Tuning of MinBias and the Underlying Event with ATLAS

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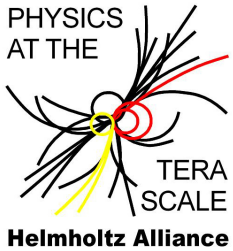
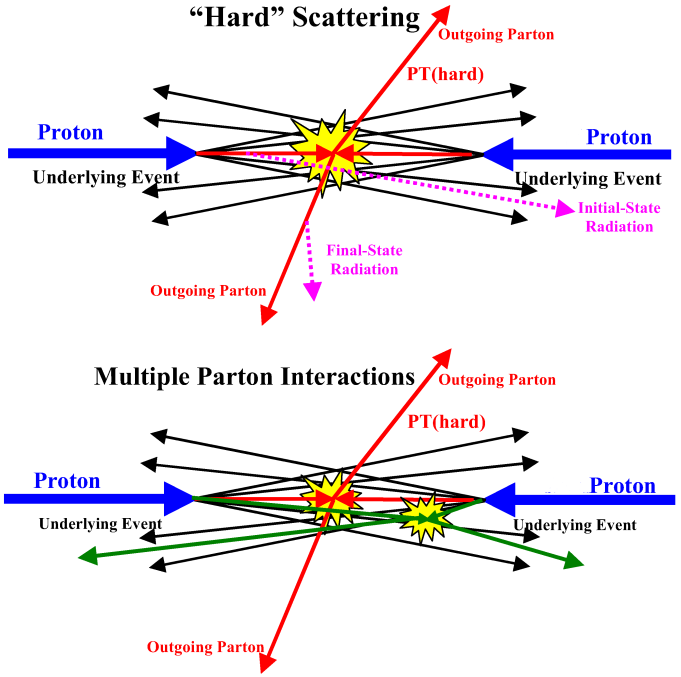
Terascale Workshop, Dresden
December 2, 2010



MC Tuning

- soft-QCD processes described by phenomenological models
  $\Rightarrow$ parameters
  - multi-parton interactions
  - ISR/FSR
  - color reconnection
  - ...
- This talk: only minimum bias and underlying event tuning (mostly showing 7 TeV data, but 900 GeV data important for tuning)
- just a biased selection!



Results from:

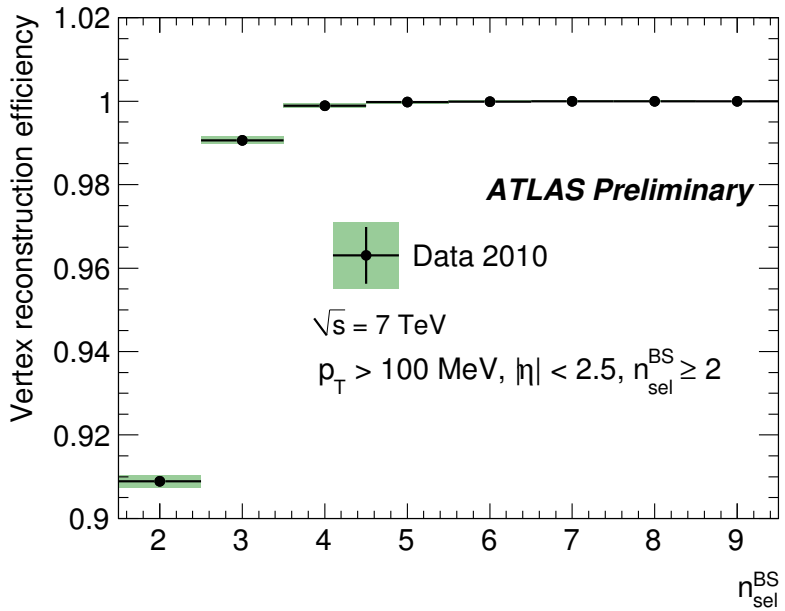
- Phys. Lett. B **688** (2010) 21
- ATL-CONF-2010-024, 029, 031, 046, 047, 081

ATLAS Minimum bias philosophy

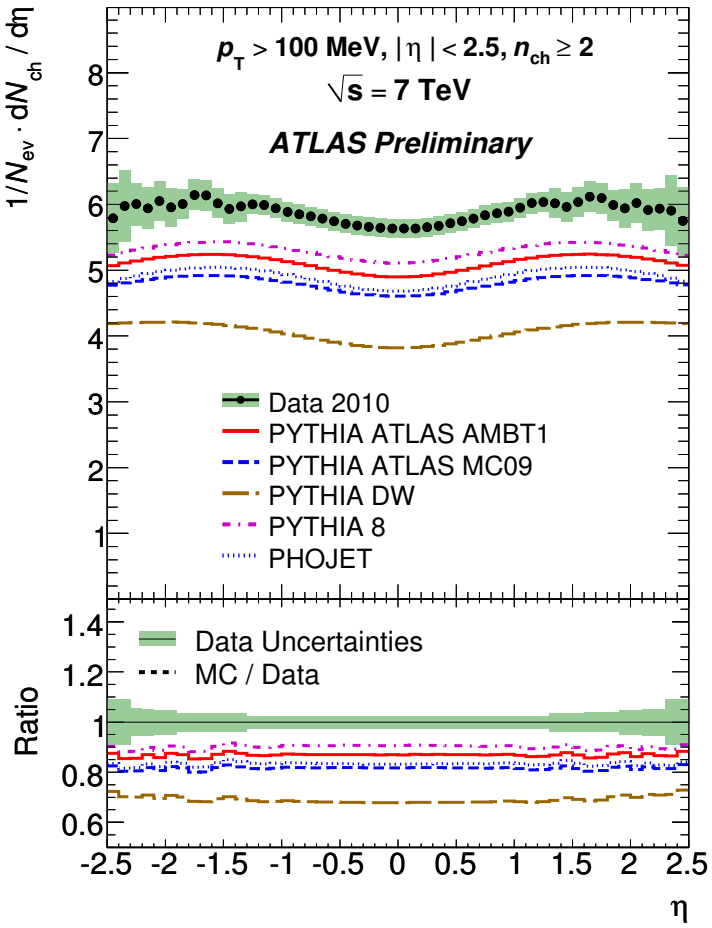
- primary charged particle spectra:
  $\frac{1}{N_{\mathrm{ev.}}}\frac{\mathrm{d}N_{\mathrm{ch}}}{\mathrm{d}\eta}$, $\frac{1}{N_{\mathrm{ev.}}}\frac{\mathrm{d}N_{\mathrm{ev}}}{\mathrm{d}n_{\mathrm{ch}}}$,
  $\frac{1}{N_{\mathrm{ev.}}}\frac{1}{2\pi p_{\mathrm{T}}}\frac{\mathrm{d}^2N_{\mathrm{ch}}}{\mathrm{d}p_{\mathrm{T}}\mathrm{d}\eta}$, $\langle p_{\mathrm{T}}\rangle$ vs. N_{ch}
- no corrections to model-dependent definition (e.g. non-single diffractive)
- no extrapolation into unmeasured phasespace
- use **well-defined** phase-space:
  $p_{\mathrm{T}} > 500\ \mathrm{MeV}, |\eta| < 2.5$,
  $N_{ch} \geq 1$ or $N_{ch} \geq 6$ (later)
  $p_{\mathrm{T}} > 100\ \mathrm{MeV}, |\eta| < 2.5$,
  $N_{ch} \geq 2$

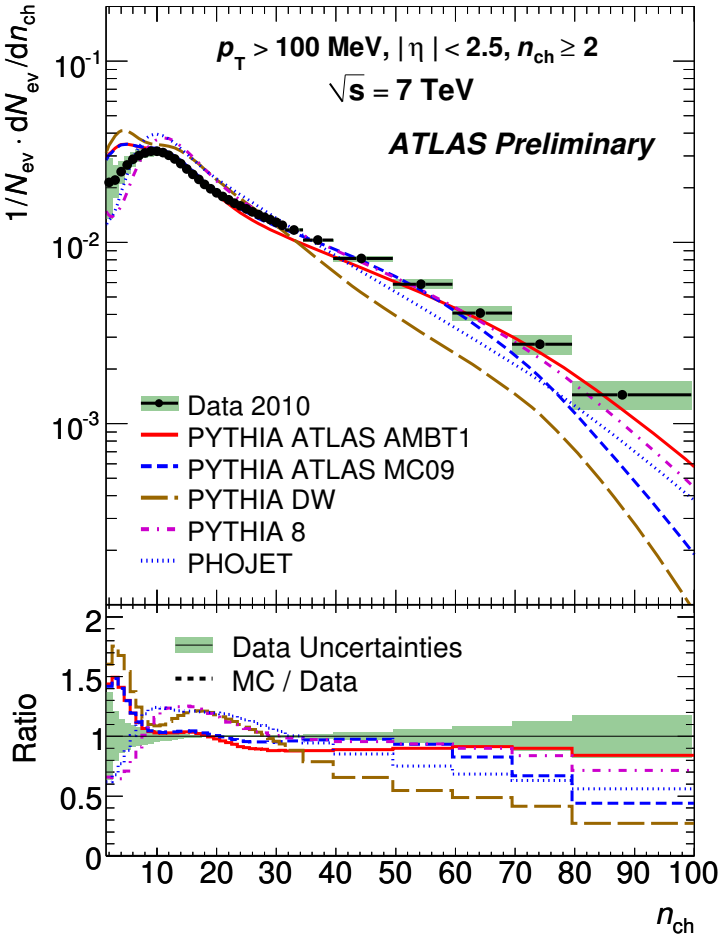
Corrections

- from data:
  - trigger
  - vertexing (tracks wrt. beamspot)



- from simulation:
  - tracking efficiency
  - secondaries, ...



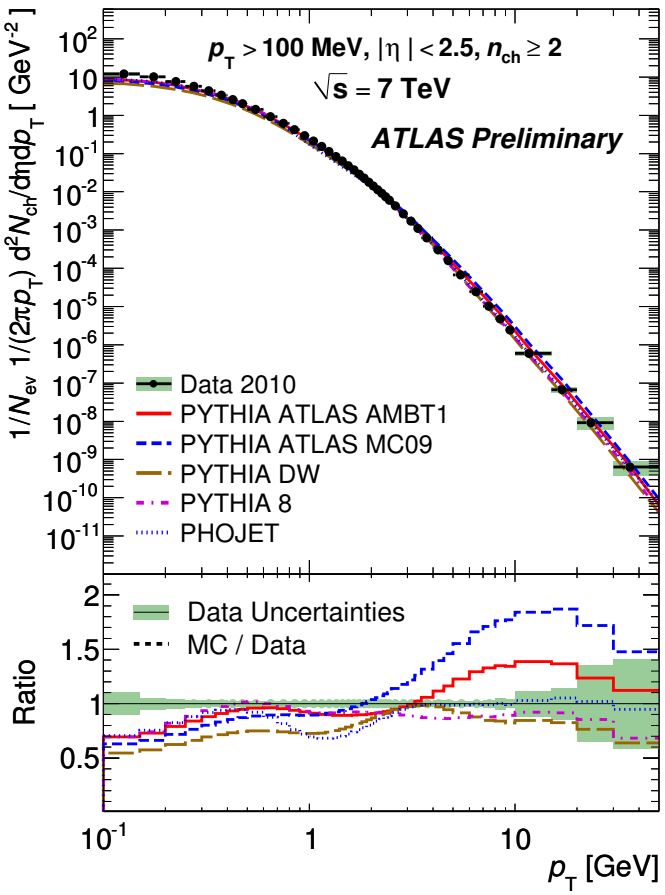


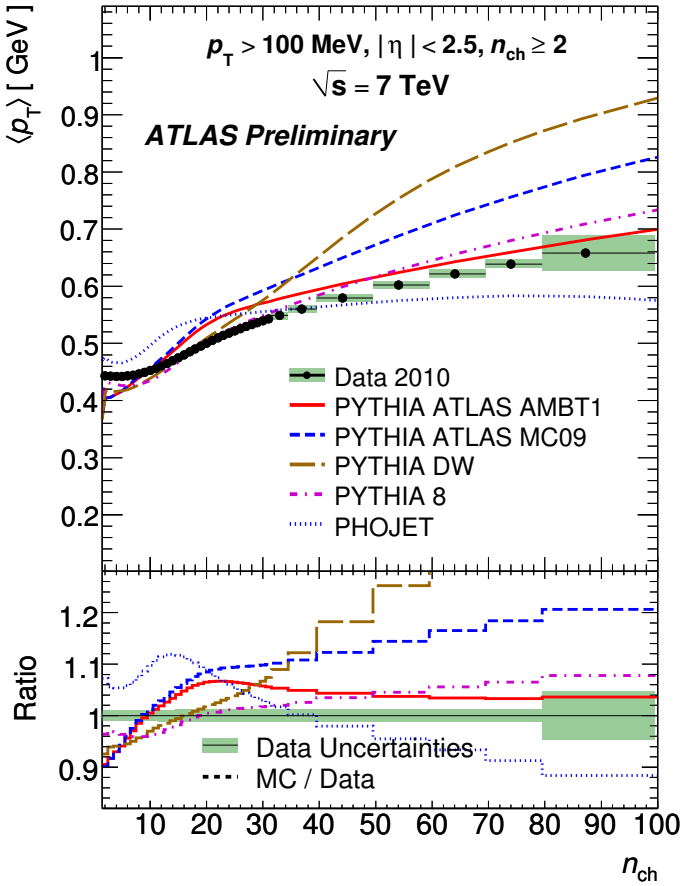
Pseudorapidity density

- all models below the data
- AMBT1 ⇒ described later

Multiplicity

- low N_{ch} overestimated
  ⇒ normalization bias





Transverse Momentum

- Pythia6 p_T-ordered shower (AMBT1, MC09) too high around 10 GeV

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

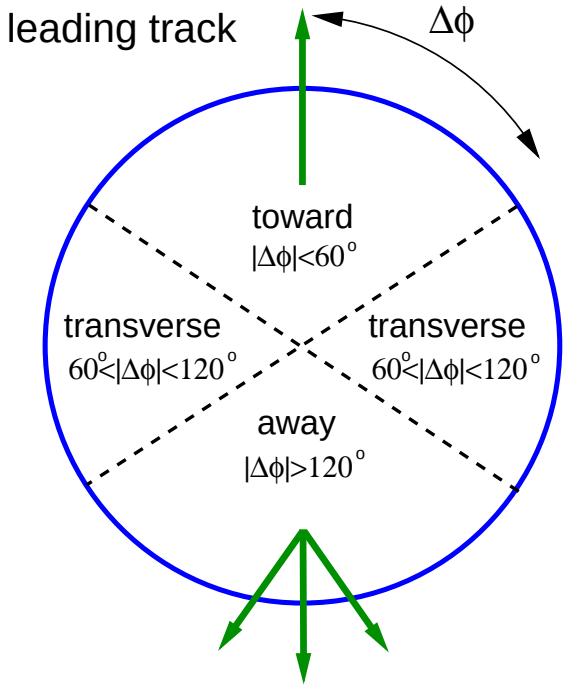
- very sensitive to colour reconnection model, e.g. DW: older model

Underlying Event

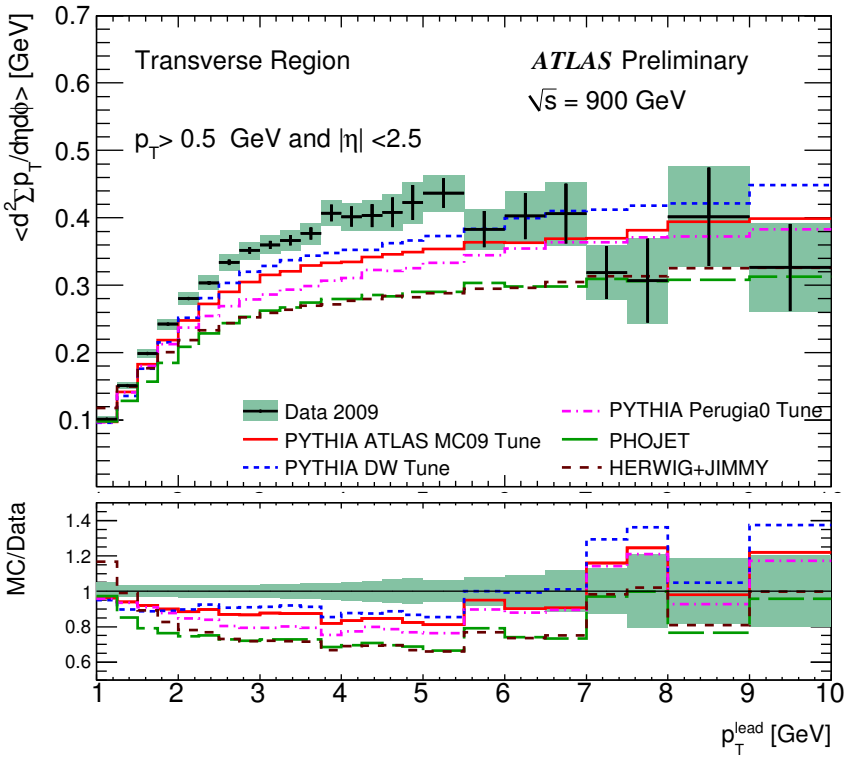
- contributions additional to hard scattering: multi-parton-interactions, ISR, ...

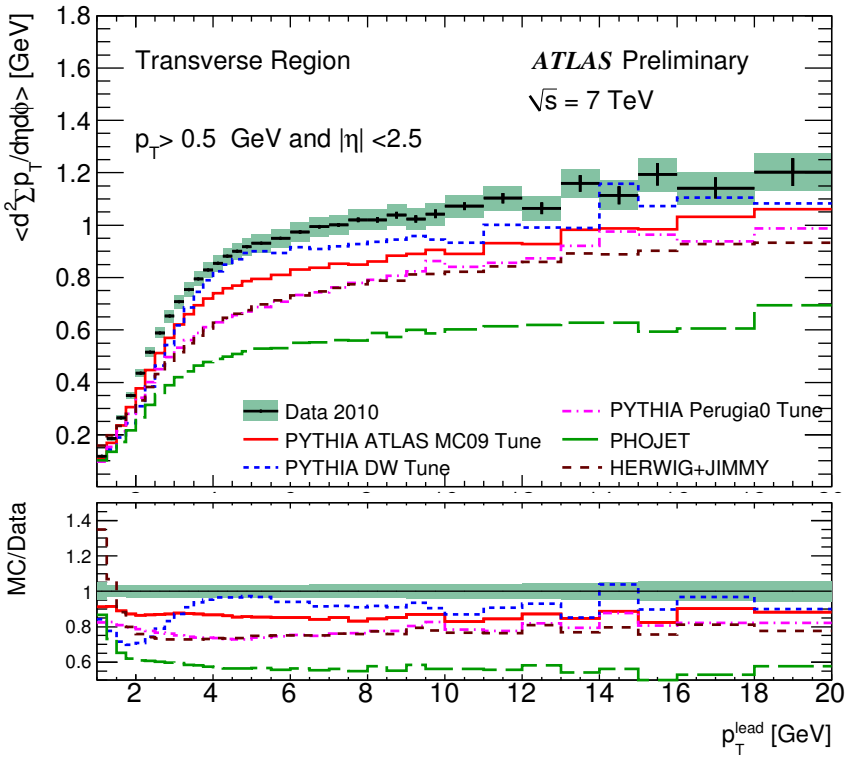
How to measure the UE?

- Separate off hard scattering region
- Assume Di-jet structure
- Region transverse in ϕ to Jets is filled mostly by UE
- in ATLAS so far:
  - Use leading track to define directions
  - fully corrected to charged particle level
- Obs.: $\langle N_{\mathrm{ch}} \rangle$ and $\langle p_{\mathrm{T}}^{\mathrm{sum}} \rangle$ densities



ATL-CONF-2010-029,
ATL-CONF-2010-081





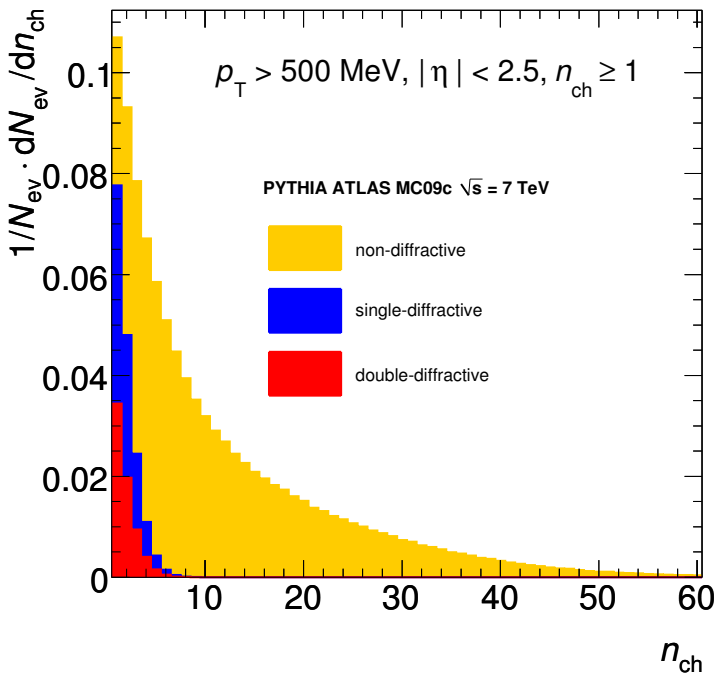
Underlying Event Data (N_{ch} profiles similar)

- pre-LHC tunes of PYTHIA6 too low, even at $\sqrt{s} = 900$ GeV
- DW best (only shown tune based on Q^2 ordered shower)
- PHOJET problematic at both energies

Diffraction Mismodelling?

- MC overshoots minbias data for small $N_{\mathrm{ch}} \Rightarrow$ normalization broken, also affects other observables
- Mismodelling of diffraction?
- diffraction-reduced phase-space: $N_{\mathrm{ch}} \geq 6, p_{\mathrm{T}} > 500\ \mathrm{MeV}$

Pythia6, $\sqrt{s} = 7\ \mathrm{TeV}$



ATLAS Minimum Bias Tune 1 (AMBT1)

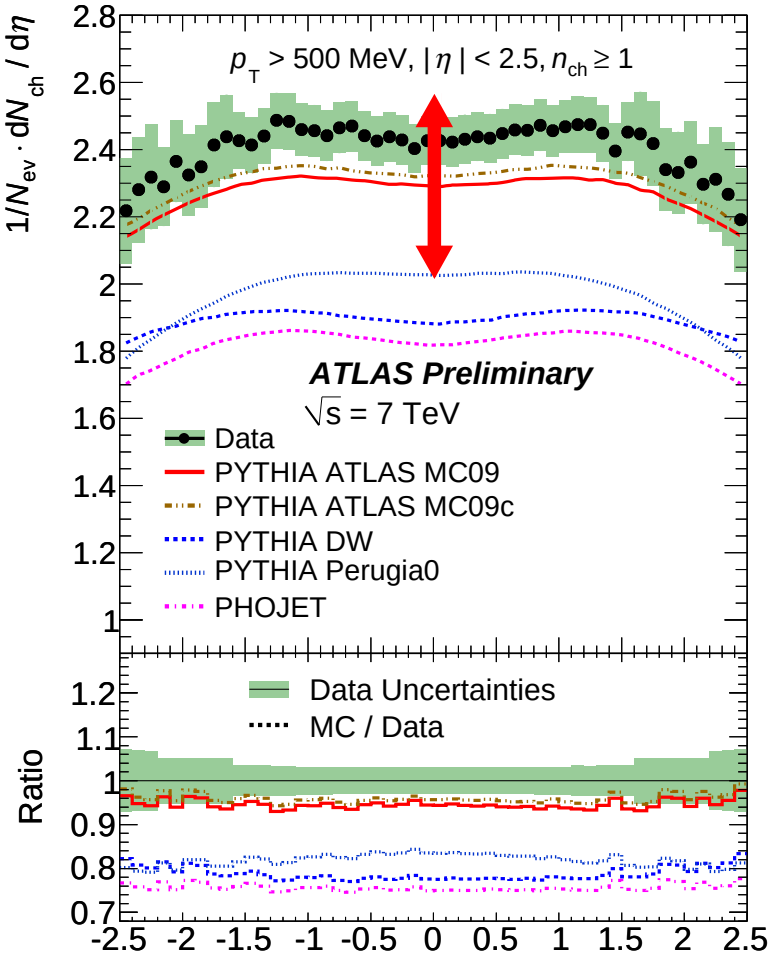
- first tune to 7 TeV LHC data
- Basis: ATLAS MC09 tune – LO* PDF, p_T ordered shower, ... (MC09 tune described in ATL-PHYS-PUB-2010-002)

Parameters considered

- regularization cut-off in $2 \to 2$ scatterings in multiple interactions:

$$p_T^{\min}(E_{cm}) = p_T^{\min}(E_{\mathrm{ref}}) \cdot \left(\frac{E_{cm}}{E_{\mathrm{ref}}}\right)^{\alpha}$$

  - $p_T^{\min}$ lower $\Rightarrow$ more activity



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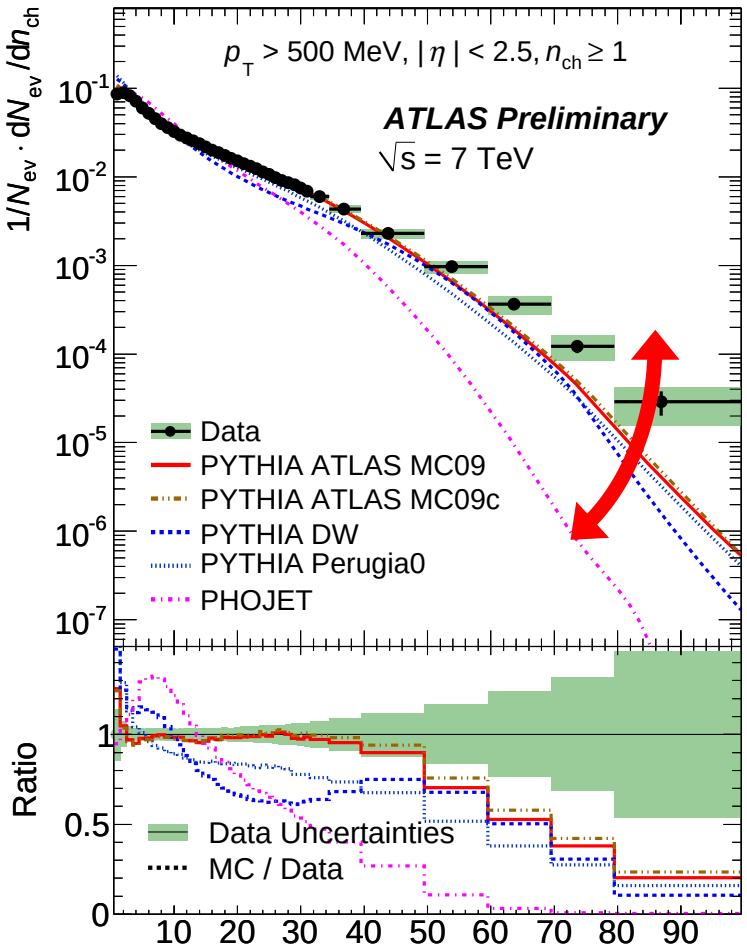
  - central $\leftrightarrow$ peripheral collisions
  - large influence on N_{ch} tail



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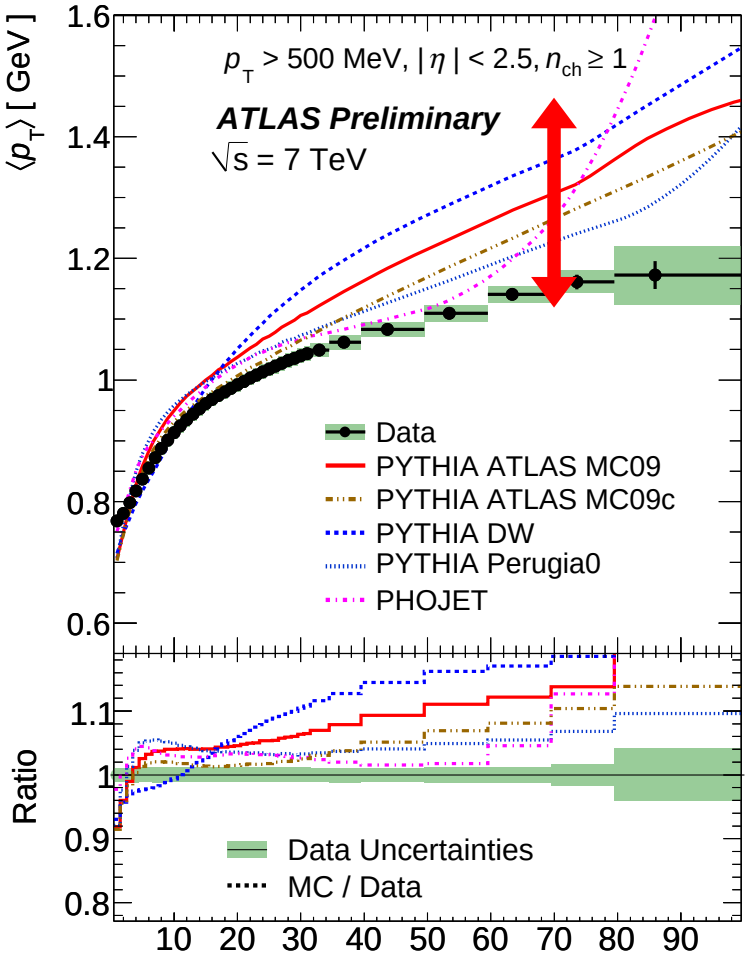
  - partition between N_{ch} and $\langle p_{\mathrm{T}} \rangle$



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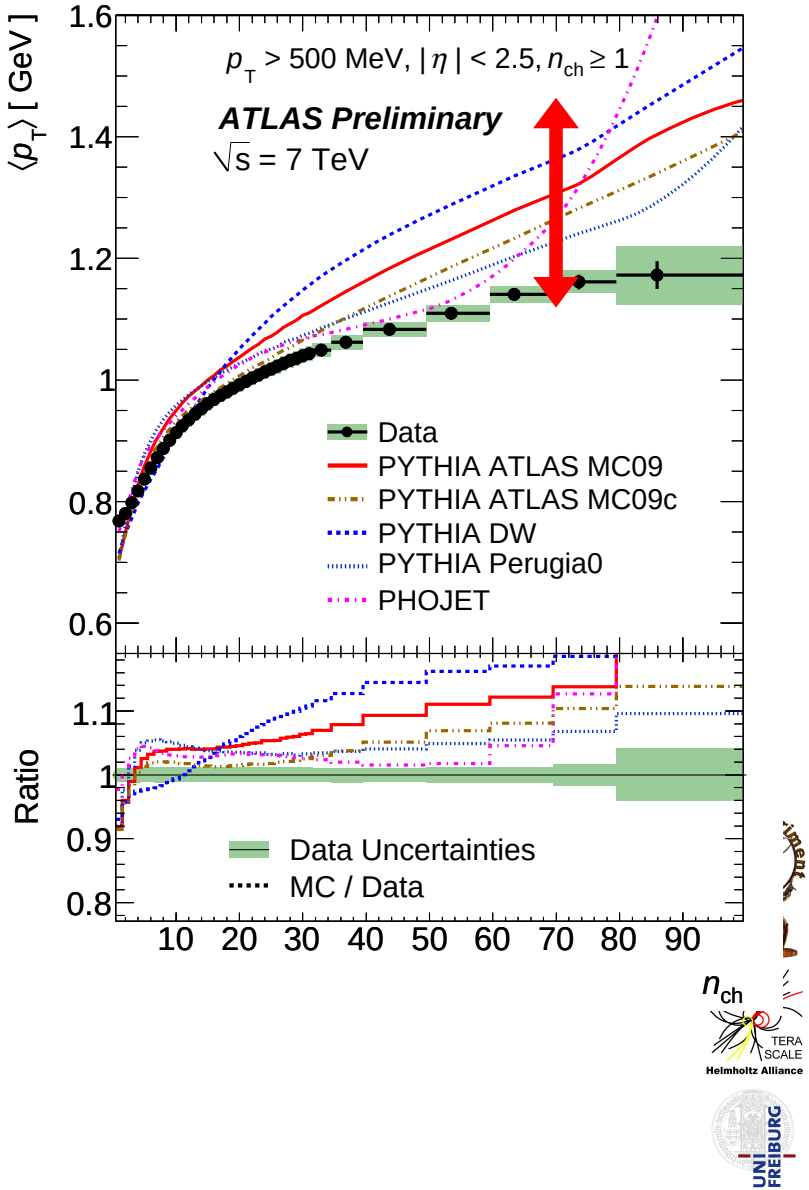
- ... (in total 5 parameters)



Tuning with Professor

1. Random parameter points

(Eur. Phys. J. C **65** (2010) 331)
similar approaches used at LEP for fragmentation tuning (hep-ex/9511011)

(1 bin, 1D example)

Tuning with Professor

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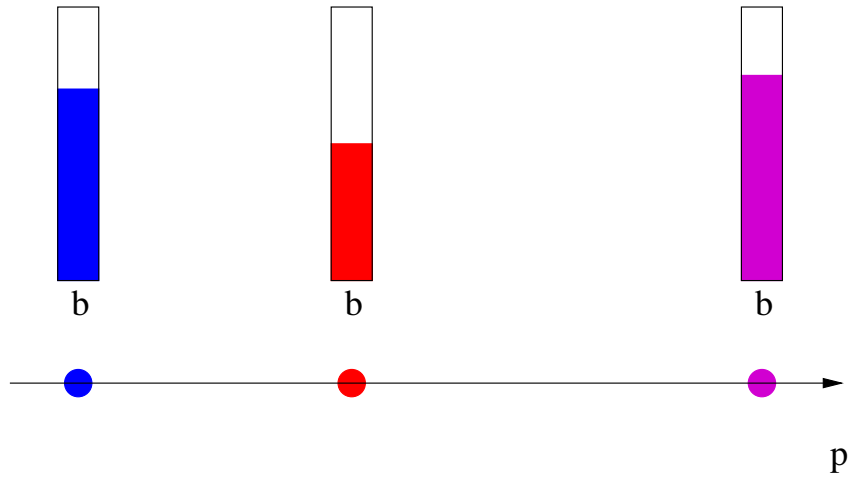

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3. Fit interpolation in each bin

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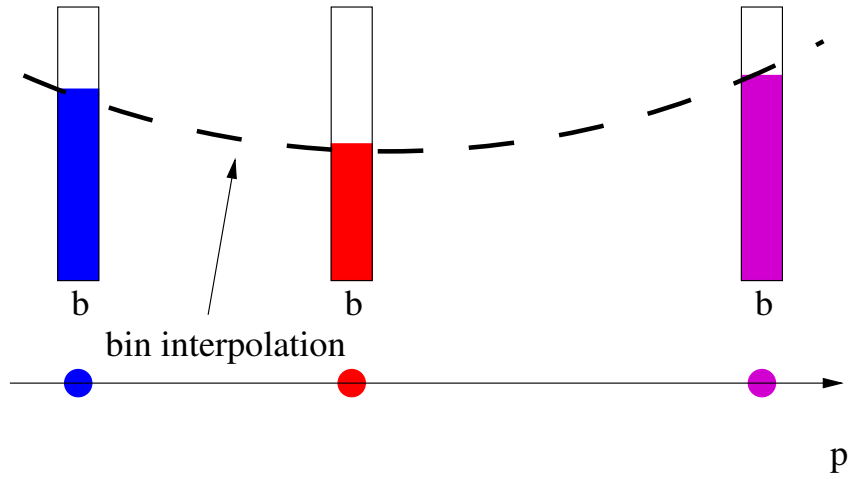

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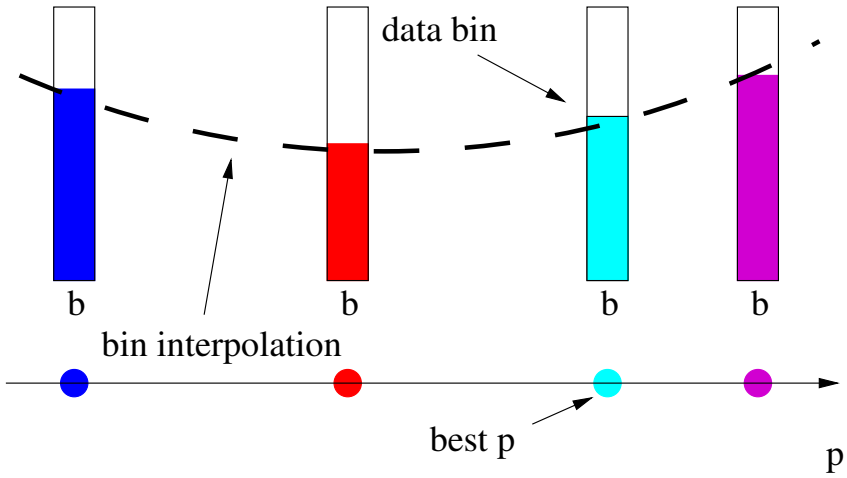

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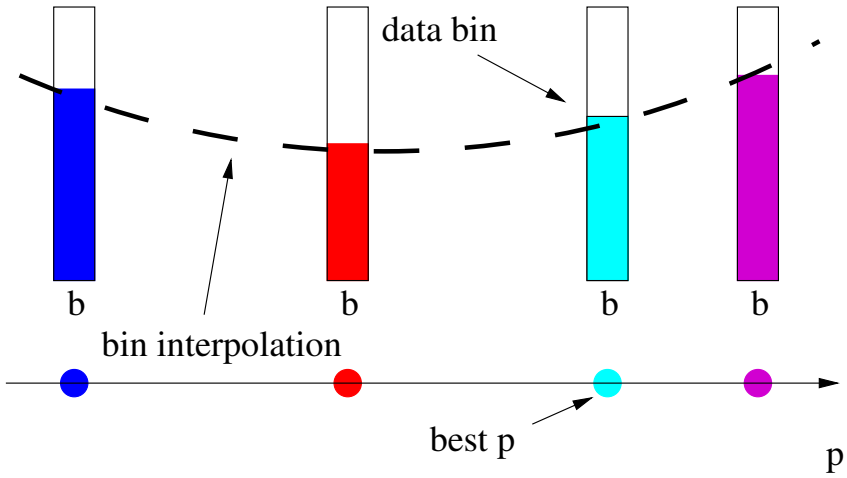
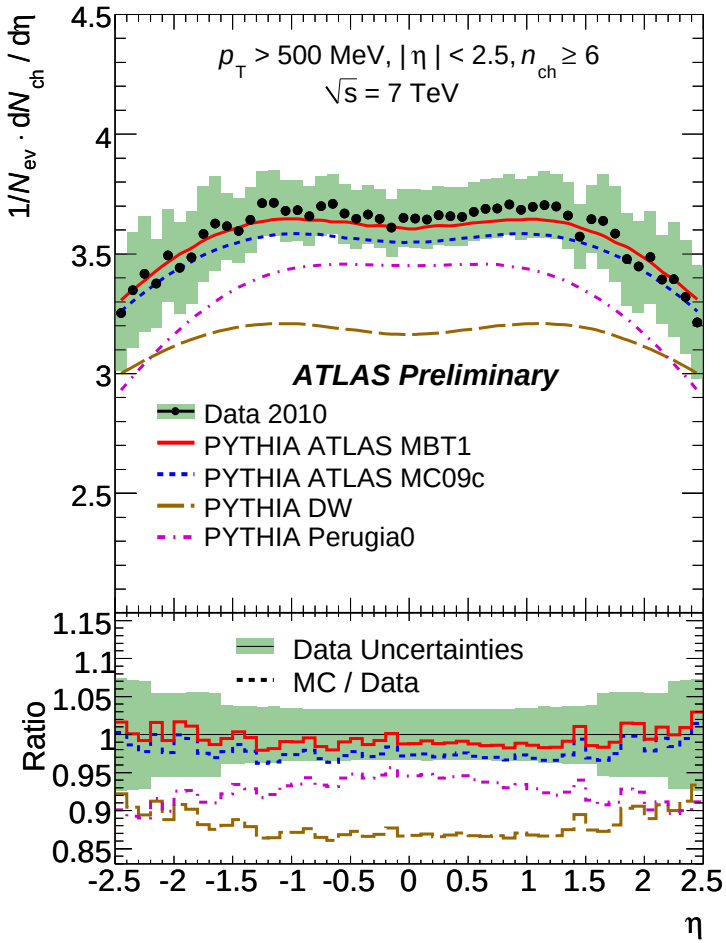
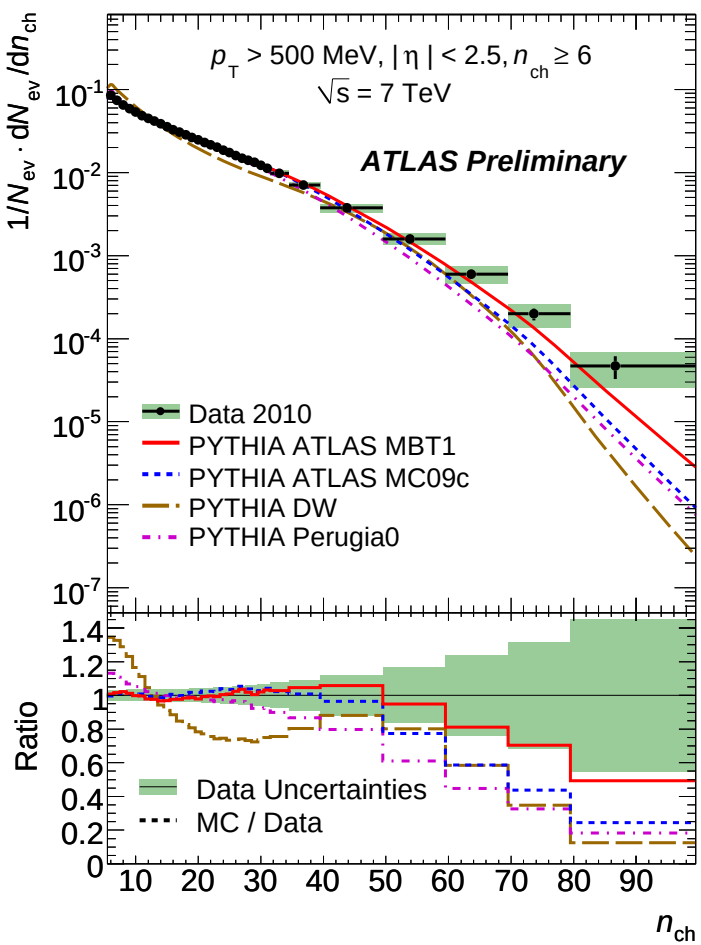


Datasets

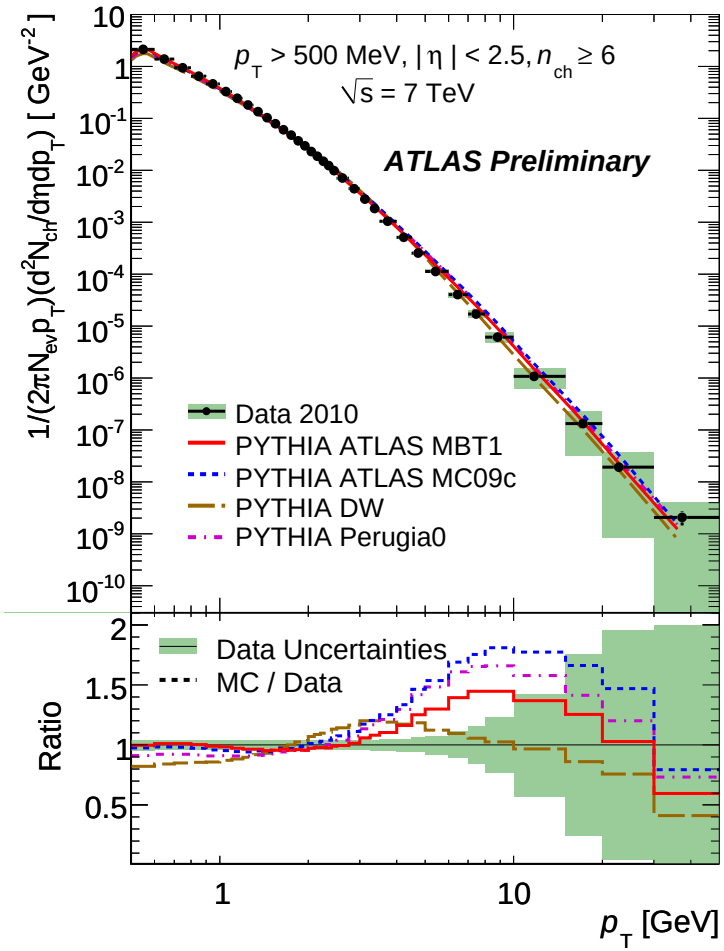
- ATLAS minbias in diffraction reduced phase-space
- ATLAS track-based UE data
- CDF UE data
- ATLAS-centric, more emphasis on minbias than on UE

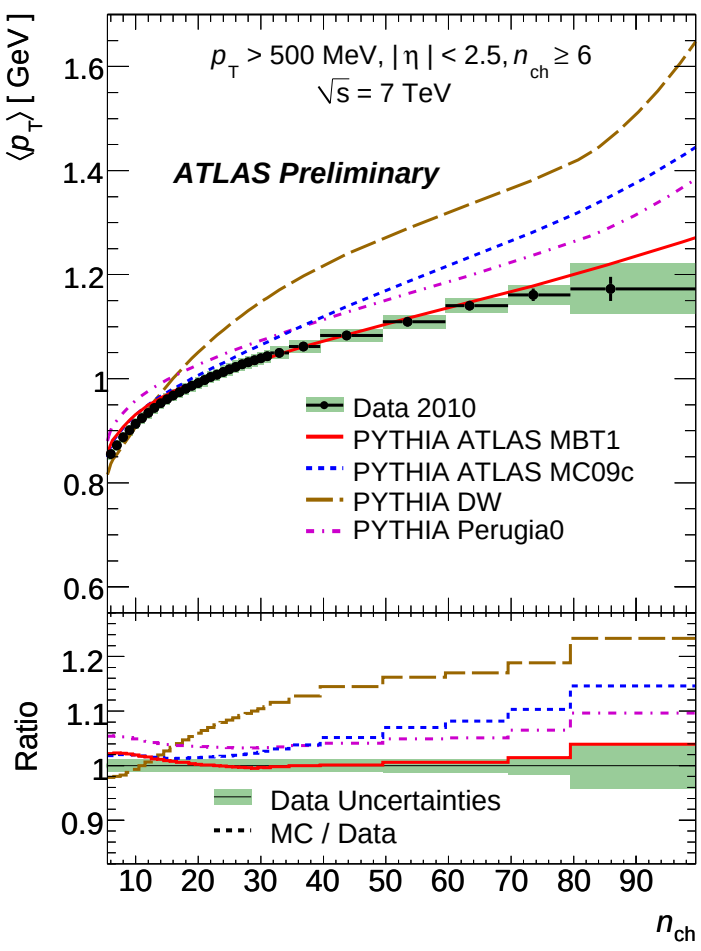




Tuning Results at $\sqrt{s} = 7$ TeV (900 GeV ⇒ similar conclusions)

- pseudorapidity density: very good description
- multiplicity: improvement of high multiplicity tail





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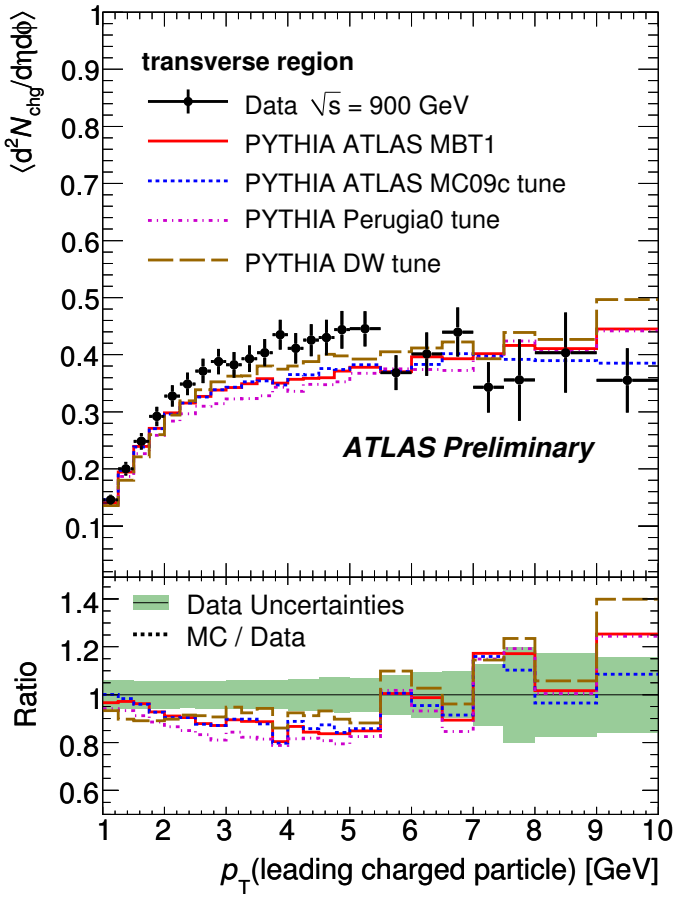
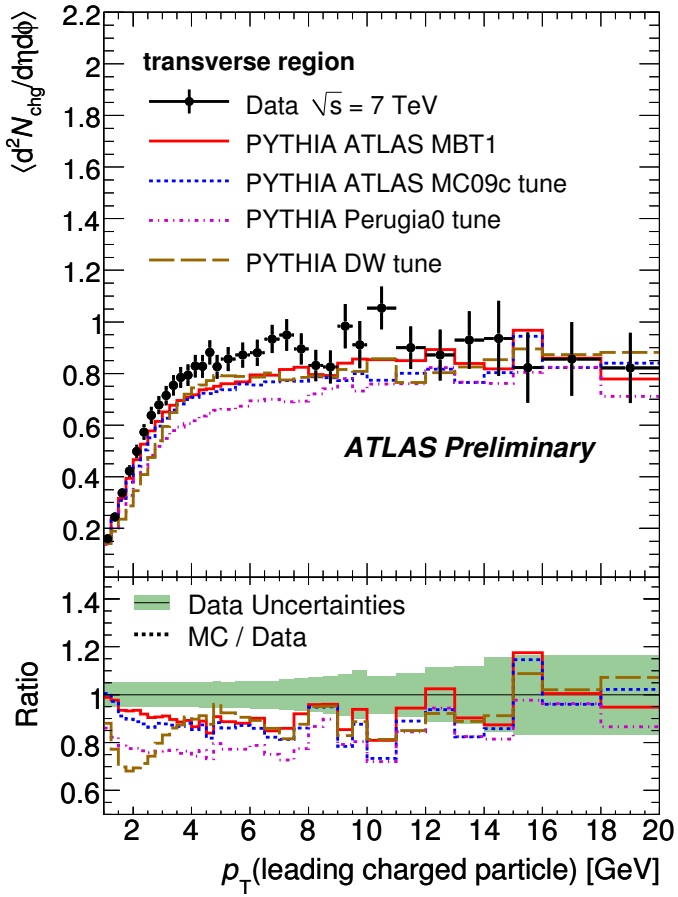
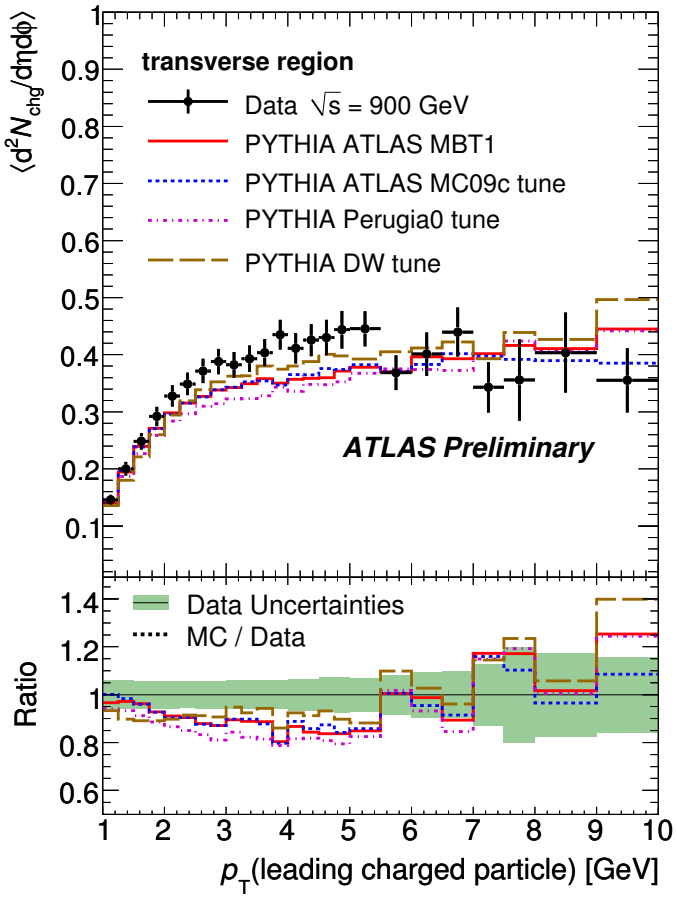
- $\langle p_T \rangle$ vs. N_{ch}: perfect description

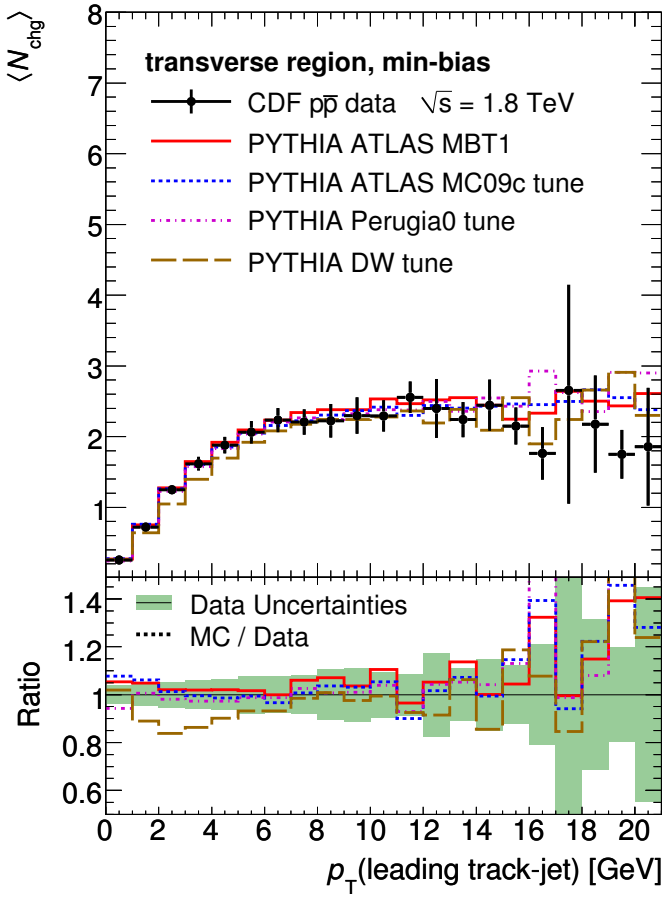




AMBT1 and Underlying Event

- no significant improvement in ATLAS UE description
- Minbias tune not necessarily an UE tune





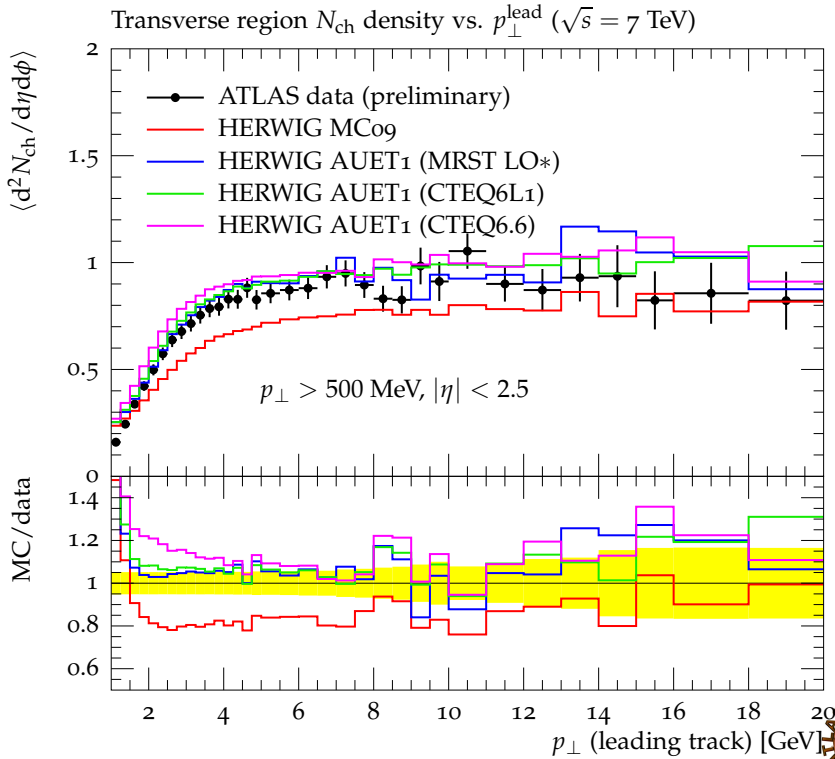
AMBT1 and Underlying Event

- no significant improvement in ATLAS UE description
- Minbias tune not necessarily an UE tune
- CDF data described well $\Rightarrow$ tension?

Atlas Underlying Event Tune 1 (AUET1)

- family (different PDFs) of tunes of HERWIG/JIMMY to ATLAS UE data
- includes also CDF data, but ATLAS-centric
- improvement of UE description
- more detail in ATL-PHYS-PUB-2010-014

ATLAS UE, $N_{ch}/p_T^{\mathrm{sum}}$ density in transverse region, $\sqrt{s} = 7$ TeV



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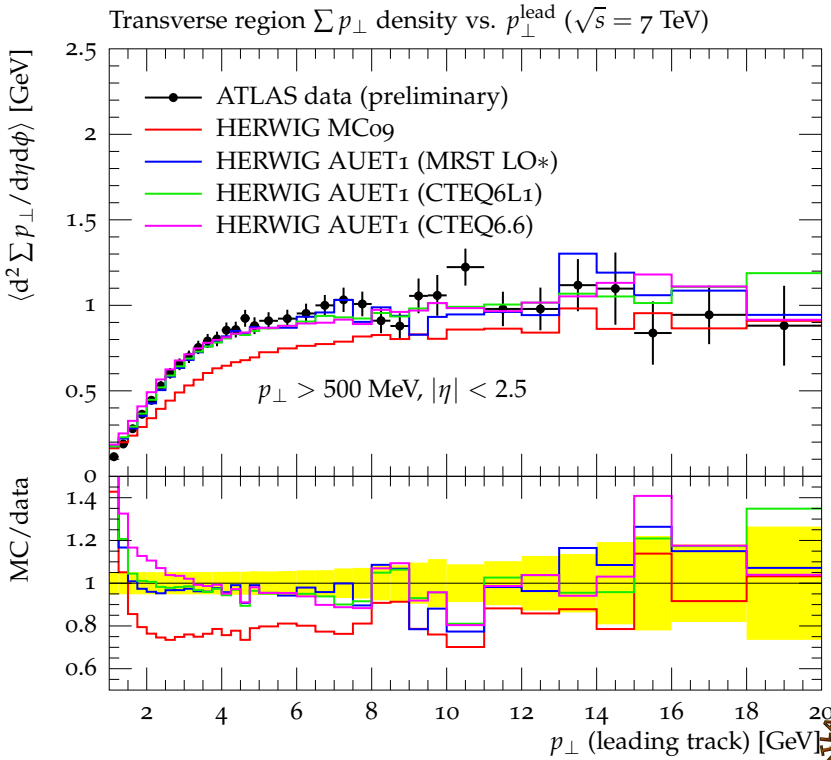

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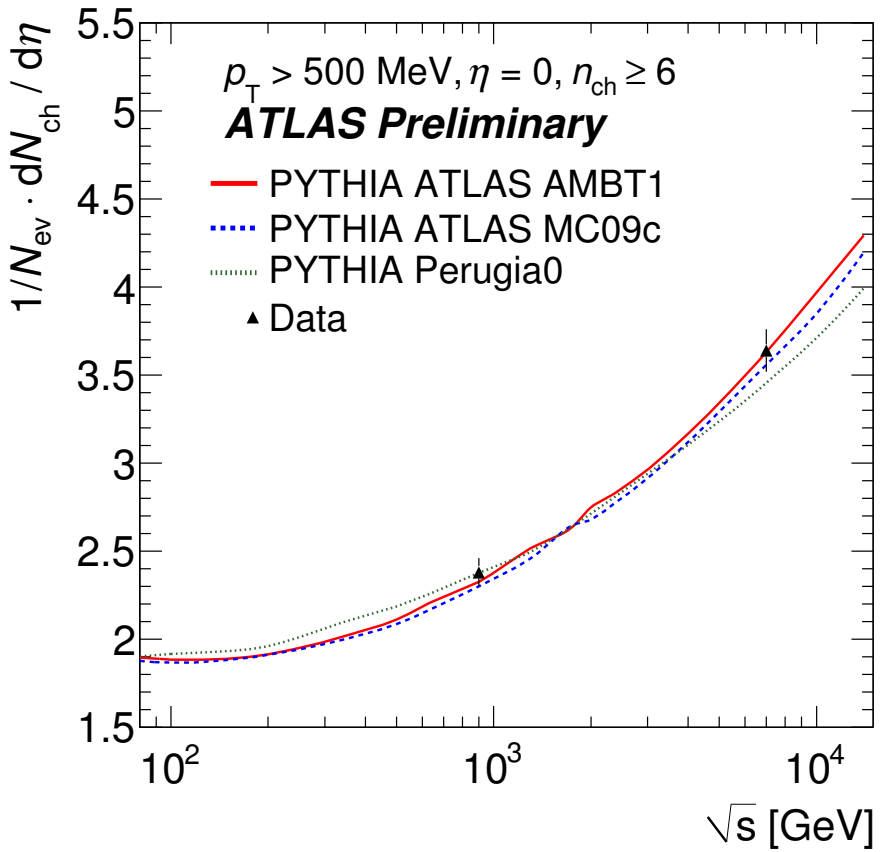
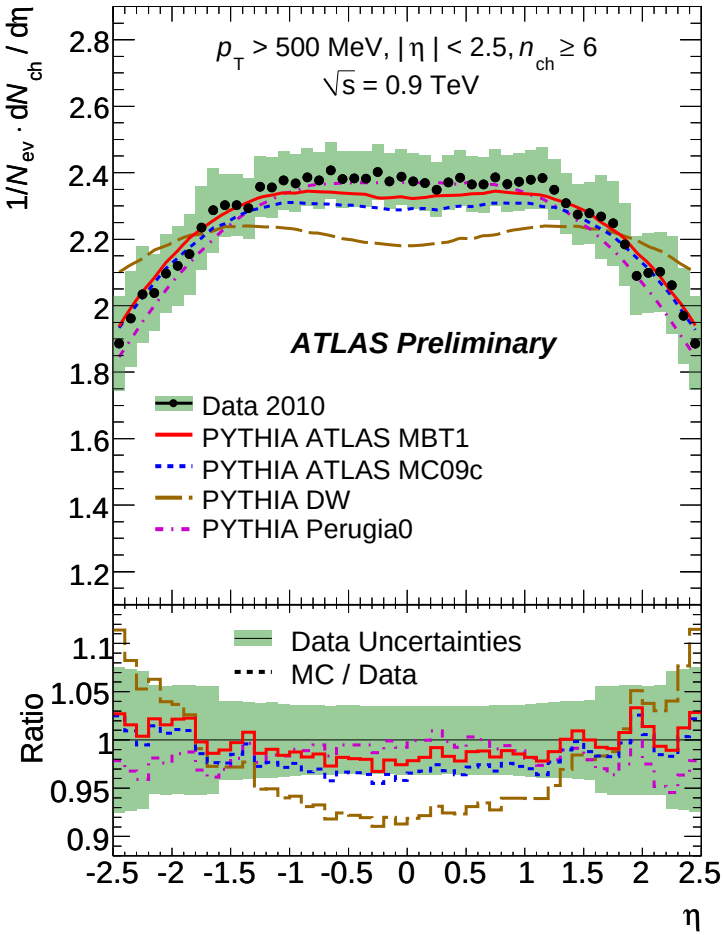
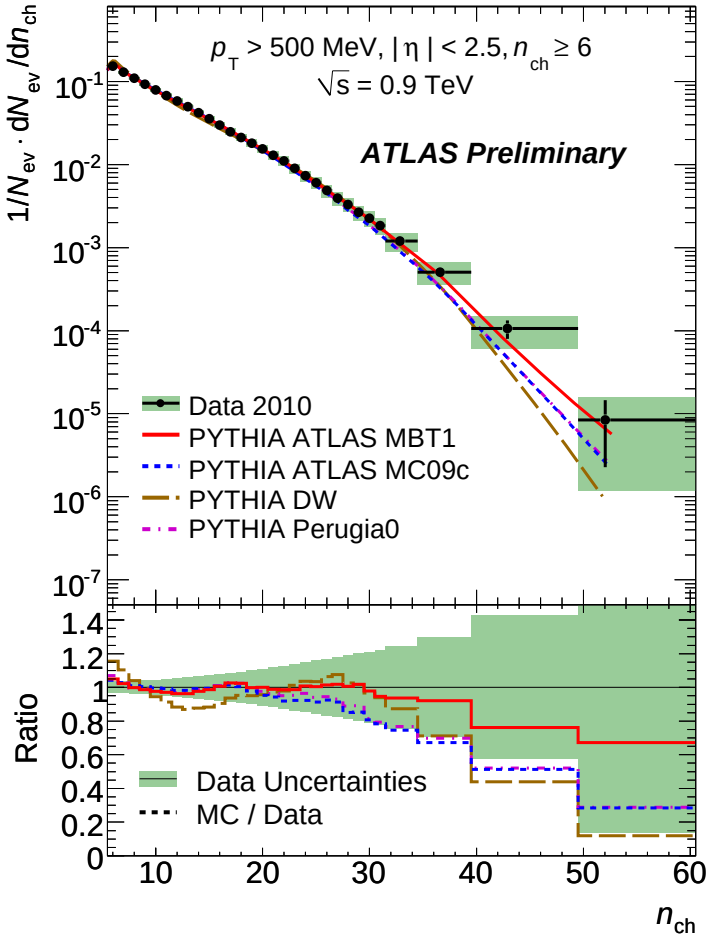
Summary

- Minbias:
  - Diffractive component overestimated (Pythia6)?
  - AMBT1: tune to special phase-space, large improvements
- Underlying Event:
  - Standard tunes too low
  - AMBT1: not much improvement
  - Tension between CDF and ATLAS data?
  - AUET1 for Herwig+Jimmy gives better description
- still room for improvement in MC tuning!







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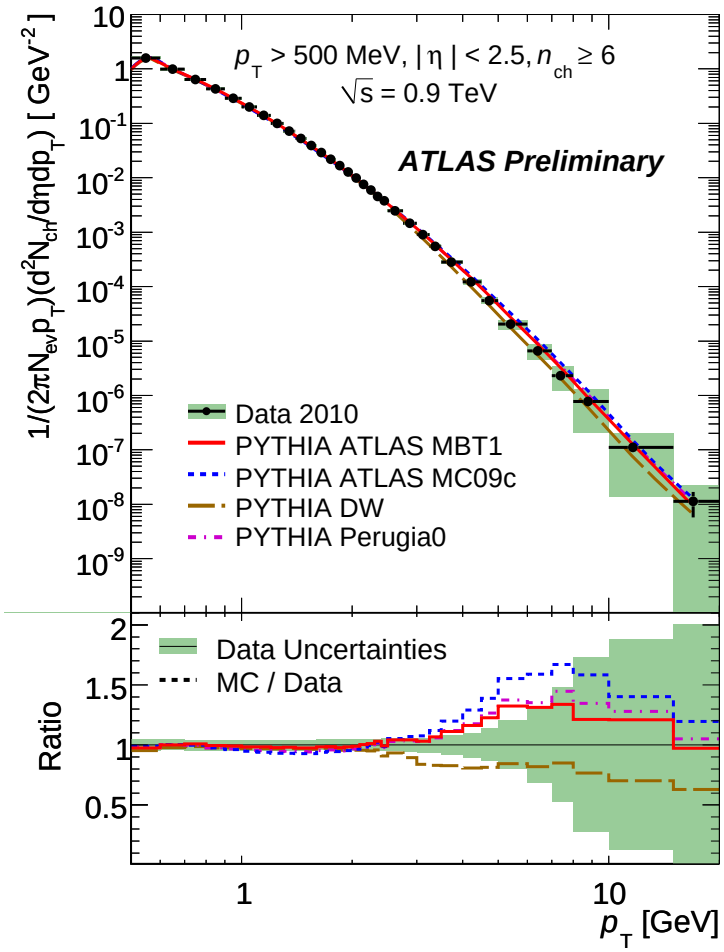

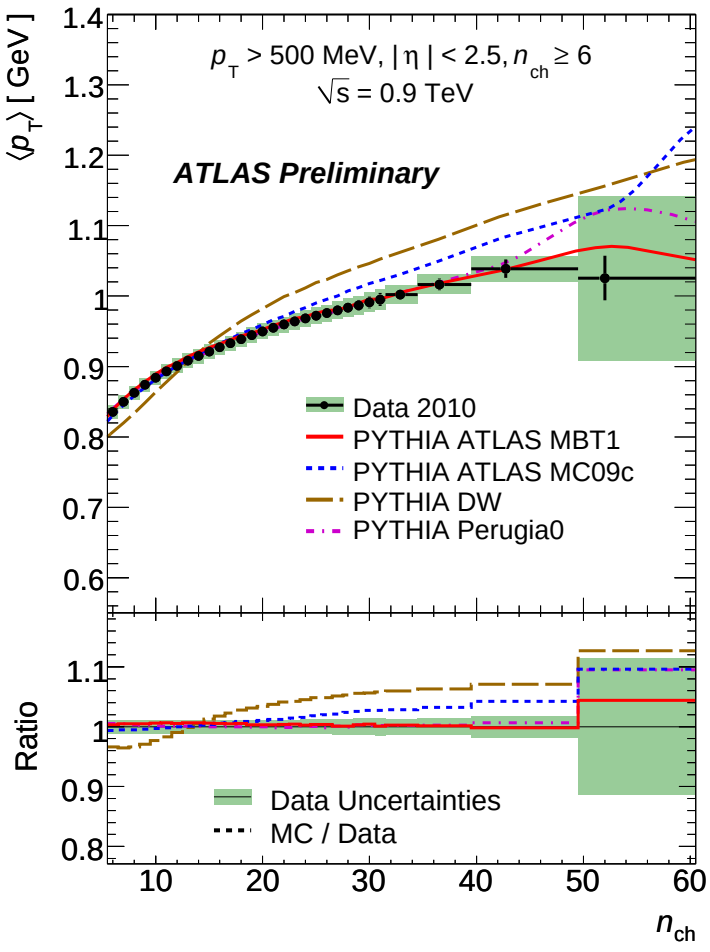

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Pythia6 parameters considered in the tuning (for AMBT1)

Parameter	Meaning	MC09c value	scanning range	AMBT1 value
PARP(62)	ISR cut-off	1.0	fixed	1.025
PARP(93)	prim. $k_\perp$ cut-off	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(82)	MPI cut-off	2.31	2.1 – – – 2.5	2.292
PARP(83)	matter overlap	0.8	fixed	0.356
PARP(84)	matter overlap	0.7	0.0 – – – 1.0	0.651
PARP(90)	MPI energy rescaling	0.248	0.18 – – – 0.28	0.250

Datasets used for Tuning

- ATLAS MinBias ($N_{\mathrm{ch}} \geq 6, p_T > 500\ \mathrm{MeV}$)
- ATLAS UE analysis
  - Used only charged multiplicities and momentum sums in the three regions.
  - only $p_T^{\mathrm{lead}} > 5.5/10\,\mathrm{GeV}$, turn-on region difficult to describe
- Non-ATLAS:
  - CDF Run 1 UE in leading jet analysis (Phys. Rev. D65 (2002) 092002)
  - CDF "MIN-MAX" cone analysis (Phys. Rev. D70 (2004) 072002)
  - CDF $\langle p_T \rangle$ vs. N_{ch} (Phys. Rev. D79 (2009) 112005)
  - CDF Z p_T and D0 dijet angular correlations (no big sensitivity)