

# Measurement of scintillation from proportional electron multiplication in liquid xenon using a needle

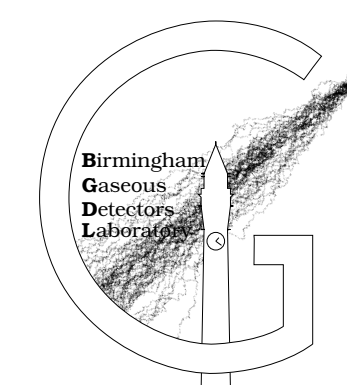
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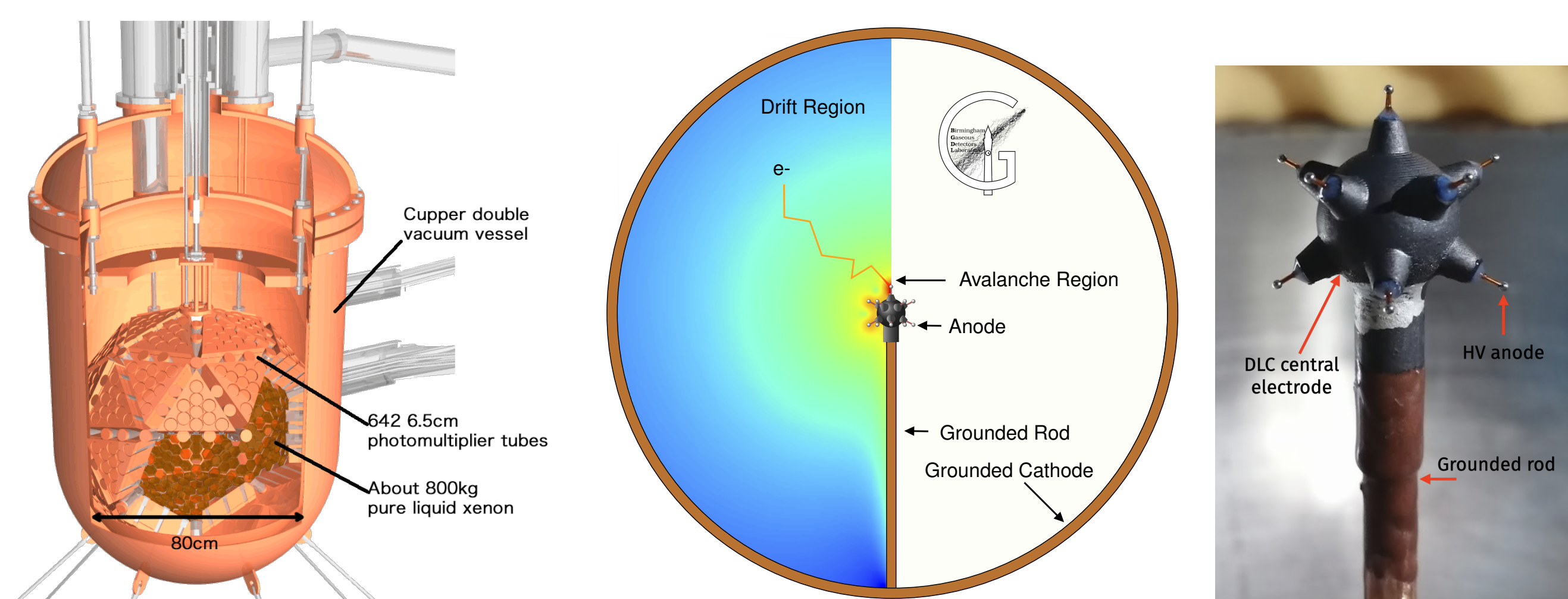
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## Introduction

- Nature of dark matter (DM) is one of the key open questions in physics
- Dual-phase liquid noble experiments lead direct DM search sensitivity [1]
  - Prompt (S1) and amplified (S2) give background discrimination
- Single-phase liquid noble detectors also successfully employed
  - Excellent photo-coverage and avoid challenges of gas-liquid interface
  - However, S1 only as amplification in liquid noble, e.g. Xe (LXe), is challenging
- Attempts at amplification in LXe difficult to scale [2–8]

## XMASS and Spherical Proportional Counters

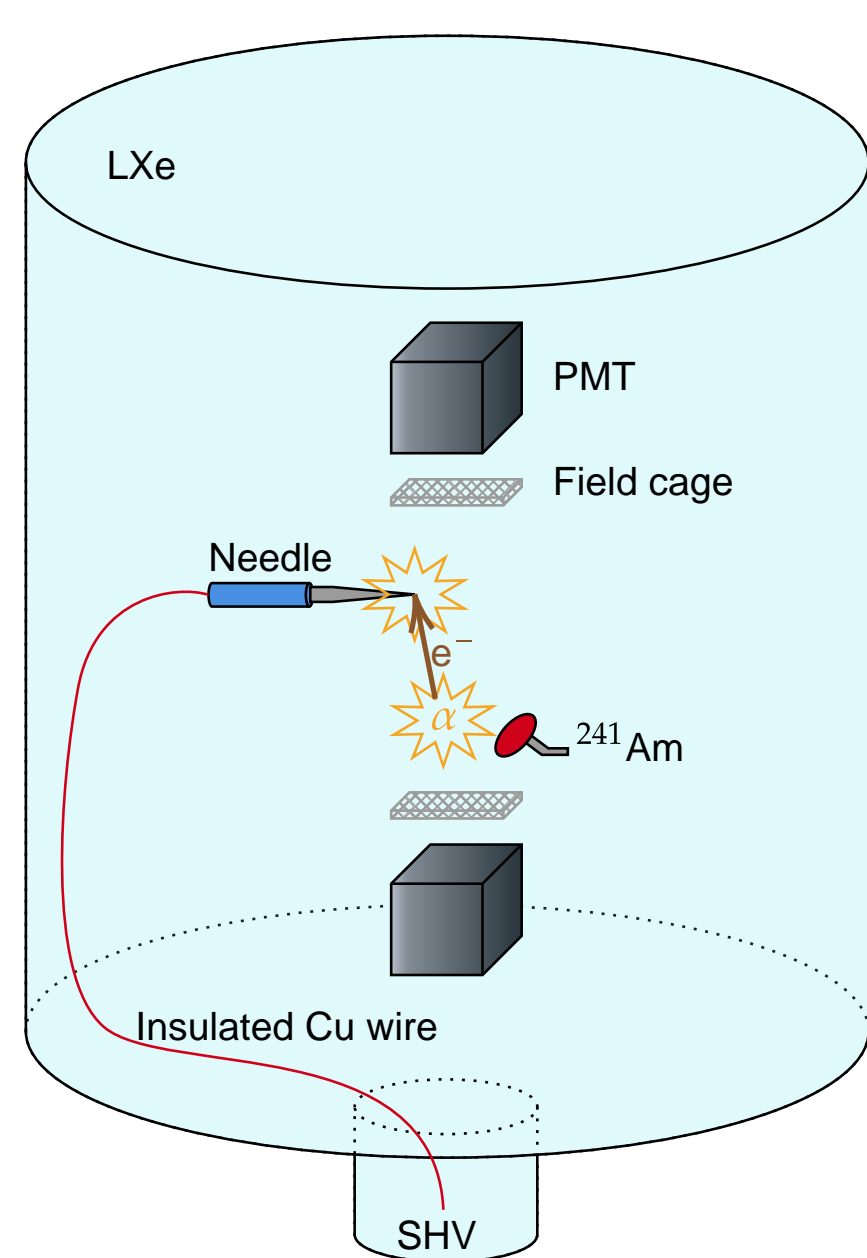
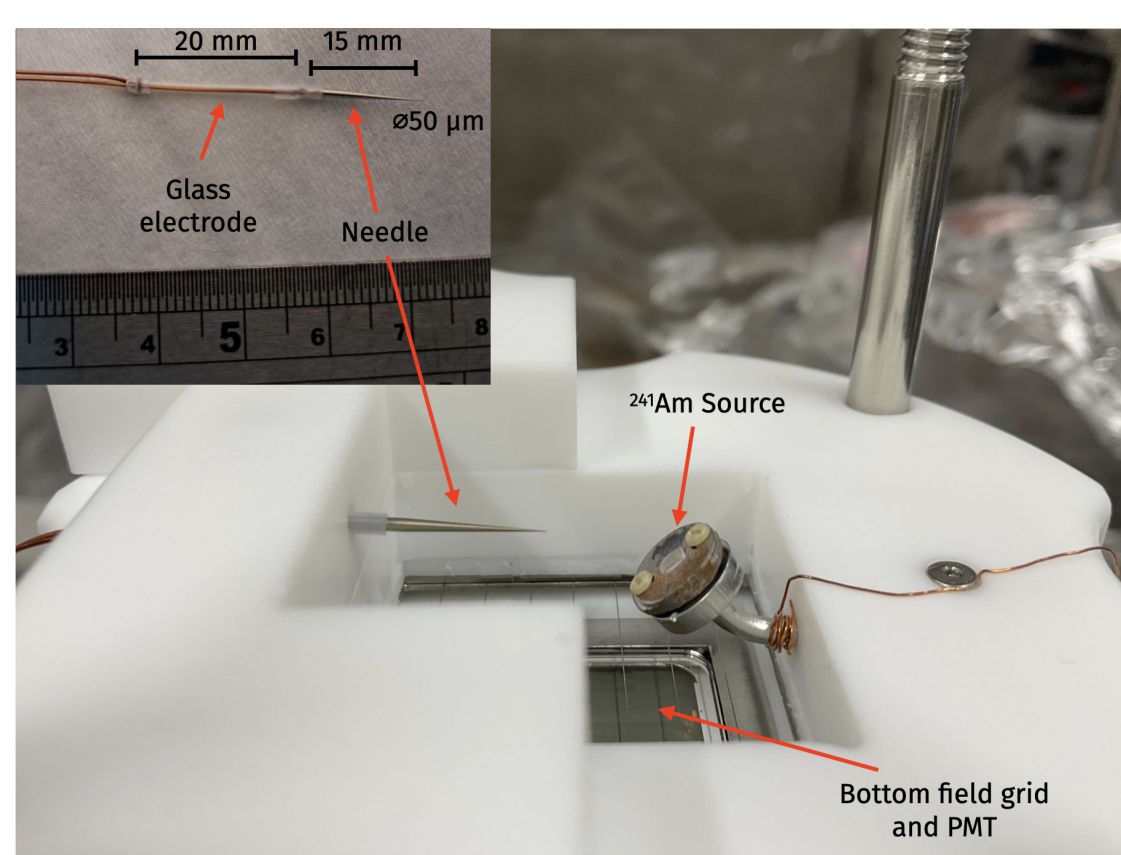
- XMASS: single-phase LXe direct DM experiment with light read-out [9, 10]
- Sensitivity could be improved with amplification structure to give S2
- Spherical proportional counter (SPC) – gaseous detector with charge read-out [11–15]. Employed by NEWS-G experiment [16, 17]
- Adapt this charge amplification structure, ACHINOS, for XMASS



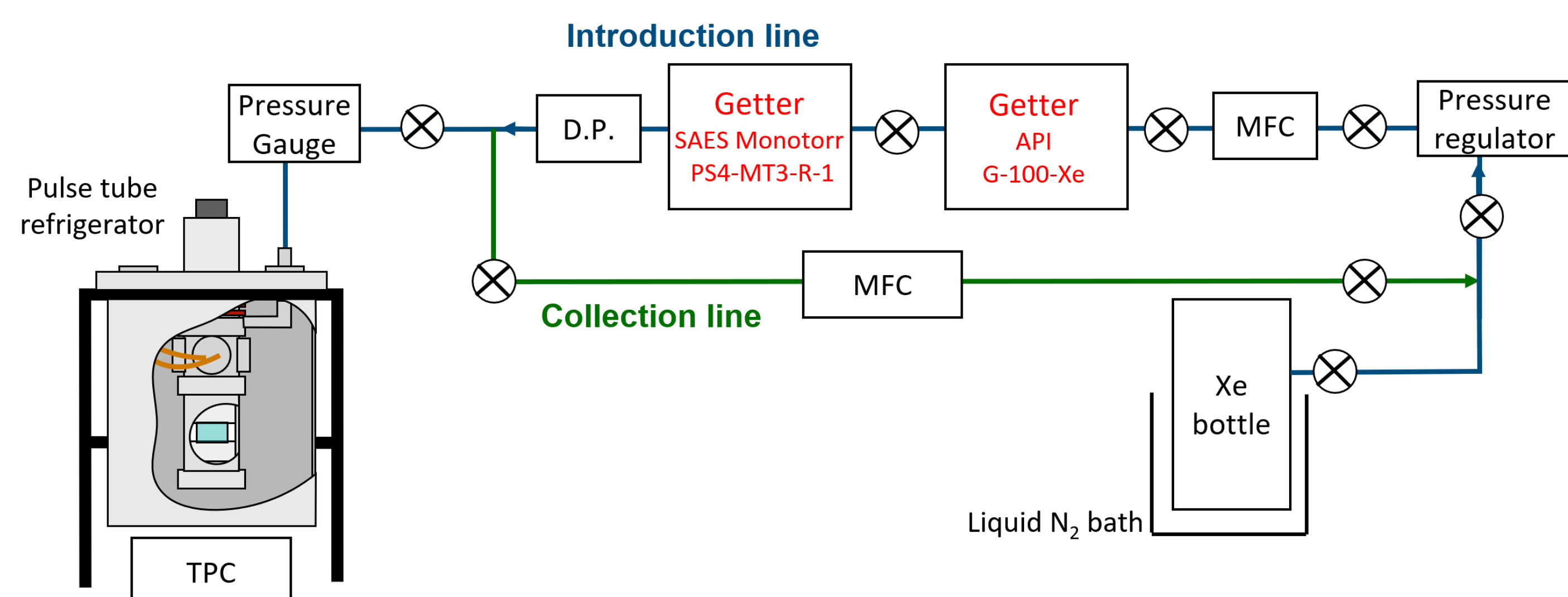
Reproduced from <https://www-sk.icrr.u-tokyo.ac.jp/xmass>

## Experimental Set-Up

- Anodes for SPC ACHINOS  $\varnothing$ (mm) – too large for high-field required in LXe
- Tests with  $\varnothing$ 50  $\mu$ m round-tip needle, with resistive soda-lime glass support electrode [18]
- Measurements performed in test TPC set-up



- 2 Hamamatsu R8520-406 PMTs biased to 792 V and 892 V (gain  $7 \times 10^6$ )
- <sup>241</sup>Am calibration source: 5.5 MeV  $\alpha$ -particle
- Chamber evacuated to  $4.5 \times 10^{-7}$  mbar and cooled over 24 hours
- Xe purified during TPC filling

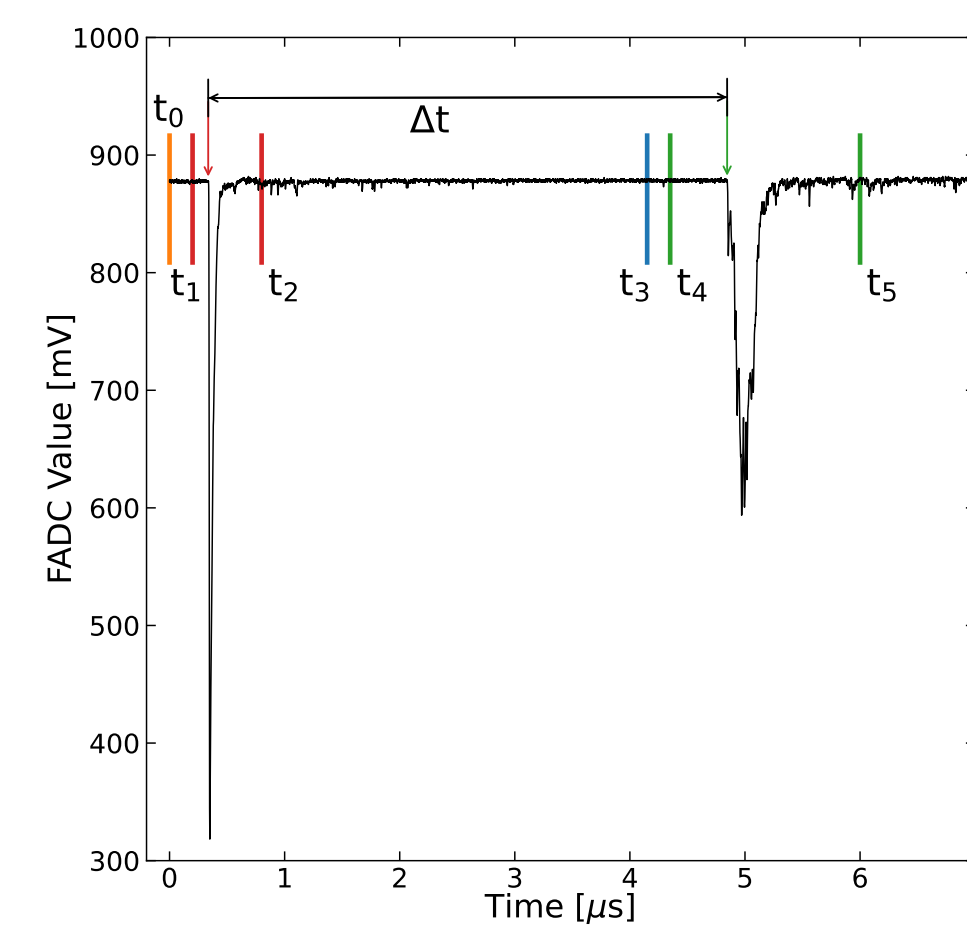


## References

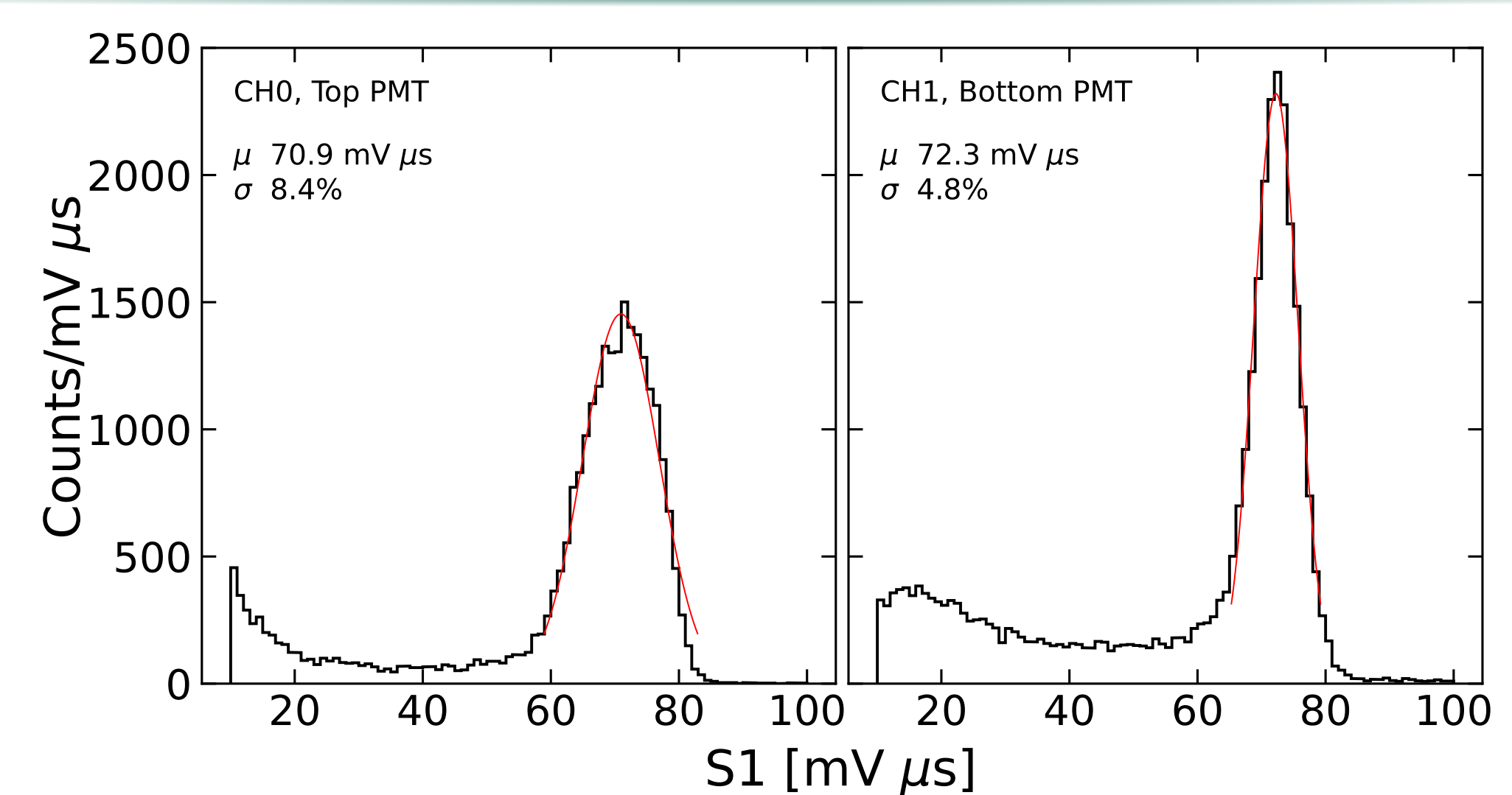
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## Pulse-shape analysis and Calibration

- Data recorded from PMTs with flash ADC with 1 GHz sampling
- Signal divided and 16 bD attenuated signal also recorded
- S1 (S2) baseline: mean FADC  $t_0$  ( $t_3$ ) to  $t_1$  ( $t_4$ )
- S1 (S2) area: integral from  $t_1$  ( $t_4$ ) to  $t_2$  ( $t_5$ )
- Onset time: time at which signal drops 1% below respective baseline
- $\Delta t$ : Time between onset times of S1 and S2



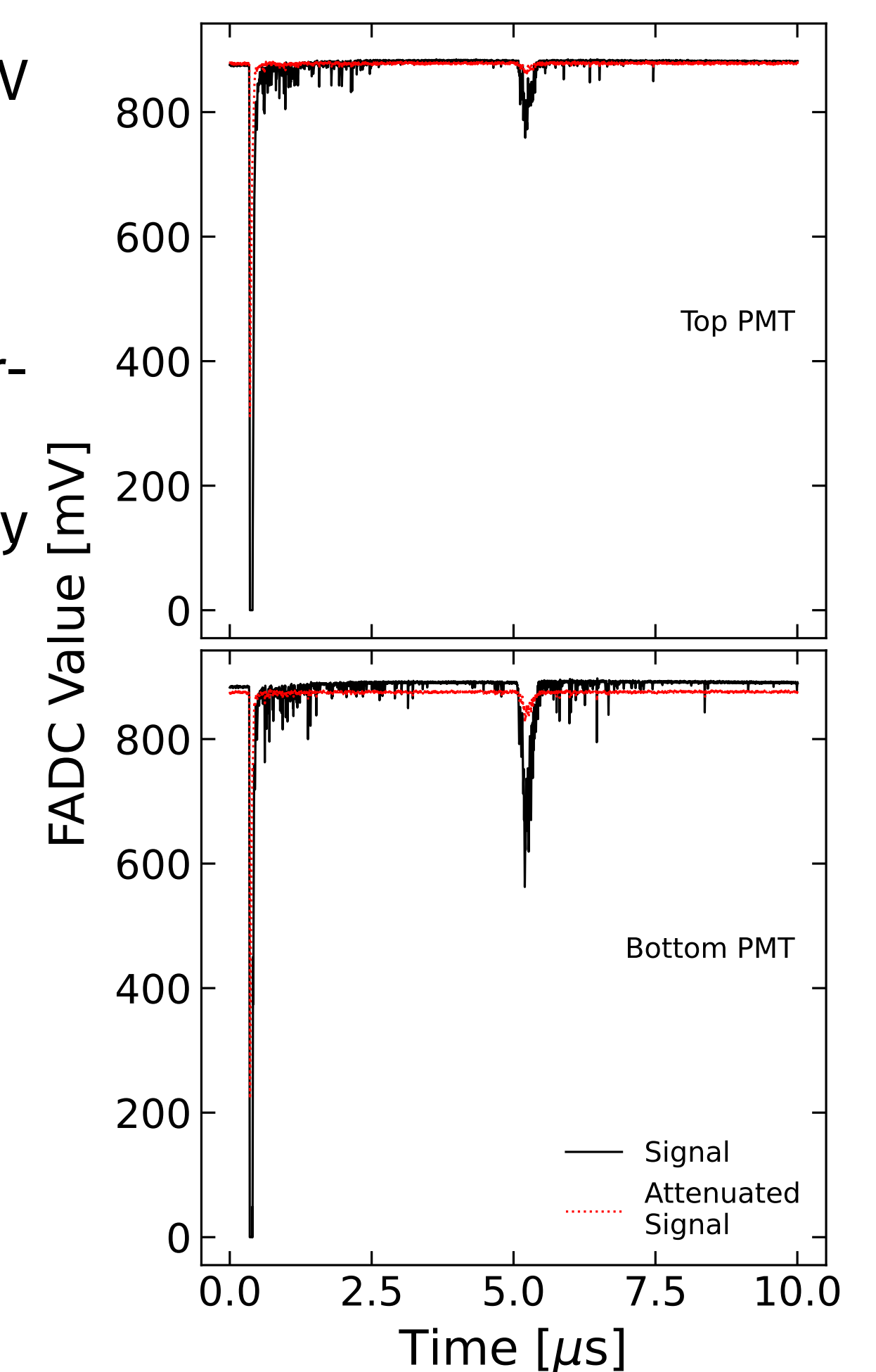
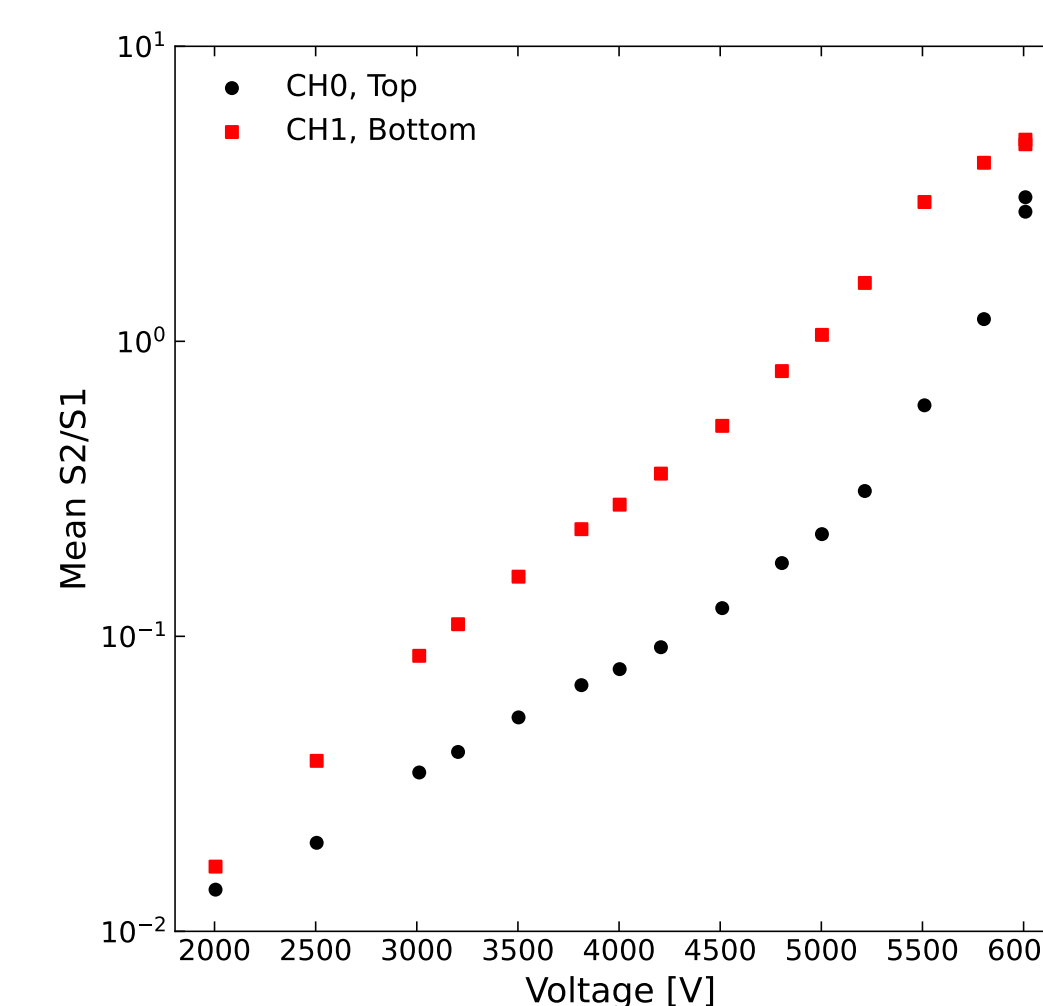
## Primary Scintillation Light, S1



- S1 signal observed when no voltage applied to needle: primary scintillation from  $\alpha$ -particle interaction
- S1 area monitored as voltage increased - observed expected decrease due to reduction in electron recombination as electric field increases

## Observation of Proportional Electroluminescence

- Needle voltage varied from 0 V to 6000 V
- Above 2000 V, S2 signal observed
  - Example shown for 4510 V
- Amplification estimated using  $S2/S1$
- Exponential increase indicates proportional amplification
- Deviation at highest voltages caused by FADC saturation



## Summary

- Promising method for electroluminescence generation in LXe
- Simulations ongoing to understand electric field and geometric effects
- Charge read-out to be implemented
- Incorporation of needles into ACHINOS-like structure is planned
- Goal of introducing structure into XMASS detector for improved sensitivity in direct DM searches