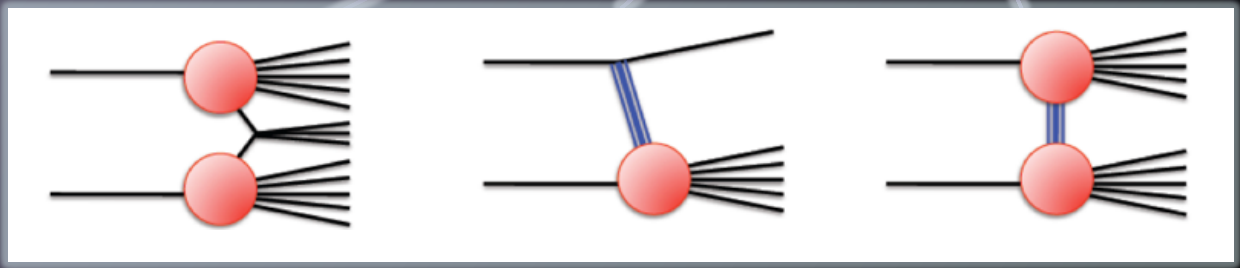
CHARGED PARTICLE MULTIPLICITIES IN INELASTIC PP EVENTS WITH THE ATLAS DETECTOR @ 0.9, 2.36 AND 7 TEV

Alison Lister
Université de Genève
On behalf of the ATLAS Collaboration

What? Why?

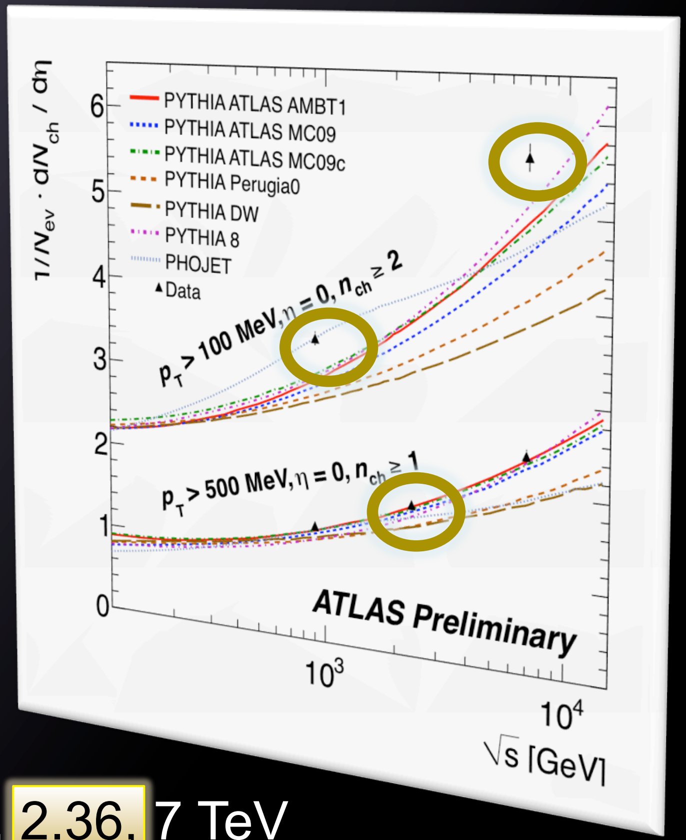
$$\sigma_{tot} = \sigma_{el} + \sigma_{ND} + \sigma_{SD} + \sigma_{DD}$$



- Improving our understanding of non-perturbative soft QCD processes
- Improving Monte Carlo models
  - Tuning of non-diffractive (ND) important for high p_T physics
    - Background events when >1 interaction per bunch crossing
    - Parameter tuning also has visible effects at high p_T (e.g. colour reconnection)
  - Diffractive models (single- and double-diffractive) vary widely and little data available to tune to

Our Philosophy

- As inclusive as possible
  - Single-arm trigger
  - Well-defined phase-space easy for MC tuning experts to use
  - No corrections back to particular components (e.g. non-single-diffractive)

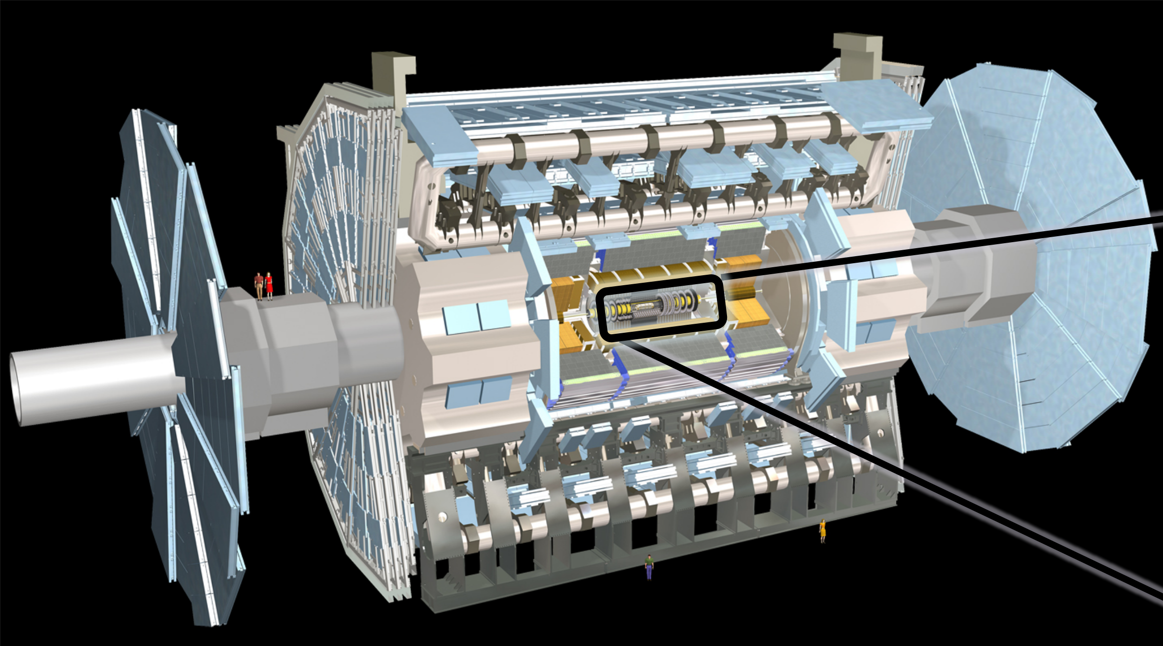


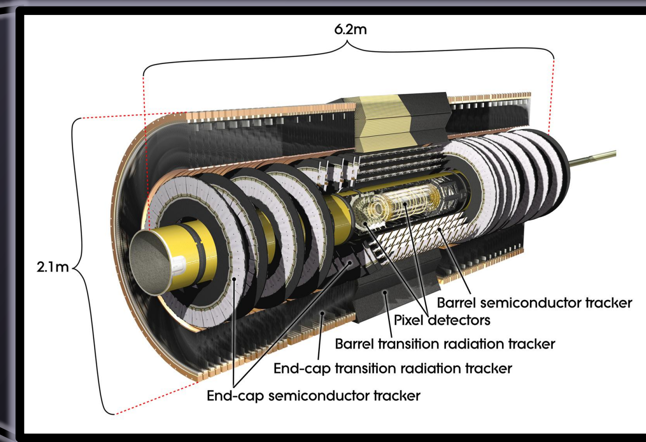
- Phase-spaces studied so far
  - Possible for all energies
    - ≥1 particle: p_T>500 MeV, |η|≤2.5: 0.9, 2.36, 7 TeV
  - Most inclusive
    - ≥2 particles: p_T > 100 MeV, |η|≤2.5: 0.9, 7 TeV
  - Suppressed diffractive contribution
    - ≥6 particles: p_T > 500 MeV, |η|≤2.5: 0.9, 7 TeV
    - Used in new AMBT1 Pythia 6 Tune

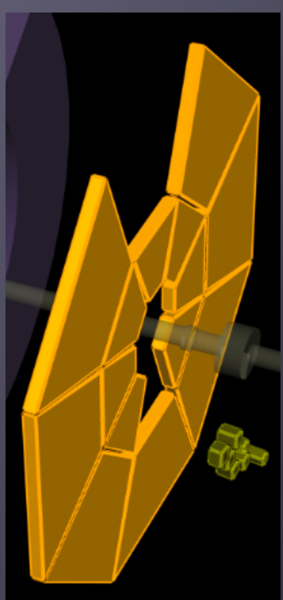
Yellow: shown today

See talk by E. Nurse
Track 3 Saturday 12:05

ATLAS







- Minimum Bias Trigger Scintillator (MBTS)
  - Inside the endap calorimeters
  - 3.6m from interaction point
  - Coverage 2.1<|η| < 3.8 in 2 disks

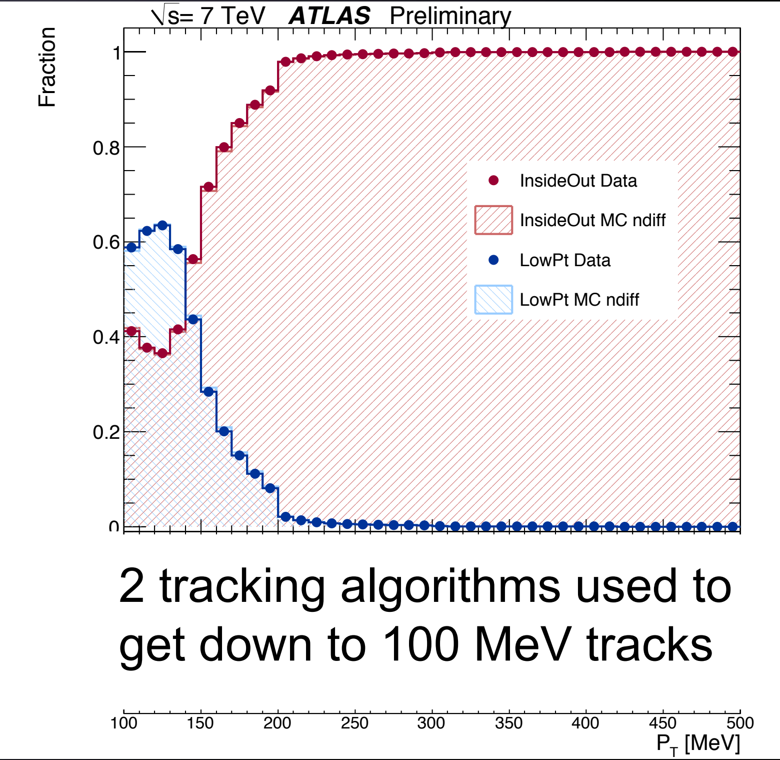
See poster by R. Kwee

- Pixel
  - 3 barrel layers, 3 endcap disks
- Silicon Tracker (SCT)
  - 4 double-sided barrel layers, 9 end-cap disks
- Transition Radiation Tracker (TRT)
  - ~ 32 hits per track

See talk by J. Fleckner
Track 1 Thursday 11:54

Dataset and Event Selection

- MBTS single-cell trigger
- 1 Reconstructed vertex
  - 2 tracks + Beam Spot
  - Remove pile-up events
    - Second vertex with ≥4 tracks
- 0.9 and 7 TeV
  - ≥2 good tracks
    - p_T > 100 MeV ; |η| ≤2.5
    - Additional tracking algorithm at low p_T
- 2.36 TeV
  - ≥1 good track
    - p_T > 500 MeV ; |η| ≤2.5
    - New tracking algorithms



2 tracking algorithms used to get down to 100 MeV tracks

- 0.9 TeV (~7 μb^{-1})
  - 360k events ; 4.5M tracks
- 7 TeV (~190 μb^{-1})
  - 10M events; 210M tracks
- 2.36 TeV
  - 6k events ; ~40k tracks

Corrections Procedure

n_{sel}^{BS}: number of tracks; cuts as close to final selection as possible without a vertex

- Corrections applied event-wise
  - Trigger
  - Vertexing

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

- Corrections applied track-wise

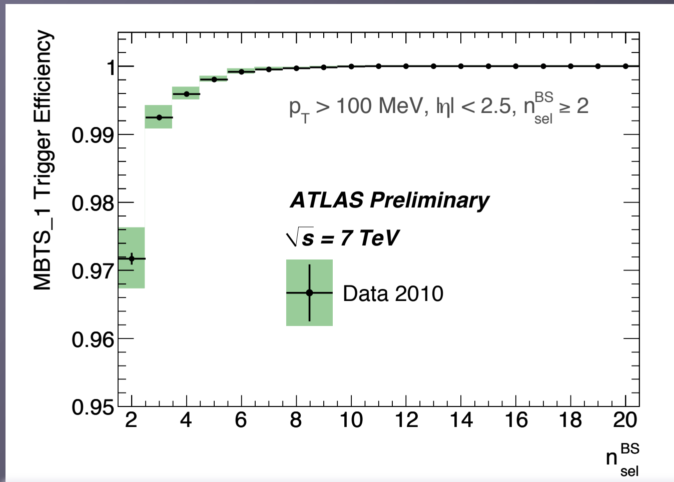
$$w_{trk}(p_T, \eta) = \frac{1}{\epsilon_{trk}(p_T, \eta)} \cdot (1 - f_{sec}(p_T, \eta)) \cdot (1 - f_{okr}(p_T, \eta))$$

- Correct for tracks out of kinematic range ($f_{okr}(p_T,\eta)$)
  - e.g track p_T above but particle p_T below cut
- Iterative Bayesian unfolding method applied to both number of particles (n_{ch}) and p_T
- Correct for events out of kinematic range
  - Events with ≥2 particles but <2 tracks

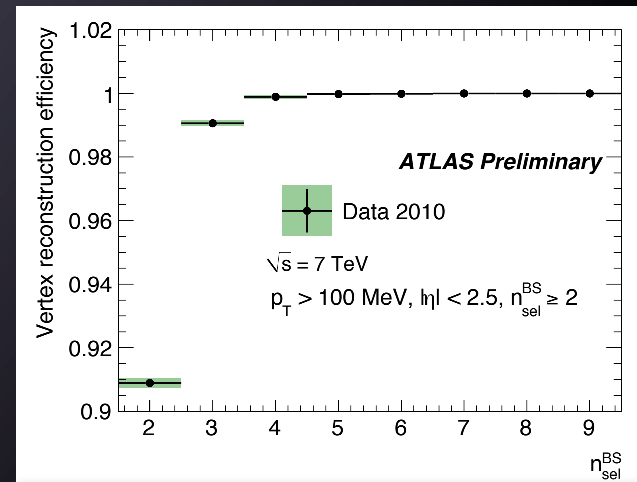
$$w_{out}(n_{ch}) = \frac{1}{(1 - (1 - \epsilon_{trk})^{n_{ch}} - n_{ch} \cdot \epsilon_{trk} \cdot (1 - \epsilon_{trk})^{(n_{ch}-1)})}$$

- $\langle p_T \rangle$ vs n_{ch}: bin by bin correction of average p_T then n_{ch} migration

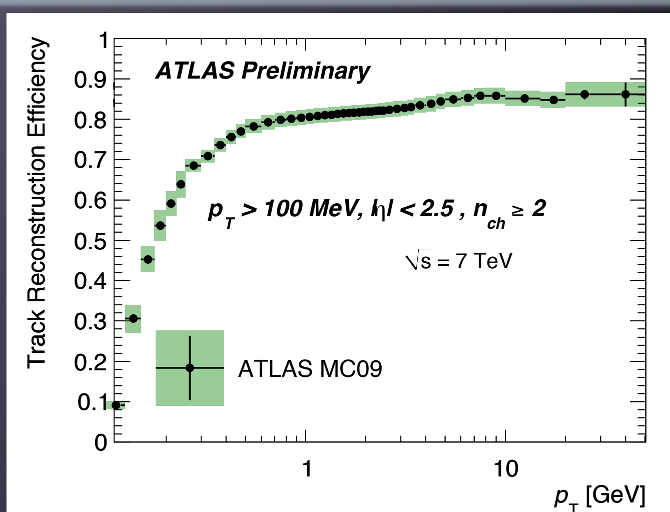
Efficiencies

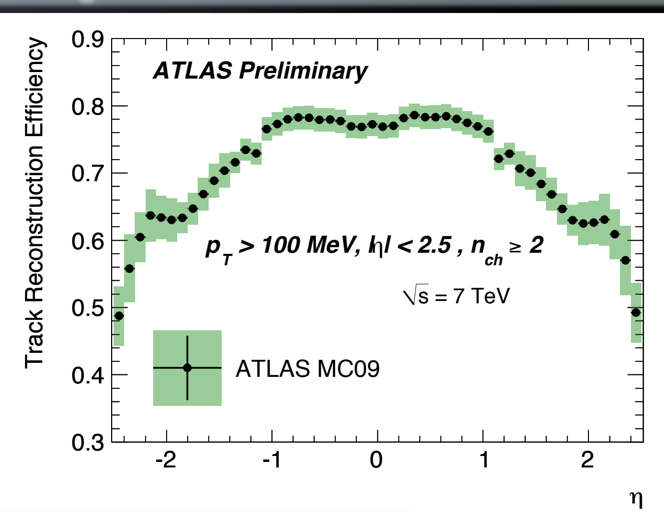


Trigger efficiency from data using orthogonal trigger



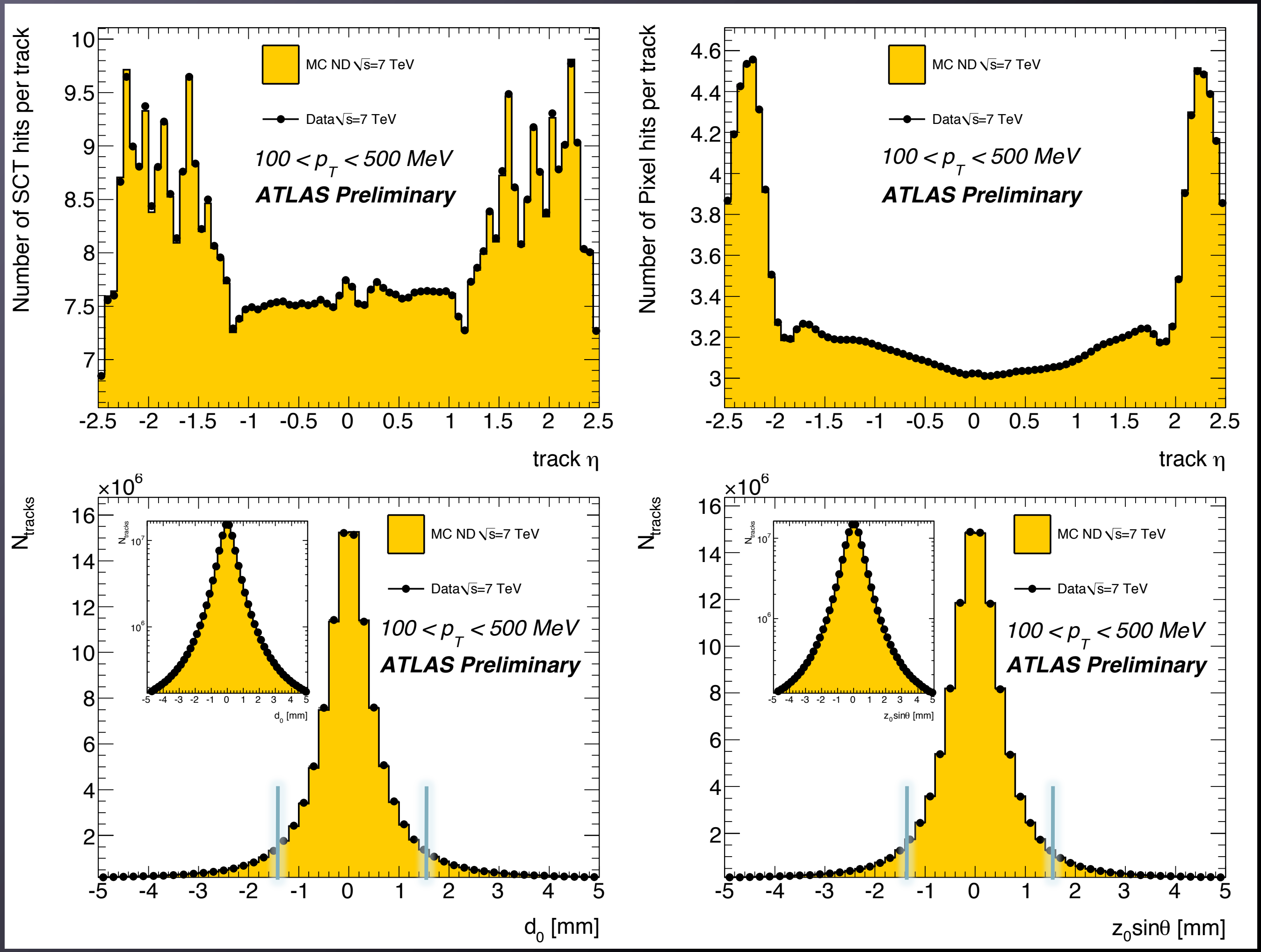
Vertex Efficiency from Data





Tracking Efficiency from MC

Low p_T Tracking: p_T < 500 MeV

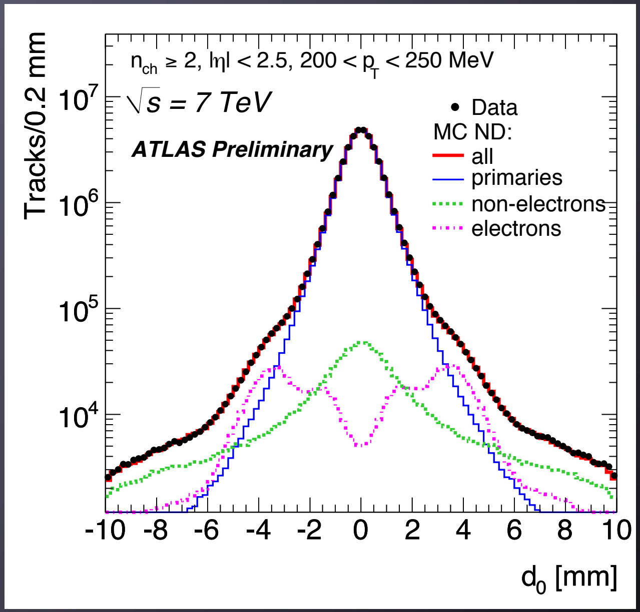


Basic track quantities in excellent agreement with MC

Some "Fun" Bits

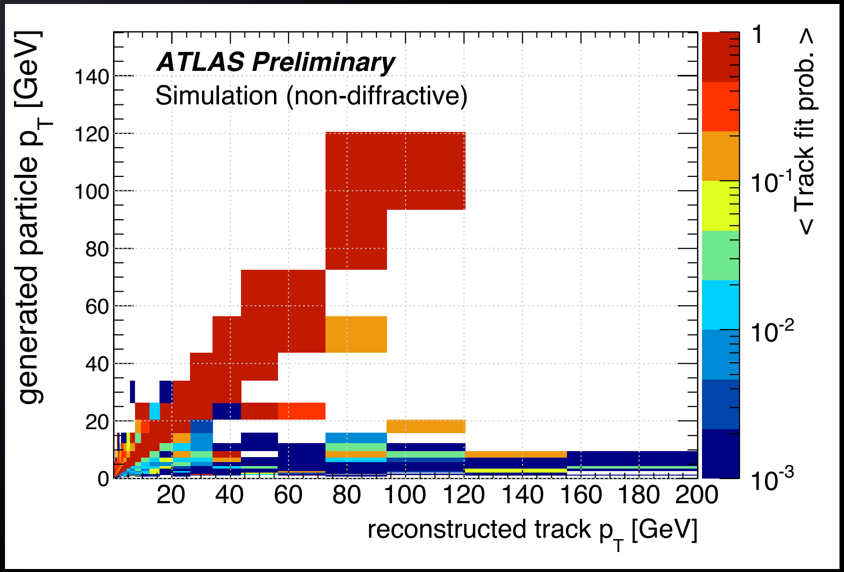
Non-primary tracks

- Fraction of non-primaries determined by side-band fit to d_0
- Requiring hit in innermost Pixel layer (layer-0) reduces contribution from conversions



High p_T tracks

- At high |η| large extrapolation distance (~1m) between Pixel and SCT
  - Some particles reconstructed at significantly higher p_T
  - Cut on the χ^2 probability of the tracks above 10 GeV



Dataset and Event Selection @ 2.36 TeV

- 2 track reconstruction methods
  - Could not use standard tracking as SCT not at nominal configuration
    - HV= 20V (nominal: 150V)
    - Reduced hit efficiency
- Test run @ 900 GeV with both SCT configurations

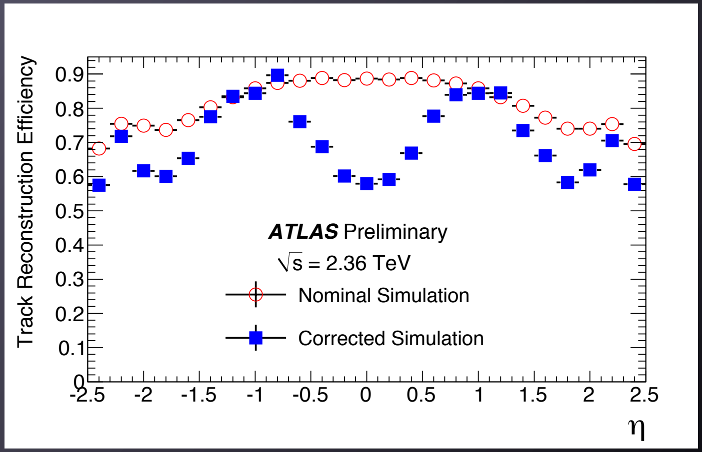
- ID tracks
  - Use whole ID information
  - More open cuts in track reconstruction
  - p_T resolution similar to full tracks
  - Used for p_T distribution

- Pixel tracks
  - Tracks from Pixel layers + primary vertex
  - Smaller material systematic
  - Degraded p_T resolution
  - Used for n_{ch} and η distributions

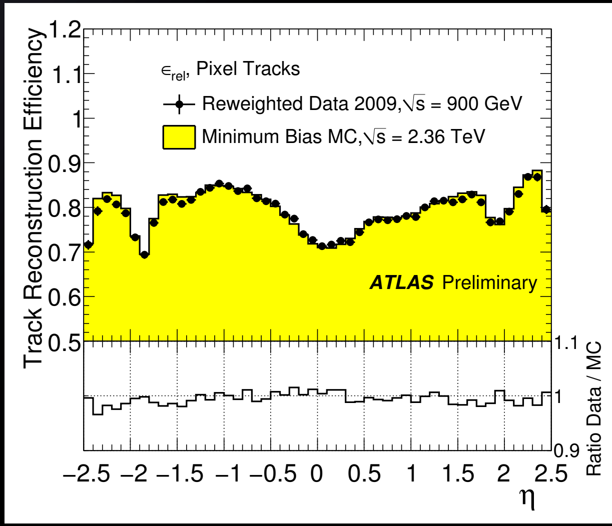
Tracking Efficiency @ 2.36 TeV

$$\varepsilon = \varepsilon_{MC} * \varepsilon_{corr}(\eta)$$

- ID tracks
  - Relative efficiency with respect to nominal tracks from test run @ 900 GeV
    - Apply ratio as correction factor @ 2.36 TeV

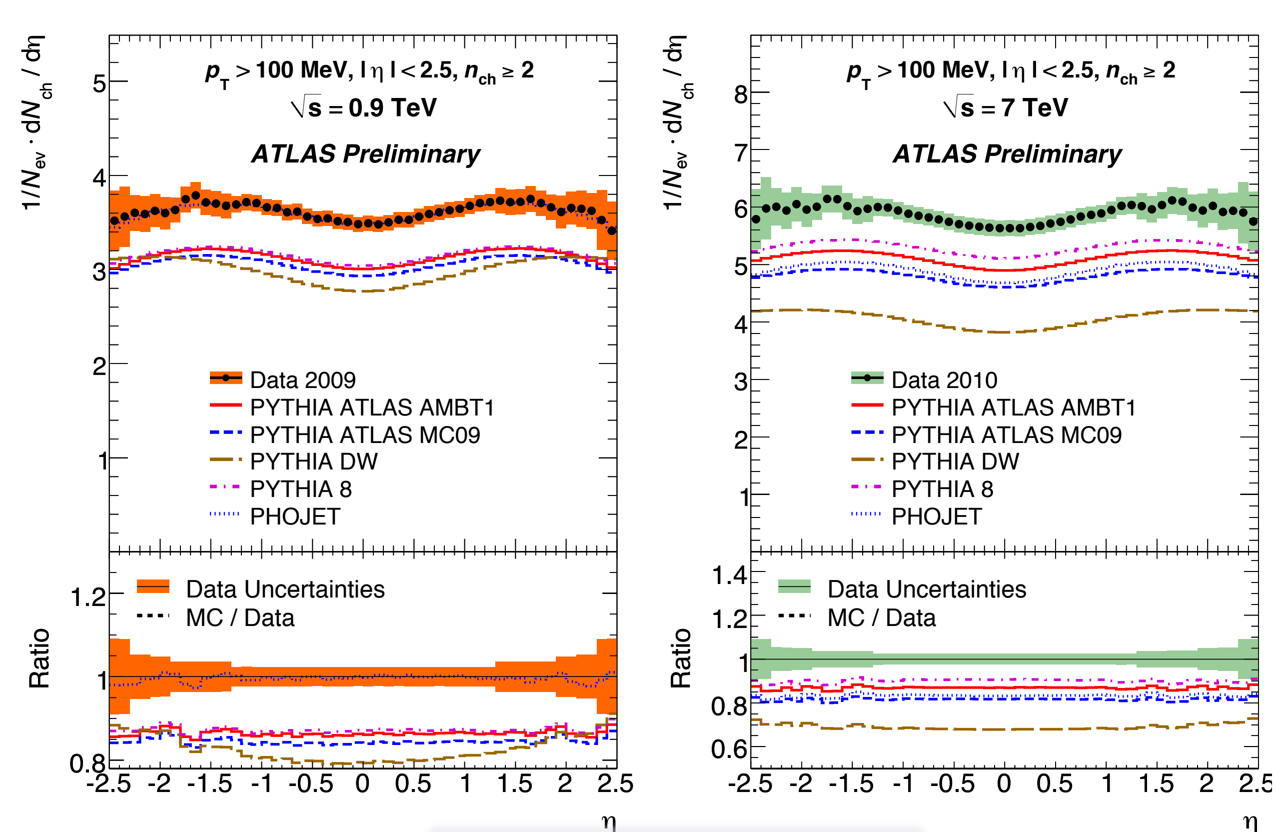


- Pixel tracks
  - Small correction to MC
    - Ratio of the relative efficiency between data and MC
    - Rel. efficiency of Pixel tracks wrt SCT+TRT only tracks

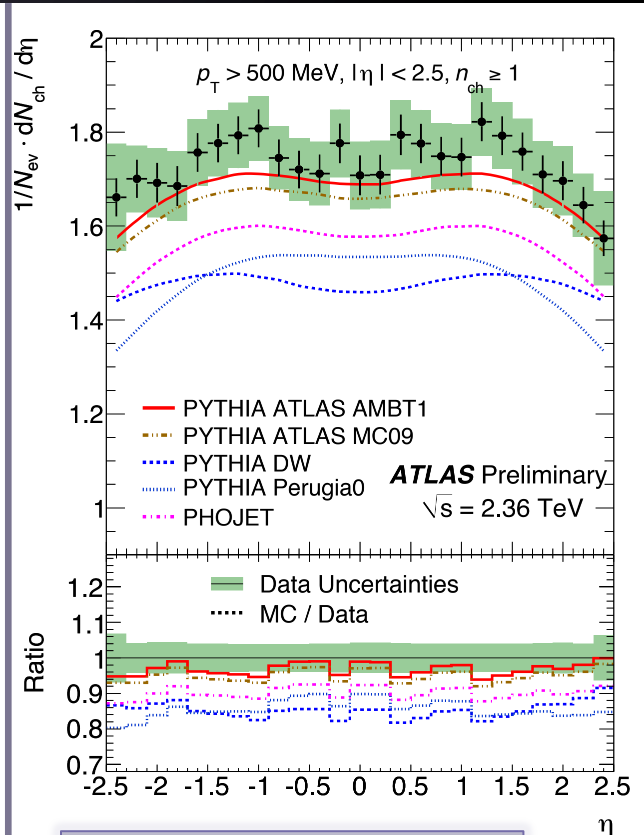


$1/N_{ev}\, dN_{ch}/d\eta$

- Very little shape variation between models
- Difference mostly in normalisation



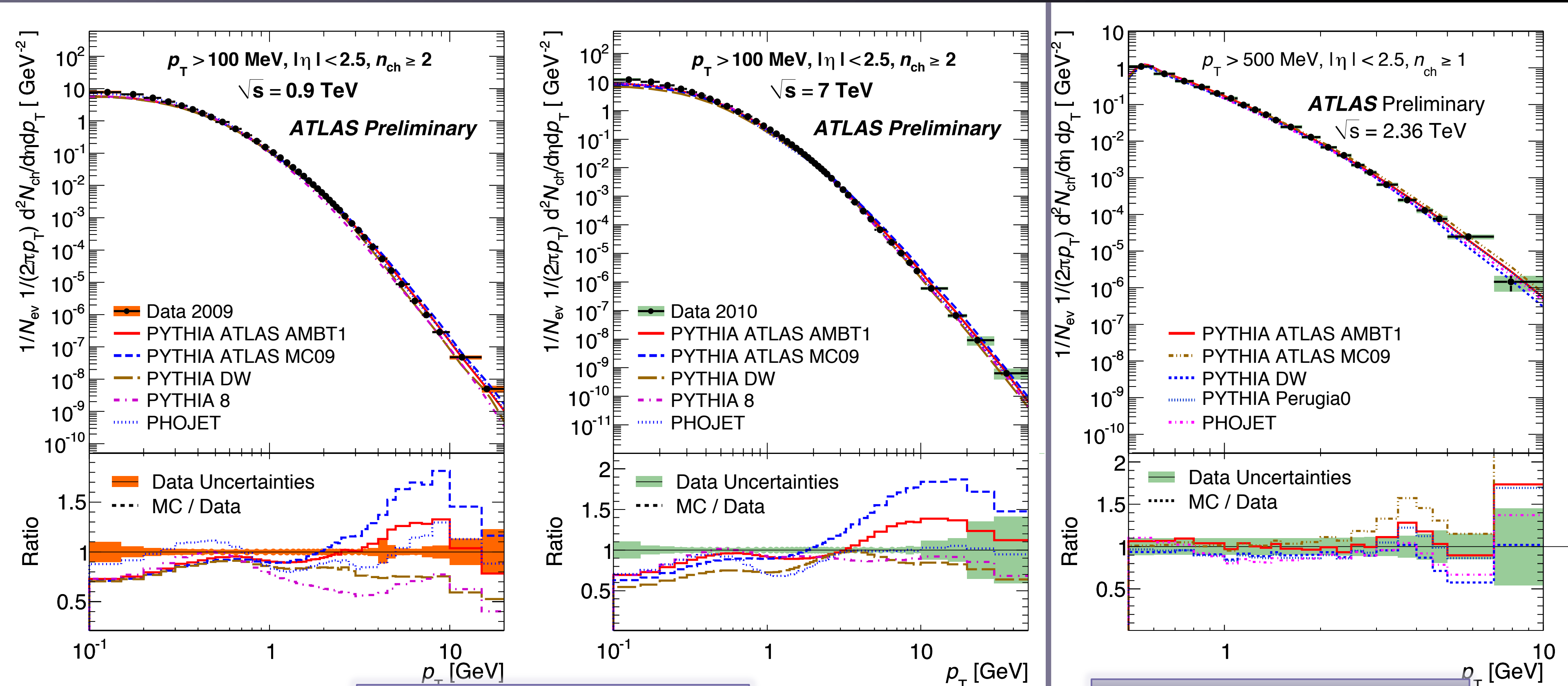
$n_{ch} \geq 2$, $p_T > 100$ MeV



$n_{ch} \geq 1$, $p_T > 500$ MeV

$1/2\pi p_T \, 1/N_{ev} \, dN_{ch}/d\eta dp_T$

- Measurements span 12 orders of magnitude
- Large disagreements at lowest p_T
- At Intermediate p_T much better agreement of new AMBT1 tune



$n_{ch} \geq 2$, $p_T > 100$ MeV

$n_{ch} \geq 1$, $p_T > 500$ MeV

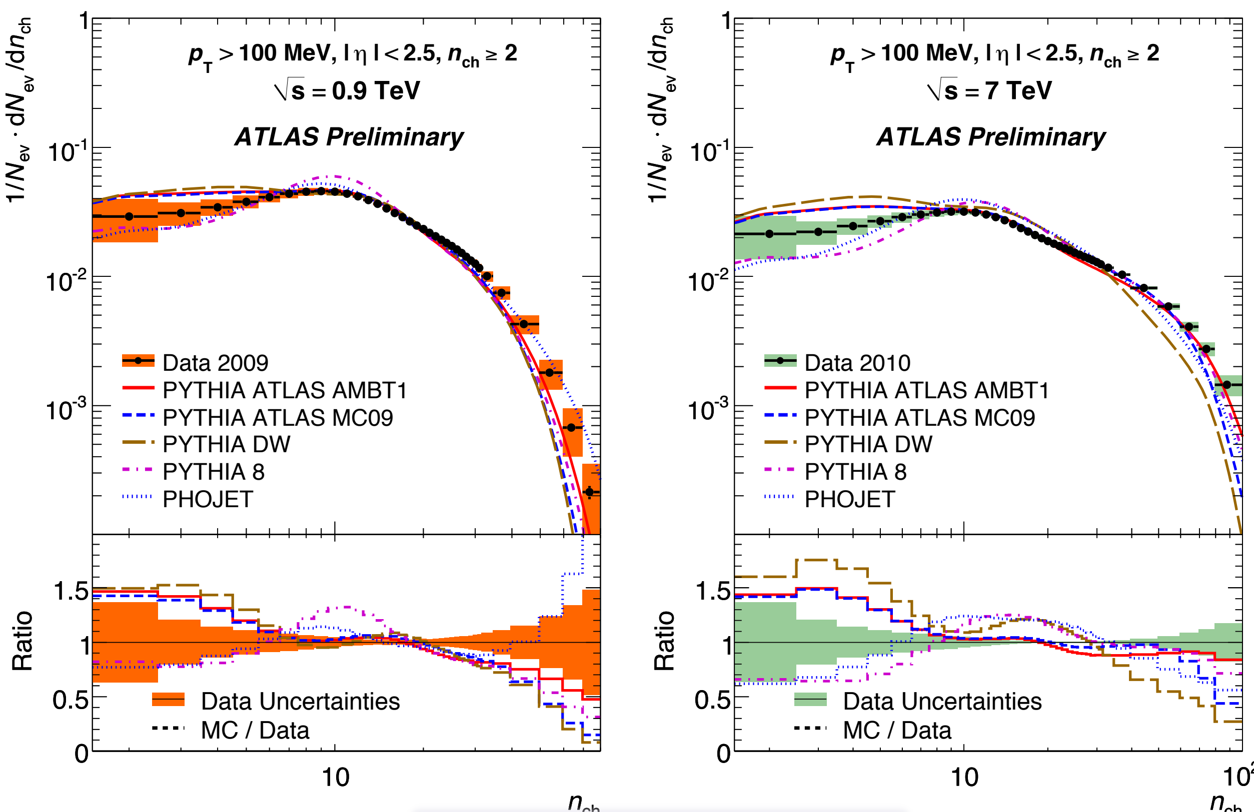
$1/N_{ev}\, dN_{ev}/dn_{ch}$

At lower p_T threshold

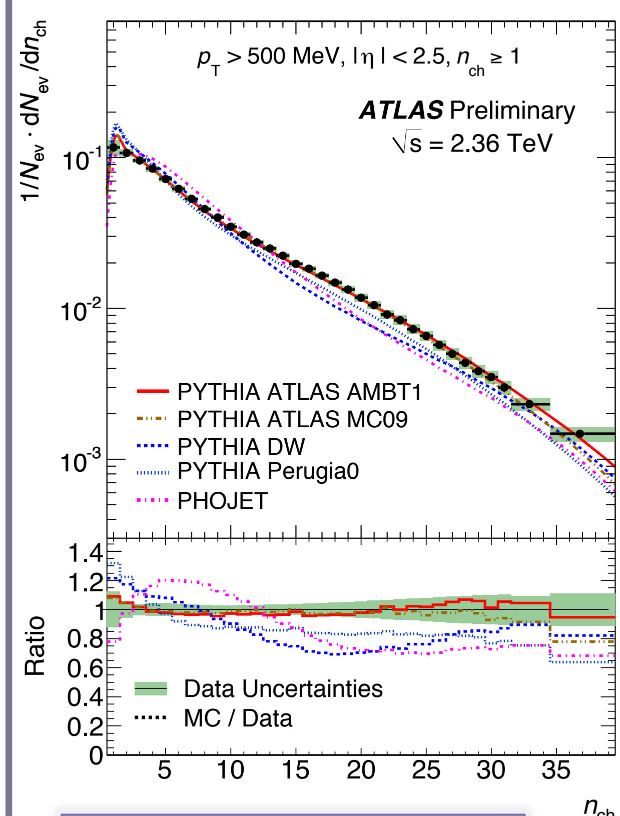
- Peak around 10 particles per event
- Both low and high values not well described by current MC

At high p_T threshold

- AMBT1 describes full spectrum better than 10%
- Other tunes have different shapes in intermediate regions



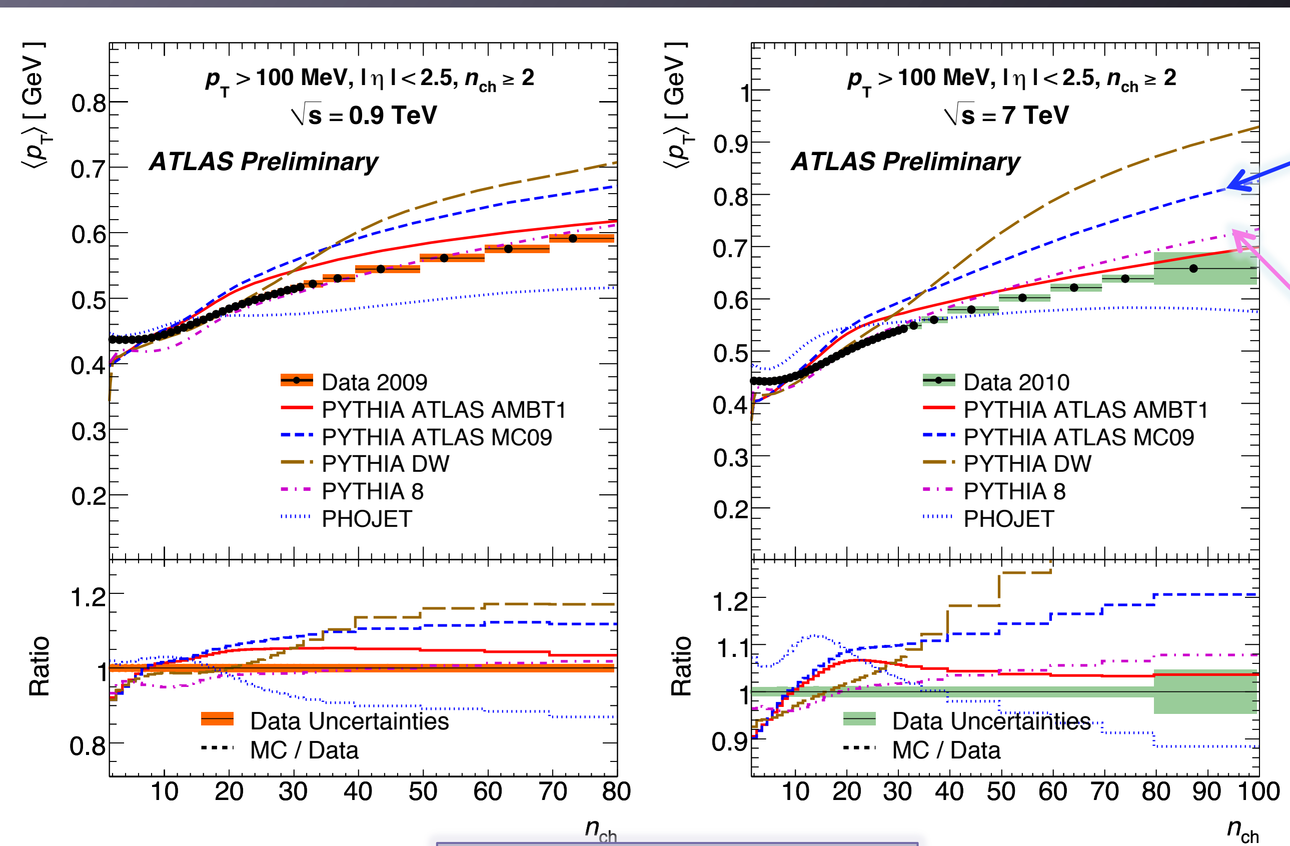
$n_{ch} \geq 2$, $p_T > 100$ MeV

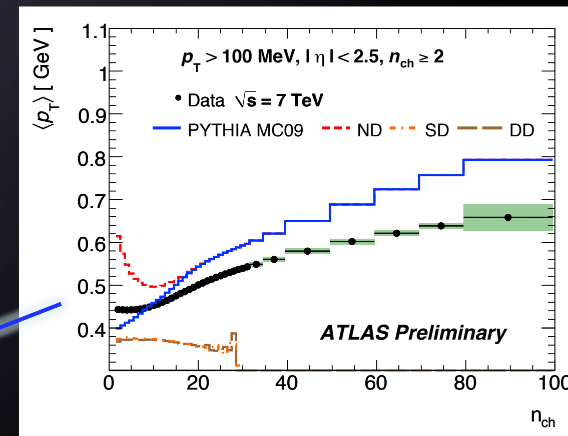


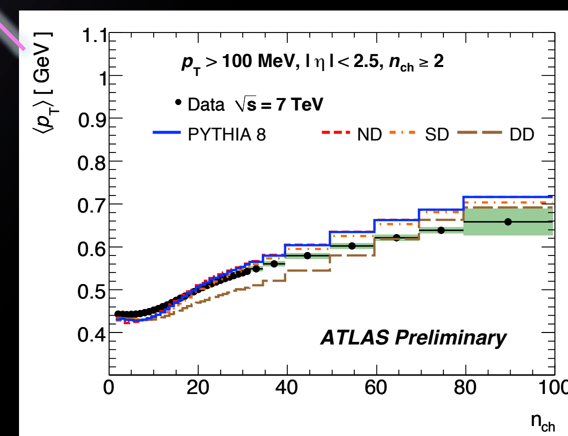
$n_{ch} \geq 1$, $p_T > 500$ MeV

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

- Shape at high n_{ch} well-modelled
- AMBT1 and Pythia8 reproduce the spectrum the best
- Low n_{ch} shape sensitive to ND,SD,DD fractions



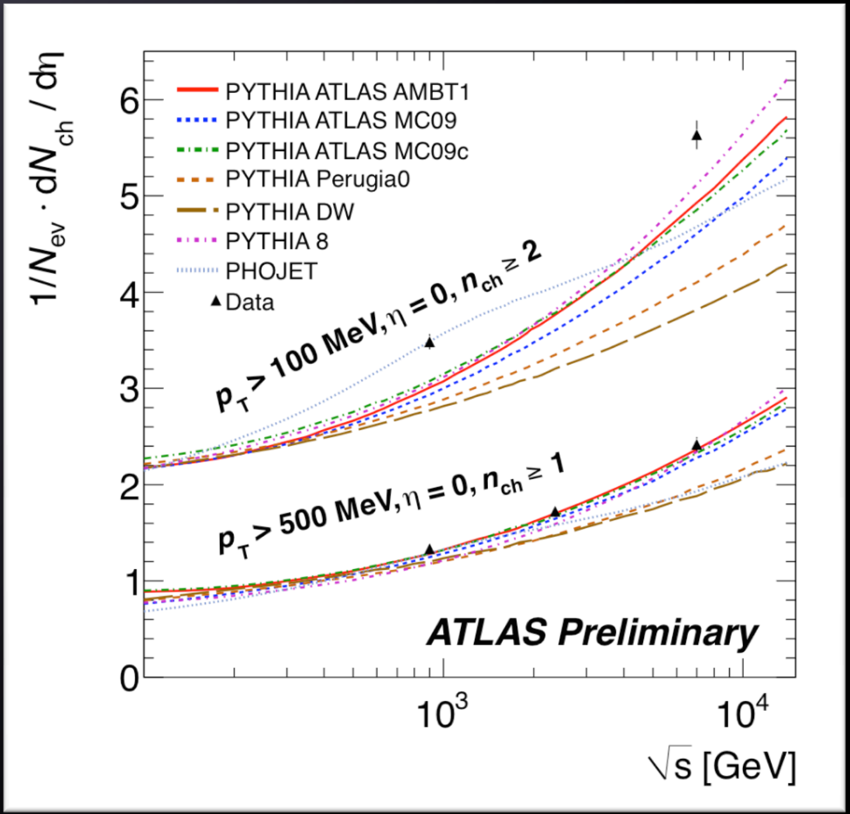




$n_{ch} \geq 2$, p_T >100 MeV

Closing Words

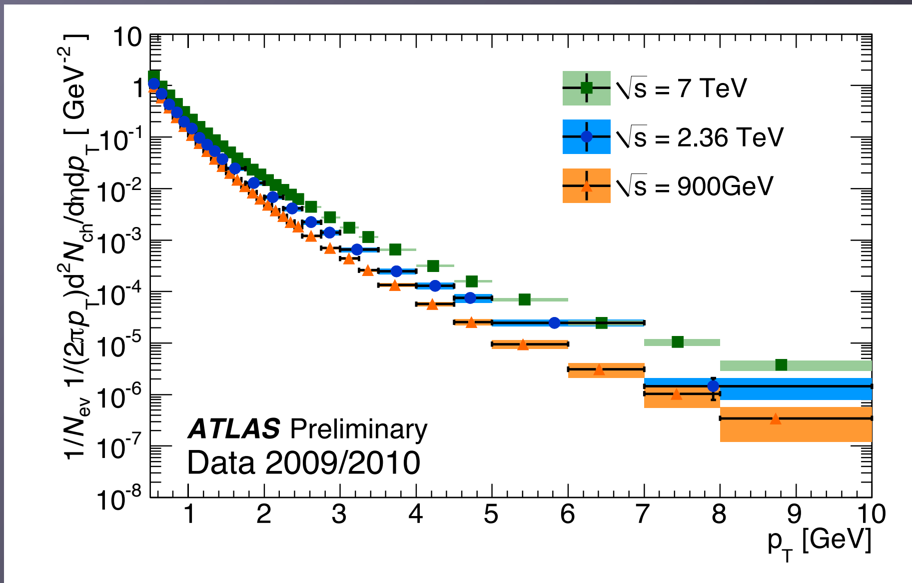
- Measure charged particles down to 100 MeV
- Measurement at 2.36 TeV possible
- No model-dependent corrections
- Measurements as inclusive as possible
  - p_T > 100 MeV
    - Significant fraction of diffractive events (order 20%)
    - MC models don't agree as well as for p_T > 500 MeV
    - Difference in energy dependence between models more visible
  - p_T > 500 MeV
    - Energy scaling for higher p_T tracks well described by AMBT1

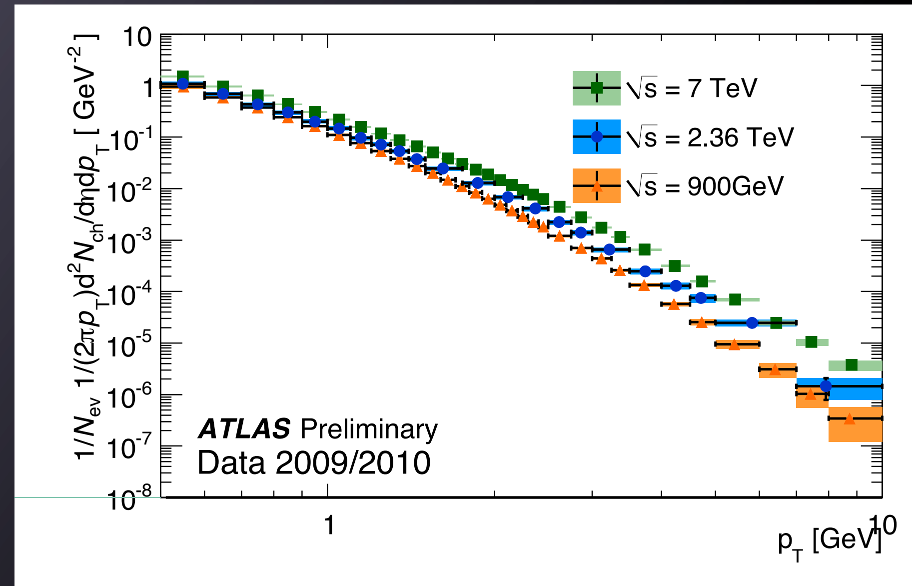


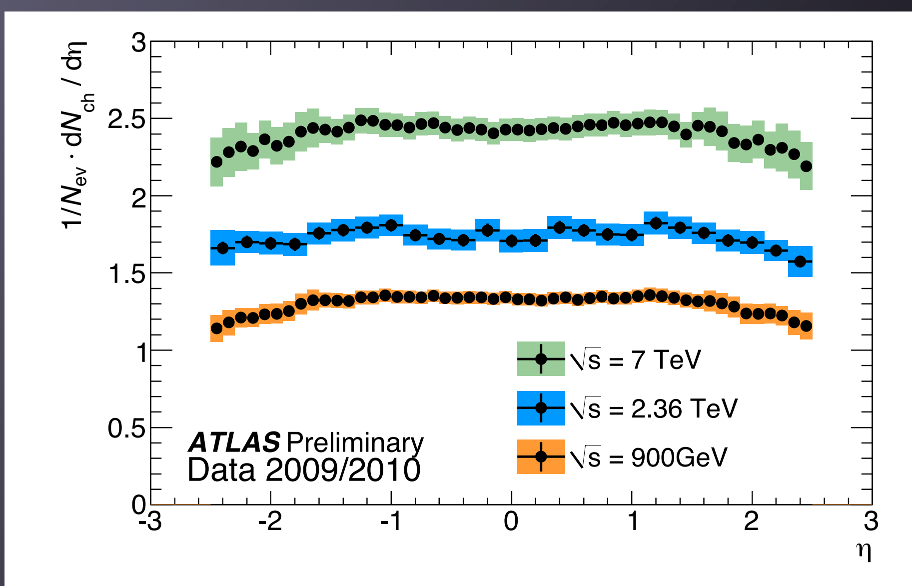
ATLAS-CONF-2010-046
ATLAS-CONF-2010-047

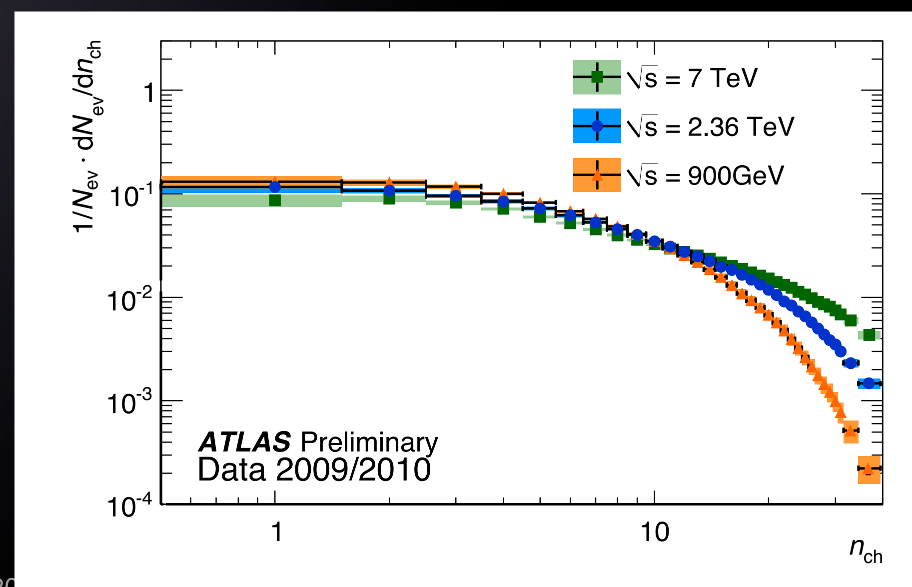
Backup

Energy Comparisons



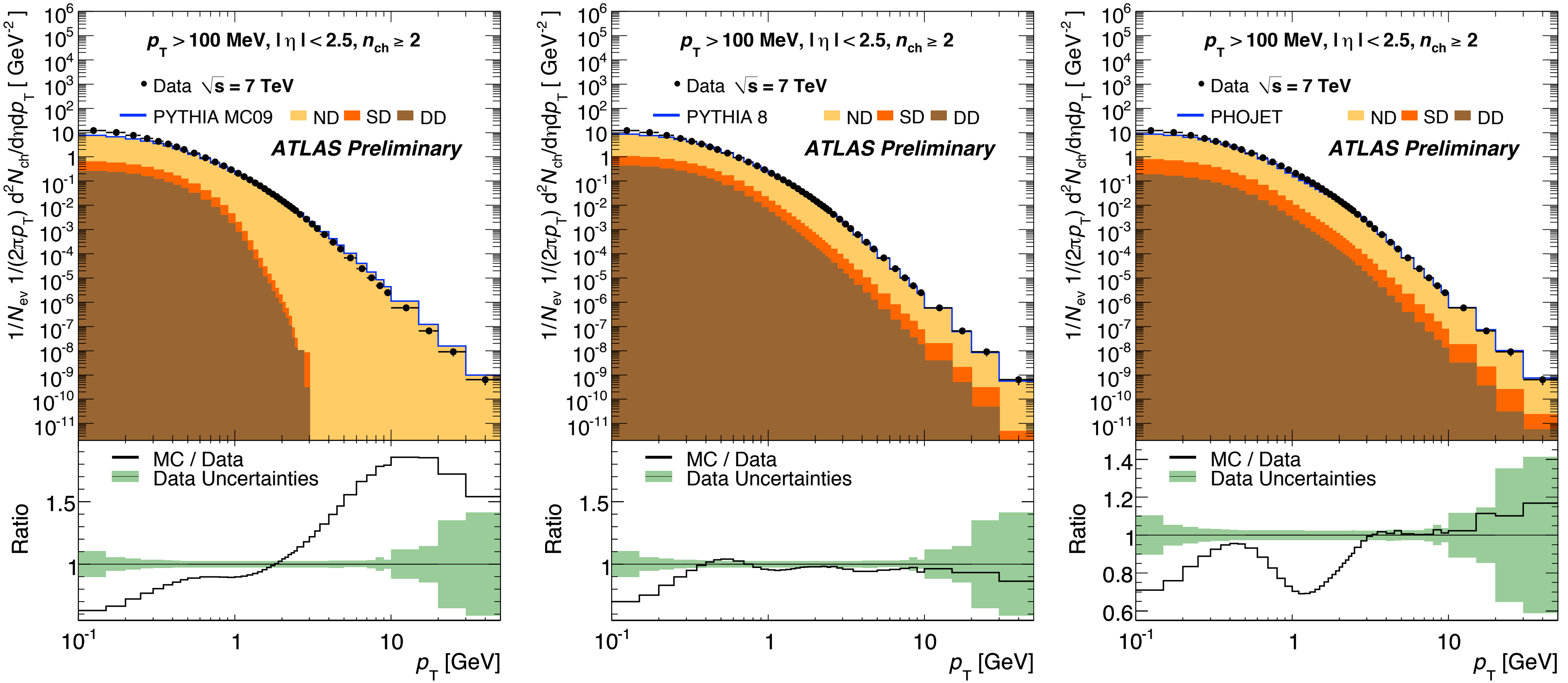






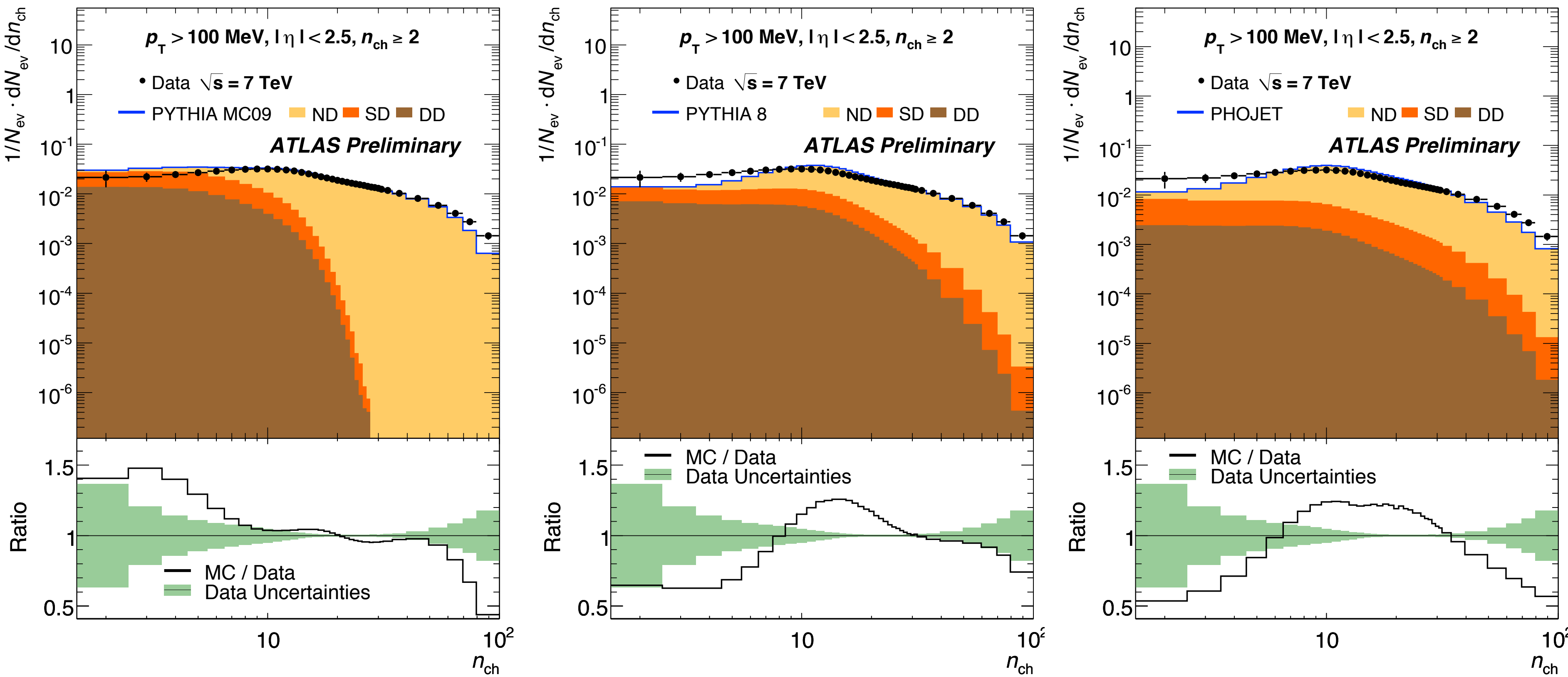
$1/2\pi p_T \, 1/N_{ev} \, dN_{ch}/d\eta dp_T$

- Comparing spectra from different diffraction models
- Pythia 6 has no hard component to diffraction



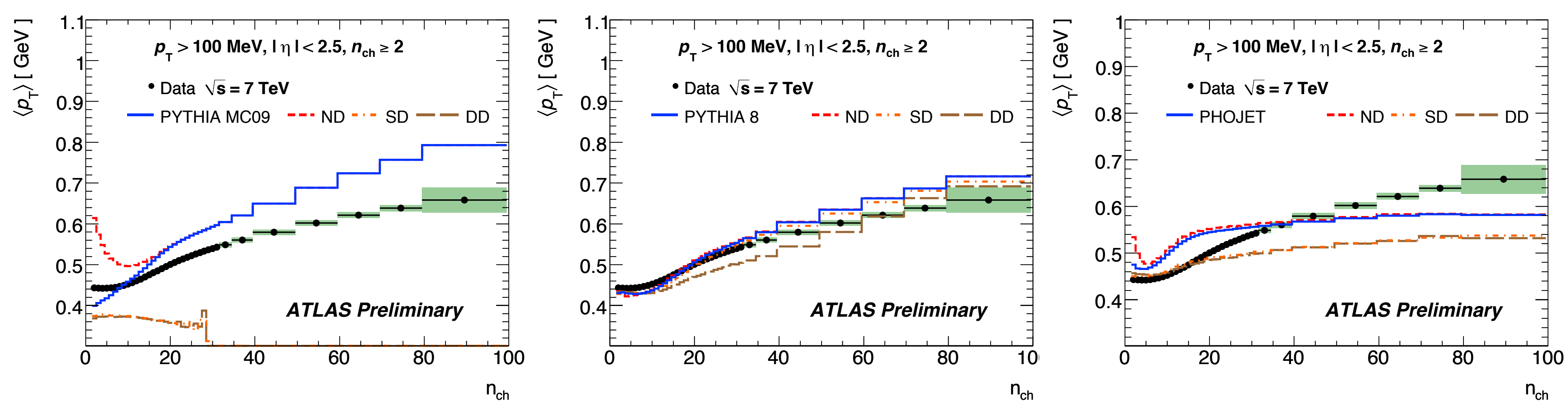
$1/N_{ev}\ dN_{ev}/dn_{ch}$

- Comparing spectra from different diffraction models
- Pythia 6 has no hard component to diffraction



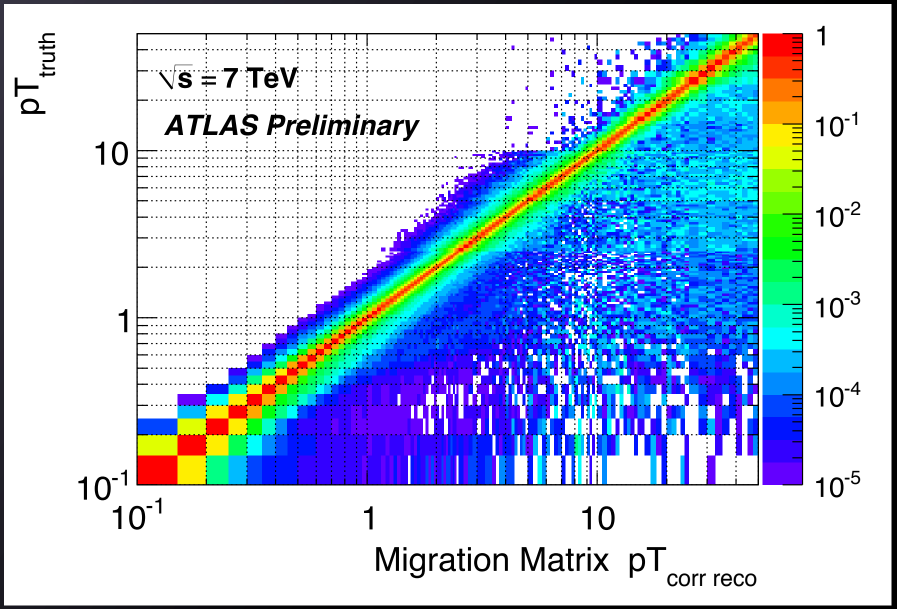
$\langle p_T \rangle$ vs n_{ch}

- Comparing spectra from different diffraction models
- Pythia 6 has no hard component to diffraction
- Shape at low nch values very different between different MC and between ND,SD,DD



Unfolding

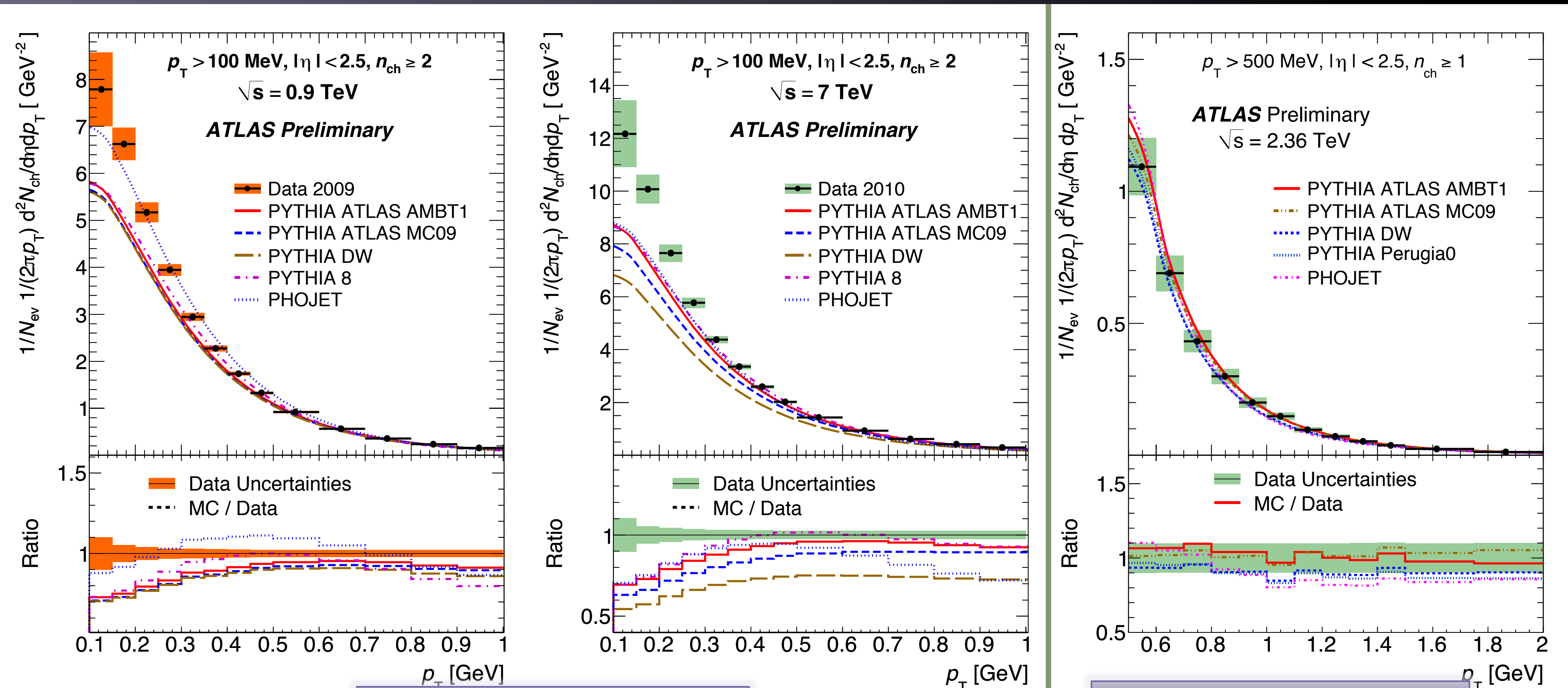
- Applied to both p_T and n_{ch}
  - Based on G. D'Agostini (NIM A362, 487-498, 1995)
  - Iterative procedure to remove dependence on initial spectrum used to fill matrix
  - Systematics due to
    - Input spectra
    - Kinematic distributions in other dimension (n_{ch} for p_T and vice-versa)



- Effect
  - p_T: Most bins ~2%, up to 10% @ 900 GeV
  - n_{ch}: factor ~3 at high and low n_{ch}

$1/2\pi p_T \, 1/N_{ev} \, dN_{ch}/d\eta dp_T$

- Measurements span 12 orders of magnitude
- Large disagreements at lowest p_T
- At Intermediate p_T much better agreement with new AMBT1 tune



$n_{ch} \geq 2$, p_T >100 MeV

$n_{ch} \geq 1$, p_T >500 MeV