Digital Signal Processing for Nuclear Physics Experiments

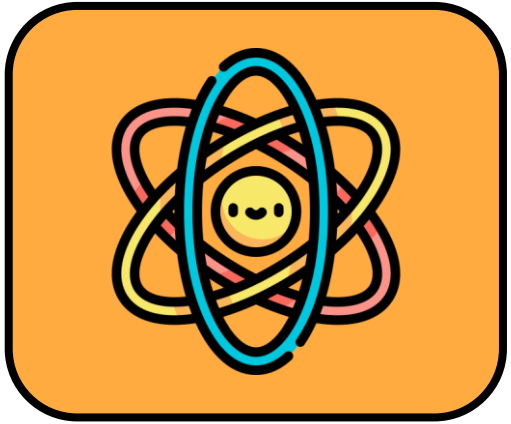
GDED

Sara-Rebeca Ban

Young Researchers & Young Engineers Days - 2025

26.02.2025

Table of contents

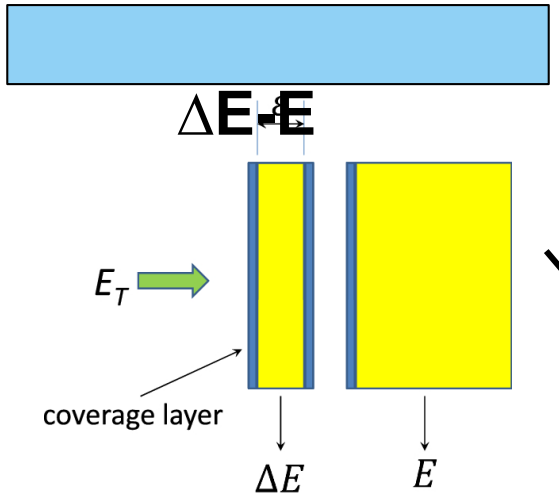


- energy
- timing
- type of the particle

HPGe

Scintillator

Silicon



ToF

Expensive

Disadvantage

Dependent on the distance between source and detector

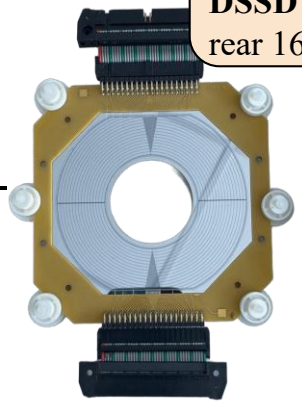
2022: Measurement of the Radiative-Decay Probability of the Hoyle State

$^{12}C\ (\alpha, \alpha' + {}^{12}C + \gamma)\ @\ 25MeV\ {}^{4}He$

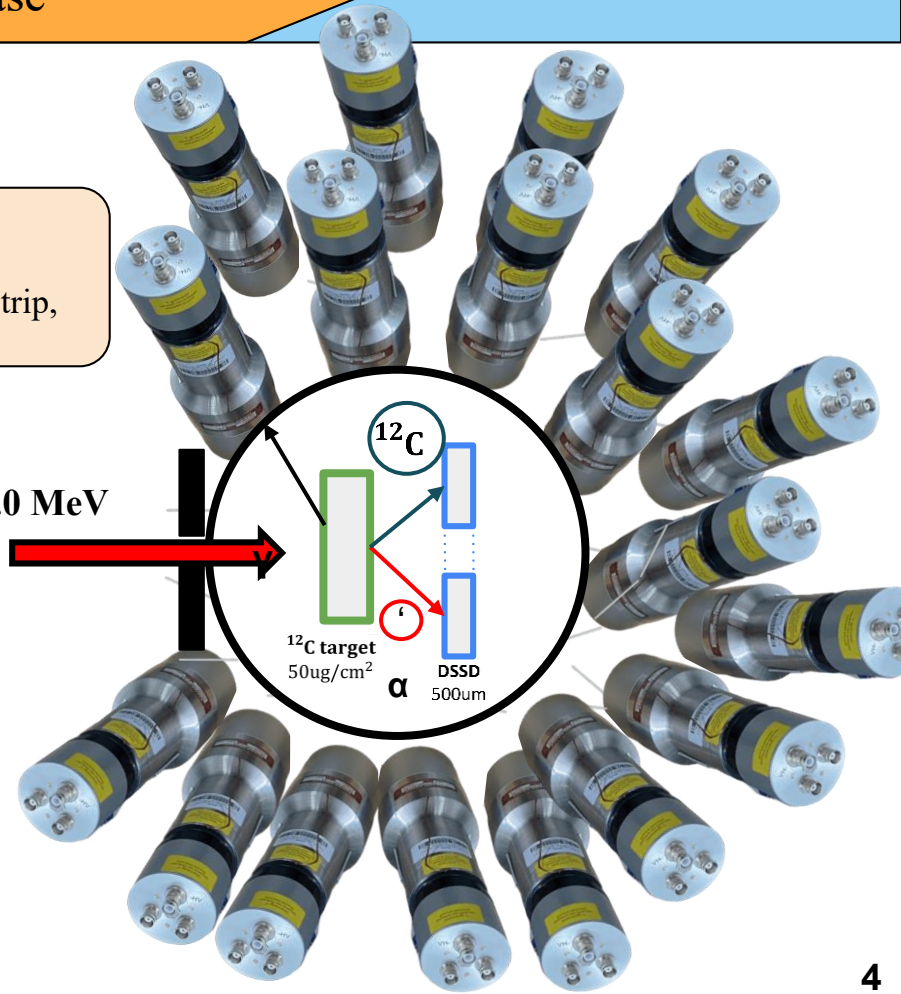
Goal: Measure radiative decay branch using α-beam on C^{12} with triple-coincidence detection.

Method: Offline Pulse-Shape Analysis (PSA) for particle identification.

ROSPHERE : (LaBr+BGO)x24
DSSD : front 16x4 strip, rear 16 strip



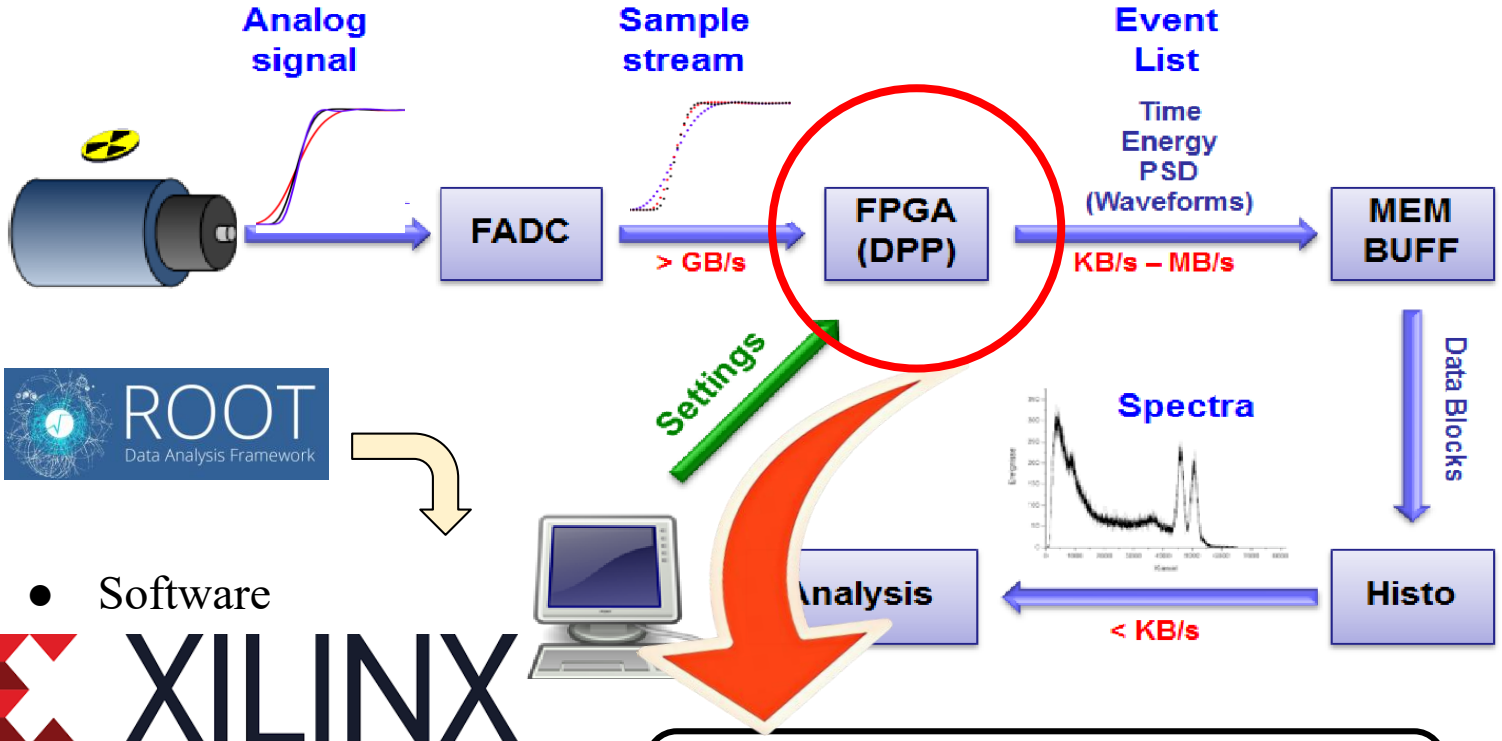
DSSD detector



Software implementation by K.Sakanashi

K. Sakanashi. Using large-area si semiconductor detectors development of waveform discrimination techniques for low-energy charged particles. Master's thesis, Osaka University, 2021.

Motivation for the development

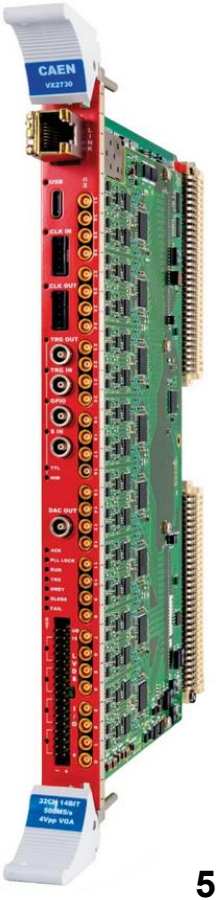


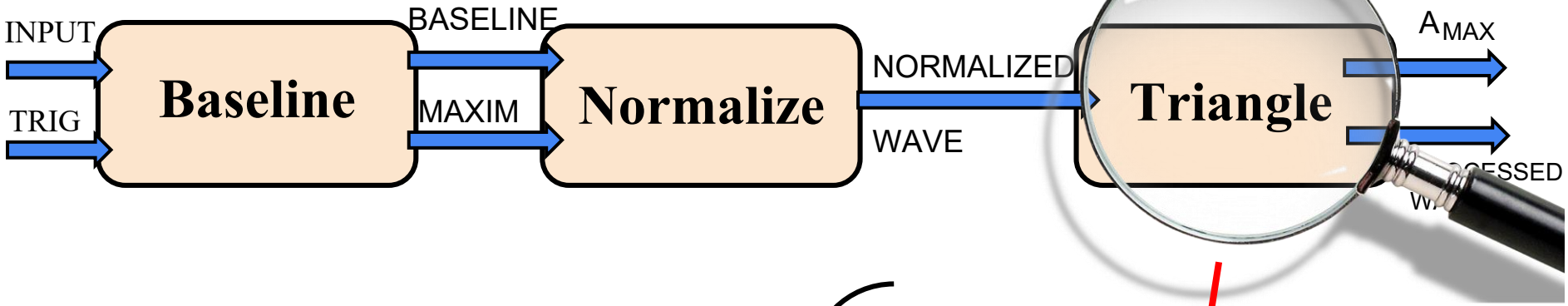
- Software

XILINX

- Hardware

Custom algorithm for DPP

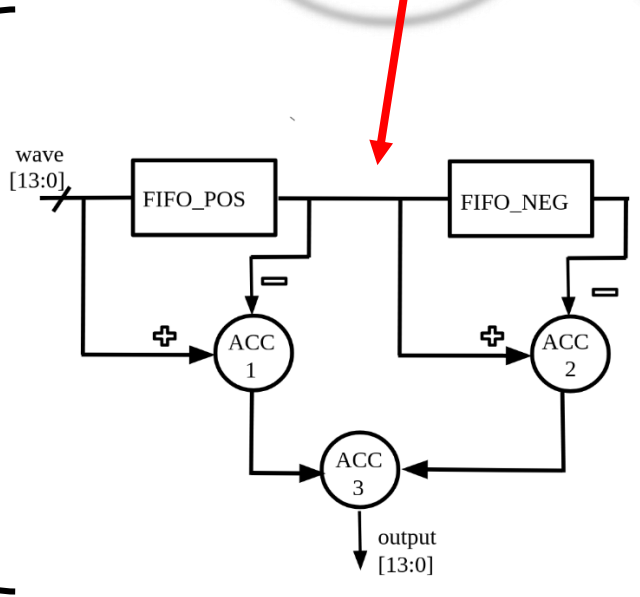




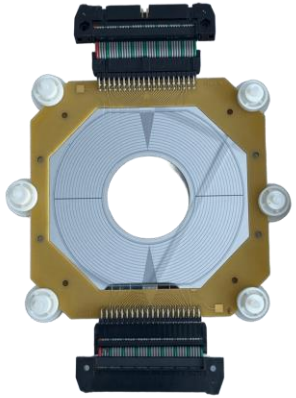
$$y_n = \frac{1}{L}\left(\sum_{k=1}^{L} x_{n+k} - \sum_{k=-L}^{-1} x_{n+k}\right)$$

y_n- output value
$x_{\bar{n}}$ input value
L- length of filter

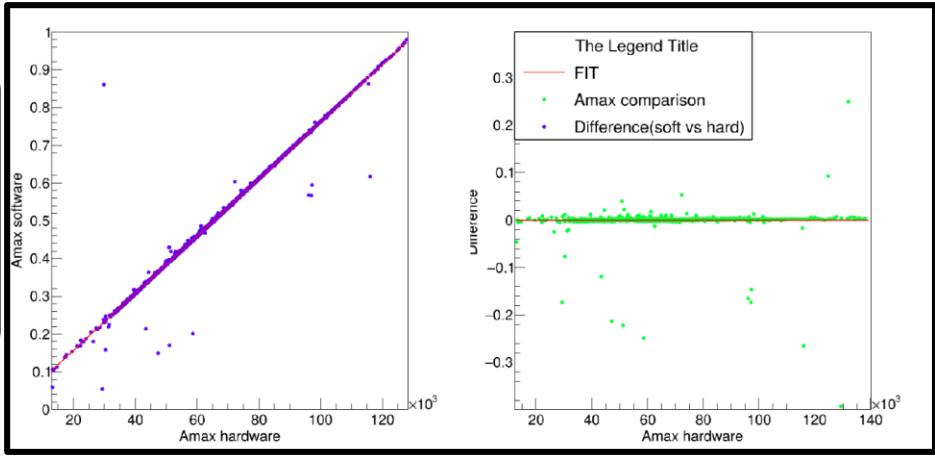
A_{max}

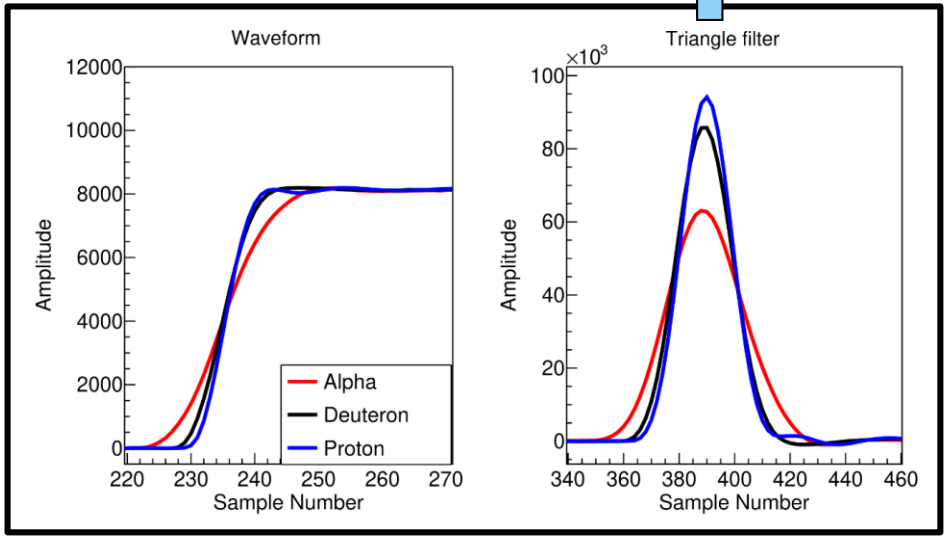


Results (1/3)



Alpha particles, deuterons, and protons can be distinguished, serving as the basis for computing the Amax value.

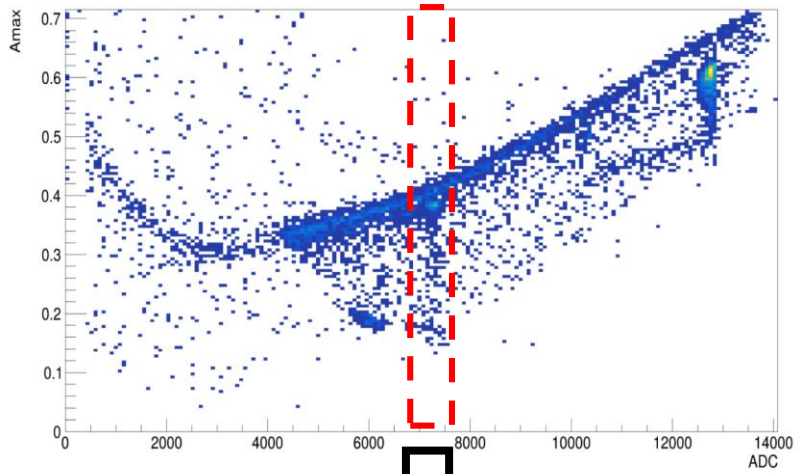




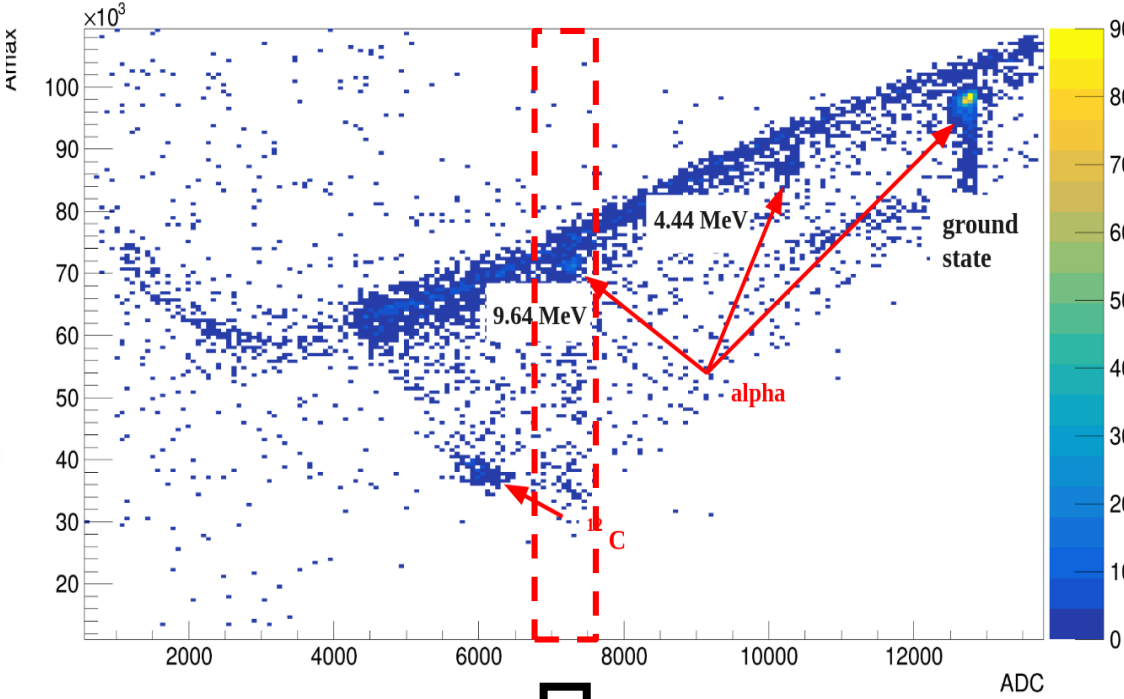
Comparison of software and hardware algorithm performance

Differences in software and hardware implementations

SOFTWARE



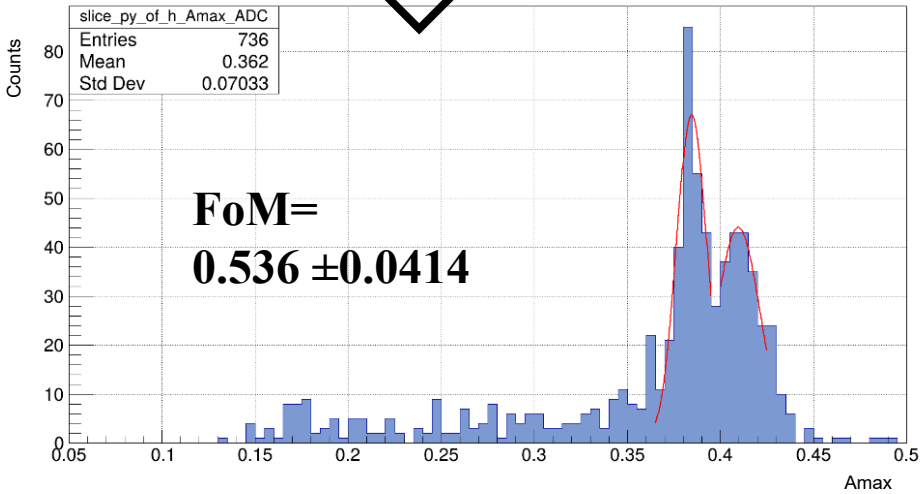
HARDWARE



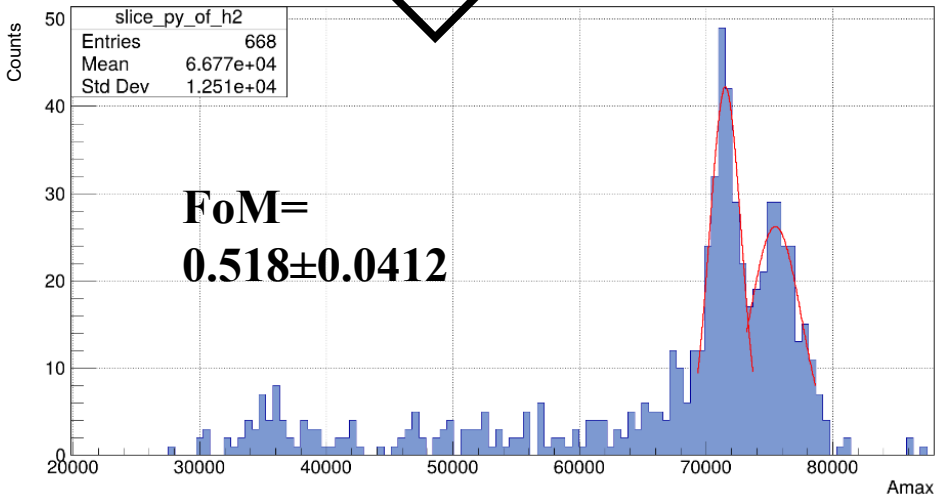
- A **strong similarity** between the two algorithms is evident.
- Clear **alpha particle separation** is observed at different energy levels.

Results (3/3)

Software



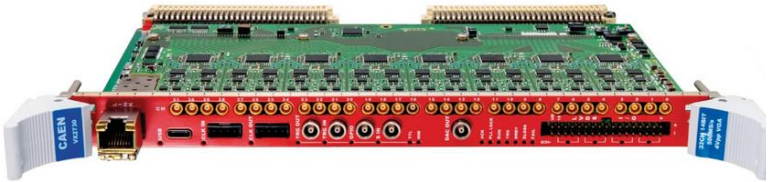
Hardware



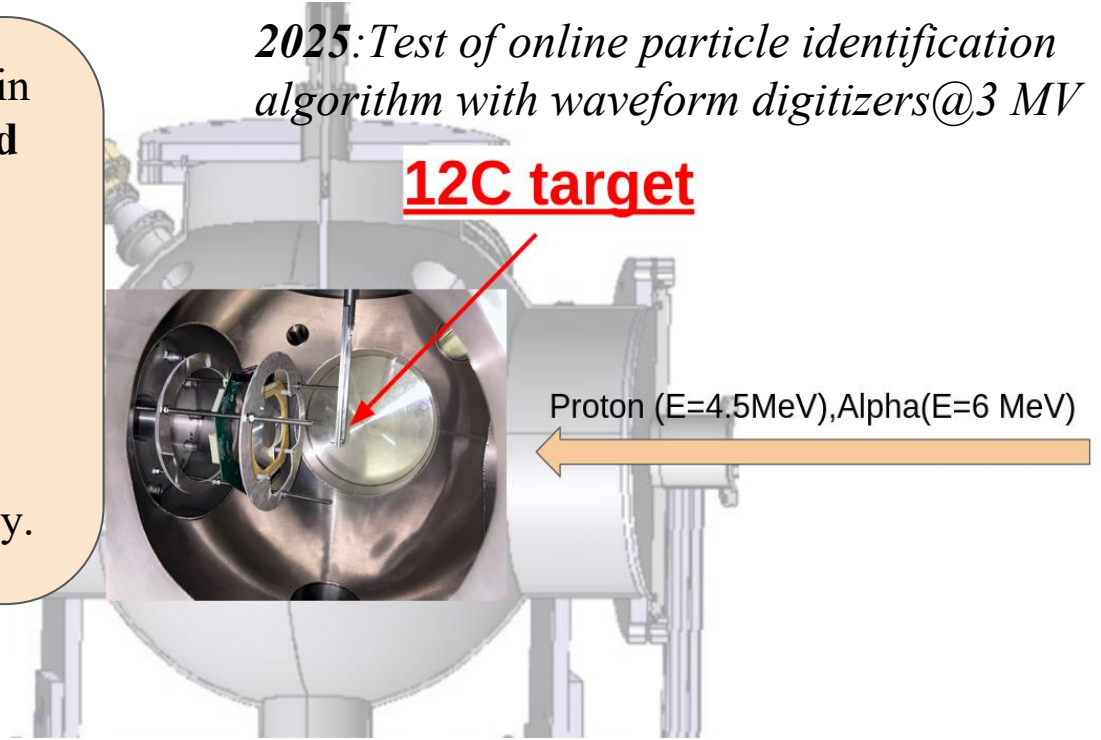
$$\mathrm{FoM} = \frac{m_1 - m_2}{\mathrm{FWHM}_1 + \mathrm{FWHM}_2}$$

- The **FoM** was calculated based on the projection of the **12.5–13.5 MeV** energy range on the **Amax** axis.
- The **difference** arises from the conversion of **floating-point** operations to **integer arithmetic**, a necessary step to facilitate hardware implementation.

- Algorithms **successfully** implemented in Xilinx Vivado using a **hardware-based approach**.
- Simulation results matched previous studies, with Amax **aligning with** software outputs.
- **Next phase:** real-time implementation and hardware analysis to enhance data processing speeds and system efficiency.



***2025**:Test of online particle identification algorithm with waveform digitizers@3 MV*



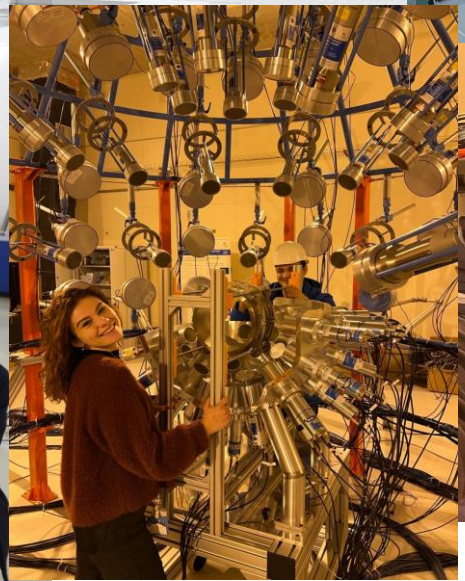
"Hardware Simulation of Particle Identification Algorithms for Silicon Detectors" by *S-R. Ban, D.L. Balabanski, Y. Fujikawa, T. Furuno, T. Kawabata, K. Sakanashi, P.-A. Soderstrom, M. Cuciuc* ***to be submitted*** *in The Scientific Bulletin of University POLITEHNICA of Bucharest, Series A*

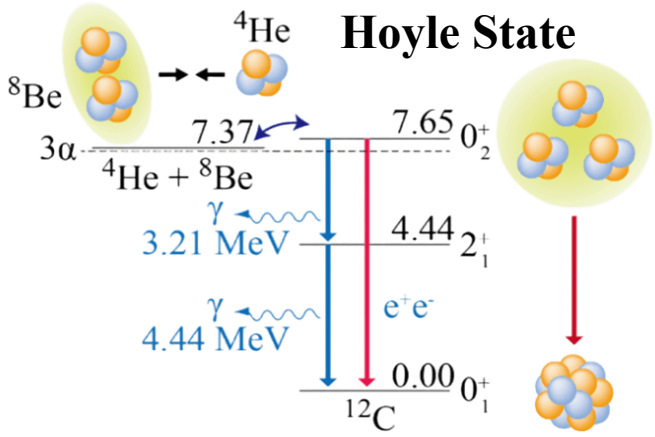
Acknowledgements
Dr. Mihai Cuciuc
Prof.Dr. Dimiter L. Balabanski

...and the entire GDED Team :)

Thank you !

Do you have any questions?





The **γ-decay** probabilities of the Hoyle state are very important parameters to determine the 3α rate in the nucleosynthesis.

$$\sigma_{FoM} = FoM\sqrt{\left(\frac{\sigma_{m_1}^2+\sigma_{m_2}^2}{(m_1-m_2)^2}\right)+\left(\frac{\sigma_{FWHM_1}^2+\sigma_{FWHM_2}^2}{(FWHM_1+FWHM_2)^2}\right)}$$