Methods of multiplicity reconstruction in heavy ion collisions in the ATLAS experiment

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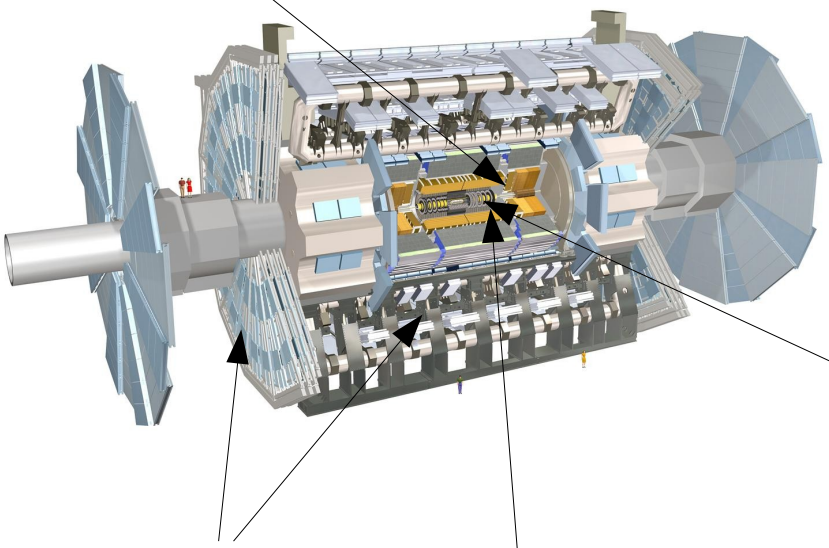
Overview:

- Atlas detector
- Full reconstruction of tracks and pixel tracks
- Tracklets in the pixel detector
- Hit counting method

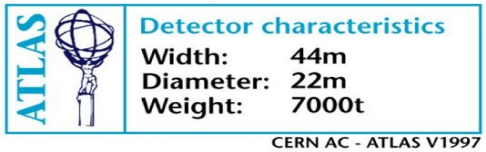
The ATLAS detector

MBTS (Minimum Bias Trigger Scintilator)

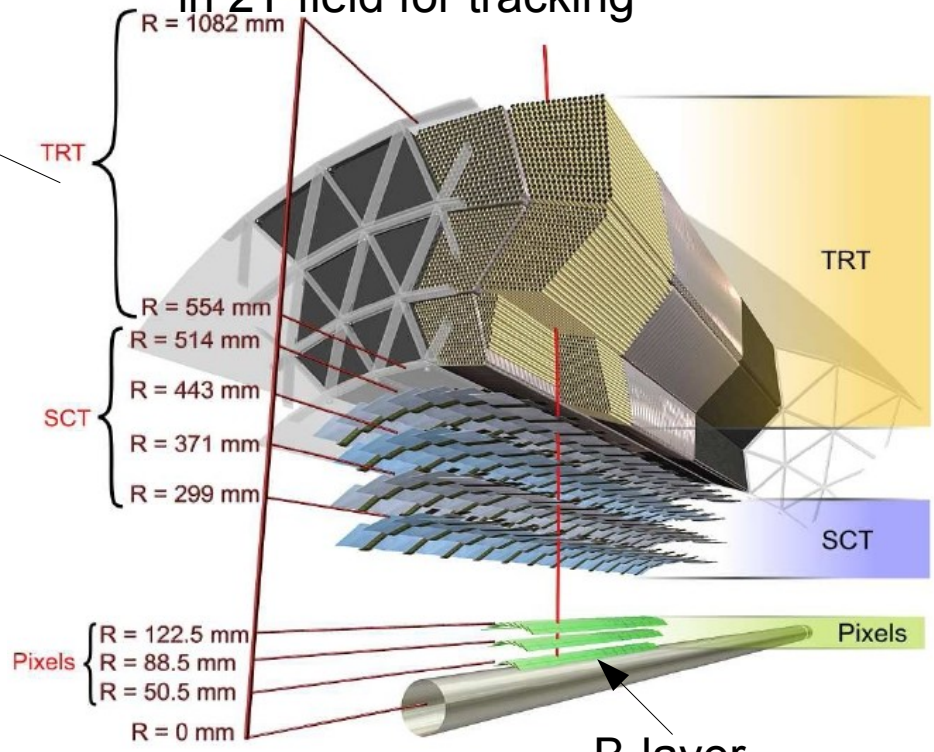


Muon chambers

Electromagnetc. and hadronic calorimeters



Inner detector
in 2T field for tracking



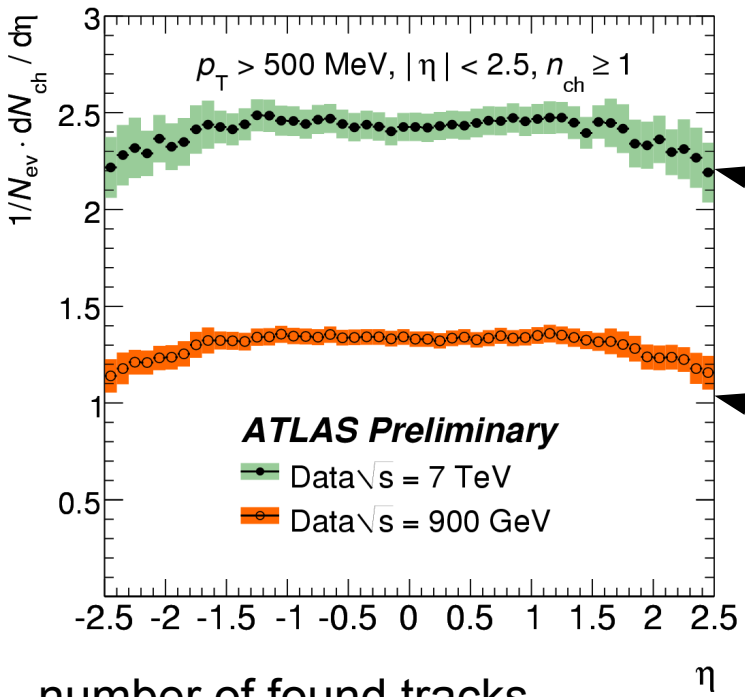
B-layer

Full track method

Full Track reconstruction:

- required at least 1 hit in the Pixel detector and 5 hits in SCT
- full pattern recognition and momentum fit
- tracks reconstructed in the range $|\eta|<2.5$
- unbiased reconstruction for $p_T>500$ MeV

Multiplicity reconstruction in p+p interactions



Reconstructed number of charged particles, N_{ch}

$$\frac{dN_{ch}}{d\eta}\Big|_{\eta=0} = 2.418 \pm 0.004(\text{stat.}) \pm 0.076(\text{syst.})$$

$$\frac{dN_{ch}}{d\eta}\Big|_{\eta=0} = 1.333 \pm 0.003(\text{stat}) \pm 0.04(\text{syst.})$$

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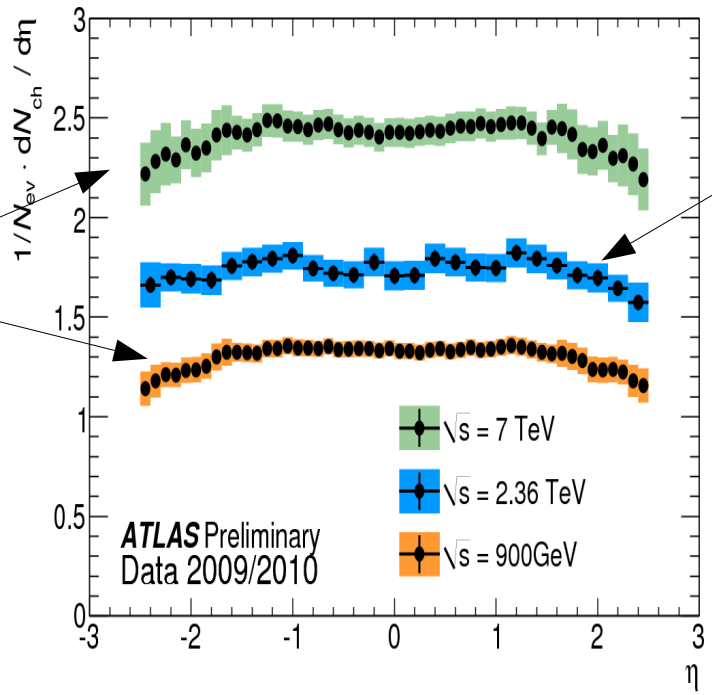
n_{ch} - number of found tracks

Pixel track method in p+p interactions p_T> 500 MeV

- Pixel tracks were reconstructed using the same inside-out track reconstruction, algorithm,but restricted to hits from the pixel detector.
- require at least 3 pixel hits.
- method suitable for an event sample with SCT high voltage switched off (unstable beam conditions)

Full track reconstruction



Pixel track method $\sqrt{s}$ = 2.36 TeV

$\frac{dN_{ch}}{d\eta}\Big|_{\eta=0}$=1.739 ± 0.019(stat) ± 0.058(syst.)

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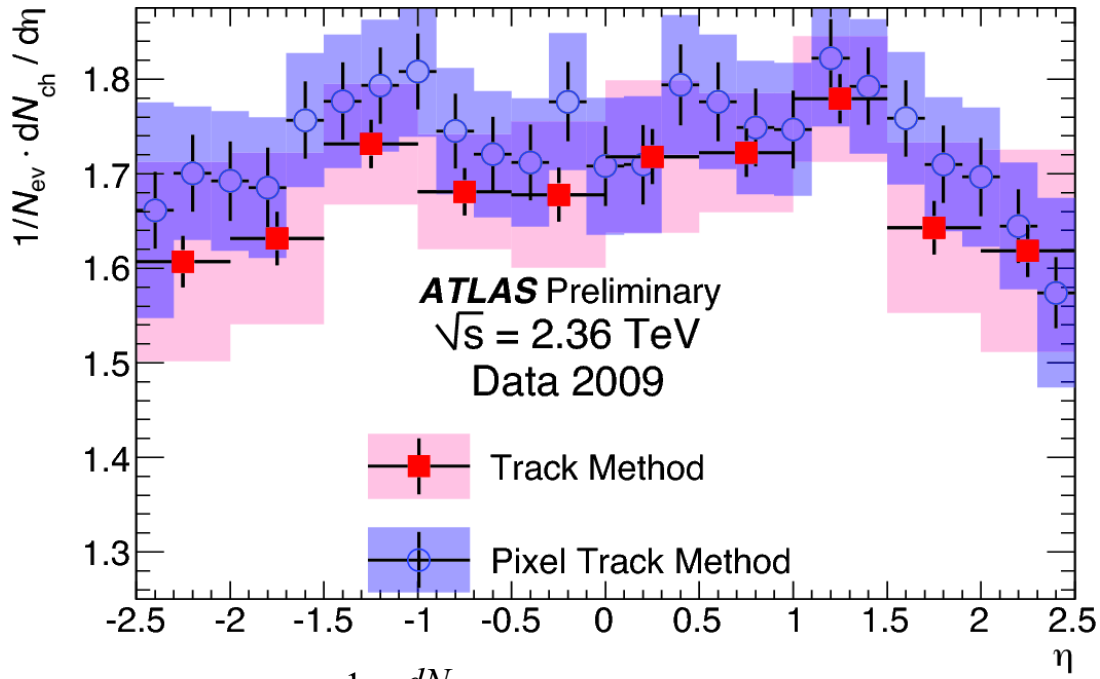
The plots presents charged particle density as a function of beam energy.
Charged particle multiplicity for energy 2.36 TeV was mesured using Pixel track method.

Comparison of pixel track & full track reconstruction methods



p_T > 500 MeV

Total systematic uncertainty on $\frac{1}{N_{ev}} \cdot \frac{dN_{ch}}{d\eta}\Big|_{\eta=0}$:

- Pixel track method $\sqrt{s}$ = 2.36 TeV - 3.5 %
- Track method $\sqrt{s}$ = 2.36 TeV - 4.5 %
- Track method for $\sqrt{s}$ = 7 TeV – 2.9 %
- Track method for $\sqrt{s}$ = 900 GeV – 2.8 %

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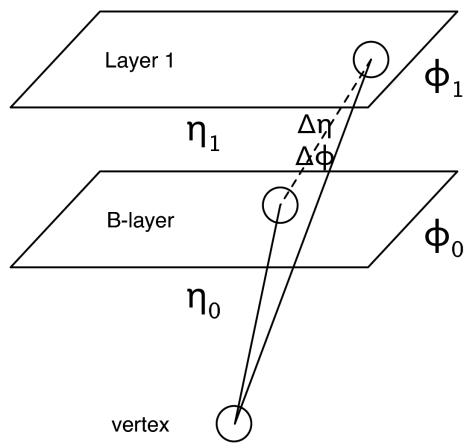
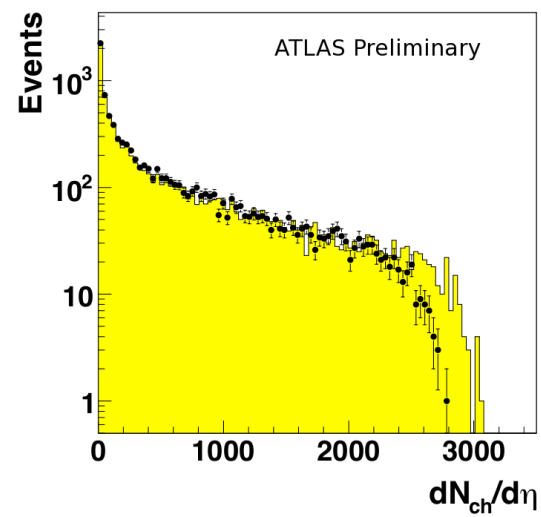
Tracklet method

- Vertex + 2 hits = tracklet
- Simplified method for heavy ion events.

$$\left.\begin{aligned} |\Delta\eta| &= |\eta_0 - \eta_1| < \eta_c \\ |\Delta\Phi| &= |\Phi_0 - \Phi_1| < \Phi_c \end{aligned}\right\} \text{Tracklet candidate}$$

η_c, Φ_c – determined from MC



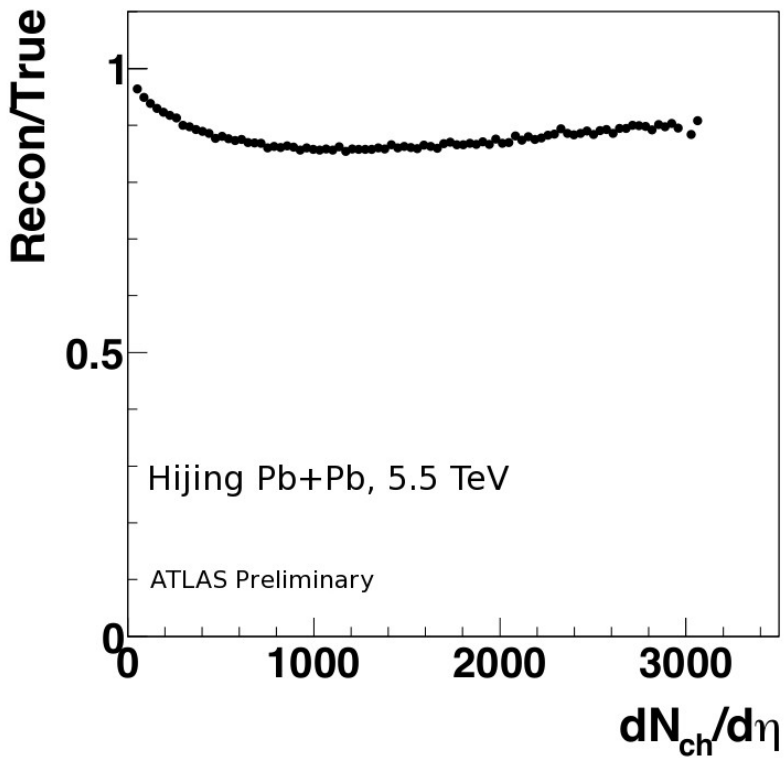


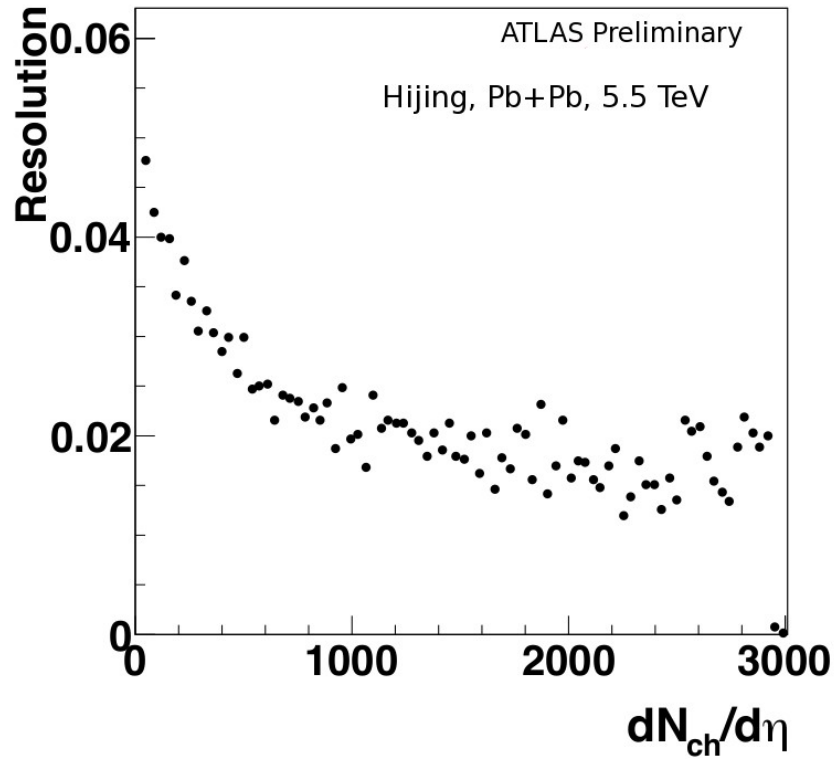
Line – simulated $dN_{ch}/d\eta$
points – reconstructed $dN_{ch}/d\eta$
Hijing, Pb+Pb, 5.5 TeV

Reconstruction algorithm.

- Loop over B-layer & layer 1 → find tracklet 0-1
- Remove used clusters – loop over B-layer and layer 2 → find tracklet 0-2
- Remove used clusters – loop over 1 and 2 layer → find tracklet 1-2
- Remove duplication due to geomery overlap and ganged pixels

Performance of tracklet method

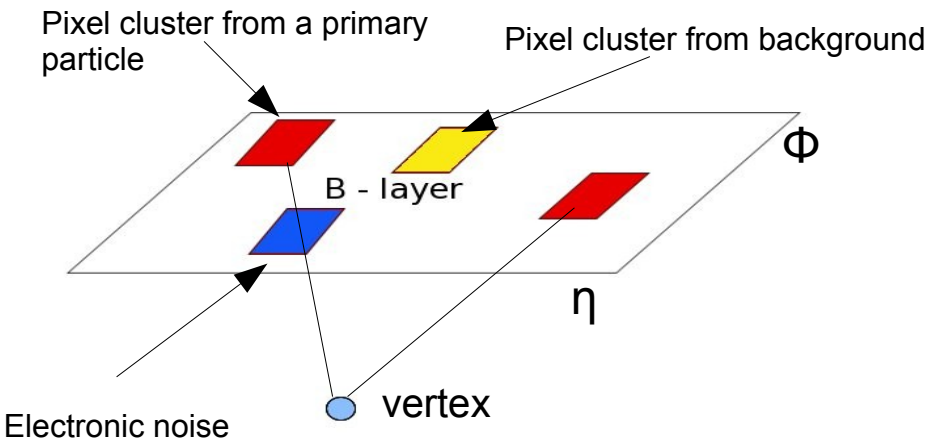


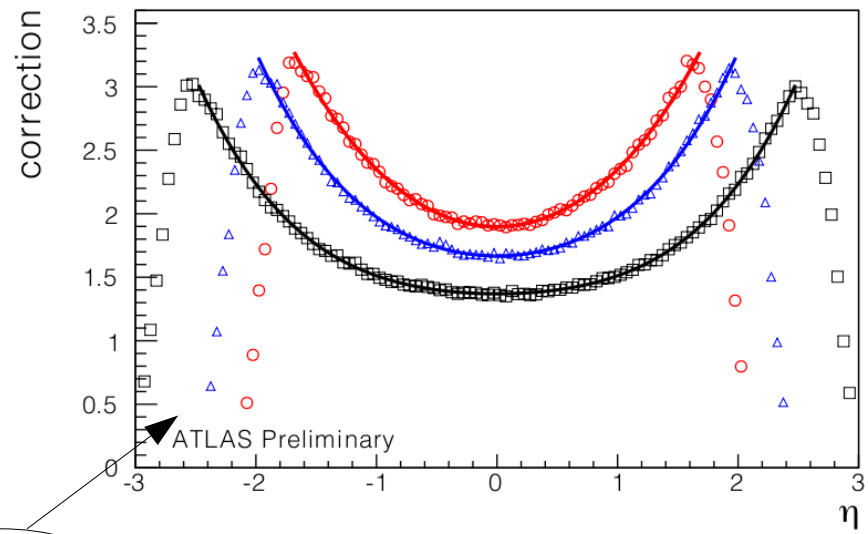


Tracklet reconstrution efficiency and multiplicty resolution for $|\eta| < 1$

Hit counting method for Pb+Pb

The simplest method of estimation of charged particle multiplicty.
Sensitive to particles with lowest p_T.





$$N_{trk,data}(\eta) = N_{cl,data}(\eta) \cdot \frac{N_{trk,MC}(\eta)}{N_{cl,MC}(\eta)}$$

$$\frac{N_{cl,MC}(\eta)}{N_{trk,MC}(\eta)}$$

$N_{trk,MC}$ - number of primary particles in MC
$N_{trk,data}$ -number of reconstructed particles in data
$N_{cl,MC}$ - number of clusters from MC
$N_{cl,data}$ - number of clusters from data

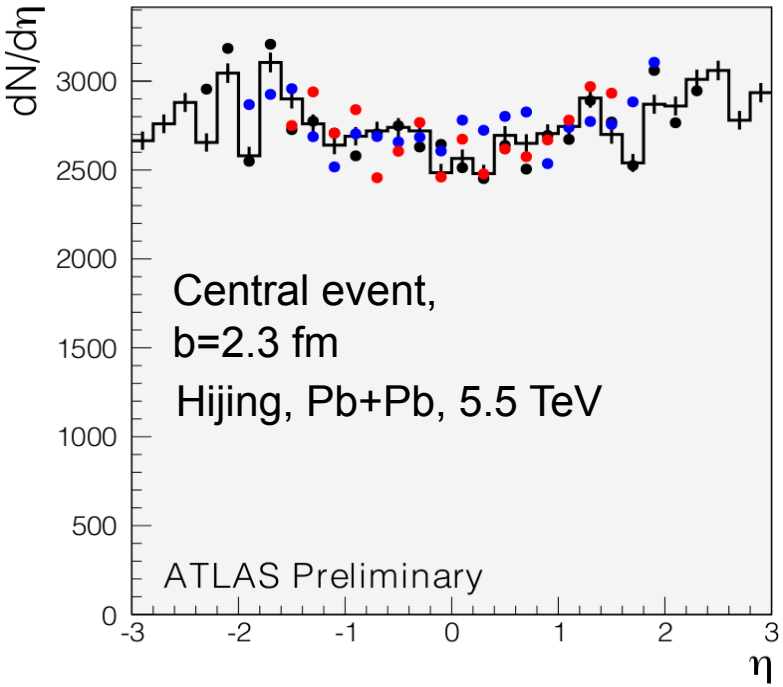
Black colour – B-layer in ID

Blue colour – 1 layer in ID

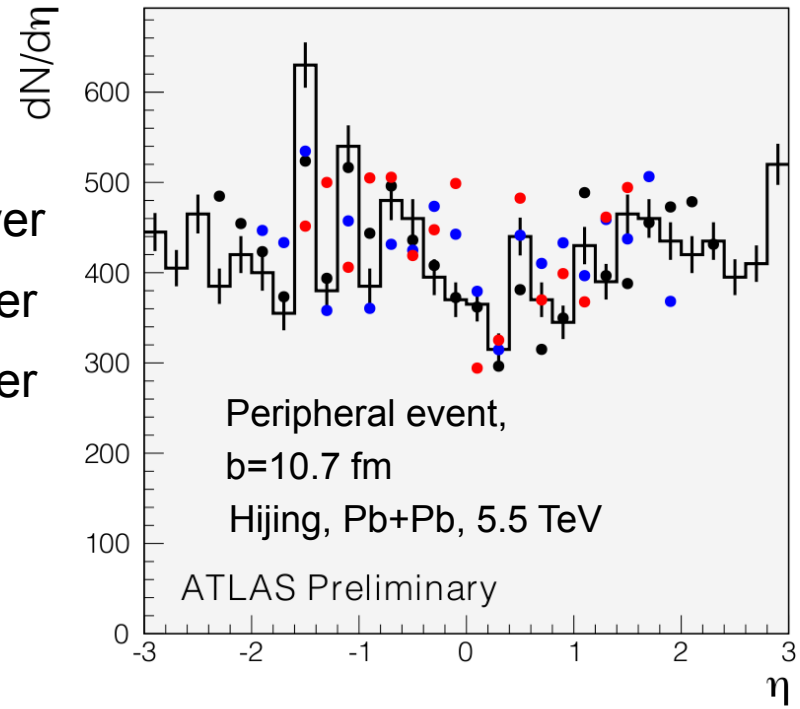
Red colour - 2 layer in ID

Hijing, Pb+Pb, 5.5 TeV

Performance of hit counting method



- B-layer
- 1 layer
- 2 layer



Different colours of points represent different layers of pixel detector.

Line – $dN_{ch}/d\eta$ for primary particles

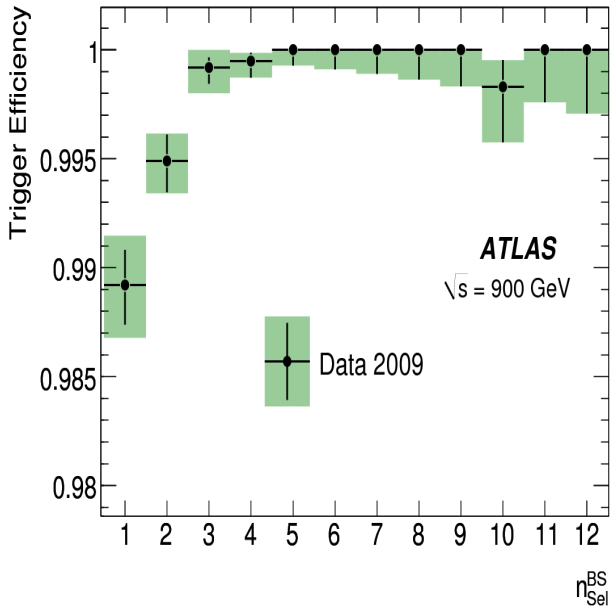
points – reconstructed $dN_{ch}/d\eta$

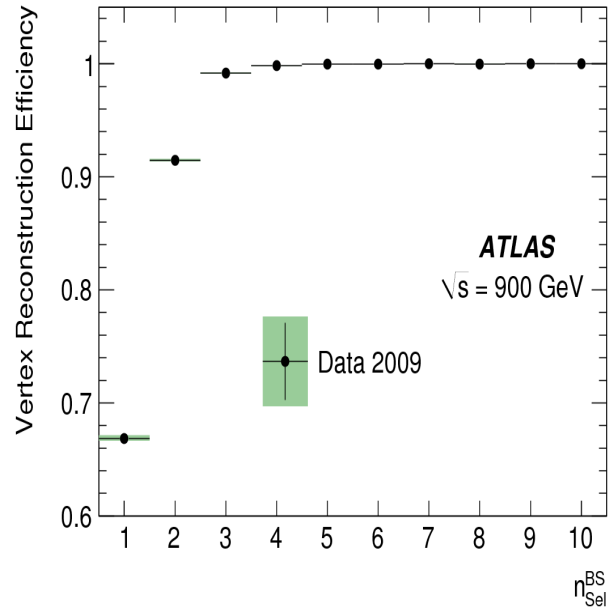
Summary:

- Various methods of multiplicity reconstruction have been presented.
- Multiplicity for p+p obtained using full track reconstruction or pixel tracks method.
- For heavy ion collisions simplified pixel tracklet method and hit counting method are developed.
  - suitable for events with high multiplicities
  - particles with low pT are included
- Precise measurement is possible for tracks with p_T>500 MeV
- More flexible methods can be used to measure multiplicity of tracks with p_T>100 MeV
- In Pb+Pb collisions simplified methods (tracklets, hit counting) may provide sufficiently good multiplicity estimates

Backup

Trigger efficiency and vertex reconstruction efficiency





N^{BS}_{Sel} – number of tracks in an event – without requirement of reconstructed vertex.

Tracks requirements: p_T > 500 MeV, Pixel hit > 0 , SCT hits > 5,

beam-spot position < 4mm.

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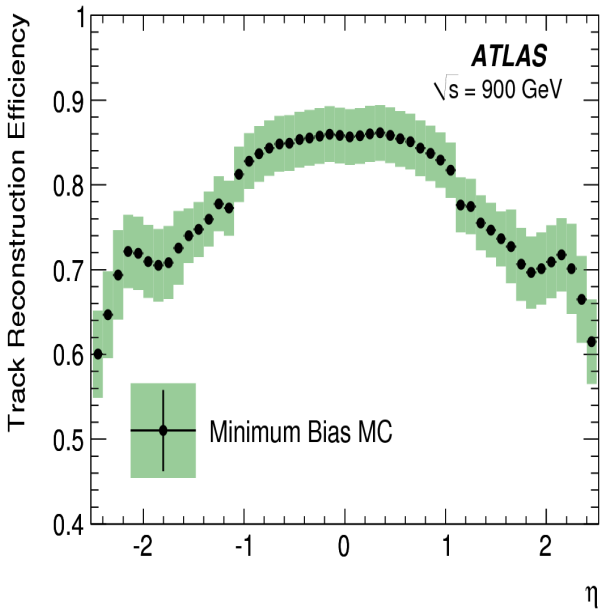
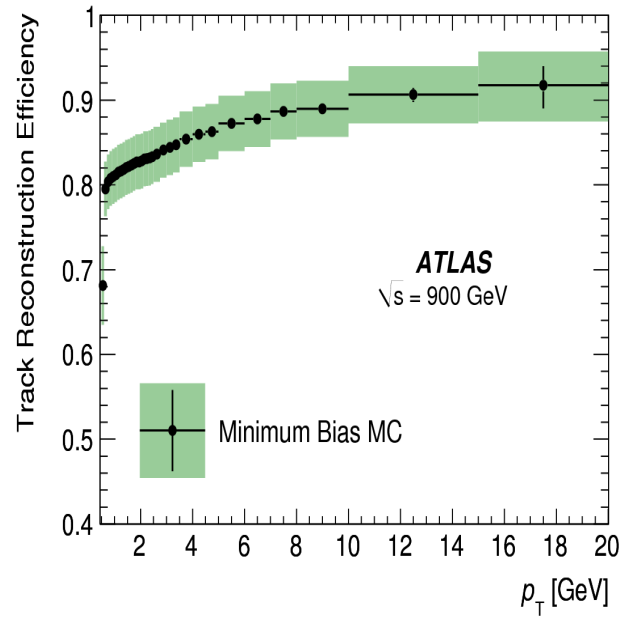
Track reconstruction efficiency for p+p at sqrt(s)=900 GeV





Systematic errors:

Trigger efficiency < 0.1%

Vertex-reconstruction efficiency < 0.1 %

Track -reconstruction efficiency 1.1%

Different MC tunes 0.4%

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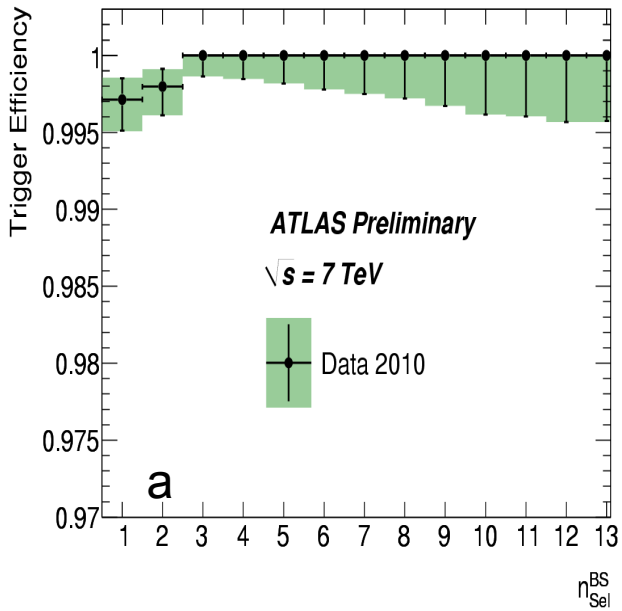
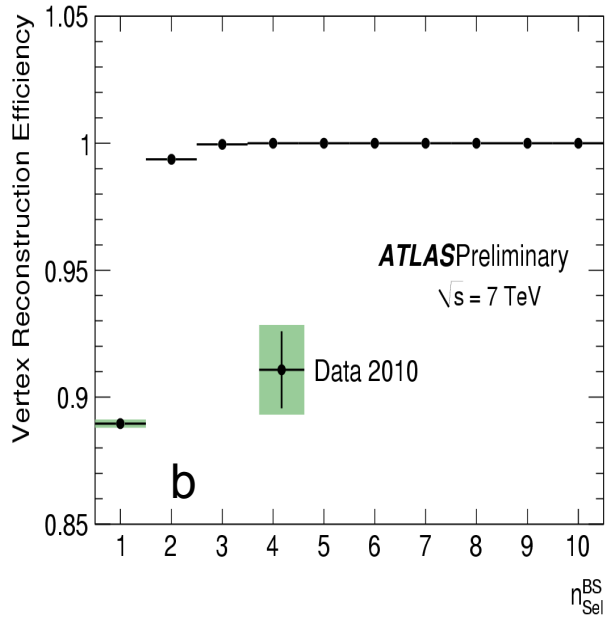
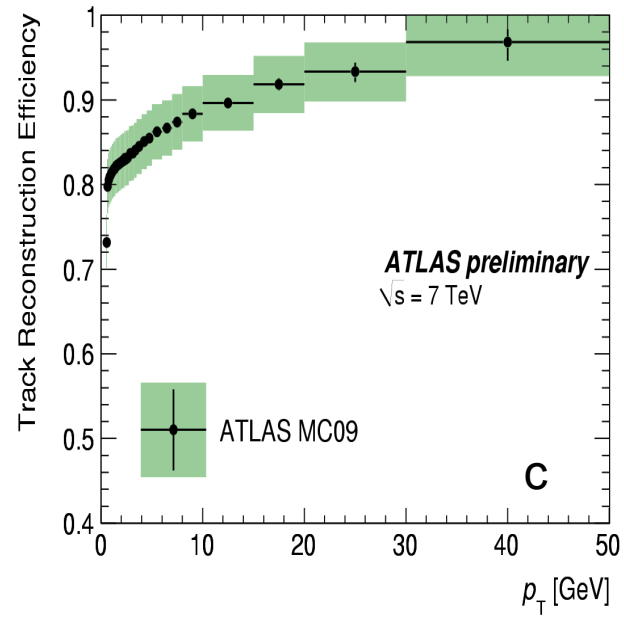
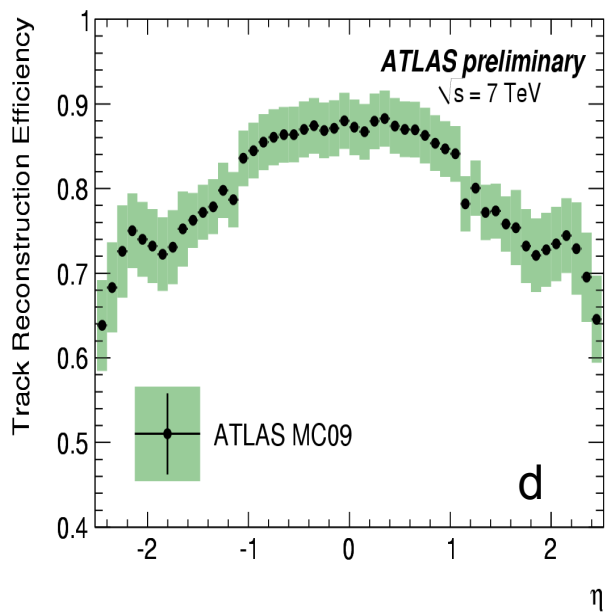
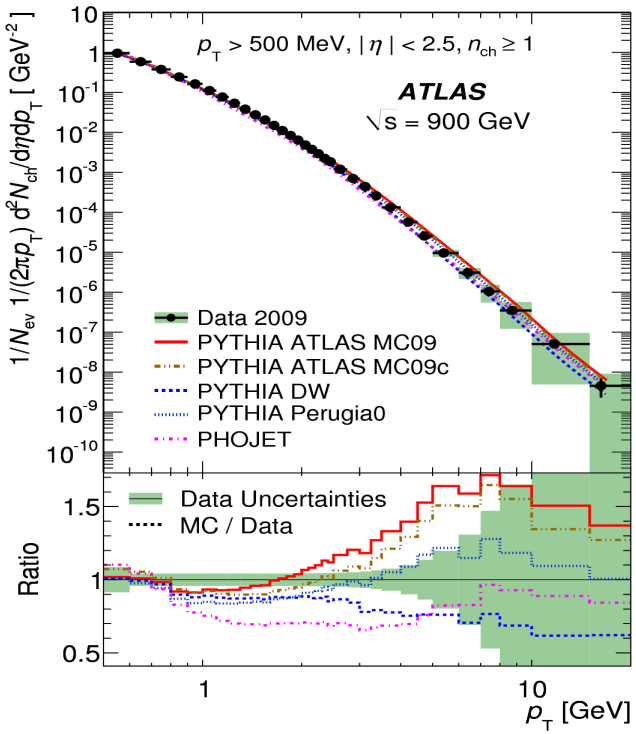


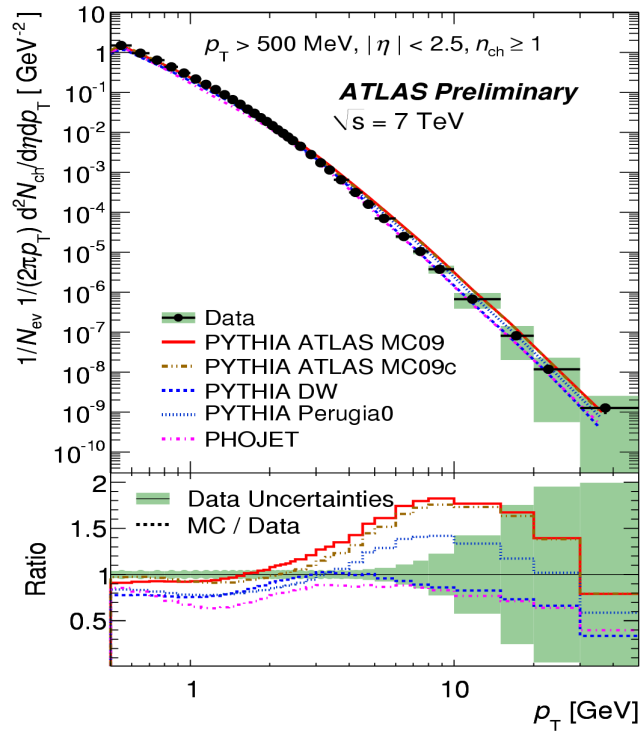






The trigger efficiency (a) and the vertex reconstruction efficiency (b) as a function of the number of selected vertex tracks nsel_BS at sqrt{s} = 7 TeV. The total uncertainties on each point are shown as shaded boxes, the vertical error bars represent the statistical uncertainty. Track reconstruction efficiency as a function of η (d) and p_T (c) for sqrt{s}=7 TeV. The total uncertainties on each point are shown as shaded boxes, the vertical error bars represent the statistical uncertainty. ATLAS-CONF-2010-024





The MC models do not reproduce the data for p_t > 0.7 GeV. Most significant difference is seen for the PHOTOJET generator.

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The spectrum is well described by ATLAS MC09 tune up to 2 GeV.

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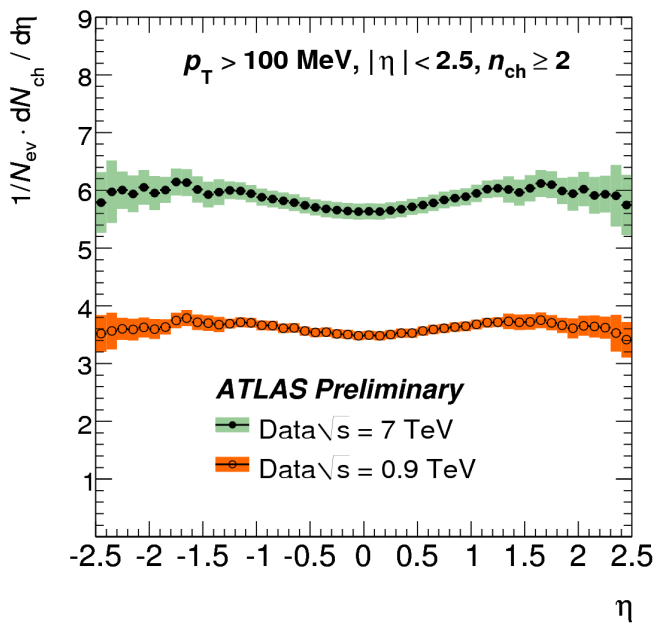
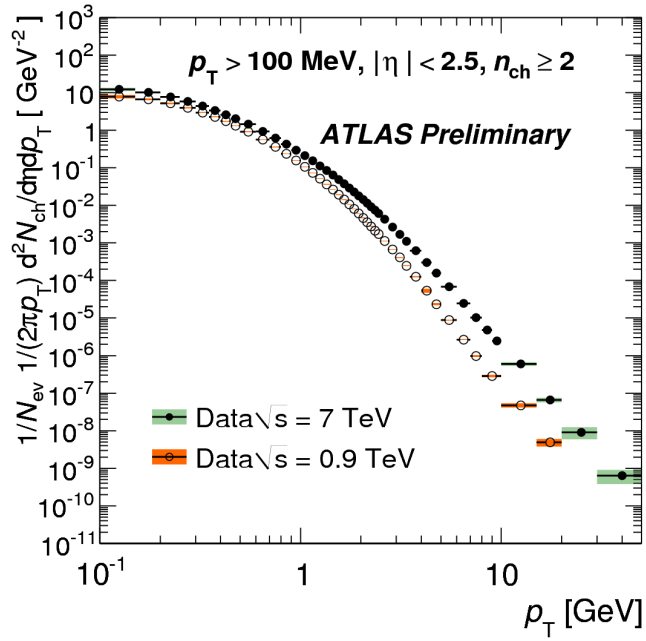
p+p interactions at $\sqrt{s}$ = 900 GeV and 7 TeV, tracks with p_T>100 MeV





Tracks requirements:

- Hit in the b-layer of the Pixel detector (when expected)
- Min. one pixel hit in any of 3 layers
- distance to primary vertex: $|d_0| < 1.5$ mm and $|z_0 \cdot \sin \quad| < 1.5$ mm
- 2 , 3 or 6 hits in SCT (for p_t > 100 MeV , p_t > 200 MeV and p_t >300 MeV respectively).
- χ^2 probability > 0.01 for reconstructed tracks with p_t > 10 GeV.

(ATLAS-CONF-2010-046)

Results from pixel track & track method

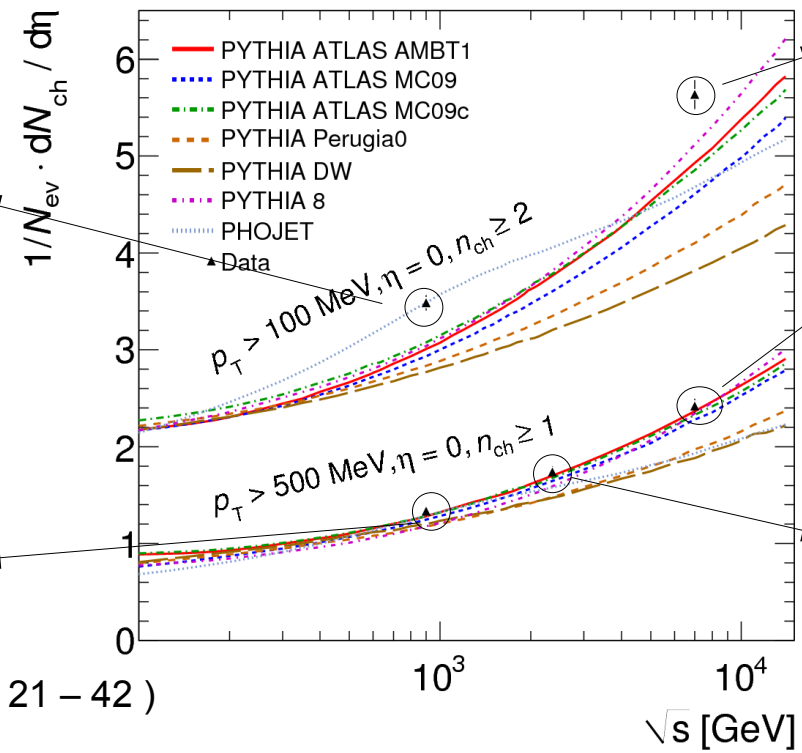
3.486±0.008 (stat.)
±0.077(syst.)
(ATLAS-CONF-2010-046)

5.635±0.002 (stat.)±0.149(syst.)
(ATLAS-CONF-2010-046)

2.418±0.004(stat.)±0.076(syst.)
ATLAS-CONF-2010-024

1.739±0.019 (stat)±0.058 (syst.)
ATLAS-CONF-2010-047

1.333±0.003(stat)
±0.04(syst.)
(Physics Letter B 688 (2010) 21 – 42)



Average charged particle multiplicity per unit of rapidity for η = 0 as a function of the center of mass energy.(ATLAS-CONF-2010-046)