ATLAS
Underlying Event study and an alternative Delta phi analysis

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Joint LHC Underlying Event and Minimum Bias workshop,
7th September 2010

Outline

- Underlying Event analysis
- Delta phi analysis, looking closer at $\Delta\phi$ distributions

Data and selection criteria

Data:
900 GeV: December 2010
7 TeV: March 30th – April 7th

EVENT SELECTION:

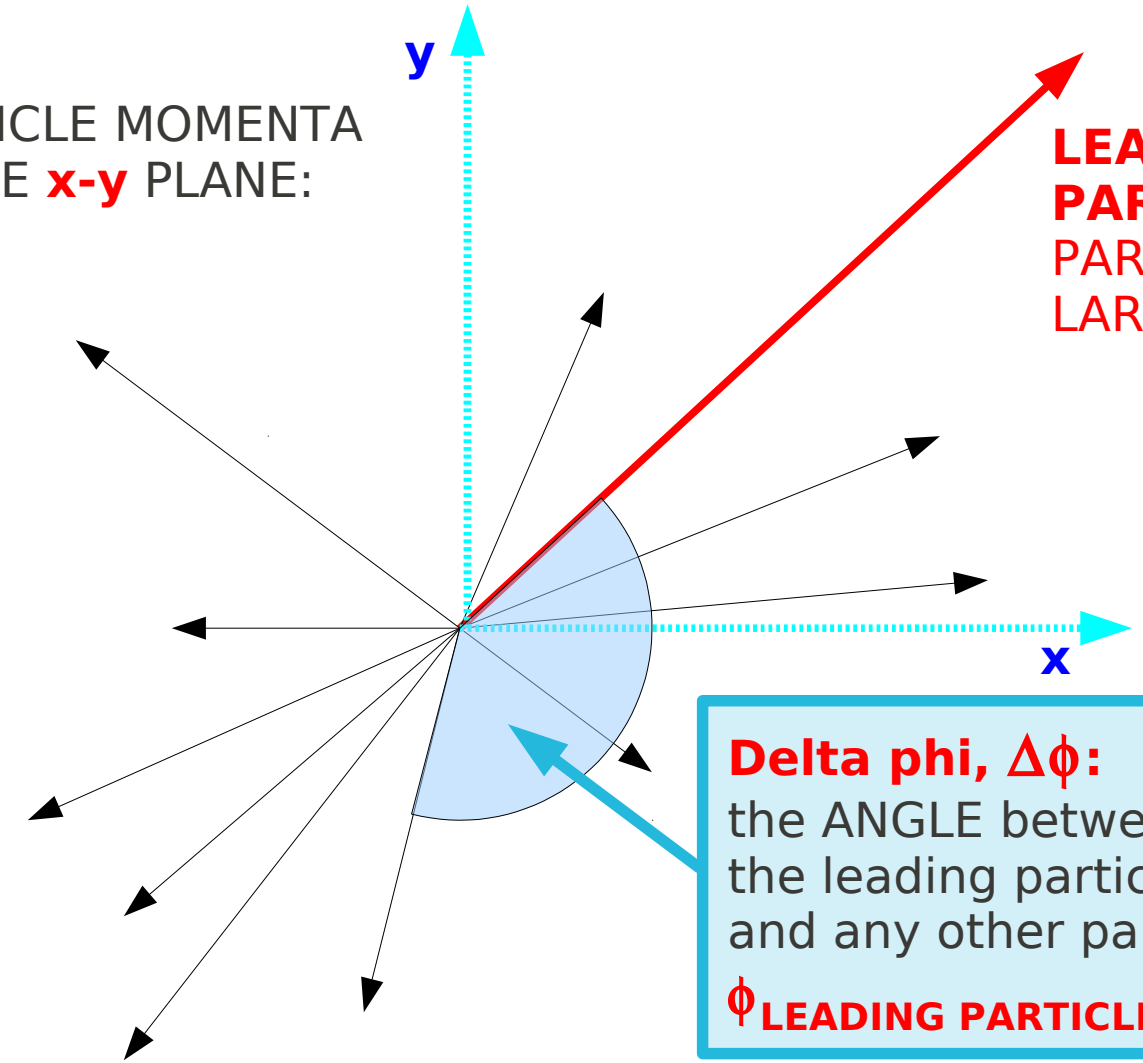
- MBTS_1 trigger
- reconstructed vertex
- no second vertex with 4 or more tracks
- at least 2 selected tracks

TRACK SELECTION:

- p_T > 500 MeV
- $|\eta|$ < 2.5, 2.0, 1.0
- at least 1 Pixel hit
- B-layer hit required if it is expected
- at least 6 SCT hits
- $|d_0|$ < 1.5mm, $|z_0 \sin\theta|$< 1.5mm
- for p_T > 10 GeV: χ^2 probability > 0.01

Definition: Delta phi, $\Delta\phi$

PARTICLE MOMENTA
IN THE **x-y** PLANE:



LEADING PARTICLE:
PARTICLE WITH LARGEST $\mathbf{p_T}$

Delta phi, $\Delta\phi$:
the ANGLE between
the leading particle
and any other particle,

$\phi_{\text{LEADING PARTICLE}} - \phi_{\text{OTHER PARTICLE}}$

Track based UE study

Track with the highest p_T tells the **direction of the hard scatter**.

Why?

- Best use of the limited statistics.
- Easier to correct back to hadron level.

Is this good?

Yes, it is: leading track is very often included in the leading jet.

Leading track: $p_T > 1.0$ GeV

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Corrected to the hadron level

- The distributions are corrected back to the hadron level and can be directly compared with the output of MC generators
- Event level corrections:
  - trigger inefficiency
  - vertex inefficiency
  - no particle with p_T > 1.0 GeV reconstructed
- Track level correction: efficiency, non-primaries, outside kinematic range
- Unfolding factor: account for resolution effects (bin migrations)

Underlying Event - Results

- 14 slides of plots:

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

  $\langle \Sigma p_T \rangle$ vs. p_T^{lead}

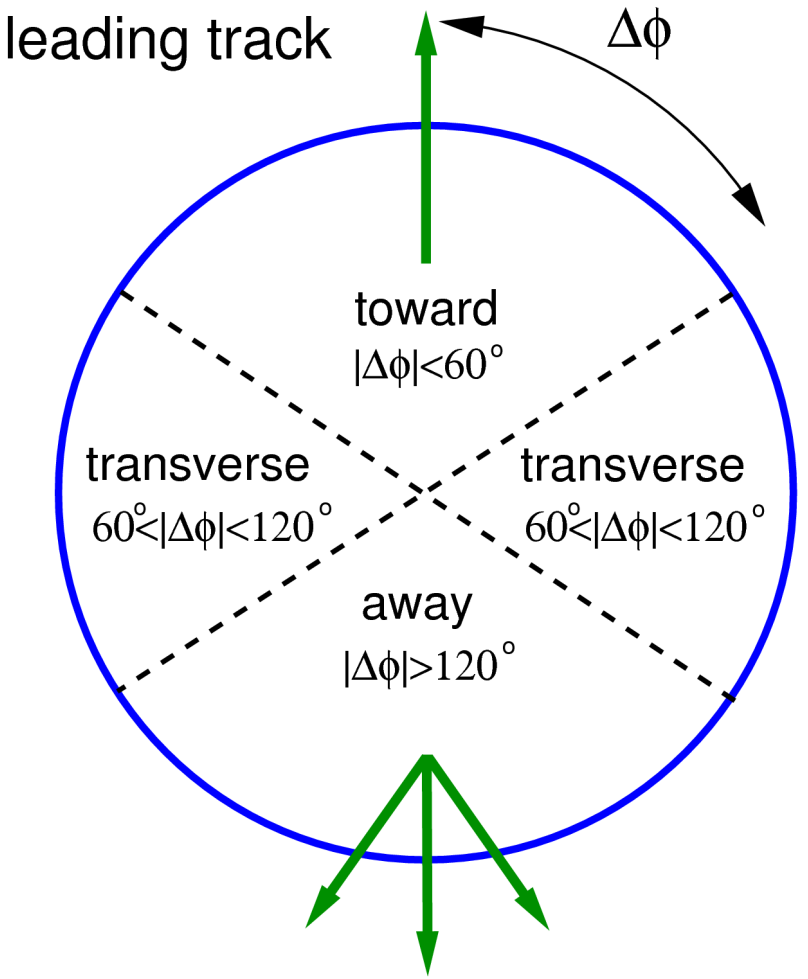
  Std. Dev. N_{ch} vs. p_T^{lead}

  Std. Dev. Σp_T vs. p_T^{lead}

  $\langle p_T \rangle$ vs. p_T^{lead}

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

  $N_{non\text{-}leading\ tracks}$ vs. $\Delta\phi$

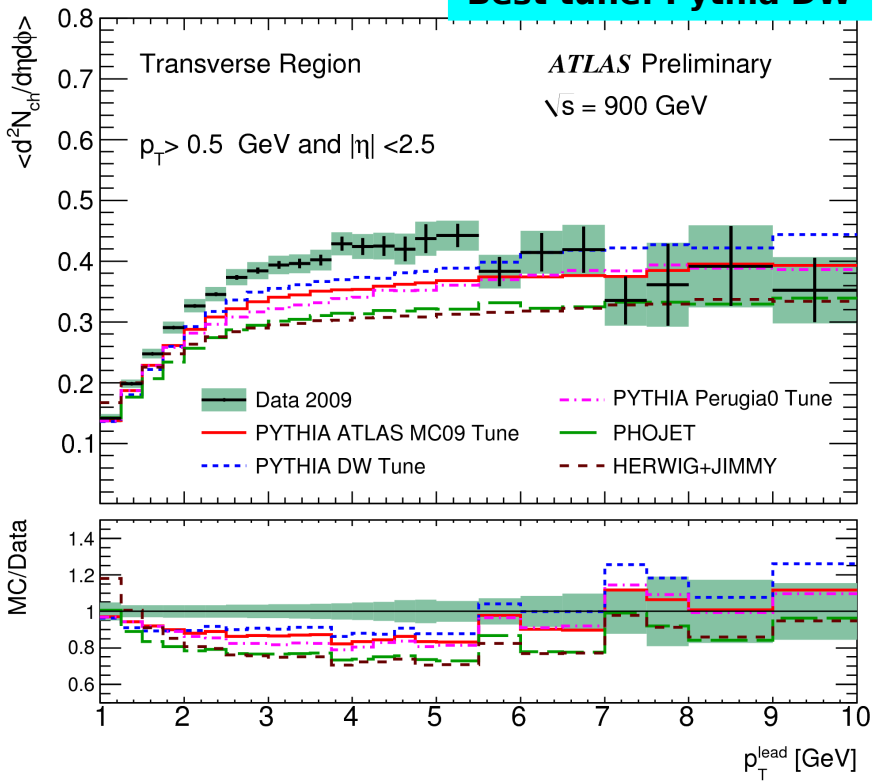


$\langle N_{ch} \rangle$ in transverse region

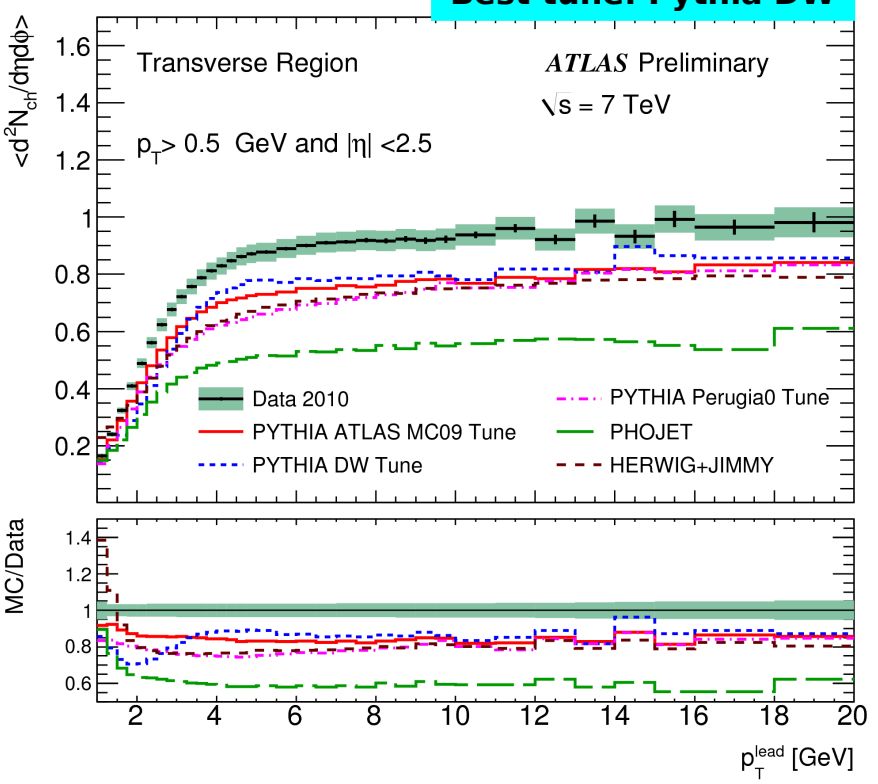
- All tunes are too low
- Best tunes are 10%-15% below the data

"Best tune": estimated by eye, sometimes difficult to decide; DON'T TAKE TOO SERIOUSLY

Best tune: Pythia DW

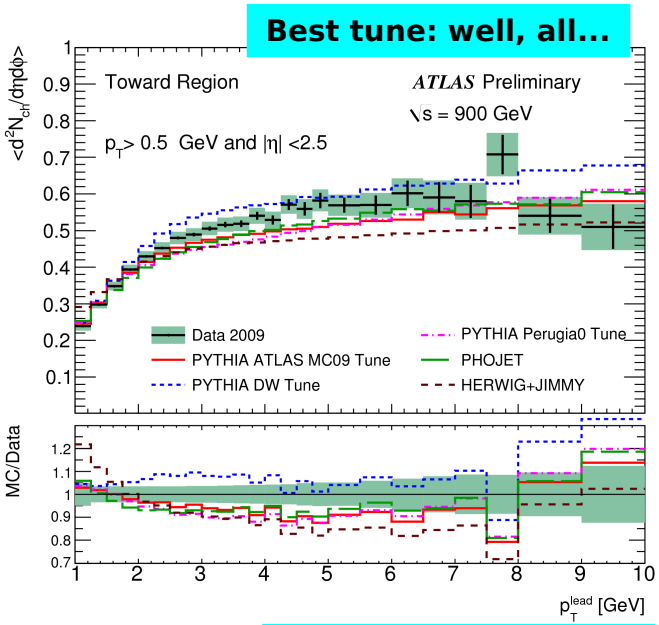


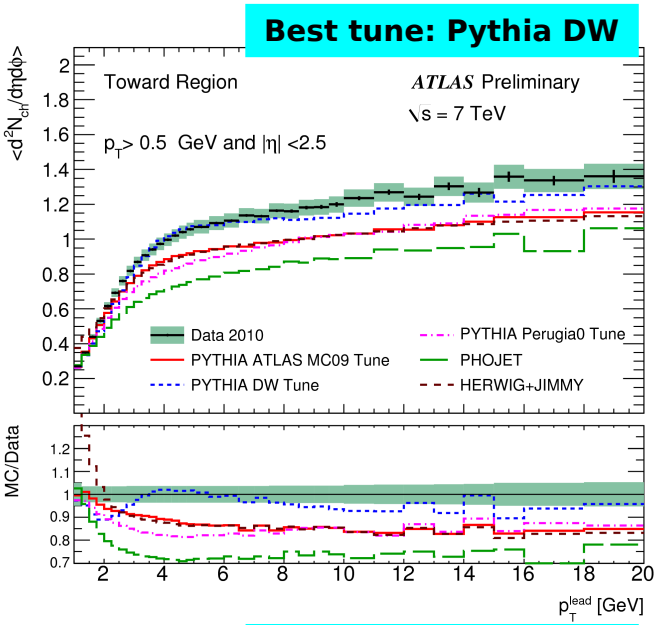
Best tune: Pythia DW

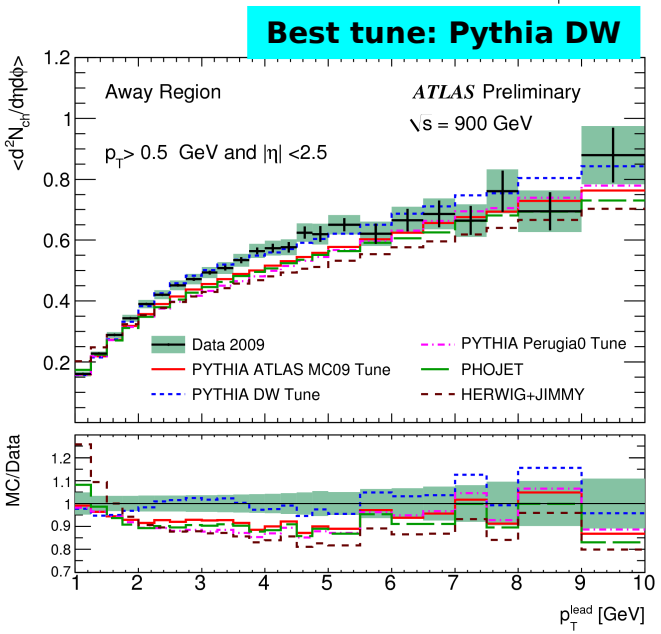


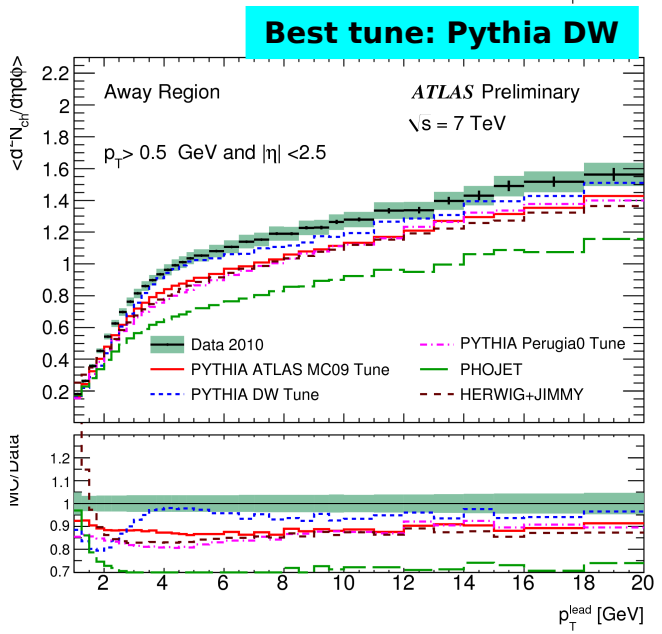
$\langle N_{ch} \rangle$ in toward and away

- generally a **better agreement** between data and MC than in the transverse region



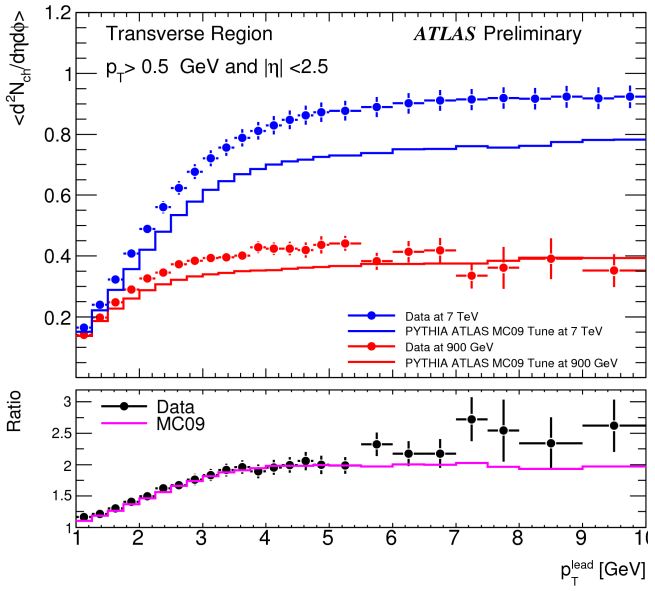


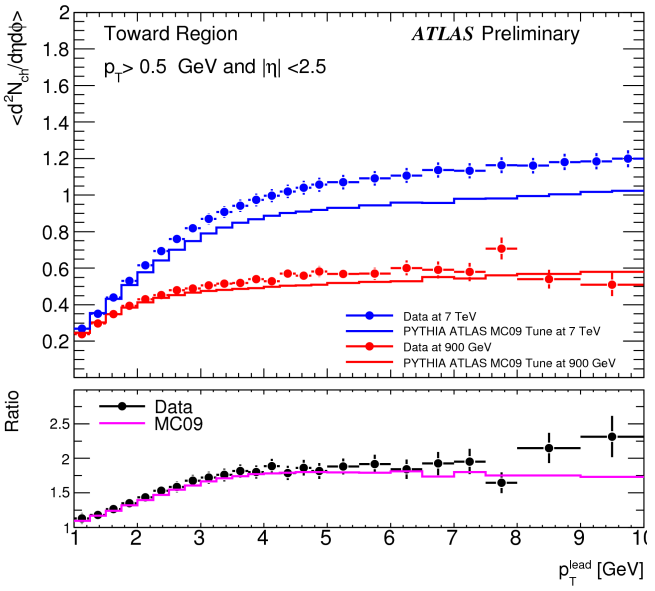


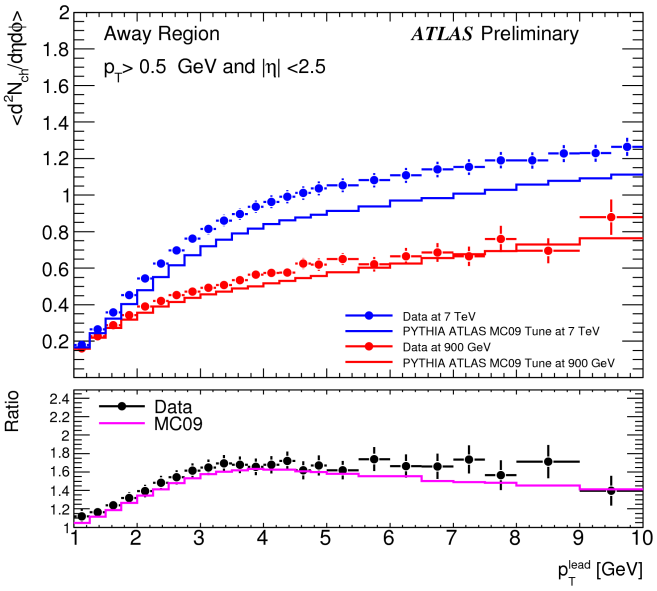


$\langle N_{ch} \rangle$: ratio 7 TeV / 900 GeV

- Pythia ATLAS MC09 tune: comparison of 900 GeV and 7 TeV plots
- the tune is below the data, but gets the ratio quite correct (only slightly underestimates)

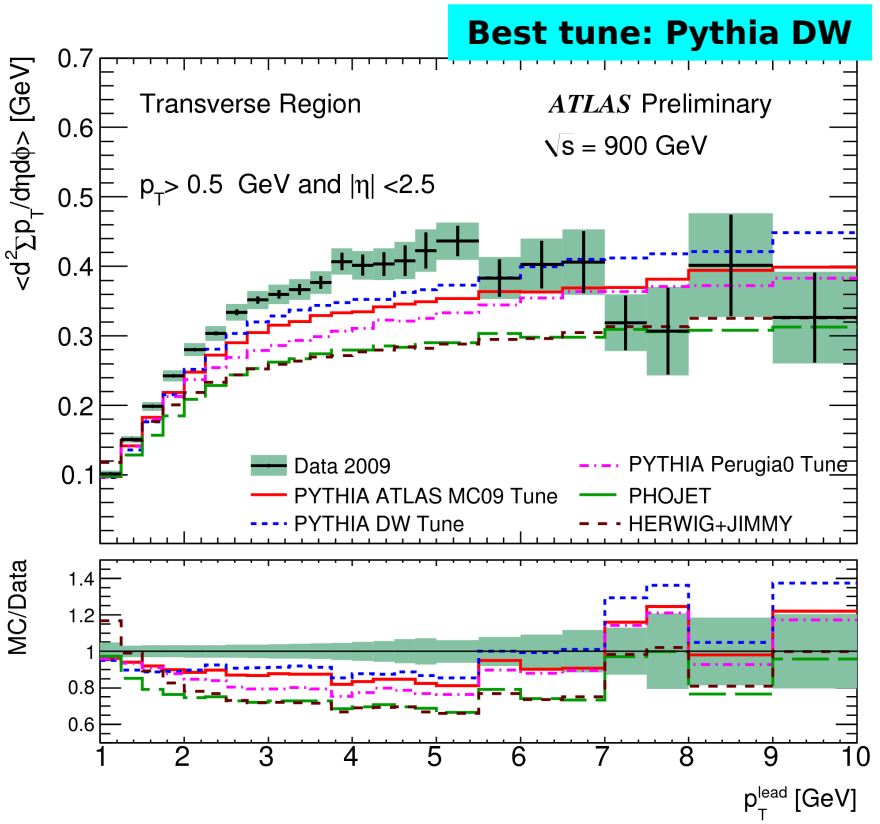


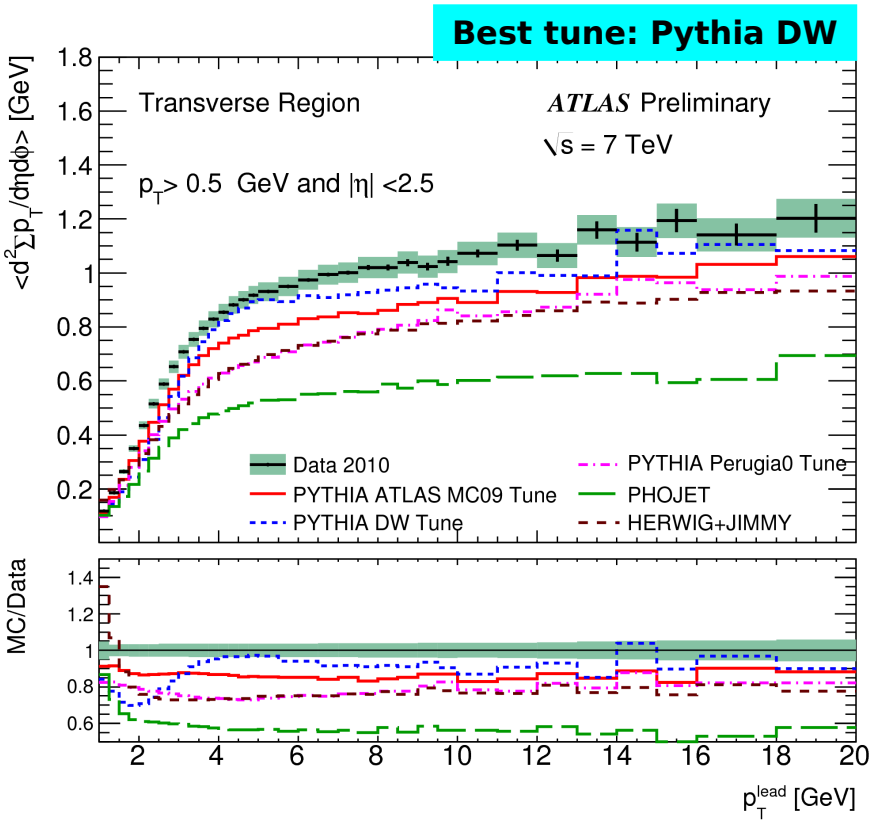




$\langle \Sigma p_T \rangle$ in transverse region

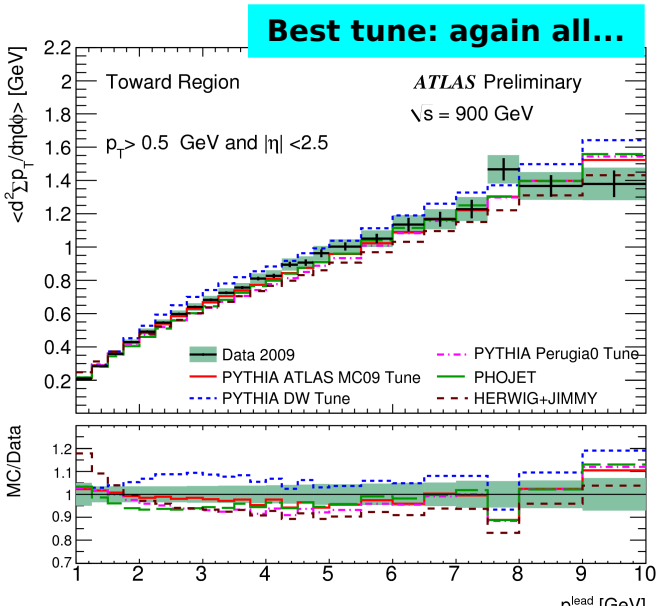
- very similar to the $\langle N_{ch} \rangle$ plots
- best tunes 10% below the data

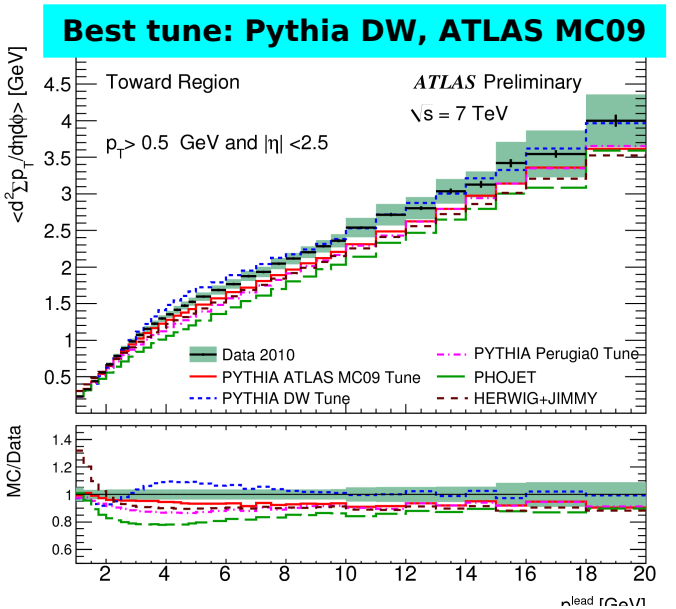


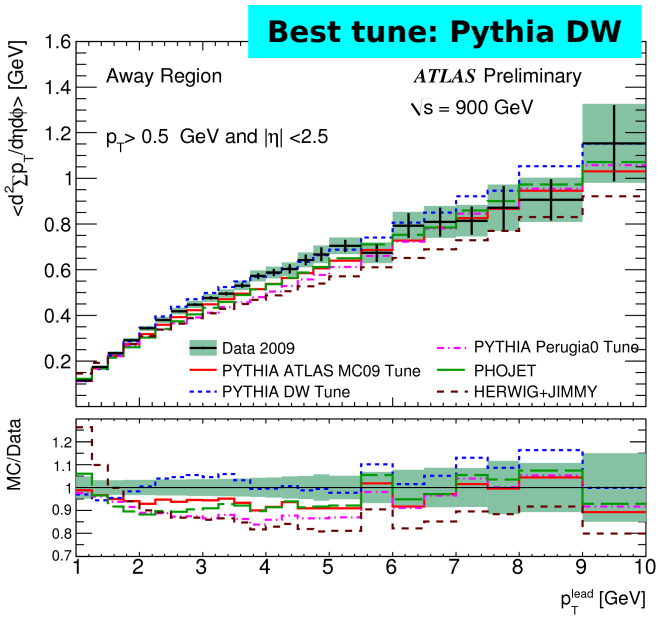


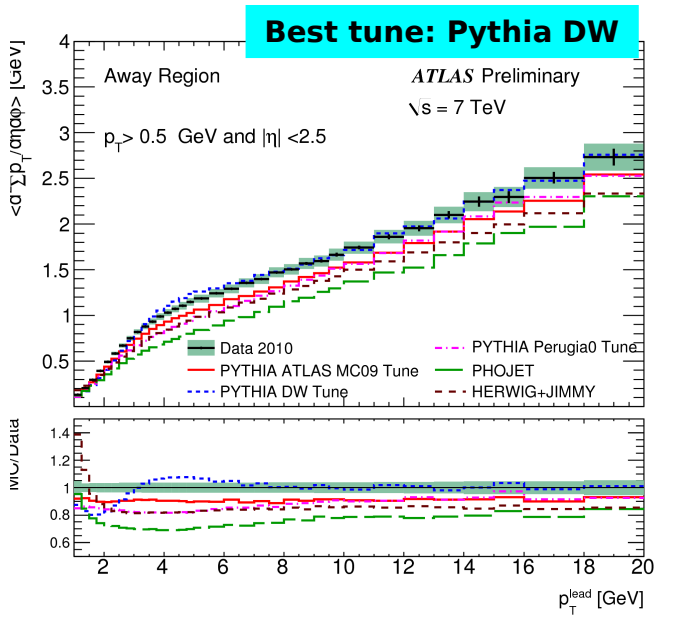
$\langle \Sigma p_T \rangle$ in toward and away reg.

- generally a **better agreement** between data and MC than in the transverse region



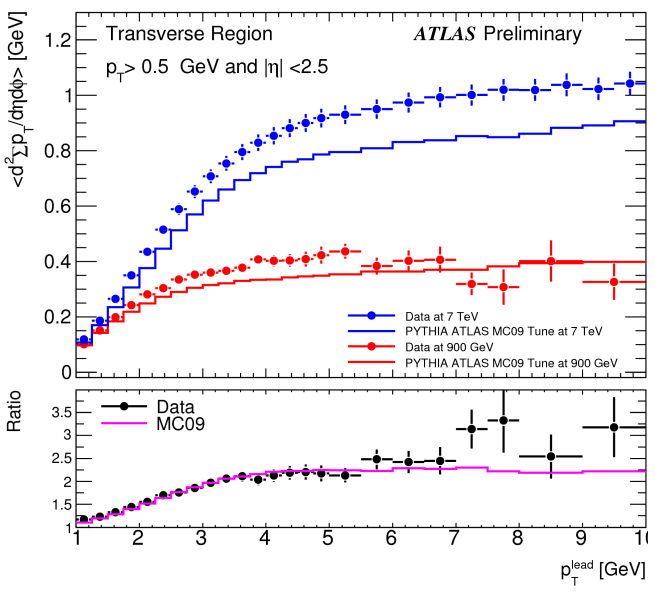


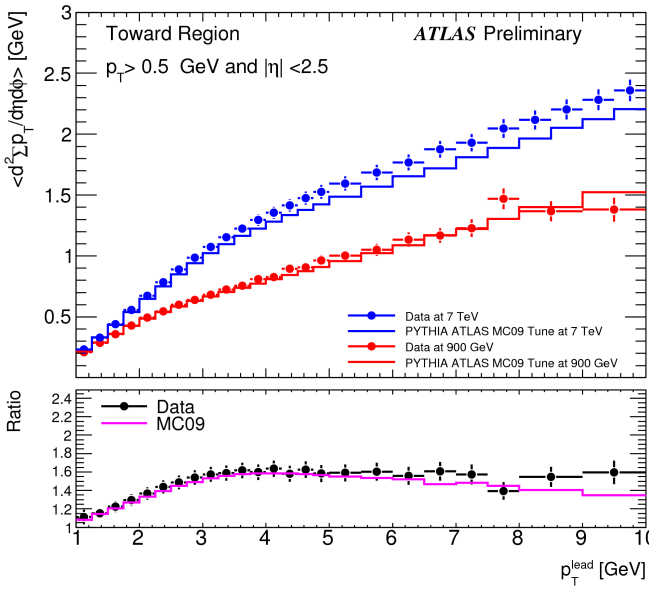


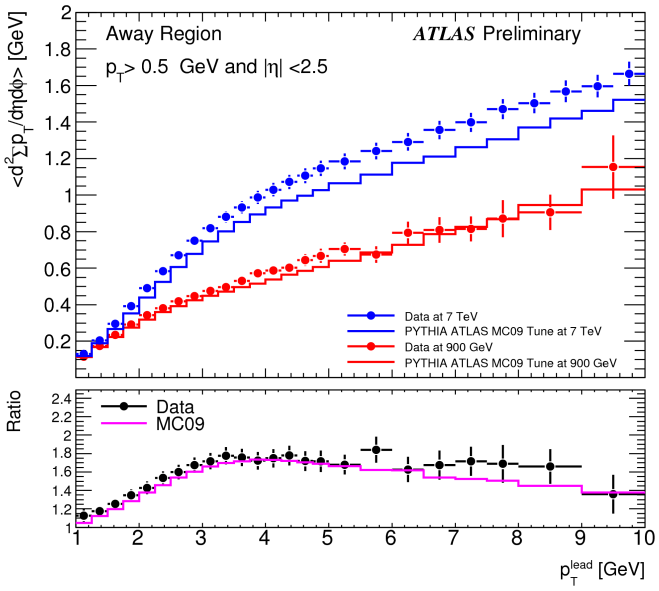


$\langle \Sigma p_T \rangle$: ratio 7 TeV / 900 GeV

- Pythia ATLAS MC09 tune: underestimates the data, but gets the increase from 900 GeV to 7 TeV roughly right.

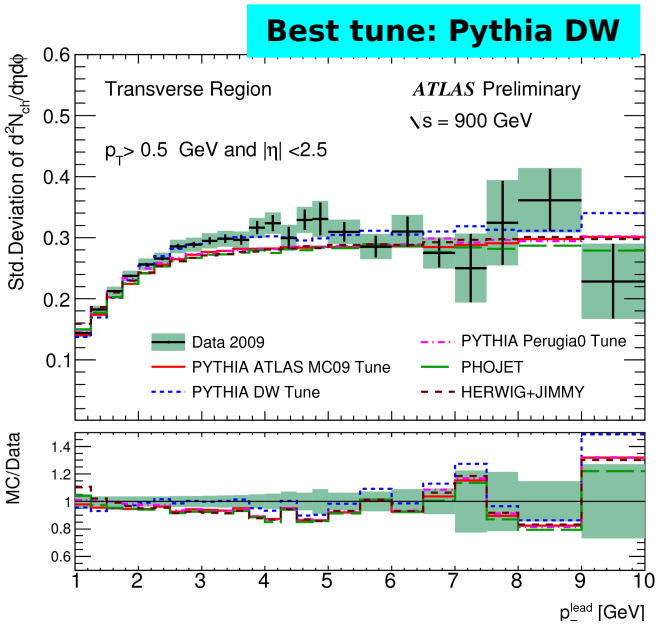


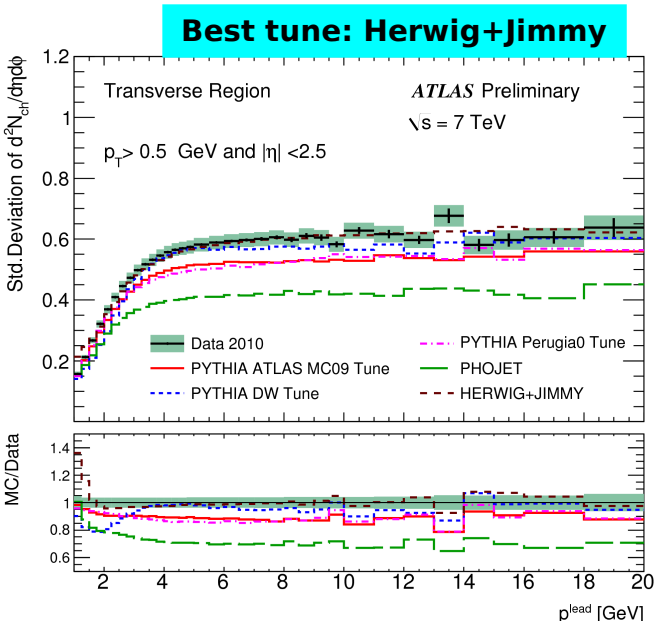


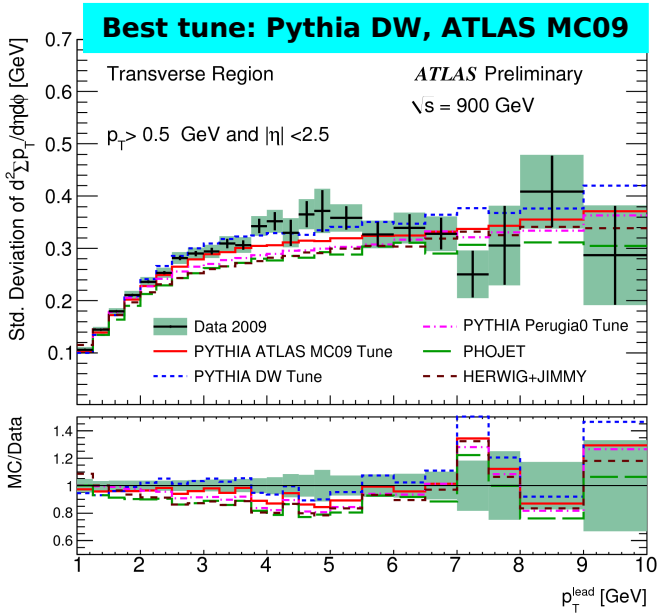


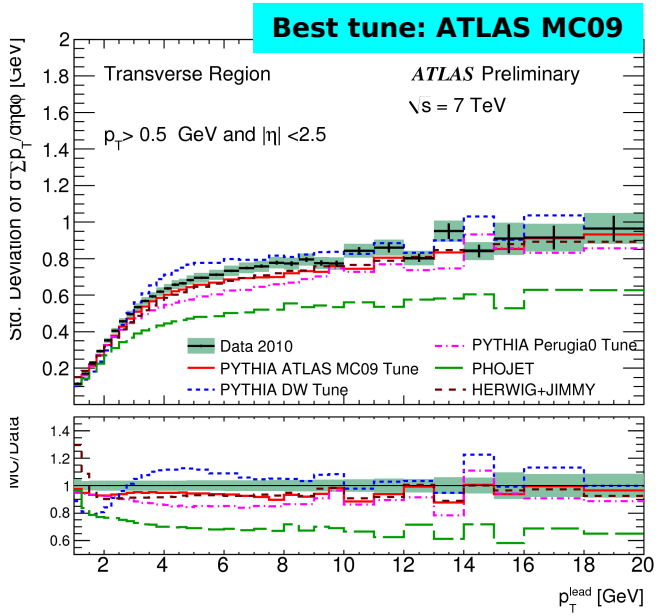
Std. Deviations in transv.r.

- MCs do a reasonably good job



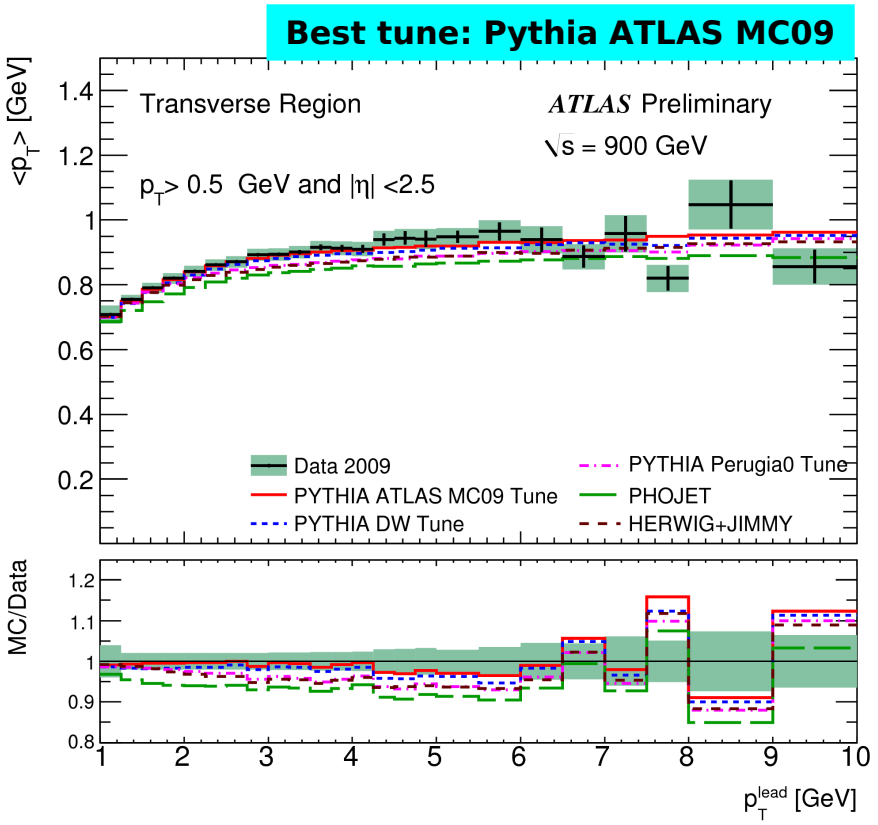


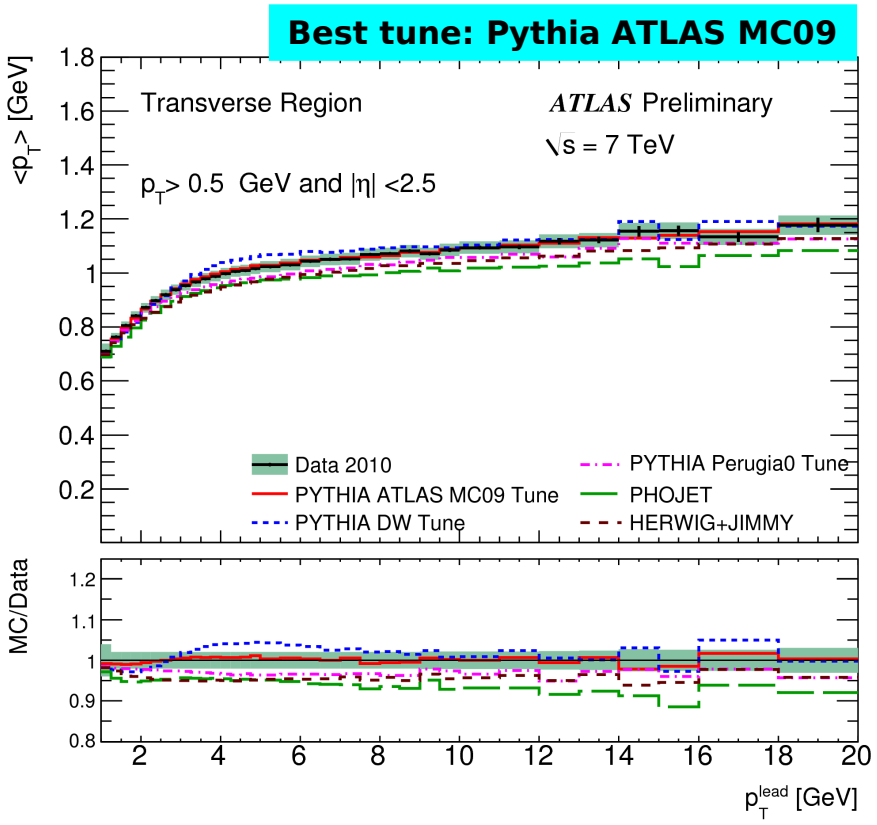




<p_T> in transverse region

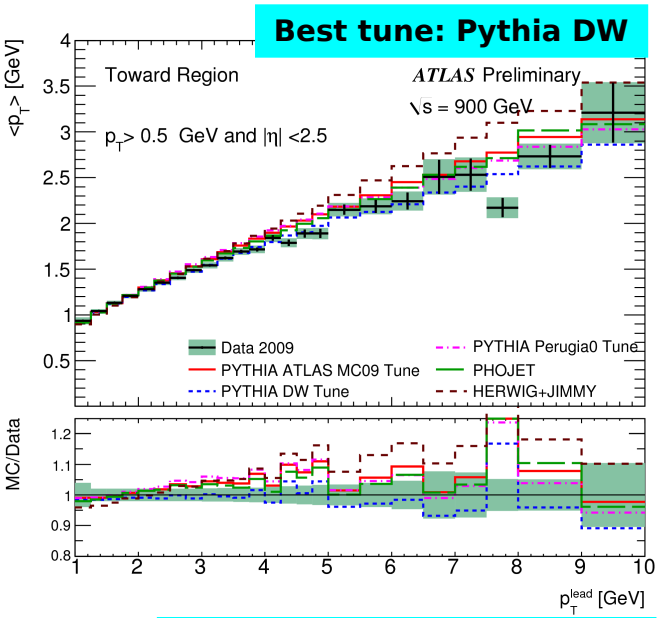
- good description by most tunes: mostly within 5% from the data

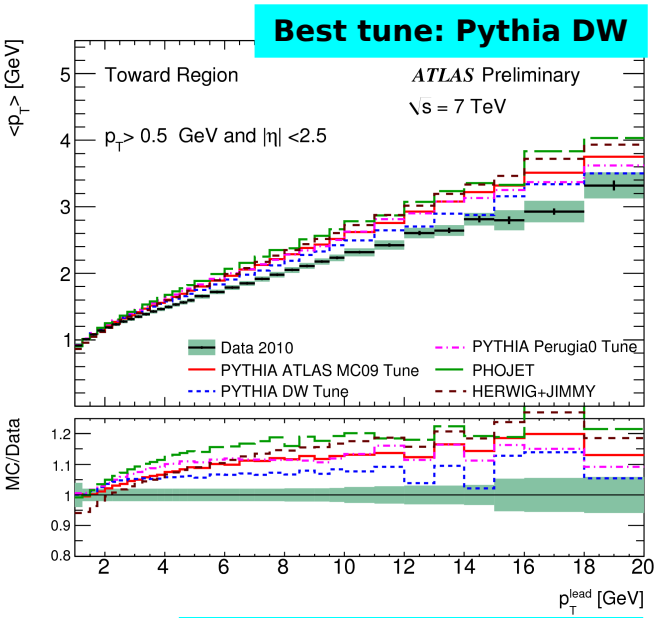


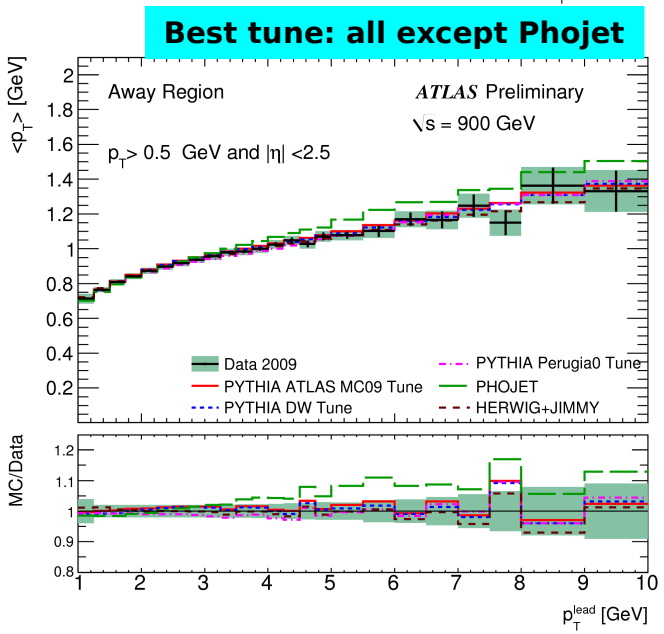


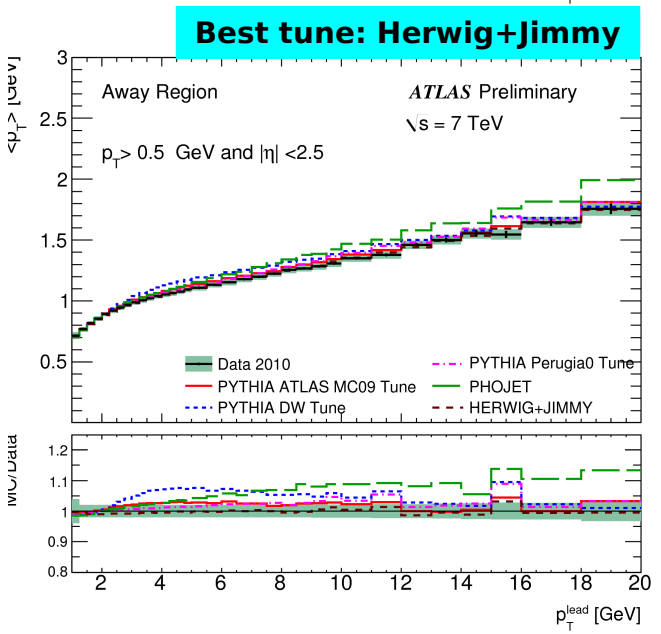
$\langle p_T \rangle$ in toward and away reg.

- Here tunes tend to be higher than the data.



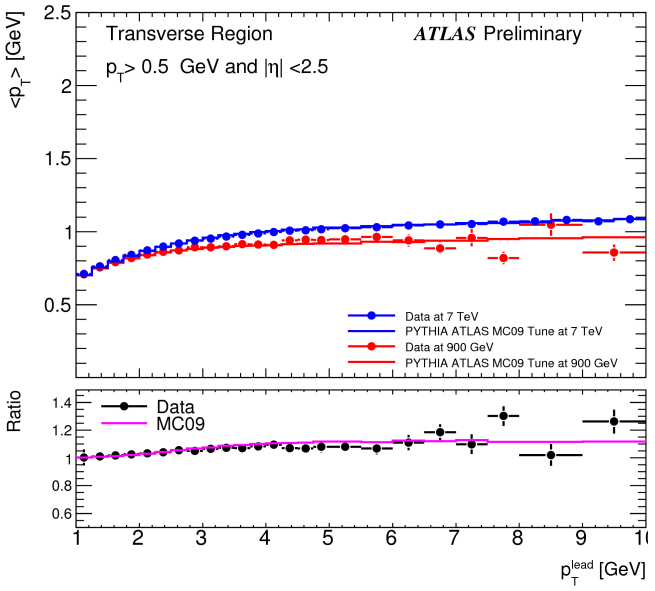


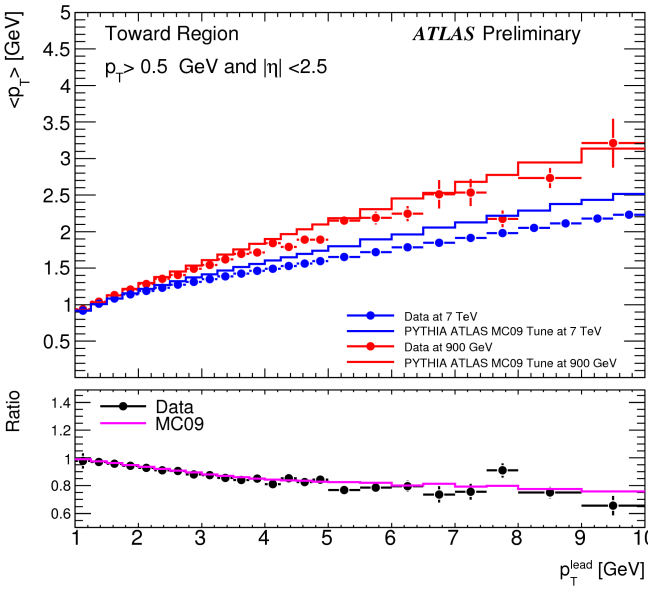


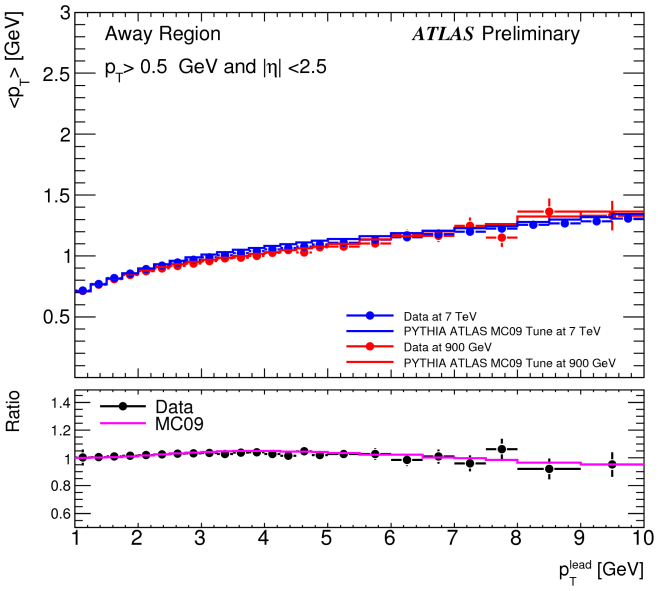


<p_T>: ratio 7 TeV / 900 GeV

- A good description of the ratio by Pythia tune ATLAS MC09

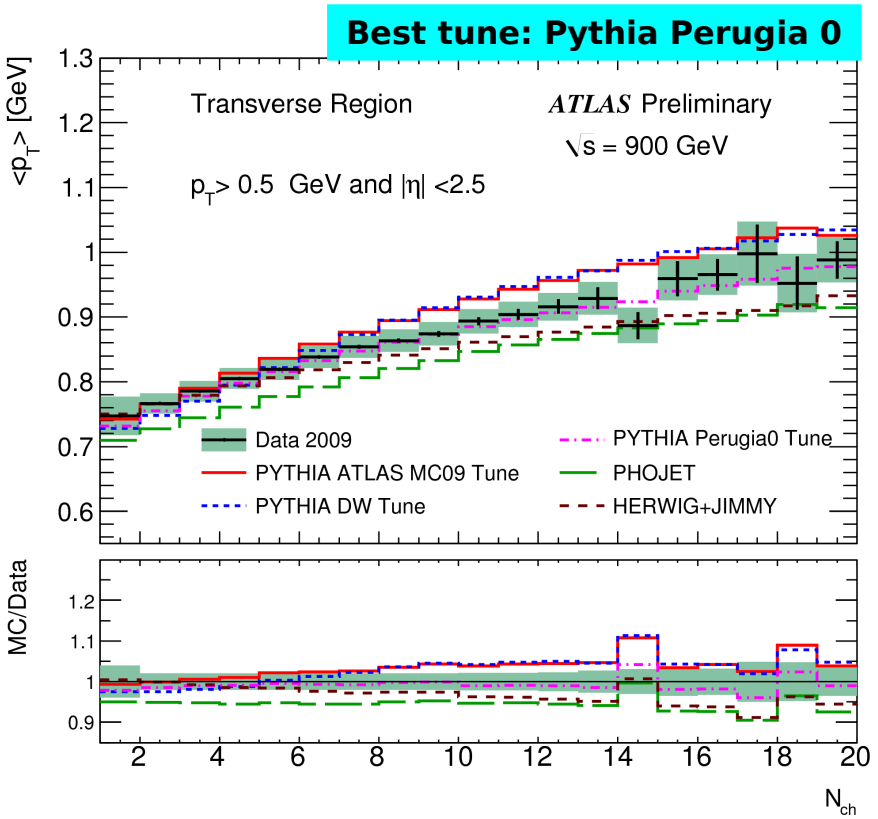


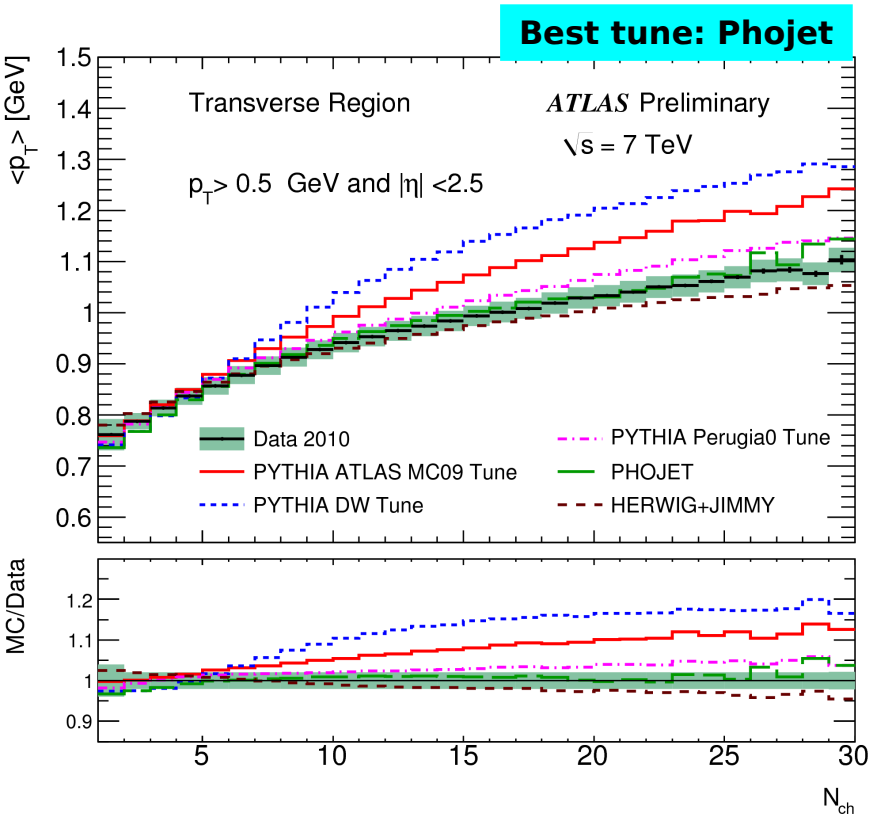




$\langle p_T \rangle$ vs. N_{ch} in transverse r.

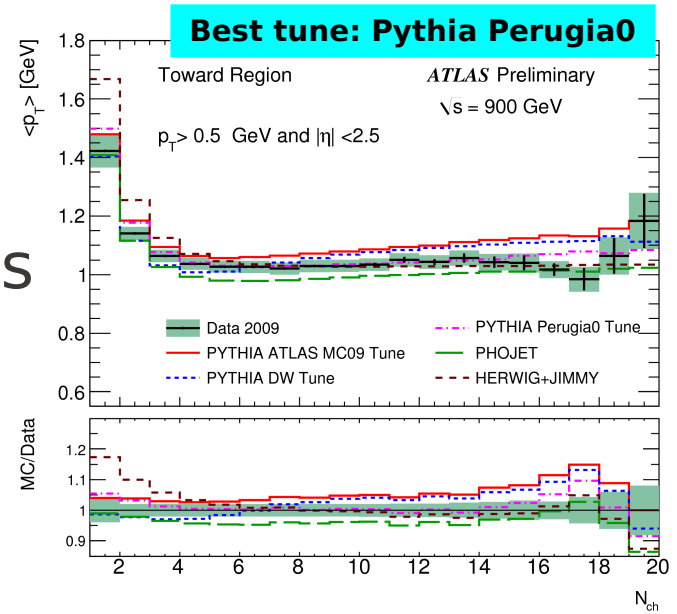
- Tunes ATLAS MC09 and Perugia0 are too high, others are fine

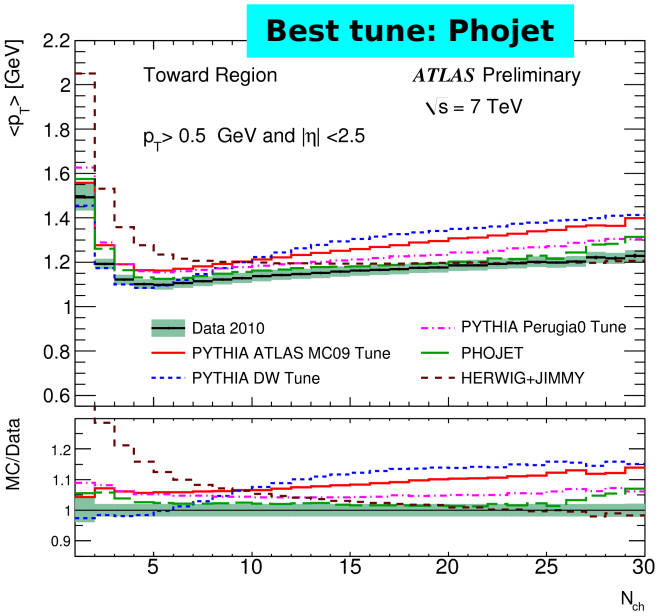


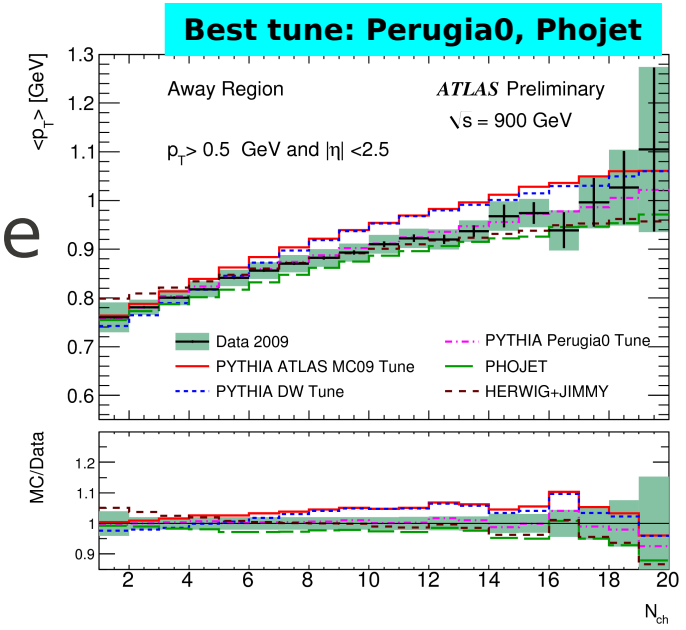


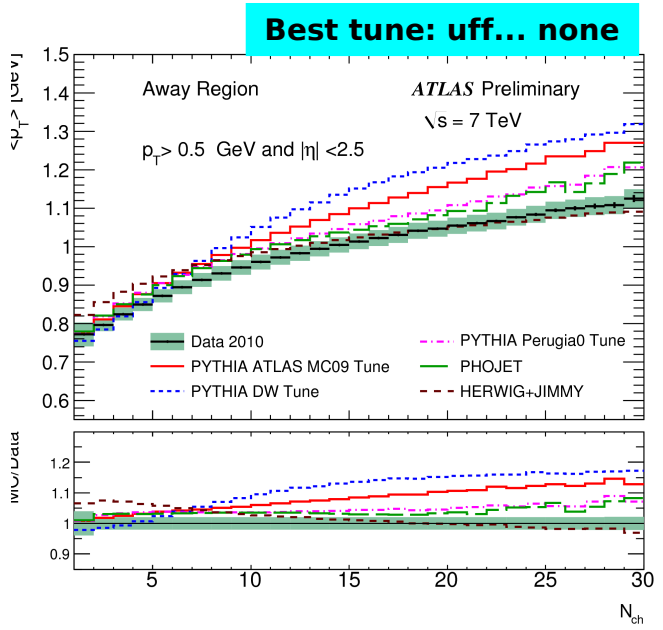
$\langle p_T \rangle$ vs. N_{ch} in toward & away

- the leading track is included, that's why you see the spike in “toward”
- ATLAS MC09 and Perugia0 are too high, others are fine
- The shapes are different than in data



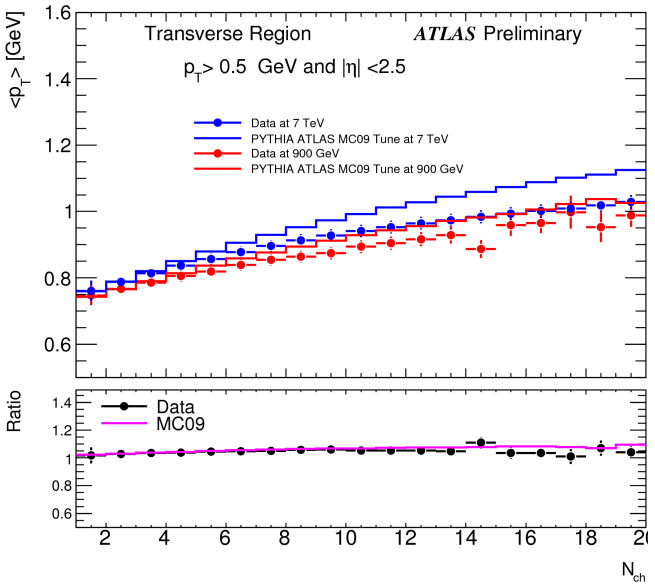


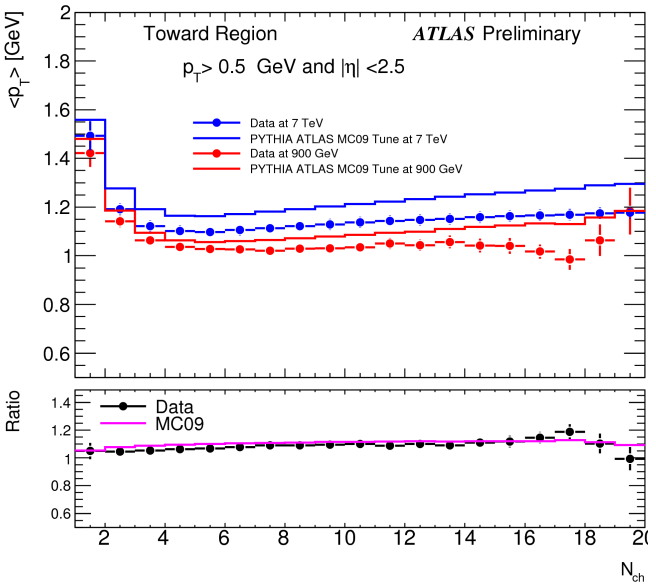


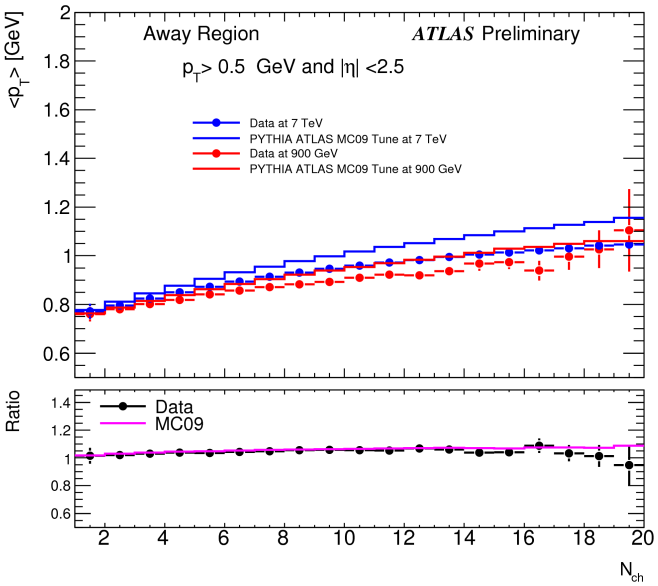


$\langle p_T \rangle$ vs. N_{ch}: ratio 7 TeV / 900 GeV

- Here the ratios between the two energies are slightly worse described

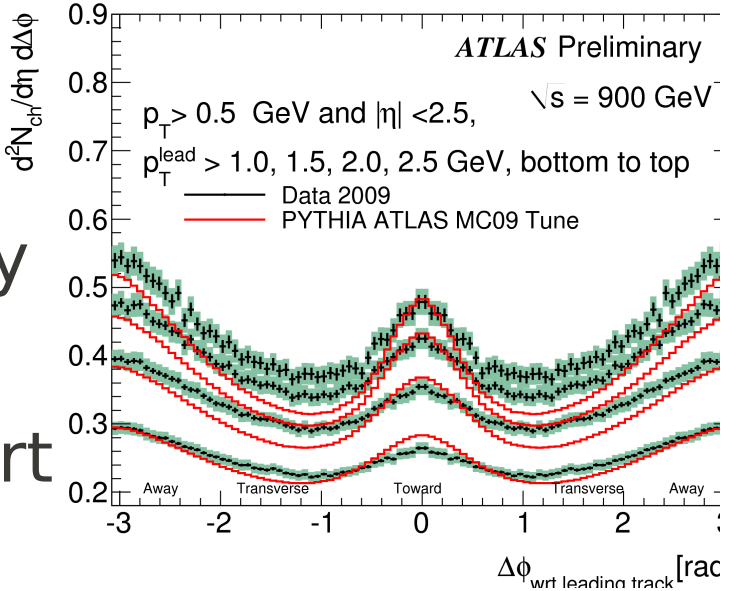


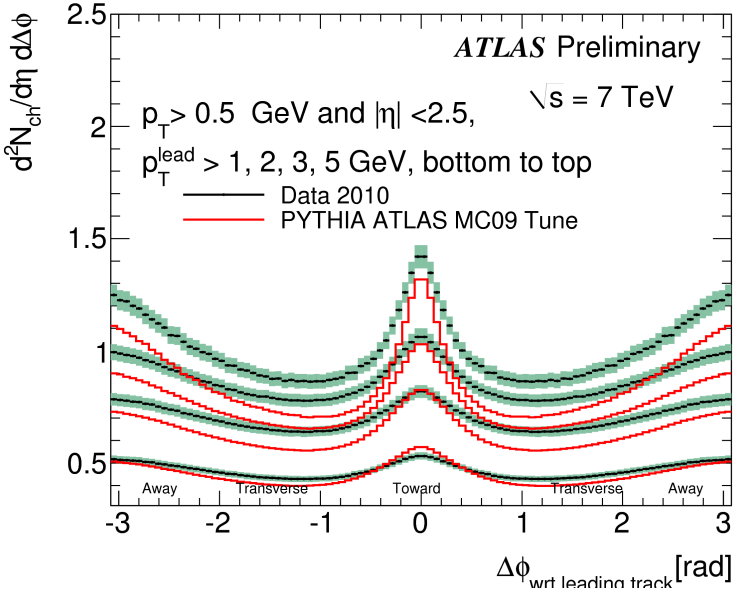


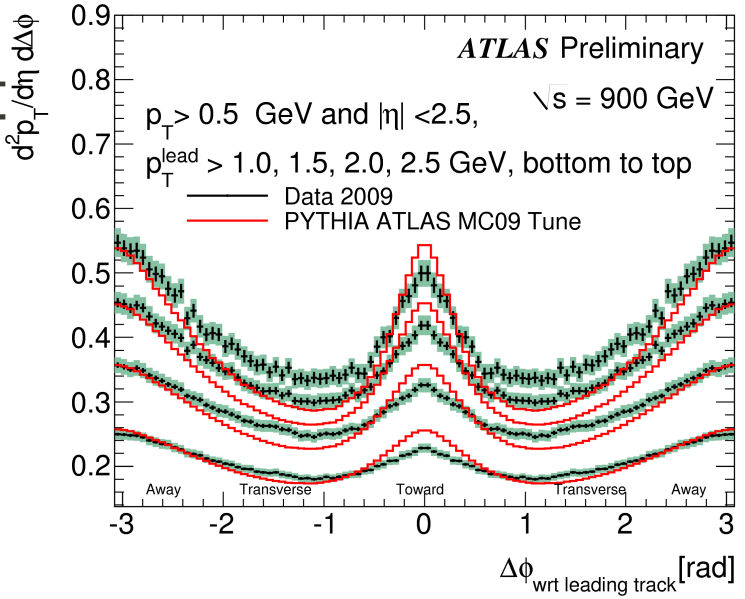


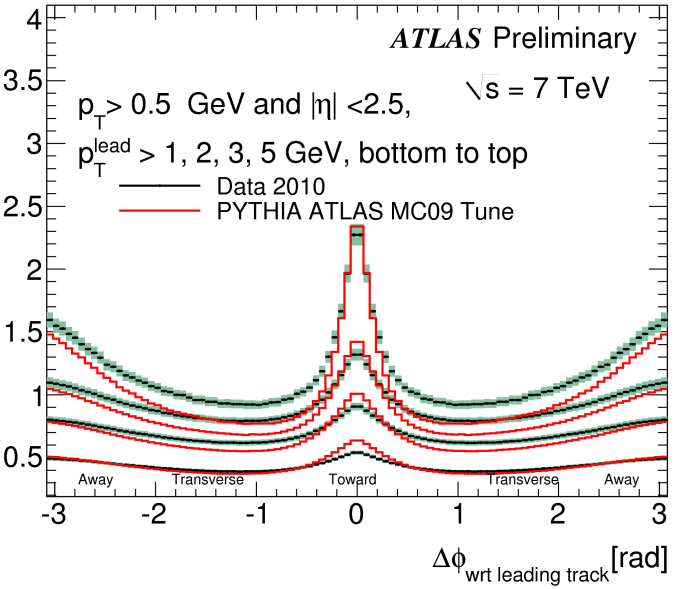
Angular distributions - Δϕ

- Δϕ shapes are not well described by MC tunes
- The next part of the talk will give more insight into the Δϕ shapes









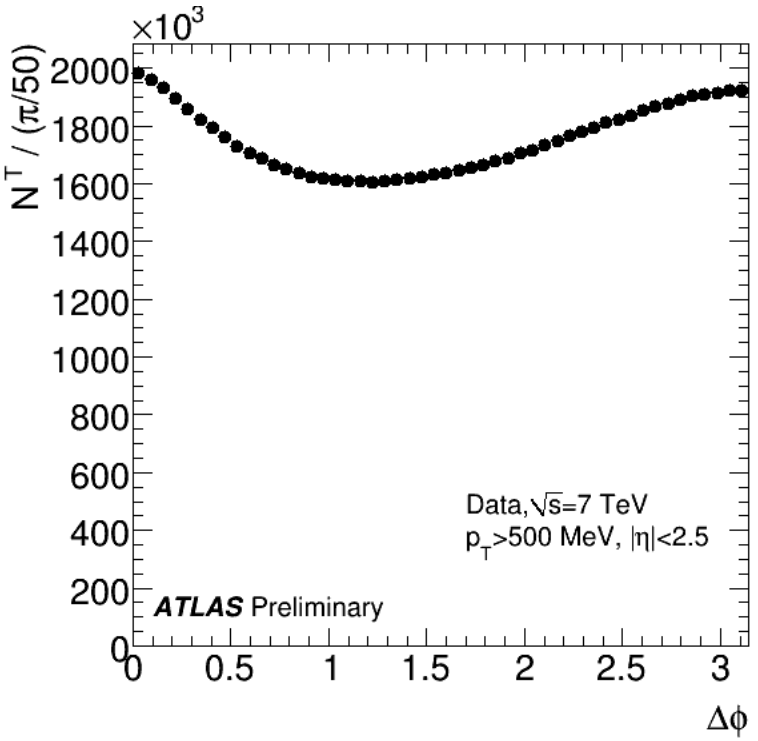
Angular distributions: $\Delta\phi$

- Take a closer look into the $\Delta\phi$ shape
- Define variables in a way to minimise the systematic error
- Systematic uncertainty small – a few percent in the most sensitive bins
- Three eta ranges: **$|\eta| < 1.0$**, 2.0, **2.5**
- ATLAS-CONF-2010-082

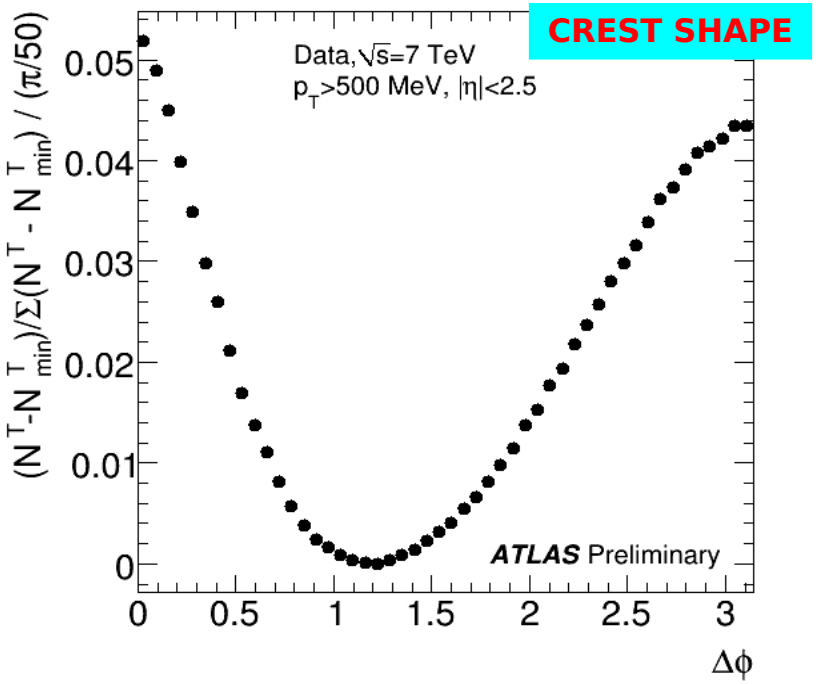
Δϕ crest shape

Δϕ is the ABSOLUTE VALUE of the angle between the tracks

Raw Δϕ distribution:

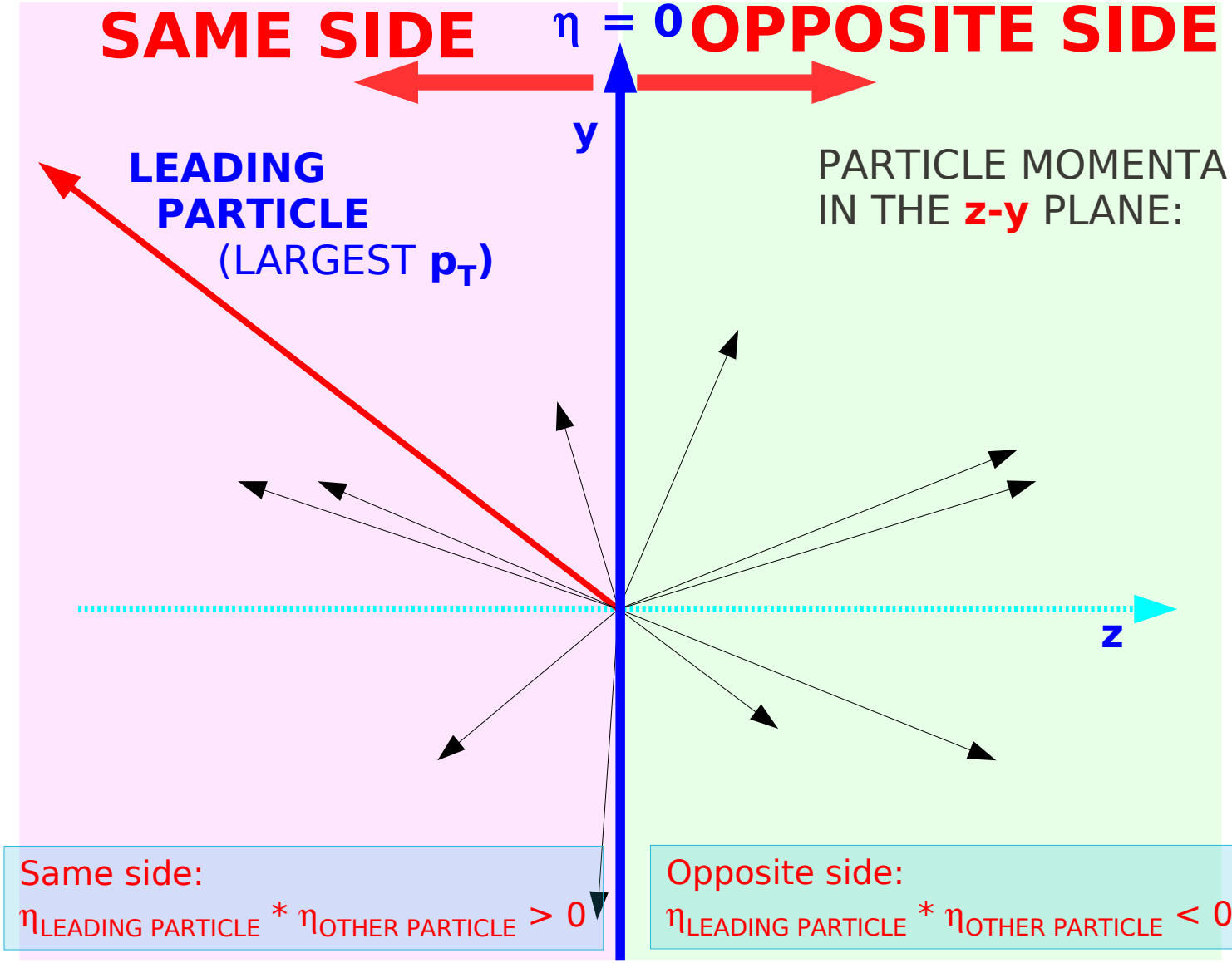


Subtract the minimum and normalise to 1:



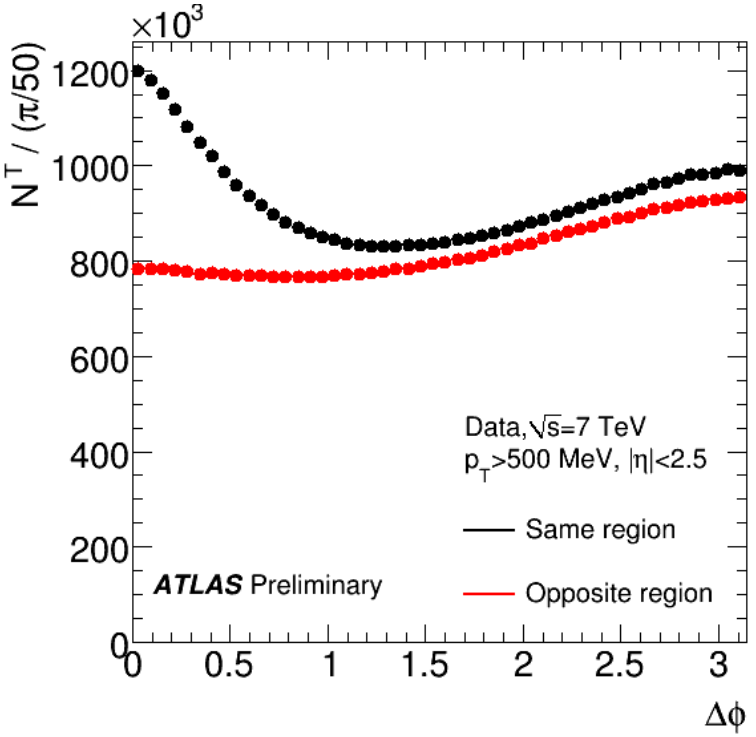
- This is one of the two observables in this measurement.
- **Tests the shape** of the event: systematic uncertainties are greatly reduced!

Definition: Same side, Opposite side

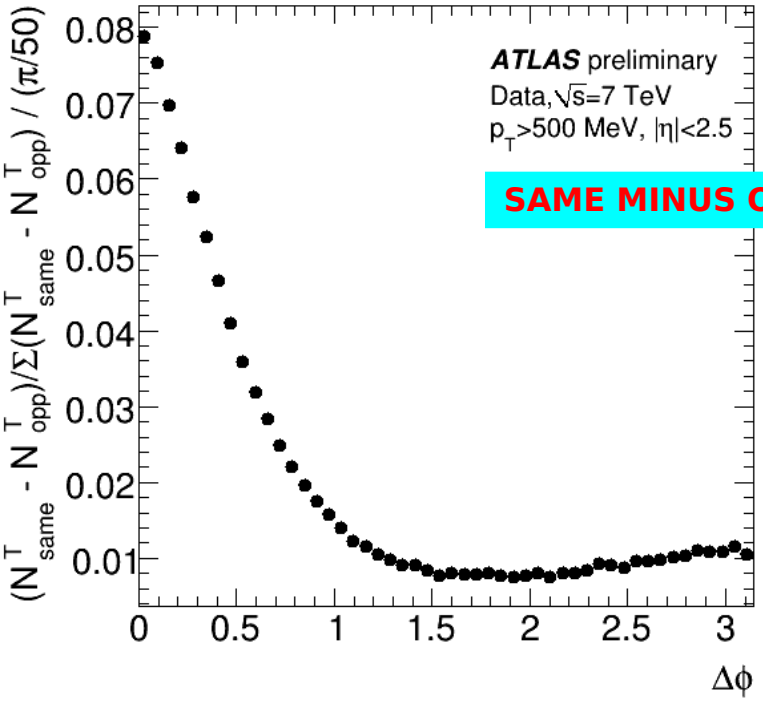


“Same minus opposite”

Raw $\Delta\phi$ distributions for both regions:



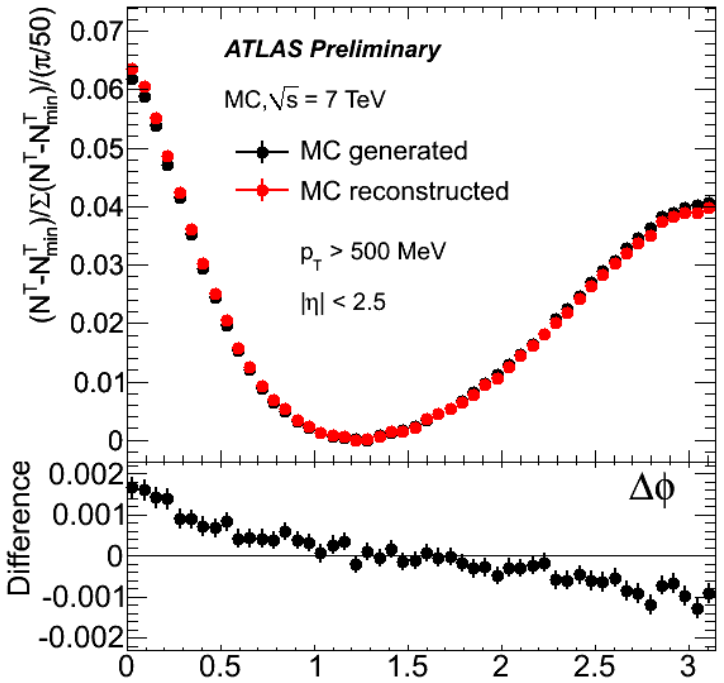
Subtract the “opposite side” distribution from the “same side distribution” and normalise to 1.0:



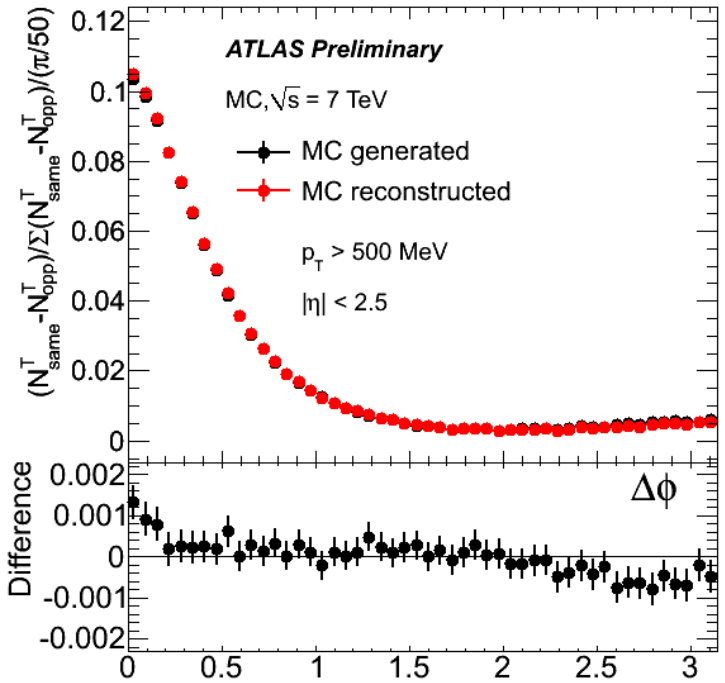
- This is the second observable in this measurement.
- **Tests the shape** of the event: systematic uncertainties are greatly reduced!

MC: generated vs. reconstructed $\Delta\phi$

CREST SHAPE



SAME MINUS OPPOSITE



- Without applying any corrections the reconstructed distributions agree reasonably well with the generated ones
- For $|\eta| < 1.0$ these discrepancies are even smaller

Corrections applied

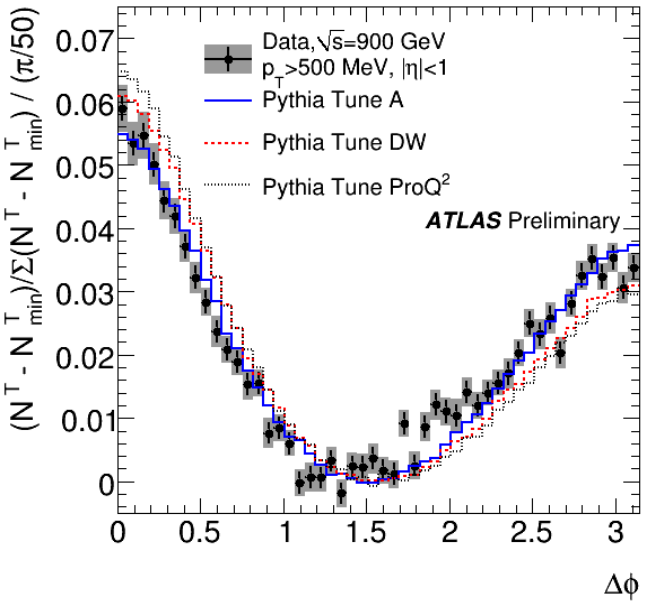
- Correct for tracking efficiency and presence of non-primary tracks
- Correct for lost leading tracks

→ Compare the corrected distributions directly to the output of MC generators

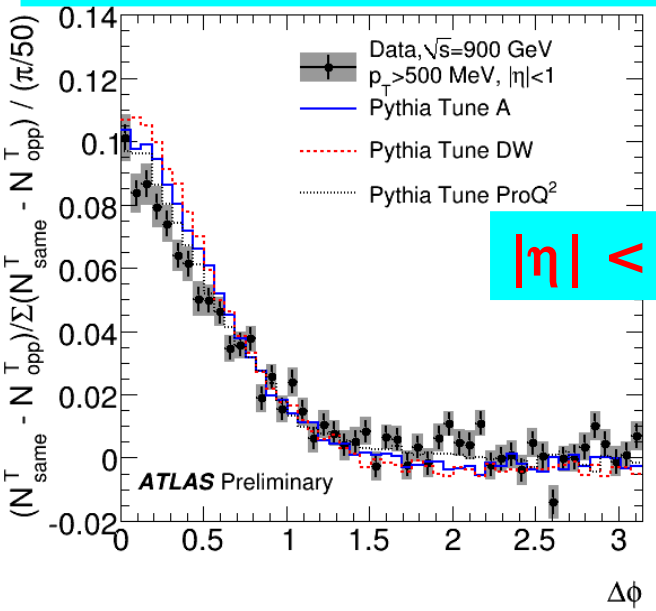
Results: **900 GeV**

- |η|<1.0: MC descriptions are ~OK
- |η|<2.5: MC descriptions are OFF
- This is true for all the tunes (no tune describes the shapes)

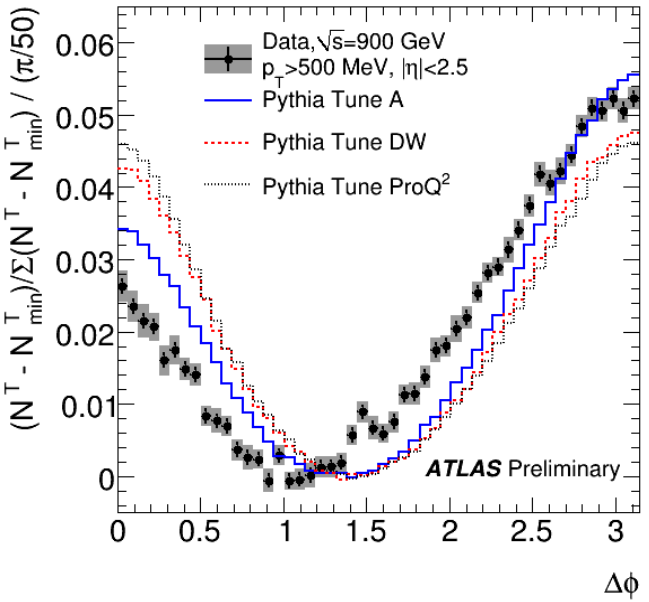
CREST shape

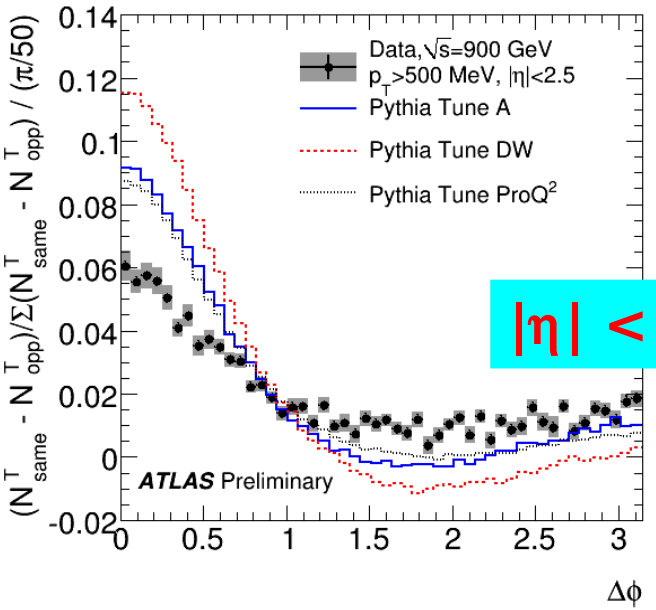


SAME minus OPPosite



|η| < 1.0



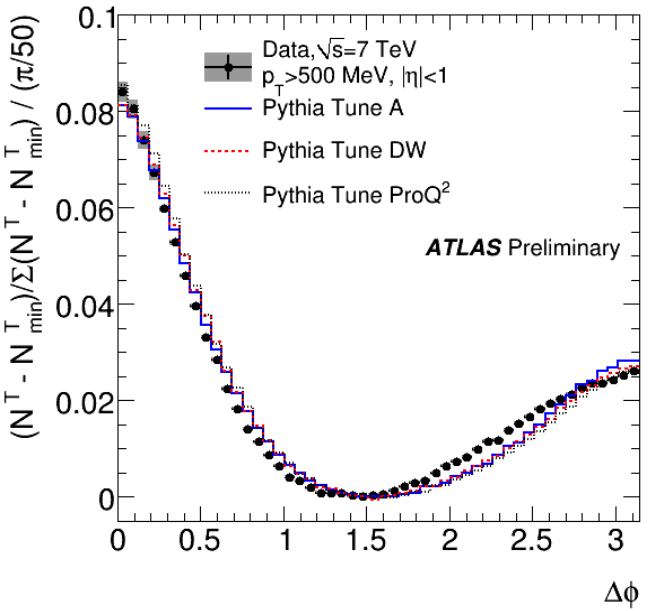


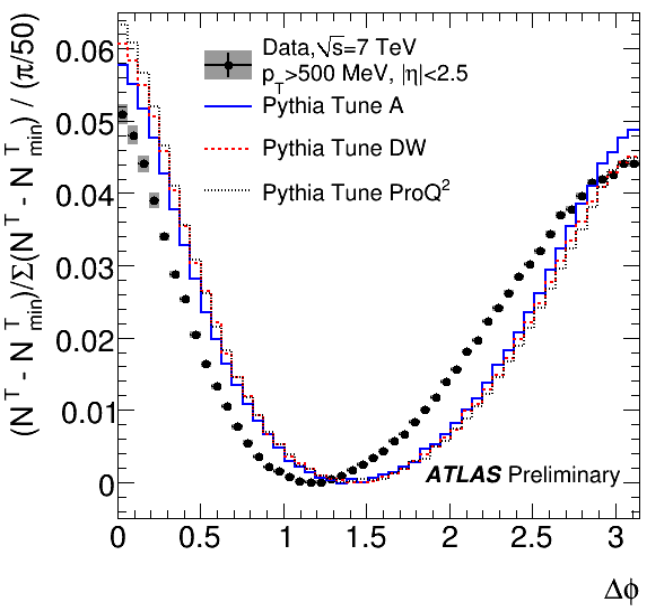
|η| < 2.5

Results: 7 TeV

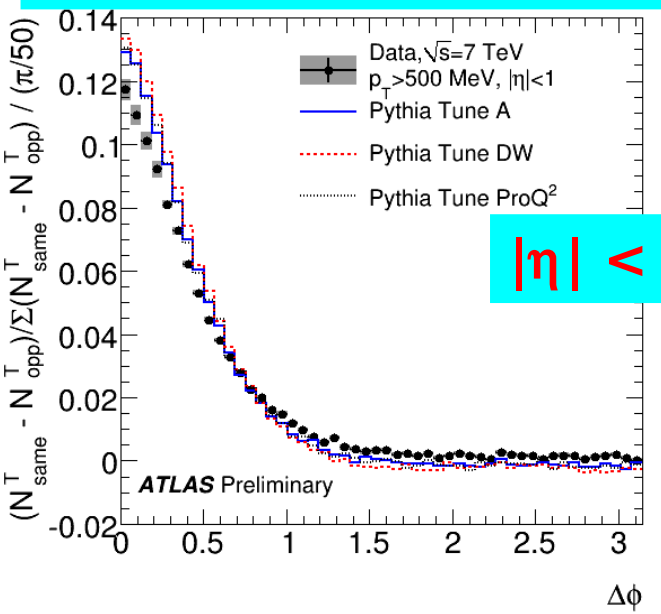
- MCs are ~OK for $|\eta|<1.0$, but not for $|\eta|<2.5$
- Shapes for 7 TeV different than for 900 GeV
- At 7 TeV tunes are closer together, but not closer to the data

CREST shape

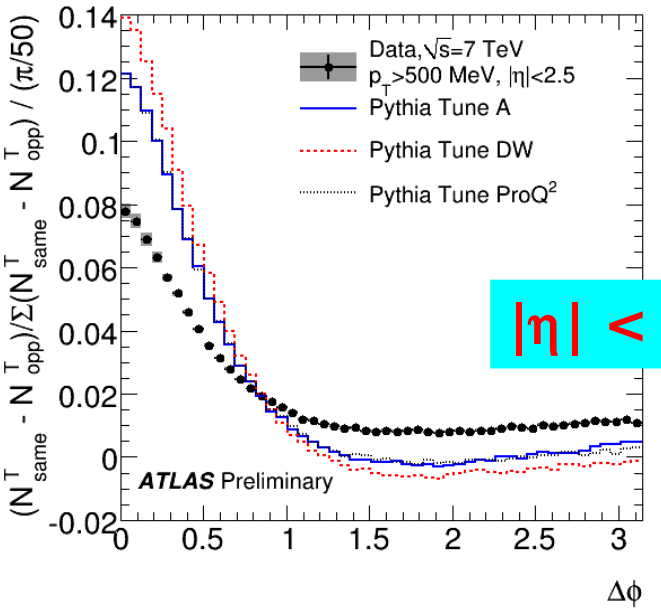




SAME minus OPPosite



|η| < 1.0



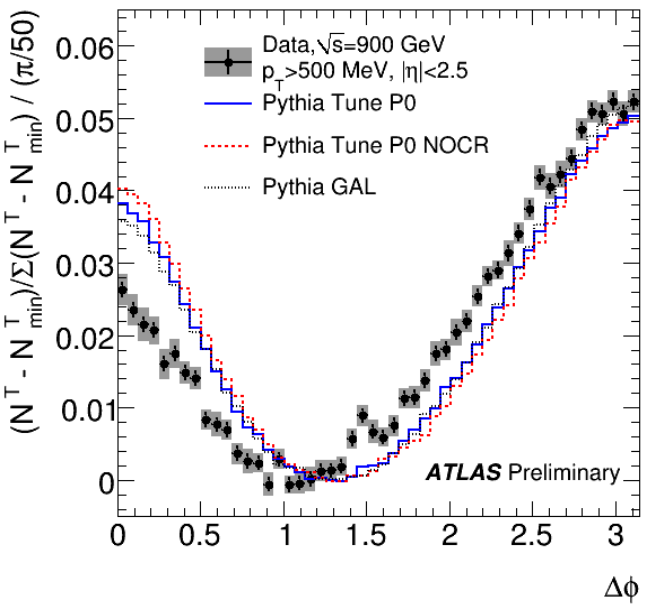
|η| < 2.5

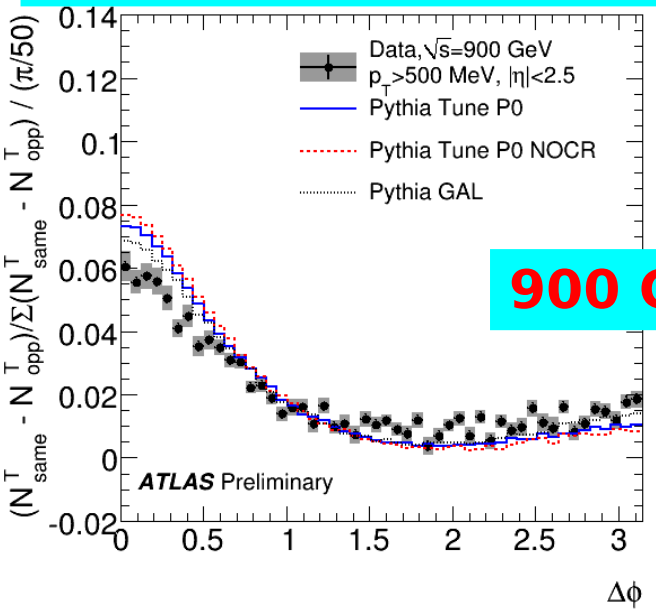
color reconnections, |η| < 2.5

- MCs are ~OK for |η|<1.0, but not for |η|<2.5
- Shapes for 7 TeV different than for 900 GeV
- At 7 TeV tunes are closer together, but not closer to the data

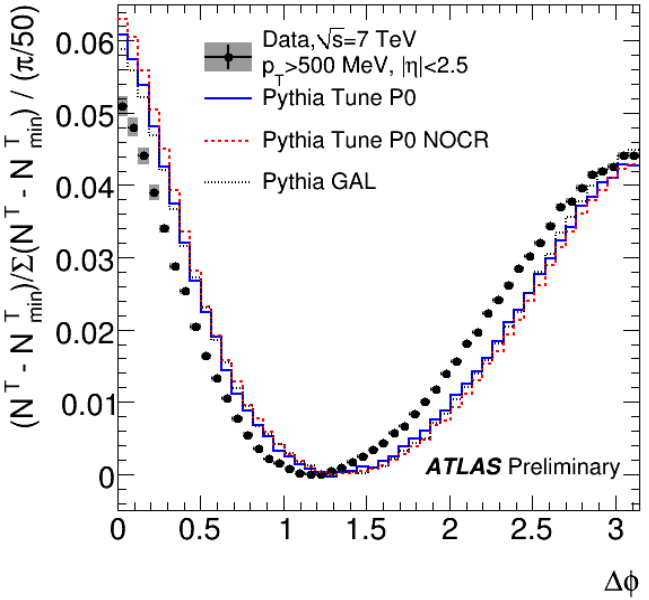
CREST shape

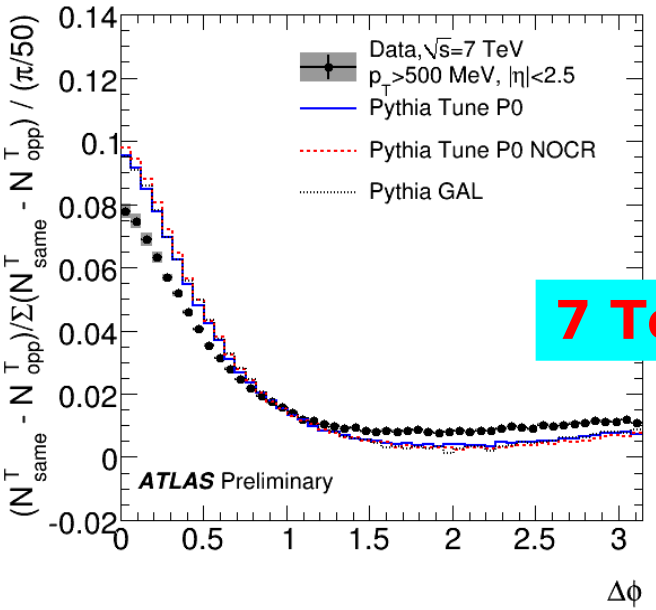
SAME minus OPPosite





900 GeV



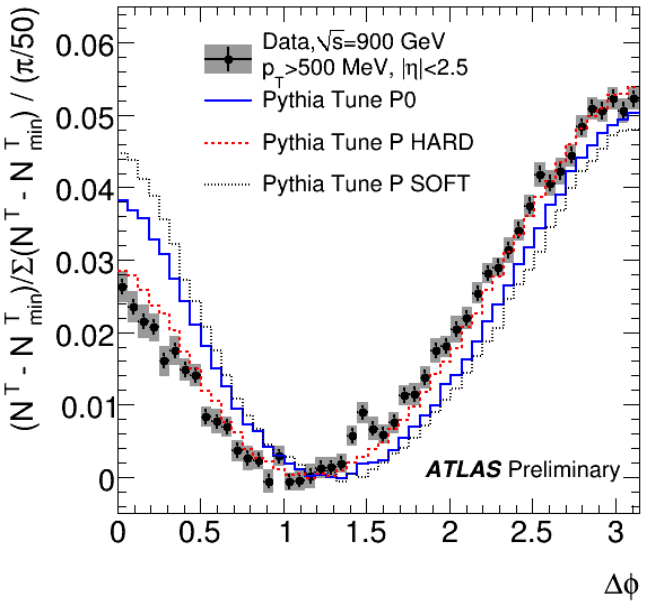


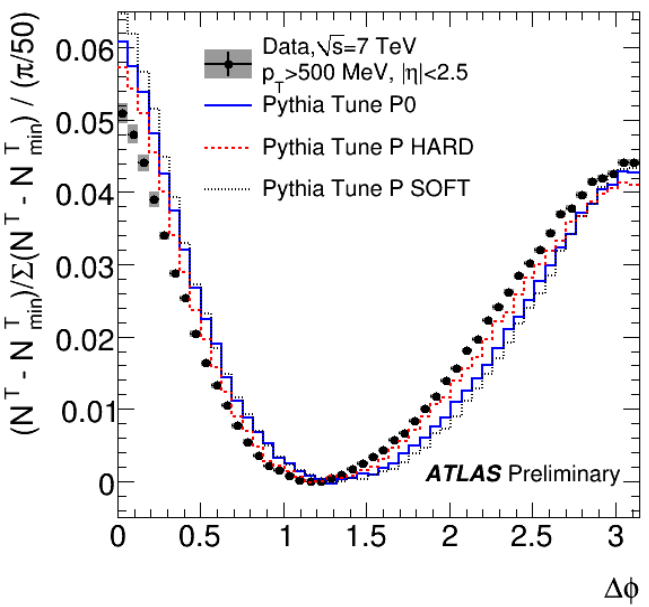
7 TeV

p_T ordered tunes, $|\eta| < 2.5$

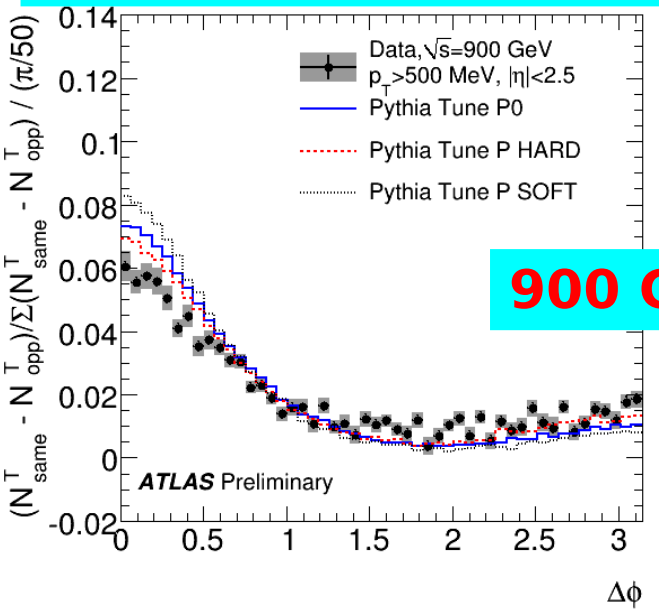
- At 7 TeV tunes are closer together, but not closer to the data
- Sensitive to shower parameters
- P HARD good for “crest” at 900 GeV, but not for 7 TeV “Same minus Opposite”

CREST shape

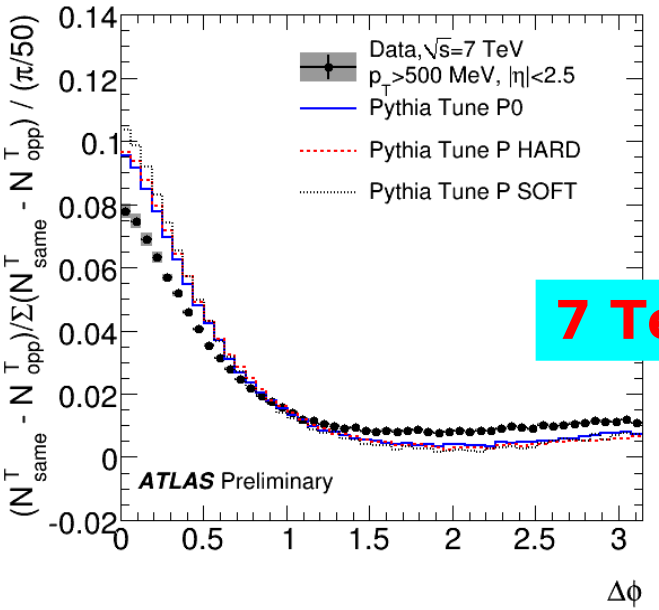




SAME minus OPPosite



900 GeV



7 TeV

Conclusions

- Track based UE study results shown:
  - pre-LHC MCs too low in the transverse region, but better in forward and away
- $\Delta\phi$ shape studied using new variables
  - variables robust by construction
  - Pythia tunes fail to describe $\Delta\phi$ distributions