Gamma and charged particle detectors with SiPMs, Si-Pin Photodiodes and silicon detectors: Spectroscopy and Identification Techniques

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Introduction & Motivation

In nuclear physics experiments, reactions often produce both gamma rays and charged particles, each carrying complementary information about nuclear structure and reaction mechanisms. To reconstruct these processes, it is essential to detect and identify both types of radiation.

This practice introduces two fundamental techniques widely used in modern nuclear physics experiments:

- **Gamma-ray spectroscopy** with scintillation detectors (NaI(Tl), CsI(Tl), LYSO) coupled to Silicon Photomultipliers (SiPMs), allowing the study of energy spectra and detector performance.
- **Charged-particle identification** using the ΔE–E telescope method, which distinguishes particles based on their energy loss in matter according to the Bethe–Bloch formalism.

Students will gain hands-on experience with detector systems, STM32-based data acquisition, and data analysis using the CERN ROOT framework.

Objectives

- Characterise gamma-ray spectra and detector response for different scintillators (NaI(Tl), CsI(Tl), LYSO) coupled to SiPMs.
- Identify charged particles using the ΔE–E technique.

Tasks

With **gamma spectroscopy**, the students will:

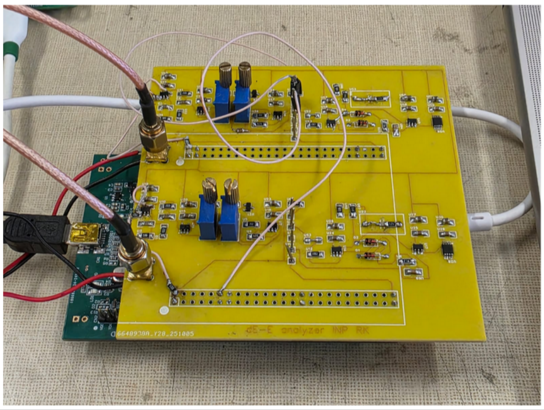
- Assemble scintillator detectors with SiPMs, set them up with a charge-sensitive preamplifier, and an STM32-based data acquisition system.
- Perform measurements with standard gamma-ray sources (^{137}Cs, ^{60}Co, ^{22}Na) for each scintillator type.
- Acquire and analyse gamma-ray energy spectra, understanding and identifying the gamma spectrum with photopeaks and Compton continuum.
- Perform energy calibration, evaluate the energy resolution (FWHM) for each scintillator, and compare their performance (energy resolution, spectral shape).

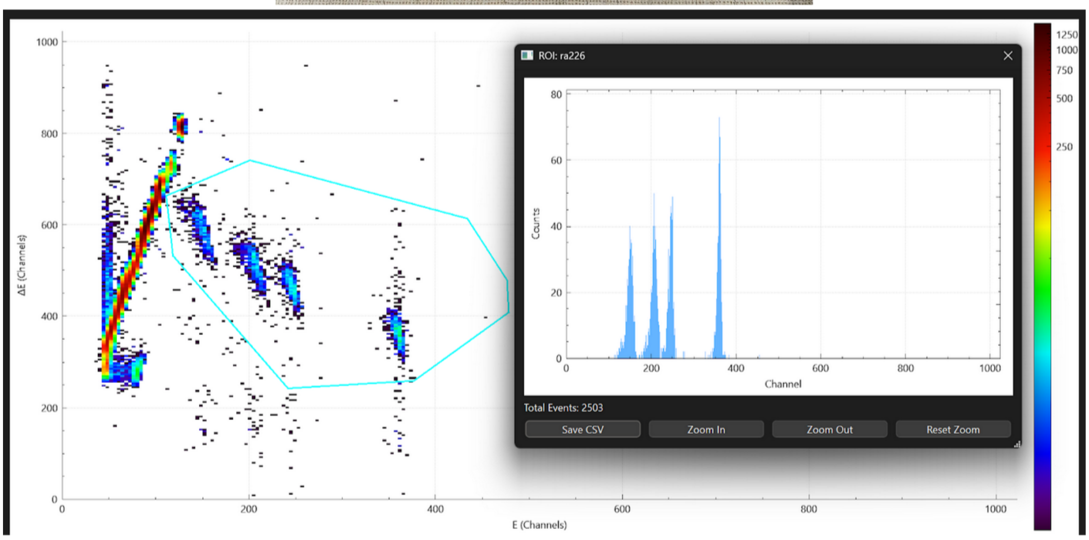
With **charged particle identification**, the students will:

- Set up a two-detector ΔE–E telescope system: a thin dE detector followed by a thick E stopping detector.
- Perform measurements with an alpha source (^{226}Ra) and acquire the data.
- Construct and analyse 2D ΔE–E spectra using the ROOT framework.
- Understand the correlation between energy loss (ΔE) and residual energy (E) based on the Bethe-Bloch stopping power formalism.
- Evaluate the particle identification by identifying different particle groups in the 2D spectrum.

Expected Outcomes

- Ability to operate SiPM-based detector systems and STM32 DAQ.
- Skills in gamma-ray calibration and resolution analysis.
- Practical experience with ΔE–E particle identification.
- Competence in analysing experimental data using CERN ROOT.





a) Two channel data acquisition board for ΔE–E measurement. b) ΔE–E spectrum by means of ^{226}Ra with a thin(12 µm) and thick(300 µm) detector.