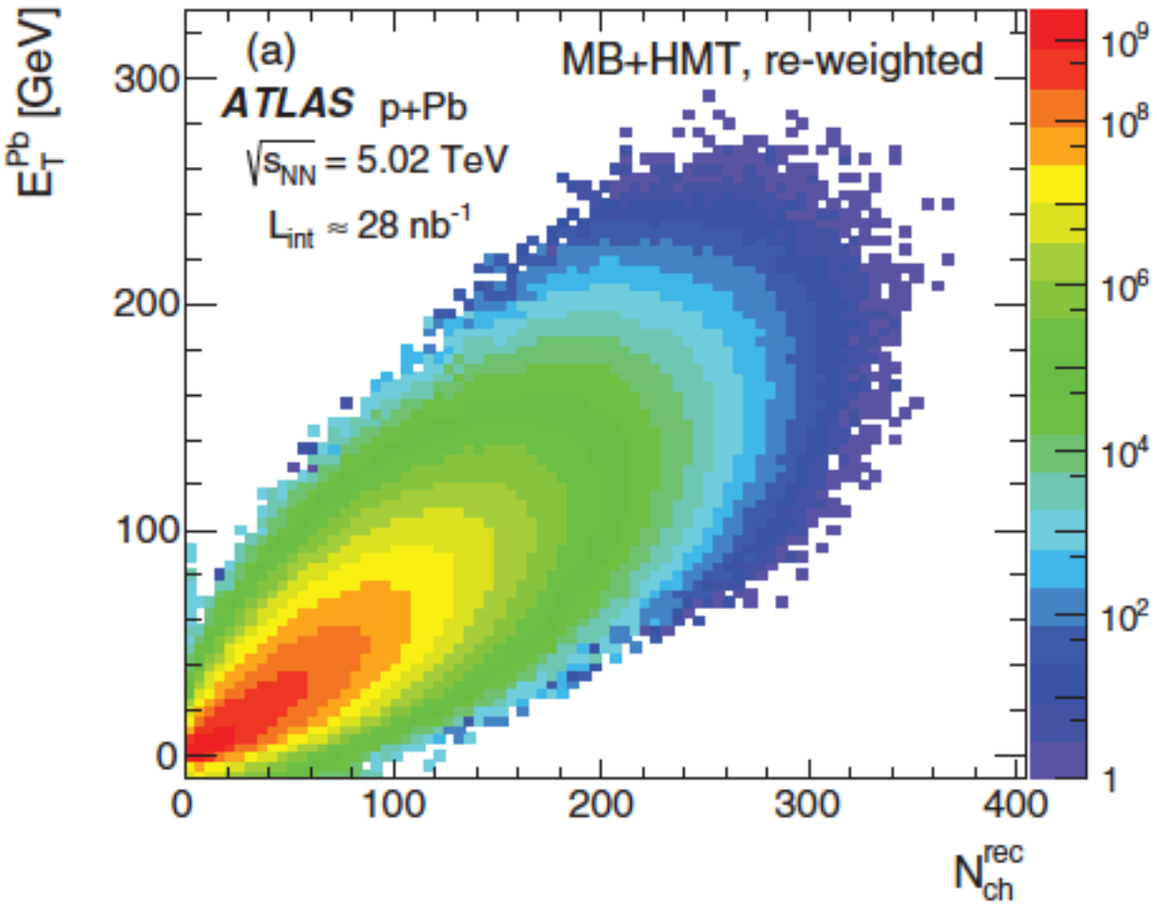
    Pb+Pb: Z and W obey binary collision scaling. Unable to test nPDF effects yet.

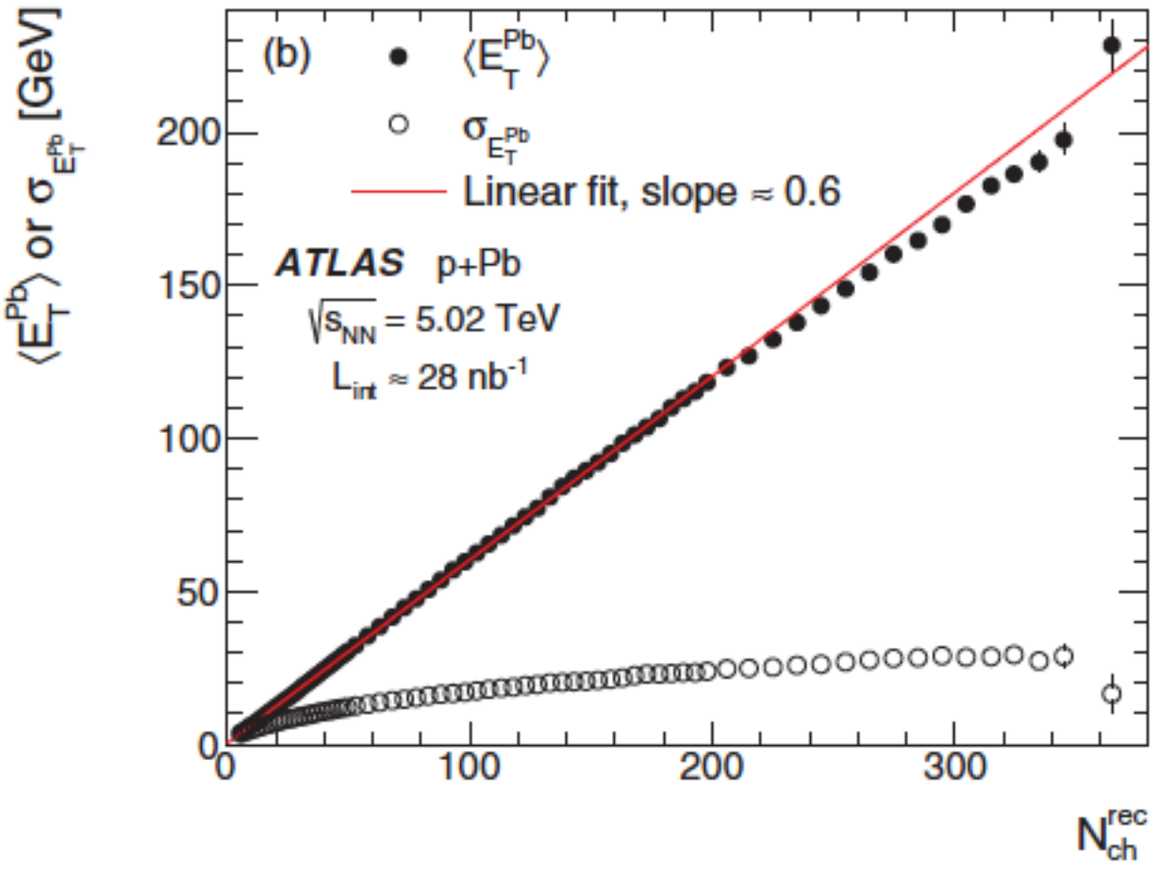
    p+Pb: Z production provides an experimental test on pPb centrality modeling.

More to come soon in *HP 2015* !

Thank you

p+Pb FCal E_T


(a)
MB+HMT, re-weighted
ATLAS p+Pb
$\sqrt{s_{NN}}$ = 5.02 TeV
L_{int} ≈ 28 nb^{-1}
E_T^{Pb} [GeV]
N_{ch}^{rec}
10^9
10^8
10^6
10^4
10^2
1
0
100
200
300
400


(b)
$\langle E_T^{Pb} \rangle$
$\sigma_{E_T^{Pb}}$
Linear fit, slope ≈ 0.6
ATLAS p+Pb
$\sqrt{s_{NN}}$ = 5.02 TeV
L_{int} ≈ 28 nb^{-1}
$\langle E_T^{Pb} \rangle$ or $\sigma_{E_T^{Pb}}$ [GeV]
N_{ch}^{rec}
0
50
100
150
200
300

Glauber and Glauber-Gribov models

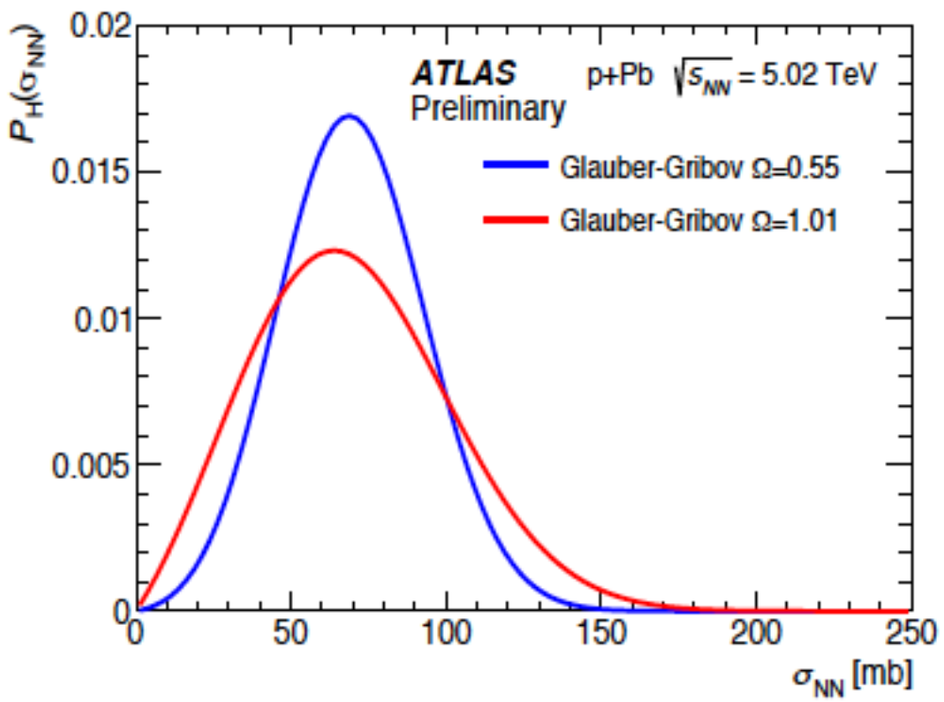
To model N_{part} distribution we used:

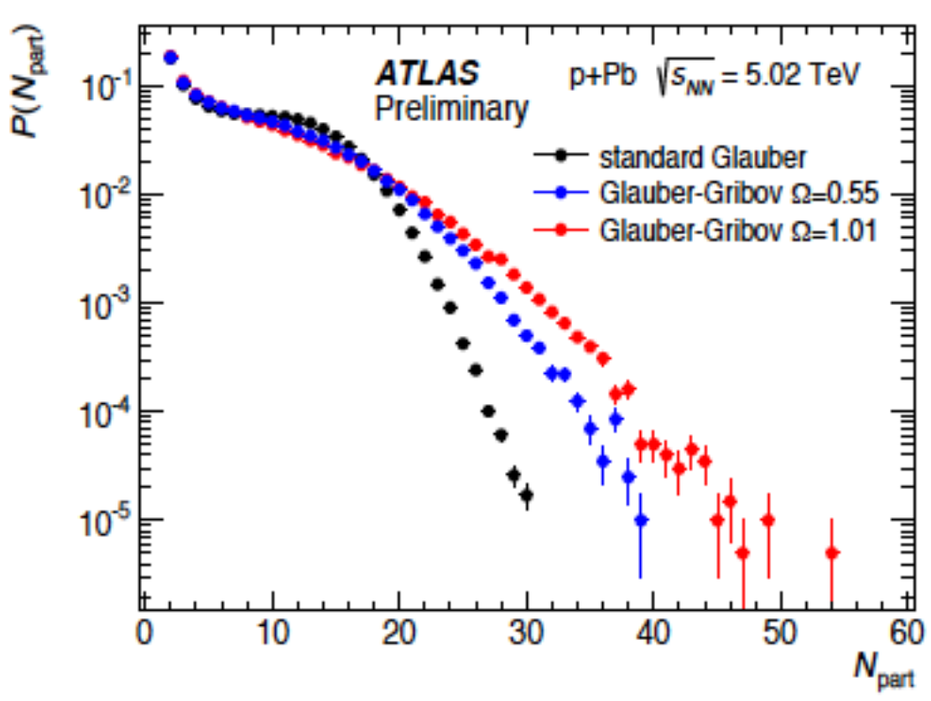
- standard Glauber with σ_{NN} cross section = 70±5mb
- Glauber-Gribov color fluctuation models, with $< \sigma_{NN} >$= 70±5mb

In GG model:

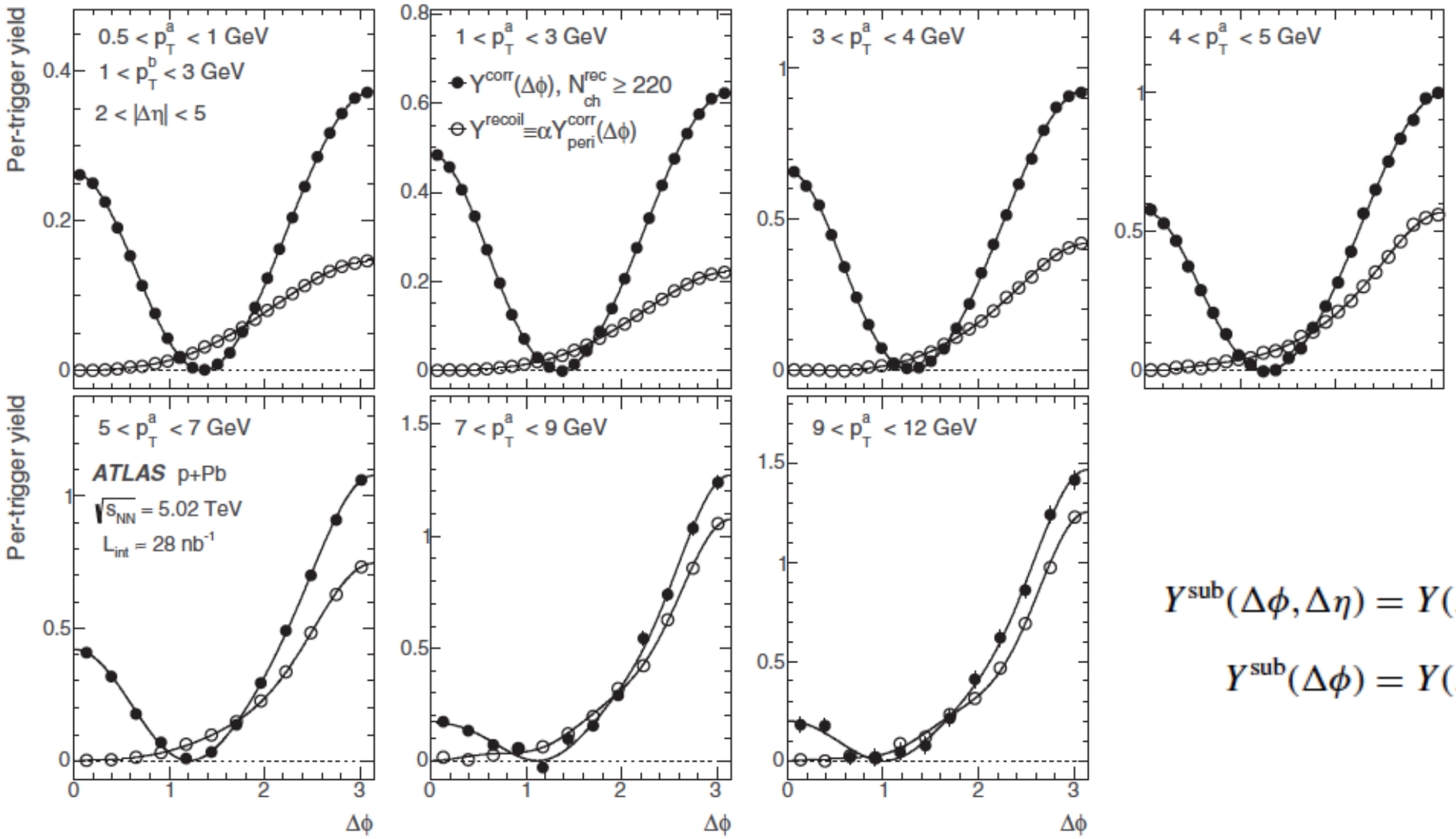
- σ_{tot} is considered frozen for each event
- parameter Ω controls the amount of fluctuations
- Ω is extracted from experimental data: 0.55 and 1.01

$$P_h(\sigma_{\rm tot}) = \rho \frac{\sigma_{\rm tot}}{\sigma_{\rm tot}+\sigma_0} exp\Big\{ - \frac{(\sigma_{\rm tot}/\sigma_0 - 1)^2)}{\Omega^2} \Big\}$$





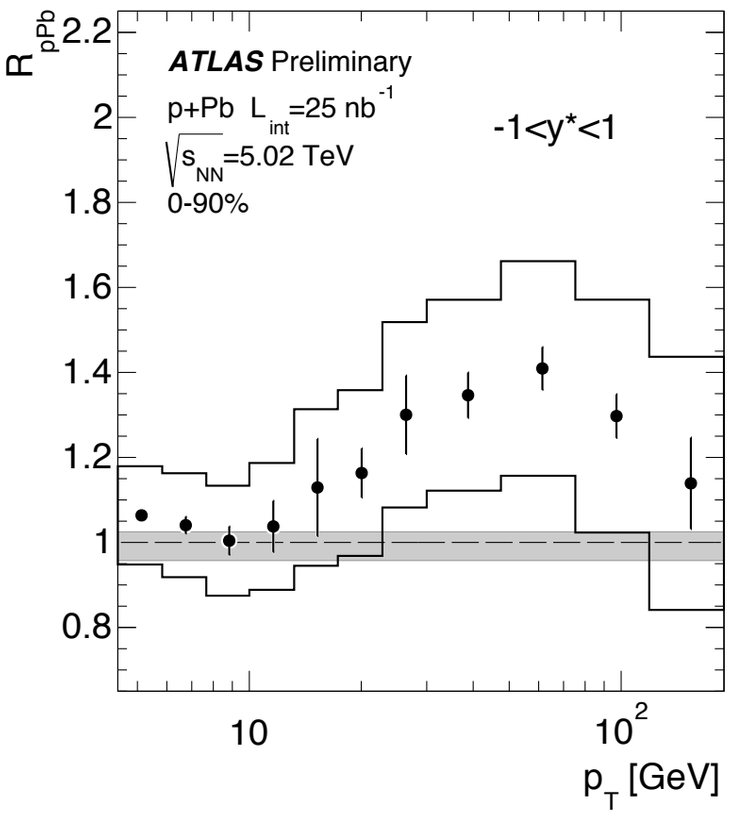
Recoil subtracting

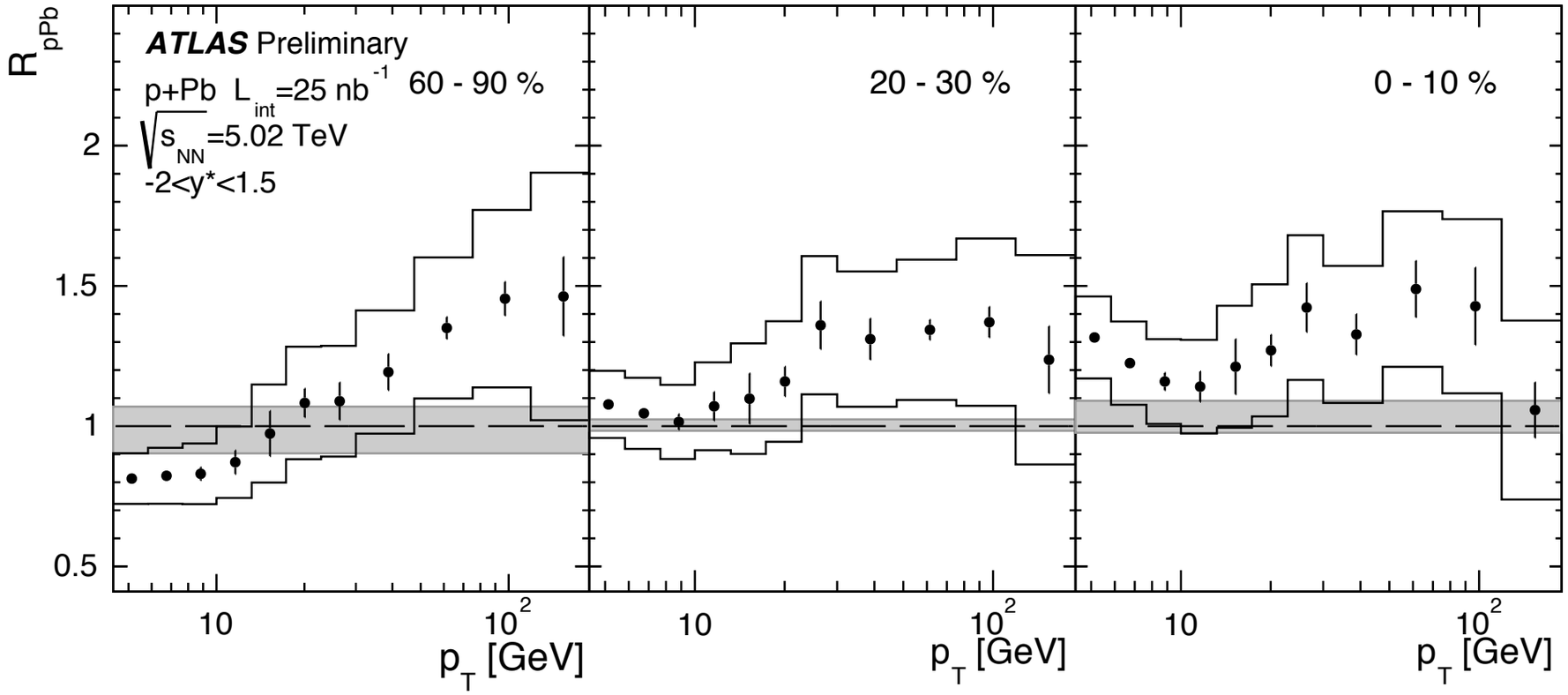


$$Y^{\mathrm{sub}}(\Delta\phi,\Delta\eta) = Y(\Delta\phi,\Delta\eta) - \alpha Y^{\mathrm{corr}}_{\mathrm{peri}}(\Delta\phi,\Delta\eta),$$

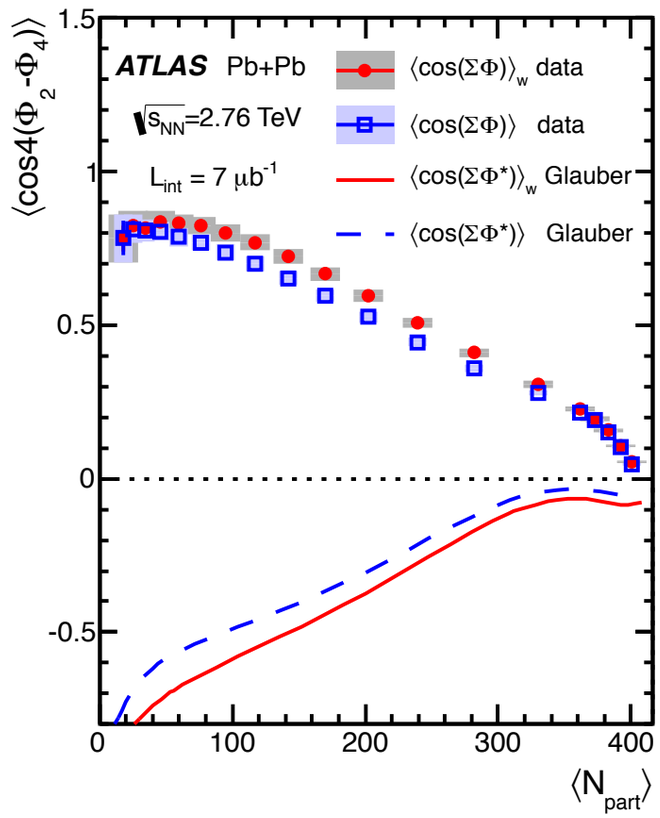
$$Y^{\mathrm{sub}}(\Delta\phi) = Y(\Delta\phi) - \alpha Y^{\mathrm{corr}}_{\mathrm{peri}}(\Delta\phi),$$

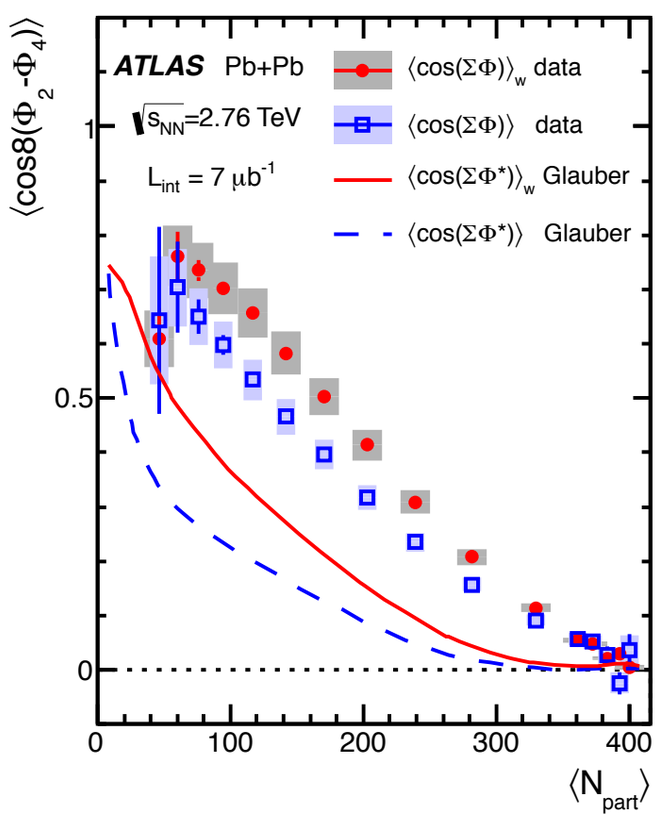
Charge particle R_{pPb}

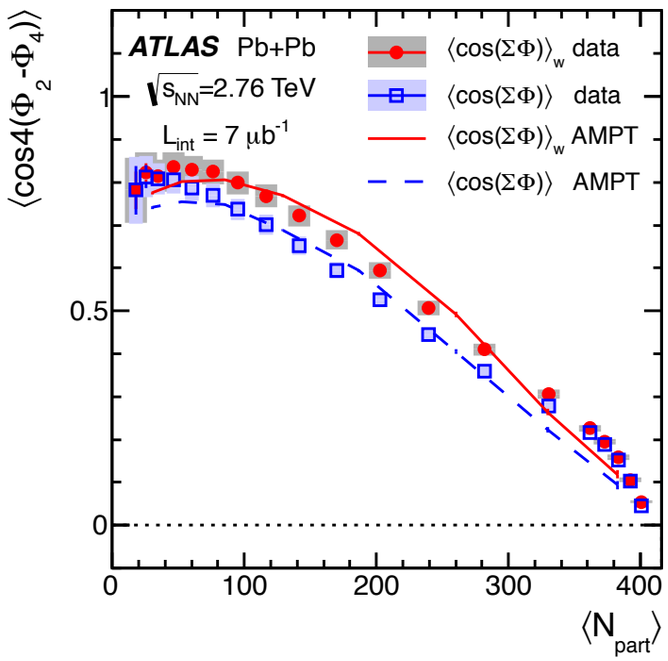


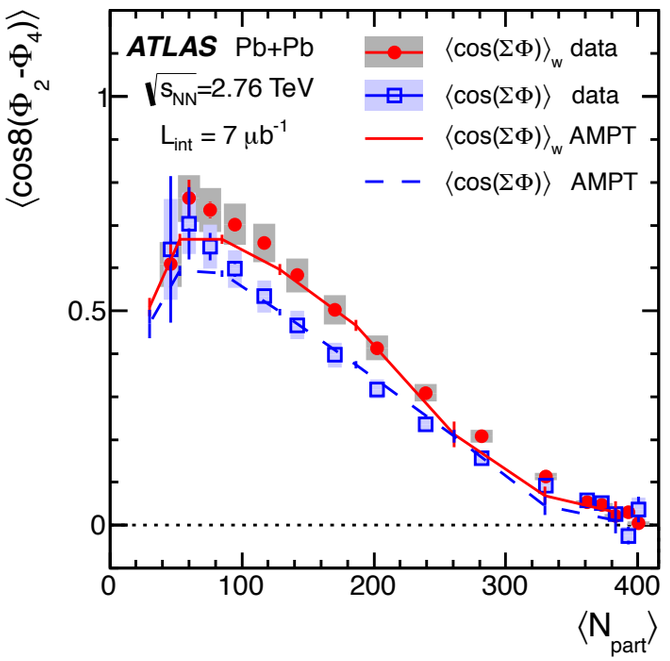


Event plane correlation

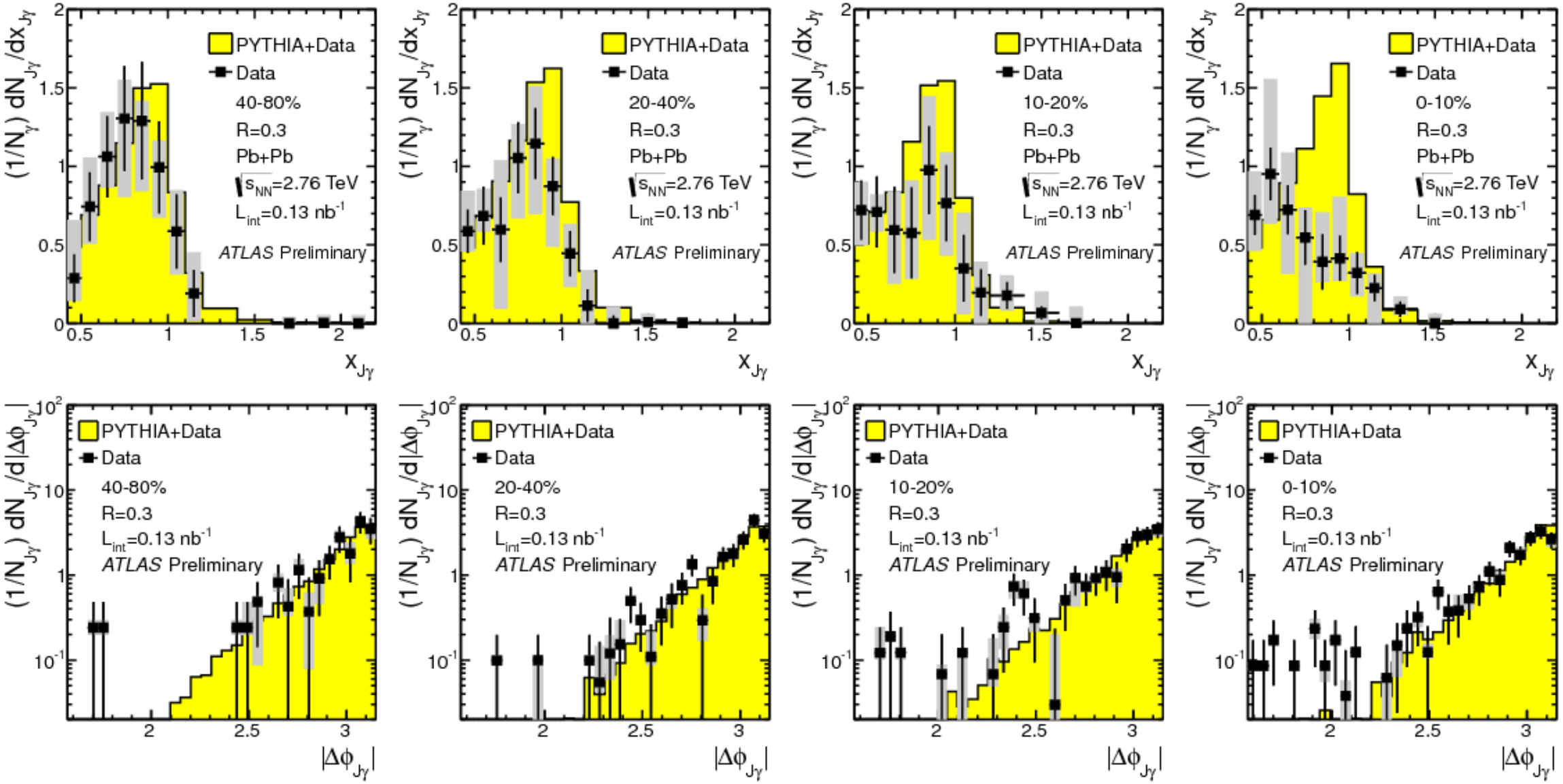








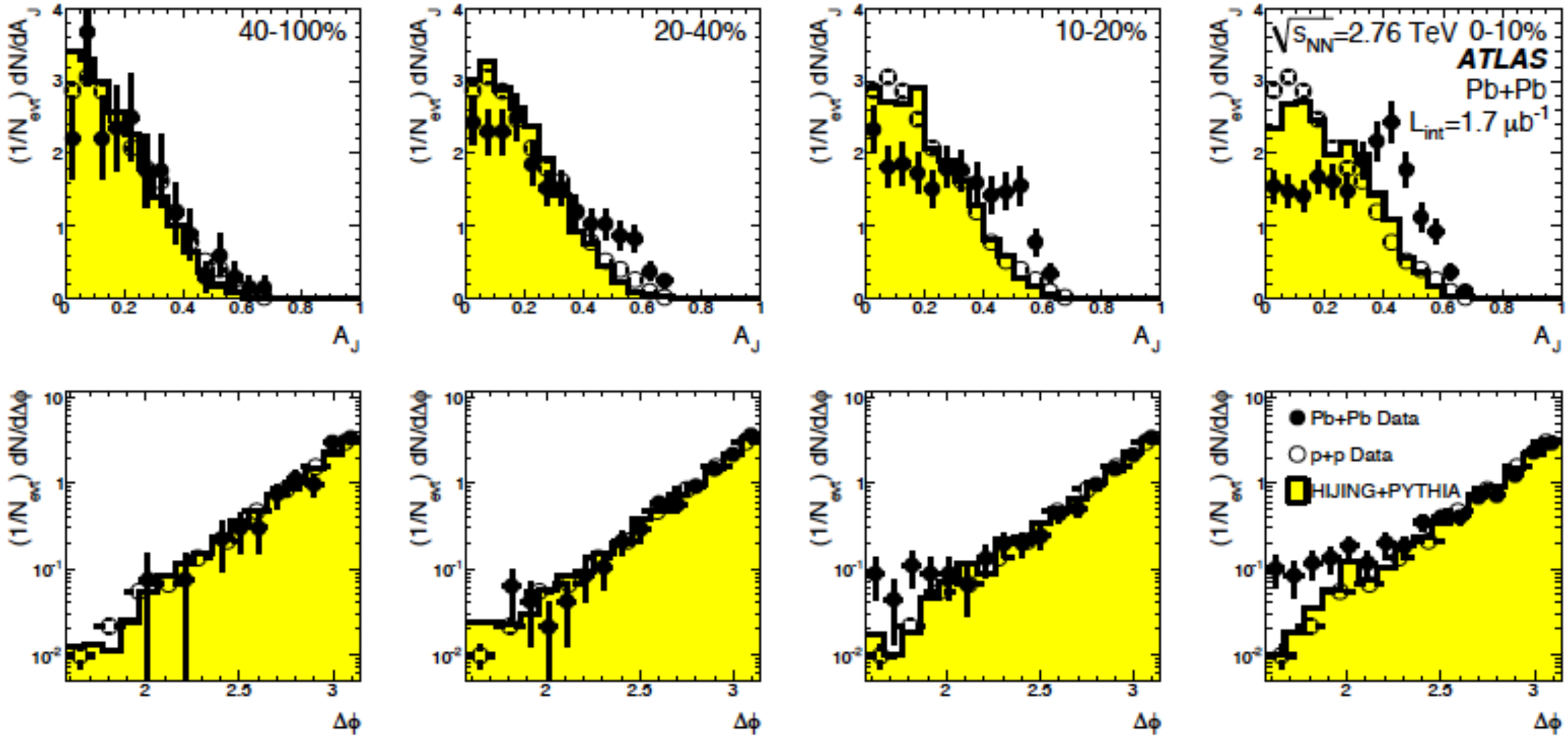
Photon+jet



https://cdsweb.cern.ch/record/1473135

$$\chi_{J\gamma} = \frac{P_{\mathrm{T}}^{J}}{P_{\mathrm{T}}^{\gamma}}$$

Di-Jet asymmetry



Phys. Rev. Lett. 105, 252303 (2010)

$$A_J = \frac{E_{\mathrm{T}}^1 - E_{\mathrm{T}}^2}{E_{\mathrm{T}}^1 + E_{\mathrm{T}}^2}$$