EP R&D

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t0-less GEM-TPC

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Part of the RD51 Collaboration

GDD Gas Detectors Development Group

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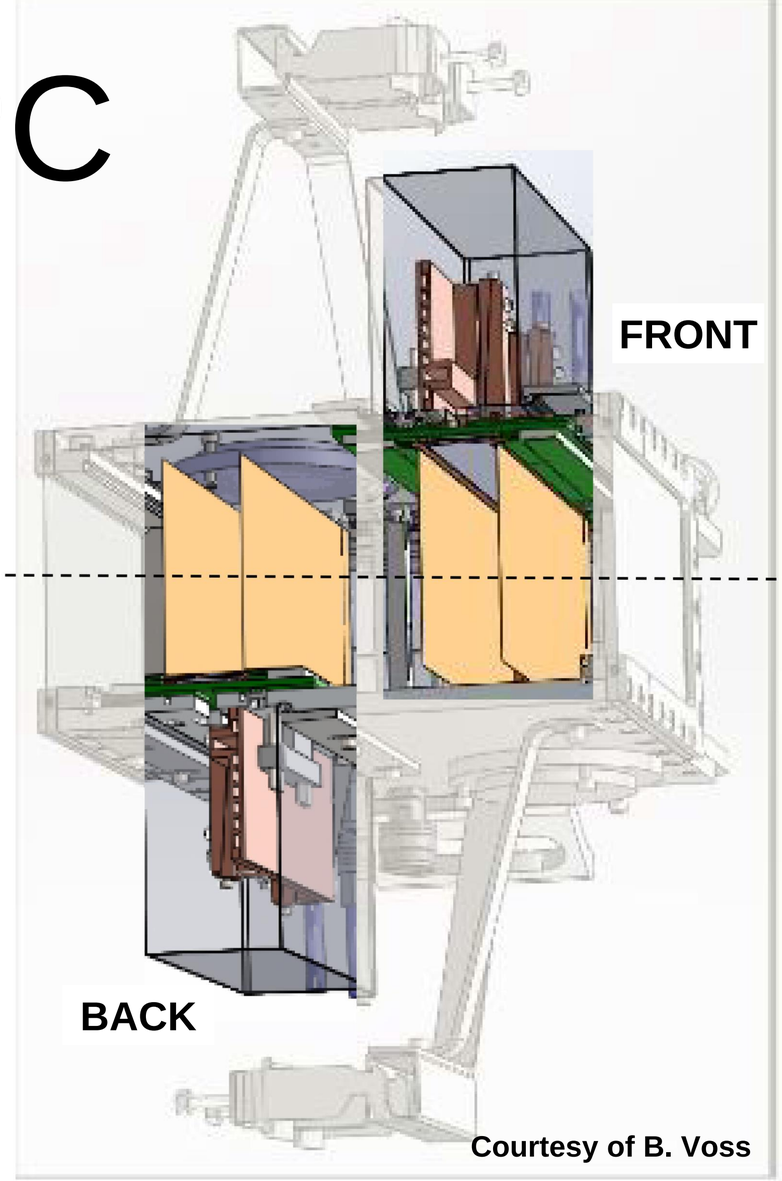
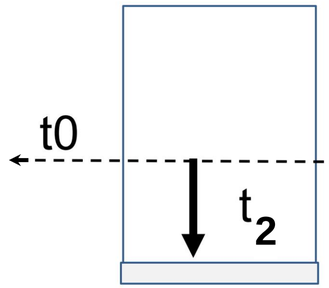
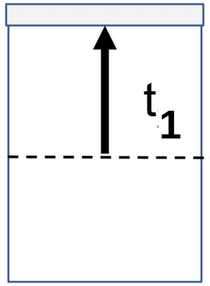
Twin GEM-TPC

F. Garcia et al.: https://doi.org/10.1016/j.nima.2017.11.088

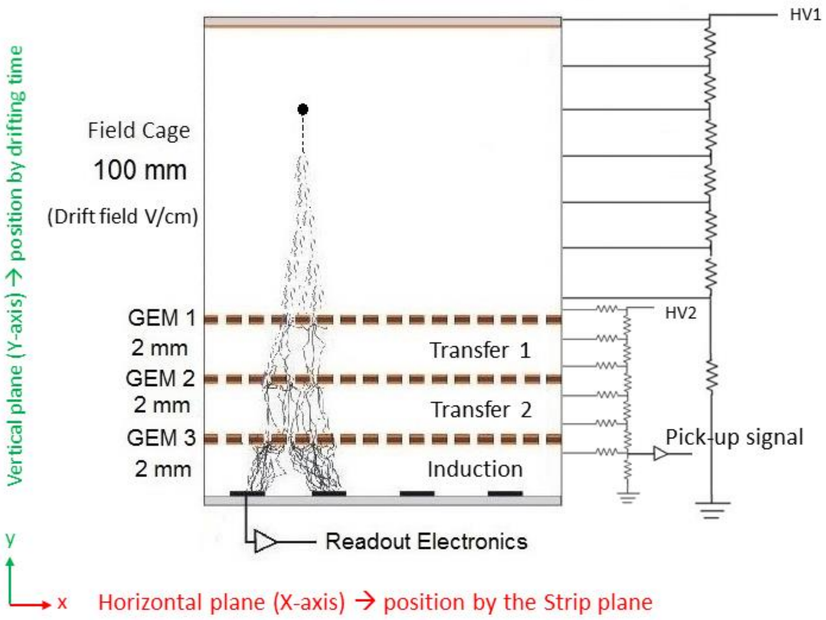


Courtesy of B. Voss





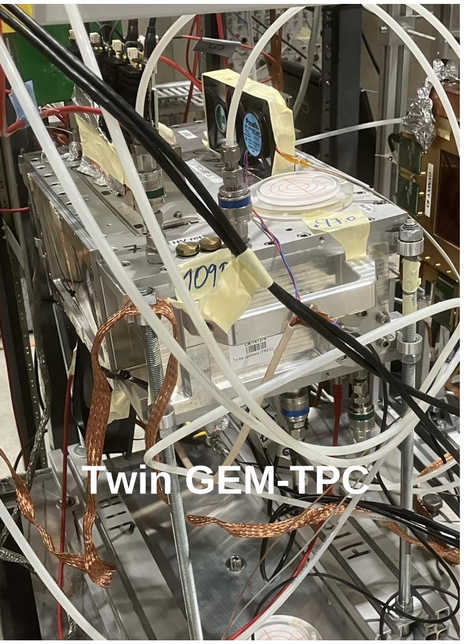
The GEM-TPC Layout and Powering scheme

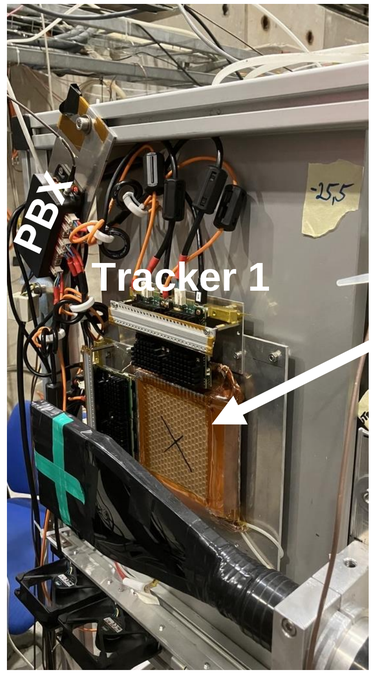


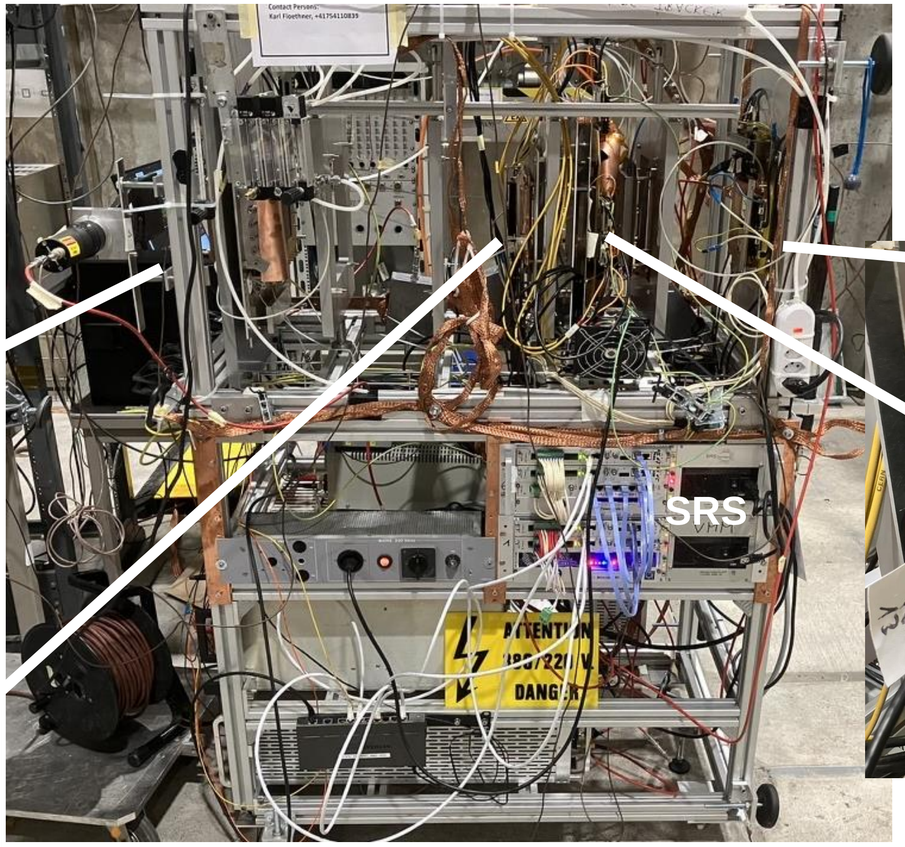
Courtesy of F. Garcia

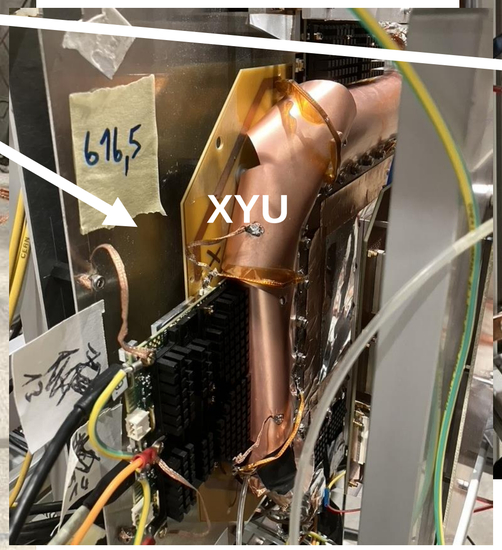
Beam Setup

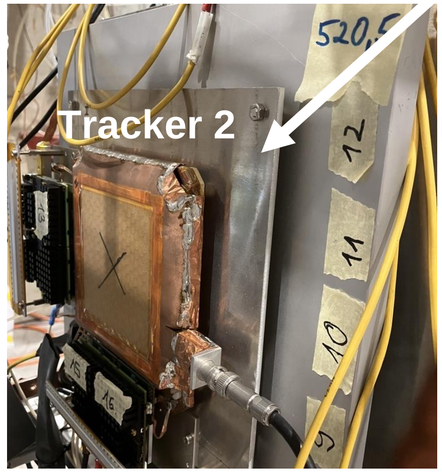
150GeV/c Muon Beam – H4 Beamline in EHN2 – RD51 test-beam

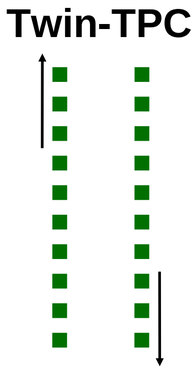


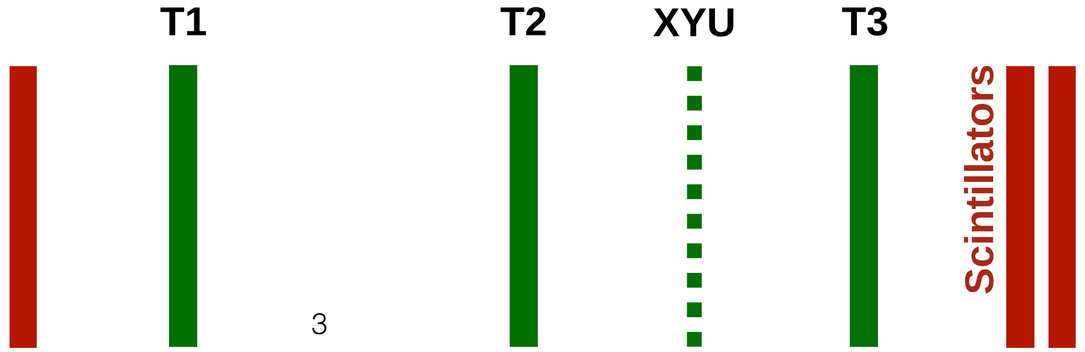












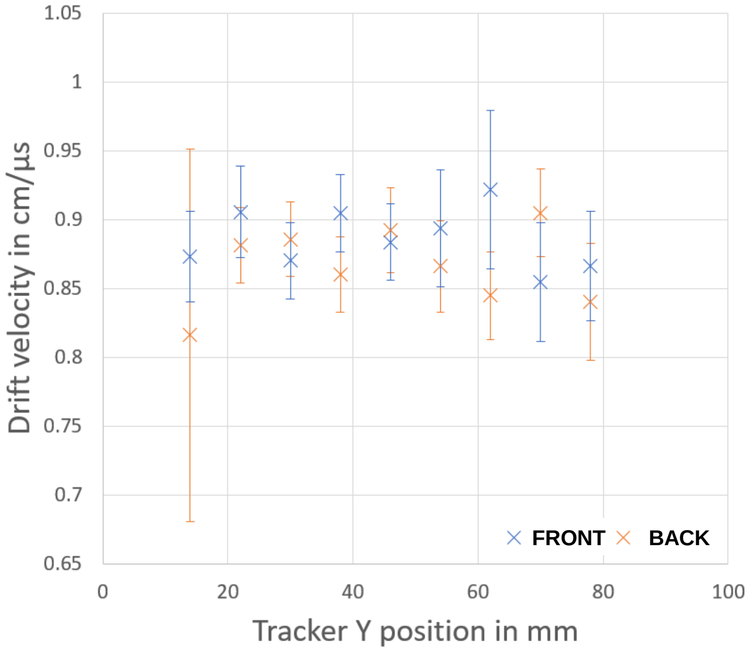
Control measurements

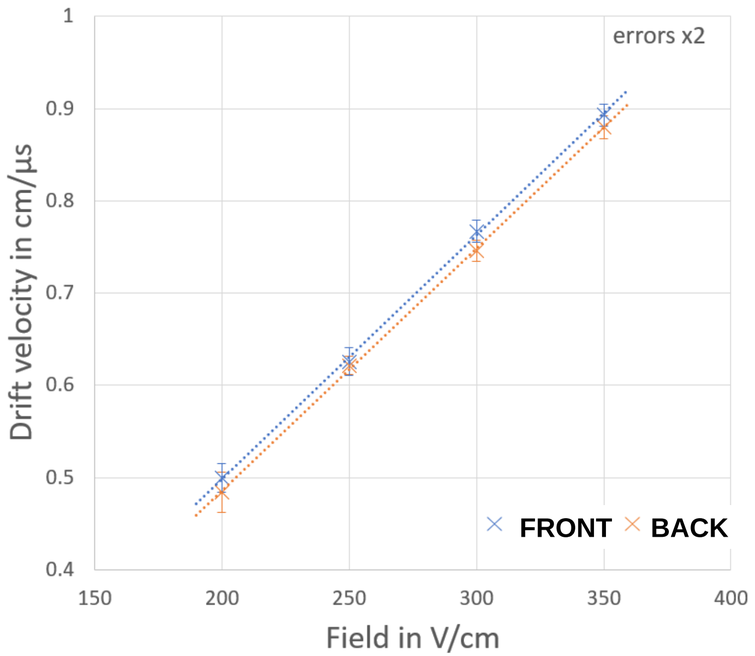
- Field scan
  - drift velocity behaves identical for both TPCs
  - difference below 2%

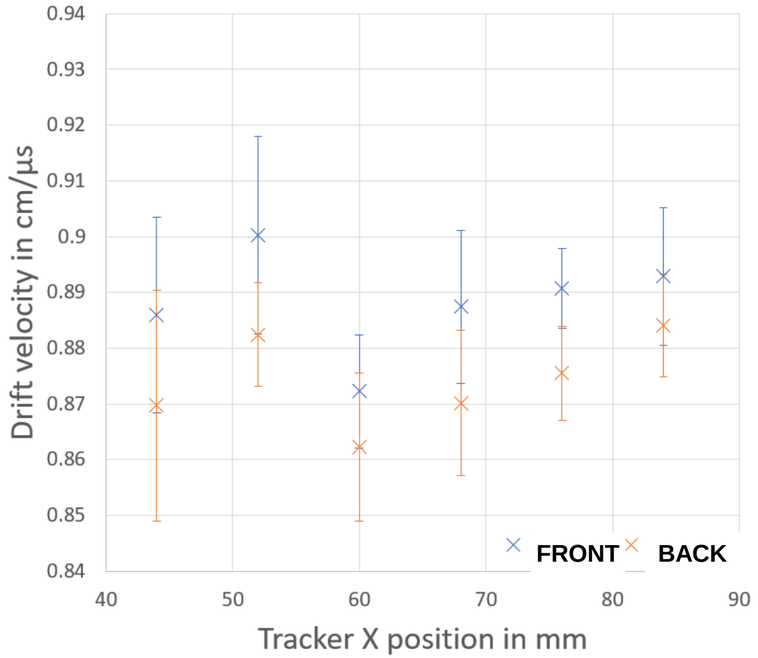
- Y position dependence
  - no significant variation
  - constant within errors

- X position dependence
  - no significant variation
  - constant within errors

→ Field can be assumed homogeneous and identical for both TPCs in first approximation







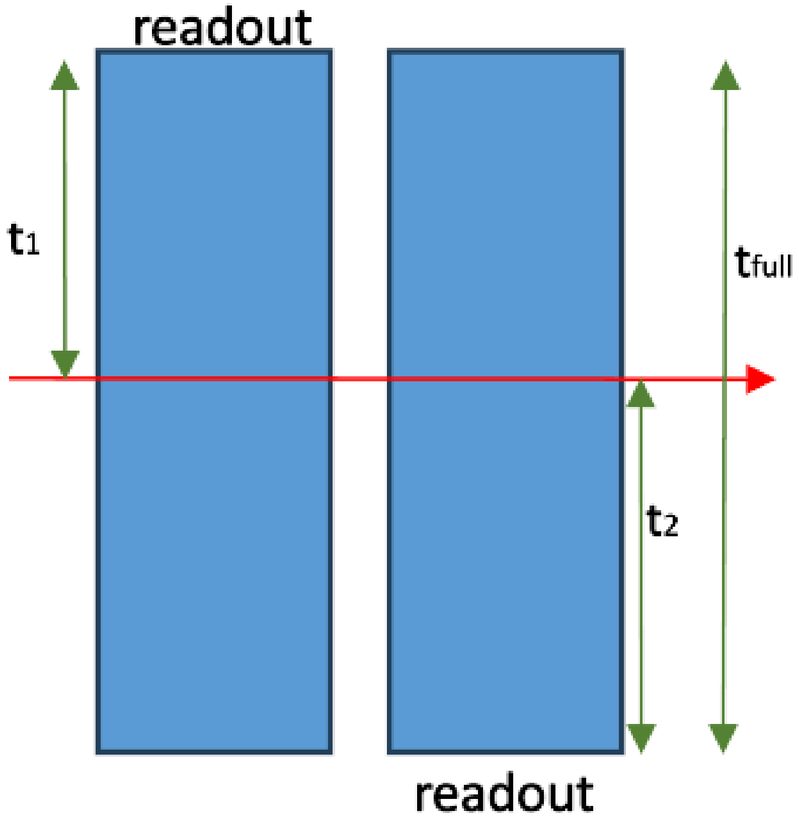
Removing t_0

Self triggered hits referring to the same absolute zero time t'_0

- Synchronised readouts
  -> $t'_{1,2} = t'_0 + t_{1,2}$ is valid for all times

- The absolute times t' can be used to get the relative times t
  -> Only possible if absolute times correspond to the same event
  -> $t'_2 - t'_1 = t'_0 + t_2 - (t'_0 + t_1) = t_2 - t_1$

- With access to the relative time and the full drift time t_{full} it is possible to extract a time corresponding to a y-value (three examples)
  -> $\frac{t'_2 - t'_1 + t_{full}}{2} = 0 \; with \; t_2 = 0, t_1 = t_{full} \rightarrow y_0$
  -> $\frac{t'_2 - t'_1 + t_{full}}{2} = t_{full} \; with \; t_1 = 0, t_2 = t_{full} \rightarrow y_1$
  -> $\frac{t'_2 - t'_1 + t_{full}}{2} = 0.5 t_{full} \; with \; t_1 = t_2 \rightarrow 0.5 y_1$



Removing t_0

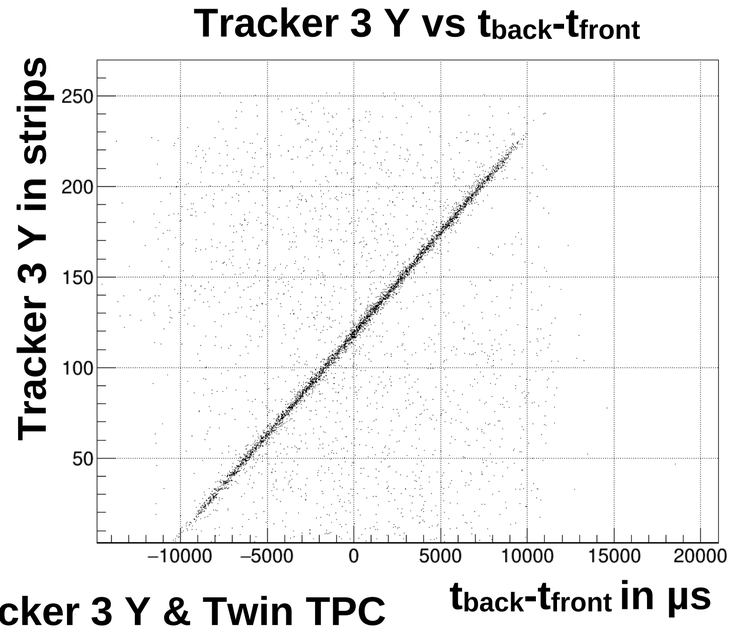
- A correlation can be checked just using the time difference of the TPCs
  -> $y \propto (t_2' - t_1' + t_{full})/2 \propto t_2' - t_1'$

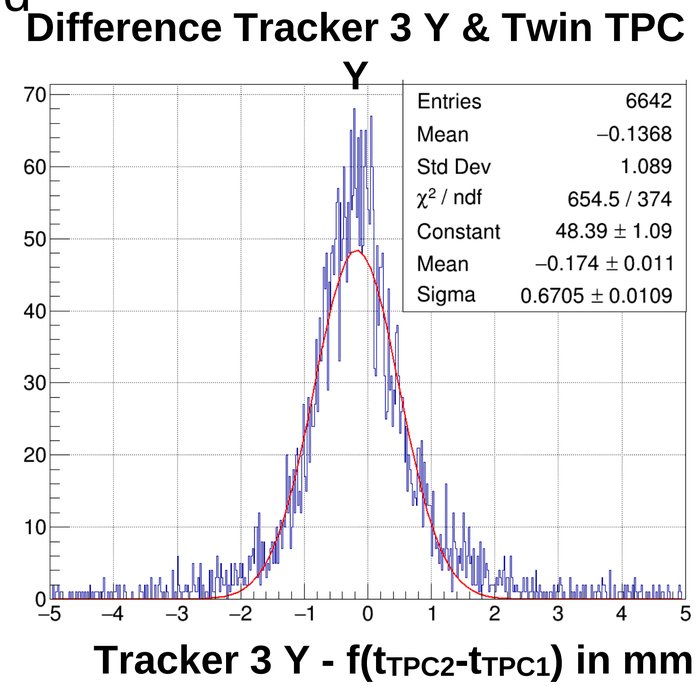
- Linear fit gives a conversion function f(t_{TPC2}-t_{TPC1})
  - y position for Twin TPC can be calculated

- Difference of Tracker 3 Y and Twin GEM-TPC Y can be plotted
  - Sigma can be seen as lower limit for resolution
    (convolution of distributions not resembling only sp. res.)
  - Coordinates can be clearly correlated with a $\sigma \approx 0.67 mm$

→ Correlation possible without external t_0

→ Twin GEM-TPC could be used as very low Material budget and stand-alone tracking station





Calculating t_{full} & t_0

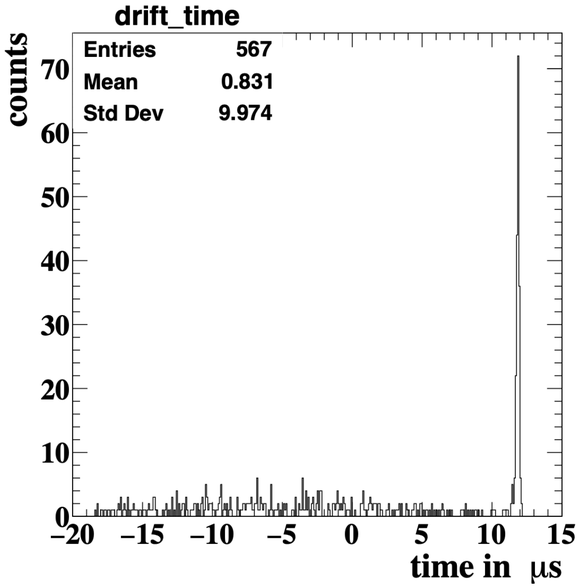
Full drift time t_{full} is still needed to get y position without outer reference

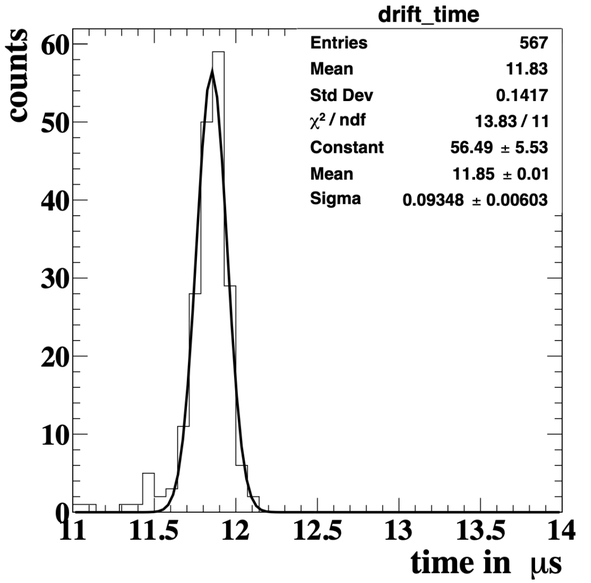
- Full drift time is either known or can be checked using t0 reference
  -> $t'_{1,2} = t'_0 + t_{1,2}$
  -> $t_{full} = t_1 + t_2 = t'_1 + t'_2 - 2t'_0$

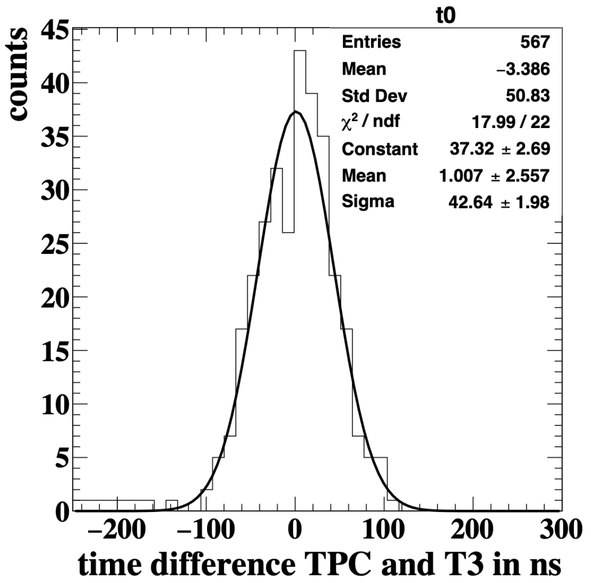
- t_{full} gives broad distribution with clear peak at 11.85 µs
  - drift velocity differs by ~4% from previous measurement

- Knowing t_{full} t0 can be calculated
  -> $t'_0 = \frac{t'_1 + t'_2 - t_{full}}{2}$

- Time difference to tracker gives first estimate for time resolution
  -> $\sigma_{T3} \approx 12ns, \sigma_{tot} \approx 43ns \rightarrow \sigma_{TwinTPC} \approx 41ns$





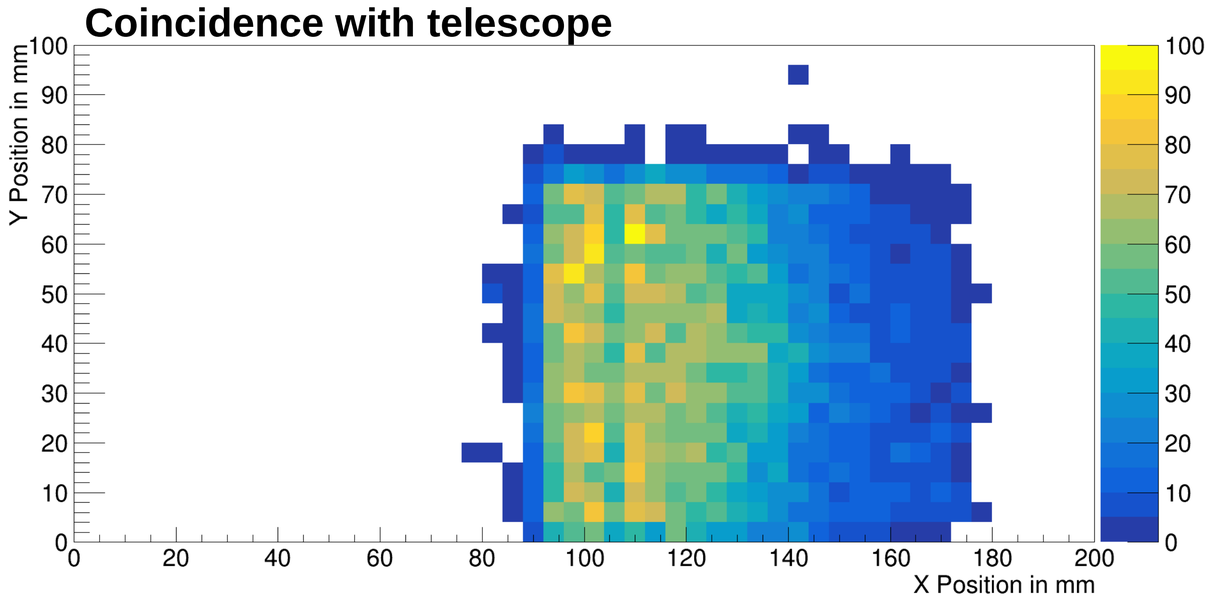


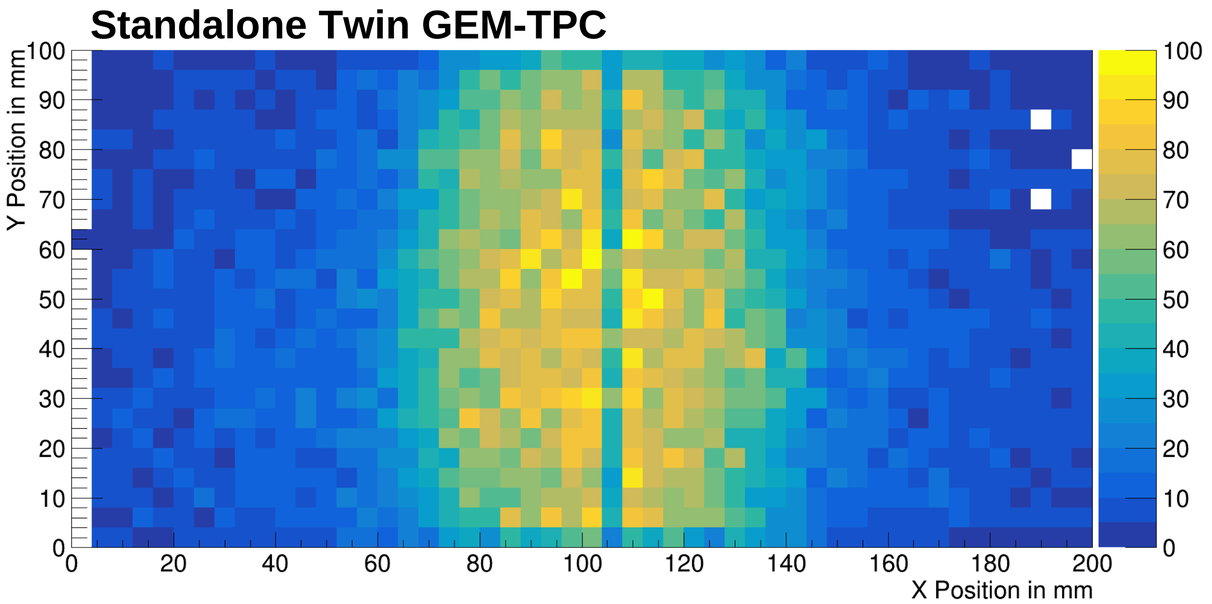
Beam Profile

150GeV/c Muon Beam – H4 Beamline in EHN2 – RD51 test-beam

Showcase without external information

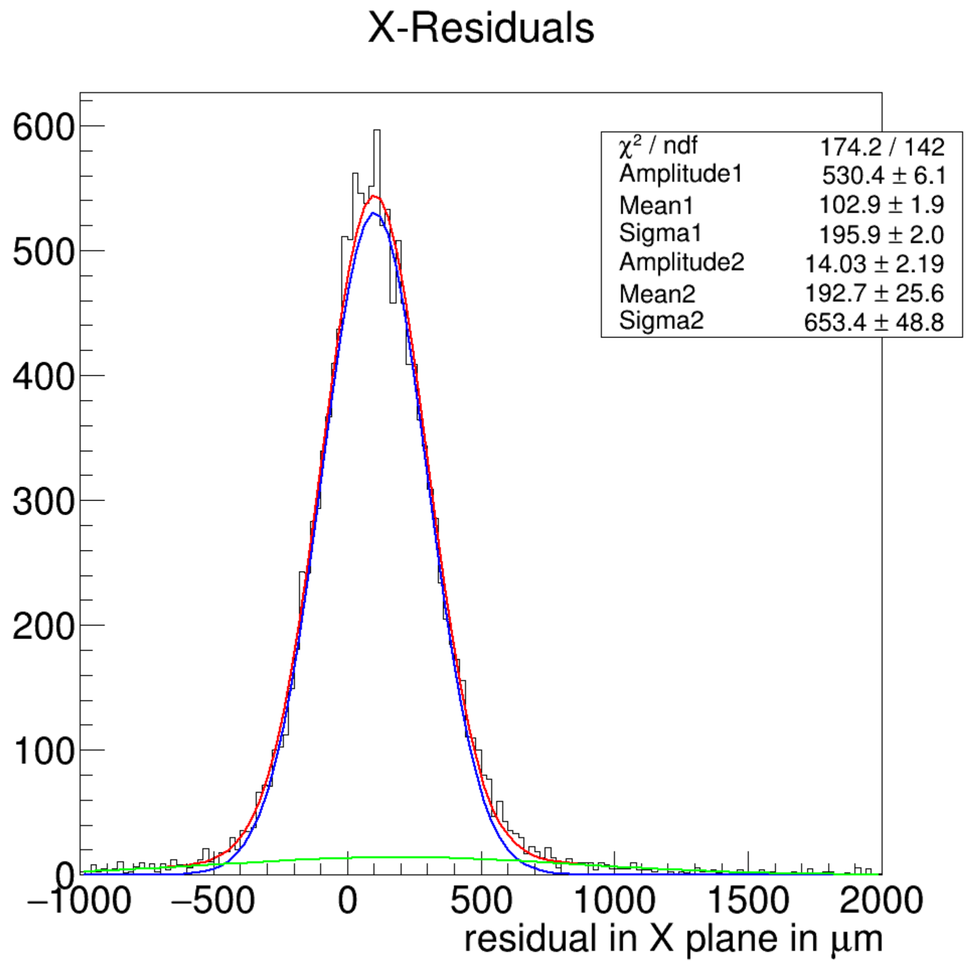
- Beam profile can be reconstructed
  - Only data from Front- and Back-TPC
  - Matching done with Front-TPC as reference (does not work well without noise-cuts)
- Cuts before matching
  - Cluster-size >2 & <10
  - Cluster adc value >800

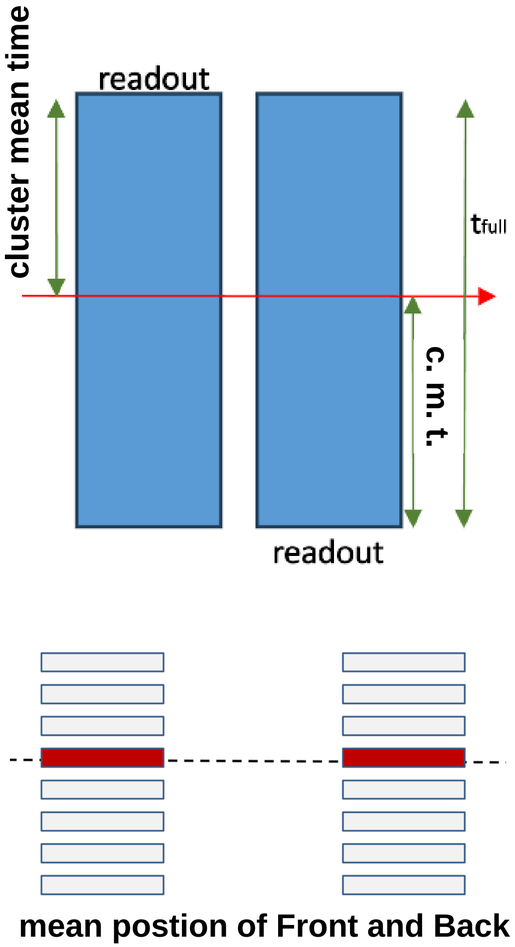


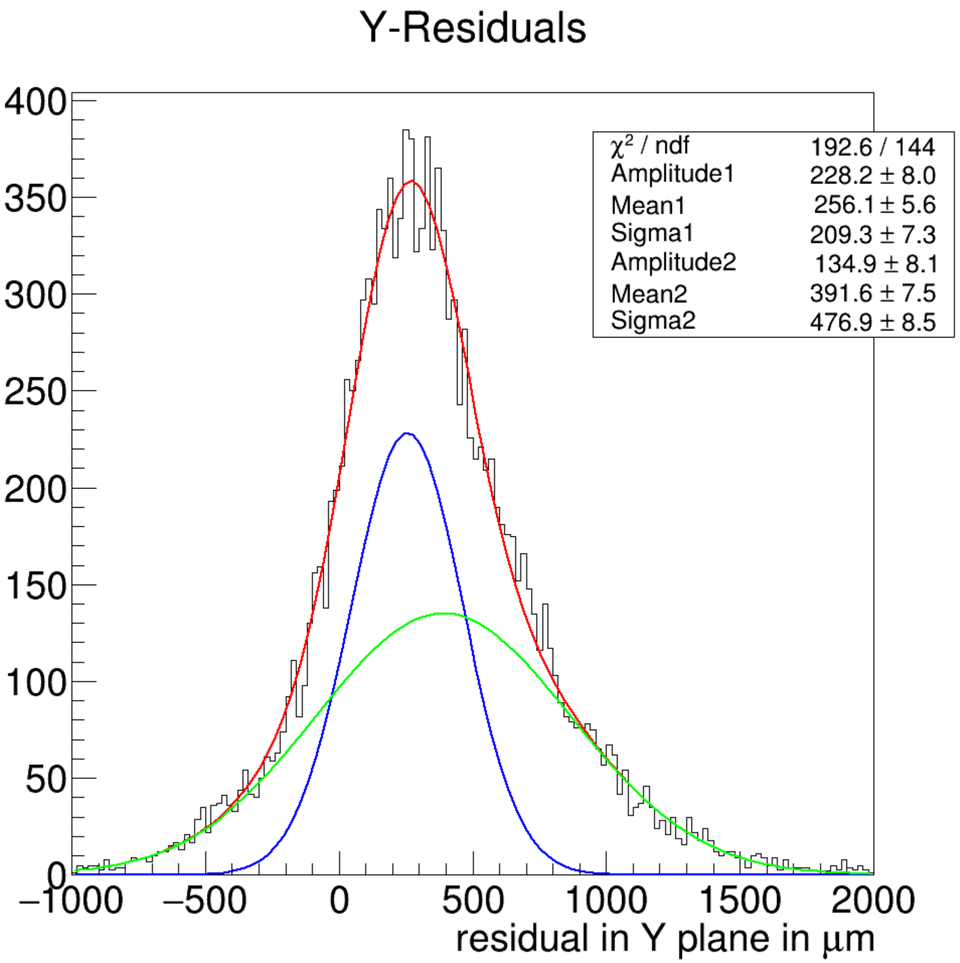


Tracking with Mean of Clusters

150GeV/c Muon Beam – H4 Beamline in EHN2 – RD51 test-beam – H5V3 orientation





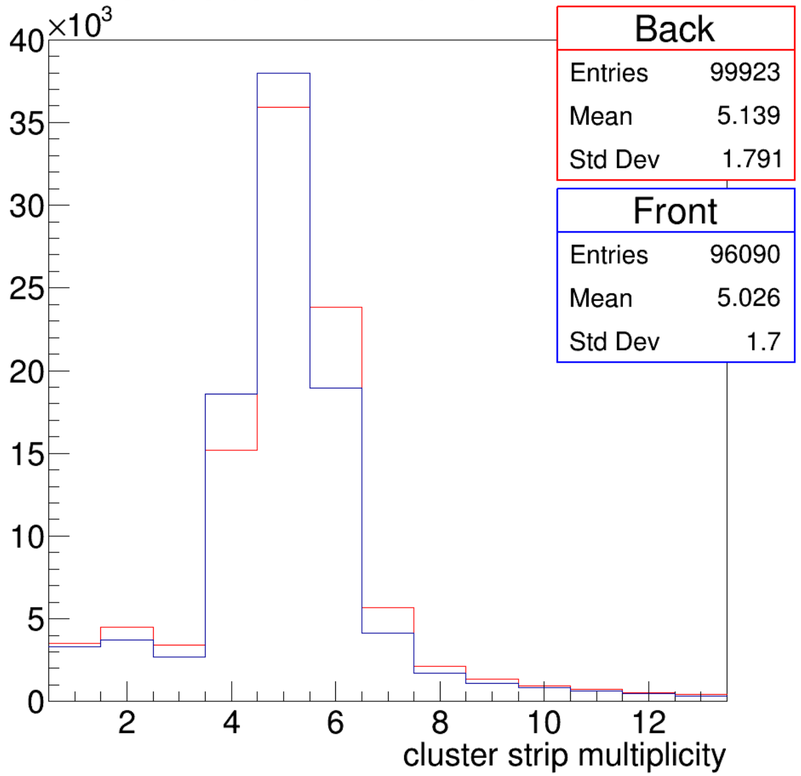


- Only gives one point per track and no information about the angle
- Could be still interesting as low material budget tracker but does not cover full potential

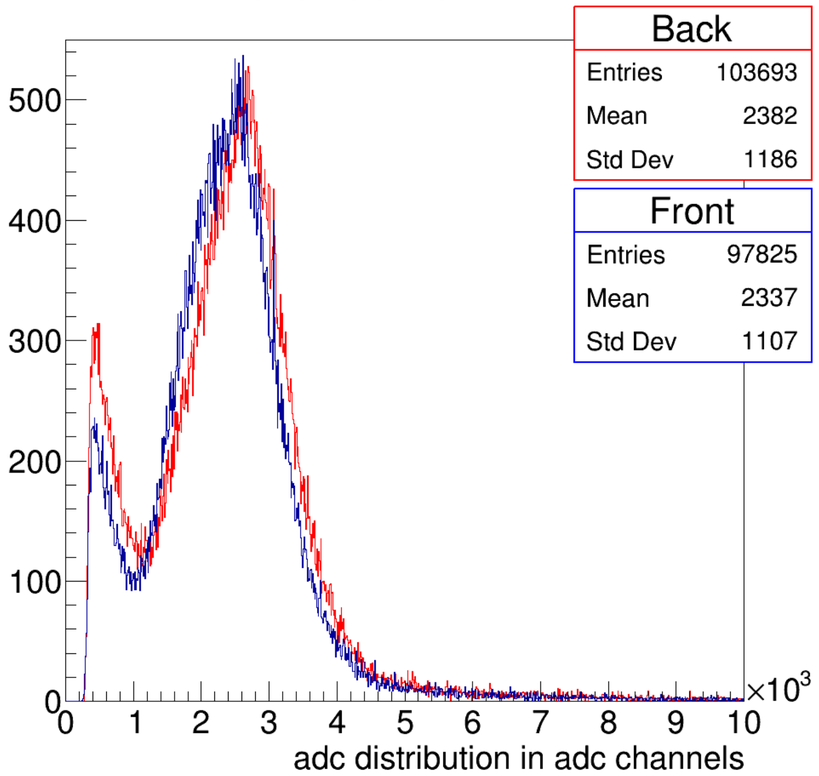
Detector Response nominal Orientation

150GeV/c Muon Beam – H4 Beamline in EHN2 – RD51 test-beam

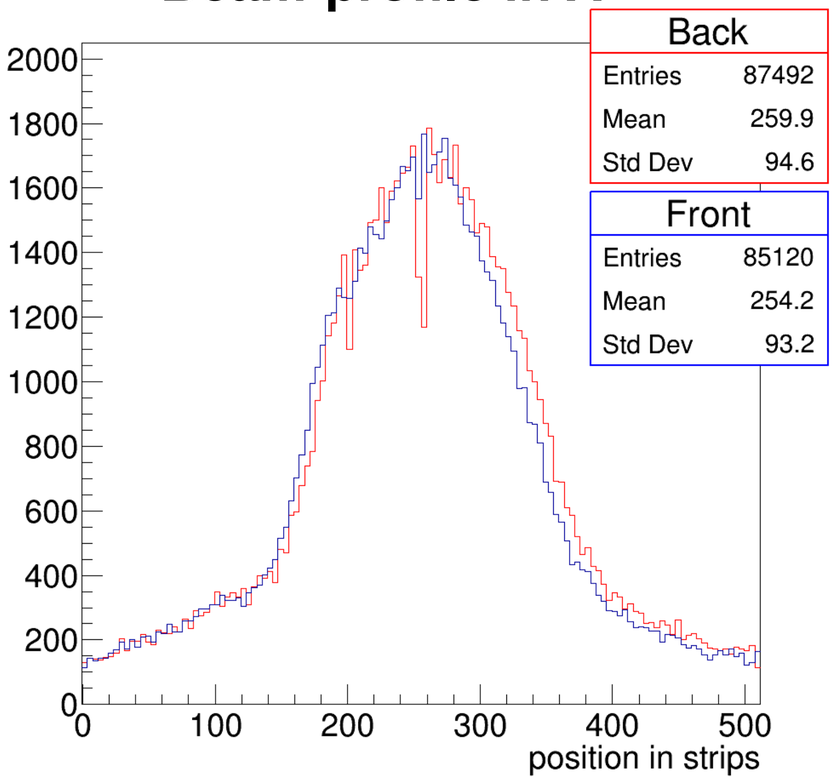
Clustersize distribution



ADC distribution



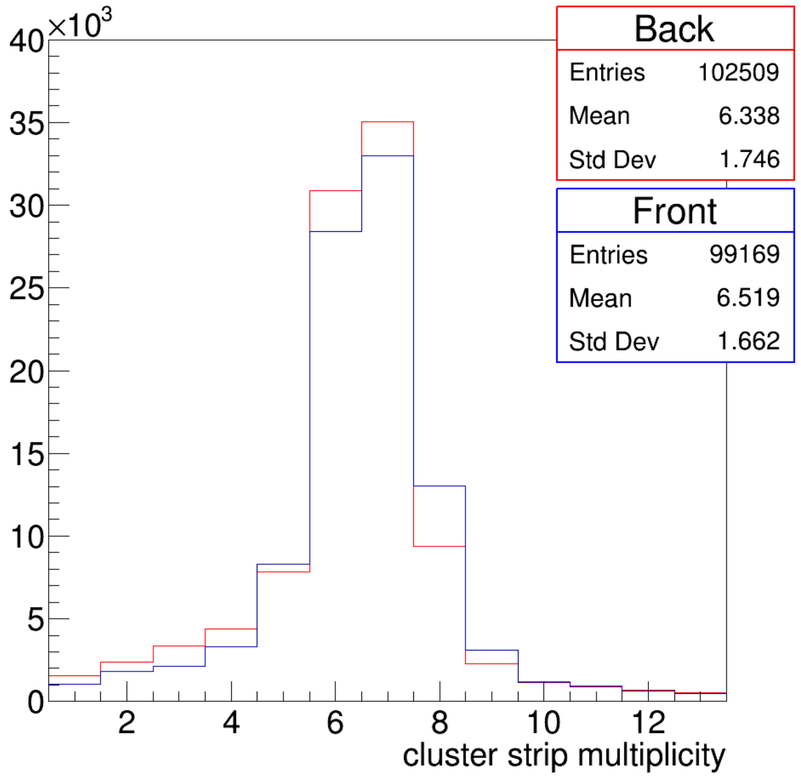
Beam-profile in X



Detector Response H5V3 Orientation

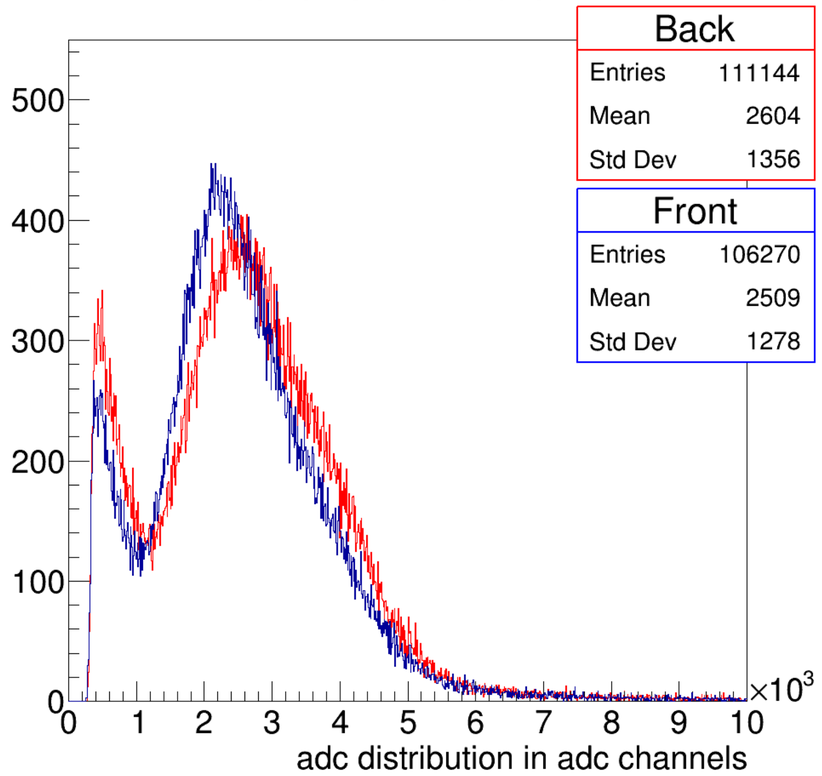
150GeV/c Muon Beam – H4 Beamline in EHN2 – RD51 test-beam

Clustersize distribution



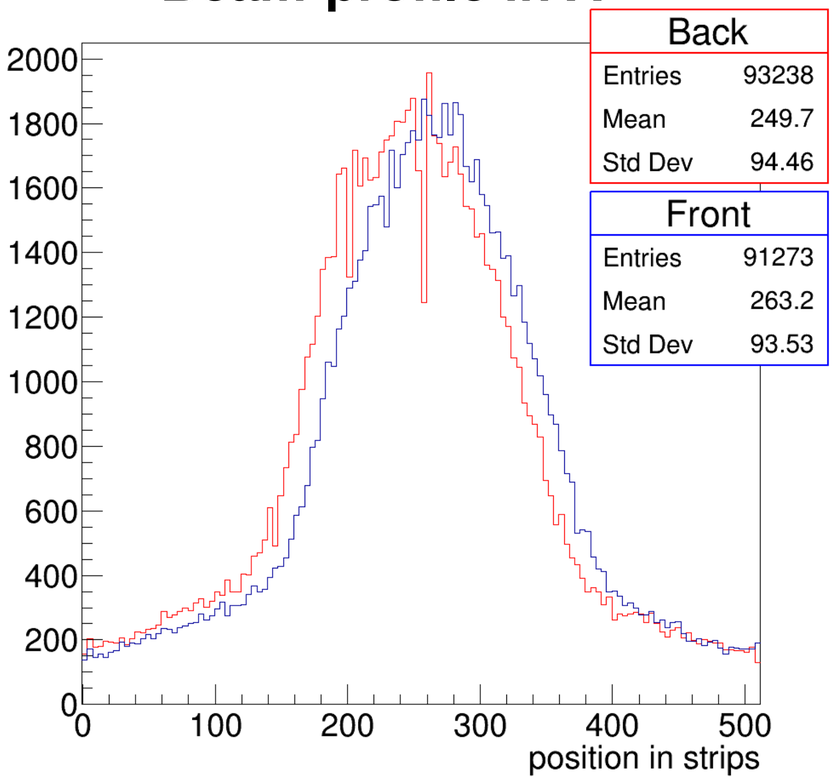
Shift to higher strip multiplicity

ADC distribution



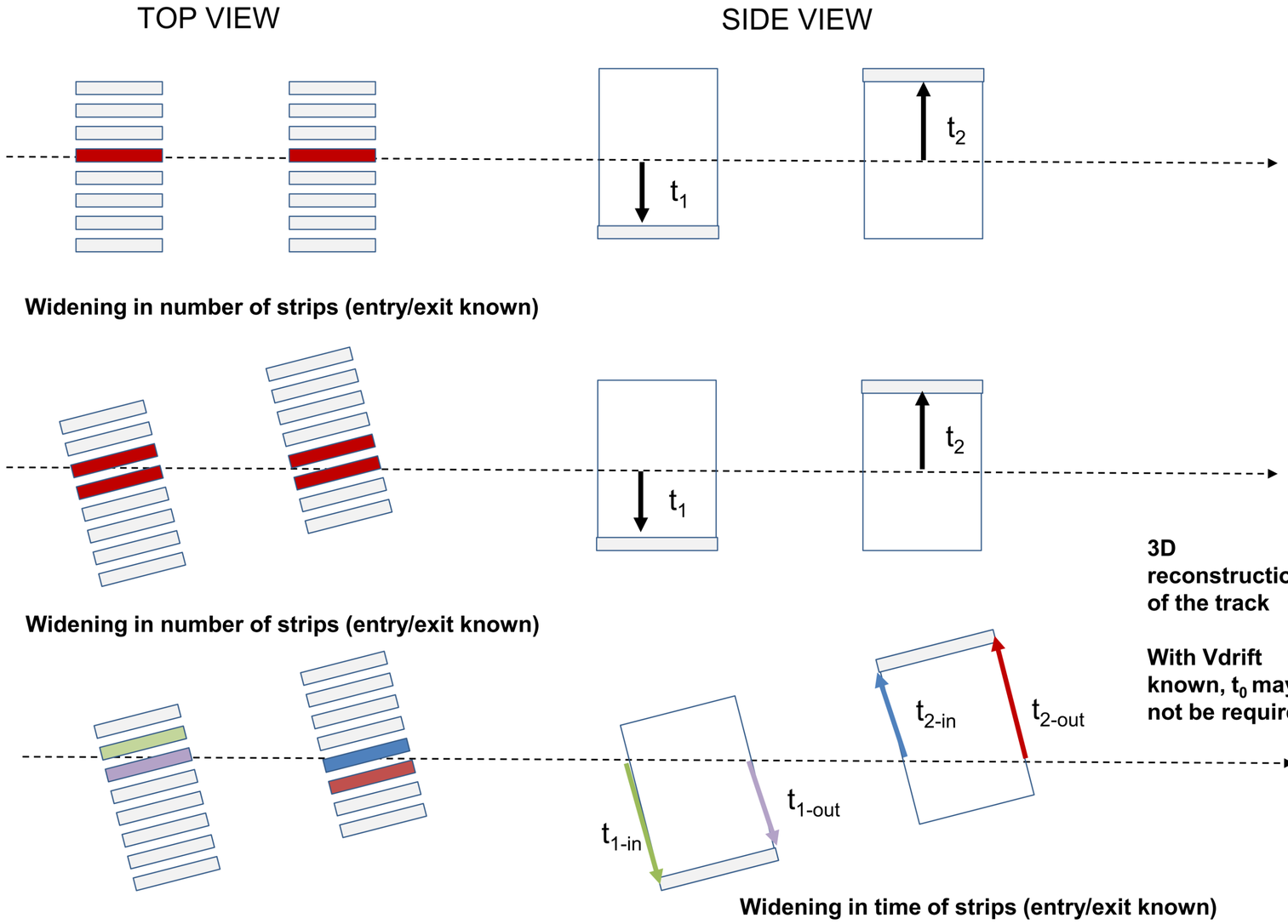
Higher mean and broader

Beam-profile in X



Shift in relative position between Front and Back

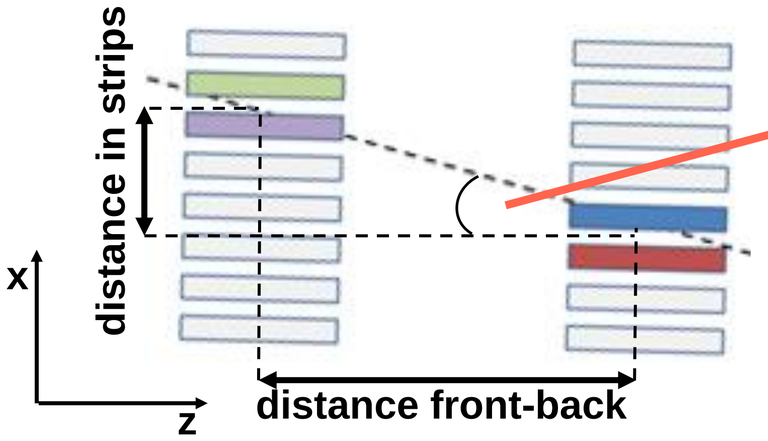
Tracking within TPC



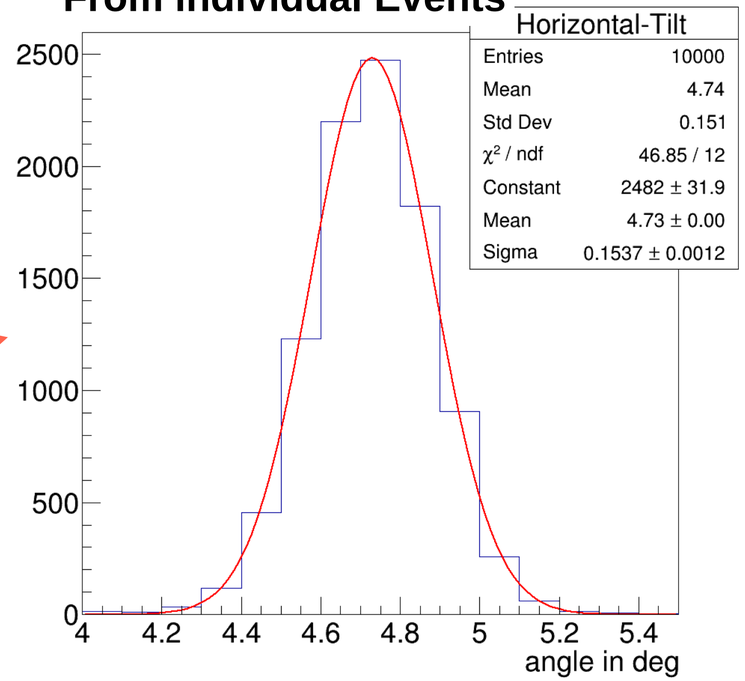
Horizontal Tilt Calculation

150GeV/c Muon Beam – H4 Beamline in EHN2 – RD51 test-beam – H5V3 orientation

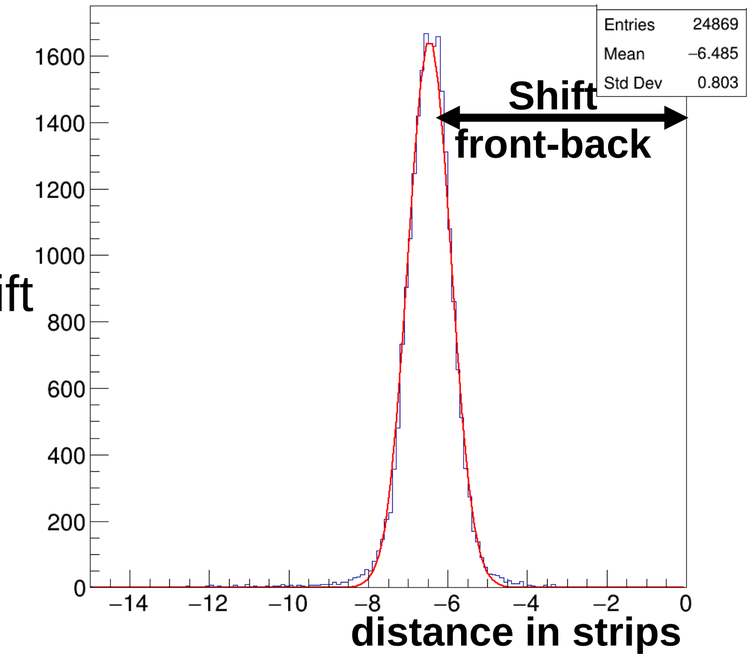
- Calculating event based
  - Calculate angle for individual events
  - Mean of distribution resembles tilt of Twin GEM-TPC setup
- Calculating based on average position shift
  - $x_{Front} - x_{Back}$ distribution needed for nominal and tilted orientation
  - Angle can be calculated with corrected shift
- The horizontal tilt 4.74(15)° is observed (fits with setting of 5°)



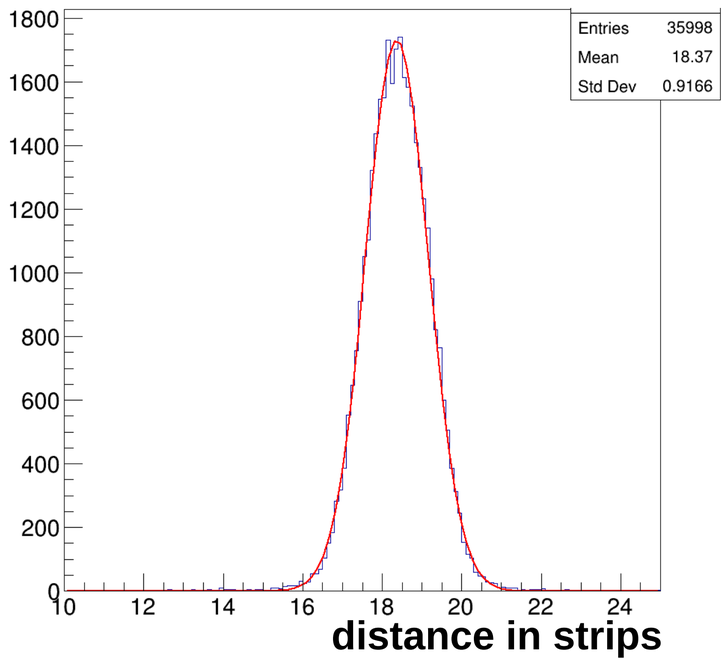
From individual Events



Nominal Position



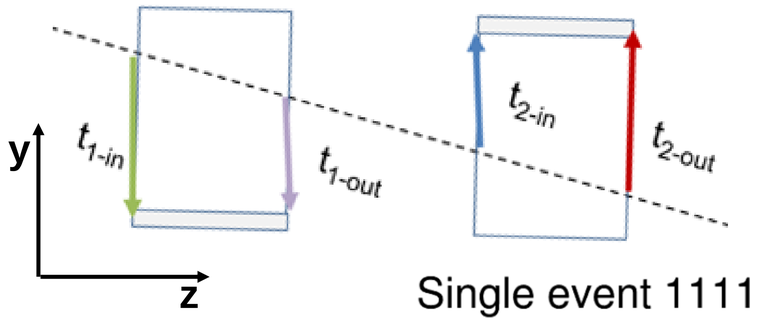
Horizontal 5° and Vertical 3°



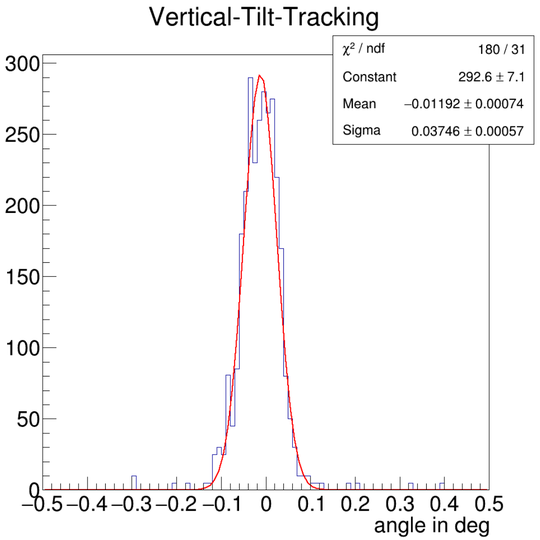
Vertical Tilt Calculation

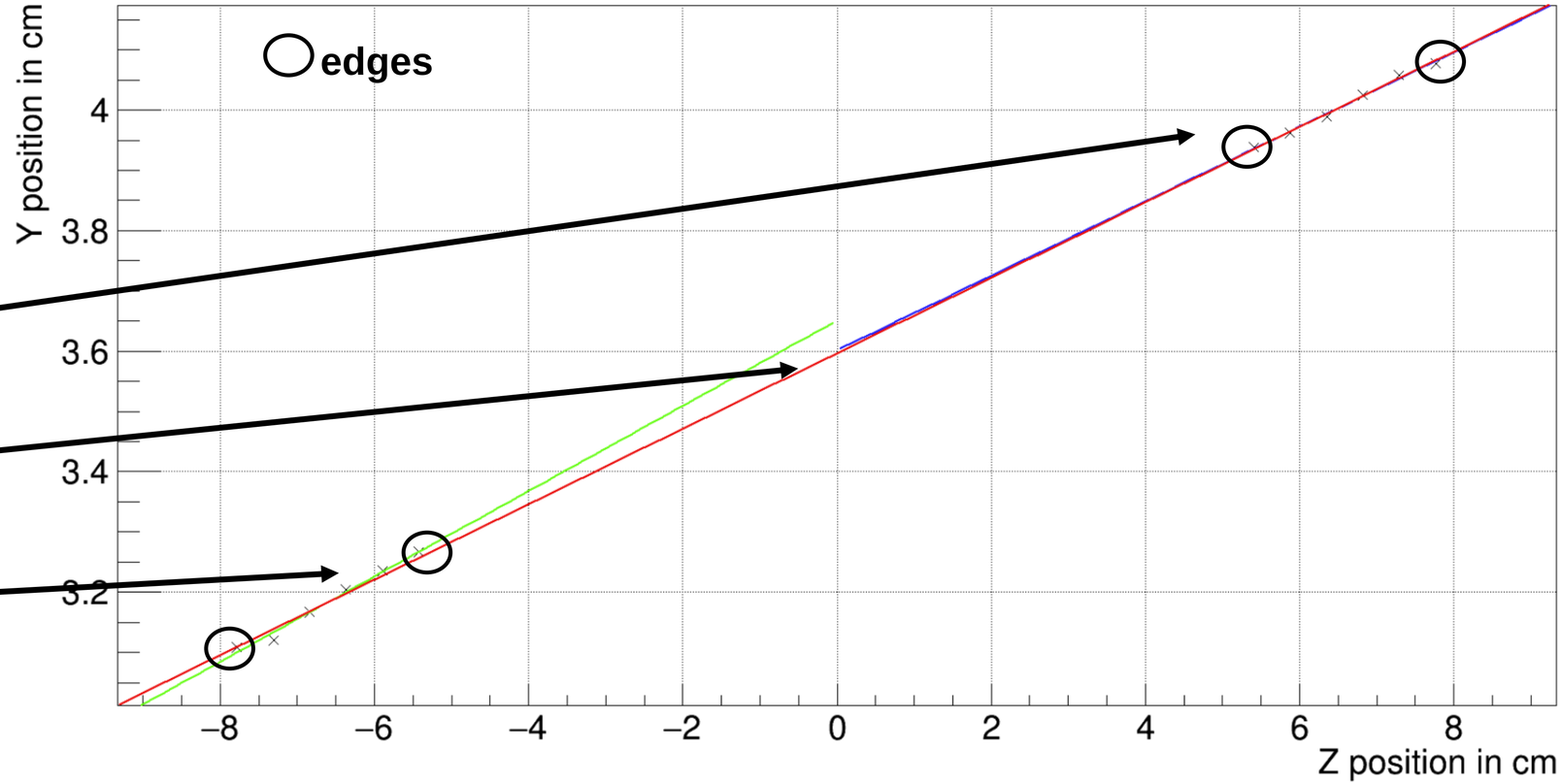
150GeV/c Muon Beam – H4 Beamline in EHN2 – RD51 test-beam – H5V3 orientation

- $\frac{t_2' - t_1' + t_{full}}{2} * vd_{rift} = y$ used to calculate y position
- Vertical tilt of telescope: -11.9(8) mdeg
- Three angles per track: (should be identical)
  - Back TPC
  - Full Twin GEM-TPC
  - Front TPC



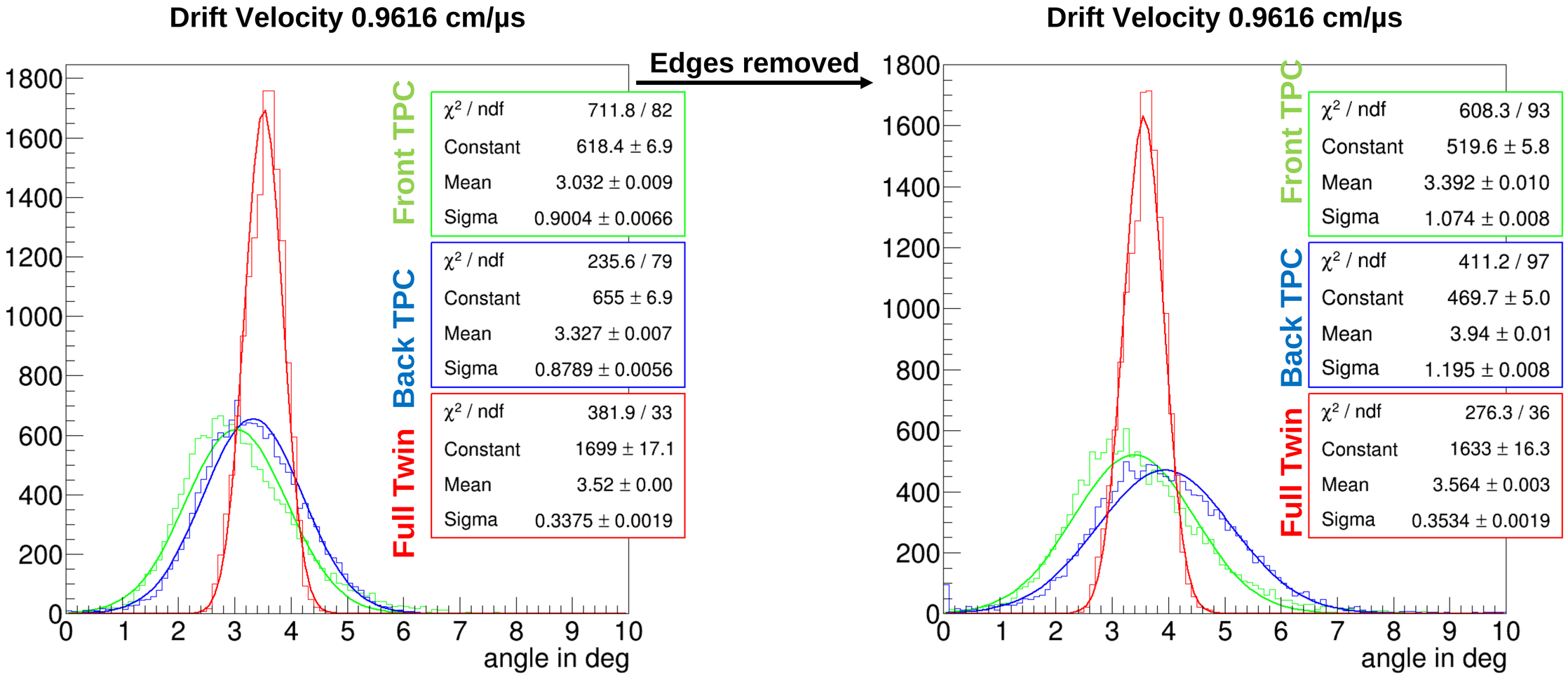
Single event 1111





Vertical Tilt Calculation

150GeV/c Muon Beam – H4 Beamline in EHN2 – RD51 test-beam – H5V3 orientation

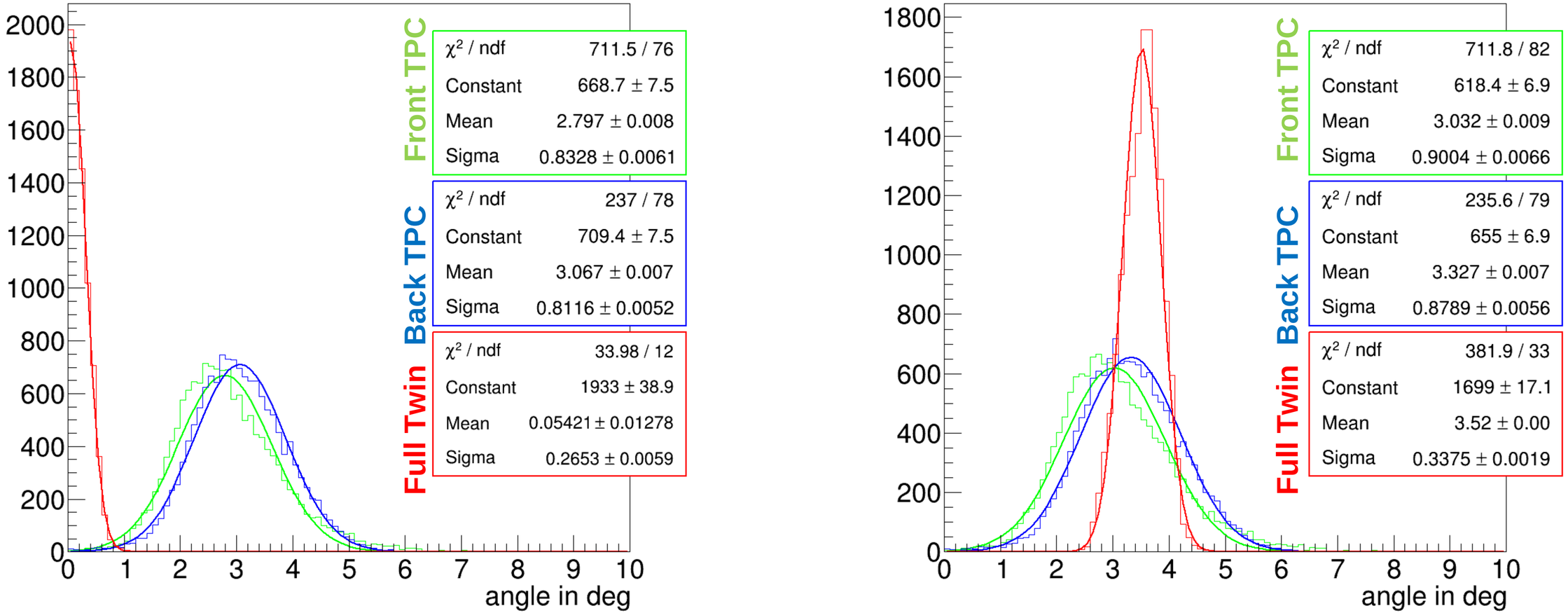


- Removing edges results in broader distributions and increased discrepence between Front- and Back-TPC

Vertical Tilt Calculation

150GeV/c Muon Beam – H4 Beamline in EHN2 – RD51 test-beam – H5V3 orientation

Drift Velocity 0.8865 cm/µs → **Adjusted drift velocity** → **Drift Velocity 0.9616 cm/µs**

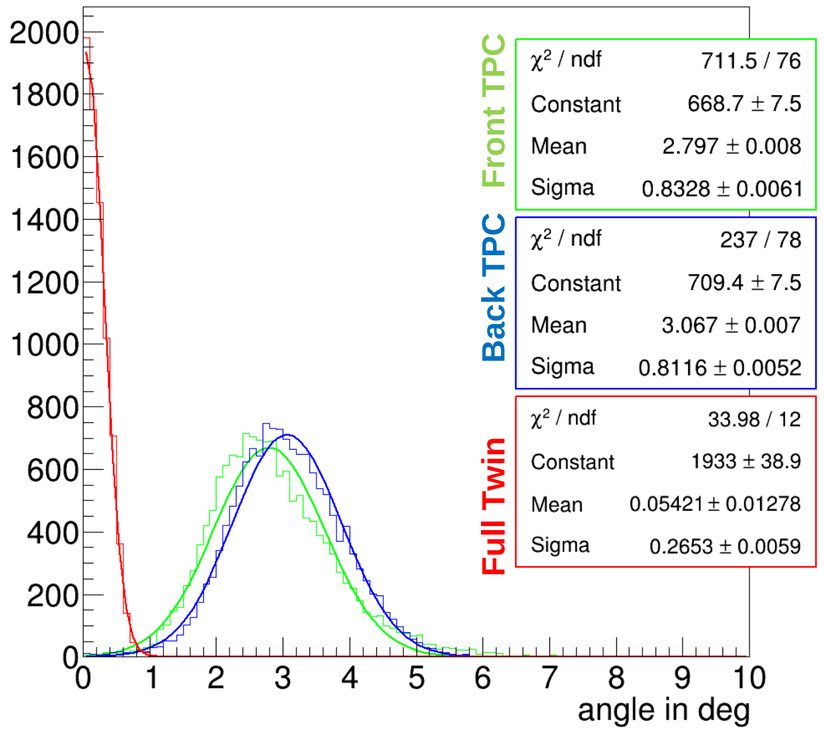


- Can correct the alignment between Front/Back but distributions are slightly wider

Vertical Tilt Calculation

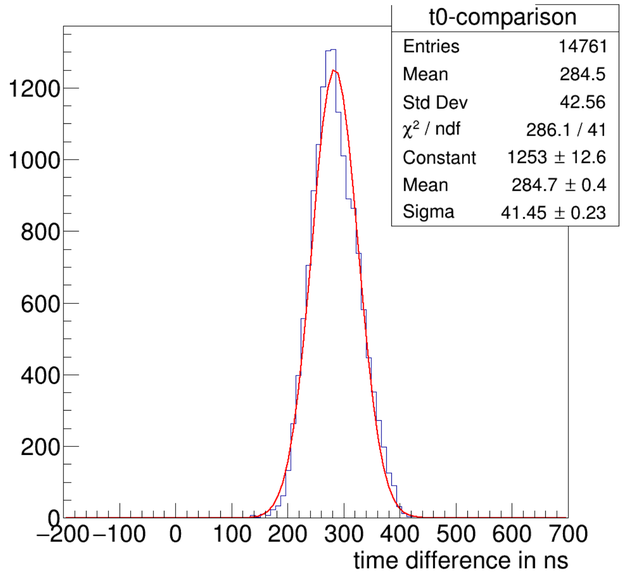
150GeV/c Muon Beam – H4 Beamline in EHN2 – RD51 test-beam – H5V3 orientation

Drift Velocity 0.8865 cm/µs

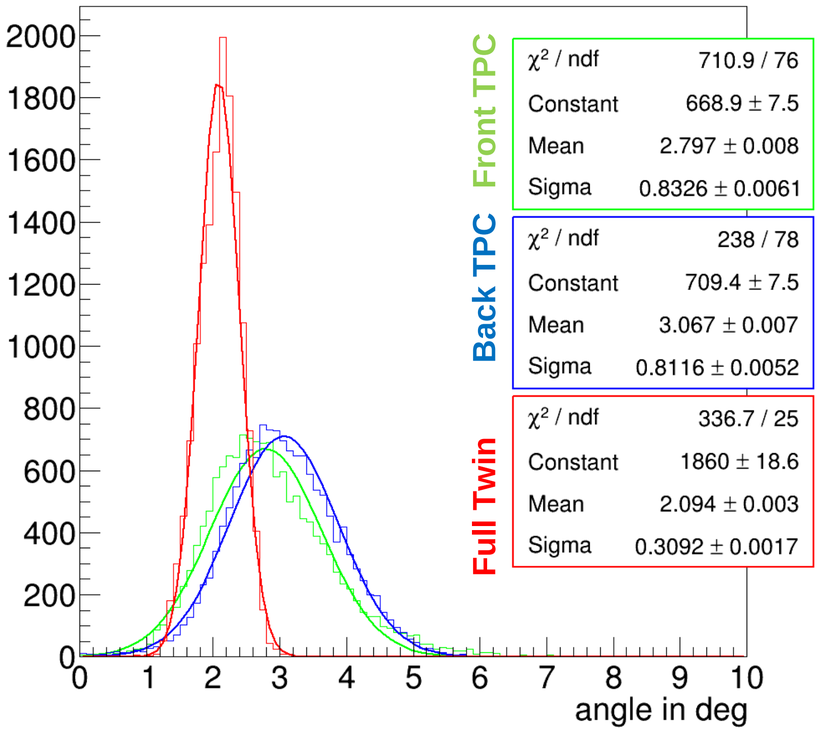


-284.7ns t_0 Offset

t_0 Offset Distribution



Drift Velocity 0.8865 cm/µs

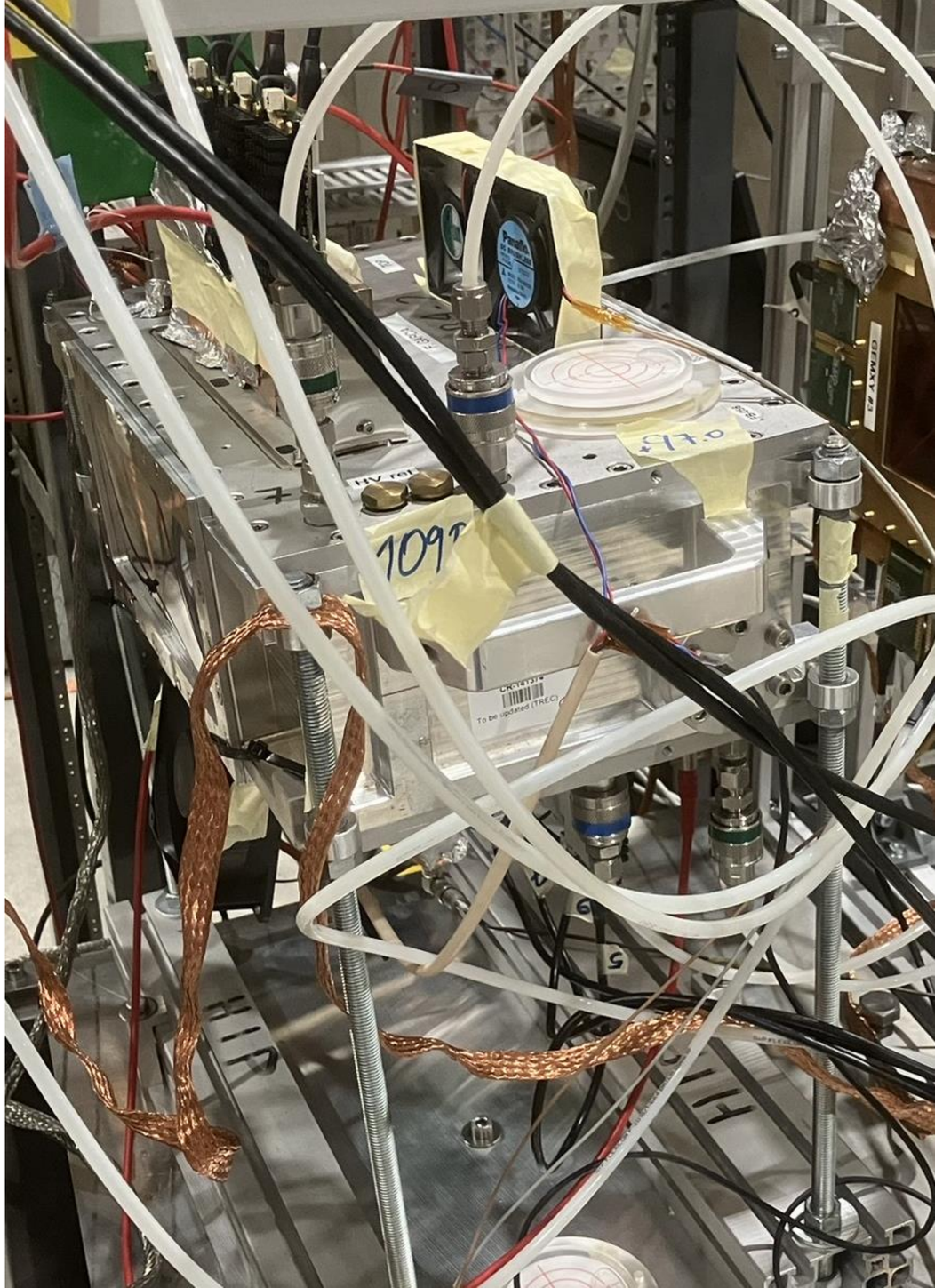


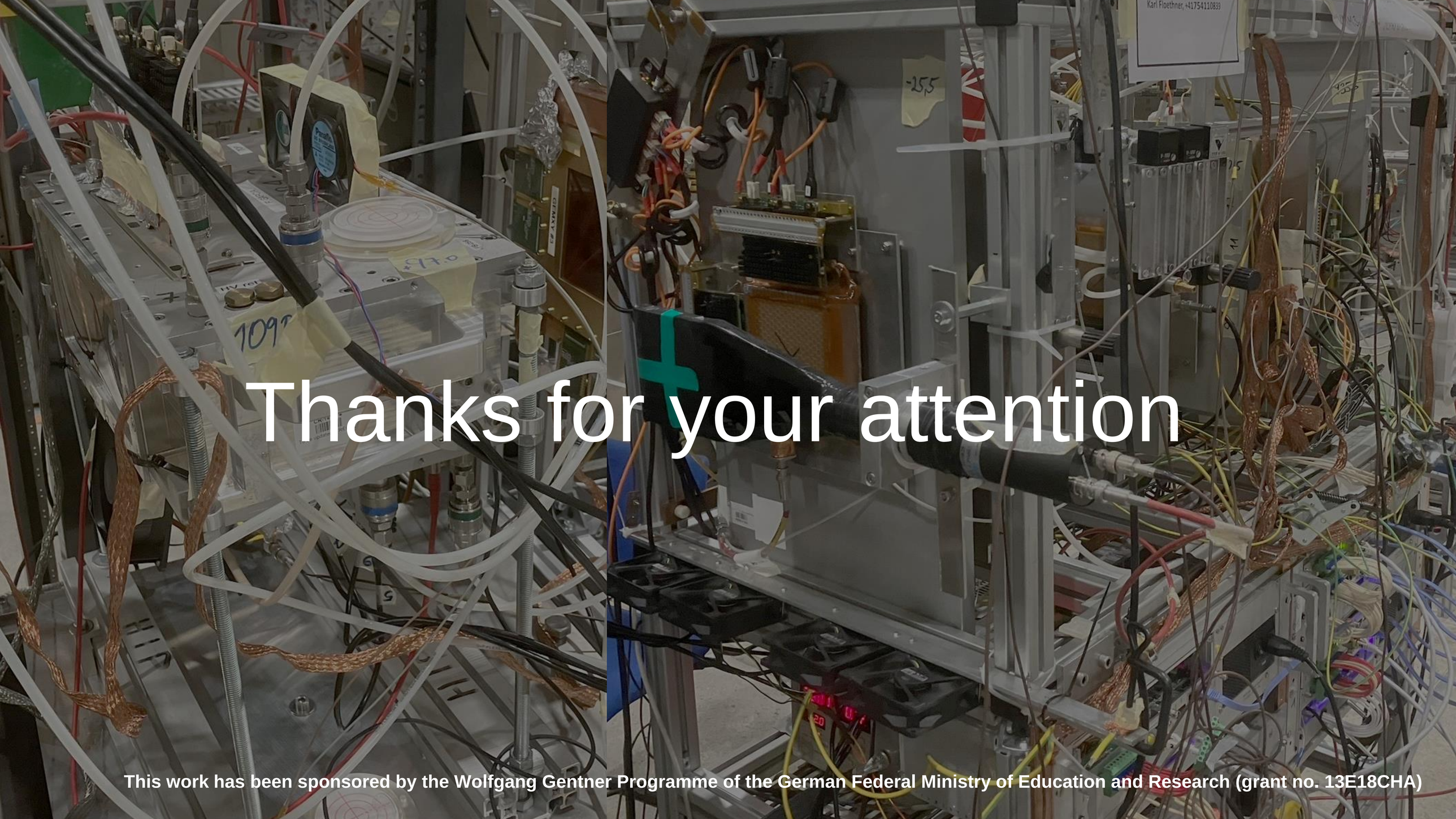
- Back/Front distributions show no change as expected
- Can correct the alignment between Front/Back

➢ The offset needs to be corrected and drift velocity adjusted for better agreement of the three slopes (Eventually different drift velocities for Back and Front)

Summary and Outlook

- The drift velocity has been checked for different fields and positions
  - Field can be assumed homogeneous and identical for both TPCs in first approximation
- Good detector response and resolutions of $\sigma < 200\mu m$ in x and $\sigma < 500\mu m$ in y
- 3D tracking works but needs to be optimized





Thanks for your attention

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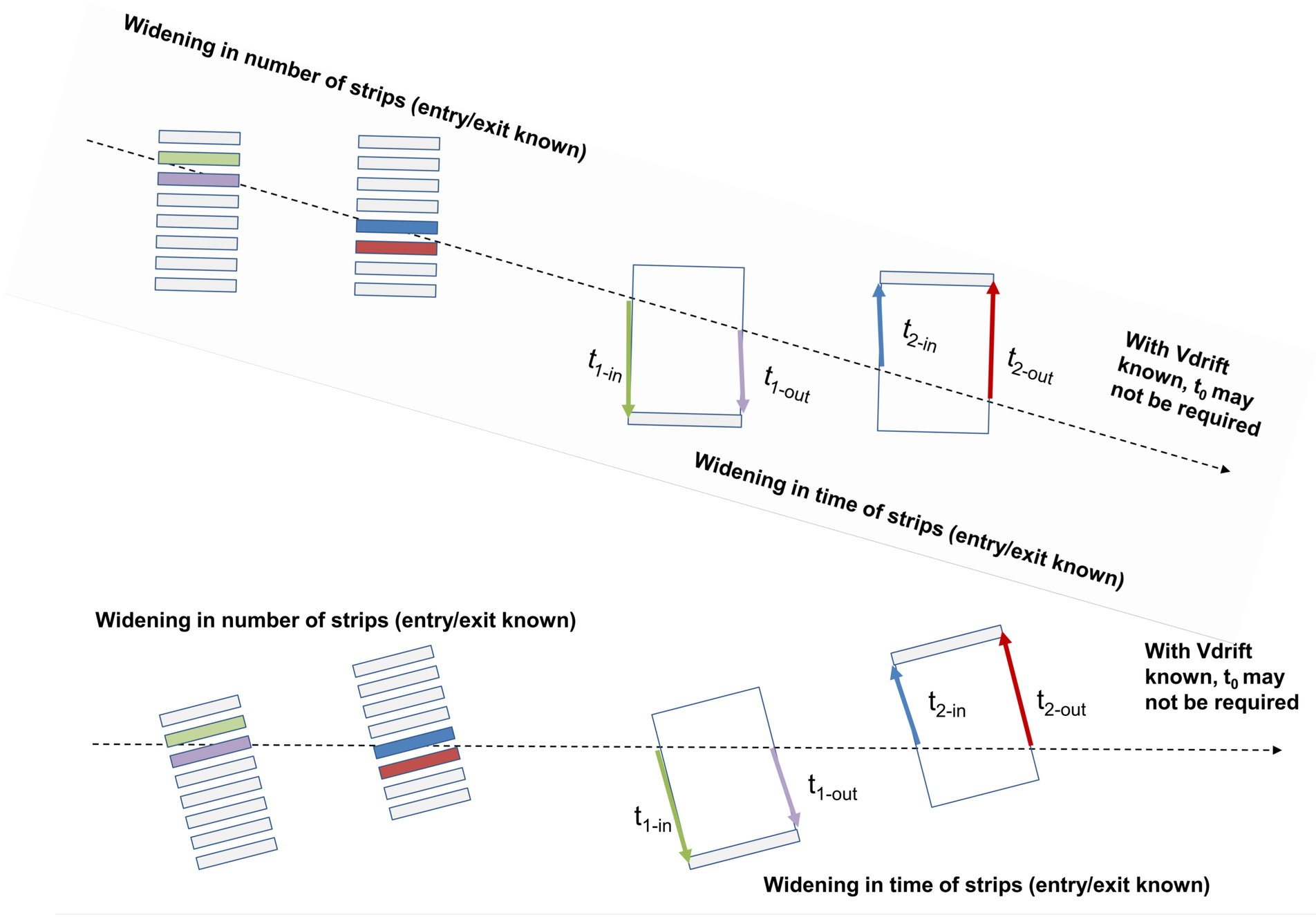
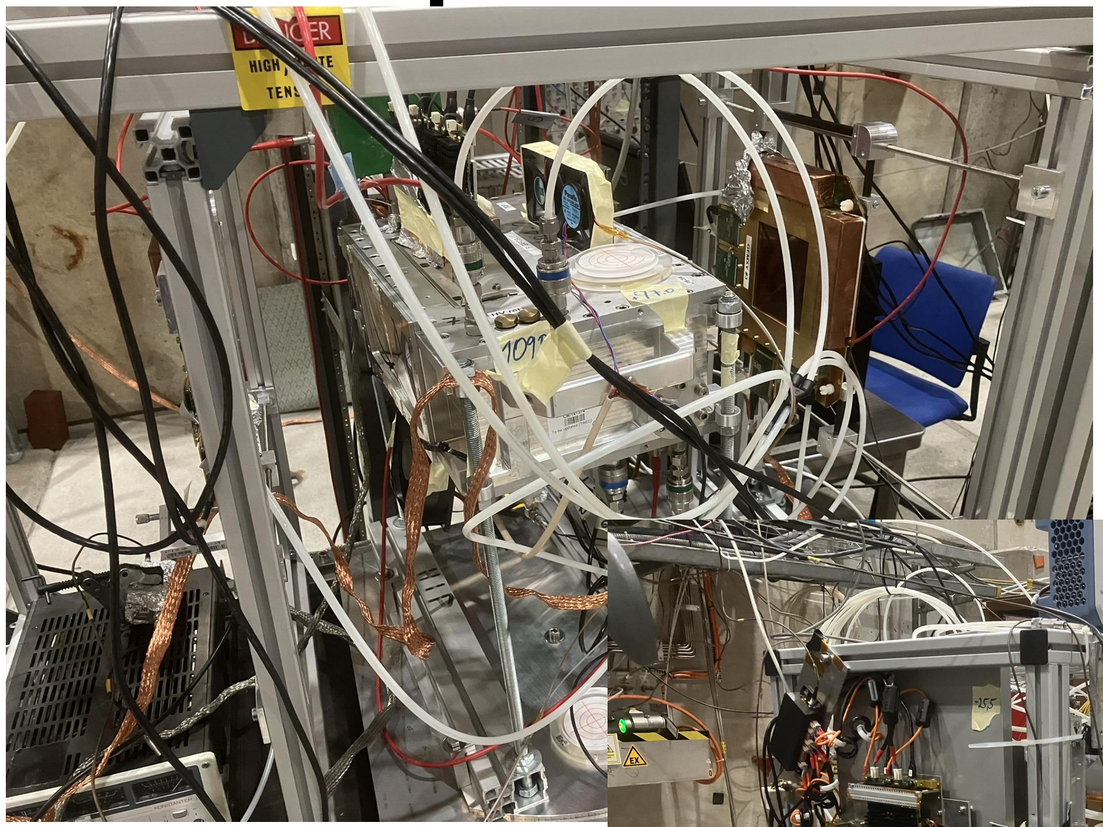
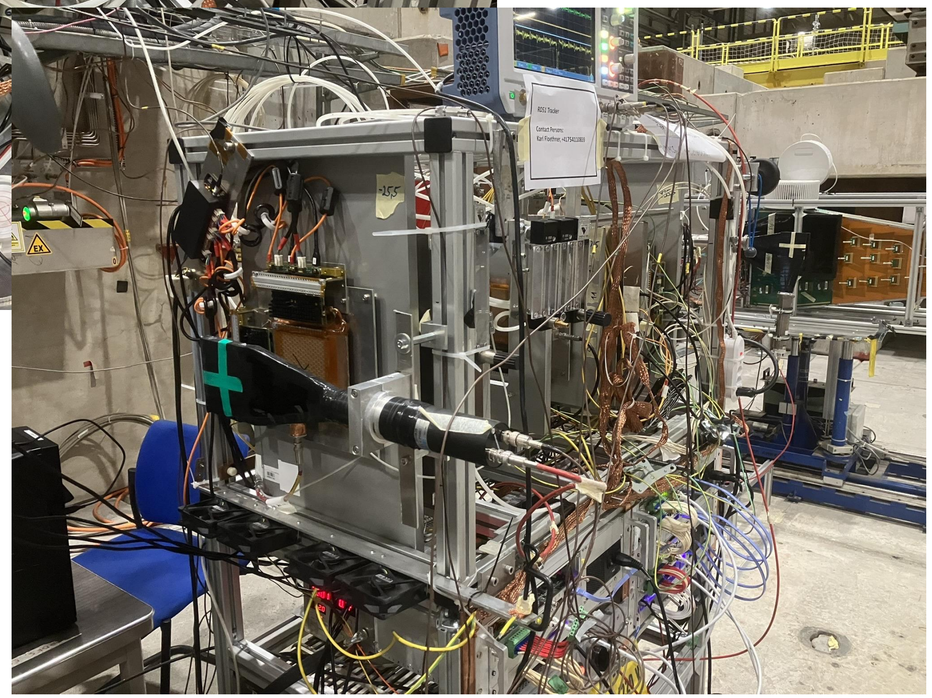


Courtesy of F. Garcia

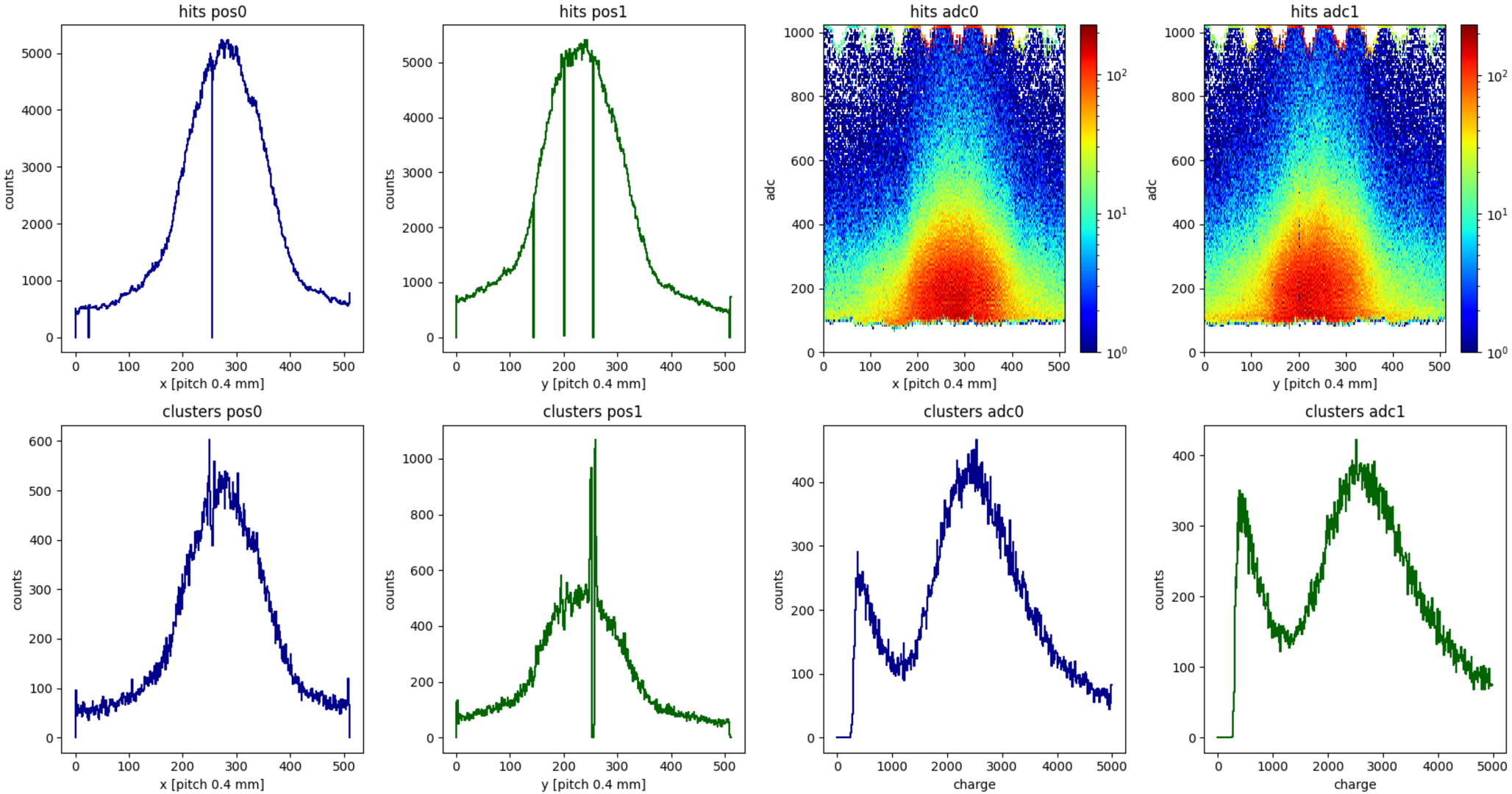
Test Beam April 2023

- Located in EHN1 at H4 beam line of the SPS (CERN, North Area)
- Three triple-GEM tracking detectors
  - Ar/CO2 70/30
  - 10 x 10 cm^2 active area
  - Gaps in mm: 3/2/2/2
  - Resistors of divider in MΩ: 1/0.55/1/0.5/1/0.44/1
- Two detectors under test (DUT)
  - XYU-GEM
  - Twin-TPC
- Three Scintillators for additional trigger information
- First time stable operation of 8 hybrids (Tracker 2/3) on one DVMM/FEC



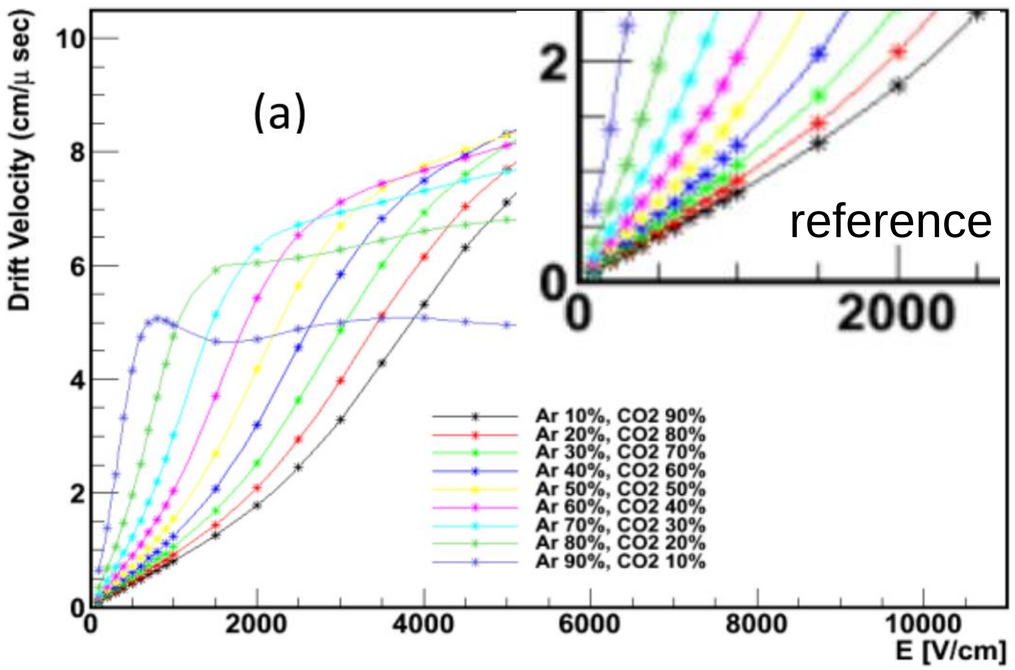


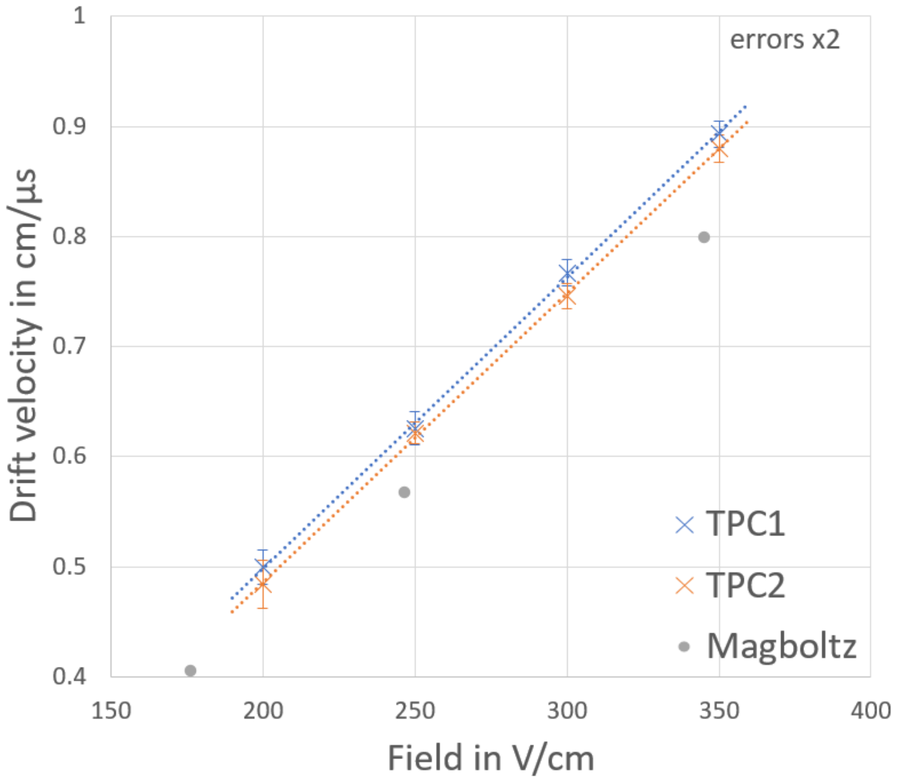
Twin TPC


hits pos0
counts
x [pitch 0.4 mm]
hits pos1
counts
y [pitch 0.4 mm]
hits adc0
adc
x [pitch 0.4 mm]
hits adc1
adc
y [pitch 0.4 mm]
clusters pos0
counts
x [pitch 0.4 mm]
clusters pos1
counts
y [pitch 0.4 mm]
clusters adc0
counts
charge
clusters adc1
counts
charge

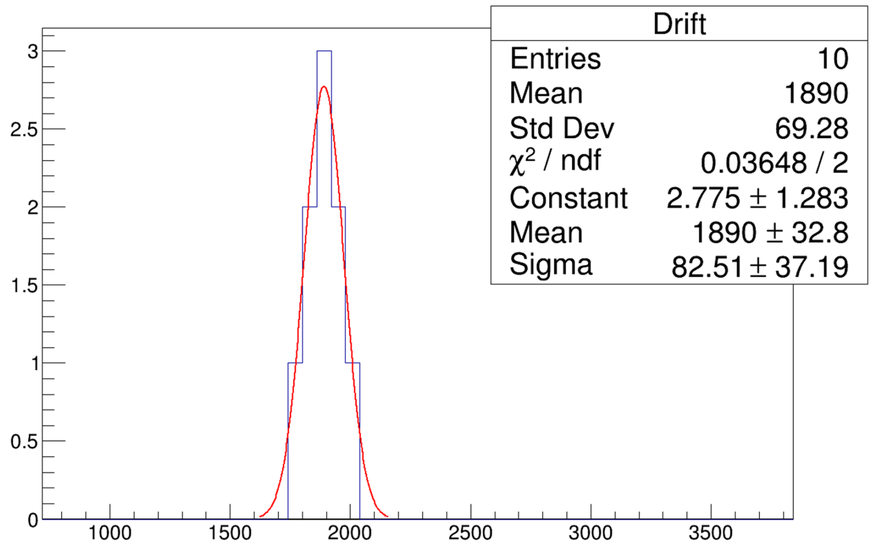
Calculating Drift Velocity

https://arxiv.org/ftp/arxiv/papers/1110/1110.6761.pdf





Example plotted time



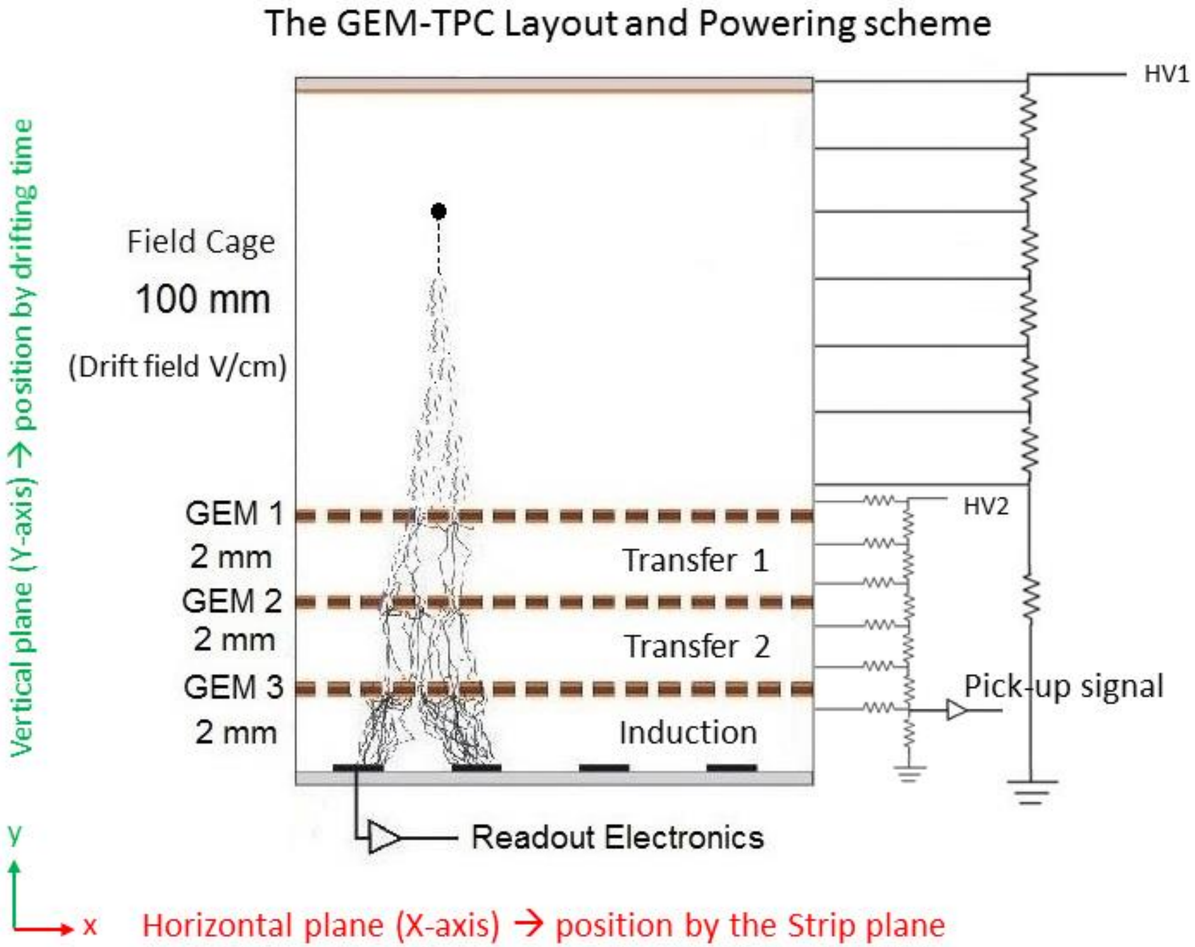
- Time calculated for different positions
  (cut on position in tracking detector)
  -> $t'_{1,2} - t'_0$ →time distribution for specific position

- Taking to different positions 2 times are obtained and the velocity can be calculated

Twin TPC

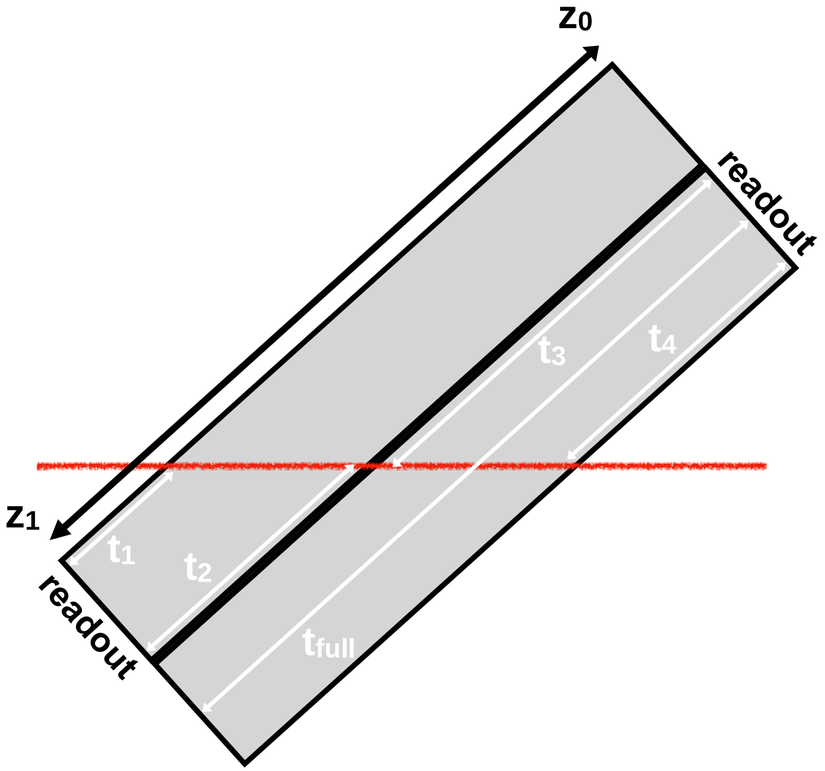
F. Garcia et al.: https://doi.org/10.1016/j.nima.2017.11.088

- Gas type: ArCO2 (70/30)
- Flow: 5 l/h
- Two HV channels per GEM-TPC (check for the run in the logbook) --> HV1 = Cathode, Voltage is high ~6 kV, current low ~100uA. HV2= GEM stack (Triple GEM), Voltage is moderate ~3 kV, current is high ~660 uA
- Four VMM3a hybrids per GEM-TPC plus one hybrid for T0
- Bottom of GEM-TPC readout by custom made preamplifiers; one per GEM-TPC
- Total drift time: 12 ns



Courtesy of F. Garcia

Twin TPC - how to get z - simplified



Self triggered hits referring to the same absolute zero time t_0'

- Synchronised readouts
  -> $t'_{1,2,3,4} = t'_0 + t_{1,2,3,4}$ is valid for all times

- The absolute times t' can be used to get the relative times t
  -> Only possible if absolute times correspond to the same event
  -> $t'_3 - t'_2 = t'_0 + t_3 - (t'_0 + t_2) = t_3 - t_2$

- With access to the relative time and the full drift time t_{full} it is possible to extract a time corresponding to a z-value (three examples)
  -> $(t'_3 - t'_2 + t_{full})/2 = 0 with t_3 = 0, t_2 = t_{full} \rightarrow z_0$
  -> $(t'_3 - t'_2 + t_{full})/2 = t_{full} with t_2 = 0, t_3 = t_{full} \rightarrow z_1$
  -> $(t'_3 - t'_2 + t_{full})/2 = 0.5 t_{full} with t_2 = t_3 \rightarrow 0.5 z_1$