rijksuniversiteit groningen

kvi - center for advanced radiation technology

JÜLICH FORSCHUNGSZENTRUM

Performance of a prototype Straw Tube Tracker (STT) for the P̄ANDA experiment

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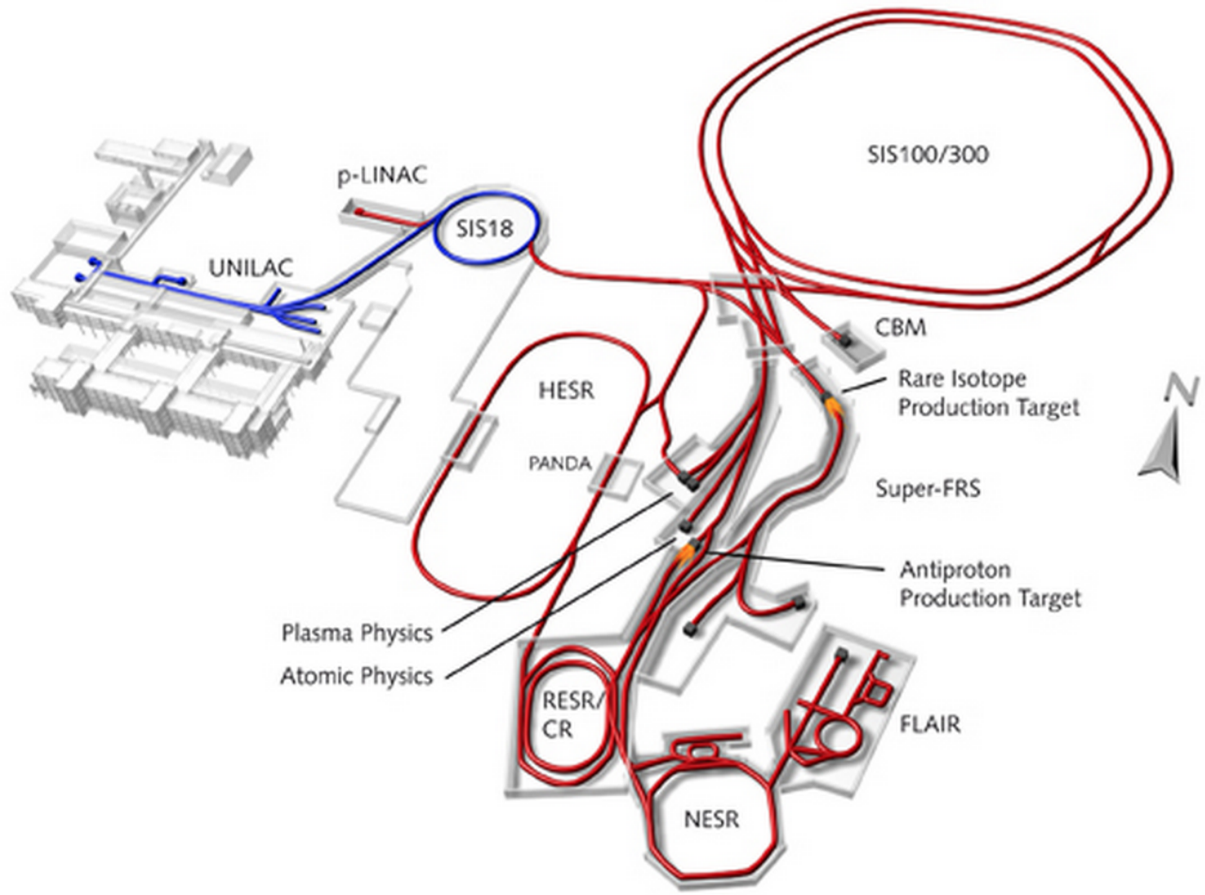
$\overline{P}$ANDA (antiProton ANnihilation at DArmstadt)

- Precise studies of antiproton-proton annihilations and reactions of antiprotons with heavy nuclear targets
- Centre-of-mass energy between 2.3 GeV and 5.5 GeV

HESR (High Energy Storage Ring)

- Luminosity: 10^{30} - 10^{32} cm^{-2} s^{-1}
- $\Delta p/p$: $4*10^{-5}$ - 10^{-4}

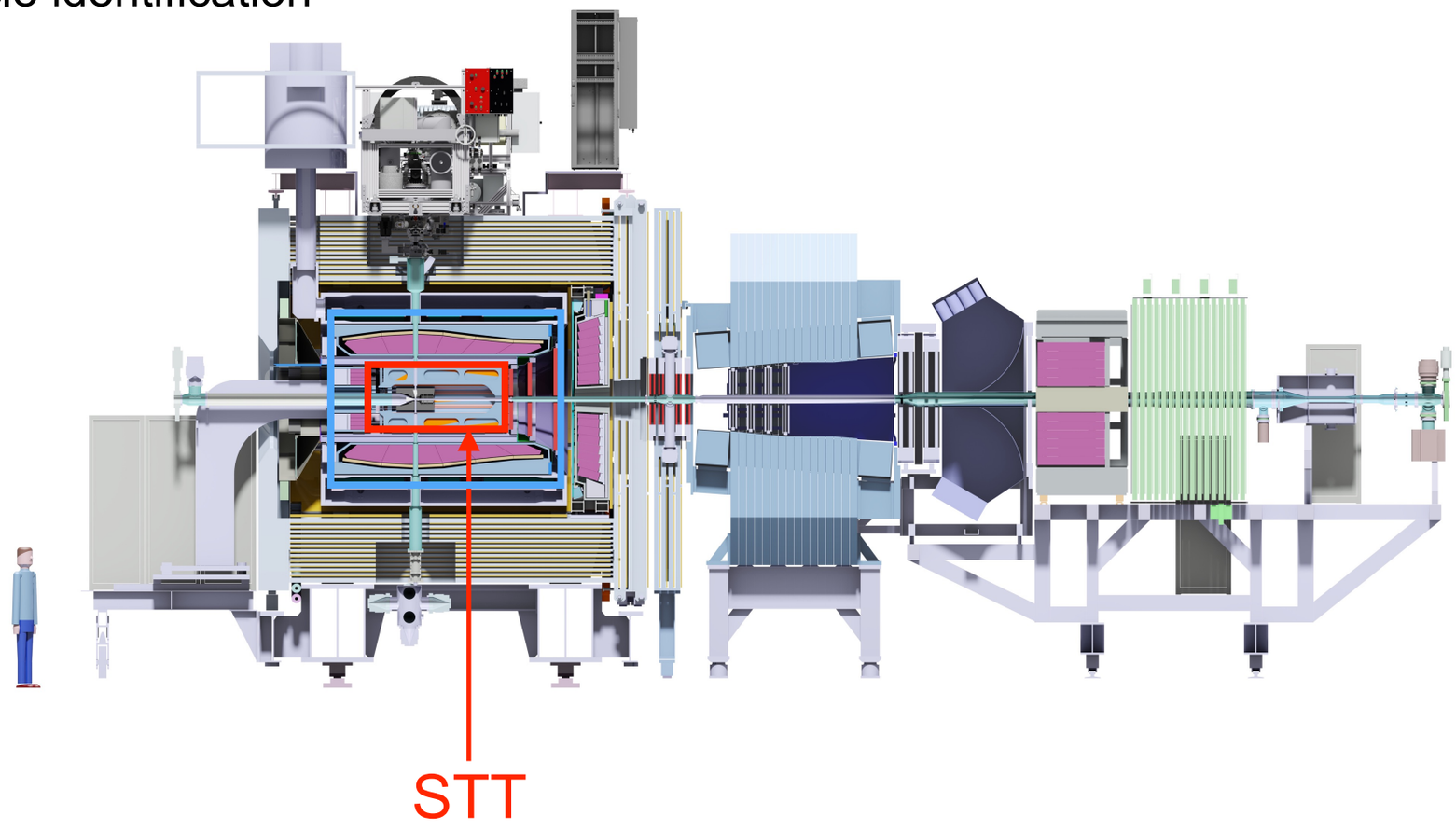


Physics: Rich spectrum of states with strange and charm quarks (unconventional states, exotic states etc.)

Expand our knowledge in spectroscopy!!!

What do we need: A detector that can handle a huge variety of final states and a large range of particle momenta and angles

- 4π acceptance
- High resolution for tracking and particle identification
- High event rate capabilities
- Flexible readout and event selection



Several sub- systems

Tracking detectors

Electromagnetic calorimeters

Muon detectors

Cherenkov detectors

Time-of-Flight detectors

STT specifications

4224 aluminised Mylar tubes

- 1.4 meters long, 1 cm diameter, thickness 27μm

27 layers of which the 8 central ones are skewed

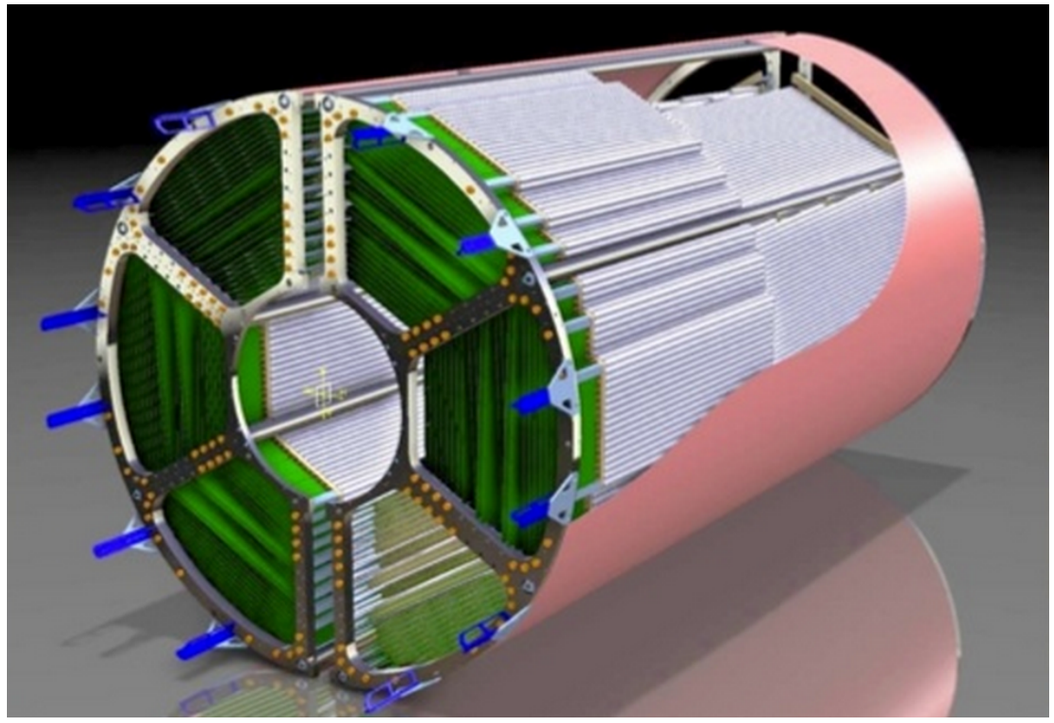
Single anode wire in the centre made of 20 μm thick gold plated tungsten+rhenium

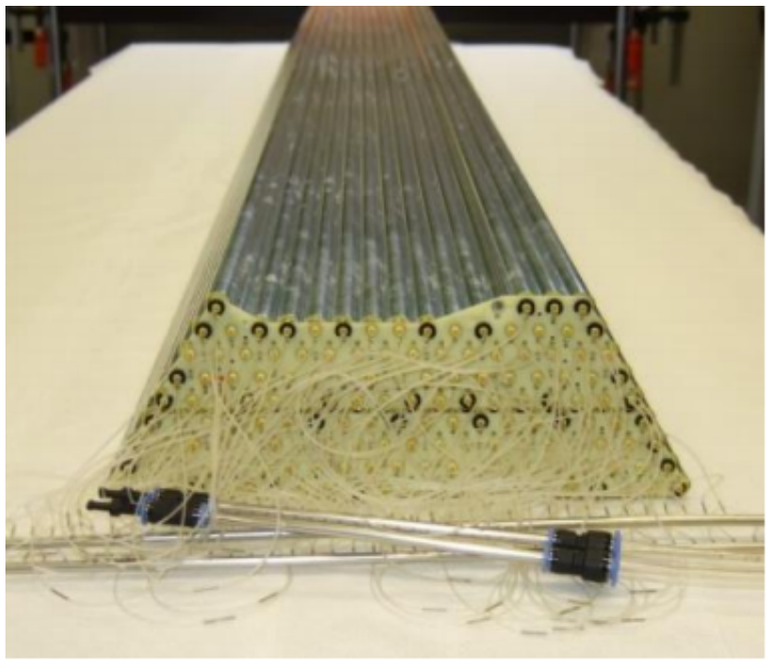
90% Ar and 10% CO_2 @ 2bar

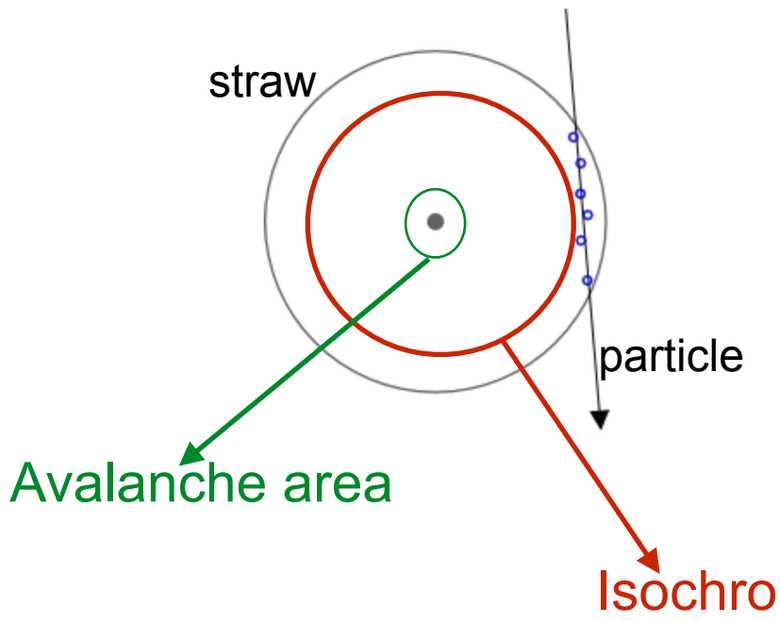
Tasks of STT

Momentum reconstruction: spatial reconstruction of trajectories of particles with few 100 MeV/c up to 8 GeV/c (~150μm)

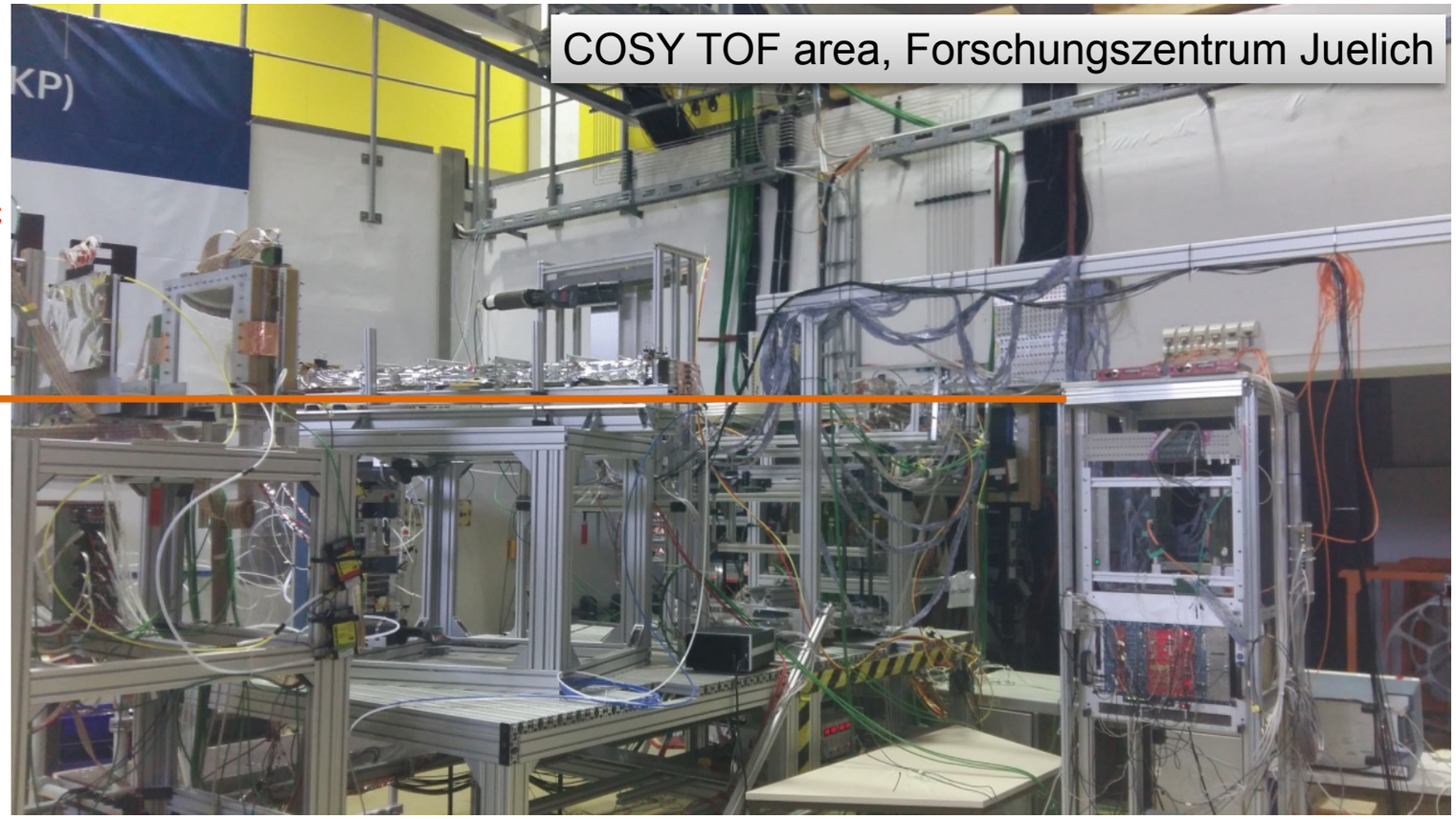
Particle identification: measurement of the specific energy-loss (dE/dx) (separation of protons, kaons and pions in the momentum region below 1 GeV/c)







Beam specifications
Particles: Protons, Deuterons
Momentum: 0.55, 0.75, 1.0, 2.95 GeV/c
0.6, 0.75, 1.5 GeV/c



STT-ASIC readout
144 channels
6 layers x 24 tubes

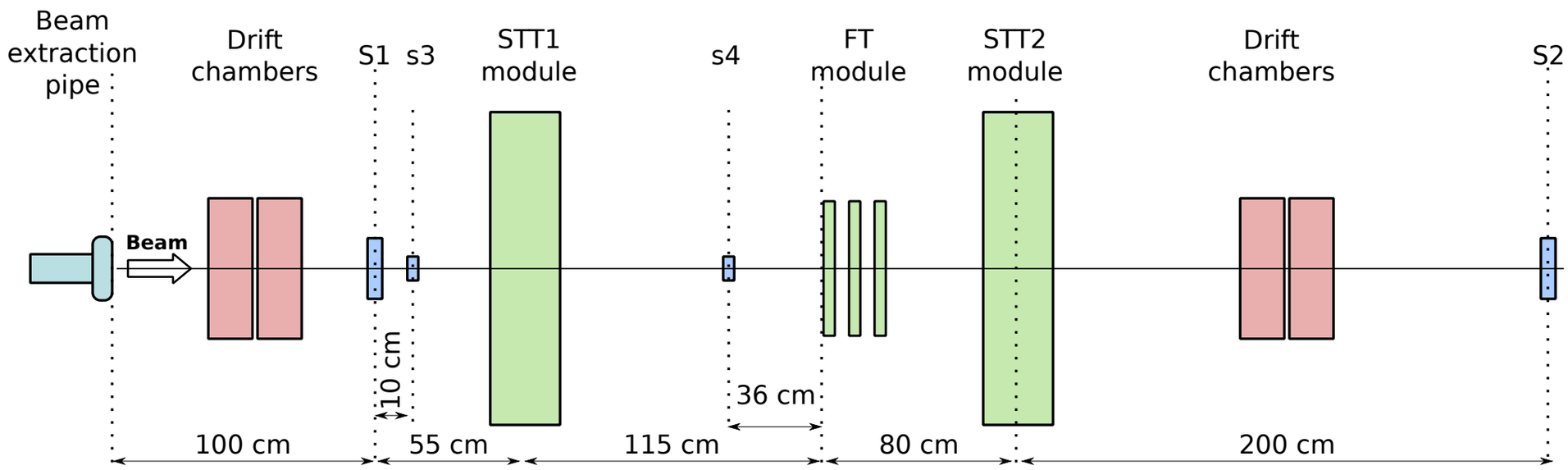


Figure from Pawel Strzempek(JU Krakow)

Readout

An Application Specific Integrated Circuit (ASIC) is being developed to read out the straw tube pulses.

- Measurement of two values: Leading Edge Time and Trailing Edge Time
- Leading Edge Time —> Drift time —> Tracking
- (Trailing Edge Time - Leading Edge Time) —> TOT/dx —>PID

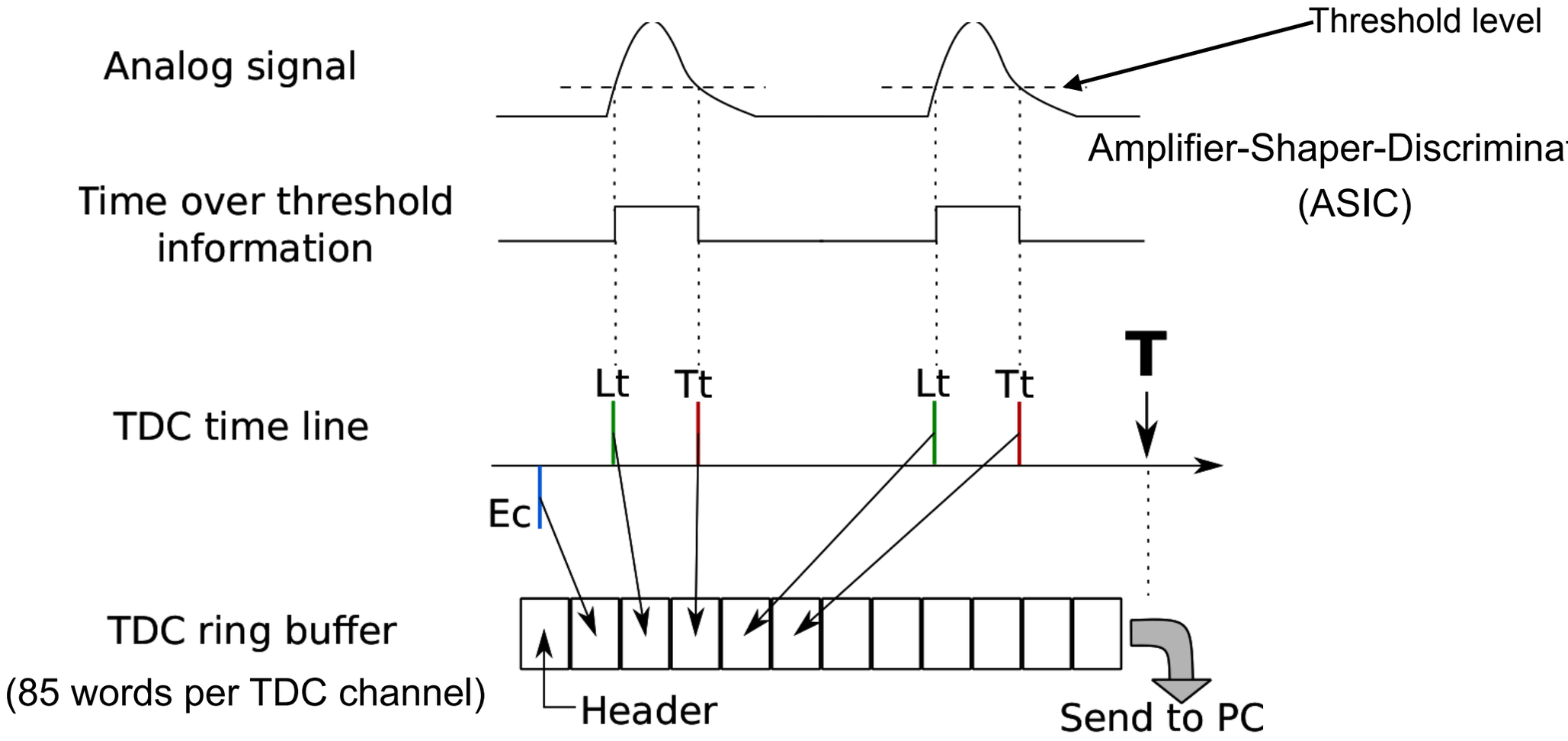
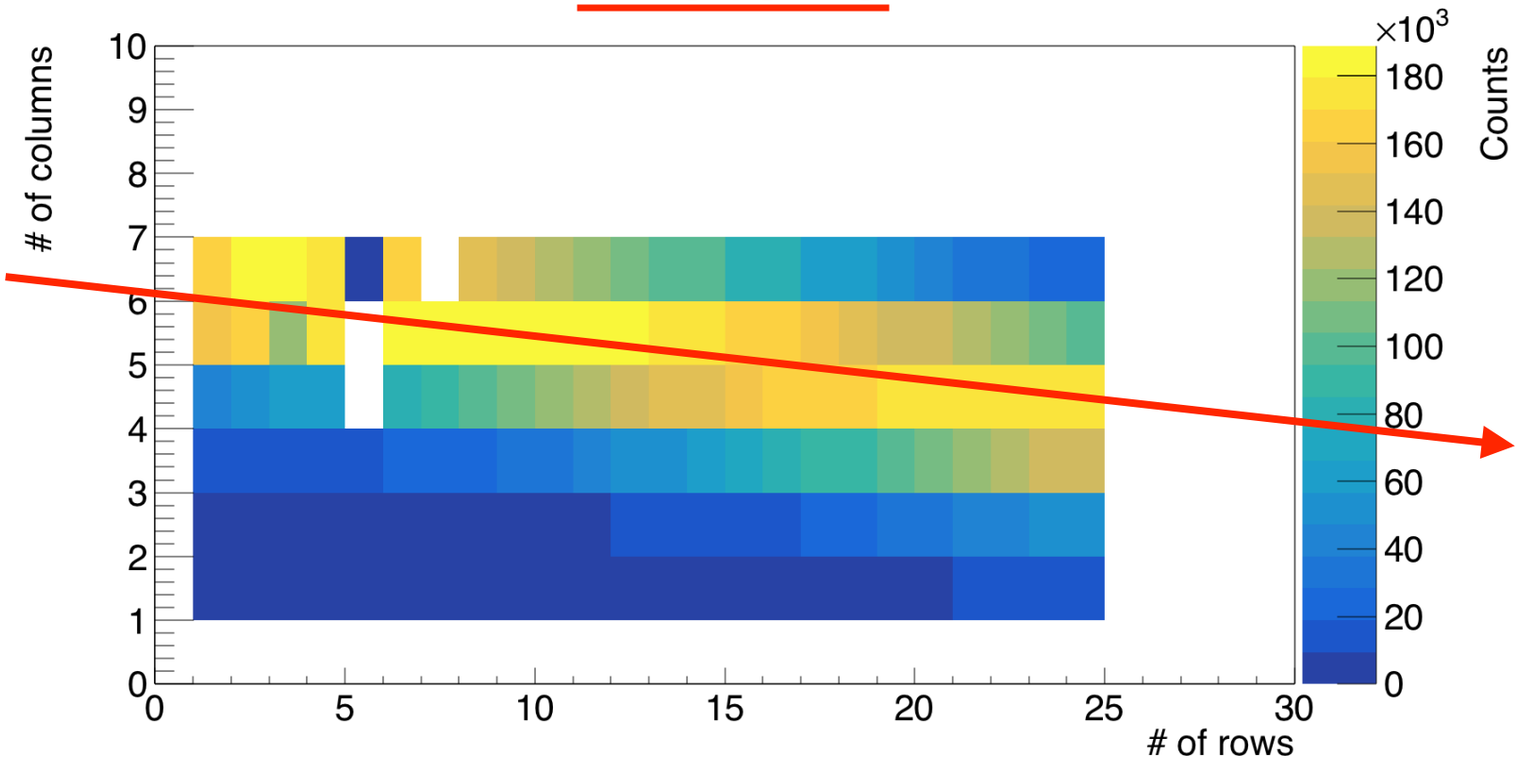
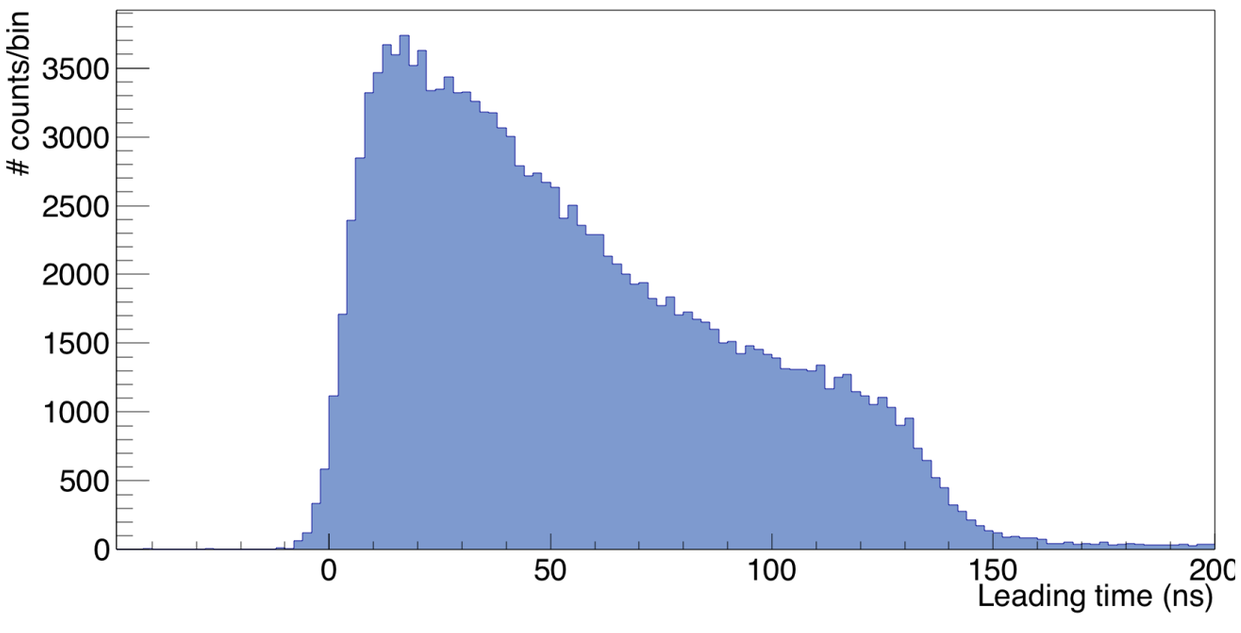
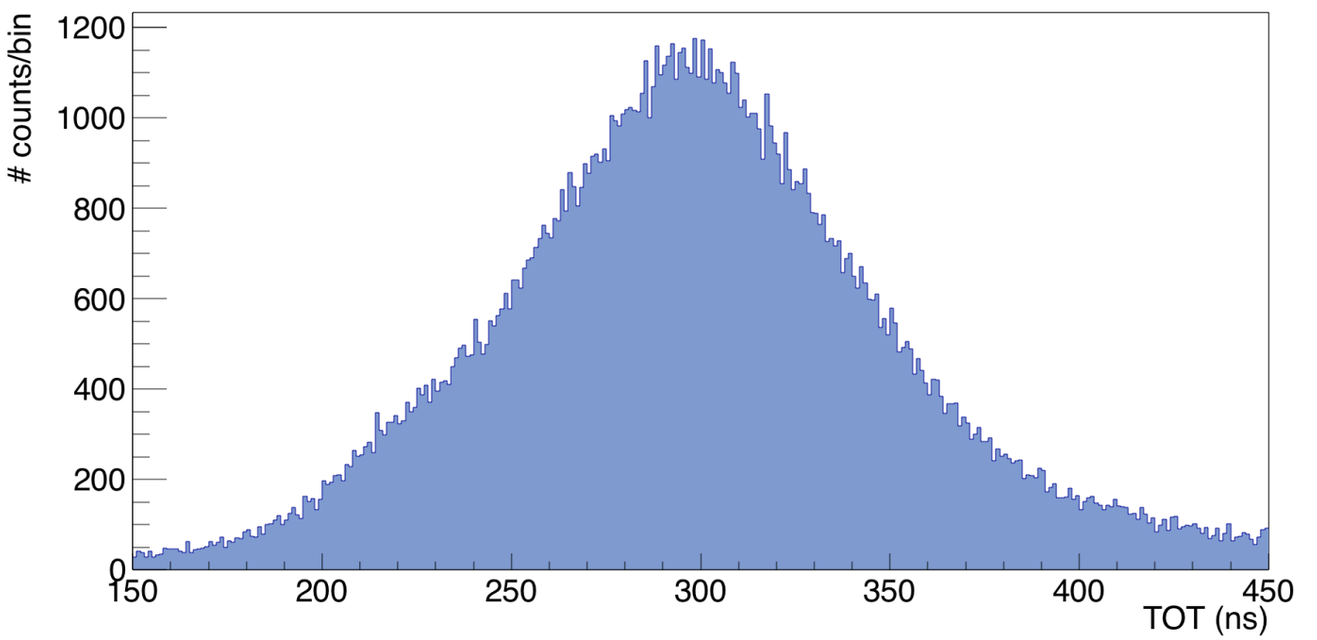


Figure from Pawel Strzempek(JU Krakow)

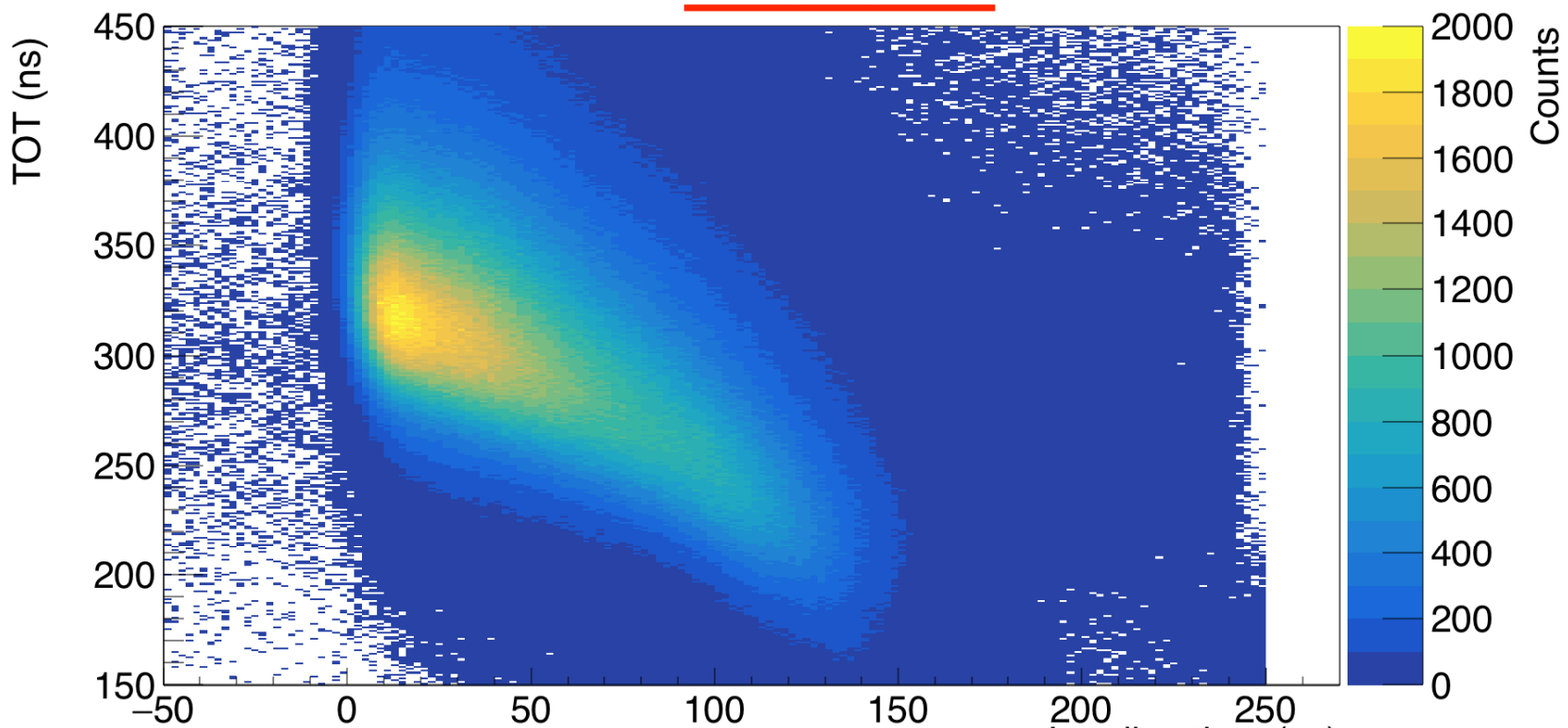
Protons


# of columns
# of rows
Counts
×10^3
180
160
140
120
100
80
60
40
20
0
10
9
8
7
6
5
4
3
2
1
0
0
5
10
15
20
25
30

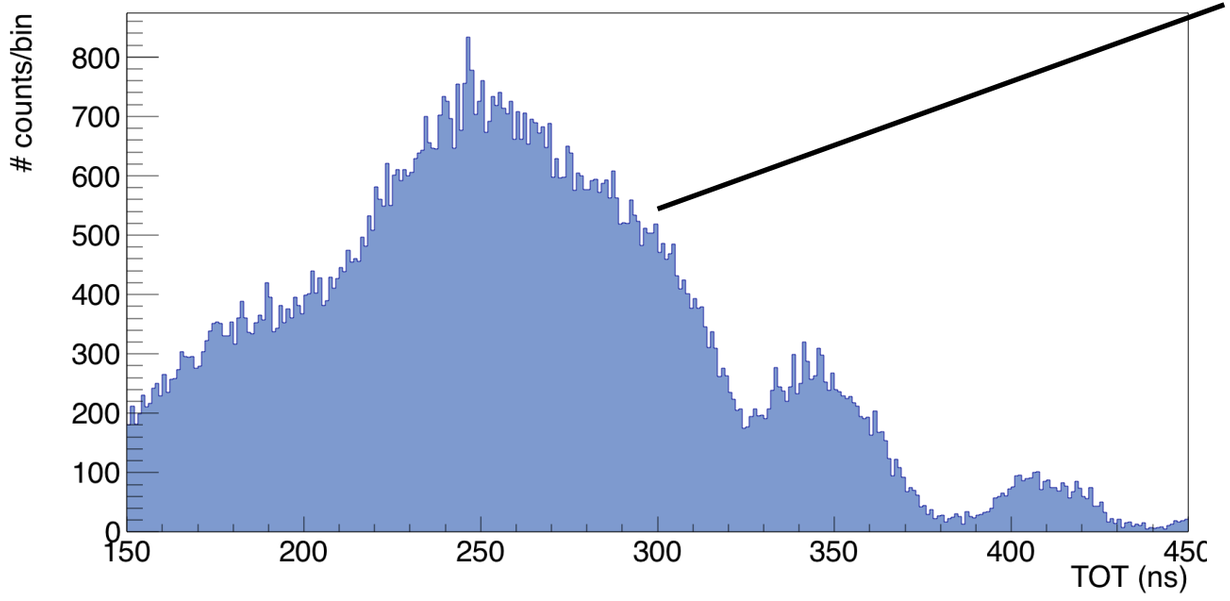

counts/bin
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200
Leading time (ns)

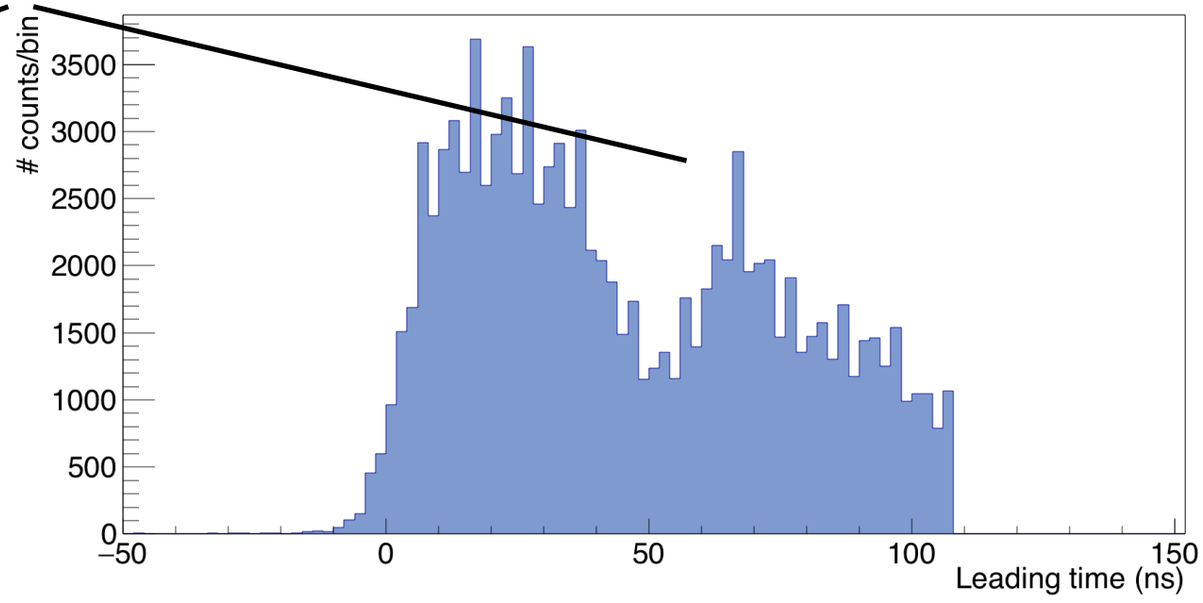

counts/bin
1200
1000
800
600
400
200
0
150
200
250
300
350
400
450
TOT (ns)

Protons



Problematic channels





Problematic channels are partially due to problems with the readout

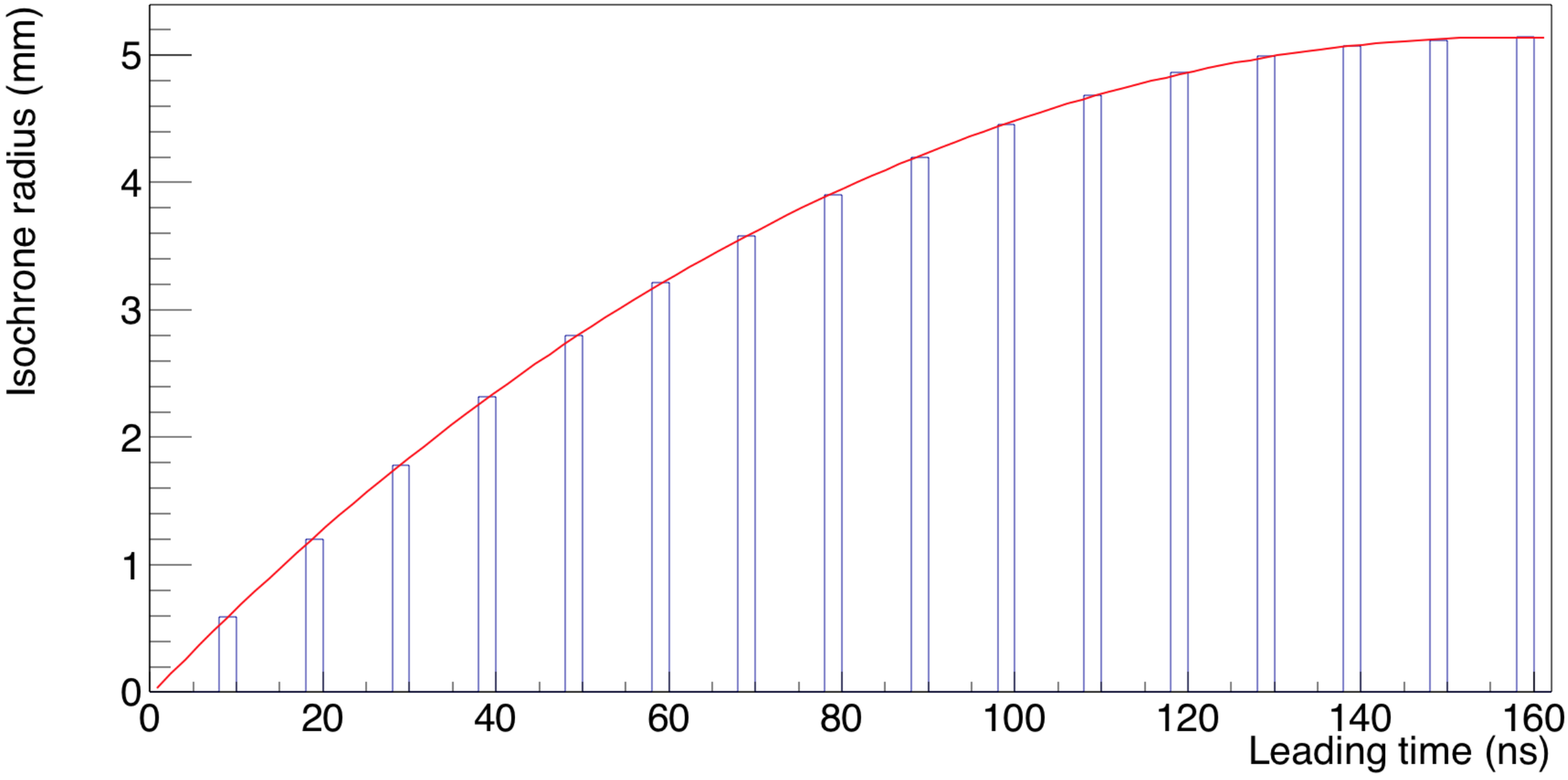
Front End Electronics (FEEs) and ASICs showed some problems:

1. Replacement

2. Skip from the analysis the problematic channels —> “clean-up”

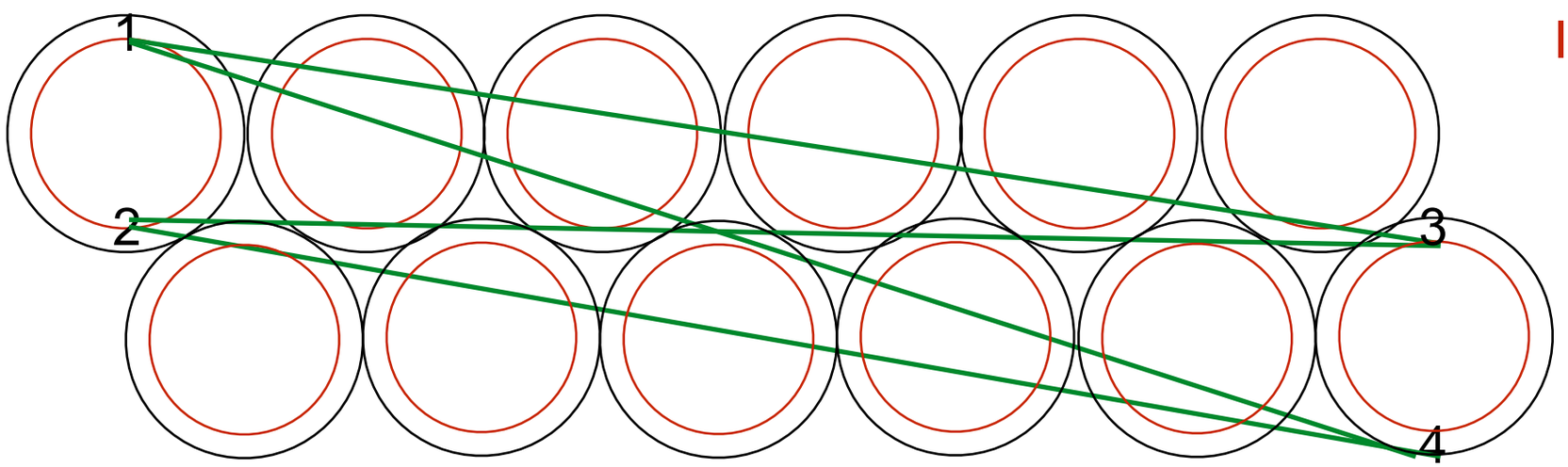
Final results with the clean up are slightly better

Deuteron beam had few problems —> “no clean-up”



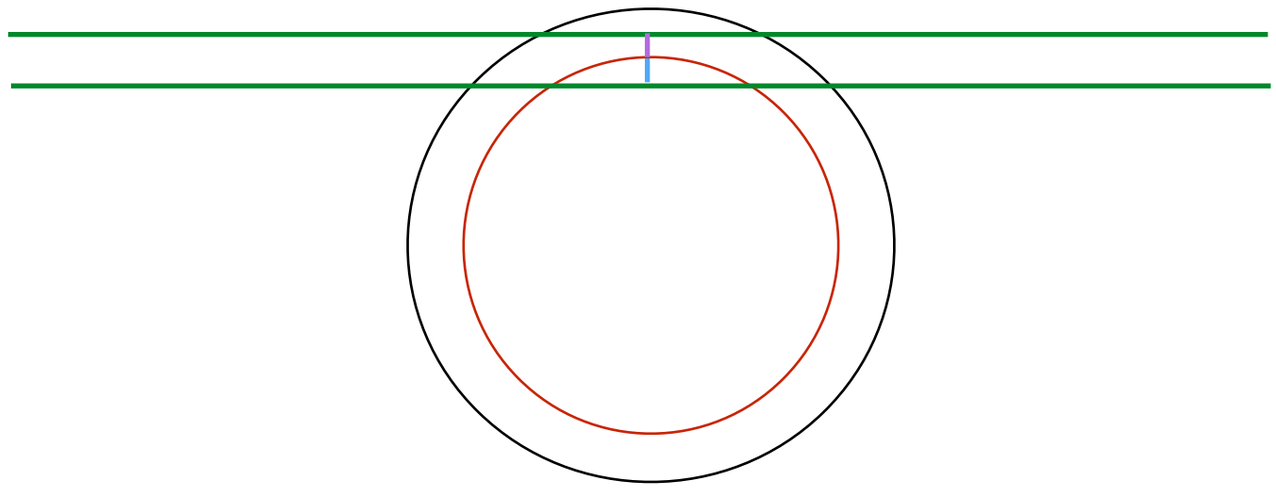
$$r(t_i) = (R_{tube} - R_{wire}) \frac{\Sigma_i N_i}{N_{total}} + R_{min}$$

Tracking



Tubes
Isochrones
Tracks

4 candidate tracks
Selection of best track
Apply minimization to the best track (Minuit function)



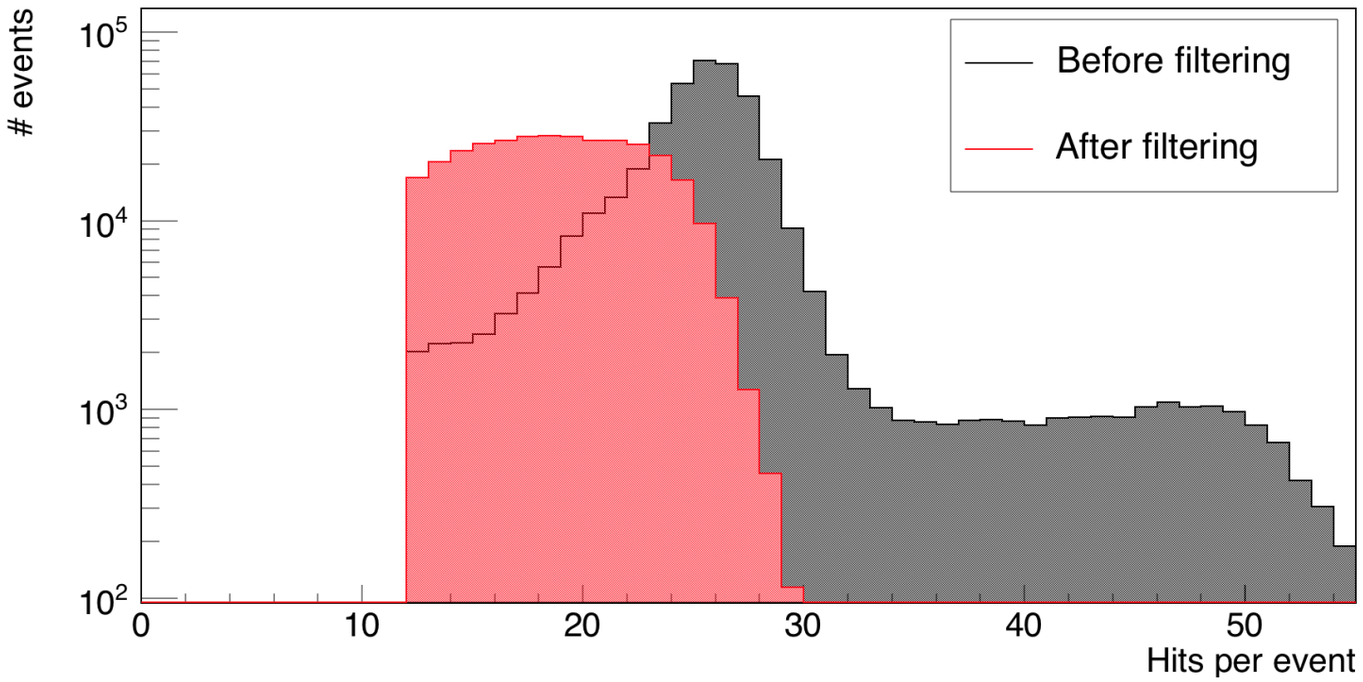
Distance between track and isochrone —> Residual —> Spatial resolution

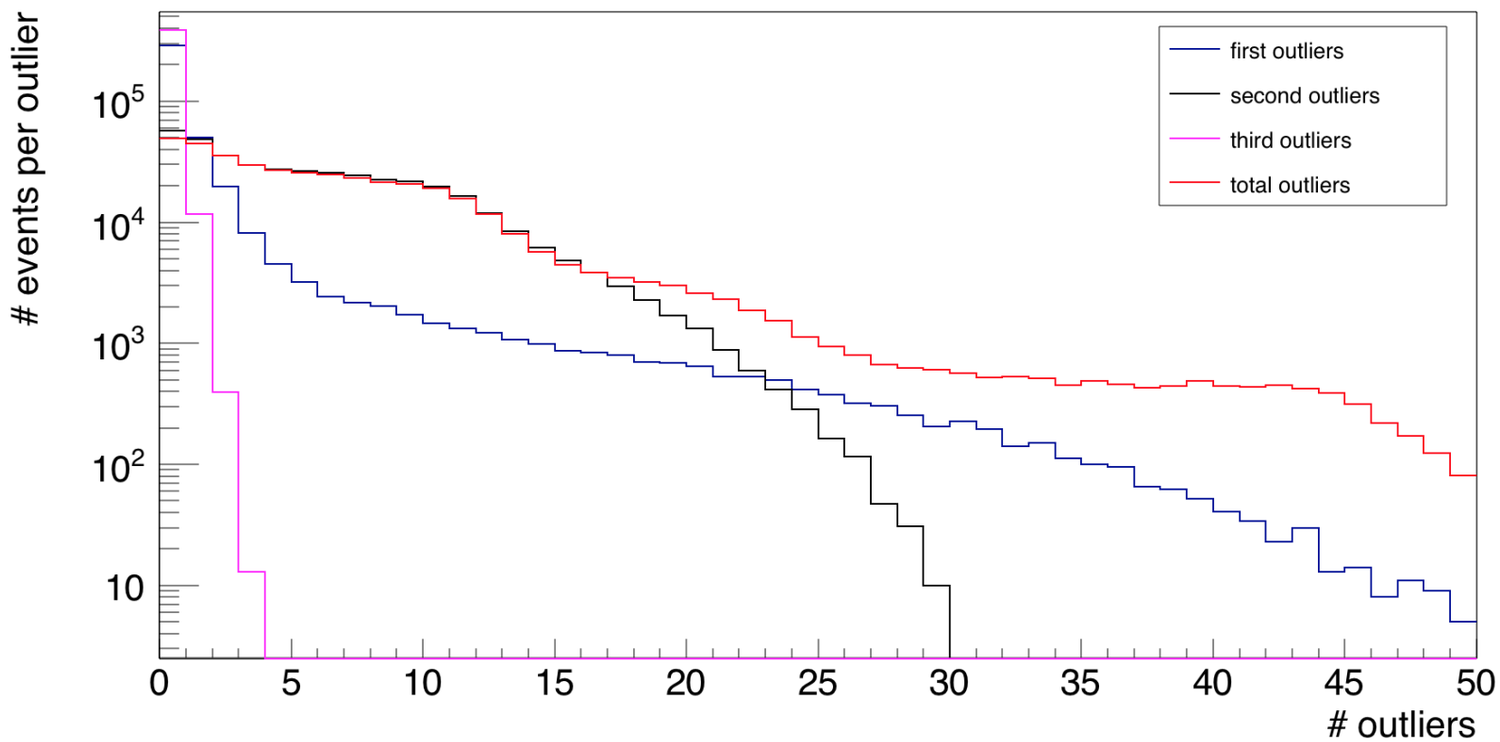
Steps and cuts for tracking

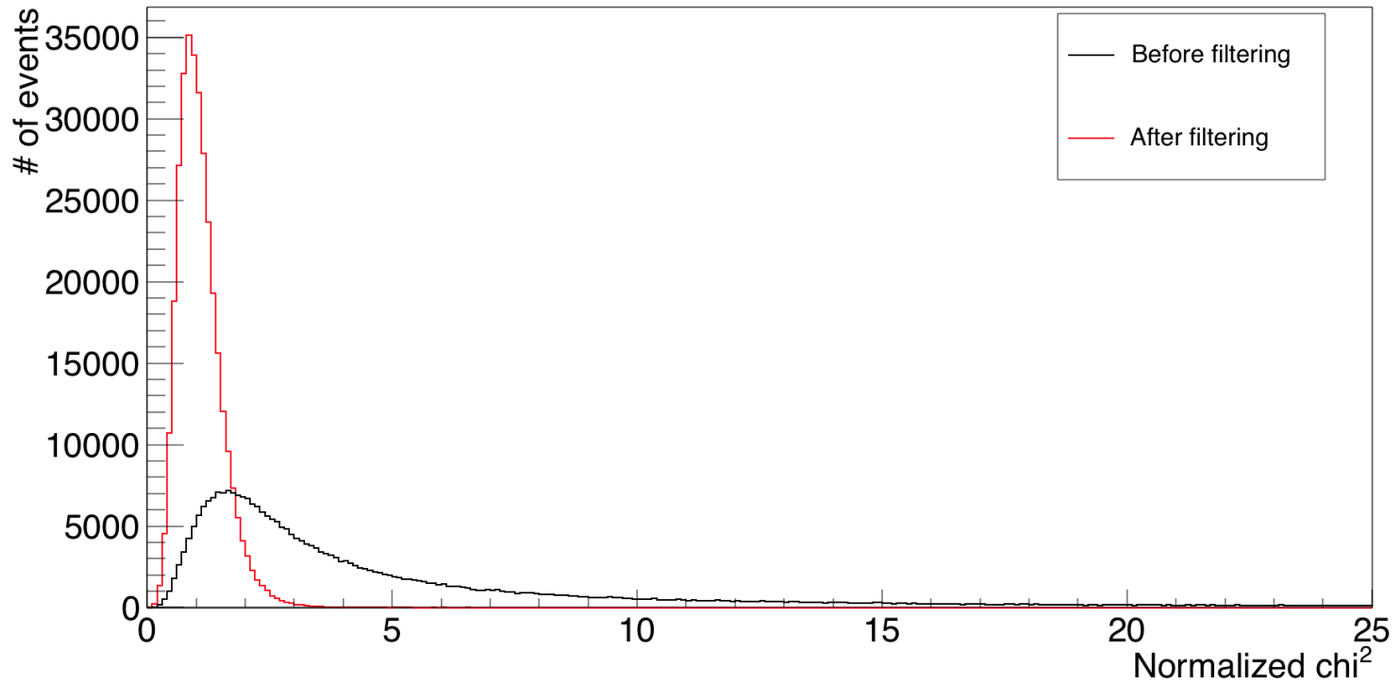
- Calculation of isochrones based on the parameters of the fit
- If isochrone is between -200μm and 0, set 200μm
- Determination of the pre-track
- Outliers #1: Distance between track and wire > 6mm, skip hit
- Apply minimization
- Outliers #2: Residual > 0.6mm, skip hit
- Apply minimization
- Outliers #3: Residual > 2.5 sigma of the isochrone error, skip hit
- Apply minimization
- Requirement: At least 12 hits per event (50% of total)
- Final track

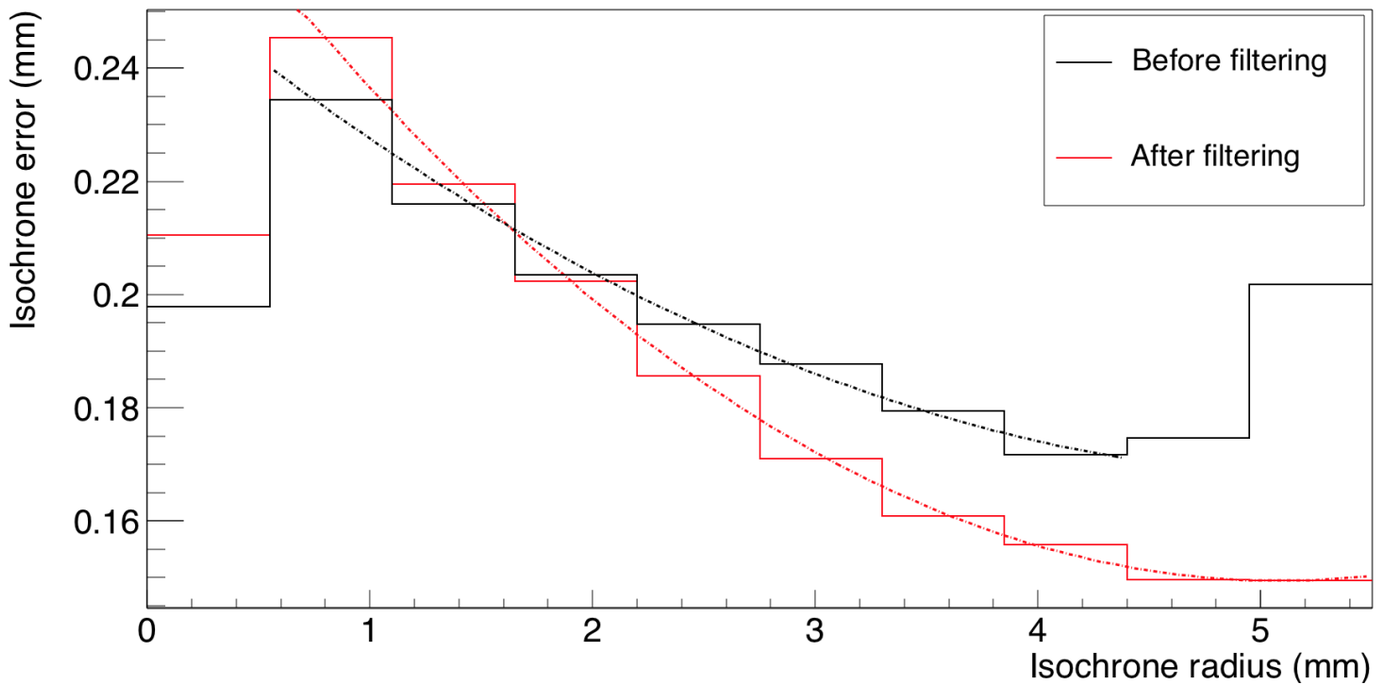
r(t) and isochrone error calculation from data

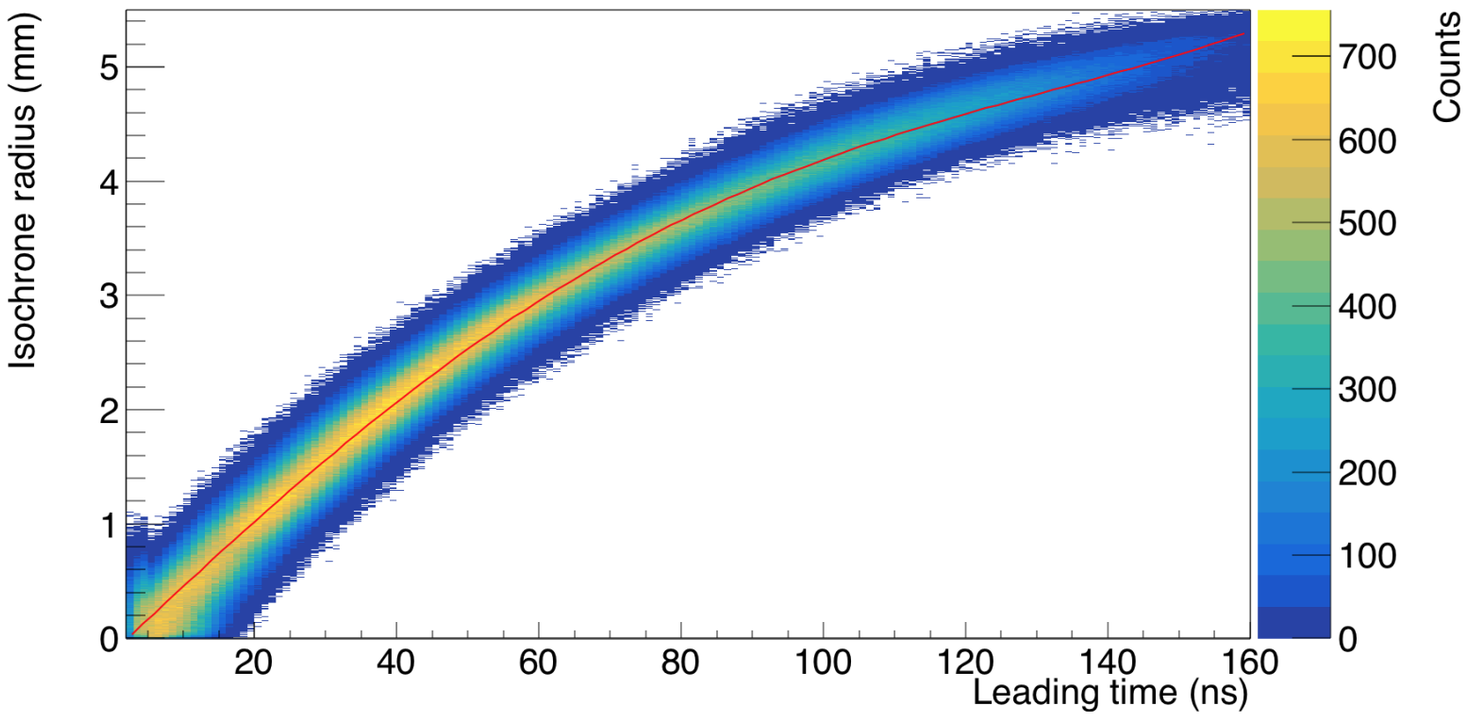
Iterate several times in order to get the best results

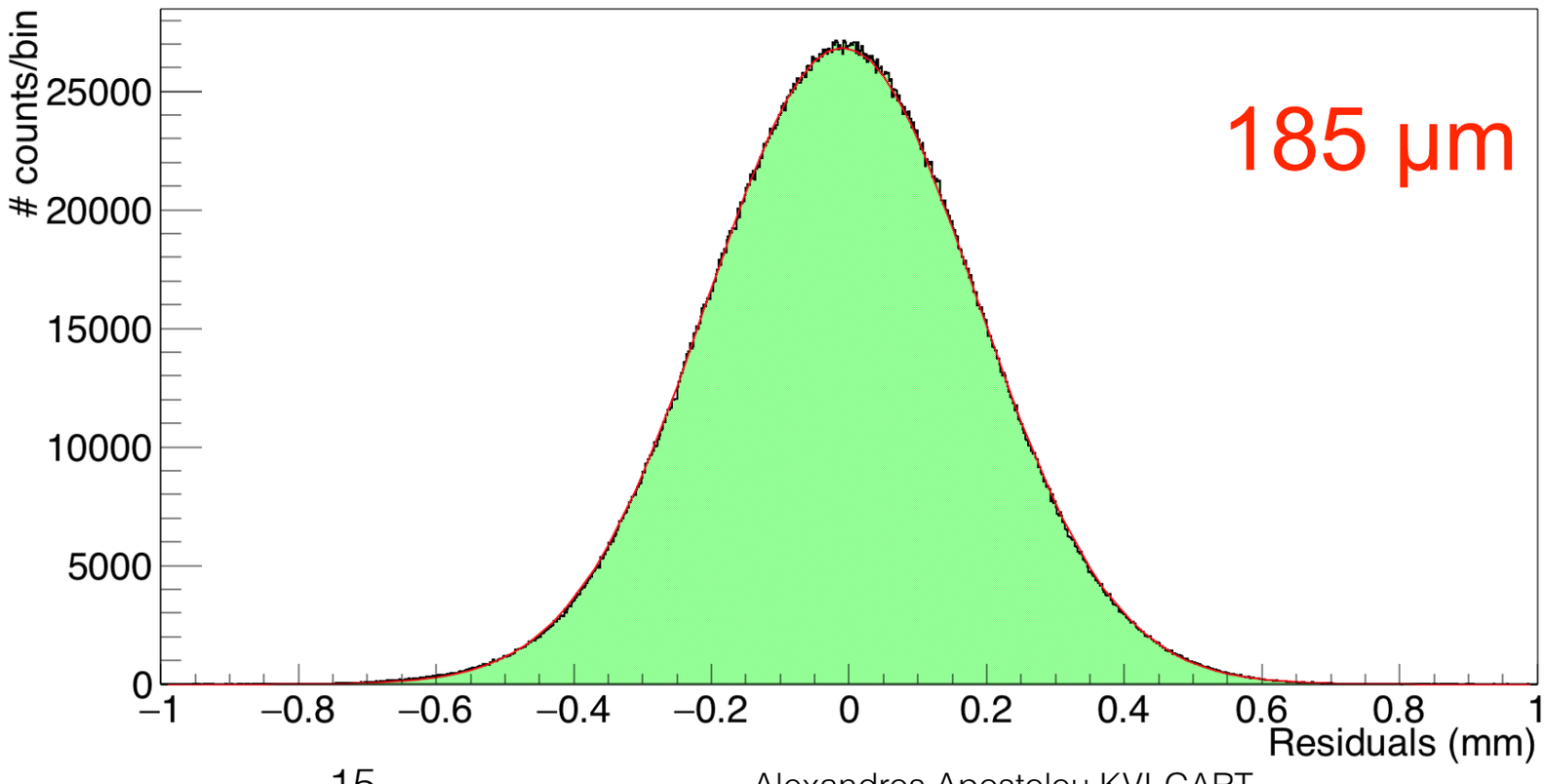

events
Before filtering
After filtering
Hits per event


events per outlier
first outliers
second outliers
third outliers
total outliers
outliers

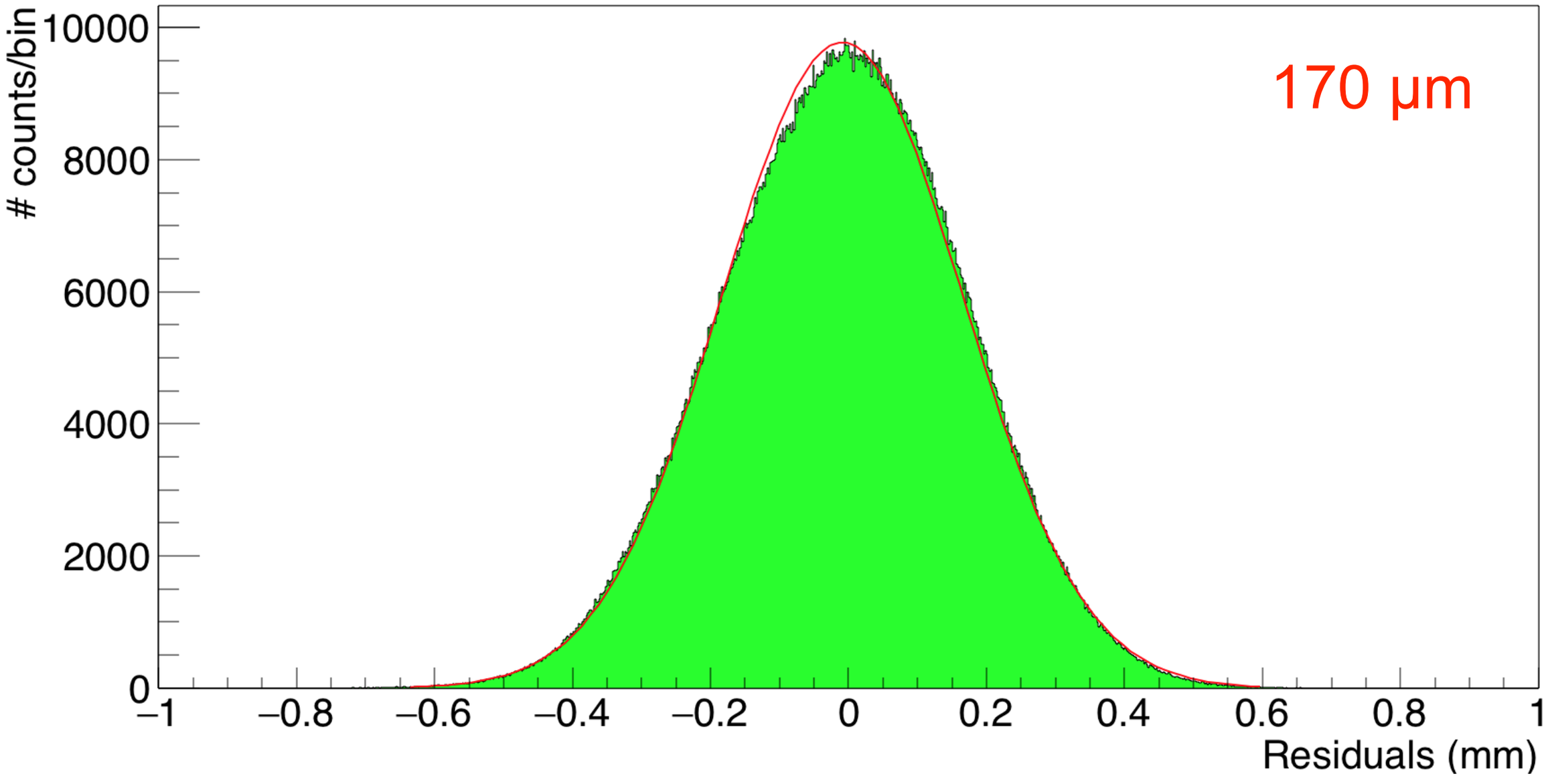

# of events
35000
30000
25000
20000
15000
10000
5000
0
0
5
10
15
20
25
Normalized chi^2
Before filtering
After filtering

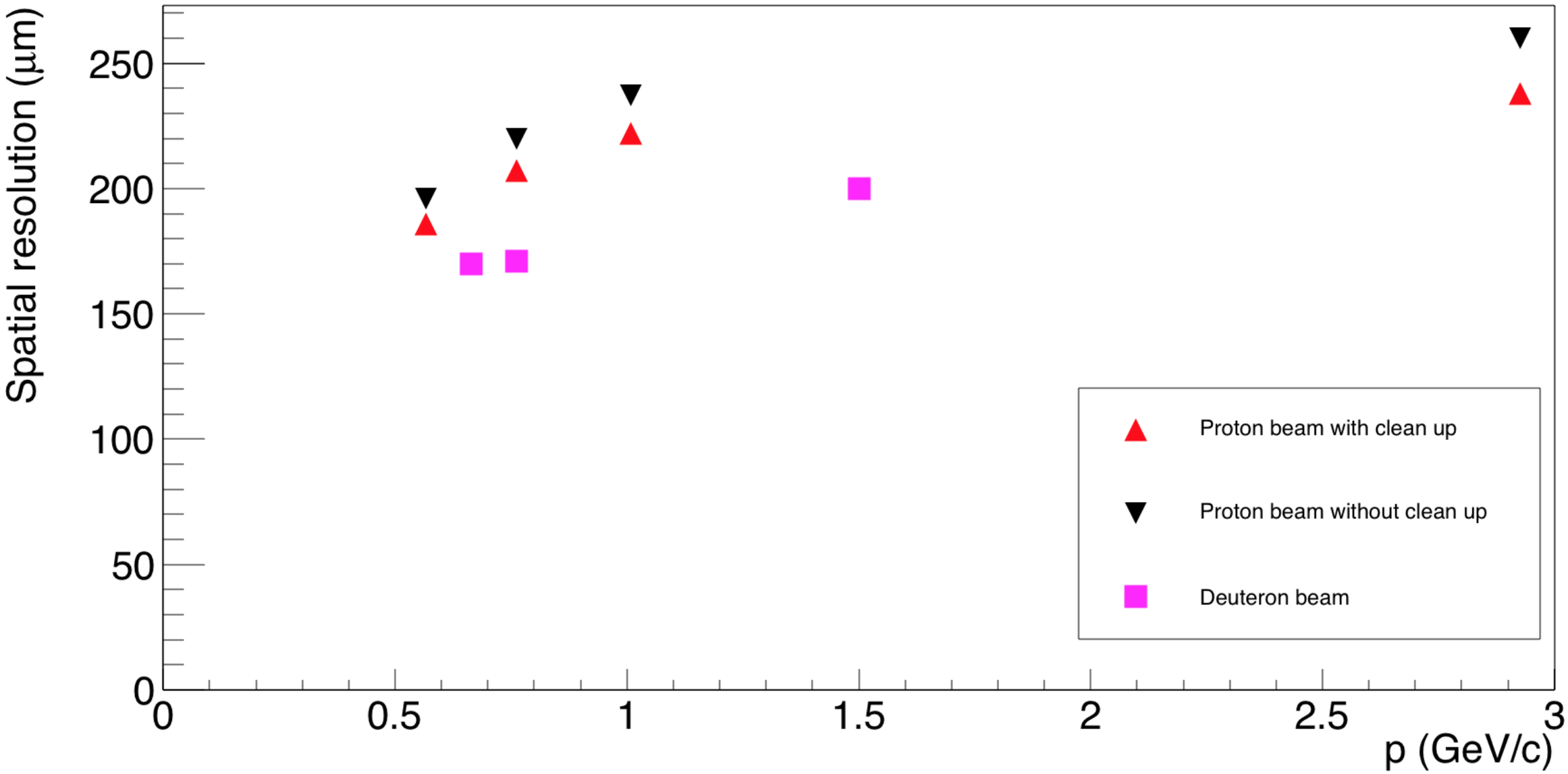

Isochrone error (mm)
0.24
0.22
0.2
0.18
0.16
0
1
2
3
4
5
Isochrone radius (mm)
Before filtering
After filtering


Isochrone radius (mm)
Leading time (ns)
Counts
0
1
2
3
4
5
20
40
60
80
100
120
140
160
0
100
200
300
400
500
600
700


counts/bin
Residuals (mm)
185 µm
0
5000
10000
15000
20000
25000
−1
−0.8
−0.6
−0.4
−0.2
0
0.2
0.4
0.6
0.8
1

Deuterons


170 µm
counts/bin
10000
8000
6000
4000
2000
0
–1
–0.8
–0.6
–0.4
–0.2
0
0.2
0.4
0.6
0.8
1
Residuals (mm)

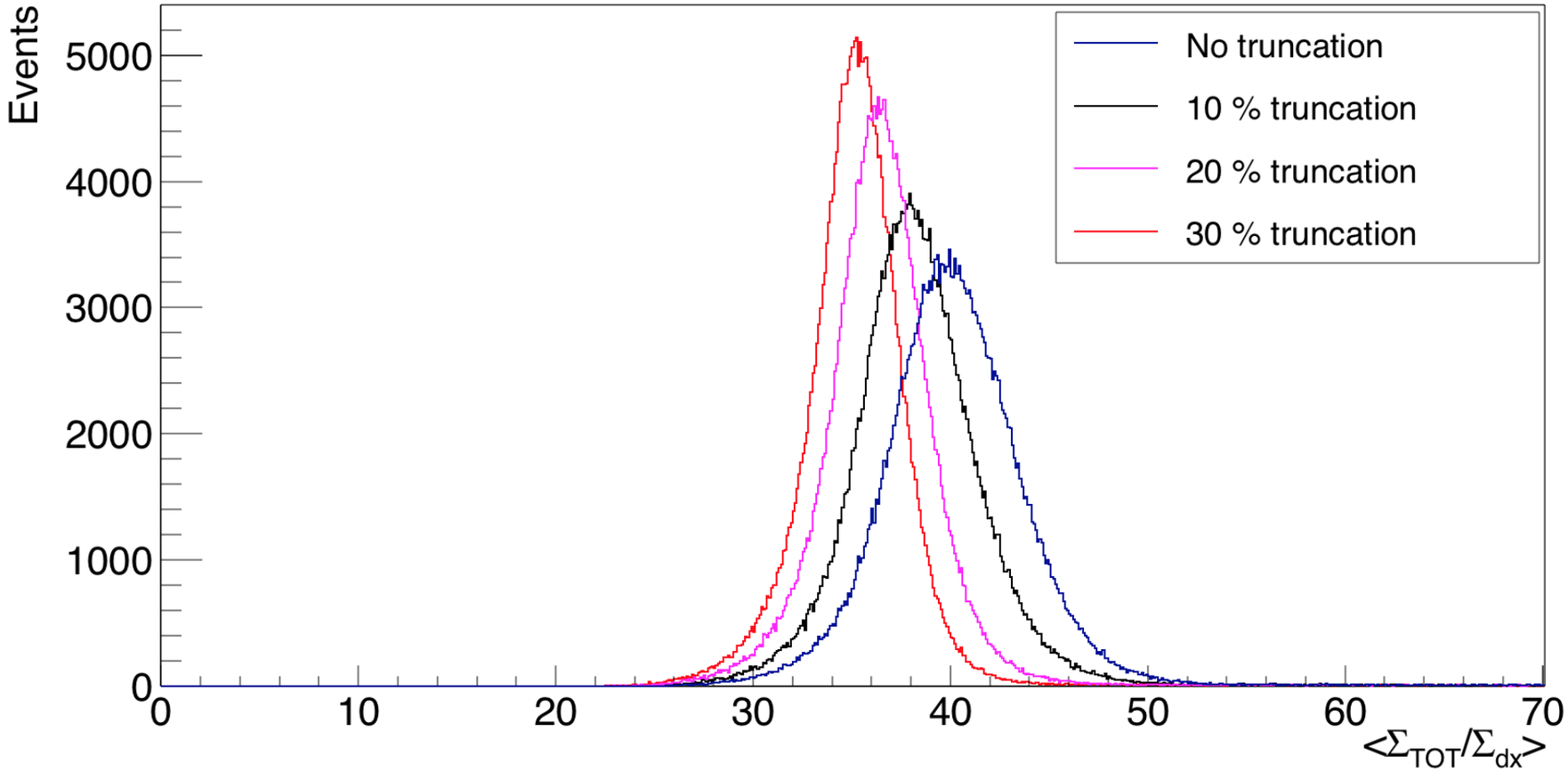

Spatial resolution (μm)
250
200
150
100
50
0
0
0.5
1
1.5
2
2.5
3
p (GeV/c)
Proton beam with clean up
Proton beam without clean up
Deuteron beam

Particle identification (PID)

- For each event: calculate TOT/dx per hit and then, calculation of Σ_{TOT}/Σ_{dx} per event

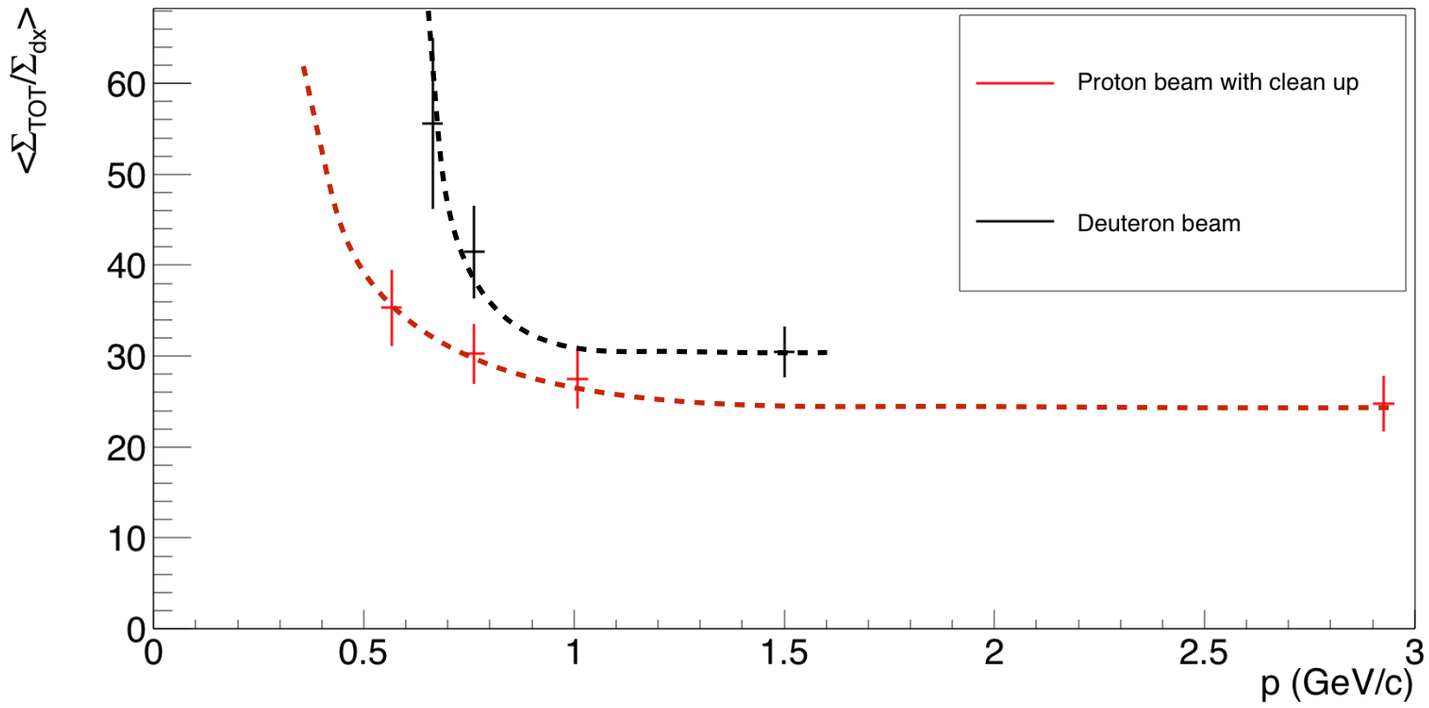
- Depending on the truncation: remove hits with the largest TOT/dx values and then, calculation of Σ_{TOT}/Σ_{dx} per event

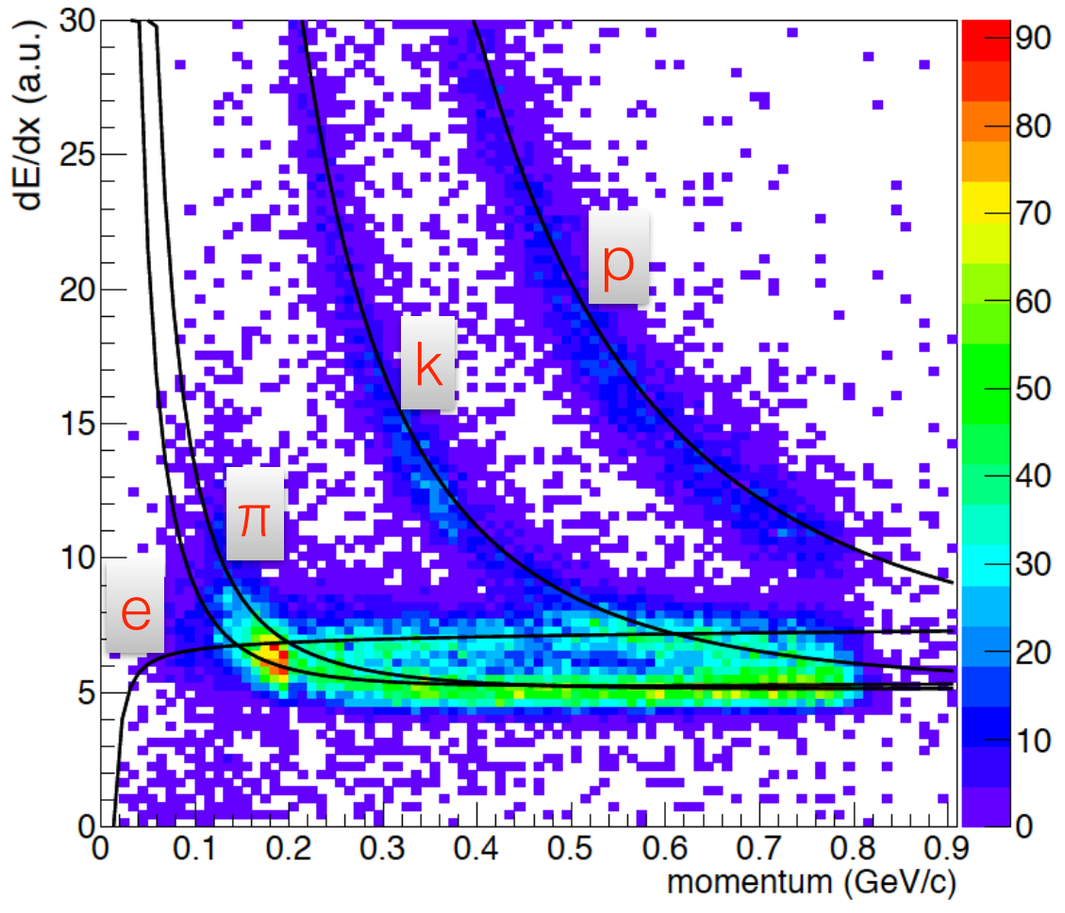
Improve resolution!



Protons: 5.5% - 8%

Deuterons: 5% - 7%





Conclusions and outlook

First tests performed with a prototype STT
Several problems with the readout
Spatial resolution is good
PID method is promising

More tests are planned

Position re-alignment
Calculation of the r(t) per straw

Larger setup+readout decision