First operation of a double phase pure liquid Argon THGEM-TPC

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Introduction

The detector presented in this talk is a liquid argon based Time Projection Chamber capable of charge multiplication.

Aims

• Low energy threshold

• Charge loss compensation allows longer drift paths

• Increase signal to noise ratio

Possible applications

• Giant detector for neutrino physics, proton decay and DM search A. Rubbia, arXiv:hep-ph/0402110, 2003

• Dark Matter imaging detector - A. Rubbia, J. Phys. Conf. Ser. 39 (2006) 129

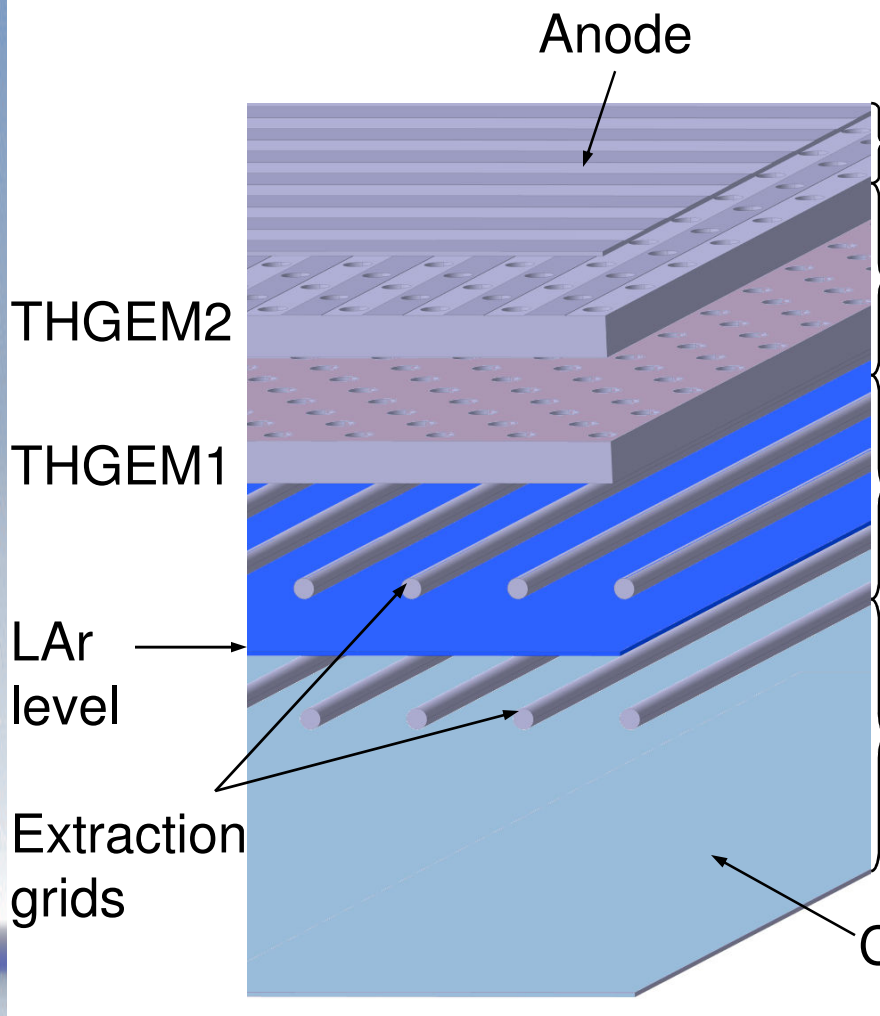
Recent articles

• A. Badertscher et al., arXiv:0811.3384, 2008

• A. Badertscher et al., arXiv:0907.2944, 2009

THGEM-TPC principle

Double phase pure argon THGEM-TPC is a **tracking** and a **calorimetric** device.



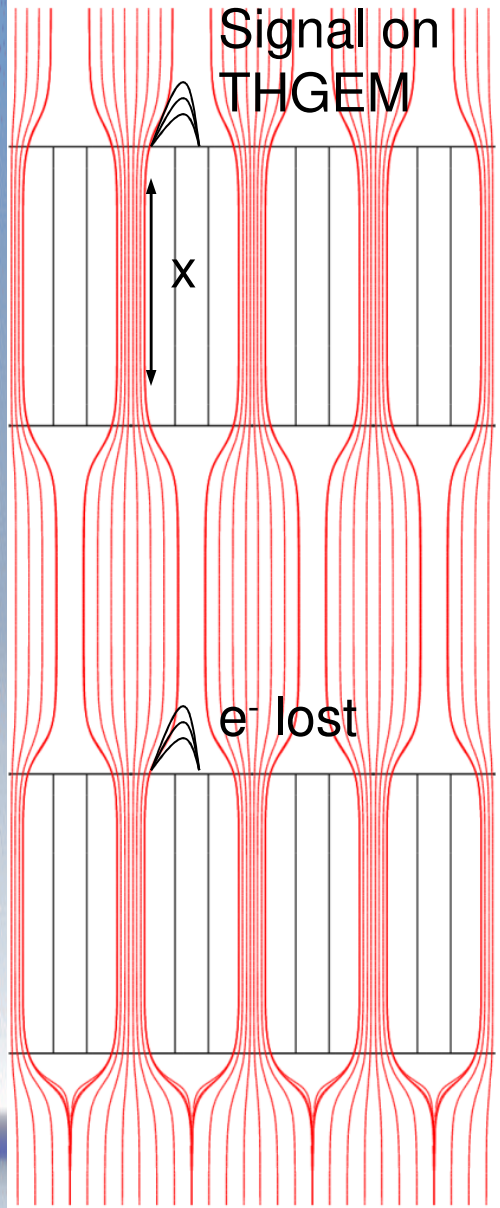
Multiplied charge induces signals on the segmented electrodes of top THGEM and anode.

e^- undergo multiplication in double stage THGEM.

e^- are extracted to the vapour via extraction grids (E_{liq} > 2.5 kV/cm)

Free e^- drift in LAr towards liquid-vapour interface

Effective gain and transparency



• Townsend multiplication mechanism $G = e^{\alpha x}$, $\alpha = Ape^{-Bp/E}$, x=1 mm (1.6 mm THGEM)

• Double stage of multiplication: increase the gain maintaining low fields in each THGEM.

$$G_{THGEM1} G_{THGEM2} = G_{THGEM}^2 = e^{2\alpha x}$$

$$\mathbf{G_{eff} = \varepsilon_{ex}\, G_{THGEM1} T_{THGEM1}\, G_{THGEM2} T_{THGEM2}}$$

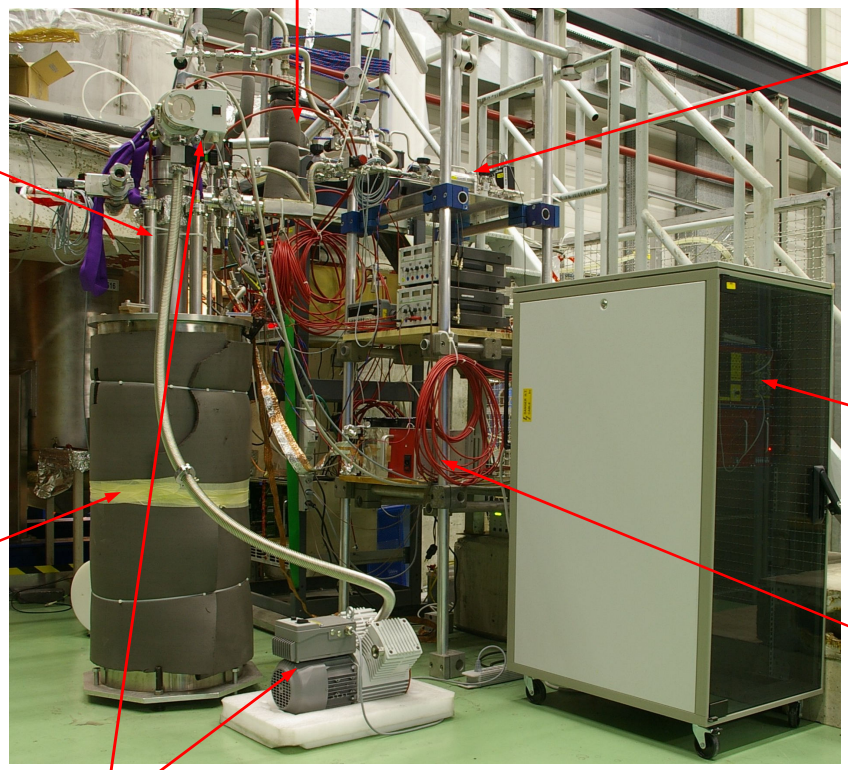
Electron diffusion in GAr -> $T_{THGEM} < 100\%$

Signal on the anode $\propto \varepsilon_{ex}\, T_{THGEM1}\, T_{THGEM2}$

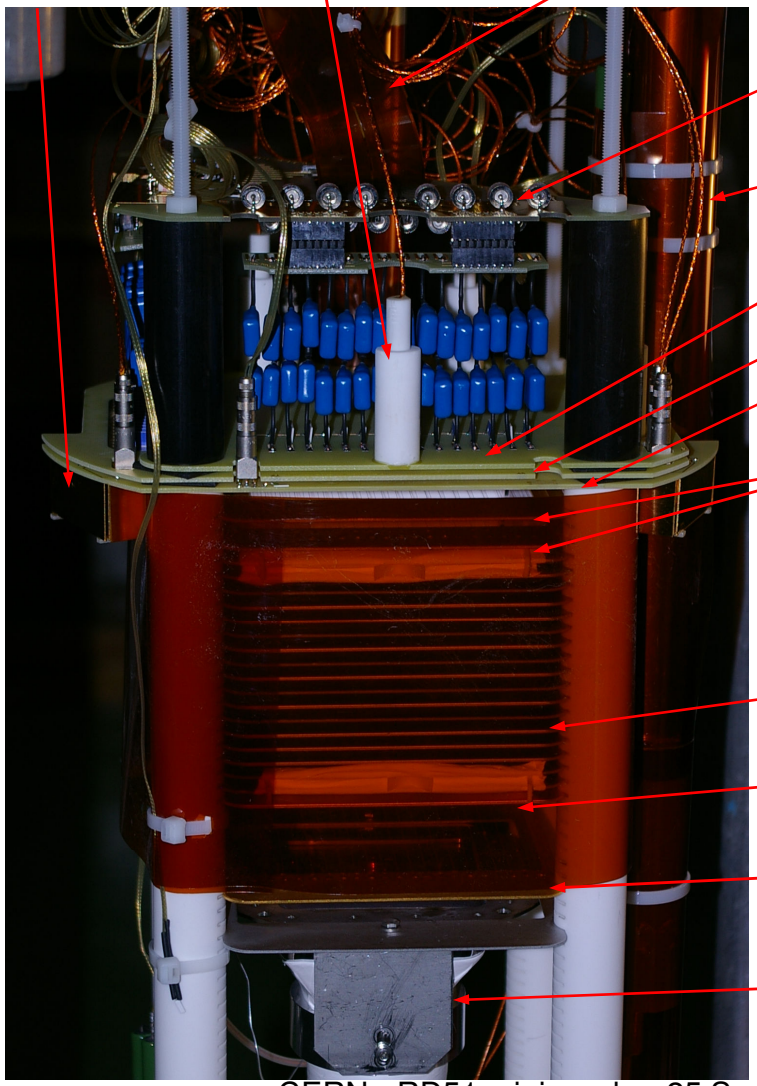
Signal on THGEM $\propto \varepsilon_{ex}\, T_{THGEM1}\, (1-T_{THGEM2})$

Optimization:
ε_{ex} and $T_{THGEM1} = 100\%$
$T_{THGEM2} = 50\%$

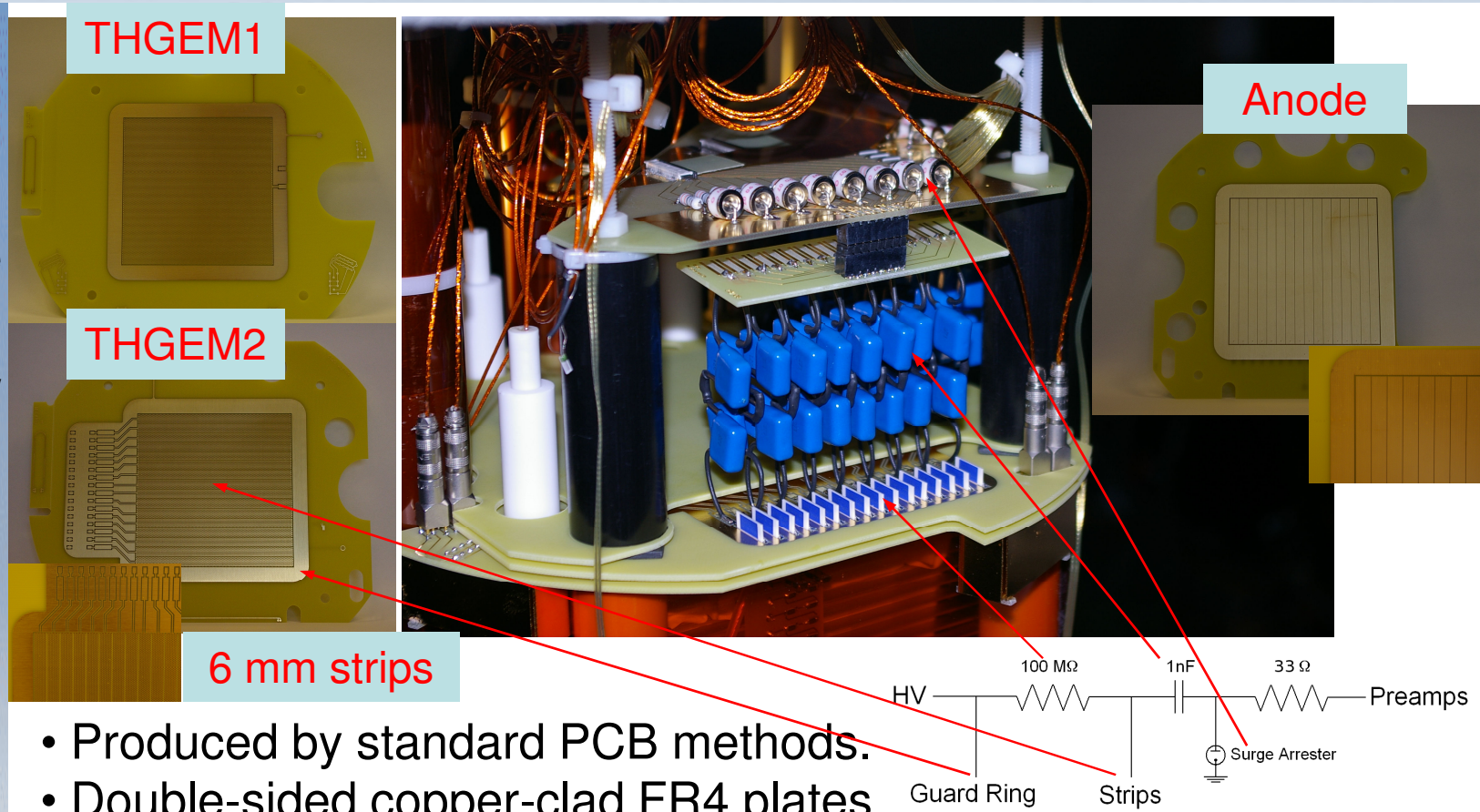
Setup overview



THGEM-TPC in detail



Double stage THGEM with anode

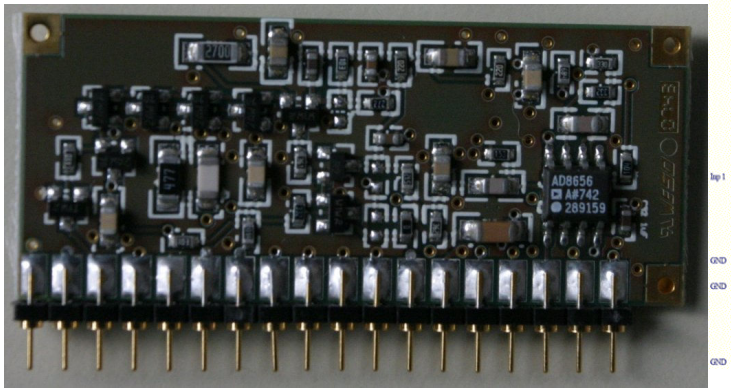


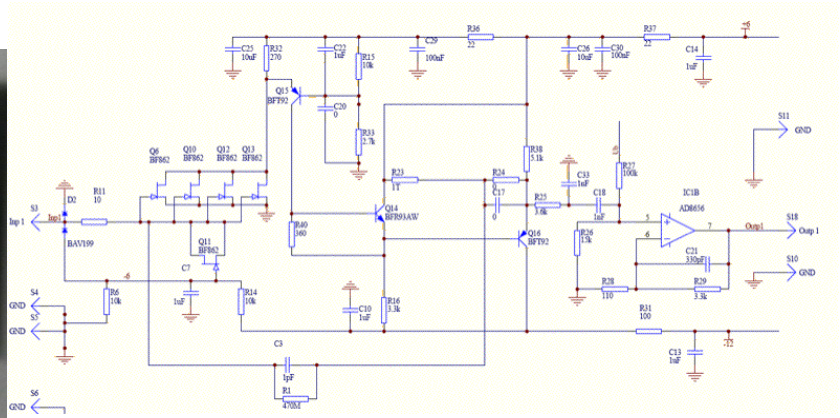
- Produced by standard PCB methods.
- Double-sided copper-clad FR4 plates.
- Precision holes by drilling.
- Thickness: 1.6 mm.
- Amplification hole diameter: 500 μm.
- Distance between centers of neighbouring holes: 800 μm.
- Segmented anode and THGEM2 top plane: 2x16 strips 6 mm wide.

Readout electronics

Novel complete readout system developed in collaboration with CAEN

- 12 bit 2.5 MS/s flash ADC's
- Programmable FPGA
- Channel-by-channel trigger and global "trigger alert".
- 256 channel crate.
- Modular system (chainable optical link)

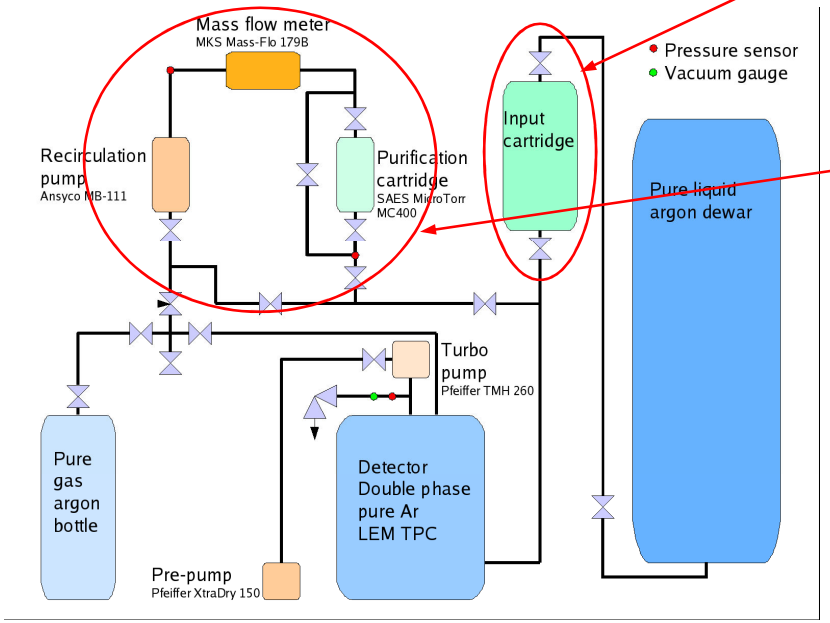




Inspired by C. Boiano et al. IEEE Trans. Nucl. Sci. 52 (2004) 1931

- Custom made front-end preamp + shaper
- Preamplifier: RC=470 us, sensitivity=12 mV/fC
- Shaper: rise time 0.6 μs, fall time 2 μs

Argon purification

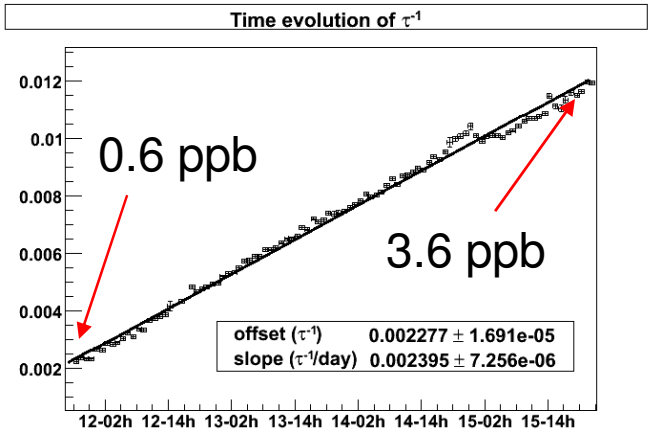


Input LAr purification

- Custom made cartridge for LAr purification at detector input.

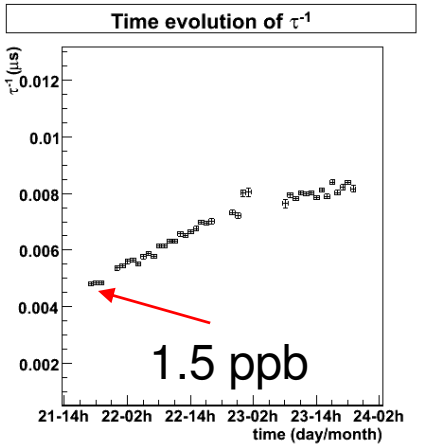
GAr purification circuit

- Heating resistors evaporate LAr in the detector.
- A metal bellows pump pushes GAr into a flow meter and SAES getter (~48h to recirculate 1 volume).
- Purified GAr condensates into the detector volume.



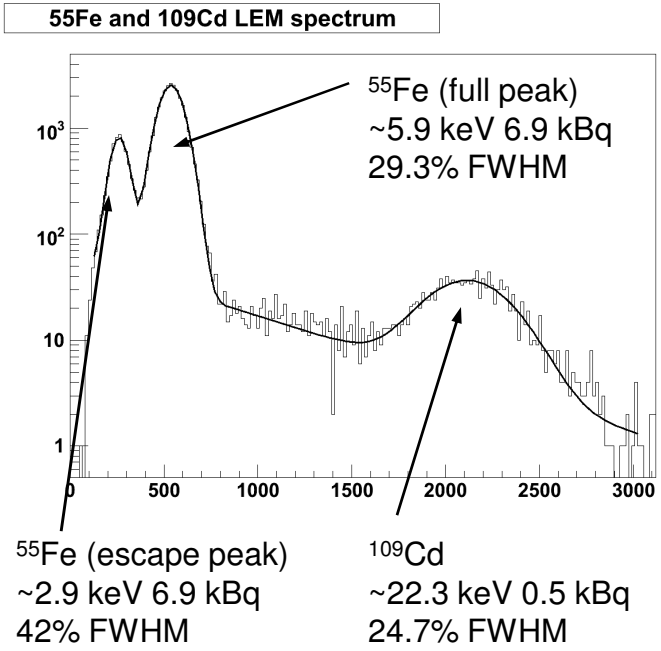
Purification

5 days



Operation in pure gas argon

Pure argon gas operation, room temperature, 1.2 bar.



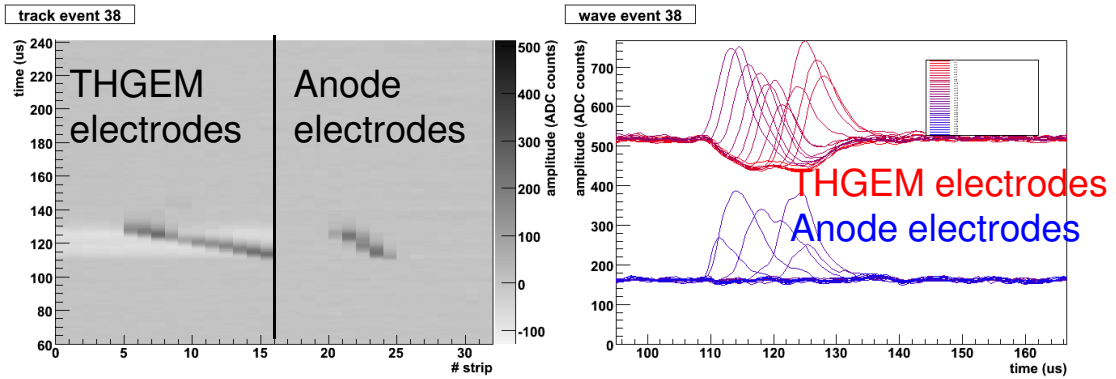
^{55}Fe and ^{109}Cd sources positioned below the cathode grid.

Deposited energy is proportional to the sum of the involved strips.

Both anode and THGEM signals can be used for the energy evaluation.

effective gain ~ 1000

Typical cosmic muon track

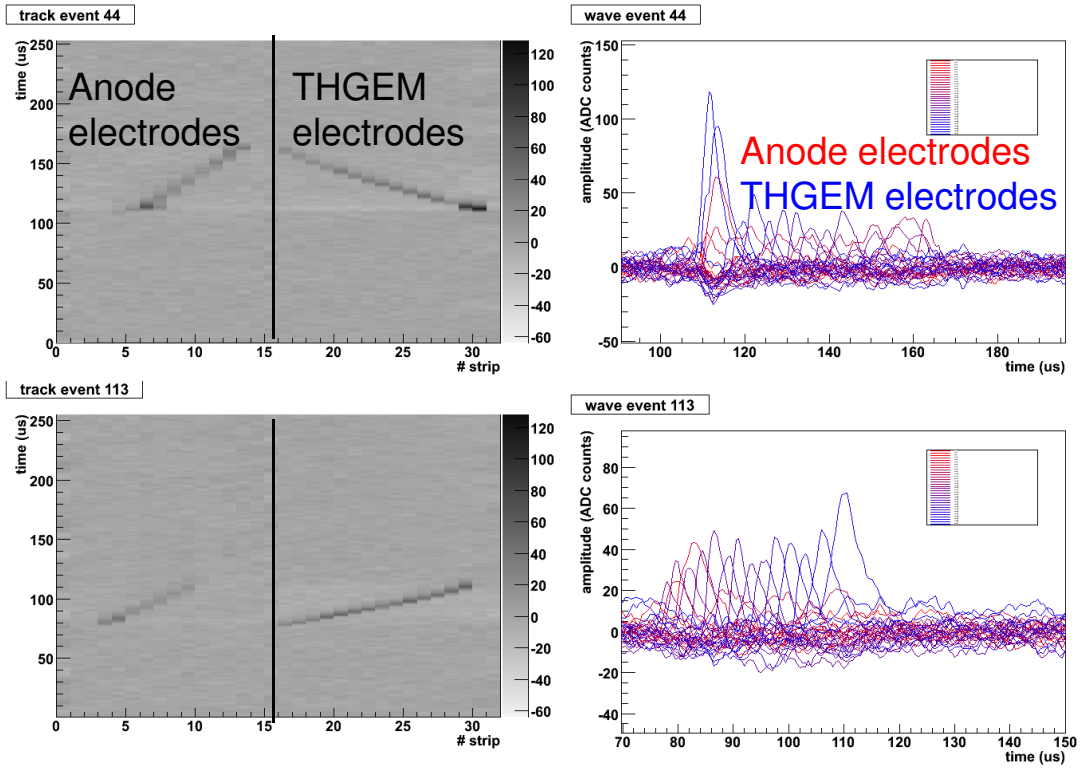


Operation in liquid Argon

THGEM-TPC can be operated with the THGEM's completely immersed in LAr without charge amplification.

Transparency test of THGEM's

- Gain = 1
- Noise reduction via digital filter
- S/N ≈ 80/5

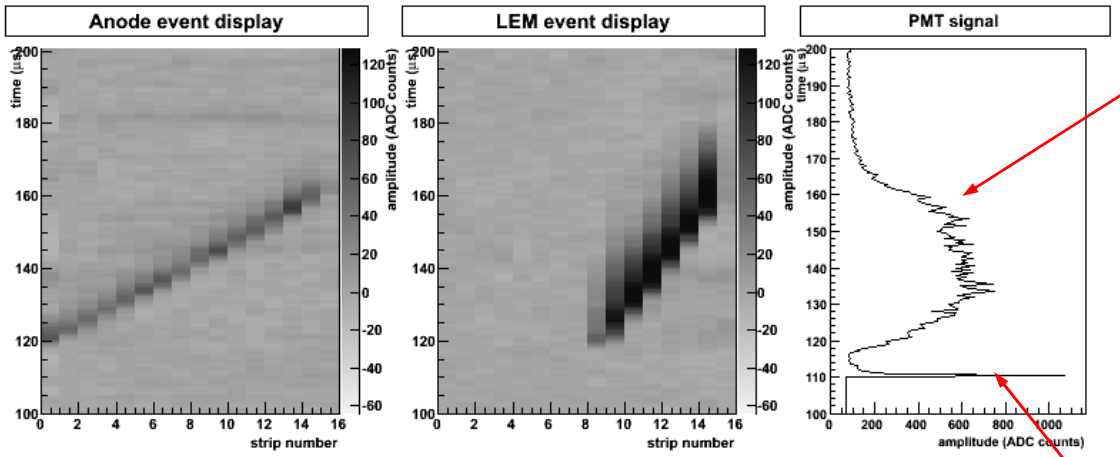


Operation in double phase (I)

Charge multiplication occurs in argon vapour:
87 K, 1 bar, ~3.4 denser than at STP.

	E (kV/cm)
Anode $THGEM_2$	1.8
$THGEM_2$	~23
$THGEM_2$ $THGEM_1$	1.3
$THGEM_1$	~23
Drift	0.6

- Trigger on PMT signal, ~4-6 Hz,
- Signals produced by cosmic rays used to estimate purity and gain



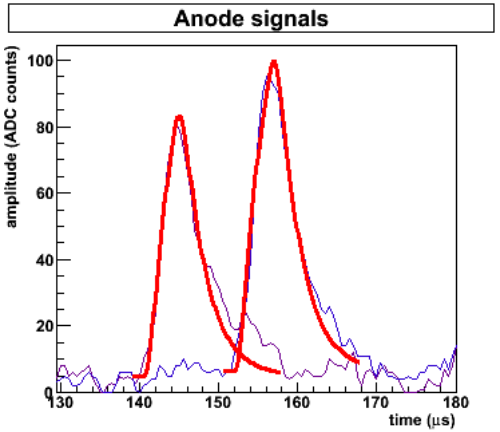
Secondary light: produced by electrons in high field regions in gas (extraction grid, THGEM holes)

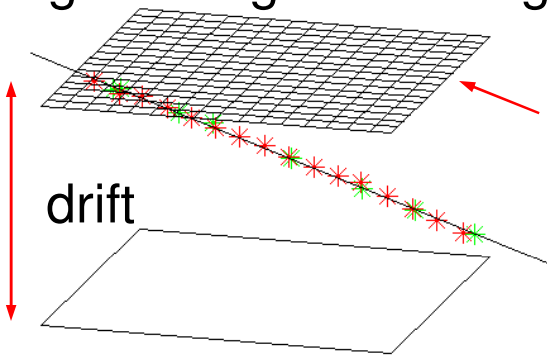
Scintillation light: primary light due to muon crossing LAr

Operation in double phase (II)

Induced signals fitted with preamp response function:

- Start of signal -> z coordinate/drift
- Signal integral -> charge reconstruction

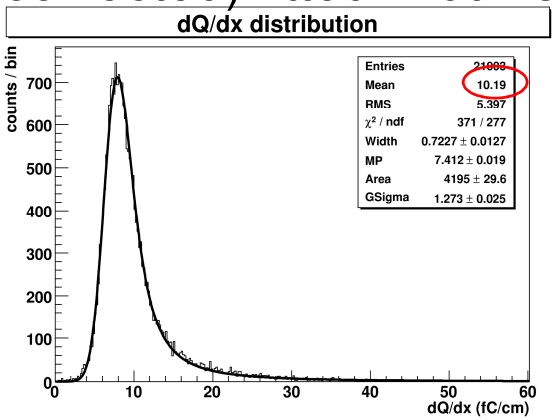




LAr-GAr interface plane

3D reconstruction of an inclined long muon track

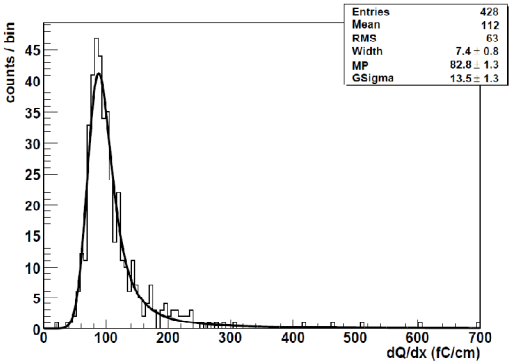
Distribution of the energy loss per unit path length (e^- lifetime corrected) fitted width Gauss convoluted Landau distribution



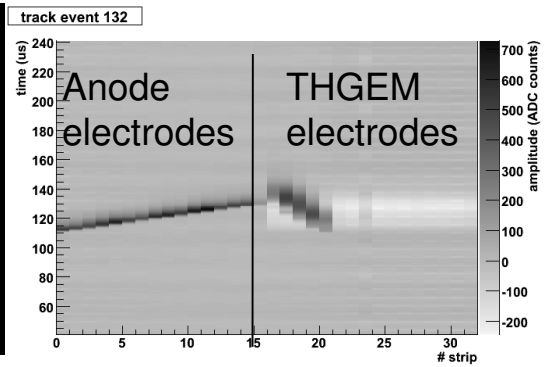
- MIP muon releases 2.1 MeV/cm
- Drift field 0.5-1 kV/cm -> ~10 fC/cm
- estimated effective Gain (anode): 1
- MP ≈ 7.4 fC/cm
- sigma ≈ 1.3 fC/cm
- resolution ≈ 13%

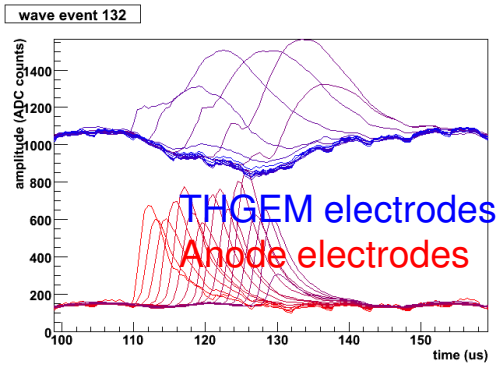
Operation in double phase (III)

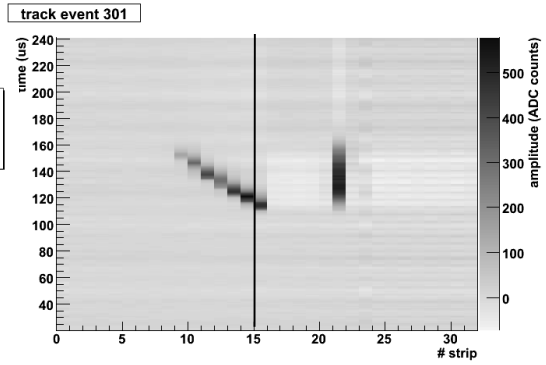
	E (kV/cm)
Anode $THGEM_2$	2.1
$THGEM_2$	~26
$THGEM_2$-$THGEM_1$	1.5
$THGEM_1$	~26
Drift	0.7

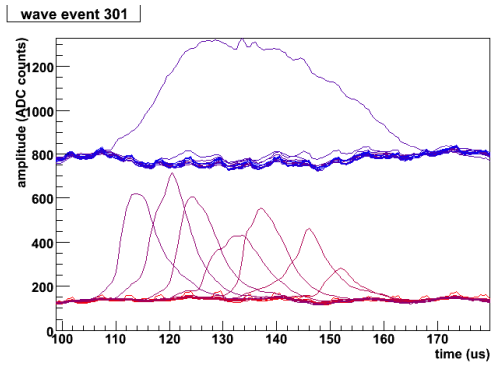


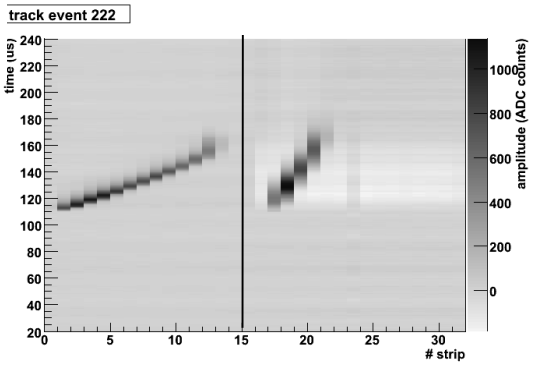
- Effective gain ~10
- Raw images
- S/N ≈ 800/10

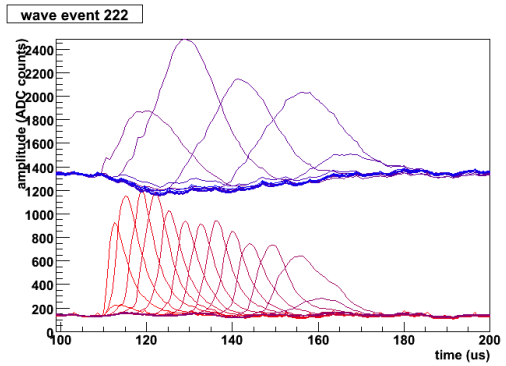








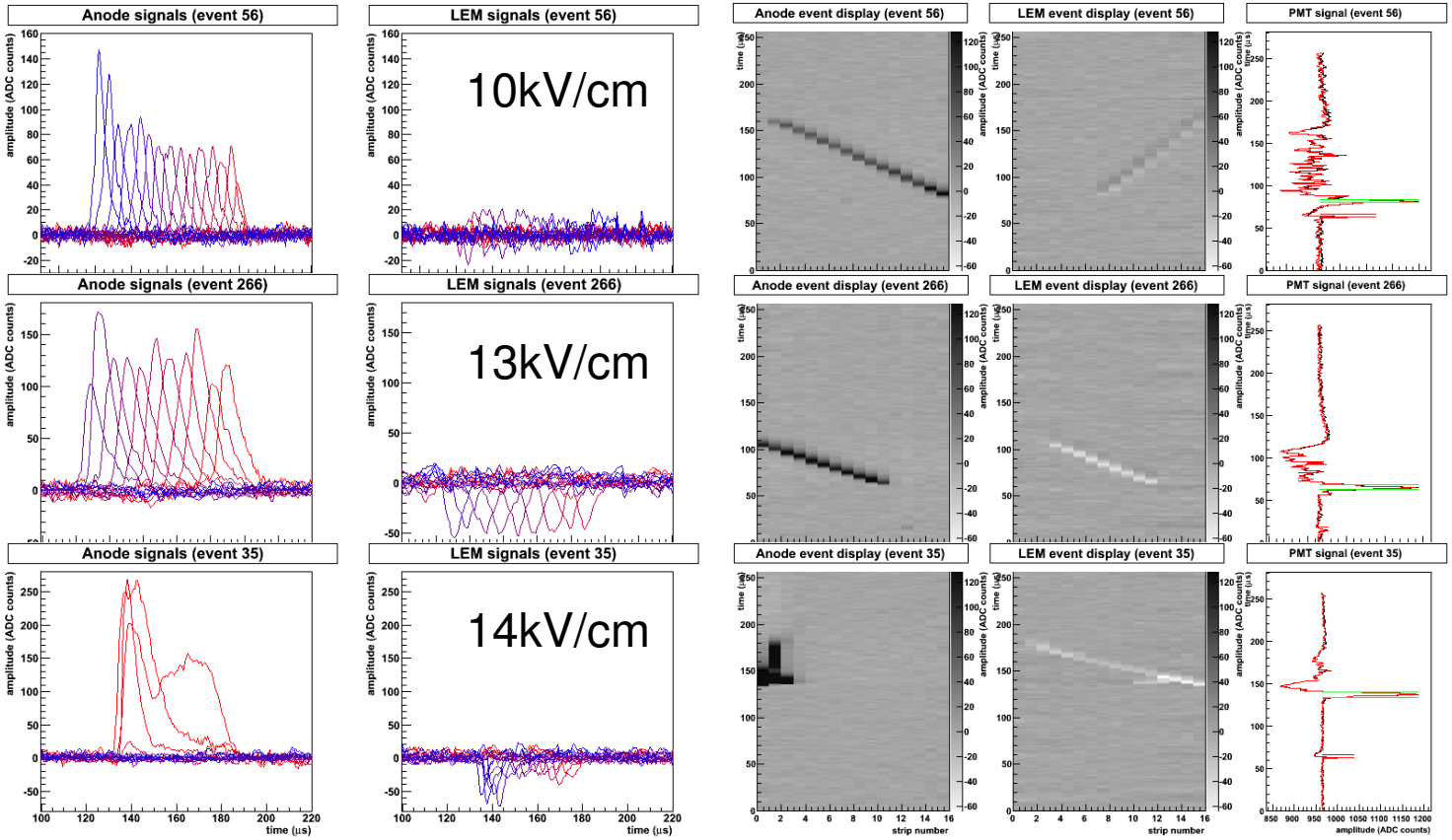




Single stage 1 mm THGEM (I)

1.6 mm THGEM's replaced by single stage 1 mm THGEM:
- Test of a THGEM with different thickness
- Further characterization of the device (reduced complexity)

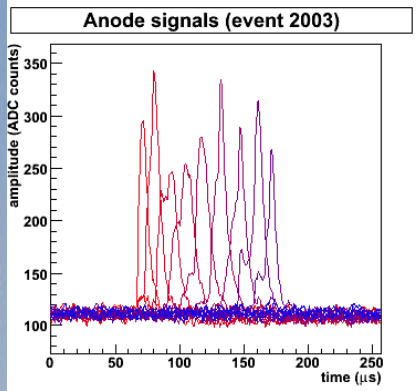
Variation of the transfer field between THGEM and anode:

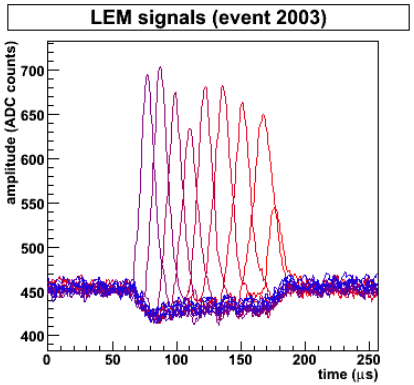


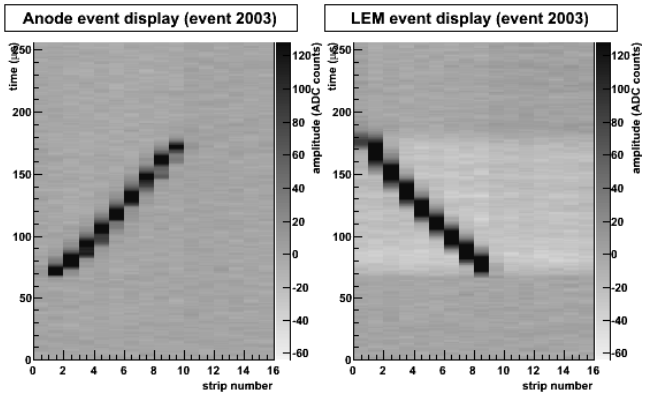
Single stage 1 mm THGEM (II)

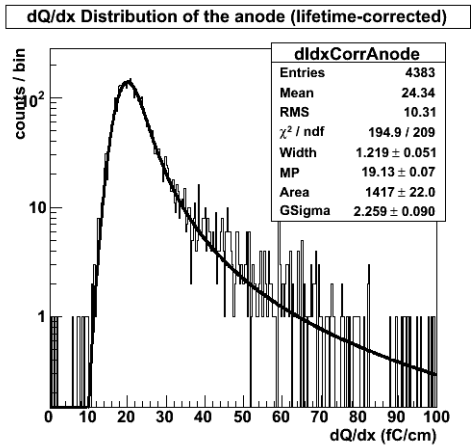
Test of different THGEM's in air:
- cleaning process (could increase voltage after some sparks)
- selection of "good" THGEM's (quality control)

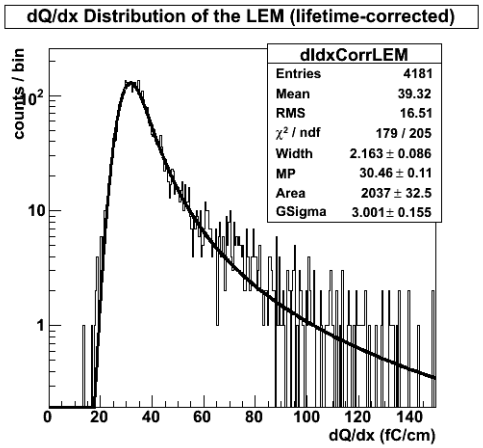
Preliminary results (36 kV/cm across the THGEM):

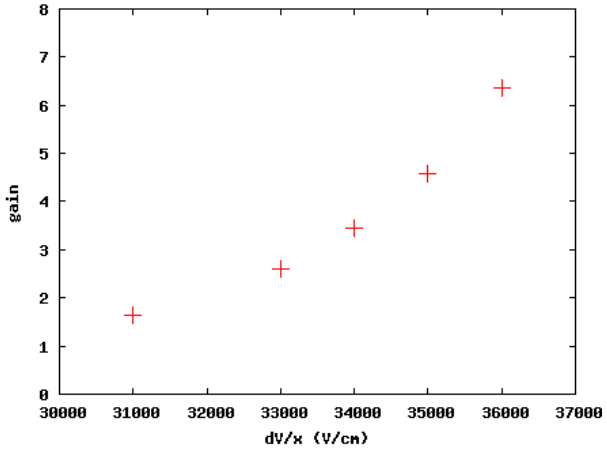












Total mean value = 64 fC/cm ⟹ gain ~ 6

Conclusions

Successful construction of a double phase pure Argon THGEM-TPC tracking and calorimetric device

Development of Readout Electronics (in collaboration with CAEN)

THGEM-TPC working in

- warm Gar: reached gain 1'000
- single phase LAr: mip tracks recorded
- double phase:
  - electrons drift 20 cm (good purity < 0.5 ppb after filling)
  - extraction and amplification works (gain 10)
  - tested double stage 1.6 mm THGEM and single stage 1 mm THGEM in double phase configuration

Outlook:

Ongoing characterization of 3 lt THGEM-TPC (single stage):

- increasing gain, study of discharges
- long term stability test

Construct 6 m^3 THGEM-TPC with strip width < 3mm.