Event characterization in ALICE

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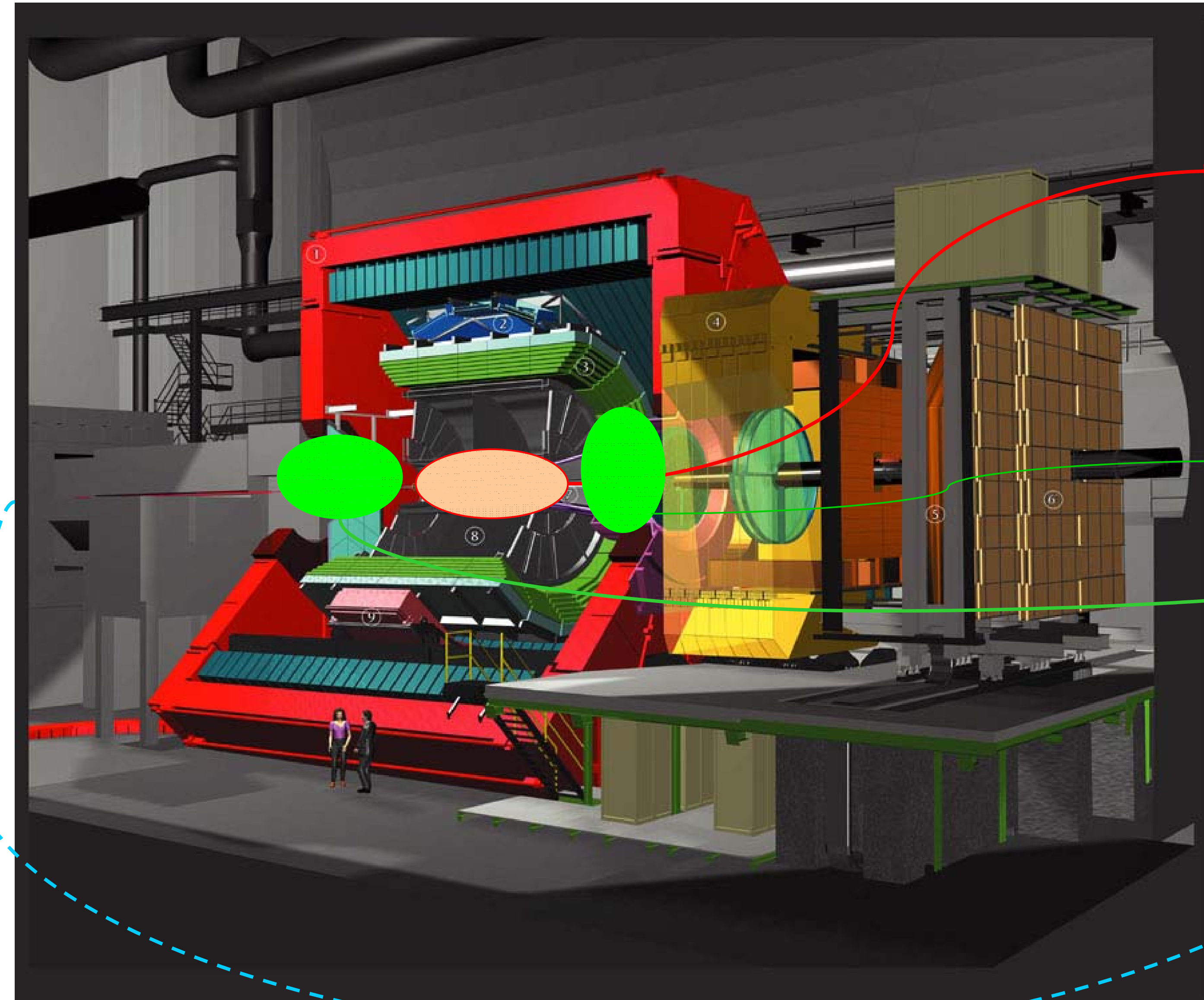
for the ALICE Collaboration

- **The ALICE detector**
- **Estimate of the centrality of the collisions (in PbPb and in pPb)**
- **Reconstruction of the charged particle multiplicity N_{ch} and of the $dN/d\eta$ distribution (in PbPb and in pp)**
- **Study of the dependence of the charged particle multiplicity on centrality (in PbPb)**
- **Conclusions**

The ALICE detector



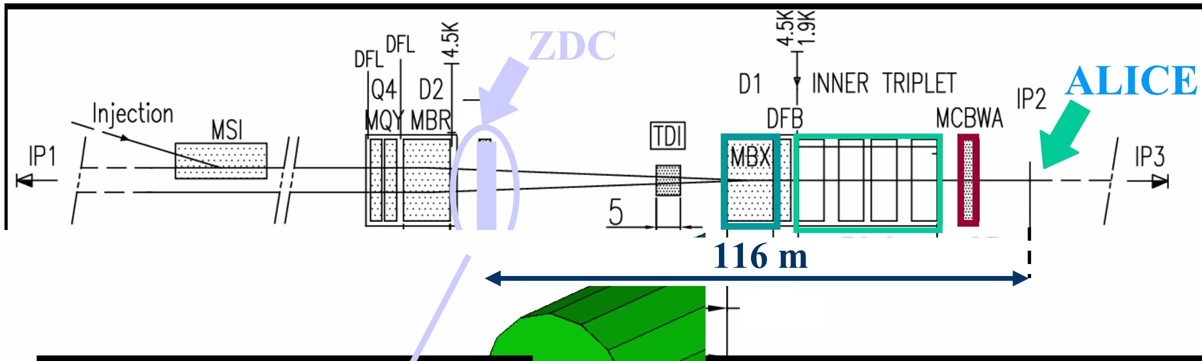
Relevant for event characterization:

Inner Tracking System (inside the TPC)

Forward Multiplicity Detectors

ZDC

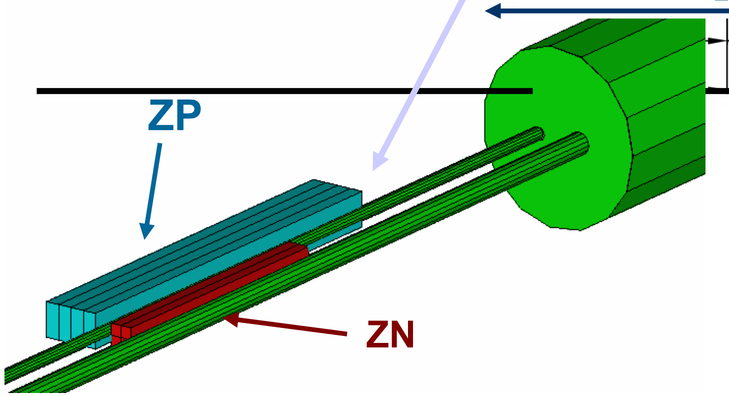
Centrality determination – PbPb collisions



• Dipole to compensate the field of the dimuon arm dipole

• Quadrupole triplet to focalize ion beams

• Dipole to separate beams



• Basic principle: $E_{ZDC} \rightarrow$ N. of spectators = E_{ZDC}/E_{beam}

Problems:

•Proton acceptance ≠ 100%
(non-trivial function of the beam optics)

•Knowledge of spectator fragmentation is crucial
• model based on the ALADIN Au-Au data
+ deuterons (estimated from NA49)

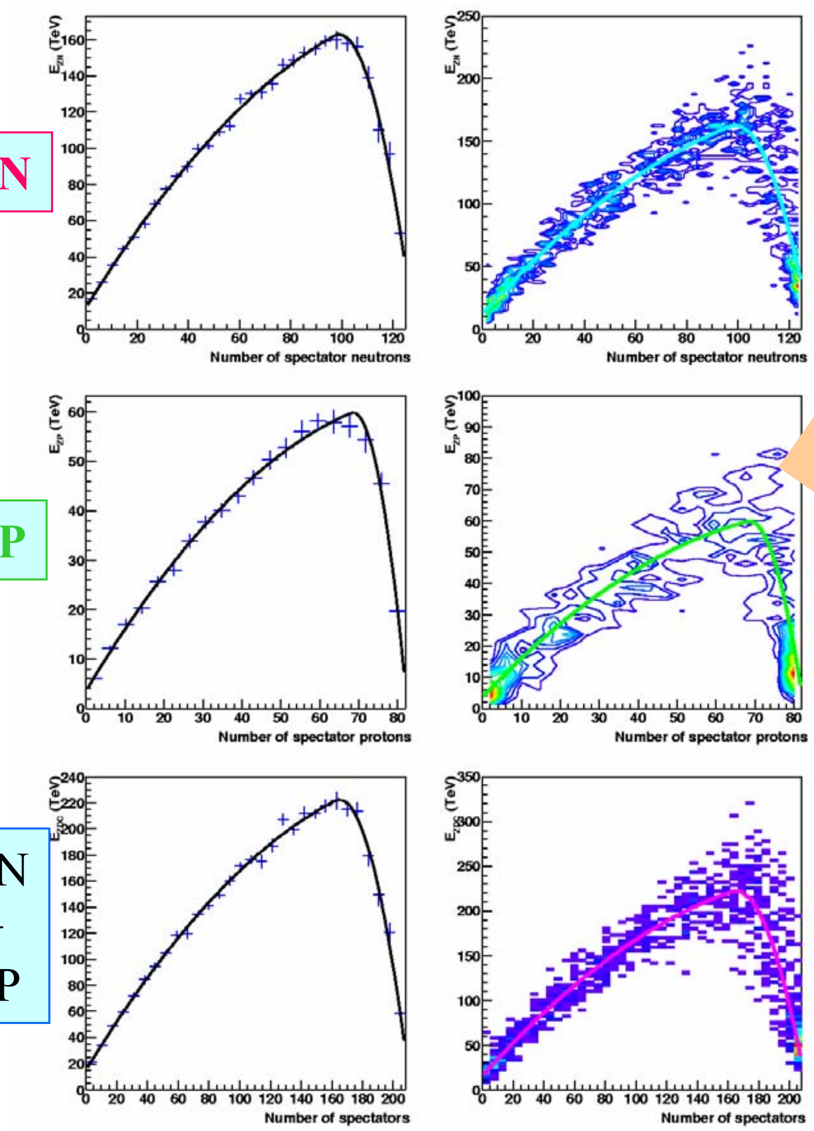
Two methods to estimate centrality of PbPb collisions from E_{ZDC} were developed

1. Event by event determination of the centrality

ZN

ZP

ZN + ZP



- **The method makes use of the correlation between the rec.energy in the ZDCs and the centrality variables b and N_{part}, as simulated with HIJING.**
- **Correlation in both calorimeters versus spectator protons and neutrons are shown**

- **<u>Spectator nucleon losses</u> (incomplete fragmentation) important for peripheral events. Correlation not monotonic**
- **Need an external information to solve this ambiguity**

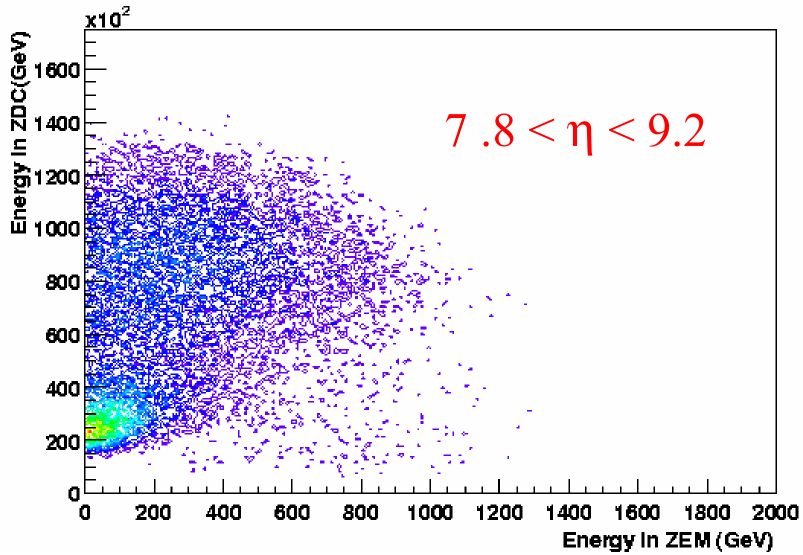
- **Use a forward e.m. calorimeter (ZEM) to have a (fast) way of selecting between the two branches of the correlation**

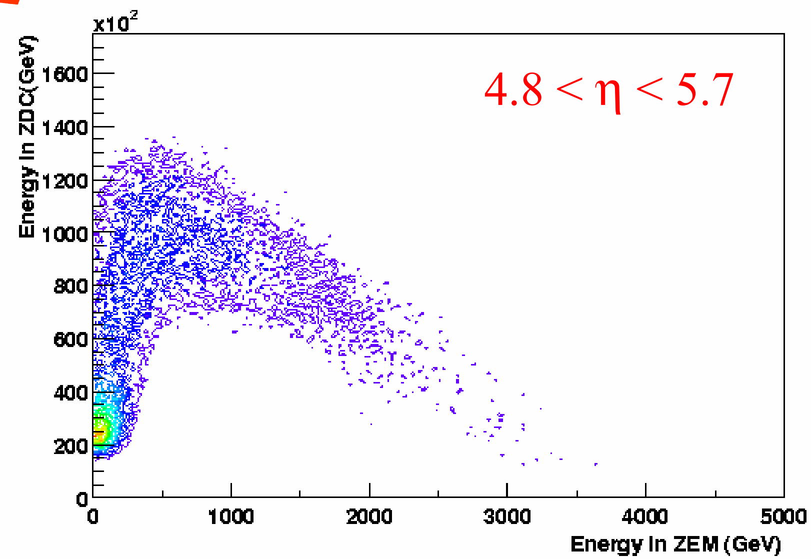
The ZEM (Zero degree EM Calorimeter)

- **We need a signal with relatively low resolution, but whose amplitude increases monotonically with centrality**

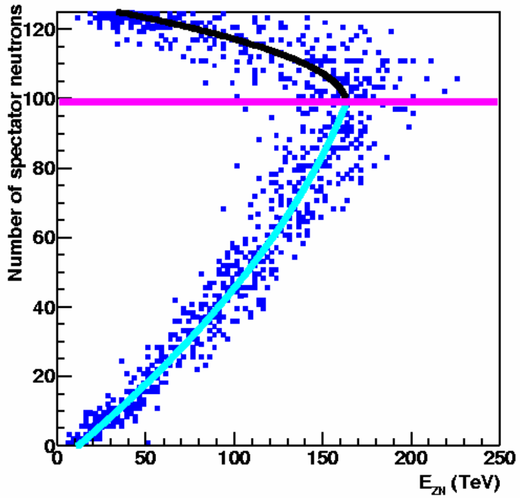
- **Initial position proposed for this device @ 116 m from IP (ZDC location)**
- **We realized afterwards that this is too forward ($7.8 < \eta < 9.2$)**

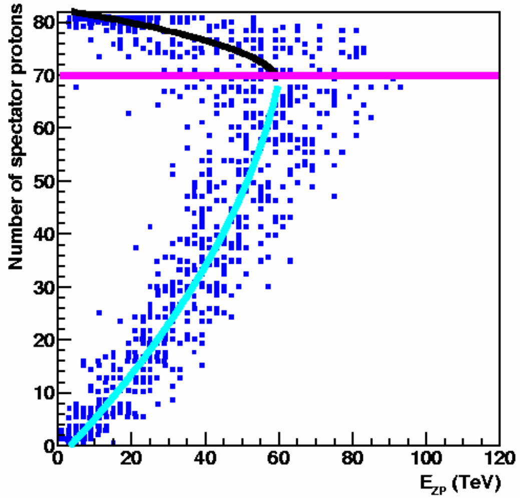
- **Shifted the calorimeter to a position @ ~ 7m from the IP**
- **Rapidity coverage $4.8 < \eta < 5.7$**



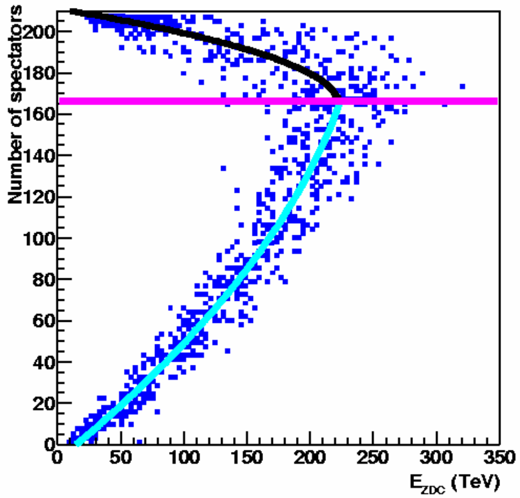


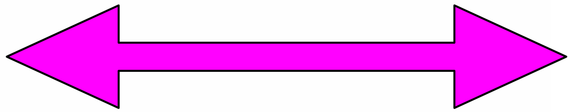
Use of the ZEM signal to solve the ambiguity

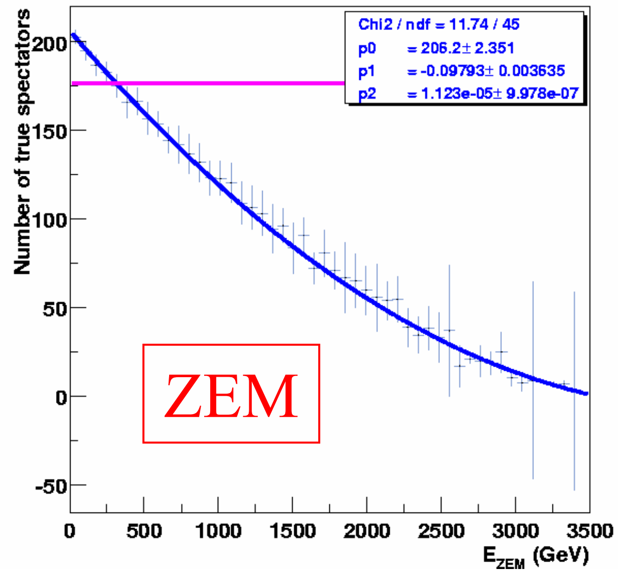




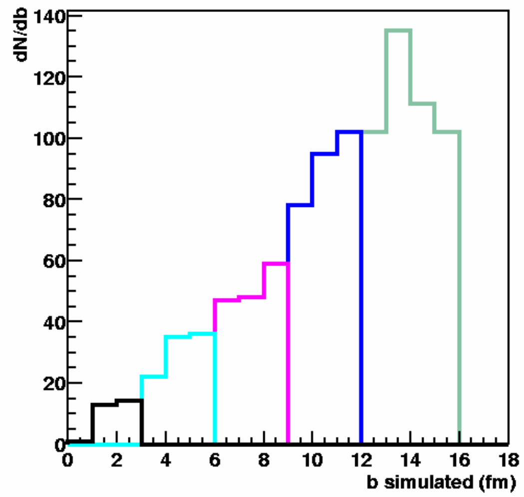
The value of E_{ZEM} corresponding to the same number of spectators at the bend of the correlation plots (E_{ZDC} vs N_{spect}), can be used as a threshold value for discriminating, at fixed E_{ZDC}, between the two branches.

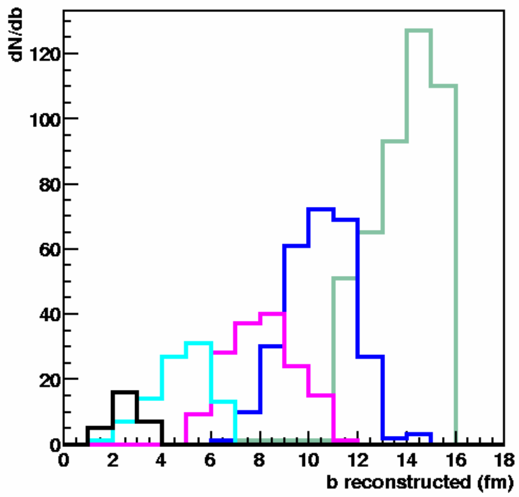






Results: centrality classes in b and N_{part}

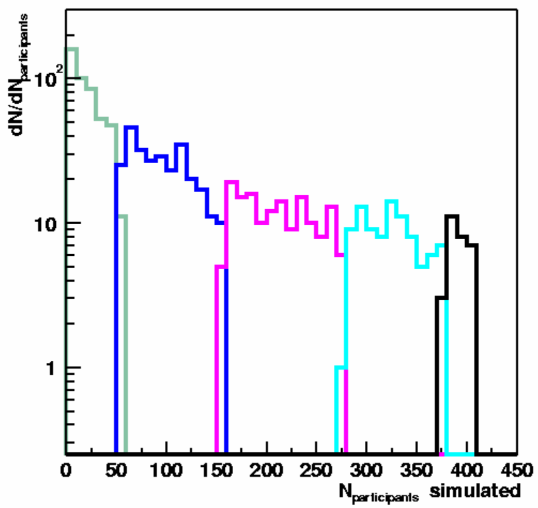


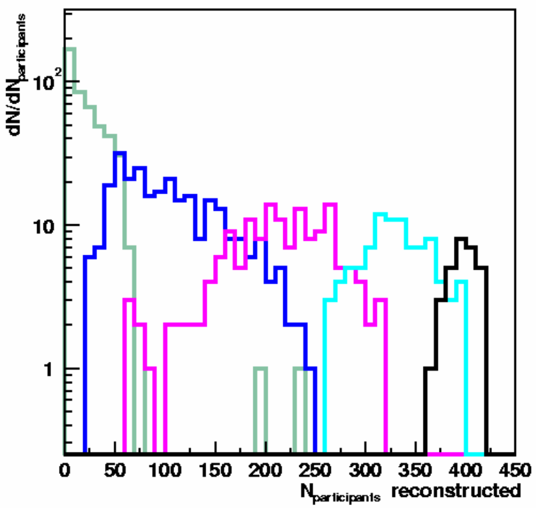


b range	$<b^{sim}>$ (fm)	$<b^{rec}>$ (fm)
0-3 fm	2.1 ± 0.6	2.6 ± 0.6
3-6 fm	4.7 ± 0.8	4.8 ± 1.1
6-9 fm	7.6 ± 0.8	8.1 ± 1.3
9-12 fm	10.6 ± 0.9	10.4 ± 1.4
12-16 fm	14.0 ± 1.1	13.8 ± 1.4

- **No significant bias in the reco.**
- **RMS<separation between classes**

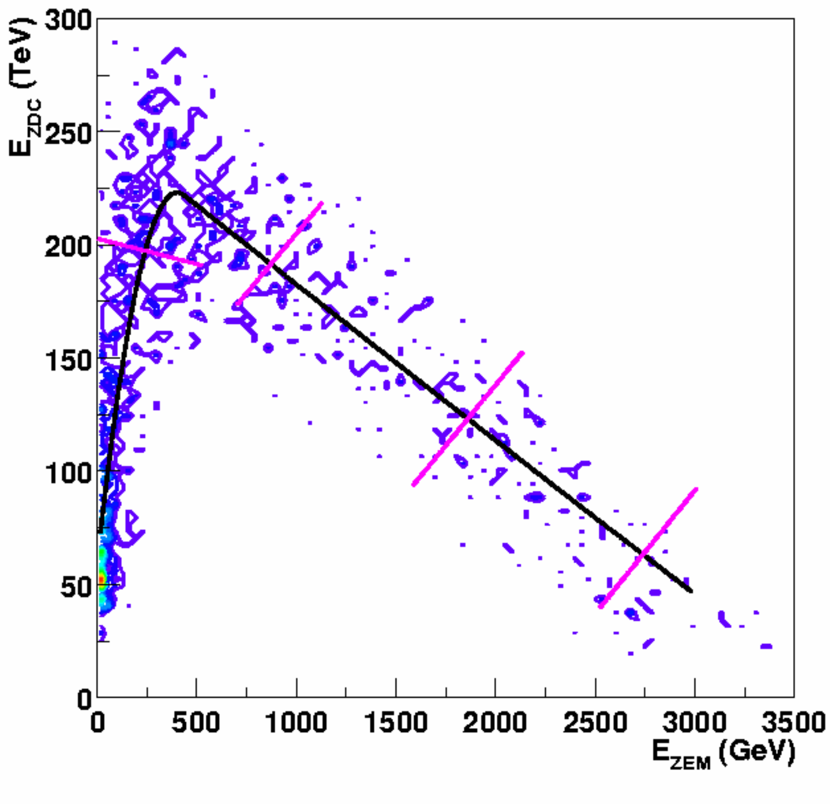
5 centrality bins can be safely defined





N^{sim}_{part} range	$<N^{sim}_{part}>$	$<N^{rec}_{part}>$
375-414	391 ± 10	395 ± 14
276-375	323 ± 28	329 ± 33
152-276	210 ± 35	211 ± 54
54-152	94 ± 28	104 ± 51
0-54	18 ± 14	21 ± 22

2. Centrality determination using E_{ZEM} vs E_{ZDC} correlation



Consider the experimental correlation E_{ZDC} vs E_{ZEM} (reconstructed variables)

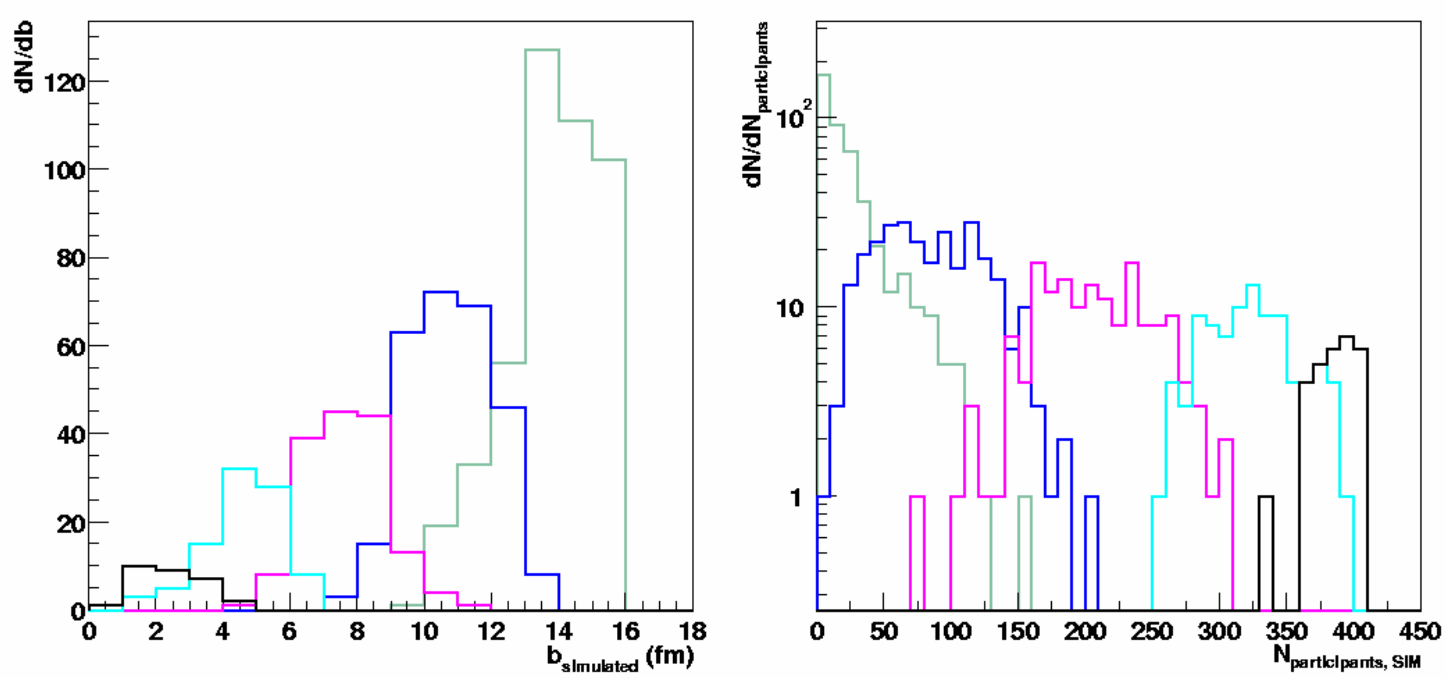
Select, perpendicularly to the correlation, event classes corresponding to regions (E_{ZEMi}, E_{ZDCi}) in the E_{ZDC} vs E_{ZEM} plane, such that

$$\iint_{E^1_{ZEM},E^1_{ZDC}} \frac{d^2\sigma}{dE_{ZEM}\,dE_{ZDC}} = \int_0^{b1} db \frac{d\sigma}{db} = x_1 \cdot \sigma_{tot}$$

where the relationship between b_i and x_i is determined by the shape of dσ/db calculated geometrically or through a Glauber model (similarly for N_{part})

This method, being based exclusively on experimental quantities, does not depend on the particular model used for the simulation

Classes in b and N_{part}: results of the second method



$b_{simulated}$ range	$<b_{sim}>$ (fm)	$<b_{reco}>$ (fm)	$<N_{part}^{sim}>$	$<N_{part}^{reco}>$
0-3 fm	2.1 ± 0.6	2.5 ± 0.9	391 ± 10	385 ± 17
3-6 fm	[illegible]	[illegible]	[illegible]	[illegible]
6-9 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9-12 fm	10.6 ± 0.9	10.8 ± 1.3	94 ± 28	84 ± 39
12-16 fm	14.0 ± 1.1	13.8 ± 1.4	18 ± 14	23 ± 25

Performance comparable to the first method

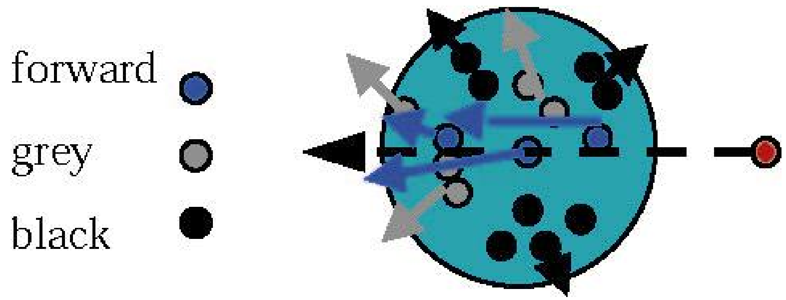
Centrality selection in pA collisions

- By studying pPb collisions in ALICE it will be possible to estimate the importance of initial and final state nuclear effects not connected with the creation of a hot medium.

- To properly understand pPb collisions, it would be helpful performing a centrality selection, through the estimate, event by event, of the number N_{coll} of binary collisions

- However in pA N_{coll} is loosely correlated with the inclusive measurement of charged multiplicity

- Possible way out → Measure grey/black nucleons (slow particles emitted by the target nucleus)

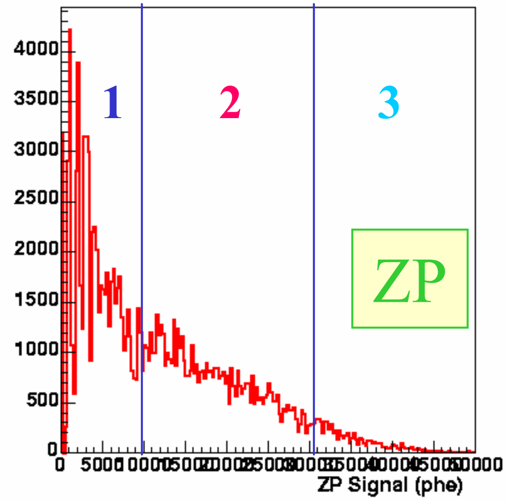


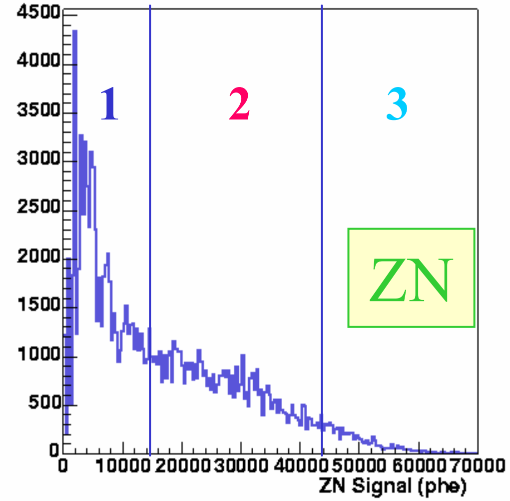
- Successfully performed at fixed target experiments (BNL-E910, NA49)

- What about colliders ? Emitted slow nucleons are Lorentz-boosted → **ZDC are the ideal detectors to measure the total energy deposited by grey/black nucleons (approach recently followed at RHIC)**

Centrality selection in pA by using cuts on E_{ZDC}

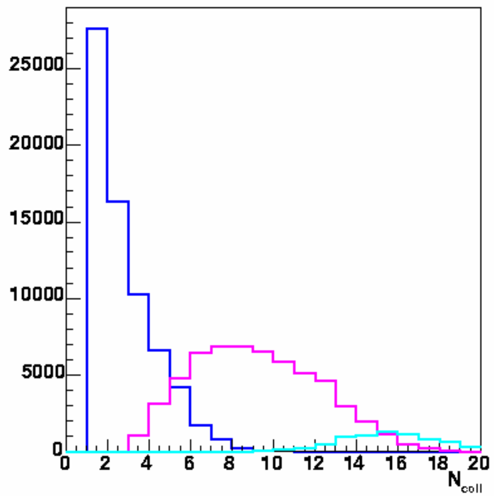
- **pPb collisions simulated with HIJING (that gives b and N_{coll} distributions)**
- **Slow nucleons sampled according to a model based on exp.data; then they are transported through the detector**
- **Result: the response of ZP and ZN calorimeters to slow nucleons (black and grey nucleons not separated)**

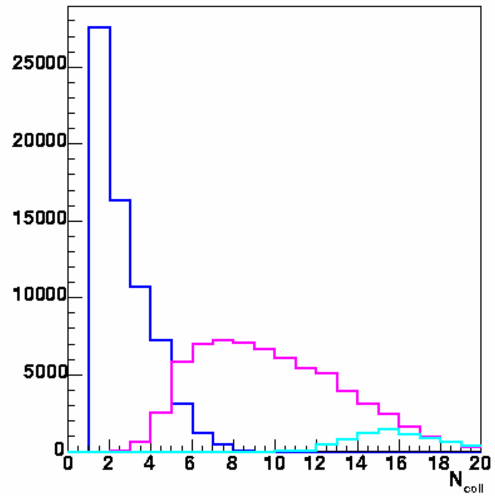




- **Selected 3 classes from ZDC spectra corresponding to defined intervals of σ_{pPb} fractions, and to intervals of N_{coll}**

	$\langle N_{coll} \rangle$ (ZP)	$\langle N_{coll} \rangle$ (ZN)
50÷100 %	2.3 (RMS 1.6)	2.2 (RMS 1.4)
5÷50 %	8.7 (RMS 3.0)	9.4 (RMS 3.5)
0÷5 %	14.9 (RMS 2.2)	15.2 (RMS 2.0)



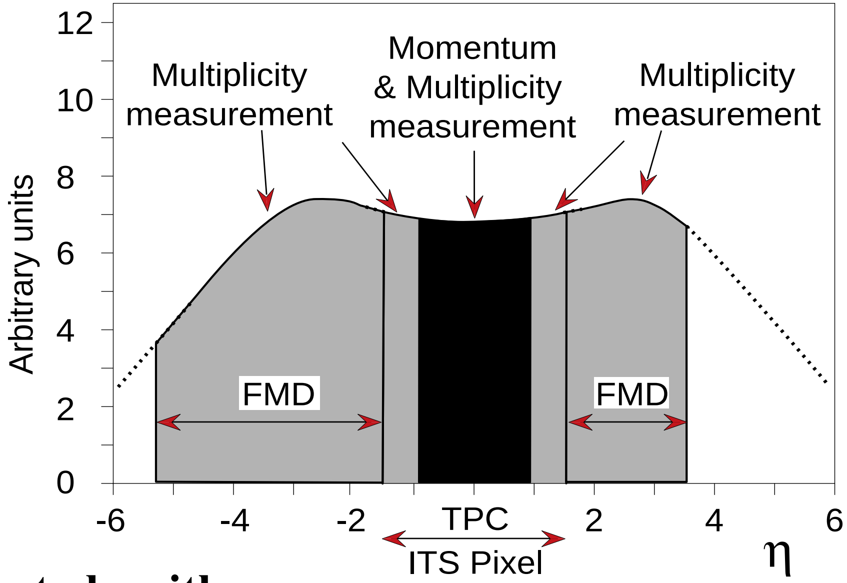


We can safely select 3 centrality bins in pA by grouping events in E_{ZDC} classes

Multiplicity measurements

- **Two detectors:**
  - **SPD (Silicon Pixel Detector, 2 cylindrical layers) in the central region;**
  - **FMD (Forward Multiplicity Detector, 5 rings of silicon strips) at forward rapidities.**

The charged particle multiplicity is measured over 8.8 rapidity units, whereas the momentum is measured in the TPC (and in the Inner Tracking System) over 1.8 rapidity units with optimal resolution.



SPD

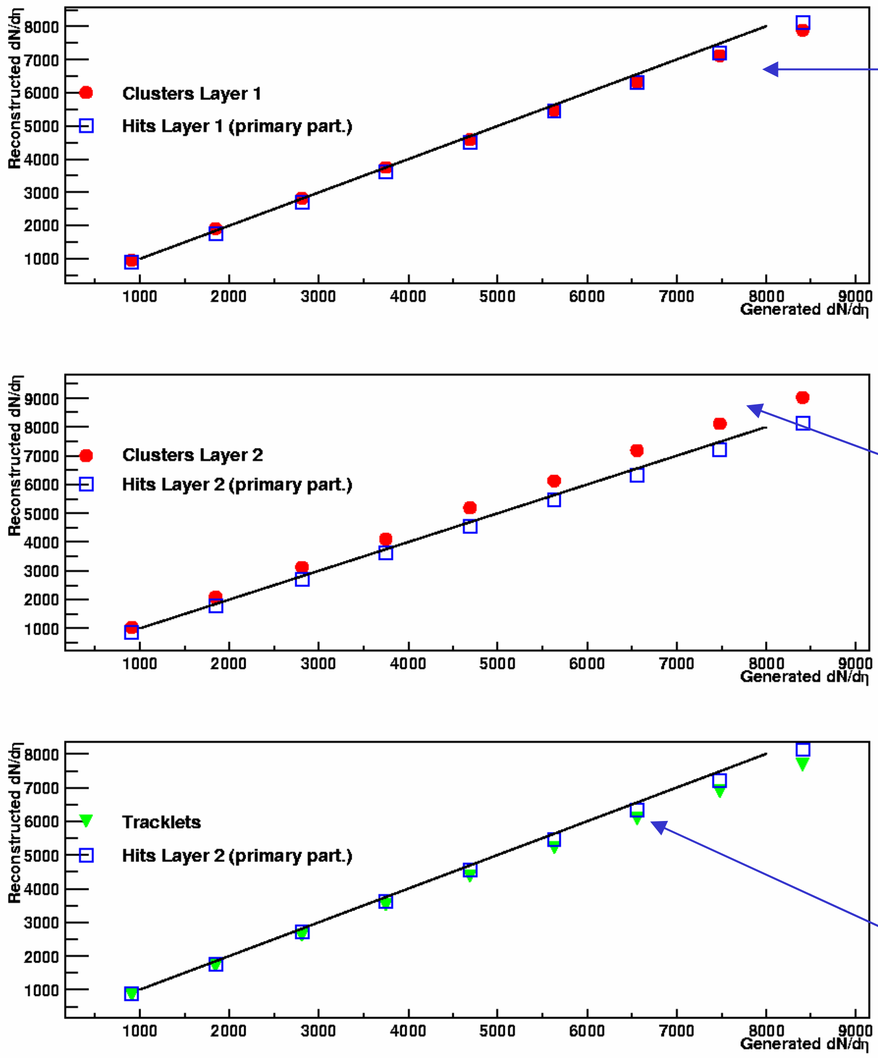
We have chosen two relatively simple and fast algorithms:

1) **cluster counting on each pixel layer (|η|<2 first layer, |η|<1.4 second layer);**
2) **counting of tracklets (association of clusters on the two layers, aligned with the estimated vertex position) (|η|<1.4)**

FMD (-3.4<η<-1.7 and 1.7<η<5.1)

Reconstruction of multiplicity based on empty pad counting.

Multiplicity reconstruction in PbPb with the SPD (I)



Layer 1 → small geometrical losses + cluster merging

Cluster counting: more sensitive to the background level

Layer2 → Secondaries produced in layer 1 +double hits (geometry)

Tracklets: more effective background rejection

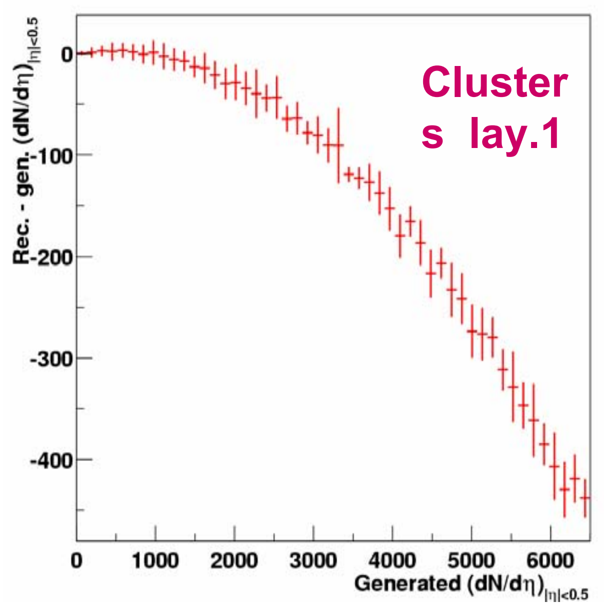
Association efficiency decreases for very high multiplicity

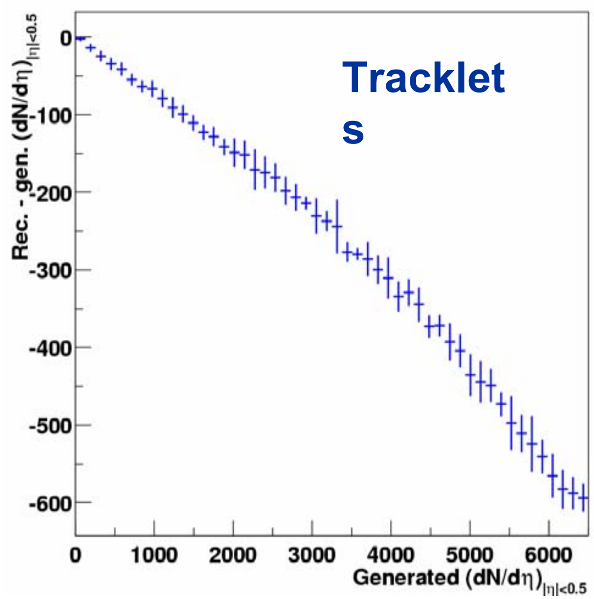
Multiplicity reconstruction in PbPb with the SPD (II)

Accuracy on the reconstructed Multiplicity:

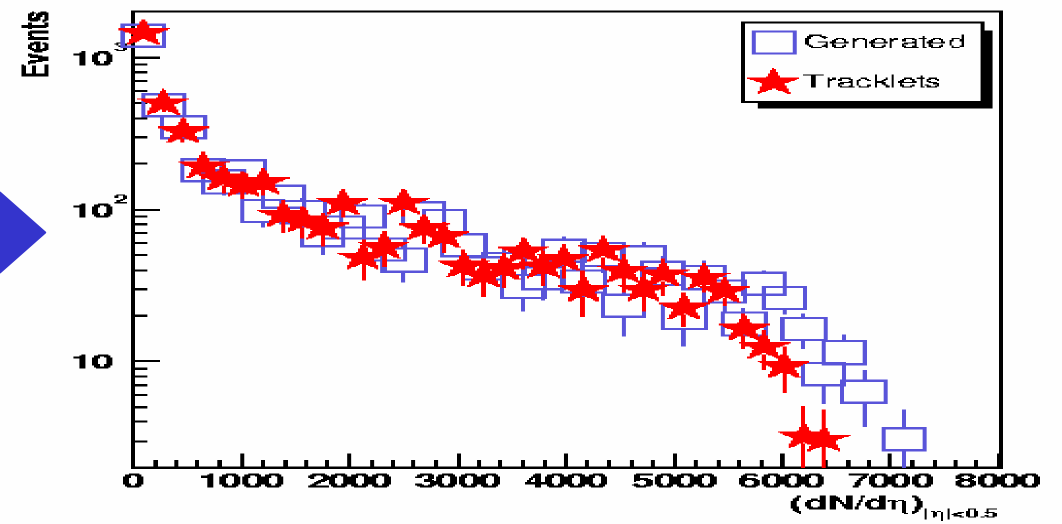
Clusters on layer 1 and tracklets BOTH slightly underestimate multiplicity

Difference <10%





Reconstructed multiplicity distribution with tracklets (HIJING events)

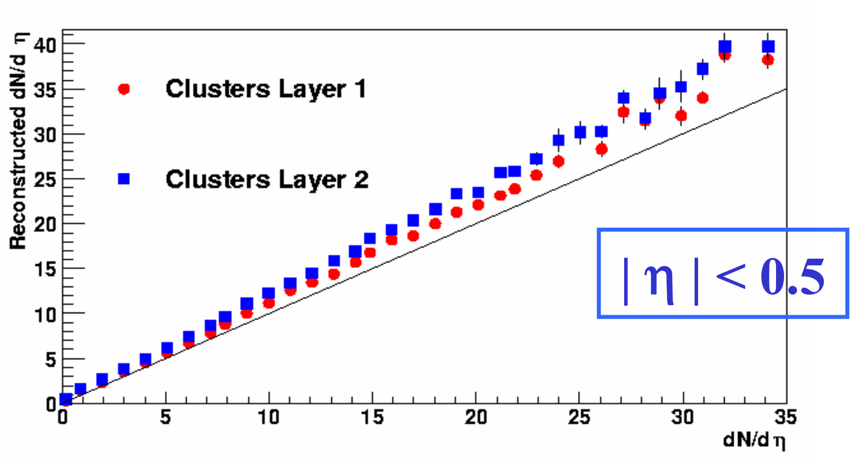


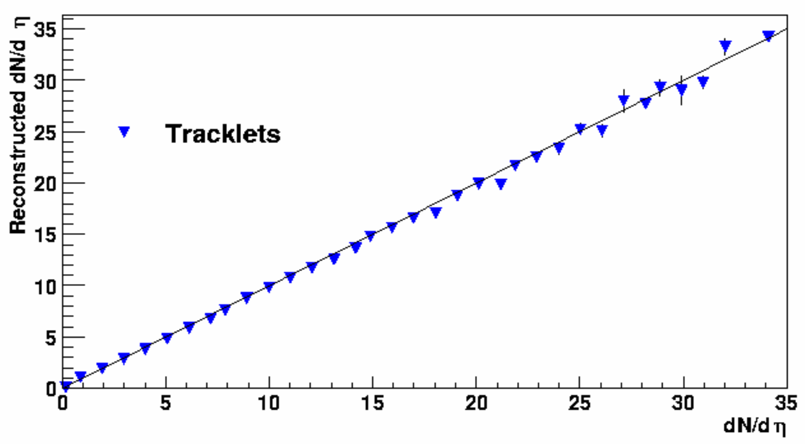
Multiplicity reconstruction in pp with the SPD (I)

Main problems with respect to the same measurement in PbPb events:

In the **low multiplicity environment**:

1) **statistical fluctuations of background** can become not negligible compared with the signal;
2) the **vertex position is not always available** (or the accuracy of its reconstruction is poor)



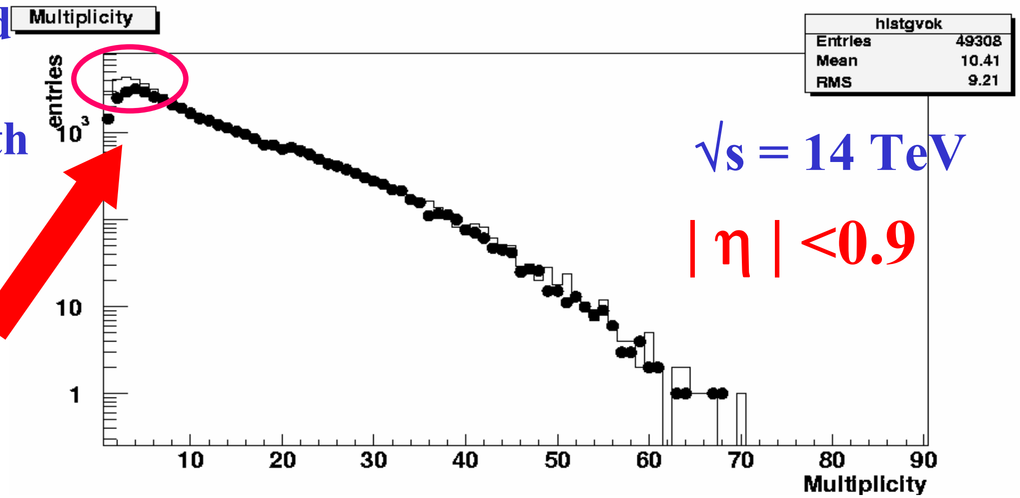


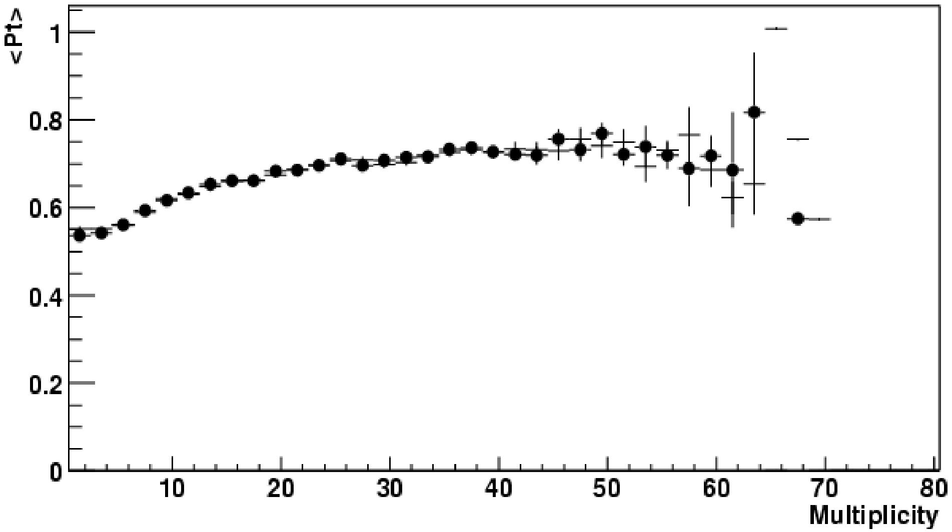
However:

1) The **effect of fluctuations can be reduced by using the tracklet method**. The low multiplicity allows to **enlarge the fiducial window** where clusters are associated to form a tracklet.
2) The **vertex position doesn't affect the cluster multiplicity**

Multiplicity reconstruction in pp with SPD (II)

Full simulation of pp events generated with PYTHIA 6.150 (pdf=CTEQ4L) Multiplicity distrib. reconstructed with tracklets, compared to the generated. Most of the systematics occurs at low multiplicities. The inefficiency of the tracklet algorithm is mainly due to the poor (or missing) vertex reconstruction for pp collisions





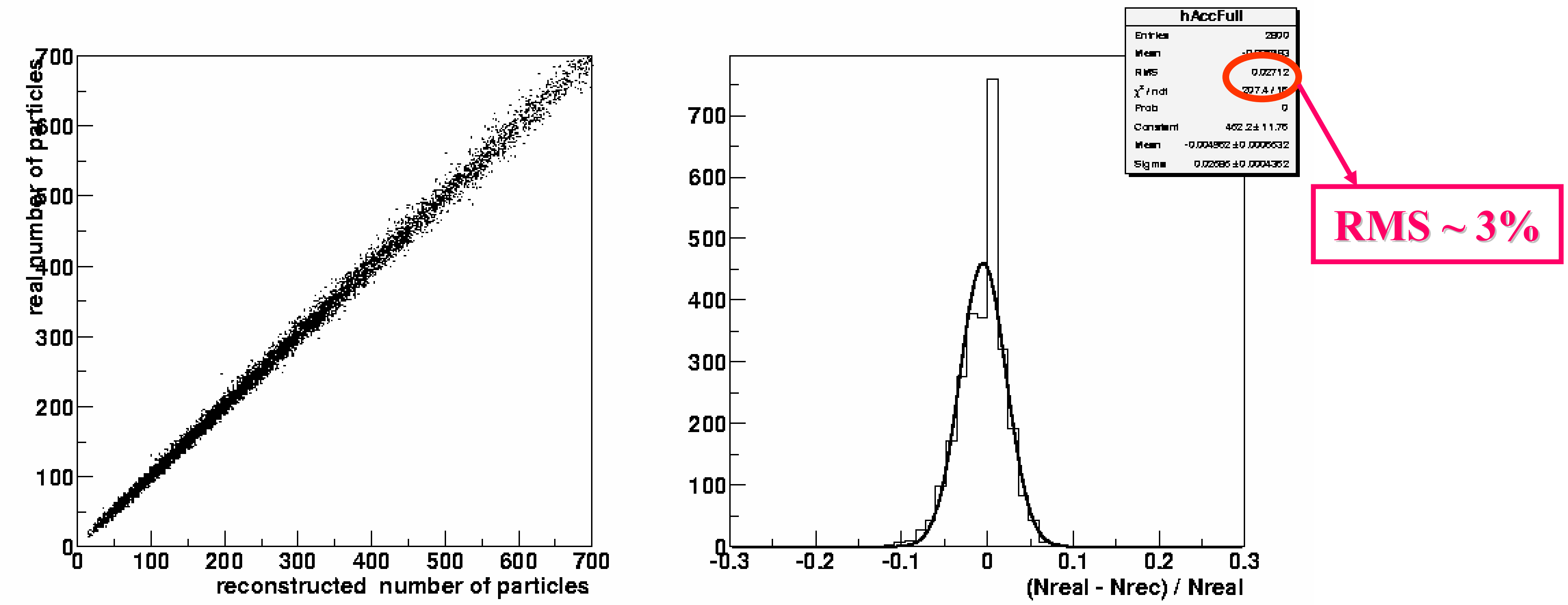
- **p_T of a track measured with TPC+ITS**
- **Correlation $\langle p_T \rangle$ vs multiplicity already studied at UA1 and Tevatron (onset of gluon radiation, minijets ??)**

- **Also for identified particles (very powerful PID system in ALICE)**

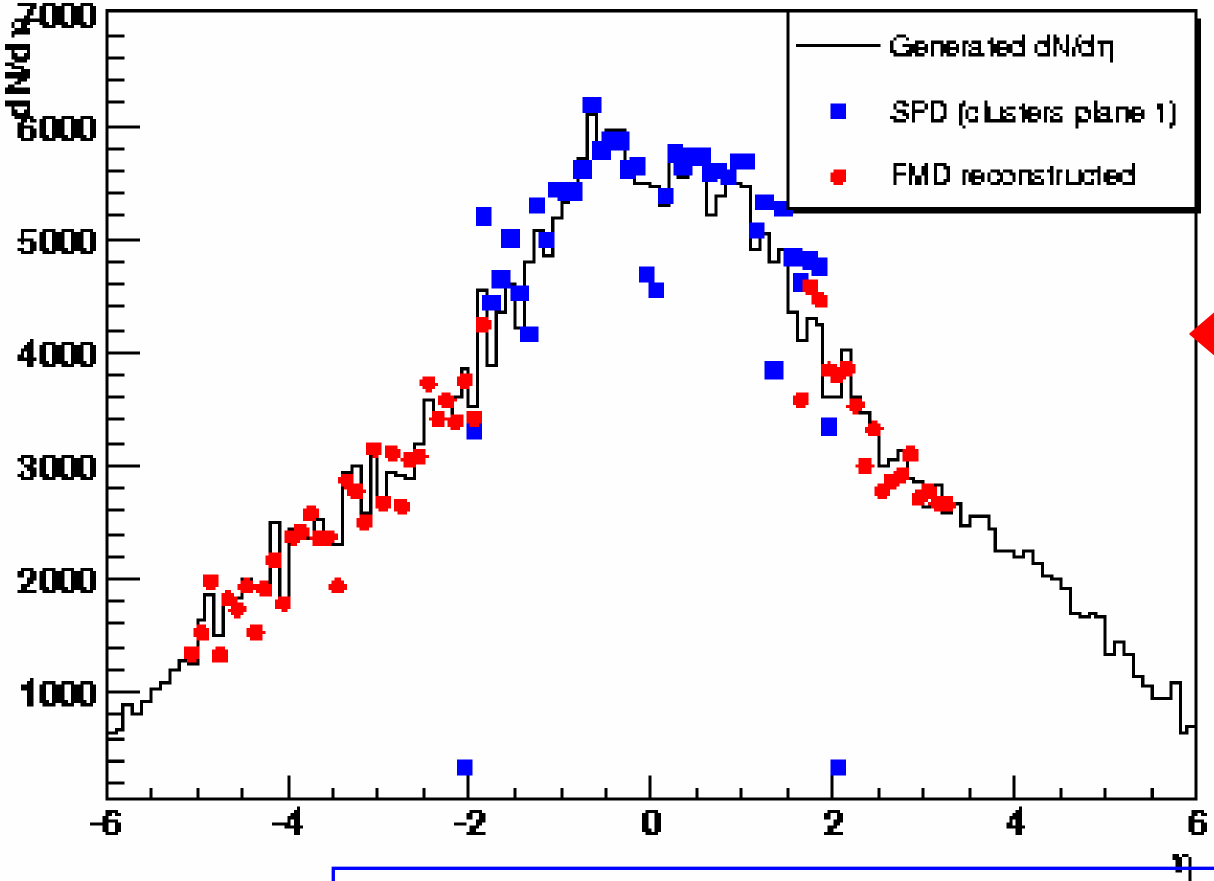
Multiplicity Rec. in the forward region with the FMD

- **Average detector occupancy ~ 1 (even larger for most central events)**
- **Multiplicity rec. based on counting of empty pads**
  - **Average occupancy $\lambda = -\ln P(0)$ (Poisson statistics) with $P(0) = N_{empty}/N_{tot}$**
  - **Multiplicity $n = \lambda \cdot N_{tot}$**

•Should be able to reach <u>an accuracy of a few percent on the multiplicity measurement</u>



Reconstruction of dN/dη distribution in Pb-Pb with FMD+SPD



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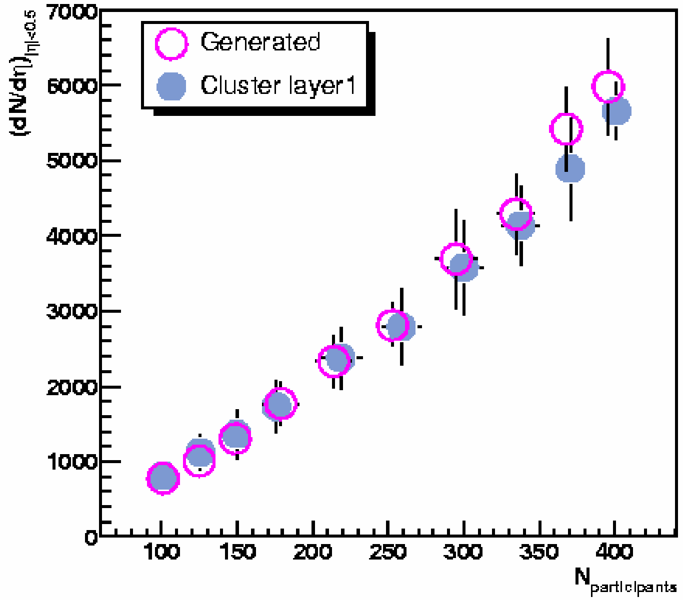
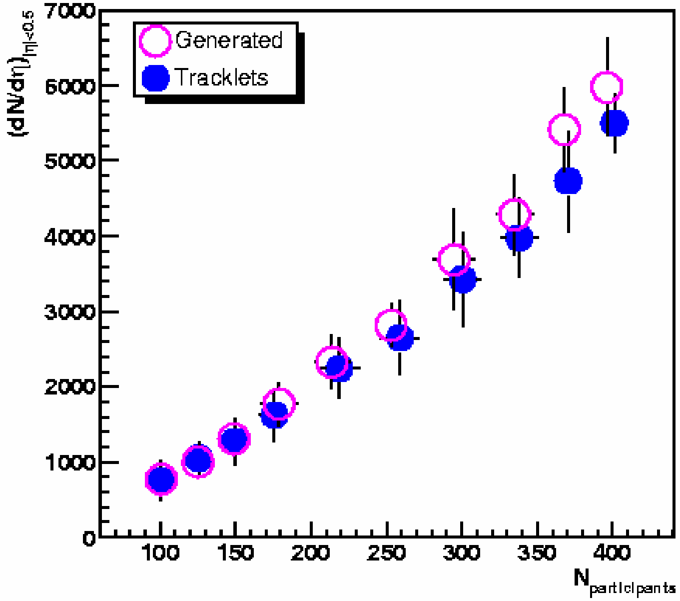
Central Pb-Pb HIJING event

- **We can have in ALICE a coverage up to ~ 10 η-units**
- **Accuracy ~ 7% in 0.1 η bins**

Study of multiplicity versus centrality (à la PHOBOS)





Multiplicity measured with SPD

10 centrality bins in N_{part} estimated event by event from the measured E_{ZDC}

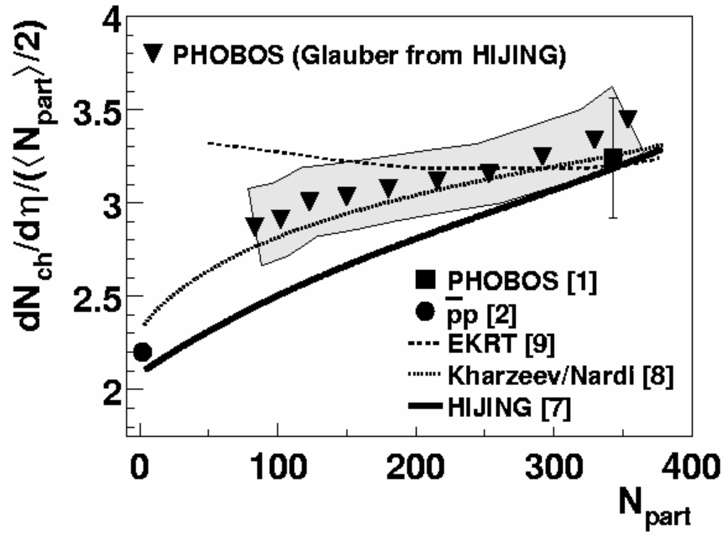
Fit with KN model

Kharzeev-Nardi model [Phys. Lett. B 507 (2001) 79]

$$\frac{dN_{ch}}{d\eta} = (1-x)n_{pp}\frac{N_{part}}{2} + x n_{pp} N_{coll}$$

$$n_{pp} = 2.5 - 0.25 \cdot \ln(s) + 0.023 \cdot \ln^2(s)$$

	x
Generated	0.61 ±0.03
Rec. clusters	0.60 ± 0.03
Rec. tracklets	0.57 ± 0.03



$N_{participants}$

Conclusions

Centrality

- **Pb-Pb collisions**
  - Two methods to measure centrality by using the ZDC have been investigated
  - Typical resolutions:
    - **$\sigma_{N_{part}}/N_{part}$ ~ 5 % for very central collisions**
    - **$\sigma_{N_{part}}/N_{part}$ ~ 25 % for semi-peripheral collisions (b ~ 8fm)**
  - Advantage of using ZDC: more direct connection with event geometry (independently of the hadro-production model)
- **p-Pb collisions**
  - **Demonstrated feasibility to select on N_{coll} using grey/black nucleons**
  - More model-dependent measurement with respect to Pb-Pb

Multiplicity

- **Pb-Pb collisions**
  - Analyzed the properties of various estimators of the charged hadron multiplicity involving the Silicon Pixel Detector (SPD) and the Forward Multiplicity Detector
  - **Checked the performance of ALICE for the combined measurement of the charged particle multiplicity (in SPD) versus centrality (with ZDC)**
- **p-p collisions**
  - Established the good performance of the multiplicity estimators defined with SPD