Update on MB Measurements in ATLAS

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Introduction

- Last presented in this WG: inclusive measurements in
  - phase space regions at all 3 energies

    $n_{ch} \geq 1$, $|\eta| < 2.5$, $p_T > 500$ MeV at $\sqrt{s} = 0.9, 2.36, 7$ TeV
  - most inclusive phase spaces

    $n_{ch} \geq 2$, $|\eta| < 2.5$, $p_T > 100$ MeV at $\sqrt{s} = 0.9, 7$ TeV
- Today will highlight the latest, final results:
  - larger n_{ch} ranges, finalization of systematics
  - new correction method for correction of $< p_T >$ vs n_{ch}
  - studied new phase spaces
    - diffraction-limited for tuning
    - hard-component
    - common phase spaces

Overview

Phase spaces studied at 900 GeV and 7 TeV:

- Nch >=1, pT > 500 MeV, |η| < 2.5 (1st paper, 900 GeV / PLHC, 7 TeV a.k.a. 1.0 / 1.5)
- Nch >=6, pT > 500 MeV, |η| < 2.5 (AMBT1 tuning, a.k.a. 1.5T)
- Nch >=2, pT > 100 MeV, |η| < 2.5 (ICHEP, a.k.a. 2.0)
- Nch >=20, pT > 100 MeV, |η| < 2.5 (new)
- Nch >=1, pT > 2.5 GeV, |η| < 2.5 (new)
- Nch >=1, pT > 500 MeV, |η| < 0.8 (new)
- Nch >=1, pT > 1.0 GeV, |η| < 0.8 (new)

2nd MB Paper:
arXiv 1012.5104
Now in New
Journal of Physics

ATLAS-CONF-2010-101

no change in selection criteria since last presentation
and same analysed dataset

Analysis Strategy

- Charged-particle multiplicity measurements:

$$\frac{1}{N_{\rm ev}} \cdot \frac{dN_{\rm ch}}{d\eta}, \quad \frac{1}{N_{\rm ev}} \cdot \frac{1}{2\pi p_{\rm T}} \cdot \frac{d^2 N_{\rm ch}}{d\eta dp_{\rm T}}, \quad \frac{1}{N_{\rm ev}} \cdot \frac{dN_{\rm ev}}{dn_{\rm ch}} \quad \text{and} \quad \langle p_{\rm T} \rangle \text{ vs. } n_{\rm ch}$$

- Correct for trigger and vertex efficiency, event-wise

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

n_{sel}^{BS} = # of tracks passing track selection criteria wrt beamspot

- Tracking efficiency correction on track-by-track basis

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

- Correct for events which have Nsel=0,1 but nch>=2

$$1/(1 - (1 - \epsilon_{\rm trk})^{n_{\rm ch}} - n_{\rm ch} \cdot \epsilon_{\rm trk} \cdot (1 - \epsilon_{\rm trk})^{(n_{\rm ch} - 1)})$$

- Nch and pT distributions corrected using 1D Bayesian unfolding.

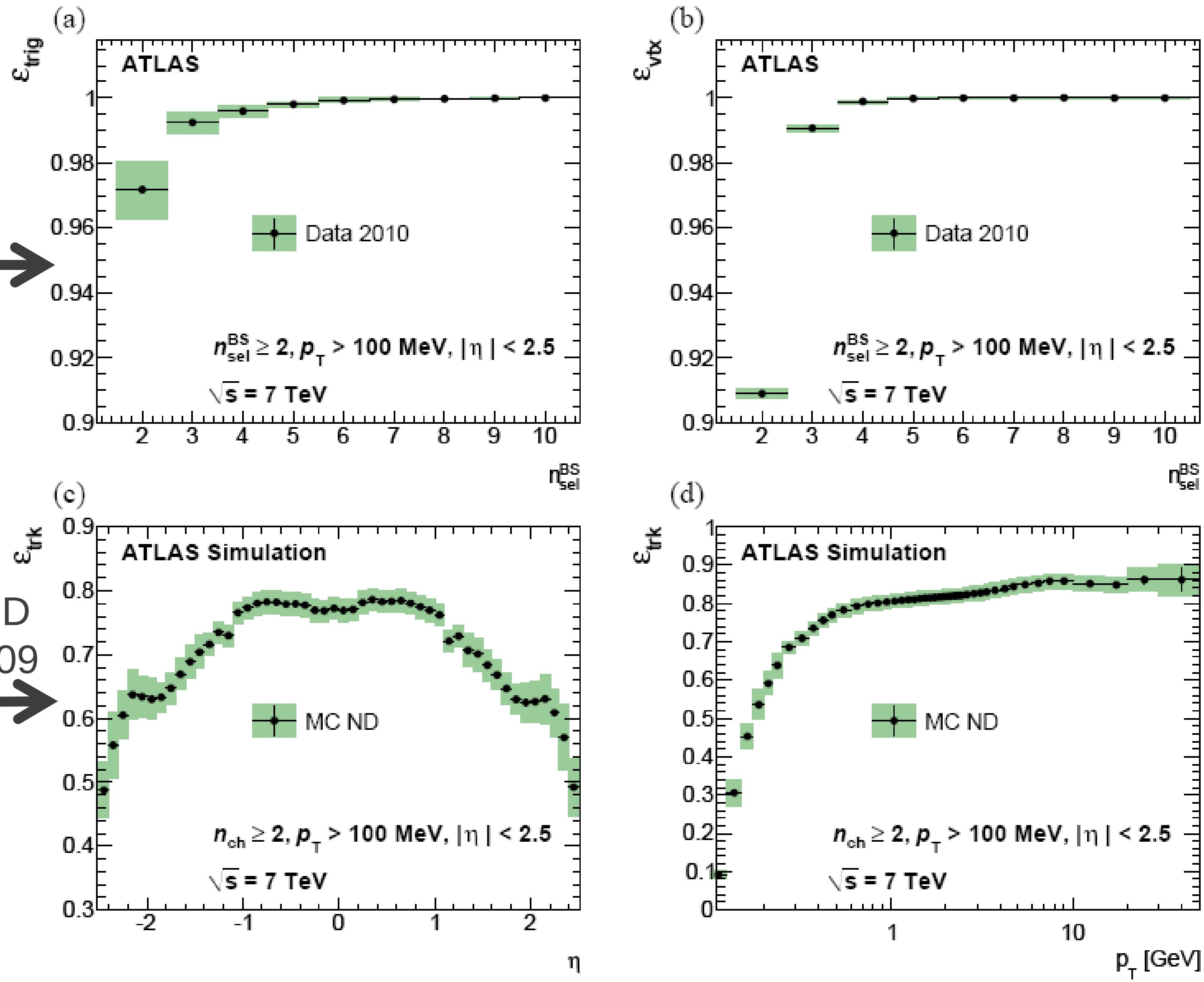
Systematic Uncertainties

- Systematic uncertainties were evaluated for each final distribution
- Dominant uncertainty comes from the tracking efficiency due to the material description
- New systematic considered for the n_{ch}-unfolding
  - accounts for the MC p_T spectrum dependence of the unfolding matrix
- A different method is now (since ICHEP) used to obtain high p_T systematics due to
  - badly reconstructed high p_T tracks (very low p_T tracks get reconstructed at high p_T tracks due to wrong track extrapolation)
  - track resolution

Event and Track Level Corrections

both
from data

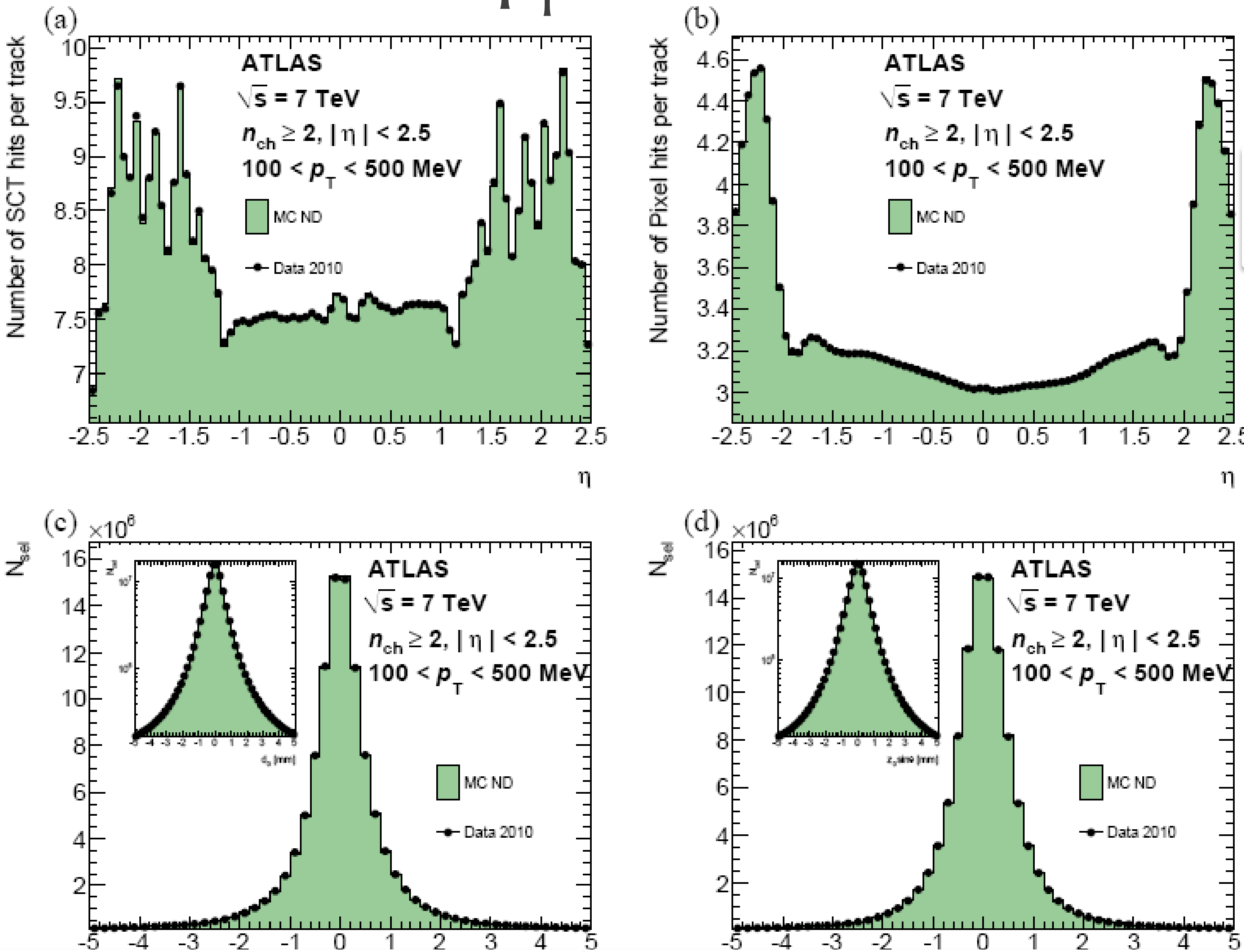
from MC ND
ATLASMC09



Data and MC comparison for tracks
$100 < p_T < 500$ MeV

hits in SCT

hits in Pixel



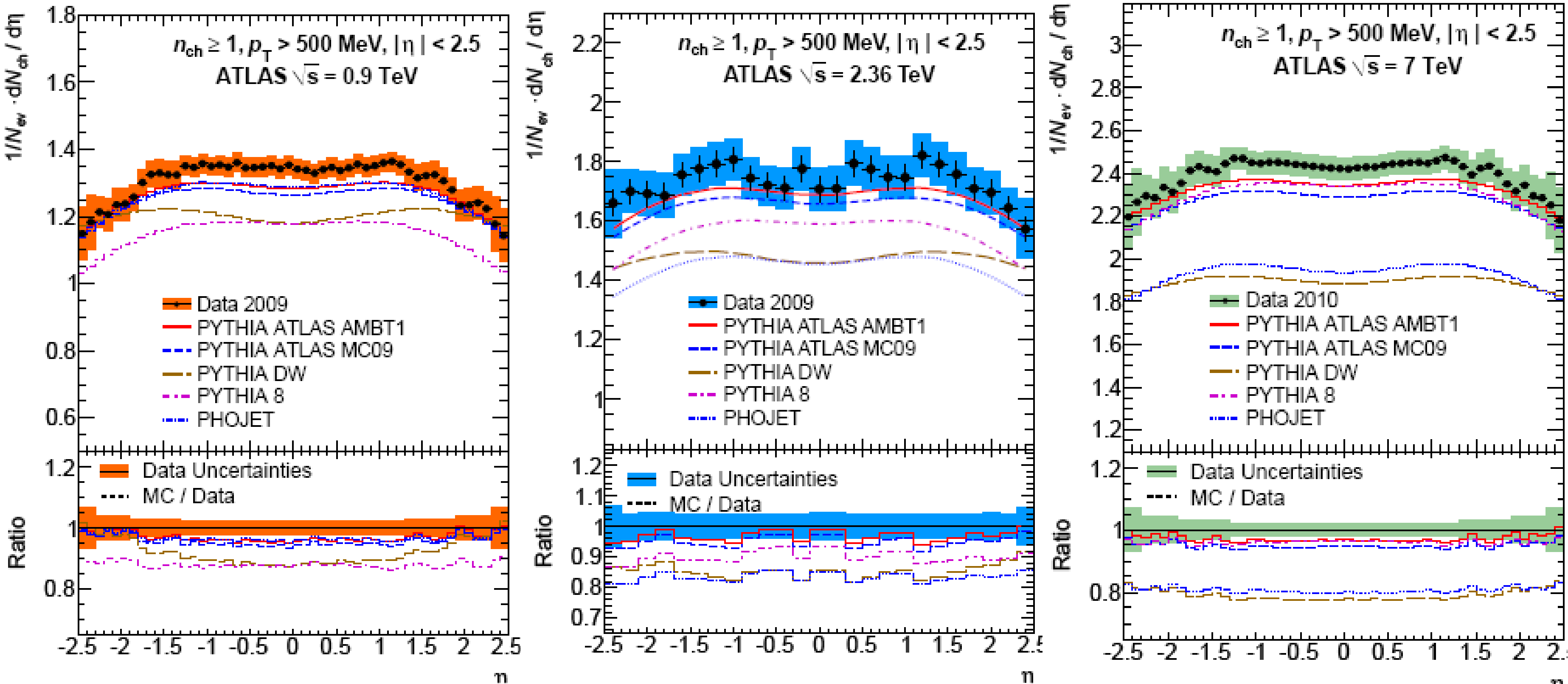
transverse impact parameter d_0 [mm] longitudinal impact parameter $z_0 \sin\theta$ [mm]

Results

Show only selected results, full results are in the paper.

$1/N_{ev}\ dn_{ch}/d\eta$

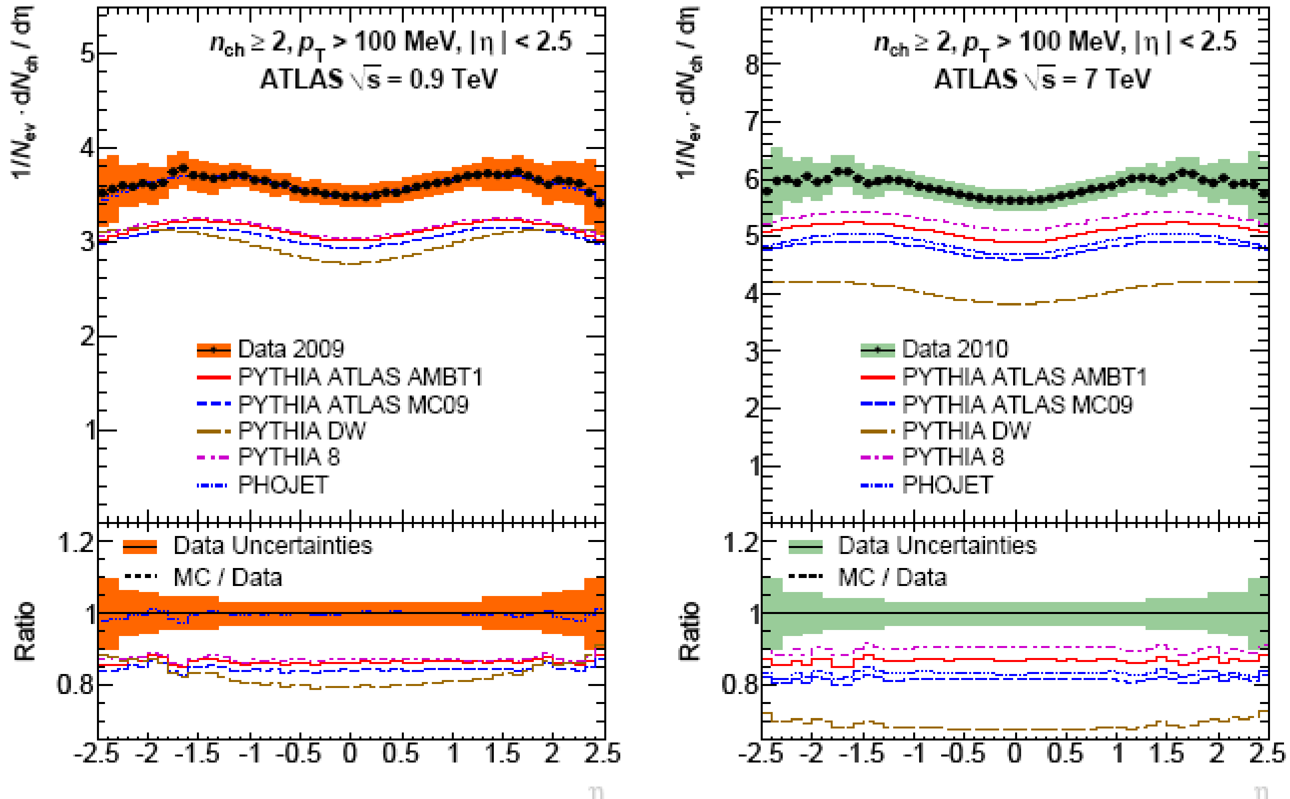
phase space at all 3 energies



- Density is roughly constant within |η| < 1
- Little shape variation between the models except for DW (has a more pronounced dip)

$1/N_{ev}\ dn_{ch}/d\eta$

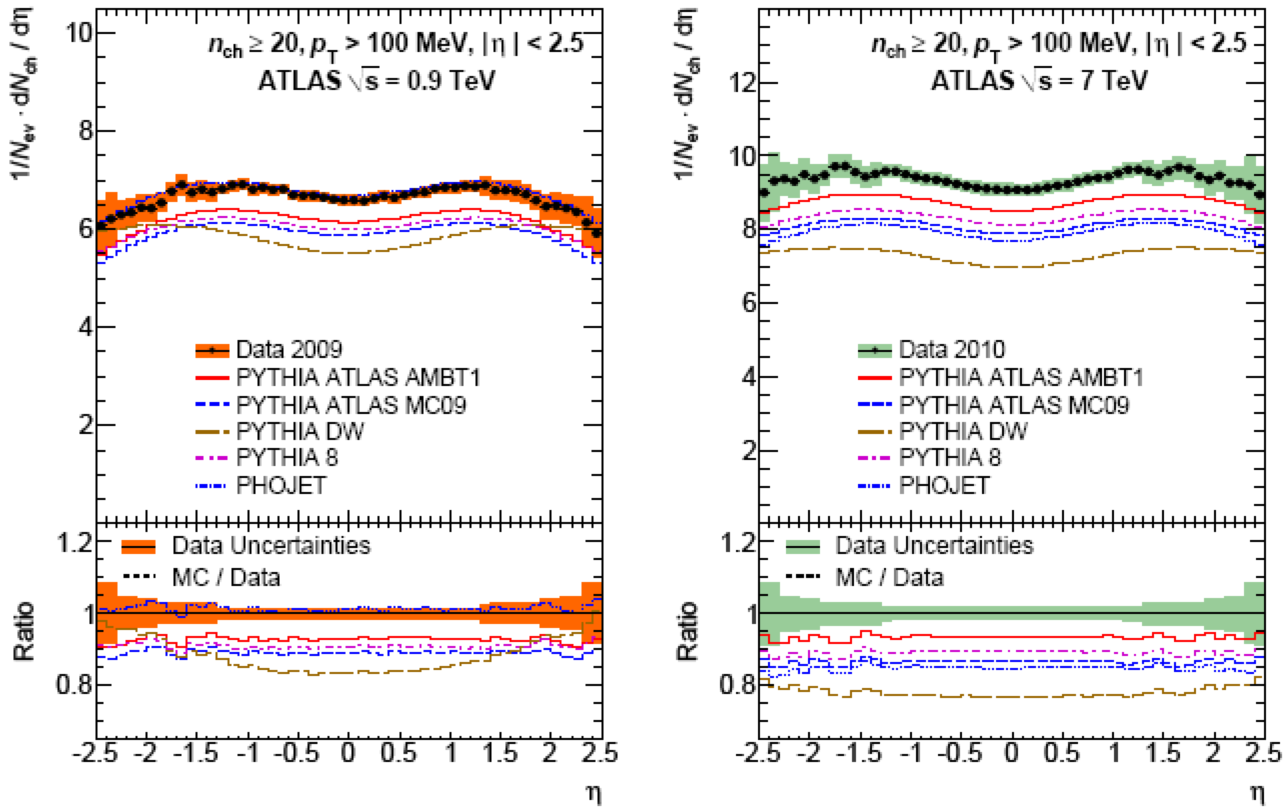
most inclusive phase space



- Even less shape variation here
- Strong variation on the normalisation by all models, none reproduce the data, not even the ATLAS tune AMBT1

$1/N_{ev}\ dn_{ch}/d\eta$

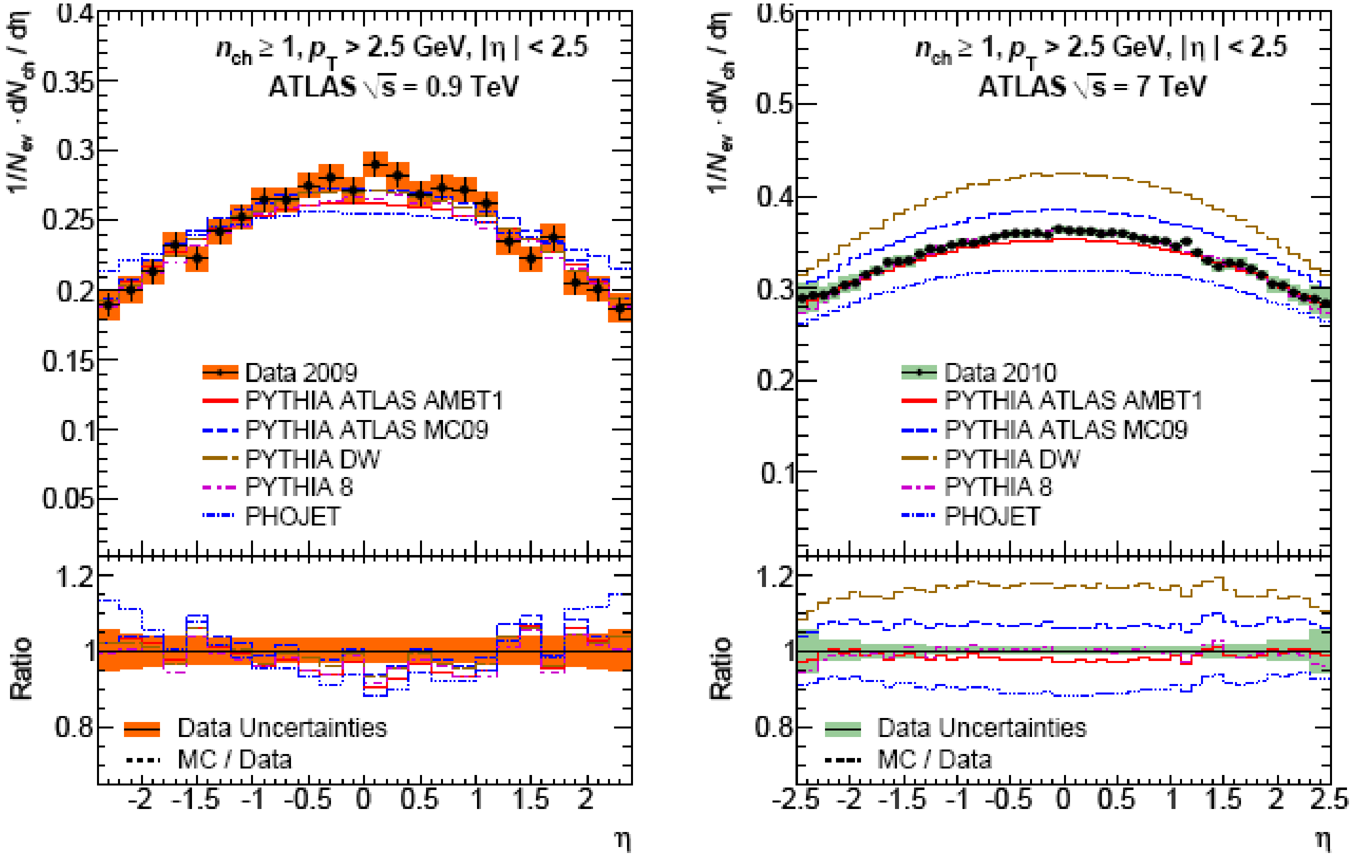
diffractive-limited phase space with $n_{ch} \geq 20$



- Situation is not significantly different when requiring 20 charged particles or more, only phojet matches data at √s = 900 GeV

$1/N_{ev}\ dn_{ch}/d\eta$

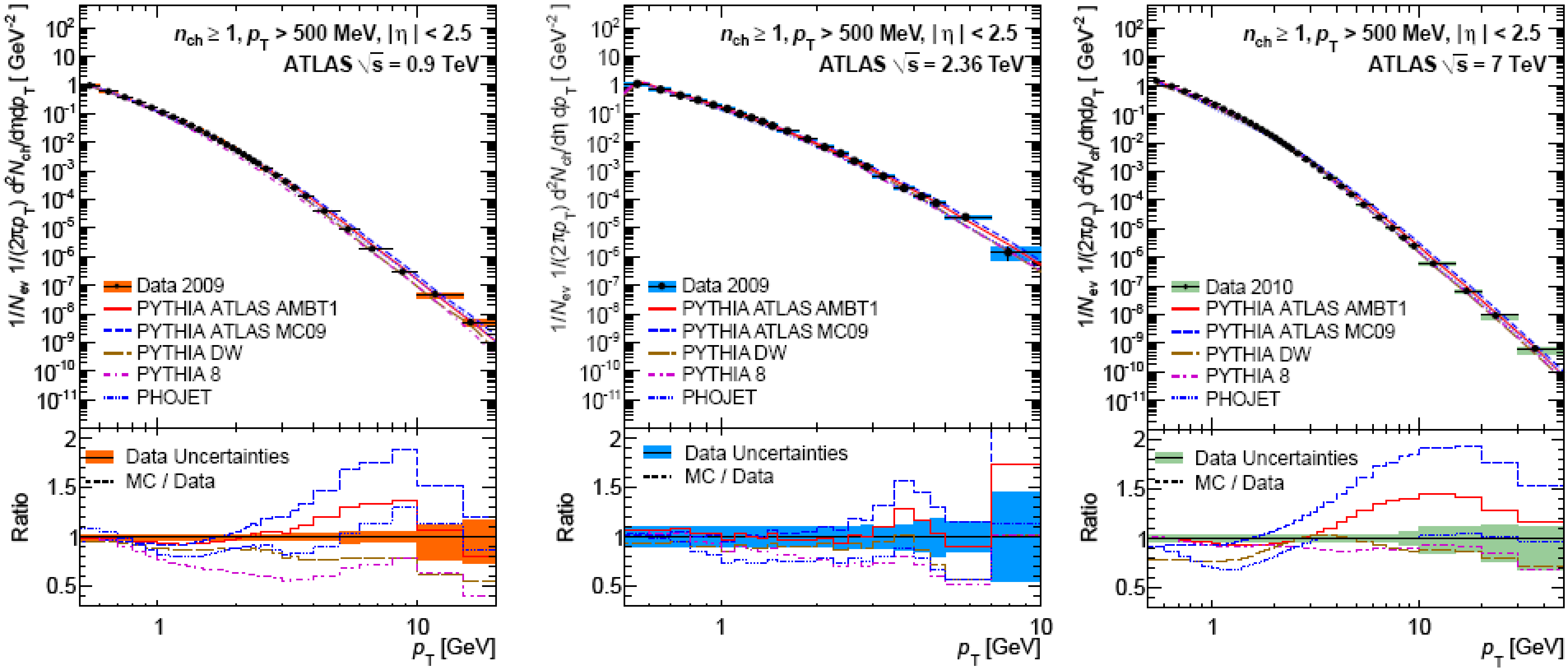
phase space with „hard"-component



- Achieve much better description of the data at √s = 900 GeV, only AMBT1 and pythia8 at √s = 7 TeV match the data

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

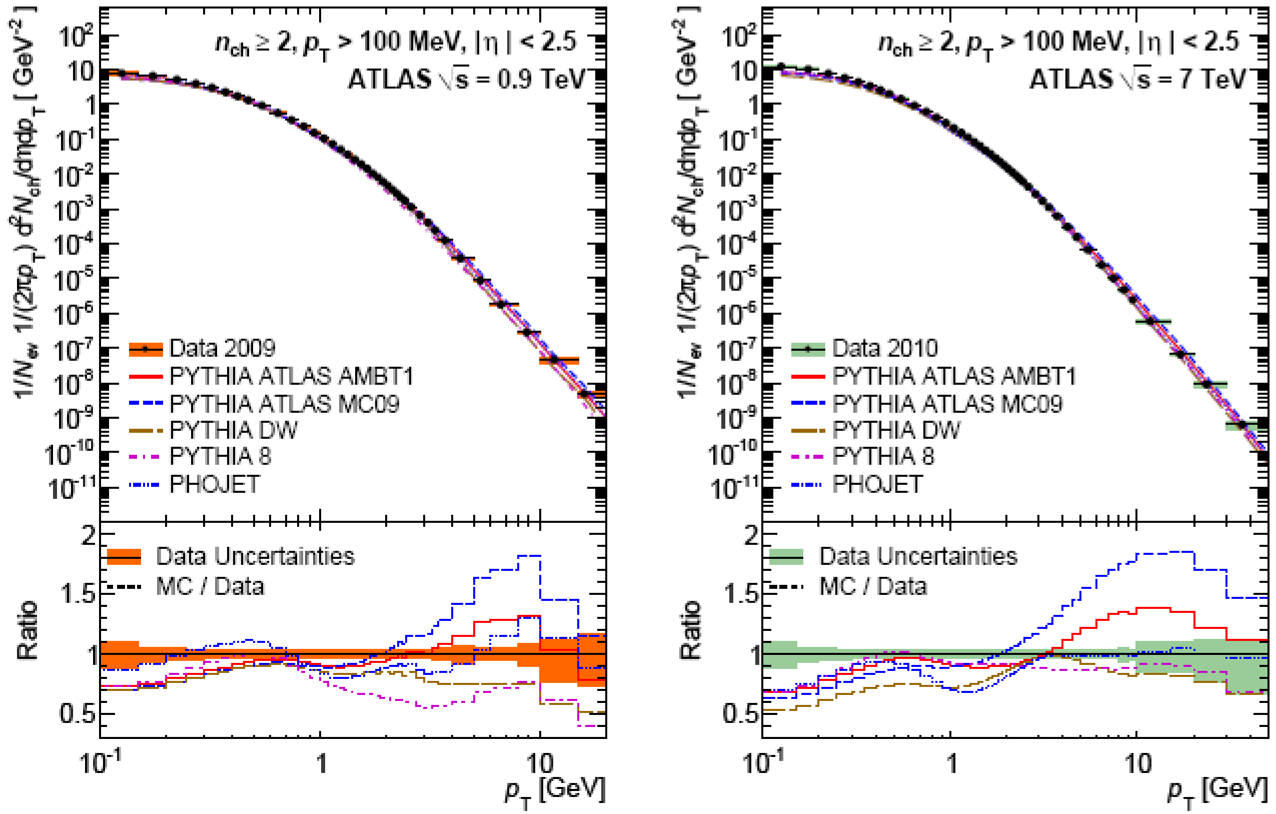
phase space at all 3 energies



- Not described by any of the models, especially above 1 GeV
- pythia8 comes quite close to the data at √s = 7 TeV

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

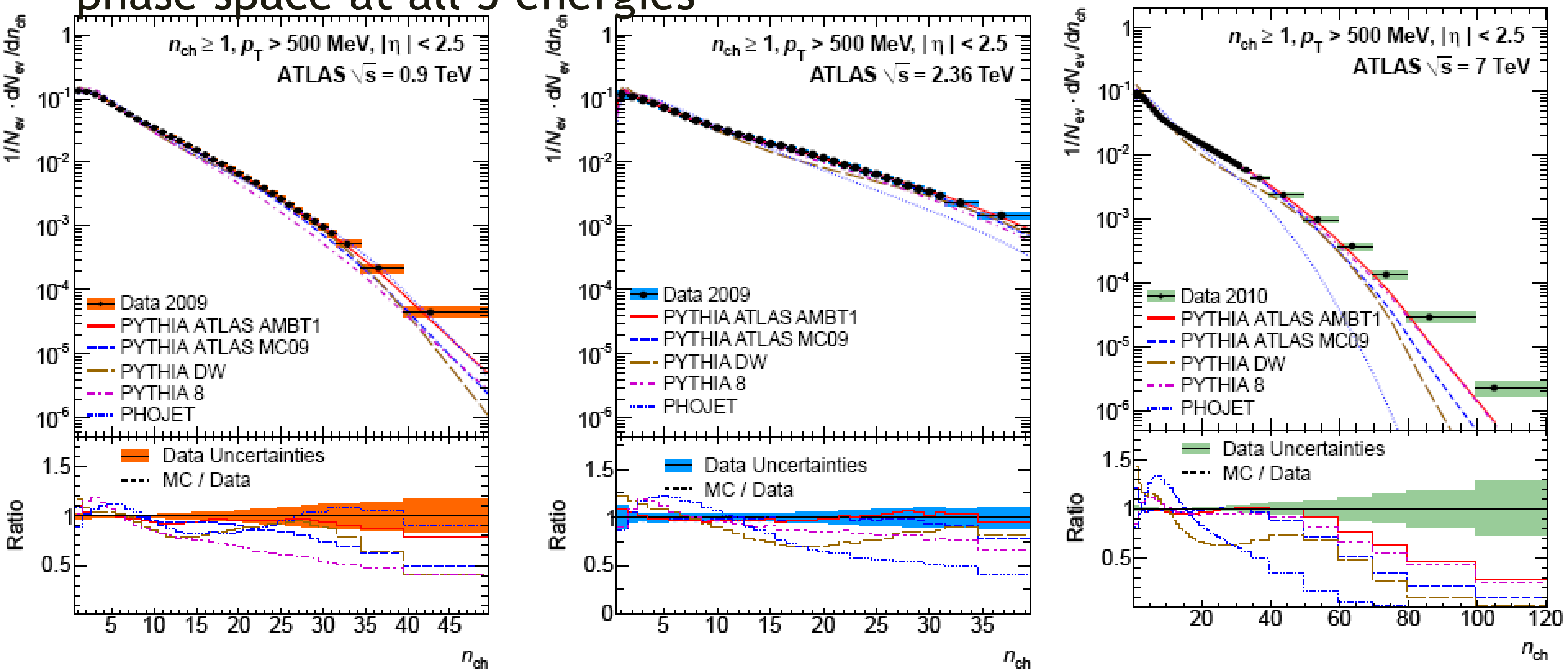
most inclusive phase space



- √s = 900 GeV phojet describes the data best over the whole range, even though the agreement is not excellent
- generally low p_T particles are underprediced, more significant at √s = 7 TeV

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

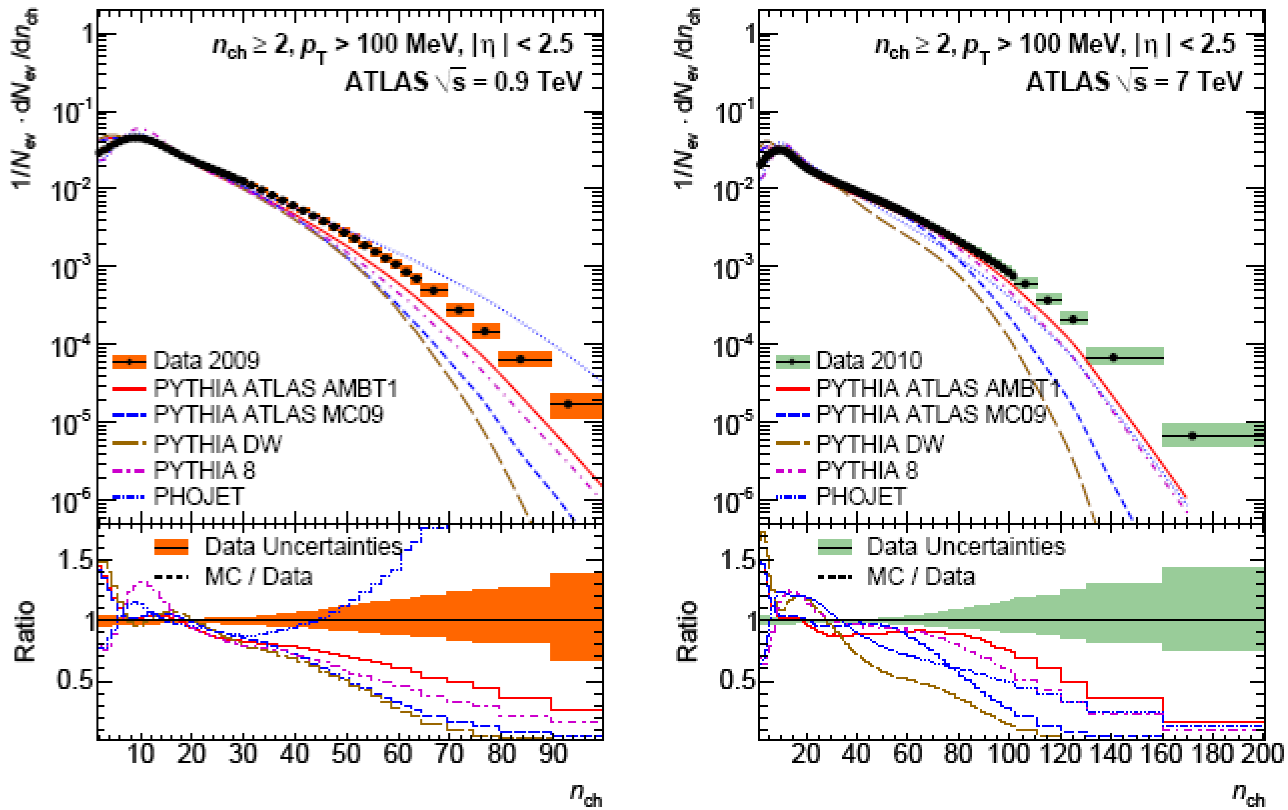
phase space at all 3 energies



- Models overpredict low-multiplicity events, compensated by underprediction of high-multiplicity events
- phojet models distribution reasonbly well but only at √s = 900 GeV

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

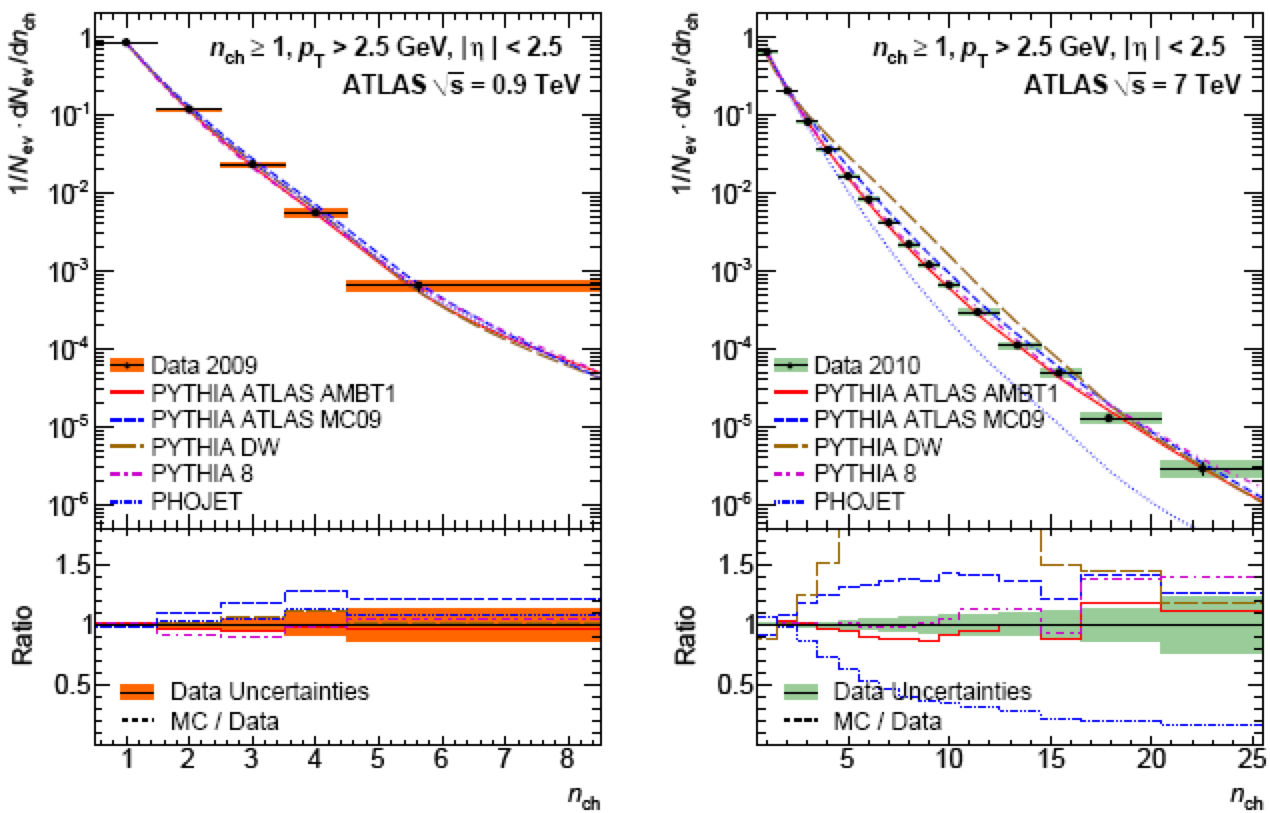
most inclusive phase space



- Variations of low and high multiplicity events are even larger here

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

phase space with hard component



- Fairly good at √s = 900 GeV, but large difference between the tunes/models √s = 7 TeV : all but AMBT1 and pythia8 are very different to the data

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

„Old“ method: correction in 2 steps

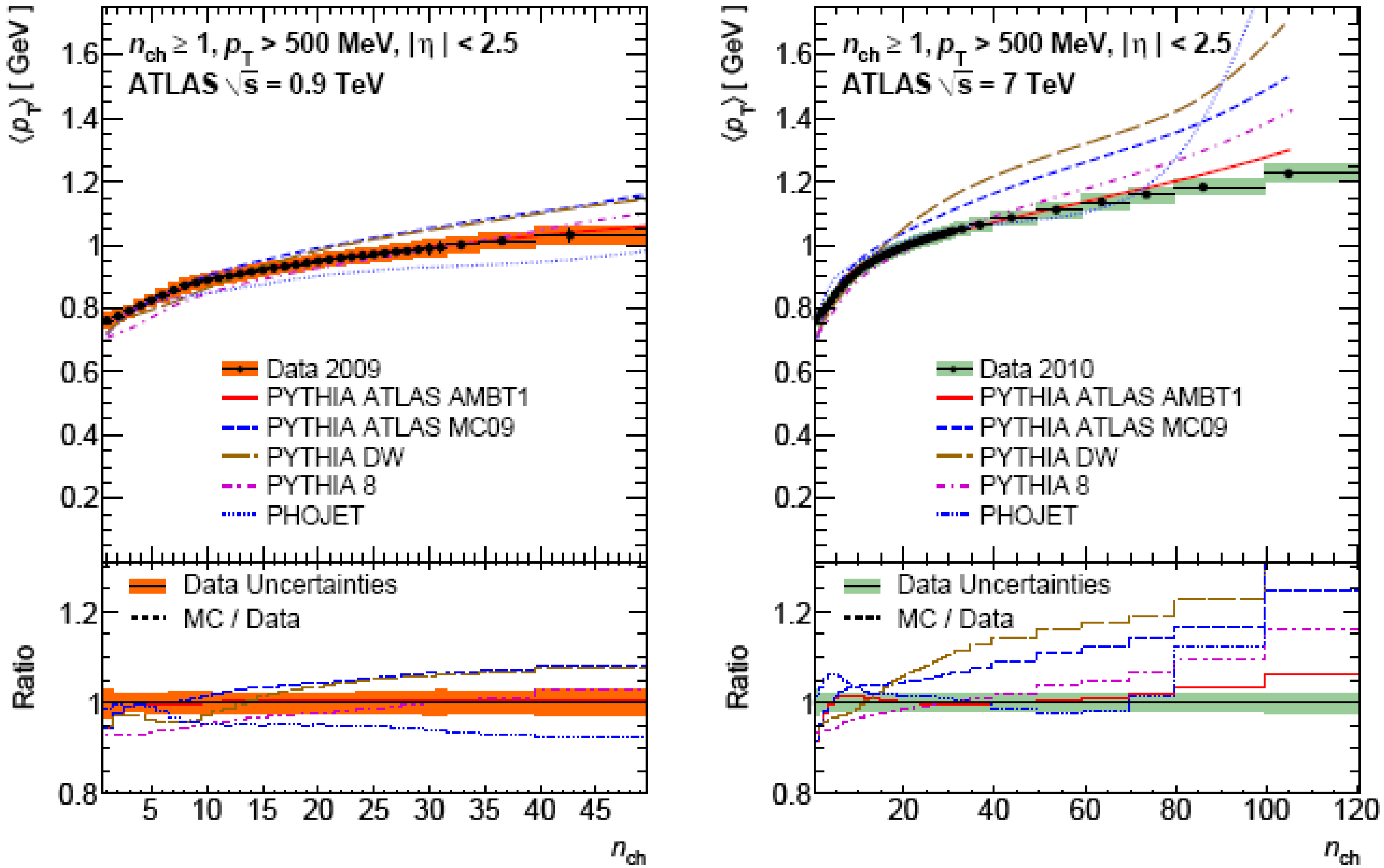
- bin-by-bin correction of $\langle p_{T\ reco} \rangle$ to $\langle p_T \rangle$
- n_{ch} unfolding

New method was developed to remove dependence of MC p_T spectrum

- Correct numerator and denominator seperately, assume
  - tracking efficiency depends only on p_T and η
  - p_T spectrum is the same in the n_{sel} bin and the n_{ch} bin the event migrates to
- Limited validity is visible in closure tests
  - considered as systematic uncertainty (estimated using different MC samples)

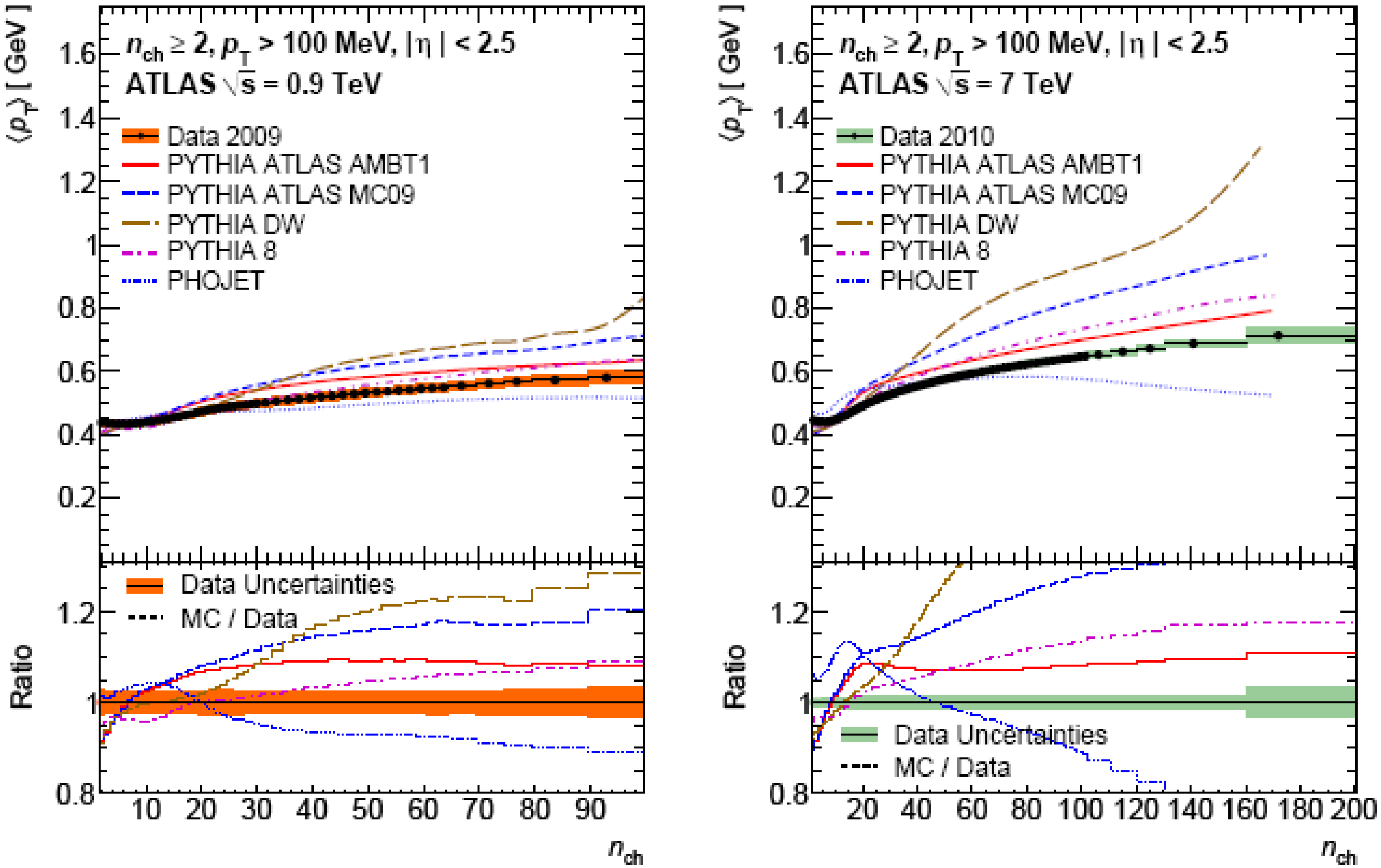
→ Change of mean values from 2% up to 4% at higher n_{ch} values in the most inclusive phase space. Understood as p_T spectrum difference between data and MC.

$<p_T>$ vs. n_{ch}



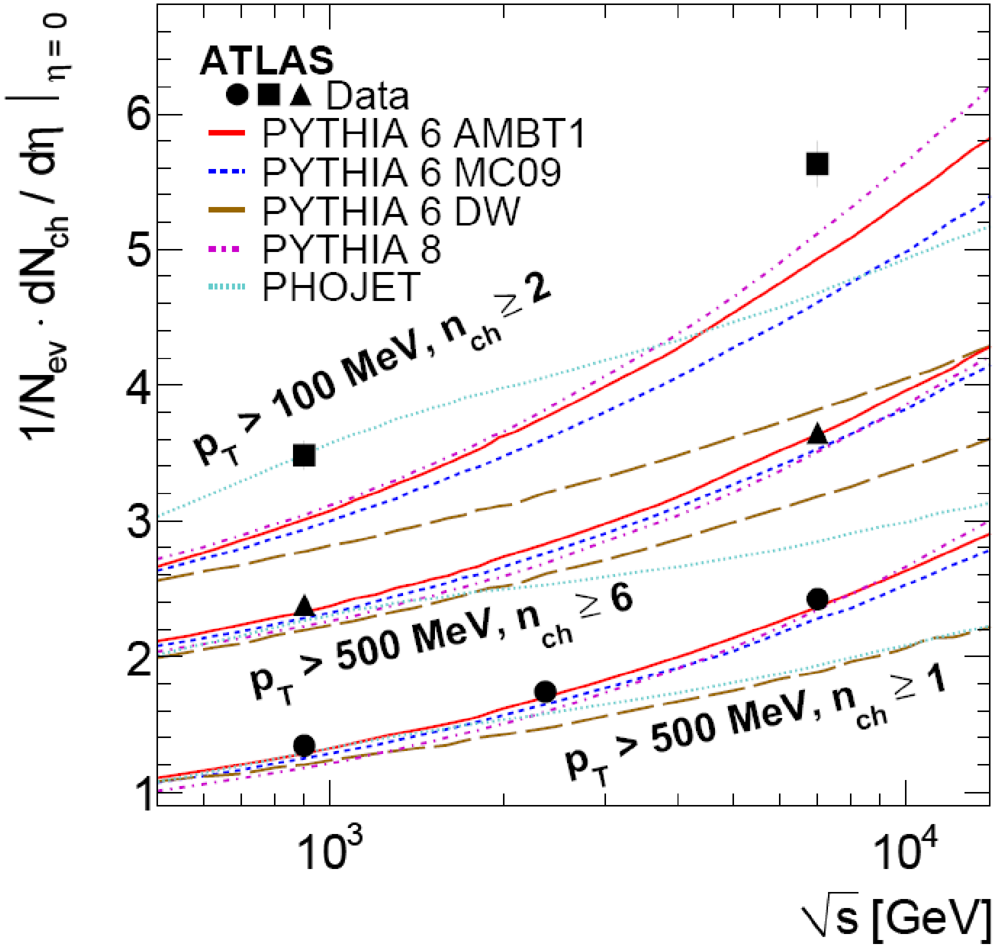
- AMBT1 tune yields the closest description of the data

$<p_T>$ vs. n_{ch}



- Still true in the most inclusive phase space, but discrepancy gets larger
- Measurements are very precise

$1/N_{ev} dN_{ch}/d\eta$ at $\eta = 0$



- The harder the p_T cut the better the agreement.
- Only data points at $\sqrt{s}$ = 900 GeV is well matched by phojet .

Extrapolation to $p_T = 0$

- For comparison purposes, extrapolate p_T spectrum down to $p_T = 0$
- Estimate number of charged-particles with $p_T < 100$ MeV with 3 different methods
- Each methods yields a correction factor that is applied to the mean charged-particle mutiplicity in bins of η averaged over |η| < 2.5
- Differences taken as syst. uncertainty

Method	cf at $\sqrt{s}$ = 900 GeV	cf at $\sqrt{s}$ = 7 TeV
1	1.065	1.063
2	1.068	1.065
3	1.055	1.051

final result

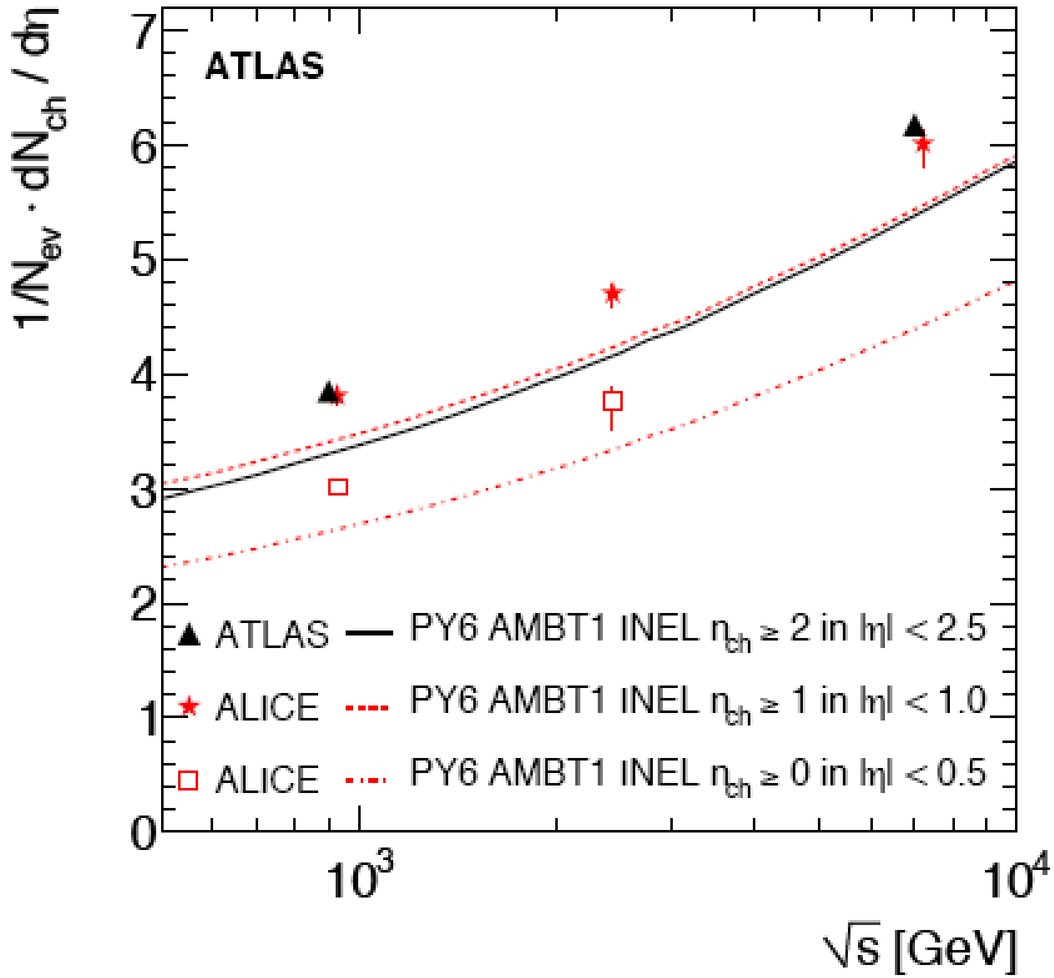
1.065 ± 0.011 (tot) at $\sqrt{s}$ = 900 GeV	**1.063 ± 0.014 (tot) at $\sqrt{s}$ = 7 TeV**

- Method 1: Use a modified Tsallis function to fit the p_T spectrum (accounts also for fact that η is measured while y is used)
- Method 2: Assume p_T distribution is flat in the lower p_T region. Extract correction factor from first measured bin $100 < p_T < 150$ MeV
- Method 3: Use AMBT1

Comparisons

- p_T extrapolation allows better comparison with ALICE data
- But: no attempt was made to correct for the $n_{ch} \geq 2$ requirement (too model dependent)

→ Comparisons are much easier in common phase spaces



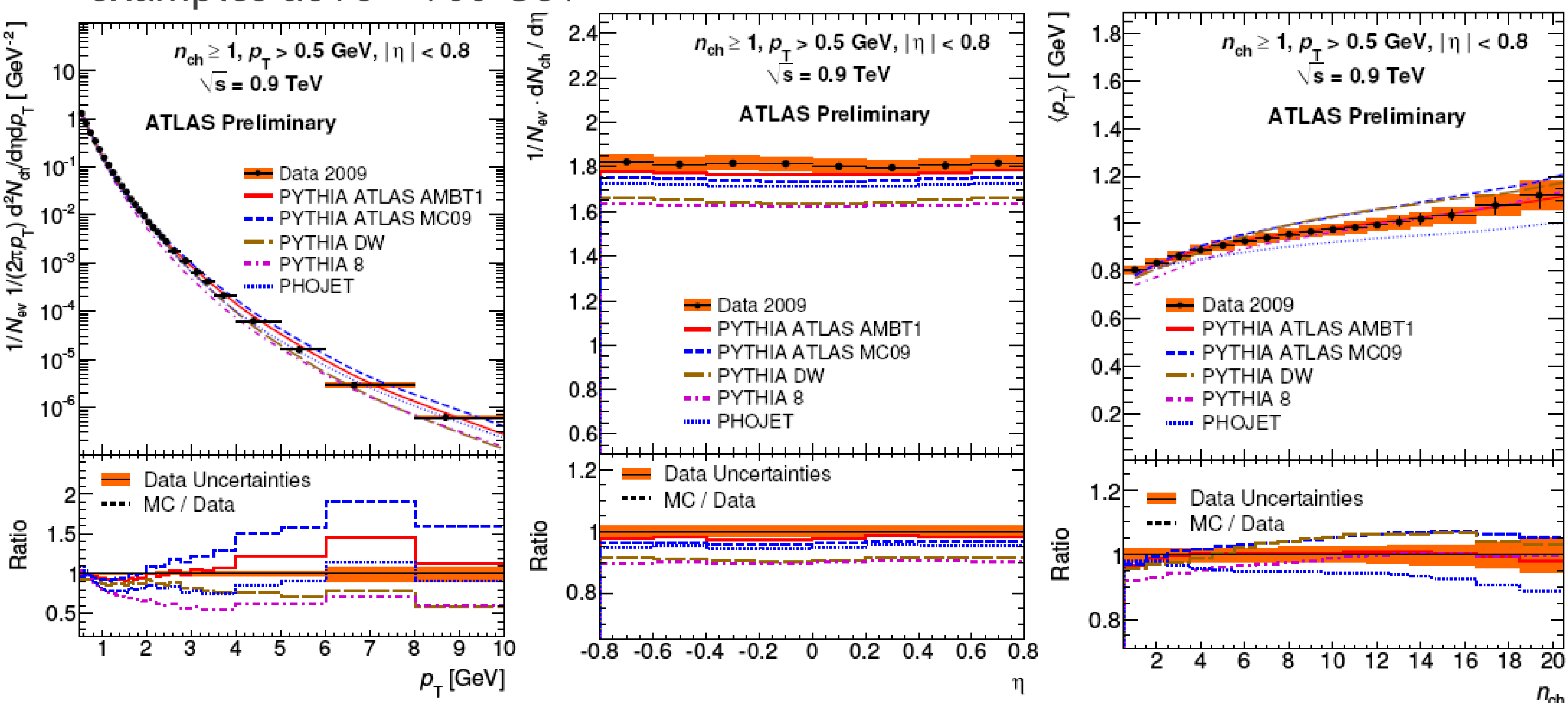
MB Common Plots

ATLAS-CONF-2010-101

- **All MB** distributions analysed in „common“ phase spaces with the same analysis procedure

$n_{ch} \geq 1$, $|\eta| < 0.8$, $p_T > 0.5, 1$ GeV at $\sqrt{s} = 0.9, 7$ TeV

examples at $\sqrt{s}$ = 900 GeV



MB Common Plots

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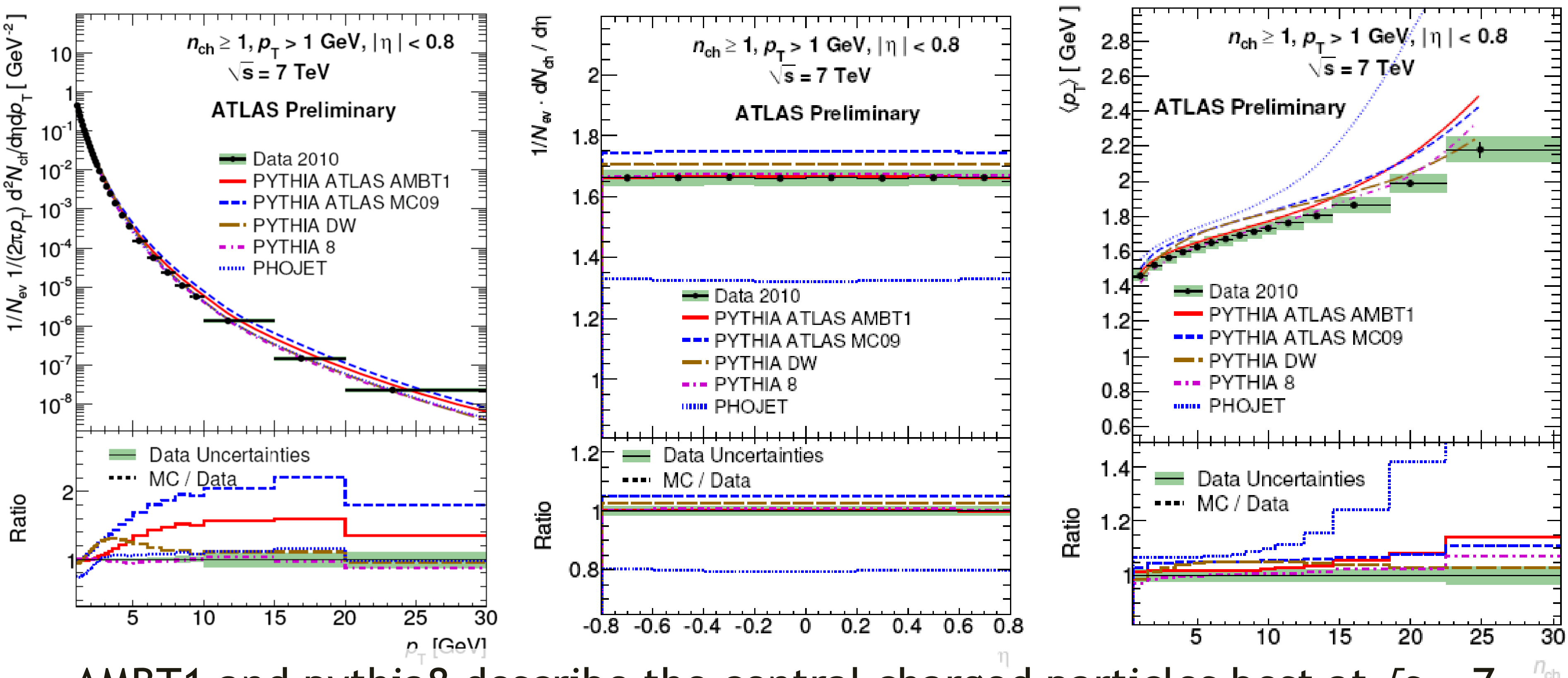
- Examples for other phase space

$n_{ch} \geq 1$, $|\eta| < 0.8$, $p_T > 1$ GeV at $\sqrt{s} = 0.9$, 7 TeV



- AMBT1 and pythia8 describe the central charged particles best at $\sqrt{s}$ = 7 TeV, but pythia8 provides a better description of the high p_T tails

Conclusion

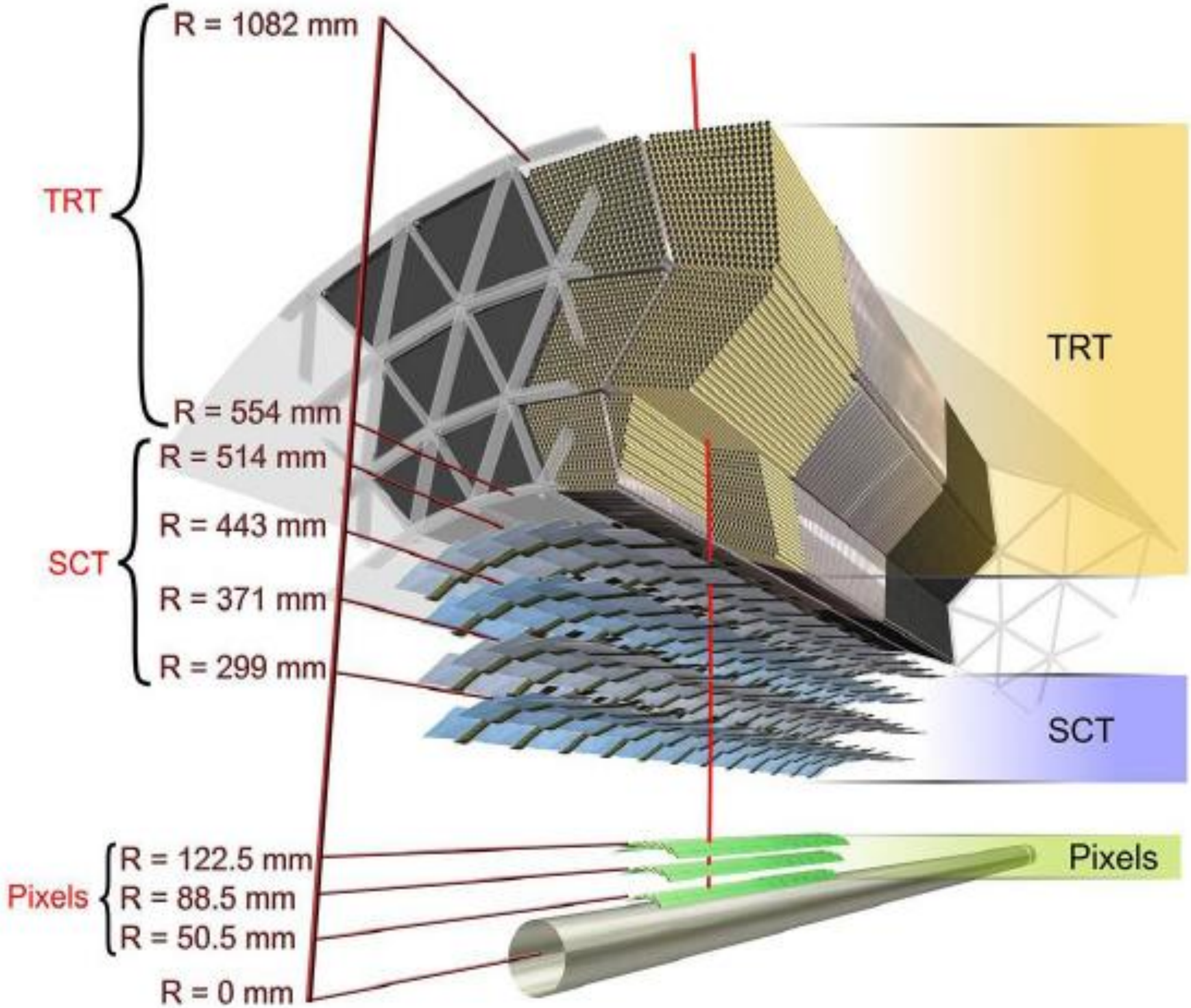
- Properties of charged-particles were studied in well defined phase space regions
- Data was corrected with minimal model dependence
- Precision of this analysis reveals clear differences between the MC models and the measured distributions
- In general agreement in models and data are better when diffractive contribution is smaller
- More analysis details in the paper

→ 2nd MB Paper: arXiv 1012.5104

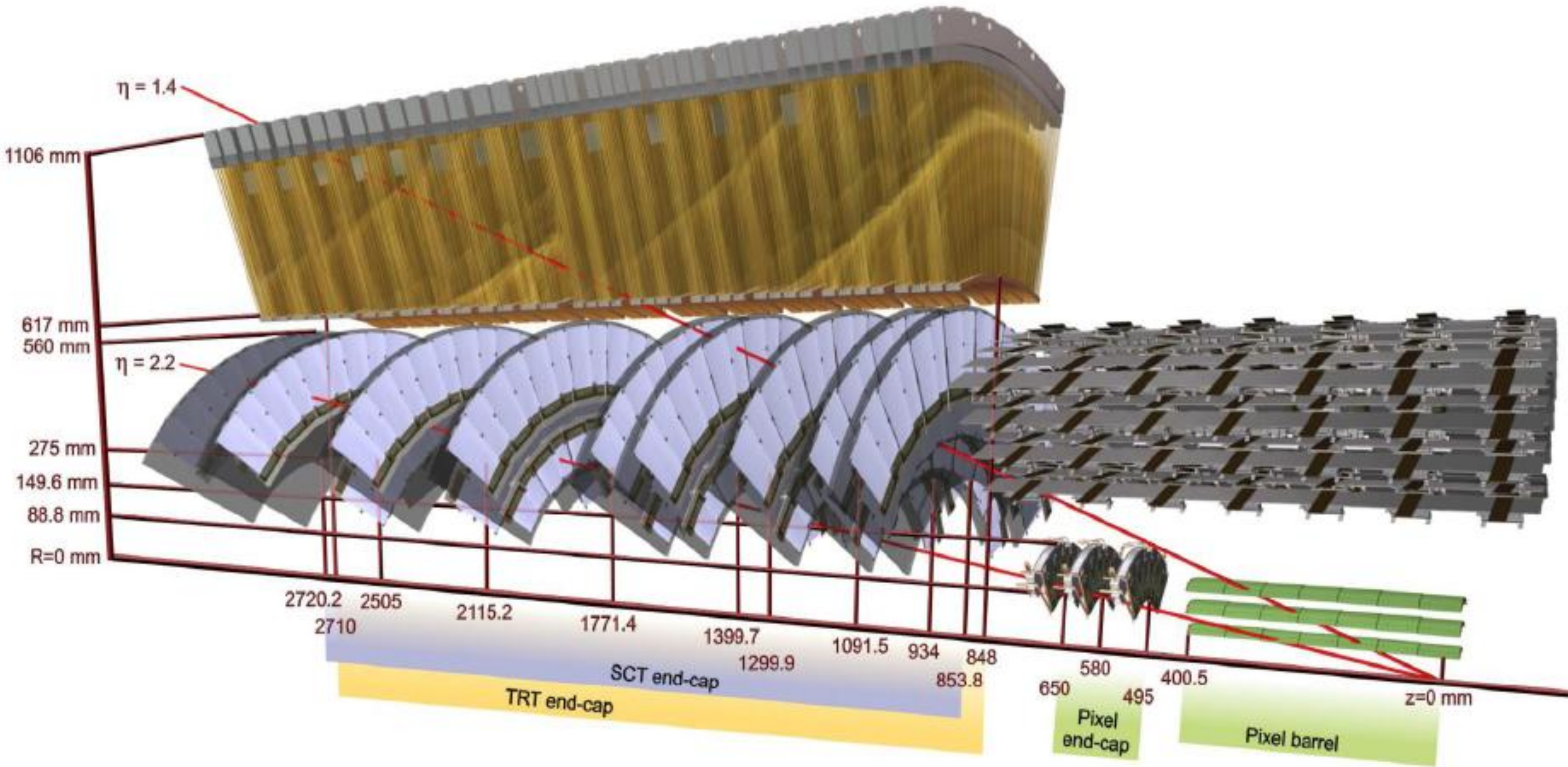
  - see also public page: https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/MinBias_02/
  - HEPDATA http://hepdata.cedar.ac.uk/view/p7918

back up

ATLAS Inner Detector Barrel



ATLAS Inner Detector Endcap



Event Selection

Requirements per event

- Single-arm trigger (MBTS_1)
- at least 1 reconstructed vertex for beam background removal
- $n_{ch} \geq 1, 6, 20$
- pile-up removal: if a second reconstructed vertex has ≥ 4 tracks

Track Quality criteria to reduce background to primary tracks

- hit in the innermost layer if expected
- 2,4 or 6 hits in the silicon strip detector depending for p_T < 100, 200 and ≥ 300 MeV (different for the analysis at $\sqrt{s}$ = 2.36 TeV)

Kinematic phase space cuts on the track

- p_T > 0.1, 0.5 or 2.5 GeV
- $|\eta| < 2.5, 0.8$

Event sample:
at $\sqrt{s}$ = 7 TeV: ~190 μb^{-1}
at $\sqrt{s}$ = 900 GeV: ~7 μb^{-1}

Systematic Uncertainty on Tracking Efficiency

Systematic Uncertainty	Size	Region
Material	$\pm 2 - 15\%$	decreases with p_T, increases with $\|\eta\|$
χ^2 prob. cut	$\pm 10\%$	flat, only for $p_T > 10$ GeV
Resolution	$\pm 5\%$ negligible -7%	$100 < p_T < 150$ MeV $0.15 < p_T < 10$ GeV $p_T > 10$ GeV
Track Selection	$\pm 1\%$	flat in p_T and η
Truth Matching	$\pm 1\%$	only for $\sqrt{s} = 2.36$ TeV Pixel Tracks
Efficiency correction factor	$\pm 4\%$	only for $\sqrt{s} = 2.36$ TeV ID Track
Alignment and other high p_T	-3% to -30%	only for $p_T > 10$ GeV averaged over η , increases with increasing p_T

$<p_T>$ vs n_{ch}

new method was developed to remove dependence of MC p_T spectrum:
correct seperatly 2 components

- **Numerator:** Sum p_T of all tracks in all events vs n_{ch}
- **Denominator:** Sum of all tracks in all events vs n_{ch}

→ apply track-by-track corrections

(track weights, no depedence on MC p_T spectrum)

→ use same n_{ch}-unfolding matrix for denominator as for $1/N_{ev}\ dN_{ev}/dn_{ch}$ correction