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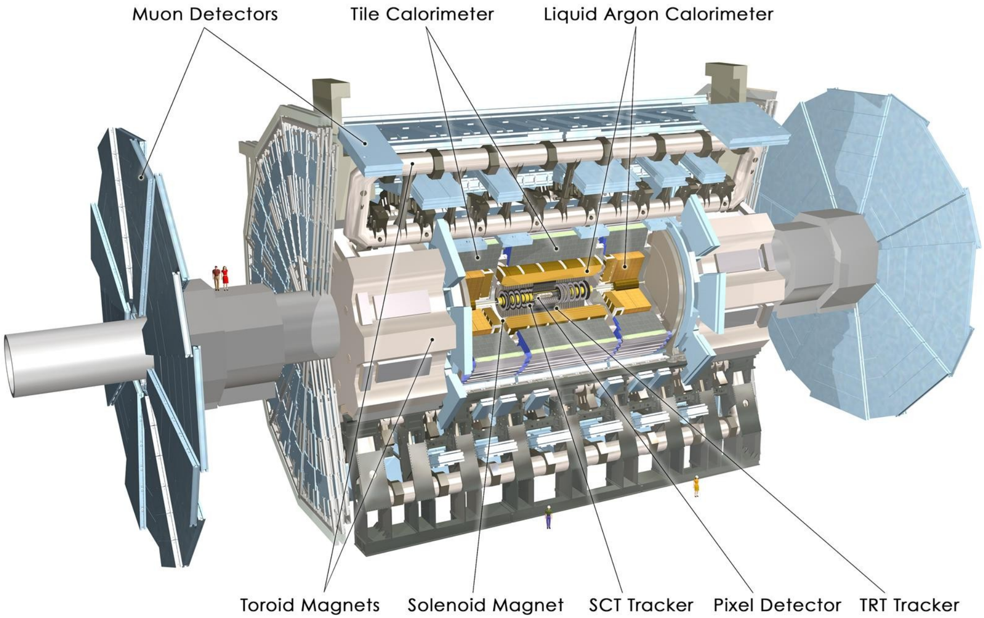
Charged Particle Correlations in Minimum Bias Events at ATLAS

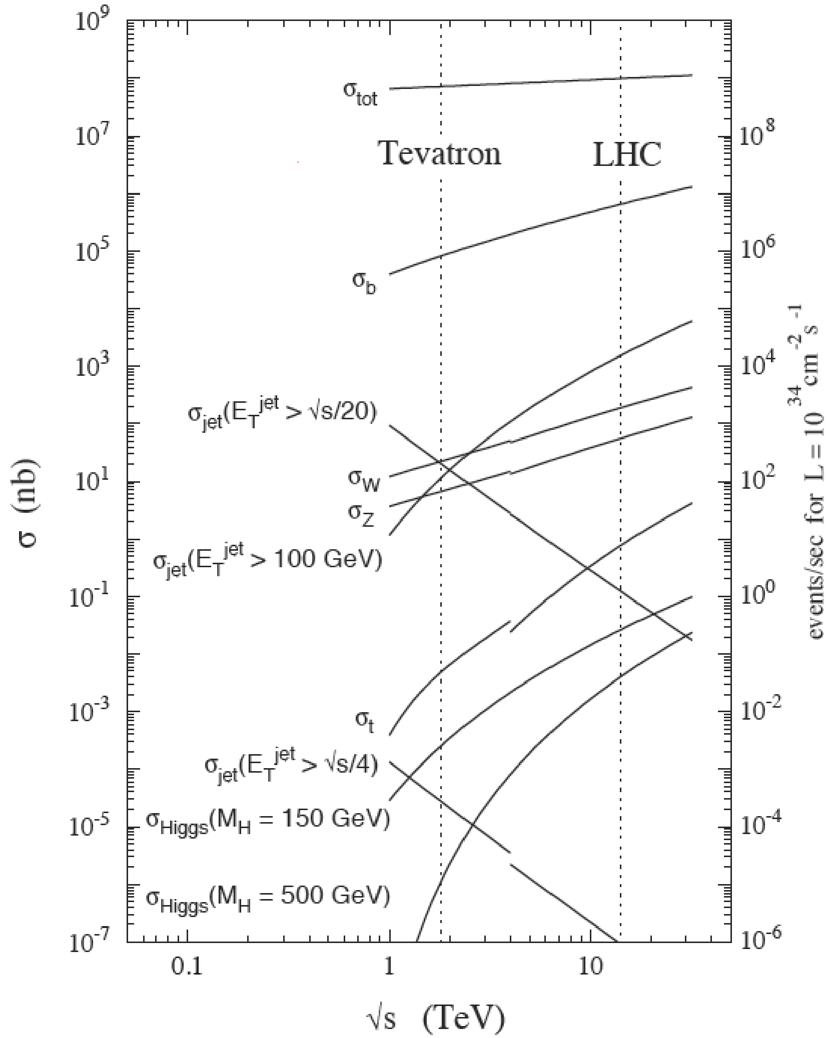
February 26th 2012, WNPPC 2012

- Physics motivation
- Minbias event and track selection
- Azimuthal correlation results
- Forward-Backward correlation results

Overview



Muon Detectors
Tile Calorimeter
Liquid Argon Calorimeter
Toroid Magnets
Solenoid Magnet
SCT Tracker
Pixel Detector
TRT Tracker



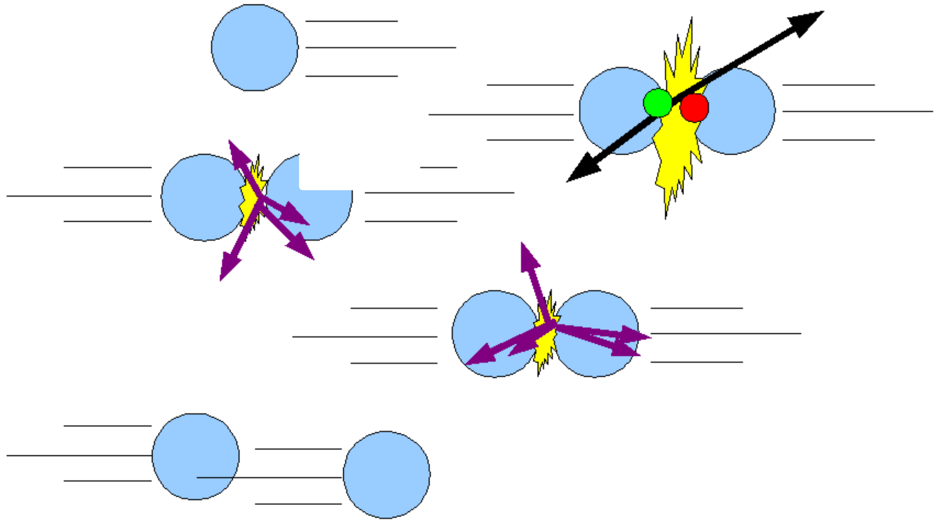
σ_tot
Tevatron
LHC
σ_b
σ_jet(E_T^jet > √s/20)
σ_W
σ_Z
σ_jet(E_T^jet > 100 GeV)
σ_t
σ_jet(E_T^jet > √s/4)
σ_Higgs(M_H = 150 GeV)
σ_Higgs(M_H = 500 GeV)
σ (nb)
√s (TeV)
events/sec for L = 10^34 cm^-2 s^-1

Physics Background

- Perturbative QCD calculations cannot be done in the "soft" regime where the transverse momentum transfer between initial and final states is small
  - Beam-beam remnants, multiple parton interactions, initial and final state radiation → long-range correlations
- Data predictions done in MC simulations via phenomenological models with many parameters
  - New/improved measurements of quantities sensitive to soft QCD effects deepens physics understanding and improves models.

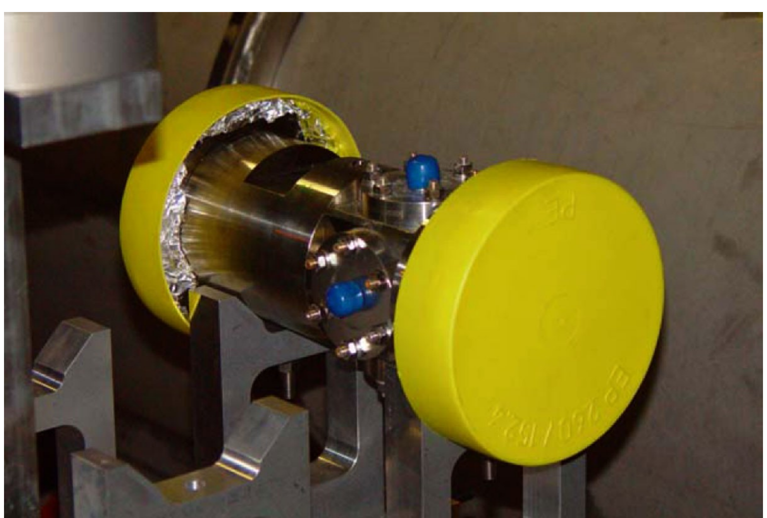
Minimum bias collisions

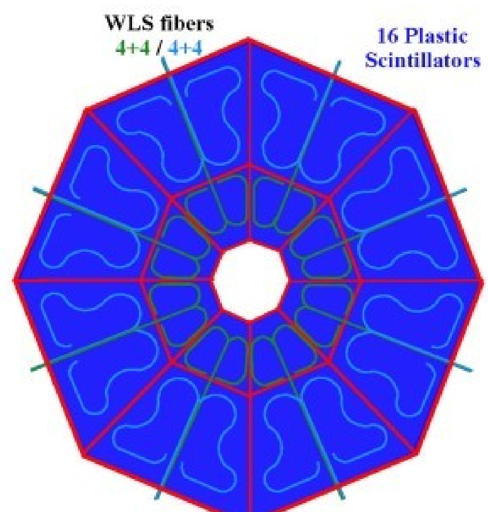
- Event sample representative of the overall collision cross-section
- Dominated by QCD 2→2 process
- Sensitive to non-perturbative “soft” QCD
- Collected using a dedicated trigger at ATLAS



Minimum bias sample

- Samples collected with the ATLAS minimum bias trigger
  - Beam Pickup Timing devices (BPTX) – signals beam presence
    - electrostatic beam pick-ups ±175 m from centre
  - Minimum Bias Trigger Scintillators (MBTS)
    - at detector ends in front of endcap-calorimeter at ±3.56 m
    - $2.09 < |\eta| < 3.84$





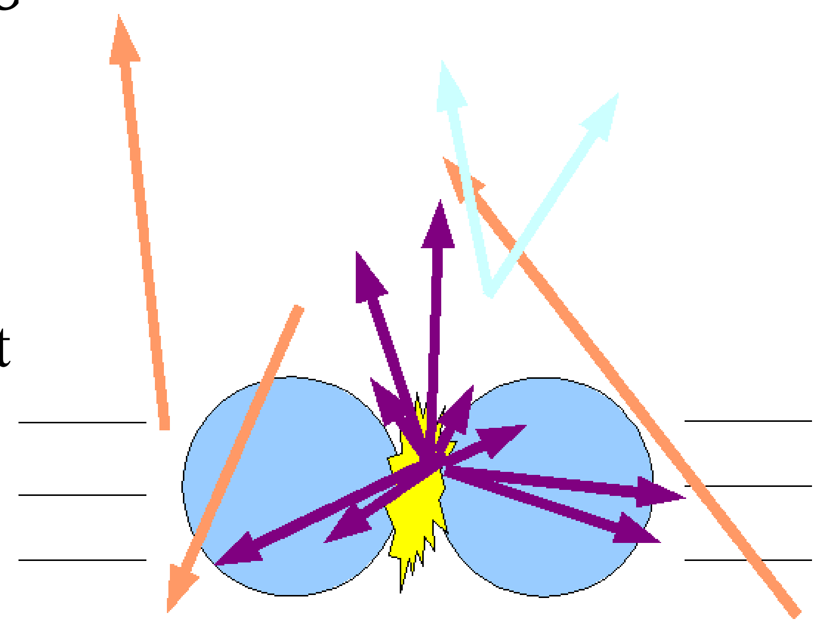
Track selection

Associate all tracks to PVs and then select good quality tracks associated to those PVs: in early ATLAS data, select events with only 1 PV.

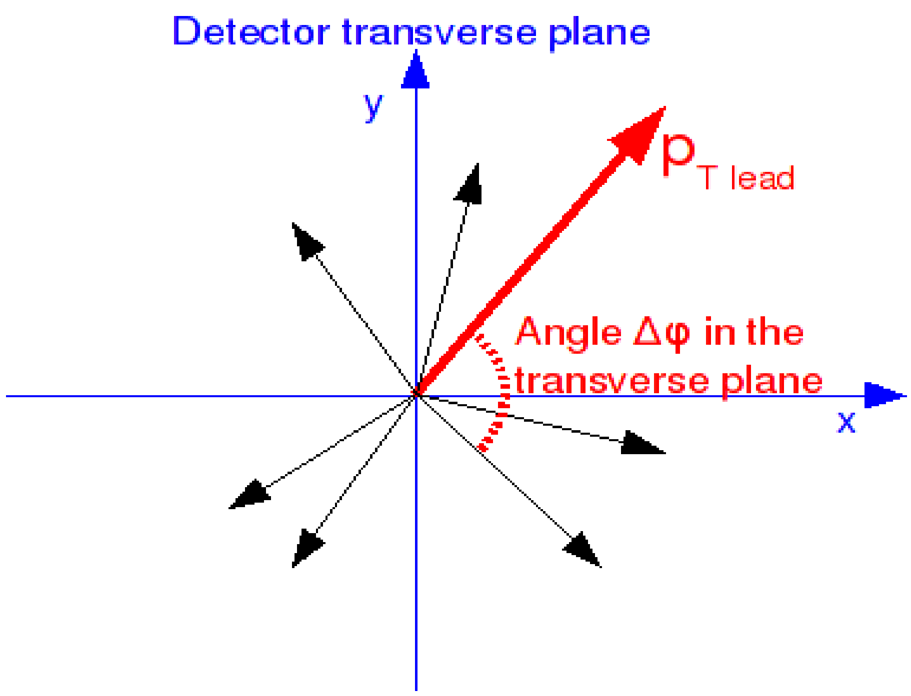
Minimize fakes, cosmics, conversions, long-lived resonances, vertex misassociatio

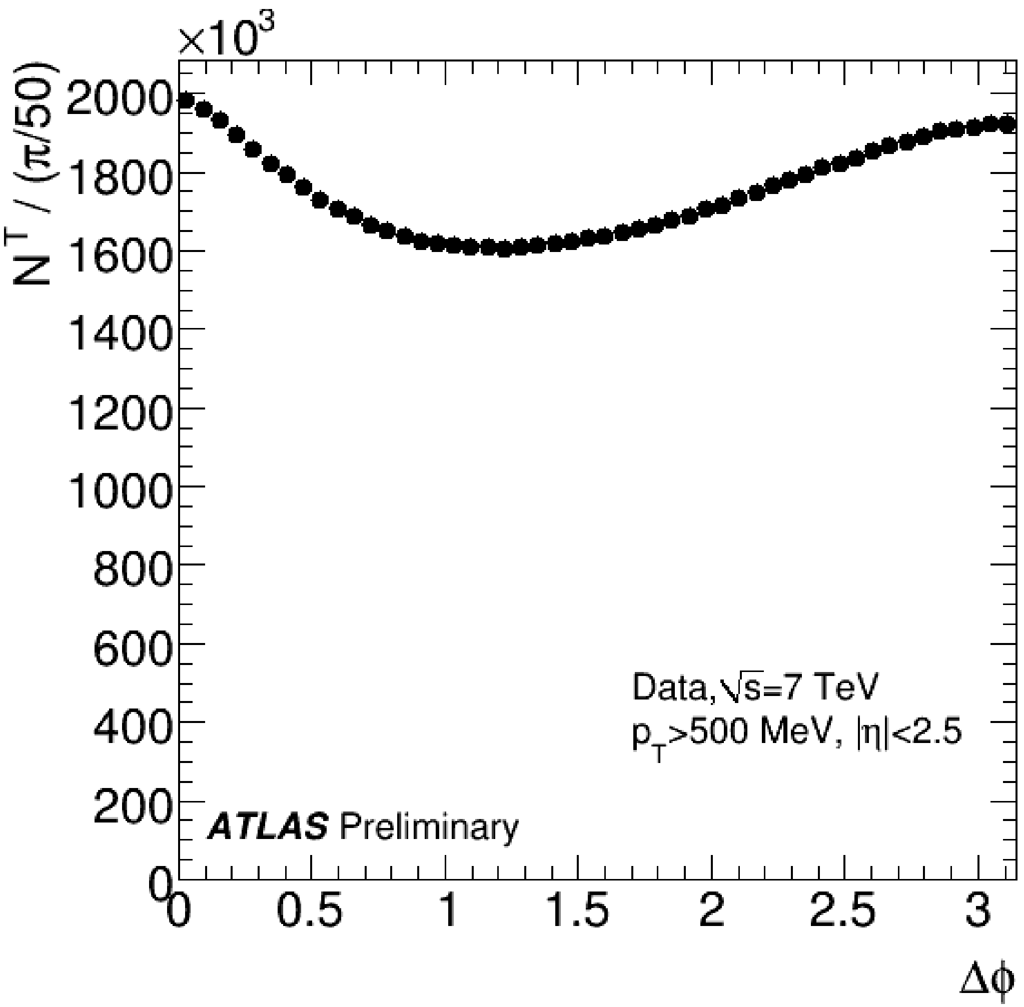
Track selection criteria:

- p_T>0.5GeV
- $|\eta|$<2.5
- Association to vertex and hit requirement



Azimuthal corr. - Crest shape





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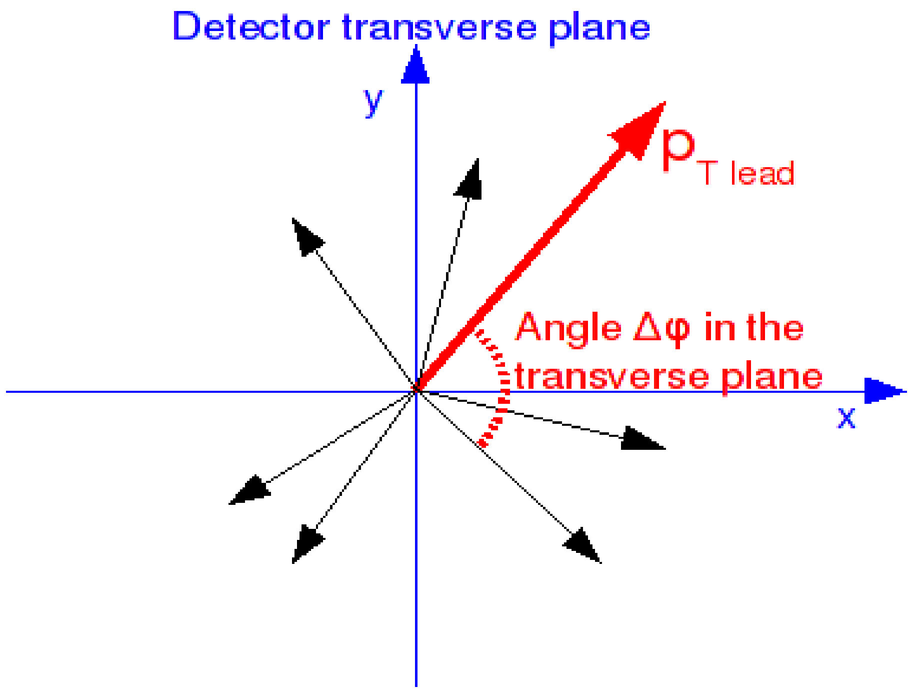

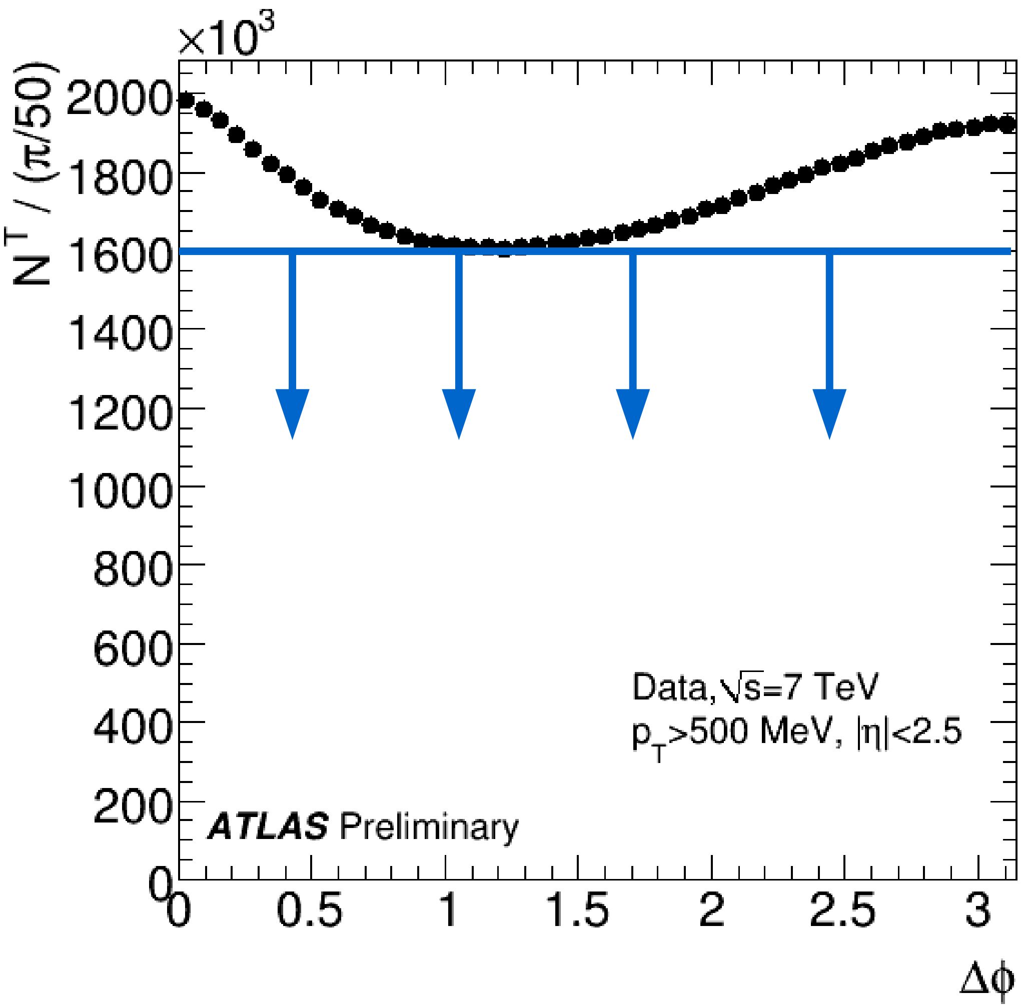

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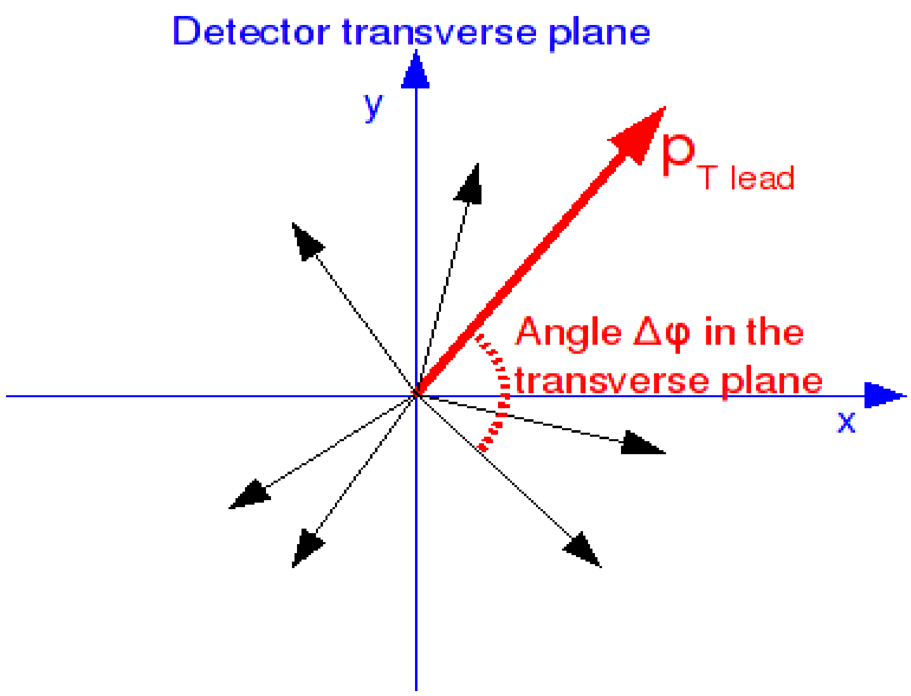
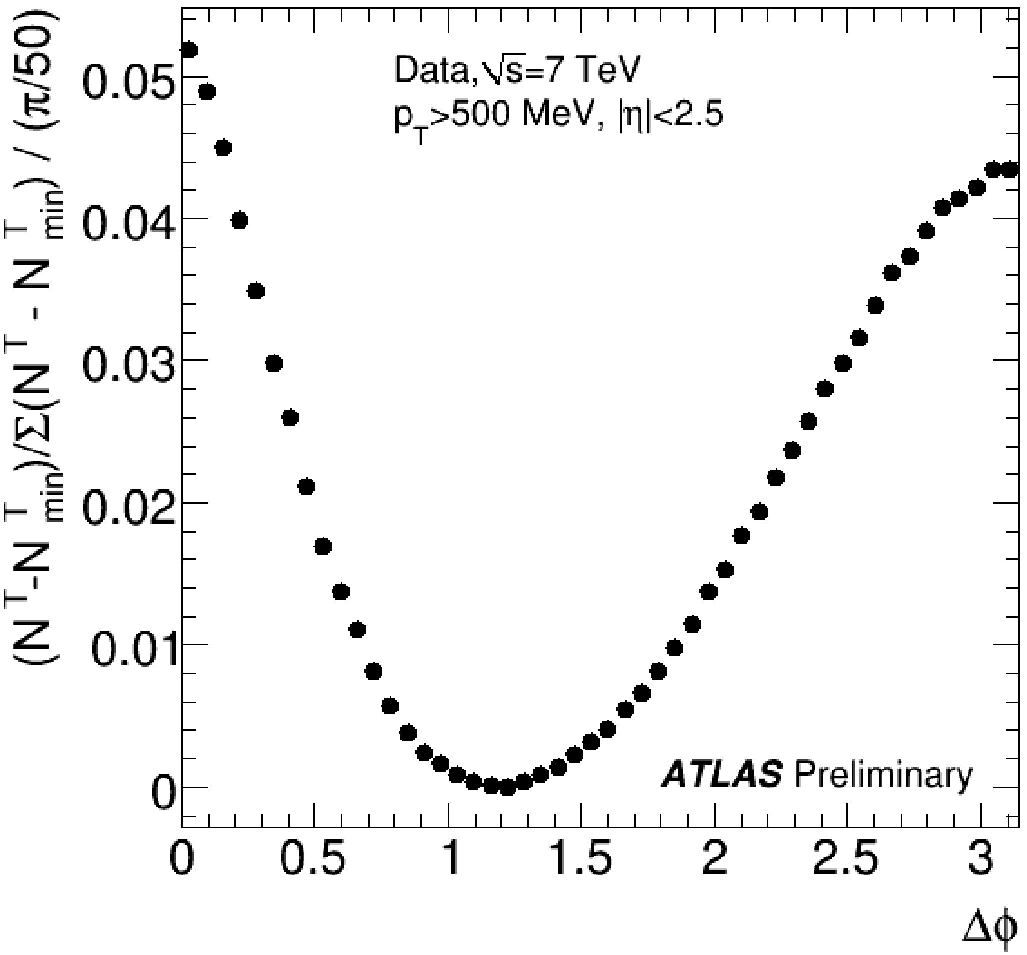
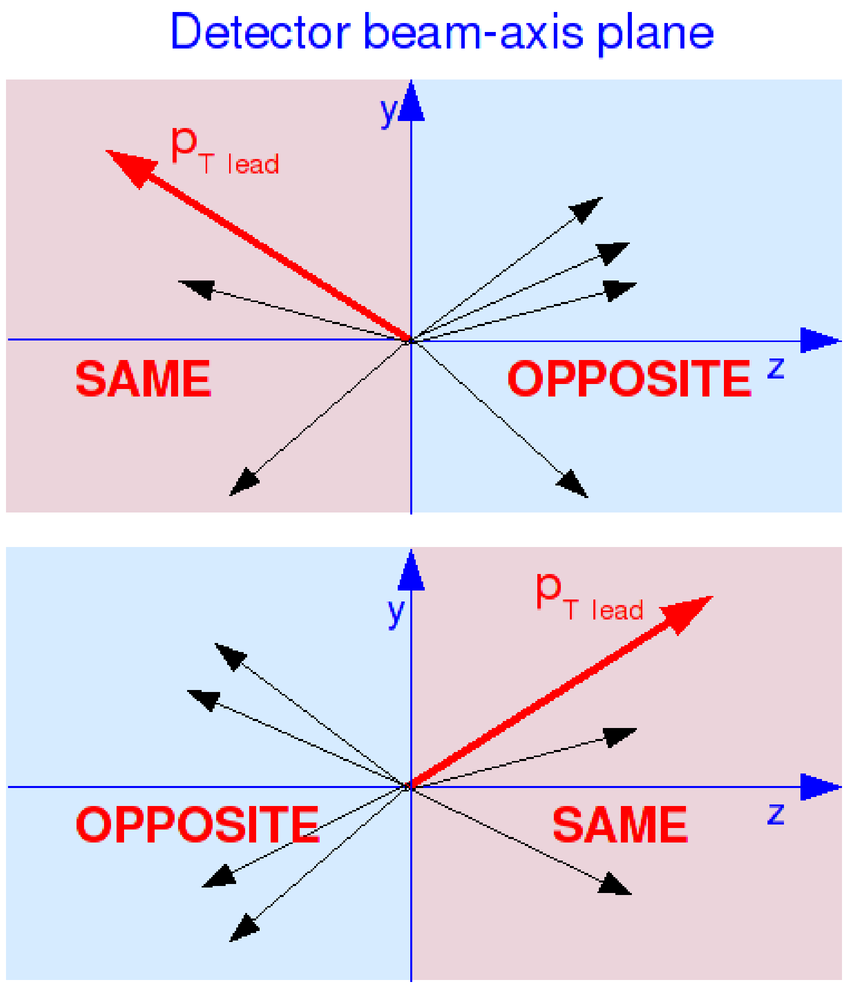


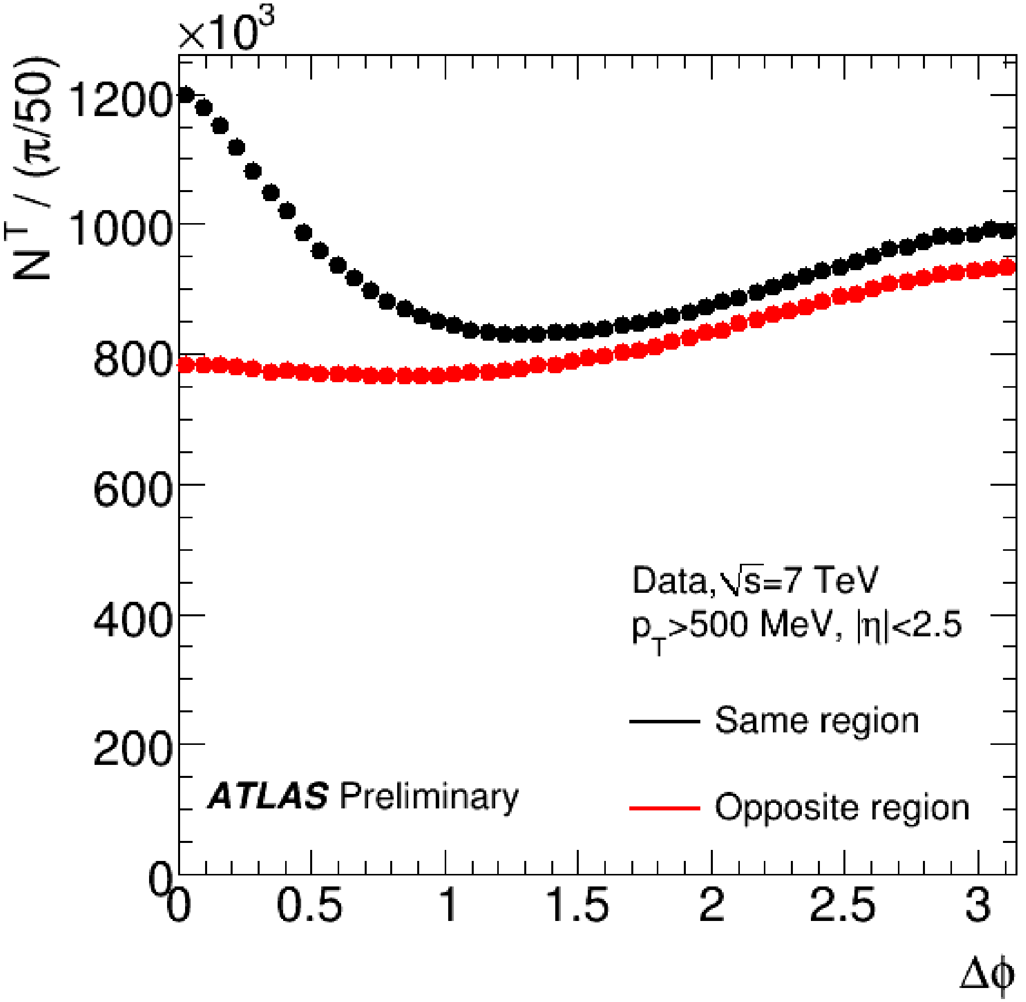


$$N^T_{sub} = \frac{(N^T - N^T_{min})}{\Sigma(N^T - N^T_{min})}$$

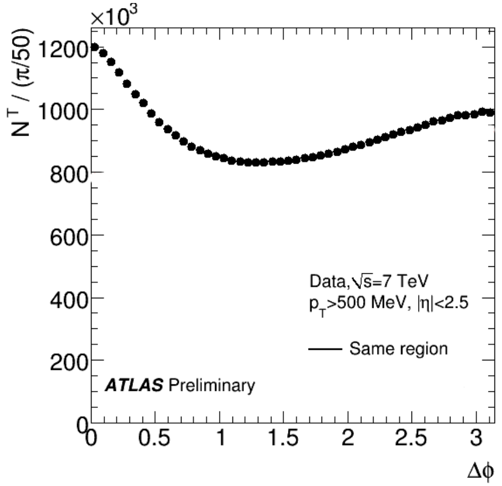
Measured crest shape characteristics: peak widths, relative heights, position of minimum

“Same minus opposite”





“Same minus opposite”



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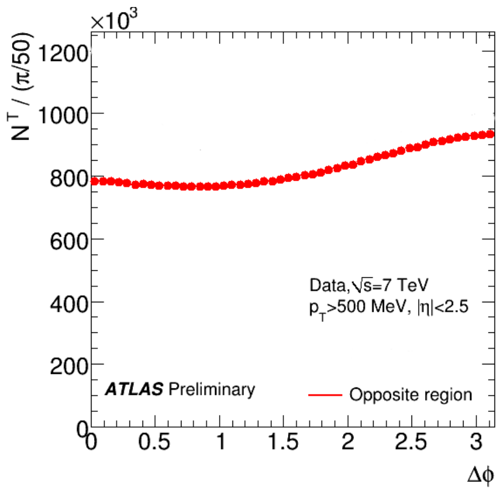

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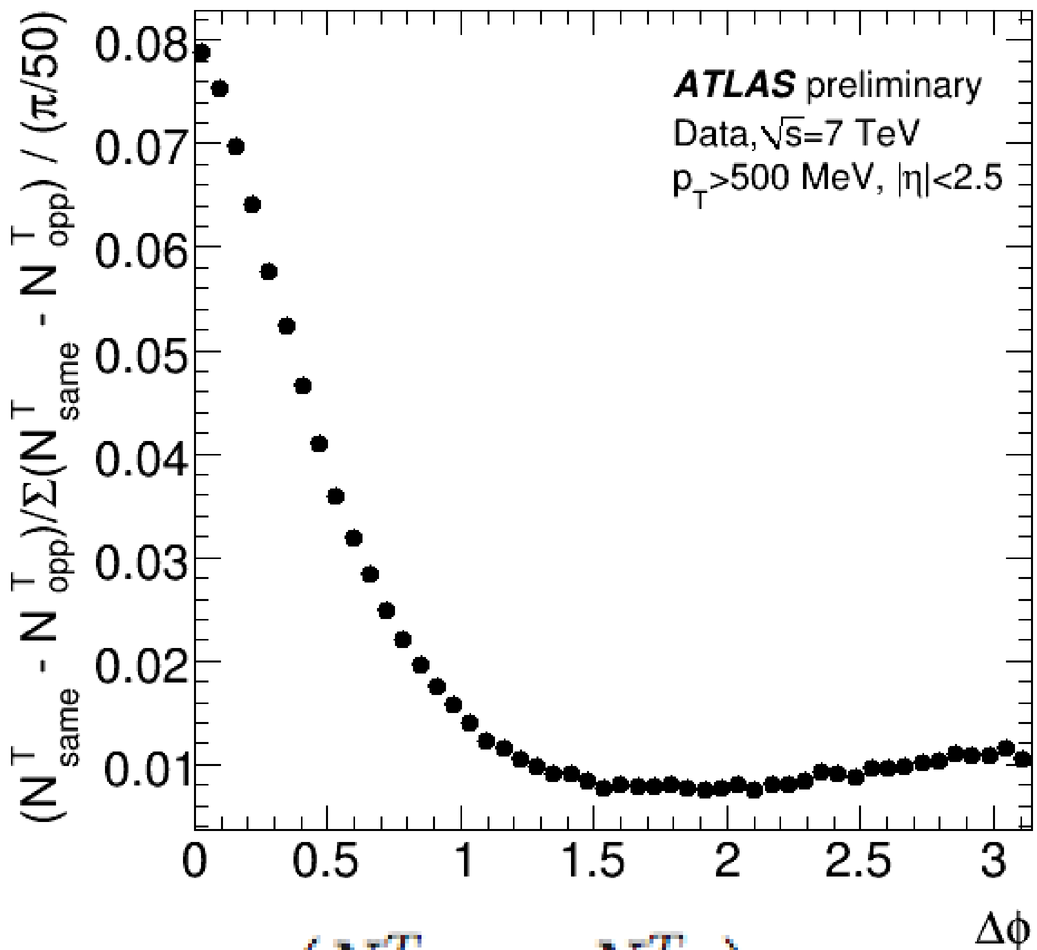
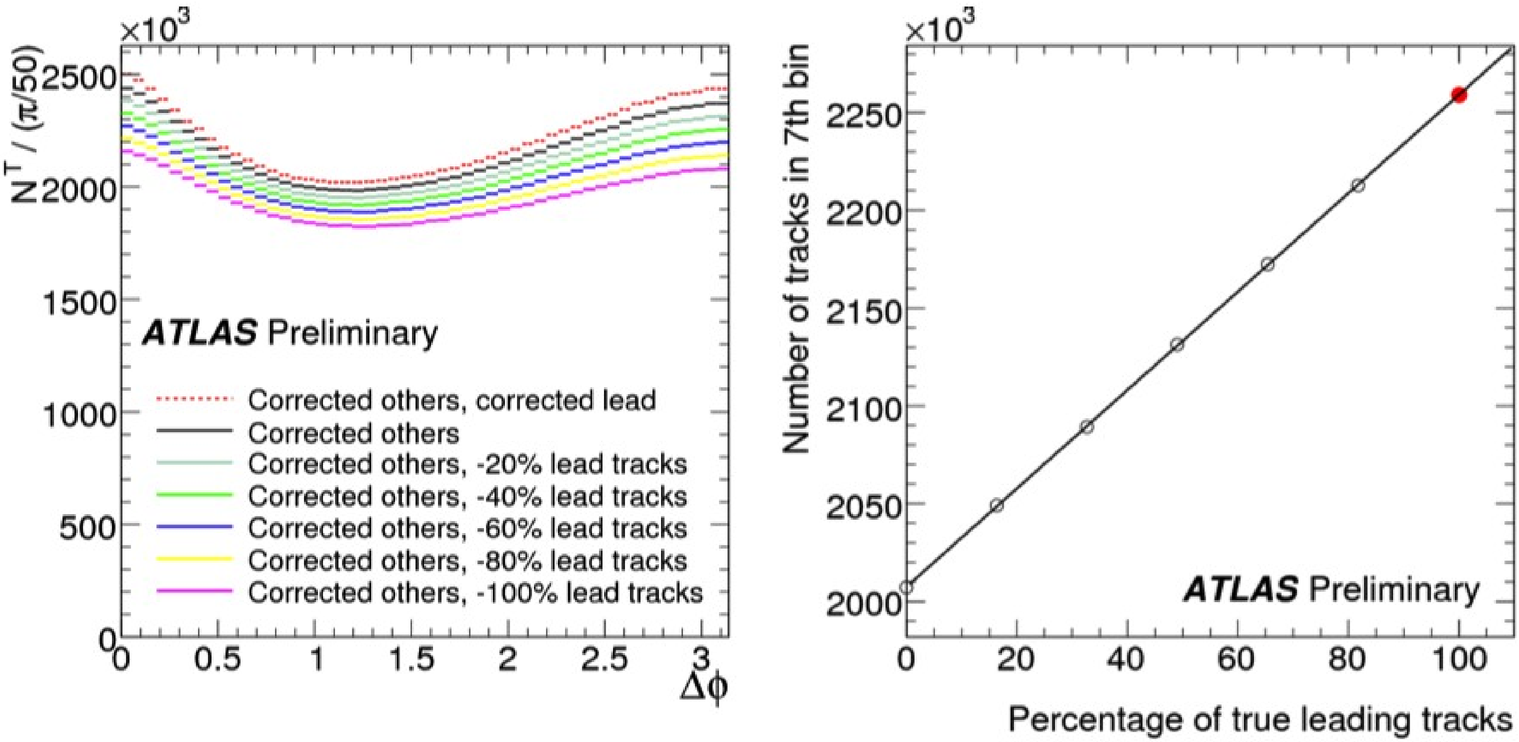


$$N^T_{SO} = \frac{(N^T_{same} - N^T_{opp})}{\Sigma(N^T_{same} - N^T_{opp})}$$

Corrections and Systematics

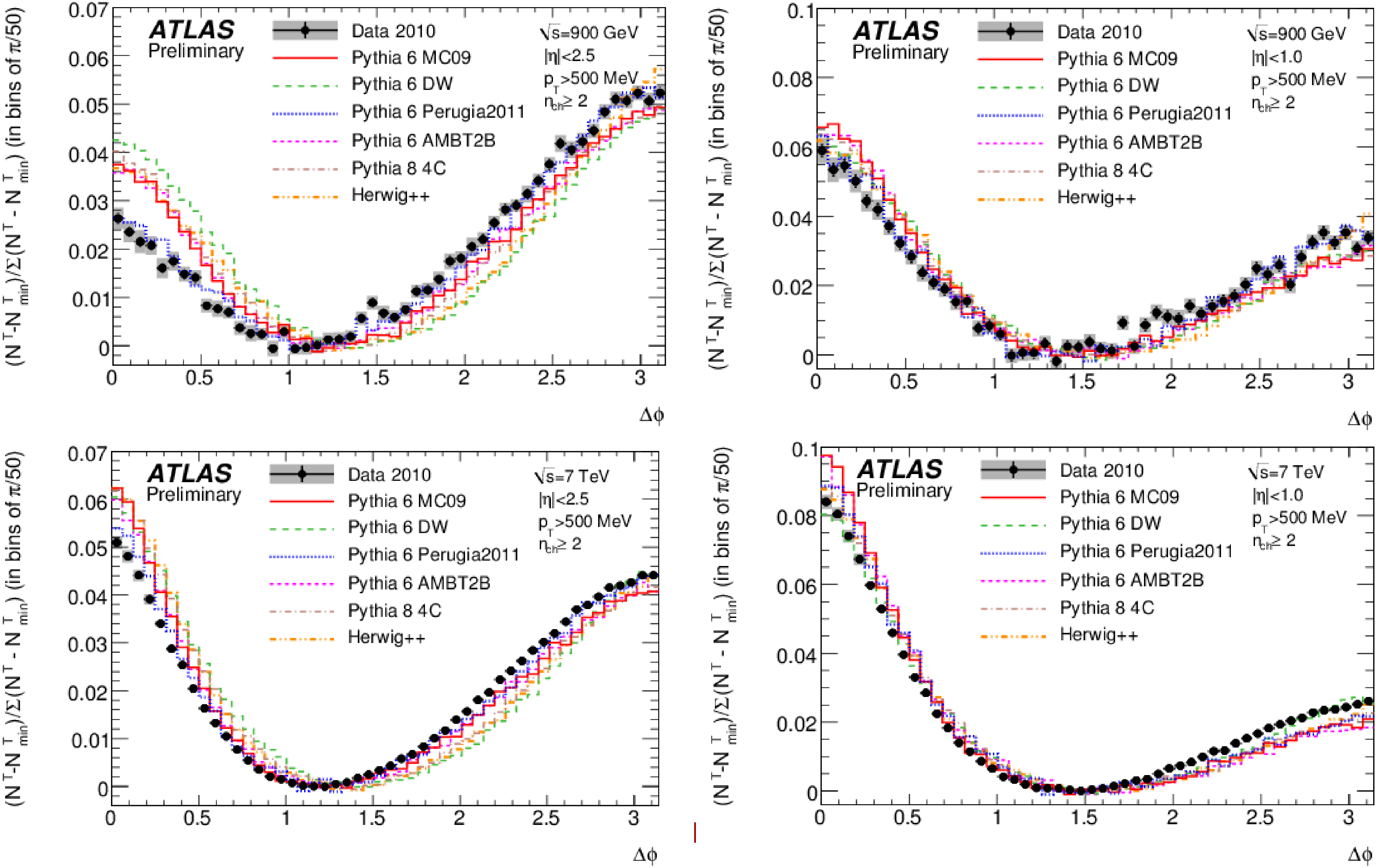
- Correct for tracking efficiency, leading and non-leading tracks



- Main sources of systematics
  - Uncertainty on event acceptance
  - Leading track correction

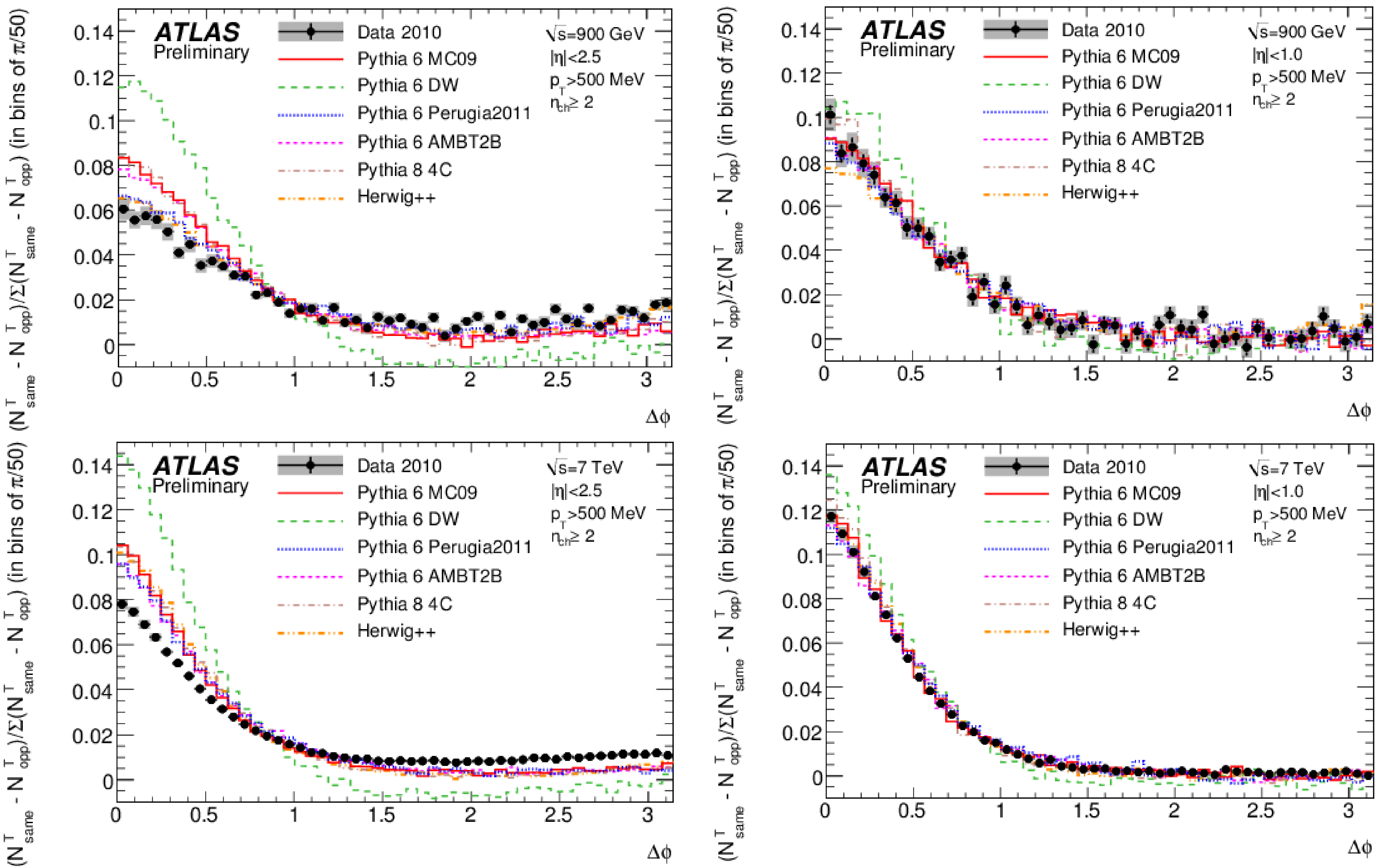
Crest shape distributions

$|\eta|<2.5$ or 1, $p_T>0.5$ GeV



"Same-opposite" distributions

$|\eta|<2.5$ or 1, $p_T>0.5$ GeV



Forward-Backward correlations

- Correlation is defined to the normalised covariance between the forward and the backward distribution, relative to the mean value of each
  - Particle multiplicity and (new!) Σp_T
  - Symmetric or non-symmetric

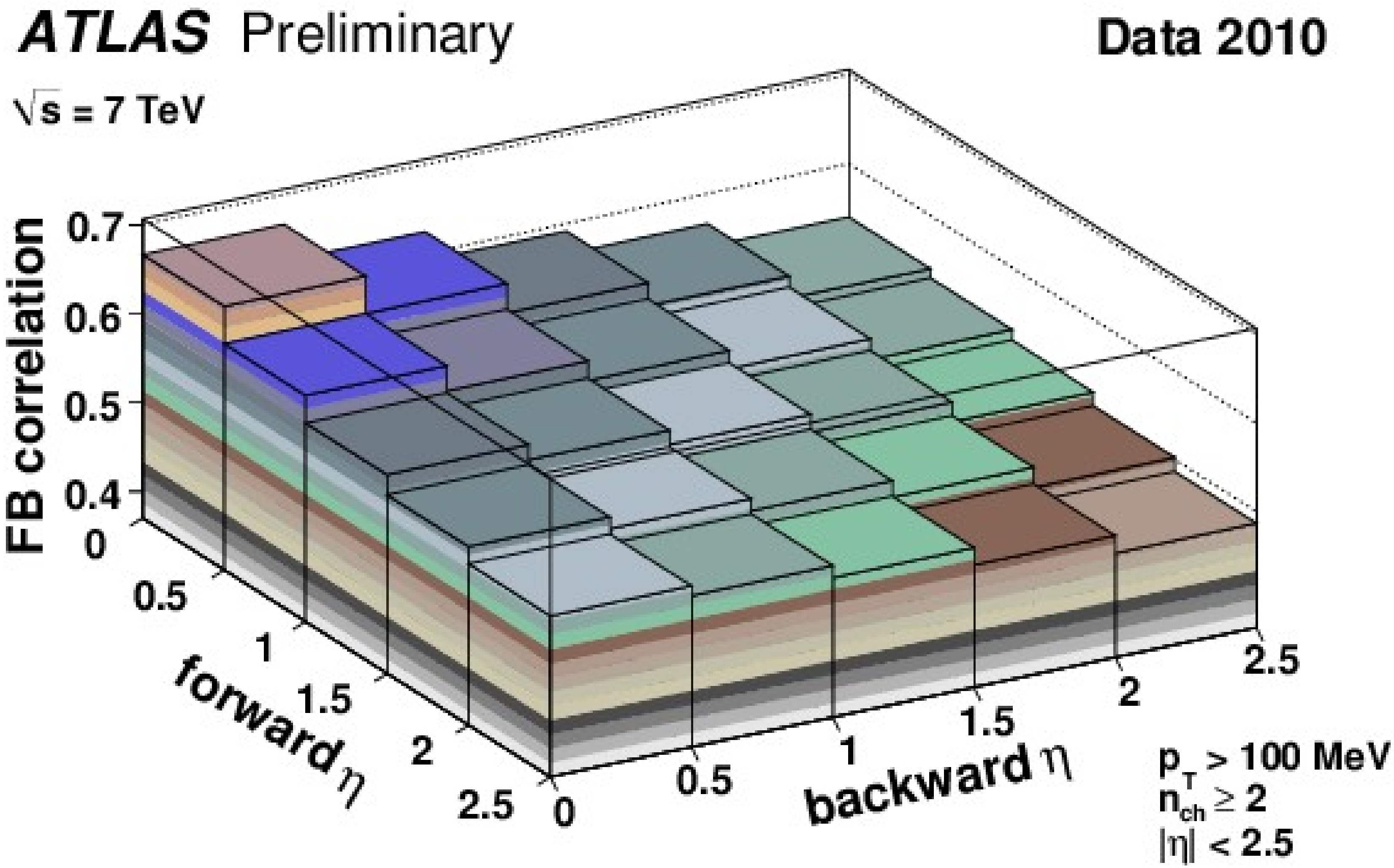
$$\rho_{fb}^{n} = \frac{\langle (n_f - \langle n_f \rangle)(n_b - \langle n_b \rangle) \rangle}{\sqrt{\langle (n_f - \langle n_f \rangle)^2 \rangle \langle (n_b - \langle n_b \rangle)^2 \rangle}} = \frac{\Sigma x_f^n x_b^n}{N \sigma_f^n \sigma_b^n}$$

$$\rho_{fb}^{p_T} = \frac{\langle (\sum p_T^f - \langle \sum p_T^f \rangle)(\sum p_T^b - \langle \sum p_T^b \rangle) \rangle}{\sqrt{\langle (\sum p_T^f - \langle \sum p_T^f \rangle)^2 \rangle \langle (\sum p_T^b - \langle \sum p_T^b \rangle)^2 \rangle}} = \frac{\Sigma x_f^{p_T} x_b^{p_T}}{N \sigma_f^{p_T} \sigma_b^{p_T}}$$

FB correlations

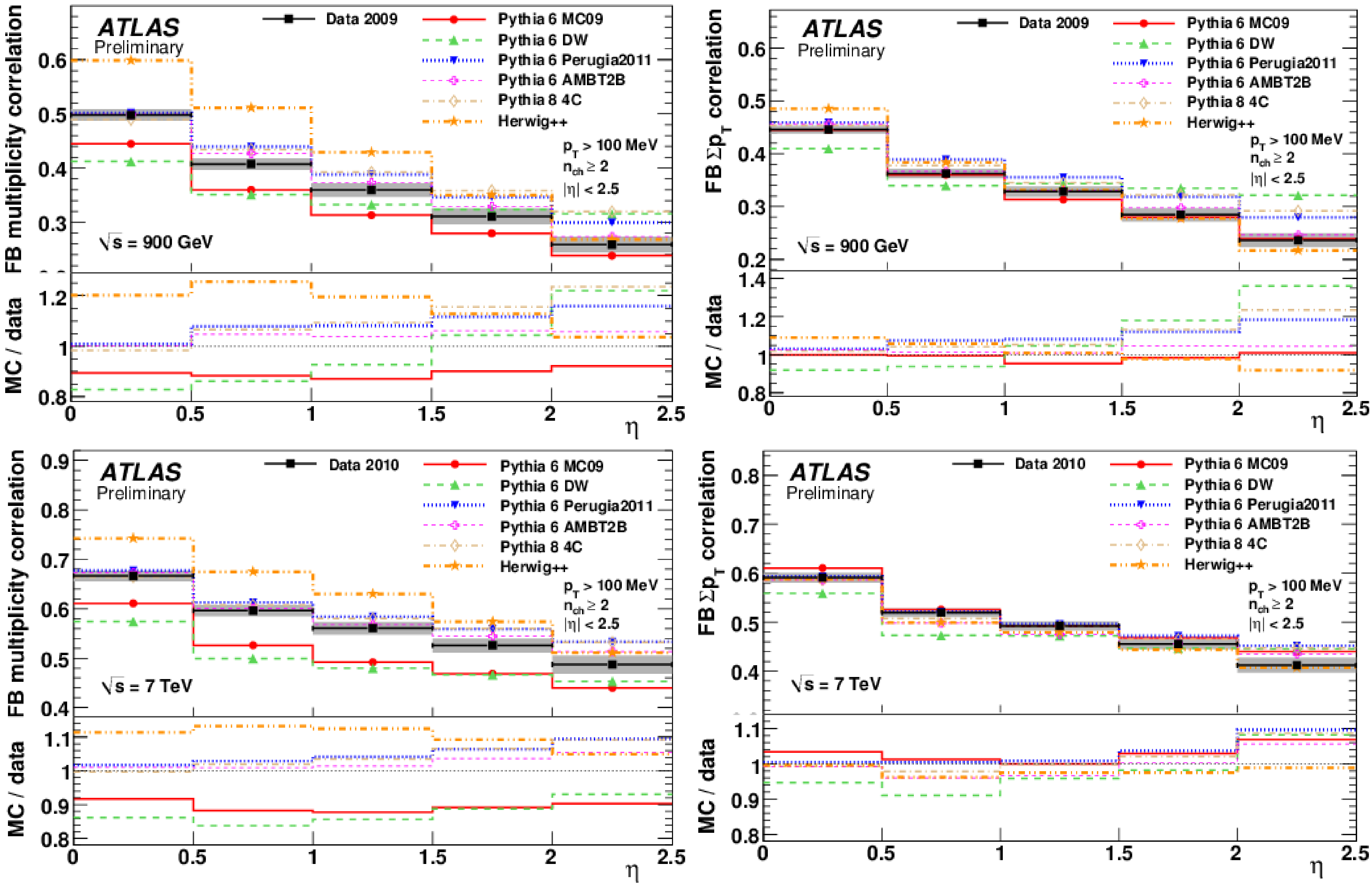
- Data corrections and unfolding to particle-level applied via a linear regression method and using MC simulations
  - Tracking, vertex definition, vertex finding, trigger, etc
- Main sources of systematic uncertainties
  - Track-finding efficiency ~1-3% depending on detector position
  - Vertex- and trigger-finding efficiencies ~0.2% each

FB Results



ATLAS Preliminary
Data 2010
$\sqrt{s}$ = 7 TeV
FB correlation
0.7
0.6
0.5
0.4
0
0.5
1
1.5
2
2.5
forward η
0
0.5
1
1.5
2
2.5
backward η
p_T > 100 MeV
$n_{ch} \geq 2$
$|\eta| < 2.5$

FB results


ATLAS
Preliminary
Data 2009
Data 2010
Pythia 6 MC09
Pythia 6 DW
Pythia 6 Perugia2011
Pythia 6 AMBT2B
Pythia 8 4C
Herwig++
p_T > 100 MeV
$n_{ch} \geq 2$
$|\eta|$ < 2.5
$\sqrt{s}$ = 900 GeV
$\sqrt{s}$ = 7 TeV
FB multiplicity correlation
FB Σp_T correlation
MC / data
η

Summary of angular correlations

- Studies soft QCD via angular and forward-backward correlations in minimum bias events
  - Overall shape well-described in many popular tunes but discrepancy in the details
- Azimuthal correlations
  - discrepancy increases with η range
- FB correlations
  - found to be much stronger at 7TeV than 900GeV
  - differ from popular MC models by up to 15% at 7TeV, more at 900GeV
- Increasingly challenging to perform at ATLAS, but valuable insights in new η and energy regimes

Backup

Overview of tunes

Tune	Characteristics	Tune	Characteristics
A	• Q^2-ordered showers • large starting scale for ISR • 1 GeV of primordial k_T	P HARD	• P0 based • more activity from perturbative physics • harder hadronization spectrum, lower primordial k_T
DW	• Similar to tune A • 2 GeV of primordial k_T • more ISR • designed fit CDF Drell-Yan data	P SOFT	• P0 based • more activity from non-perturbative physics • softer hadronisation, more active beam remnant fragmentation
ProQ^2	• Q^2-ordered showers • tuned with Professor	P0 NOCR	• P0 based • no colour reconnections • tuned with Professor
P0	• interleaved p_T-ordered showers • annealing colour reconnections • large amount of MPI	GAL	• P0 based • colour reconnection probability related to change in area defined by colour strings (generalized area law)