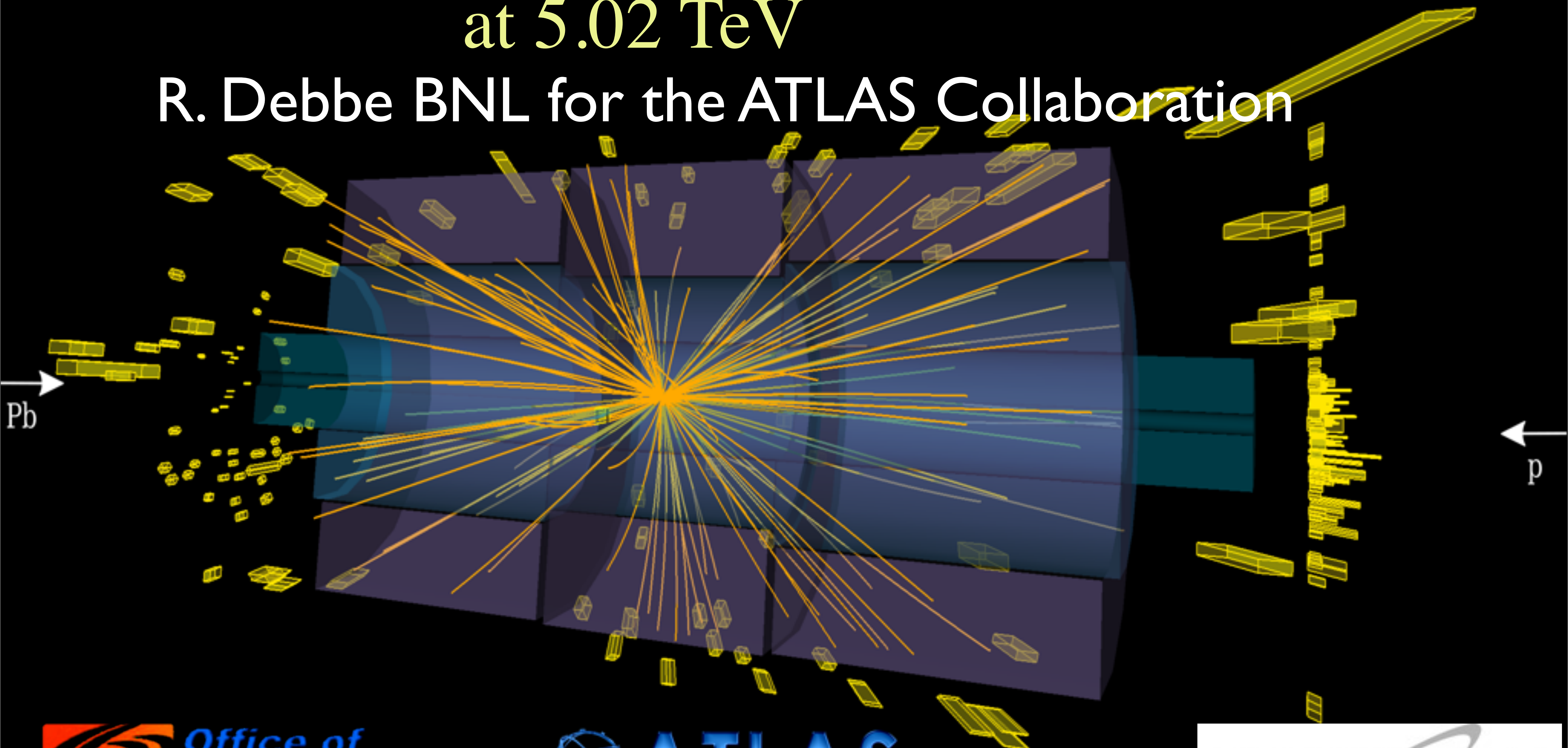
ATLAS Measurement of the centrality dependence of the charged particle dn/dη in p+Pb at 5.02 TeV

R. Debbe BNL for the ATLAS Collaboration



Office of Science
U.S. DEPARTMENT OF ENERGY

ATLAS EXPERIMENT

BROOKHAVEN NATIONAL LABORATORY

QM2014 Darmstadt 19-24 May

Physics context

pA collisions have been used to study hadronic interactions in nuclear environment. Soft particle production found to scale as A^{α}, an indication of coherent multiple soft interactions in the target (Cronin effect).

In the RHIC program d+Au were produced as base line for cold nuclear matter to compare to the sQGP environment produced in Au + Au collisions.

Asymmetric system; kinematic window to small x components in the nuclear wave function of the A target which may be mostly glue. (CGC)

Outline

- RHIC results
- The ATLAS detector
- Event selection
- Centrality definition
- Extraction of multiplicities
- Summary

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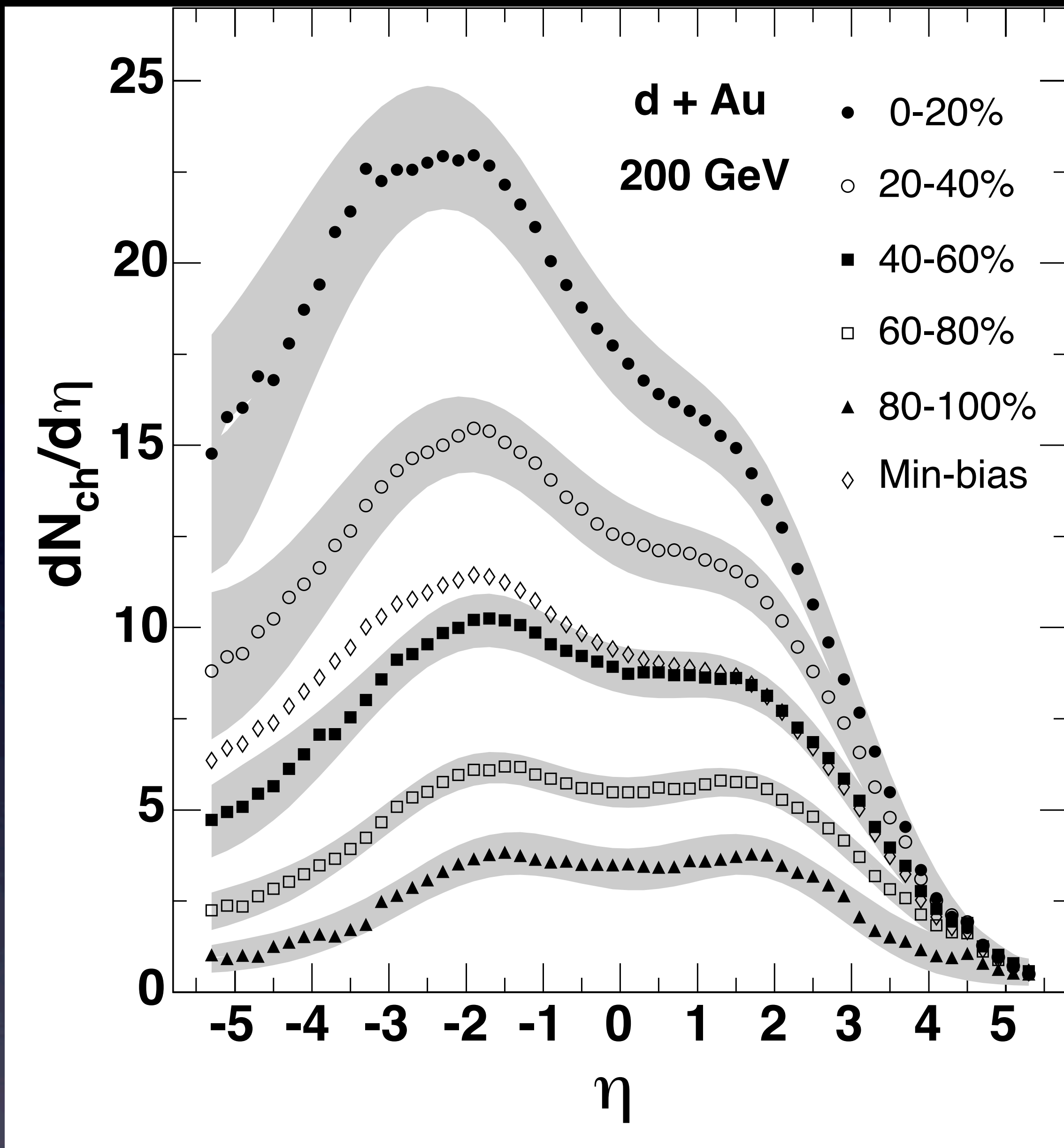
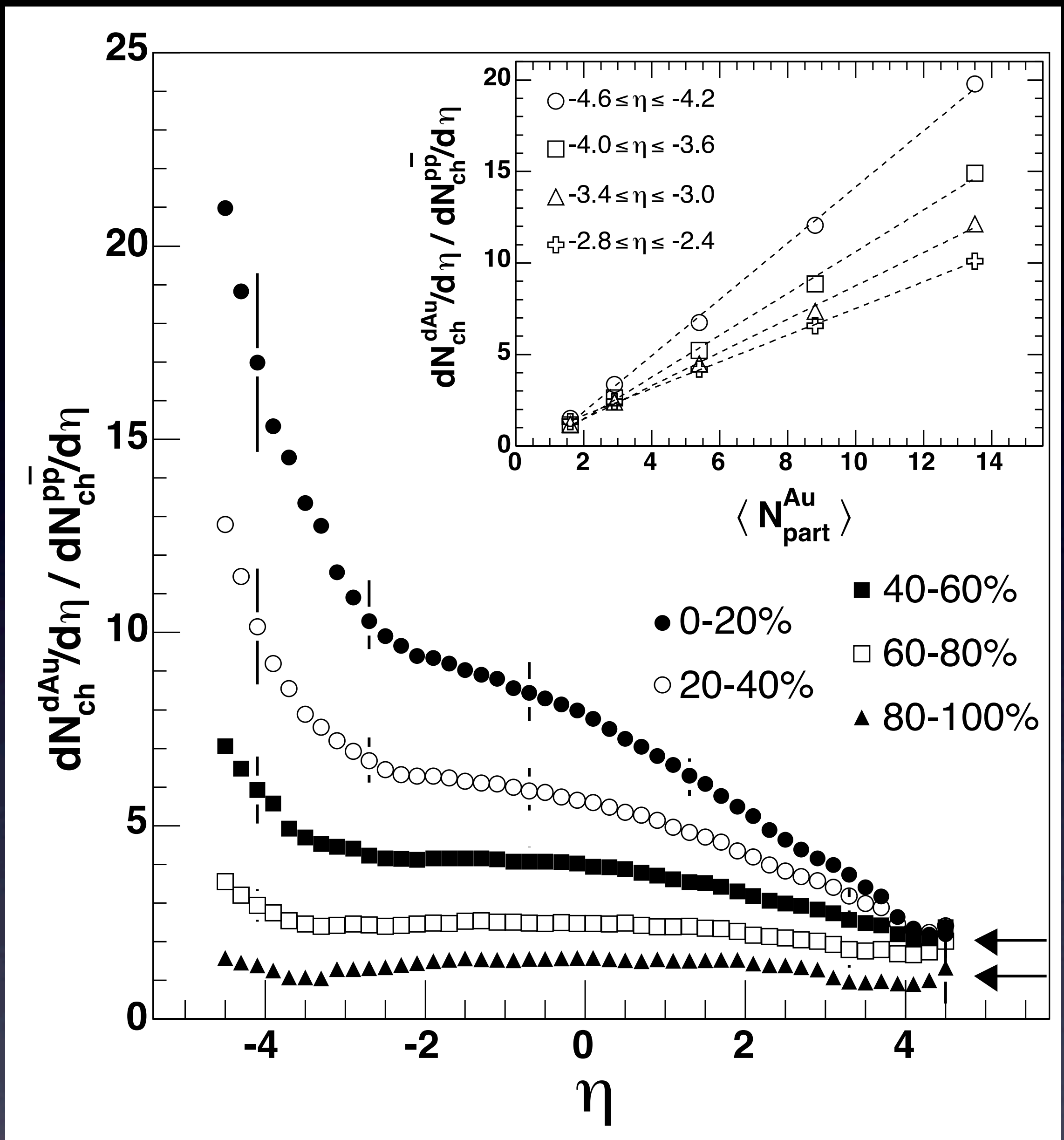
RHIC results and motivation





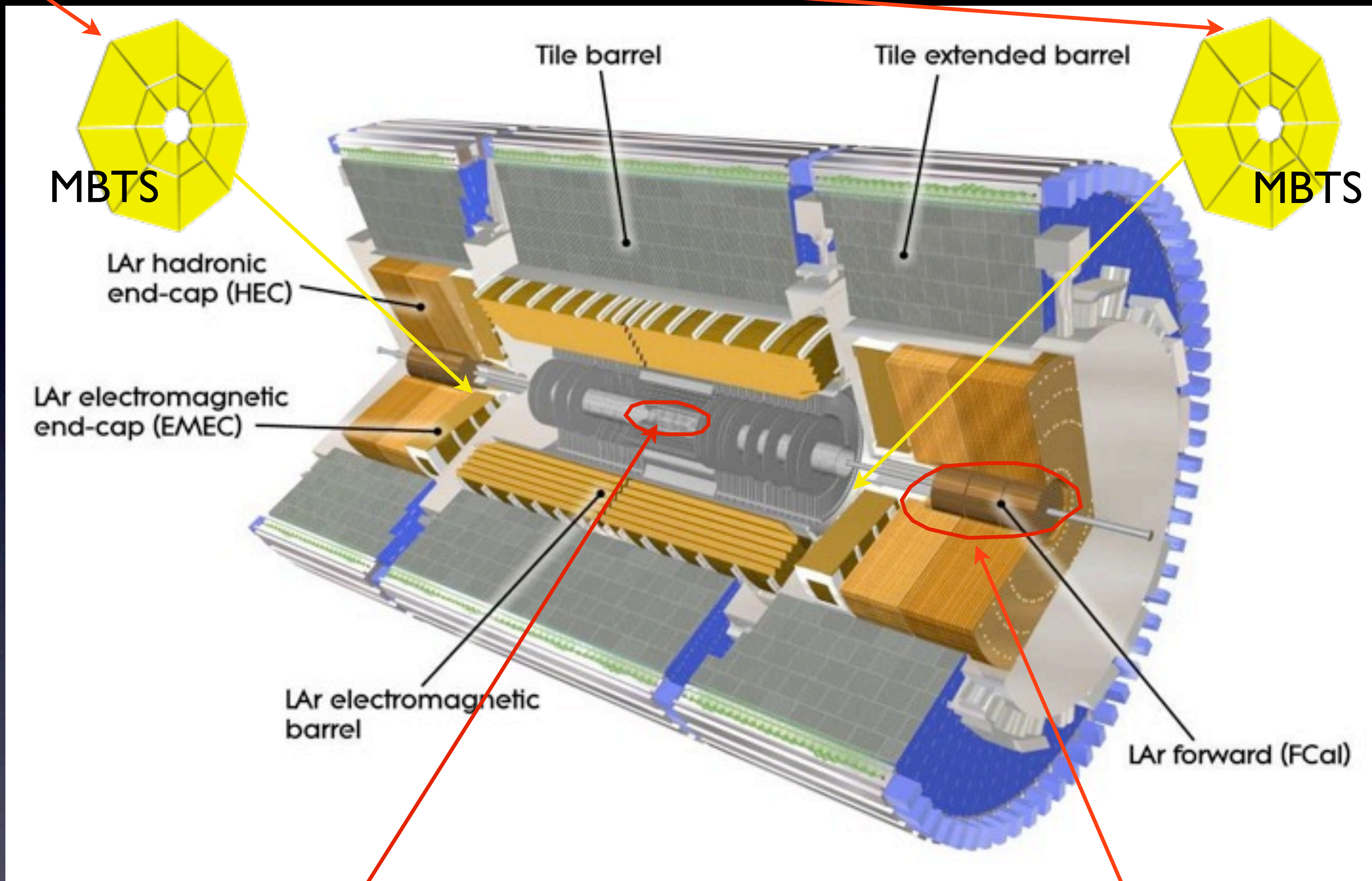
← Au d →

Particle production on the target side centered ~2 η units away from mid-rapidity, grows fast with centrality. Lower mult. on d side but also scales with centrality

Ratio to pp̄ at same energy shows the “triangular” distribution possibly due to “nuclear attenuation” or saturation effects, “Triangle” ends at ~3 units of pseudo-rapidity

The ATLAS detector

Min Bias trigger
$2.1 < |\eta| < 3.9$



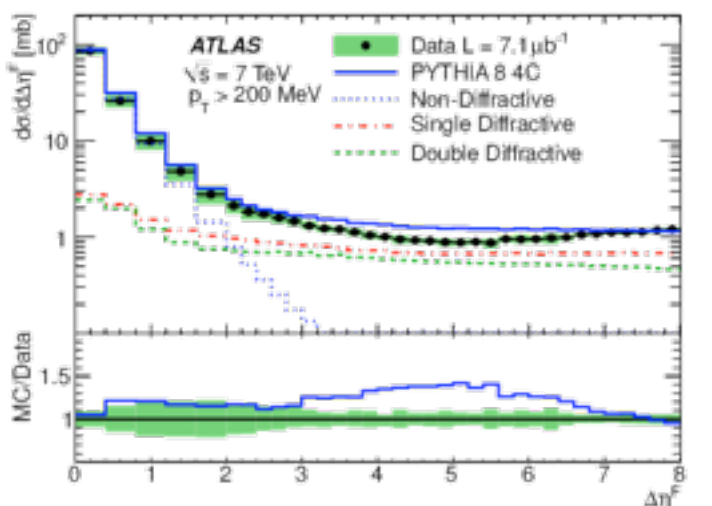
Multiplicity measured with the PIXEL detector. Barrel $|\eta| < 2.2$.
Endcaps $1.6 < |\eta| < 2.7$.

Centrality of events extracted from E_T in Pb going FCal.
$3.2 < \eta < 4.9$.

Event Selection

Data collected in the 2012 p+Pb pilot run with L_{int} = 1 μb^{-1}
4 TeV p beam + 1.57 TeV Pb center of mass 5.02 TeV at y=-0.465

- Trigger: MBTS_2 (at least two hits in MBTS detectors)
- Time difference between MBTS A and C: $|\Delta t|<10$ns
- Event with reconstructed vertex (at least 2 tracks p_T>100MeV)
- Pile-up: events with two “good” vertices rejected (10^{-4} effect)
- Rapidity gap $\Delta\eta^{Pb} \leq 2$ to eliminate diffractive events.



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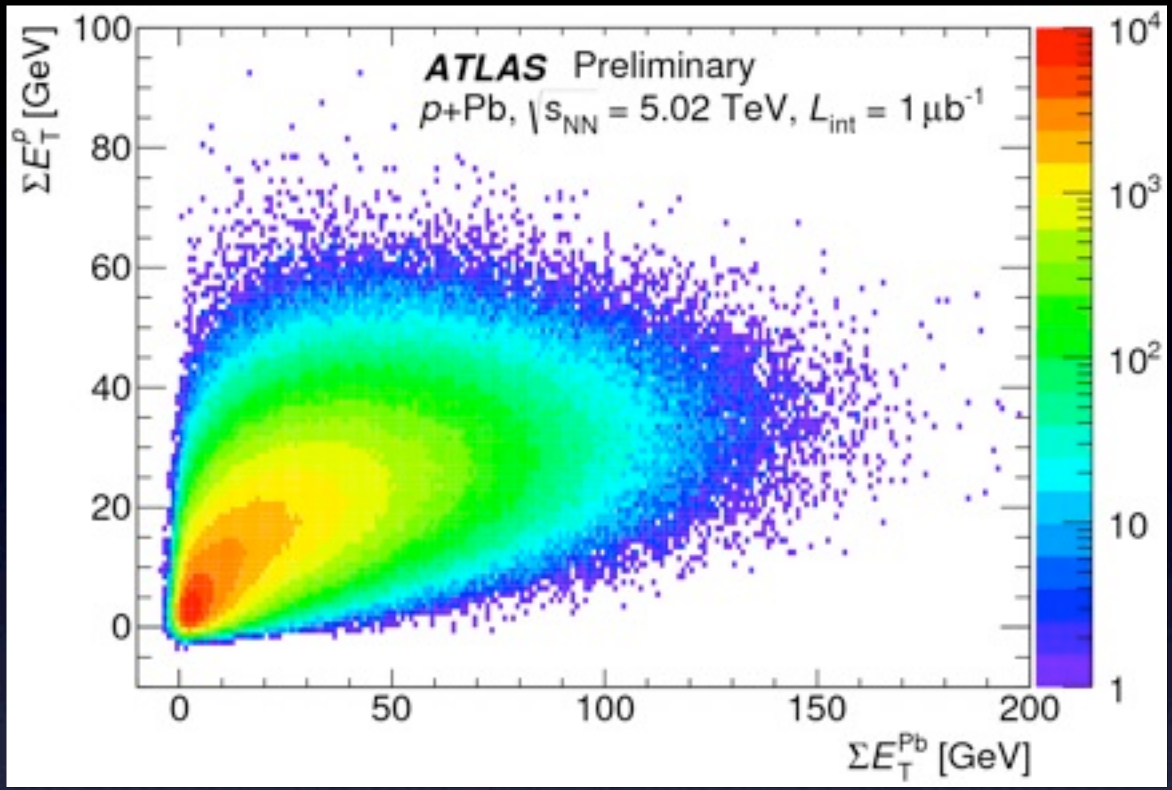
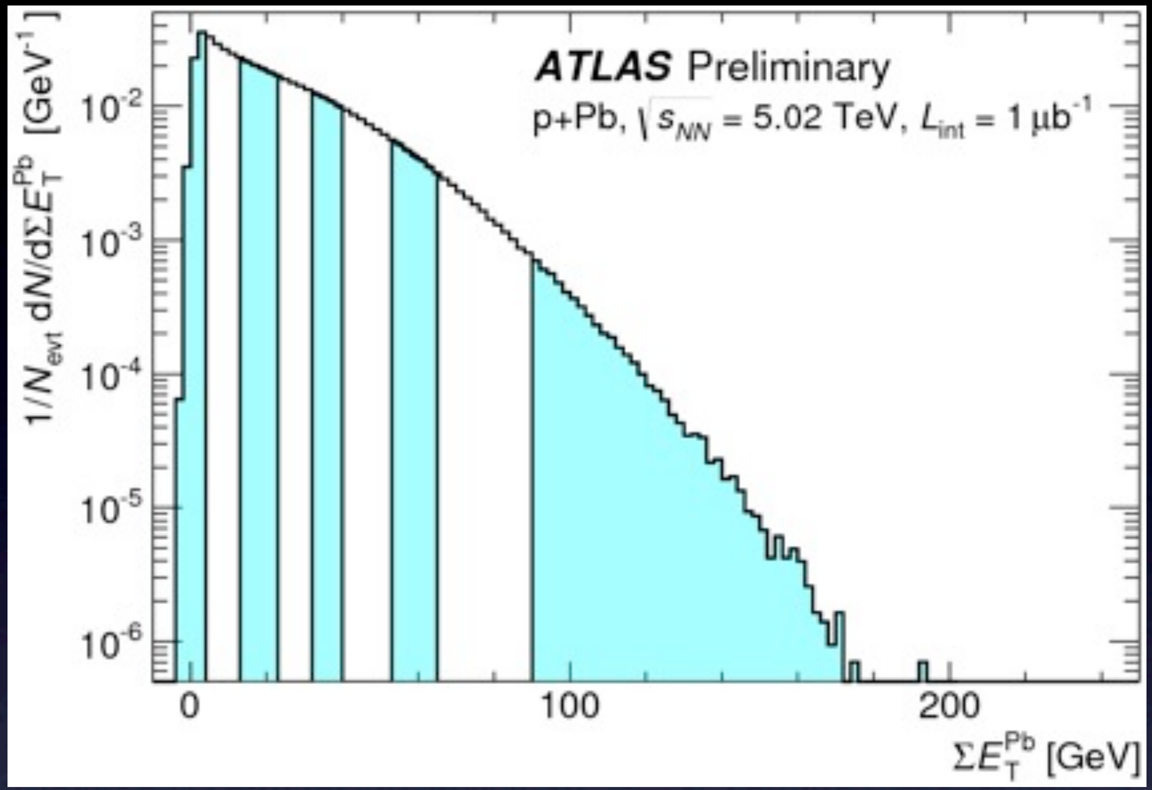
Centrality Definition





Centrality of the event is characterized with energy deposited in the Pb-going FCal (A)

Centrality intervals 0-1, 1-5, 5-10...60-90%

We exclude 90-100%

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Centrality definition cnt.

Glauber and Glauber-Gribov models

To model Npart distribution we used:

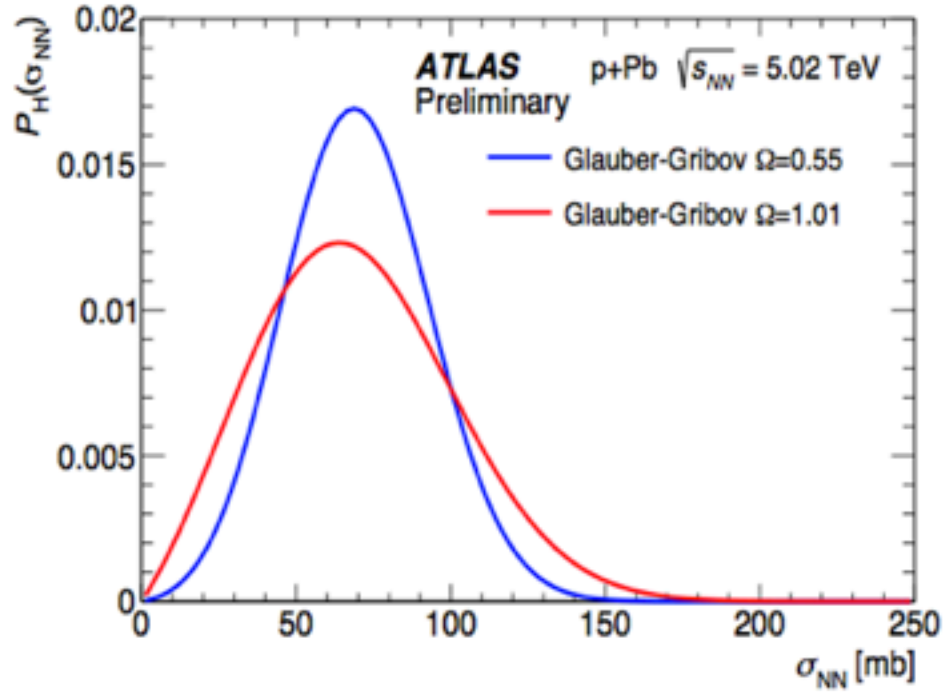
- standard Glauber with σ_{NN} cross section = 70±5mb
- Glauber-Gribov color fluctuation models, with $<\sigma_{NN}>$ cross section = 70±5mb

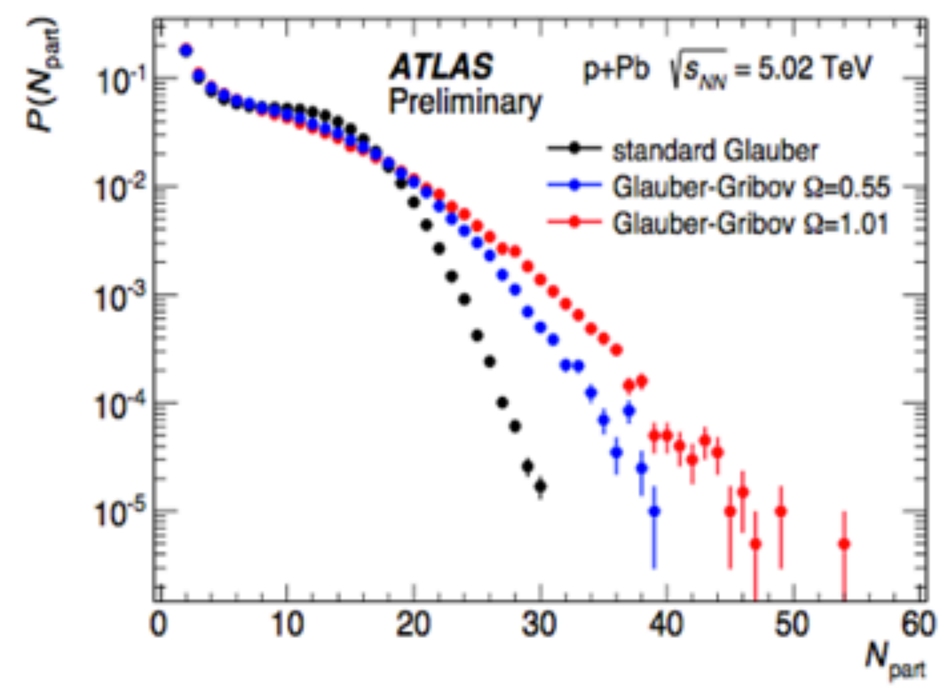
In Glauber-Gribov model:

- σ_{tot} is considered frozen for each event
- parameter Ω controls the amount of fluctuations
- Ω is extracted from experimental data: 0.55 [PLB633 (2006) 245–252] and 1.01 [PLB 722 (2013) 347–354]

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

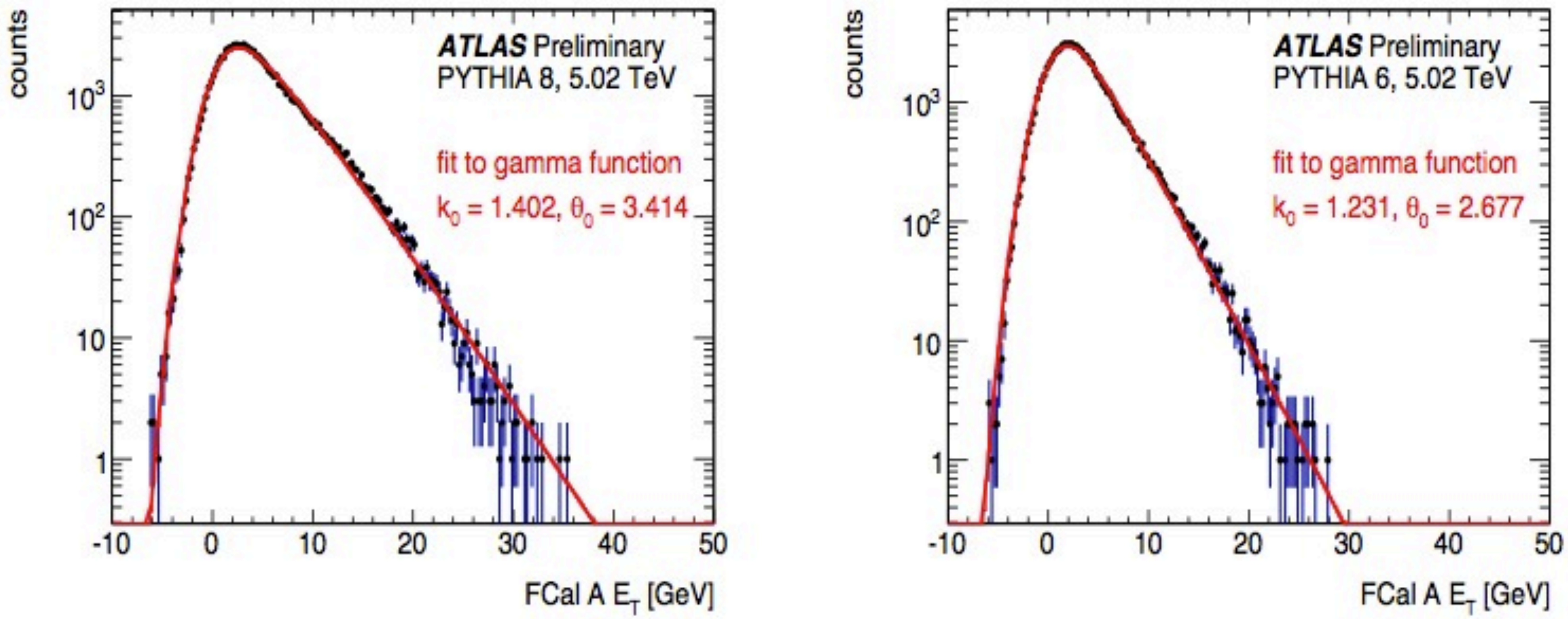
$$P_H(\sigma_{NN}) = \frac{1}{\lambda} P(\sigma_{NN}/\lambda)$$





Constructing FCal ΣE_T^{Pb} response

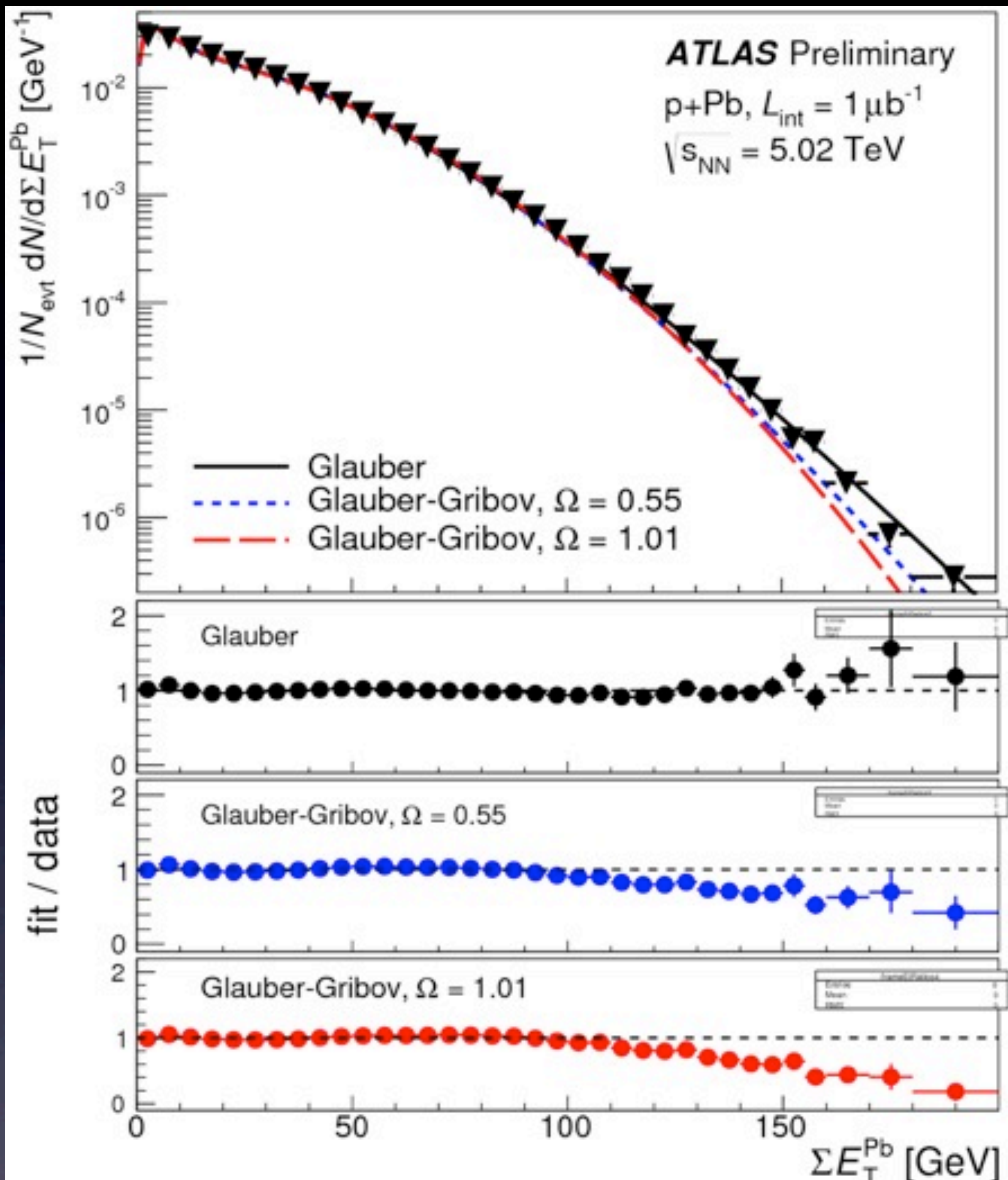
E_T distribution modeled by PYTHIA simulated taking into account FCal response in p+Pb configuration and were approximated by Gamma(k,θ) distributions



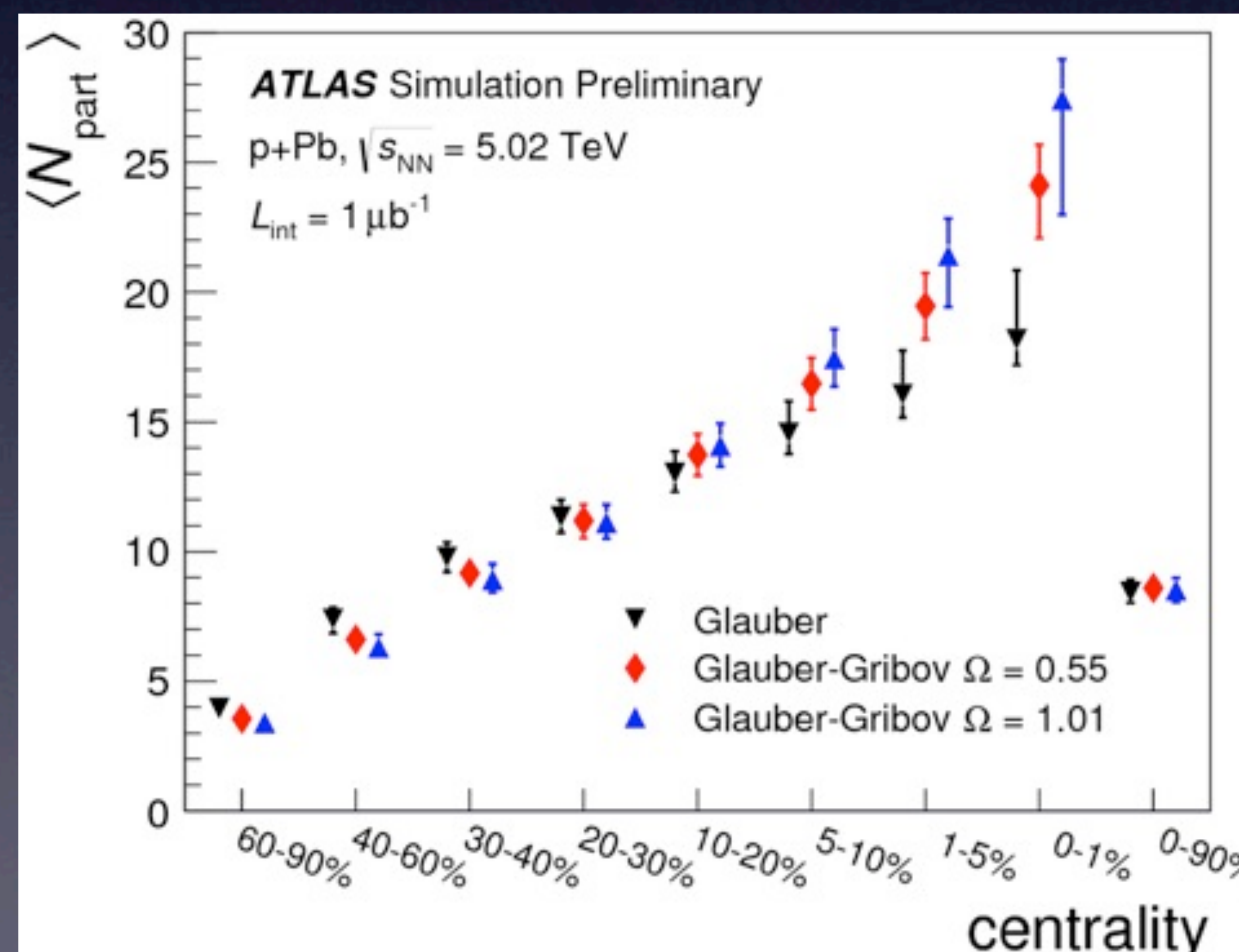
Convolution of N_{part} Gamma(k,θ) was taken as Gamma(k(N_{part}),θ(N_{part}))

We allowed: $k(N_{part}) = k_0+k_1*(N_{part}-2)$; $\theta(N_{part}) = \theta_0+\theta_1*(\log(N_{part}-1))$;
In WN : $k(N_{part}) = k*N_{part}$; $\theta(N_{part}) = \theta$;

E_T response for N_{part} was weigthed according to Glauber or Glauber-Gribov model and fitted to the data



dN_{evt}/dE_T is extracted by summing the gamma distribution corresponding to different N_{part} values. The sum is weighted by $P(N_{part})$



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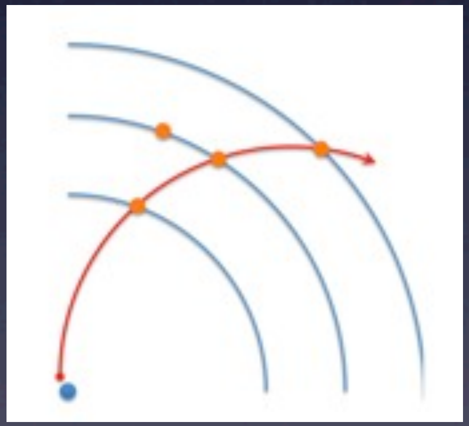
Extraction of multiplicities

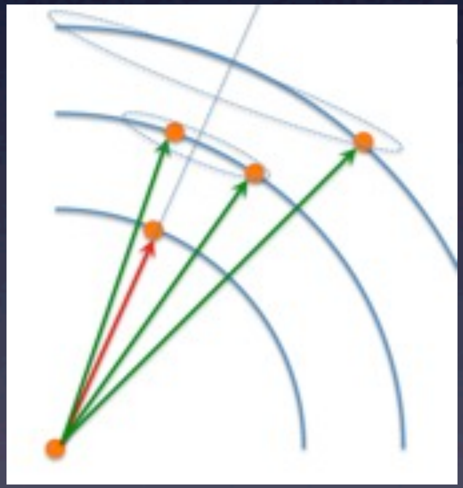
Use the Pixel detector only because of its low p_T acceptance.
Three analysis method used in parallel:
Count standard "pixel tracks": Lowest acc. few fakes
Tracklet method 1: Largest acc. some fakes
Tracklet method 2: large acc. needs fake estimate.

pixel tracks:



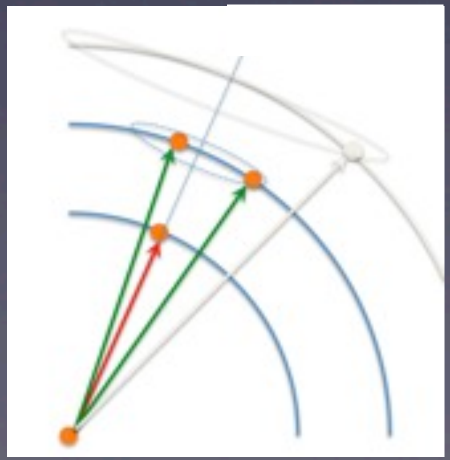
ATLAS ID tracker
seeded + Kalman filter
also used to re-weigh
HIJING MC

tracklet method 1:



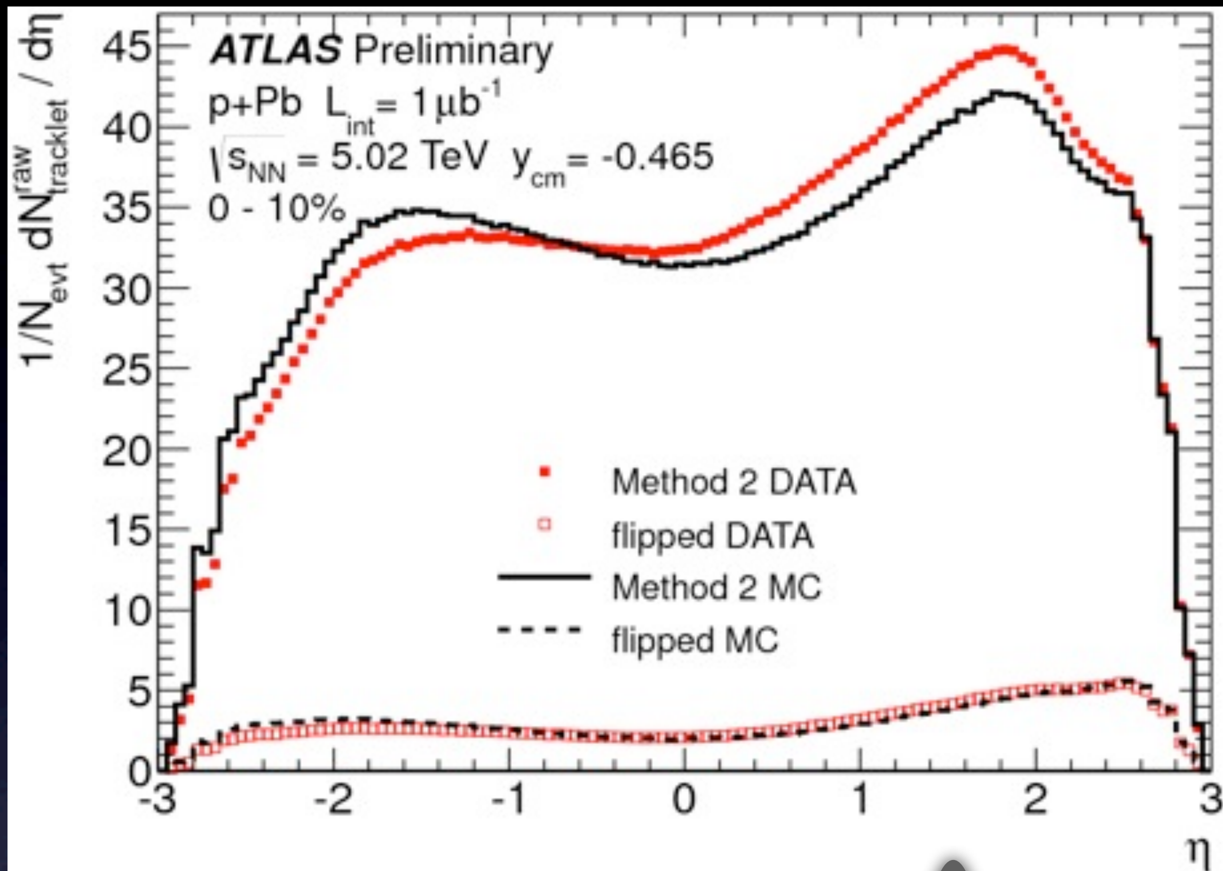
vertex+2hits or clusters
no sharing on first layer
search on layers 2 and 3:
$|\Delta\eta|<0.015$, $|\Delta\varphi|<0.1$, $|\Delta\eta| < |\Delta\varphi|$

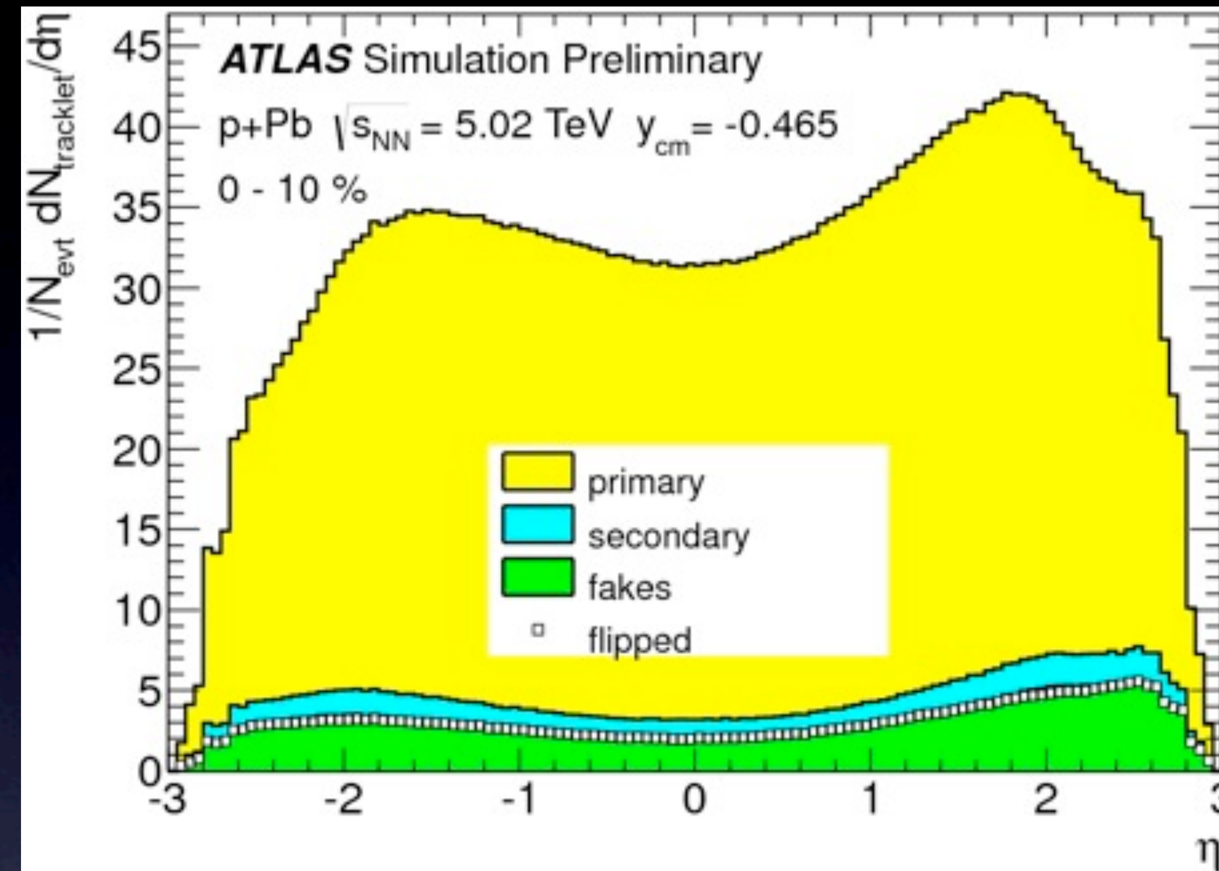
method2:



use all combination of clusters
found in the first two pixel layers.
same search "cone". Allows for
fake estimate.

Estimate of Fake Tracklets

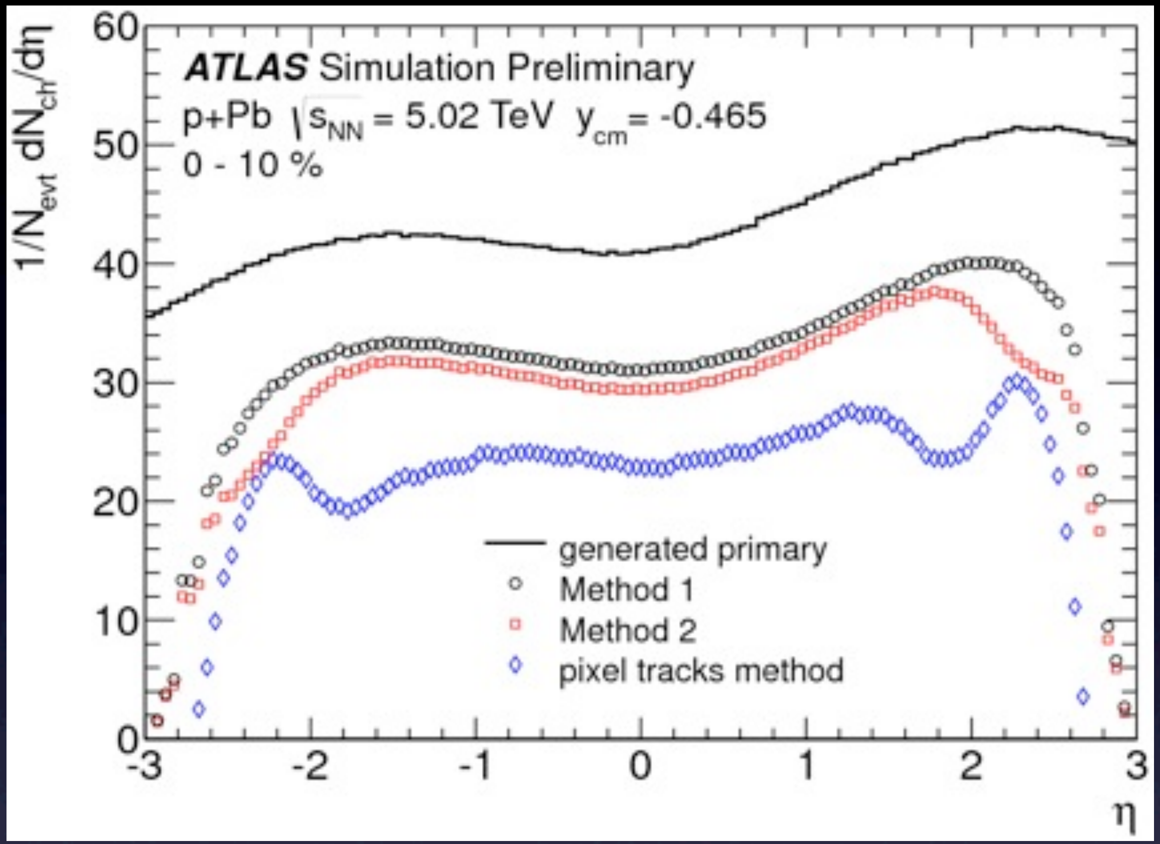


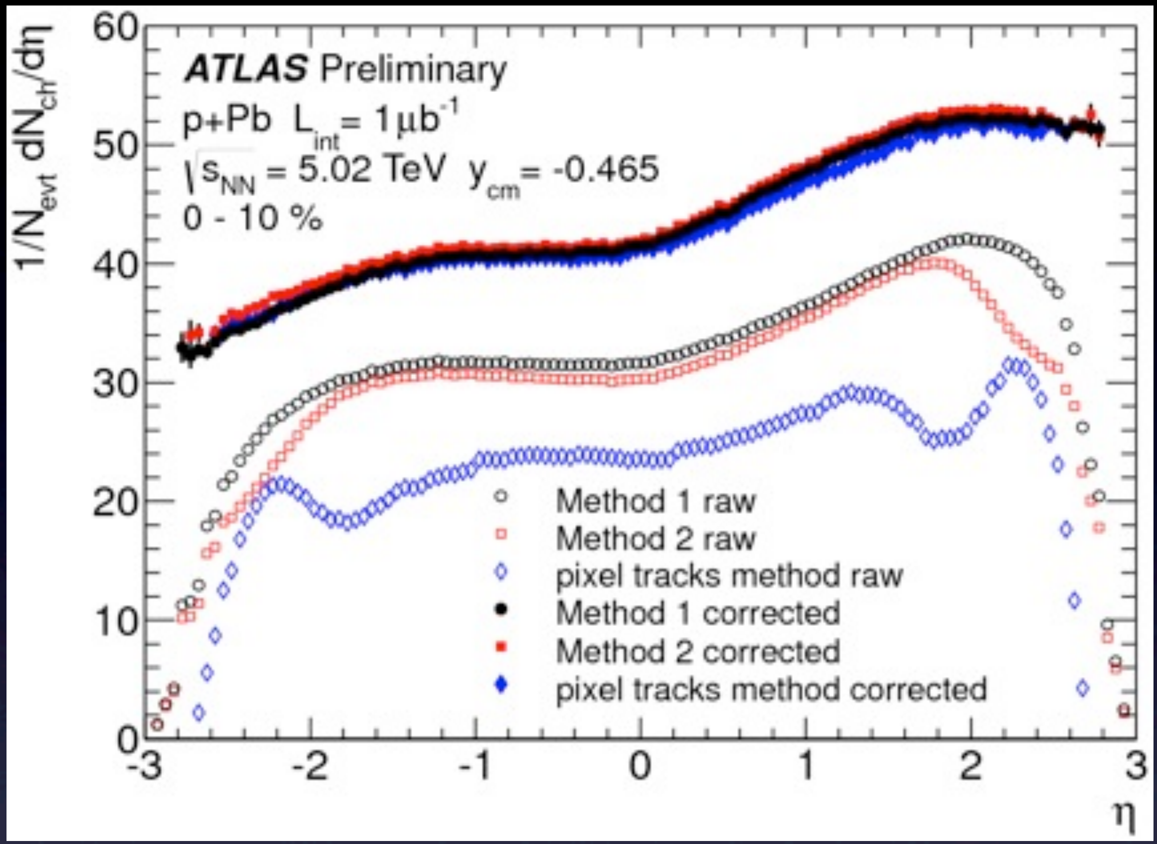


"flipped" x and y coordinates of B1 and B2 layer clusters are mirrored with respect to the vertex: $(x - x_{vtx}, y - y_{vtx}) \rightarrow (-(x - x_{vtx}), -(y - y_{vtx}))$

Good agreement, it provides fake correction

Corrections for each method





Method 1 is selected as the one to extract the multiplicities.
Method 2 used to estimate systematic uncertainties.
Pixel track method used as consistency check.

$$C(O, z_{\rm vtx}, \eta) \equiv \frac{N_{\rm pr}(O, z_{\rm vtx}, \eta)}{N_{\rm rec}(O, z_{\rm vtx}, \eta)},$$

$$\frac{dN_{\rm ch}}{d\eta} = \frac{1}{N_{evt}} \sum_{z_{\rm vtx}} \frac{\Delta N^{\rm raw}(O, z_{\rm vtx}, \eta) C(O, z_{\rm vtx}, \eta)}{\Delta\eta},$$

Systematic Uncertainties

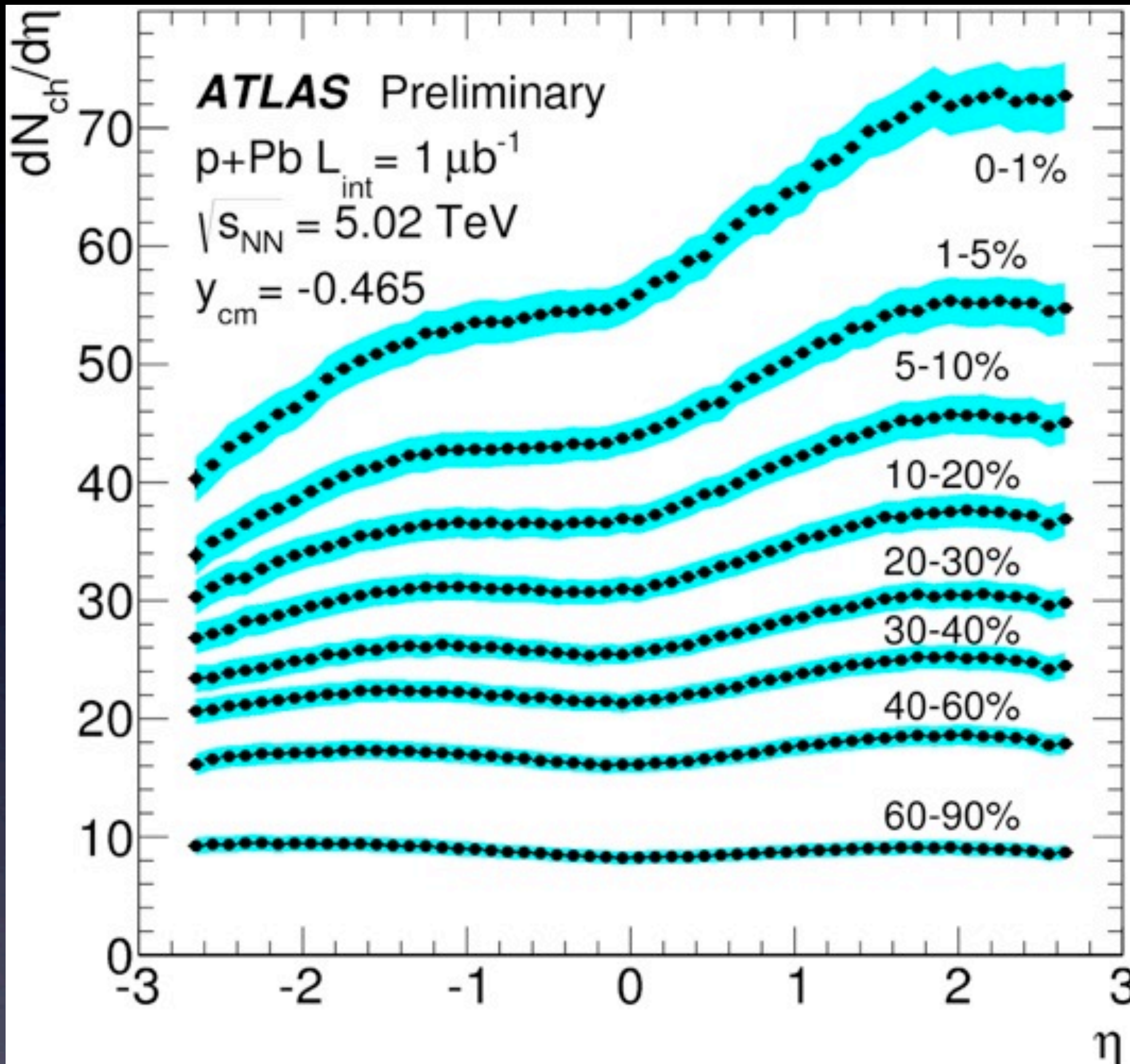
Sources:

- Inaccuracies in detector description
- Track selection criteria.
- Difference between data and Event generator.

Magnitude of uncertainty estimating by changing parameter values within acceptable ranges.

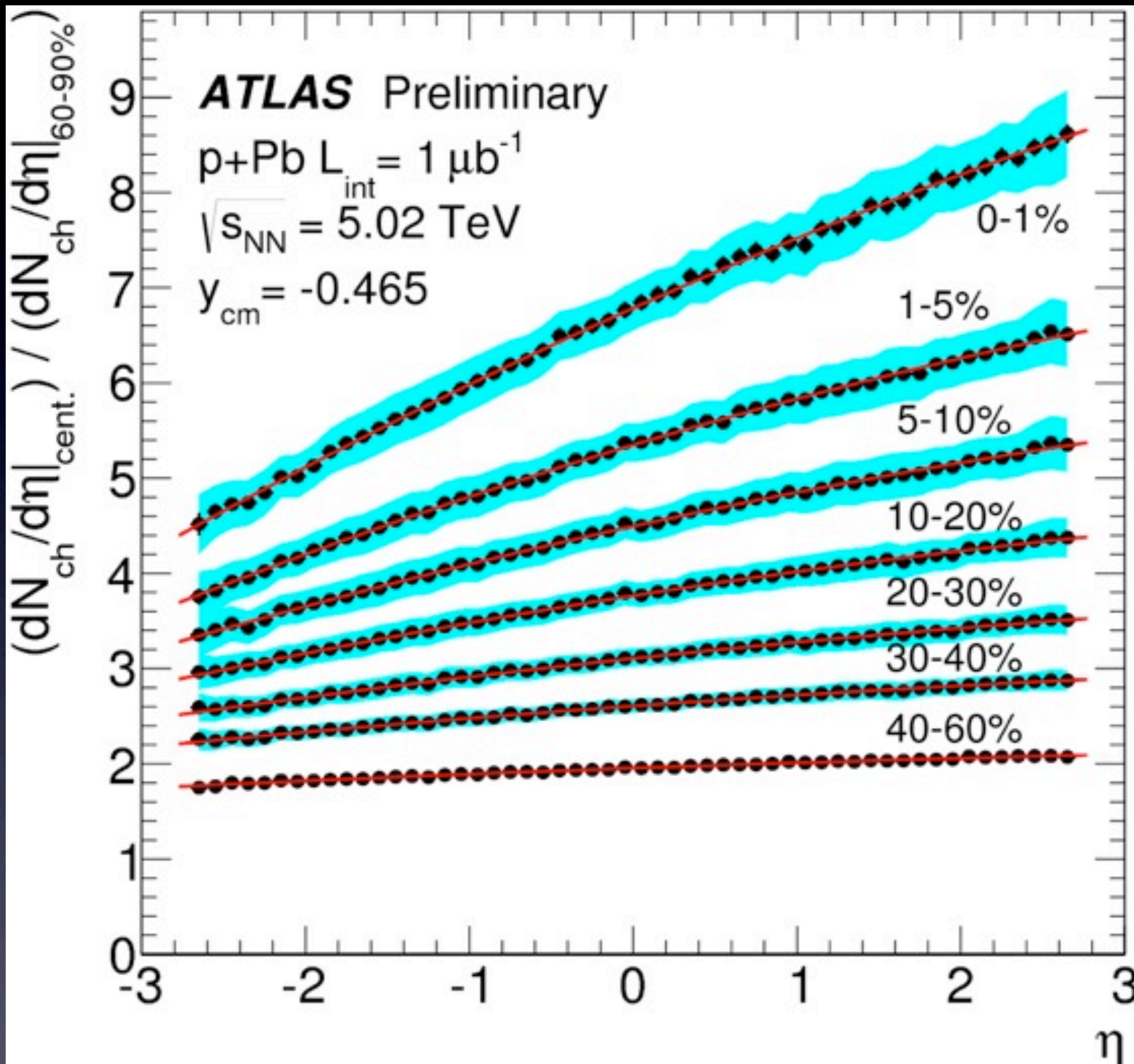
	Uncertainty 60-90%		Uncertainty 0-1%	
Source	barrel	endcap	barrel	endcup
MC detector description	1.7%		1.7%	
Extra material	1%	2%	1%	2%
Tracklet selection	0.5%	1.5%	0.5%	1.5%
p_T re-weighting	0.5%	0.5%	0.5%	3.0%
Extrapolation to p_T=0	1%	2.5%	1%	2%
Particle composition	1%		1%	
Analysis method	1.5%	2.0%	1.5%	2.5%
Event selection	5.0%	6.0%	0.5%	0.5%

Results: Multiplicity in centrality samples



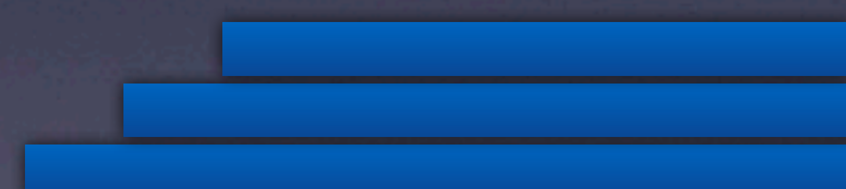
$dN_{ch}/d\eta$ is measured in $|\eta| < 2.7$ for 8 centrality samples.
Jacobian dip visible at all centralities. Negative values of η probe small-x in the Pb target while positive ones relate to larger values of x. Contrast between these two regions in the Pb target grows with centrality.

Results cont.



← P Pb →

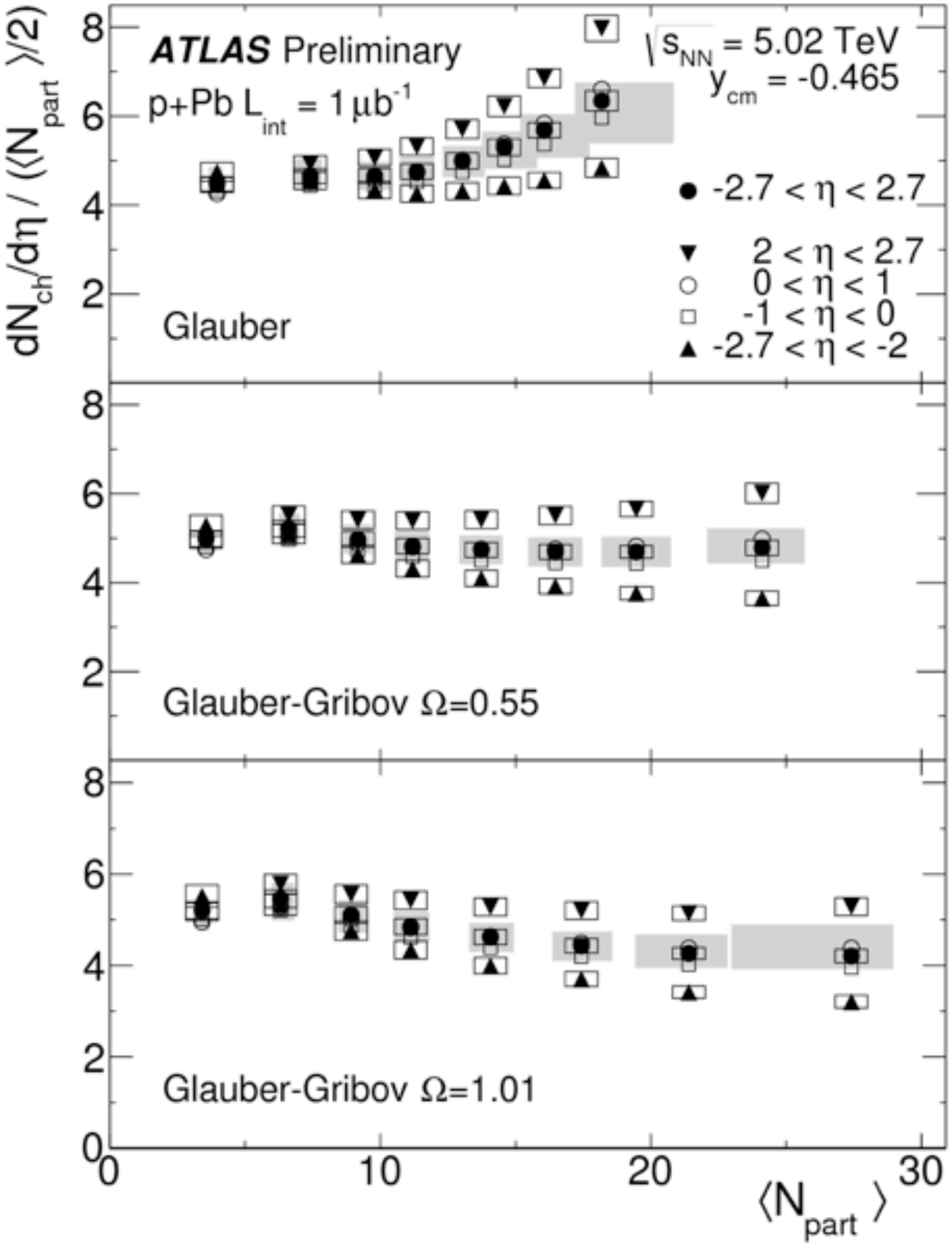
"Subtracting" the shape of pp by dividing by the most peripheral distribution brings forth a very clean "triangular" distribution



S. Brodsky and J. Gunion beam fragmentation and string breaking

Results cont.

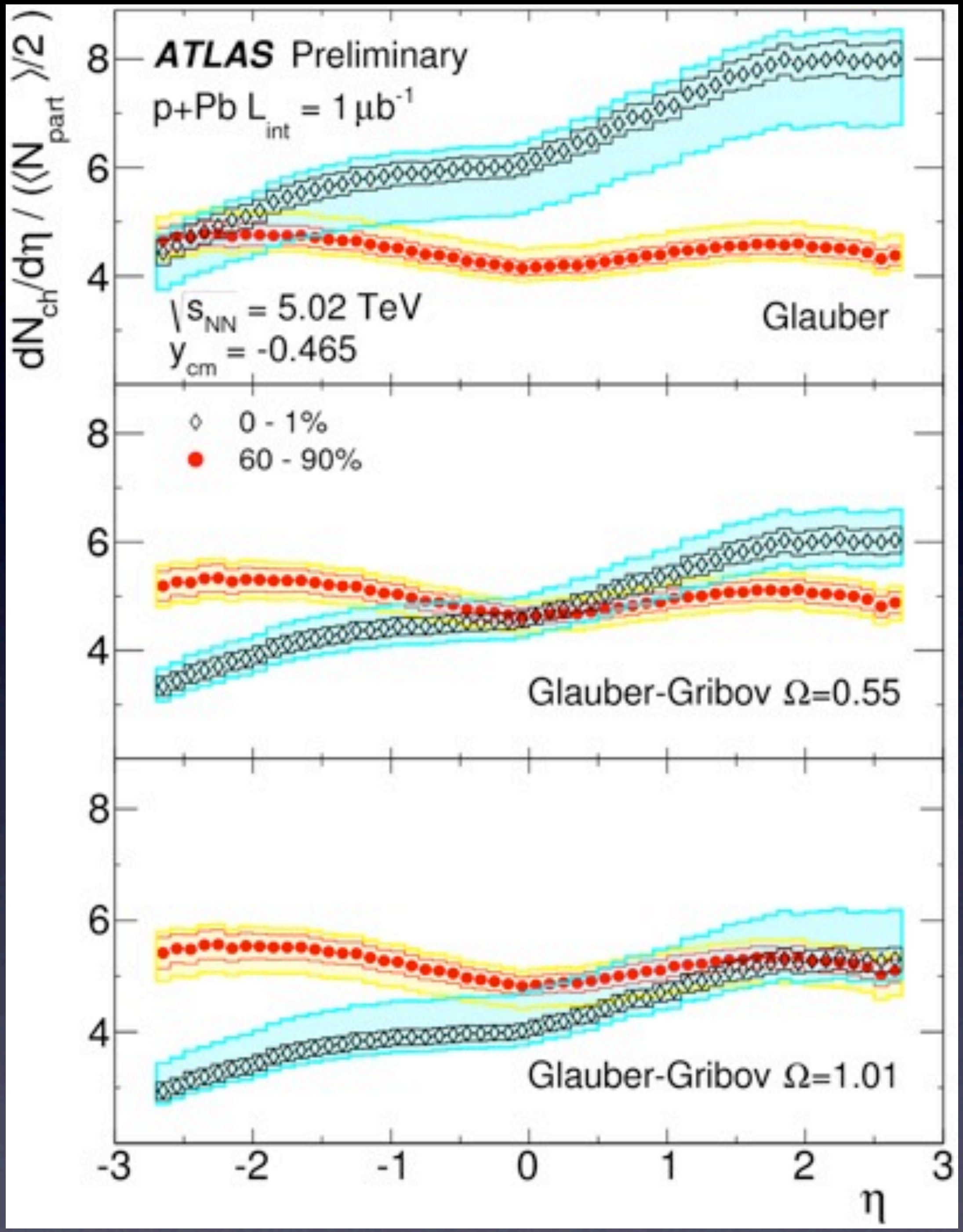
This ratio is built to show the presence of scaling of the multiplicity per pair of participant nucleons.
Standard Glauber shows the least scaling.
Glauber-Gribov which includes fluctuations in the cross-section shows highest Npart scaling at Ω=0.55



Glauber model comparisons

$dN_{ch}/d\eta$ per pair of participants from two centrality samples shown for three Glauber type models

Model calculations are shown as colored bands. Data statistical errors are smaller than symbols and systematic uncertainties are shown with unfilled boxes

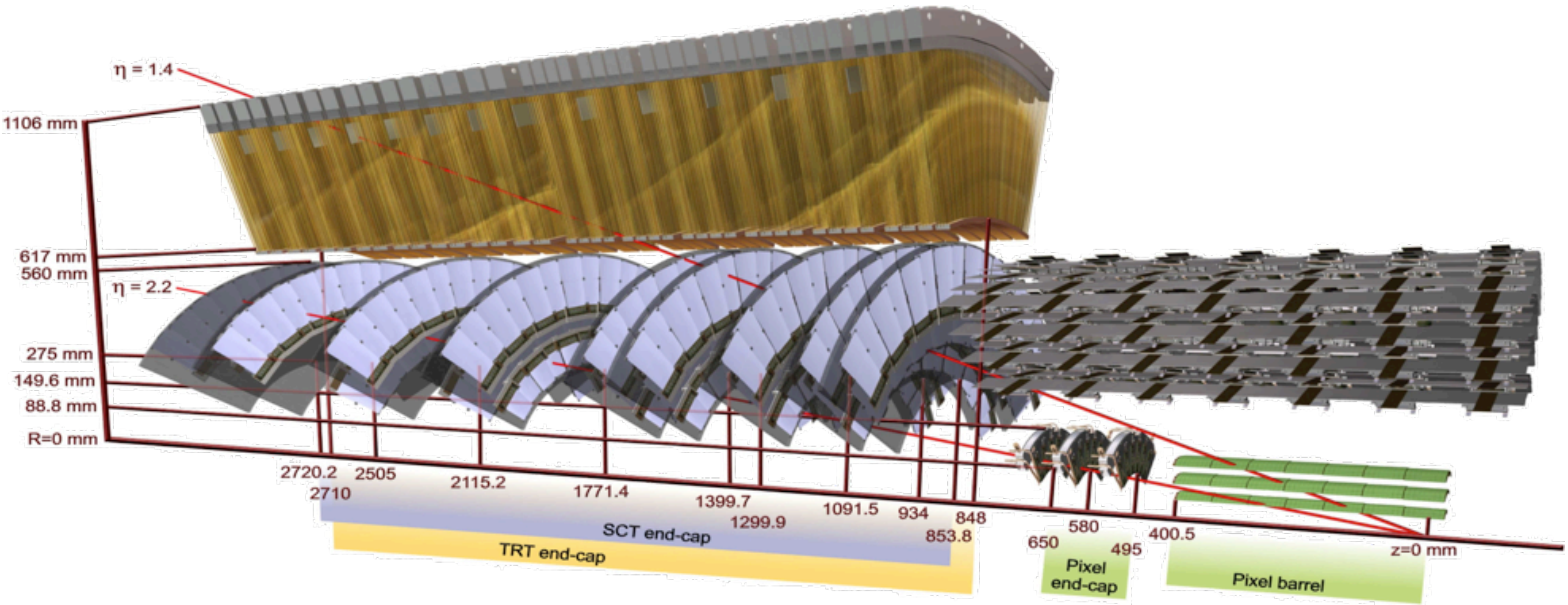


Summary

The ATLAS experiment has measured charged particle multiplicities as function of pseudo-rapidity and the centrality of the events.
The scaling of the average multiplicity per participant pairs is linear and well described by Glauber type models.
Compared to the most peripheral sample (proxy for p+p) the resulting distributions are remarkably "triangular" within the rapidity coverage of the detector.

Backup slides

ATLAS Inner Detector system



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