TopoClusters for UE studies using 900 GeV data

S.Chekanov, J.Proudfoot, R.Yoshida, J.Zhang
(HEP division, ANL, USA)

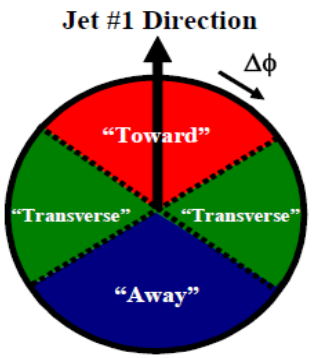
C.Bertella, P.Francavilla, C.Roda
(Universita` e I.N.F.N. Pisa, Italy)

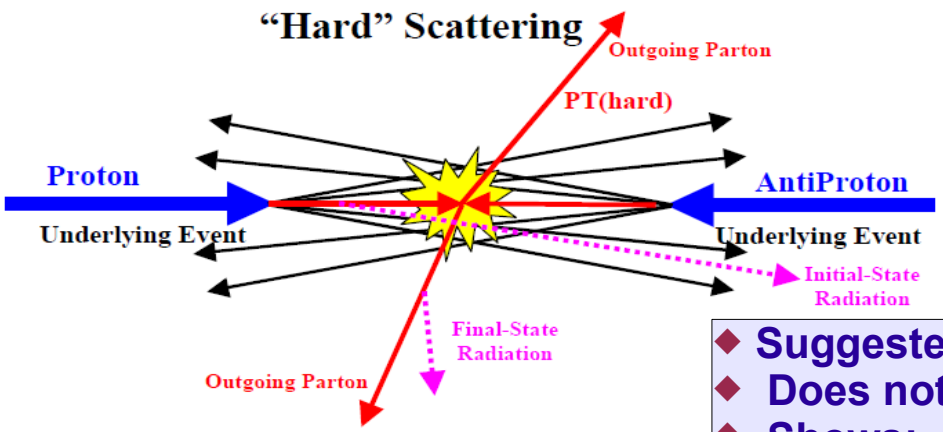
April 22, 2010

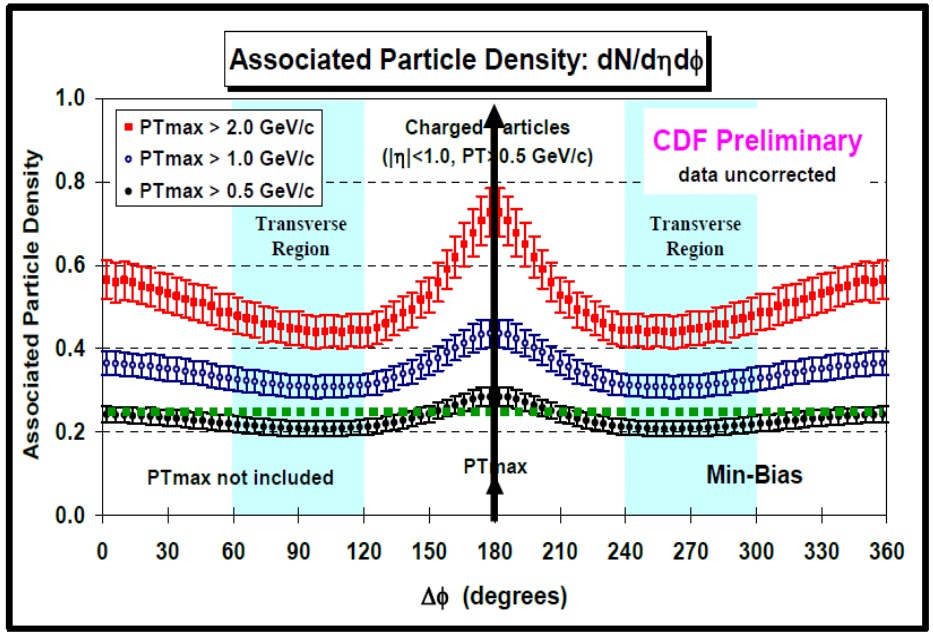
softQCD Meeting. Status report

Underlying event studies at Tevatron

R.Field,
Acta Phys. Pol. B
36, No. 2 (2005) 167







The "underlying event" consists of
- hard initial & final-state radiation
- beam-beam remnants
- possible multiple parton interactions

- **Suggested by R.Field as early LHC measurement**
- **Does not require jet algorithms**
- **Shows:**
  - average jet size (leading, 2nd leading)
  - "birth" of the leading two jets as scale increases
- **Useful for:**
  - Understanding of energy flow around a leading jet
  - Energy flow in regions sensitive to underlying events ("transverse regions")
  - MC tunning

Plan of this talk

- Event & TopoCluster selection
- TopoClusters properties (LH calibration and EM-scale)
- Detector-level distributions, correction factors, unfolded distributions
- What measurements can be considered?
  - Must be **sensitive to the physics we are interested in** (i.e.UE)
  - Must be **instrumentally well measured**
    - Small bin-by-bin correction factors: C= N(gen)/N(reco) = purity / efficiency
    - Means small instrumental systematics
      - Small sensitivity to miscalibration, cut threshold effects, energy scale etc.

Event & Topocluster selection

- Good runs Solenoid=ON, Toroid=ON
  - 141565, 141707,141746,141748,141811,142166,142191,142193,142195,142383
- Monte Carlo sample: ATLAS-GEO-08-00-02 (r1051)
- L1_MBTS_1 trigger
- At least 3 tracks for the primary vertex
- Calibrated TopoClusters
- Concentrate on the central region |eta|<2.5
  - Cross check with tracks, easy to understand

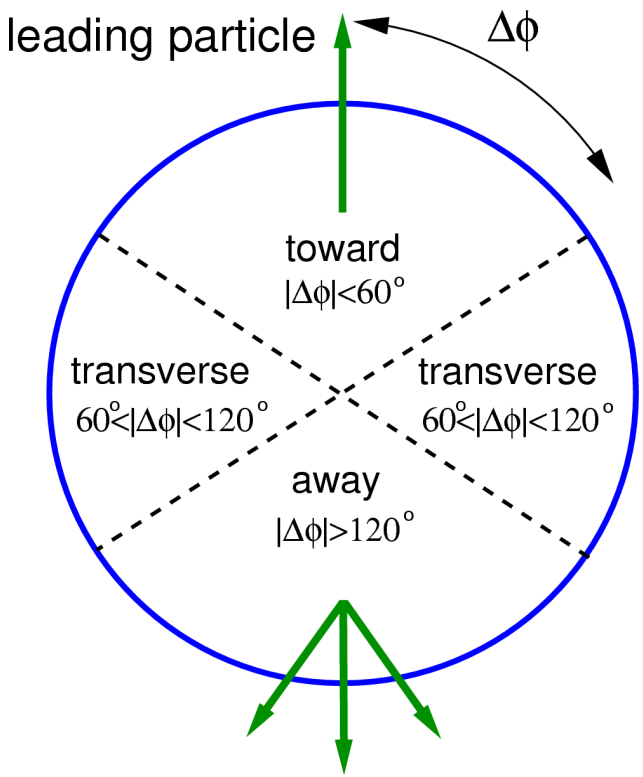
Analysis is done using ESD's (ESD->Ntuples->Histograms) at ANL Tier3

UE measurements:

Repeat the tracking measurements presented in ATL-COM-PHYS-2010-164 and ATL-COM-PHYS-2010-164

- Select on the highest pT particle (cluster)
- Use it as an energy scale
- Calculate difference in azimuthal angle between particle and any other particle in event

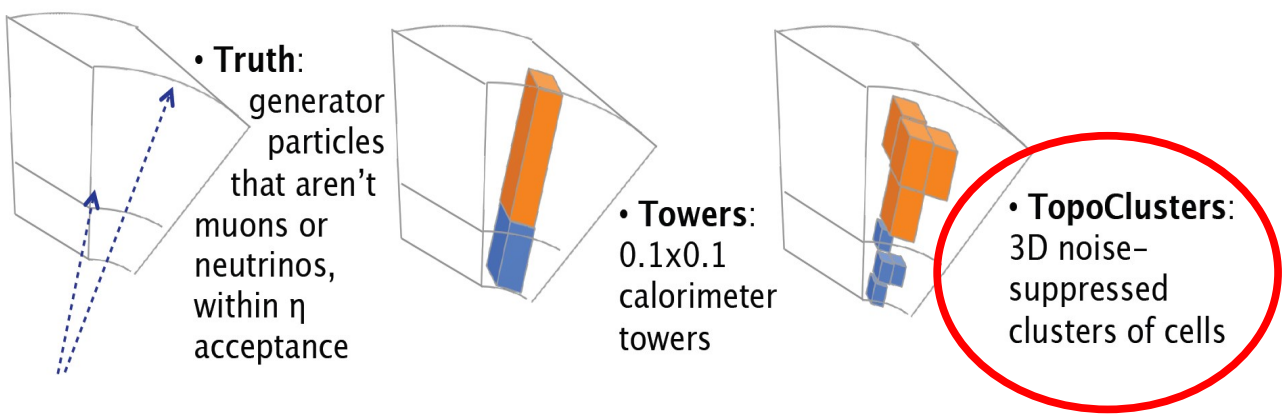
- Repeat the same for different pT's of the leading cluster
- Look at different regions (toward, transverse, away) and
  - <pT> as a function of pT(lead)
  - <pT> as function of N(clusters)
  - Same for densities and energy flows



Goals

- **Use TopoClusters for the UE studies**
  - Systematically completely independent of tracking
  - Look at a complete final state (charged & neutral particles)
  - More relevant for future jet-based studies
- **Understand relationship between a particle and a TopoCluster**
- **Understand energy scale, resolution, unfolding procedure & systematic**
- **As a side study, to check what exactly goes into the jet constituents**

Picture from P.Loch's talk



Expected features:

- threshold effect (for TopoClusters with energy ~1 GeV, <E/p> ~ 0.3)
- energy scale uncertainties
- magnetic field distorts the initial direction of charged particles entering the calorimeter
- large resolution (picking highest-pT cluster does not always mean going to a large energy scale)
- particles with large pT inside jets can be represented by fewer clusters (overlap effects)
  - can lead to a significant unfolding correction at large pT

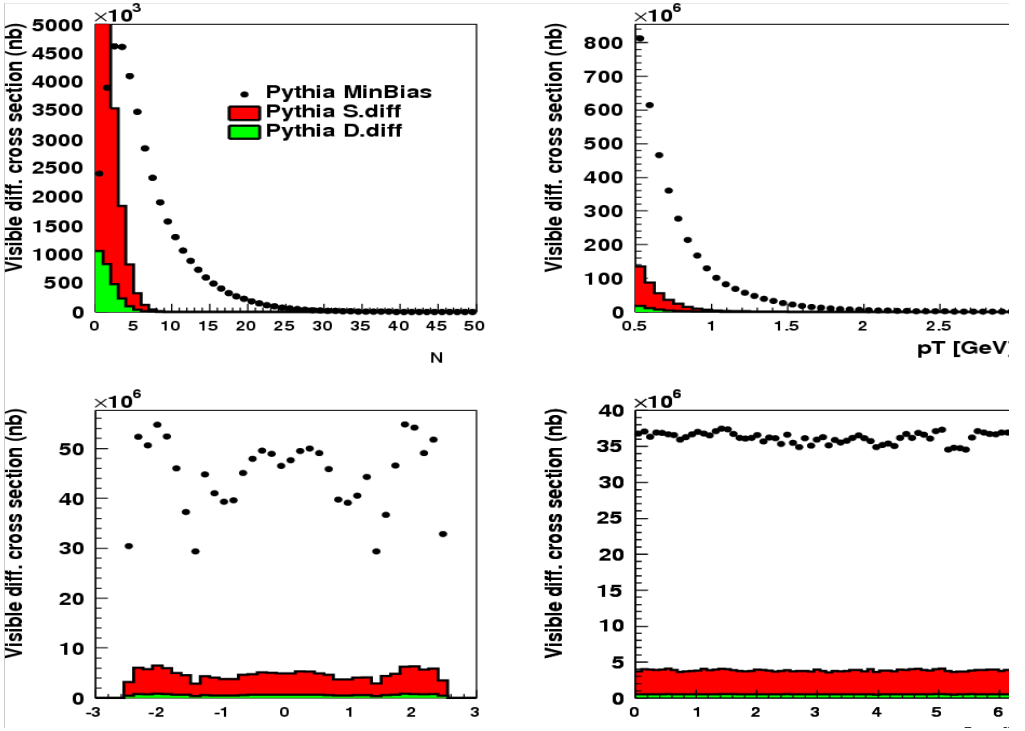
Contribution from single and double diffraction

- Reconstruct visible differential cross sections from MinBias, Sdiff, Ddiff:
  - mc09_900GeV.105003.pythia_sdiff.recon.AOD.e466_s655_s657_d257_r1023
  - mc09_900GeV.105004.pythia_ddiff.recon.AOD.e466_s655_s657_d257_r1023
- Diffractive cross sections ~50% of MinBias (truth level)
- MinBias L1_MBTS_1 rejection factors:
  - Sdiff - 65%
  - Ddiff - 55%
  - MinBias - 2-3%

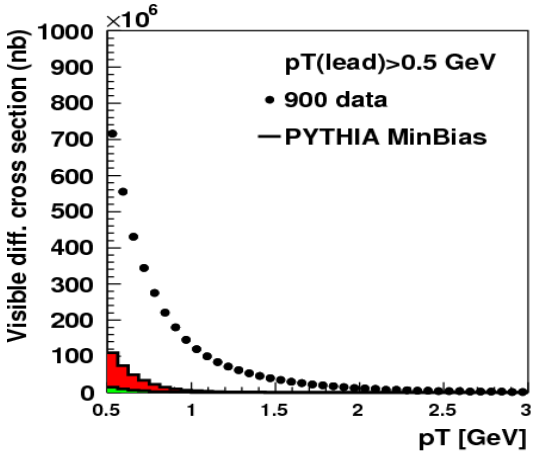
SD has significant contribution for low-multiplicity events

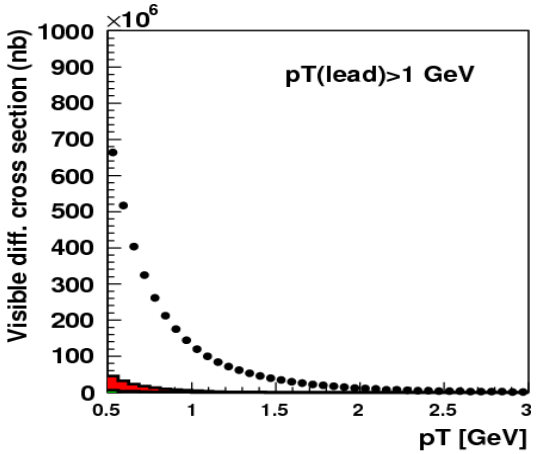
* leading cluster is excluded

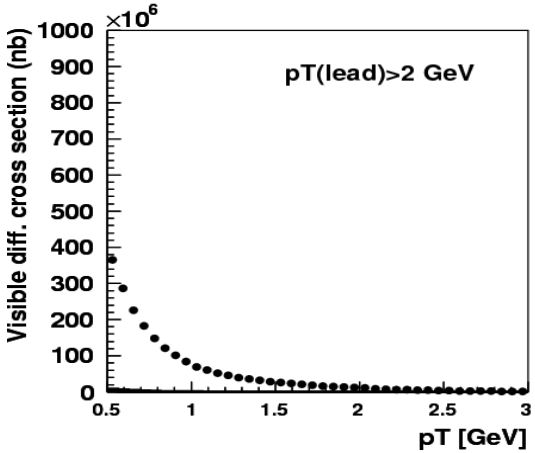
TopoCluster distributions



Diffractive contribution as a function of pT(lead) at the detect-or-level after MBTS trigger







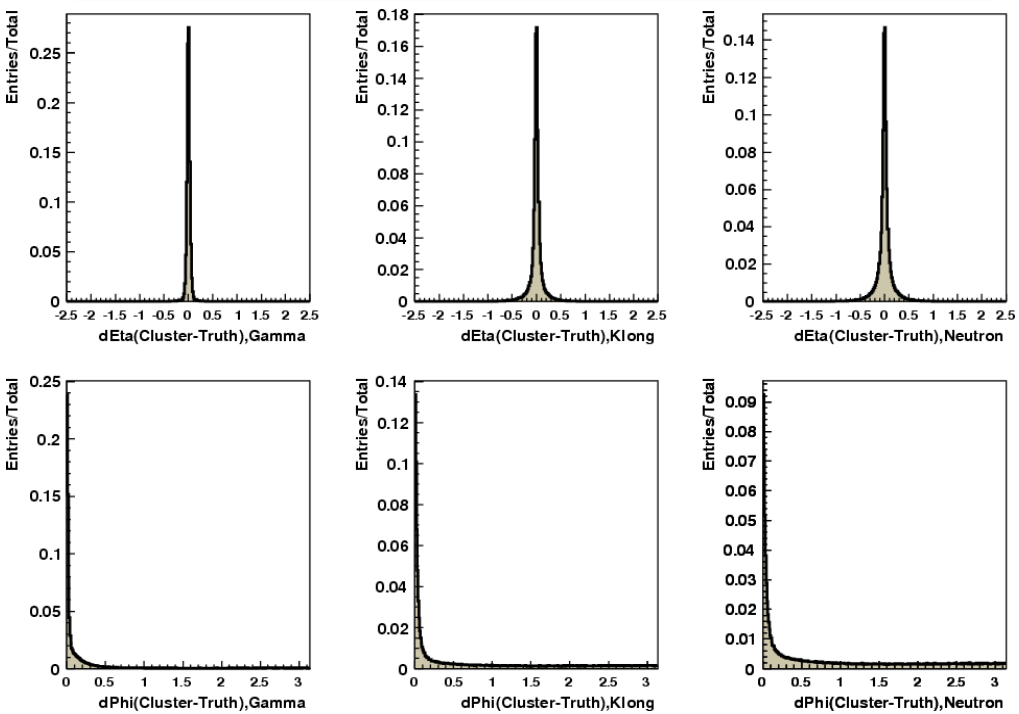
Diffractive contribution is small at large pT(lead)
Consider events for pT(lead)>1 GeV where contribution from diffraction is smaller than the overall uncertainty (~5% energy scale!)

Clusters	pt>0.5 GeV	pT>1 GeV	pT>2 GeV
SD	7%	3%	<1%
DD	1%	1%	<1%

Required properties: Good position measurement

- **Good position measurements**
  - Limitations: if we are interested in corrections to the truth level, only neutrals have good match with topoclusters
    - ✓ charged particles are bended in the magnetic field. Affects dφ measurements

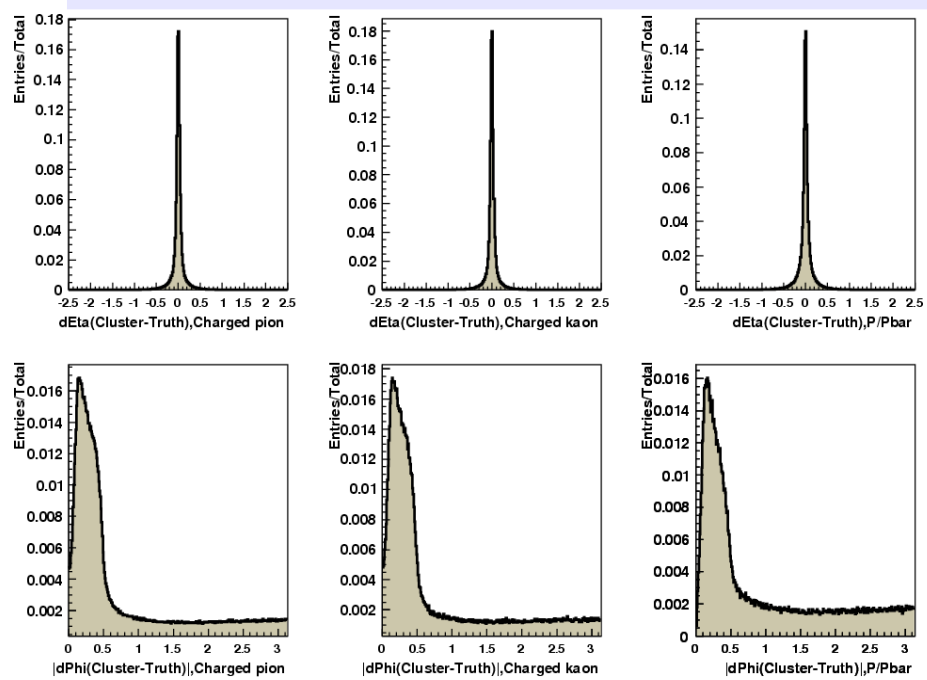
Gamma | Klong | Neutron



Take a topocluster closest in η to a truth particle (pT>1 GeV) and look at dφ

- perfect correlation for neutrals
- broader spectrum for charged hadrons due to the magnetic field

pi+/- | K+/- | p+/-

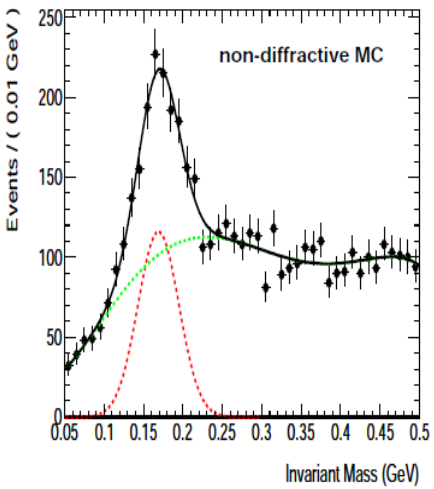


Good spatial association of topoclusters with the truth particles in the Pythia MinBias MC

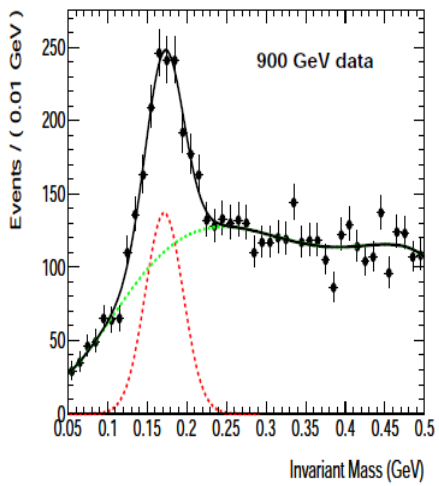
What about the energy measurement?

Required properties: Energy measurements

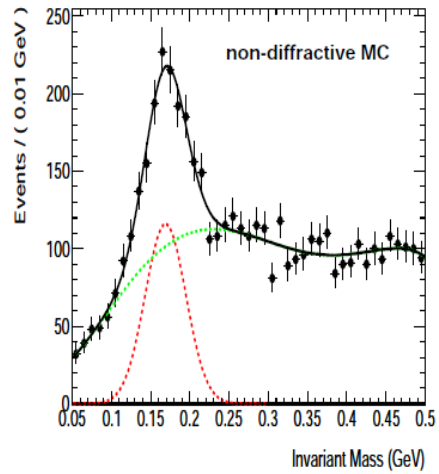
- Good energy measurements:
  - Limitations:
    - ✓ Electromagnetic TopoClusters are overcorrected after LHC
    - ✓ EM-scale clusters closer to the truth



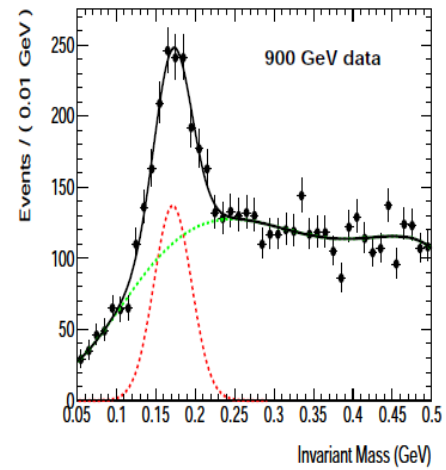
Mean: 169.0±2.1
Sigma: 25.9±2.4



Mean: 171.6±1.8
Sigma: 23.9±1.9



Mean: 169.0±2.1
Sigma: 25.9±2.4



Mean: 171.6±1.8
Sigma: 23.9±1.9

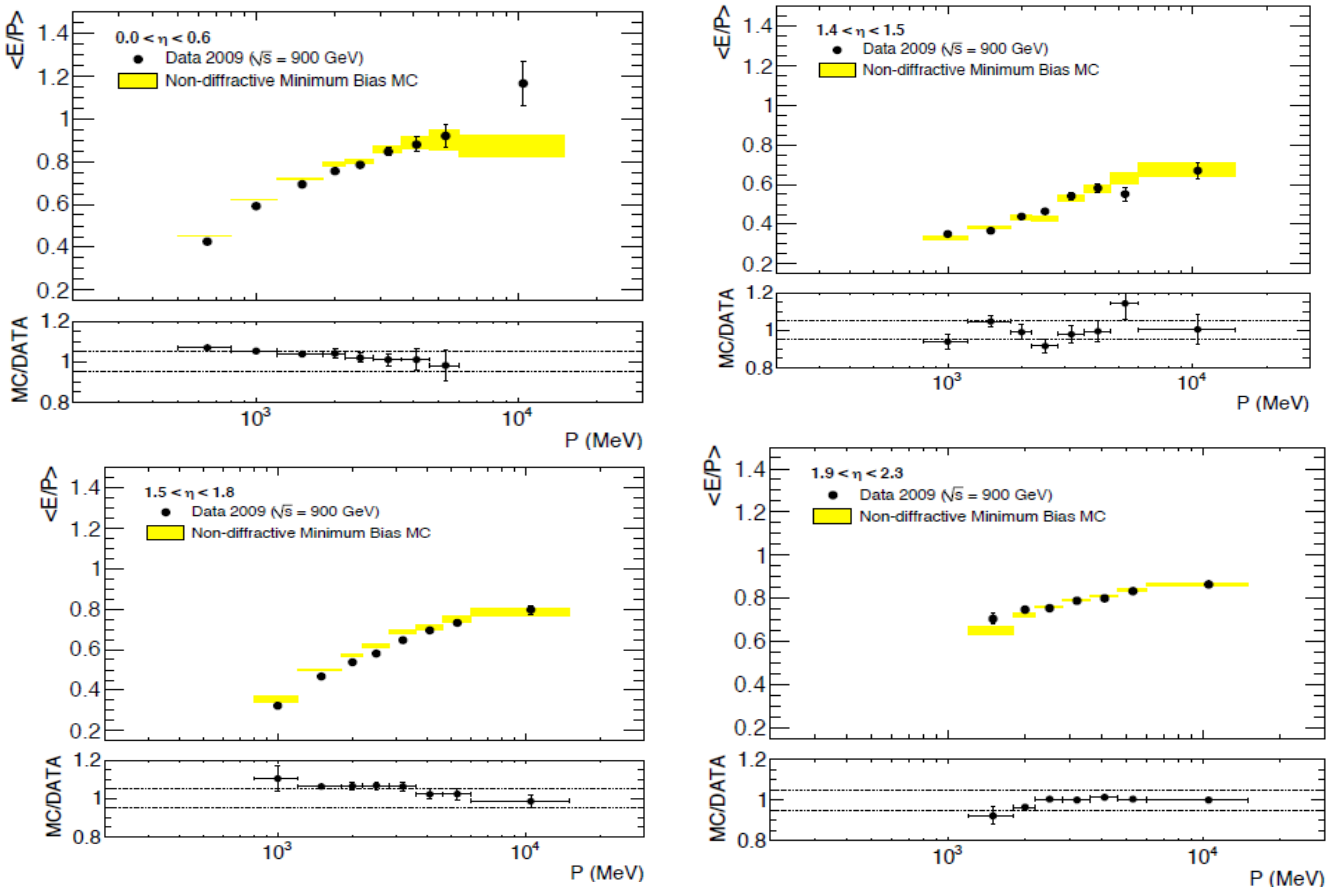
For EM TopoClusters, data and MC agree for calibrated and uncalibrated clusters within 3 MeV (~1%)

- **See J.Zhang's talk :** **http://indico.cern.ch/getFile.py/accesscontribId=49&sessionId=6&resId=0&materialId=slides&confId=88935**

Required properties: Energy measurements

http://indico.cern.ch/getFile.py/access?contribId=3&resId=0&materialId=paper&confId=87760

- Energy measurement for charged hadrons
- Presented by I.Vivarelli



For hadronic TopoClusters, data and MC agree for calibrated and uncalibrated clusters within ~5%

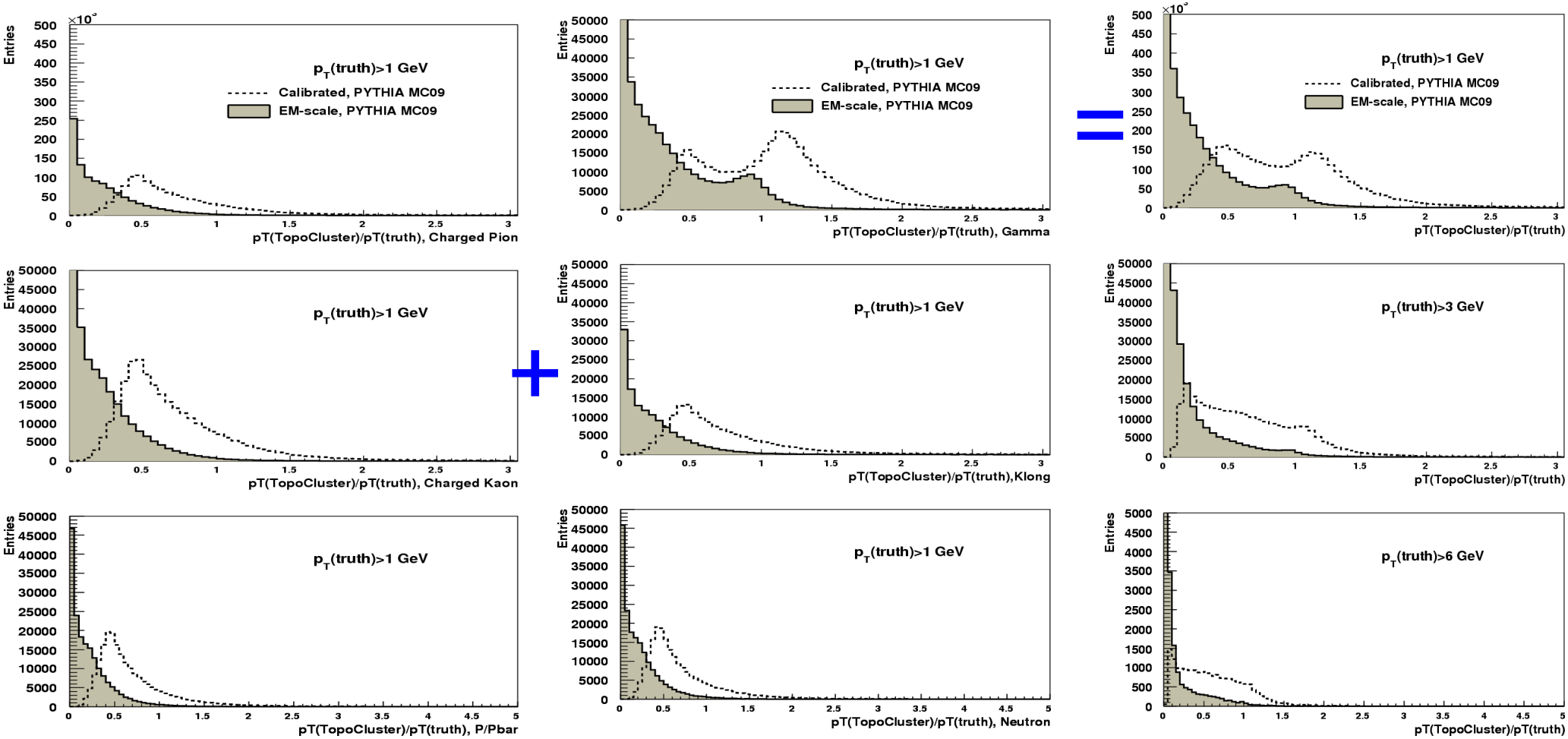
- **Concentrating on counting-type observables:**
  - Inaccurately reconstructed pT affects the number of counted objects via threshold pT cut (=500 MeV)
  - Leads to large detector corrections for some distributions. Differences between data and MC must be inluded in systematics calculations

TopoCluster resolution for different particle types

Charged hadrons

Neutrals

All truth particles

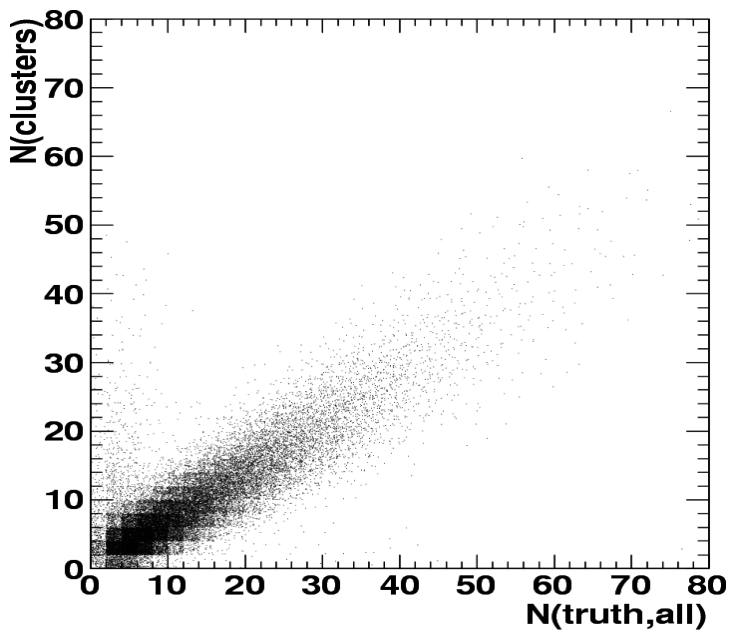


- **Measured energy is 50% lower for hadrons (after LH calibration)**
- **But over-corrected for photons**
- **In overall, the resolution at low energies (~0.5-1 GeV) is dominated by photons**

Matching with dR<0.1

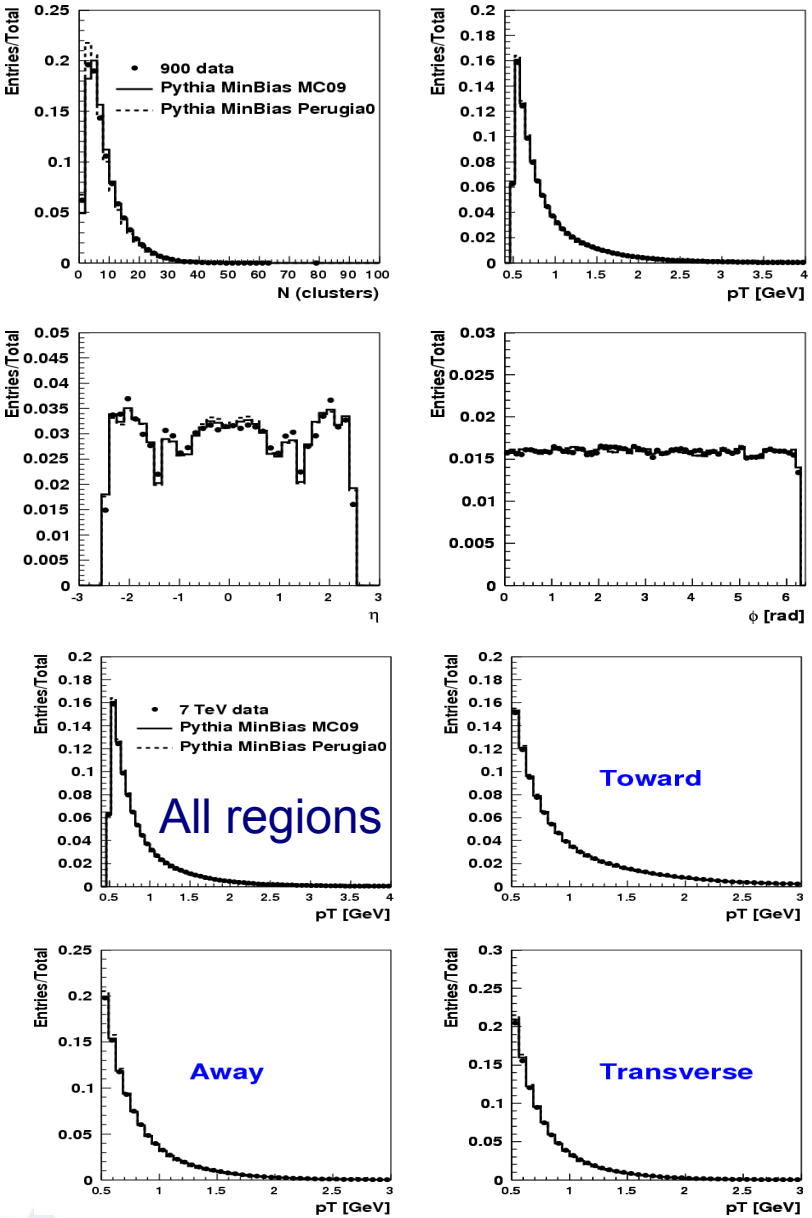
Required properties: association with average multiplicity

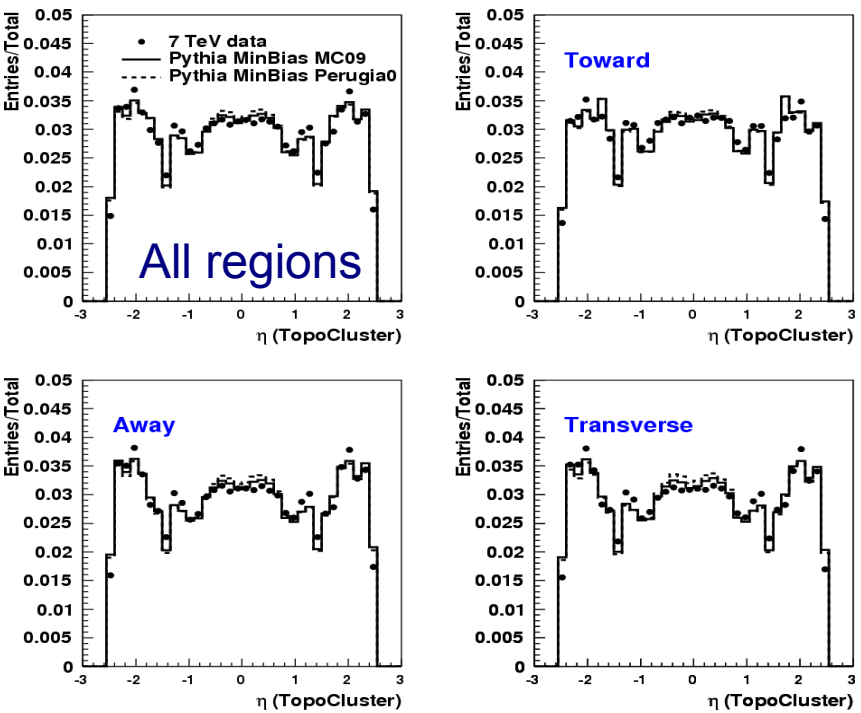
- Good association with the number of truth hadrons
  - important for “particle measurements”)
  - Good correlation between N(clusters, LHC) and true stable particles



TopoCluster properties

All regions



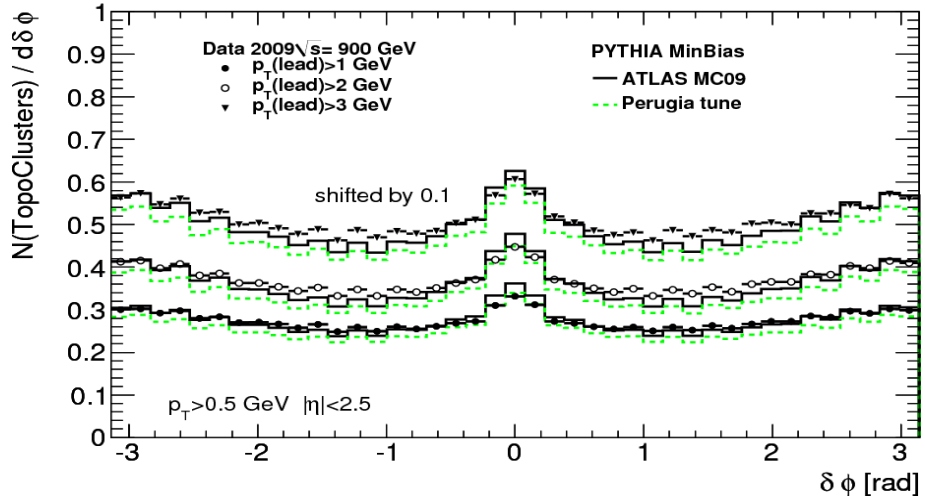


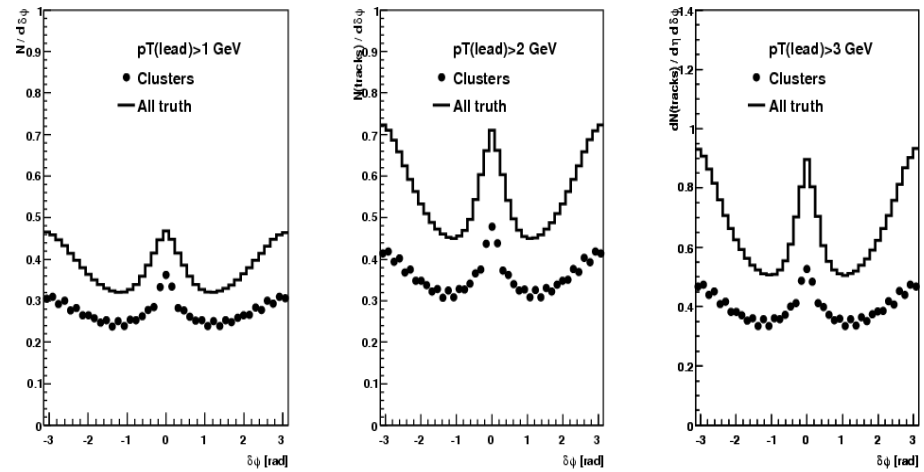
(requested by Emily)

- Comparison with MC (MC09 and Perugia0)
- Good agreement, almost no difference between the MC tunes
- Difference between MC and data at low N(cluster) due to the diffraction

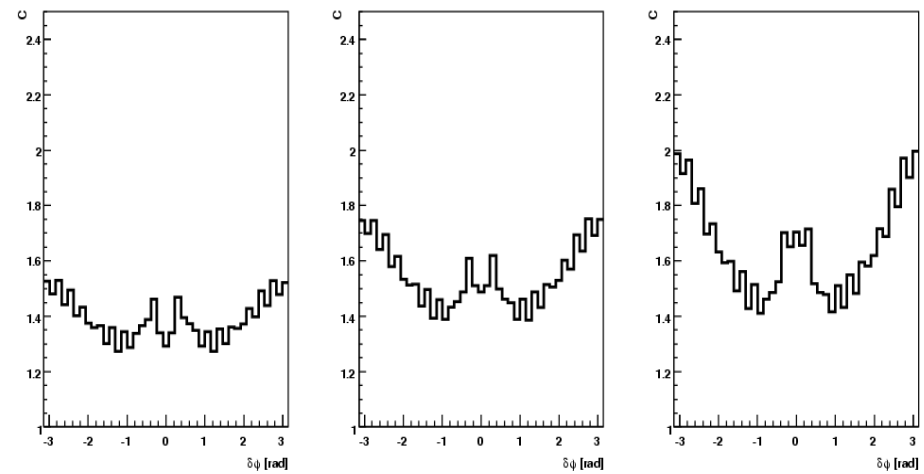
δφ measurements: particle densities

detector-level

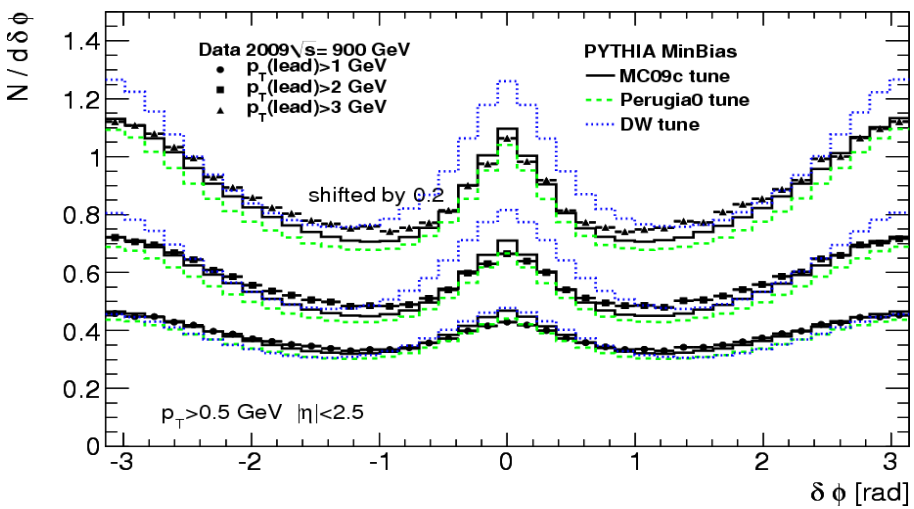




bin-by-bin corrections



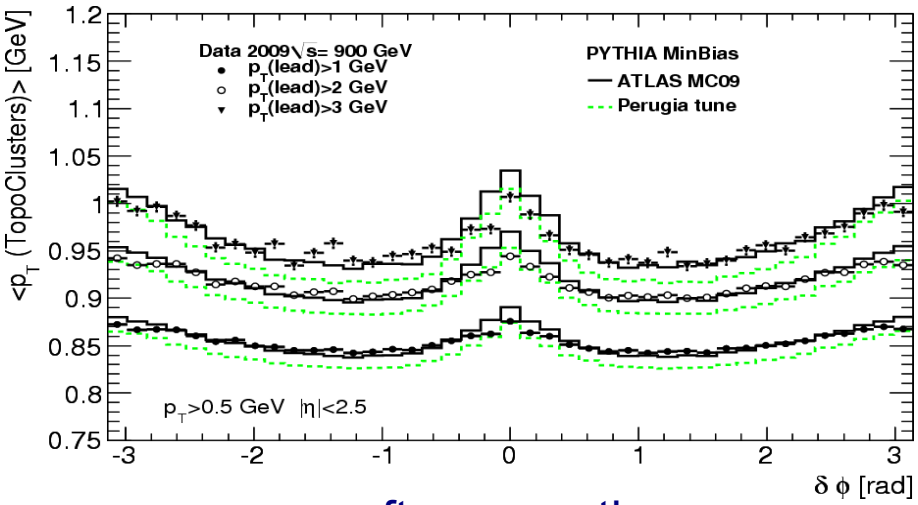
after correction

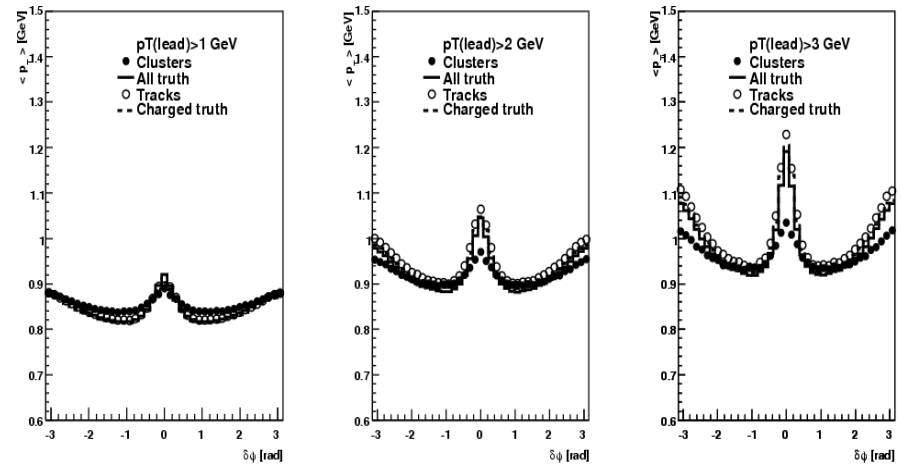


- "birth" of the leading jet (at δφ=0) and second leading jet (δφ=-π,π)with increase of pT
- Shows "average size" of leading (δφ=0) and second leading jet
- Differences with Pythia MinBias in shapes and normalization
- Correction factors are not small, but the same difference between data and MC is already present at the detector levels. Similar conclusion is obtained for "Energy flows"

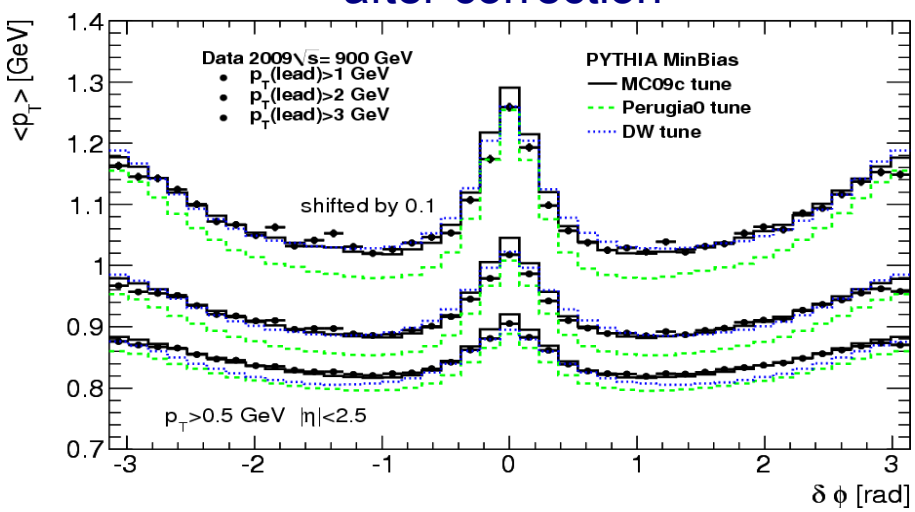
δφ measurements: average pT

detector-level

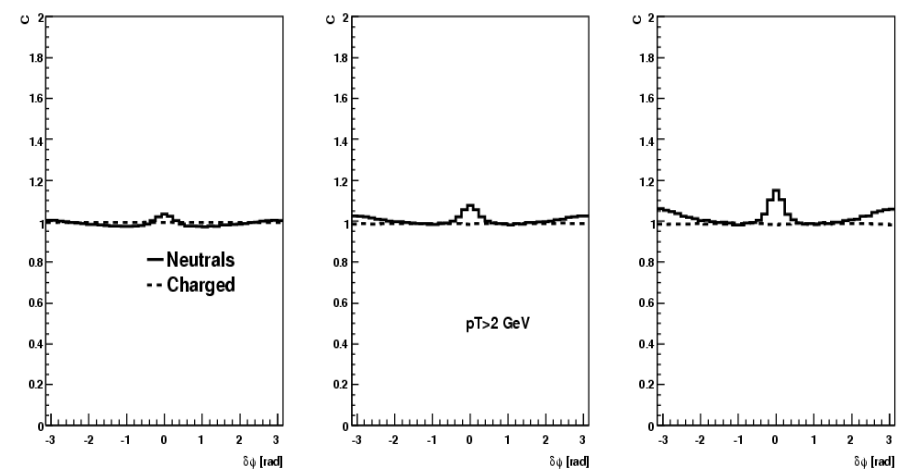




after correction



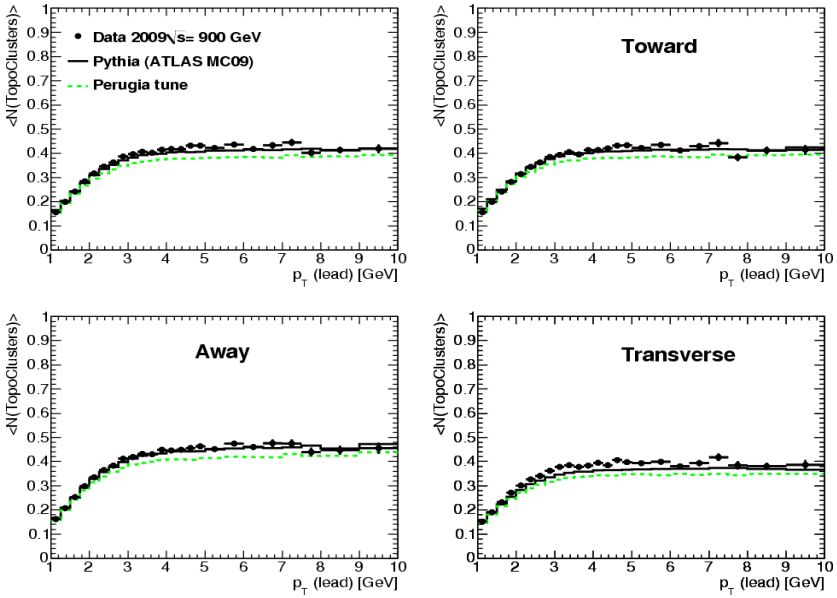
bin-by-bin corrections



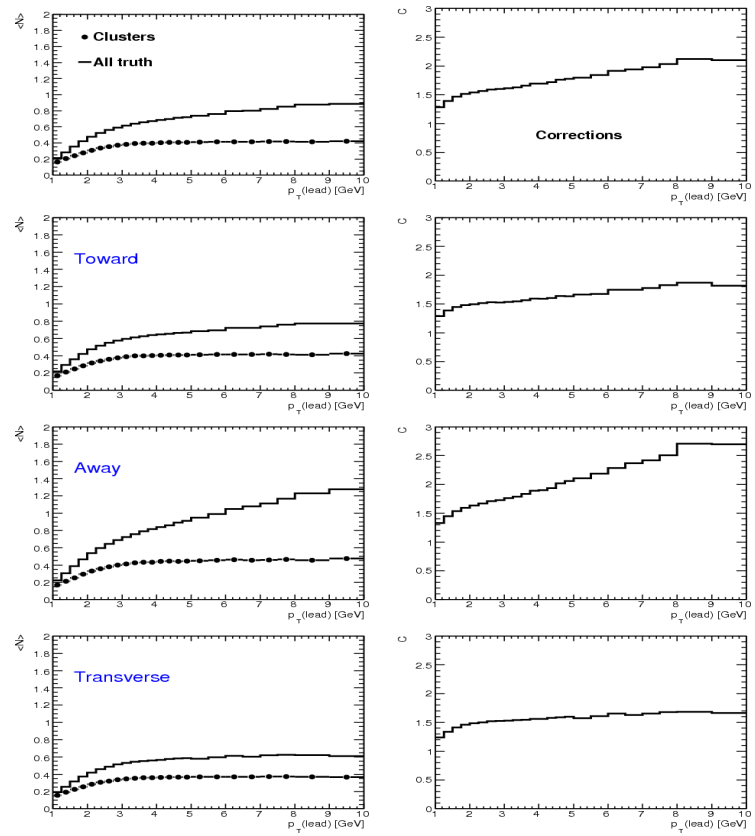
- Conclusions as before: difference between the tunes are seen already at the detector level
- But the detector correction is small. Small PT(min) threshold effect

Densities as a function of pT(lead)

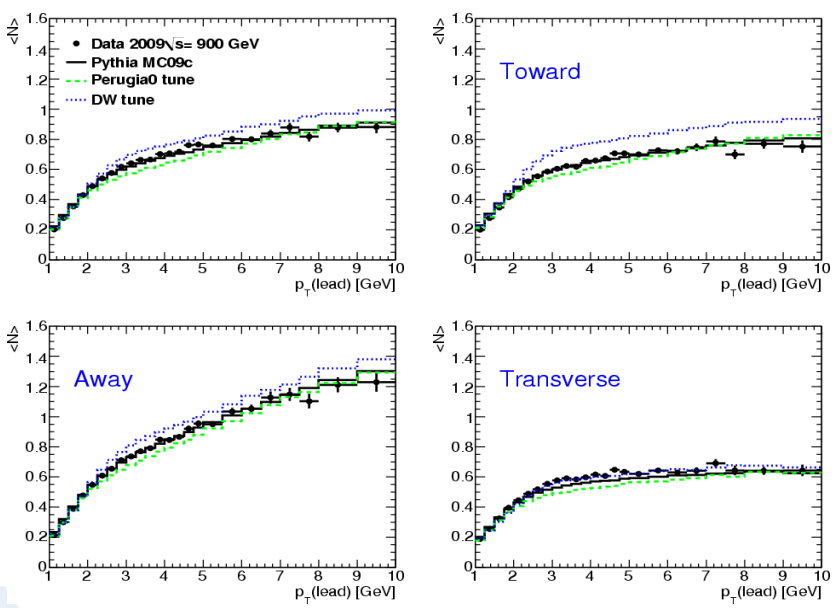
detector-level



bin-by-bin corrections



after correction



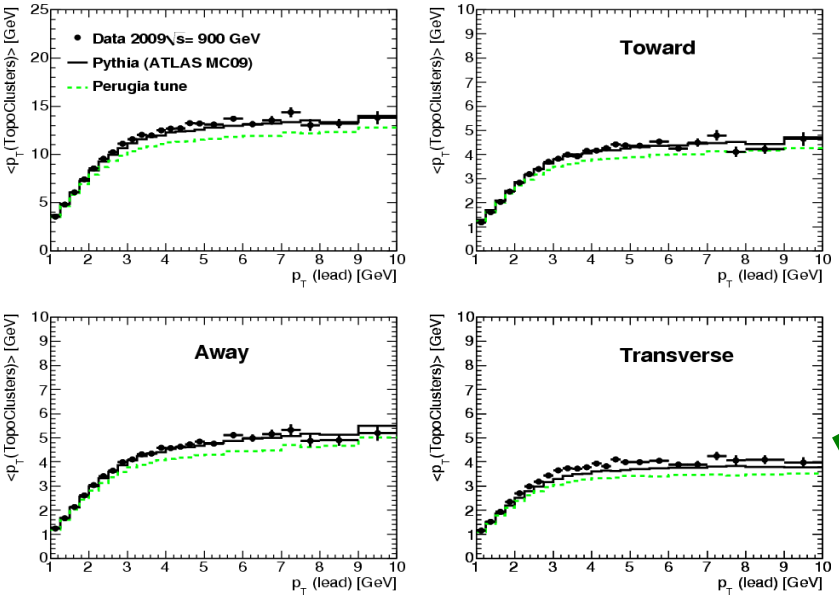
- corrections are rather large at large pT(lead)

- rise as a function of pT(lead) is driven by corrections (picking lead TopoCluster does not mean going to harder scale due to the resolution effects)

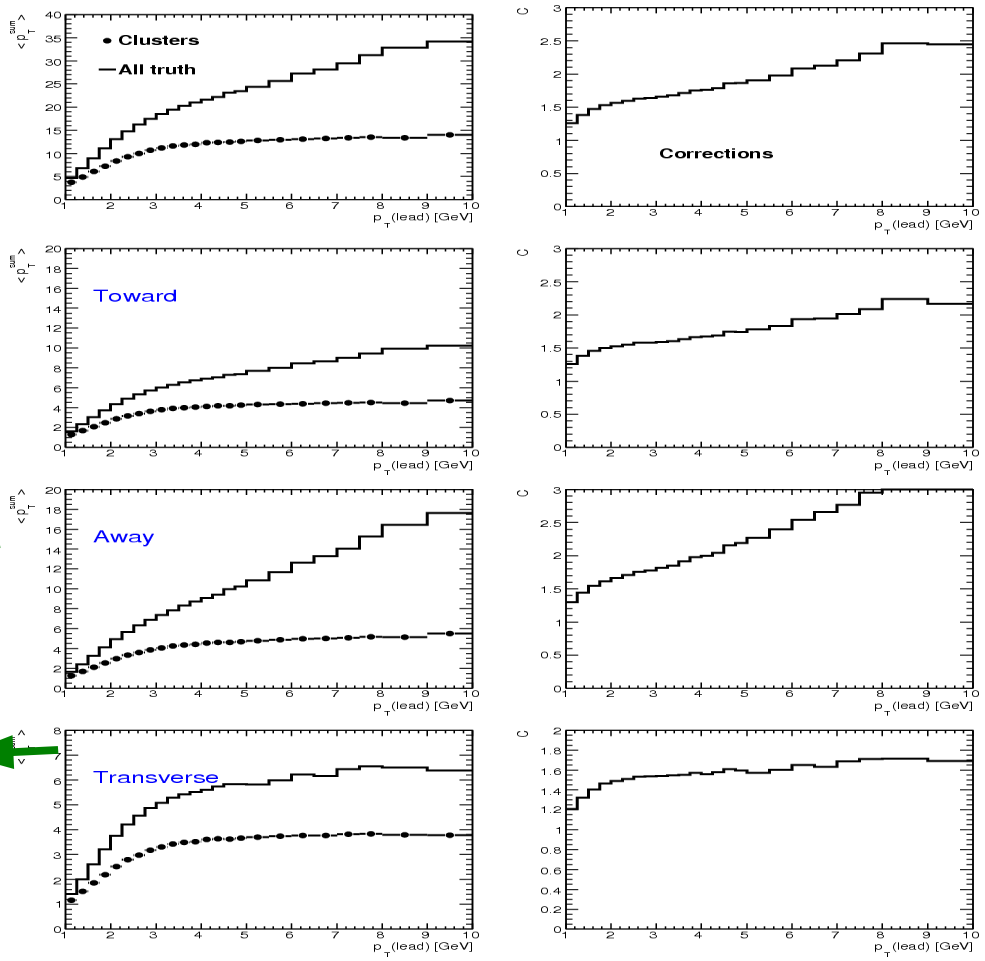
- but difference between data and MC remains the same after the correction. We do not lose this information by applying the bin-by-bin corrections!

Average pT of all particles as a function of pT(lead)

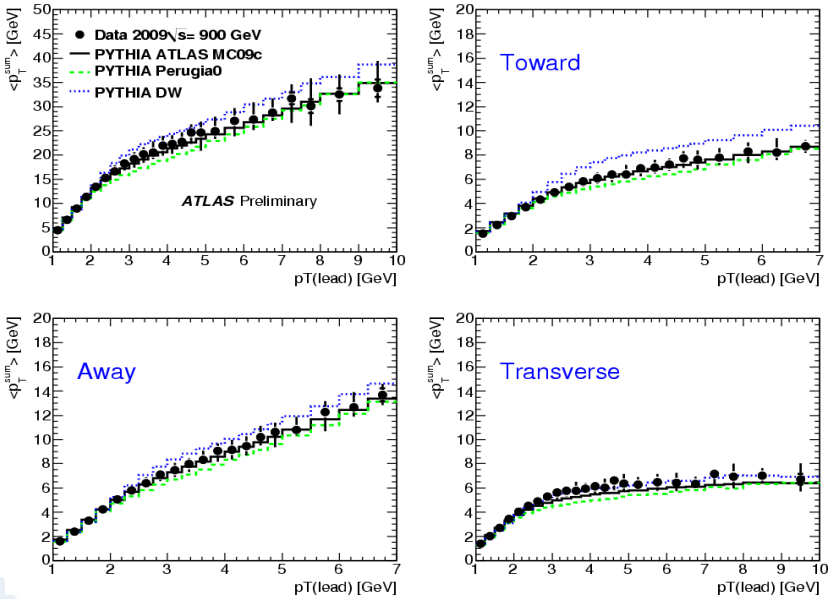
detector-level



bin-by-bin corrections



after correction

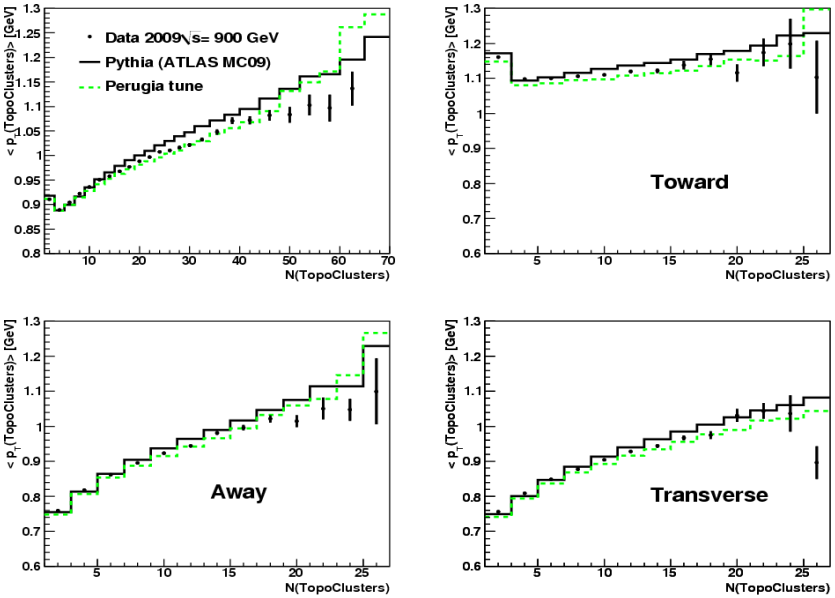


Corrections are rather large at large pT(lead)

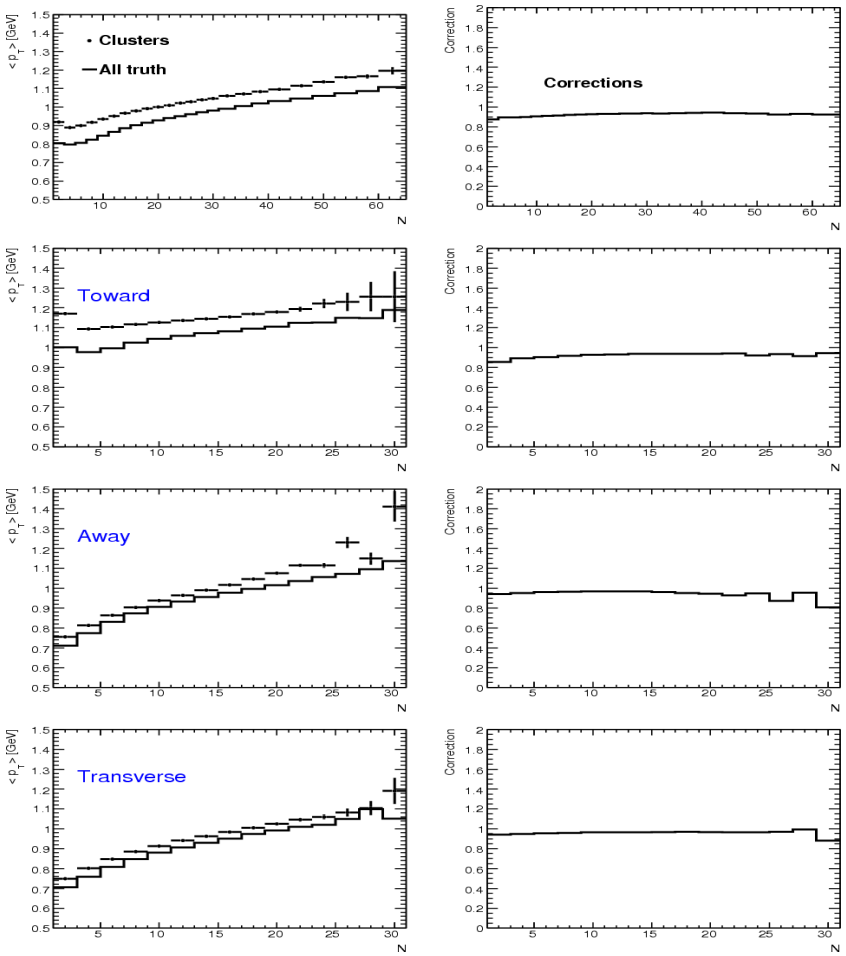
The rise as a function of pT(lead) is driven by corrections (picking lead TopoCluster does not mean going to harder scale due to the resolution effects)

Average pT as a function of multiplicities

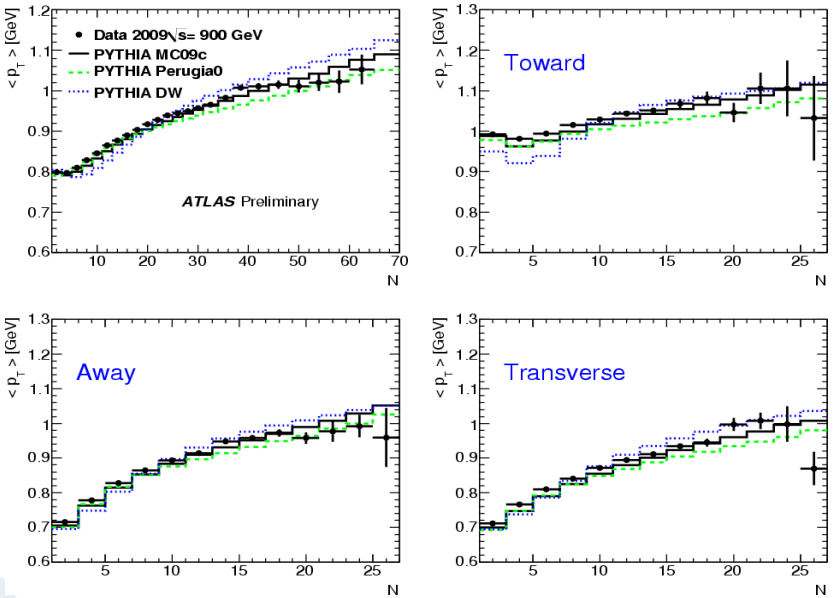
detector-level



bin-by-bin corrections



after correction

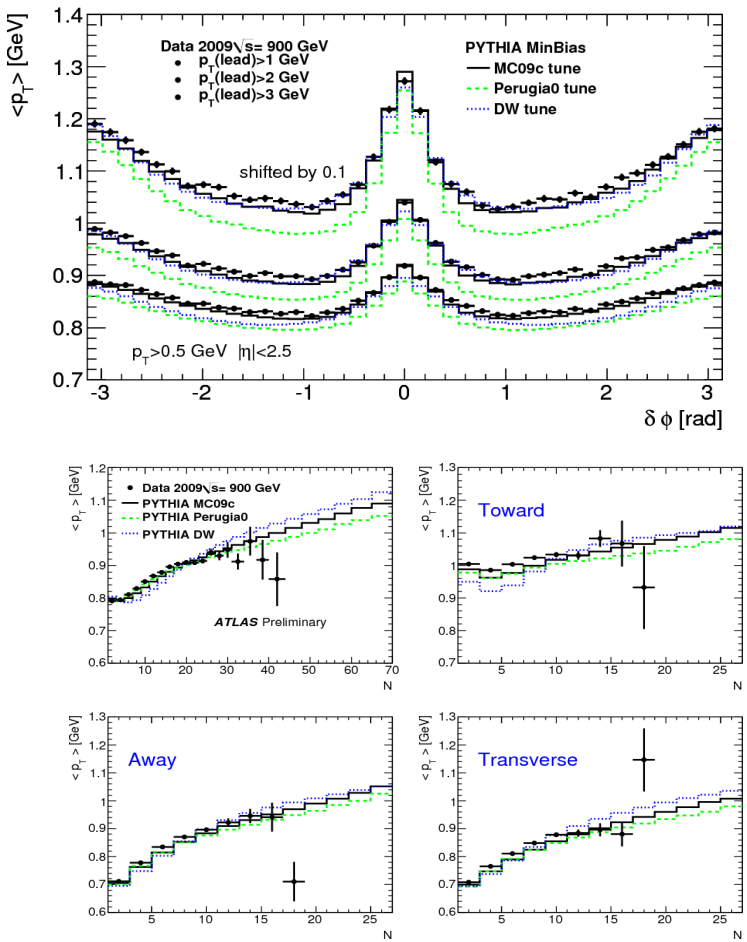


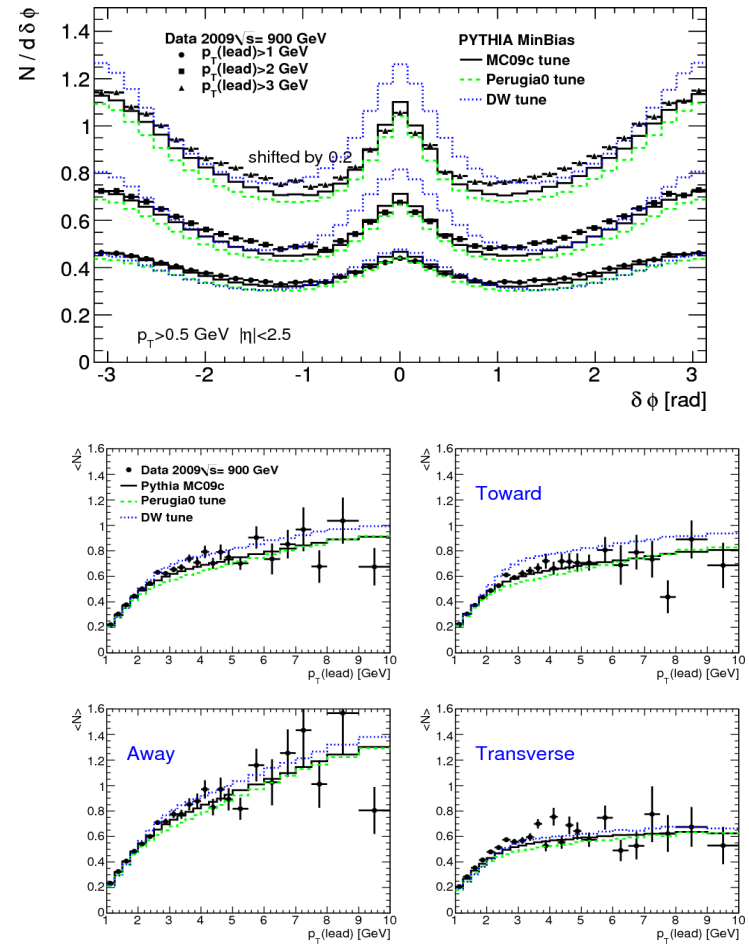
Corrections are small (~1)

Inefficiency affects both X and Y axes.

δφ measurement at EM-scale: particle densities

after bin-by-bin corrections

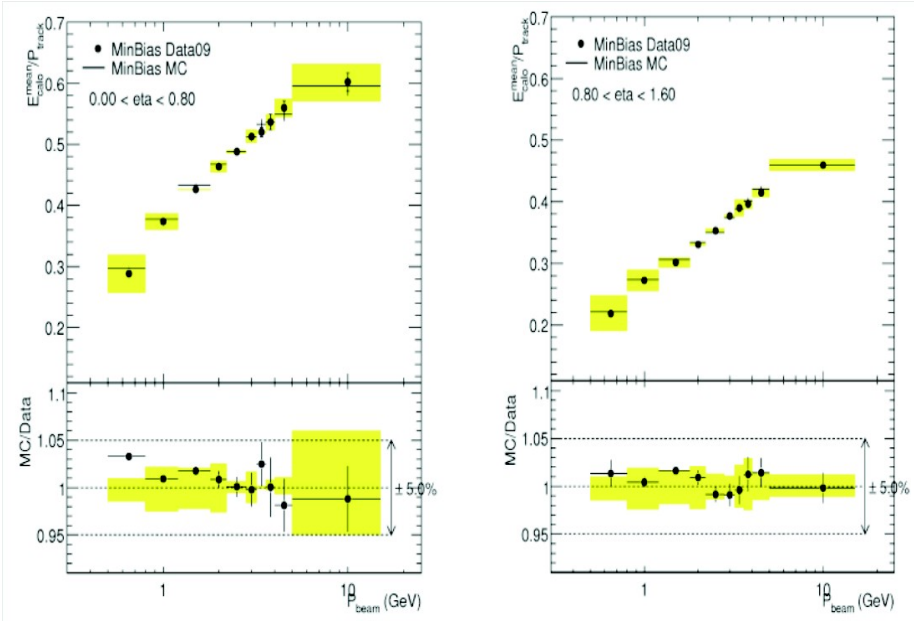




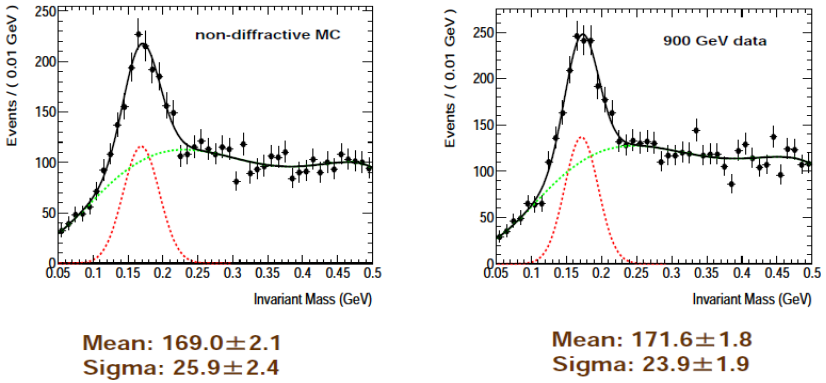
Corrections are significantly larger (50-100%) even after reducing pT>200 MeV (but keeping pT(truth)>500 MeV). Uncorrected and corrected distributions have very similar features as for calibrated clusters when it comes to comparisons with MC distributions.

- **Good agreement with the calibrated scale**
- **±5% energy scale uncertainties will be larger than difference between EM and CL scales**

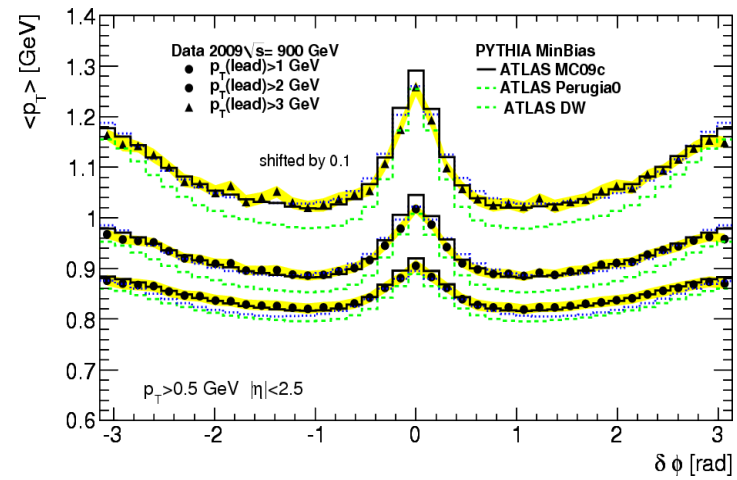
Systematic uncertainties

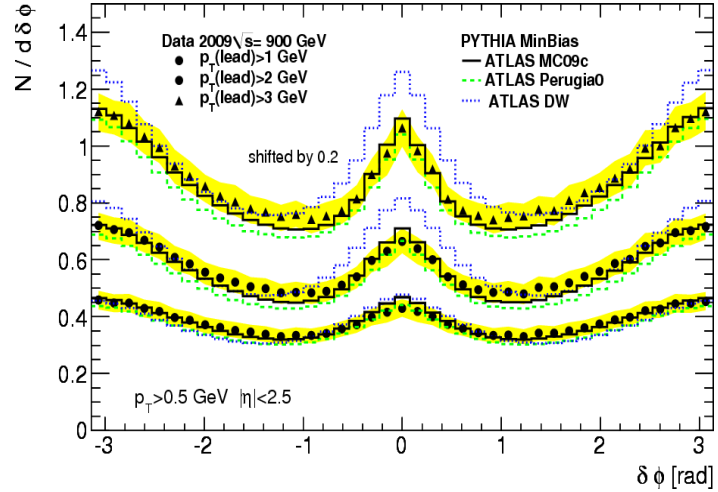


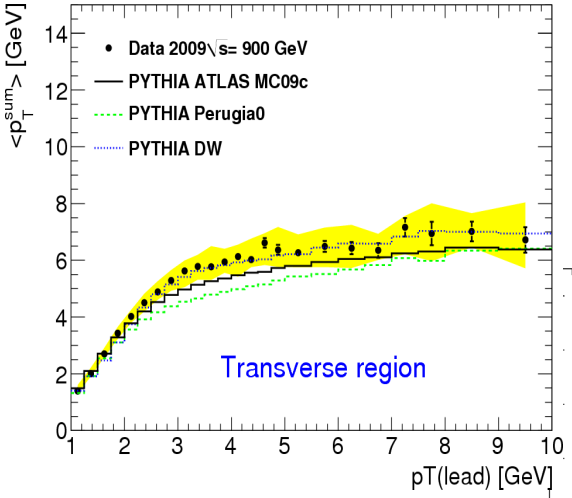
- Reject events with N(clusters)<3 (diffraction)
- ±5% energy scale
- 10 MeV electronic nose shift in MC
- ± 0.025 rad for cluster centers φ and η (shift by 1 EM cell)
- +10% extra material.
- Using Peruji0 for unfolding
  - A typical difference between bin-by-bin corrections ~1%
- Repeat the entire analysis using EM-scale clusters
- +3 MeV shift to account for the difference between data and MC for pi0 peak



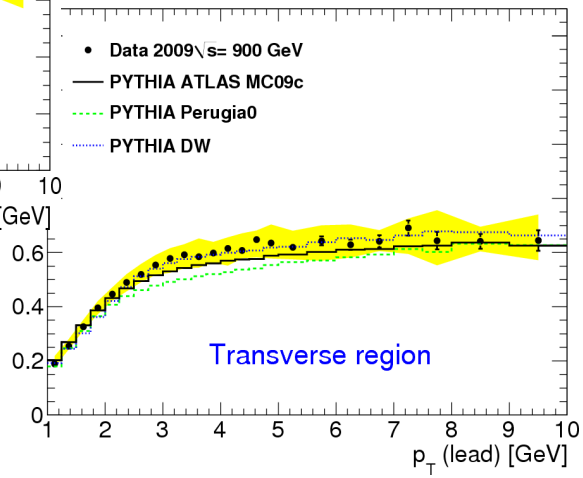
Figures with systematics included

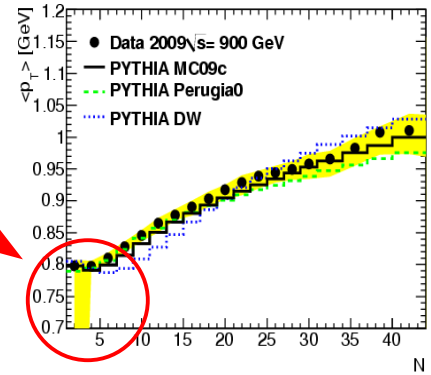


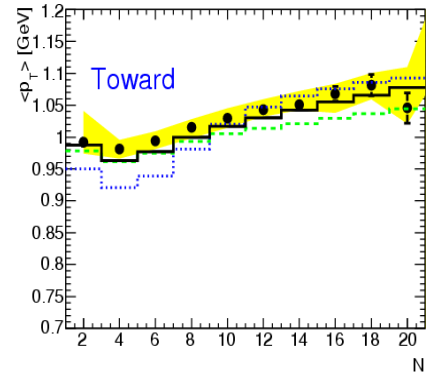


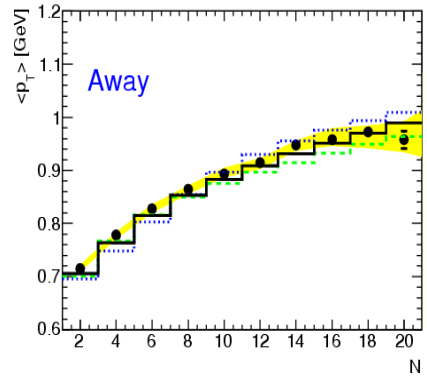


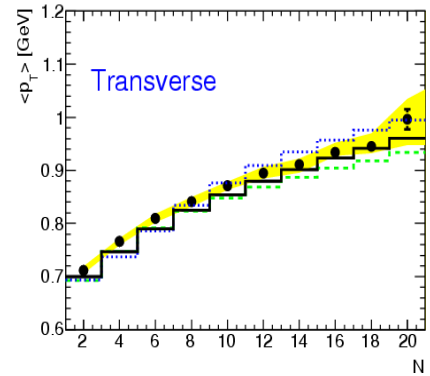
(systematics: N>3)



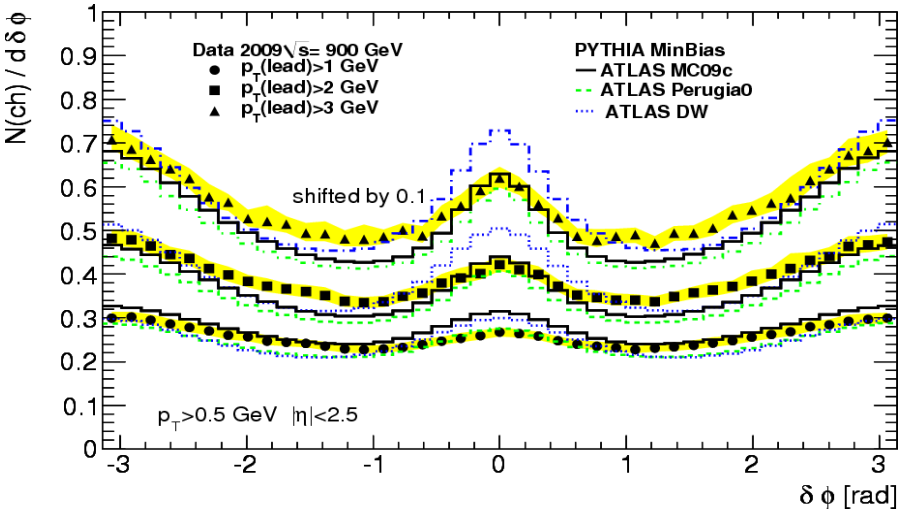


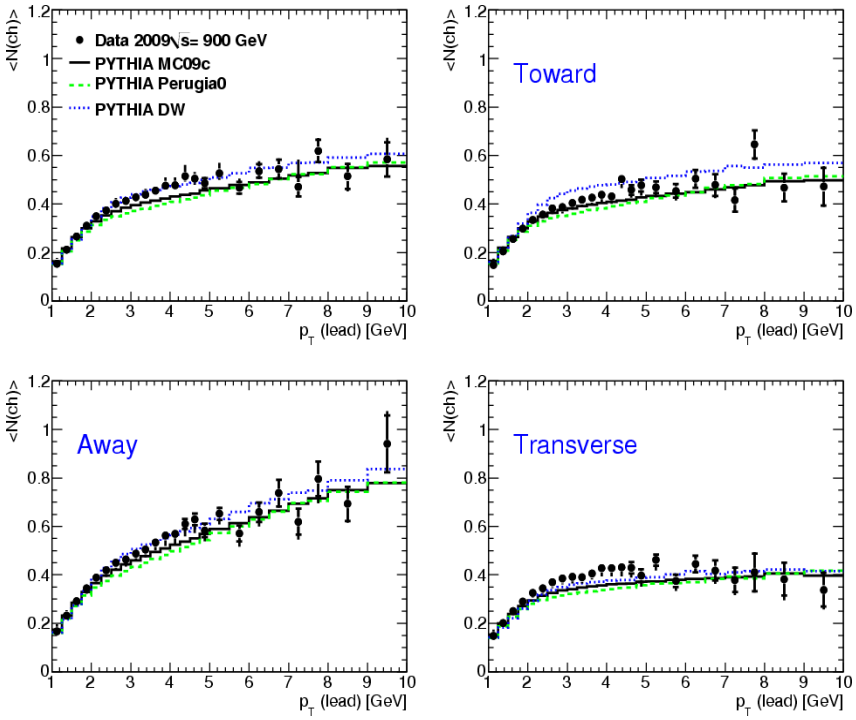




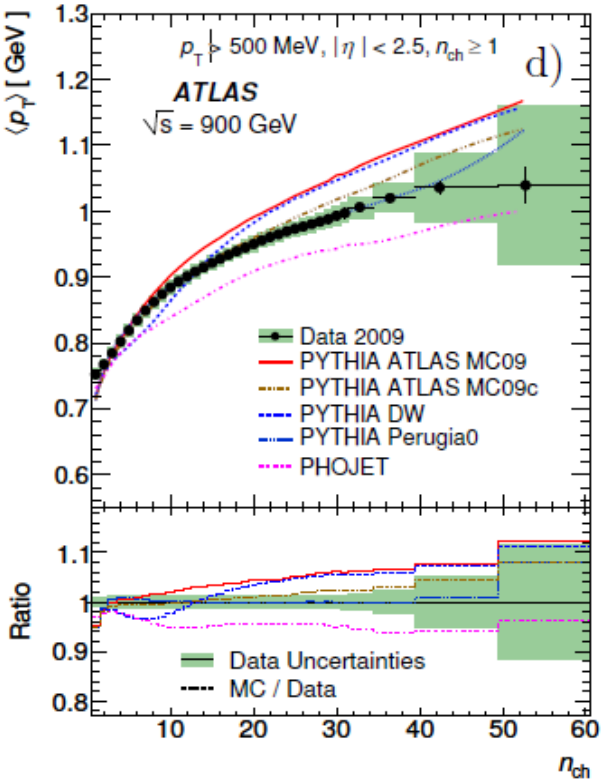


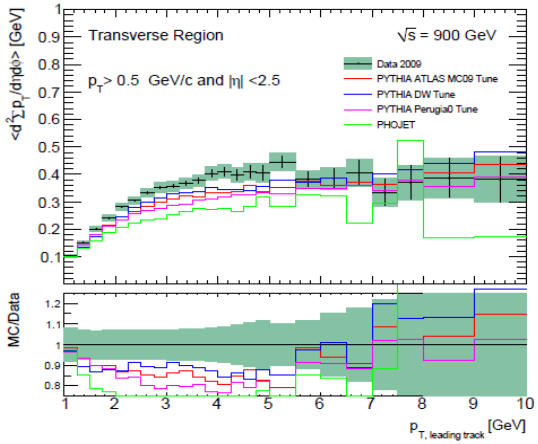
Results are similar as in the UE/MinBias tracking notes





ATL-COM-PHYS-2010-165



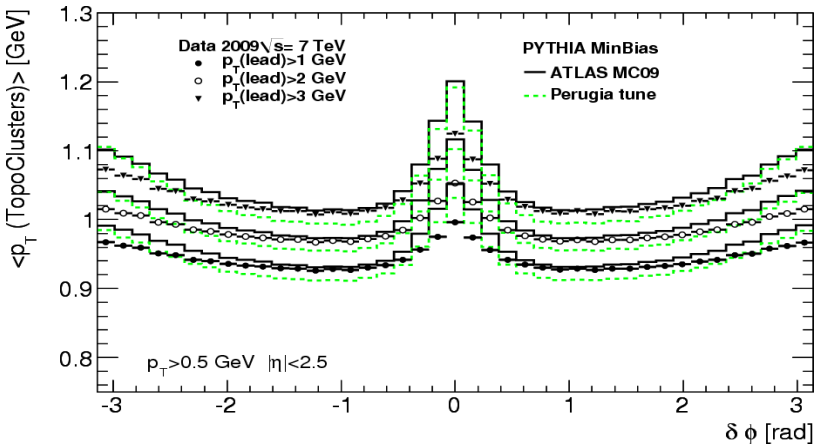


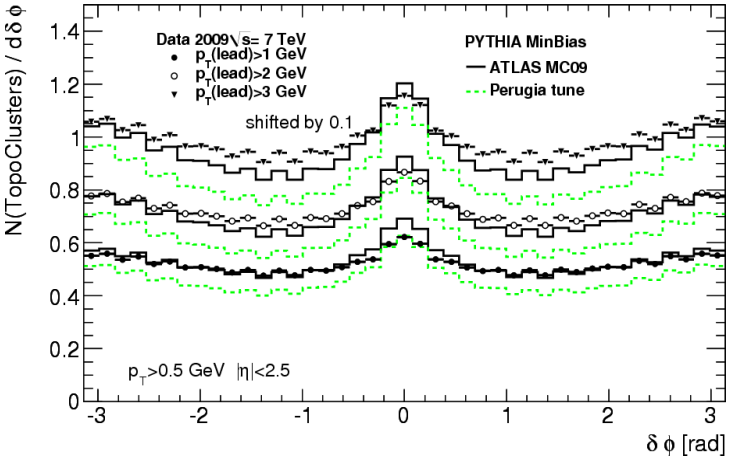
ATL-COM-PHYS-2010-164

First look at 7 TeV data (detector-level)

Run **152166**

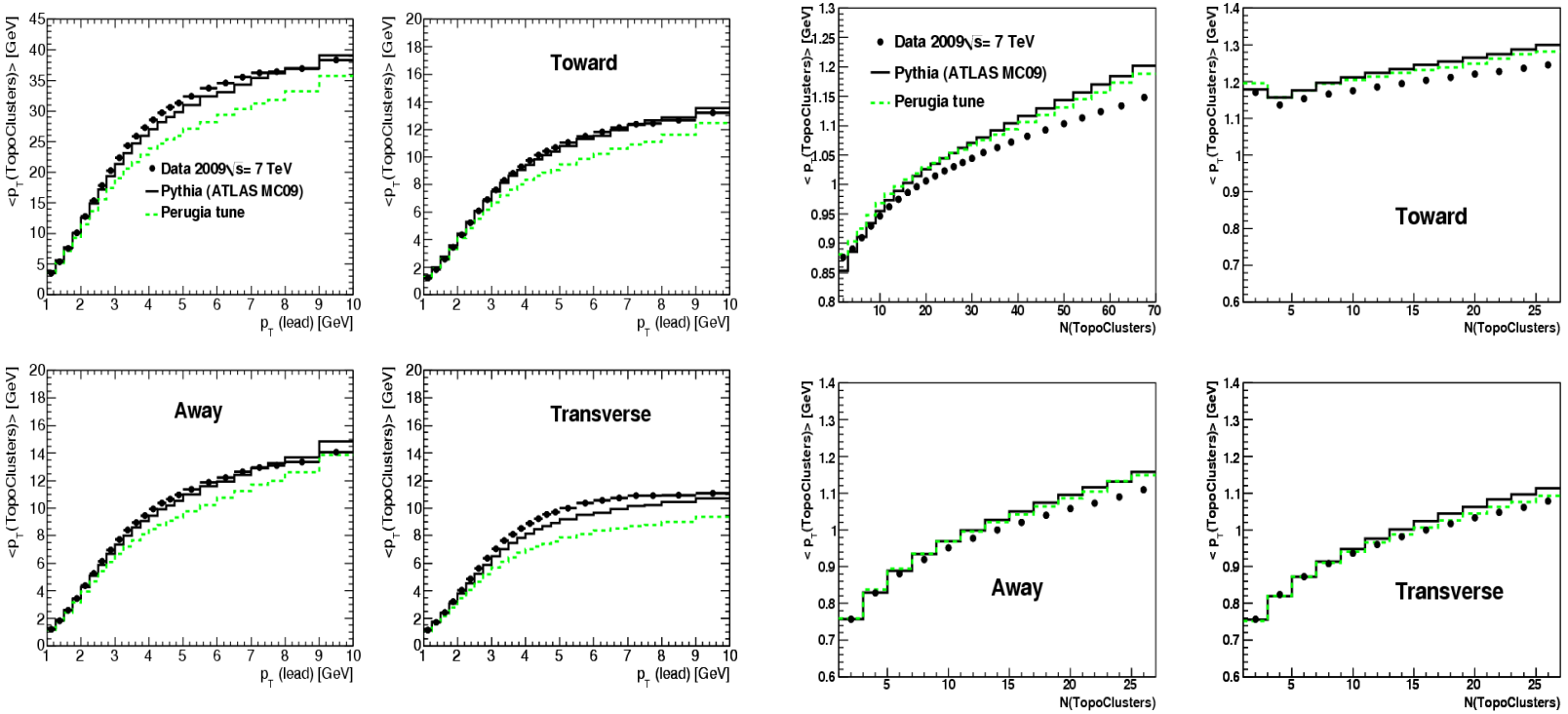
Event selection cuts as for the MinBias analysis





Similar conclusions as for the 900 GeV analysis

(but stronger discrepancies!)



Summary

- **Studies based on TopoClusters confirm the conclusions for charged-particle UE studies.**
  - MC tunes have smaller particle activity in the transverse regions
  - Monte Carlo tunes disagree with data
    - the largest problem with Perujia0 and DW tunes
- **Provide systematically independent check of our track-based measurements**
- **Concentrate on the distributions which have small bin-by-bin corrections using calibrated TopoClusters**
  - <pT> vs N and <pT> as function δφ have detector correction ~1
- **Can we trust other distributions ("particle densities" as a function pT(lead)) which have the corrections >50%?**
  - Large detector correction comes from the threshold effect at pT(min)
  - Good indication that the effect is well reproduced by MC simulation (see the pi0 peak)
  - ±5% energy-scale systematics will be dominant anyway. Also see the next bullet!
- **Calibrated clusters have significantly smaller bin-by-bin corrections than EM-scale Topo-Clusters (~100% correction!)**
  - But the physics conclusion will not change using the EM-scale
  - Given that the correction factors are large, probably we should vote for the calibrated clusters (even if the energies of calibrated clusters are over-corrected)
- **First results using 7 TeV data indicate larger discrepancies with MC**
  - And again confirm the observations using tracks (see Deepak/Gabriel's talk)

First draft of the note is available for the authors