ALICE Underlying Event Measurements

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ALICE Experiment 201

International Research Training Group
Development and Application of Intelligent Detectors

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Outline

- Introduction: why and how measuring the UE?
- Data correction procedure
- Systematic uncertainties

- ALICE UE Measurement and MC comparison:
  - @ $\sqrt{s}$ = 900 GeV
  - @ $\sqrt{s}$ = 7 TeV

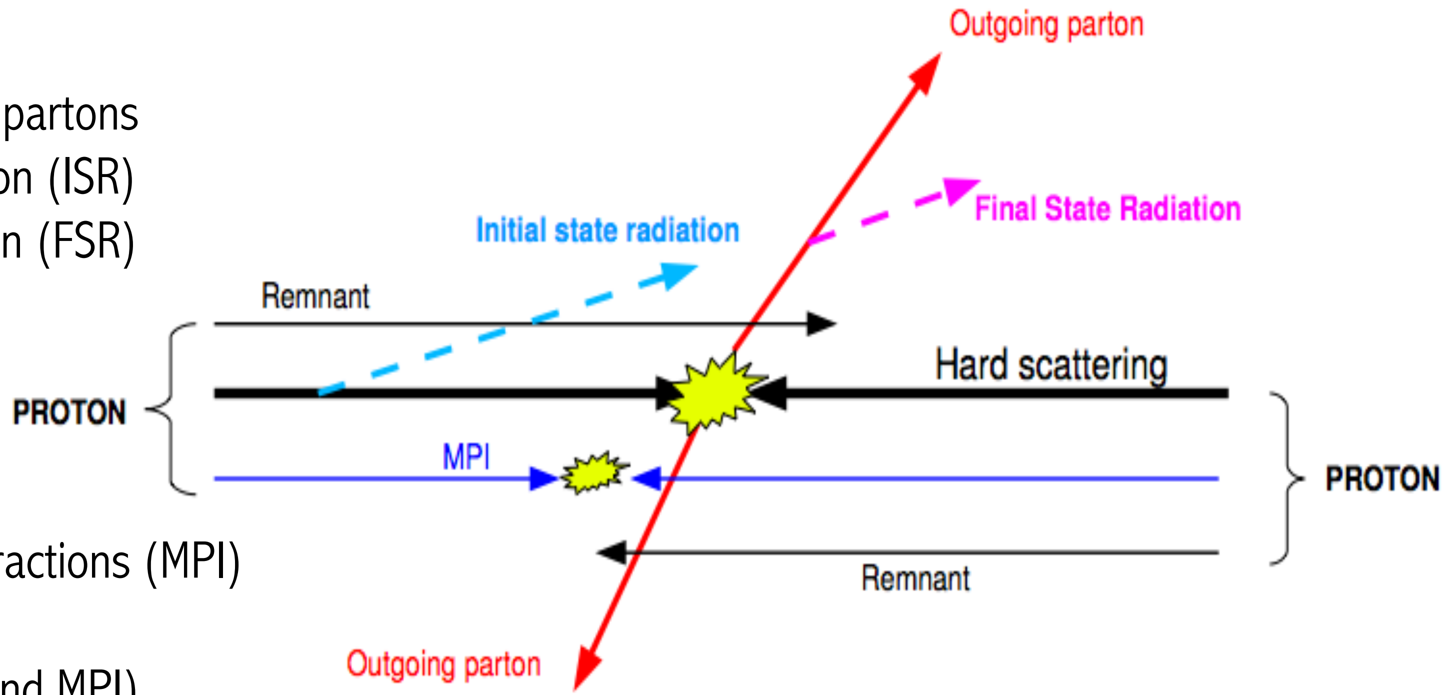
- Conclusions

The Underlying Physics

We define the UE as everything else but the hardest scattering in a pp collision.

Three regimes...

HARD:
- jets from outgoing partons
- Initial-state-radiation (ISR)
- Final-state-radiation (FSR)



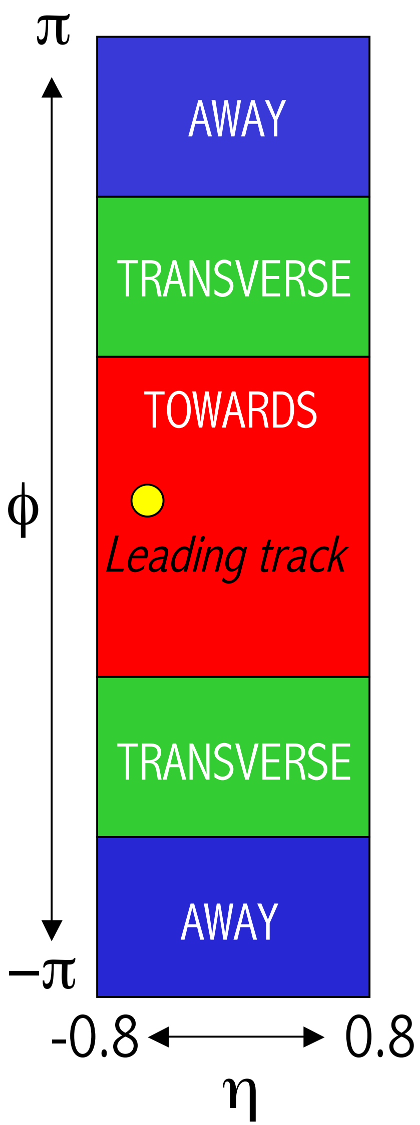
SEMI-HARD:
- Multi-partonic-interactions (MPI)

SOFT:
- Beam-remnants (and MPI)

Hard-scattering and UE are NOT separated in terms of hardness

FACTORIZATION:
- short distance (perturbative)
- **long distance (data constrained)**

Experimental Method



On event-by-event basis:

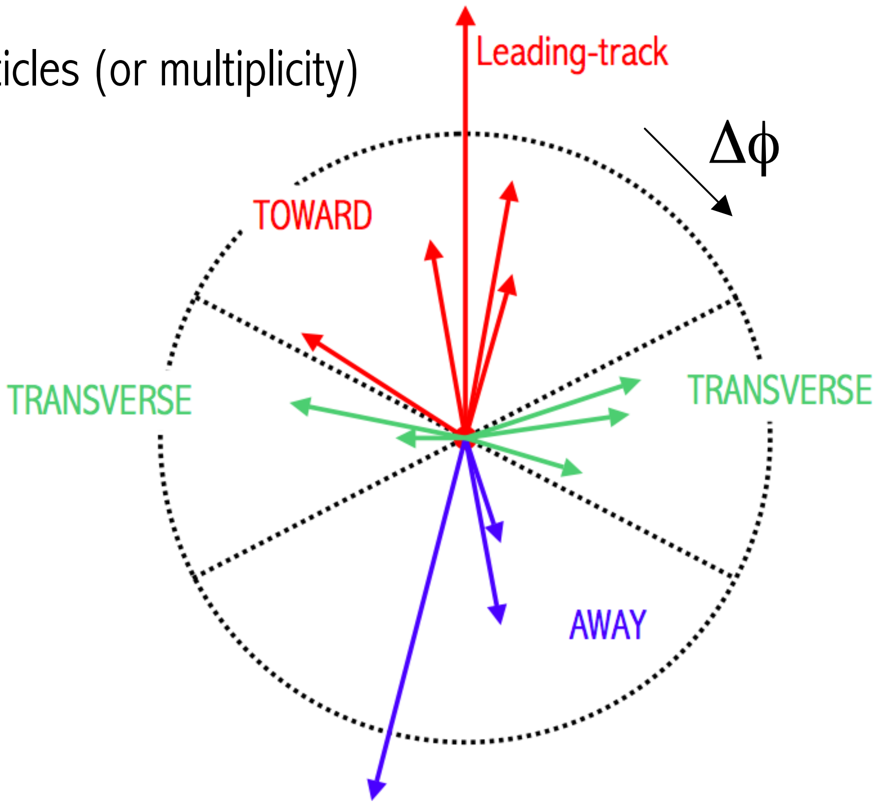
1) Identify the leading object in the event

2) Build **TRANSVERSE REGIONS** w.r.t. it

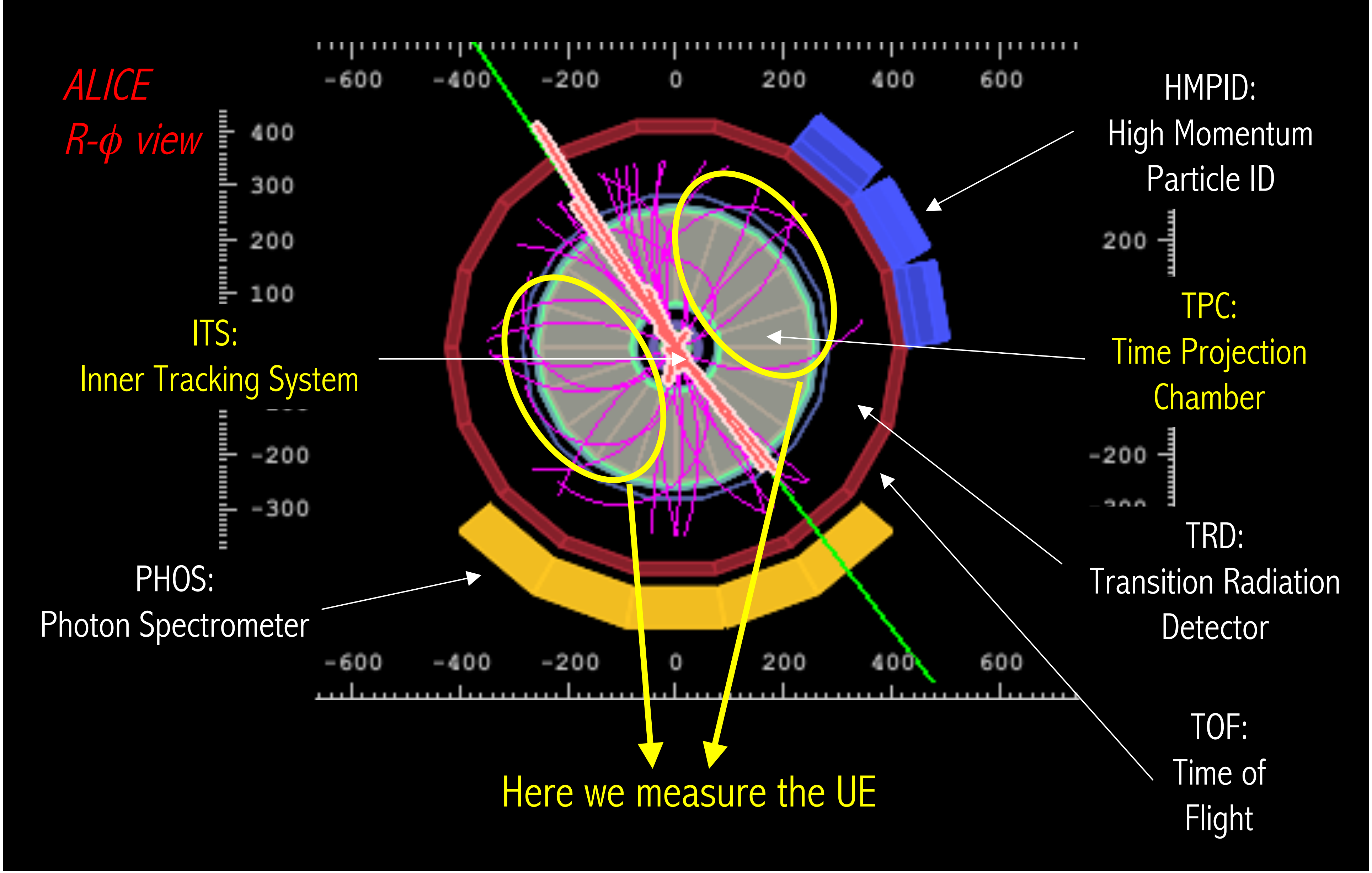
3) Compute Σp_T of charged particles (or multiplicity) in the different regions

SETTINGS:

- pT > 0.5 GeV/c (tracks and leading-track)
- $|\eta|<0.8$
- leading-track not included in distributions



pp collision @ 7 TeV in ALICE



Data correction procedure

DETECTOR LEVEL

Data correction procedure

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Correct for detector effects:

EVENT LEVEL

- trigger
- vertex reconstruction
- leading track misidentification

TRACK LEVEL

- tracking efficiency
- contamination

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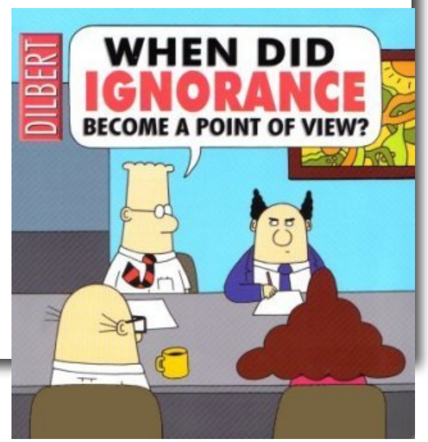
Estimate systematic errors:

(uncertainties in systematic correction factors)

- track cuts
- particle composition
- model dependence
- non closure in MC



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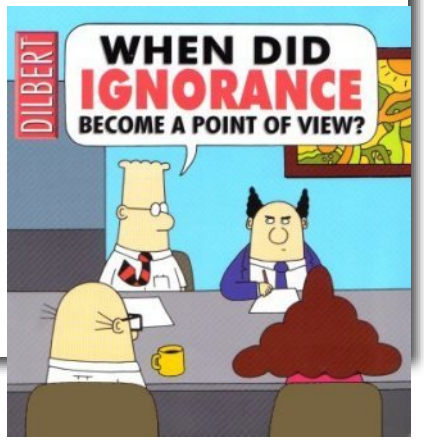
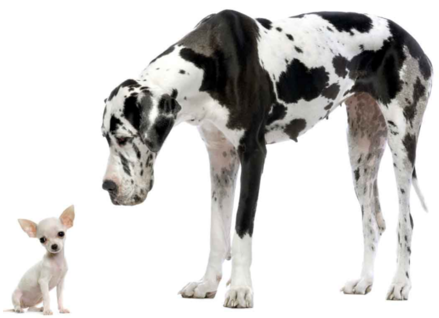


Neglect what is small:

- cosmics
- pile-up
- material budget
- beam-gas



Data correction procedure

DETECTOR LEVEL

Correct for detector effects:

EVENT LEVEL

- trigger
- vertex reconstruction
- leading track misidentification

TRACK LEVEL

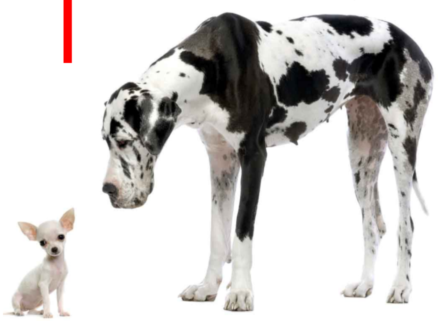
- tracking efficiency
- contamination

PARTICLE LEVEL

(compare with theory)

Neglect what is small:

- cosmics
- pile-up
- material budget
- beam-gas



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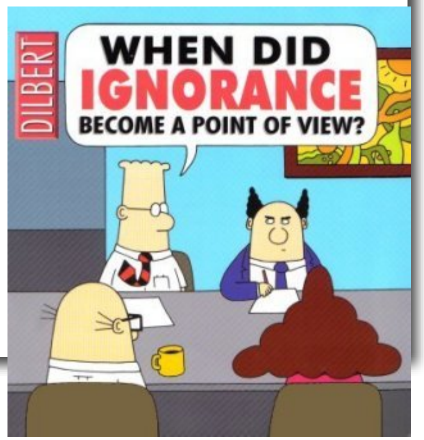
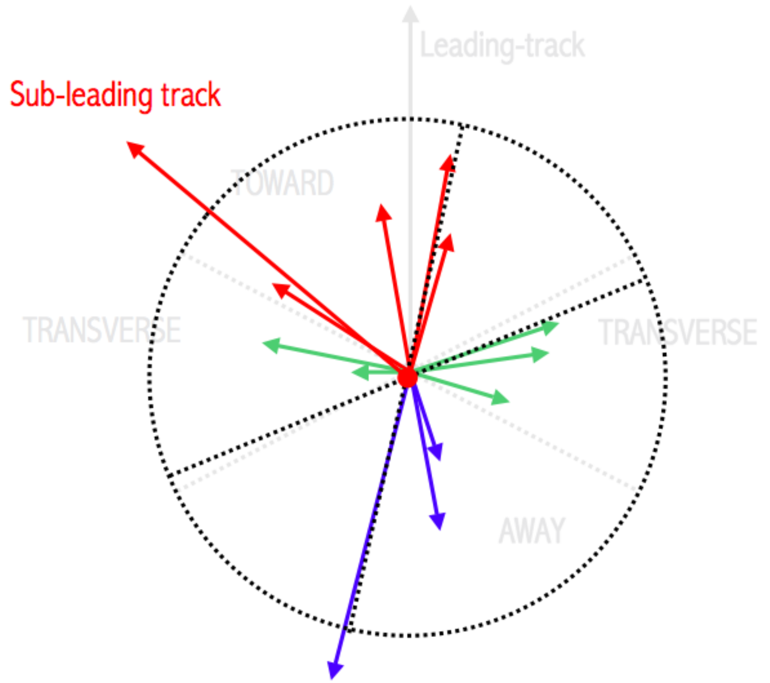


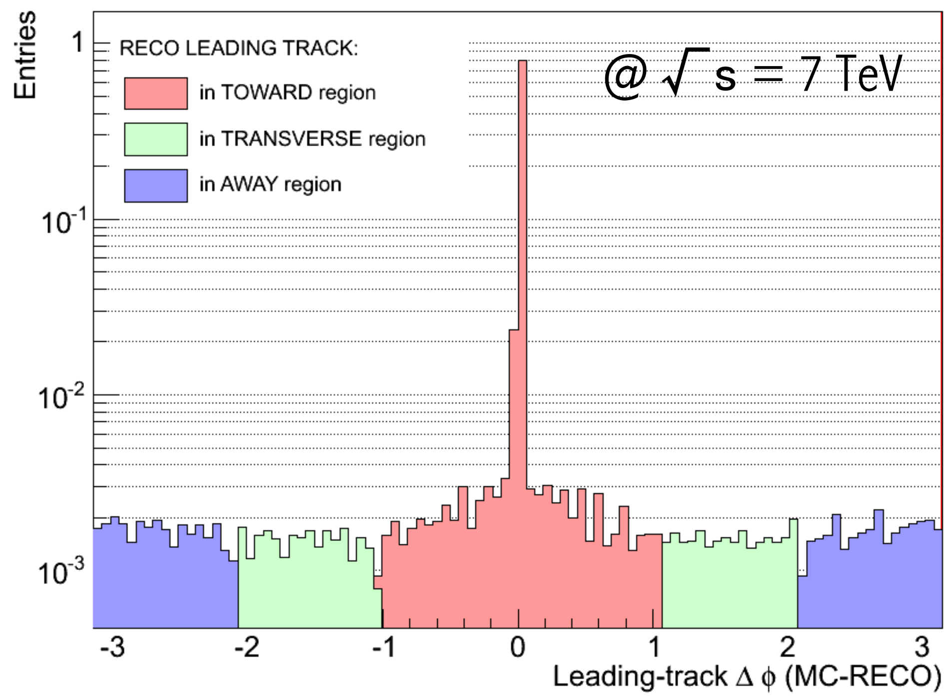
Leading track misidentification

If instead of the leading-track, the sub-leading is taken...

- **Bin migration:**
  along leading-track p_T axis (X)
- **Event disorientation:**
  effect on number density or Σp_T (Y)

In ~ 5% of the cases the sub-leading track falls in the transverse region.





Data driven estimate of bias

Assume that the misidentification is due to tracking efficiency only:

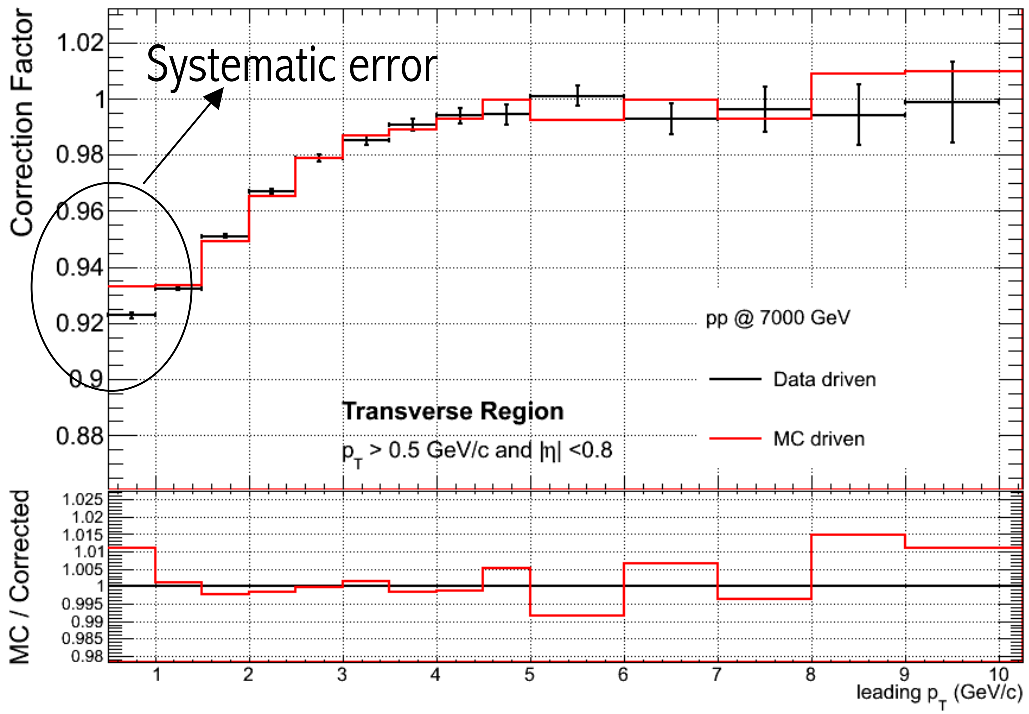
- Starting from the reconstructed distribution, for each event:
  - **apply the tracking efficiency a second time on the data**
  - with the help of a random number generator decide if the leading-track is reconstructed

- if it is reconstructed:
  - use the reconstructed leading track to define topological regions

- if not:
  - **use the sub-leading track instead** the correction is extracted as function of leading track p_T

Monte Carlo driven estimate of bias

Example: misidentification bias on number density distribution.



In the Monte Carlo driven procedure the correction comes from the ratio between events defined by:

- reconstructed leading-track
- true leading-track

The data driven correction is validated by its compatibility with the Monte Carlo driven correction.

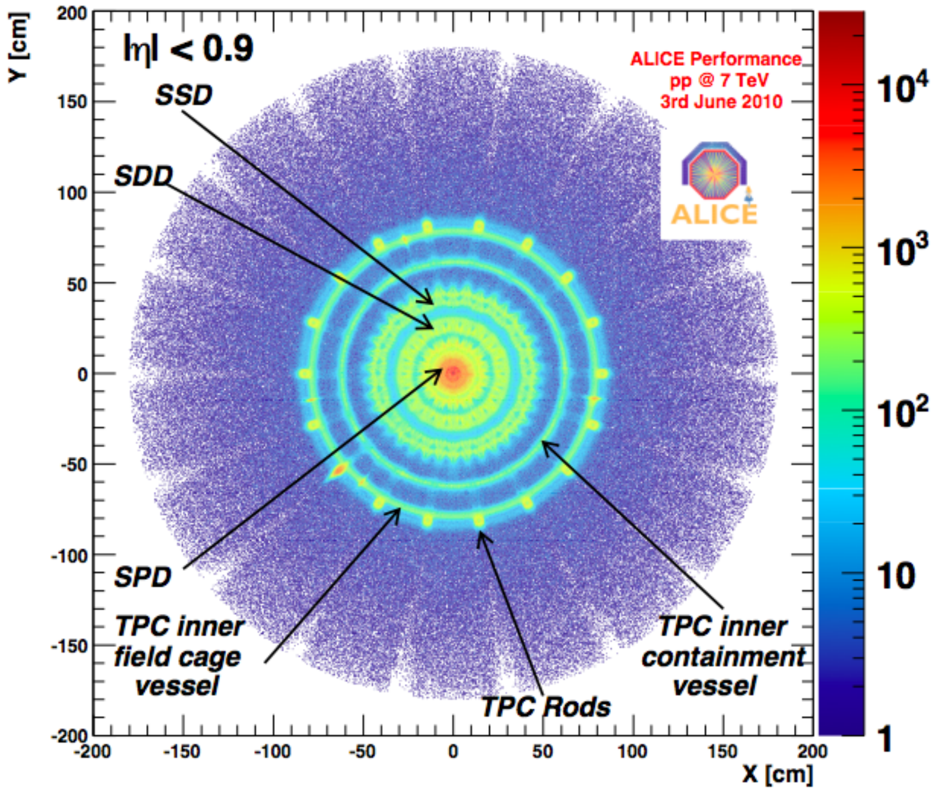
Track Cuts

- Combined information from
  Time Projection Chamber (TPC) and
  Inner Tracking System (ITS)

- Cuts optimized to minimize contamination from secondaries:
  - produced in silicon layers and thermal shield
  - from strangeness decays

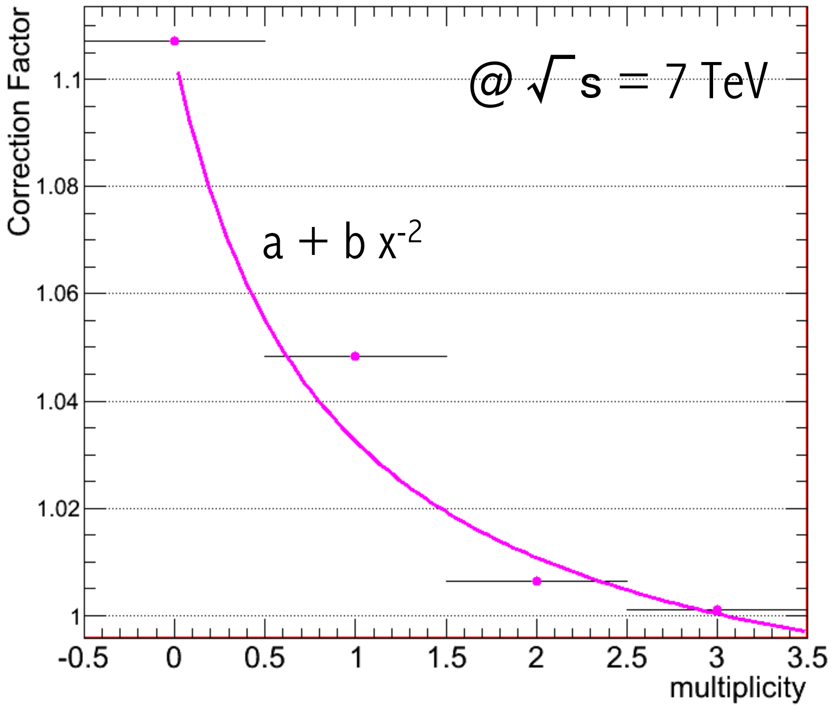
- Require hits in ITS inner layers

- p_T dependent DCA_{XY} cut
  (7σ of distribution)



ALICE tomography from the photon conversions working group.

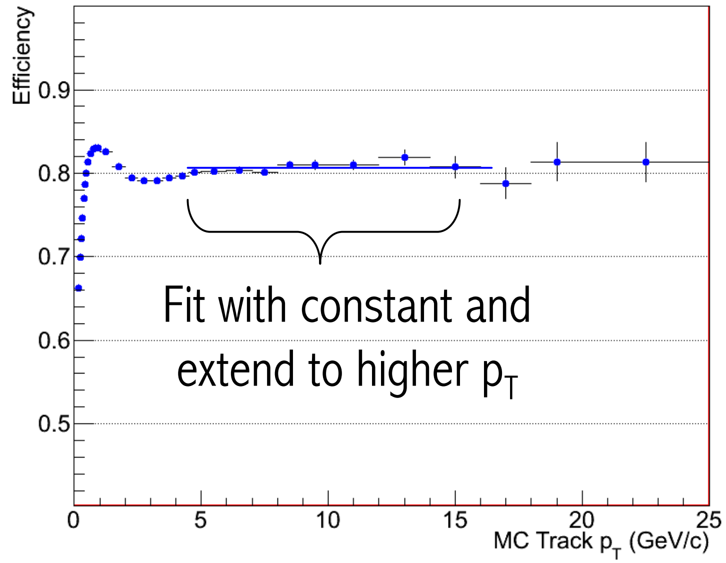
Vertex and tracking efficiency

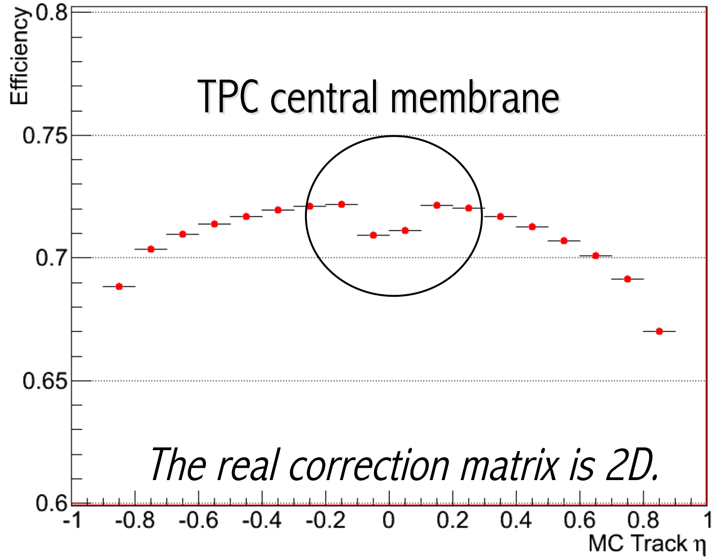


VERTEX RECONSTRUCTION EFFICIENCY:

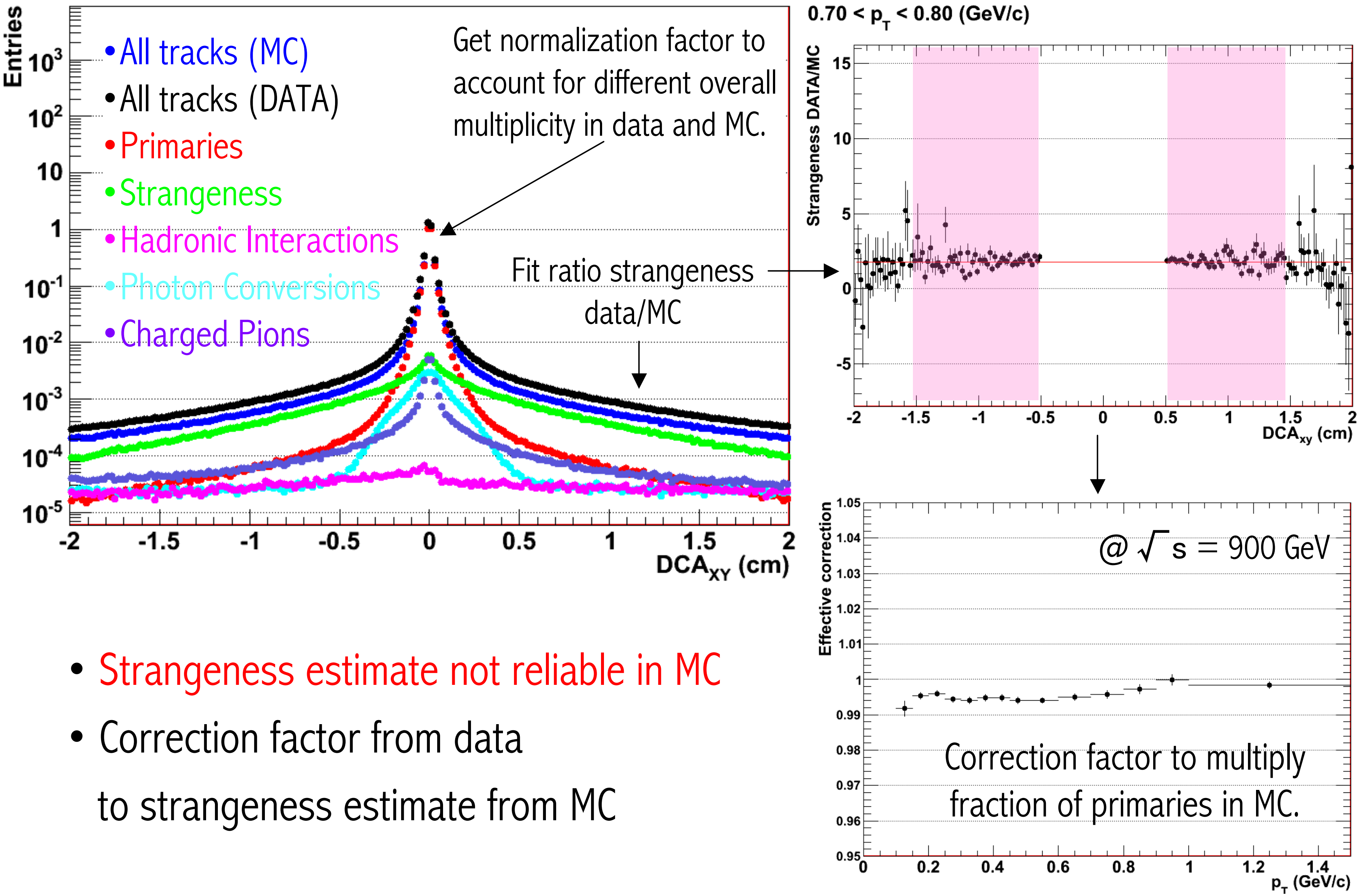
- Correction as function of multiplicity
- Convert measured multiplicity into true via correction factor
  (from profile of response matrix)
- Fit correction factor vs. true multiplicity

TRACKING EFFICIENCY:





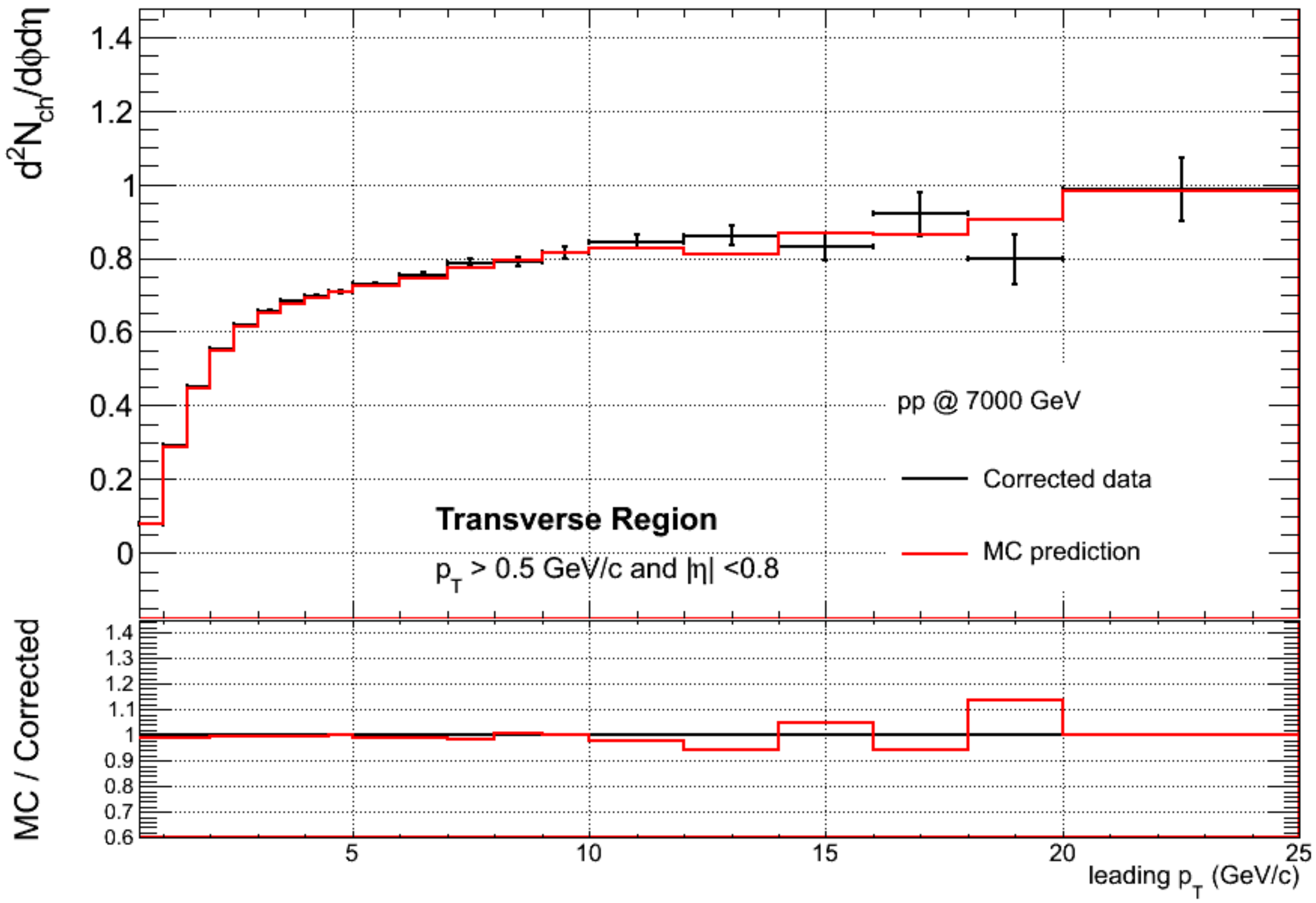
Secondaries contamination



- Strangeness estimate not reliable in MC
- Correction factor from data to strangeness estimate from MC

Example of correction validation

- PYTHIA sample corrected with factors from PHOJET.
- Final step: all corrections included.
- Non-closure effect: 2% in first leading p_T bin



Summary of corrections

	Relevant Variables	Correction	
		1_{st} bin	Other
Misidentification bias	lead. track p_T	~10%	< 5%
Vertex reconstruction	measured multiplicity	~10%	< 5%
Tracking efficiency	track pT , η	~30%	~20%
Contamination	track pT , η	~10%	< 5%

Systematic errors

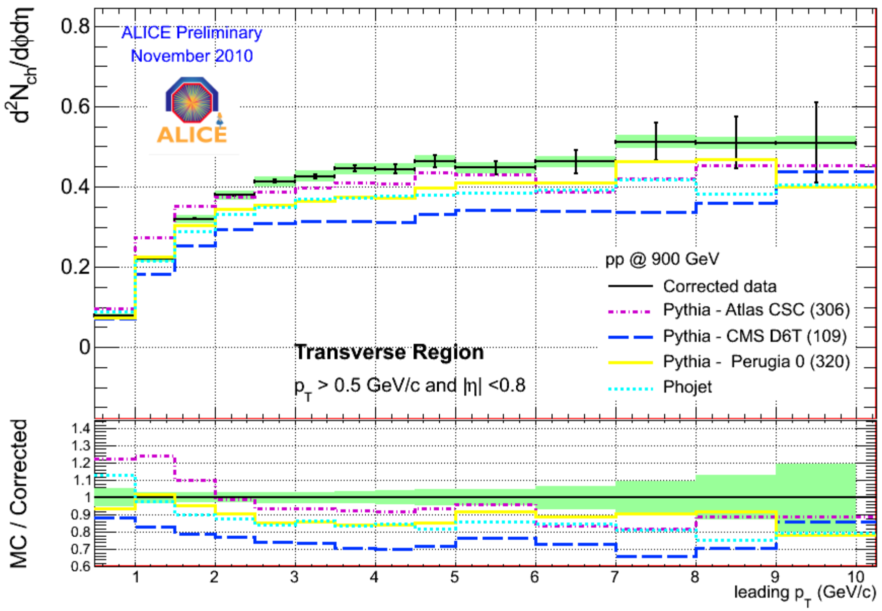
Values for 7 TeV in % (900 GeV similar)	$0.5 < p_T < 1$ (GeV/c)	$p_T >$ (1 GeV/c)
Particle composition	0.8	
ITS/TPC efficiency	1.0 (+0.5)	0.6 (+0.5)
Track Cuts	3	
Misidentification bias	**4-5**	0
MC dependence (x-correction)	2	0
MC dependence (data corrected w/ both)	0.8	
Vertex efficiency correction	1	0
Strangeness estimation	**2** (for $p_T < 1.5$)	1
Diffraction	0	
Triggering efficiency	0	
Beam-gas	0	
Pile-up	0	

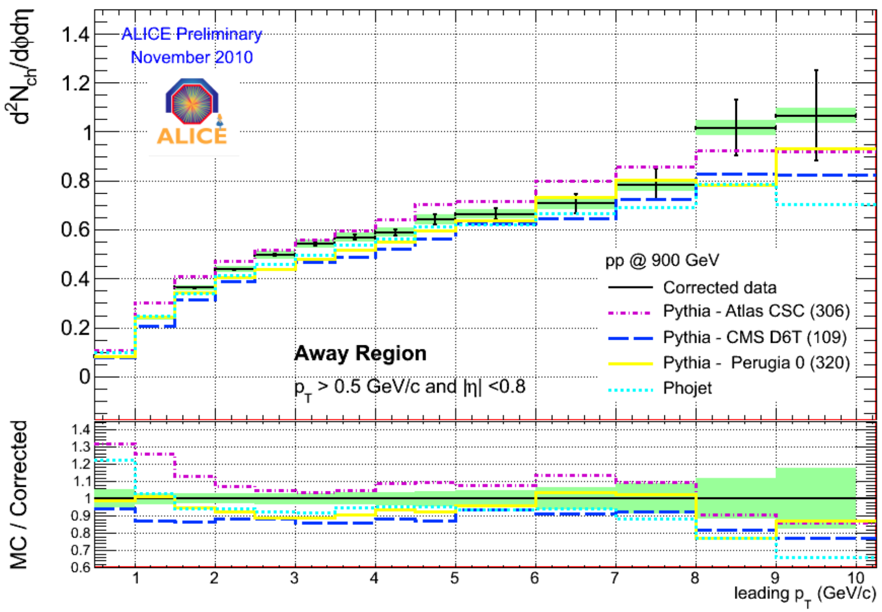
* Ranges indicate different uncertainty for different distributions.

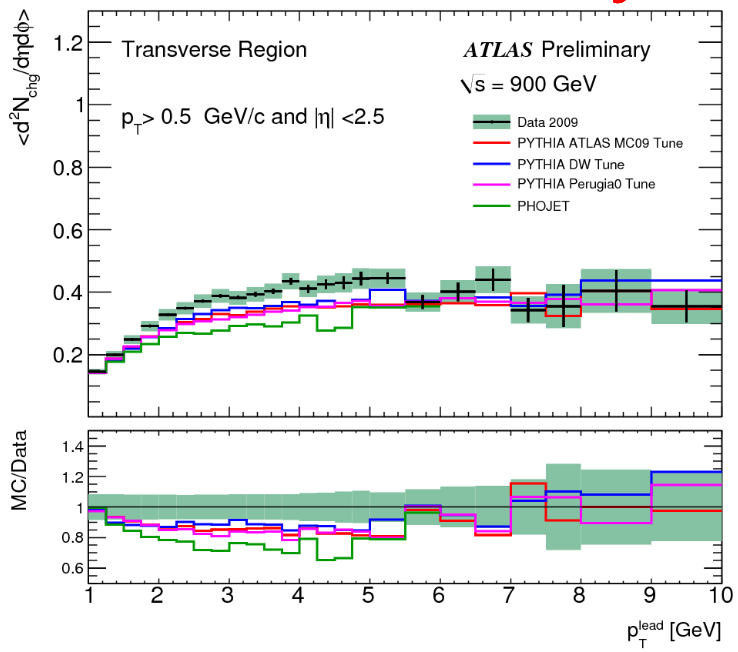
Corrected Data

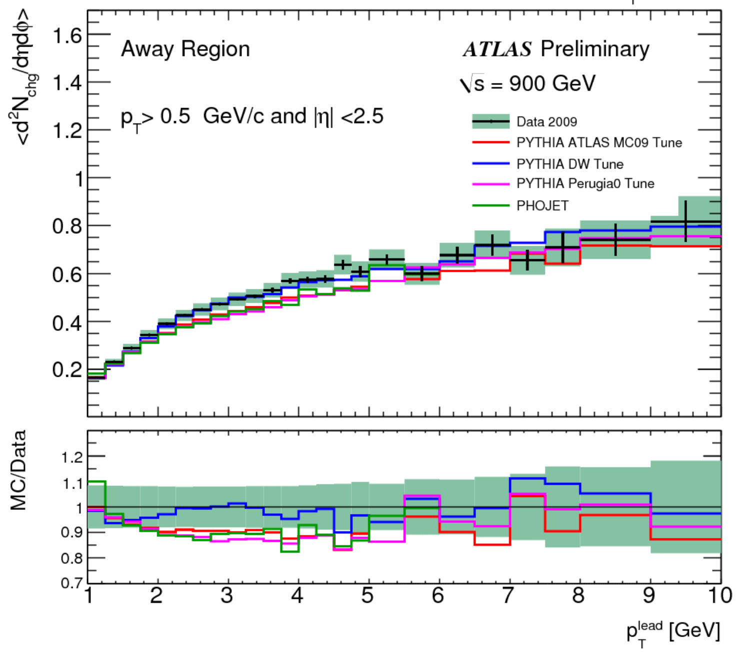
Compared with ATLAS results from ATLAS-CONF-2010-029 (May 2010)

Results @ 900 GeV: number density









Good agreement ALICE/ATLAS

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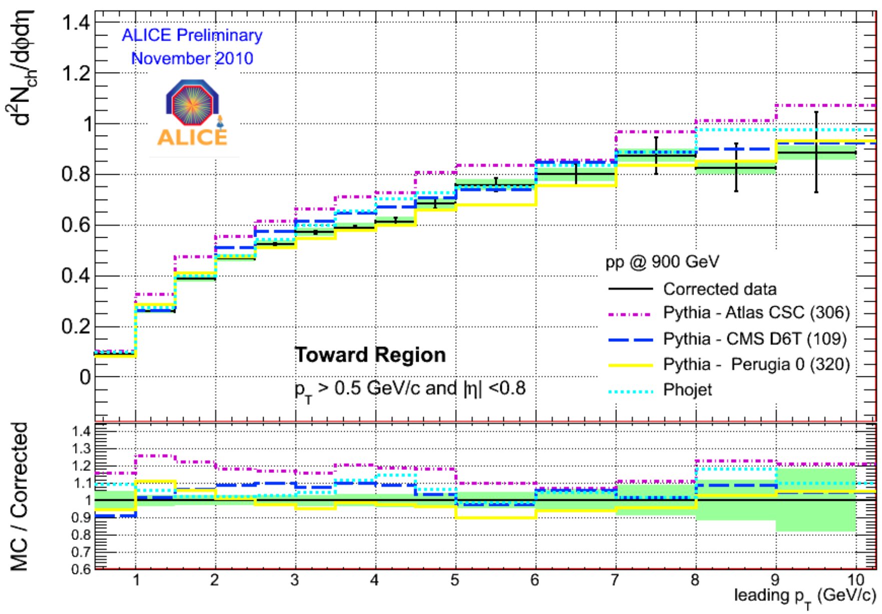
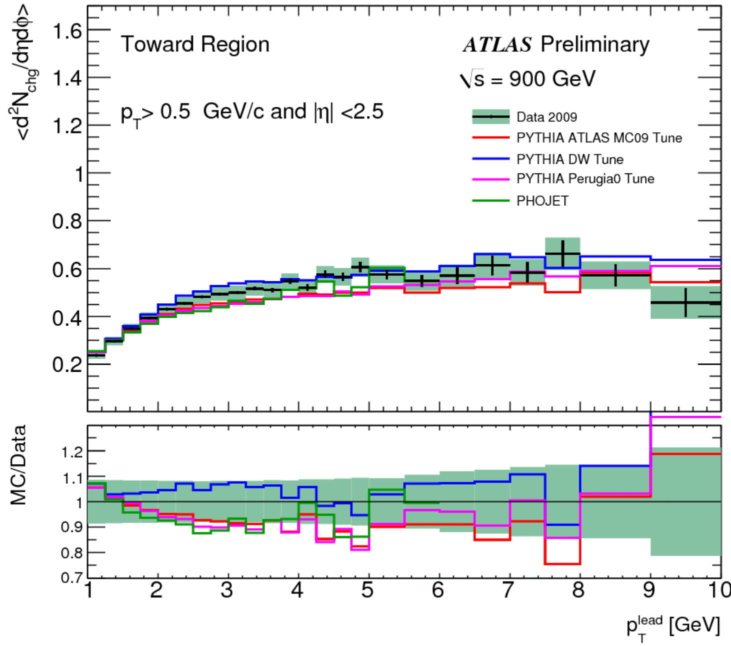
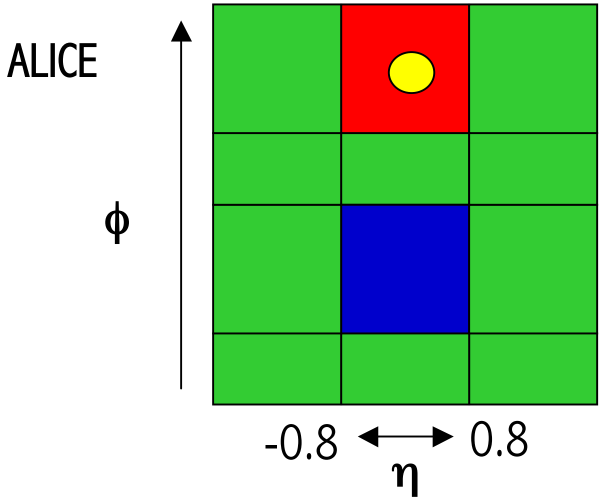


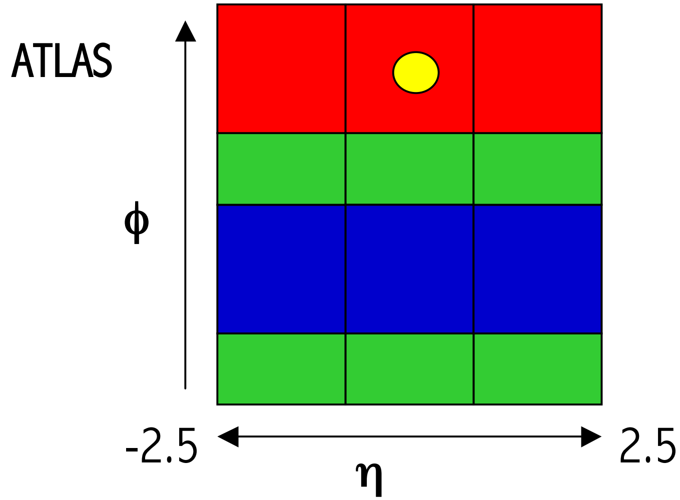
~ 0.8



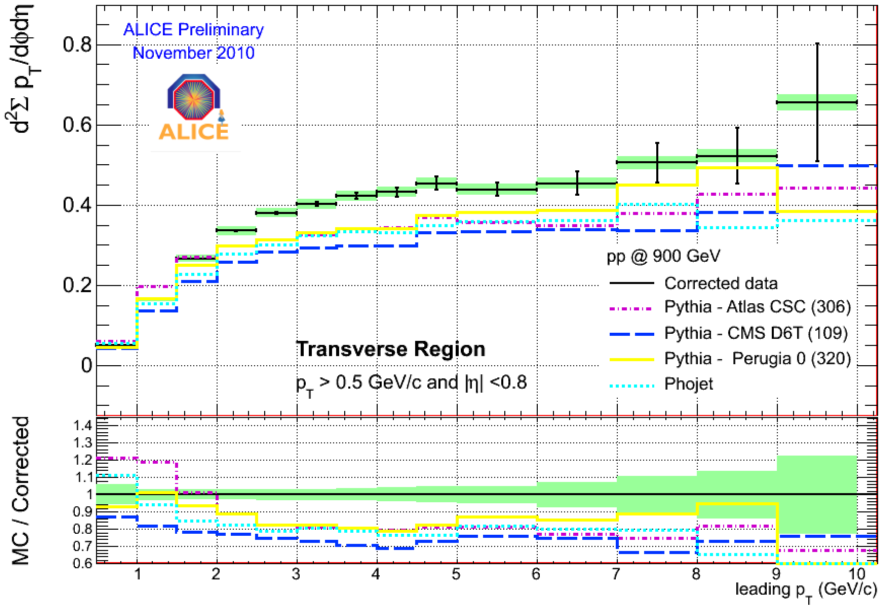
~ 0.5

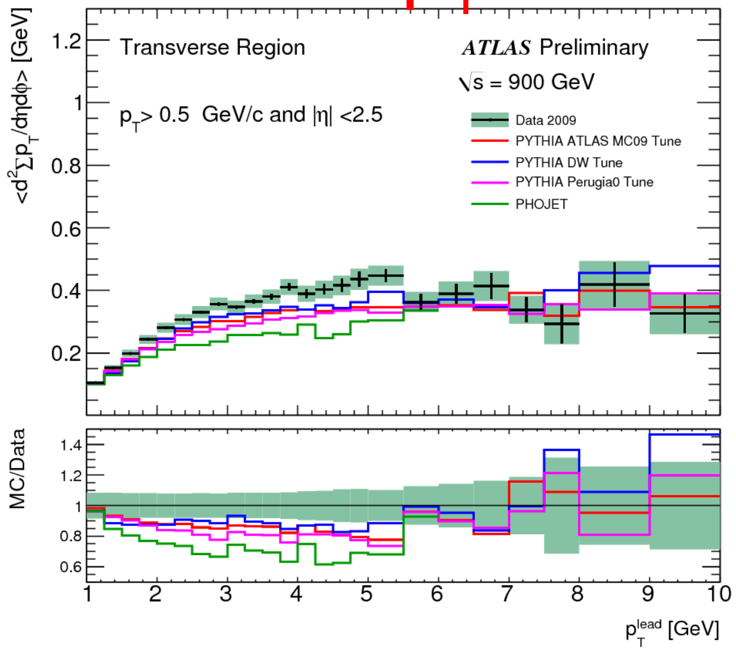
- Difference explained by acceptance
- Numerically confirmed by adding “1 part Towards” + “2 parts Transverse”

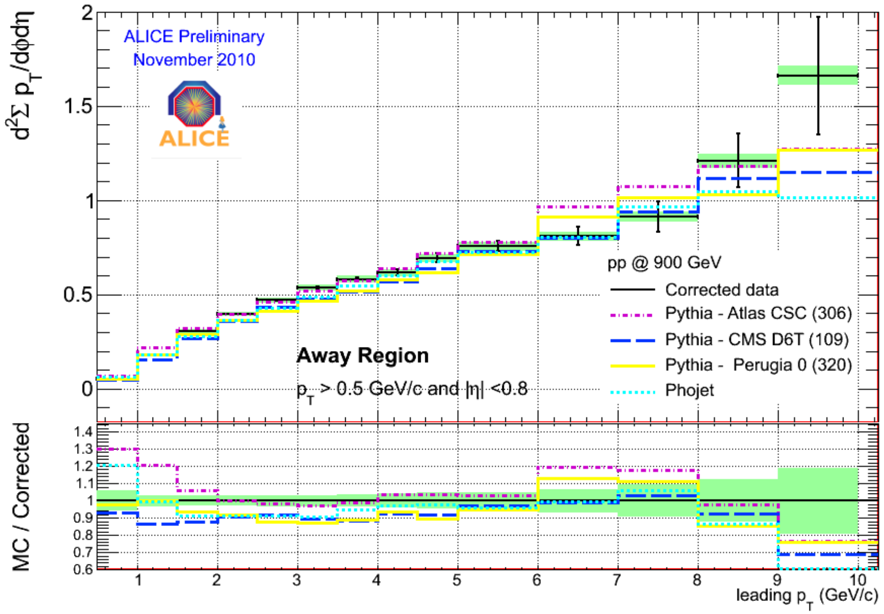


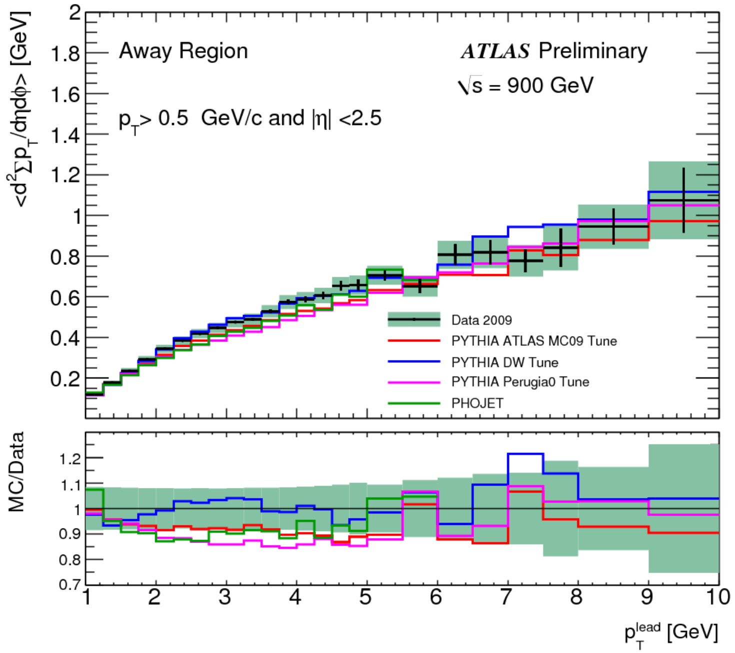


Results @ 900 GeV: sum p_T









ATLAS measures lower values than ALICE

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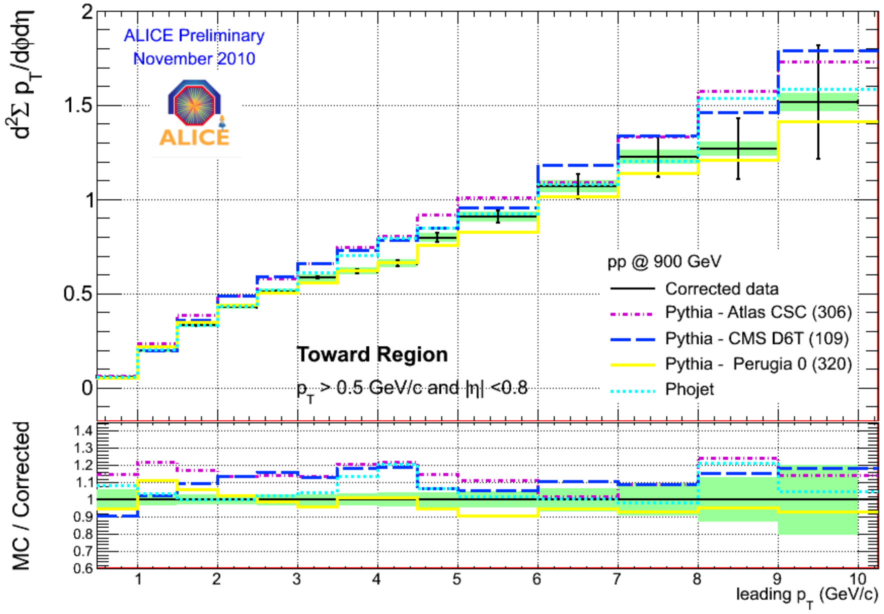
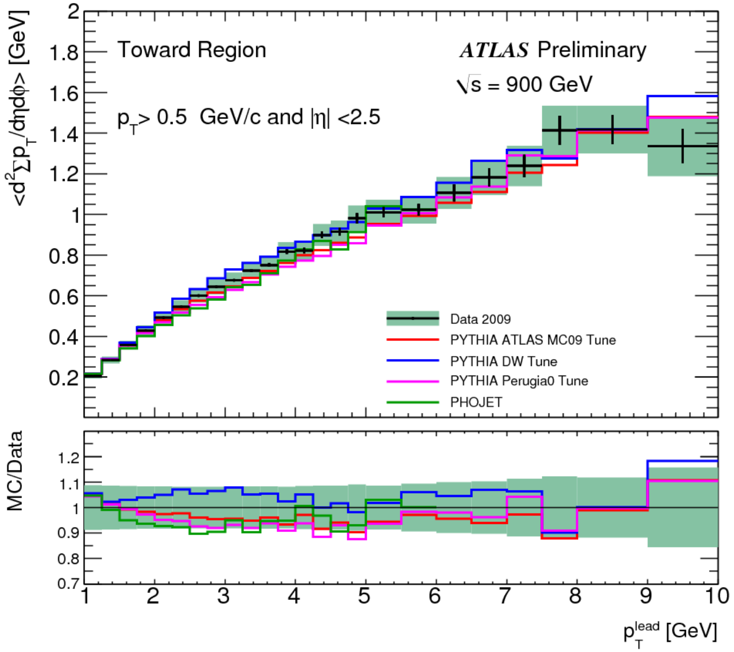
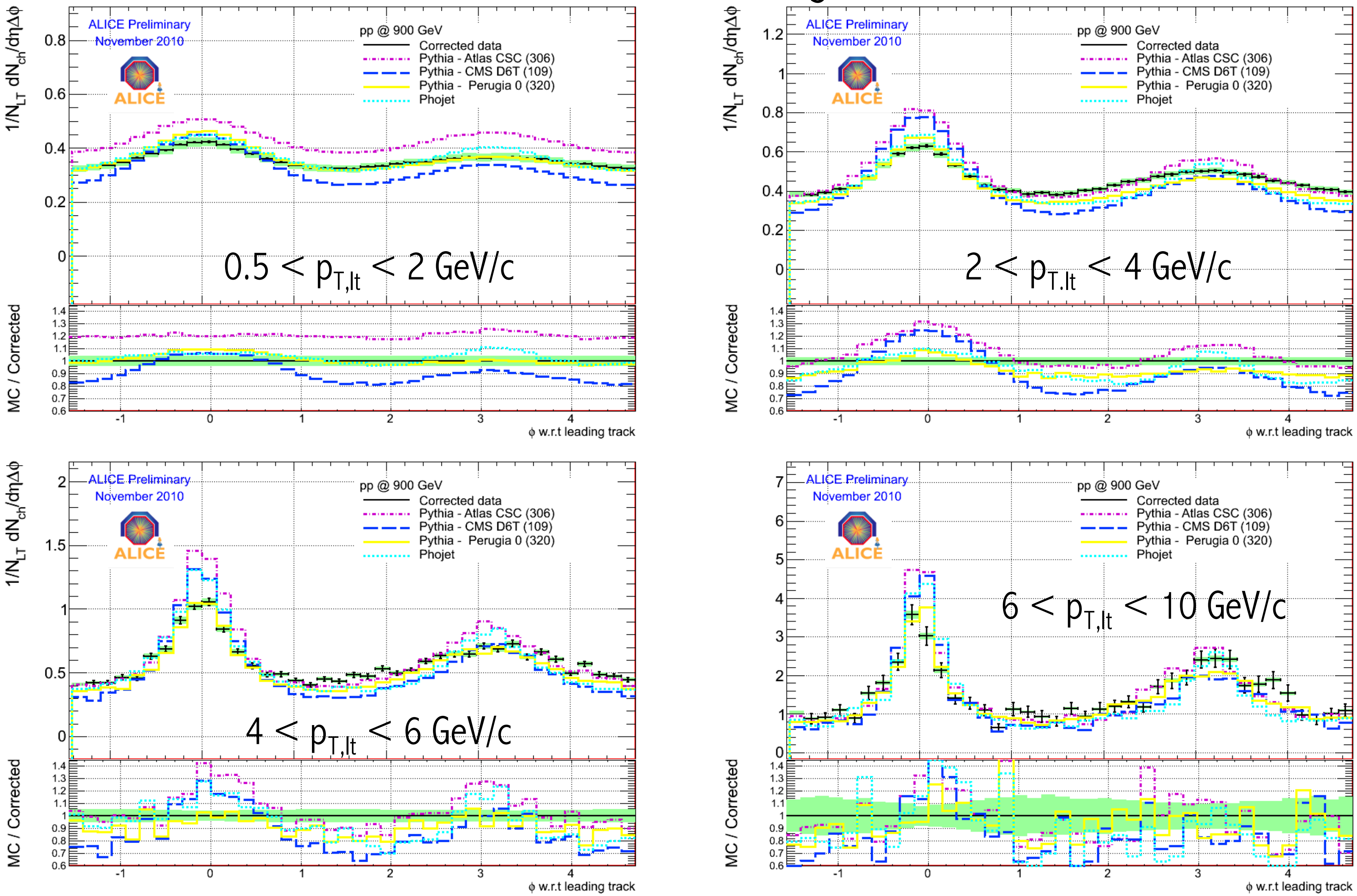




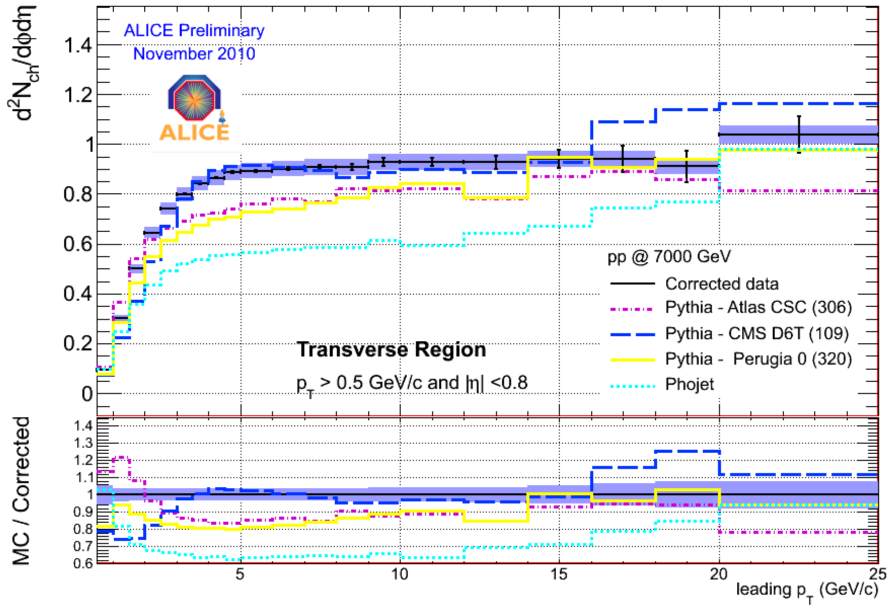
- ALICE and ATLAS data are not directly comparable:
  - different acceptance
  - ALICE excludes leading track from distributions
- Favored tune: Perugia 0

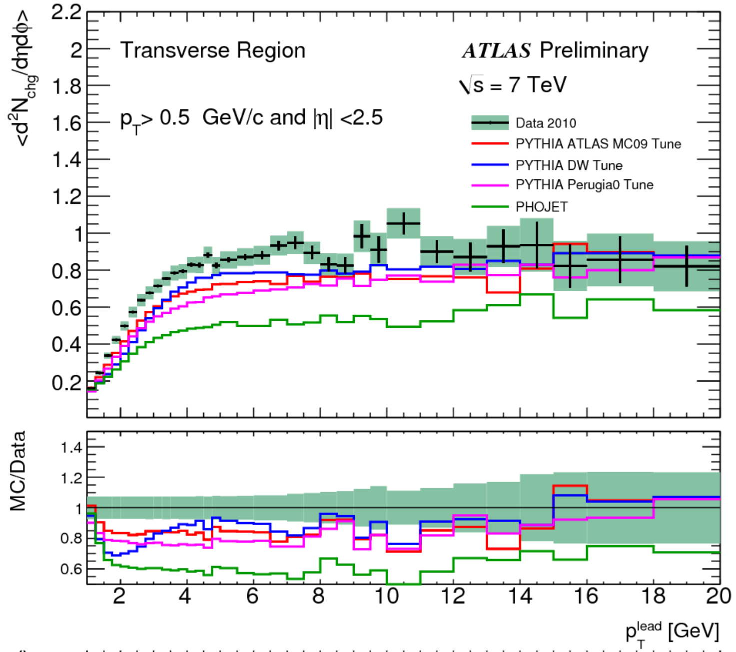
Results @ 900 GeV: Δφ correlation

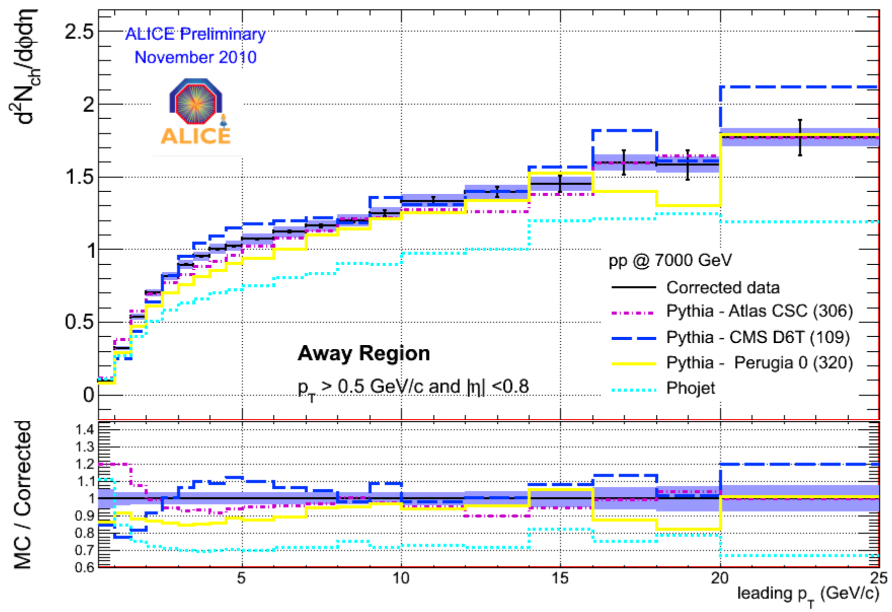
Azimuthal correlation between leading track and all tracks.

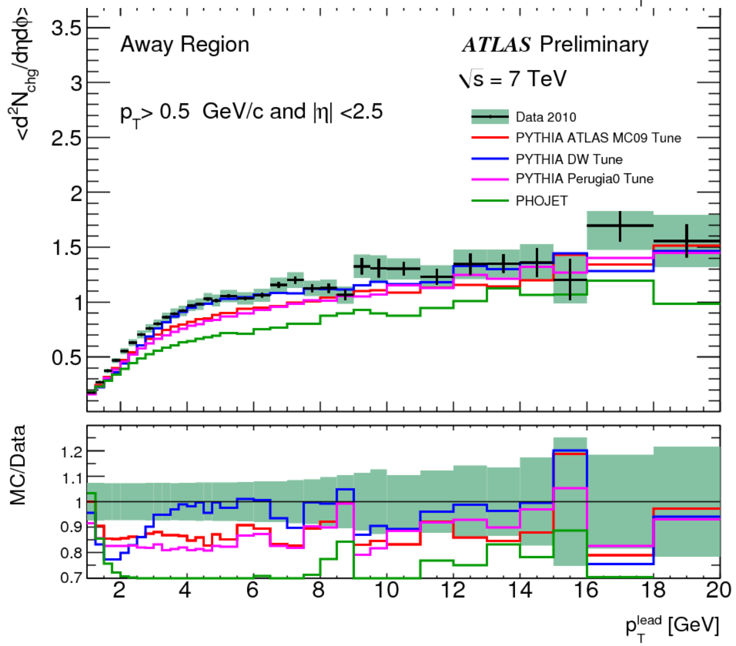


Results @ 7 TeV: number density









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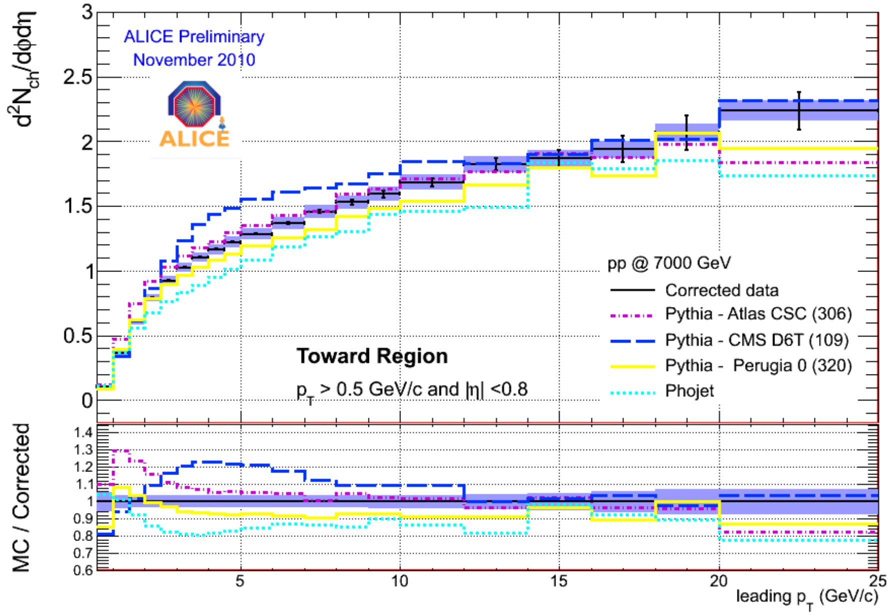
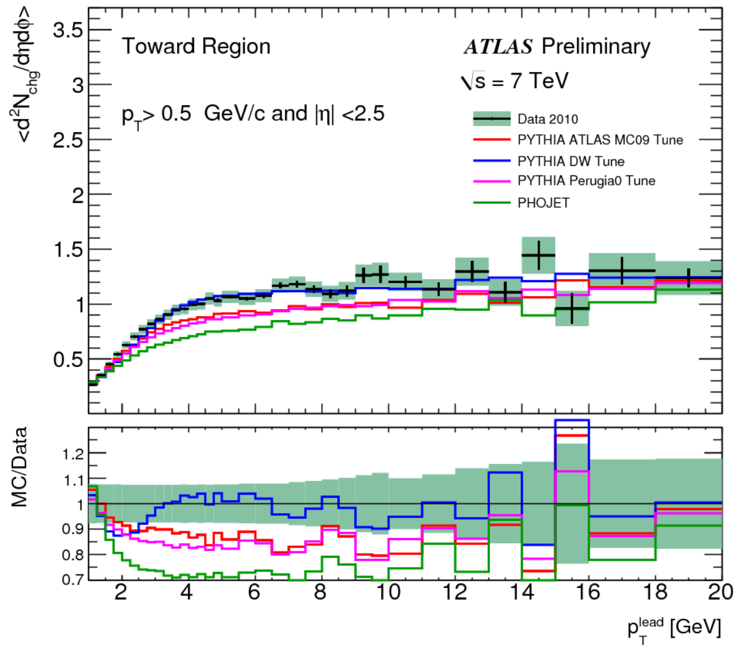
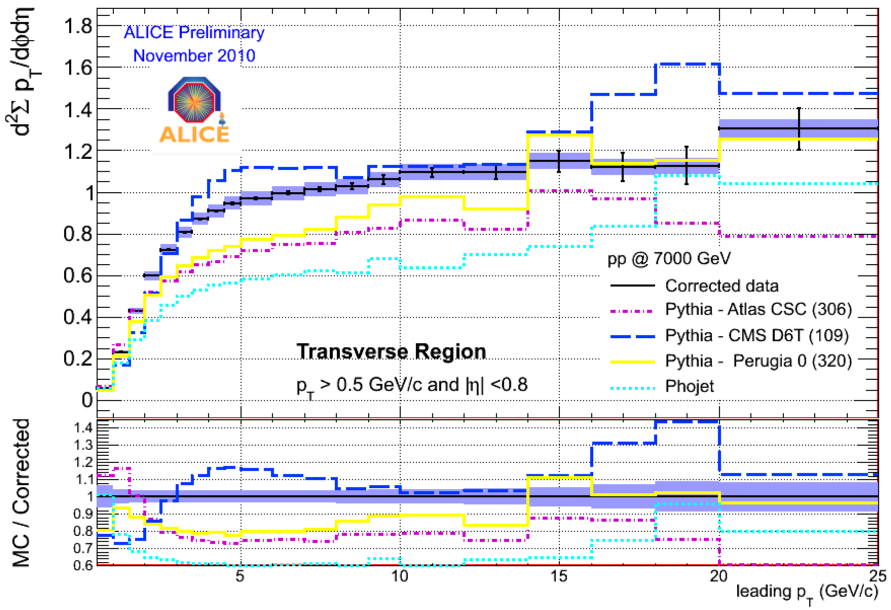
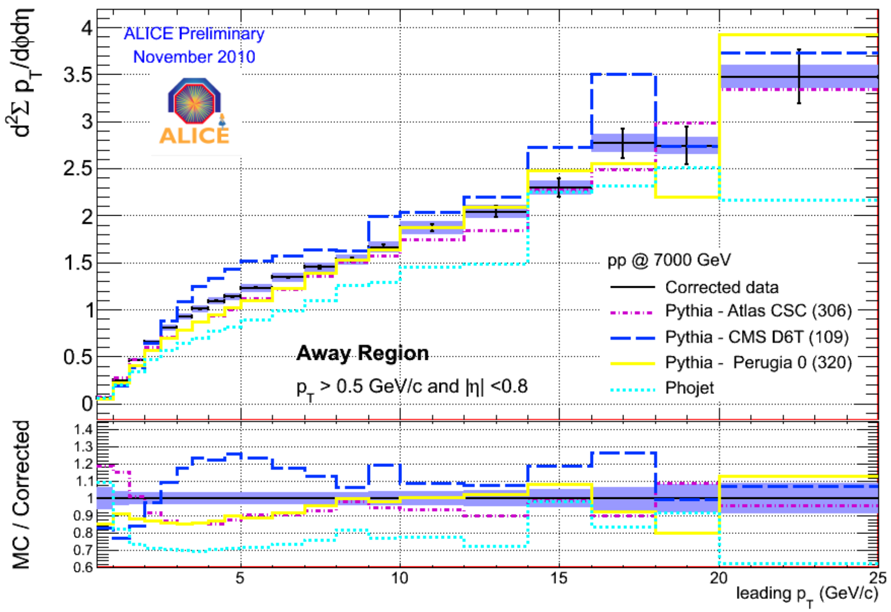


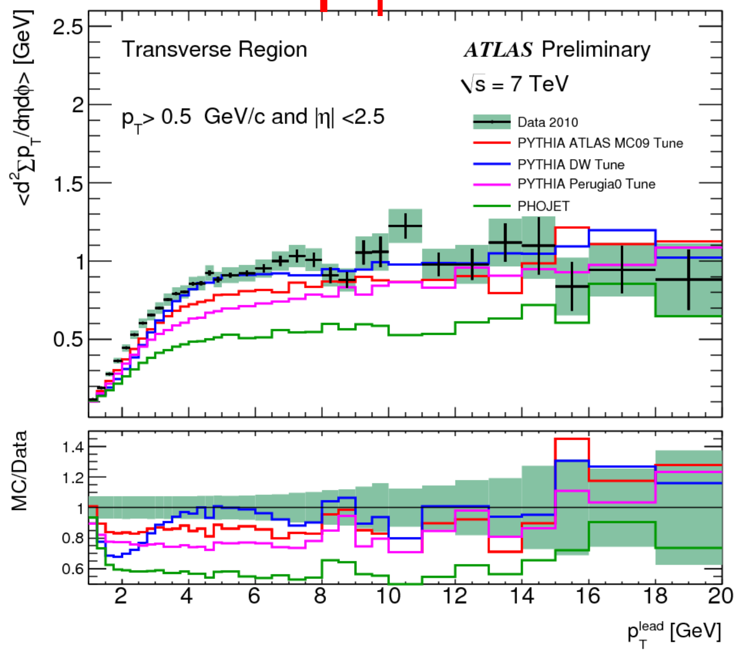


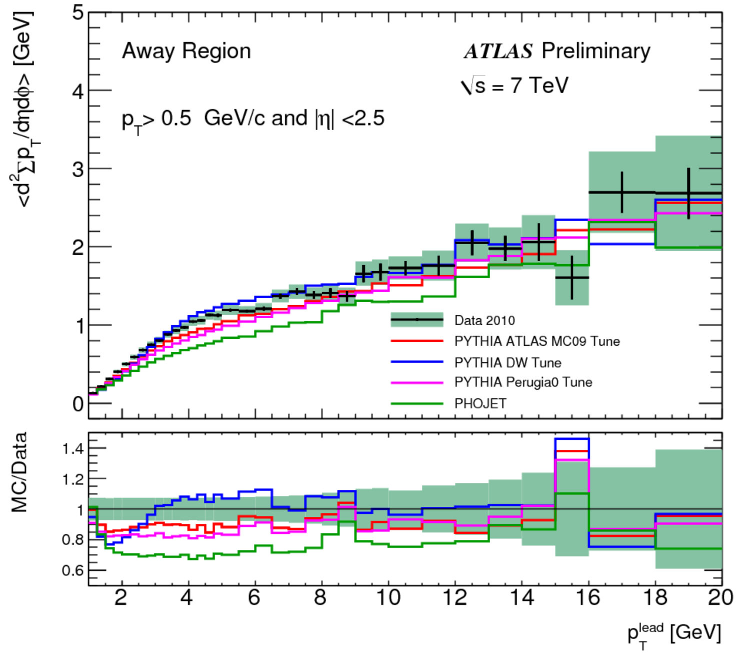
Discrepancy explained by considerations on acceptance
(same as $\sqrt{s}$ 900 GeV).

Results @ 7 TeV: sum p_T









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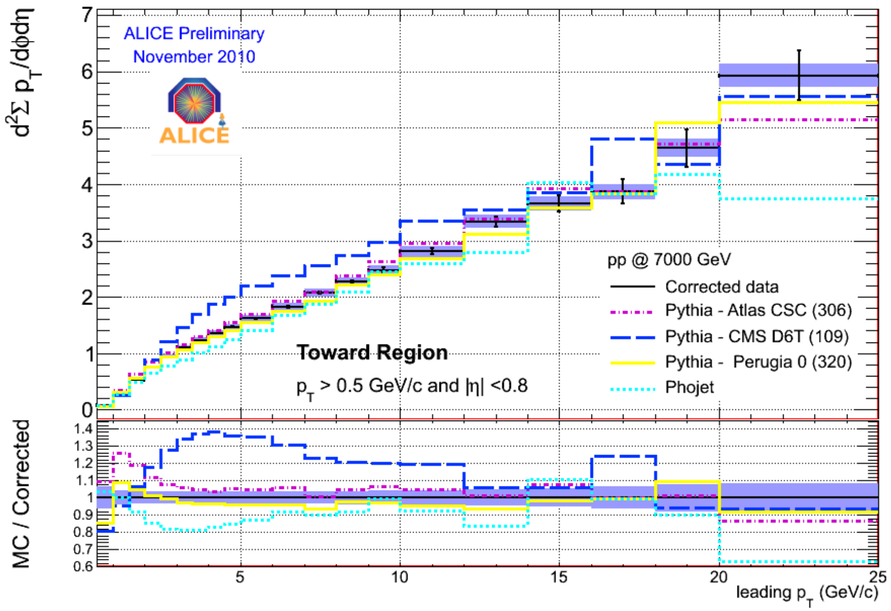
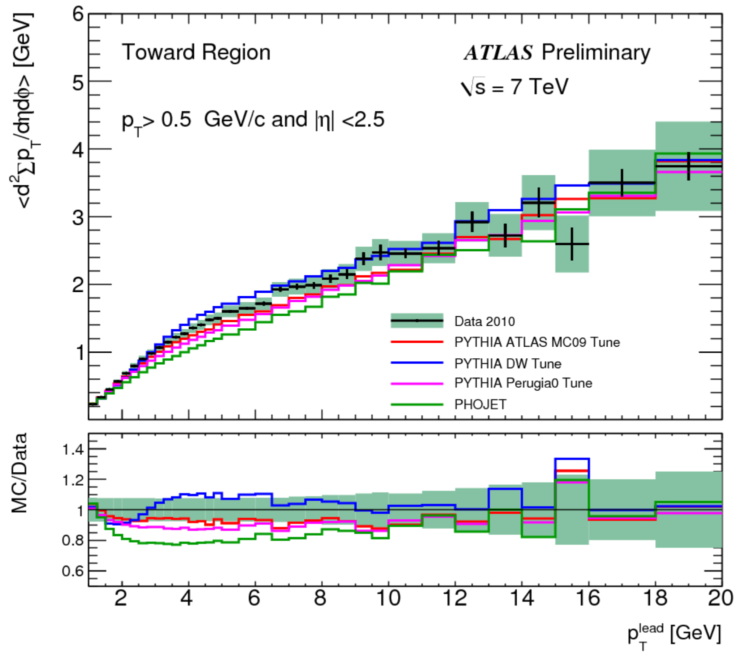
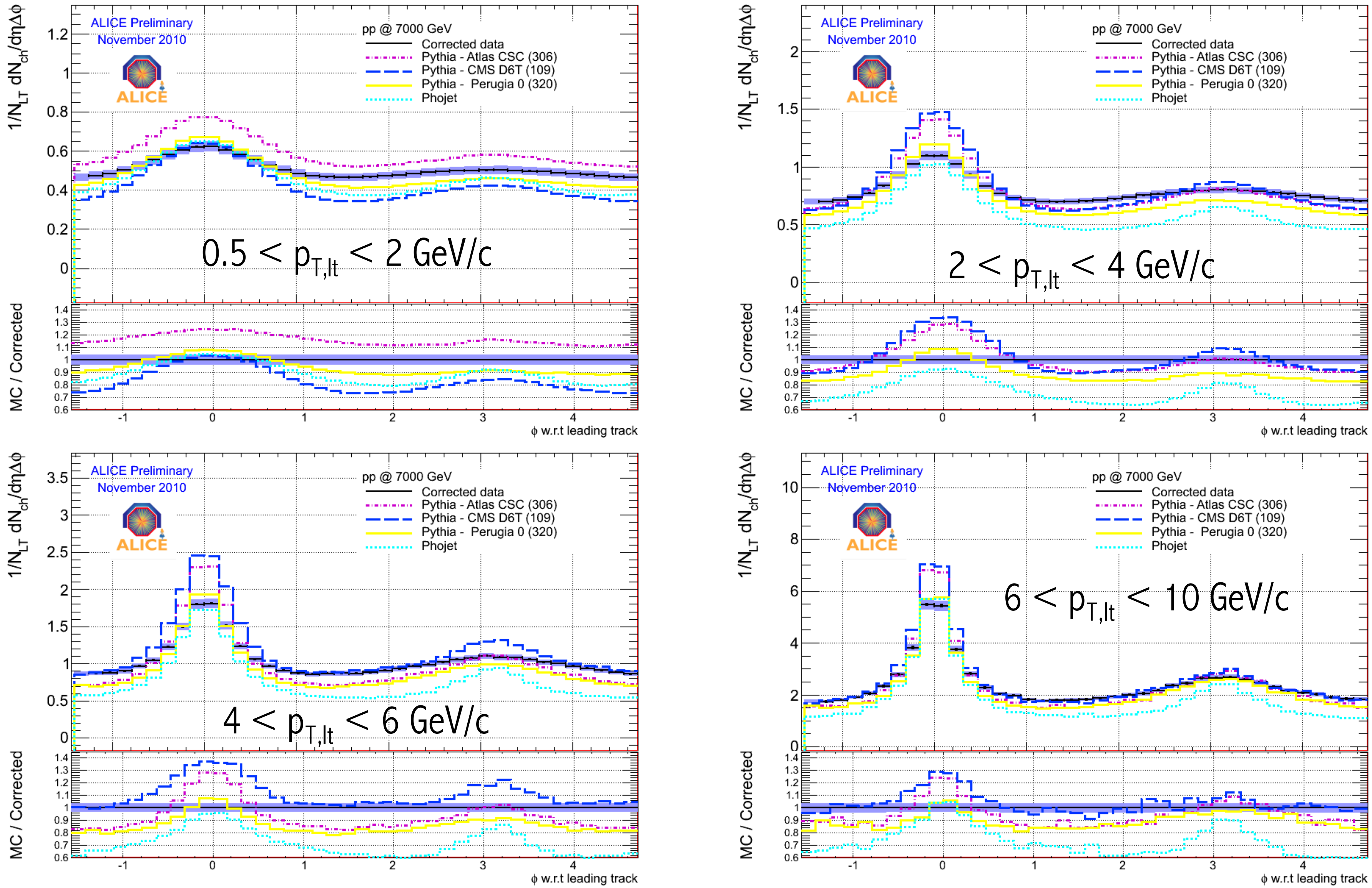




- Remember:
  - different acceptance ALICE/ATLAS
  - ALICE excludes leading track from distributions
- Favored tunes Transverse + Away:
  - Perugia 0: low p_T (< 2 GeV/c)
  - CMS D6T: high p_T
- Favored tune Towards: Perugia 0

Results @ 7 TeV: Δϕ correlation

Azimuthal correlation between leading track and all tracks.



Conclusions

- ALICE has measured the Underlying Event in transverse regions w.r.t. leading track at $\sqrt{s} = 900$ GeV and $\sqrt{s} = 7$ TeV
- Charged particles analysis
- Data corrected to particle level
- Fair comparison with ATLAS results:
  - Different acceptance (discrepancy in toward region)
  - ALICE excludes leading track from distributions
- Comparison with various PYTHIA tunes and PHOJET:
  - Perugia 0 favoured tune at 900 GeV
  - Perugia 0 favoured tune at 7 TeV for $p_T < 2$ GeV/c
  - CMS D6T favoured tune at 7 TeV for higher p_T

BACKUP

Motivations

- Understand particle production mechanisms at LHC
  (models fail to reproduce data...)

- A pp di-jet event is NOT just 2 jets + Minimum Bias
(QCD radiation, MPI ...)

- Experimental point of view: define observables more sensitive to hard/soft
component of the UE

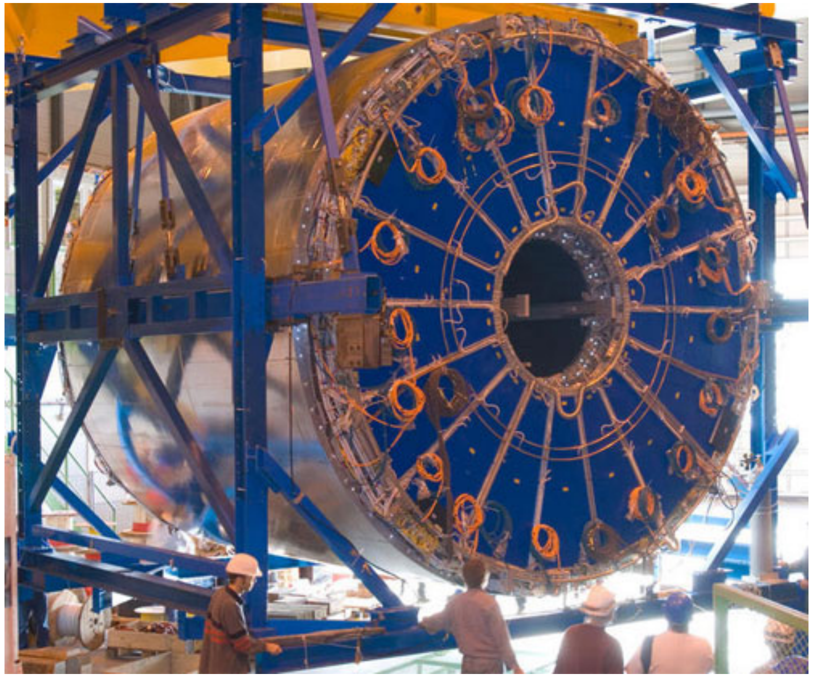
- Correct jet measurements for soft-UE for fair comparison with NLO pQCD

- Constrain phenomenological model for the non-perturbative aspect
(Monte Carlo/tune)

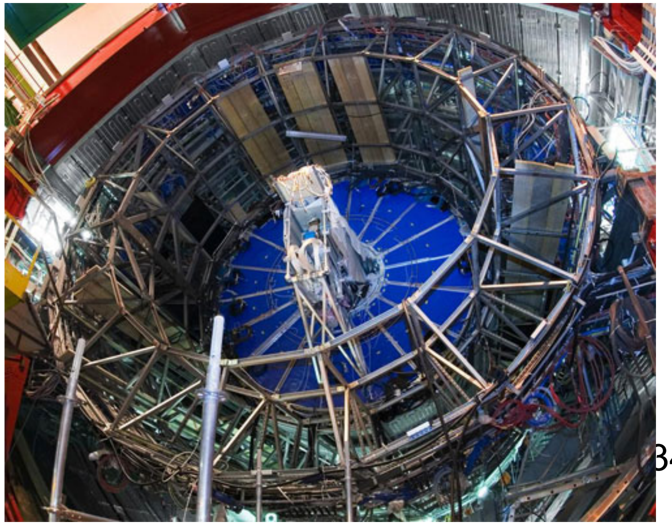
Detectors used in the analysis:

Time Projection Chamber (TPC)

ALICE → high track density in heavy-ion collisions (up to 8000 in central rapidity unit).
High granularity and good 2-track separation → 3D hit information and many points in the track (plus weak magnetic field).



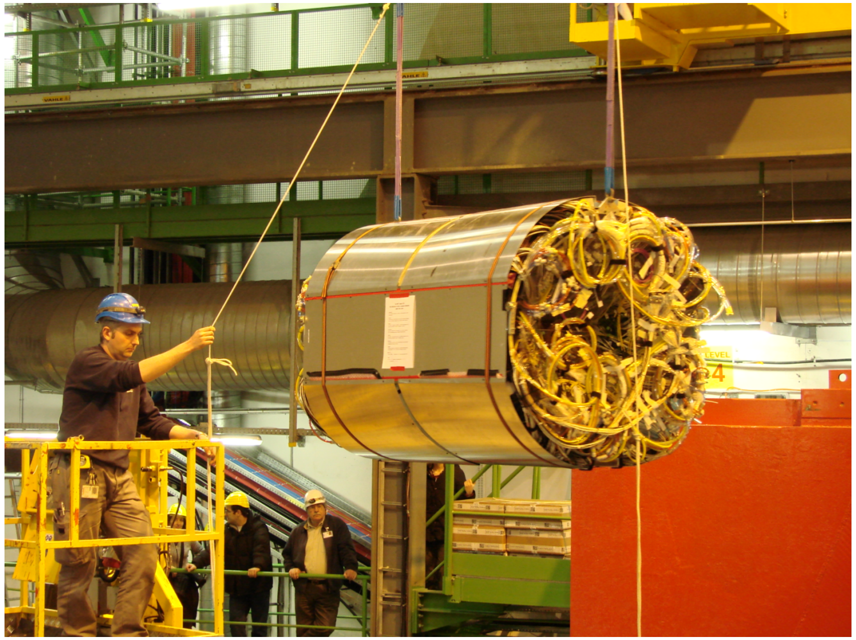
TPC: main device in the central barrel to **detect charged particle tracks and perform particle identification** (ionization density).
Can cope with up to 20000 tracks in a single Pb-Pb interaction. BUT it's slow (200 Hz)!

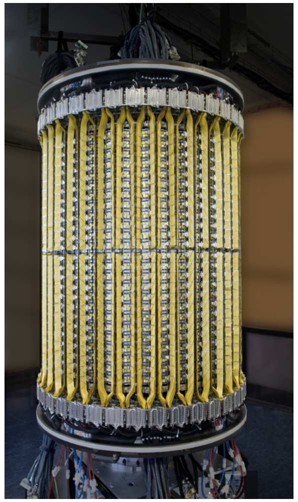


Min. Radius: ~ 80 cm (limited by hit density)
Max. Radius: ~ 280 cm (10% dE/dx resolution)
Acceptance: $|\eta| < 0.9$

Detectors used in the analysis:

Inner Tracking System (ITS)

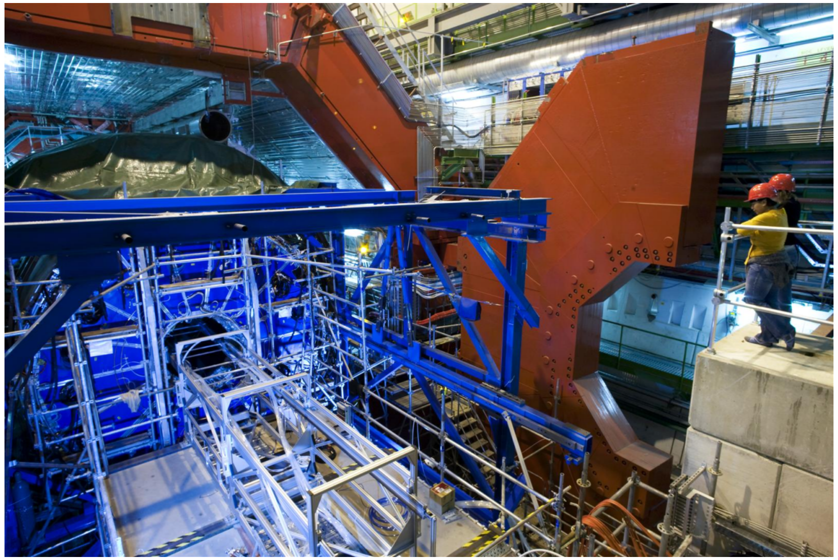


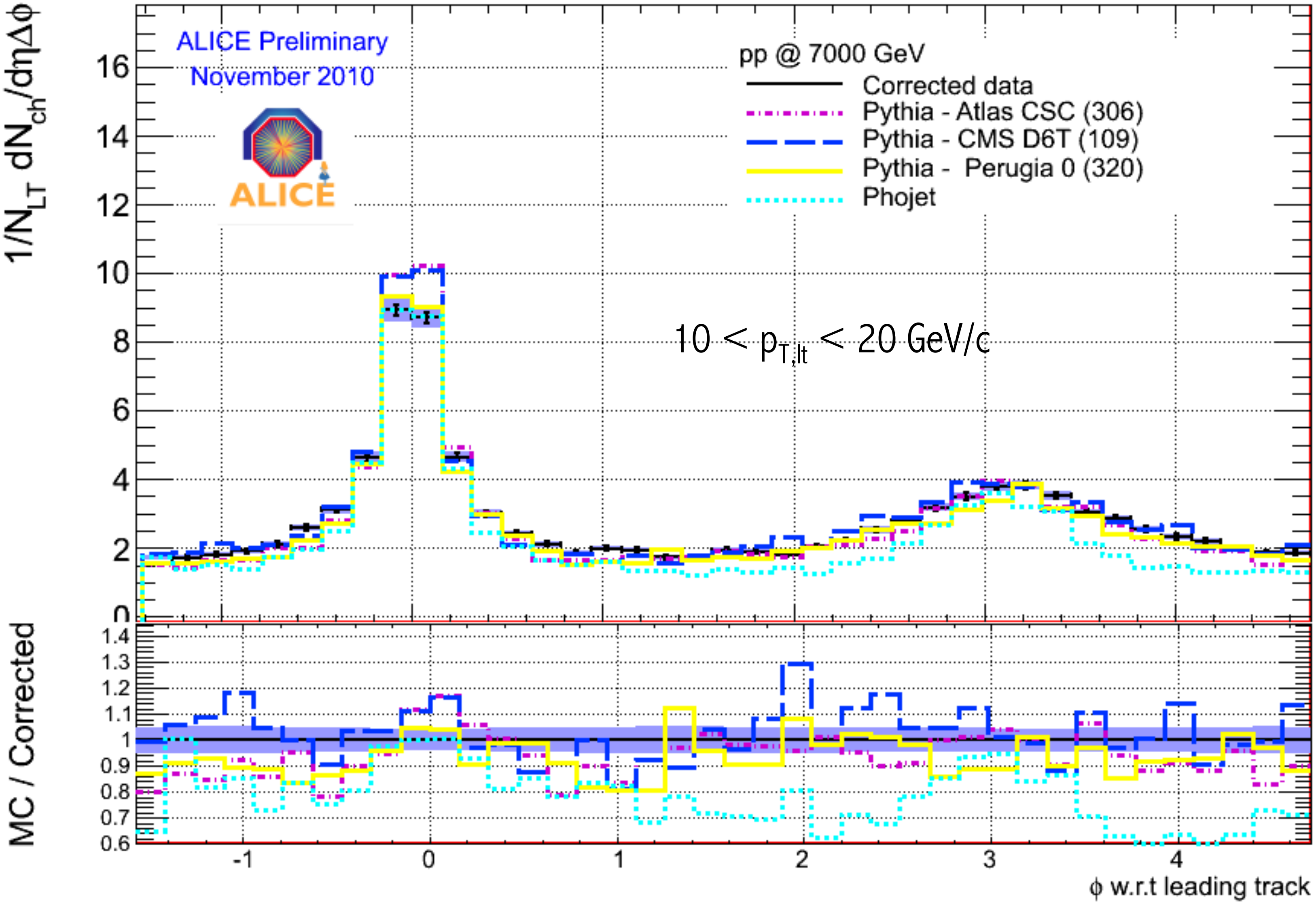


6 silicon layers:
- 2 x pixel (intrinsically 2D)
- 2 x drift (intrinsically 2D)
- 2 x strip

R ~ 4-44 cm
$|\eta| < 0.9$

- **Vertexing detector plus dE/dx** in non-relativistic region (stand-alone low p_T spectrometer).
- High granularity and excellent spatial resolution.
- About 90 tracks per cm^2 in innermost layers.




ALICE Preliminary
November 2010
ALICE
pp @ 7000 GeV
Corrected data
Pythia - Atlas CSC (306)
Pythia - CMS D6T (109)
Pythia - Perugia 0 (320)
Phojet
10 < $p_{T,lt}$ < 20 GeV/c
$1/N_{LT}\ dN_{ch}/d\eta\Delta\phi$
MC / Corrected
ϕ w.r.t leading track