Measurements with the 2 Quadboards + GEMs Module in the EUDET Large Prototype TPC

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GEFÖRDERT VOM

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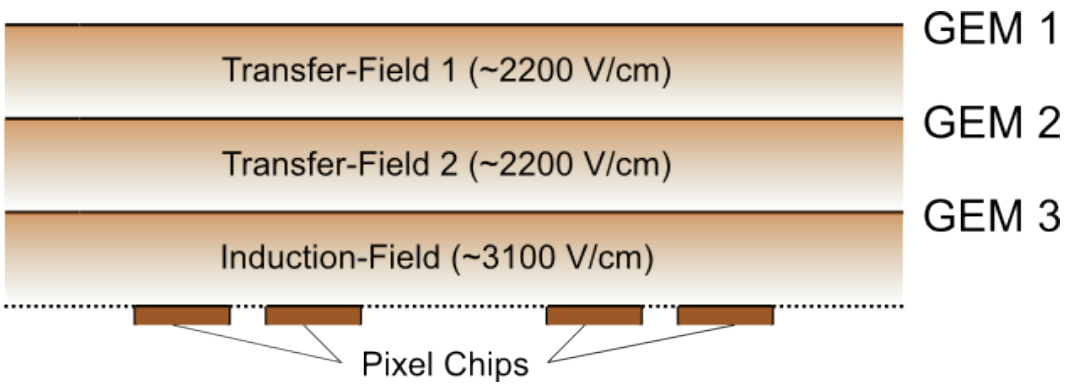
The Module

- Amplification with standard CERN GEMs (triple GEM stack)
- 1 mm transfer and induction gaps
- Readout with 8 Timepix chips (two Quadboards designed by NIKHEF)
- 256 x 256 pixels per chip; 55 µm x 55 µm pixel size
- >0.5 Mio channels (largest number of channels ever installed in a TPC)



The Module

anode plane

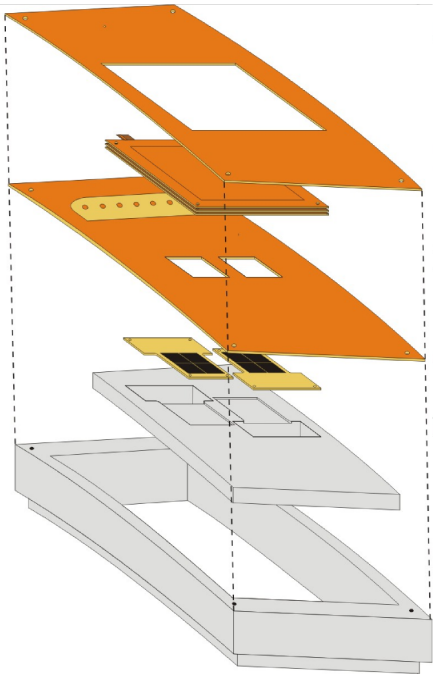
GEMs

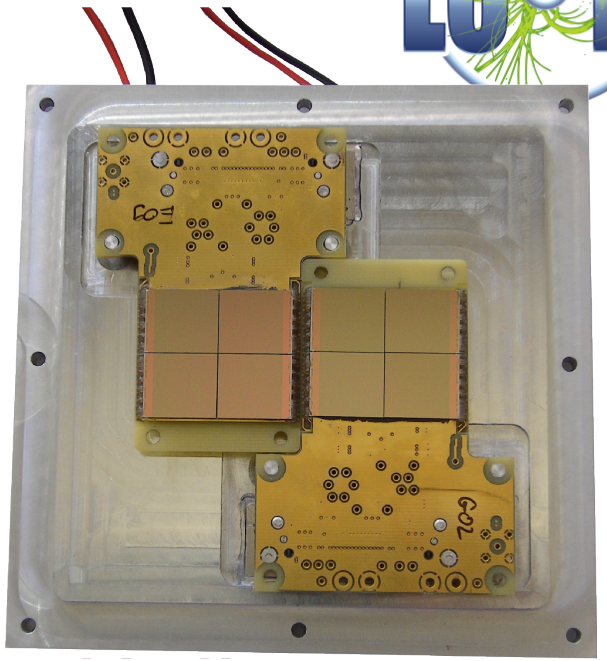
readout plane

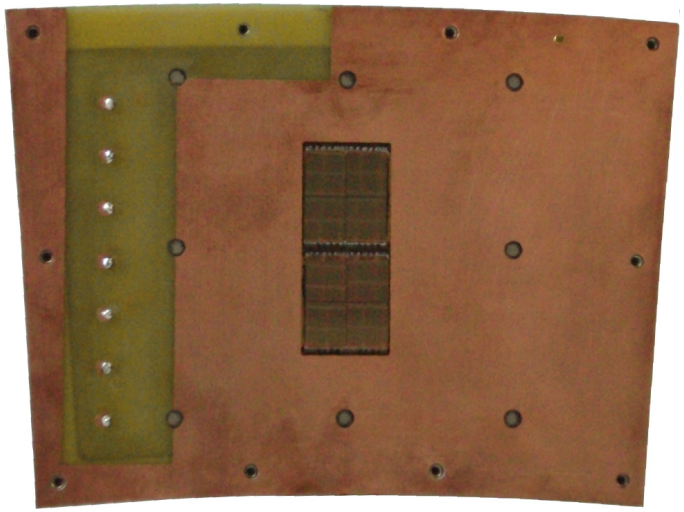
quad-boards

reinforcement of anode plane

redframe







Readout

Hardware

Originally planned:

- Readout with Prague USB readout
  - Quadboards cannot be addressed with these devices
  - Discussion with developers could not solve the problems

For the 2009 test beam:

- Quadboards read out by Muros (one from Freiburg, one from Bonn)
  - Systems are needed in the institutes
  - Muros is not produced any more
  - No devices available on stock

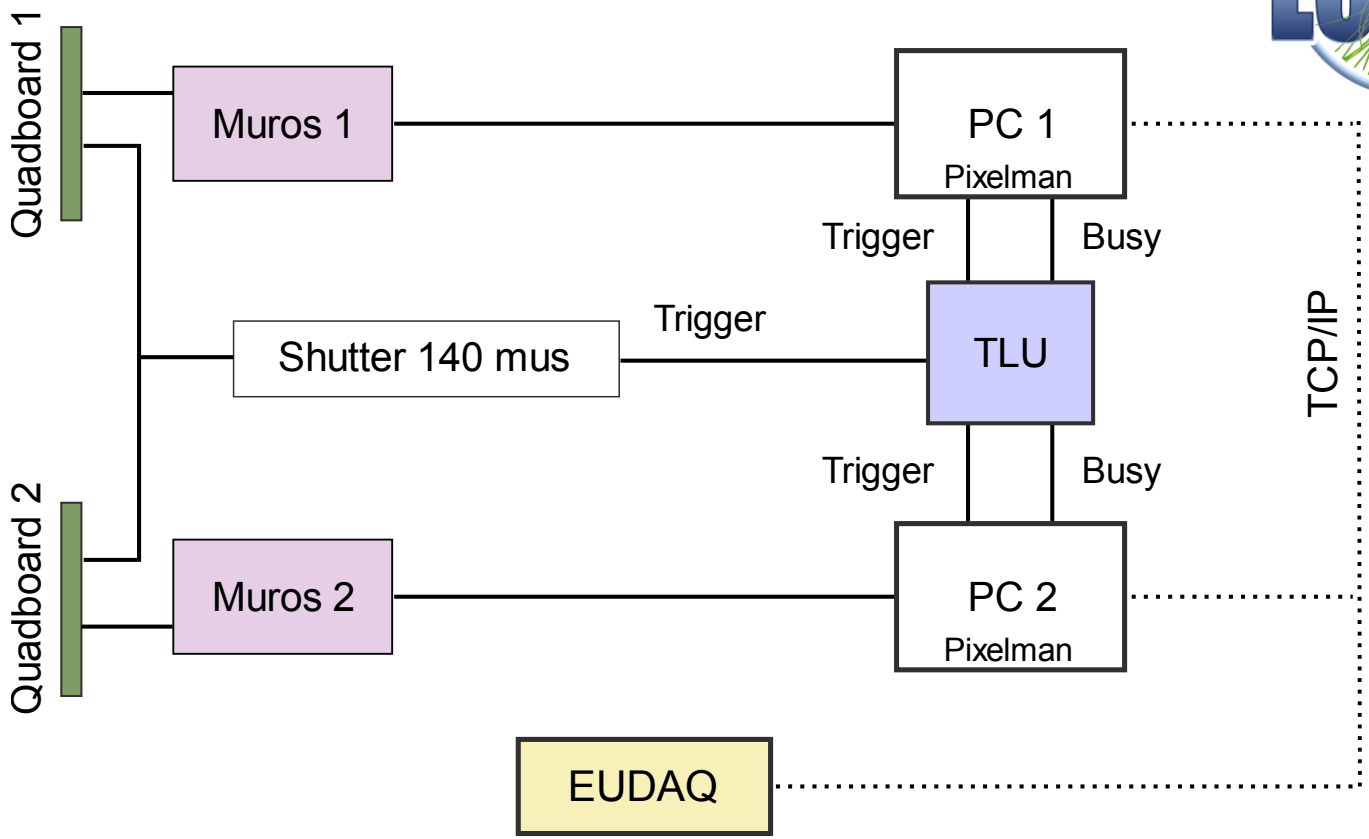
Need readout for taking data at the LP

Software

- Pixelman with EUDAQ plugin
  - Latest version does not support external shutter any more

  $\Rightarrow$ Bypass Muros and connect shutter directly to the chips

Readout Scheme



- DAQ PCs synchronised with **T**rigger **L**ogic **U**nit
  - Trigger is send to PCs and precision gate generator
  - Busy handshake ensures synchronisation
- Data is send to EUDAQ

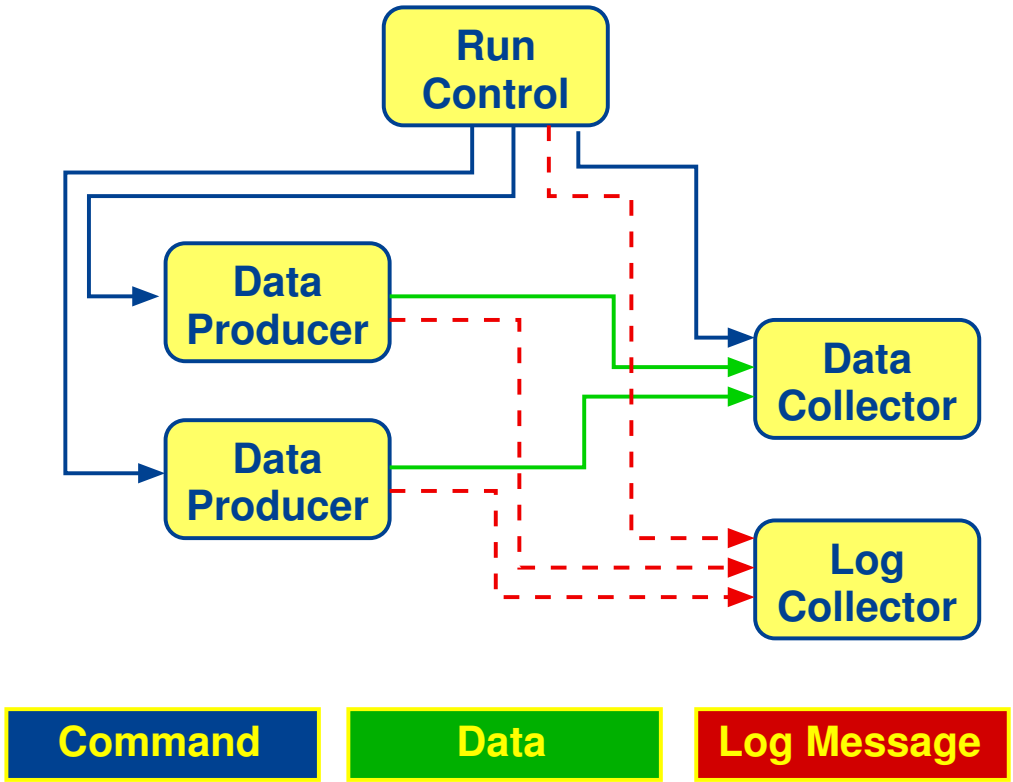
EUDAQ: The EUDET Data Acquisition System

DataProducer: Pixelman plugin which communicates with EUDAQ

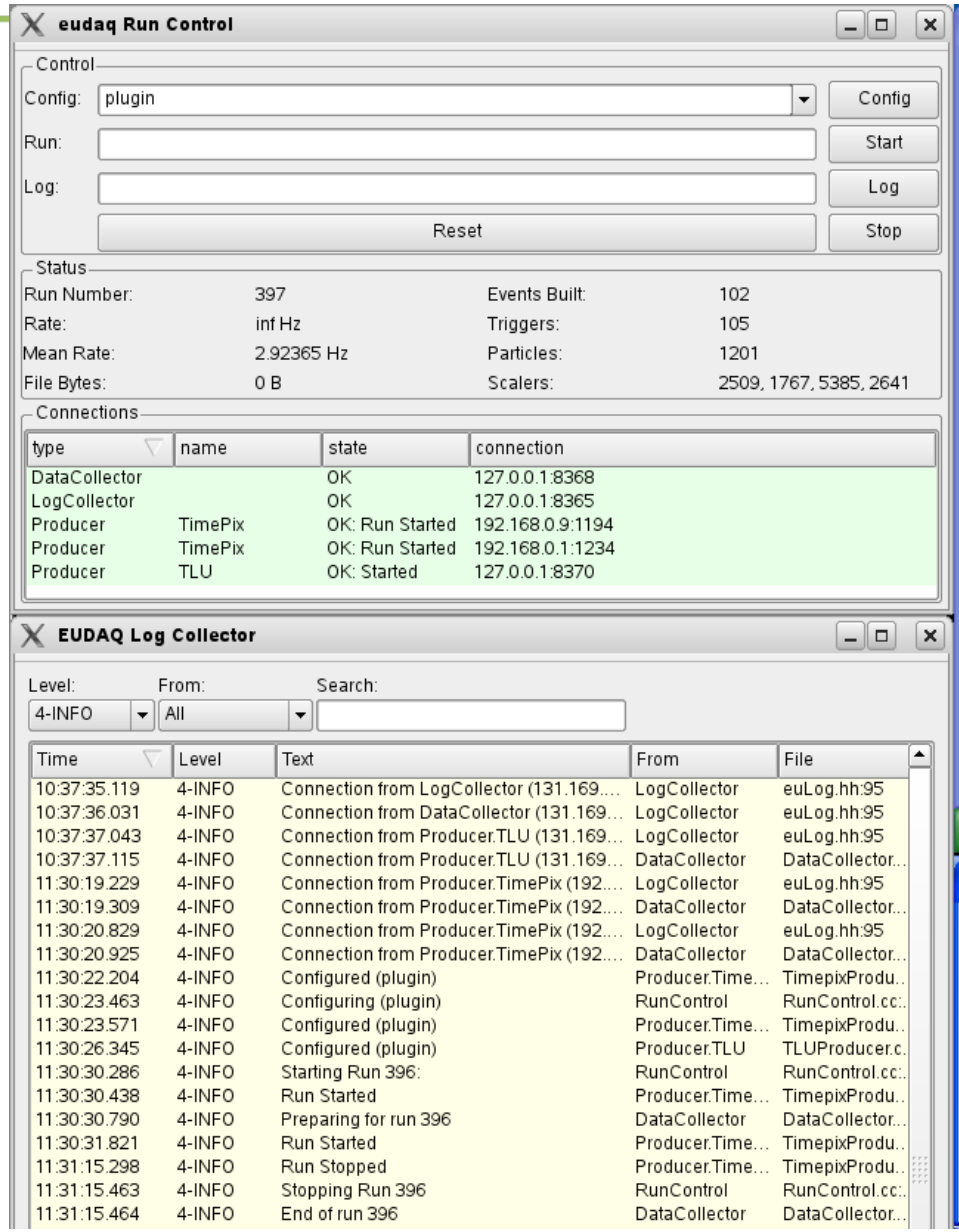
- Receives commands from Run Control
- Sends data to Data Collector
- Sends messages to Log Collector

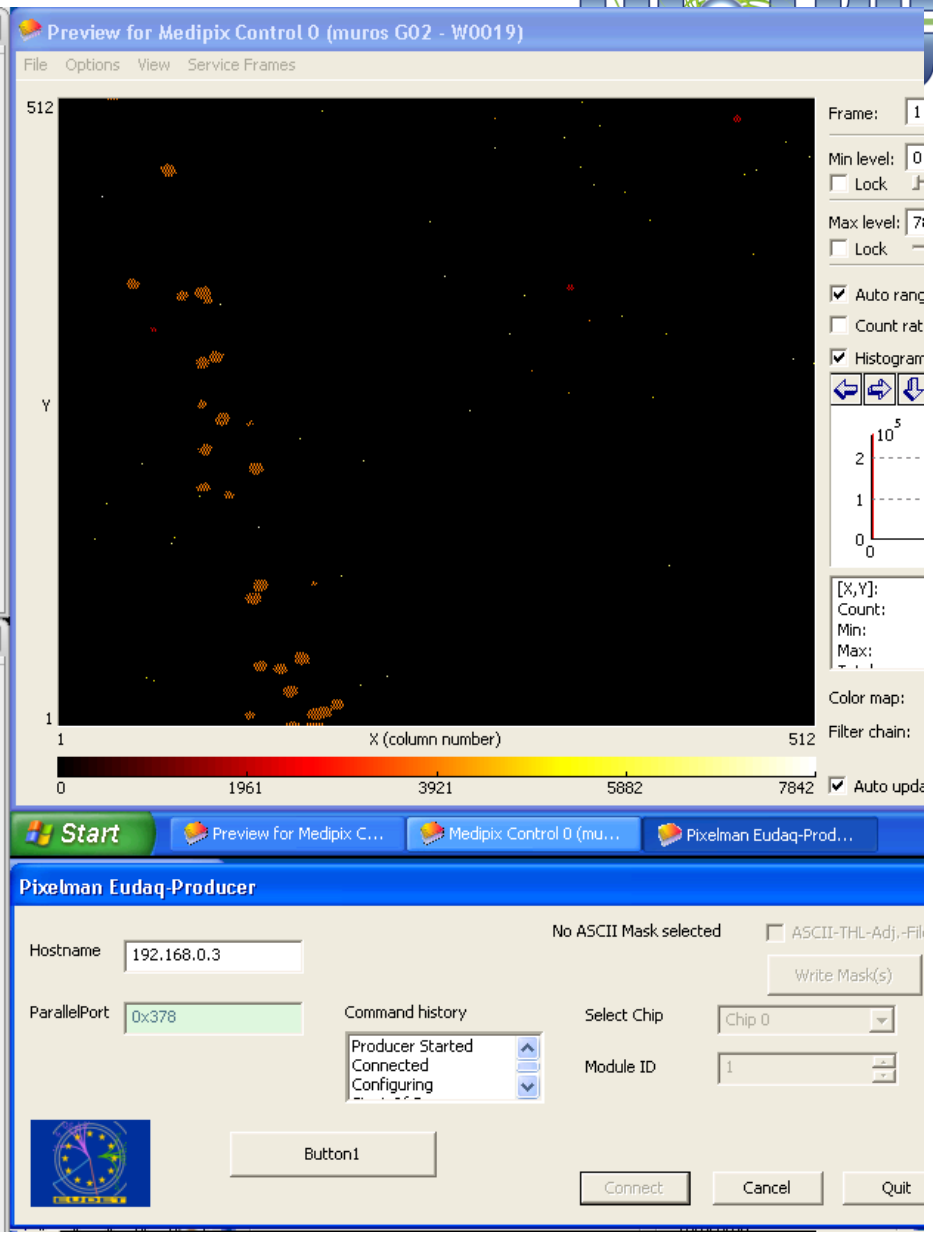
DataCollector:

- Receives raw data
- Performs event building
- New: Plugin mechanism
  LCIO converter plugin for every raw data format
- Data collector writes common LCIO file



Screenshot





EUDAQ RunControl and LogCollector Pixelman event display and PixelmanProducer

Parameters Settings

He/CO_2 70/30:

Drift distances [cm]	4.3 ; 10 ; 15 ; 20 ; 25 ; 30 ; 40 ; 50
Angles	5° ; 10° ; 0° ; -5° ; -10°
Particle energies	1 GeV ; 1.6 GeV ; 2.6 GeV ; 3.8 GeV ; 5 GeV
GEM voltage	355 V ; 370 V ; 385 V ; 395 V ; 405 V ; 415 V
Magnetic field	0 T ; 1 T

440,000 events recorded

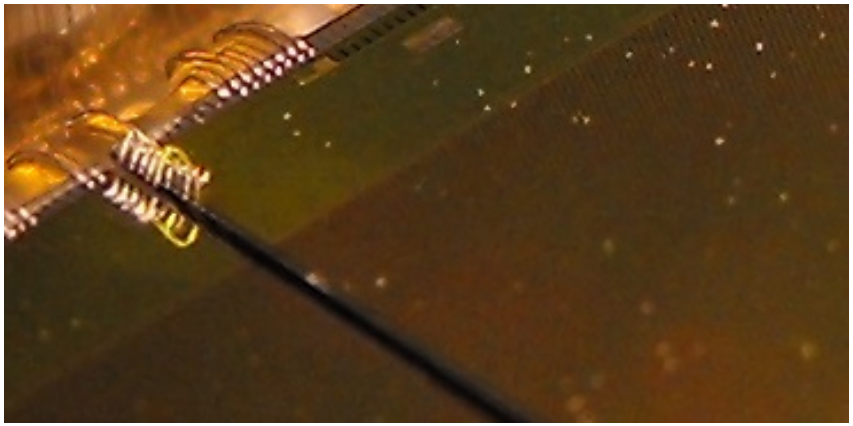
T2K Gas (Ar/CF_4/Isobutane 95/3/2):

Drift distances [cm]	4.3 ; 10 ; 15 ; 20 ; 25 ; 30 ; 40 ; 50
Angles	5° ; 10° ; 0° ; -5° ; -10°
Particle energies	1 GeV ; 1.6 GeV ; 2.6 GeV ; 3.8 GeV ; 5 GeV
GEM voltage	260 V ; 270 V ; 280 V
Magnetic field	0 T ; 1 T
Laser Dots with 1 T	

245,000 events recorded

Breakdown

- Module worked fine in He/CO_2 for two weeks.
  No HV problems
- Frequent trips in T2K gas (module and field cage).
  In the last night of data taking a discharge destroyed one Quadboard



- Bond wires reach into the induction gap (some of them were not protected with glue)
- Brown spot on the GEM at position of bond wires

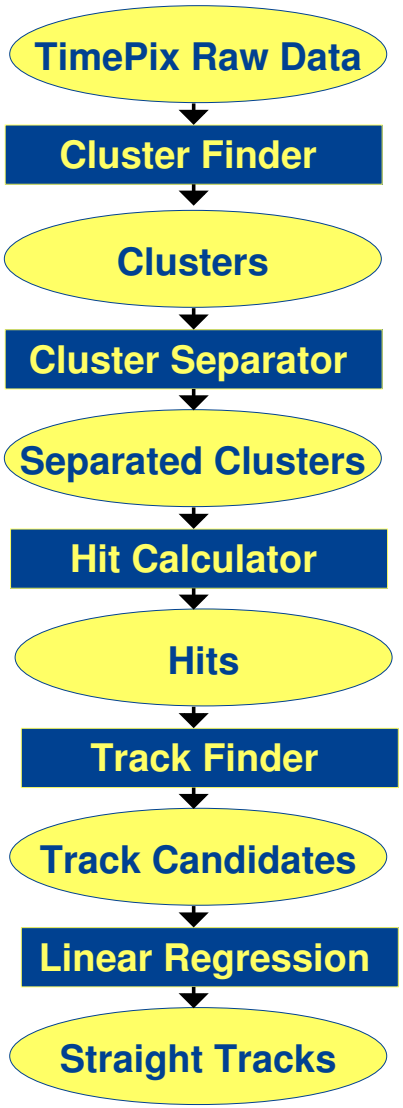
Short term solution:

- Protect all bond wires with resin
- Make bonds as flat as possible

Long term solution:

- Through silicon vias on the chip

Reconstruction with MarlinTPC

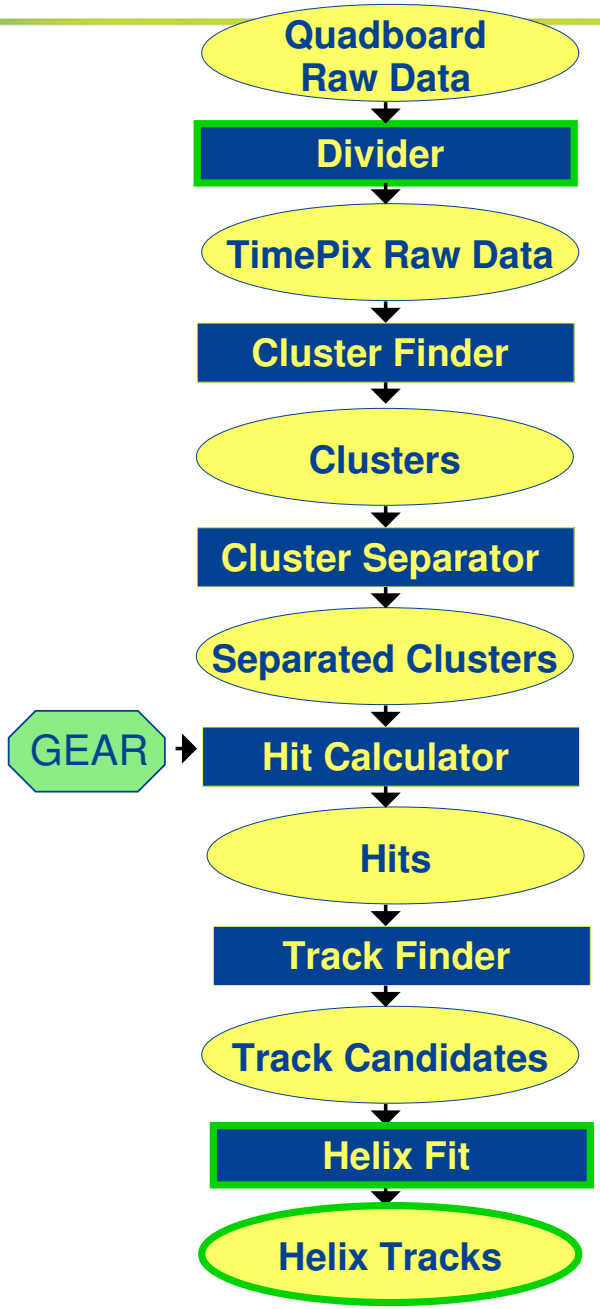


Reconstruction flow:

- Find individual clusters
- Separate clusters
- Calculate 3D hits
- Find tracks
- Fit tracks

$\longrightarrow$ already done for single chips without magnetic field

Reconstruction with MarlinTPC



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Needed for LP module:

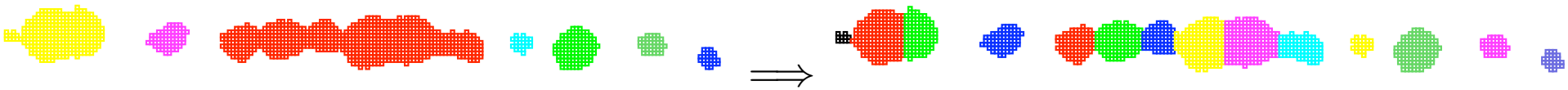
- Alignment of the individual chips
  - Subdivide Quadboard raw data into data of single chips
  - Include the exact geometric alignment of the chips with GEAR
- Adapt existing processors for multiple chips
- Fitting of curved tracks

Example: Cluster Separator

Clusters are split along cluster axis

Short drift distances:

- Algorithm works fine



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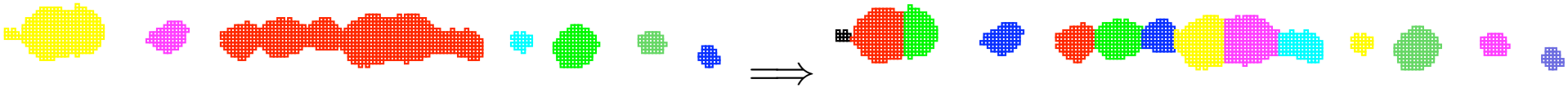
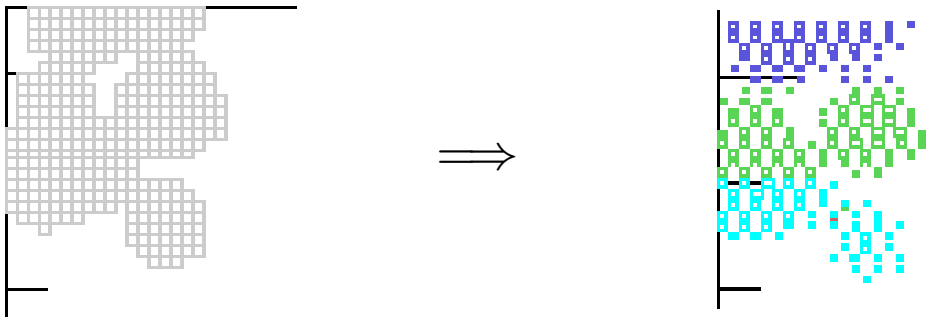


Long drift distances:

- Algorithm does not perform well due to transverse diffusion



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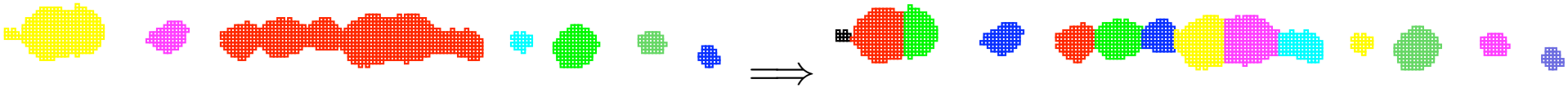
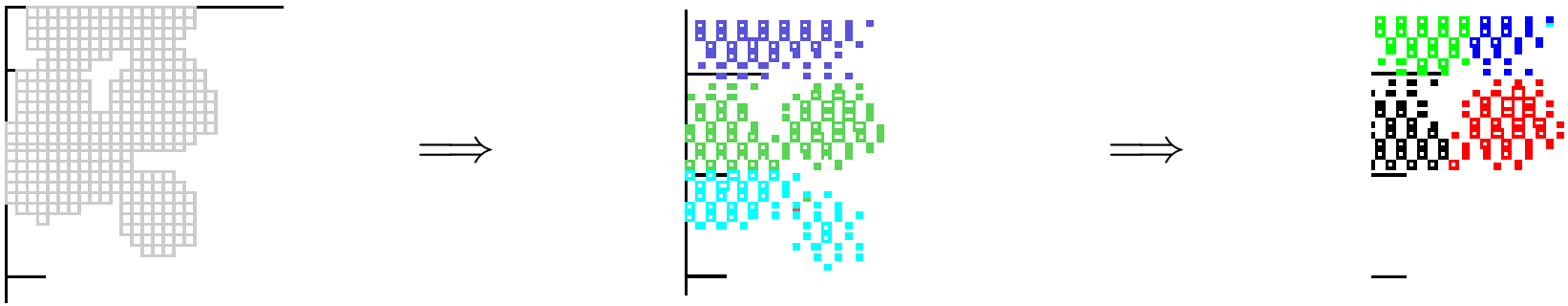


Long drift distances:

- Algorithm does not perform well due to transverse diffusion
- Intermediate solution: Apply algorithm twice

$\Rightarrow$ Works, but not optimal

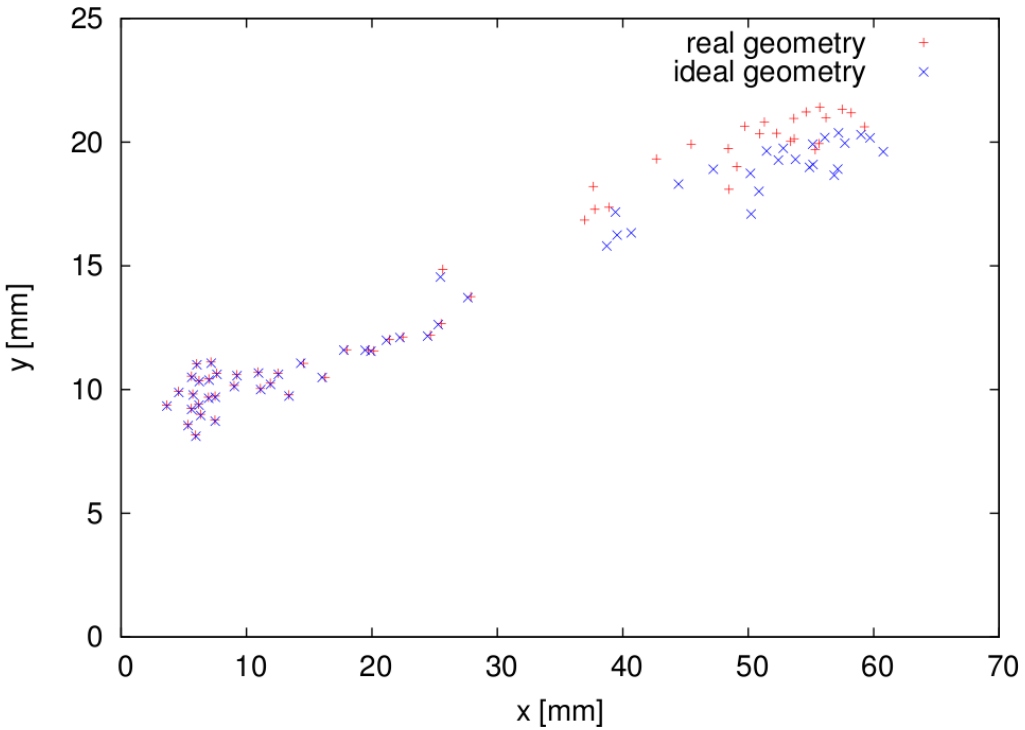
- Goal: Implement new algorithm (island cluster finder)



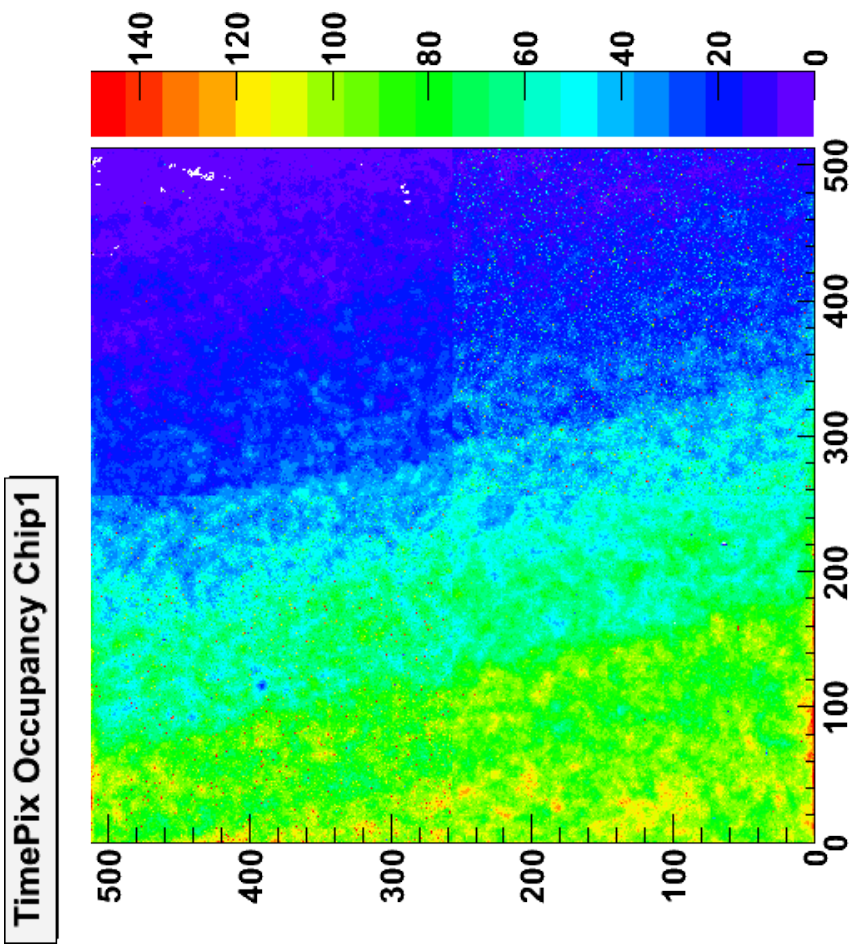
Alignment

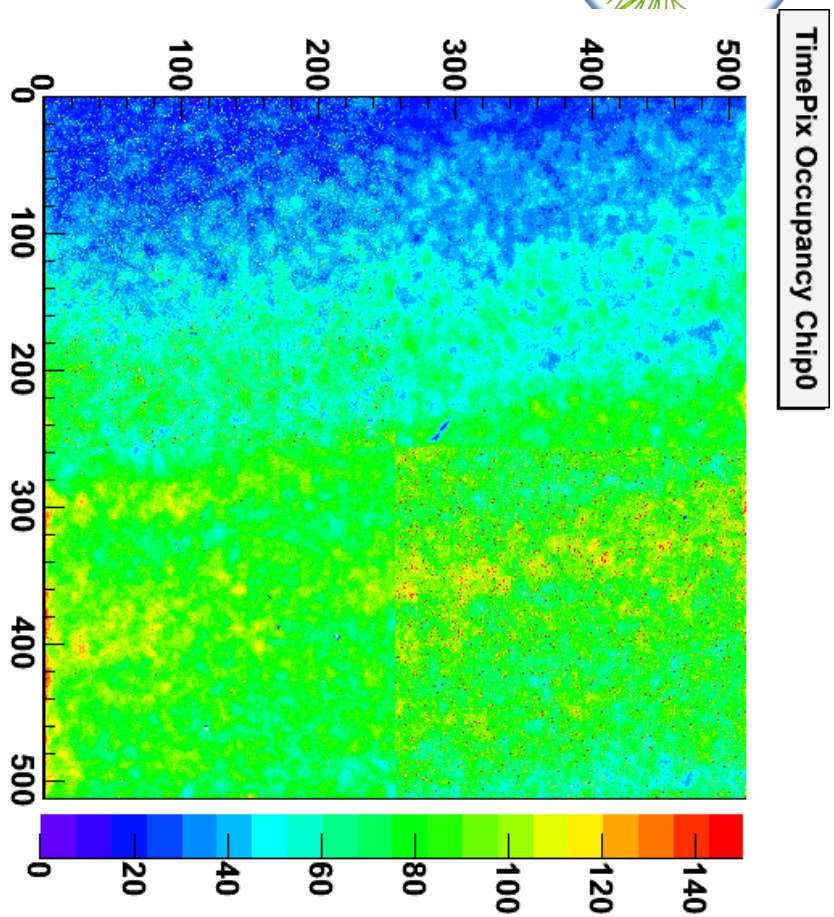
Geometry file:

- Position of the chips has been measured with movable table and microscope
- Exact geometry is provided by GEAR: Displacement of each individual chip can be defined



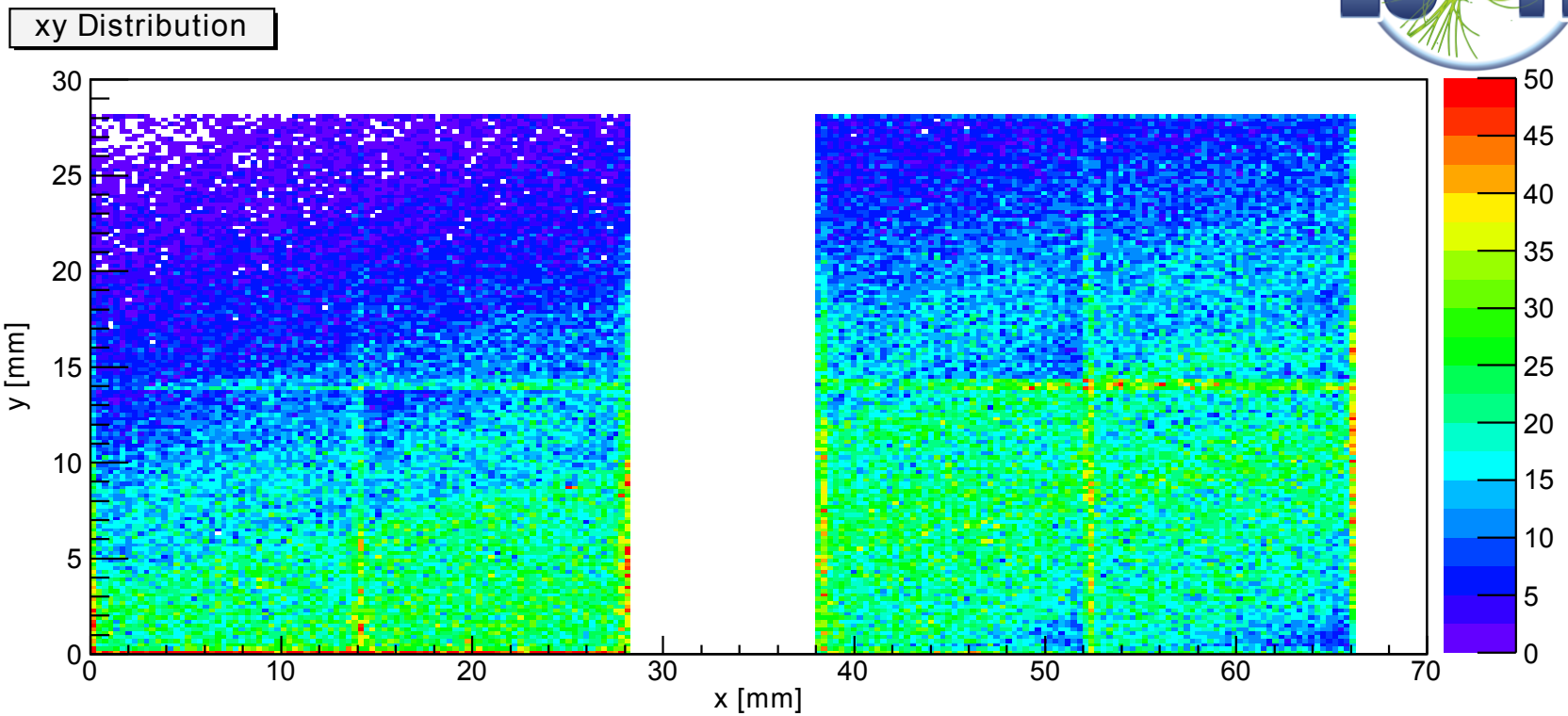
Occupancy





- Homogeneous response over the whole module
- Beam profile clearly visible
- Hot area near the gap between the boards

xy Distribution



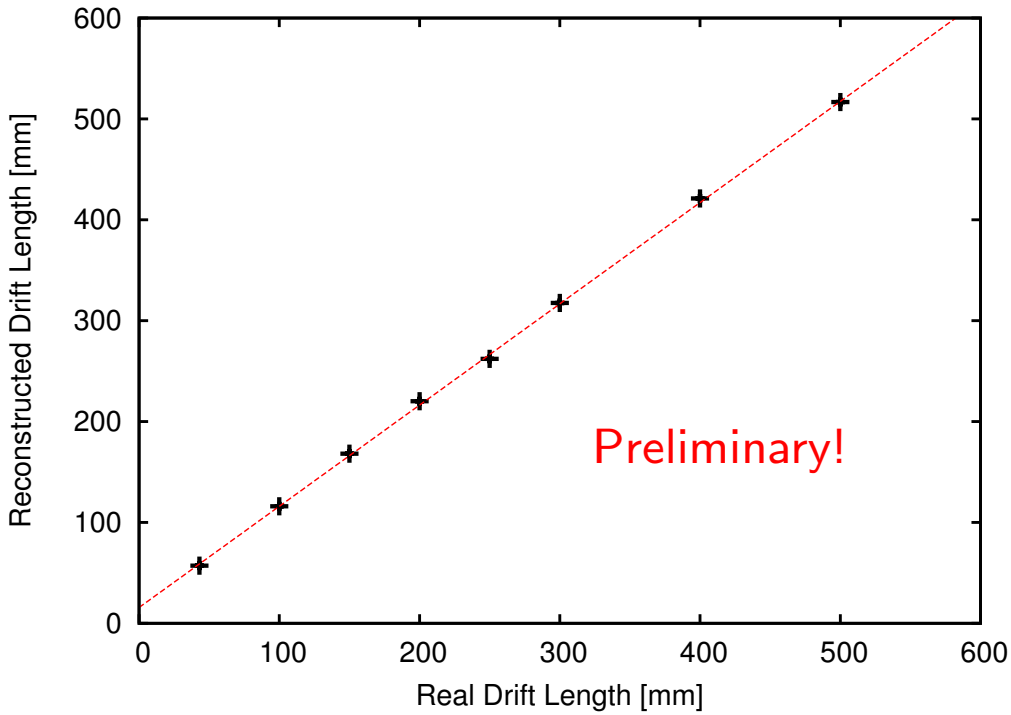
- Distribution of reconstructed hits is similar to raw occupancy

⇒ Reconstruction is working fine

- Reconstruction artefacts lead to clearly visible chip boarders

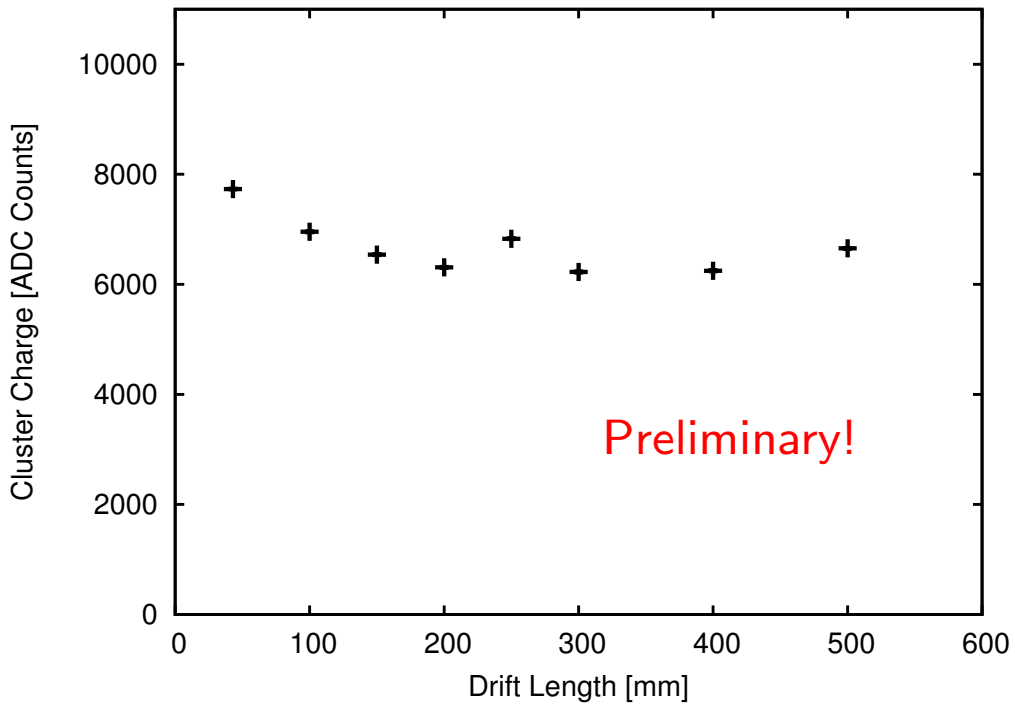
⇒ Improve algorithm

z Coordinates



- Convert drift time to drift length using drift velocity from Magboltz
- Fit:$z' = (1.00 \pm 0.01)z + (15.6522 \pm 2.283)$
- Offset corresponds to cable and trigger delay (uncorrected)
- Indication for homogeneous drift field, little contamination in gas mixture and correct reconstruction

Charge Per Hit



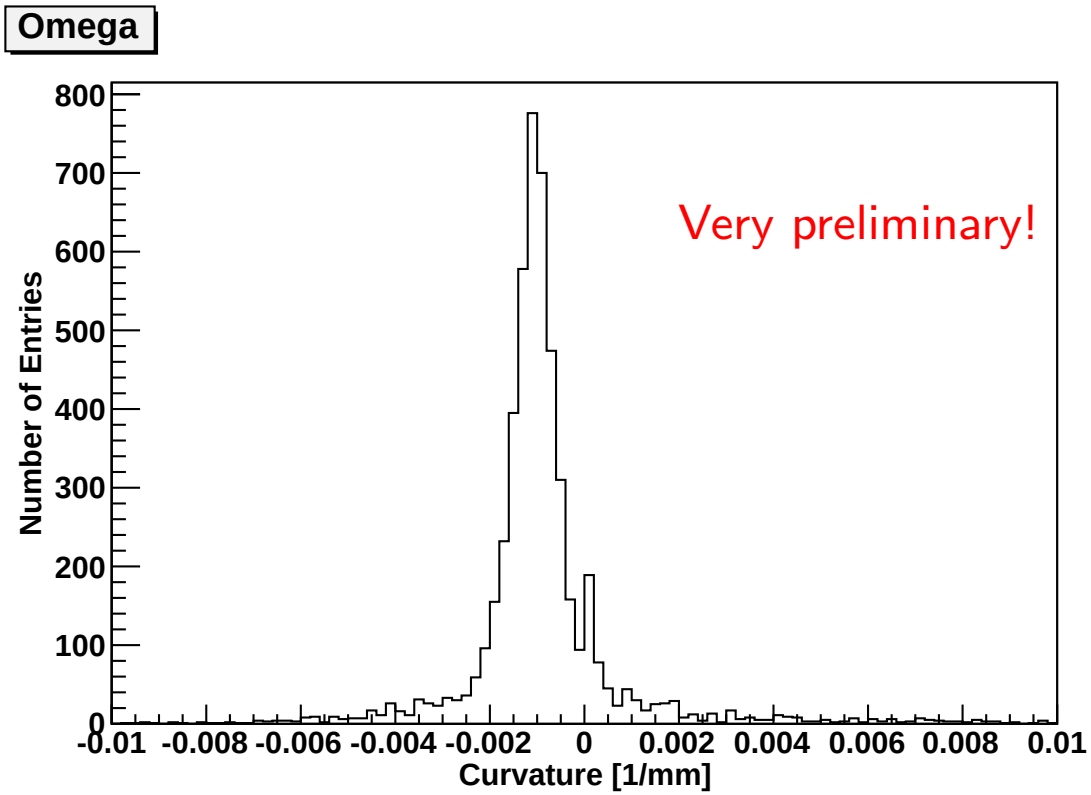
- After 20 cm drift distance the charge per cluster is constant

$\Rightarrow$ Each reconstructed cluster corresponds to a single electron

Curvature

Reconstructed curvature:

- Particle energy 1 GeV
- Magnetic field 1 T



Summary & Outlook

Summary

- LP-Module with two Quadboards + GEMs successfully operated
  - World record: more than 500,000 channels
- DAQ and synchronisation with EUDAQ and TLU
- Breakdown due to discharges is understood
- First analysis plots look like expected
- Curvature of tracks can be reconstructed

Outlook

- Improve reconstruction algorithms
- Study track properties (momentum resolution)
- Fix damaged Quadboard
- Where to get working readout electronics?