Performance of a TPC with Triple GEM and Pixel Readout at long drift distances

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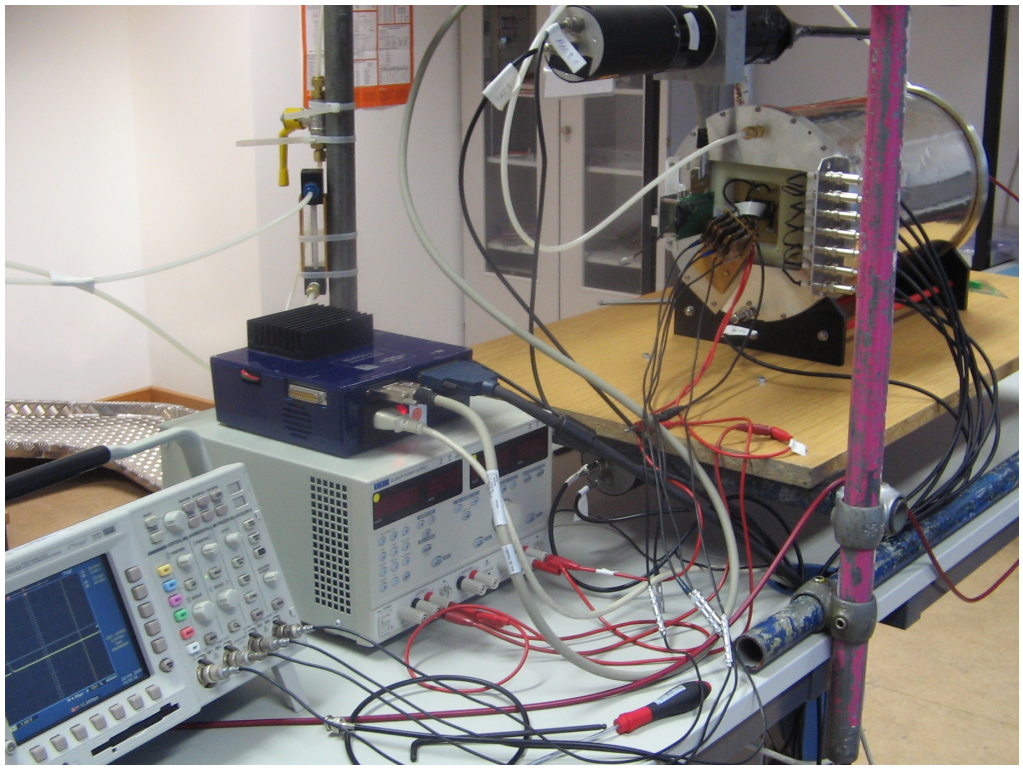
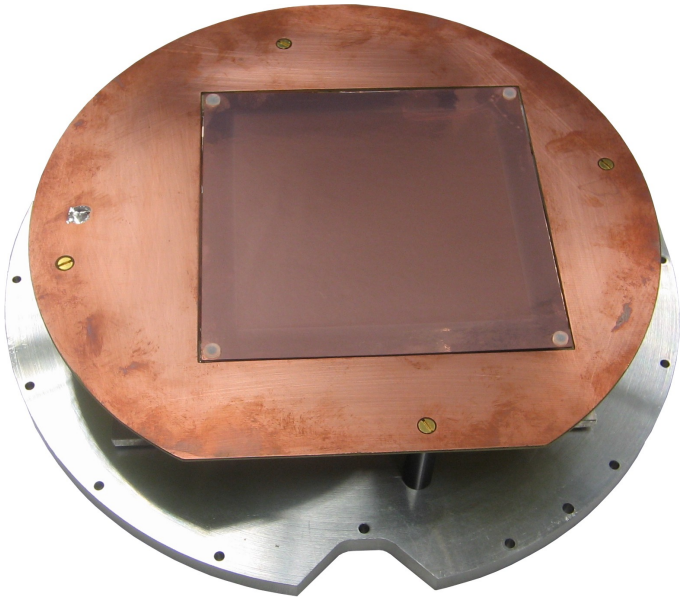
GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

TPC Test Setup

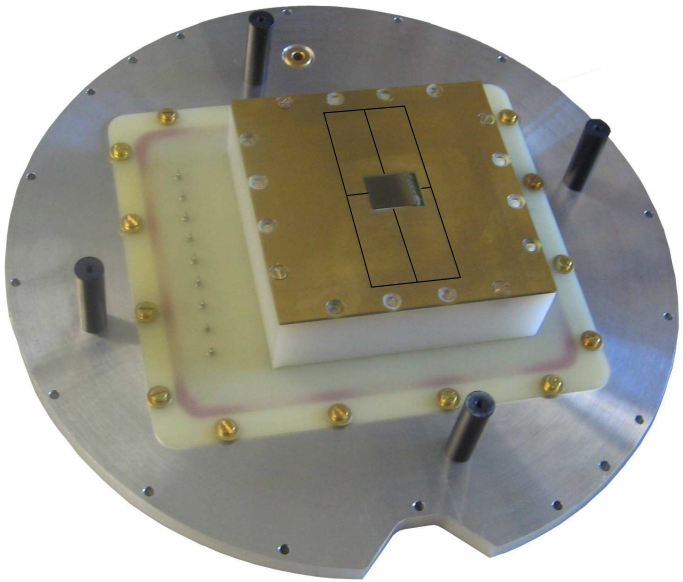


- Field cage designed and produced in Aachen
  - 26 cm diameter
  - 26 cm drift distance
  - Low material budget: 1 % X_0
  - Drift field up to 1 kV/cm
  - Fits into 5 T magnet at DESY
- Trigger for cosmic muons: Scintillators above and below the chamber
  - Veto circuit: Only one shutter window per recorded frame
- TimePix readout with Muros and PixelMan

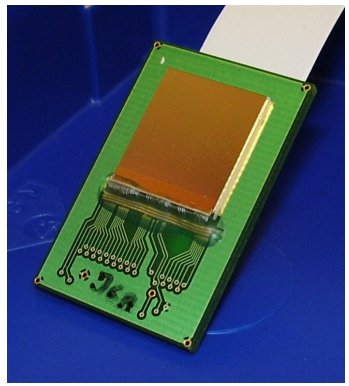
Gas Amplification and Readout



- Triple-GEM stack
- 1 mm transfer gaps and induction gap
- 390 V across each GEM
- Transfer field 2500 V/cm
- Induction field 3000 V/cm



- TimePix
  - 256×256 Pixel^2
  - 55×55 µm^2 pixel size
  - Active area 14×14 mm^2
- Single chip board
  Modified Freiburg design to glue board into readout plane from the back
- 4 large pads, connected to preamps and oscilloscope



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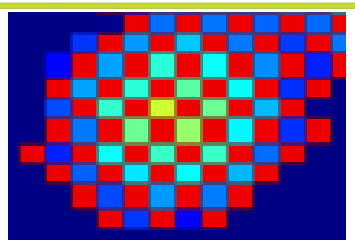
Measurements with Cosmics

More than 40,000 tracks
in 1 month of data taking

TimePix operated in "Mixed Mode":
Chequerboard pattern with pixels alternating in

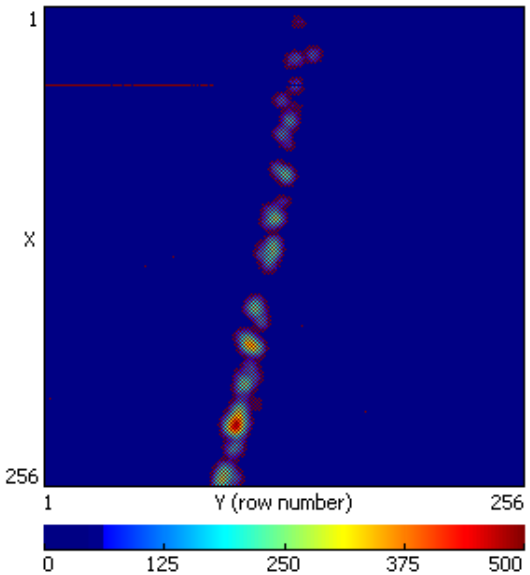
- Time Mode
- Time-Over-Threshold Mode
  proportional to charge



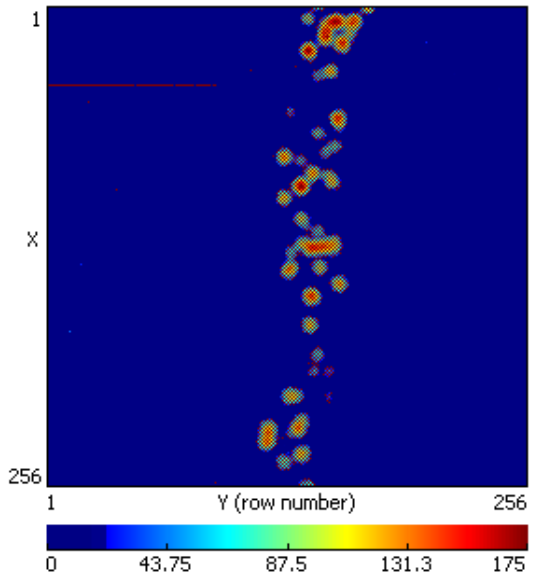
Cluster recorded in mixed mode

- Red: Time
- Blue to green: Charge

- Gas: Ar/CO_2 70/30
- Drift field: 500 V/cm
- GEM voltages: 390 V
- Transfer fields: 2500 V/cm
- Induction field: 3000 V/cm



short drift distance



long drift distance

PixelMan Event Display

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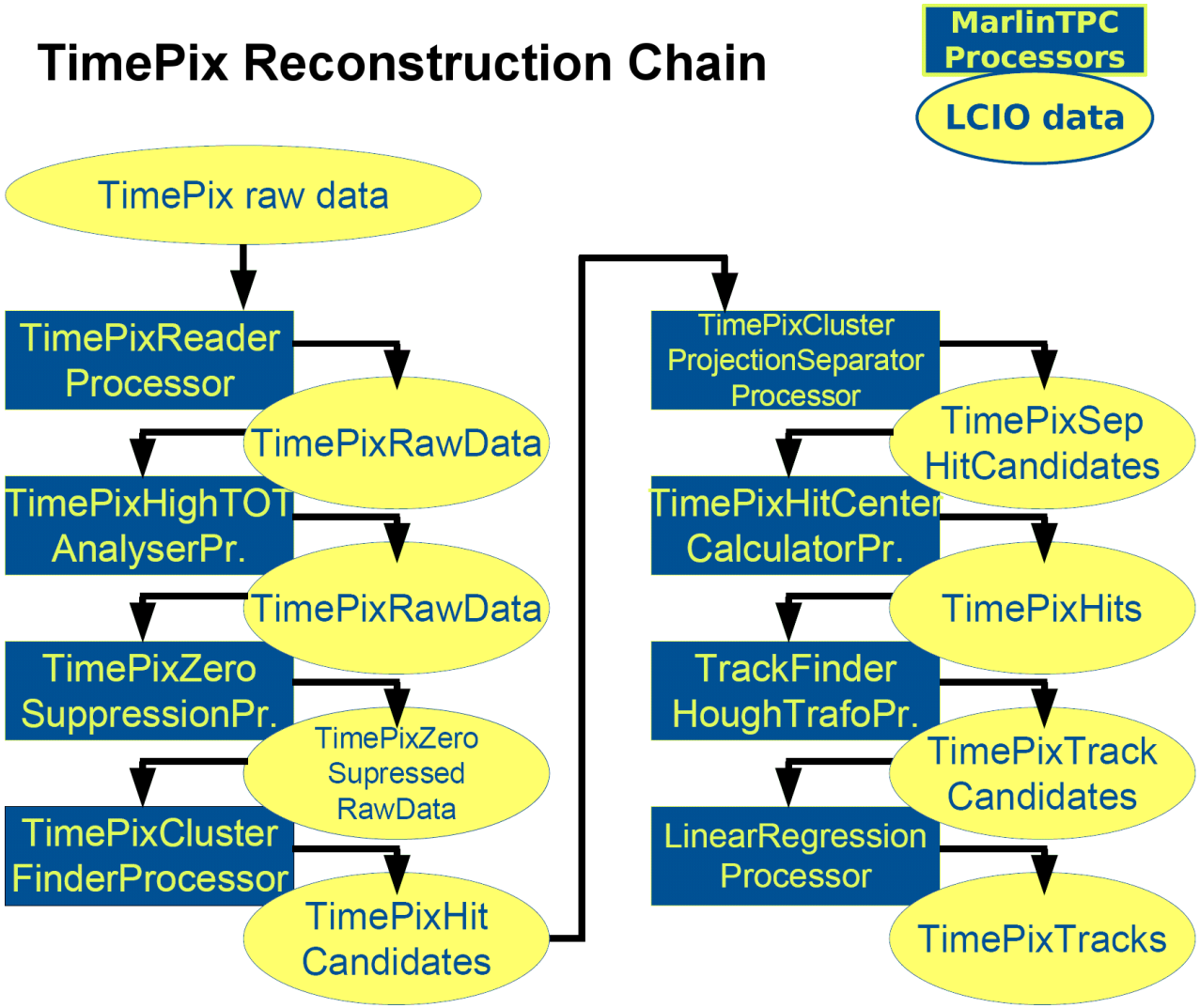
Reconstruction and Analysis: MarlinTPC

MarlinTPC is the TPC simulation, digitisation, reconstruction and analysis package for the Marlin framework

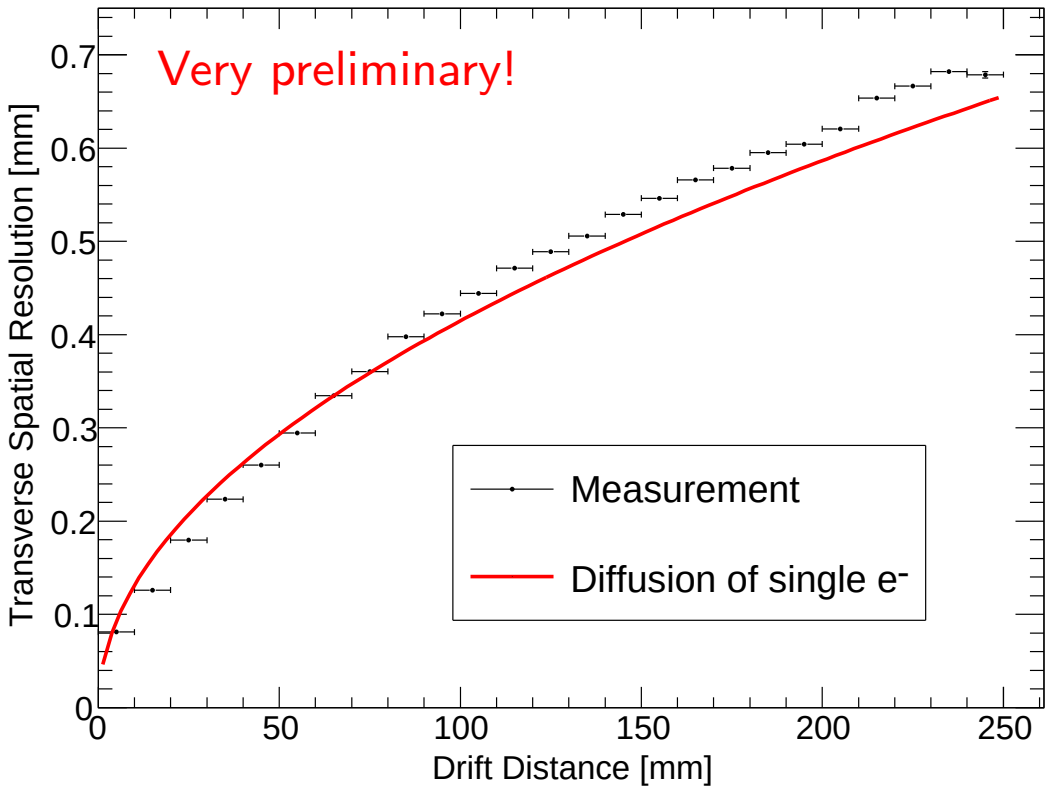
TimePix Reconstruction Chain



Very modular with more than 50 processors, suited for all kinds of TPC readout (GEMs/Micromegas, ADCs, TDCs, TimePix)

- Reader for TimePix data from PixelMan
- Complete TimePix reconstruction chain
- Analysis processors (e. g. to determine spatial resolution)
- TimePix digitisation

Spatial Resolution



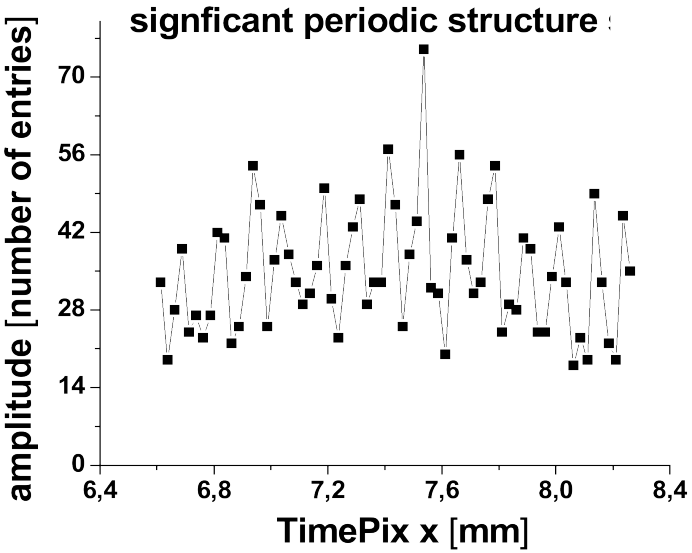
Current interpretation:

- Short drift distances: Multi-electron clusters
- Long drift distances: Single-electron clusters?

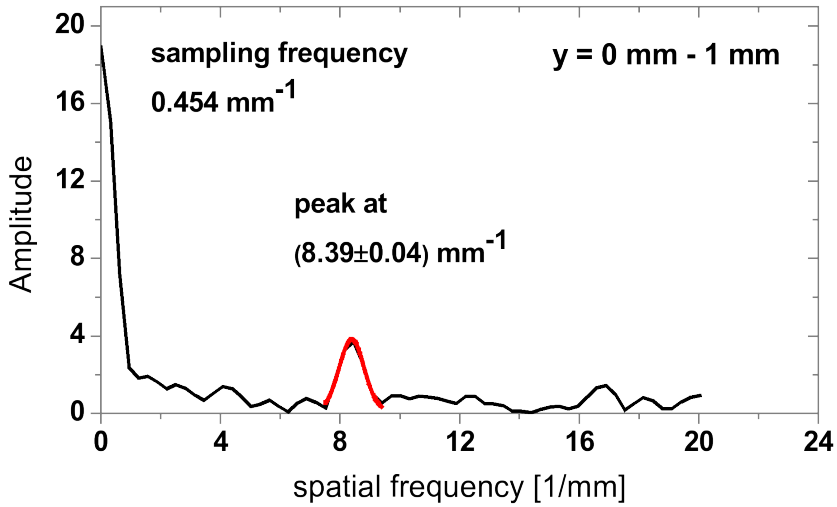
To be confirmed!

Results from Freiburg Test Beam

GEM structure shows up in reconstructed data



Fourier analysis



- Fourier transform: Period is 119 $\pm$ 6 µm (GEM pitch in x-projection is 120 µm)
- Signal only shows up in first millimetre
- For larger drift distances signal is smeared out due to diffusion

- Drift gap 6 mm
- Transfer gaps 2 mm each
- Induction gap 1 mm

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GEM structure measured in Bonn

- Dedicated high statistics run with ^{90}Sr source untriggered, no z information available
- Long drift distance $\approx$25 cm
- GEM spacing: 1 mm transfer gaps and induction gap

GEM structure measured in Bonn

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- Long drift distance ≈25 cm
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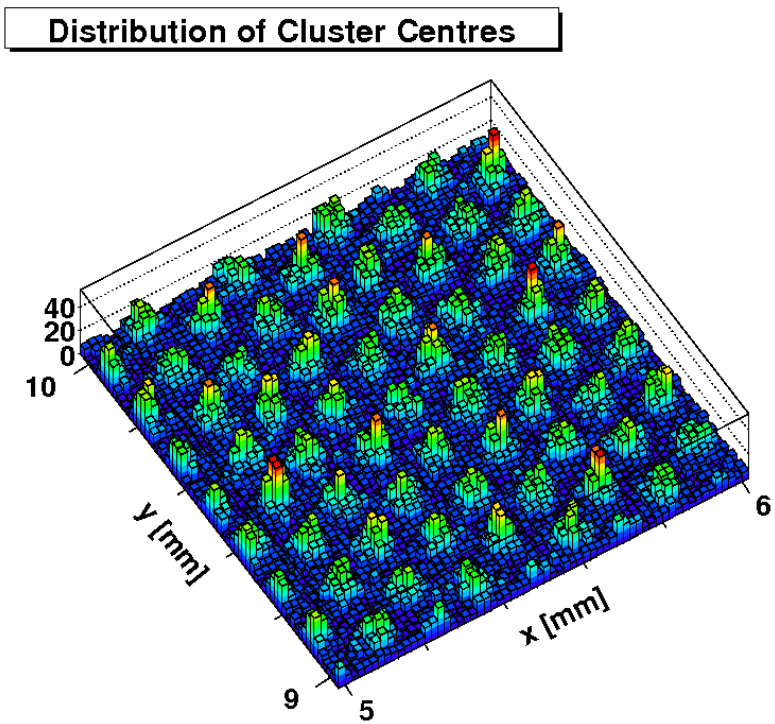

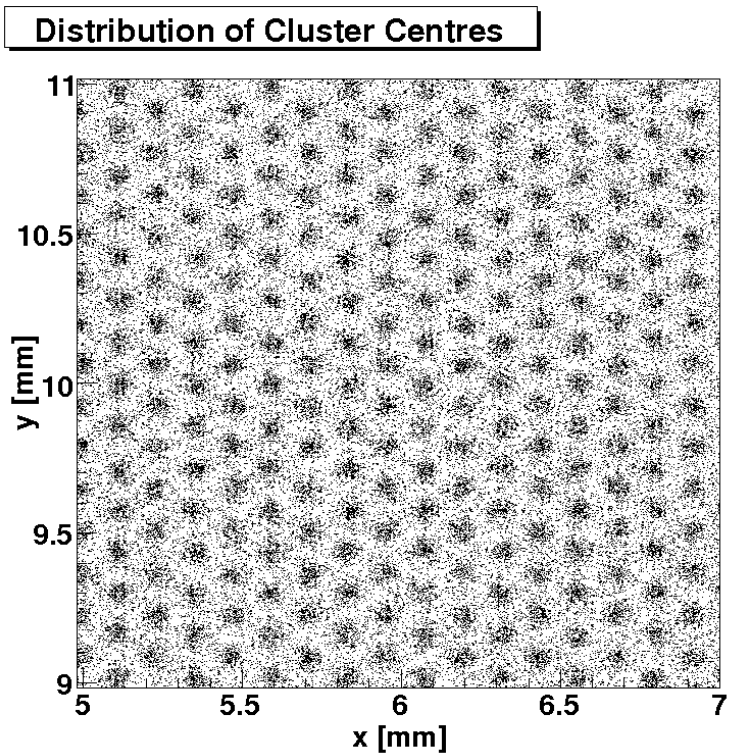

We can see every single GEM hole!

Measurement of GEM Structure

Current interpretation:
Spatial separation of the electrons originating from multiple-electron clusters occurs due to the transverse diffusion.

- Very small drift distances:
  All electrons of a primary cluster pass through the same GEM hole,
  GEM structure shows up
- Medium drift distances:
  Electrons of a primary cluster pass through neighbouring GEM holes,
  GEM structure is washed out
- Long drift distances:
  Individual electrons can be separated,
  GEM structure shows up

Problems with this interpretation:

- Number of reconstructed clusters at large drift distances is smaller than expected number of primary electrons (about 1/3)
  - Attachment?
  - Low single electron efficiency?
  - Do reconstructed clusters contain only single electrons?

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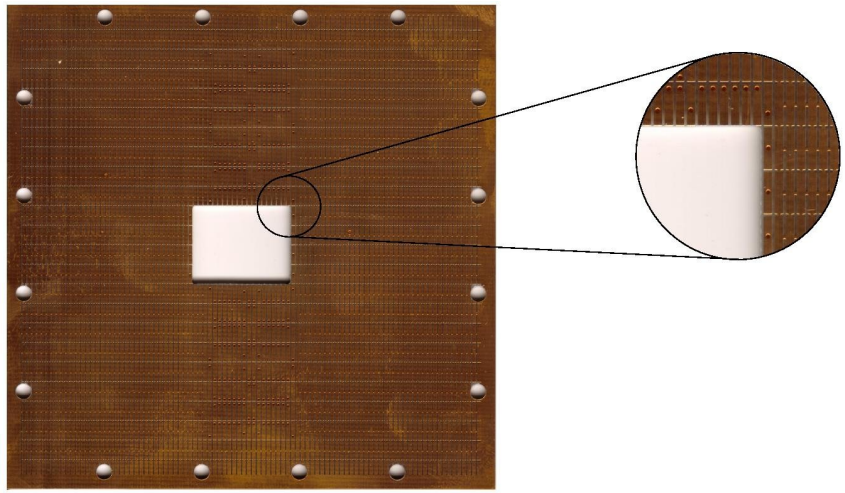
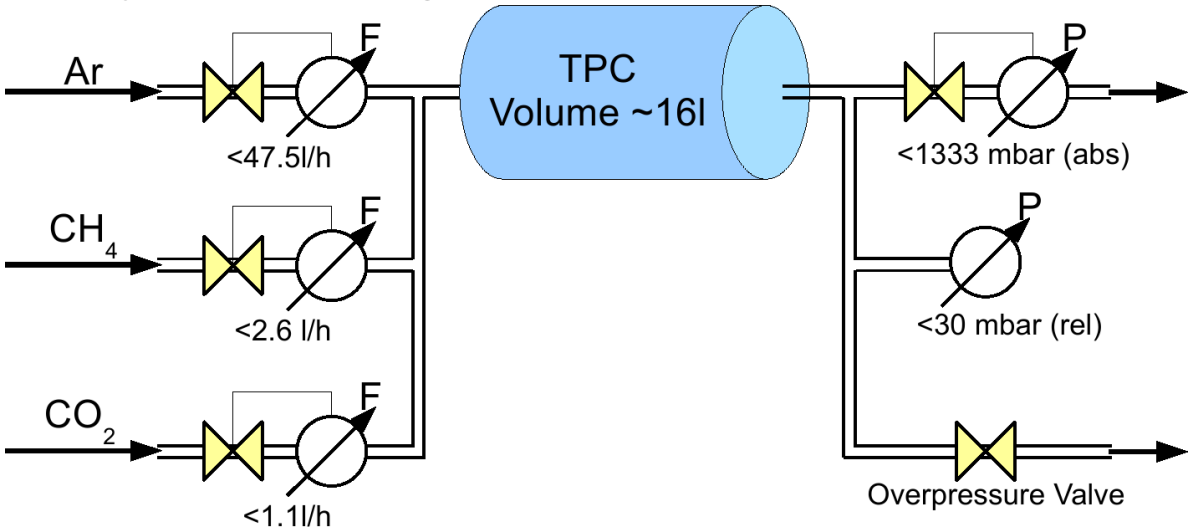
Next Steps

- Combined readout:
  Pad plane with 256 pads, 1×4 mm^2 + TimePix



- Gas system to mix gases and keep pressure constant



Post-Processing of TimePix

Freiburg group is testing MediPix chips with enlarged pixels ($110 \times 110\ \mu m^2$), post-processed on per chip level by FMF (Freiburger Metallforschungszentrum)

Bonn has established first contact with IZM:
Institut für Zuverlässigkeit und Mikrointegration, Berlin

Institut
Zuverlässigkeit und
Mikrointegration

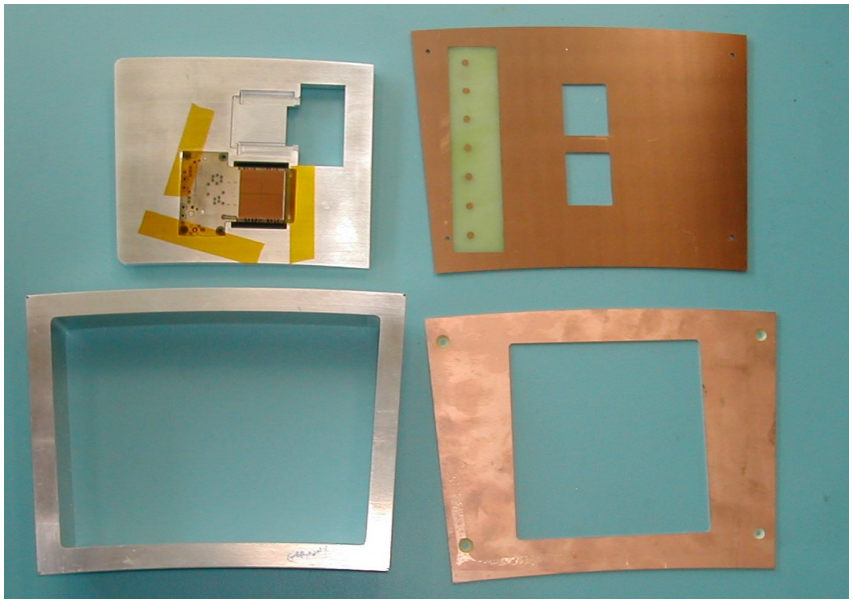
Post-Processing of TimePix chips — on wafer level:

- **Enlarging pixel size**
  by adding metal pads on a passivation
- **Silicon through vias**:
  replacing wire bonds by bump bonds
- **InGrid** — plans to learn technology from Twente University

Contributions to the development of a TimePix successor chip.

LP Module with 3GEM + TimePix

- 3 standard GEMs 10 $\times$ 10 cm^2
- 1 mm transfer gaps and induction gap
- Two quad-boards (NIKHEF) with 4 TimePix chips each



anode plane

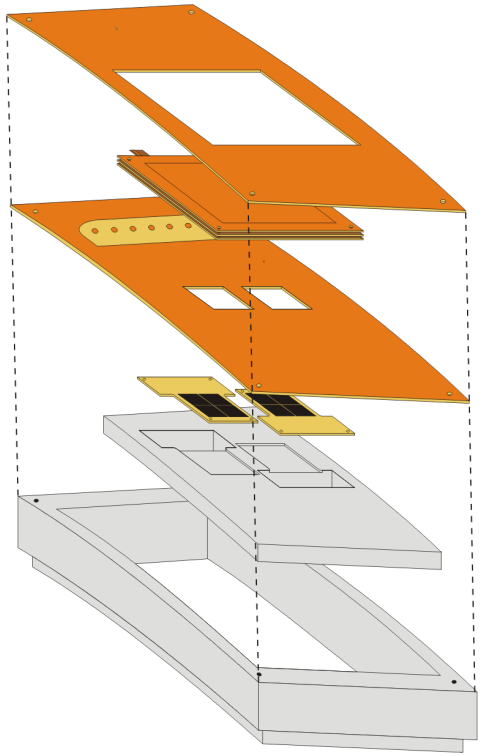
GEMs

readout plane

quad-boards

reinforcement of anode plane

redframe



- Currently testing quad-board

Summary and Outlook

TPC with 3GEM + TimePix readout

- Over 40,000 cosmic track recorded
- Individual GEM holes can be resolved
- Full TimePix support in MarlinTPC

Plans

- Combined pads + TimePix readout
- Wafer post-processing of TimePix

End of this Month:

- Test beam with 3 GeV electron beam from ELSA in Bonn
  High statistics z-scans

End of this Year:

- Measurements at EUDET large prototype