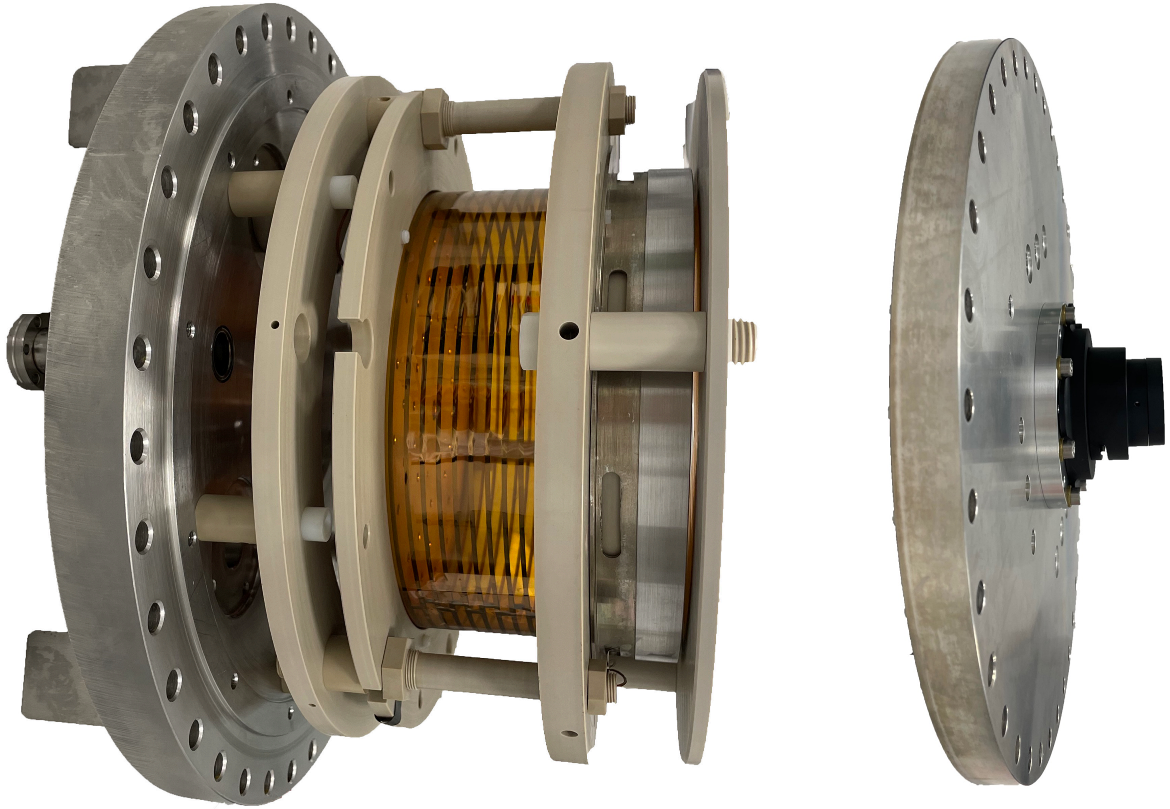
Young Researcher's Day 2022

University of Geneva

# Enhanced Light Detection with an Optical Time Projection Chamber

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# Introduction

- Physics motivation for an optical gaseous TPC
- TPC working principles
- Current TPC set-up
- First light detection
- Further measurements
- Future work

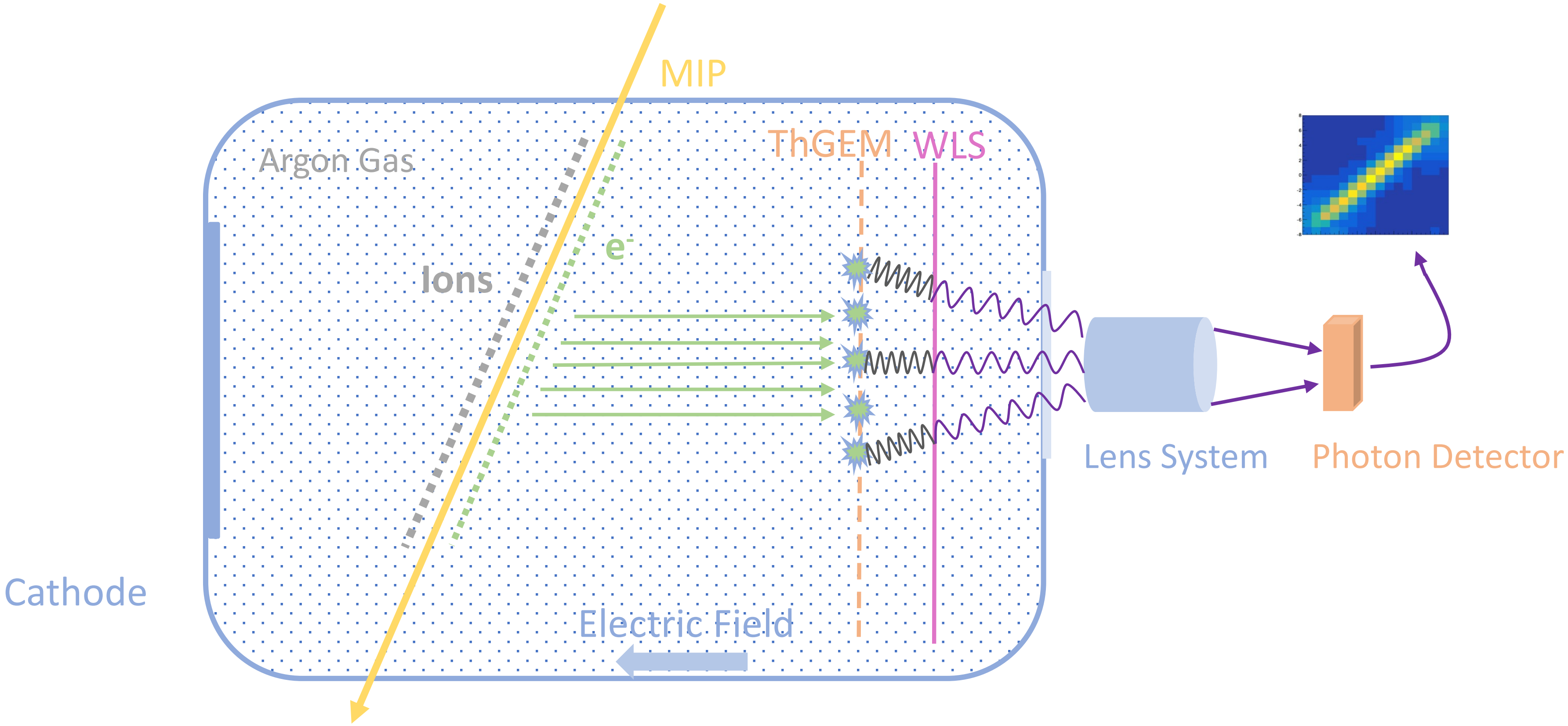
# Why Gas?

- Particle detection momentum threshold reduced (at the moment, state of the art TPC: 450 MeV/c [N. Abgrall et al., 2010])

# Why Optical?

- High Granularity Read-Out
- Cost effective Scale Up
- Readout decoupled from the main body
- Possibility to use pure gas compositions
- Good properties when increasing gas density (pressure)

# Optical Time Projection Chamber

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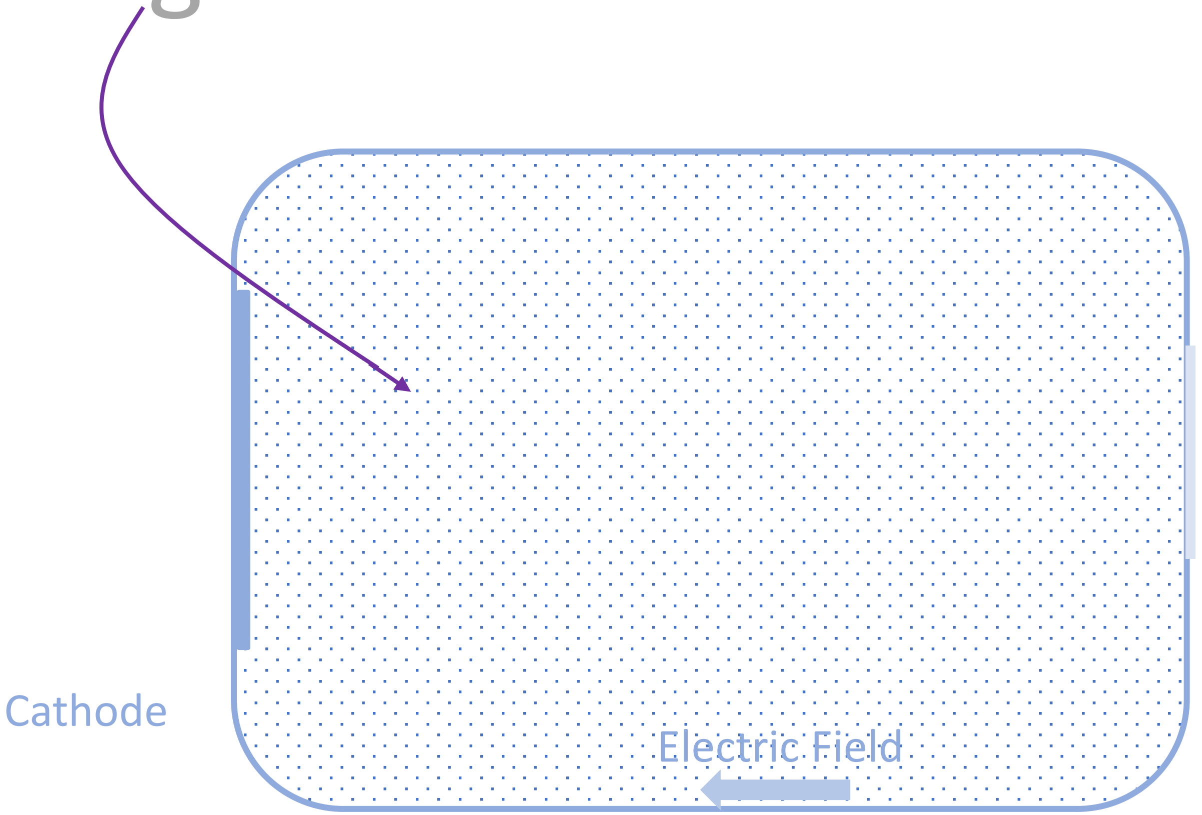
# Argon Gas

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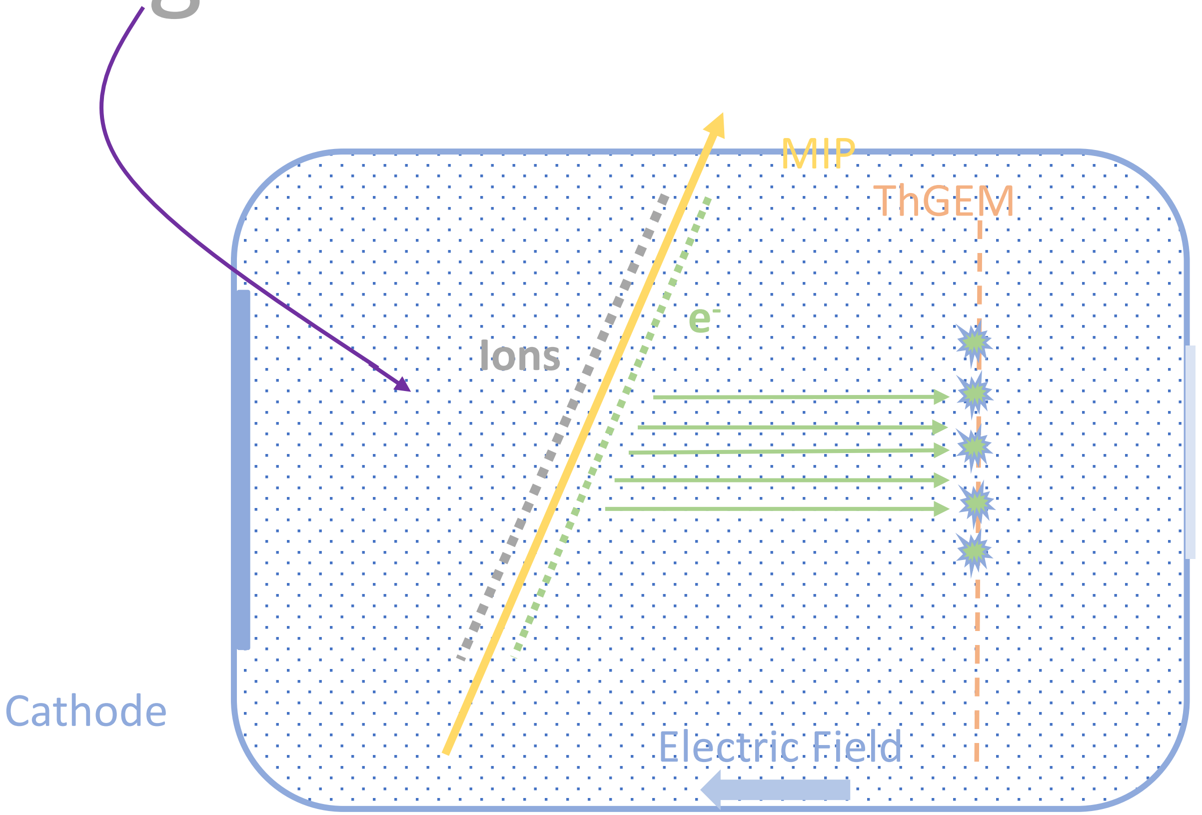
# Argon Gas

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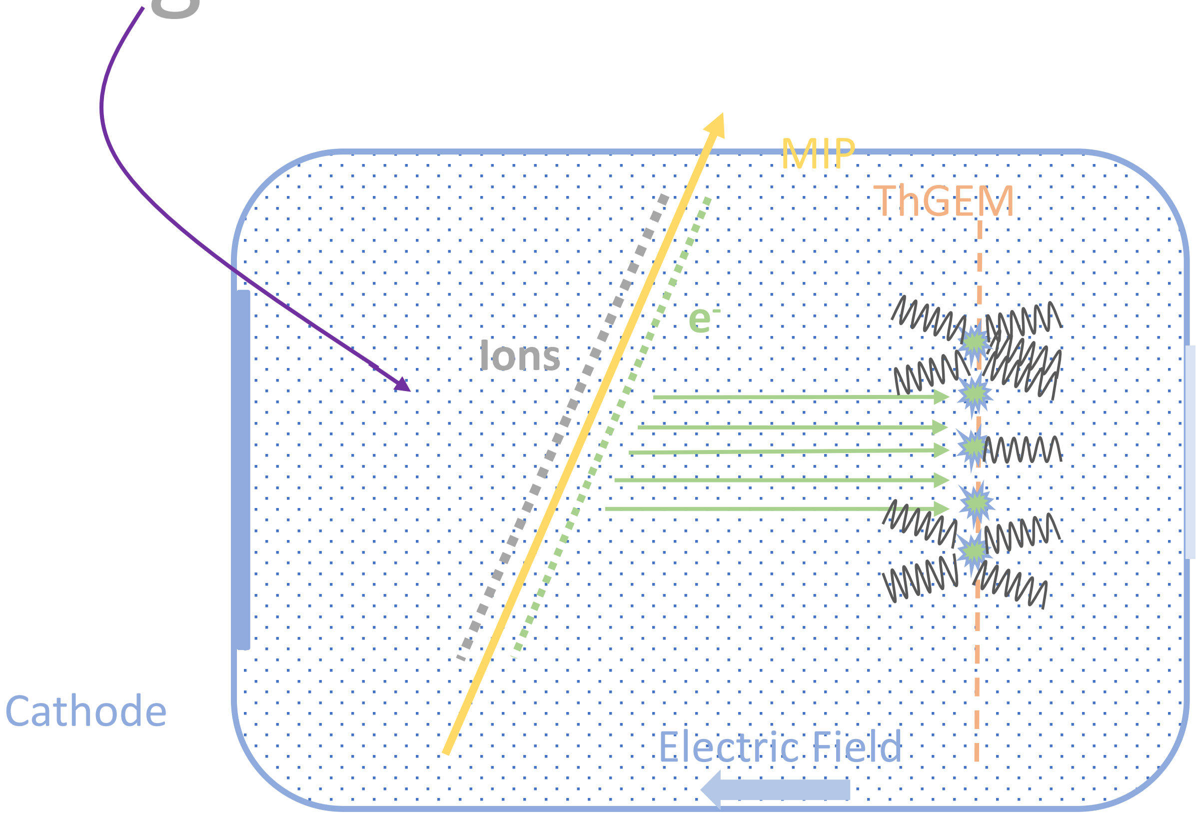
# Argon Gas

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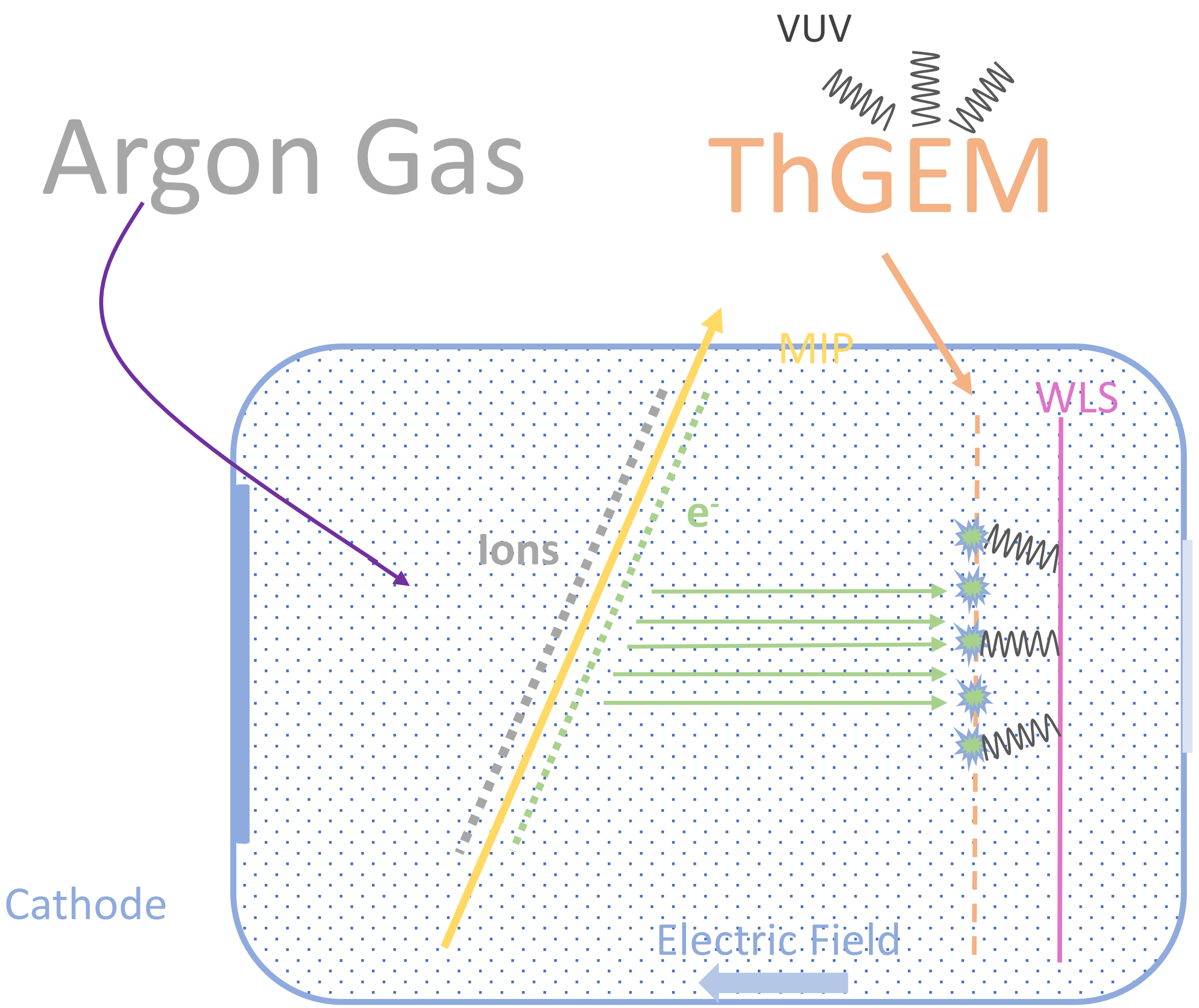


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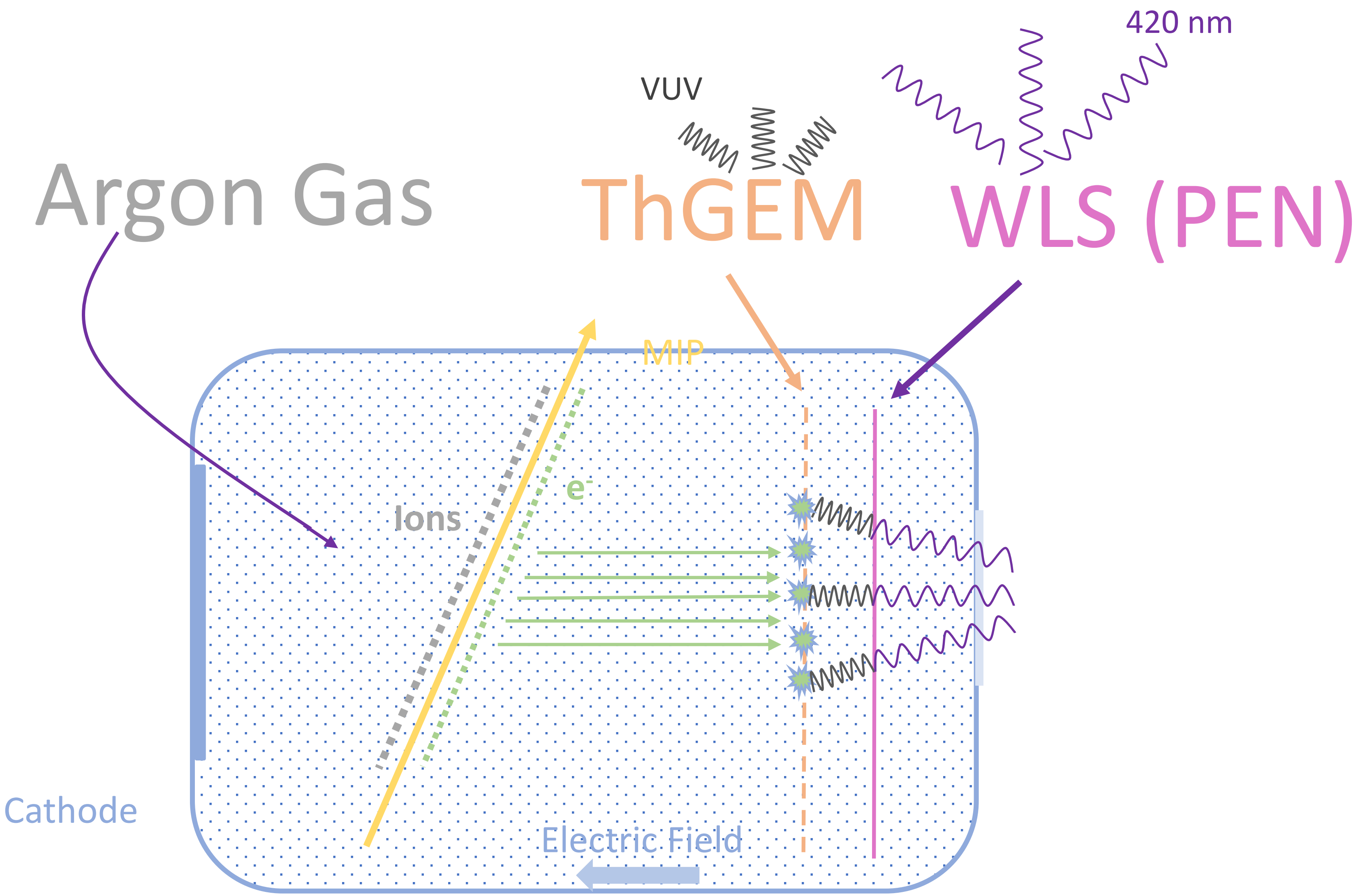


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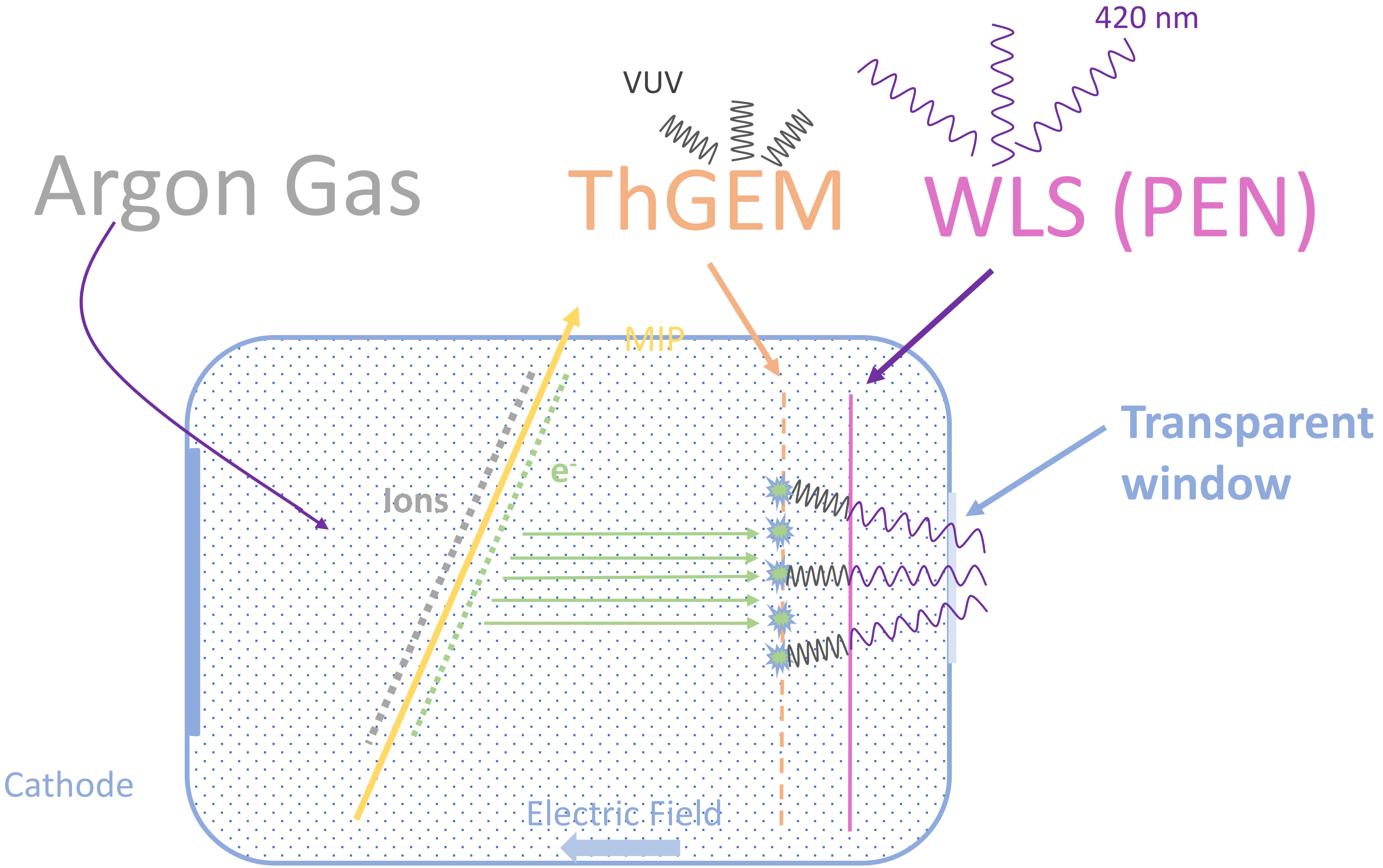


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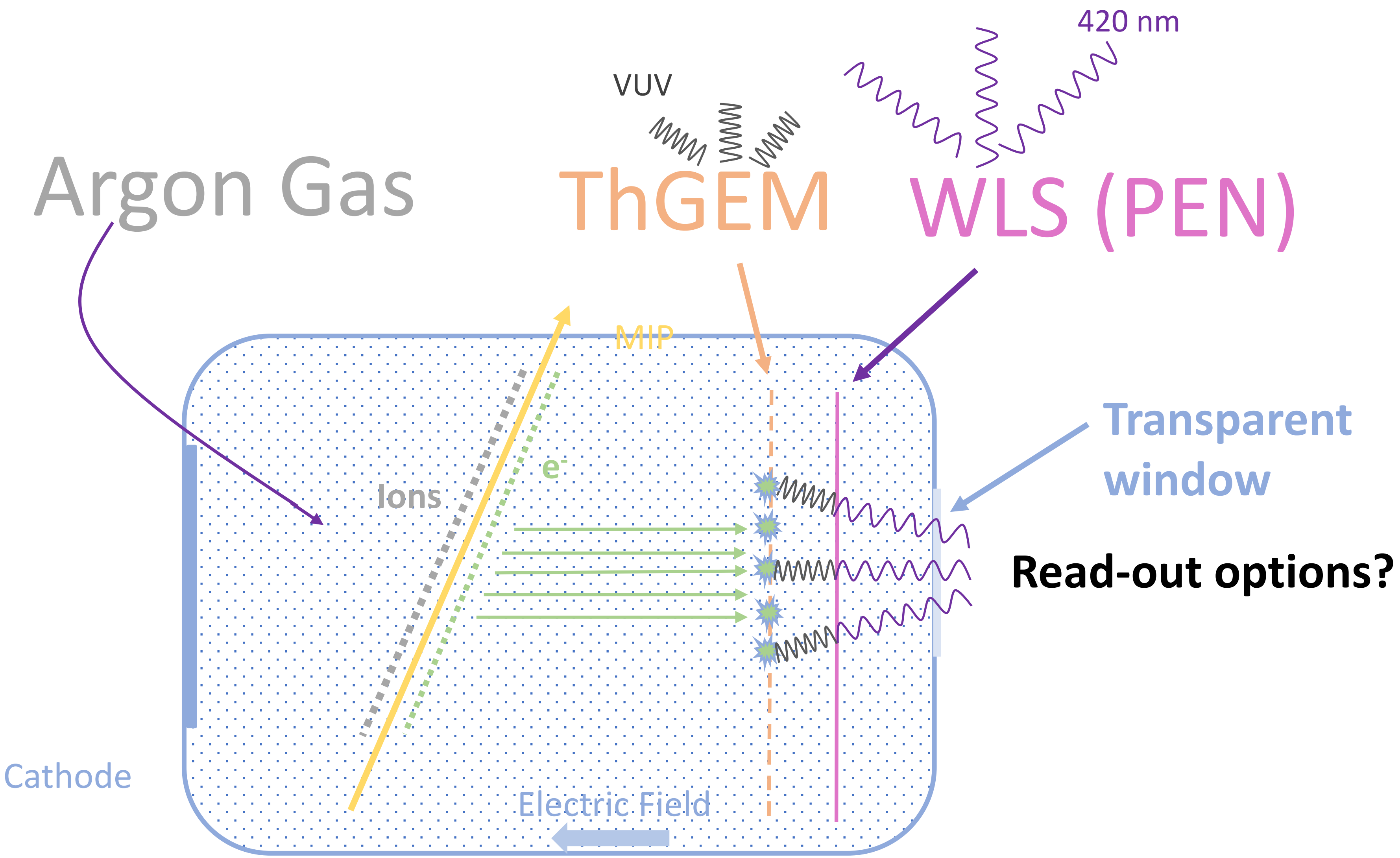


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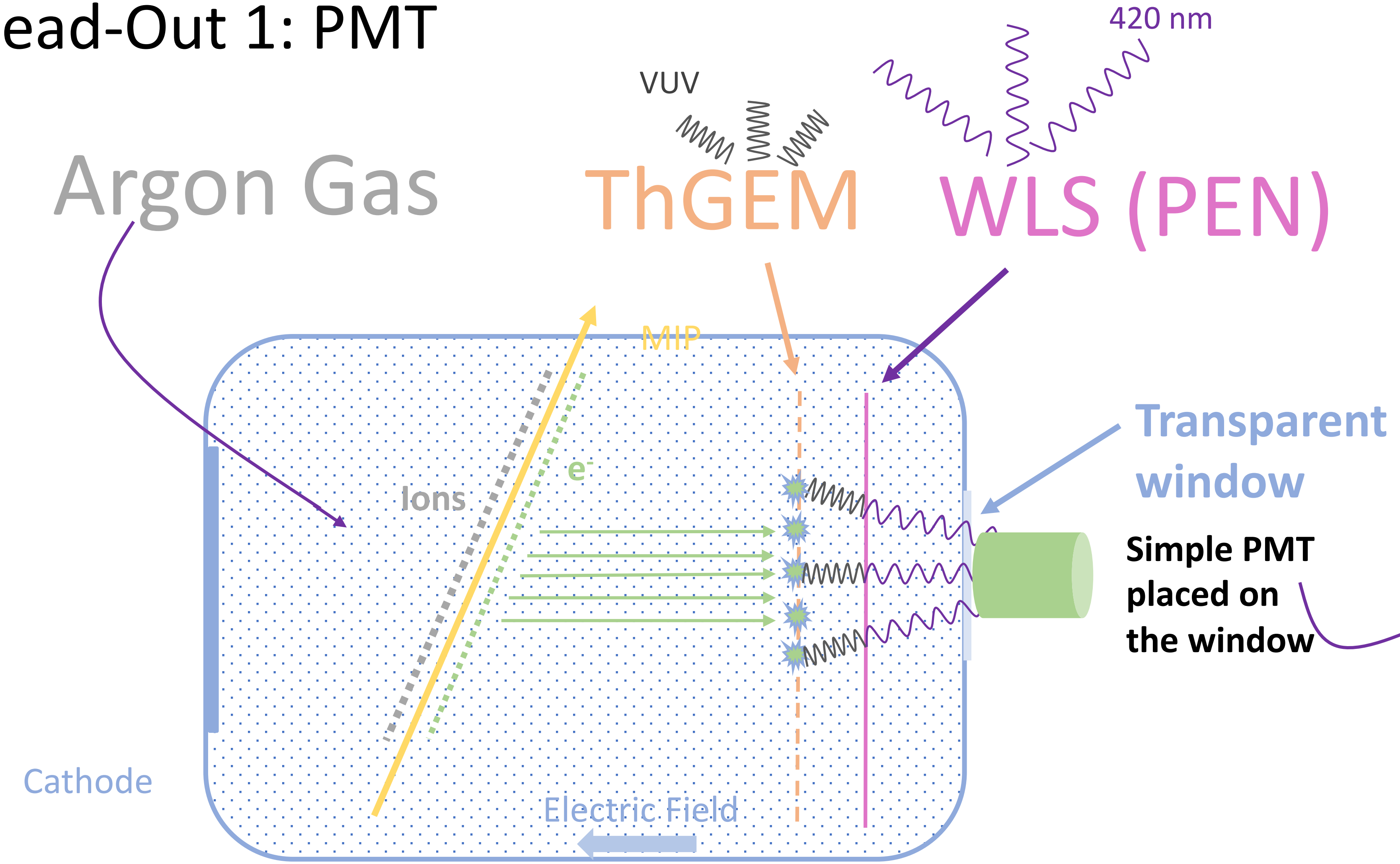
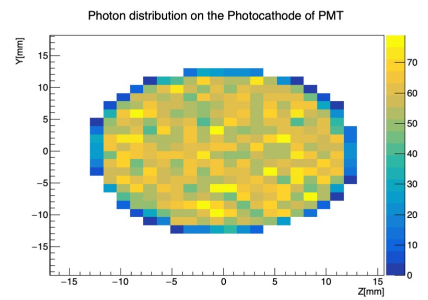
# Read-Out 1: PMT

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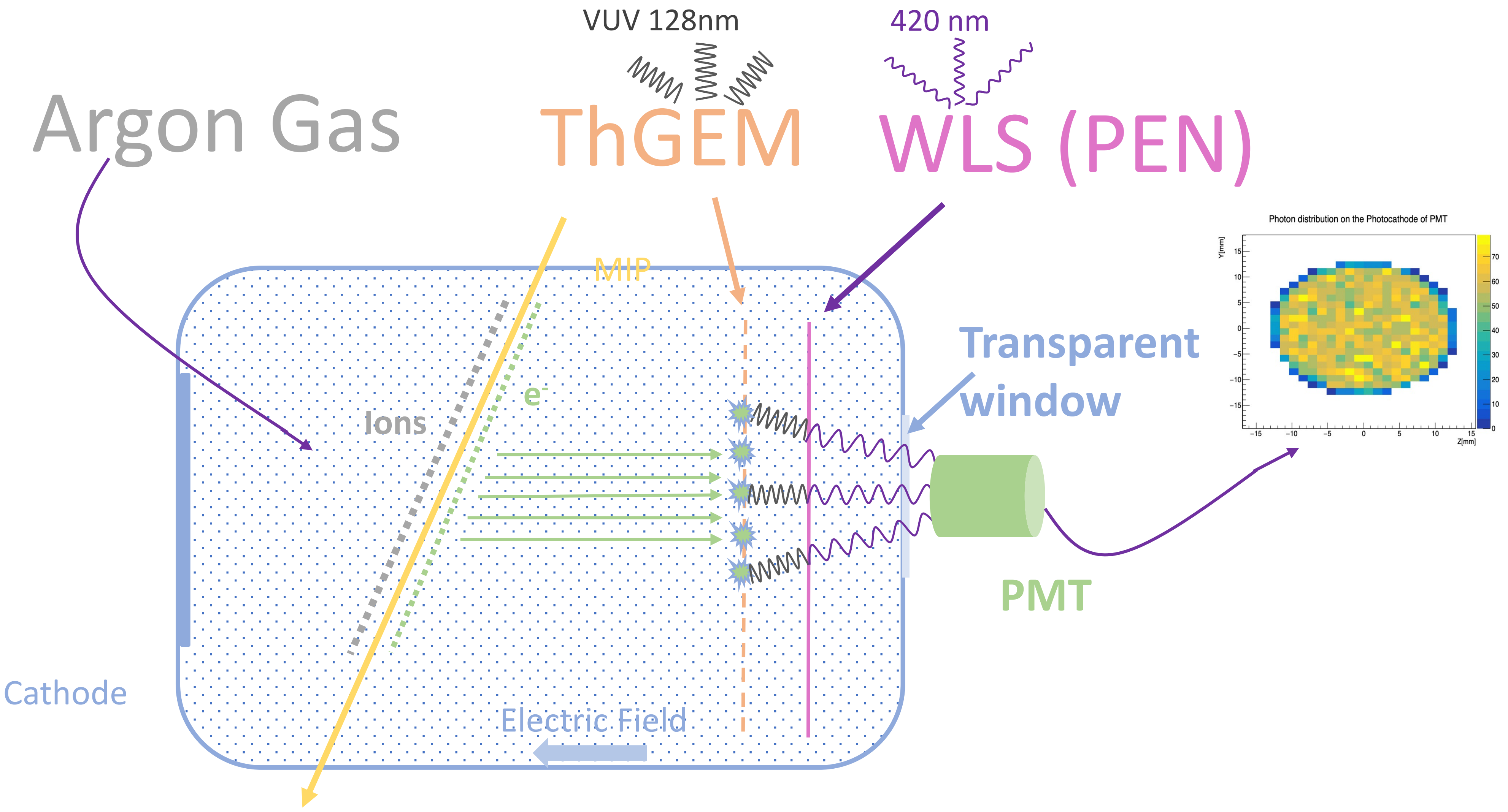


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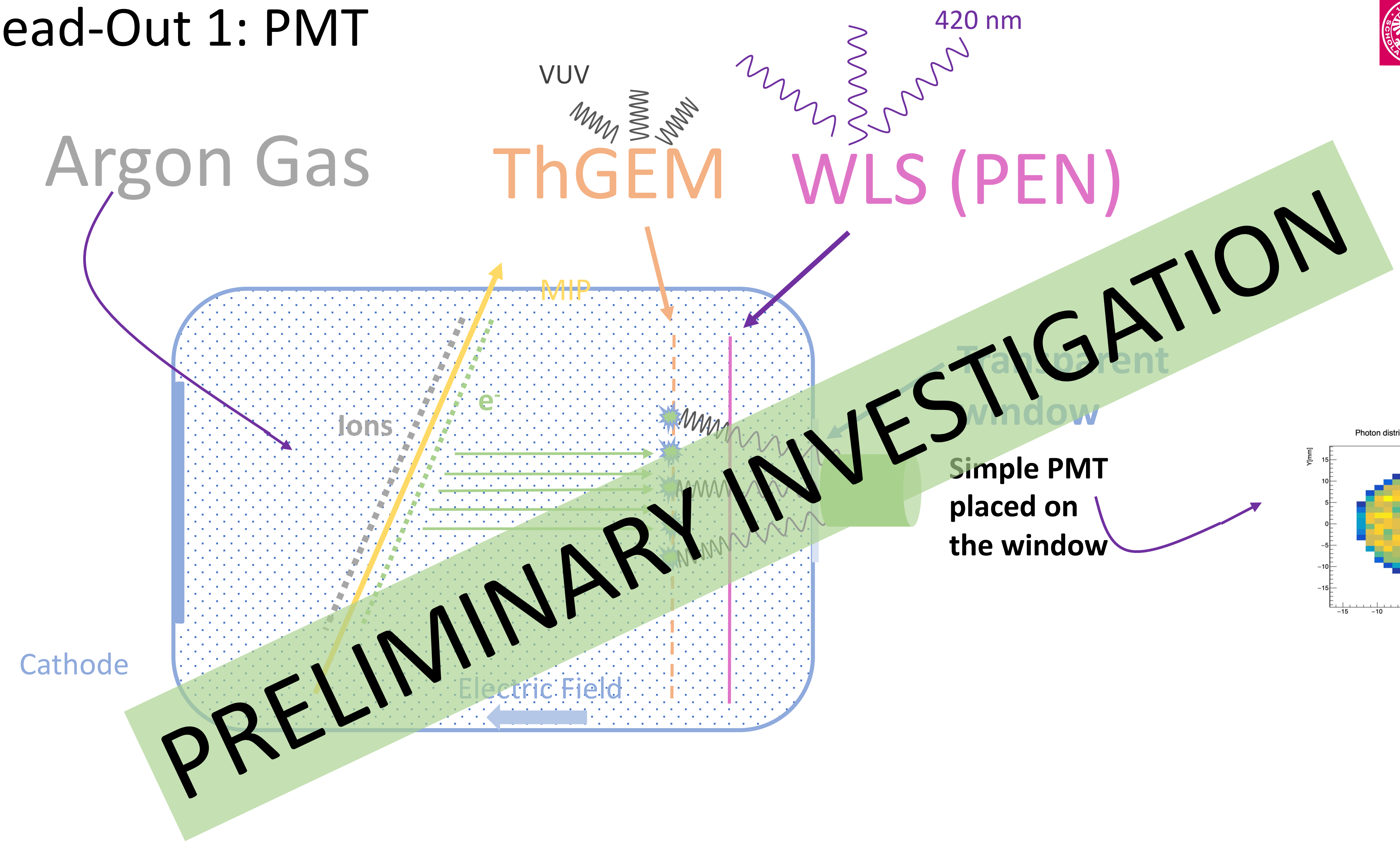
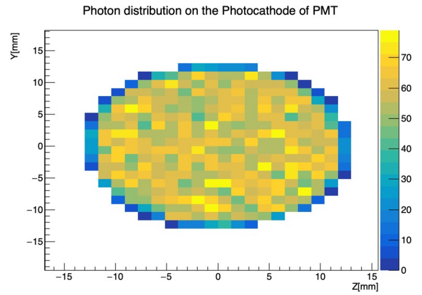
# Read-Out 1: PMT

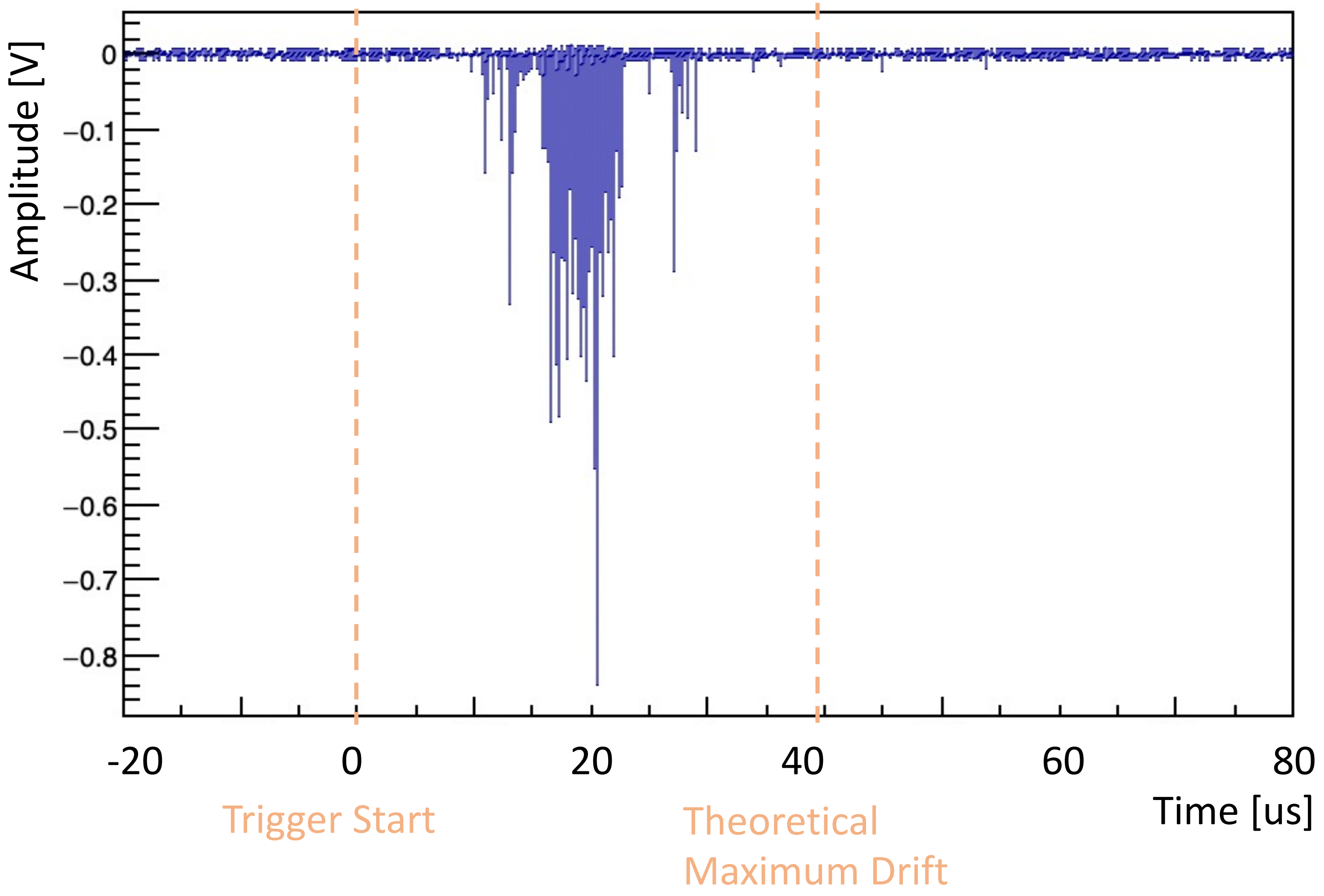



**Simple PMT placed on the window**



# Cosmic Ray Event

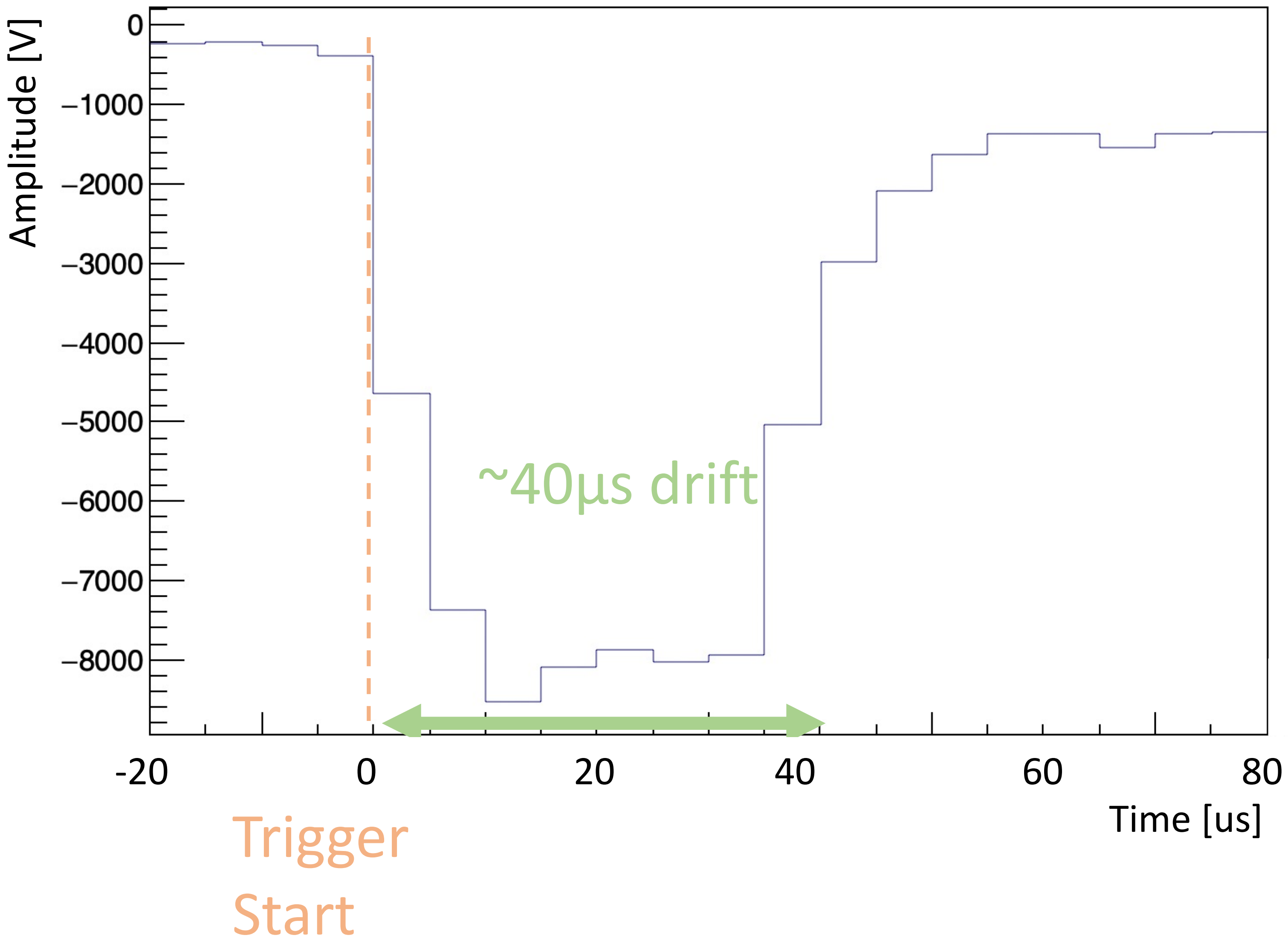
- Cosmic Ray Trigger
- Max Drift Time Expected 40us
- Waveform (WF) compatible with signal



# Waveform Sum

- Thousands events
- Waveforms added
- Drift time compatible with expectation
- Signal rate compatible with trigger efficiency

- First light detection!



# Focus on Light Amplification

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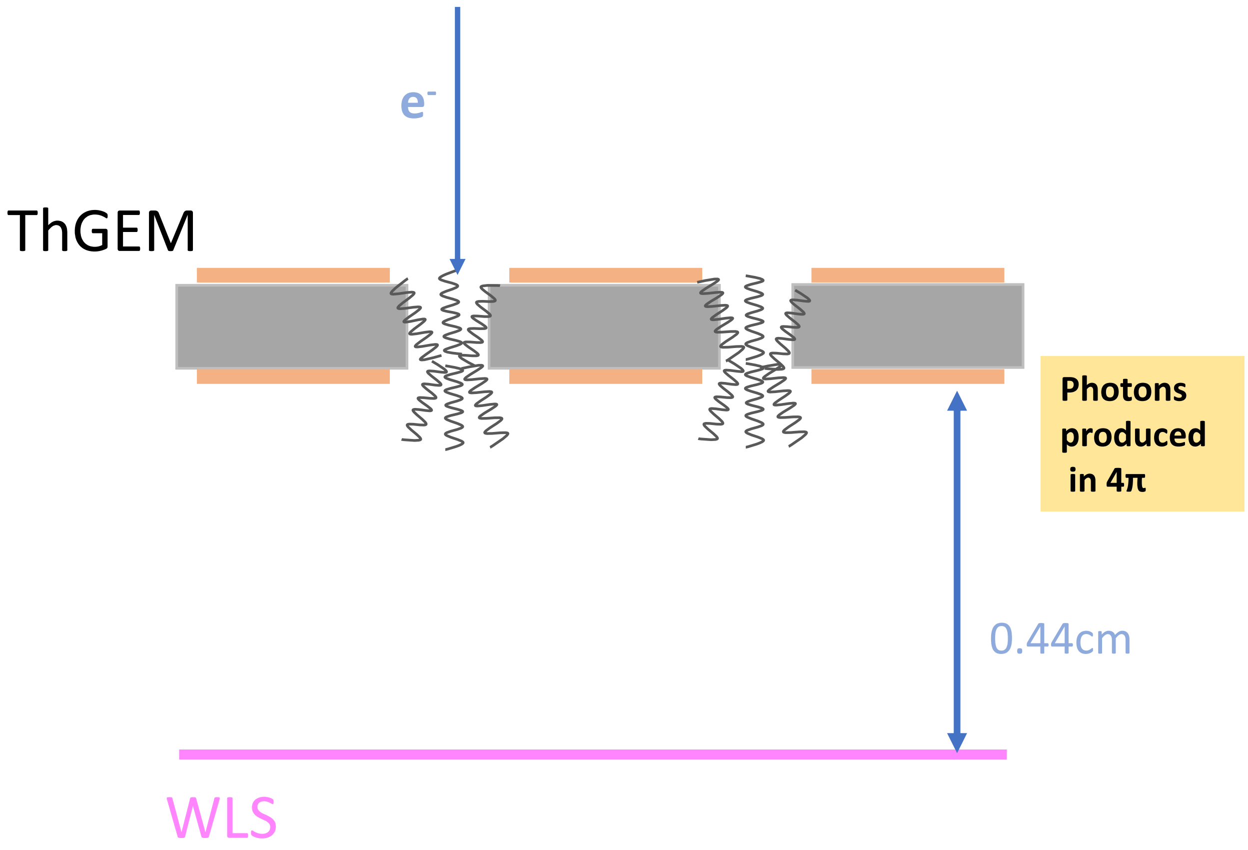
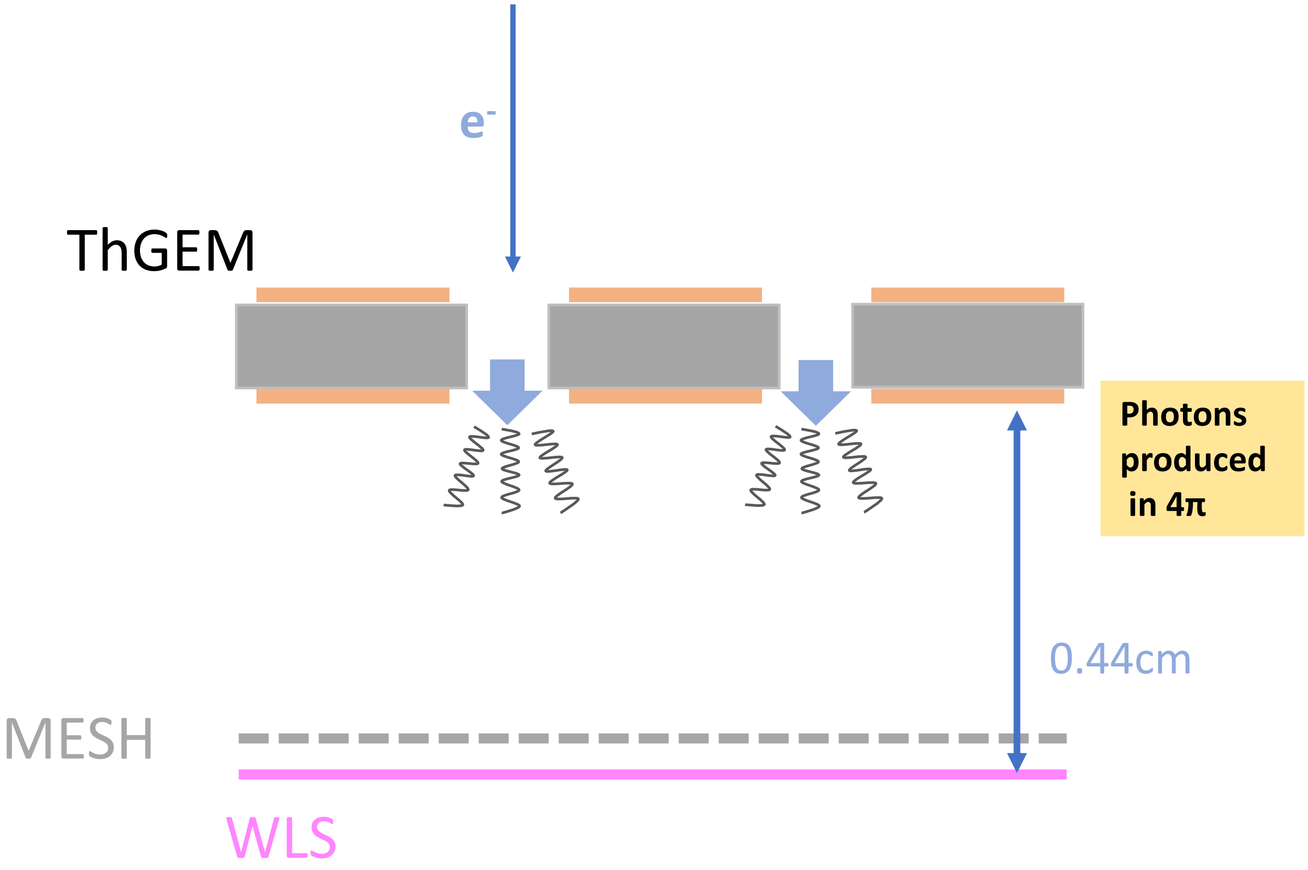
- Electrons amplified in ThGEM
- VUV light produced inside ThGEM hole (towards exterior [T. Lux, 2018])



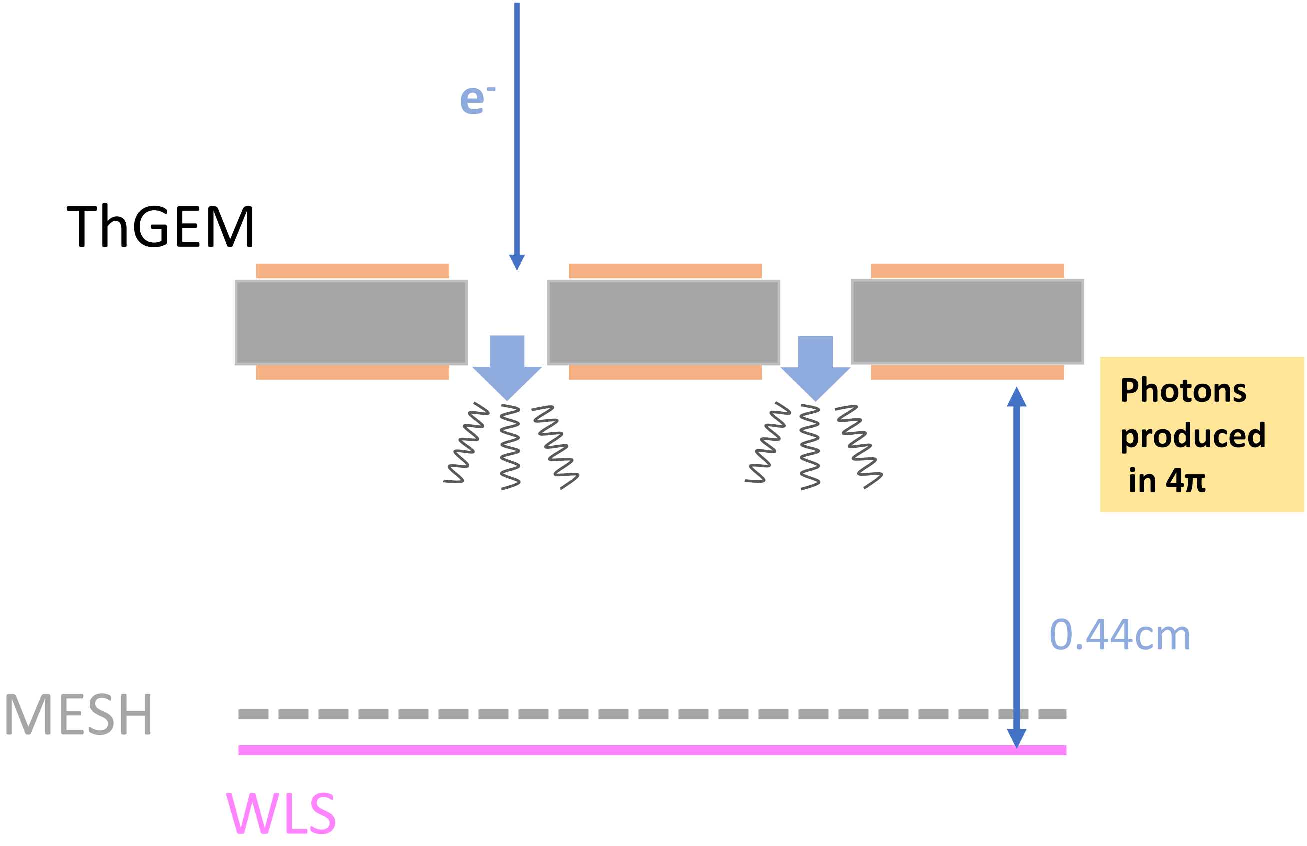
# Adding an extra mesh (Mesh)

- Move further down the photon production point



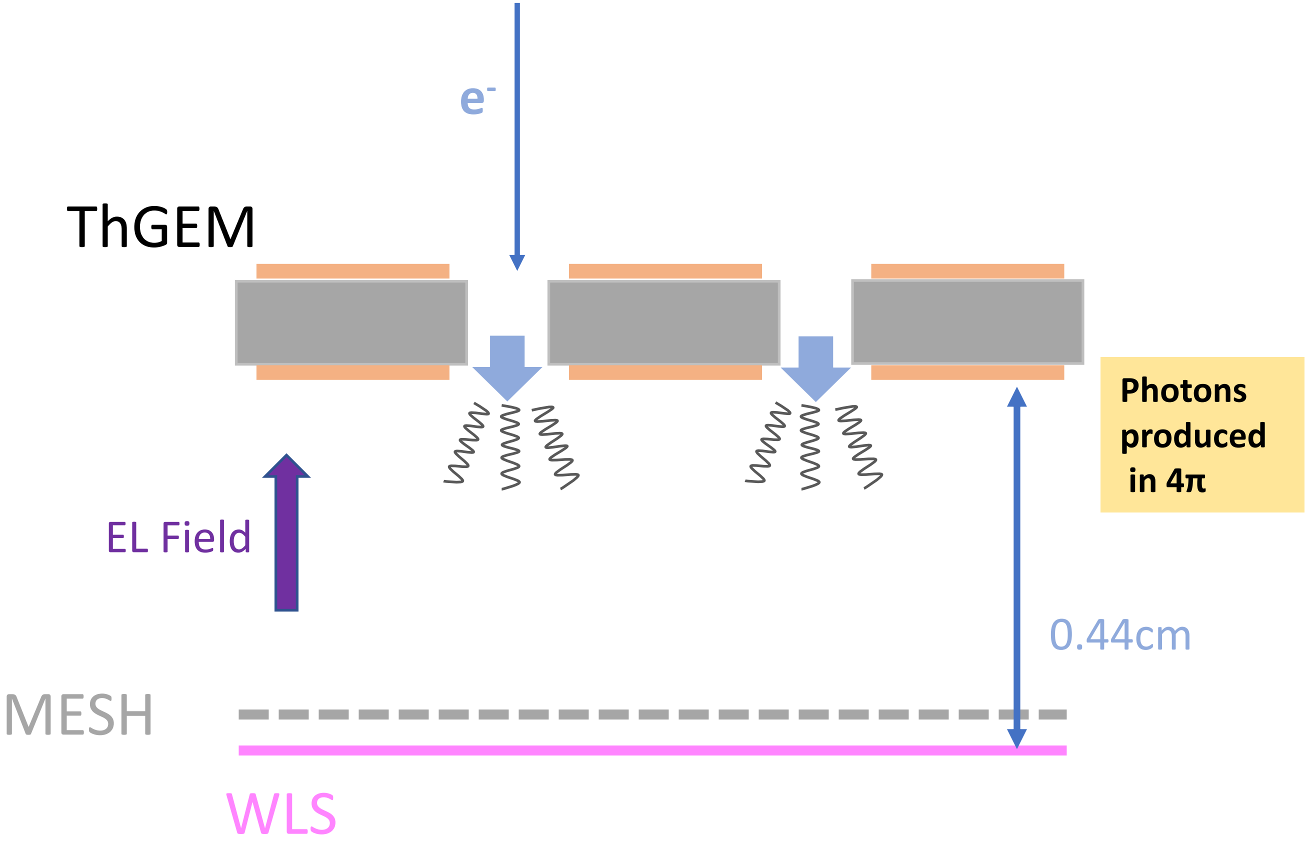
# Adding an extra mesh (Mesh)

- Move further down the photon production point
- Avoid electron deposition on the wavelength shifter (non conductive material)



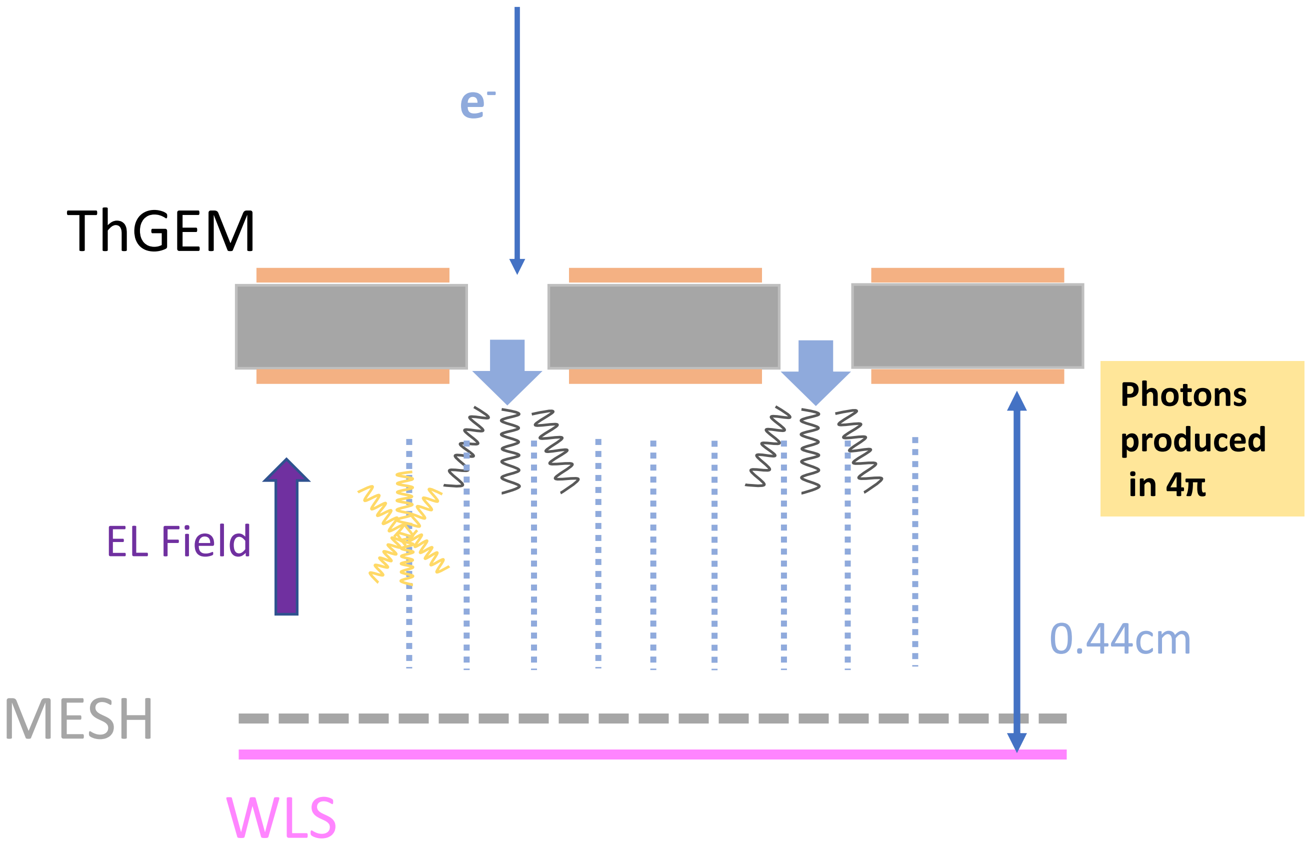
# Adding an extra mesh (Mesh)

- Move further down the photon production point
- Avoid electron deposition on the wavelength shifter (non conductive material)
- PEN mesh set at several different voltags -> **EL electric field**



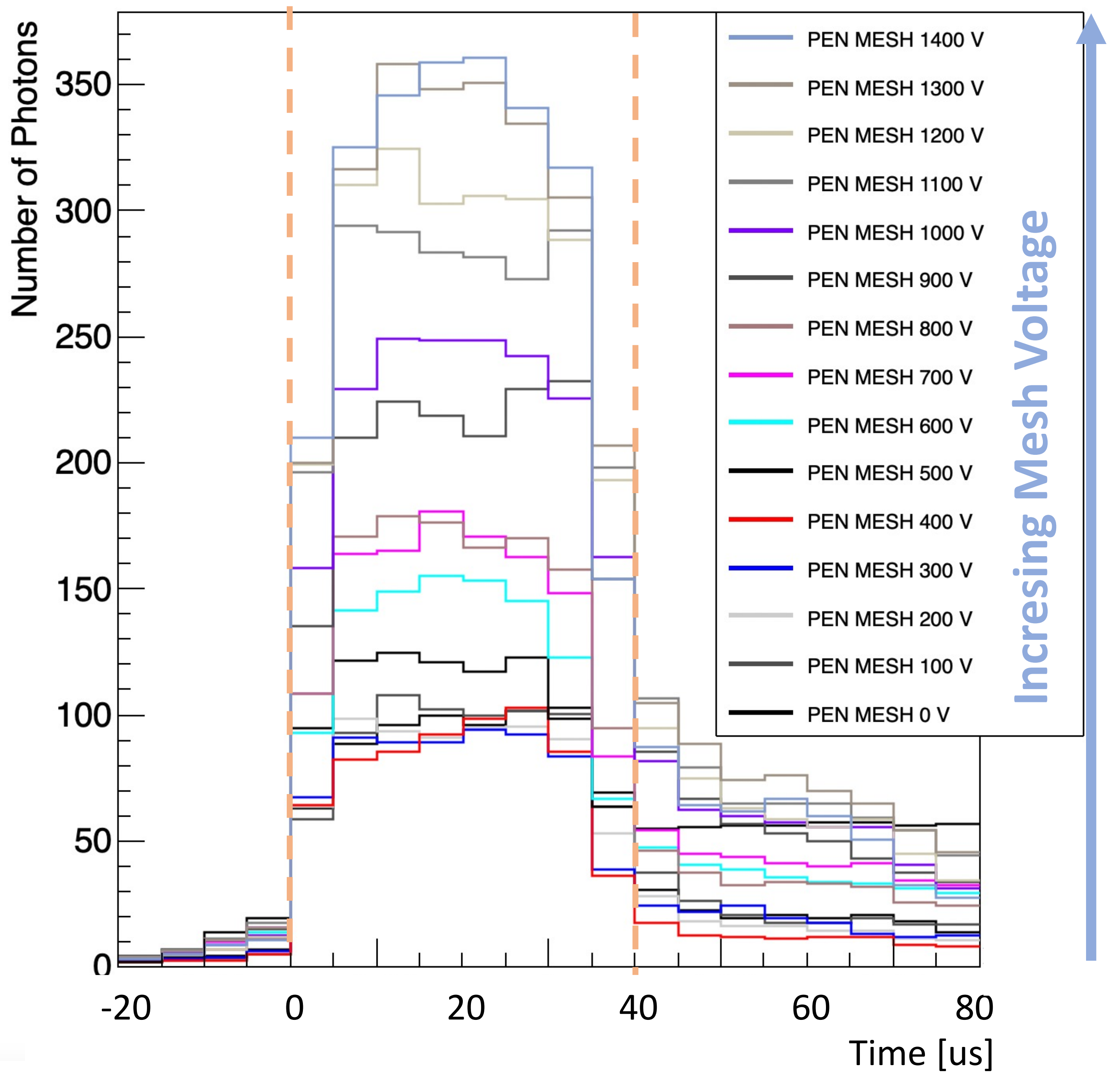
# Adding an extra mesh (Mesh)

- Move further down the photon production point
- Avoid electron deposition on the wavelength shifter (non conductive material)
- PEN mesh set at several different voltags -> **EL electric field**
- **Extra photons can be produced (via Electroluminescence)**



# Mesh Voltage Scan

- PEN Mesh voltage increase from 0 -> 1400V (steps of 100V)
- Gain increase starting from 500V
- Yield increase with PEN mesh V



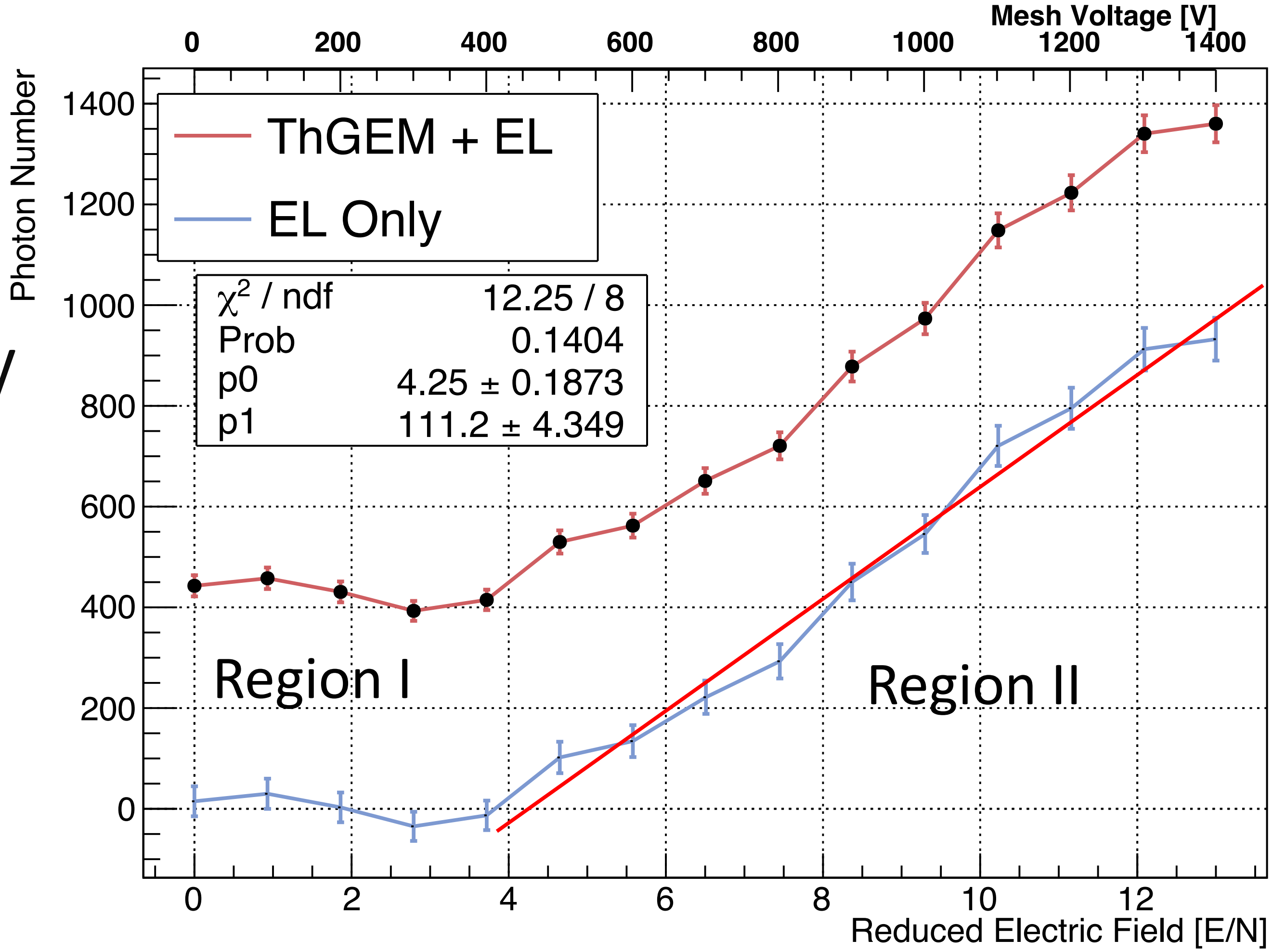

**normalised per trigger number

# Absolute Photon Gain

- Two components: **ThGEM and EL**
- Only ThGEM contribution below 400V
- EL starts to contribute above 400V

- **Photon Yield Increase ~3x.**

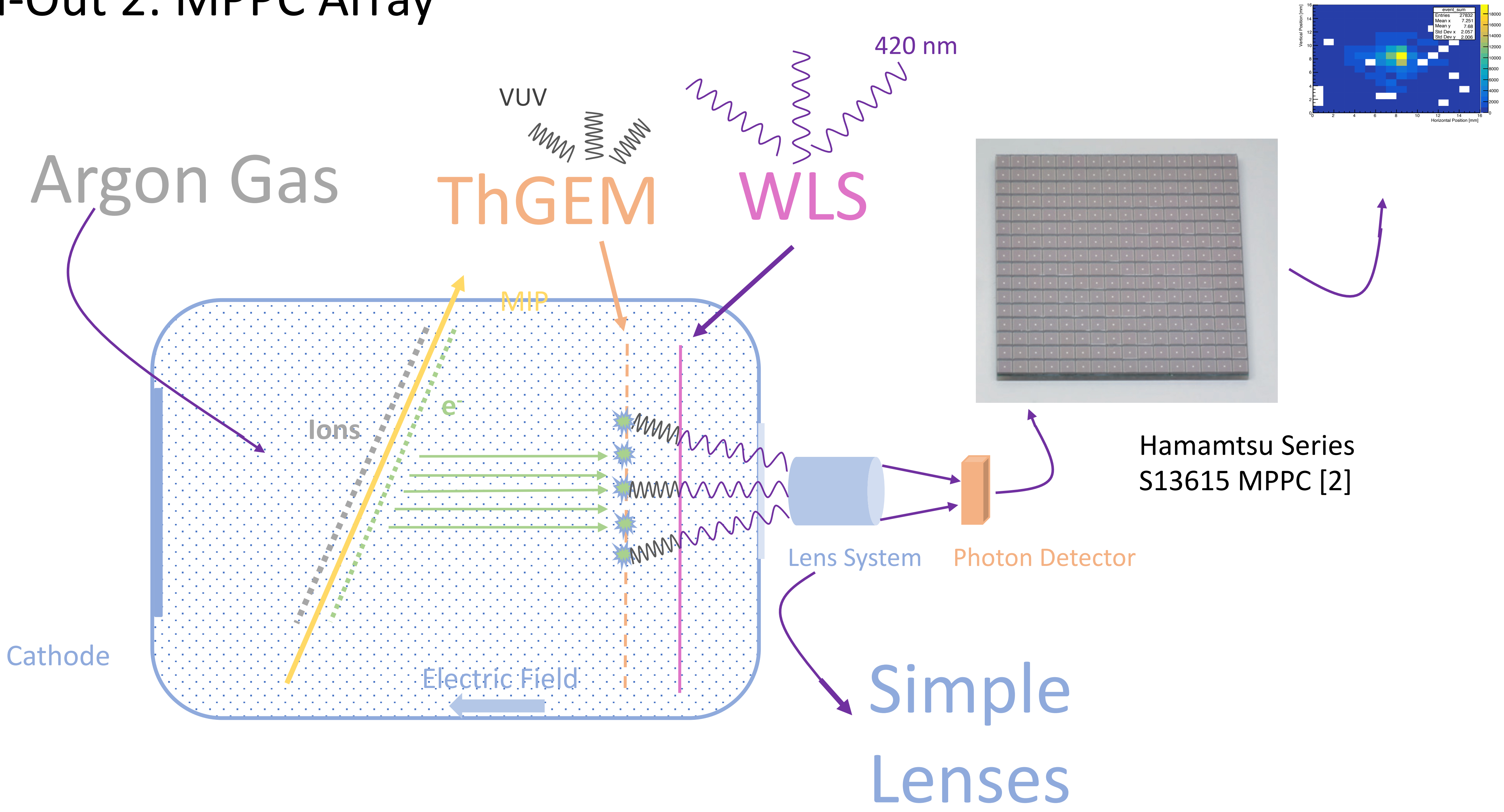
Region 1 expectation: 4300 photons*




$$Y = N_{\gamma}^{ThGEM} + \alpha_{EL} N_{e^-}^{ThGEM}$$

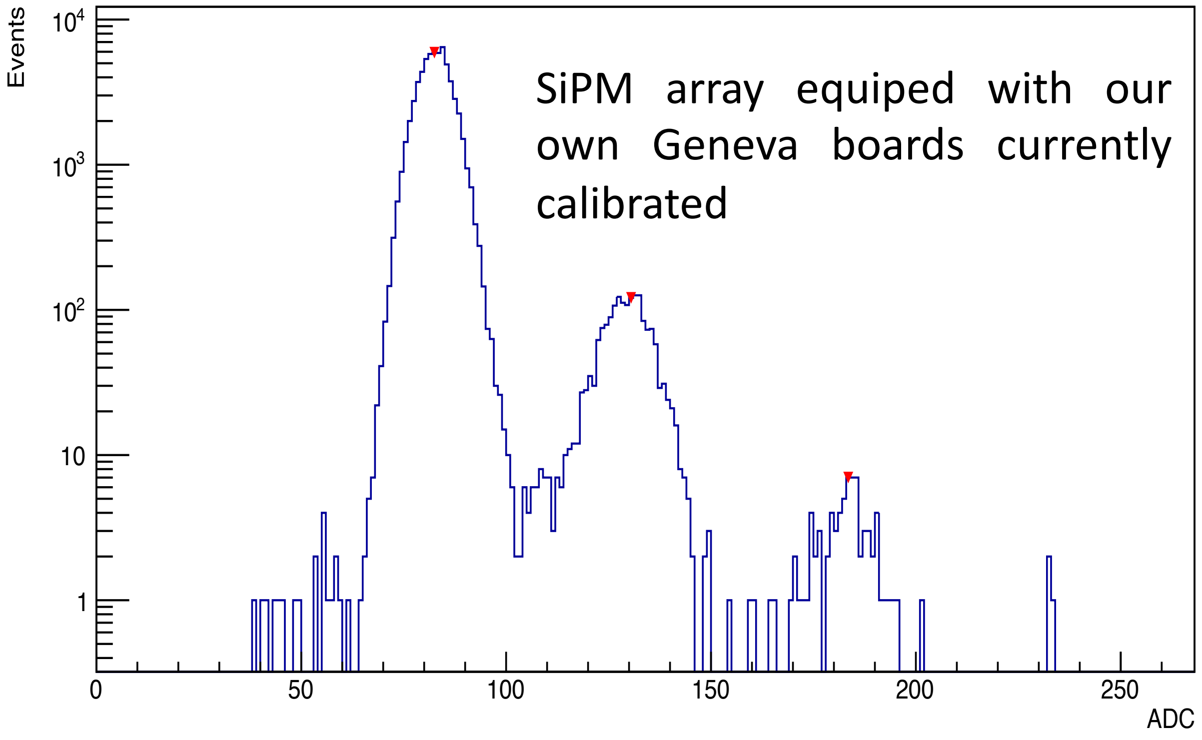
* Number of photons determined through simulation with big uncertainties.

# Read-Out 2: MPPC Array

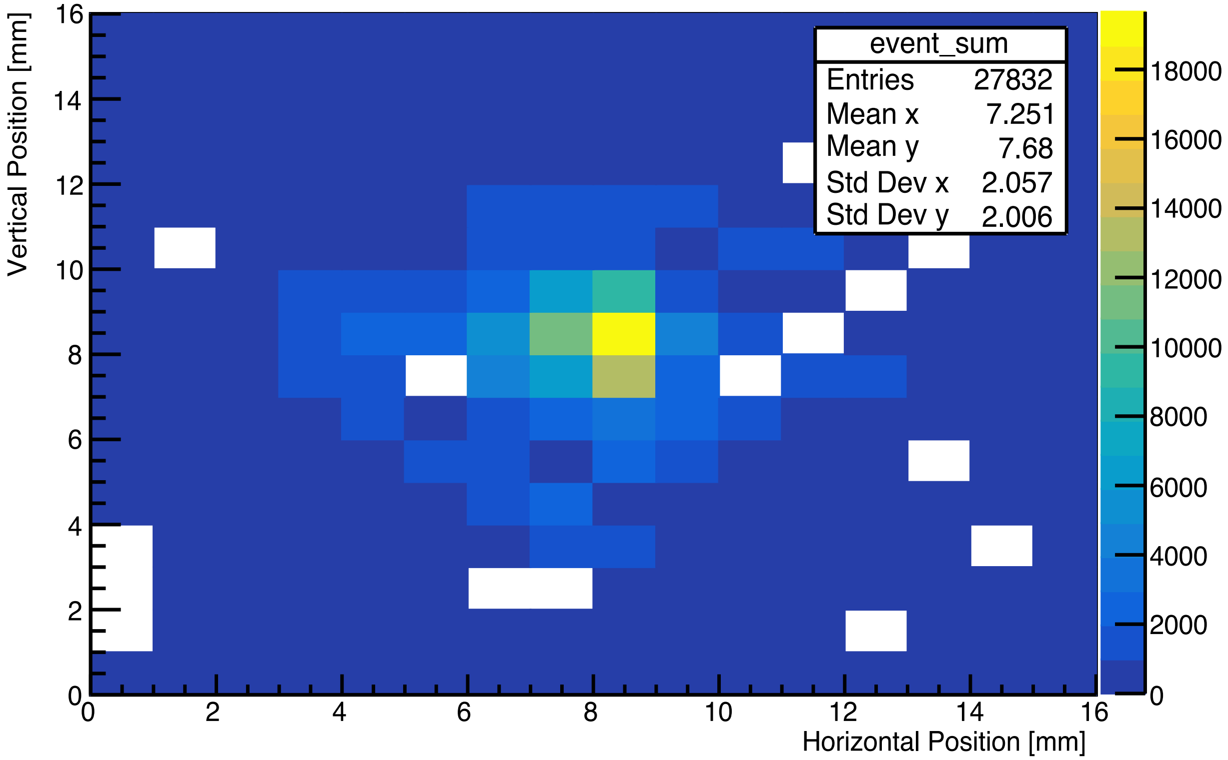


# Preliminary results with SiPM array

## SiPM Characterisation

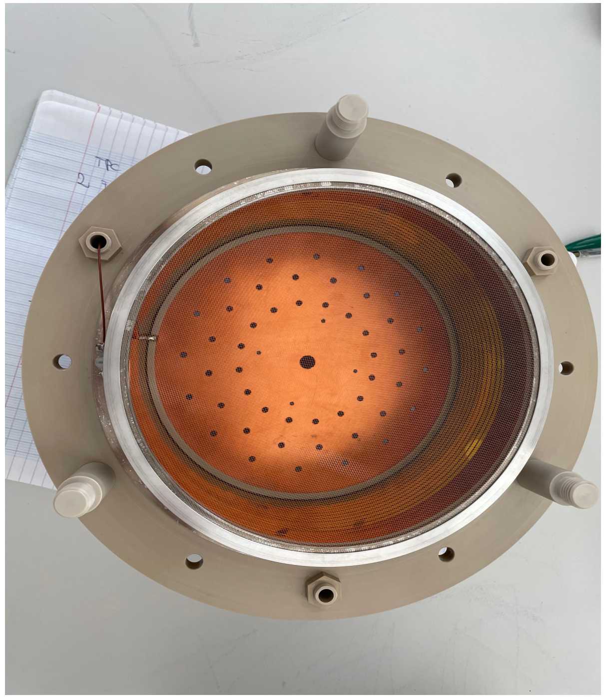


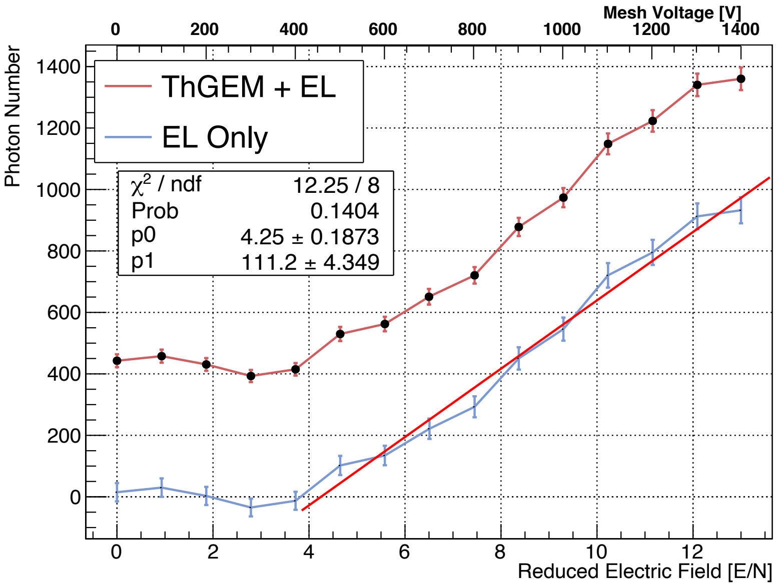

## Using $^{243}$Am source (1Bq)

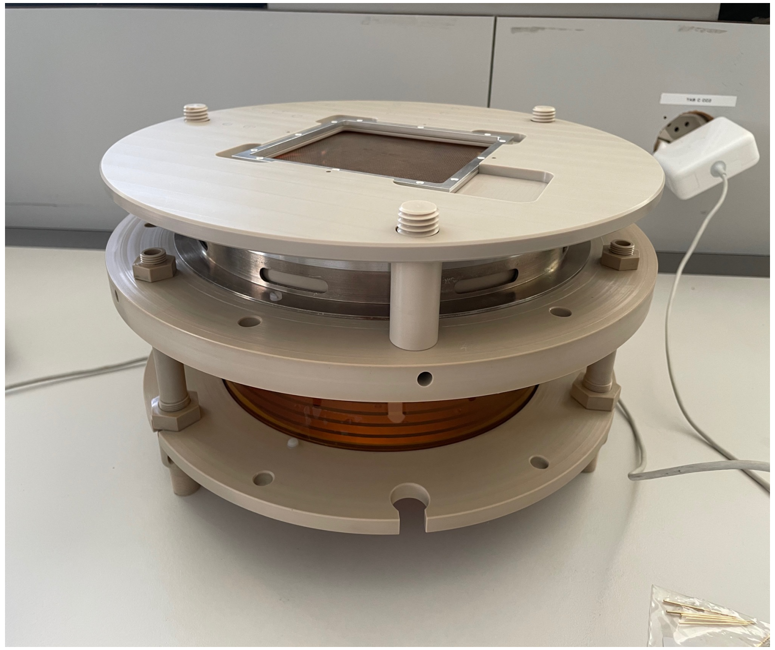


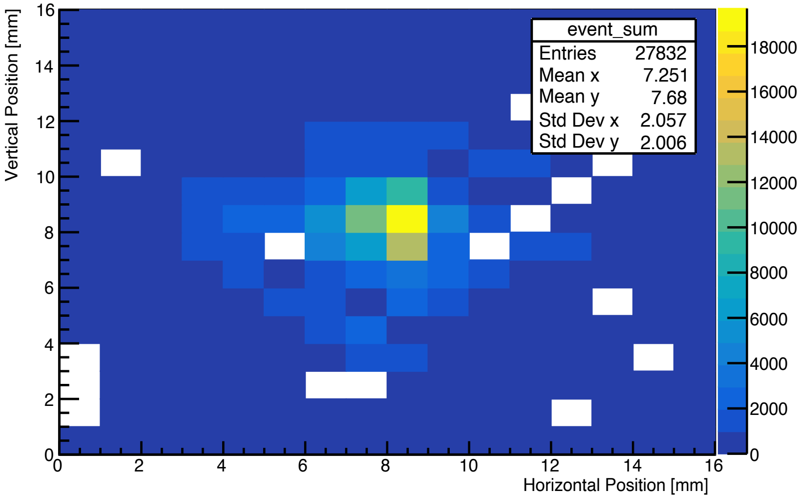
# Conclusion:

- Light detection with 1 ThGEM only
- Yield enhanced up to 4 times through EL
- MPPC array set up and ready for track reconstruction





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# Bibliography


[1]N. Abgrall et al. (2011) Time Projection Chambers for the T2K Near Detectors, Nucl.Instrum.Meth.A 637

[2]https://www.hamamatsu.com/content/dam/hamamatsu-photonics/sites/documents/99_SALES_LIBRARY/etd/R6427_R7056_R7057_TPMH1377E.pdf

[3] T. Lux (2018) Charge and Light Production in the Charge Readout System of a Dual Phase LAr TPC. JINST

[4] C.A.B Oliveira et Al. (2011). A simulation toolkit for electroluminescence assessment in rare event experiments. Physics Letter B

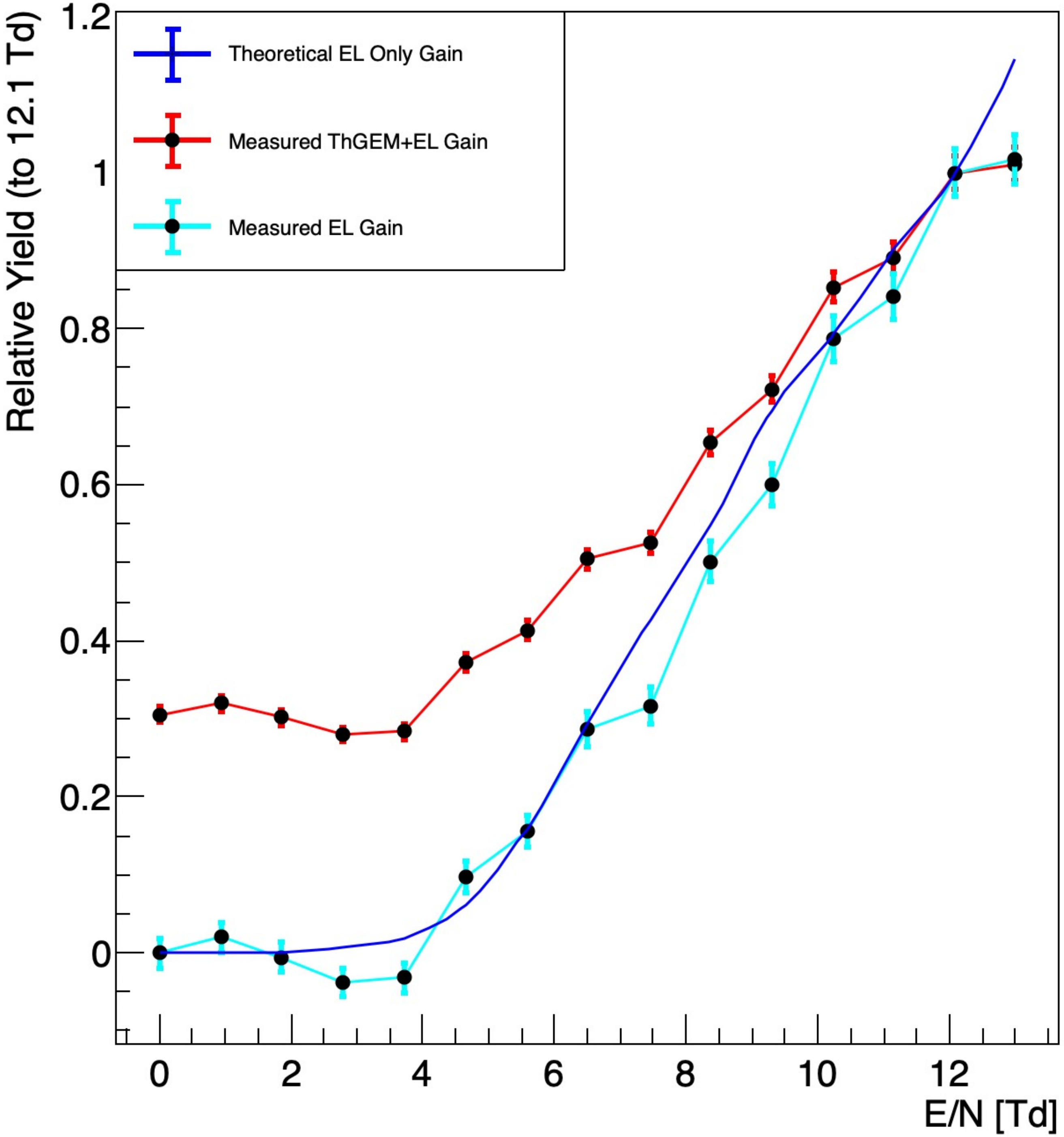
# Backups

# Comparison to Literature

- Relative gain plot:

$$\text{Point @ X} = \frac{Gain\ @\ X}{Gain\ @\ 1200V}$$

- EL Gain follows theory curve
- EL threshold point between 4 and 5 Td confirmed by previous results [Oliveira, 2011].

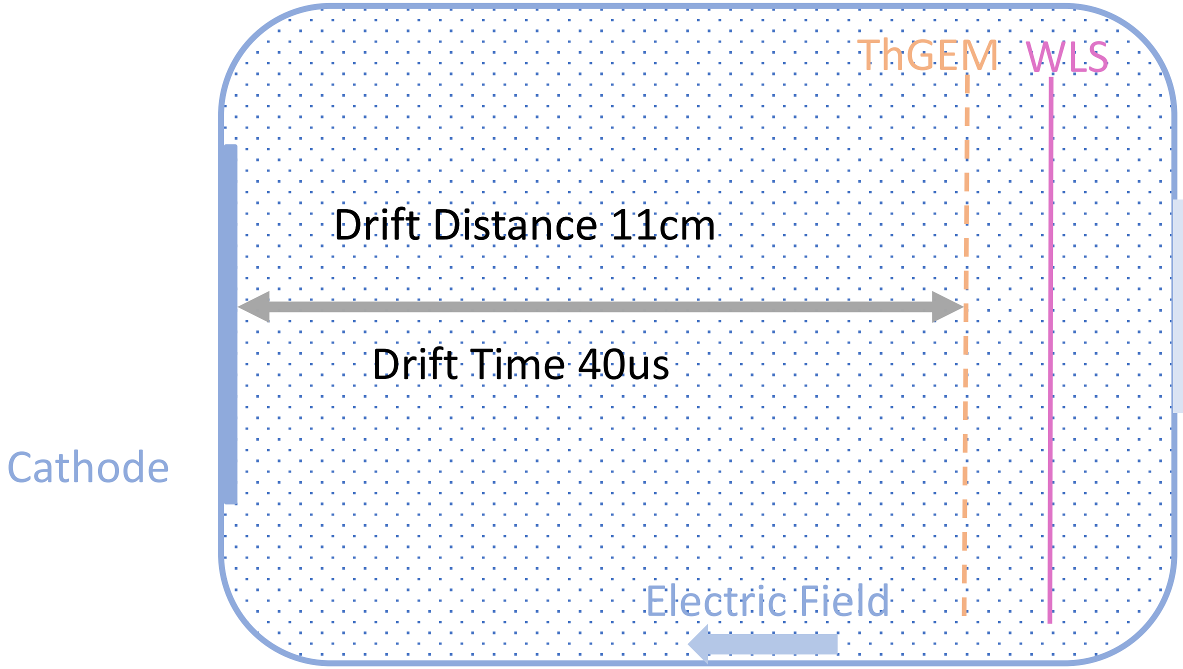


# TPC geometry and E-Fields

- Active volume of 3.5l
- Drift distance 11.5cm
- Drift Field 190V/cm
- Drift Velocity 0.28cm/us
- Drift Time ~40us

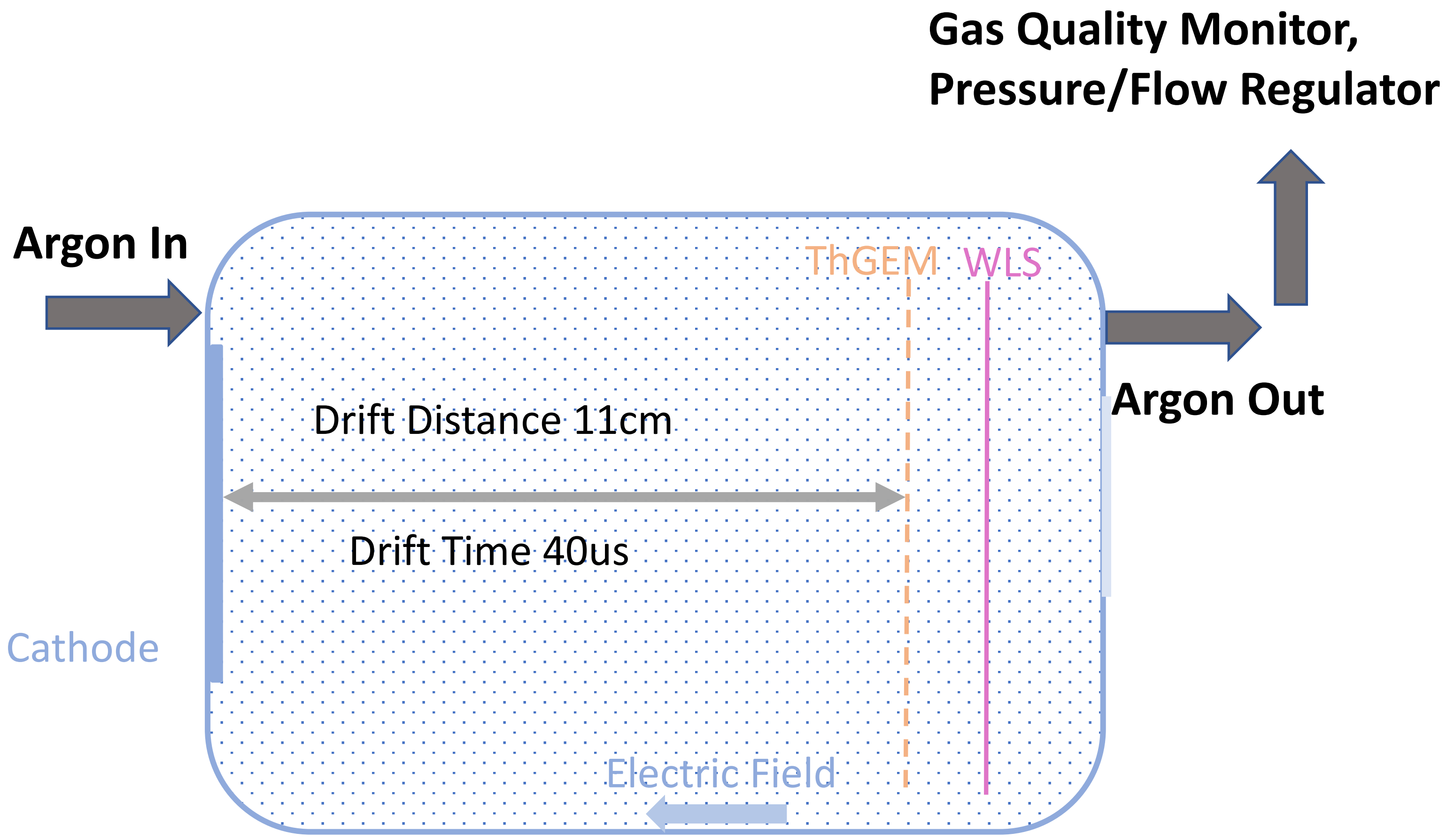
Thick GEM:

- Thickness 1mm
- Voltage Drop: 1400V
- Gain 500 pht/el [add citation]



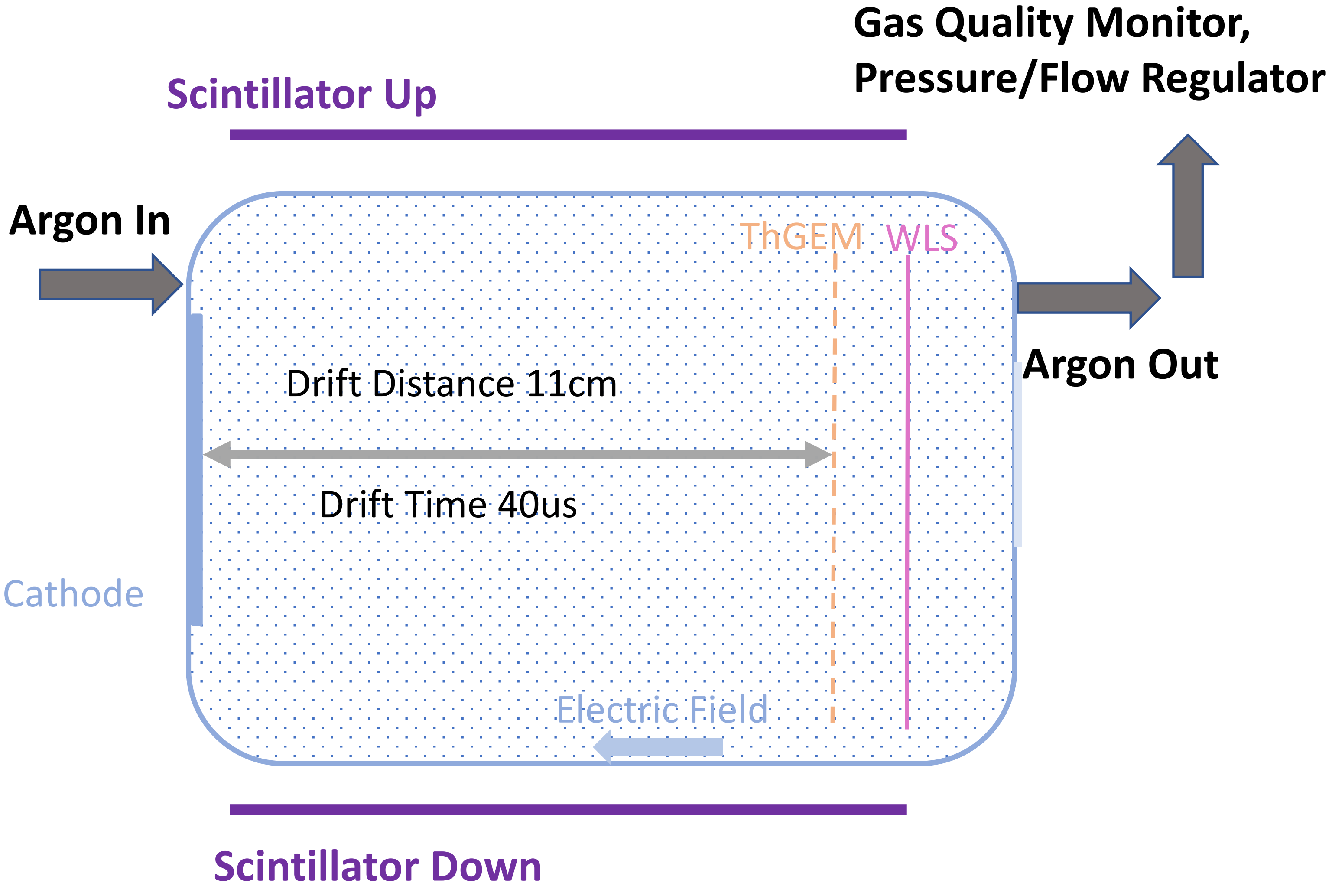
# Gas System

- Gas In -> Gas Out
- Active flush of 15l/h
- $H_2O$ @ 100ppm
- $O_2$ @ 8ppm
- Pressure @ 1 bar



# Trigger System

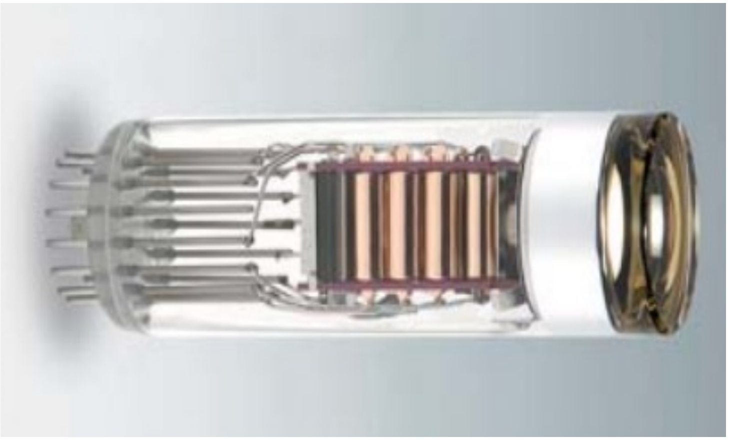
- 7 coincidences / min
- 50% efficiency*

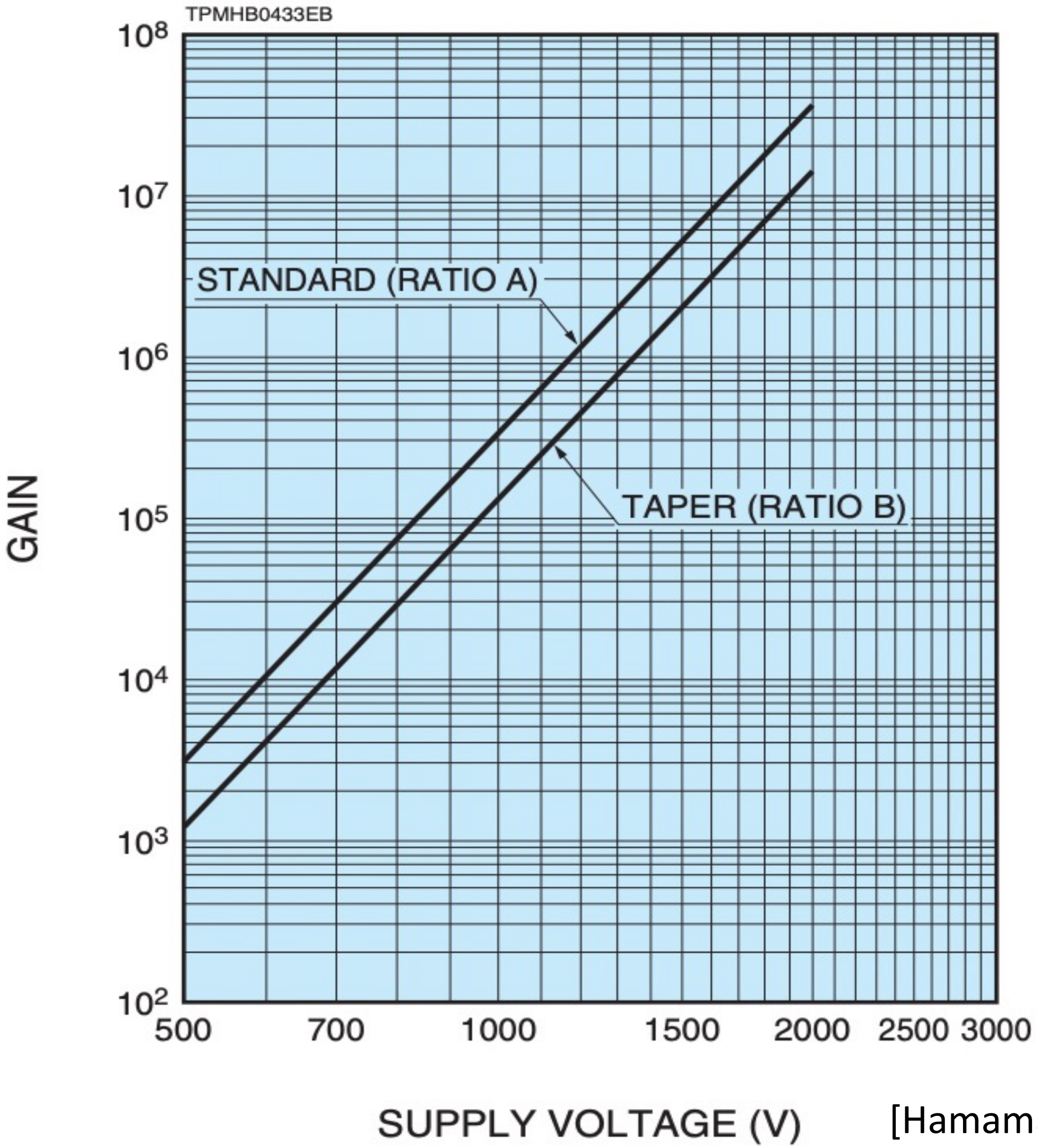



*cosmic ray crossing active area

# Photo-Multiplier Tube†

- Model: Hamamatsu R6427
- Base: Hamamatsy E2624
- QE Peak: ~25% @ 400nm
- Gain: $10^7$ @ 1650V

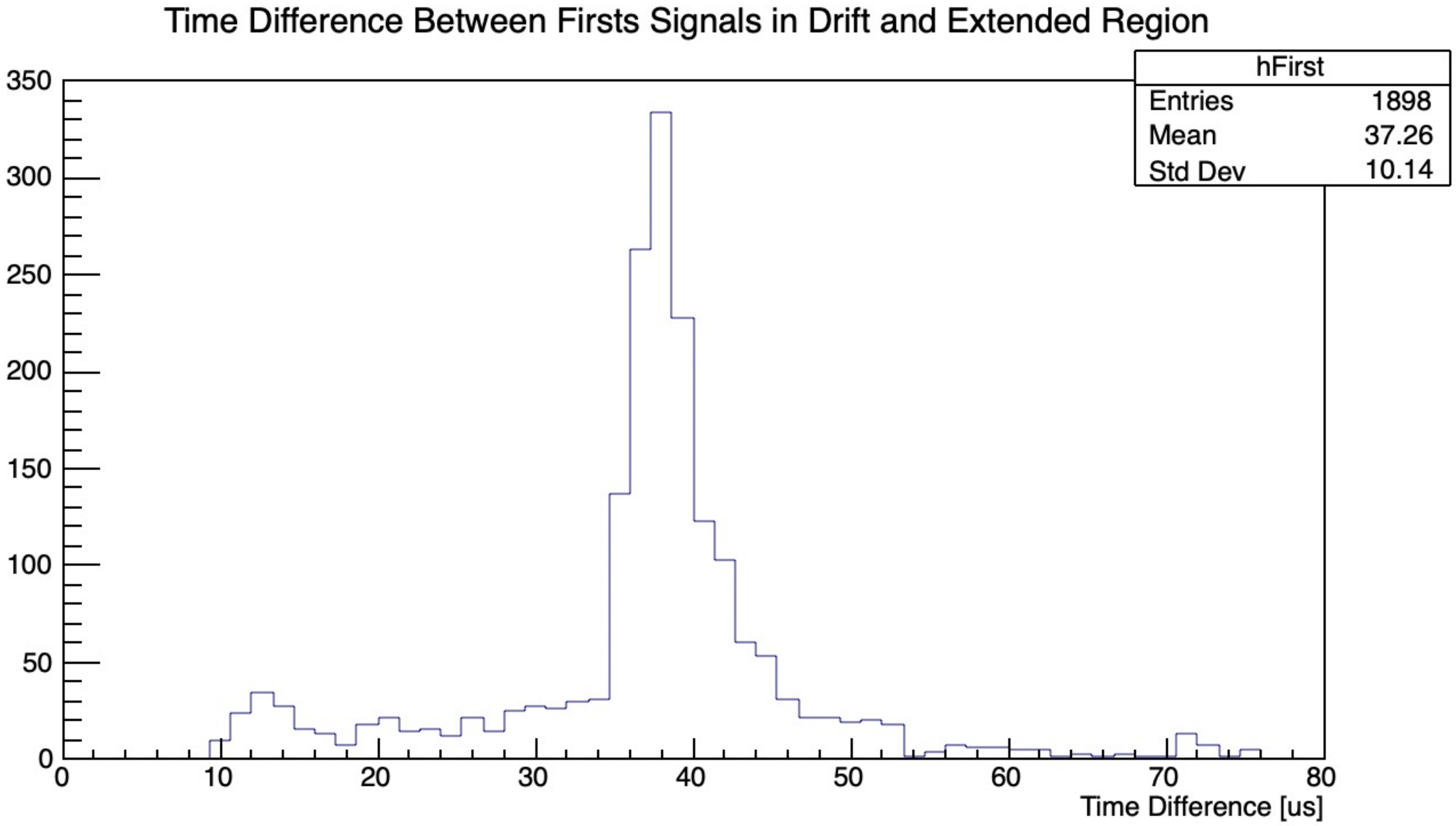





[Hamamatsu Handbook]

†Preliminary read-out approach

# Cathode photo-electrons



# Photons detected with a PMT (Simulation)

Light produced by 4 GeV Muon

Crossing the detecor perpendicularly

Simulation Photon Count: 4300

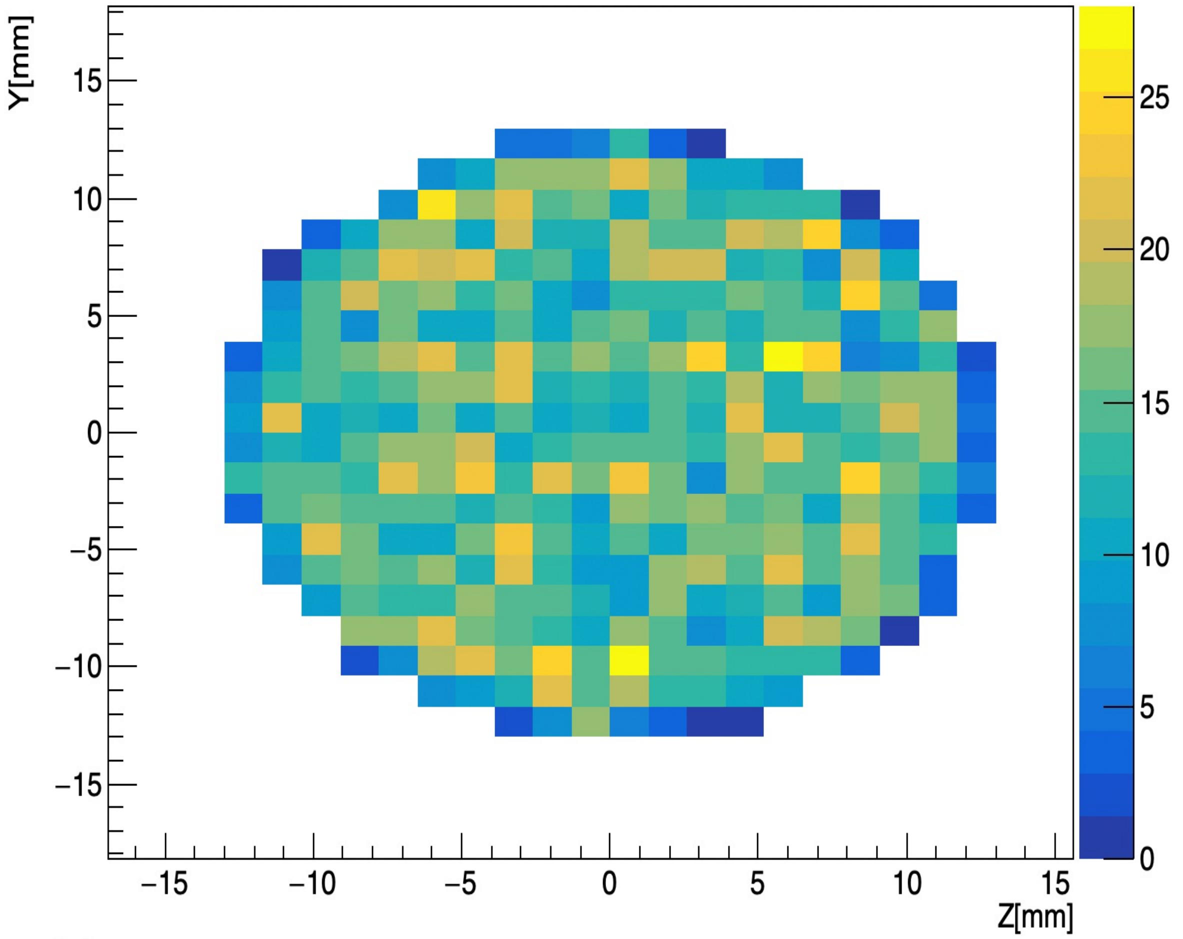
<u>Taken into account:</u>

e$^-$/ion pair production

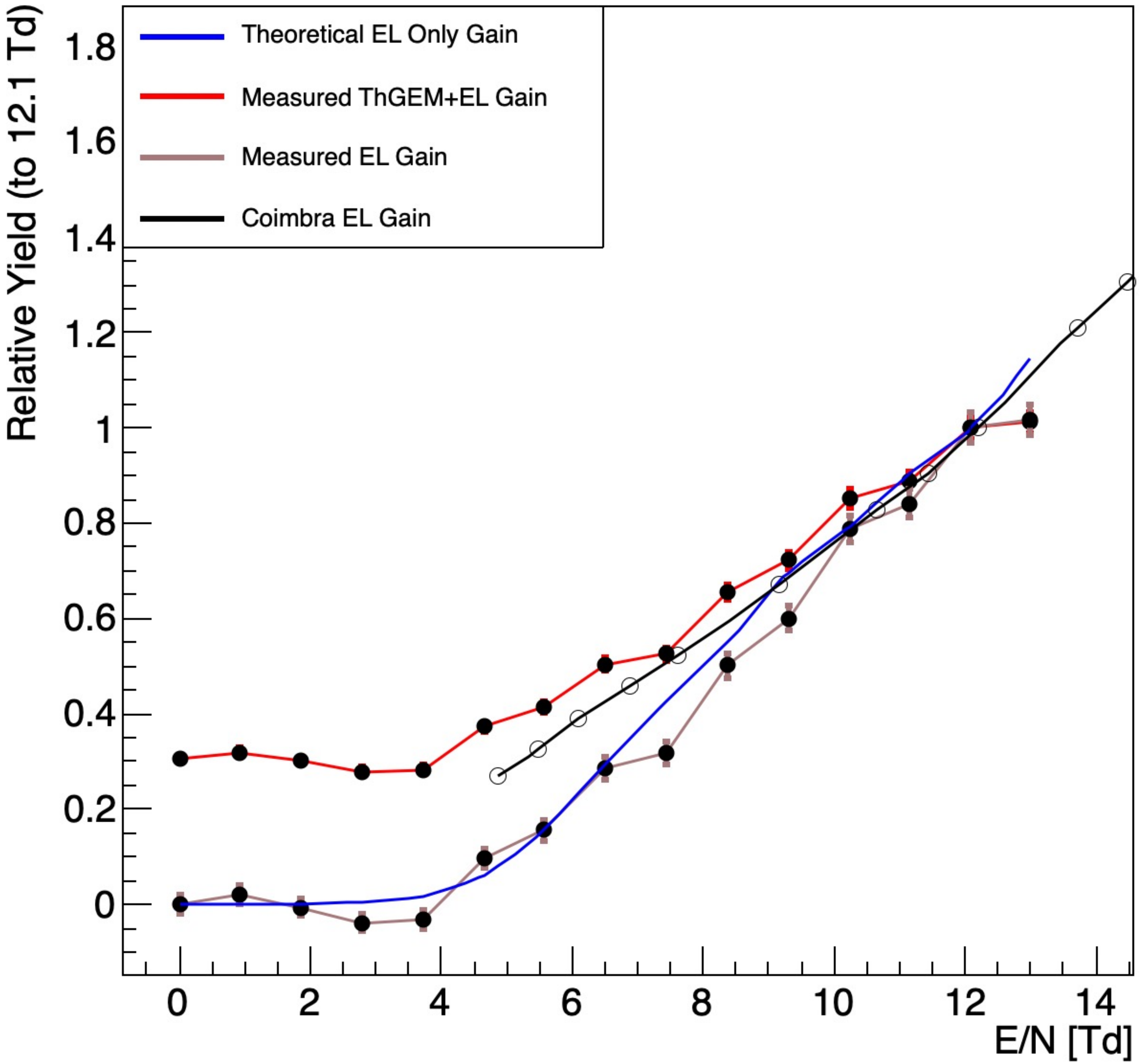
diffusion

ThGEM gain

WLS, PMT efficiency



# E/N Graph



Theoretical EL Only Gain
Measured ThGEM+EL Gain
Measured EL Gain
Coimbra EL Gain
Relative Yield (to 12.1 Td)
E/N [Td]
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2
4
6
8
10
12
14

# Pure Argon Drift Parameters