Kentros Report

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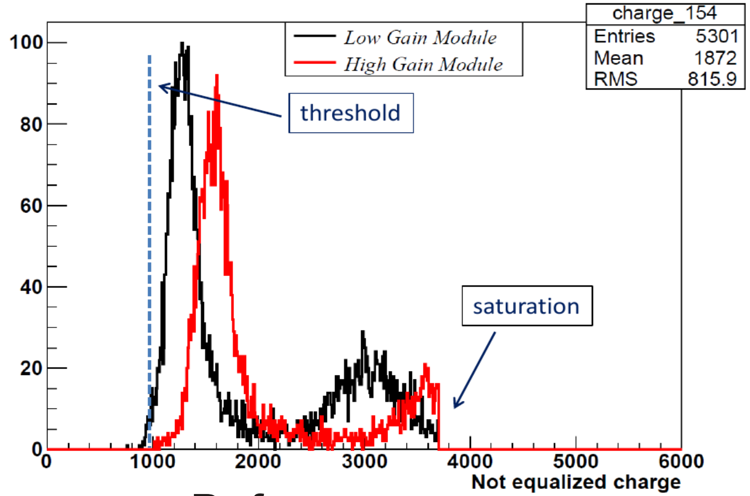
Equalization

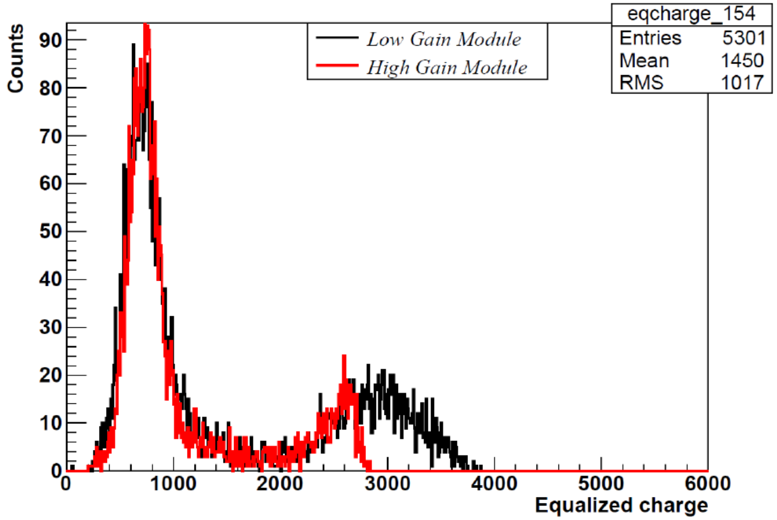
Quadratic correction:
$q_{eq}=a(i)*q^2 + b(i)*q + c(i)$

i: module number
Reference points:
- q0: pedestal center
- q1: sum(q1,inf) (protons) = 1/3 of the expected value*
- q2: sum(0,q2) (alpha) = 1/3 of the expected value**

*) expected value calculated on a high-gain module
**) expected value calculated on a low-gain module



Before

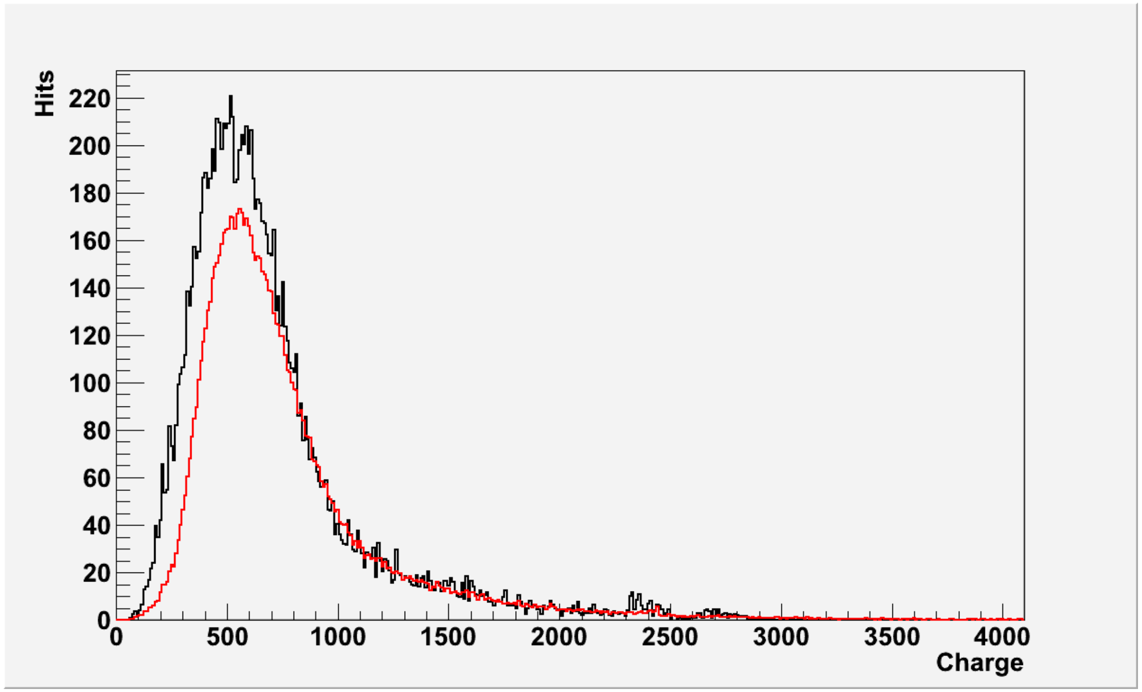


After

Quadratic term is small (~ few %) but it is required to perfectly align the distributions

Charge Efficiency

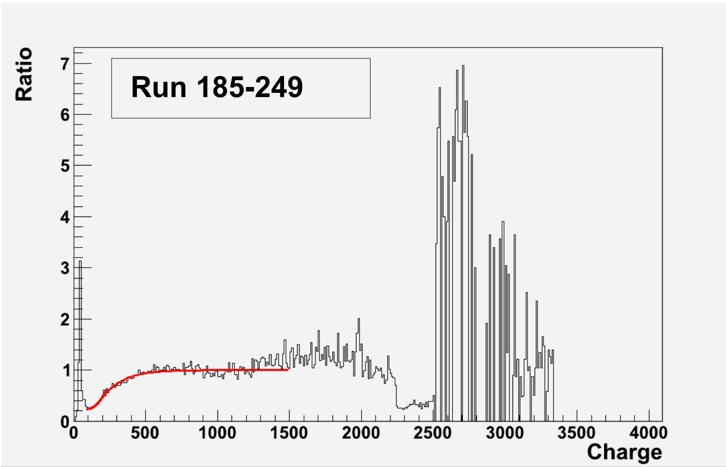
Two modules with higher gain values are chosen as reference. The mean of the charge histograms for all modules is calculated and compared with the mean of two modules of reference.

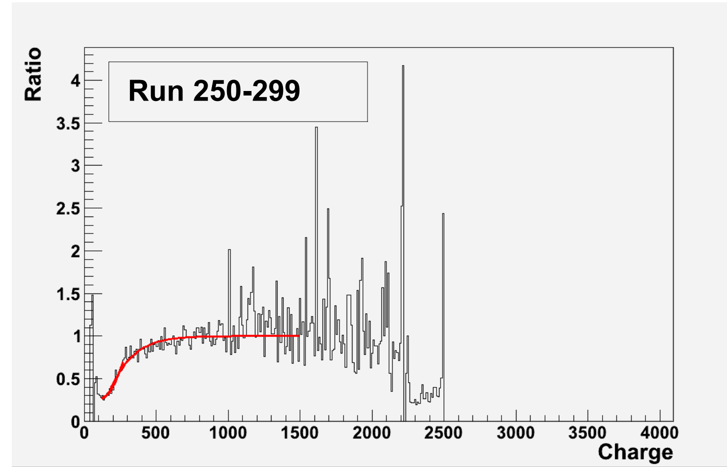


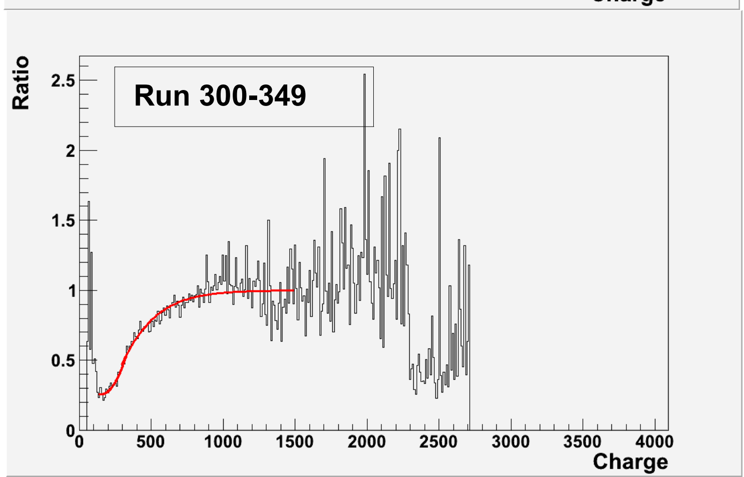
Charge histogram of modules with high gain (Runs 400-449)

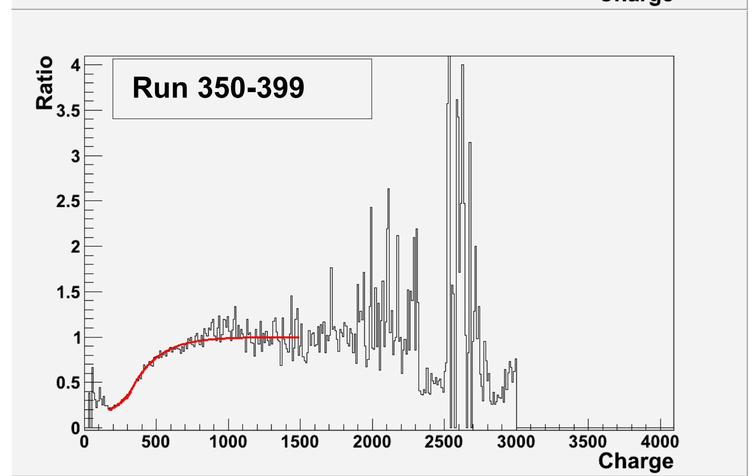
Mean for all modules (Runs 400-449)

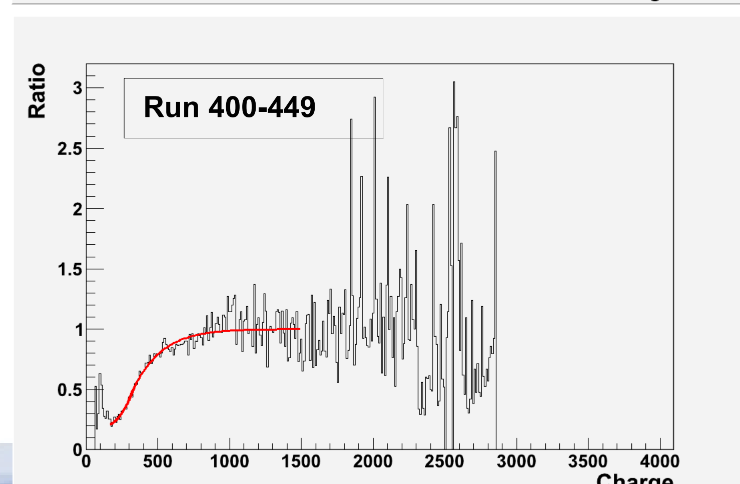
Efficiency Vs Charge of Small EndCap

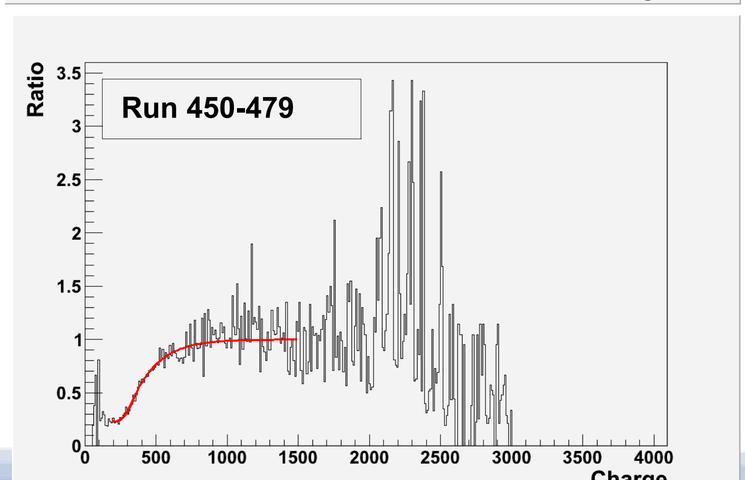




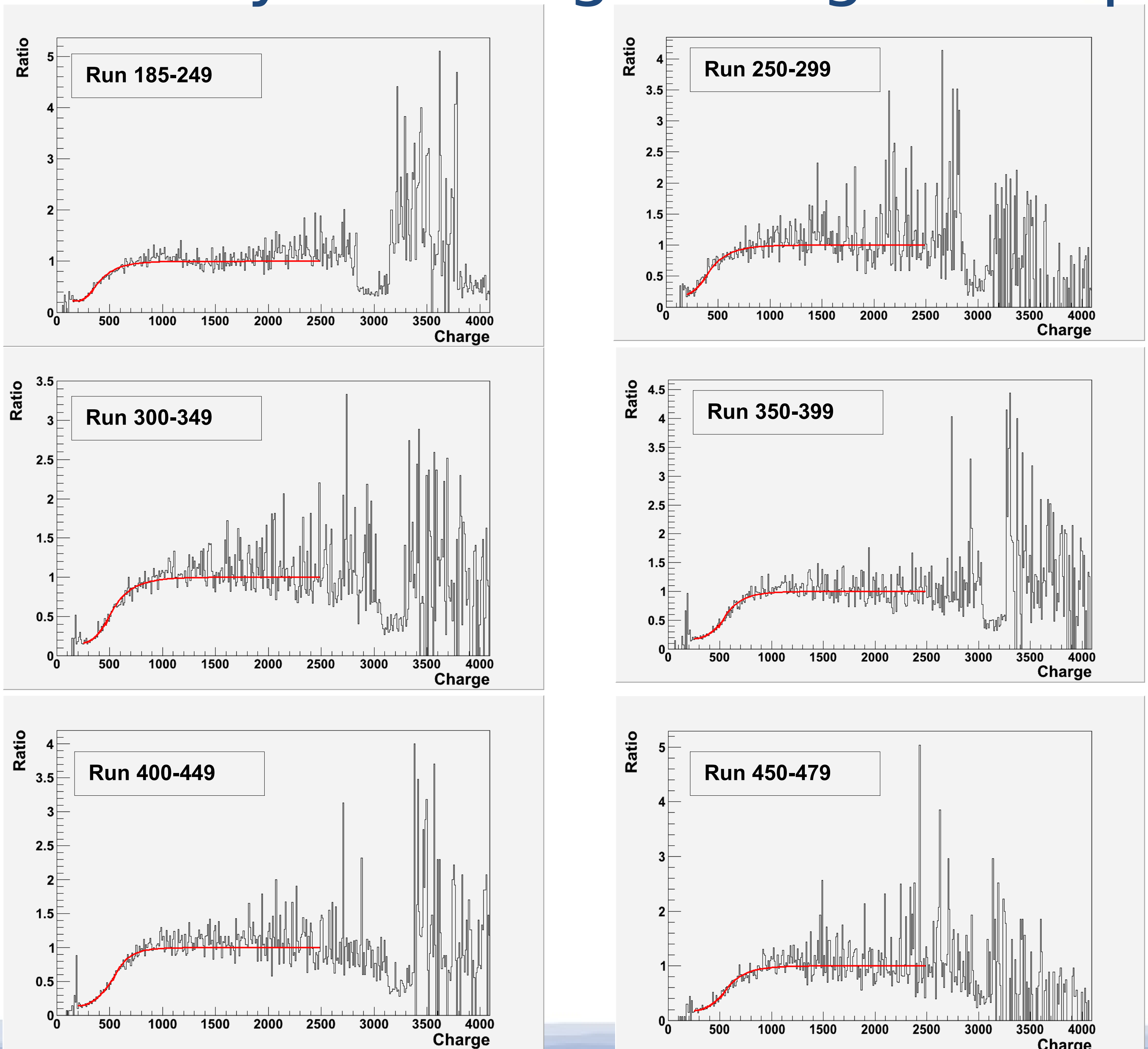




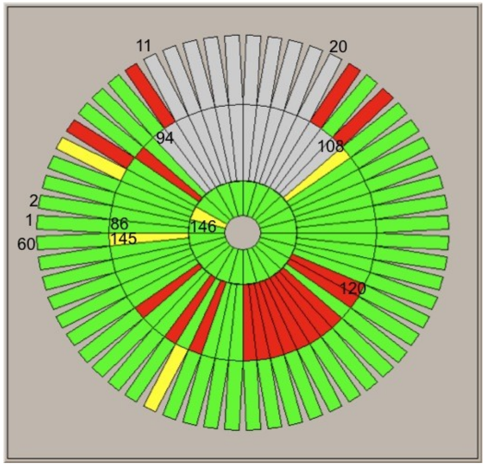




Efficiency Vs Charge of Big EndCap



Geometric efficiency



Missing modules

Modules under threshold

- For each run: mean and stddev per each subdetector
- Threshold: mean – 3 σ
- Modules under threshold at least in one run per group are excluded

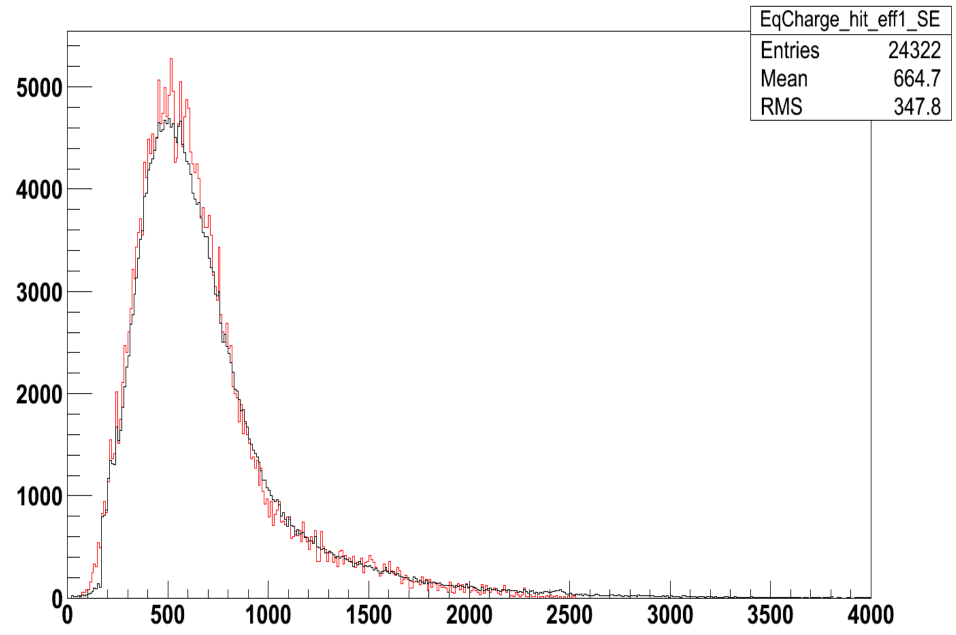
The geometric efficiency is calculated by considering only modules that are present and over threshold in all runs of the group.

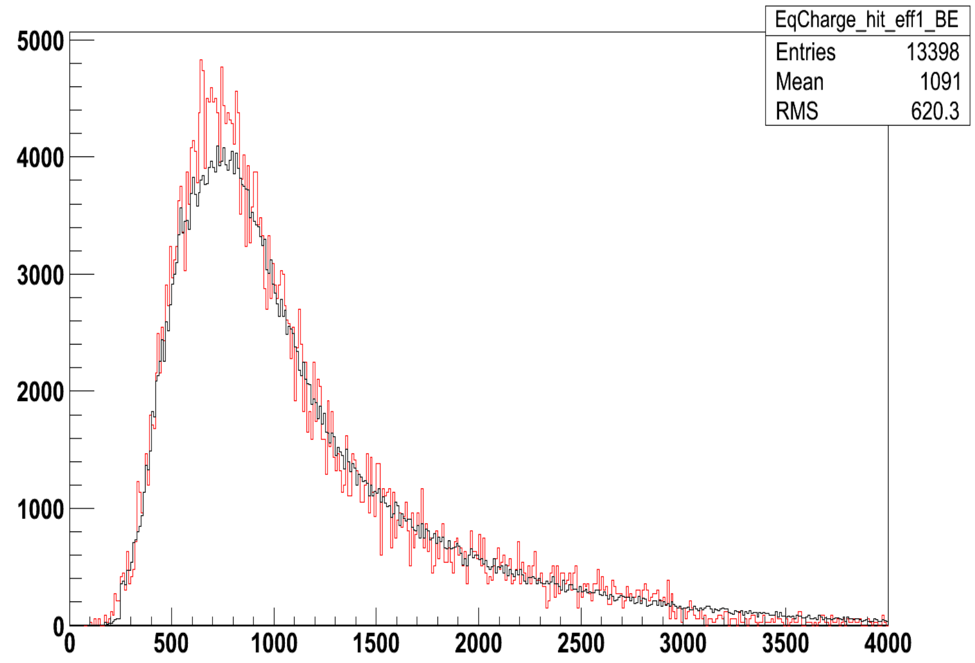
Geometric efficiency

Group	Small Endcap	Big Endcap
185-249	23	29
250-299	23	28
300-349	23	30
350-399	24	30
400-449	23	30
450-479	24	30
	24 (24)	45 (60)

Geometric and charge efficiency

The geometric and charge efficiencies are taken into account in the calculation of the total hits.
Two modules with higher gain values are chosen as reference, rescaled with their geometrical efficiencies.



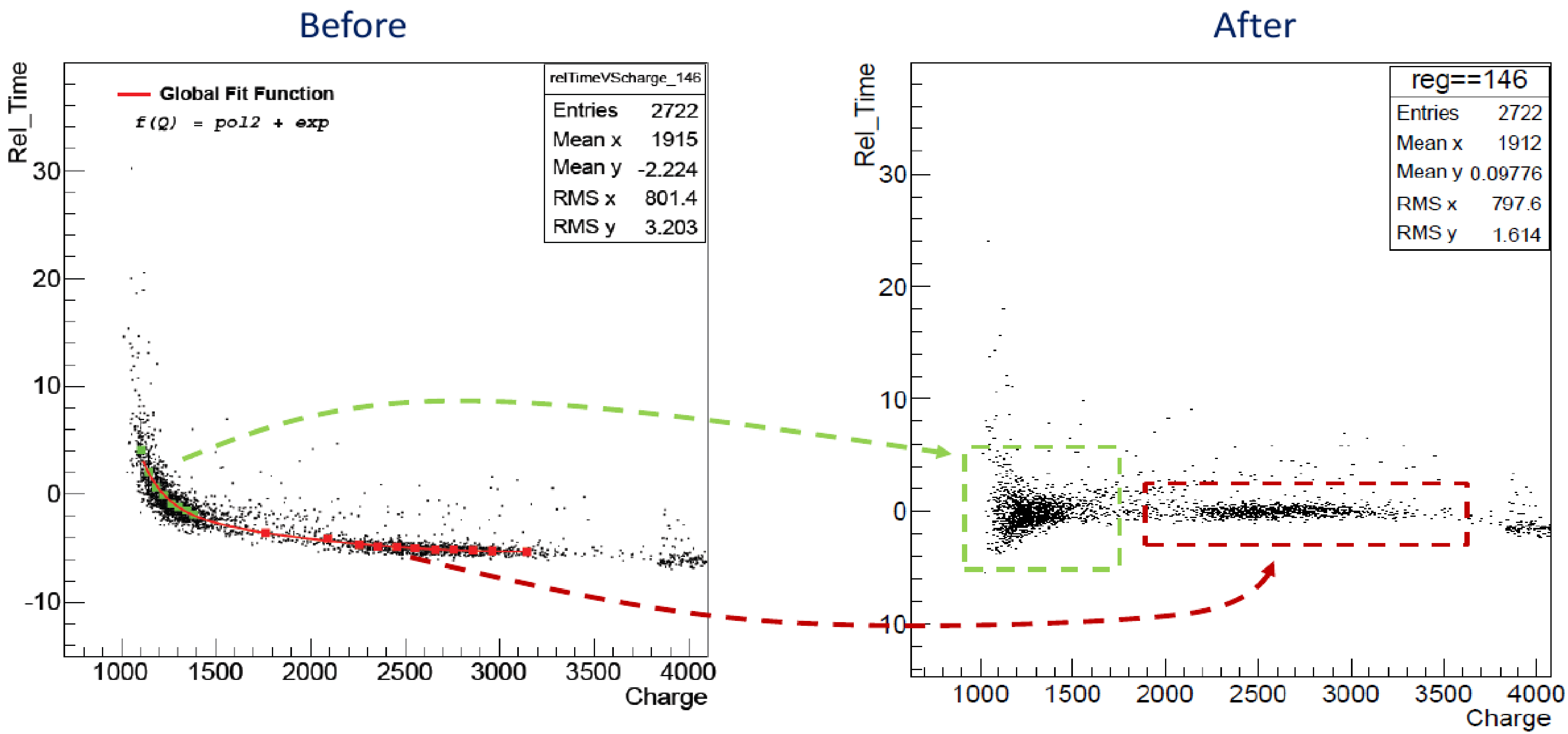


Charge histogram of modules with high gain (Runs 400-449)

Charge histogram for all modules (Runs 400-449)

Time walk correction

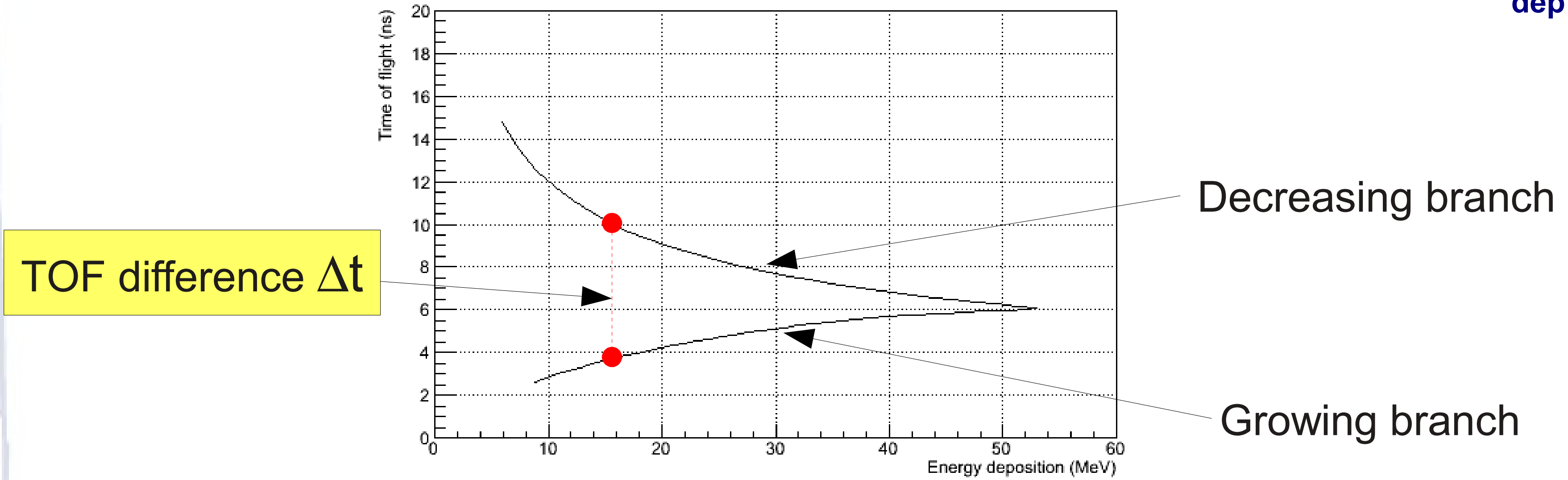
Fitting function: $$F(Q) = p_0 + p_1 \cdot Q + p_2 \cdot Q^2 + \exp(p_3 + p_4 \cdot Q)$$



Charge-E_{dep} calibration

TOF difference at equal E_{dep}

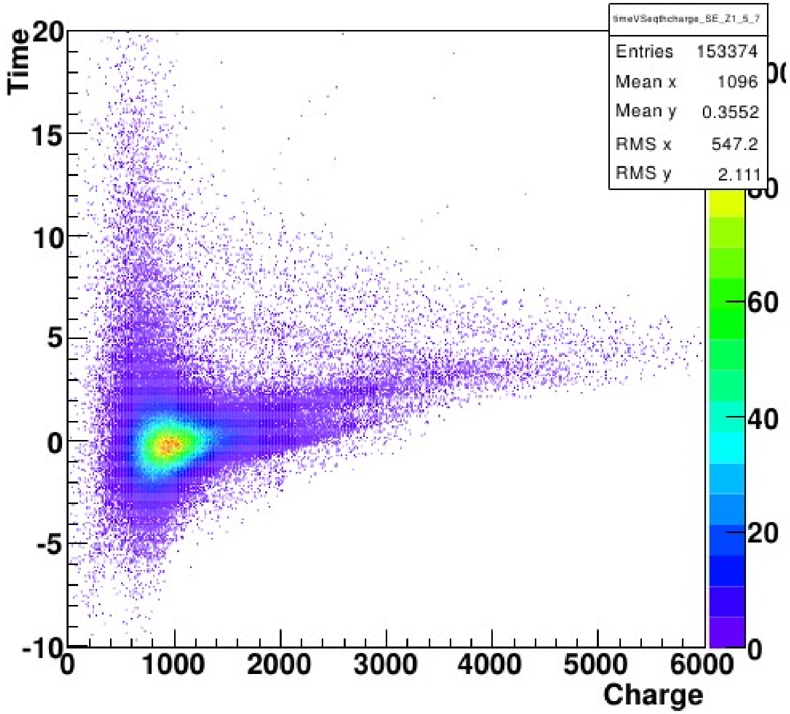
- The TOF-Ed curve has **two branches**
    1) E_{dep} **growing** with time
    2) E_{dep} **decreasing** with time
- Points on the two branches of the curve that have the **same E_{dep}**



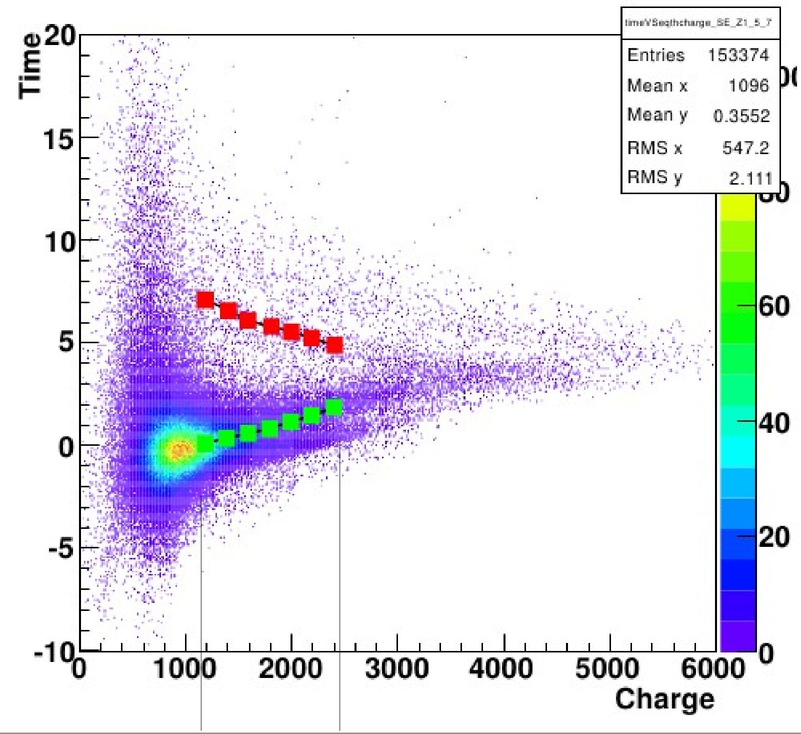
- Δt is a function of E_{dep}
- It does not depend on the proton energy distribution

Fit of Z=1 points on experimental data

Selected polar angles 5<θ<7 degrees on the Small Endcap



•A band is selected around each of the two branches (*starting guess*) slightly larger than the visible "stripes"
•The charge range is divided in small intervals
•The average time is found for each interval inside the band



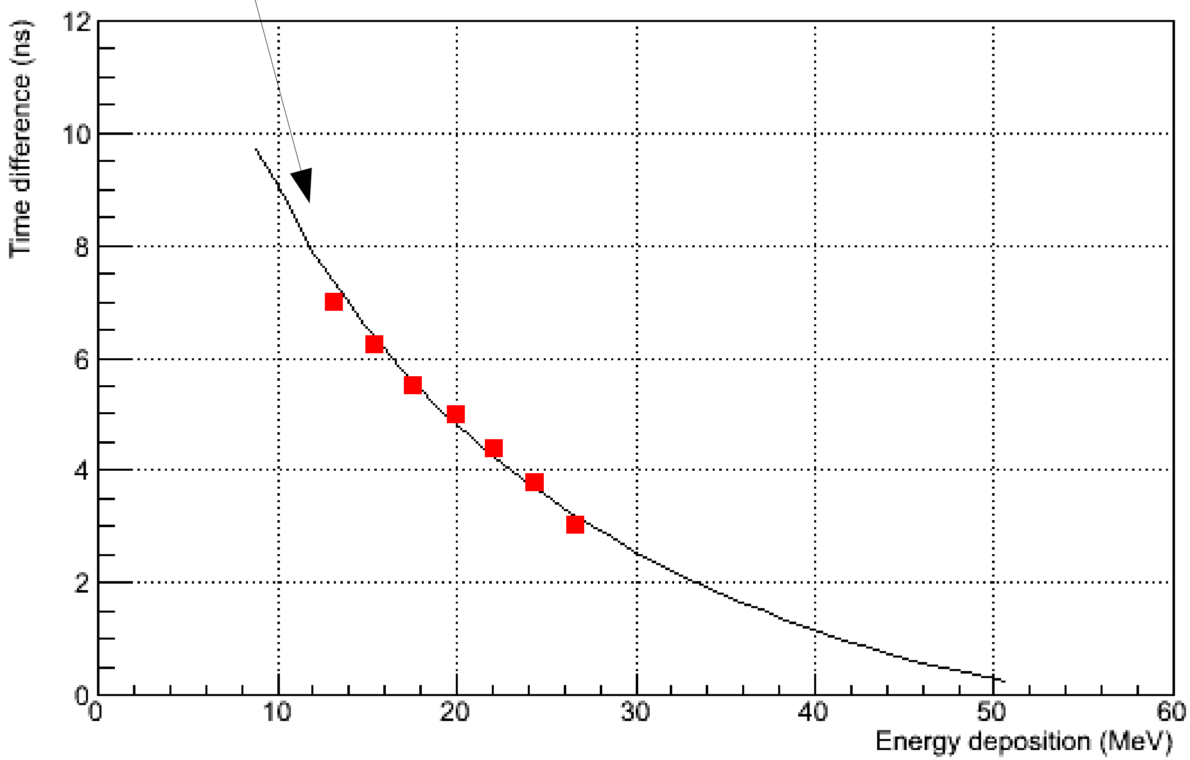
•For each couple of points with equal charge on the two branches we evaluate the time difference Δt
•**This difference is not affected by the time walk effect**

Limits of the interval for a reasonable fit
The two branches start to superimpose

Evaluation of calibration factor

Theoretical curve of Δt versus E_{dep}

■ Experimental points



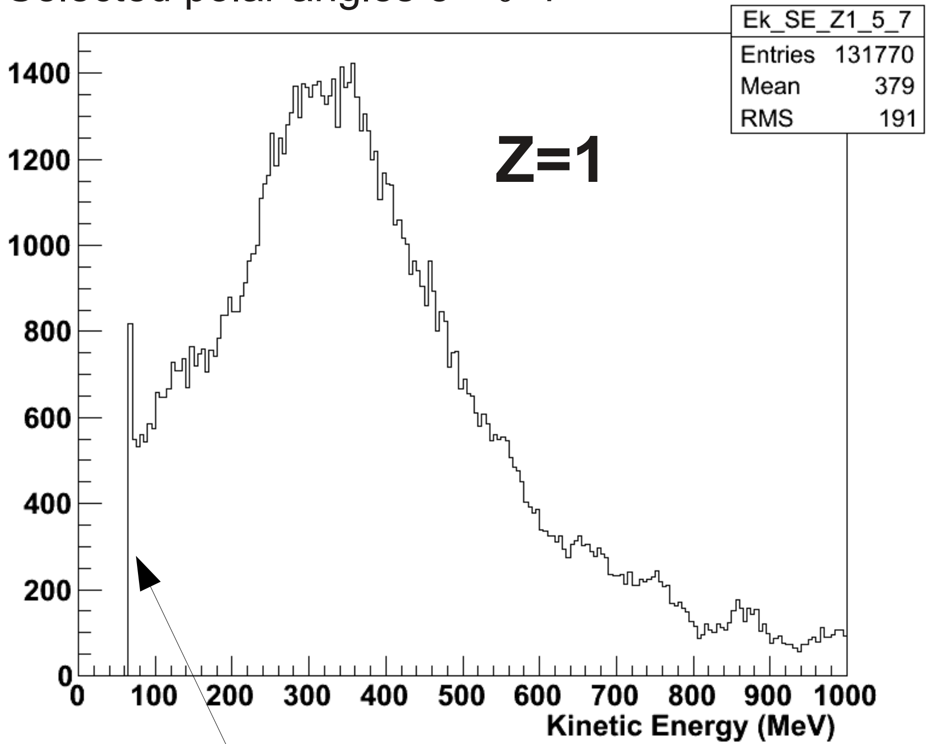
- The charge of the experimental points is multiplied by the factor that makes them best fit the theoretical curve (minimum χ^2)
- This factor is the **calibration factor**

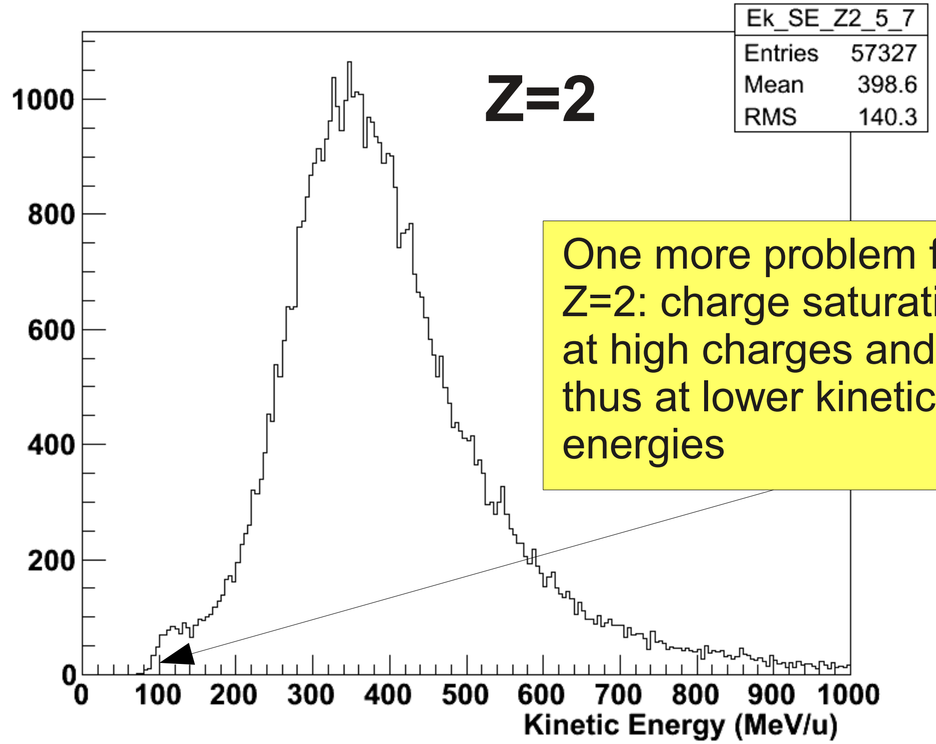
Kinetic Energy distribution from E_{dep}

Edep vs Ek curves from Monte Carlo simulations for different thicknesses

Edep → Ek

Selected polar angles 5°<θ<7°





One more problem for Z=2: charge saturation at high charges and thus at lower kinetic energies

Problem: for each value of E_{dep} there are **two** possible values of E_k, corresponding to the **growing branch** and to the **decreasing branch**. At the moment, we are not distinguishing between the two possibilities, and protons with E_k<65 MeV are erroneously attributed to the growing branch. We will be able to discriminate protons belonging to the two branches using the time-of-flight information.

Time calibration

kentros hit time relative to Start Counter:

$\mathbf{t_{rel} = (t_{KE} - t_{Trg,KE}) - (t_{SC} - t_{Trg,SC})}$

t_{KE}: hit time measured by kentros TDC

t_{SC}: starting time measured by Start Counter TDC

$t_{Trg,KE}$, $t_{Trg,SC}$: time of the same reference trigger signal read by kentros TDC and by the SC TDC

t_{rel} is related to the particle TOF (t_F) as:

$\mathbf{t_{rel} = t_F + t_{scint} + t_w + t_0}$

t_{scint}: transit time of scintillation signal

t_w: time walk

t_0: constant time difference

The time walk correction is made by fitting the t_{rel} vs q distribution with a proper function

$\mathbf{t_{fit}(q)}$

The time walk effect depends on TDC threshold and on the charge gain → it varies from one module to the other

Time calibration

$\mathbf{t_{corr} = t_{rel} - t_{fit}}$
the time distributions t_{corr} are aligned for all modules of the same subdetector

t_{corr} still differs from the time of flight:

$$\Delta t = t_F - t_{corr} = t_{fit} - t_{scint} - t_w - t_0$$

Δt is a function of q and θ

If we look at small angular regions (e.g. $5^o<\theta<7^o$) in each region Δt will be a function of q only
Our approach was to intercalibrate it with the kinetic energy evaluated from the energy deposition:

$$E_{dep} \rightarrow E_k \rightarrow t_F(E_k)$$

We are using two points for time calibration:
- the average TOF and equalized charge q_{eq} of Z=2 particles
- the average TOF and equalized charge q_{eq} of Z=1 particles *evaluated on the two modules with the highest gain*

For other values of q_{eq} a linear interpolation can be used:

$$\Delta t(q_{eq}) = \Delta t_1 + (\Delta t_2 - \Delta t_1)\cdot(q_{eq} - q_1)/(q_2 - q_1)$$

Using Δt, the time of flight of each particle is evaluated as:

$$t_F = t_{corr} + \Delta t(q_{eq})$$

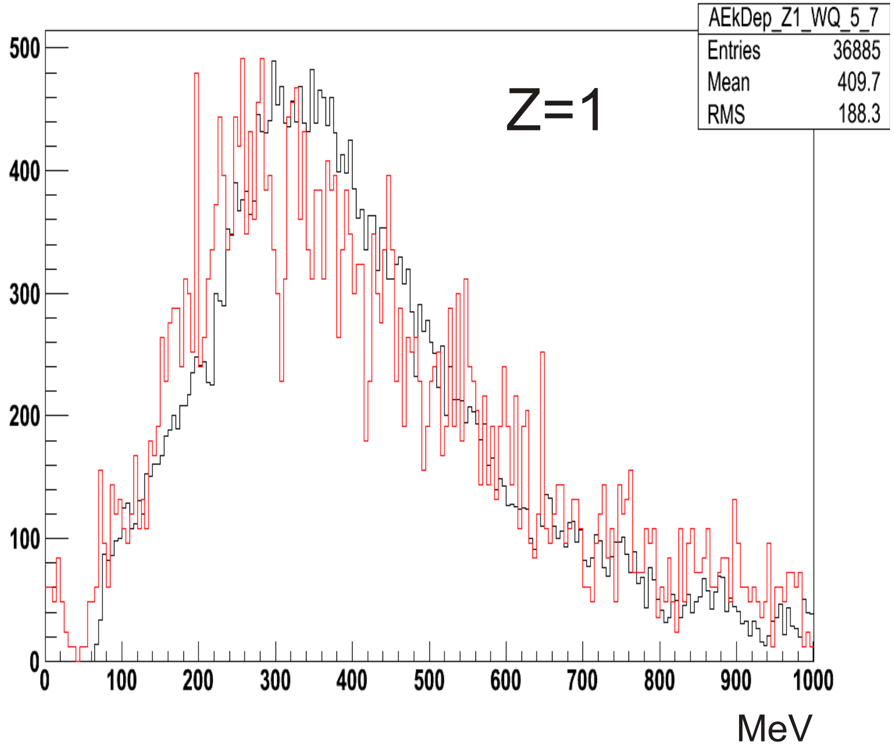
Time calibration

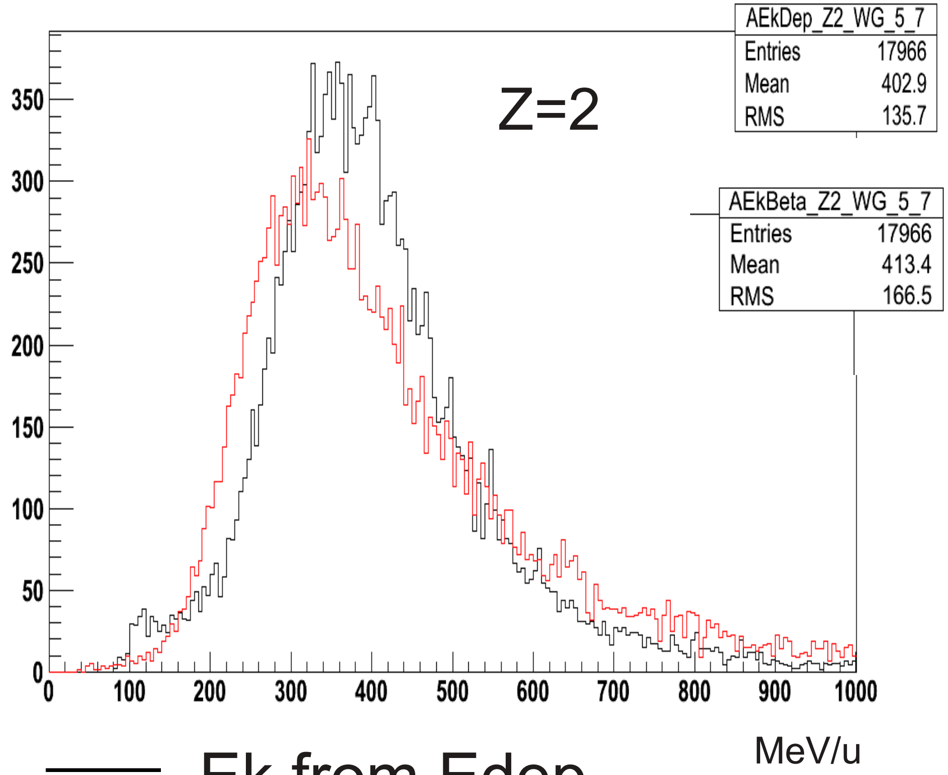
The particle kinetic energy can be evaluated from t_F

The kinetic energy evaluated from the charge and that evaluated from the TOF are not completely independent, because they are intercalibrated.

=> In practice, this means that they have the same average values.

However, the *shapes* of the distributions (and thus also their width) are independent.



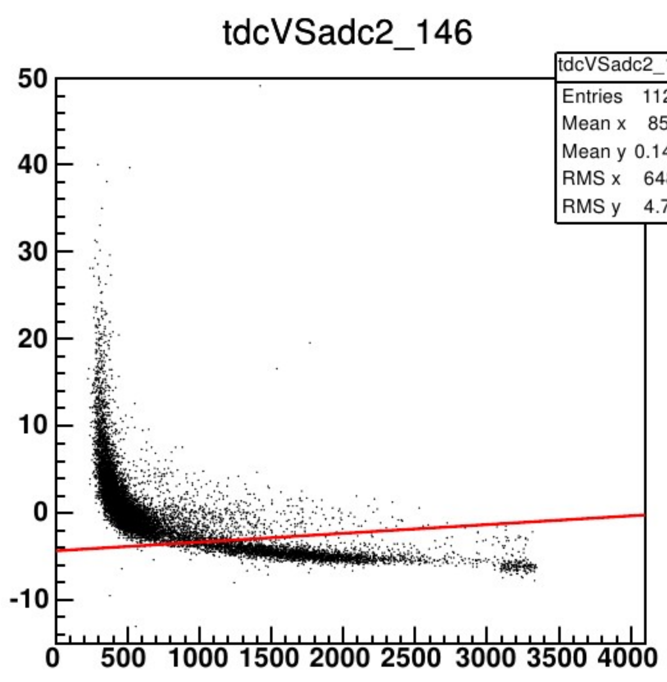


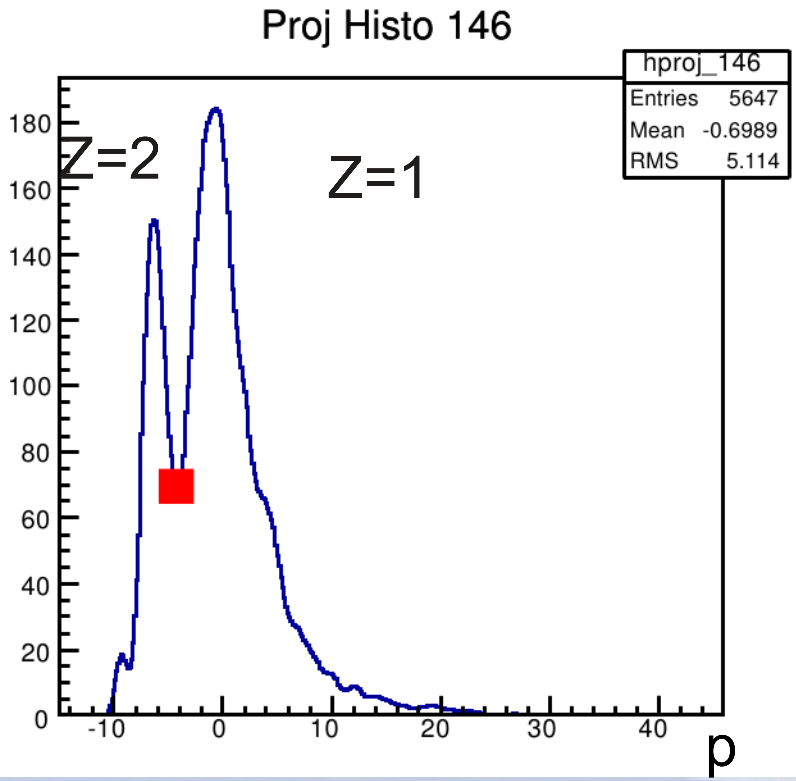
Ek from Edep

Ek from beta

Particle Id

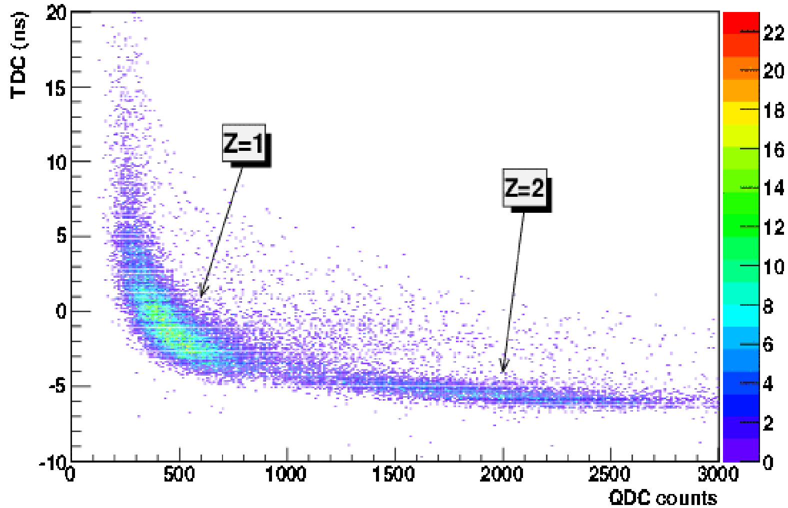
Method 1: relies only on kentros hit data (time, charge)
Z=1 particles release less energy => the TDC time is larger because of the time walk effect
Linear separation on the time-charge plane
The time vs charge distribution is projected on a axis PERPENDICULAR to the red axis
linear combination of t and q: $p = at + bq + c$

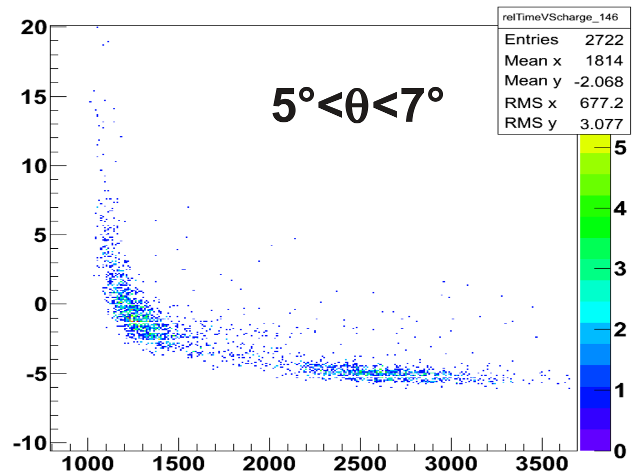


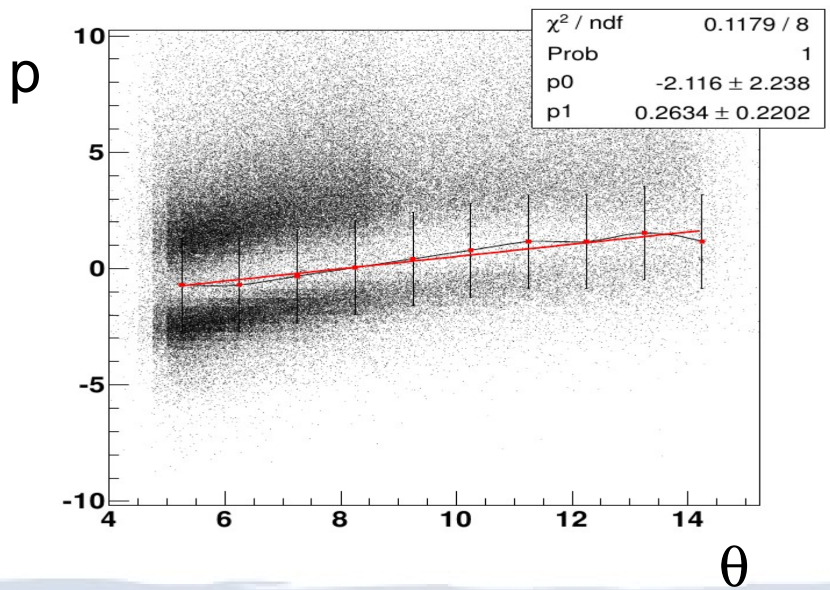


Particle Id

Method 2: separation depends on polar angle





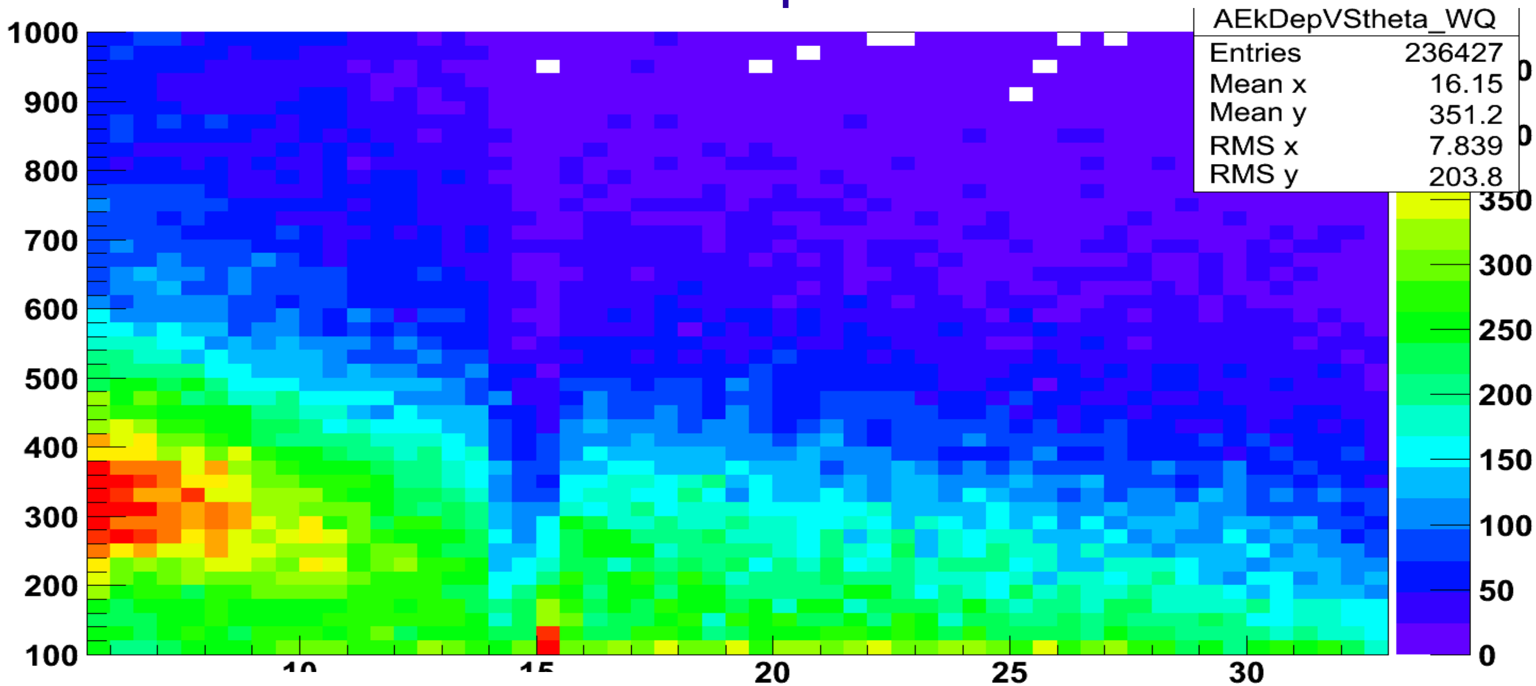


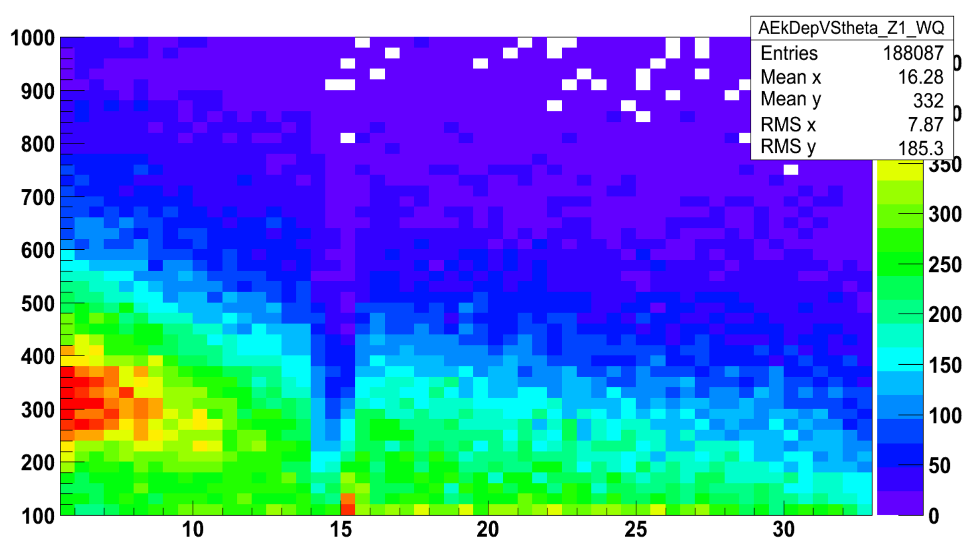
Optimal separation for each (small) angular region

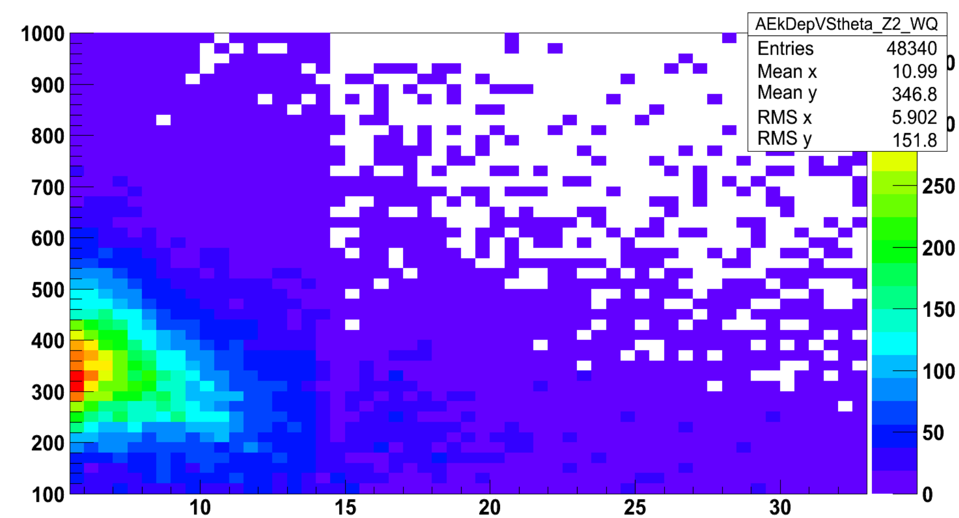
Linear fit

Particle ID is made by a plane in the (Q,t,θ) space

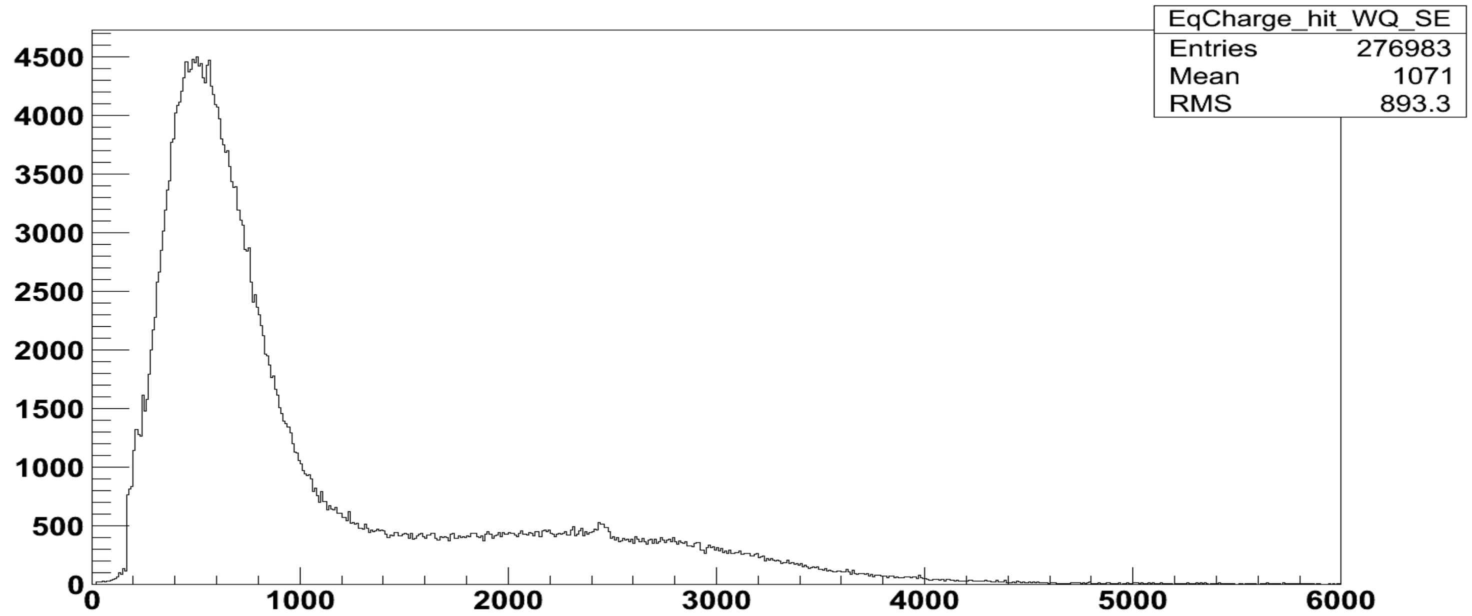
Ek (from E_{dep}) vs theta

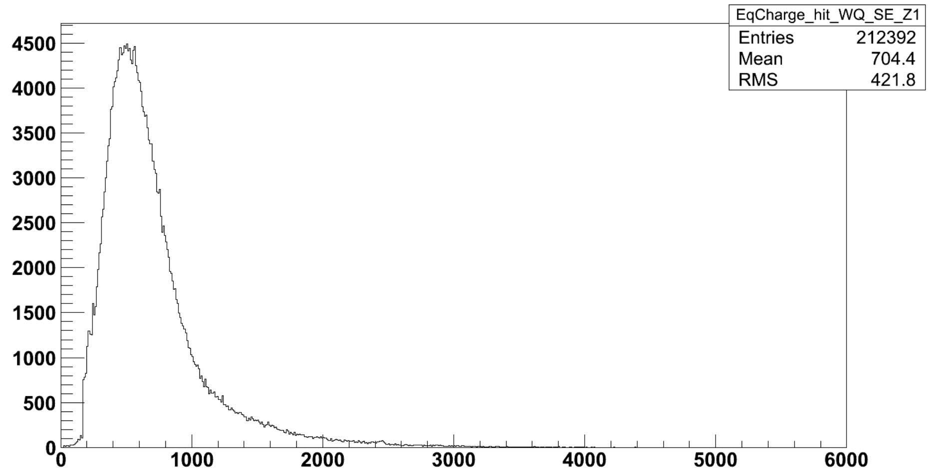


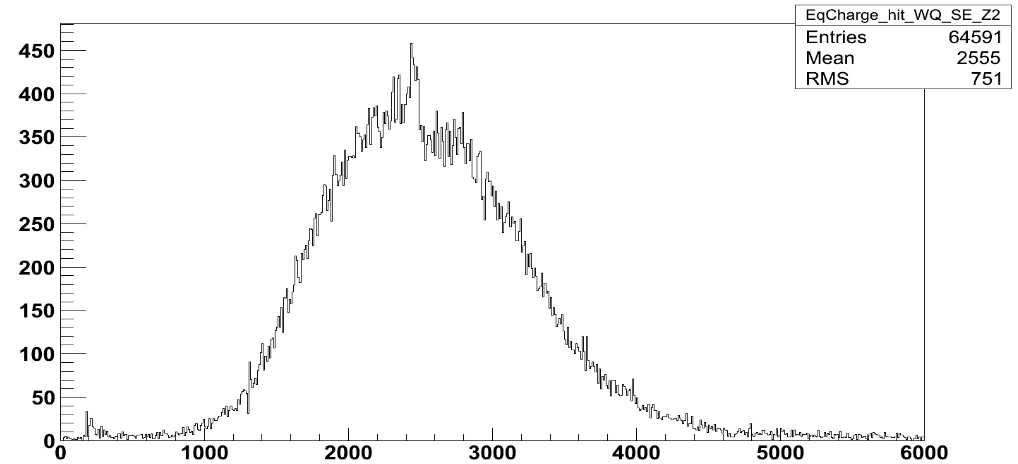




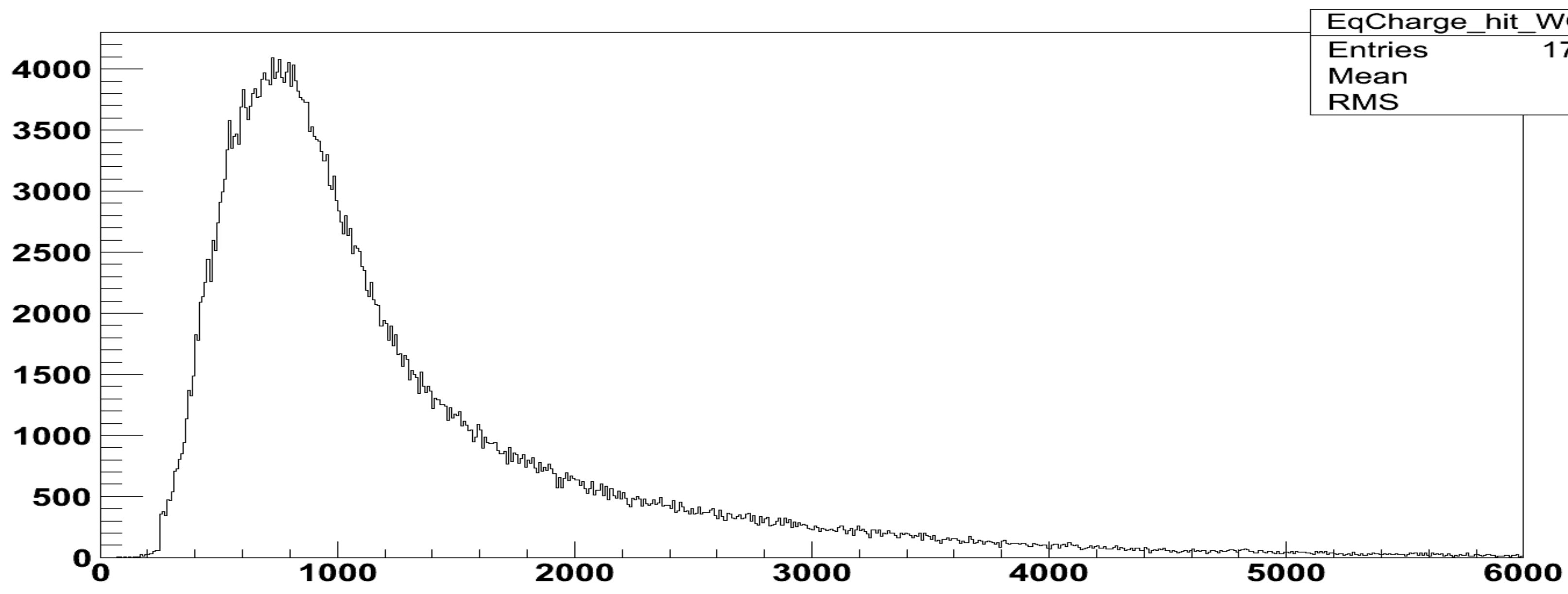
Calibrated hits on Small Endcap

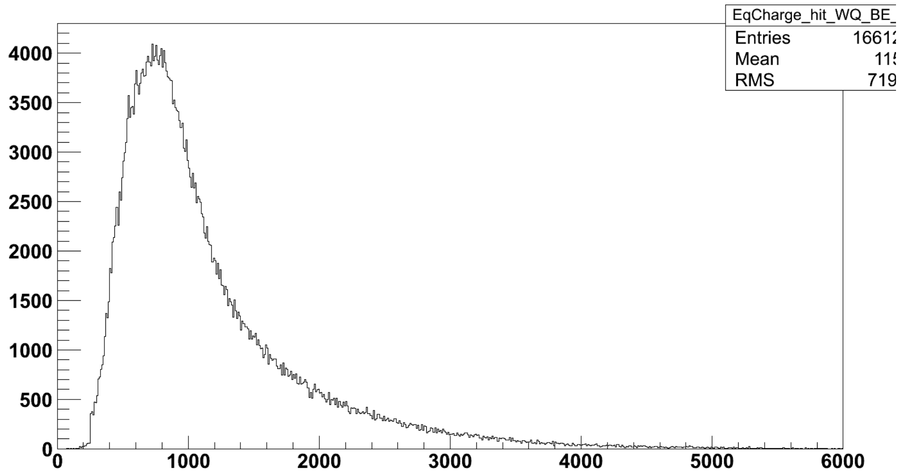


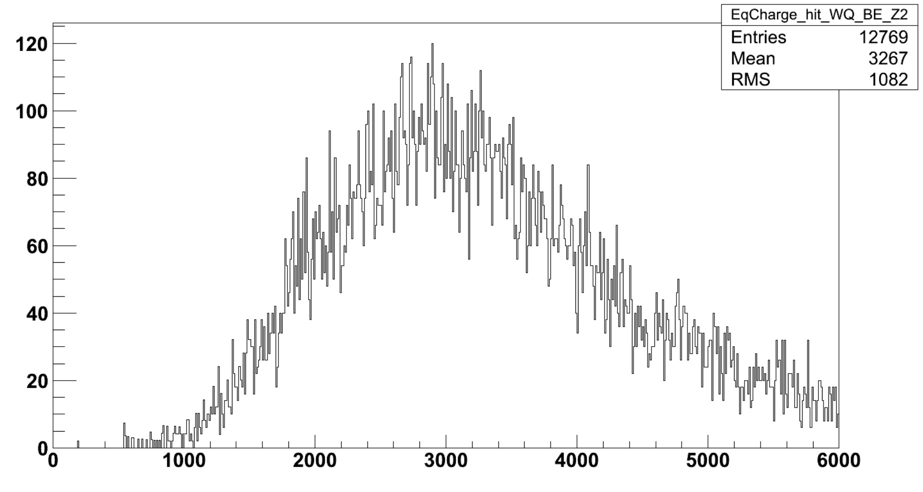




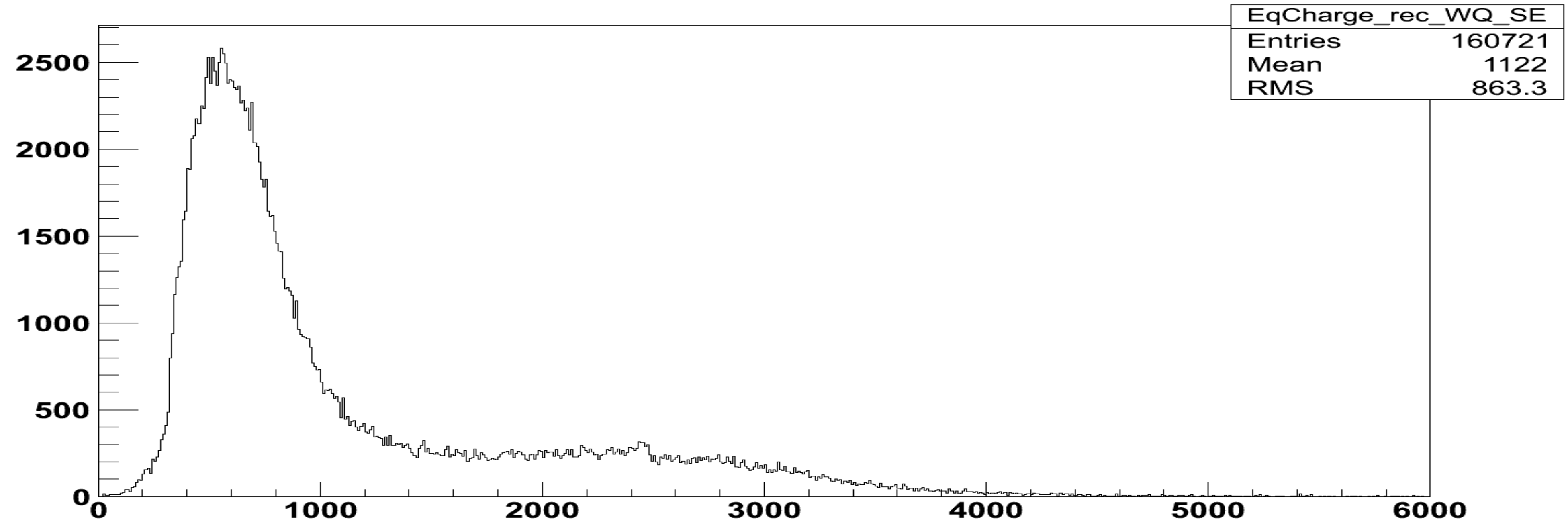
Calibrated hits on Big Endcap

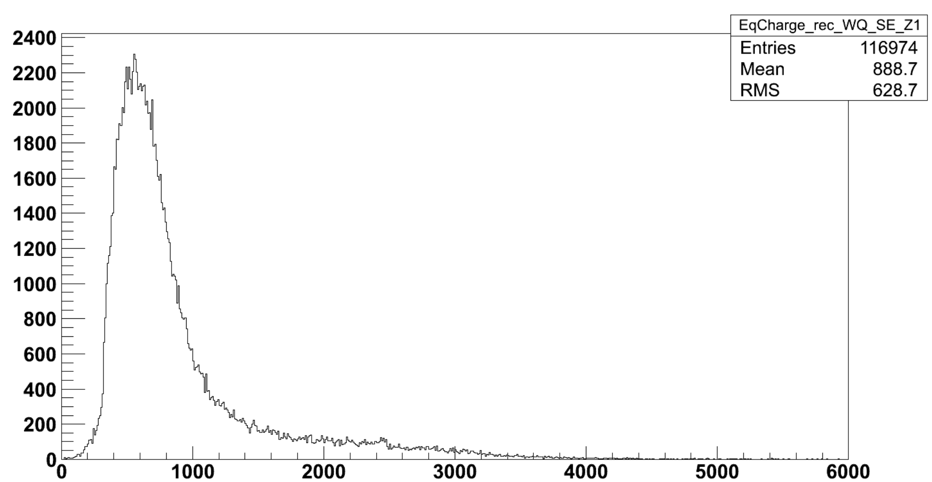


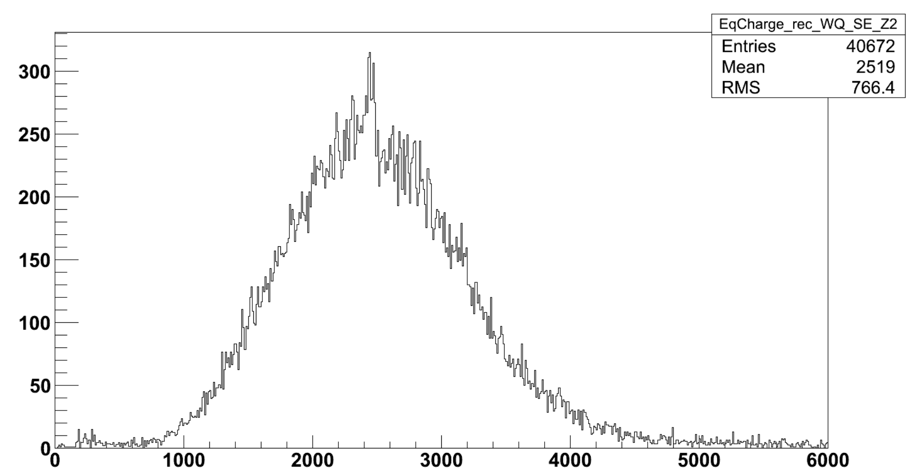




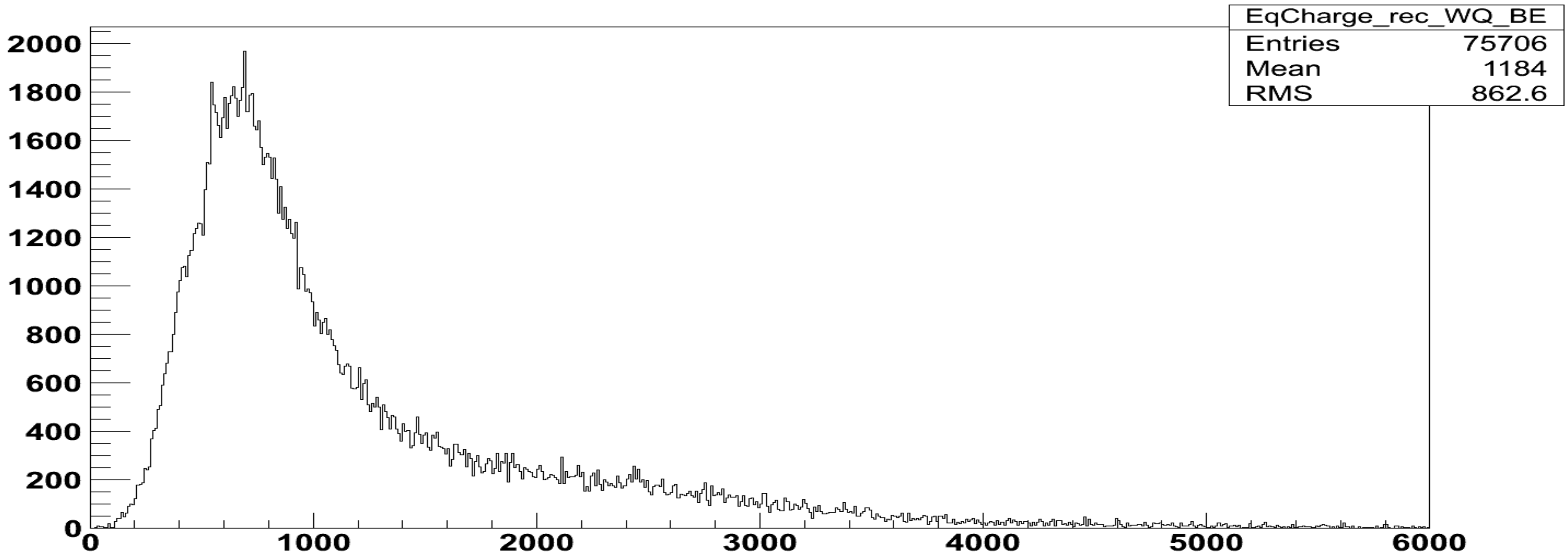
Matched hits on Small EndCap

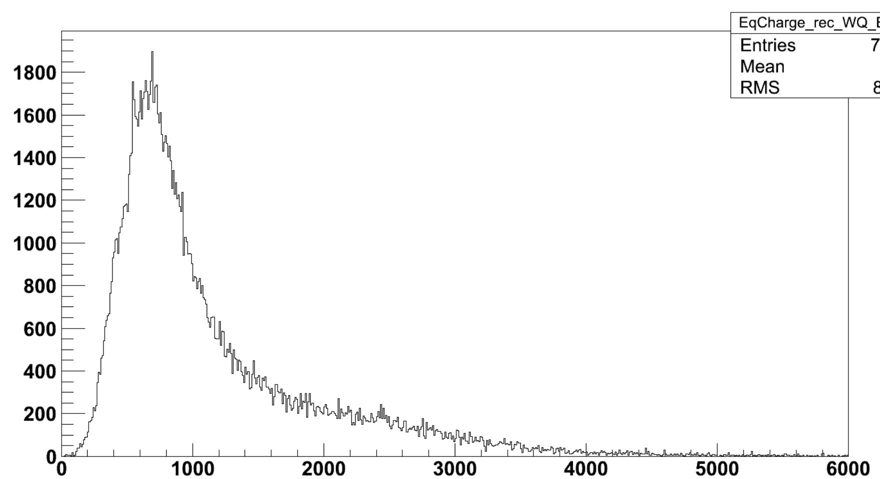


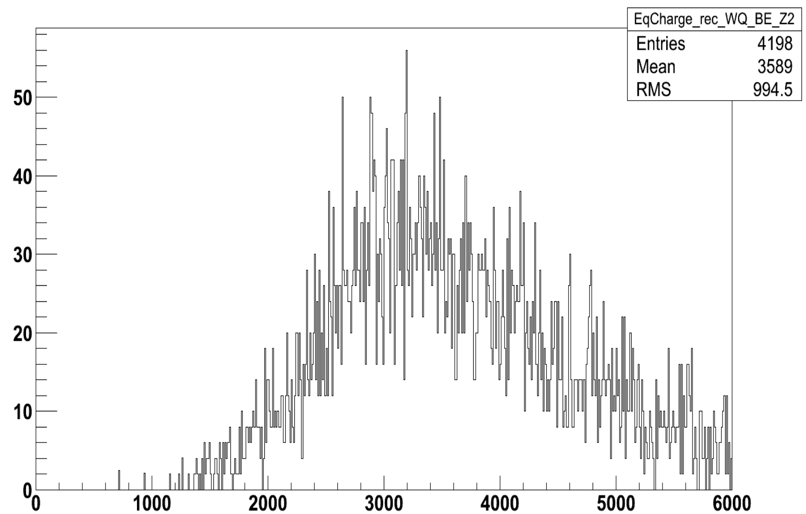




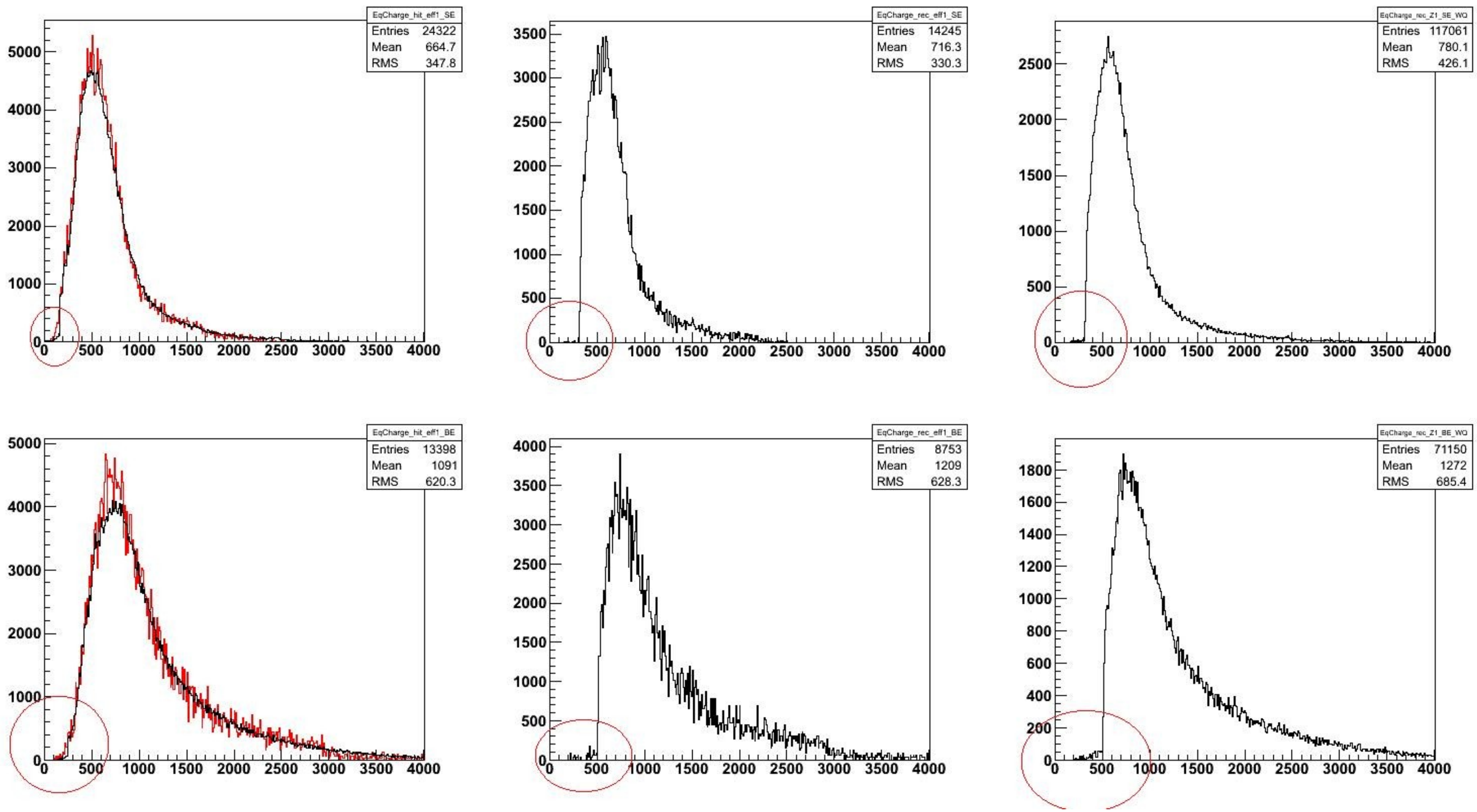
Matched hits on Big EndCap







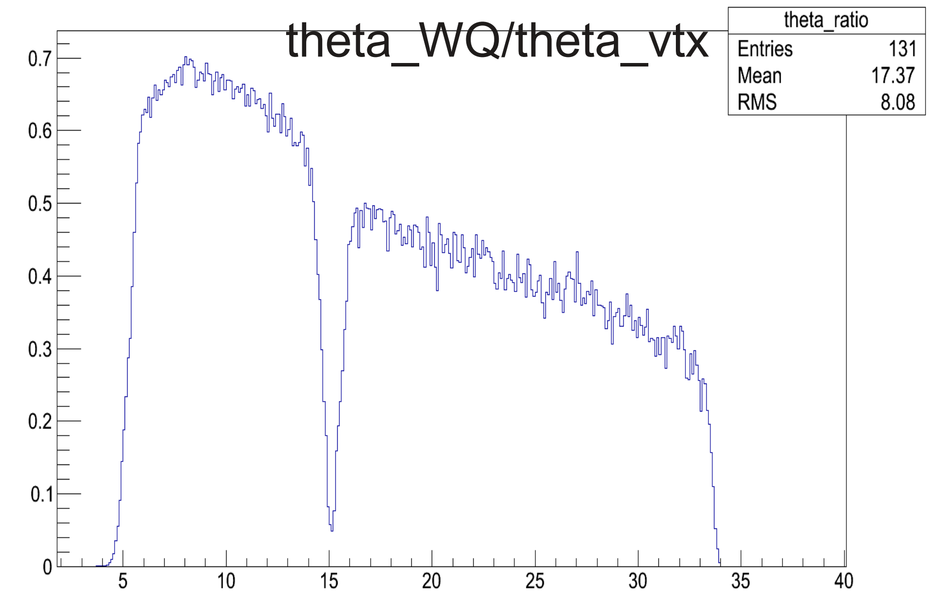
Problem on small charge

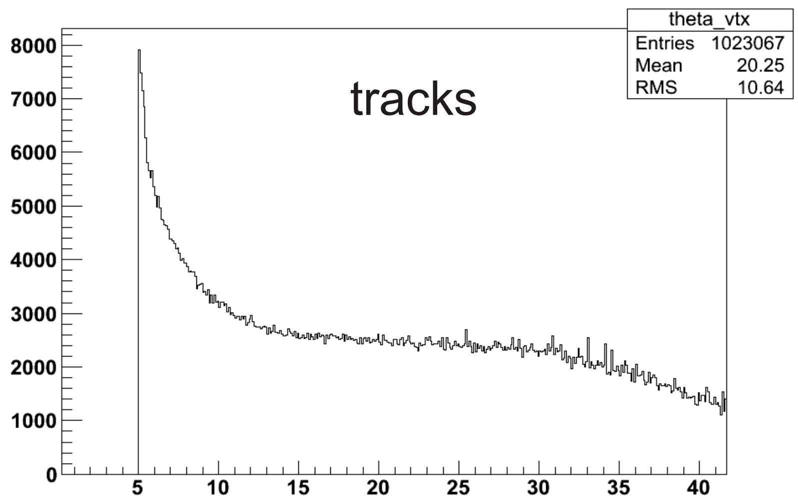


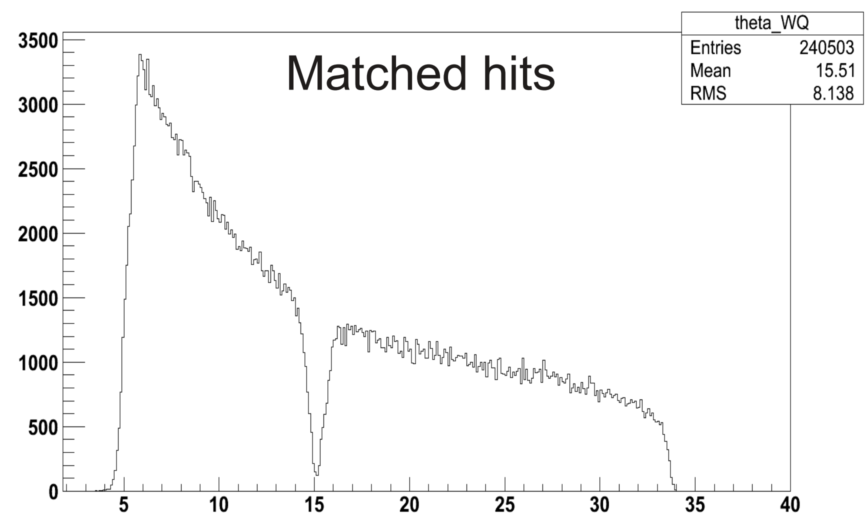
We see a drop on the distribution of matched hits for small charges.
Events are present in unmatched hits distros → not a problem of threshold
Maybe a problem of track efficiency for high energy protons or low polar angles?

Polar angle distributions

The number of matched tracks per track decreases with polar angle.
But there is a decrease of the ratio also for small angles.







Numbers

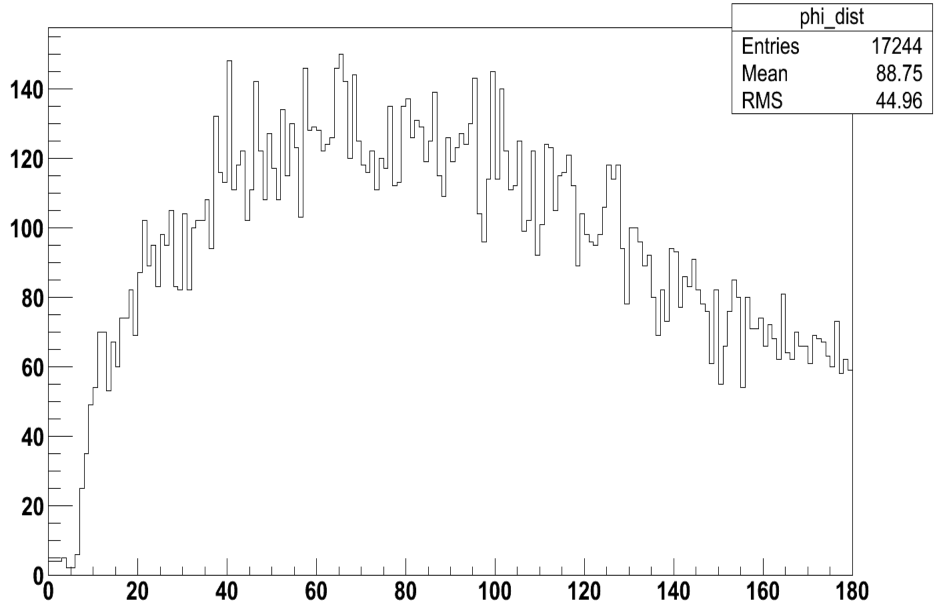
Run set	Sub detector	hits	Matched hits	Matched tracks	Vertex tracks
250-299	**SE**	147185	84196	82597	189256
	BE	203873	96242	96795	279109
300-349	**SE**	297739	179048	174429	329696
	BE	358692	178853	180618	451679
350-399	**SE**	374379	209141	206457	397642
	BE	455668	199277	199719	533011
400-449	**SE**	340359	185170	181775	346866
	BE	415240	164094	164391	481456
450-479	**SE**	152012	89323	88260	172919
	BE	193191	90829	91166	229422

We are missing (at least) 50% of the hits and of the tracks.
Are we reconstructing only 1/3 of the events?

Azimuthal angular distance to the closest unmatched track

For each unmatched hit we evaluated the distance in azimuthal angle of the module center to the closest unmatched track.

No unmatched tracks are present inside the azimuthal angle of the module of the unmatched hit.



Future work

- Azimuthal angular distributions
  - To be tested again
  - Comparison with MC
- Merge SE and BE distros around 15°
- Time calibration → to be included in the framework
- Ek from TOF → to be included in the framework
- Discrimination of the two branches of TOF vs Ed curves
- Intercalibration with TOF wall
- Estimate energy resolution