LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

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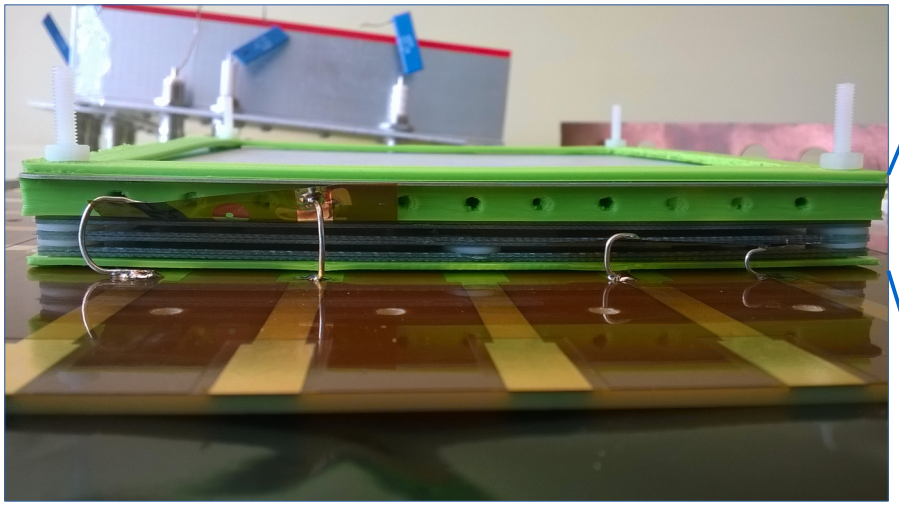
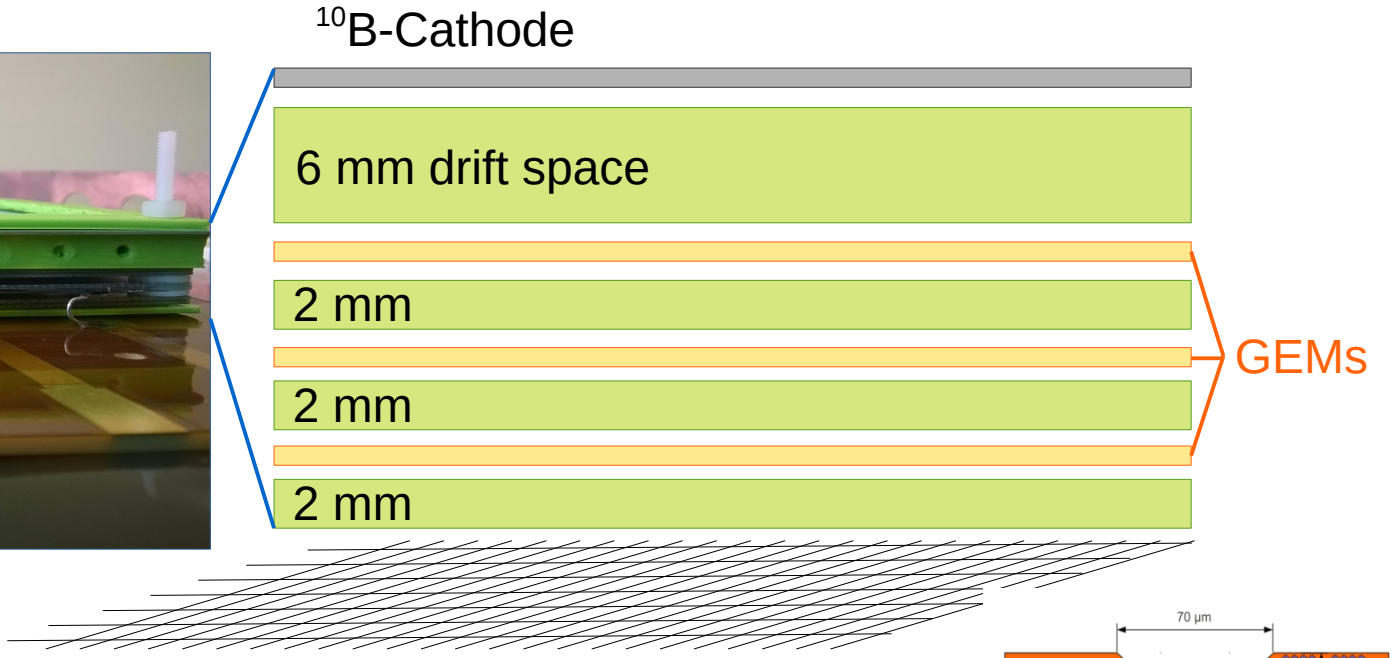
TPC-like analysis for thermal neutron detection using a GEM-detector

13th Pisa Meeting on Advanced Detectors

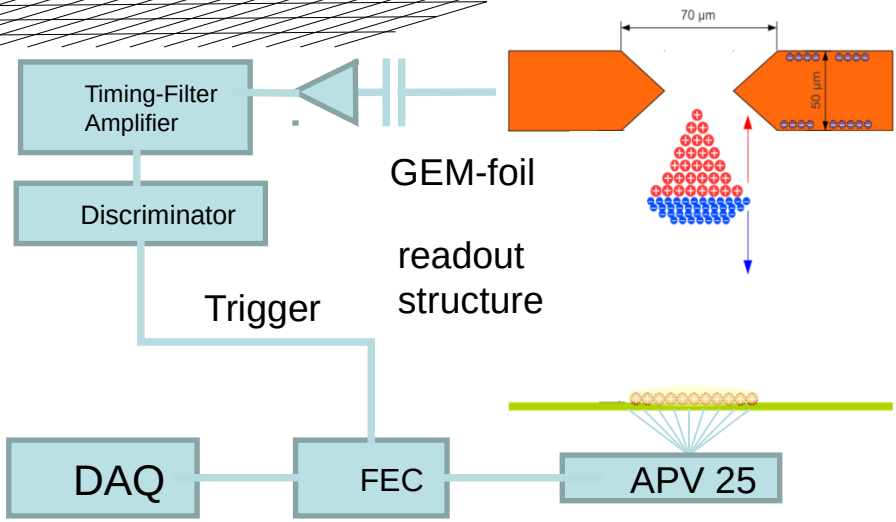
Triple GEM Detector





APV25 readout

- 2 µm ^{10}B-converter cathode *
- 6 mm drift space → active volume of 100*100*6 mm³
- Ar-CO_2 93:7 Vol.% gas mixture
- 3 GEM-foils
- 250 -strips in X and Y direction (0.4 mm pitch)
- 4 APV25 frontend boards, time resolving readout



* Provided by H. Takahashi (Tokyo University)

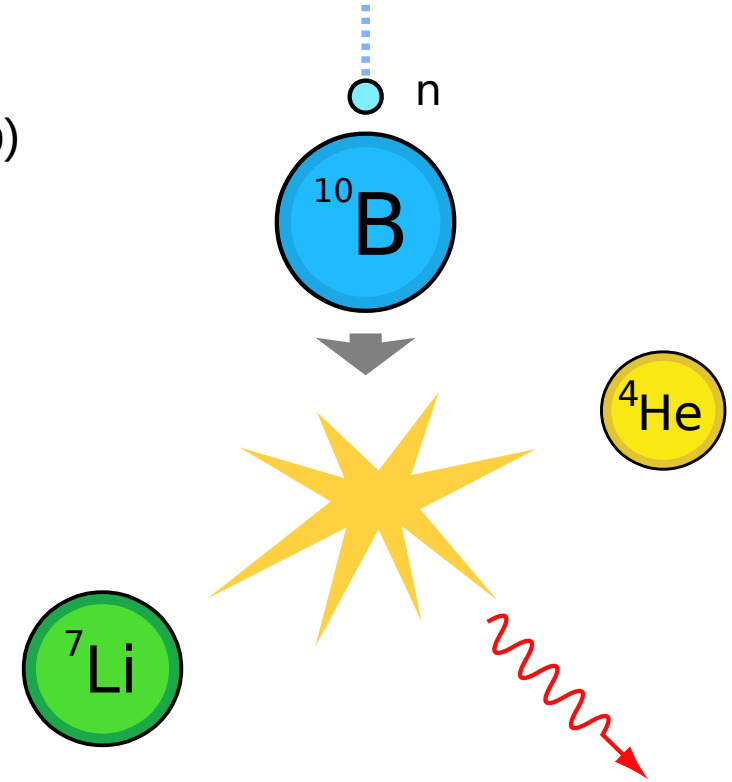
^{10}B Single converter layer

- ^{10}B has high neutron capture cross section (σ= 3835±9 b)

  $^{10}B + n_{th} \rightarrow {}^{7}Li + {}^{4}He + Q(2.8\ MeV)$ (6%)

  $^{10}B + n_{th} \rightarrow {}^{7}Li + {}^{4}He + \gamma + Q(2.3\ MeV)$ (94%)

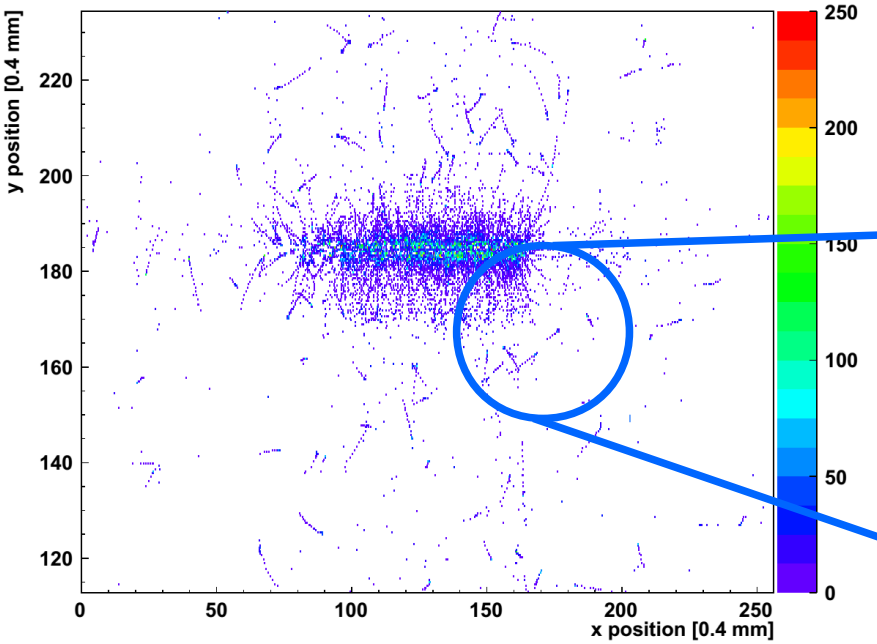
- Li and Helium ions are produced back to back in converter cathode
- Photon can escape detector (detection efficiency < 1%)

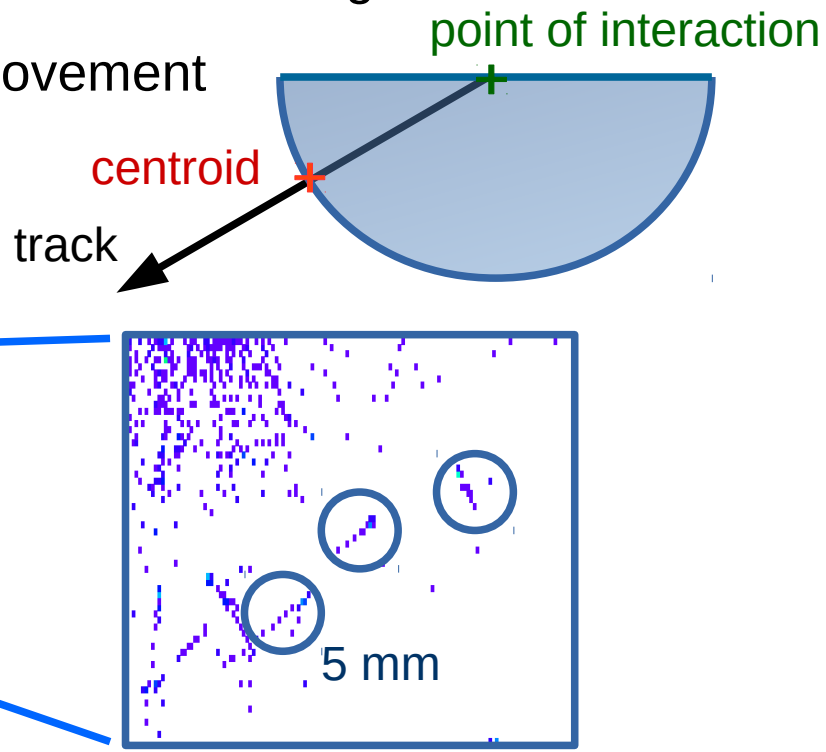


- Ions produce tracks of 4-8 mm in the drift region (energy and ion dependent)
- Detection of one ion with efficiency close to 100 %

Spatial Information

- Ions form straight tracks in the active volume
- Start of track ≙ interaction point in converter foil
- Standard analysis: Centroid method → FWHM ~ 0.8 track length
- Determination of track direction useful for improvement



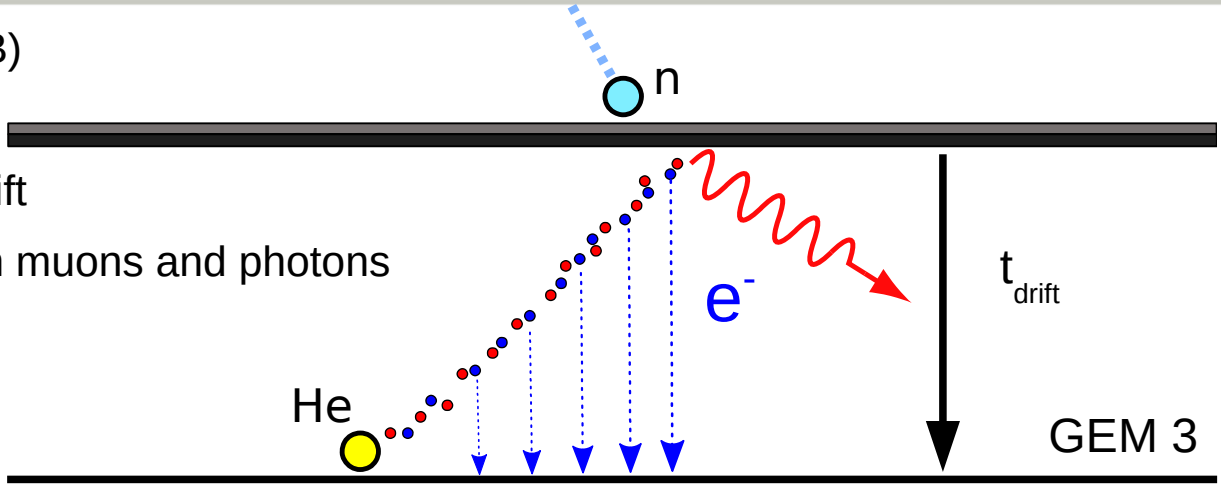


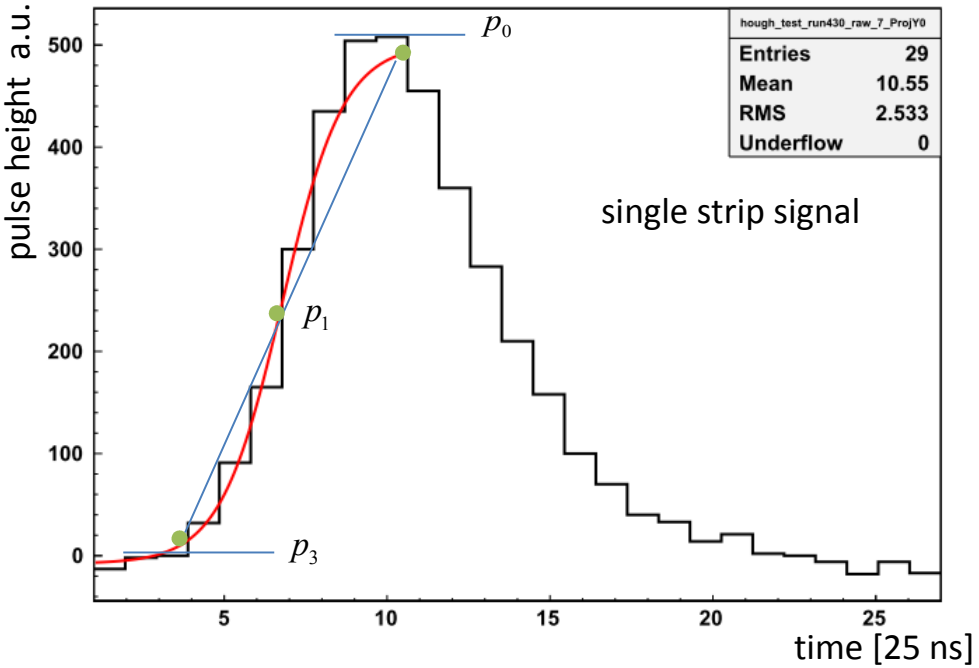
µTPC-Tracking

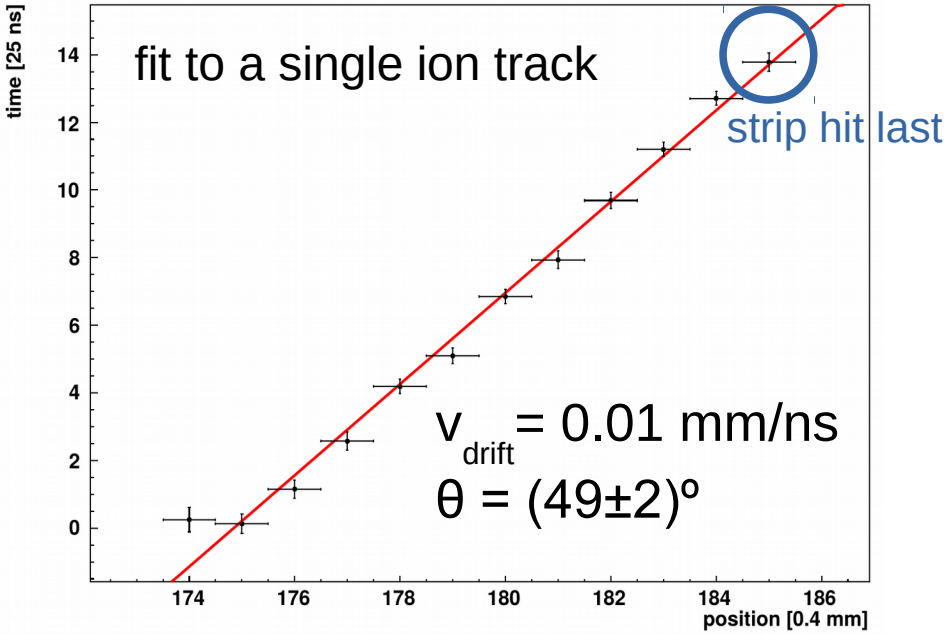
- Z-position fixed by cathode (2 µm of ^{10}B)
- Good time resolution of readout

  → angle of ions determines electron drift
- Reconstruction successfully tested with muons and photons
- Ions slow down very fast (<5 ns)

drift time ~150 ns → z ∝ t

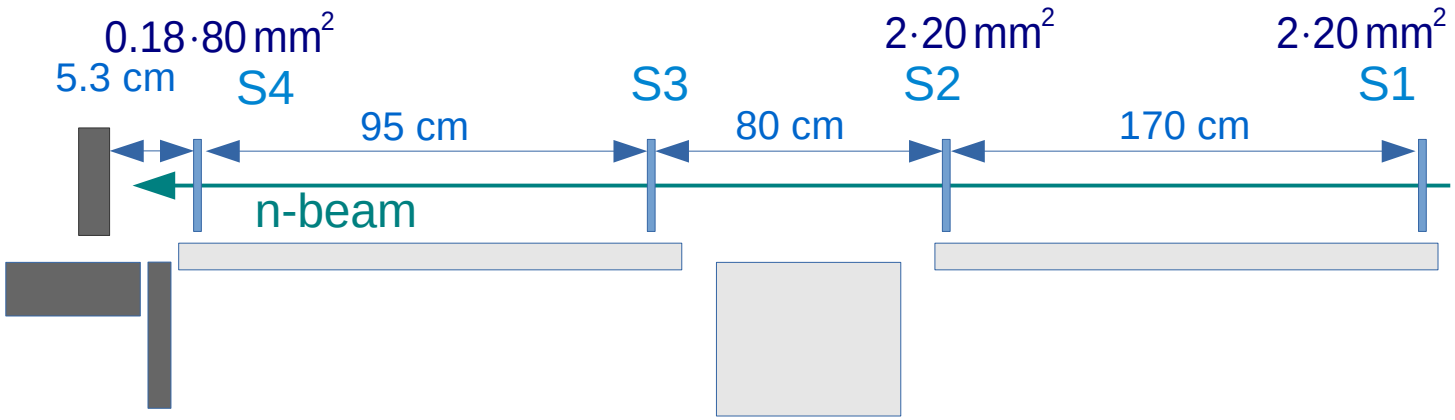






Thermal Neutron Setup

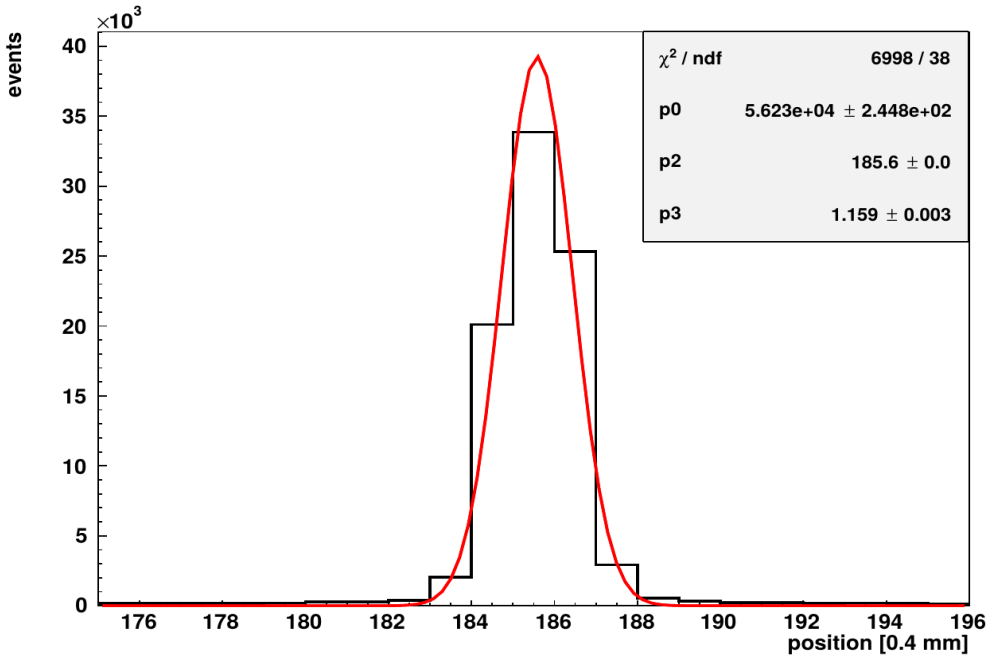
- Determination of spatial resolution at Reasearch Reactor FRM II Garching (October 2014)
- Collimated beam of 4.7 Å neutrons (13.4 meV)
- Total width of beam spot at cathode 250 µm
- 2 µm ^{10}B converter cathode with 7% conversion efficiency

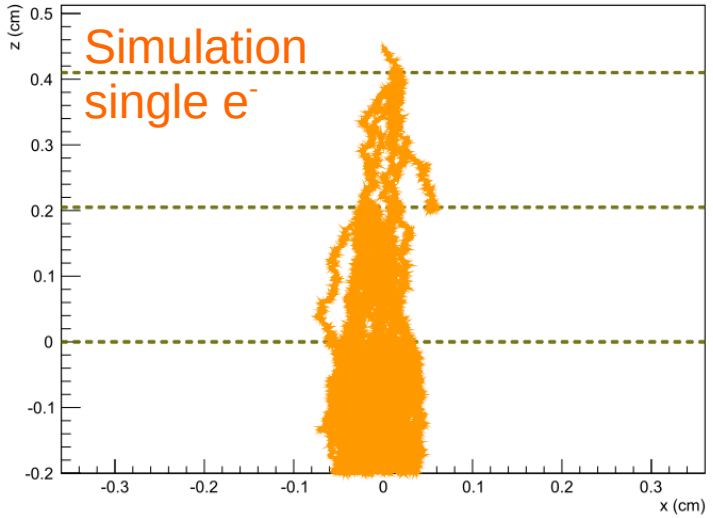


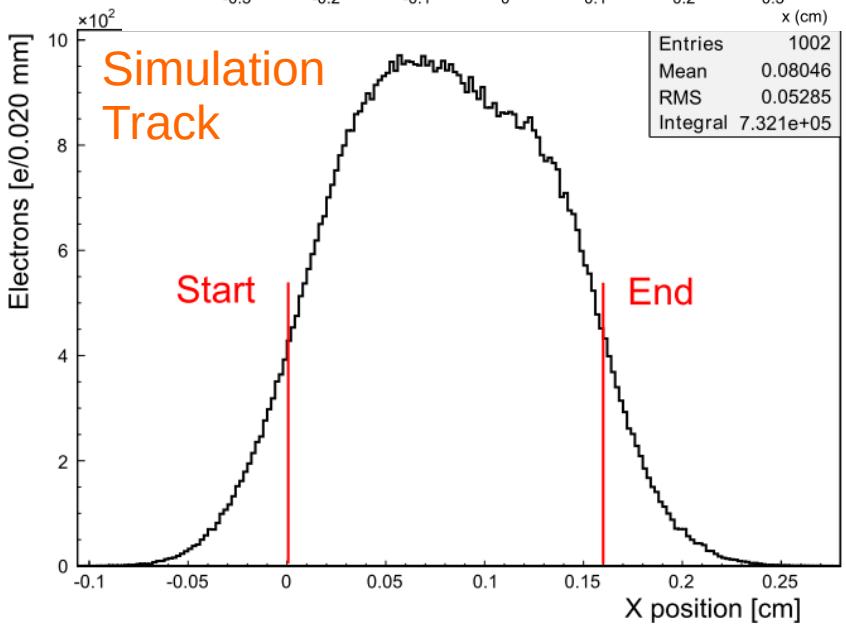
Analysis using Last Strip Info

- Strip last hit drastically improves resolution → 330 µm *
- Charge is spread over about 2 strips for single electron

  → overcompensation of starting point





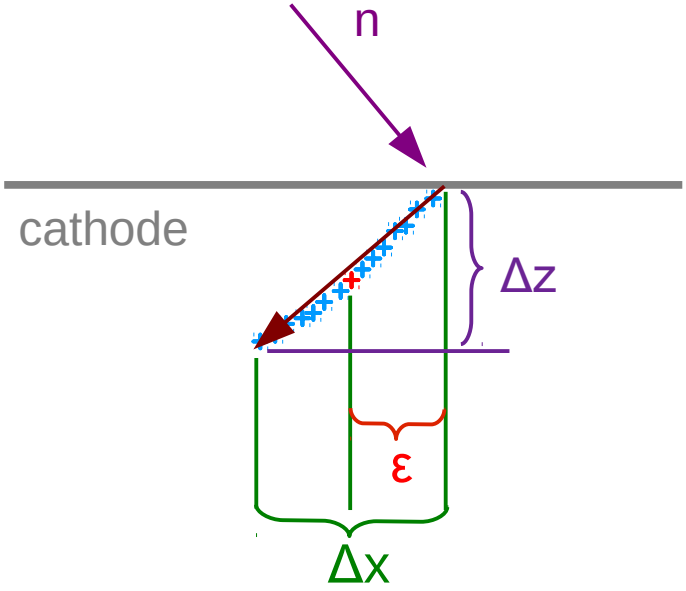


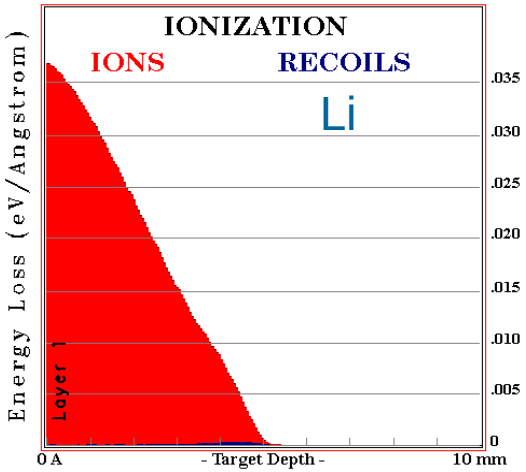
*For single GEM much better resolution (<200µm):

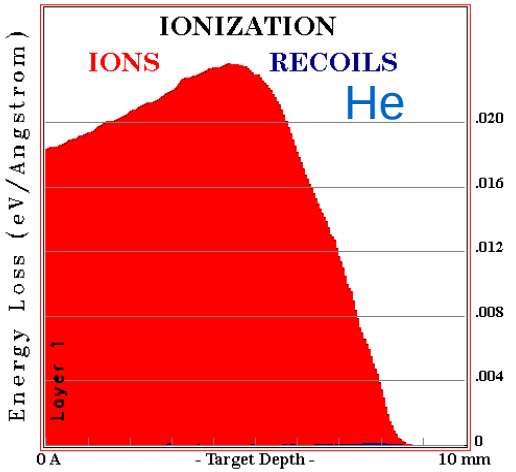
D. Pfeiffer et al., The µTPC Method: Improving the Position Resolution of Neutron Detectors Based on MPGDs, JINST 10 (2015) P04004

µTPC -like Full Reconstruction

- Center of charge position (x_c) is well defined for Li and He tracks
- Start position can be extrapolated if inclination angle of track is known
- $x_0 = x_c + \mathrm{sgn}(\theta)\, \varepsilon\, (\Delta x, \theta, dE/dx)$
- ε is dependent of :
  - Track length (projected)
  - dE/dx along the track
  - Inclination angle







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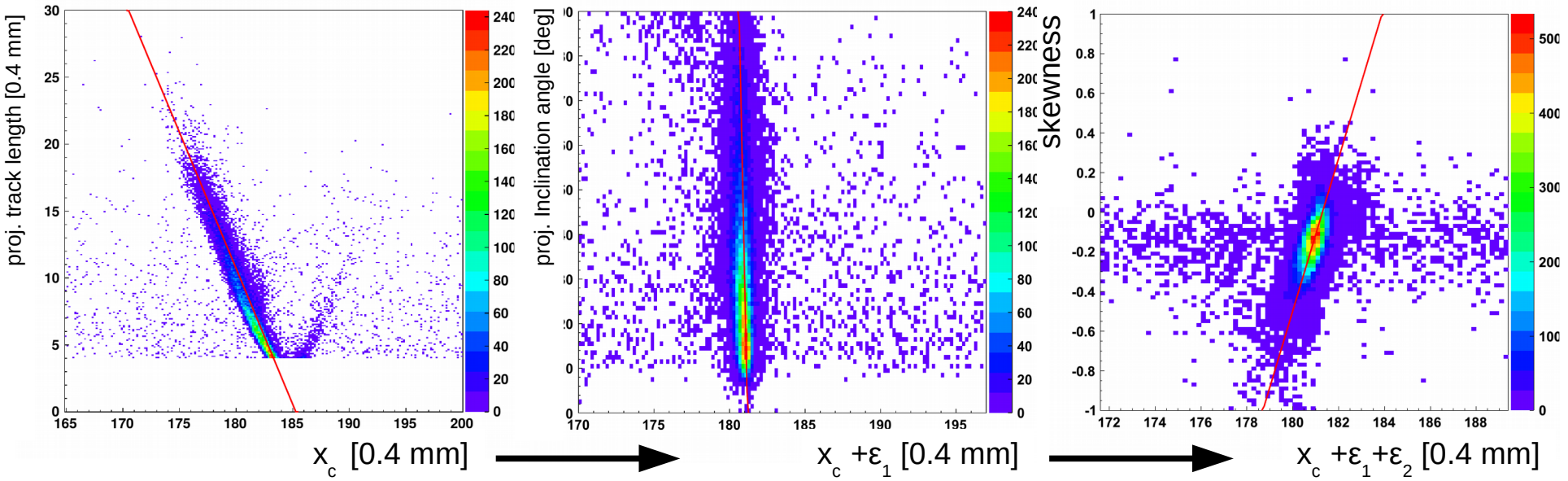


- Correction factor determined by fits to position distributions to length, angle and dE/dx-skewness
- Iterative process, values are not independent from eachother

Resolution Enhancement

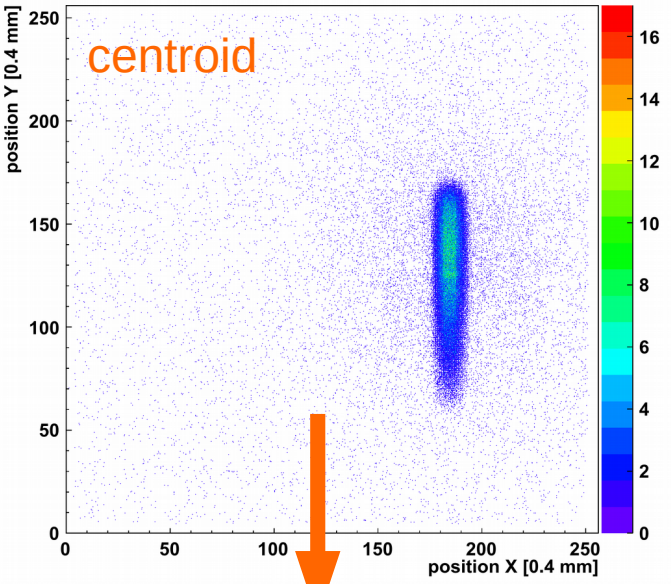
$$\varepsilon(\Delta x, \vartheta, \eta) = (0.31\,\Delta x - 0.0137\,\Delta x^2) + (0.008\,\vartheta) + (1.99\,\eta) + 1.331$$

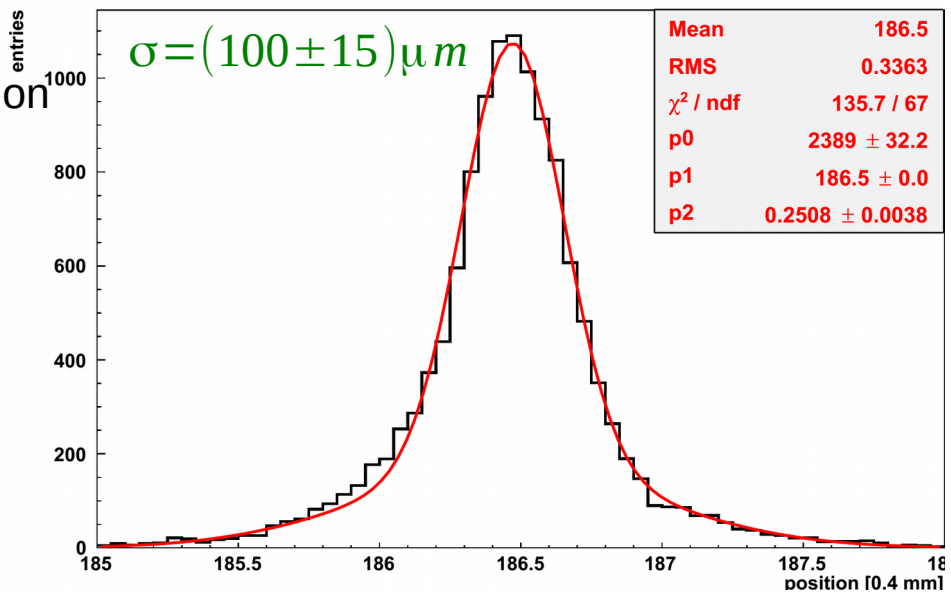
- Spatial resolution in the same order as slit width

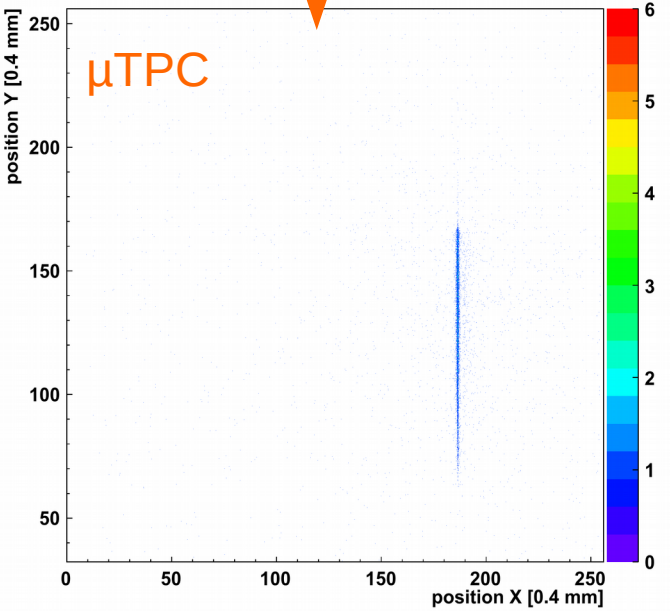
$\Rightarrow$ Convolution of boxcarfunction with Gaussian:

$$f(x) = p_0 \left(erf\left(\frac{a + (x-\mu)}{\sqrt{2}\sigma}\right) + erf\left(\frac{a - (x-\mu)}{\sqrt{2}\sigma}\right) \right)$$

- p_0 :pre-factor
- a: half width of slit
- μ: center of slit
- σ: standard deviation







Summary

- µTPC-principle improves the tracking of the charged products of the $^{10}B+n$ reaction considerably
- The spatial resolution of a GEM-detector for thermal neutrons could be increased from 1.4 mm to 0.1 mm (σ) by self consistent calibration
- The detection efficiency is only slightly influenced by this method, nearly all tracked ions are used in the analysis (80%+)

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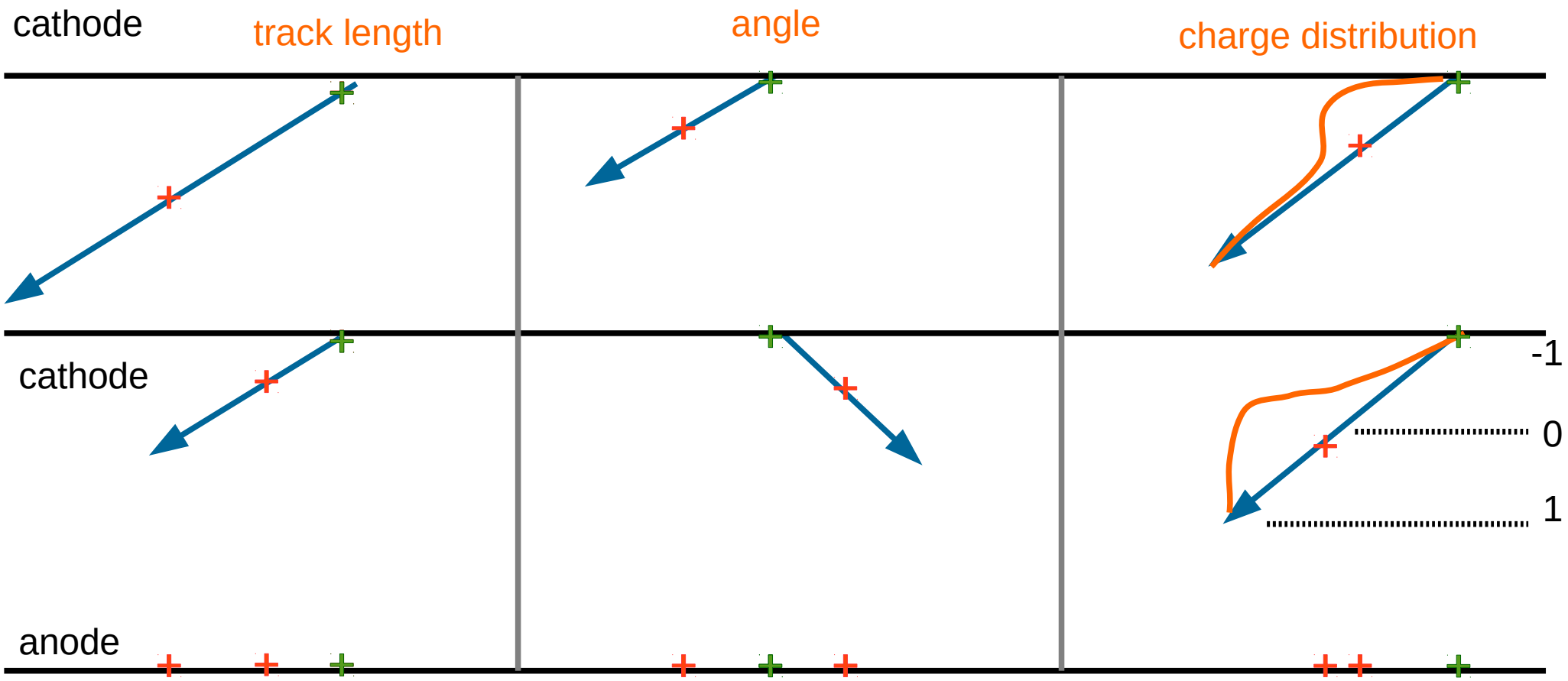
Thank you!

Position Dependencies (proj.)



centroids for different parameters
Interaction point