Bubble-assisted Liquid Hole-Multipliers: a local dual-phase noble liquid detector concept

E. Erdal, L. Arazi, M. L. Rappaport, D. Vartsky and A. Breskin

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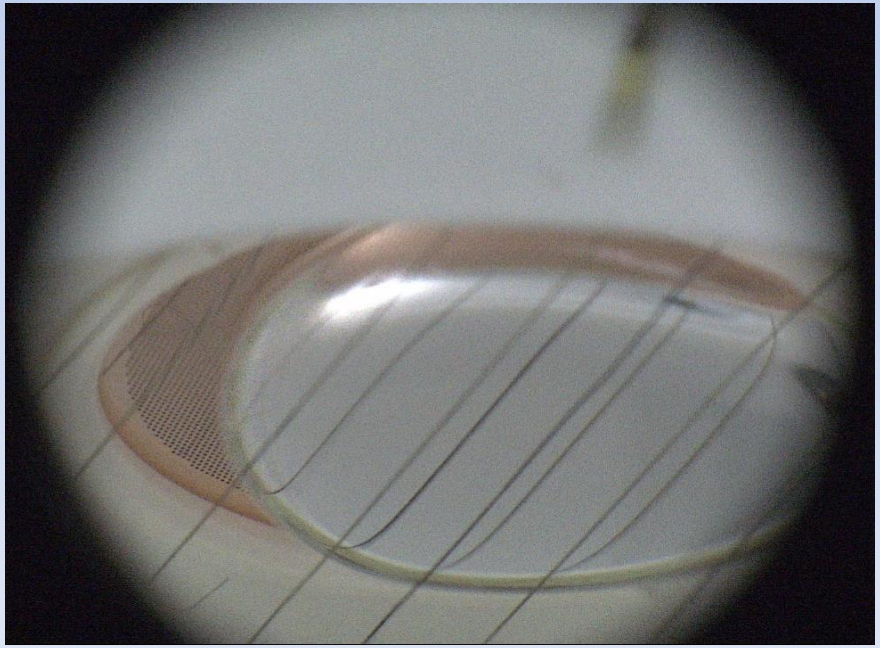
Vienna Conference on Instrumentation
February 2016



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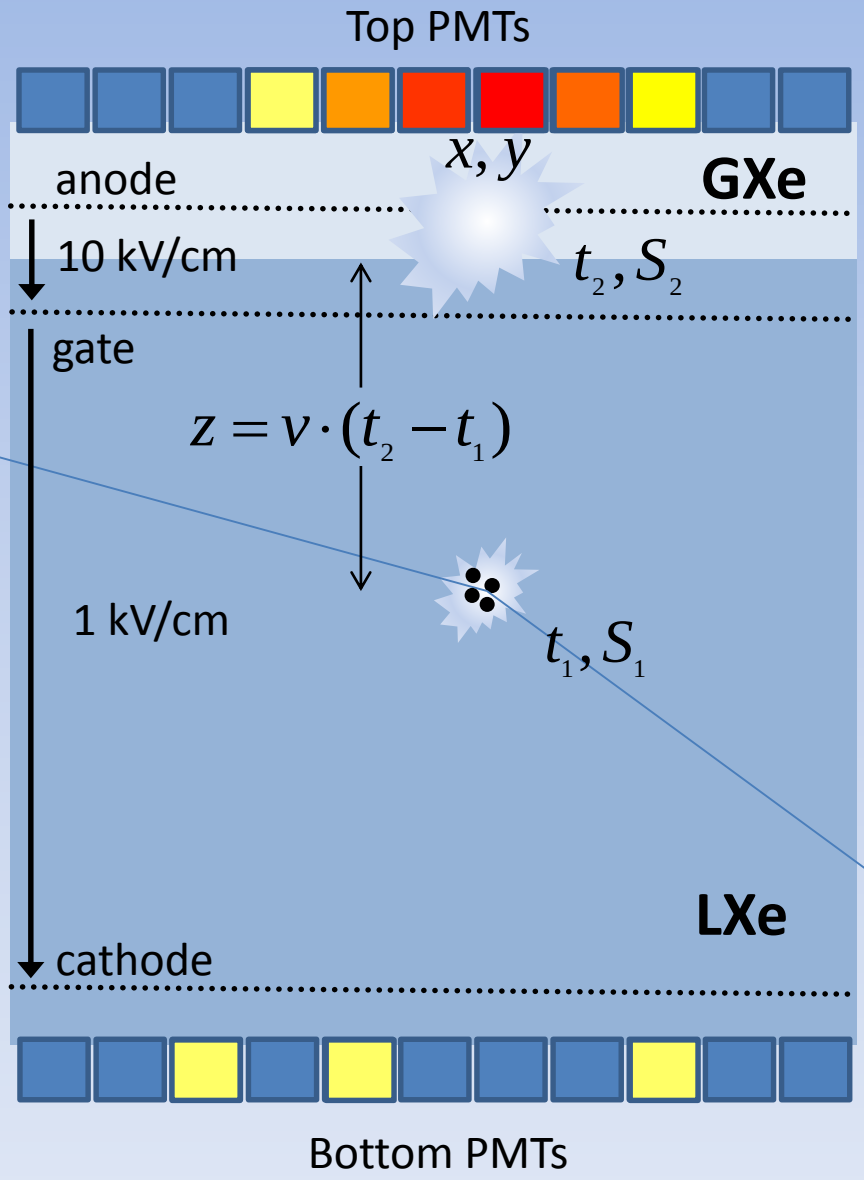
‘Classical’ dual-phase Time Projection Chamber



Hit pattern on top PMT array → *x,y*

Time difference $t_2 - t_1$ → *z*

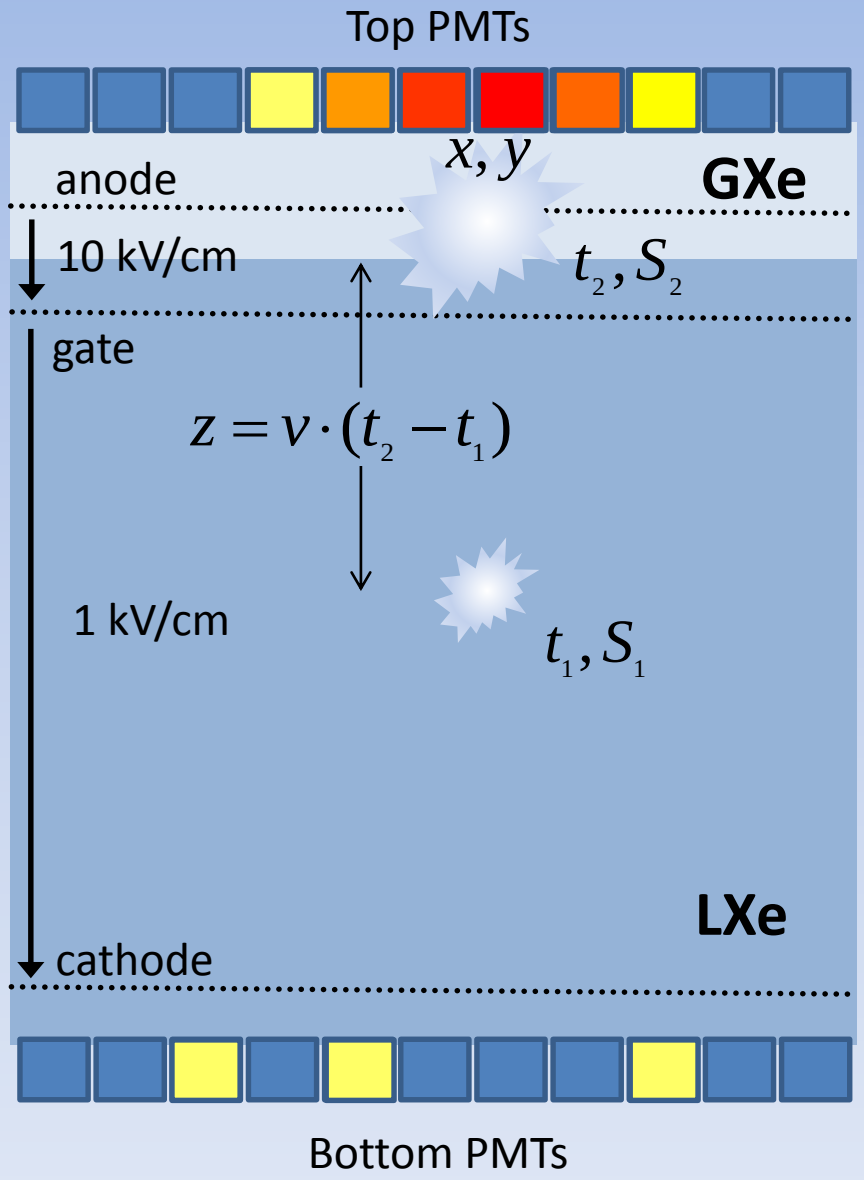
S2/S1 → background discrimination

$\left(\frac{S_2}{S_1}\right)_{nuclear\ recoil}$ *Signal*

<

$\left(\frac{S_2}{S_1}\right)_{electron\ recoil}$ *Background*

Scaling up of 'traditional' dual-phase TPC

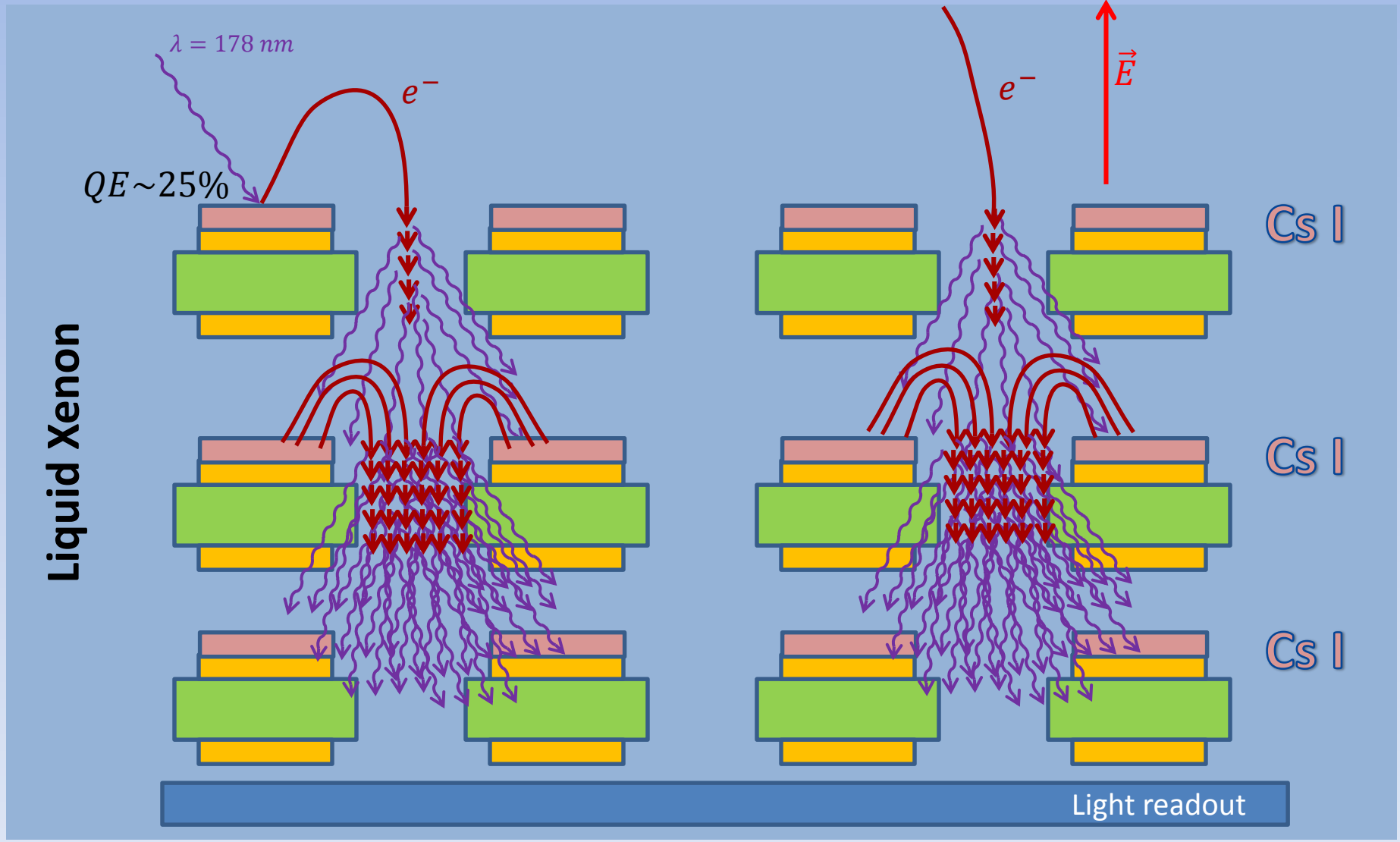


$$S_2 \propto N_e \; d_{gas}(E/\rho \; - const)$$

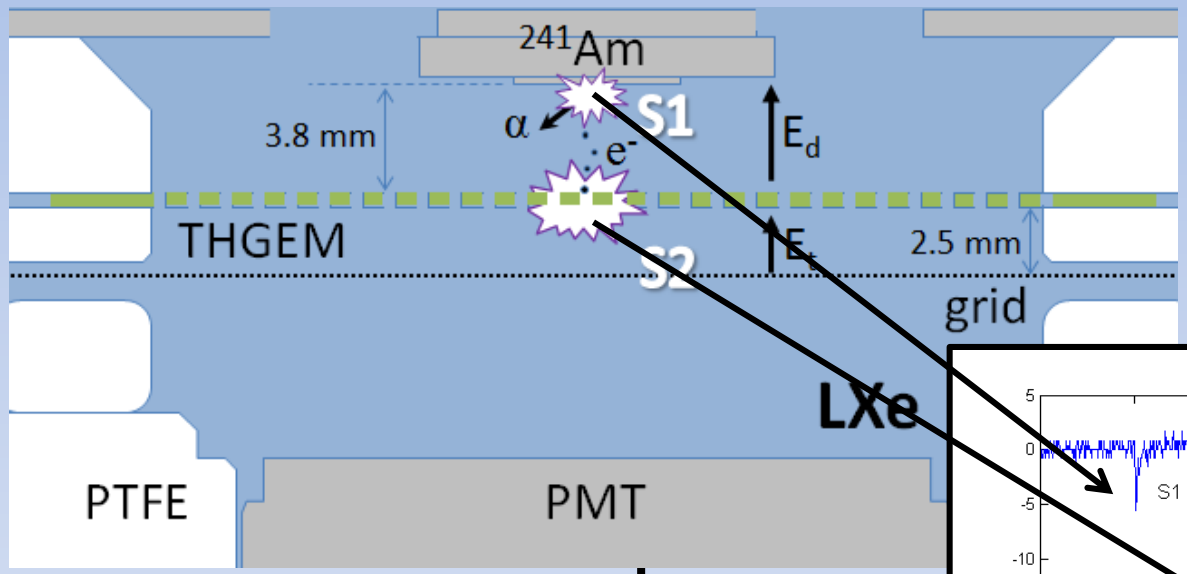
Concerns: grid deformation, sloshing waves, changes in liquid level, tilt, thermodynamic instabilities, bubbles affecting liquid surface

Liquid Hole Multipliers (LHM)

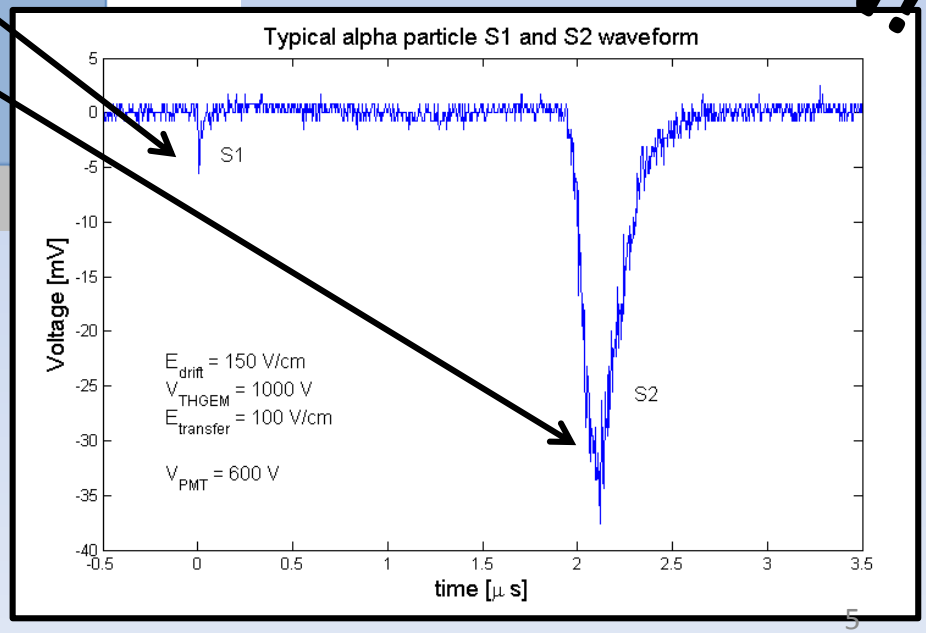
A. Breskin *J. Phys. Conf. Ser.* **460** (2013) 012020



Can one induce Electroluminescence in THGEM holes immersed in LXe?



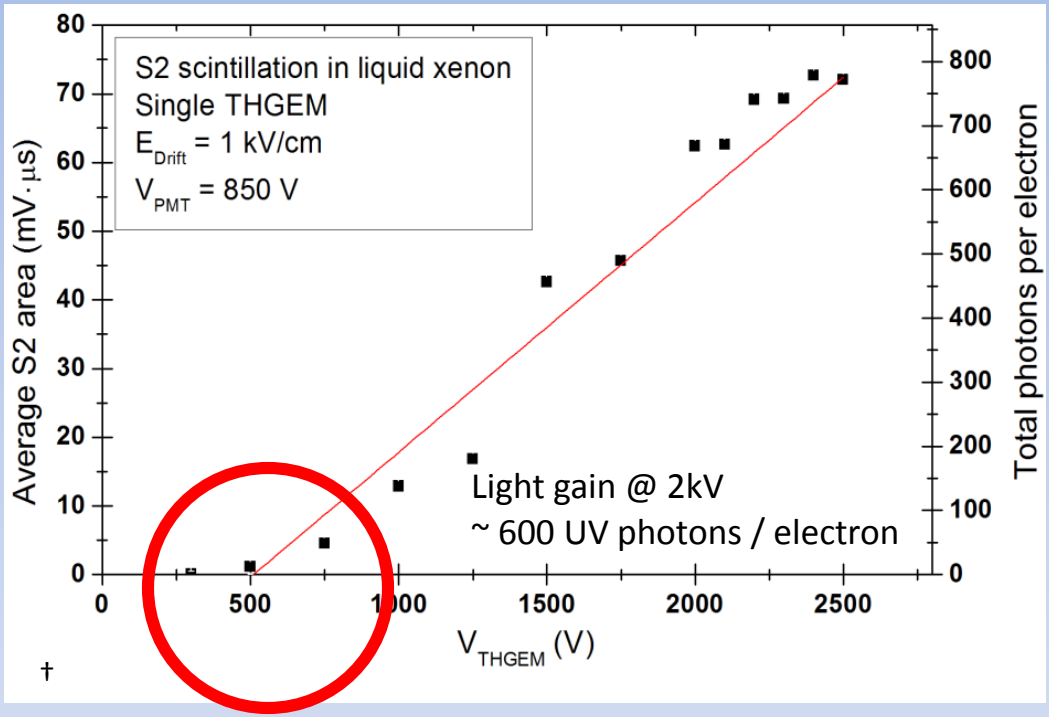
YES, WE CAN!



Oscilloscope Tektronix TDS5054B

L. Arazi et al. 2013 *JINST* **8** C12004 [arXiv:1310.4074]

Electroluminescence “in THGEM holes”



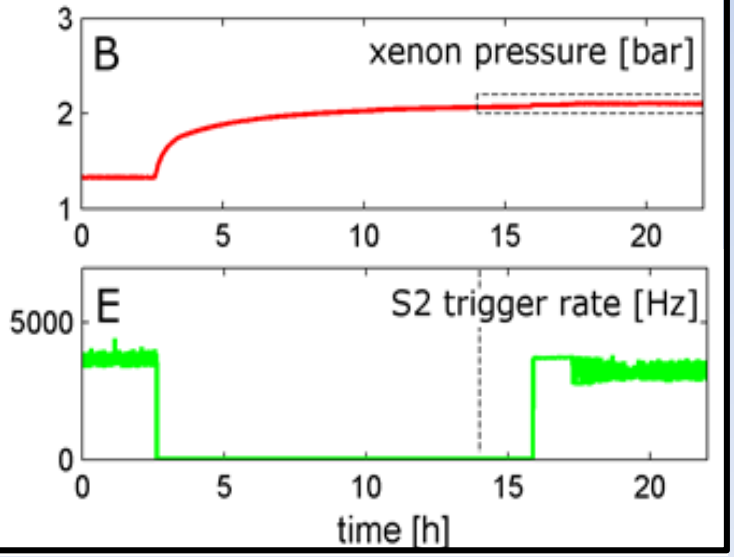
†

Threshold for electroluminescence:

Vapor (@ 170K): ~ 2-3 kV/cm ††

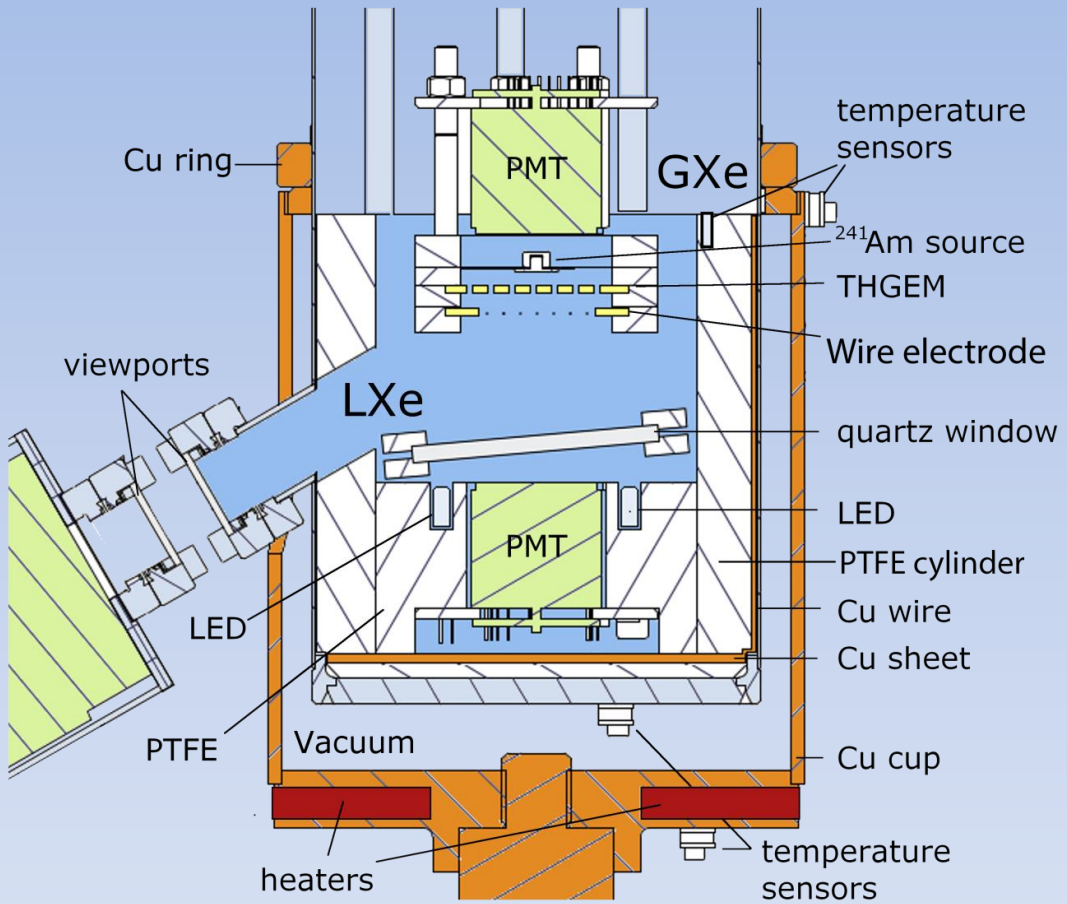
Liquid: 400 - 700 kV/cm †††

Indirect proof of bubble-assisted electroluminescence: killing light by abrupt pressure change.
Interpretation: bubbles collapse! ††††



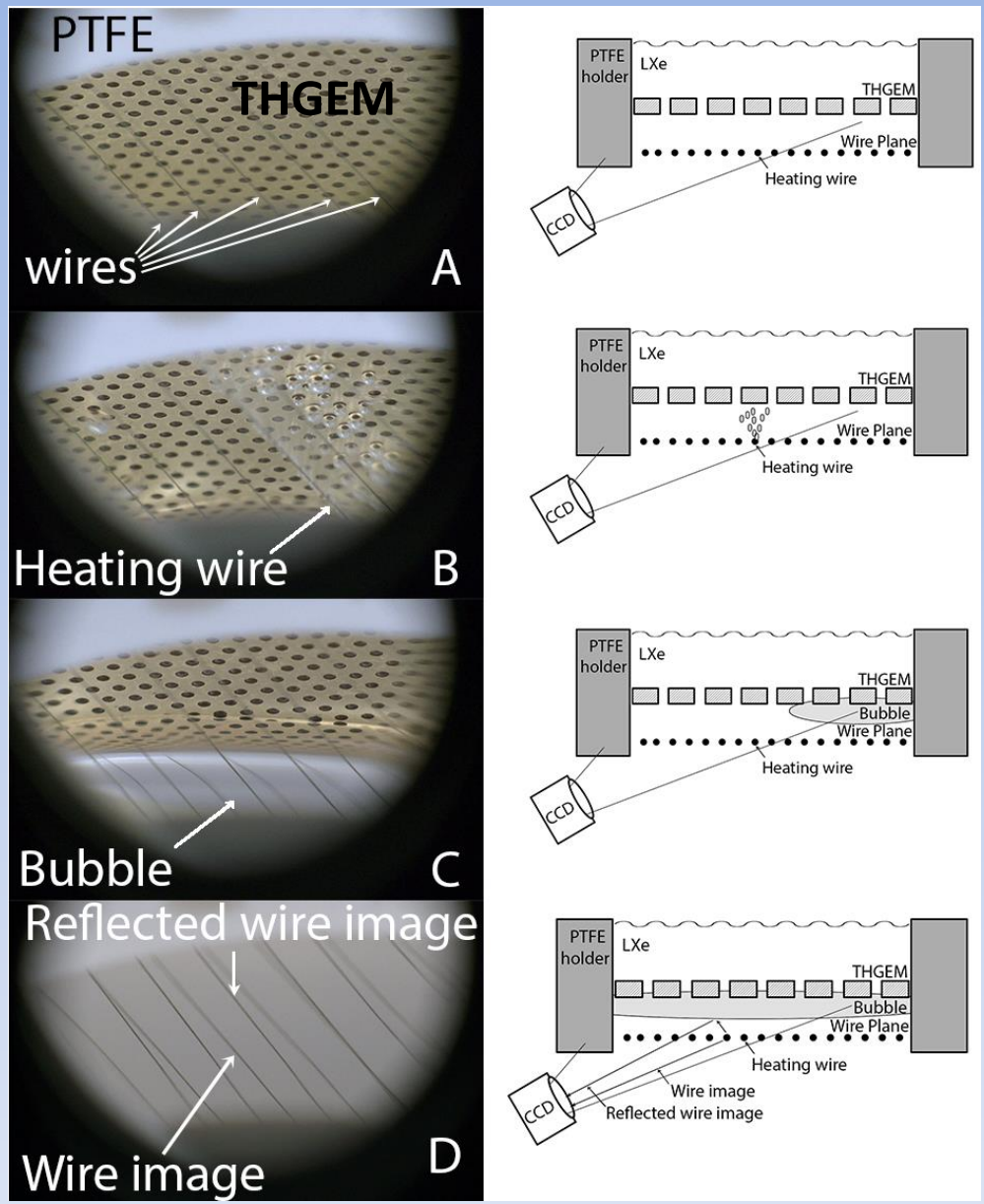
† L. Arazi et al. 2013 *JINST* **8** C12004 [arXiv:1310.4074]
††C.M.B. Monteiro et al. 2007 *JINST* **2** P05001.
††† T. Doke, Nucl. Intrum. Meth. 196 (1982).
†††† L. Arazi et al. 2015 *JINST* 10 P08015 [arXiv:1505.02316].

Seeing is believing



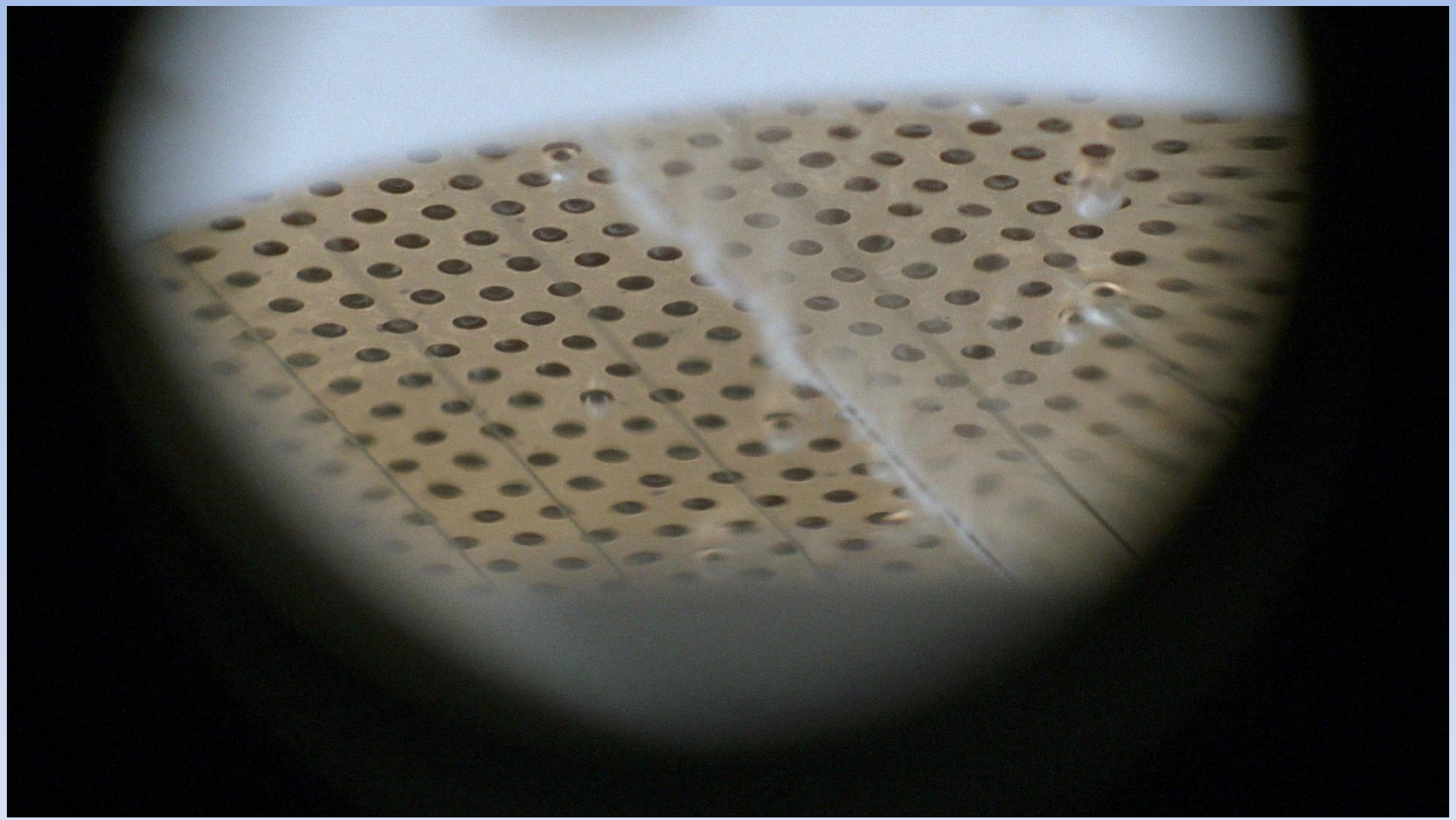
E. Erdal et al. 2015 JINST **10** P11002 [arXiv:1509.02354]

And bubbles… there are!



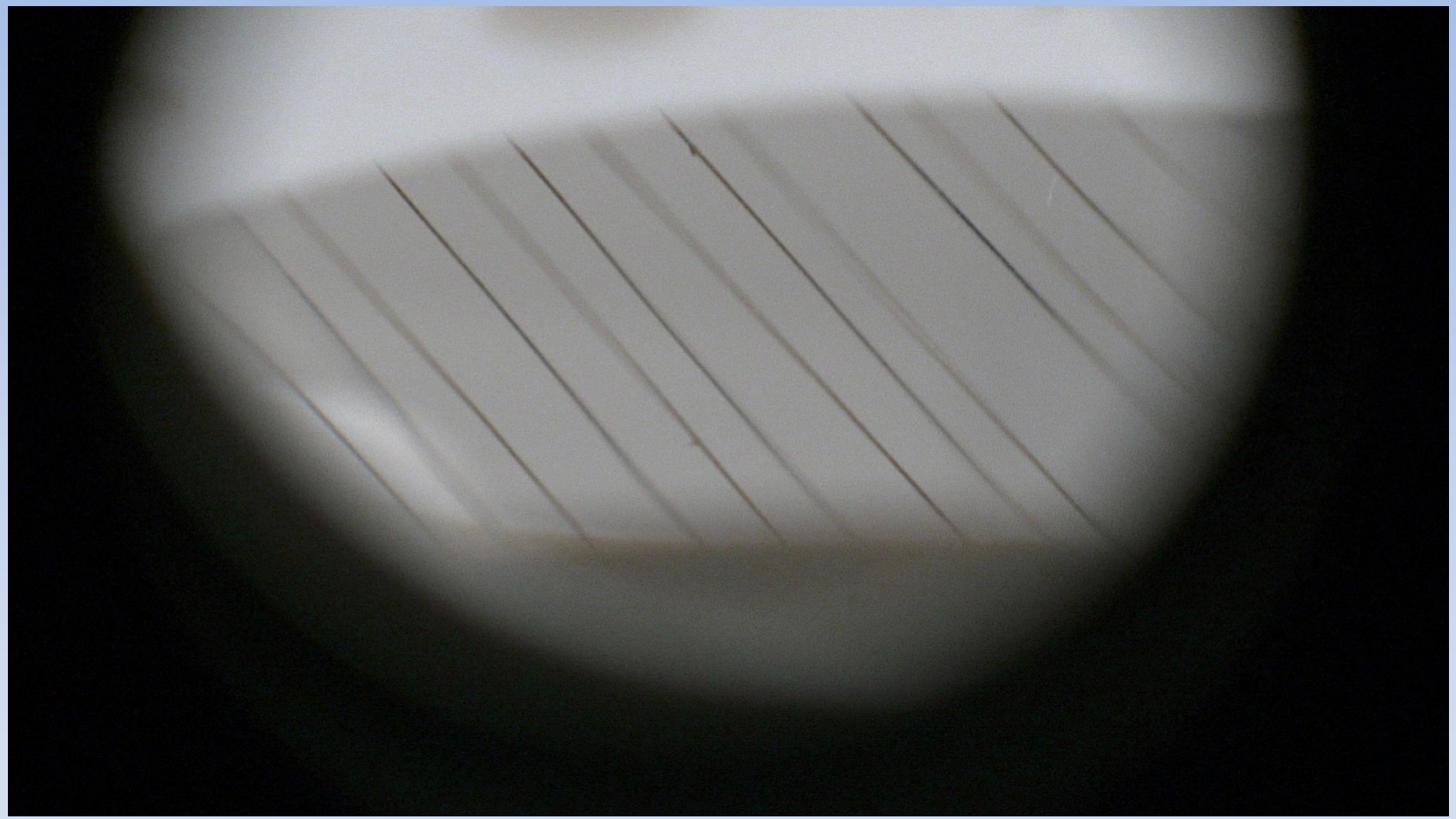
E. Erdal et al. 2015 JINST **10** P11002 [arXiv:1509.02354]

Bubble Inflation



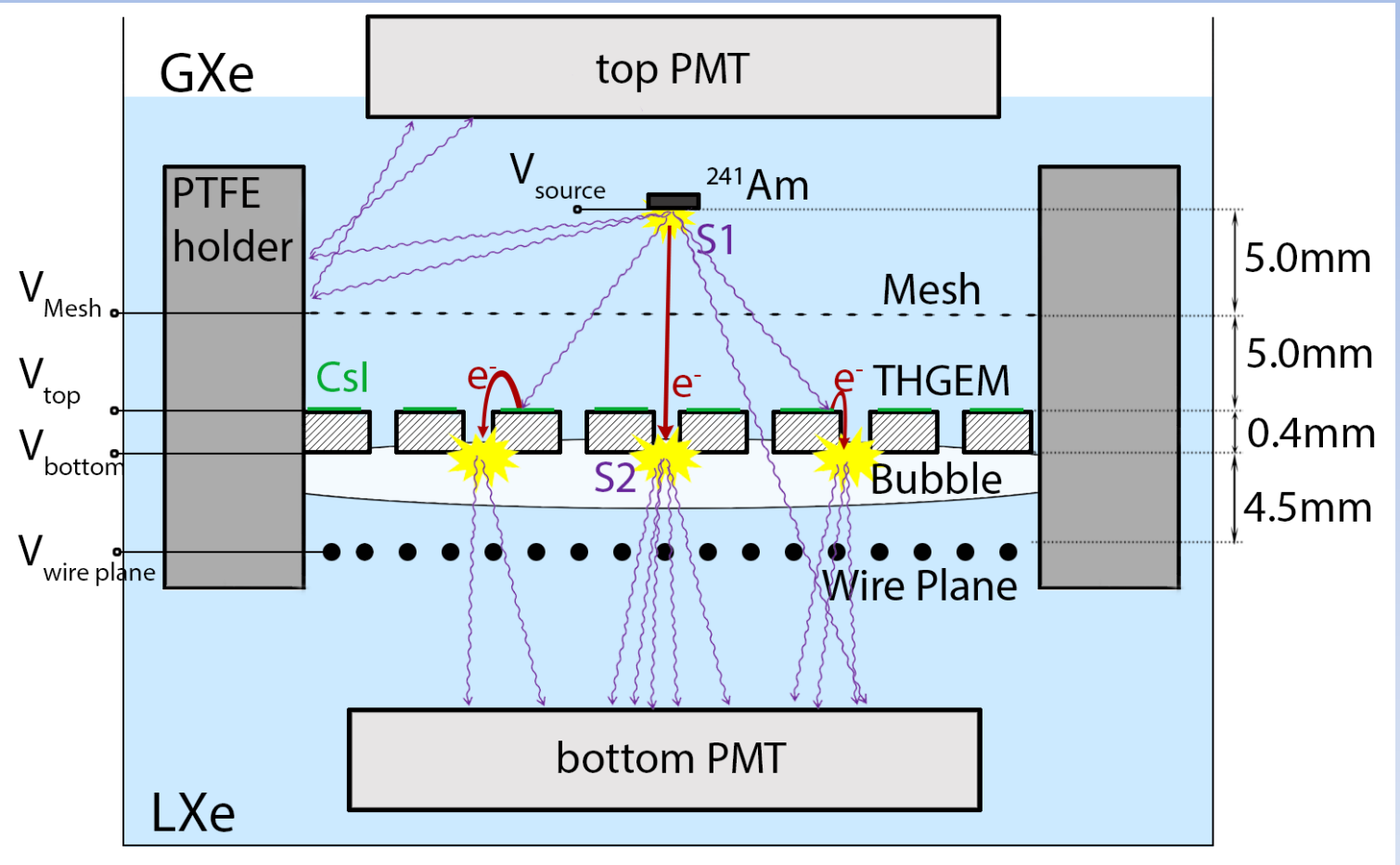
E. Erdal et al. 2015 JINST **10** P11002 [arXiv:1509.02354]

Bubble breathing

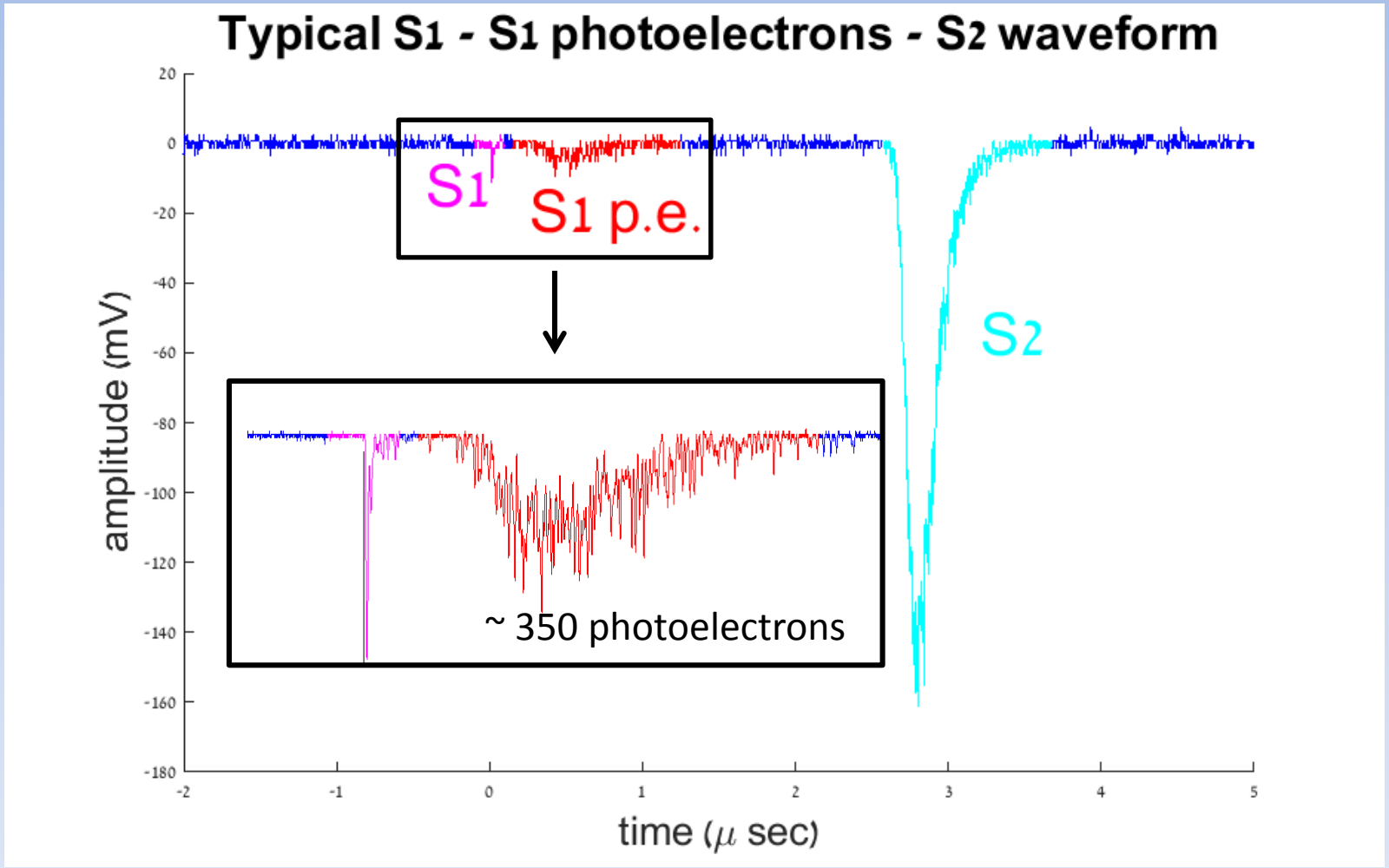


E. Erdal et al. 2015 JINST **10** P11002 [arXiv:1509.02354]

Towards single photon sensing: **THGEM/CsI** photocathode

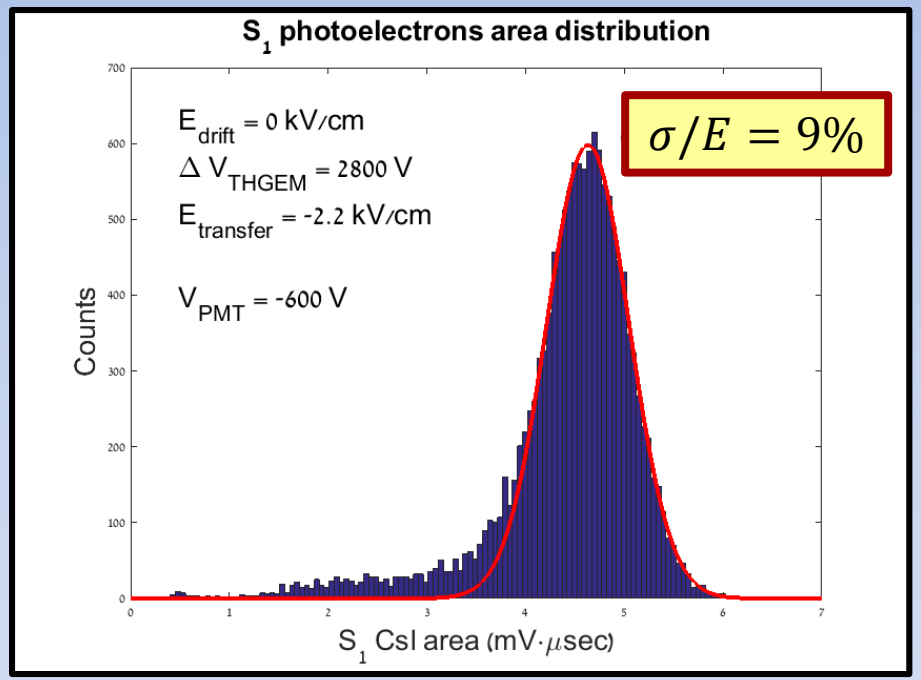


Towards single photon sensing: **THGEM/CsI** photocathode

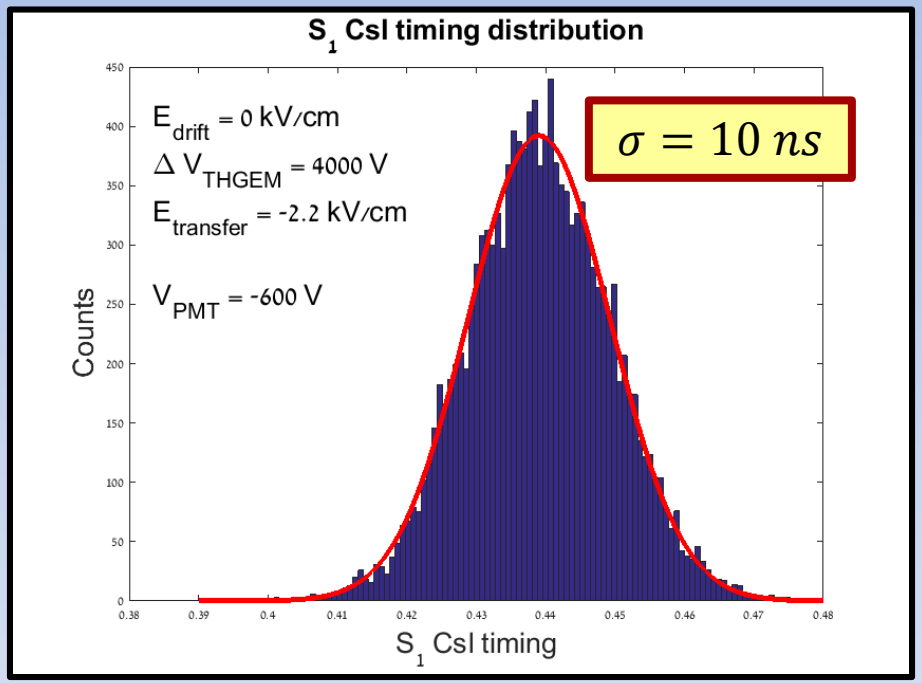


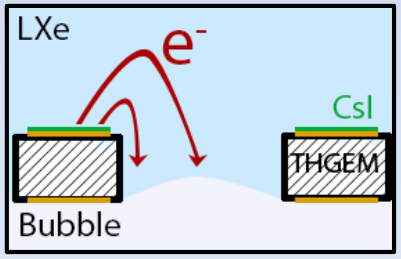
Towards single photon sensing: **THGEM/CsI** photocathode

Energy (S1')



Timing (S1')

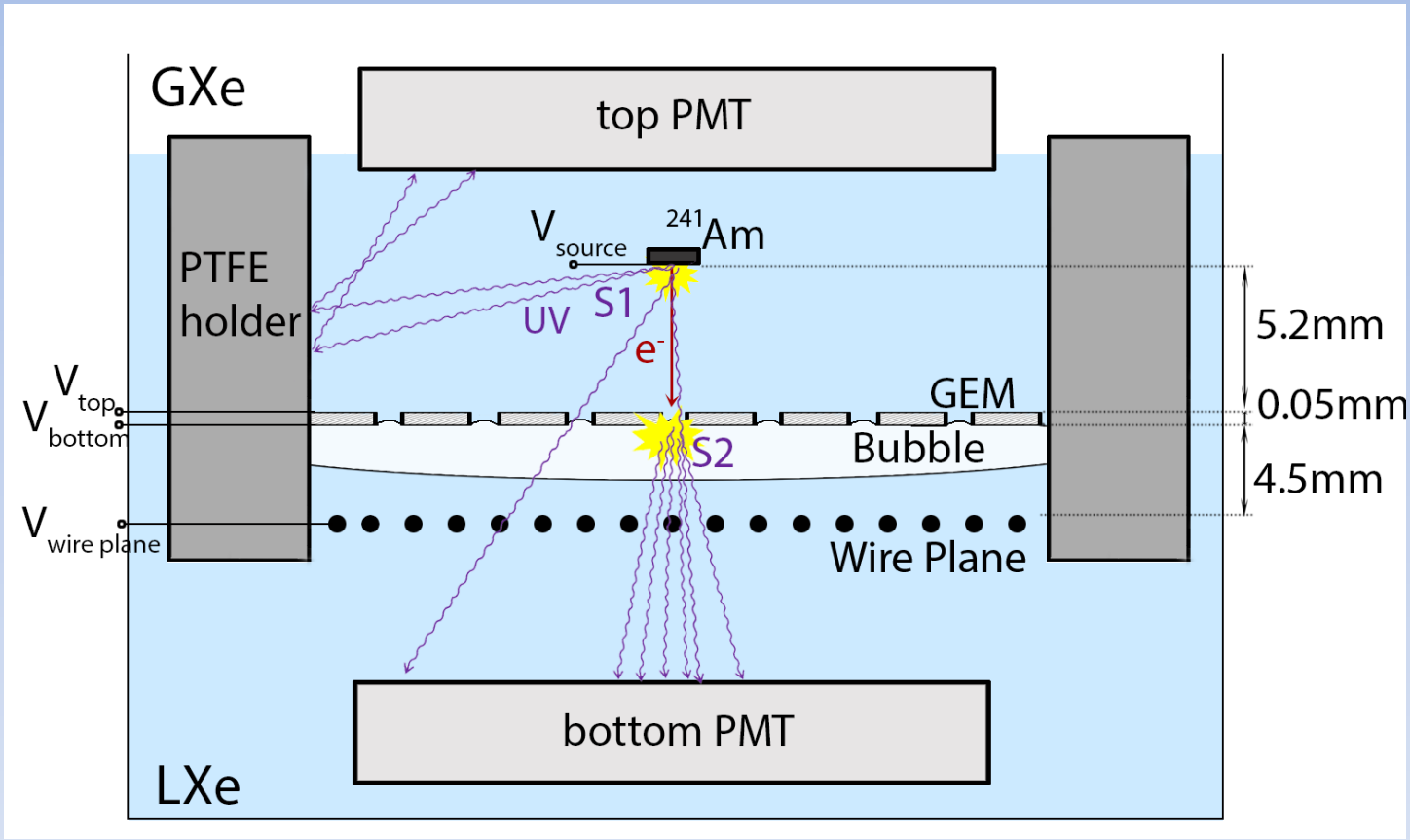




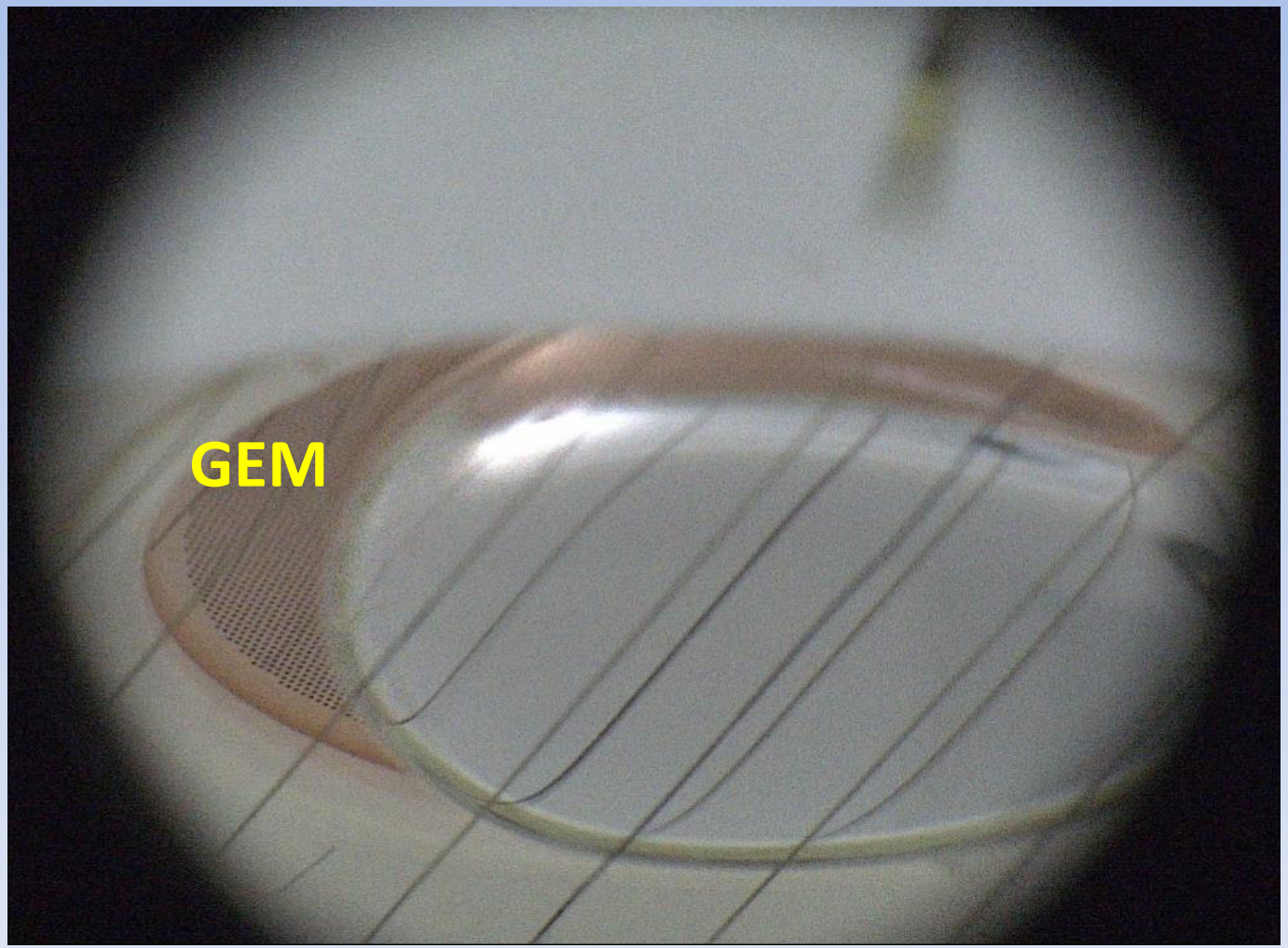
Electrons liberated at different distances from the hole differ in drift time (LXe is slow ~ $2mm/\mu\ sec$)

→ Expect better timing resolution is a GEM.

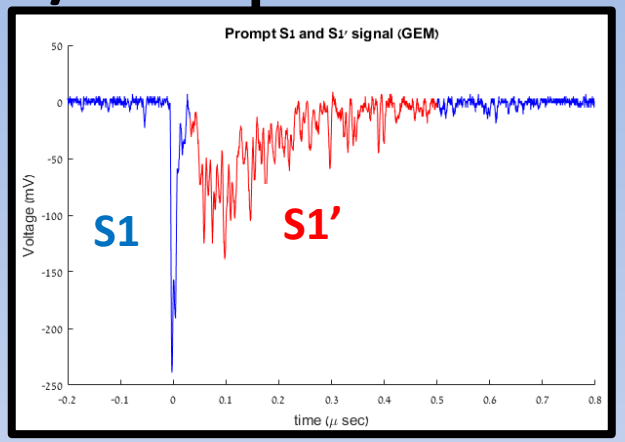
GEM based bubble assisted LHM



GEM based bubble-assisted LHM

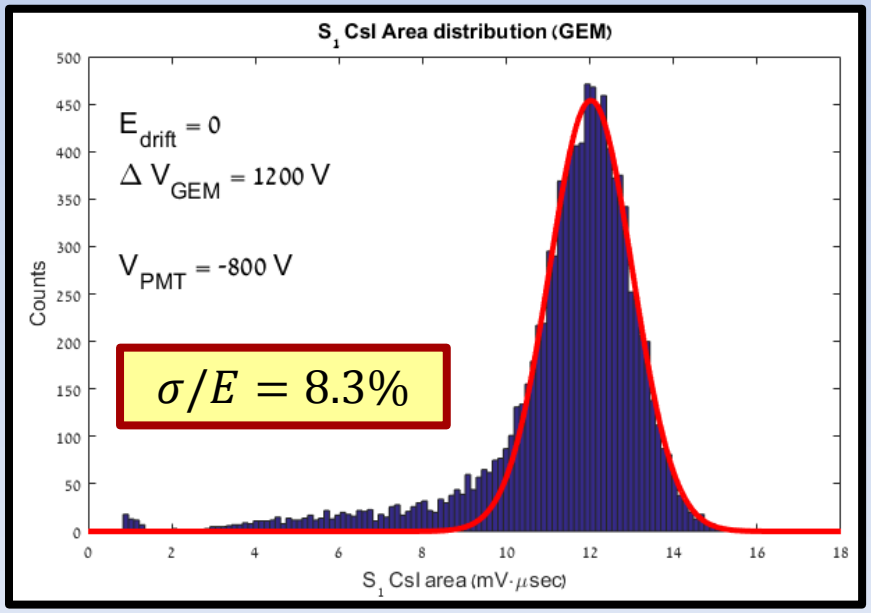


Towards single photon sensing: **GEM/CsI** photocathode

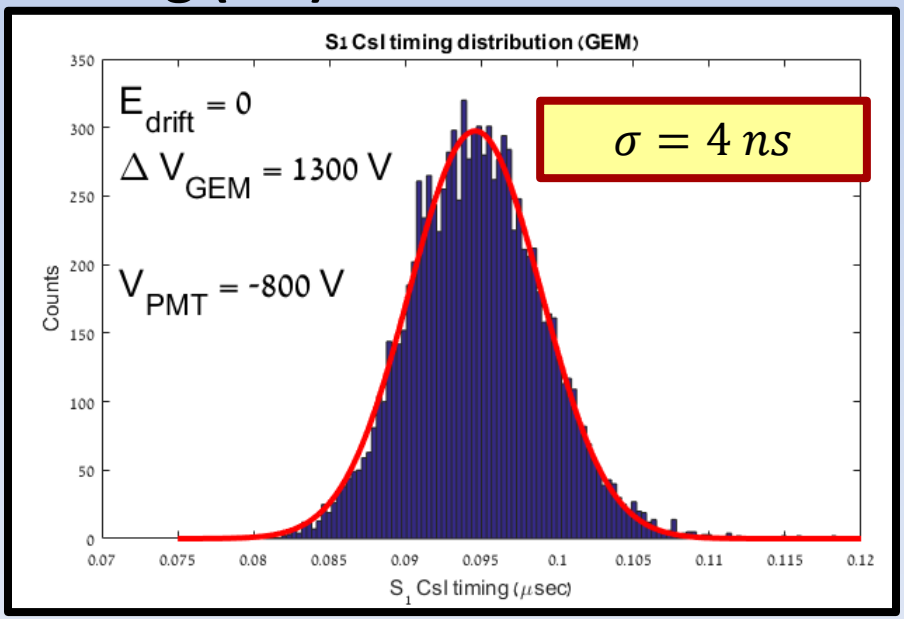


~ 400 photoelectrons

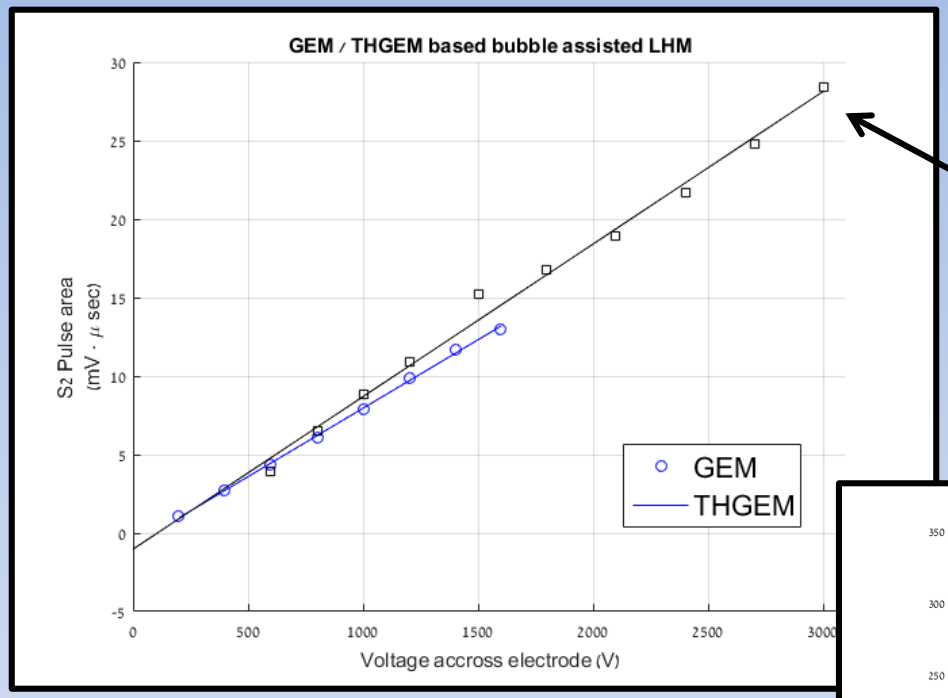
Energy (S1')



Timing (S1')

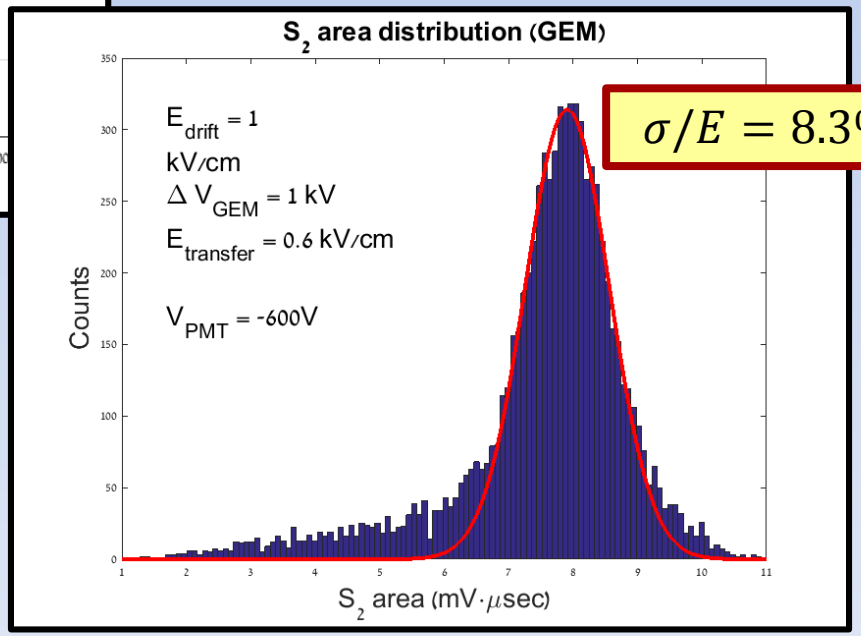


GEM bubble-LHM photon yield & E-resolution



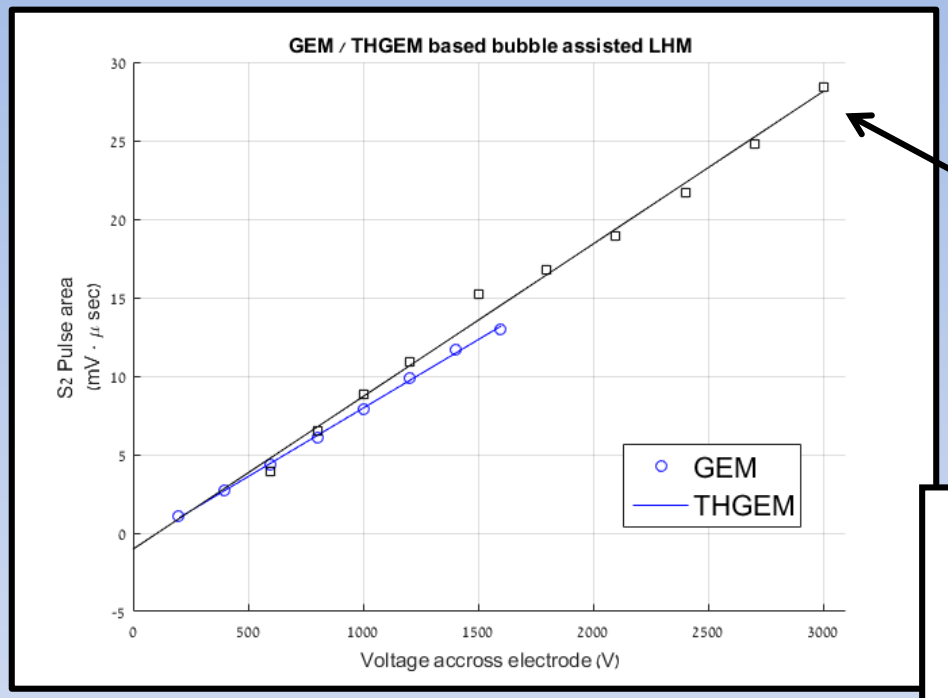
~50 photons to 4 π per electron

Energy (S2) - GEM



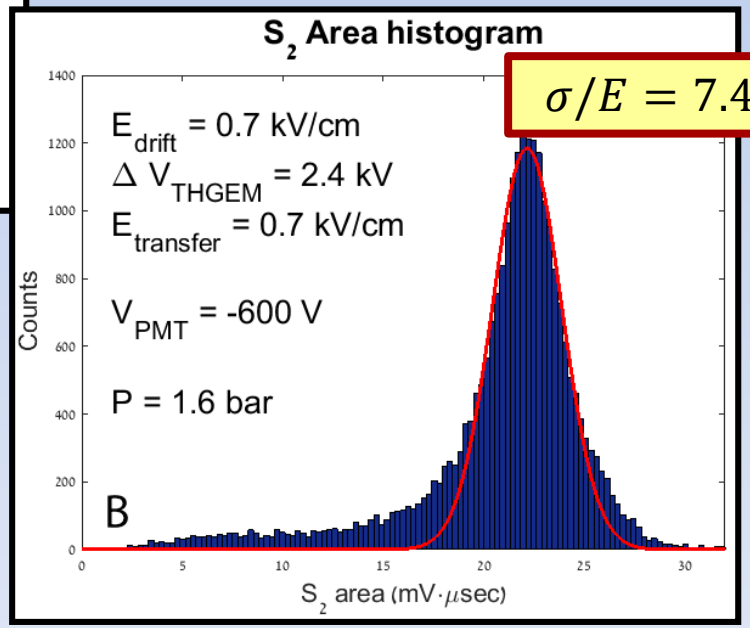
$\sigma/E = 8.3\%$

GEM bubble-LHM photon yield & E-resolution



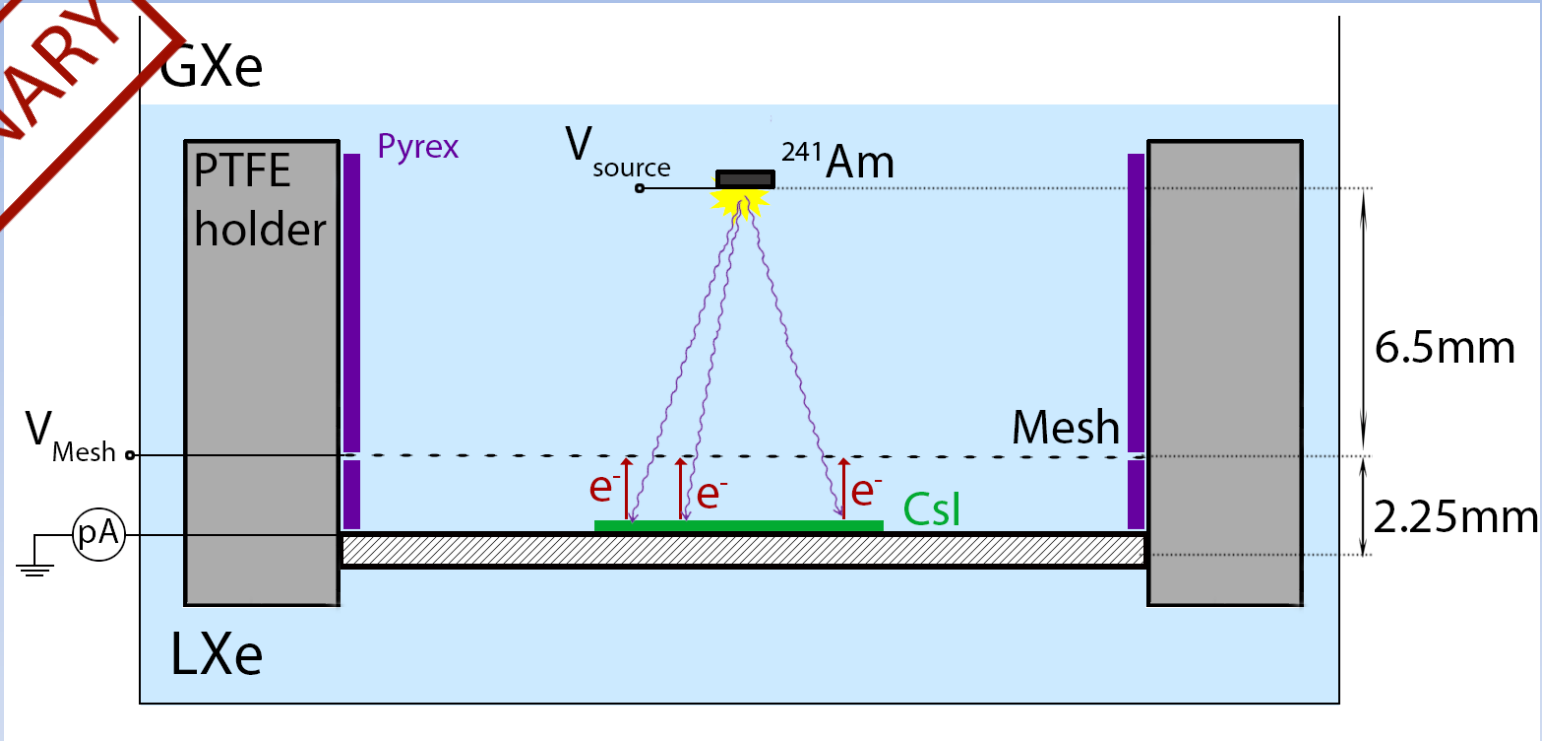
~50 photons to 4 π per electron

Energy (S2) - THGEM



Towards single photon sensing:
Effective CsI Quantum Efficiency in LXe

PRELIMINARY

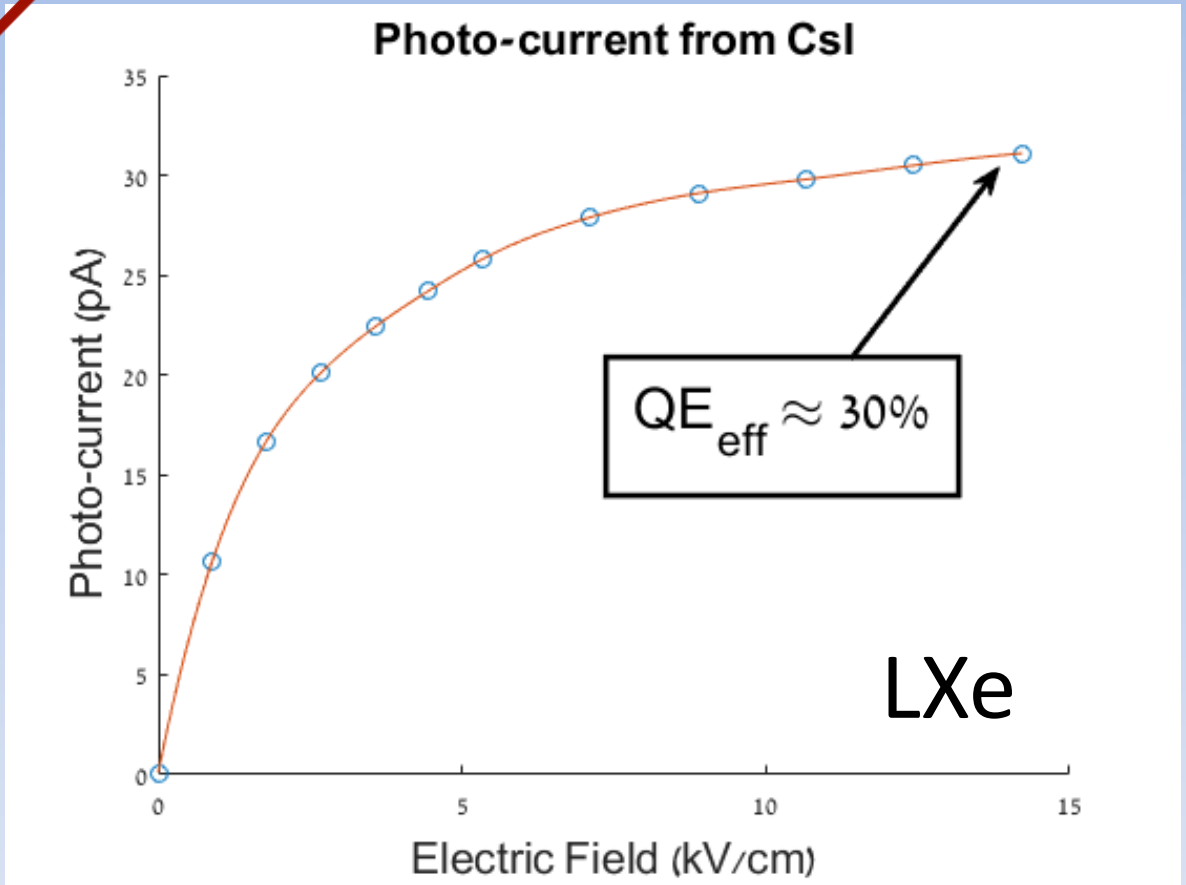


$$I = \frac{E}{W_s} \cdot f \cdot \left(\frac{\Omega}{4\pi}\right) \cdot T \cdot e^{-} \cdot QE_{eff}$$

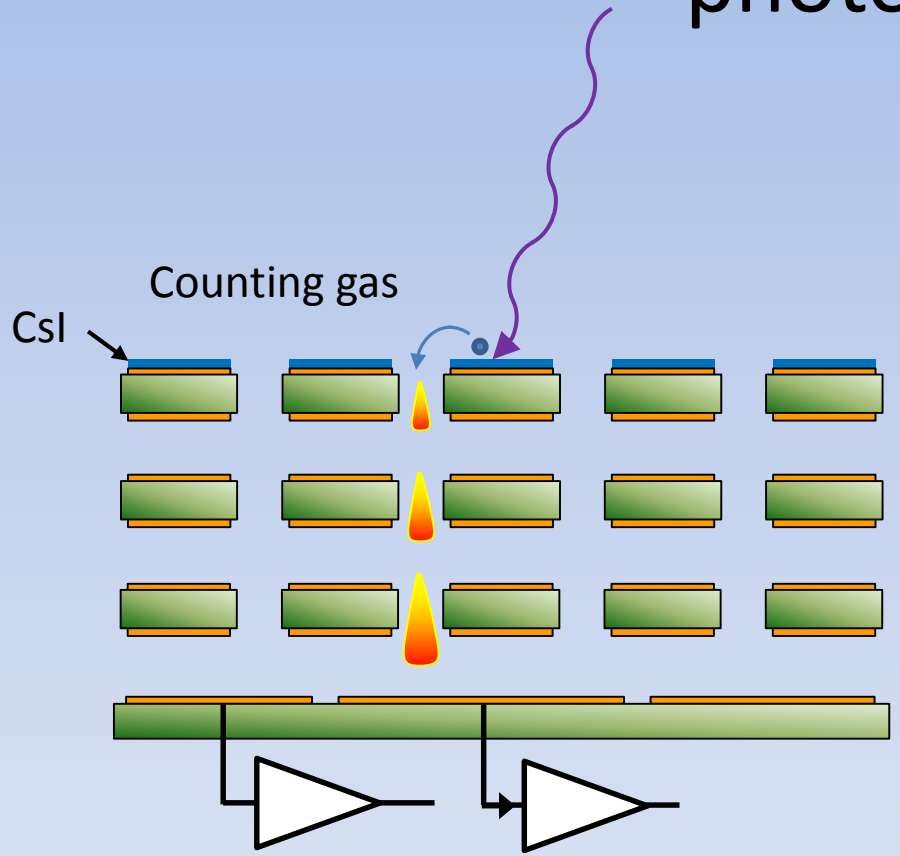
E – energy of alpha particle
W_s – mean energy per photon
f – rate of alpha emission into LXe
Ω – solid angle towards photocathode
T – Mesh transmission

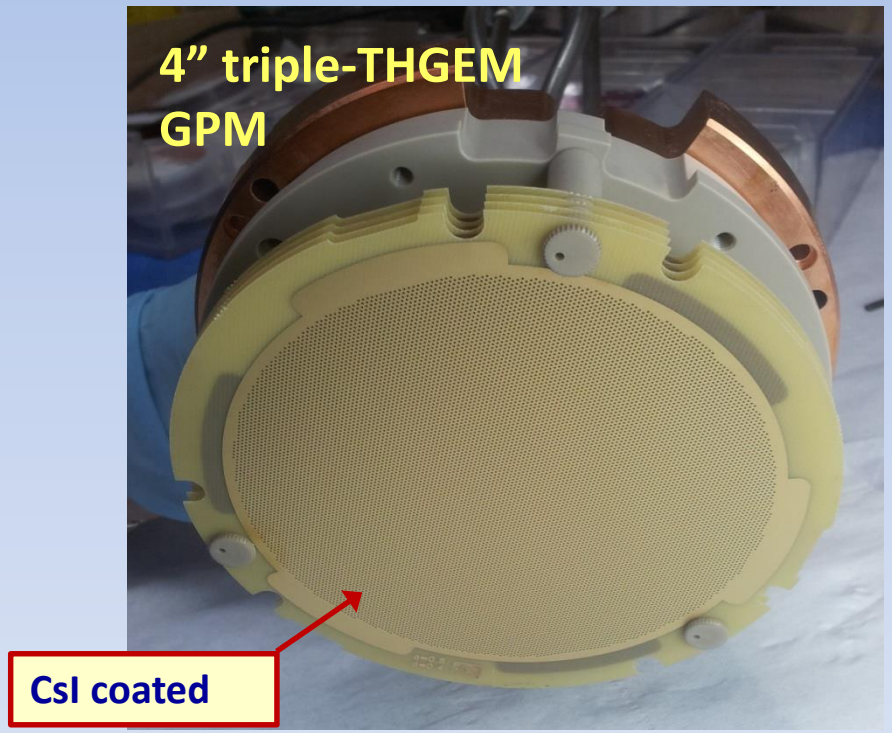
Towards single photon sensing:
Effective CsI Quantum Efficiency in LXe

PRELIMINARY



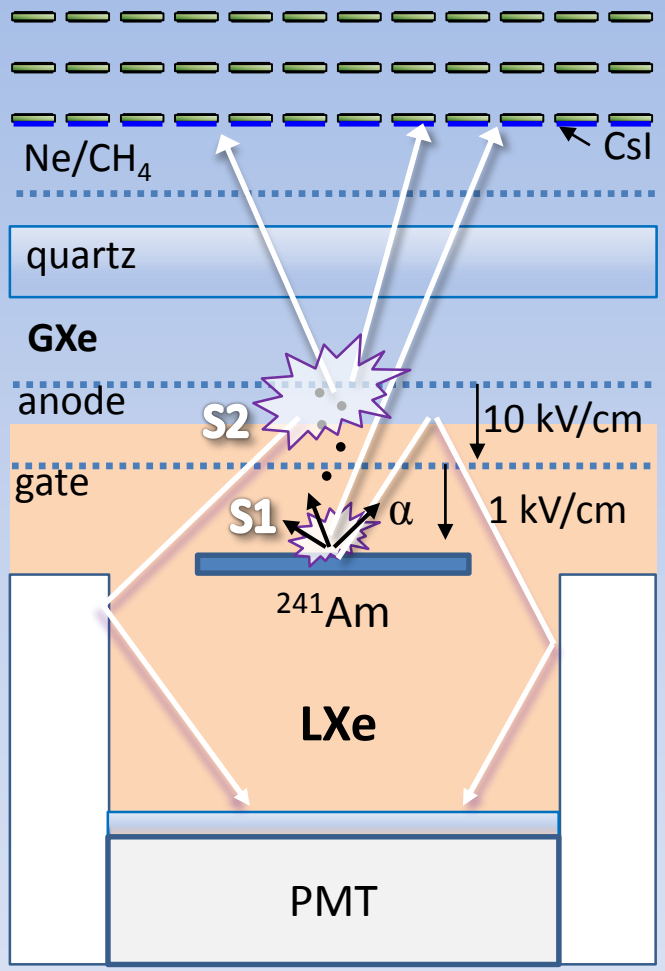
Gaseous Photo Multiplier (GPM) Triple THGEM with reflective CsI photocathode

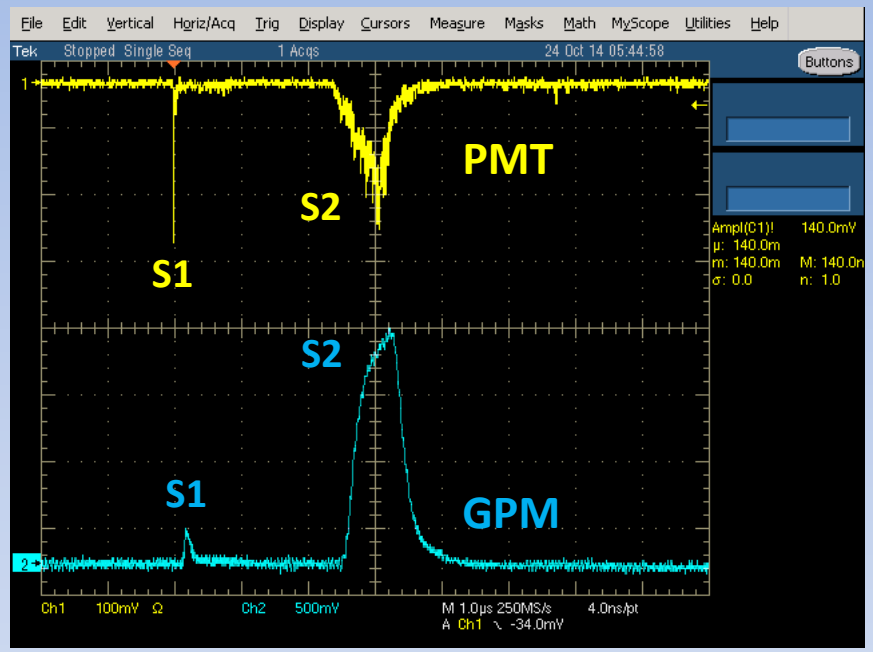




L. Arazi et al. 2015 JINST **10** P10020 [arXiv:1508.0041]

First demo of S1 & S2 recording by GPM + dual-phase LXe TPC !

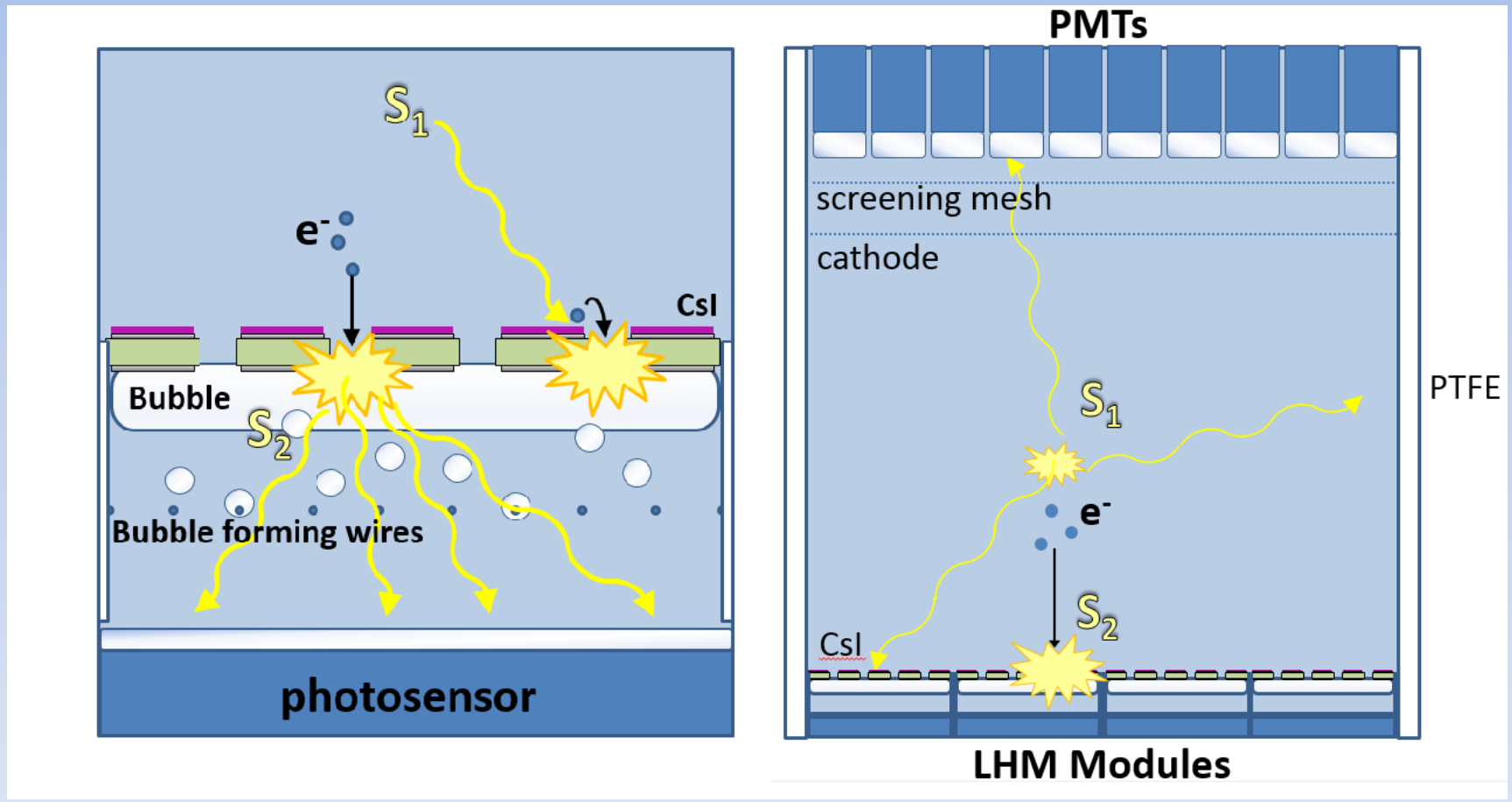




Detects single photons AND massive S2 signals!

L. Arazi et al. 2015 JINST **10** P10020 [arXiv:1508.0041]

We have a dream…



Summary - highlights

- Proved electroluminescence in a bubble in LXe
- Bubbles stable over days
- Good energy resolution (σ/E ~7.5% for ~6,000 electrons)
- Detection of UV photons with a CsI photocathode - immersed in LXe ("LHM photosensor")
- Effective QE in LXe~ 30%
- Large-area cryogenic GPM - Large dynamic range: Single photons and massive S2 signals recorded in LXe TPC

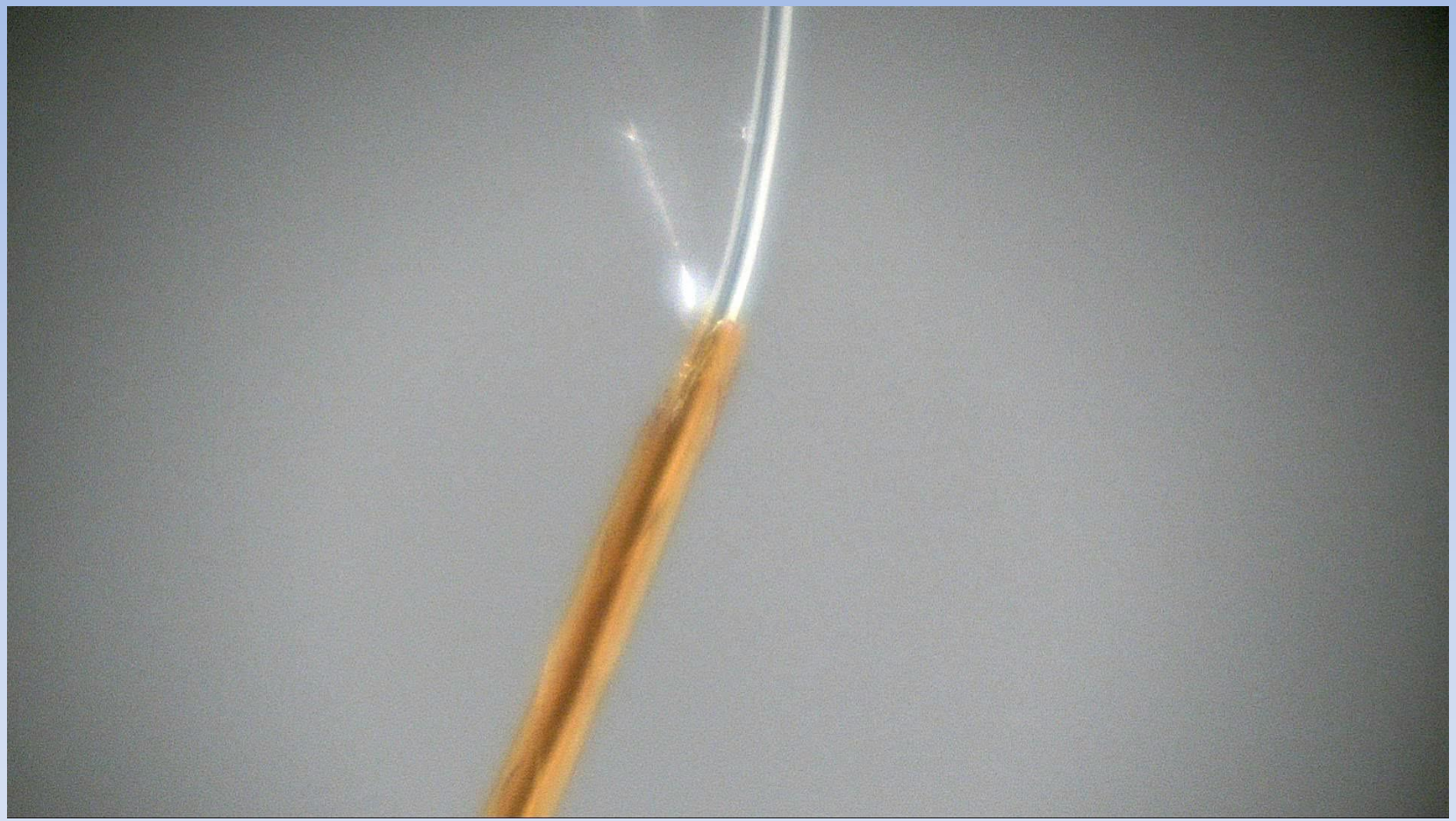
Challenges ahead….

- Different LHM electrodes and structures
- Cascaded multiplication process
- Possibility of a large-area bubble-assisted LHM
- Bubble generation in greater depth
- LHM readout with GPM

Thank you for your attention

Backup slides

Boiling on the tip of a wire

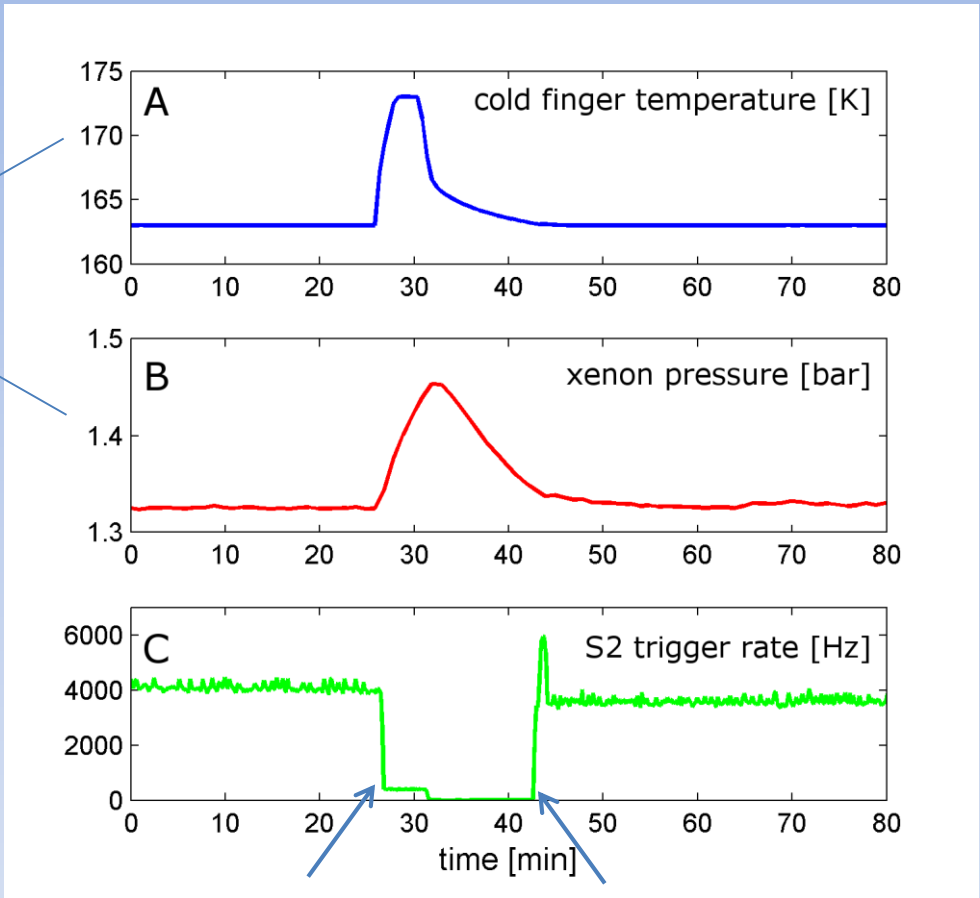


E. Erdal et al. 2015 JINST **10** P11002 [arXiv:1509.02354]

S2 response to pressure changes

Rapid pressure changes induced by changing the cold finger temperature

S2 disappears when the pressure increases, and reappears when it drops back

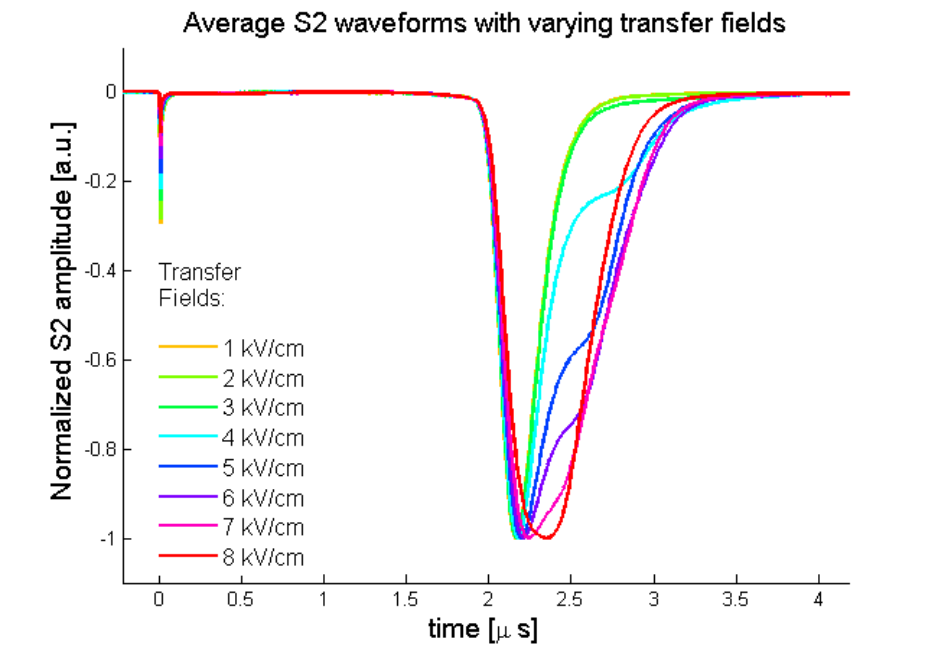


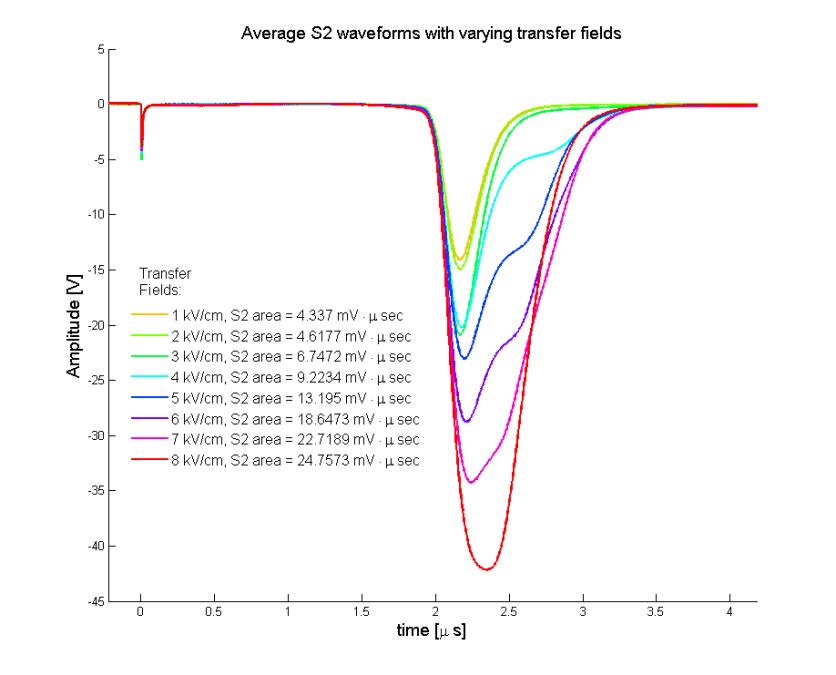
bubbles collapse & bubble formation stops

bubble formation resumes

L. Arazi, E. Erdal, A. E. C. Coimbra, M. L. Rappaport, D. Vartsky, V. Chepel and A. Breskin, *Liquid Hole Multipliers: bubble-assisted electroluminescence in liquid xenon*, 2015 *JINST* 10 P08015 [arXiv:1505.02316].

Electroluminescence in transfer gap
Evaluating gas layer thickness





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