Charged particle multiplicity in p+Pb collisions in the ATLAS experiment

B.Żabiński for the ATLAS Collaboration
IFJ PAN, Kraków

OUTLINE:

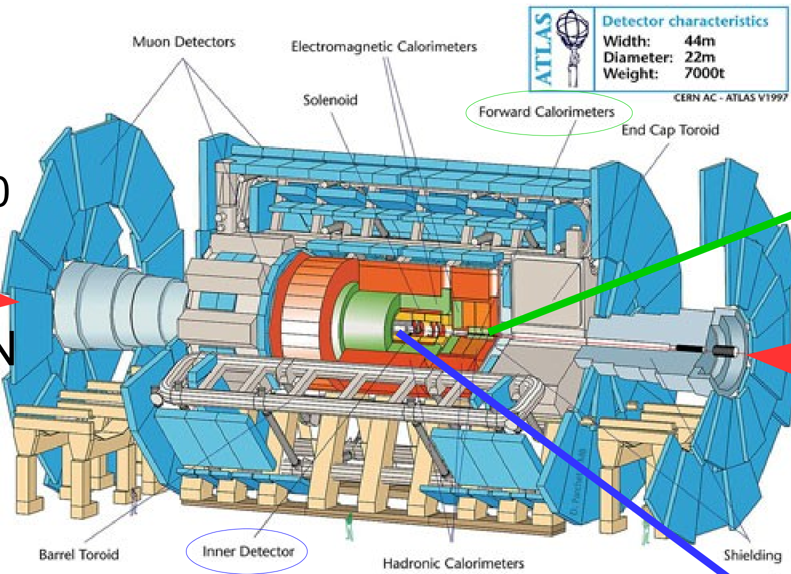
- The ATLAS detector
- Centrality estimation
- Methods
- Corrections
- Systematic uncertainties
- Results
- Summary

The ATLAS detector

C side $\eta < 0$

Pb

1.52 TeV/N



A side $\eta > 0$

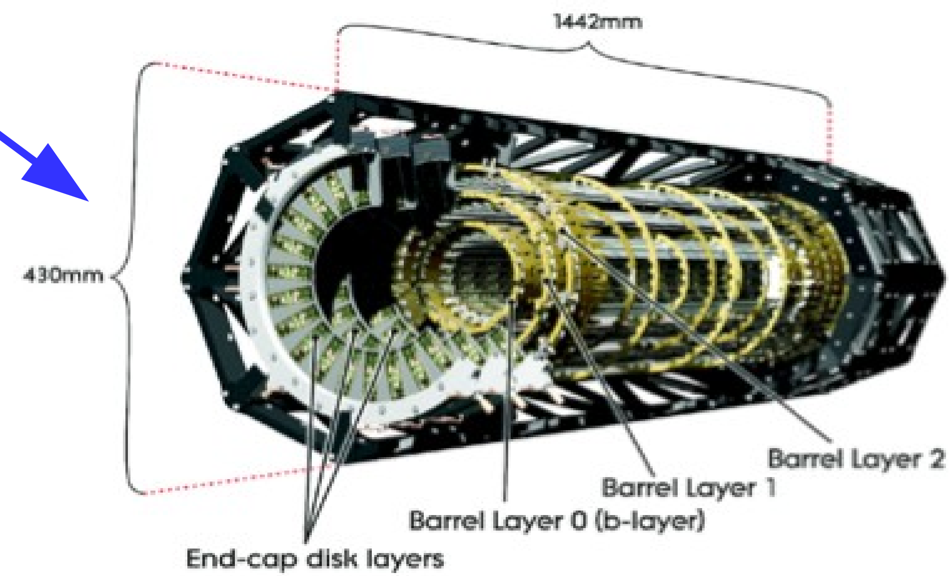
p

4 TeV

Forward calorimeter (Fcal):

- centrality determination
- $3.1 < |\eta| < 4.9$

Pixel detector

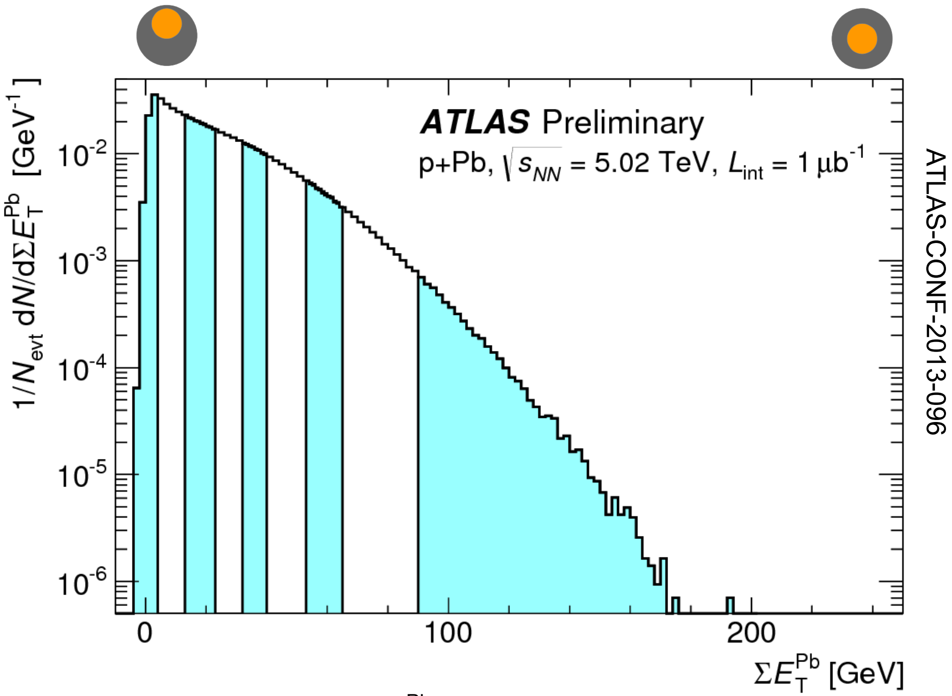


JINST 3 (2008) S08003

Pixel detector:

- Tracking device, very close to the beam pipe (first layer at 50.5 mm)
- Consists of 3 layers in barrel and 6 disk in endcaps
- 1744 modules with over $80*10^6$ pixels
- 2 T magnetic field

Centrality determination



Distribution of ΣE_T^{Pb} divided to 9 centrality regions

p+Pb data from 2012 run are used (L_{int}~1μb^{-1})

Number of events used in analysis ~ 2.1 M corresponds to 98 ± 2 % inelastic events

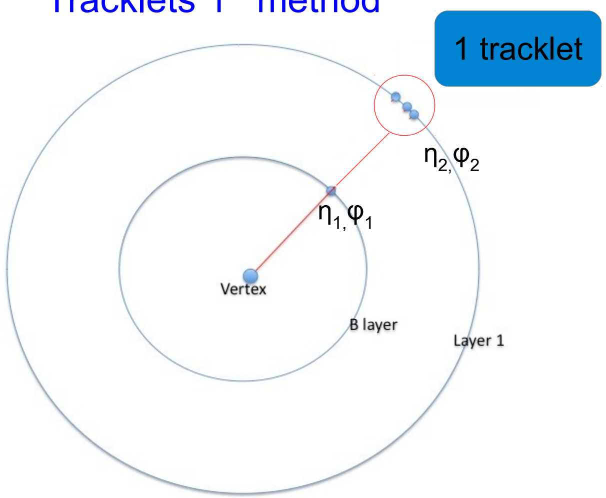
- Eight centrality intervals 0-1%, 1-5%, 5-10 %, 10-20 %, 20-30 %, 30-40 %, 40-60 %, 60-90 % were used in this analysis
- The most peripheral events (90-100%) excluded due to large systematic uncertainties on the event acceptance efficiency and the event composition

Methods in $dN_{ch}/d\eta$ measurement

Three methods in this analysis were used. Two different versions of tracklets method and pixel tracks method.

Tracklet – two hits in different layers of pixel detector, compatible with reconstructed vertex.

Tracklets 1th method



$|\Delta\eta| = \eta_1 - \eta_2$

$|\Delta\varphi| = \varphi_1 - \varphi_1$

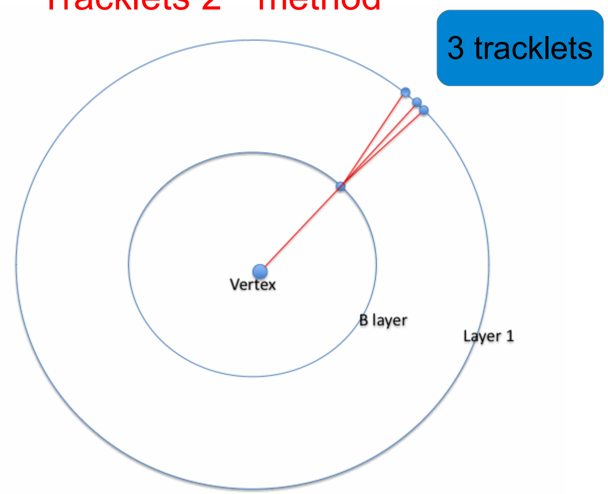
Tracklet selection cuts:

$|\Delta\eta| < 0.015$

$|\Delta\varphi| < 0.1$

$|\Delta\eta| < |\Delta\varphi|$

Tracklets 2nd method

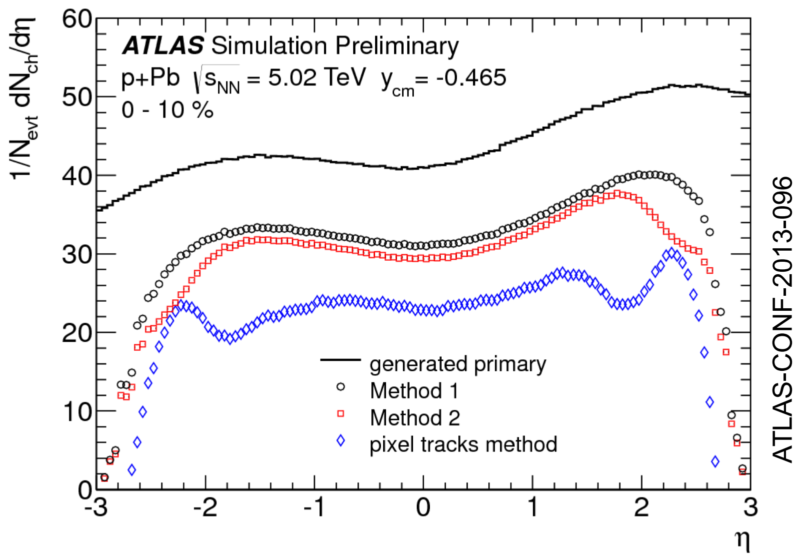


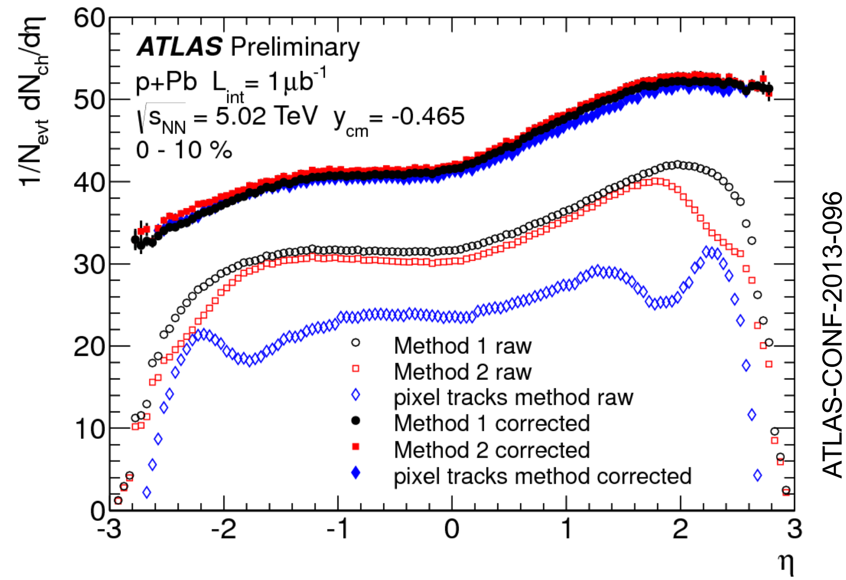
One hit in B-Layer, hits from second pixel layer in the search region are merged to form a single tracklet. This reduces the number of fake tracklets.

All combinations of pixel hits are allowed. No reduction of the number of fake tracklets.

Pixel tracks method – uses results of the standard track reconstruction algorithm, but restricted to the pixel detector, which provides a measurement of transverse momentum. This method was used as a cross-check.

Corrections:





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

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

N_{pr} – number of charged particles at generator level
N_{rec} – number of reconstructed tracks or tracklets

ΔN^{raw} – number of reconstructed tracks or tracklets
N_{evt} – total number of analyzed events

Correction calculated in 8 intervals of detector occupancy and 7 intervals of z_{vtx} (50 mm width)

Correction includes several effects:

- Inactive area in detector and reconstruction efficiency
- Contribution of residual fakes and secondary particles
- Losses due to tracks or tracklets selection cuts including those for particles with $p_T < 100$ MeV

Systematic uncertainties:

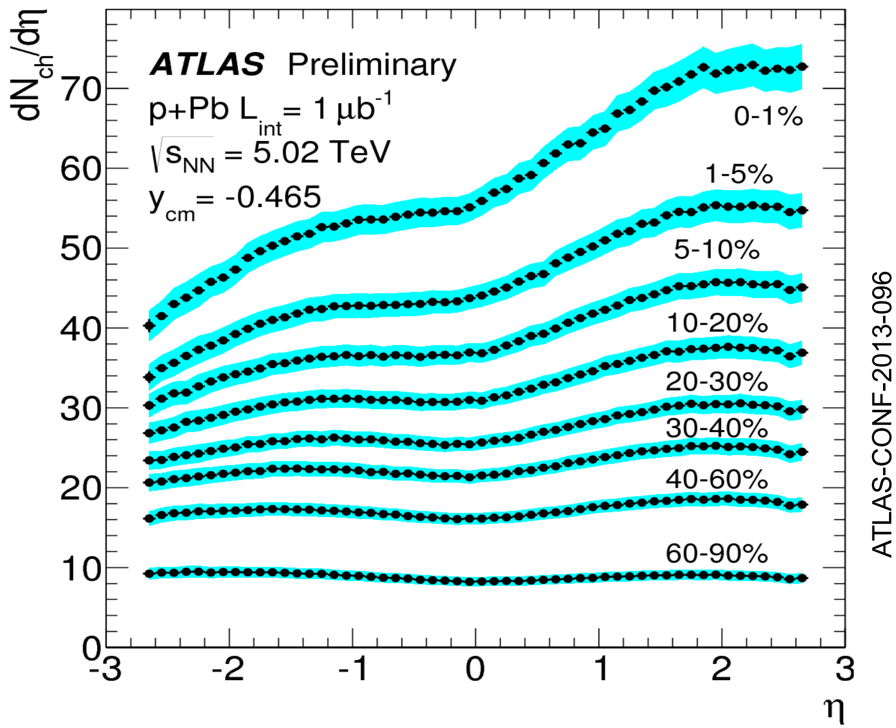
Three main sources of systematic uncertainties:

- Detector description in simulations
- Sensitivity on selection criteria
- Difference between properties of generated particles used in the MC and the known properties of Data

Source	60 – 90 % Barrel	60 – 90 % endcap	0 – 1 % Barrel	0 – 1 % endcap
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 %

ATLAS-CONF-2013-096

$dN_{ch}/d\eta$:



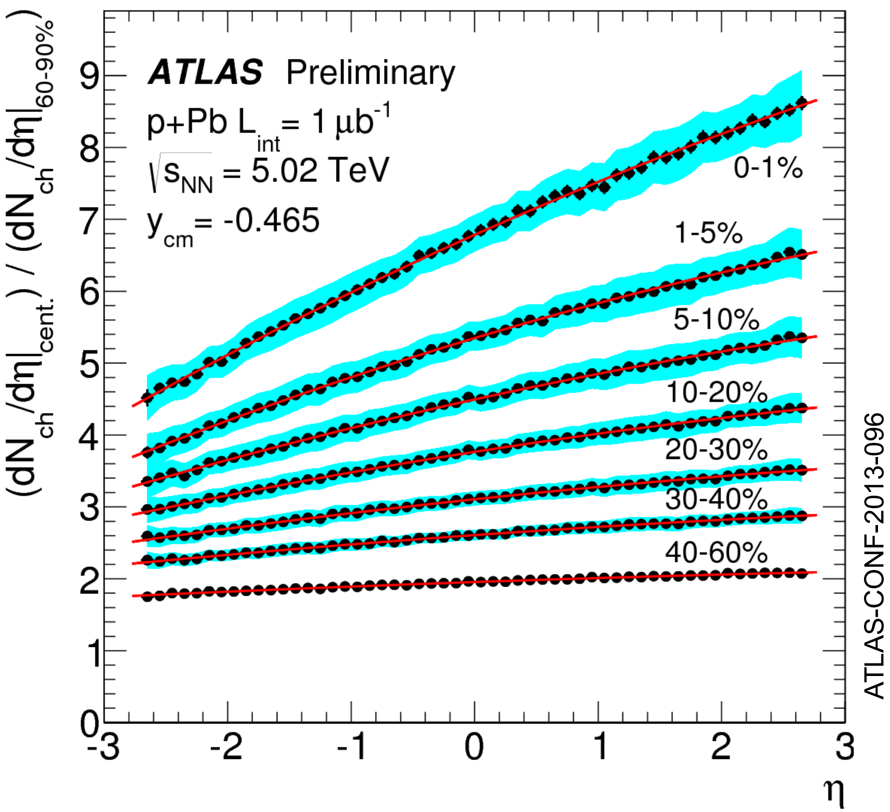
Charged particle density for eight centrality classes, measured in the pseudorapidity interval $|\eta| < 2.7$

1) Charged particle density increases with centrality

2) Asymmetric distribution - more particles are produced in Pb-going side

3) $dN/d\eta$ for peripheral p+Pb events (centrality 60-90 %) is similar to $dN/d\eta$ in p+p collisions [New J.Phys. 13 (2011) 053033]

$(dN_{ch}/d\eta)$ / $(dN_{ch}/d\eta)|_{(60\text{-}90\%)}$:



dN/dη distribution in different centrality classes divided by dN/dη for peripheral collisions (centrality 60-90%). Red lines present 2nd order polynomial fitted to data points.

Centrality Ratio	a	b	c
0 – 1 % / 60 – 90 %	-0.33 ± 0.006	0.77 ± 0.05	6.78 ± 0.28
1 – 5 % / 60 – 90 %	-0.030 ± 0.005	0.515 ± 0.031	5.35 ± 0.22
5 – 10 % / 60 – 90 %	-0.0218 ± 0.0035	0.377 ± 0.021	4.49 ± 0.18
10 – 20 % / 60 – 90 %	-0.0169 ± 0.0025	0.269 ± 0.014	3.77 ± 0.14
20 – 30 % / 60 – 90 %	-0.0113 ± 0.0020	0.182 ± 0.010	3.11 ± 0.11
30 – 40 % / 60 – 90 %	-0.0076 ± 0.0016	0.122 ± 0.006	2.61 ± 0.08
40 – 60 % / 60 – 90 %	-0.0037 ± 0.0011	0.0595 ± 0.0031	1.95 ± 0.06

Parameters of the function $(a\eta^2+b\eta+c)$ fitted to the ratio of dN/dη.

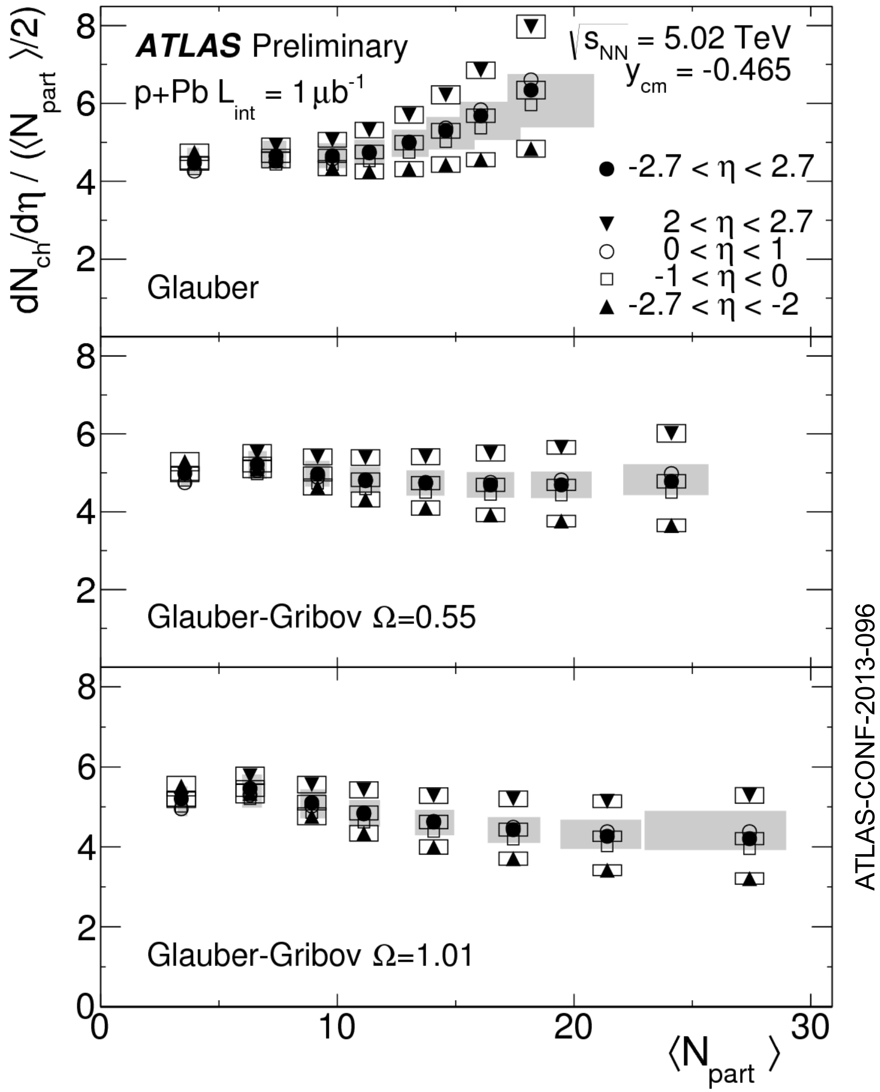
ATLAS-CONF-2013-096

1.) Double-peak structure disappears after division by dN/dη for 60-90 % centrality

2.) The ratios increase nearly linearly with pseudorapidity and the slopes increase with centrality

3.) For very central collisions the ratio increases almost by a factor 2 in the measured η range.

$dN_{ch}/d\eta/(<N_{part}>/2)$



dN/dη/(<N_{part}>/2) as a function of <N_{part}> for three implementation of Glauber model and five η-regions. Open boxes represent systematic uncertainty of dN/dη only. Shaded boxes show the total uncertainty including systematic <N_{part}> errors.

Three different Glauber model implementations were used to obtain N_{part}

1) For standard Glauber [Ann. Rev. Nucl. Part. Sci 57 (2007) 205-234]: dN/dη increases starting from $N_{part} \approx 10$.

2) In Glauber-Gribov [Phys. Lett. B 633 (2006) 245-252] implementation with Ω = 0.55: dN/dη is relatively flat.

3) For Glauber-Gribov implementation with Ω = 1.01: dN/dη decreases.

Summary:

- Charged particle density for p+Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV was measured in η range from -2.7 to 2.7 and for 8 centrality classes
- The shape of dN/dη changes with centrality. It is nearly symmetric in peripheral collisions and highly asymmetric in central collisions.
- dN/dη for peripheral p+Pb events is similar to dN/dη in p+p collisions
- Ratio of $(dN_{ch}/d\eta)$ for central collisions to $(dN_{ch}/d\eta)|_{(60\text{-}90\%)}$ for peripheral one is approximately linear in η. Slope of the ratio strongly depends on centrality
- The $dN_{ch}/d\eta/(\langle N_{part}\rangle/2)$ dependence on N_{part} → sensitive to the Glauber modeling, especially in the most central collisions.

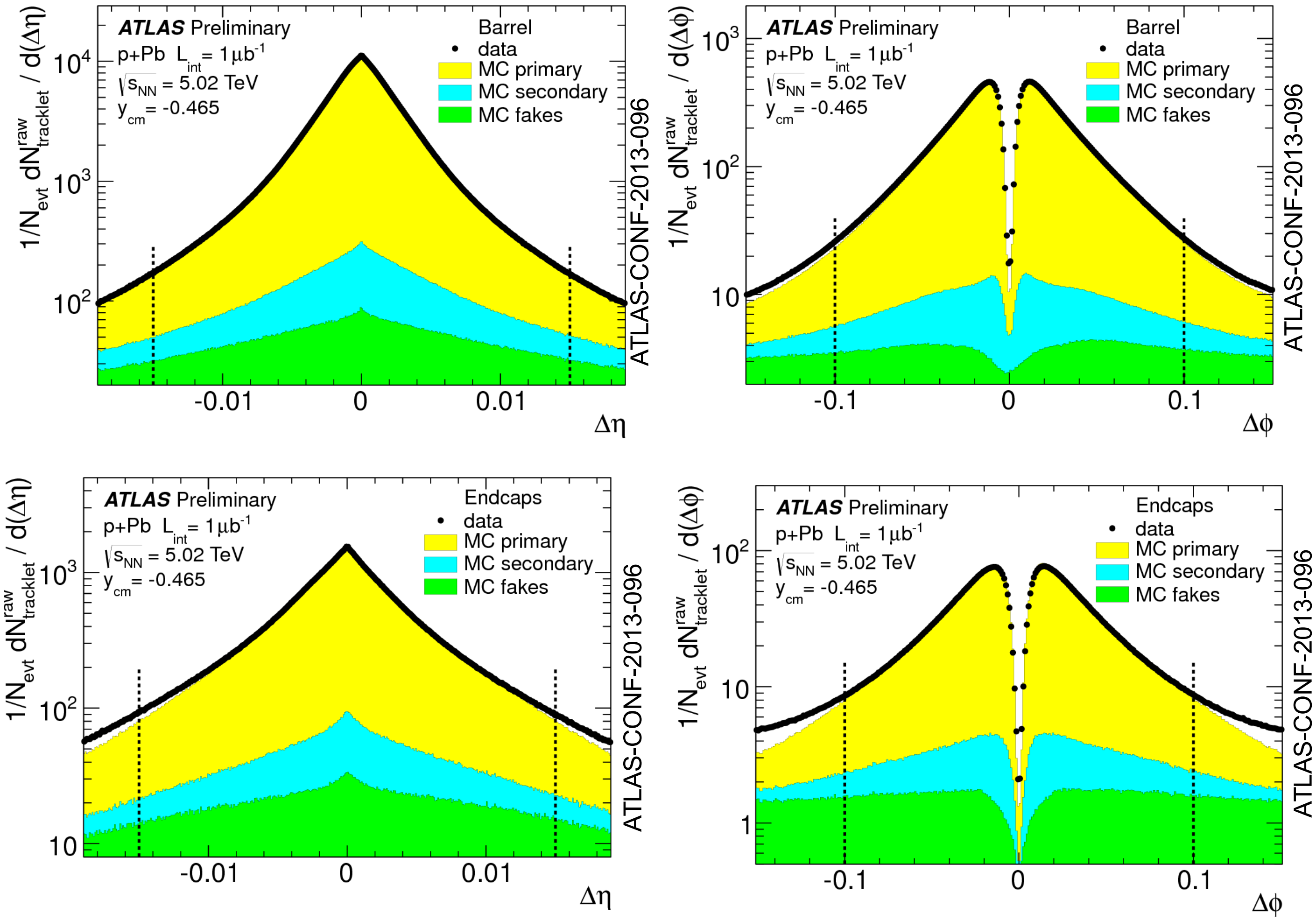
Thank you

Event Selection:

- p+Pb data from 2012 run are used (L_{int}~1μb^{-1})
- At least one hit in each side of the MBTS (i.e for 2.1 <|η| < 3.9)
- Time difference between two sides of MBTS less than 10 ns
- Reconstructed vertex $|z_{vtx}|$ < 175 mm, at least two tracks with p_T> 100MeV
- Pileup reduced by rejection of events with two vertices separated in z by more than 15 mm
- Rejection of electromagnetic and diffractive events – required pseudorapidity gap $\Delta\eta^{Pb}_{gap} < 2.0$

Number of events used in analysis ~ 2.1 M corresponds to 98 ± 2 % inelastic events

Comparision of Data and MC in Δϕ nad Δη



„flipped" method

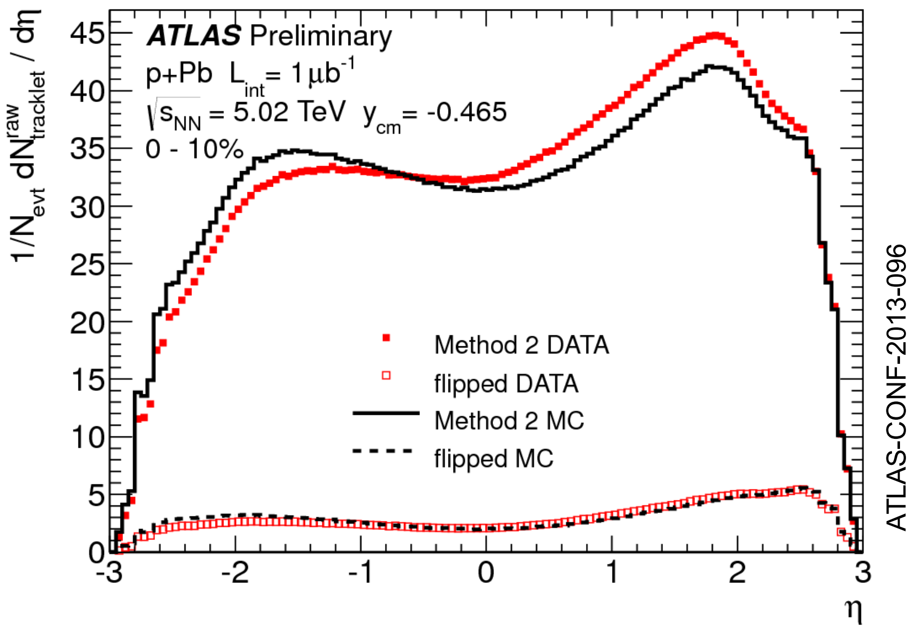
$(x\text{-}x_{vtx},\ y\text{-}y_{vtx}) \rightarrow (-(x\text{-}x_{vtx}),-(y\text{-}y_{vtx}))$

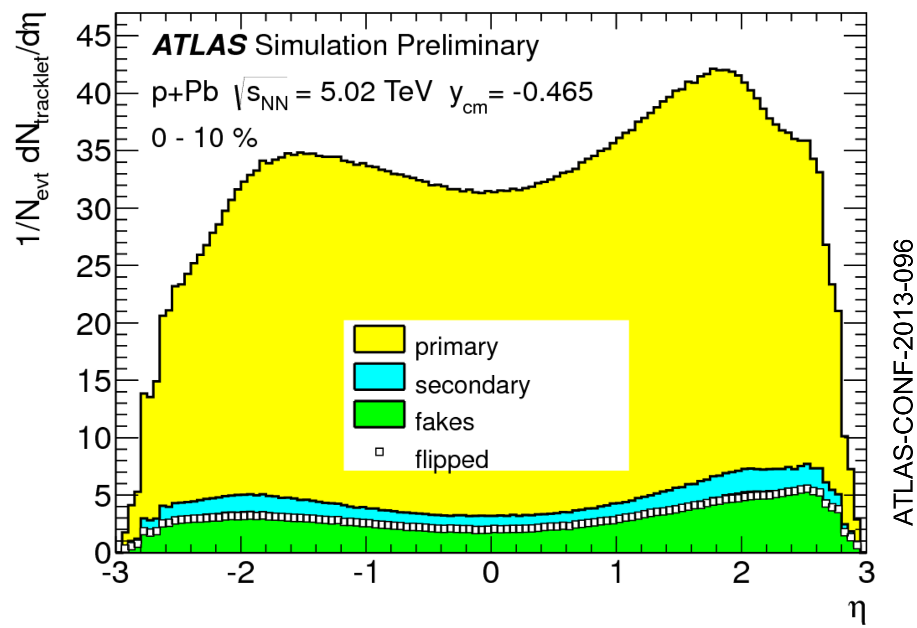
$N_{2p}(\eta) = N^{ev}_{2p}(\eta)\text{-}\ N^{fl}_{2p}(\eta)$

$N^{ev}_{2p}(\eta)$ – yield of tracklet using method 2

N^{fl}_{2p}- yield obtained from by flipping the clusters in the 2nd layer.

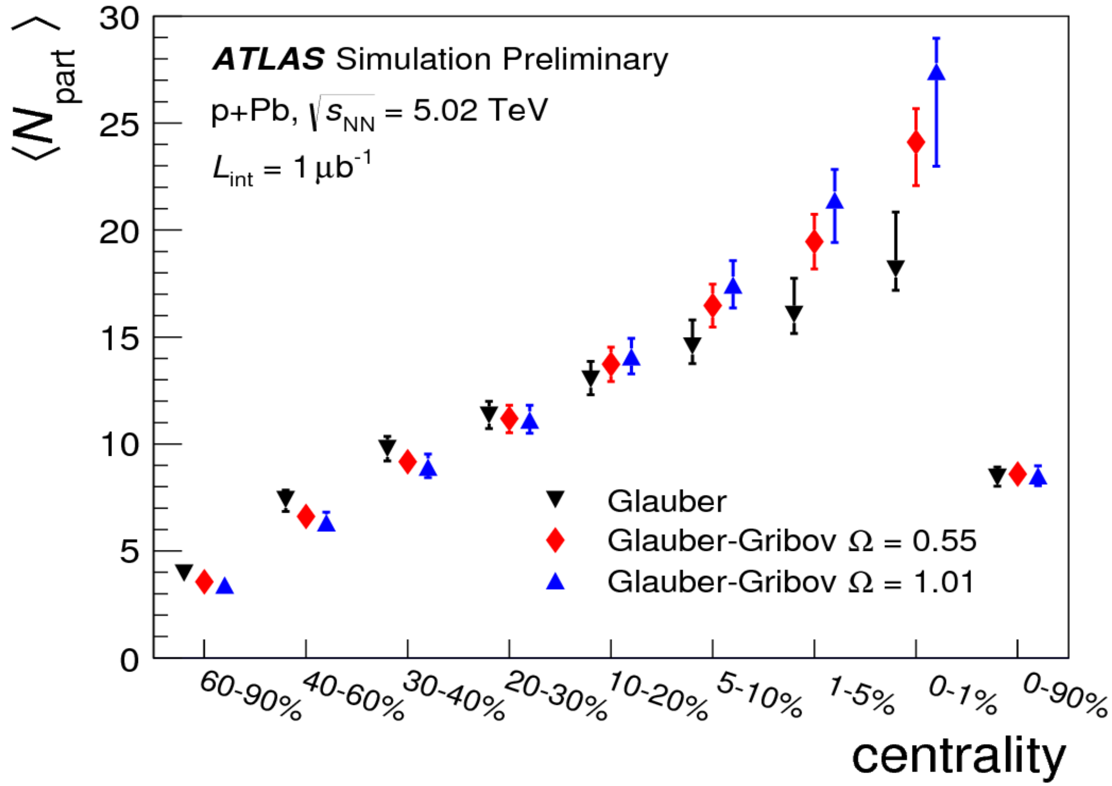
Comparison of Data and MC:



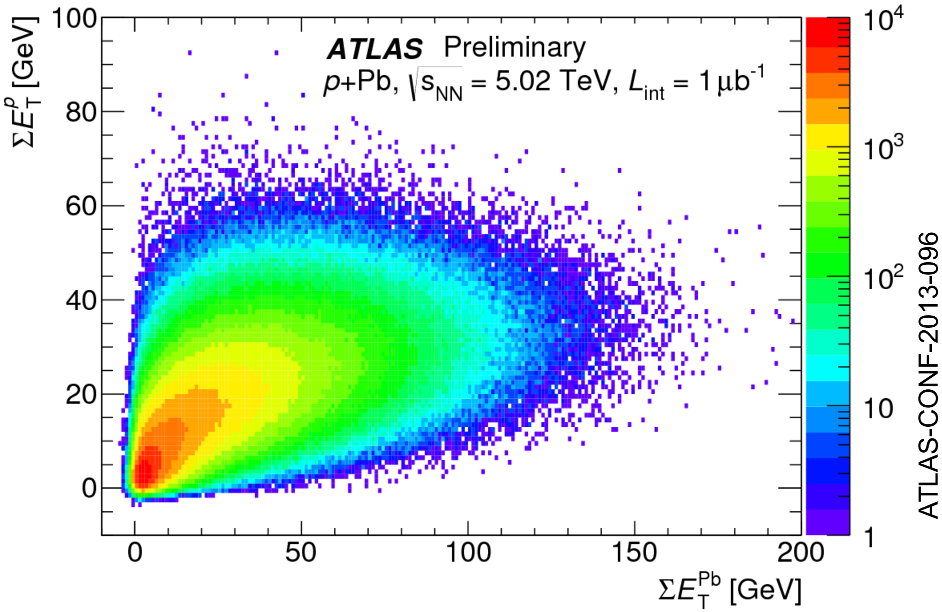


- Method 2 has largest contribution of fakes. For centrality 0-10% contribution of fakes reach 16% at large eta.
- Acceptance effects and fake fraction are well reproduced by Monte Carlo simulation – good agreement in the results

$\langle N_{part} \rangle$ as a function of centrality



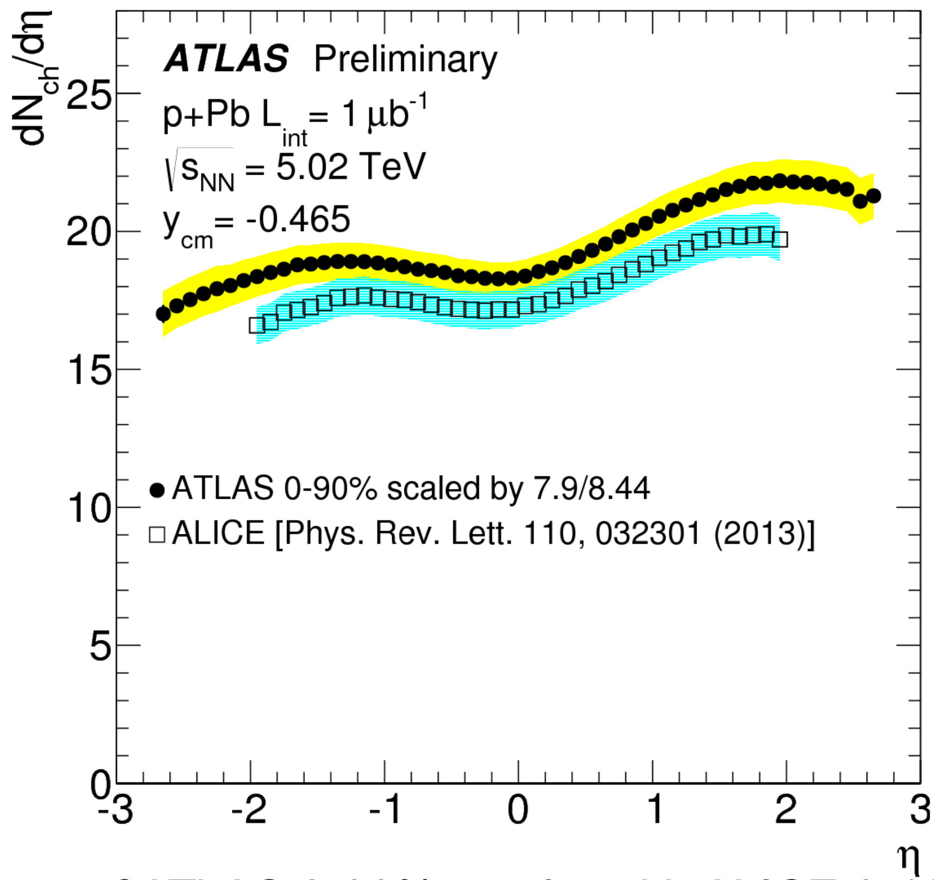
$\langle N_{part} \rangle$ as function of centrality intervals. Values of N_{part} has been obtained by fitted to the measured ΣE^{Pb}_{T} distribution Glauber's models.



Correlation between ΣE_T on proton-going side (-3.2 > η > - 4.9) and ΣE_T lead-going side (3.2 < η < 4.9).

$\Sigma E_T{}^{p}$ saturates rapidly with increasing $\Sigma E_T{}^{Pb}$ → $\Sigma E_T{}^{Pb}$ is more sensitive to nuclear geometry and was used to estimate centrality intervals

Comparison of results from ATLAS and ALICE experiment



Comparison of ATLAS 0-90% results with ALICE 0-100% minimum-bias $dN_{ch}/d\eta$. ATLAS distribution has been multiplied by the minimum-bias N_{part} value from the ALICE measurement and divide by the 0-90% $\langle N_{part} \rangle$ from ATLAS.