Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

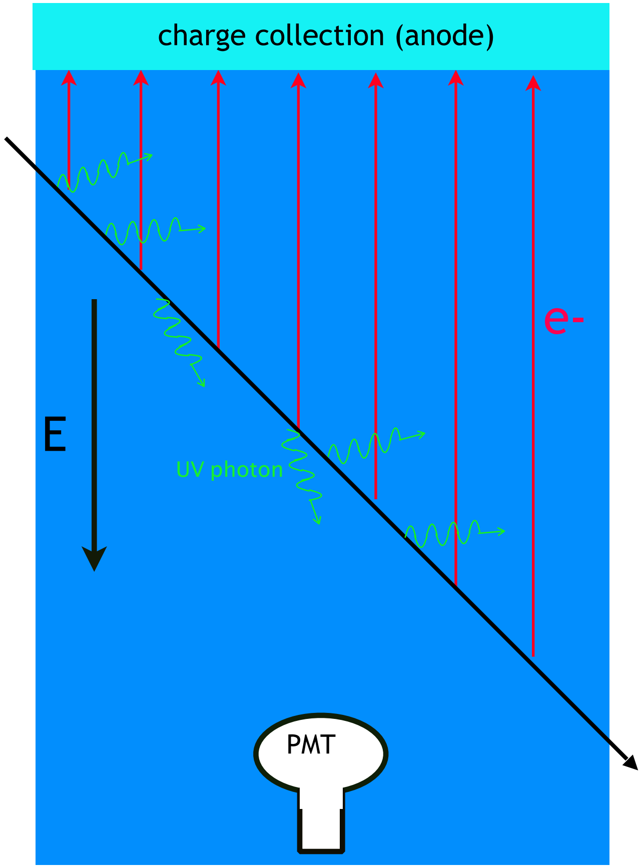
Recent results of LAr LEM TPC R&D

Shuoxing Wu

on behalf of
C. Cantini, L. Epprecht, A. Gendotti, S. Horikawa, L. Periale, S. Murphy, G. Natterer, C. Regenfus, F. Resnati, F. Sergiampietri, A. Rubbia, T. Viant and S. Wu

Institute for Particle Physics, ETH Zurich

Introduction - the Liquid Argon (LAr) TPC



LAr properties

Deisity	1.4 g/cm
Boiling point @ 1 atm	87.3 K
Triple point	83.8058 K, 68.89 kPa
W_{ion}	23.6 eV
Stopping power (MIP)	2.1 MeV/cm
Rayleigh scattering length	90 cm
radiation length	14 cm
Molière radius	9.25 cm
Percentage	0.93%

- ***Light production in LAr:***
  - 128 nm wavelength, ~5×10^4 photon/MeV
  - LAr transparent to its own scintillation
- ***Charge production and transportation in LAr:***
  - 10 fC/cm (MIP)
  - Drift velocity of 2 mm/μs @ 1 kV/cm
  - Diffusion ≈ mm after meters' drift

Giant LAr TPC suits neutrino detection

LAGUNA-LBNO programme and GLACIER

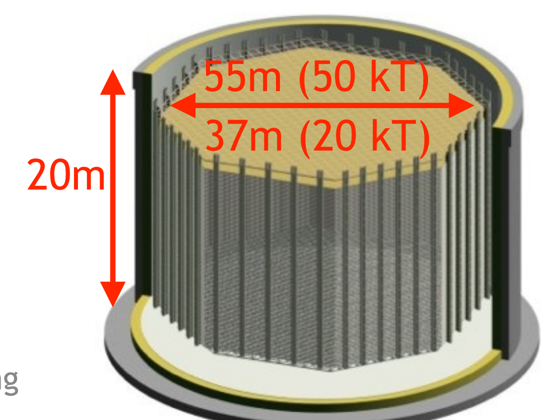
Large Apparatus for Grand Unification and Neutrino Astrophysics and Long Baseline Neutrino Oscillations

LAGUNA-LBNO physics:

1. Accelerator based neutrino physics
   - Mass Hierarchy determination
   - δ_{CP} measurement
   - Sterile neutrino
2. Neutrino astronomy:
   - Solar neutrino
   - Atmosphere neutrino
   - Super-nova neutrino
3. Proton decay search

Giant Liquid Argon Charge Imaging expERiment

- Double phase LAr LEM TPC
- Two detectors with 20 kton and 50 kton fiducial mass as far detector for LAGUNA-LBNO



ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Milestones towards GLACIER

➢ **2003: the GLACIER concept**

- A. Rubbia, Experiments for CP-violation: A giant liquid argon scintillation, Cherenkov and Charge imaging experiment? arXiv:hep-ph/0402110

➢ **Proof of principle with 10x10 cm² double phase LAr LEM-TPC prototype:**

- A. Badertscher et al., "Operation of a double-phase pure argon Large Electron Multiplier Time Projection Chamber: Comparison of single and double phase operation "NIM A617 (2010) p.188-192
- A. Badertscher et al., "First operation of a double phase LAr Large Electron Multiplier Time Projection Chamber with a two-dimensional projective readout anode" NIM A641 (2011) p.48-57

➢ **First successful operation of a 40x76 cm² device in November 2011:**

- A. Badertscher et al., "First operation and drift field performance of a large area double phase LAr Electron Multiplier Time Projection Chamber with an immersed Greinacher high-voltage multiplier " JINST 7 (2012) P08026
- A. Badertscher et al., "First operation and performance of a 200 lt double phase LAr LEM-TPC with a 40x76 cm² readout", JINST 8 (2013)P04012

➢ **10x10 cm² double phase LAr LEM-TPC prototype: further R&D towards final, simplified charge readout for GLACIER:**

- Long-term operation of a double phase LAr LEM Time Projection Chamber with a simplified anode and extraction-grid design, JINST 9 P03017
- Performance study of the effective gain of Large Electron Multipliers in LAr-LEM TPCs, paper on arXiv soon

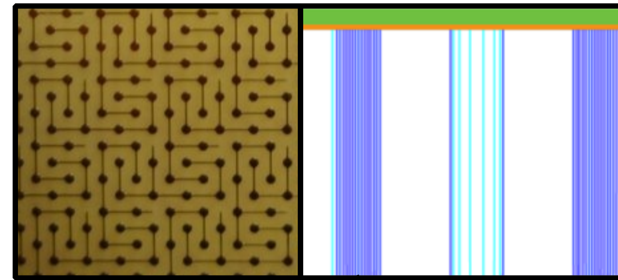
➢ **Future**

- **3x1x1m³** pre-prototype to be put in B182@CERN
- **6x6x6m³** prototype (WA105) to be operated at CERN NA approved by CERN SPSC.

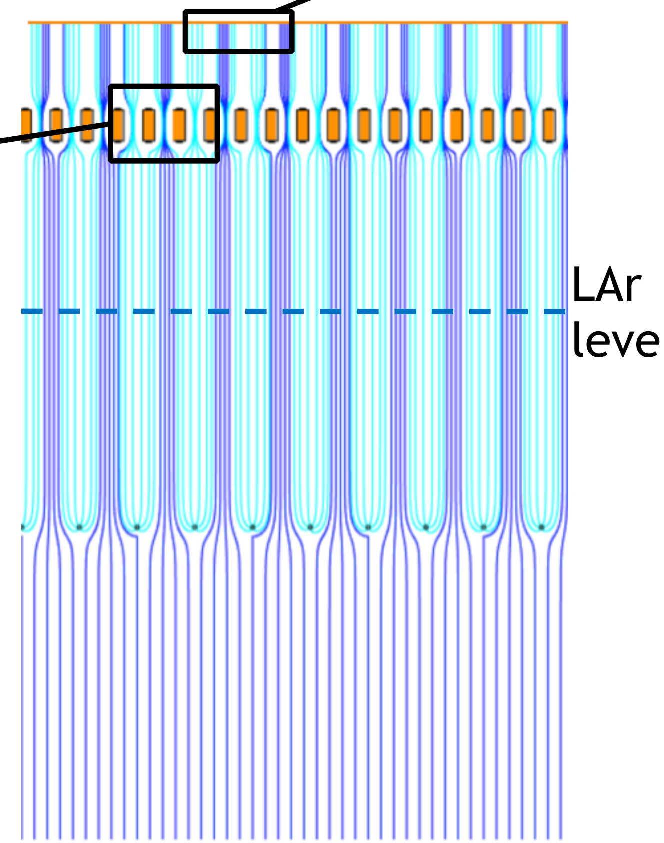
Final goal: Giant LAr LEM TPC as far detector for a Long Baseline Neutrino Oscillation (LBNO) experiment (SPSC-EOI-007)

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

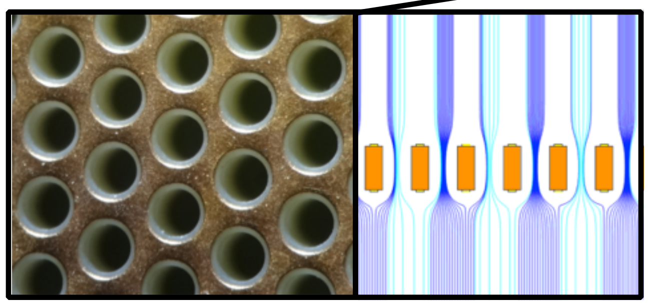
The novel double phase readout



4.) Charge collection on a multilayer 2D anode readout (symmetric unipolar signals with two orthogonal views)



3.) Charge multiplication in the holes of the Large Electron Multiplier (LEM)



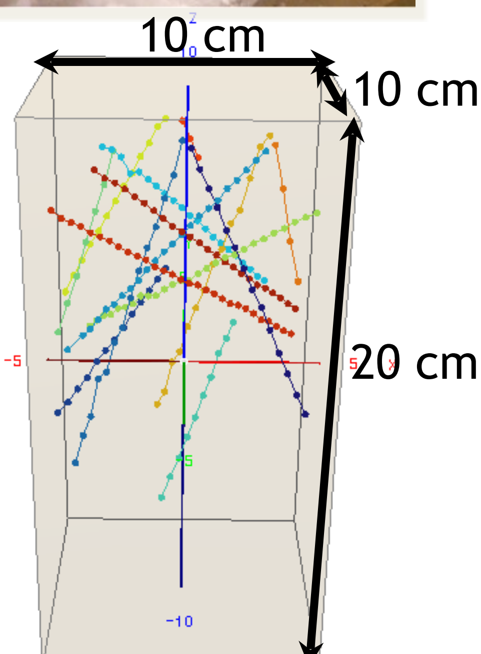
2.) Drift electrons are efficiently extracted into the gas phase

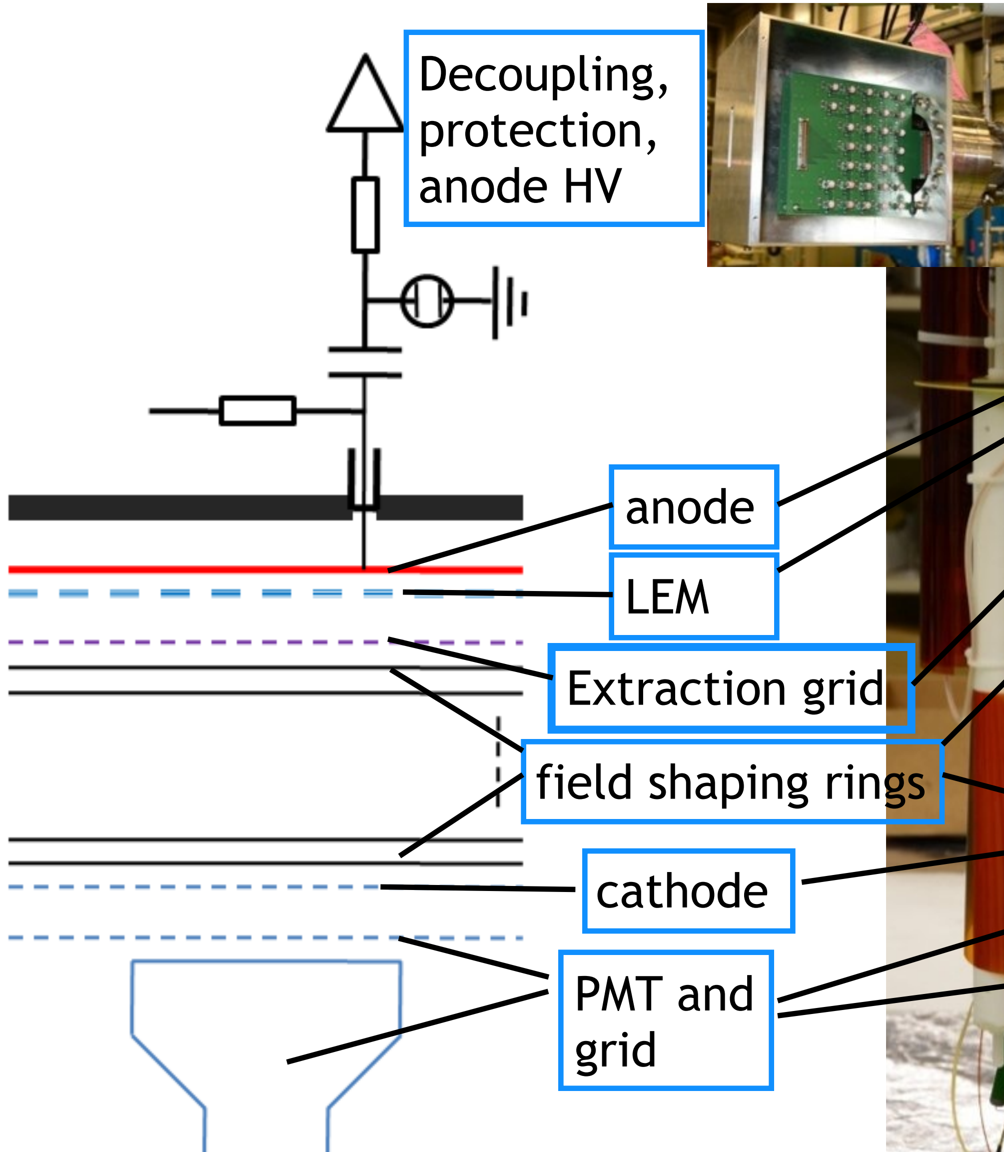
1.) Ionization electrons drift towards the liquid argon surface

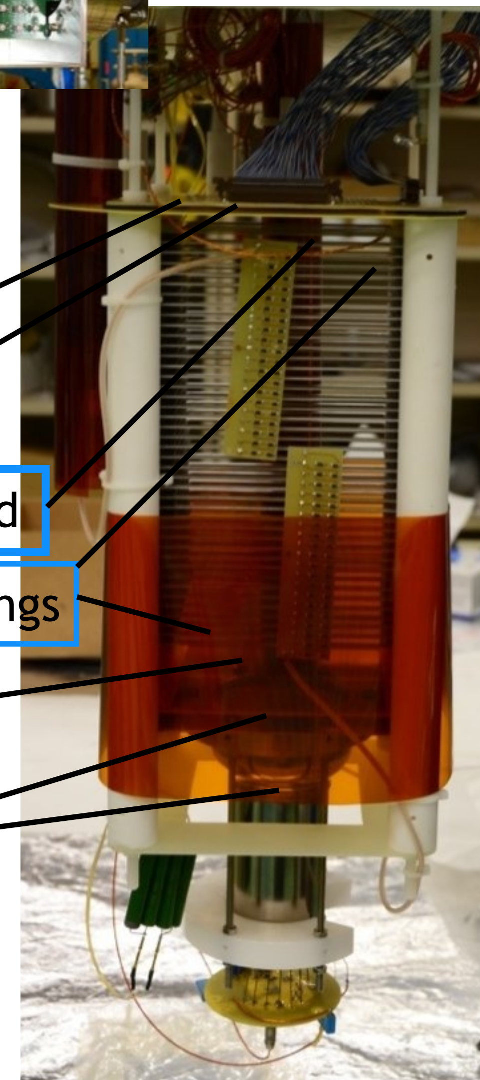
For MIPs:
- 10 fC/cm — ~20 k e^- for each strip (3 mm pitch) — SNR of 20 (noise of 1000 e^-)
- SNR of 100 — gain of 10 is needed

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

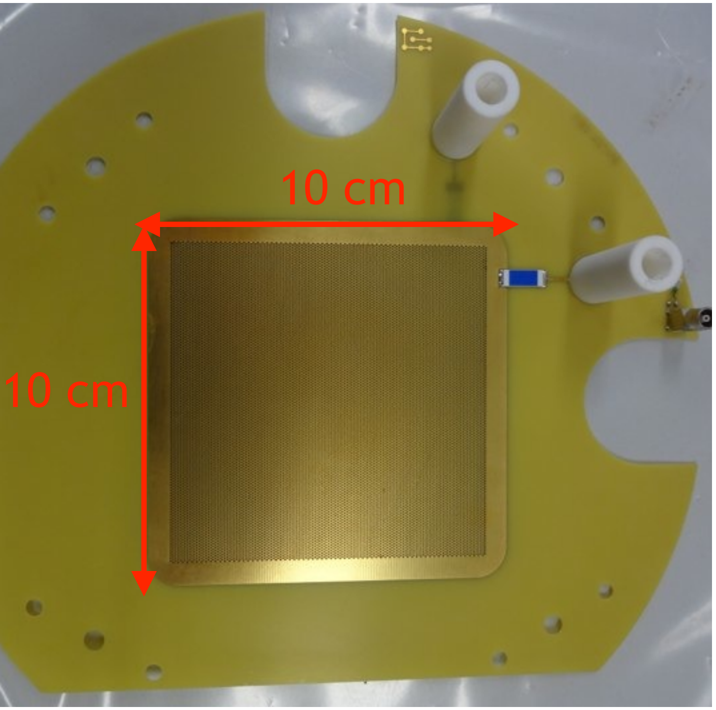
The 10x10x20 cm^3 LAr LEM TPC





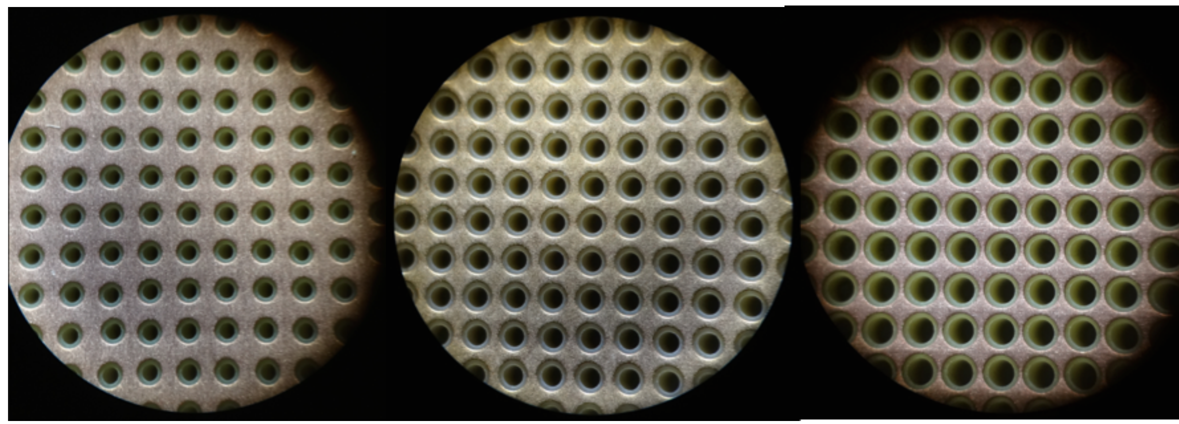


The Large Electron Multiplier (LEM)



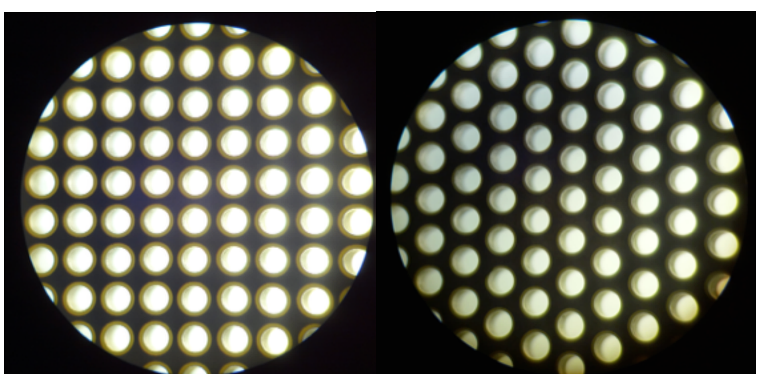
Hole diameter:

300 µm 400 µm 500 µm



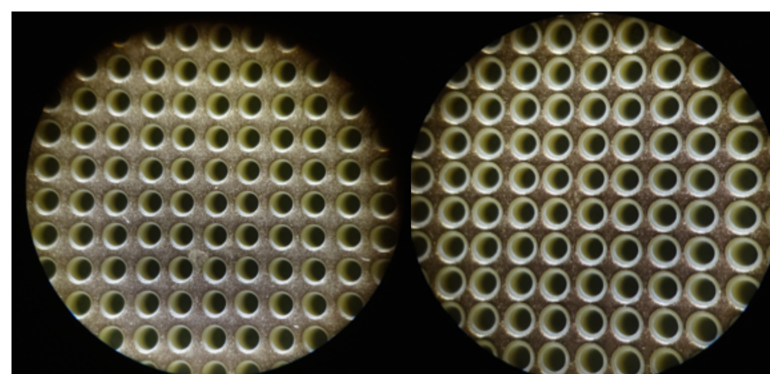
Hole layout:

square hexagonal



Rim size:

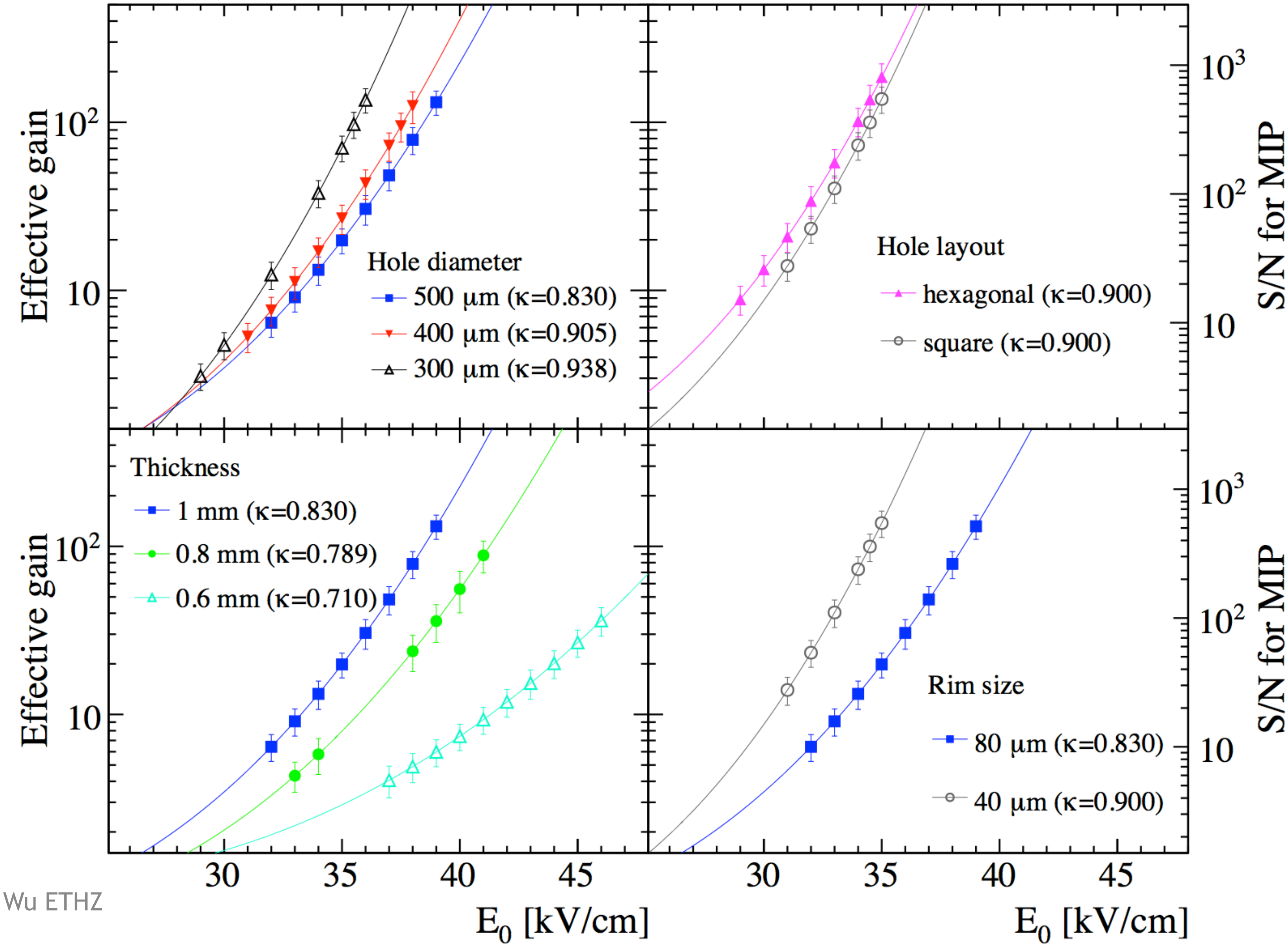
40 µm 80 µm



ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

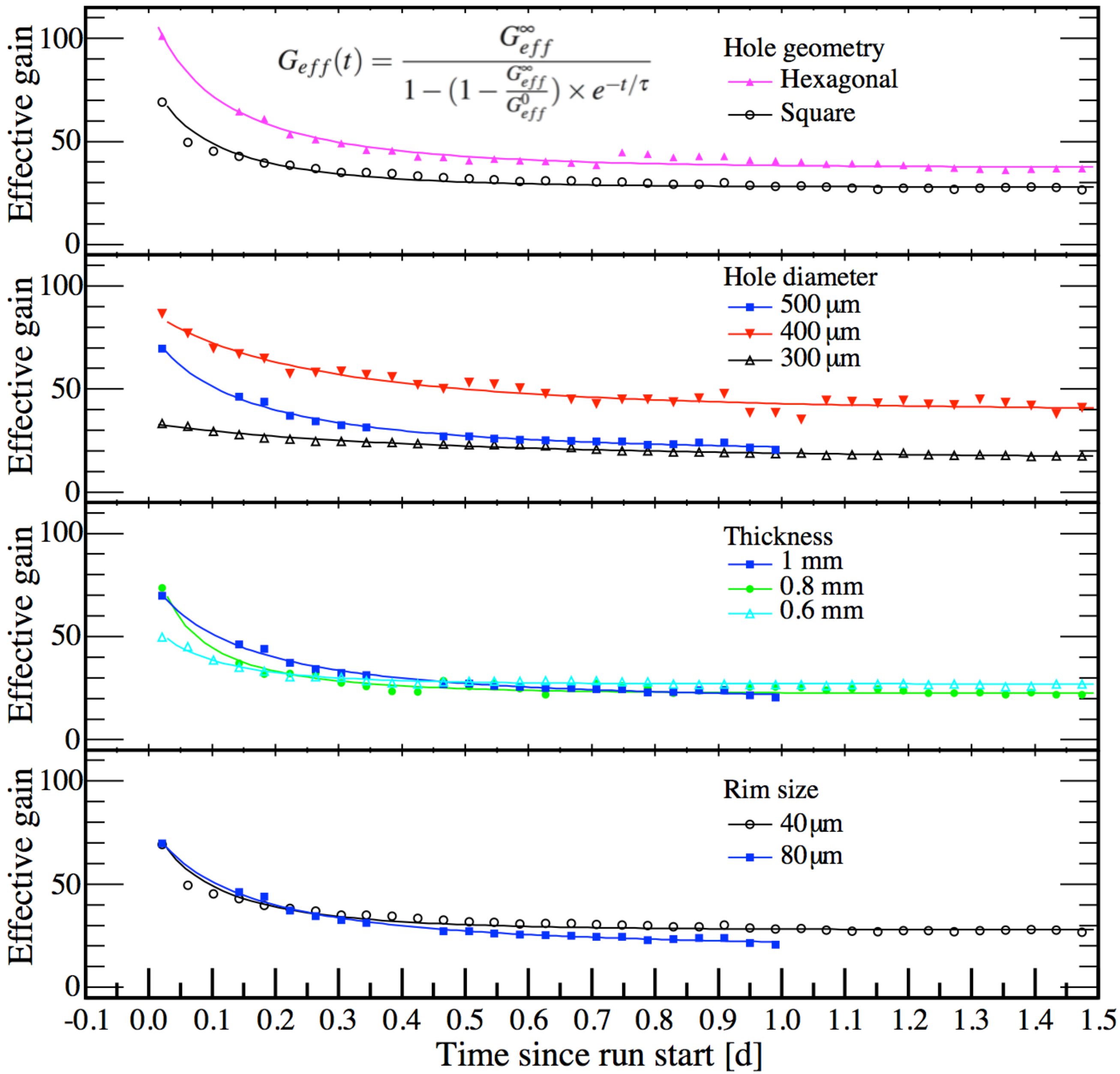
LEM gain curves

Fitting function: $G_{eff}(E,\rho,t) \equiv \mathscr{T} e^{\alpha(\rho,E)x} \times \mathscr{C}(t)$ $\alpha(\rho,E) = A\rho e^{-B\rho/E}$



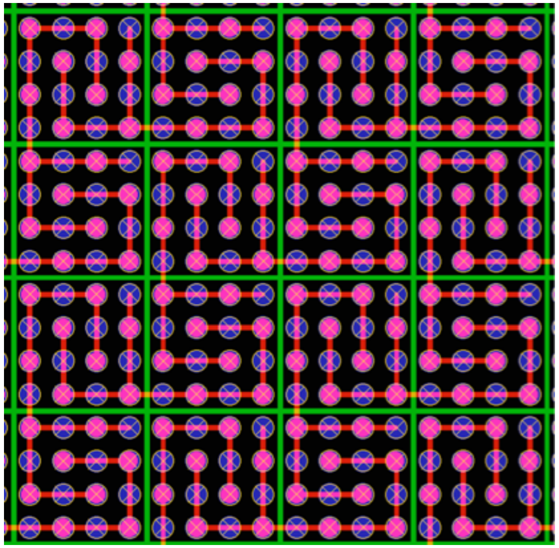
tested parameter	value	$\mathscr{T}$	x (mm)	G_{eff}^{max}	E_0^{max} (kV/cm)
hole layout	hexagonal	0.59± 0.18	0.96±0.07	182	35
	square	0.34± 0.14	0.94±0.08	123	35
hole diameter	500 μm	0.46± 0.14	0.73±0.05	124	39
	400 μm	0.41± 0.11	0.81±0.05	124	38
	300 μm	0.20± 0.03	0.88±0.04	134	36
thickness	1 mm	0.46± 0.14	0.73±0.05	124	39
	0.8 mm	0.46± 0.15	0.69±0.06	88	41
	0.6 mm	0.58± 0.2	0.55±0.06	36	46
rim size	40 μm	0.34± 0.14	0.94±0.08	123	35
	80 μm	0.46± 0.14	0.73±0.05	124	39

LEM gain stabilities

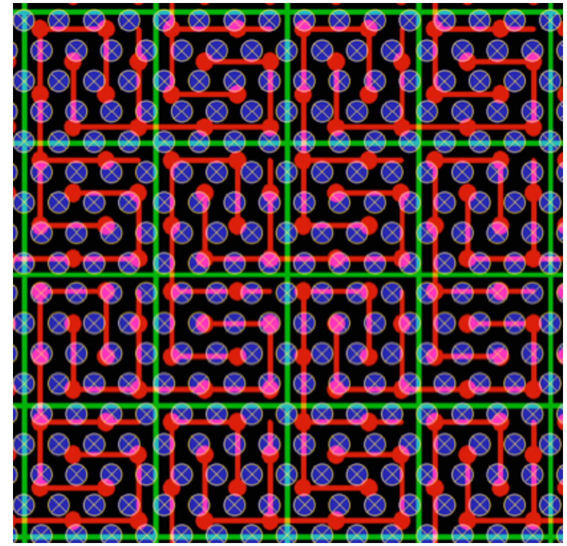


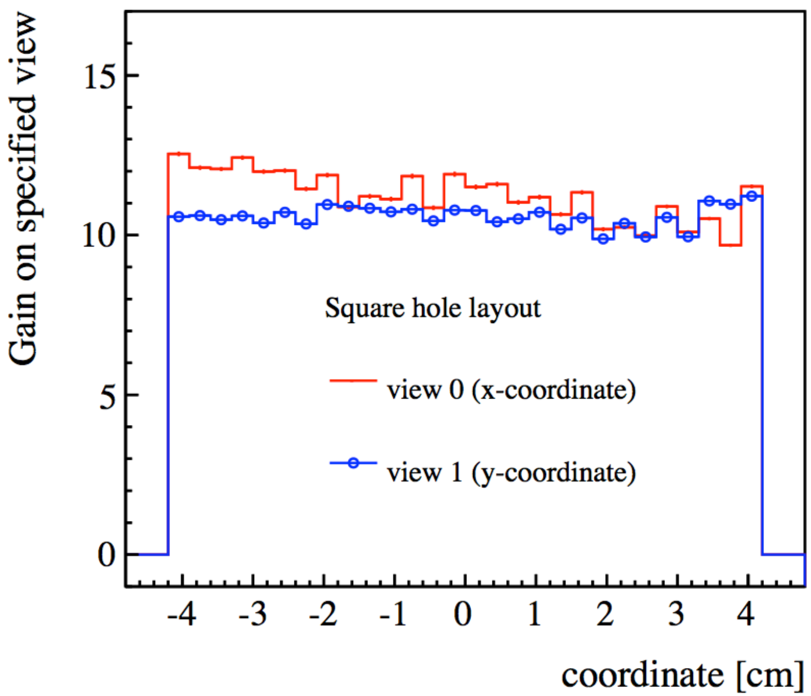
tested parameter	value	E_0 [kV/cm]	run-time [hrs]	Number of discharges	τ [days]	G^0_{eff}	G^∞_{eff}	$\frac{G^0_{eff}}{G^\infty_{eff}}$
geometry	hexagonal	34	110	0	0.32±0.07	99	35	2.7
	square	34	52	0	0.30±0.02	65	27	2.4
hole	500 μm	38	24	0	0.53±0.05	70	20	3.5
	400 μm	37	50	2	0.53±0.07	84	40	2.1
	300 μm	33.5	75	3	0.75±0.04	32	16	2.0
thickness	1 mm	38	24	0	0.53±0.05	70	20	3.5
	0.8 mm	42	82	0	0.24±0.02	73	22	3.3
	0.6 mm	46	95	1	0.18±0.01	51	27	1.9
rim size	80 μm	38	24	0	0.53±0.05	70	20	3.5
	40 μm	34	52	0	0.29±0.02	65	27	2.4

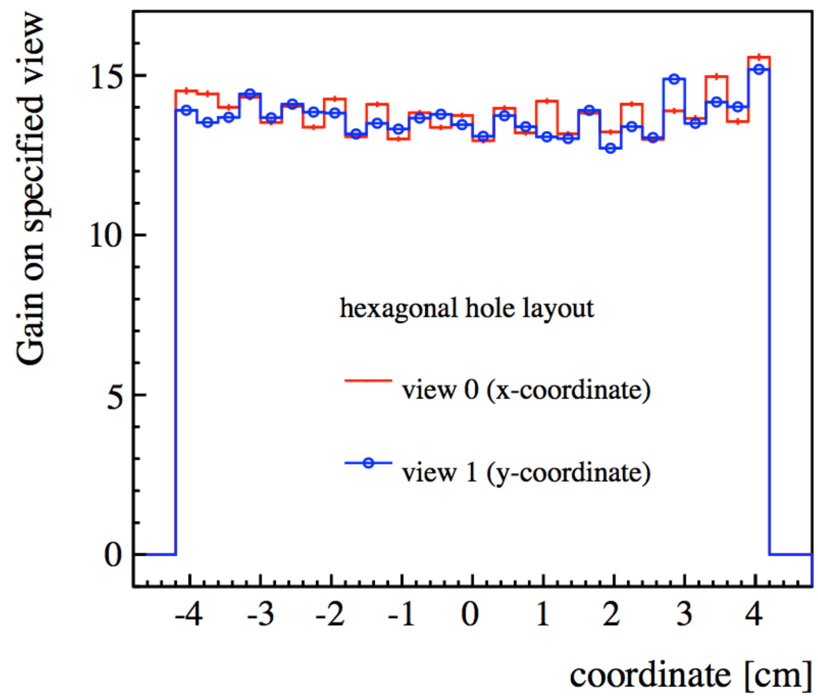
Alignment vs. no alignment



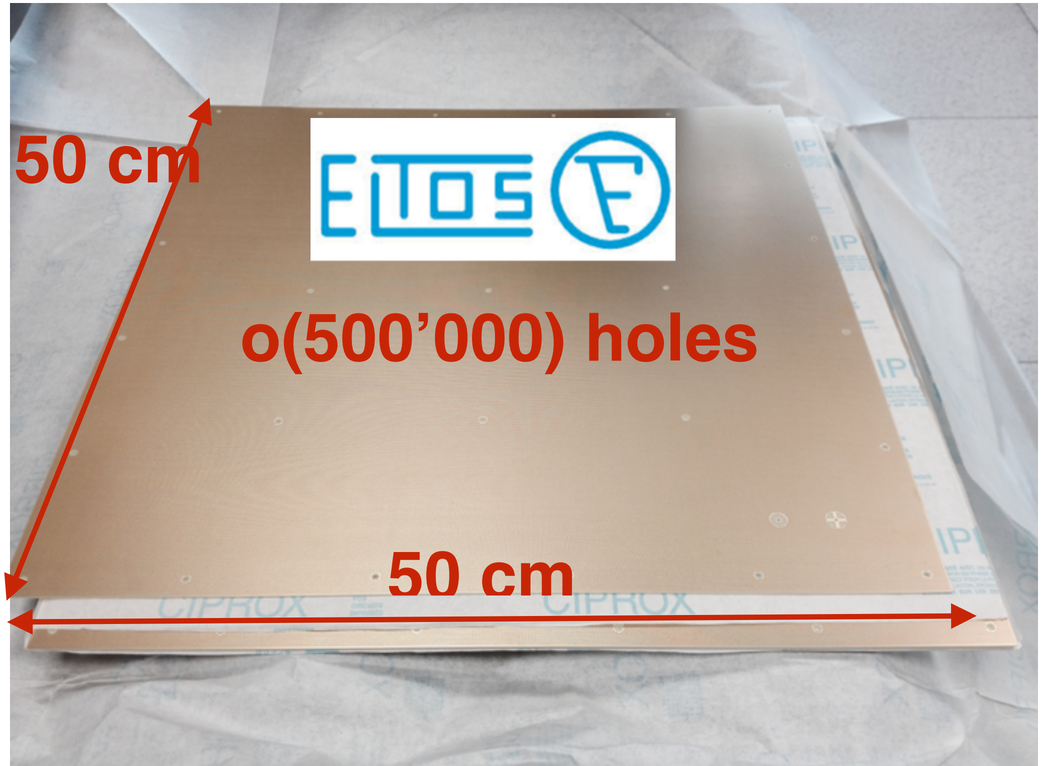
● anode pad
⊗ LEM hole
– extraction grid

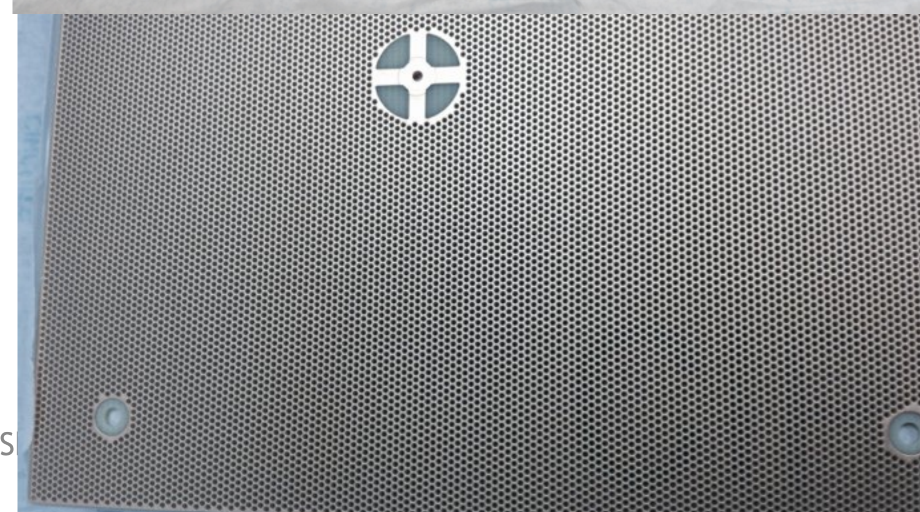




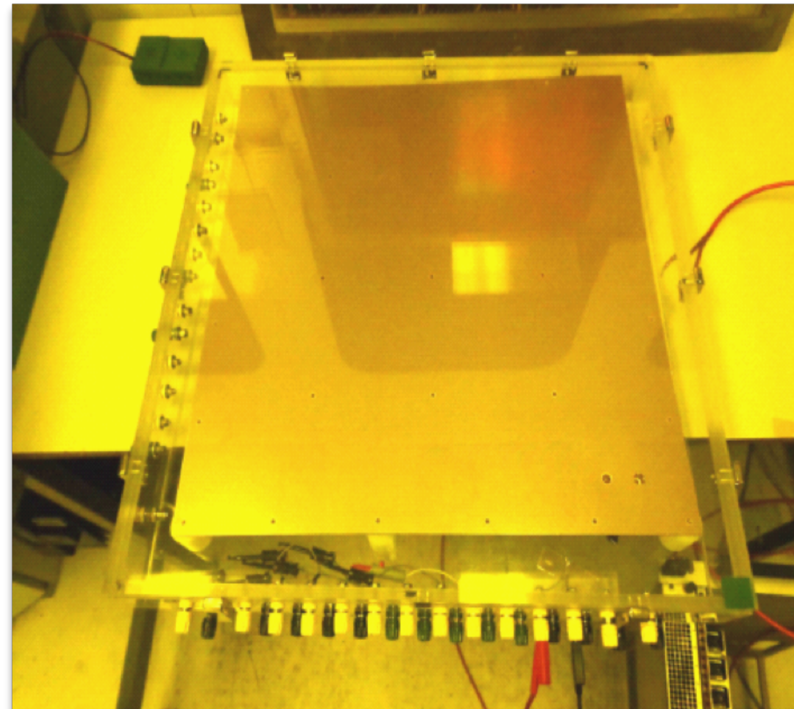


Towards large area: – the 50x50 cm^2 LEM





test at Rui’s lab

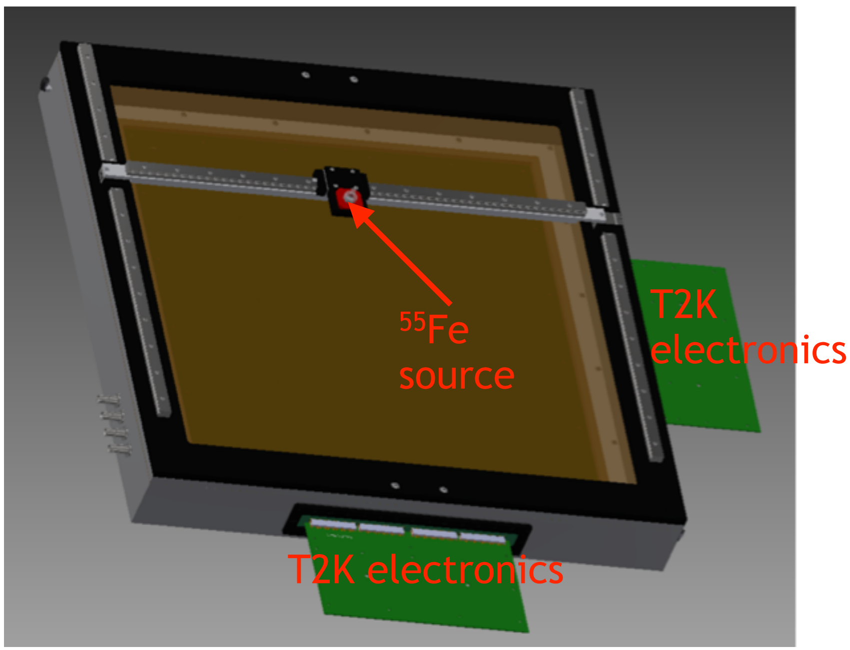


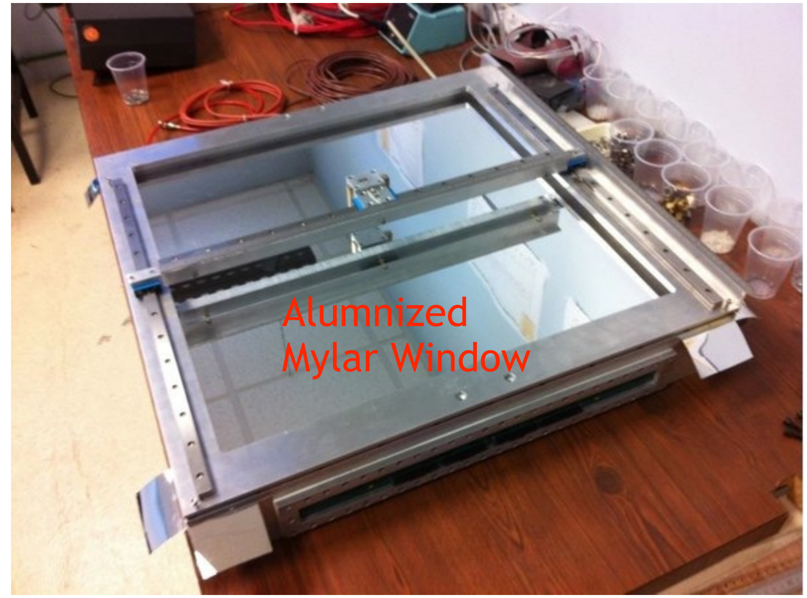
Test in box filled with N_2:

- 3.5 kV, <10 nA for all 4
- best 3.92 kV, 3 nA

Next step:
– 50x50 cm2 LEM gas test

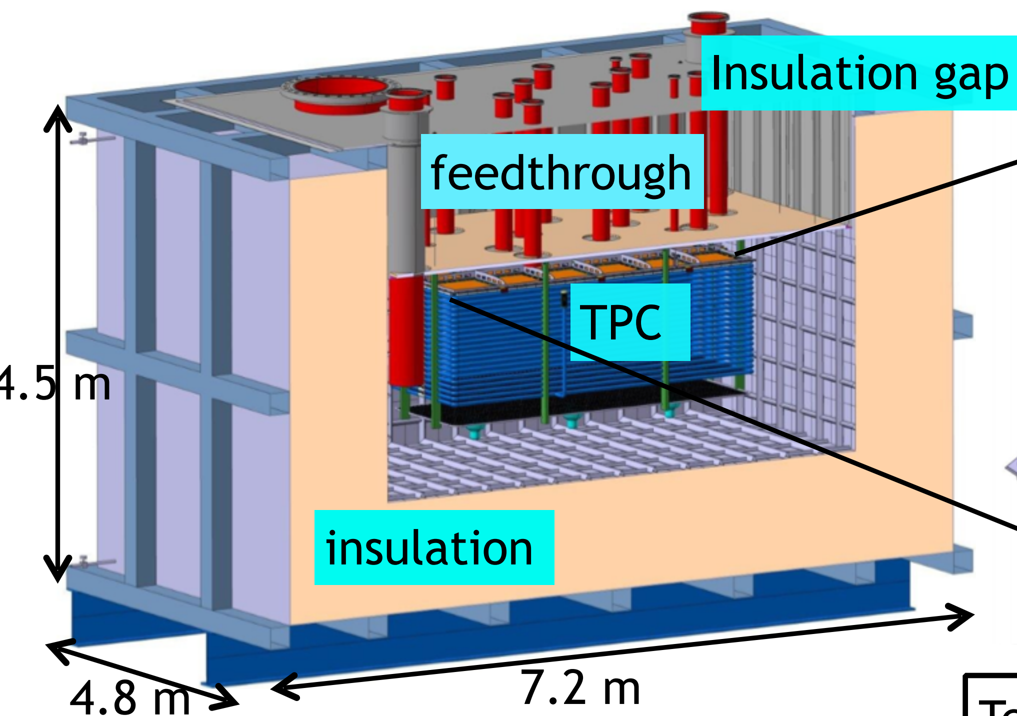
DE LA RECHERCHE À L'INDUSTRIE
cea



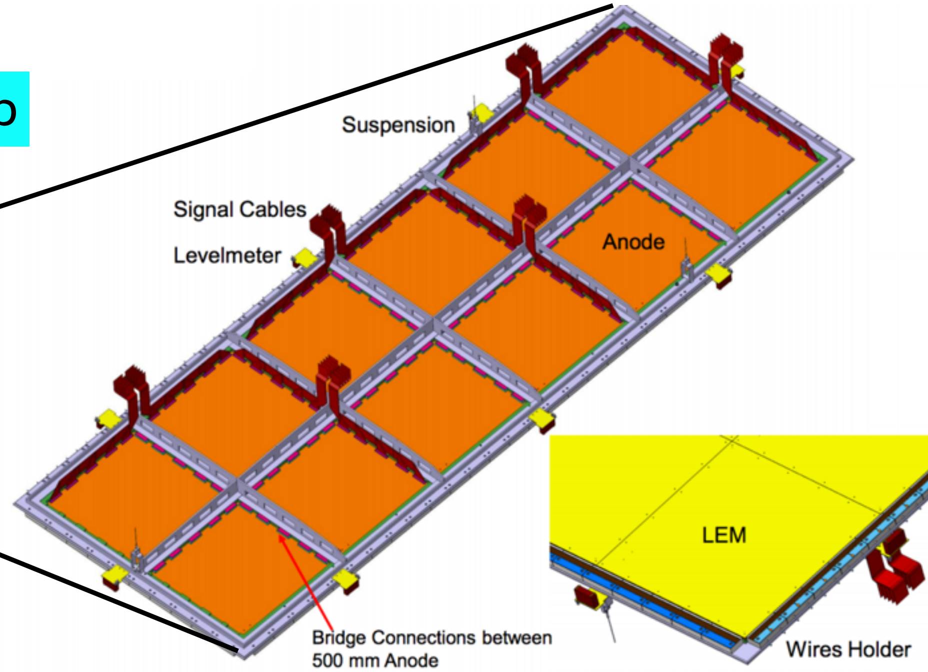


The 3x1x1 m^3 LAr LEM TPC

5 ton (fiducial) double phase LAr TPC



$3x1\ m^2$ charge readout system:



Time scale:2014-2015
Site: B182@CERN

Technical goal:
LAr purity in non-evacuated membrane tank, performance of large area readout, cold front-end electronics…

Summary

- ➢ Systematic inspections on LEM design parameters on 10x10 cm^2 samples performed.
- ➢ Initial gain over 100, stable gain over 20 were reached by all the LEMs
- ➢ Gain uniformity within ±10% achieved by matching extraction grid with anode strips
- ➢ 4 50x50 cm^2 LEMs were successfully produced without defect. Over 3.5 kV was reached in N_2 with leakage current within 10 nA.

Thank you and questions?