Analysis of data recorded by a GEM LPTPC

Martin Ljunggren
on behalf of the LCTPC Collaboration

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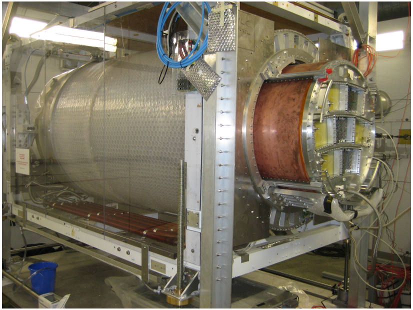
LUND UNIVERSITY

A Time Projection Chamber for a future Linear Collider

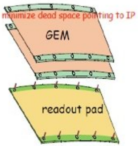
www.lctpc.org

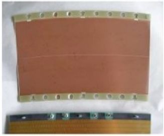
Outline

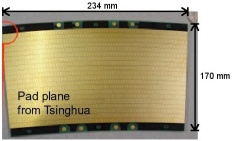
- The Large Prototype TPC with GEM readout
- Readout electronics
- Track reconstruction
- Distortion correction
- Spatial resolution
- Momentum resolution

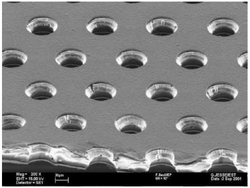


GEMs and pad plane









- 5152 pads, approximately 1x5 mm, organized in 28 rows
- A GEM-foil consists of 5 μm Cu-layers separated by 100 μm of insulating material
- Hole size: 70 μm
- Pitch: 140 μm
- 360V between Cu-layers
- Two GEM foils give a gain of about 10^4
- "T2K-gas": 95% Ar, 3% CF_4, 2% isobutane

Instrumentation

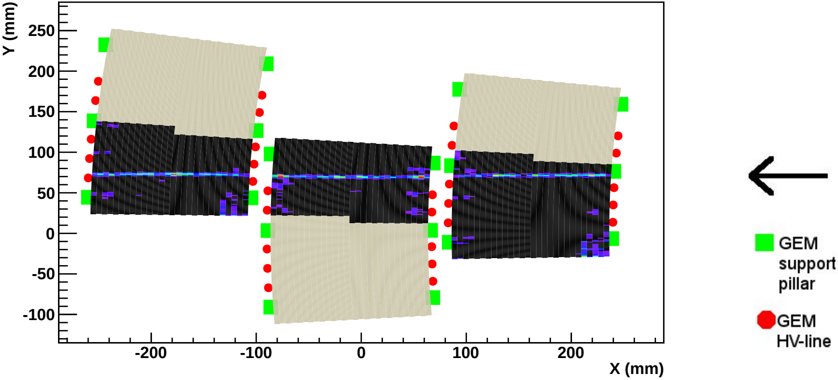


Figure: The instrumented region of the pad planes (black)

Readout electronics

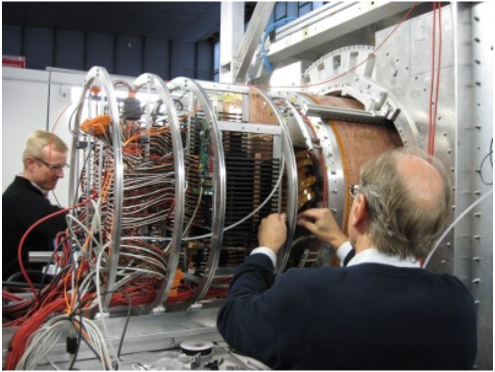
PCA16:

- 16 channel preamplifier and shaper
- Modified version of PASA-chip from ALICE.
- Programmable gain, shaping and decay time.

ALTRO:

- Originally developed for ALICE.
- Sampling at 20 MHz
- Pedestal subtraction and zero suppression
- Capable of storing 1024 10 bit ADC samples.

Next step: Integration of preamplifier and ADC into one chip (S-ALTRO).



Due to the large number of readout channels and the small space available on the pad modules, the electronics had to be connected with 30 cm long Kapton®cables.

Event display

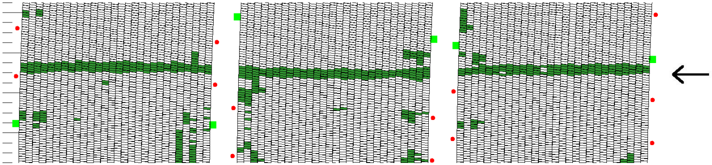


Figure: Typical event without magnetic field. Drift distance: 5 cm

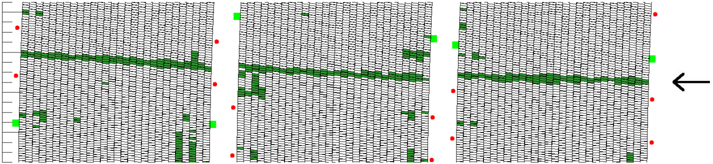


Figure: Typical event with magnetic field. Drift distance: 10 cm

Track reconstruction

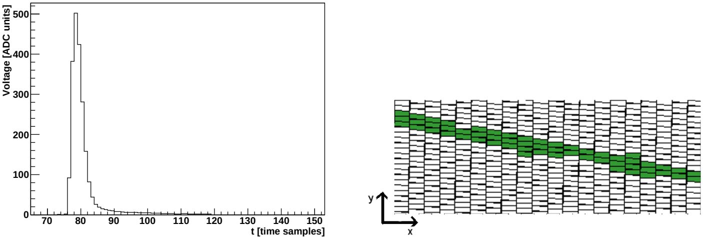


Figure: **Left**: Typical pulse. **Right**: Typical track.

- Time is reconstructed as the voltage weighted average of the five samples around the peak.
- Adjacent pulses are grouped into clusters where coordinates are determined by e.g. $y = \frac{\sum Q_i y_i}{\sum Q_i}$ where Q_i is the charge of the pulse and y_i is the corresponding y-coordinate of the pad.
- For tracking, a simple track reconstruction algorithm was used.

Residuals

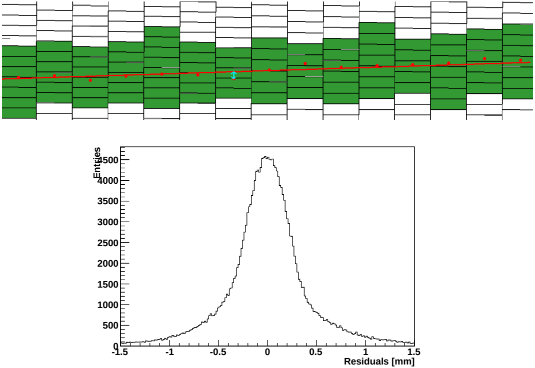


Figure: **Upper**: Magnified event display. **Lower**: Residuals integrated over the full track length from 10000 tracks with 7 cm drift length and B=0T, $\sigma \approx 0.31$ mm for a Gaussian core accounting for 95% of the total area. Distortion correcions have been applied.

Distortions

If the residuals are plotted against pad row, they should line up around zero. However:

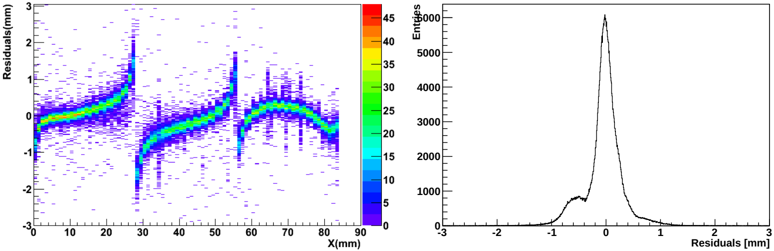


Figure: **Left**: Residuals for 10000 tracks vs pad row for B=1T and drift length of 10 cm. **Right**: Residuals integrated over the full track length using 10000 tracks from the same run

After corrections

Corrected using Millipede, see “A new method for the high-precision alignment of track detectors”, Volker Blobel

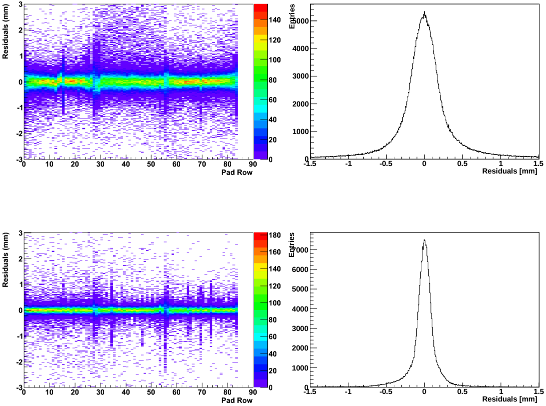


Figure: **Left**:Residuals for 10000 tracks vs pad row for B=0T and drift length of 5 cm (upper) and B=1T and drift length of 10 cm (lower) **Right**: Residuals integrated over the full track length using 10000 tracks from the same run, $\sigma \approx 0.16$ mm (upper) and $\sigma \approx 0.077$ mm (lower) for a Gaussian core accounting for 95% of the total area

Resolution in bend plane

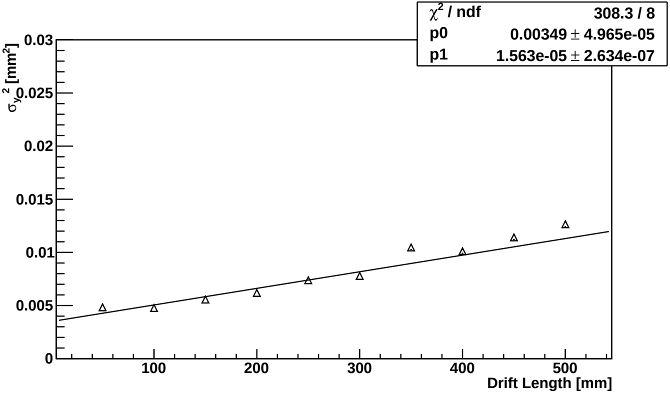


Figure: Measured resolution for different drift lengths. The line crosses the y-axis at 0.00349 mm^2 which corresponds to an intrinsic resolution of $\sigma_y(0) = 59.1 \pm 0.4 \mu$m.

Comparison with theoretical predictions.

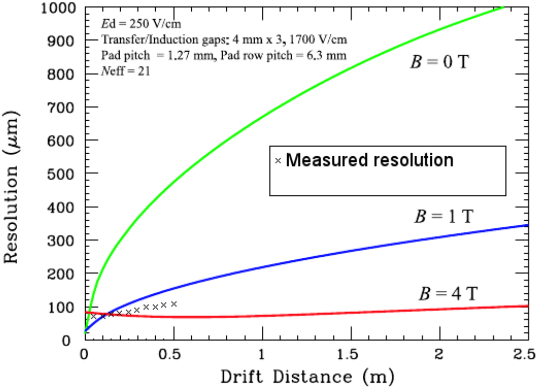


Figure: Predicted resolution for different magnetic field strengths and slightly different conditions. Also shown are the points measured experimentally (shown in prev. slide)[1].

[1] K. Ackermann et.al. Nucl.Instrum.Meth.A623:141-143,2010

Resolution in Z

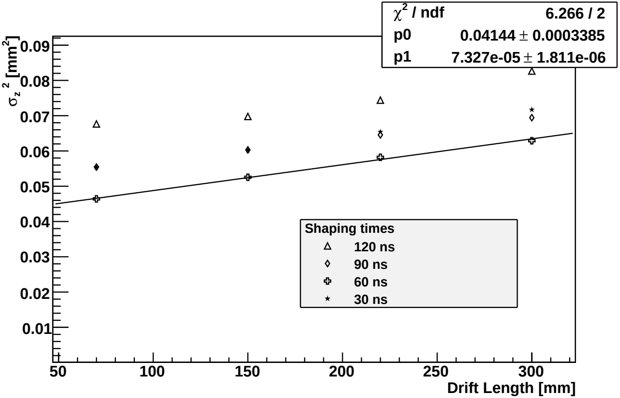


Figure: Measured resolution in the z-direction for different drift lengths and shaping times. The best results are obtained with a shaping time of 60ns. Extrapolating the fitted line to half the drift length of the final TPC gives $346 \pm 9\mu$m which is well below the desired resolution of 500μm. An extrapolation to the full drift length (2.15 m) gives $446 \pm 9\mu$m, still below the goal resolution.

Momentum measurements

- $p \approx 0.3B \cdot R$
- $\sigma(1/p) \approx 9.2 \cdot 10^{-3} \pm 0.0002 \text{ GeV}^{-1}$
- The track fit includes all points along a reconstructed track.

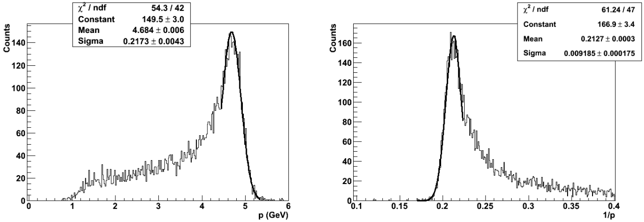


Figure: Measured track momenta (left) and 1/p-distribution (right) at a drift length of 15 cm.

- The momentum resolution has been calculated from a gaussian fit to the peak covering 42% of the total area.
- However, the momentum spread of the beam is $\approx 5\%$ which gives $\sigma(1/p) \approx 0.01 \text{ GeV}^{-1}$ at 5 GeV, and therefore the measured width is fully consistent with the beam spread.

Theoretical momentum resolution

- Glückstern's formula: $\delta(\frac{1}{P_T}) = \frac{\sigma_y}{0.3L^2B}\sqrt{\frac{720}{N+4}}$
- $N = 84$, $L \approx 48$ cm and $B = 1$ T.
- $\sigma_y \approx 76\ \mu$m (drift of 15 cm) gives $\sigma(1/p) \approx 3 \cdot 10^{-3}\ \text{GeV}^{-1}$.

Summary

- Test measurements with a TPC using GEM readout have been performed.
- Corrections for electric field distortions have been introduced using the Millepede software package.
- Results on spatial resolution show that σ_y at zero drift is $59.1 \pm 0.4 \mu m$ and σ_z at zero drift is $216 \pm 7 \mu m$.
- Result on momentum resolution is $\sigma(1/p_t) \approx 9.2x10^{-3} \pm 0.0002 GeV^{-1}$ at a drift length of 15 cm. The momentum spread of the beam is however non negligible.
- Theoretical estimation on momentum resolution at $\sigma_y \approx 76\ \mu\text{m}$ gives $\sigma(1/p) \approx 3 \cdot 10^{-3}\ \text{GeV}^{-1}$.
- Results on spatial resolution are consistent with the goals for the full size ILD TPC.

Resolution

- Track parameters from fit gives too optimistic estimation of the resolution.
- Use geometric mean of widths of the distributions with investigated cluster included, σ_{inc}, and excluded, σ_{exc}, from fit respectively. [1]
- $\sigma = \sqrt{\sigma_{inc} \cdot \sigma_{exc}}$

[1] D.C.Arogancia et.al. Nucl.Instrum.Meth.A602:403-414,2009