STT DATA ANALYSIS RESULTS

STRAW EFFICIENCY

23.06.2020 I GABRIELA PEREZ

PANDA COLLABORATION MEETING

OUTLINE

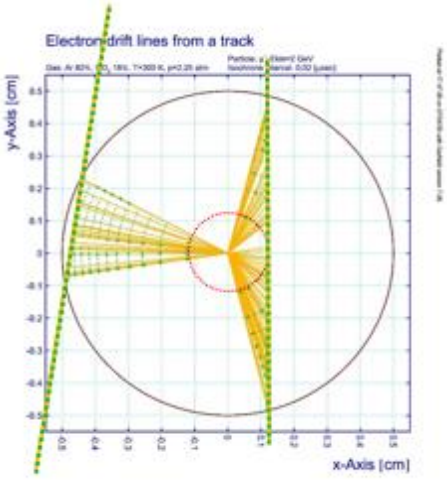
- Testbeams at COSY
- Calibration/tracking method overview
- Straw radial efficiency
- Summary

TESTBEAMS AT COSY

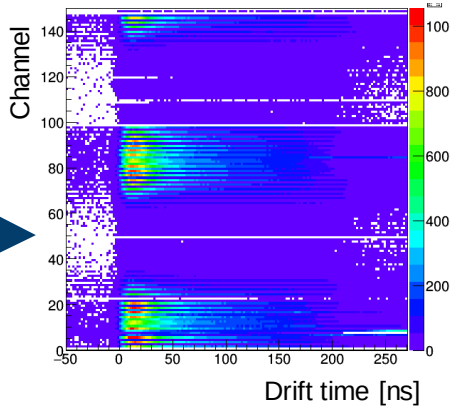
- Setups with 24 straws per layer:
  - Particle tracks with > 24 hits simmilar to PANDA STT case
- Proton and Deuteron beams
- Momentum range: 0.5 - 3.0 GeV/c
- Ar/CO2 gas mixture

- Raw data:
  - Channel ID (i_{chann}, , i_{straw}, i_{layer})
  - Time information (t_{LE}, t_{TE})
  - Signal pulse width ($ToT = t_{TE}$-t_{LE})

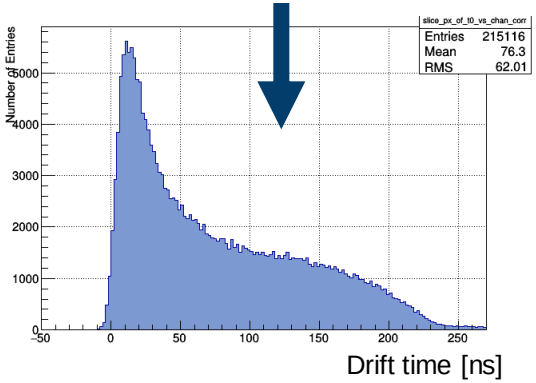
- The straw radial efficiency was obtained for 3 proton datasets at different beam momenta.



Drift path of electrons from the particle's path to the anode wire

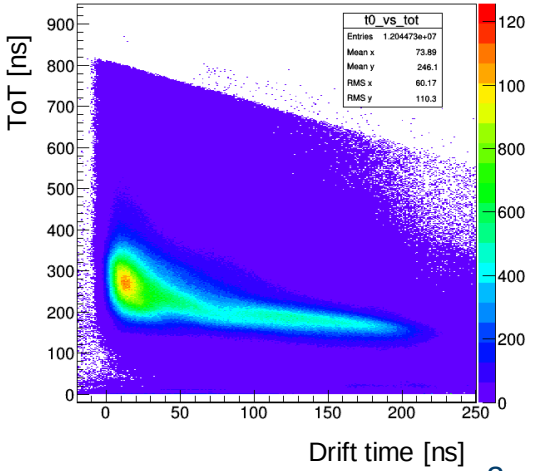


Drift time spectra

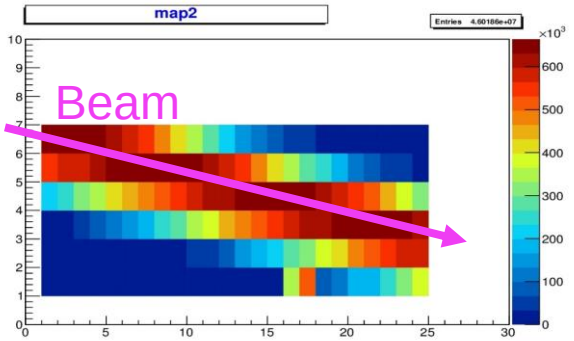


Drift time spectrum of a single channel

One of the two straw test systems.



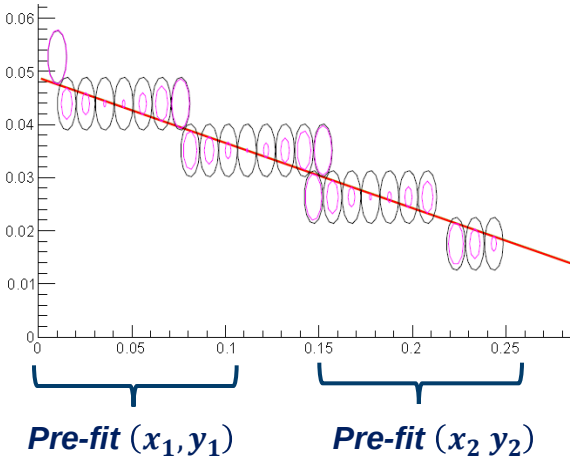
SELF-CALIBRATION



i. Isochrone parametrization

$$\frac{N_{Total}}{R} = \frac{\sum_{t_{min}}^{t_i} N_i}{r(t_i)} \rightarrow r(t_i) = (r_{tube} - r_{wire}) \times \frac{\sum_{t_{min}}^{t_i} N_i}{N_{Total}} + r_{wire}$$

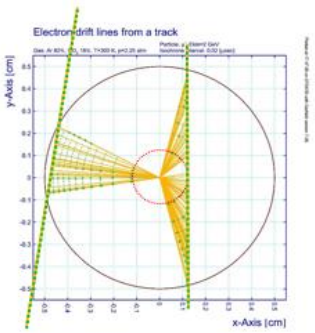
ii. Determination of straws center position : using channel ID information (i_{straw}, i_{layer}).

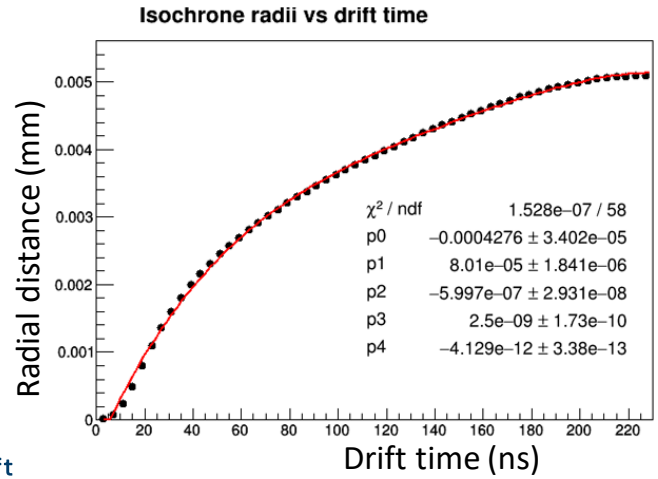


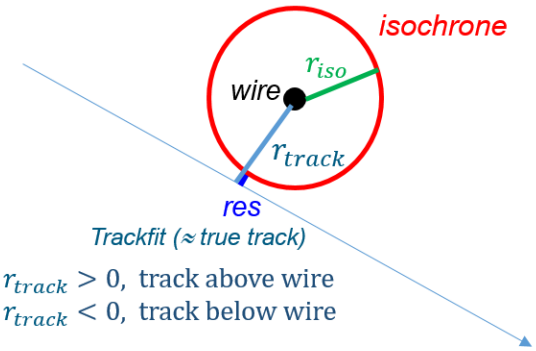
iii. Tracking and systematic error correction (due to *e.g.* gravitational sag):

i. Residuals minimization by *Iterative process*

ii. Single outlier rejection throughout method



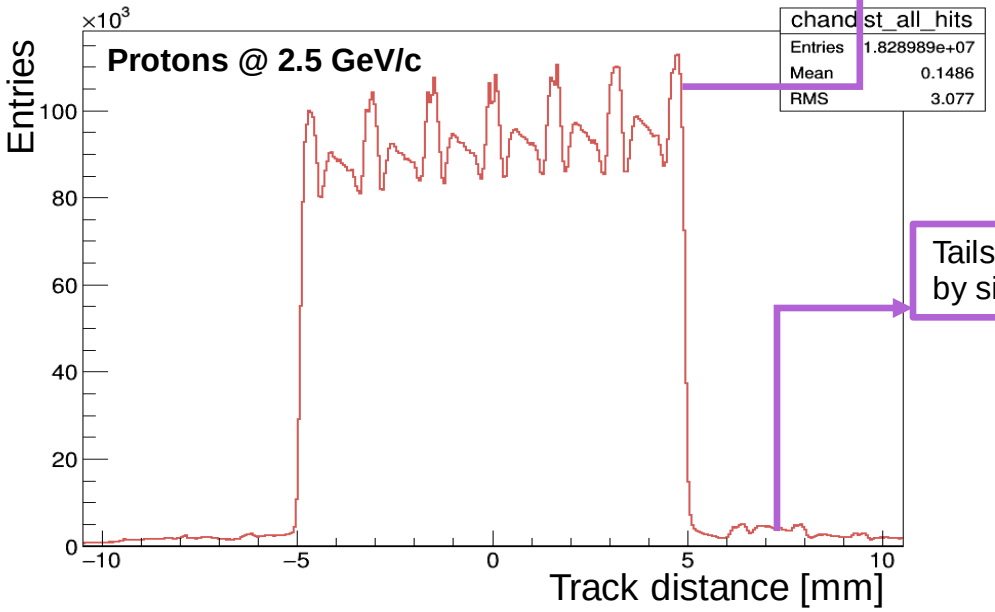




STRAW EFFICIENCY

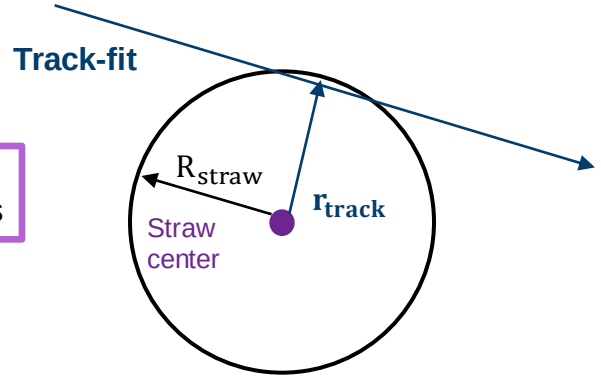
- **AIM:** To compare how many hits are expected vs how many are registered.
- Tracking is performed (up to 8 iterations).
- The **allowed maximum distance** from the straw center to the track is determined from the r_{track} **distribution**. The threshold is defined as the maximum bin content.
  - i. The active straw diameter can be defined by the ~ 70 – 80 % threshold (before straw wall)
  - ii. The total straw diameter can be defined by the ~ 5 – 10 % threshold (including straw wall)
  - iii. An average between i. and ii. is chosen as the **allowed maximum distance** for a hit:

Average Straw Radius		
R (left) [mm]	R(right) [mm]	Diam [mm]
-4.962	5.013	9.975



Fraction of narrow pencil beam at specific angle on top of broader beam distribution with broader angular region. Given the efficiency definition, this shape wont affect the final value.

Tails are mainly caused by single noisy channels



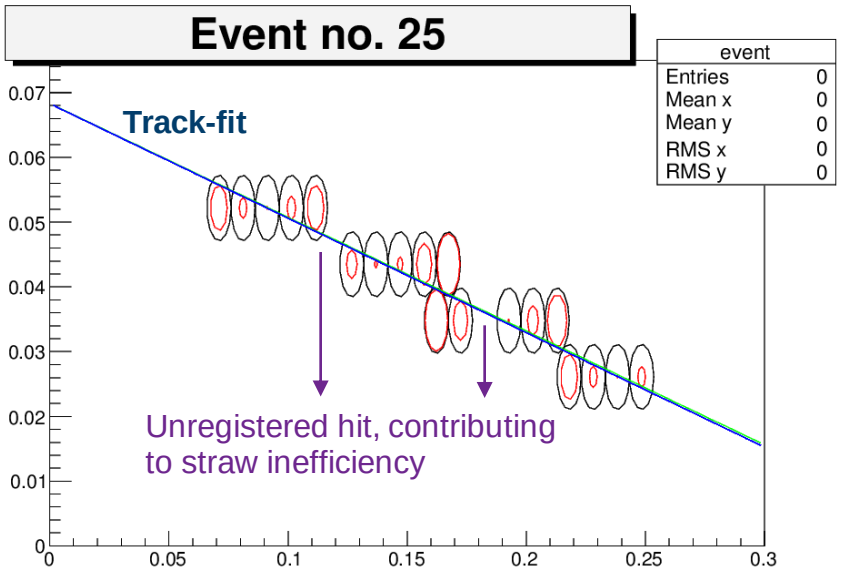
Straw parameters	
Inner diameter	Straw pitch
10.00 mm	10.14 mm

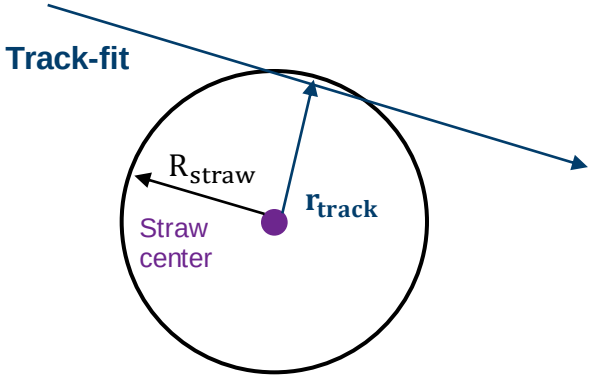
STRAW EFFICIENCY

- For each event, the number of expected hits within the **allowed maximum distance** is defined as $N_{expected\ hits}$.

- For each expected hit, one checks if there is a drift time registered in same channel within a 250 ns window. This is defined as $N_{registered\ hits}$.

- The **straw radial efficiency** is obtained dividing the track distance distribution from the $N_{registered\ hits}$ by the one from the $N_{expected\ hits}$.



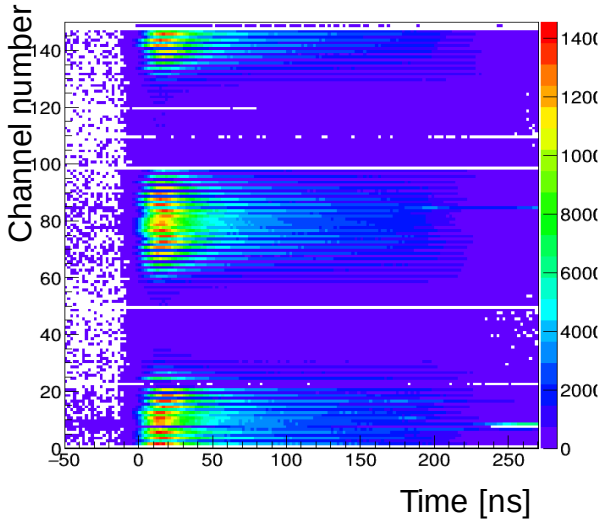


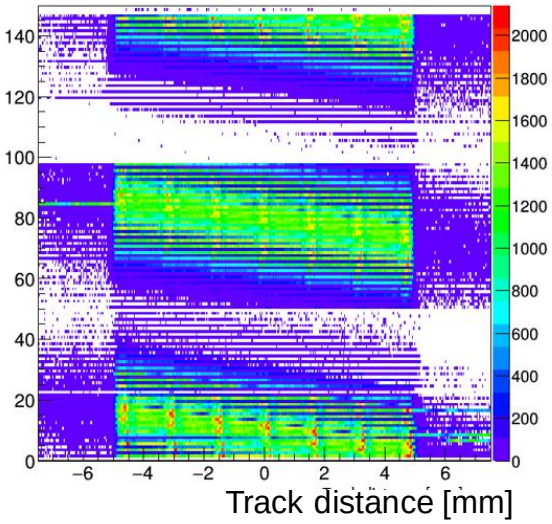
- **Single faulty straws are removed from this efficiency study since the main interest is the typical, characteristic straw efficiency.**

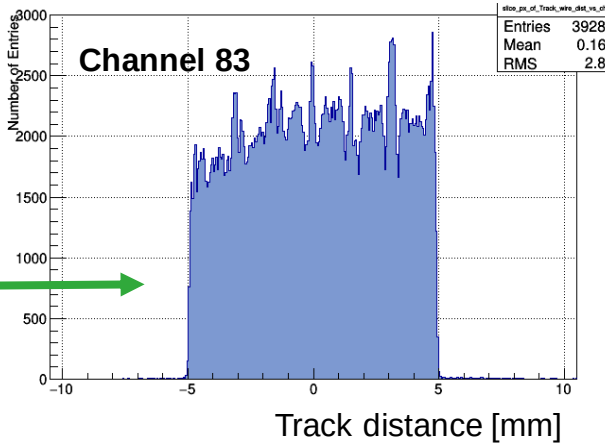
Single faulty straws (e.g. improper ASIC set parameter, causing afterpulse/improper drift times) are identified based on:

- Drift time spectrum
- r_{track} distribution

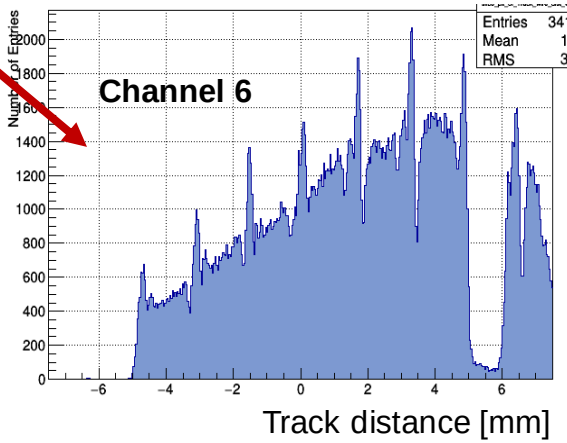
7 channels (out of 150) are taken out from the efficiency calculation.



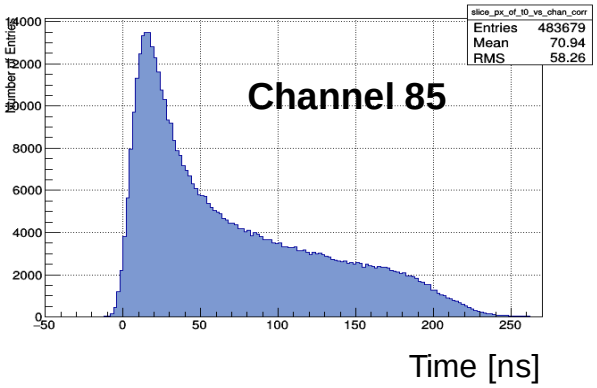




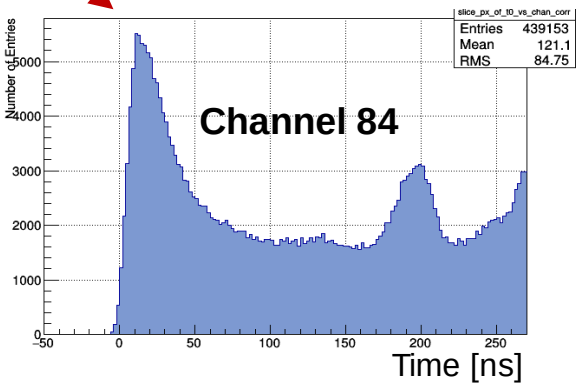
Expected track distance distribution



Not expected track distance distribution

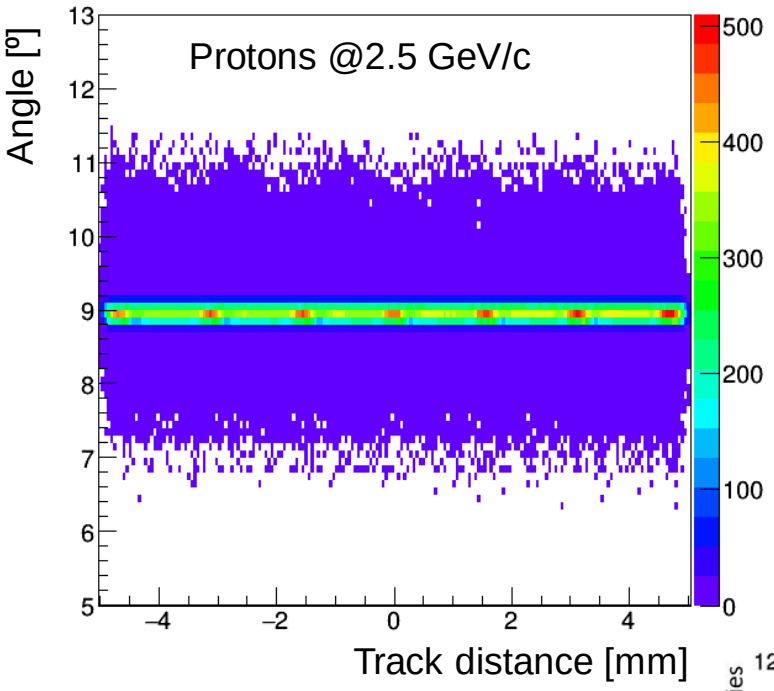


Expected drift time spectrum



Not expected drift time spectrum

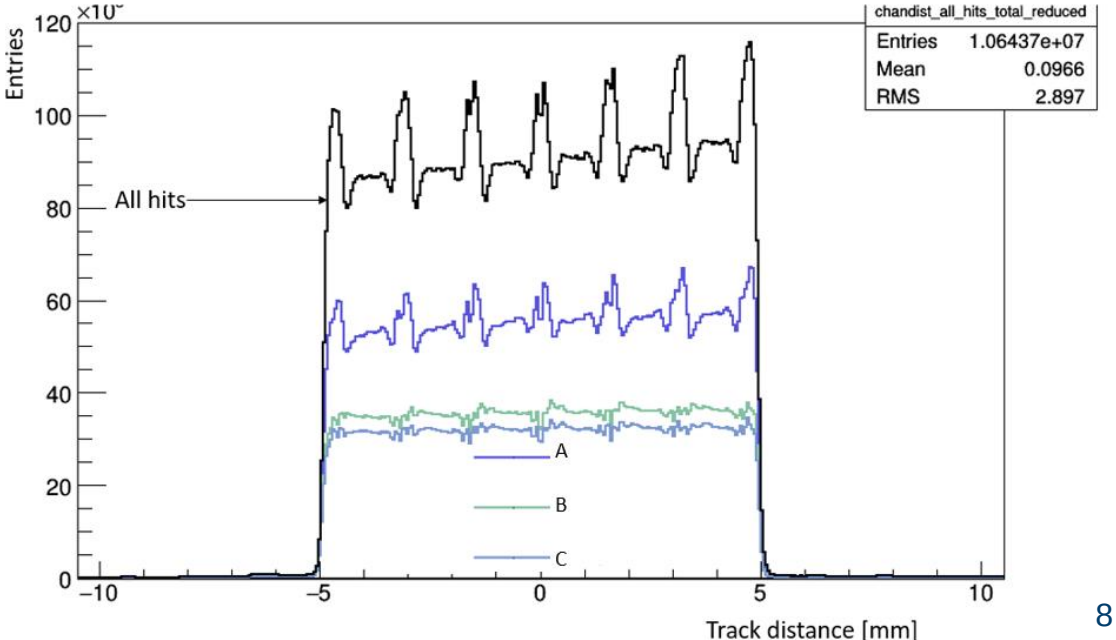
Track distance (r_{track}) distribution pattern



- Fraction of narrow pencil beam at specific angle (~ 8.9 ° in 2.5 GeV/c case) on top of broader beam distribution with broader angular region.
- Distribution can be smoothened by applying an angle cut.
- Angle cut is applied to get more uniform distribution for the radial efficiency determination.

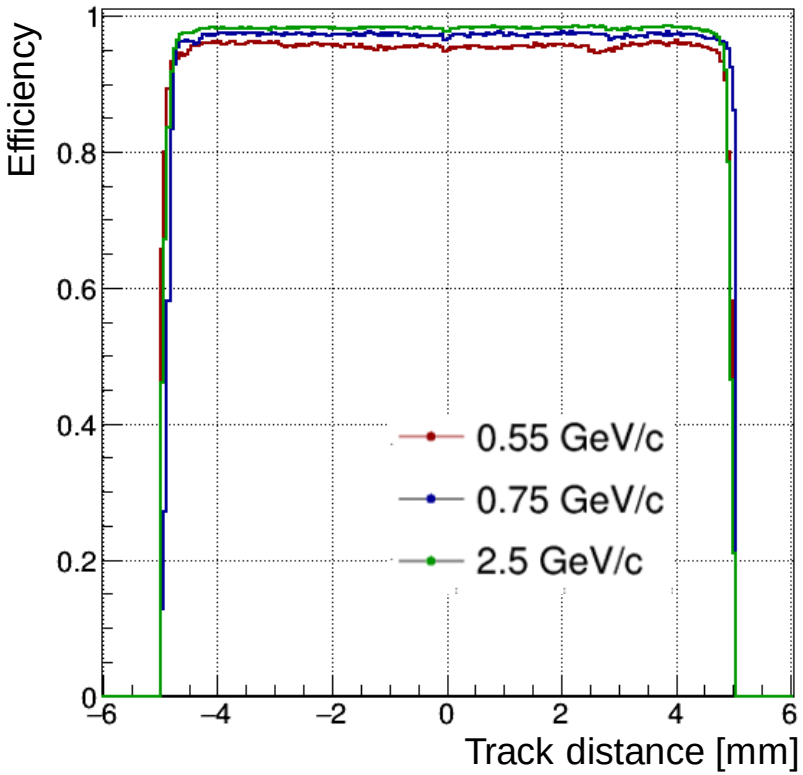
Angle cut:

A) 8.9° < Angle < 9 °
B) 8.8° < Angle < 9 °
C) 8.7° < Angle < 9 °



STRAW RADIAL EFFICIENCY

- Obtained from dividing the track distance distribution obtained from the $N_{registered\ hits}$ by the one obtained from the $N_{expected\ hits}$.



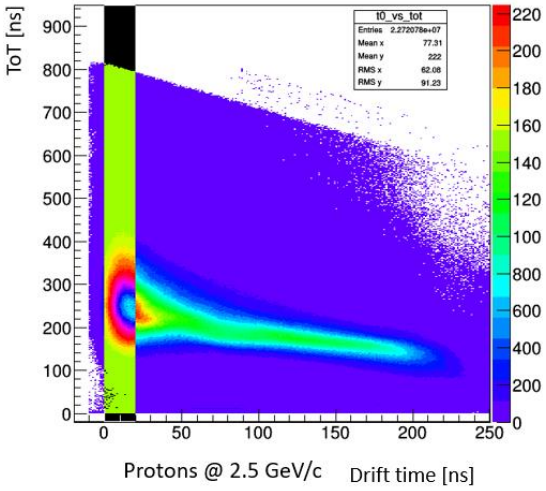
Proton datasets	
Mom [GeV/c]	Average radial efficiency
2.5	98%
0.75	97%
0.55	95%

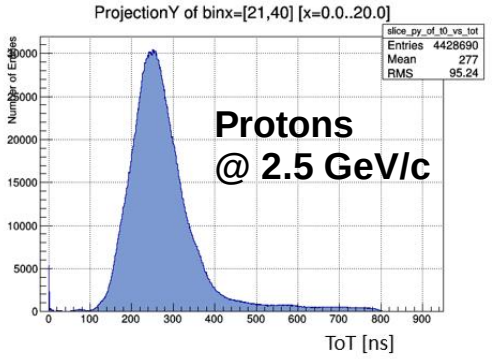
Table. Average efficiency comparison between proton datasets.

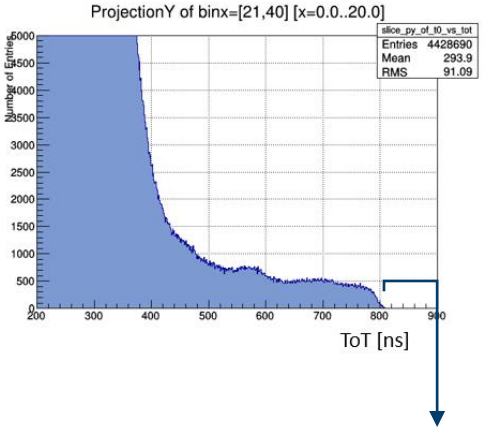
1. The efficiency is underestimated due to effects such as finite track resolution (~ 100μm) and slight errors in the tube positions (reco track inside of straw but in reality it is outside) .
2. The drop towards the straw edge is attributed to smaller number of produced ionisation electrons (*i.e.* shorter track length).
3. Active/efficient max. straw radius is about 4.95 mm for minimum ionizing protons.
4. Unexpected lower efficiency results for lower beam momenta datasets. Explanation by signal readout TDC time window limit on next slide.

STRAW RADIAL EFFICIENCY

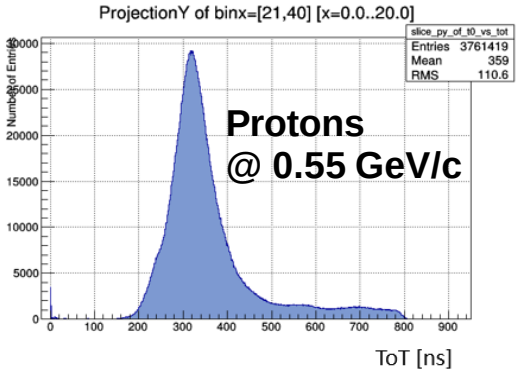
- A hit is registered only if both t_{LE} and t_{TE} are within the read out time window.
- Hits with long t_{TE} (*i.e.* large ToT) surpassing the read out time window are lost.
- Signal widths on average are broader for the lowest momentum dataset, therefore the hit loss is bigger in this case.
- Inefficiency due to cutoff is about (1-5)%, depending upon the beam momentum.

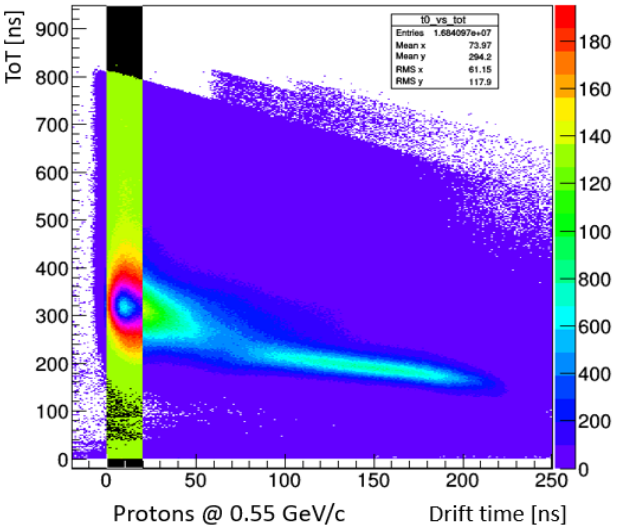


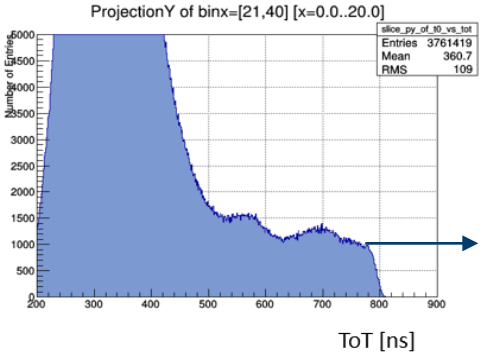




~ 500 entries







~ 1,000 entries

SUMMARY

- The straw radial efficiency has been determined for 3 proton datasets.
- Even though a good efficiency has been achieved, it could be underestimated because of the finite track resolution (~ 100μm) and slight errors in the tube positions (reco track inside of straw but in reality it is outside).
- These efficiency results includes the whole readout chain, *i.e.* efficiency losses could be included by electronic readout.
- Lower hit efficiency at lower beam momentum caused by the TDC time window limit.
- The active/efficient max. straw radius is 4.95 mm for minimum ionizing protons.
- Efficient straw diameter is 9.91 mm for 2.5 GeV/c protons and 9.975 mm for 0.55 GeV/c protons. This is comparable with 10.00 mm inner straw diameter and 10.14 mm straw pitch

THANK YOU
QUESTIONS?

BACK UP

SELF-CALIBRATION

iii. Tracking and systematic error correction :

i. Pre-fit line using positions of fired straws.

ii. $r(t_i)$ calculation for each hit.

iii. Track residuals definition: $r_{res} = |r_{track}| - r_{iso}$

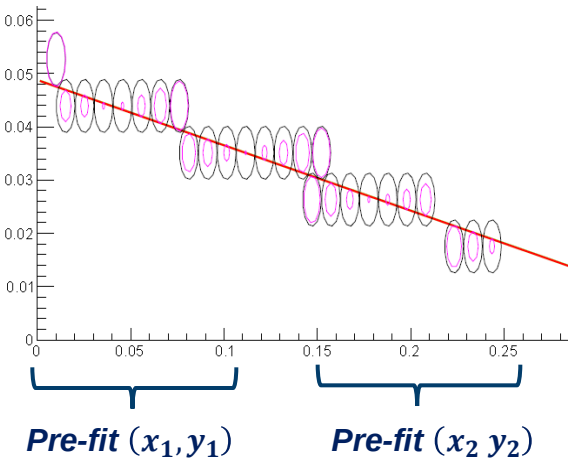
iv. Best line fit through residuals minimization:

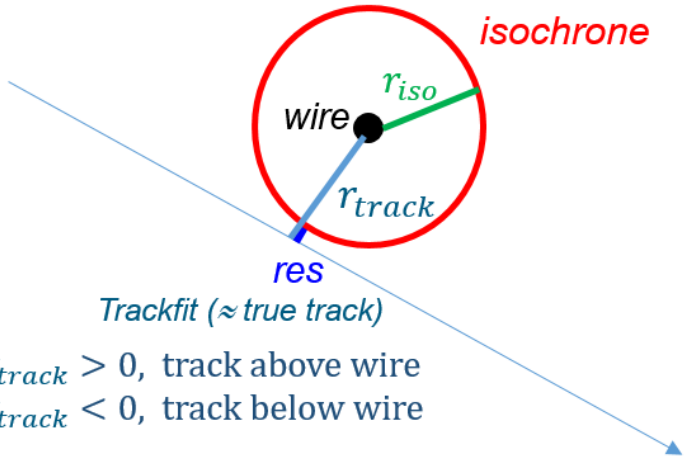
$$\frac{\chi^2}{ndf} = \left(\frac{1}{n_{hits} - 2}\right) \sum_{n=1}^{n_{hits}} \frac{r_{res}^2}{\sigma_{iso}^2(r)}$$

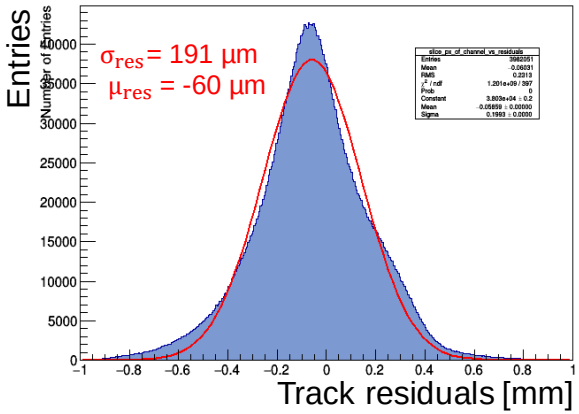
v. Single outliers rejection:

- i. If $|r_{track}| < 900$ µm
- ii. If distance $|r_{track}| > 2.5 \times \sigma_{iso}(r)$
- iii. Maximum number of outliers < 8

vi. Spatial resolution defined as the width of residuals distribution $\boldsymbol{\sigma_{res}}$.







JÜLICH Forschungszentrum

SELF-CALIBRATION

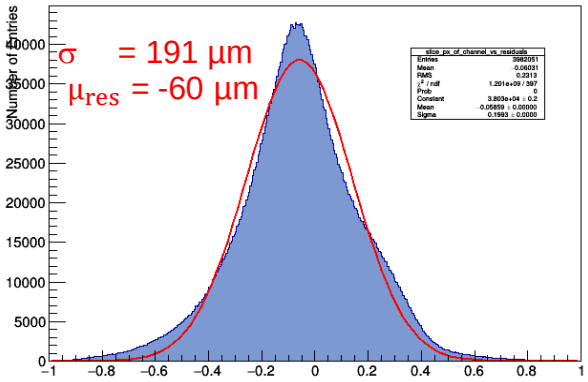
vii. Systematic error determined by residuals distribution mean $\boldsymbol{\mu_{res}}$

viii. Correction by shifting the isochrones parametrization:

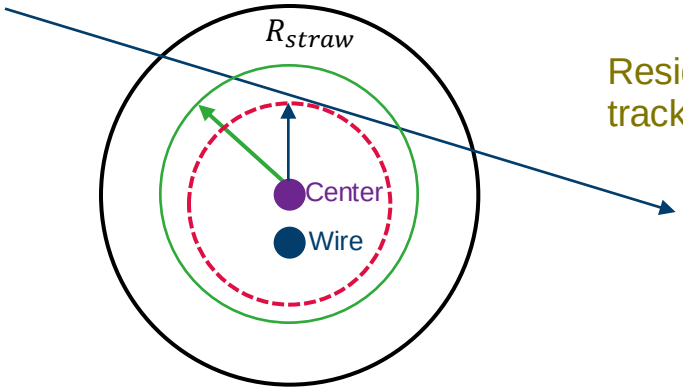
$$\mathbf{r_{new} = r(t_i) + \mu_{res}}$$

i. Re-fit using new isochrones $\mathbf{r_{new}}$

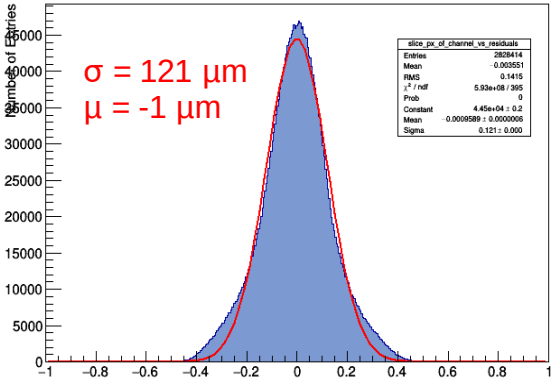
ii. Iterative process until residual distribution shift is negligible, *i.e.* $\boldsymbol{\mu_{res} \sim 0}$



$$r_{res} = |r_{track}| - r_{iso} < 0 \rightarrow \mathbf{r_{new} < r(t_i)}$$



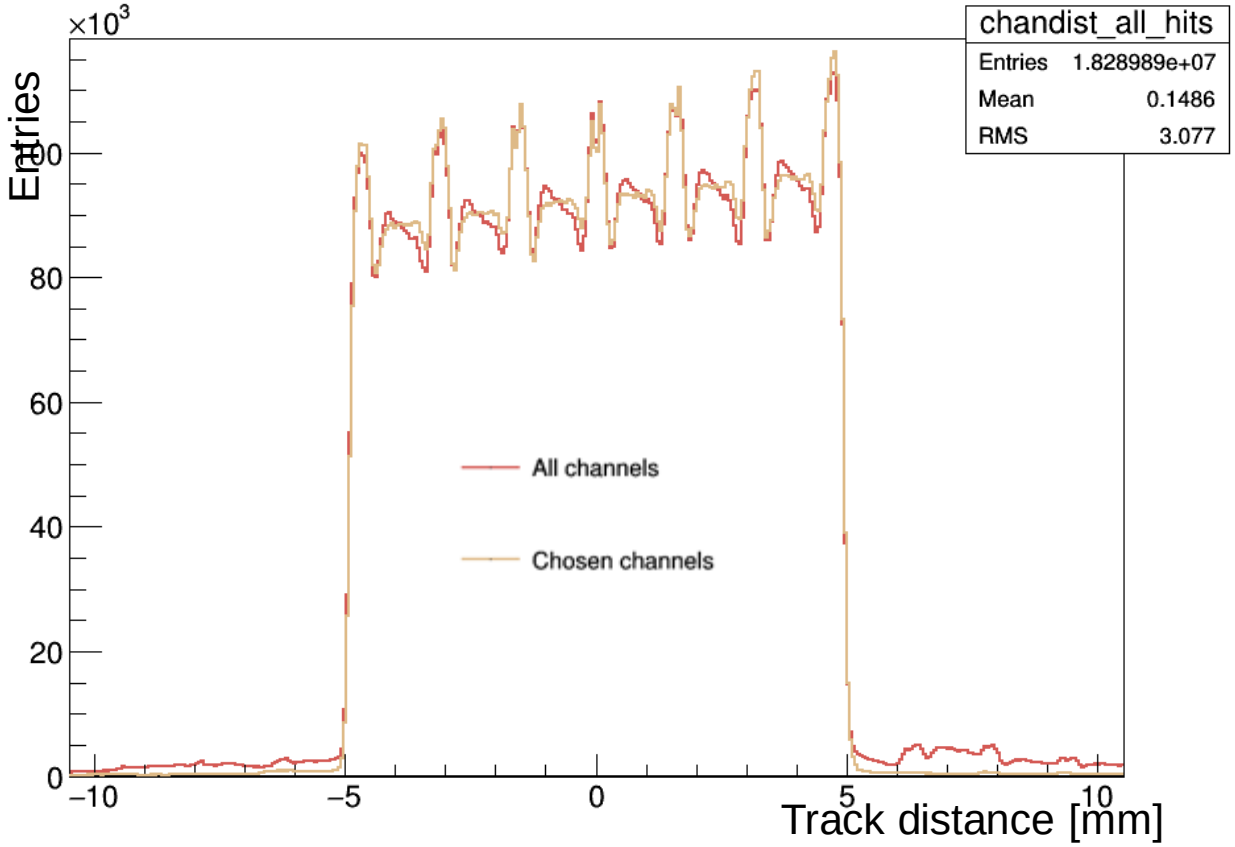
Residuals separately calculated for tracks above and below the wire !



A track crossing ***above*** the ***straw center*** will give ***negative residuals*** and therefore the $r(t_i)$ correction yields a ***smaller isochrone radius***

- At ~ 6 iterations, the resolution value stabilizes
- Final resolution in general is $\sigma_{r\varphi} < 130$ µm (PANDA design goal of $\sigma_{r\varphi} = 150$ µm)

Protons @2.5 GeV/c



After removing 7 channels (out of 150) :

- Track distance distribution tails have been removed.

STRAW EFFICIENCY PER CHANNEL