Alphabeast :

a CMOS based Detector for Neutron Dosimetry

ON BEHALF OF THE DESIS TEAM

Djokhar BETELGUERIEV

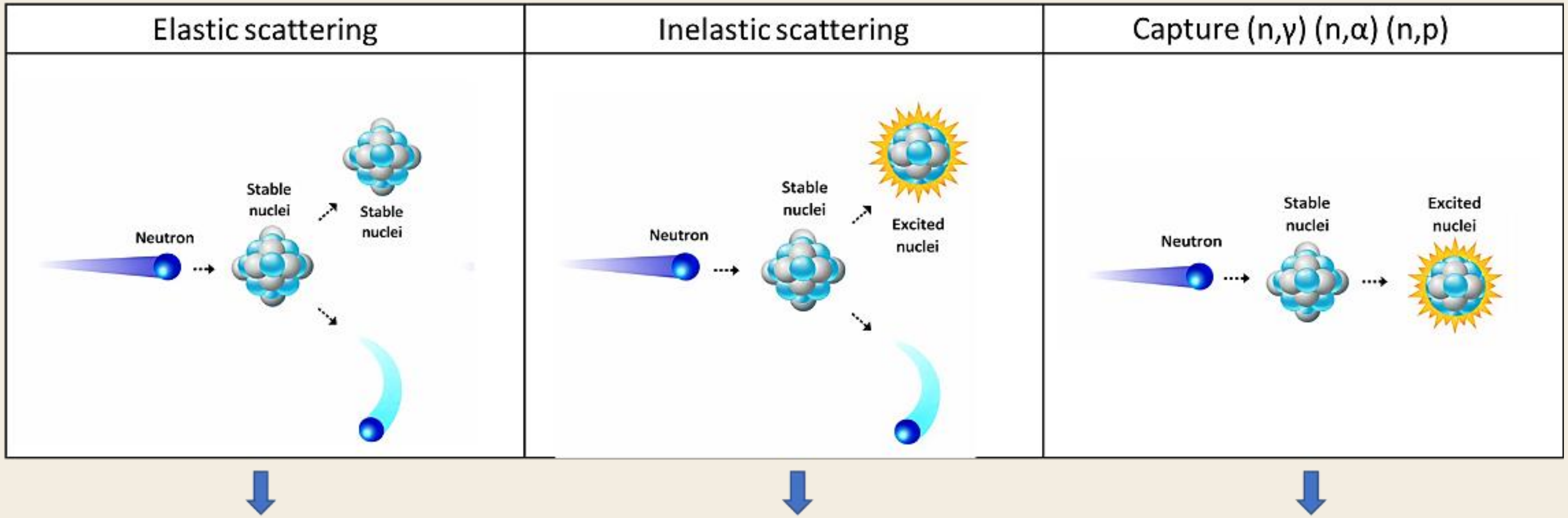
djokhar.betelgueriev@iphc.cnrs.fr

Institut Plurisdisciplinaire Hubert Curien, CNRS, Strasbourg, France

AlphaBeast sensor: purpose and operating principle

Motivation: Why Detecting Neutrons Matters

Neutrons are indirectly ionizing radiation:
they generate charged secondary particles with high LET through nuclear interactions.



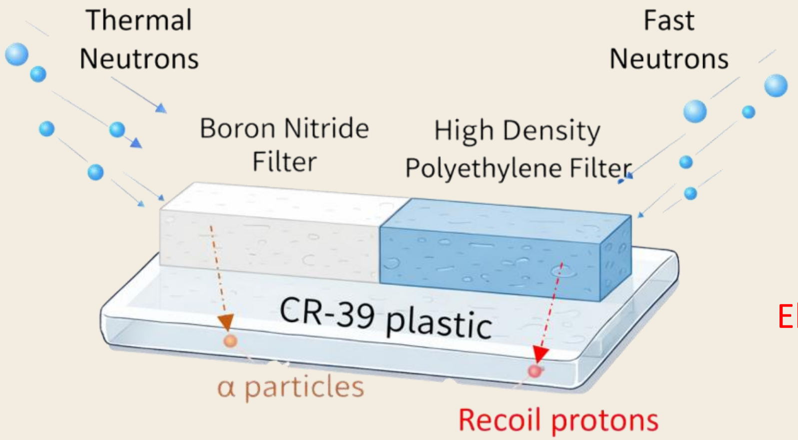
Recoil nuclei / protons → high energy deposition | **Nuclear excitation → secondary radiation** | **Neutron absorption → emission of α, p or γ**

Neutron dosimetry relies on detecting the secondary particles produced by these interactions.

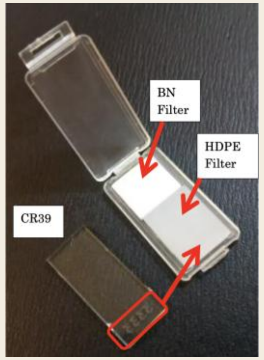
Current Standard : CR-39 Passive Detectors

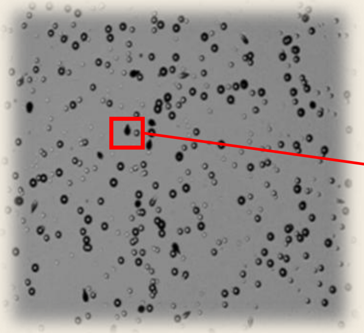
$^{10}B(n,\alpha)^{7}Li$

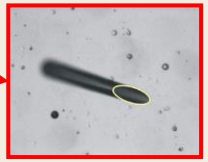
neutron capture -> alpha emission



Elastic scattering on hydrogen → recoil protons

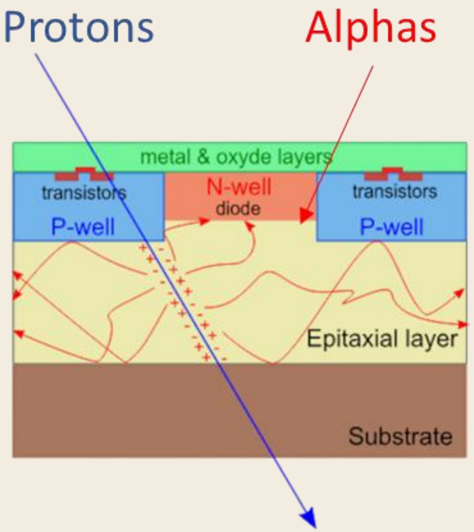


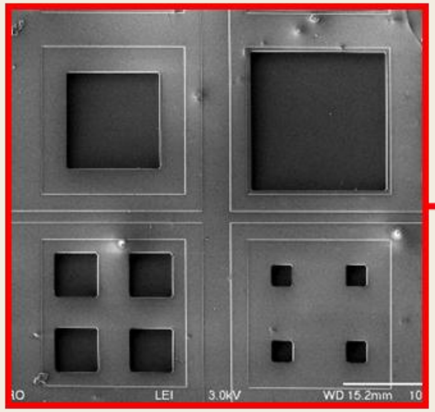


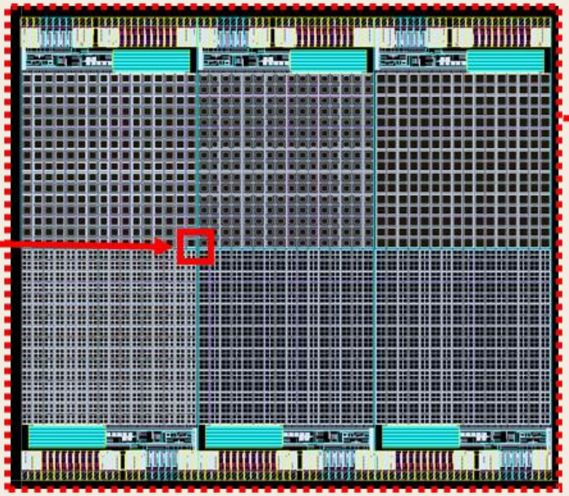


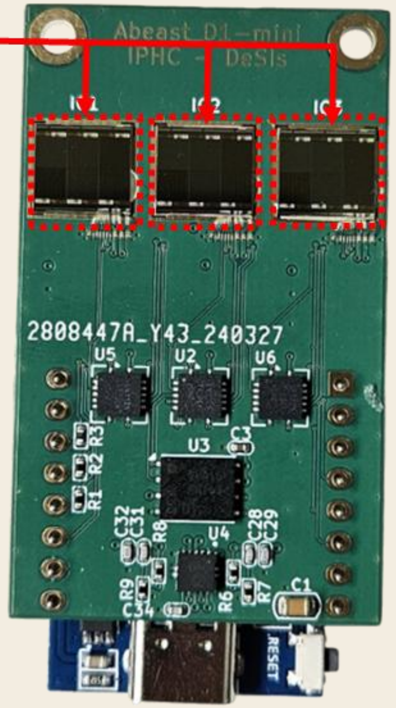
- Single use
- No real-time
- Time consuming

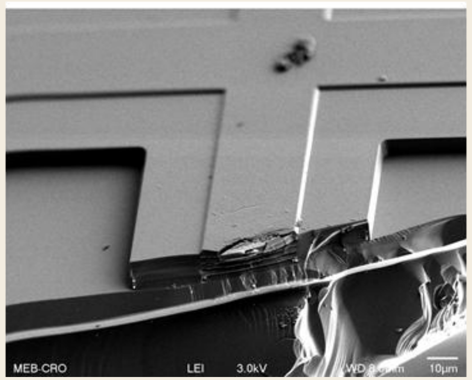
Alphabeast : CMOS Technology

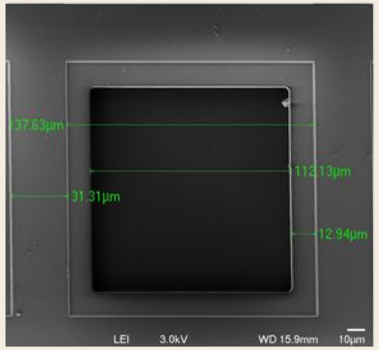










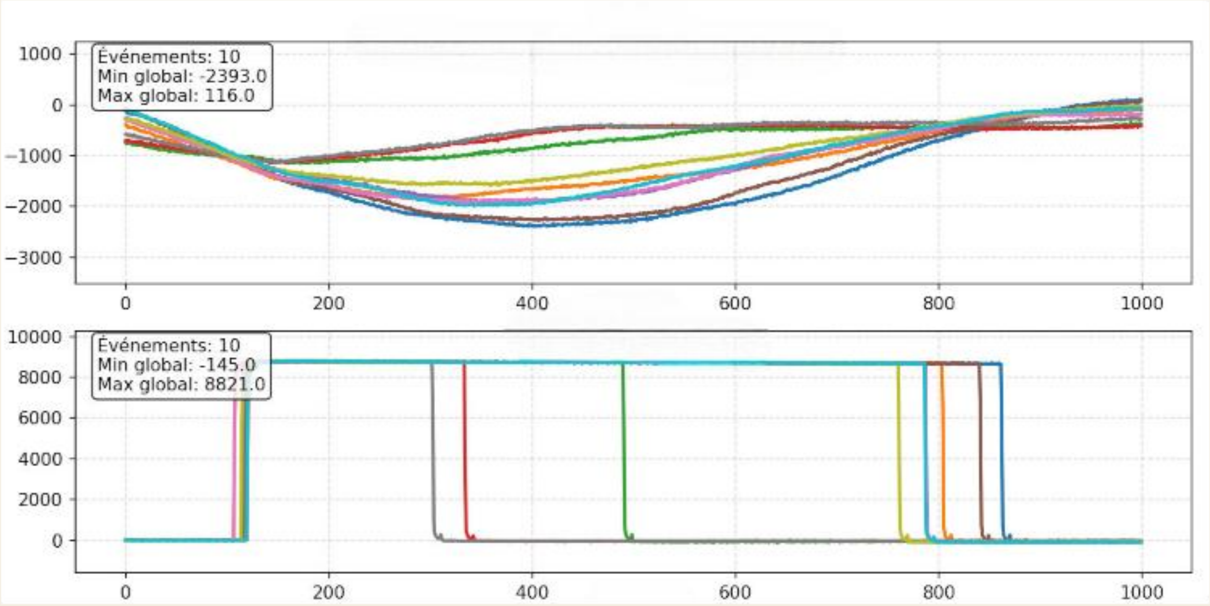


- **The silicon oxide layer acts as a surface filter**, reducing leakage and surface noise.
- The **size of the collection well is optimized to balance signal and noise**

Mono-abeast sensor (analog signal)

Analog Output
(10 hits, threshold : 235 ⇔1000 ADC ⇔336keV)

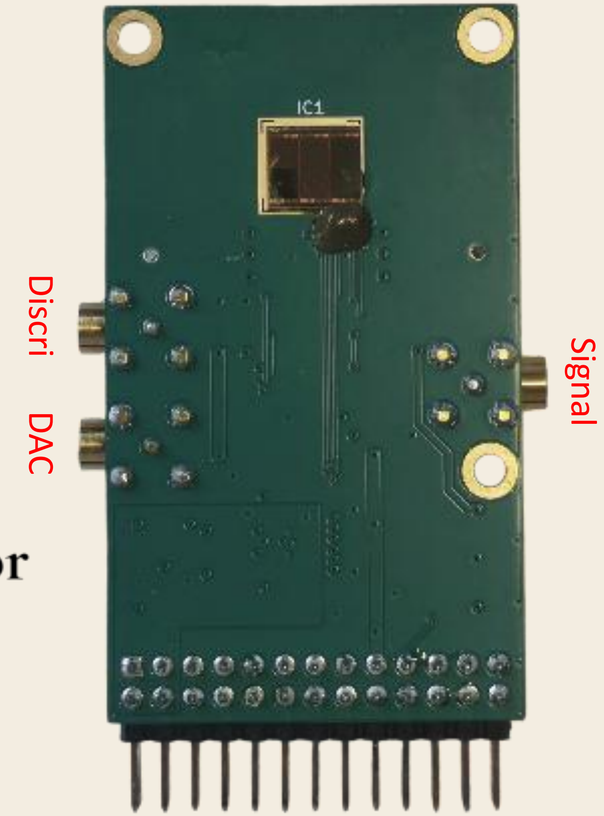
ADC values



Signal

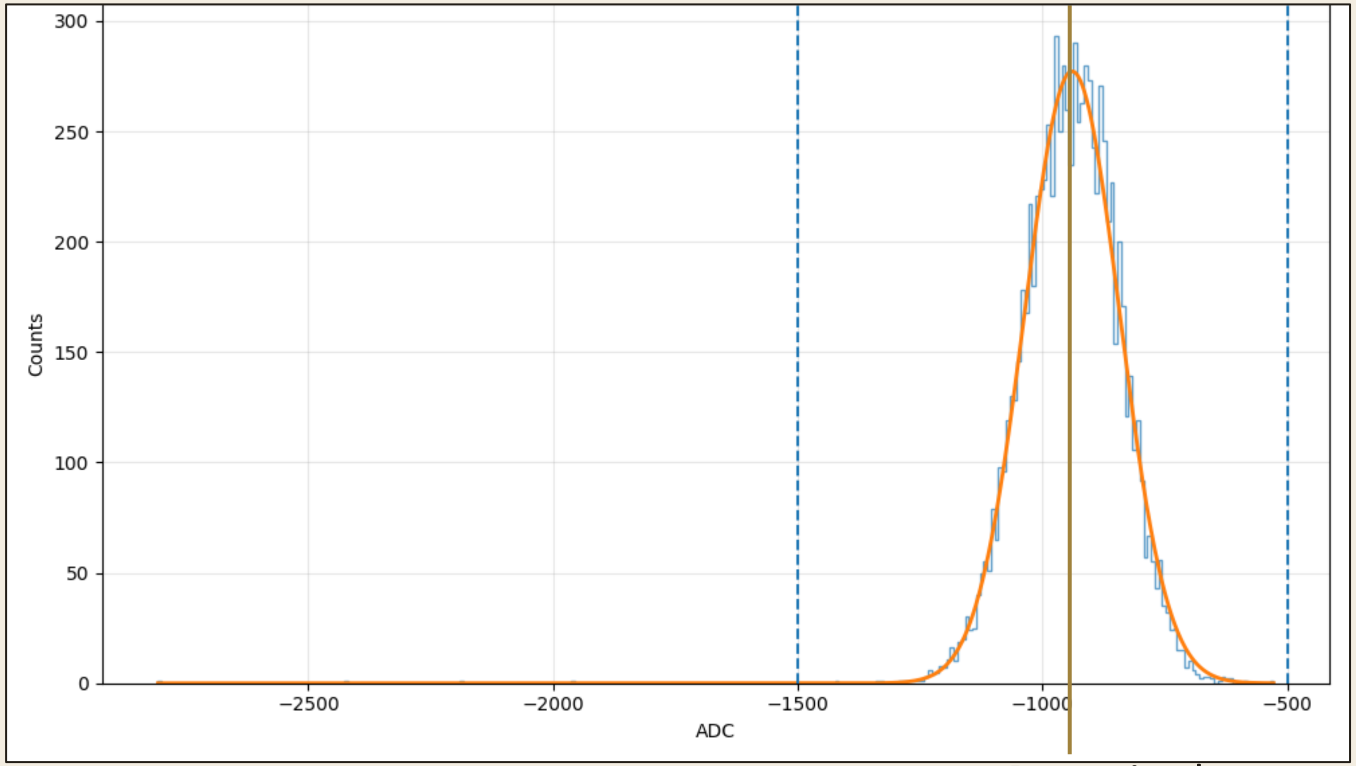
Discriminator Step

Samples (1 step = 312,5 ps)

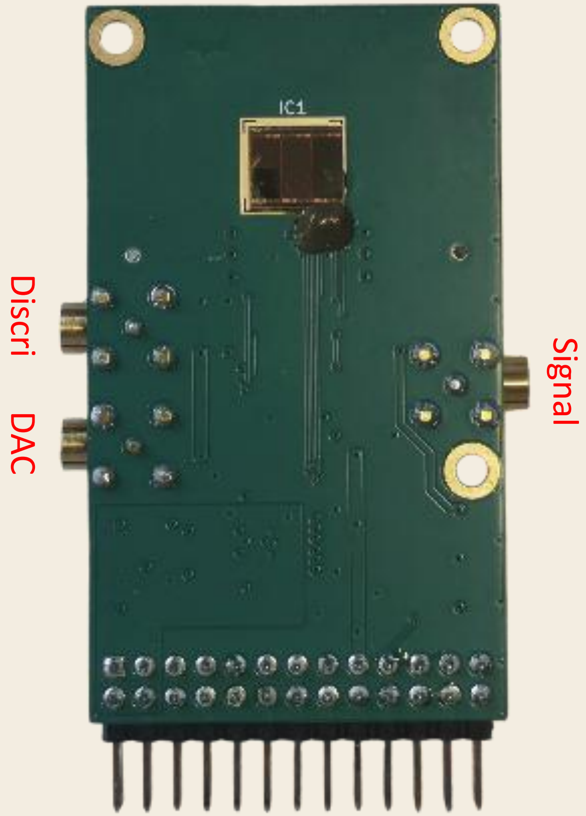


Mono-abeast sensor (analog signal)

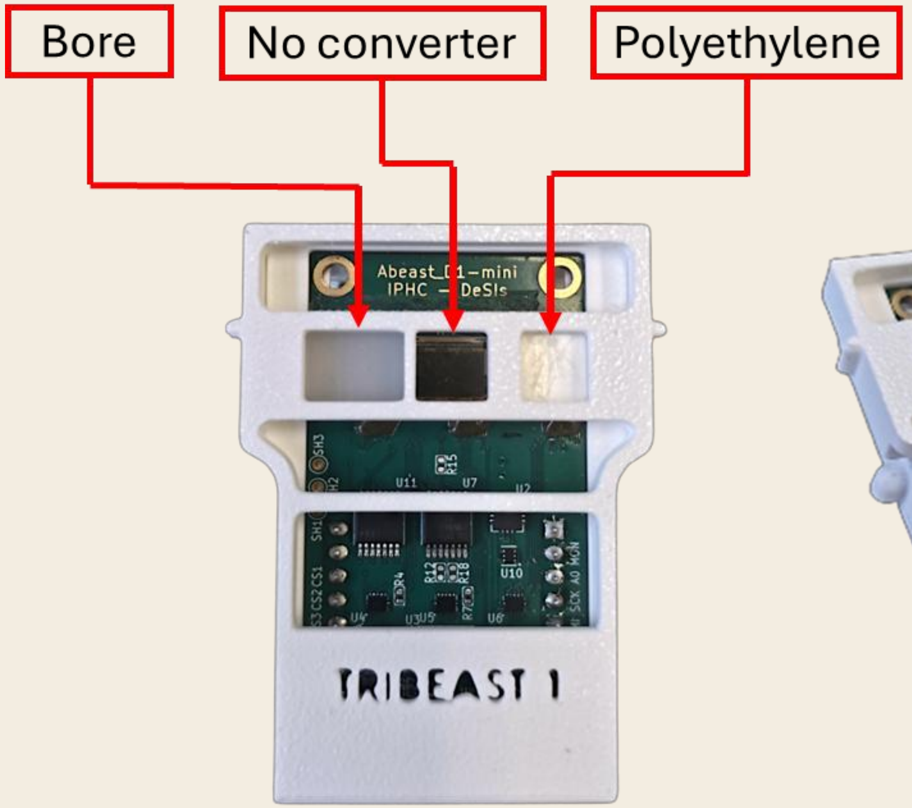
Analog min Amplitude distribution

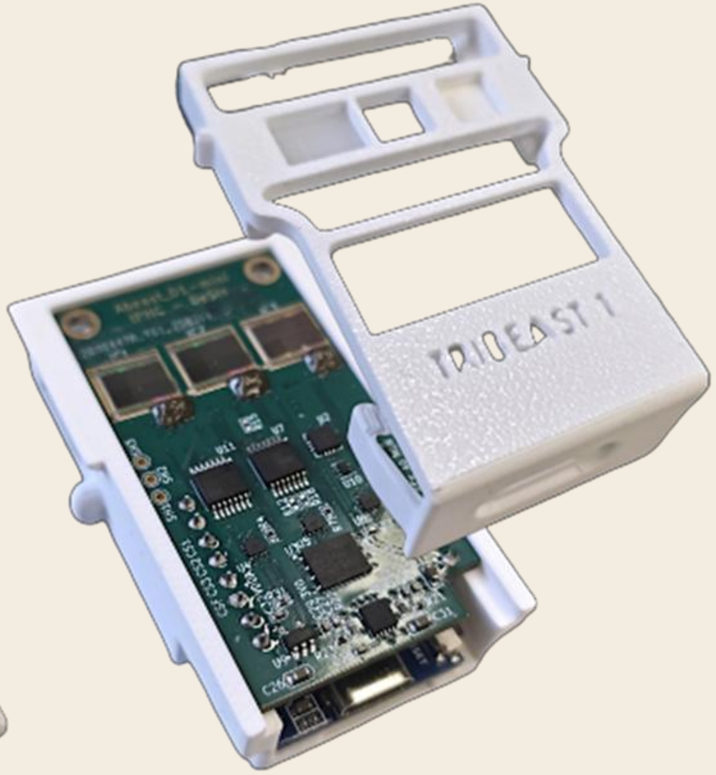


Deposited energy

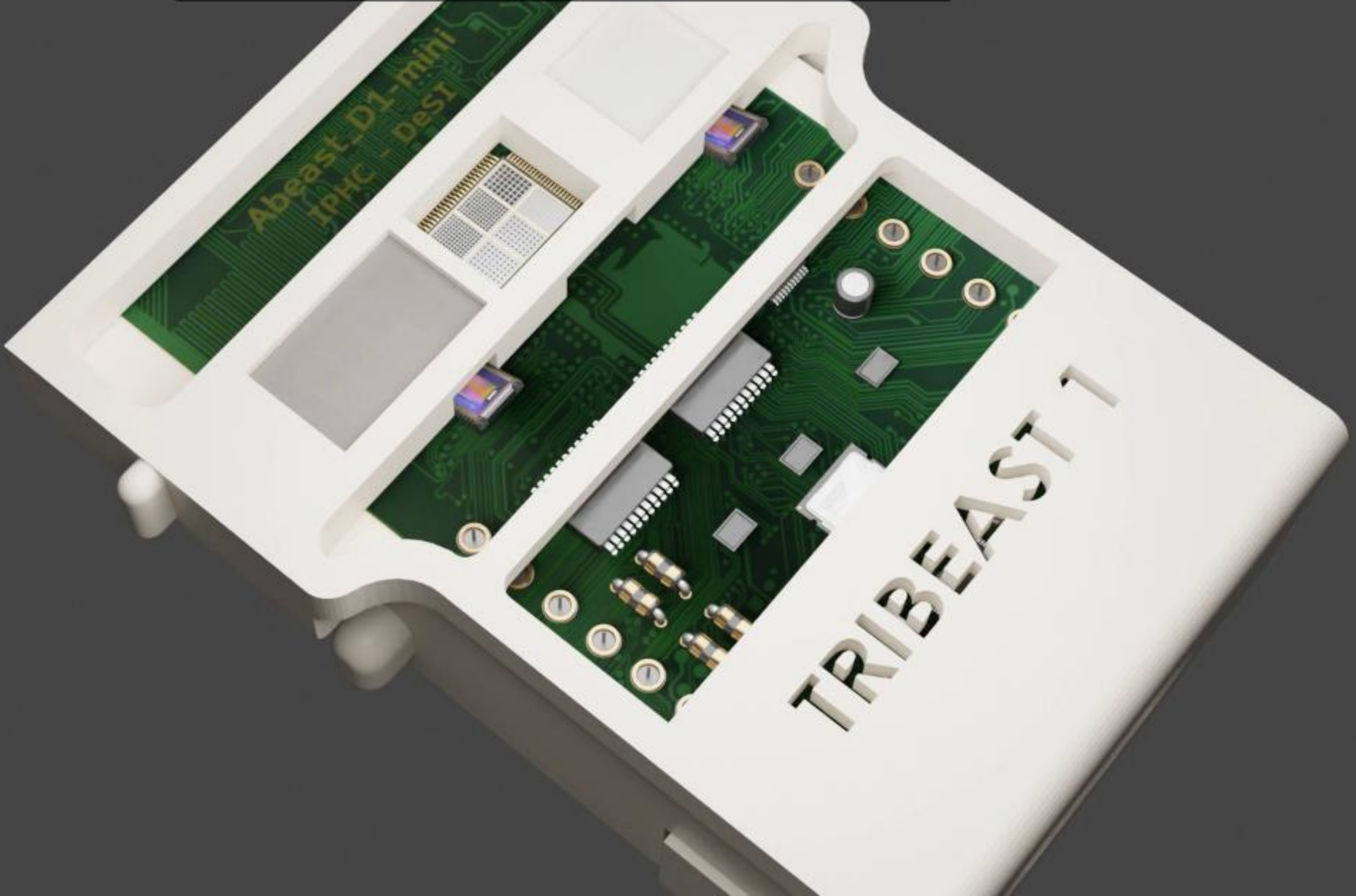


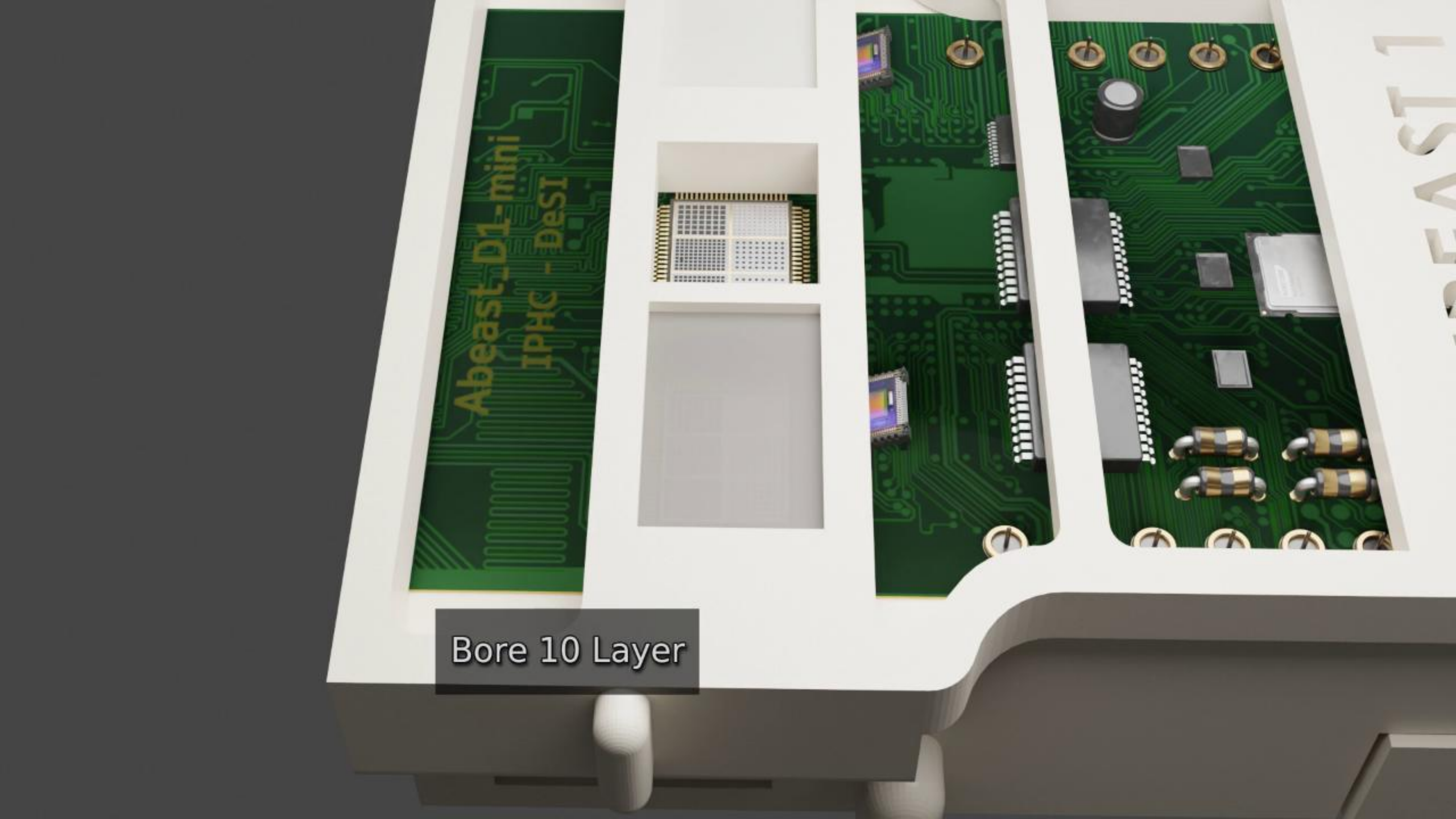
Tri-beast sensor (neutron couting)





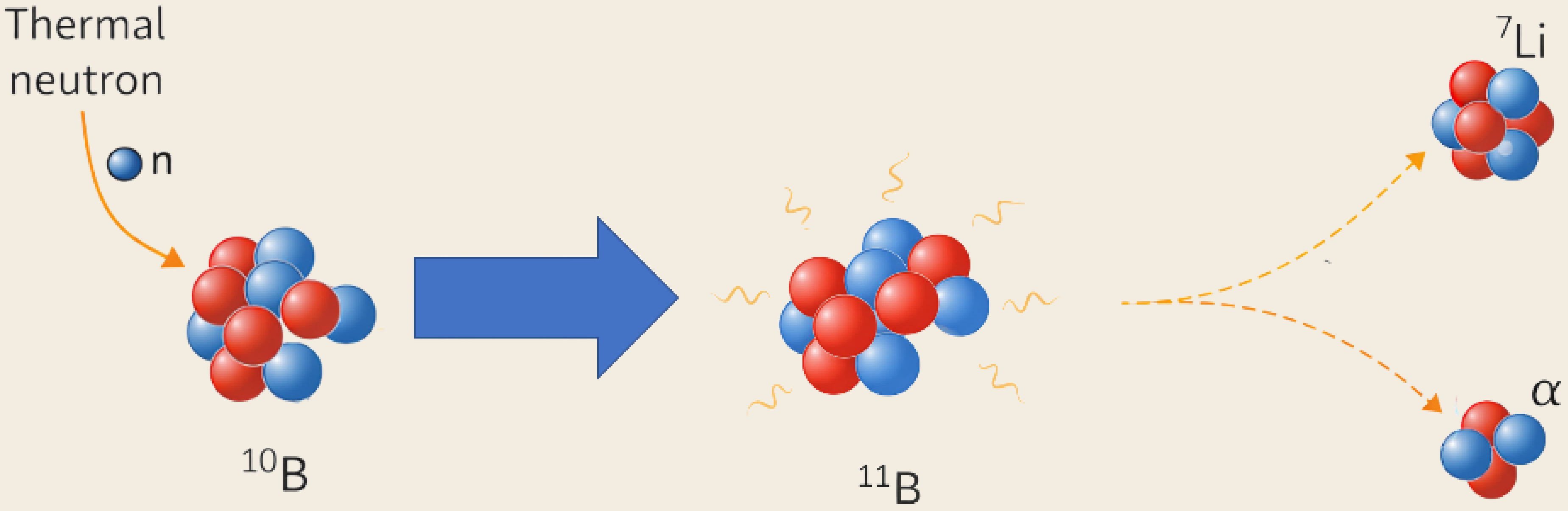
Case 1 : Thermal Neutron



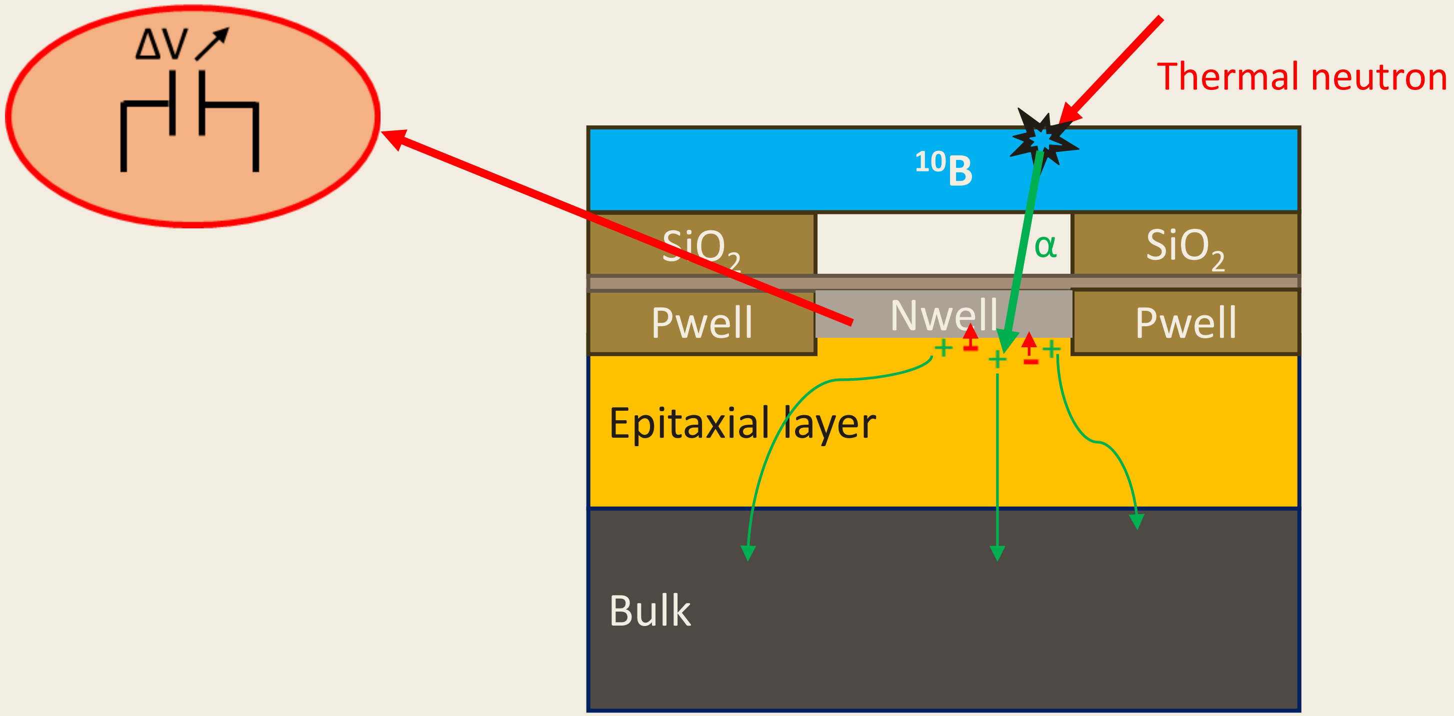

Abeast_D1-mini
IPHC - DeSI
Bore 10 Layer

Boron Neutron Capture

$^{10}B(n,\alpha)^{7}Li$



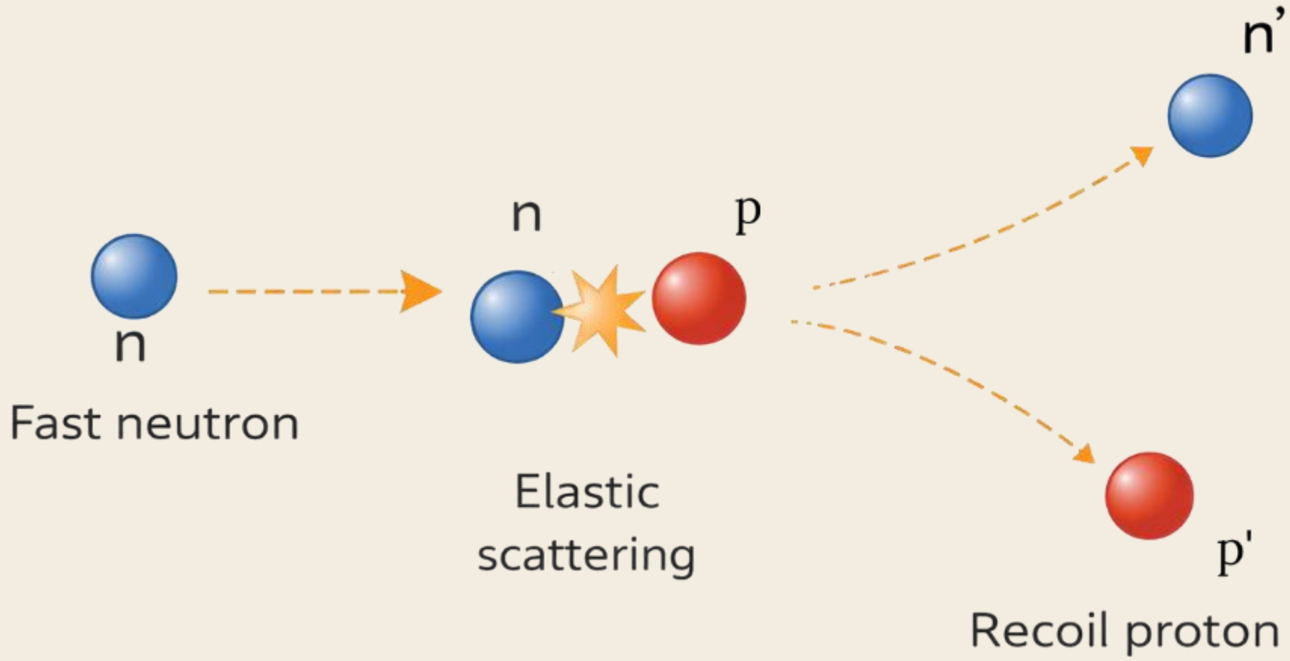
Alphabeast : Thermal Neutron Conversion via Boron Capture



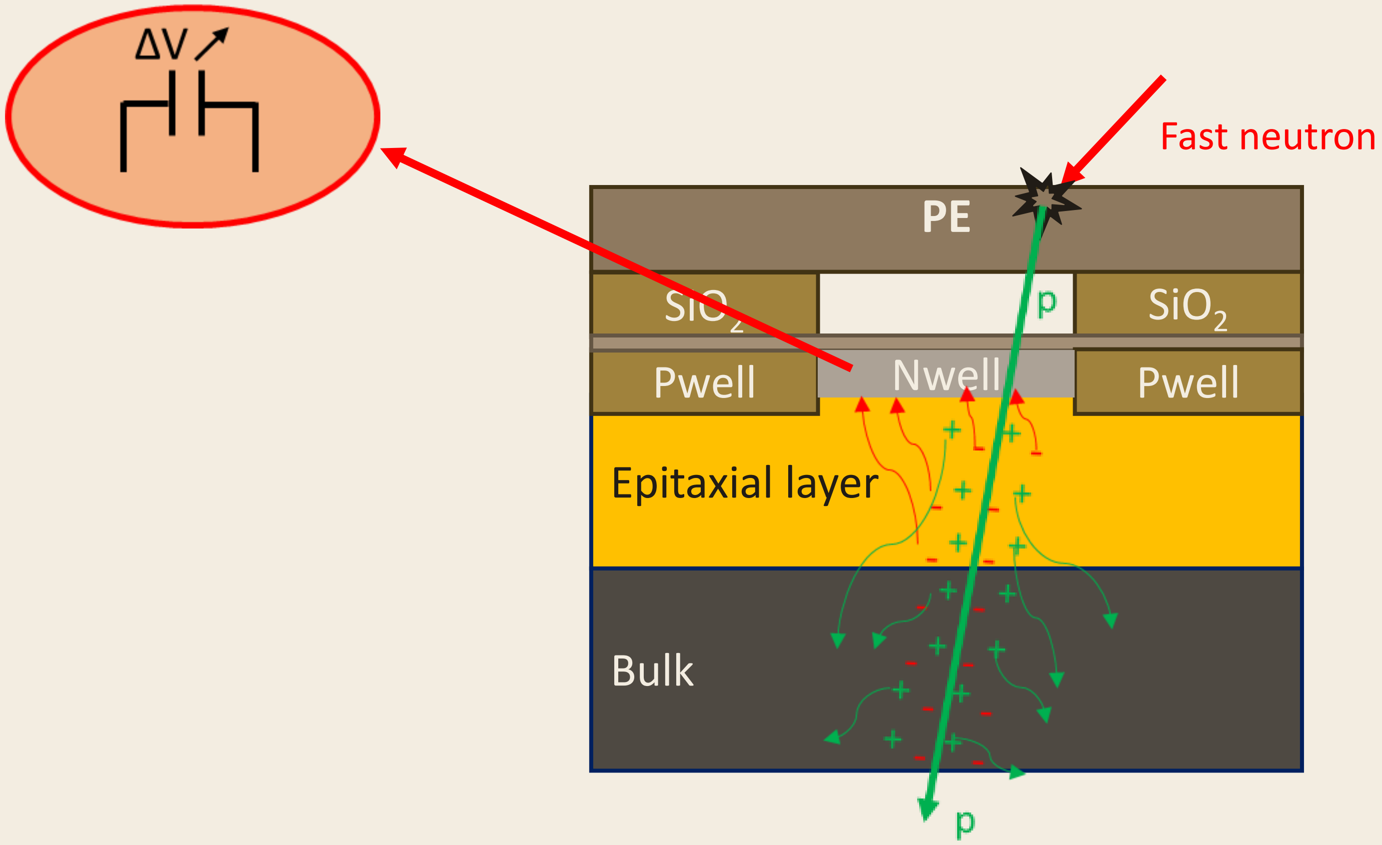
Case 2 : Fast Neutron


Polyethylene Layer
Abeast_D1-mini
IPHC - DeSI

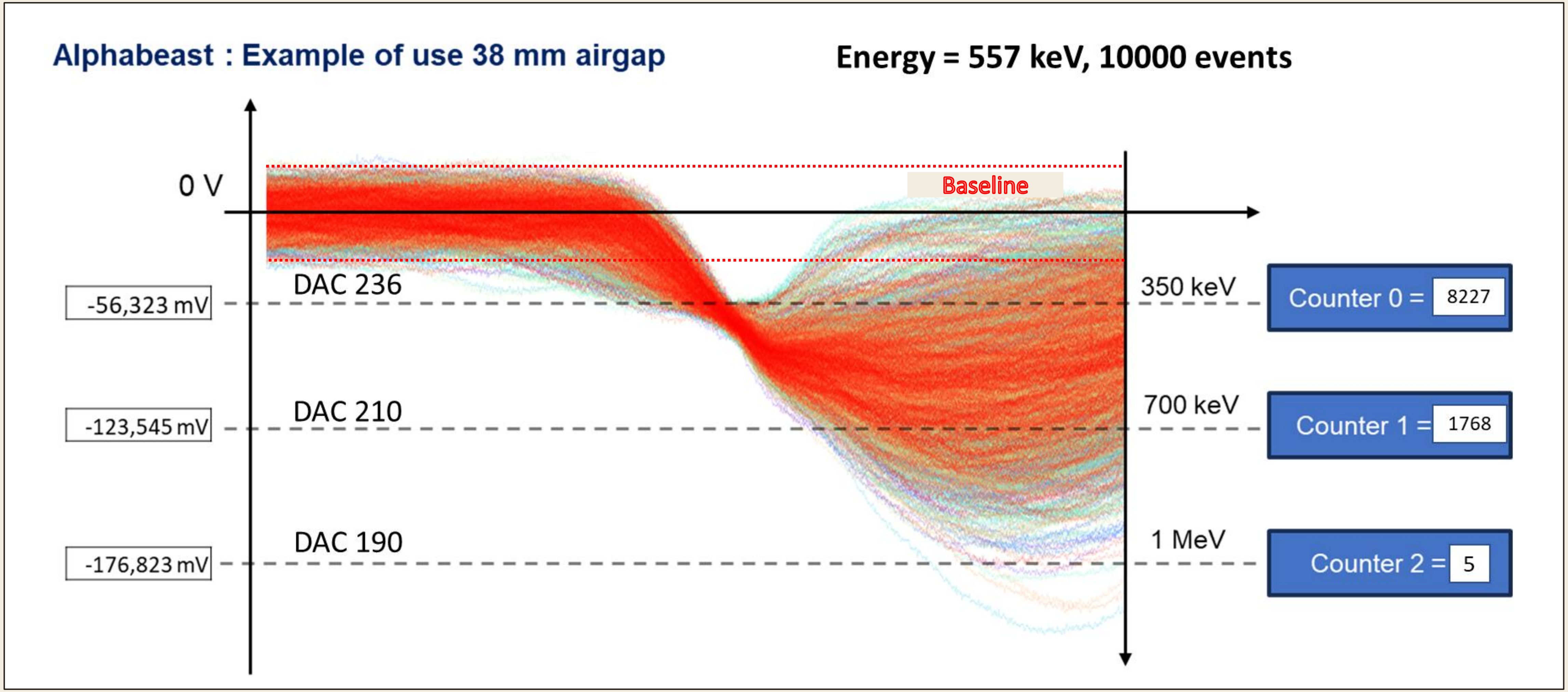
Fast Neutron Elastic Scattering



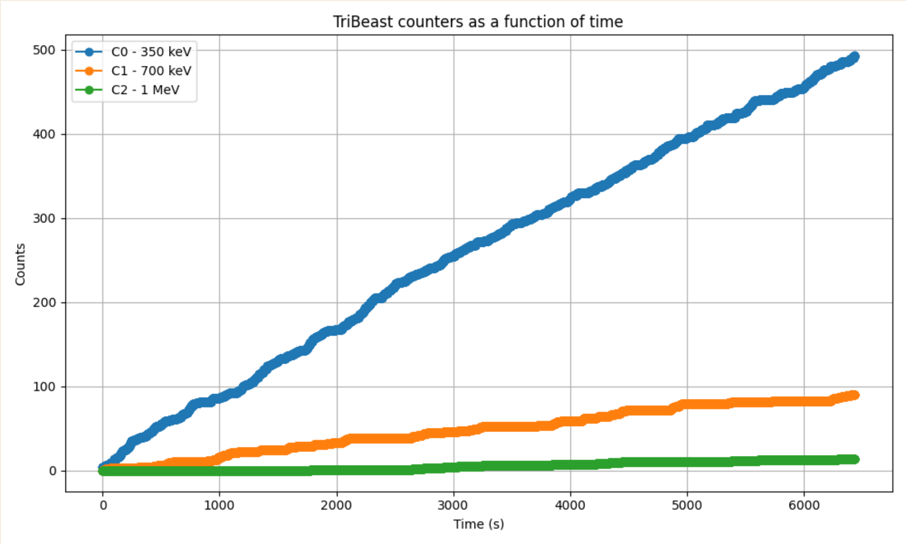
Alphabeast : Fast Neutron Conversion via Proton Recoil

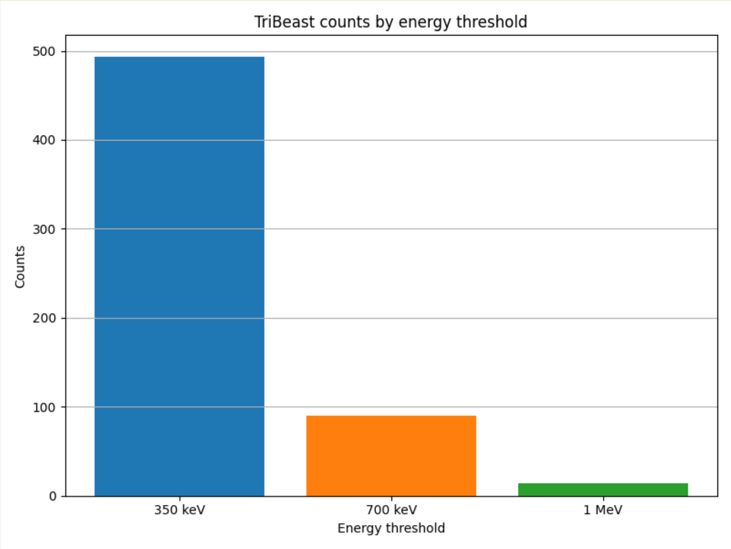


Tri-beast sensor : internal thresholds (neutron counting)



Tri-beast sensor : internal thresholds (neutron counting)

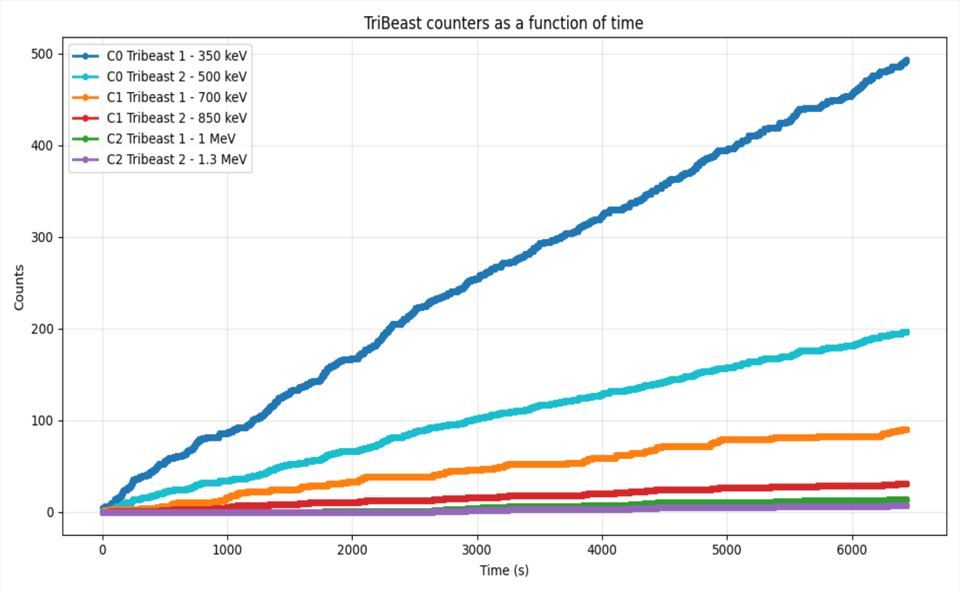


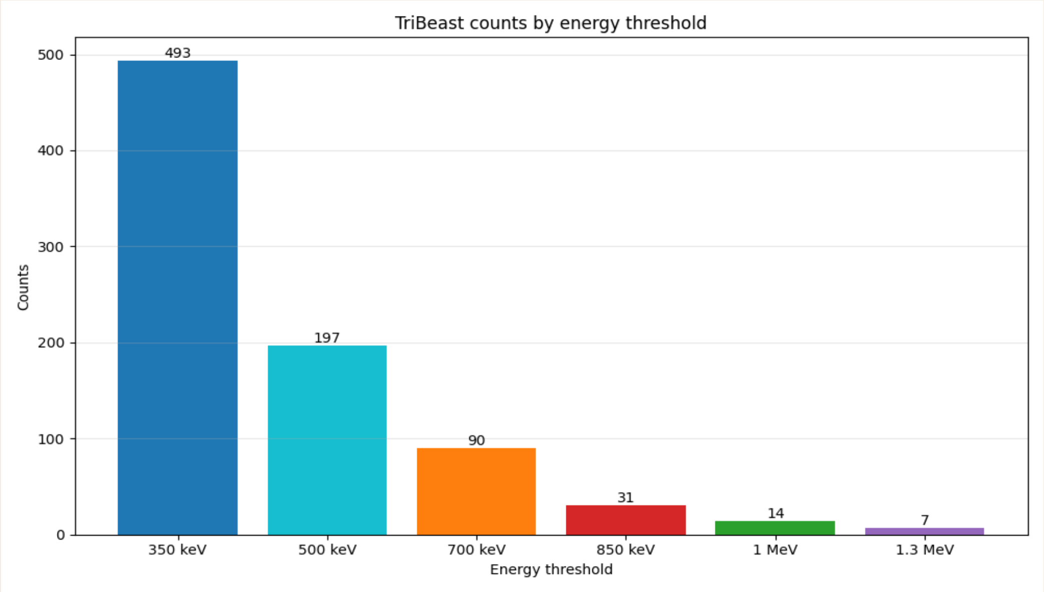



TRIBEAST 1

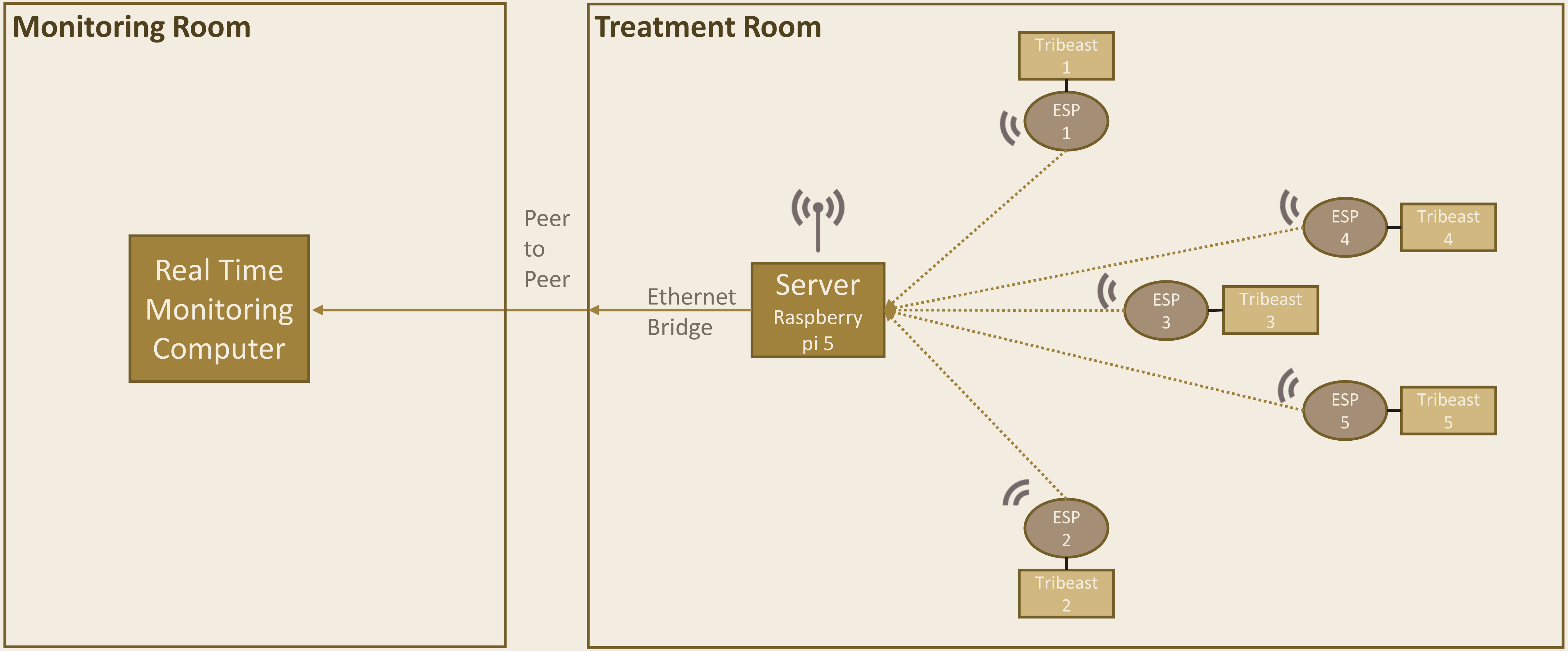

TRIBEAST 1
TRIBEAST 2

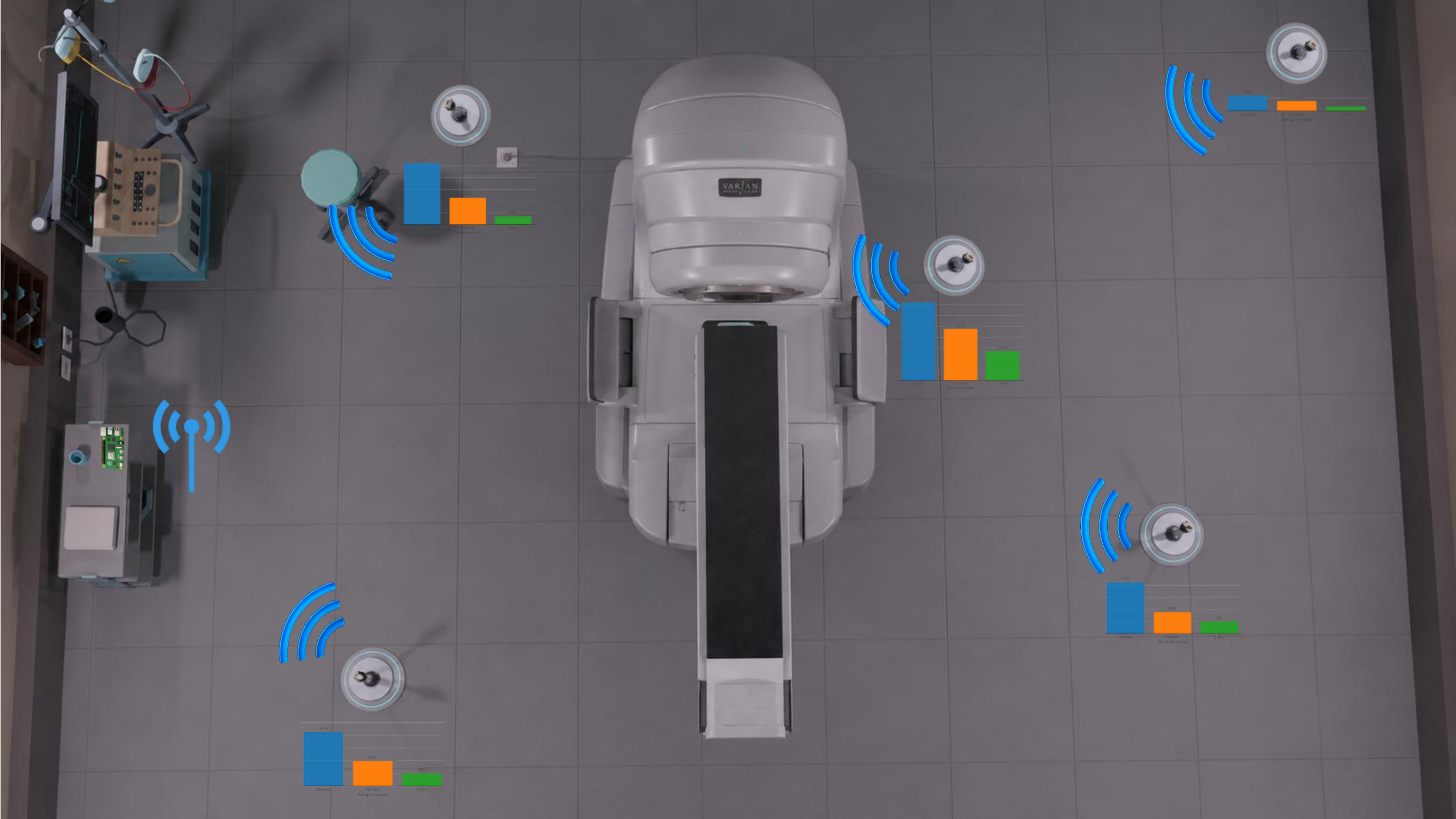
Tri-beast sensor : internal thresholds (neutron counting)

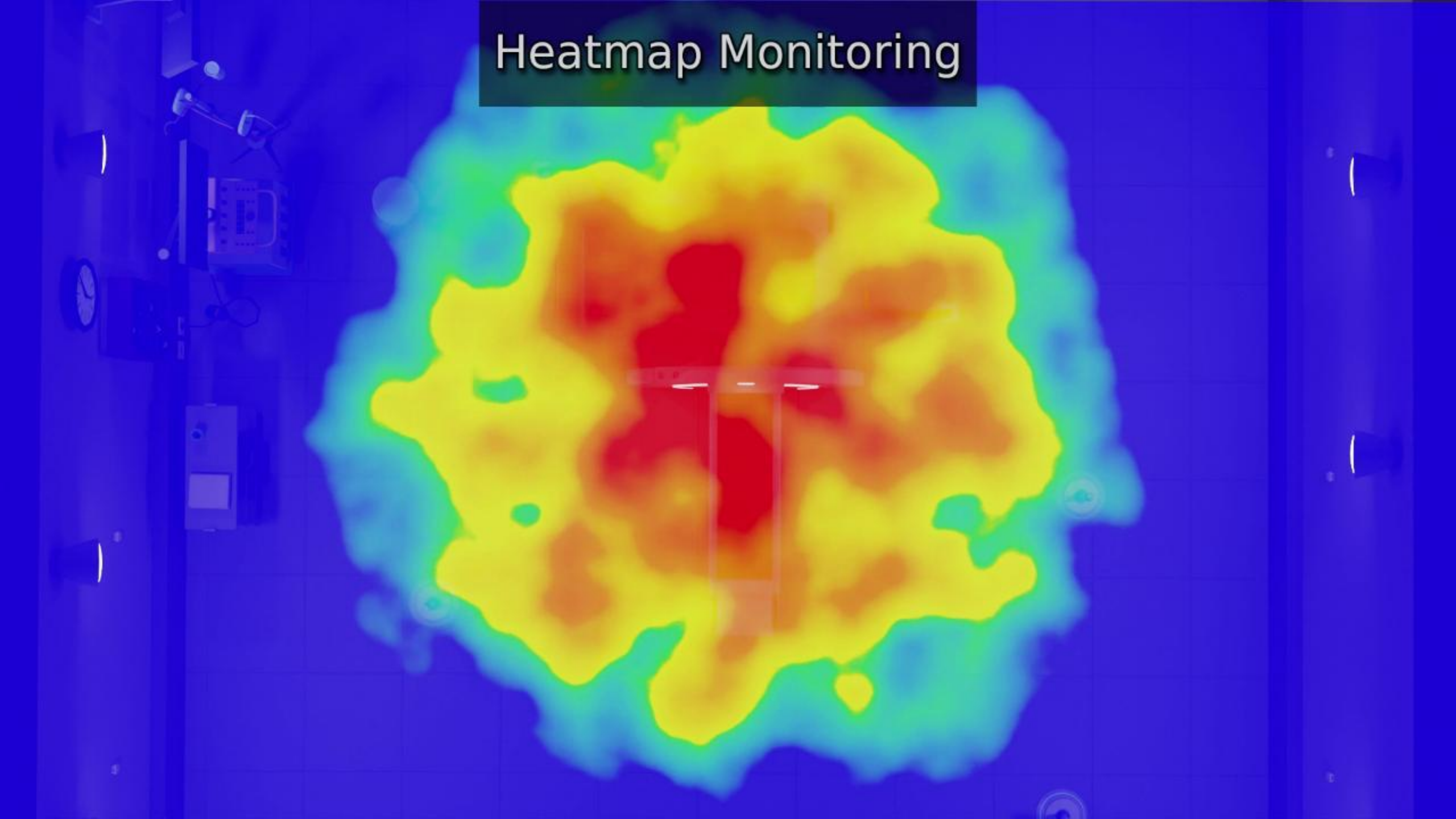




Tri-beast sensors network

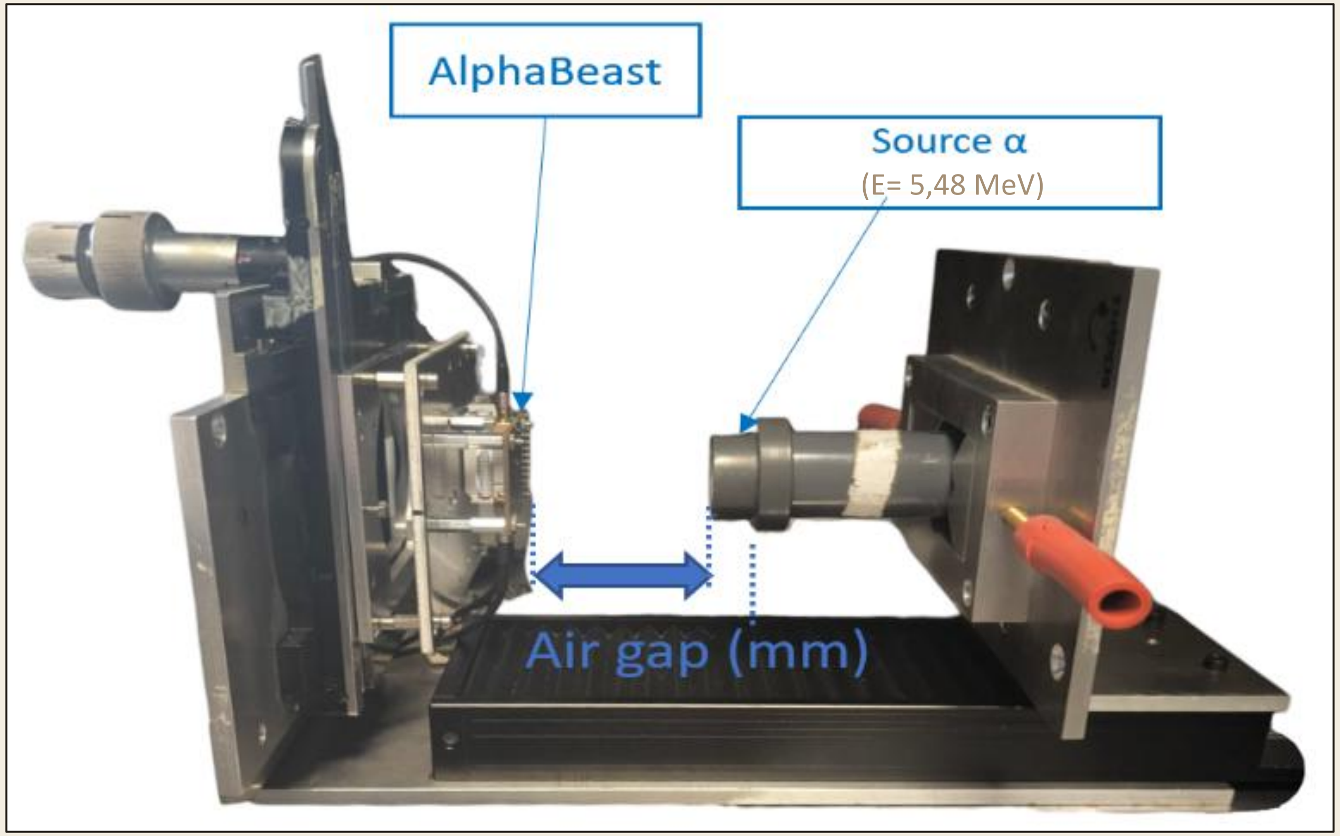


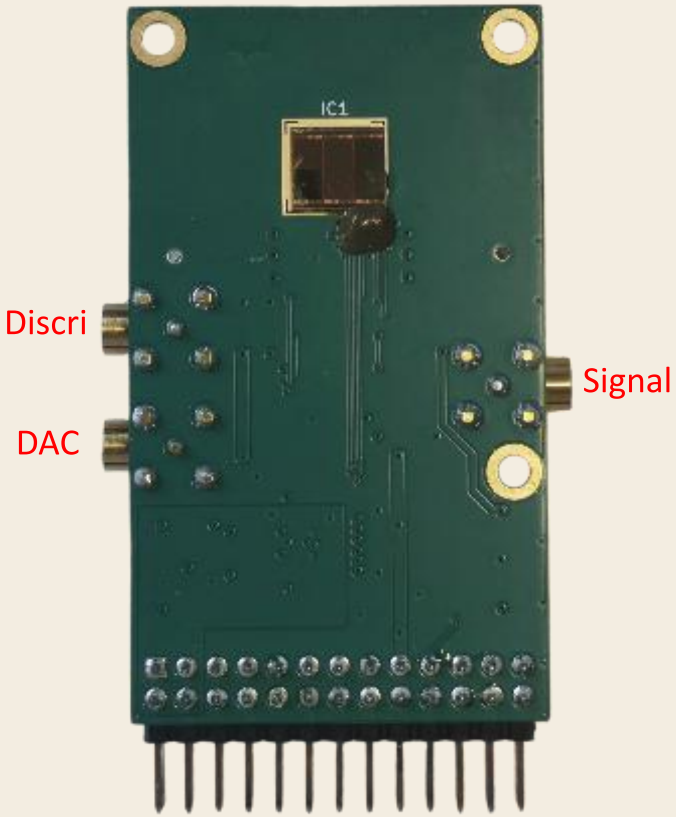



Heatmap Monitoring

Laboratory tests

^{241}Am source sensor calibration





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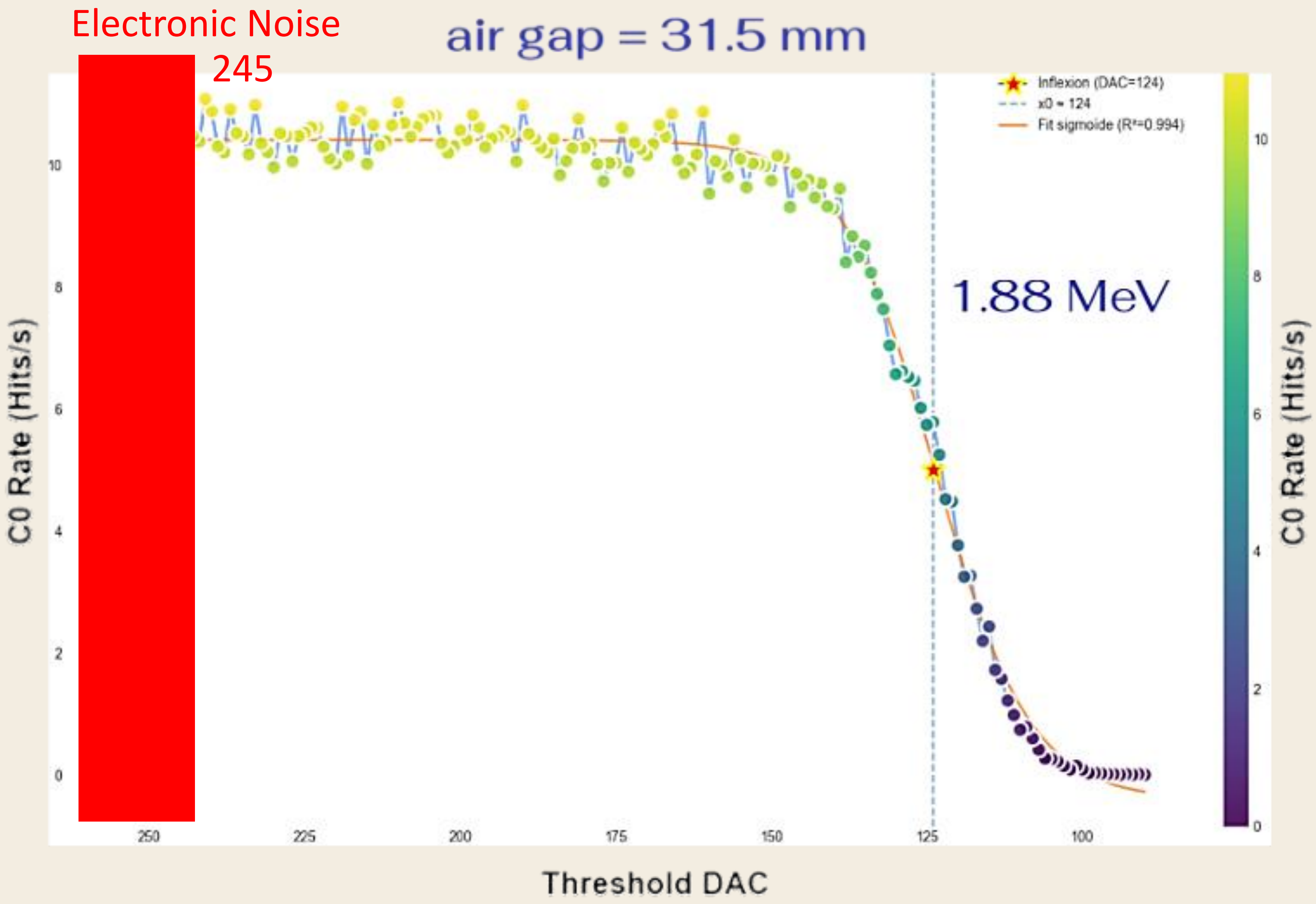

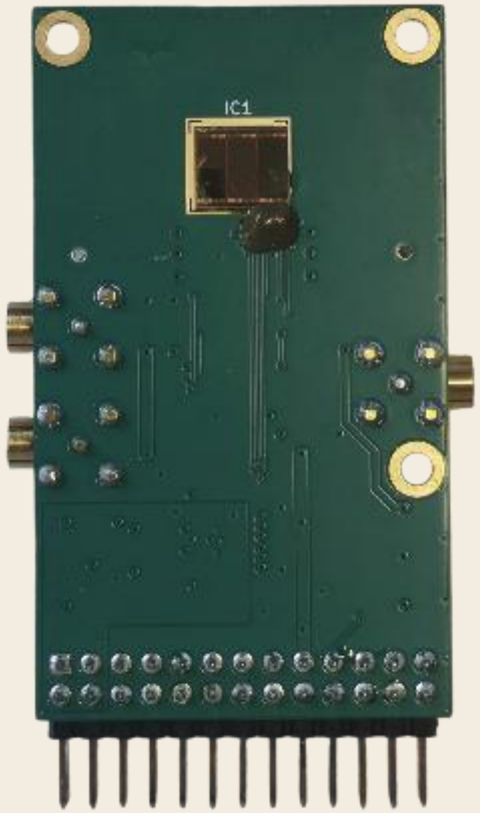

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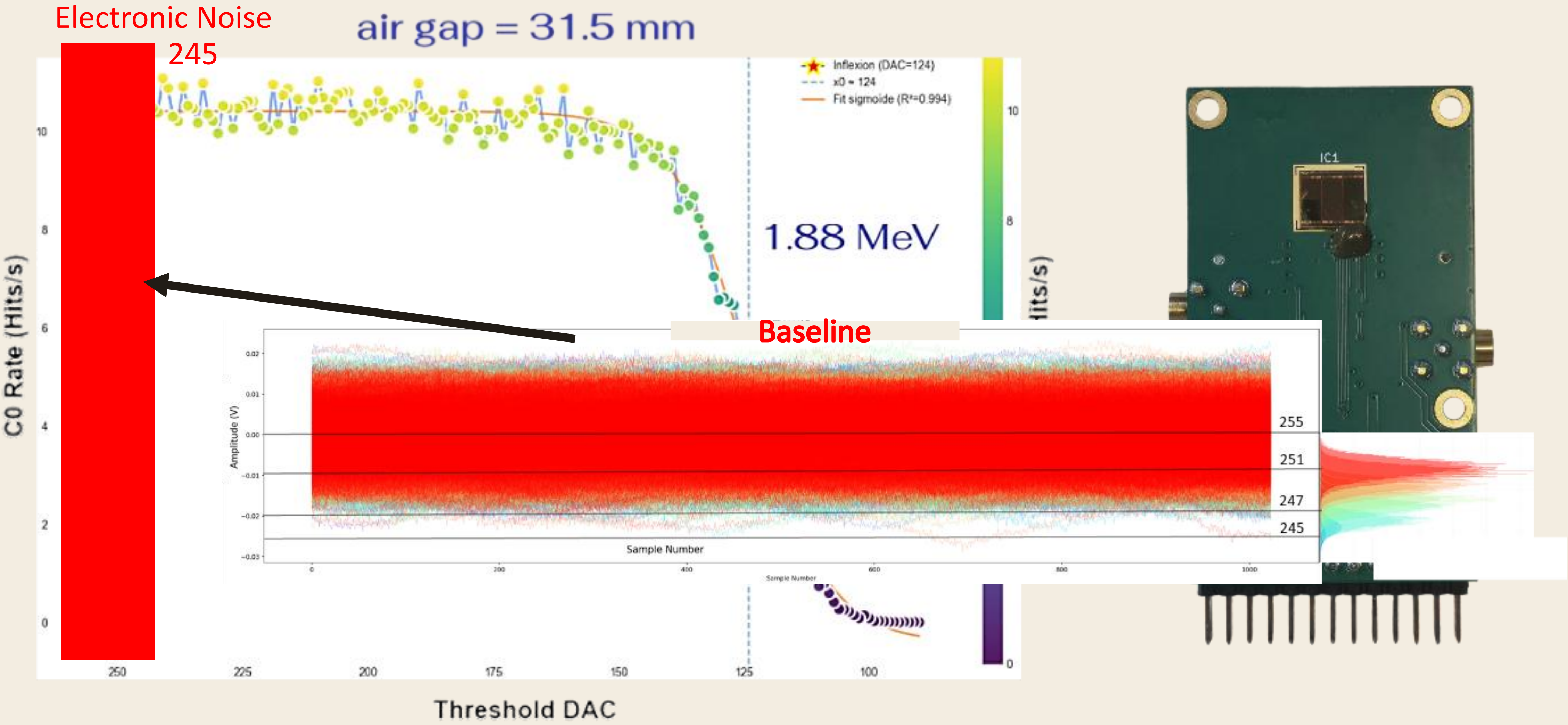

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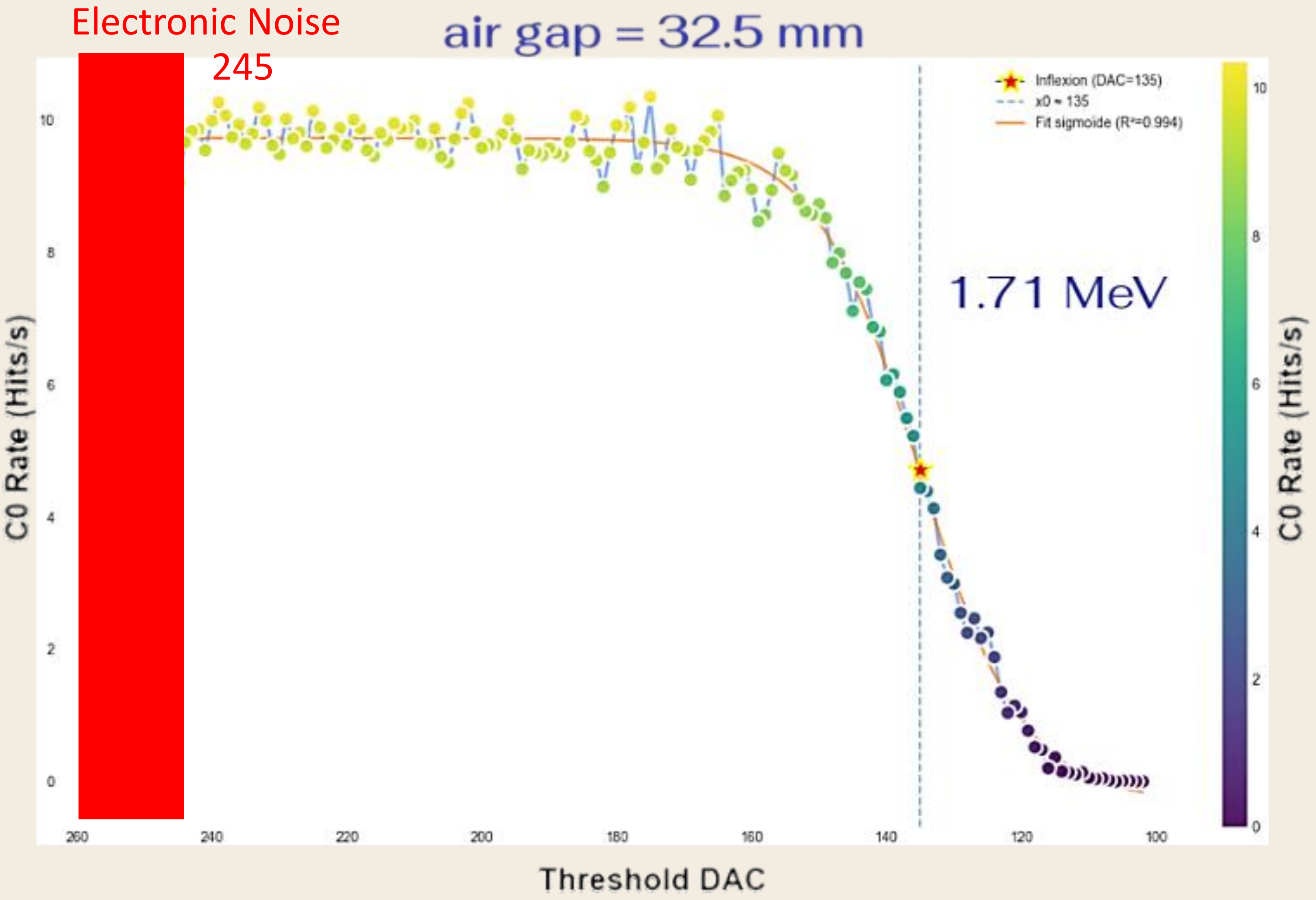

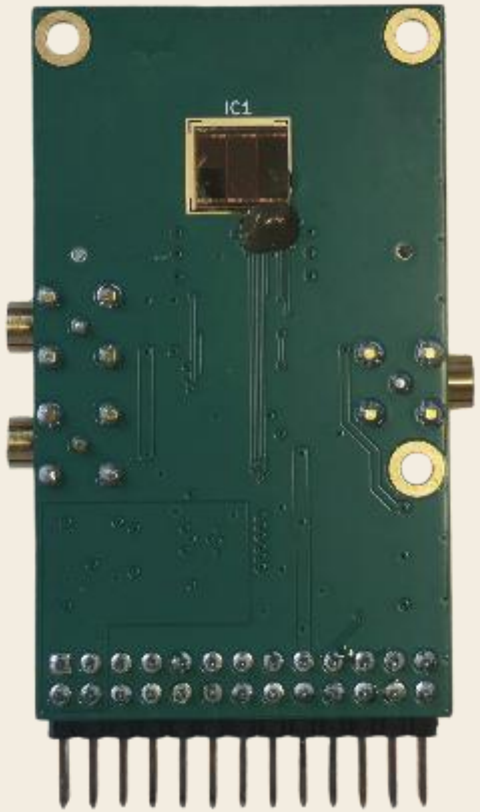

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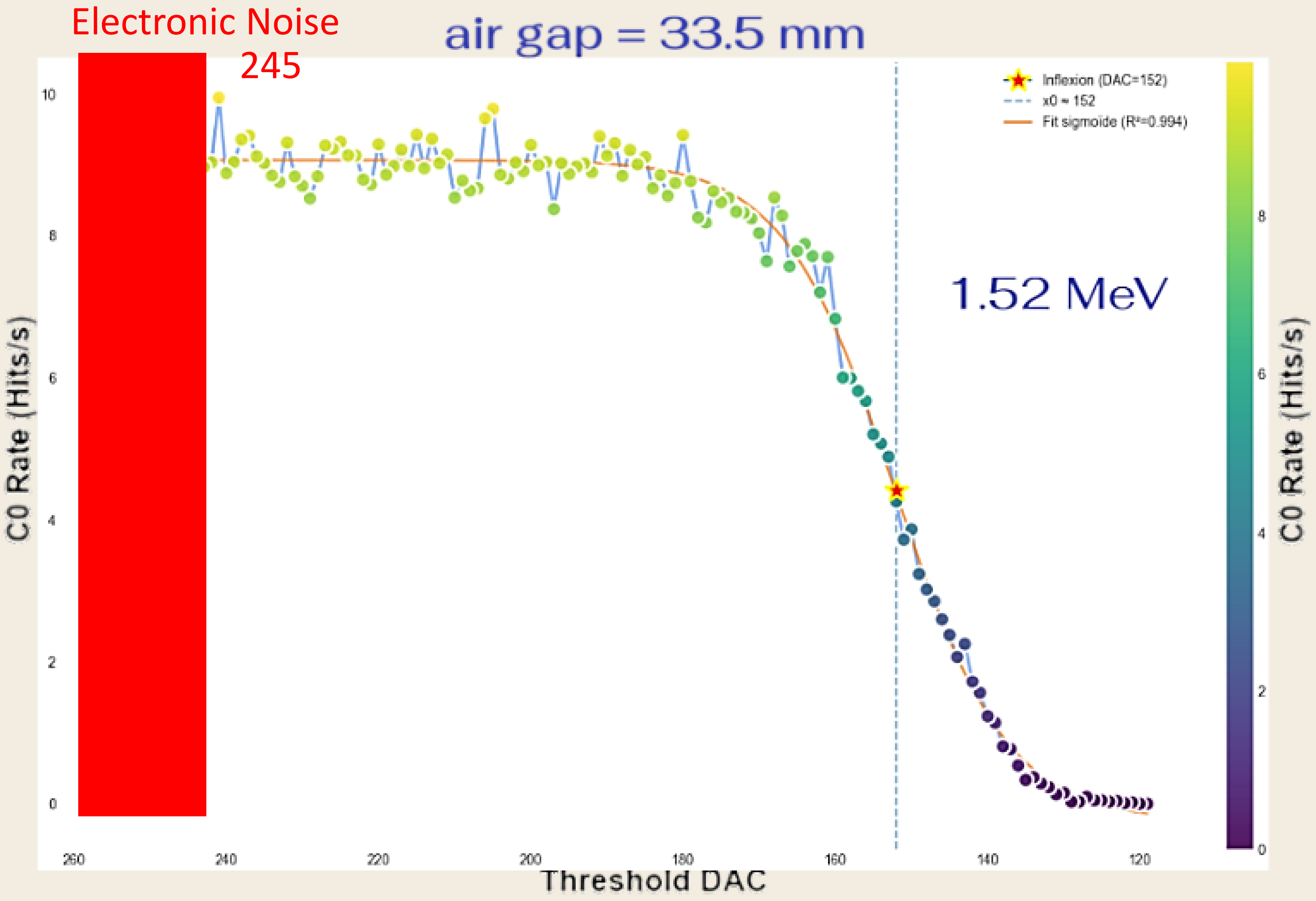

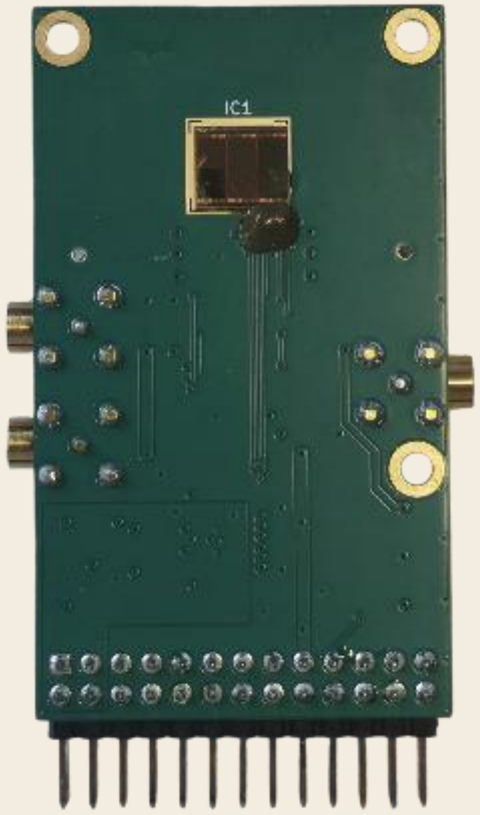

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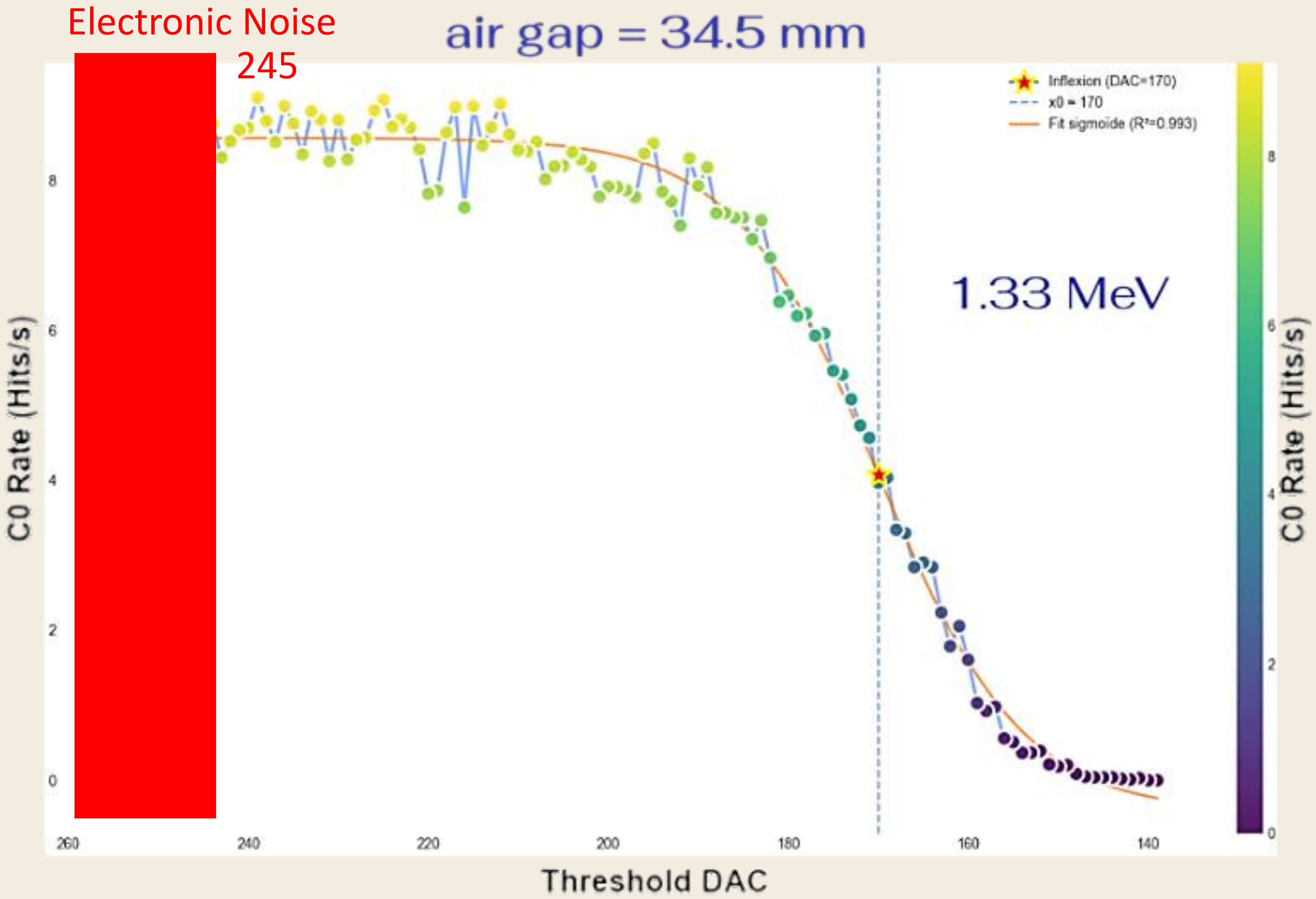

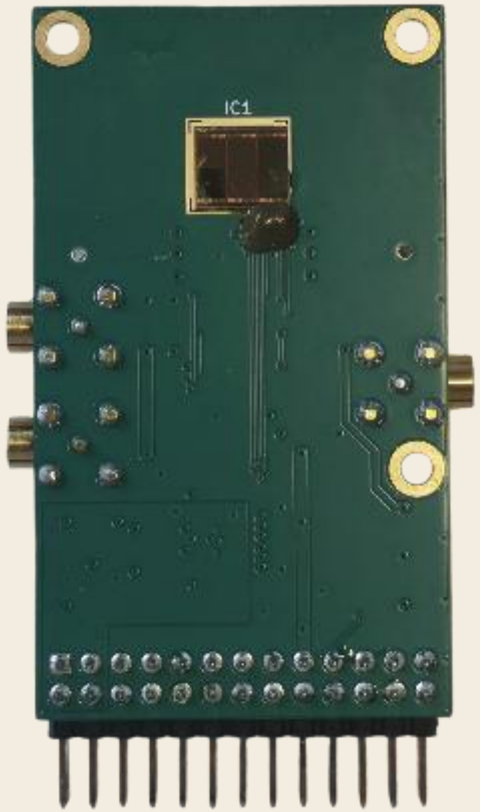

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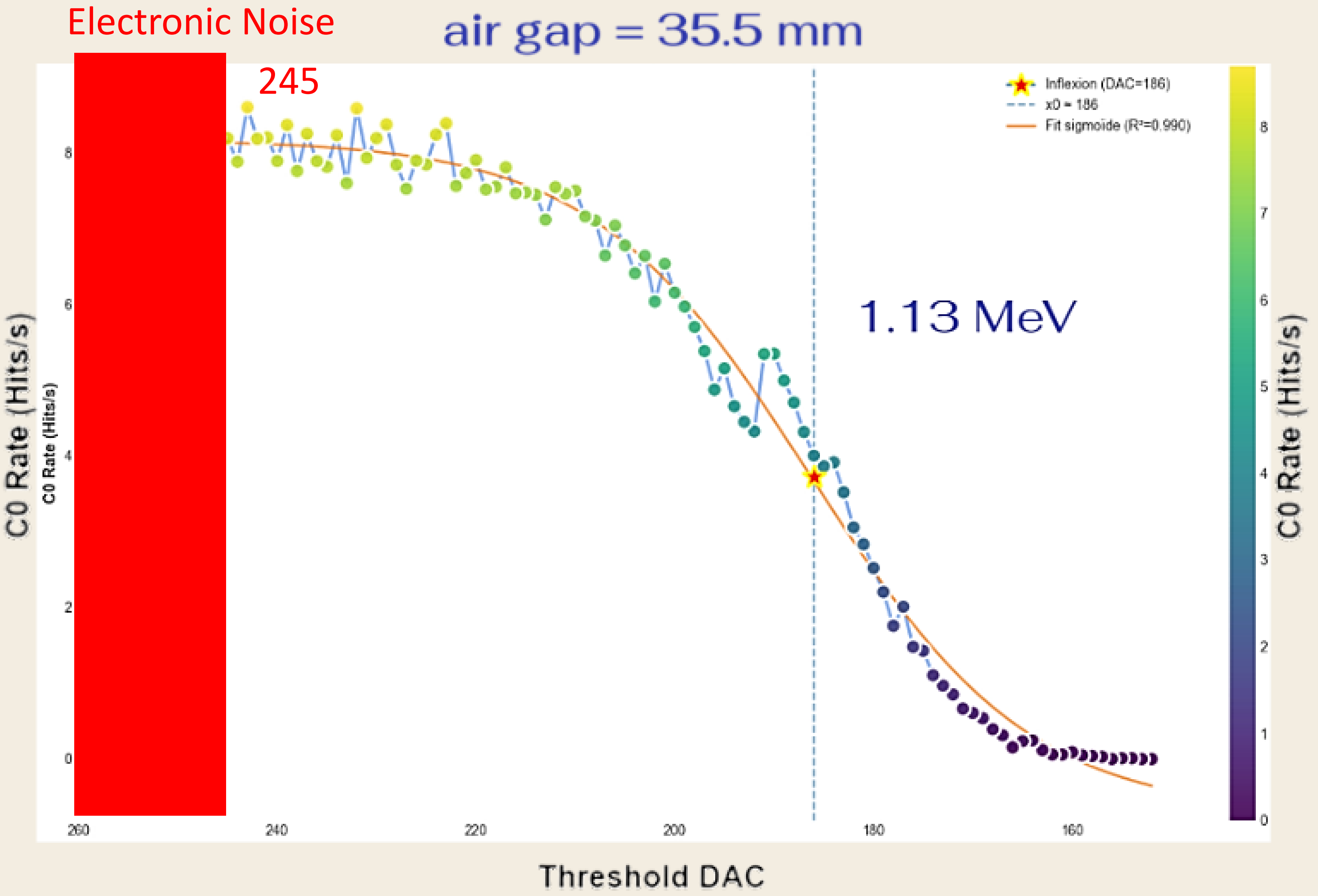

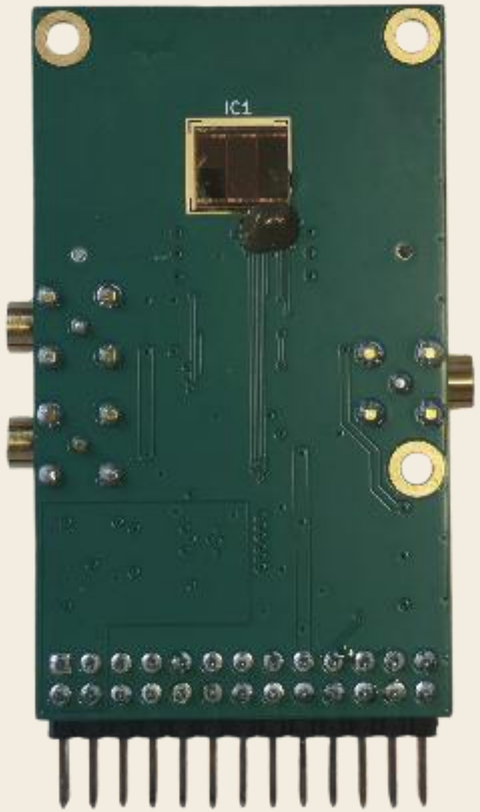

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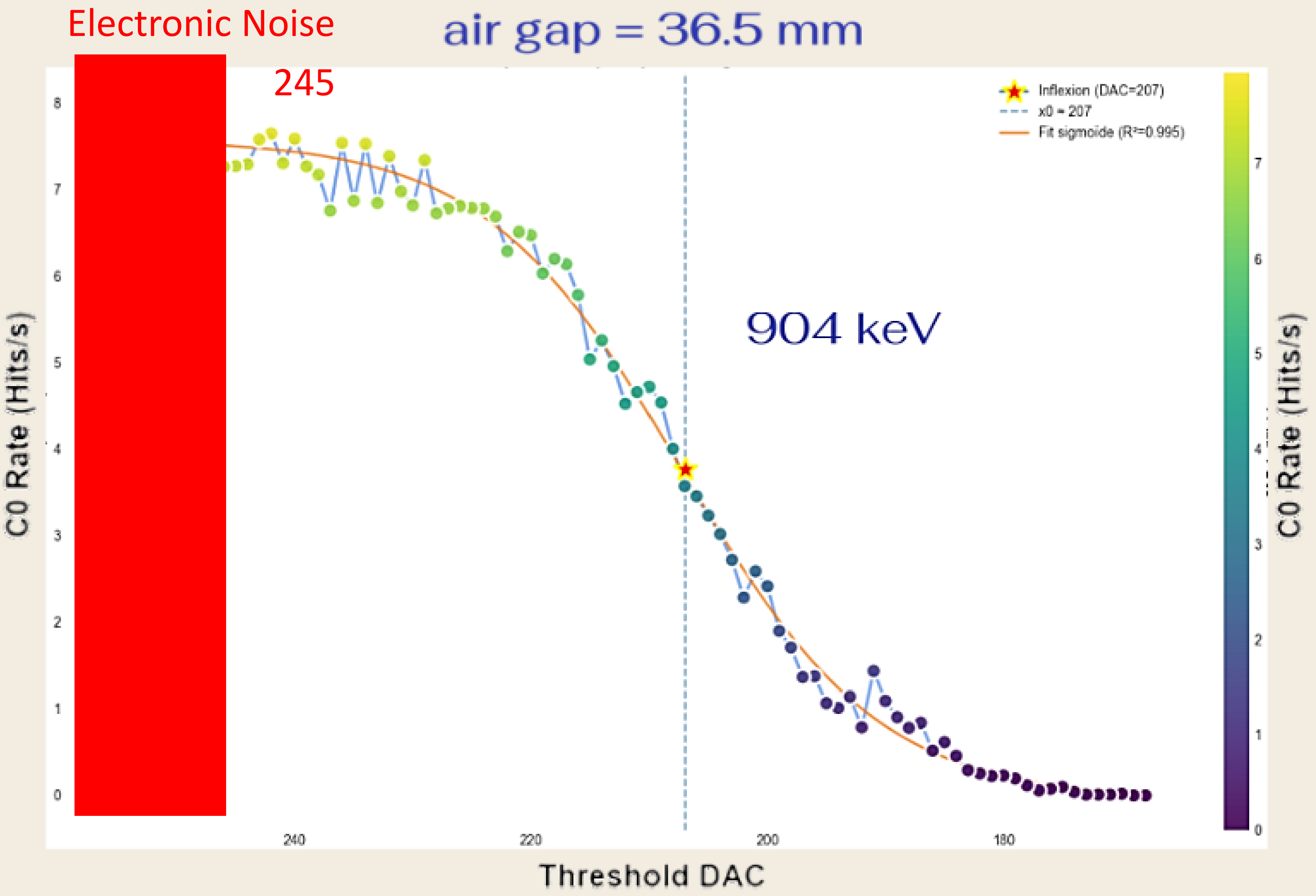

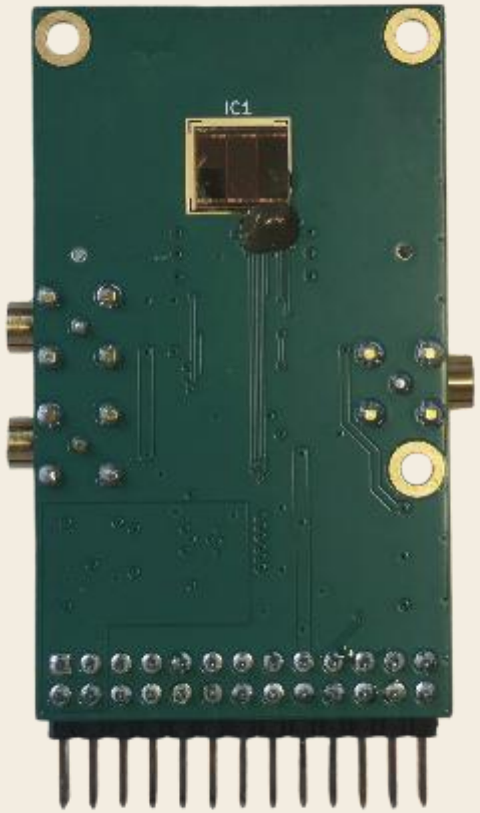

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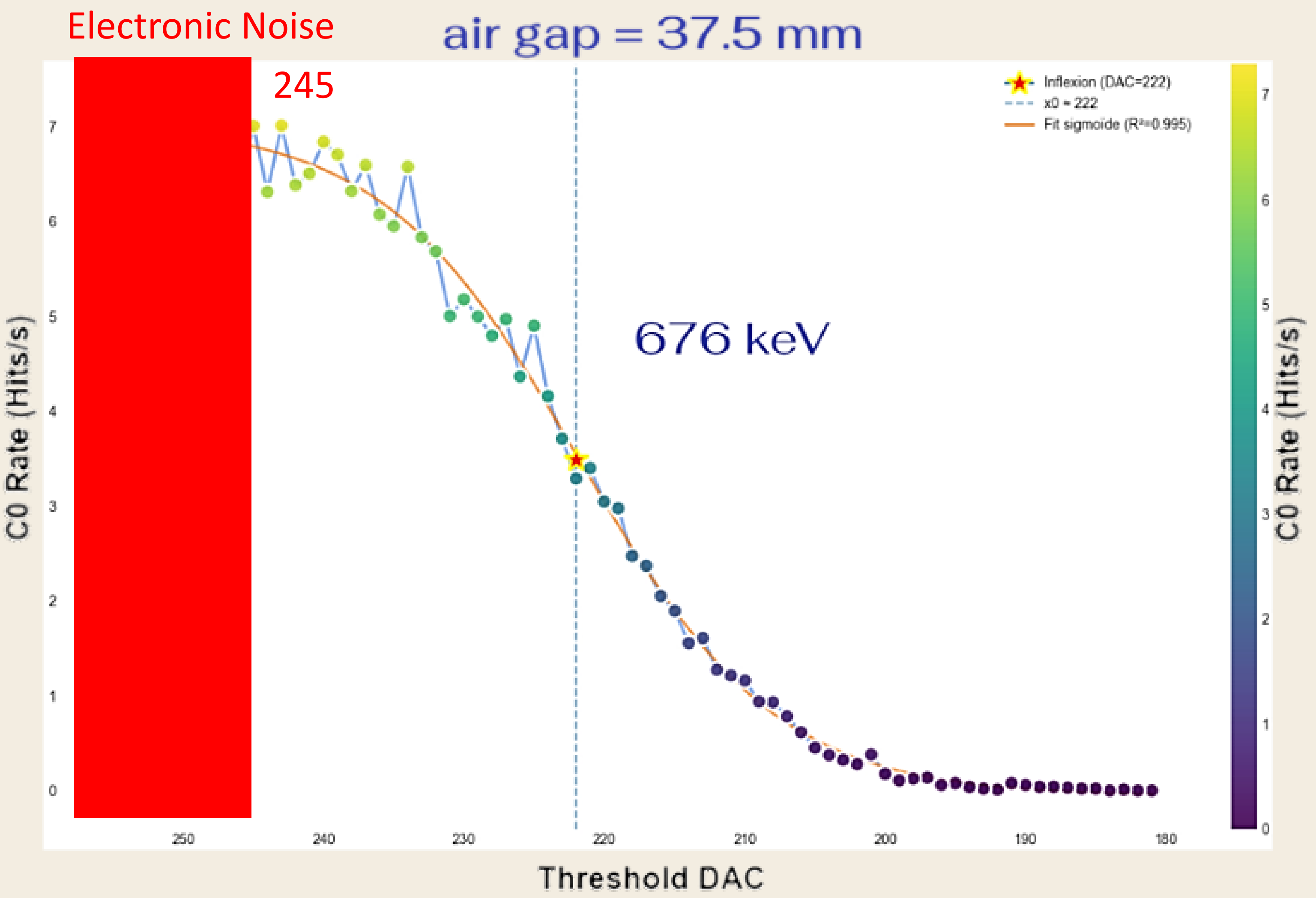
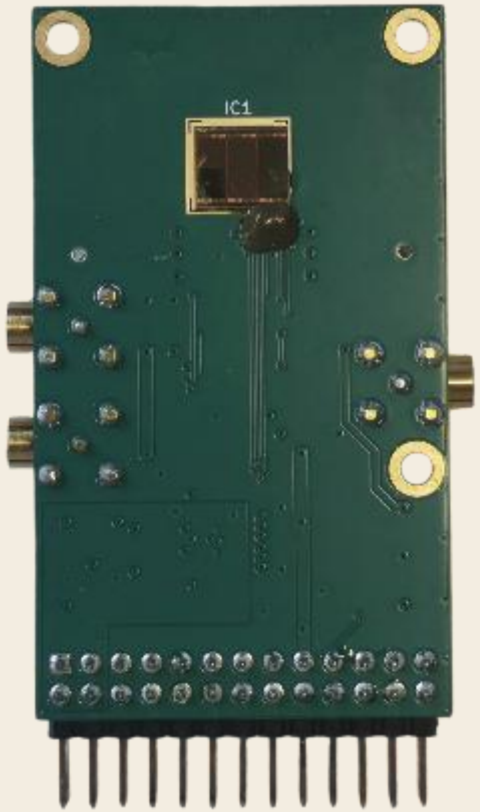
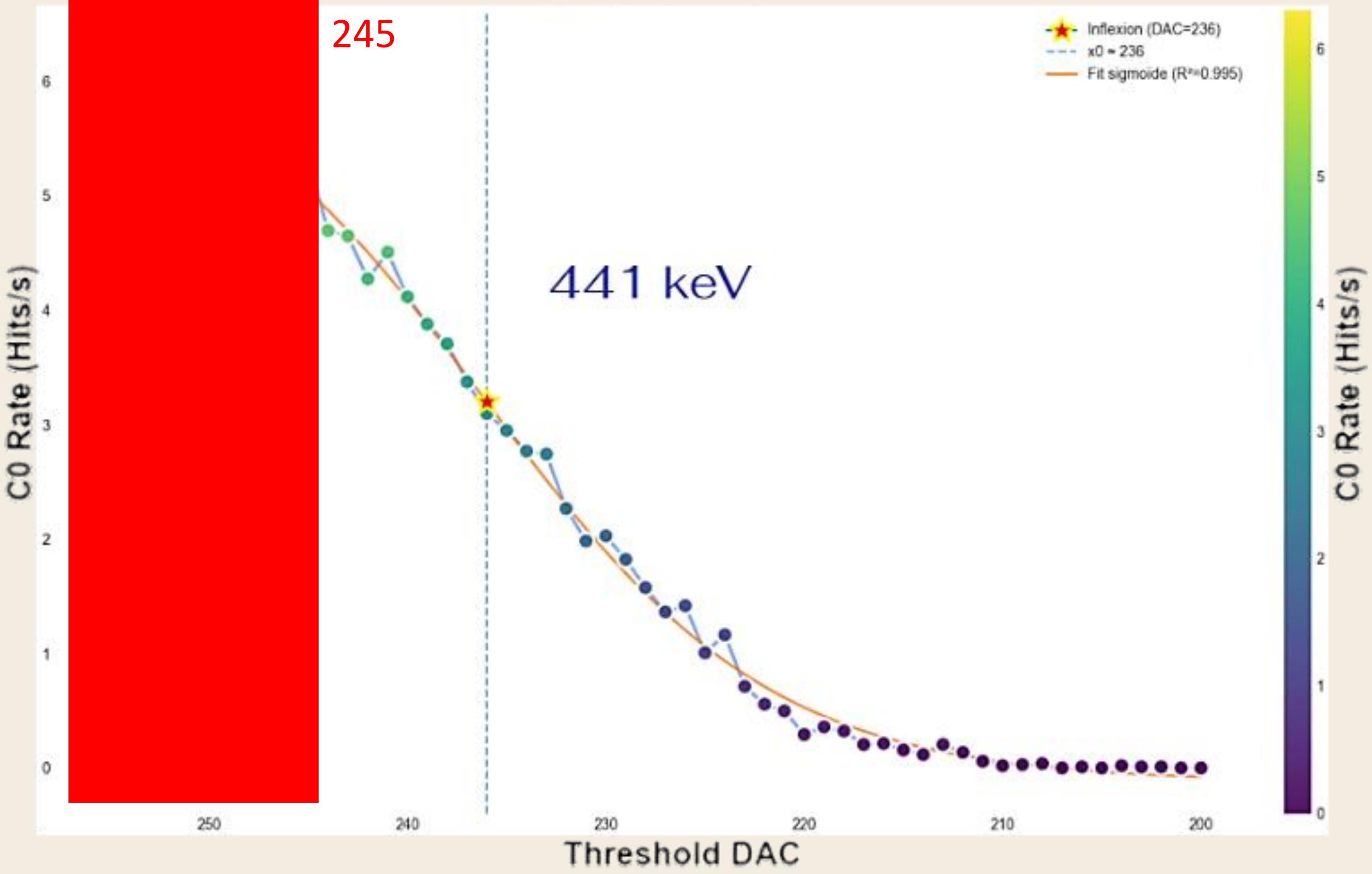


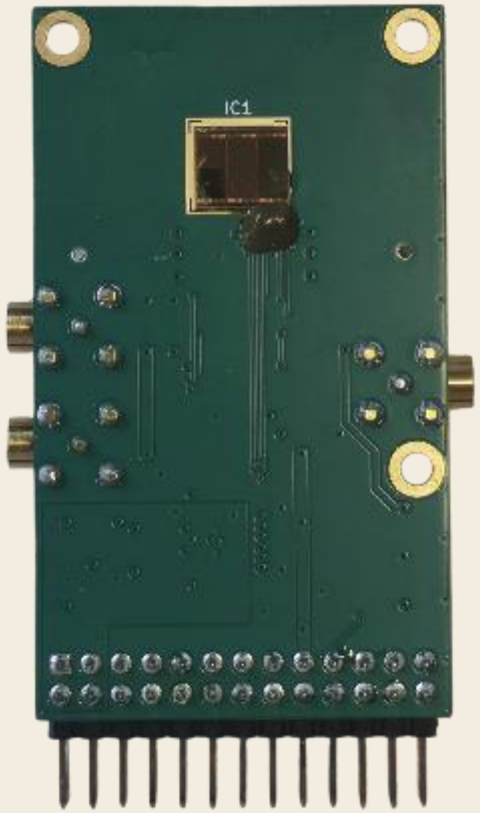


^{241}Am source sensor calibration

Electronic Noise

air gap = 38.5 mm





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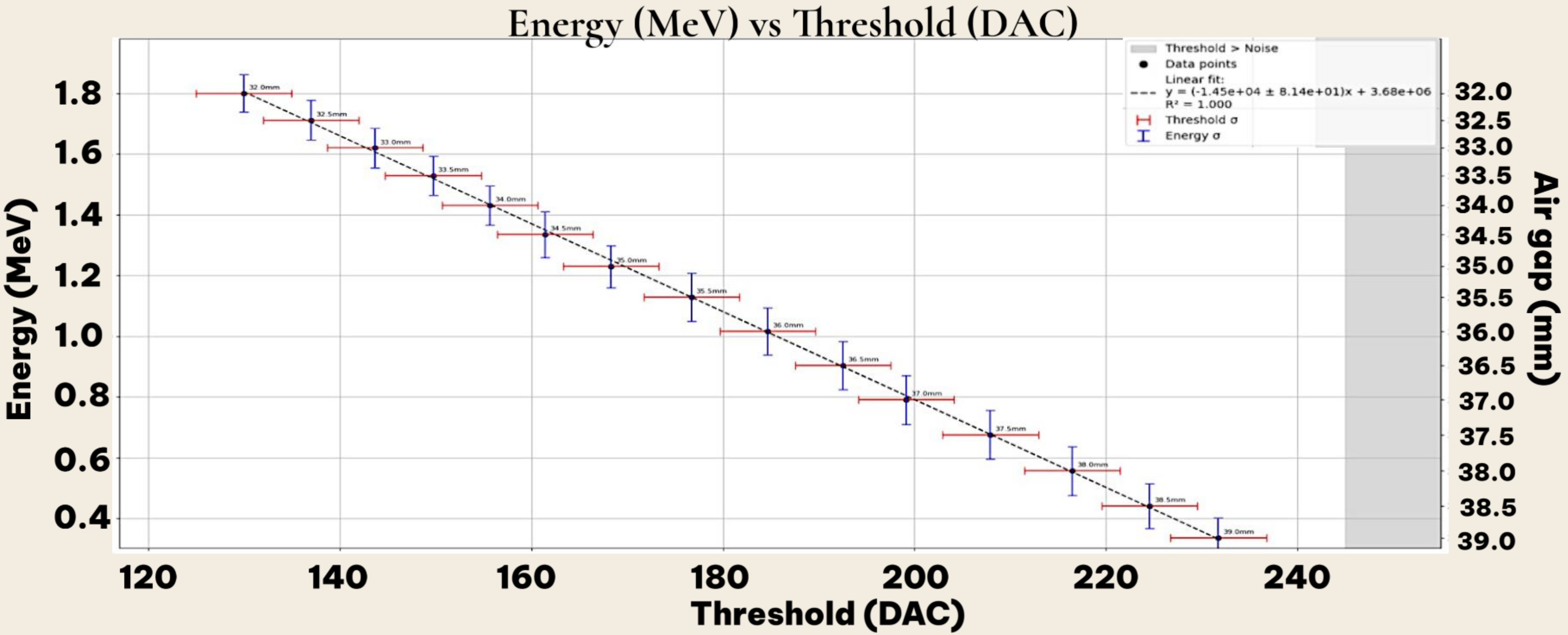

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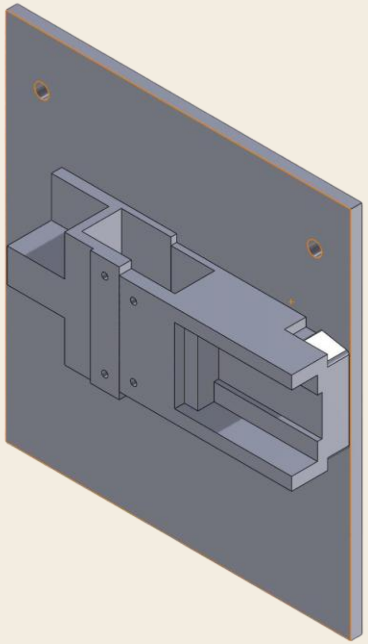
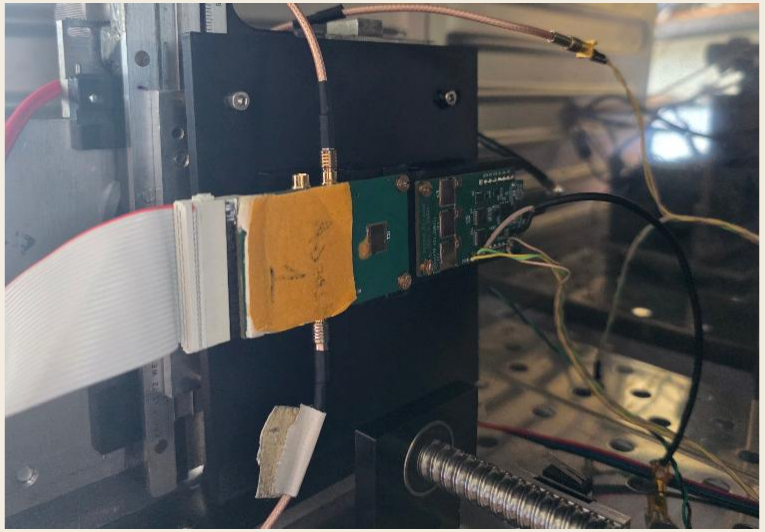
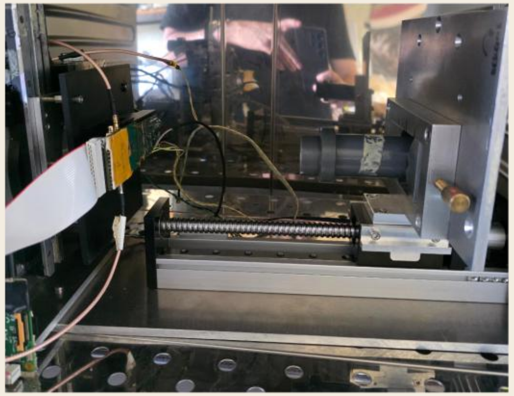
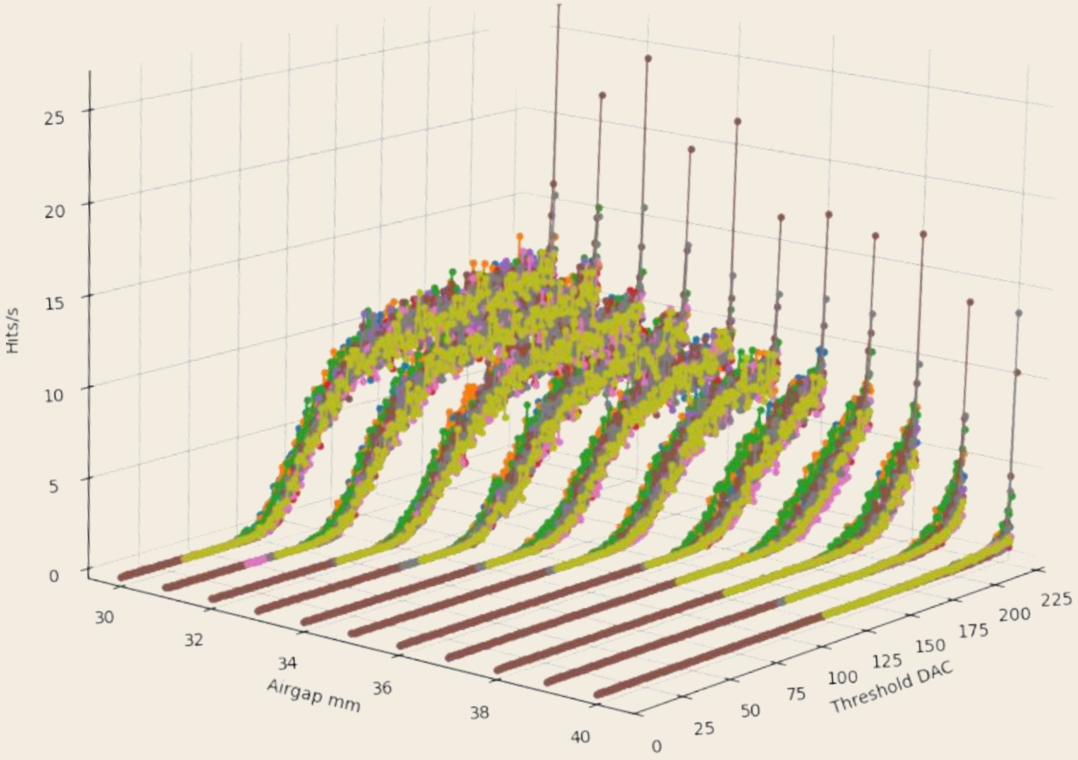
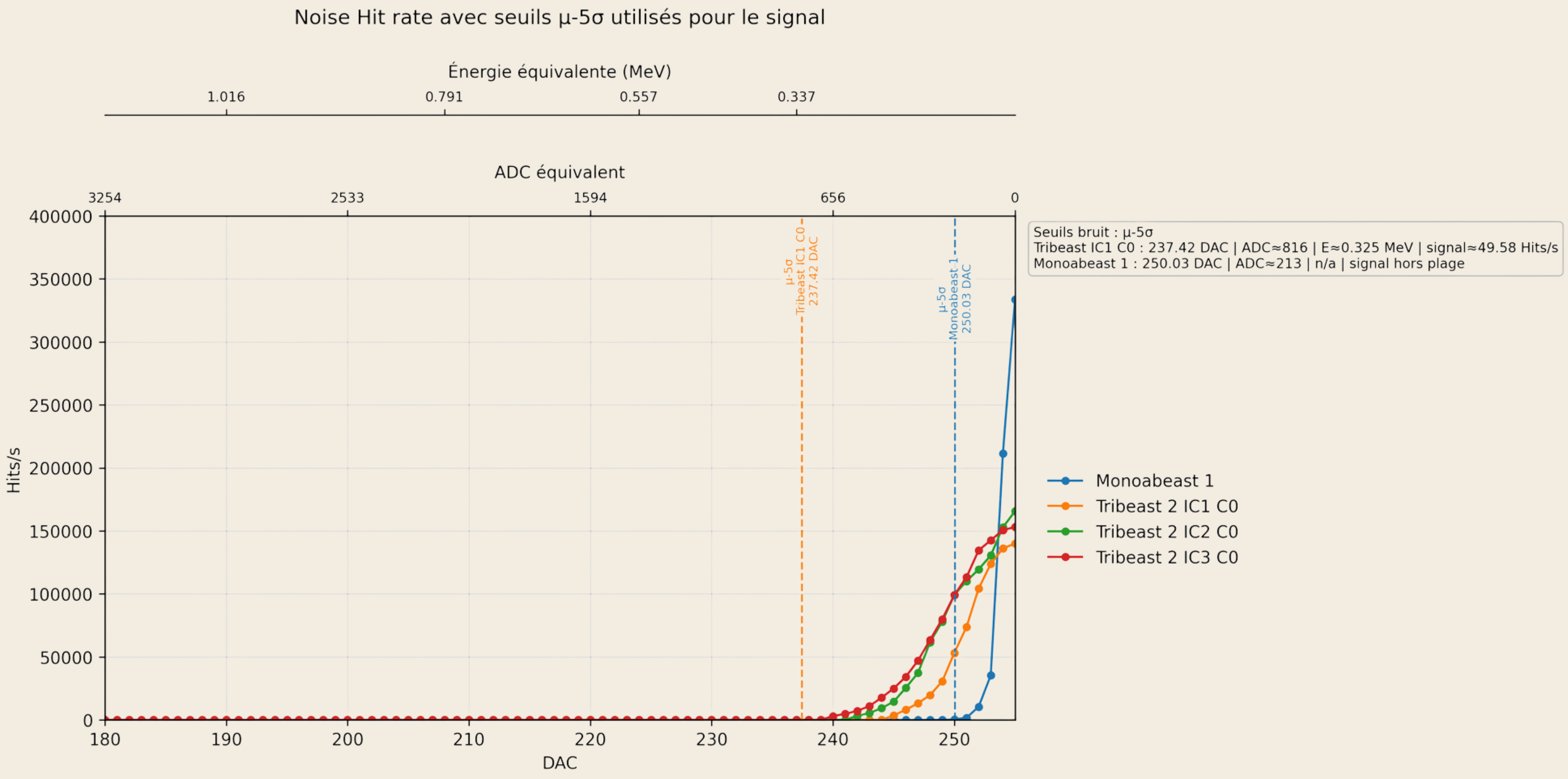






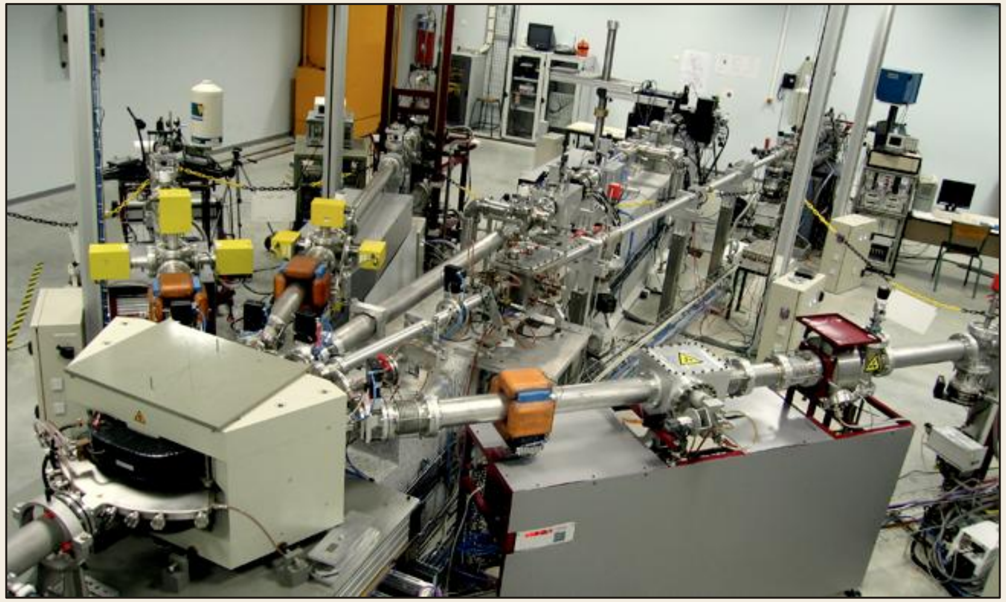


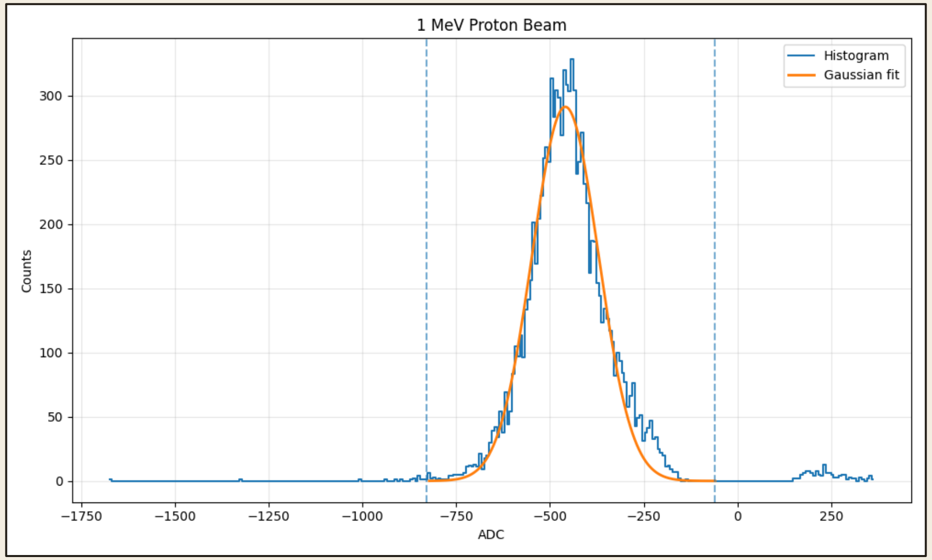
Electronic Noise



AIFIRA facility (Bordeaux-France)

- Micro-beam (< 1 μm) facility with alpha and proton up to 3 MeV
- Scanning of the sensor to test the homogeneity of the response
- Detection efficiency calculations





<u>Detection efficiency</u>:

Fast neutrons (10 MeV)

$\boxed{\varepsilon_{fast} \approx 3 \times 10^{-5}\ \text{hit}/(\text{n.s}^{-1}.\text{cm}^{-2})}$

Thermal neutrons

$\boxed{\varepsilon_{th} \approx 4 \times 10^{-4}\ \text{hit}/(\text{n.s}^{-1}.\text{cm}^{-2})}$

Experiments

General methodology

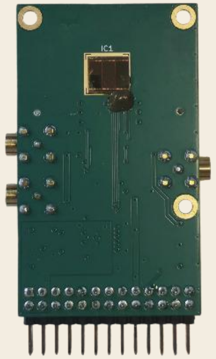
- We have tested the Alphabeast sensors in different environments
- Our main goal is to evaluate the reliability of the measurements by comparing data from :

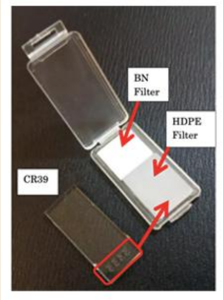
  - **mono-beast** (ADC distributions -> countings for fast/thermal neutrons)

  - **tri-beast** (countings for fast/thermal neutrons)

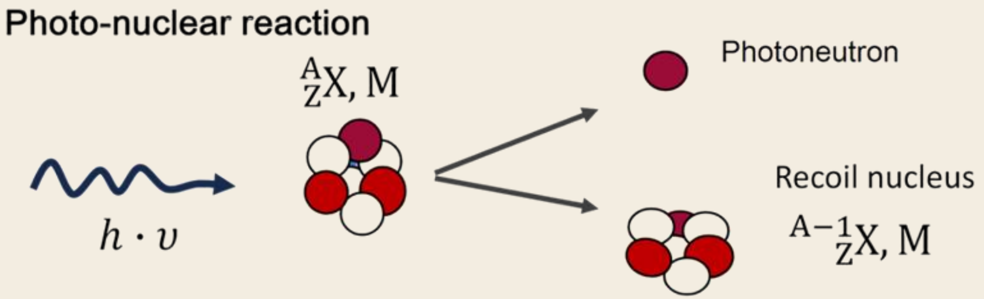
  - **CR-39** (countings for fast/thermal neutrons)

  - **Monte-Carlo simulations** (neutrons fluences)

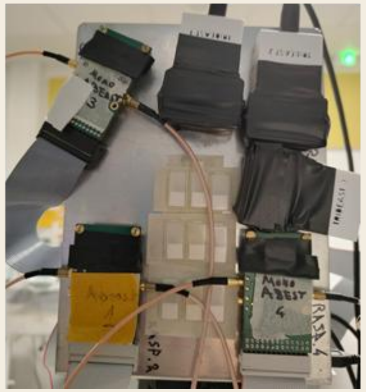


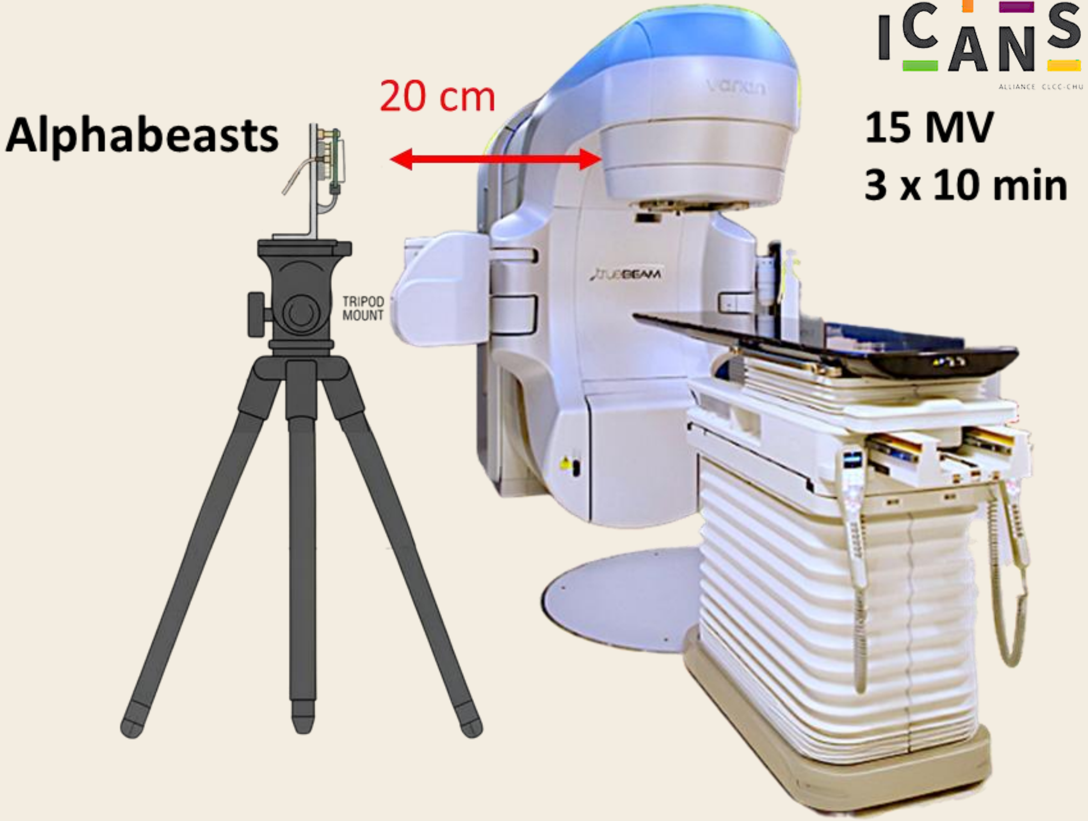


Neutron Monitoring in a Clinical Radiotherapy Environment

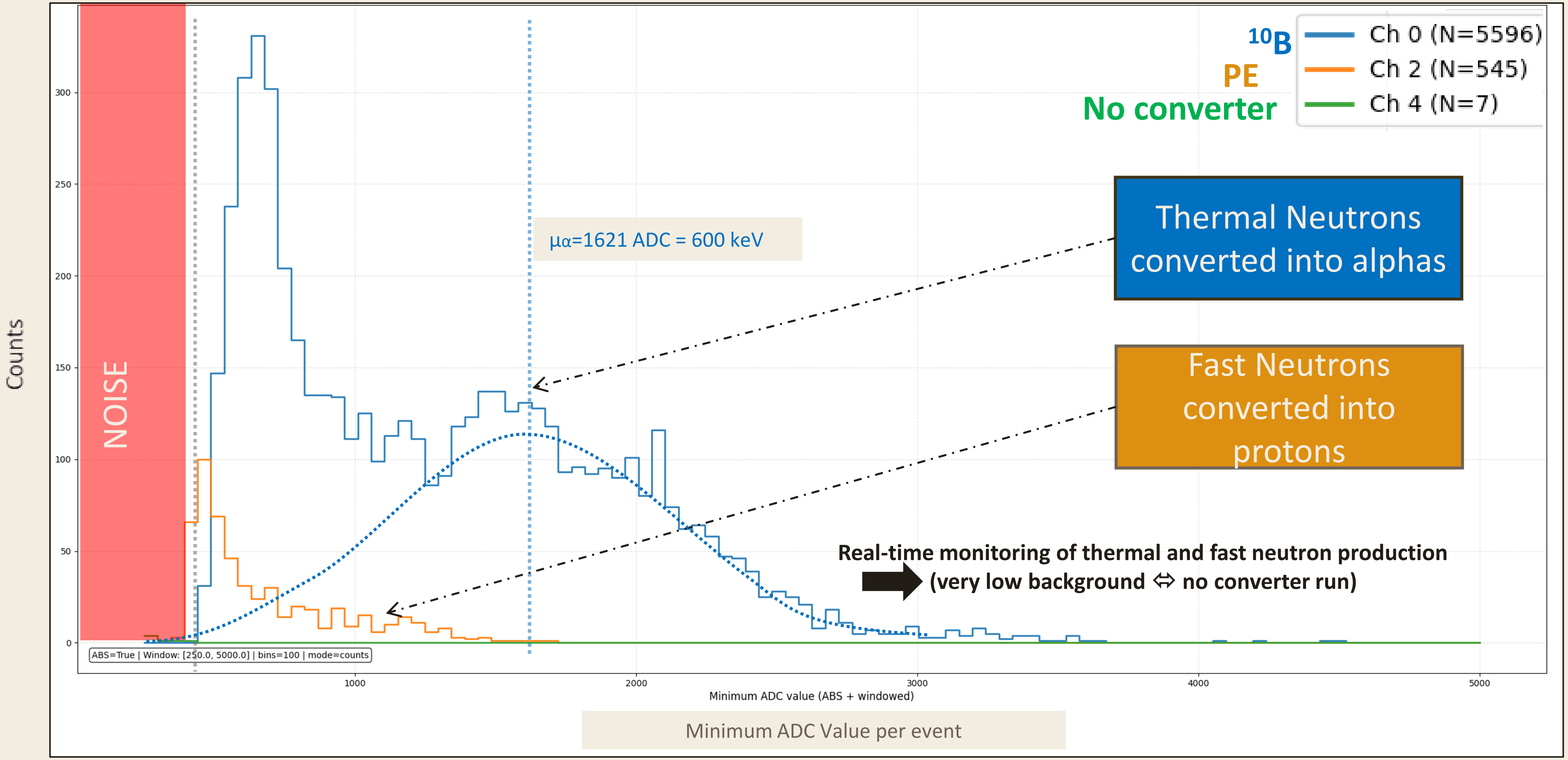


$$^{A}_{Z}X + \gamma \rightarrow ^{A-1}_{Z} X + n$$

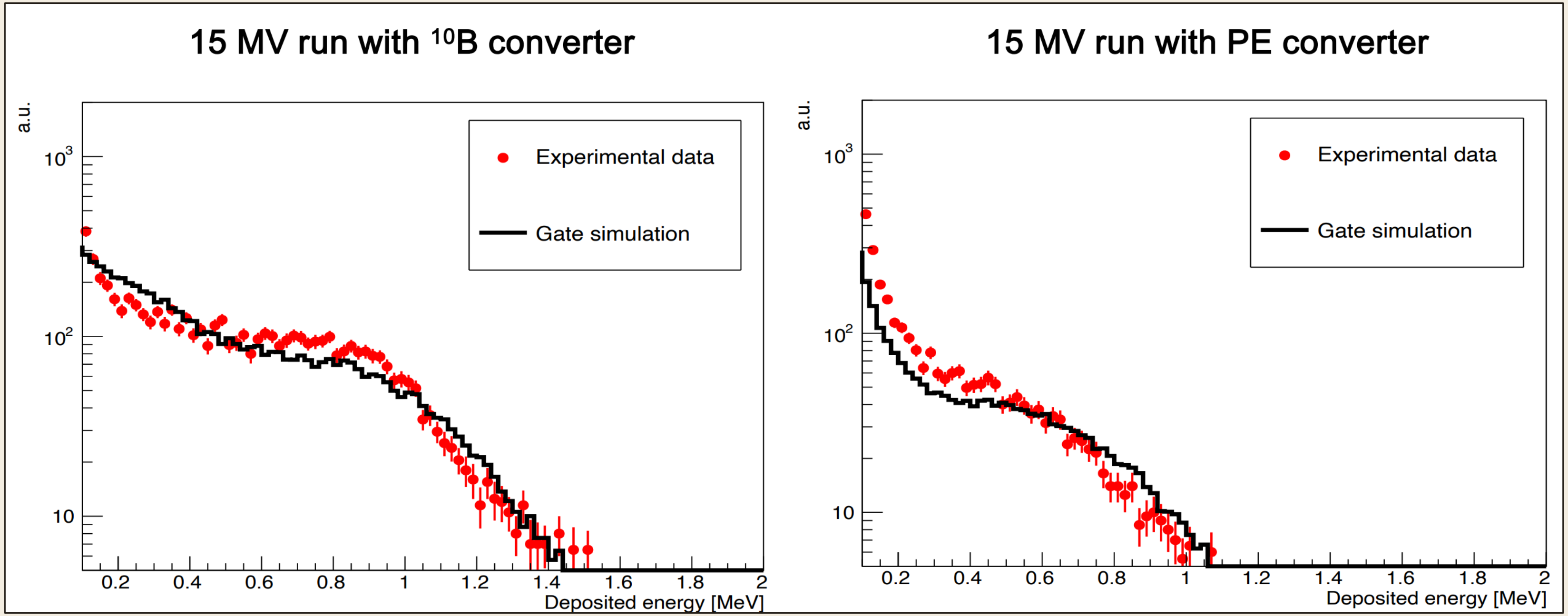




Neutron Energy Deposition Histograms in a Clinical Radiotherapy Environment



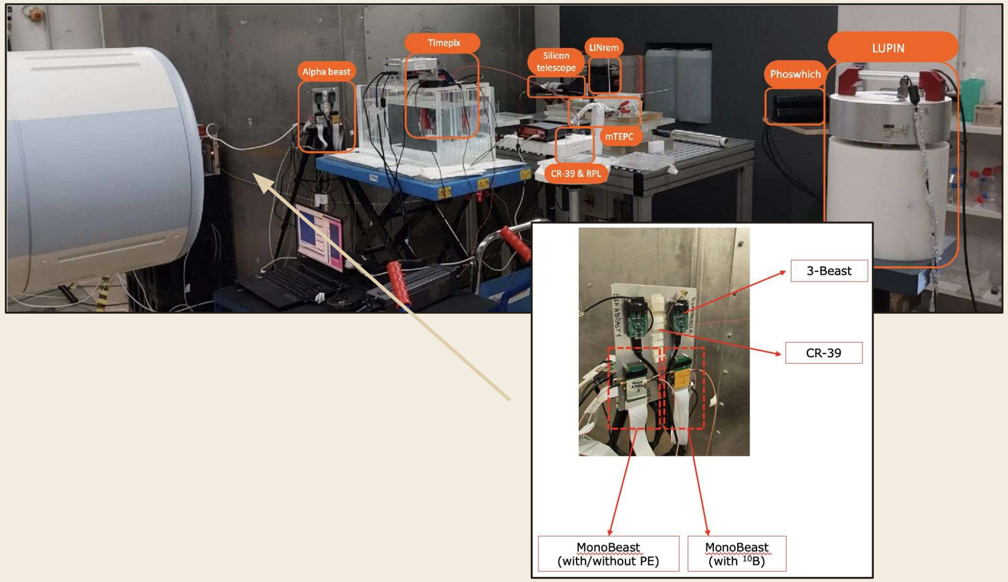
Neutron Monitoring in a Clinical Radiotherapy Environment

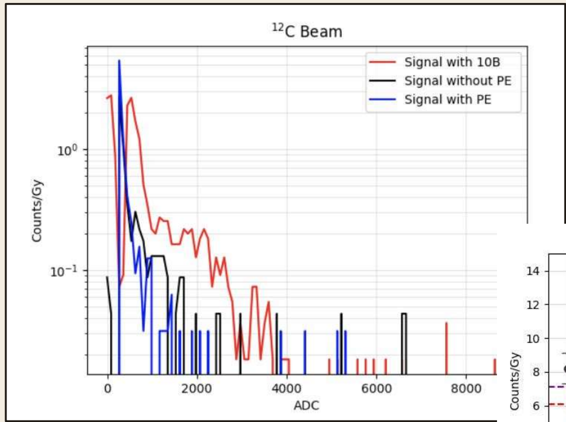


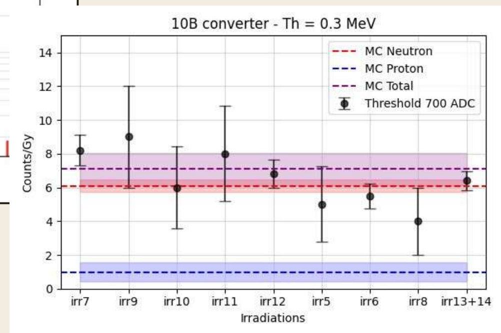
Good agreement between calculated deposited energy and signal distribution for both thermal and fast neutrons

Neutron Monitoring in a hadrontherapy room

- Experiment at HIT in 11/2025 with EURADOS WG9 members
- Inter-comparison of 8 neutron detectors (C and O beams)



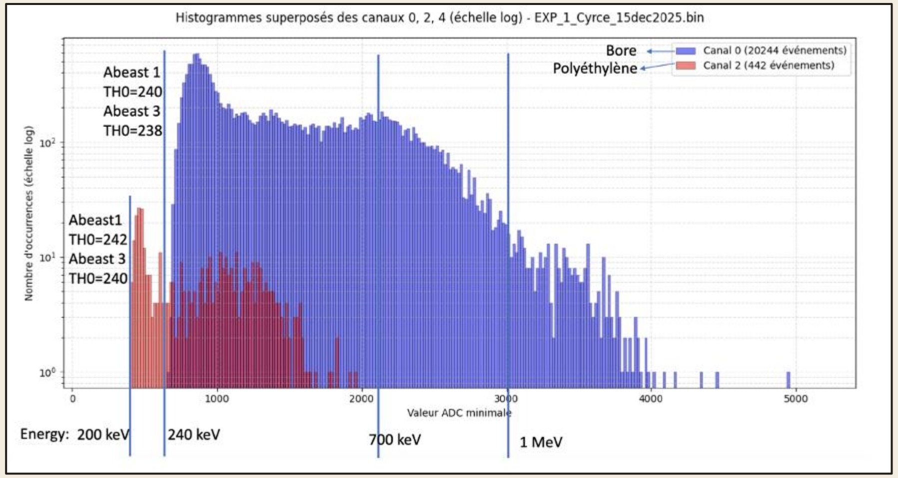


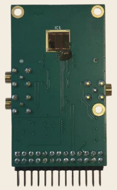


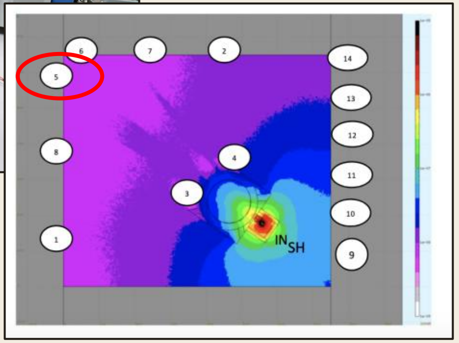
Real-time monitoring of thermal neutron production for different irradiation conditions
Inability to measure the fast neutrons component (contamination of secondary protons)

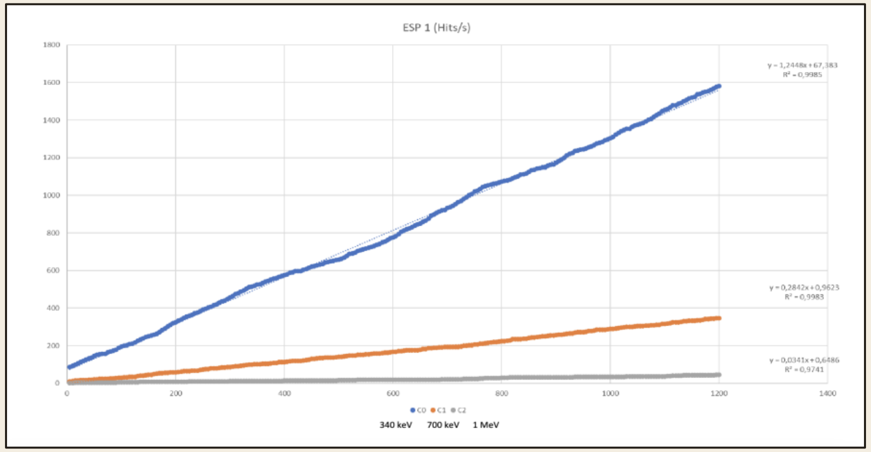
Neutron Monitoring in a cyclotron casemate

- Experiment at CYRCé cyclotron (IPHC)
- Neutron fluence monitoring for activation calculations







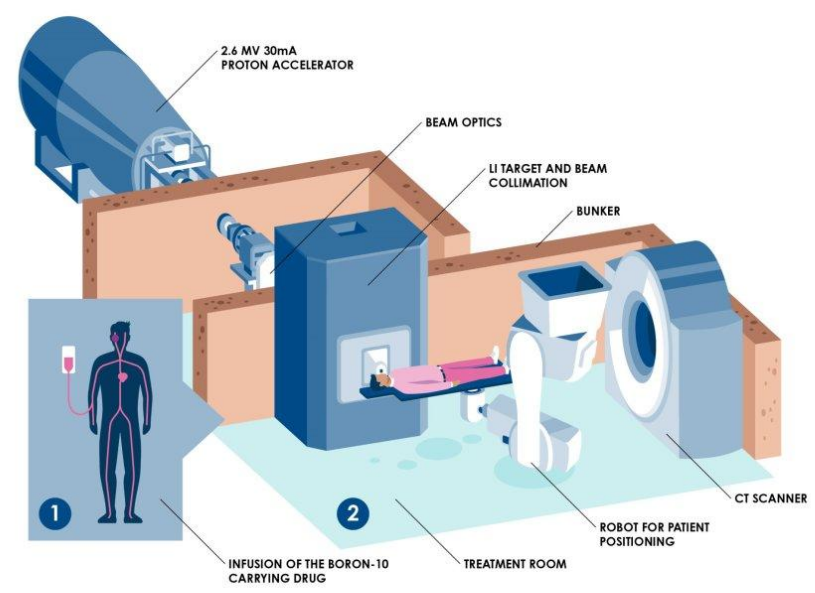


Real-time monitoring of thermal neutron production during cyclotron operation
Unexpected secondary protons contaminations (on-going MC calculations)

Upcoming Experiment

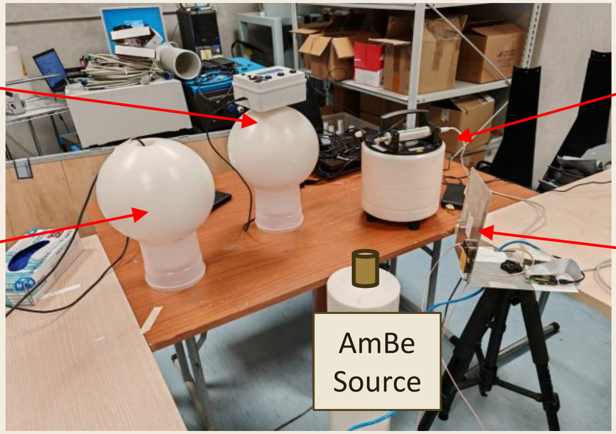
CNAO Experiment in collaboration with Radioprotection team

Boron-Neutron Capture Therapy (BNCT)



- CNAO Radioprotection team is looking for the a neutron detector for neutron ambient dosimetry inside the BNCT treatment rooms.
- Their current system saturates in these conditions
- AlphaBeast has a higher saturation limit → they contacted us to start some tests to check its feasibility with their neutron sources
- Next experiments will include testing in experimental beam room and possibly in a thermal neutron reactor

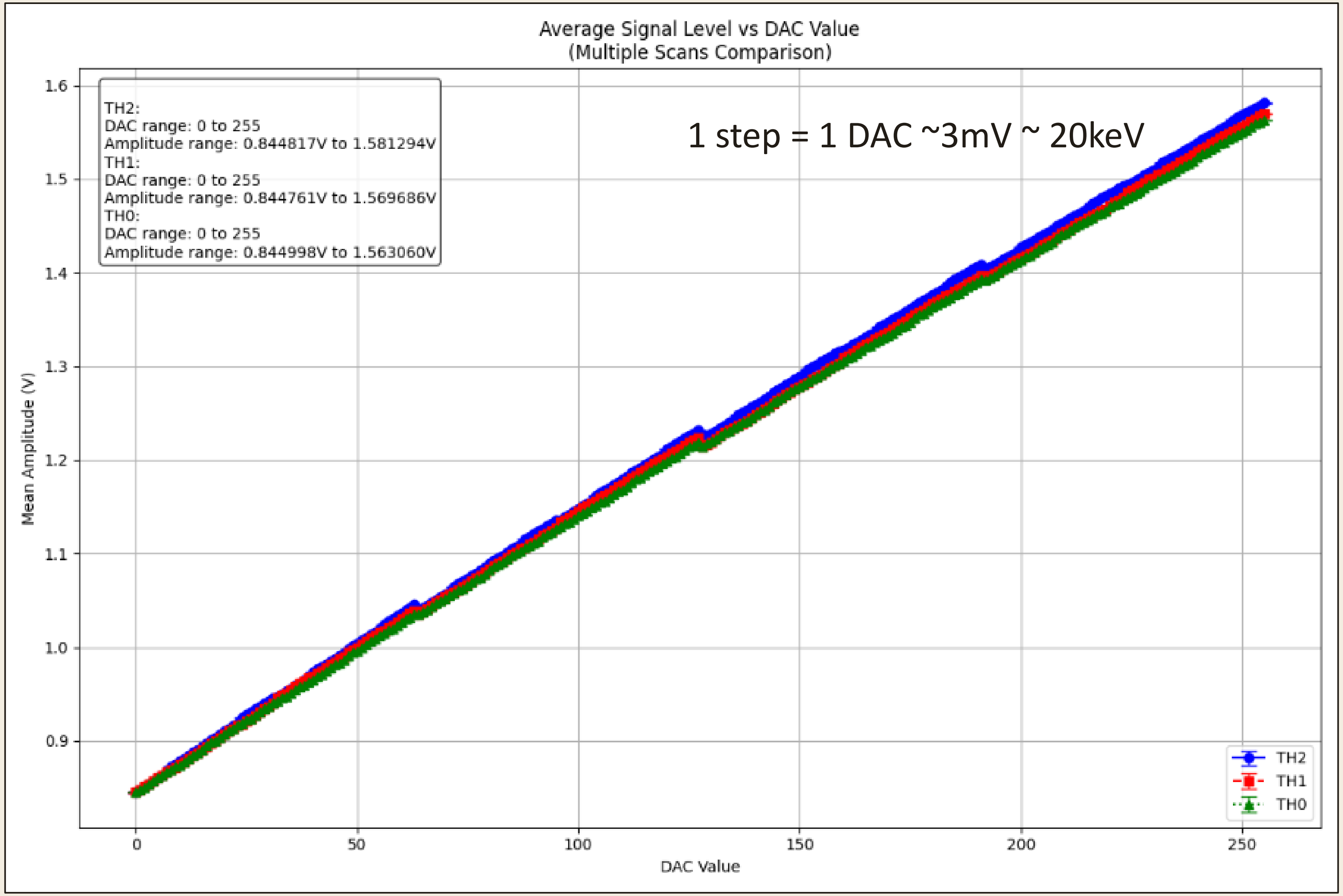
Preliminary test



Merci

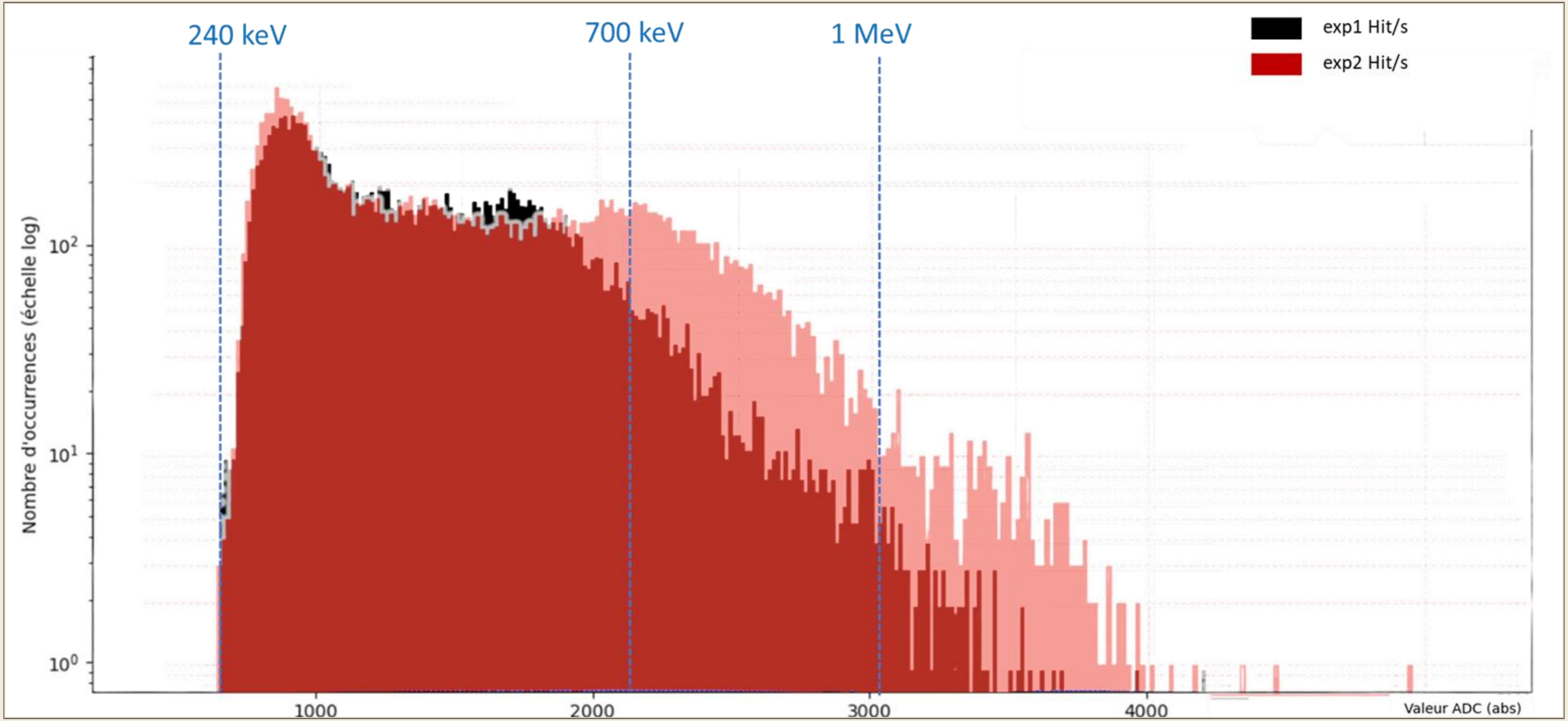
Thank you for your attention

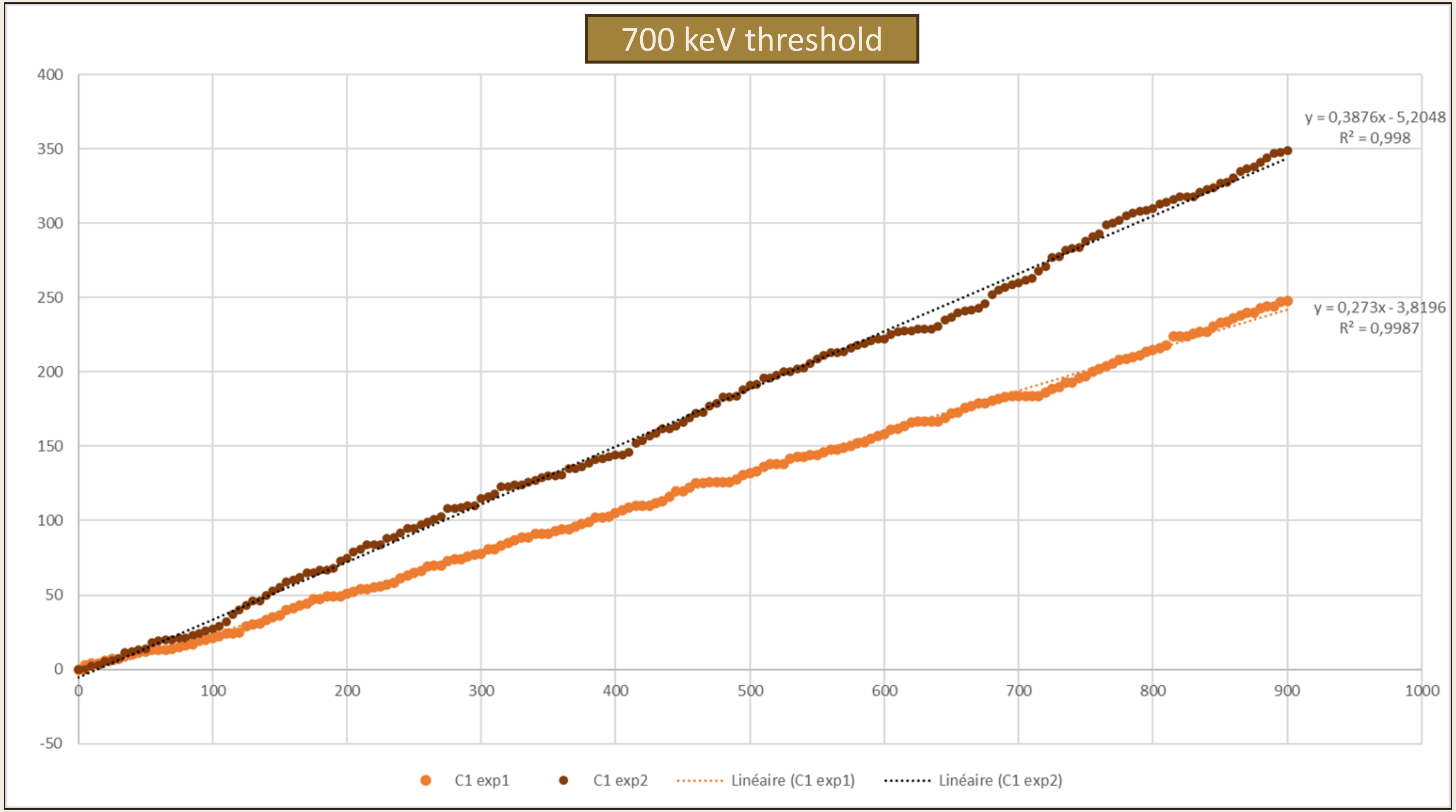
Annexes



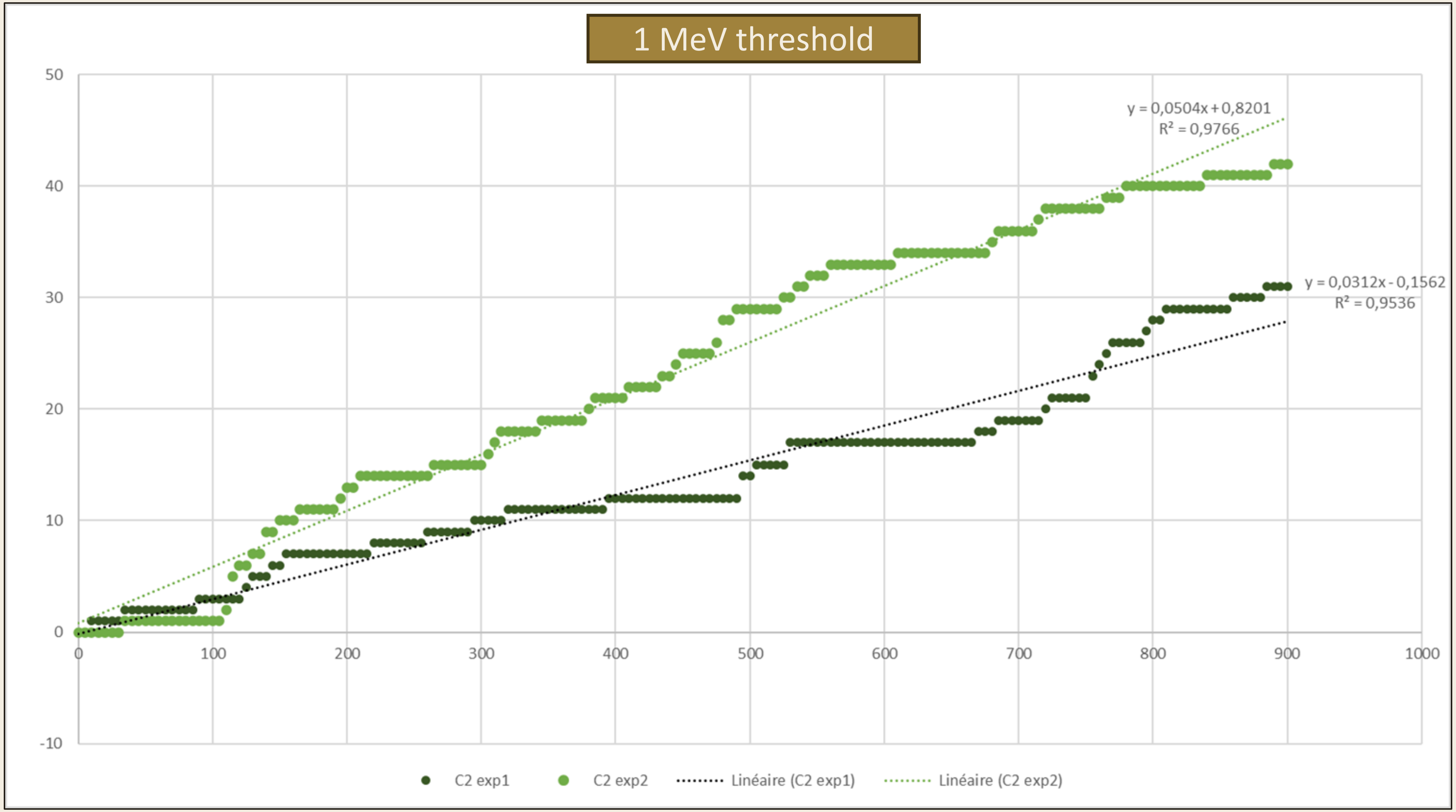
Average Signal Level vs DAC Value
(Multiple Scans Comparison)
TH2:
DAC range: 0 to 255
Amplitude range: 0.844817V to 1.581294V
TH1:
DAC range: 0 to 255
Amplitude range: 0.844761V to 1.569686V
TH0:
DAC range: 0 to 255
Amplitude range: 0.844998V to 1.563060V
1 step = 1 DAC ~3mV ~ 20keV
Mean Amplitude (V)
DAC Value
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0
50
100
150
200
250
TH2
TH1
TH0

Counters & Analog





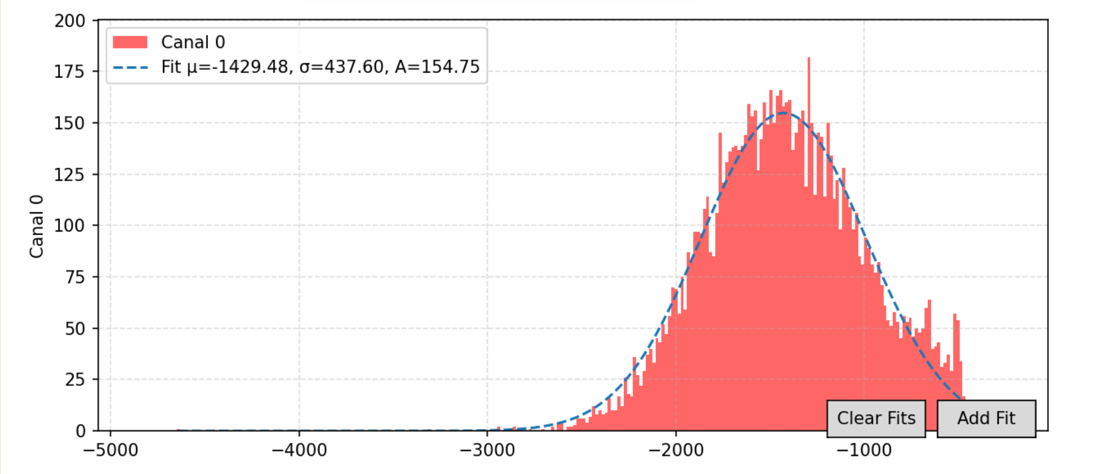
700 keV threshold
y = 0,3876x - 5,2048
R² = 0,998
y = 0,273x - 3,8196
R² = 0,9987
400
350
300
250
200
150
100
50
0
-50
0
100
200
300
400
500
600
700
800
900
1000
C1 exp1
C1 exp2
Linéaire (C1 exp1)
Linéaire (C1 exp2)



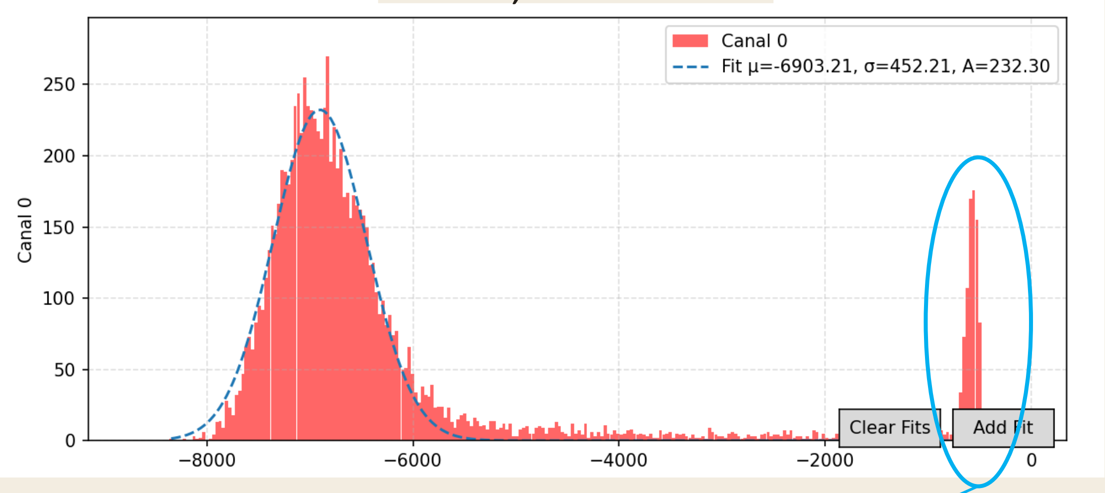
1 MeV threshold
y = 0,0504x + 0,8201
R² = 0,9766
y = 0,0312x - 0,1562
R² = 0,9536
50
40
30
20
10
0
-10
0
100
200
300
400
500
600
700
800
900
1000
C2 exp1
C2 exp2
Linéaire (C2 exp1)
Linéaire (C2 exp2)

High Amplitudes Pile up effect

38 mm air gap
557keV

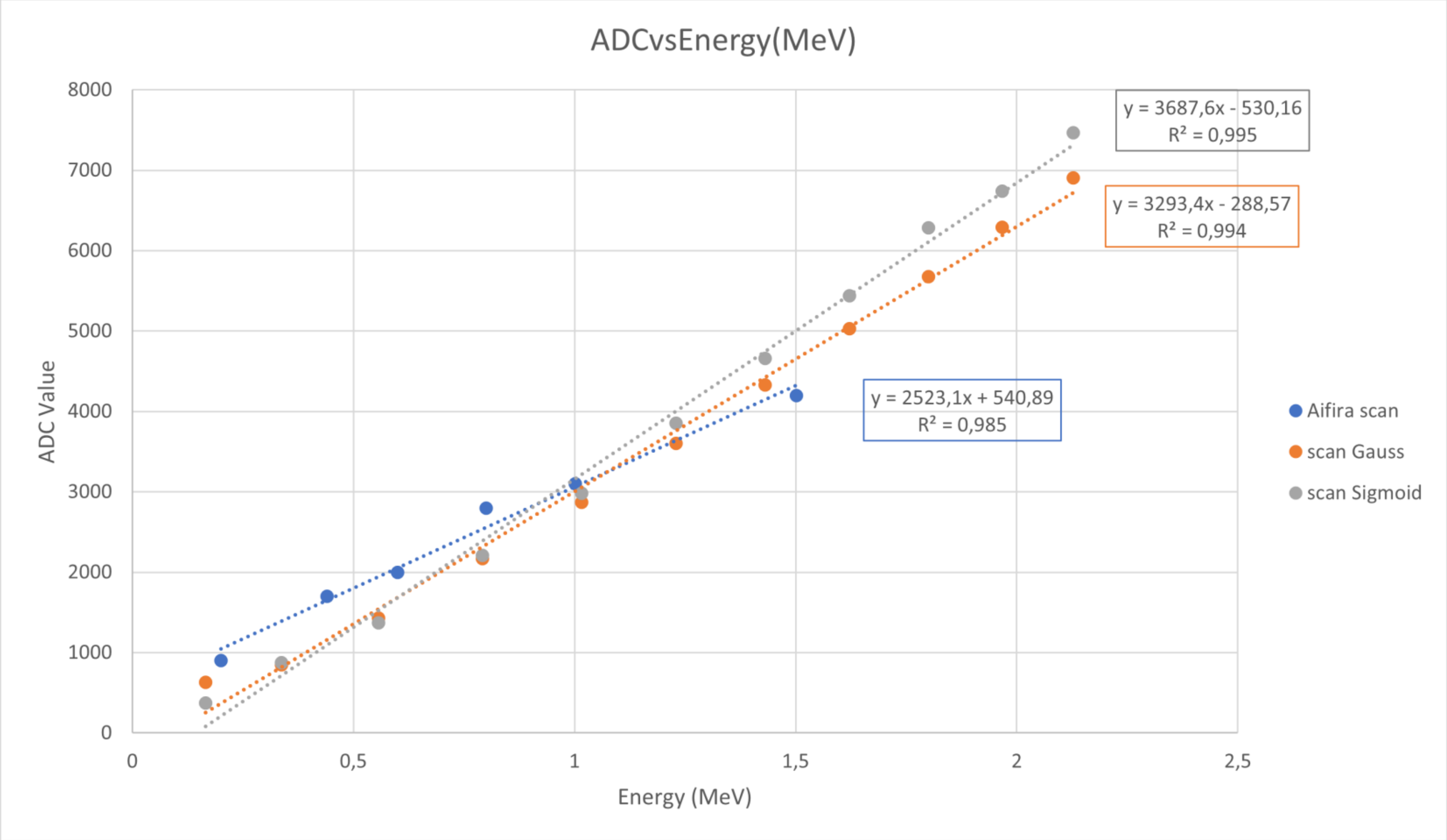


30 mm air gap
2,13MeV



PILE-UP INDUCED BASELINE SHIFT

Comparing 2 different methods of calibration



Alphabeast Energy Resolution