ALICE Underlying Event and Event Shape Measurements

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International Research Training Group

Development and Application of Intelligent Detectors

Introducing event shape analysis (ESA)

- known from the analysis of e+e- collisions
- recently applied in the hadronic collisions to study the high energy flow in hadronic events.
- To our knowledge it is the first time that an attempt is made to study the event shapes in minimum bias events
- The interest of Event shape variables is that they are intrinsically infrared safe and may allow to study separate parts of the collision phase space.
- In the present work we limit ourselves to the variable which is called the **transverse sphericity**:

$$\mathbf{S_{xy}} = \sum_i \begin{pmatrix} {p_x^{(i)}}^2 & p_x^{(i)} p_y^{(i)} \\ p_x^{(i)} p_y^{(i)} & {p_y^{(i)}}^2 \end{pmatrix}$$

$$S_\perp \equiv \frac{2\lambda_2}{\lambda_2 + \lambda_1}$$

=0, "pencil-like" events.

=1, isotropic events.

Statistics:

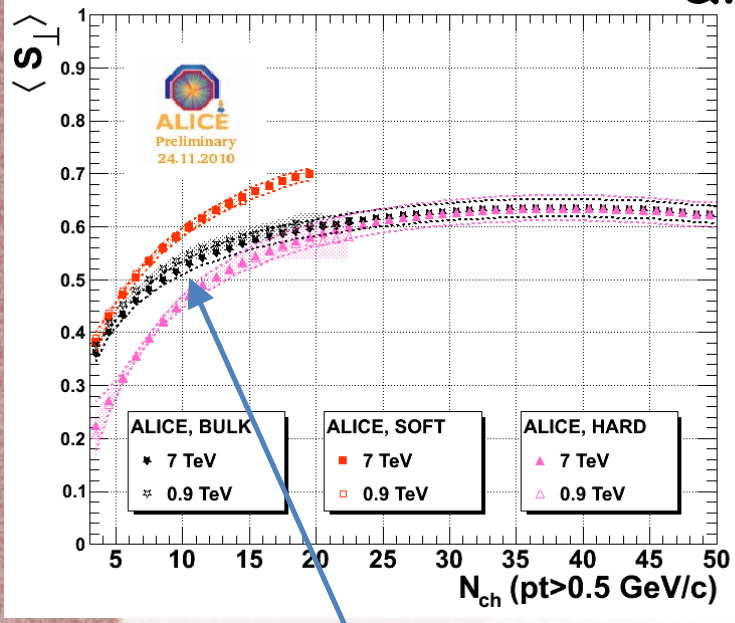
7 TeV: ~ 234.3 million of MB events.
After Physics Selection + |vtx_{z}|<10 + More than 3 primary tracks:
~ 74.9 million of events.
Runs with small mu~ 0.04.

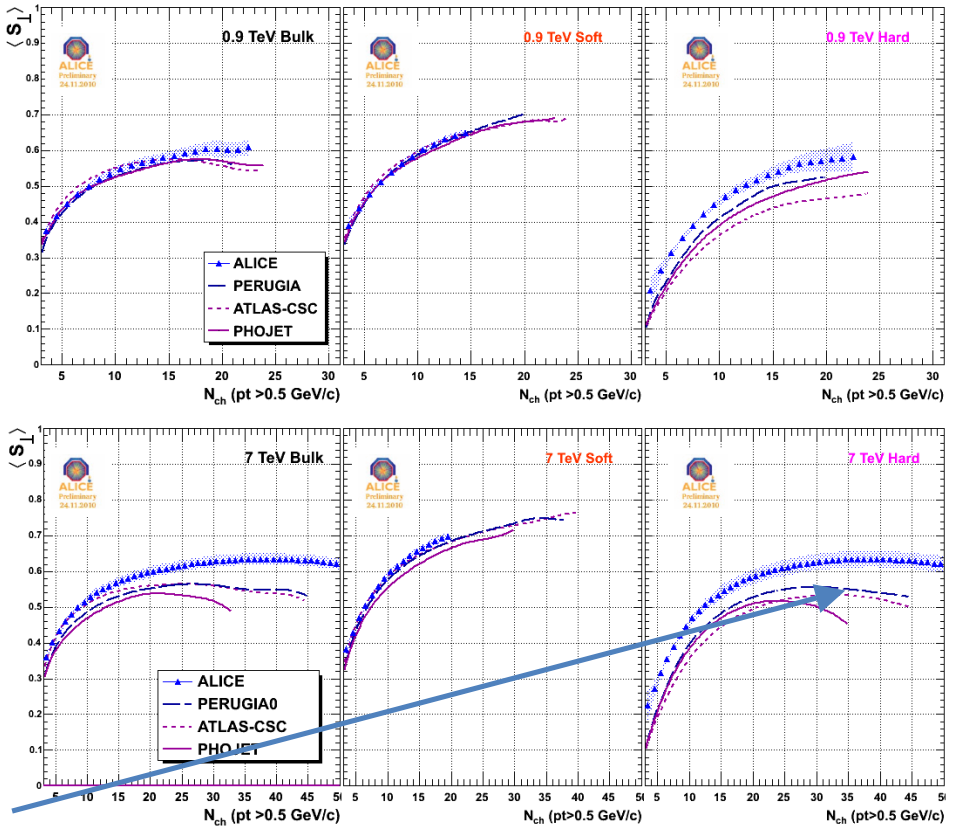
0.9 TeV:).~ 5 million of MB events.
After of selection:~ 0.86 million of events.

Track Selection:

|eta|<0.8, pt>0.5
Multiplicity corrected and sphericity unfolded

Mean sphericity vs multiplicity for hard and soft





- Big differences in sphericity of soft and hard events
- The generators have a decrease in sphericity at high multiplicity

More pronounced at 7TeV

ALICE UE Working Group

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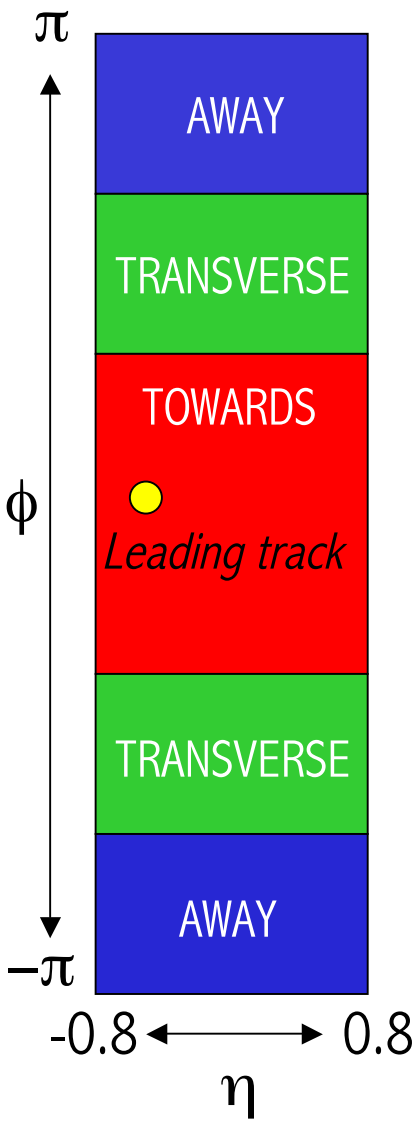
Outline

- Introduction: the analysis method
- Event and track selection
- Data correction procedure
- Systematic uncertainties

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

- Summary and outlook

Experimental Method

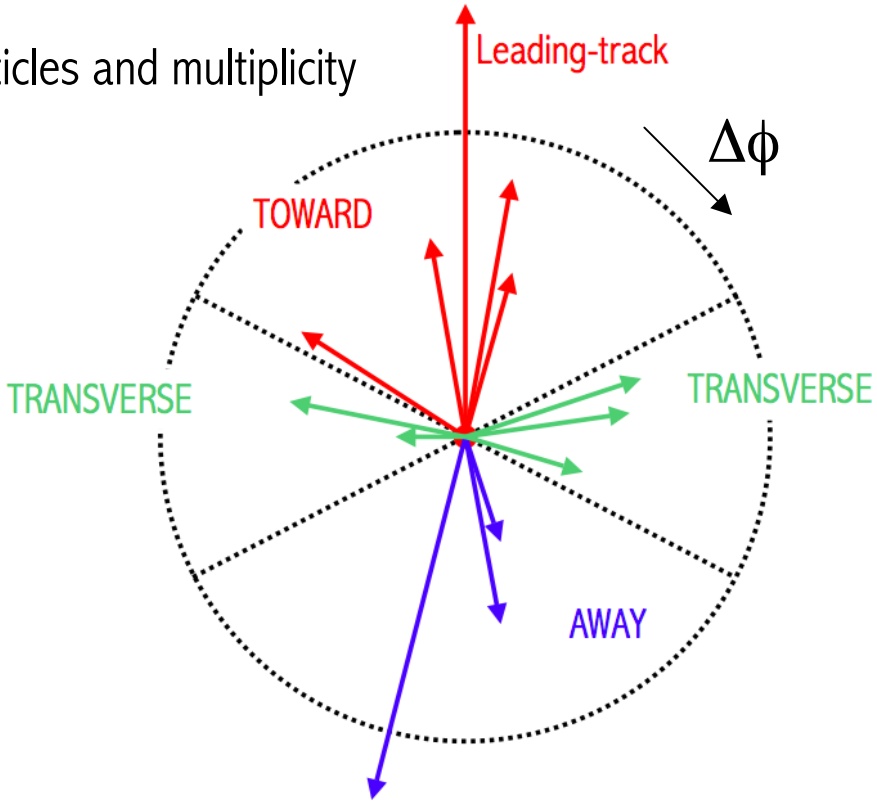


On event-by-event basis:

1) Identify the leading track in the event

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

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



SETTINGS:

- pT > 0.5 - 1 GeV/c (tracks and leading-track)
- $|\eta| < 0.8$
- leading-track not included in distributions

Event selection

- MB trigger: 1 hit in Silicon Pixel or in one of the forward rapidity V0 scintillators

- Beam-gas rejection
- Pile-up rejection

- Reconstructed vertex with at least 1 track
- Vertex within 10 cm from nominal interaction point along beam axis

- Leading track with $p_T > p_{T,MIN}$

- Effect of cosmic events negligible

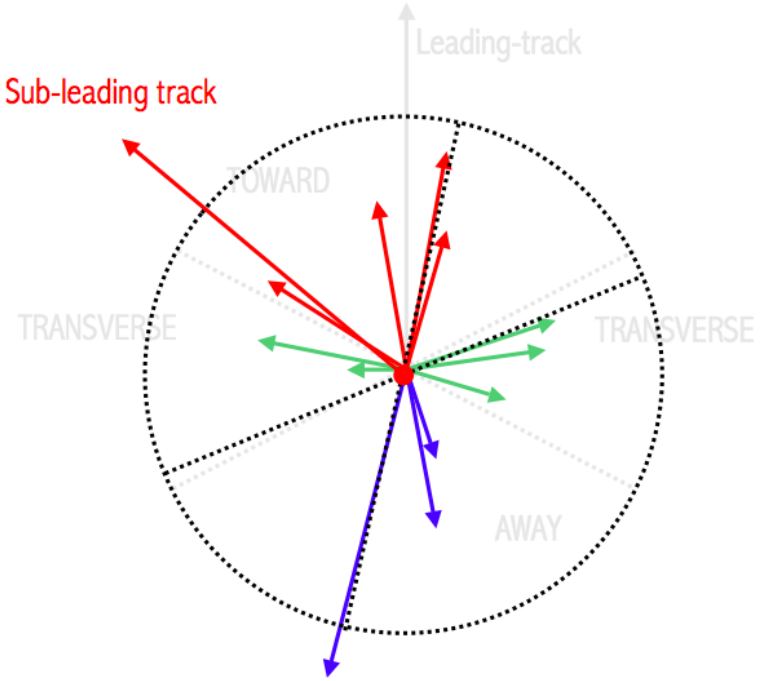
- Diffractive events included in the sample

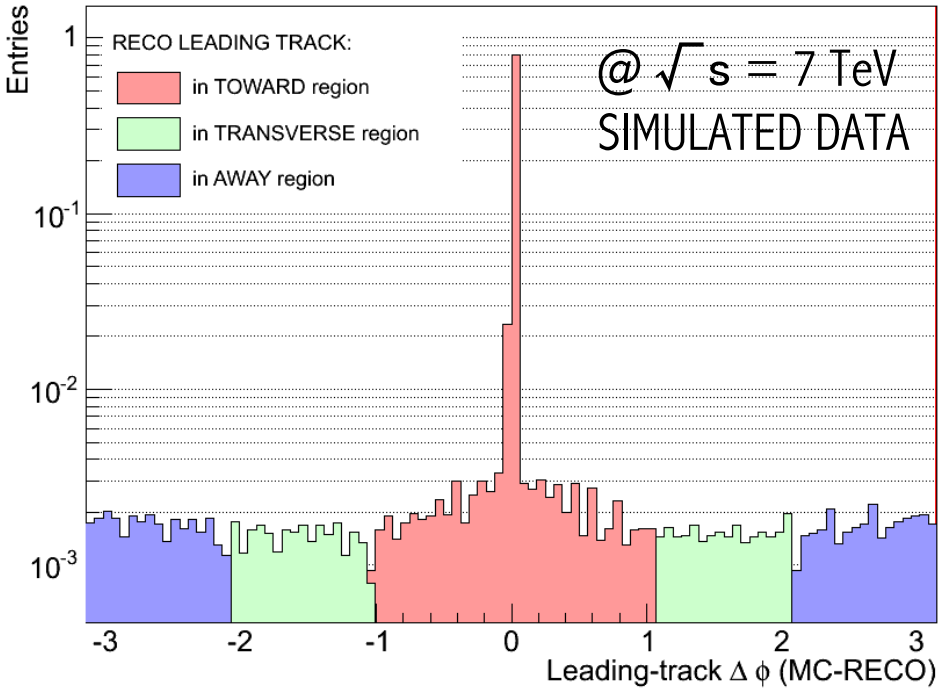
Leading track misidentification

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:

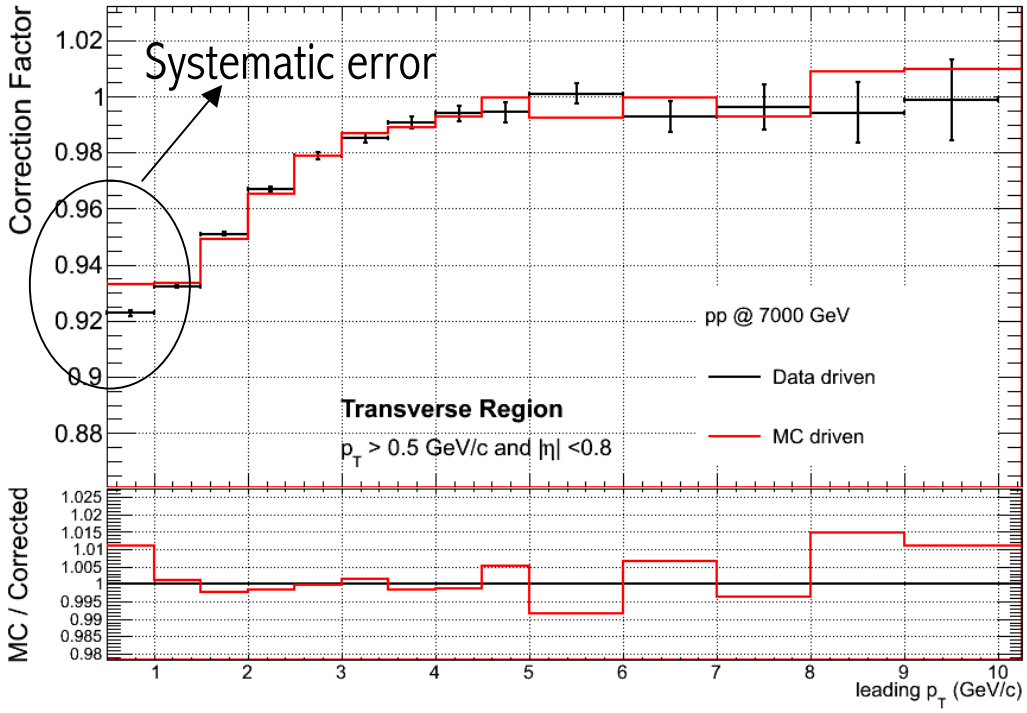
- Starting from the reconstructed distribution, for each event:
  - apply the tracking efficiency a second time on the data
  - with the help of a random number generator decide if the leading-track is reconstructed

- 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.

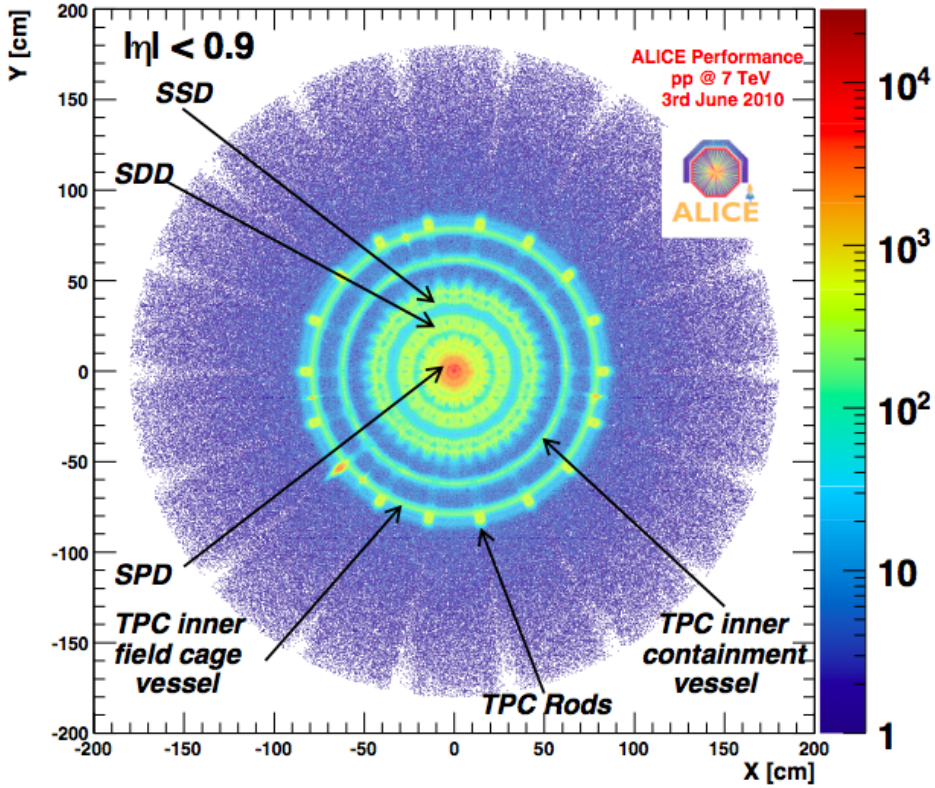
Track Cuts

- 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

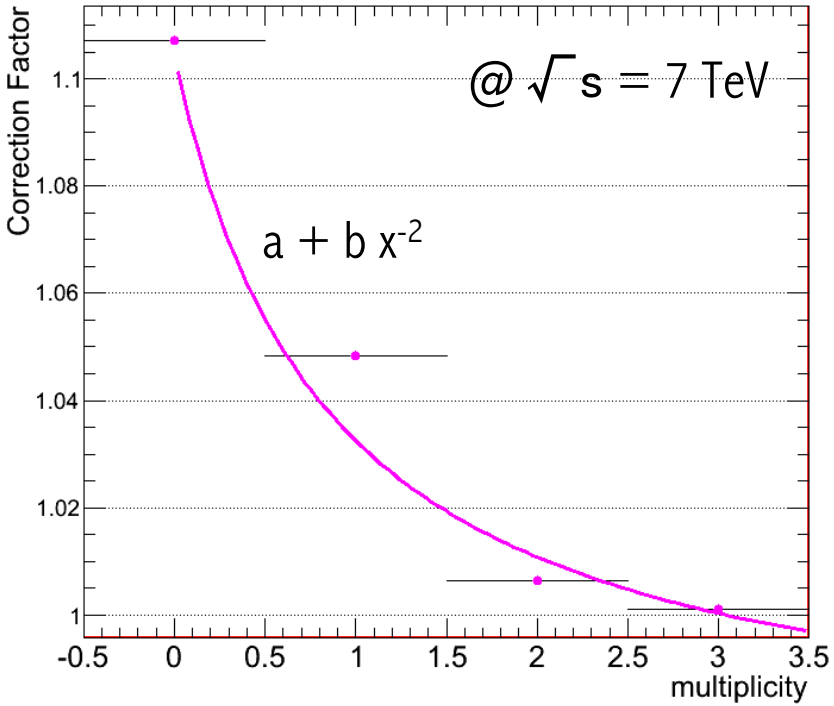
- Require hits in ITS inner layers

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



ALICE tomography from the photon conversions working group.

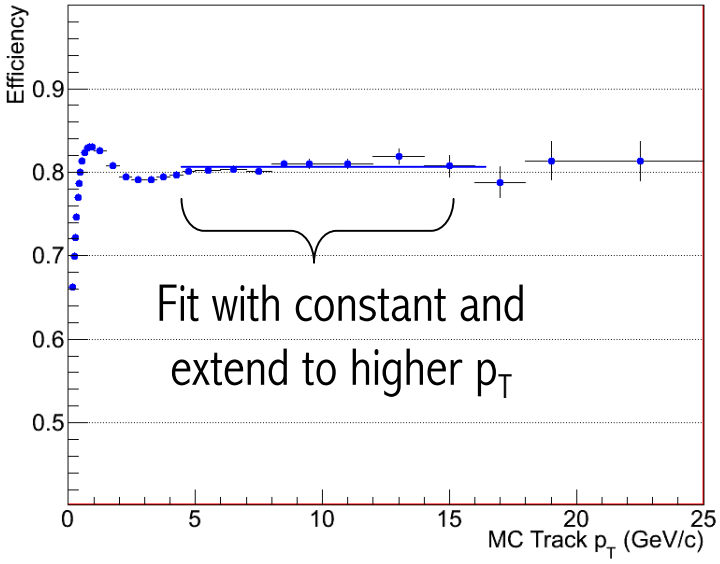
Vertex and tracking efficiency

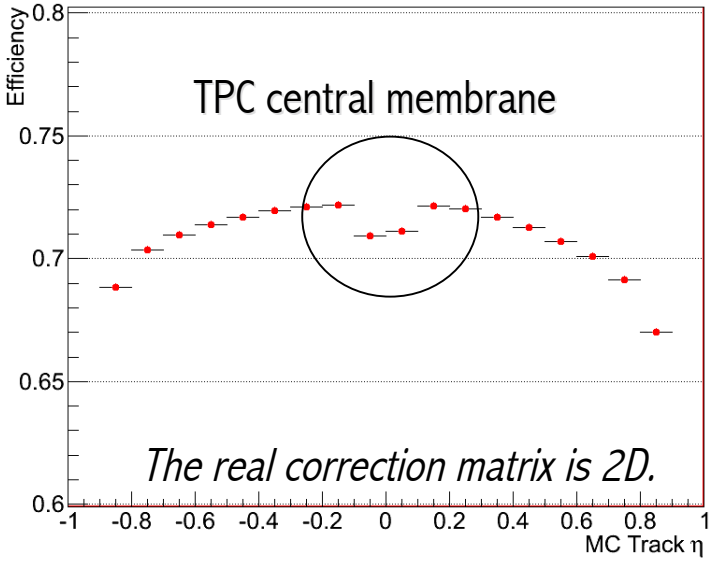


VERTEX RECONSTRUCTION EFFICIENCY:

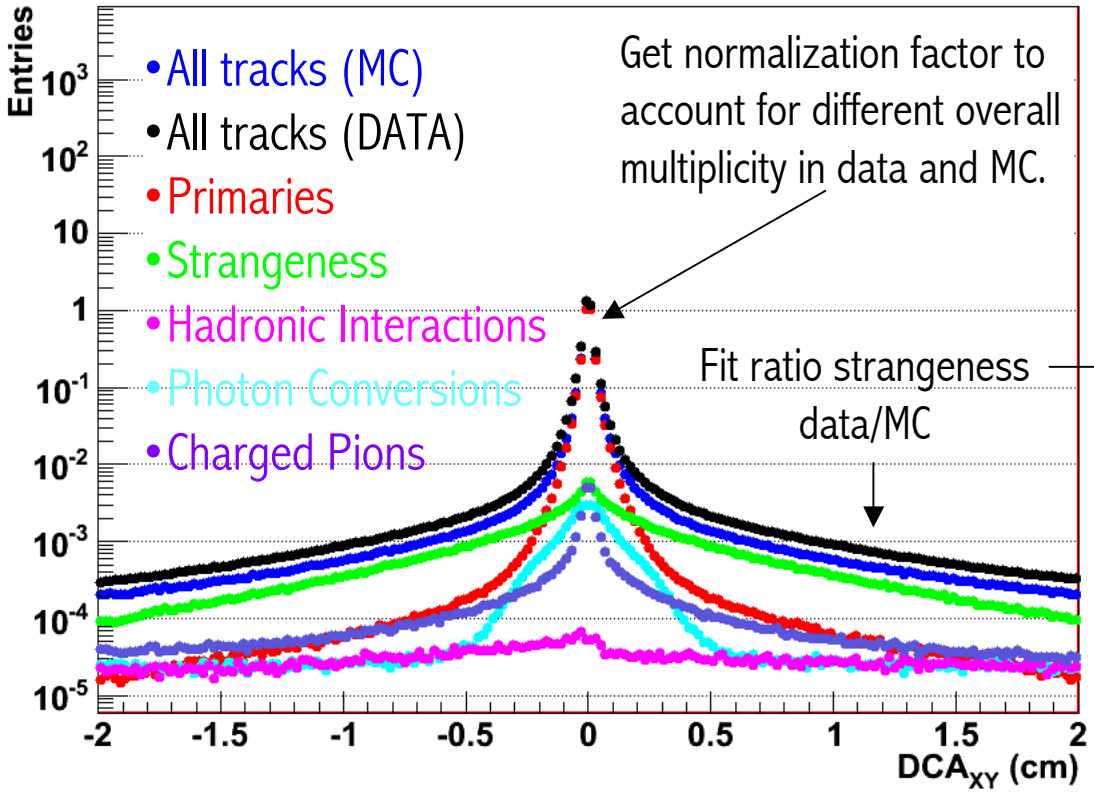
- Correction as function of multiplicity
- Convert measured multiplicity into true via correction factor
  (from profile of response matrix)
- Fit correction factor vs. true multiplicity

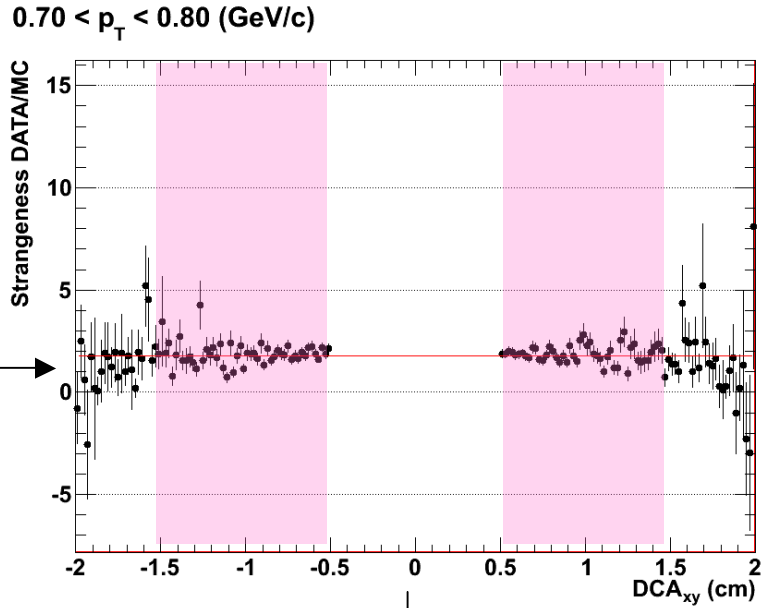
TRACKING EFFICIENCY:

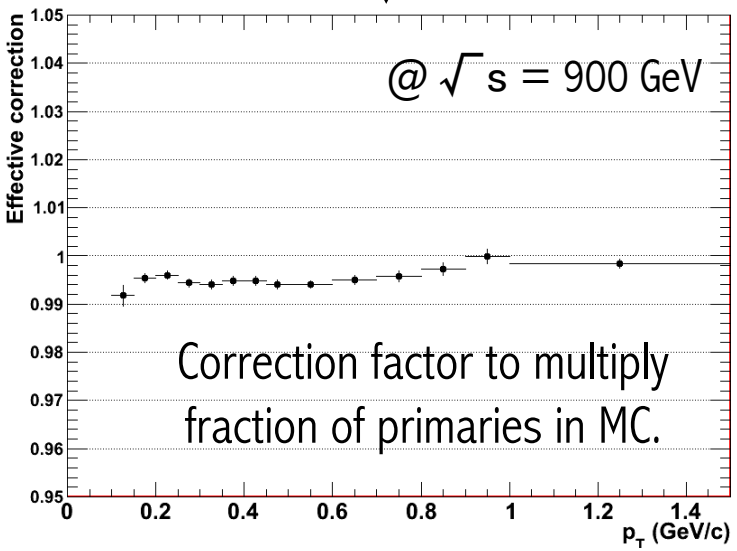




Secondaries contamination



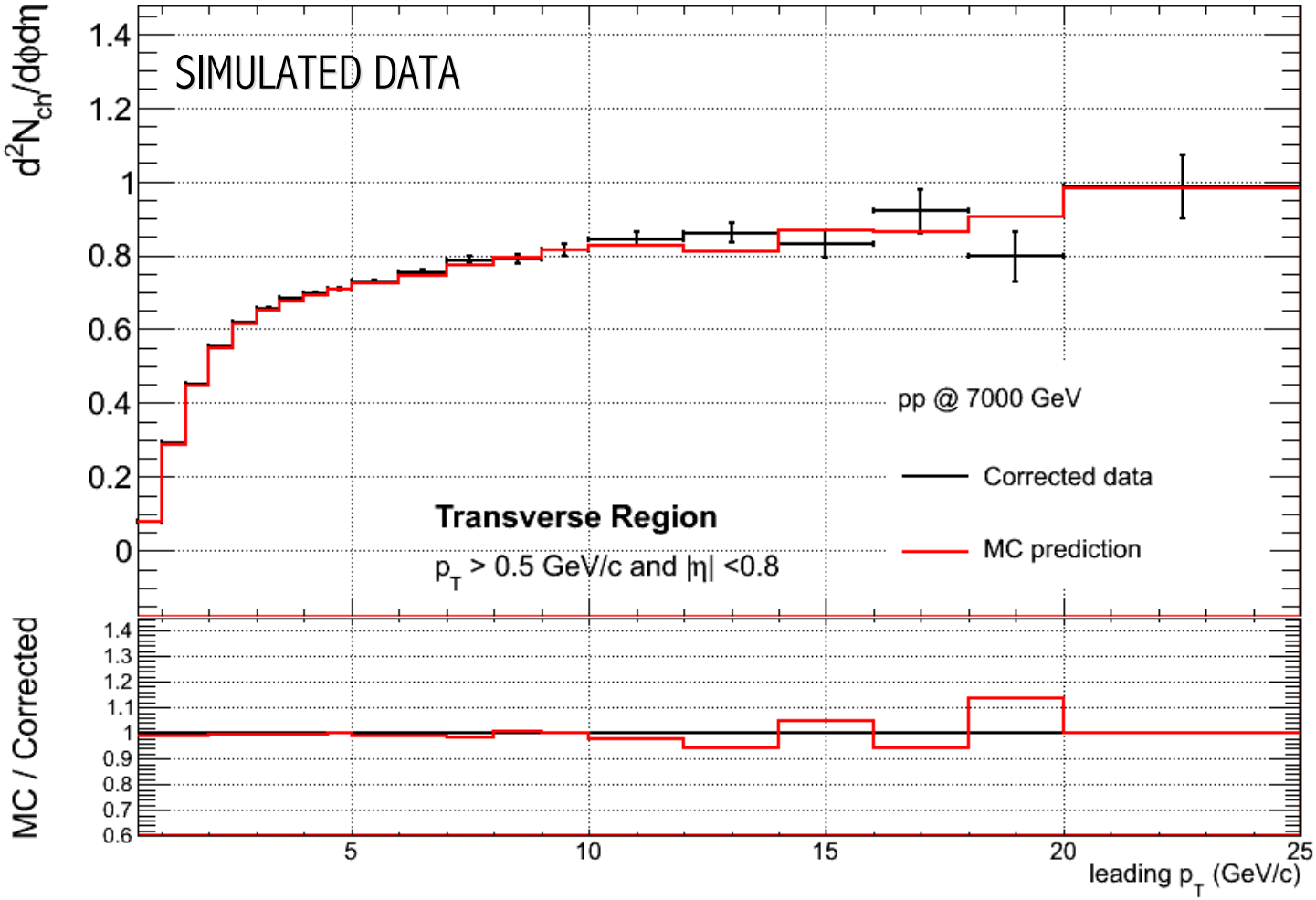




- Strangeness estimate not reliable in MC
- Correction factor from data to strangeness estimate from MC

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	
		900 GeV	7 TeV
Misidentification bias	lead. track p_T	< 5%	< 8%
Vertex reconstruction	measured multiplicity	< 0.7%	< 0.3%
Tracking efficiency	track pT , η	< 19%	< 19%
Contamination	track pT , η	< 3%	< 3%

Systematic uncertainties

- Detector efficiency
- Leading track misidentification
- Vertex reconstruction efficiency
- Choice of track cuts

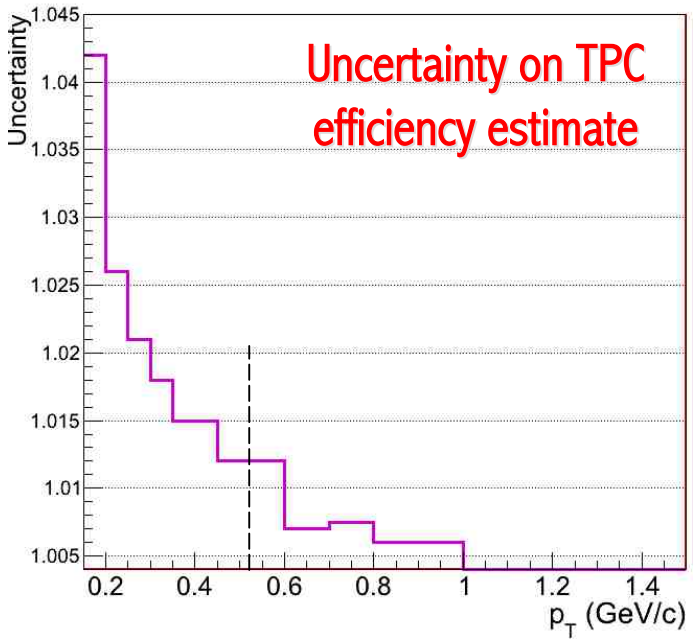
- Particle composition
- Data-driven strangeness estimation

- Model dependence
- Non closure in MC

Detector effects

ITS/TPC tracking:

- Imprecision in MC detector description
- ITS: irrelevant for $p_T > 0.5$ GeV/c
- TPC: smaller than 1.2% for $p_T > 0.5$ GeV/c
- Maximum effect on final distributions < 1%



Vertex reconstruction:

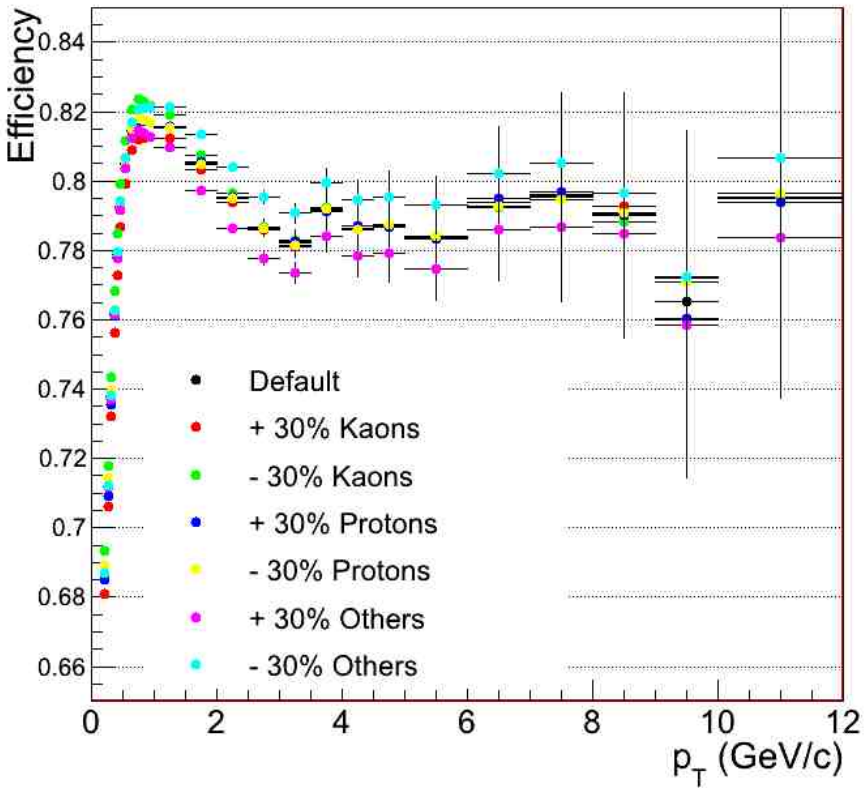
- require at least 1 or 2 contributing tracks
- error given by maximum variation in final distributions

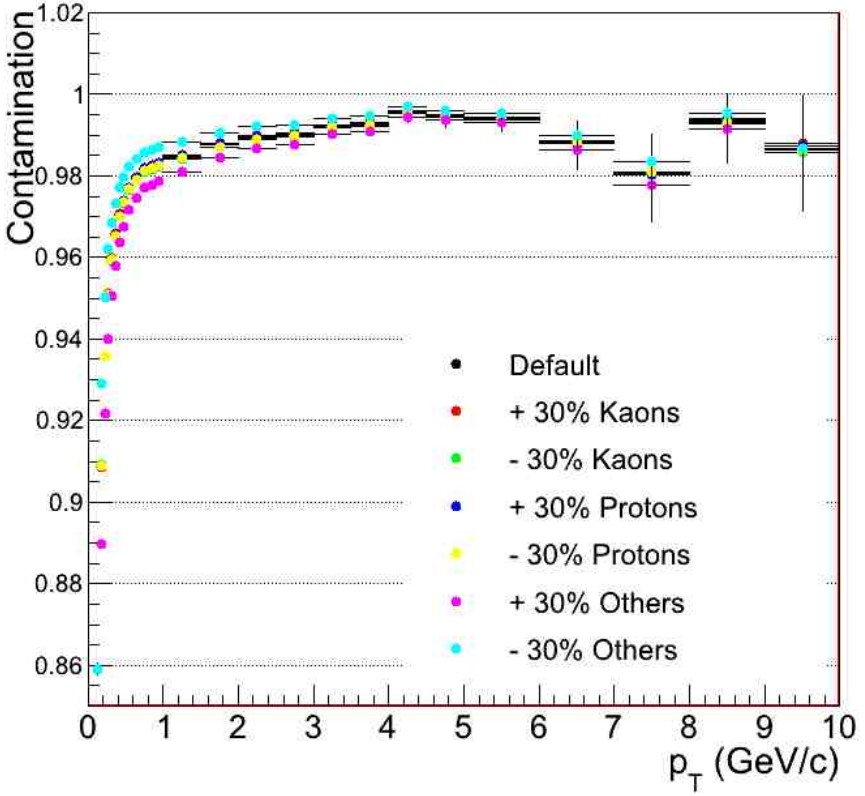
Choice of track cuts:

- Assign lower and upper value to most relevant cuts:
  - minimum number of TPC clusters
  - maximum χ^2 of TPC clusters
  - **number of σ accepted in DCA_{XY} distribution**
- error given by different variations in data and MC

Particle composition

- consider Protons, Kaons and all others
- vary relative yields of 30% w.r.t. default
- effect of modified efficiency on final distributions





Systematic errors

Values for 7 TeV in % (900 GeV similar)

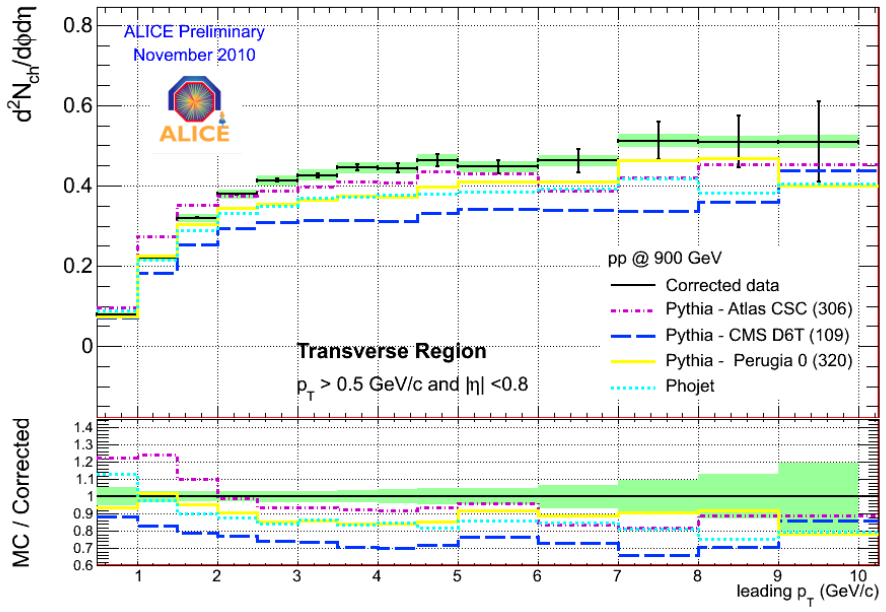
	$0.5 < p_T < 1$ (GeV/c)	$p_T >$ (1 GeV/c)
Particle composition	0.8	
ITS/TPC efficiency	1.0 (+0.5)	0.6 (+0.5)
Track Cuts	3	
Misidentification bias	**4-5**	0
MC dependence (x-correction)	2	0
MC dependence (data corrected w/ both)	0.8	
Vertex efficiency correction	1	0
Strangeness estimation	**2** (for $p_T < 1.5$)	1

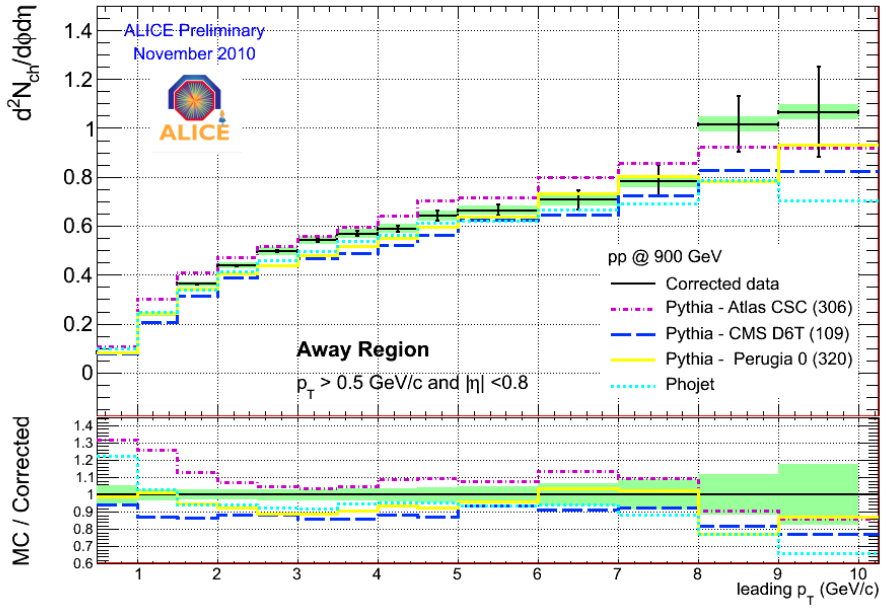
* Ranges indicate different uncertainty for different distributions.

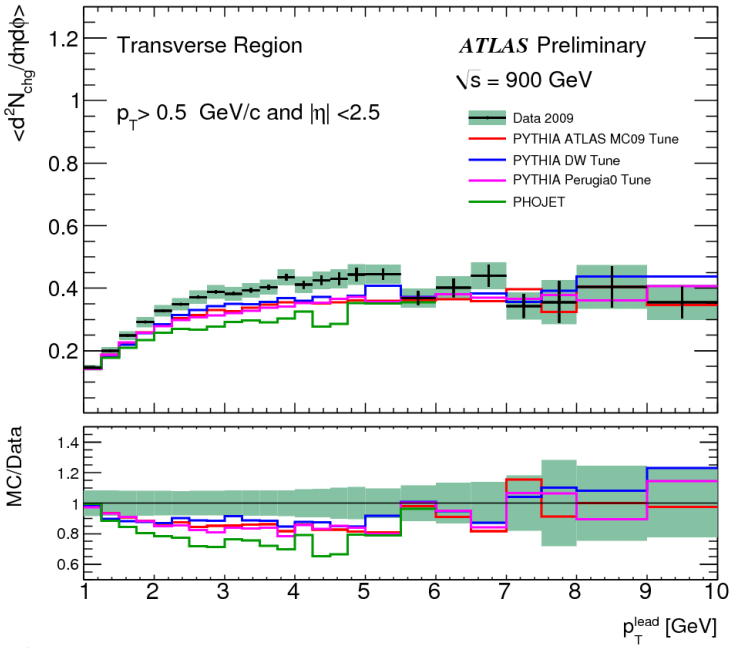
Corrected Data

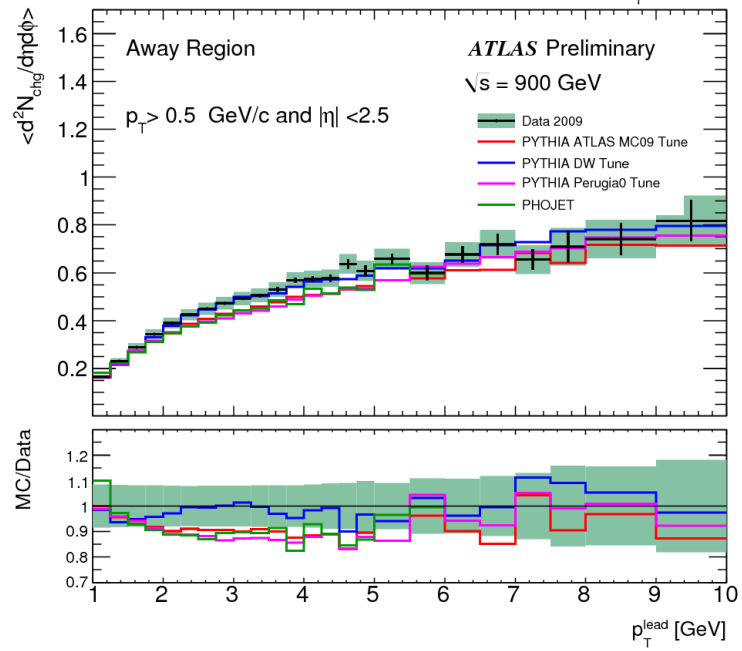
Compared with ATLAS results from
ATLAS-CONF-2010-029 (May 2010)

Results @ 900 GeV: number density



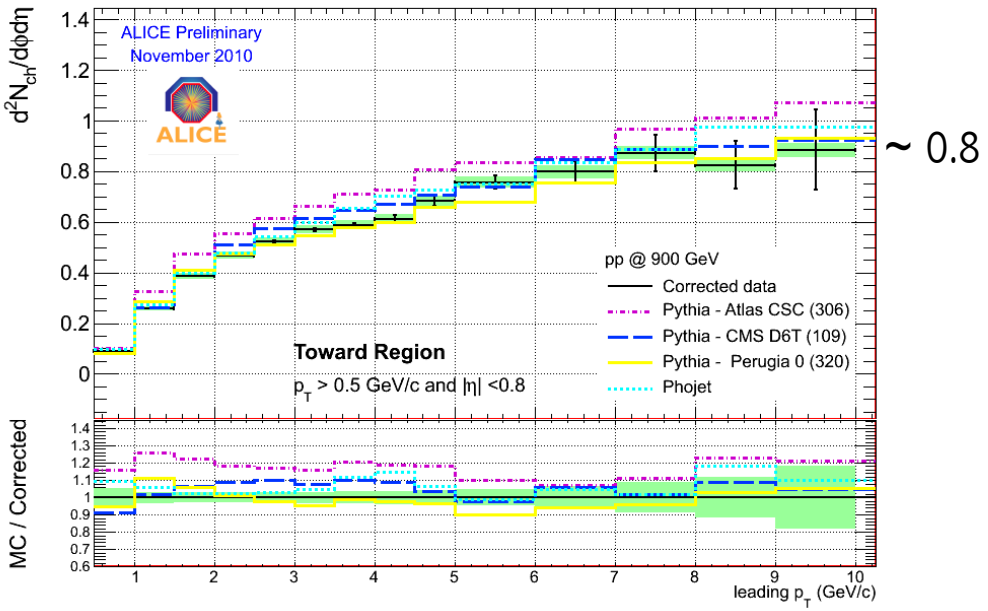




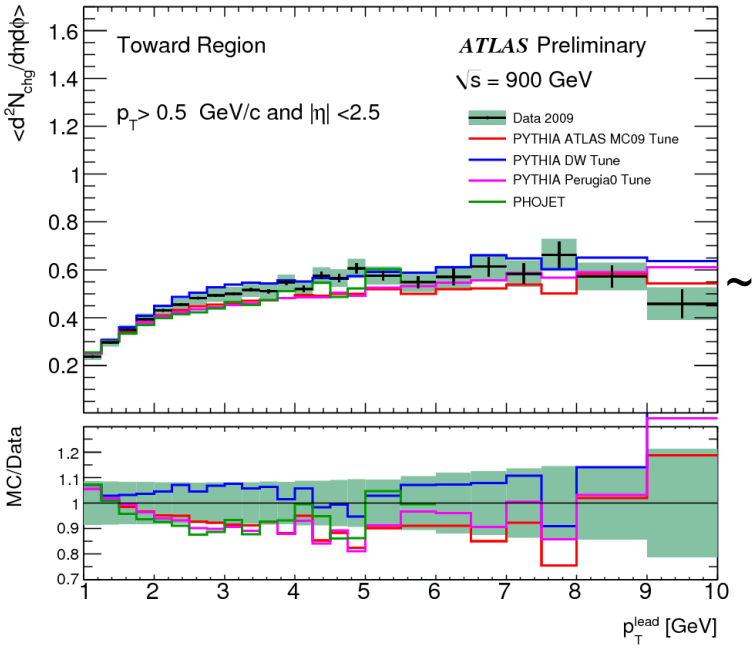


Good agreement ALICE/ATLAS

Results @ 900 GeV: number density

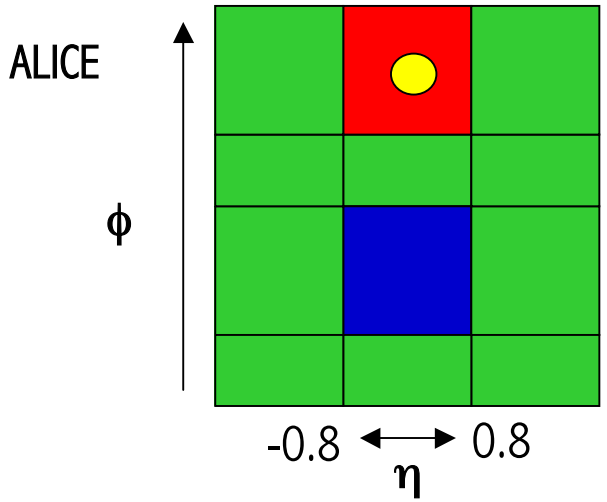


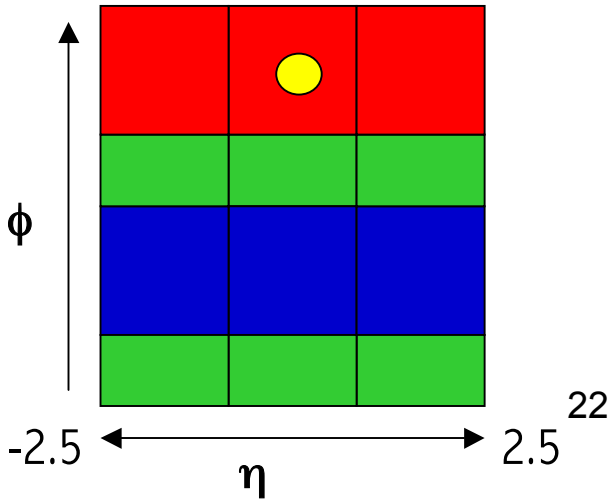
~ 0.8



~ 0.5

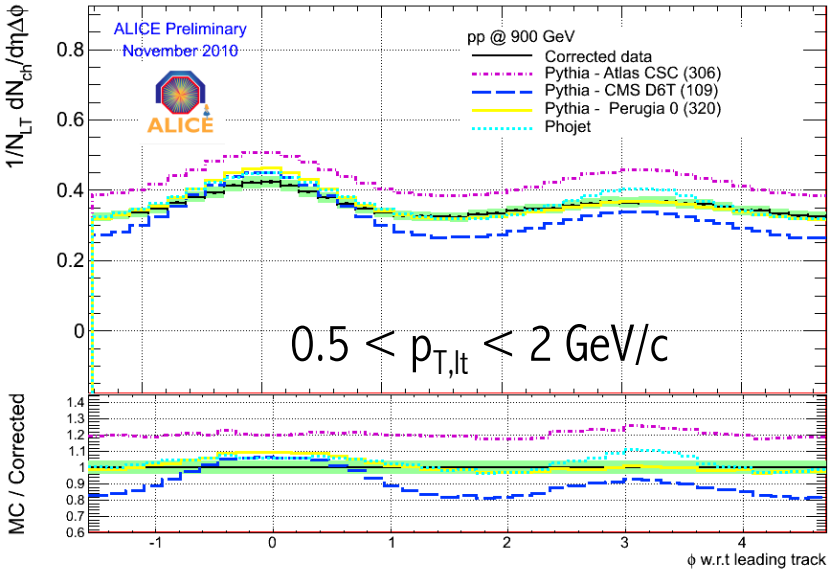
- Difference explained by acceptance
- Numerically confirmed by adding "1 part Towards" + "2 parts Transverse"

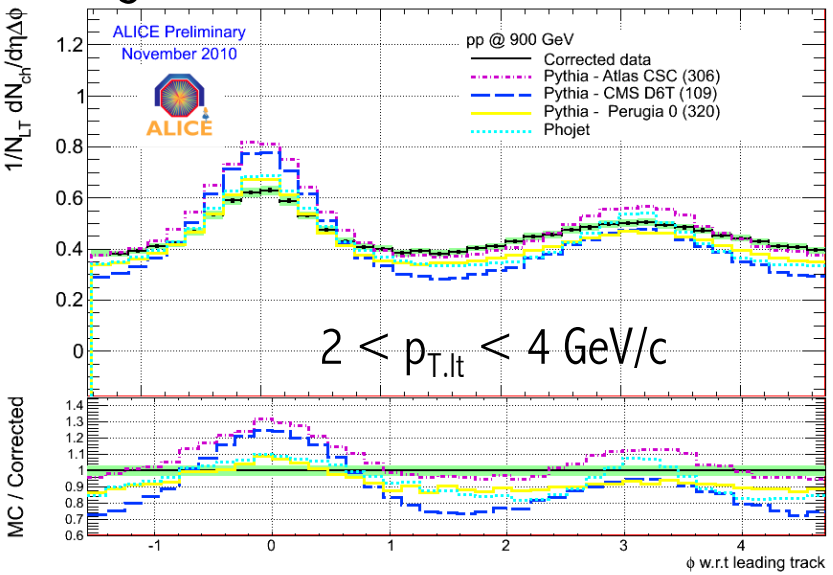


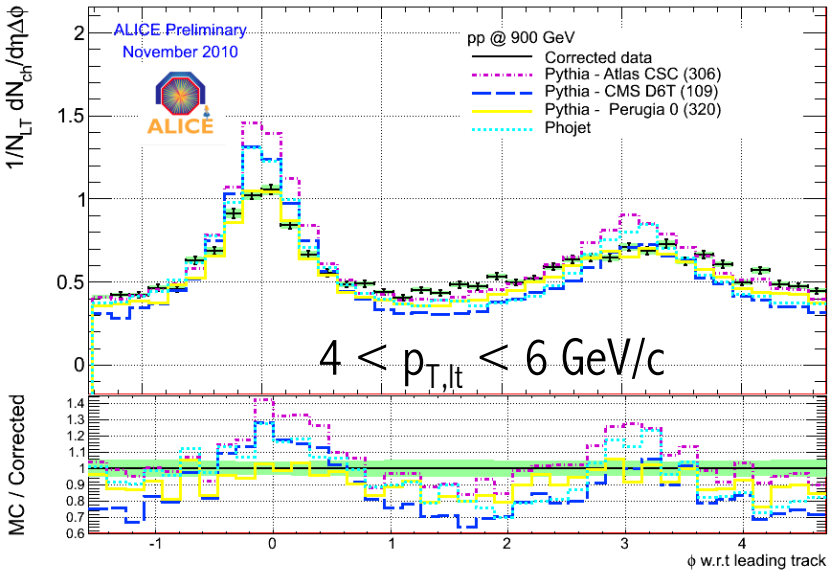


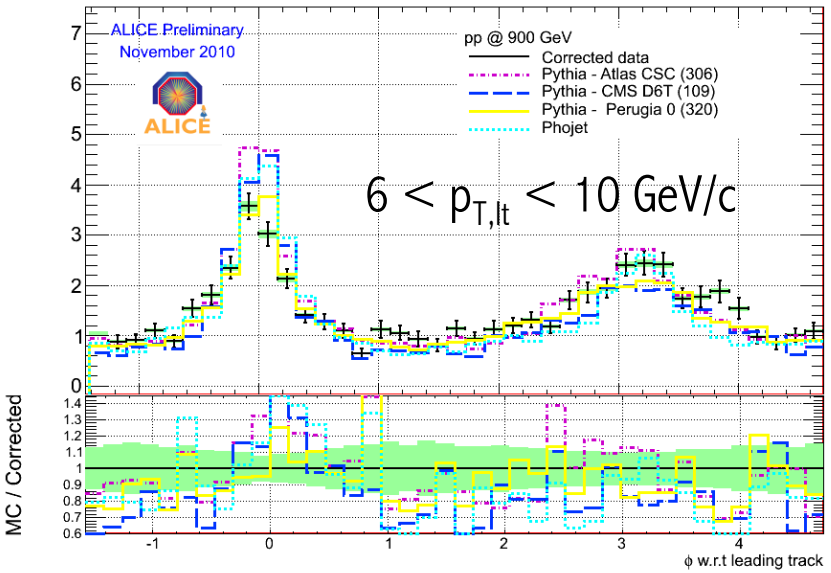
Results @ 900 GeV: Δϕ correlation

Azimuthal correlation between leading track and all tracks.

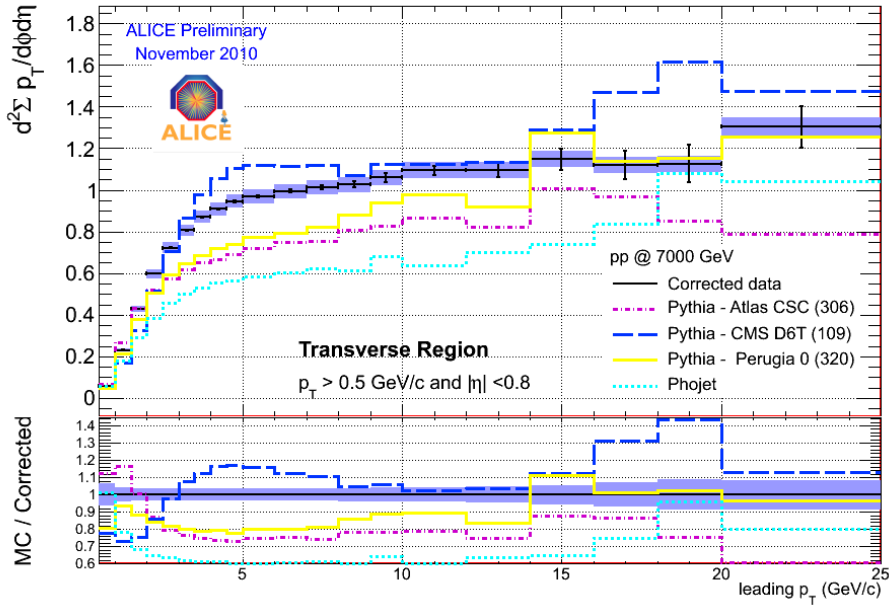


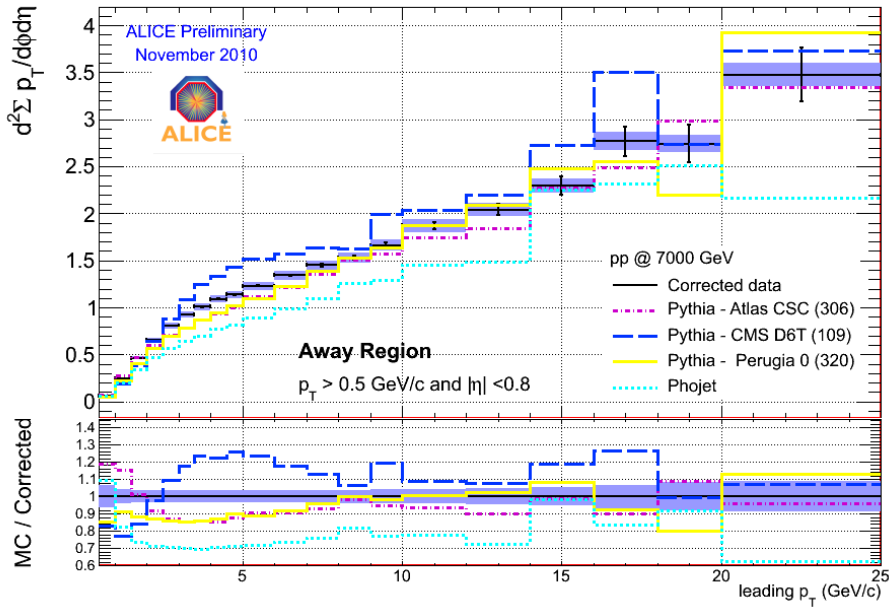


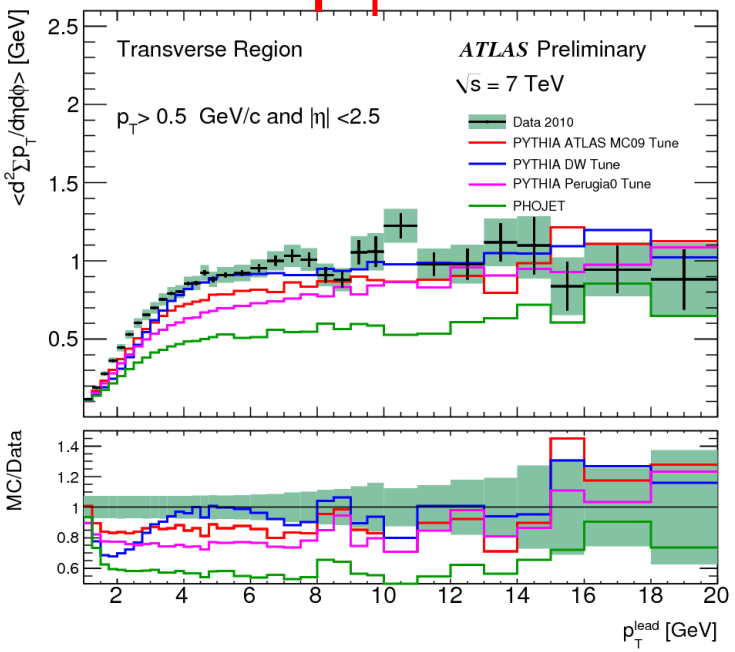


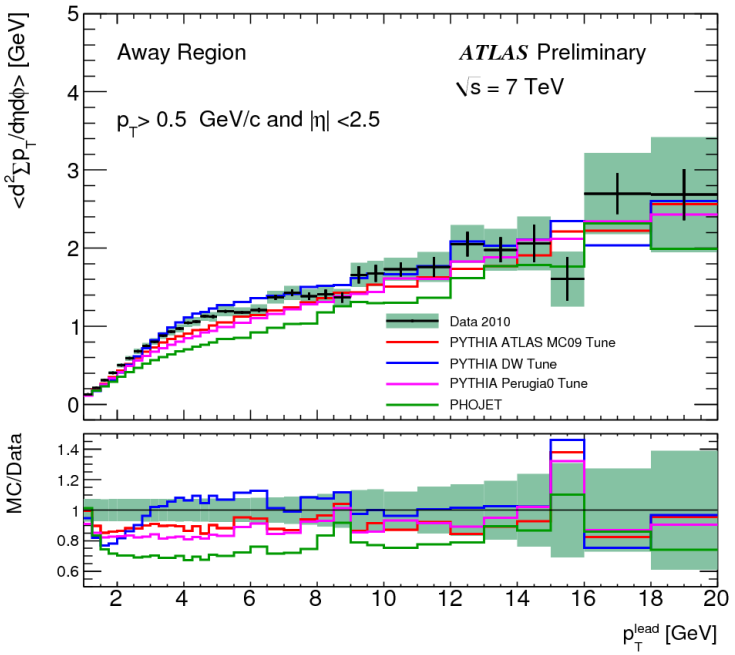


Results @ 7 TeV: sum p_T



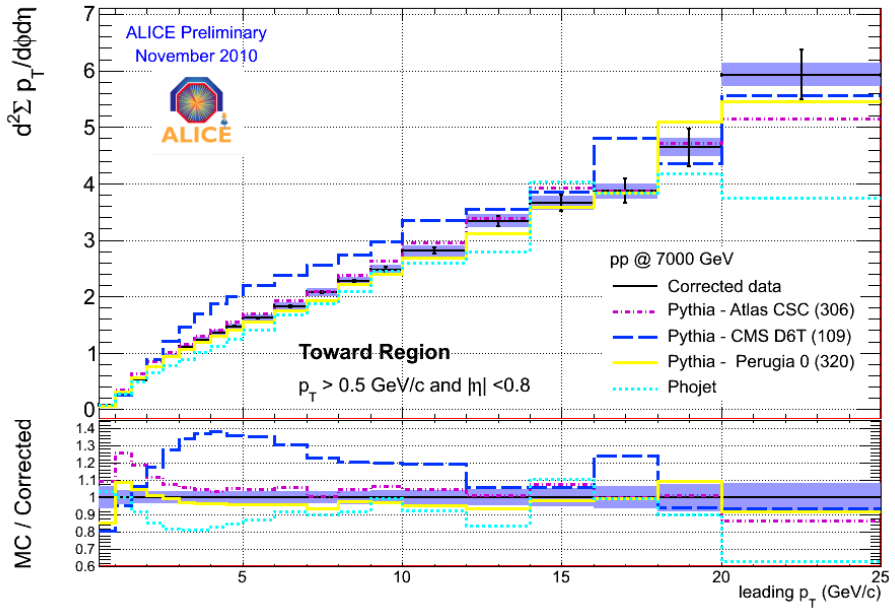


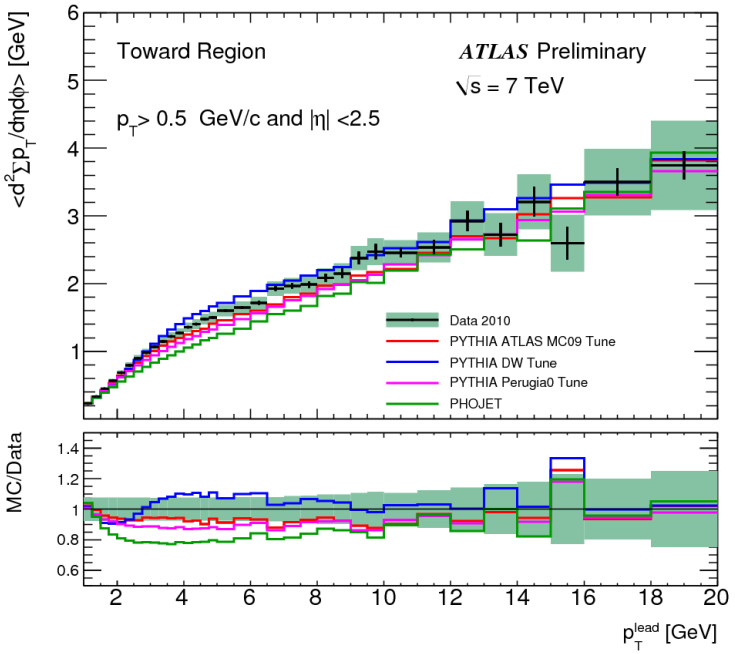




ATLAS measures lower values than ALICE

Results @ 7 TeV: sum p_T





- Remember:
  - different acceptance ALICE/ATLAS
  - ALICE excludes leading track from distributions

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
- Good agreement with ATLAS results

- **Work in progress:**
  - Public note in preparation
  - More statistics at $\sqrt{s} = 7$ TeV
  - Lower pt cut-off to 0.15 GeV/c

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

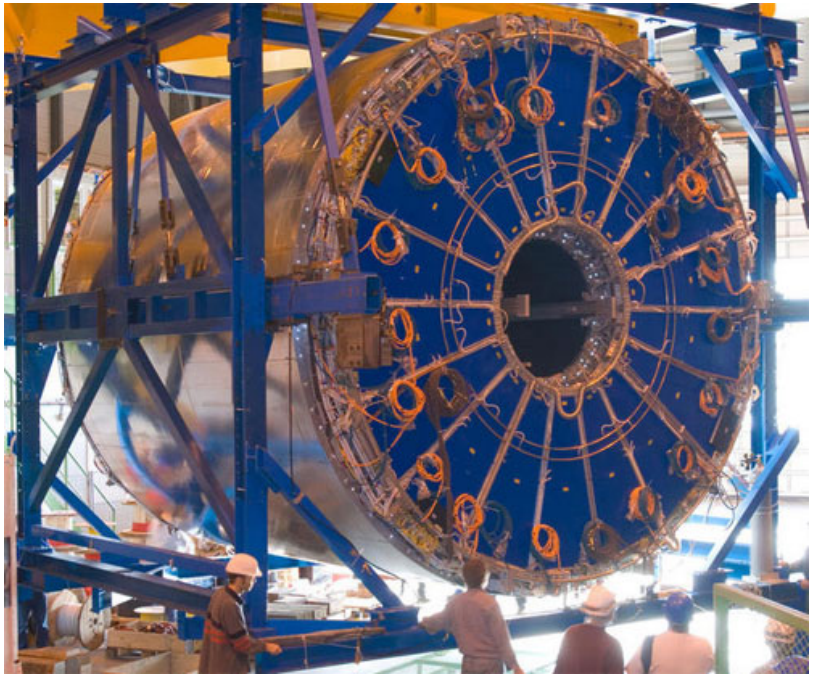
- Correct jet measurements for soft-UE for fair comparison with NLO pQCD

- 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).

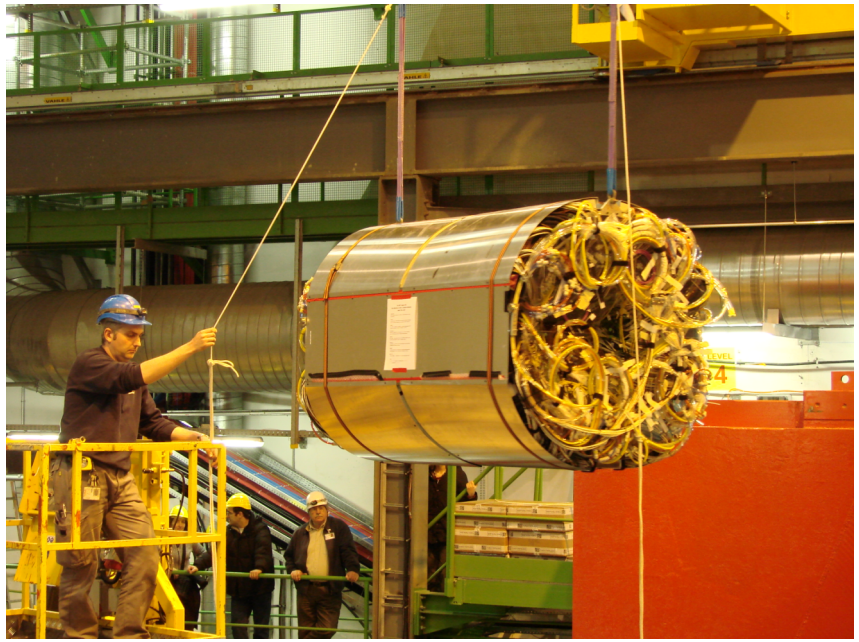


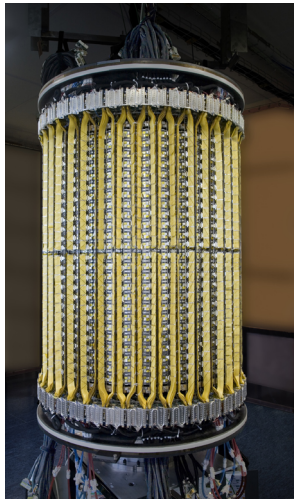
TPC: main device in the central barrel to **detect charged particle tracks and perform particle identification** (ionization density).
Can cope with up to 20000 tracks in a single Pb-Pb interaction. BUT it's slow (200 Hz)!

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)



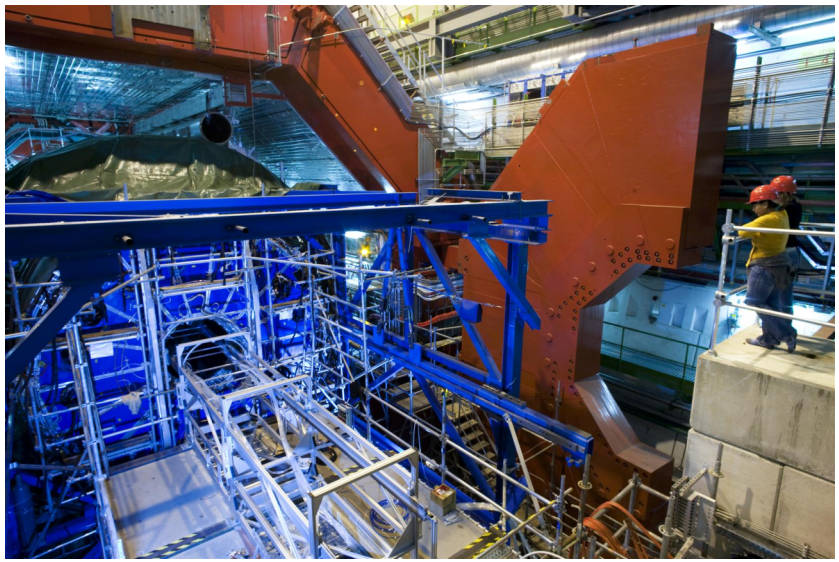


6 silicon layers:

- 2 x pixel (intrinsically 2D)
- 2 x drift (intrinsically 2D)
- 2 x strip

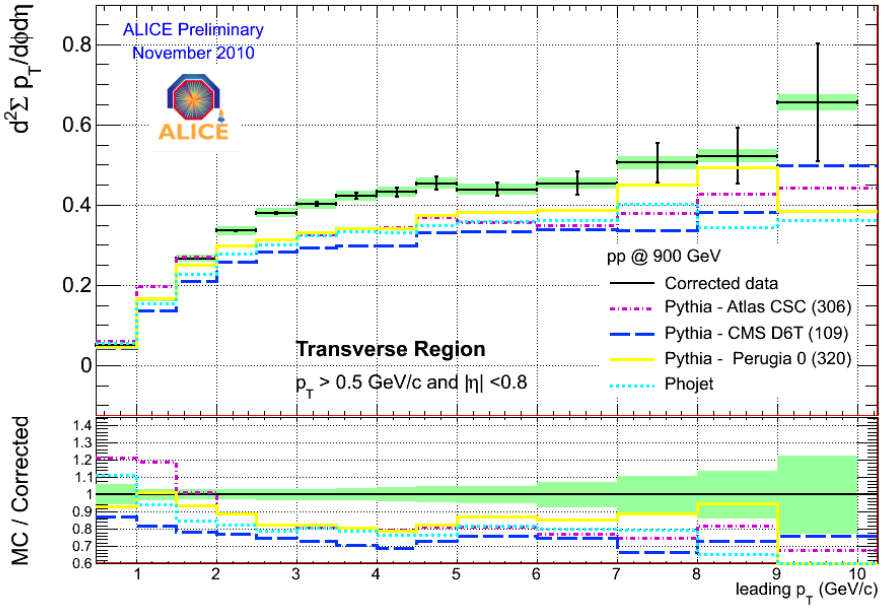
R ~ 4-44 cm

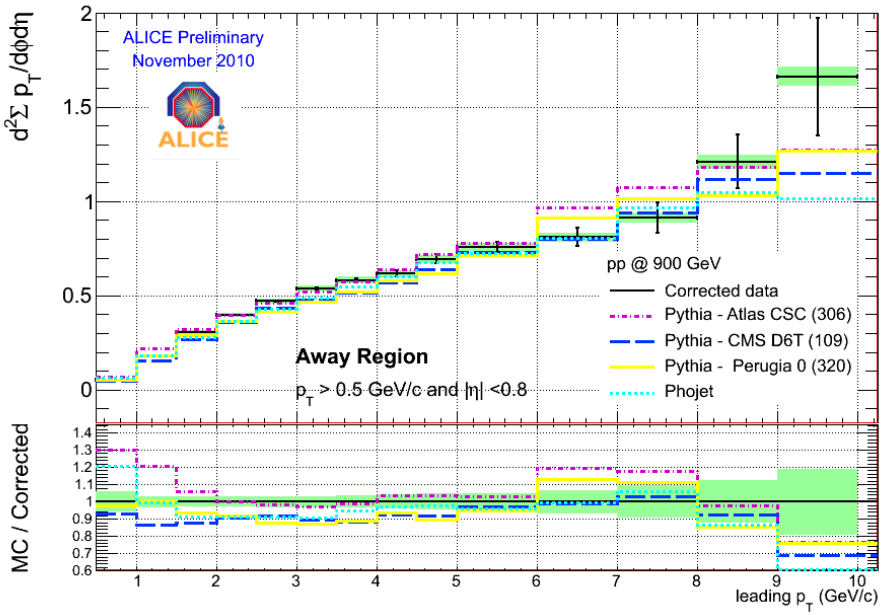
$|\eta| < 0.9$

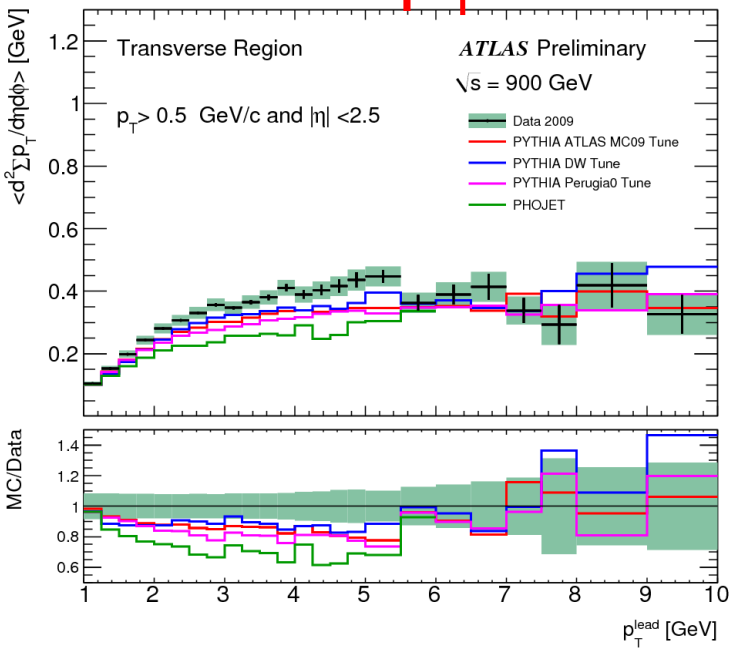


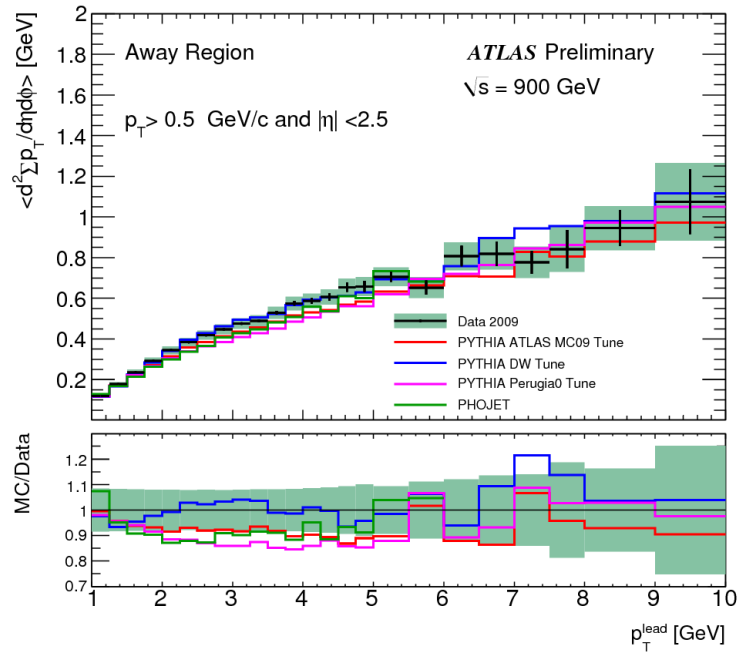
- **Vertexing detector plus dE/dx** in non-relativistic region (stand-alone low p_T spectrometer).
- High granularity and excellent spatial resolution.
- About 90 tracks per cm^2 in innermost layers.

Results @ 900 GeV: sum p_T



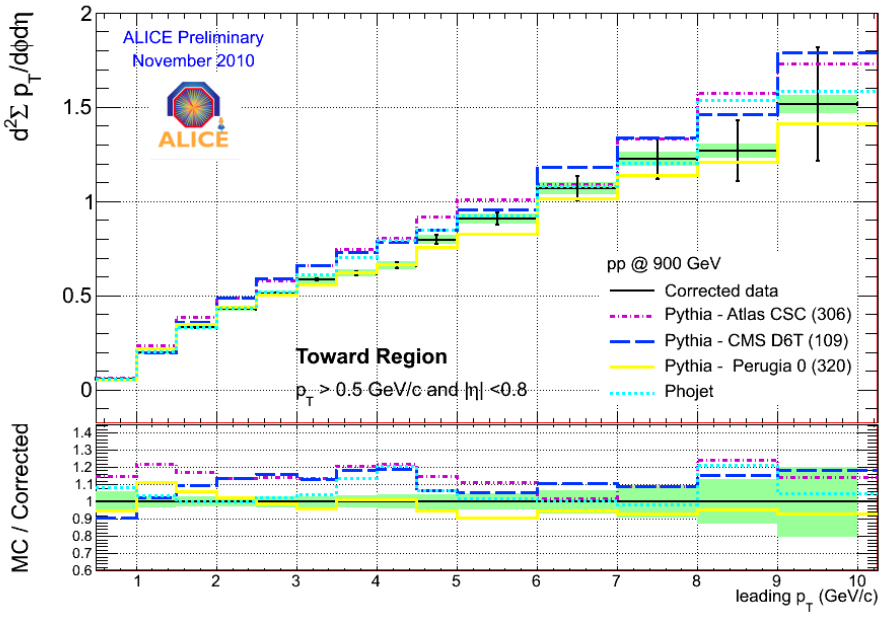


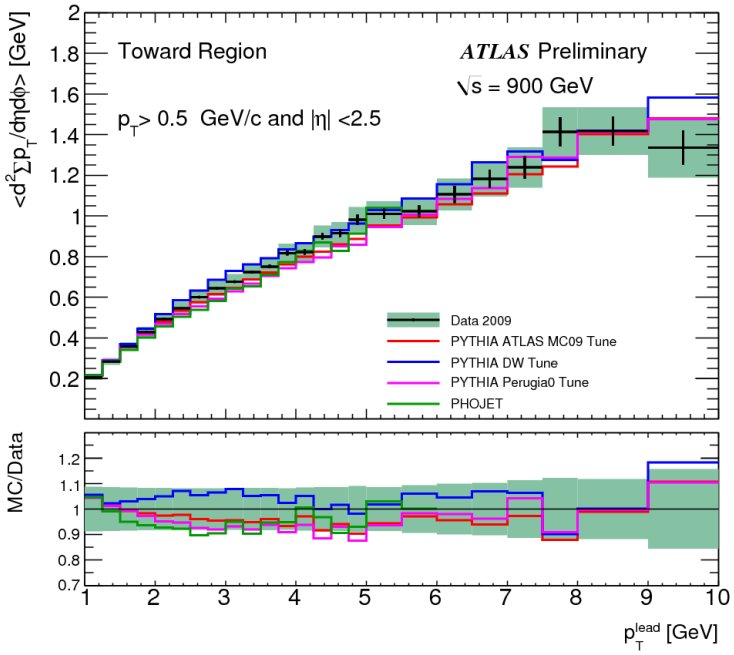




ATLAS measures lower values than ALICE

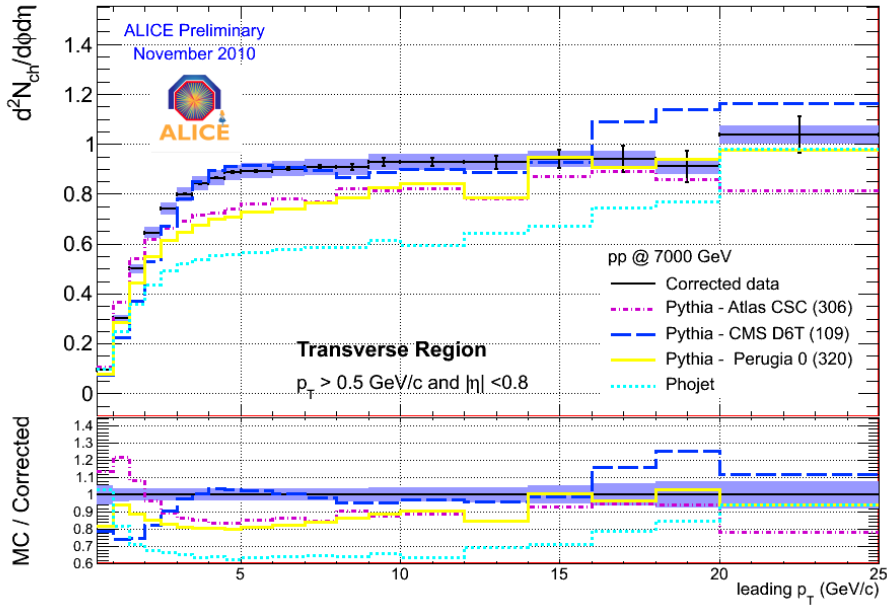
Results @ 900 GeV: sum p_T

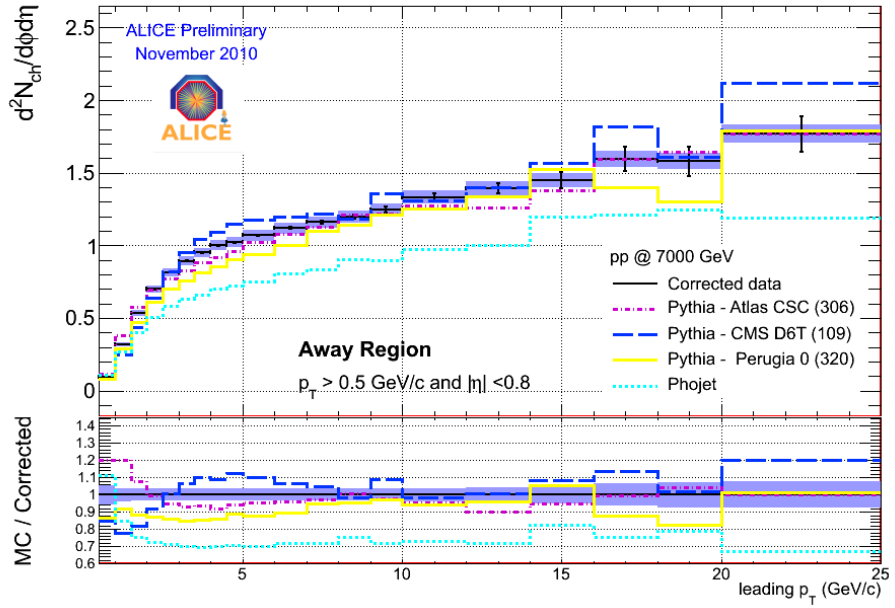


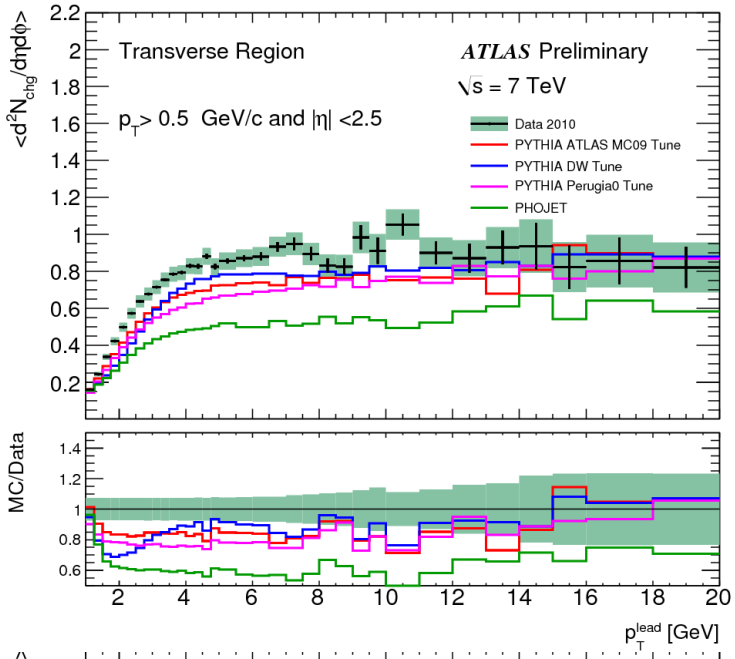


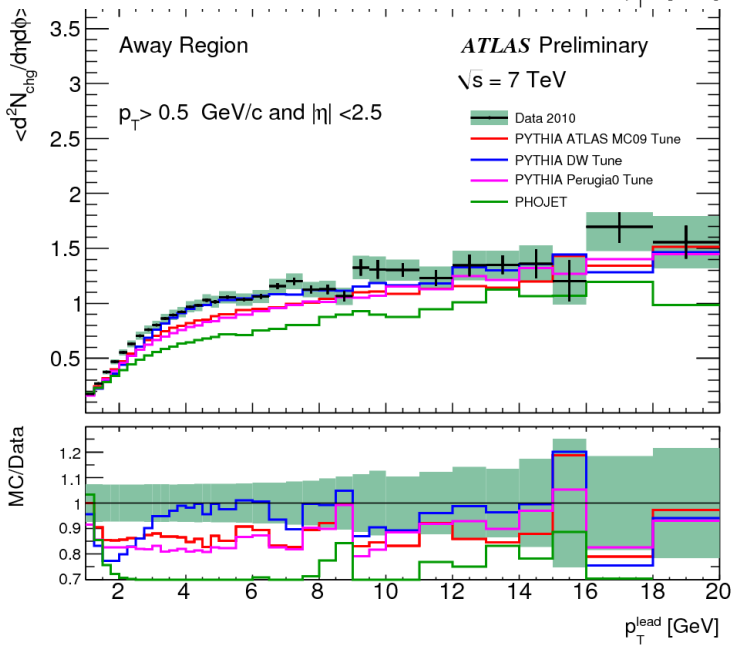
- ALICE and ATLAS data are not directly comparable:
  - different acceptance
  - ALICE excludes leading track from distributions
- Favored tune: Perugia 0

Results @ 7 TeV: number density



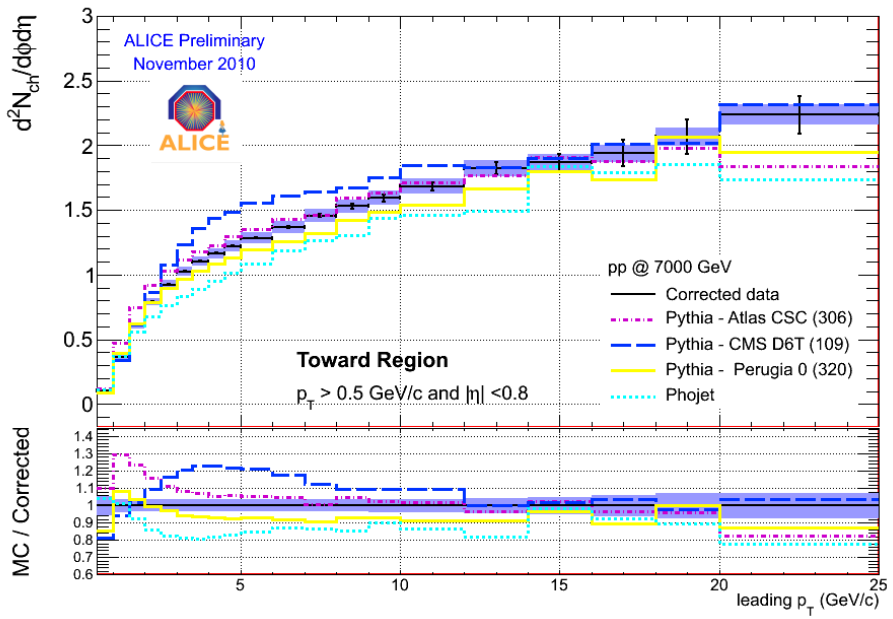


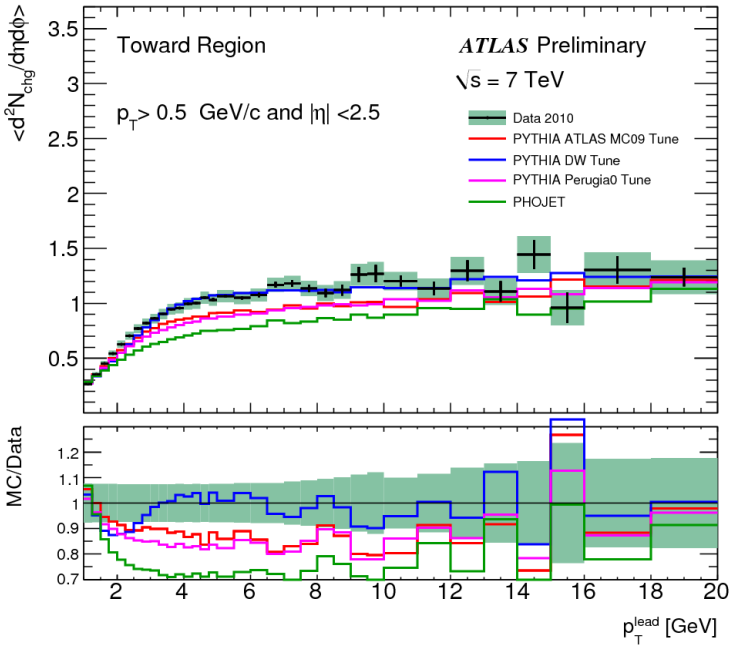




Good agreement ALICE/ATLAS

Results @ 7 TeV: number density

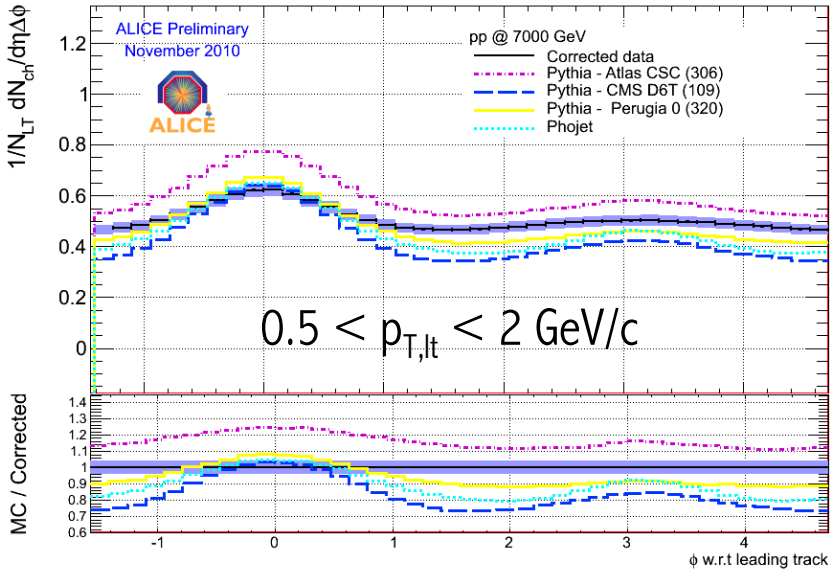


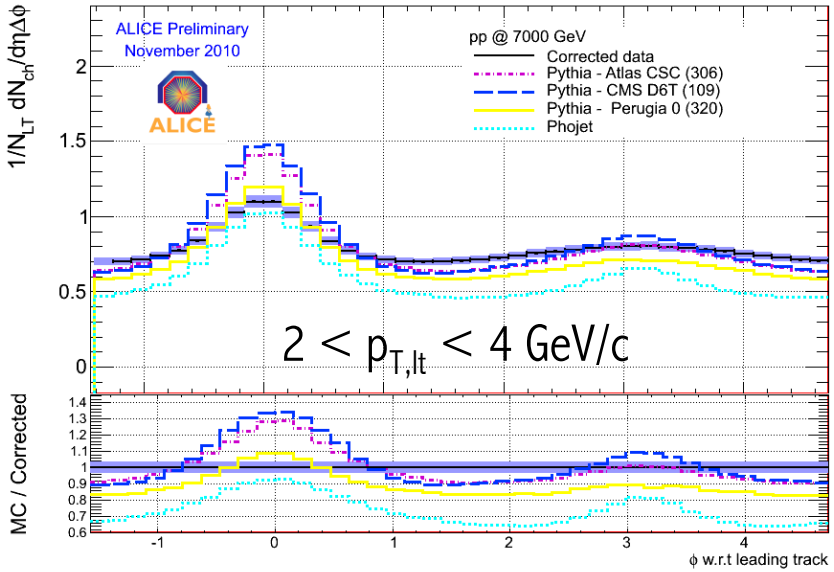


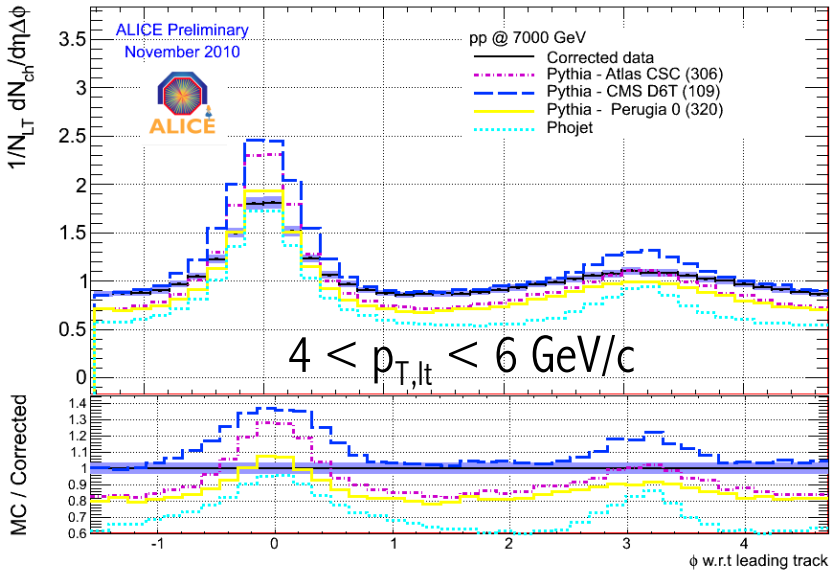
Discrepancy explained by considerations on acceptance
(same as $\sqrt{s}$ 900 GeV).

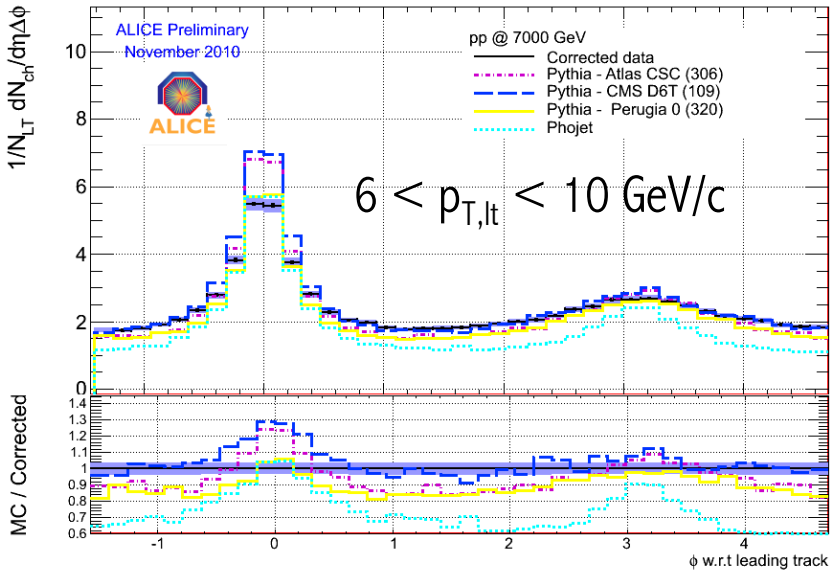
Results @ 7 TeV: Δφ correlation

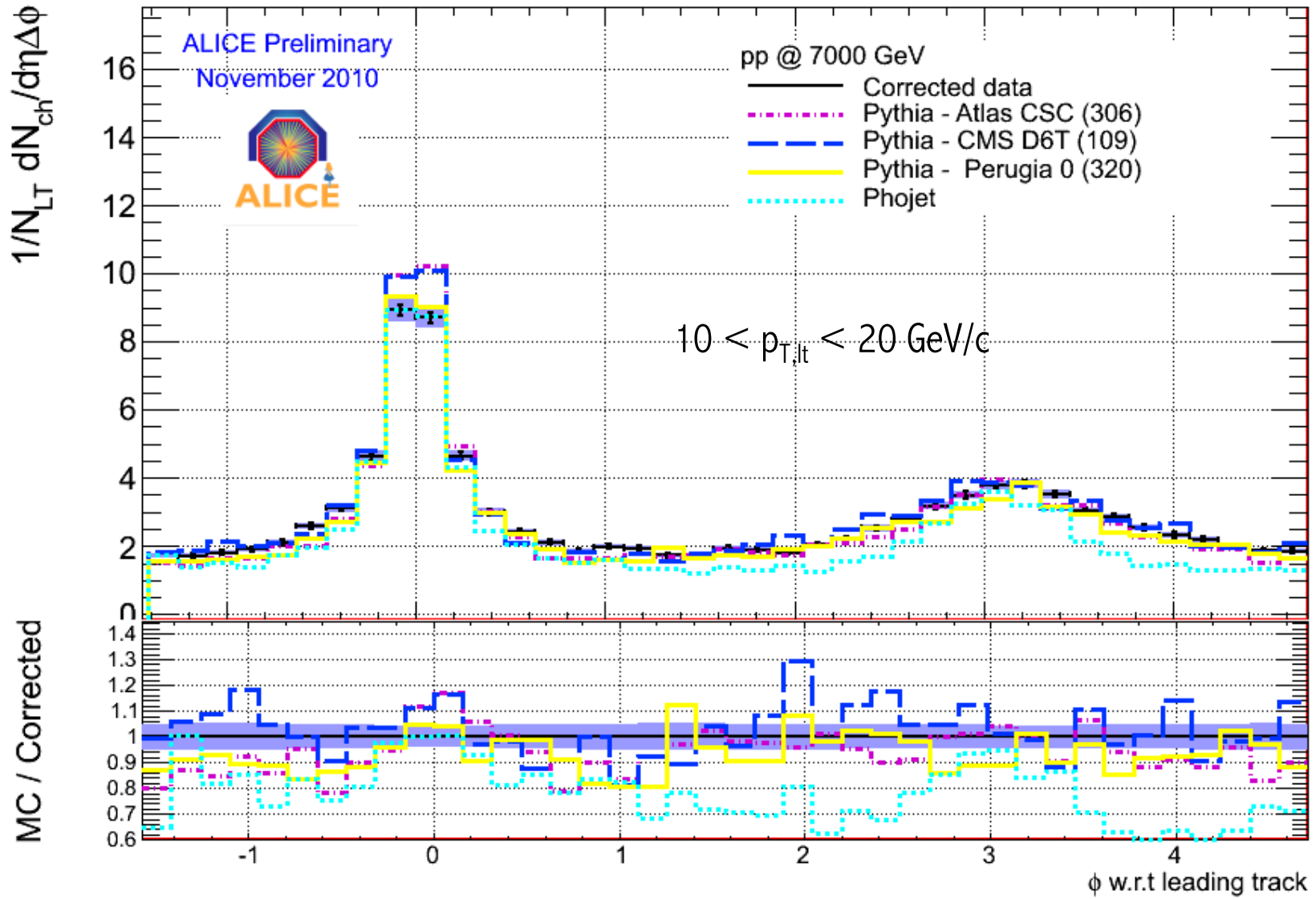
Azimuthal correlation between leading track and all tracks.










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/dηΔφ
MC / Corrected
φ w.r.t leading track