Testbeam Measurements with the DESY GridGEM TPC Prototype Module

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LCWS 2012

October 24th, 2012

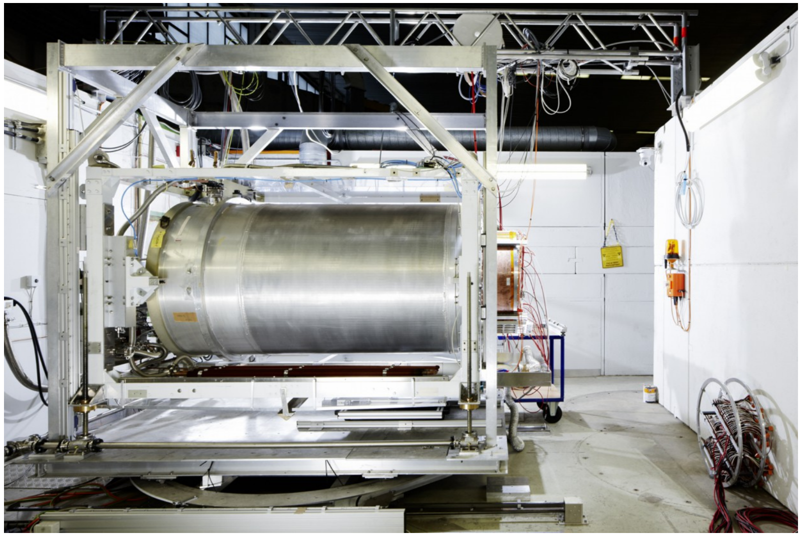
HELMHOLTZ GEMEINSCHAFT

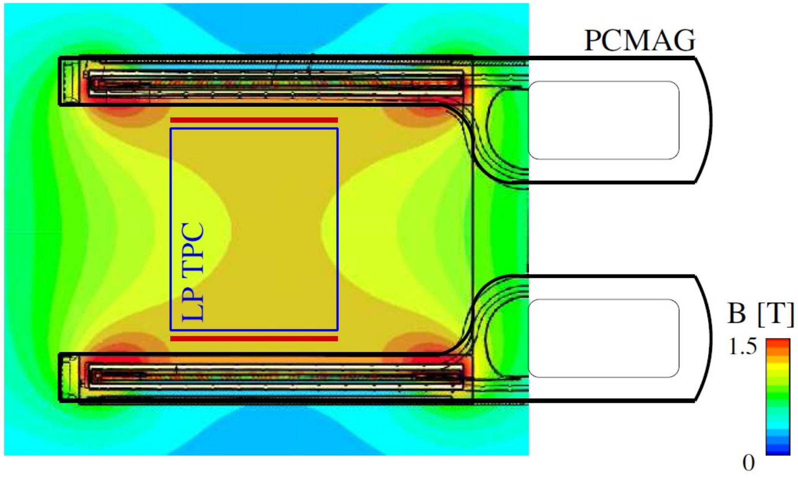
LC TPC

DESY

Testbeam Setup at DESY

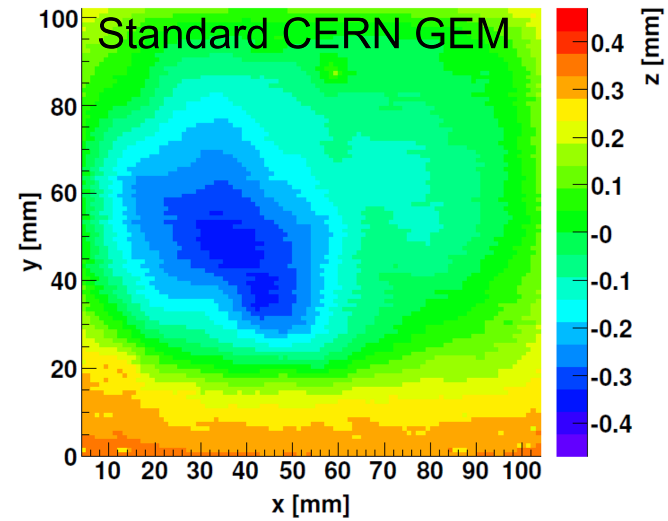
- Setup at DESY II test beam, area T24/1
  - e^+/e^- from 1 GeV to 6 GeV
- PCMAG Magnet
  - 1T, inhomogeneous magnetic field
  - TPC positioned at most homogenous field
- Movable stage in three axis
- HV and gas system including slow control
- Cosmic and beam trigger
- TPC prototype (Large Prototype)
  - Ø 73 cm, max. drift length ~60 cm
- Work in progress
  - Photo electron laser calibration system
  - Silicon reference detector

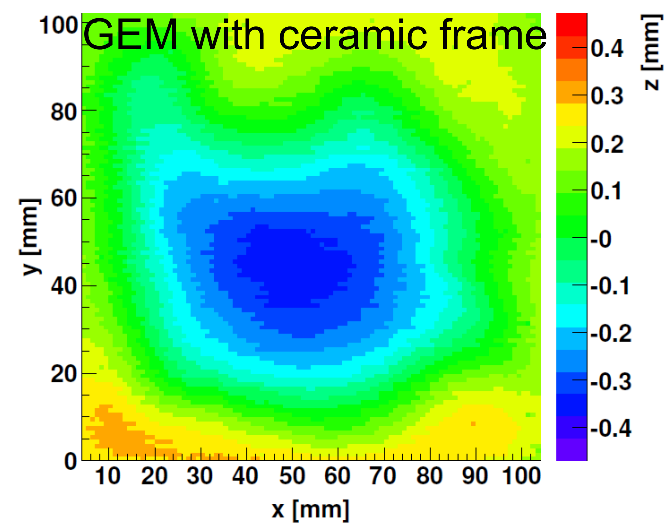




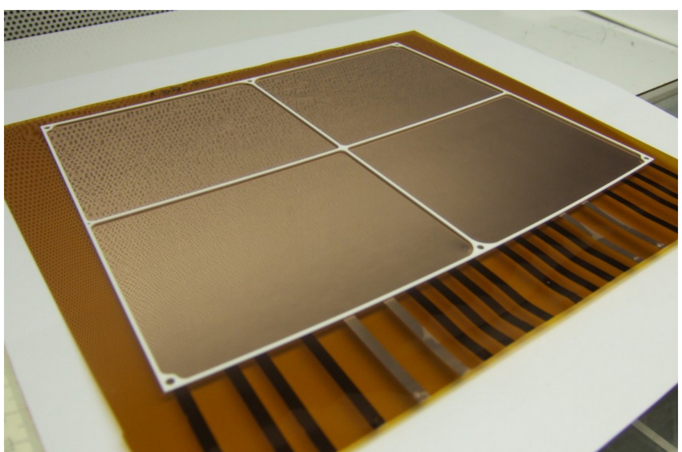
DESY GridGEM Module

- GEM module with integrated support structure
- Aluminum Oxide grid
  - Lightweight material
  - Minimal dead space
- Topologies of standard 10x10 cm^2 CERN GEMs and GEMs with ceramic grid comparable
- Flatness of GEMs is an important issue
  - More homogenous electric field
  - Less gain variation → better dE/dx resolution



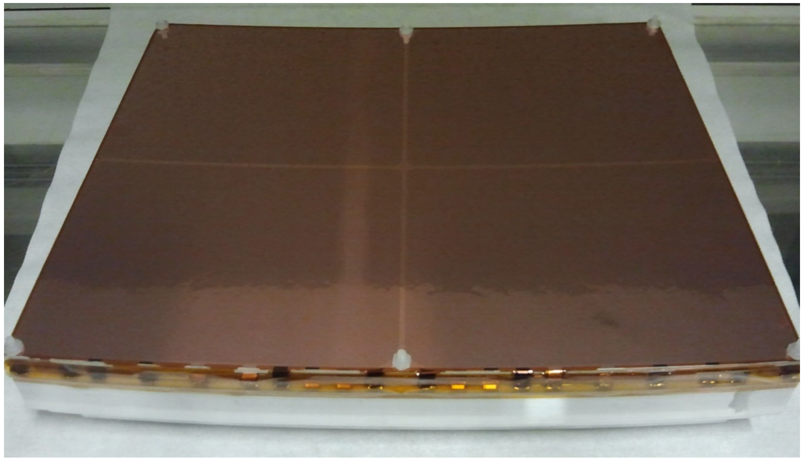


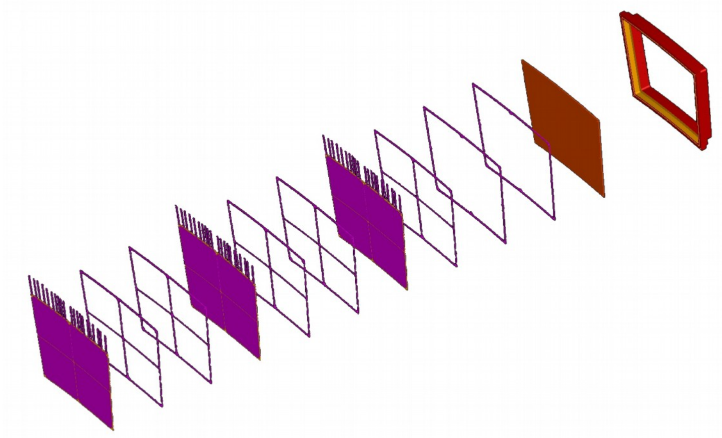
Measurements by Lea Hallermann



DESY GridGEM Module

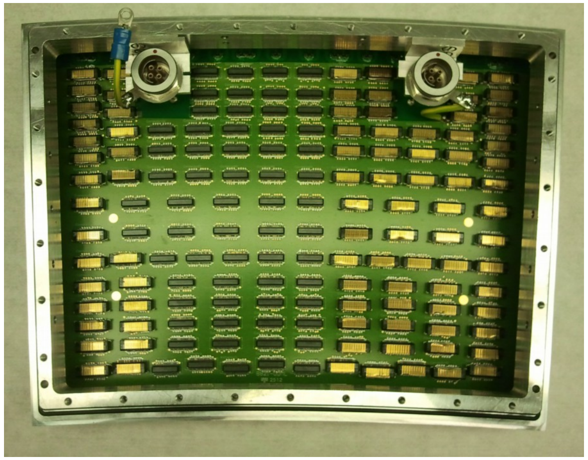
- Triple GEM Module
- Fully sensitive readout board ~23 x 17 cm^2
- Bottom side of the GEM divided in 4 sectors
  - Reduces energy stored in one sector to avoid destructive discharges
- Top side not divided
  - More homogeneous electric field

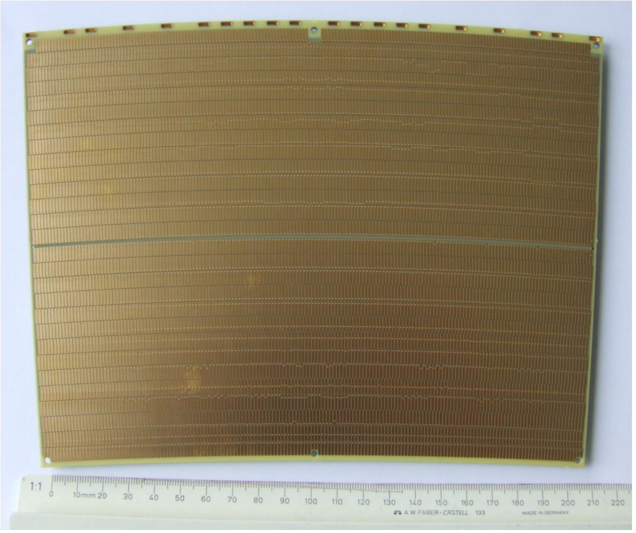


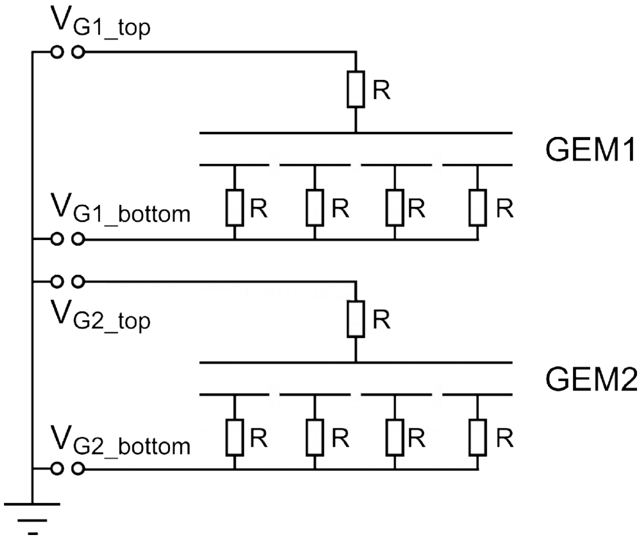


DESY GridGEM Module

- Fully sensitive readout
  - 4829 readout pads (size 1.26 x 5.85 mm^2)
  - Board designed by University of Bonn
- HV distribution
  - Each GEM side powered individually
  - Protection resistors very close to GEM

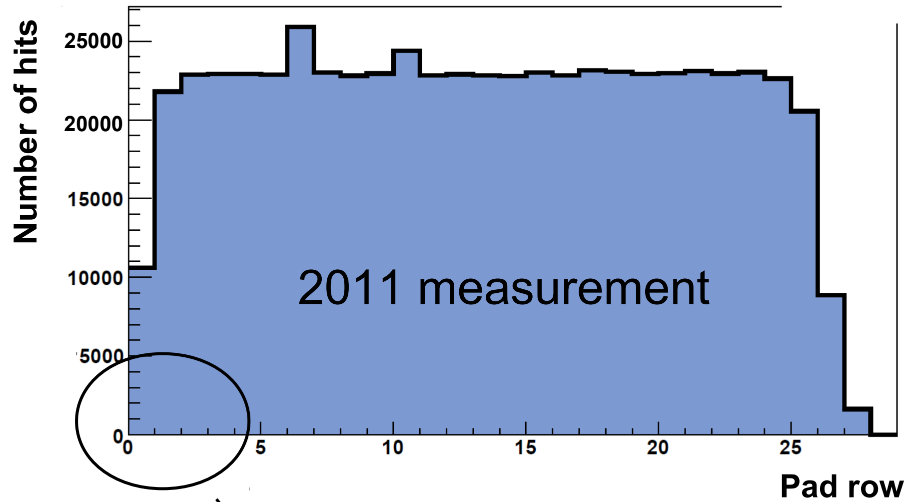


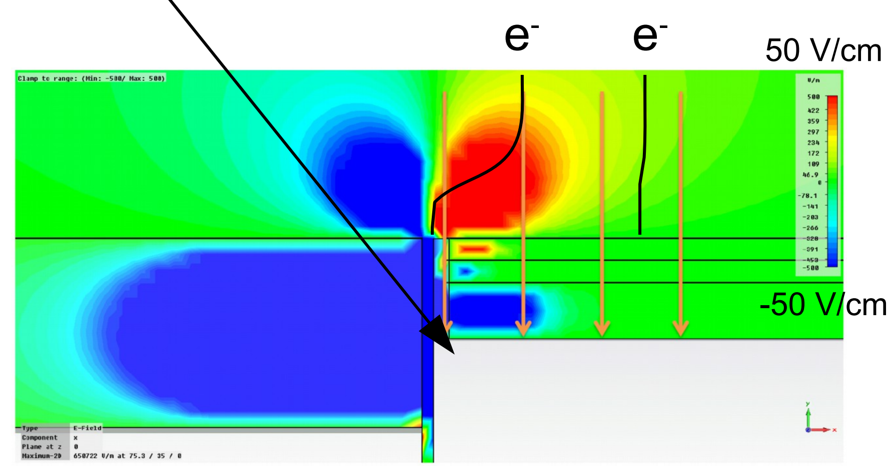




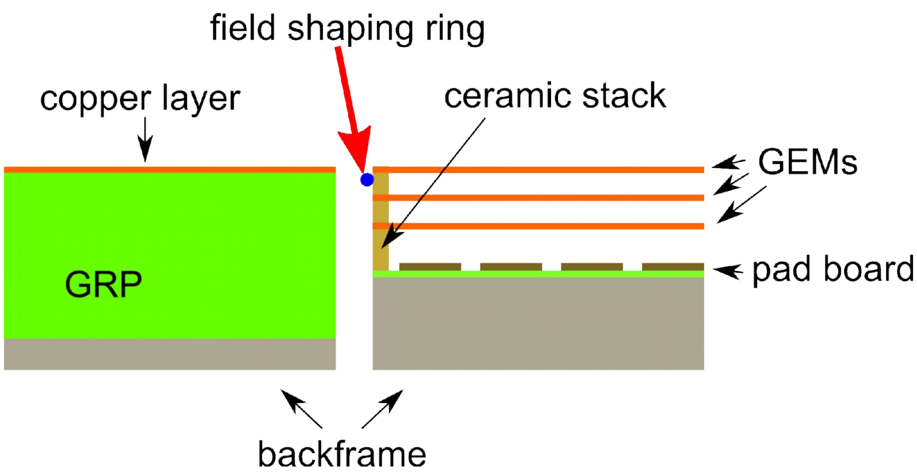
Field Shaping Ring

- Measurements show low hit efficiency at the borders of the module
- Simulations:
  Drift field distortions due to gap between two modules
- Solution: introduce additional electrode (field shaping) in gap between modules



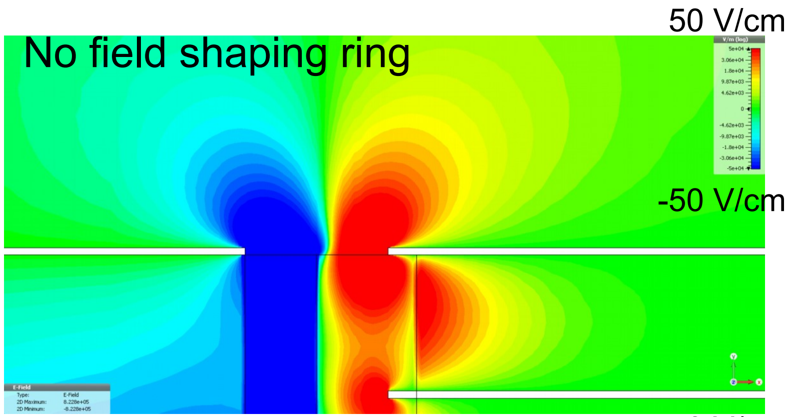


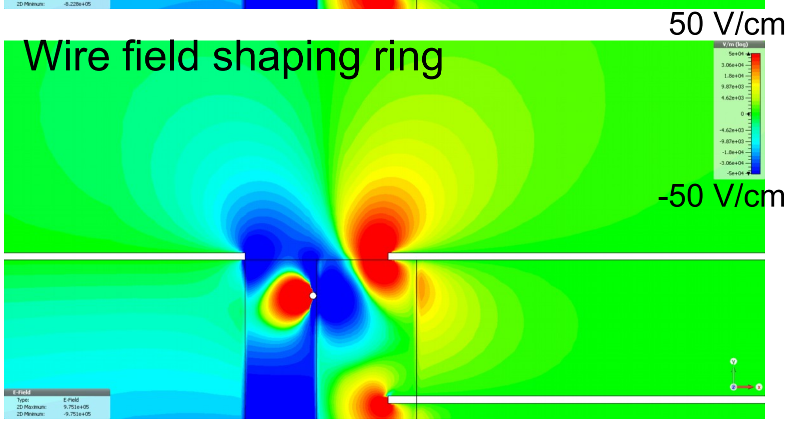
Color coding shows horizontal E-field

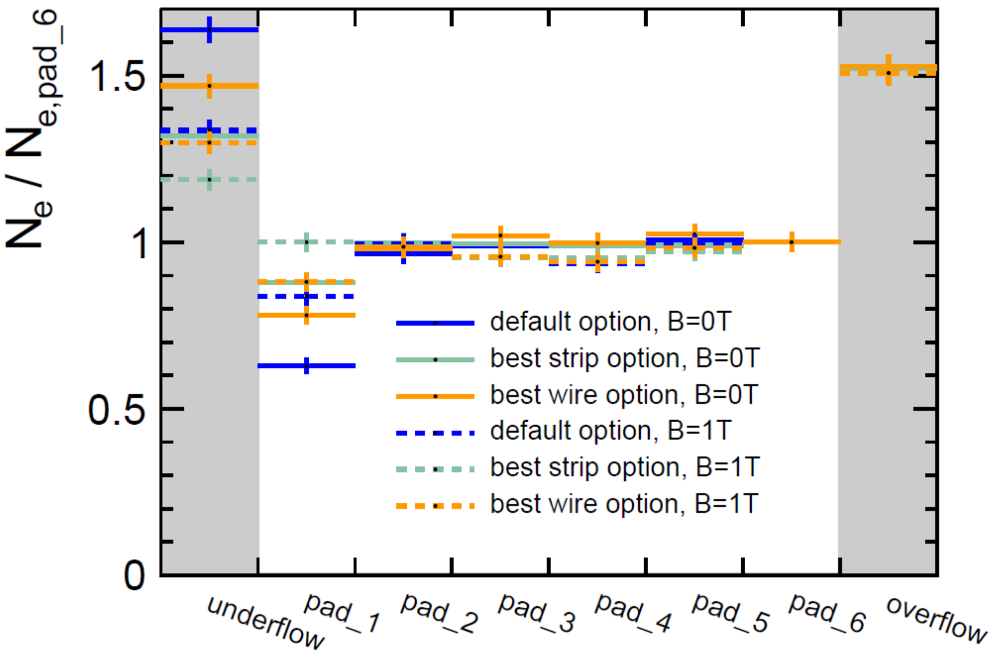


Field shaping rings

- Results from Simulation:
  Use field shaping ring to shape the field in the transition region
- Magnetic field enhances hit efficiency



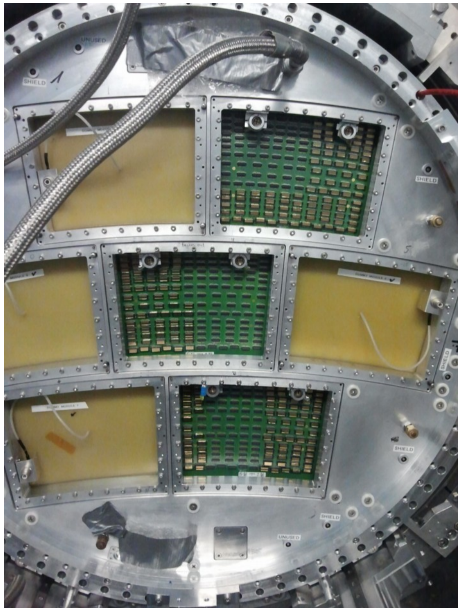


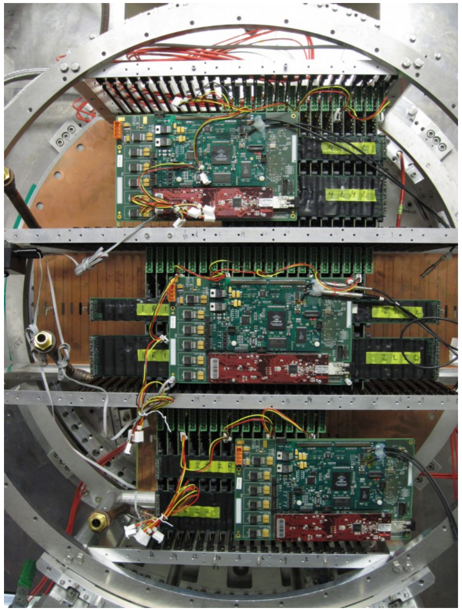


Simulation by Klaus Zenker

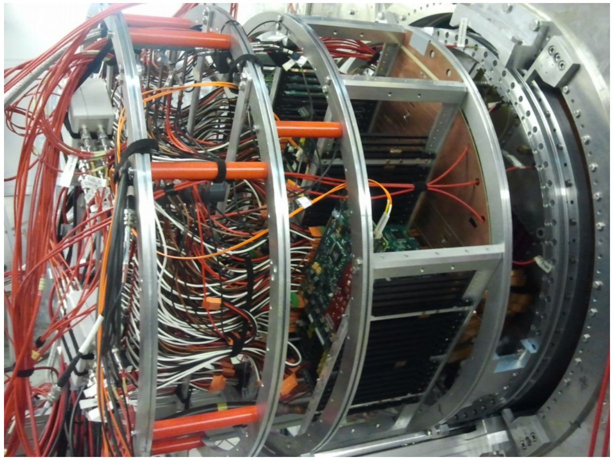
Complete Setup

Three readout modules installed in the end plate





Complete setup of the three module campaign



Electronic boards installed and connected to the modules

Measurement Campaigns:

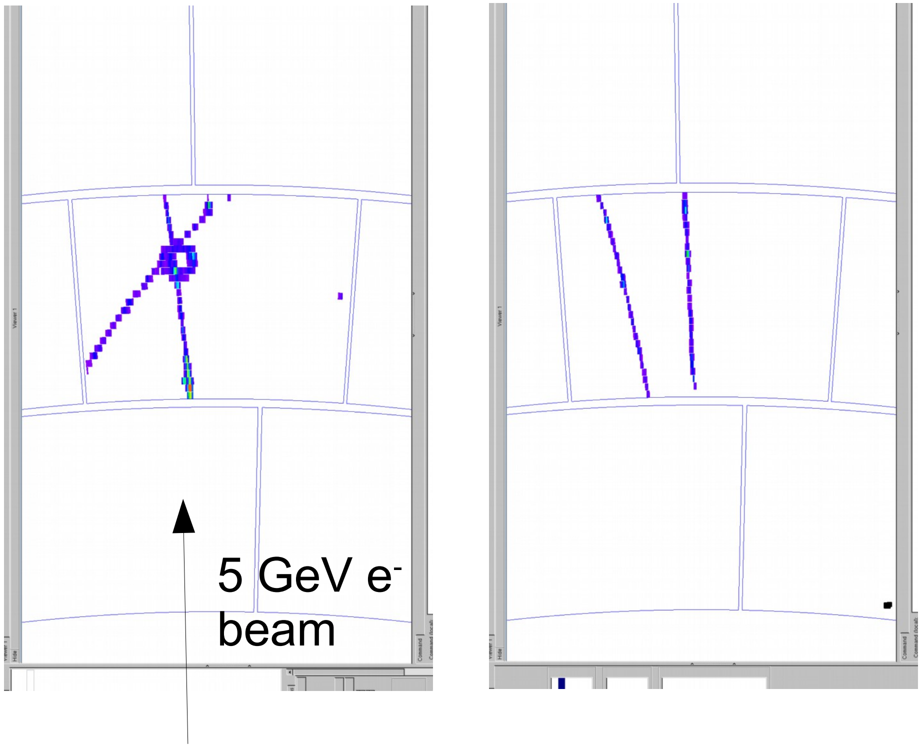
-One Module

-Three Modules

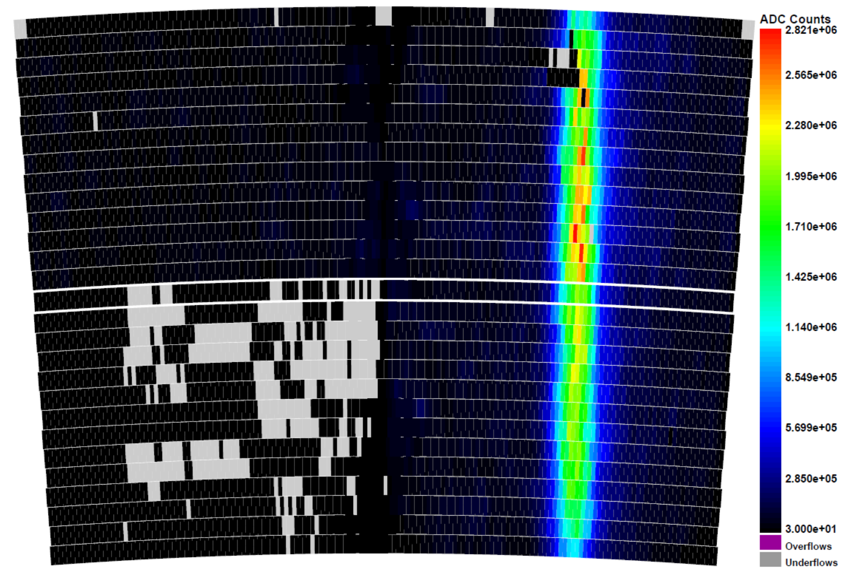
Single Module Campaign

- Testing of modifications and complete setup
- Module performed very well
  - HV worked stable and reliable
- Working point
  - ~130V/cm drift field (at the diffusion minimum for T2K gas)
  - Potential across GEMs: 250 V
  - Transfer fields: 1500 V/cm
  - Induction field: 3000 V/cm
- Problems with field cage
  - Lost two sectors of the module due to discharge from field cage to module
  - Had to operate at low drift field

First Look at the Data

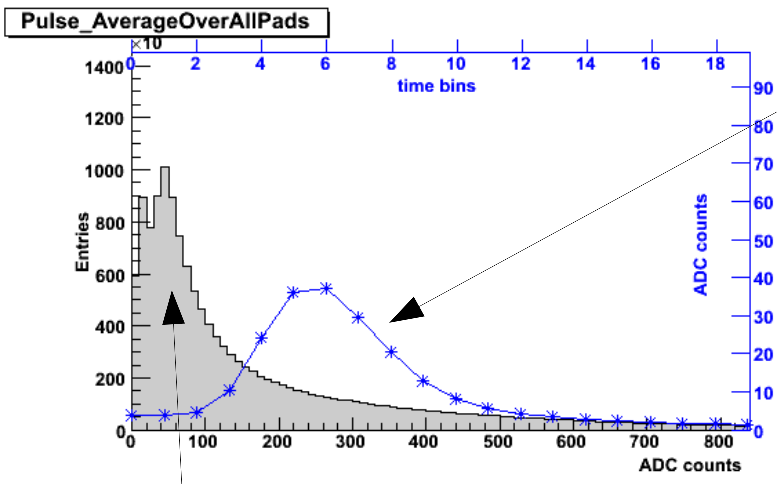


Event displays with a single module installed in the Large Prototype



Integrated charge of one measurement run

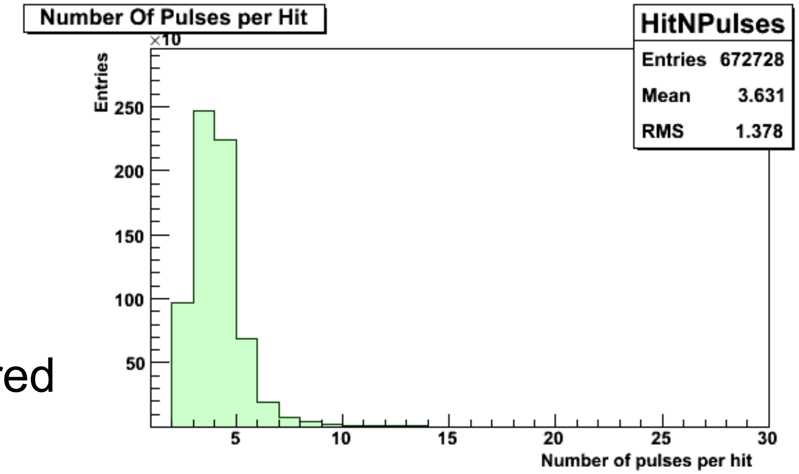
First Look at the Data



Time profile of average pulse

- rise time around 150 ns
- S/N ≈ 55

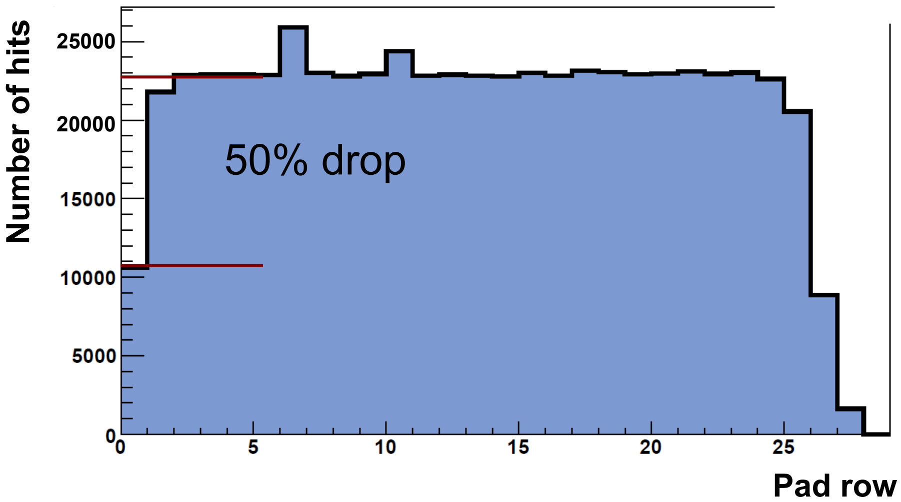
Integrated charge of each pulse in one measurement run

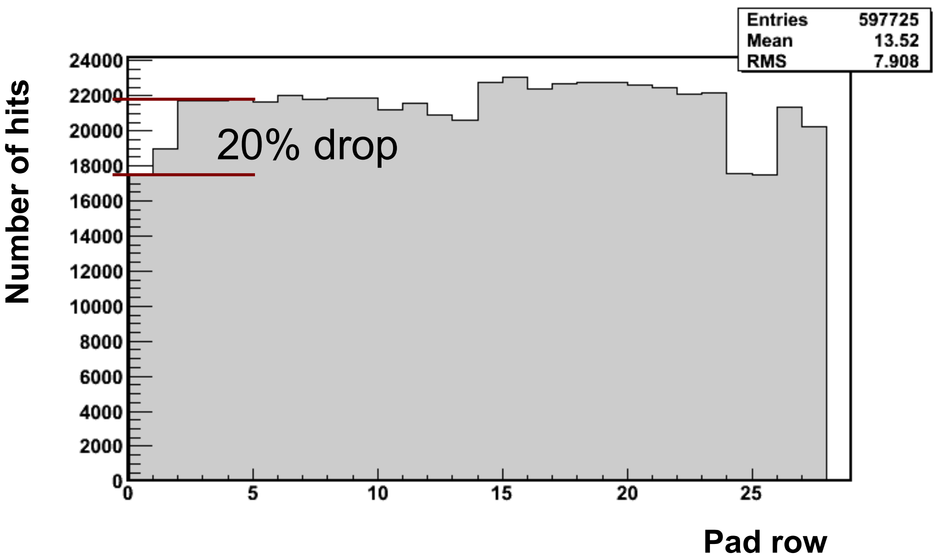


Number of neighboring pads fired for one hit

Single Module Data

- Number of hits per row
  - 20000 events
  - Module without field shaping ring
  - No magnetic field used
  - Efficiency loss at the border of the module

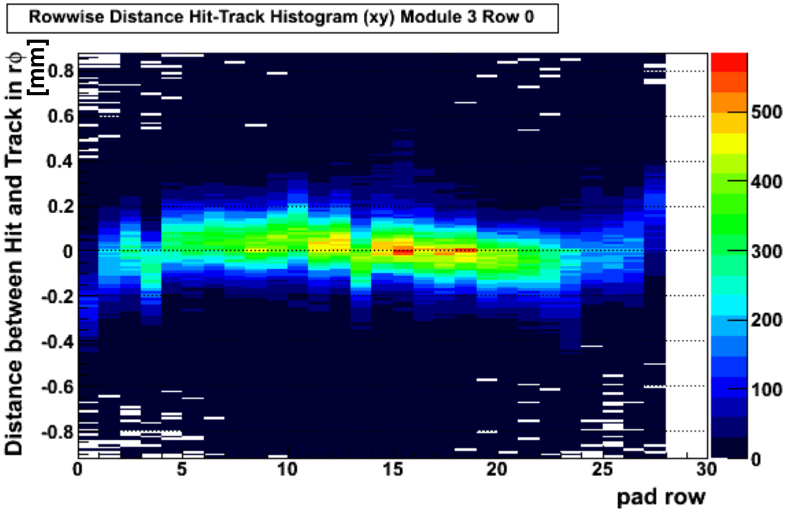


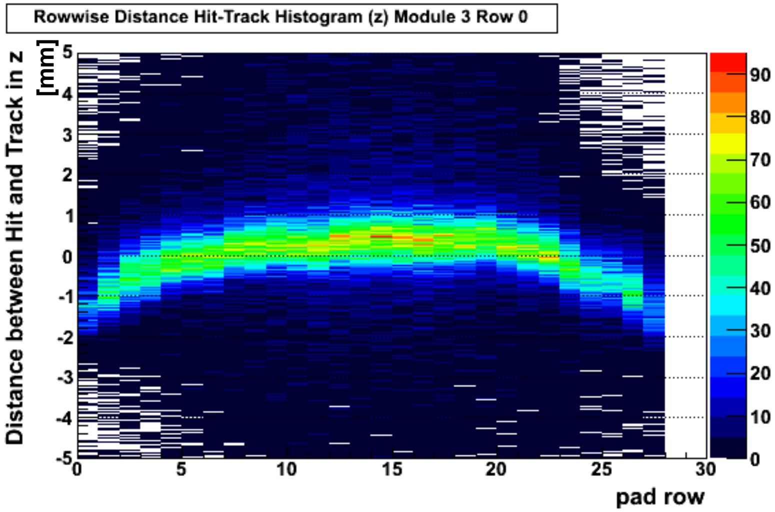


- 20000 events
- Module with field shaping ring
- With magnetic field
- Efficiency increase at edge of module

Residuals in rφ and z

- Find tracks using Hough transformation method
- Do first estimate of track parameters based on binned Hough transformation
- Residual estimation: Distance between reconstructed space point and the track for each row
  - Space point is included in track search

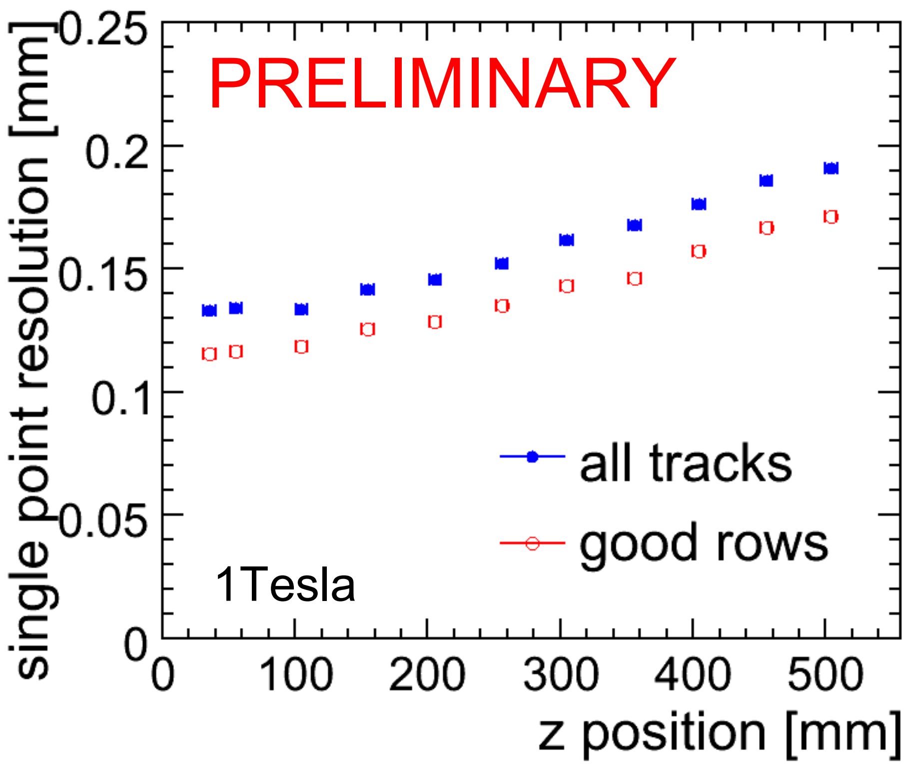




Clear sign of field distortions!

Single Point Resolution

- Estimate resolution from geometric mean of residuals including and excluding the hit in the track finding
- Note: results from track fit based on binned Hough transform: limited precision

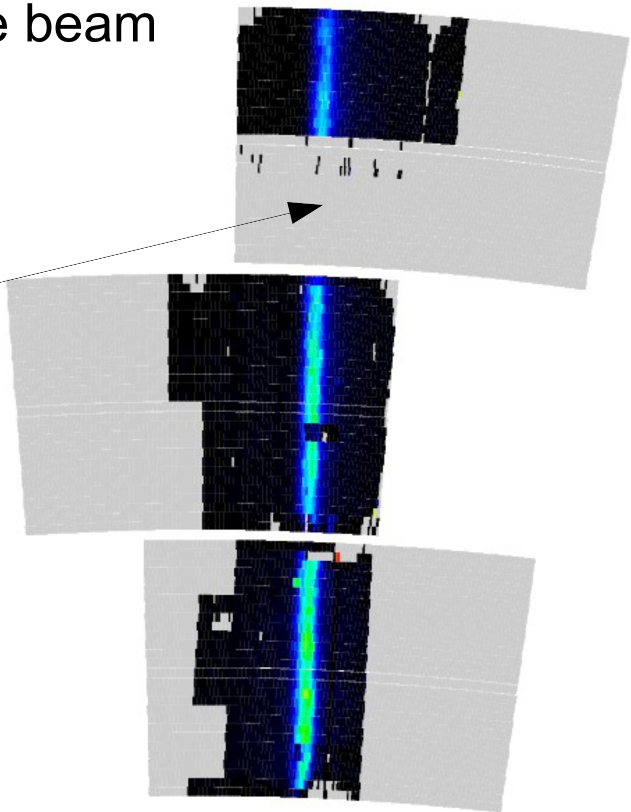


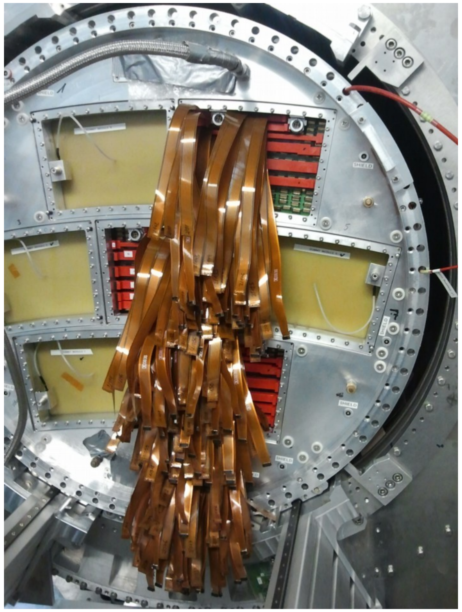
Looks reasonable for first analysis, but more careful study needed

Three Module Campaign

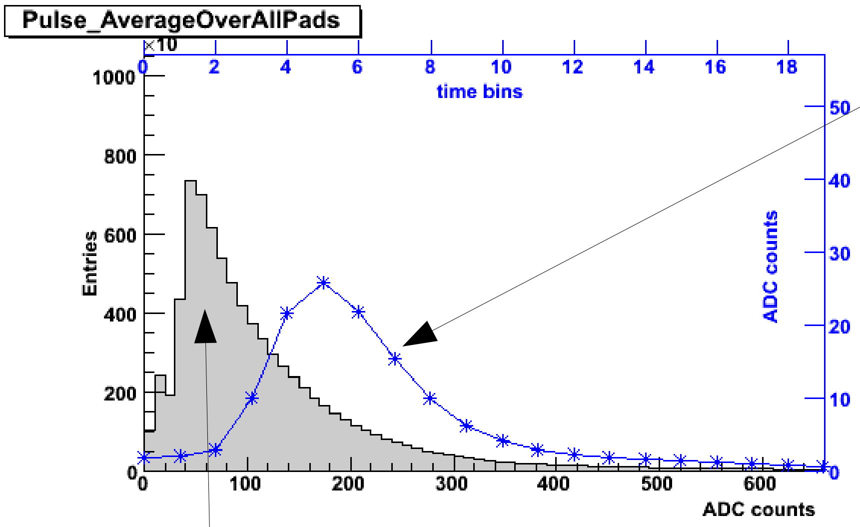
- Equipped endplate with three modules
- Read out approx. 7000 channels along the beam
  - Maximal lever arm
- Same setting as single module

Broken GEM sector due to discharge of the field cage





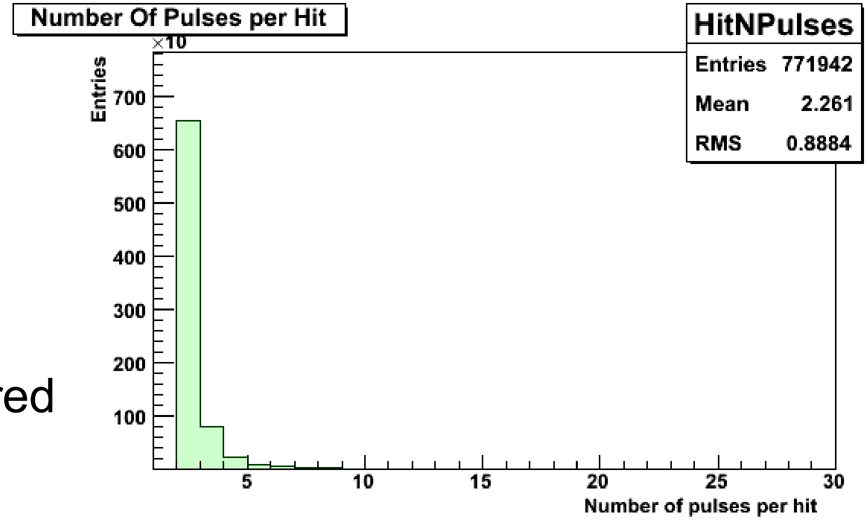
First Look at the Data



Time profile of average pulse

- S/N ≈ 35

Integrated charge of all pulses in one measurement run



Number of neighboring pads fired for one hit very small

Problems with Three Module Campaign

- Observed: rapid deterioration of data quality
- Eventually understood due to development of a serious gas leak in the module
- Forced us to end the campaign prematurely after 1 day

- Post mortem: leak was due to a failed glue joint between the readout board and the backframe: need to improve gluing procedure

Summary and Outlook

- Three triple GridGEM modules were constructed and tested in the Large Prototype TPC
- Modules performed well with no sign of instability or deterioration with time
- Failed glue joint with resulting gas leak forced us to stop the measurements
- Serious problems with the field cage found

Next steps:

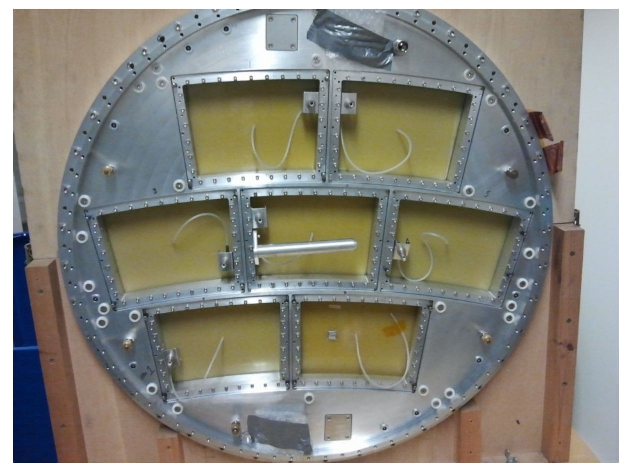
- Repair the field cage in time for Japanese campaign in December
- Repair modules in time for next beam early 2013

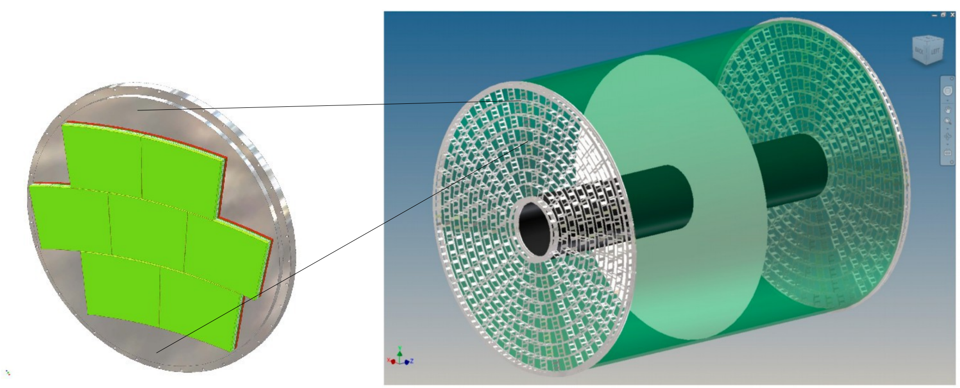
- I would like to thank our colleagues from Japan, Lund and Bonn for their support in many areas.

Backup

Large TPC prototype

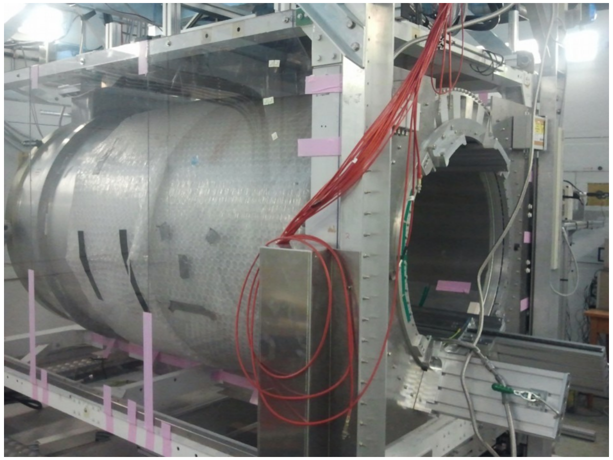
- Large TPC Prototype
  - Lightweight material (1.25 % X_0)
  - Ø 73 cm, max. drift length ~ 60 cm
- End plate created at the University of Cornell
  - Up to seven readout modules
  - Similar shape as a ILD-TPC module
  - Dimensions 22 cm x 17 cm

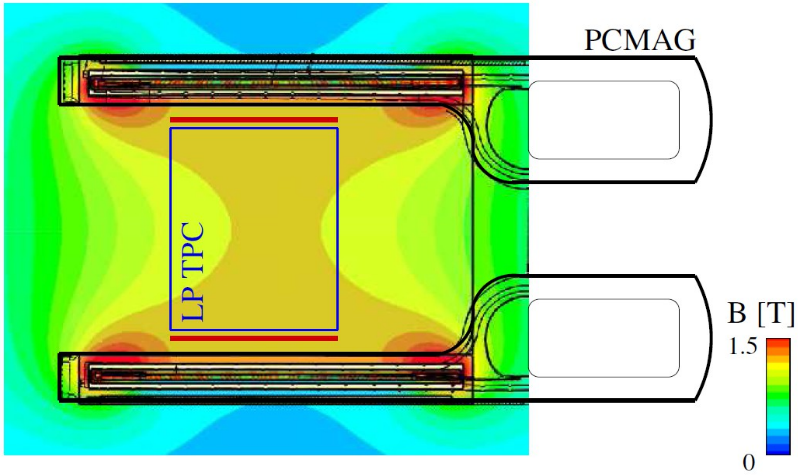




PCMAG

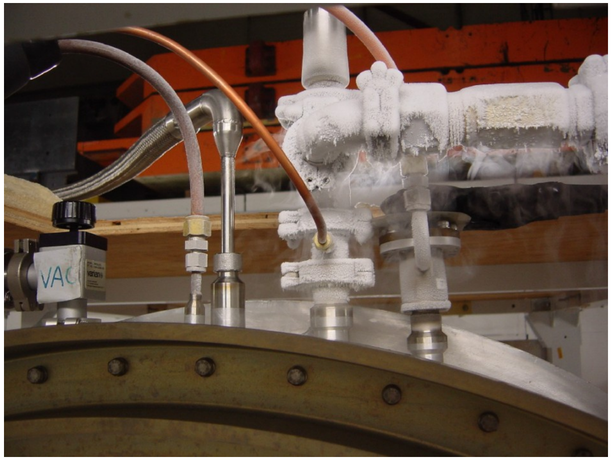
- **P**ersistent **C**urrent, superconducting **MAG**net
- Ø 1 m, length = 1.3 m
- Modification to use cryo coolers and constant current
- Thin coil and wall (0.2 X_0)
- No return yoke
  - Inhomogeneous magnetic field
- Max. central magnetic field: 1.2 T
  - Working point: 1 T (~430 A)



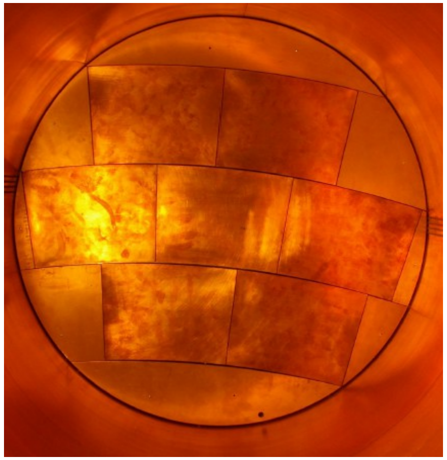


PCMAG

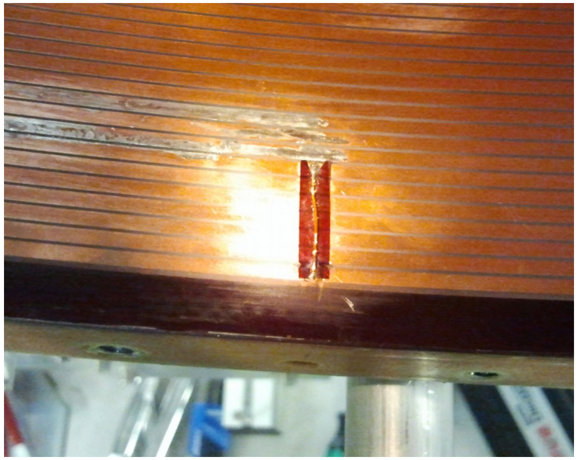
- Before:
  - Liquid Helium reservoir for cooling
  - Persistent current
- Problems:
  - Liquid Helium is expensive
  - Insertion of some air during each refill of the Helium
  - The air froze and blocked the liquid Helium
- Now:
  - Using cryo coolers
  - Constant current



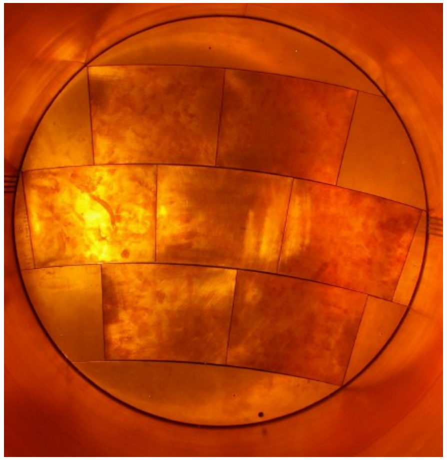
First One Module Campaign



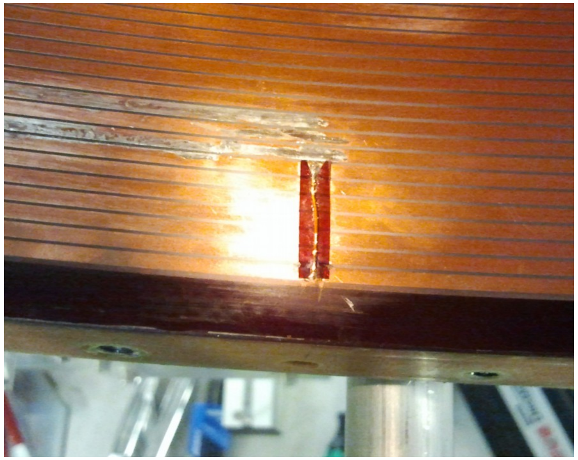
- Trip of the field cage caused
  - Two sectors of the topmost GEM broken
  - Trip of the field cage causes a chain reaction on the anode plane including the readout module
  - The potential of the topmost GEM side is greatly reduced
  - A destructive discharge between the two GEM sides occurs
- Connection of the 7th Strip causes the trips
  - Short distance between the wire connection to the 7th strip and the 1st strip



First One Module Campaign

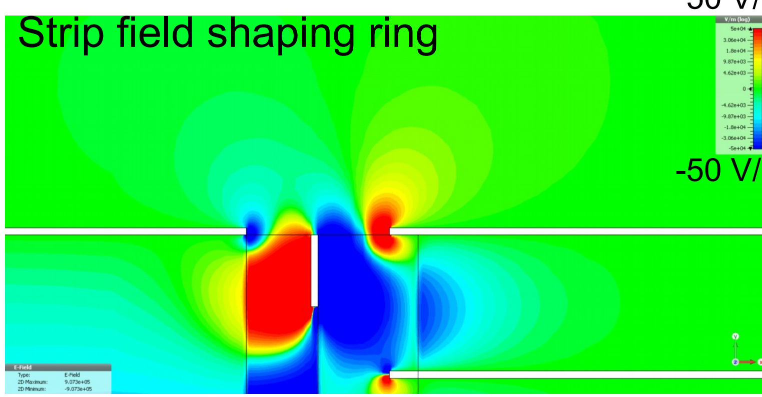


- Solution to protect the modules:
  - 10 MΩ protection resistors behind the dummy modules and shields
  - Decouple capacity of the dummy modules from the cable
  - Chain reaction stills occurs, but with less energy
- Solution to stop the trips of the field cage
  - Increase the potential of the first strip



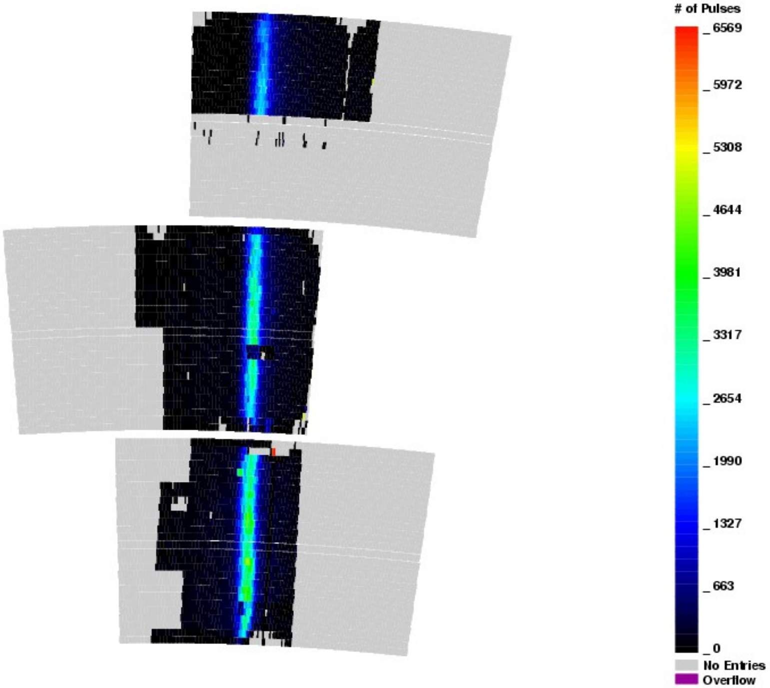
Field Shaping

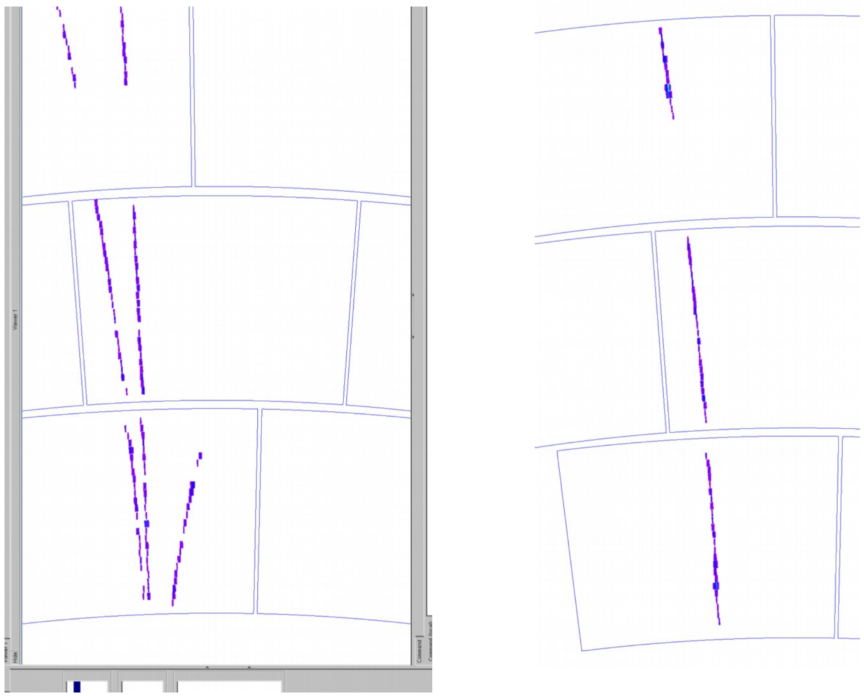
- Field Shaping options:
  - Different electrodes
    - Wire
    - Strip
  - Different potentials
    - Top GEM potential
    - Transfer field potential
    - Inverse transfer field potential



Three Module Data

Number of pulses of one data run





Event displays with the modules installed in the Large Prototype