PRIMARY SCINTILLATION YIELD IN XENON FURTHER EXPERIMENTAL STUDIES

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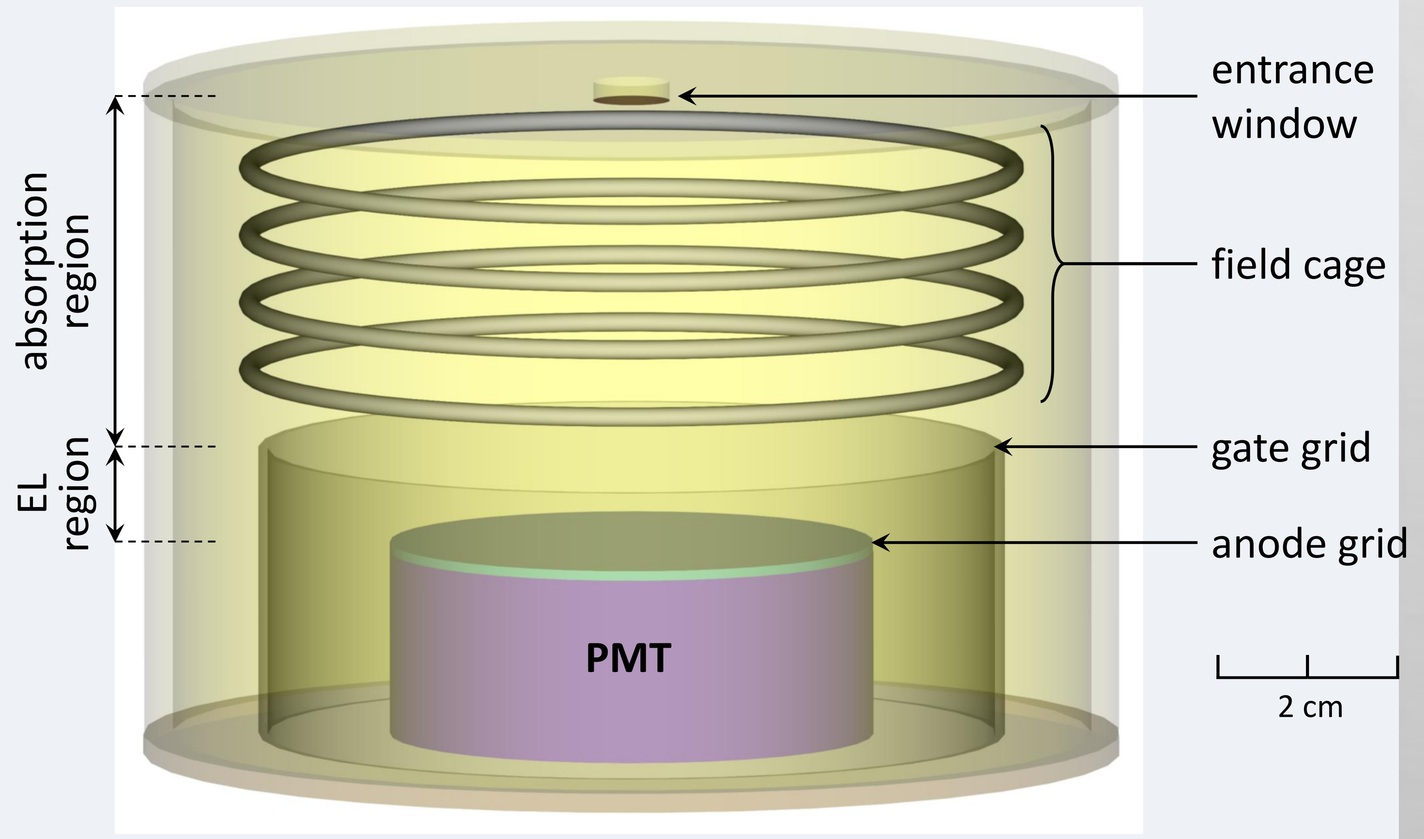
INTRODUCTION

XENON SCINTILLATION HAS BEEN WIDELY USED IN RECENT PARTICLE PHYSICS EXPERIMENTS [1-3]. HOWEVER, INFORMATION ON PRIMARY SCINTILLATION YIELD IN THE ABSENCE OF RECOMBINATION IS STILL SCARSE AND DISPERSED. THE MEAN ENERGY REQUIRED TO PRODUCE A VACUUM ULTRAVIOLET (VUV) PHOTON (W_{SC}-VALUE) IN GASEOUS XENON HAS BEEN MEASURED IN THE RANGE OF 30-120 EV, [4] AND REFERENCES THEREIN. LOWER W_{SC}-VALUES ARE OFTEN REPORTED FOR α - PARTICLES COMPARED TO ELECTRONS PRODUCED BY γ - OR X-RAYS, BEING THIS DIFFERENCE NOT UNDERSTOOD. THEREFORE, WE PERFORMED A SYSTEMATIC STUDY FOR THE W_{SC}-VALUE IN XENON, USING A GAS PROPORTIONAL SCINTILLATION COUNTER (GPSC).

EXPERIMENTAL SETUP

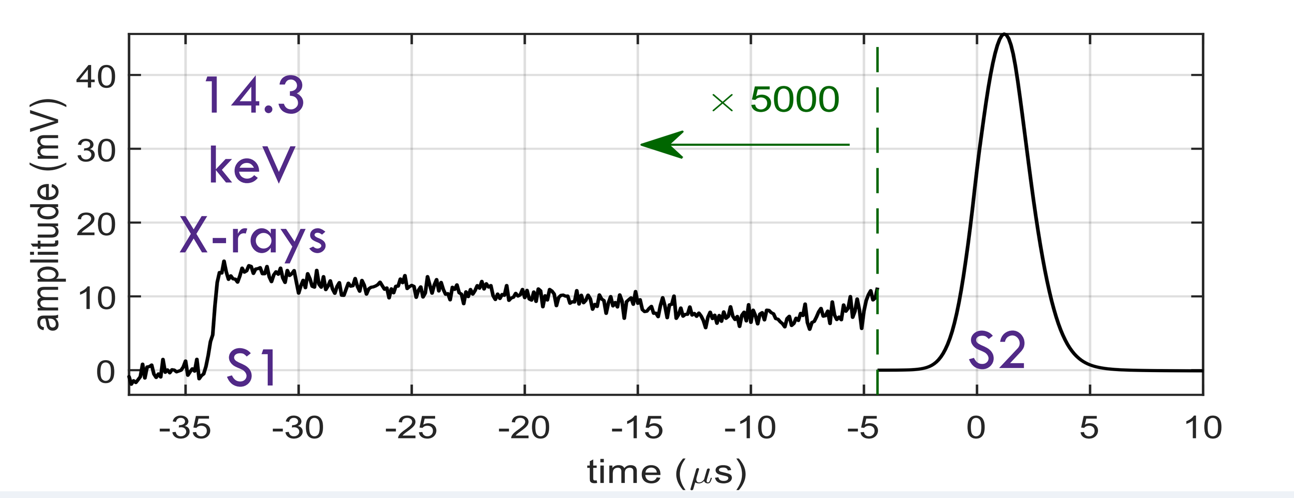
THE GPSC HAS A **3.6-CM THICK ABSORPTION REGION** AND A **1-CM THICK ELECTROLUMINESCENCE REGION.** THE FORMER IS DELIMITED BY THE DETECTOR ENTRANCE WINDOW AND THE GATE WIRE-GRID, WHILE THE LATTER IS ESTABLISHED BETWEEN THE GATE AND THE ANODE-GRID, PLACED JUST ABOVE THE PHOTOSENSOR, A 2" PHOTOMULTIPLIER TUBE (PMT). A FIELD CAGE ACCOUNTS FOR ELECTRIC FIELD UNIFORMITY ALONG THE FULL ABSORPTION REGION.

THE W_{SC}-VALUE WAS MEASURED FOR **X-RAYS** (5.9-25 KEV) AND **α-PARTICLES** (2.3 MEV) FROM ^{244}CM, ^{55}FE, ^{109}CD AND ^{141}AM COLLIMATED RADIOACTIVE SOURCES. WAVEFORMS PRODUCED AT THE PMT OUTPUT WERE RECORDED WITH BEING THE SECONDARY SCINTILLATION USED AS THE TRIGGER.



ANALYSIS METHODOLOGY

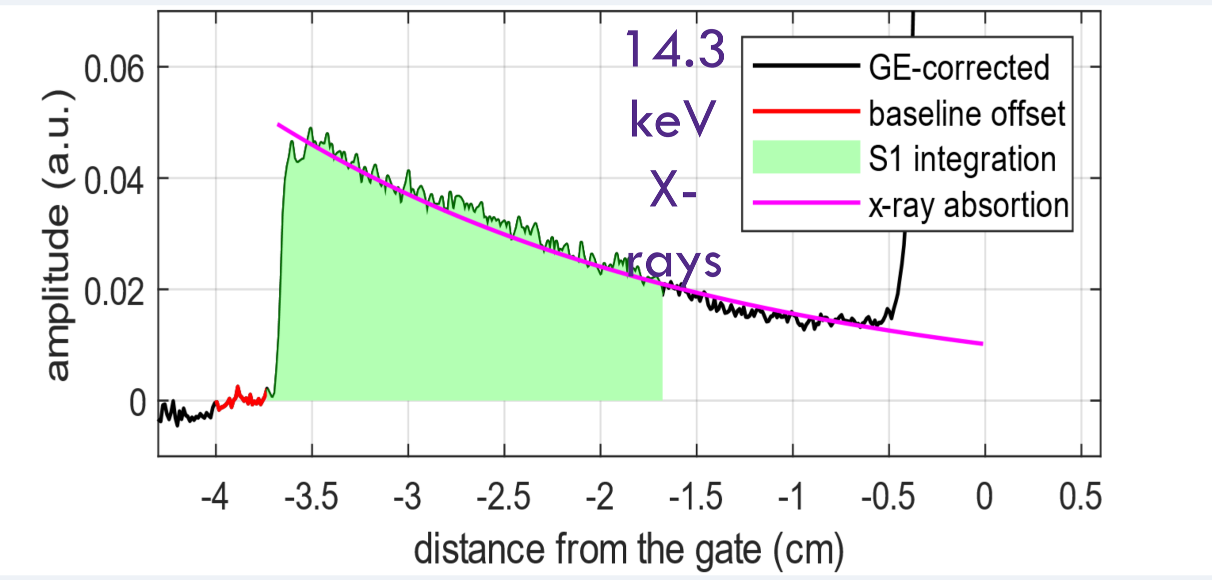
THE PRIMARY SCINTILLATION SIGNAL (S1) IS ABOUT 3 ORDERS OF MAGNITUDE SMALLER THAN THE SECONDARY SCINTILLATION SIGNAL (S2), HARDLY DISTINGUISHABLE FROM THE ELECTRONIC NOISE. THEREFORE, WE RELY ON THE AVERAGE WAVEFORM COMPUTED FROM SEVERAL X-RAY EVENTS TO CANCEL OUT THE BASELINE FLUCTUATIONS. FOR α-PARTICLES THE STRONGER S1 ENABLES THE W_{SC} MEASUREMENT ON A EVENT-BY-EVENT BASIS, ALLOWING TO CROSSCHECK THE AVERAGE WAVEFORM METHOD. AS AN EXAMPLE WE SHOW THE AVERAGE WAVEFORM OBTAINED FROM 1 MILLION 14.3-KEV X-RAY EVENTS:



THE ANALYSIS METHODOLOGY CAN BE SUMMARIZED AS FOLLOWS:

1. X-RAY ENERGIES ARE SELECTED USING THE S2-INTEGRAL DISTRIBUTION.
2. THE ELECTRON DRIFT VELOCITY IS COMPUTED FROM THE TIME ELAPSED BETWEEN S1 AND S2, ENABLING TO PRESENT THE AVERAGE WAVEFORM AS A FUNCTION OF DISTANCE.
3. THE WAVEFORM IS CORRECTED FOR THE DETECTOR GEOMETRICAL EFFICIENCY (GE) OBTAINED FROM GEANT4-SIMULATION.
4. THE S1 EMISSION IS INTEGRATED ALONG THE FIRST 2 CM OF DEPTH.
5. FINALLY, THIS VALUE IS CORRECTED FOR THE BASELINE OFFSET AND FOR THE RATIO OF INTERACTIONS OCCURRING WITHIN THE INTEGRATION REGION, WHICH IS ESTIMATED FROM THE THEORETICAL X-RAY ABSORPTION LAW.

EXAMPLE: S1 INTEGRATION OF THE GE-CORRECTED WAVEFORM:



RESULTS

Energy (keV)	w_{sc} (eV)	error (sta./sys.)
5.9 (Mn K-s)	50.1	10% / 25%
9.4 (Pt L-α)	40.2	15% / 25%
14.3 (Pu L-α)	43.1	10% / 25%
18.1 (Pu L-β1,β2)	43.8	12% / 25%
21.5 (Pu L-Υ)	45.9	15% / 25%
22.0 (Ag k-α)	44.5	10% / 25%
25.0 (Ag k-β1,β2)	50.0	15% / 25%
2300 (α, average method)	46.6	5% / 25%
2300 (α, per-event method)	46.5	5% / 25%

THE W_{SC}-VALUES OBTAINED FOR ELECTRONS PRODUCED BY X-RAYS ARE CONSIDERABLY LOWER THAN THE VALUES REPORTED IN THE LITERATURE (120-60 KEV [4]) AND ARE SIMILAR TO THE VALUES OBTAINED FOR α-PARTICLES. THE S2 YIELDS (NOT SHOWN HERE) ESTIMATED USING THE SAME METHODOLOGY ARE IN GOOD AGREEMENT WITH SIMULATIONS [4], WITHIN A 10%-DIFFERENCE. THIS RESULT, TOGETHER WITH THE GOOD AGREEMENT BETWEEN AVERAGE AND EVENT-BY-EVENT METHODS OBSERVED FOR α-PARTICLES DEMONSTRATES THE RELIABILITY OF OUR ANALYSIS AND GE SIMULATION MODEL.

CONCLUSIONS

DESPITE THE LARGE UNCERTAINTIES (BEING IMPROVED) WE MAY CONCLUDE THAT THE W_{SC}-VALUE DOES NOT SIGNIFICANTLY DEPEND NEITHER ON THE NATURE OF THE INTERACTING PARTICLE NOR ON ITS ENERGY.

REFERENCES

[1] E. APRILE, ET AL. (XENON), EUR. PHYS. J. C 77 (2017), 881.
[2] D. S. AKERIB, ET AL. (LUX-ZEPLIN), PHYS. REV. D 101 (2020), 052002.
[3] P. FERRARIO, ET AL. (NEXT), JHEP 10 (2019), 052.
[4] C. D. R. AZEVEDO, ET AL., JINST 11 (2016), C02007.

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