Single or double?
Liquid detectors at a crossroads

Vitaly Chepel

For LXe R&D group

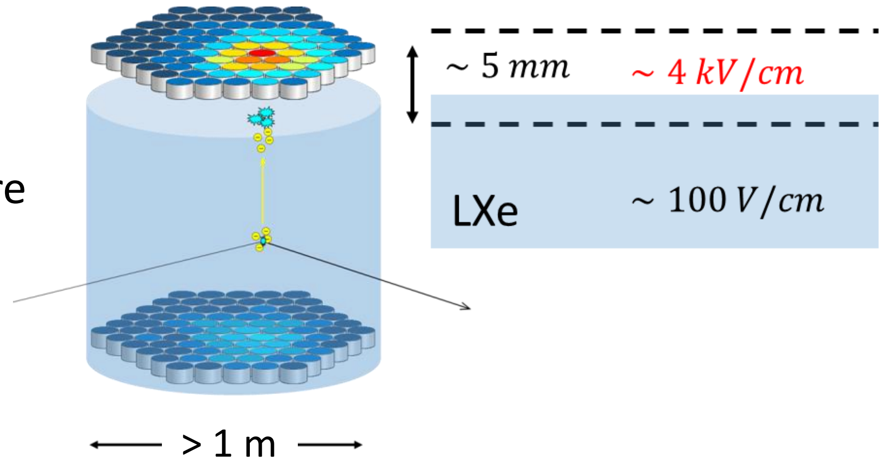
Motivation

Two-phase liquid detectors are probably the most versatile detectors for low energies and rare events

Liquid surface – inconvenient but worth of suffering (at least it was until now)

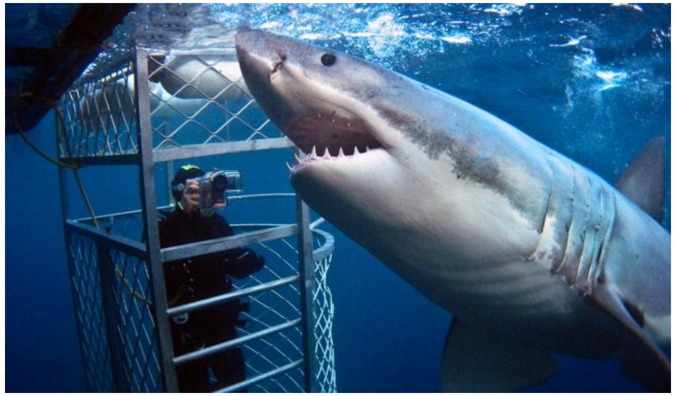
Problems associated with it:

- Should be in a strong E field for electron extraction → between two multiwire electrodes at ~5 mm between them → **wire sagging**
- Undersurface charge drift/diffusion
- Possible ripples, acoustic effects, instabilities in a strong E field



The bigger the detector the bigger the problem

Alternatives: dive or float



"No surface, no problem" – back to single (liquid) phase.

" We are one" – Electrodes & surface – floating electrodes:

Outline

1. **Our efforts on development of floating electrodes**

2. **Single phase: Work on electroluminescence in liquid xenon**

   a) **Light on narrow strips of a Microstrip plate (base for MSGC – microstrip gas chamber)**

   b) **Light on narrow strips of a VCC – Virtual Cathode Chamber**

Collaboration: LIP and Weizmann Institute of Science

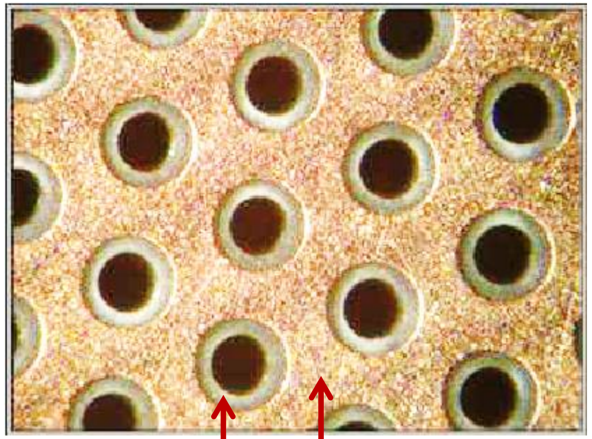
1. Floating electrodes – THGEM

LXe density **2.9** g/cm3

FR4 density **2.0±0.2** g/cm3 - dielectric material used to make THGEM

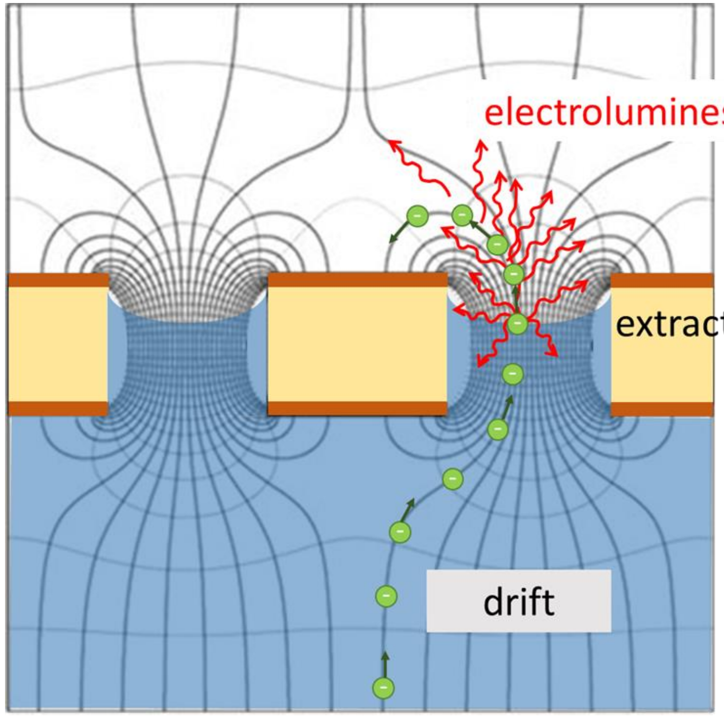
If copper cladding is not too heavy → THGEM **should float** on the surface of LXe

THGEM

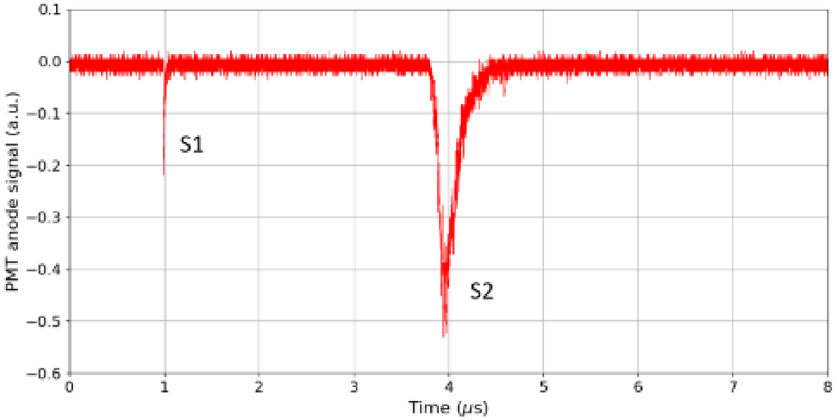


0.4 mm holes

FR4 copper



α −source



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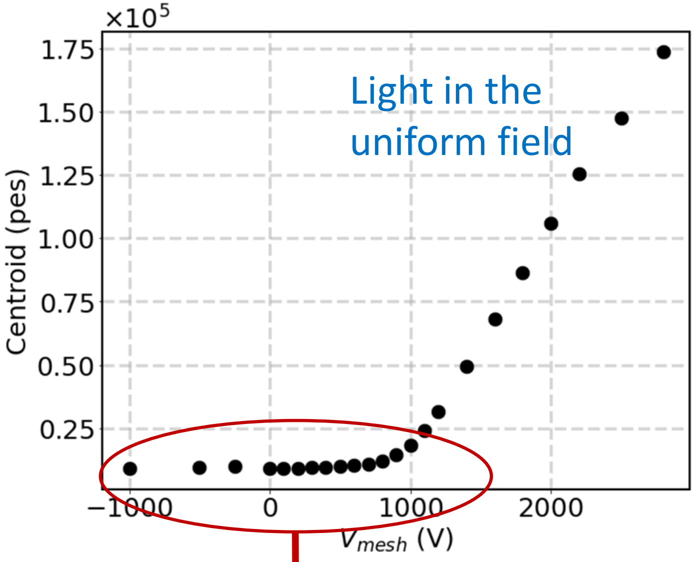
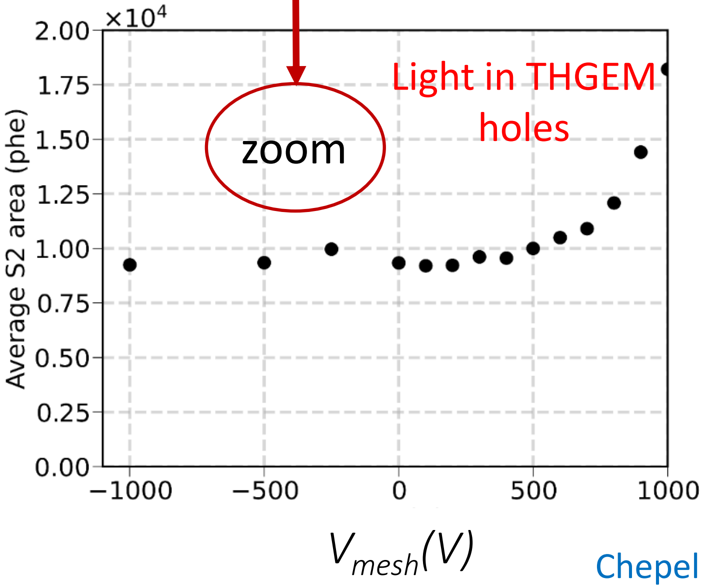
1. Floating electrodes – devil in details





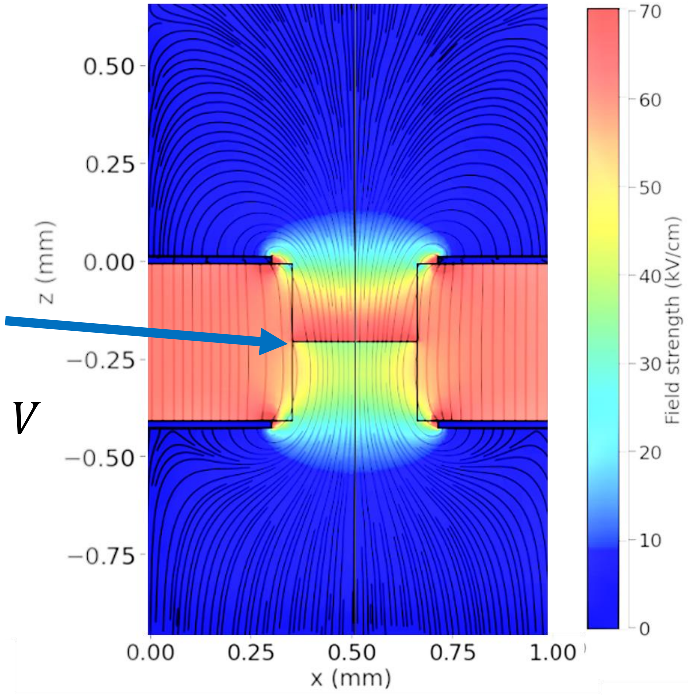
COMSOL:

$$\Delta V_{extr} = 0$$

Assumed LXe level

$$\Delta V_{THGEM} = 2500\ V$$

$$\Delta V_{drift} = 400\ V$$



Fields near the interface:

$$E_{gas} \sim 70\,\frac{kV}{cm}$$

$$E_{liq} \sim 40\,\frac{kV}{cm}$$

Generated in the hole:

~1 phe/drifting electron

~20-50 ph/drifting electron in 4π

Not impressive…

LXe in the hole: is it really like this?

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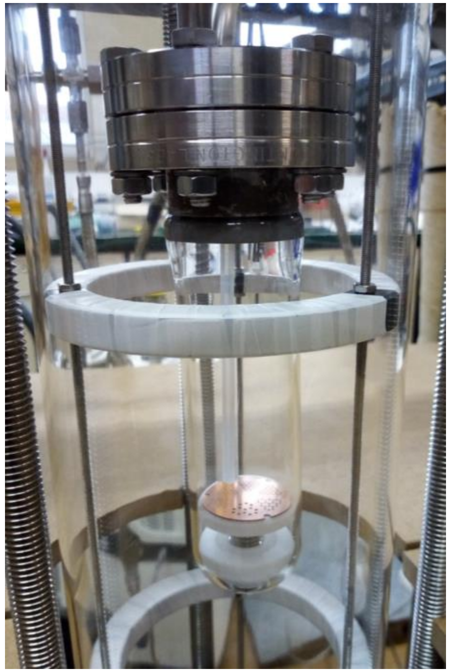
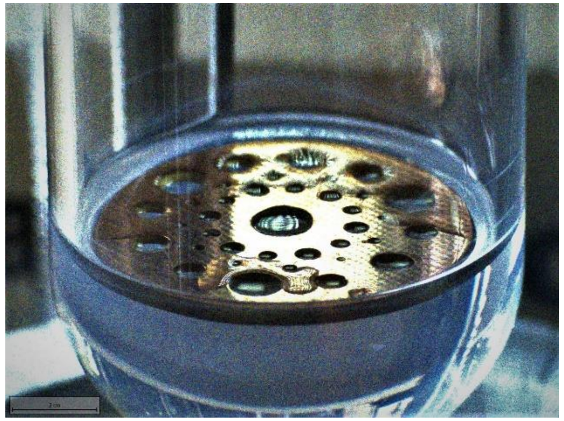
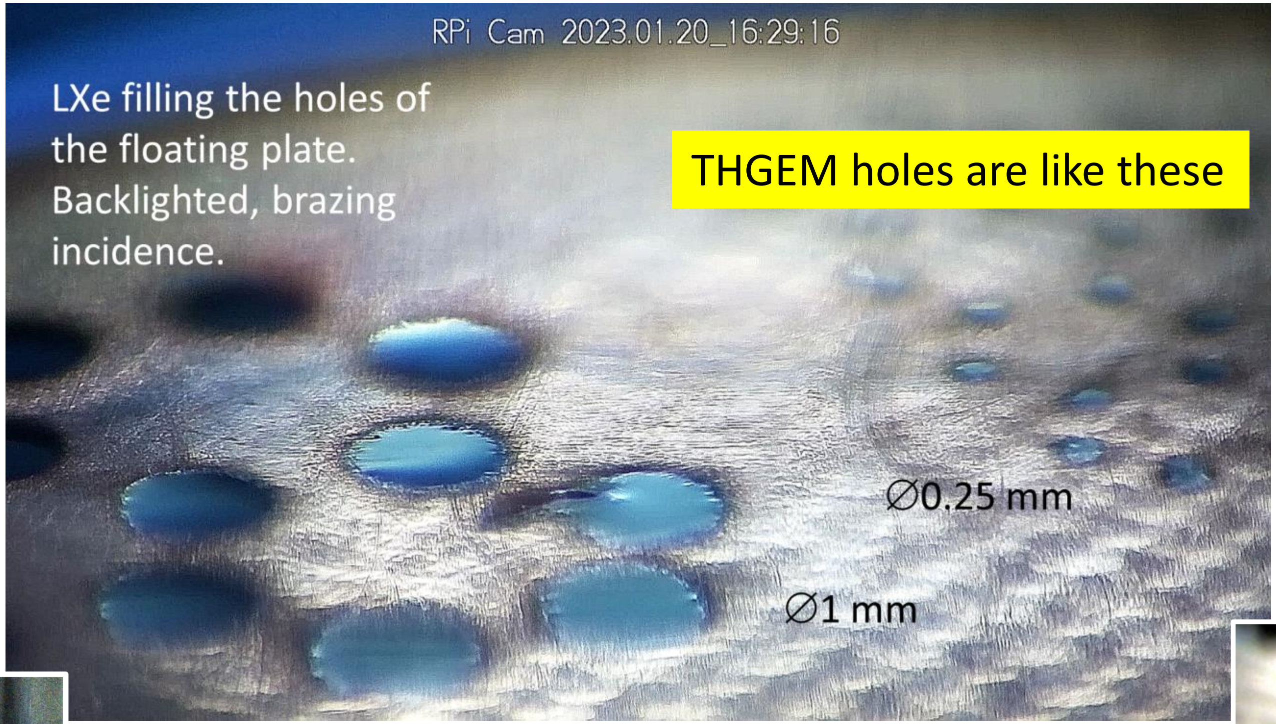
1. Floating electrodes – devil in details





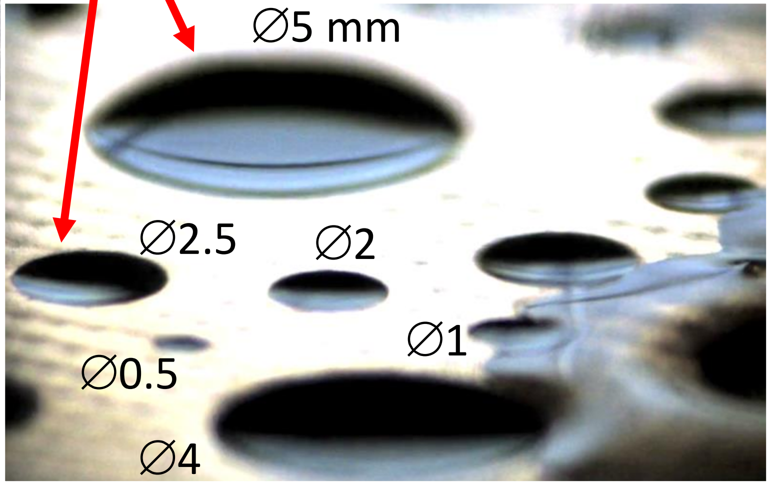


No space for gas in the hole even for ∅1 mm

Thicker plate with bigger holes:

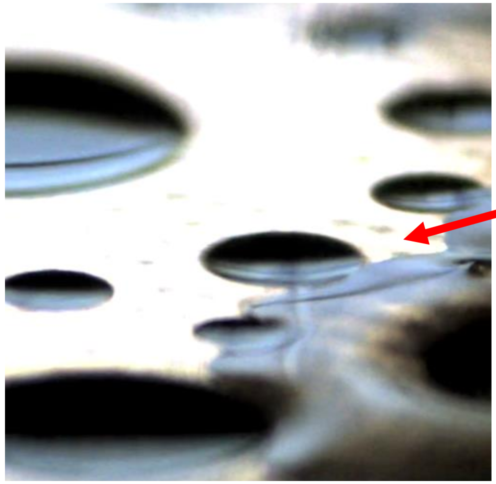
Meniscus

FR4 1.6mm thick



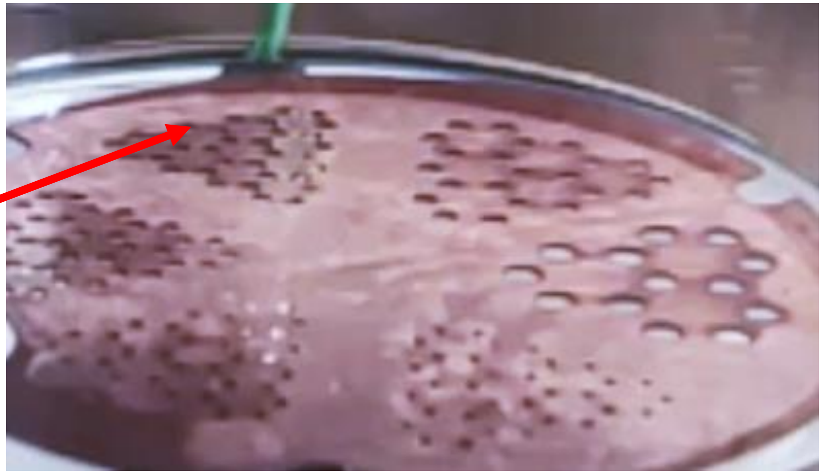
1. Floating electrodes – wettability studies (ongoing)

Wettability of copper

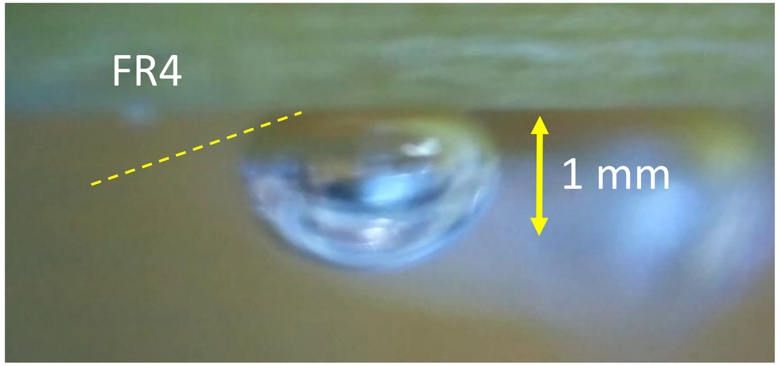


polished

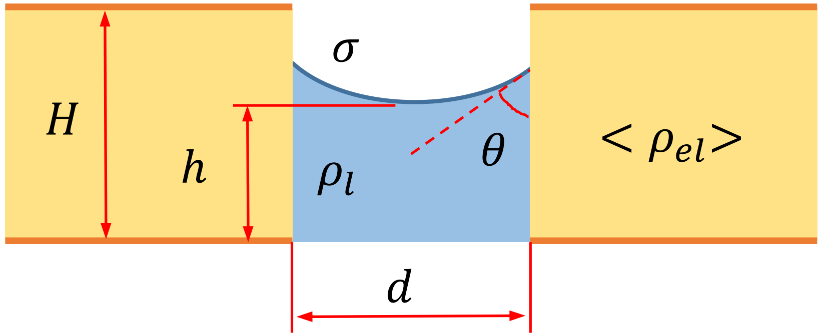
etched



Xe gas bubble in LXe showing high wettability of FR4 by LXe:



Modelling is crutial – COMSOL badly needed

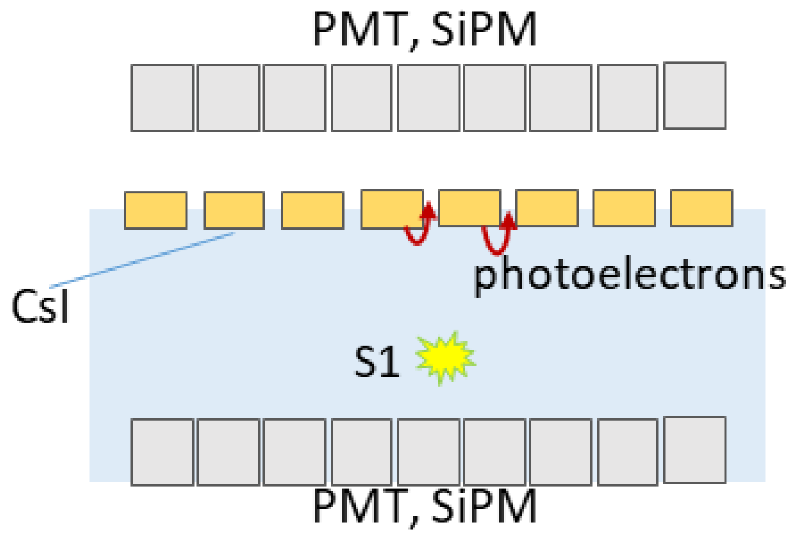


$$h \approx H \frac{< \rho_{el} >}{\rho_l} + \frac{4\sigma}{\rho_l g d} \cos\theta$$

1. Floating electrodes – remaining questions/further work

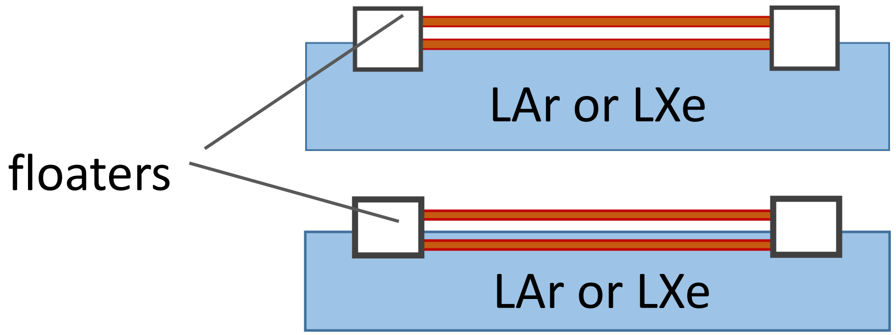
Prove of principle – successful. Open questions:

1. Opacity for VUV (S1 problem) – CsI photocathode? Quartz substrate?
2. Physics – meniscus profile, wettability, field effects, electron transmission efficiency
3. Structure optimization – thicker THGEM? Bigger holes?
4. Works in LAr (1.4 g/cm^3)?

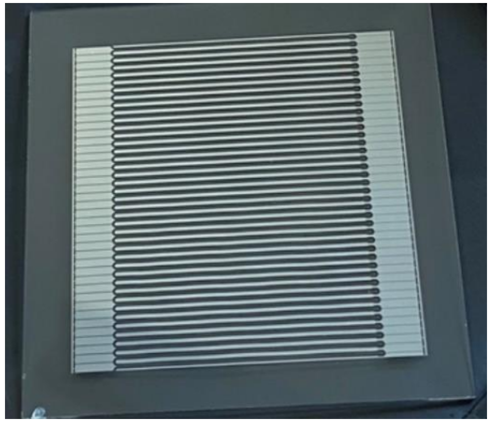


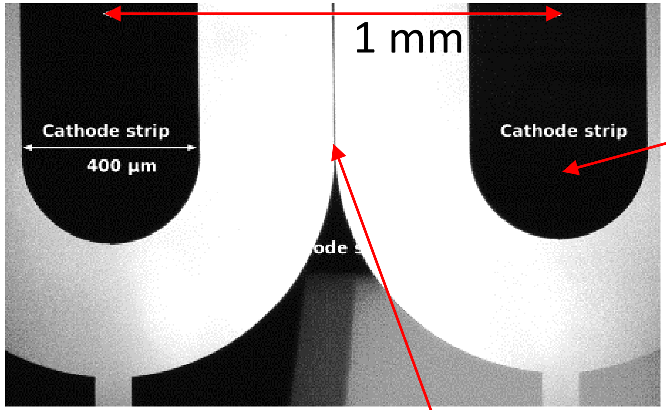
Many plastics float in LAr. The question is whether one can make a THGEM-like electrode from them.

Other possible configurations:



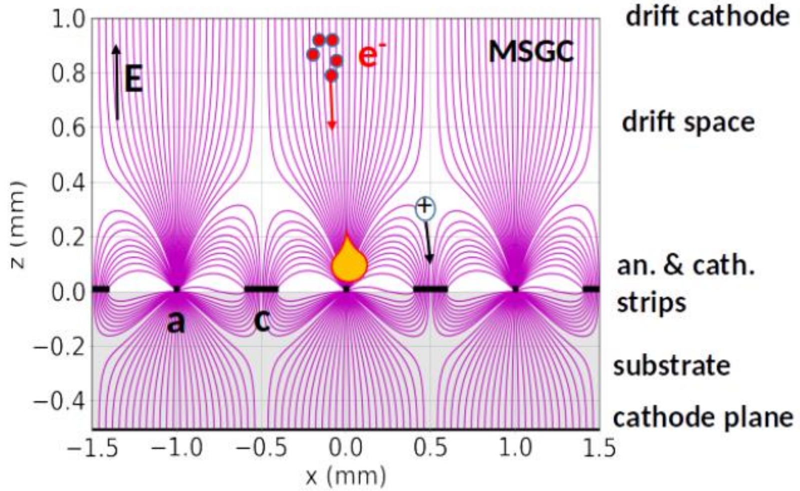
2a. Microstrip plate in LXe (WIS)





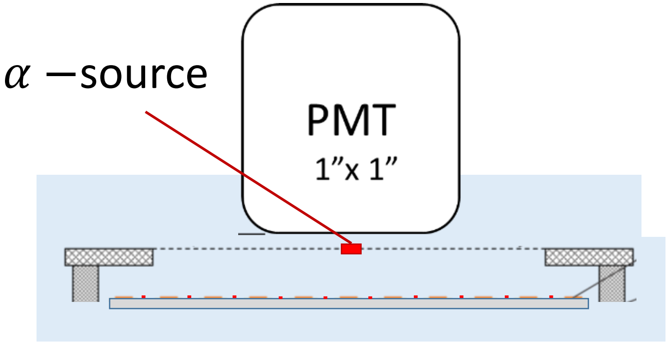
Cathode 400 μm

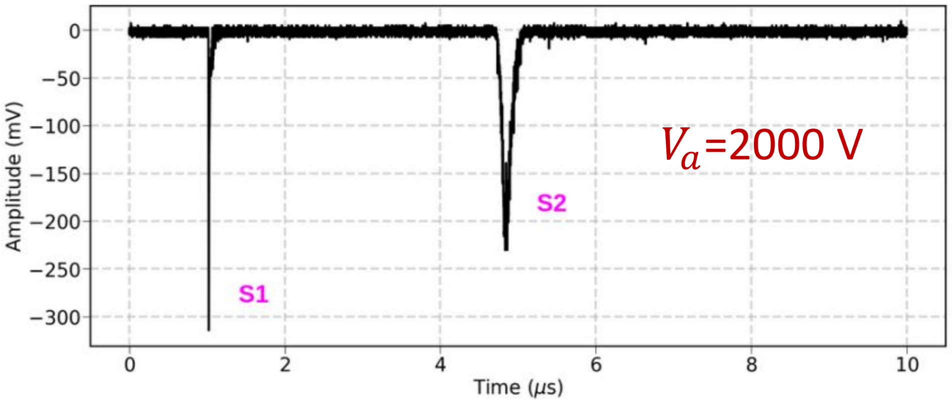
Anode 8 μm



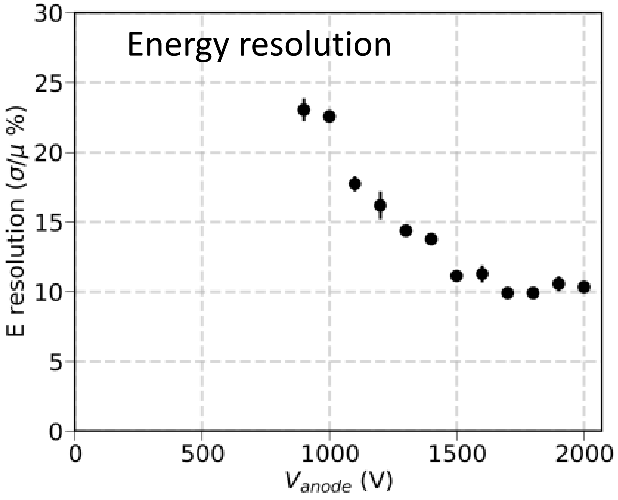
5x5 cm^2 D263 Schott glass 0.5 mm thick (same as we used to observe electron multiplication in LXe back in 1995)

Policarpo e. a. NIMA365(1995)568





35.5±2.6 VUV phot/drifting e$^-$ in 4π



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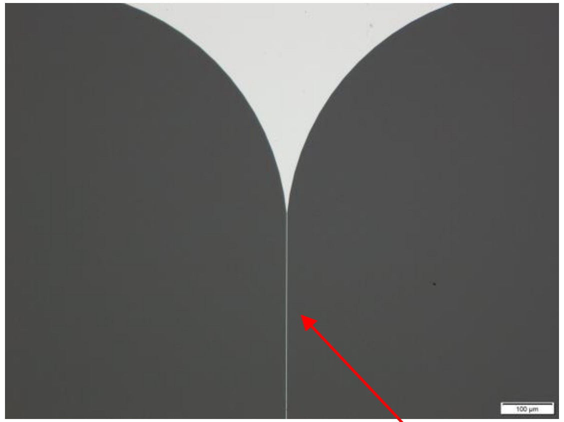
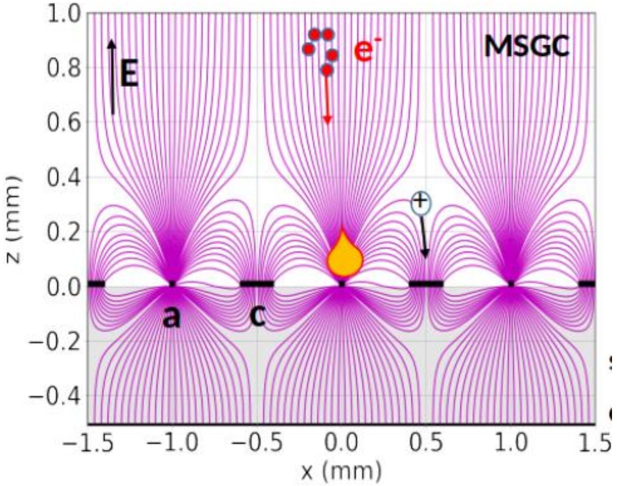
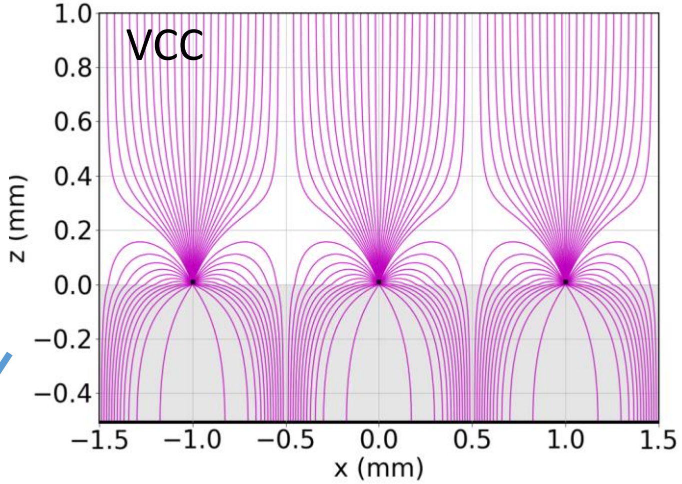
2b. Virtual Cathode Chamber (VCC) vs Microstrip plate

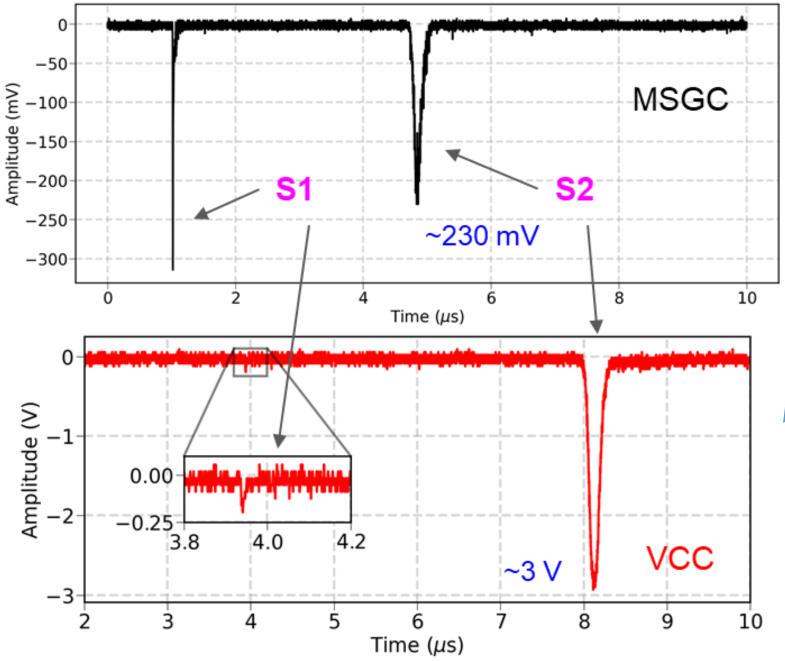
No cathode strips; **the cathode is on the other side of the plate** (Capeans e. a. NIMA400(1997)17)



anode strip (Cr) 2 μm wide







V_{source} = -2.0 kV
$V_{cathode}$ = ground
V_{back} = -2.0 kV
V_{anode} = +1.6 kV

ΔV = 1.6 kV

V_{source} = - 2.0 kV
V_{back} = - 1.75 kV
V_{anode} = +3.25 kV

ΔV = 5.0 kV

(Experiment at WIS)

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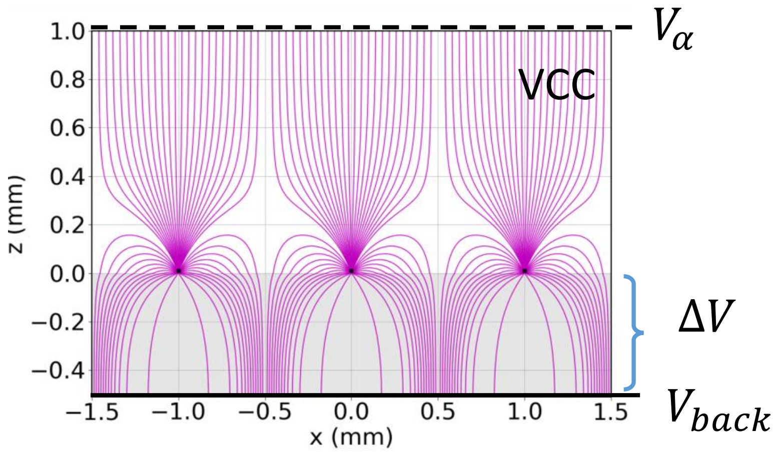
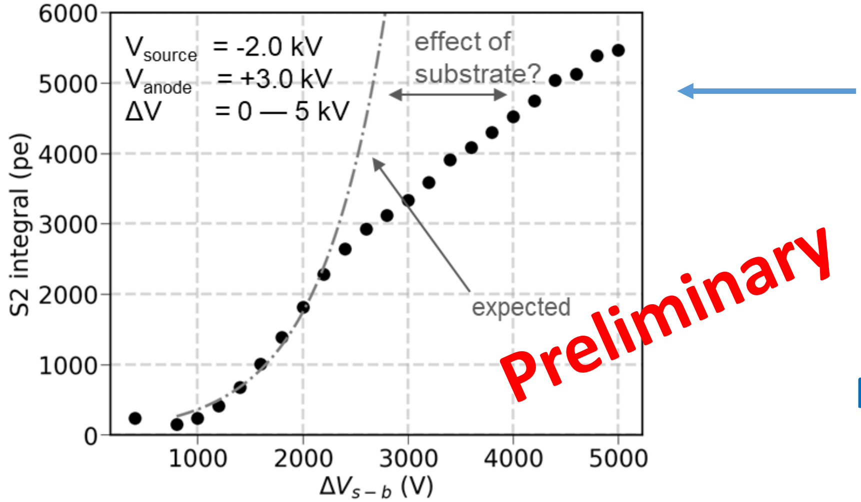
2b. VCC – who is in details, remember?





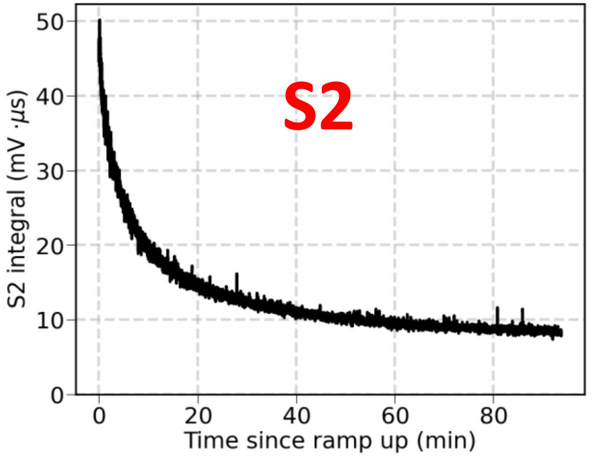
~ 30 photons/drifting e⁻

At more or less stable conditions (in small steps, after waiting a few min)

Max ~ 500 photons/electron observed

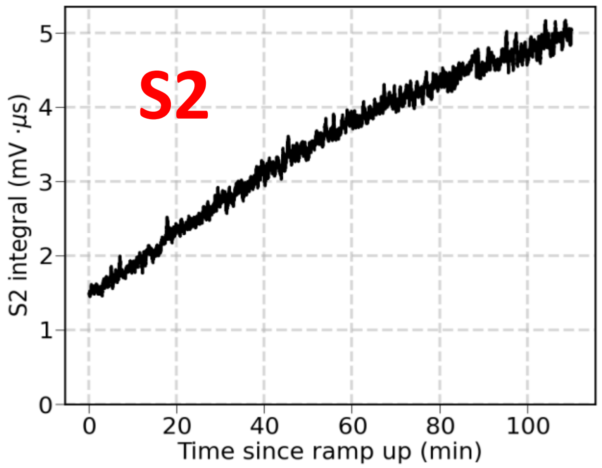
Fixed drift field $(V_\alpha - V_{back} \neq 0)$

$\Delta V = 0 \rightarrow 2\ kV\ (t = 0)$



Fixed ΔV

Drift $E = 0 \rightarrow 1.6\frac{kV}{cm}\ \ (t = 0)$



Charging up? – 40 Bq source, $G \lesssim 10$ …

Effect of glass conductivity?

$(\sim 10^{11}\ \Omega \cdot cm$ at room T, $\times 10^3 - 10^4$ in LXe)

Effect of glass polarization?

Glass – kind of Pestov black glass

One thing is clear – the substrate matters

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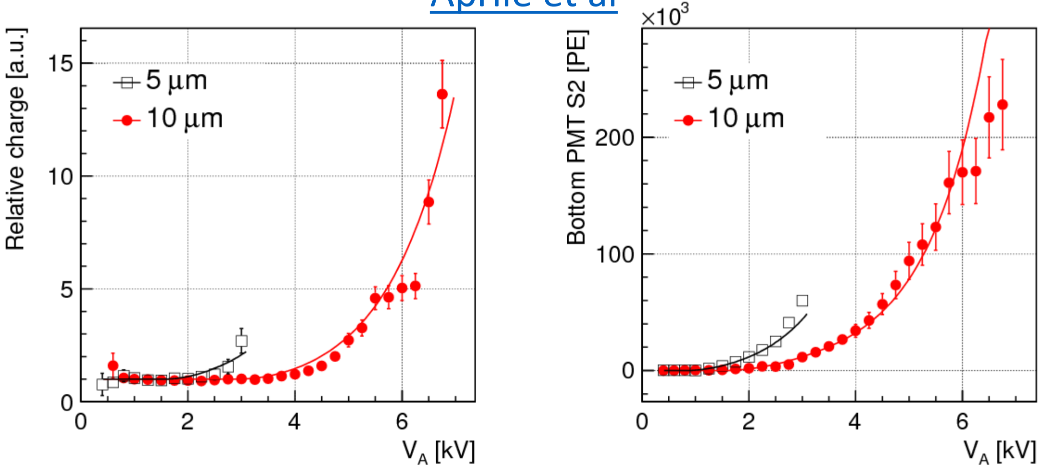
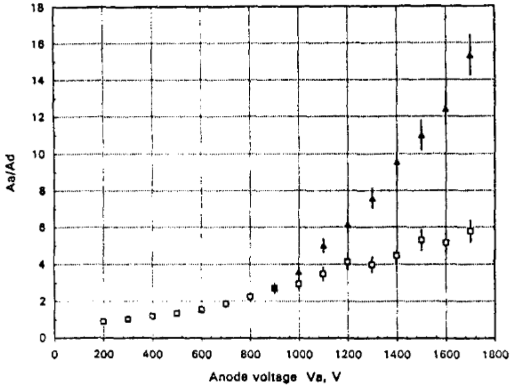
EL amplification in LXe

- Thresholds
  - Charge multiplication ~ 725 kV/cm Aprile et al
  - Electroluminiscence ~ 412 kV/cm Aprile et al
  - Microstrips measurements in agreement Martinez-Lema et al
- Thin wires (5-25 µm)
  - ~ 290 photons/ie, ~x14 charge gain @ 6.75 kV Aprile et al
  - 17 photons/ie @ 3.6 kV & single electron sensitivity Qi et al
  - 29 photons/ie @ 4.4 kV Tönnies et al
- Microstrips
  - ~x10 e^- multiplication @ 1.7 kV Policarpo et al
  - ~33 photons/ie @ 2 kV Martinez-Lema et al

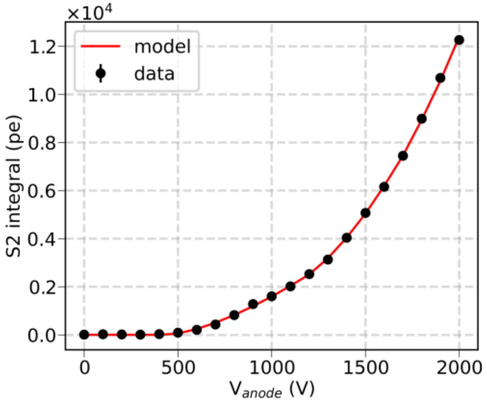
Aprile et al



Policarpo et al



Martinez-Lema et al



2. Microstrips: what next

Prove of principle – successful.

Advantage - No liquid-gas interface

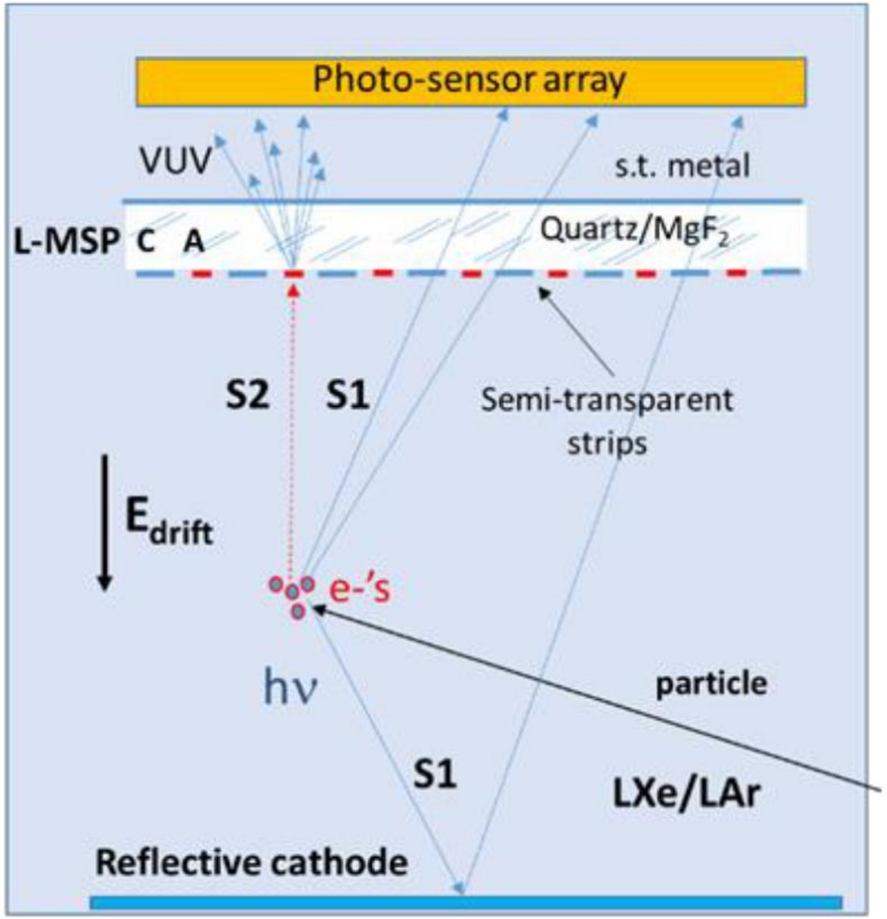
- Reduced instabilities (interface ripples)
- No delayed e^- emission or e^- transfer inefficiency through interface
- No gate-interface-anode alignment problems
- Potential improvement for S2-only events (e.g. lower background)

Drawbacks

- Electric fields ~few 100 kV/cm required for electroluminescence (EL)
- So far, lower light yield than dual-phase detectors (except VCC right after applying the voltage)

Open questions:

1. Substrate polarization/charging up/…?
2. VUV transparent substrate
3. Works in LAr ?



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