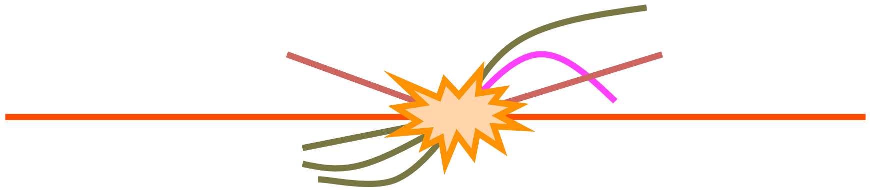
ATLAS first results

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



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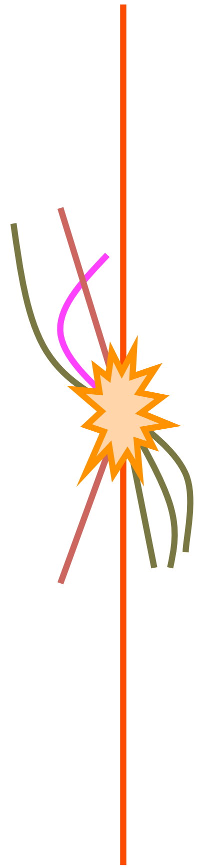
Overview



- Introduction
  - Goals and distributions
- Event selection
  - Trigger
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- Systematics
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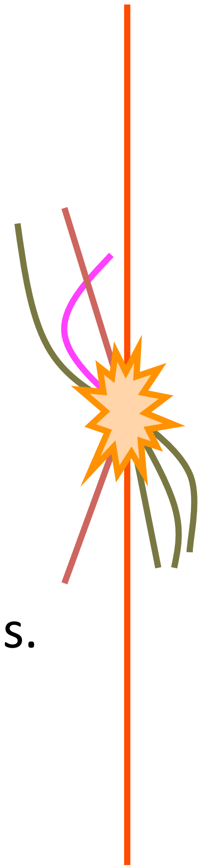
Introduction



- Measure primary charged particle multiplicity distributions from inelastic events.
  - Kinematic range $|\eta|<2.5$ & $p_T > 500$MeV
  - 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.
  - Define primary as mean life time $\tau > 0.3 \times 10^{-10}$s
- Correct reconstructed-track distributions back to hadron level for all detector effects.
  - Measure trigger and vertex corrections from data.
- Results are compared with PYTHIA 6.4.21 tunes, PHOJET 1.12 + PYTHIA 6.4.21, and other measurements.

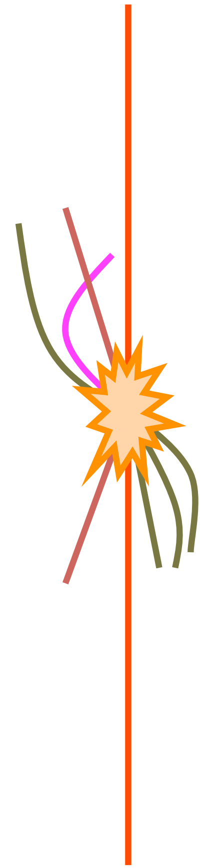
Distributions

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

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

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

$$\langle p_T \rangle \text{ vs. } n_{ch}$$



n_{ch} – number of primary charged particles in an event.

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

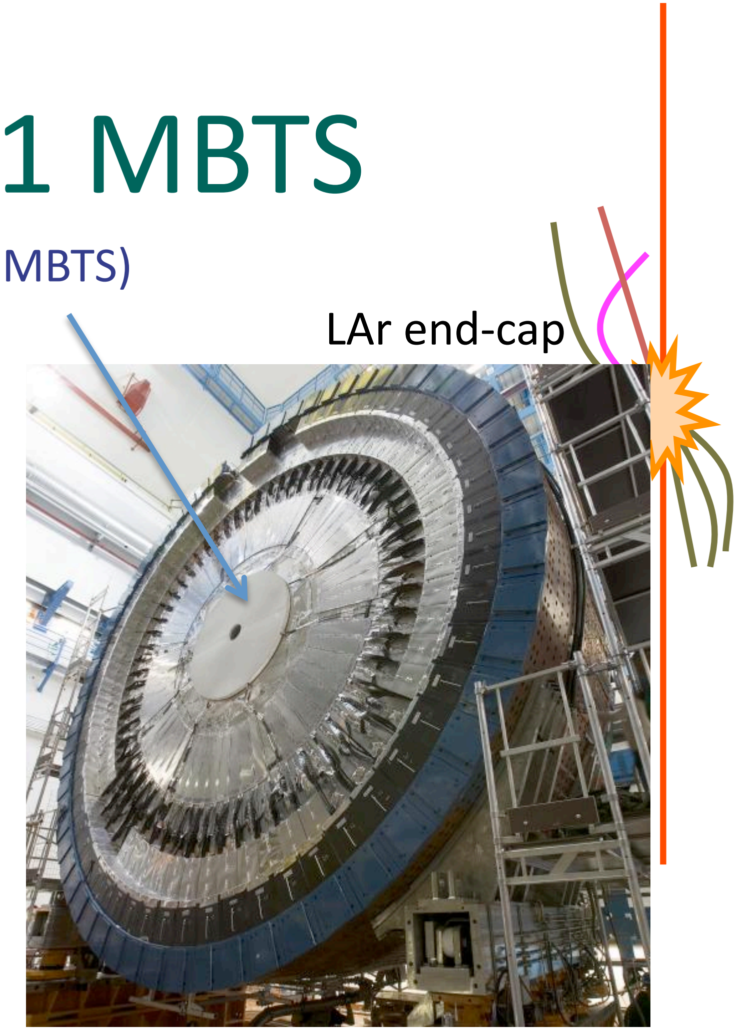
N_{ev} – Number of events.

N_{ch} – Total number of primary charged particles.

Analysis Trigger: L1 MBTS

Minimum Bias Trigger Scintillators (MBTS)

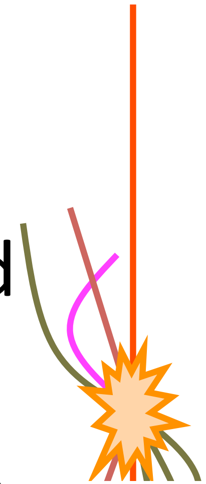
- Require 1 or more counter from **either** side above threshold (L1_MBTS_1)
- 455593 events were selected using the L1 MBTS trigger.
  - Stable beams.
  - Data quality selection requiring fully operational Inner Detector, trigger and solenoid B-field.

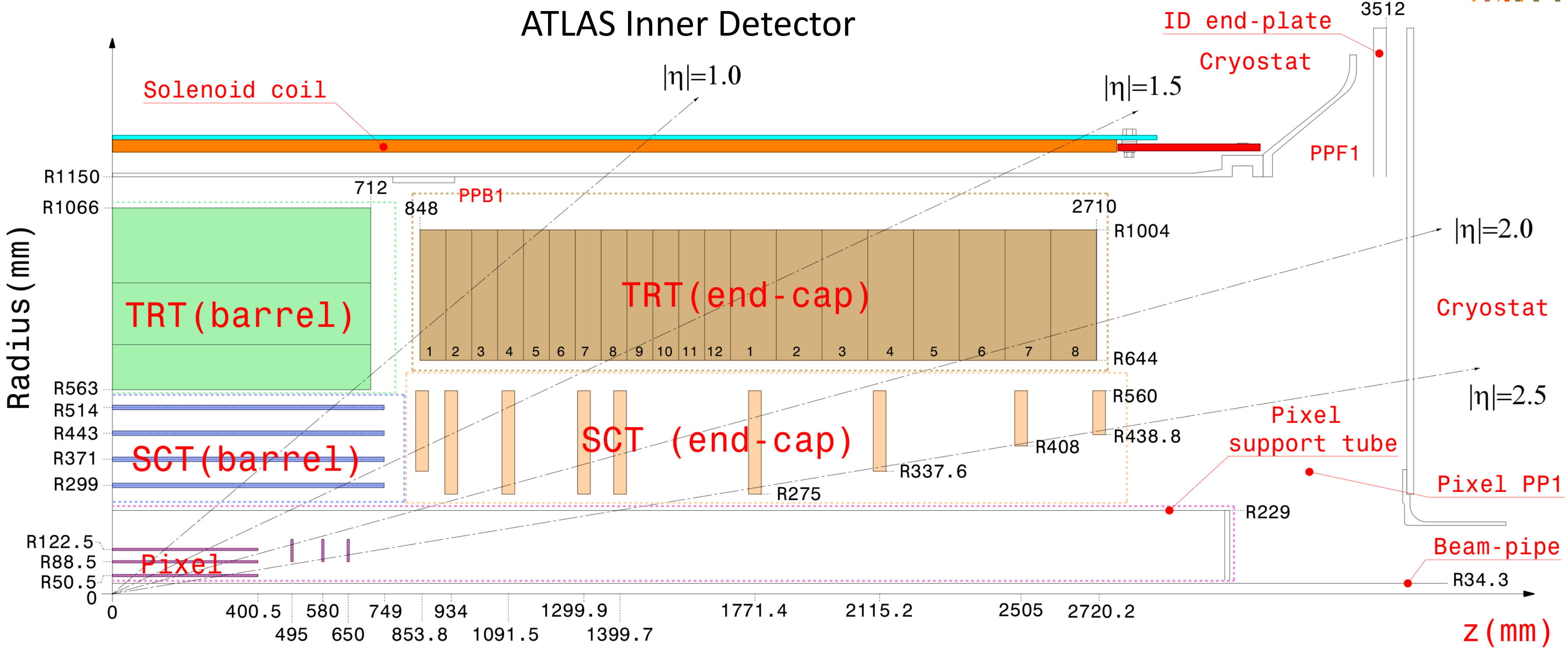


z = ±3560 mm, 8 units in ϕ, 2 units in η ($2.09 < \eta < 2.82$, $2.82 < \eta < 3.84$)

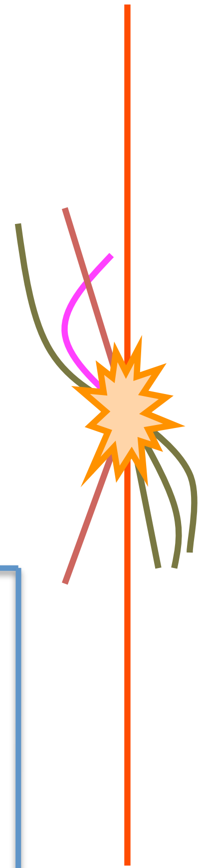
Control Trigger

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





Offline Selection

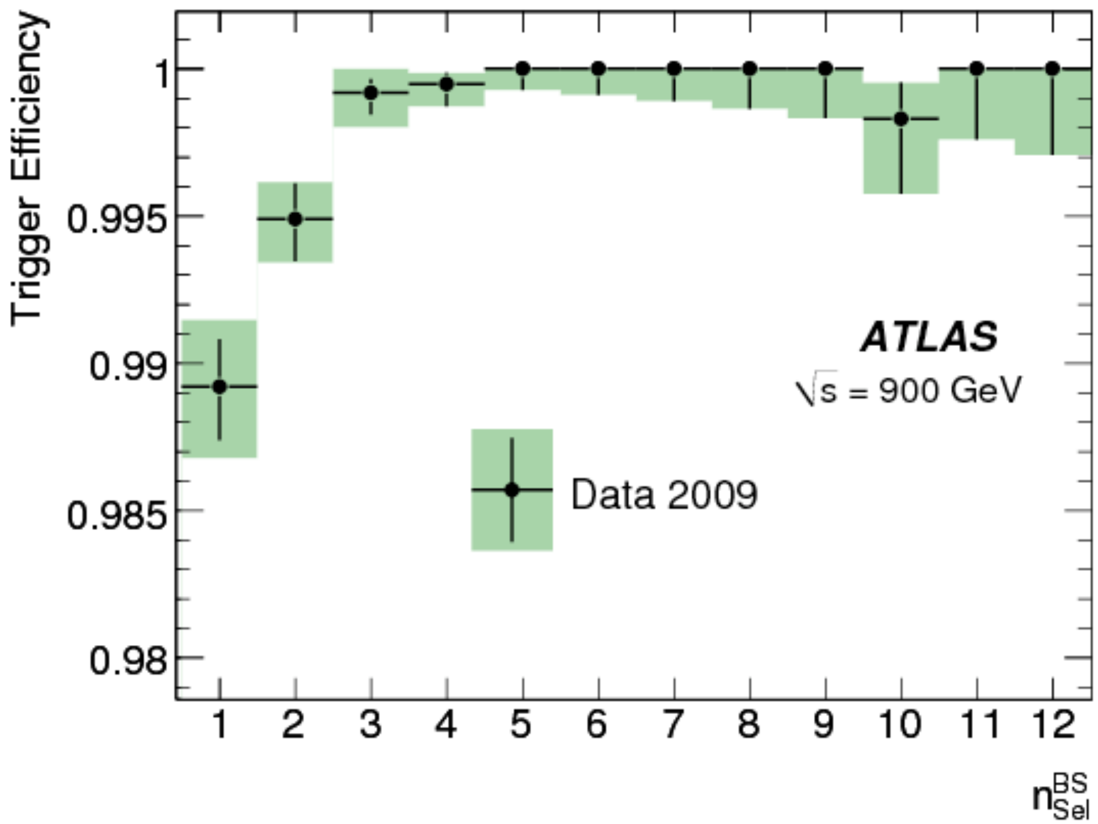


- Track selection for analysis (sel):
  - p_T > 500MeV
  - $|\eta|$ < 2.5
  - Number of Pixel Hits ≥ 1
  - Number of SCT Hits ≥ 6
  - $|d_0^{PV}|$ < 1.5 mm
  - $|z_0^{PV} \sin(\theta^{PV})|$ < 1.5 mm
  - Inside out track reconstruction
- Event selection:
  - L1 MBTS trigger (L1_MBTS_1)
  - Primary vertex without beam-spot constraint and including three or more tracks (p_T > 150MeV).
  - Number of selected tracks (n_{Sel}) ≥ 1
- 326201 events and 7904122 tracks pass this selection.

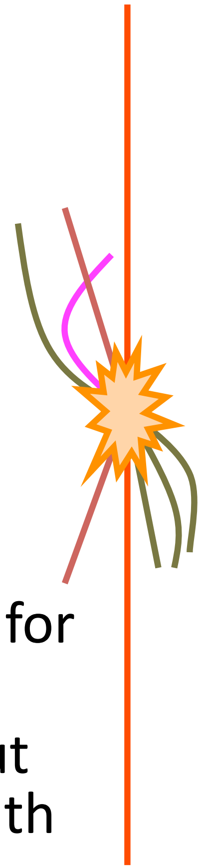
L1 MBTS Trigger Efficiency

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

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

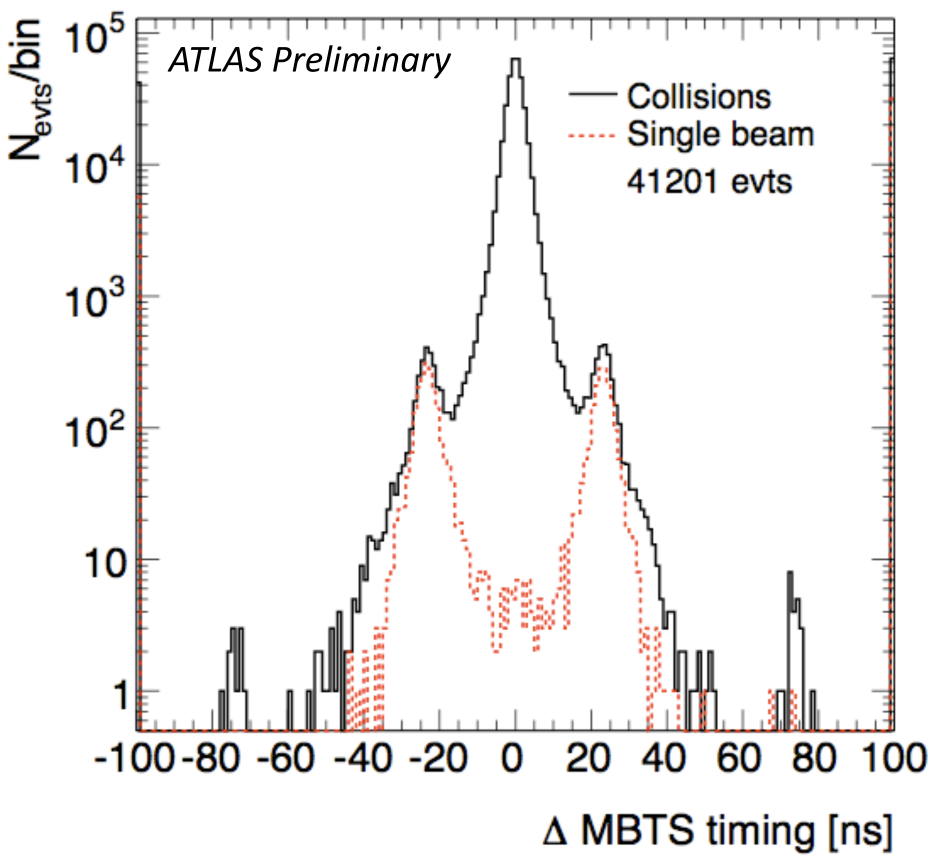


- Efficiency is close to 1 for offline selection.
- Track selection without primary vertex, but with impact parameter wrt beam spot (BS)
  - Selected tracks, but dropping
    - $|d_0^{PV}| < 1.5$mm
    - $|z_0^{PV} \sin(\theta^{PV})| < 1.5$mm
  - Require $|d_0^{BS}| < 4$mm

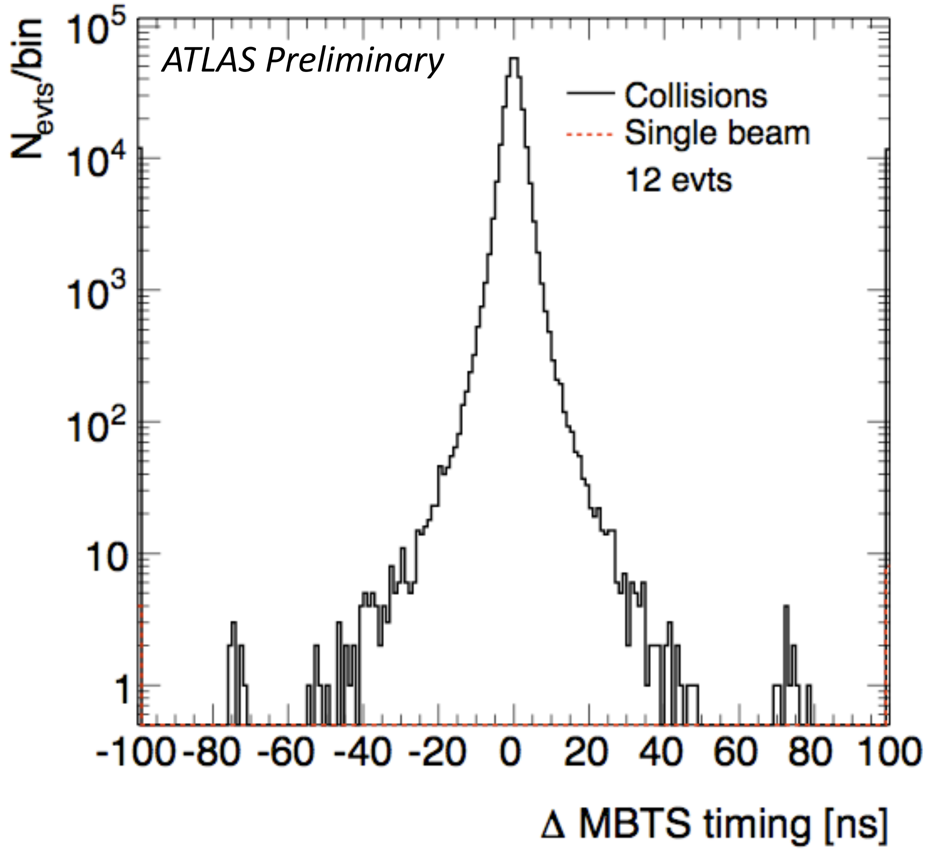


Beam Background

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

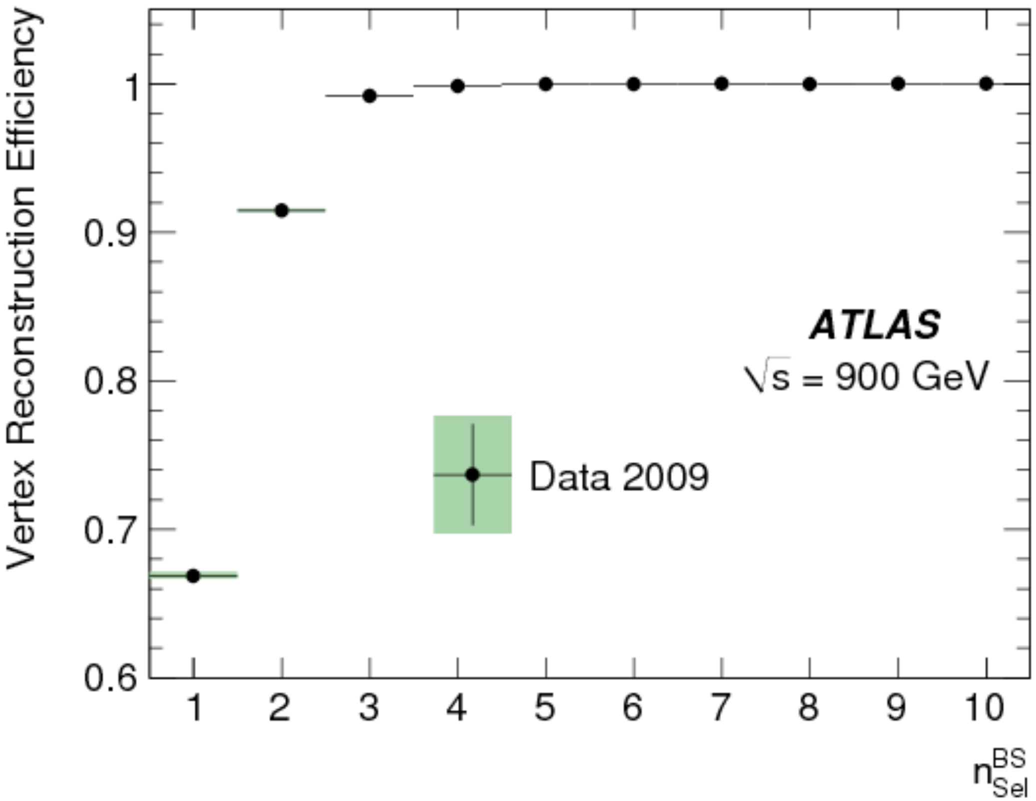


Trigger Selection



Full Offline Selection

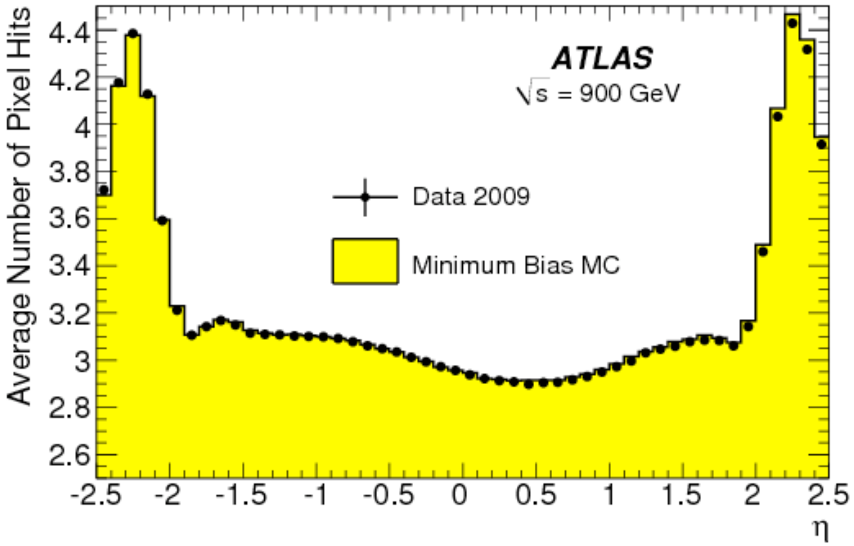
Vertex Efficiency

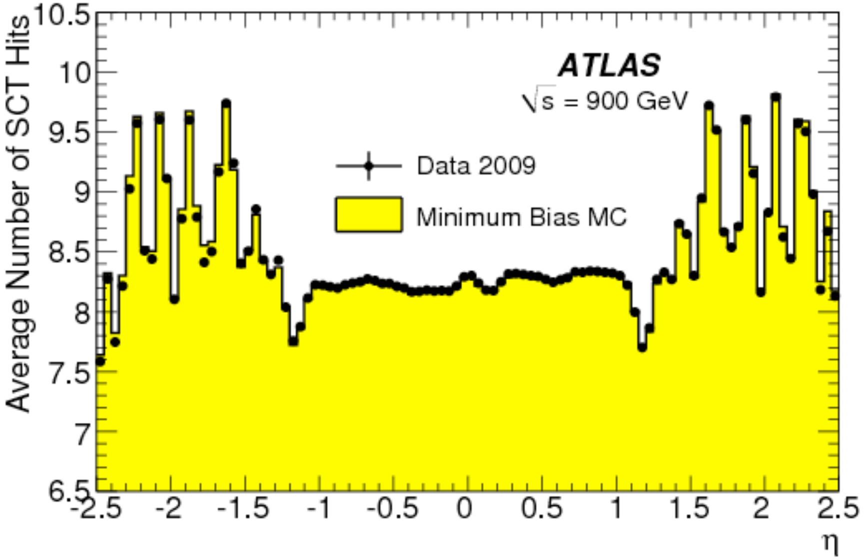


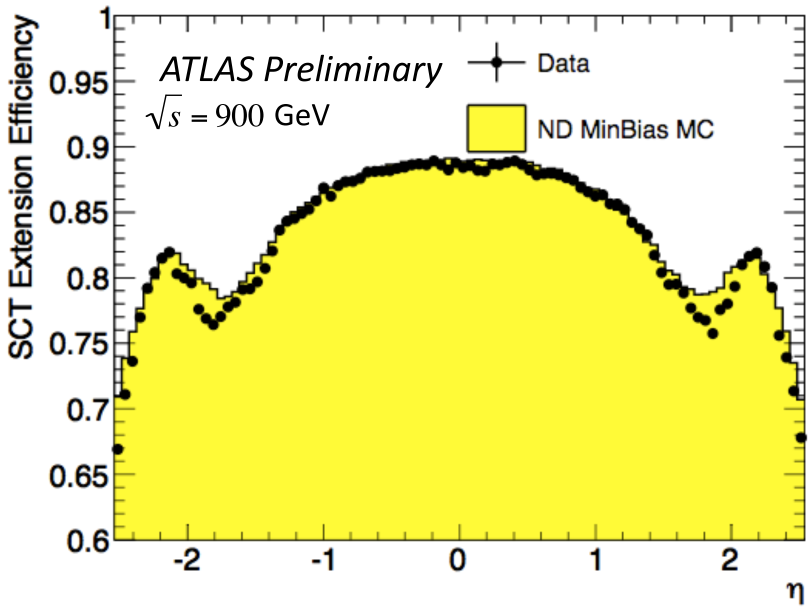
- Measured from data:
  - L1 MBTS selected events.
  - Selected tracks, but dropping
    - $|d_0^{PV}| < 1.5$mm
    - $|z_0^{PV} \sin(\theta^{PV})| < 1.5$mm
  - Require $|d_0^{BS}| < 4$mm
    - Impact parameter with respect to beam spot (BS)
- Tiny systematic from beam background.

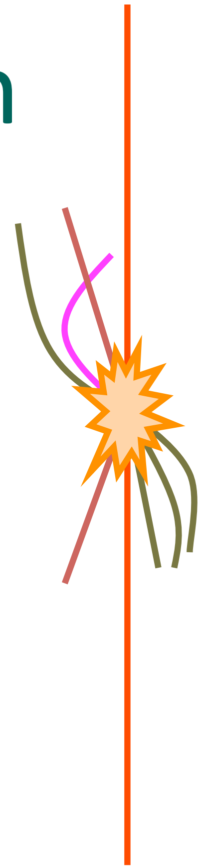
No effect on p_T spectrum within statistical uncertainties.
Shaping of η for $n_{Sel} = 1$ corrected for.

Validating Inner Detector Simulation



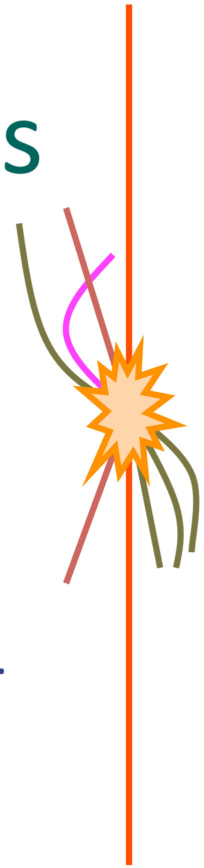




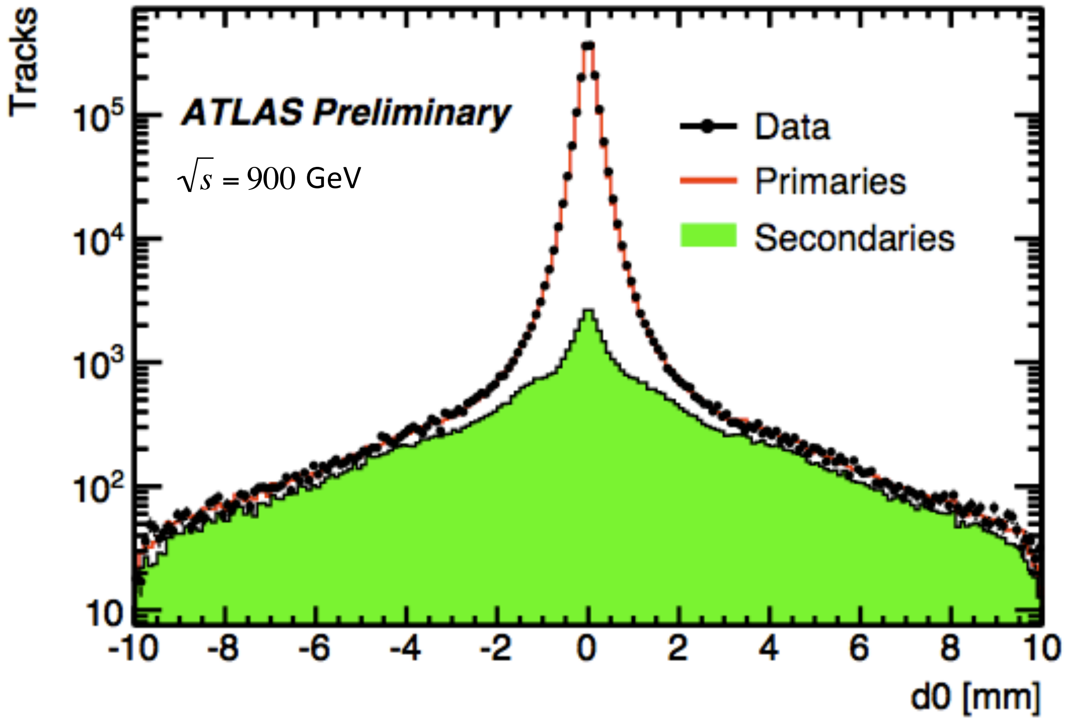


Detailed study of material, alignment, and resolution.

Particles from Secondary Interactions



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

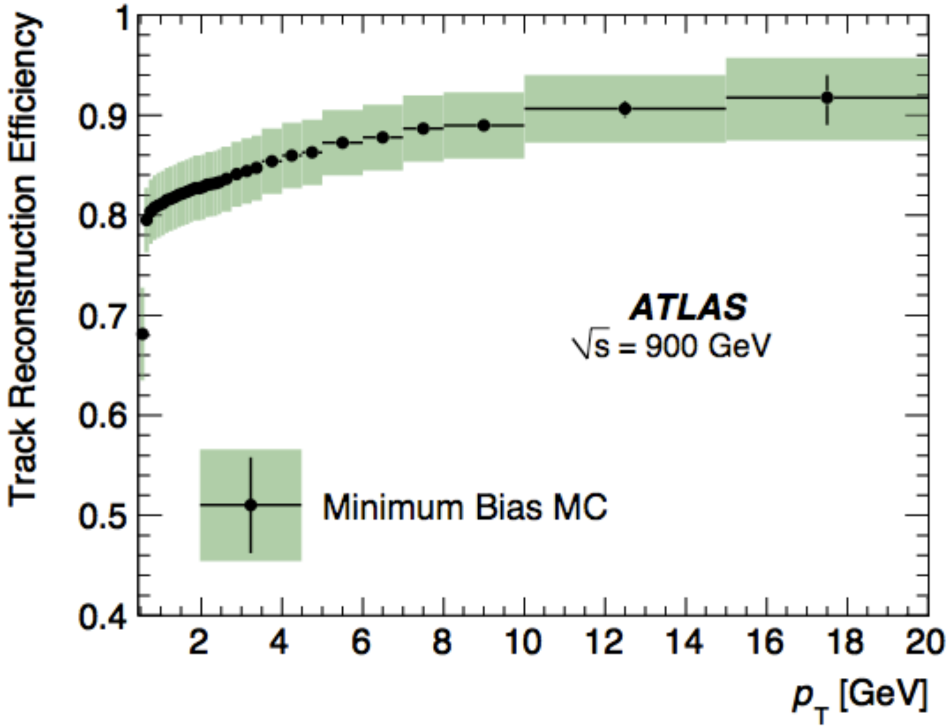


Compare Monte Carlo and data.

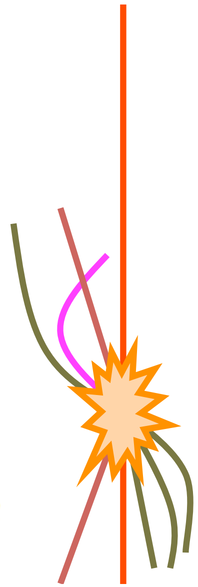
Fit Monte Carlo to data within
2.0 mm < $|d_0^{PV}|$ < 10 mm

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

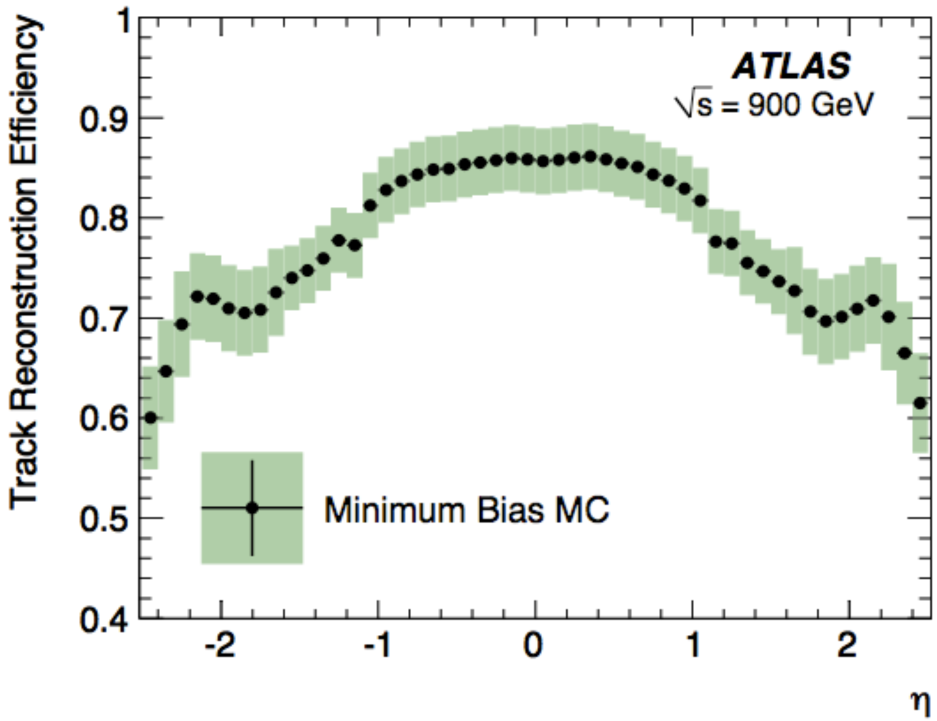
Selected Tracking Efficiency



Best match between track and MC



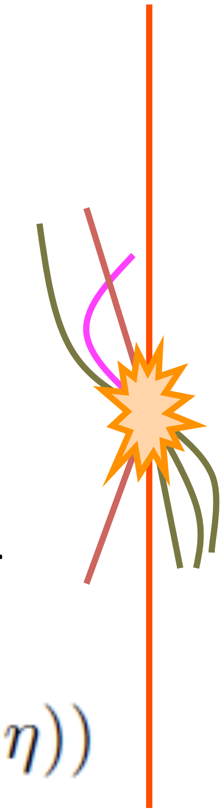
$$\epsilon_{\rm bin}(p_{\rm T},\eta) = \frac{N_{\rm rec}^{\rm matched}(p_{\rm T},\eta)}{N_{\rm gen}(p_{\rm T},\eta)}$$



Global systematic dominated by conservative material estimate.

Higher systematic error in regions with more material

Correction Procedure



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

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

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

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

p_T resolution effect

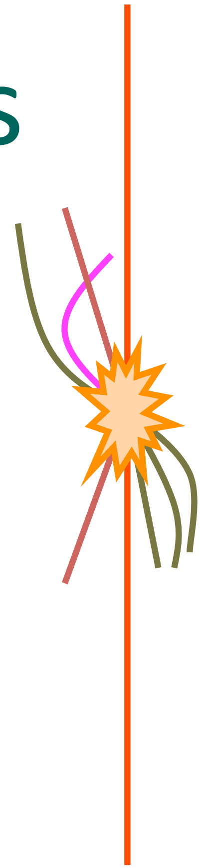
- Correct n_{sel} to n_{ch} using $M_{ch,sel}$
  - Filled from MC, applied, refilled, converges after 4 iterations.
- Correct for events with n_{sel} = 0 and n_{ch} > 0 using:

$$1/(1-(1-\epsilon(n_{\rm ch}))^{n_{\rm ch}})$$

Mean track reconstruction efficiency

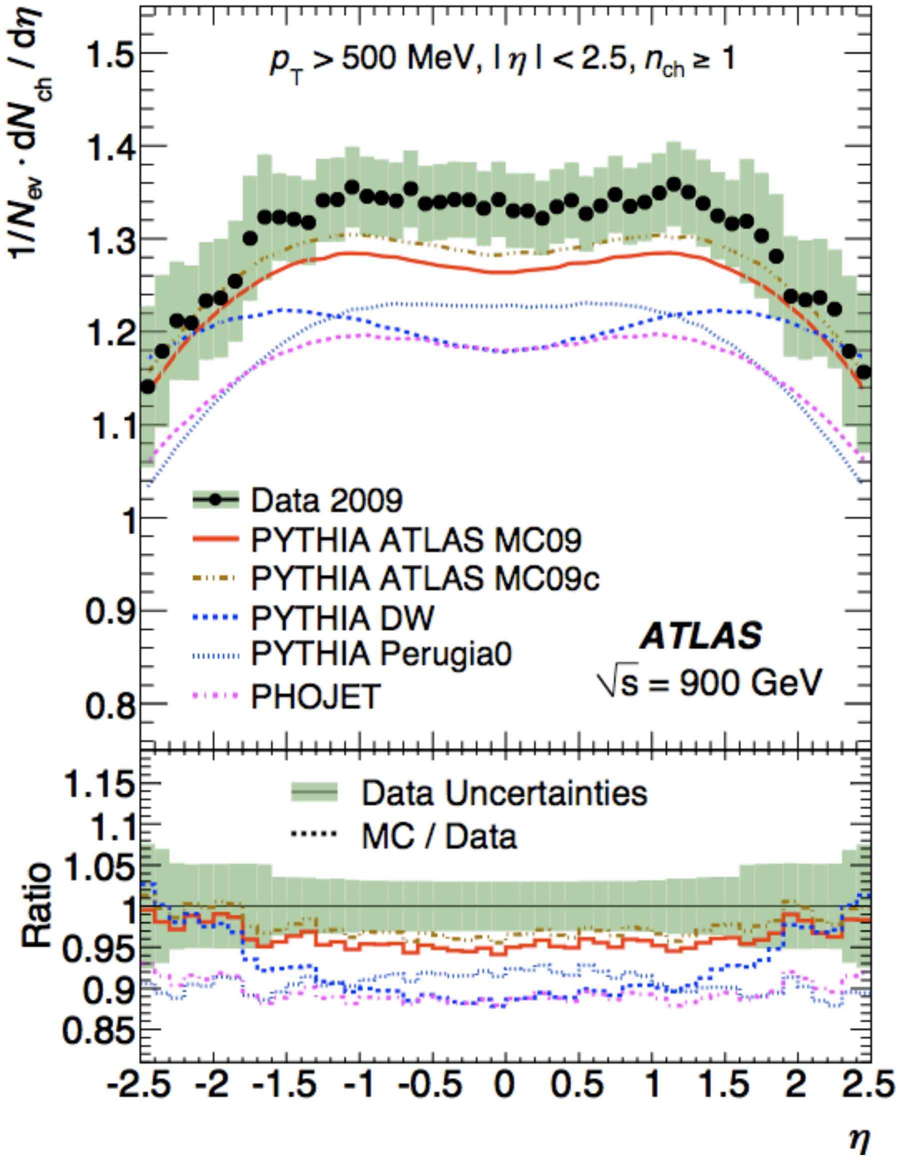
Table of Systematic Uncertainties

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 $(1/N_{ev})\cdot(dN_{ch}/d\eta)$ at $\eta = 0$	
Track-reconstruction efficiency	4.0%
Trigger and vertex efficiency	$< 0.1\%$
Secondary fraction	0.1%
Total uncertainty on N_{ev}	-1.2%
Total uncertainty on $(1/N_{ev})\cdot(dN_{ch}/d\eta)$ at $\eta = 0$	2.8%

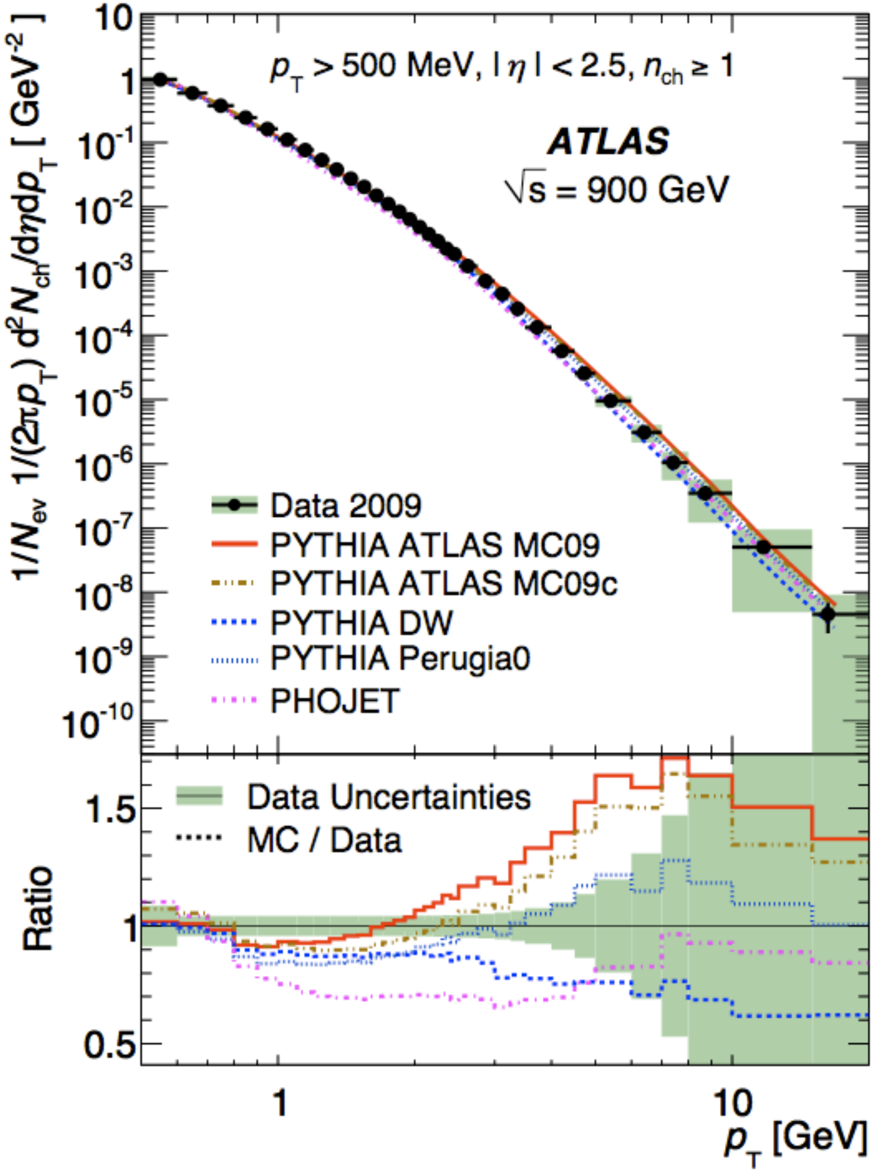


N_{ev} defined for $n_{ch} \geq 1$, N_{ev} uncertainty therefore anti-correlated with track-reconstruction

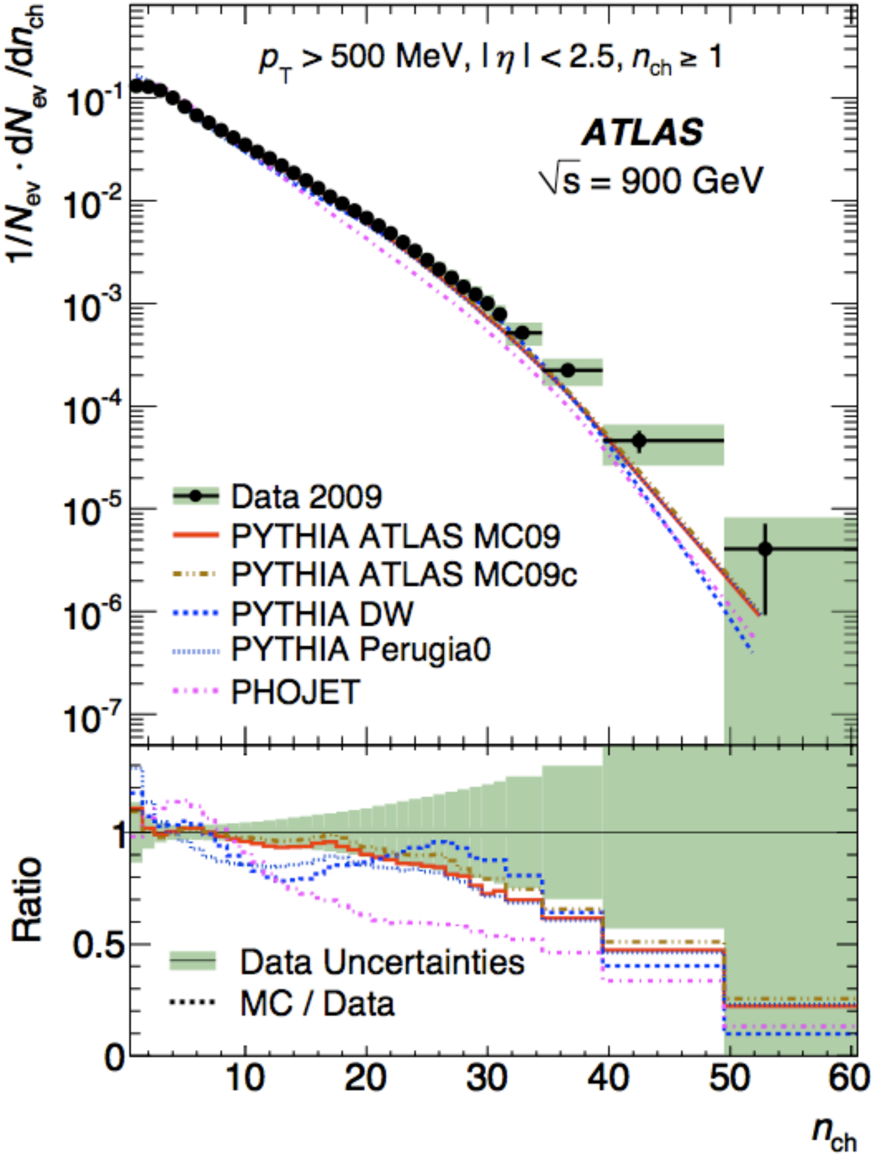
$dN_{ch}/d\eta$



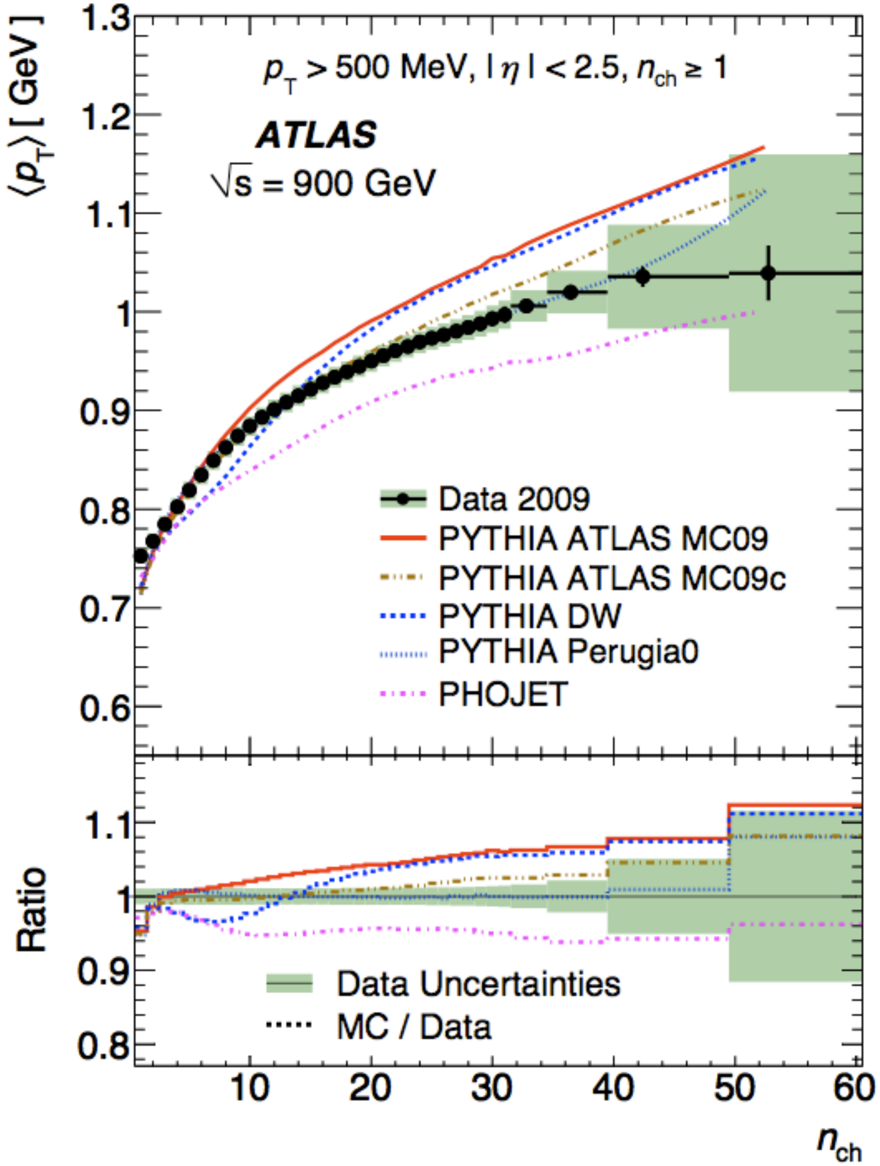
$1/p_T \, dN_{ch}/dp_T$



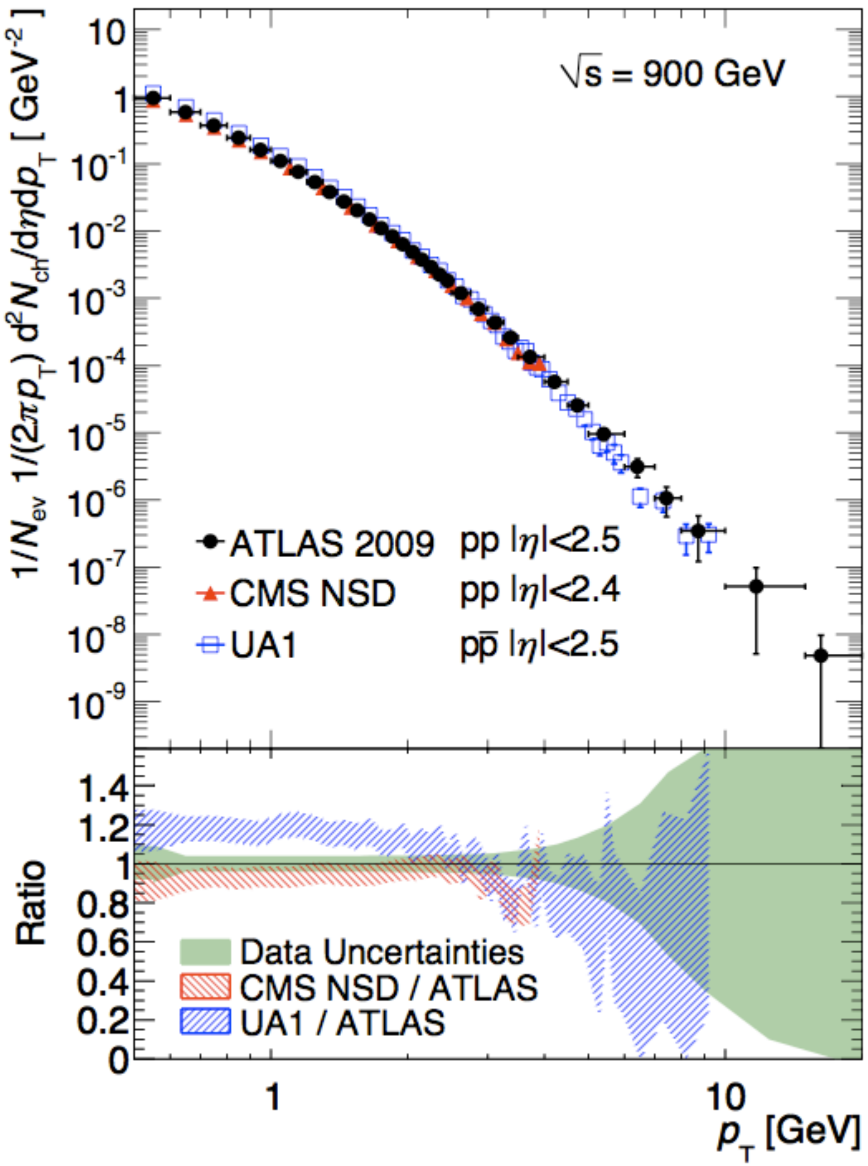
dN_{ev}/dn_{ch}



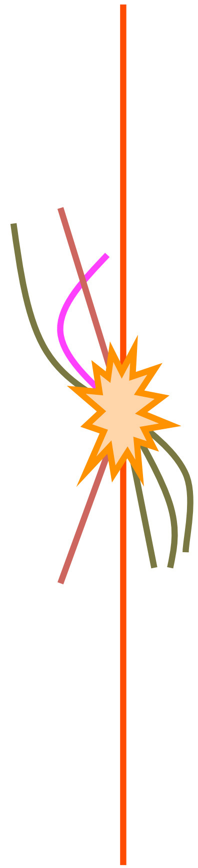
$<p_T>$ vs n_{ch}



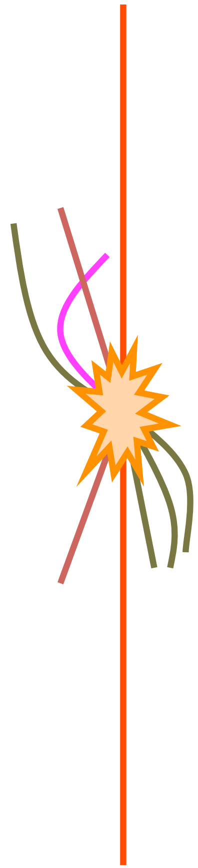
Comparison: $1/p_T\, dN_{ch}/dp_T$



- 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.



Conclusions



- Charged particle multiplicities were studied from 300k interactions of pp at $\sqrt{s}$=900GeV within
  - $|\eta|<2.5$ and $p_T > 500$MeV
  - $n_{ch} \geq 1$ ($|\eta|<2.5$ and $p_T > 500$MeV)
- Data were fully corrected with minimal dependence.

- The charged-particle multiplicity per event and unit of pseudorapidity at η=0 is measured to be 1.333±0.003(stat.)±0.040(syst.).
  - 5-15% higher than Monte Carlo models.
- Selected kinematic range and precision highlight clear differences between MC models and data.