Project: Basics of Particle Detection and Dosimetry (Medipix MX-10 & Atom Fast)

1. Introduction

The project focuses on advanced technologies for particle detection, imaging, and dosimetry. It combines two complementary approaches: high-resolution particle tracking using pixel detectors and real-time dose rate measurement using scintillation detectors.

Medipix is a family of readout chips and detector assemblies for particle detection and imaging developed by the Medipix Collaborations (https://medipix.web.cern.ch). The original concept of Medipix is that it works like a camera, detecting and counting each individual particle hitting the pixels when its electronic shutter is open. This enables high-resolution, high-contrast, low noise images — making it unique for imaging applications. Pixelman software for control and evaluation of Medipix/Timepix detectors was developed and licensed by the Institute of Experimental and Applied Physics (IEAP) of the Czech Technical University in Prague. The R/O interface MX-10, based on the Medipix/Timepix detector, is produced by the Czech company Jablotron in cooperation with IEAP.

Atom Fast is a compact scintillation dosimeter based on a CsI(Tl) crystal and a silicon photomultiplier (SiPM). It is designed for rapid assessment of ambient dose equivalent rate and supports GPS-based radiation mapping. Unlike the Medipix, which provides spectroscopic and tracking information, Atom Fast offers continuous dose monitoring with fast response, making it ideal for radiation safety surveys.

Students will learn how to work with both types of detectors: a pixel detector for particle identification and track analysis, and a scintillation dosimeter for dose rate measurements. They will set measurement parameters, evaluate experimental data, distinguish different types of radiation, and perform environmental radiation monitoring including background and cosmic rays (muons). Students will also build simple experiments to examine the properties of radioactivity and radiation shielding.

2. Description

Students' workplaces will be equipped with an MX-10 Edukit (Medipix-based pixel detector) and several Atom Fast 8850 scintillation dosimeters. At first, students will learn how to control both devices, understand measured data, and draw charts under the guidance of a supervisor. Afterwards, they will independently perform their own experiments.

The Medipix detector allows visualization of particle tracks (alpha, beta, gamma, muons) and identification of radiation types by track morphology. The Atom Fast dosimeter provides real-time dose rate measurements (μSv/h) and supports statistical analysis, shielding experiments, and GPS mapping.

Students will present the results of their own measurements during the final presentation.

[Medipix]() particle detector:


Atom Fast dosimeter and work with it:

3. Practice plan

Part 1: Medipix MX-10 – Particle Tracking and Identification

- Introduction
  - Theory
  - Medipix MX-10
  - Weak radiation sources: uranium glass, thorium rod, potassium sulfate
- Alpha radiation from ^{241}Am source
  - Introduction to ^{241}Am, particle beam collimation
  - Alpha particles energy loss in air
  - Alpha particles energy loss in matter
- Gamma radiation from ^{241}Am source
  - Spectrum, cross-section, energy loss in air
  - Energy loss in matter, radiography, X-ray fluorescence
- Natural background radiation, radon
- Preparation of the final presentation

Part 2: Atom Fast 8850 – Dosimetry and Radiation Safety

- Introduction to scintillation detectors
  - Principle of operation: CsI(Tl) crystal + SiPM
  - Types of photon radiation (gamma, X-ray, bremsstrahlung)
  - Interaction mechanisms: photoelectric effect, Compton scattering, pair production
- Background radiation measurement
  - Natural radiation background concept
  - Statistical processing: mean, standard deviation, SEM
  - Radon and ventilation effects
- Distance dependence (inverse square law)
  - Experimental verification of $I \propto {}^{1}/_{r^2}$
  - Background subtraction
  - Least squares fitting
- Shielding experiments
  - Exponential attenuation law
  - Half-value layer (HVL) for *P*b, *Al*, *Fe*, glass
  - Comparison of shielding efficiency
- Dynamic measurements
  - Moving source: linear trajectory (Lorentz-shaped peak)
  - Circular trajectory (constant distance verification)
  - Speed estimation from dosimeter data
- Statistical analysis and data processing
  - Uncertainty estimation, confidence intervals
  - Student's t-test for comparing datasets
  - Required number of measurements
- GPS mapping of radiation background
  - Data collection with GPS tagging
  - Using Global Mapper Pro for map generation
  - Identification of anomalous zones
- Individual dosimetry and documentation
  - Dose calculation, annual limits (NRB-99/2009)
  - Filling dosimetric log and declaration forms

4. Prerequisites

- Knowledge of school mathematics and physics.
- Basics of computer knowledge: MS Windows, MS Office (especially PowerPoint), plotting charts in MS Excel or Origin (desirable).
- If possible, to have a personal laptop with MS Windows, Office, and Origin installed.
- For GPS mapping: smartphone with Bluetooth and GPS (Android or iOS).

5. Recommended number of participants

4 persons recommended, 8 persons maximum (2 persons per one detector kit in this case).

6. Supervisors

Dr Kirill Gikal, senior engineer of the Scientific-Engineering Group of the JINR University Centre.
Mr Lev Pavlov, engineer of the Scientific-Engineering Group of the JINR University Centre.
Mr Konstantin Timoshenko, engineer of the Scientific-Engineering Group of the JINR University Centre.

7. Recommended literature

[1] V. Vicha. Experiments Using Pixel Detectors in Teaching Nuclear and Particle Physics.
[2] F. Knoll. Radiation detection and measurement.
[3] NRB-99/2009 (Russian Federation Radiation Safety Norms).
[4] ICRP Publication 103 (2007) – The 2007 Recommendations of the International Commission on Radiological Protection.