Advances in sCVD Diamond Detectors: Quality Control, Energy Resolution, and Statistical Fluctuations

EuPRAXIA-DN Camp I: Technologies

April 7-8, 2025
Pisa, Italy

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Diamond Detectors

Chemical vapor deposition (CVD) Diamond

- ***e_{gap} = 5.47 eV***
- ***E_{ion}=13.1eV***

✓ **Radiation hard semiconductor**

✓ **Temperature insensitive (up to 500 K)**

✓ **Low dark current (pA)**

✓ **Intrinsically low noise**

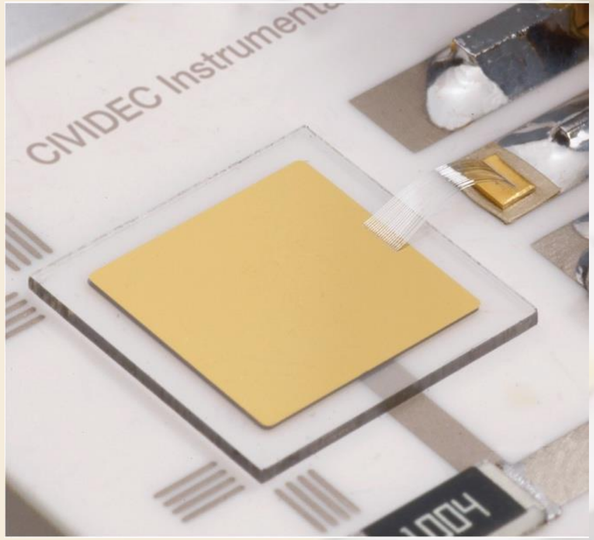
✓ **Fast response (ns charge collection)**

✓ **Expensive**

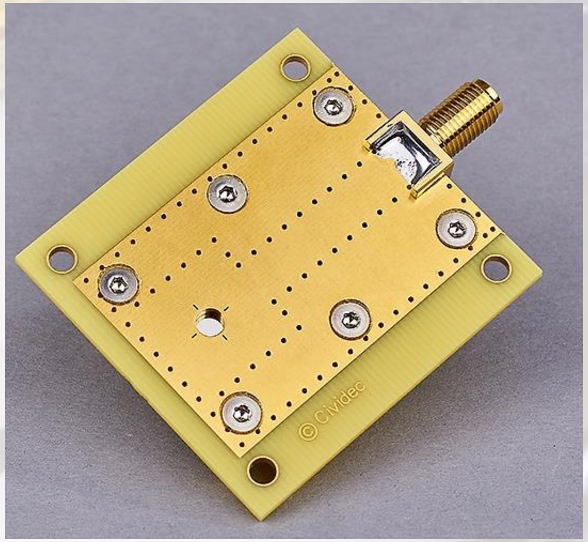
Development Process

Crystal*

Sensor *

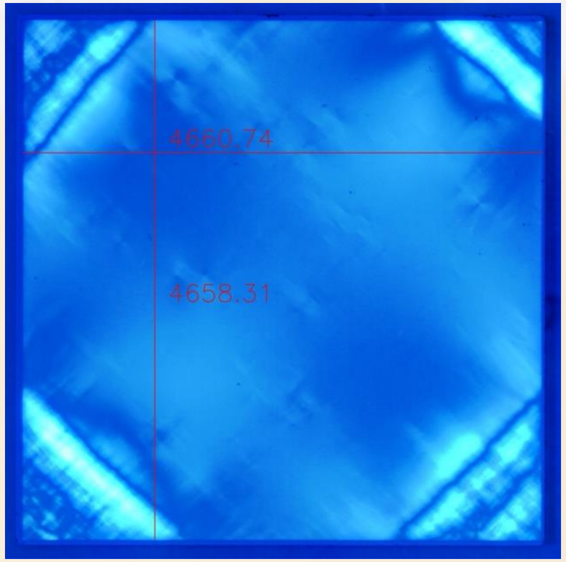


Detector*

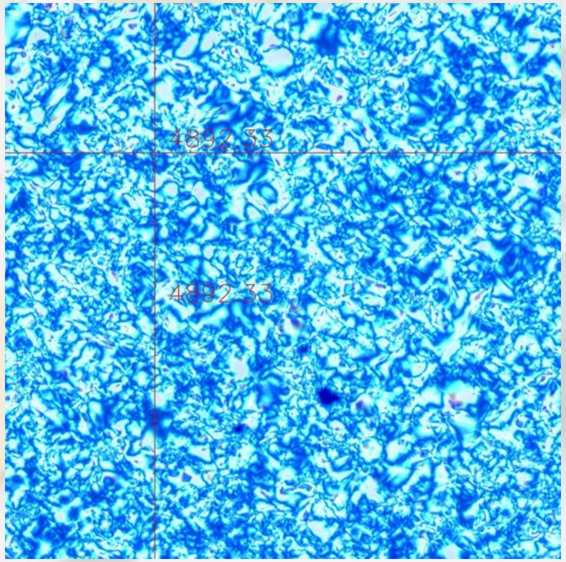


* *CIVIDEC:* *https://cividec.at/*
**Element6:* *https://www.e6.com/*

Quality Control - I



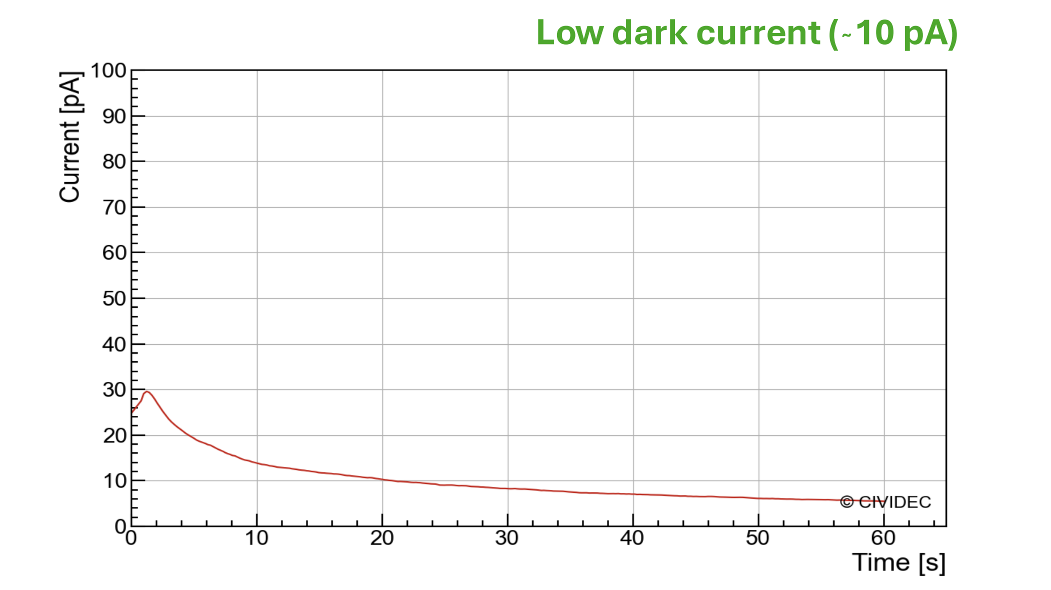
sCVD

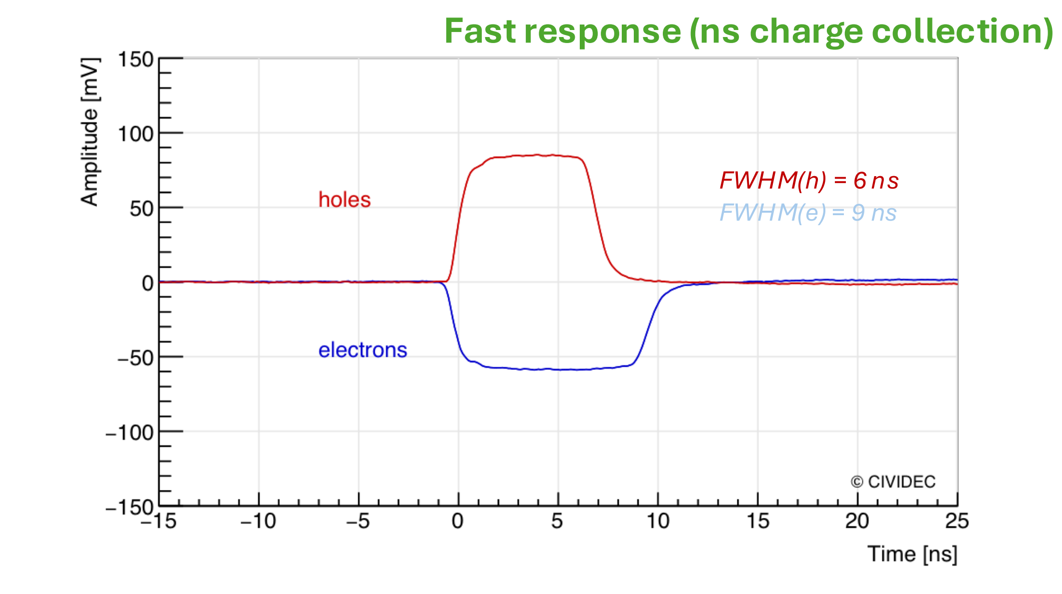


pCVD

Crystal Quality : Cross Polarized visible light microscopy

Quality Control - II



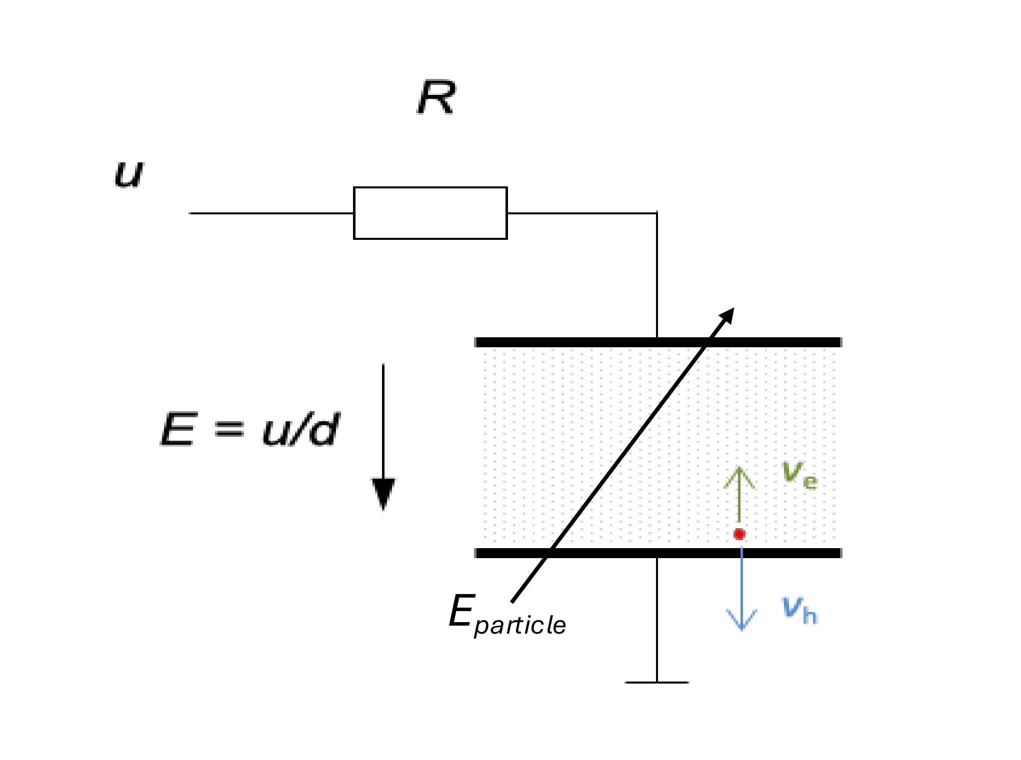


Sensor Quality: It and TCT profile after metallization.

Performance:Energy resolution

High-precision alpha spectroscopy

Ionization in Diamond Detectors

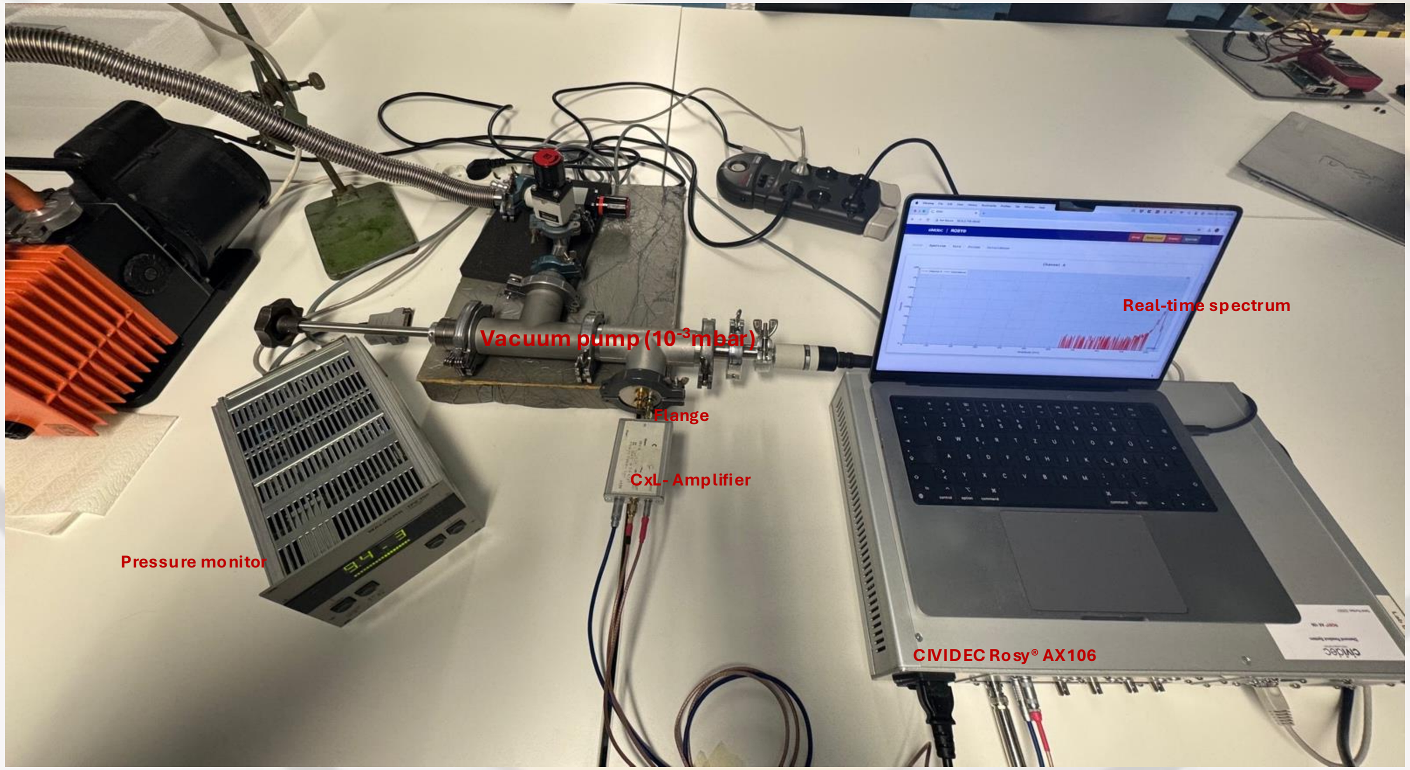


Courtesy: Dr. Christina Weiss

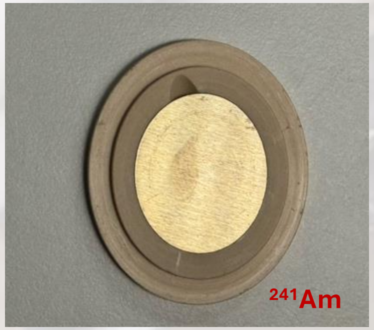
$$N_e + N_h = E_{ion}/E_{particle}$$

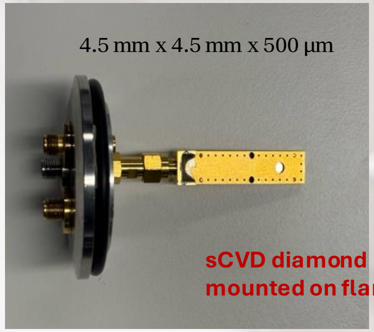
$$Q_{ion} = (N_e + N_h) . e$$

Experiment Setup

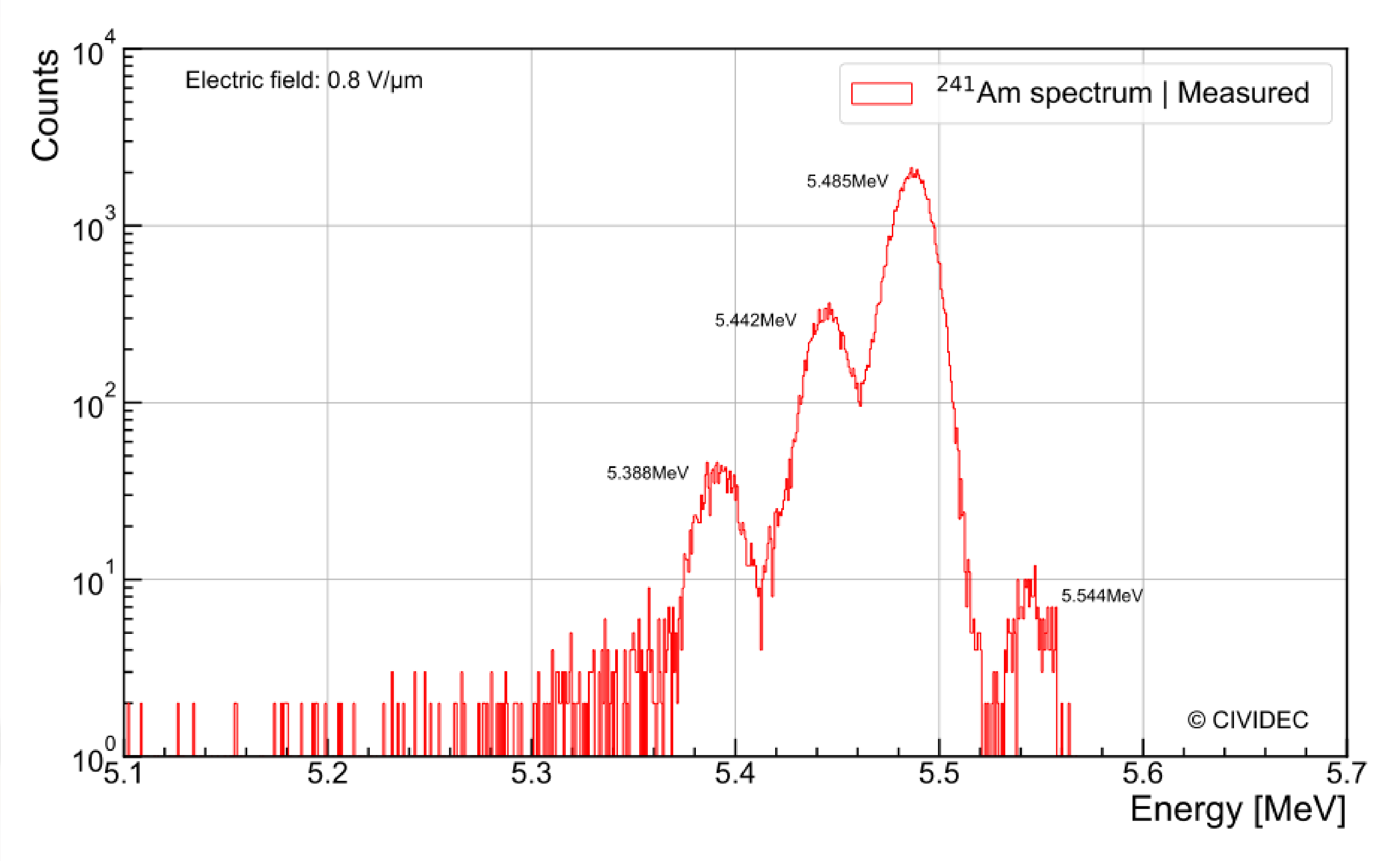


Experimental setup at Atomic Institute, TU Wien





Measured Spectrum



Response of sCVD diamond detector to the α-particles of ^{241}Am.

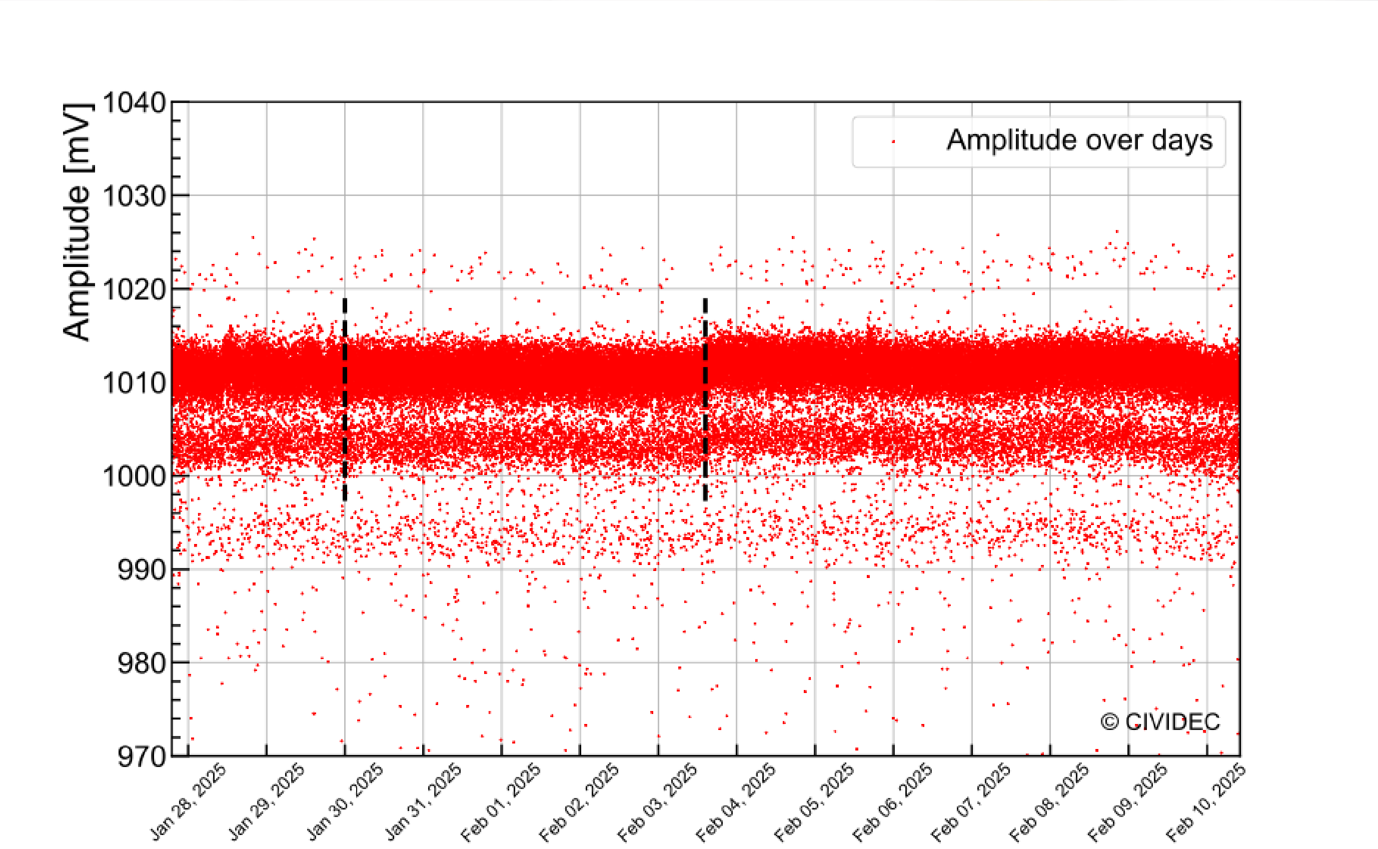
Factor Impacting the Energy Resolution

Factor	Methodology	Sigma [keV]
Source (10 nm)	via Geant4 simulation	1.21
Air	Vacuum	NaN
Electrode (100 nm Ti)	via Geant4 simulation	3.73
Electronic noise	Electronic calibration at CIVIDEC	5.69
Statistical Fluctuations	Theoretically/Literature	2.39

$$\sigma^2 = \sigma^2_{stat} + \sigma^2_{electronic} + \sigma^2_{electrode} + \sigma^2_{source}$$

$$\sigma = 7.31\ \text{KeV}$$

Environmental conditions



The pulse amplitude as a function of time is shown.

Results

Results	Method	FWHM [keV]
Experiment*	No peak fitting or offline analysis	16.68
Pomoski[1]	Gaussian fitting	17
Shimaoka[2]	Gaussian fitting	16.7

*the FWHM is derived from the stable amplitude time window of data recorded.

[1] https://doi.org/10.1002/pssa.200671127

[2] https://doi.org/10.1002/pssa.201600195

Statistical Fluctuations

$$\sigma^2_{experimental} = \sigma^2_{source} + \sigma^2_{electrode} + \sigma^2_{stat} + \sigma^2_{electronic}$$

$$\sigma_{stat}\ (Poisson\ distribution) = \sqrt{N}$$

$$\sigma_{stat}\ (Detector) = \sqrt{F}.\sqrt{N}$$

N (total number in e-h pairs) = $\frac{E_{particle}}{E_{ion}}$

F = Fano Factor

$E_{particle}$ = Deposited energy

E_{ion} = Ionization energy

*$F_{literature}$ = 0.08

*$F_{experiment}$ = 0.03

*R. C. Alig, S. Bloom, and C. W. Struck, Phys. Rev. B 22, 5565 (1980).

*the accuracy of the Fano Factor evaluation is primarily dependent on the precision of other measurement factors mentioned in the above equation.

Thank you for your attention !

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