Development of the GEM-based Read-Out Chambers for the ALICE TPC

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for the ALICE TPC Collaboration

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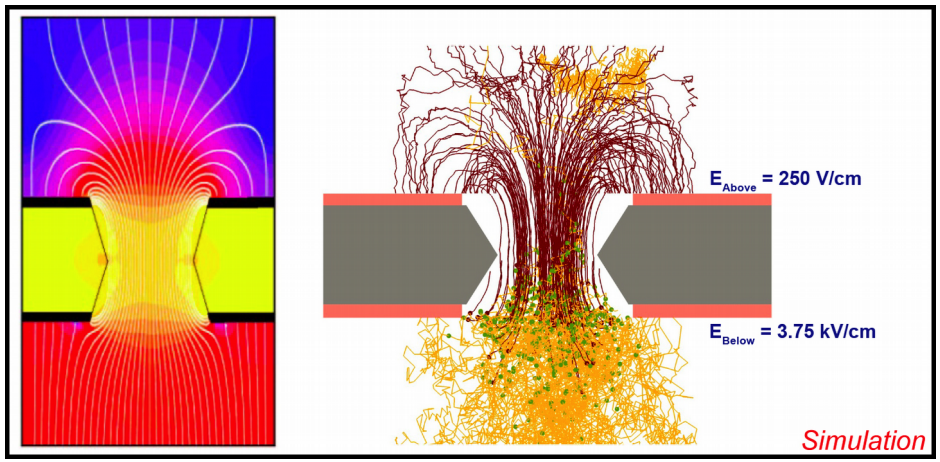
ALICE TPC upgrade

- **ALICE TPC will operate at a factor 100 higher readout rate after LS2**
  - 1-2 MHz p-p and 50 kHz Pb-Pb collisions
  - no gating and continuous readout
- **GEMs as an alternative for MWPC readout**
  - no issue with rate capability
  - possibility to efficiently block ions
  - lower (effective) gain since signal is produced by electrons (fast) + lower noise



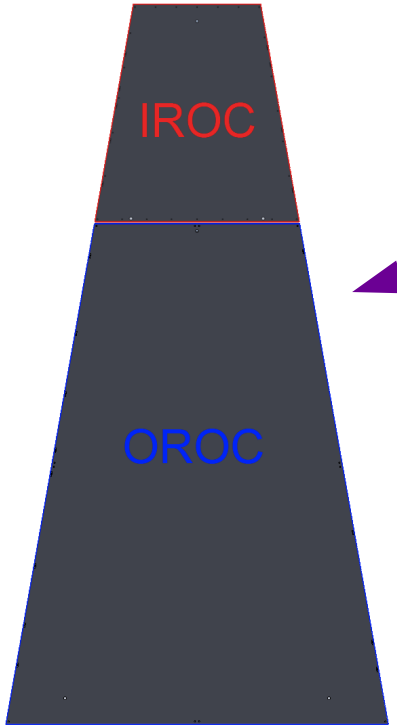
- **Issues for GEM upgrade**
  - dE/dx resolution for PID *(Nov/Dec 2012)*
  - stability under LHC conditions *(Jan/Feb 2013)*
  - gain stability (charging up, rate dependence)
  - IBF (ongoing measurements, simulations)
  - new electronics (polarity, continuous readout)

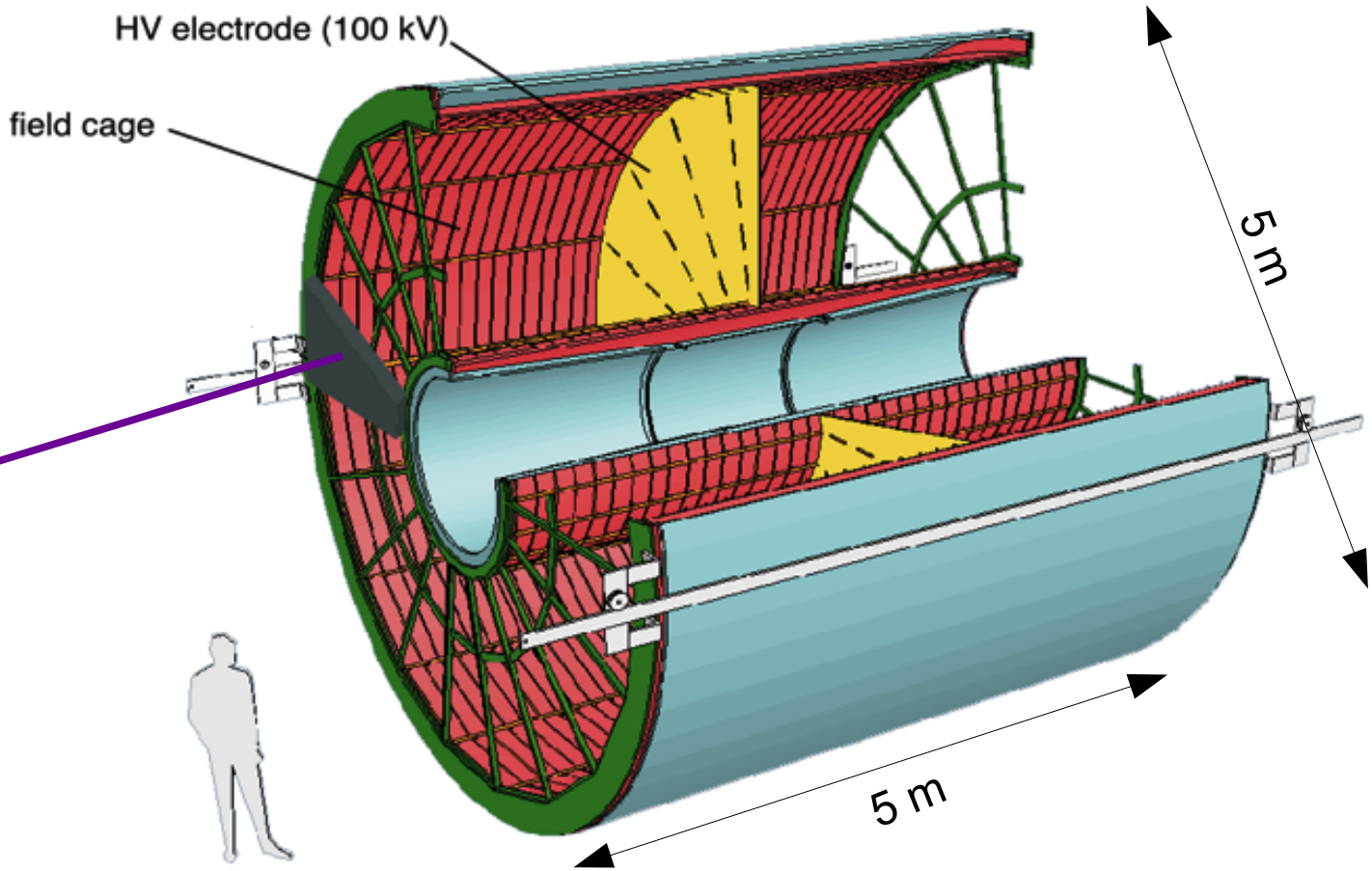
ALICE TPC

2 x 18 IROCs

Inner **R**ead **O**ut **C**hambers

50 cm × 47 cm (29 cm)





2 x 18 OROCs

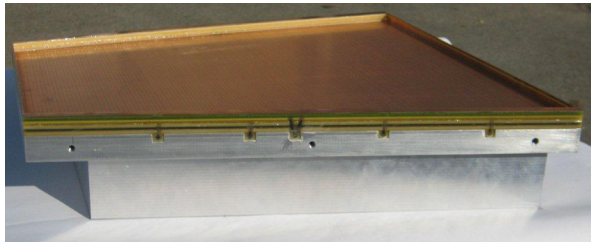
Outer **R**ead **O**ut **C**hambers

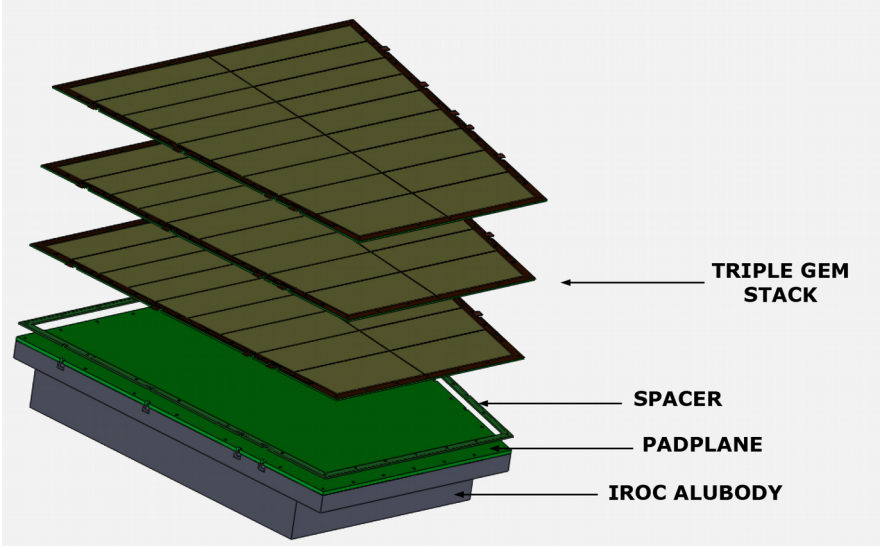
114 cm × 87 cm (47 cm)

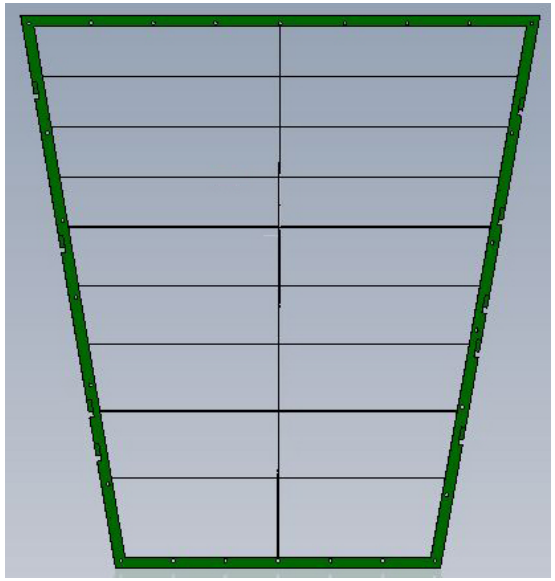
GAS:

- Ne-CO_2 (90-10)
- 90 m^3
- v_{drift} = 2.73 cm/µs (@ 400 V/cm)

GEM – IROC prototype @ TUM

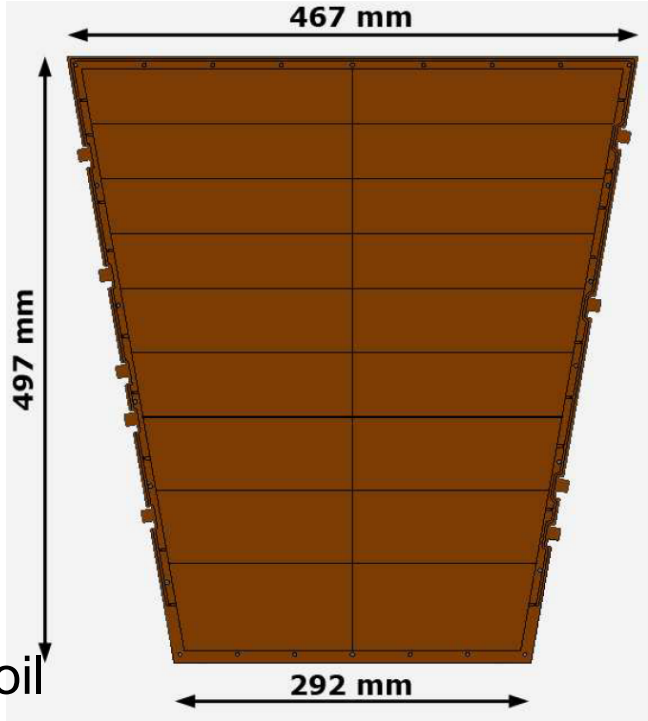




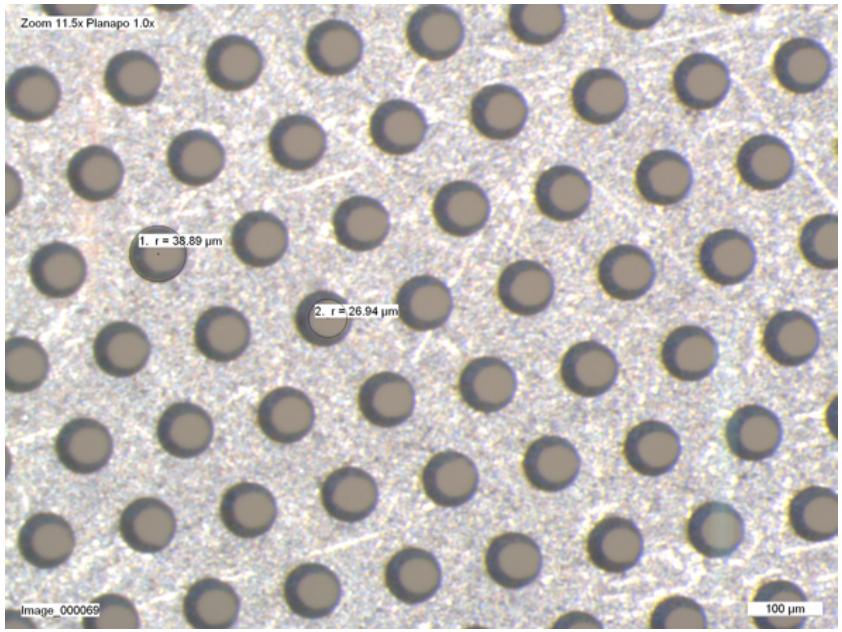


GEM foils for IROC prototype

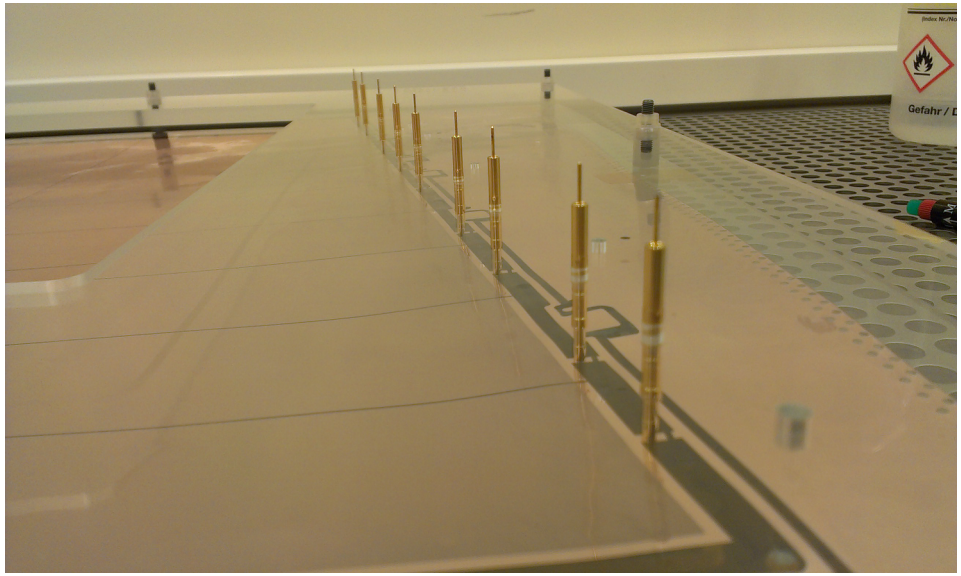
- 3 single-mask, large-size foils
- **Inner/Outer hole diameter: 50/70 µm**
- **Pitch: 140 µm**
- **18 sectors** (top side segmented), **~100 cm² each**
- **2 mm frames (G10 fiber glass) glued on bottom side**
- Thickness of spacer grid: 400 µm
- Additional frame (spacer) between pad plane and bottom foil

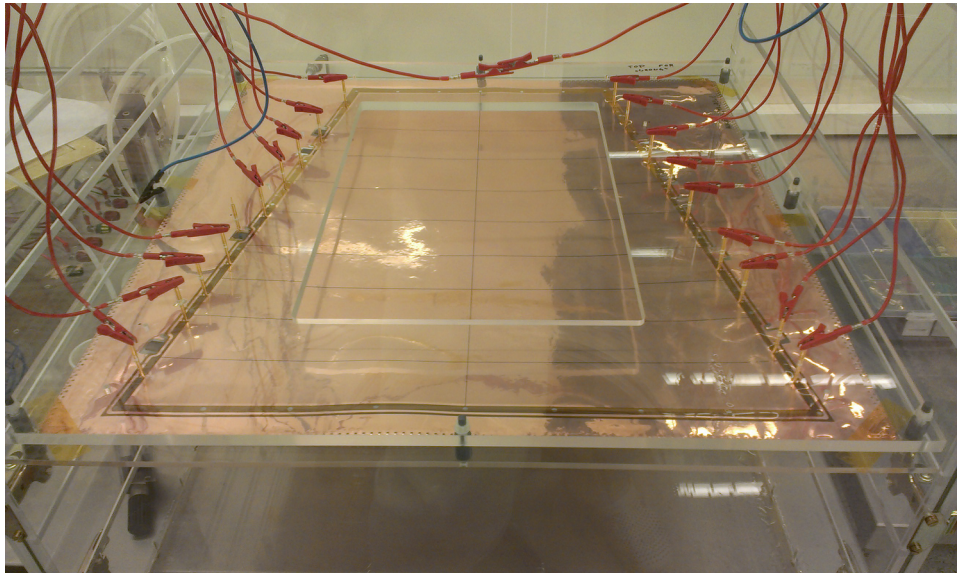


Quality Assurance



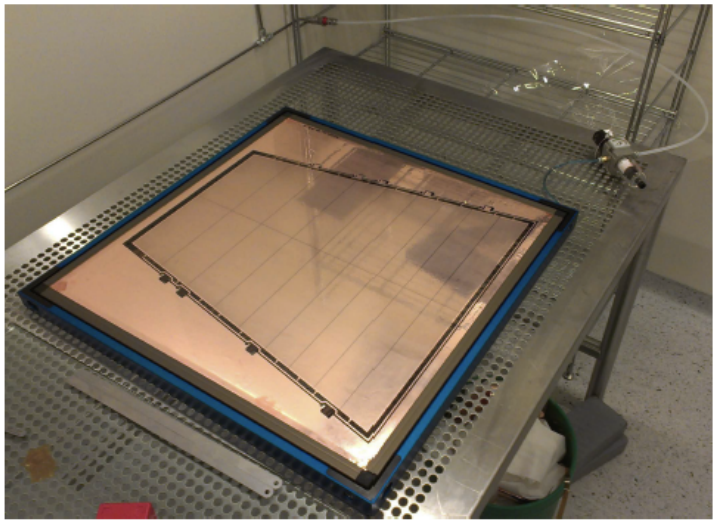
- **Microscope check**
  - hole size measurement
  - search for defects
- **HV check**
  - Test in box flushed with N_2
  - 550 V (max. 600 V) applied
  - Measure leakage current *(< 0.5 nA)*
  - Measure spark rate *(< 3 per each HV step)*
  - Performed at each step of assembly



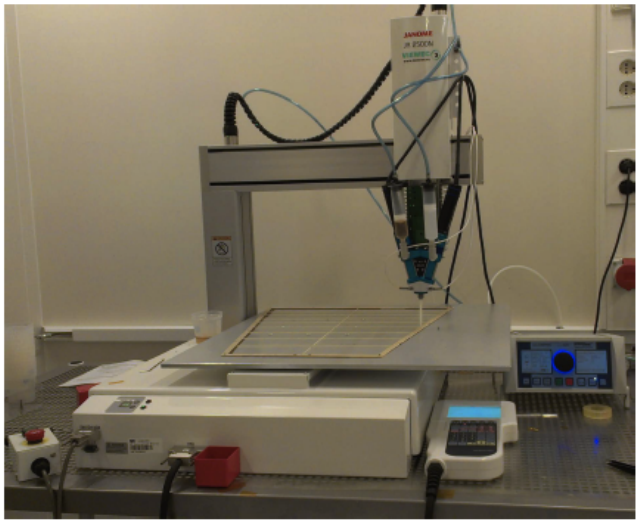


Gluing procedure

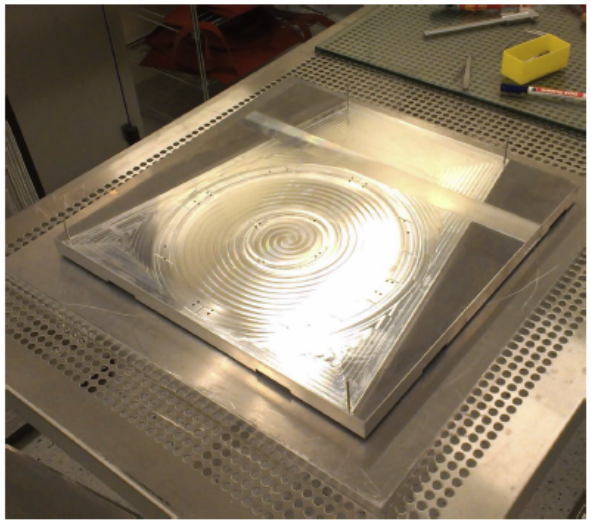
1. Stretching (DEK frame, 10 N/cm)



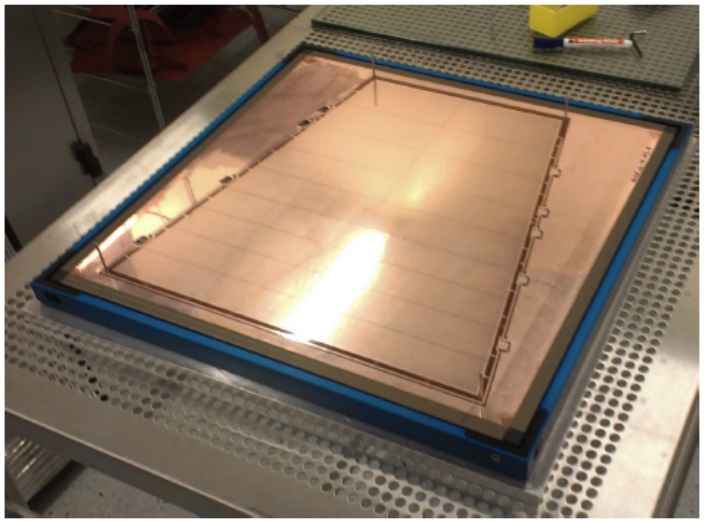
2. Glue dispensing (ARALDITE 2011)



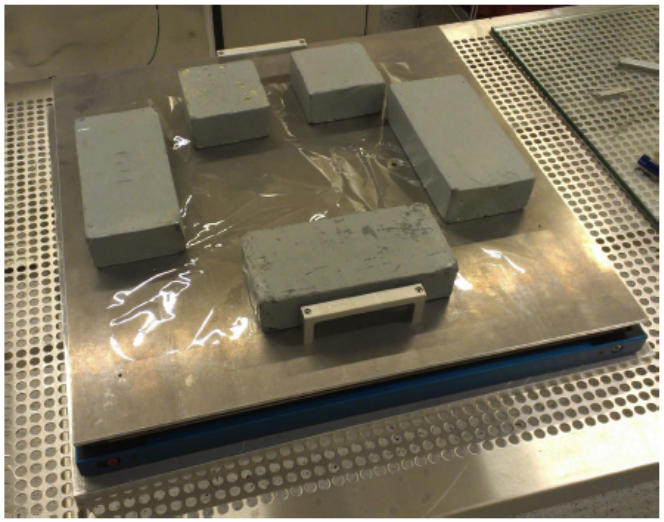
3. Alignment tool



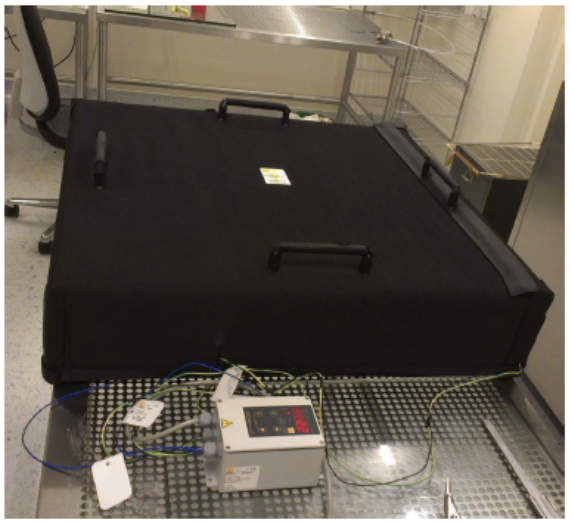
4. Foil glued onto the frame



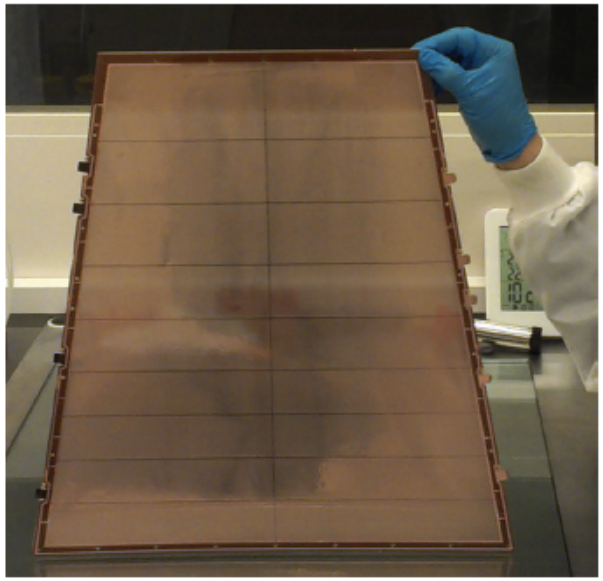
5. Counterweight for gluing



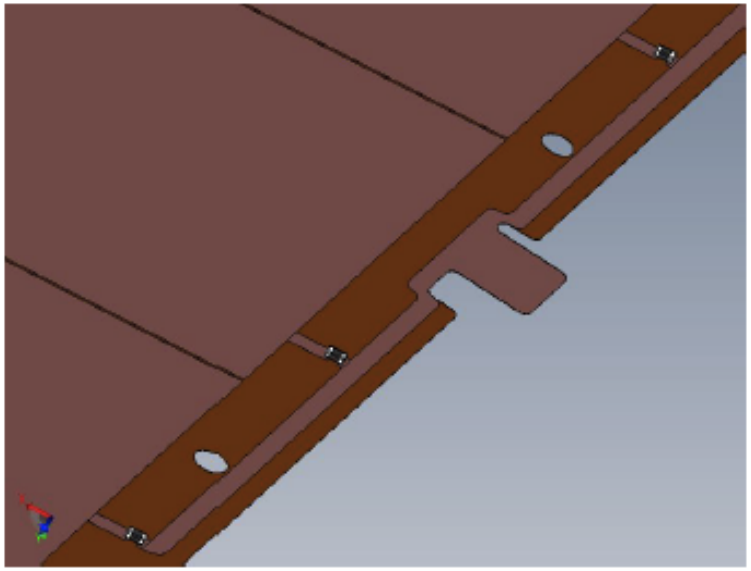
6. Curing the glue (70°C for 20h)



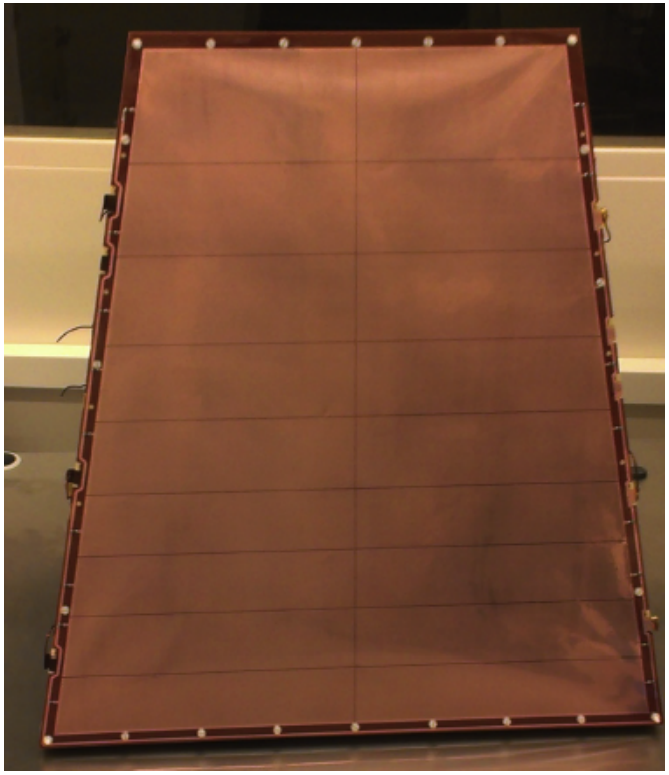
Detector assembly



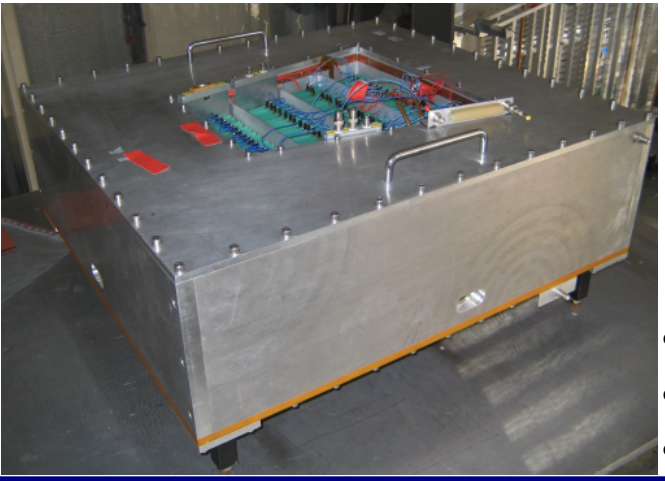
- Raw material cut off
- HV test
  (lower leakage currents after curing the glue in high T)



- Loading resistors (SMD)
- HV wires connection

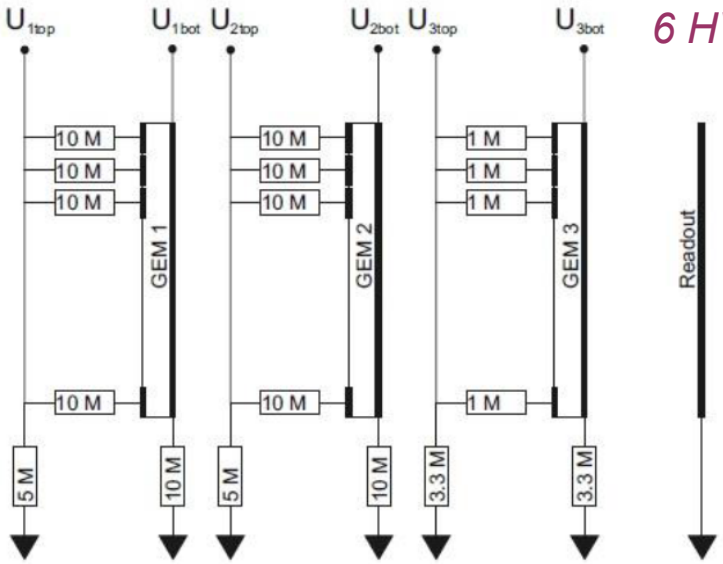


- Mounting the stack
- Wrinkles on the foil(s):
  - Nylon screws,
  - Number of screws,
  - Position of screws/holes

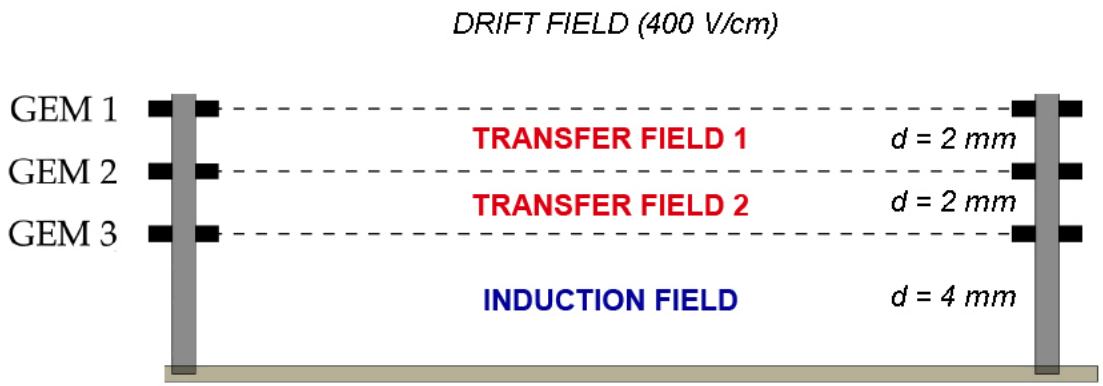


- GEM IROC in a modified test box with the filed cage
- Drift length: ~11 cm
- Adjustable potential on the last strip of the FC

HV supply & settings



6 HV channels used (adjustable potentials)



"Standard" settings
- stability-optimized
- 100 % for Ar/CO_2 70/30

Transfer Field 1 = 3730 V/cm
Transfer Field 2 = 3730 V/cm
Induction Field = 3730 V/cm

GEM1 = 400 V
GEM2 = 365 V
GEM3 = 320 V

- Scaling factors: 69%, 70%, 71%, 72%, 73% (scaling both GEMs and Fields)
- Resulting gains: ∼ 1500 – 6000

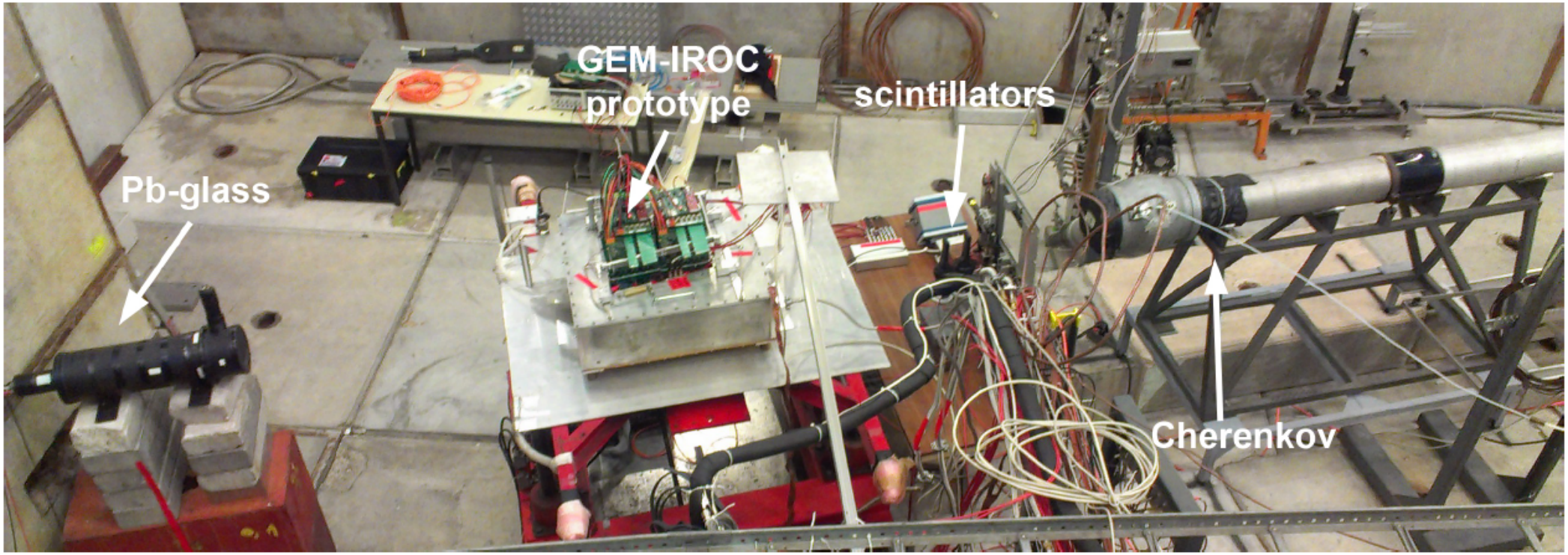
Transfer Field 1 = 3800 V/cm
Transfer Field 2 = 200 V/cm
Induction Field = 3800 V/cm

GEM1 = 225 V
GEM2 = 235 V
GEM3 = 285 V

- Scaling factors: 100%, 103%, 105%, 107% (scaling only GEMs)
- Transfer Field 2: 200, 400, 600, 800 V/cm
- Resulting gains: ∼ 900 – 6600

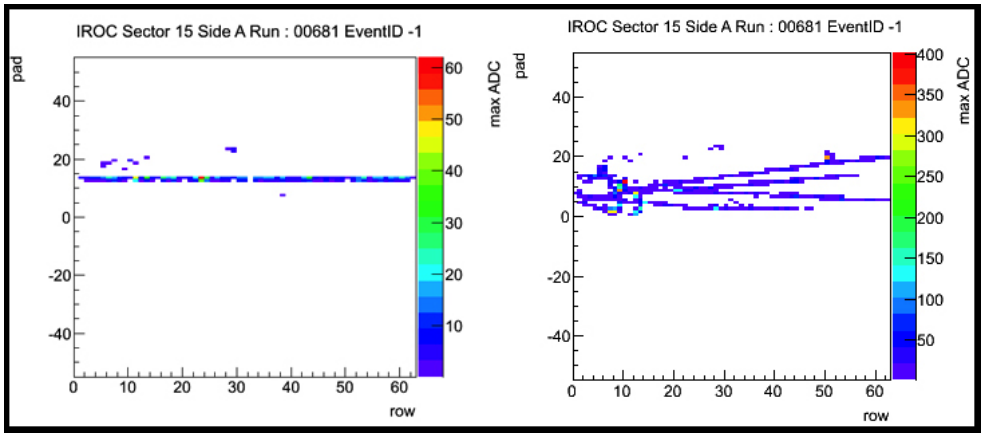
"IBF" settings
- IBF optimized (4 %)
- increasing gain in GEMs
- low T2 field
- (4x4 matrix)

PS test beam

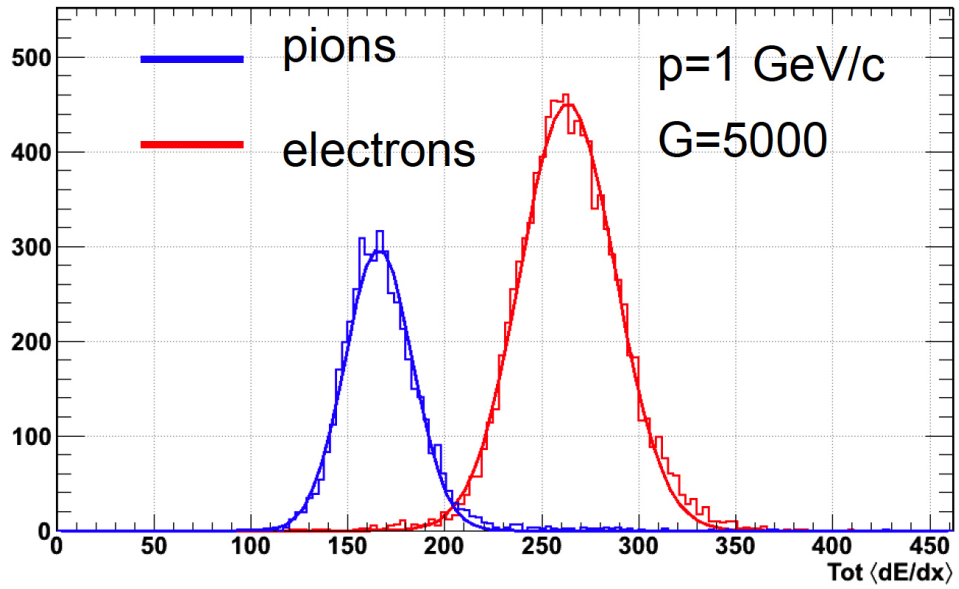


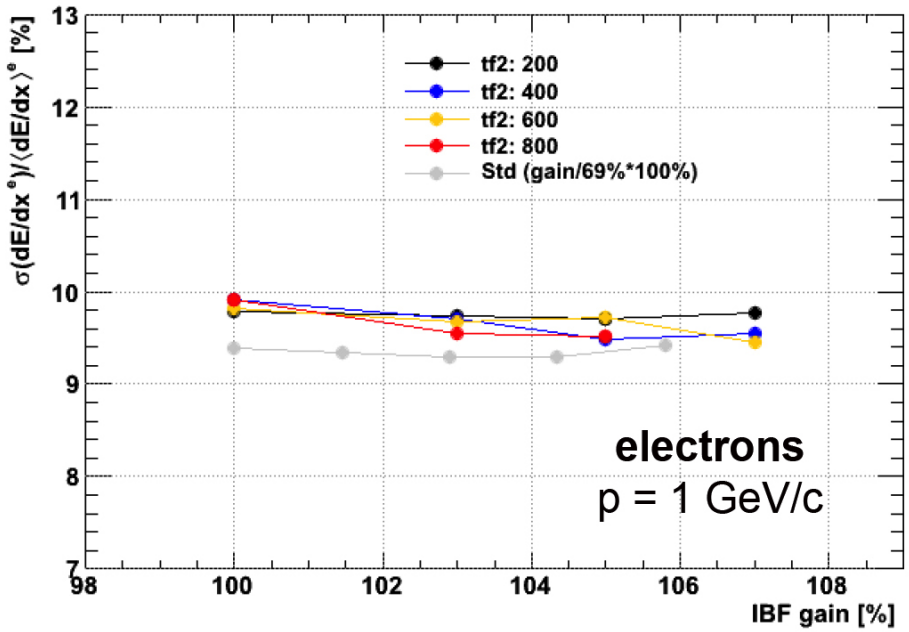
PS East Area – T10 beamline

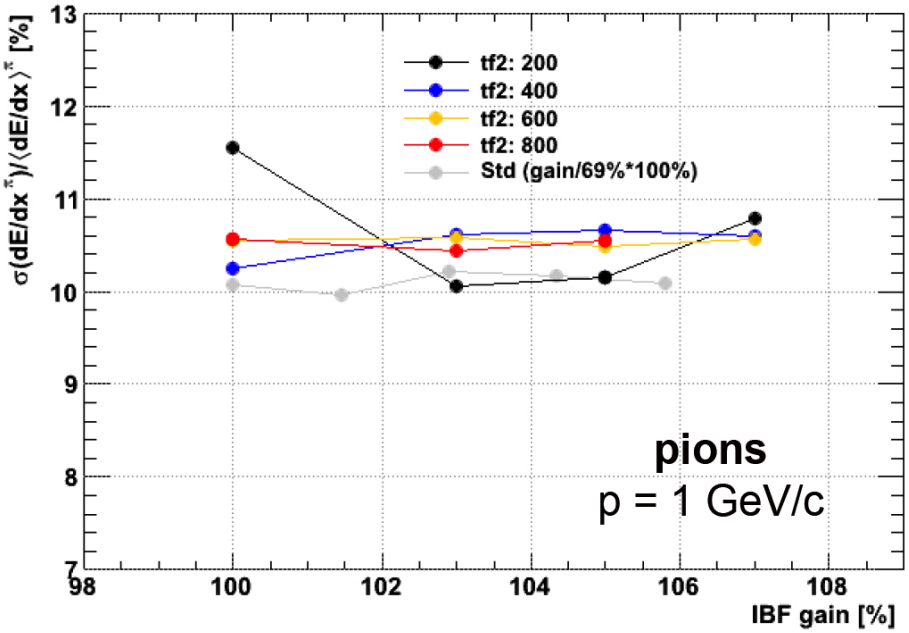
- Data taken for different beam settings:
  - **1 GeV/*c*, 2 GeV/*c*, 3 GeV/*c* negative (e^-, π^-)**
  - **1 GeV/*c*, 6 GeV/*c* positive (e+, π+, p)**
- GEM settings: "standard" and "IBF"
- Gas mixture: Ne-CO_2 (90-10)
- 64 pad rows read-out (7 cm wide) with 10 EUDET FEC (PCA16+ALTRO) – *borrowed from LCTPC via Lund*



dE/dx measurements



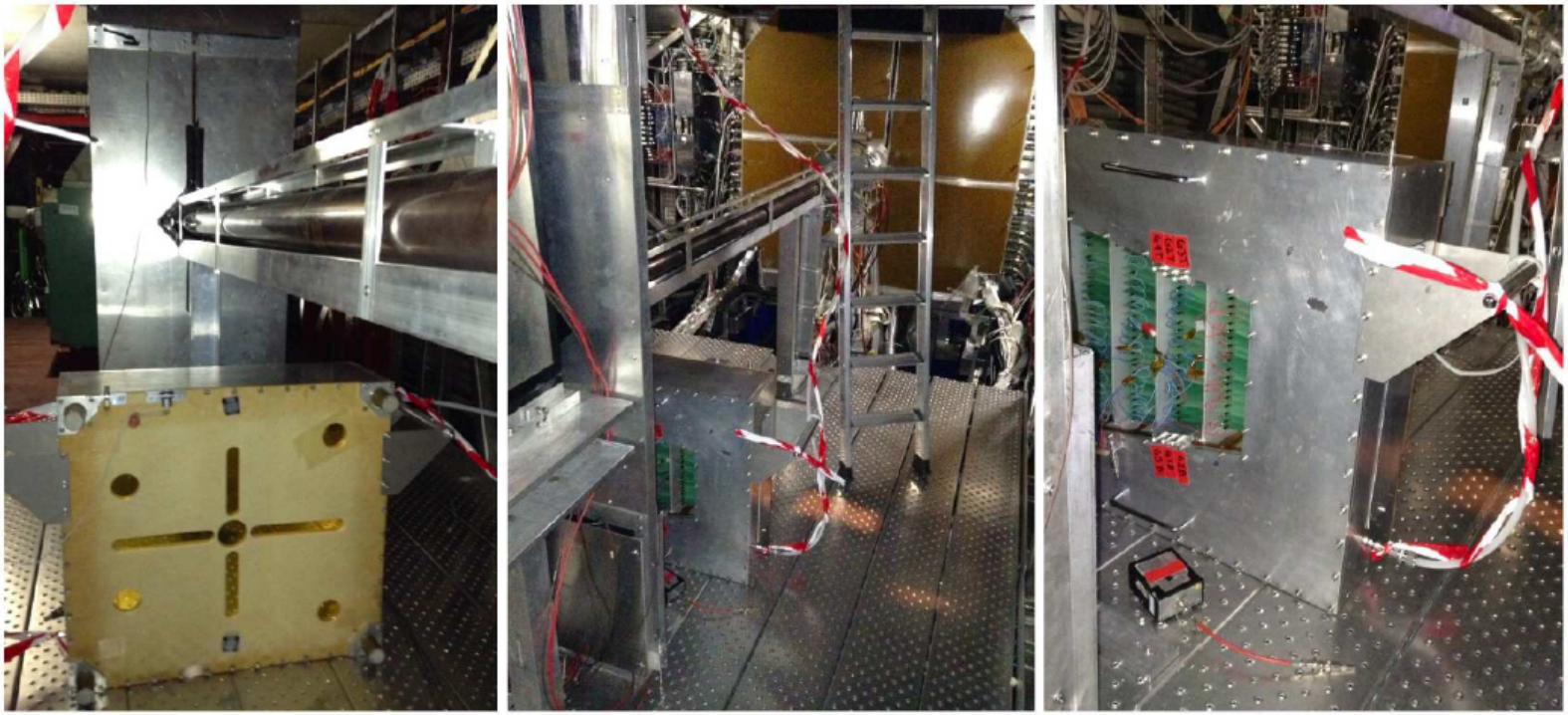




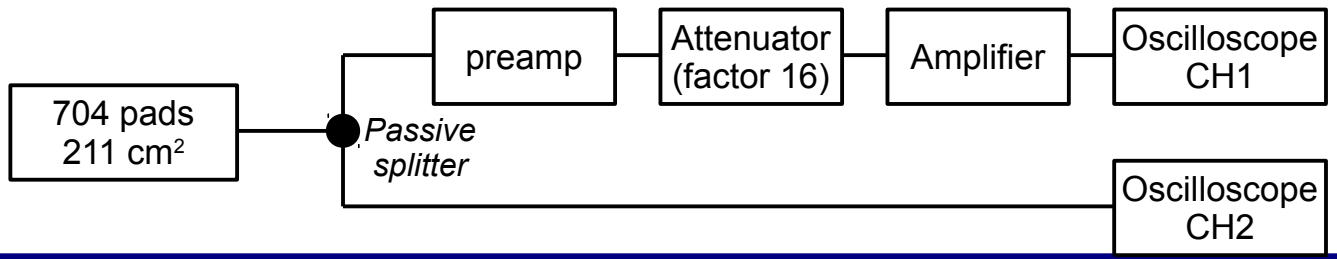
***dE/dx* measurements**

- Gain equalization using tracks
- No T/P correction
- Truncated mean of cluster charge (5 - 70 %)
- For comparison:
  IROC only in ALICE TPC $\sigma_E/E \approx 9.5$ % (for high η)

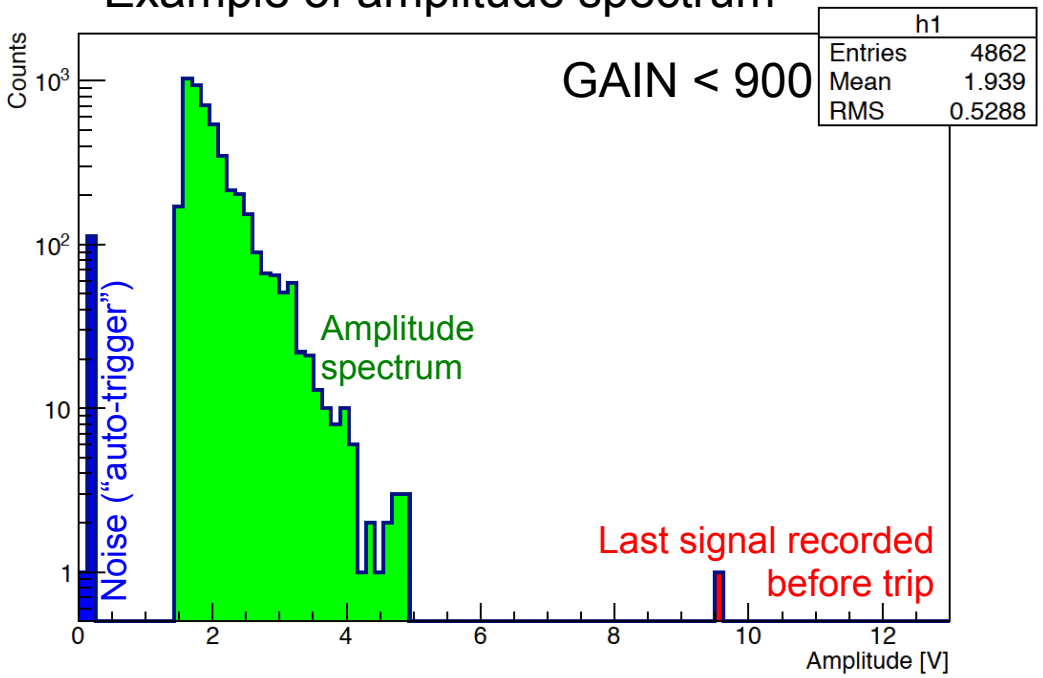
Test under LHC conditions



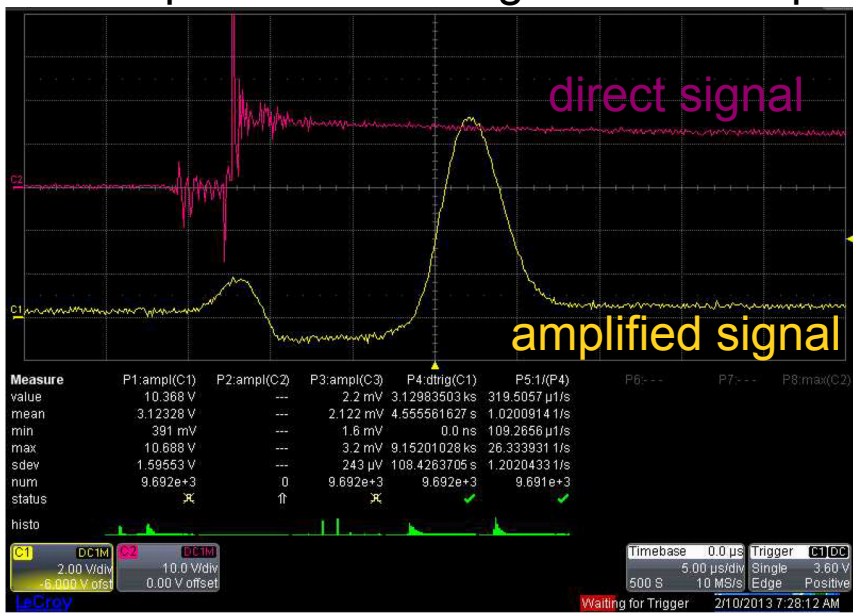
- p-Pb period 2013 (3 weeks)
- Prototype installed at the ALCIE cavern under the beam pipe (η ≈ 2.6)
- 200 kHz interaction rate
- Particle rate ~5000 kHz per rapidity unit
- Standalone readout: waveforms, discharges, trips
  - Trig. Rate < 10 Hz (recording highest signals)



Example of amplitude spectrum



Example of the last signal before trip



- **23 trips occurred** *(+ 8 during the PS beamtime)*
  - 20 at lowest "IBF" settings, 2 at "standard", 1 while ramping up
  - 21 with beam, 2 without
  - All included G1 (absolute voltages?)
  - Highly ionizing particles? (heavy fragments)

- **7 shorts developed in the GEM-foils**
  - 1 x GEM1; 3 x GEM2; 3 x GEM3;
  - **Shorts developed in the sectors with problems at the QA – HV step;**
  - **No correlations with foil defects found**

Importance of QA

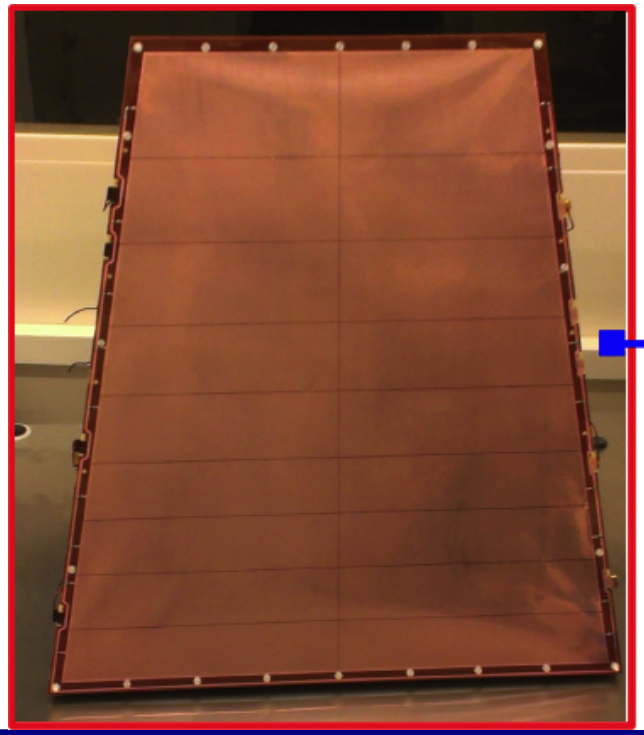
Stability in Ne

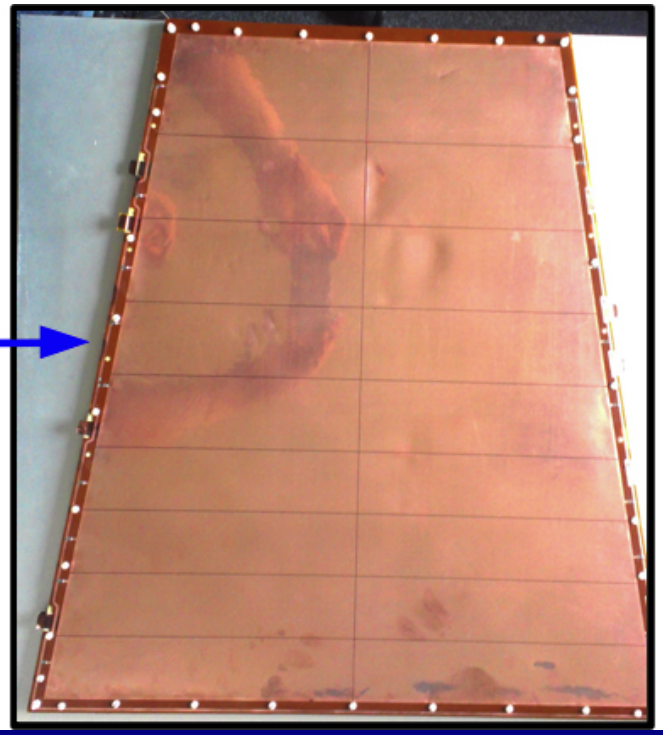
- **Do we operate at breakdown limits?**
  - Systematic studies in Ne-based gas mixtures needed
  - Gas choice
    - Ne-CO_2 (90-10) , Ne-CO_2-N_2 (90-10-5) + others
  - HV settings
    - IBF+Stability optimized
  - Other parameters (production, quality, HV supply, etc.)

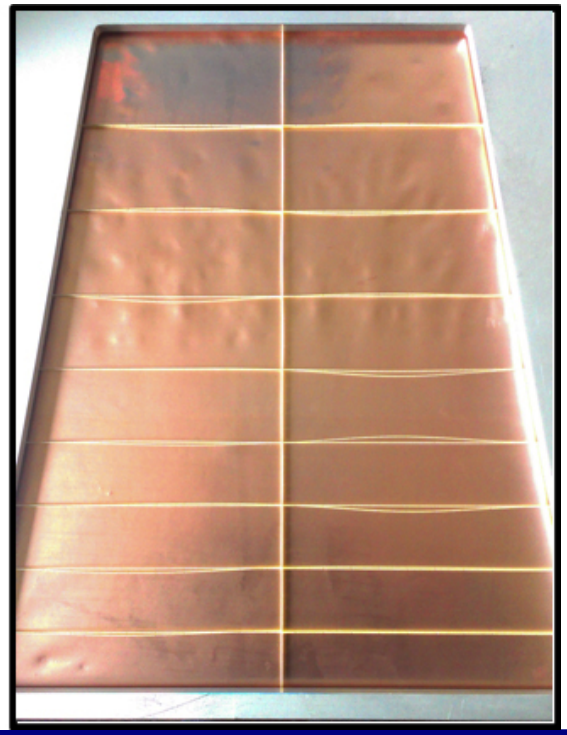
Improvements in "wrinkle issue"

- Remnants of glue sticking out from the holes removed
  → *small grooves around the holes in a new frame design*
- New, more rigid, screws (Polyamid 6.0 with 25% glass fibers)
- Additional mounting holes **around the corners** and on the sides
- Frame on top of the stack, to distribute the pressure (not on the pictures)
- *Work in progress (frame bending → tension still not kept)*
- *Alternative R&D: NS2, new methods*

New foils/frames in the production

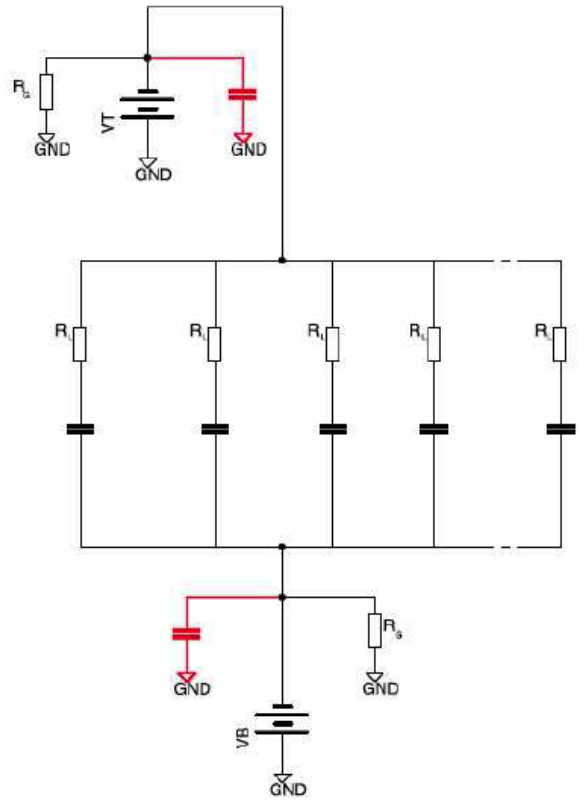


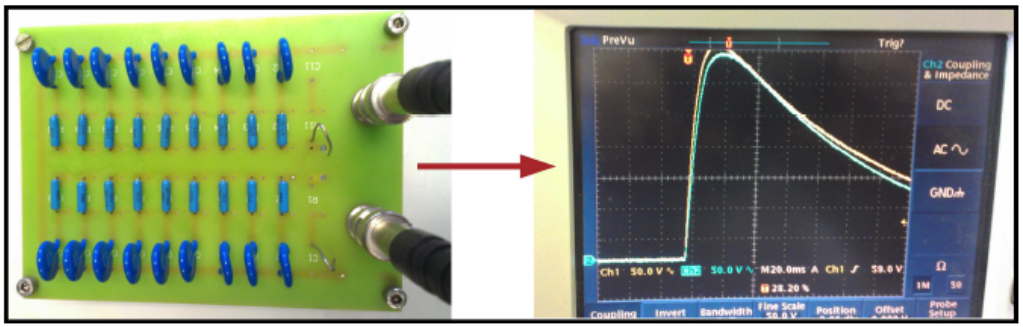


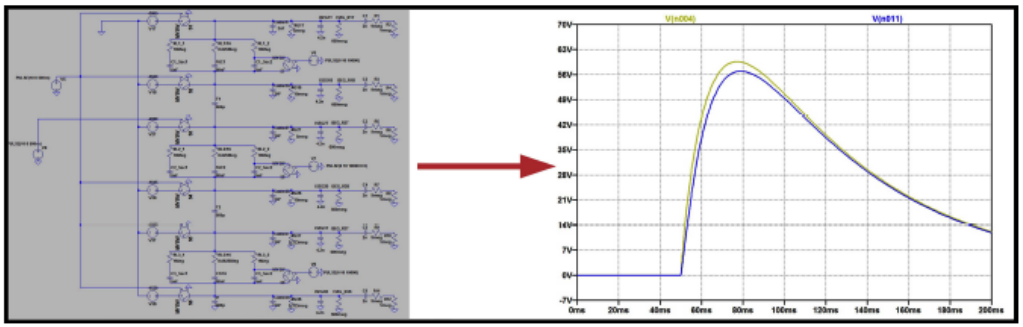


HV supply

- Loading resistors
  - 10 MΩ for top (**G1**) and middle (**G2**) foils
  - 1 MΩ for bottom (**G3**) foil
- Each side powered independently (6 HV channels)
  - ΔV across the GEM must not increase after the trip
  - top side must discharge faster than bottom
  - crucial role of parasitic capacitances (cables!)
- Grounding resistors
  - **G1T** → 5 MΩ; **G1B** → 10 MΩ
  - **G2T** → 5 MΩ; **G2B** → 10 MΩ
  - **G3T** → 3.3 MΩ; **G3B** → 3.3 MΩ
- Tested with GEM-model and LTspice simulations



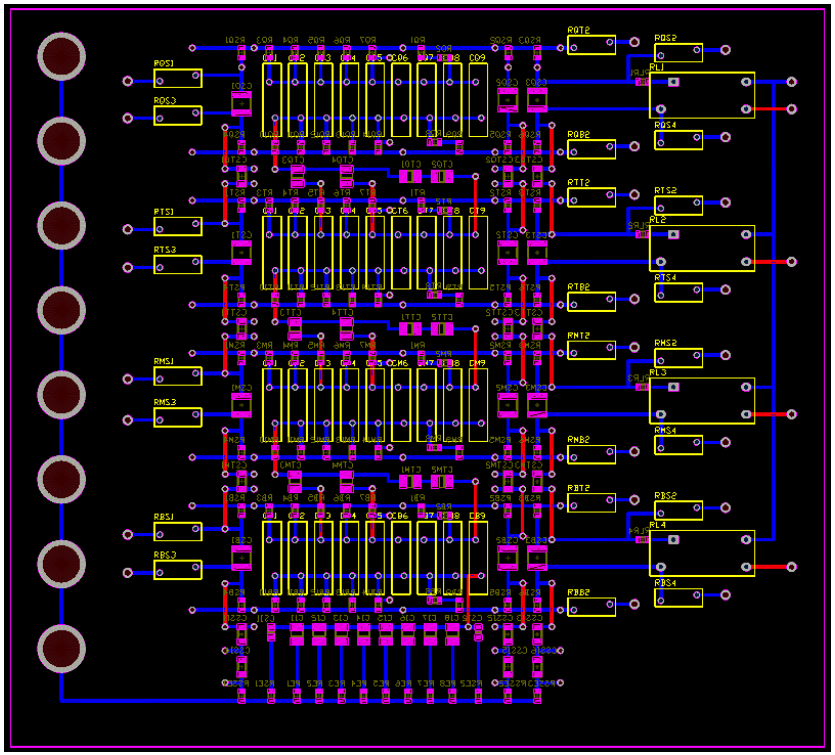


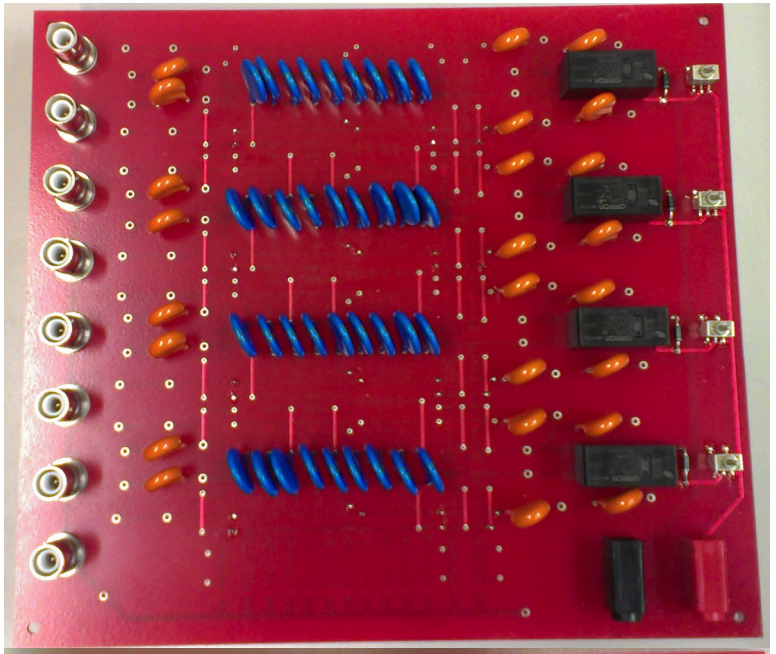


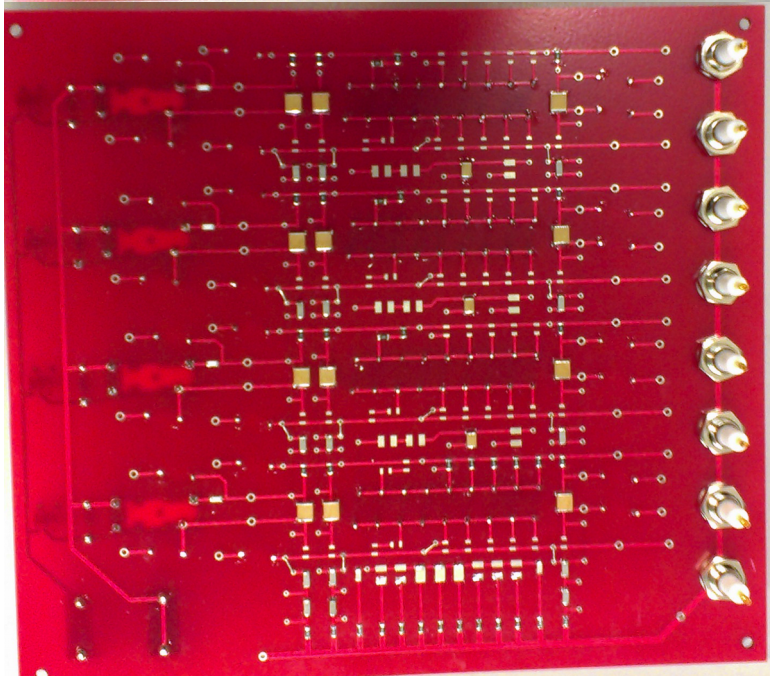
Power Supply studies

PS time characteristics

- tripping times/delays
- PCB GEM model:
  - 3, 4-GEM stack
  - R_L on top or (and) bottom
- **+ simulations**
  - Various Transfer/Induction gaps
  - "Discharges" in GEMs
  - Scope readout (AC coupling via capacitors)

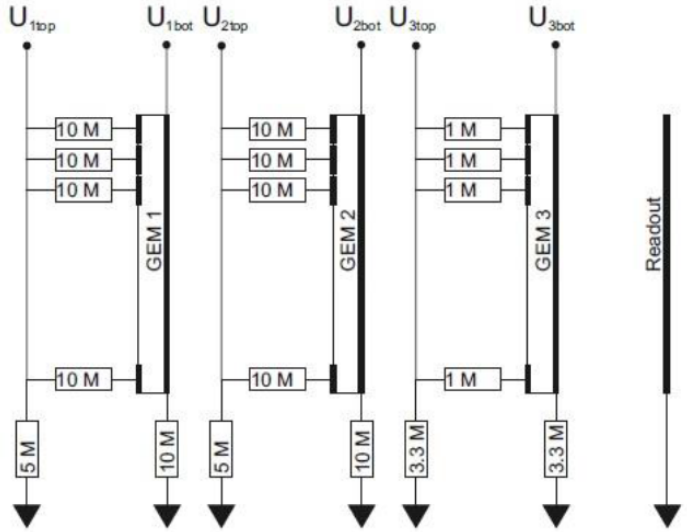


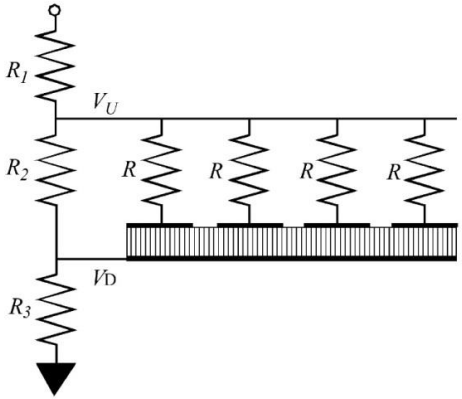


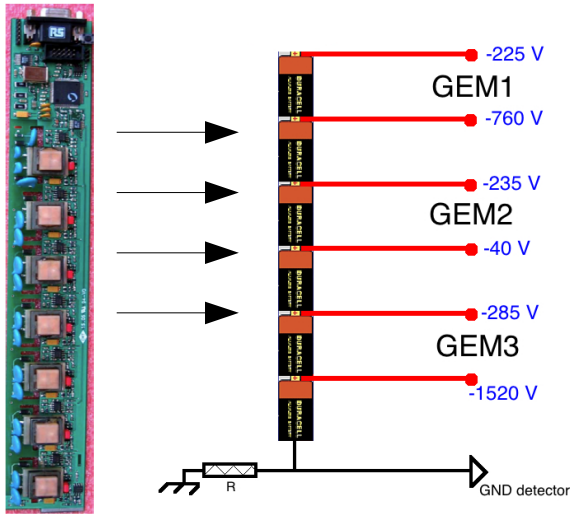


Stability and long-term operation

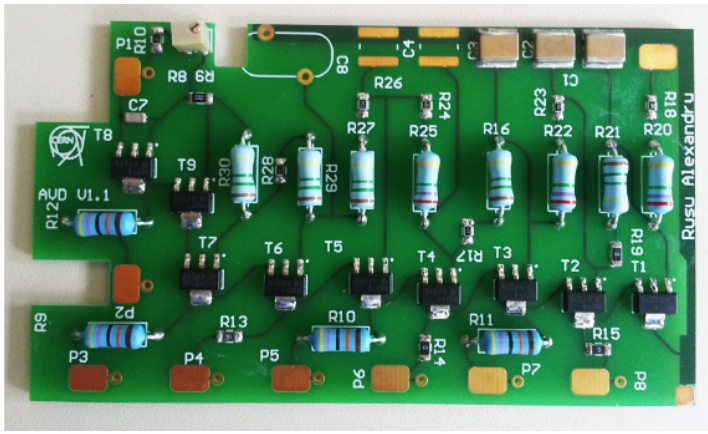
- **HV Supply**
  → safe trip after the discharge
  - Independent HV channels
  - Resistor chain
  - Active HV divider
  - **+ fast shutdown**





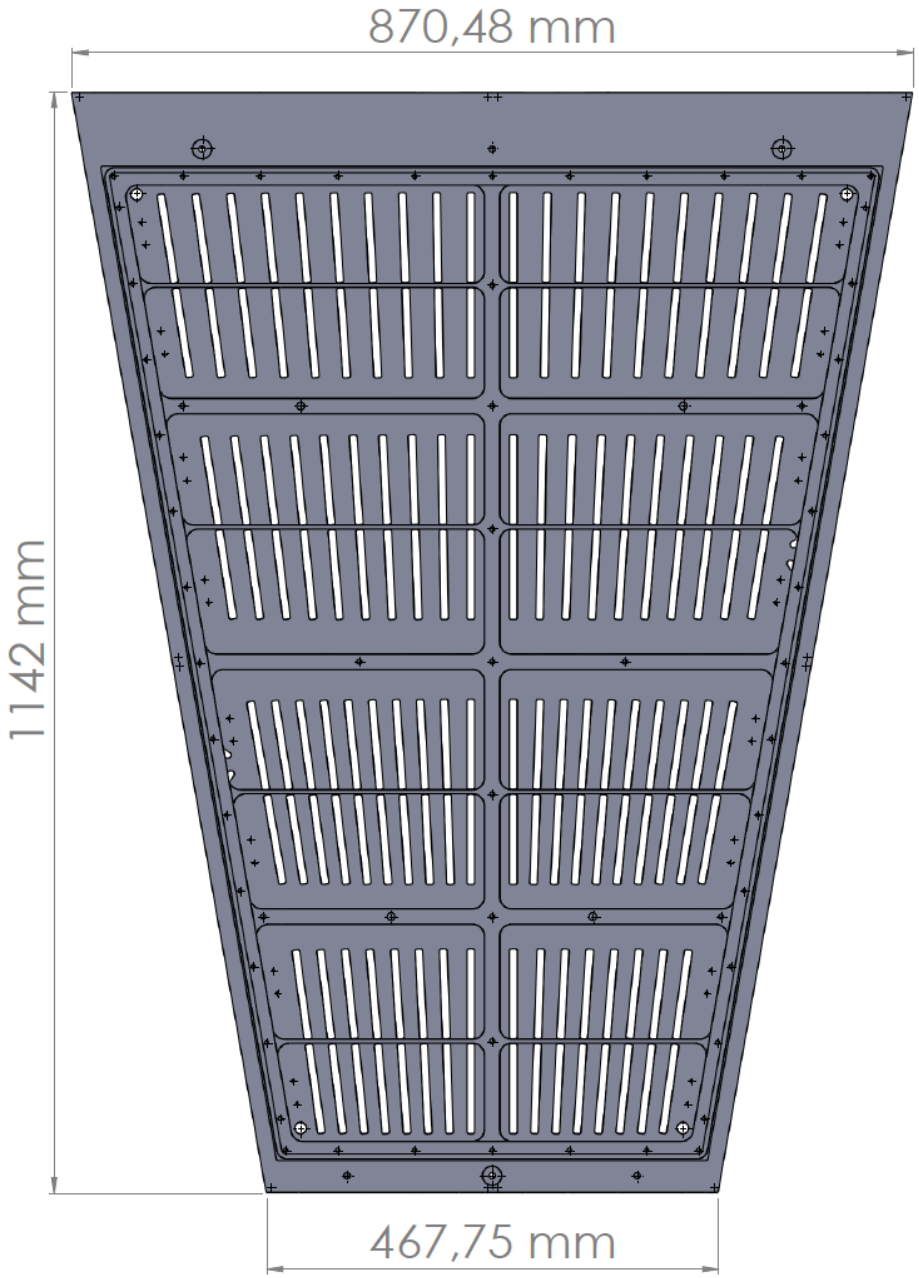


"Frascati" Active HV Divider
E. Corradi et al., NIM A 572 (2007) 96



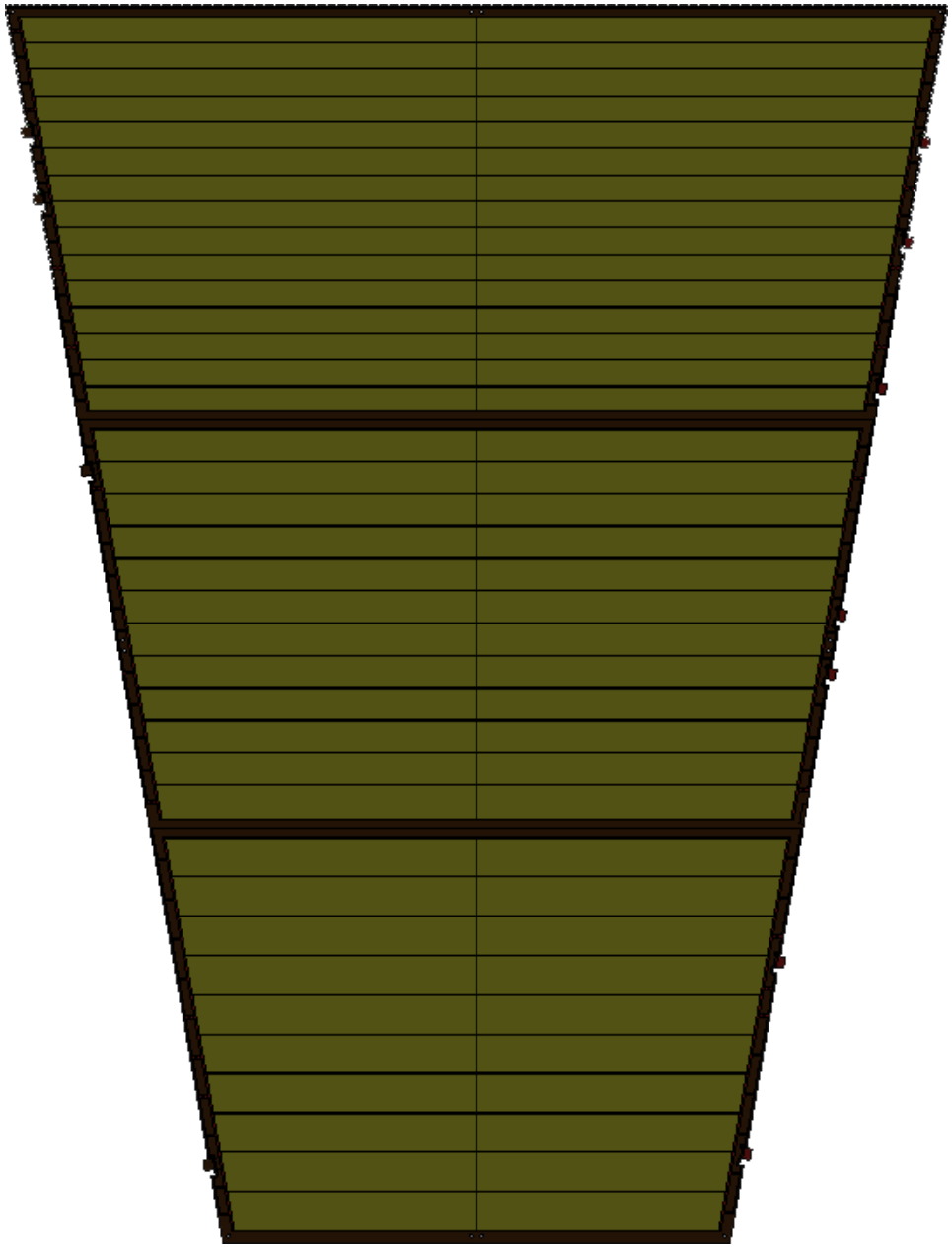
SRS AVD
H. Muller, RD51 Miniweek, 23.04.2013

OROC



- 4 times larger than IROC!!!
- Foils
  - 3 independent foils (frames)
  - splicing the foils – dead area smaller

First foil(s) design



- **3 foils + 3 frames (10 mm wide)**
  - 30 sectors (~100 cm^2 each)
  - 24 sectors
  - 20 sectors
- **4 pad rows (out of 96) lost with such a frame configuration**
- **Spacer grid follows sectorization of GEM-foils**
  - may be enlarged
  - foil bending studies (FEM) ongoing
  - foil tension must be kept!

Summary & Outlook

- First GEM IROC prototype for ALICE designed, assembled and operated
- Good d*E*/d*x* resolution has been demonstrated with beams at the CERN PS
- Stability under LHC conditions tested during p-Pb beamtime

- Issues to be addressed:
  - Stability of the GEM system
    - discharge probability
    - discharge propagation (FEE protection)
  - IBF (and many other parameters) – optimization in progress
- Definition of assembly procedure for IROCs and OROCs under way


THANK YOU!