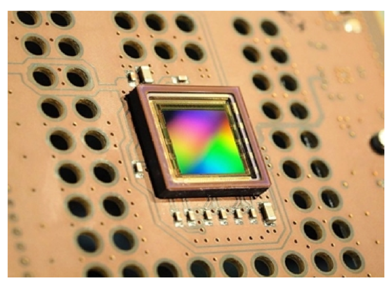
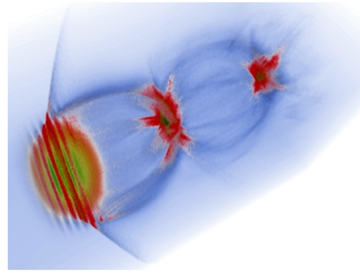
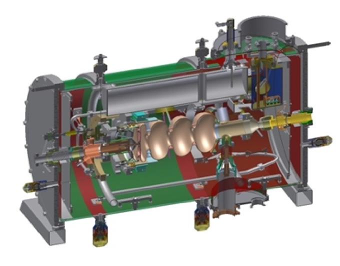
High precision Time Projection Chamber (TPC)







Uwe Krämer and Paul Malek

Matter and Technologies
Detector Development

TPC performance

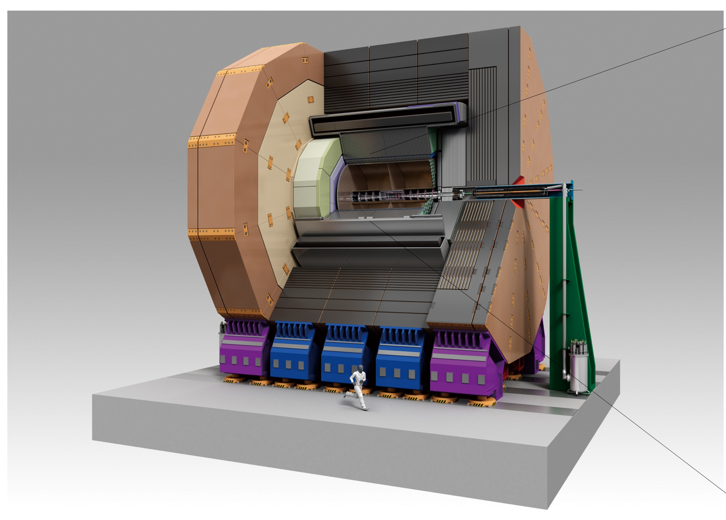
- TPC principle used since late 1970s for tracking detectors
- Traditionally using multi-wire proportional chambers for gas amplification / readout
- Modern Micro Pattern Gaseous Detectors (MPGD): reduced ExB distortions and increased granularity of readout
  →higher spatial resolution
  →reduced material budget

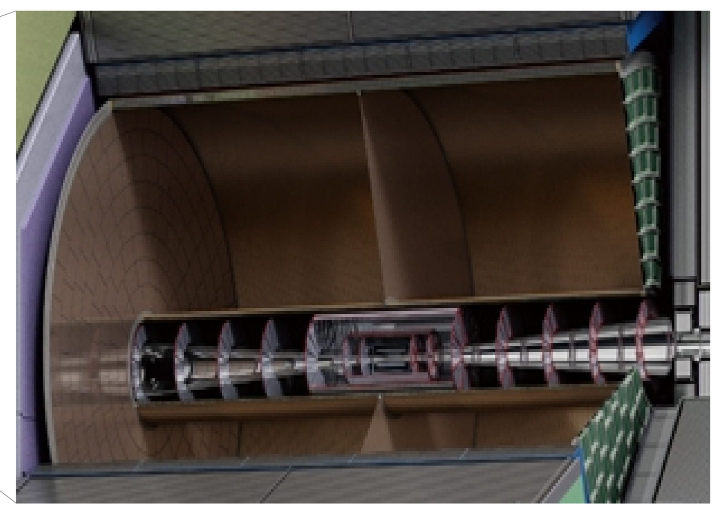
rφ single point resolution of older TPCs:

- DELPHI rφ resolution = 250 µm
- TRIUMF rφ resolution = 180 µm
- ALEPH rφ resolution = 150 µm
- ALICE rφ resolution = 350 µm

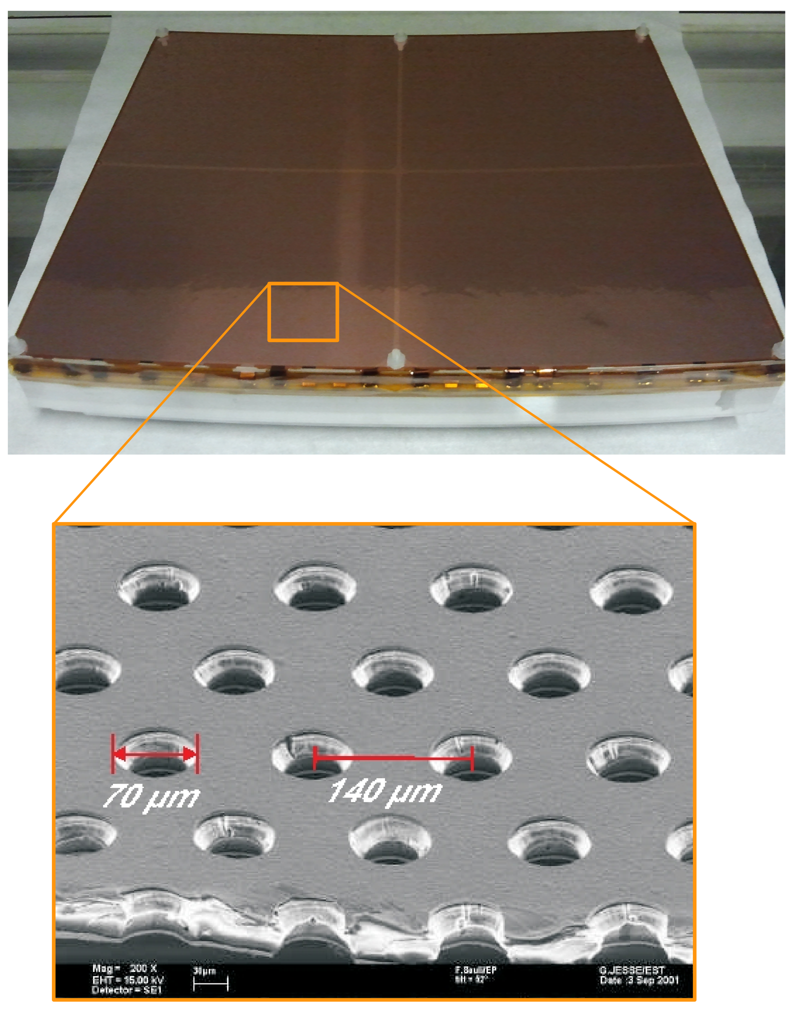
Goal is to build a large scale TPC achieving[1]:

- O(200) space points along each track
- **σ ~100 µm single point in the rφ plane**
- σ ~300 µm single point in the z direction.
- σ ~ 10^{-4}/GeV/c momentum resolution





Gas Electron Multiplier (GEM) Module



TPC readout modules using Gas Electron Multiplier (GEM) in integrated structure[2]:

- Three stacked GEM foils
- Amplification of ~30 per foil = total amplification of ~27000
- T2K gas used for drift and amplification
- Ceramics grid between foils for spacing and mechanical stability
- Pad plane for electric readout (1.26mm x 5.85mm)
- 4864 channels per module

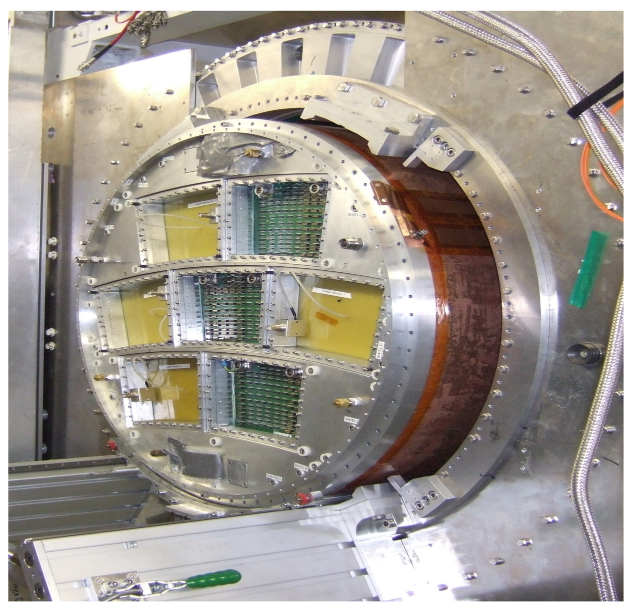
The design of the module is driven by operation goals:

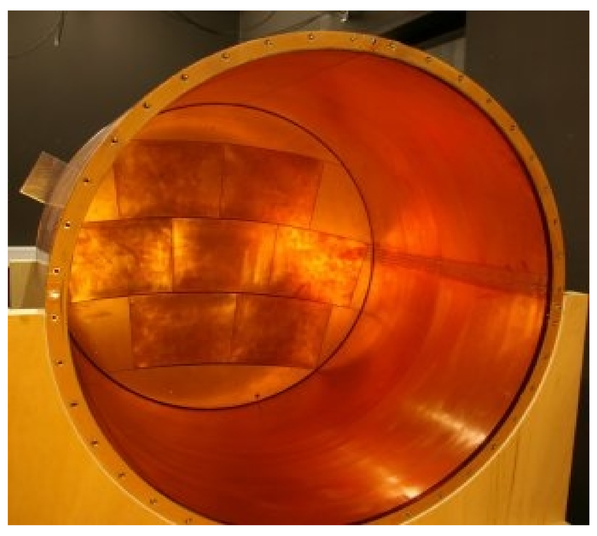
- GEMs are divided into 4 sectors
  → HV stability
- Triple GEM stack
  → stable operation at high gain
- Thin ceramic mounting structure
  → good GEM flatness and minimal insensitive area
- 28 space points along track per module

The Large Prototype at the testbeam

Permanent setup in testbeam area T24/1:

- 1T Magnet
- Movable around 3 axes
- 85 cm usable inner diameter
- Scintillator triggers for beam and cosmics
- Laser alignment system
- Two phase CO_2 cooling system
- 1 to 6 GeV electrons available





Large prototype built to fit within PCMAG to compare different technologies:

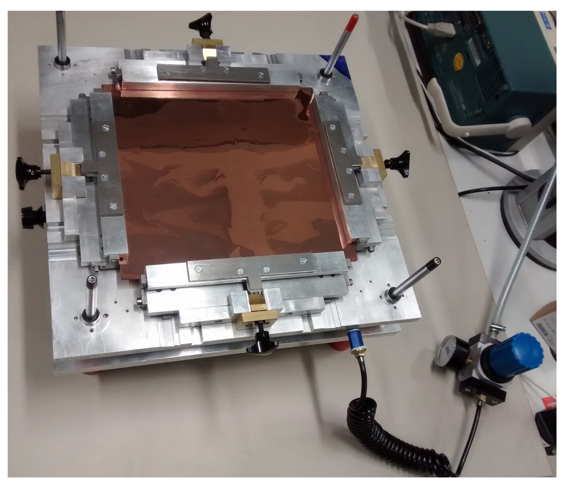
- Length = 61 cm
- Diameter = 77 cm
- able to host up to 7 modules of dimensions ~22x17 cm².
- Designed for up to 350 V/cm drift field = 25 kV cathode voltage

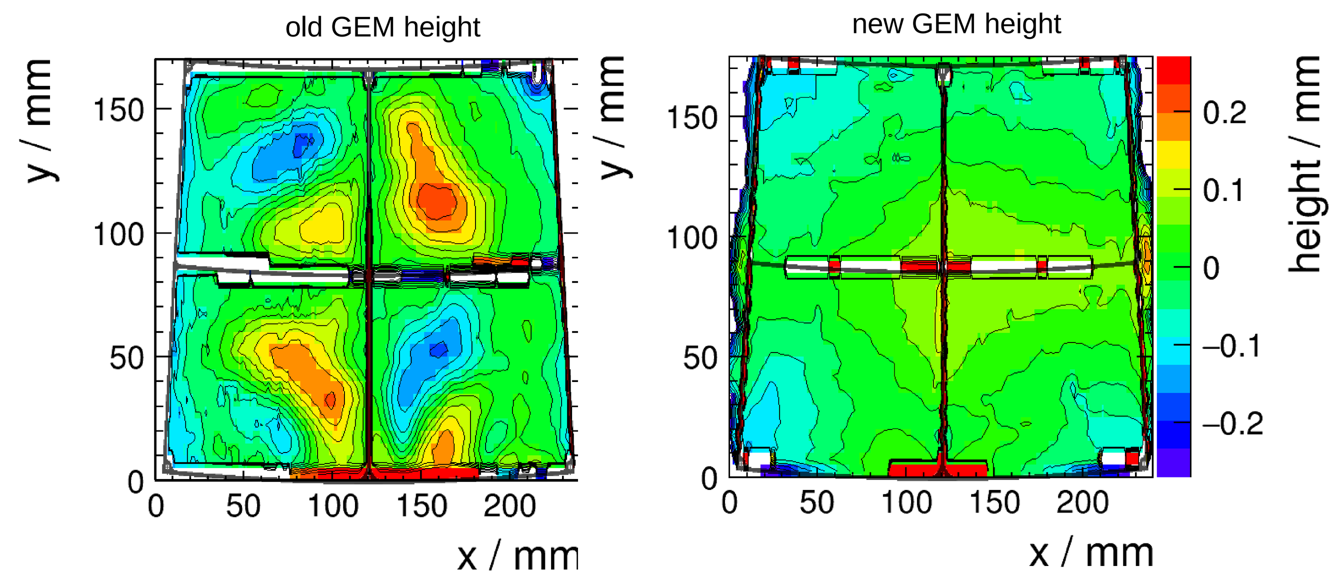
Module Production and Flatness

Electron collection and extraction, and thereby the effective gain, as well as dE/dx resolution depend on GEM flatness.

Dedicated tooling developed to[3]:

- Provide reliable and reproducible gluing of GEMs onto a ceramics grid
- Allow controlled stretching of the foil to ensure reproducible improved flatness.

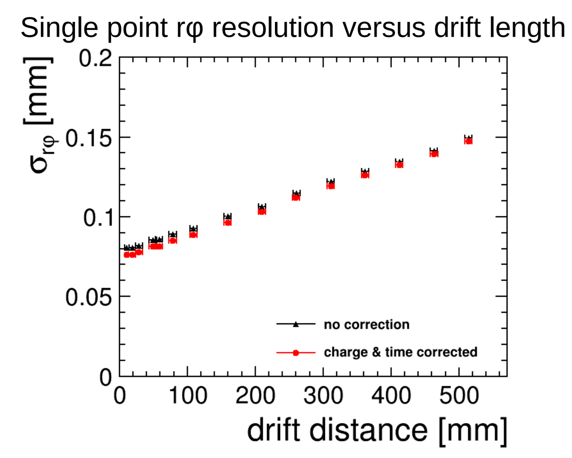


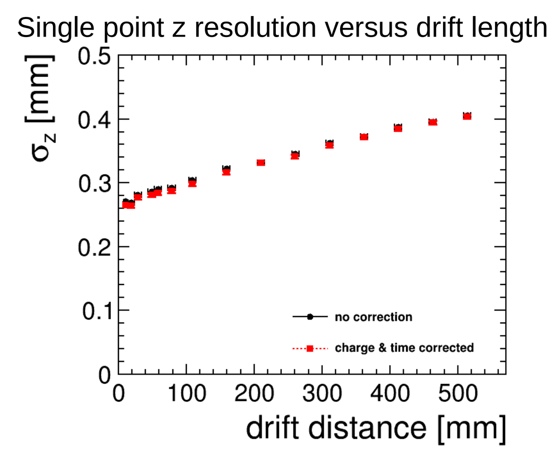


Single hit resolution

Extrapolation of testbeam results to ILD parameters shows[2]:

- ~100 µm single point rφ resolution is reachable
- ~350 µm single point z resolution has been achieved

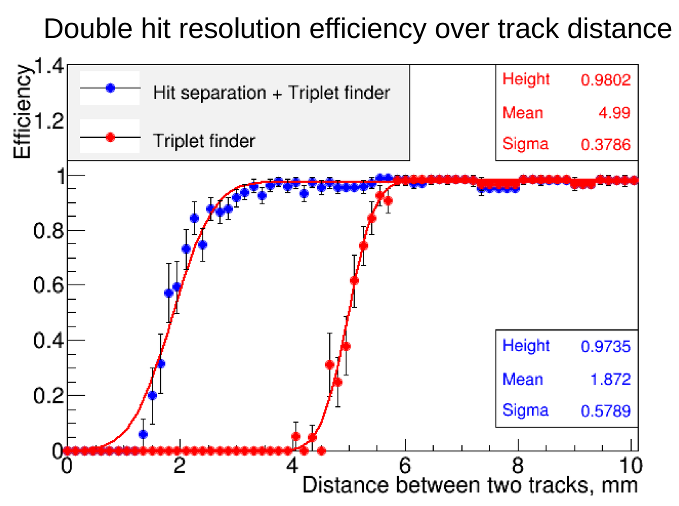




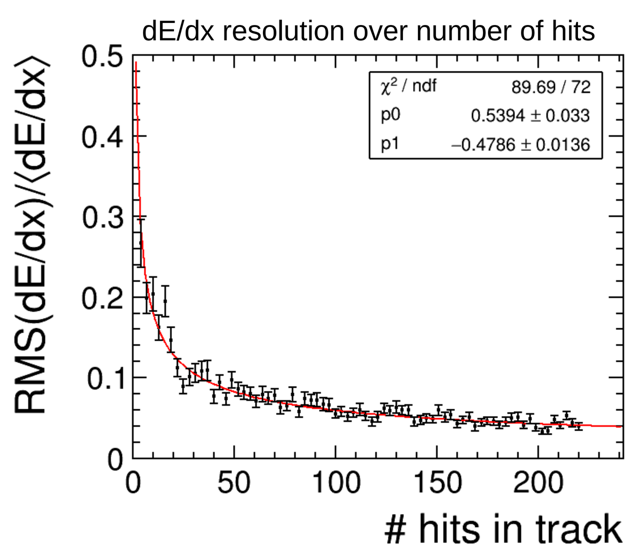
Double hit resolution (DHR)

Improvement of hit separation algorithm:

- Previous algorithms = simple either or hit assignment → DHR ~5 mm.
- New algorithms = use of the pad response function for hit separation
  → DHR ~2 mm.



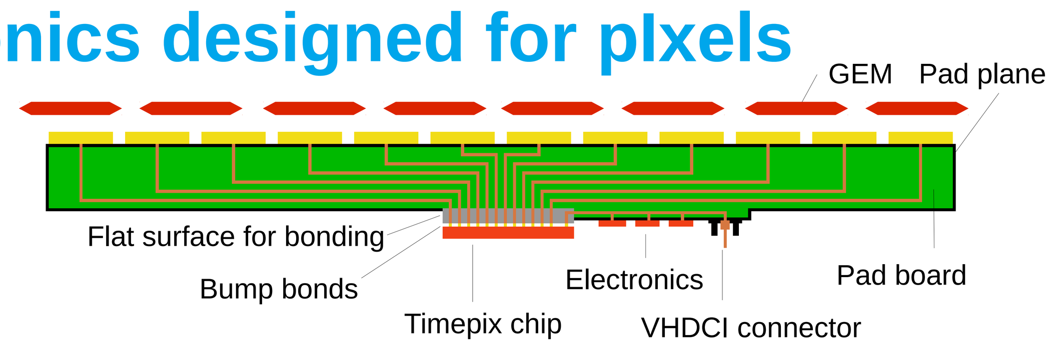
dE/dx resolution



High number of hits allow particle identification by dE/dx:

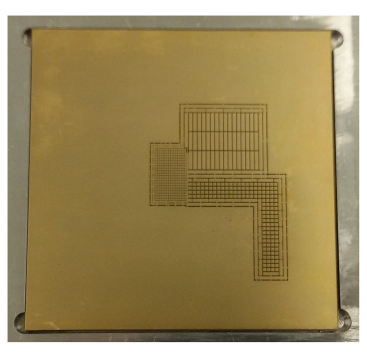
- Extrapolation of testbeam results show:
  → ~5% resolution on dE/dx is reachable with small ILD size TPC.
  (ALICE = 9% dE/dx resolution)

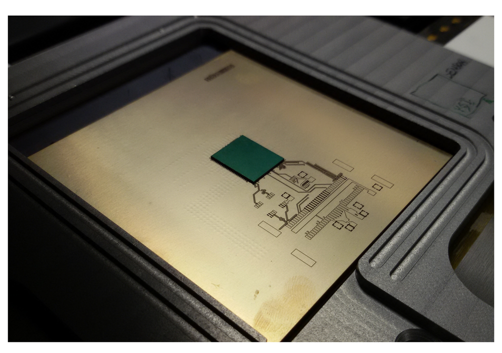
ROPPERI - Readout Of a Pad Plane with ElectRonics designed for pIxels

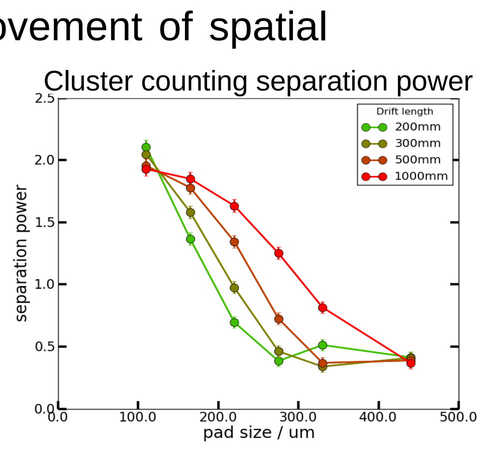


Advantages:

- Highly integrated high granularity readout
- dE/dx determination by measurement of primary ionization cluster
- Nearly arbitrary pad sizes
- Square pads, several pads per charge cloud → improvement of spatial resolution







1) The International Linear Collider Technical Design Report - Volume 4: Detectors Behnke et. al., arXiv:1306.6329 [physics.ins-det]

2) A time projection chamber with GEM-based readout, D. Attié et. al. NIM A, Volume 856, 2017, Pages 109-118

3) Development of a GEM based TPC Readout for ILD, Paul Malek, arXiv:1703.05719 [physics.ins-det]

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RESEARCH FOR GRAND CHALLENGES

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