

A SiPM-Based Compton Camera with Walk-Rejecting Trigger for Monitoring Targeted Radionuclide Therapy



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Istituto Nazionale di Fisica Nucleare

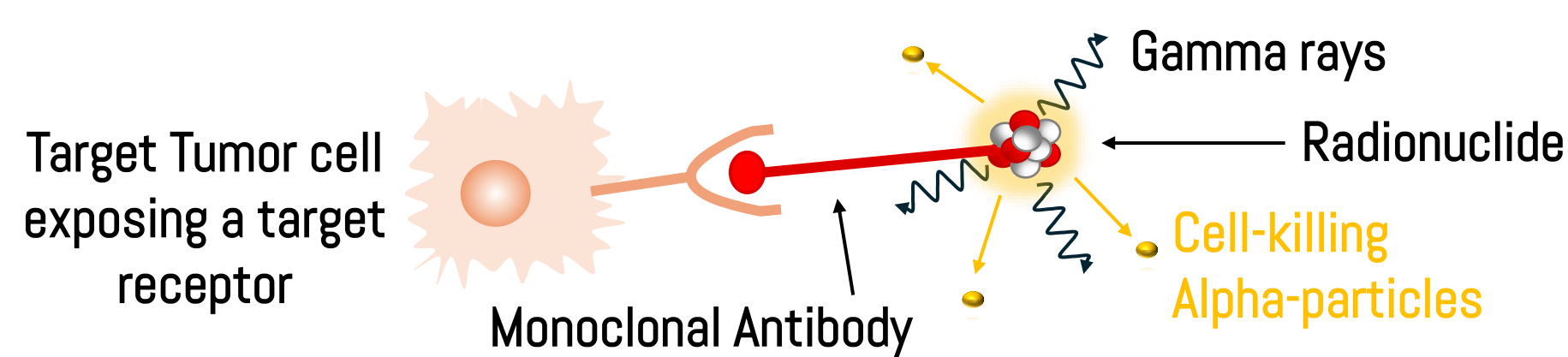
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Key Points

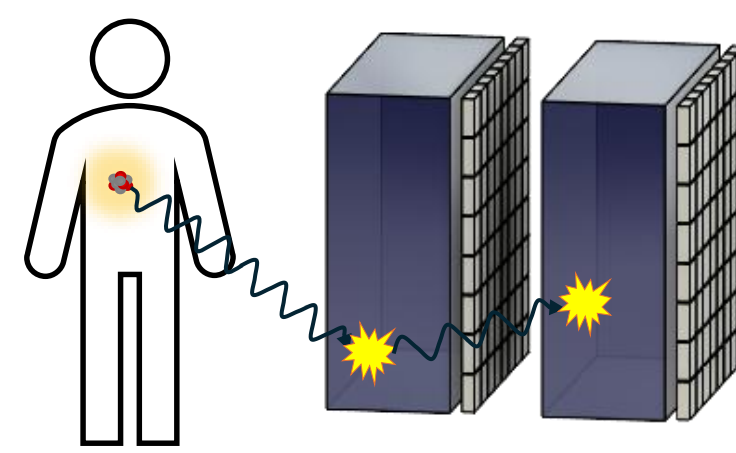
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- In **Targeted Radionuclide Therapy**, beta- or alpha-emitting sources are bound with targeting molecules to deliver localized irradiation to the tumorous cells.
- Emitted Gamma Rays** can be detected to monitor radionuclide distribution.



2

In a **Compton camera** the collimation is purely electronic. Higher statistics can be achieved than conventional SPECT methods.



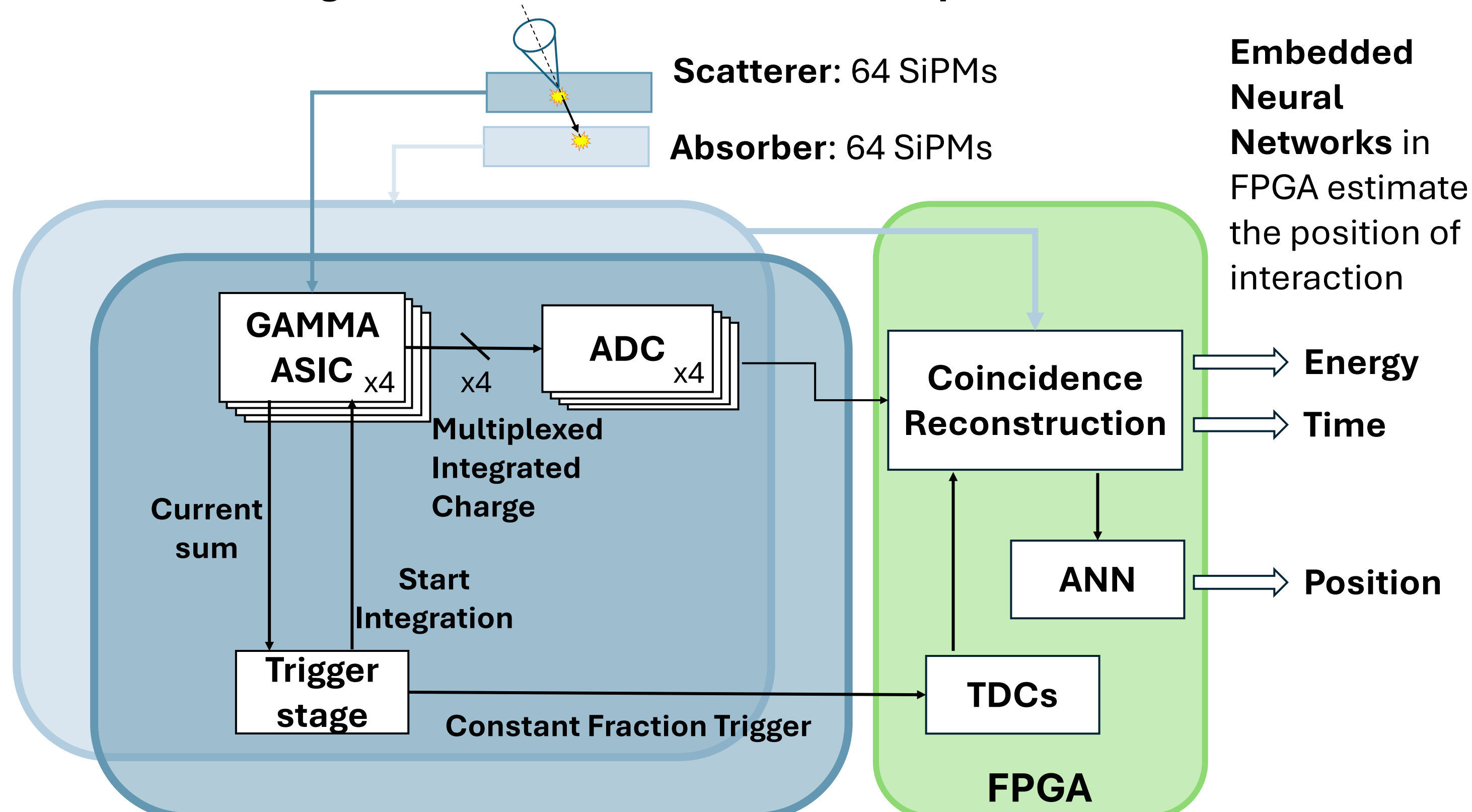
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The **AIDER project** aims at designing a Compton camera optimized for monitoring Targeted Radionuclide Therapy.

AIDER System Requisites	
Energy Resolution	3% @ 662 keV
Energy Range	50keV – 1 MeV
Time Resolution	<1ns
Final planar dimensions	10 cm x 10 cm

1. Proposed Architecture

Gamma rays undergo **Compton scattering** in the two layers and from the measured energies we can retrieve a **cone of response**.

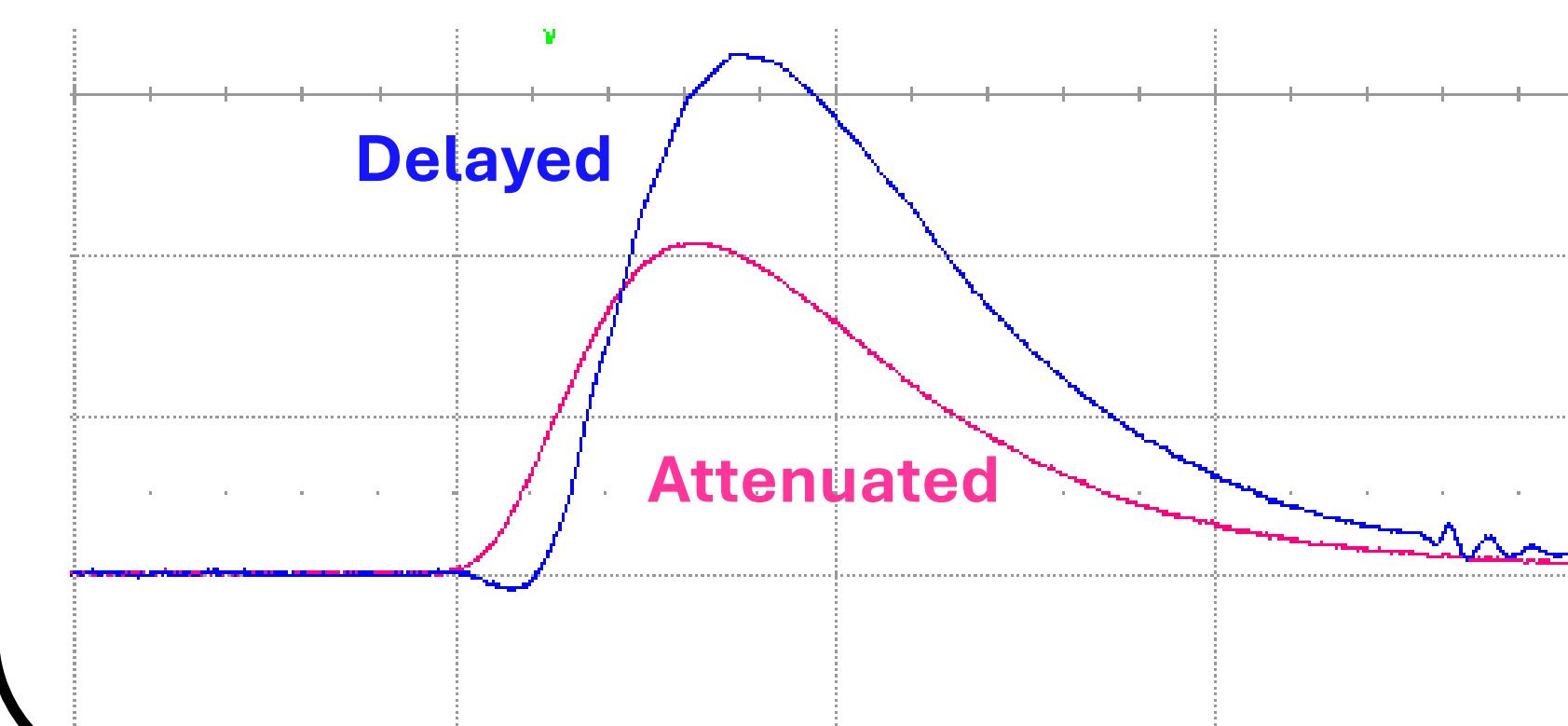
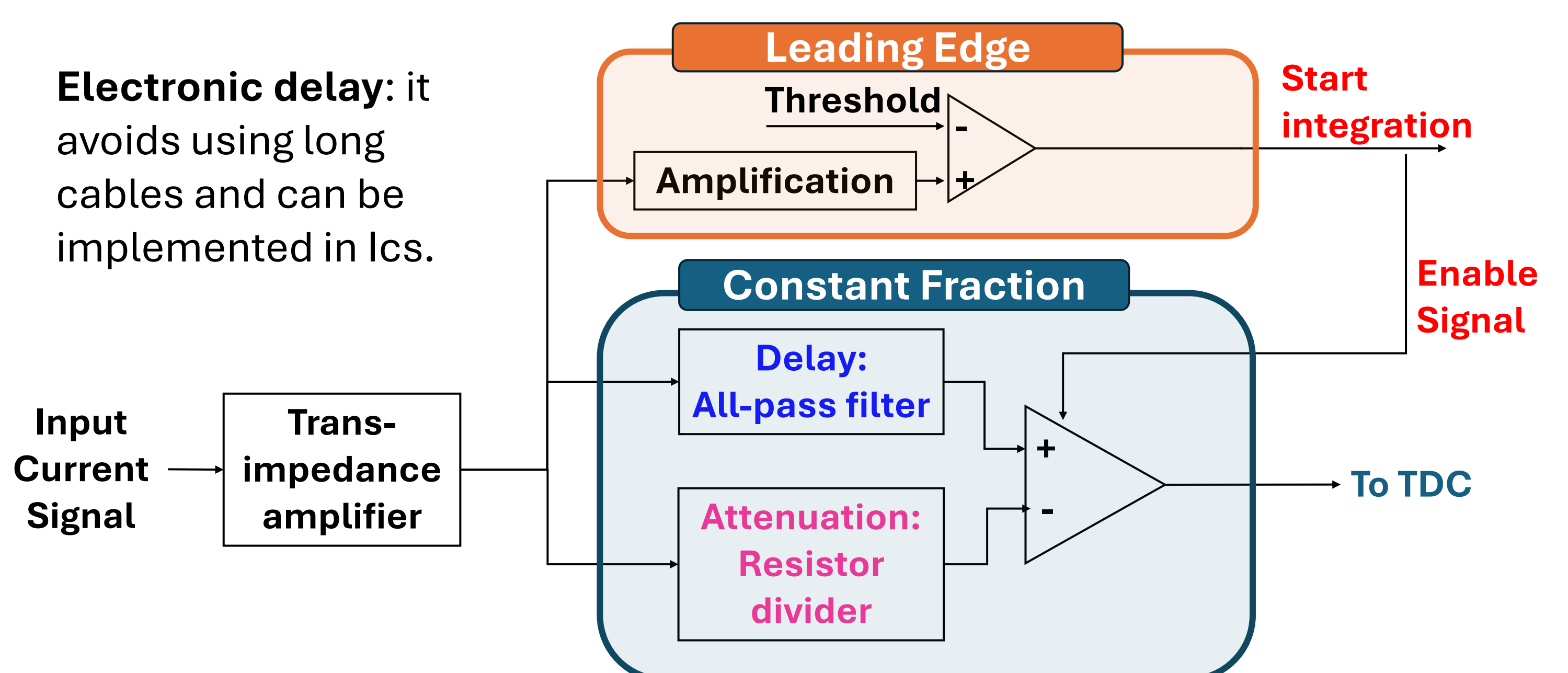


2 Units: **Absorber + Scattemer** readout

- Gamma ASICs**[1] provide separate **charge integrators** for each **SiPM**.
- Coincidence logic relies on **external trigger circuit**.
- Multiple modules can be connected to increase the number of readout channels.

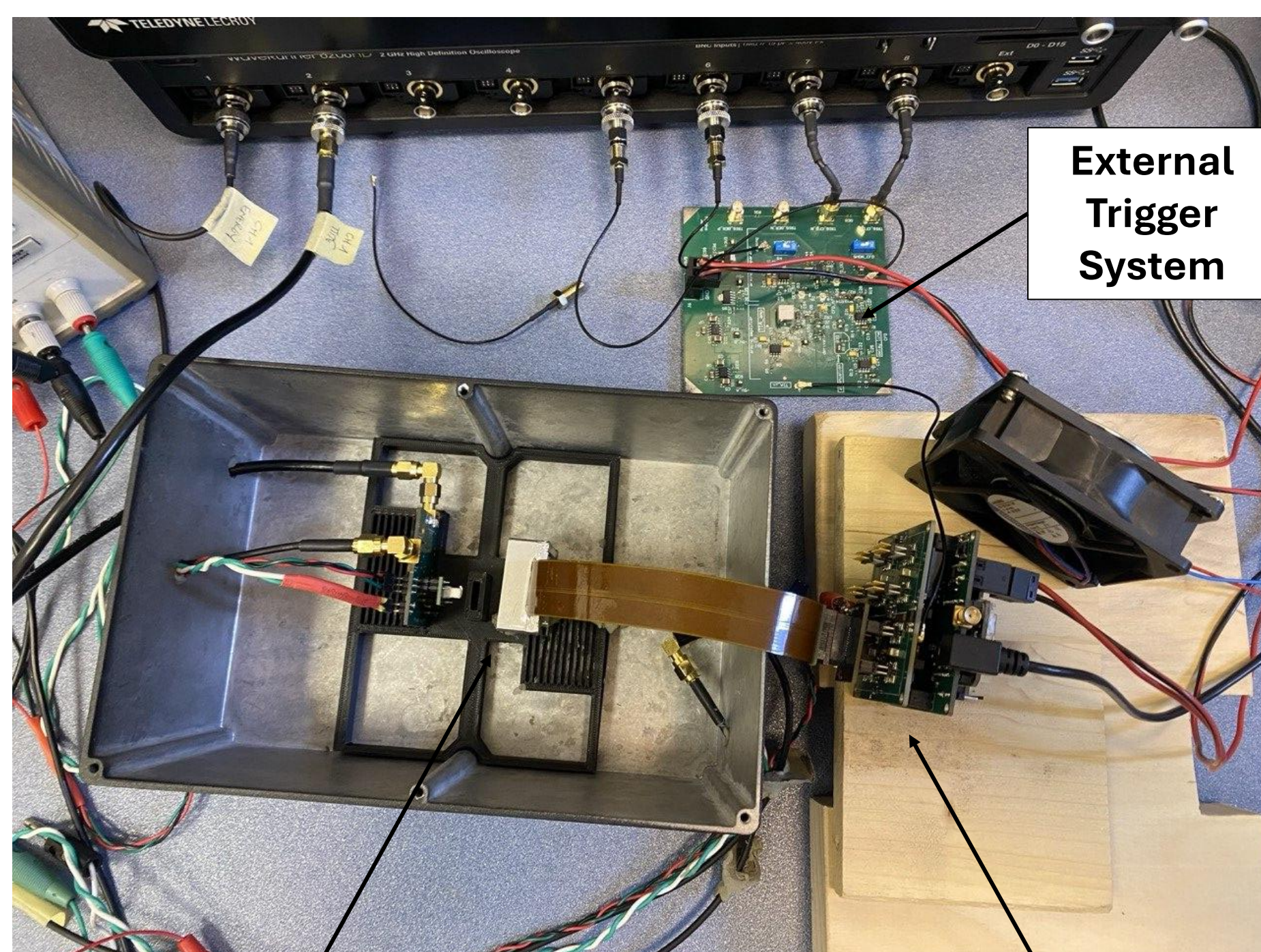
2. Novel Trigger Stage

This **Constan Fraction** implementation allows to **apply coincidence logic** to gamma rays of different energies.



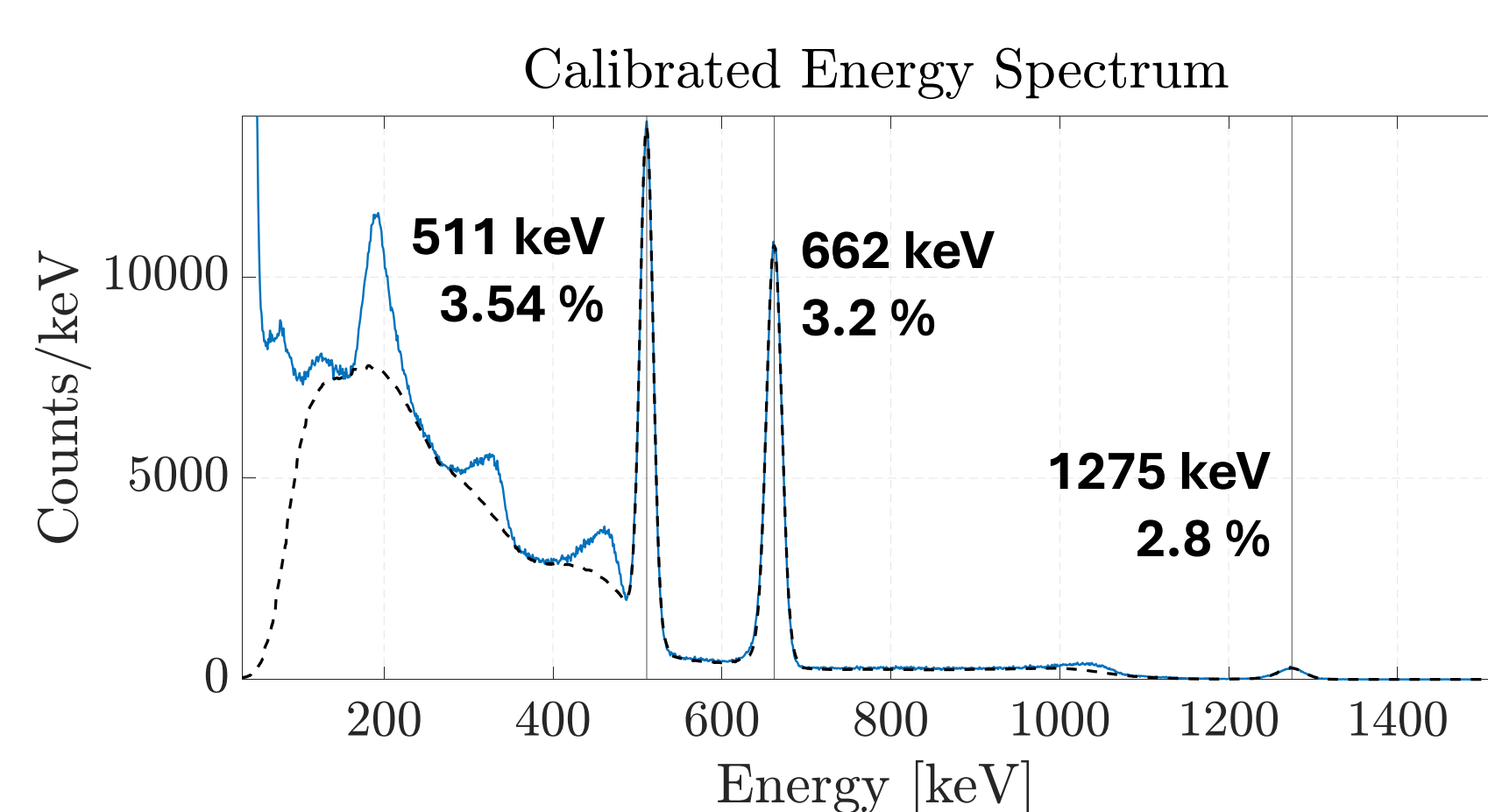
Walk Rejection: The crossing point of the delayed and of the attenuated signal represents a time stamp independent from the amplitude.

3. Preliminary Prototype Characterization

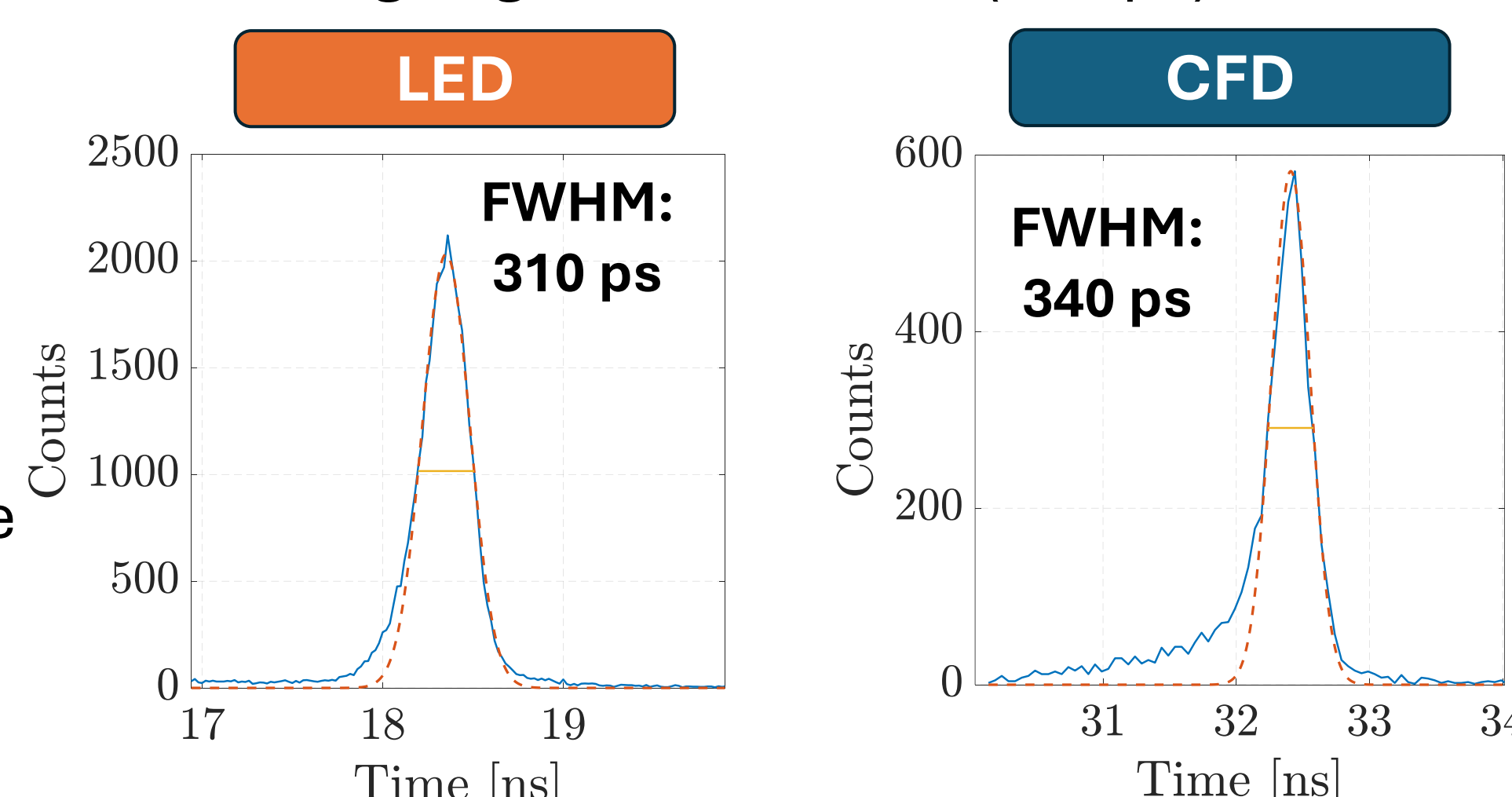


A first prototype has been realized coupling the **Benedicte Detector** [2] with an **external trigger circuit**. We used a single **25 mm x 25 mm x 5 mm** detector layer provided by **Damavan Imaging** made of **Lanthanum BromoChloride** and **16 SiPMs**.

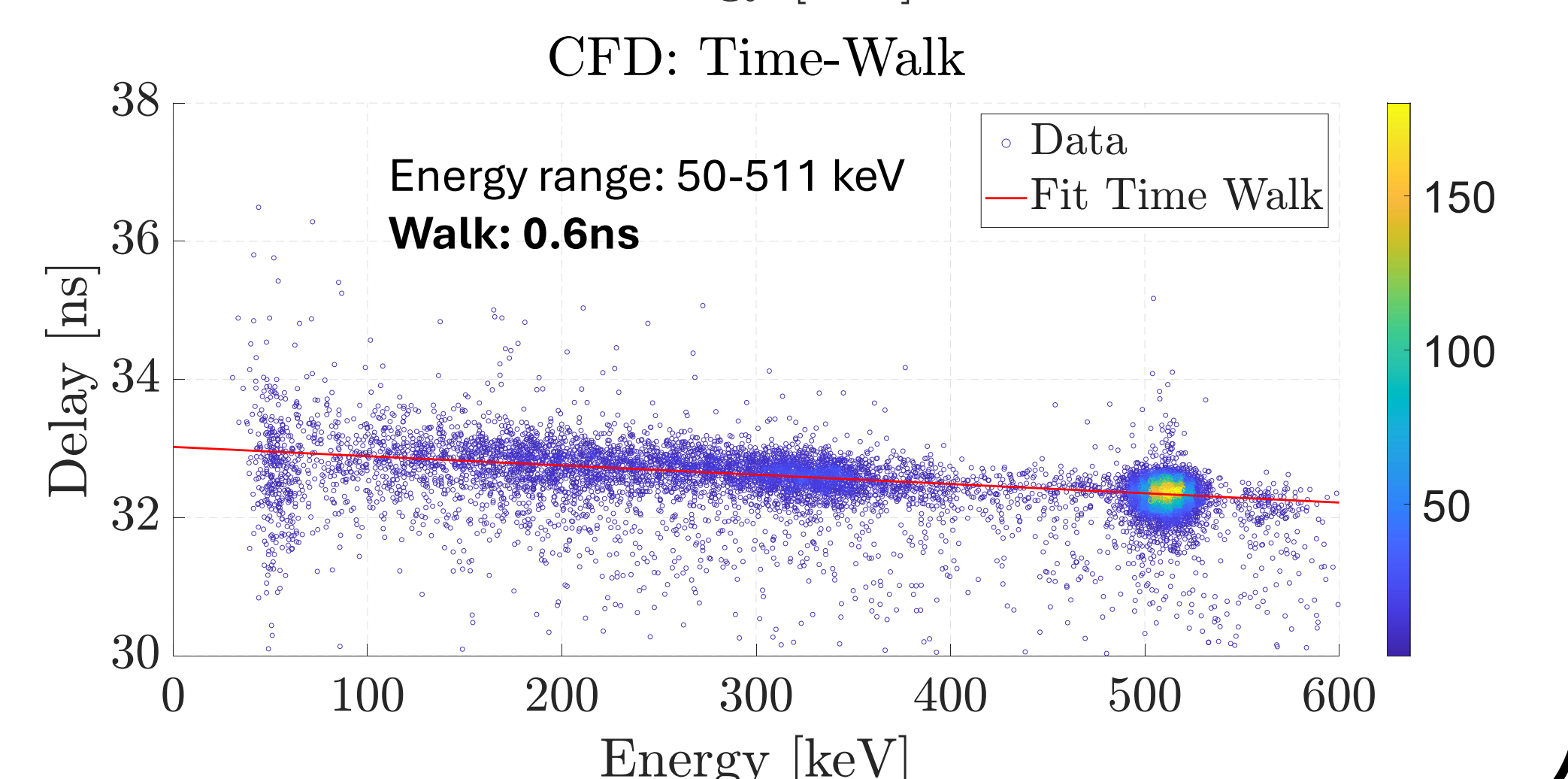
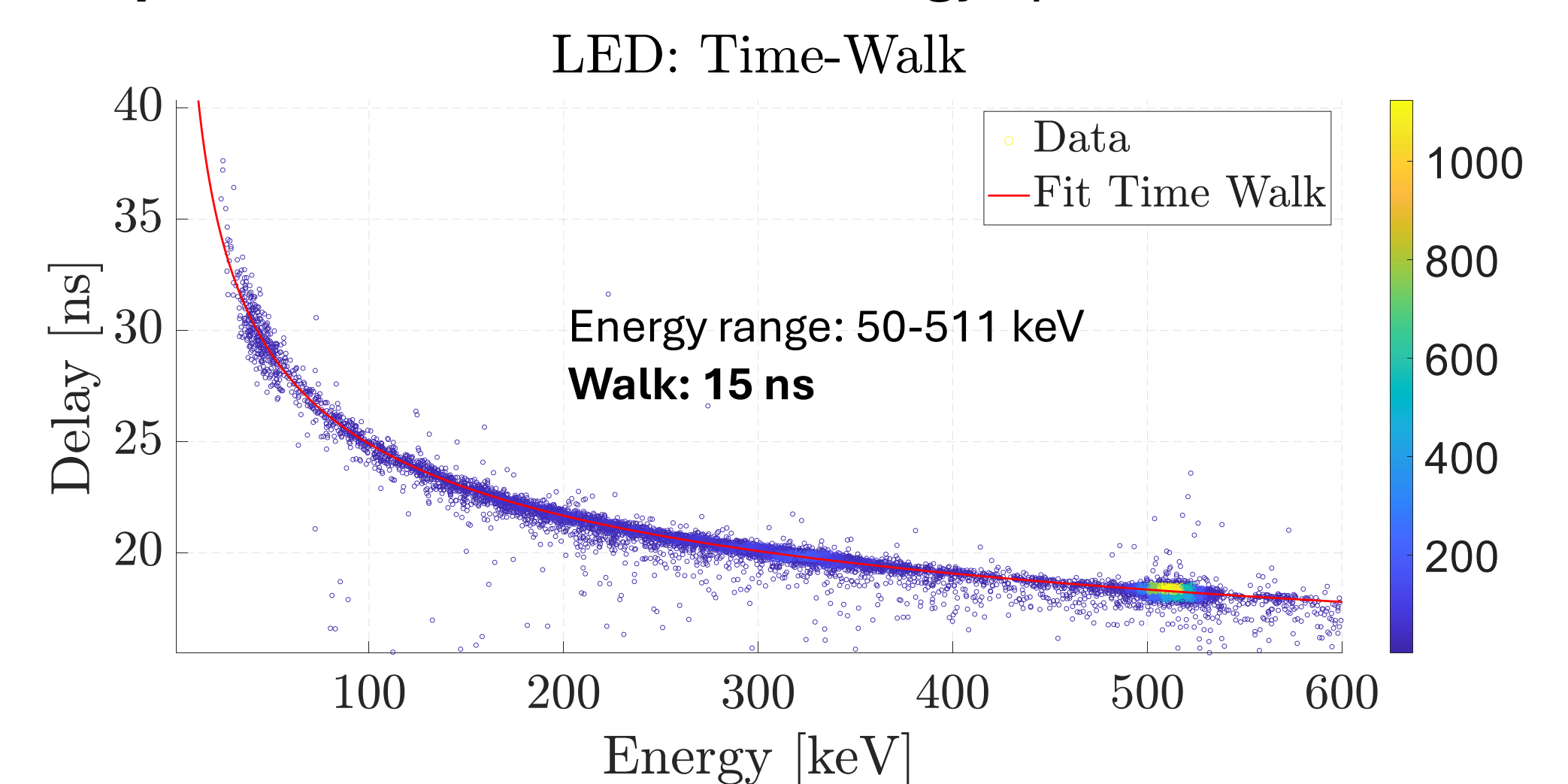
Energy characterization shows **3.2%** energy resolution at **662 keV**.



Constant Fraction Discriminator achieved a **time resolution of 340 ps**, comparable with Leading Edge Discriminator (310 ps).



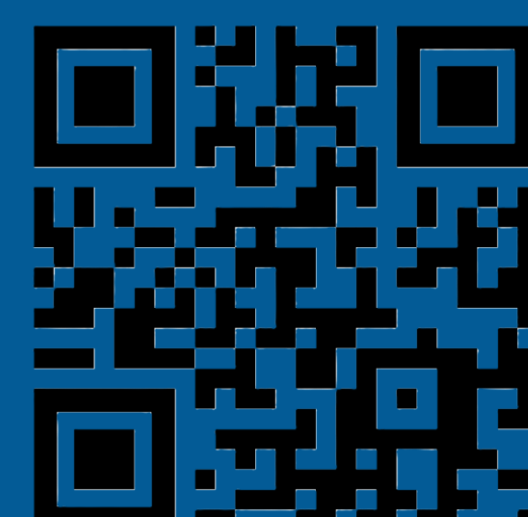
Leading Edge stage suffers from **time-walk**: pulses of different energies trigger at different times. **Constant Fraction Discriminator** provides a nearly **uniform response** across the entire energy spectrum.



[1] L. Buonanno, D. Di Vita, M. Carminati, C. Fiorini, "GAMMA: a 16-Channel Spectroscopic ASIC for SiPMs Readout with 84dB Dynamic Range", IEEE Trans. Nuclear Science, vol. 68, no. 10, pp. 2559-2572, Oct. 2021, doi: 10.1109/TNS.2021.3107333

[2]. A. Caracciolo et al., "BENEdICTE (Boron Enhanced NEutron CapTurE) Gamma-Ray Detection Module", 2021 presented at NSS/MIC, Piscataway, NJ, USA, 2021, pp. 1-3, doi: 10.1109/NSS/MIC44867.2021.9875911.

Interested in the
AIDER Project?
Check:
<https://aider.ific.uv.es/aider/>



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Design and Simulations of a Collimator for SPECTMeasurements in a BNCT Facility

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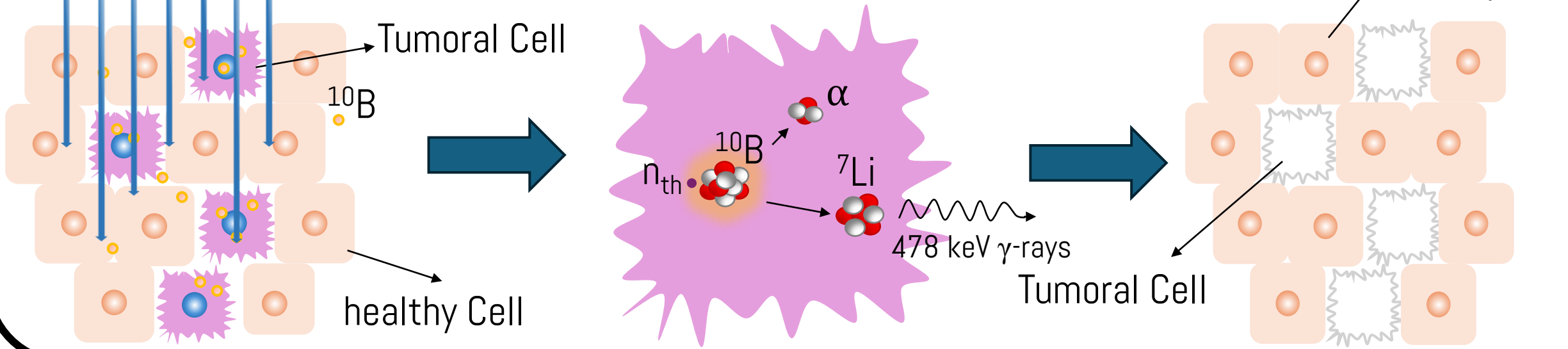
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Introduction

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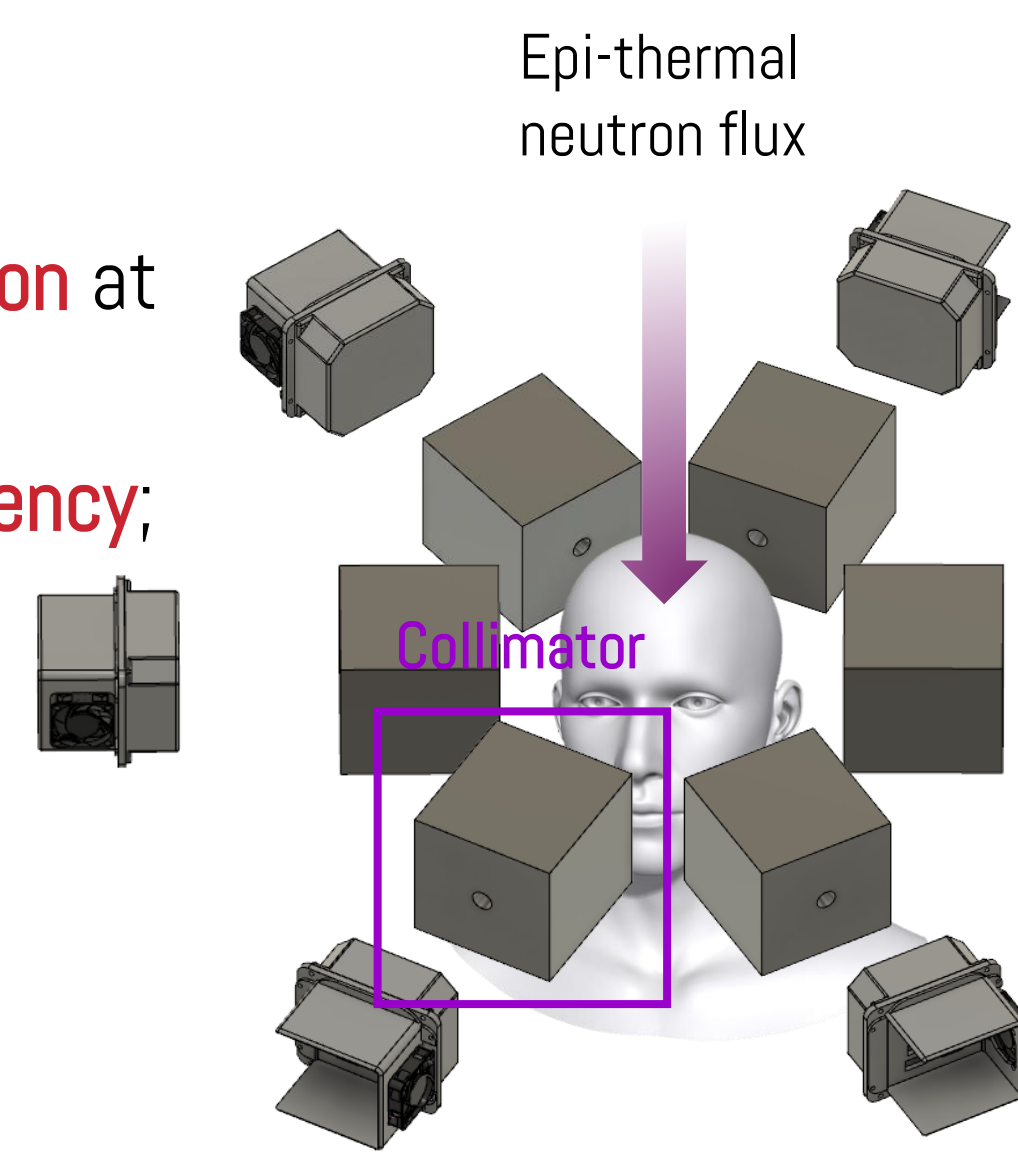
- Boron compounds are selectively absorbed by cancer cells.
- Tissues are irradiated with an **epi-thermal neutron flux**.
- Neutron capture by ^{10}B** generates high-LET secondary particles, destroying cancer cells and sparing normal cells.
- Emitted gamma rays at **478 keV** can be **detected for dose monitoring and localisation**.



BNCT-SPECT System specifications:

- Good **energy resolution** at 478 keV;
- High **detection efficiency**;
- Spatial resolution** lower than 1 cm.

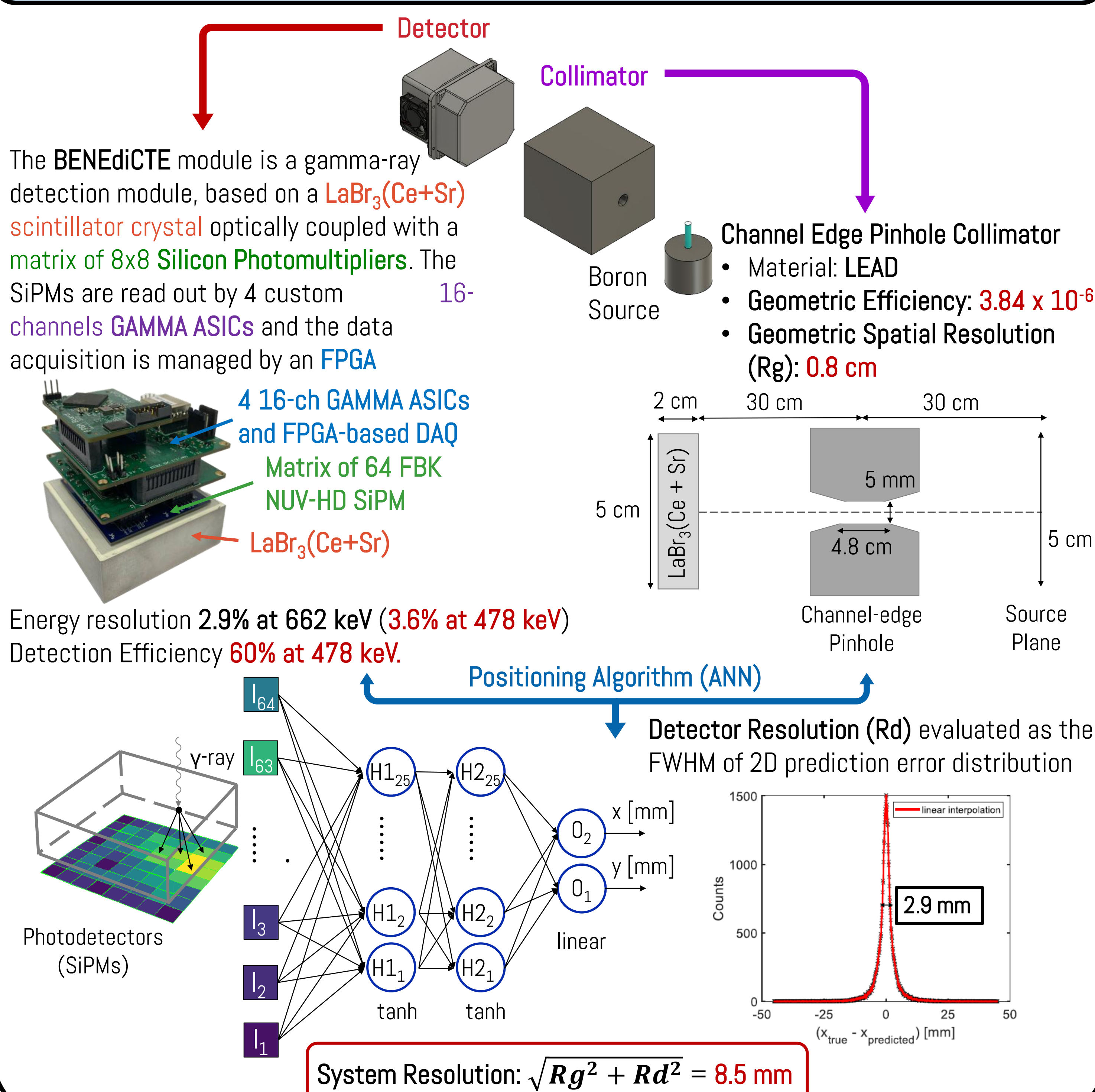
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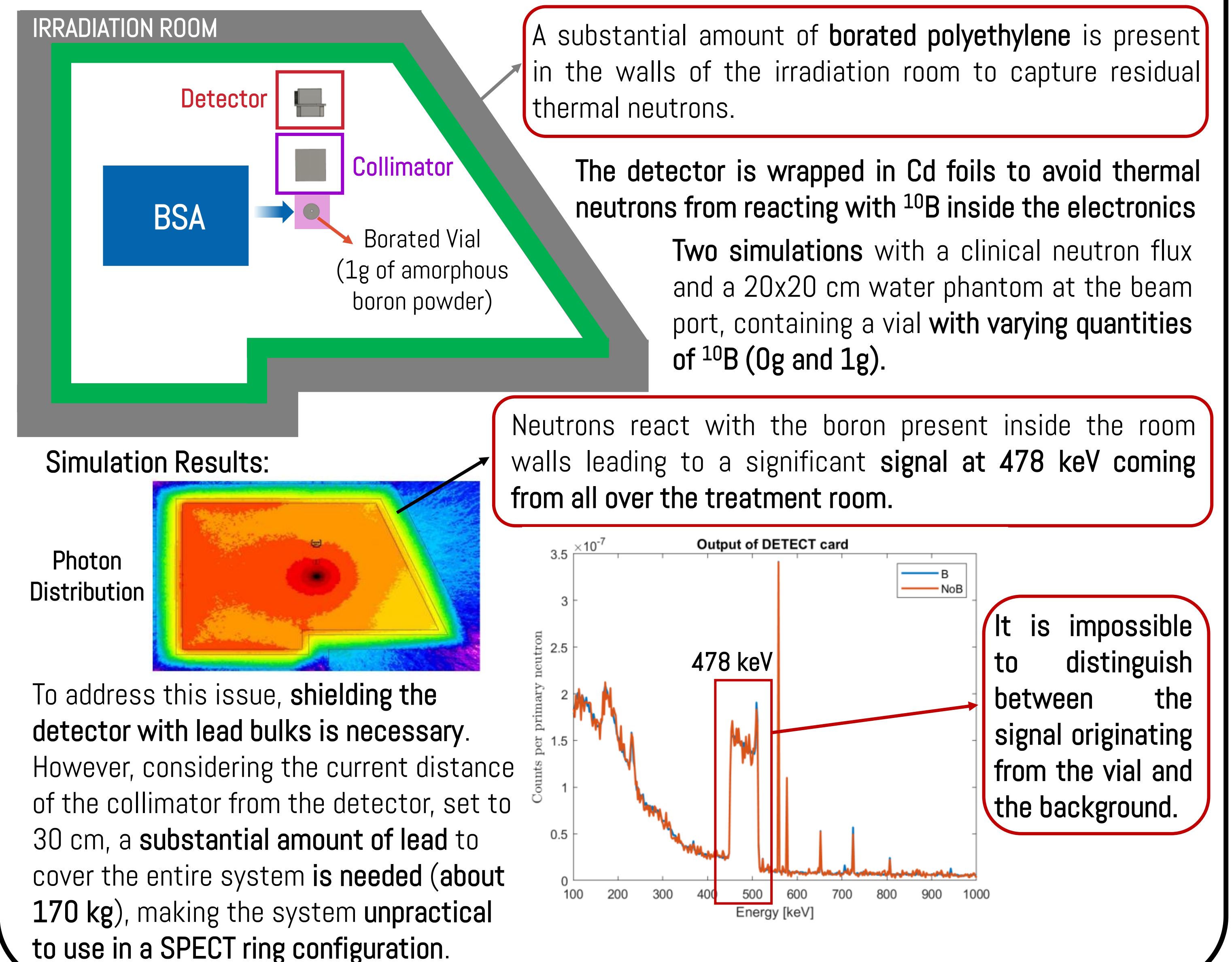
In many BNCT clinical facilities, **borated polyethylene** is commonly used in the walls of the irradiation room to shield thermal neutrons. This leads to **huge background radiation at 478 keV** that makes difficult to detect signal from small quantities of boron (usually down to 10-20 ppm).

Proposed SPECT System



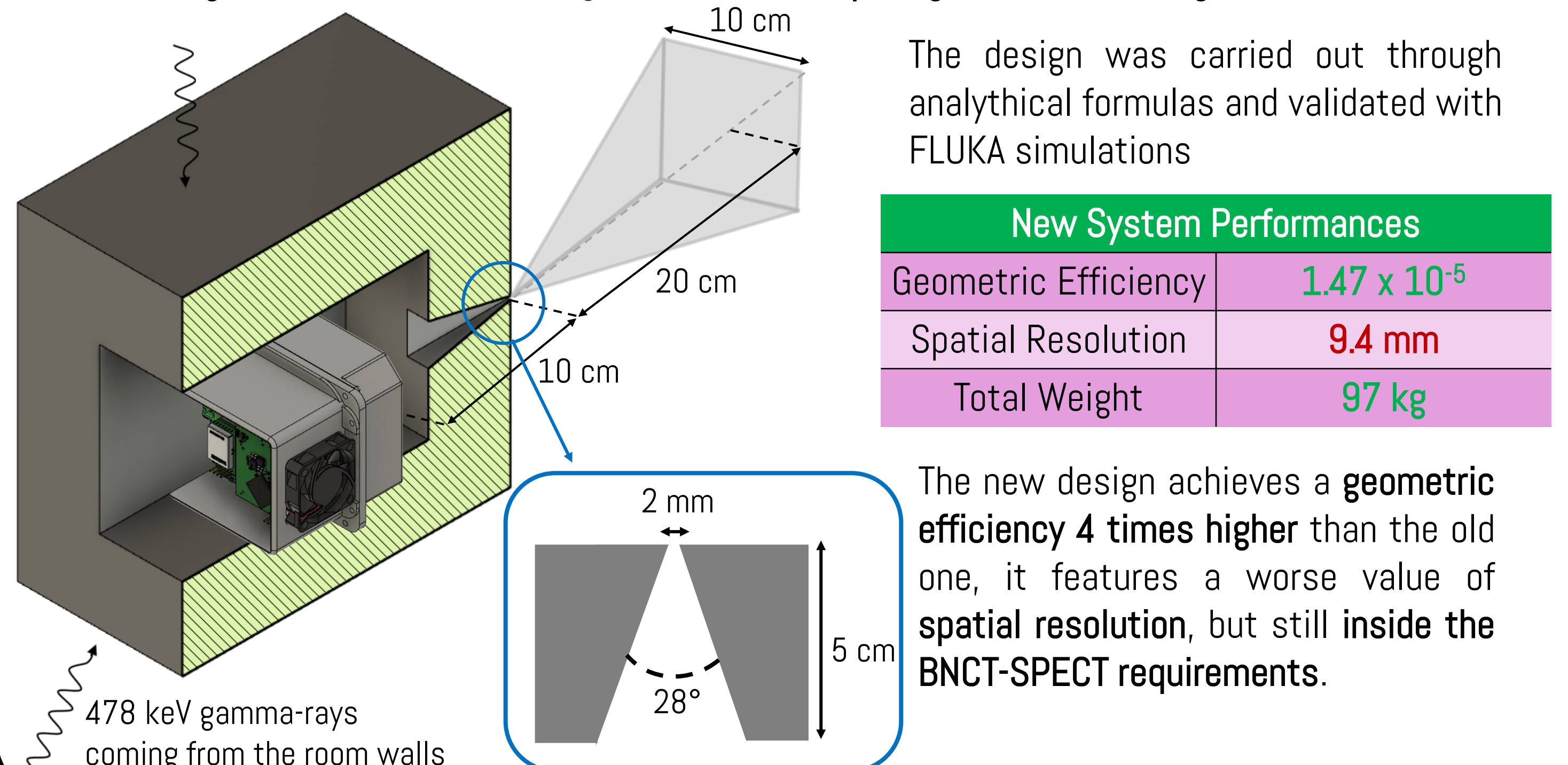
Even though the system has been designed ad hoc to differentiate between the boron signal and background radiation generated from hydrogen neutron capture and annihilation photons, **challenges** have emerged under clinical measurement conditions.

FLUKA simulations conducted using the parameters of the **Nagoya BNCT facility** in Japan



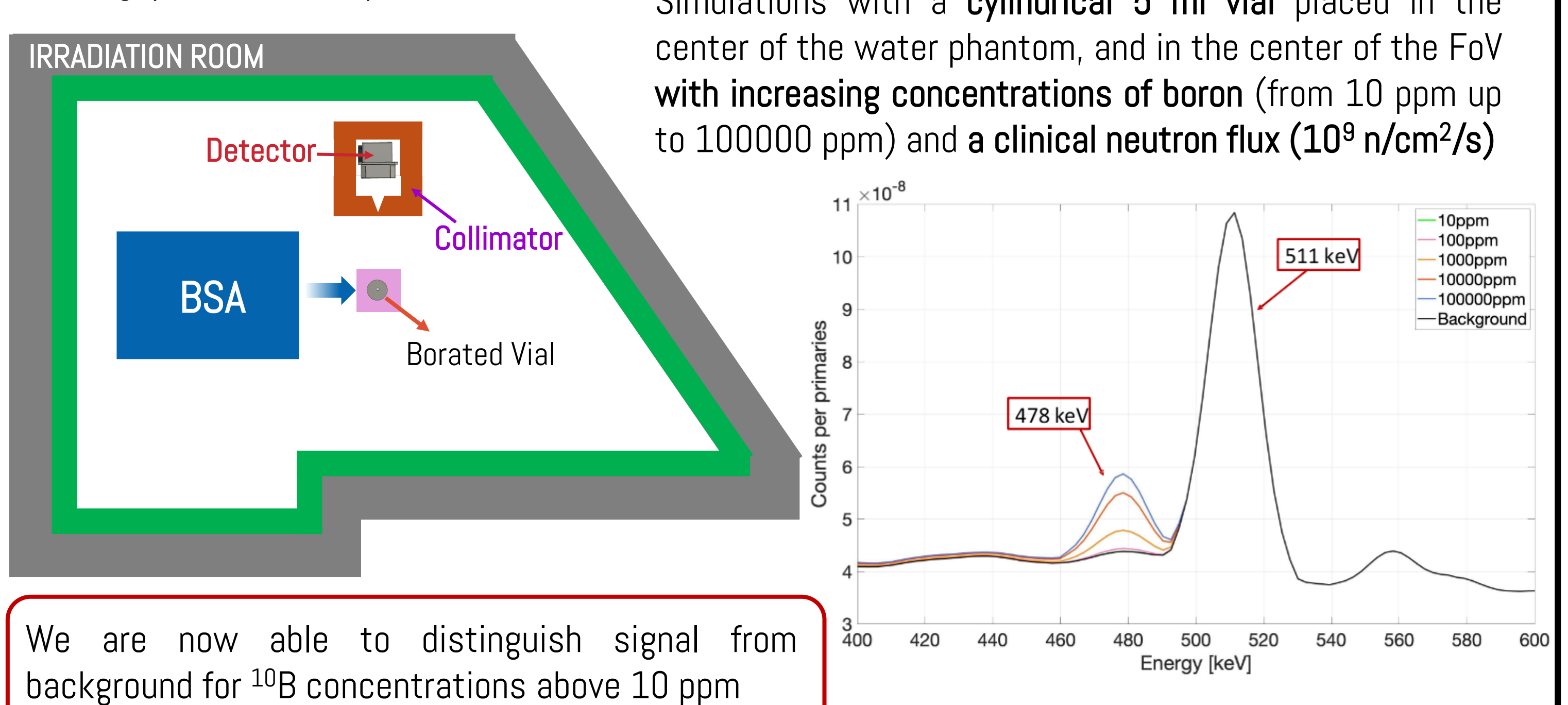
New Collimator Design

A new collimator aimed at addressing the encountered limitations has been designed. Our new objective is to **maintain the current system performances** while **expanding the Field of View (FoV)** and **shielding the detector** from background radiation **sparing material** for weight and size.



New Design FLUKA simulations

A new set of FLUKA simulations has been conducted with the same clinical irradiation parameters of the Nagoya BNCT facility.



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