Measuring Alpha Quenching Factors in Liquid Argon using Argon-1

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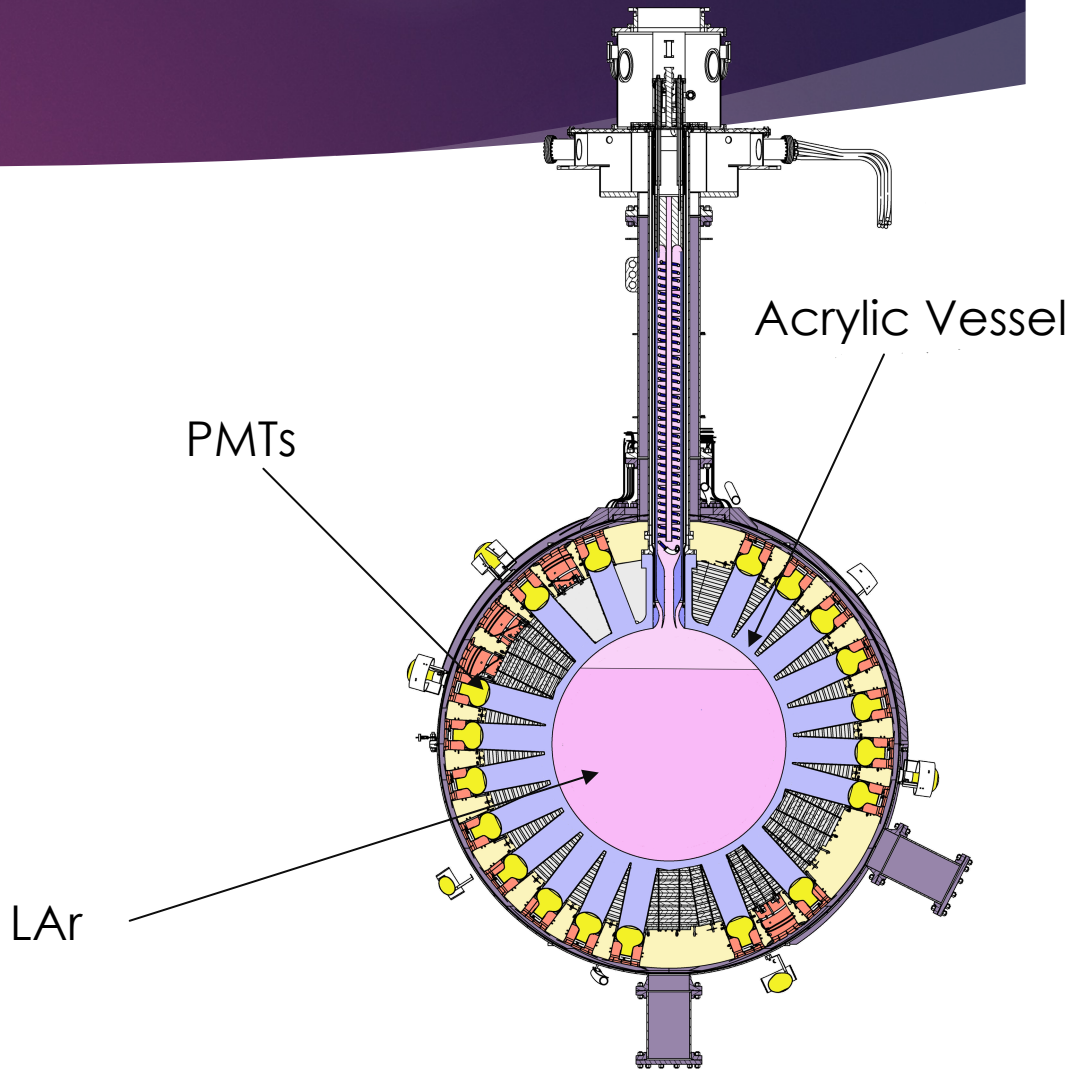
Outline

- The DEAP-3600 Experiment
- Alpha Quenching
- Argon-1 at Carleton
- Alpha sources and deployment
- Measurements so far and Outlook

DEAP-3600 Experiment

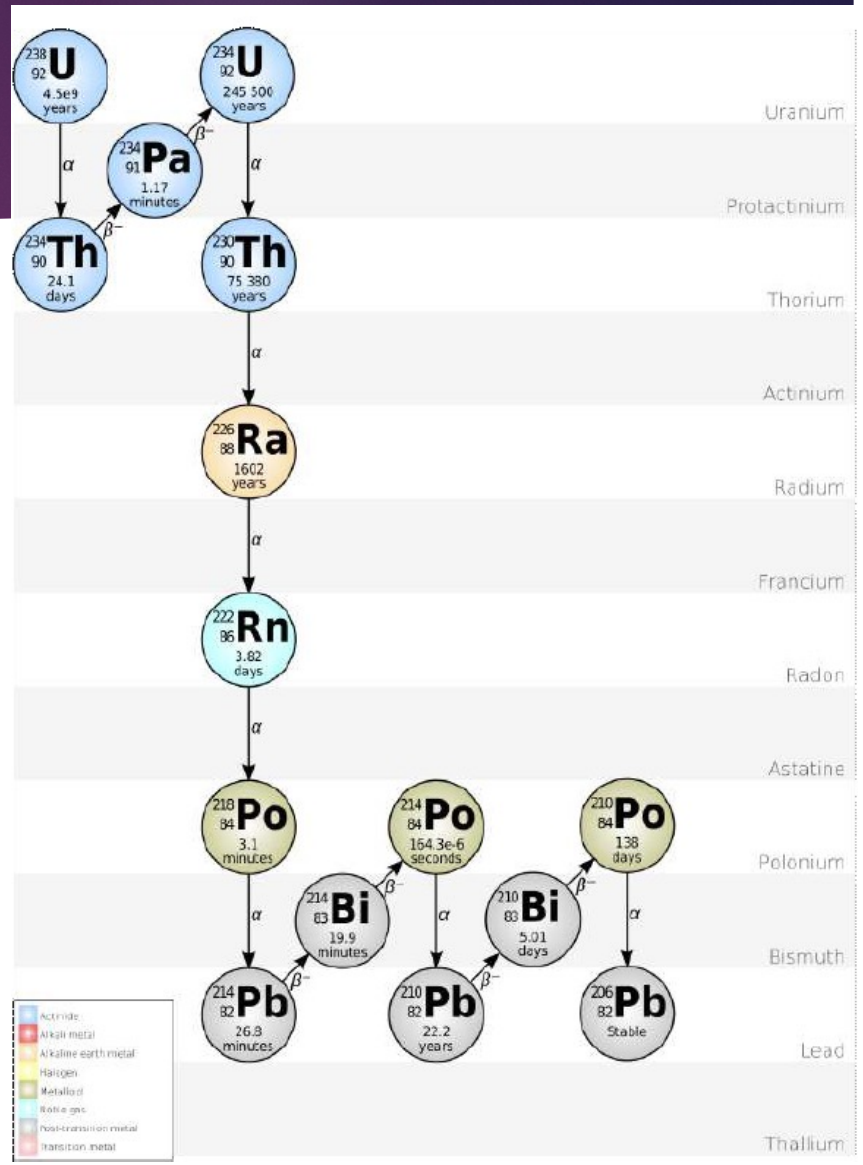
- Single phase liquid argon (LAr) detector searching for WIMP dark matter
- Collect scintillation light produced by recoil Ar
- Located 2km underground at SNOLAB in Sudbury, ON
- Difference in argon excimer decay times allows for background suppression using pulseshape discrimination

$$\chi + N \rightarrow \chi' + N'$$



Alpha Backgrounds

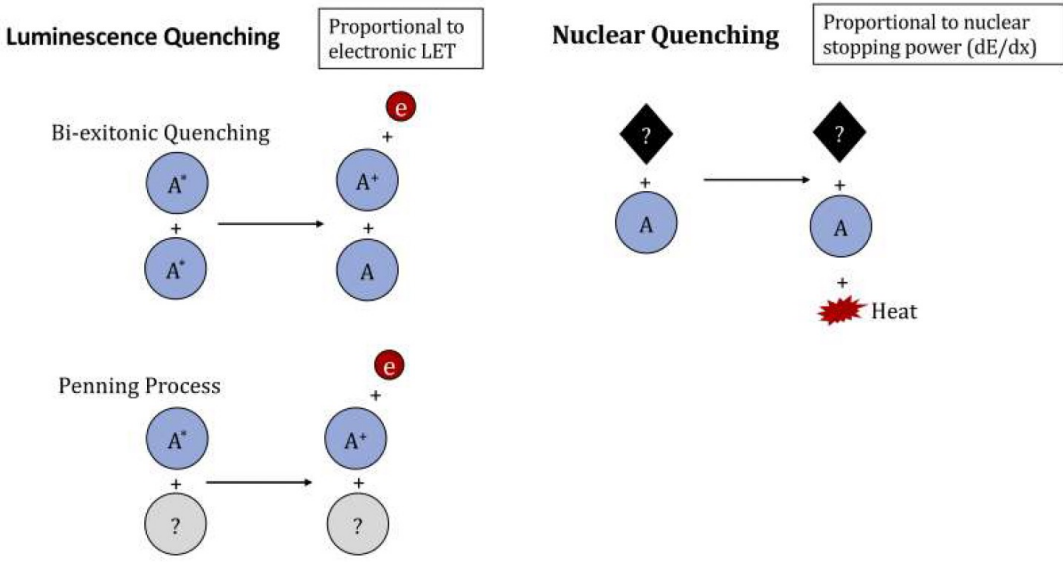
- Alpha decays from naturally occurring Uranium, Thorium and their progeny will produce NR events
- If alpha energy is sufficiently degraded, can mimic WIMP signal
- Understanding the reconstruction of alphas in DEAP-3600 is key for proper background model



Quenching

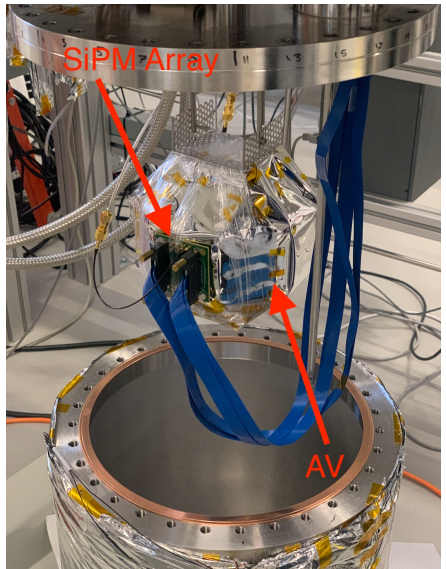
- For NRs, not all event energy will produce scintillation light (loss due to heat, luminescence quenching)
- Quantify this "quenching factor" ($Q_f = 1$ no quenching, $Q_f = 0$ completely quenched)
- Q_f in general is a function of energy
- Goal of Argon-1 measurement is to probe Q_f for low energy alphas (100s keV)
- For more information on quenching from DEAP data, please see Susnata Seth's talk in W3-6 session, June 8th at 3:15pm

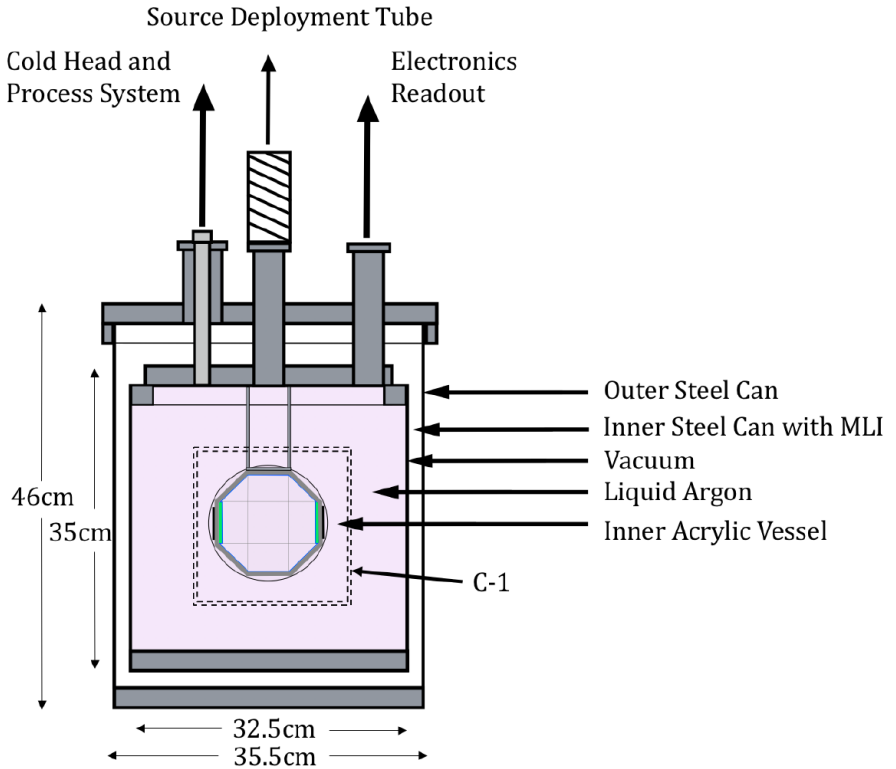
$$Q_f = \frac{\text{Detected Energy}}{\text{Total Energy}}$$



Argon-1

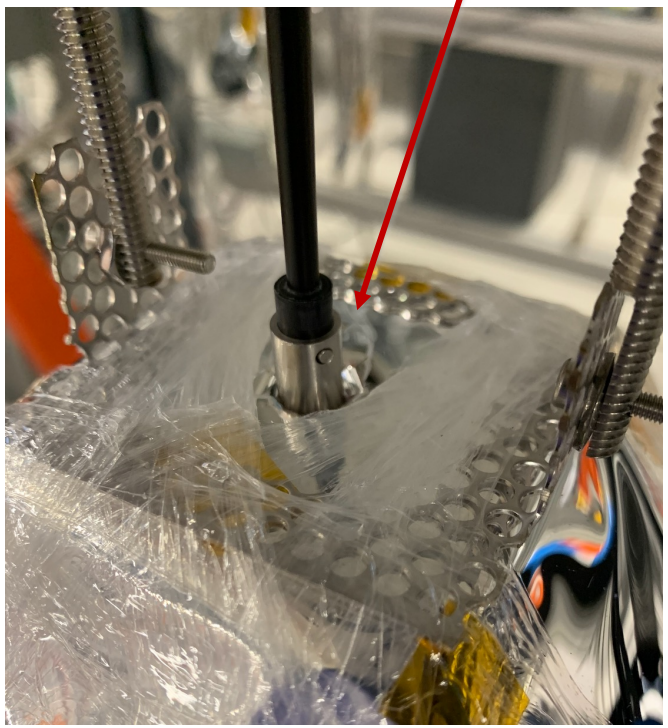
- Modular single phase liquid argon detector in Carleton nOble Liquid Detector Laboratory (COLD Lab)
- 26-sided polyhedron, each panel coated with 1um TPB
- Contains ~30kg LAr total condensed ~10% in AV
- Signal detection facilitated by (currently) Hammatsu MPPC Silicon Photomultipliers (SiPMs)





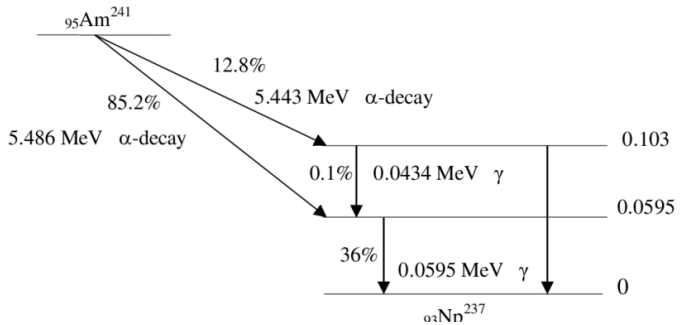
Source Deployment

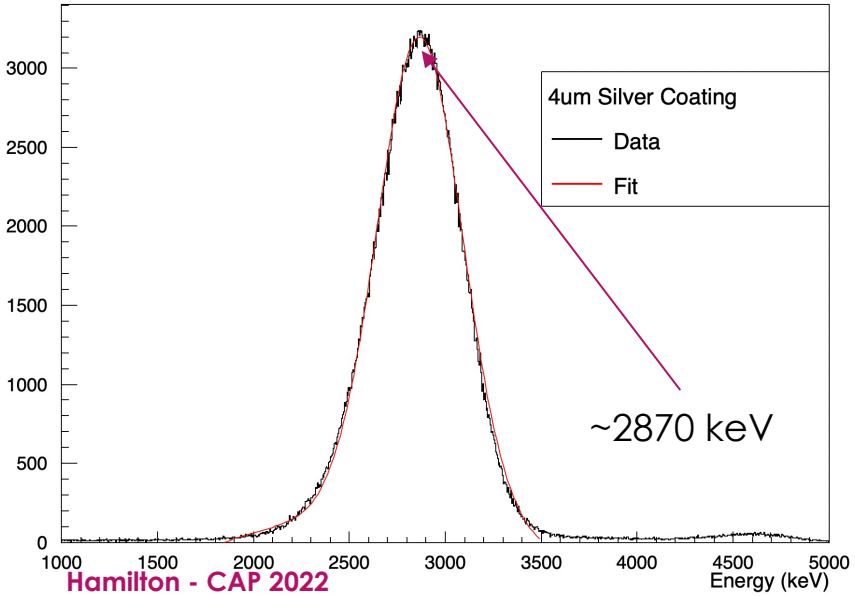
- Linear actuator installed with gate valve to allow for deployment of multiple sources without warming detector
- Source change to take ~1 day to ensure purity
- Height set such that the alpha source is flush with AV panel

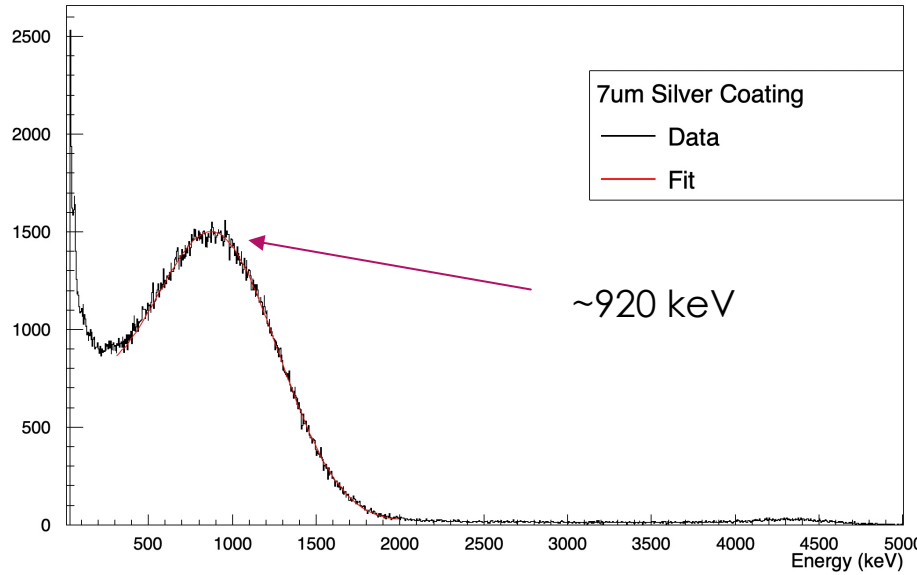


Current Alpha Sources

- ^{241}Am sources coated with varying thicknesses of silver, degrade energy
- 7 sources total, energy measured with Ortec alpha counter







Measurement

- Quenching factor calculated as

$$Qf = \frac{\mathrm{PE}}{\mathrm{E}_\alpha \times \mathrm{LY}}$$

- PE: # of detected photoelectrons in SiPM
- E_α: Source energy measured with counter
- LY: Light yield of detector (units of PE/keV)

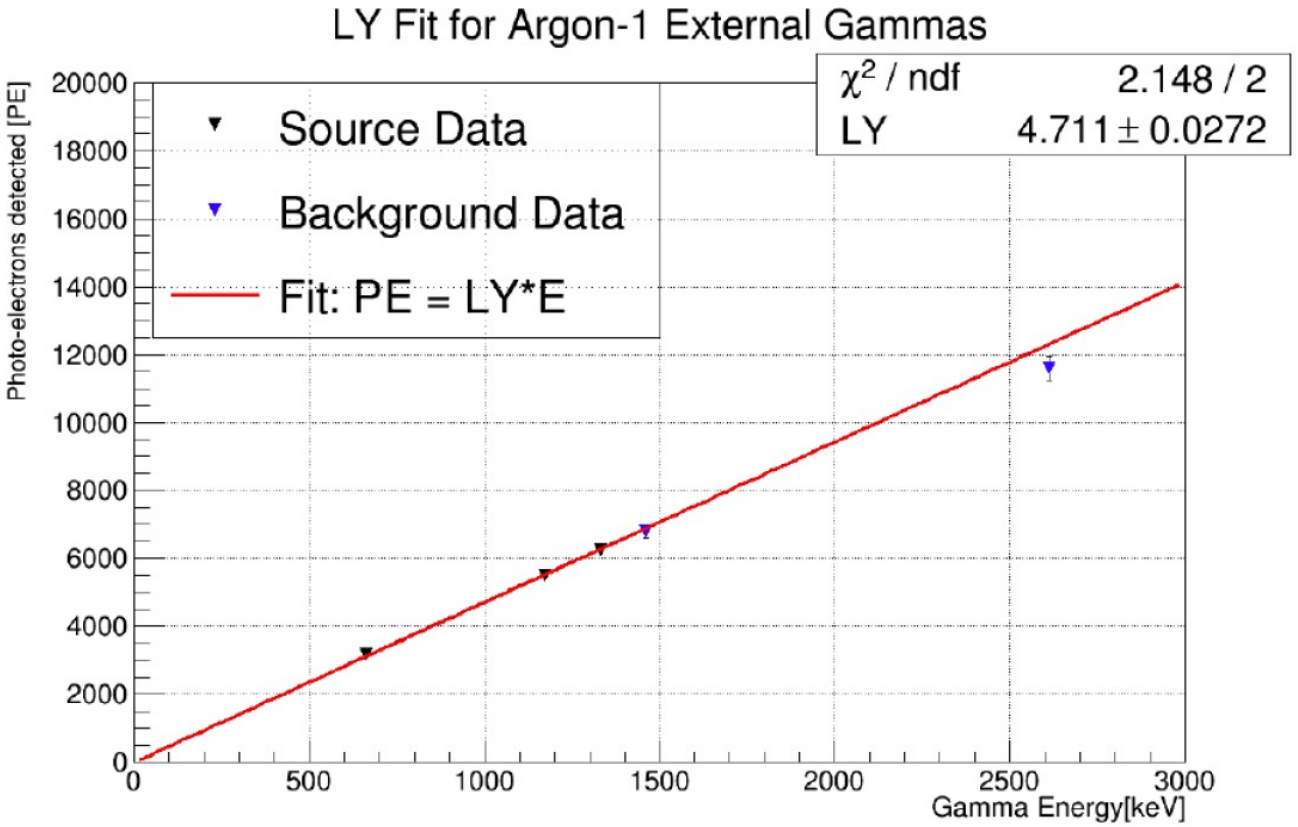
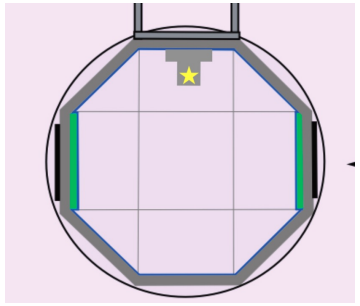


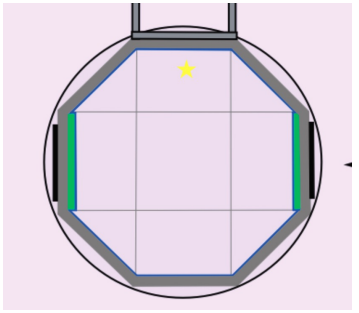
Fig: Light yield fit from Summer 2021 run (David Gallacher)

Shadowing

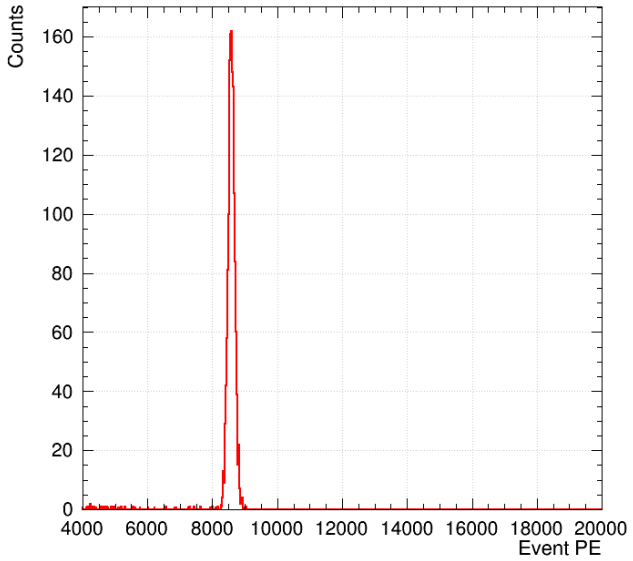
- Shadowing of light due to presence of source must be corrected for
- $Qf = \frac{\mathrm{PE}}{\mathrm{E}_{\alpha} \times \mathrm{LY} \times \sigma_{shad}}$
- MC shows nominally ~40% of light shadowed, investigating angular dependence

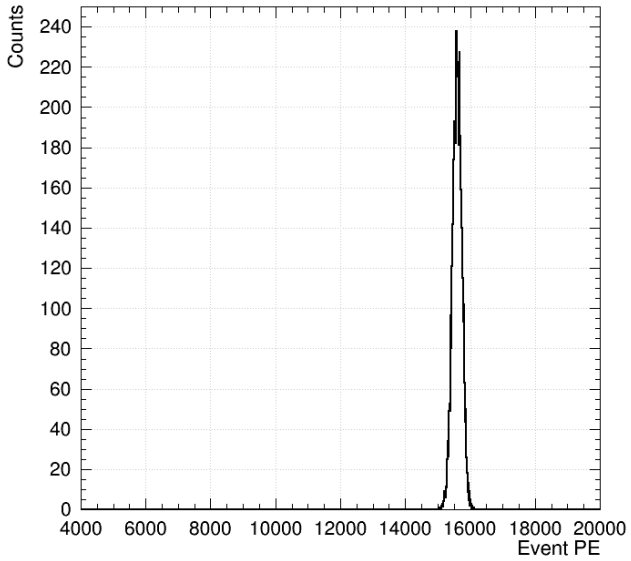


Shadowed 4.5MeV



Not Shadowed 4.5MeV



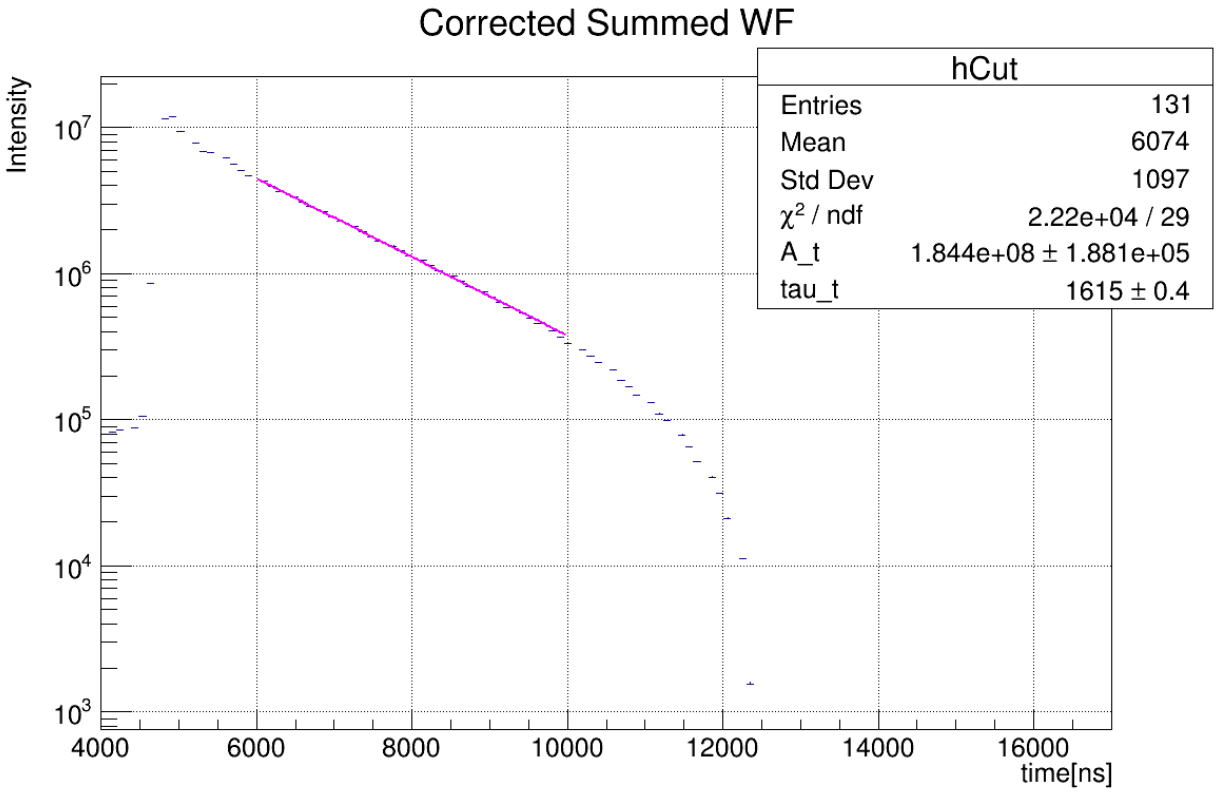


Current Status

- Argon-1 successfully cooled down
- Argon triplet lifetime fit consistent with previous run (purity)
- Fit with simple exponential:

$$f(t) = Ae^{-t/\tau}$$

- Gamma source calibrations underway to obtain light yield of current run

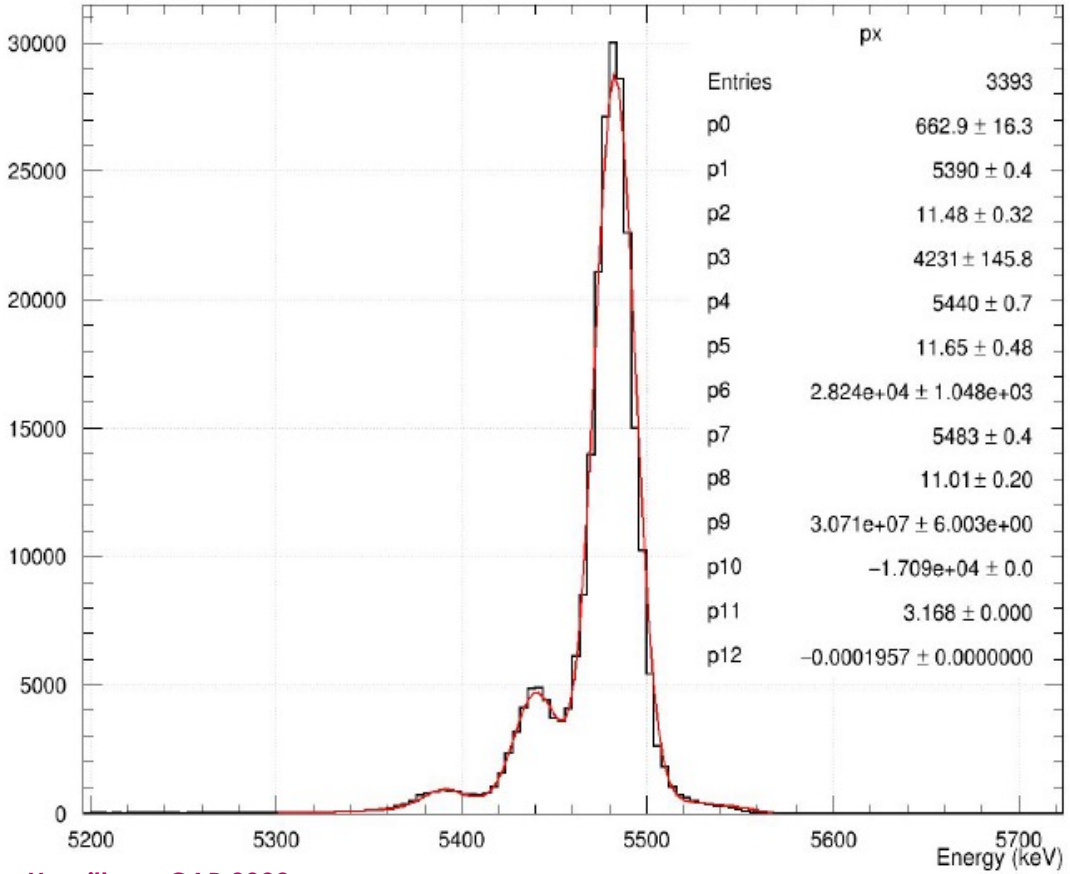


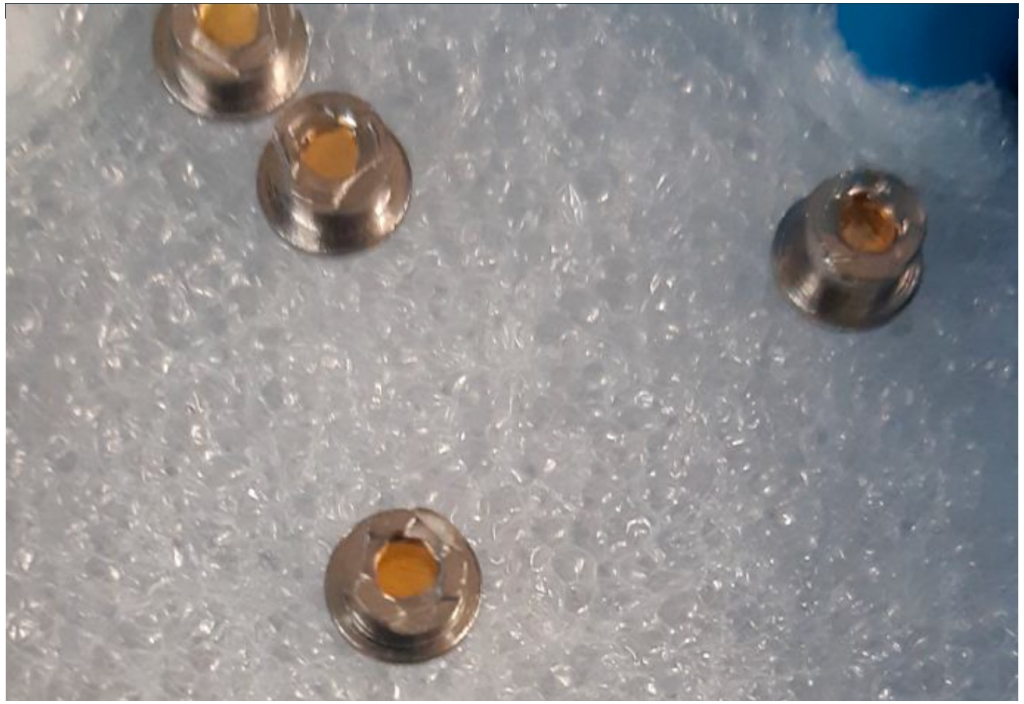
Summary and Outlook

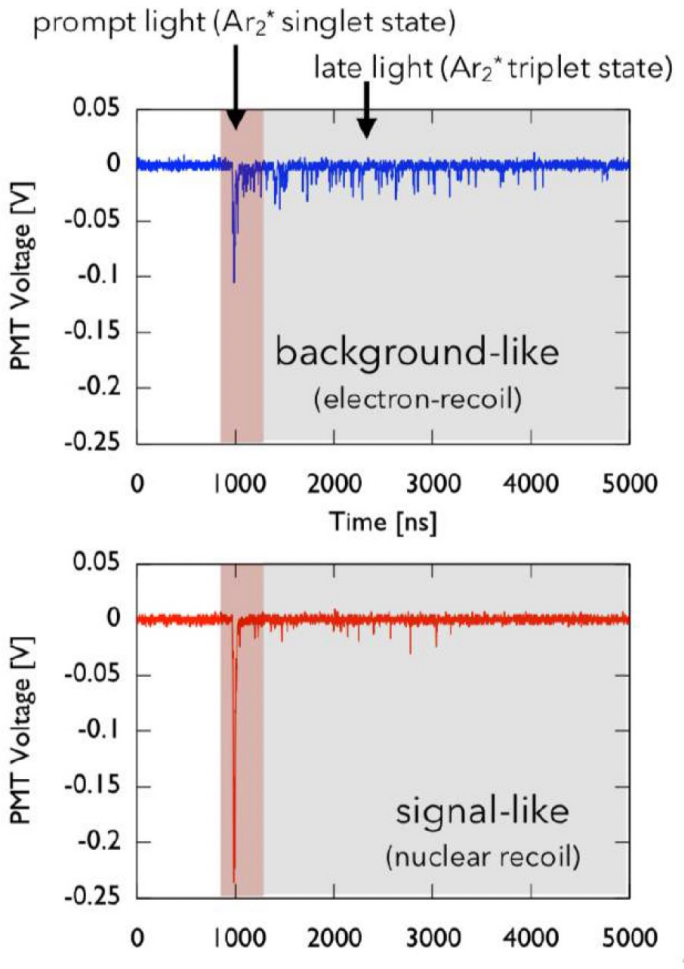
- Understanding alpha quenching in LAr plays a key role in development of background model
- Argon-1 is equipped to measure quenching factors at low energies using coated americium sources
- Recalibration of detector currently underway
- Alpha sources expected to be deployed within the next few weeks

- Thank you! Questions?

Backup


px
Entries 3393
p0 662.9 ± 16.3
p1 5390 ± 0.4
p2 11.48 ± 0.32
p3 4231 ± 145.8
p4 5440 ± 0.7
p5 11.65 ± 0.48
p6 2.824e+04 ± 1.048e+03
p7 5483 ± 0.4
p8 11.01 ± 0.20
p9 3.071e+07 ± 6.003e+00
p10 −1.709e+04 ± 0.0
p11 3.168 ± 0.000
p12 −0.0001957 ± 0.0000000
30000
25000
20000
15000
10000
5000
0
5200
5300
5400
5500
5600
5700
Energy (keV)




prompt light (Ar_2^* singlet state)
late light (Ar_2^* triplet state)
PMT Voltage [V]
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
background-like
(electron-recoil)
0
1000
2000
3000
4000
5000
Time [ns]
PMT Voltage [V]
signal-like
(nuclear recoil)