# TOF Status

TOF Group, 30 November 2011

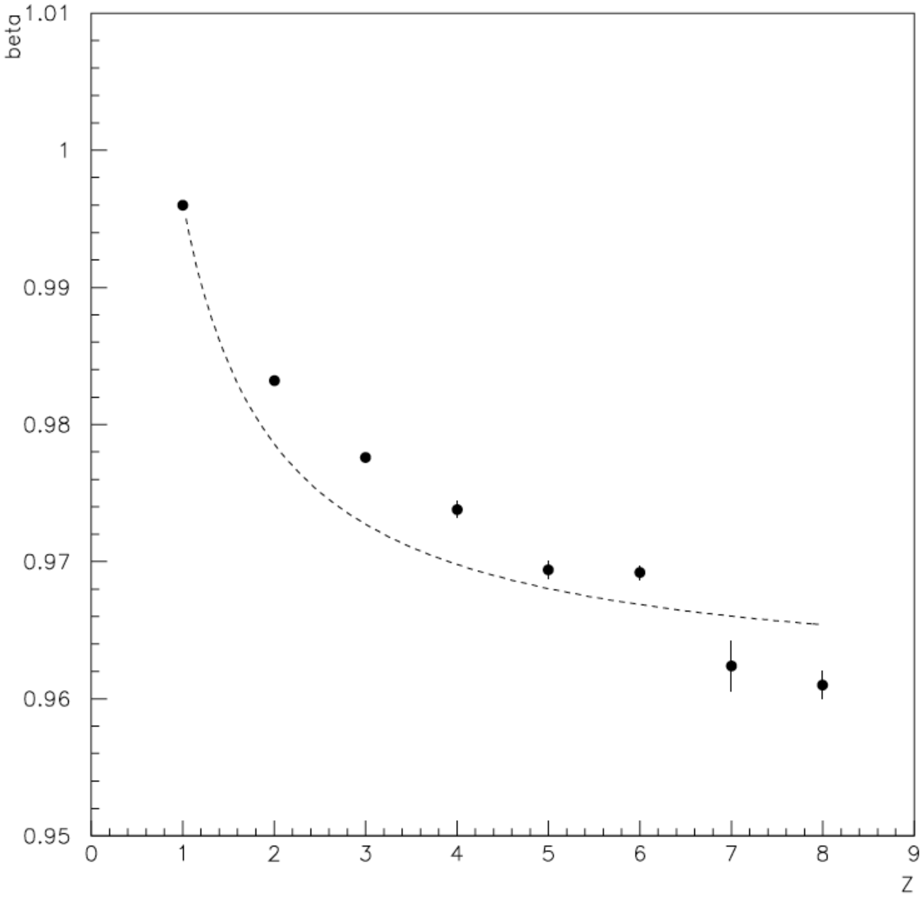
# Points

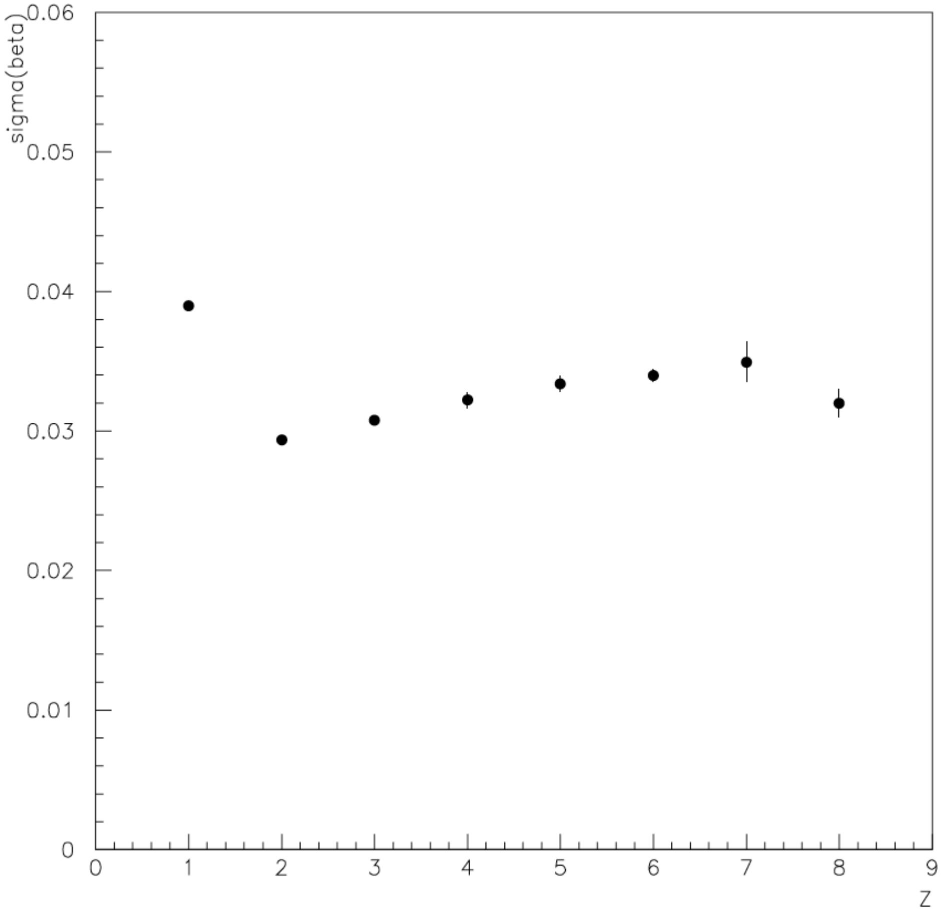
- TOF beta mesurement
- TOF Charge measurement

# TOF Beta measurement

Problems with the present gbatch version (B530/B538):

- Measured beta at high rigidity is lower than expected for Z>1
- Beta resolution is worse than expected



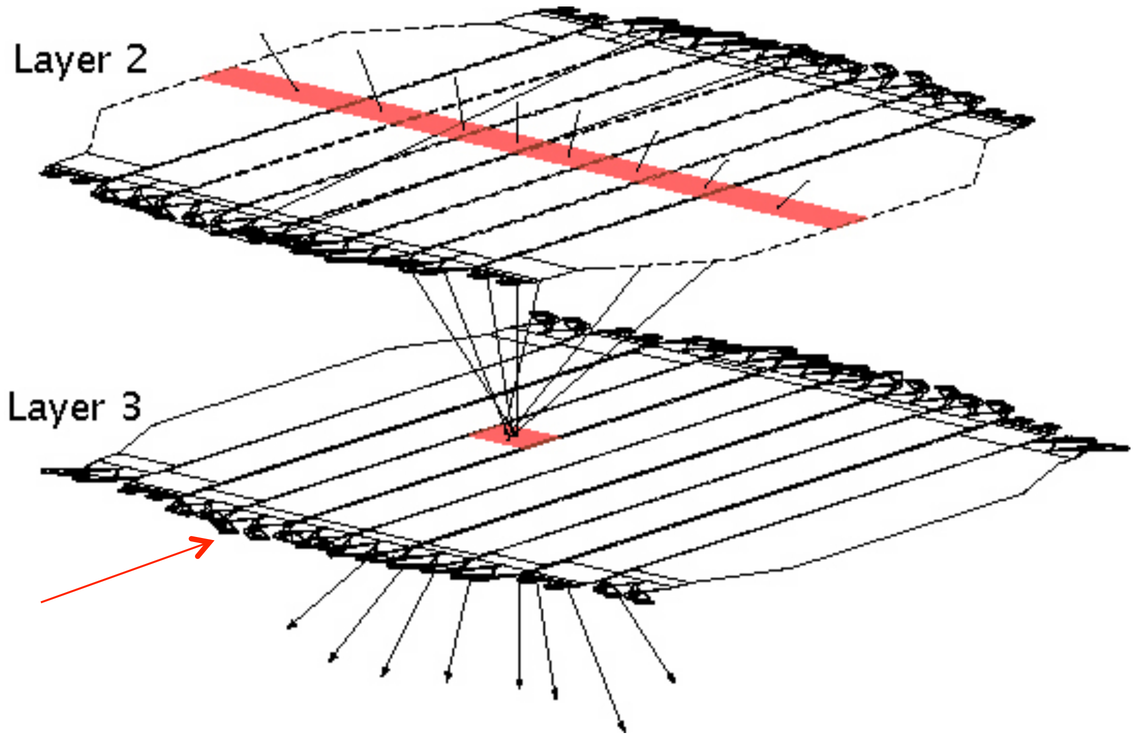



# TOF Beta measurement

Identified problem: one single slewing constant for all counter sides

Solution: perform a high statistics calibration of each slewing constant (one per counter side)

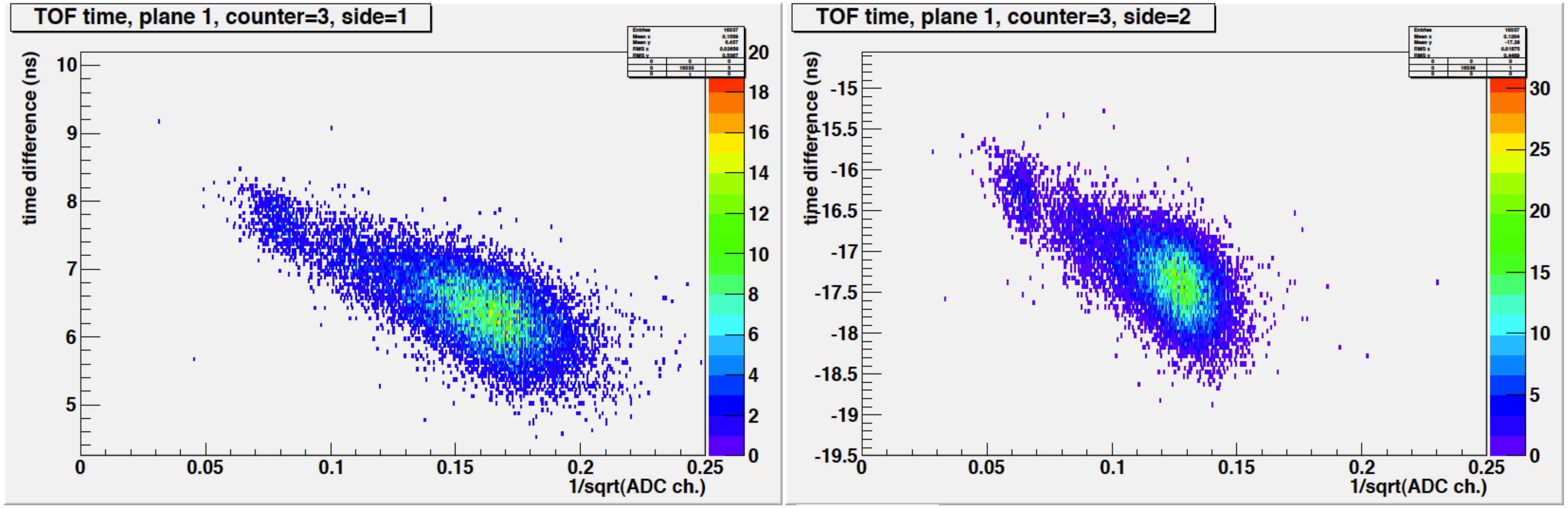
Side time: each side of another layer



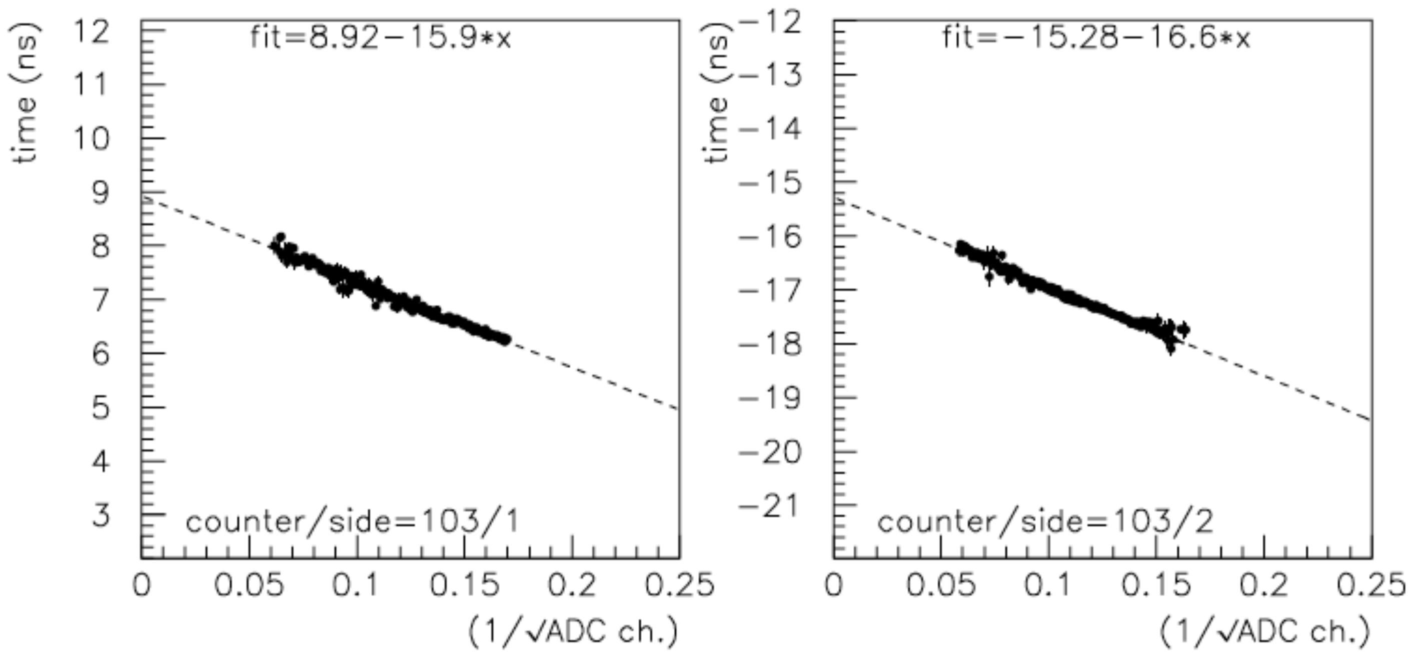

Reference time: mean time of one counter in one layer (e.g. counter 4)

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

# TOF Beta measurement – slewing correction sample plots




Fits:



# TOF Beta measurement – zero-time sample plots

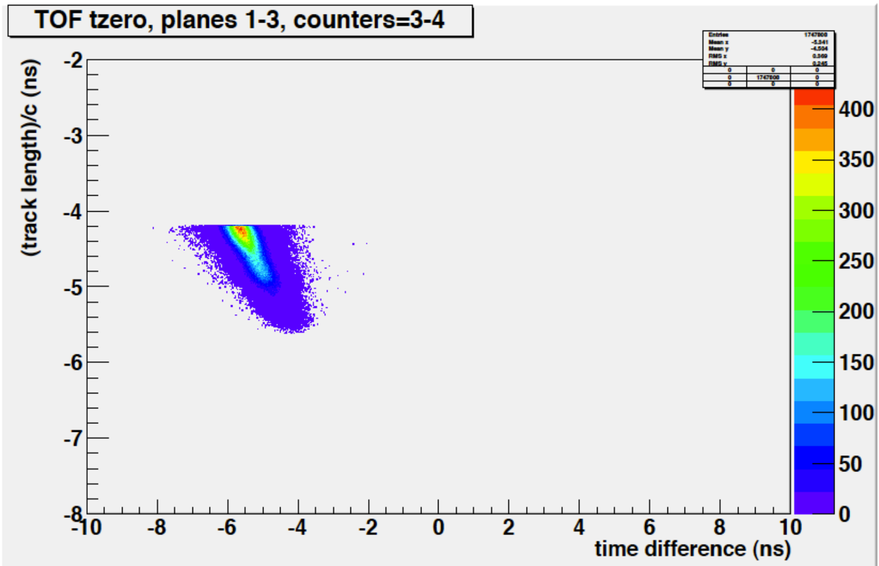
Layer combinations: 1-3, 2-3, 1-4, 2-4

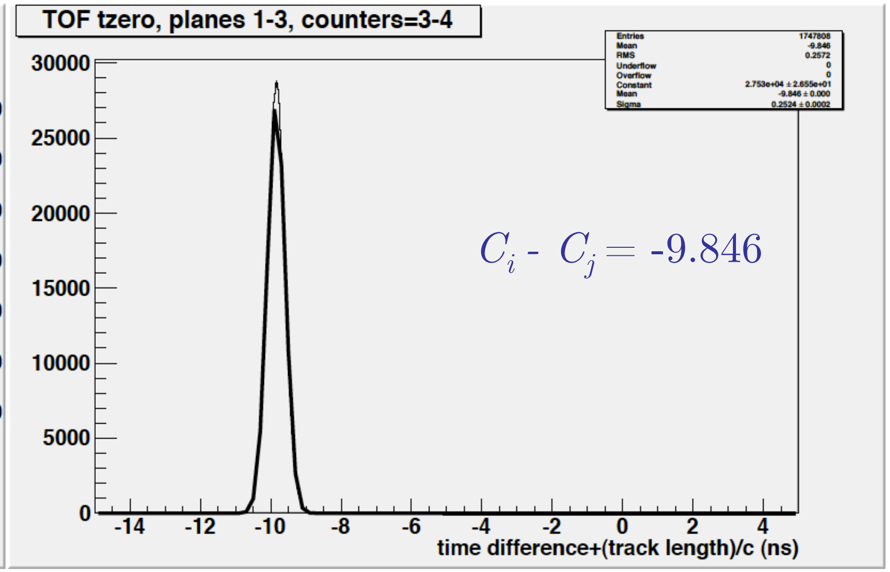
Plot:

$$\left(\frac{t_{m_1} + \frac{s_{1i}}{\sqrt{A_1}} + t_{m_2} + \frac{s_{2i}}{\sqrt{A_2}}}{2}\right)_i - \left(\frac{t_{m_1} + \frac{s_{1j}}{\sqrt{A_1}} + t_{m_2} + \frac{s_{2j}}{\sqrt{A_2}}}{2}\right)_j + \frac{l_{ij}}{v}$$

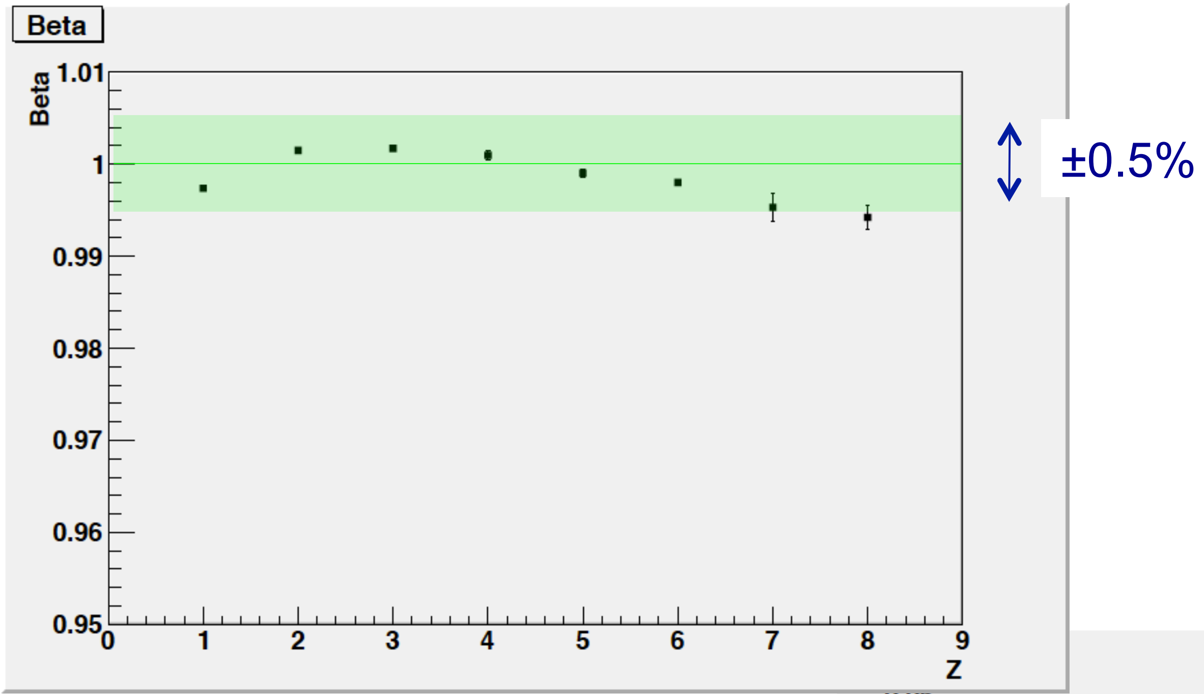
where:

- $i$ and $j$ are counters from different layers
- $A_{1,2}$ is the amplitude of the signal on side 1 or 2



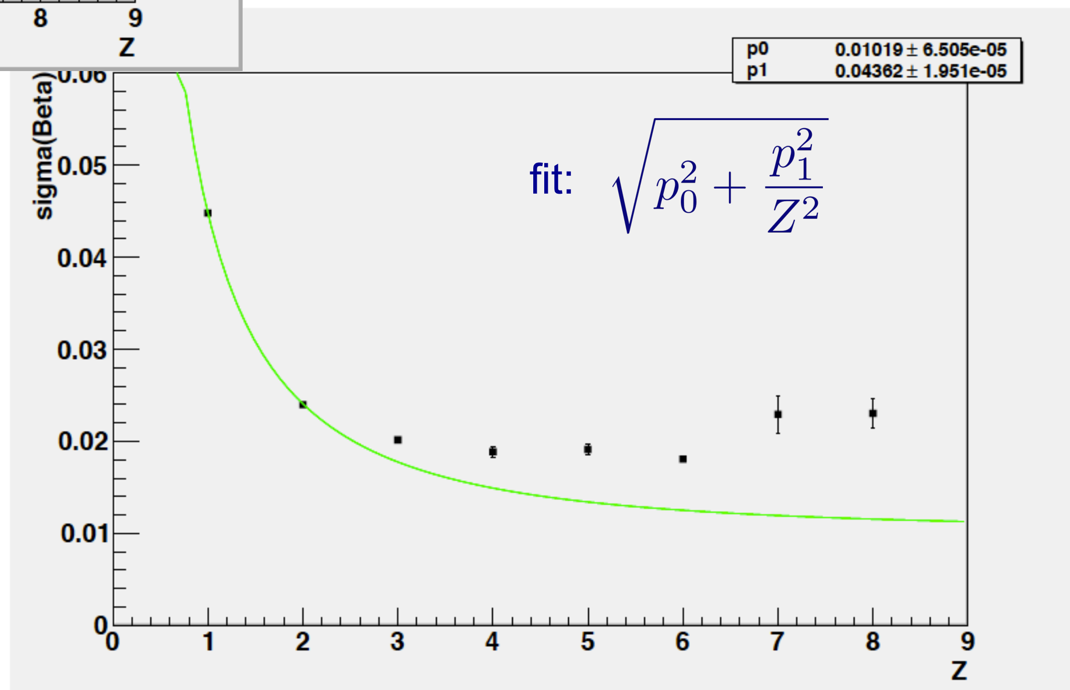



# TOF Beta measurement - Results




Beta

Beta resolution



# TOF Beta measurement - conclusions

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

1. Compute the slewing parameters for each counter side with strict definition of the hit point in the counters, using all particles and with adequate statistics.
2. Compute the zero-times using the slewing corrections computed in point 1.

A single slewing calibration needs a very long period of time (at least 2 months of data), but it is stable with time and running conditions.

Zero time calibrations can be repeated every 2 million triggers (as it is done now).

# TOF Beta measurement

Work done:

- the new calibration procedure has been tested

Work to be done (L. Quadrani):

- calibrate all data using the new procedure
- implement the use of the new constant files in the next reconstruction program version

# TOF charge measurement

Problems with the present gbatch version (B530/B538):

- No real procedure for determining the charge with the TOF is present (just some PDFs of unkown origin)

Two steps solution:

a) study $\beta$=1 particles with all B530/pass2 events (and “old” tracker charge reconstruction)
b) study $\beta$ correction with all B538/pass2 events (and “new” tracker charge reconstruction)

# Event selection and analysis – beta = 1

1. Trigger: all triggers

2. One and only one good track (Chi2<20, fit with inner tracker)
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): $Z = \frac{\sqrt{\mathrm{TrCharge :: GetMean}}}{6.2}$

Charge measured by TOF anodes (from reduced mean of Edep): $Z = \frac{\sqrt{\mathrm{ReducedMean}}}{1.289}$

Charge measured by TOF dynodes (from reduced mean of Edepd): $Z = \frac{\sqrt{\mathrm{ReducedMean}}}{1.149}$

5. Charge selection: $|Z - i| < 0.3$ ; $i$=1,..,8
6. Relativistic particle selection ($\beta$ > 0.994): $Z = 1: \;\; R > 9\,\mathrm{GV}$

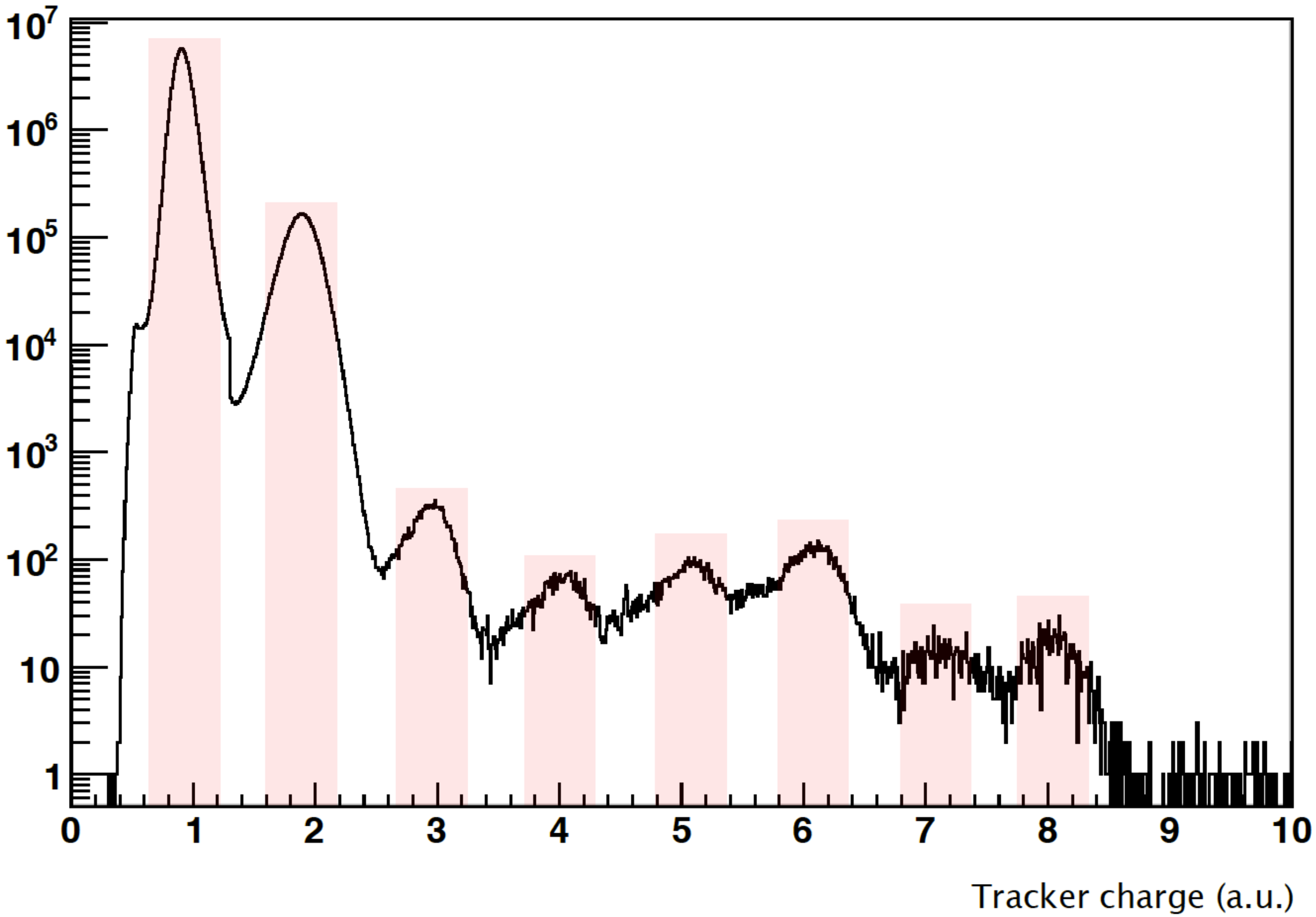
$Z > 1: \;\; R > 20\,\mathrm{GV}$

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

# Event selection and analysis

Charge selection from tracker charge (computed with “old” – pre-November 2011 – algorithm)

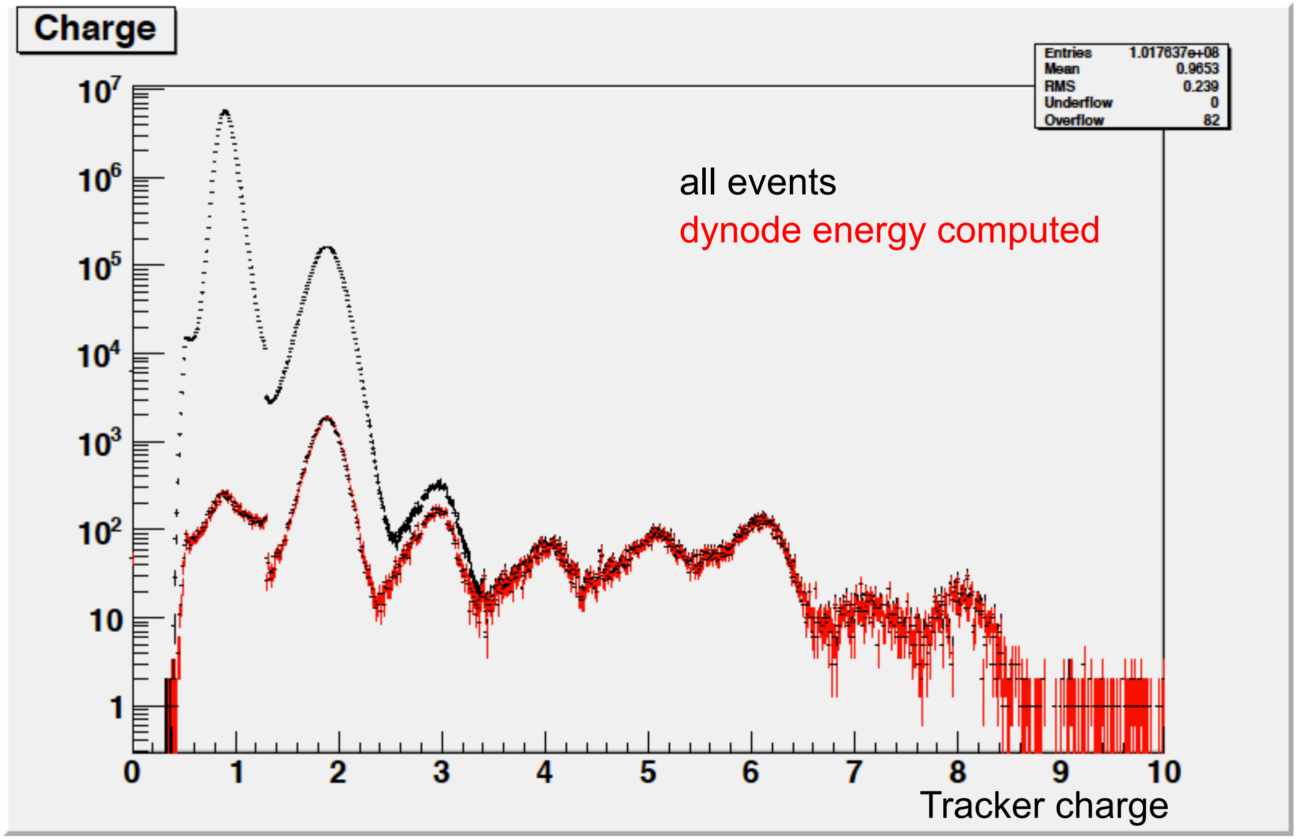


# Event selection and analysis

The anode energies are taken from: TofCluster->Edep
The dynode energies are taken from: TofCluster->Edepd

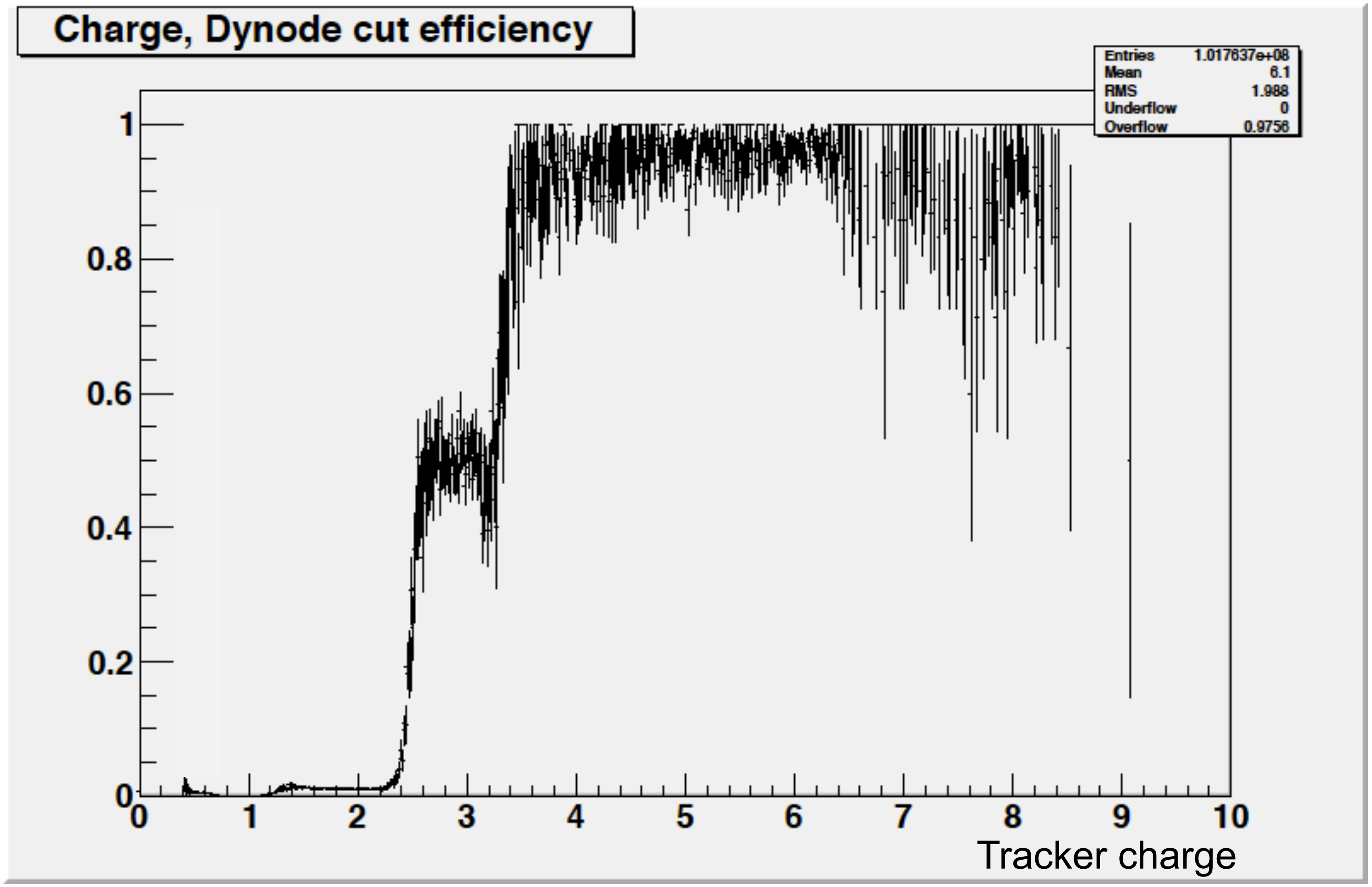
The reduced energy is computed as the average of the three lowest energies.

The dynode energy is only computed for events in which the counters hit by the particle have all dynode ADCs present (i.e., retained by the compression algorithm):
TofRawSide->adcd[i]>0, i=0,..,2(3)



# Event selection and analysis

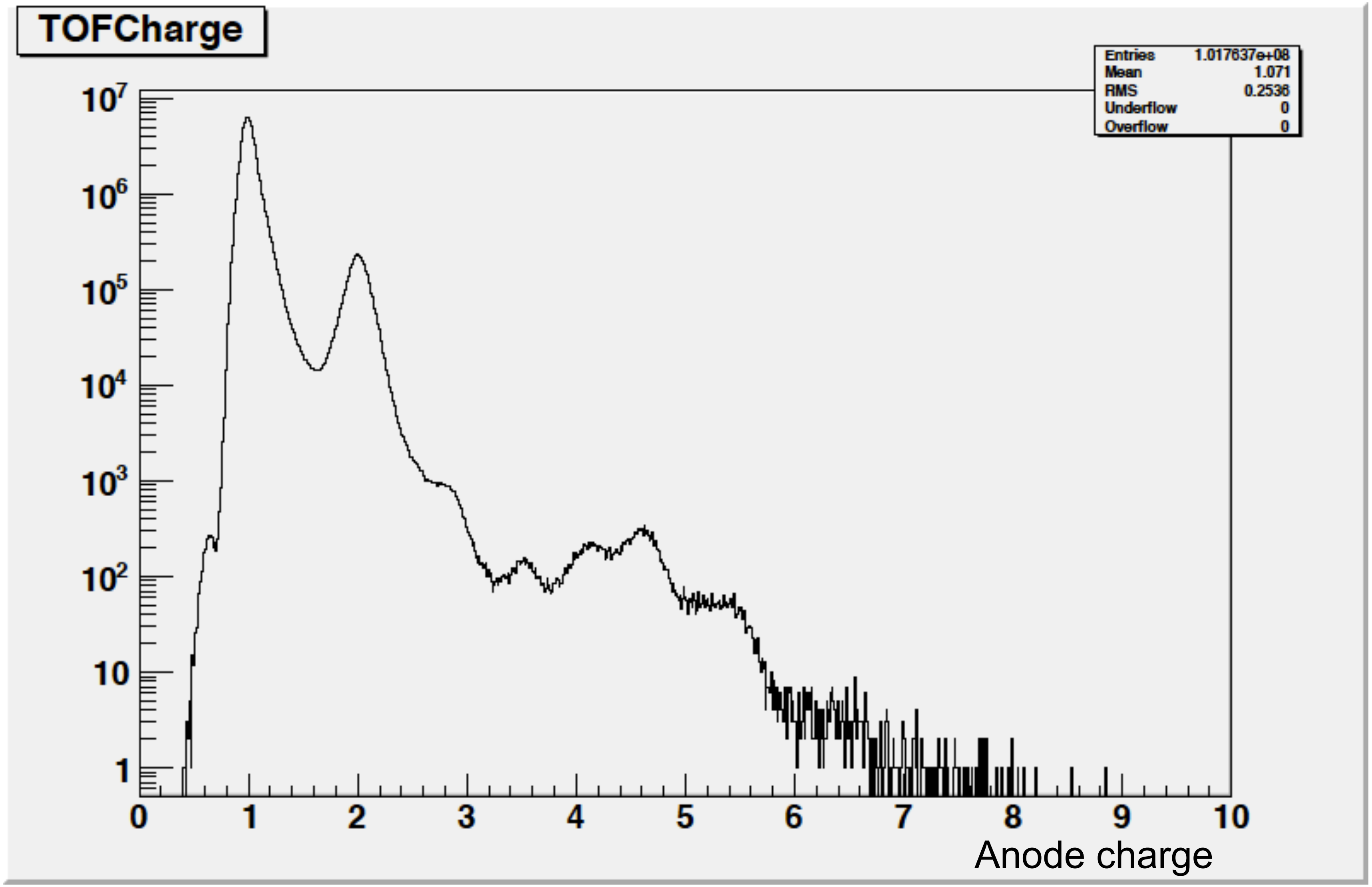
## Dynode selection efficiency



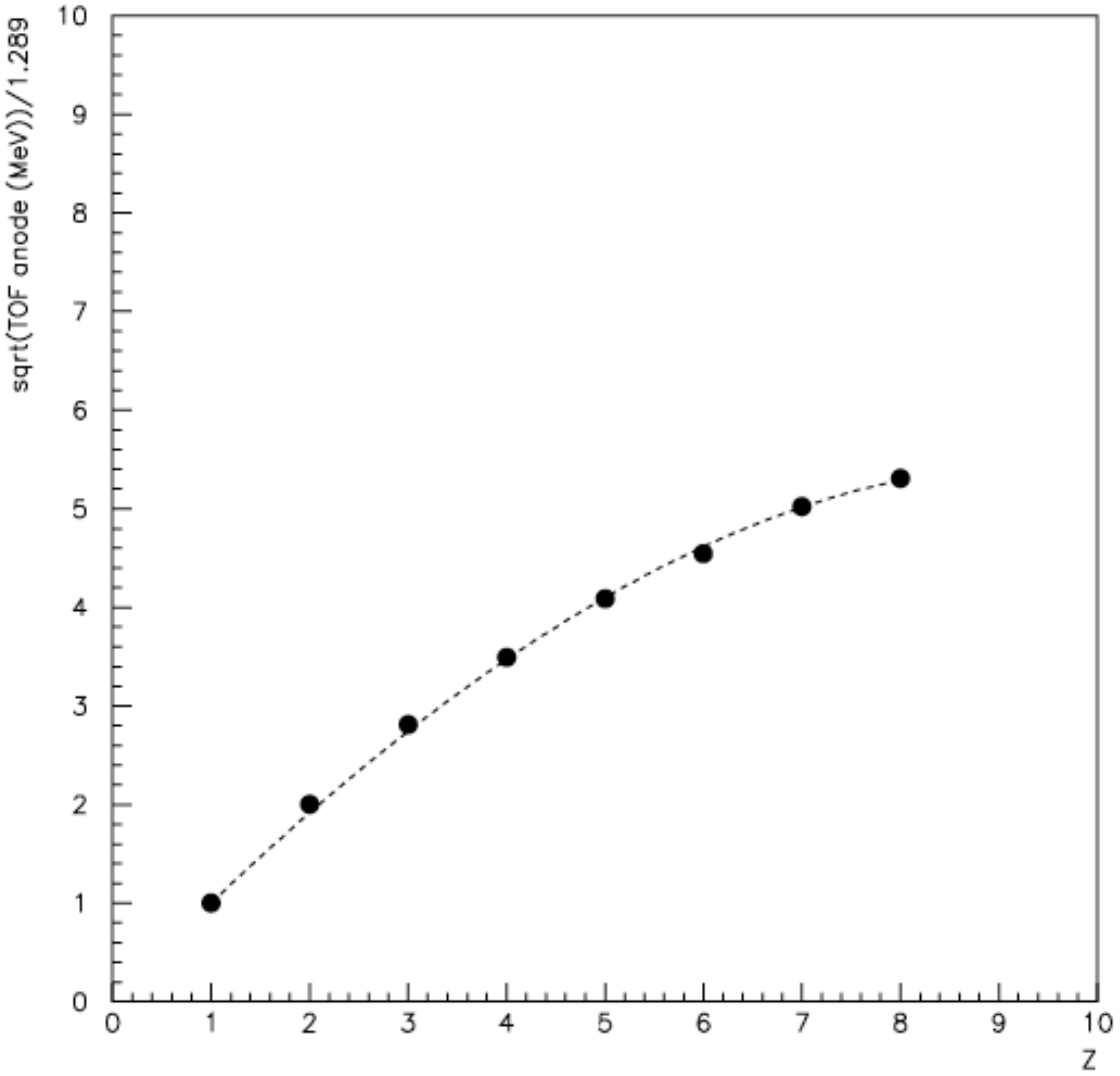

About 50% of the Z=3 events does not have all dynodes present.
The efficiency is >90% for Z≥4.
Few PMTs contribute to the dynode inefficiency (see next pages)

# Results – Anode charge

Anode charge: $Z = \dfrac{\sqrt{\mathrm{ReducedMean}}}{1.289}$



# Results – Anode charge




The anode signal heavily saturates for Z>2.

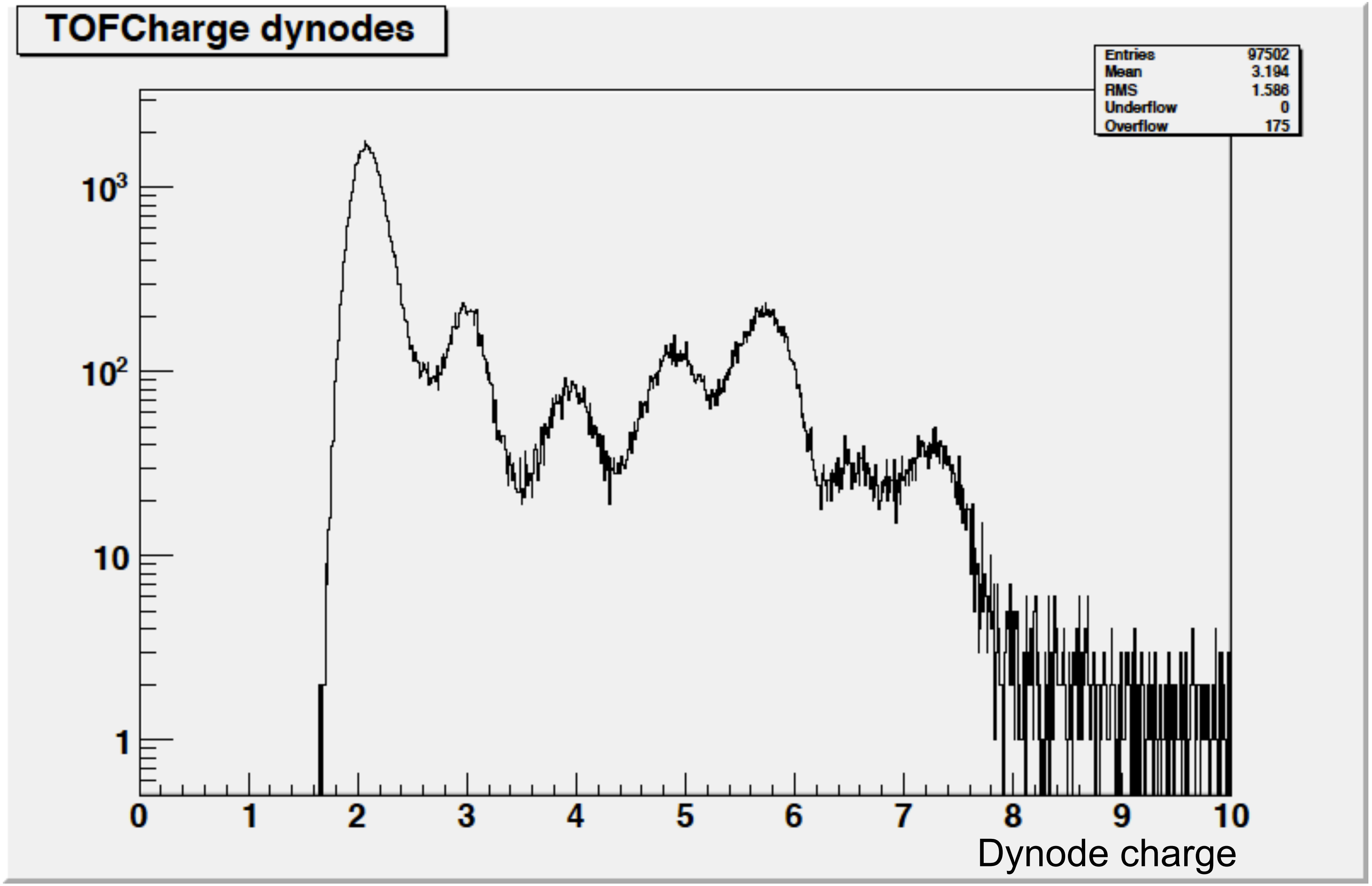
The dashed line is a fit:

$$Z_{\mathrm{anode}} = (1 - a - b)Z + aZ^2 + bZ^3$$

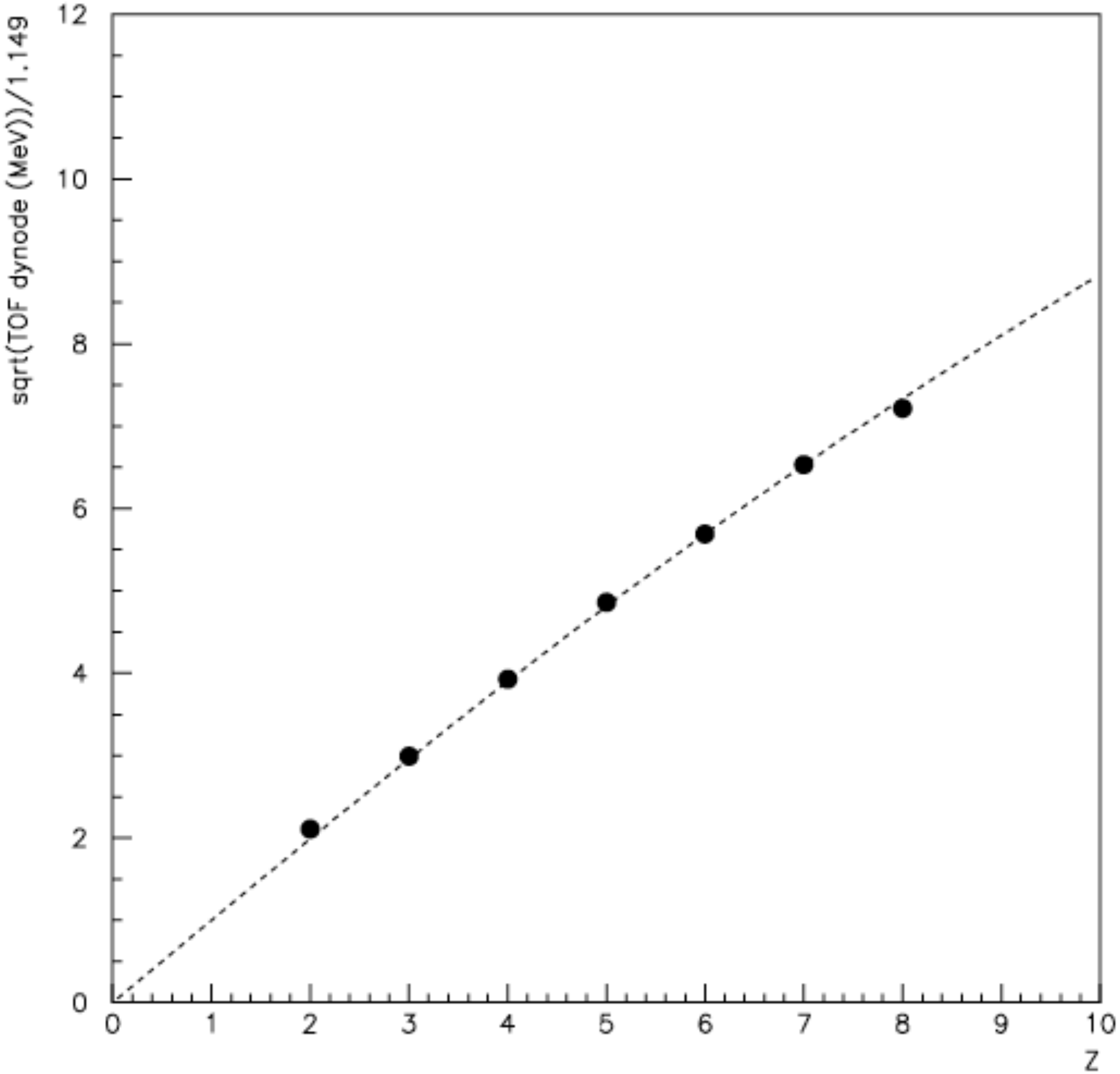
with:
$a$=-0.03853
$b$=-0.00109

# Results – Dynode charge

Dynode charge: $Z = \frac{\sqrt{\text{ReducedMean}}}{1.149}$



# Results – Dynode charge




The dashed line is the Birks' law:

$$Z_{\text{dynode}} = \frac{Z}{\sqrt{1 + aZ^2 + bZ^4}}$$

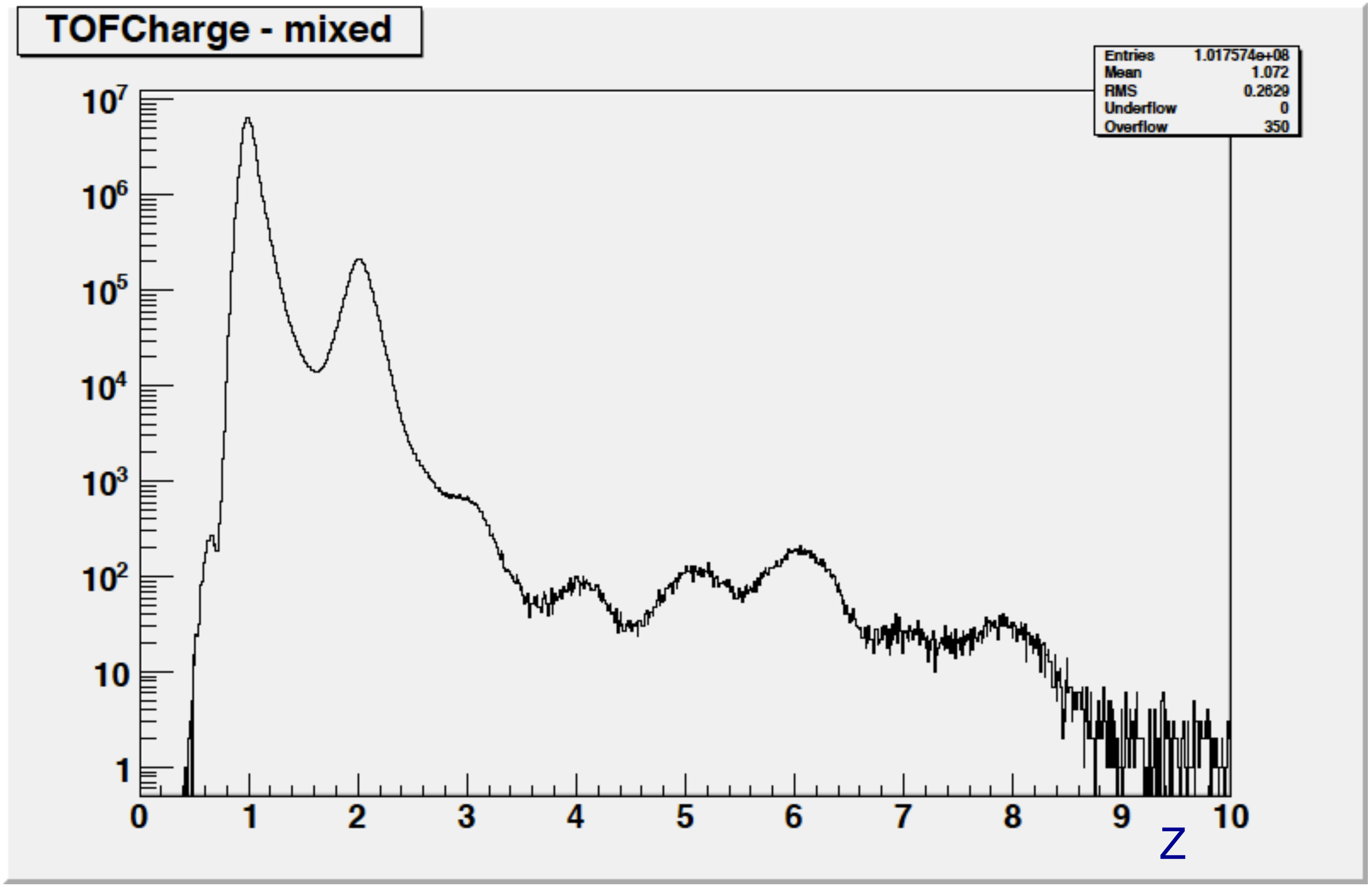
with the parameters:

$a = 3.3 \times 10^{-3}$
$b = -5 \times 10^{-6}$

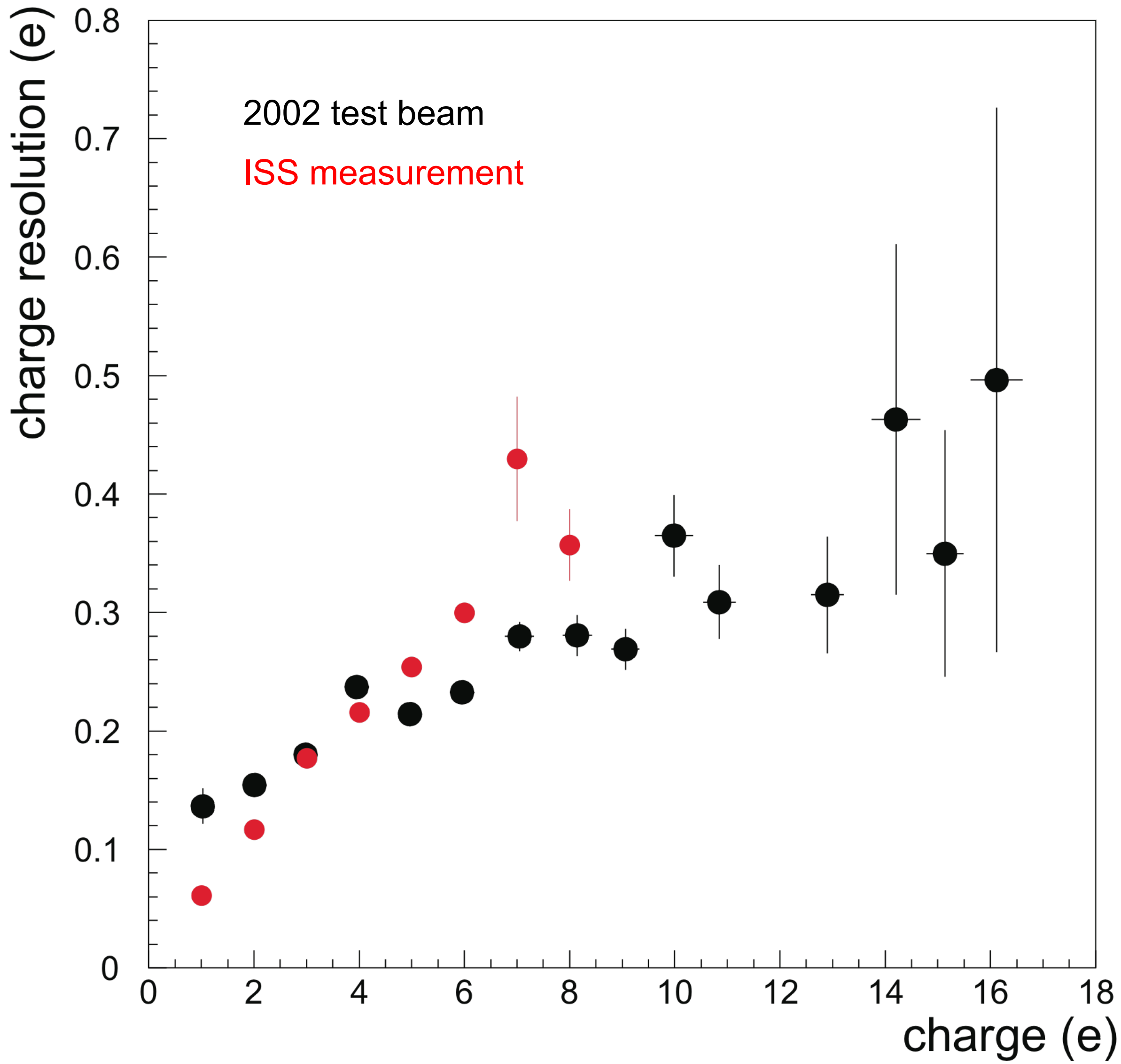
as measured in the 2002 test beam (D. Casadei, "Direct measurement of galactic cosmic ray fluxes with the orbital detector AMS-02", PhD thesis, University of Bologna, 2003; V. Bindi et al., NIM-A, 623 (2010) 968)

# Strategy for TOF charge measurement

- correct both anode and dynode charge by inverting the fits in the previuos plots
- use the dynode charge if all dynodes are present
- use the anode charge if not all dynodes are present



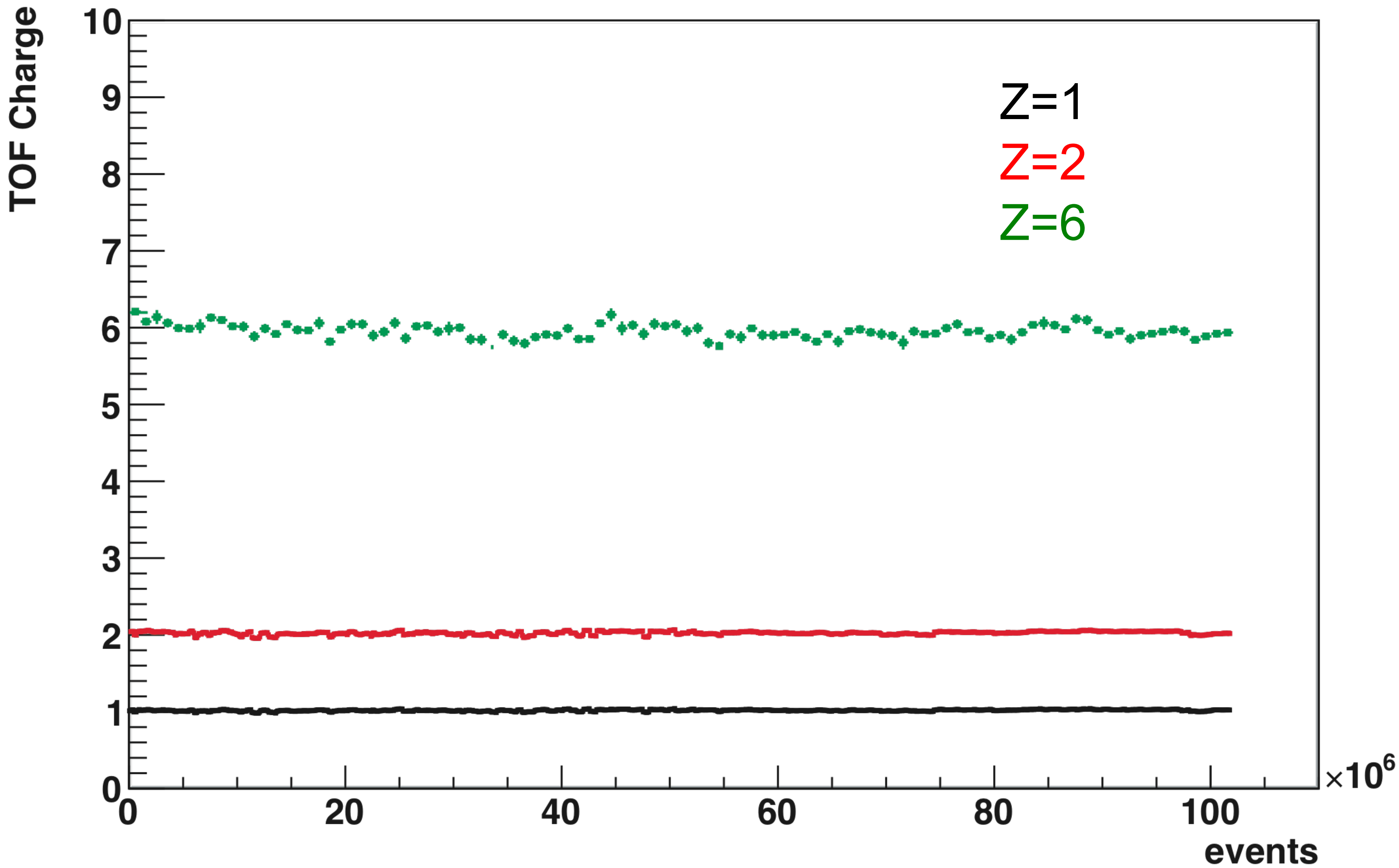
# Results – Charge resolution




Z=1 and Z=2: anode
Z>2: dynode

The charge resolution compares quite well with the expectations from the 2002 test beam (V. Bindi et al., NIM-A, 623 (2010) 968)

# Results – Stability



# Charge vs. beta

$$\frac{dE}{dx} = K\rho z^2 \frac{Z}{A}\frac{1}{\beta^2}\left(\frac{1}{2}\ln\frac{2m_e c^2\gamma^2\beta^2 T_{max}}{I^2} - \beta^2 - \frac{\delta}{2}\right)$$

$$K = 4\pi N_A r_e^2 m_e c^2$$
$$N_A = 6.02 \times 10^{23}\,\mathrm{mol}^{-1}$$
$$r_e = 2.82 \times 10^{-13}\,\mathrm{cm}$$
$$m_e c^2 = 0.511\,\mathrm{MeV}$$
$$c = 2.998 \times 10^{10}\,\mathrm{cm\,s}^{-1}$$
$$\langle Z/A\rangle_{\mathrm{polystyrene}} = 0.538\,\mathrm{g}^{-1}\mathrm{mol}$$
$$\rho_{\mathrm{polystyrene}} = 1.060\,\mathrm{g\,cm}^{-3}$$
$$I = 68.7\,\mathrm{eV}$$
$$T_{max} = \frac{2m_e c^2\beta^2\gamma^2}{1 + 2\gamma\frac{m_e}{m} + \left(\frac{m_e}{m}\right)^2}$$

$ze$ = incoming particle charge

$\beta = v/c$ of incoming particle

$\gamma$ = incoming particle relativistic factor

$m$ = incoming particle mass

$$\frac{dE}{dx} \cong \frac{P_1}{\beta^2} z^2 \left(\ln\left(P_2\gamma^2\beta^2\right) - \beta^2\right)$$

$$z = \sqrt{\frac{\frac{dE}{dx}}{\frac{P_1}{\beta^2}\left(\ln\left(P_2\gamma^2\beta^2\right) - \beta^2\right)}}$$

# Charge vs. beta - event selection and analysis

1. Trigger: all triggers

2. One and only one good (Chi2<20) track reconstructed with inner tracker

3. At least 3 TOF layers with a cluster associated to track

4. R>0, $\beta_{TOF}>0$

Charge measured by TOF anodes (from reduced mean of Edep): $Z = \frac{\sqrt{\mathrm{ReducedMean}}}{1.289}$

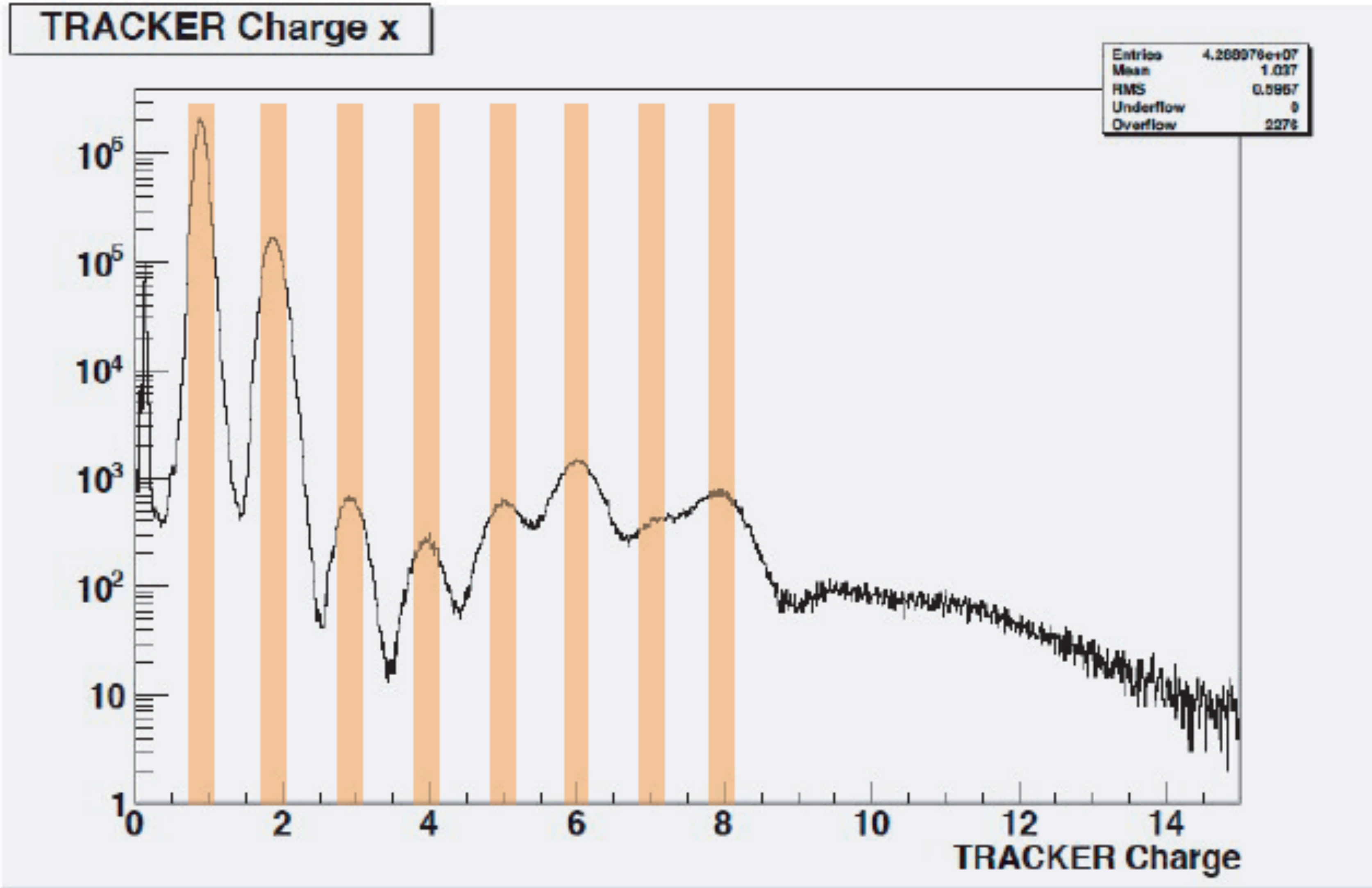
Charge measured by TOF dynodes (from reduced mean of Edepd): $Z = \frac{\sqrt{\mathrm{ReducedMean}}}{1.149}$

All runs reconstructed with pass2, B538 gbatch version
Tracker charge reconstructed with Oliva's last (11 November 2011) version of TrRecon

- 237,575,742 recostructed events
- 77,116,530 events satisfying selection criteria 2, 3 and 4

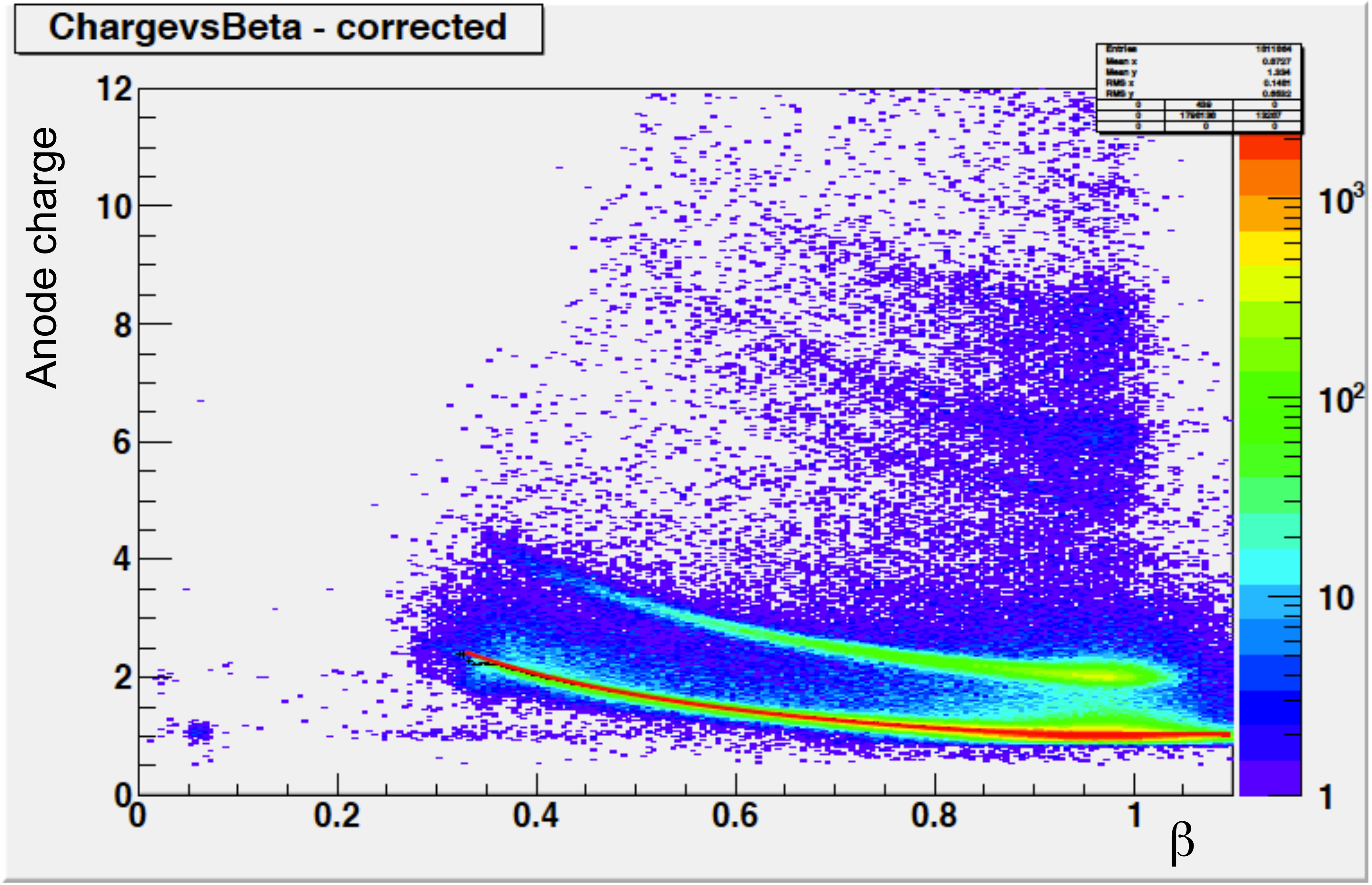
# Event selection and analysis

## Charge selection from tracker charge (computed with the “new” – November 2011 – algorithm)



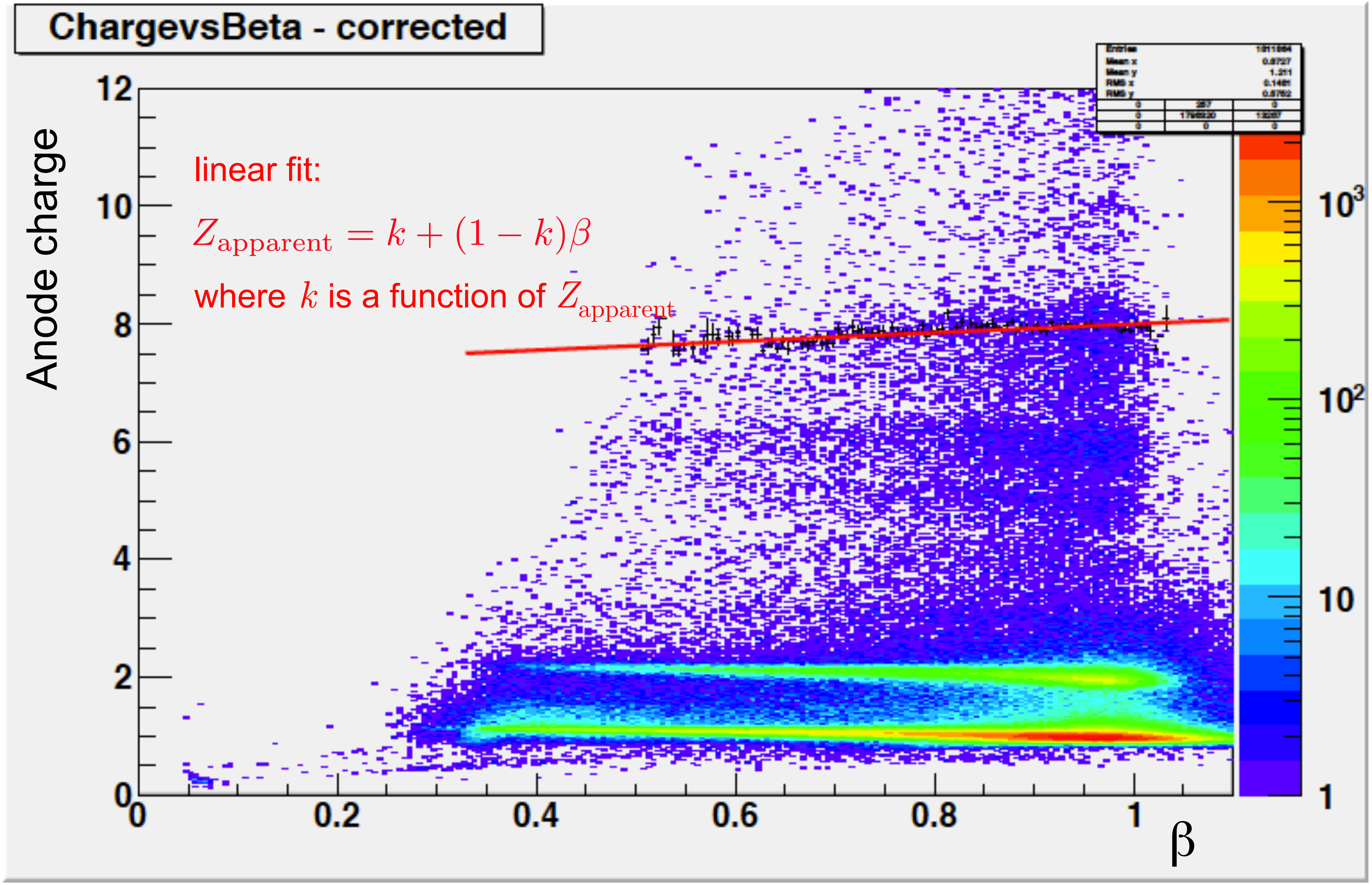
# Charge vs. beta - anode

Anode charge after correcting for anode saturation. Bethe-Block fit for Z=1.



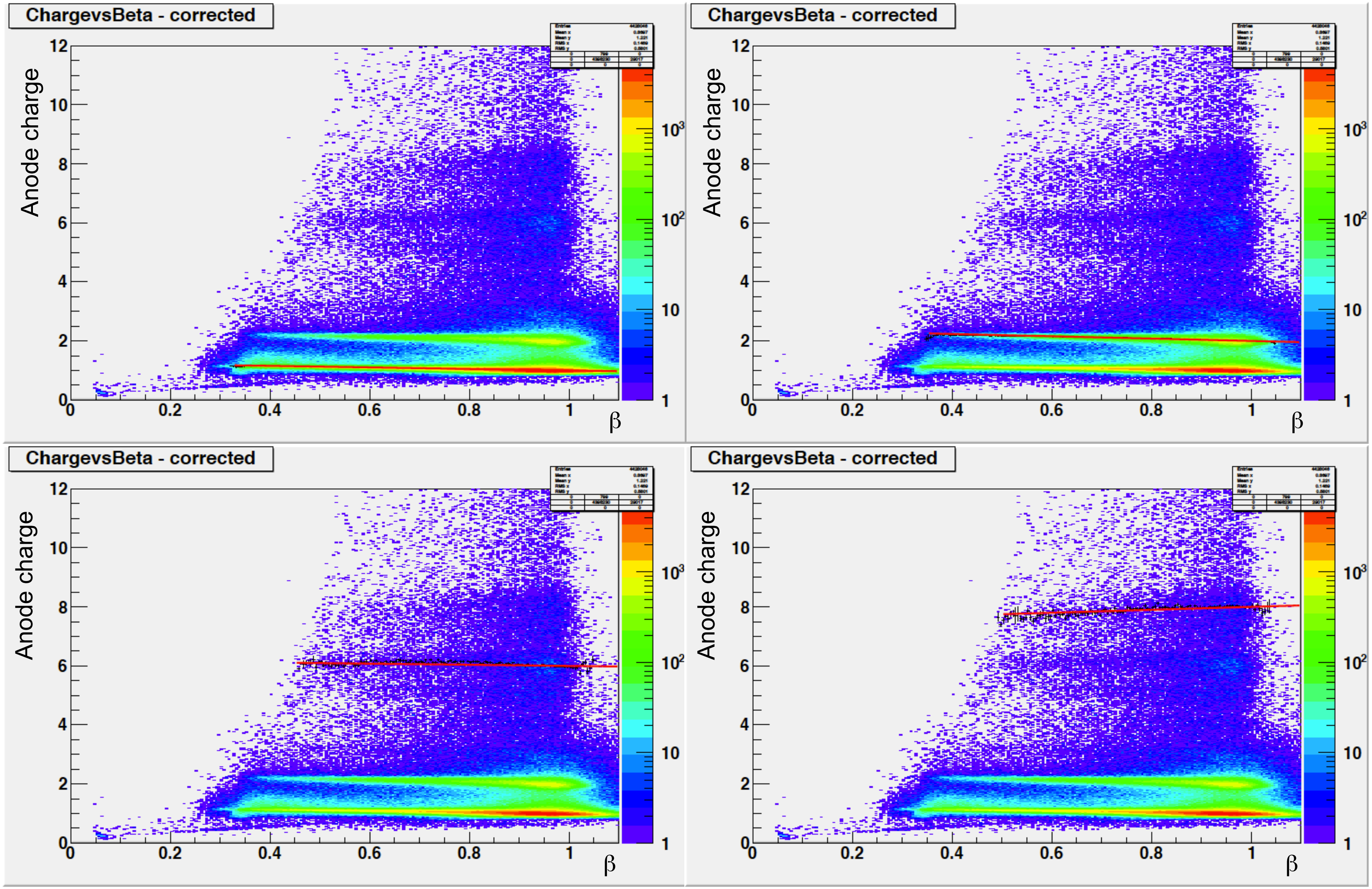
# Charge vs. beta - anode

Anode charge after correction for anode saturation and Bethe-Block (fitted for Z=1).
High charges are overcorrected at low beta.



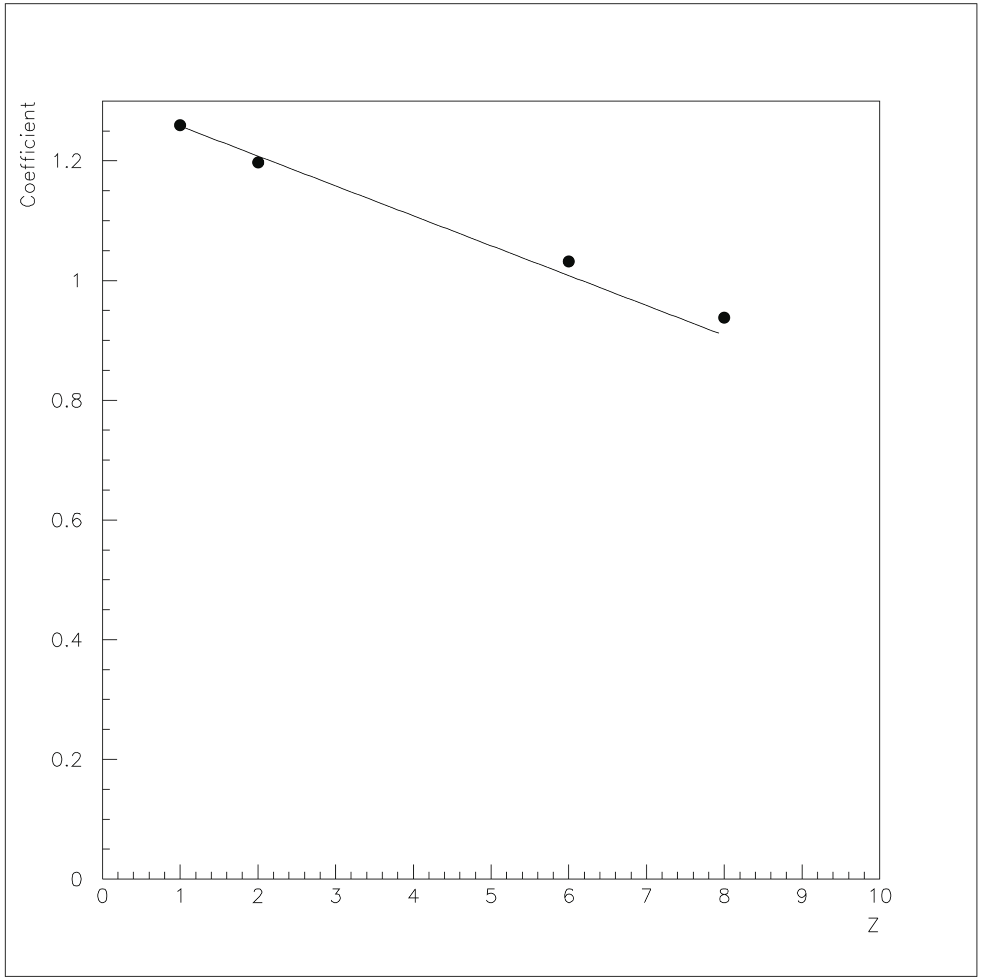
# Charge vs. beta - anode

Anode charge after correction for anode saturation and Bethe-Block (fitted for Z=1).



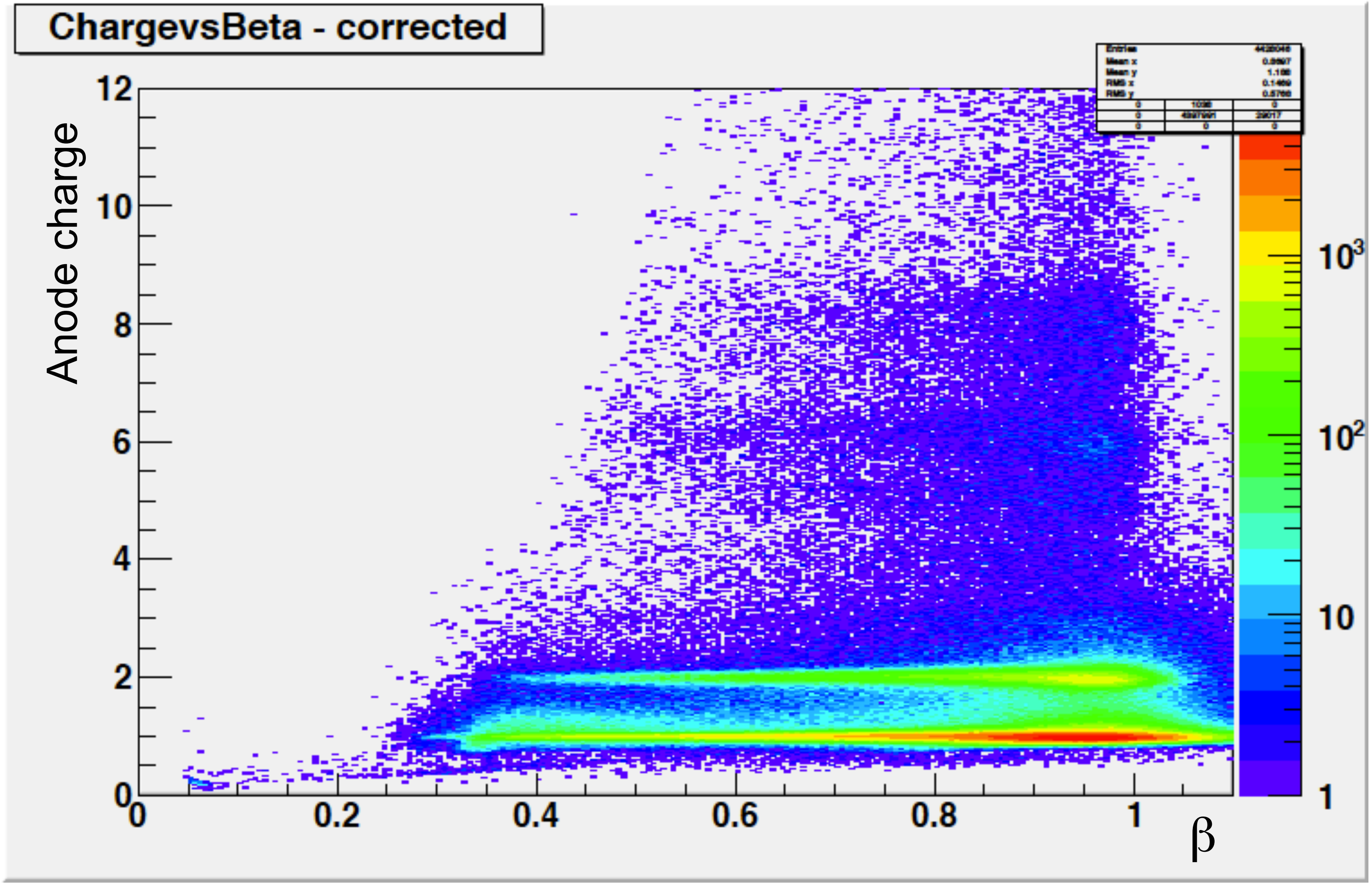
# Charge vs. beta - anode

## Linear fit coefficient vs. Anode charge

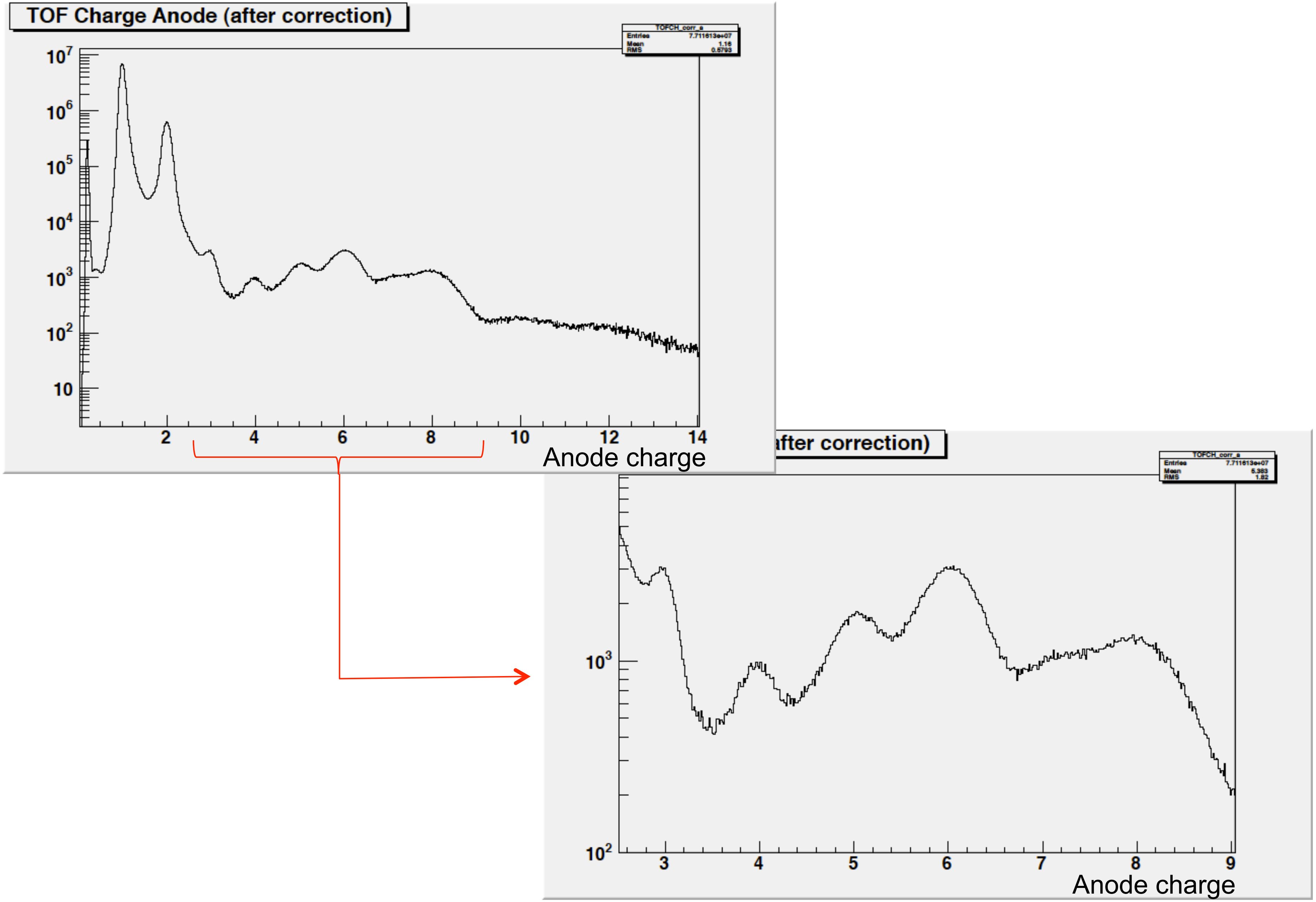


# Charge vs. beta - anode

Final plot after supplementary linear correction.

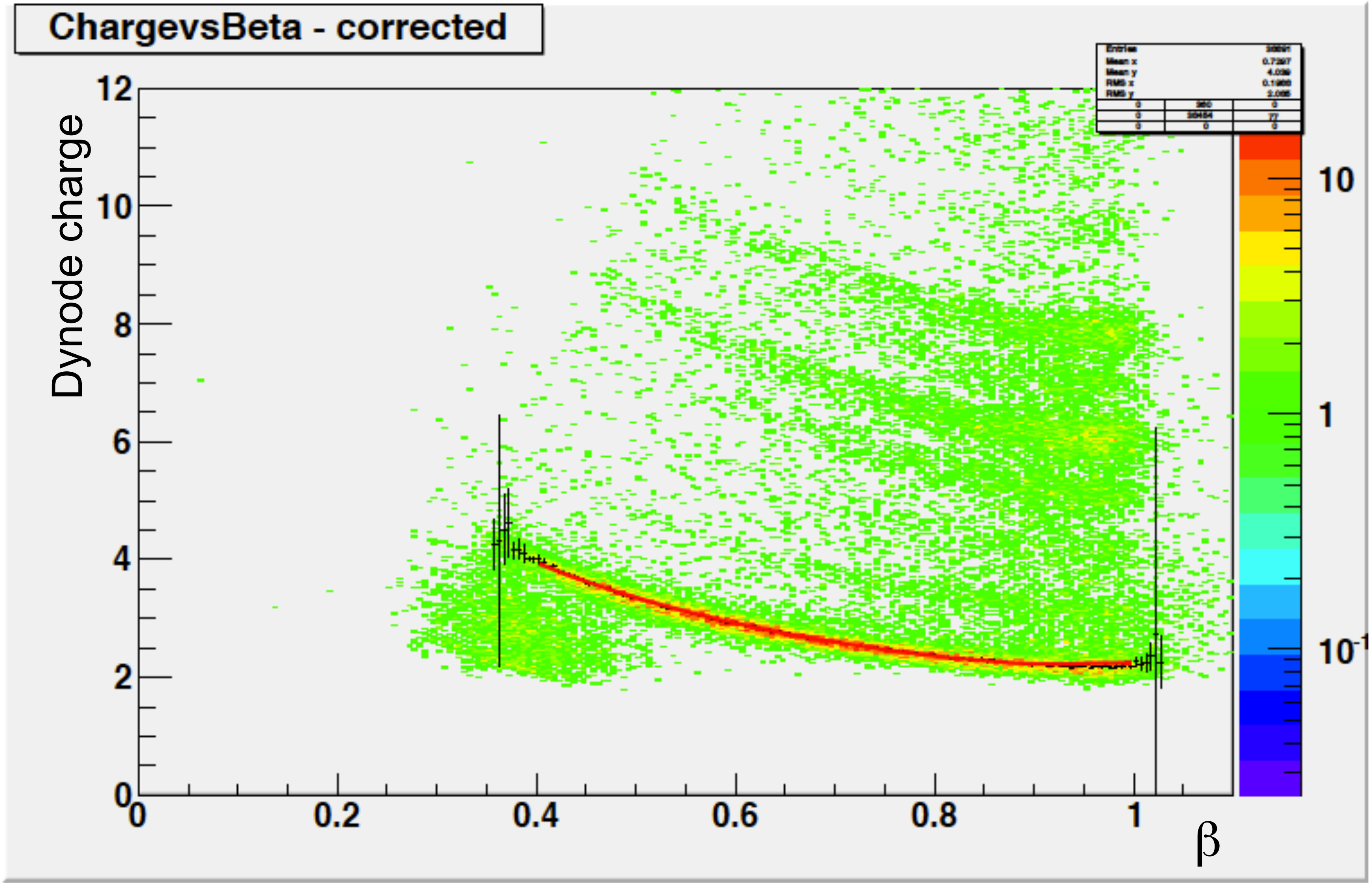


# Charge vs. beta – anode - final



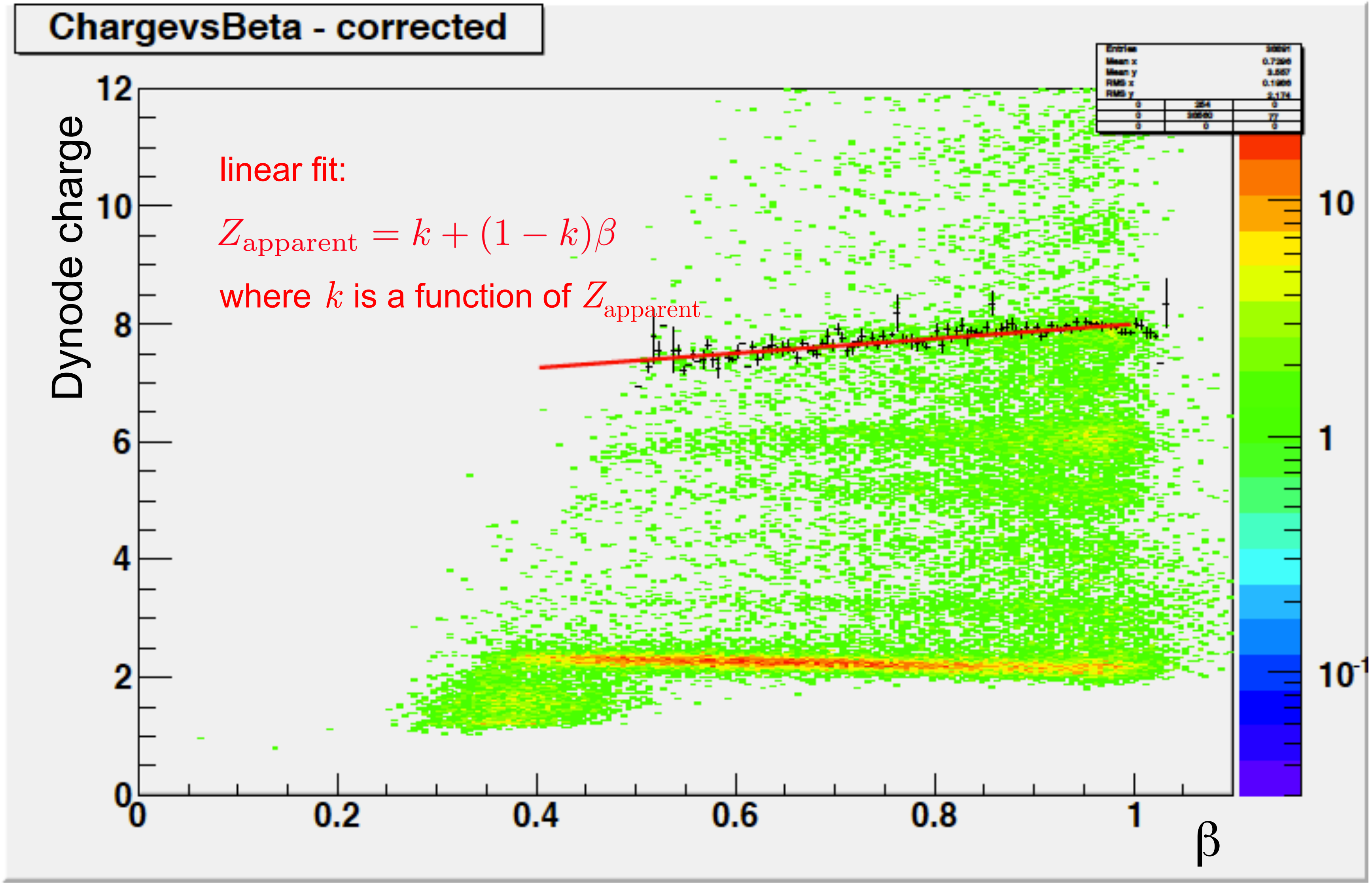
# Charge vs. beta - dynode

Dynode charge after correcting for Birks. Bethe-Block fit for Z=2.



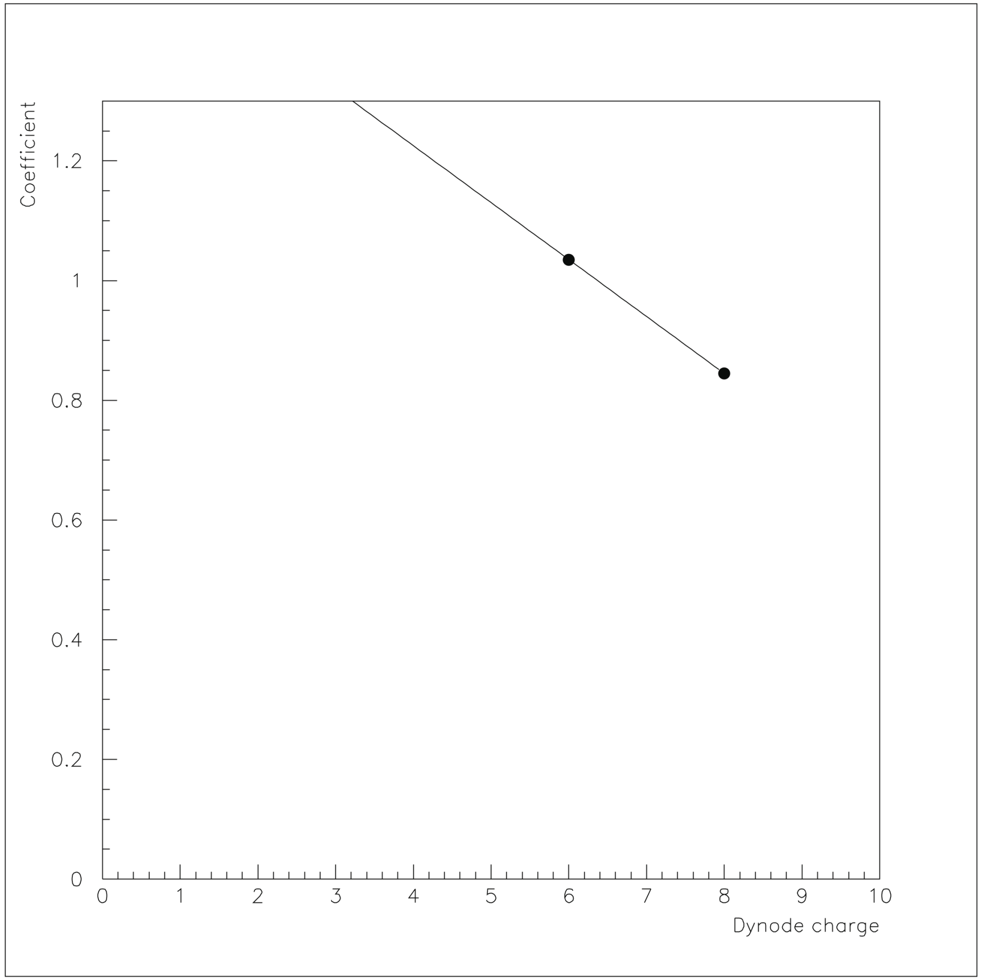
# Charge vs. beta - dynode

Dynode charge after correction for Birjks and Bethe-Block (fitted for Z=2).
High charges are overcorrected at low beta.



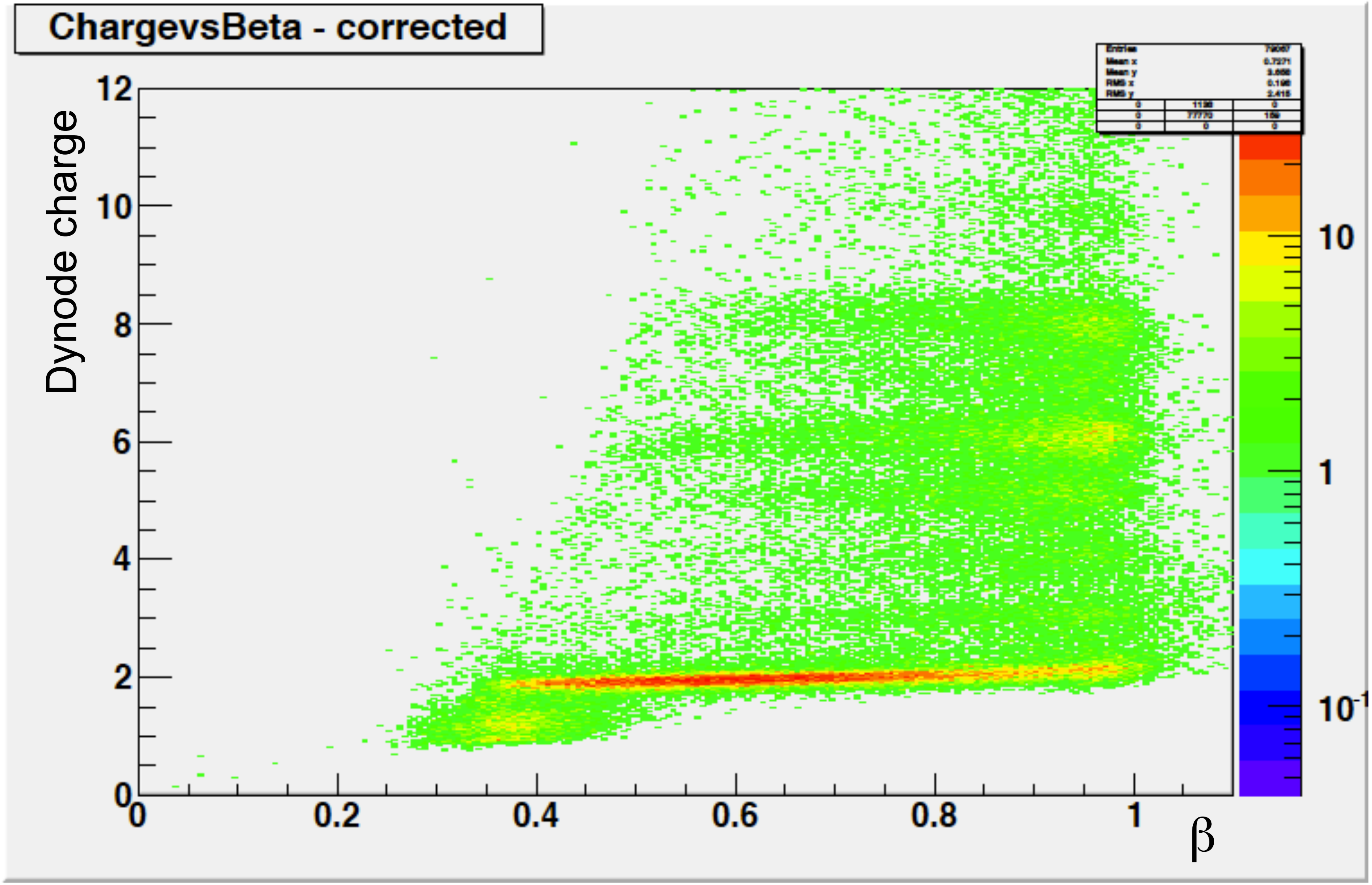
# Charge vs. beta - dynode

## Linear fit coefficient vs. Dynode charge

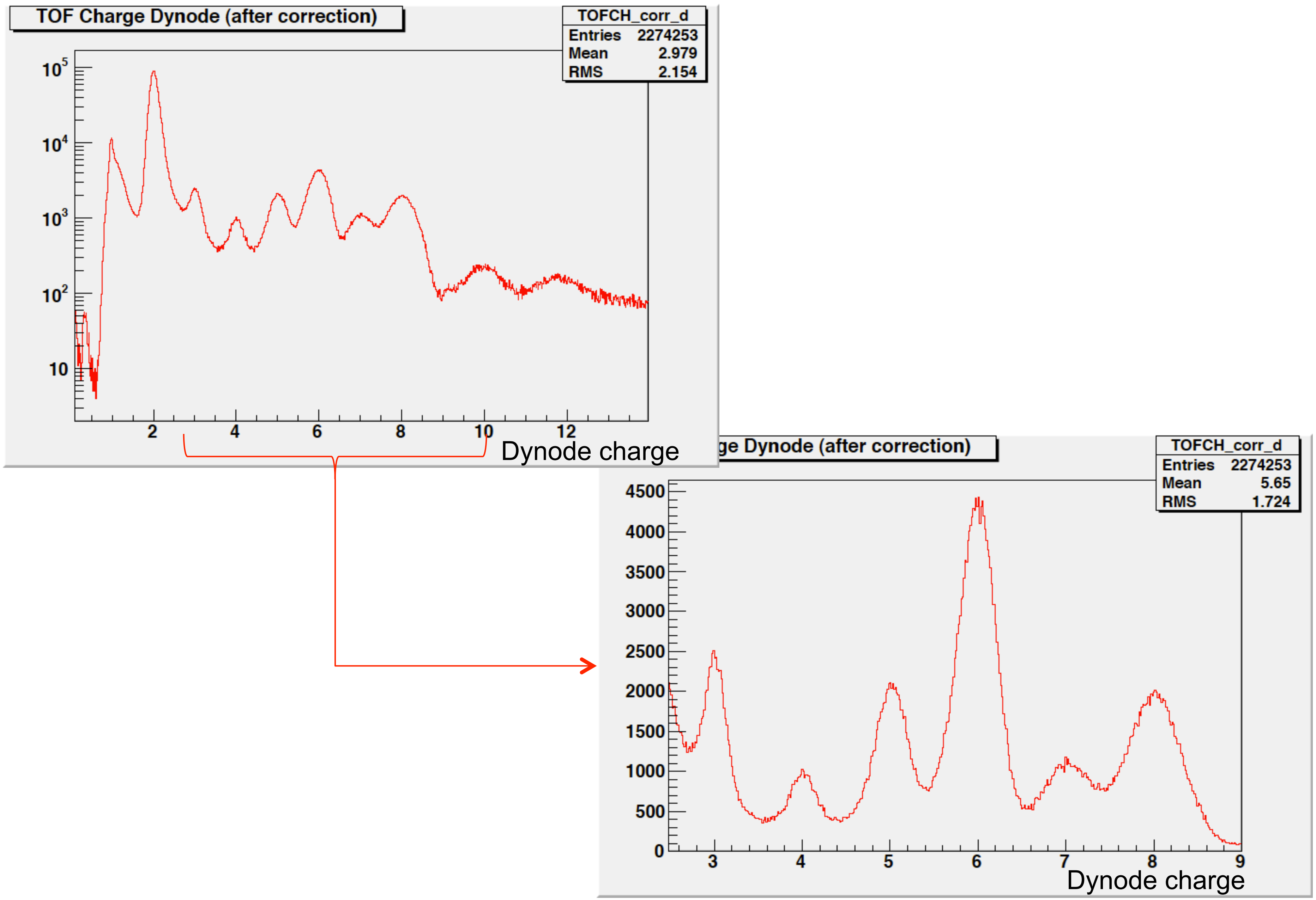


# Charge vs. beta - dynode

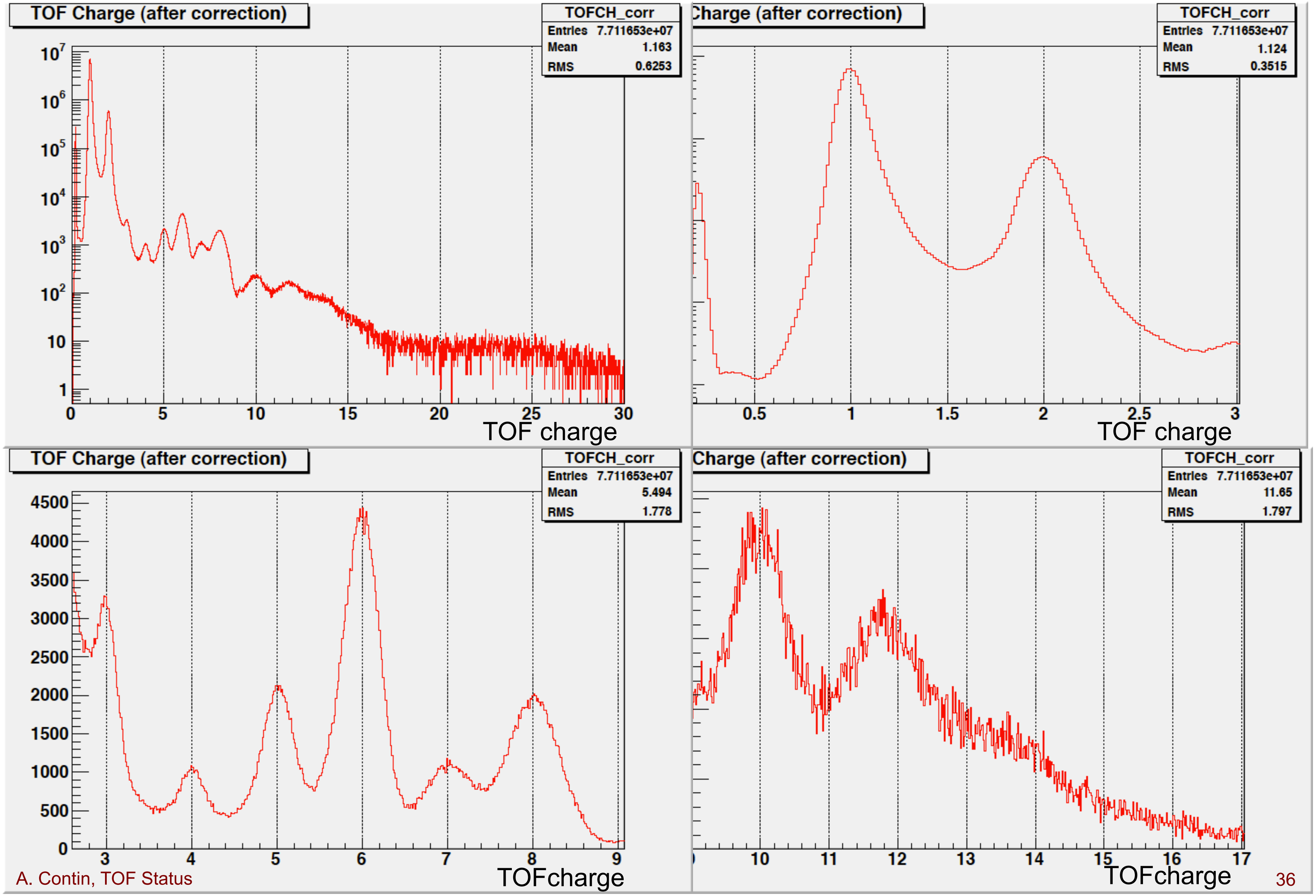
Final plot after supplementary linear correction.



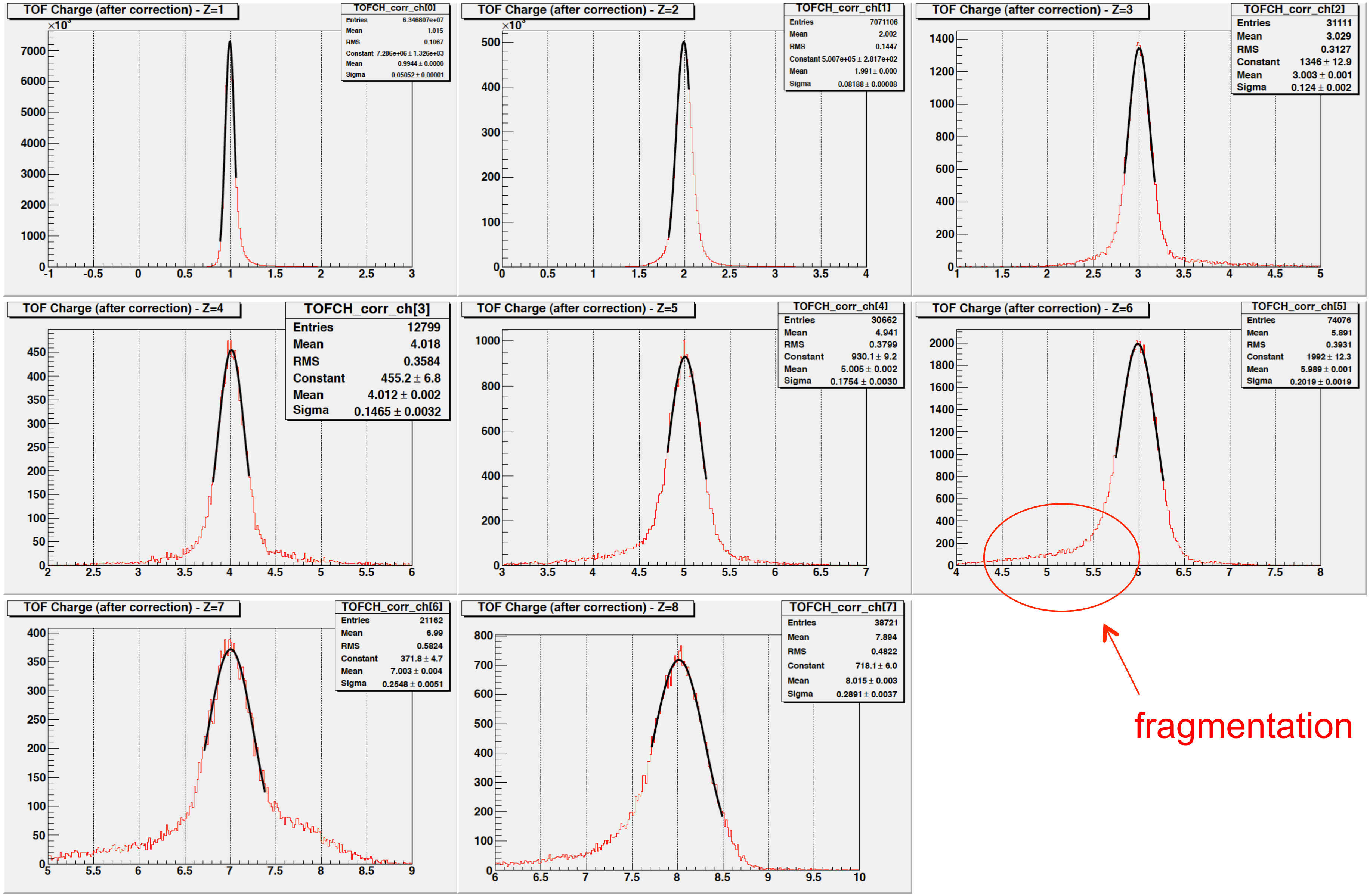
# Charge vs. beta – dynode - final



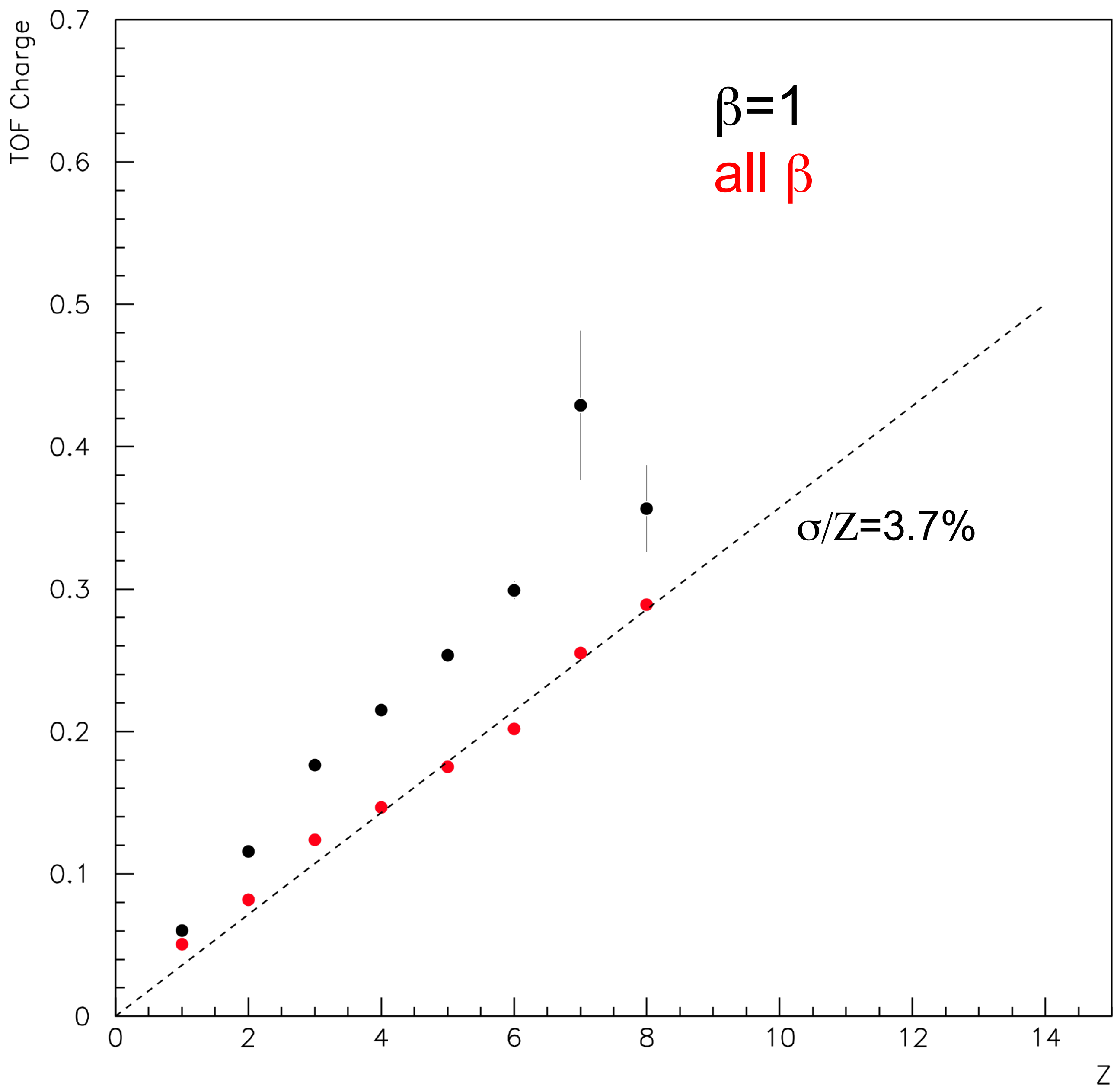
# Final TOF Charge – Dynodes, or Anodes if dynodes not all present



# TOF Charge, selecting charge with Tracker (±0.3e around peak)

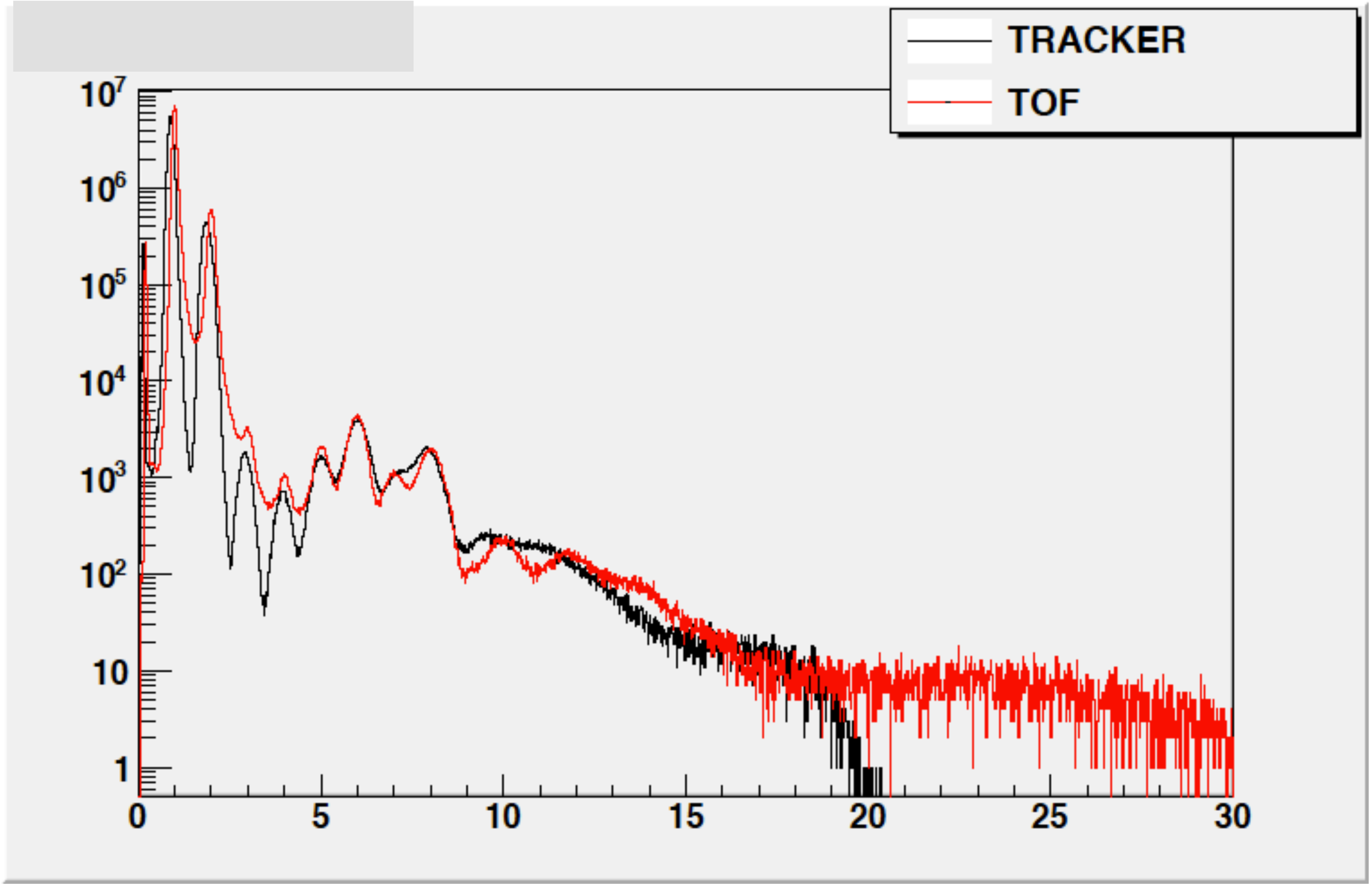


# TOF Charge resolution

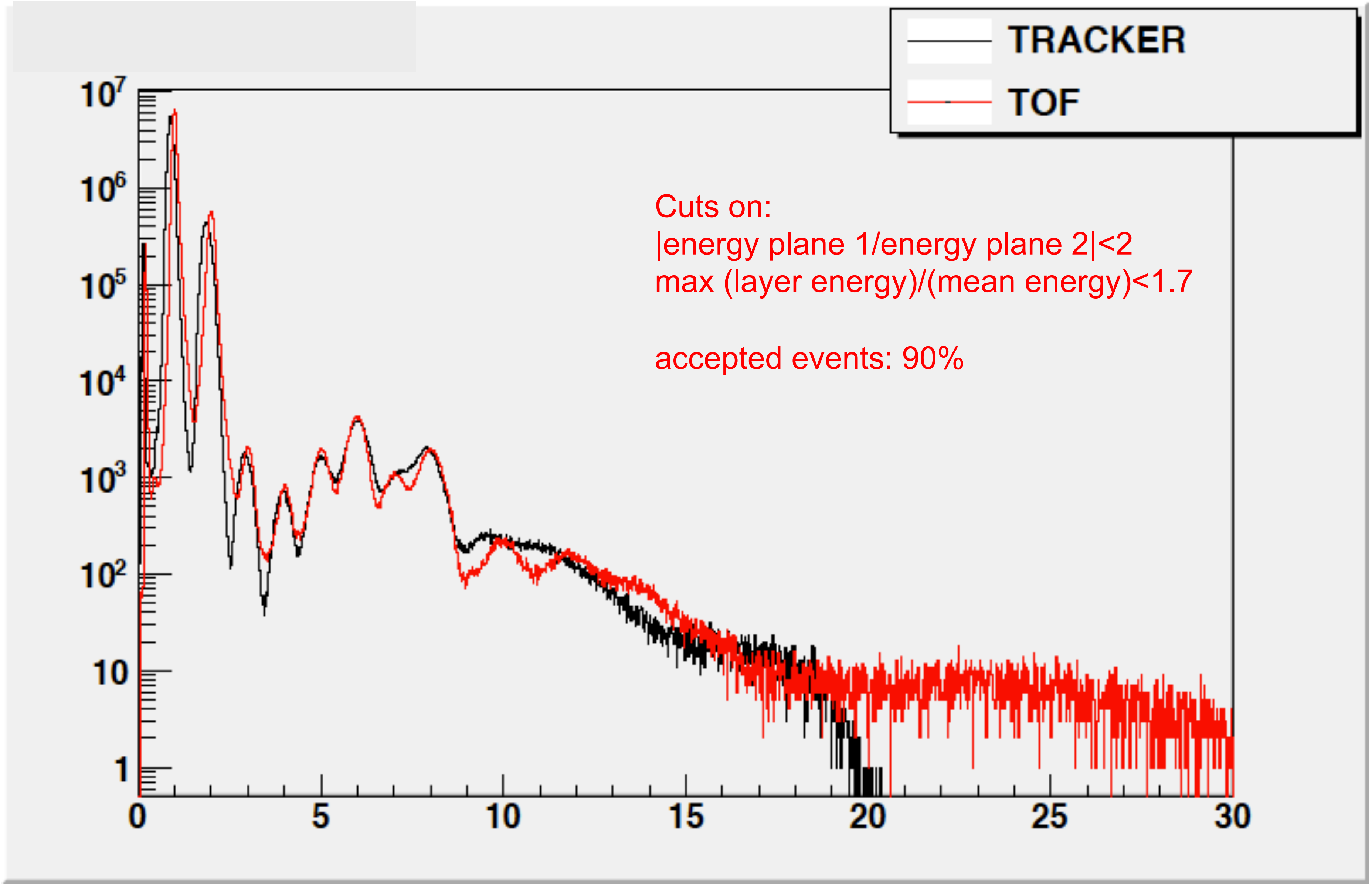



The difference is probably due to the different TRACKER charge selection

# Comparison with Tracker



# Low charge background – example of cuts



# Conclusions

TOF anodes saturates for charge Z>2, so they can be used mainly for Z=1 and Z=2.

Most of TOF dynodes give good signals for Z≥3.

The Birks' behaviour for dynodes is as expected.
The charge resolution is as expected.

To be studied:
- low charge background on higher charges (A. Contin)
- fragmentation (V. Bindi and Tracker people)
- MonteCarlo (F. Palmonari, Qi Yan)

To be done:
- PDFs (V. Bindi)

# Be/B – B538/pass2 (one week of data)