Xenon spectroscopy for rare event searches

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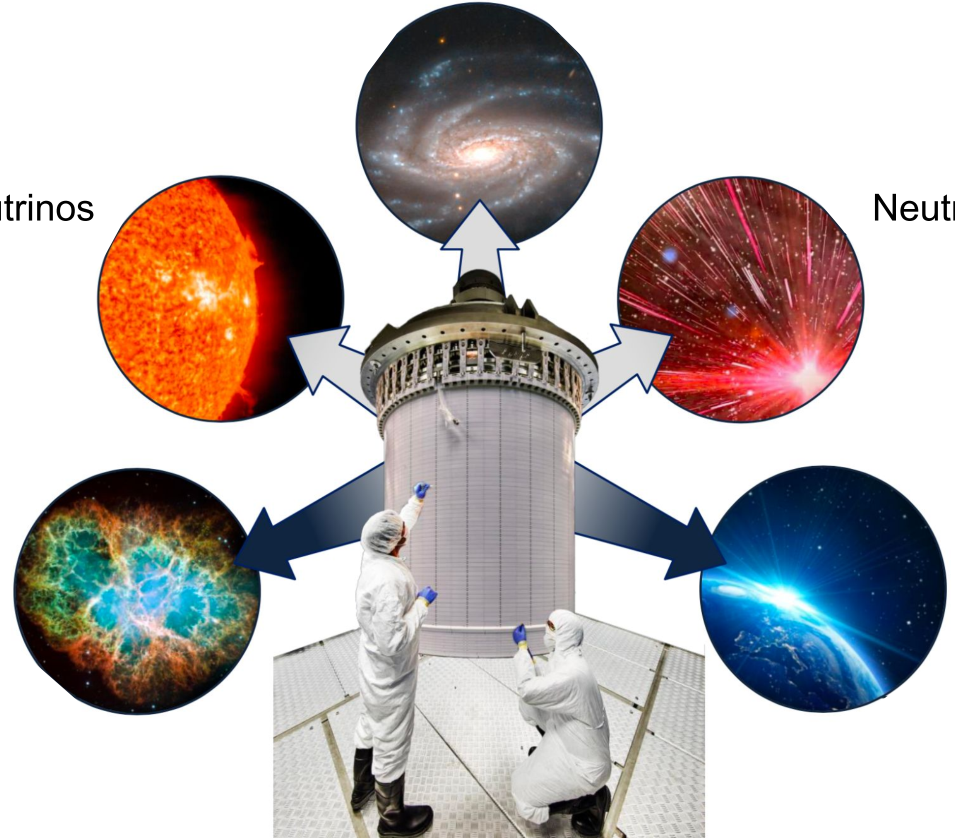
Sep 23rd, 2022
Light Detection in Noble Elements (LIDINE) 2022

Imperial College London

Rare event searches



XLZD

XENON Dark Matter Project

DARWIN

arxiv:2203.02309

A Next-Generation Liquid Xenon Observatory for Dark Matter and Neutrino Physics

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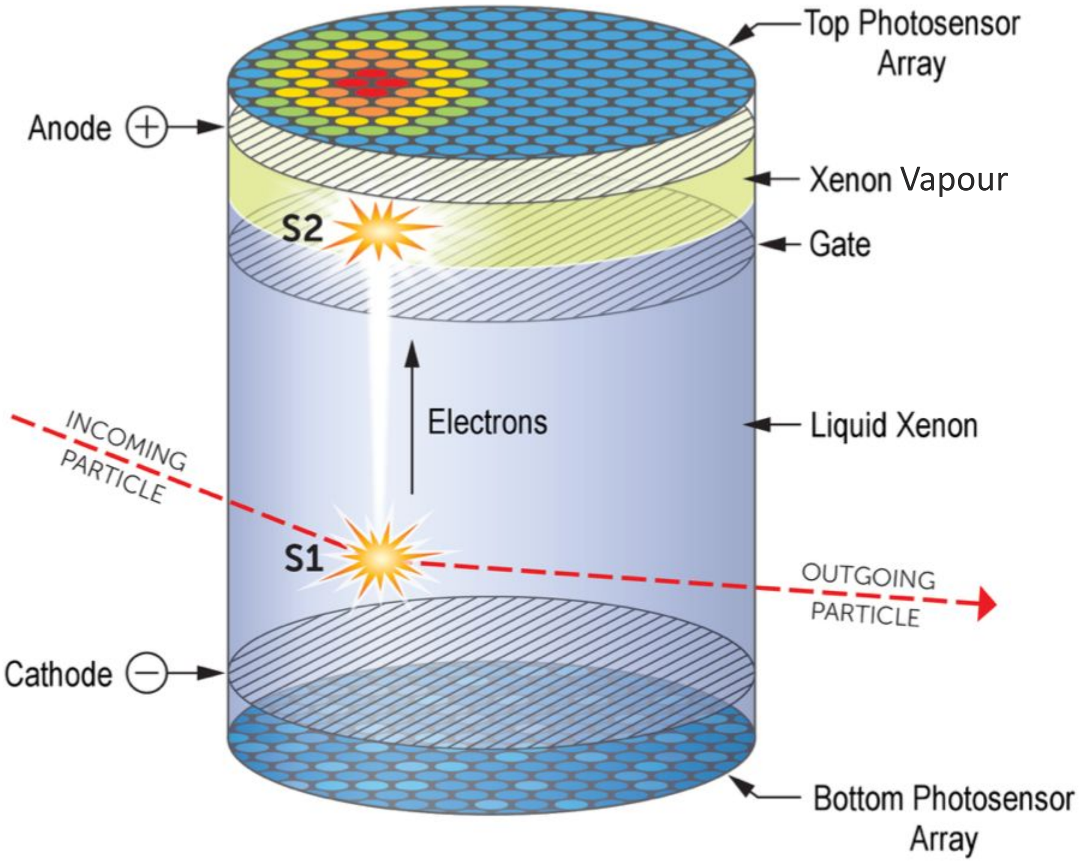
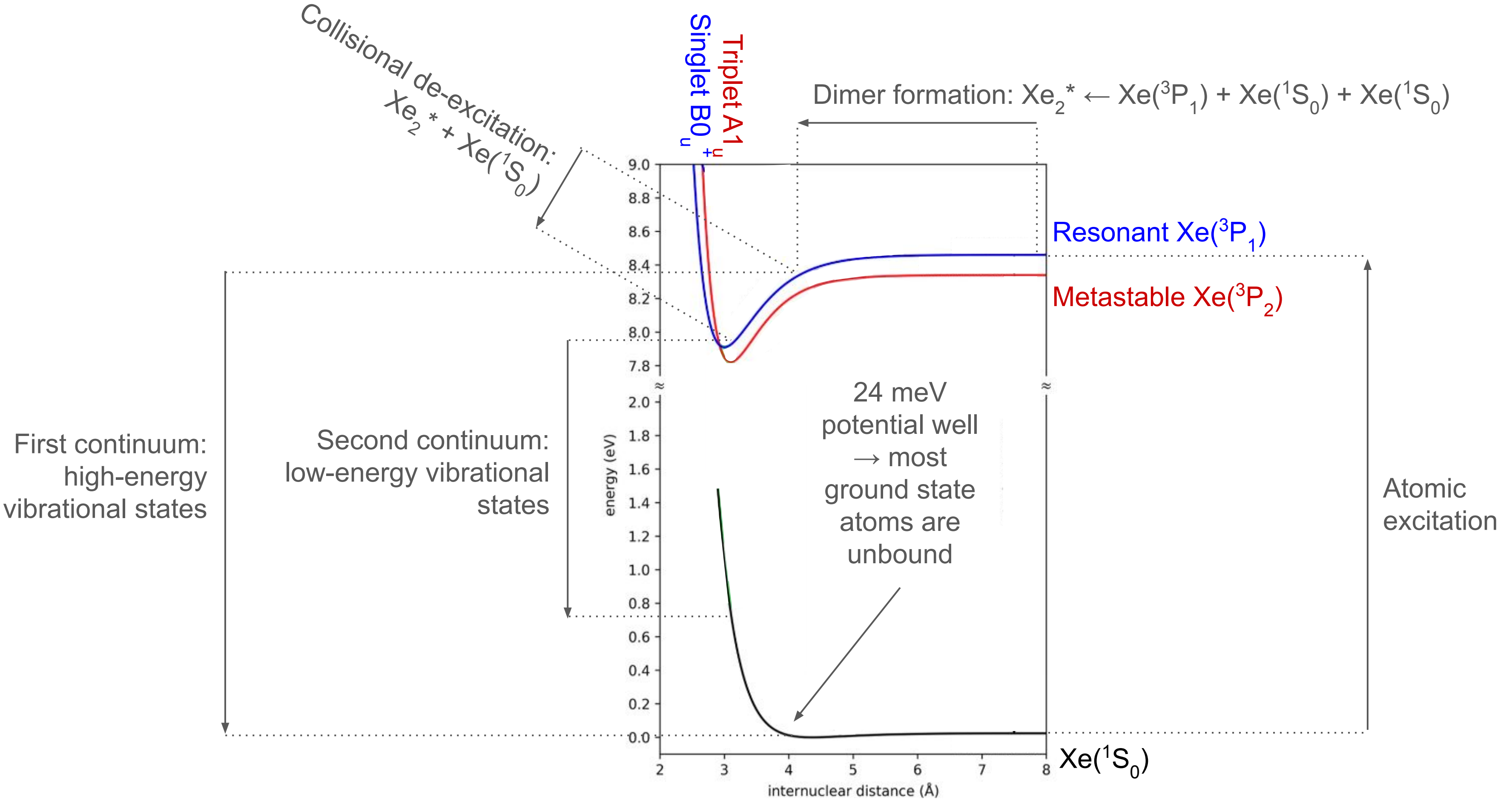
Dual-phase Xe time projection chambers

S2: electroluminescence in vapour

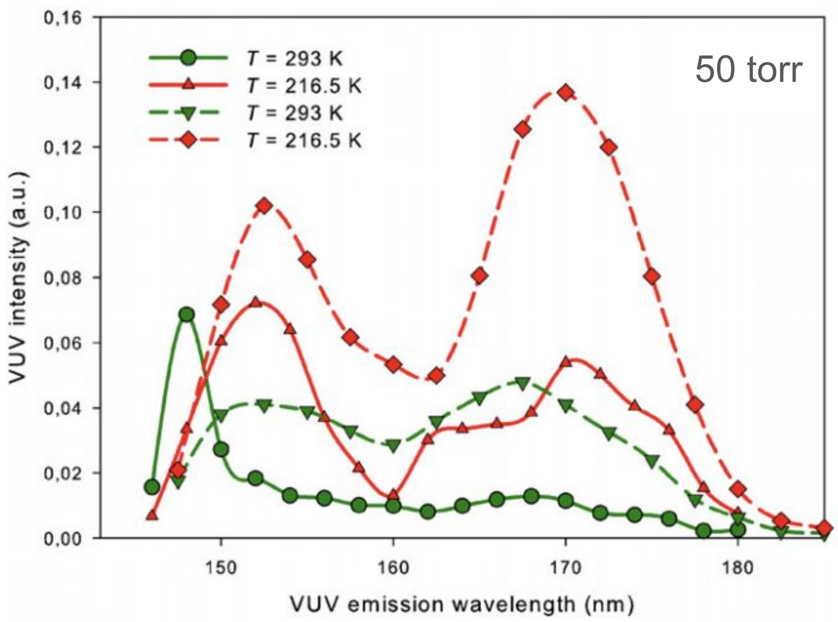
S1: scintillation in liquid

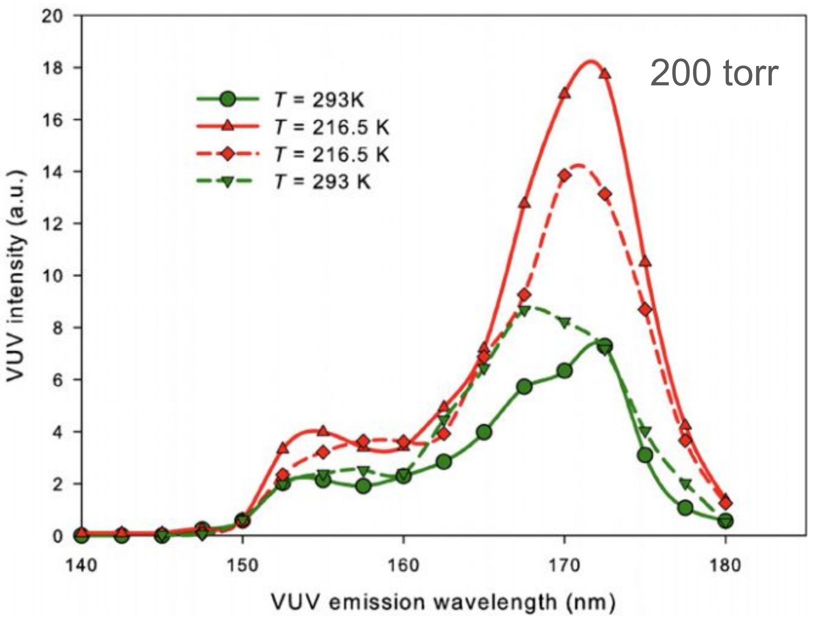


Xe_2* molecular luminescence



1st and 2nd Continua





2-photon laser-induced fluorescence technique selects resonant (–), metastable (**--**) states [Marchal 2010]

Greater density, via changes in pressure or temperature, elevates the second continuum (~170 nm)

Dual-phase Xe TPC: P = 1000-2000 torr, T = 170-184 K

Scintillation & electroluminescence

	Medium	Temperature (K)	Pressure (torr)	Mean Wavelength (nm)	FWHM (nm)	References
S1	GXe	300	760	174.5	15	Jortner 1965
		300	750-7500	175	15	Saito 2002
	LXe	160	-	178	14	Jortner 1965
			-	174	10	Fujii 2015
S2	GXe	300	760	171	12	Takahashi 1983

LXe scintillation measurements exist from [Fujii 2015] but no measurements of electroluminescence in cold vapour in the literature

No measurements for S1 and S2 in the same conditions (liquid/gas equilibrium)

No measurements for solid/gas equilibrium

Scintillation & electroluminescence

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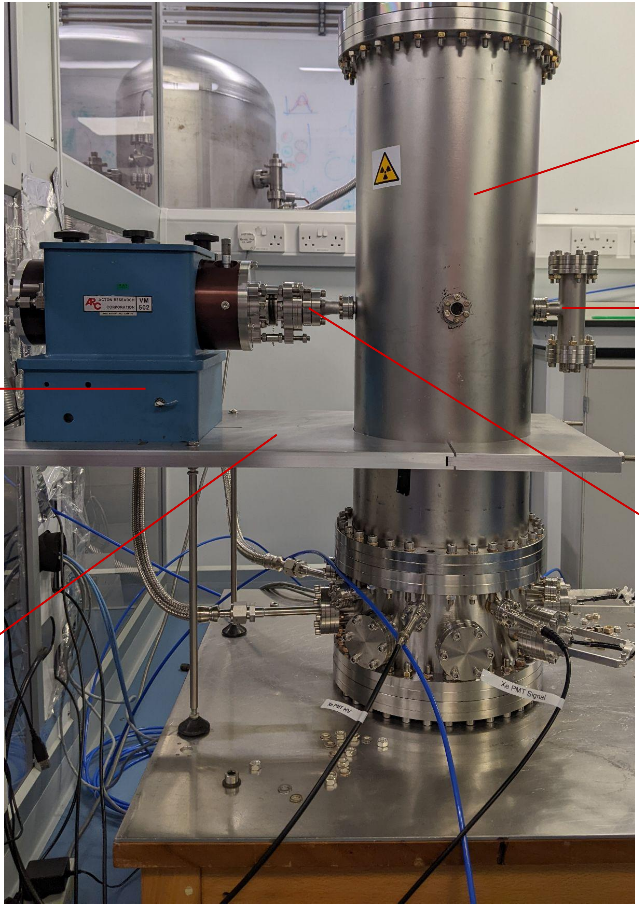
Few-nm wavelength differences affect optical parameters significantly in the VUV regime

Inform rigorous optical models of detectors

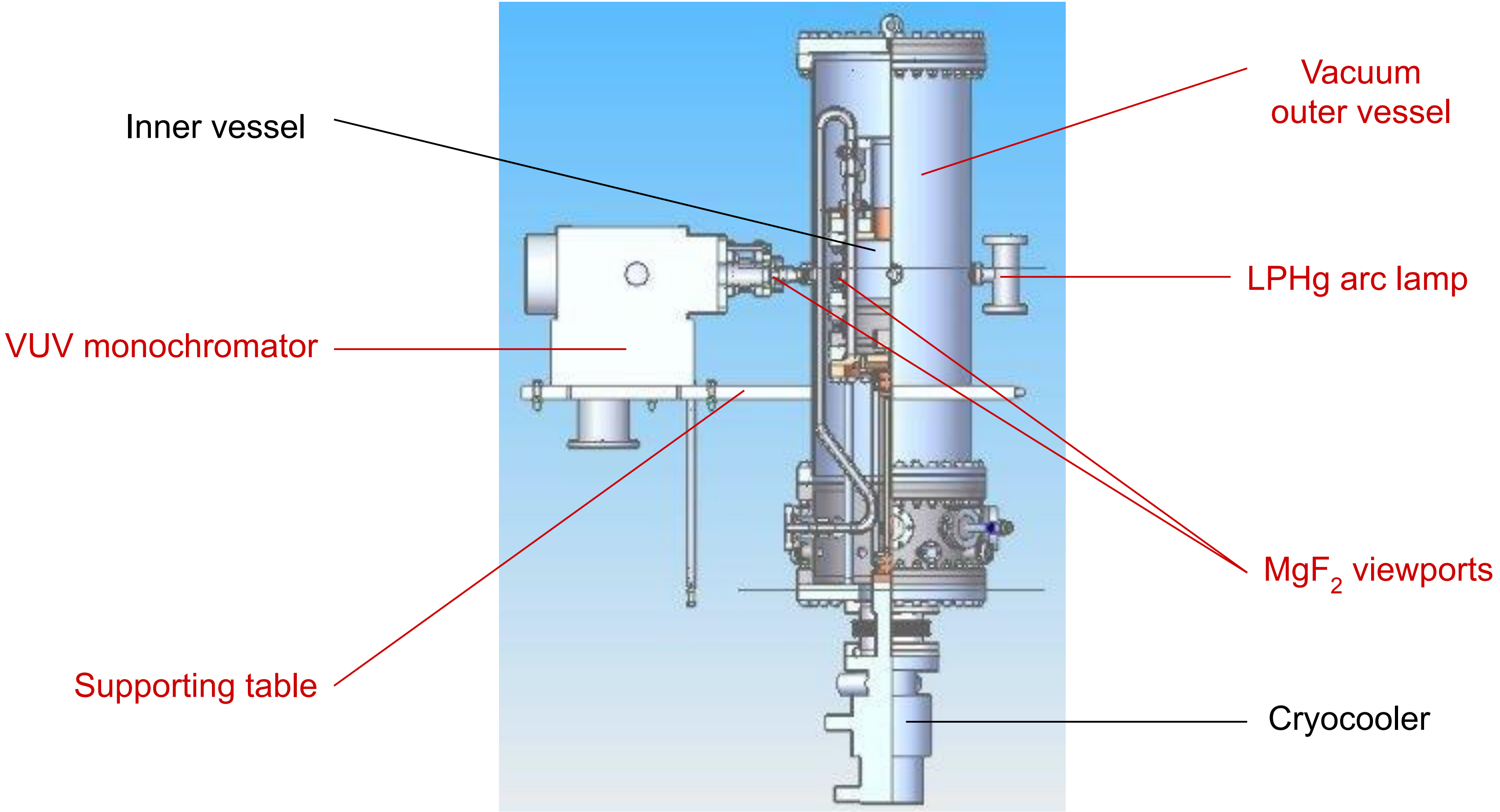
Slightly different emission spectra for S1 and S2 would lead to different inferred quanta

There are implications for photoionisation yield and fluorescence yield induced by S1 and S2 light (i.e. nuisance electrons/photons)

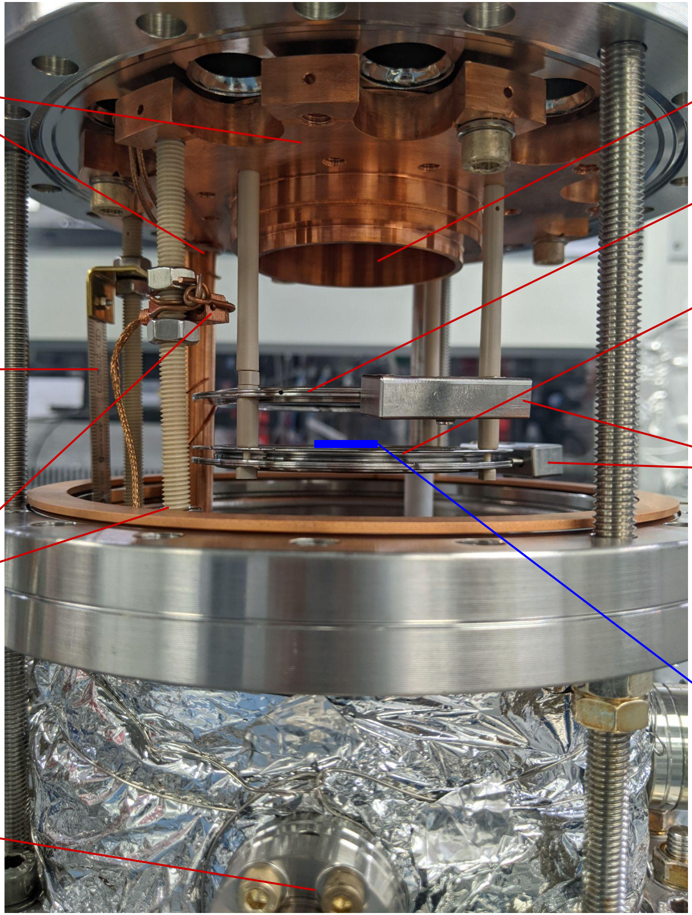
External setup



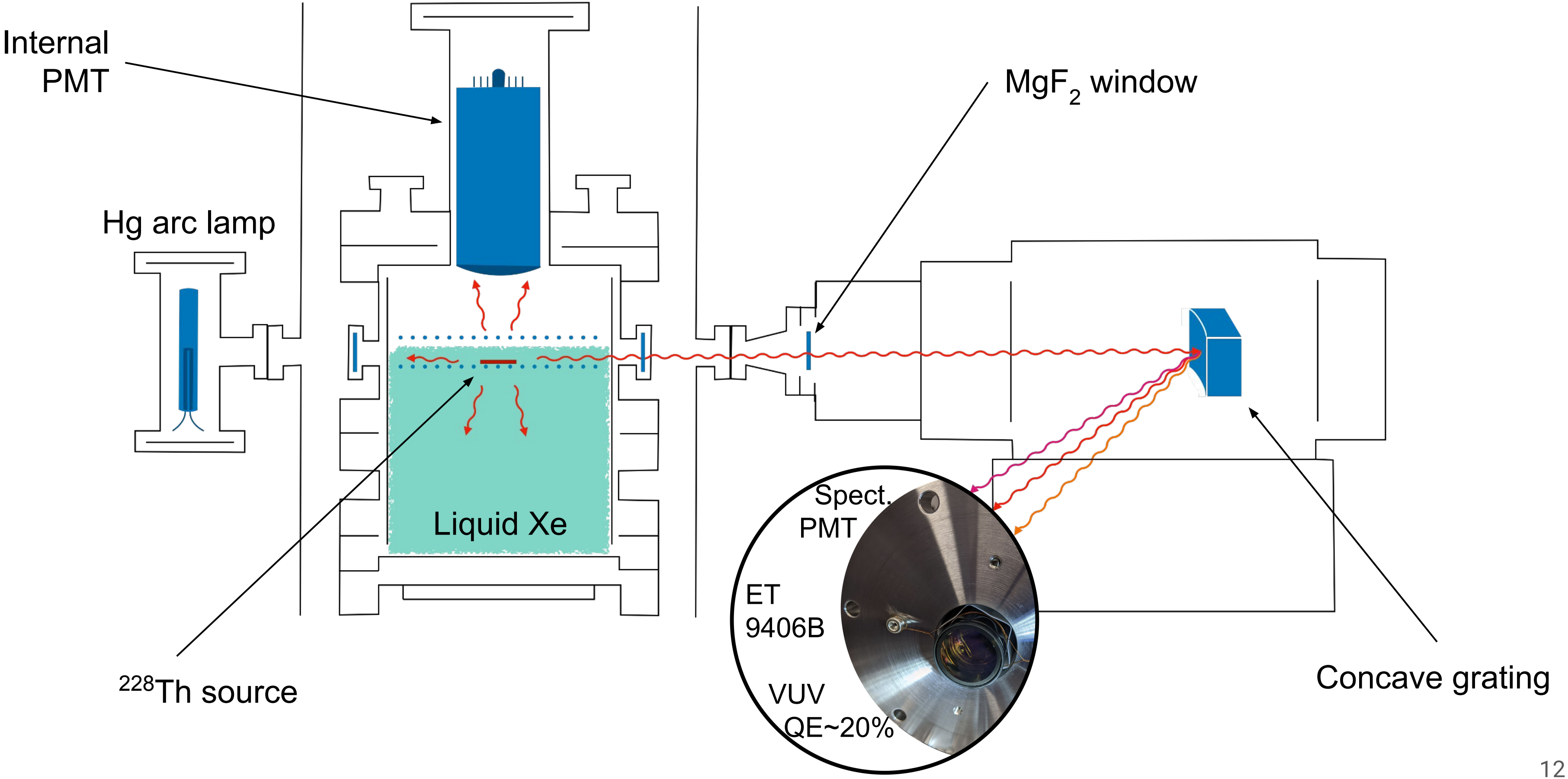
External setup



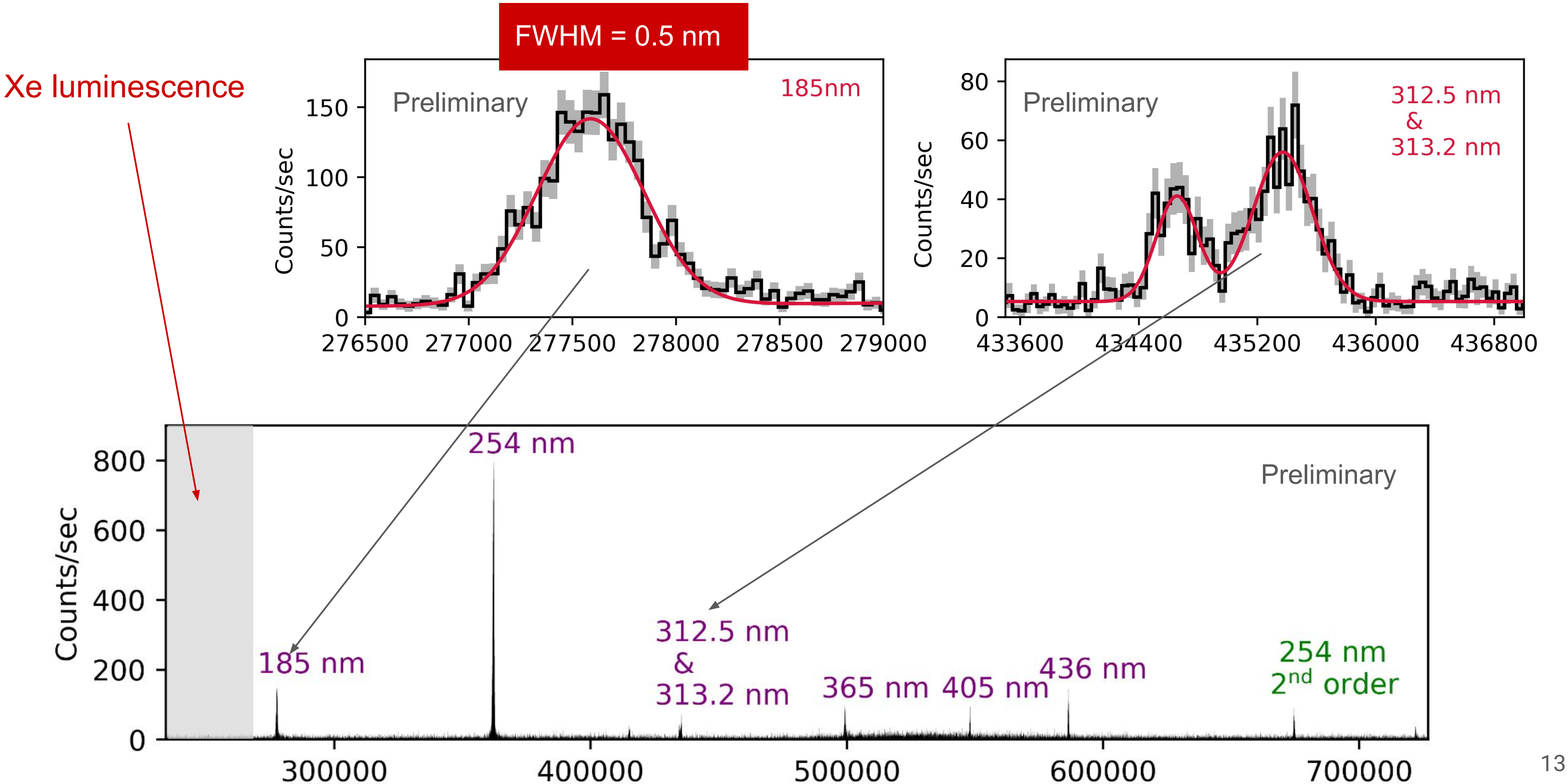
Internal setup



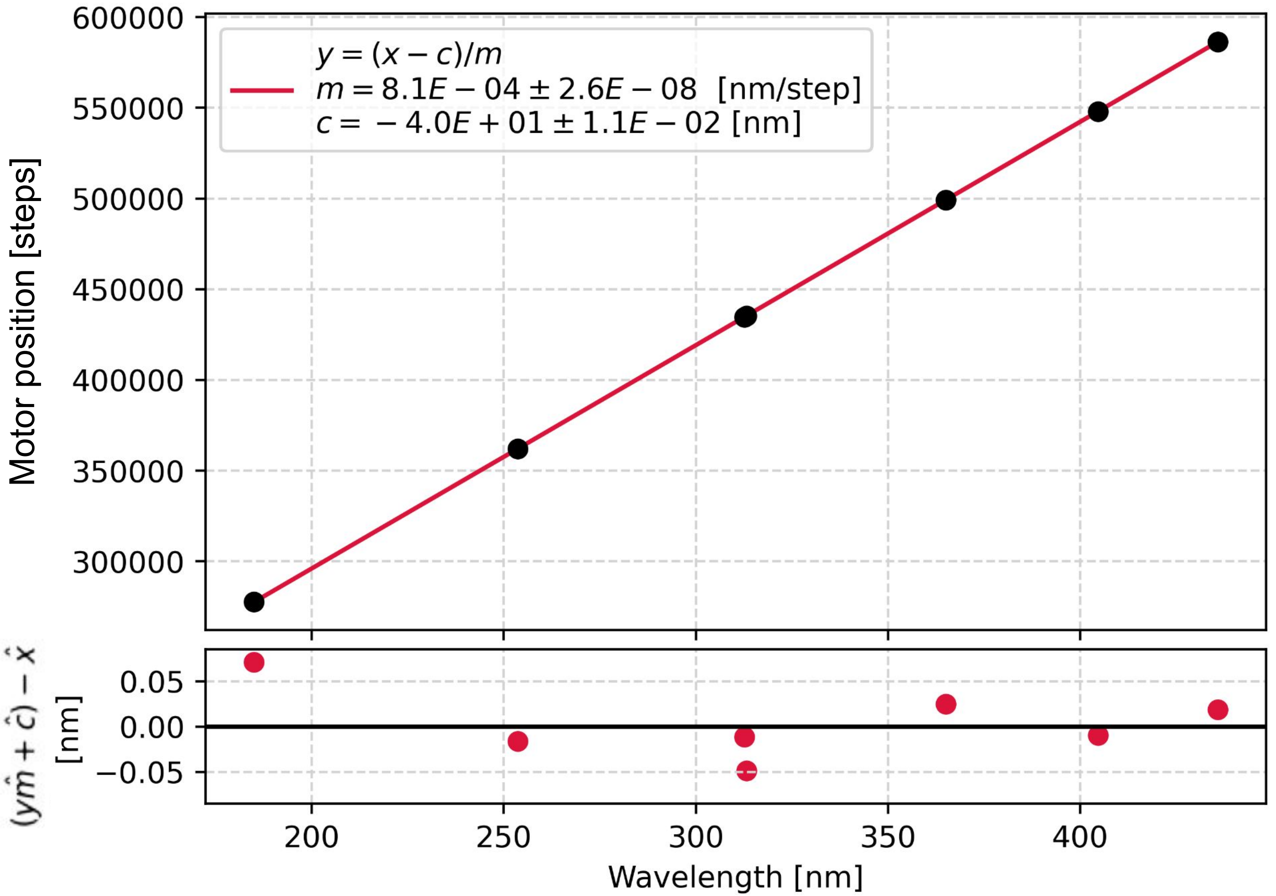
Path of light



LPHG arc lamp calibration



HG arc lamp calibration

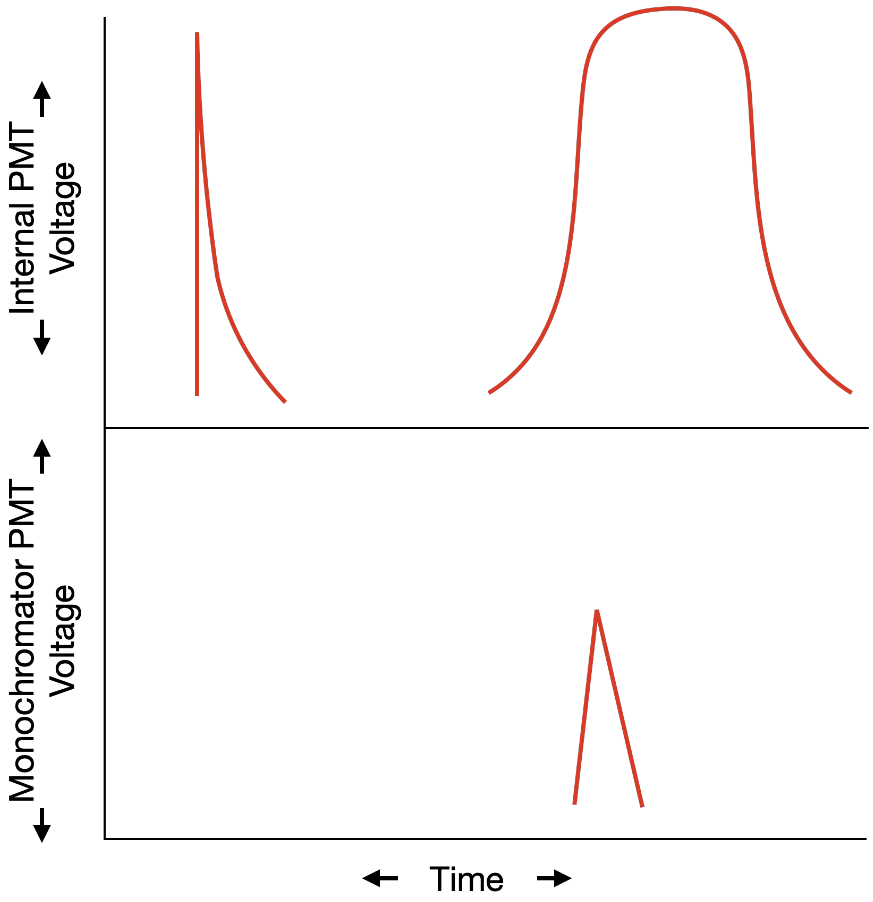


Coincidence measurement

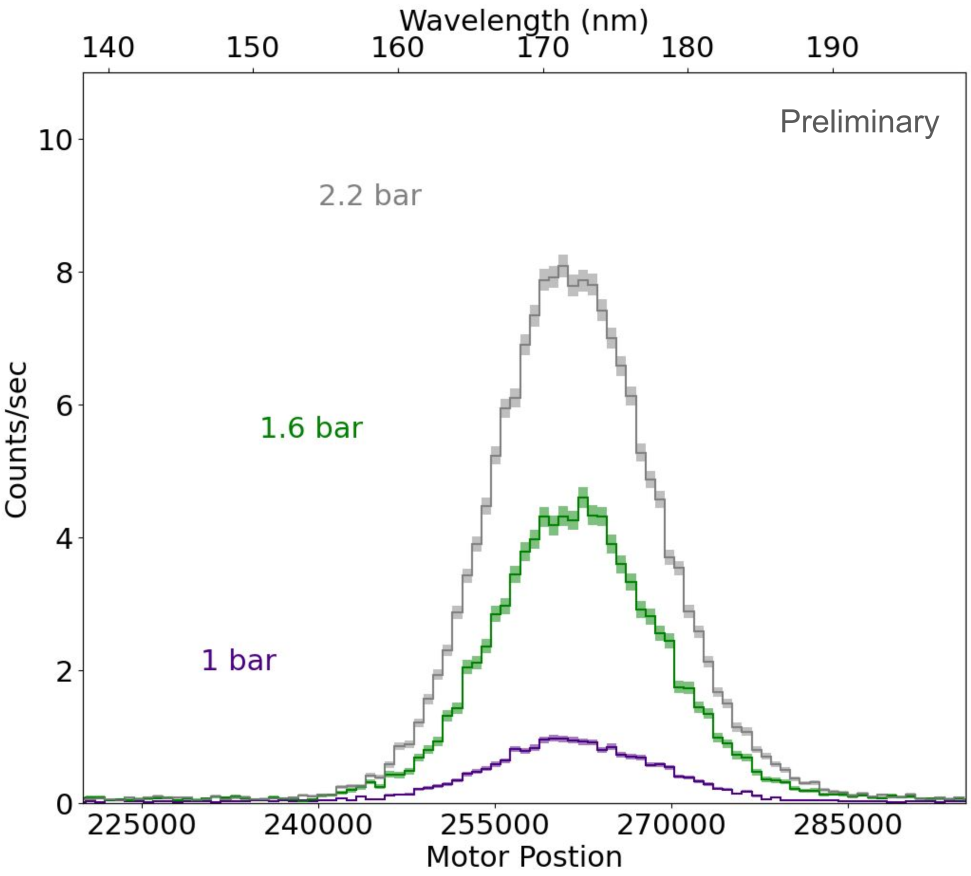
Digitize individual phe from the spectroscopy PMT in coincidence with the internal PMT

Minimize dark count background

Example shown here is from room temperature electroluminescence



Data in gaseous xenon



Room temperature

Electroluminescence

Reduced electric field of 15.3 Td

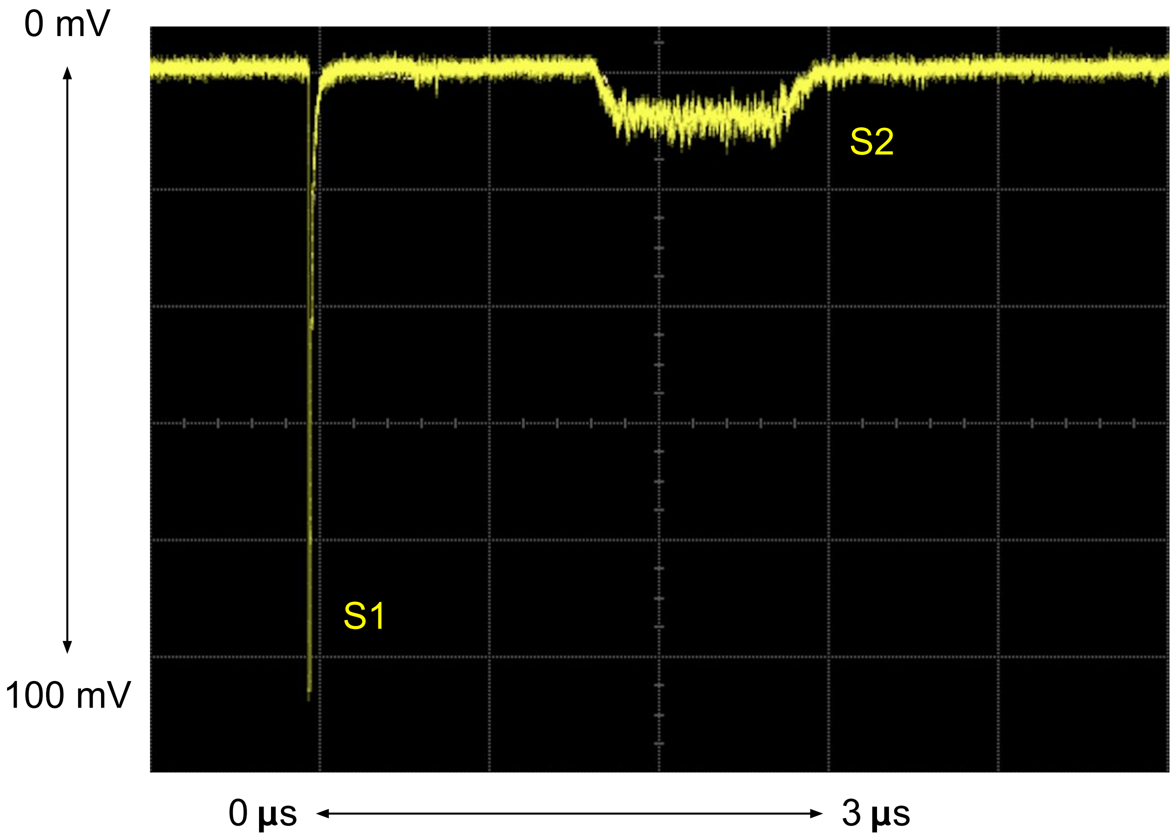
Approximate central wavelength at 1.6 bar (171 nm) agrees with data from Takahashi 1983

Data in liquid xenon

Distinguishable S1s and S2s

Stable, but low, electron lifetime due to contamination event before run

H_2O ice deposition on internal (cold) MgF_2 viewport absorbing VUV light



Conclusions and next steps

Spectroscopy measurement is set up and delivers good spectral resolution

Can operate the LXe chamber stably and deliver high electric fields

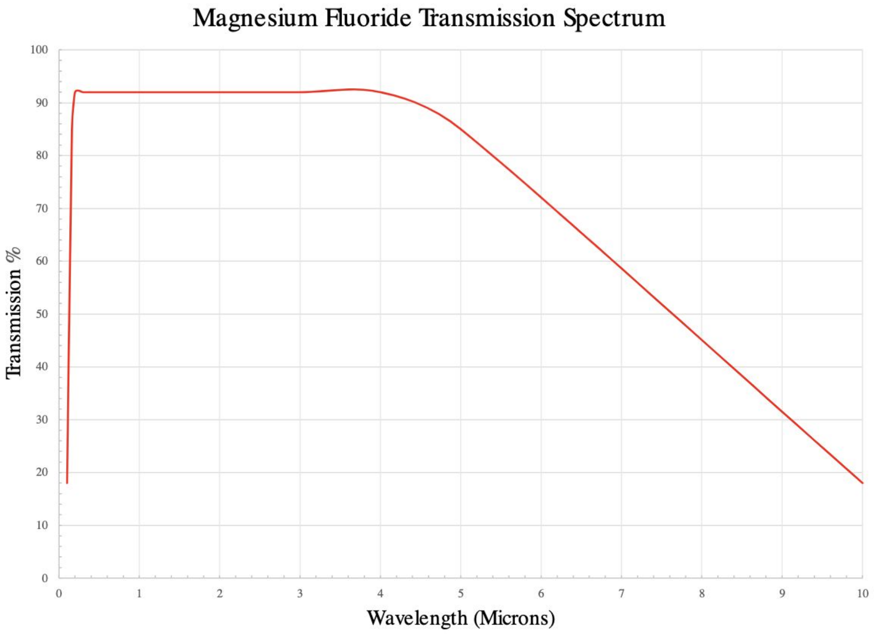
Can acquire high-quality calibration and xenon data

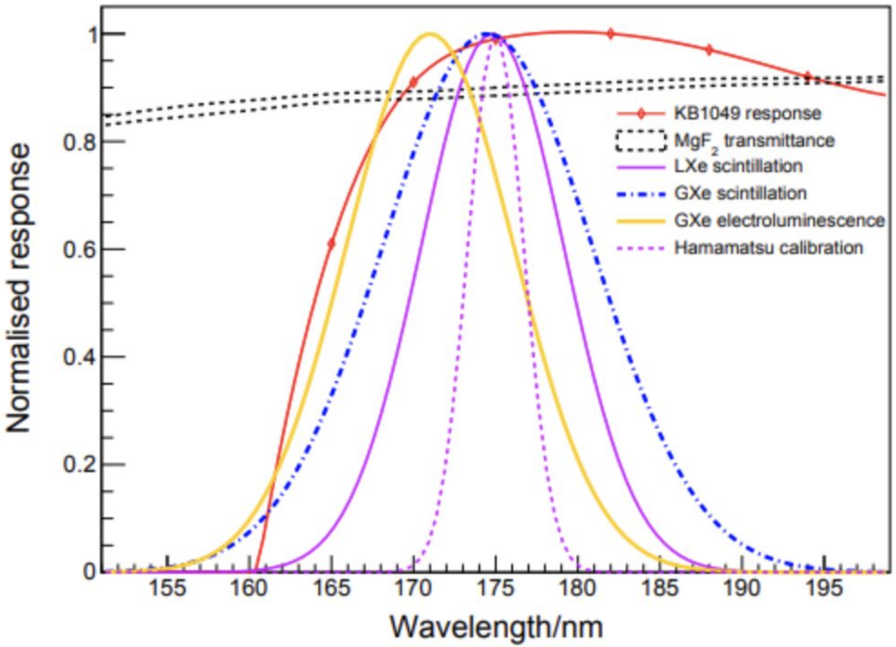
Next steps

- Resolve the xenon purity issue
- Improve the outer vessel vacuum
- Take two-phase data (liquid/gas, solid/gas)

Backup

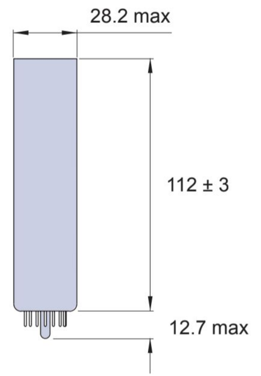
Transmittance MgF_2 Window



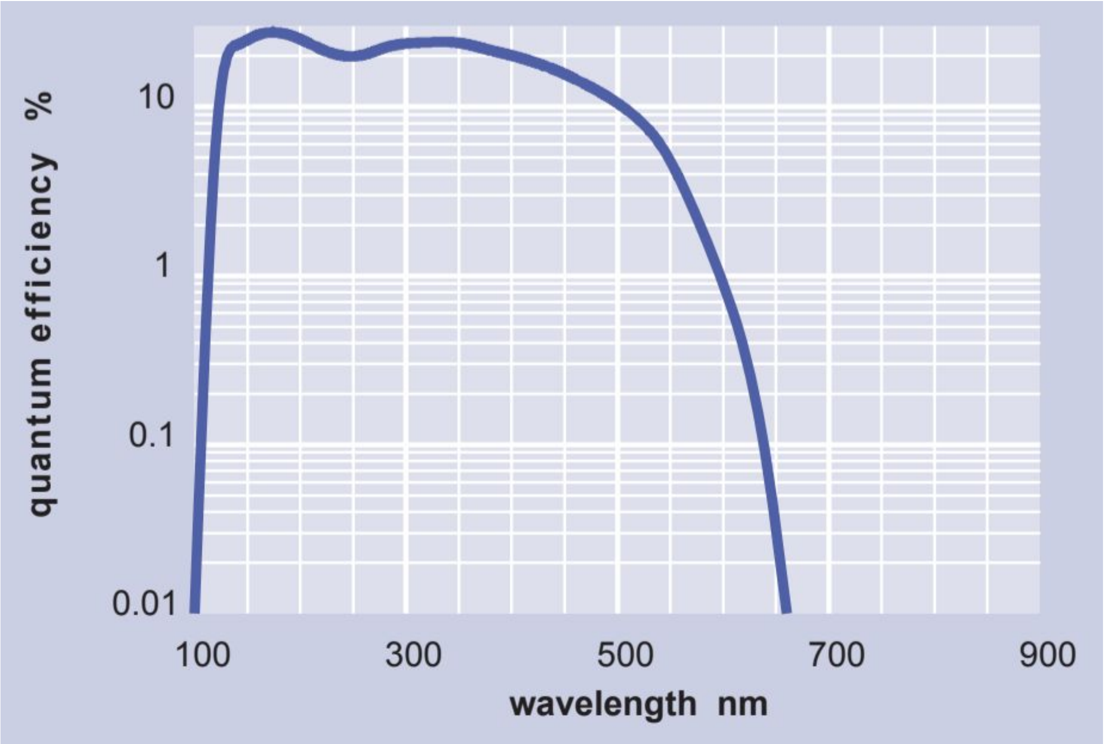


Spectroscopy PMT

29 mm (1.13") photomultiplier
9406B series data sheet



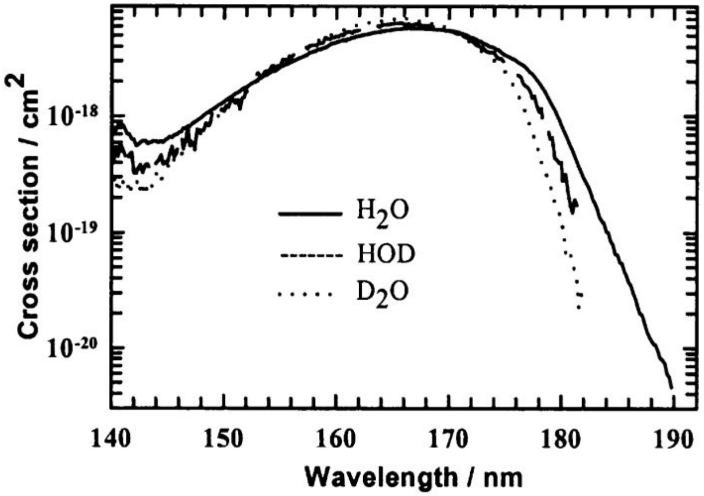
Absolute QE
Measurements in
[121.6 to 200.0] from
18.1% to 23.5%

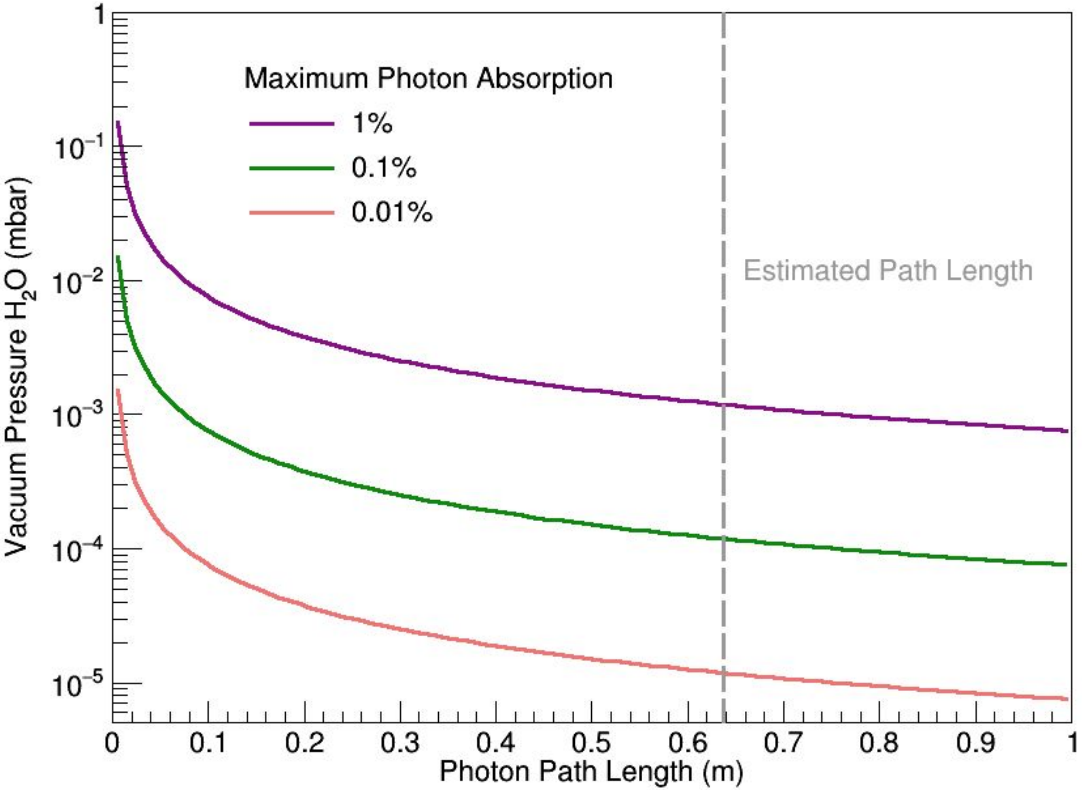


VUV Absorption

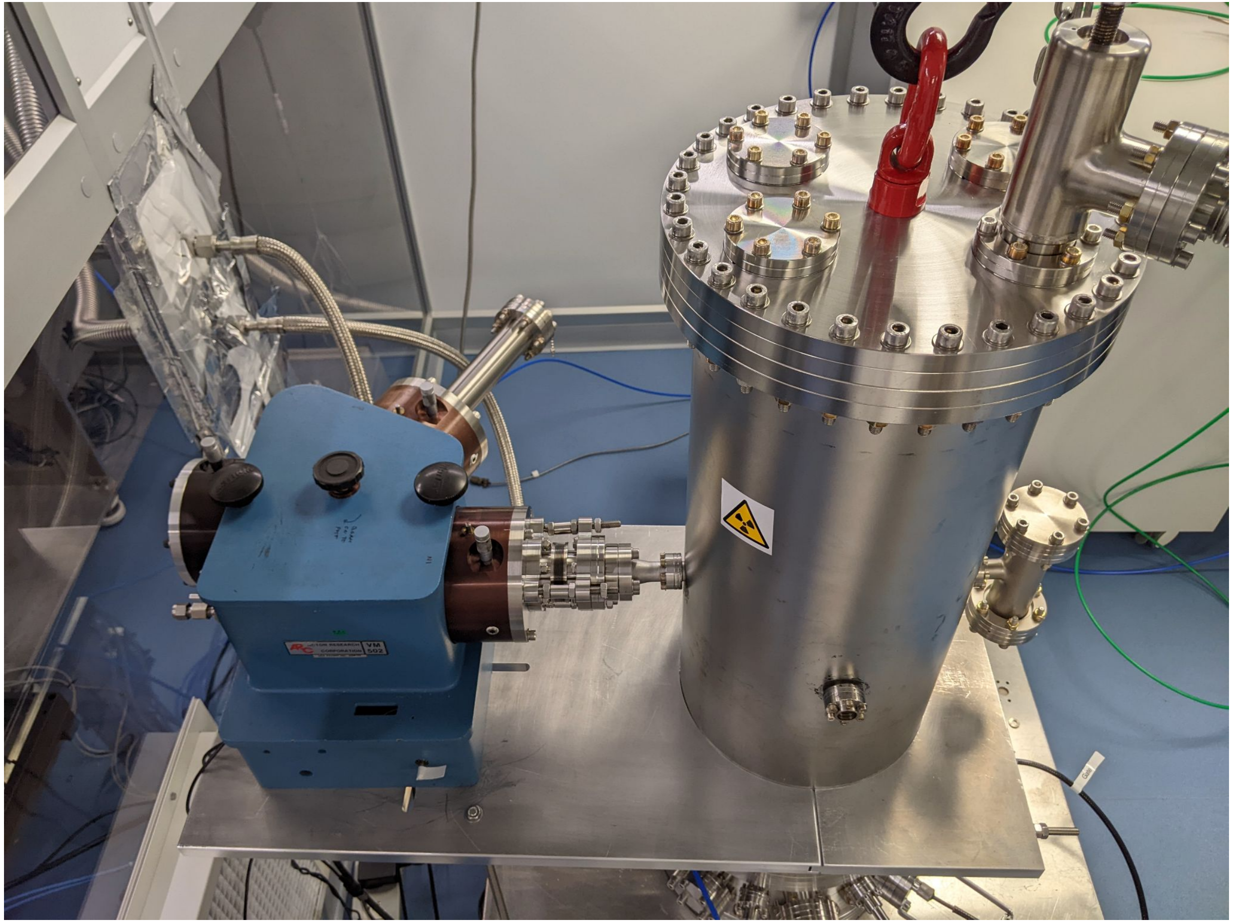
λ_{max} = 167 nm

σ_{max} = 54 x 10 $^{-19}$ cm^2





Path of light



Path of light