Wavelength Shifter Deposition for DEAP-3600

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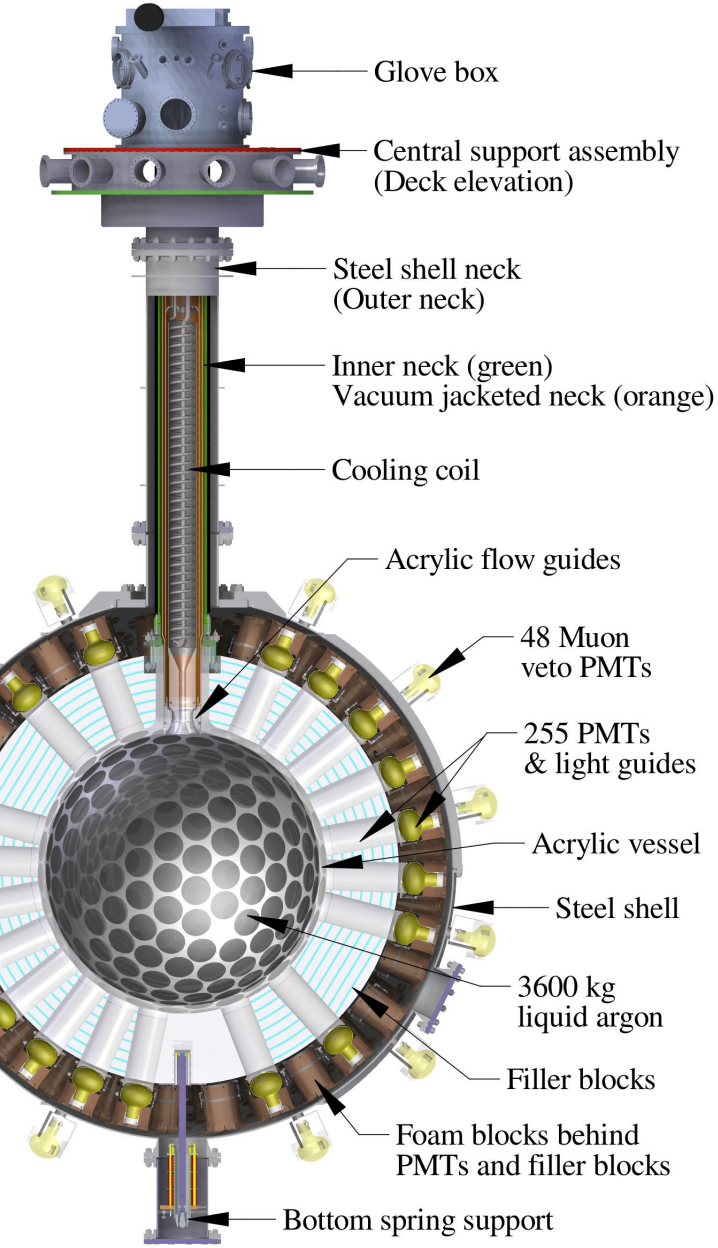
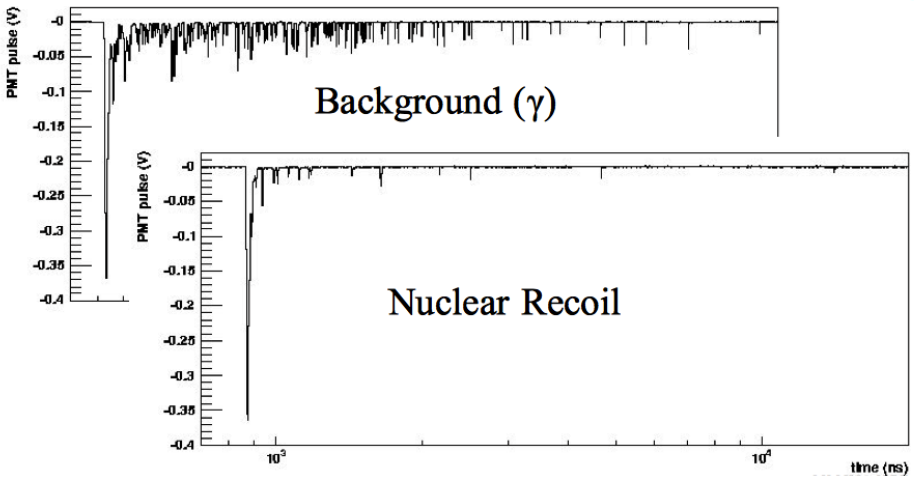
Outline

- DEAP Overview
- Deposition Source: Construction and Theory
- Deployment System
- Systems Testing
- Final Coating
- Conclusion

Dark Matter Experiment using Argon Pulse-shape Discrimination



- 3600kg single phase liquid argon (1000kg fiducial)
- Nearing construction completion at SNOLAB: 6000 m.w.e.
- SI dark matter search with sensitivity: 10^{-46} cm^2 for 100 GeV WIMP
- Pulse-shape discrimination
  - 2 argon dimer states: τ_1 =6ns, $\tau_3 = 1.6\mu$s
  - discriminate β/γ vs. n.r.



Optical Processes

Argon Scintillation

Excitation: Ar^* (1)

$$Ar^* + Ar + Ar \rightarrow Ar_2^* + Ar$$
$$Ar_2^* \rightarrow 2Ar + \gamma$$

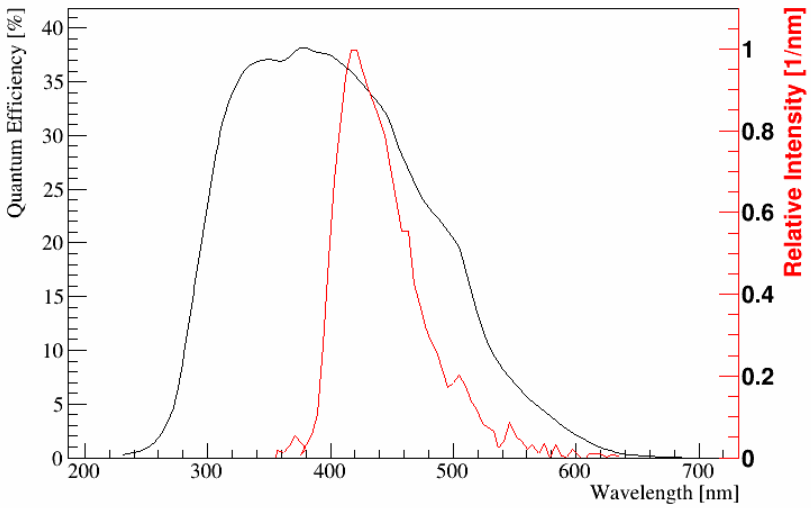
Ionization: Ar^+ (2)

$$Ar^+ + Ar \rightarrow Ar_2^+$$
$$Ar_2^+ + e^- \rightarrow Ar^{**} + Ar$$
$$Ar^{**} \rightarrow Ar^* + heat$$
$$Ar^* + Ar + Ar \rightarrow Ar_2^* + Ar$$
$$Ar_2^* \rightarrow 2Ar + \gamma$$

(1) and (2) yield 128nm VUV photons

Wavelength Shifting

1,1,4,4-tetraphenyl-1,3-butadiene converts VUV to visible



PMT quantum efficiency curve, TPB reemission spectrum

$\Longrightarrow$ coat inner surface of AV

Source Construction

- Rn budget $<$ 10mBq
- Machined from 316 stainless hemispheres
- 20 equidistant 14mm holes
- Watlow coil heater
- Copper crucible
- 2 RTDs
  - source
  - crucible
- 2 PTFE line-level voltage cables

Source Theory

- Maintain vapor pressure in source for sufficient m.f.p. to ensure random TPB molecule motion.
- Sublimation temperature $\simeq 200°$C

Pressure - m.f.p relation:

$$p = \frac{R_a T}{\lambda \sqrt{2} \pi d^2 N_a}; \lambda \simeq 0.55\mathrm{cm}$$

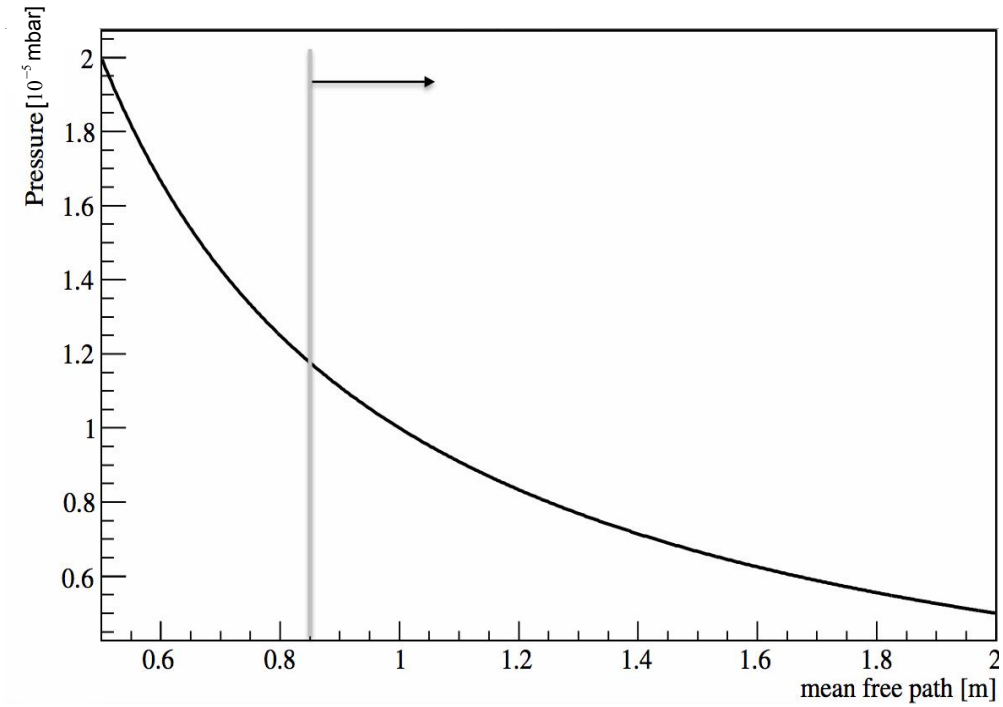
Population to maintain pressure:

$$N_p = \frac{pV}{k_B T}$$

Emission rate:

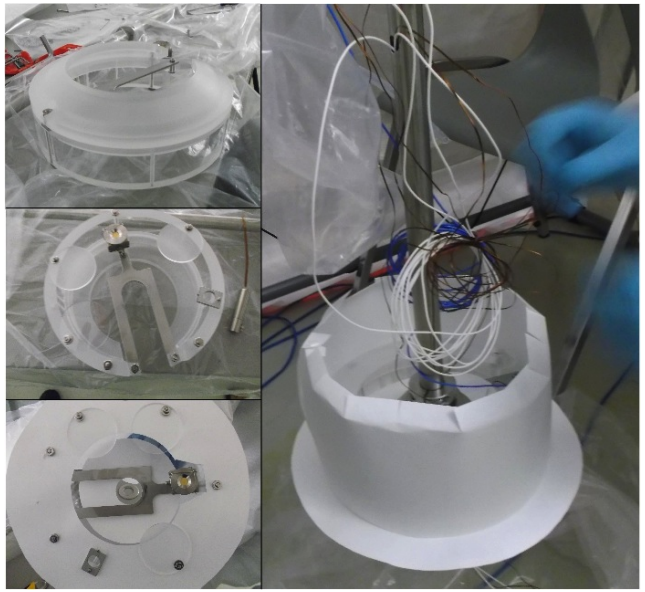
$$\frac{N_{exit}}{t} = \frac{1}{6} \frac{N_p}{V} \langle \upsilon \rangle A_h$$

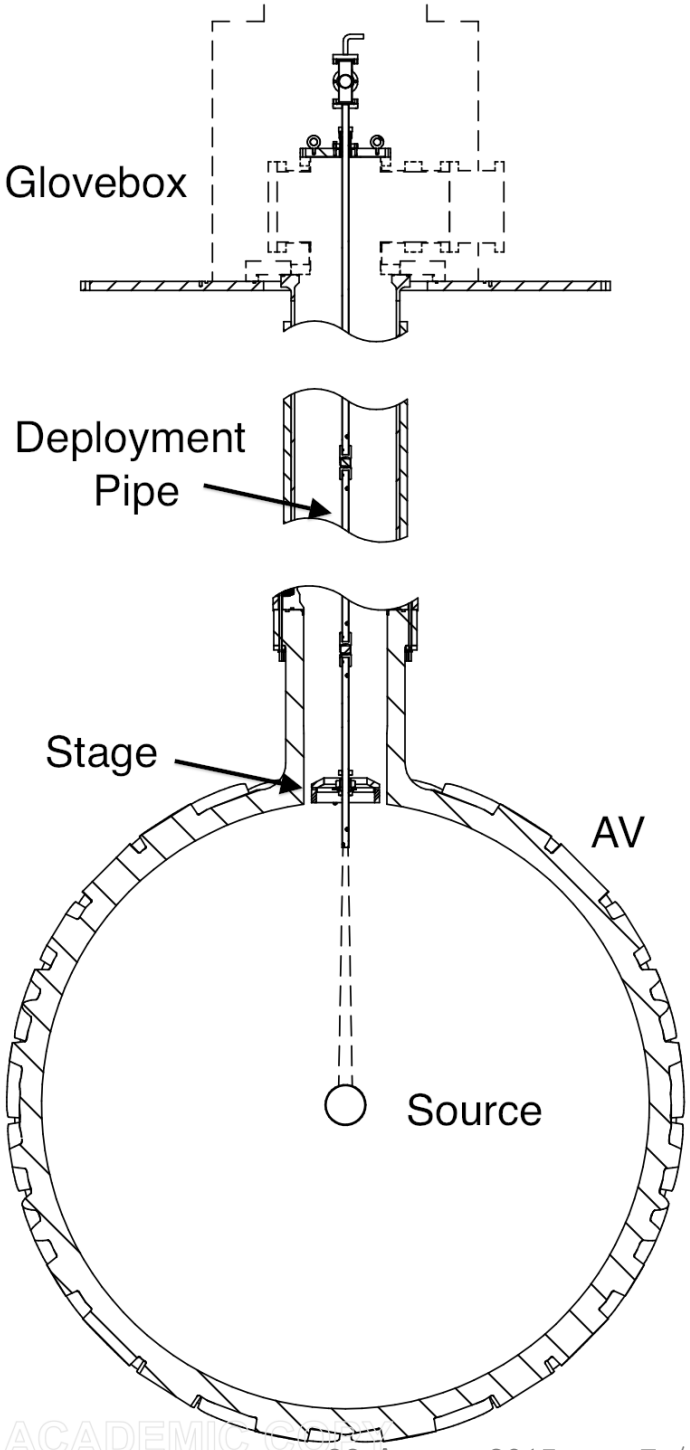
AV Vacuum: $\lambda > 0.85$m



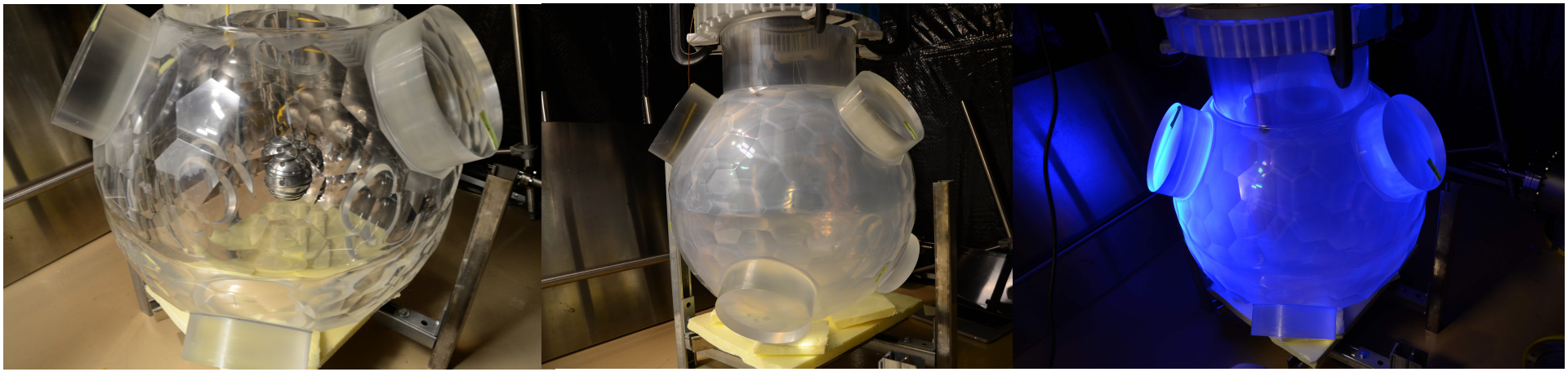
Deployment System

- 4m 0.75" articulated pipe
- 10CF top flange to vacuum system
- Vacuum electrical/purge feedthrough top cross
- Quick Disconnect flange-fitting adapter
- Stage: bumper, baffle, mounting

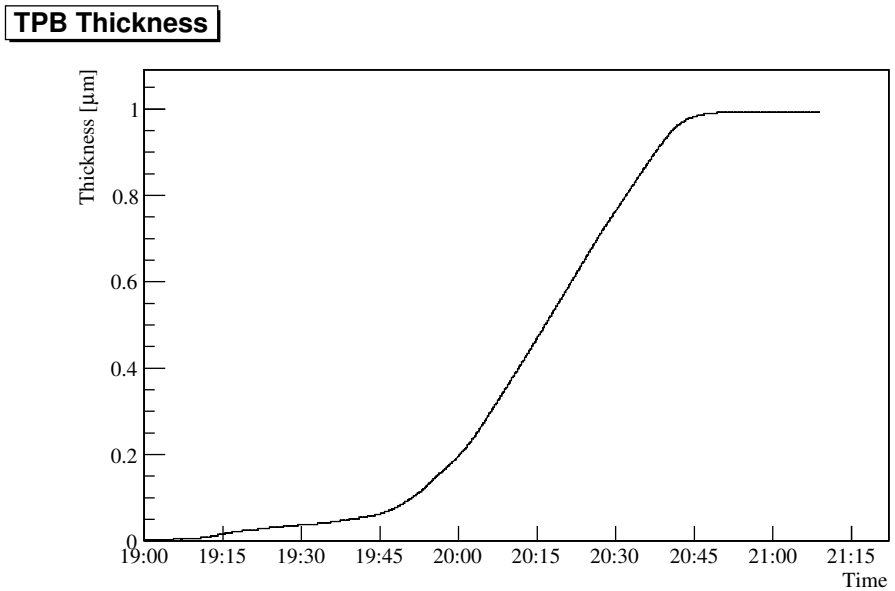




Testing

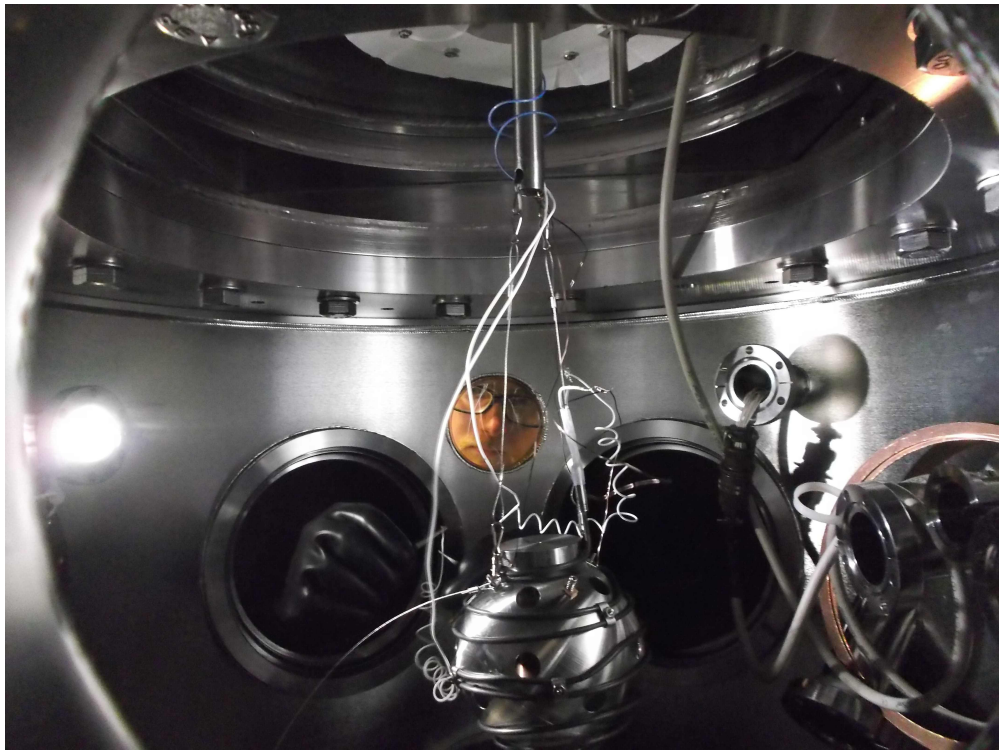


- First 4π test deposition in April 2013
- 0.883g evaporated, 0.984μm thickness over $0.8m^2$
- See video: deap3600.ca/video



Deposition

- All work done through glovebox, purged with radon-scrubbed boil-off nitrogen
- AV vacuum bake: lowers gas load and quenching species
- Pre-baking of TPB: brought to 150°C under rough vacuum
- Deployed and pumped to base gauge pressure 7×10^{-6} mbar



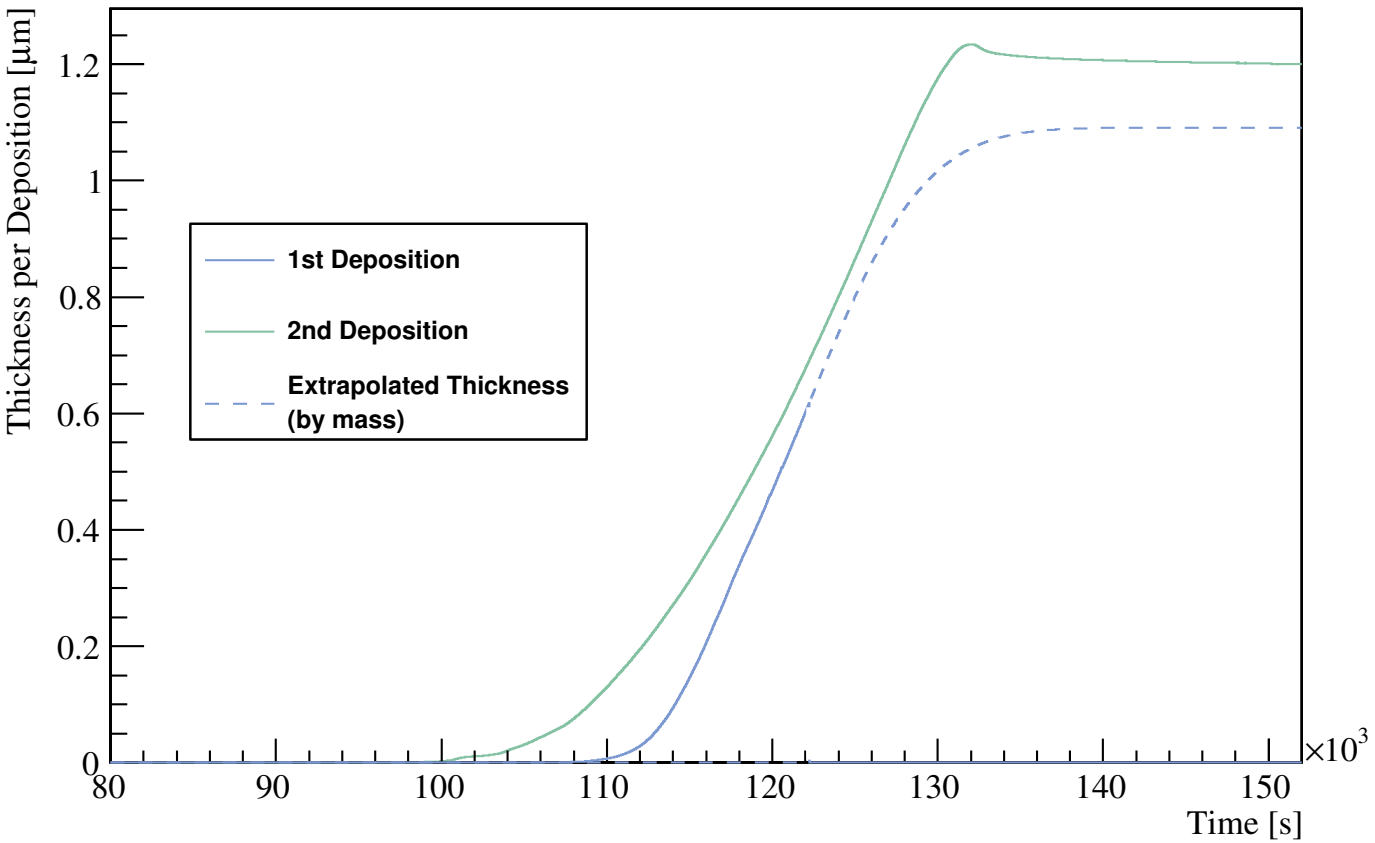
Depositions:

1st 19 June 2015: 14.0 ± 0.1g

2nd 27 June 2015: 15.4 ± 0.1g

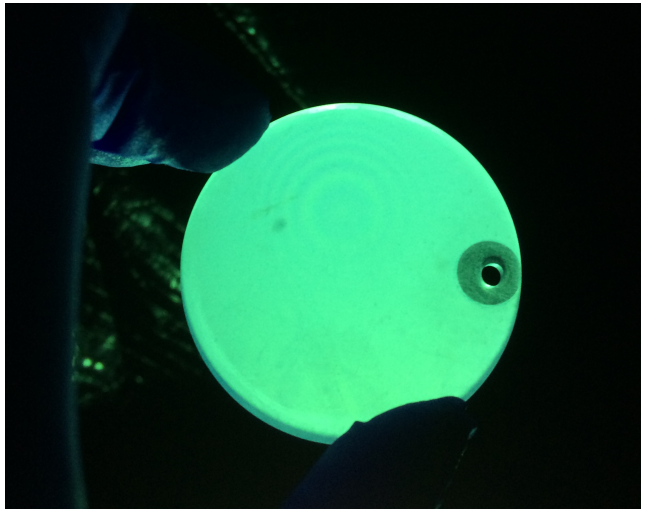
Deposition

- Thickness: coverage vs. background vs. feasibility
- Collected with Inficon Front-loaded Quartz monitor, SQM-242 deposition controller
- Potential shadowing from cables



Conclusion

- Wavelength shifting required to make visible VUV signal from Ar
- Targeted micra-scale coating of 1,1,4,4-tetraphenyl-1,3-butadiene over $9m^2$
- Custom evaporation system developed
- Vacuum bake of AV in surface preparation
- 2 depositions: 29.4 ± 0.2 g 3.00 ± 0.02 μm by mass



- By-mass and direct thickness measurement agree within targeted tolerance
- Early surface background estimates ongoing
- Nonuniformity $< 25\%$