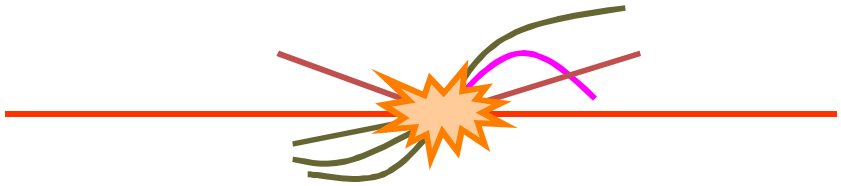
Charged-particle multiplicities in pp interactions at √s = 900 GeV



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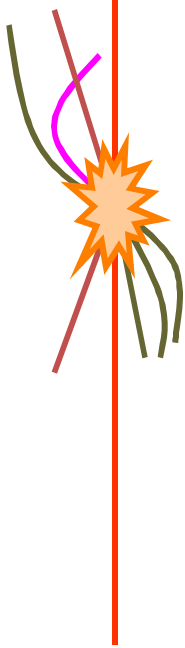
On behalf of the ATLAS Collaboration

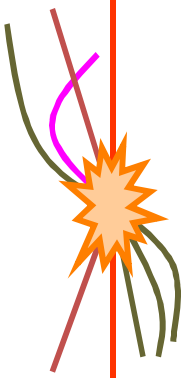
Preliminary results

Overview



- Introduction
  - Goals and distributions
- Event selection
  - Trigger
  - Vertex
- Corrections
- Results
- Systematics
- Conclusion

Introduction



- Measure charged particle multiplicity distributions from inelastic events.
  - Require $N_{ch} \geq 1$ ($|\eta|<2.5$ & $p_T > 500$MeV).
    - Removes model dependence from trigger and vertex corrections.
  - No removal of Single Diffractive component.
- Kinematic range $|\eta|<2.5$ & $p_T > 500$MeV
- Correct reconstructed-track distributions back to hadron level for all detector effects.
  - Measure trigger and vertex corrections from data.

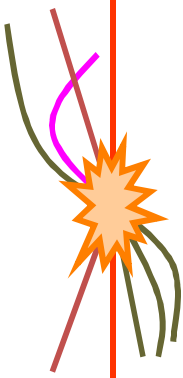
Distributions

$$\frac{1}{N_{ev}} \cdot \frac{dN_{ch}}{d\eta}$$

$$\frac{1}{N_{ev}} \cdot \frac{1}{2\pi P_T} \cdot \frac{d^2 N_{ch}}{d\eta dp_T}$$

$$\frac{1}{N_{ev}} \cdot \frac{dN_{ev}}{dN_{ch}}$$

$$\langle p_T \rangle \text{ vs. } N_{Ch}$$



N_{ev}

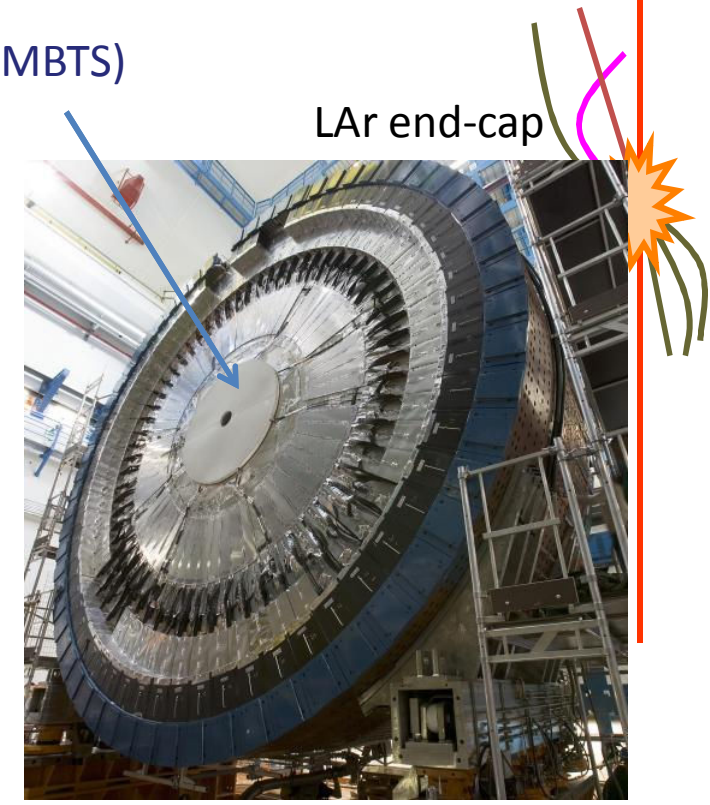
N_{ch}

for events with $N_{ch} \geq 1$ ($|\eta| < 2.5$ & $p_T > 500$MeV)

Analysis Trigger: L1 MBTS

Minimum Bias Trigger Scintillators (MBTS)

- Require 1 or more counter from either side above threshold.
- 455593 events were selected using the L1 MBTS trigger.
  - Data quality selection requiring fully operational Inner Detector, trigger and solenoid B-field.



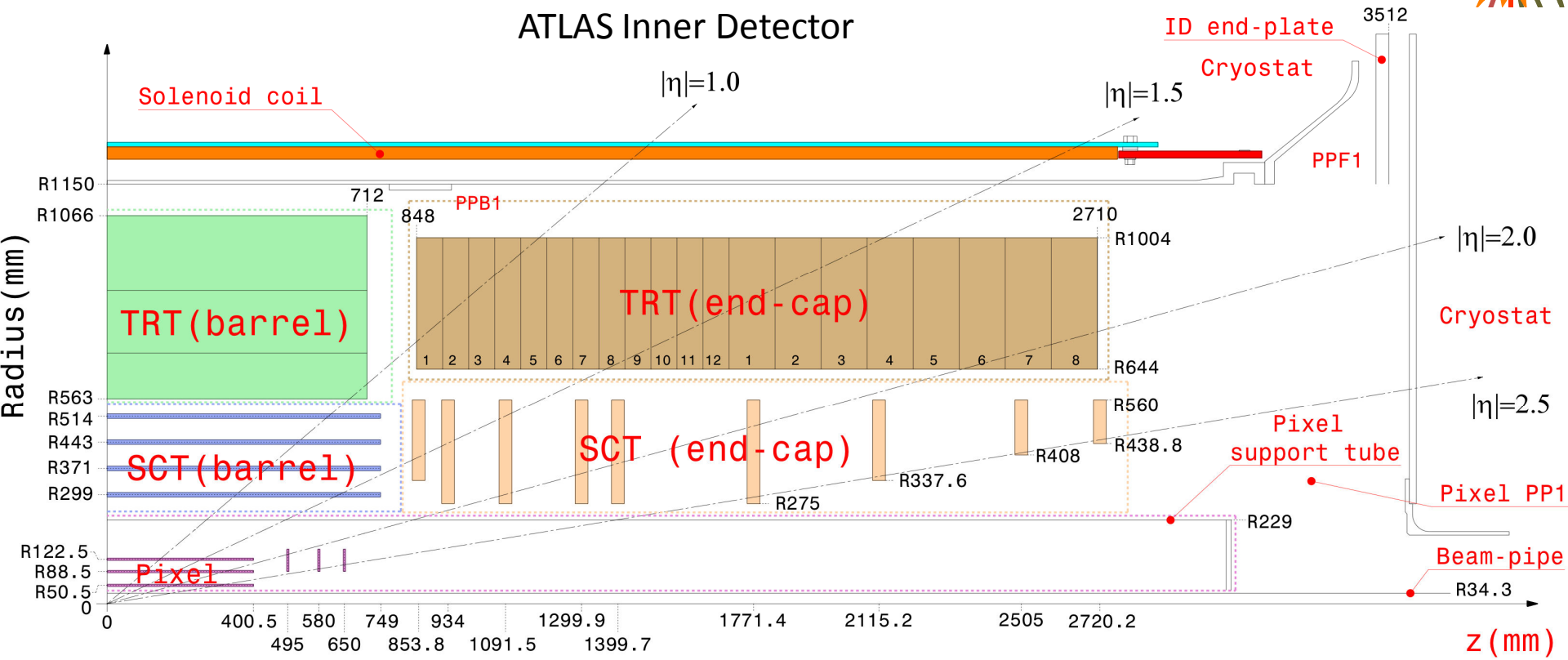
z = ±3560 mm, 8 units in ϕ,

2 units in η (2.09 < η < 2.82,

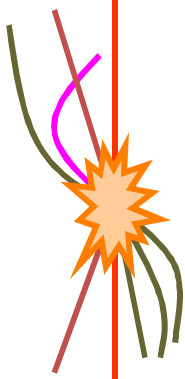
2.82< η < 3.84)

Control Trigger

- L1 Beam-pickup, filtered by L2 Pixel and Silicon microstrip (SCT) spacepoints, and EF track.



Trigger Efficiency

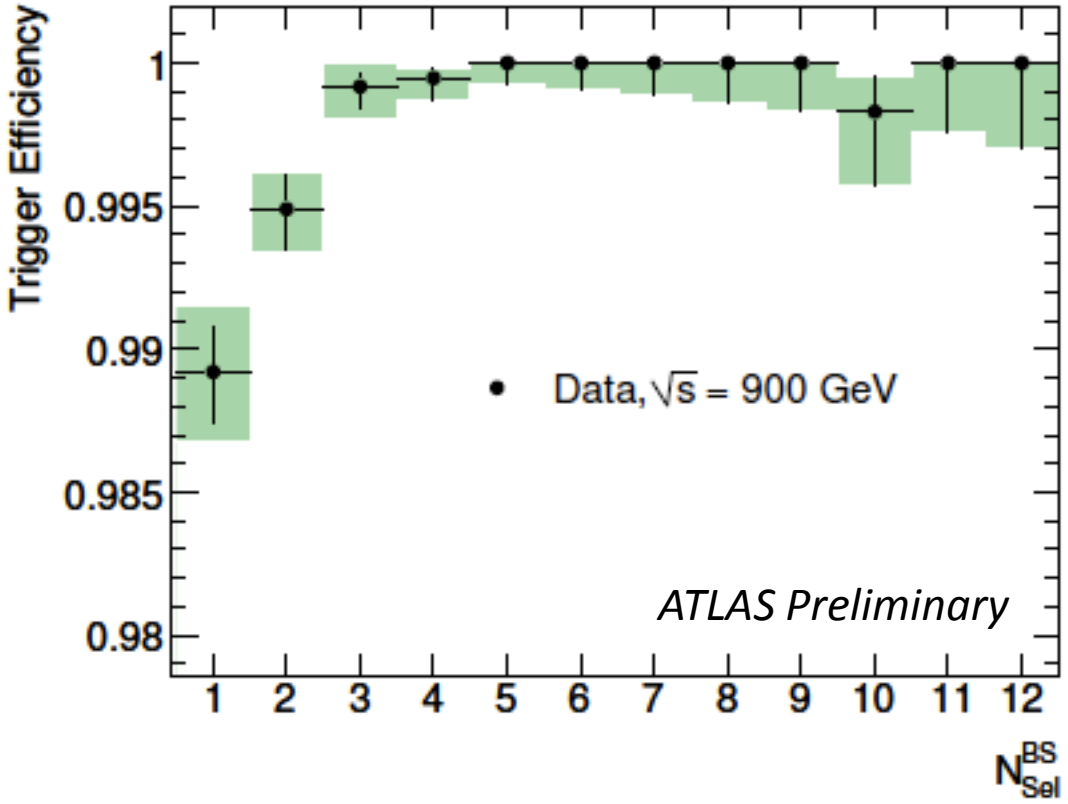


- Measured from data using Inner Detector trigger (mbSpTrk) sample.
  - Efficiency of the L1 MBTS trigger for inelastic events with a track within ID acceptance and offline selection.

$$\varepsilon(L1\_MBTS\_1) = \frac{L1\_MBTS\_1 \,\&\, offline \,\&\, mbSpTrk}{offline \,\&\, mbSpTrk}$$

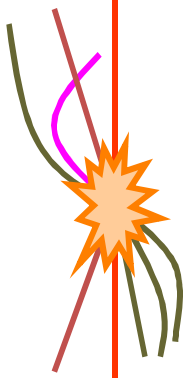
L1 MBTS Trigger Efficiency

Measured from data using control trigger.
No affect on p_T and η spectrum within statistical uncertainties.



- Efficiency is close to 1 for offline selection.
  - Selected tracks, but dropping
    - $|d_0^{PV}| < 1.5$mm
    - $|z_0^{PV} \sin(\theta^{PV})| < 1.5$mm
  - Using $|d_0^{BS}| < 4$mm
- Small systematic error contributions:
  - Trigger correlation
  - Different track selection.
  - Statistical limit on p_T and η bias

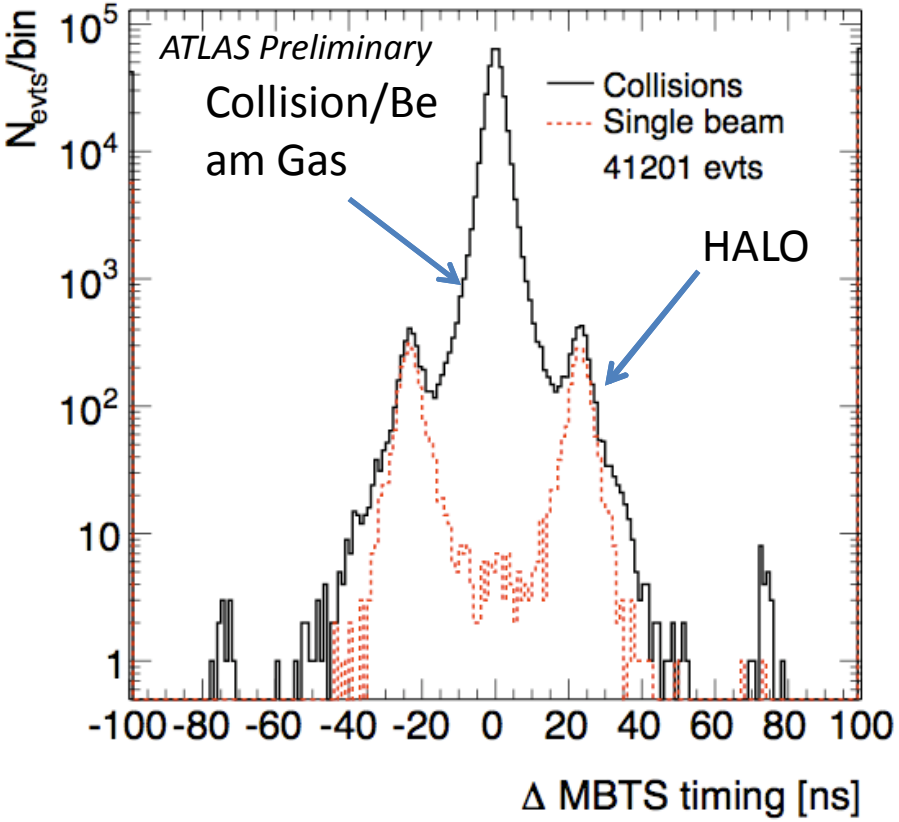
Offline Selection



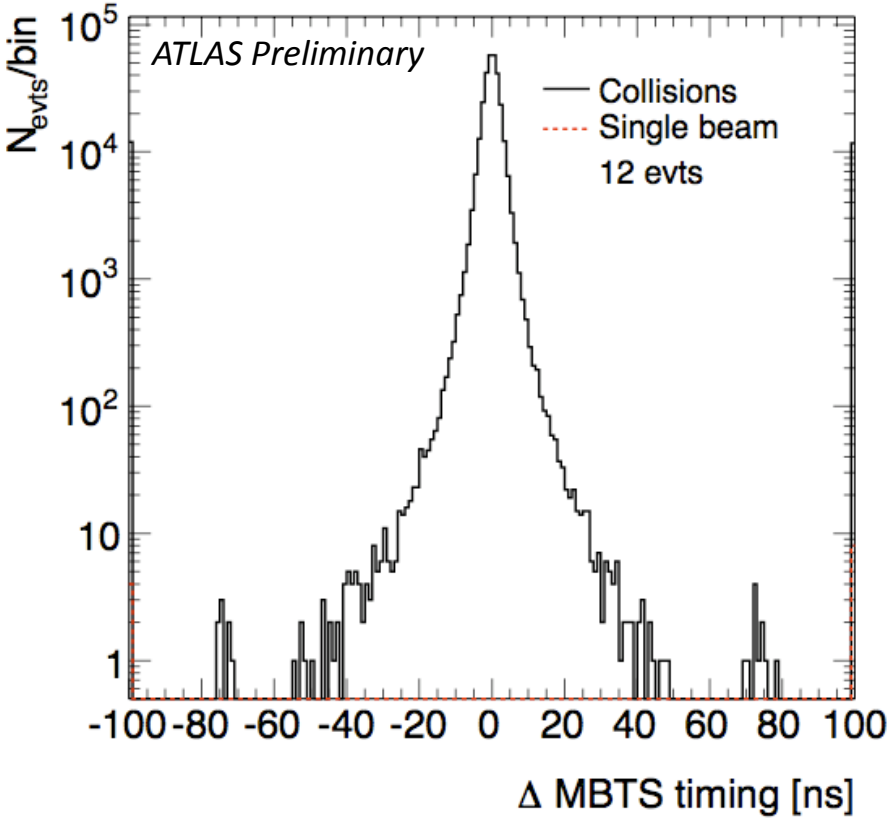
- Track Selection:
  - $p_T > 500MeV$
  - $|\eta| < 2.5$
  - Number of Pixel Hits ≥ 1
  - Number of SCT Hits ≥ 6
  - $|d_0^{PV}| < 1.5$ mm
  - $|z_0^{PV} \sin(\theta^{PV})| < 1.5$ mm
  - Inside out track reconstruction
- Event Selection:
  - L1 MBTS trigger
  - Primary vertex without beam-spot constraint and including three tracks ($p_T > 150MeV$).
  - Number of selected tracks ≥ 1

Beam Background

Measure time difference from offline readout of MBTS
(Time cut is not used in analysis selection.)

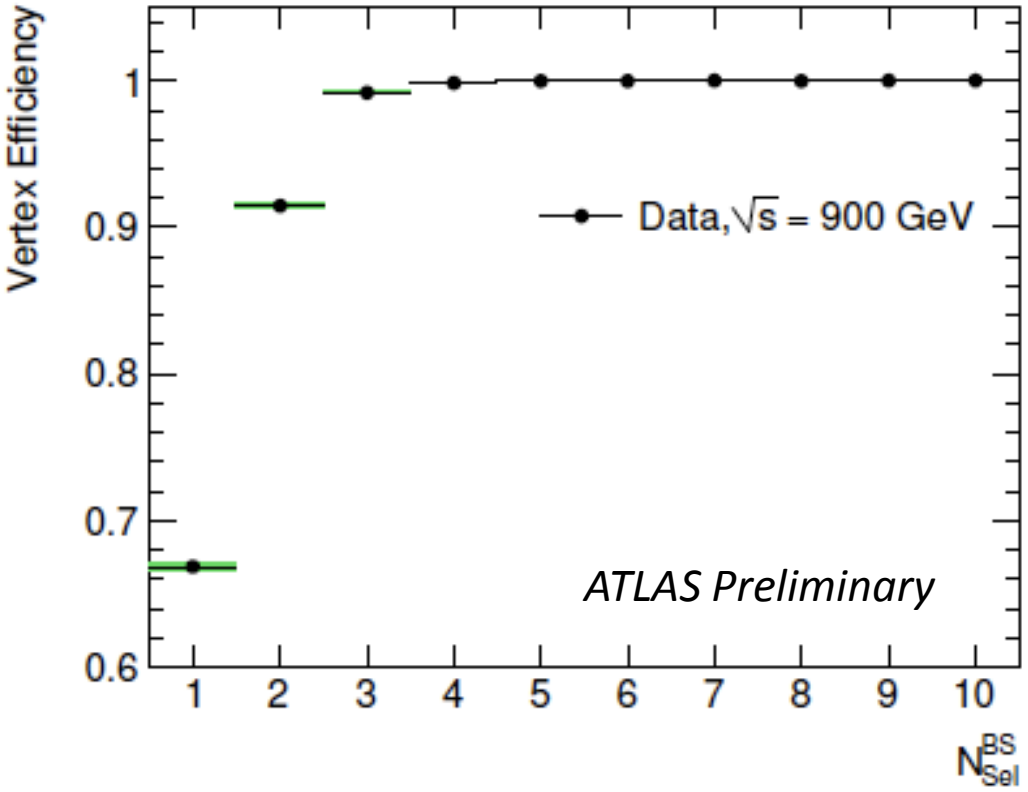


Trigger Selection



Full Offline Selection

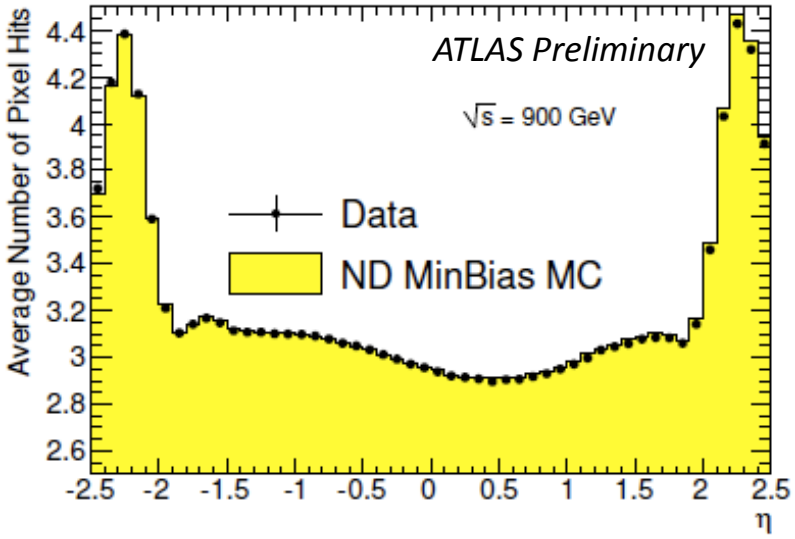
Vertex Efficiency

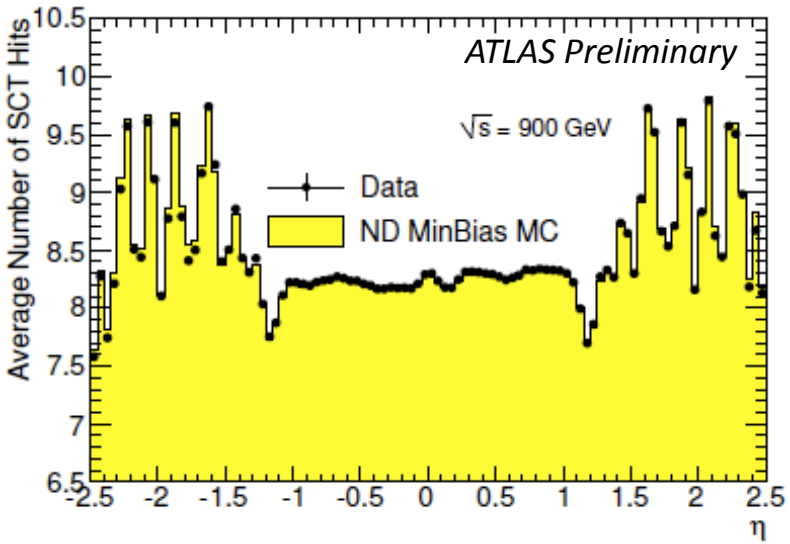


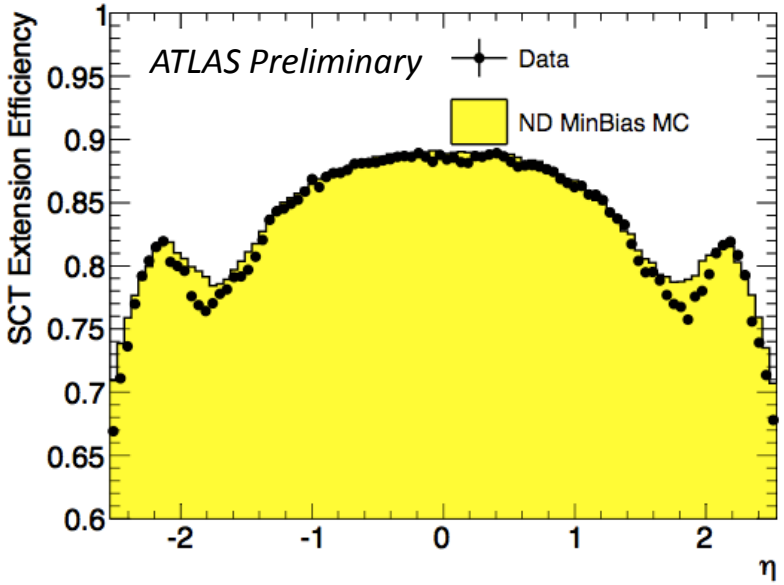
- Measured from data:
  - L1 MBTS selected events.
  - Selected tracks, but dropping
    - $|d_0^{PV}| < 1.5$mm
    - $|z_0^{PV} \sin(\theta^{PV})| < 1.5$mm
  - Using $|d_0^{BS}| < 4$mm
- Tiny systematic from beam background.

No affect on p_T spectrum within statistical uncertainties.
Shaping of η for $N_{Sel} = 1$ corrected for.

Validating Inner Detector Simulation



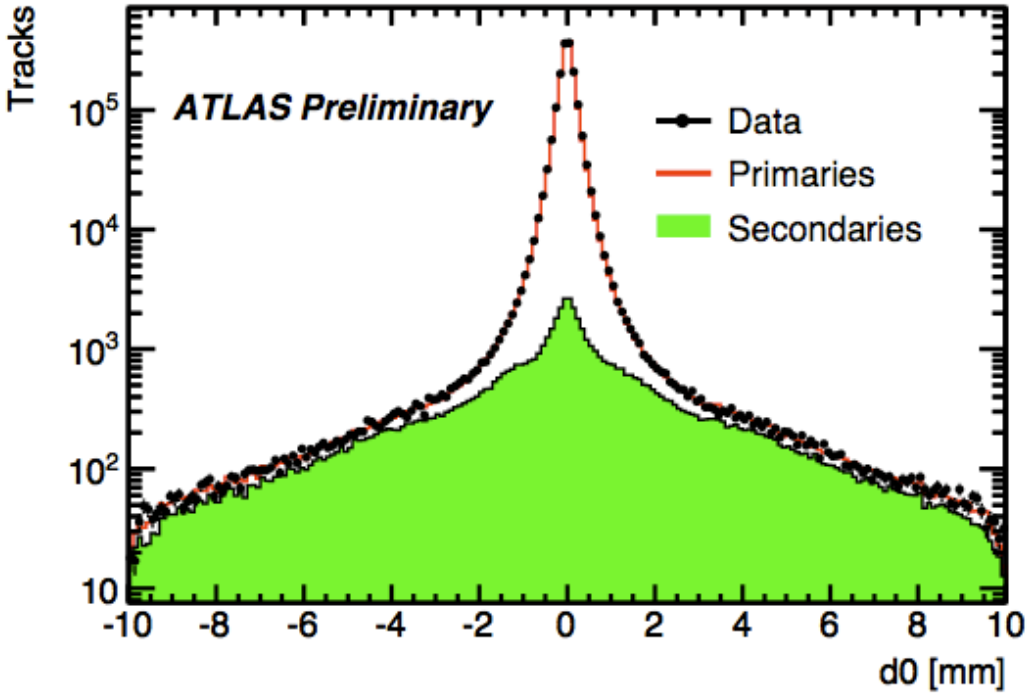




Detailed study of material, alignment, and resolution.

Particles from Secondary Interactions

- Sources of secondary interactions:
  - Nuclear interactions
  - Weakly decaying particles (K_s, Lambda etc.)
  - Pion decays

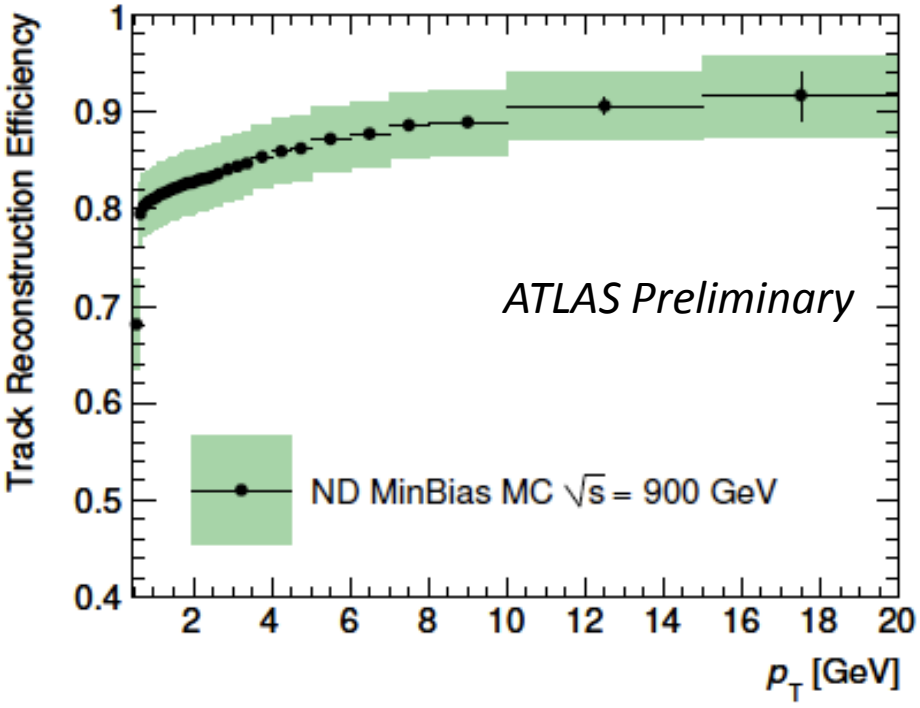


Compare Monte Carlo and data.

Fit Monte Carlo to data within
$2.0 \text{ mm} < |d_0^{PV}| < 10 \text{ mm}$

Determine fraction of tracks inside
$|d_0^{PV}| < 1.5 \text{ mm}$
$|z_0^{PV} \sin(\theta^{PV})| < 1.5 \text{ mm}$
to be
$2.20 \pm 0.05 \text{ (stat.)} \pm 0.11 \text{ (sys.)} \%$

Tracking Efficiency

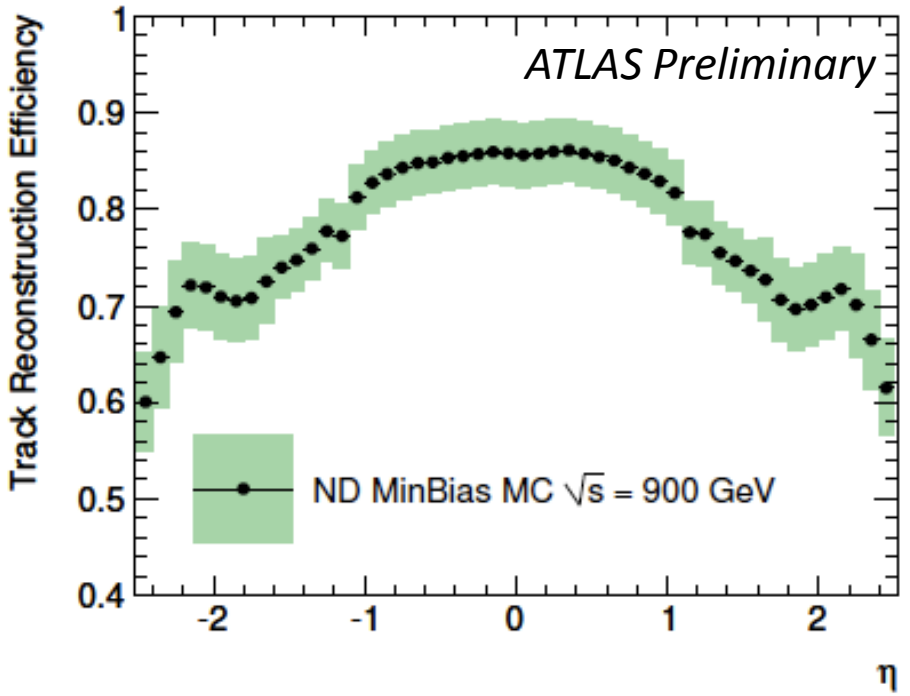


Global systematic dominated by conservative material estimate.

Higher systematic error in regions with more material

Best match between track and MC particle within a cone of 0.05

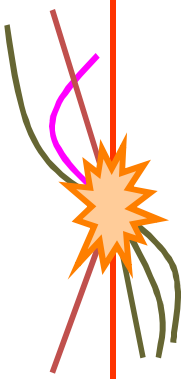
$$\epsilon_{\mathrm{bin}}(p_{\mathrm{T}},\eta) = \frac{N_{\mathrm{rec}}^{\mathrm{matched}}(p_{\mathrm{T}},\eta)}{N_{\mathrm{gen}}(p_{\mathrm{T}},\eta)}$$



Correction Procedure

- Correct for the effect of the trigger and primary vertex reconstruction efficiency on an event-by-event basis:

$$w_{\mathrm{ev}} = \frac{1}{\epsilon_{\mathrm{trig}}(N_{\mathrm{Sel}}^{\mathrm{BS}})} \cdot \frac{1}{\epsilon_{\mathrm{vtx}}(N_{\mathrm{Sel}}^{\mathrm{BS}})}$$



- Correct for track-reconstruction efficiency (P_T, η) on a track-by-track basis:

$$w_{\mathrm{trk}} = \frac{1}{\epsilon_{\mathrm{bin}}(p_{\mathrm{T}}, \eta)} \cdot (1 - f_{\mathrm{sec}}(p_{\mathrm{T}})) \cdot (1 - f_{\mathrm{okr}})$$

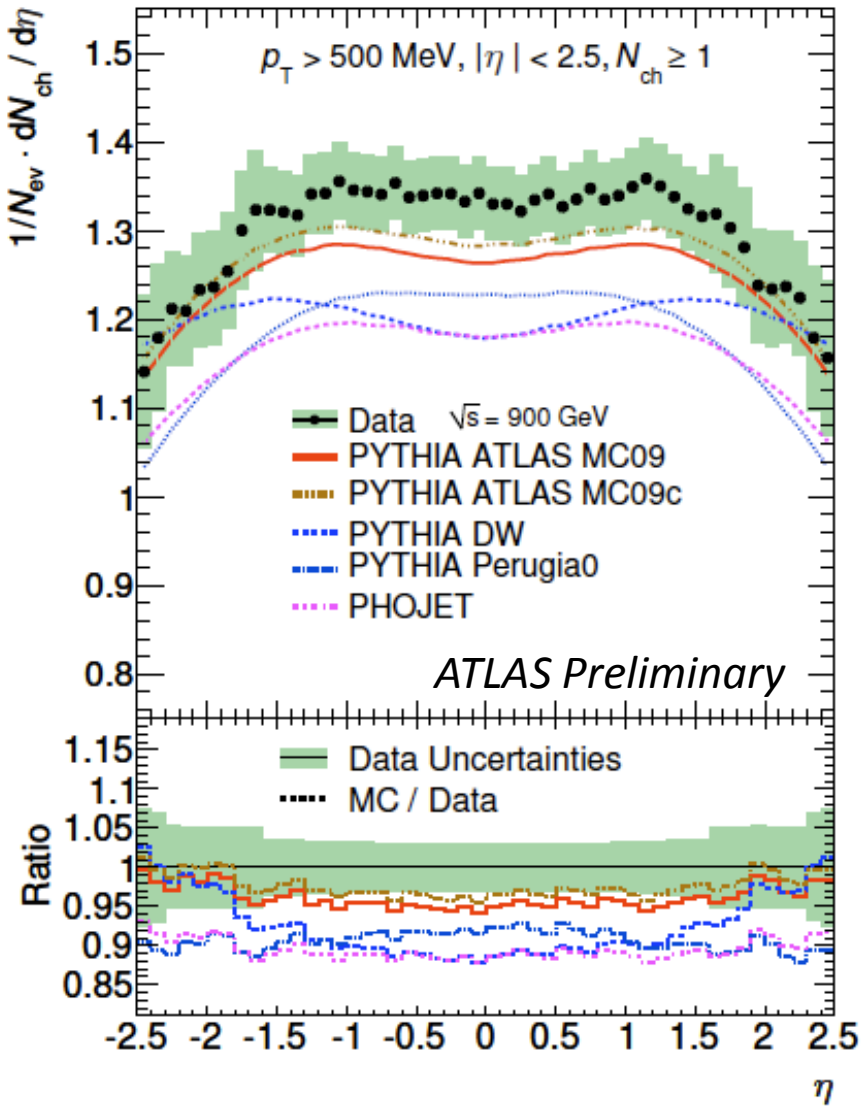
p_T resolution effect

- Correct N_{sel} to N_{ch} using $M_{ch,sel}$
  - Filled from MC, applied, refilled, converges after 4 iterations.
- Correct for events with $N_{sel} = 0$ and $N_{ch} > 0$ using:

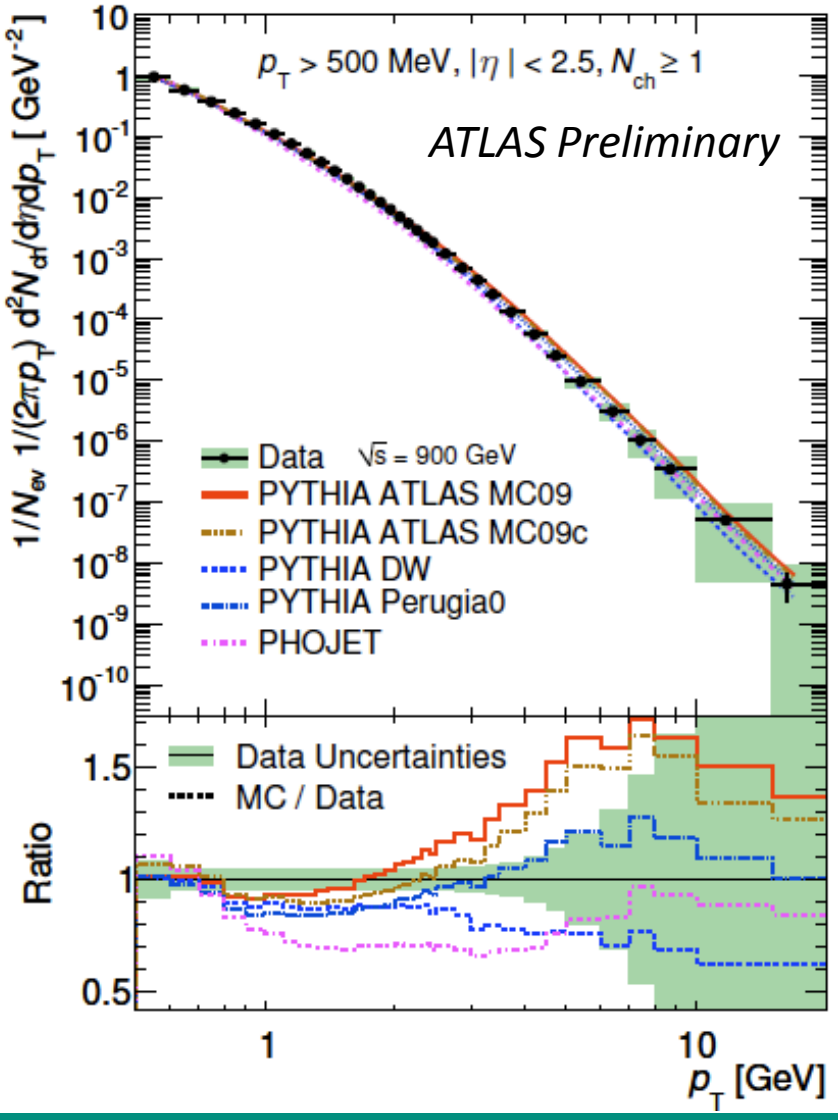
$$1/(1 - (1 - \epsilon(N_{\mathrm{ch}}))^{N_{\mathrm{ch}}})$$

Mean track reconstruction efficiency

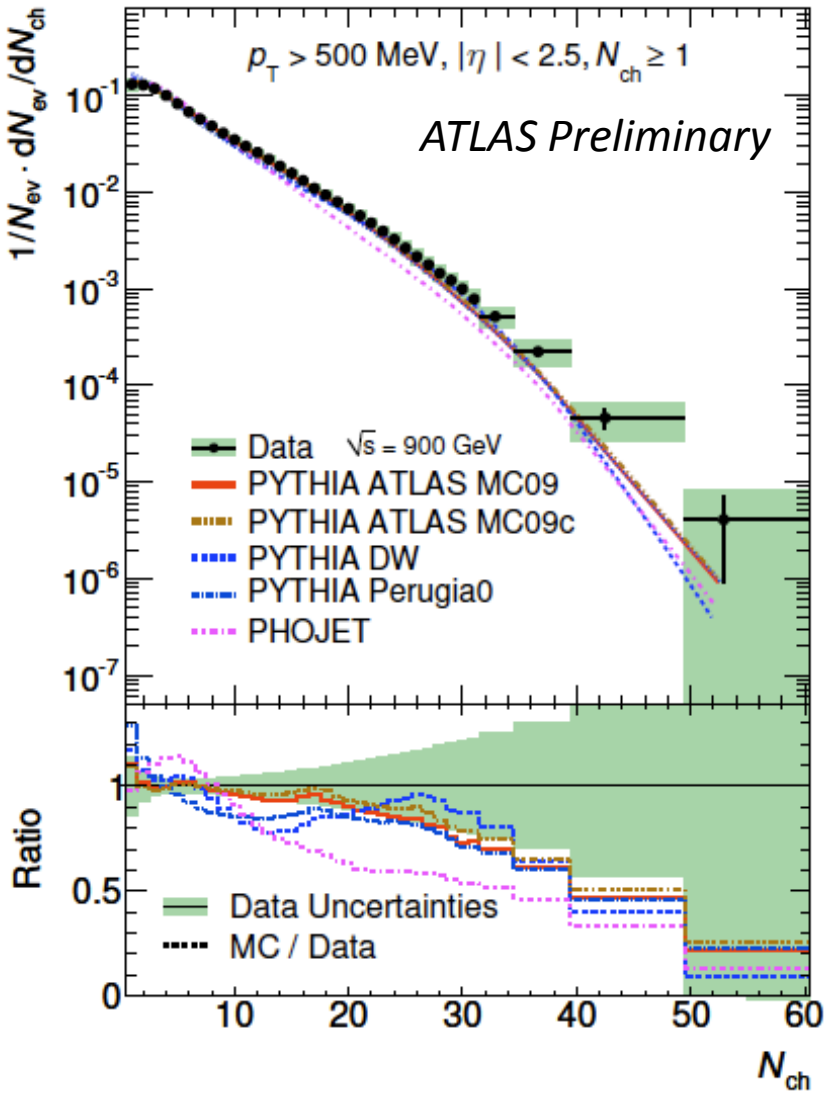
$dN_{ch}/d\eta$



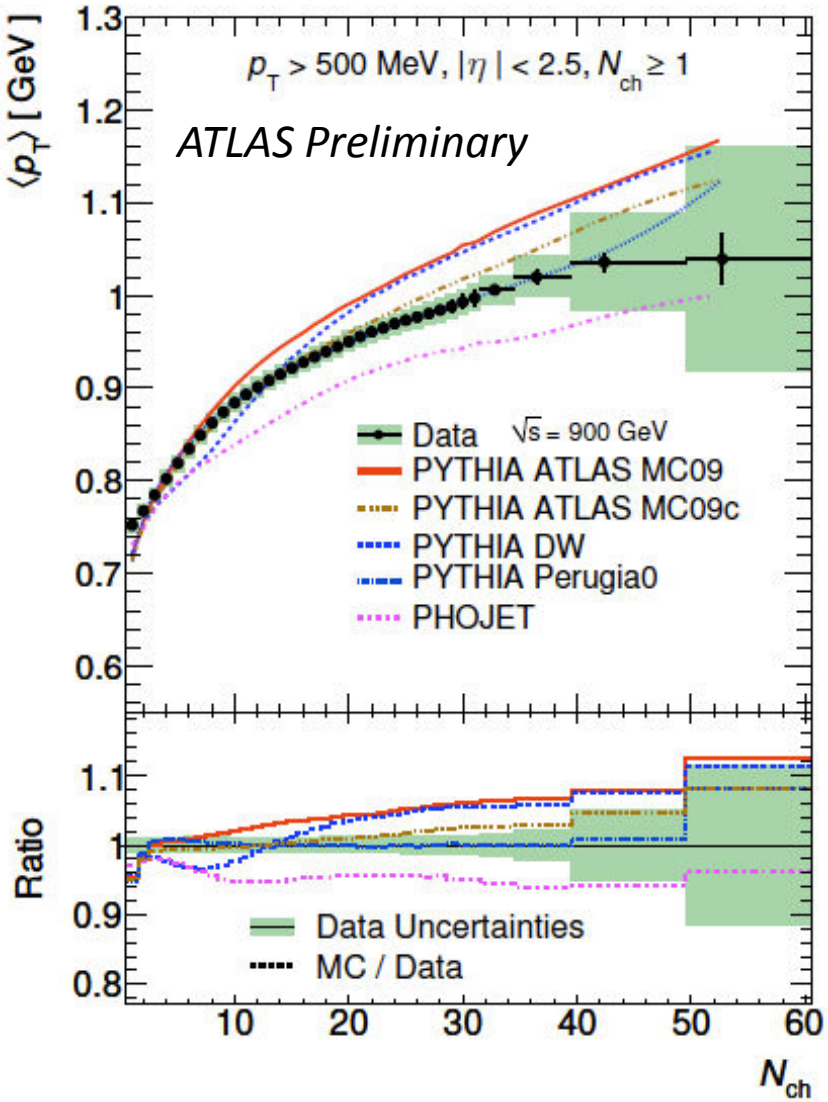
$1/p_T\, dN_{ch}/dp_T$



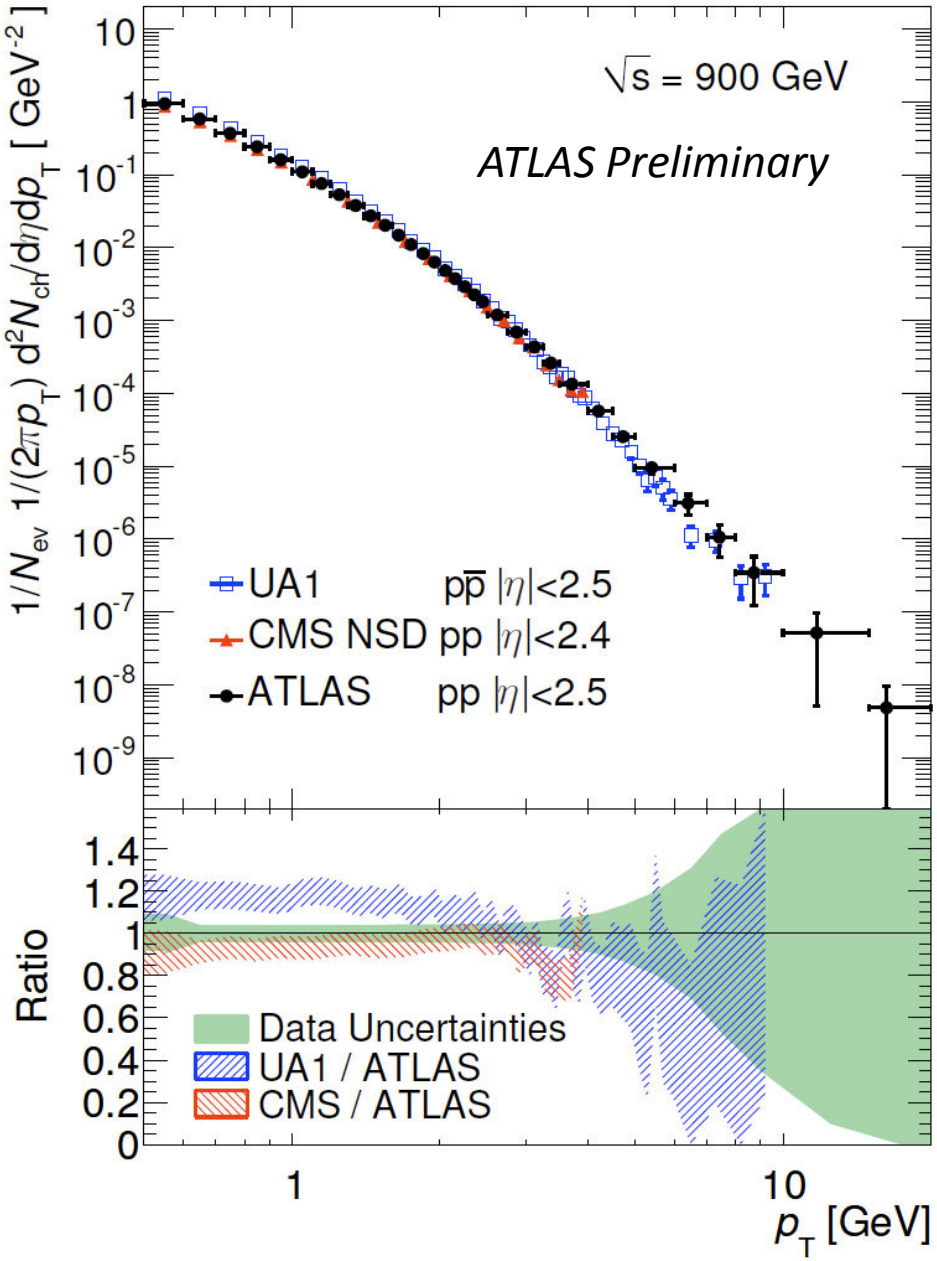
dN_{ev}/dN_{ch}



$\langle p_T \rangle$ vs N_{ch}



Comparison: $1/p_T\, dN_{ch}/dp_T$

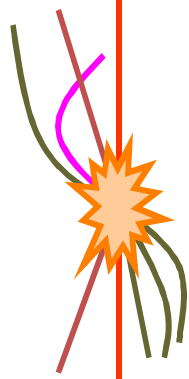


- p_T spectrum similar to CMS NSD result.
  - Agree within uncertainties when ATLAS is converted to CMS NSD.
- Interpreted UA1 data are higher at low p_T
  - Expect this is a measurement definition difference.

Table of Systematic Uncertainties

ATLAS Preliminary

Systematic uncertainty on the number of events, N_{ev}	
Trigger efficiency	$< 0.1\%$
Vertex-reconstruction efficiency	$< 0.1\%$
Track-reconstruction efficiency	1.1%
Different MC tunes	0.4%
Total uncertainty on N_{ev}	1.2%
Systematic uncertainty on $1/N_{ev} \cdot dN/d\eta$ at $\eta = 0$	
Track Reconstruction	4.2%
Trigger and vertex efficiency	$< 0.1\%$
Secondary fraction	0.2%
Total uncertainty on N_{ev}	-1.2%
Total uncertainty on $1/N_{ev} dN/d\eta$ at $\eta = 0$	3.0%



Conclusions

- Minimized model dependencies.
- The charged-particle multiplicity per event and unit of pseudorapidity at $\eta=0$ is measured to be $1.333\pm0.003(\text{stat.})\pm0.040(\text{syst.})$.
  - 5-15% higher than Monte Carlo models.
- Differences between Monte Carlo predictions and measured data are most pronounced as a function of η and in $\langle p_T \rangle$ vs. N_{ch}