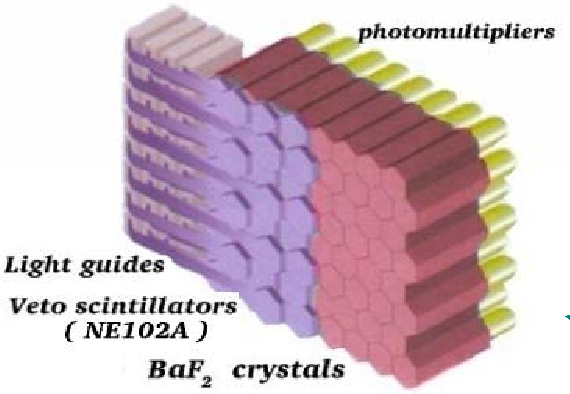
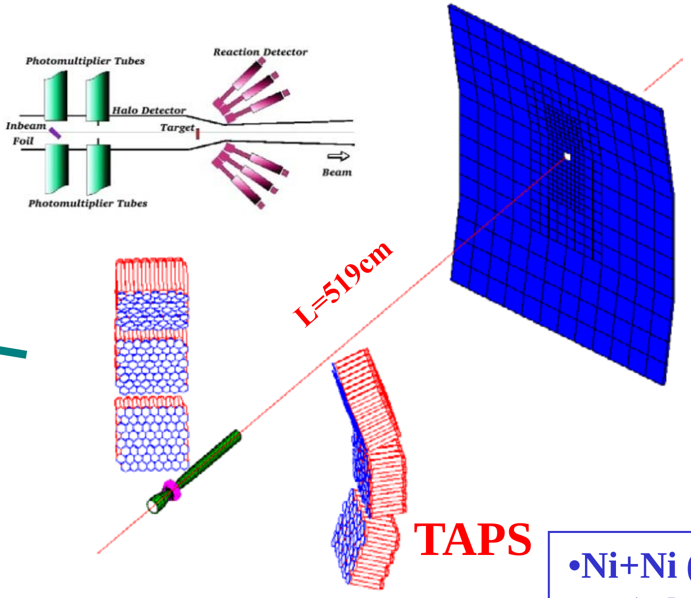
Reaction plane and centrality in Au+Au collisions with FW @TAPS and FW@HADES

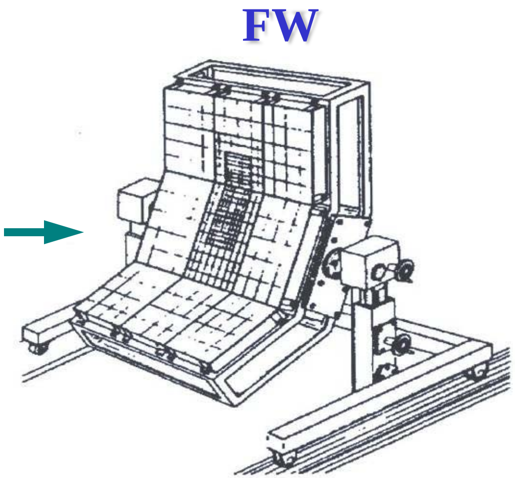
- Overview of FW@TAPS experiments
- Spectator's charge and Centrality
- Reaction plane

TAPS and KAOS FW



$$\frac{\sigma_E}{E} = \frac{0.59\%}{\sqrt{E[GeV]}} + 1.9\%$$





1994-5; GSI

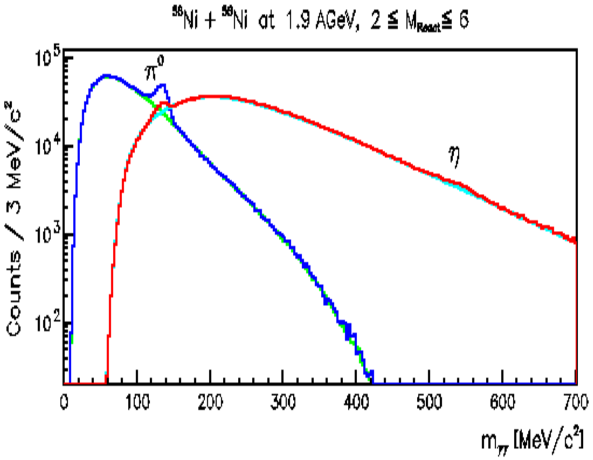
$$m_{\gamma\gamma} = \sqrt{2E_{\gamma 1}E_{\gamma 2}(1-\cos\theta_{12})}$$

PION trigger → 2xE_γ> 15 MeV in two blocks

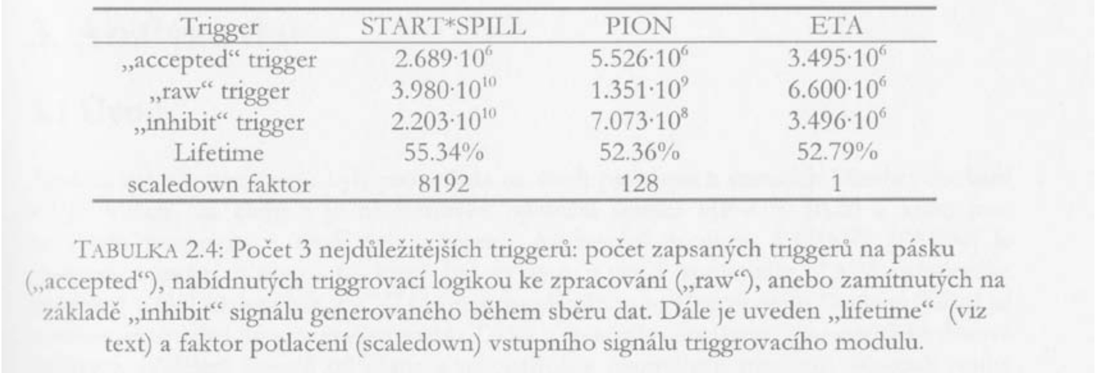
ETA trigger → 2xE_γ> 90 MeV in two towers

- **Ni+Ni (1.9AGeV) and Ca+Ca (2AGeV), see Arkadii Taraněnko; PhD 2001;**
- **Au+Au (0.8AGeV) , see**

Radek Pleskač; PhD 2003 (flow)
Annette Wolf; PhD 1997 (centrality)



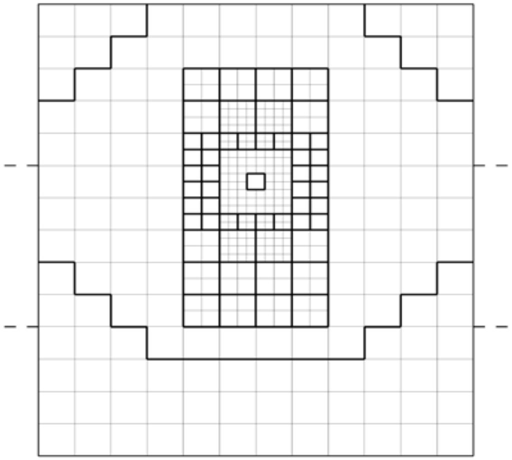
Au+Au (0.8 AGeV); ~ 12 Mevents on tape



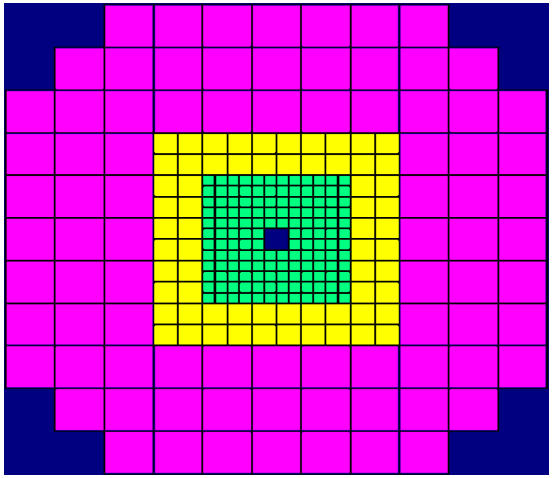
Trigger	START*SPILL	PION	ETA
„accepted“ trigger	$2.689\cdot10^6$	$5.526\cdot10^6$	$3.495\cdot10^6$
„raw“ trigger	$3.980\cdot10^{10}$	$1.351\cdot10^9$	$6.600\cdot10^6$
„inhibit“ trigger	$2.203\cdot10^{10}$	$7.073\cdot10^8$	$3.496\cdot10^6$
Lifetime	55.34%	52.36%	52.79%
scaledown faktor	8192	128	1

TABULKA 2.4: Počet 3 nejdůležitějších triggerů: počet zapsaných triggerů na pásku („accepted“), nabídnutých triggrovací logikou ke zpracování („raw“), anebo zamítnutých na základě „inhibit“ signálu generovaného během sběru dat. Dále je uveden „lifetime“ (viz text) a faktor potlačení (scaledown) vstupního signálu triggrovacího modulu.

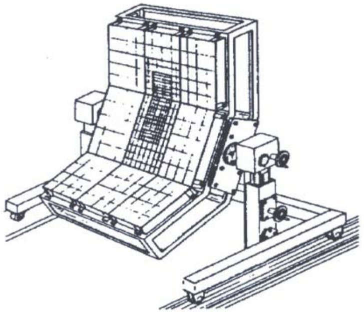
FW@TAPS and FW@HADES

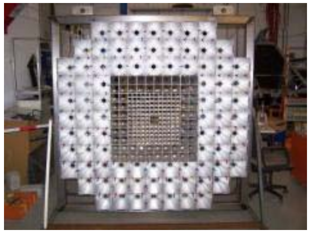


320 BC408 scintillator modules
Analog summing (grouping) into 188 signal - channels, see thick lines
Distance to target 519cm; carbon tube with diameter 70mm and thickness 1 mm
$\theta = 0.4^0\text{-}11.3^0$
each channel : ΔE/Δx and TOF



288 BC408 scintillator modules
thickness 2.54 cm
Distance to target 650 cm; Helium bag
$\theta = 0.7^0\text{-}7.7^0$
each channel : ΔE/Δx and TOF



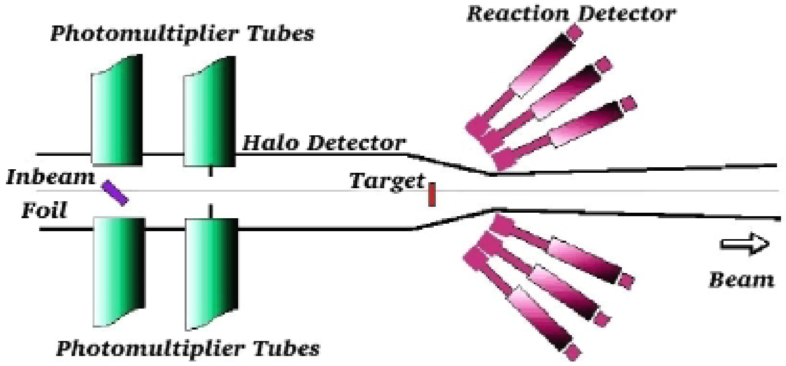


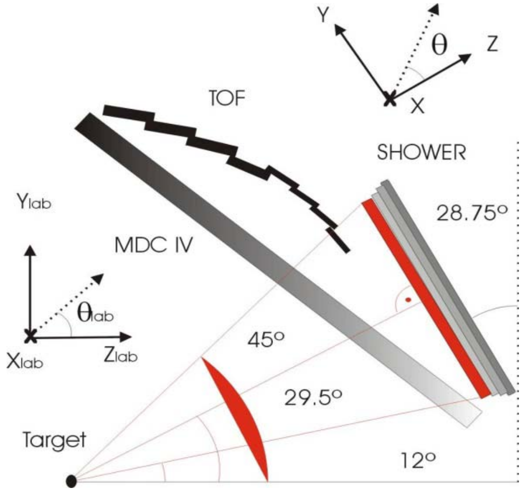
140 small (4x4 cm^2); PMT XP2982

64 middle (8x8 cm^2); PMT XP2262

84 large (16x16 cm^2); PMT XP2262

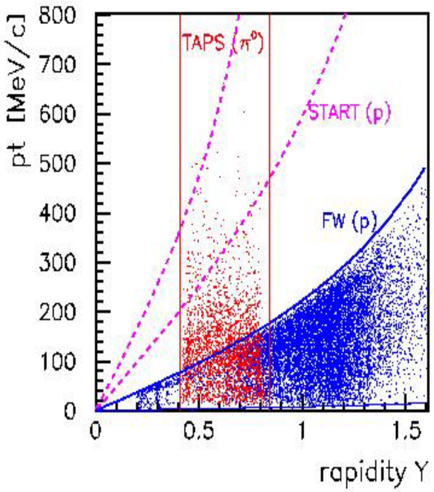
Reaction trigger: TAPS and HADES

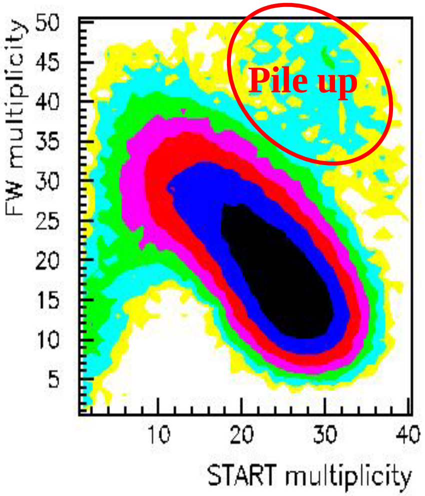


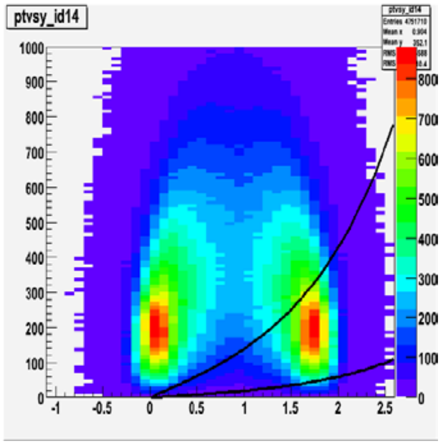


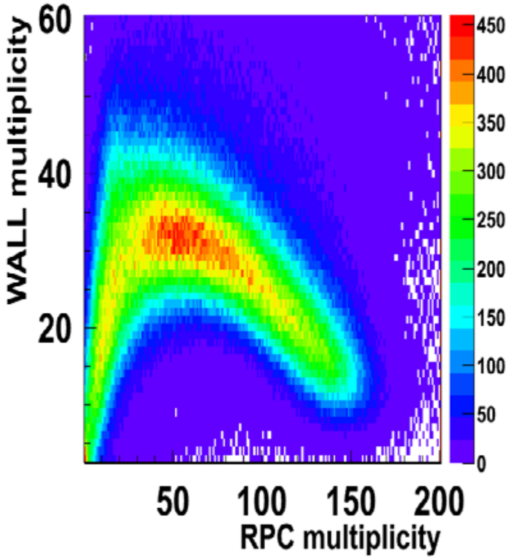
Reaction detector consist from 48 NE102A scintilators
≈10cm from target, θ = 14.6^0-43.2^0
below results from experiment!!

Reaction detector consist from RPC
≈200cm from target, θ = 12^0-45^0 ;
below results from simulation(left) and experiment (right)

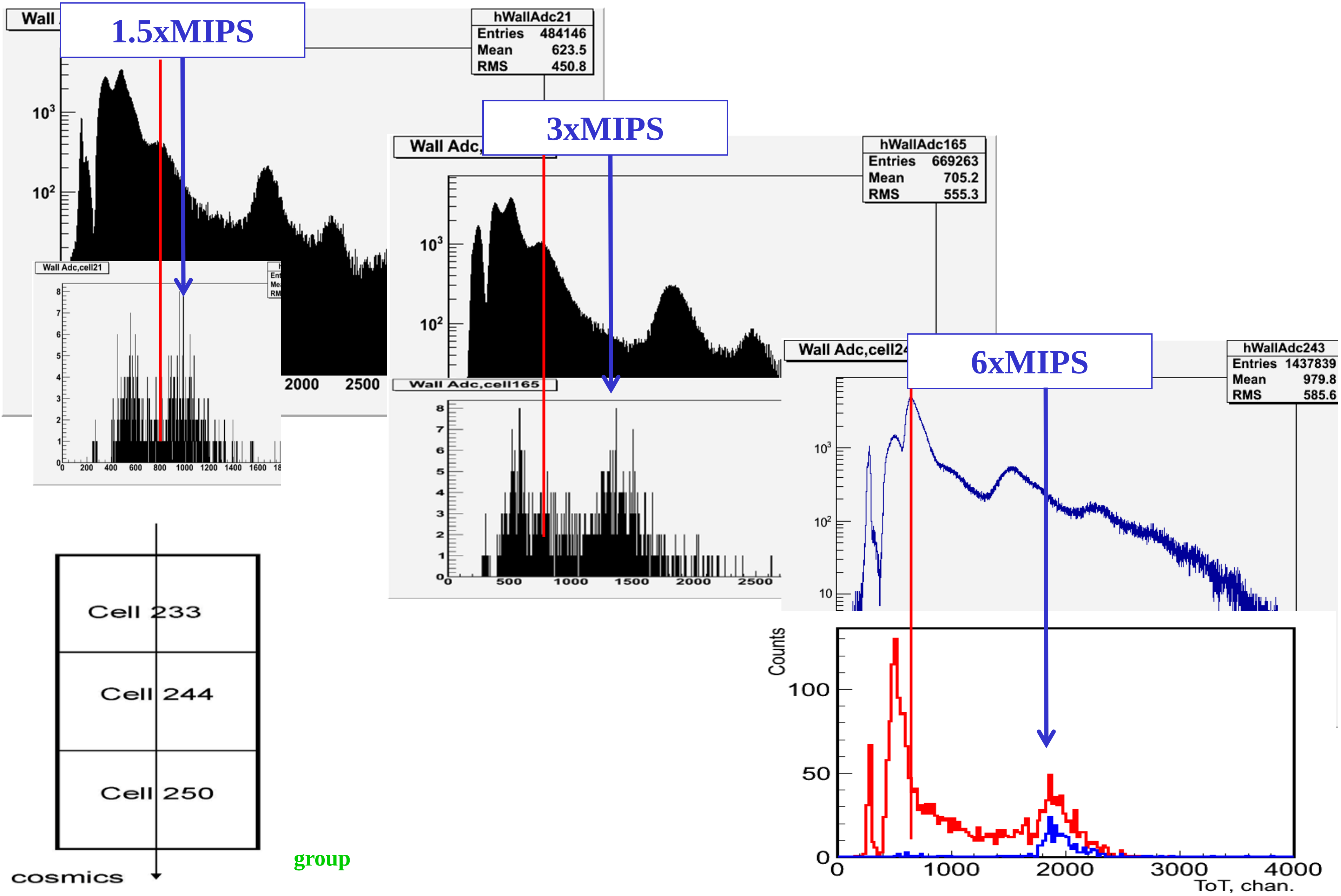






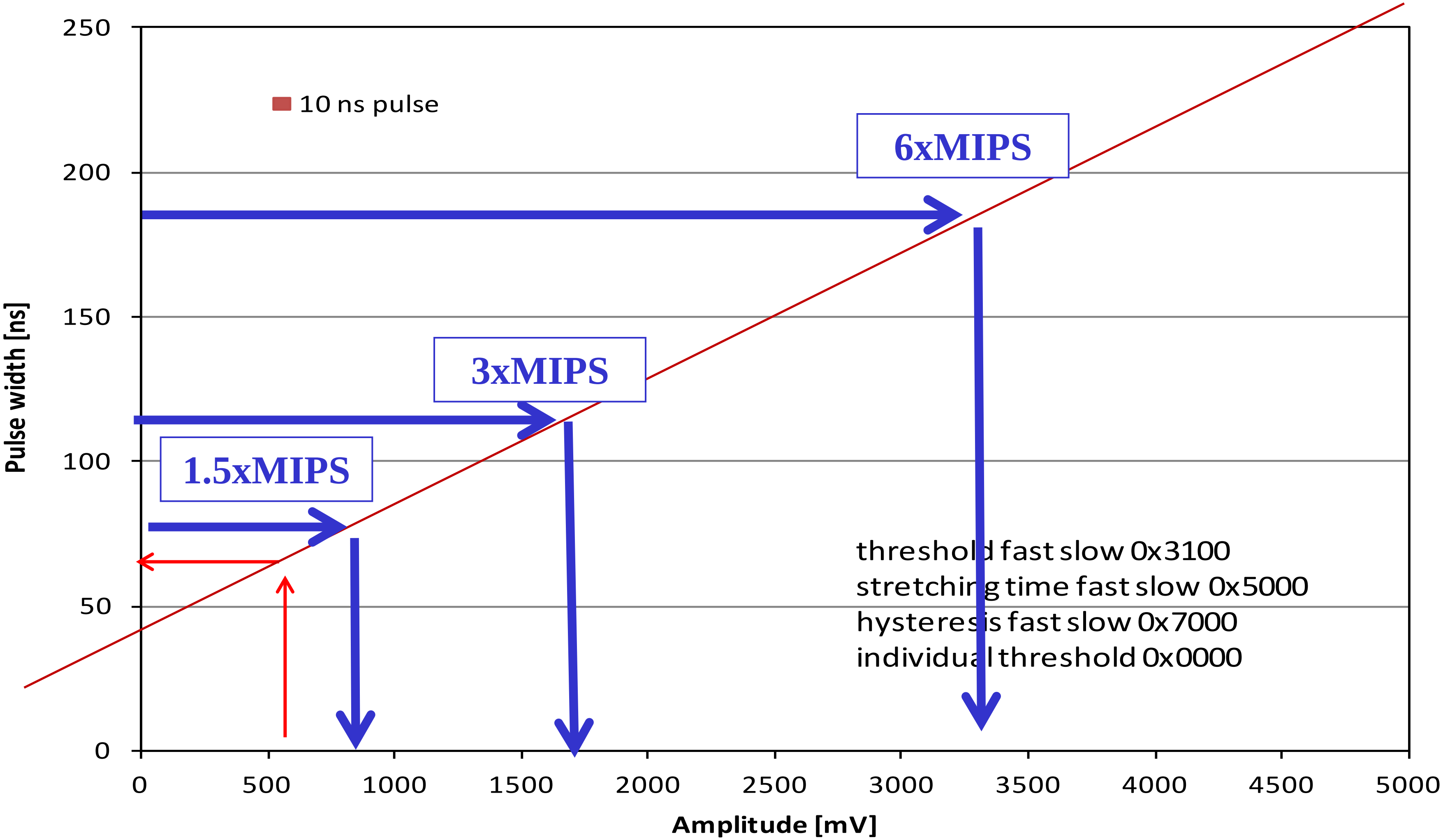


Charge: Calibration of FW@HADES by cosmics



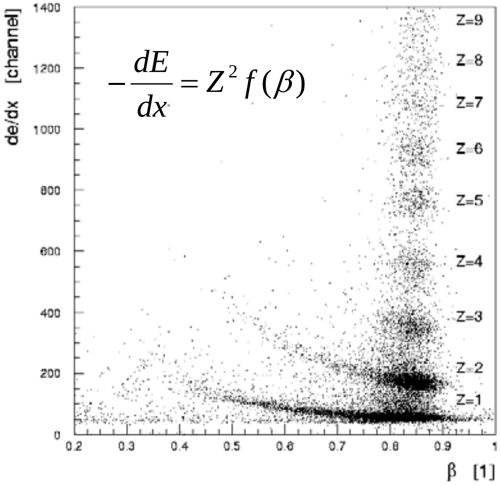
group

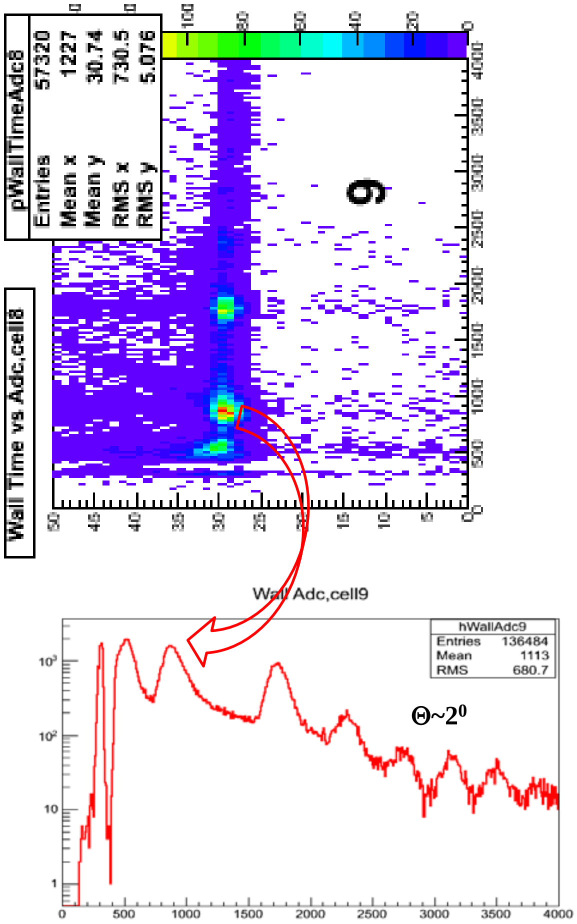
Charge: HADES FW AddOn
cell 244

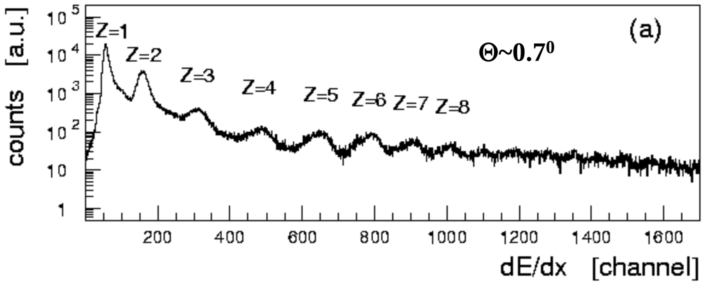


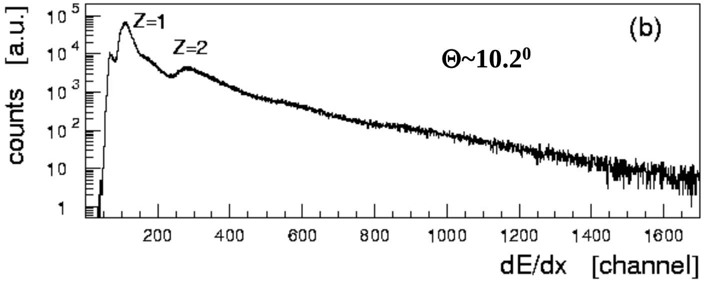
threshold fast slow 0x3100
stretching time fast slow 0x5000
hysteresis fast slow 0x7000
individual threshold 0x0000

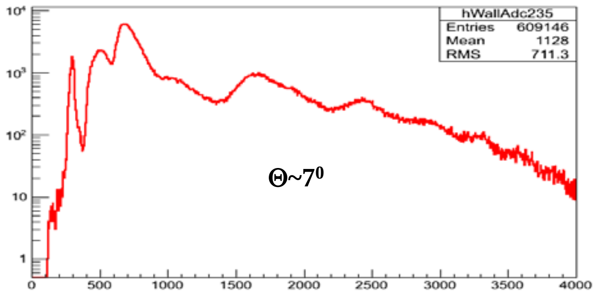
Charge in FW: TAPS and HADES



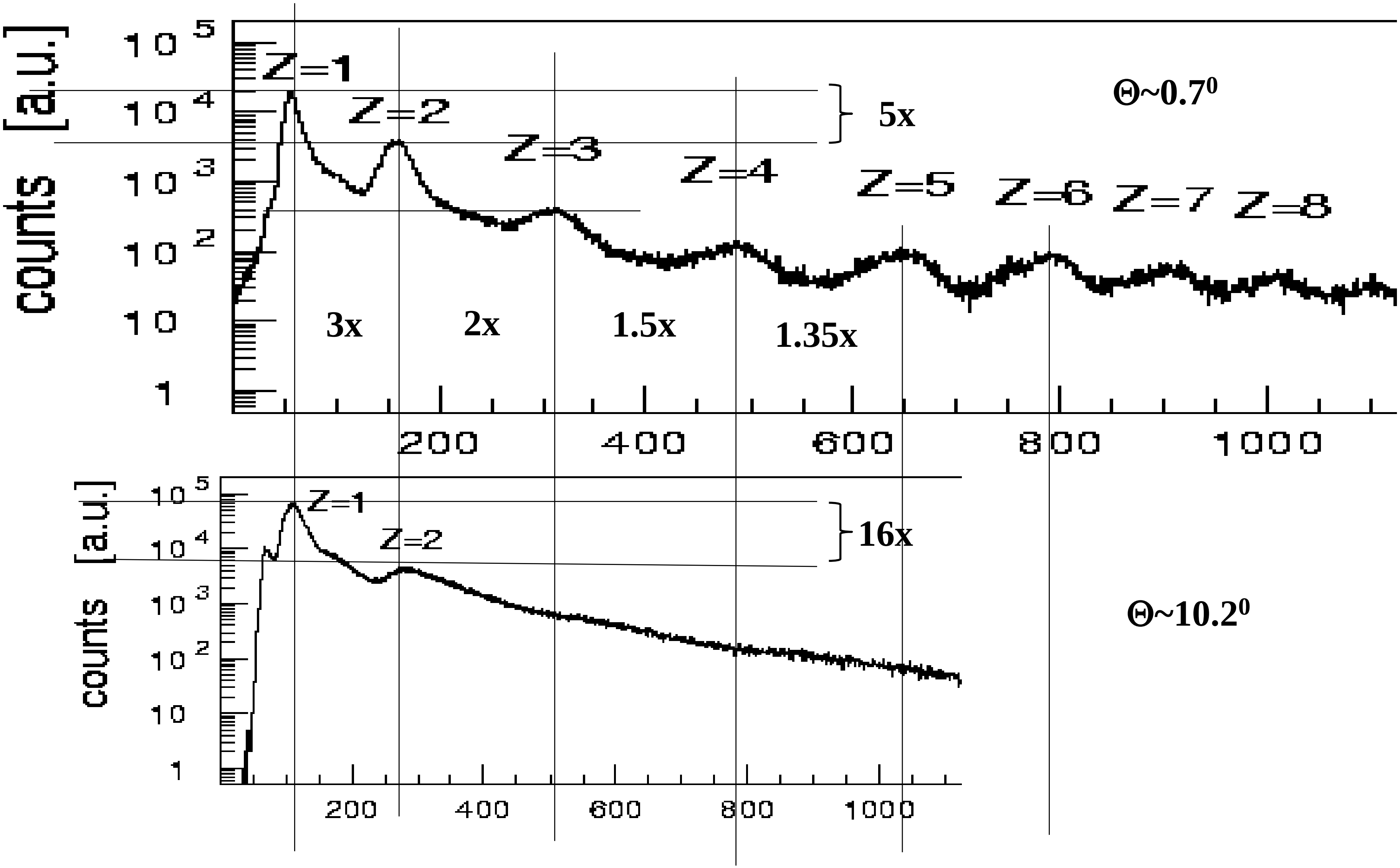




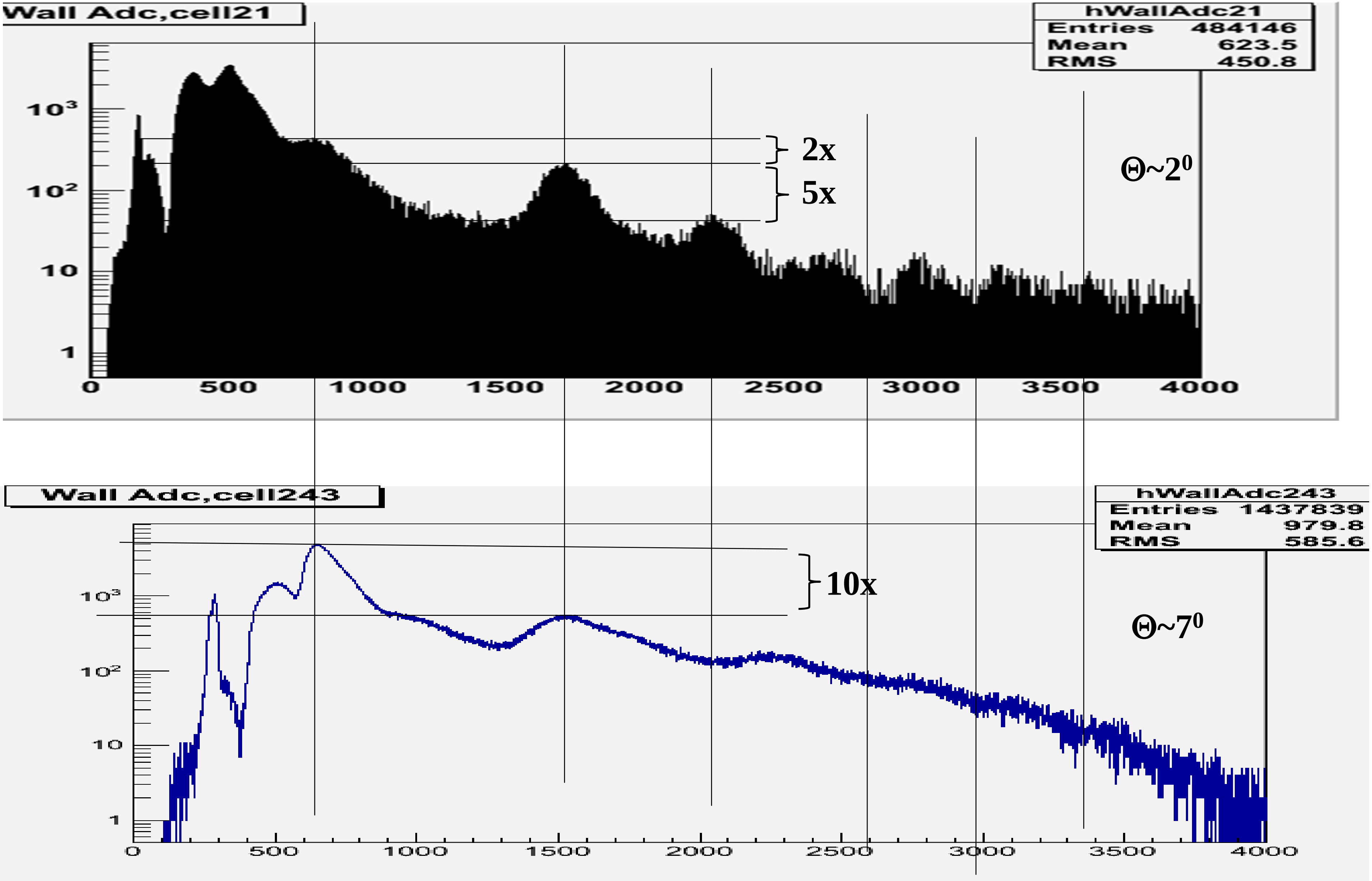




Charge details: FW@ TAPS



Charge details: FW@HADES



Total Charge of spectators: FW@TAPS

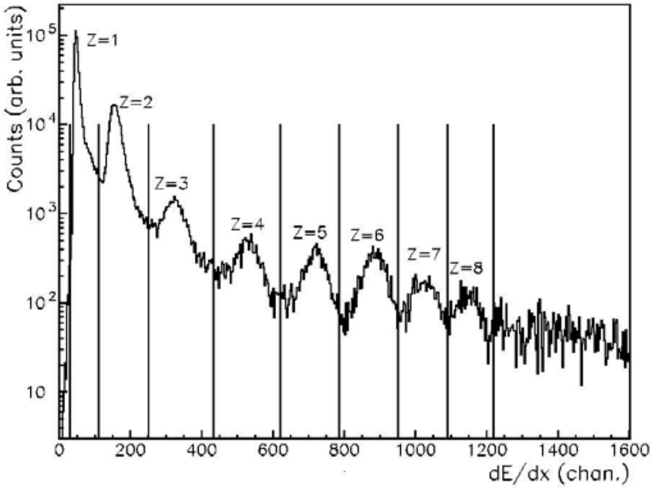
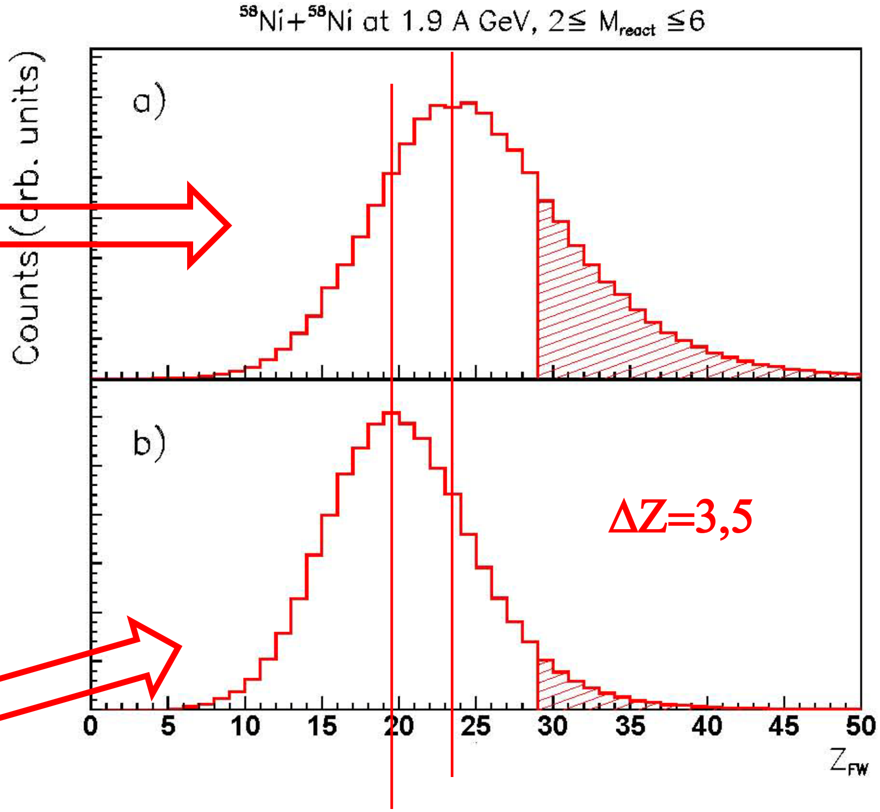


Figure 4.4: dE/dx for charged particles detected in a single FW module. The data are from the ^{58}Ni+^{58}Ni reaction at 1.9 *A* GeV.



ΔZ=3,5

Figure 4.5: The distribution of the total charge (Z_{FW}) of particles detected in the FW for two methods of charge calibrations of the FW (see discussion in the text). The hatched regions represent the fraction of events with $Z_{FW} > Z_{proj}$. The data correspond to bin $2 \leq M_{react} \leq 6$ in hit multiplicity of the reaction detector for reaction ^{58}Ni+^{58}Ni at 1.9 *A* GeV.

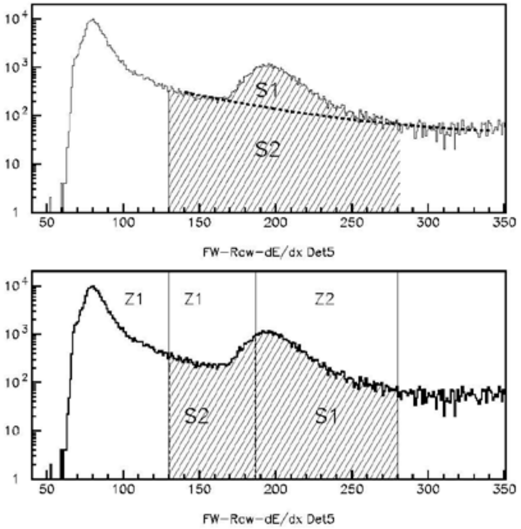
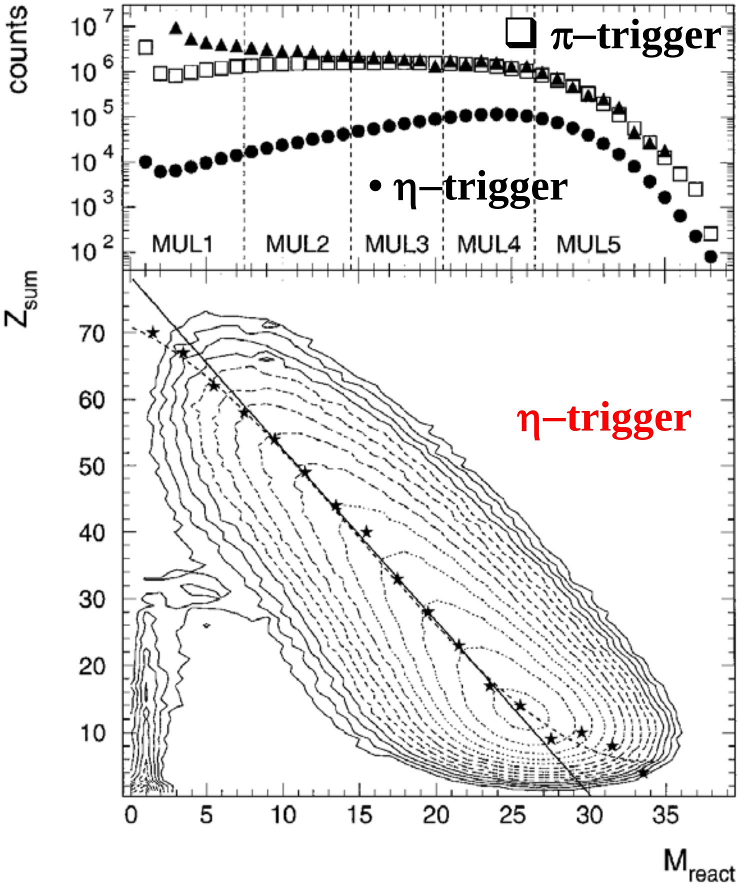


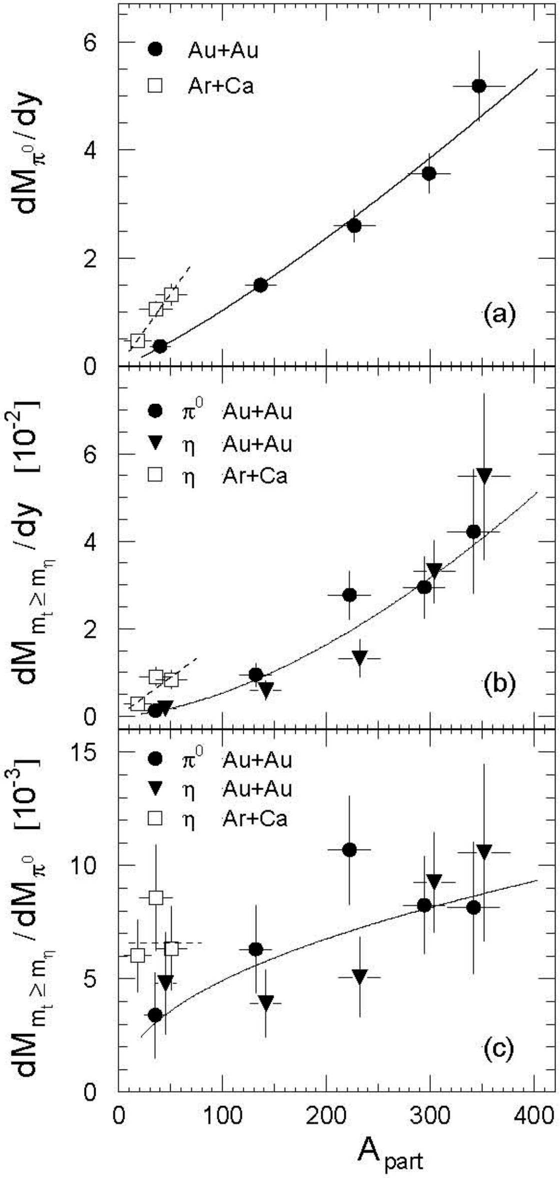
Figure 4.6: The example of separation of particles with Z=1 and Z=2 in the dE/dx spectrum for a single FW module. The data are from the ^{58}Ni+^{58}Ni reaction at 1.9 *A* GeV.

Centrality: TAPS

Au+Au (0.8 AGeV)



$$A_{part} = 2A_{proj}\left(1-\frac{Z_{sum}}{Z_{proj}}\right)$$

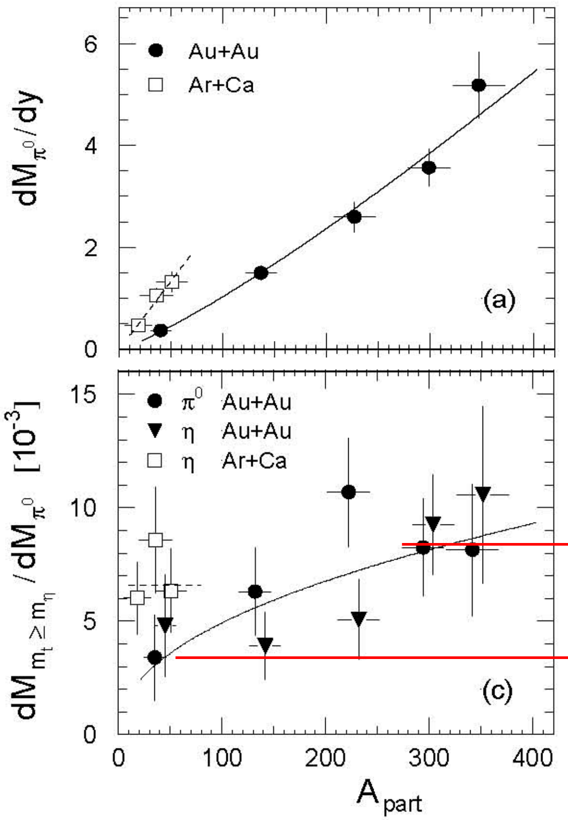


A.R.Wolf et al. (TAPS): ***Multistep Production of η and Hard π0 Mesons in Subthreshold Au-Au Collisions*****; PRL 80 (1998) 5281**

Centrality: TAPS and HADES

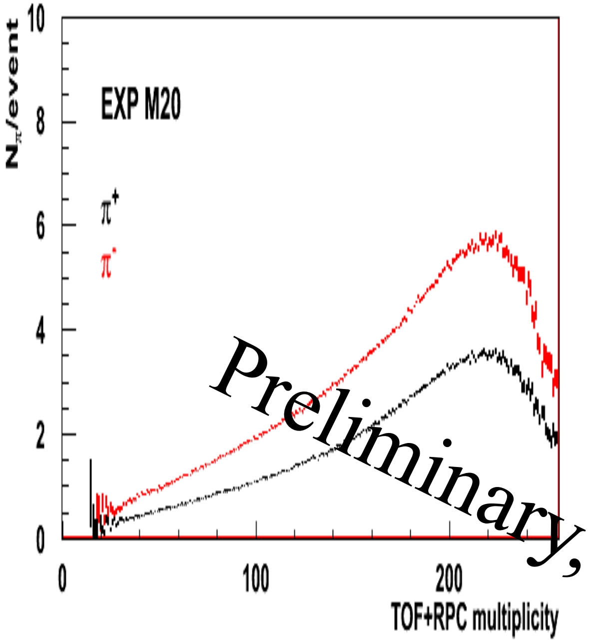
π^0 @ Au+Au (0.8 AGeV)

A.R.Wolf et al. (TAPS): PRL 80 (1998) 5281

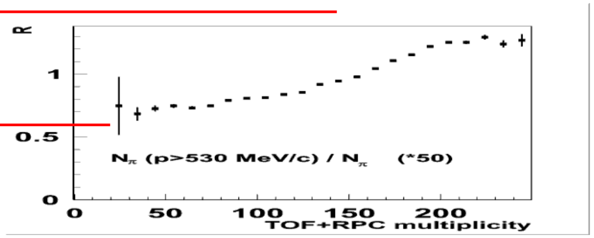


$$A_{part} = 2A_{proj}\left(1 - \frac{Z_{sum}}{Z_{proj}}\right)$$

π^- @ Au+Au (1.24 AGeV)



Relative yield of “hard” pions



Centrality -conclusions

Calibration of dE/dx @ HADES

- one has to check (and produce) dE/dx versus beta (TOF) plot and look for bending of corresponding ridges!!!

- But this maybe not enough, as we have much higher HV settings in FW@HADES as compare to FW@TAPS

- calibration by cosmic is definite answer to avoid misidentified noise peak as Z=1!!!!

FW@TAPS versus FW@HADES

- High Z visible only for small modules close to the beam – up to Z~8, not so pronounced @ HADES

- Countrate goes rapidly down with Z, even for small $\Theta \sim 1^0$
  - protons/Helium like ~ 5x ; ~ 2x @ HADES for small $\Theta \sim 2^0$
  - Helium/Lithium like ~10x ; ~ 5x @ HADES for small $\Theta \sim 2^0$
  - …
- For big modules $\Theta \sim 10^0$ only helium like particles visible, similar @ HADES

- low statistic of high Z particles, even at small modules, can be due to strong bias to central collisions (π^0 ~ trigger) , not so @ HADES, data dominated by semi-peripheral collisions?

- Z_{sum} can be used to determine A_{part}

- observed dependence of multiplicity on A_{part} of subthreshold produced η and hard π0 mesons is non-linear at 800 AMeV;

- **what about dileptons and/or Kaons at 1240 AMeV?**

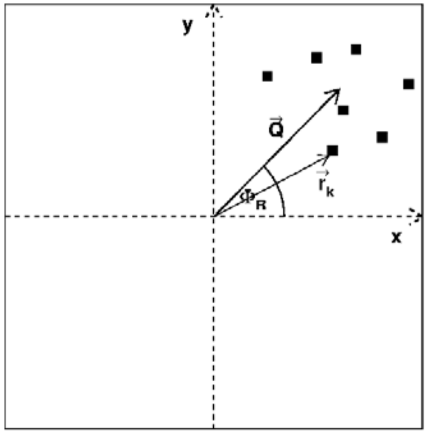
R

Reaction plane reconstruction

modified transverse momentum method

The reaction plane is defined by the beam momentum and by the vector of impact parameter.

In experiment we can take instead of the impact parameter vector an approximate vector *Q*. According to the modified transverse momentum method is vector *Q* calculated as



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

Position of particle hit in FW.

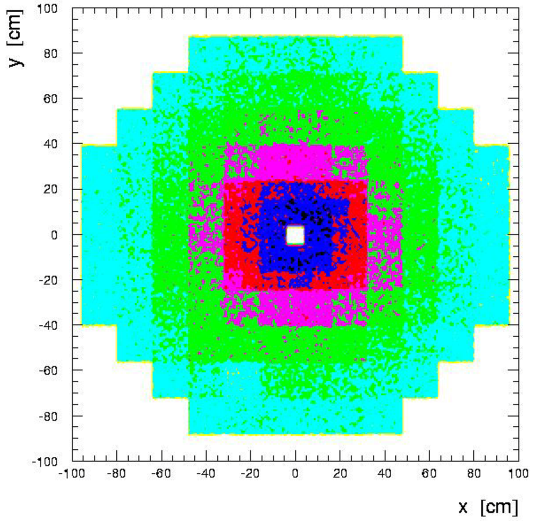
The sum goes through all particle hits in event.

The norm of the position vector.

References:

- **P. Danielewicz, G. Odyniec, *Phys. Lett. 157B, 146 (1985)***
- **J.Y. Ollitrault, arXiv:nucl-ex/9711003**

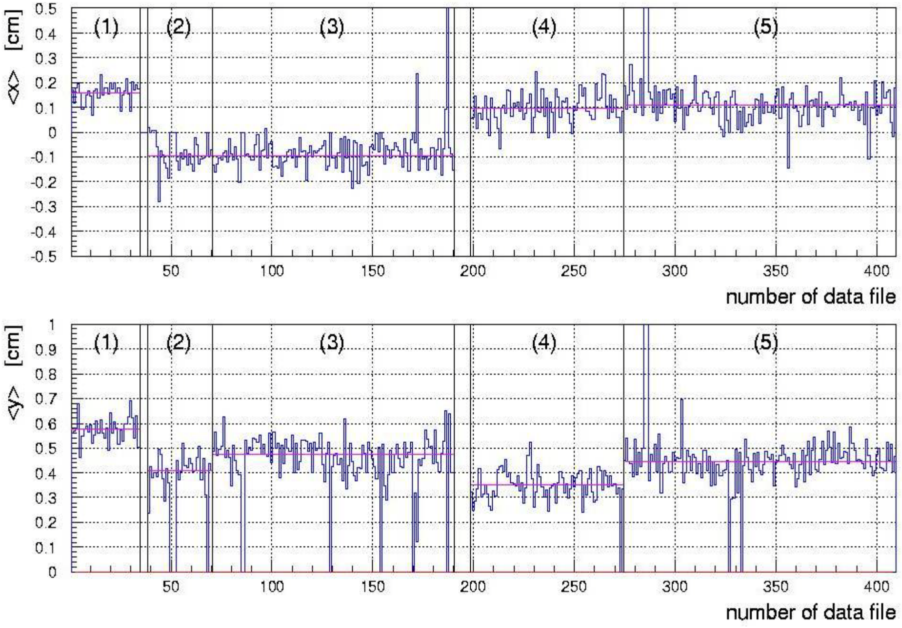
Beam position: FW@TAPS Au+Au 800 AMeV

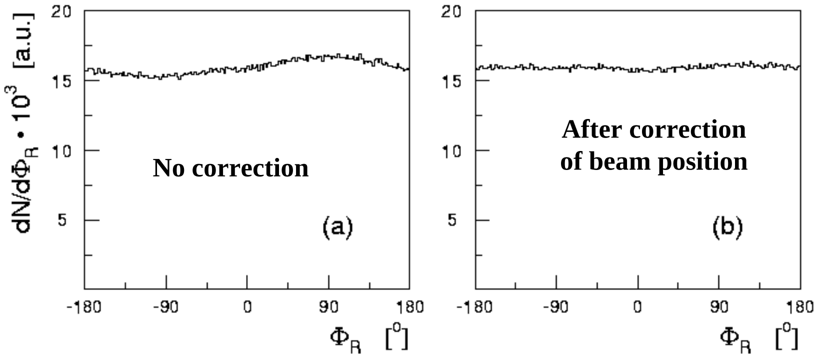


$$\vec{r}_0 = \frac{1}{N}\sum_{k=1}^{N}\frac{1}{M_k}\sum_{i=1}^{M_k}\vec{r}_i$$

***N*-events, each with multiplicity M_k**

Beam position was changing through the time!!!!

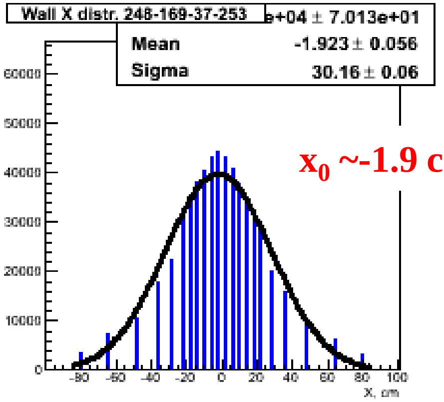




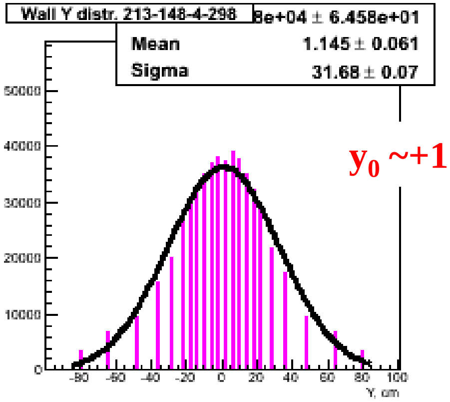
Beam position: FW@HADES Au+Au 1240 AMeV

day 103

Z~1

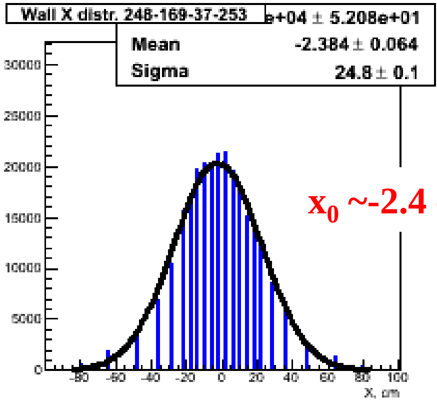


x_0 ~-1.9 cm

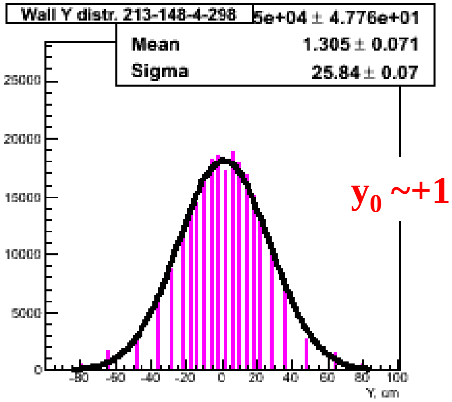


y_0 ~+1.1 cm

Z~2



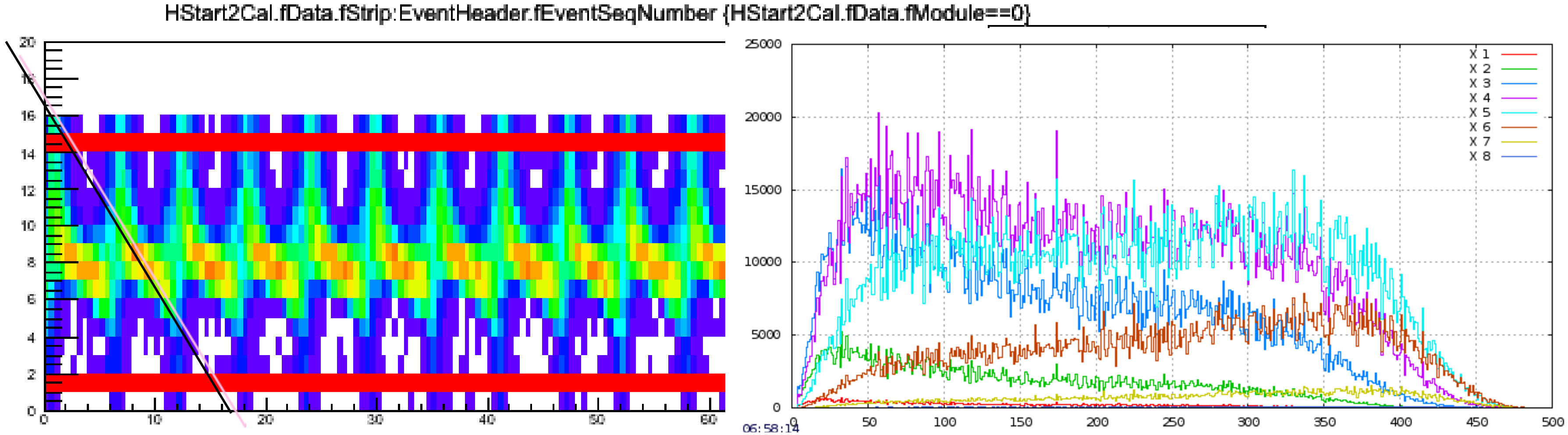
x_0 ~-2.4 cm



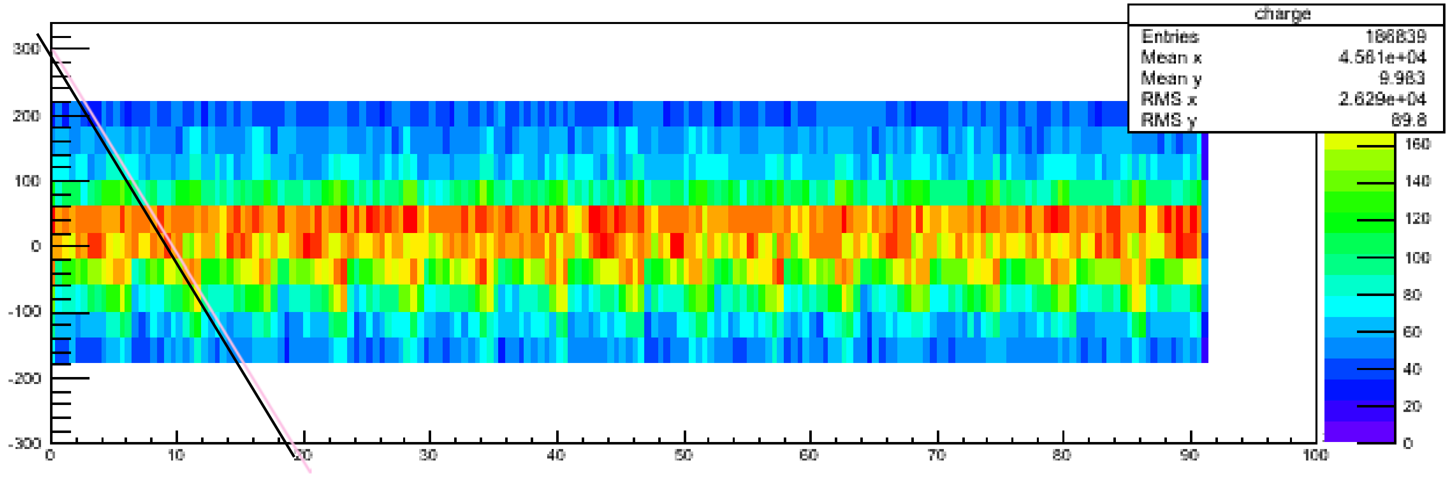
y_0 ~+1.3 cm

Beam position during spill: FW@HADES Au+Au 1240 AMeV

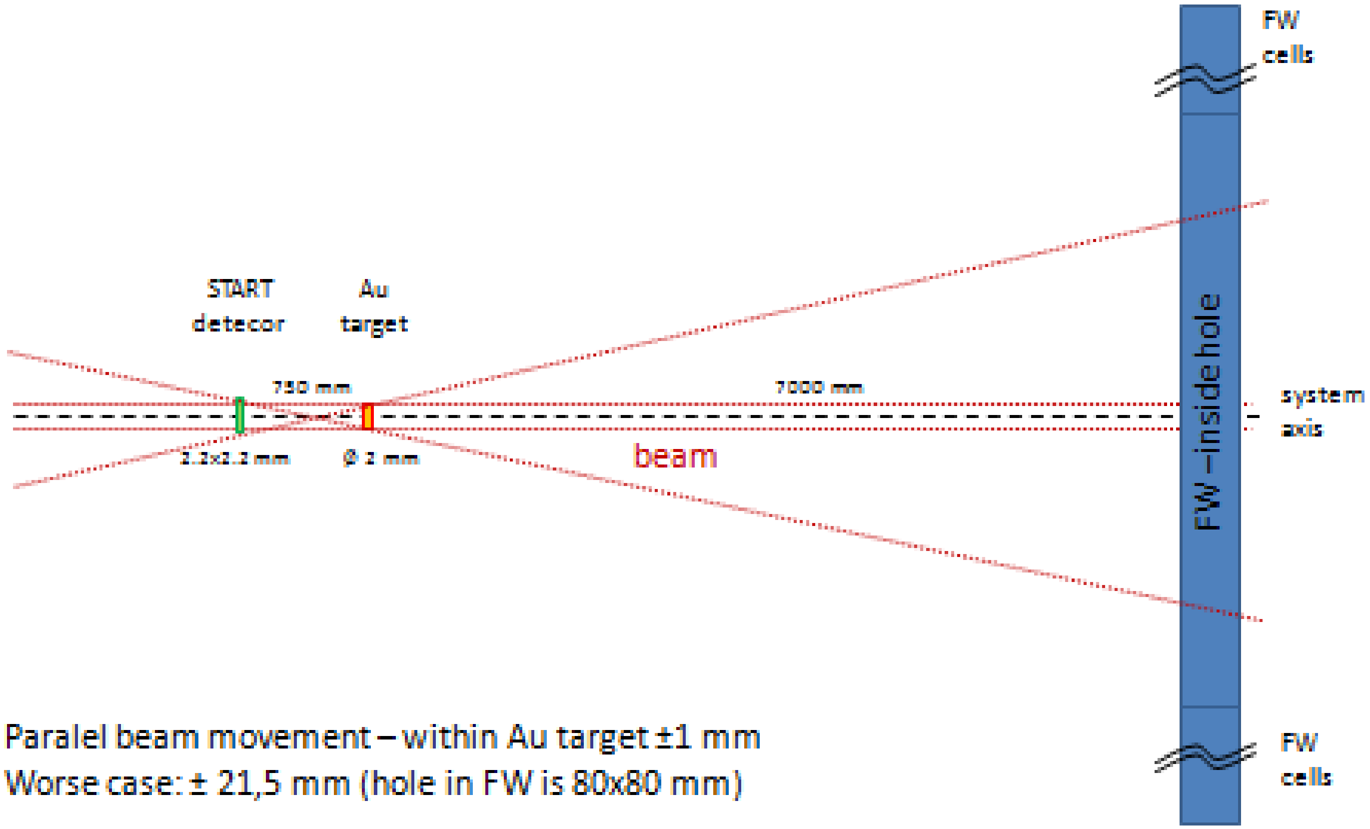
Beam position movement during spill at Start (280 mikron/stripe)



Beam position movement during spill at FW



Possible movement of beam spot at FW during spill



Paralel beam movement – within Au target ±1 mm
Worse case: ± 21,5 mm (hole in FW is 80x80 mm)

For simplification – only one Au target is taken into account!

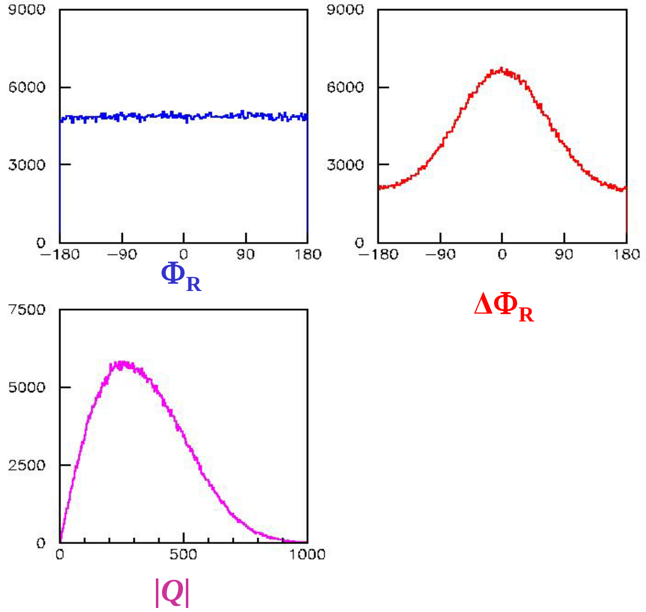
Reaction plane resolution

$$\vec{Q} = \sum_{i=1}^{M} \frac{\vec{r}_i - \vec{r}_0}{\left|\vec{r}_i - \vec{r}_0\right|}$$

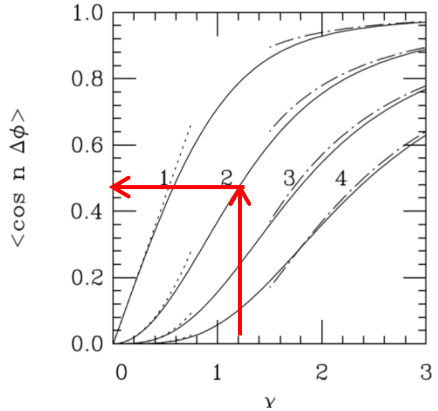
M-hits in one event

Random division of each event into two subevents:

$\Delta\Phi_R = \Phi_1 - \Phi_2$; $M = M_1 + M_2$

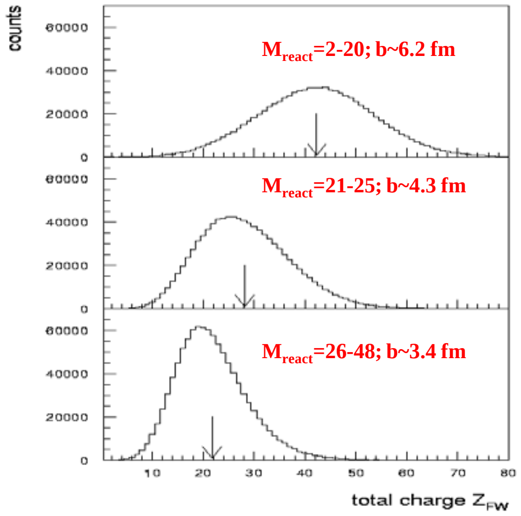


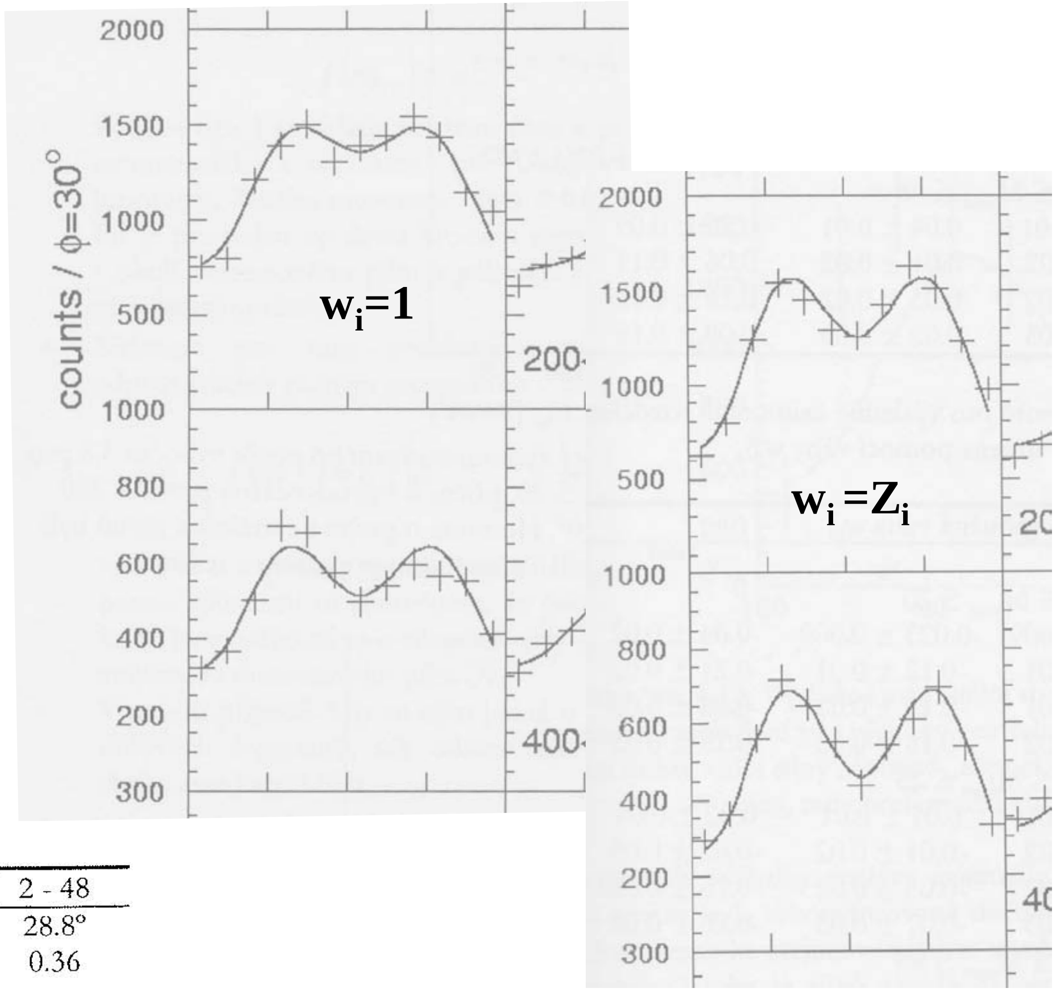
$$\frac{N(90^0 \leq \Delta\Phi_R \leq 180^0)}{N(0^0 \leq \Delta\Phi_R \leq 180^0)} = \frac{\exp(-\frac{\chi^2}{2})}{2}$$



$$v_2^{true} = v_2^{meas} / < \cos(2\Delta\Phi_{Plane}) >$$

Reaction plane: FW@TAPS Au+Au 800 AMeV



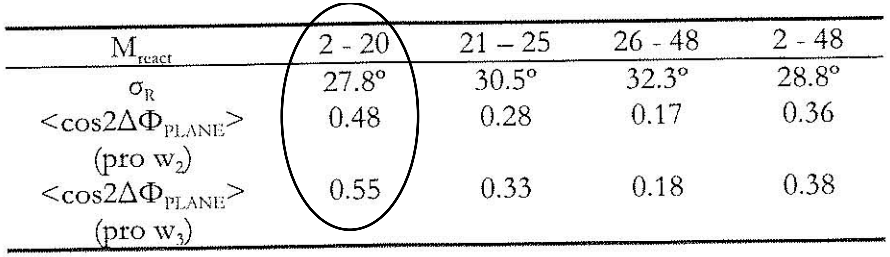


$$\vec{Q} = \sum_{i=1}^{M} w_i \frac{\vec{r}_i - \vec{r}_0}{\left|\vec{r}_i - \vec{r}_0\right|}$$

M-hits in one event

Experimental resolution deduced from data:

- **for used weight**
- **for each range in centrality**



M_{react}	2 - 20	21 – 25	26 - 48	2 - 48
σ_R	27.8°	30.5°	32.3°	28.8°
$<\cos 2\Delta\Phi_{PLANE}>$ (pro w_2)	0.48	0.28	0.17	0.36
$<\cos 2\Delta\Phi_{PLANE}>$ (pro w_3)	0.55	0.33	0.18	0.38

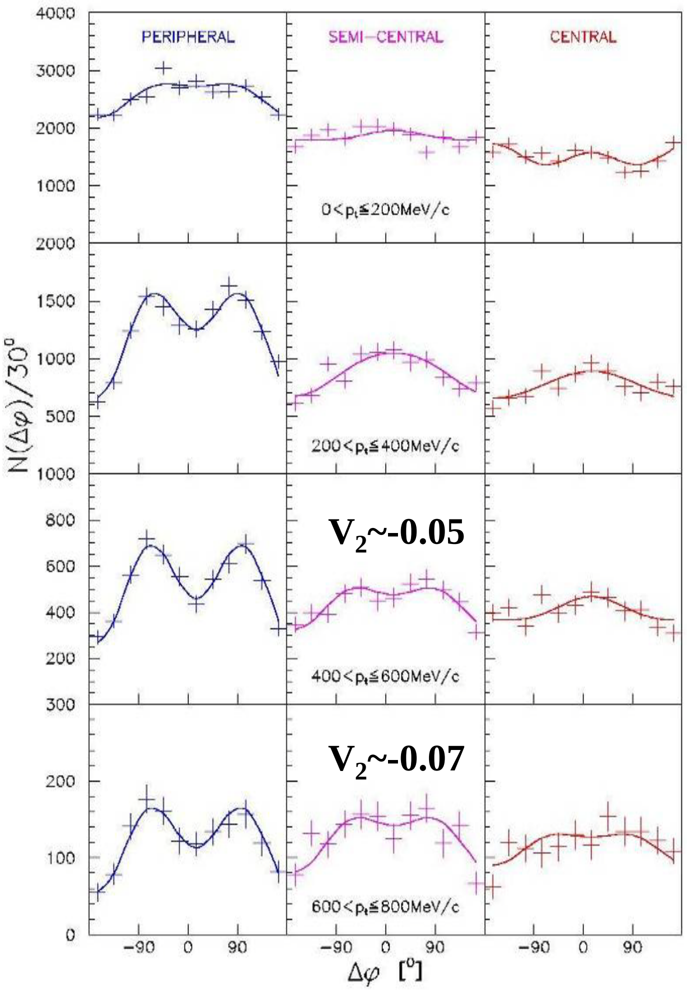
Table from Pleskac PhD thesis; w2=1;w3=Z_i

$$v_2^{true} = v_2^{meas} / < \cos(2\Delta\Phi_{Plane}) >$$

Mesons flow:TAPS and HADES

at midrapidity

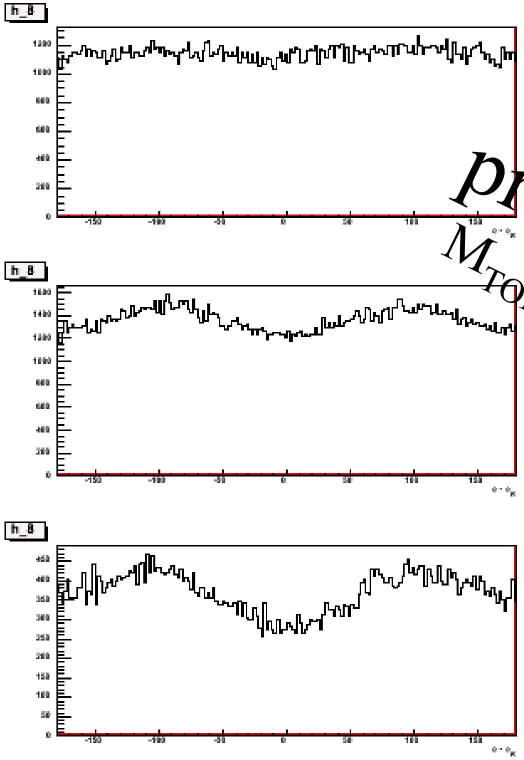
π^0 @ Au+Au (0.8 AGeV)



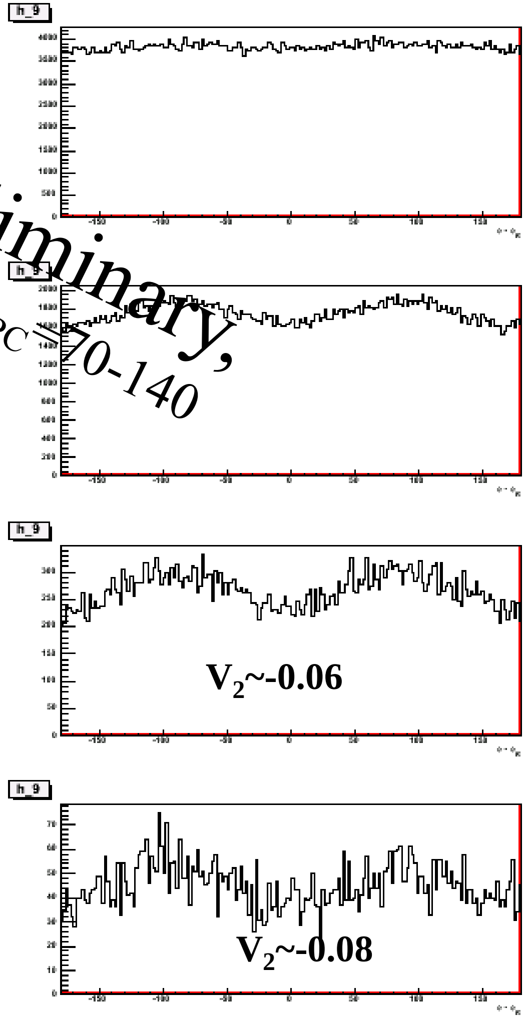
V_2~-0.05

V_2~-0.07

π^+ @ Au+Au (1.2 4AGeV)



π^- @ Au+Au (1.24 AGeV)

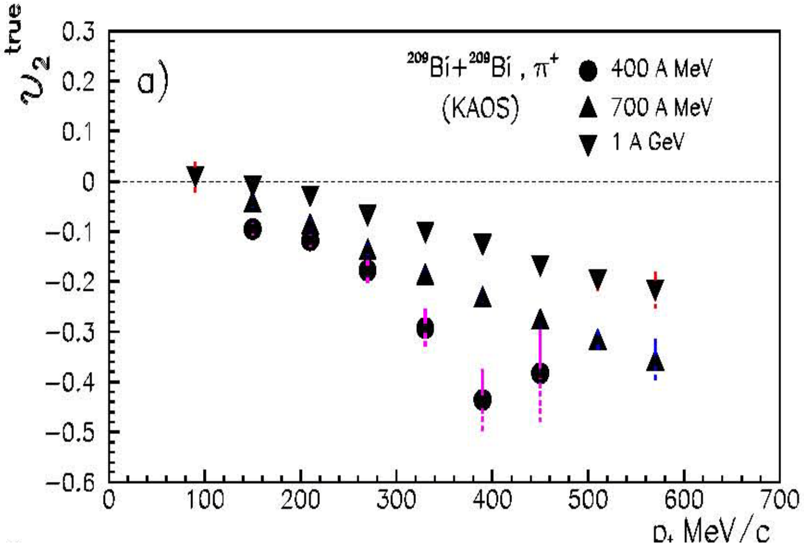


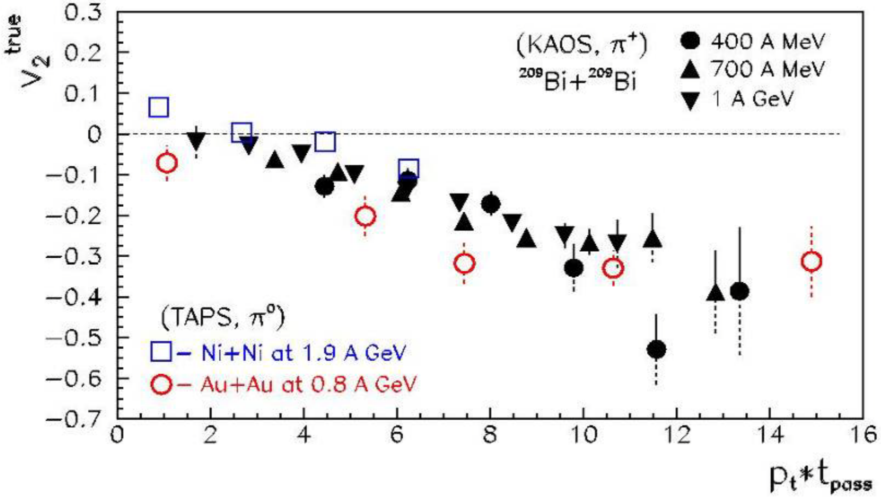
V_2~-0.06

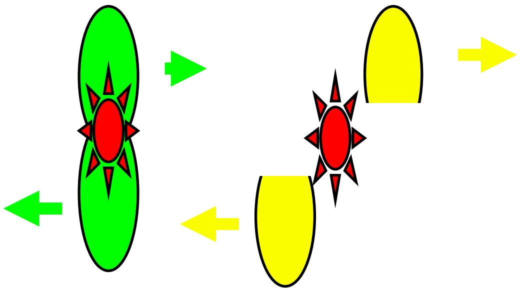
V_2~-0.08

preliminary,
$M_{TOF+RPC}$=70-140

Pion mesons flow as a function of momenta







Shadowing model

Passing time of spectator’s zone relative to participant zone

$$t_{pass}=2R/(\beta_{cm}\gamma_{cm})$$

has to be compared with time it takes pions to reach spectator‘s zone, i.e. with $t_{tr}\sim 1/p_t$

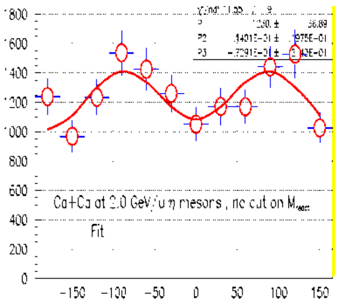
Reaction clock?

- **Ni+Ni (1.9AGeV) and Ca+Ca (2AGeV), see**
Arkadii Taraněnko; PhD 2001;

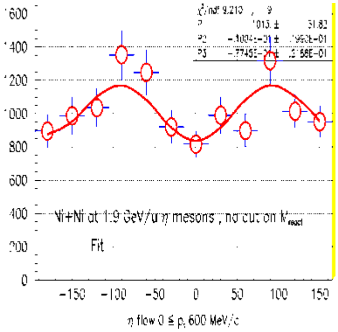
- **Au+Au (0.8AGeV) , see**
Radek Pleskač; PhD 2003

TAPS η mesons flow results

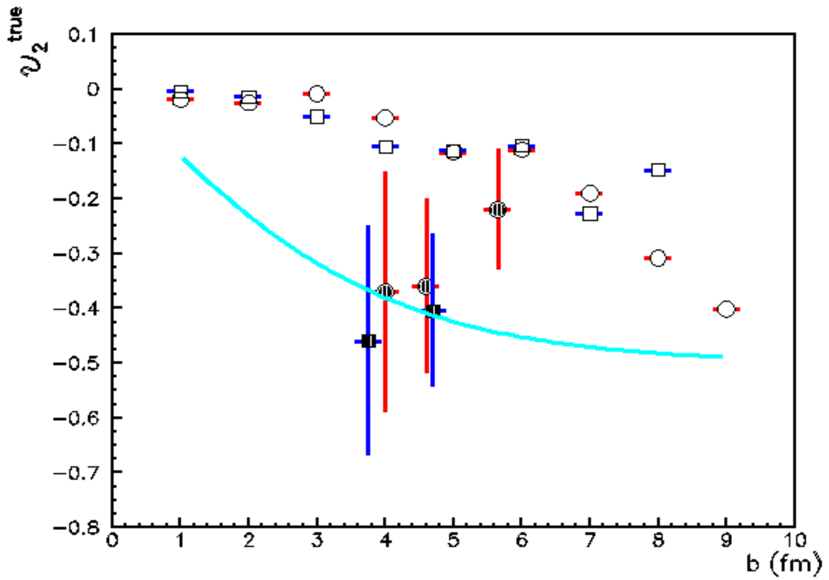
η@ Ca+Ca (2AGeV)



η@ Ni+Ni (1.9AGeV)



Elliptic flow of η ~ impact parameter



- Impact parameter b deduced from measured $<A_{SP}>$ assuming geometry of two overlapping spheres
- BUU calculations (open symbols) increase with the increase of impact parameter b (courtesy of W.Cassing et al.)
- Line indicate prediction of absorption model $v_2=0.5(1-R)/(1+R)$, $R=\exp(b/\lambda)$, $\lambda=2$ fm ; λ is mean free path of meson in cold nuclear matter

- Both pion and eta mesons have comparable mean free paths in spectator matter (λ ≈ 2-6 fm)
- Hence, different elliptic flow at 2 AGeV has to be associated with difference in freeze out times. While for pions $t_{freezeout}$~25 fm, for eta mesons $t_{freezeout}$~10 fm.
- π are emitted rather late, they don't see any spectators, their in-plane enhancement correspond to the shape of expanding collision zone
- η are emitted early, their azimuthal pattern is strongly influenced by their final state interaction in cold matter

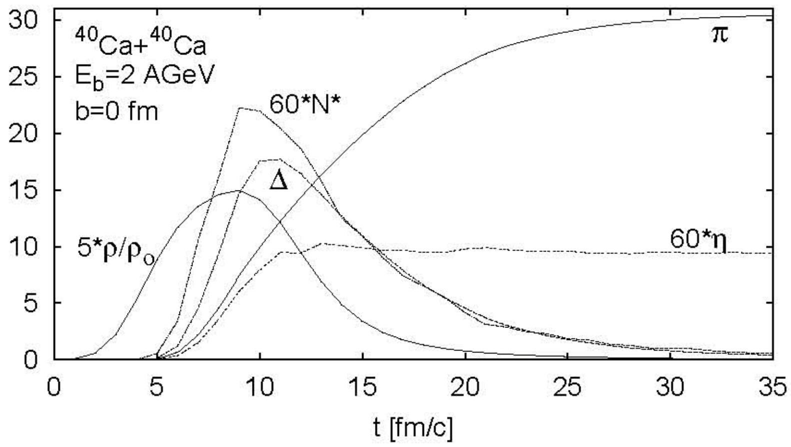


Figure 7.6: The prediction of the BUU model for the time evolution of various quantities in the central collision of ^{40}Ca+^{40}Ca at 2 A GeV [Wolf98].

Reaction plane -conclusions

FW@TAPS

- With weight of hit = 1, (Z=1, Z=2 … hits are treated the same), reaction plane resolution is already good ~ 29^0; dominated by high multiplicity of particles (hits)

- both pions and eta mesons at midrapidity are shadowed by spectators, i.e. their emission is suppressed in-plane (corresponding v2 is negative)

- beam position@FW, i.e. at distance of about 5-6 meters from target moves during experiment, correction had to be done for each data-file

FW@HADES

- beam position@FW maybe moves even during the spill in the range of milimeters. If yes, how to correct for that ??? No time in spill info in DST!!!

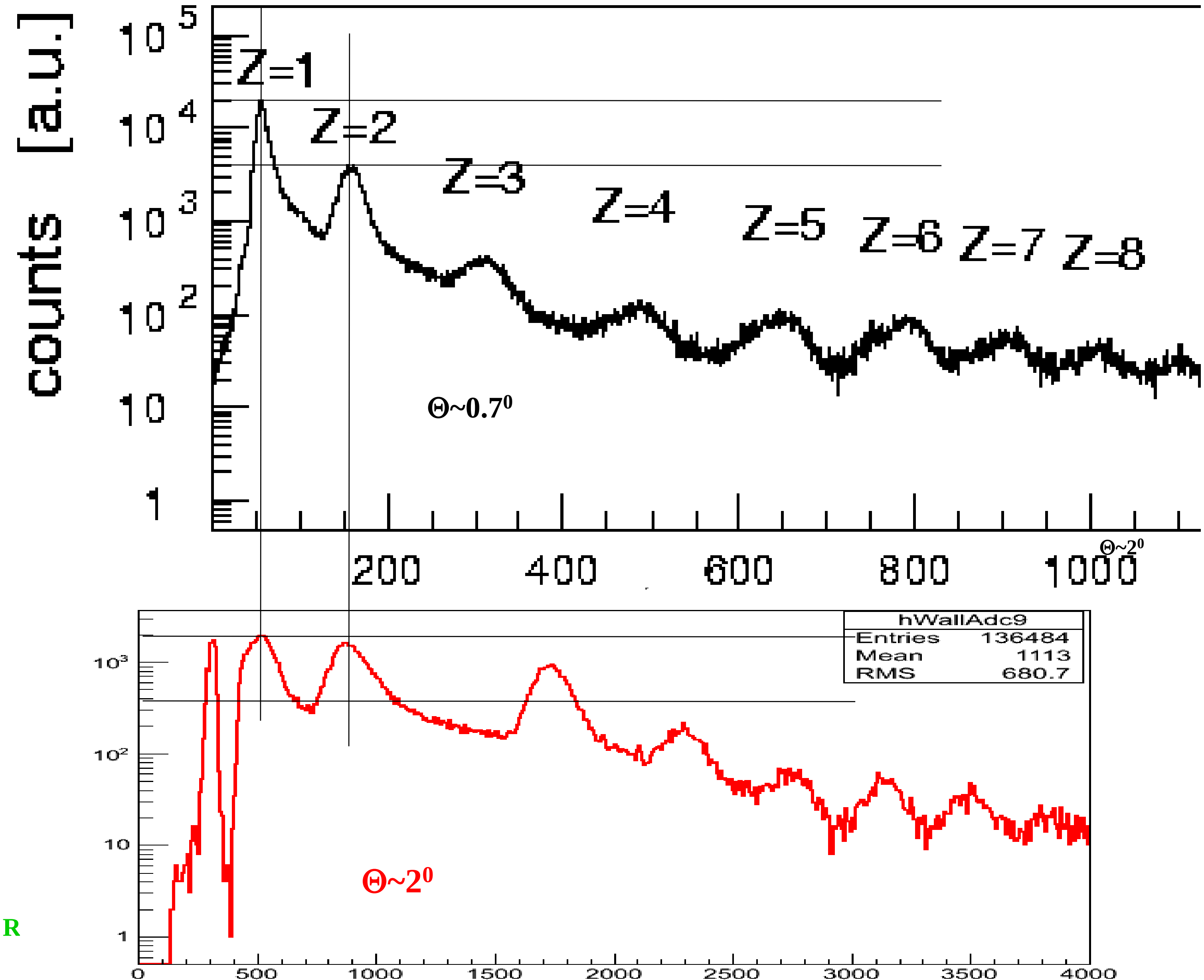
- preliminary results indicate same v2 values for π^- in HADES as observed previously for π^0 in TAPS

- **Is any shadowing of other sources of dileptons? If not, is corresponding v2 positive?**

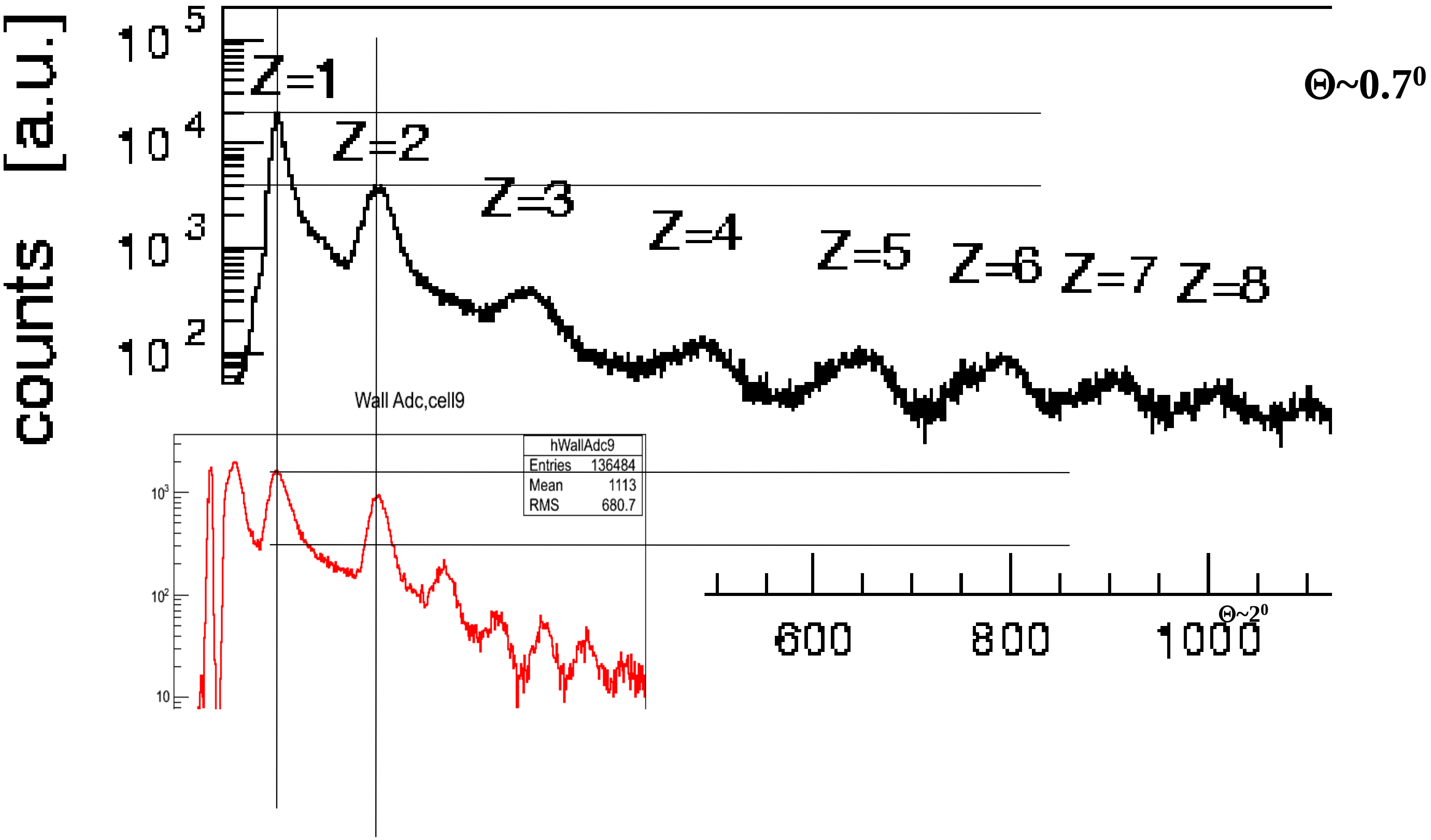
Thank you

Backup

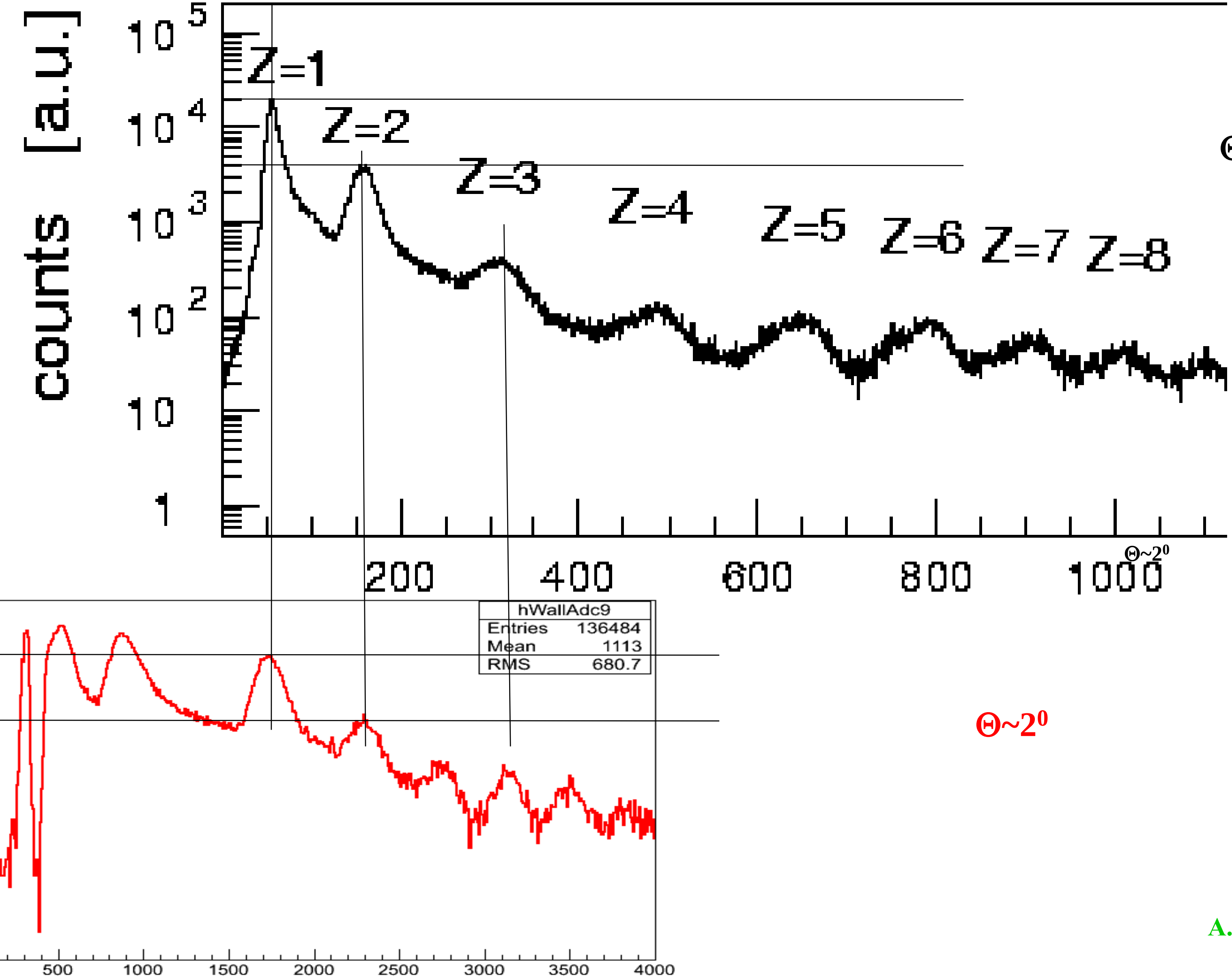
Charge details: try to match TAPS and HADES -1



Charge details: try to match **TAPS** and HADES -3



Charge details: try to match TAPS and HADES -2

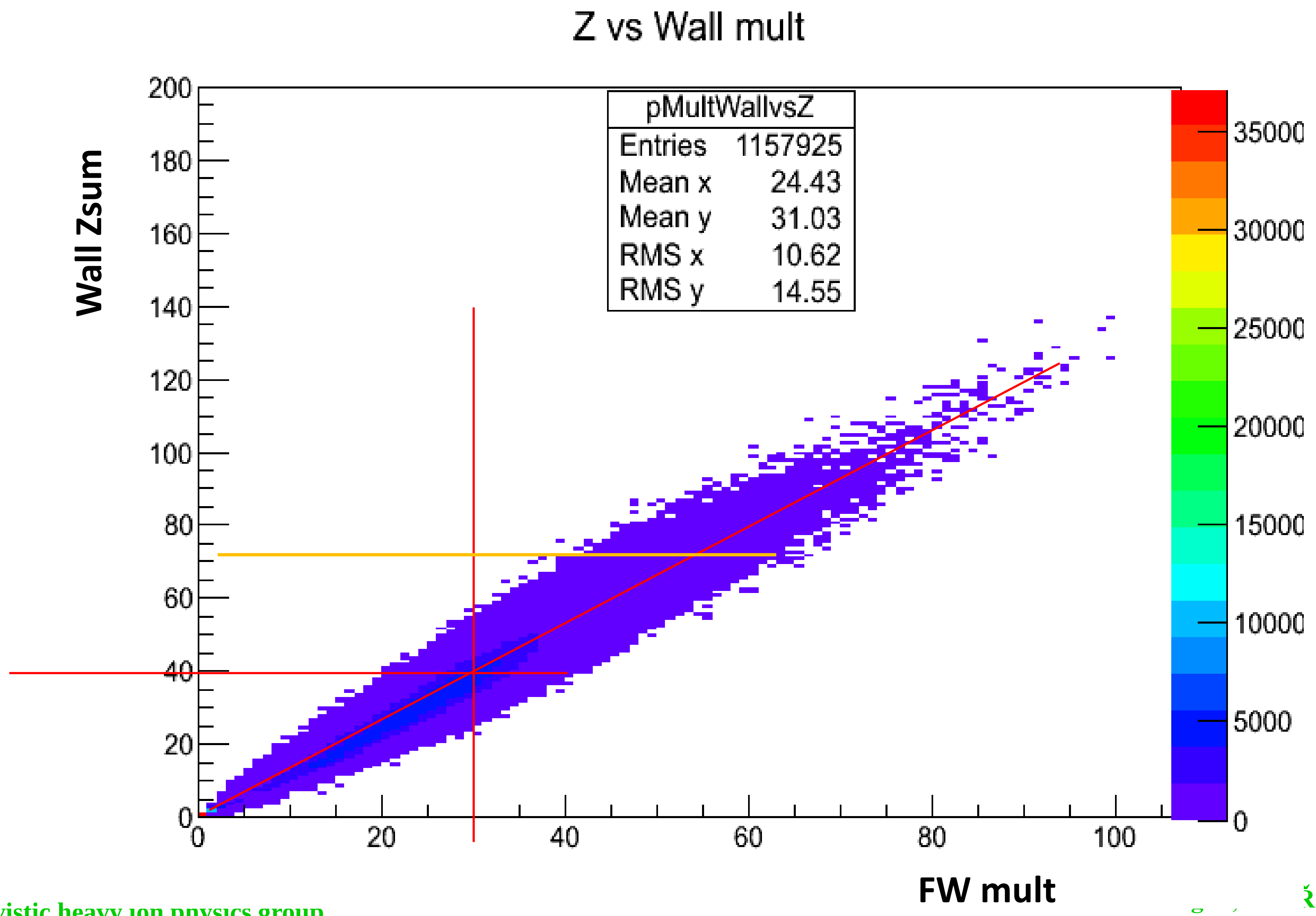


Θ~0.7^0

Θ~2^0

A.Kugler, NPI Řež

Zsum and FWmult



Zsum and TOFmult