university of groningen / kvi - center for advanced radiation technology

JÜLICH FORSCHUNGSZENTRUM

Analysis Software for ADC-based Readout

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31. January 2017

Outlines

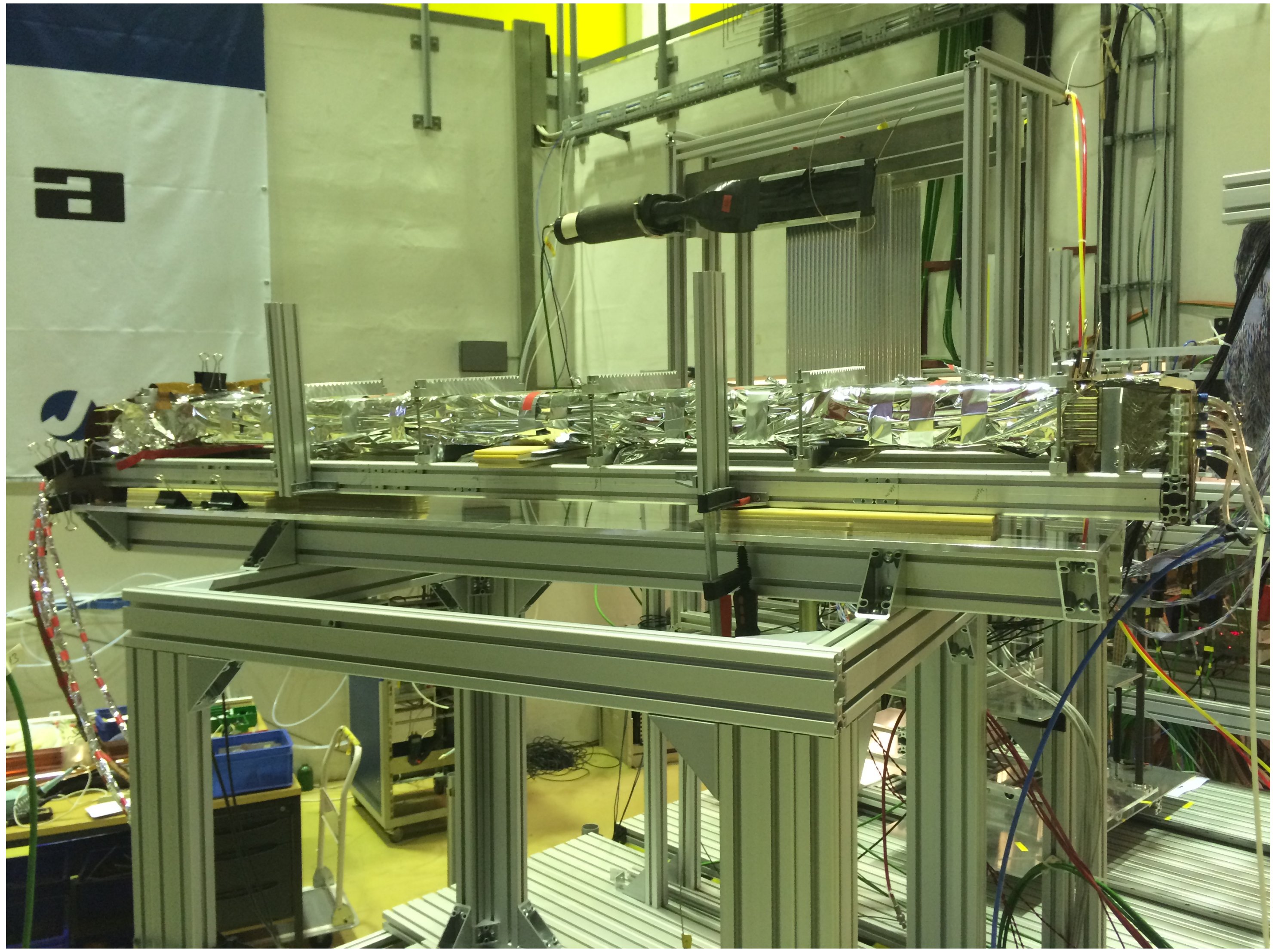
- Beam time setup April and November 2016
- Analysis method review
- Results of spatial and energy resolution
- Summary and outlook

STT beam tests in April and November 2016

- In April 2016, for the first time in COSY-TOF area , almost 10 days beam with time 3 prototype detectors

1. STT with flash ADC read out
2. STT with ASIC read out
3. Forward tracker with ASIC readout

- April 2016: Proton beam with 4 different momenta (0.55 GeV/c, 0.75 GeV/c, 1.00 GeV/c and 2.95 GeV/c)
- November 2016: Deuteron beam with 3 different momenta (0.6GeV/c, 0.75 GeV/c and 1.5GeV/c)
- Different high voltages (1750V, 1800V & 1850V)



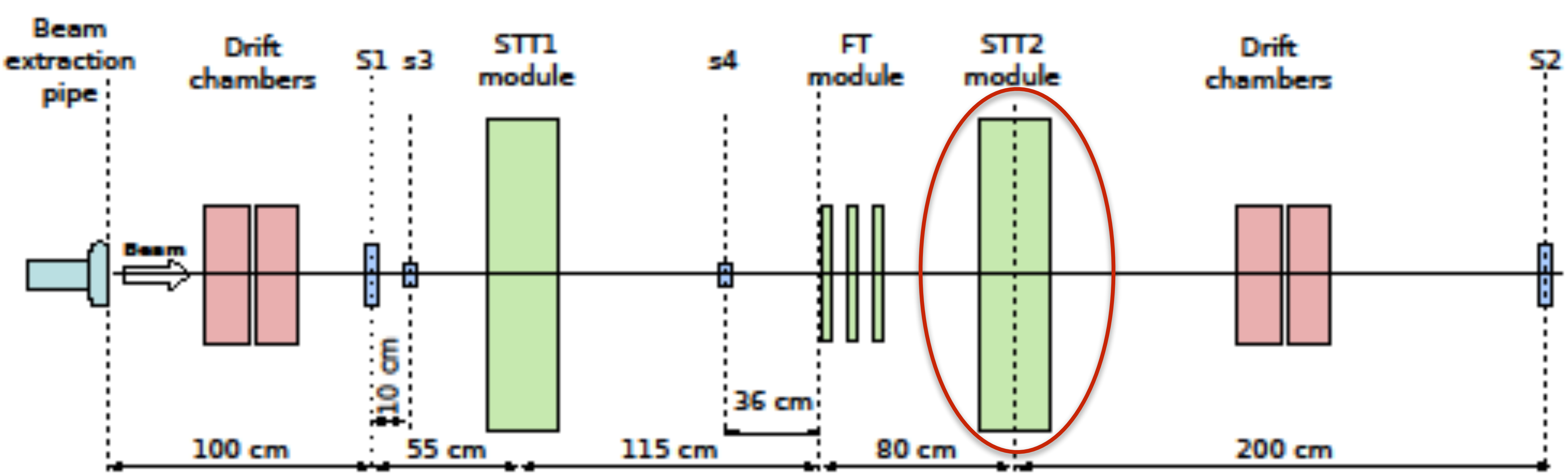


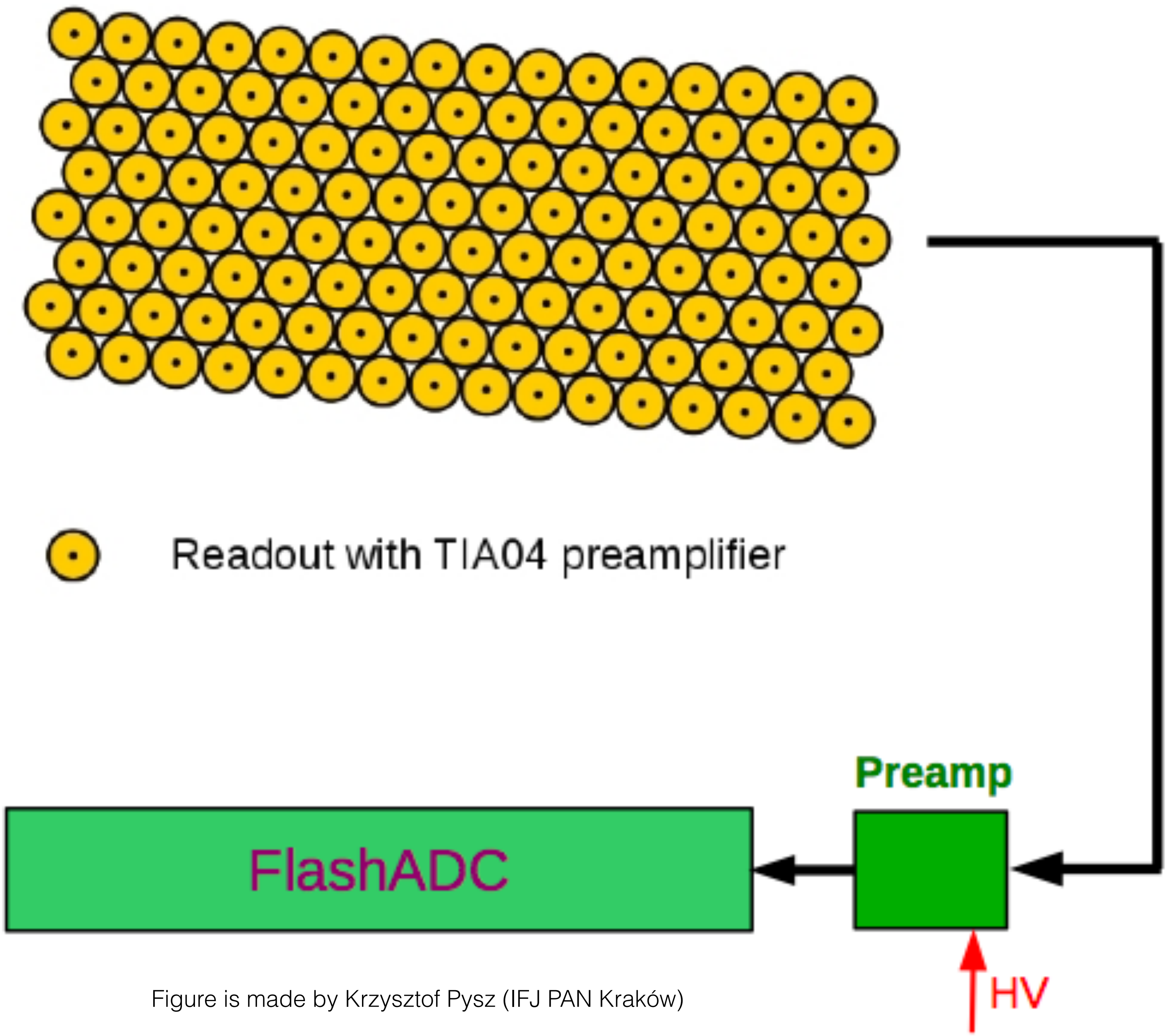
Figure is made by Pawel Strzempek (JU Krakow)

Beam time setup April 2016

Proton beam

0.55 GeV/c
0.75 GeV/c
1.00 GeV/c
2.95 GeV/c

Various beam intensities



12 m
coax
Cable
Signal/HV

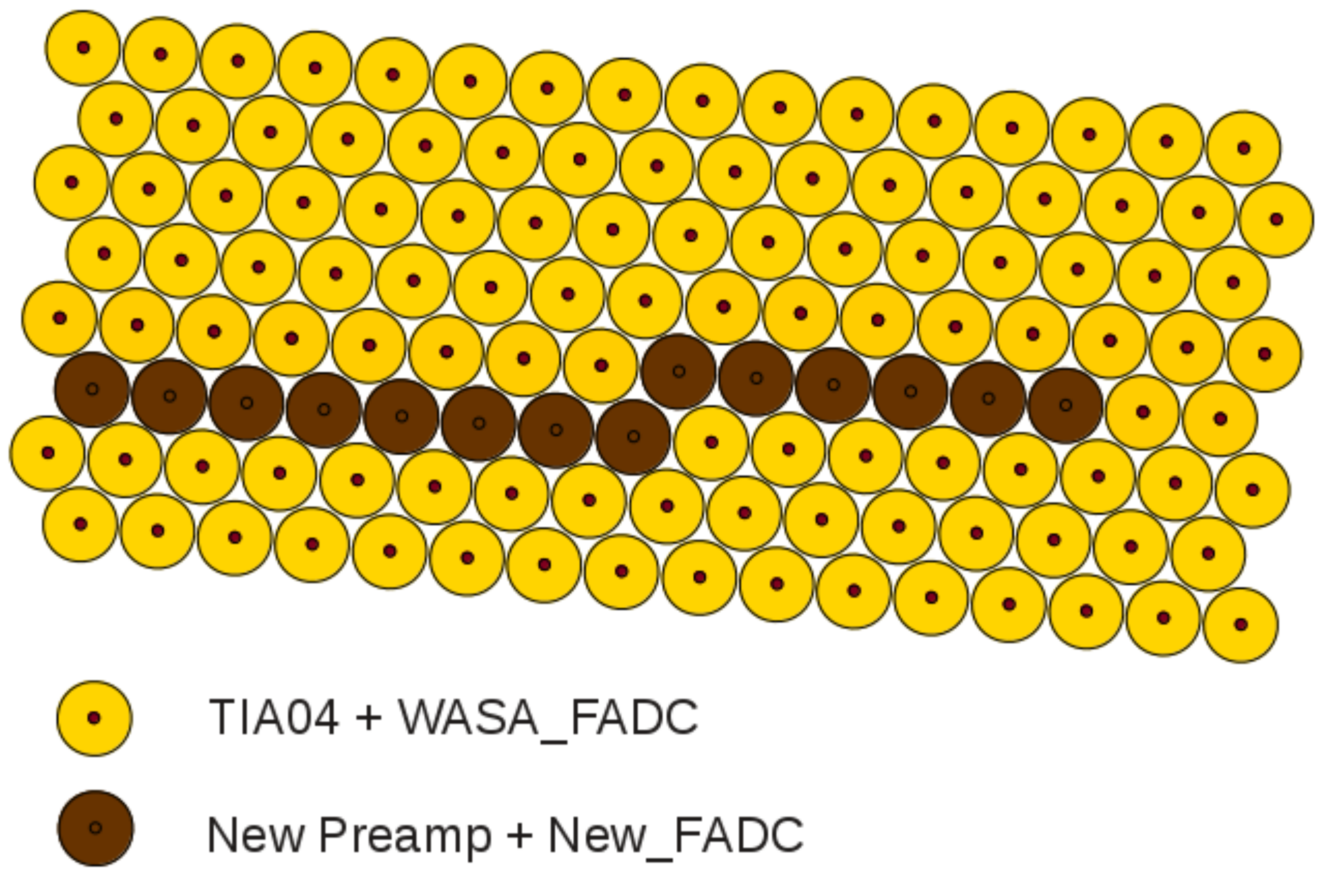
MK7501

75 Ω

Figure is made by Krzysztof Pysz (IFJ PAN Kraków)

Beam time setup November 2016

Deuteron beam



0.6GeV/c
0.75 GeV/c
1.5 GeV/c

First beam time with the new f-ADC with on board integrated preamplifier (14ch)

Various beam intensities

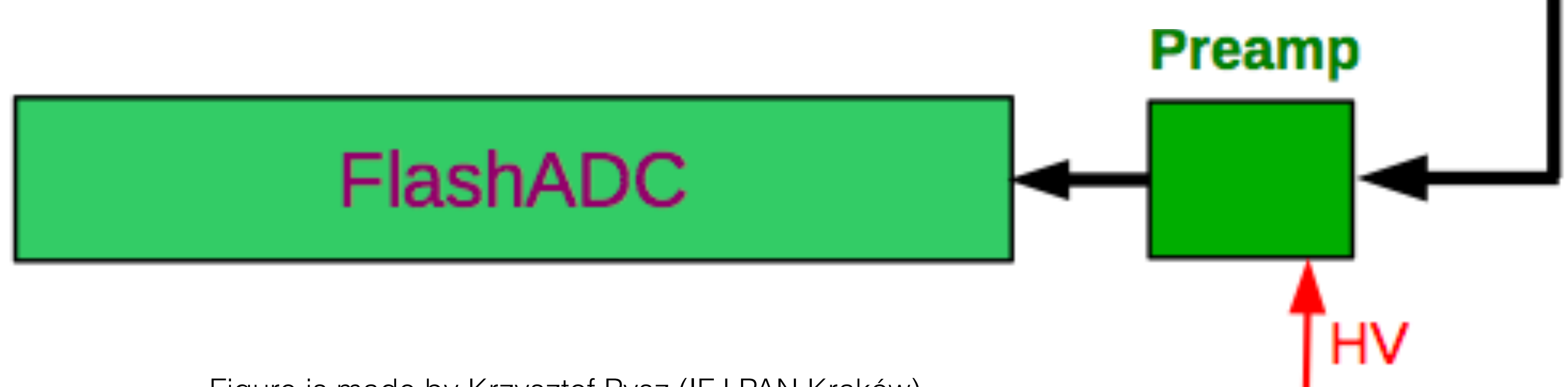


Figure is made by Krzysztof Pysz (IFJ PAN Kraków)

Analysis Method

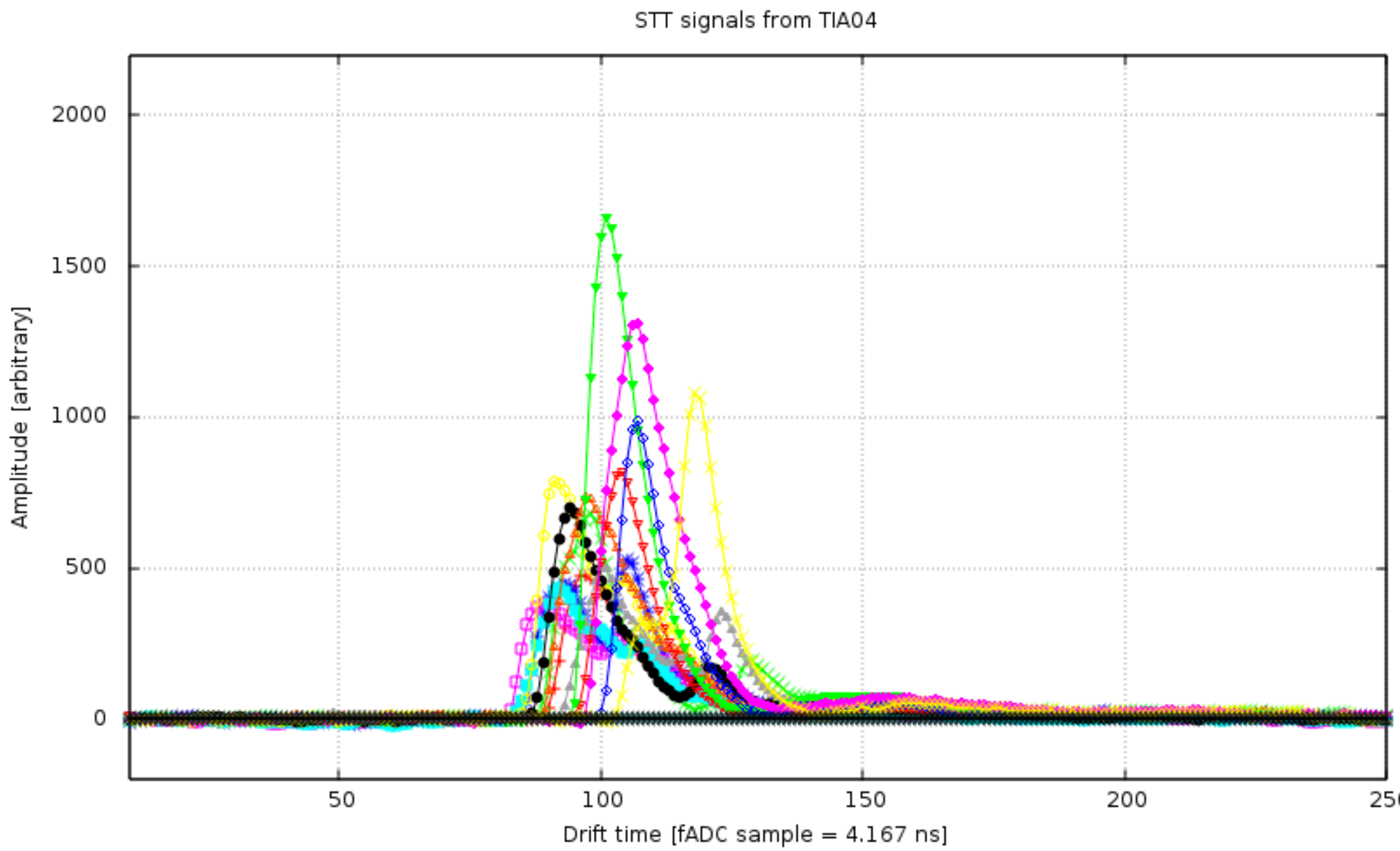
1.Signal Shape Analysis

2.Tracking

3.Energy loss measurement

Pulse shape analysis

- Time estimation
- Energy loss estimation



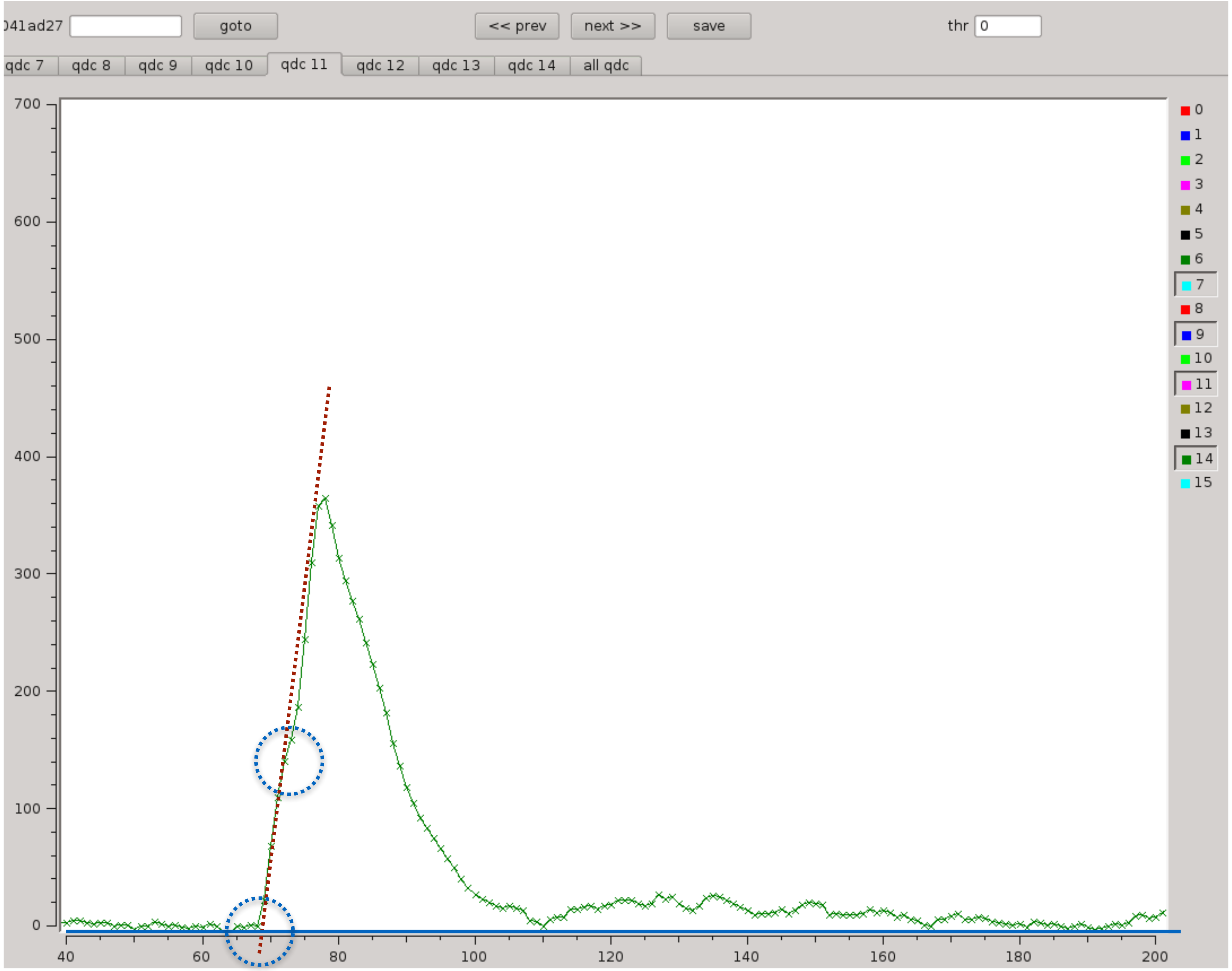
Signal sampled with 240 MHz flash-ADC

Time estimation

Checking the decrease on the leading edge

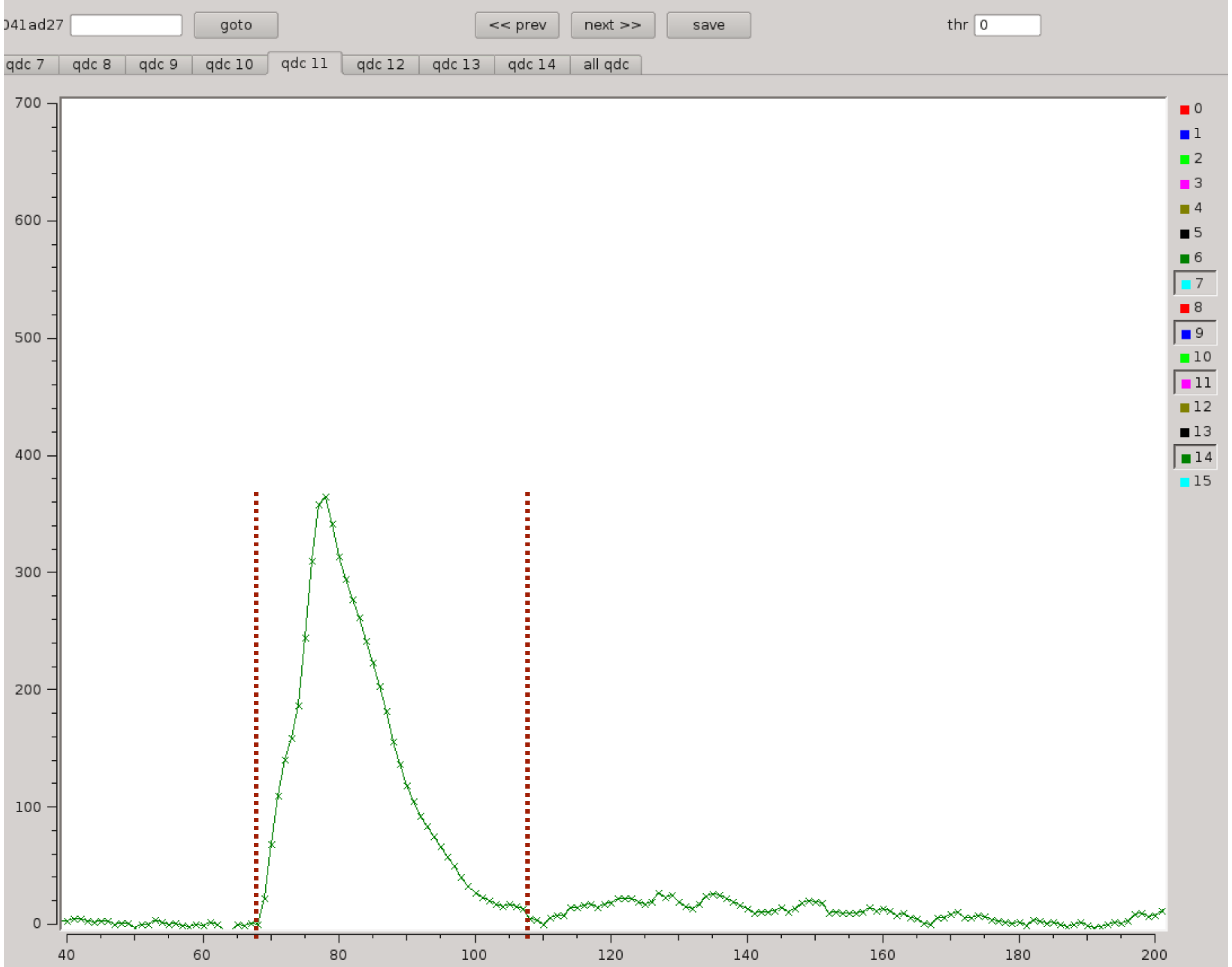
↓

Zero crossing time calculated for highest steepness of leading edge



Energy estimation

Integration over 40 samples from the onset of the signal



Analysis Method

1. Tracking

- Drift time spectra
- Calculation of radius-drift time (calibration curve)
- Track reconstruction
- Calculation of the path length

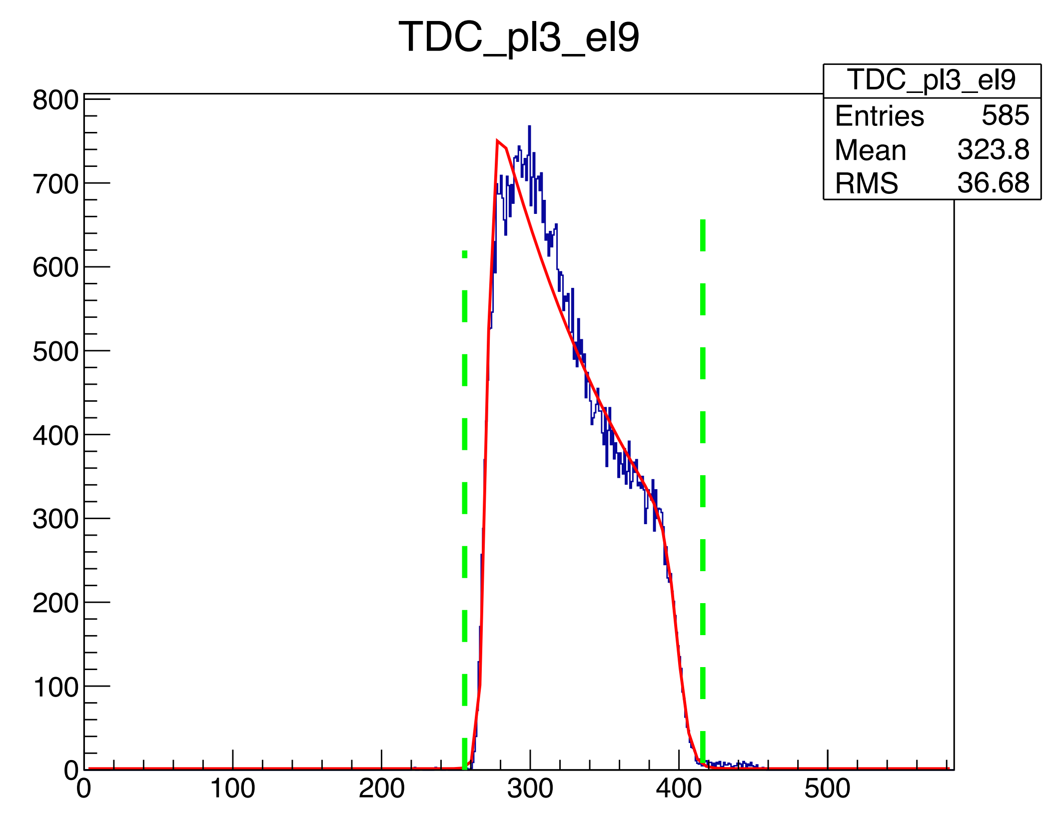
Analysis Method

Calibration

- For each tube the parameters of the drift time distribution are derived from the fit performed with the following empirical function:

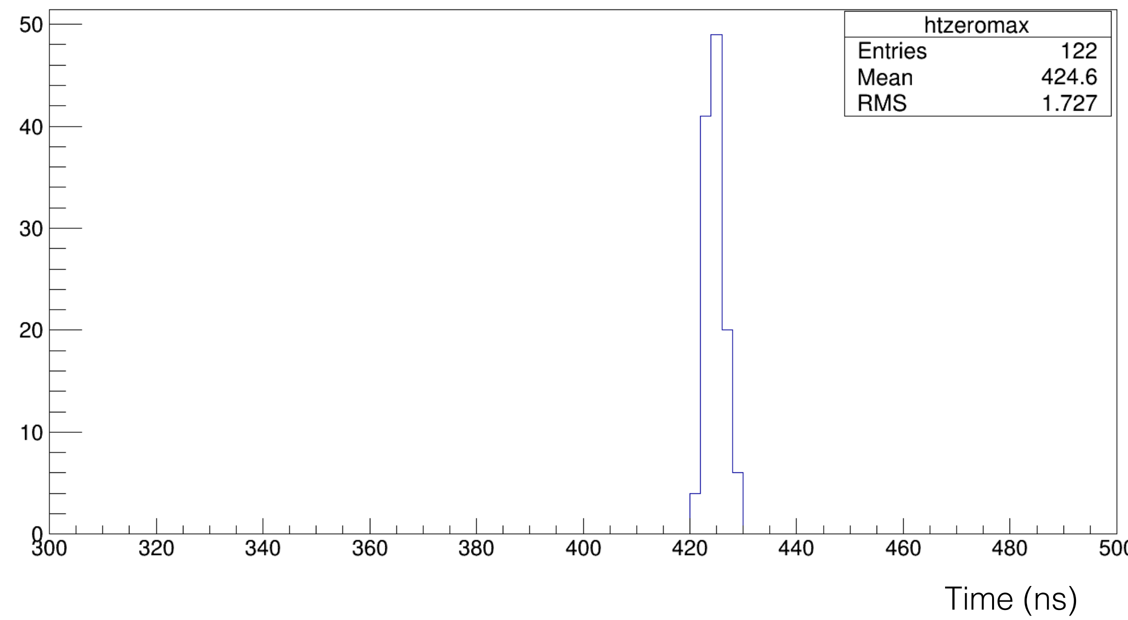
$$\frac{\mathrm{d}n}{\mathrm{d}t} = P_1 + \frac{P_2\,[1 + P_3 \exp((P_5 - t)/P_4)]}{[1 + \exp((P_5 - t)/P_7)]\,[1 + \exp((t - P_6)/P_8)]}$$

- The minimum and maximum drift times, t_0 and t_{max} , corresponds to a track traversing the tube close to the wire and to the cathode wall.
- The value of t_0 , depends on delays of signal cables and front-end electronics, and HV setting.
- $\Delta t = t_{max} - t_0$ depends only on the drift properties of the tubes.

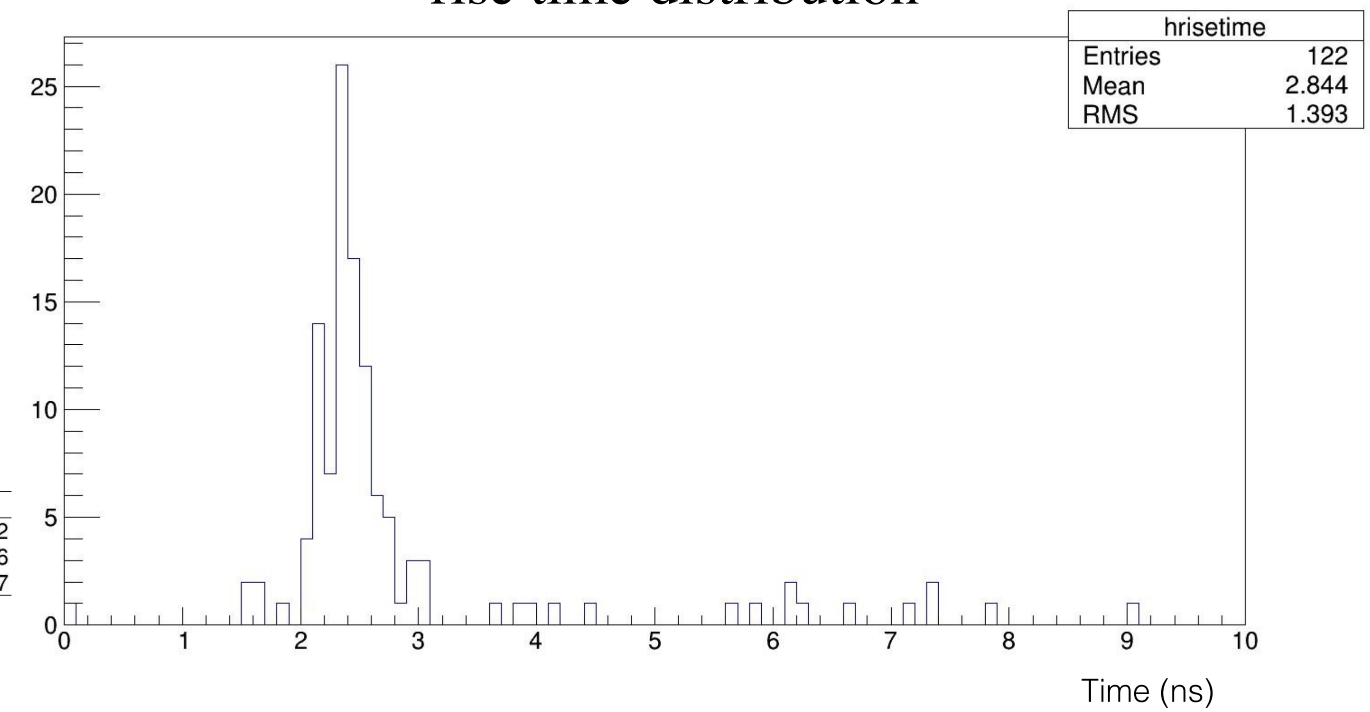


Fitted time spectrum of an illuminated tube

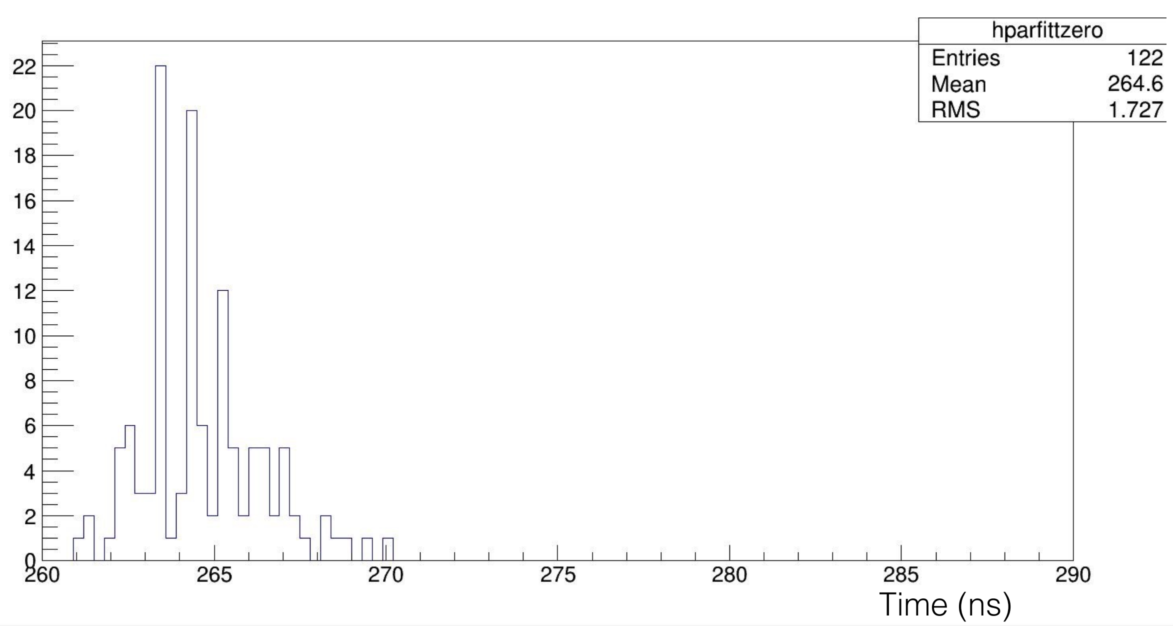
t_{max} distribution



rise time distribution



t0 distribution



Analysis Method

The primary information from the tubes:

Analysis Method

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The drift time distribution of the arriving signals, the number of tracks traversing the tubes within a time interval:

$$\frac{\mathrm{d}n}{\mathrm{d}r} = \frac{N_{\mathrm{tot}}}{R_{\mathrm{tube}}}$$

$$\frac{\mathrm{d}n}{\mathrm{d}t} = \frac{\mathrm{d}n}{\mathrm{d}r}\frac{\mathrm{d}r}{\mathrm{d}t} = \frac{N_{\mathrm{tot}}}{R_{\mathrm{tube}}}\frac{\mathrm{d}r}{\mathrm{d}t}.$$

$$r(t) = \frac{R_{\mathrm{tube}}}{N_{\mathrm{tot}}}\int_0^t \frac{\mathrm{d}n}{\mathrm{d}t'}\mathrm{d}t'.$$

n is the number of tracks and r is the wire distance.

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n is the number of tracks and r is the wire distance.

$$r(t_i) = \frac{\sum_{i=1}^{i_t} N_i}{N_{tot}} \cdot (R_{tube} - R_{wire}) + R_{wire}.$$

$$r(t) = p_0 + p_1 t + p_2(2t^2 - 1) + p_3(4t^3 - 3t) + p_4(8t^4 - 8t^2 + 1) + p_5(16t^5 - 20t^3 + 5t)$$

Analysis Method

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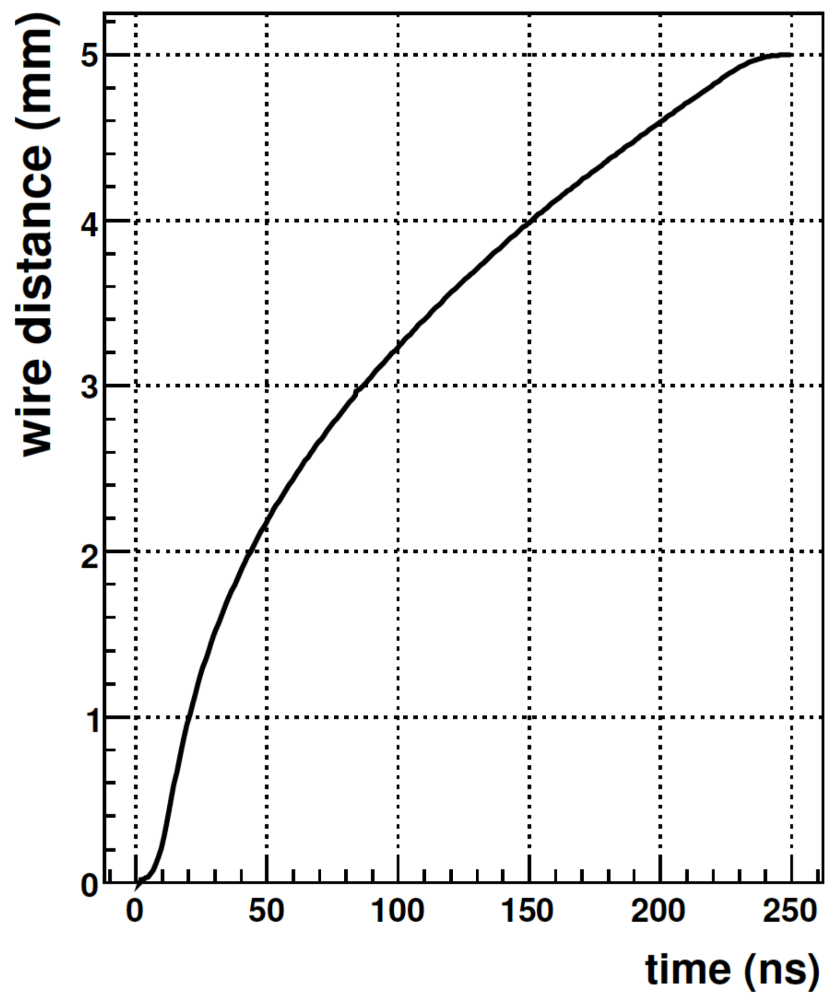

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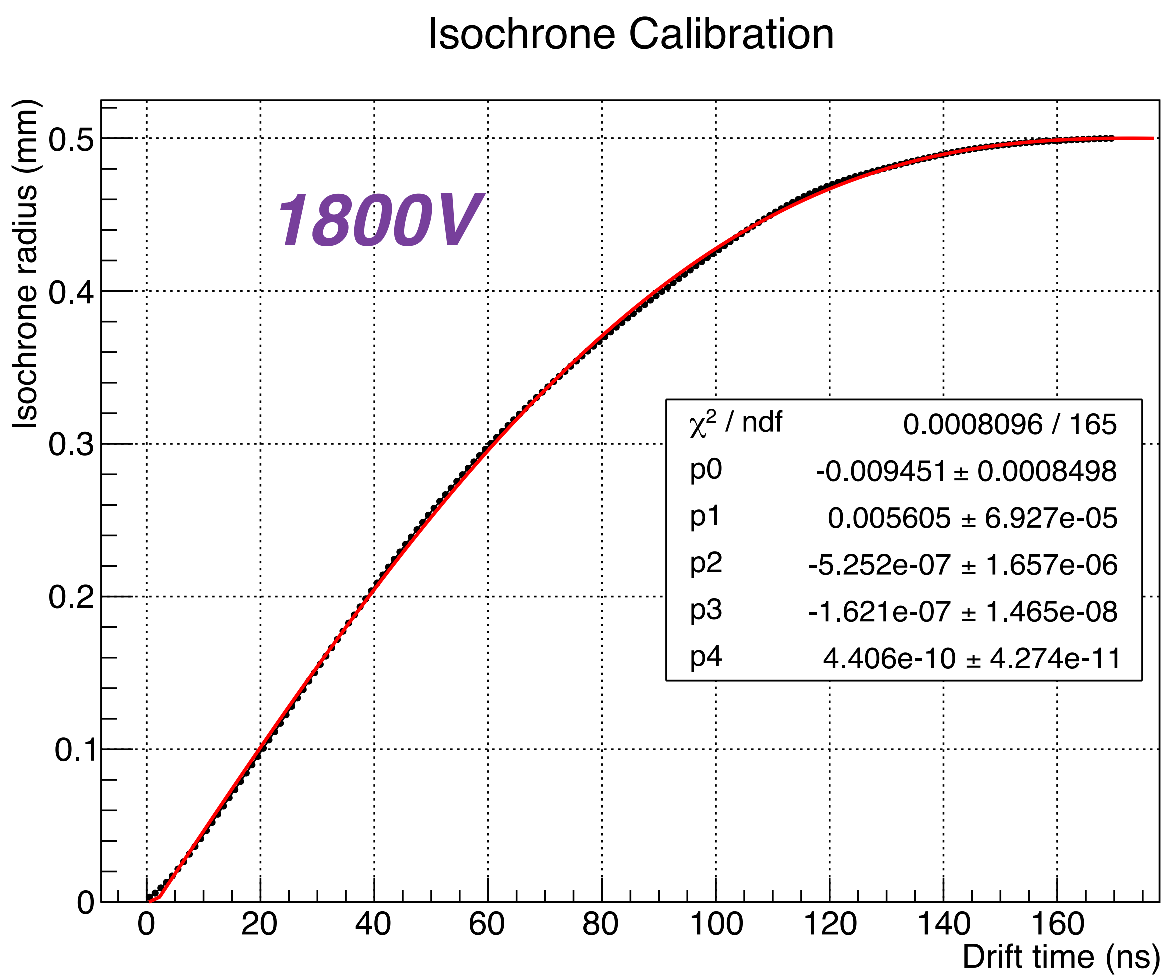
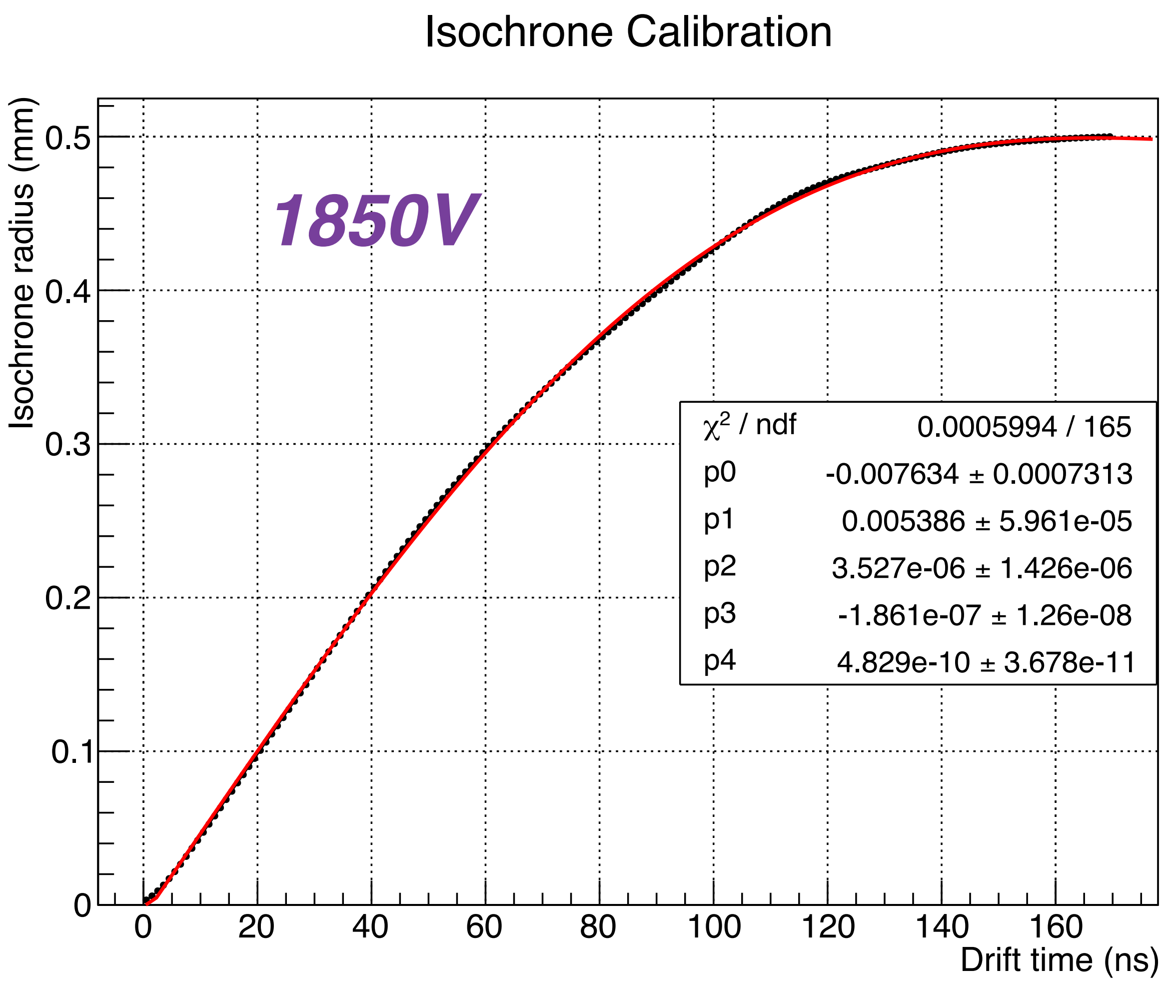
Data from April 2016, Isochrone calibration

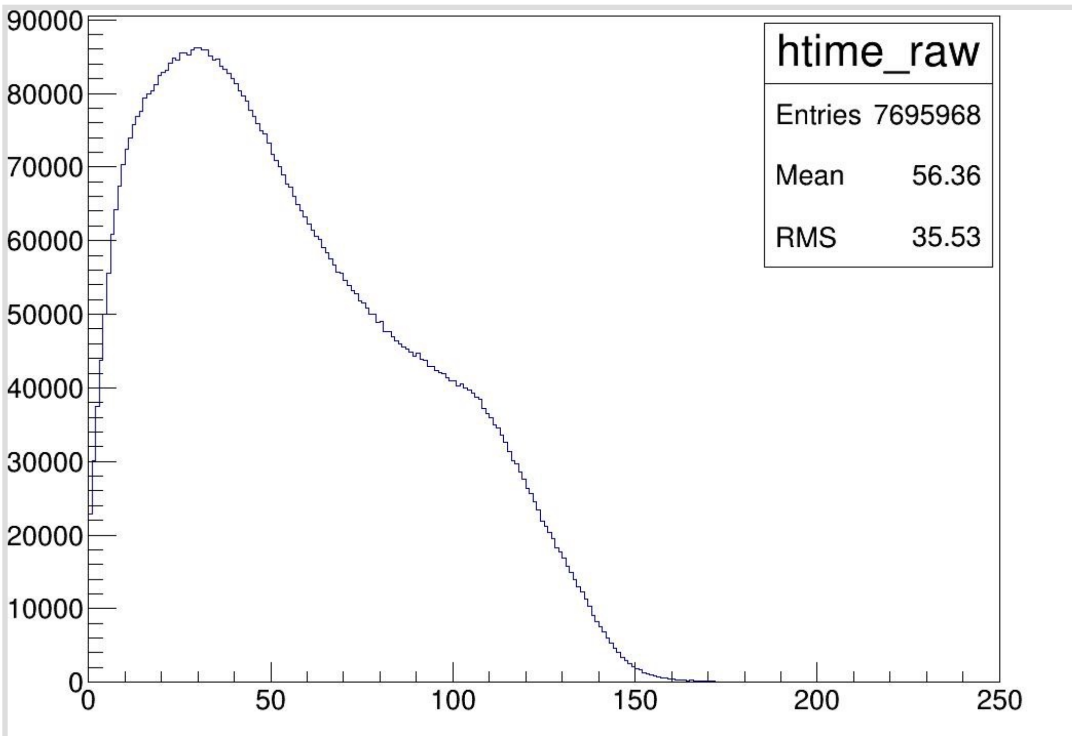
- Clean beam condition, data taken for different intensities
- Equal samples of data collected at different momenta
- Obtained calibration curve used for the analysis of data





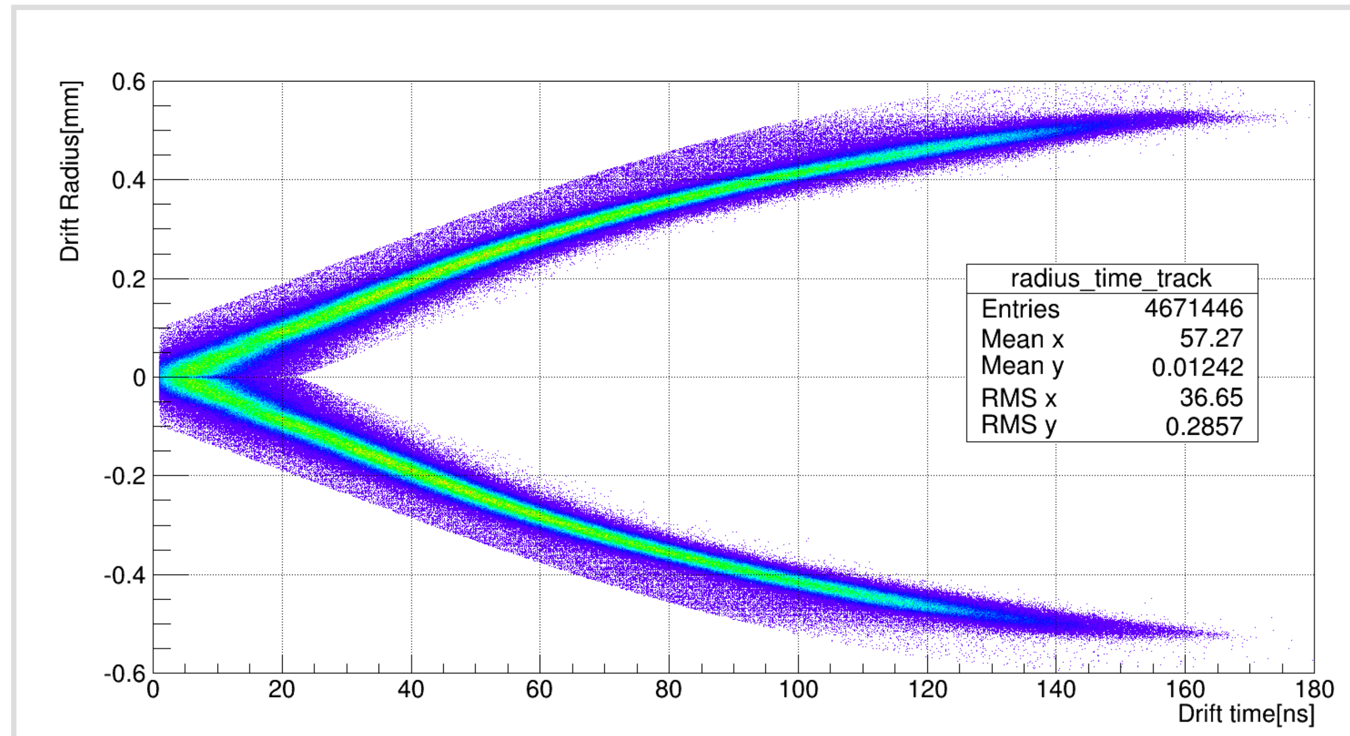
Mitglied der Helmholtz-Gemeinschaft

Drift Time



Drift time (ns)

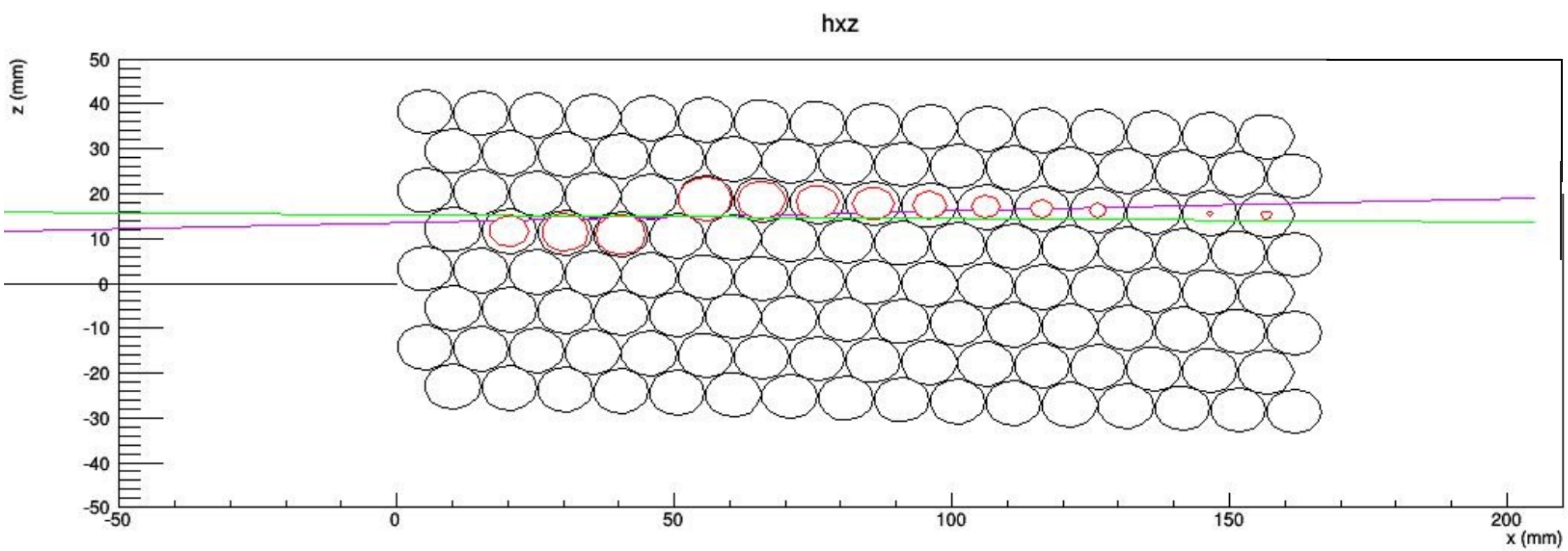
Drift Time - Drift Radius



Track reconstruction

- Pre-fit
- Fit by using Minuit minimization

The observables measured by the straw tubes are not the (x; y) coordinates of the particle hits, but the (x; y) coordinates of the firing wires and the drift times.

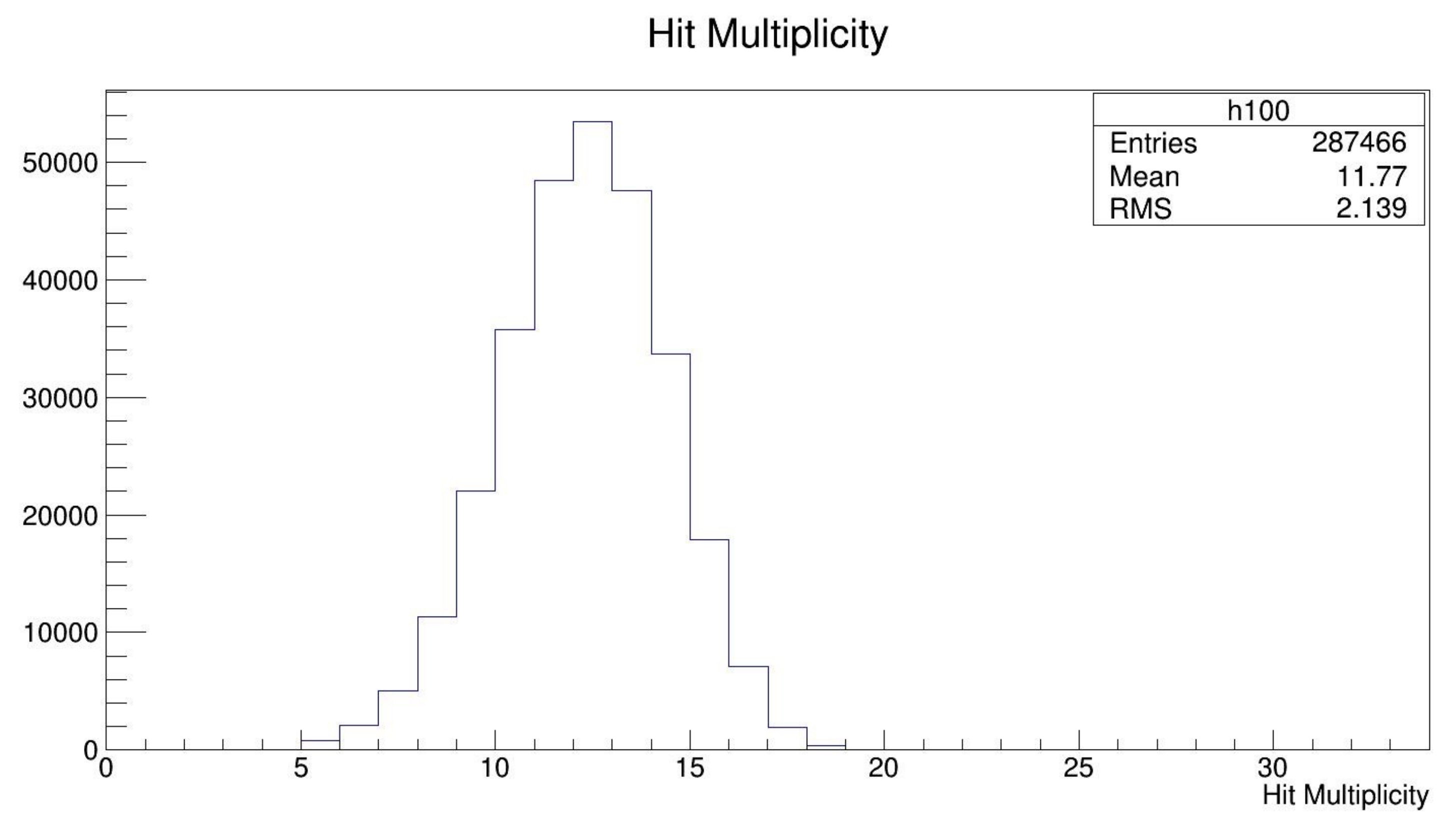


Cuts applied (Filtering)

- Cut on the minimum number of hit

- After Prefit:

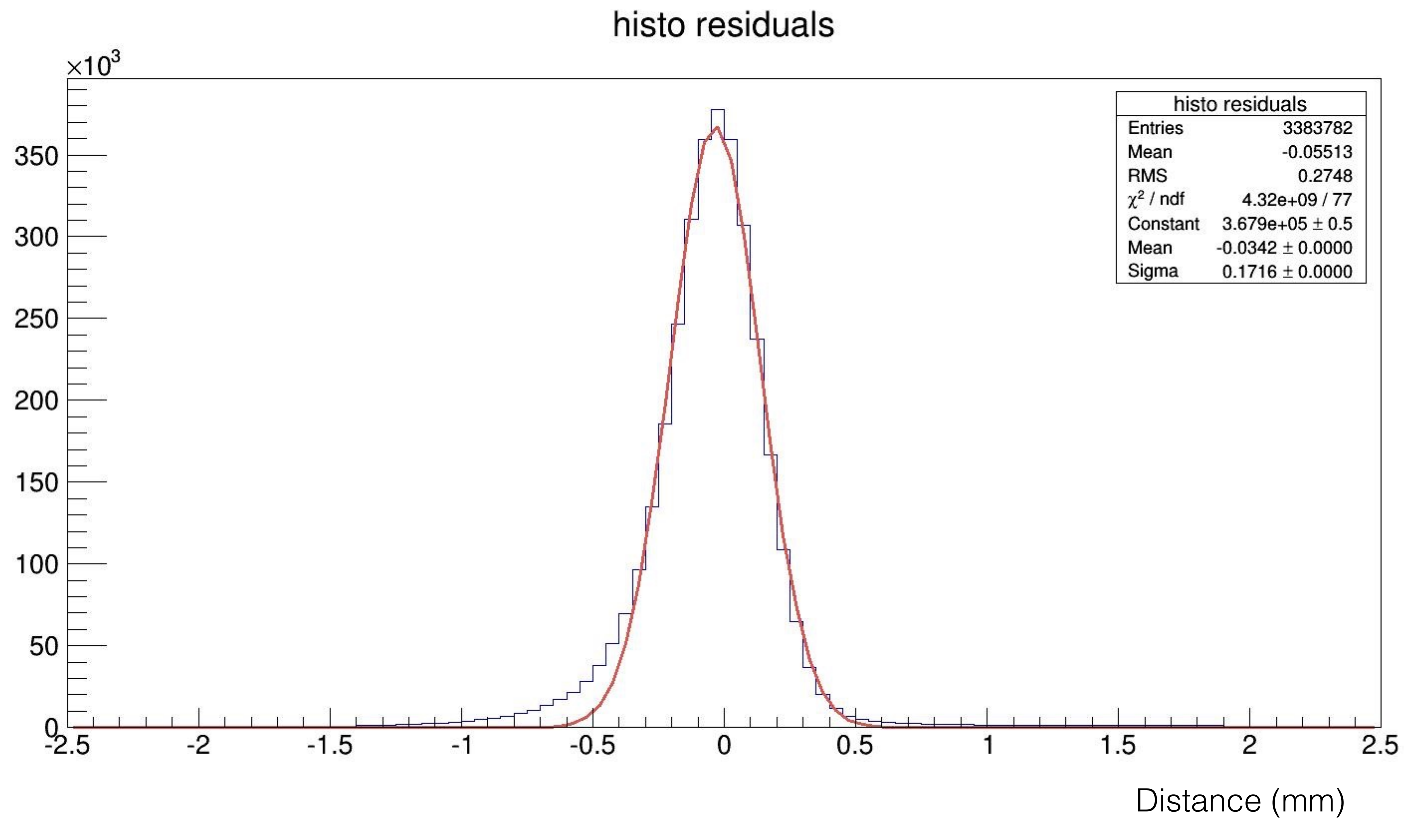
First cut is applied to check the quality of the events:
If the distances of each hit to the Prefit line is larger than 0.9 cm then the event is identified as noisy and is rejected and the profit is repeated for N-1 hit. (it's a very loos cut about 40 times of the mean distance)



- For each hit the residuals are calculated.and if the Δr_i is larger than 0.2 cm (~ 10 times the $\boldsymbol{\sigma}$ of the mean residual distribution) the hit is rejected and the prefit is repeated without that rejected hit.

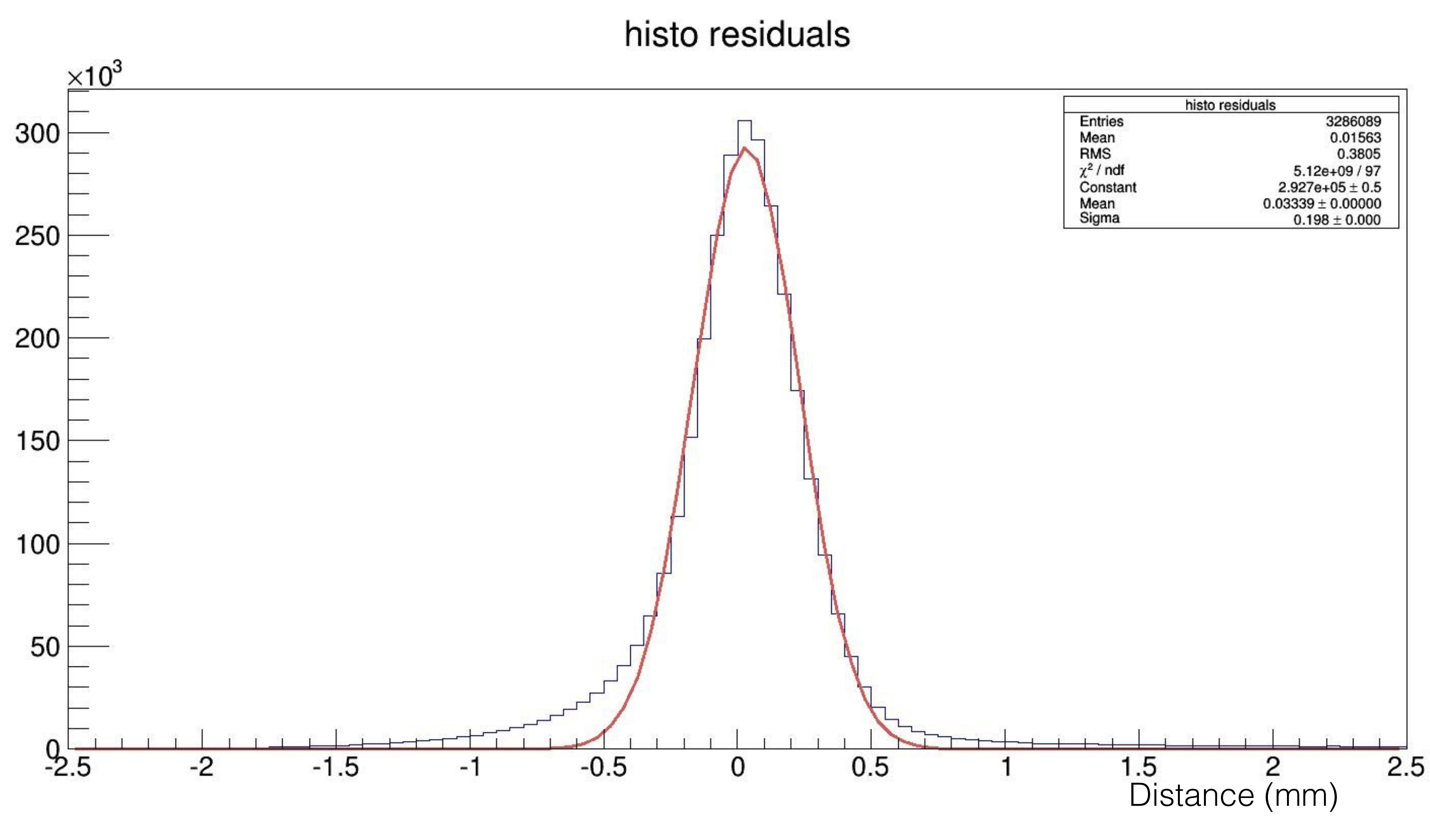
$$\Delta r_i = r_{i,fit}(a,b) - r_{i,raw} = \frac{|y_i - (a + bx_i)|}{\sqrt{1+b^2}} - r_{i,raw}.$$

Residual distribution for 3 GeV/c, 1800V



Filtering

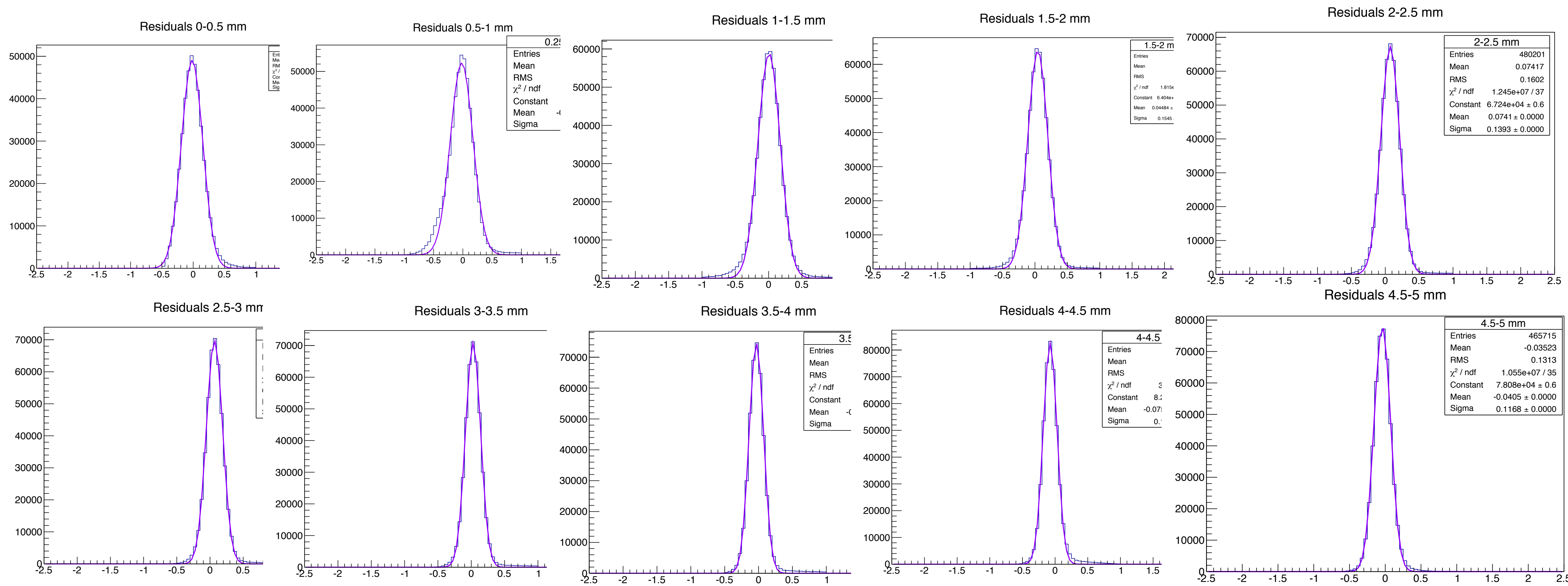
σ(spatial resolution) = 171 (µm)



No filtering

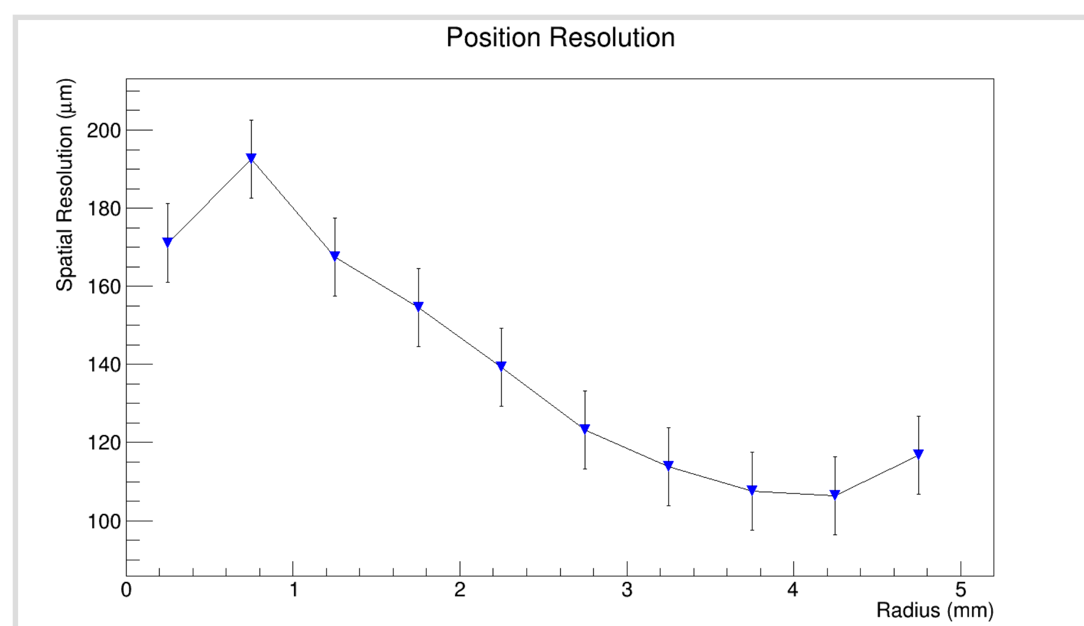
σ(spatial resolution) = 198 (µm)

Residual distribution for 0.550 GeV/c, 1800V

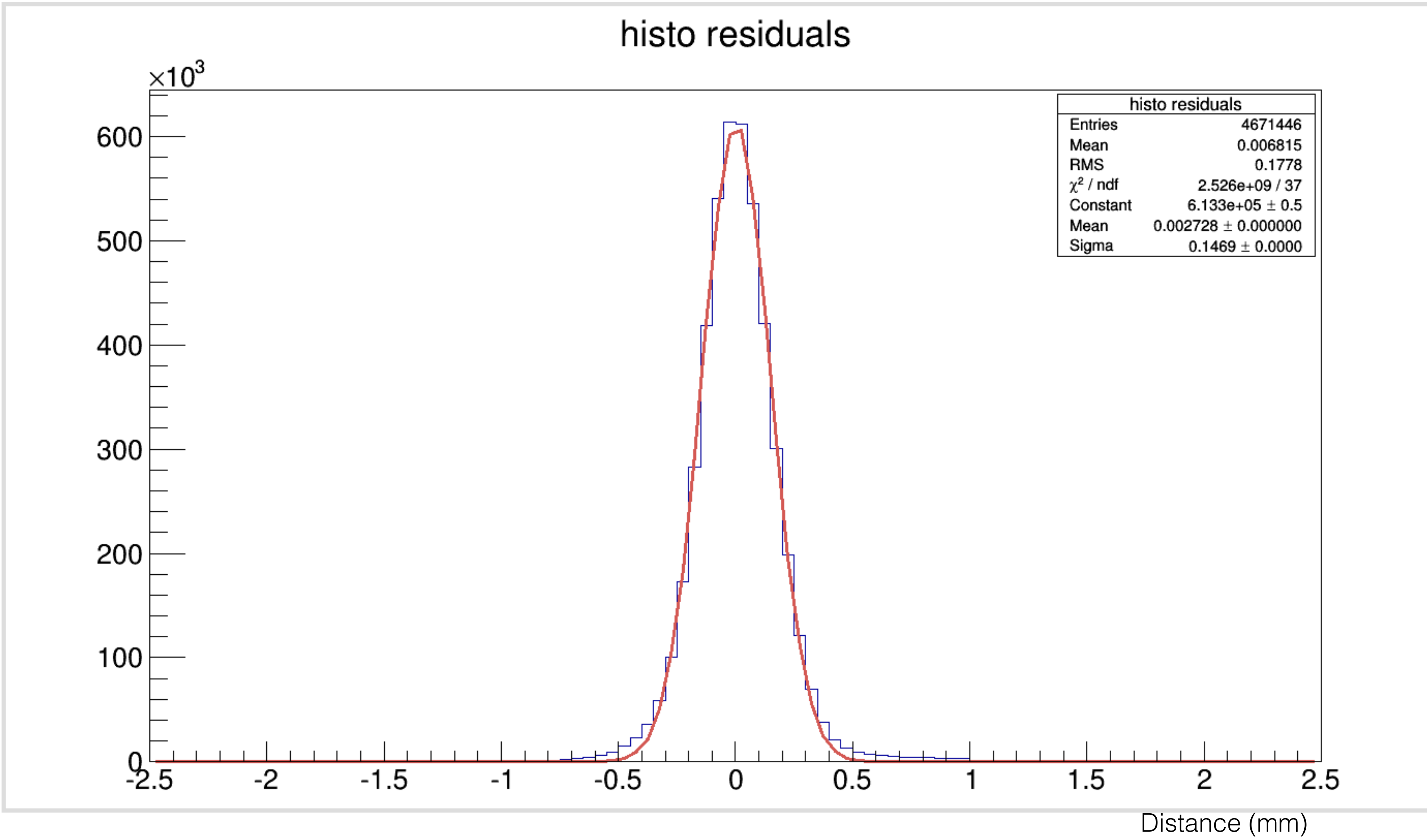


Position Resolution

for 0.550 GeV/c, 1800V



Residual distribution for 0.550 GeV/c



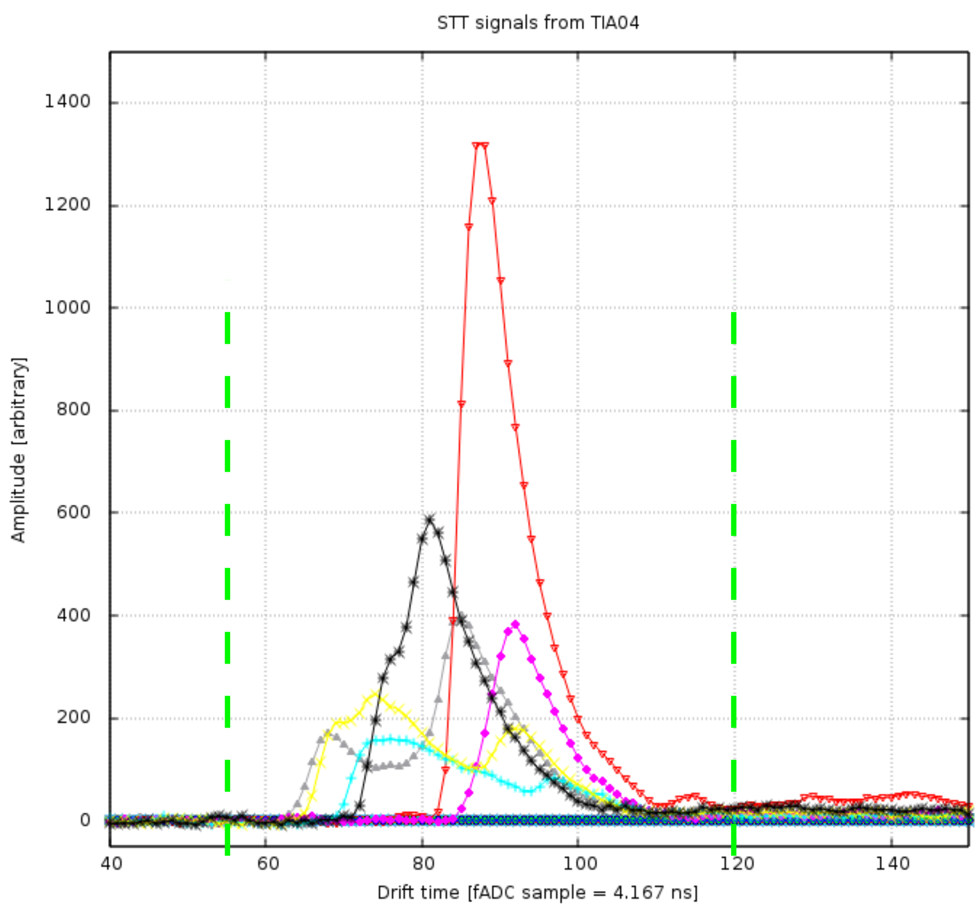
The best achieved spatial resolution at 0.550 GeV/c proton momentum:

at 1800V is $\boldsymbol{\sigma}_{\text{(spatial resolution)}} = 146 \pm 1\%$ (μm)

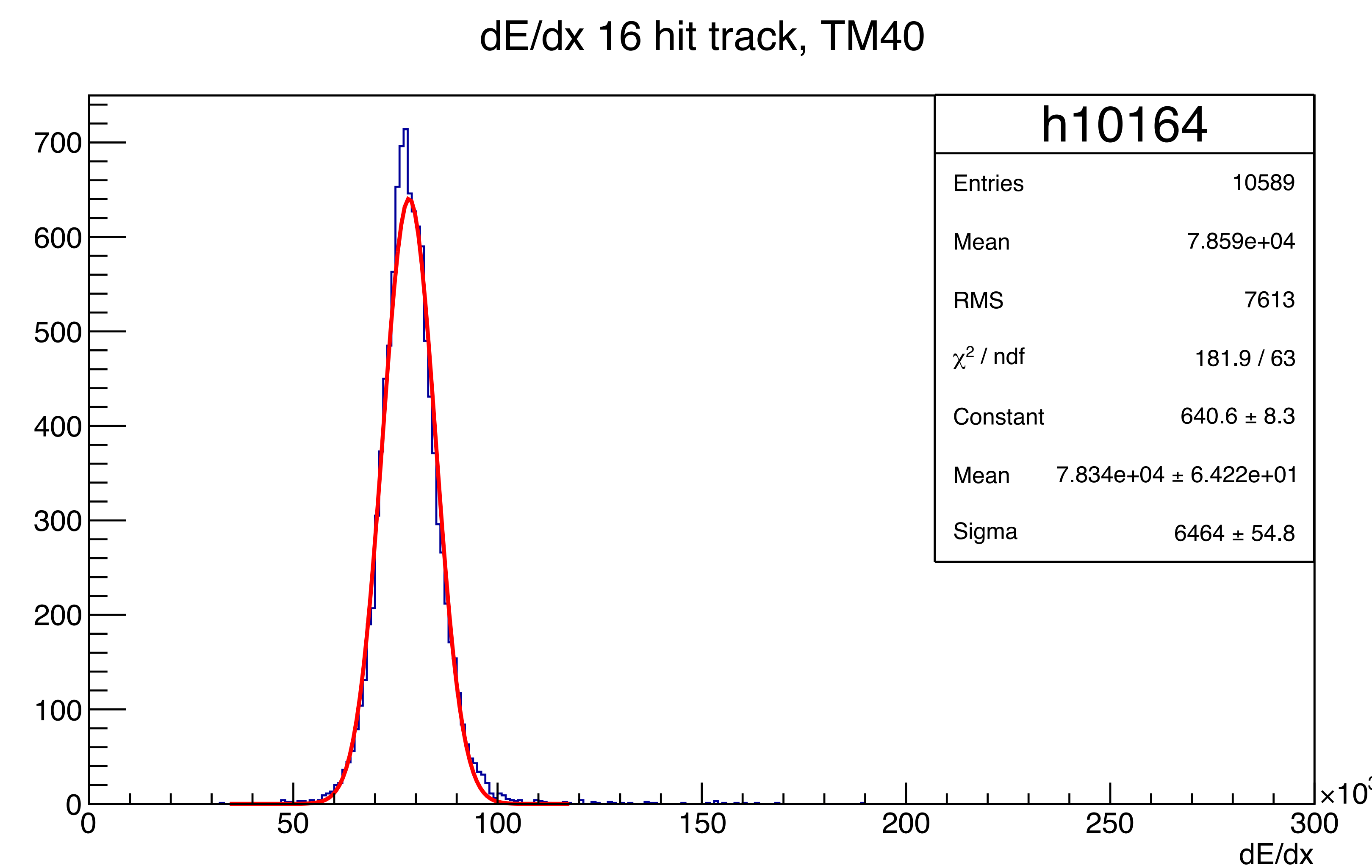
Analysis Method

2.Energy loss measurement

- Energy loss estimation (Integrated charge)
- Normalization to path length
- Selective measurement of energy losses with Truncation mean (cut of largest energy losses per track)

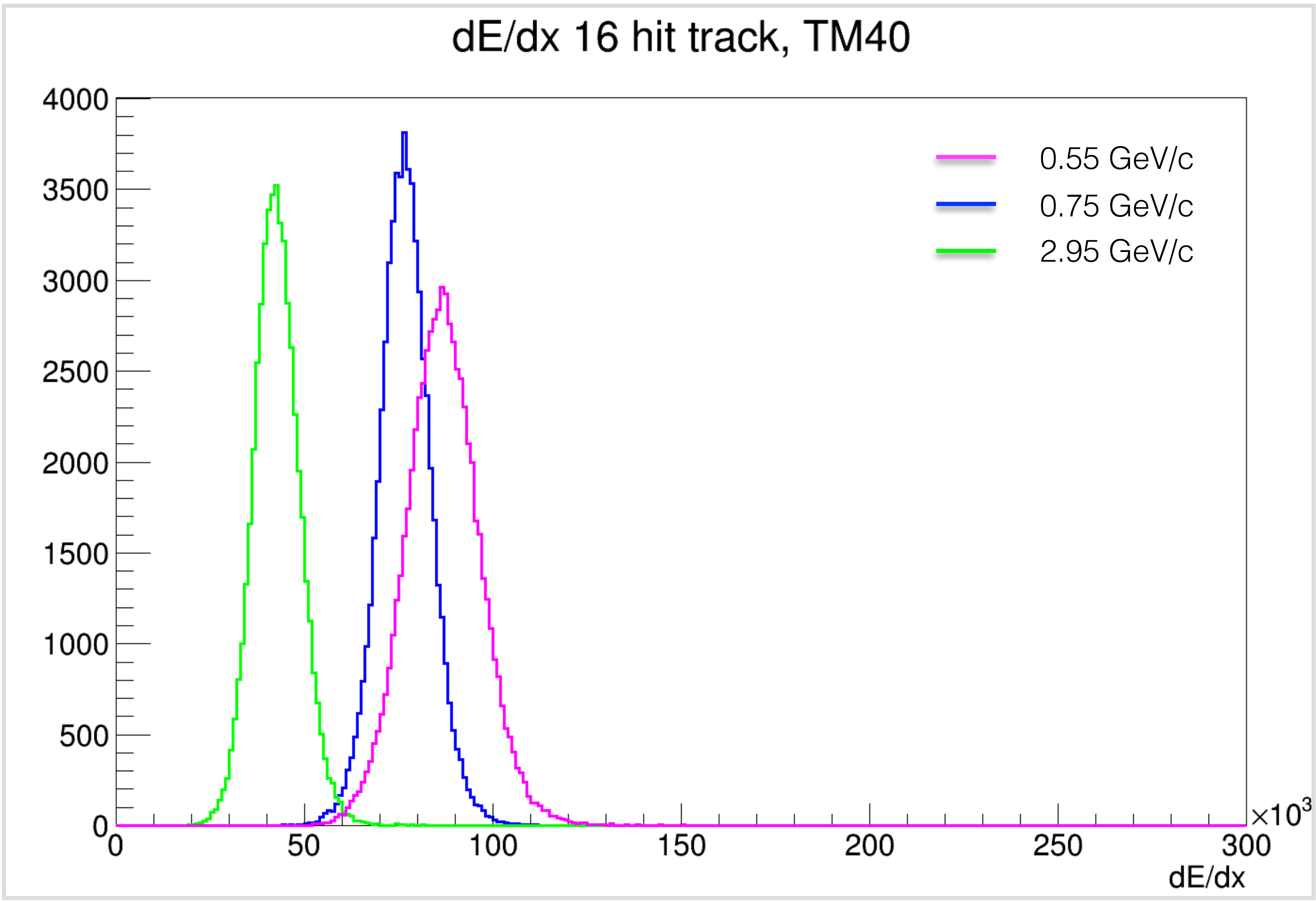


Results of the energy Resolution for example at 0.55 GeV/c



The best achieved energy resolution (for reconstructed tracks of 16 hits, 0.550 GeV/c proton momentum : $\boldsymbol{\sigma}_{(dE/dx)} \sim 8.2\%$

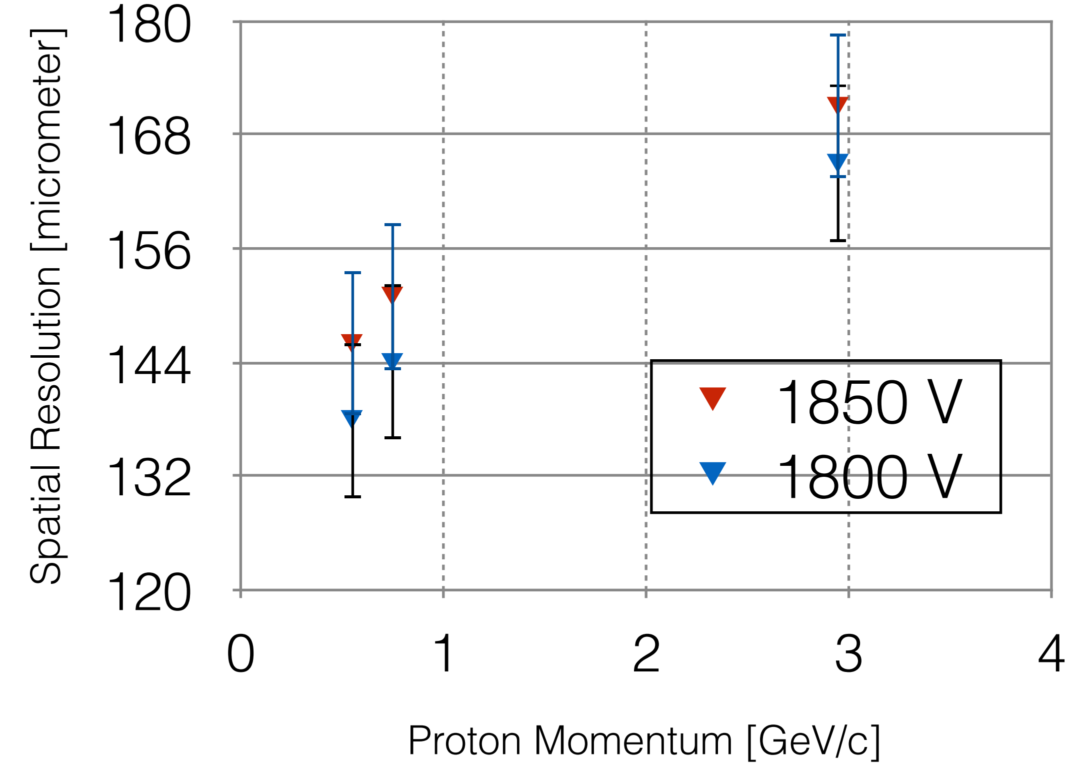
Energy distribution for different momenta at 1800V



Summary of current results

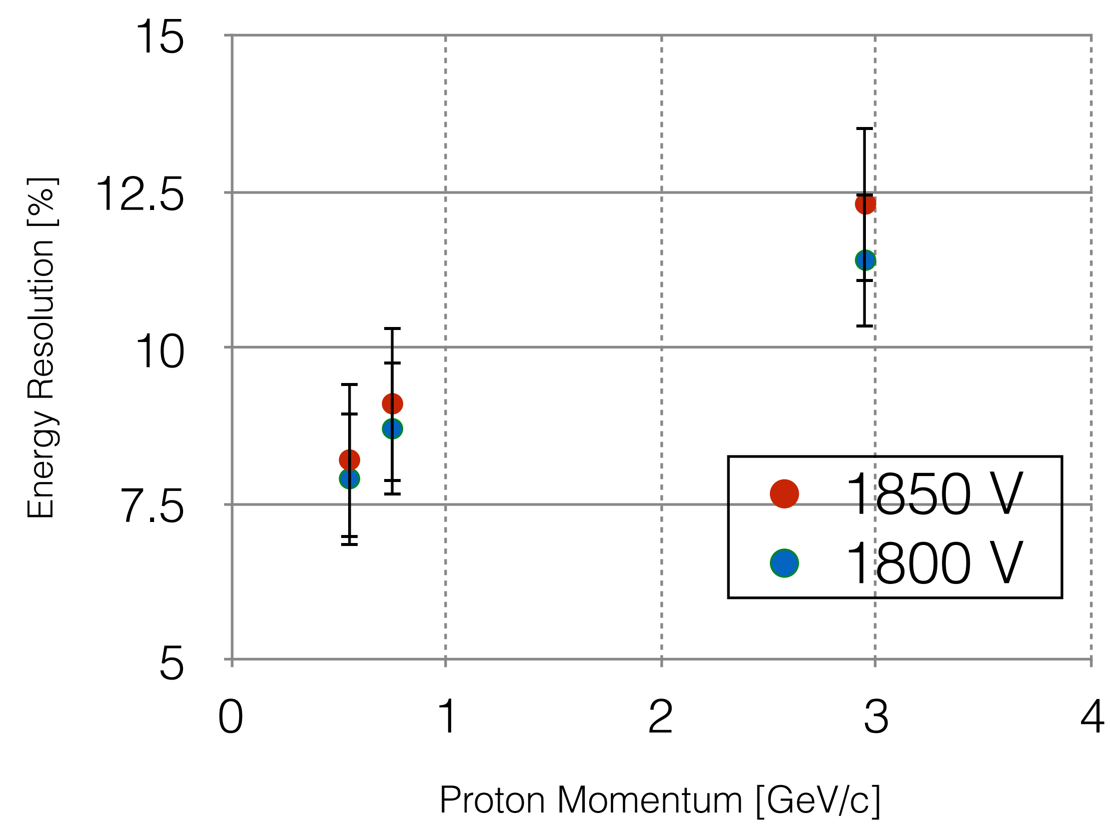
Summary of the results for reconstructed tracks

	Spatial resolution (μm) HV=1800 V	Spatial resolution (μm) HV=1850 V
0.550 GeV/c	146	138
0.750 GeV/c	151	145
2.95 GeV/c	171	165



For the energy resolution the truncation mean of 40% applied to initial dE/dx distributions

	Energy resolution [%] HV=1800 V	Energy resolution [%] HV=1850 V
0.550 GeV/c	8.2	7.9
0.750 GeV/c	9.1	8.7
2.95 GeV/c	12.3	11.4



Summary & Outlook

- The beam tests in COSY- TOF area were successful
- Clean beam condition, data taken for different intensities, low noise level
- The results of the spatial and energy resolutions look good and promising
- The next step is to analyze the data taken with deuteron beam and the there is a good chance to see the separation power of the STT prototype between deuterons and protons.
- Data analysis is still in progress ….


Thank You!
JÜLICH

Back up

$$\Delta r_i = r_{i,fit}(a,b) - r_{i,raw} = \frac{|y_i - (a + bx_i)|}{\sqrt{1+b^2}} - r_{i,raw}.$$

Δr_i is the residual of the i^{th} tube,

$r_{i,fit}$ is the distance of closest approach of the best fit line found in the center of tube i.

$r_{i,raw}$ indicates the radius computed using the r(t) relation

$$\frac{\mathrm{d}n}{\mathrm{d}t} = P_1 + \frac{P_2\left[1 + P_3 \exp((P_5 - t)/P_4)\right]}{\left[1 + \exp((P_5 - t)/P_7)\right]\left[1 + \exp((t - P_6)/P_8)\right]}$$

The number of tracks *dn* traversing the tube within the time interval *dt*.
The minimum and the maximum drift times, t_0 and t_{max}
P_1 is the noise level
P_2 is a normalization factor
P_3 and P_4 are related to the shape of the distribution
P_5 and P_6 are the values of t_0 and t_{max}
P_7 and P_8 describe the slope of the leading and trailing edge of the distribution