Studies of particle production in inelastic pp events with the ATLAS detector

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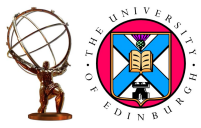
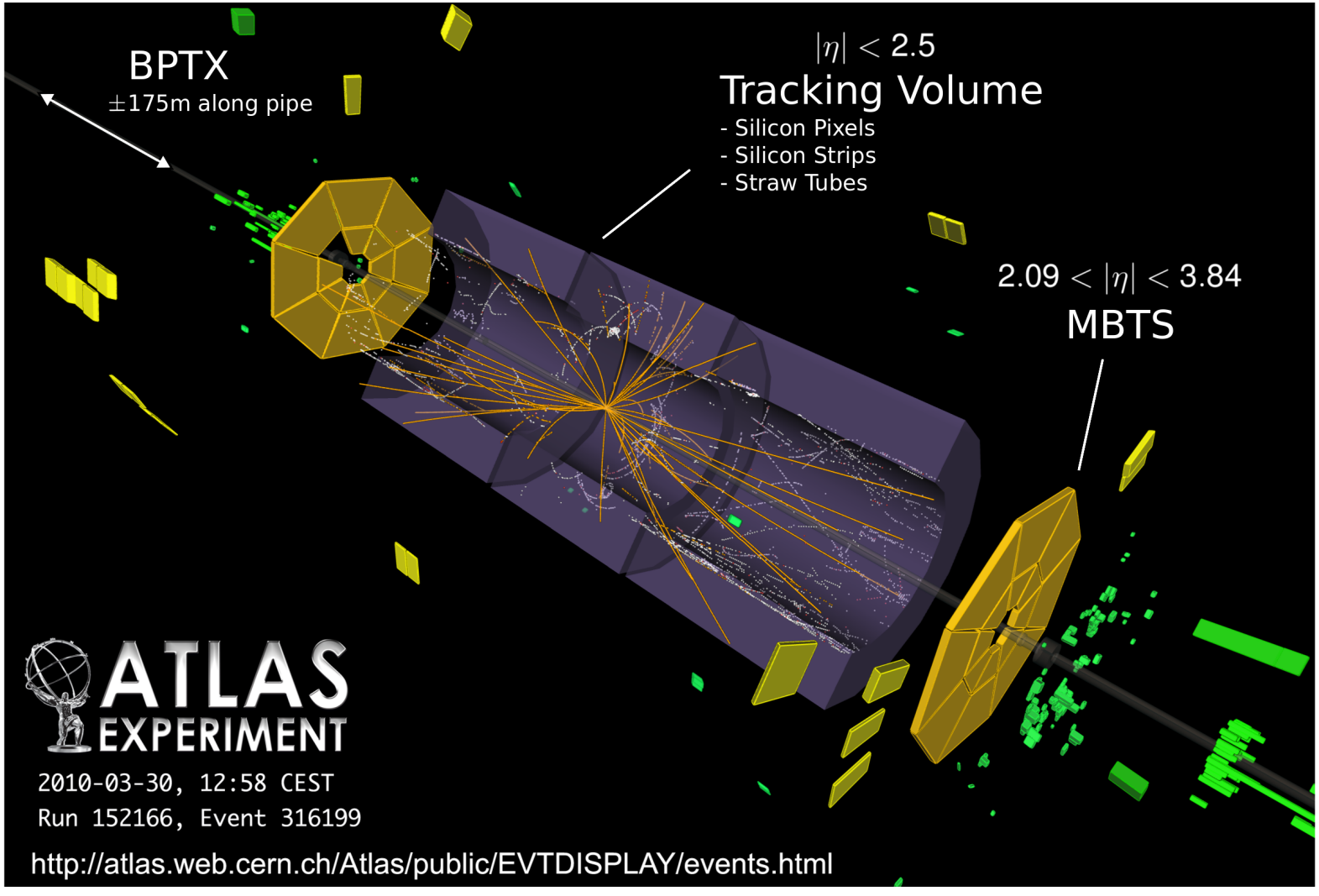
Introduction

Presenting some early measurements made as a test of the detector performance - tracking in particular - and as a test of the Monte Carlo models used to simulate collisions

Outline

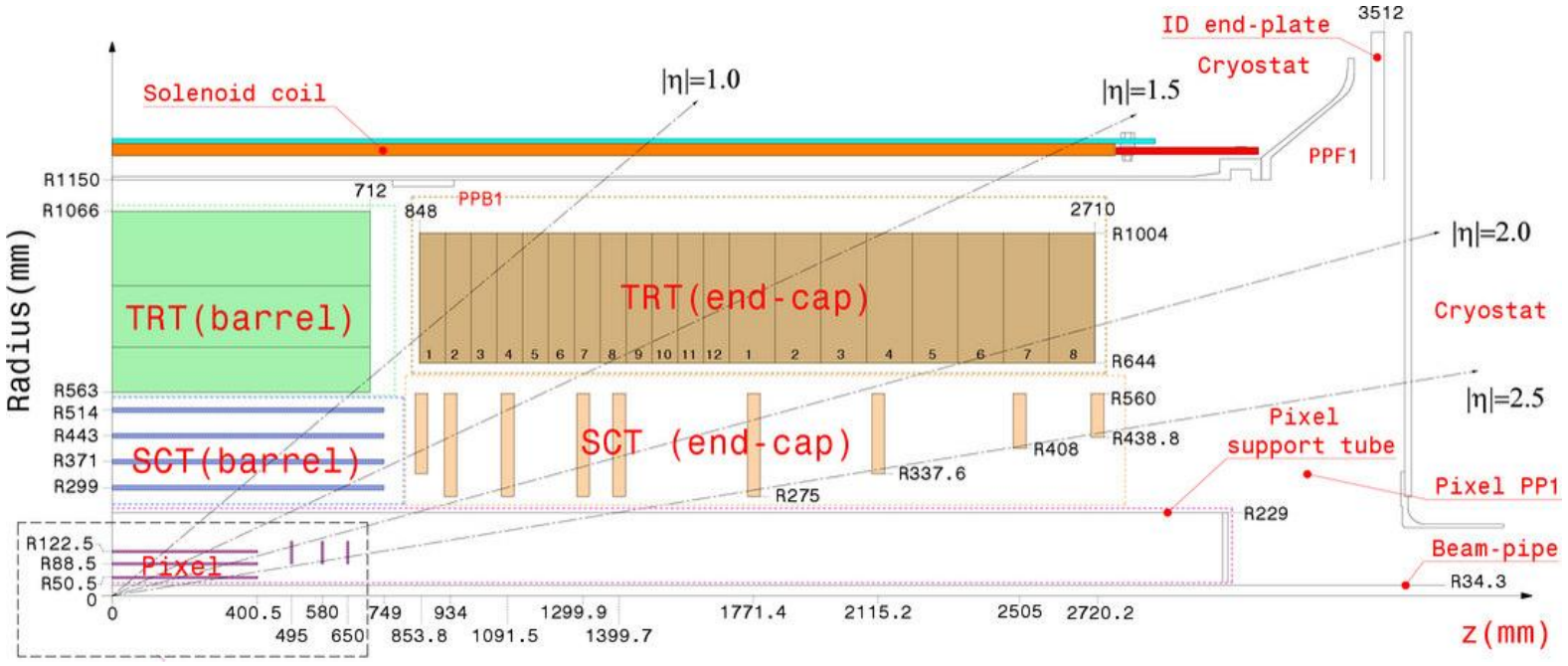


Tracking and Triggering



The Minimum Bias trigger requires BPTX and either of the MBTS

Tracking



For the low $|\eta|$ region:

- 3 layers of silicon pixels, resolution 10 by 115 μm
- 4 double layers of single-sided silicon strips, 17 by 580 μm
- 73 layers of straws, r-ϕ resolution 130 μm

All within a 2T magnetic field

Outline

Event Selection

Primary vertex quality cut

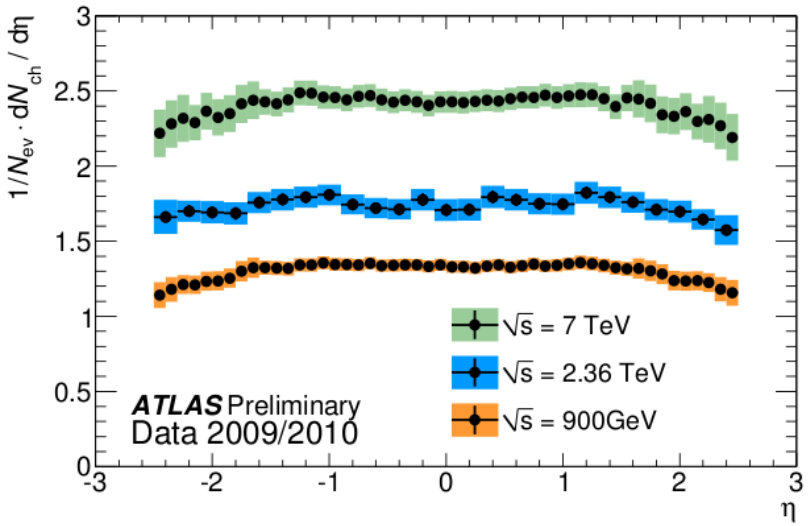
- Three tracks with $p_T > 150$ MeV
- Transverse closest approach to the beam spot < 4 mm
- Reject the event if there is a second primary vertex with ≥ 4 tracks

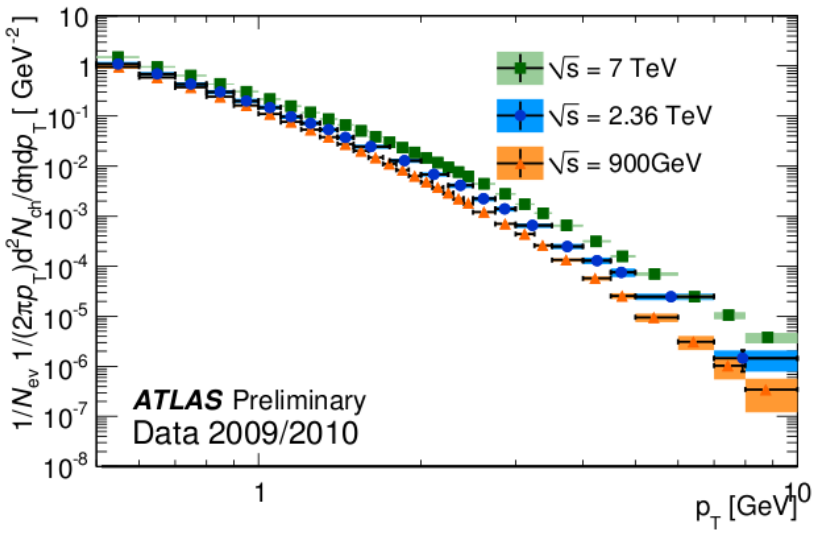
Track quality cut

- Track $p_T > 500$ MeV
- At least 1 pixel hit and 6 strip hits
- Track must come within 1.5 mm (trans and long) of the primary vertex

Measurements at different $\sqrt{s}$

Charged particle density vs:





Pseudorapidity (η)

Transverse momentum (p_T)

Coloured regions are combined statistical and systematic errors

Tuning with ATLAS Data

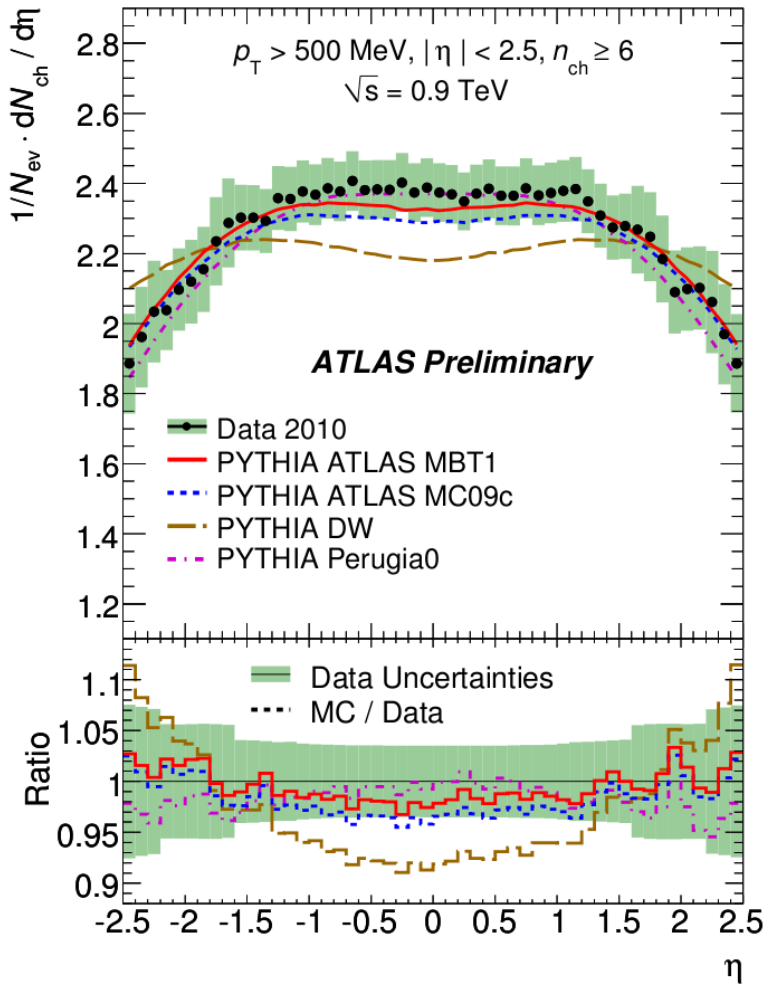
ATLAS Minimum Bias Tune 1 (AMBT1) has been made using the $\sqrt{s} = 900$ MeV and 7 TeV data

- Also tuned to the underlying event distributions (previous talk by Claus)
- Included CDF and D0 results as well to keep compatibility

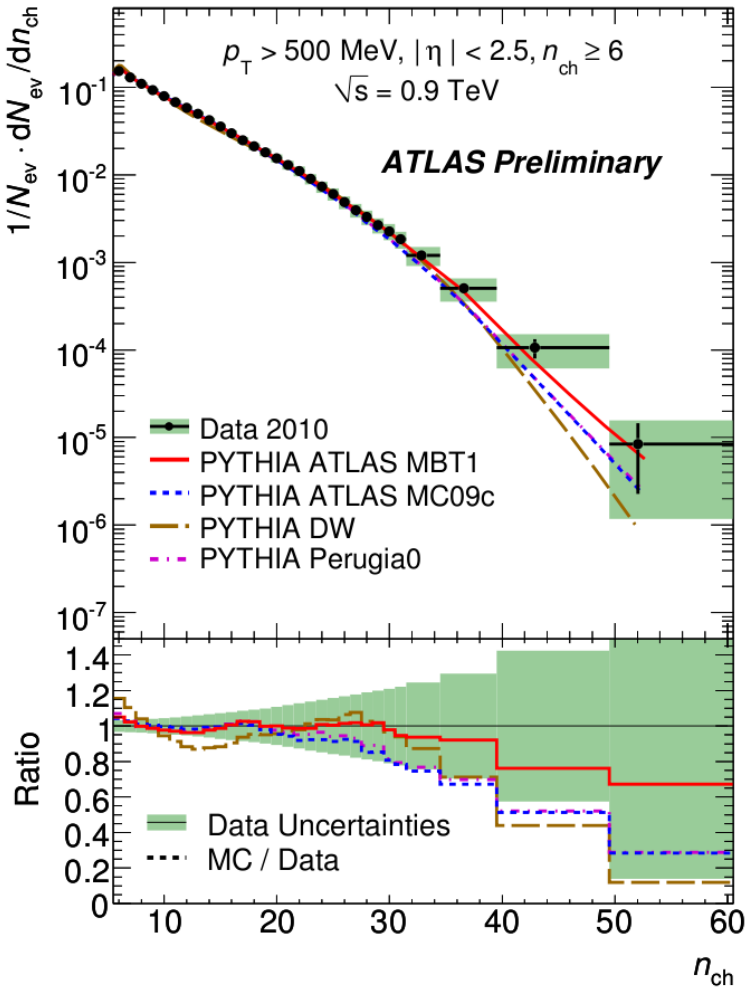
No extrapolation: results from a well-defined phase space

- $|\eta| < 2.5$: the extent of the ATLAS tracking volume
- $p_T > 500$ MeV for track quality
- Require more than 6 charged tracks per event to remove diffractive contributions

Comparisons with MC at $\sqrt{s} = 900$ GeV

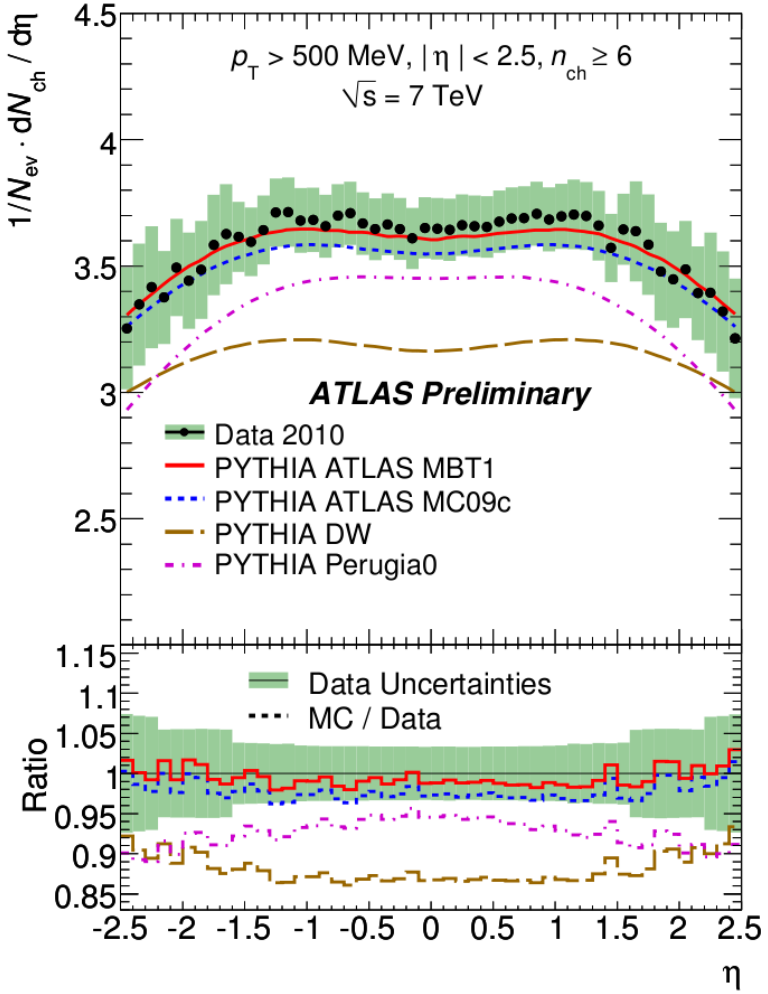


Charged particle density vs η

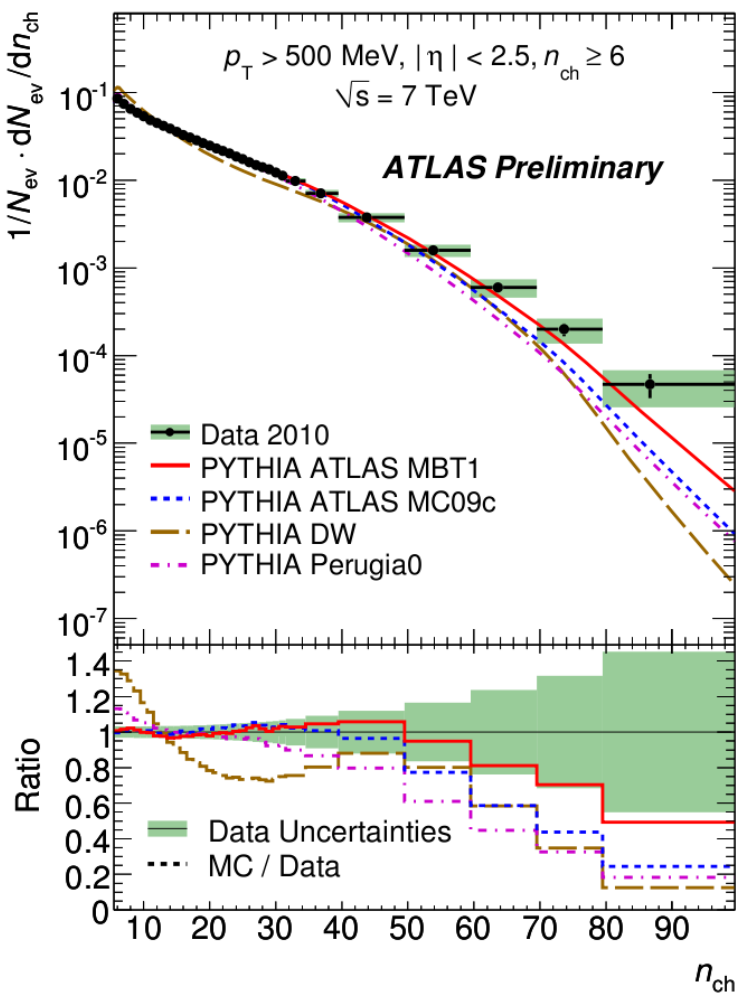


Charged particle multiplicity

Comparisons with MC at $\sqrt{s} = 7$ TeV



Charged particle density vs η



Charged particle multiplicity

AMBT1 Tuning

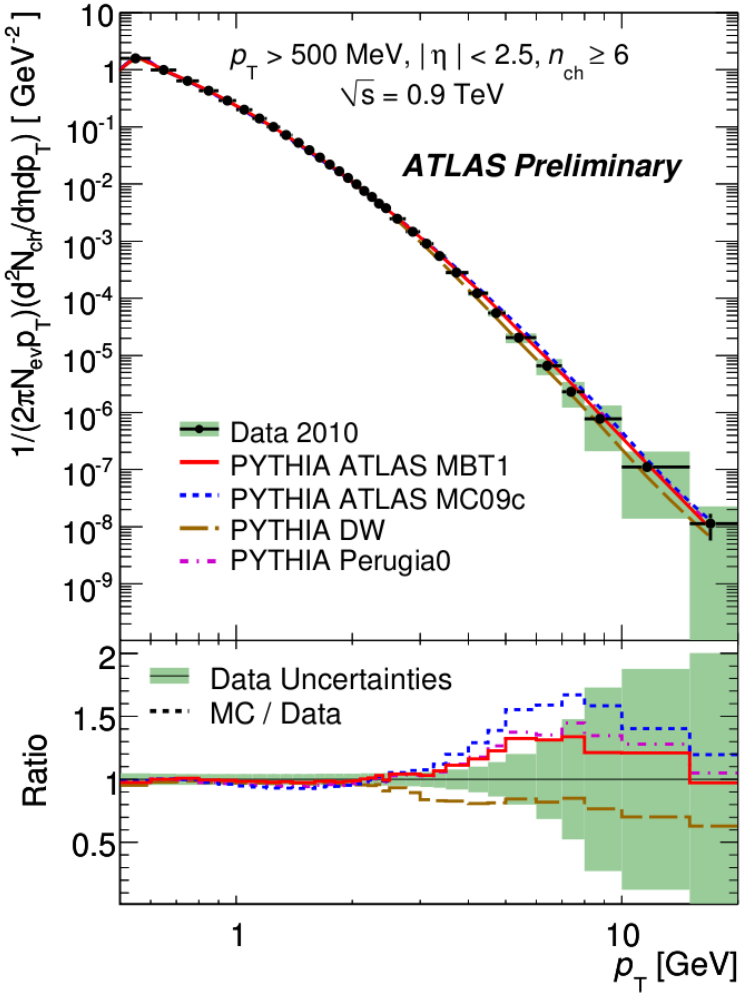
The low p_T cut-off for MPI was reduced by the tune, meaning the diverging cross-section has greater effect and more particles are produced

	MC09c	AMBT1
PARP(82)	2.31	2.292

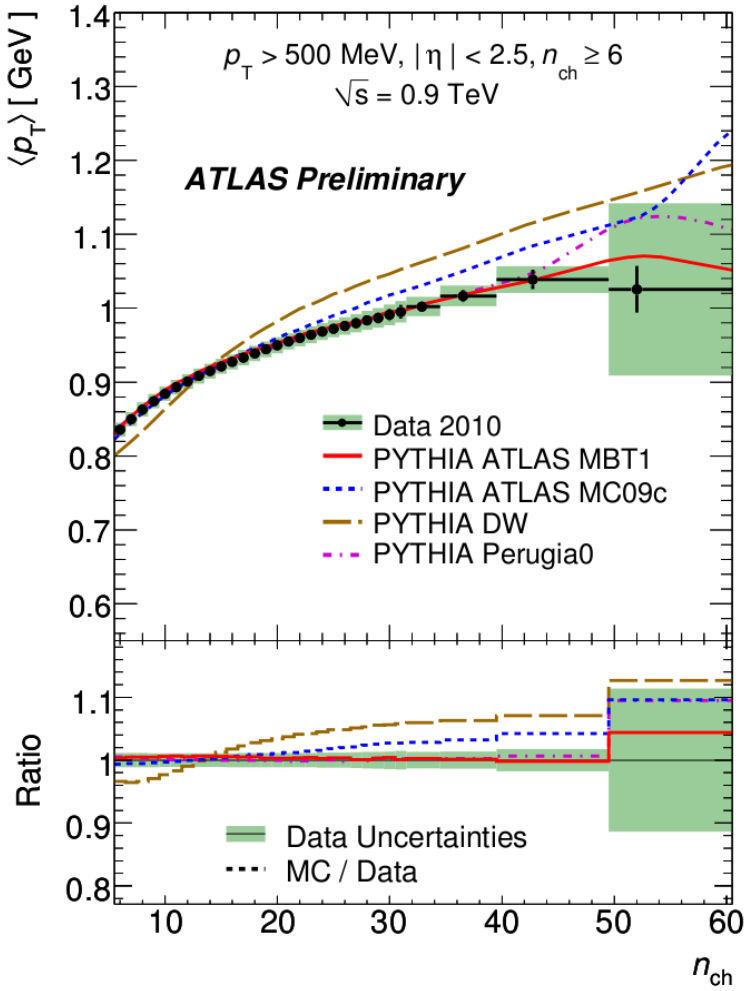
PARP(90) governing energy extrapolation was tuned but did not change, suggesting this part of the model is well-motivated by physics consistent across Tevatron and LHC data

Also some changes in the parameters describing the proton hadronic matter distribution

Comparisons with MC at $\sqrt{s} = 900$ GeV

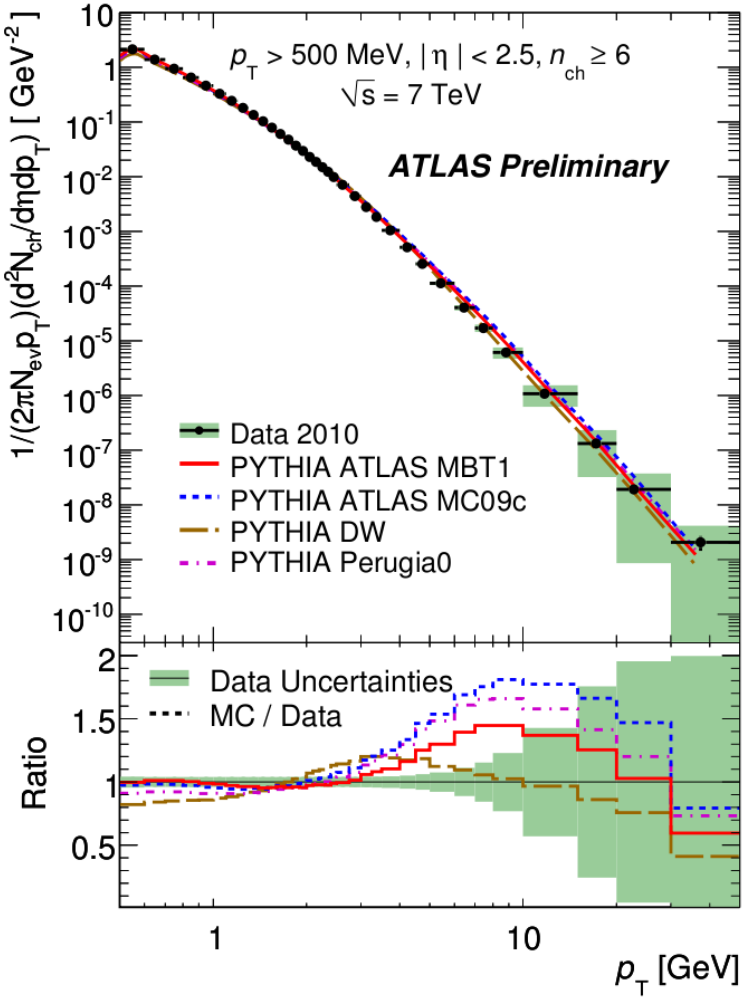


Charged particle density vs p_T

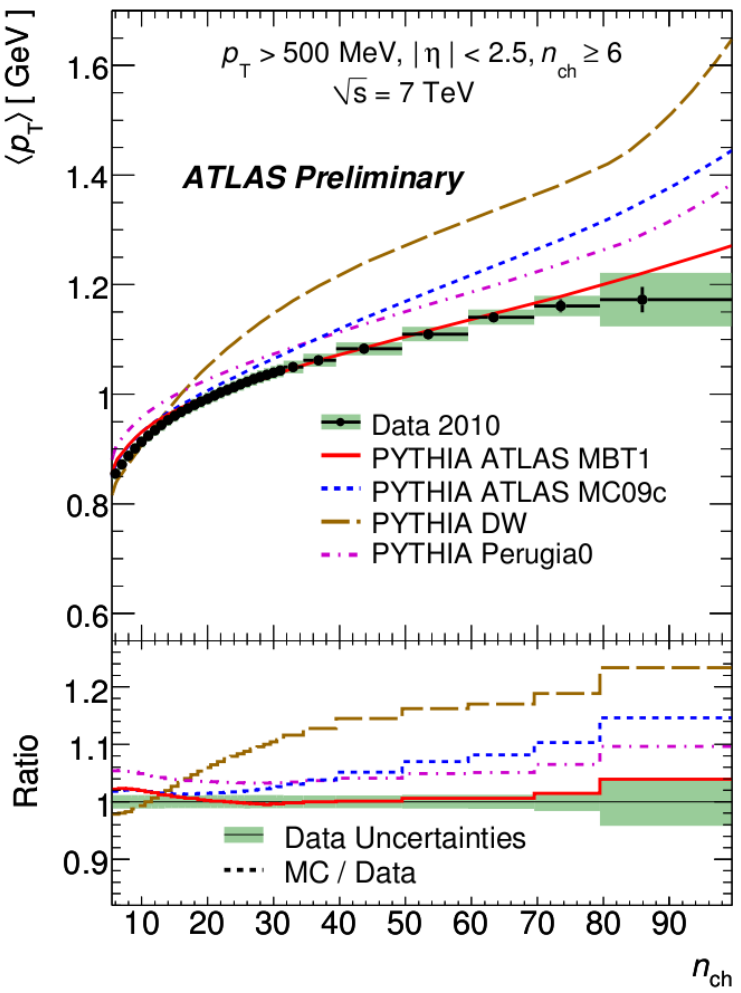


Mean p_T vs charged particle number

Comparisons with MC at $\sqrt{s} = 7$ TeV



Charged particle density vs p_T



Mean p_T vs charged particle number

AMBT1 Tuning

Two parameters relating to colour reconnection (CR) were tuned, resulting in a softer p_T spectrum

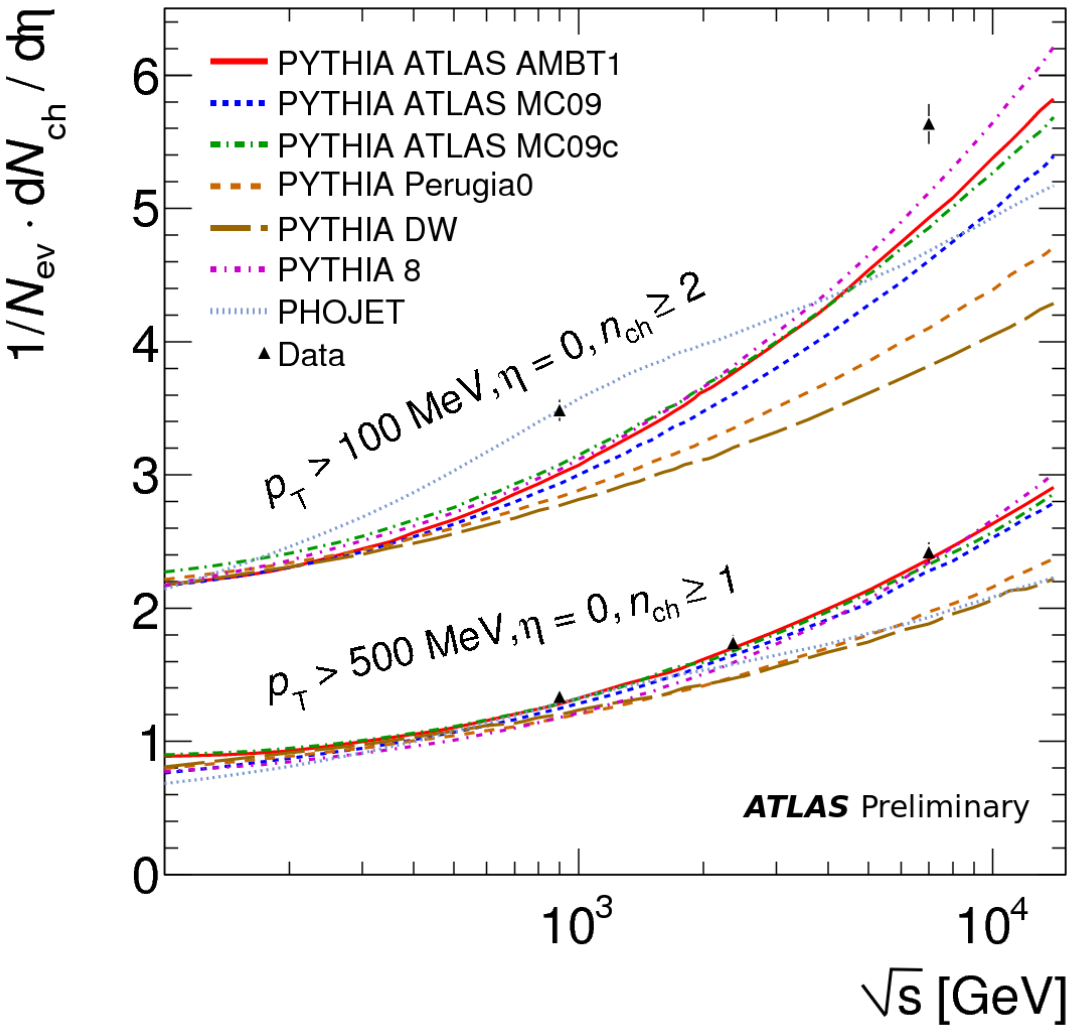
	MC09c	AMBT1
PARP(77)	0.0	1.016
PARP(78)	0.224	0.538

PARP(77) suppresses CR for high momentum hadrons

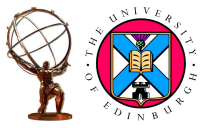
PARP(78) indicates the strength of CR

Still work to do!

From the minimum bias analysis using 100 MeV tracks:



Outline



Decays

K_s^0 mesons

- Decay to $\pi^+\pi^-$ with branching ratio 69%
- Proper flight length 2.7 cm

Λ^0 baryons

- Decay to $\mathrm{p}\pi^-$ with branching ratio 63%
- Proper flight length 7.9 cm

$\overline{\Lambda^0}$ bayons decay to $\overline{\mathrm{p}}\pi^+$

Event Selection

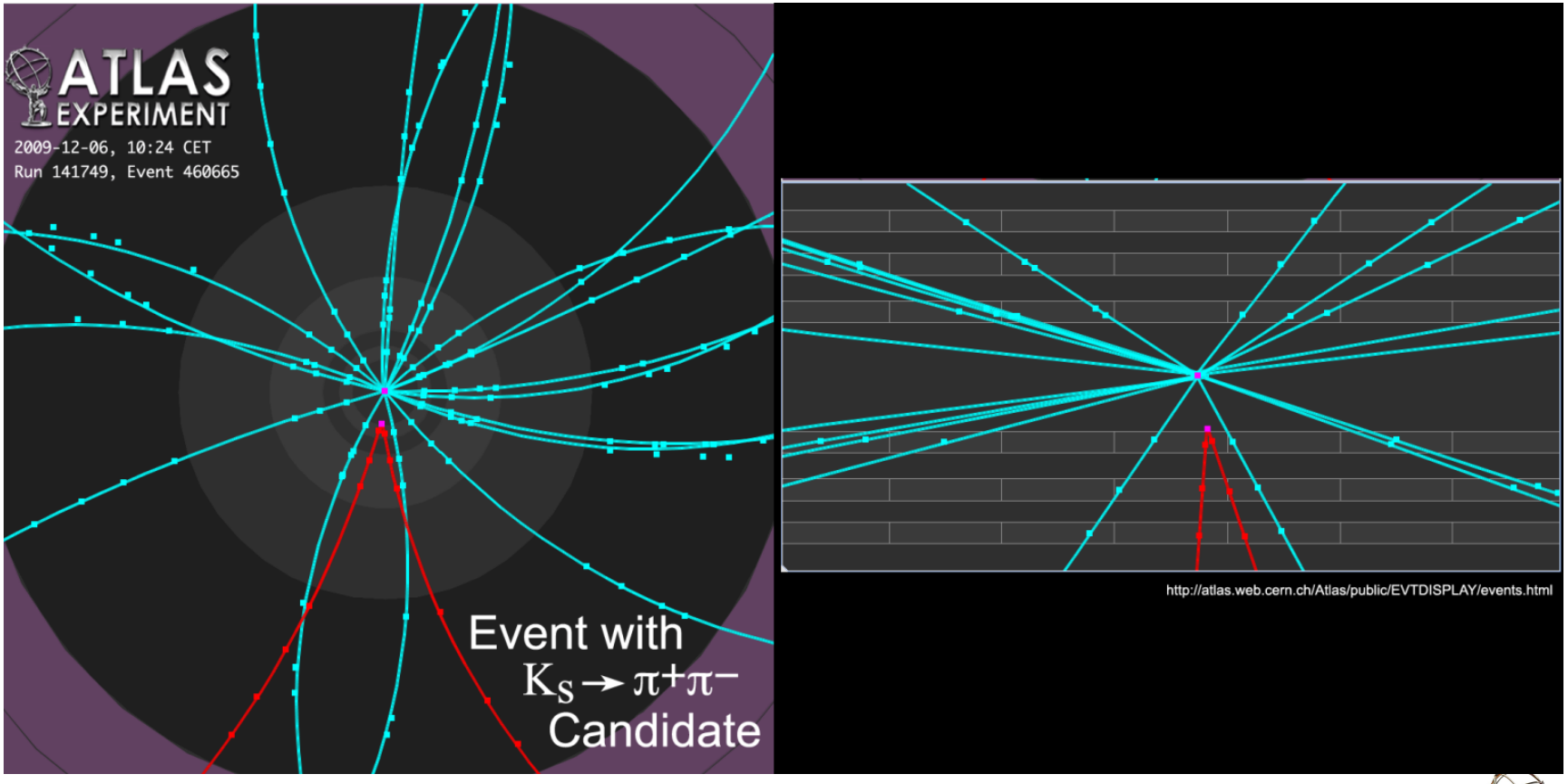
Look for a secondary vertex formed by two oppositely charged tracks

- Require vertex fit $\chi^2 < 15$
- Both tracks must have $p_T > 100$ MeV and ≥ 2 silicon hits

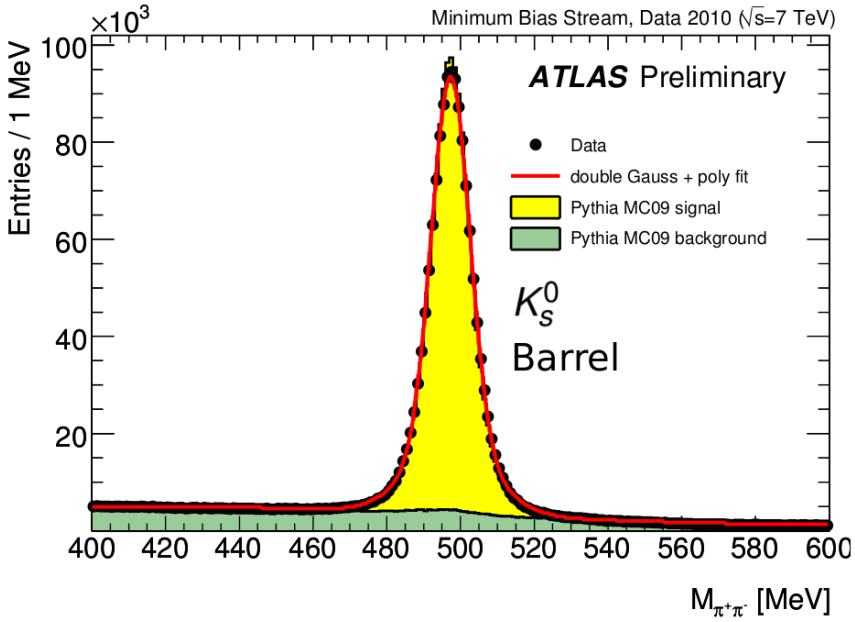
Particle	Flight Length	$\cos\theta_K$
K^0_s	> 4 mm (transverse)	> 0.999
Λ^0	> 30 mm (3D)	> 0.9998

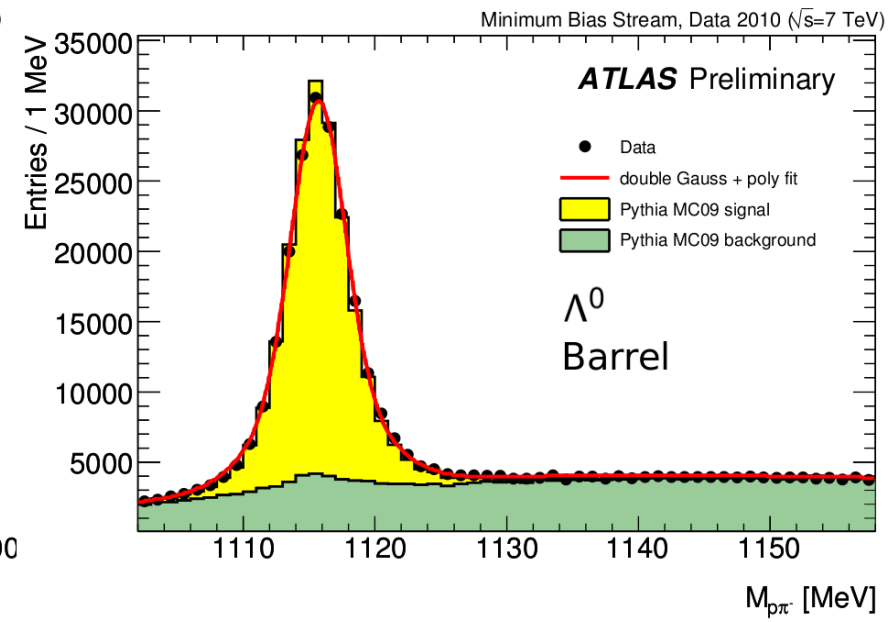
Where θ_K is the angle between the flight direction and the momentum

Example Event



Measured Masses



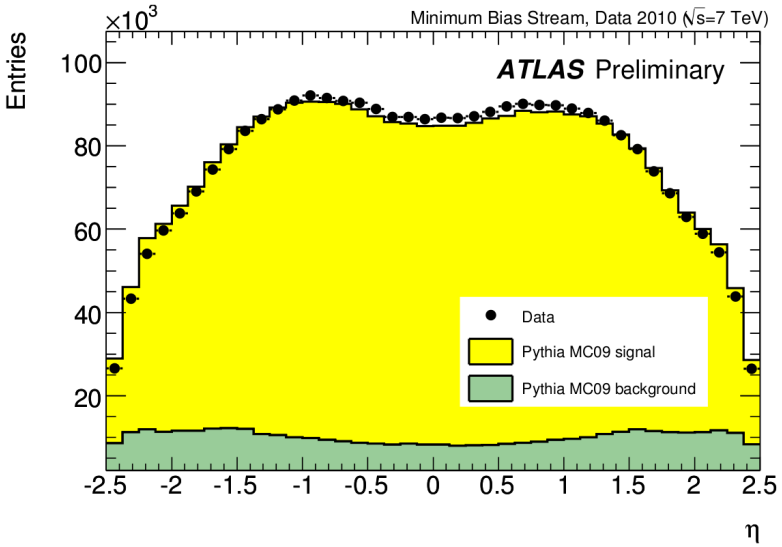


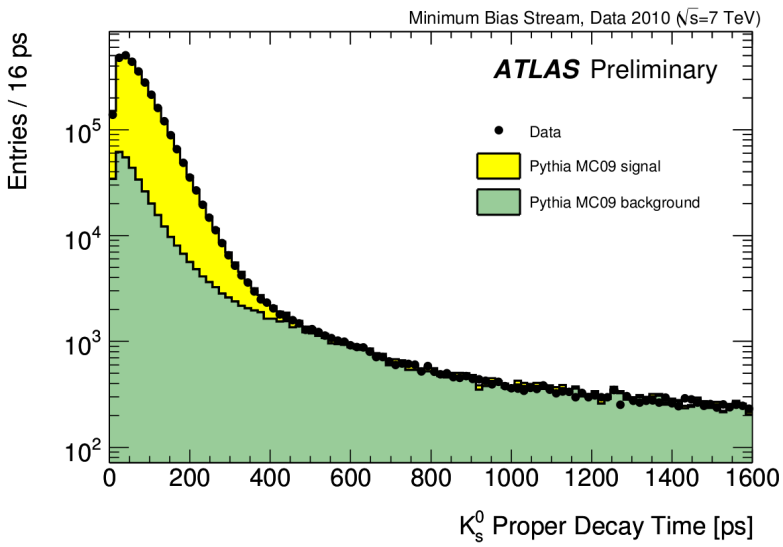
Particle	Barrel ($\lvert\eta\rvert < 1.2$) Mean	Width	Endcaps ($1.2 < \lvert\eta\rvert < 2.5$) Mean	Width	PDG
K^0_s	497.427 ± 0.006	5.60	497.797 ± 0.016	10.45	497.614 ± 0.024
Λ^0	1115.73 ± 0.01	2.28	1115.78 ± 0.02	3.84	1115.683 ± 0.006
$\overline{\Lambda^0}$	1115.79 ± 0.01	2.32	1115.79 ± 0.02	3.87	1115.683 ± 0.006

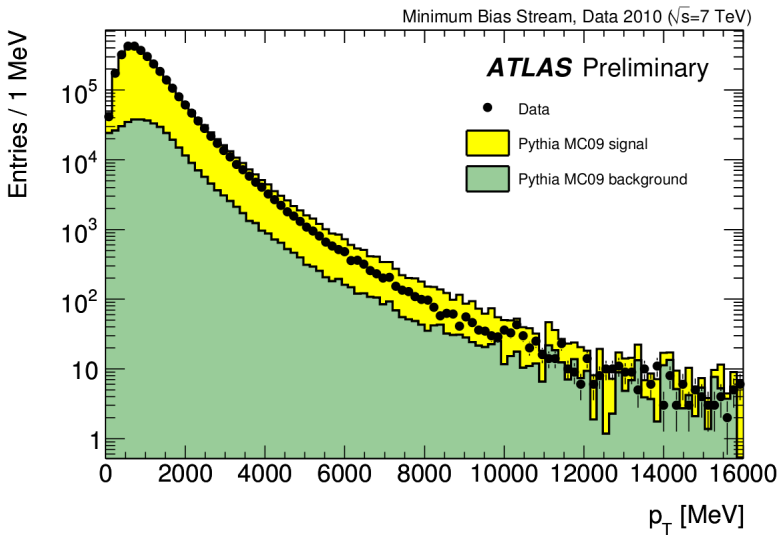
"Width" is full width half maximum / 2.35 - resolution, not decay width

All units MeV

K_s Kinematic Distributions

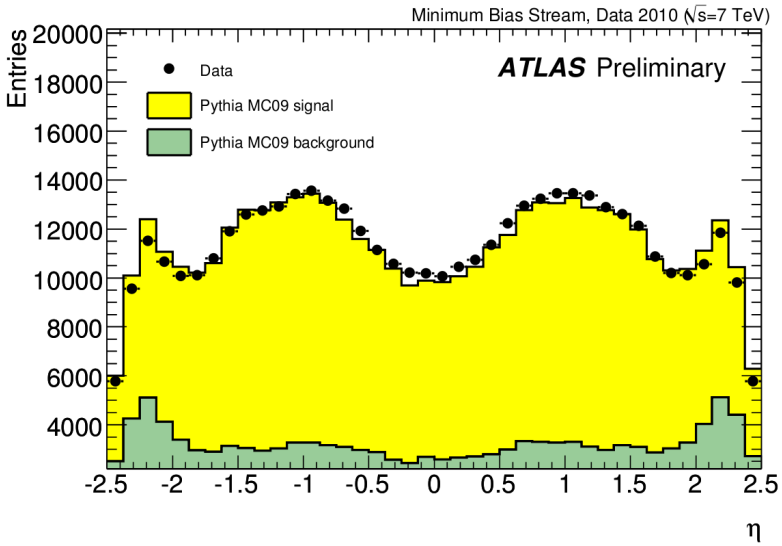


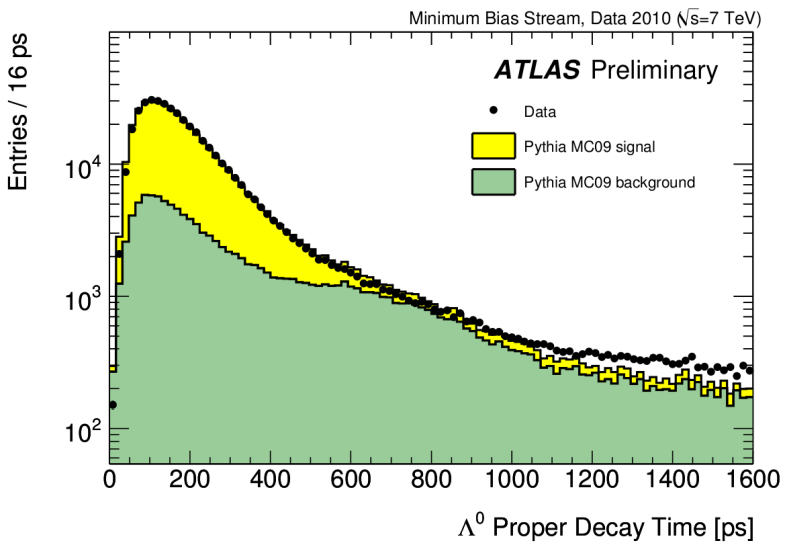


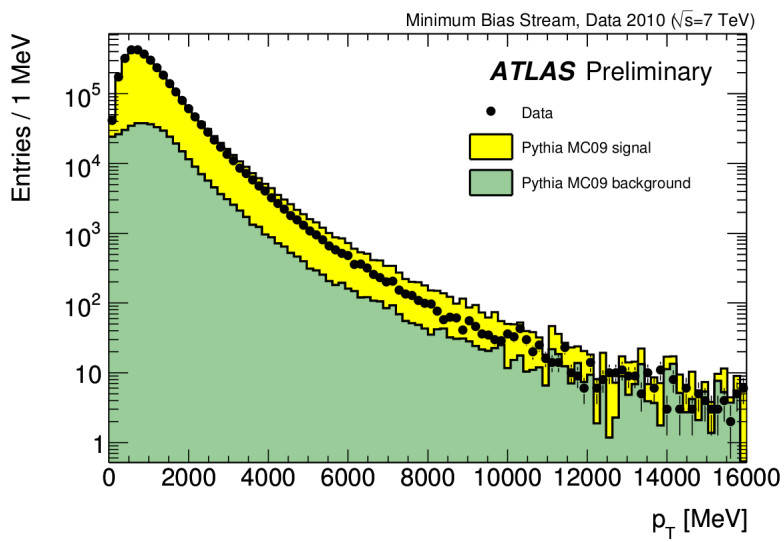


- Using events with $|M_{data} - M_{PDG}| < 20$ MeV
- Signal to background ratio adjusted in MC to match data

Λ^0 Kinematic Distributions

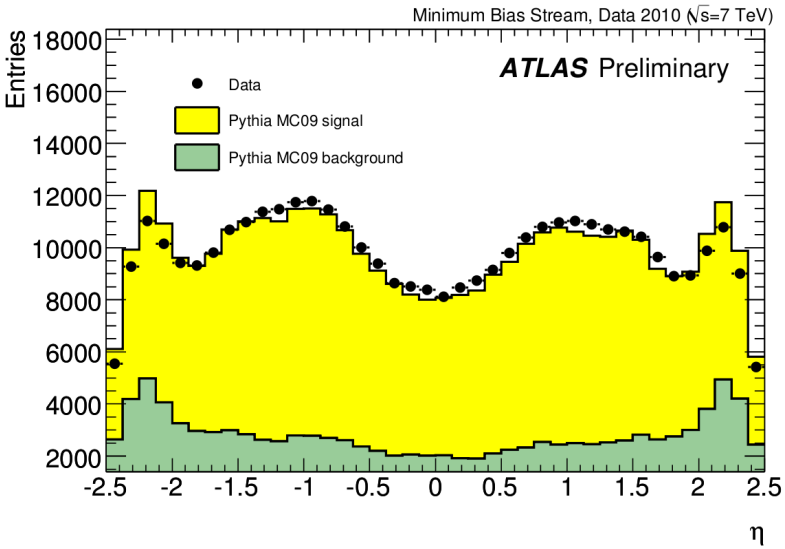


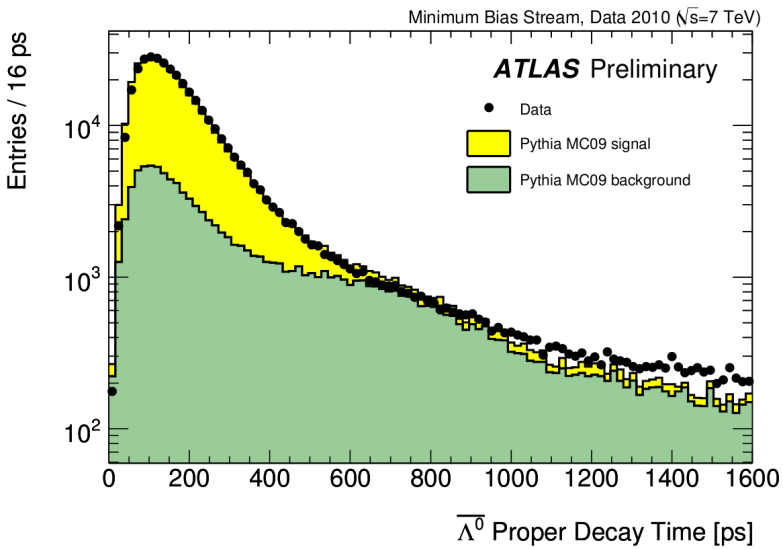


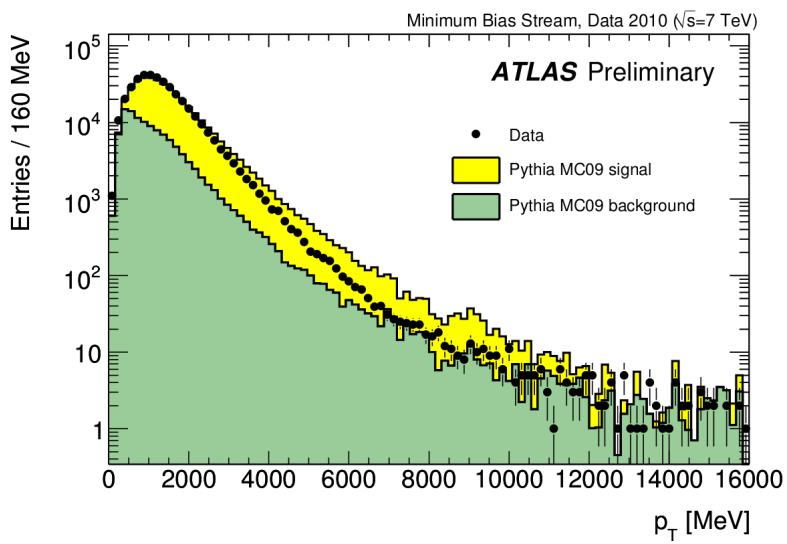


- Using events with $|M_{data} - M_{PDG}| < 7$ MeV
- Signal to background ratio adjusted in MC to match data

$\overline{\Lambda^0}$ Kinematic Distributions







- Using events with $|M_{data} - M_{PDG}| < 7$ MeV
- Signal to background ratio adjusted in MC to match data

Summary

Minimum bias:

- The minimum bias distributions have been measured at $\sqrt{s} = 0.9$, 2.36 and 7 TeV
- Greater density of charged particles than predicted by previous MC tunes, AMBT1 gives better agreement

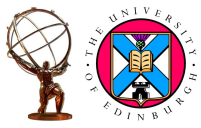
K_s^0 and Λ^0 reconstruction:

- Measured masses consistent with PDG values
- MC consistent with data except for tails of p_T distributions
- Physics production measurement in progress

Thanks to...

Emily Nurse, Jed Biesiada and Andy Buckley for their help with this talk

Everyone who worked on these analyses!



Further Reading

Charged particle multiplicities in pp interactions at $\sqrt{s} = 0.9$ and 7 TeV in a diffractive limited phase space measured with the ATLAS detector at the LHC and a new Pythia6 tune
ATLAS-CONF-2010-031

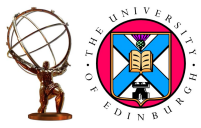
Kinematic Distributions of K_s^0 and Λ_0 decays in collision data at $\sqrt{s} = 7$ TeV
ATLAS-CONF-2010-033

Charged particle multiplicities in pp interactions for track $p_T > 100$ MeV at i$\sqrt{s} = 0.9$ and 7 TeV measured with the ATLAS detector at the LHC
ATLAS-CONF-2010-046

Charged particle multiplicities in pp interactions at $\sqrt{s} = 2.36$ TeV measured with the ATLAS detector at the LHC

ATLAS-CONF-2010-047

BACKUP



AMBT1 Details

Parameter	Related model	MC09c value	Tuning range	AMBT1 value
PARP(62)	ISR cut-off	1.0	fixed	1.025
PARP(93)	Primordial kt	5.0	fixed	10.0
PARP(77)	CR suppression	0.0	0.25 - 1.15	1.016
PARP(78)	CR strength	0.224	0.2 - 0.6	0.538
PARP(83)	MPI (matter fraction in core)	0.8	fixed	0.356
PARP(84)	MPI (core of matter overlap)	0.7	0.0 - 1.0	0.651
PARP(82)	MPI (p_T^{min})	2.31	2.1 - 2.5	2.292
PARP(90)	MPI (energy extrapolation)	0.2487	0.18 - 0.28	2.50

100 MeV selections

Primary vertex quality cut

- Two tracks with $p_T > 100$ MeV + beam spot constraint
- Track trans and long errors < 5 and < 10 mm respectively
- Track transverse closest approach to the beam spot < 4 mm
- Tracks with ≥ 1 pixel, ≥ 4 strip and ≥ 6 total hits
- Reject the event if there is a second primary vertex with ≥ 4 tracks

Track quality cut

- Track $p_T > 100$ MeV
- At least 1 pixel hit
- 2, 4 or 6 strip hits for $p_T > 100$, 200 or 300 MeV
- Track must come within 1.5 mm (trans and long) of the primary vertex
- $\chi^2 < 0.01$ if $p_T > 10$ GeV to remove mis-measured tracks