Study of the reaction plane reconstruction for HADES and CBM at SIS-100

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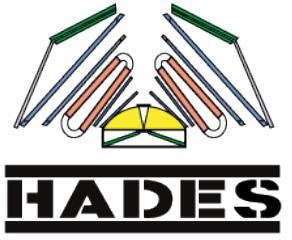
- ***FW results from HADES test beam 2011***
- ***Reaction plane reconstruction at CBM***

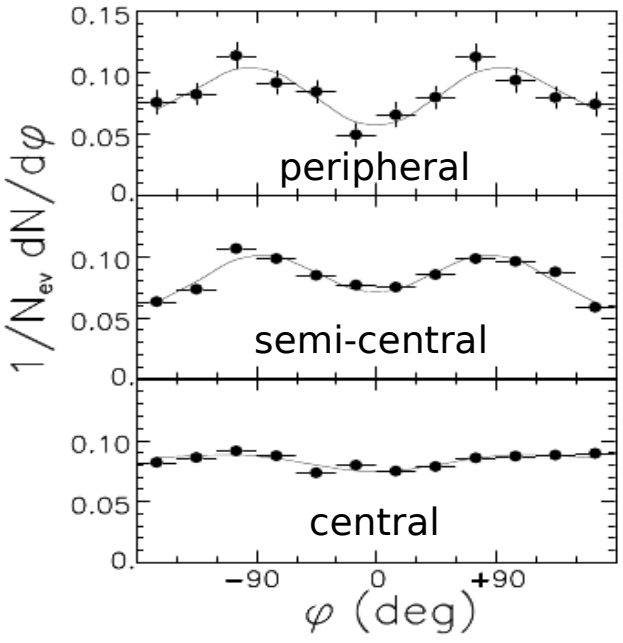
23rd Indian-Summer school of physics and 6-th HADES summer school
October 3 – 7, 2011
Rez/Prague, Czech Republic



Flow analysis and azimuthal angular distributions

Azimuthal angular distribution of K^+ for peripheral, semi-central and central events in collisions of *(Au@1AGeV)+Au by KaoS collaboration. PRL.81(1998)1576-1579*

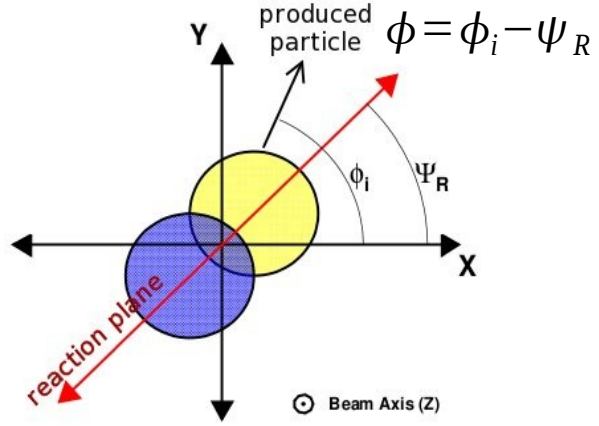
K^+ in (Au@1AGeV)+Au by (KaoS)



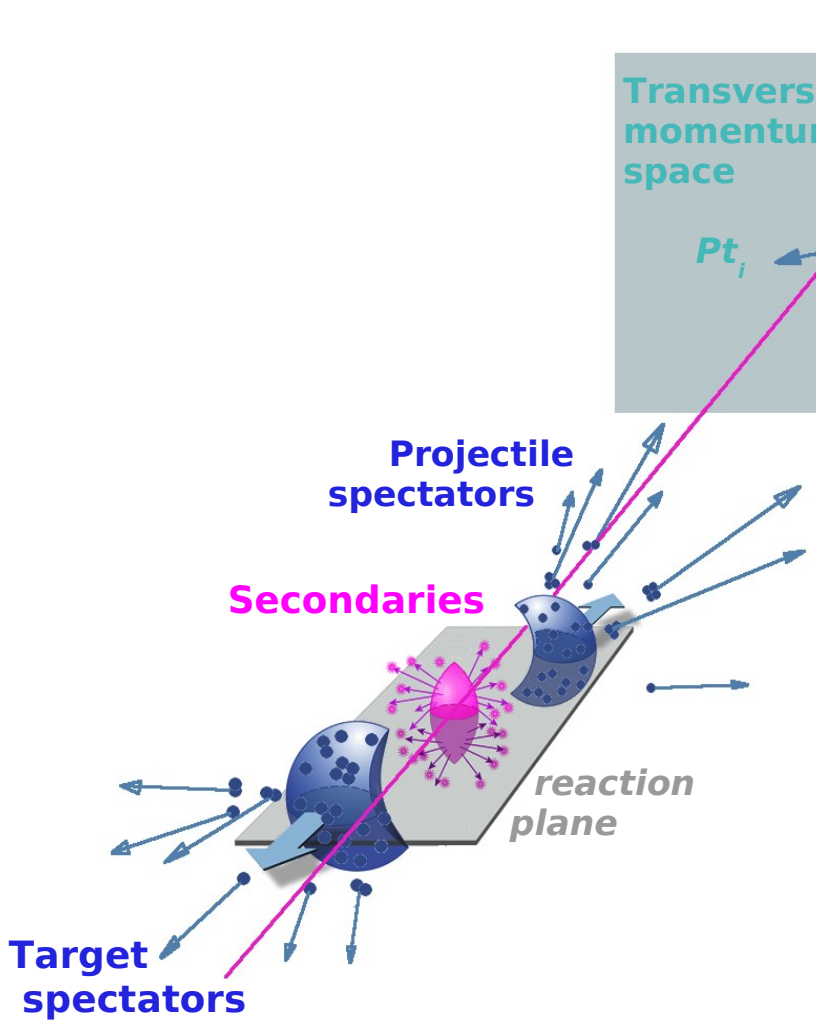
In the frames of Fourier decomposition of obtained azimuthal distributions:

$$\frac{dN}{d\phi} = C\left(1 + 2a_1\cos(\phi) + 2a_2\cos(2\phi)\right)$$

which allows determination of directed (a_1) and elliptic (a_2) flows one may draw conclusions about the in-plane and out-of plane emission of K^+, in medium potential...



Reconstruction of reaction plane
(transverse momentum method)



$$\vec{Q} = \sum_{i=1}^{Nsp} w_i \vec{p}_i^{\,t}$$

where:

Q – reaction plane vector;
Nsp – number of spectators detected;
w_i – weight factor:

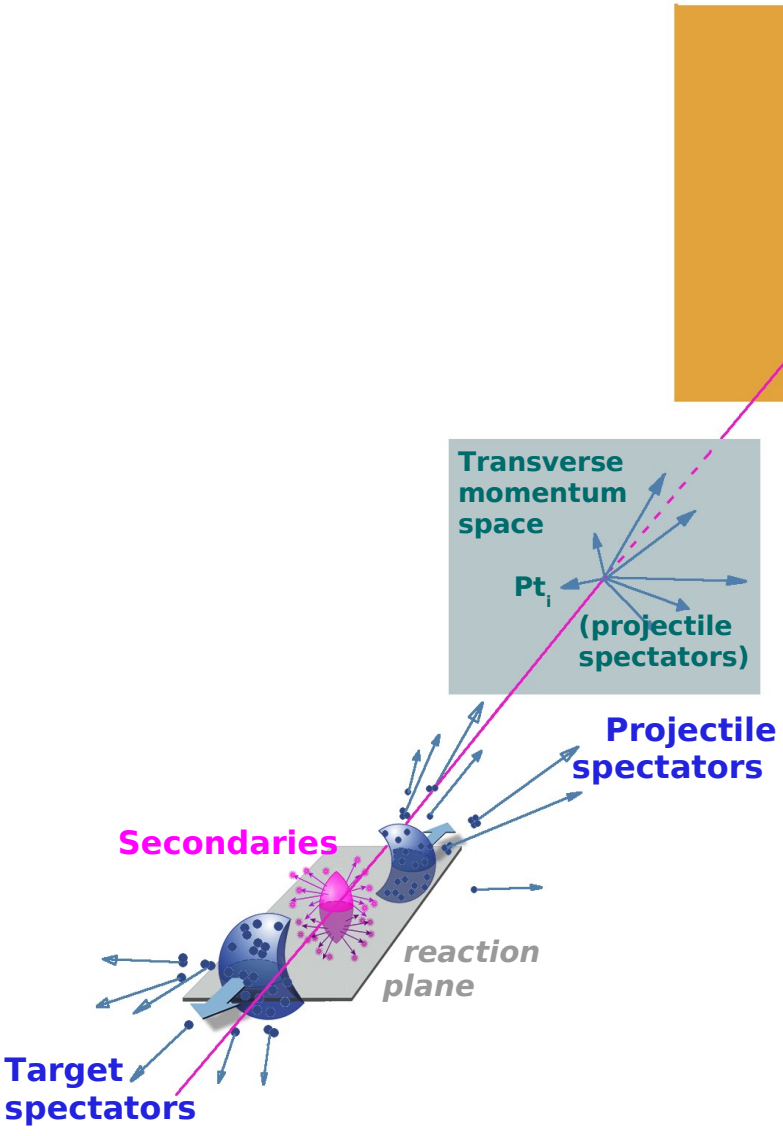
$w_i > 0$ flying forward,

$w_i < 0$ flying backward;

p_i^t – transverse momentum vector.

See e.g. [PL.157B,146,1985].

Reconstruction of reaction plane
(modified transverse momentum method)



$$\vec{Q} = \sum_{i=1}^{Nsp} w_i \frac{\vec{r}_i}{|\vec{r}_i|}$$

where:

Q – reaction plane vector estimate;
Nsp – number of fragments;
w_i – weight factor:

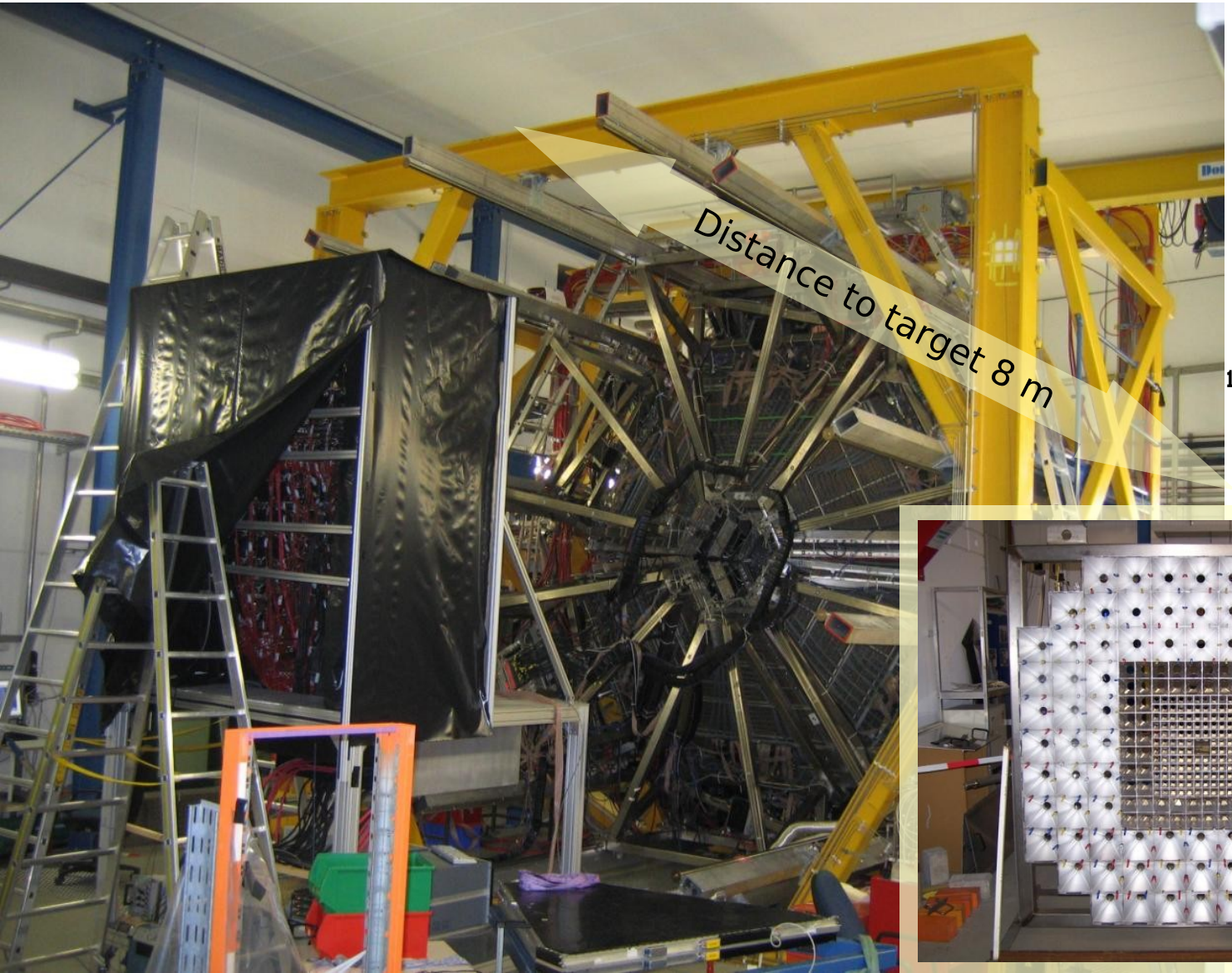
$w_i > 0$ if flying forward,

$w_i < 0$ if flying backward,

absolute value is set to mass (m) or charge (Z) of the spectator fragment;

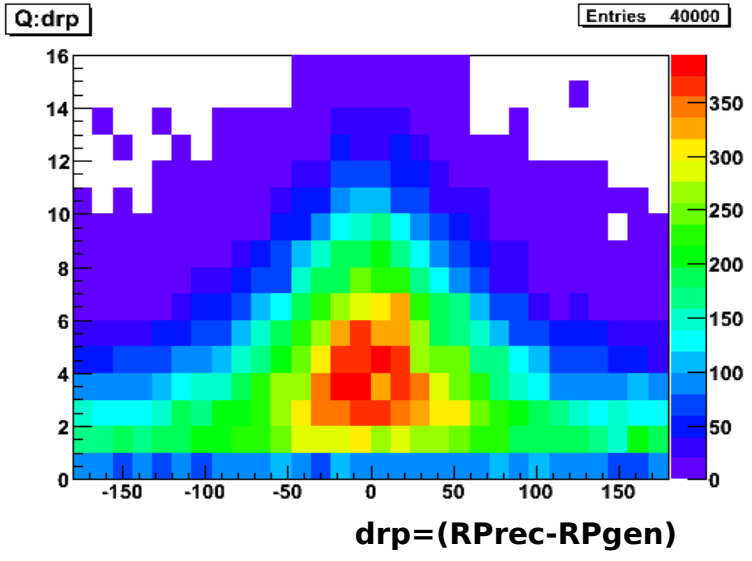
r_i – position vector of cell hit.

HADES Forward Wall, installed: March 2007
Fully operational: summer 2010, 2011



140 small 4x4cm
64 middle 8x8cm
84 large 16x16cm
cells

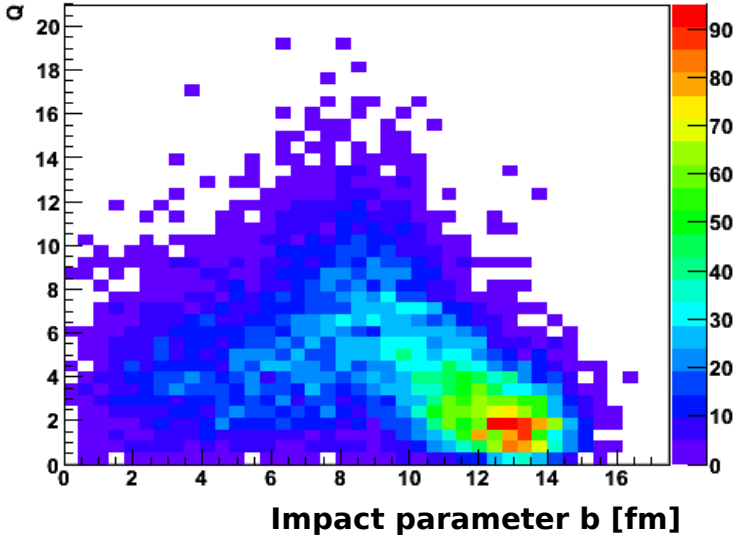
Simulation (Au@1.25AGeV)+Au SHIELD + hGeant

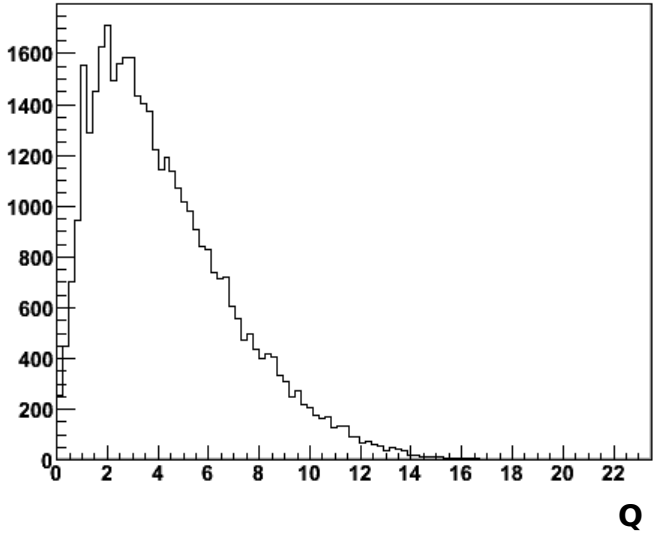


FW is 8m from target, spectators selected by time-of-flight.

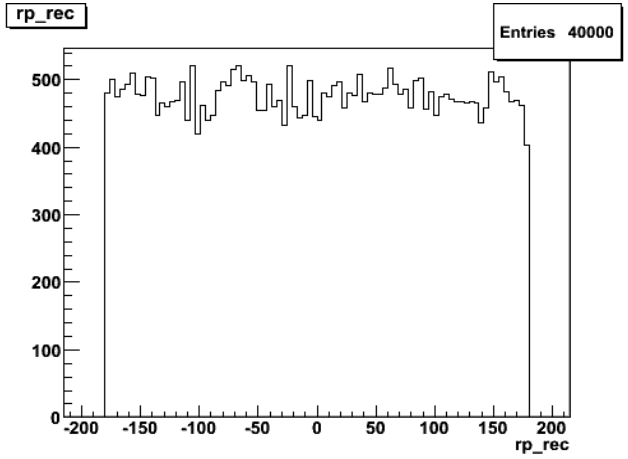
Higher values of |Q| lead to better reaction plane determination:
0<|Q|<4 : poor RP angle resolution
4<|Q|<14 : higher resolution

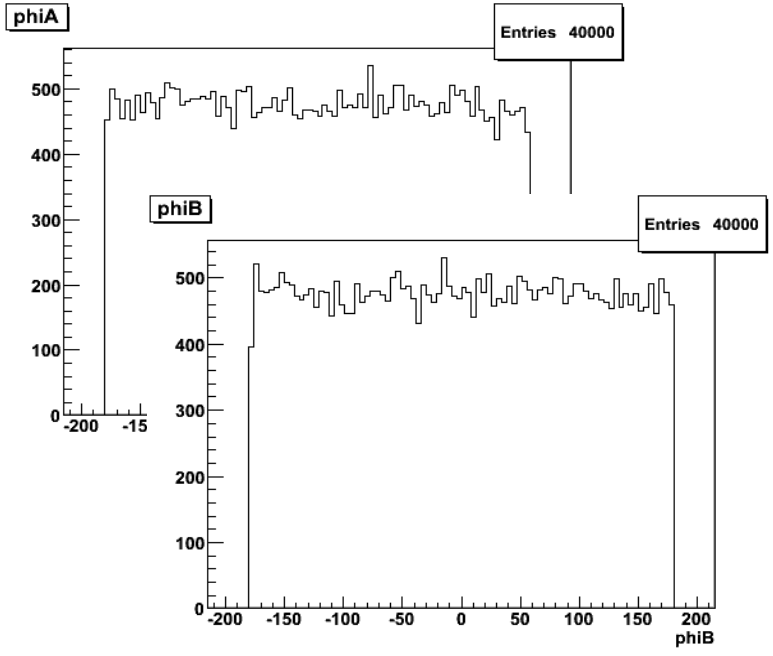
By selecting |Q|>4 we also suppress peripheral events





Simulation (Au@1.25AGeV)+Au SHIELD + hGeant



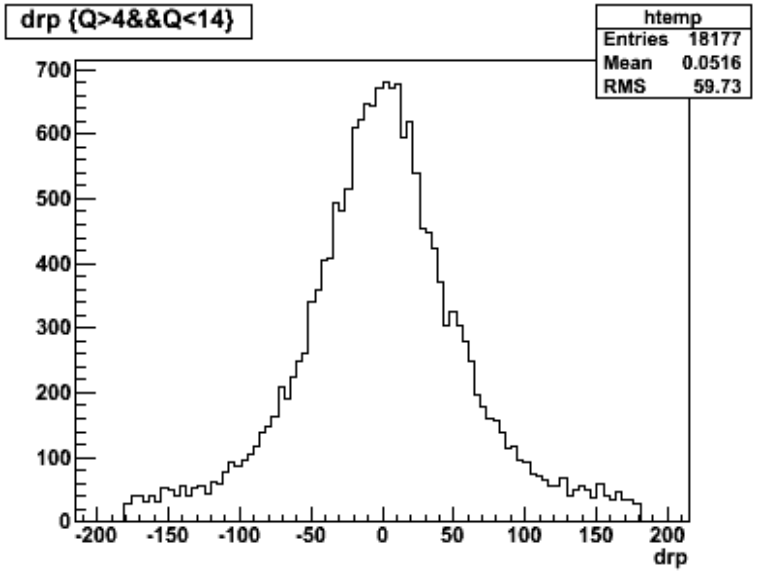


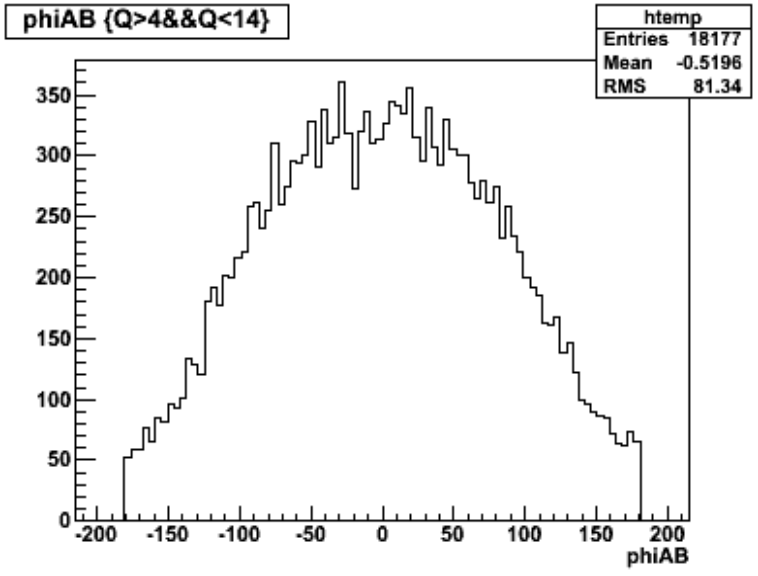
Standard procedure to estimate the resolution of the reaction plane determination in real data is following:
hits of an event are randomly divided into two equal groups: A and B determining the reaction plane in each group separately.

Reaction plane angle determination based on whole hits in FW of the event and in two subgroups A and B show flat distribution.

Difference between the reaction plane reconstruction in two subgroups determines the reaction plane resolution of the whole event.

Simulation (Au@1.25AGeV)+Au SHIELD + hGeant





Simulation w/o trigger conditions:
Event selection: for 4<|Q|<14

reaction plane angle resolution for all hits in FW from each event:

RMS=60°

Gaussian fit sigma=48° (in central part)

Gaussian fit sigma=37° {5<b<10 & Q>6} / K.Lapidus HADES coll.meeting. 2010 /

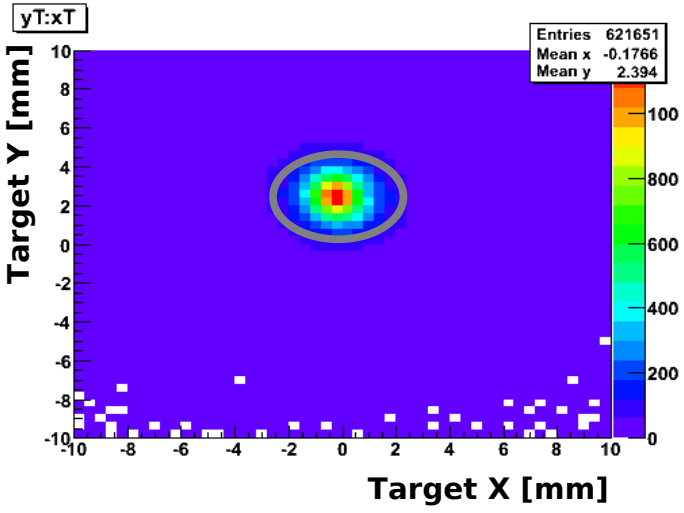
NB: the estimate is done comparing with reaction plane from SHIELD.

Estimate of reaction plane resolution from two subgroups (A and B) of hits in each event:

RMS=81.34°/√2 = 58°

i.e. in a good agreement with the one obtained with knowledge of reaction plane angle from simulation.

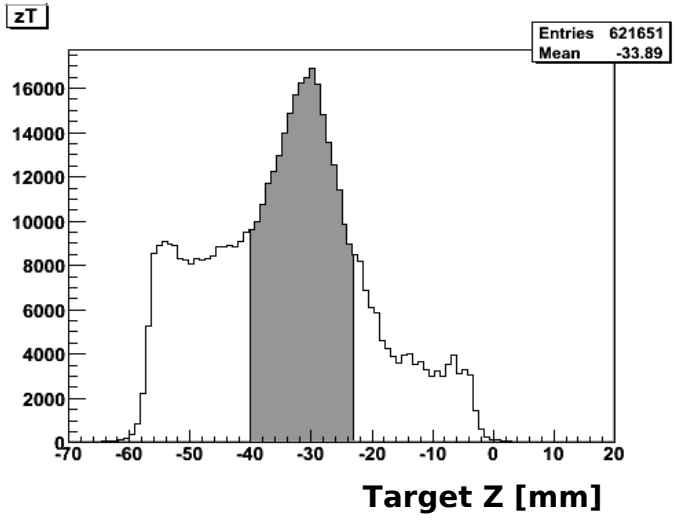
(Au@1.24AGeV)+Au HADES 2011 test beam (events selection)

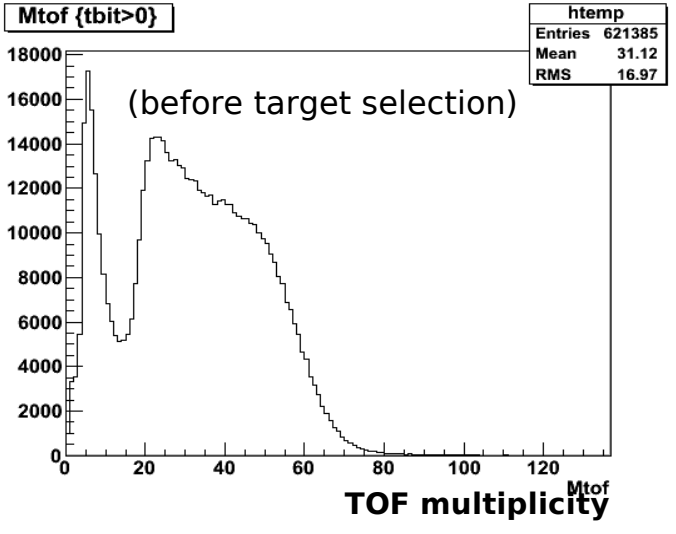


Data selection:
day 229 several files after 01:46

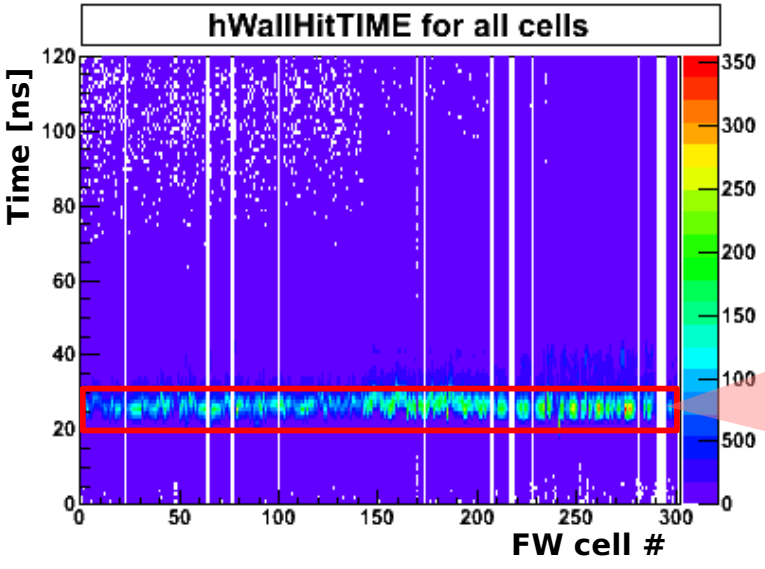
Target selection:
$\{(x^2+y^2)^{1/2}<3.33\text{mm}\}$ && {-40<z<-23}mm

Spectator selection by time-of-flight

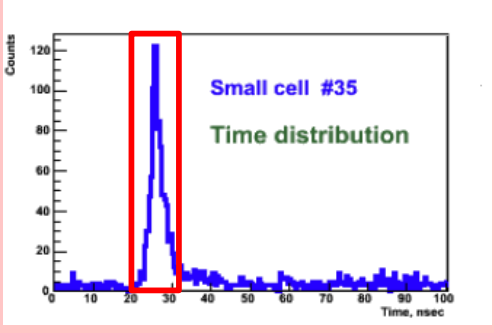


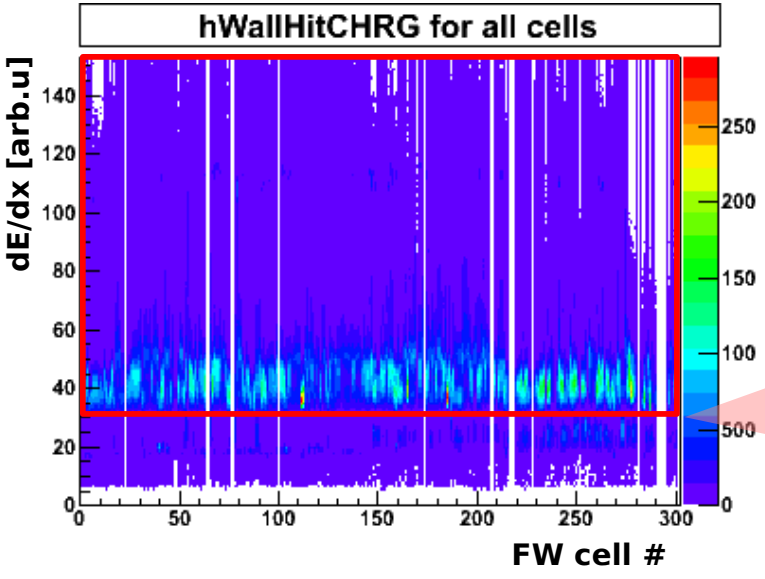


(Au@1.24AGeV)+Au HADES 2011 test beam (spectators selection by FW information)

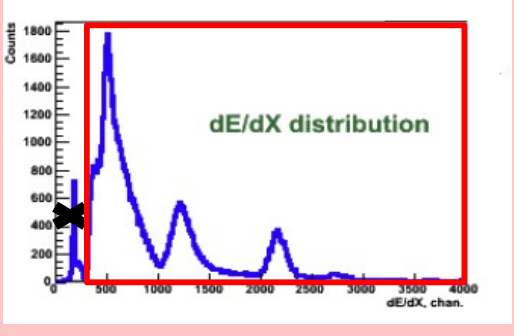


Time-of-flight needed by spectators to travel from target to FW cell is selected

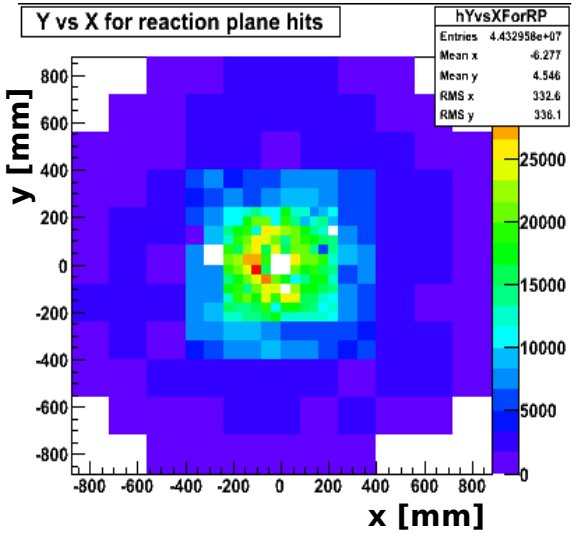


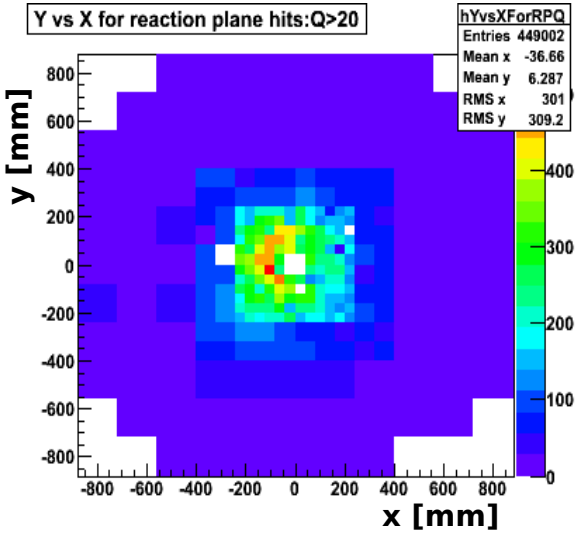


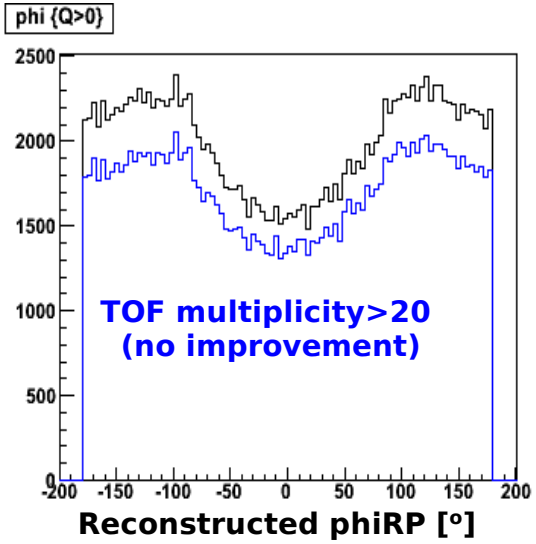
All charges accepted, but pedestals are taken away



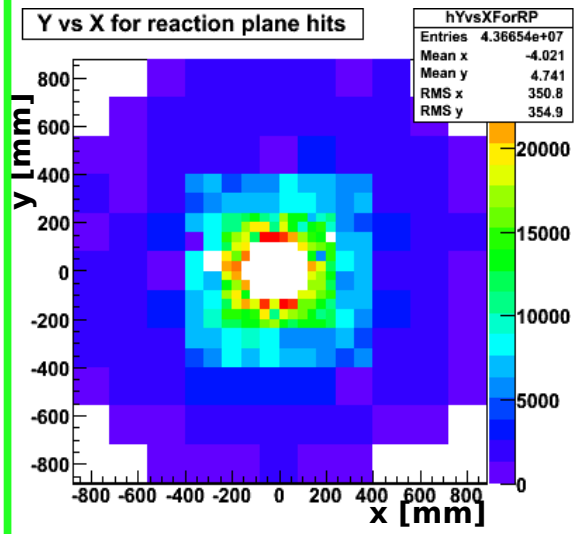
(Au@1.24AGeV)+Au HADES 2011 test beam
FW azimuthal anisotropy

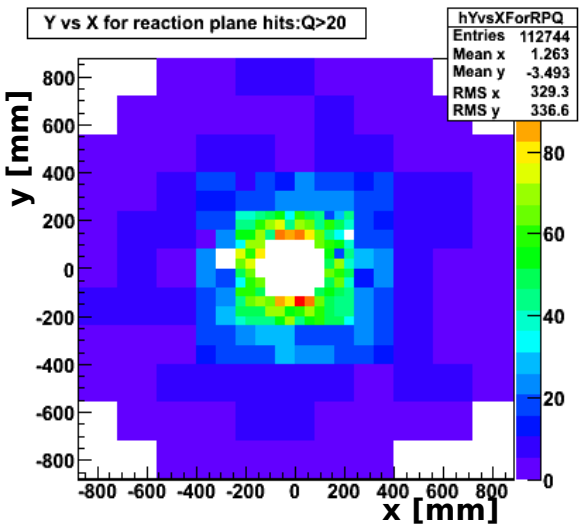


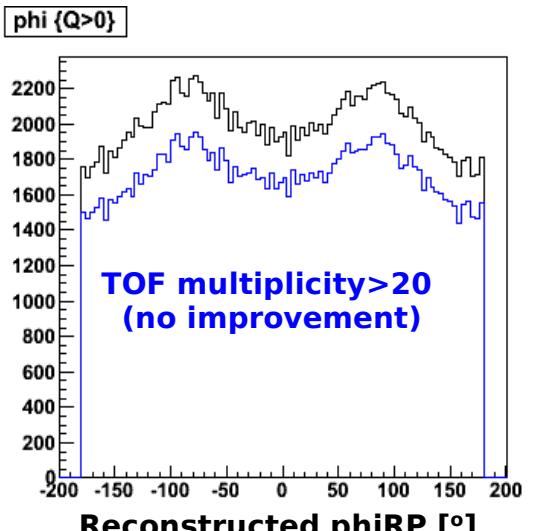




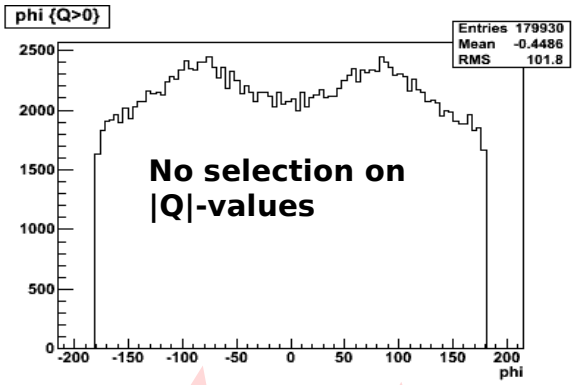
Adjusting for beam shift x=x-(-7.2mm) y=y-(-1mm); and Rmin = 138mm (to gain isotropy)

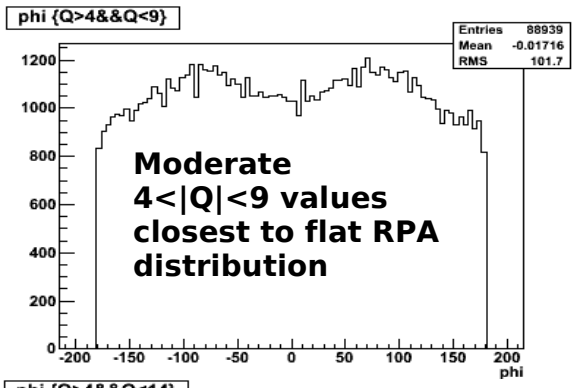


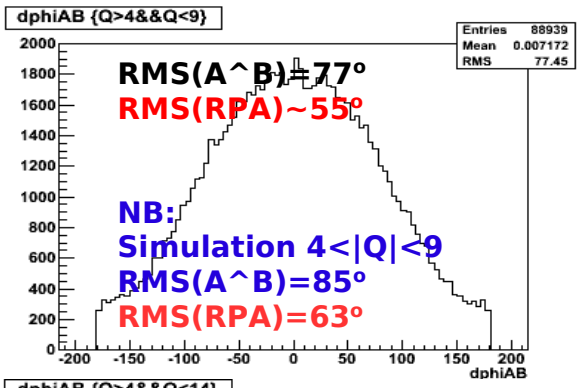


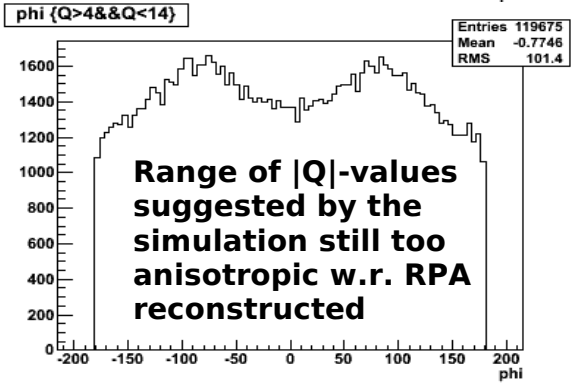


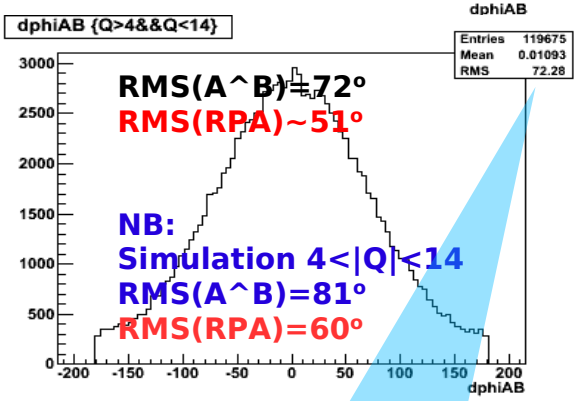
(Au@1.24AGeV)+Au HADES 2011 test beam RPA distribution

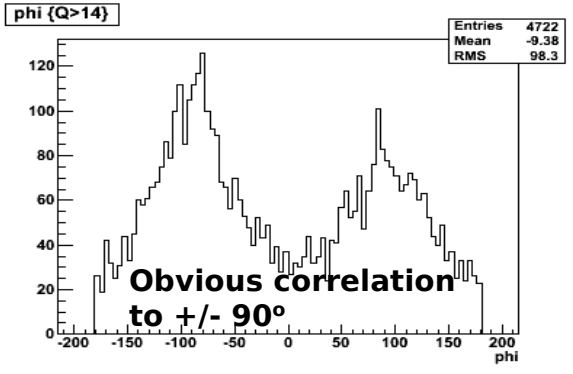












Preferable directions (systematics)

Reasonable agreement with simulation for the given distortion from an ideal case

Conclusion

Reaction plane determination in HADES is done with FW

HADES test beam Aug'11 data of (Au@1.24AGeV)+Au reaction analyzed. Reaction plane reconstruction accuracy in simulation and real data are in agreement.

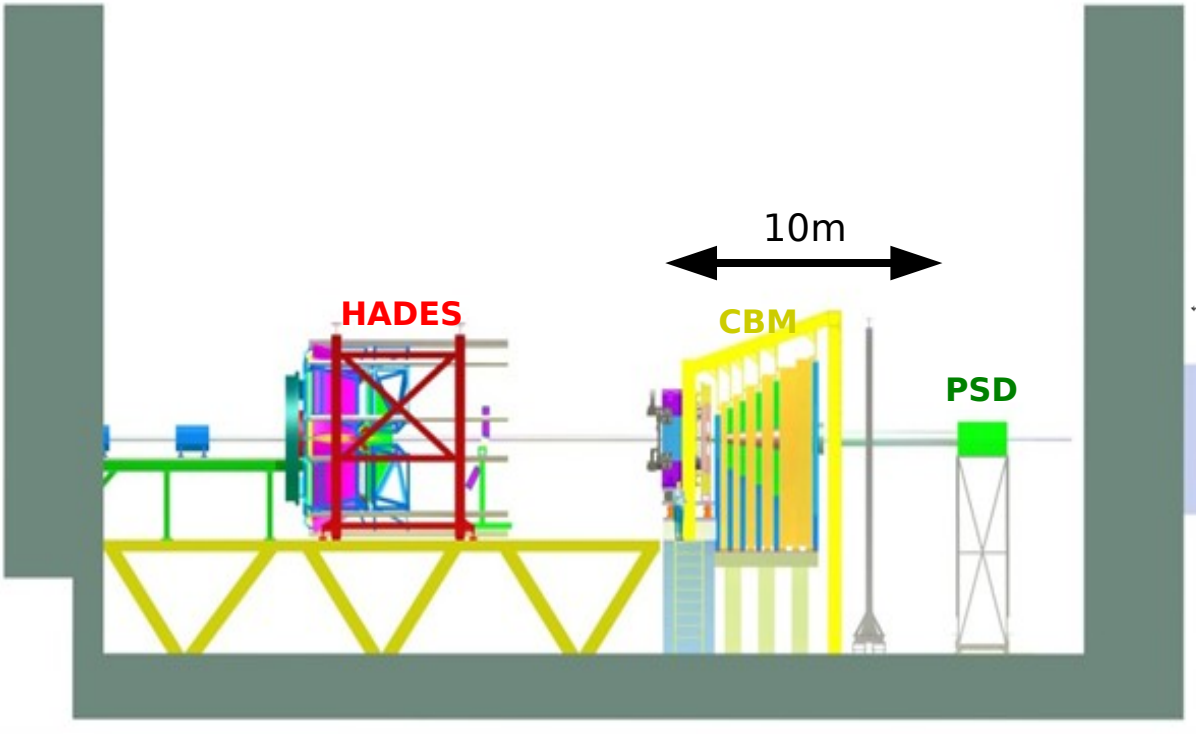
Some azimuthal anisotropy in reaction plane reconstruction is seen from real data and leads to systematics. Suppression of this anisotropy can be done by alignment and geometrical cutoff in FW acceptance. Probably this anisotropy can be reduced by improving the beam quality.

FW may be useful to control the beam quality during the experimental run.

Forward wall team:
INR Moscow:
O.Busygina, M.Golubeva, F.Guber, A.Ivashkin, A.Reshetin, A.Sadovsky, E.Usenko
NPI Řež:
A.Kugler, Yu.Sobolev, O.Svoboda, P.Tlusty, V.Wagner.

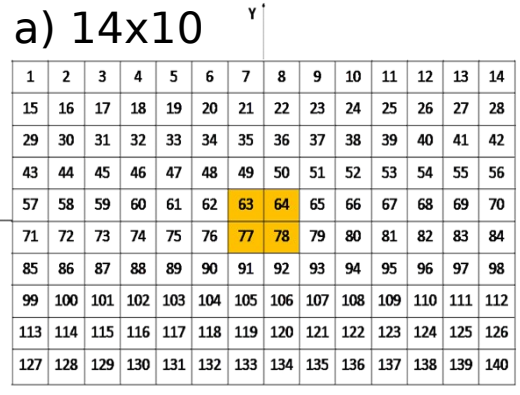
Approach to reaction plane reconstruction in CBM experiment at SIS-100

At a distance of 10m from CBM target the projectile spectator detector (PSD) shall be at least 140x100cm^2 in transverse dimensions.

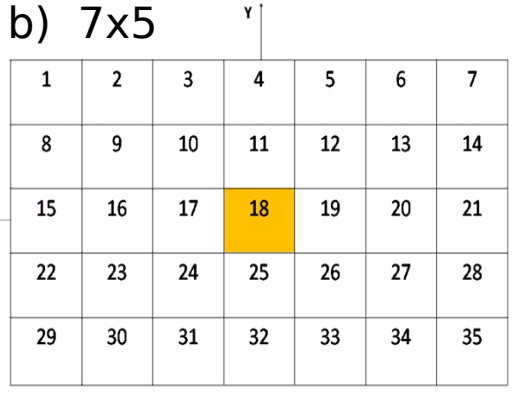


Granularity:

a) 14x10



b) 7x5

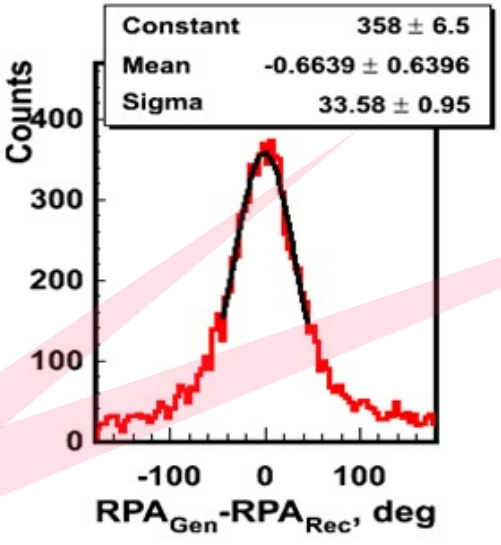


CBM *(Au@8AGeV)+Au*: magnetic field switched off
influence of beam hole based on geant hits

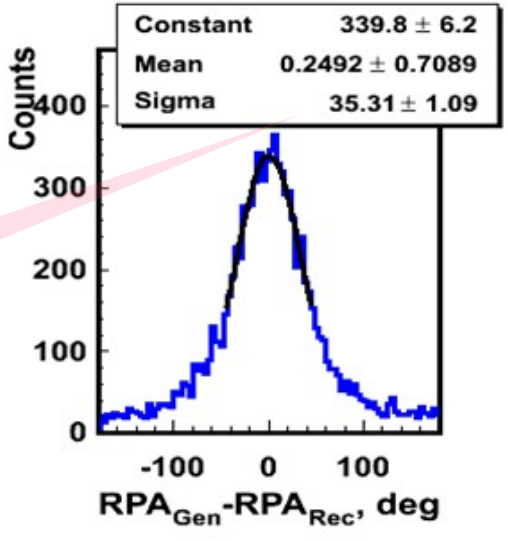
ideal coordinate resolution detector
(GEANT hits)

with
and
without
the beam hole

Reaction plane resolution reconstructed based on exact spectator coordinates (all spectators, no charge information is used) compared to generated reaction plane angle.
Based on simulation with SHIELD+Geant4



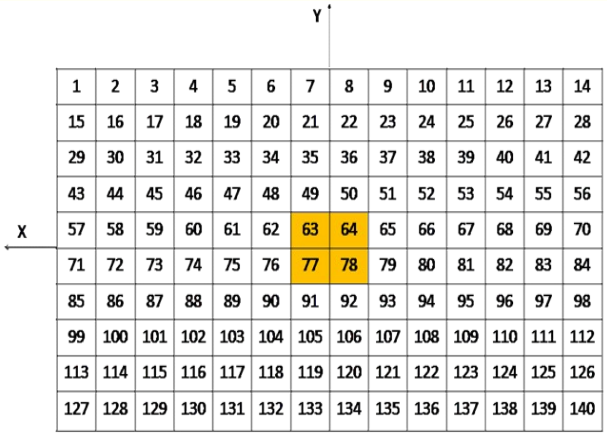
Geant hits
w/o beam hole



Geant hits
with central hole
of 20x20cm^2 size

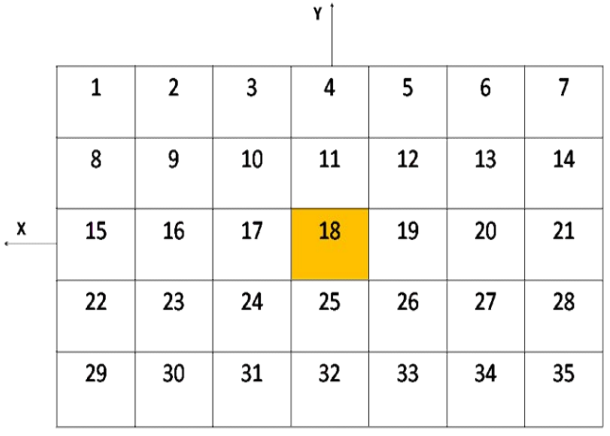
Beam hole does not affect the reaction plane determination

CBM *(Au@8AGeV)+Au*: magnetic field switched off
influence of cell size

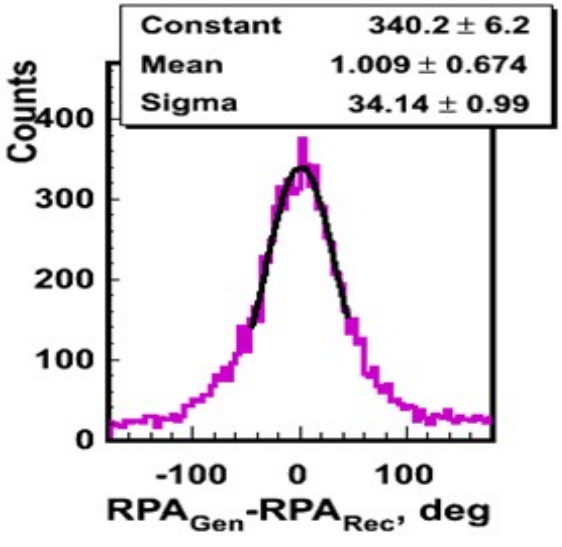


10x10cm^2 cell hits

Two kinds of detector granularity with beam hole



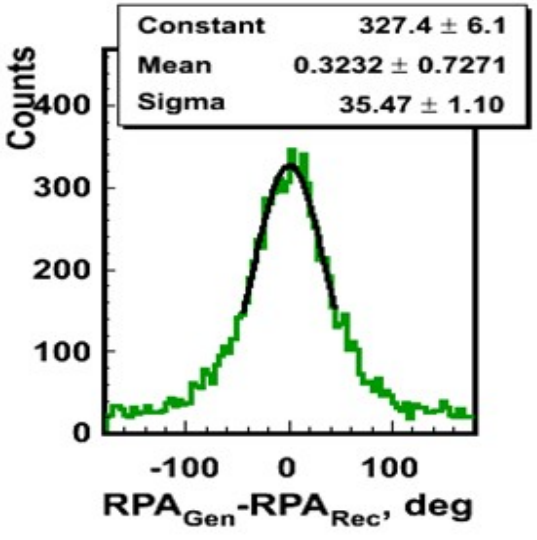
20x20cm^2 cell hits



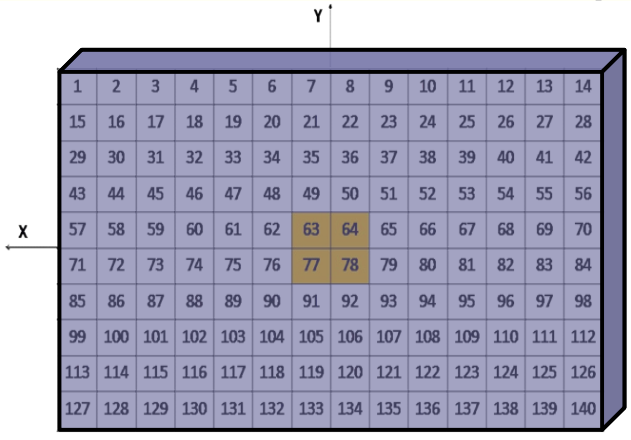
No difference in reaction plane resolution

all spectators, no charge information is used

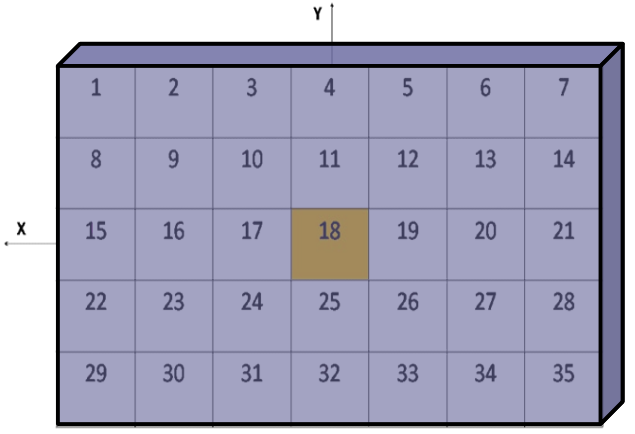
Based on simulation with SHIELD+Geant4



CBM *(Au@8AGeV)+Au*: magnetic field switched off
Forward Wall implementation (influence of cell size)

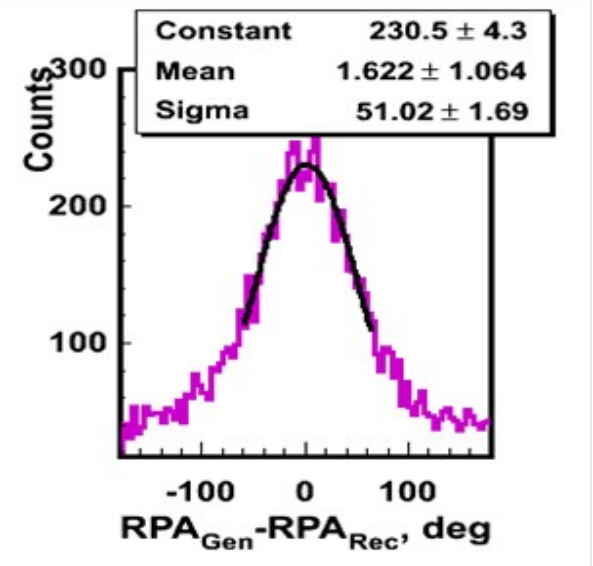


Forward Wall
(neutrons excluded)
for two
granularity cases
with beam hole



10x10cm^2 cell hits

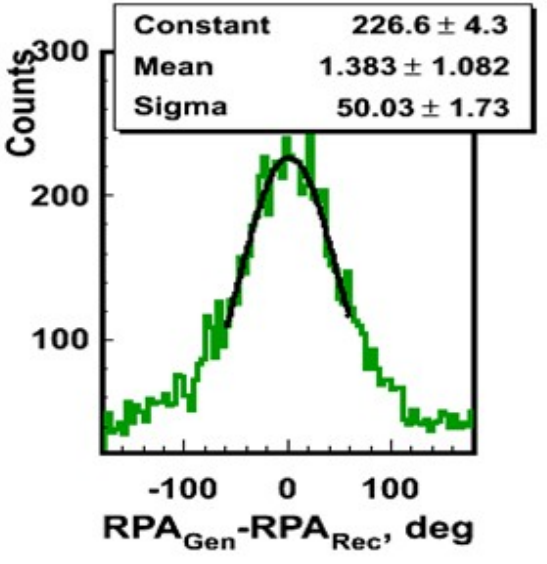
20x20cm^2 cell hits



No difference in reaction plane resolution

charged spectators only (no charge information is used for reaction plane reconstruction)

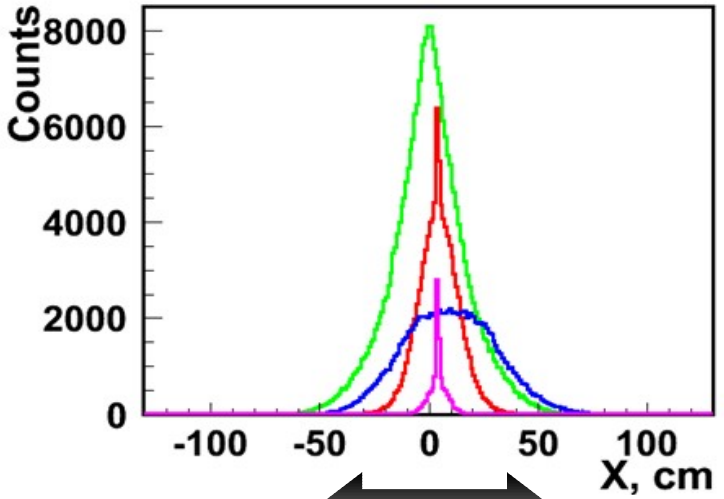
Based on simulation with SHIELD+Geant4

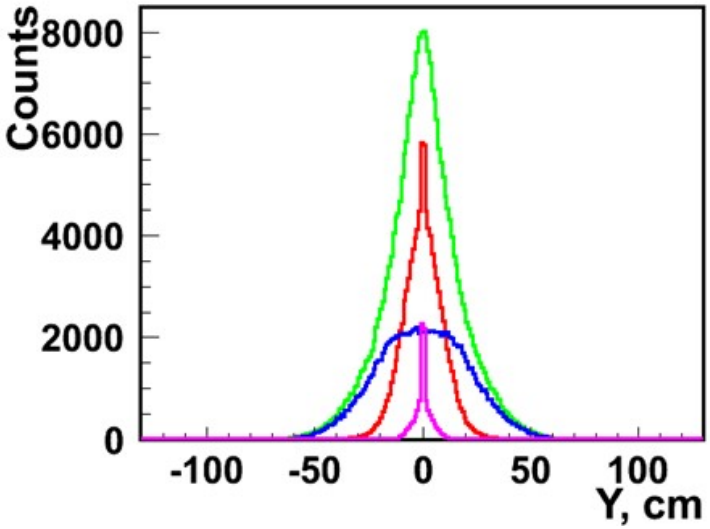


CBM *(Au@8AGeV)+Au*: influence of magnetic field on spectator positions 10m downstream

Spot sizes of the spectators at the entrance surface of projectile spectator detector.

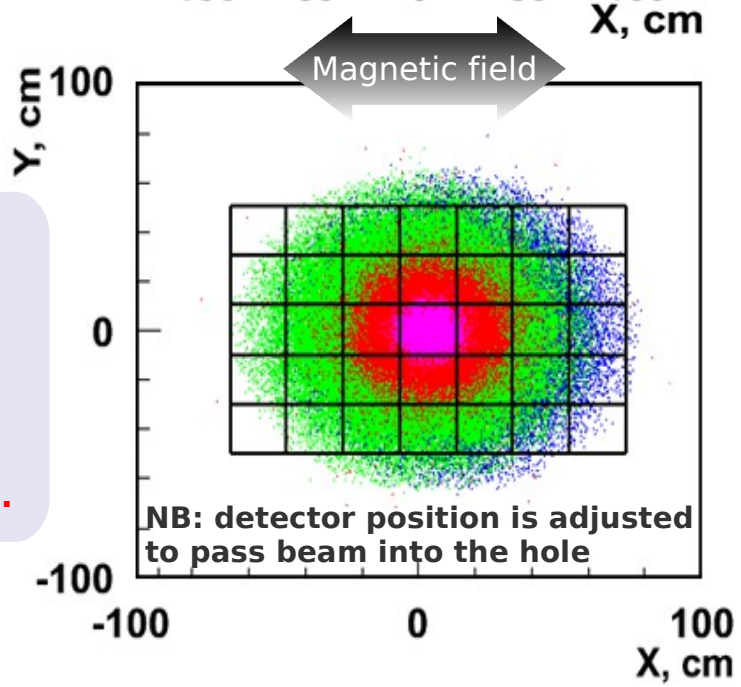
NB: Simulation *(Au@8AGeV)+Au* with SHIELD (*multi stage dynamical model including fragmentation*) with GEANT4 transport in the detector material.



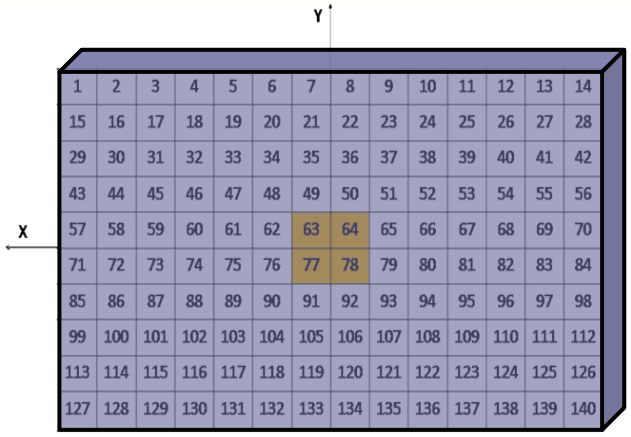


Colors:

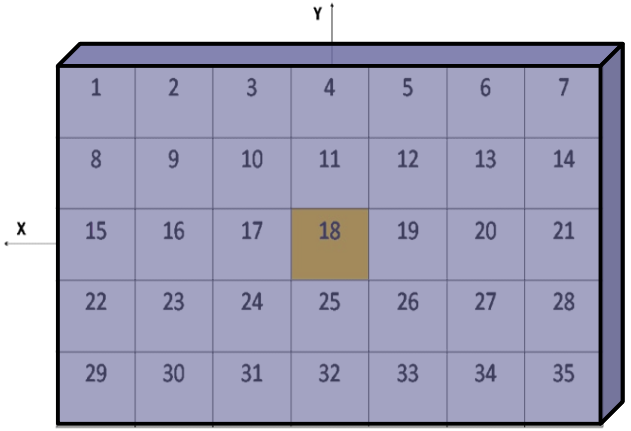
Protons,
Neutrons,
and
fragments
A={2,3},
A={4,5,6,...



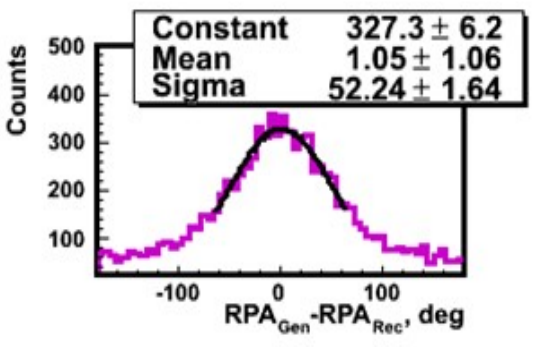
CBM *(Au@8AGeV)+Au*: with magnetic field
Forward Wall implementation



Forward Wall (neutrons excluded) for two granularity cases with beam hole



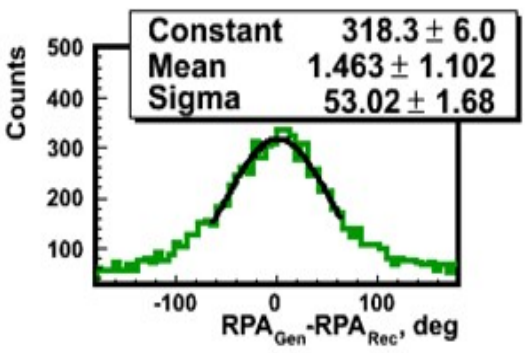
10x10cm^2 cell hits



No difference in reaction plane resolution

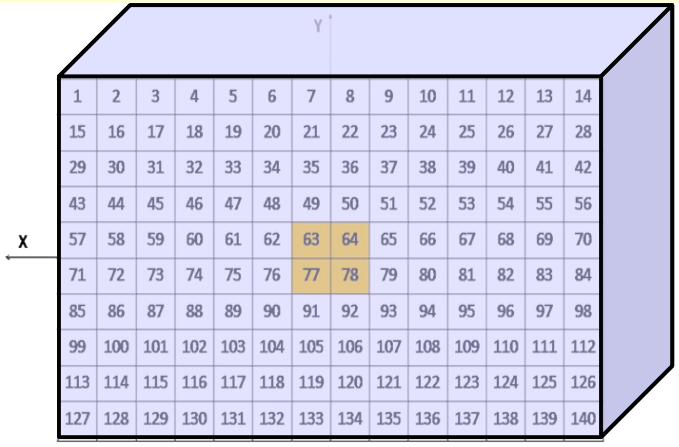
charged spectators only (charge information is now used for reaction plane reconstruction)

20x20cm^2 cell hits

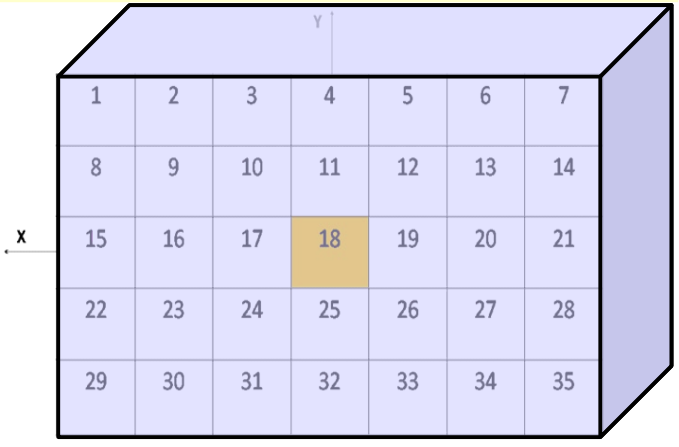


An average shift of few cm. of charged spectator hits in horizontal axis due to magnetic field was subtracted from the coordinate of cell hits while reaction plane reconstruction. This is needed to account for spacial anisotropy brought by the magnetic field. I.e. reaction plane resolution with magnetic field (after correction) is slightly worse compared to no field condition and factor 1.5 worse to the ideal coordinate resolution case.

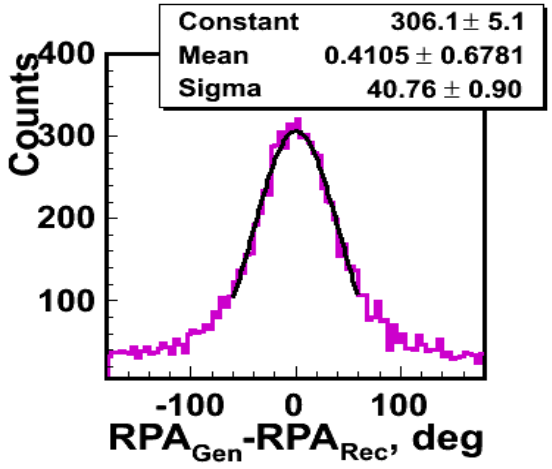
CBM *(Au@8AGeV)+Au*: with magnetic field
HCAL implementation



Hadron calorimeter (neutrons included) for two granularity cases with beam hole



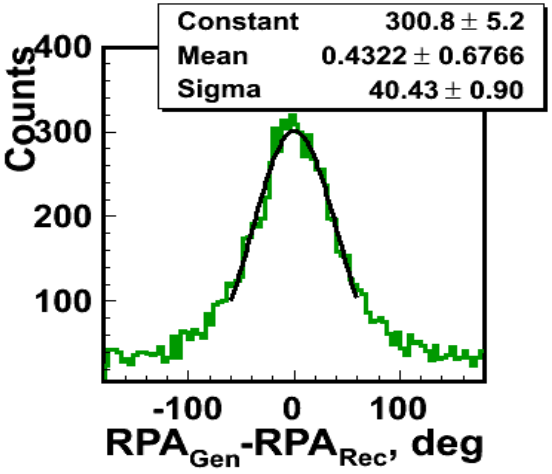
10x10cm^2 cell hits



No difference in reaction plane resolution

hadron shower energy deposition information is now used for reaction plane reconstruction

20x20cm^2 cell hits



Reaction plane is calculated relative to the “center of gravity” of deposited spectator's energies in the modules of calorimeter. Significant improvement!

Conclusion

In case of CBM experiment it is shown that hadron calorimeter can be used for reaction plane determination and will provide better results compared to scintillator hodoscope.

HCAL detector has an advantage in reaction plane determination compared to scintillator hodoscope.

In case of HCAL the resolution of reaction plane reconstruction with and without magnetic field is ~40º (Gaussian fit).

PSD proposal team:
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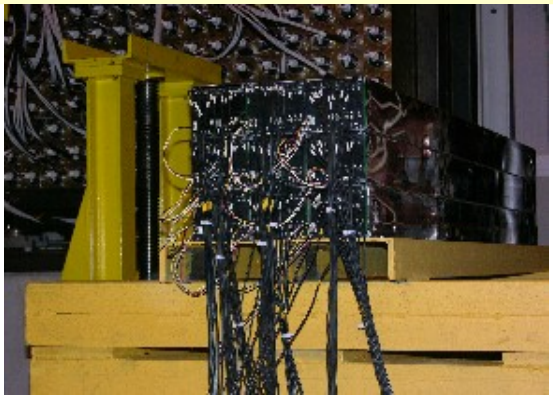
NPI Řež:
P.Tlusty, A.Kugler

Backup slides

PSD prototype



Compensating hadron calorimeter (lead/scint. ratio is 4/1).

Expected energy resolution is: $\frac{\sigma_E}{E} < \frac{60}{\sqrt{E(GeV)}}$

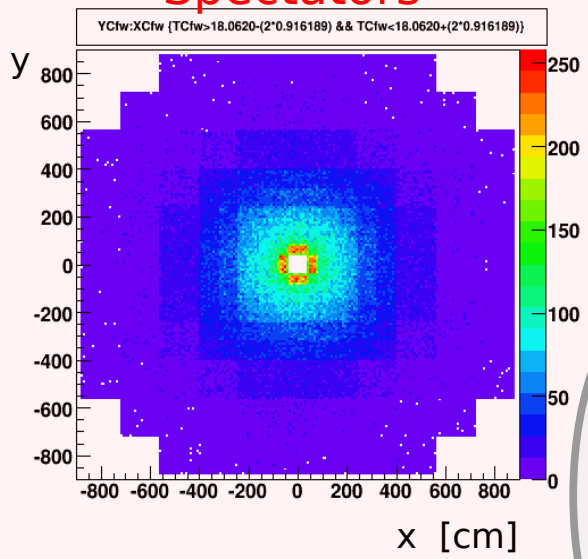
Setup of 3x3 modules of was tested at SPS (CERN)

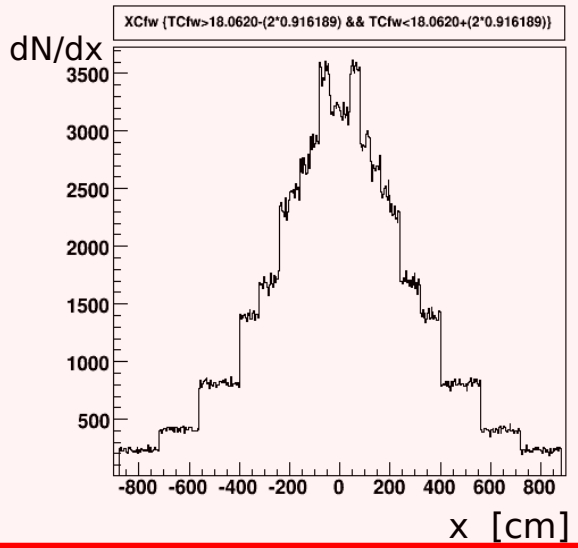
Obtained resolution:
Stochastic term ~ 55%
Constant term ~ 3.6%

$$\frac{\sigma_E}{E} = \frac{0.55}{\sqrt{E(GeV)}} + 0.036$$

Simulation: FW fired cells distribution Au+Au@1.25AGeV (selection of spectators in FW)

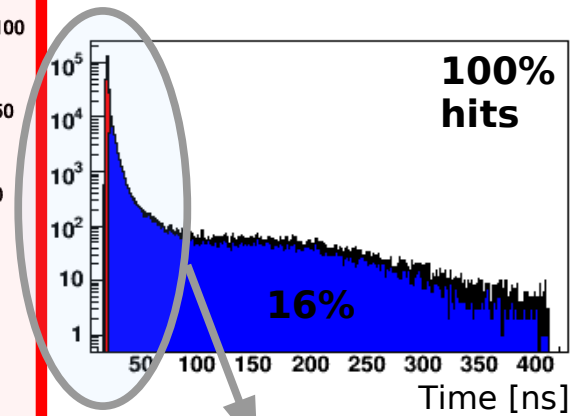
Spectators

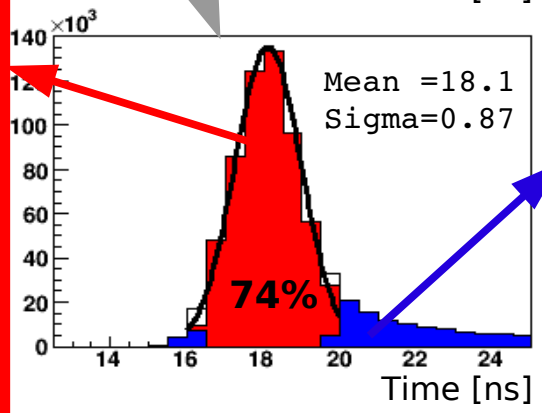




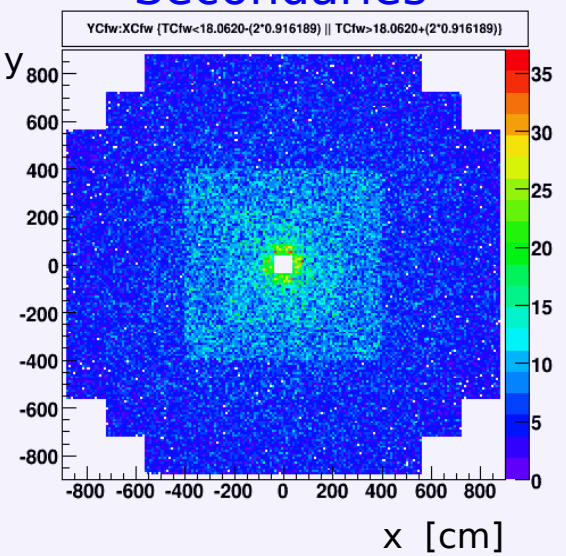
Selecting spectators by peak at time-of-flight distrib. in FW cells

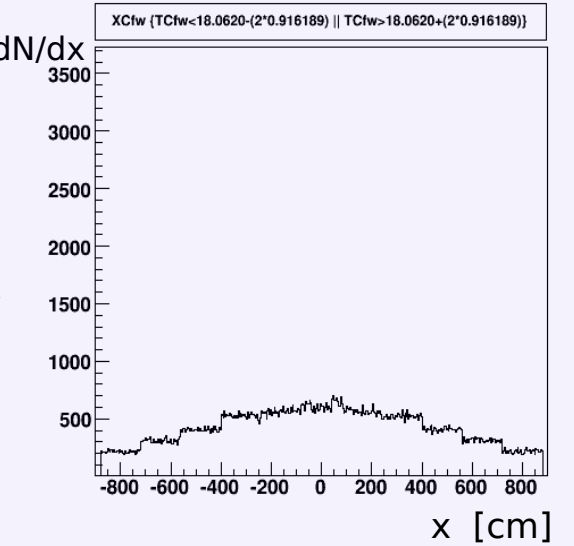
(left): inside 2sigma
(right): outside2sigma





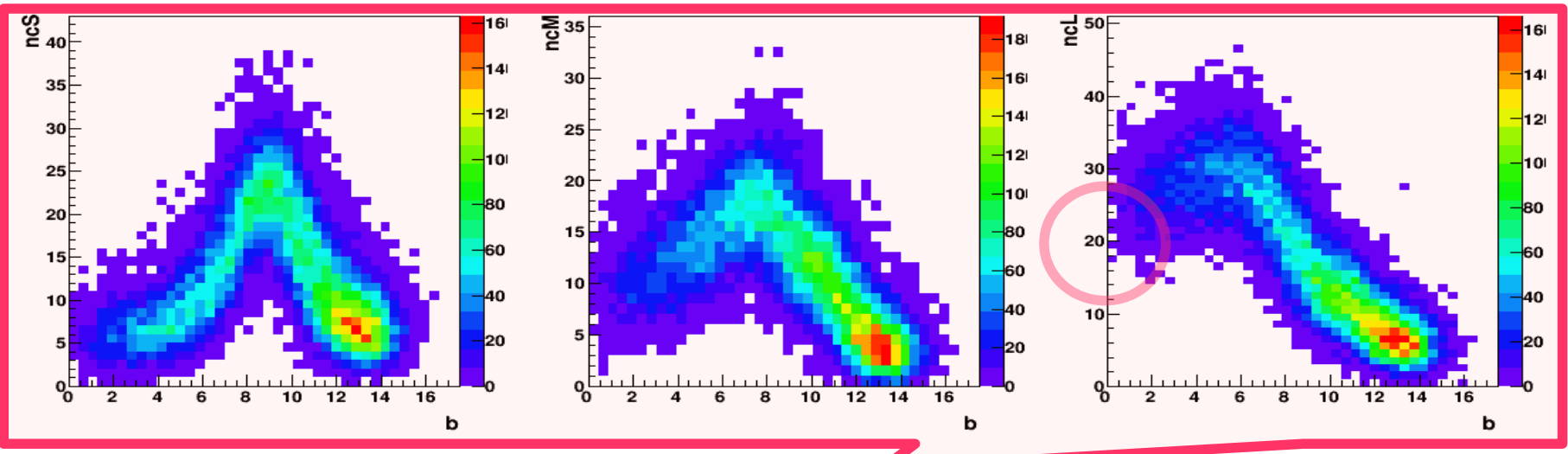
Secondaries





Number of fired FW cells (S,M,L) vs. b

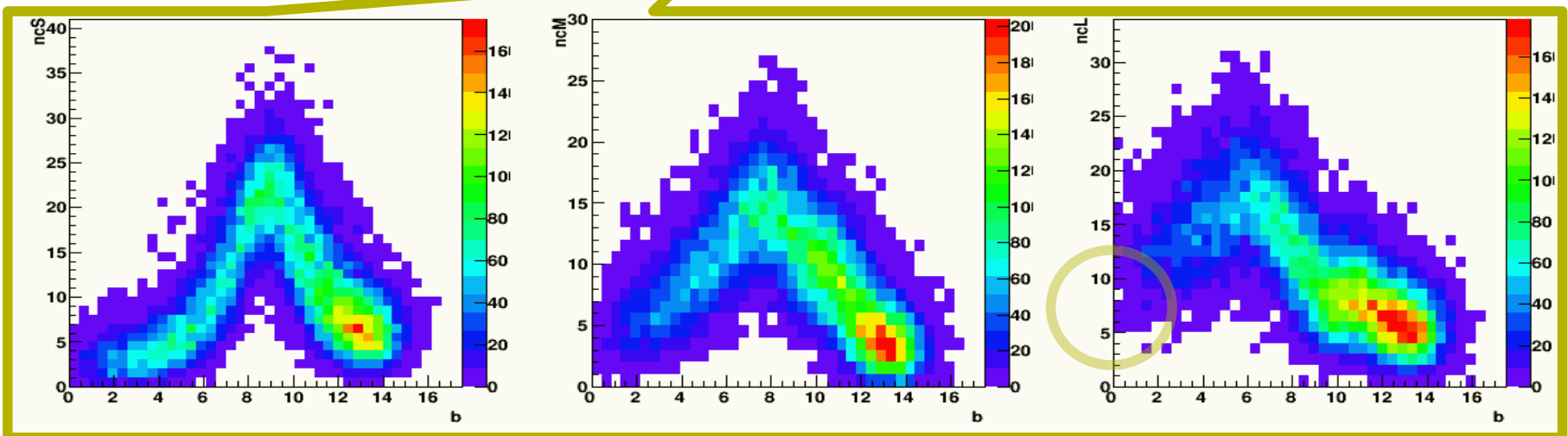
Small size cells | Medium size cells | Large size cells



Restriction on time-of-flight at FW cells:

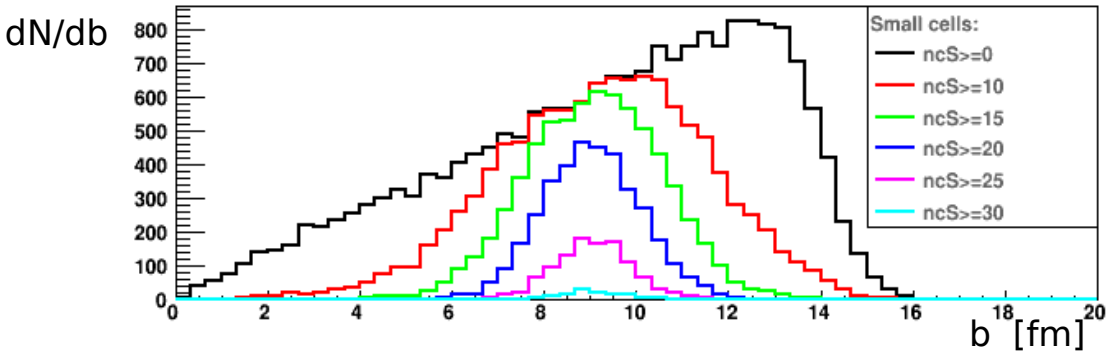
secondaries (top)

spectators (bottom)

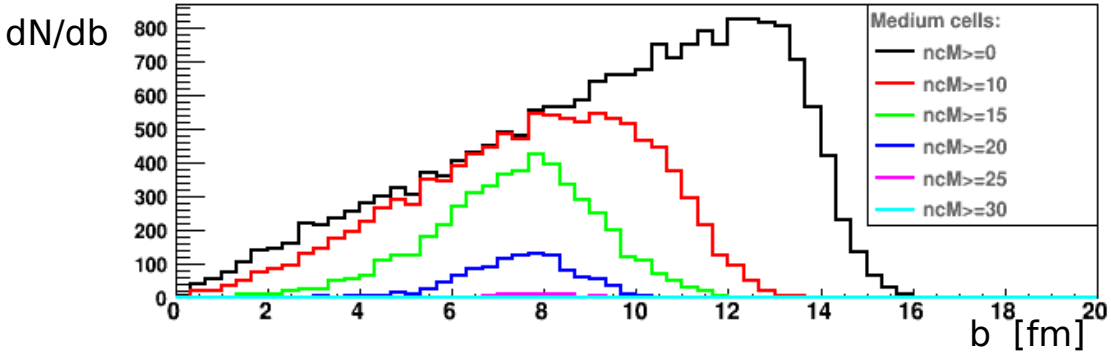


dN/db for different cut on num. fired cells

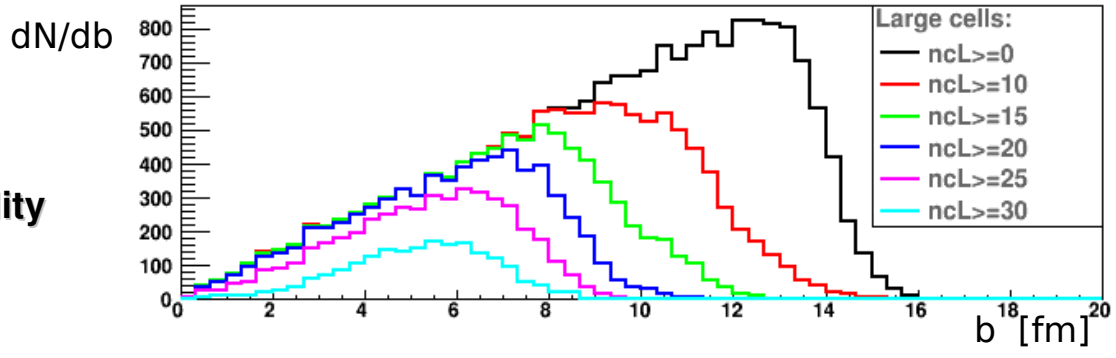
Increasing number of small cells fired selects b~9



Increasing number of medium cells fired selects b~8



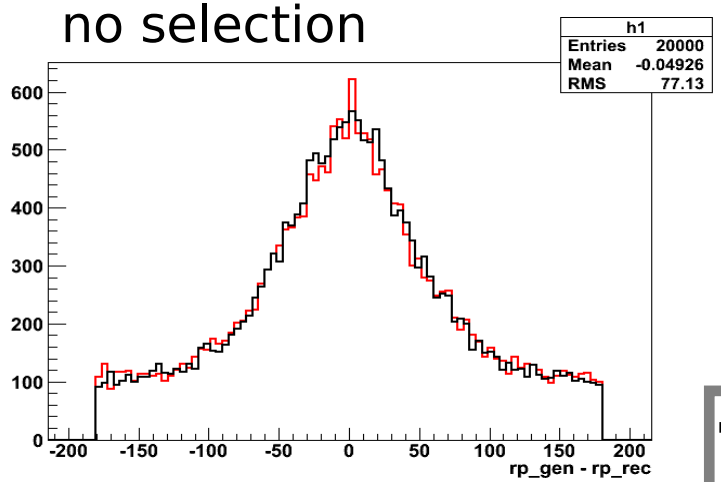
Increasing number of large cells fired selects b~6



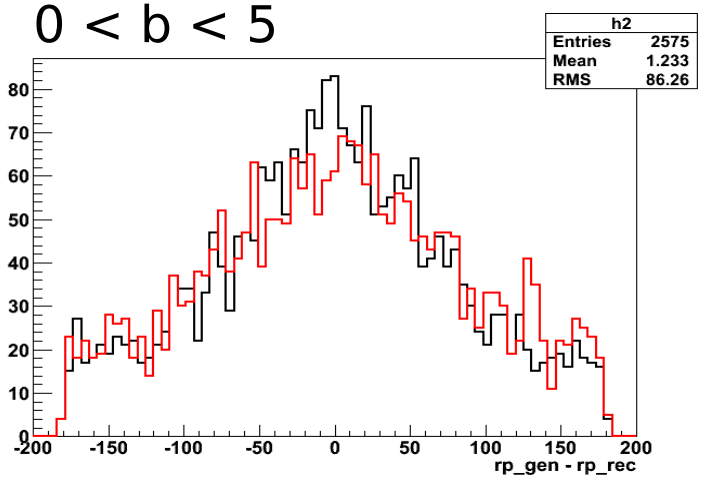
This can be applicable for centrality selection in off-line analysis.

Reaction plane reconstr.: Au+Au@1.25GeV/u

no selection

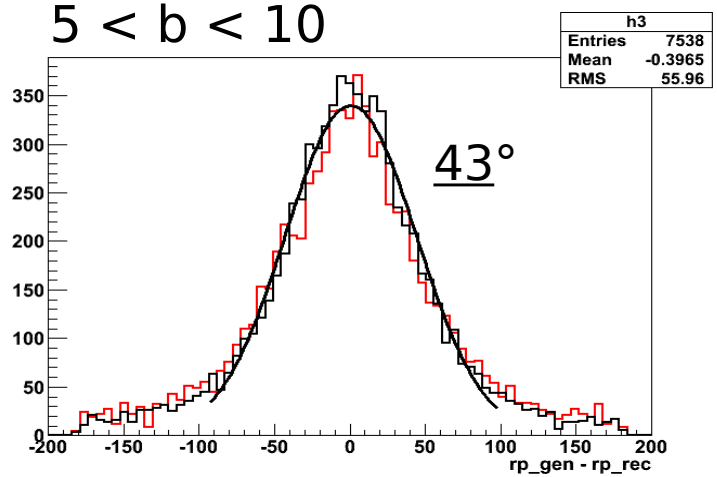


0 < b < 5

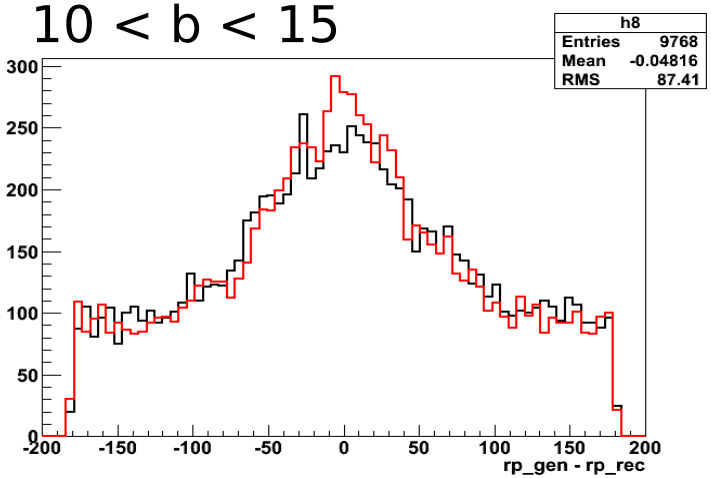


no weight
Z weight

5 < b < 10



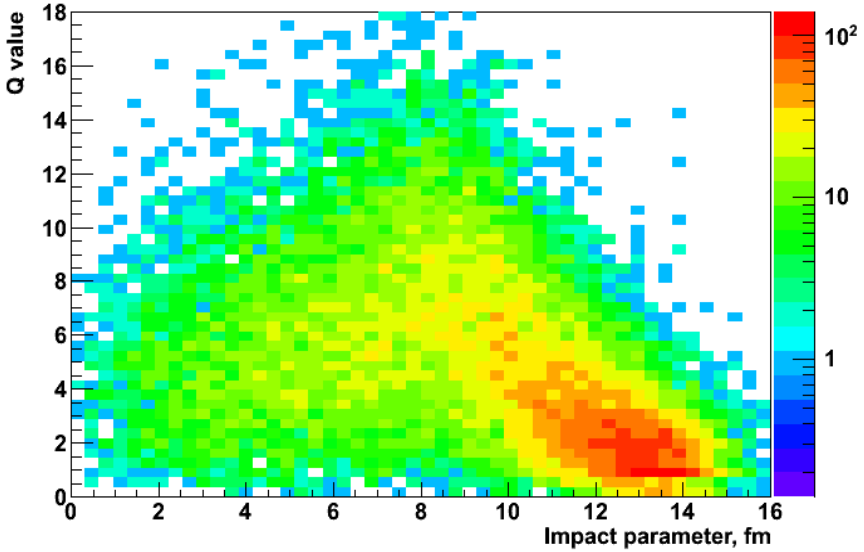
10 < b < 15

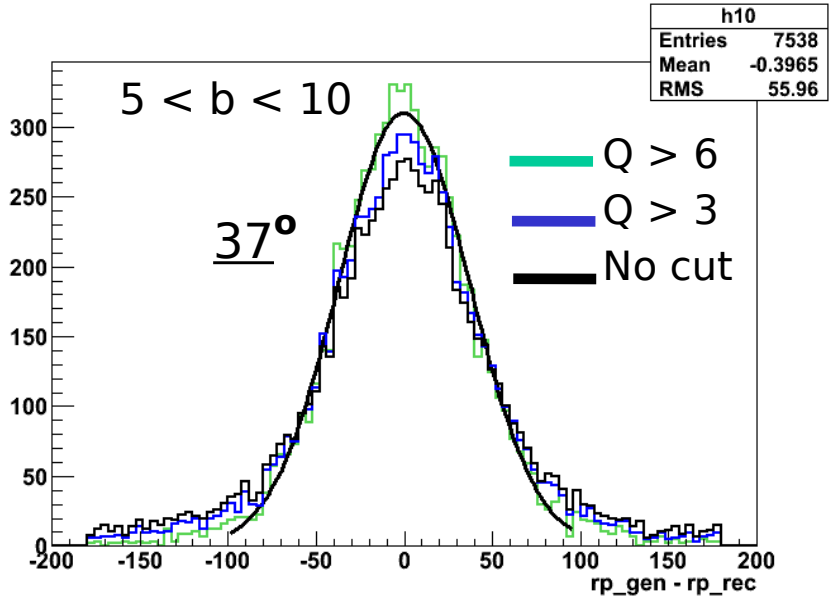


⇉ K.Lapidus (HADES coll.meet 2010, GSI)

Reaction plane recons. : Au+Au@1.25GeV/u

Cut on Q value helps in
suppression of tails and
improves the resolution





Simulations with FW
located at 5-7m from target

⇉ K.Lapidus (HADES coll.meet. 2010, GSI)