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Progress on double phase LAr LEM-TPC

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RD51 mini week - CERN - 23/02/10

Introduction

- A double phase pure argon LEM-TPC is a tracking and calorimetric device capable of charge amplification.
- Possible applications are:
  - Giant detector for neutrino physics and proton decay.
    A. Rubbia, arXiv:hep-ph/0402110, 2003
  - Dark matter imaging detector.
    A. Rubbia, J. Phys. Conf. Ser. 39 (2006) 129
  - Recent articles:
    1) A. Badertscher et al., arXiv:0811.3384, 2008
    2) A. Badertscher et al., arXiv:0907.2944, 2009

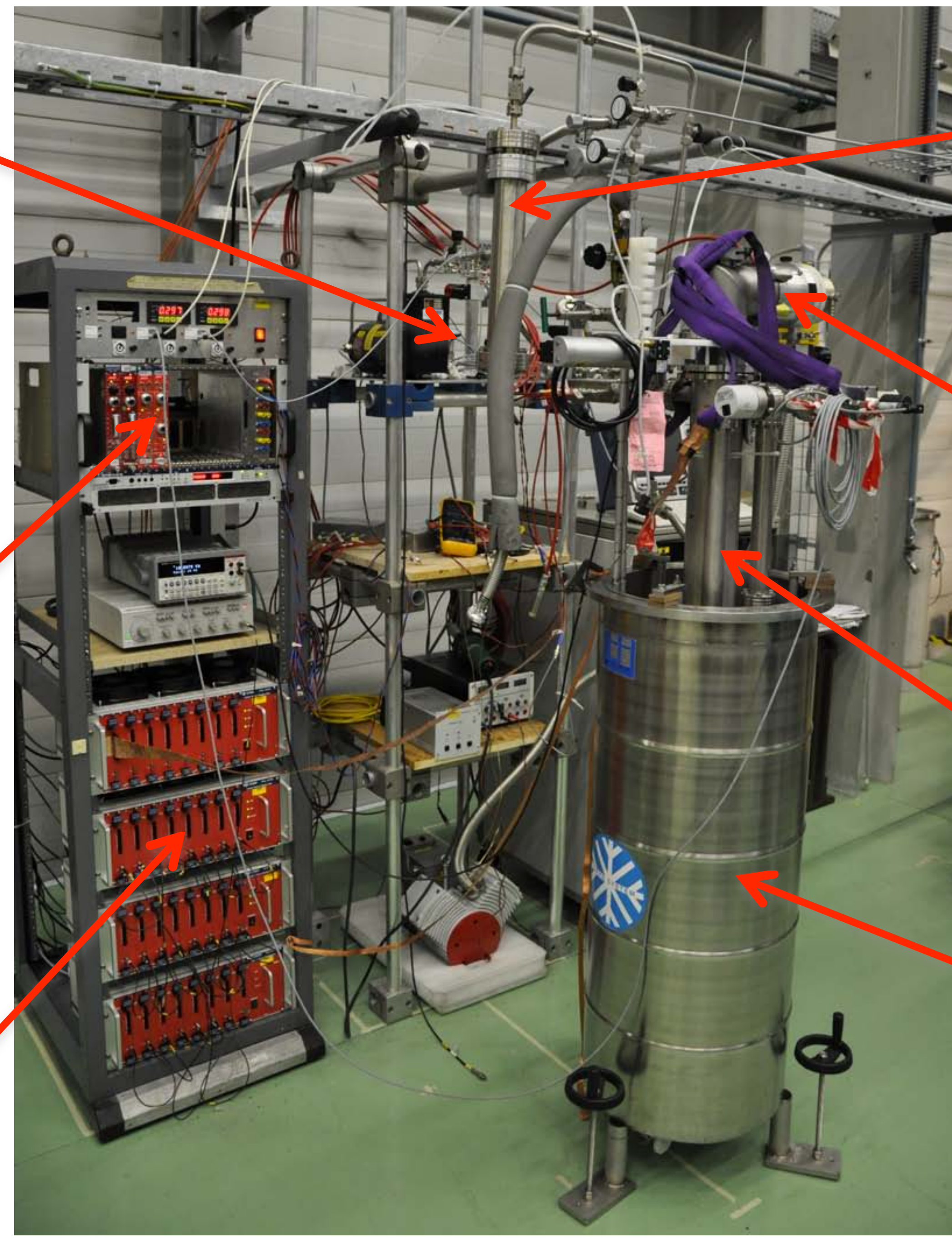
Working principle

- Charge and light are produced by an ionizing event in the LAr.
    - VUV light is detected by PMTs, it provides the time reference of the event.
- The charge is drifted to the LAr surface and extracted into the vapour phase.
    - The drift field is 0.5-1kV/cm, the extraction field (>2.5kV/cm) is provided by two grids.
- The charge is driven into the LEM holes where the electron multiplication occurs.
- The moving charges induce signals on the readout electrodes.

3L setup @ CERN

argon purification system

input purification cartridge



power supplies

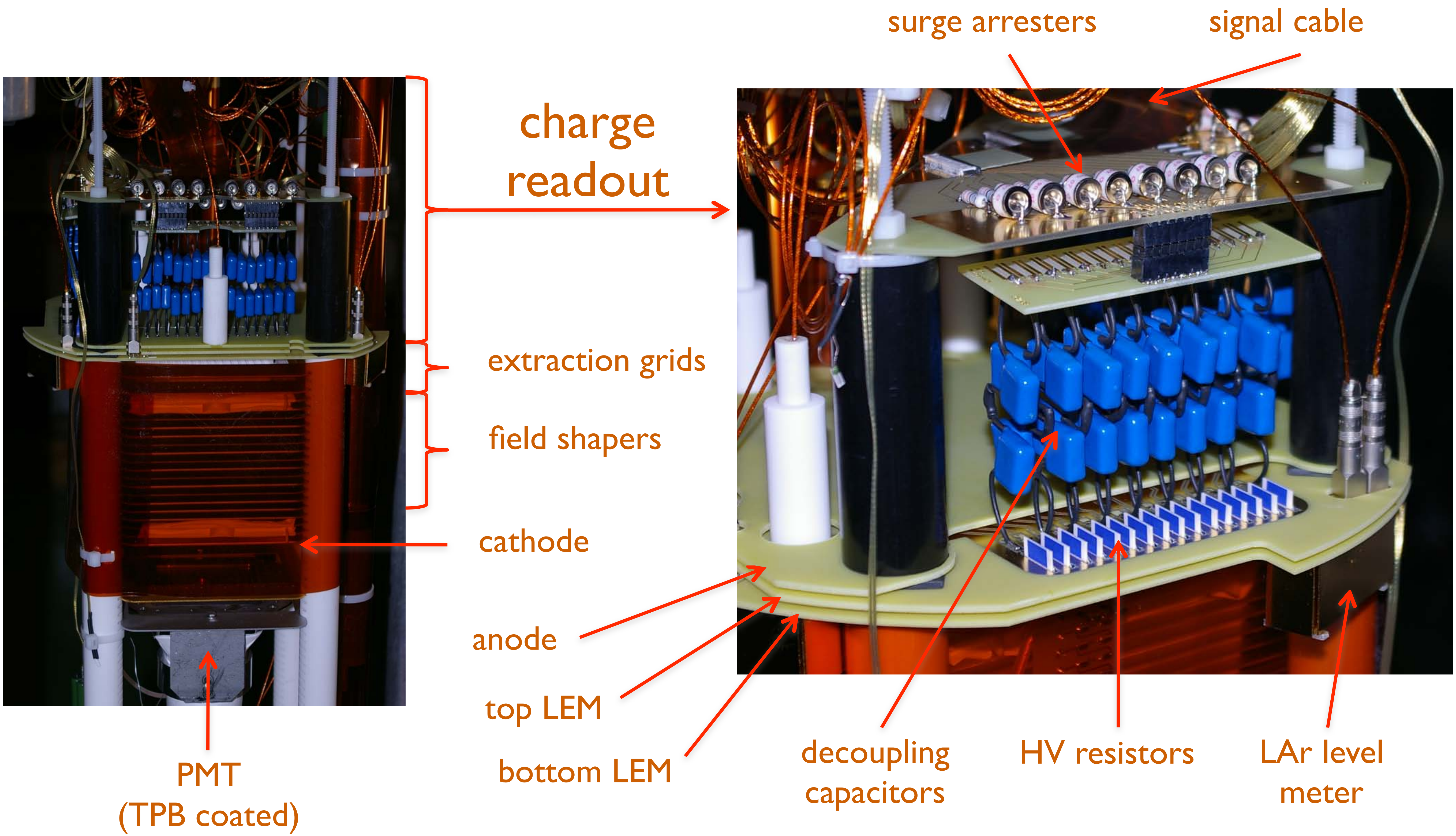
turbo pump

detector vessel

charge DAQ system

cryostat (LAr bath)

Detector details



LEM: production

Characteristics:

- High discharge resistivity.
- Mechanically robust.
- Possibility to cover large areas.

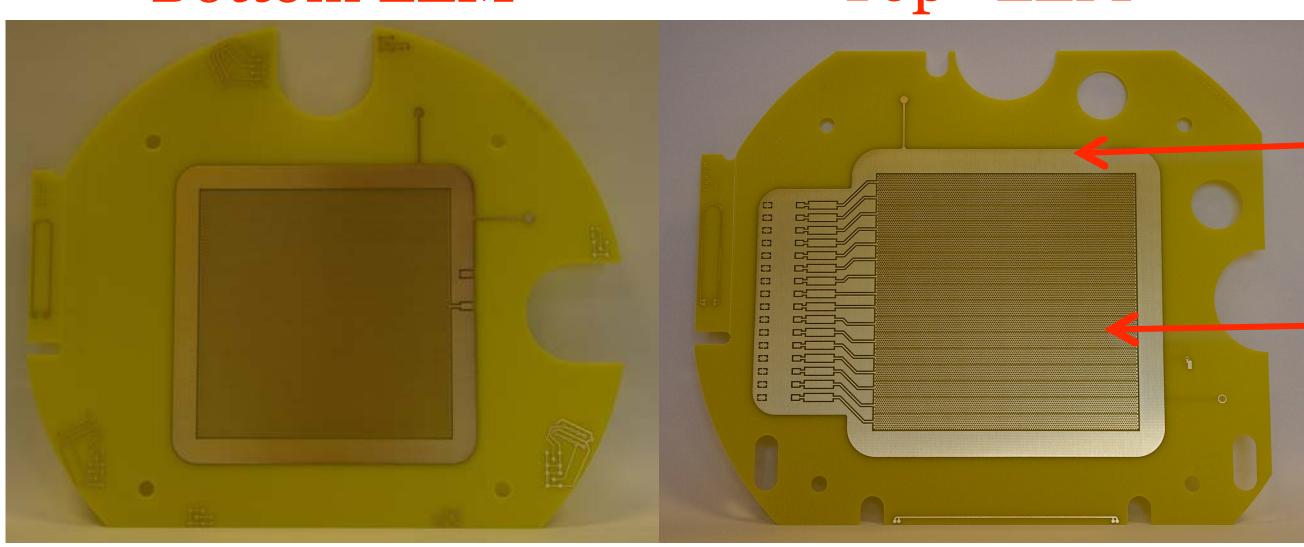
Standard PCB technique:

- Double sided copper cladded FR4 plate.
- Precision holes by drilling.
- Etched rims.

Manufacturer:
Multi PCB Ltd (Germany)

total area	10×10 cm^2
thickness	1.0, 1.2, 1.6 mm
hole diameter	500 μm
hole pitch	800 μm
rim size	50 μm
segmentation	16 strips, 6 mm pitch

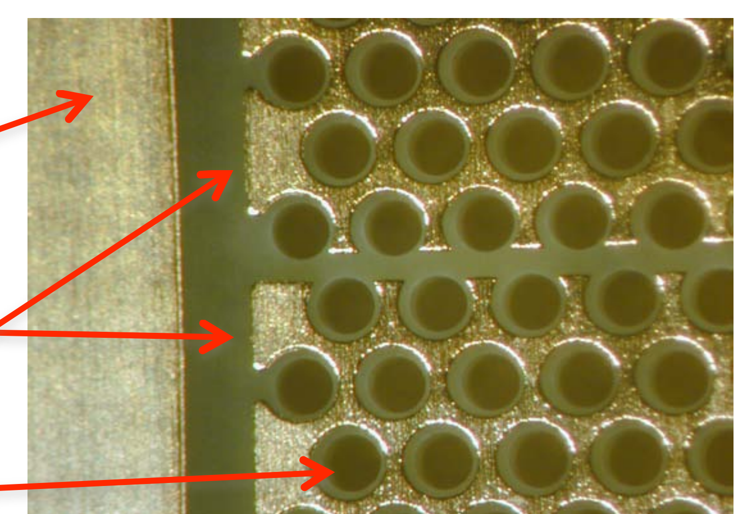
Bottom LEM Top LEM



guard ring

6 mm strips

dielectric rim

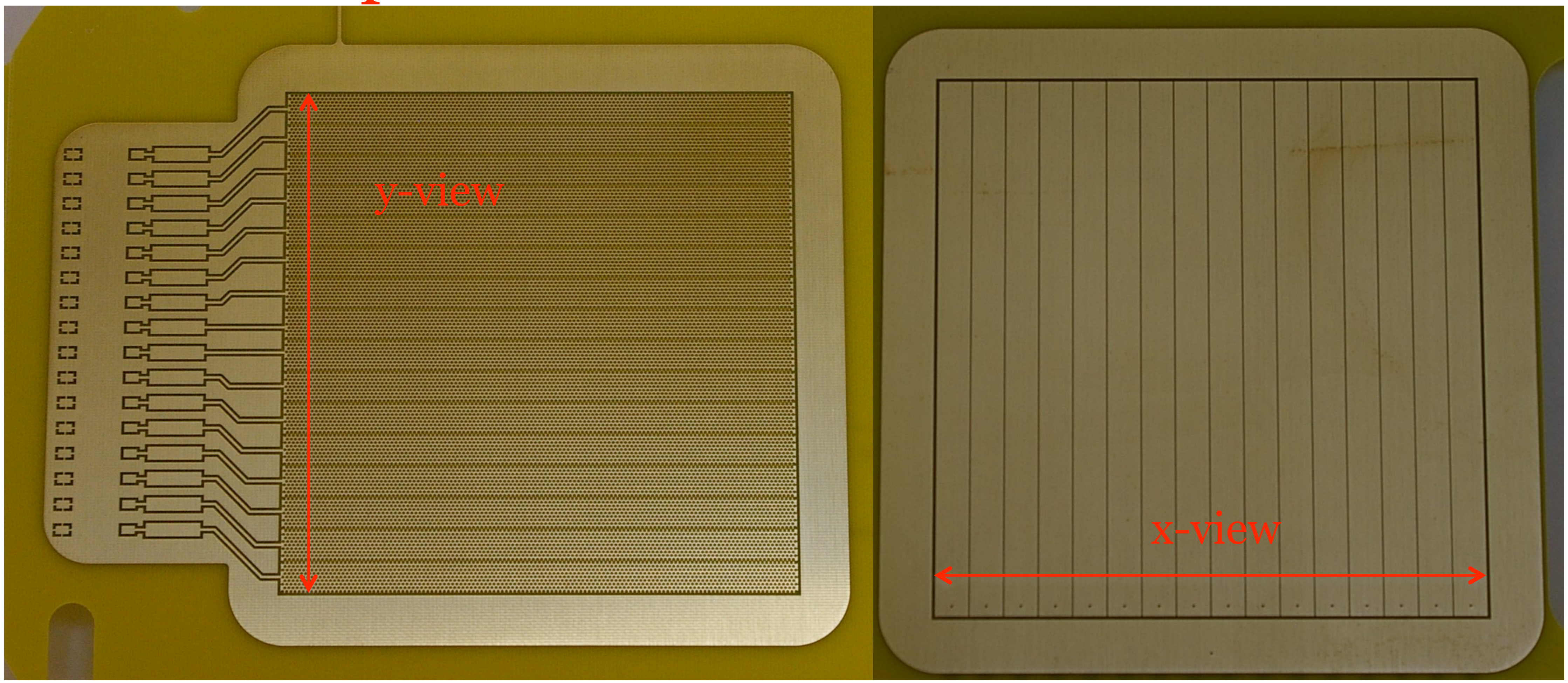


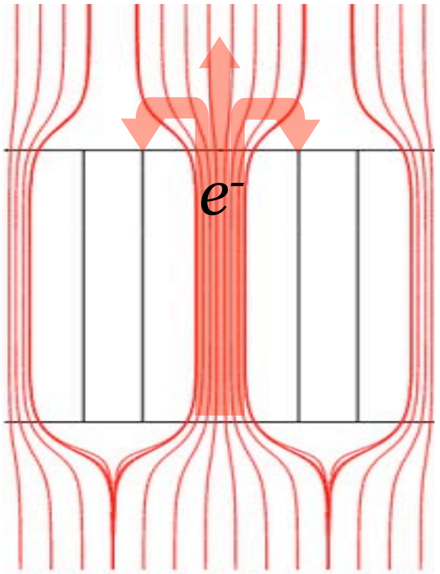
LEM: charge readout

After the amplification the electrons induce signals on segmented electrodes. Two views and drift time allow the spatial reconstruction.

Top LEM and anode segmented: 2x16 strips, 6 mm pitch

Top LEM Anode

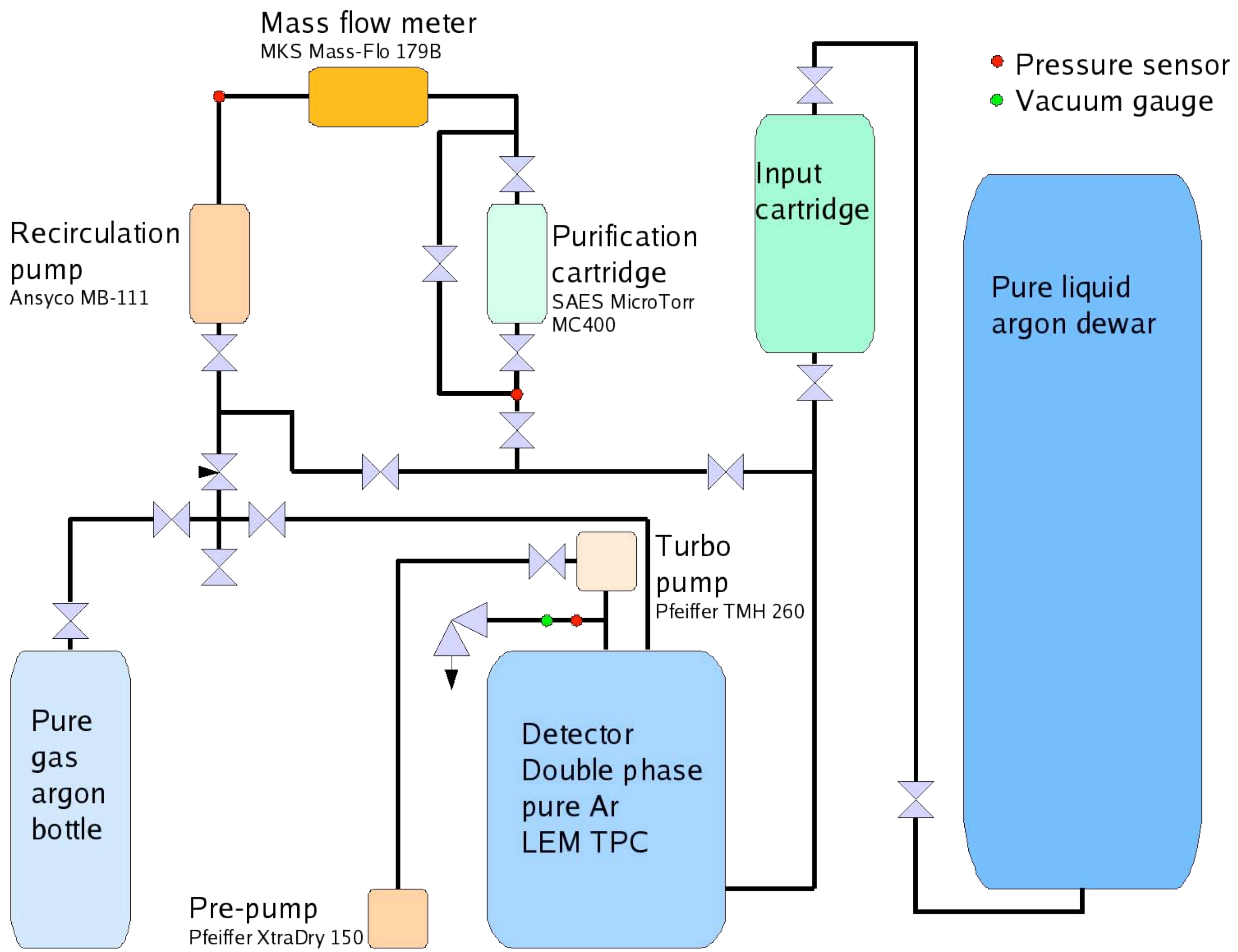




Ideal configuration:
50% collected on the top LEM
50% collected on the anode

LAr purification system

To drift 20 cm @ 1kV/cm the impurities have to be ~2ppb (O_2 eq). LAr purification is needed.



Input purification:

- A custom made cartridge purifies LAr at the detector input.

Recirculation:

- Heating resistors evaporate LAr in the detector.
- A metal bellows pump pushes GAr through a commercial getter (1volume in 48h).
- The pure GAr condensates in the detector volume.

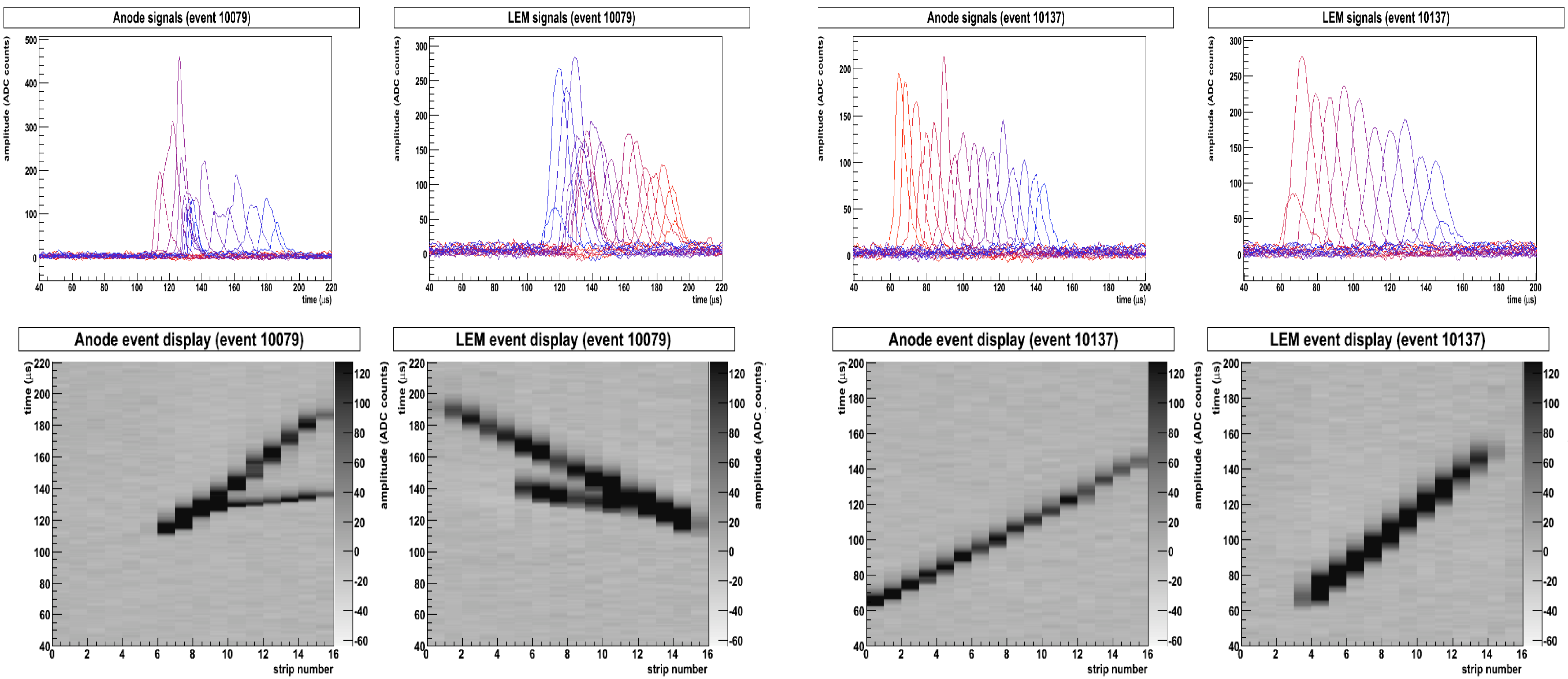
LEM-TPC: imaging device

Double phase operation (87K, 1 bar)

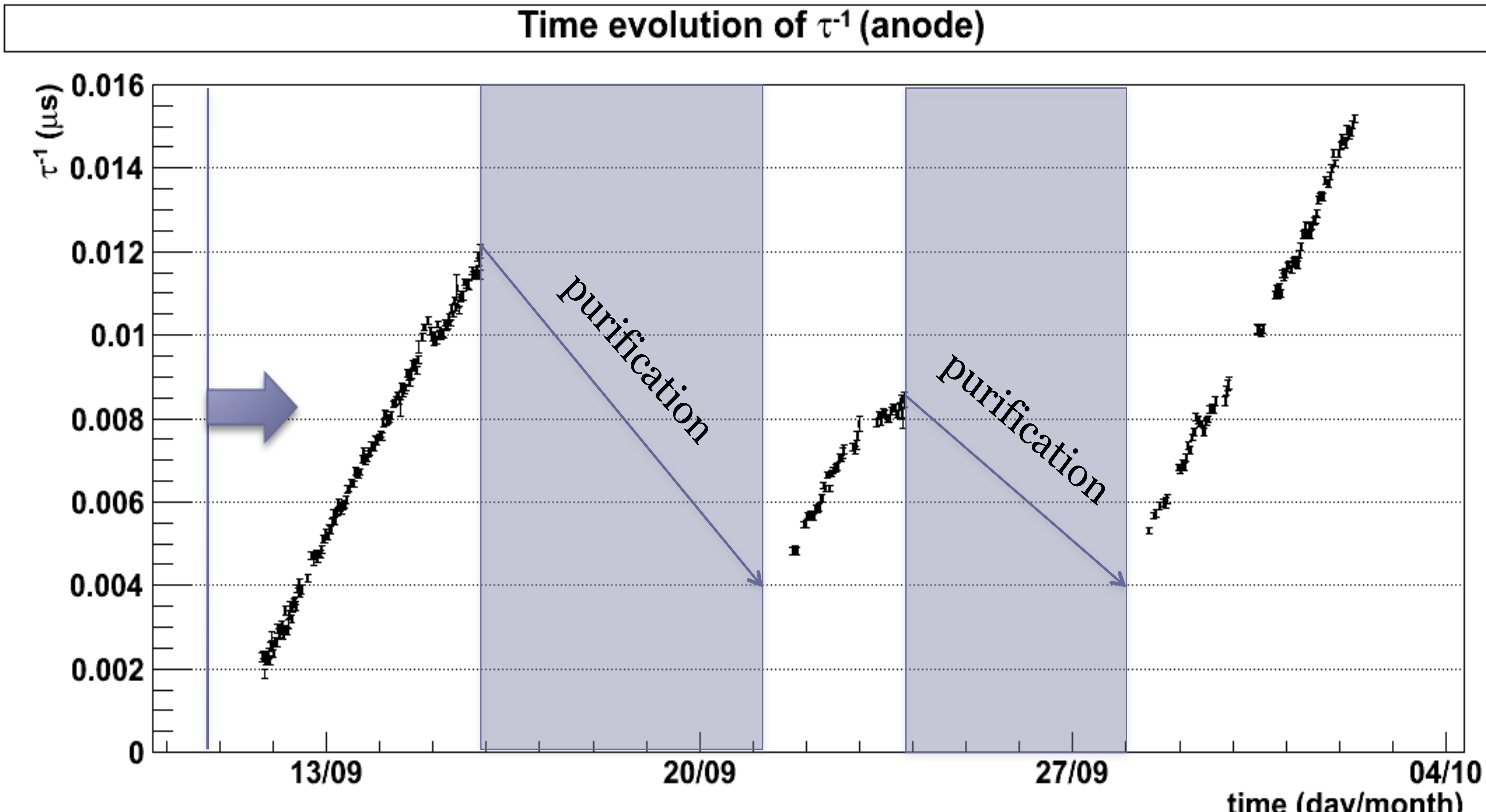
Gain ~ 6.5

LAr purity ~ 2ppb

Typical comic muon tracks



LAr purity



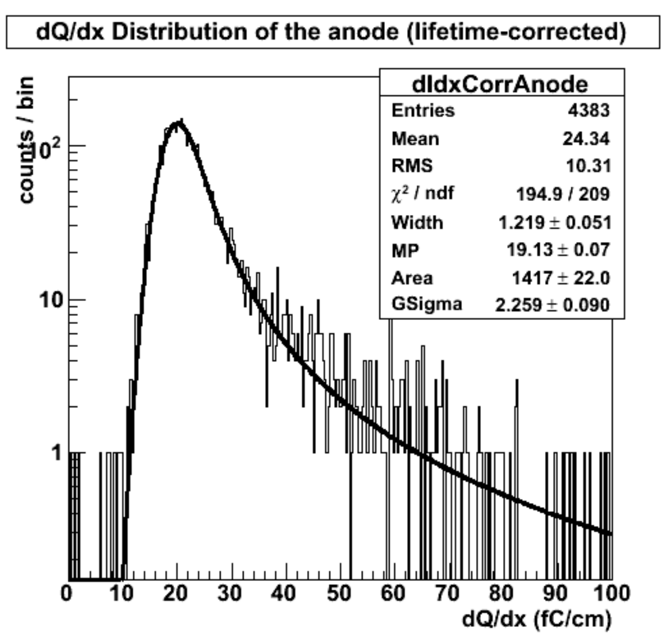
Very good purity at the beginning (<1ppb O_2 eq).
LAr purification behaves as expected.

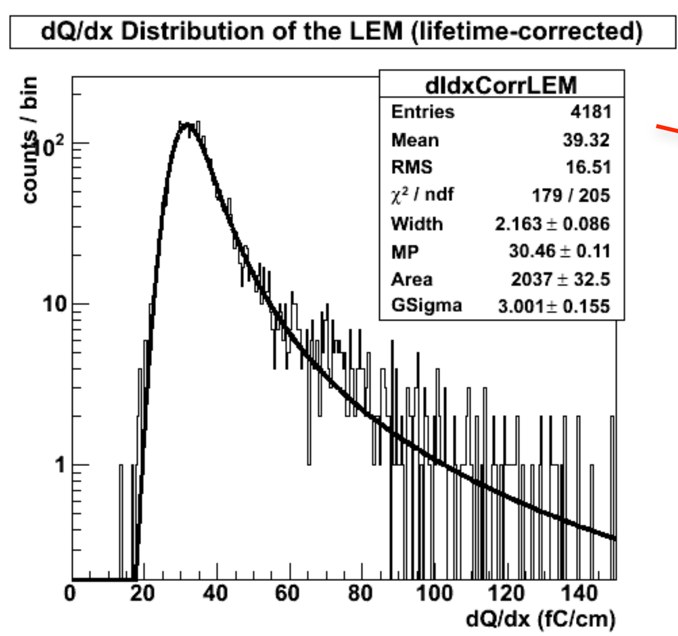
Cosmic muon data

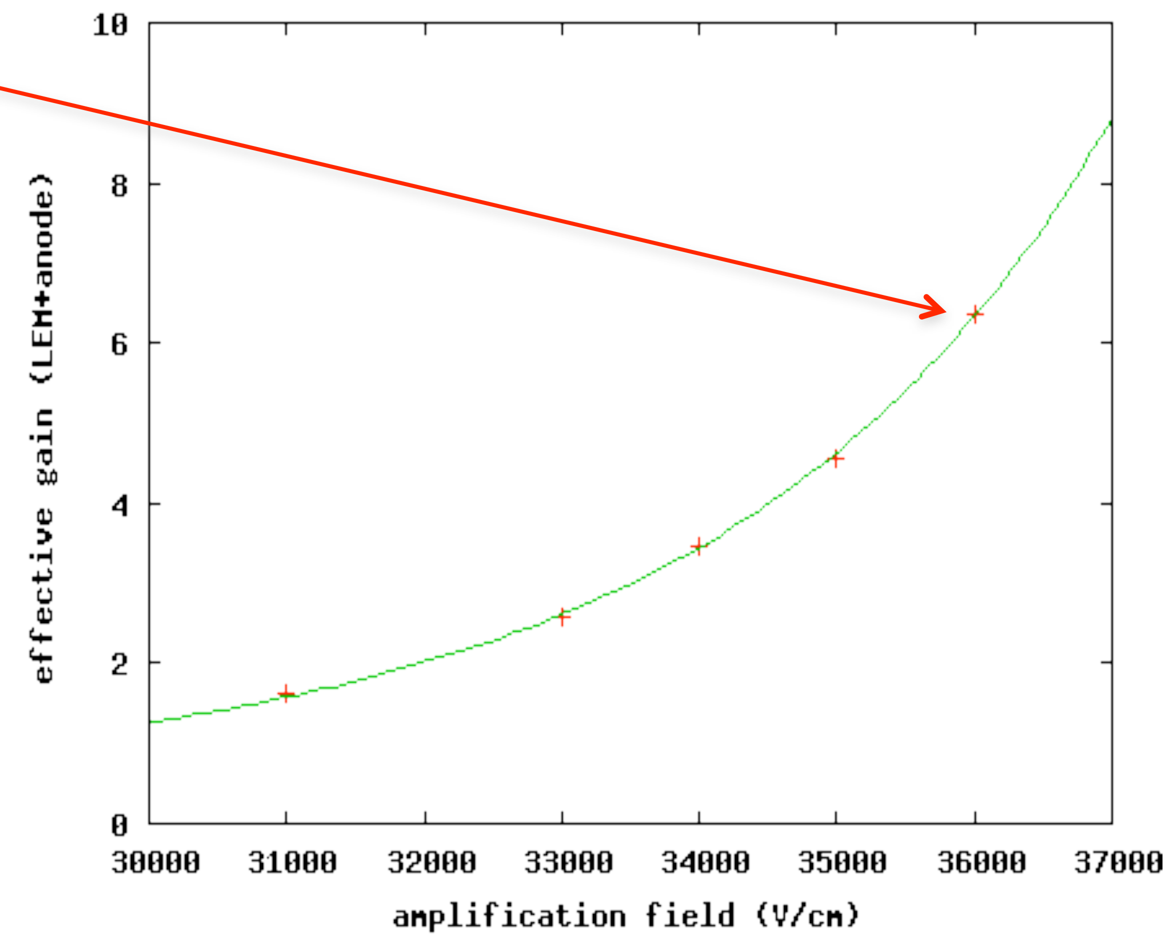
1) 3D reconstruction of the events.
2) Evaluation of the track length (dx) below each strip.
3) Evaluation of the charge (dQ) collected by each strip.

A Gauss convoluted Landau distribution is fitted to dQ/dx distribution of long muon tracks

- In LAr a MIP releases ~2.1MeV/cm.
- dQ/dx (@500V/cm) ~10fC/cm

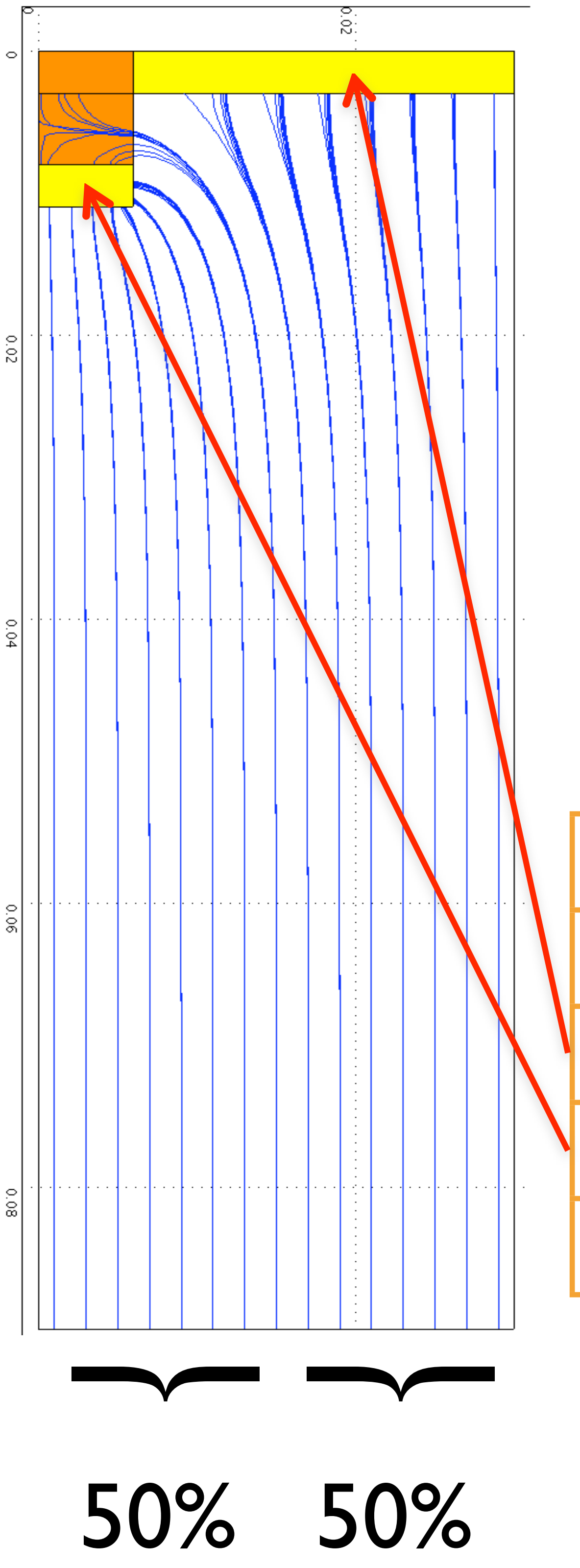


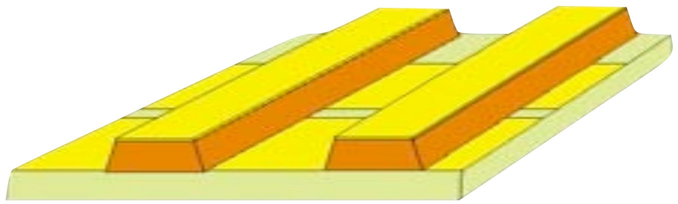




- Energy resolution ~12%
- Gain ~6.5
- S/N (mip) ~60

Two views anode (I)





Compass Experiment

Readout pitch	3mm
Strip pitch	600µm
Covered strip width	500µm
Exposed strip width	120µm
Kapton thickness	50µm

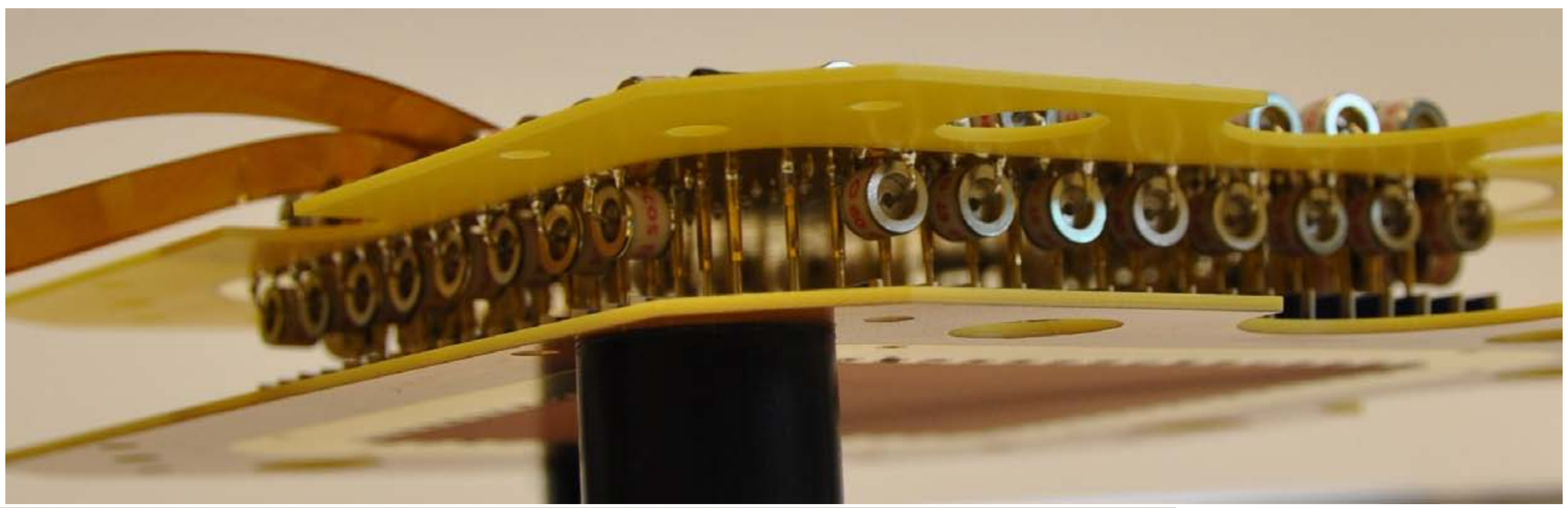
Advantages:

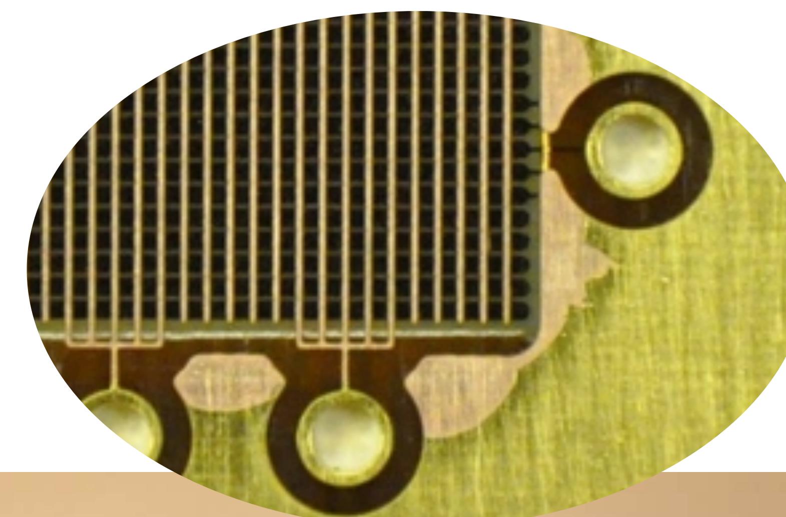
- Decouple the amplification and the readout stages.
- The charge coming from the LEM is shared between X and Y coordinates.
- No strips and capacitors on the LEMs.
- Same signal shape of both coordinates.

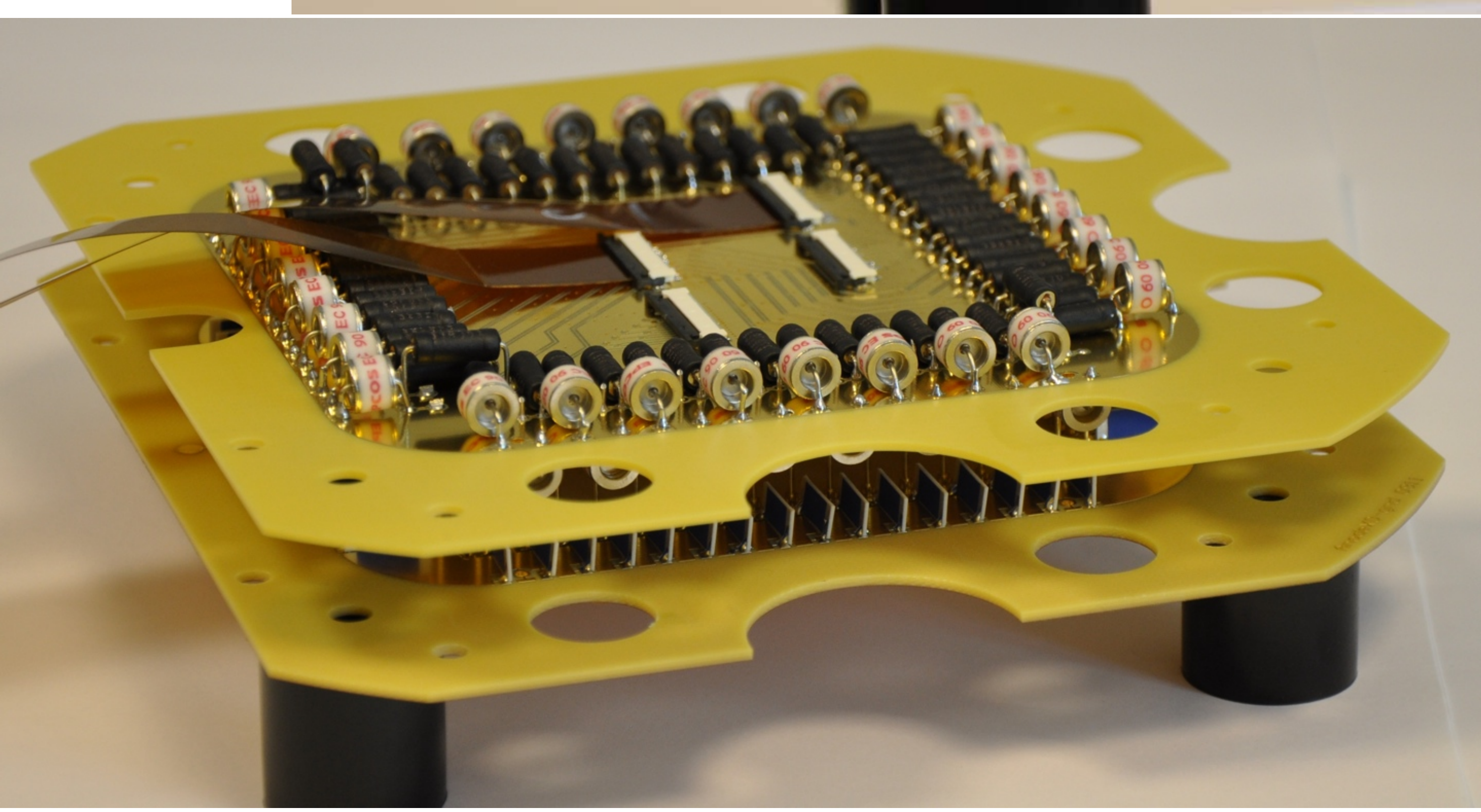
Two views anode (II)

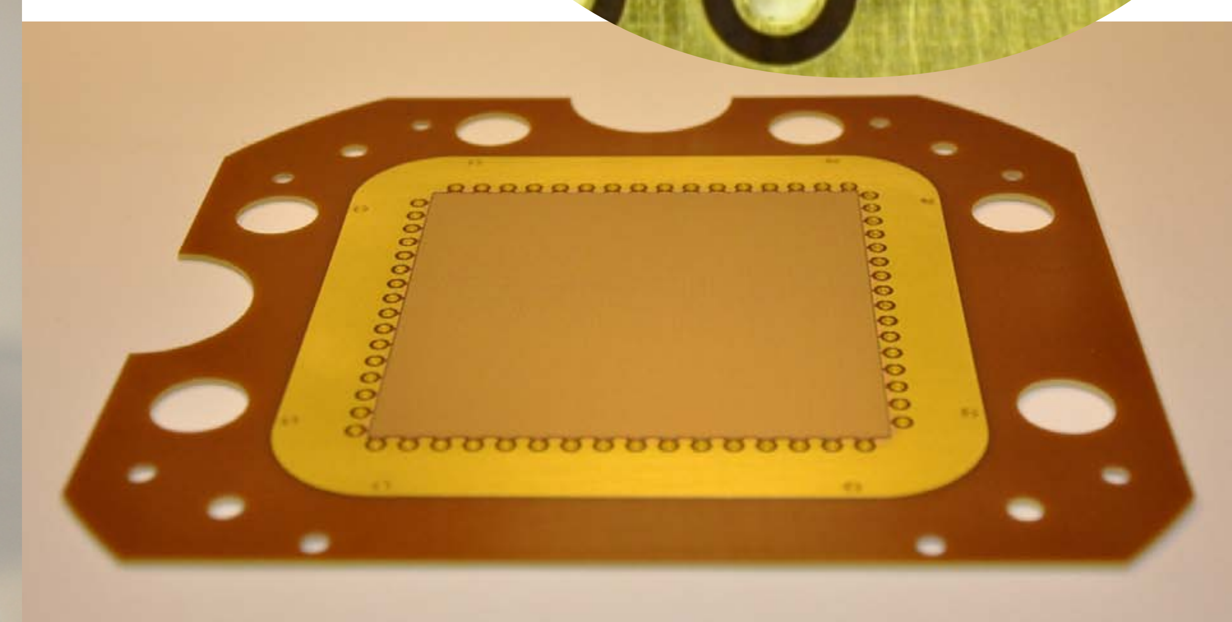
A $10x10cm^2$ prototype is already produced and soon will be tested.

Acknowledgements go to CERN PCB workshop.









Improved LEM design & manufacturing

Thanks to discussion with Rui de Oliveira the LEMs were design as an independent amplification device improving the manufacturing procedures.

Design:

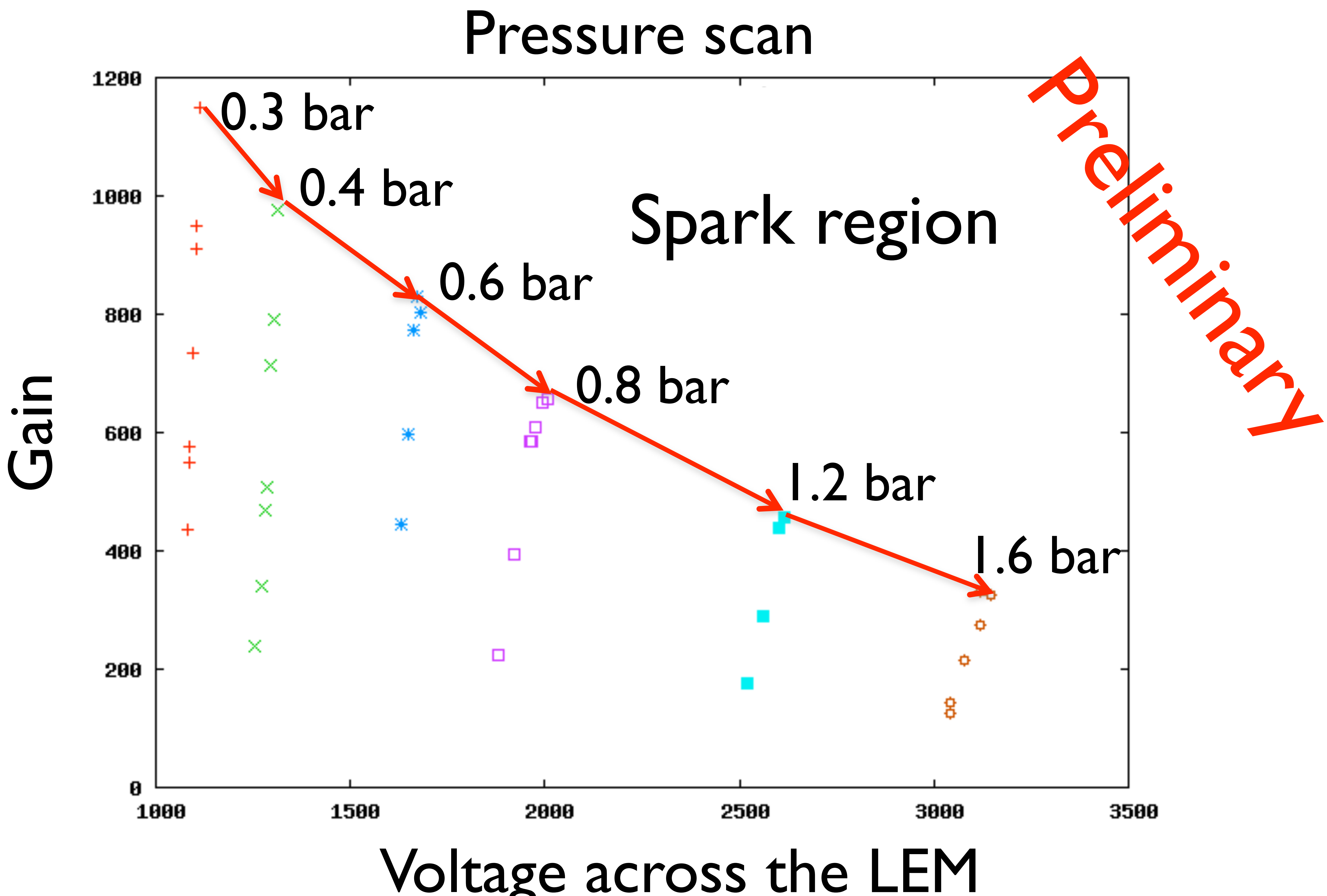
- No strips on the LEMs (smaller probability of discharge).
- Smaller rim and perfectly centered on the hole.
- Thicker electrodes (more spark resistant).

total area	10×10 cm^2
thickness	0.6, 1.0, 1.6 mm
hole diameter	500 μm
hole pitch	800 μm
rim size	10 μm

Tests:

- The LEMs had been tested in air.
- Test in pure gas argon at different pressure are ongoing.
- Important measure for the understanding of the device in pure argon gas.

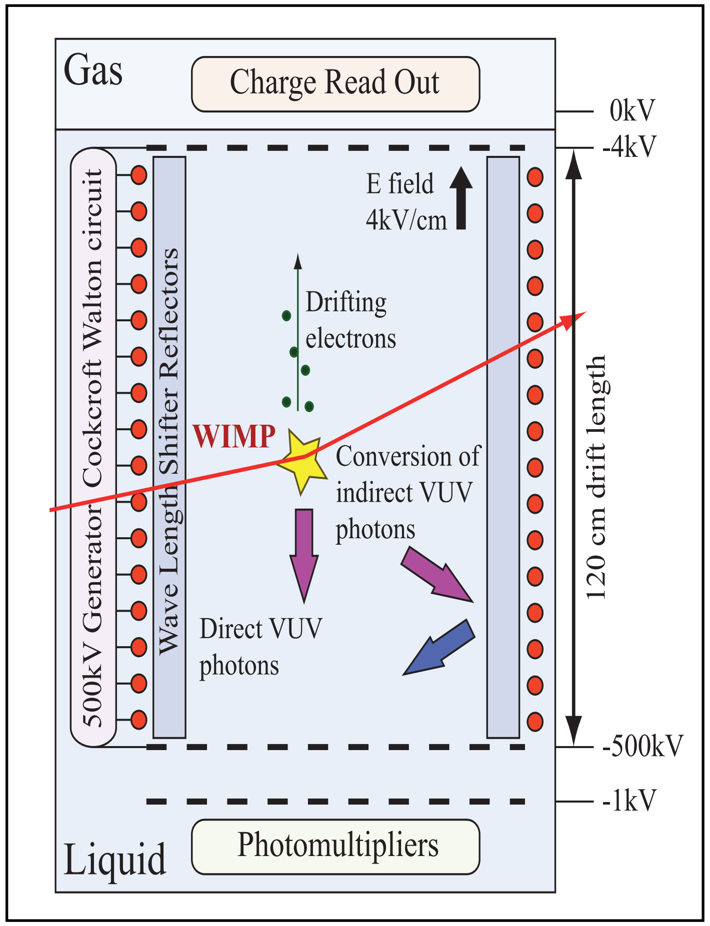
GAr test of 1.6mm LEM

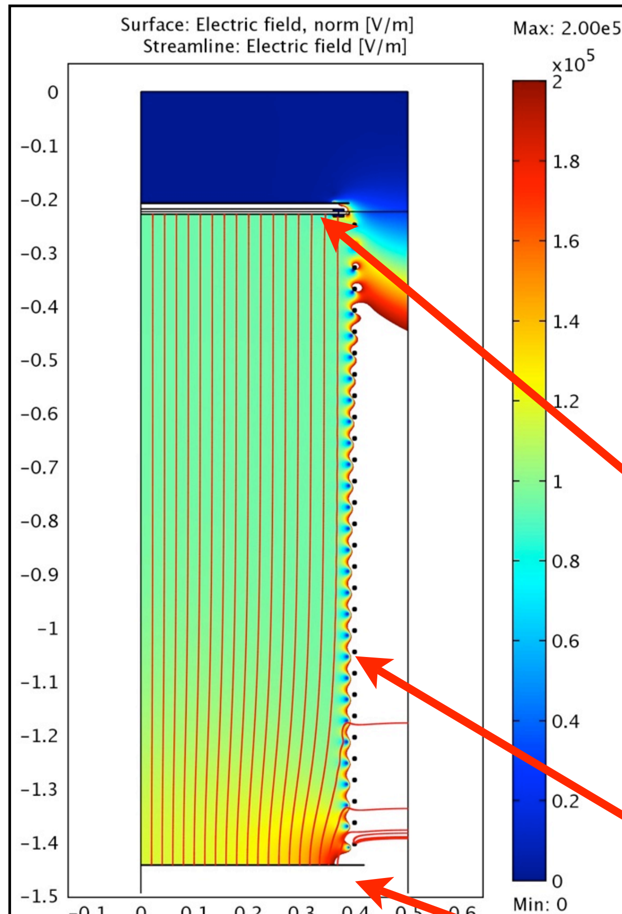


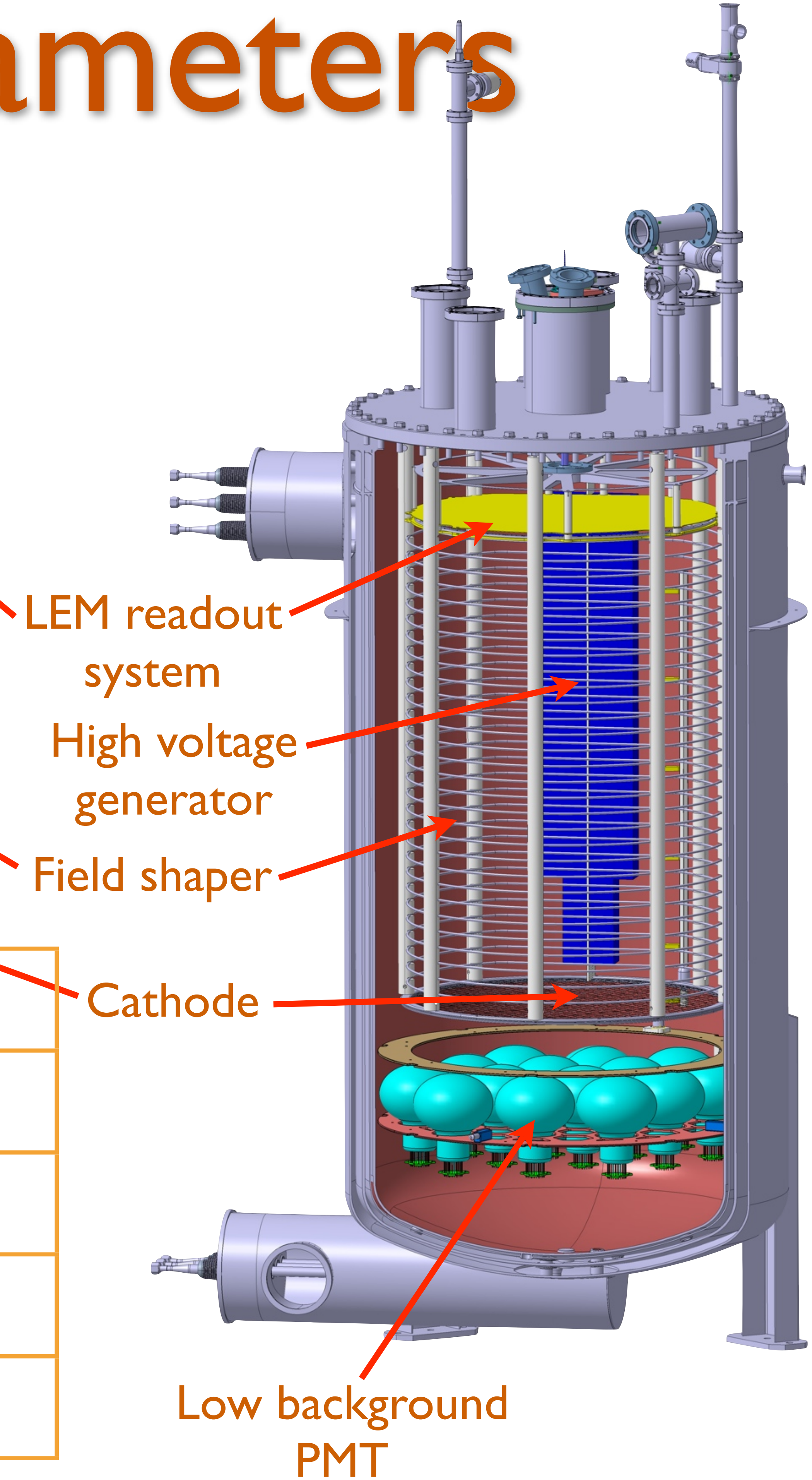
Status of ArDM experiment

- ArDM (RE18) is a ton scale dark matter search experiment, the detector is under development at CERN.
- The detector already operated (single phase LAr) on surface (blg. 182).
- Light yield measurements were performed irradiating the detector with different radioactive sources.
- A new run (double phase conditions) with a temporary charge readout system is planned for middle of April.
- The aim is to build a LEM readout system for ArDM detector.

Design parameters

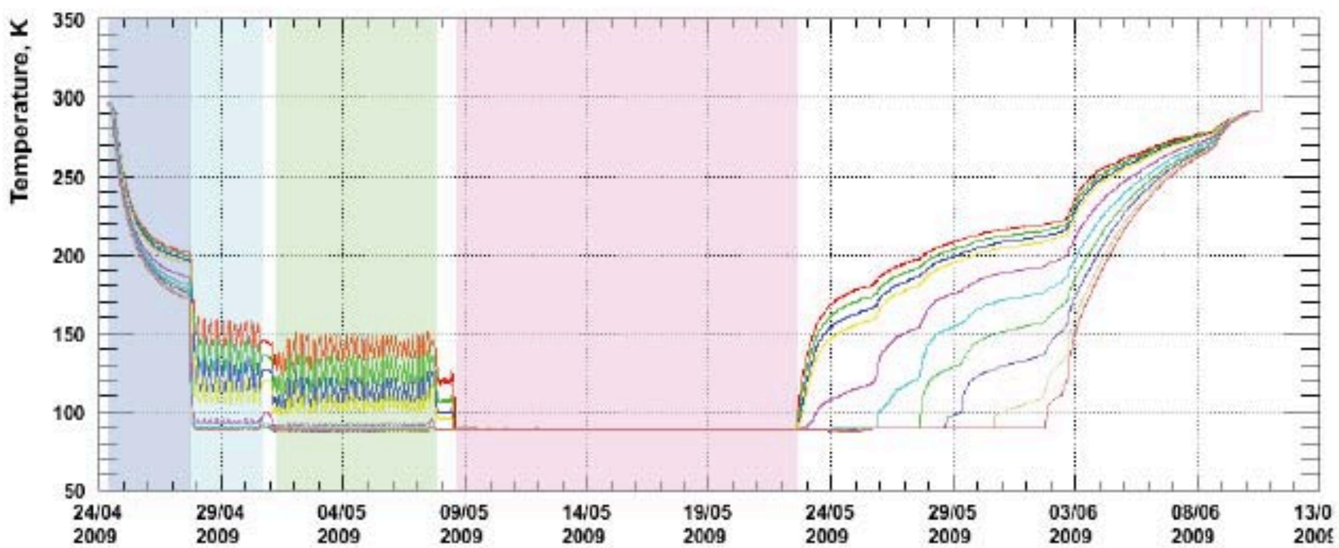






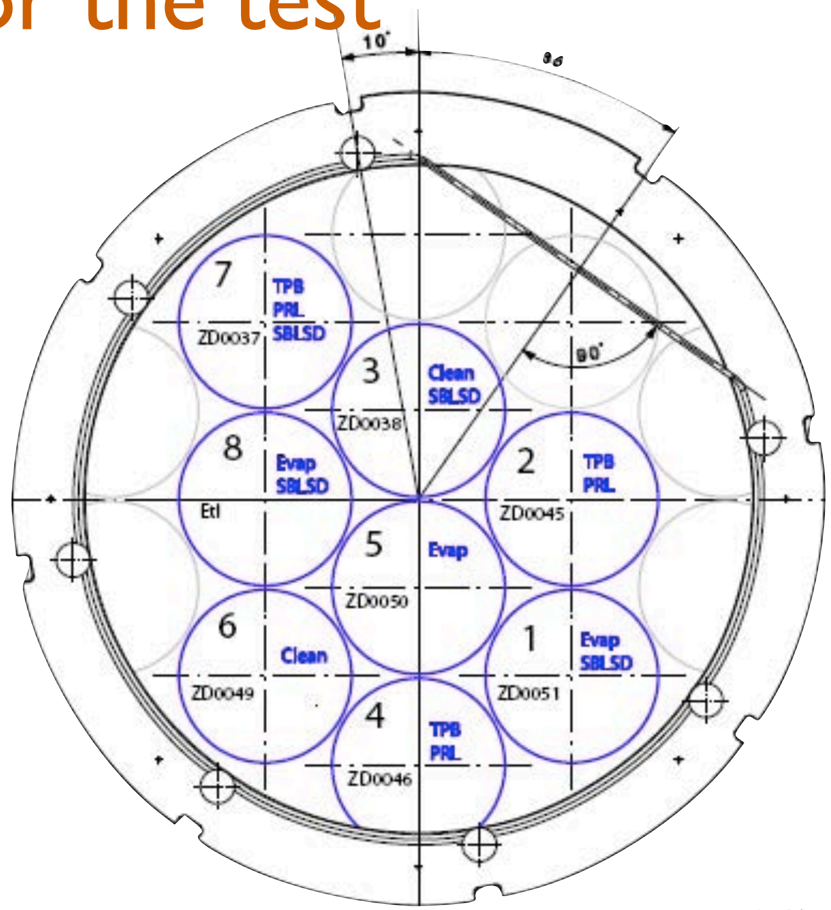
Drift length	120cm
Diameter	80cm
Target mass	850kg
Drift field	1-4km
Recirculation speed	~100l/h

2009 cool down test



1) Cool down. Detector under vacuum.
2) Measurements in cold pure argon gas.
3) Detector half filled with LAr - Measurements.
4) Detector fully filled with LAr - Measurements.
5) Warm-up phase.

8 PMT were installed for the test

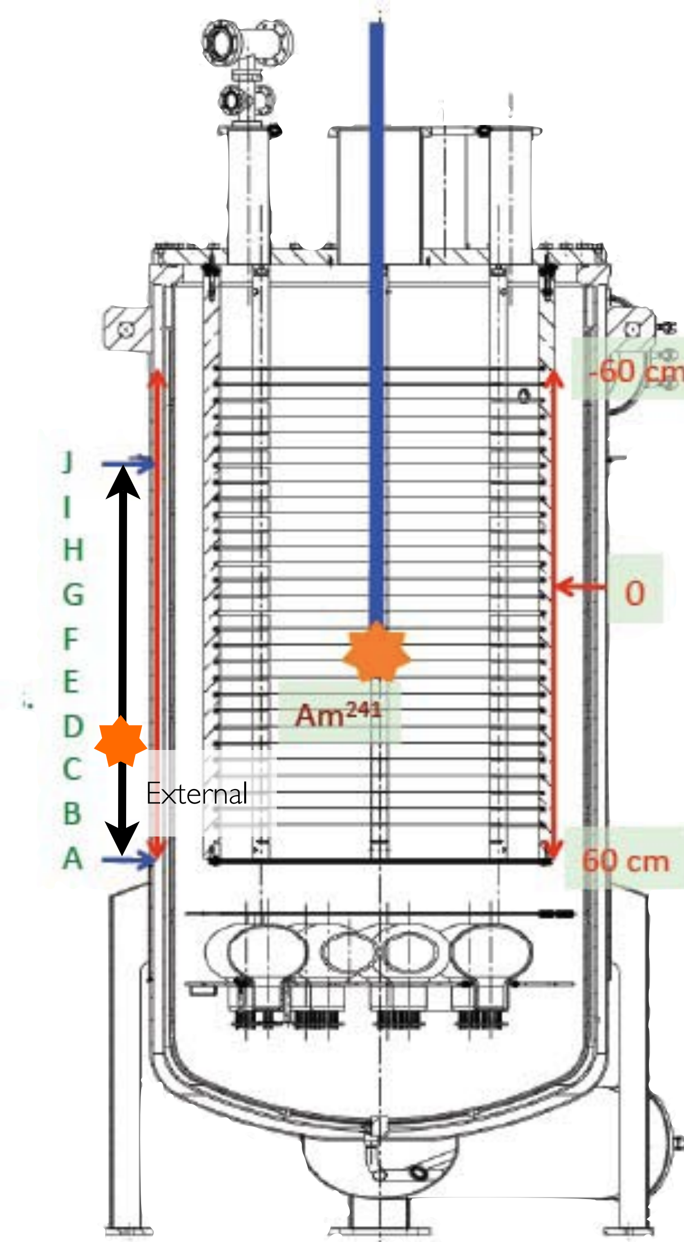


Internal sources:

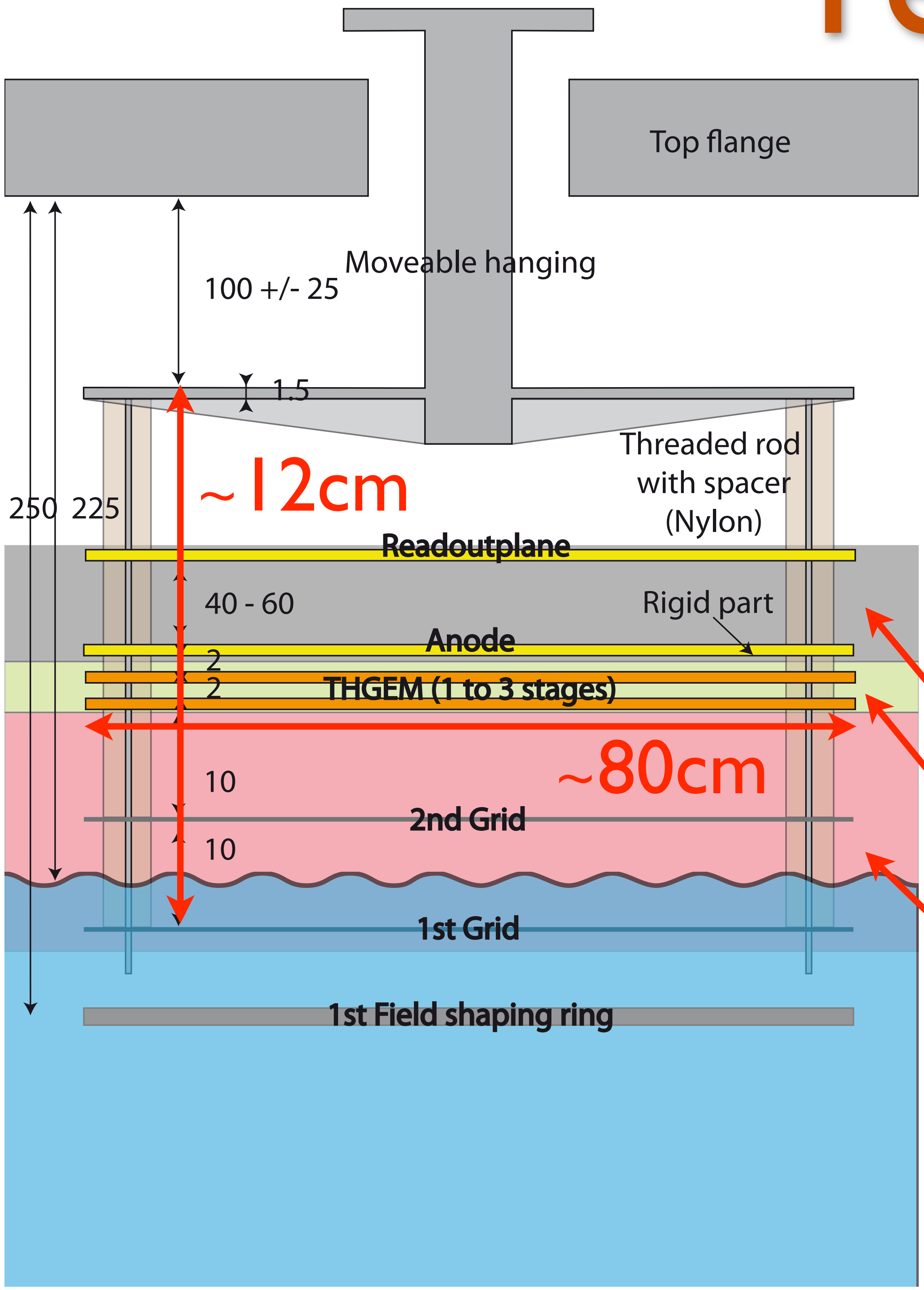
- Movable ^{241}Am (40kBq, α γ).

External sources:

- ^{22}Na (20kBq, γ).
- ^{137}Cs (190kBq, γ).
- Am-Be (n γ).



Upgrade of ArDM charge readout



The system has to be modular (sandwich approach).

The holder and the movable hanging already exists.
The mechanical reference will be the anode.

Independent layer:

1. Anode and signal routing PCB.
2. LEM stage(s).
3. Extraction grids.

Conclusions & outlooks

- Operated a double phase pure argon LEM-TPC.
  - Detector properties well understood and reproducible.
  - Very stable conditions achieved.
- Test in double phase condition the new LEMs and the two views anode.
- Design and produce the charge readout system for ArDM.
  - Final LEM geometry to be decided.
  - Engineering problems have to be solved (rigidity of the system, spacers needed, wiring, ...).
  - The aim is to produced ∅80cm LEM in one piece
($60x60 cm^2$ LEMs have been already produced).
  - Discuss the possibility of assembling the two views anode with different smaller pieces.

ArDM charge readout

- The following considerations are extrapolated from the result of the 3l setup.
- Considering S/N = 10 @ 10keV$_{ee}$ → G ~300 is required.
- Surface operation goals:
  - Study the behaviour of the LEM readout system.
  - Perform the characterization with cosmic muons.
- Shallow depth operation goals:
  - Increase the gain up to design operation.
  - Study the intrinsic background.
  - Learn how to deal with high rate and pileup.

ArDM Operation

- Surface operation:
  - ~200Hz of cosmic muons crossing the detector (~2MeV/cm).
  - To avoid discharges event induced the required gain is 10-50.
  - Single amplification stage is enough.
- Underground operation:
  - Muon rate is reduced of a factor 100.
  - The required gain is 100-1000.
  - Double amplification stage is needed
    (three amplification stages are feasible only with thin LEMs).

Summary of observations

- The single 1.6mm LEM gains some hundreds.
- Good discharge hardness.
- Well defined breakdown voltage.
- The maximum gain decreases with pressure (density).
- We need to gain at higher density (87K, 1bar ~3.5x STP):
  - If the number of collision in the holes and the energy of the accelerated electrons is constant, the gain is constant too.
  - $K_{e-} \propto \Delta V/(d \cdot \rho)$, $\#_{coll} \propto d \cdot \rho$ with ρ: GAr density, d: scale factor.
  - We need to keep constant $d \cdot \rho$.
    Example:
    The gain of 1mm LEM @ 1bar is the same as the gain of 0.5mm LEM @ 2bar (ΔV constant)