Infrared scintillation light in xenon

Teresa Marrodán Undagoitia, June 4th

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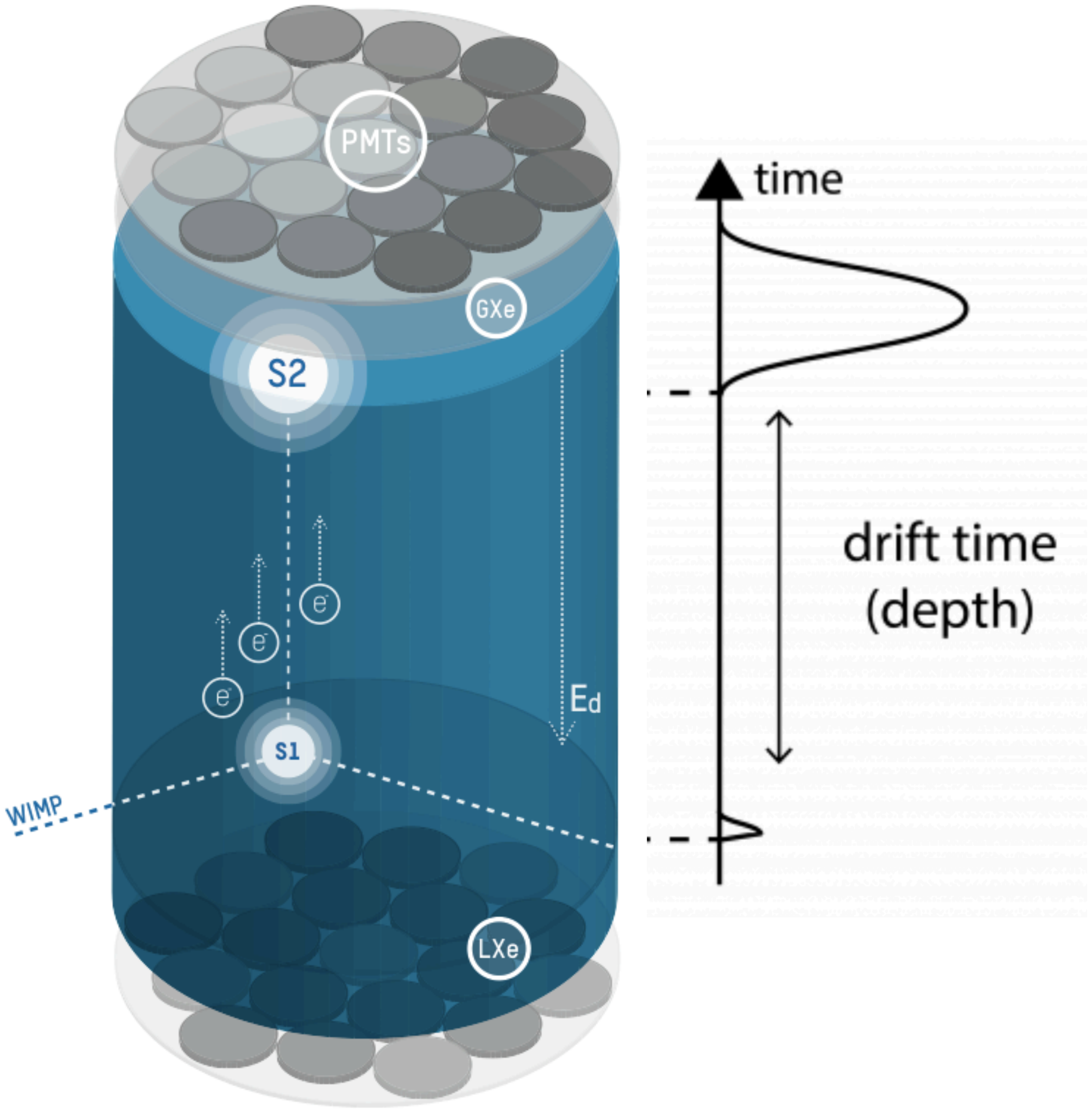
State-of-the-art: UV light detection

- Scintillation and ionisation are both detected through 178 nm light (S1&S2)
- Are we using all information available?

NO, infrared photons are also emitted!

- Application: additional signal and eventually particle discrimination



Liquid xenon TPC working principle

Scintillation mechanism in xenon

A. Xe excitation or ionization

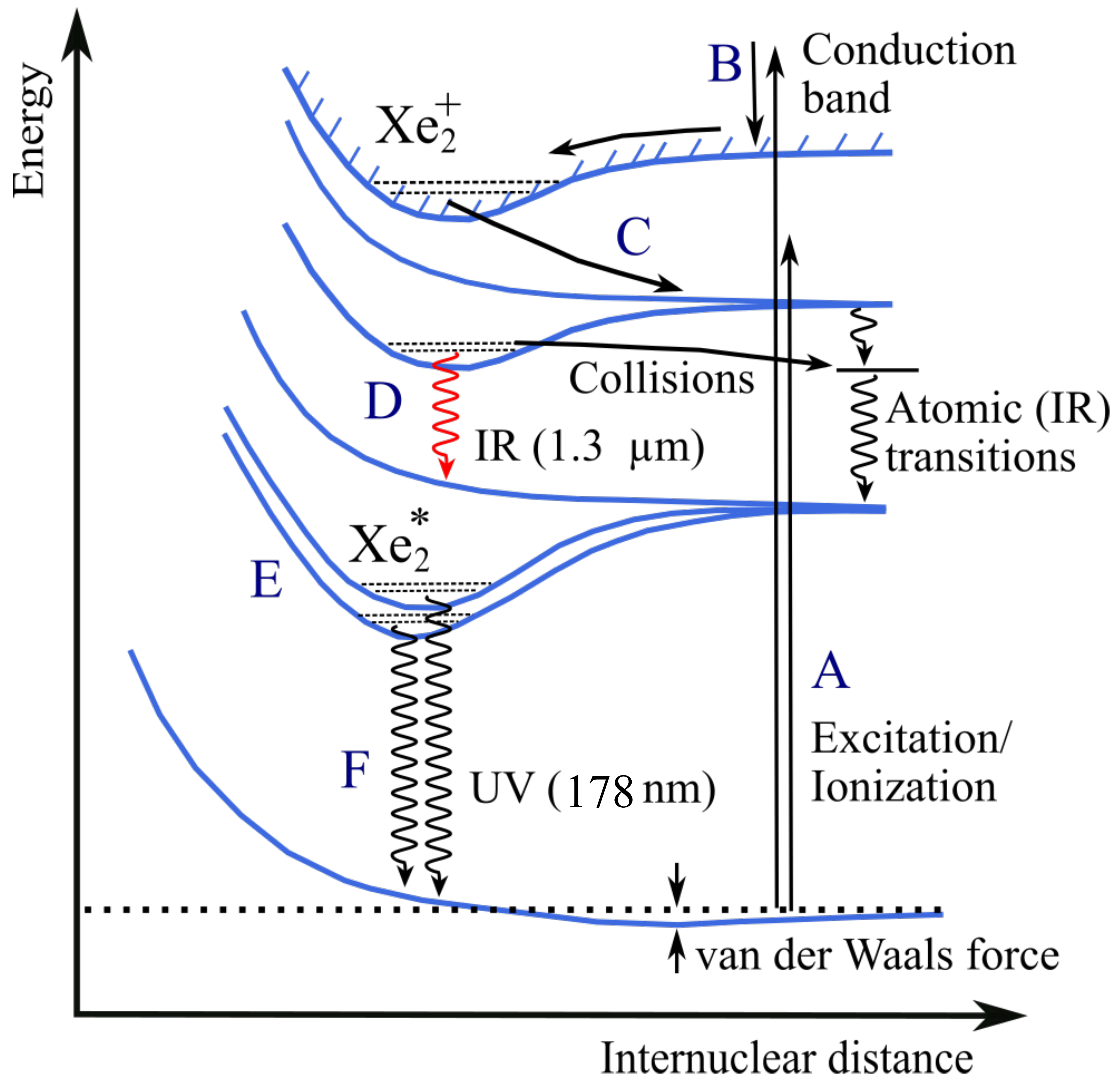
B. Recombination of freed e-

C. Relaxation with atomic de-excitation or …

D. Excimer infrared emission at ~ 1.3 µm

E. Lowest excimer states

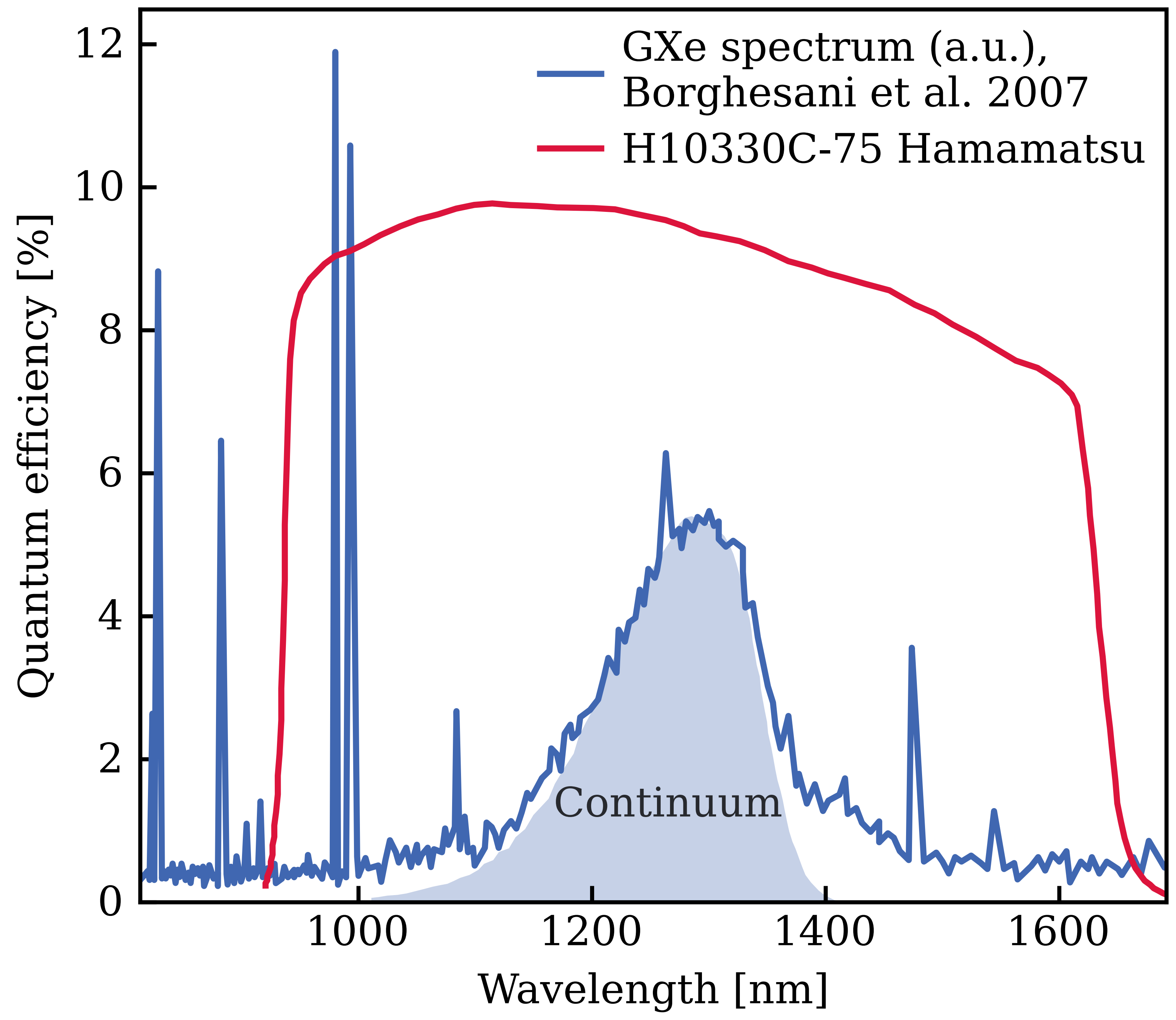
F. Known ultraviolet emission

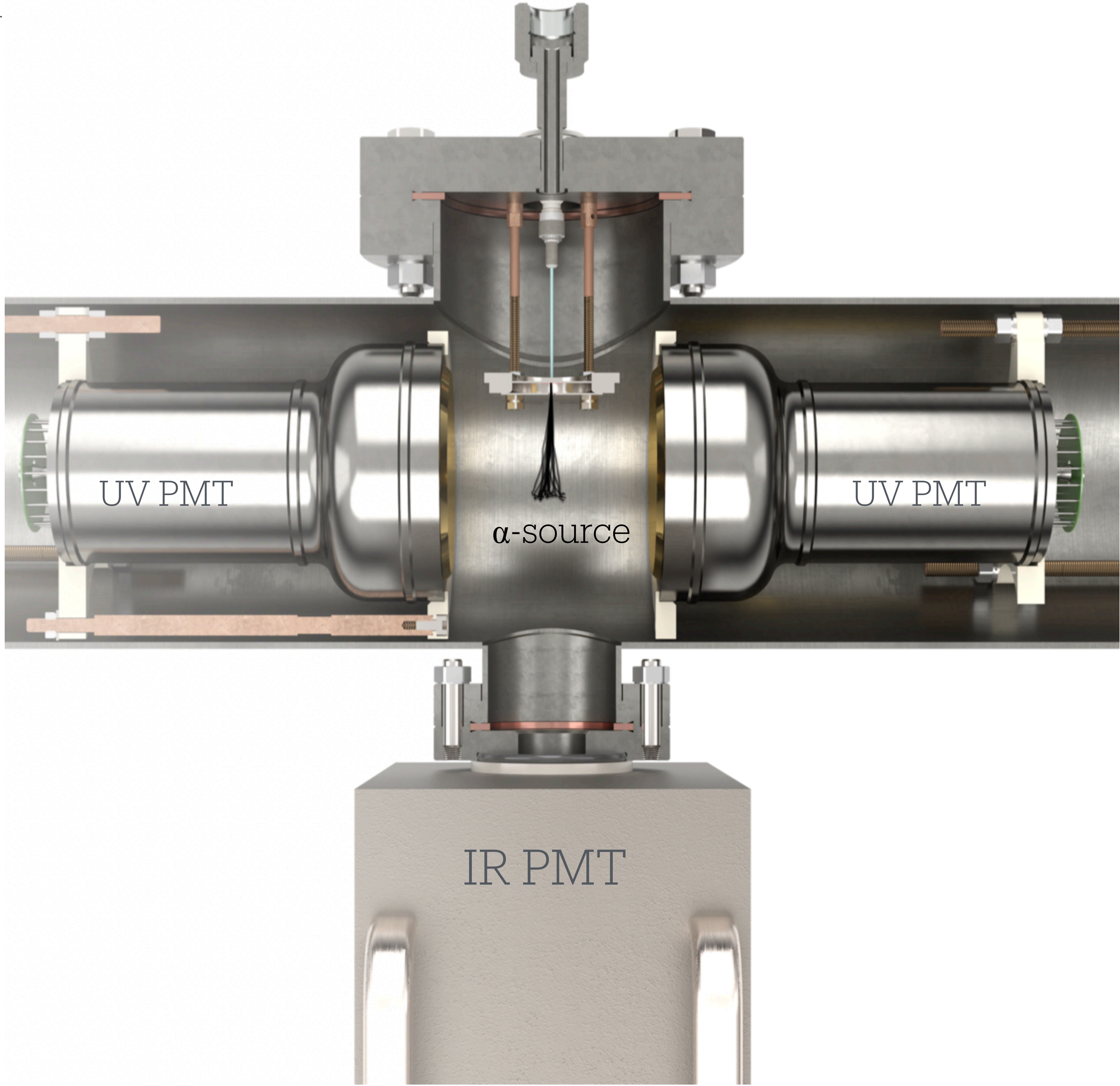


Inspired by Borghesani et al., 2001

New R&D in gaseous xenon

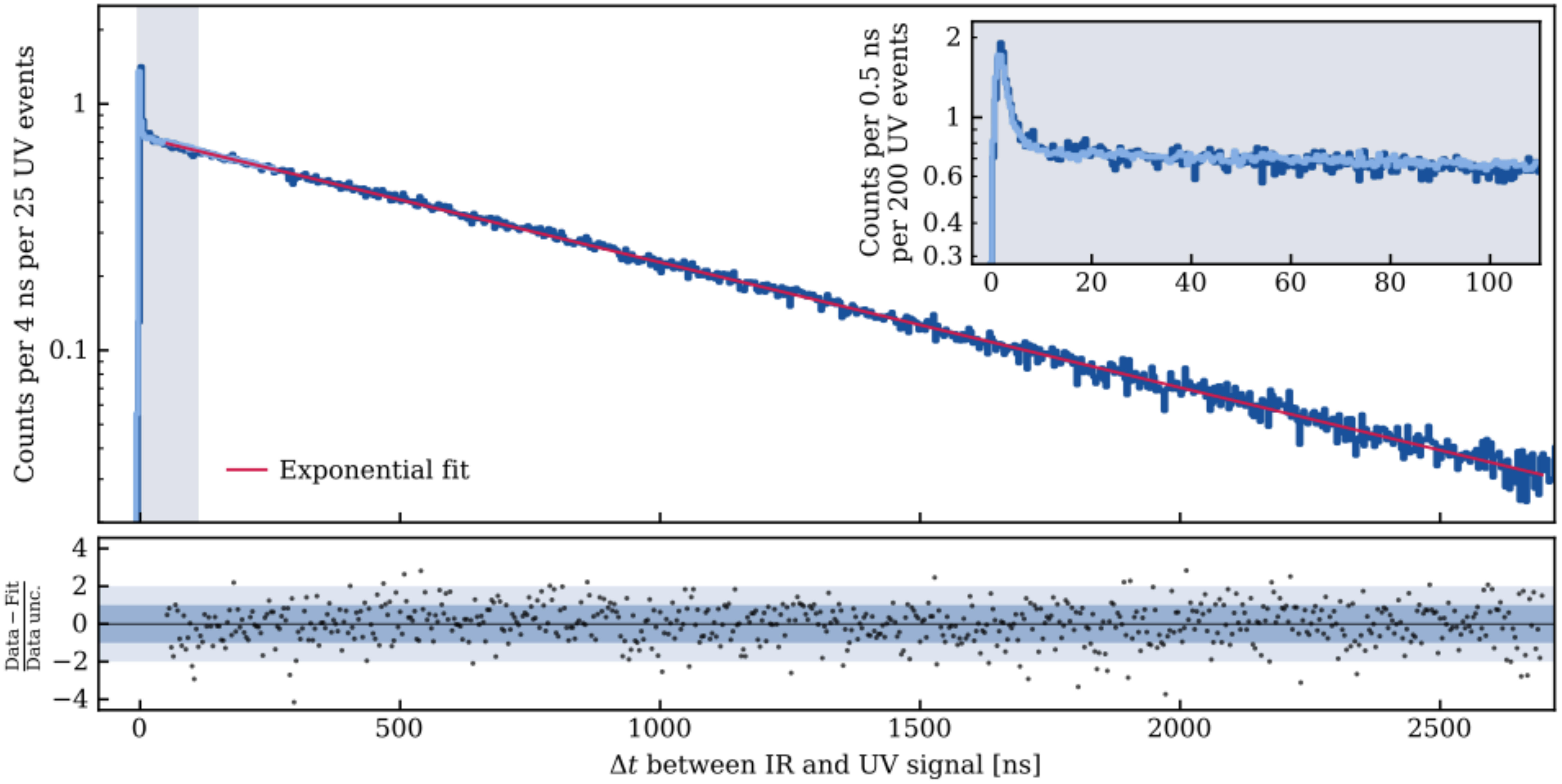
Understanding IR signal production and its potential





- IR sensitive PMT
- Simultaneous UV & IR detection of GXe @ 1 bar
- Excitation with alpha source

Pulse shape and light yield



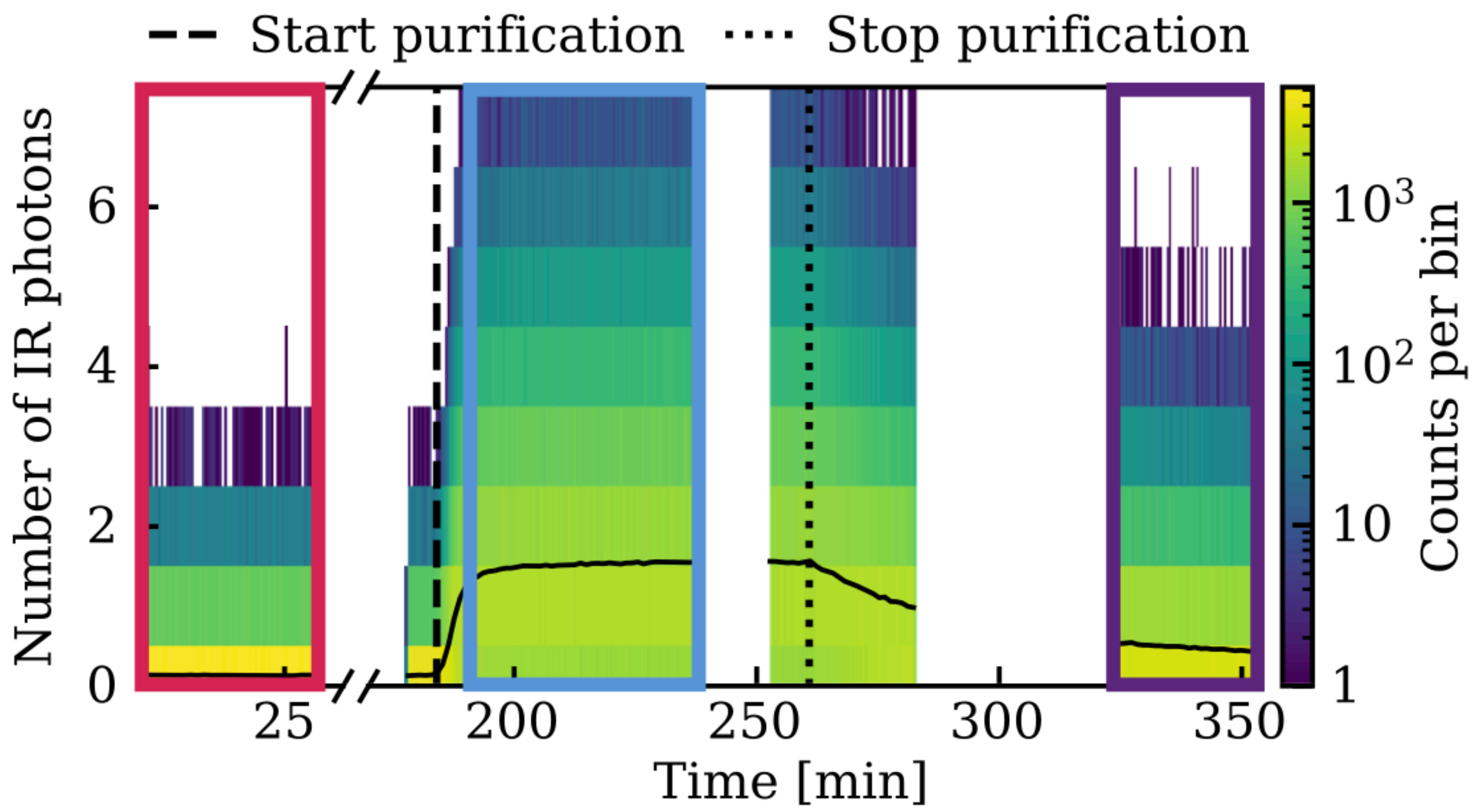
JINST 19 (2024) C02080 & arXiv:2401.09262

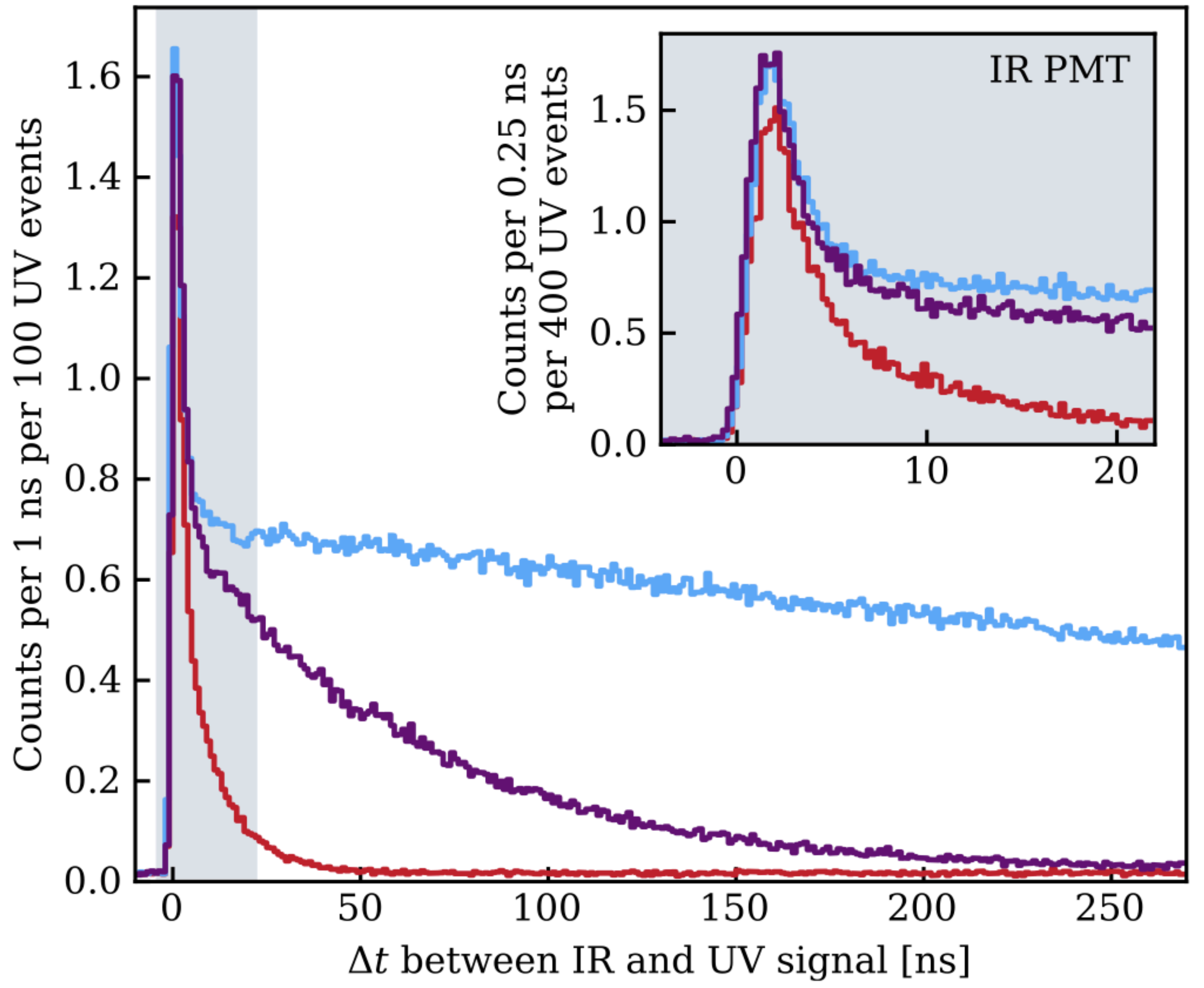
- Single photon counting: low infrared light collection
- Two time constants: Fast O(ns) with < 1% amplitude, and slow O(μs)
- Light yield for GXe @ 1 bar: 6000 ph/MeV (1/4 of UV yield)

Study of purity

- Clear increase of signal with start of xenon purification
- Fast component only slightly affected by impurities
- Slow component very strongly affected by impurities (consistent with Borghesani ’25)

Eur. Phys. J. C 83 (2023) 482 & arXiv:2303.09344





Understanding IR timing

The problem

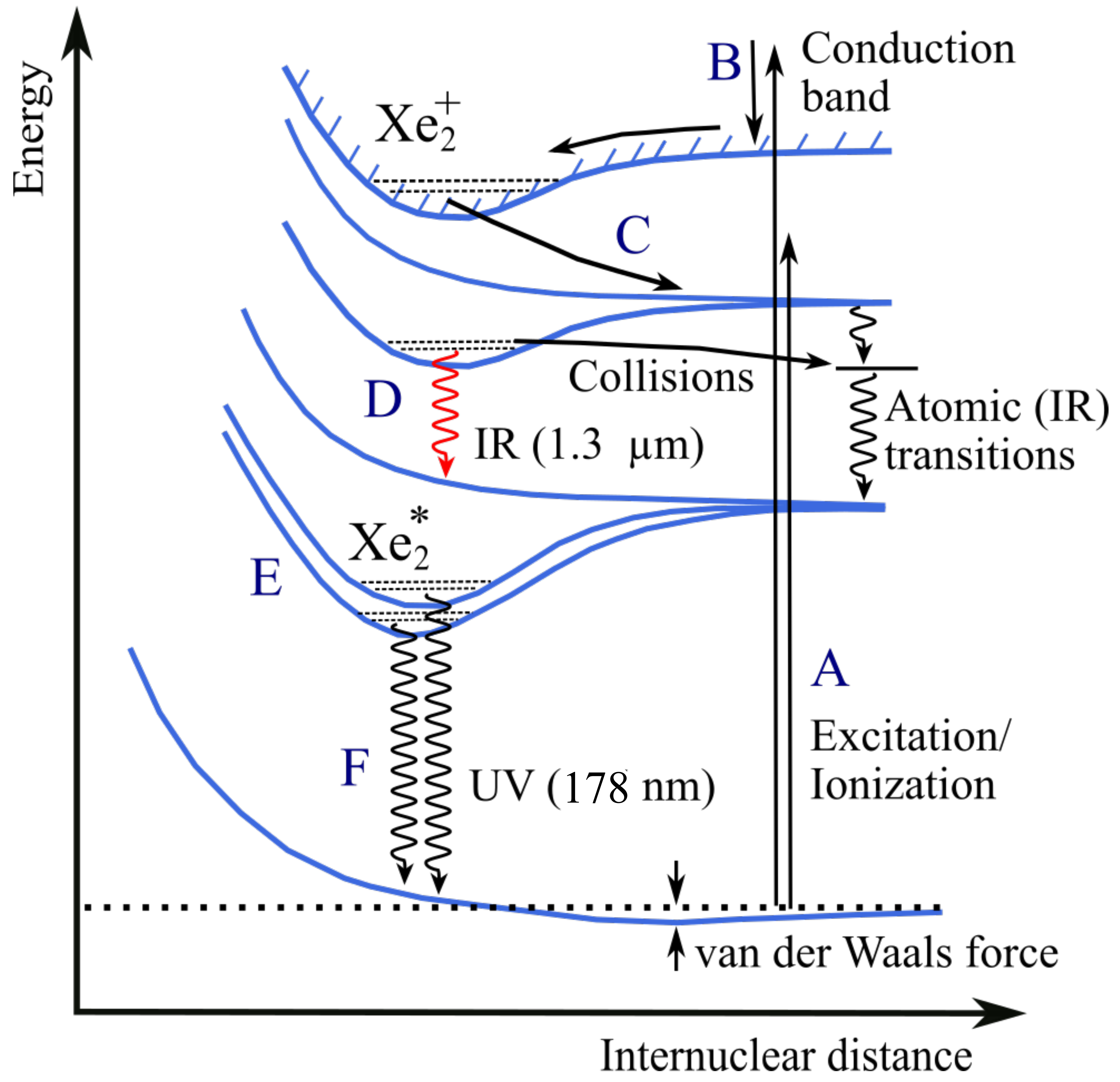
IR precursor states

$\mathcal{O}$(ns) ✓ $\mathcal{O}$(μs) ✗

UV precursor states

~ 5/100 ns

Ground state



Need to understand the origin of the slow infrared component!

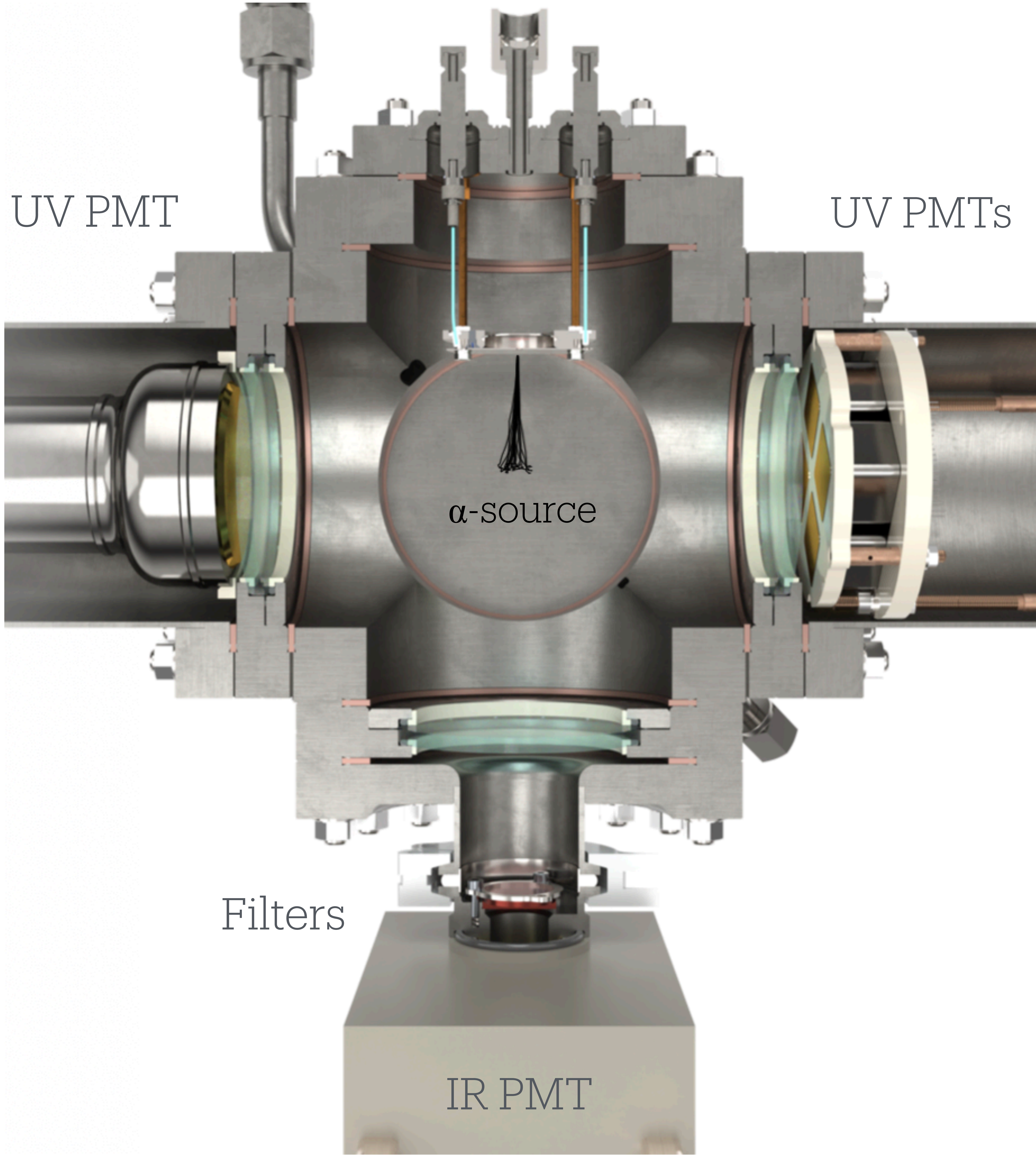
New setup

Wavelength dependence

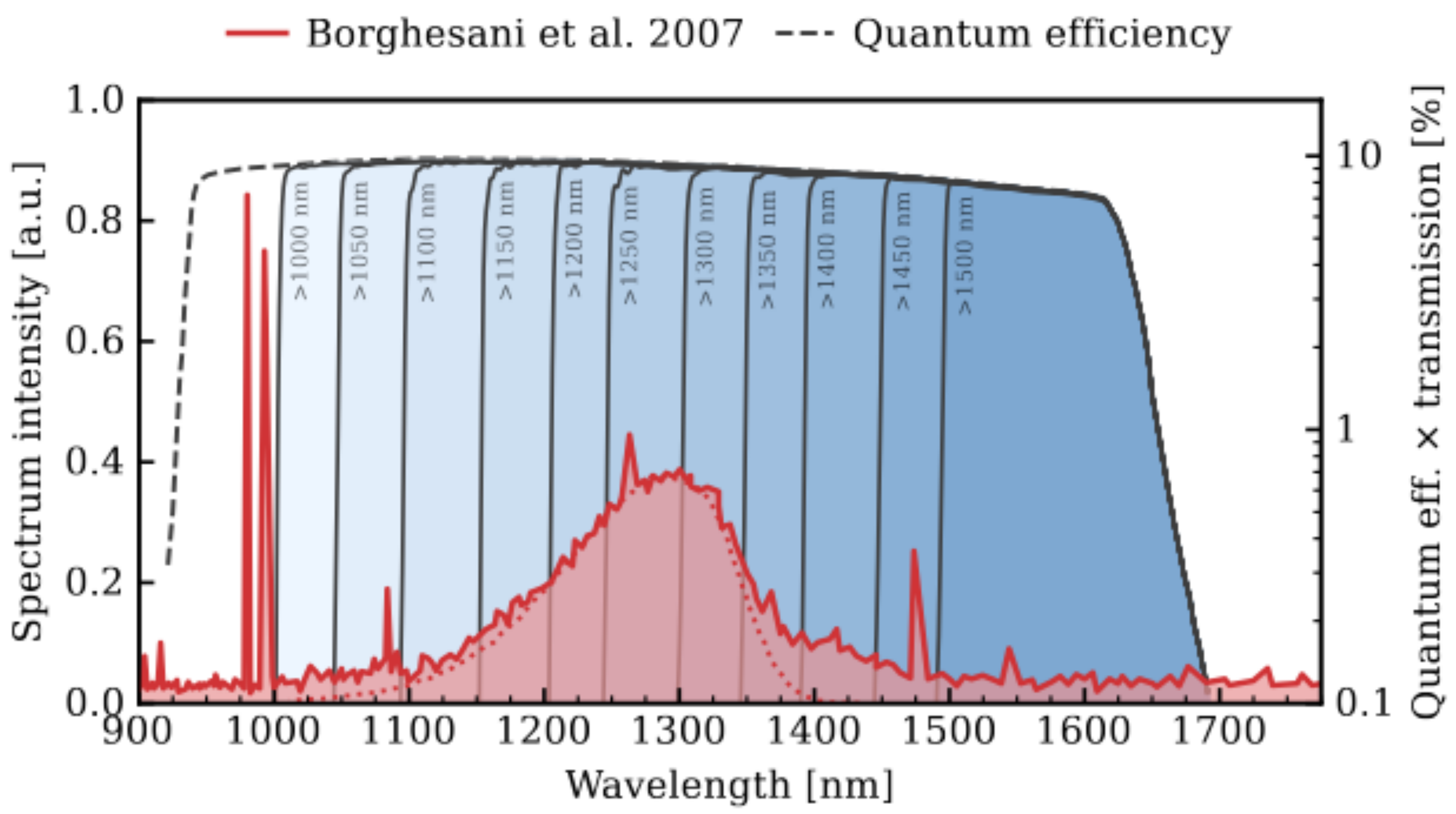
- New chamber allowing for higher pressures

Thanks to R.Santorelli & V. Pesudo for the window design

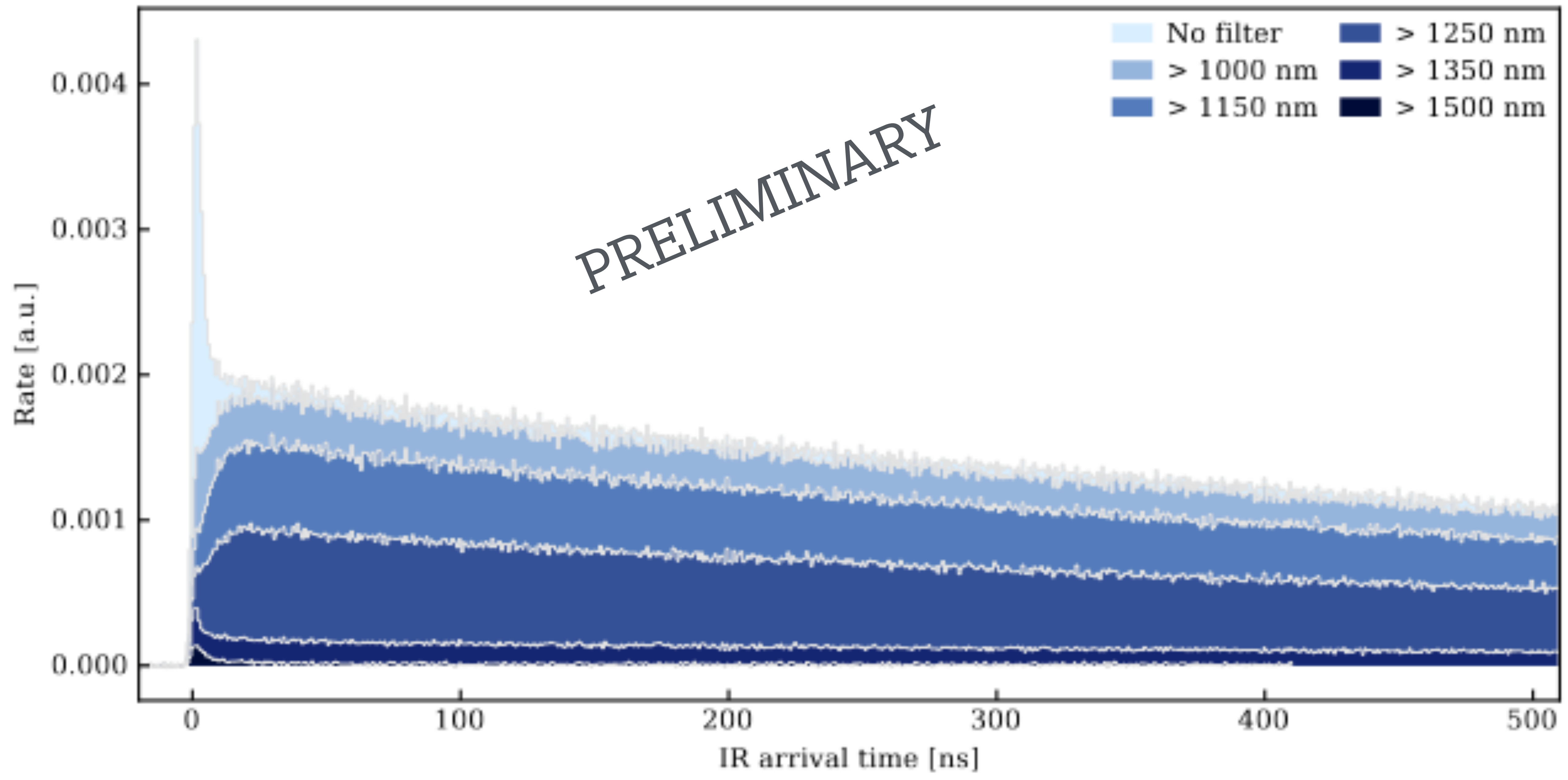
- Optical filter to scan infrared wavelengths
- 4 PMTs (1 inch) for position reconstruction
- Measurement: wavelength-resolved infrared timing



Origin of time components



- Good agreement with excimer emission
- Collaboration with a theory group to find the transition responsible for the IR emission (group of Milan Oncak)



CONFIRMATION:

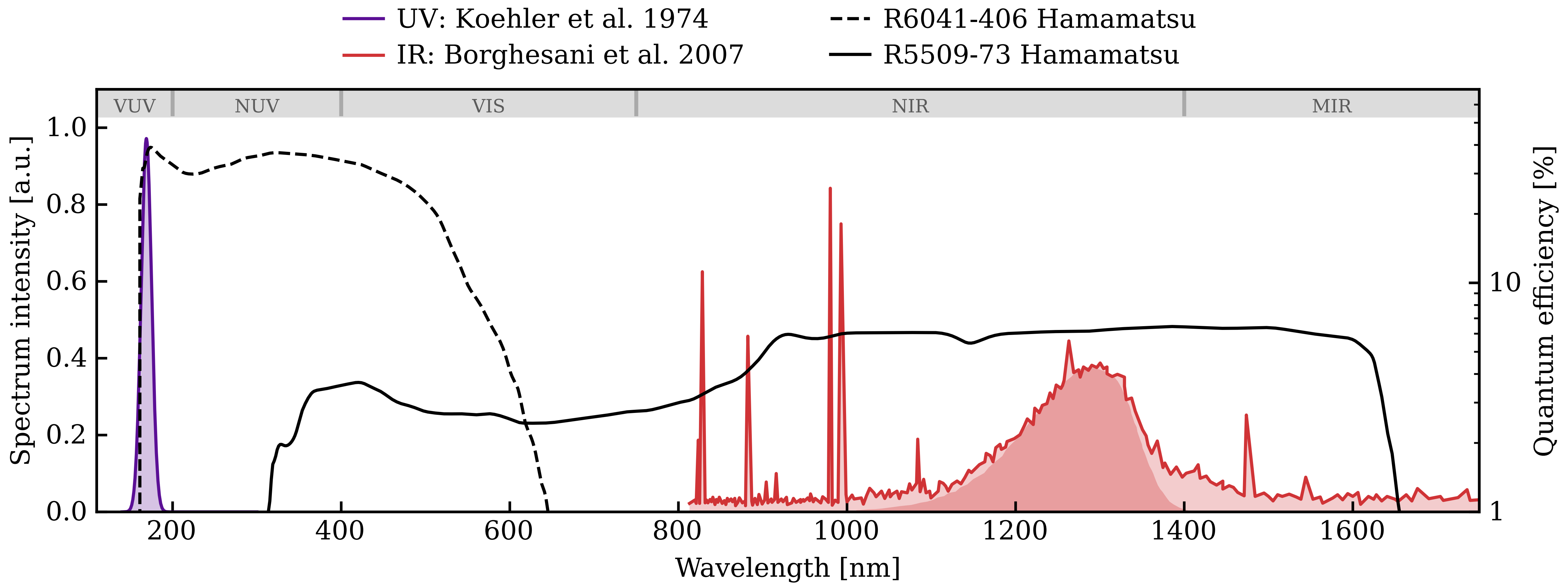
- Fast component: from atomic lines
- Slow component: from excimer de-excitation

Infrared emission in the liquid?

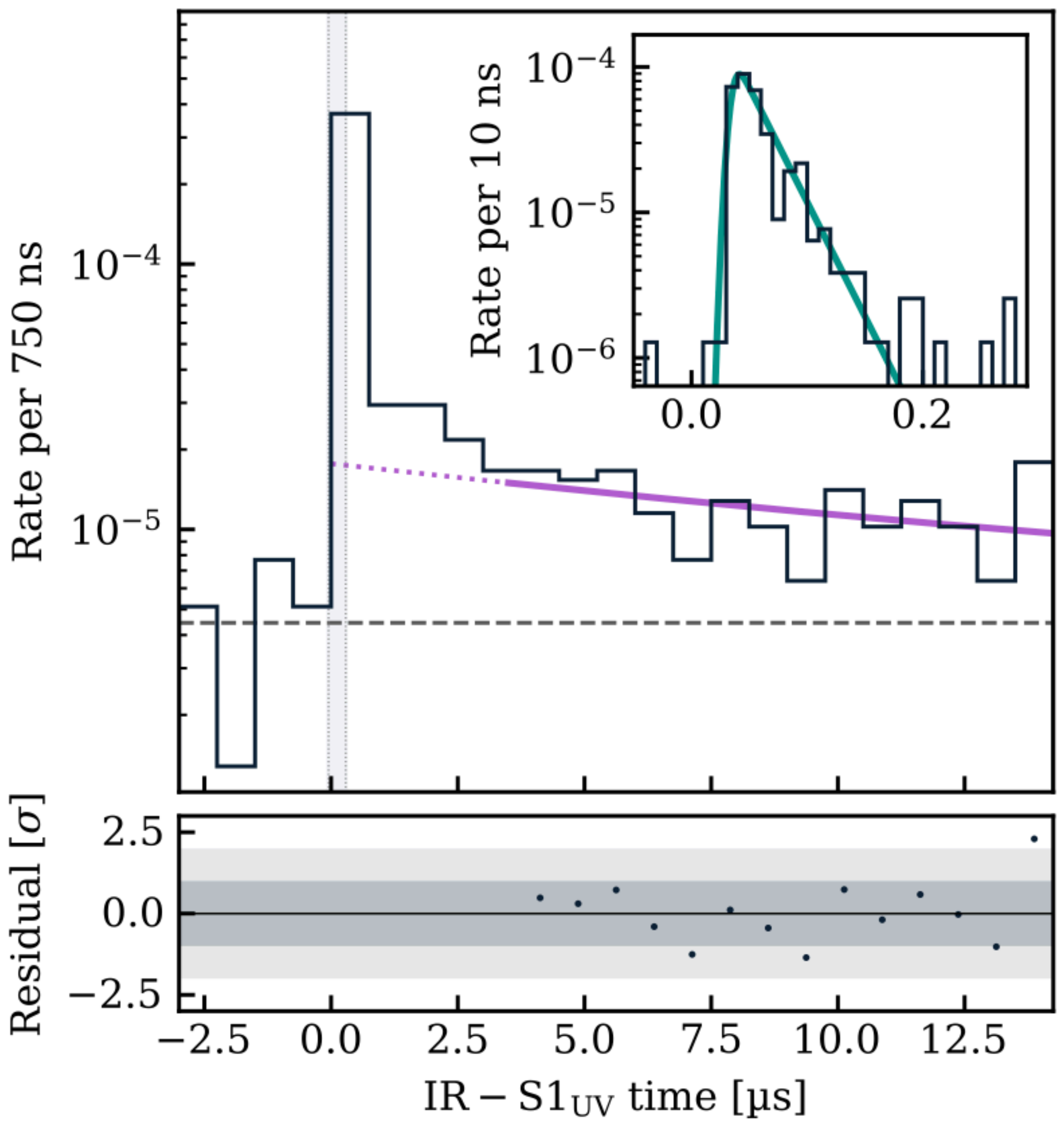
First IR measurement in a dual-phase TPC

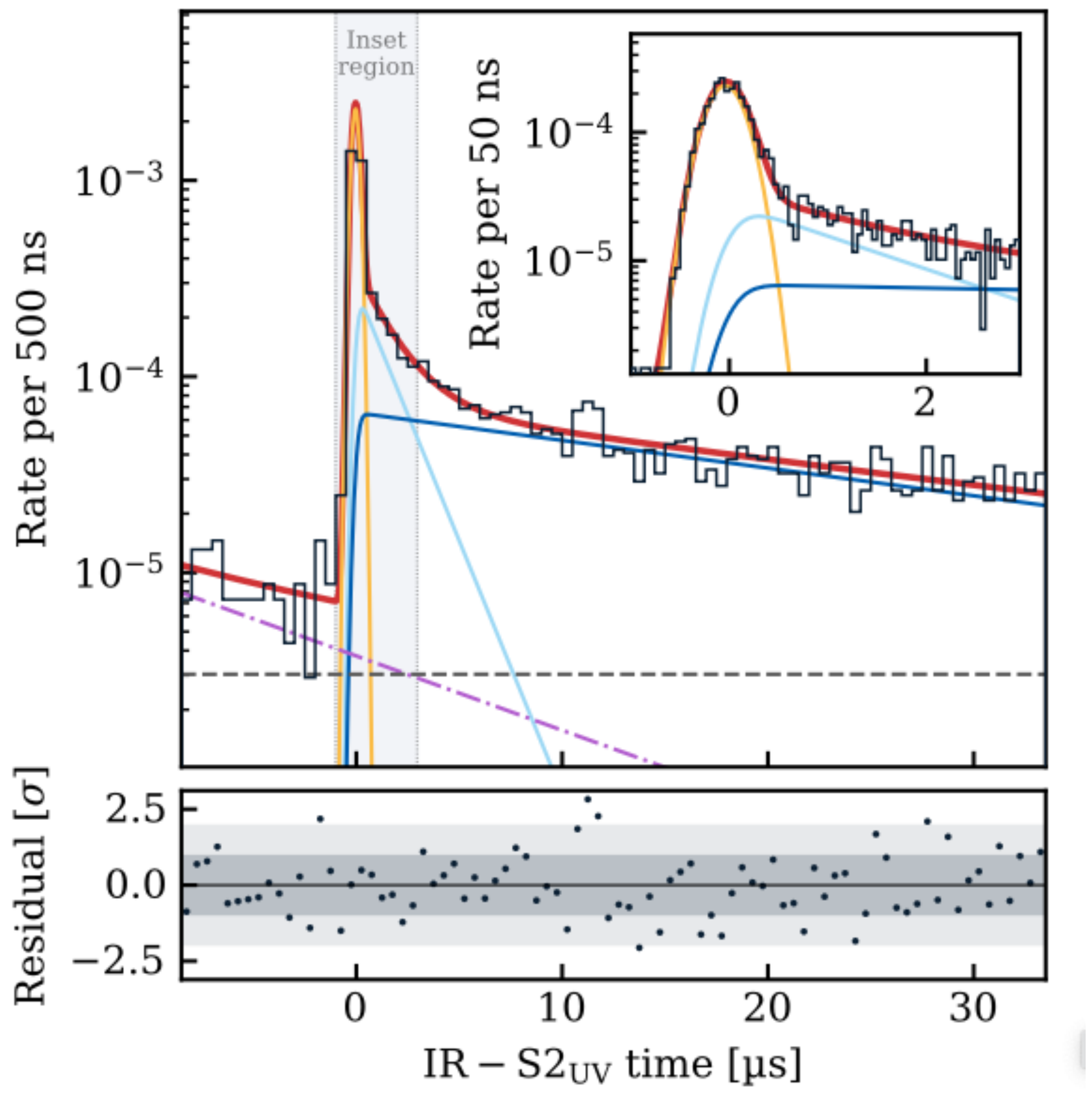
- PMTs sensitive to IR (top) & UV (bottom) light
- Alpha particles dissolved in LXe (^{222}Rn, ^{218}Po & ^{214}Po)
- Difficulty: IR-PMT bias voltage unstable during the measurements

HeXe TPC @ MPIK Heidelberg



Signal and timing in the liquid





Sci.Technol. 3 (2025) 1638362 & arXiv:2505.24682

- Infrared emission in coincide and after $S1_{UV}$ and $S2_{UV}$ (latter expected from gas setup)
- In electroluminescence, electron excitation
- Time constants and amplitudes differ for α/β, promising for particle discrimination (needs confirmation!)

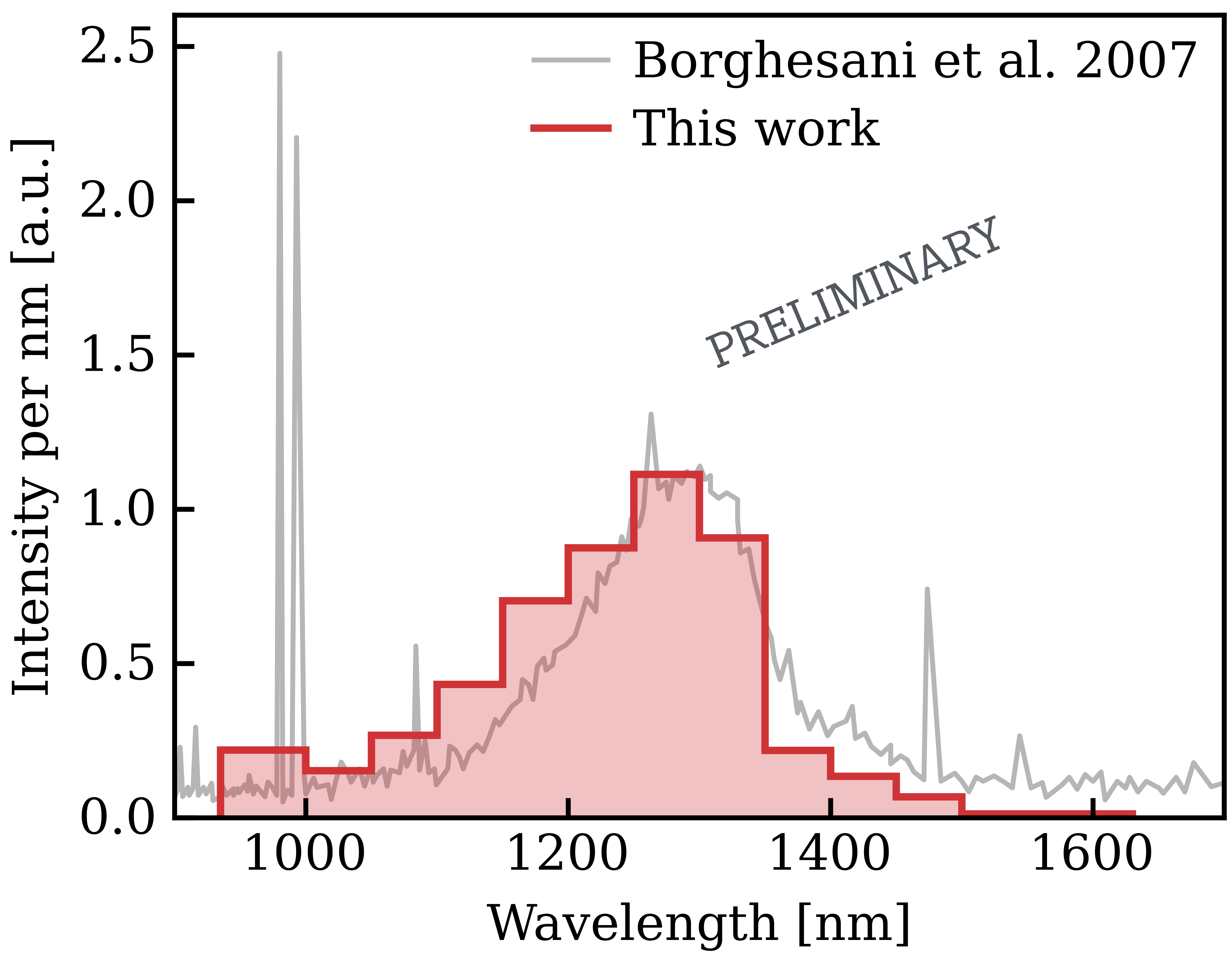
THANKS!

- IR signal promising, properties being investigated
- Research relevant for XLZD, PandaX-20T, MEG, NEXT ...

Our team at MPIK: Robert Hammann, Kai Böse, Steffen Form, Humaira Nazneen & Teresa Marrodán Undagoitia

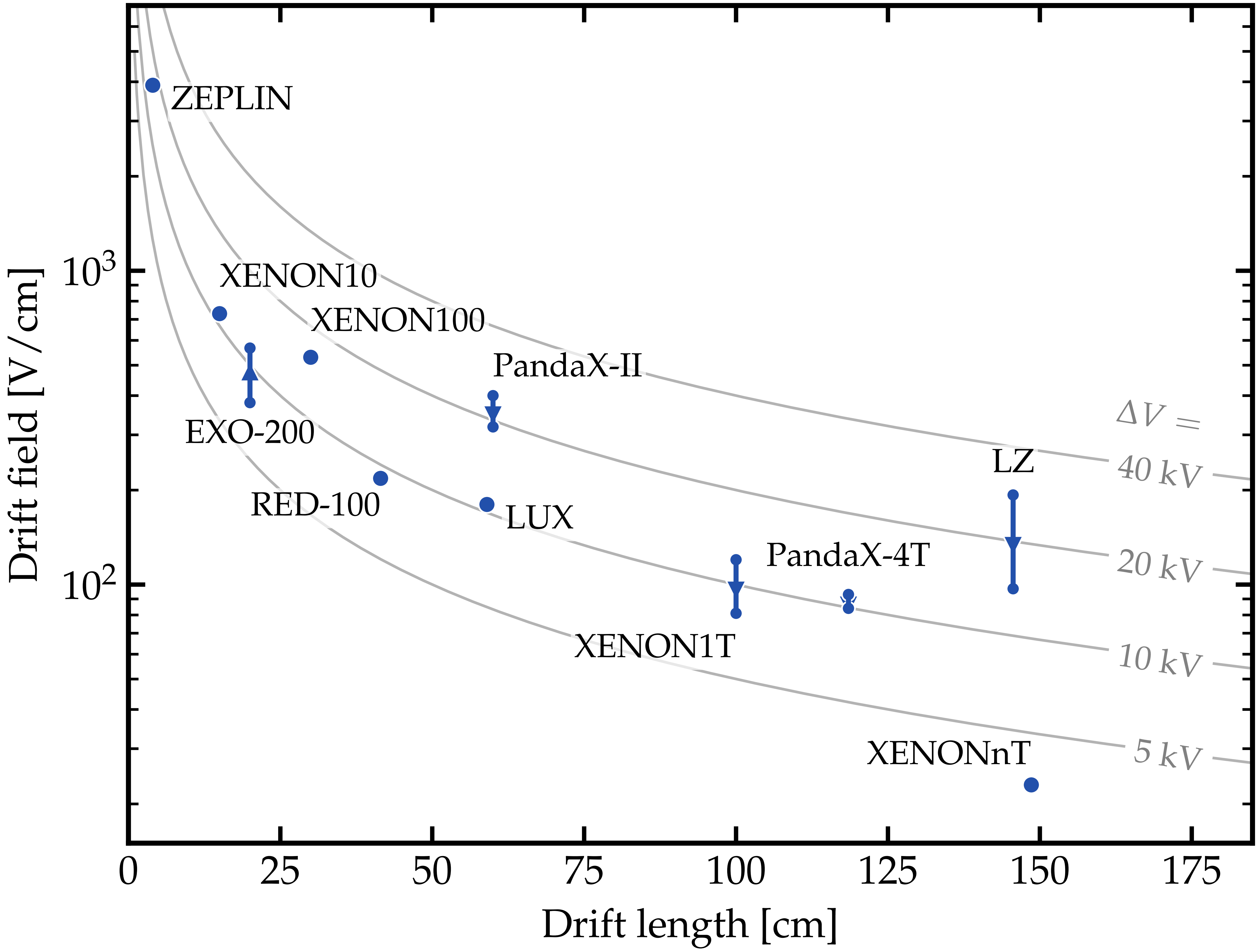
Preliminary spectrum

- Signal calculated for each wavelength region
- Good agreement with excimer emission
- Reminder: slow component is the dominant component
- Collaboration with theory to find the transition responsible for the emission (group of Milan Oncak)



Summary and future applications

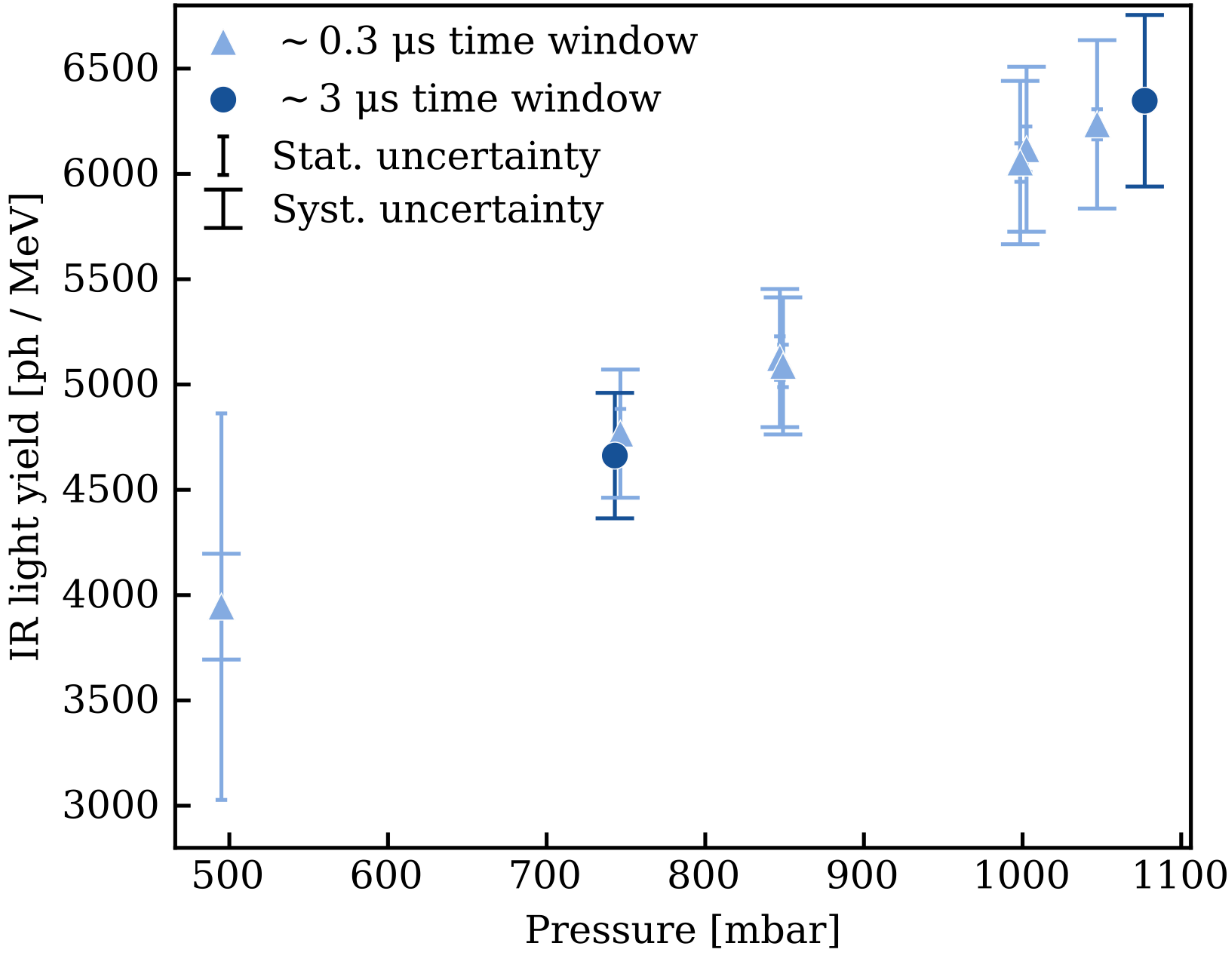
- New IR signal confirmed
- Origin of emission under investigation
- Particle discrimination needs confirmation
- Future detectors might need additional discrimination power
- Appropriate IR sensors need to be found!



Electric field applied versus TPC length

Study of pressure and light yield

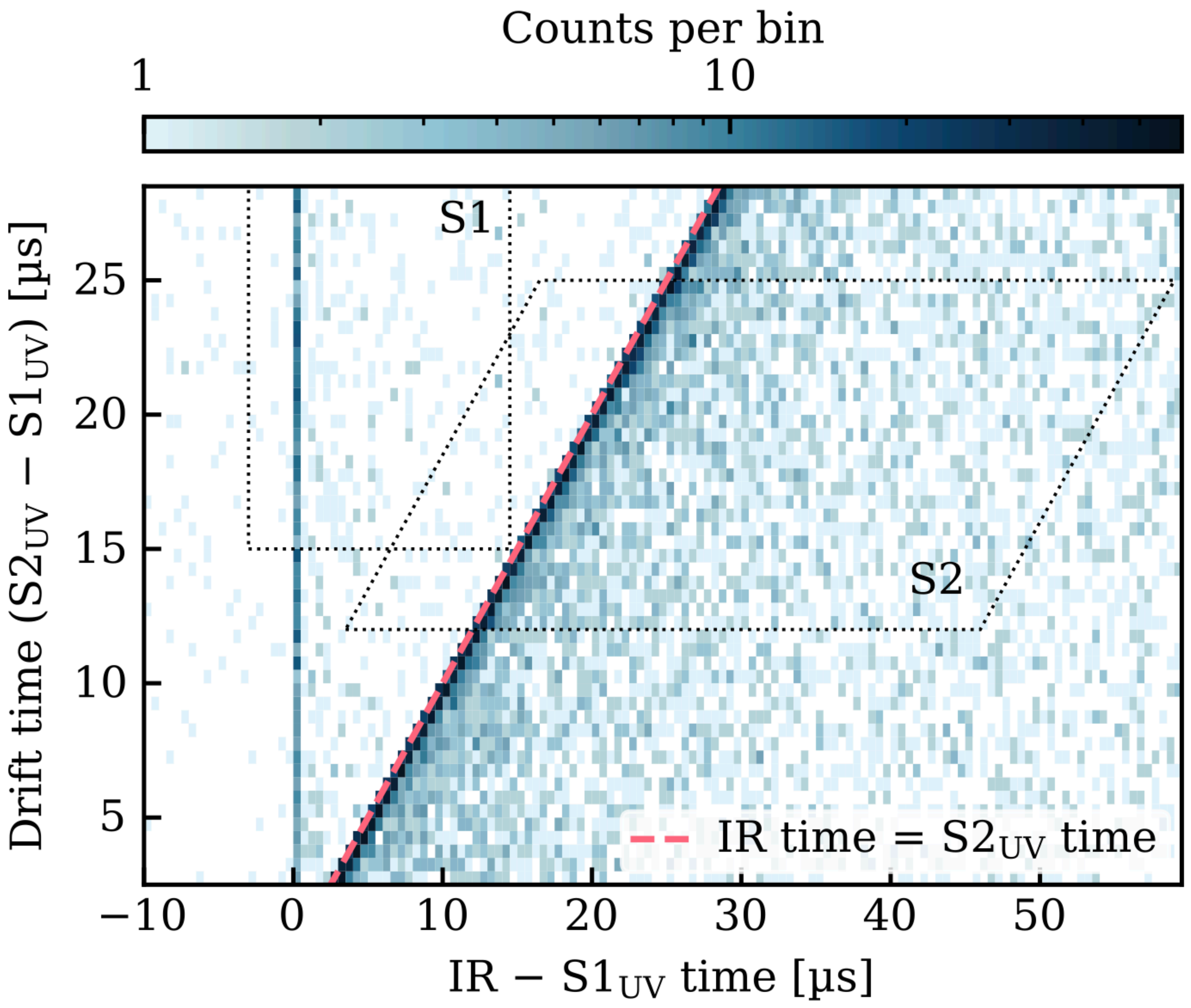
- Pressure regime: (500 - 1080) mbar
- Light yield: linear increase with pressure
- Time profile: slow time constant longer and lower amplitude as the pressure decreases
- Further investigation ongoing



JINST 19 (2024) 02, C02080 & arXiv:2401.09262

Backup: IR emission in LXe

- IR pulse time to $S1_{UV}$ and $S2_{UV}$
- Deeper in the TPC, larger time to search for $S1_{IR}$
- Regions selected for time fit



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Infrared readout

- If IR in the liquid is large enough: use $S1_{IR}$ for discrimination?
- If IR in the liquid too small: use $S2_{IR}$ in the gas to improve S1 and single electron S2 separation?

IR readout in addition to UV readout

- In between PMTs?
- Or along the teflon wall?