Track studies of underlying event using 900 GeV MinBias data

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Underlaying event studies at Tevatron

R.Field,
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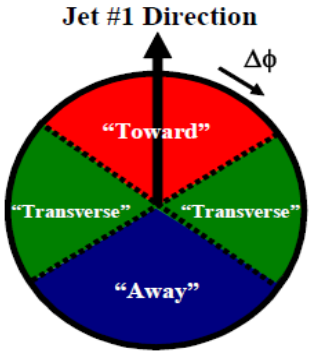
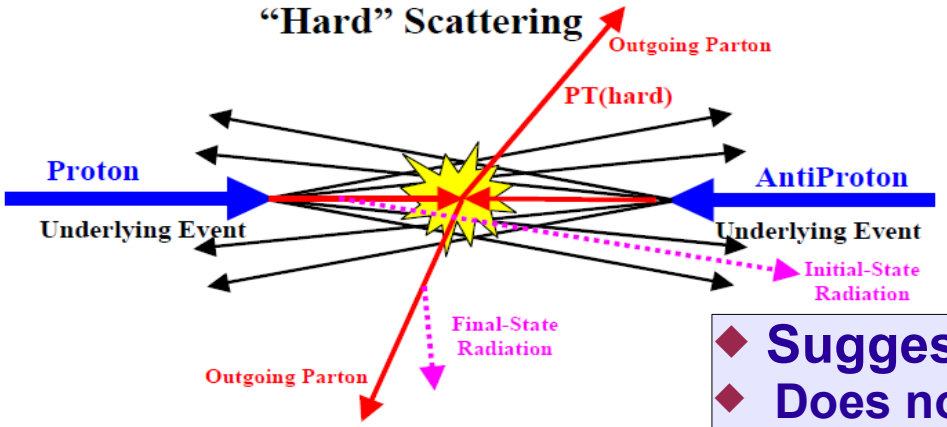
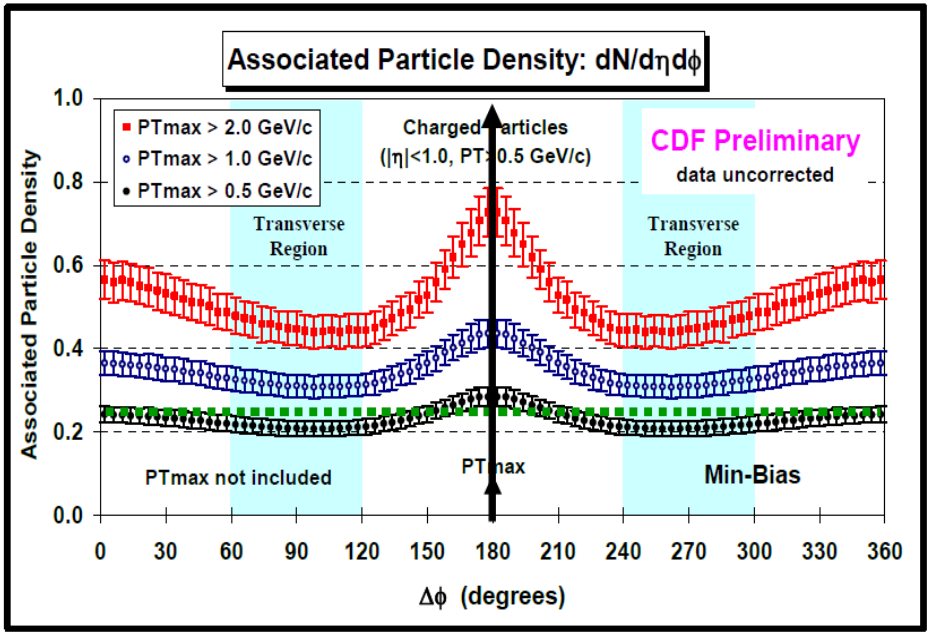






The "underlying event" consists of
- hard initial & final-state radiation
- beam-beam remnants
- possible multiple parton interactions

- **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

Goals

- **Use 900 GeV data and try to reproduce the CDF MinBias plot**
- **Use the same cuts as for MinBias note**
- **Use tracks (fitted to the vertex) and CaloTopo clusters**
  - Can we get consistent physics message?
- **Compare the results with Monte Carlo predictions (Pythia MinBias)**
  - Can Pythia MinBias reproduce the data?

Difficulties

- **Comparing not only shapes but also normalization (i.e. densities)**
- **More exposed to detector effects (but also to physics!)**

Plan of this talk

- **Energy flow analysis using tracks**
- **Correcting for diffraction (SD,DD)**

Event and track selection

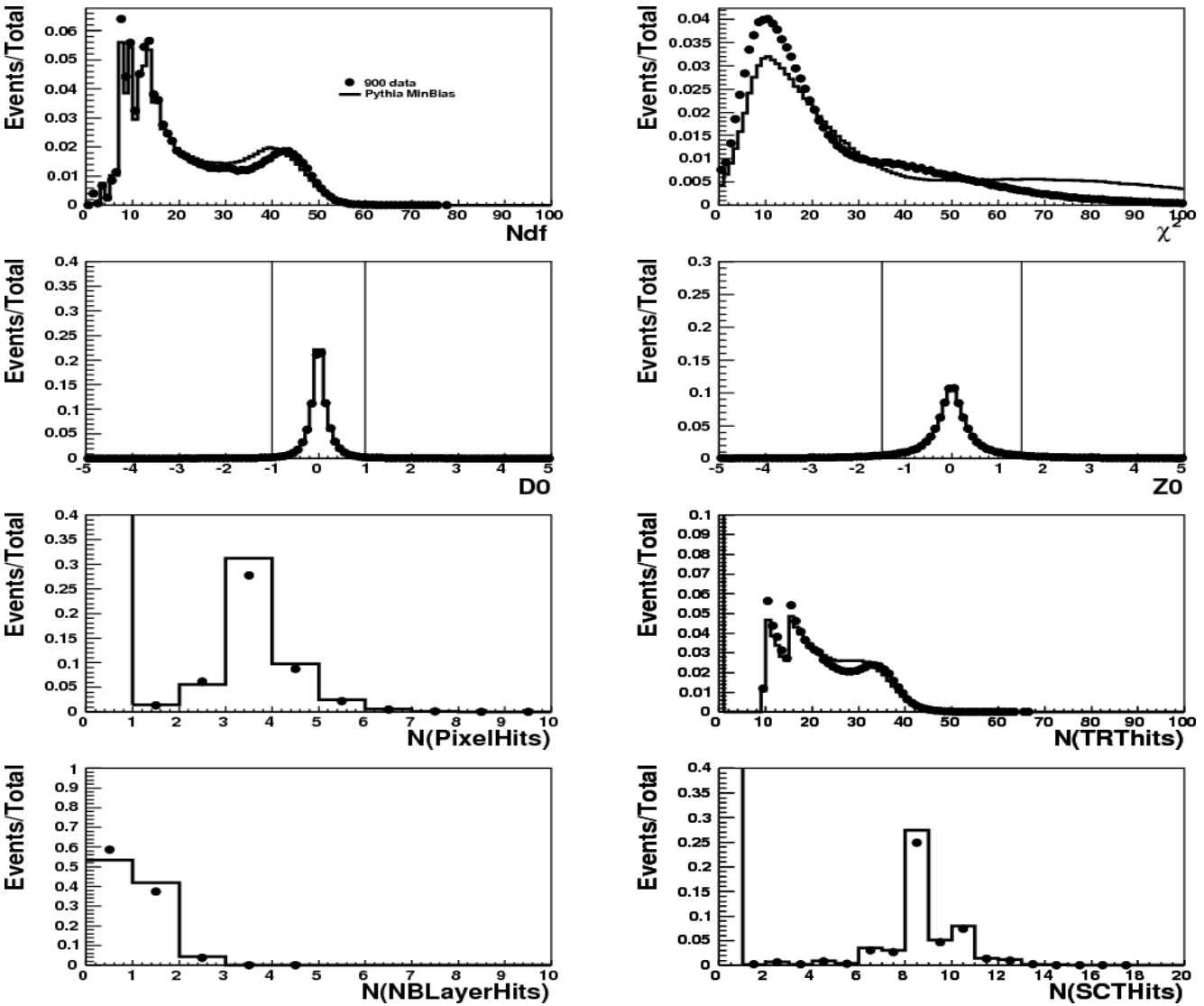
- **Good runs Solenoid=ON, Toroid=ON**
  - **141565, 141707,141746,141748,141811,142166,142191,142193,142195,142383**
- **Tracks re-referenced to the primary vertex using ESD (1st reprocessing)**
- **Monte Carlo sample: ATLAS-GEO-08-00-02 (r1023)**
  - PYTHIA MinBias sample (single+double diffraction will be discussed later)
  - mc09_900GeV.105001.pythia_minbias.recon.AOD.e500_s674_s675_d272_r1043
- **L1_MBTS_1_1 trigger**
- **At least 3 tracks for the primary vertex**

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

Track selection cuts (as for the MinBias note):

- |d0|<1 mm
- |z0|<1.5 mm
- N(PixelHits)>0 & N(SCThits)>5, 65 Pixel modules removed
- pT(track)>0.5 GeV and |eta(track)|<2.5

Track quality distributions

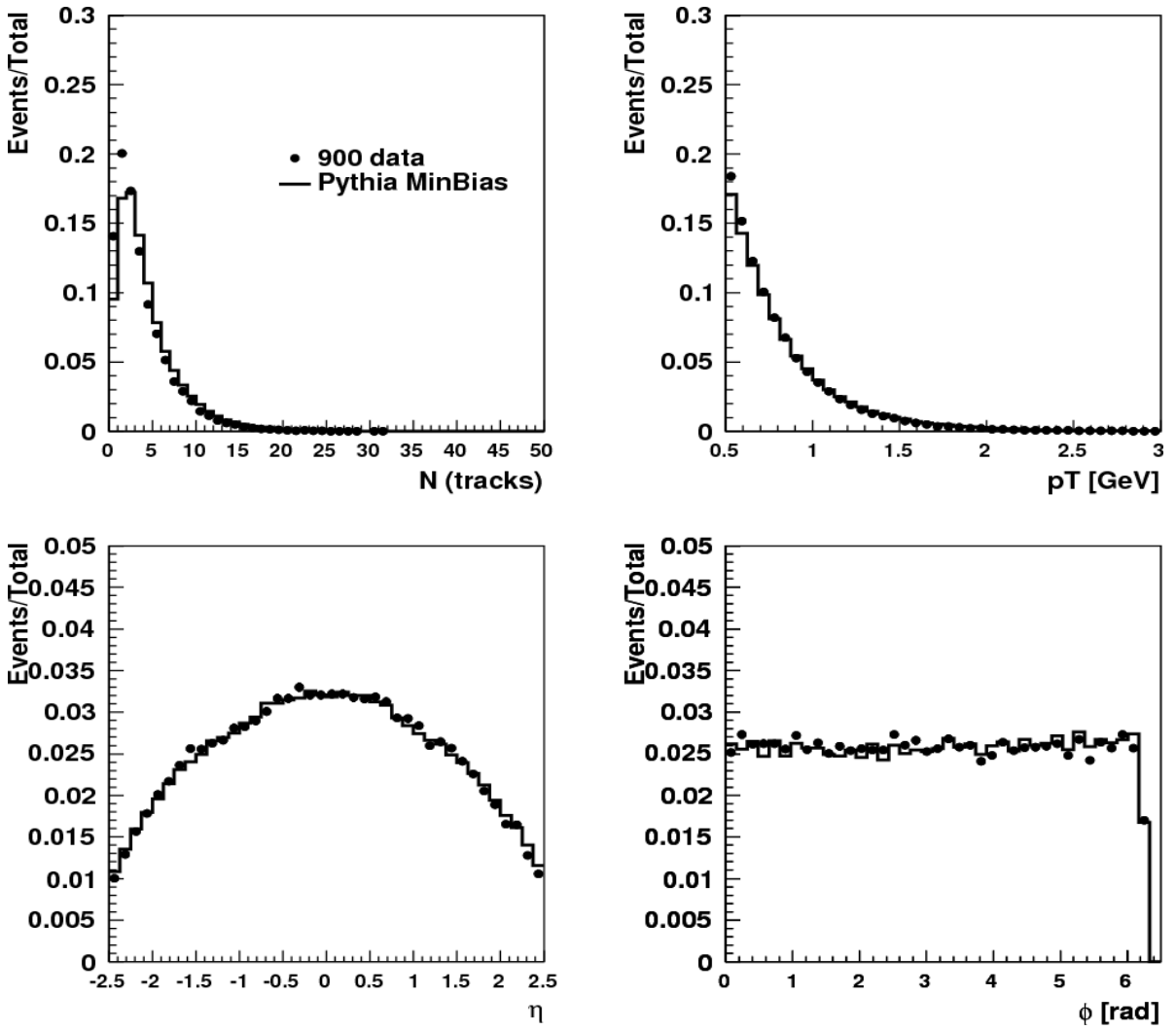


(all plots before any cuts)

Most important distributions: d0 and z0

Use sufficiently loose selection cuts to avoid biases for the final comparisons with MC

Normalized track distributions

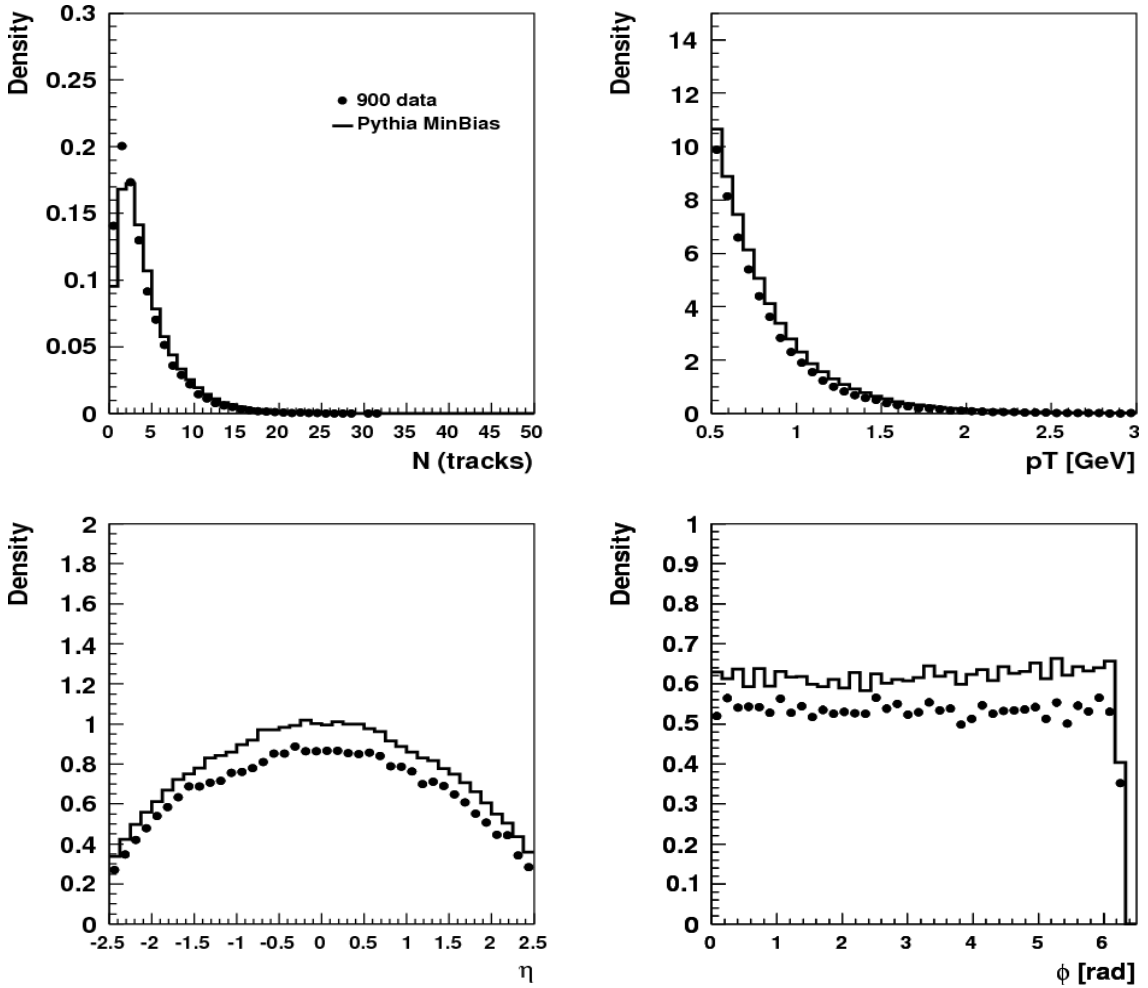


- Reasonable agreement between data and MC for shapes (but not for pT)
- Event rate with small-number of tracks (pT>0.5 GeV) is underestimated in MC due to diffraction (see next)

Track densities

Density=N / (binWidth x N(tot))

N(tot)- number of events with a (leading) track above pT>0.5 GeV (leading track is excluded)

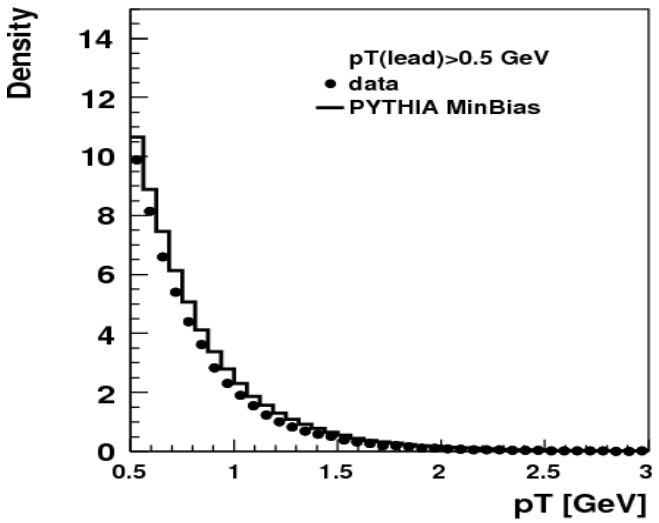


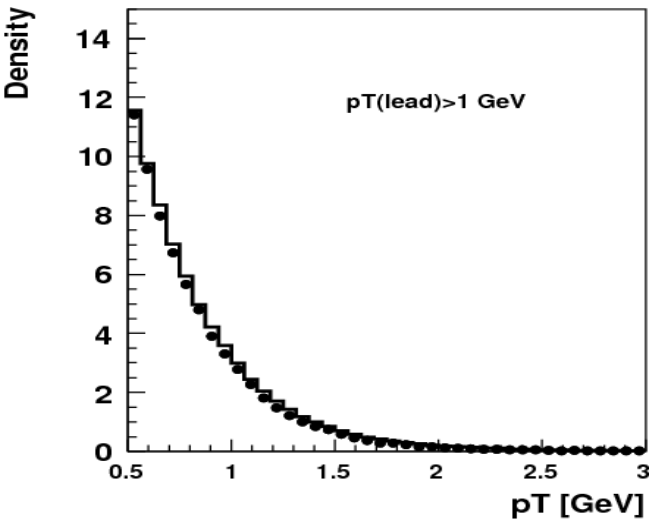
- Difference in normalization. Contribution from diffraction (via N(tot))

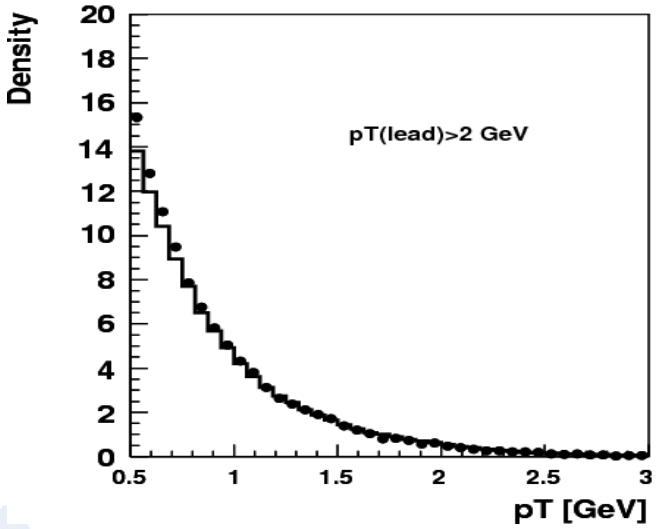
Densities as a function of pT(leading)

Density=N / (binWidth x N(tot))

N(tot)- number of events with a track above pT>0.5 GeV





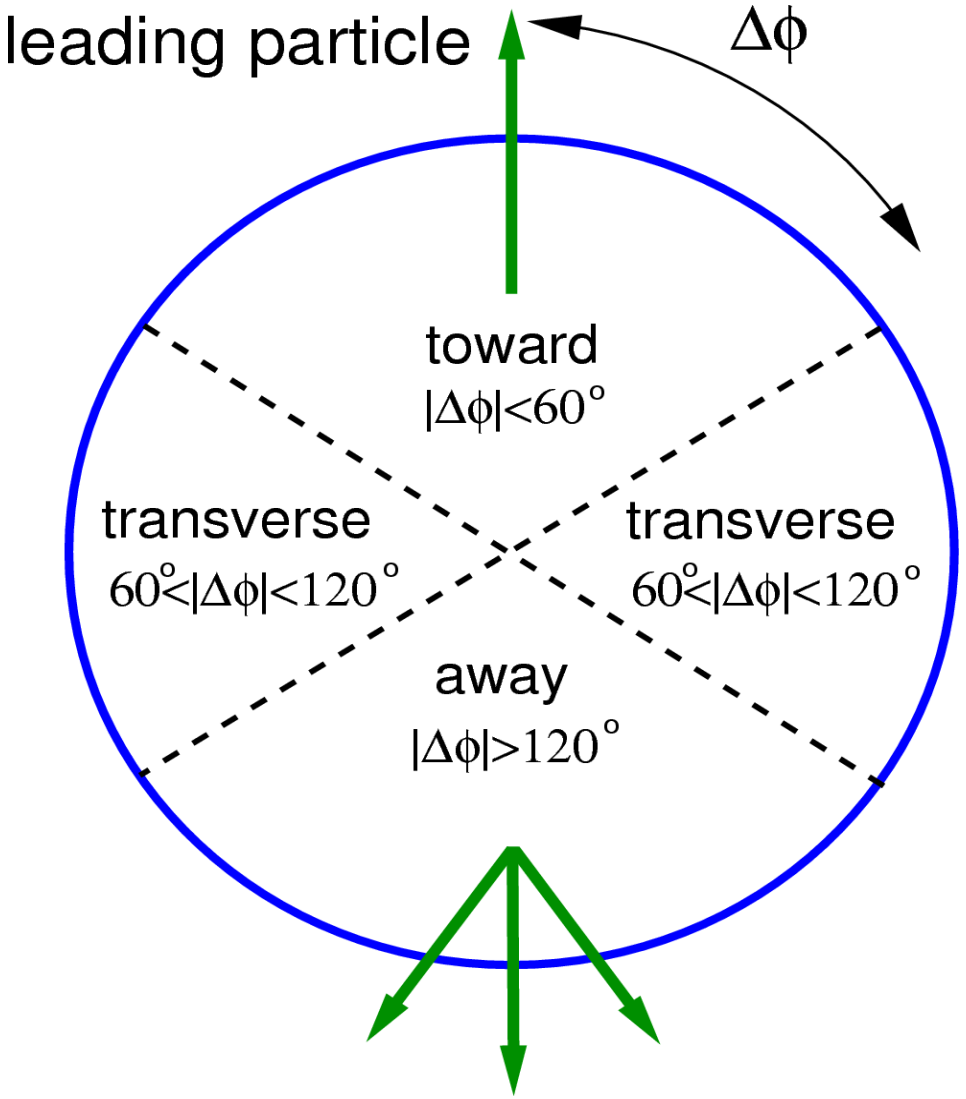


* leading in pT track is excluded

PYTHIA MinBias overestimates data at pT(lead)>0.5 GeV (diffraction)

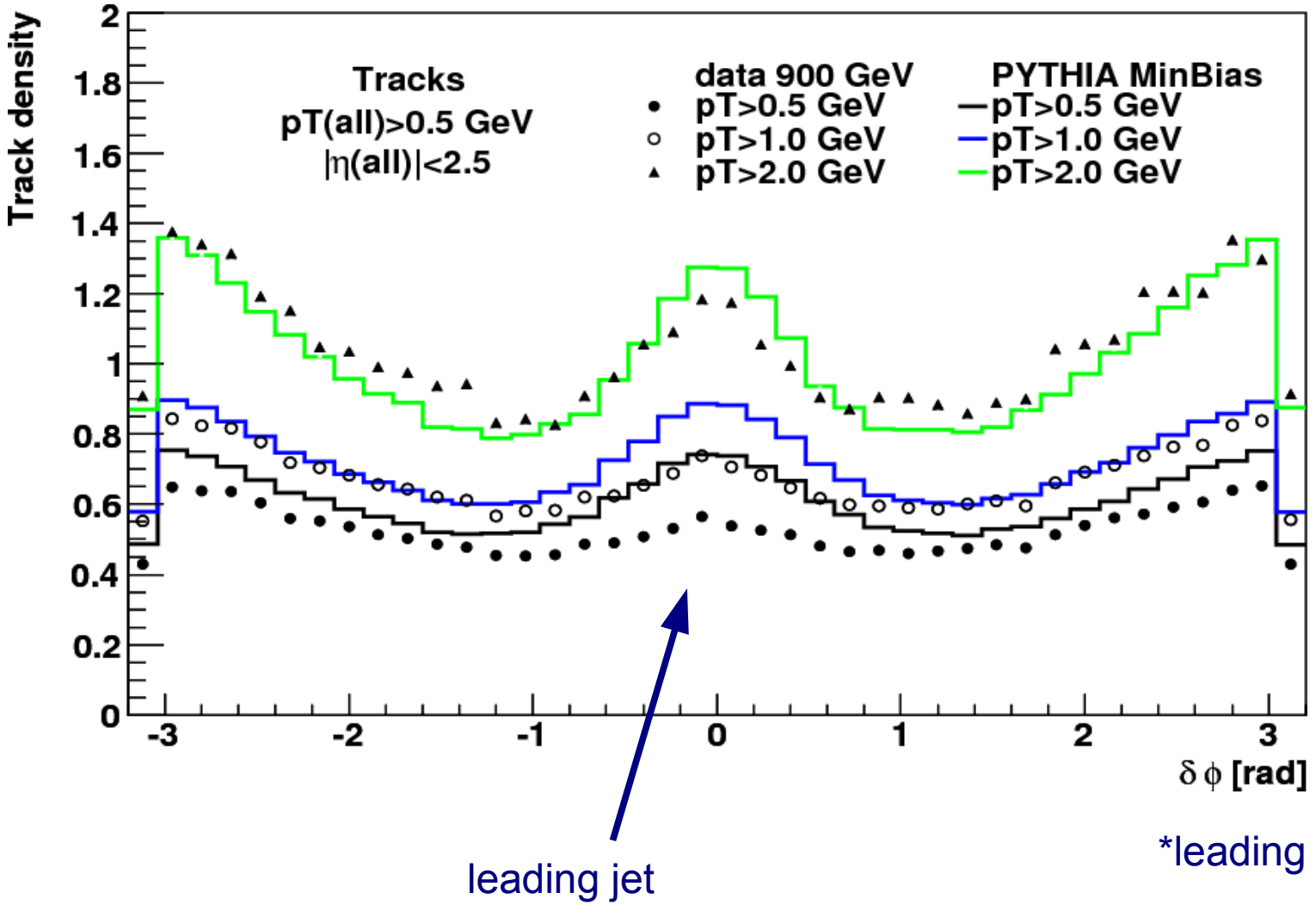
But underestimates normalization at pT(lead)>2 GeV

Energy flow calculations



- Select on the highest pT track
- Use angle of the track at the IP as the reference direction
- Calculate difference in azimuthal angle between this track and any other track in event
- Calculate densities excluding the leading jet:
  - N / (N(tot)xBinWidth)
- Repeat the same for different pT's of the leading track
- Use the same procedure for To-poClusters

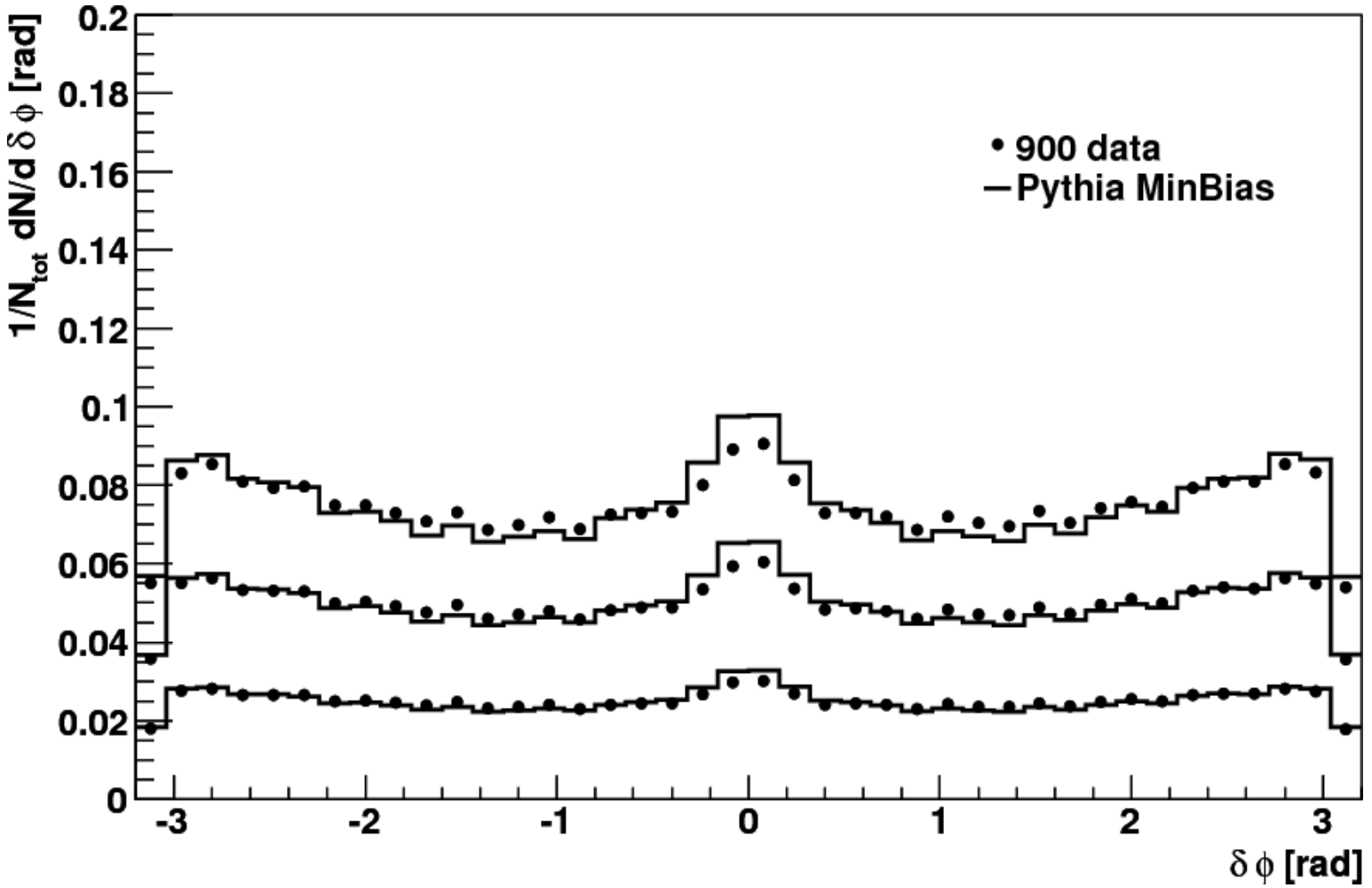
Track densities as a function of pT(lead.)



*leading track is excluded

- "birth" of 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
- Some differences with Pythia MinBias in shapes and normalization (to be discussed later)

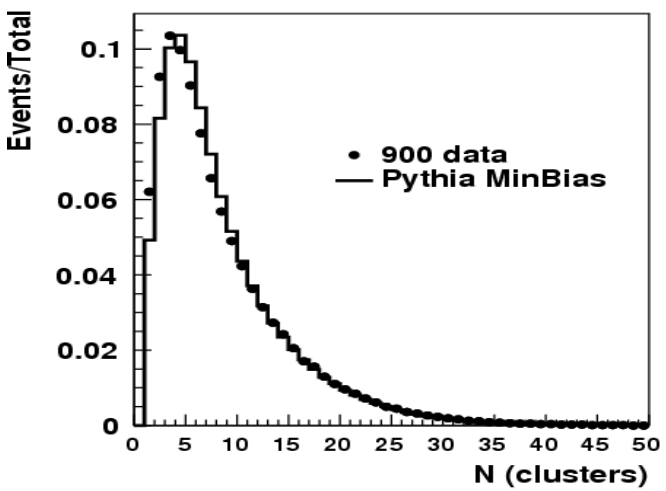
Shape comparison

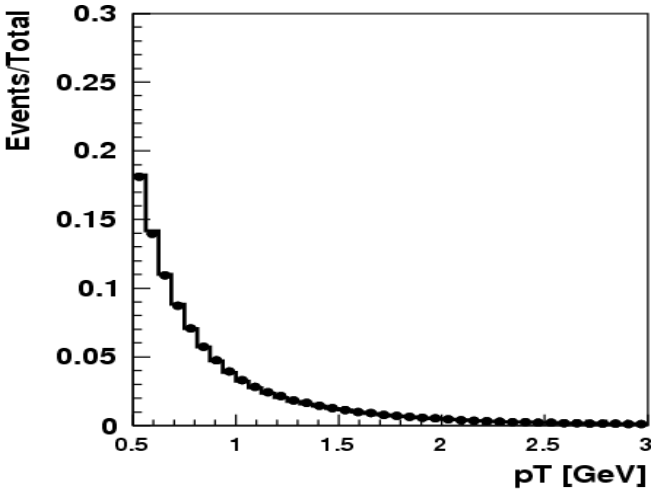


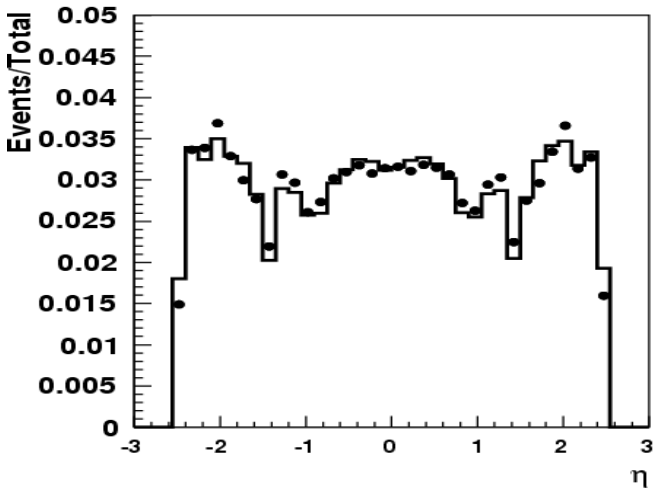
Distribution for pT>0.5,1,2 GeV are normalized to 1,2,3 (for MC and data)
Differences between MC and data for shapes

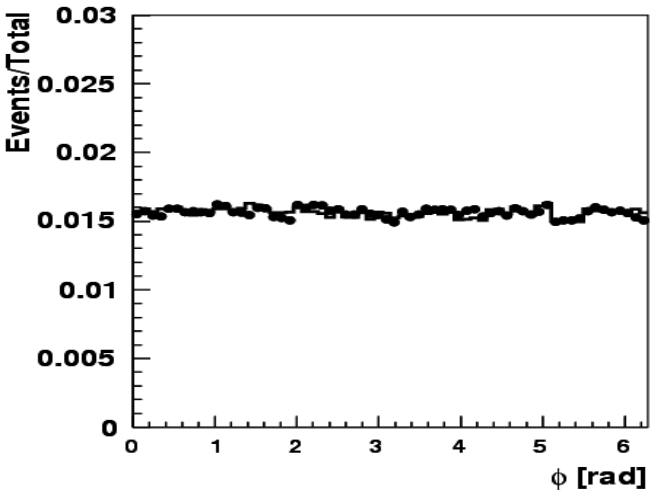
TopoClusters distributions

Cuts as for tracks: pT>0.5 GeV and |eta|<2.5



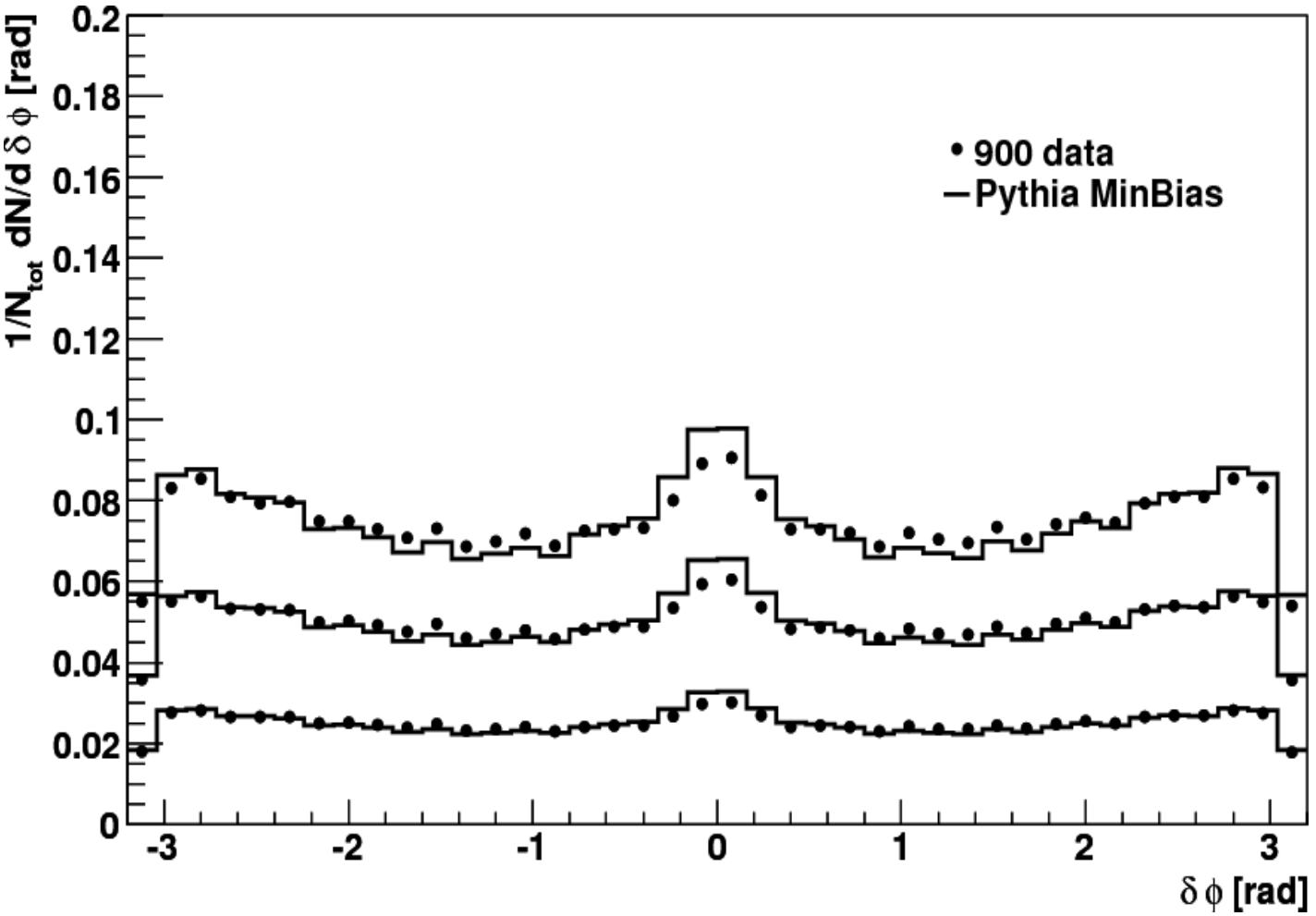






Reasonable agreement

Comparing shapes



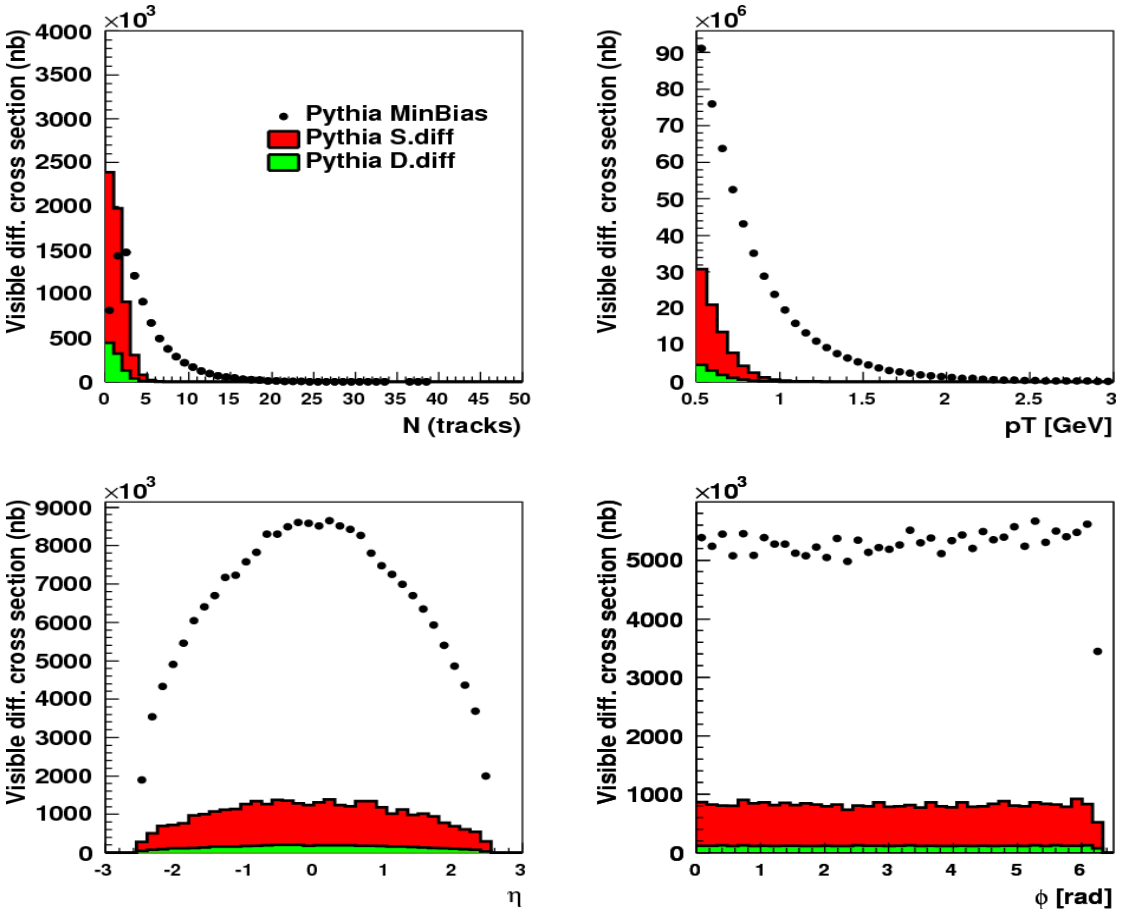
Distribution for pT>0.5,1,2 are normalized to 1,2,3 (for MC and data)
Differences in shapes near the region affected by the leading jet
Similar difference as for the track studies

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_1 rejection factors:
  - Sdiff - 65%
  - Ddiff - 55%
  - MinBias - 2-3%

SD has significant contribution for low-multiplicity events

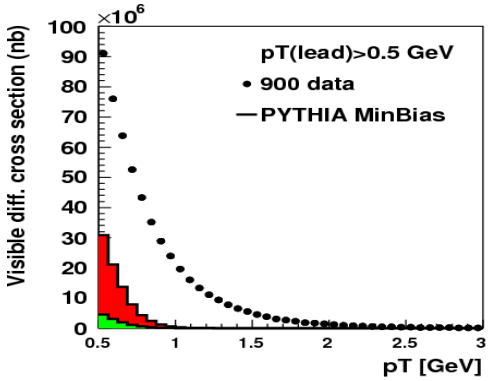
Tracks

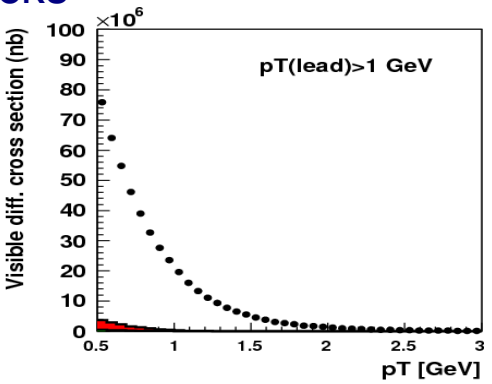


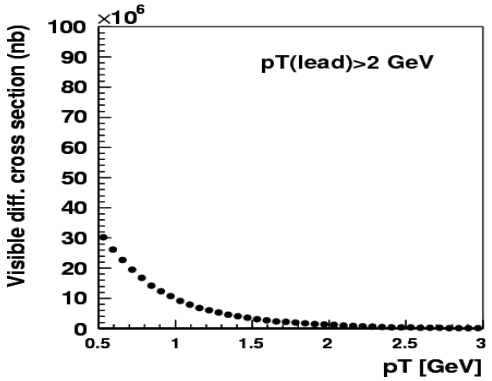
* leading track is excluded

Diffractive contribution as a function of pT(lead)

Tracks







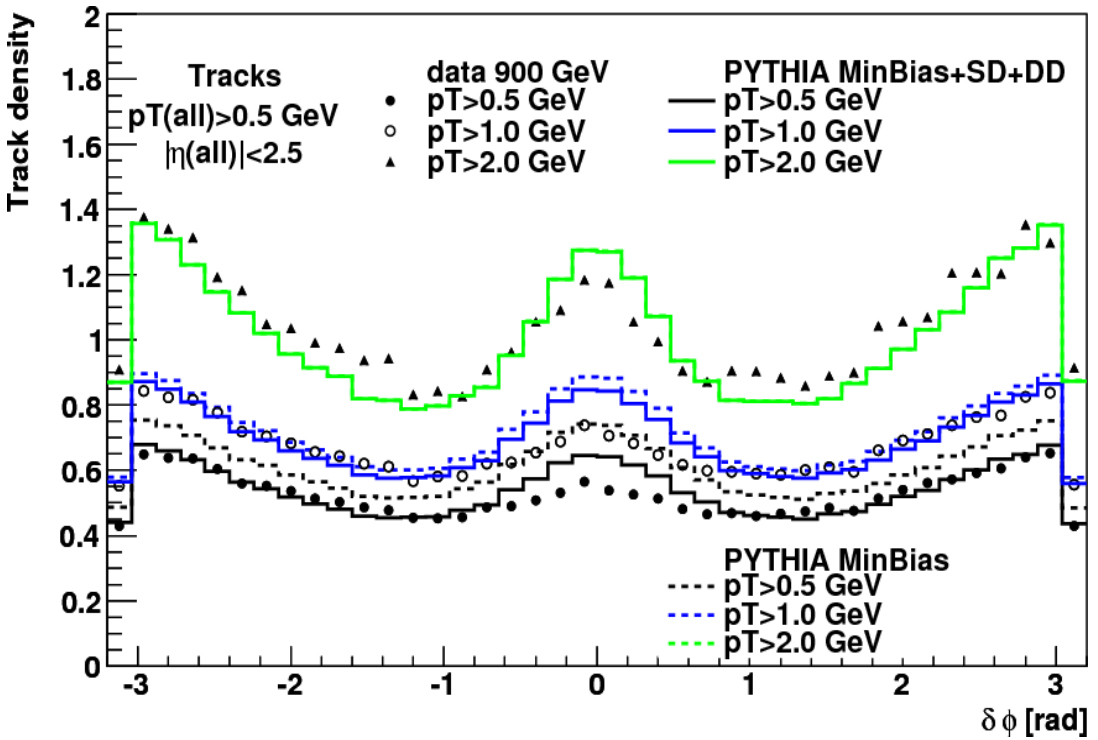
Diffractive contribution is small at large pT(lead)

Fractions of diffractive events:

Tracks	pt>0.5 GeV	pT>1 GeV	pT>2 GeV
SD	13%	3%	<1%
DD	2%	1%	<1%

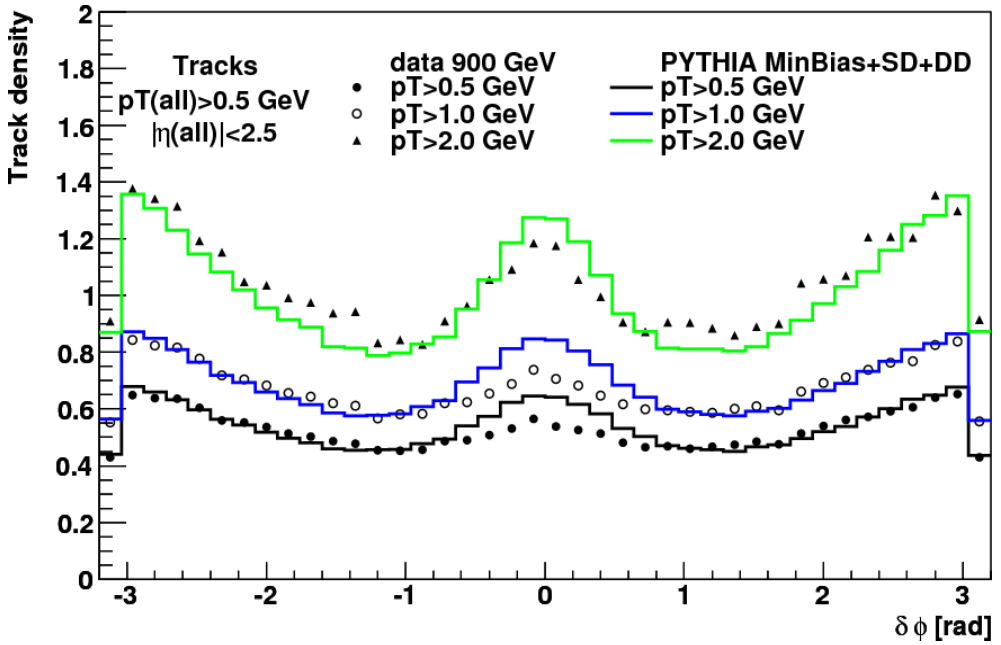
Energy flows corrected for diffraction

Reconstruct energy flows for
each components (MB,SD,DD)
and combine contributions using corresponding weights



Diffractive contribution improves agreement for tracks at low pT

Same with diffraction included



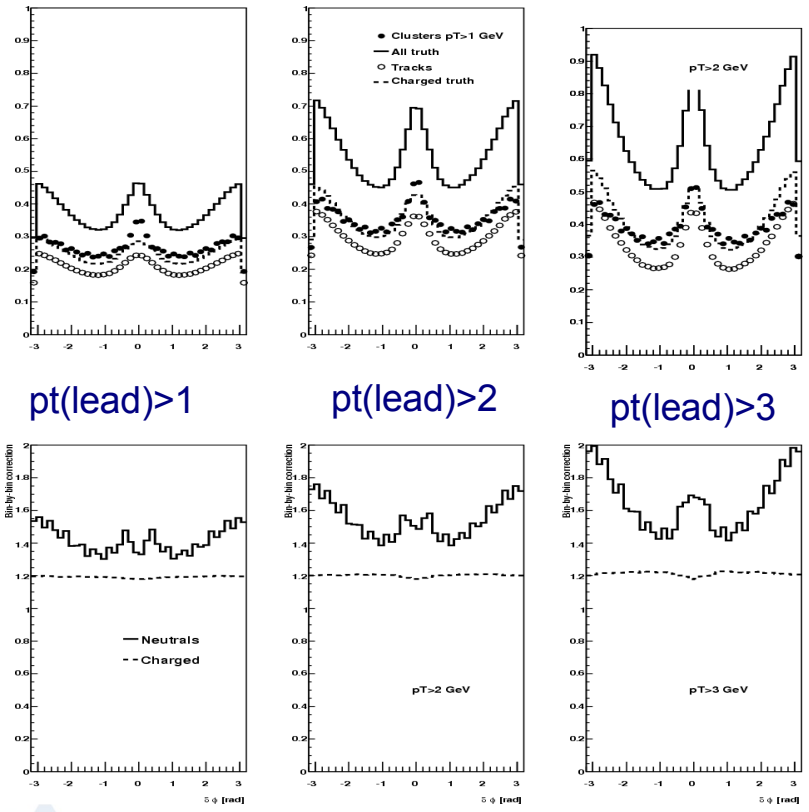
Track density is ~30% lower than TopoCluster density (which includes neutrals)

The agreement is reasonable, but not perfect (no systematics!)

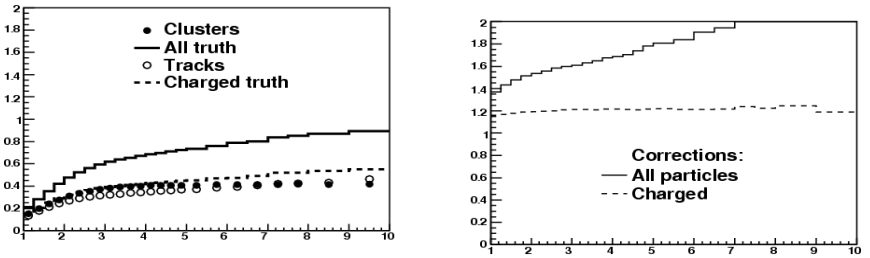
Both tracks & clusters show rather similar difference with MC

Correction factors and purity

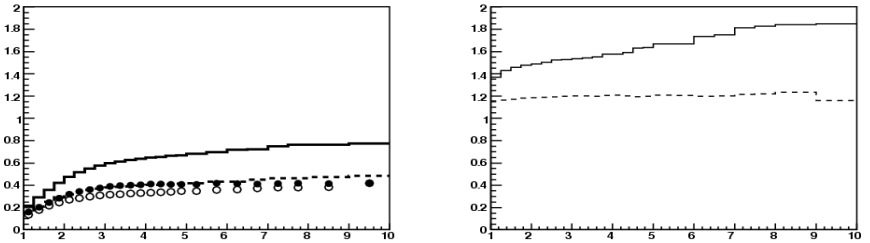
- Correction factors defined as C=N(gen)/N(reco) ~ 1.20
- Takes care of efficiencies and purities
  - C= N(gen)/N(reco) = purity / efficiency
  - Purity=N(gen & reco) / N(reco)
  - Efficiency = N(gen & reco) / N(gen)



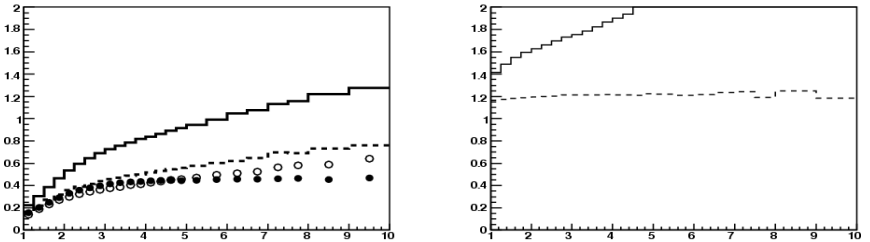
All regions



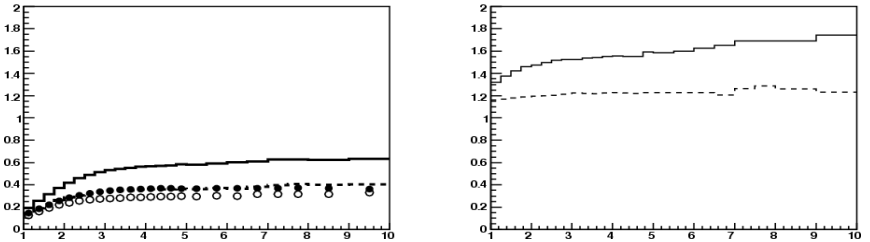
Toward



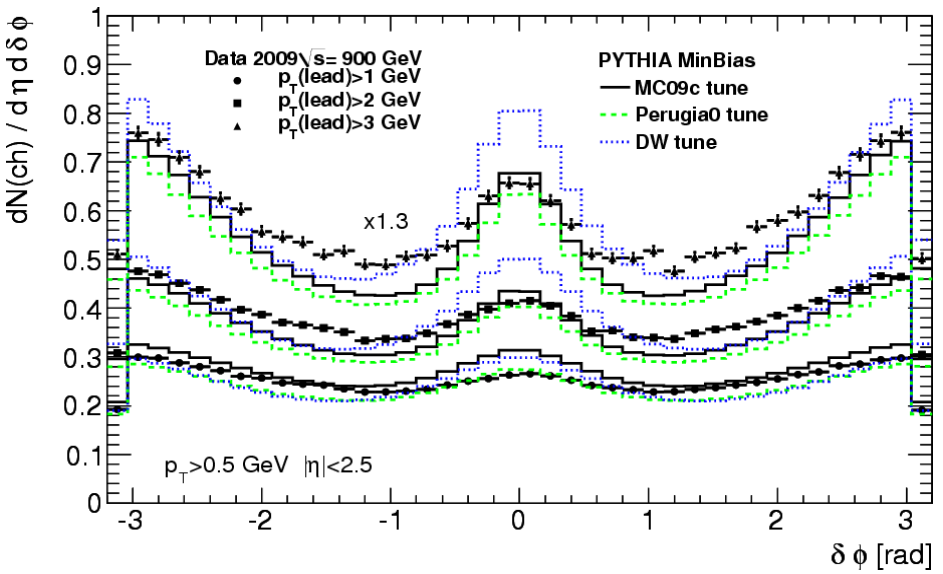
Away

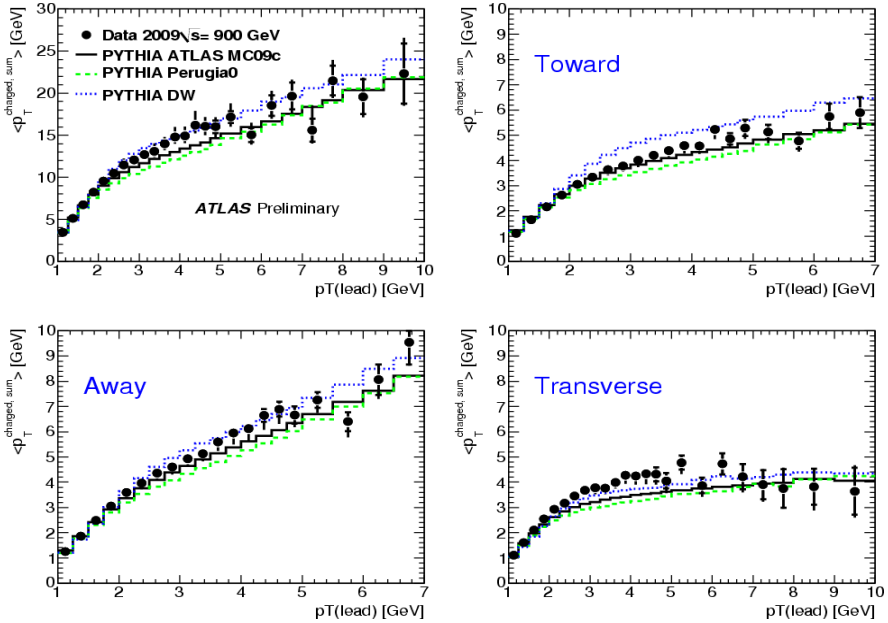


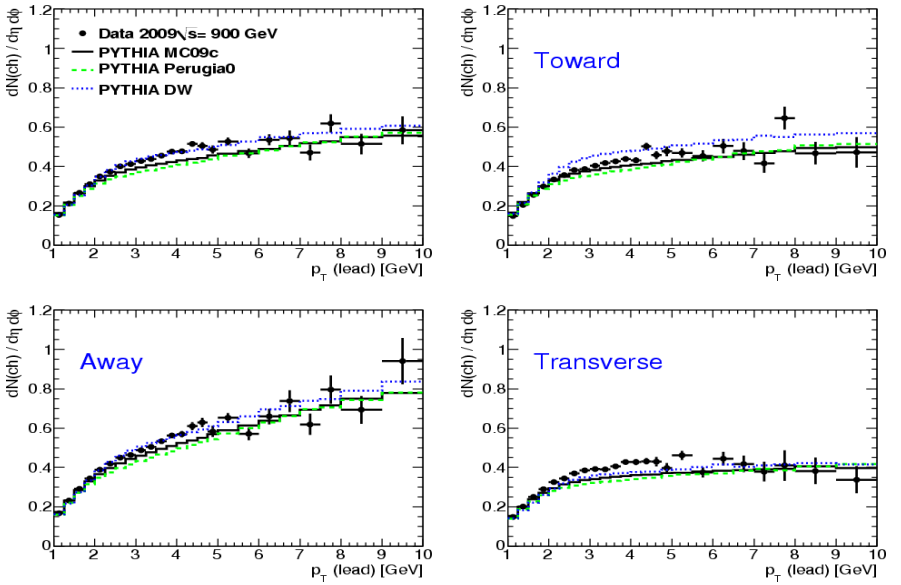
Transverse

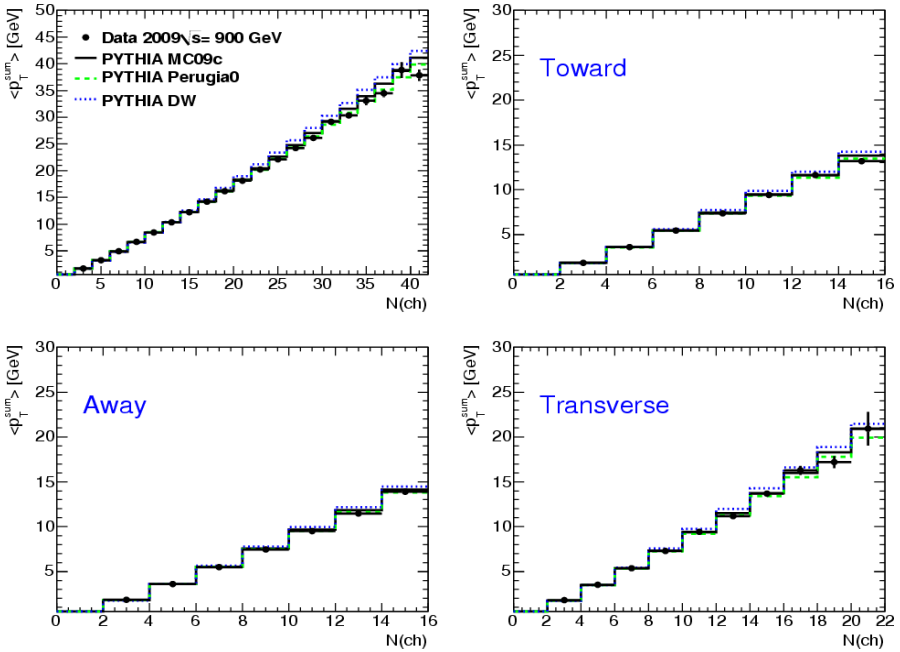


After bin-by-bin correction



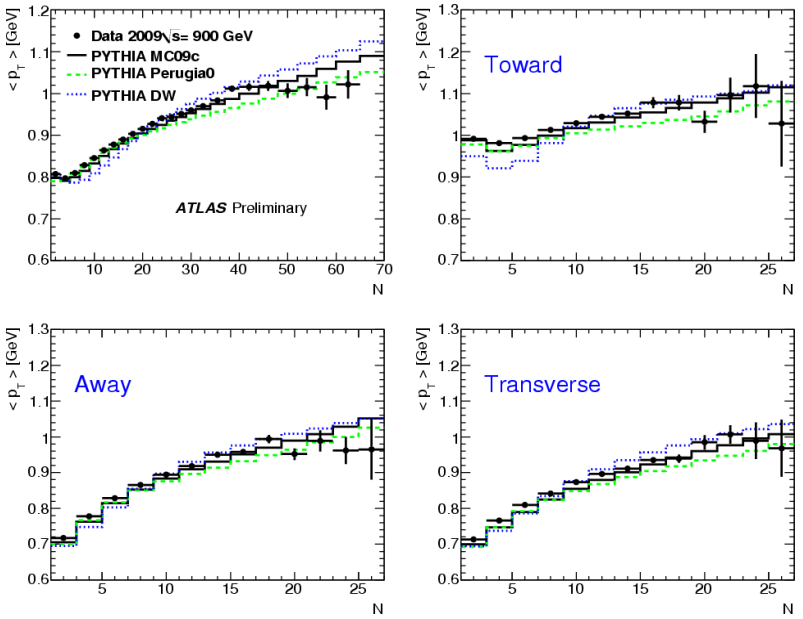


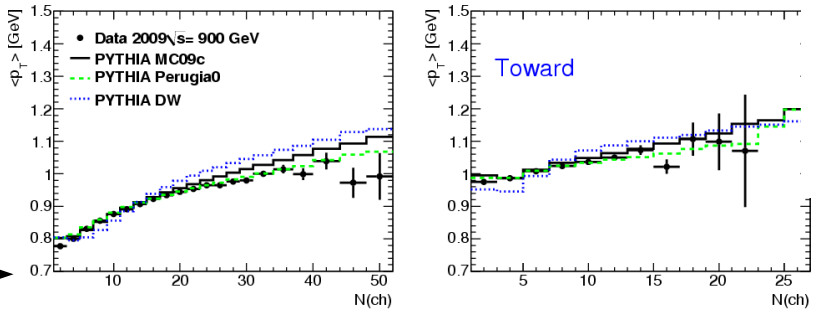




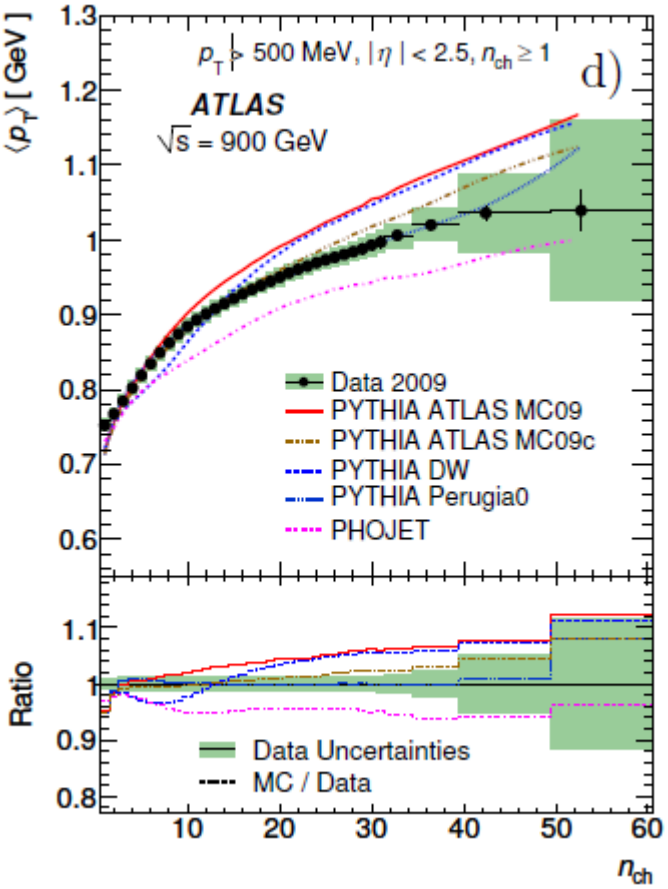
.. as in the MinBias paper

After the bin-by-bin unfolding using TopoClusters





Using bin-by-bin corrections for tracks



Leading track is included to compare with the MinBias paper

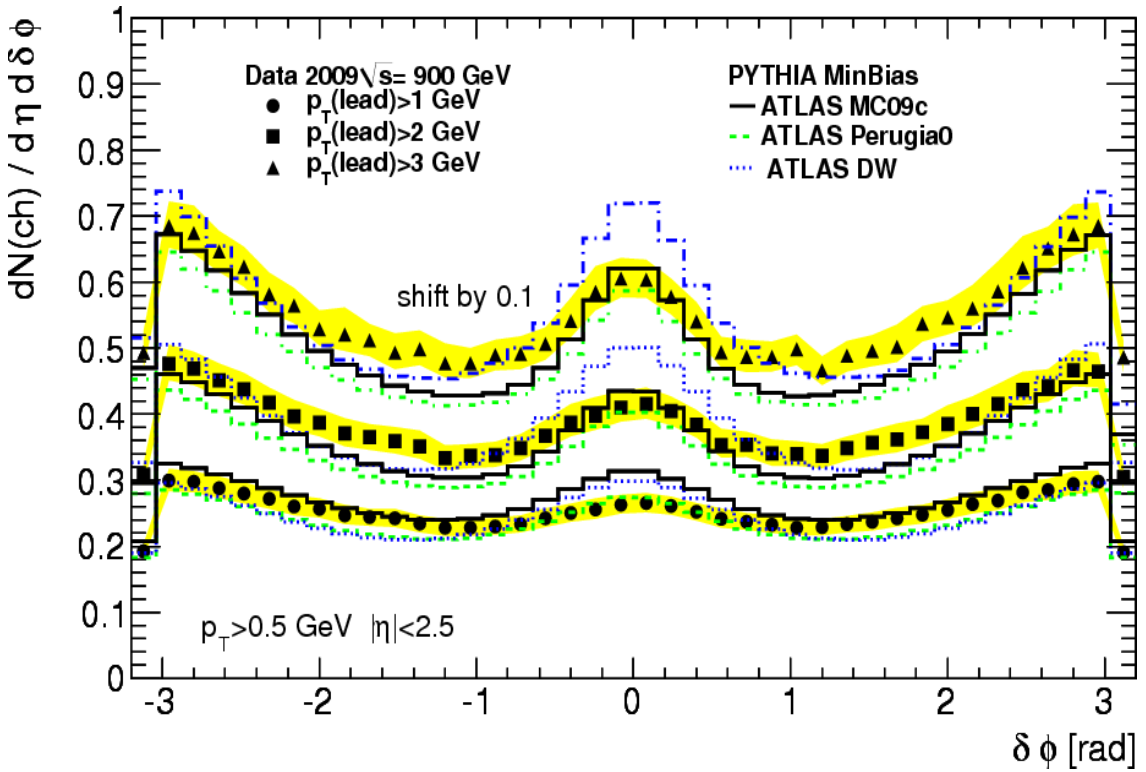
Systematic uncertainties

Nr	Variataion	Density as dphi	Density as pT(lead)	Why?
1	N(track)>3	<1%	<1%	Reduce diffractive events
2*	pT(min)±1%	-/+ 2%	-/+2%	Difference with MC in resolution at pt=0.5 GeV
3*	pt(min,lead)±1%	-/+2%	-/+2%	- same but at large pT
4*	Eta(max)±1%	+/-2%	+/- 1%	- same but for Eta
5	N(SCT hits) +1	<2%	<3%	Tighter selection
6	Z0 cut - 0.5 mm	<1%	<1%	Tighter prim. track
7	D0 – 0.5 mm	<1%	<1%	-//-
8*	phi(track)±1%	<1%	<1%	Diff, in phi resolution
9	5% scaling of bin-by-bin-corrections	<1-2%	<1-2%	From the MinBias. Estimate for efficiency correction
10	10% extra material	+2.5%	+2-4%	Decreases efficiency (increases correction)
11	Pythia with Perugia tune	<1%	<1%	Dependence on MC tune
12	1 or 100 day alignments	<0.5%	<0.5%	Difference in alignment

Shows average uncertainties for all data points relative to the measured value of the densities (in %)

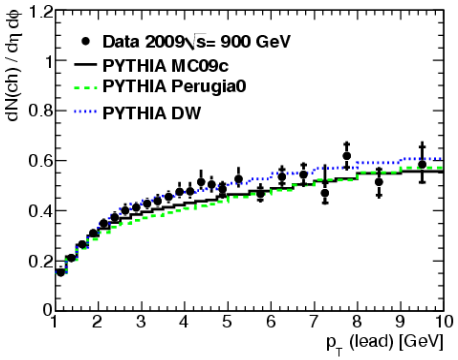
Variations in the data only are shown as (*)

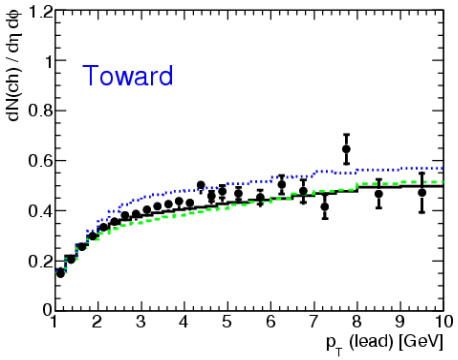
Plots with systematic uncertainties included

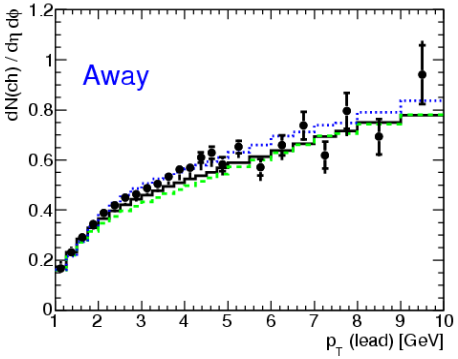


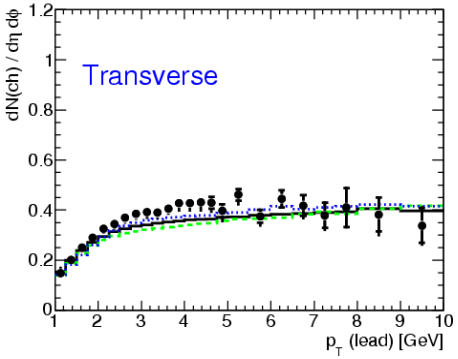
Yellow band: statistical plus systematical error added in quadrature

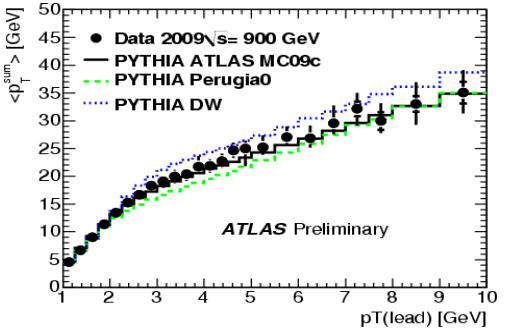
Plots with systematic uncertainties included

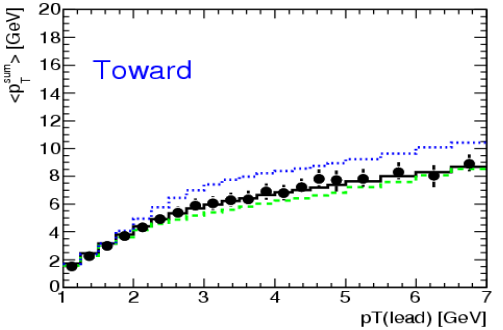


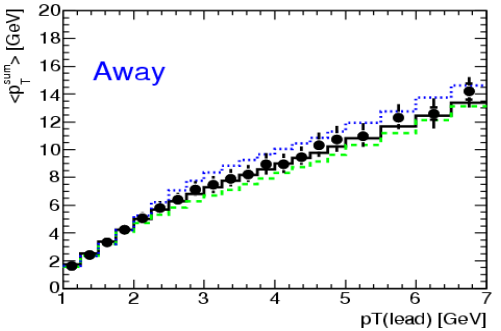


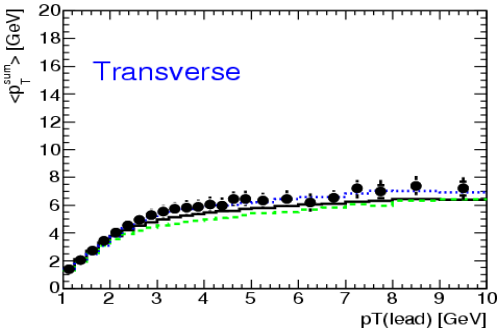




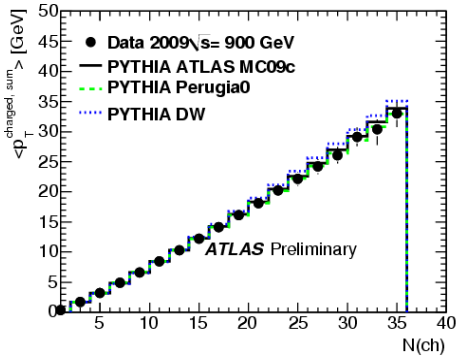


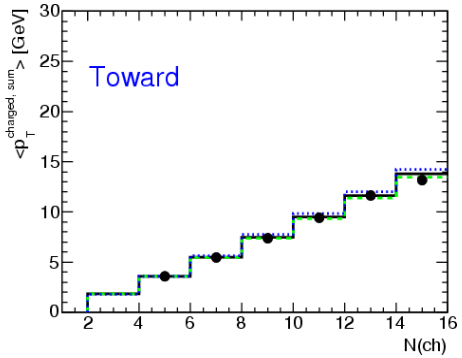


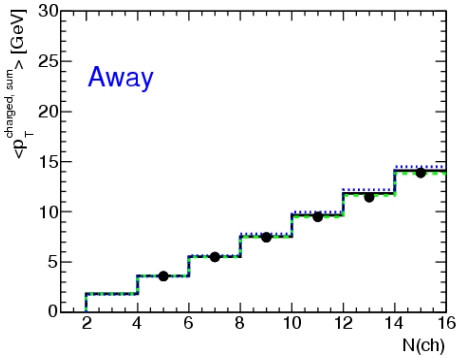


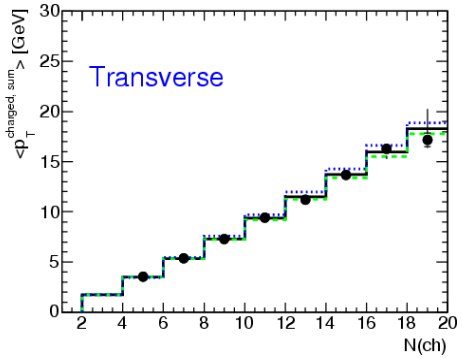


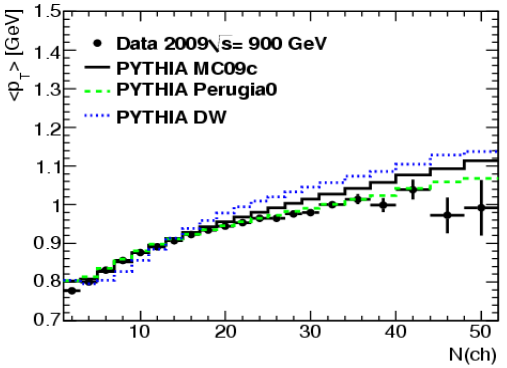
Plots with systematic uncertainties included

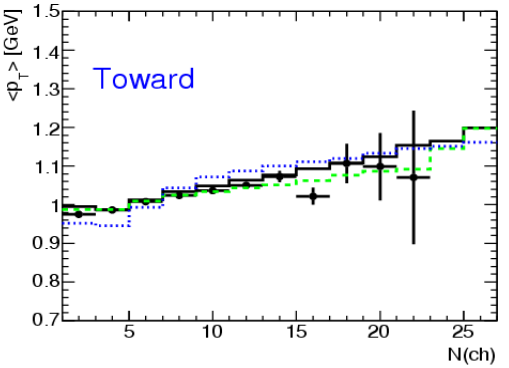


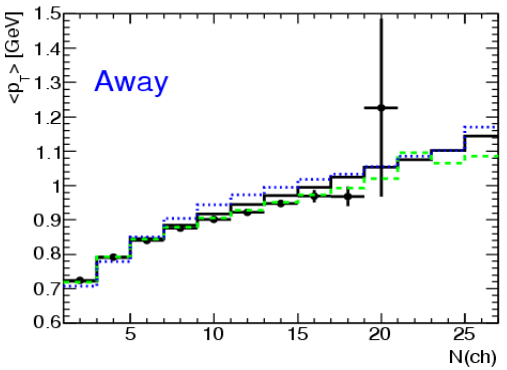


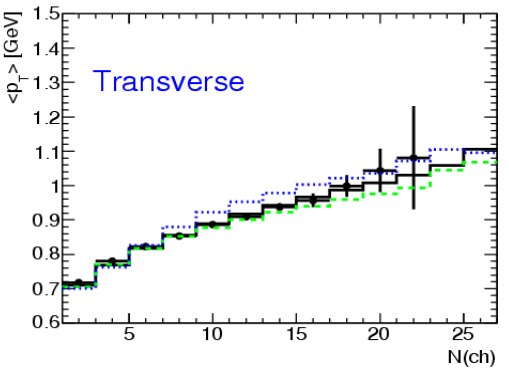




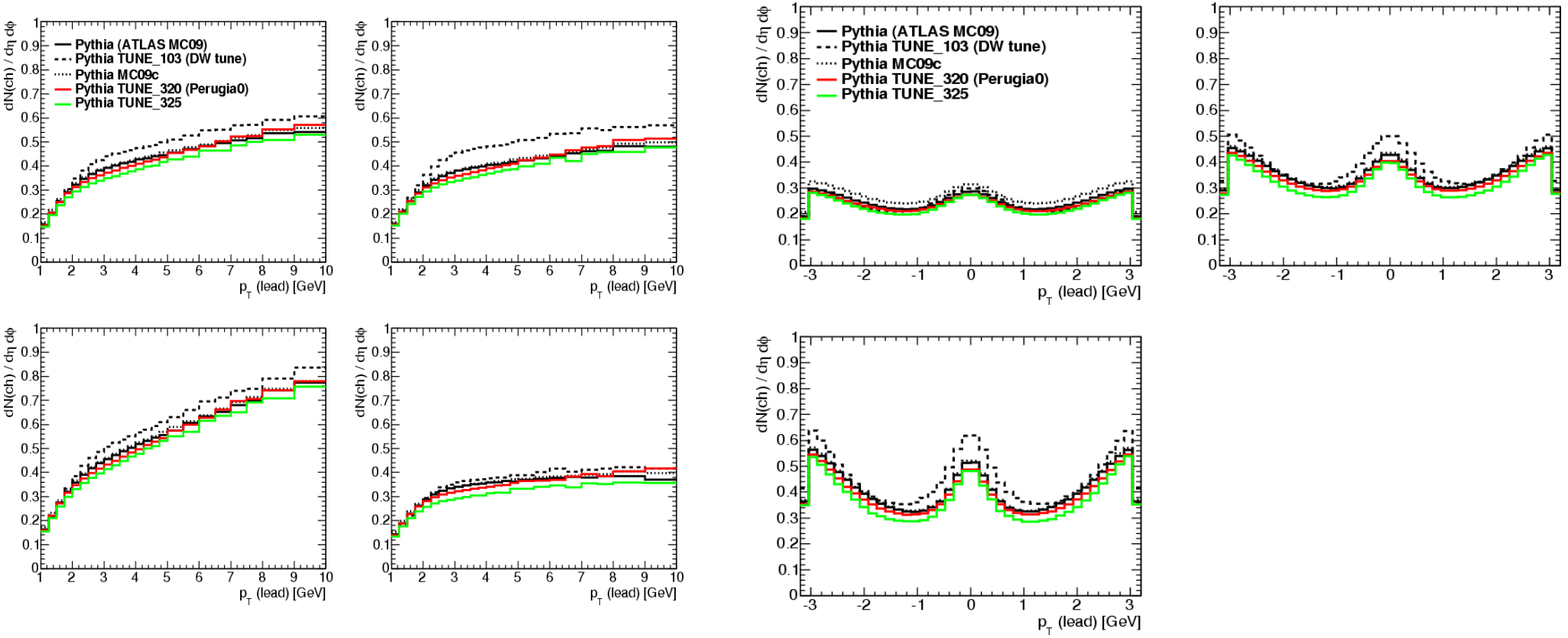








Pythia truth



Done using NtupleMakerTruth: http://atlaswww.hep.anl.gov/asc/WebSVN/
Ntuples with truth level (pT>450 MeV) ~ 10 GB each.
Using exactly the same Pythia option files as for MC09 production
25M events for the tune 103 and 230. Done on 50-core farm (30 min runtine)
Can be copied to any available location