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

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LP-Module 2 Quadboards + GEMS

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 μ m x 55 μ m 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









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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



- DAQ PCs synchronised with Trigger Logic Unit
 - Trigger is send to PCs and precision gate generator
 - Busy handshake ensures synchronisation
- Data is send to EUDAQ

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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

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EUDAQ RunControl and LogCollector Martin Killenberg (Universität Bonn)



He/CO₂ 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/CF₄/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 ; <mark>270 V</mark> ; 280 V
Magnetic field	0 T ; 1 T
Laser Dots with 1 T	

245,000 events recorded

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Breakdown

- $\bullet\,$ 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
- \rightarrow already done for single chips without magnetic field

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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

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- Adapt existing processors for multiple chips
- Fitting of curved tracks



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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



Example: Cluster Separator

Clusters are split along cluster axis

Short drift distances:

Algorithm works fine



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



- Distribution of reconstructed hits is similar to raw occupancy
- \Rightarrow Reconstruction is working fine
 - Reconstruction artefacts lead to clearly visible chip boarders
- \Rightarrow Improve algorithm

z Coordinates 600 500 Reconstructed Drift Length [mm] 400 300 200 Preliminary! 100 100 200 300 400 500 600

Real Drift Length [mm]

- 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



- 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



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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?