First observation of electroluminescence in liquid xenon with microstrip plates

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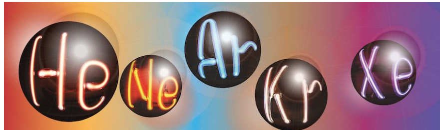


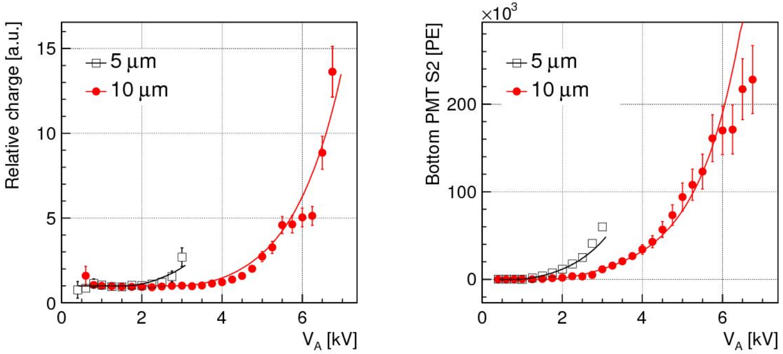
Single-phase detectors

- Advantages
  - No liquid-gas interface
    - Reduced instabilities (interface ripples)
    - No delayed e^- emission or e^- transfer efficiency through interface
    - No gate-interface-anode alignment problems
    - Horizontal drift→sporadic bubbling not a concern
    - Potential improvement to the S2-only energy resolution
  - Different geometries possible
    - Radial TPC (see talk by Jianyang Qi)
    - Symmetric central cathode TPC→lower voltages needed
- Challenges
  - High EL and CM thresholds →amplification requires extreme electric fields

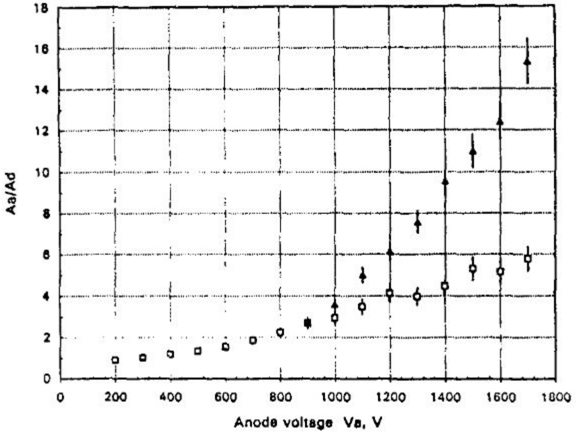
EL amplification in LXe

- Thresholds
  - Charge multiplication ~ 725 kV/cm Aprile et al
  - Electroluminiscence ~ 412 kV/cm Aprile et al
- Thin wires (5-25 µm)
  - ~ 290 photons/ie @ 6.75 kV Aprile et al
  - ~ x14 e^- multiplication @ 6.75 kV Aprile et al
  - single electron sensitivity Qi et al
- Microstrips
  - ~x10 e^- multiplication @ 1.7 kV Policarpo et al
  - Unknown light yield → *this talk*

Aprile et al

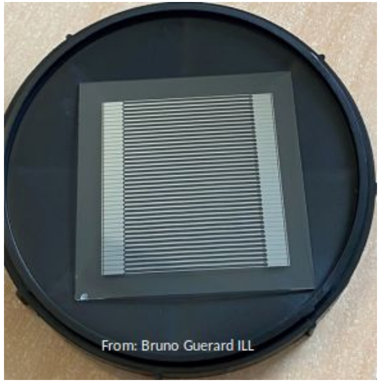


Policarpo et al

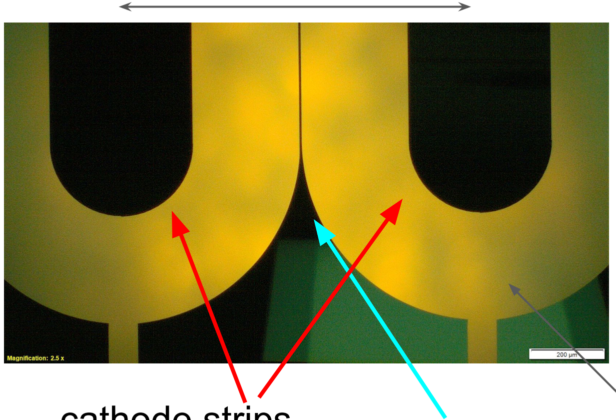


Microstrips

- First proposed by A. Oed in 1988 for the MicroStrip Gas Chamber (MSGC)
- Thin strips deposited on a substrate (ideally VUV-transparent)
- Original design: cathode and anode strips interleaved



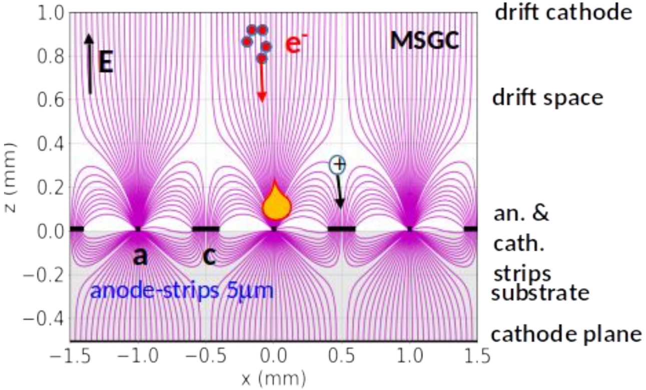
1 mm



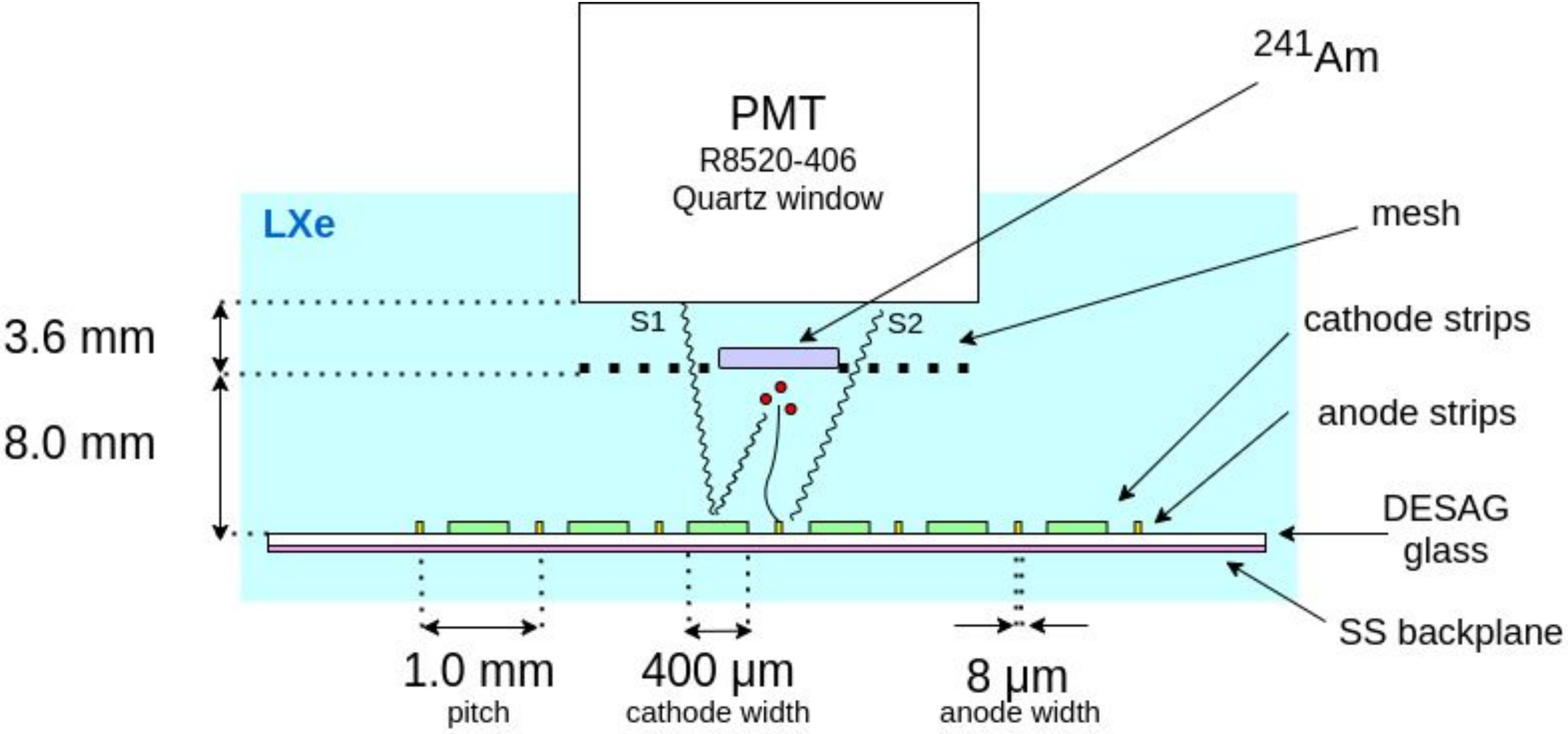
cathode strips

anode strip

light seen through the substrate

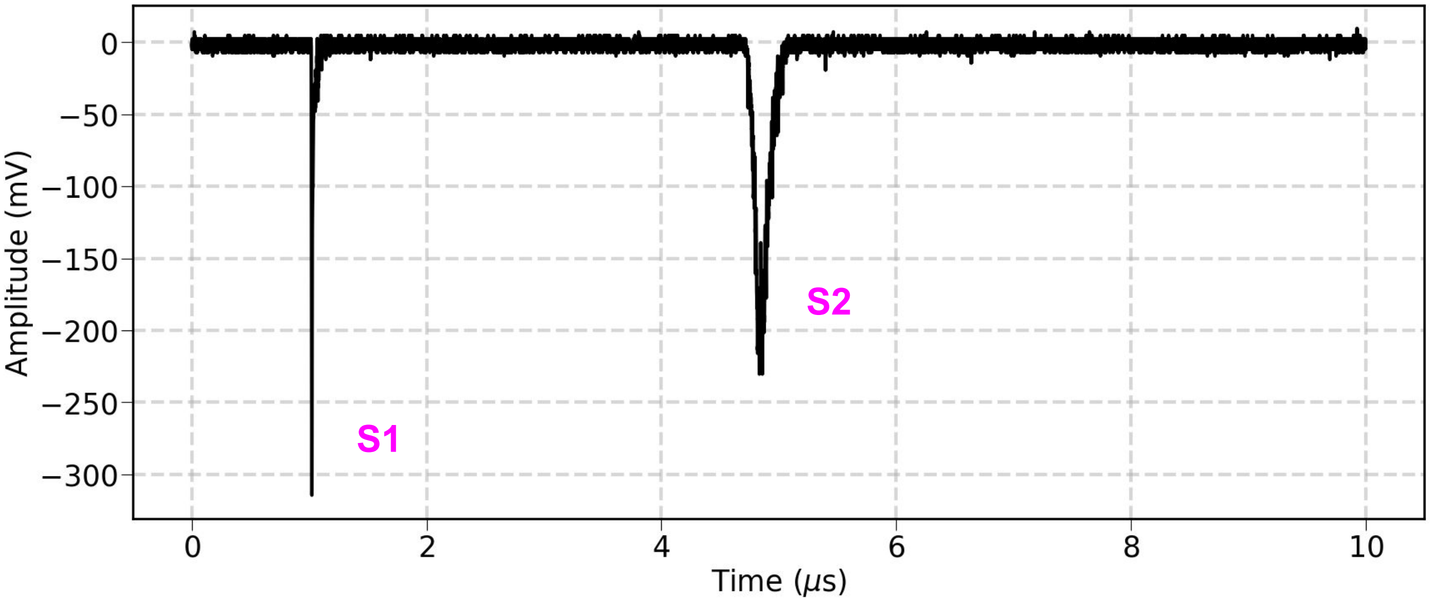


Our setup


PMT
R8520-406
Quartz window
^{241}Am
LXe
mesh
cathode strips
anode strips
DESAG glass
SS backplane
S1
S2
3.6 mm
8.0 mm
1.0 mm
pitch
400 µm
cathode width
8 µm
anode width

A typical PMT waveform

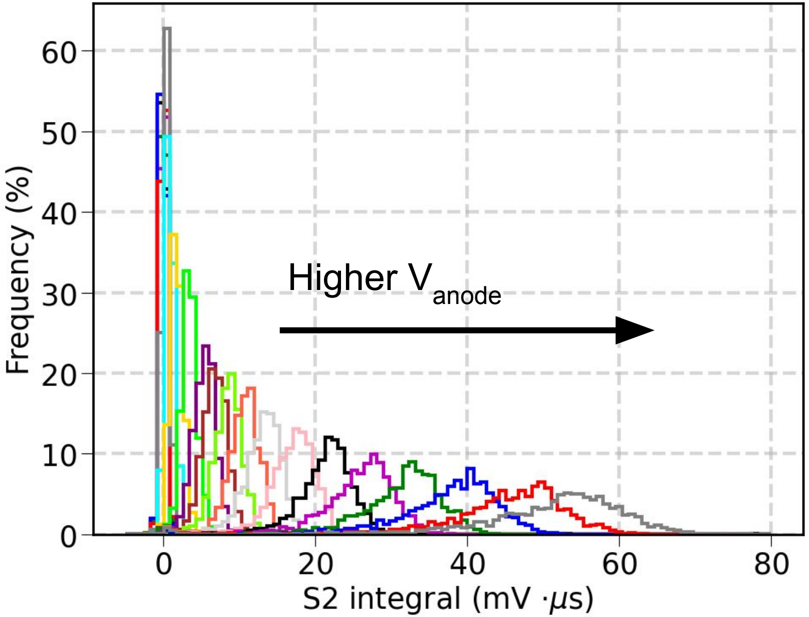
V_{source} = -2.0 kV
$V_{cathode}$ = ground
V_{back} = -2.0 kV
V_{anode} = +1.6 kV



Integrated S2 signal

V_{source} = -2.0 kV
$V_{cathode}$ = ground
V_{back} = -2.0 kV
V_{anode} = 0 — 2 kV

- PMT waveform integrated on a fixed S2 window
- Integral of S2 increases with V_{anode}
- Max V_{anode} = 2 kV due to anode-to-cathode discharges
- EL threshold @ V_{anode} ~ 500 V



Light yield

- Conversion to pes based on in-situ PMT calibration
- Light yield @ V_{anode} = 2 kV
  - If e^- lifetime ≫ drift time → LY = 33 ph/ie
  - If e^- lifetime ≈ drift time → LY ≳ 100 ph/ie

$$LY = \frac{S2}{\frac{\Omega}{4\pi} \cdot T \cdot QE_{PMT} \cdot N_{ie}}$$

mesh transparency

from alpha particles

$\Omega \sim 10.5$ %
$T \sim 81\%$
$QE \sim 28\%$
$N_{ie} \sim 15500 \sim 2.5$ fC

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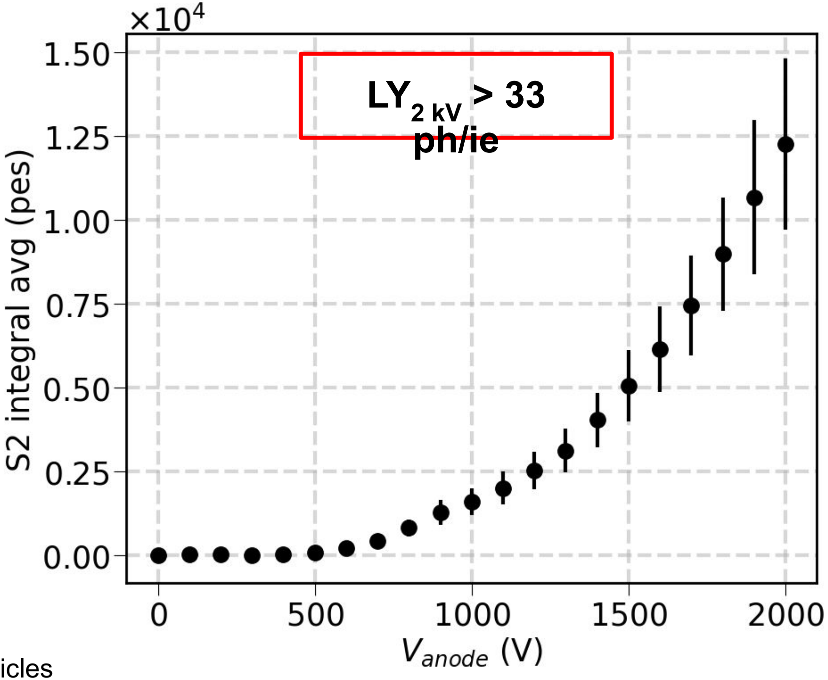

$LY_{2\ kV}$ > 33 ph/ie

*Error bars represent std, not uncertainty

Data modeling

- Data fitted to the a CM & EL model
  - EL threshold (θ_4) ~ 465 kV/cm
  - CM threshold (θ_2) ~ 785 kV/cm
  - ~x3 e^- multiplication @ 2 kV
  - In agreement with Aprile et al

V_{source} = -2.0 kV
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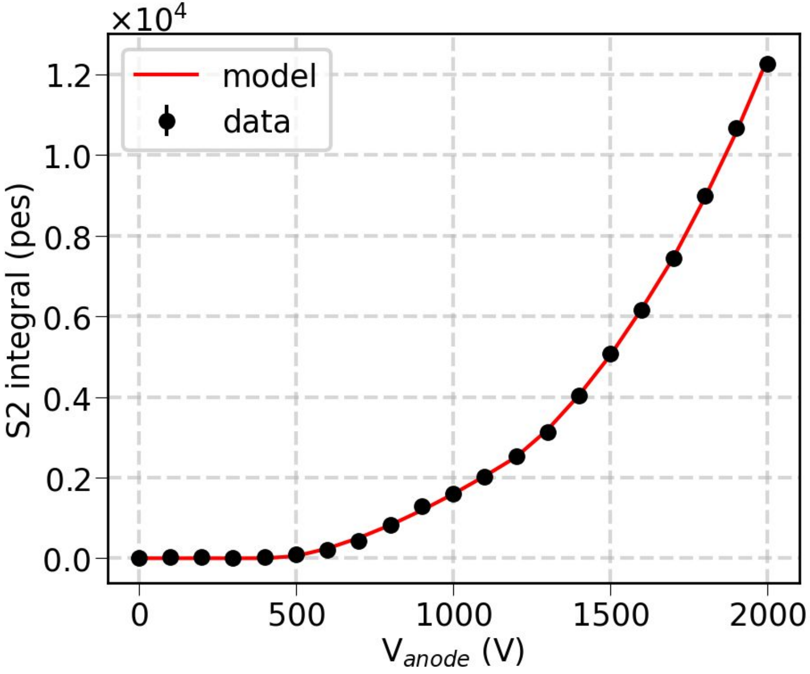
V_{anode} = 0 — 2 kV



Aprile et al

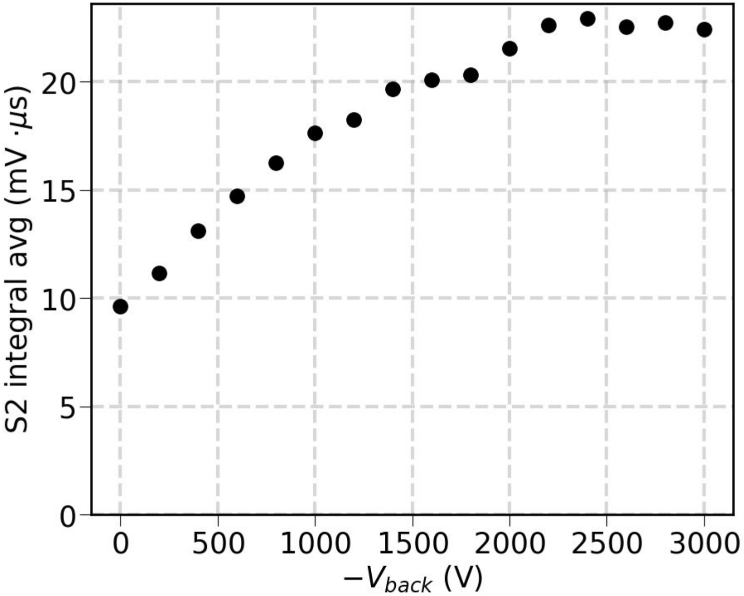
$$\begin{cases} \dfrac{dN_e}{dx} = N_e(x) \cdot \theta_0 \cdot e^{-\frac{\theta_1}{E(x)-\theta_2}} \\ \dfrac{dN_\gamma}{dx} = N_e(x) \cdot \theta_3 \cdot (E(x) - \theta_4) \end{cases}$$

E(x) from COMSOL

Backplane bias

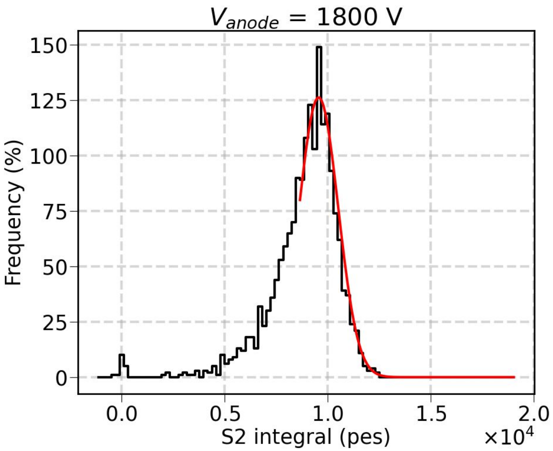
V_{source} = -2.0 kV
$V_{cathode}$ = ground
V_{anode} = +1.6 kV

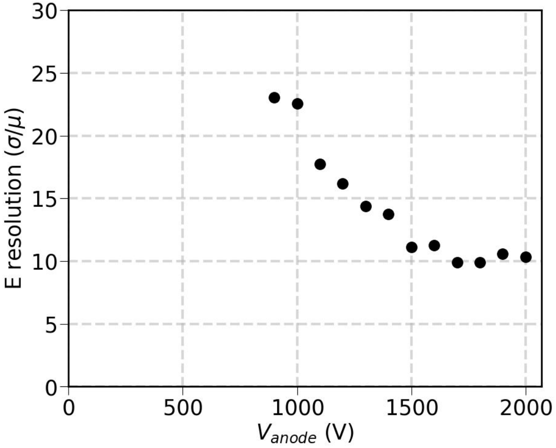
- Biasing the backplane improves the field configuration
  - Increases the field strength in the vicinity of the anode strips
  - Helps focusing the electrons to the anode strips
- The effect is most noticeable below 2 kV
  - Higher values don't improve light production significantly



Energy resolution

- Gaussian fit to the high-energy side of the S2 integral spectra
- σ/μ = 9.9 % @ 1800 V
- Similar to the results obtained with 10 μm wires by [Aprile et al]
- Can be improved
  - Thinner strips →Higher fields
  - Larger anode-cathode distance

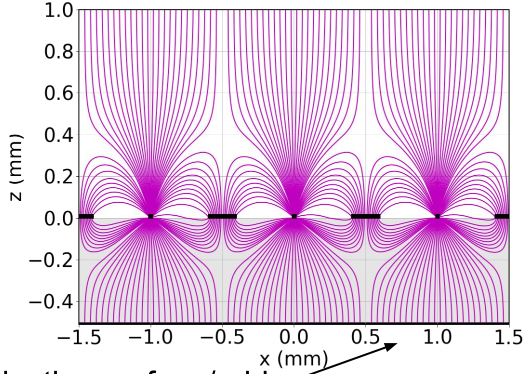




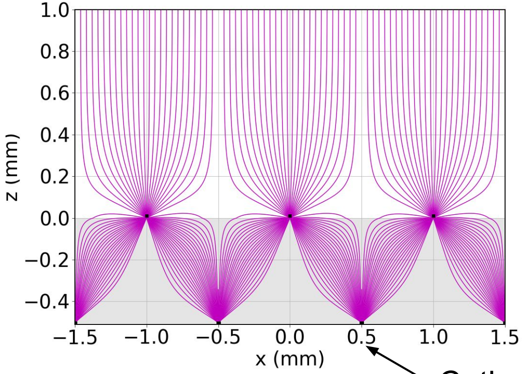
Can we do better?

- Performance limited by anode-to-cathode discharges (hundreds of µm apart)
- Higher voltages → higher light and charge yields
- Other configurations have been proposed without cathode strips on the front
    - COated CAthode - COnductive LAyer electrode ( , Bouclier et al 1991)
    - Virtual Cathode Chamber (VCC, Capeans et al, 1997)

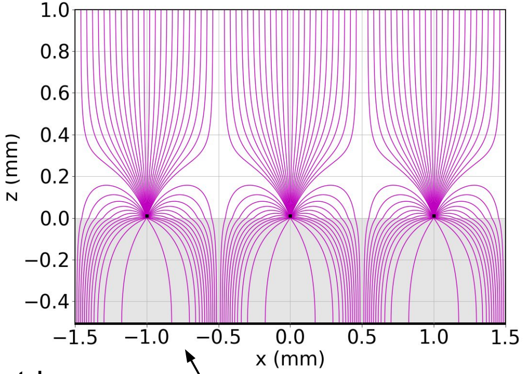
MSGC



COCA-COLA



VCC



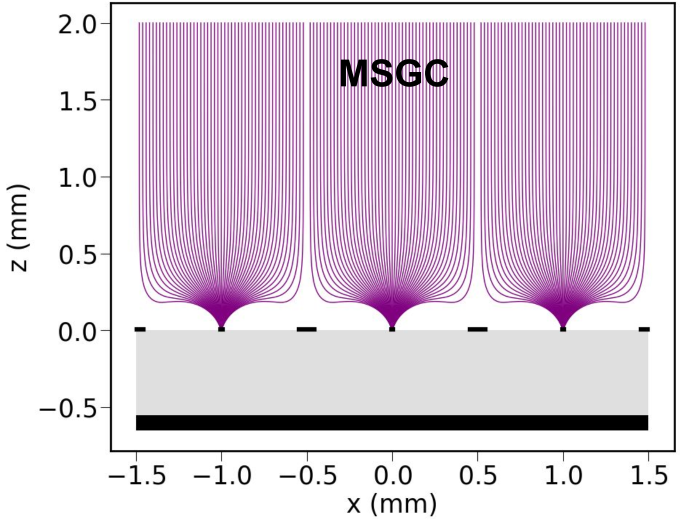
Conductive surface/grid

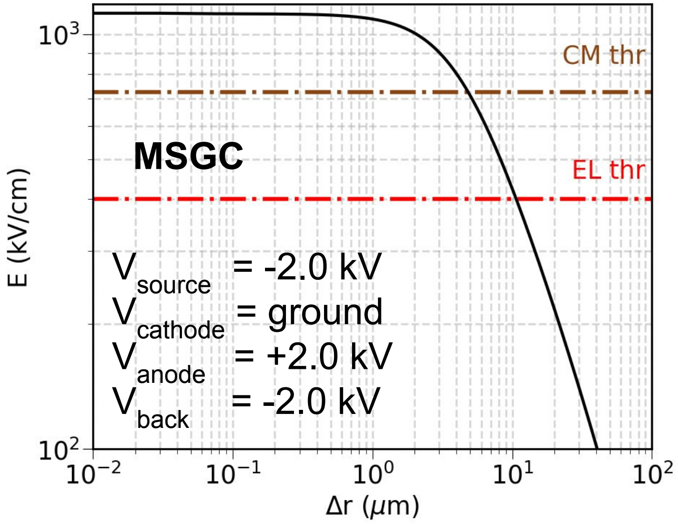
Cathode strips

Conductive surface/grid

Field simulations

- COMSOL simulations of the MSGC geometry
    - Field strength
    - Field lines
- Field vs Δr ≡ distance to anode strip along drift line
- MSGC at V_{anode} = 2 kV
    - EL threshold crossed at Δr ~ 10 μm
    - CM threshold crossed at Δr ~ 5 μm

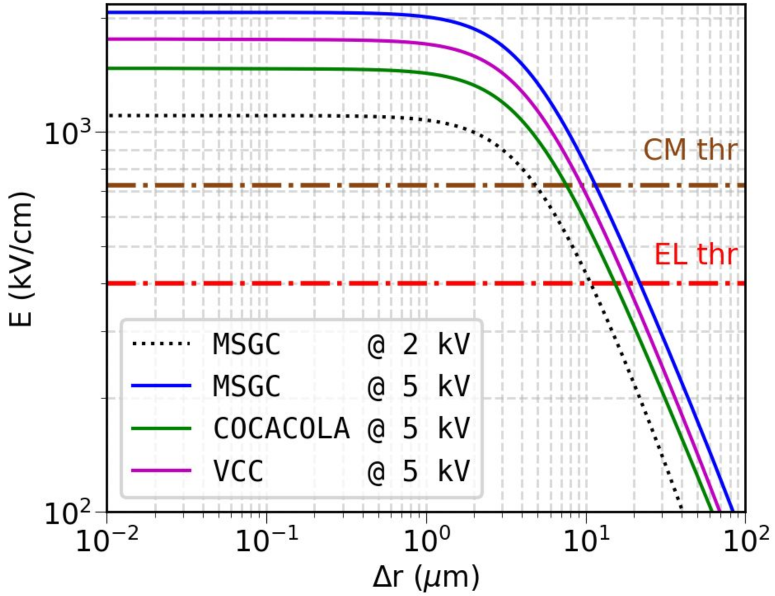




Prospects: MSGC vs COCA-COLA vs VCC

- MSGC has the best field configuration
  - But operation is limited to ~2 kV a-to-c
- COCA-COLA & VCC can operate at higher voltages without discharges
  - higher e^- multiplication and light yields
- COCA-COLA potential
  - ~x14 e^- multiplication
  - ~525 photons / ie
- VCC potential
  - ~x40 e^- multiplication
  - ~1670 photons / ie

- 1-10 nm thick strips
- anode 8 μm wide
- COCACOLA cathode 200 μm wide
- MSGC cathode 400 μm wide



Summary

- Single-phase detectors →solutions to problems faced by dual-phase TPCs
- Microstrip plates
  - EL & CM in liquid →high charge and light yields
- We observed for the first time EL in LXe using a microstrip plate
  - Low charge and light yields due to 2 kV a-to-c bias discharge limit
    - > 33 ph/ie @ $V_{anode} = 2$ kV (potentially $\gtrsim 100$ photons/ie)
    - ~x3 e^- multiplication @ $V_{anode} = 2$ kV
- Other MSP designs
  - Higher anode potentials available
    - Much higher light & charge yields + detector stability
  - COCA-COLA
  - VCC

Paper in preparation!

Thank you for your attention