# TOF beta resolution

A. Contin

TOF Group, September 2011

# Goals

Measure the TOF beta resolution for different ions.

# Principle of the measurement

Beta is measured by fitting the *track length vs. time* plot.

Track lengths between different layers are given by the track extrapolation into TOF planes.
Time is given by TOF as paddle time after calibration (see Tutorial - A. Contin talk at KSC, February 2011):

Calibration constant (1 for all counters)

$$-\frac{l_{ij}}{v} = \left(\frac{t_{m_1} + \frac{s}{\sqrt{A_1}} + t_{m_2} + \frac{s}{\sqrt{A_2}}}{2}\right)_i - \left(\frac{t_{m_1} + \frac{s}{\sqrt{A_1}} + t_{m_2} + \frac{s}{\sqrt{A_2}}}{2}\right)_j + C_i - C_j$$

Calibration constants
(1 per counter)

$l_{ij}$ = positive track length from plane i to plane j = $l_i$ - $l_j$
Time difference is negative because times are measured relative to FT time.
All constants are determined at the same time with a global minimization procedure.

# Principle of the measurement

If the slewing calibration constant is set to 0, the following equation provides the linear fit needed to compute it.

$$-\frac{l_{ij}}{v} - \underbrace{\left[\left(\frac{t_{m_1}+t_{m_2}}{2}\right)_i + C_i\right]}_{\text{TofRawCluster->time}_i} + \underbrace{\left[\left(\frac{t_{m_1}+t_{m_2}}{2}\right)_j + C_j\right]}_{\text{TofRawCluster->time}_j} = \frac{s}{2}\left[\left(\frac{1}{\sqrt{A_1}}+\frac{1}{\sqrt{A_2}}\right)_i - \left(\frac{1}{\sqrt{A_1}}+\frac{1}{\sqrt{A_2}}\right)_j\right] + C$$

$\frac{l_{ij}}{v}$: ParticleR->TOFTLength[i] - ParticleR->TOFTLength[j]

$\frac{1}{\sqrt{A_1}}$: TofRawCluster->adca[0]$_i$

$\frac{1}{\sqrt{A_2}}$: TofRawCluster->adca[1]$_i$

$\frac{1}{\sqrt{A_1}}$: TofRawCluster->adca[0]$_j$

$\frac{1}{\sqrt{A_2}}$: TofRawCluster->adca[1]$_j$

$C$: residual constant

$\frac{s}{2}$ is the parameter fitted by the calibration program

# Event selection and analysis

1. Trigger: all triggers

2. One and only one good track (Chi2<10, at most one central plane missing)
3. Only four TOF clusters (one per layer) made by only one counter
4. All TOF clusters used in the fit

Charge measured by TRACKER (function TrCharge::GetMean): $Z = \frac{\sqrt{\mathrm{TrCharge :: GetMean}}}{6.2}$

Also used the charge measured by TOF (from reduced mean of Edep): $Z_{\mathrm{TOF}} = \frac{\sqrt{\mathrm{ReducedMean}}}{1.4}$

5a. Charge selection: $|Z - i| < 0.3$ ; i=1,..,8
5b. Additional charge selection with TOF, for $Z$=1: $Z_{TOF}$<1.4; for $Z$=2: $Z_{TOF}$<2.4

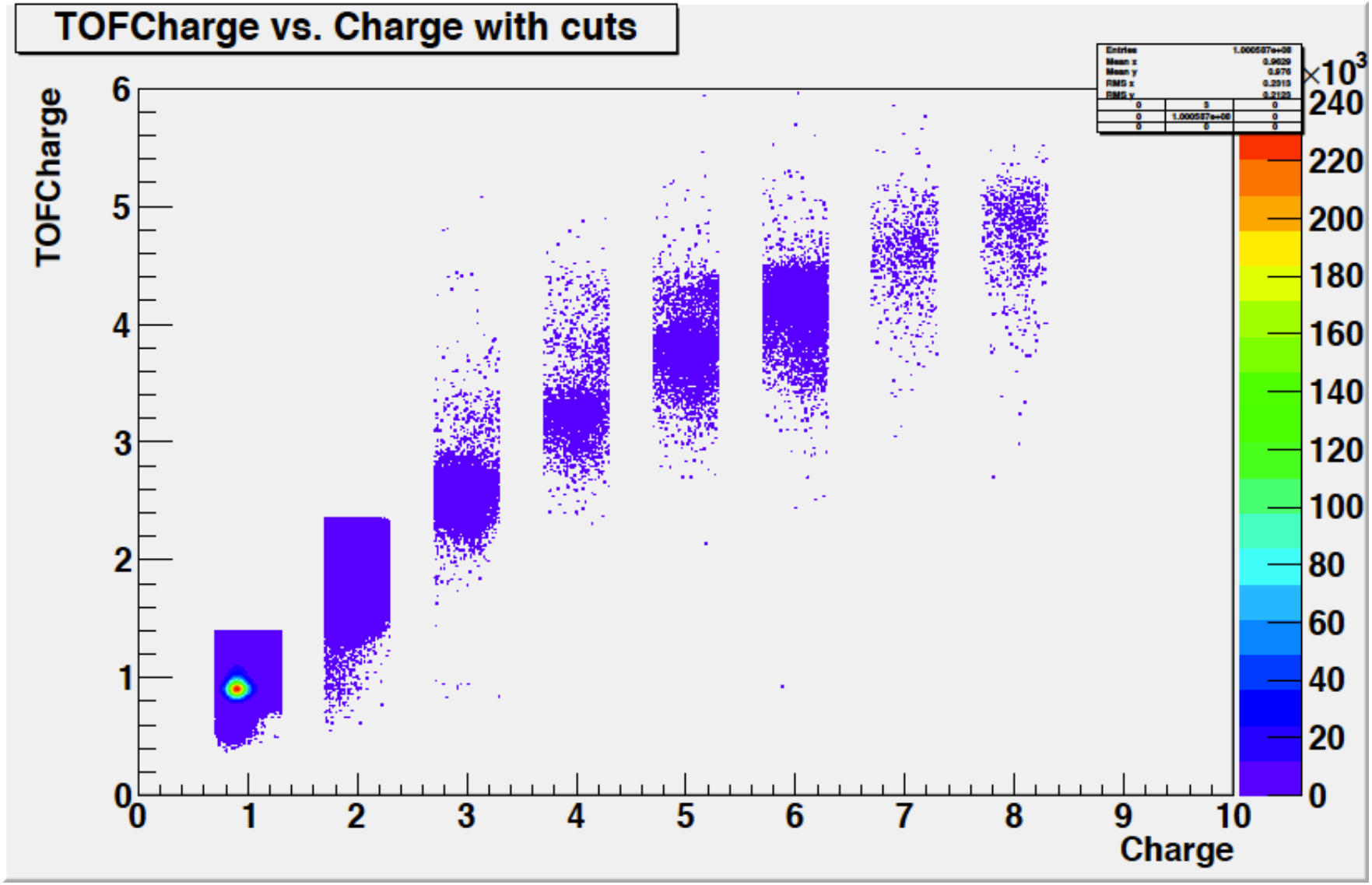
6. Relativistic particle selection ($\beta$ > 0.994): $Z = 1 : \ R > 9\,\mathrm{GV}$

$Z > 1 : \ R > 20\,\mathrm{GV}$

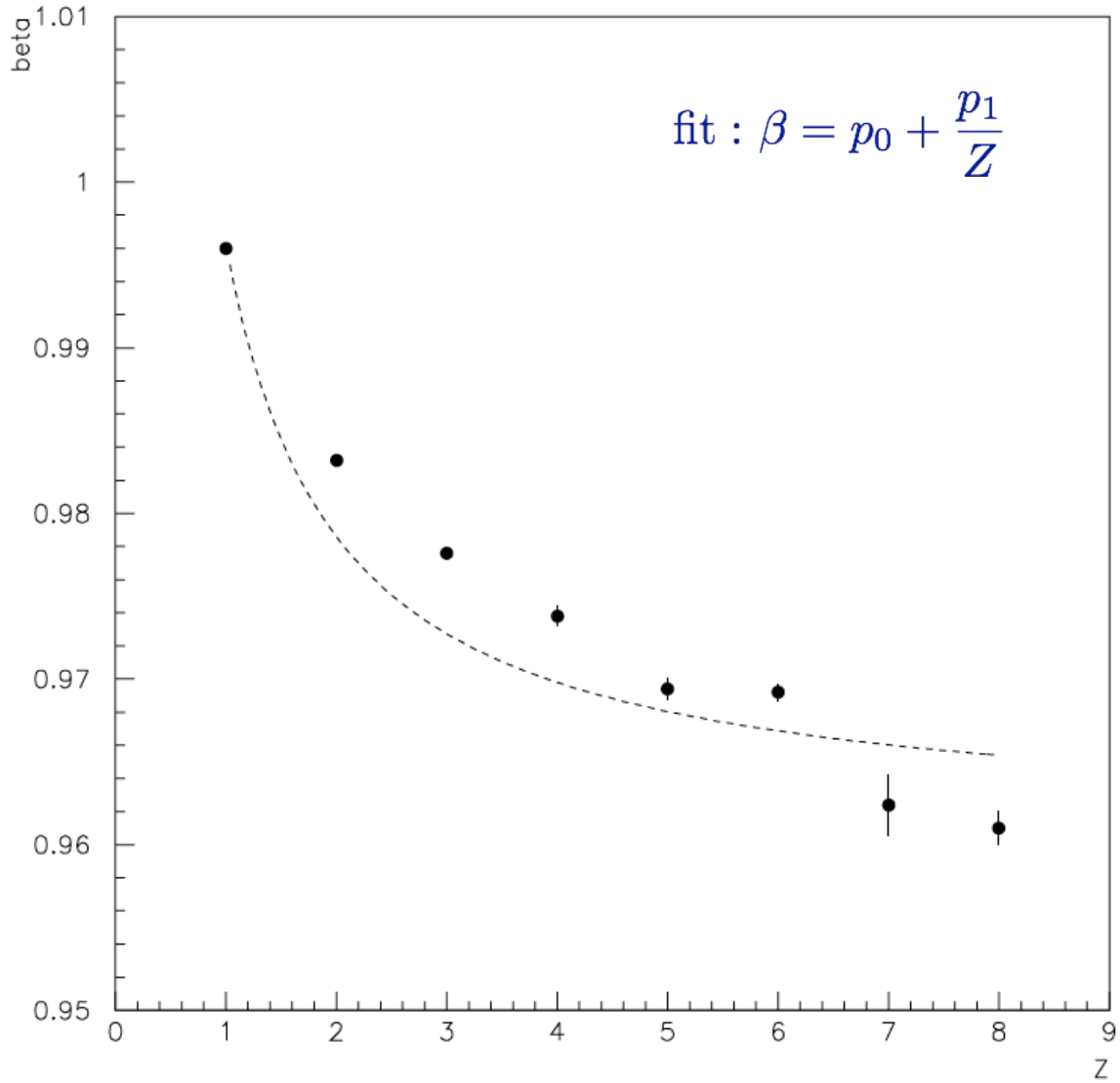
All runs reconstructed with pass2, B530 gbatch version

- 2,993,758,400 recostructed events
- 1,325,933,613 events satisfying selection criteria 2 and 3
- 100,058,304 events satisfying also selection criteria 4, 5 and 6

# Charge selection

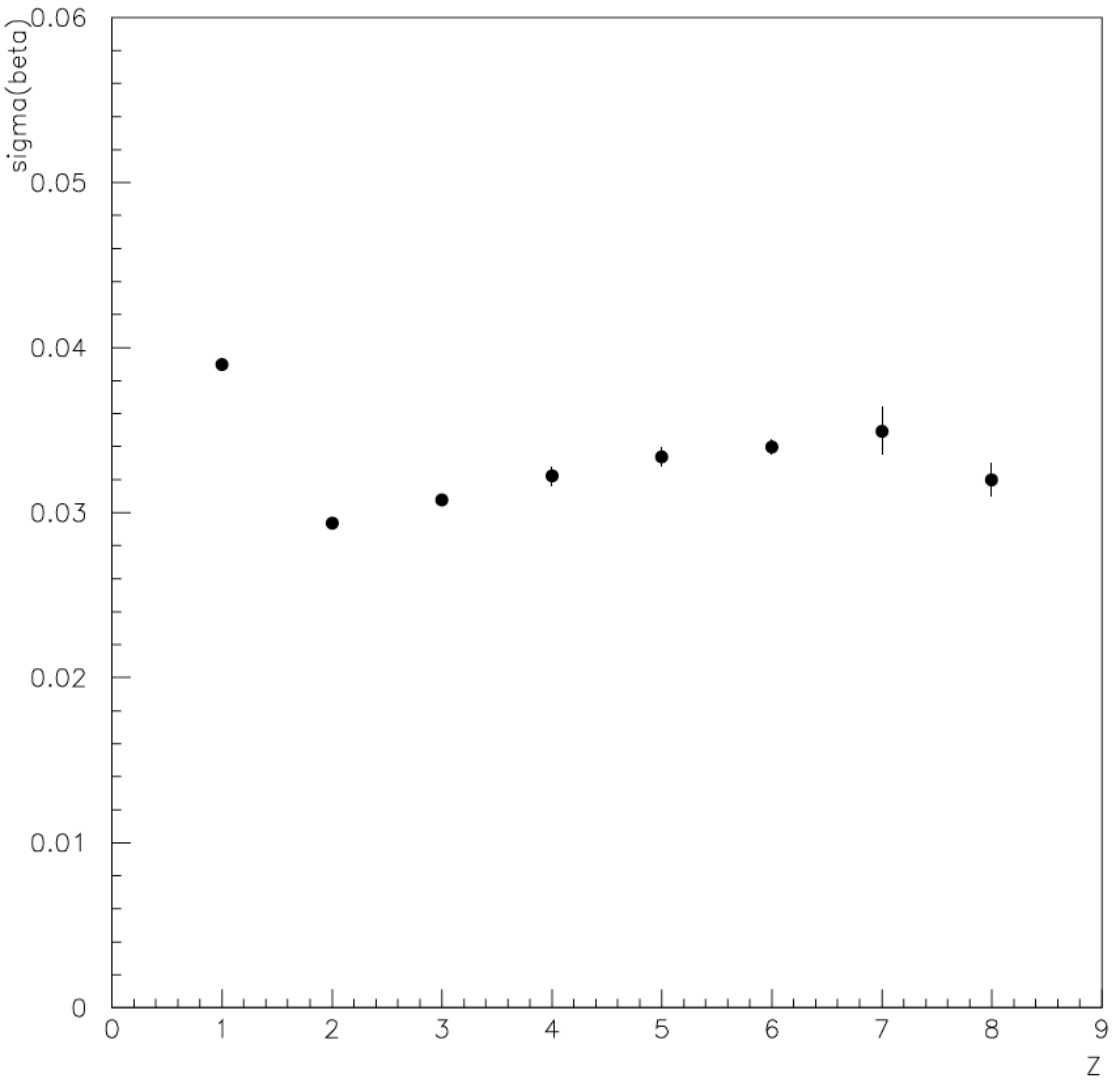


# Results - Mean Beta (from BetaR class)




The mean value of $\beta$ decreases as the inverse of Z, i.e. as the inverse of the square root of the amplitude.
This points to wrong slewing corrections applied to the counter time.

# Results - Beta resolution (from BetaR class)




The beta resolution does not decrease as expected.

# First conclusion

Slewing corrections have to be reviewed:

- Compute slewing in the most accurate way for each counter side using:
  - only protons
  - all ions
- Compute zero-time for all counters
- Compute beta for protons and ions

# Slewing corrections

Layer combinations: 1-4, 2-3

- Counter 4 in one of the two layers is used in turn as reference
- Particles are selected which cross the counters within ±5 cm from the counter center in both layers
- Plot:

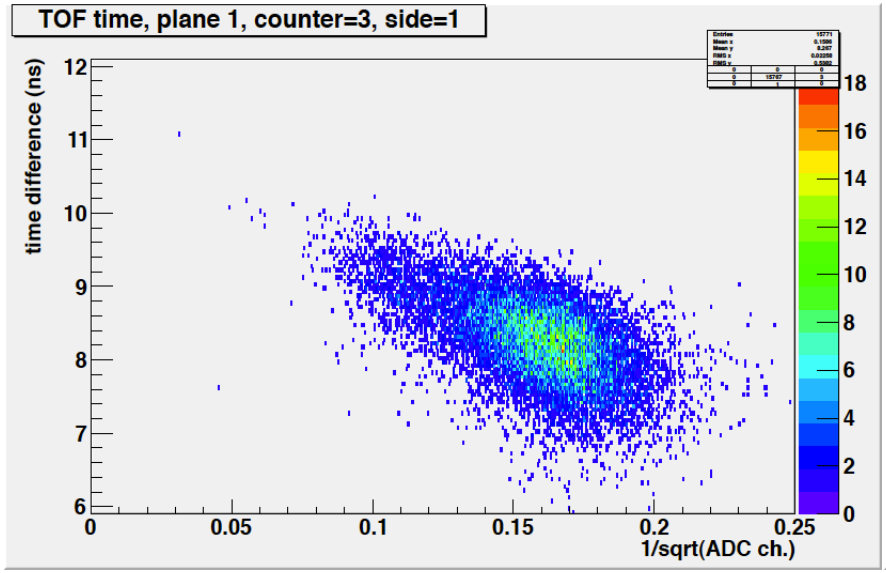
$$[t_{m_s}]_{i,l1} - \left[\left(\frac{t_{m_1} + t_{m_2}}{2}\right)\right]_{4,l2} \quad \text{vs.} \quad \frac{1}{\sqrt{A_{i,s}}}$$

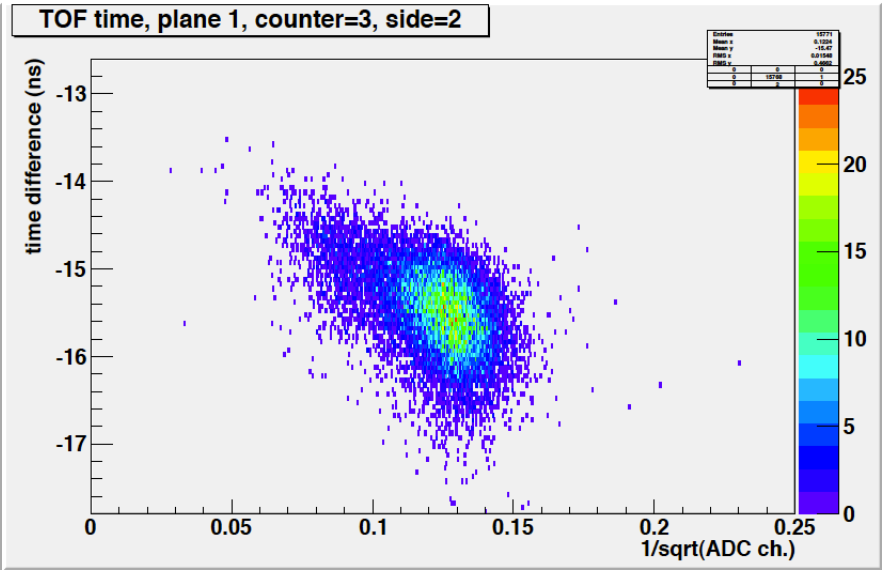
where:

- $i$ is the counter under measurement
- $s$ is the side under measurement
- $l1$ is the layer under measurement,
- $l2$ is the reference layer (layer 1 for layer 4, layer 4 for layer 1, layer 2 for layer 3 and layer 3 for layer 2)
- $A_{i,s}$ is the amplitude of the signal on side $s$ of counter $i$

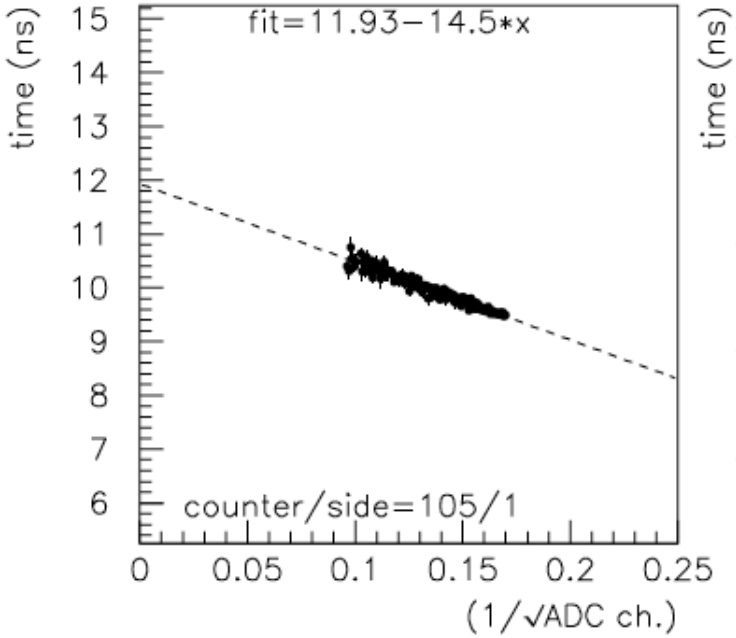
$t_m$ is variable sdtm in class TofRawCluster
$A$ is variable adca in class TofRawCluster

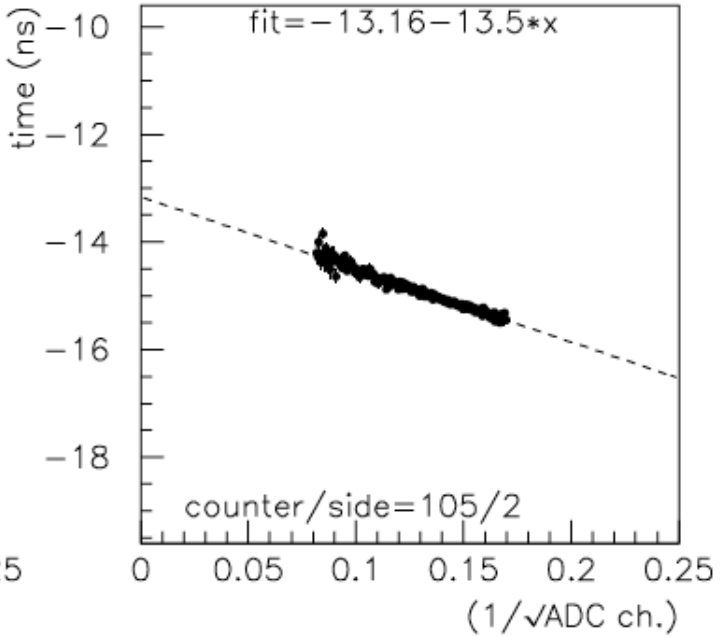
# Sample plots using only Z=1 particles



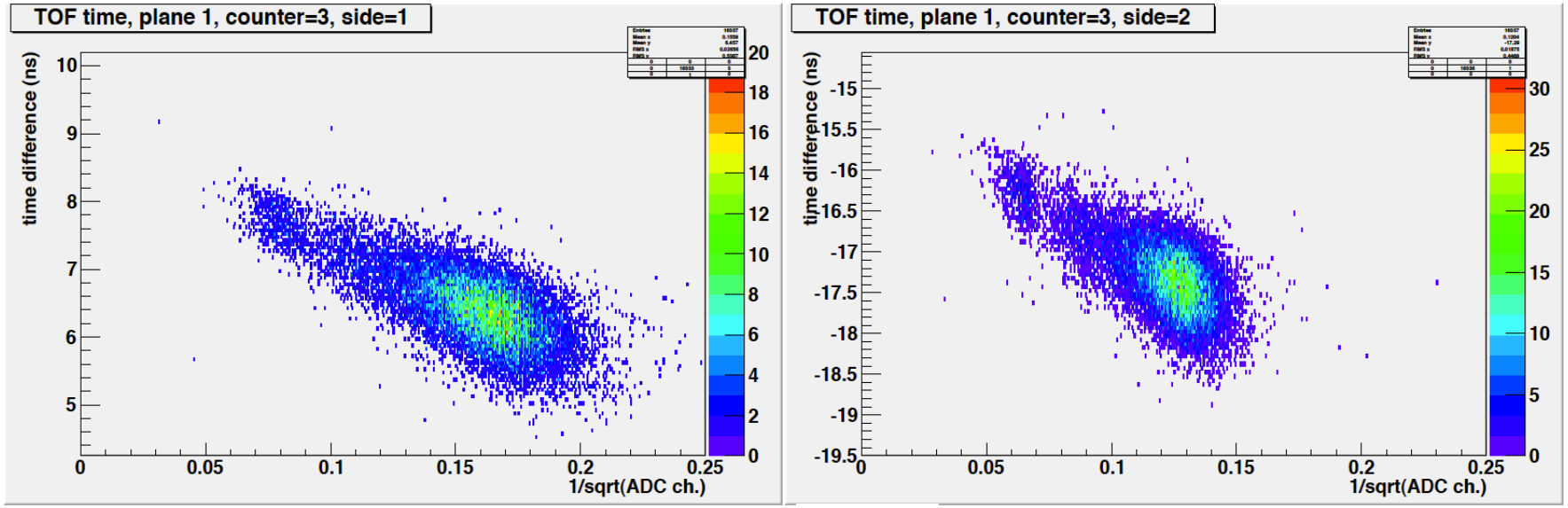




Fits:

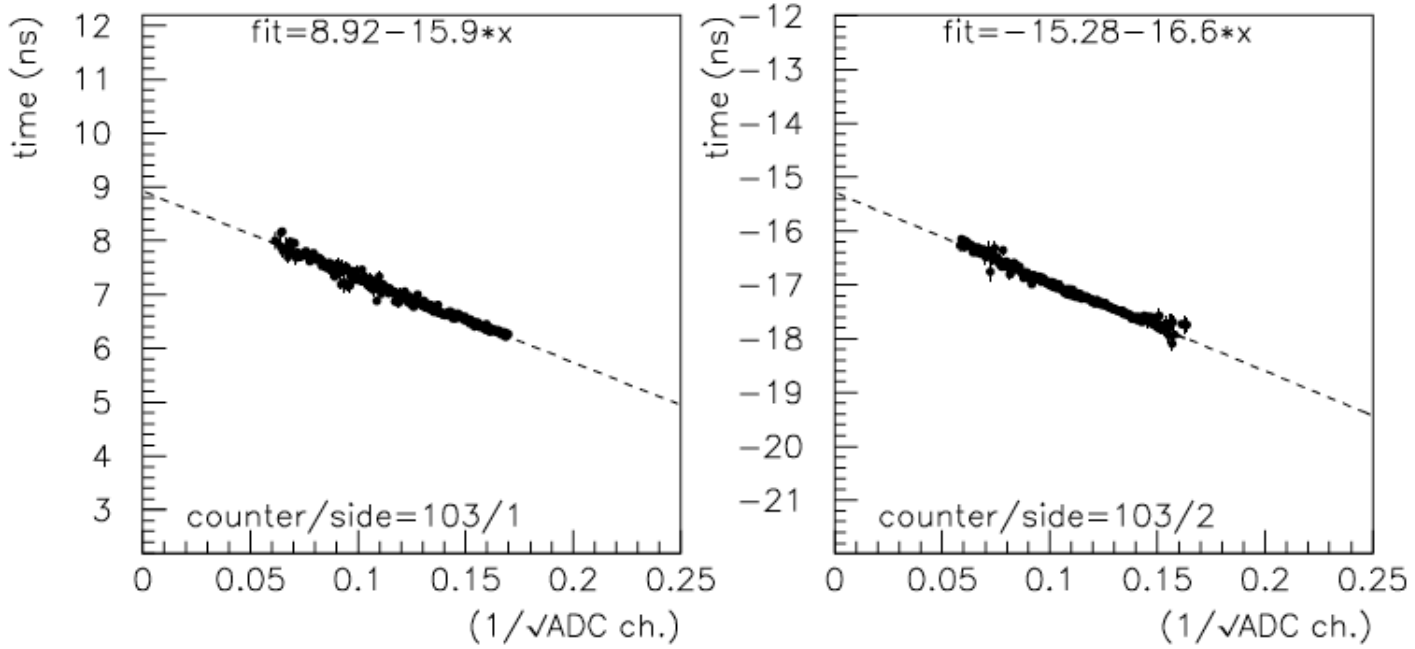


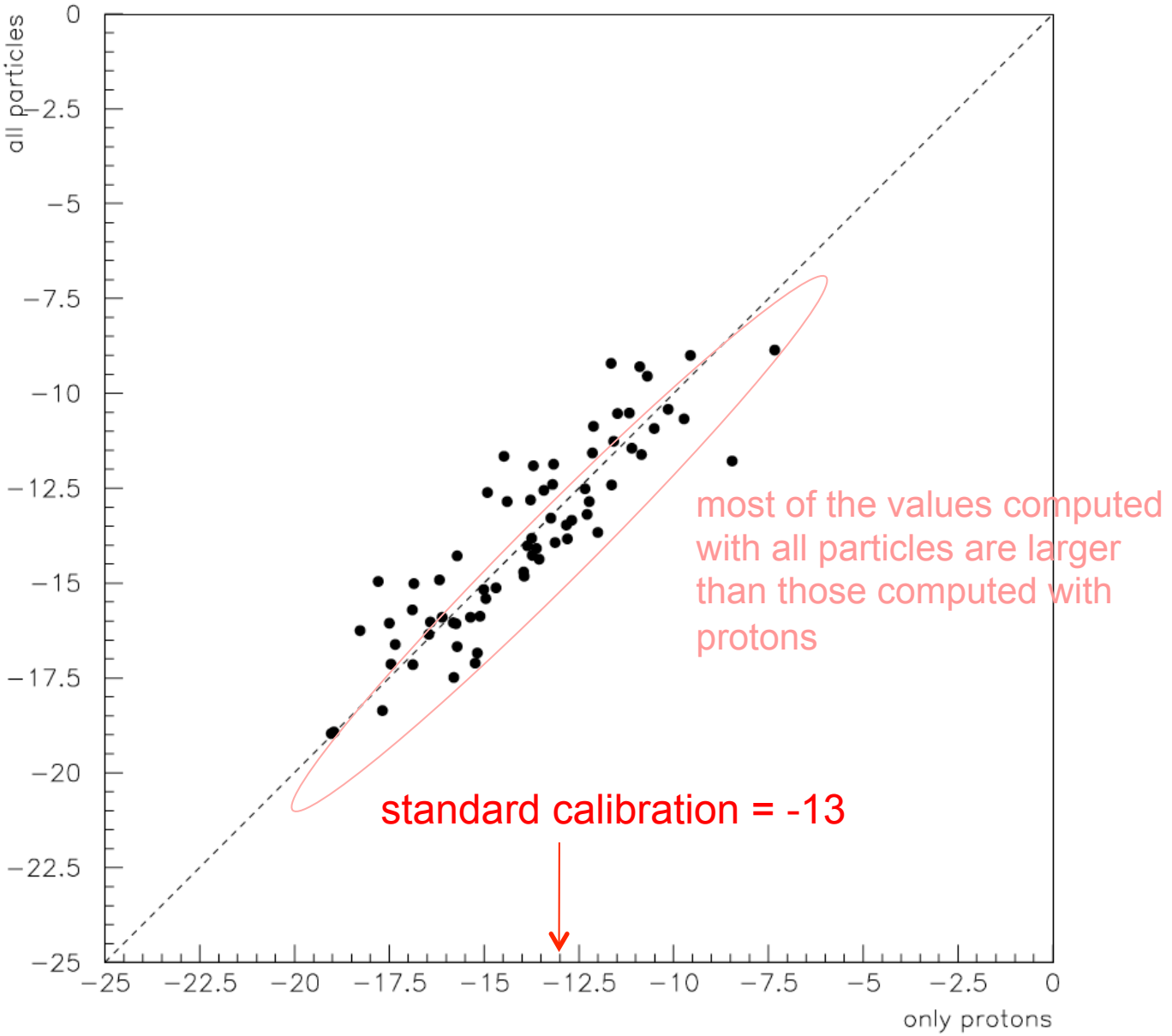
# Sample plots using all partricles (including ions)




Fits:



# Slewing constant distribution



# Zero times

All layer combinations: 1-3, 2-3, 1-4, 2-4

- Plot:

$$\left(\frac{t_{m_1}+\frac{s}{\sqrt{A_1}}+t_{m_2}+\frac{s}{\sqrt{A_2}}}{2}\right)_i-\left(\frac{t_{m_1}+\frac{s}{\sqrt{A_1}}+t_{m_2}+\frac{s}{\sqrt{A_2}}}{2}\right)_j+\frac{l_{ij}}{v}$$

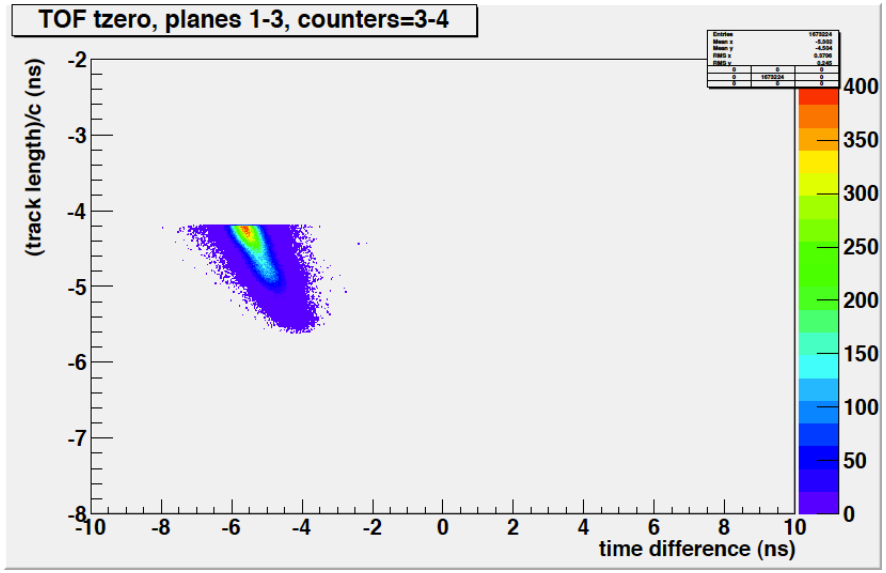
where:

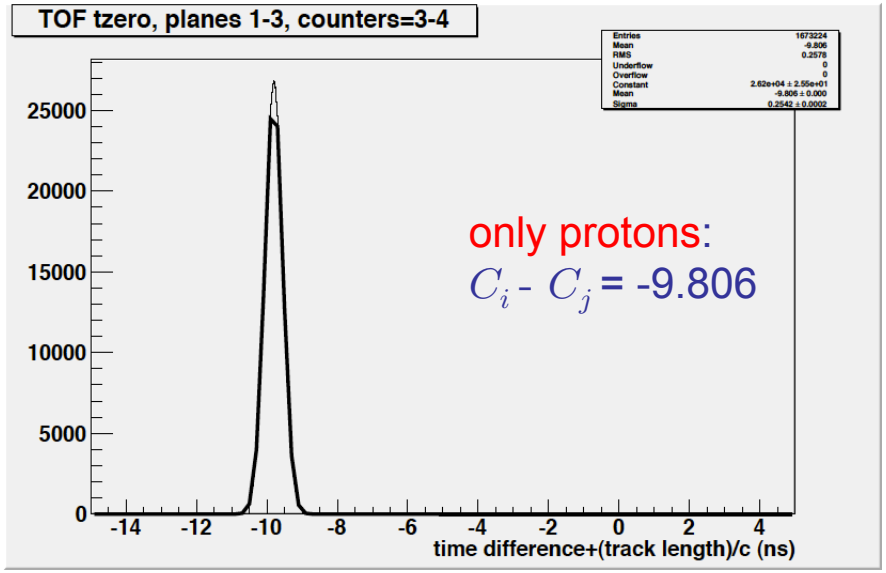
- $i$ and $j$ are the counters from different planes
- $A_s$ is the amplitude of the signal on side $s$

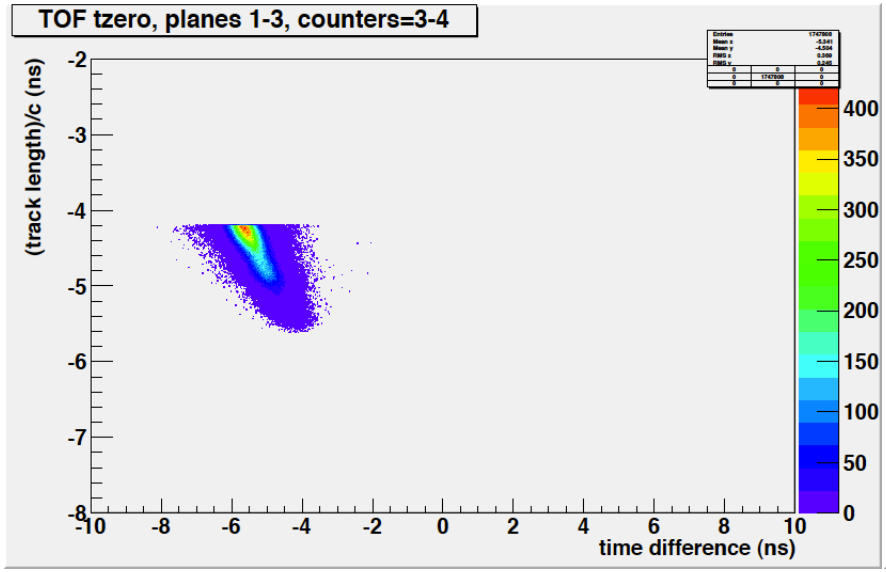
The fit of the distribution gives the difference between the zero time constants of the two counters involved: $C_i$ - $C_j$

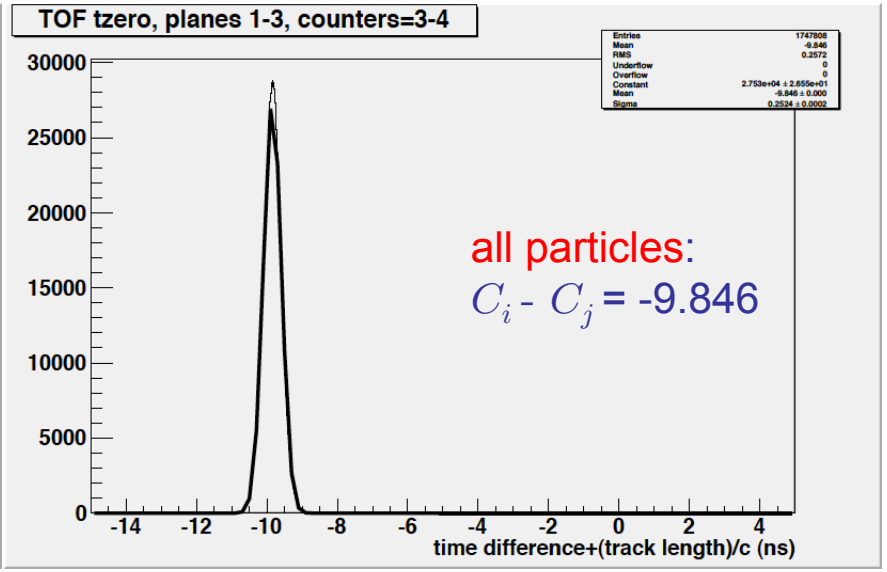
$t_m$ is variable sdtm in class TofRawCluster
$A$ is variable adca in class TofRawCluster

# Sample plots



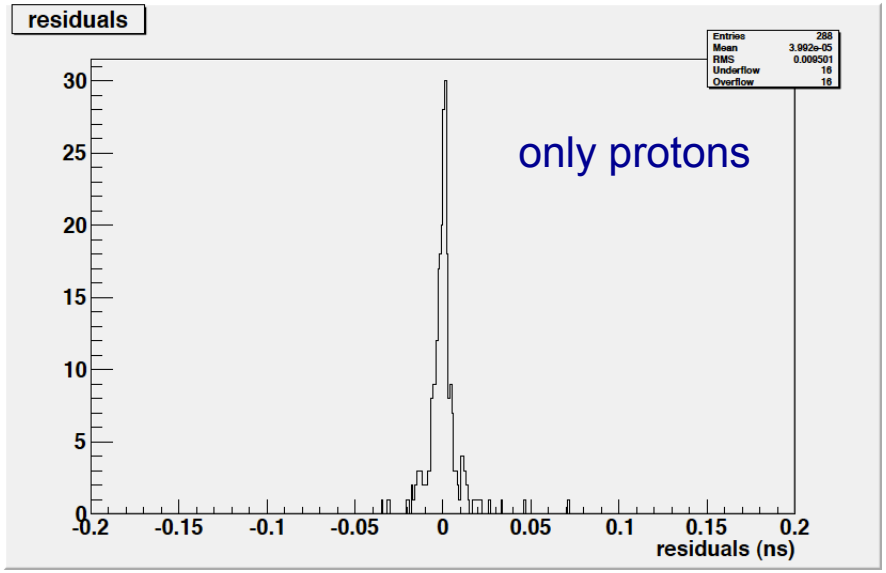



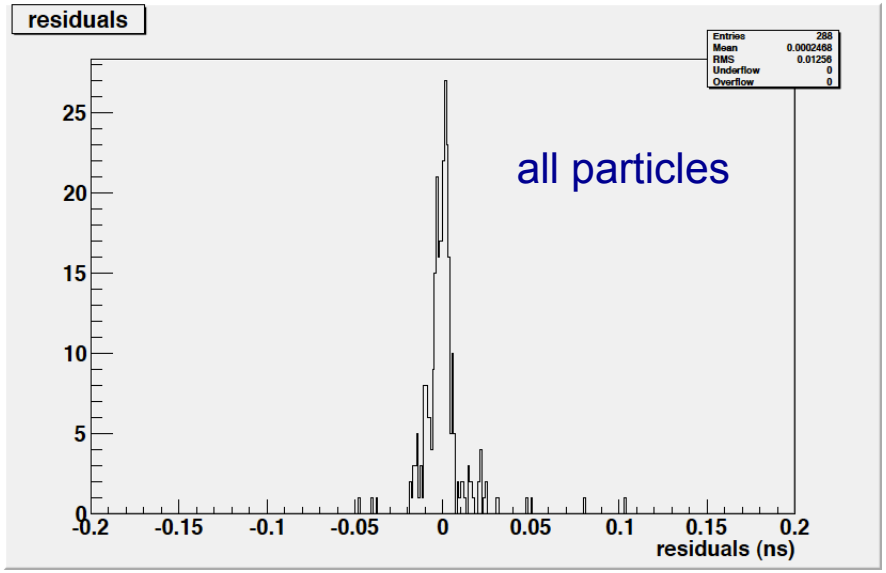




Note: 40 ps corresponds to about 1% in beta.

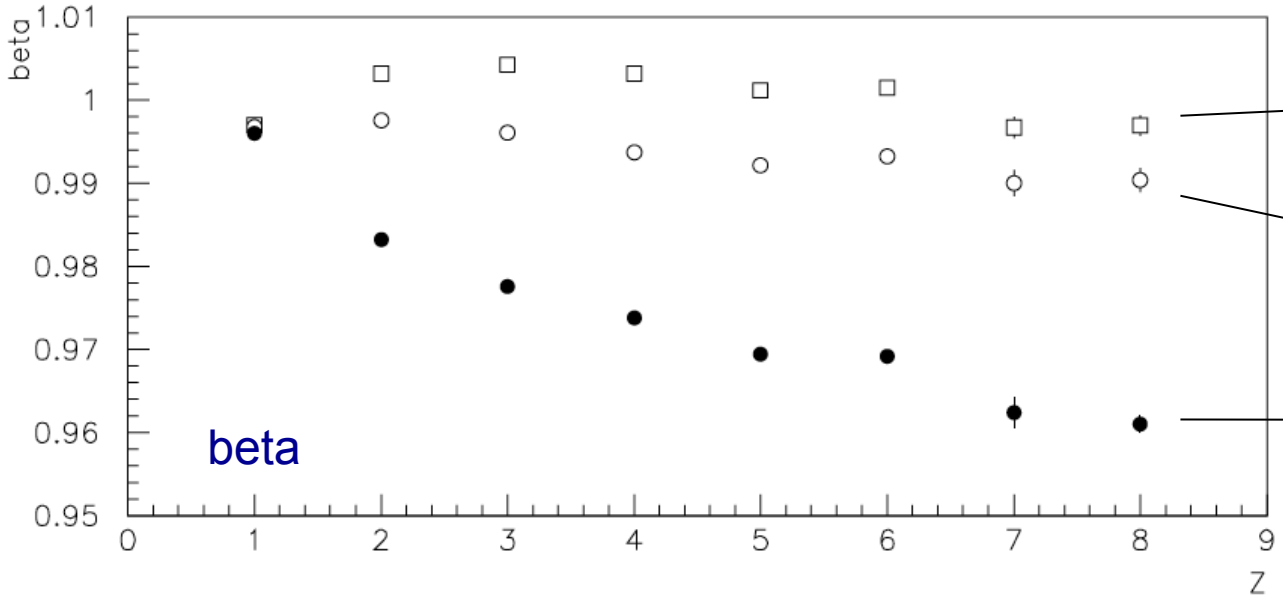
# Single counter zero time

Global fit with 34 constants and 288 measurements.



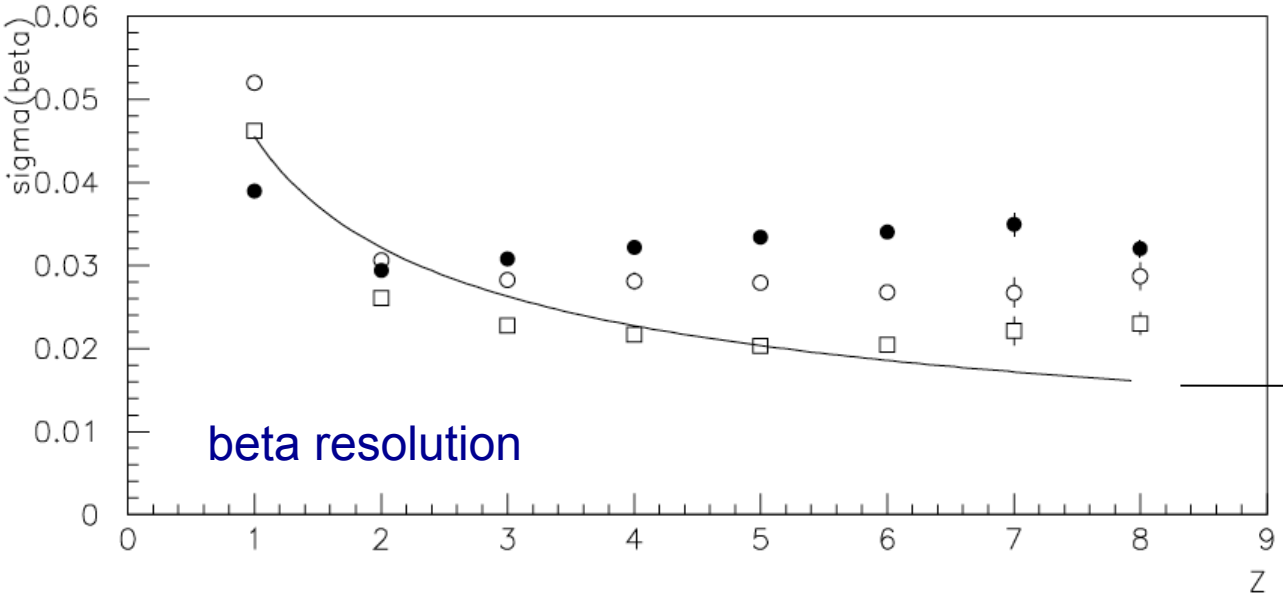
# Beta measurement versus charge




all particles slewing calibration

only protons slewing calibration

standard calibration




Fit to “all particles slewing calibration”:

$$\sqrt{p_0^2 + \frac{p_1^2}{Z^2}}$$

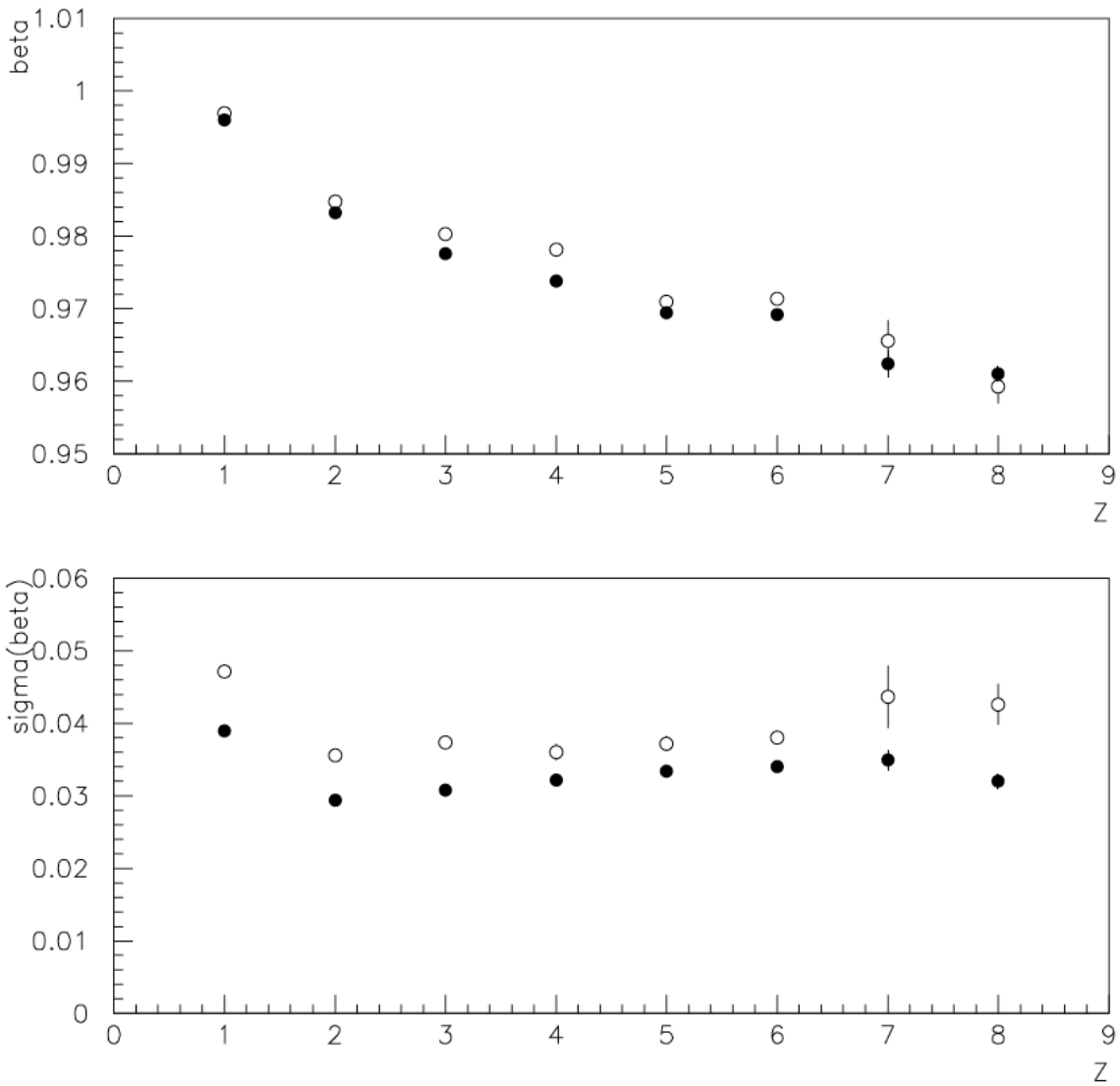
# Conclusion

The slewing/zero-time calibration must be done in two steps:

1. Compute slewing parameters with strict definition of the hit point in the counters and using all particles.
2. Compute the zero-times with the slewing correction applied.

# Comparison with the standard calibration

Repeat the zero time calibration using a fixed parameter (=13) for slewing correction




○ this analysis with fixed slewing correction

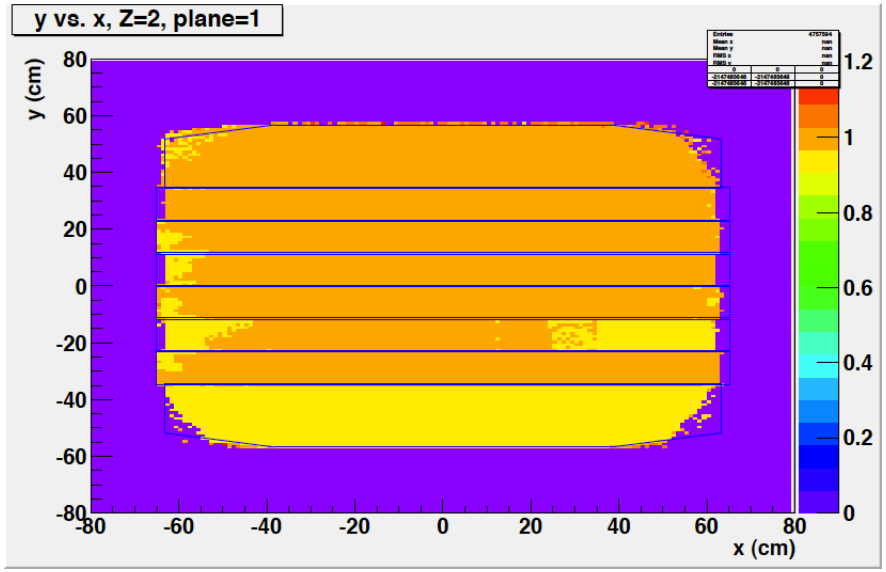
● standard calibration

The difference in resolution is expected because this analysis uses all data, while the standard calibration is repeated every day

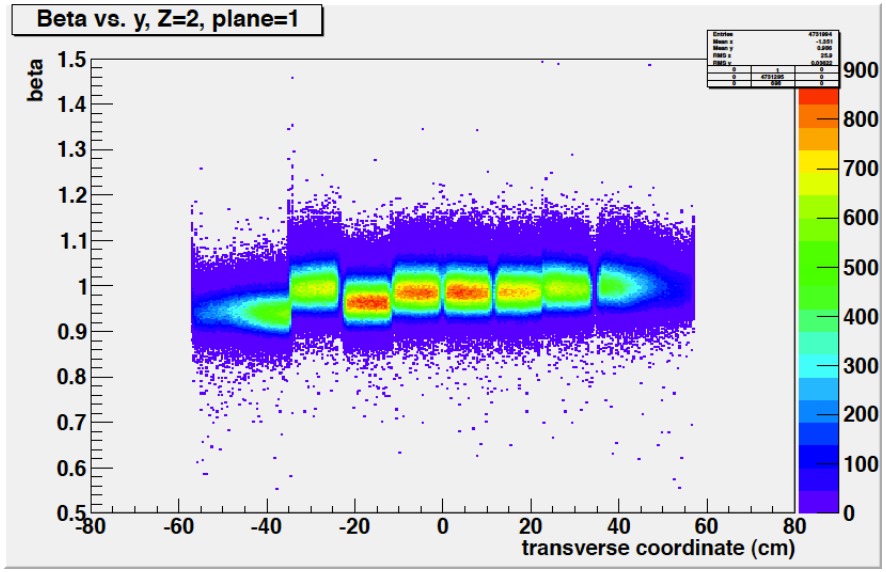
# WHY?

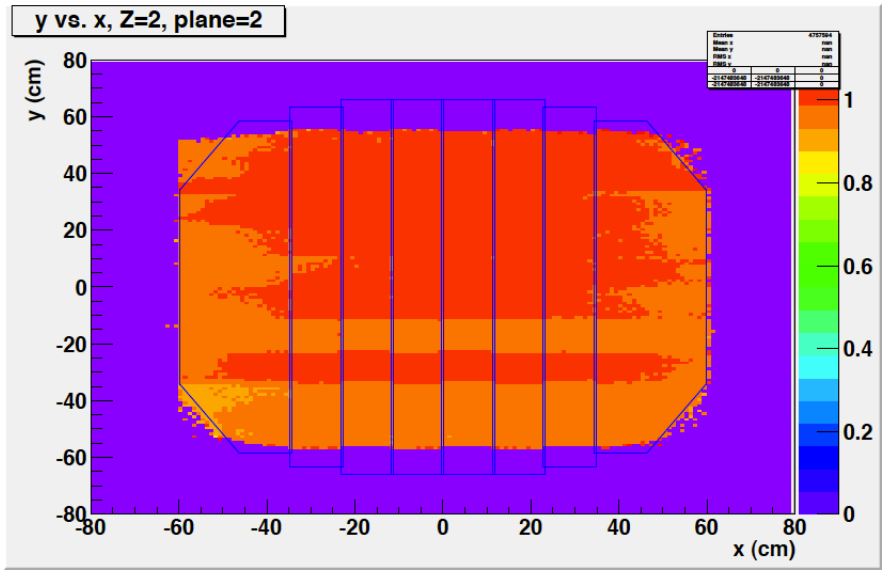
## Analysis with constant slewing parameter, Z=2

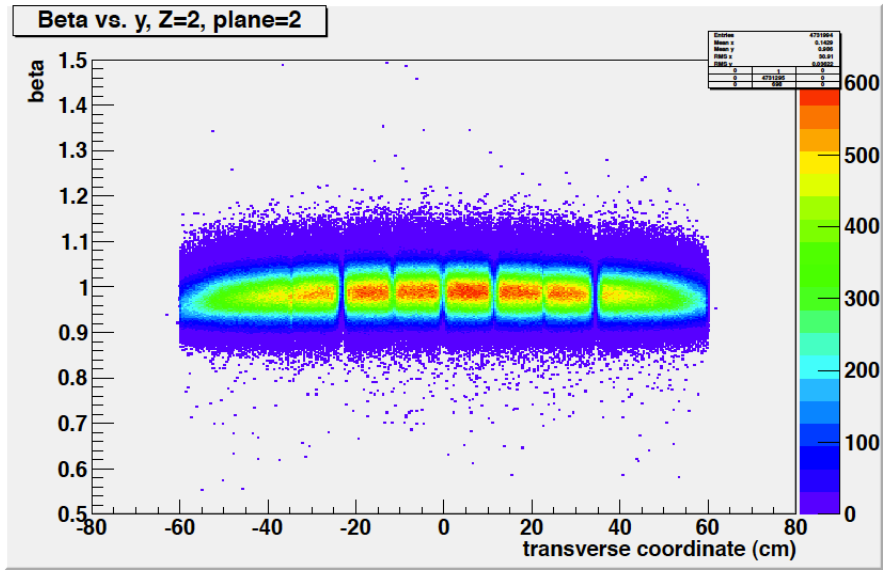
beta vs. position



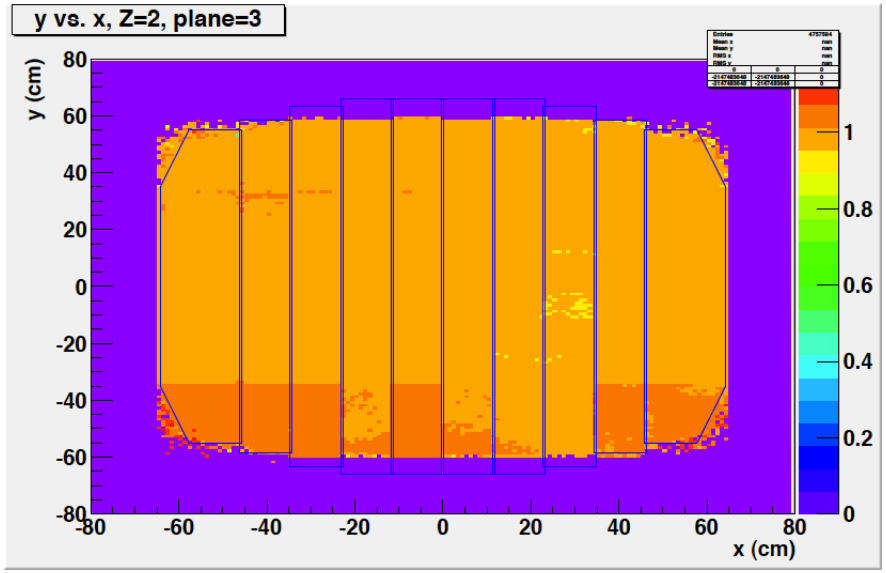

beta vs. transverse position

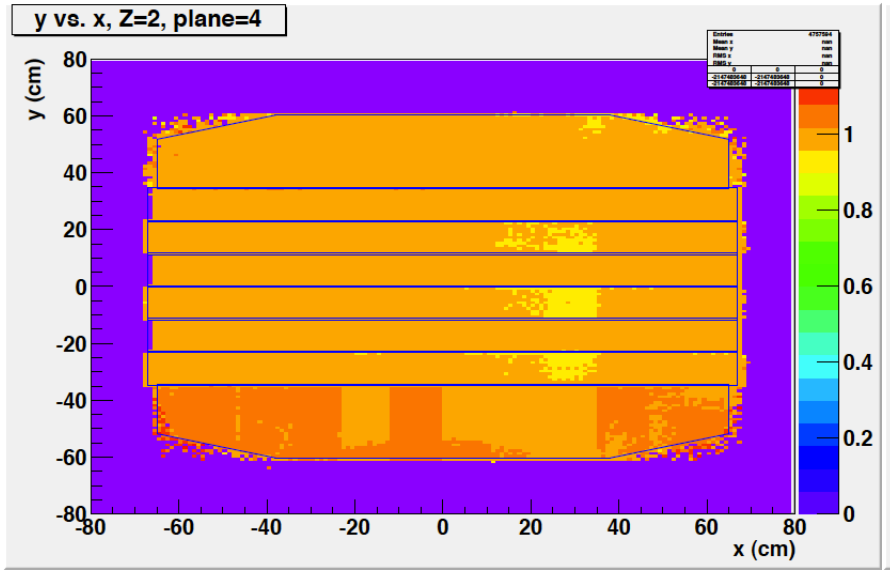


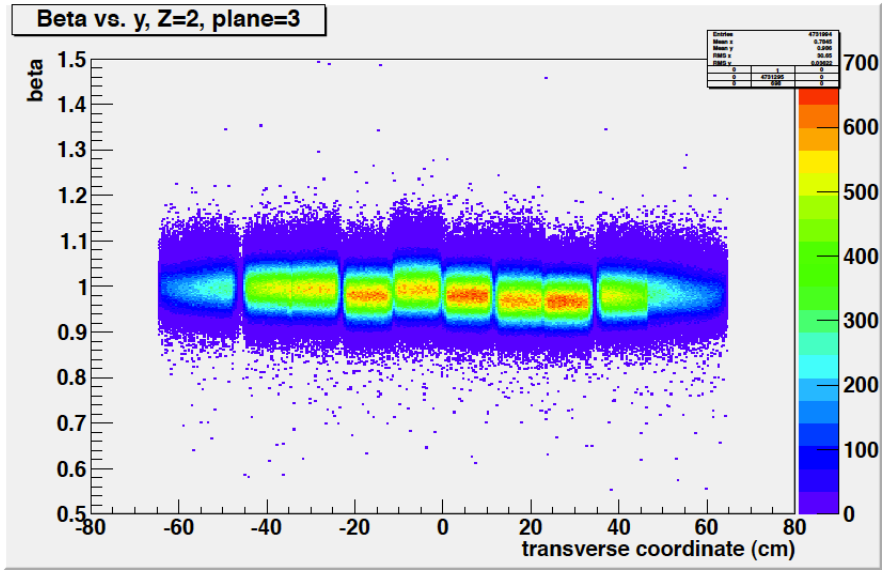



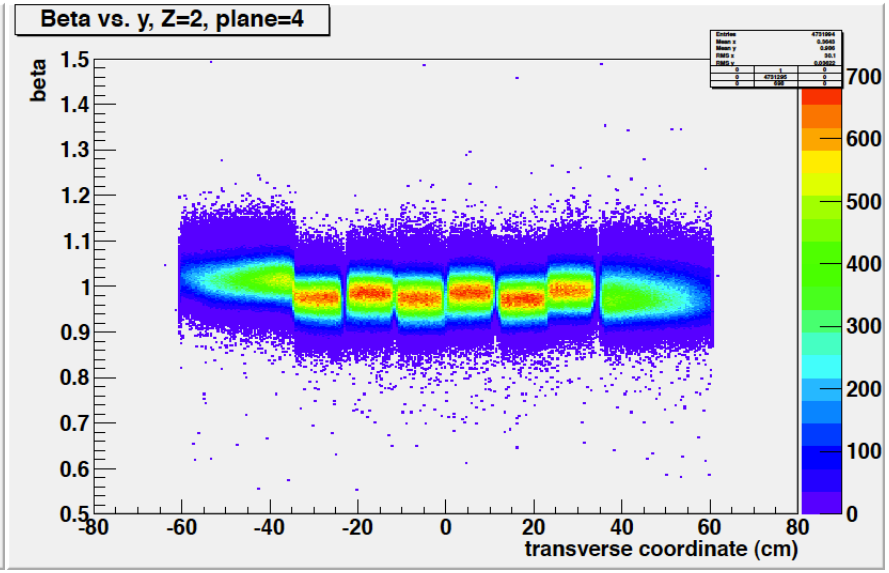
## beta vs. position




## beta vs. transverse position



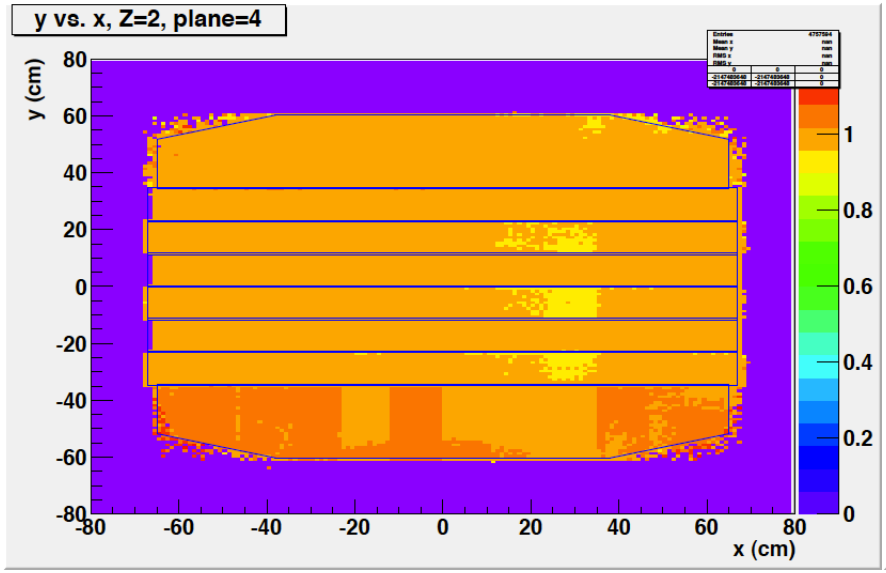



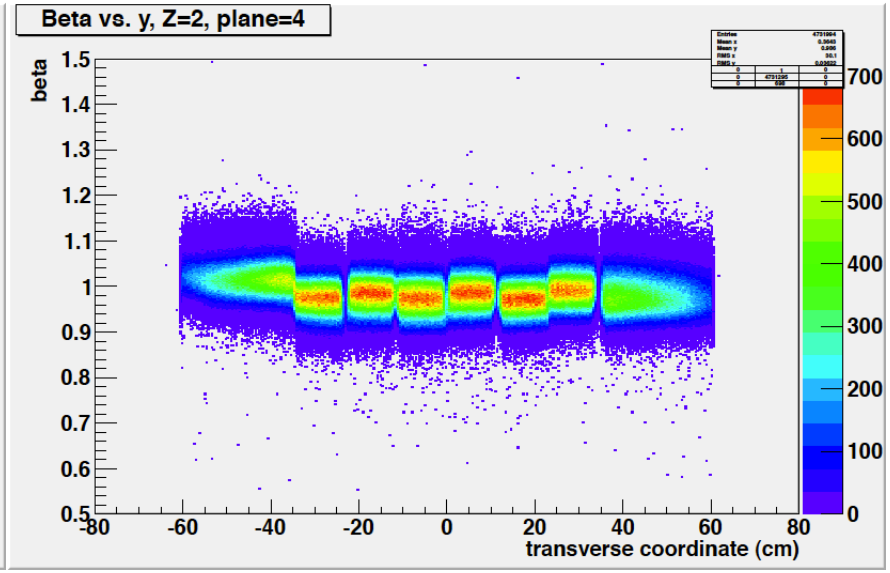
## And the effects are amplified for higher charges

beta vs. position

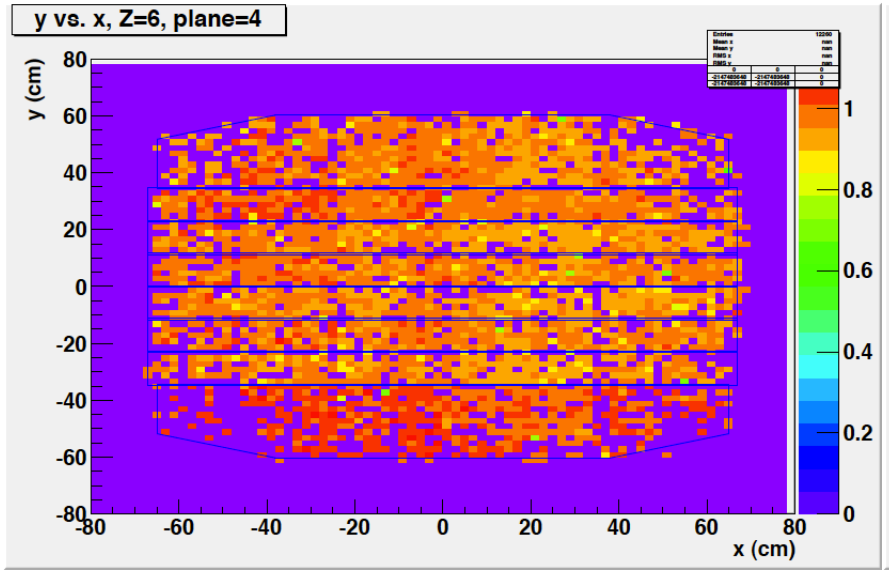
beta vs. transverse position

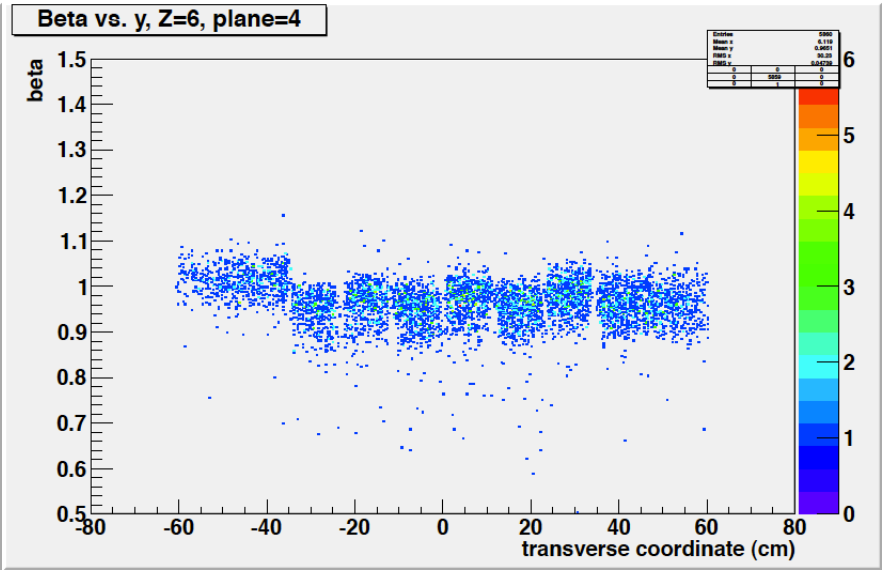
Z=2



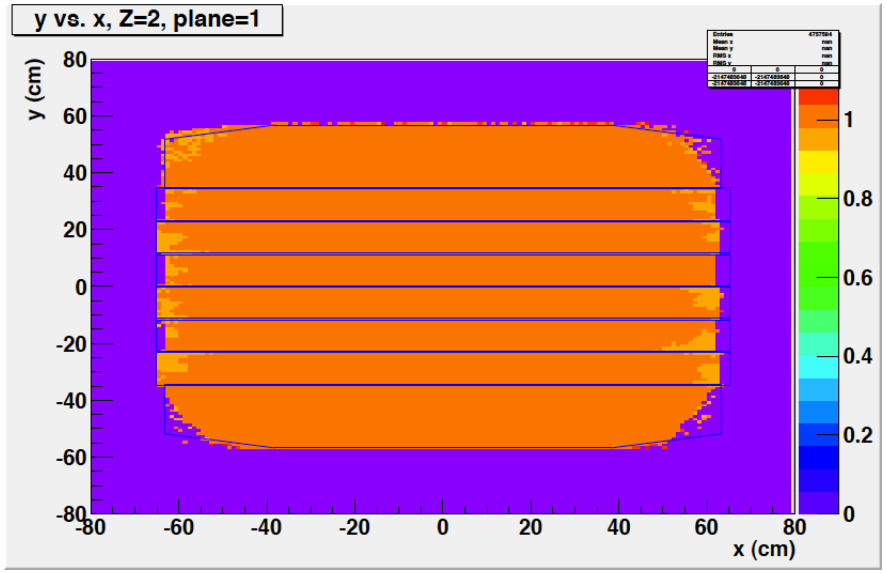

Z=6

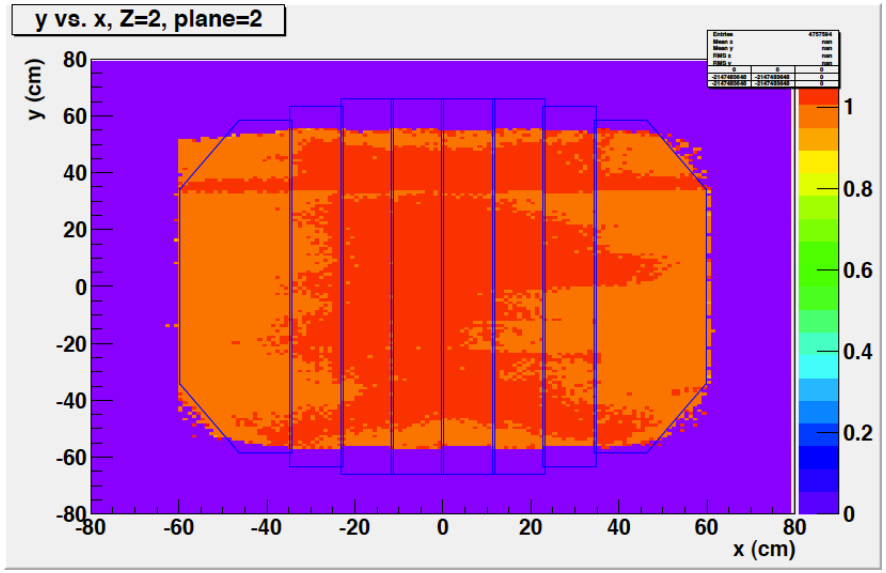


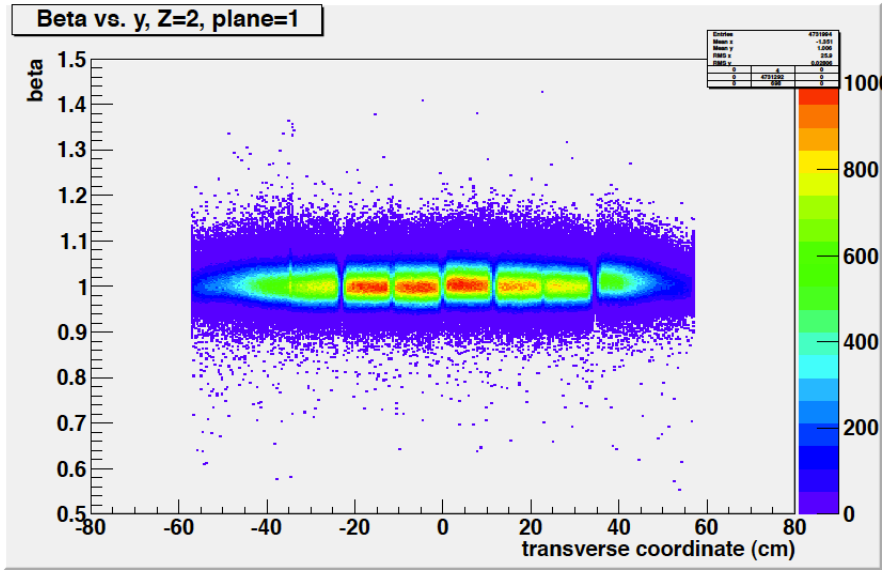
# Analysis with slewing parameters computed with all particles, Z=2

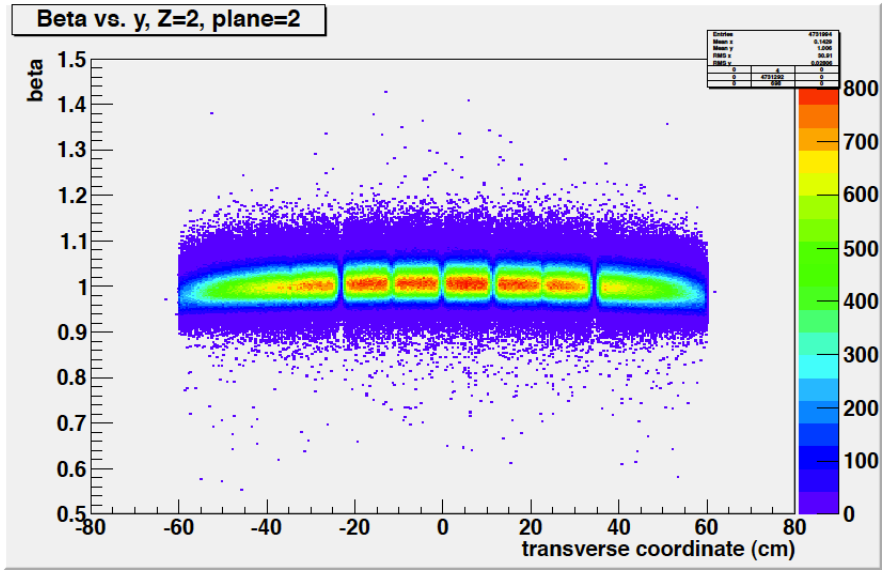
## beta vs. position



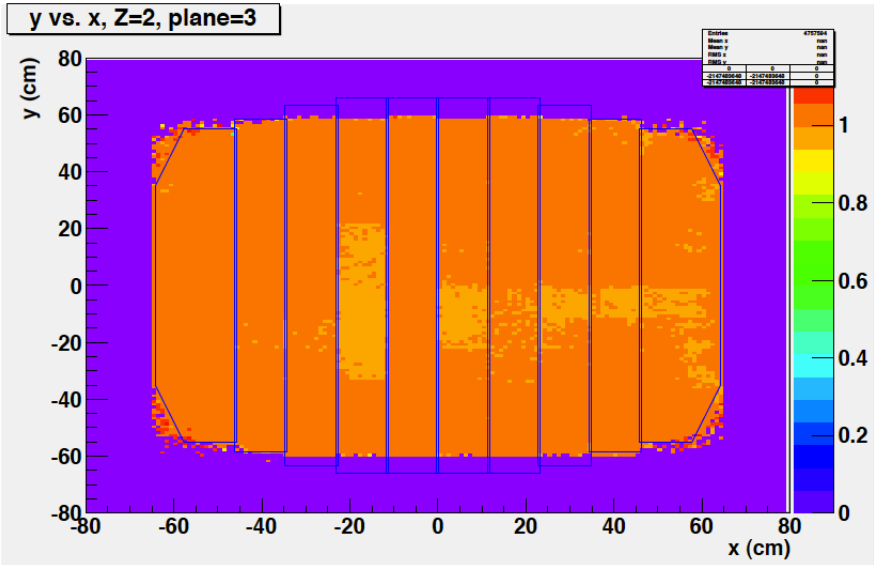



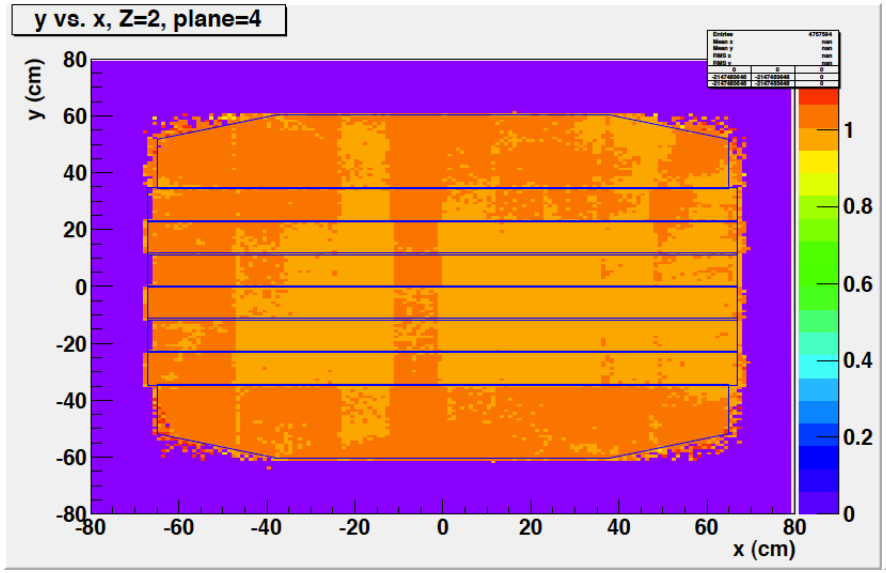

## beta vs. transverse position



## beta vs. position




## beta vs. transverse position