ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

ETH Institute for
Particle Physics

First results from the double phase argon LEM-TPC with a projective 2D anode

A. Badertscher, A. Curioni, L. Epprecht, L. Knecht, D. Lussi,
A. Marchionni, G. Natterer, F. Resnati, A. Rubbia, T. Viant

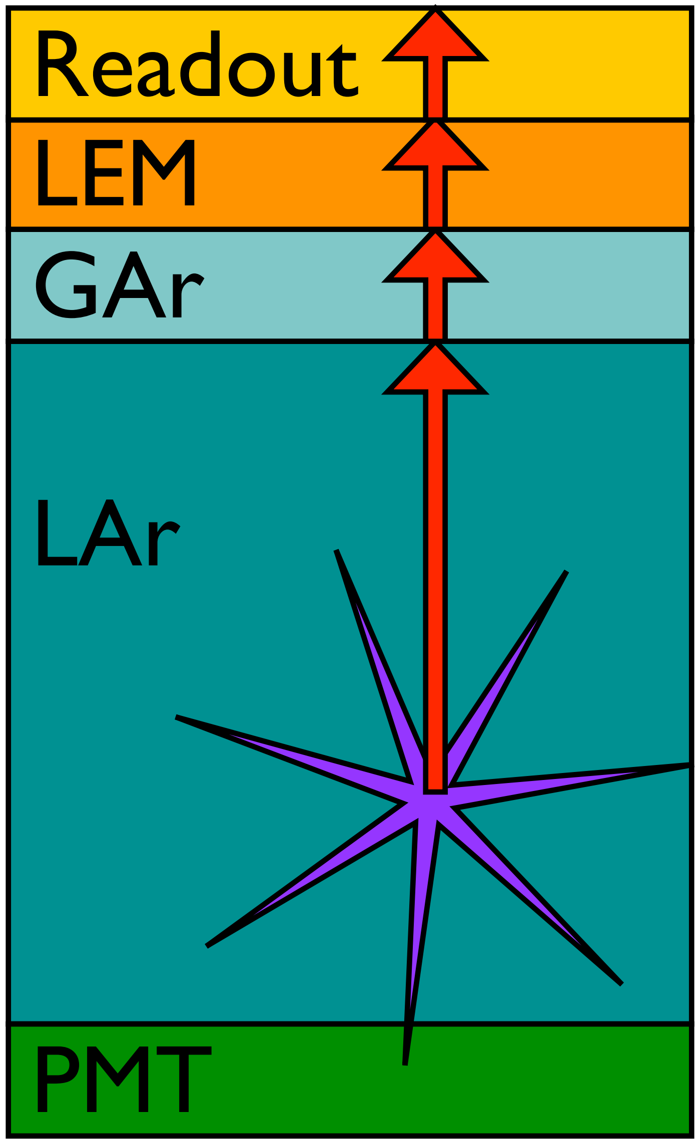
RD51 mini-week - CERN - 20 July 2010

Introduction

- A double phase pure argon LEM-TPC is a complete tracking and calorimetric detector capable of signal amplification.
- Applications:
  - Giant detector for neutrino physics and proton decay search (A. Rubbia, arXiv:hep-ph/0402110, 2003)
  - Dark matter imaging detector (A. Rubbia, J.Phys. Conf. Ser. 39 (2004) 129)
- Recent articles:
  - A. Badertscher et al., Nuclear Science Symposium Conference Record (2008) 1328-1334
  - A. Badertscher et al., Nuclear Inst. and Methods in Physics Research, A 617 (2010) 188-192

Double phase LEM-TPC

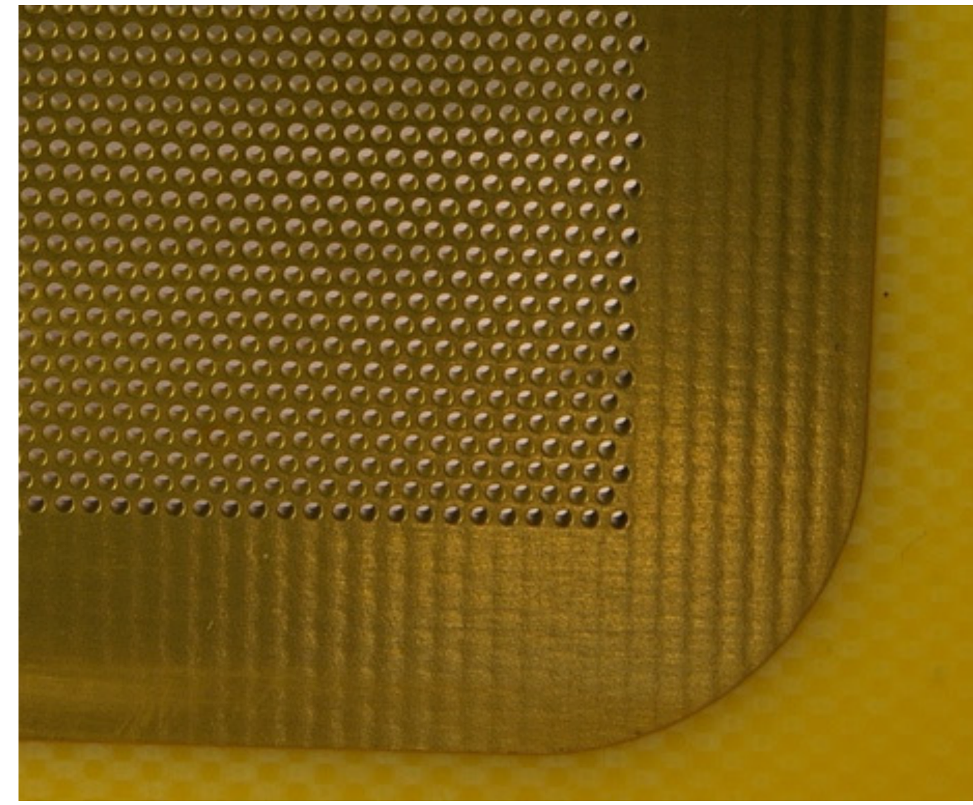
- Ion/e$^-$ pairs are produced in liquid argon by an ionizing event.
- Primary scintillation light is detected with TPB coated PMT (time reference of the event).
- Electric field drifts the electrons up to the liquid-vapor interface (500-1000 V/cm).
- e$^-$ are extracted into the vapor phase (>2500 V/cm).
- Electron avalanche is produced in GAr due to high electric field in the holes of a LEM (Large Electron Multiplier).
- Moving charge induces signals on the projective 2D anode.

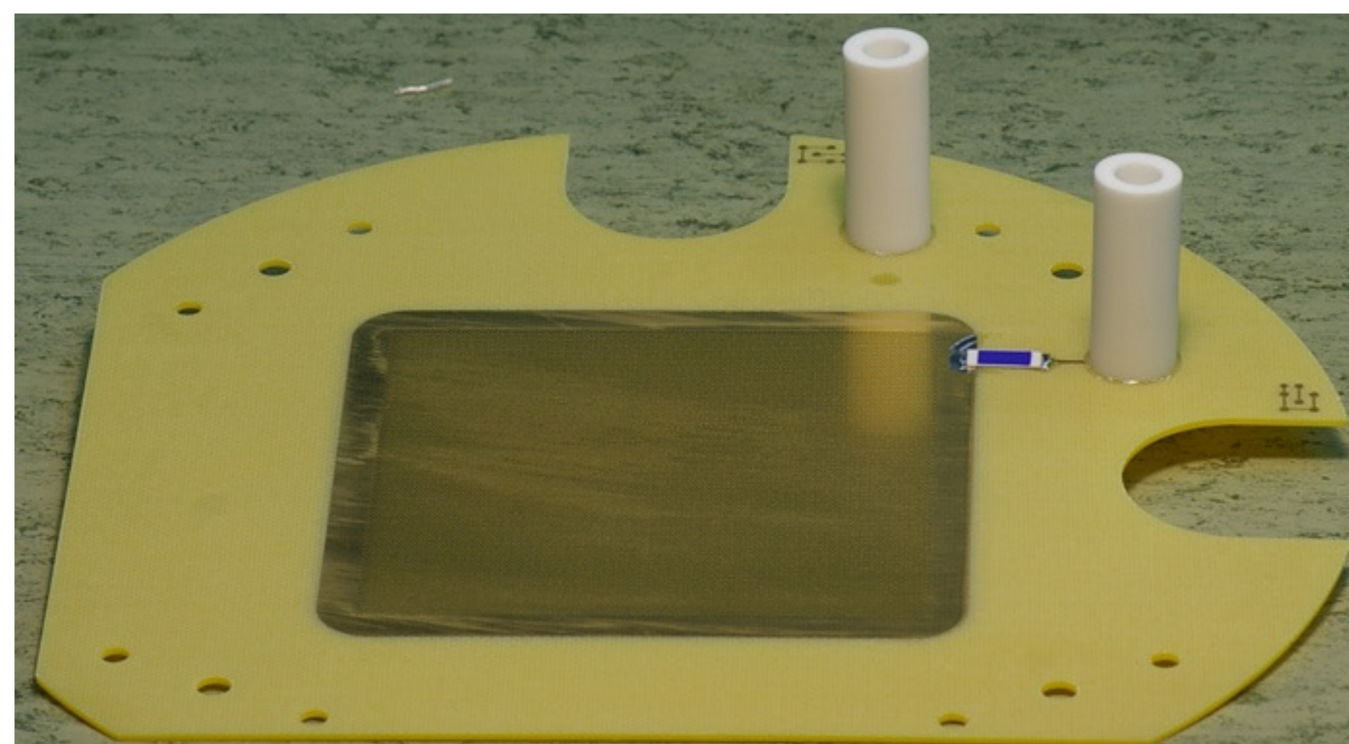


Large Electron Multiplier

- A LEM is a macroscopic gas hole multiplier (=thick GEM).
- Double-sided copper-cladded FR4 plates (1 mm thick).
- Precision holes by drilling.
- Etched dielectric rims (reduced discharge probability).
- High discharge resistivity.
- Mechanically robust.
- Possibility to cover large areas.

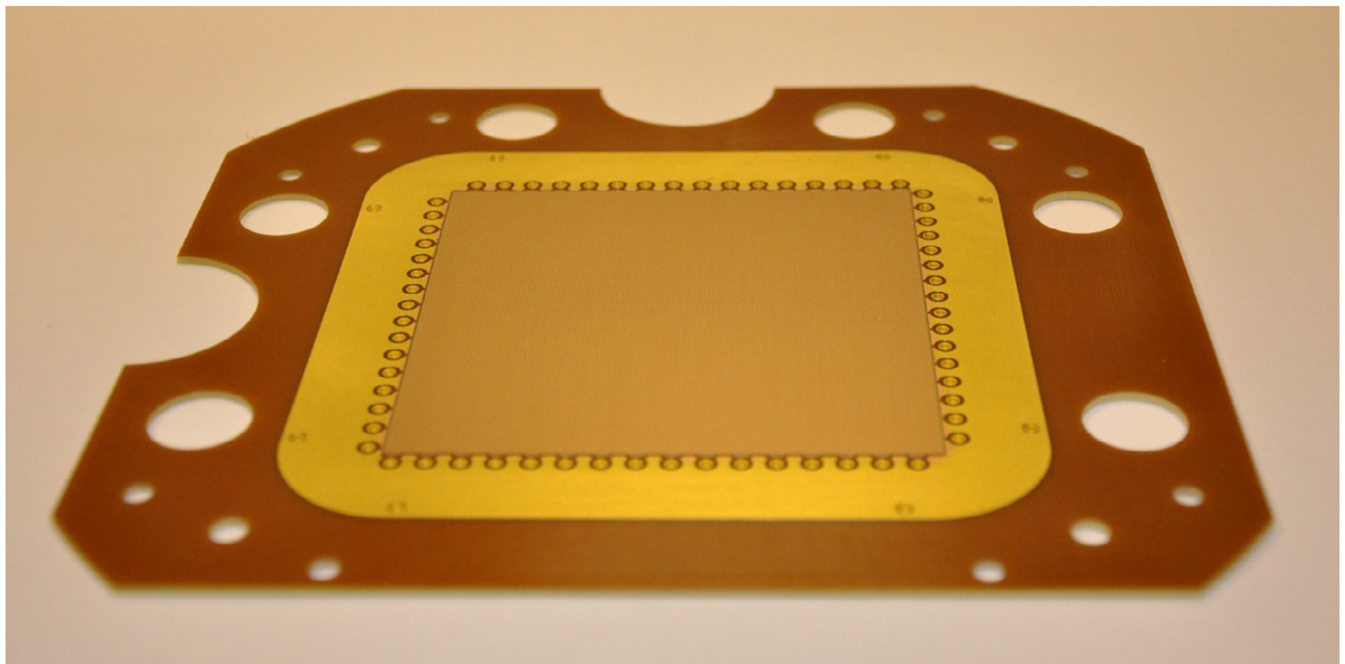
Total area	10x10 cm^2
PCB thickness	1 mm
Hole diameter	500 μm
Hole pitch	800 μm
Rim size	30-40 μm

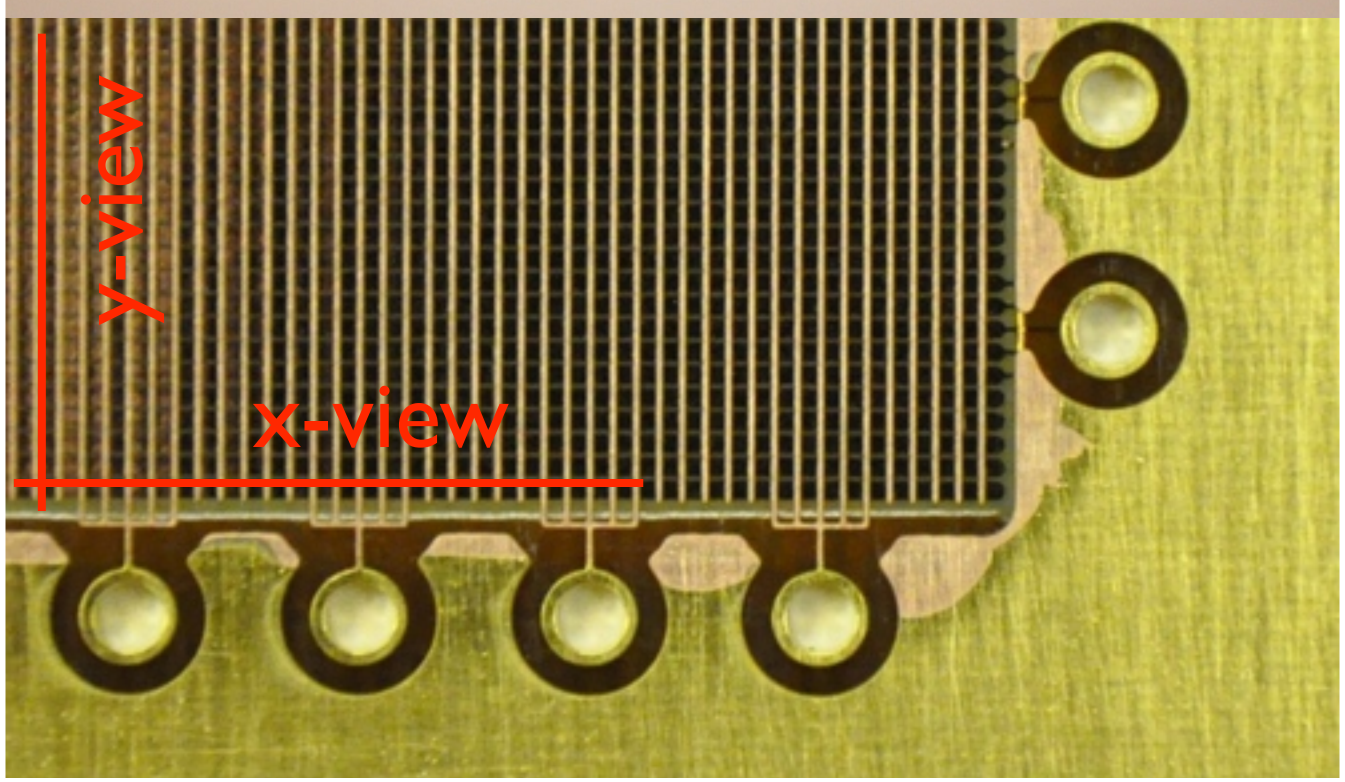




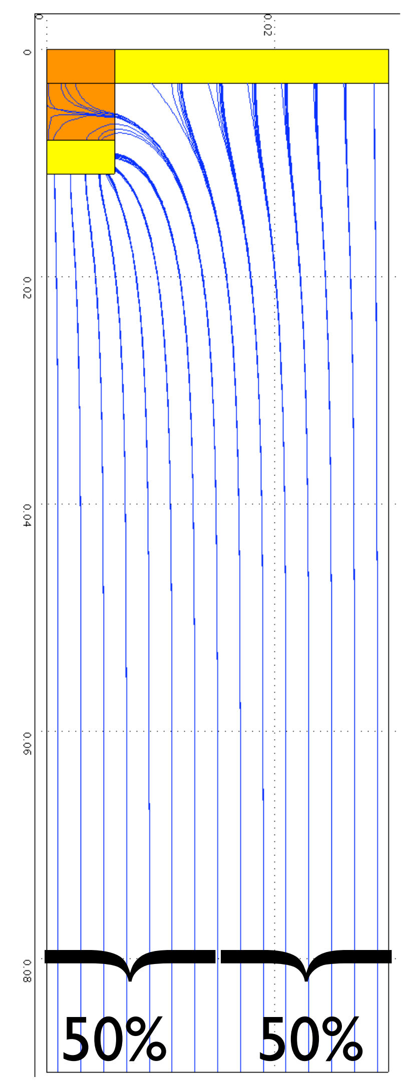
Two views anode

Acknowledgments to the
CERN-PCB workshop



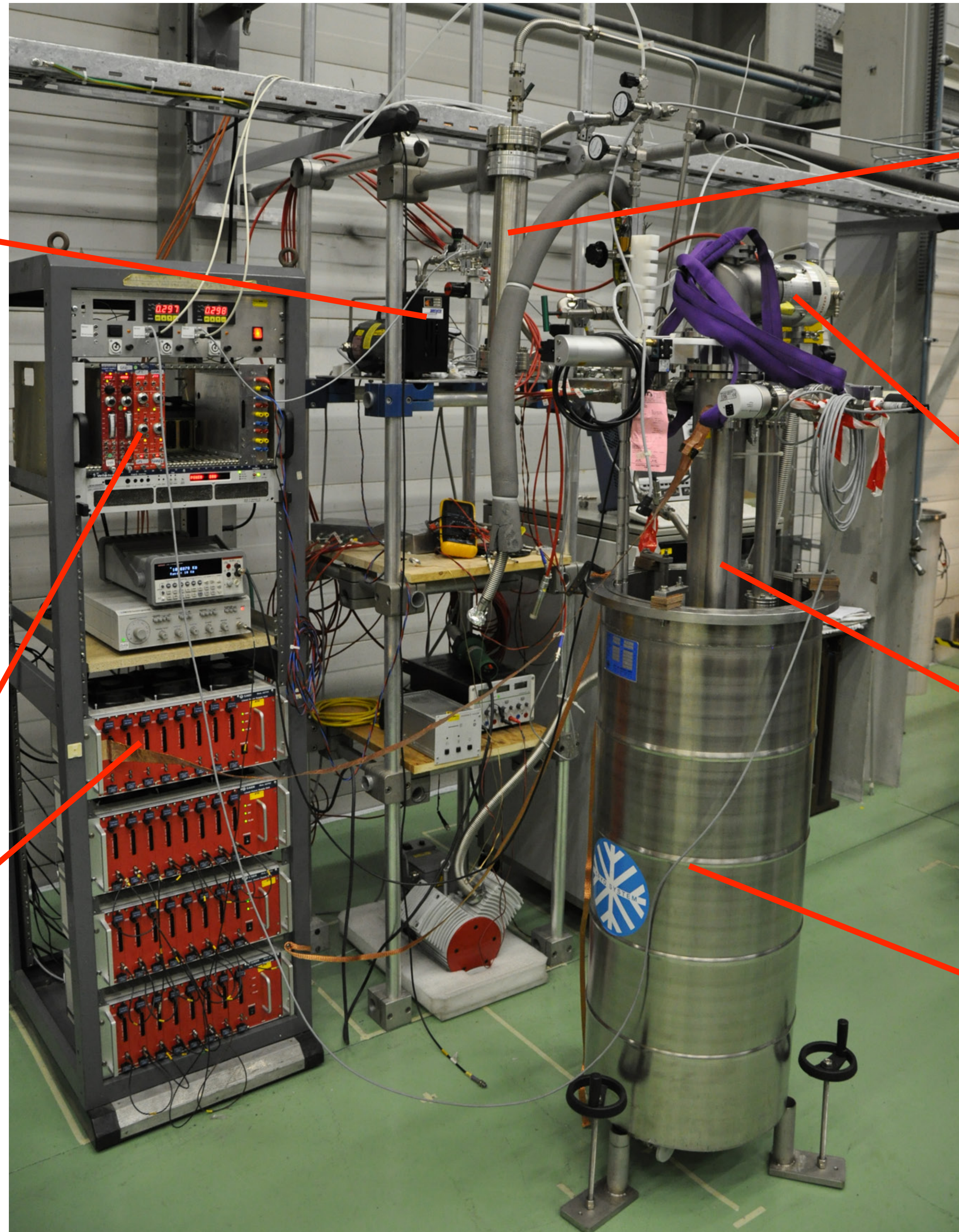


- Decouple the amplification and the readout stages.
- The charge coming from the LEM is shared between X and Y coordinates.
- No strips and capacitors on the LEMs.
- Same signal shape of both coordinates.

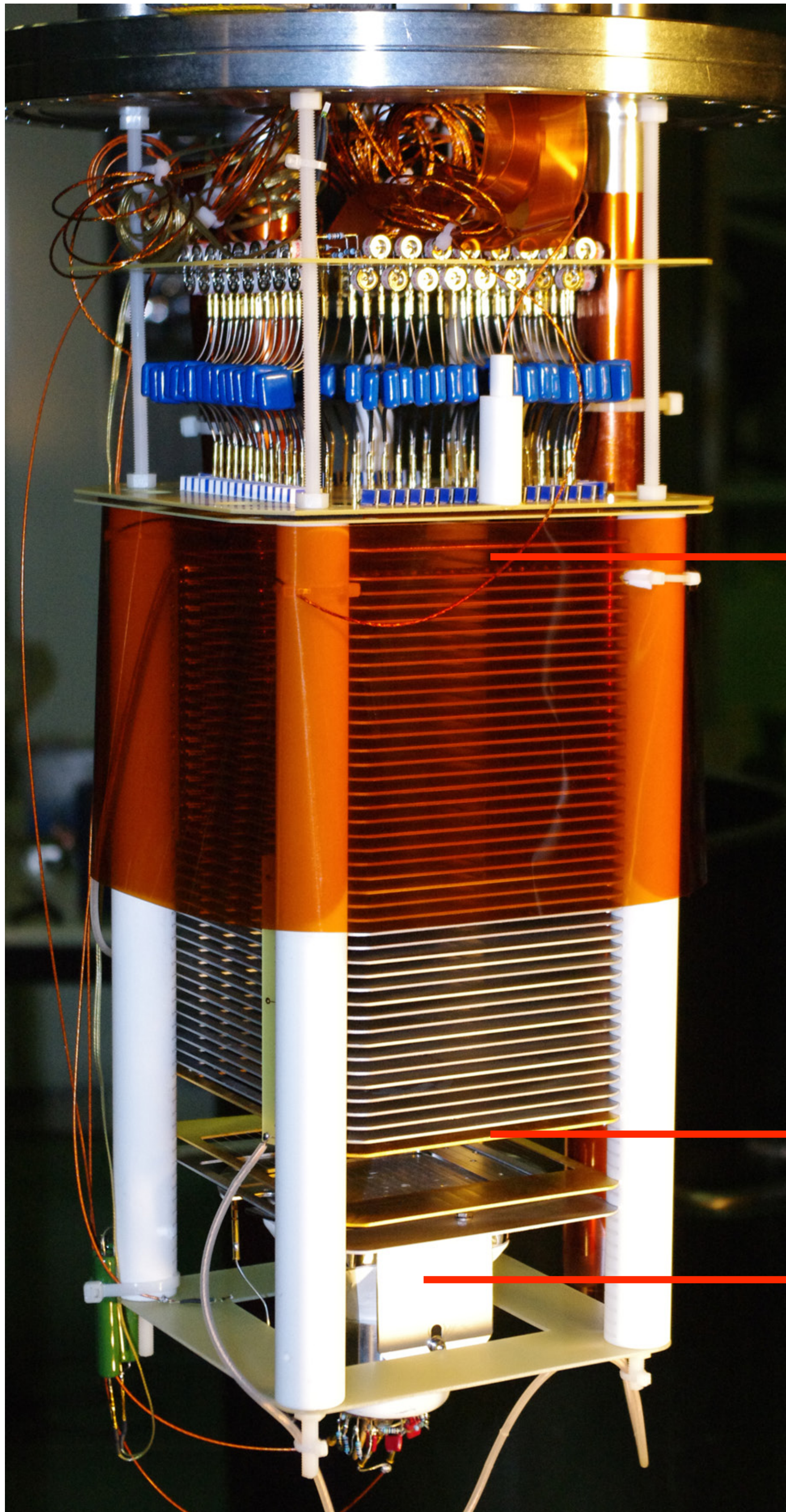


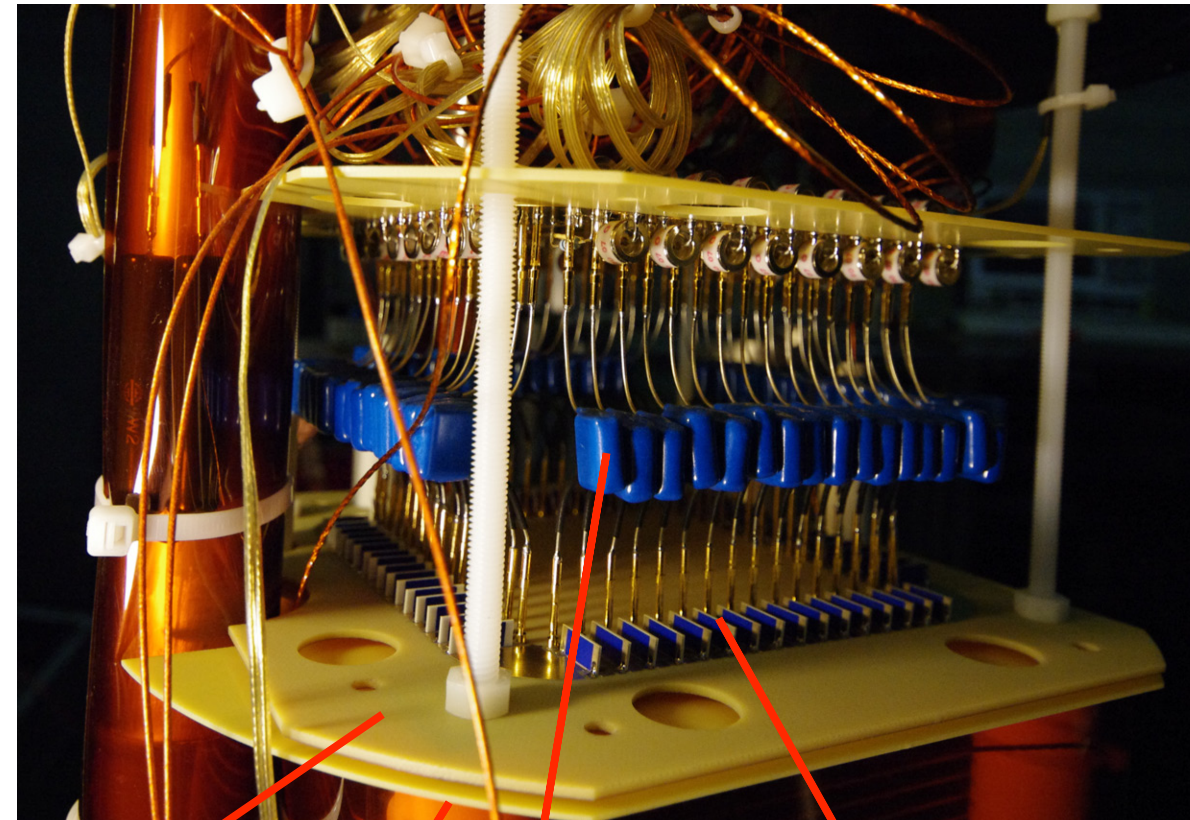
Readout pitch	3 mm
Strip pitch	600 μm
Exposed strip width	120 μm
Covered strip width	500 μm
Kapton thickness	50 μm
# strips	2x32

Setup overview



The detector





The run

- Purpose of this test:
  - First test of the projective 2D anode in cold.
  - Gain study of a single 1 mm LEM.
- Filling procedure:
  - Before filling: vacuum of 10^{-6} mbar achieved (reduction of impurities due to out-gassing).
  - Filling: liquefaction - 12 hours - of pure argon gas (impurities < 0.1 ppb after passing through a commercial getter).
- Operation:
  - The detector vessel was kept at 87 K with open LAr bath (bain-marie).
  - 8 days long run without argon purification (signal degrades due to the increment of electronegative impurities).

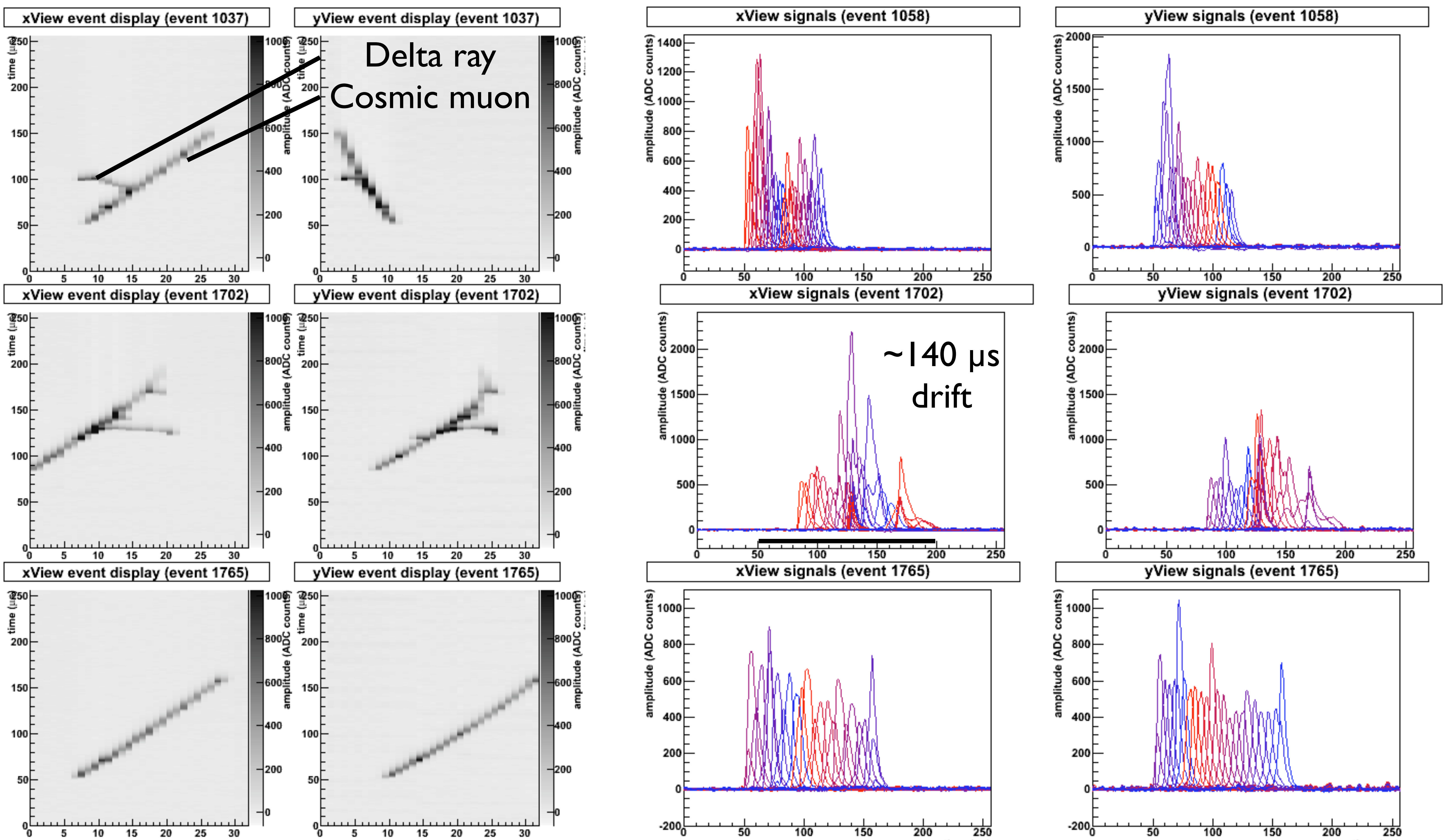
Event display

T = 87 K, P = 1 bar

LAr purity ~ 1 ppb [O_2] eq

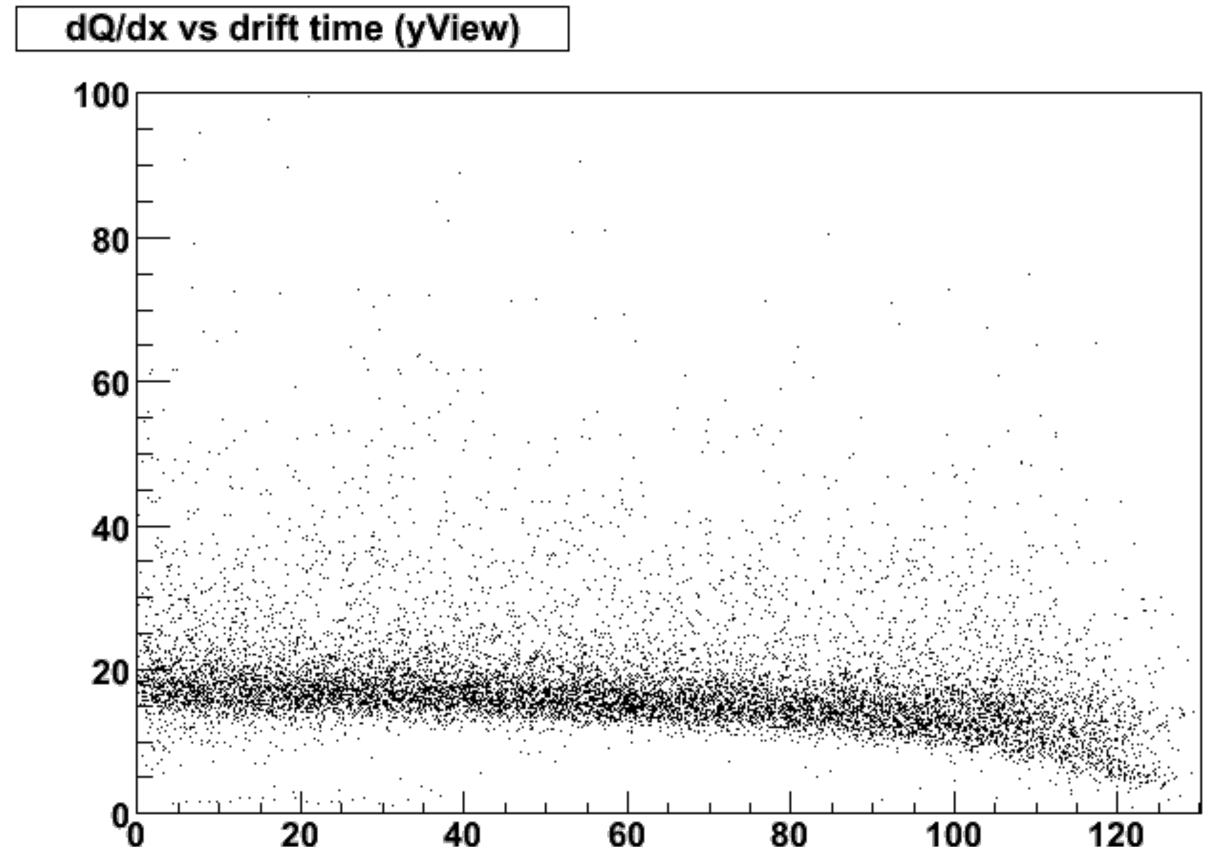
Double phase operation

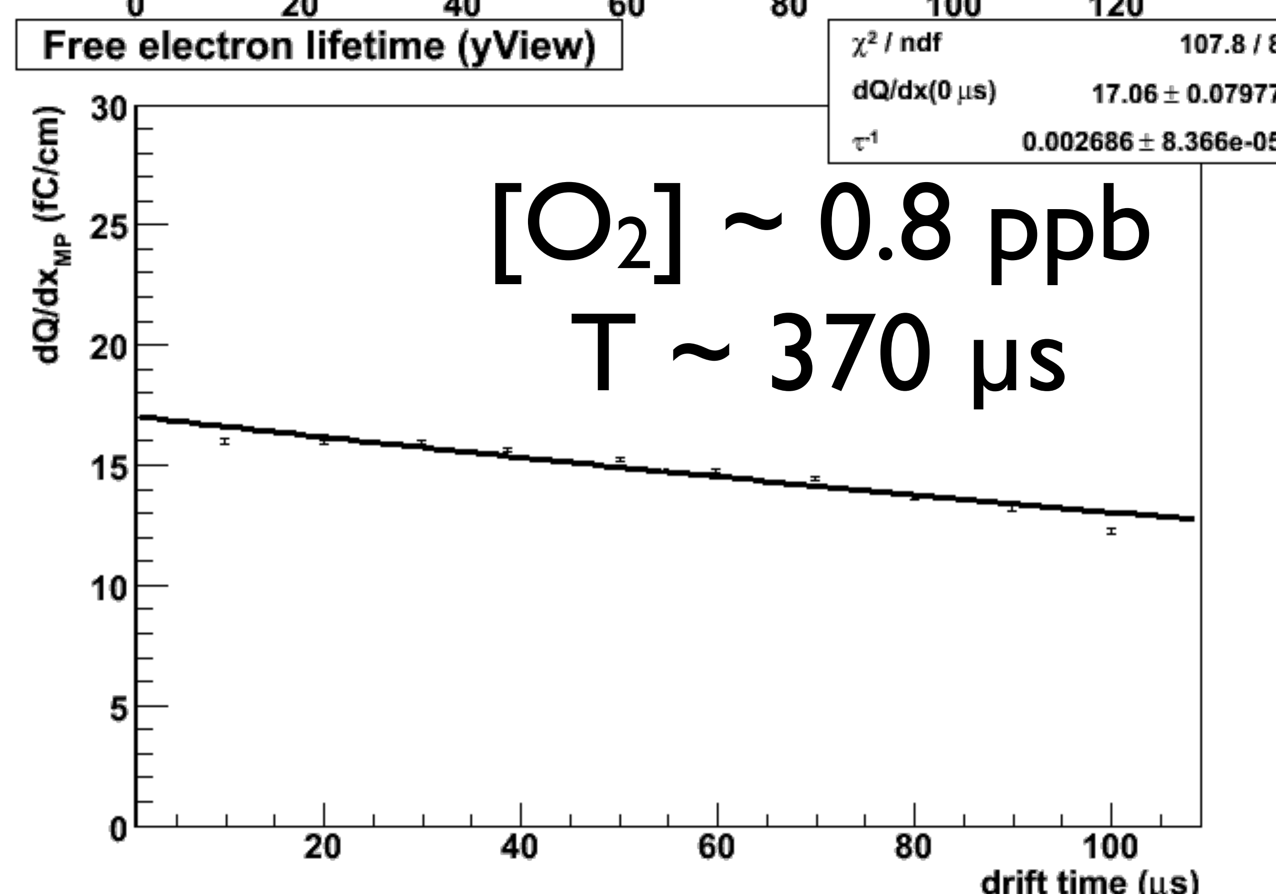
Effective gain ~ 26



3D analysis

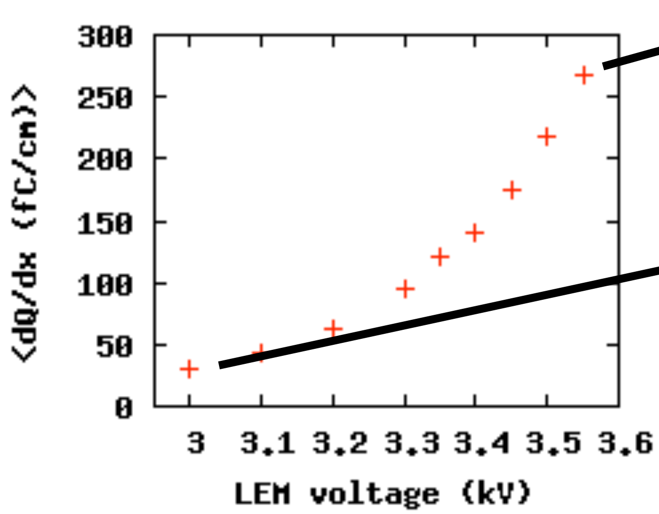
- Drifting electrons in LAr are trapped by electronegative impurities (O_2, H_2O, CO_2, ..).
- The collected charge is attenuated of a factor $e^{-t/\tau}$
  - Where t is the drift time.
  - Drifting e- lifetime: τ ~ 300 μs ppb / [O2].
- 3D reconstruction of long muons tracks -> dQ/dx.
- Evaluation of the drifting e^- lifetime and the effective gain from dQ/dx distribution.





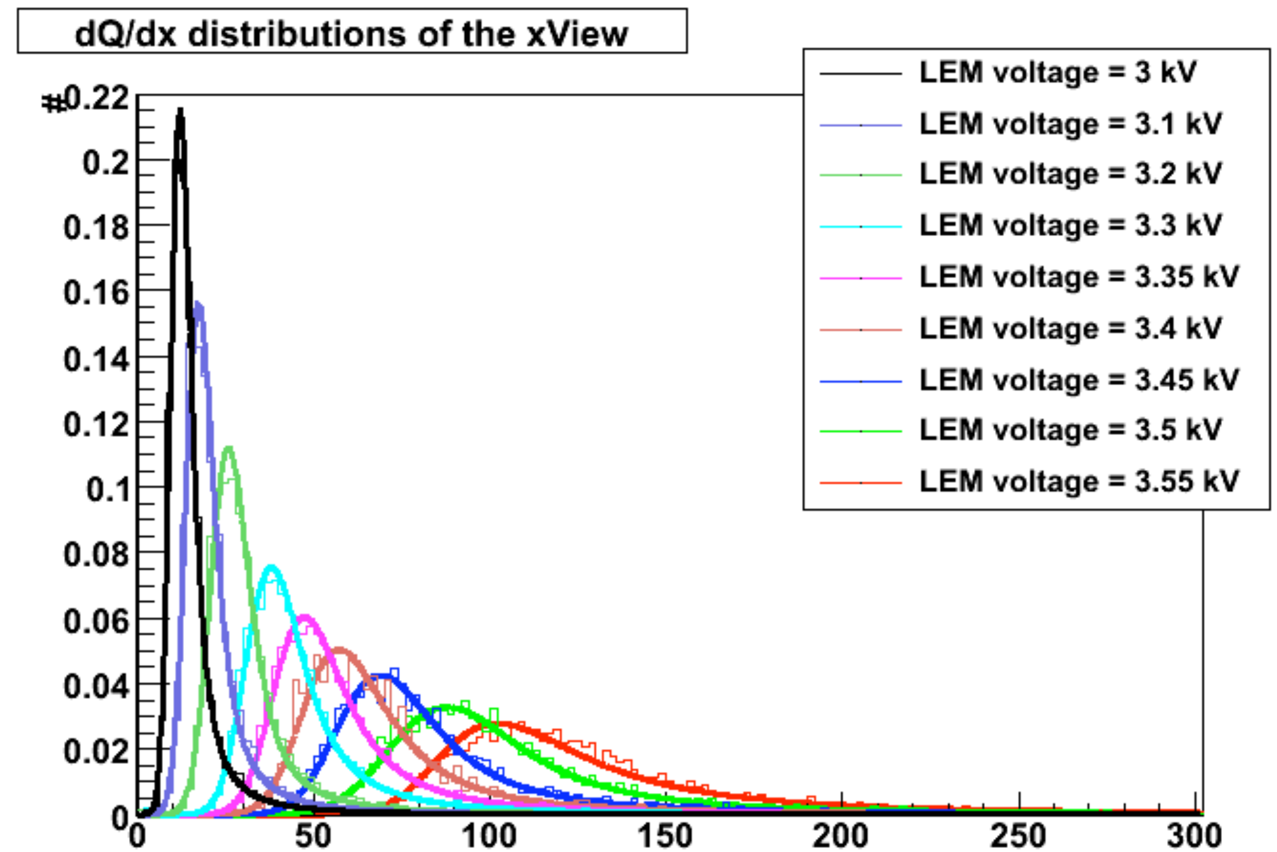
The effective gain

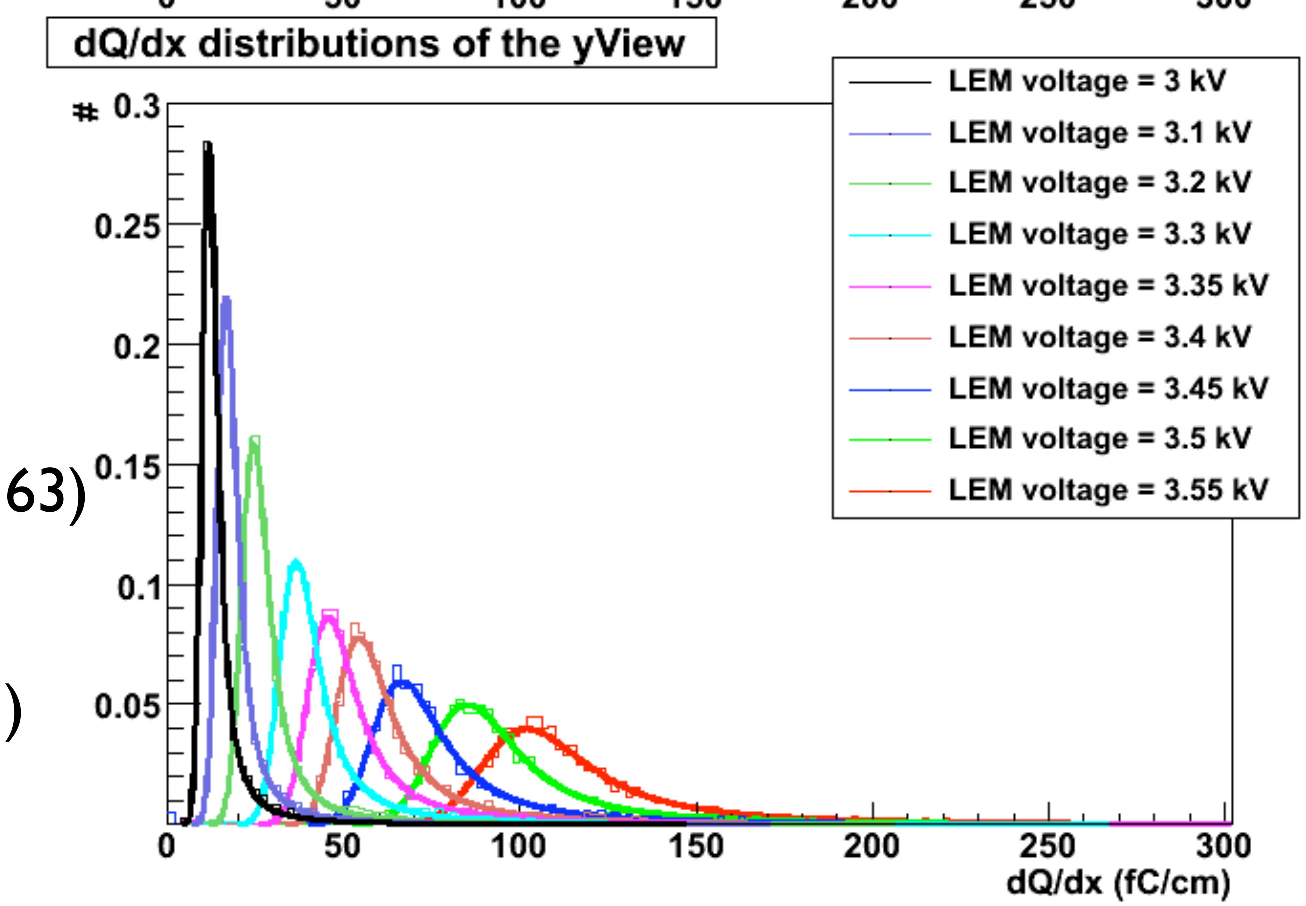
- A Gauss-convoluted Landau function is fitted to the dQ/dx distribution of reconstructed muon tracks.
- The effective gain is defined as the ratio of the collected charge (X + Y views) and the ionization charge in LAr:
  - The average charge released by a MIP in LAr (electric field: 500 V/cm) ~ 10 fC/cm.



eff. gain ~ 27
S/N (x, y) ~ (260, 163)

eff. gain ~ 3
S/N (x, y) ~ (31, 21)

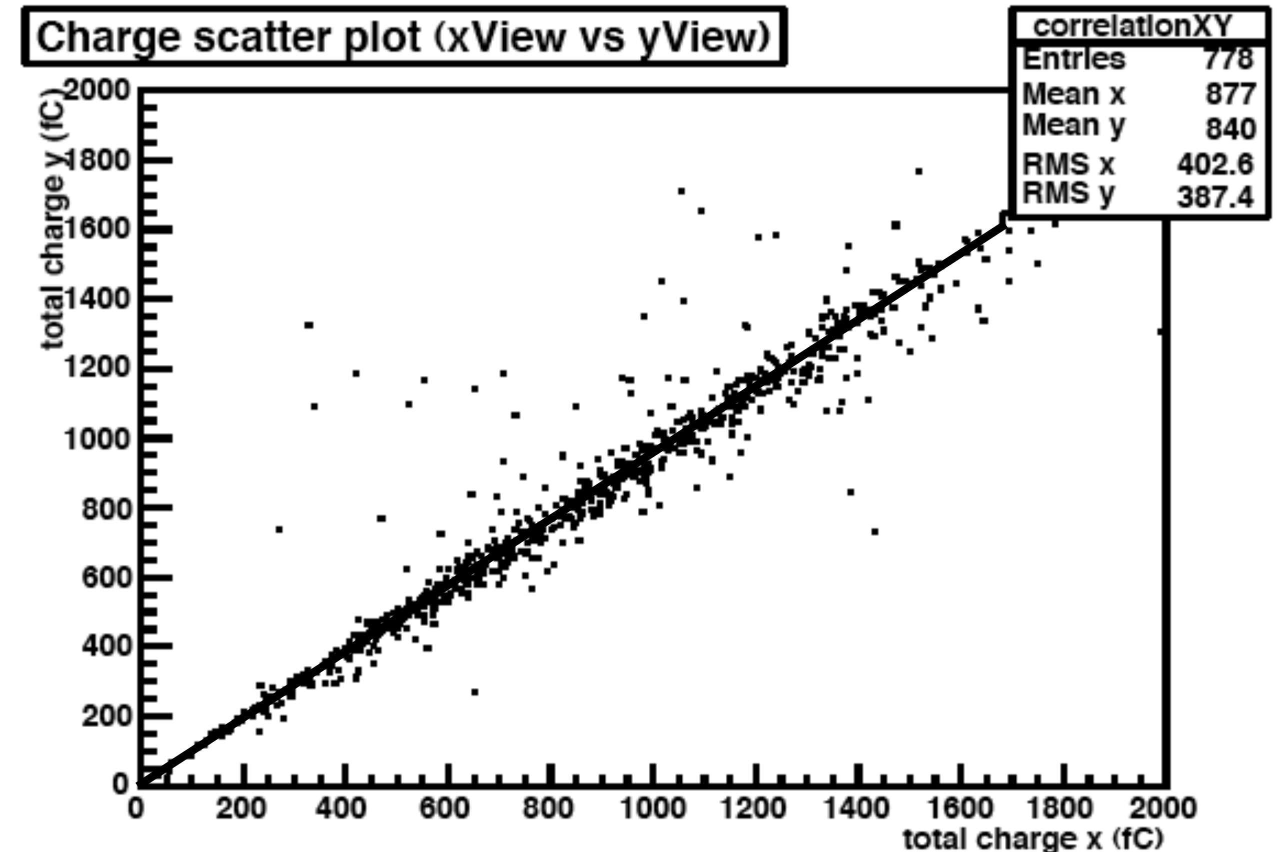


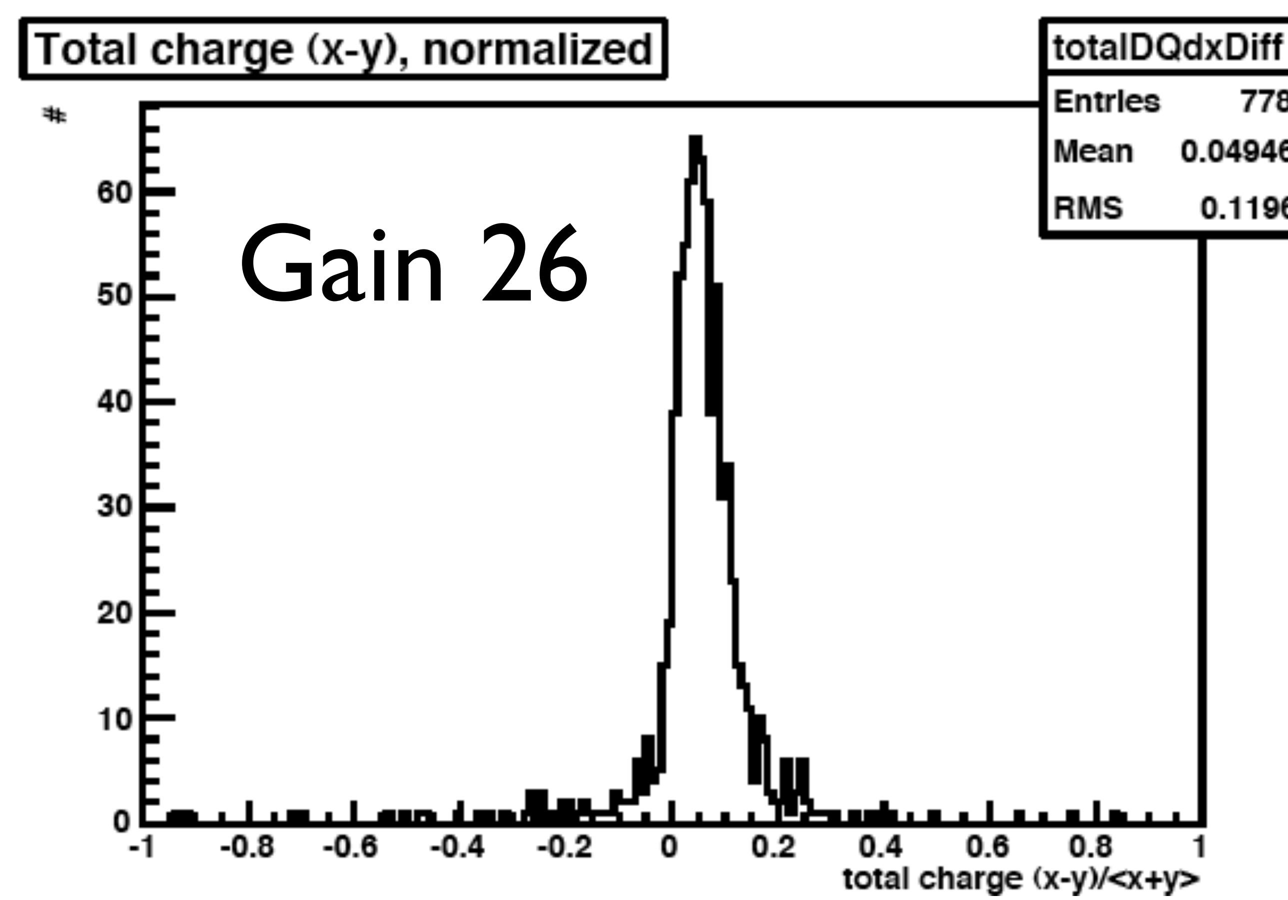


2D anode characterization

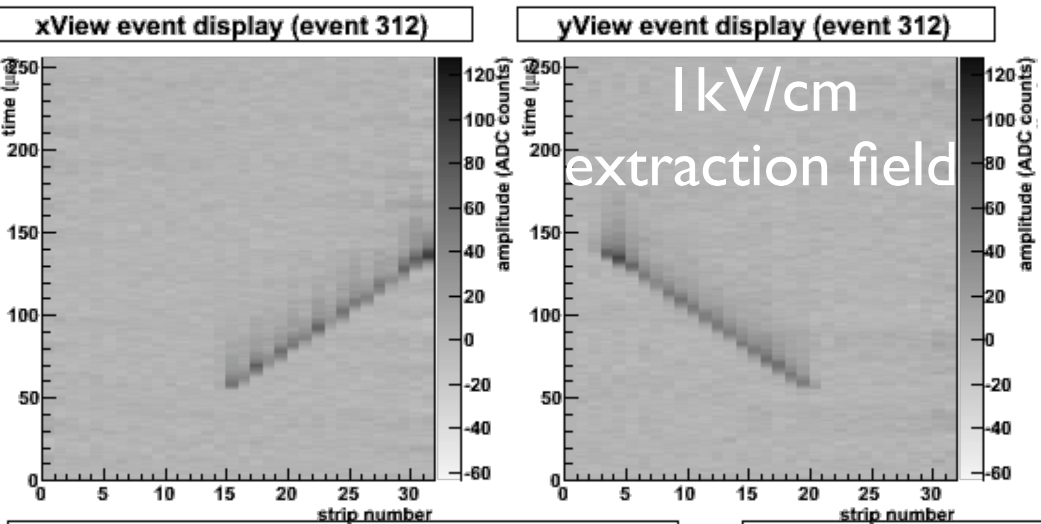
- The geometry parameter of the two views anode were chosen to share the charge equally between the X and Y views.
- Selecting long muons the total charge collected one each set of strips shows: (X-Y)/<X+Y> ~ 5%.

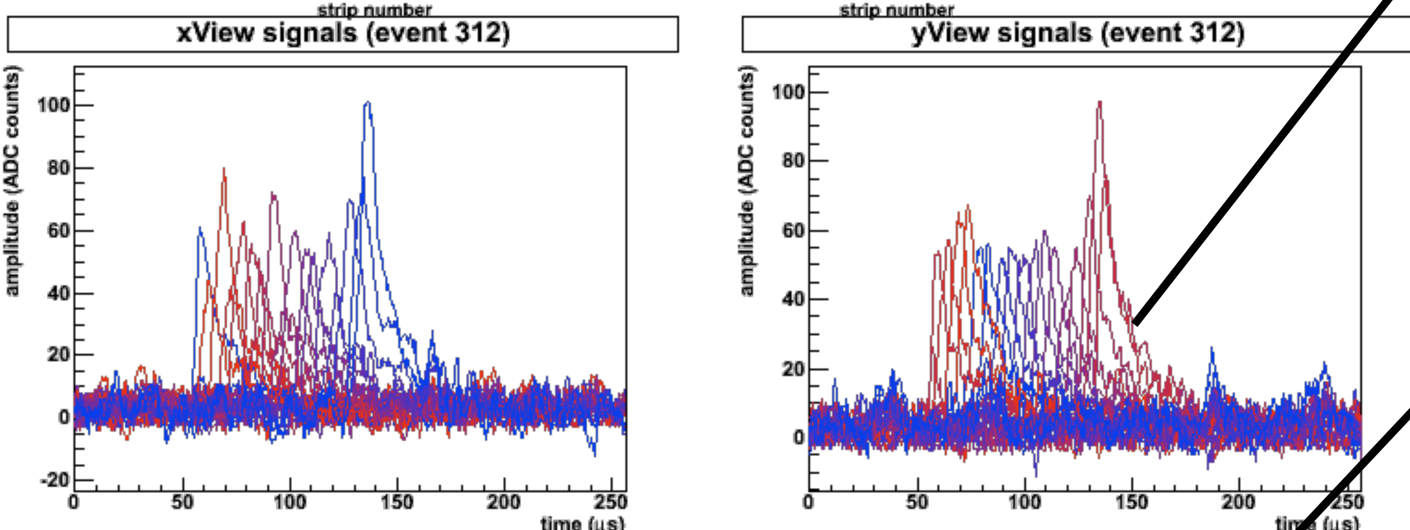
Anode-LEM	3 kV/cm
LEM	35.5 kV/cm
LEM-Grid	1.5 kV/cm
Extraction	3 kV/cm
Drift	0.5 kV/cm

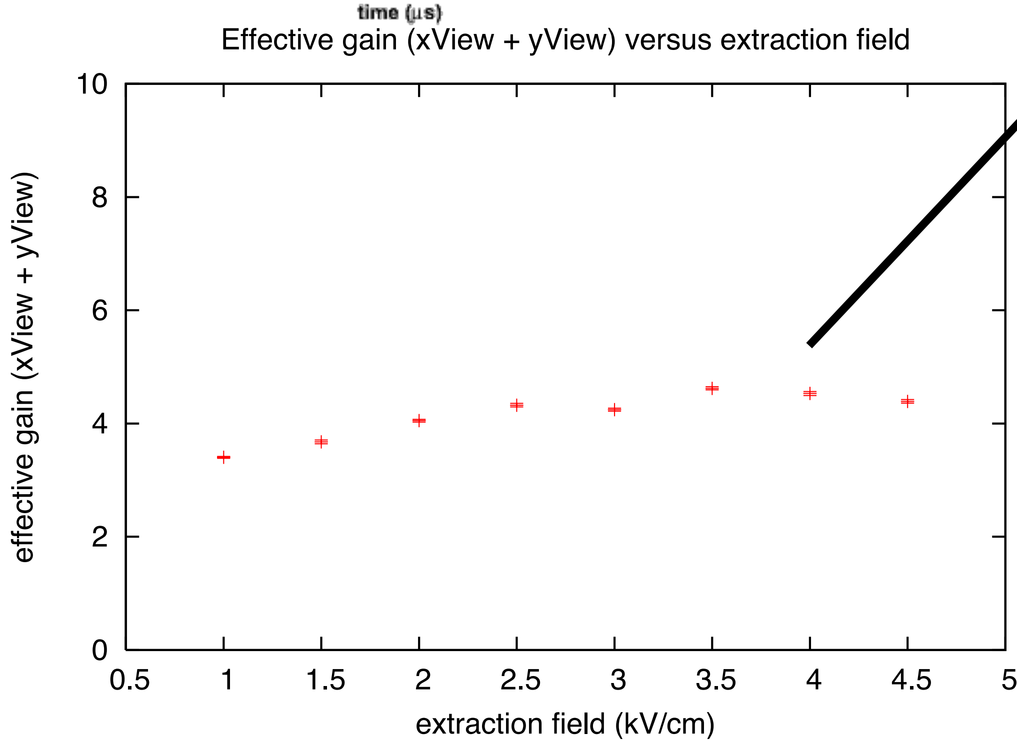




Extraction field considerations





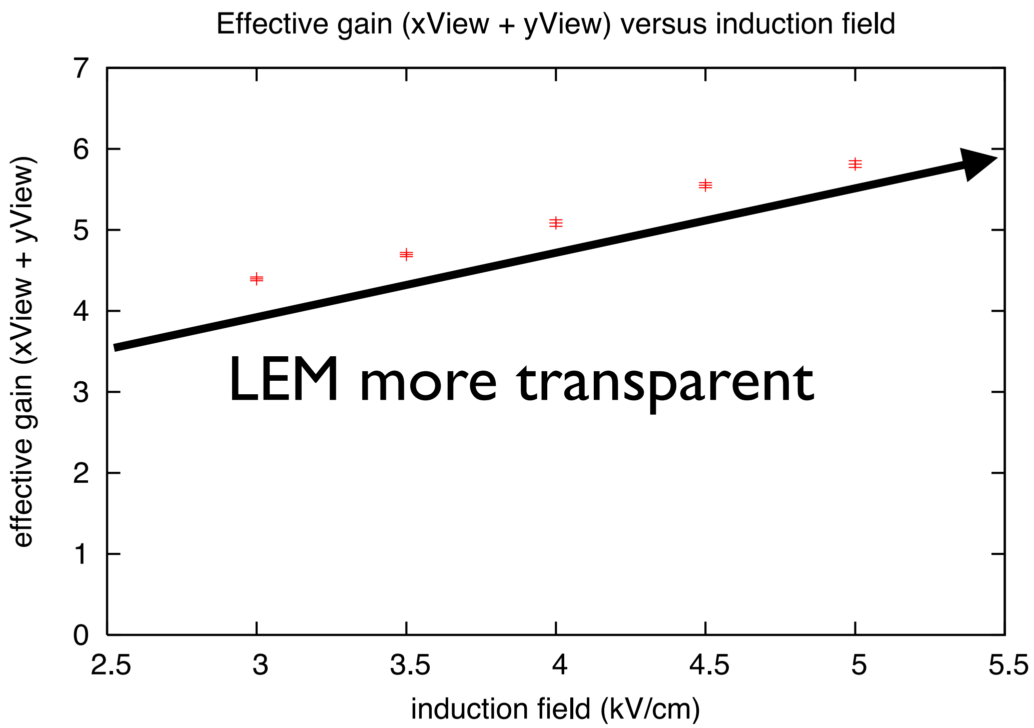


Usual extraction field is > 2.5 kV/cm

- Signal amplitude decreases at low extraction fields.
- The extraction time increases as the field decreases (order of 20 μs @ 1 kV/cm).
- But the charge integral does not strongly depend on the field.

Anode-LEM	3 kV/cm
LEM	30 kV/cm
LEM-Grid	1.5 kV/cm
Extraction	**x**
Drift	0.5 kV/cm

Electric field scans

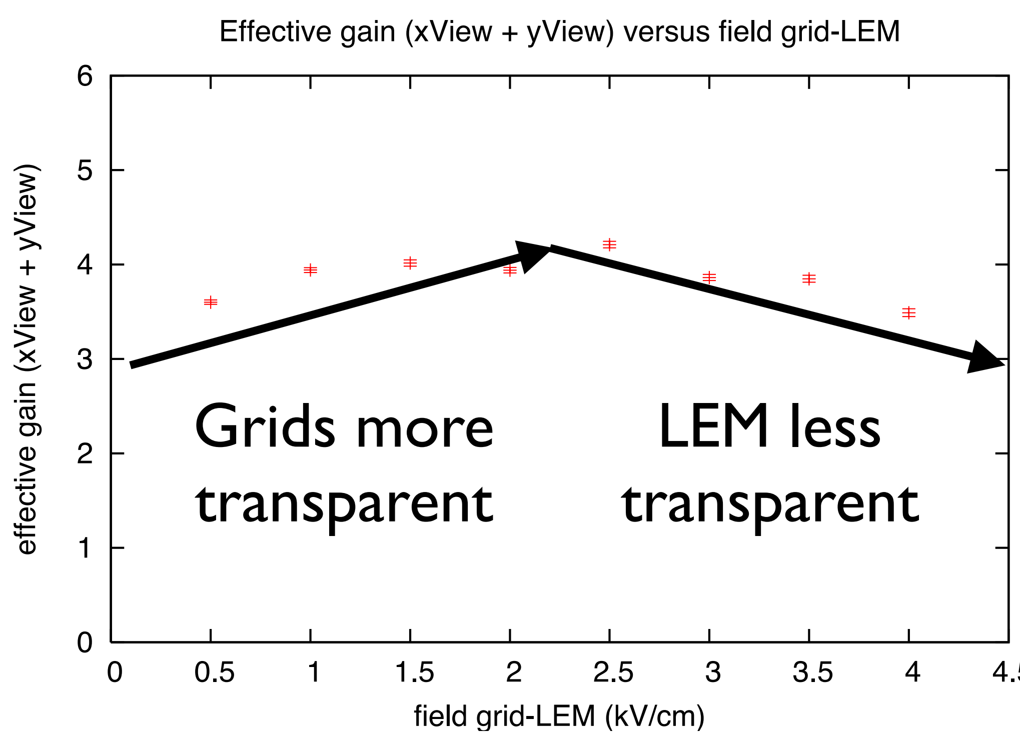


- Scan of the induction field.
- Improve the LEM transparency.

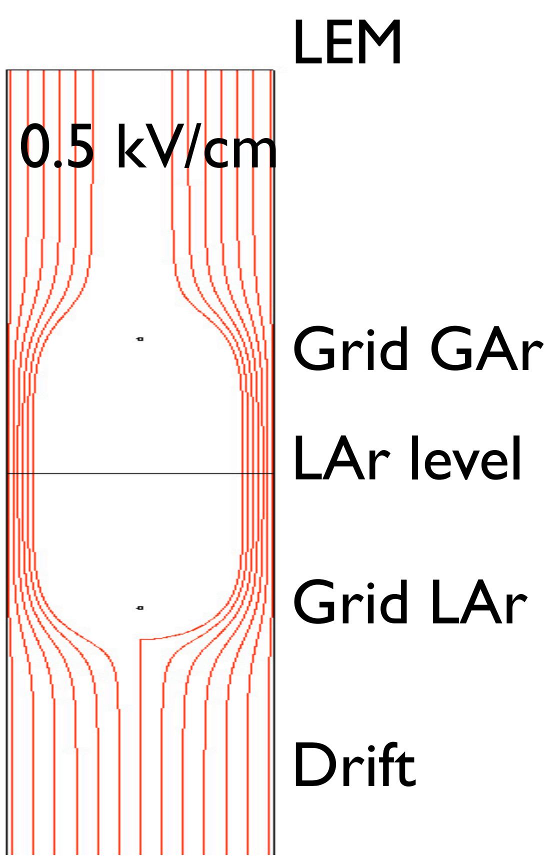
Anode-LEM	**x**
LEM	30 kV/cm
LEM-Grid	1.5 kV/cm
Extraction	3 kV/cm
Drift	0.5 kV/cm

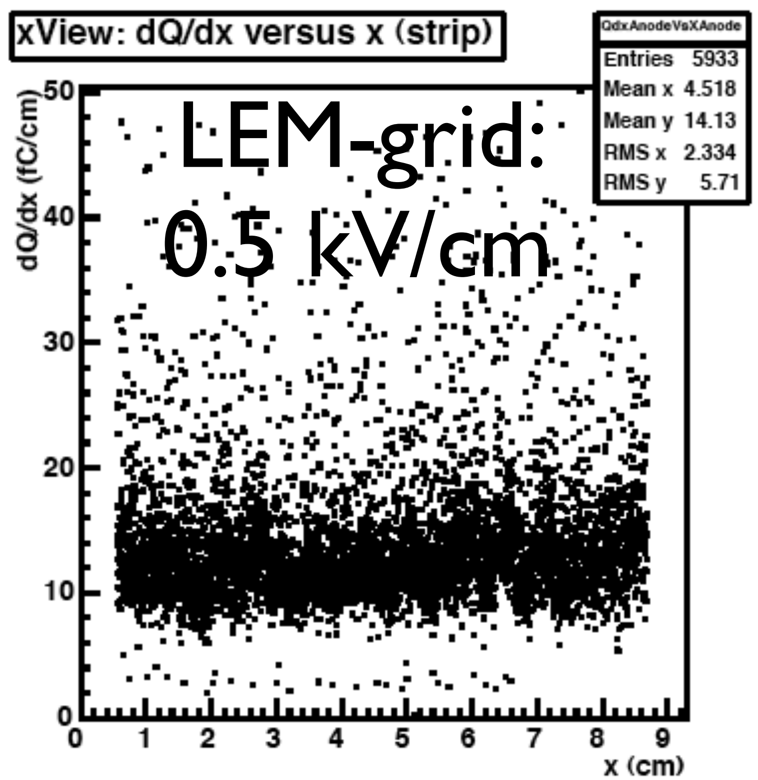
- Scan of the field above the extraction grids
- There is an optimal field.

Anode-LEM	3 kV/cm
LEM	30 kV/cm
LEM-Grid	**x**
Extraction	3 kV/cm
Drift	0.5 kV/cm

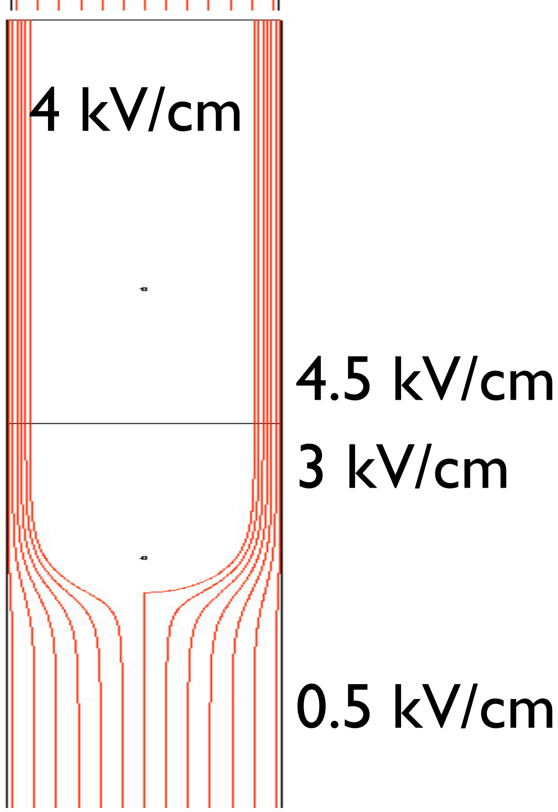


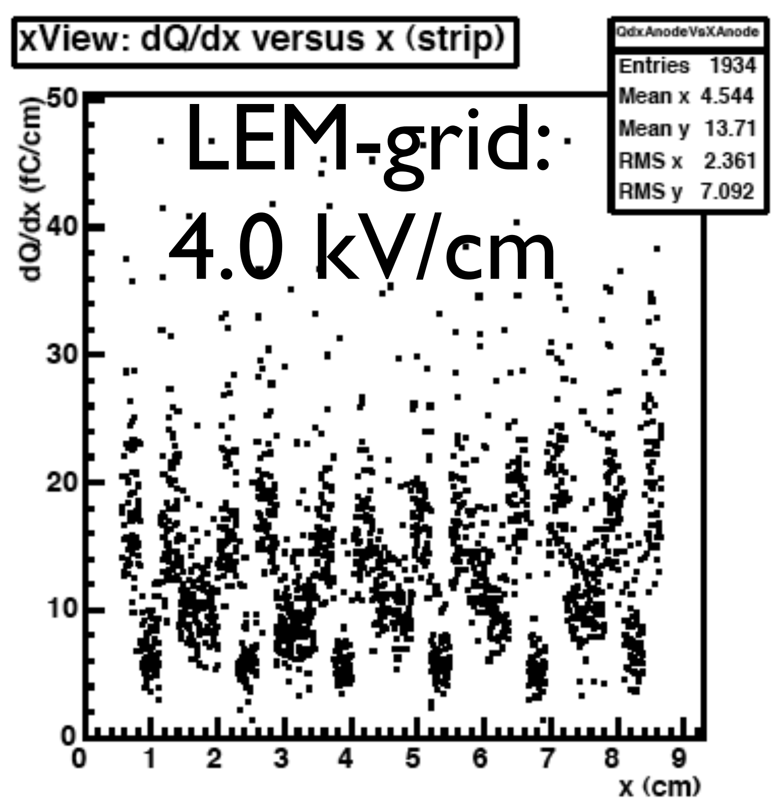
Effect of the extraction grids





- The grids focus the electrons between the wires.
- Amount of charge collected varies with the position (one dimension only).
- The pattern of the grid becomes more evident increasing the field between the grid and the LEM.





Nominal field configuration

Anode-LEM	3 kV/cm
LEM	30 kV/cm
LEM-Grid	x
Extraction	3 kV/cm
Drift	0.5 kV/cm

Conclusions & outlook

- Production and successful operation of a double phase argon LEM-TPC with a two views anode readout:
  - Recorded cosmic muons with a pitch of 3 mm and with an excellent S/N ratio.
  - The device reaches an effective gain of more than 25.
  - Very good charge sharing between the X and Y view.
  - The behavior of the detector is well understood and under control.
- We are designing and constructing a LEM-TPC (40x80 cm^2):
  - To be installed in October on a charged particle beam in J-PARC (Japan).
  - The goal is to address the capability to identify charged pions, kaons and muons by dE/dx.
- The LEM-TPC technique can be used also for direct dark matter search in the ArDM experiment (RE18):
  - The gain needed to fulfill ArDM requirements is 1000 -> double LEM stage.