Primary scintillation yield in gaseous Xe for electrons and α-particles

Carlos A.O. Henriques*, J.M.R Teixeira, R.D.P. Mano, P.A.O.C. Silva, C.M.B. Monteiro, J.M.F. dos Santos

* henriques@uc.pt

LIBPhys, University of Coimbra, Portugal

LIBPhys-UC

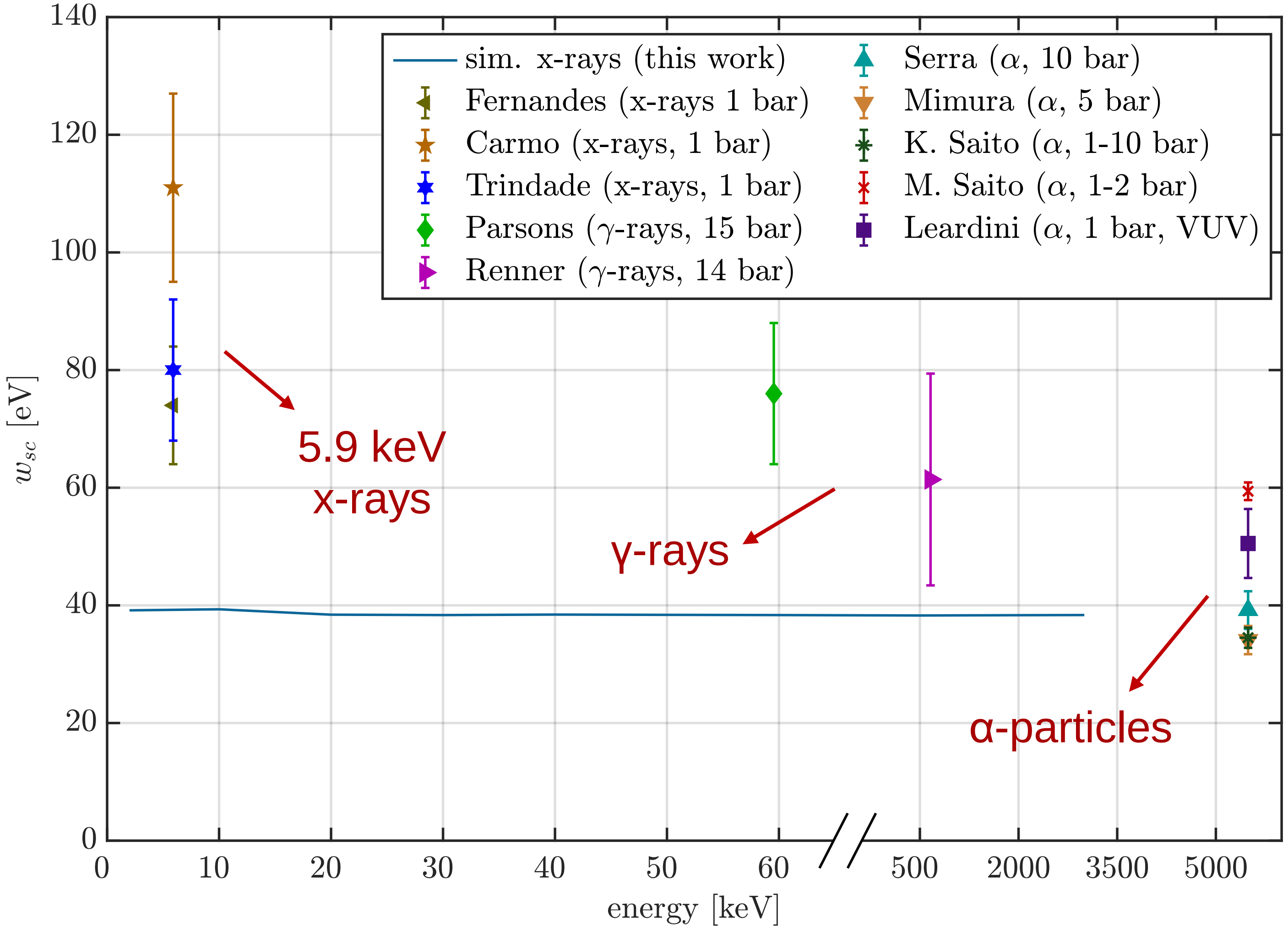
fct Fundação para a Ciência e a Tecnologia

1290 UNIVERSIDADE D COIMBRA

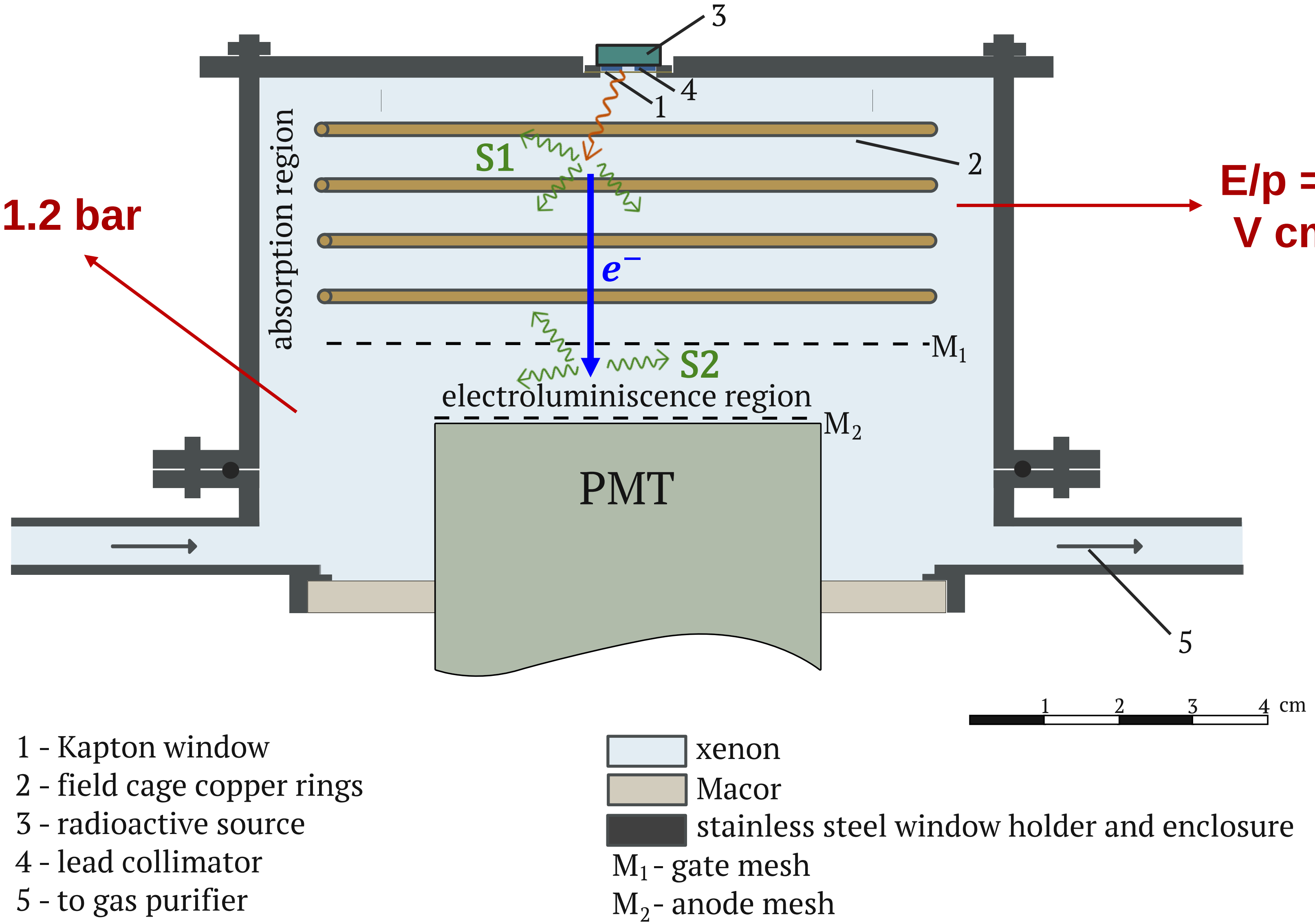
Motivation – the w_{sc} parameter

- Primary scintillation have been widely used in many rare-event detection experiments (e.g., dark matter, neutrino physics…)

- Yet, experimental data on the **average energy required to produce a scintillation photon (w_{sc}-value)** in the absence of recombination is still scarce and dispersed



Experimental setup – scintillation chamber

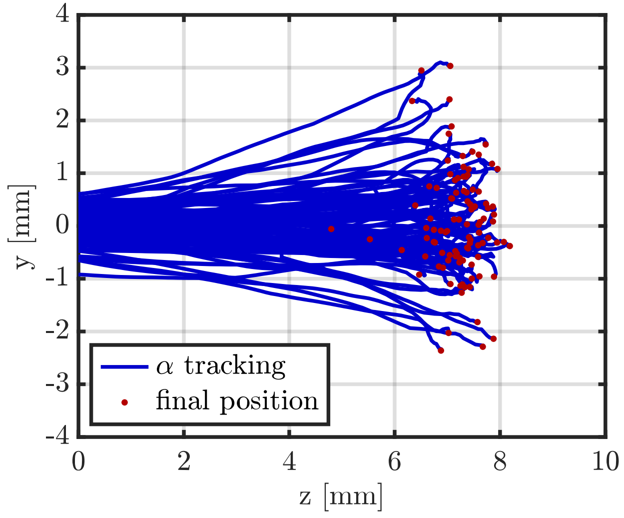


Xe at 1.2 bar

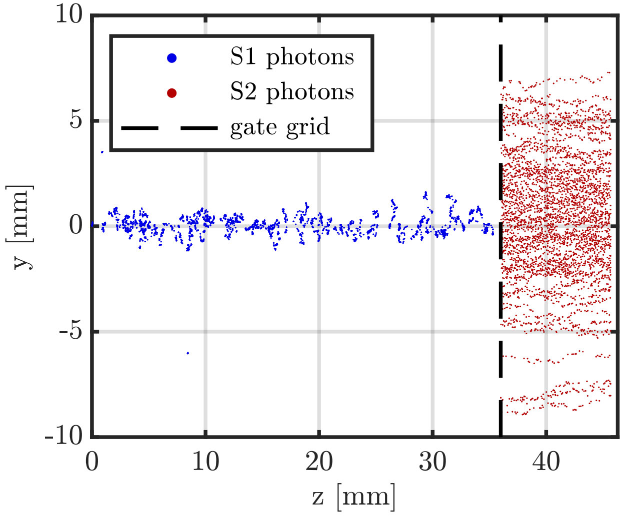
E/p = 70–300 V cm^{-1} bar^{-1}

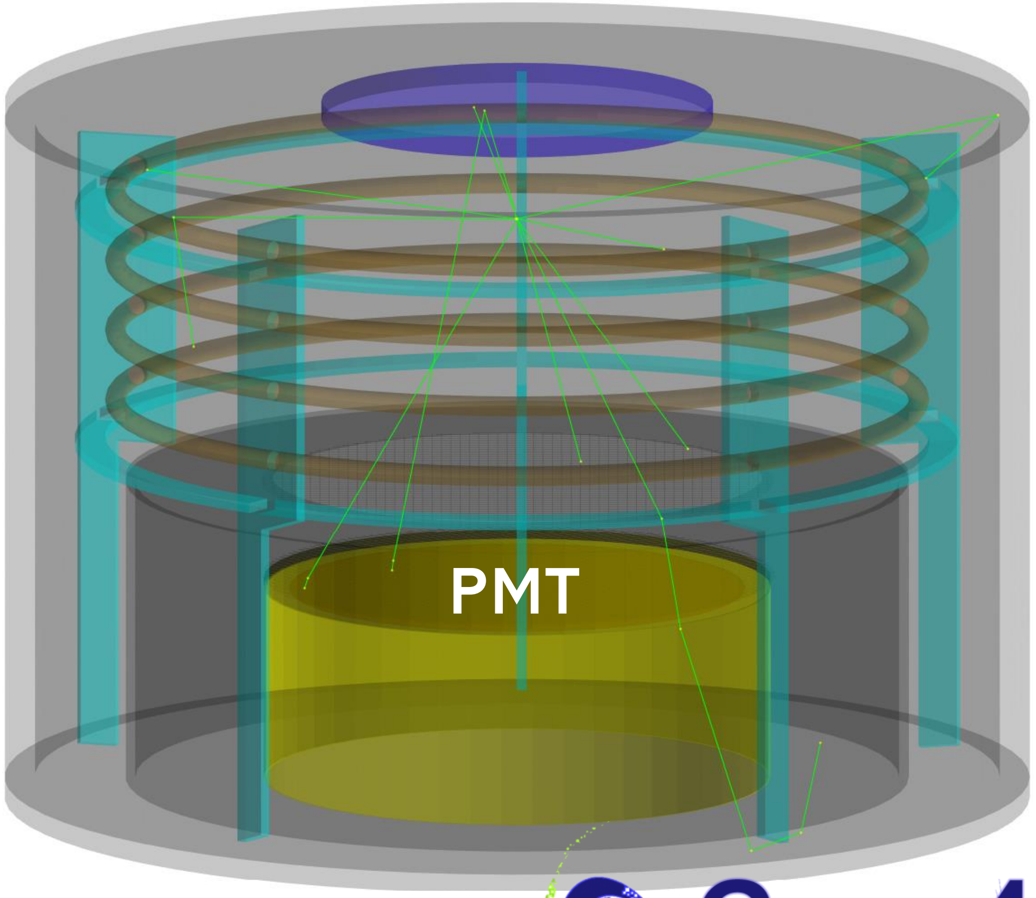
Full optical simulation

α-particles



X-rays





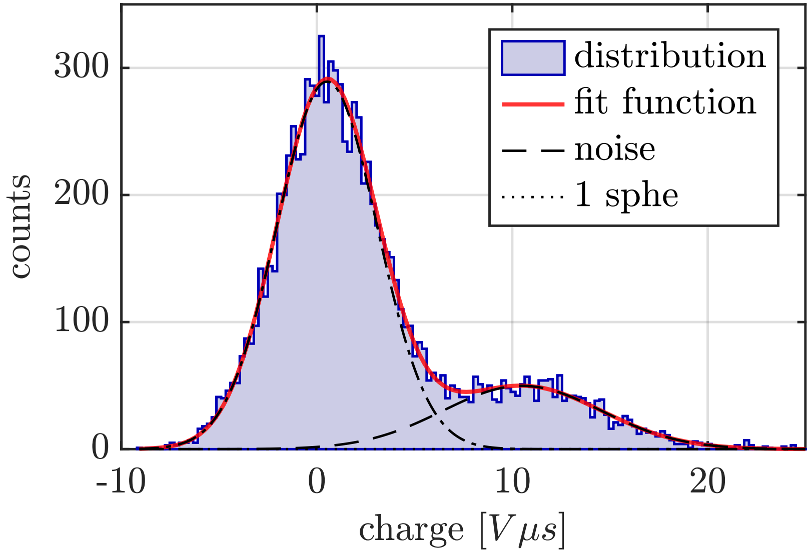
- Full optical simulation (GEANT4)
- Cluster distribution of ionization electrons (GEANT4 + DEGRAD)
- Electron diffusion (GARFIELD++)

GEANT4
A SIMULATION TOOLKIT

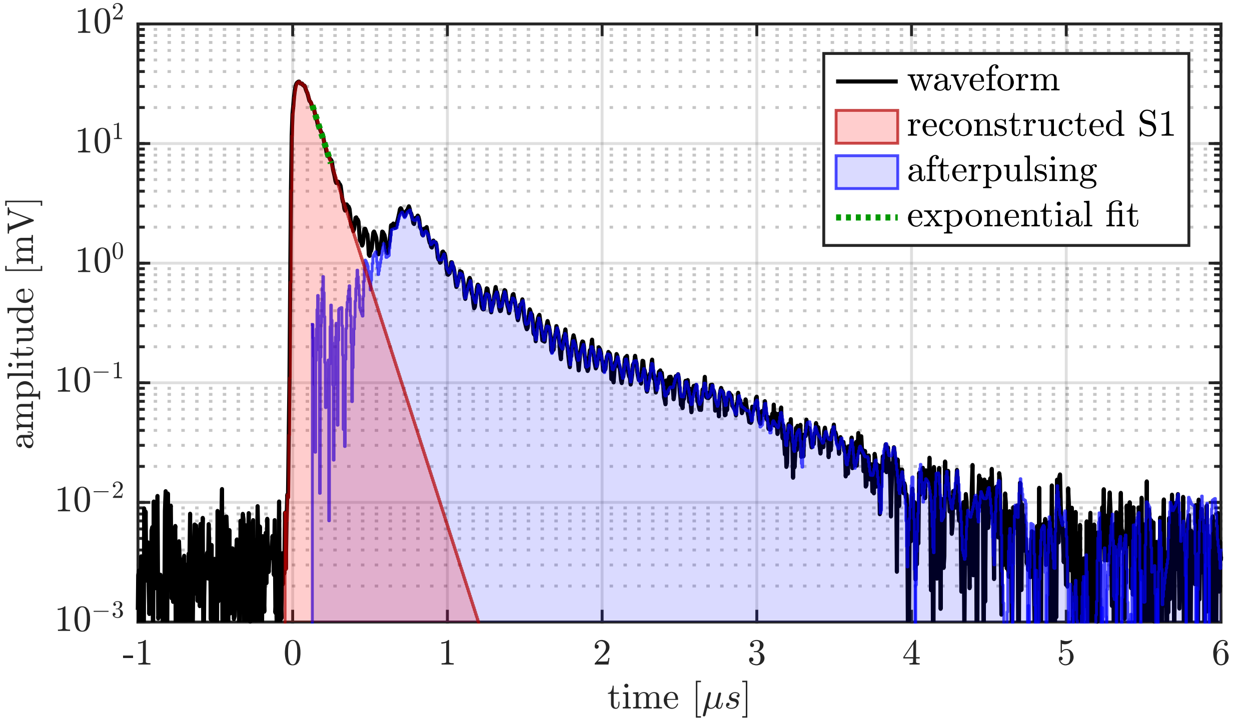
PMT calibration

- PMT single photoelectron calibration (including pulse reflections in cable terminations)
- PMT afterpulsing is also accounted for, contributing by ~25%

PMT single photoelectron distribution

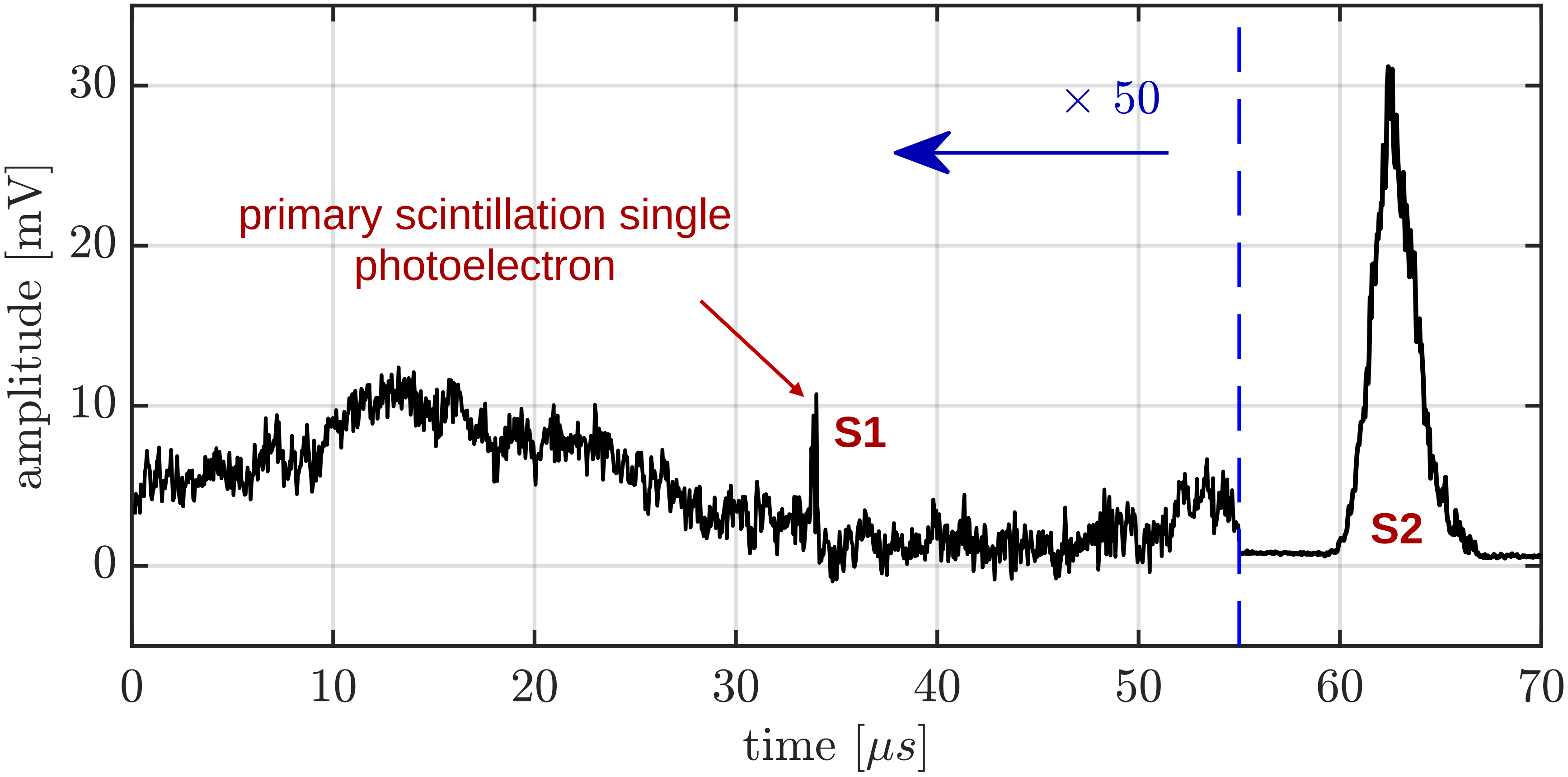


PMT afterpulsing (α-particles S1 average waveform)



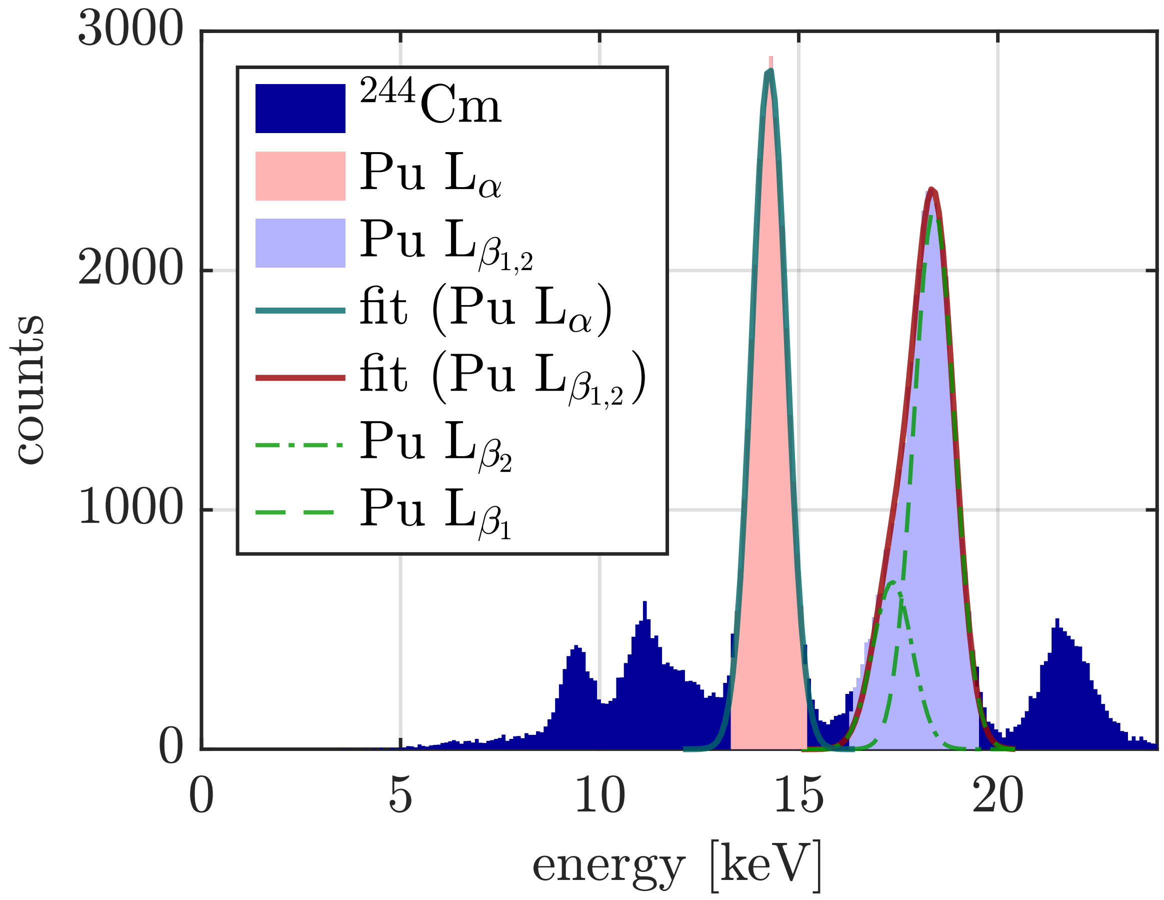
Data analysis method – X/γ-rays

Typical PMT waveform from an X-ray event



Data analysis method – X/γ-rays

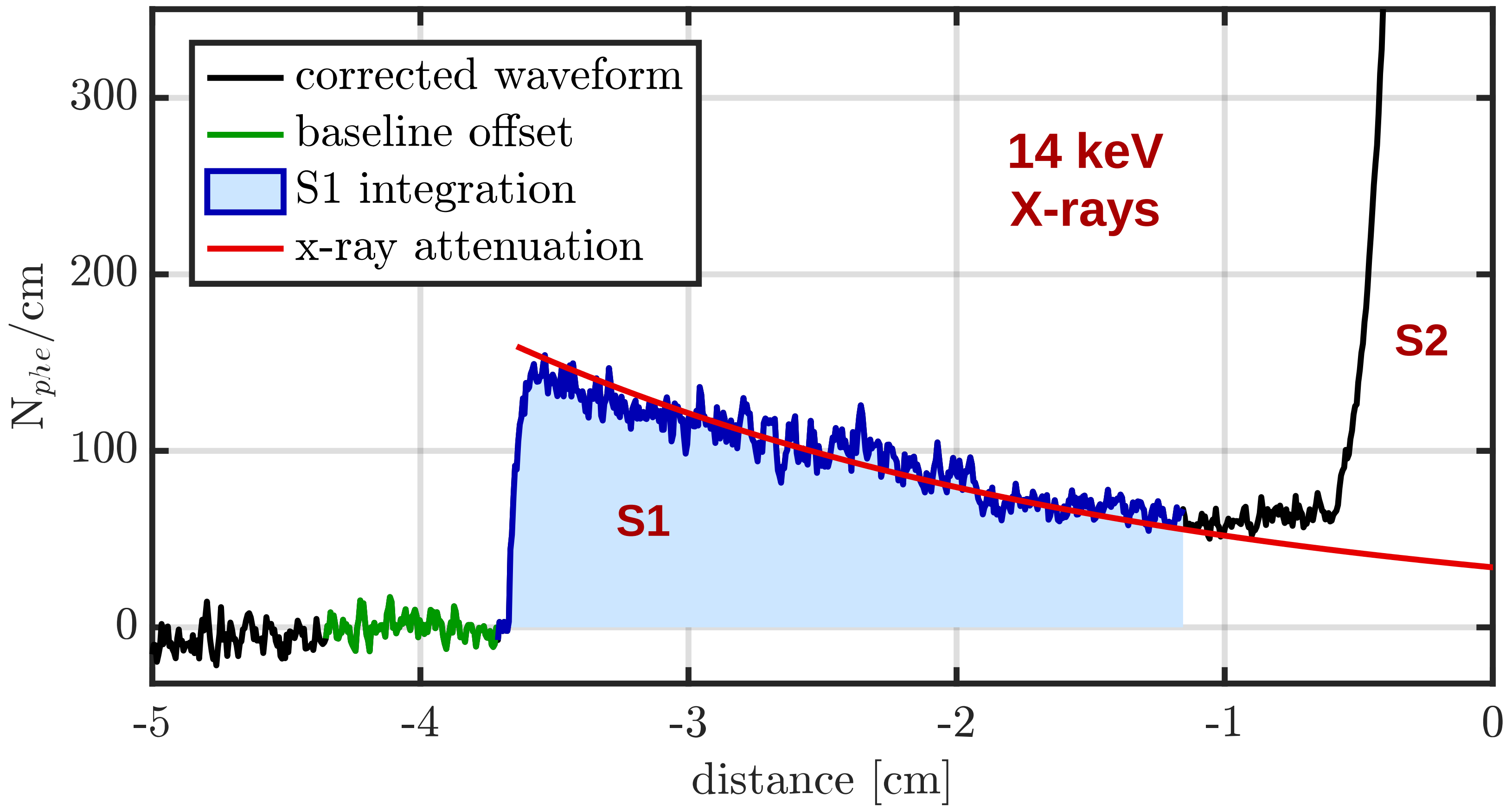
- Pulse-shape background discrimination
- Energy cuts
- Pulse duration cuts
- Position cuts (using experimental electron drift velocities)
- Neutral bremsstrahlung correction



Data analysis method – X/γ-rays

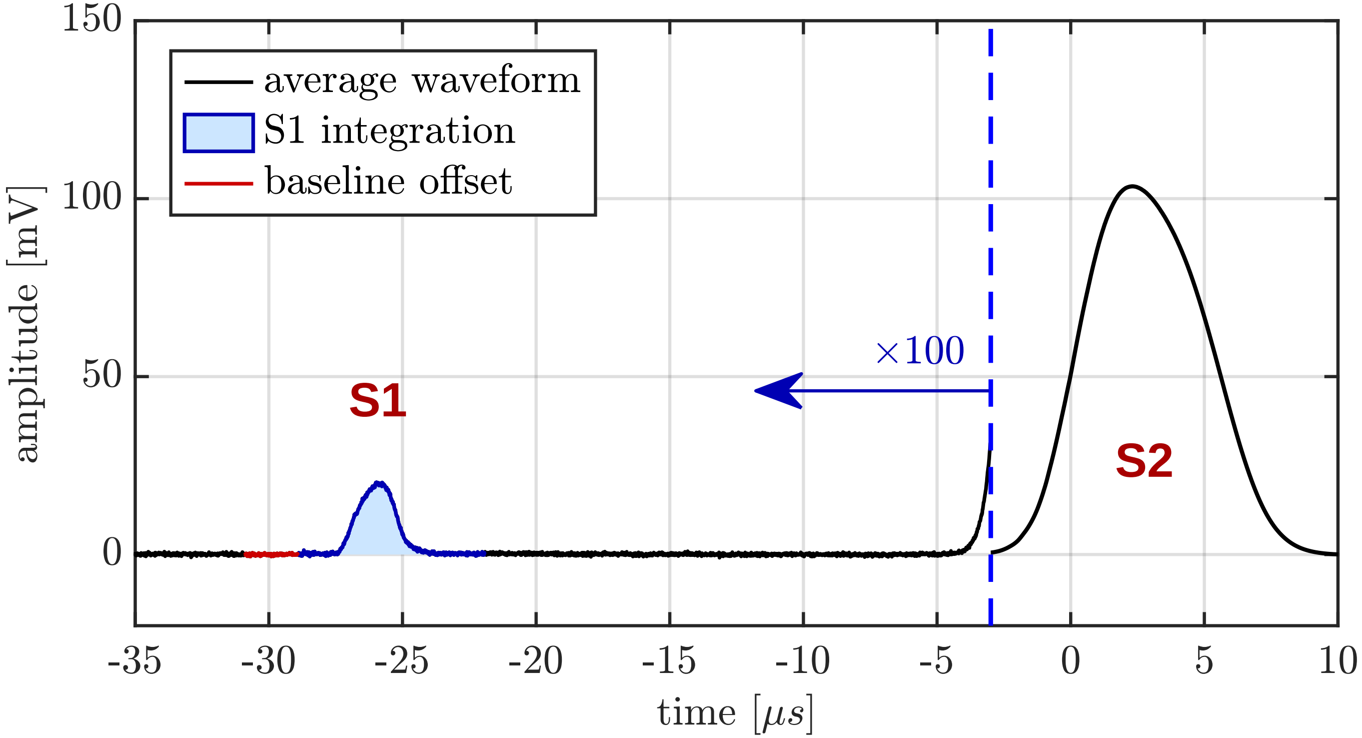
Average waveform *vs* distance

corrected for the simulated geometric efficiency

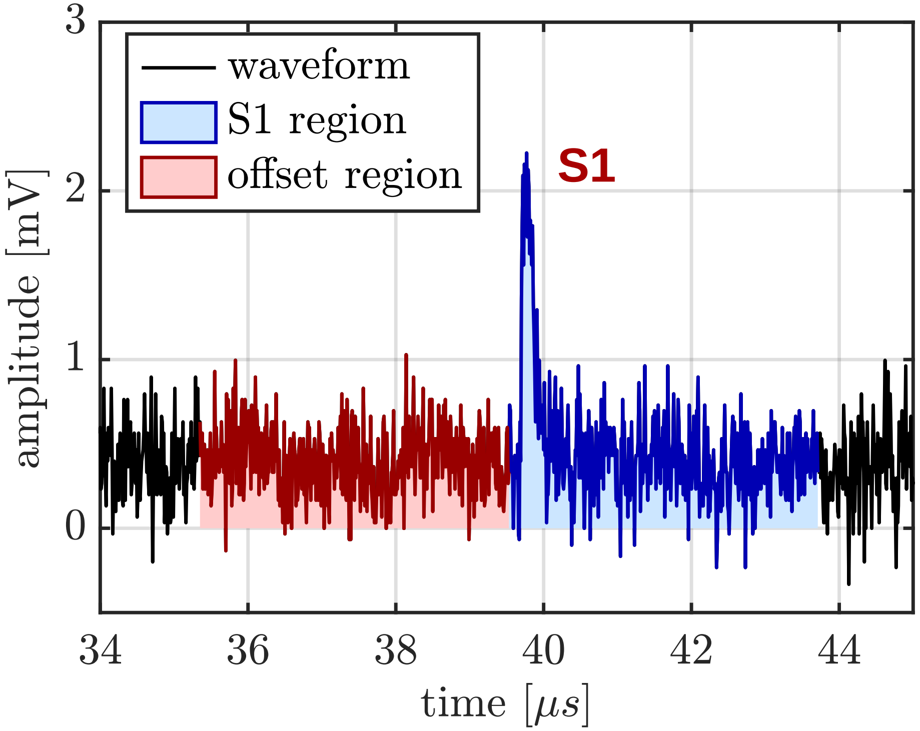


Data analysis method – α-particles

Average waveform

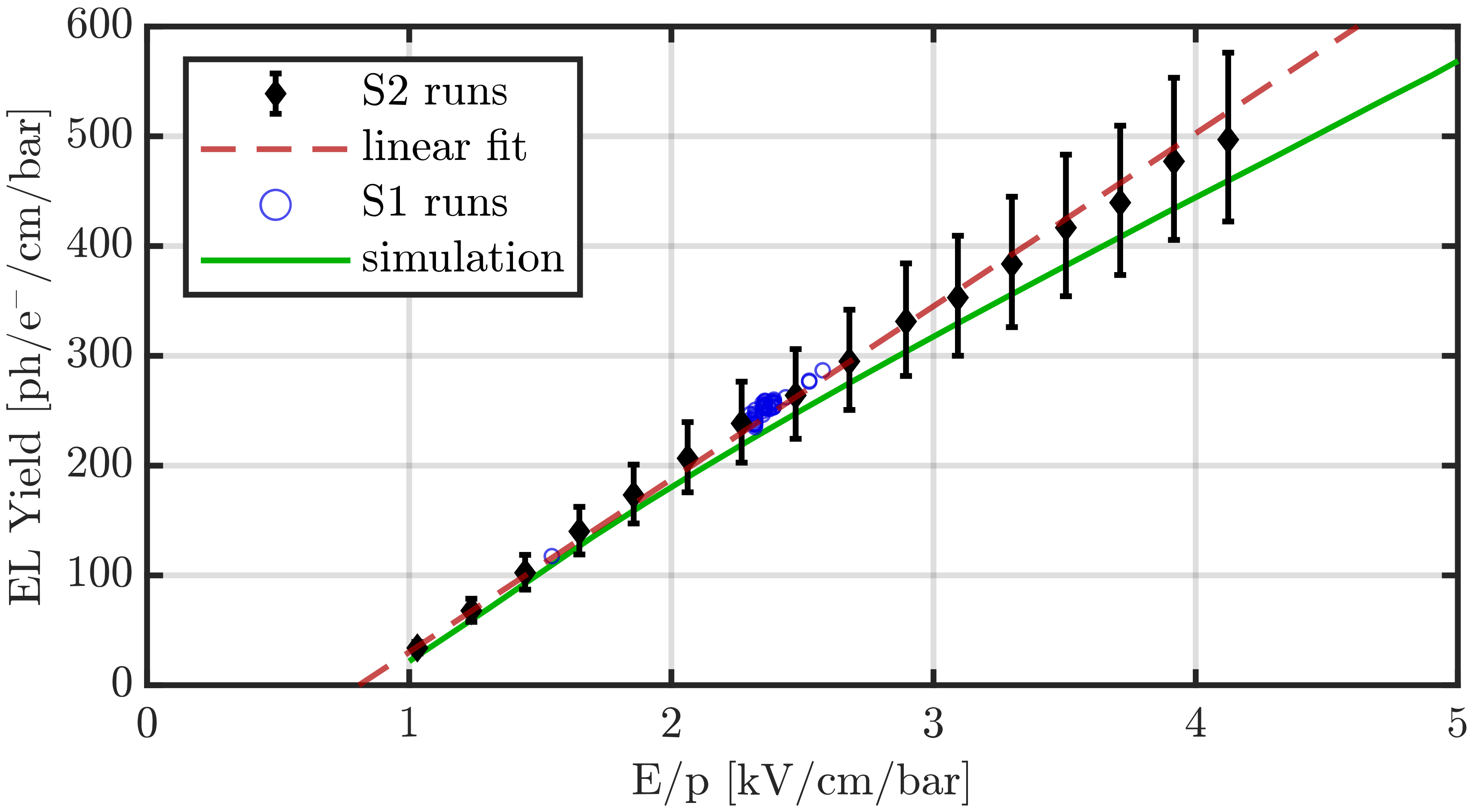


Single waveform

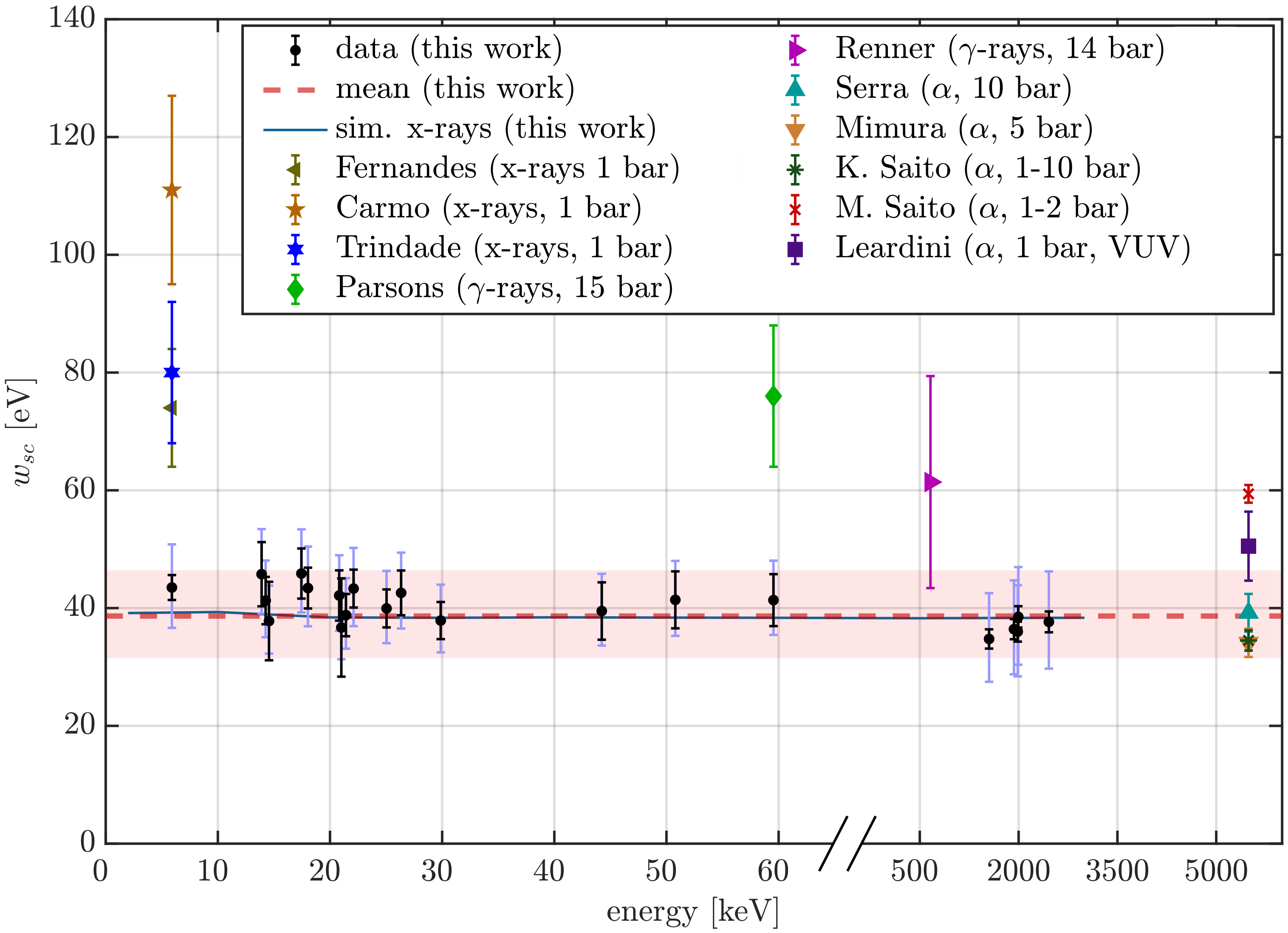


Results – secondary scintillation (S2)

Absolute secondary scintillation yield in Xe *vs* E/p



Results – w_{sc} parameter (S1)



Conclusions

w_{sc} (eV)	observations
38.7 ± 0.6 (sta.) $^{+7.7}_{-7.2}$ (sys.)	3^{rd} continuum neglected
43.5 ± 0.7 (sta.) $^{+8.7}_{-8.1}$ (sys.)	2^{nd} continuum
483 ± 7 (sta.) $^{+110}_{-105}$ (sys.)	3^{rd} continuum
39.9 ± 0.6 (sta.) $^{+8.0}_{-7.4}$ (sys.)	$2^{nd}+3^{rd}$ continua

Assuming a 3^{rd}-to-2^{nd} continua ratio of 0.09 (S. Leardini *et al.*, Eur. Phys. J. C 82 (2022) 425)

- No meaningful dependency on the incident radiation type or energy was found
- Our w_{sc}-value agree with both simulations and most of literature data for α-particles
- We replicated some literature's results using their methods (X-rays), two major systematic error sources:
  - The lack of a proper photon transport simulation model (~50% error)
  - Oscilloscope trigger as the only means (a bad one) for event selection (up to 200% error)

Thank you for your time

Acknowledgments

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