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"Geometry simulation of the Zero Degree Calorimeter at NICA-SPD using Geant4"

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Outline

Introduction to ZDC at NICA-SPD

Joint Institute for Nuclear Research

SCIENCE BRINGS NATIONS TOGETHER

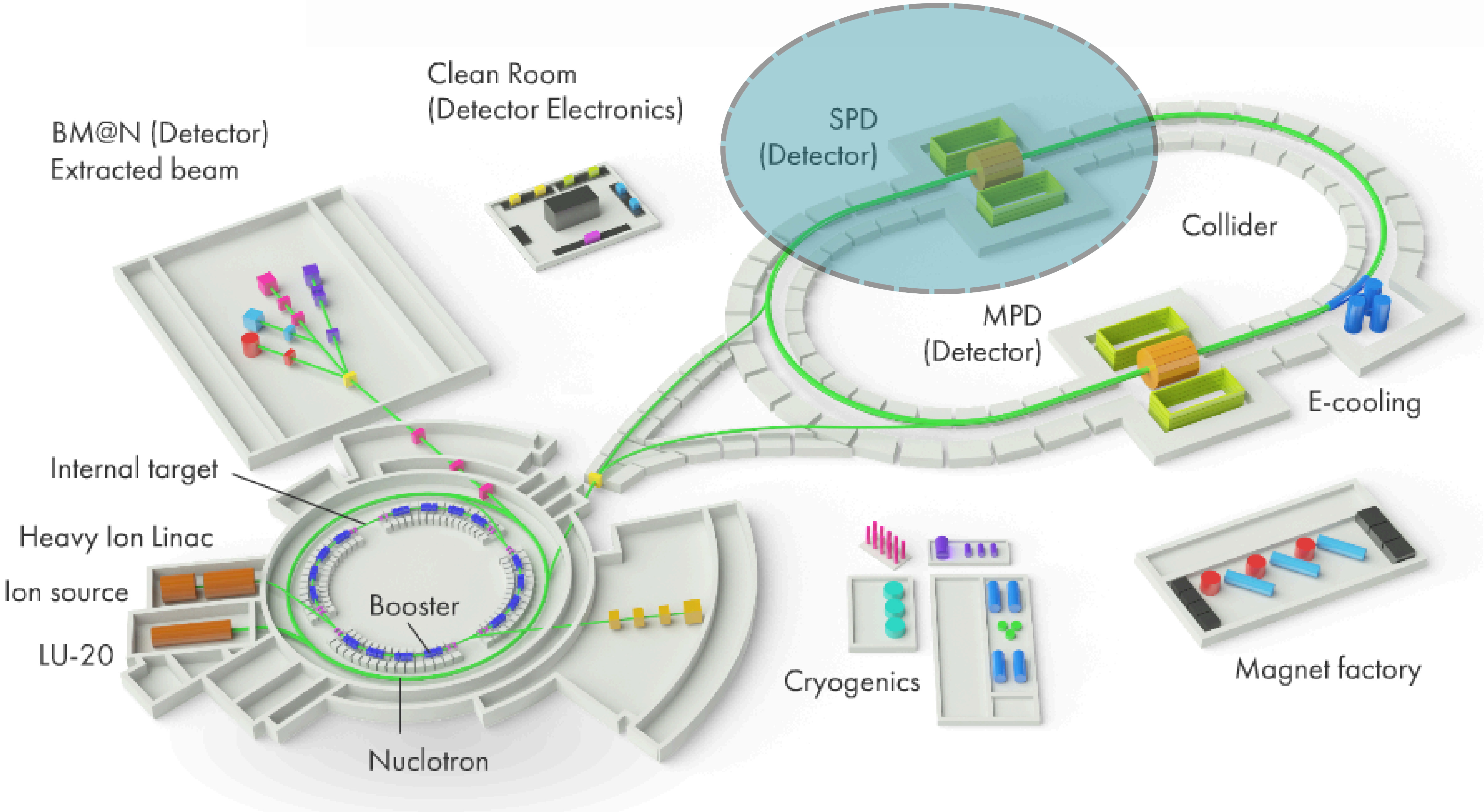
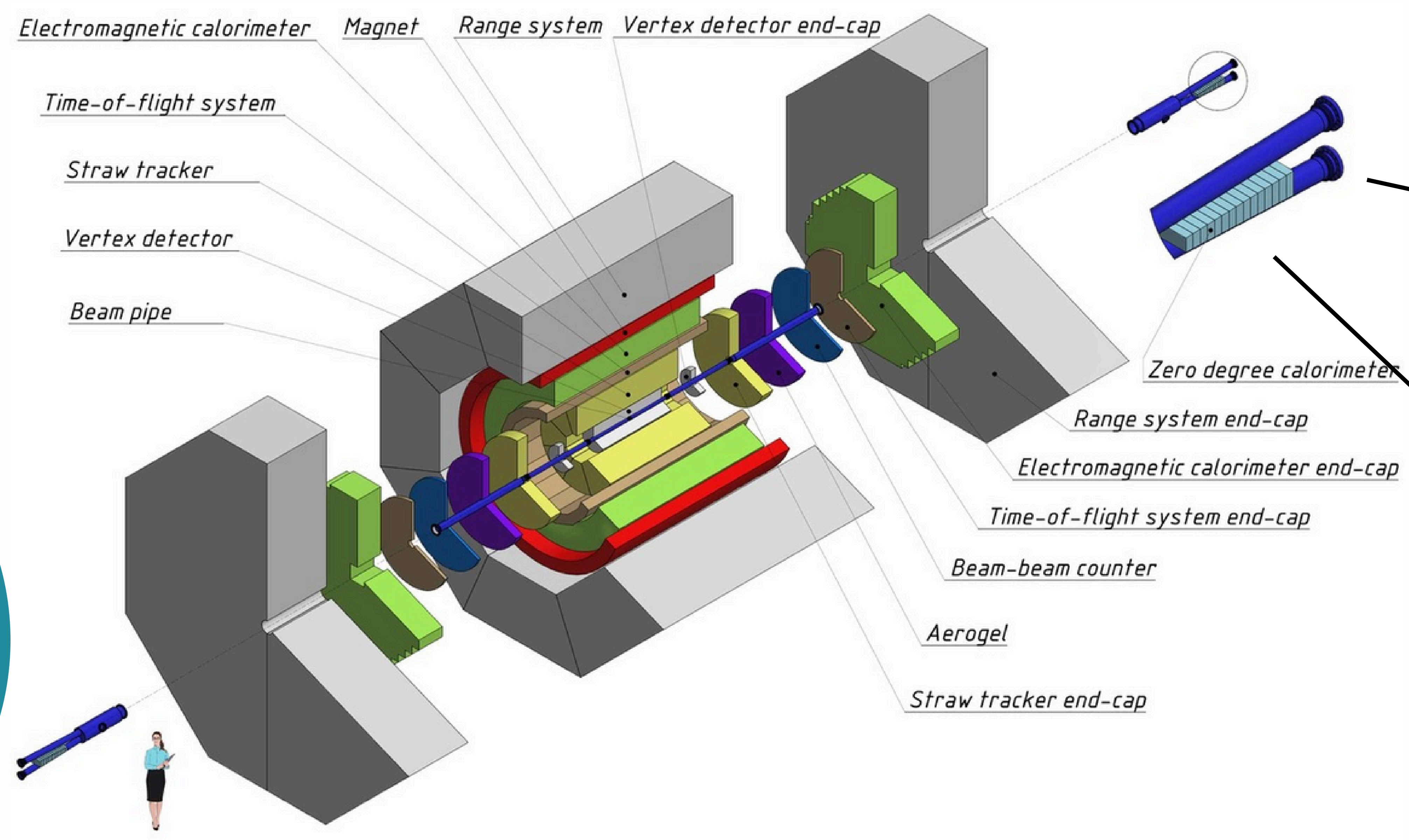


Figure 1: NICA project outline



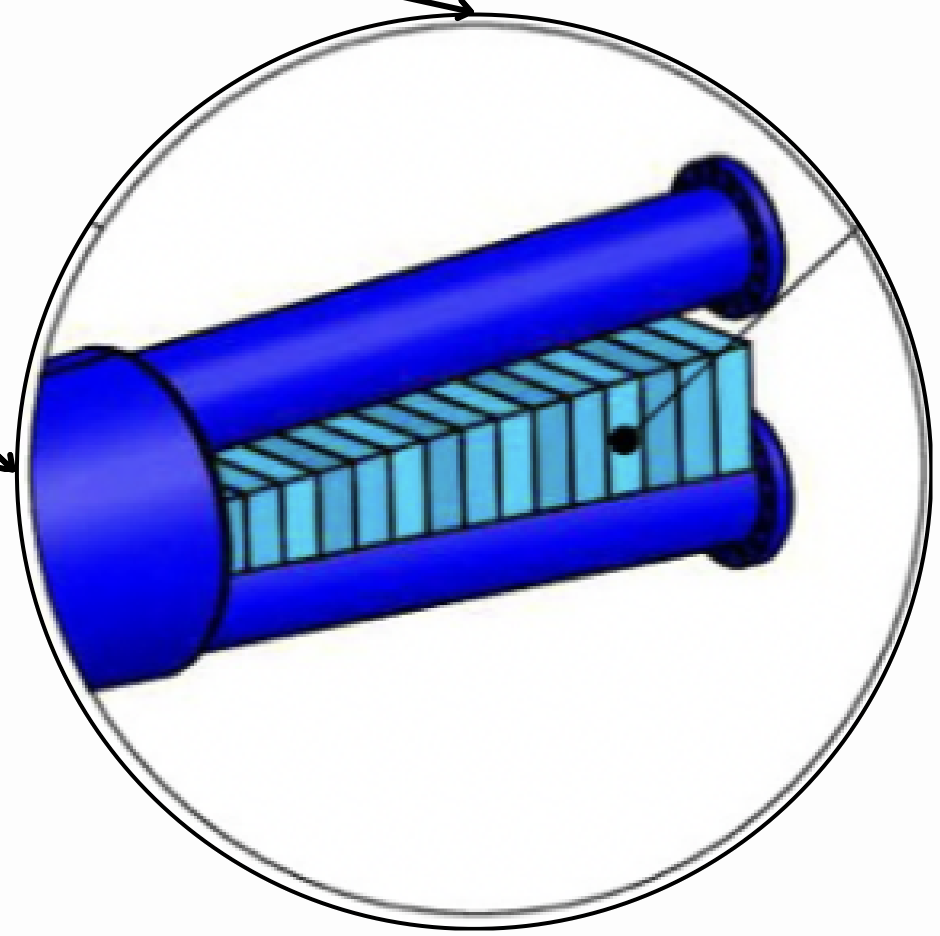


Figure 2: General layout of the SPD setup.

ZDC's main tasks are:

- luminosity measurement.
- spectator neutron tagging.
- time tagging of the events for event selection.
- local polarimetry with forward neutrons.

ZDC Geometry Setup

Electromagnetic part

Scintillator thickness, mm 5

Absorber thickness, mm 5

PCB thickness, mm 1

Hadronic part

Scintillator thickness, mm 10

Absorber thickness, mm 13

PCB thickness, mm 1

Total

Thickness, mm 611

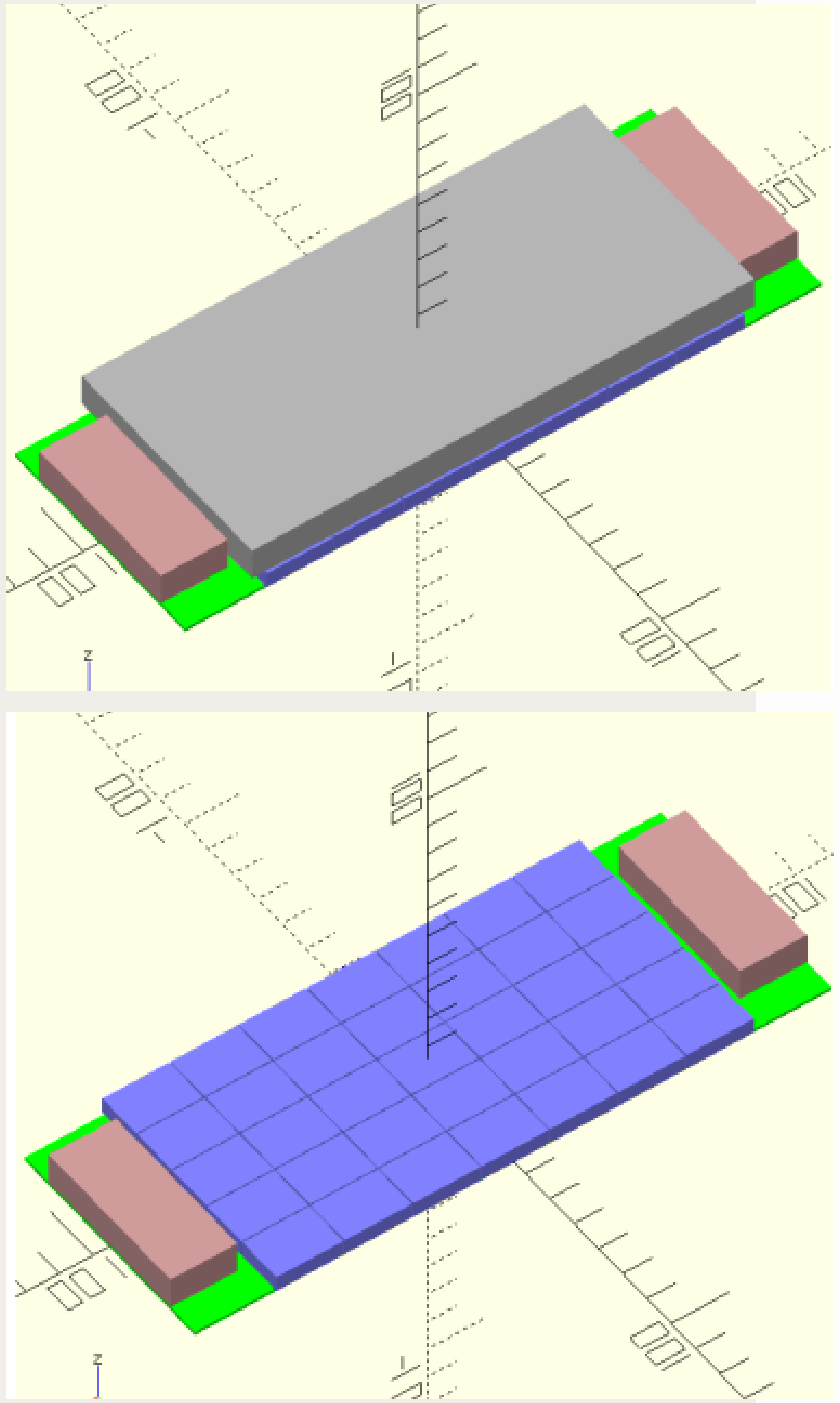
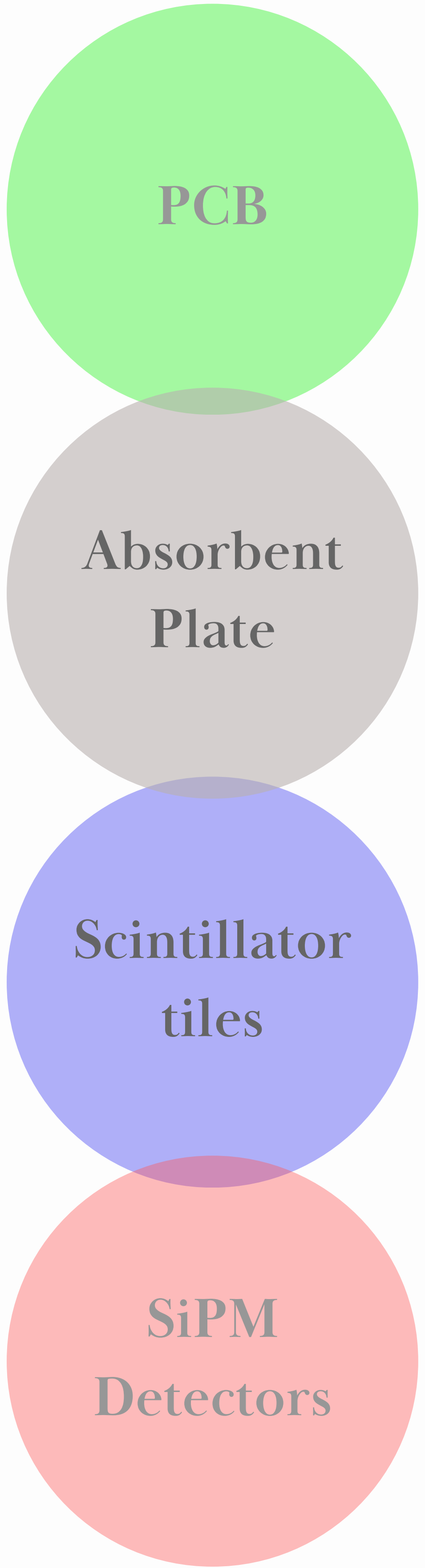


Figure 3: A single ZDC module



FREECAD SOFTWARE

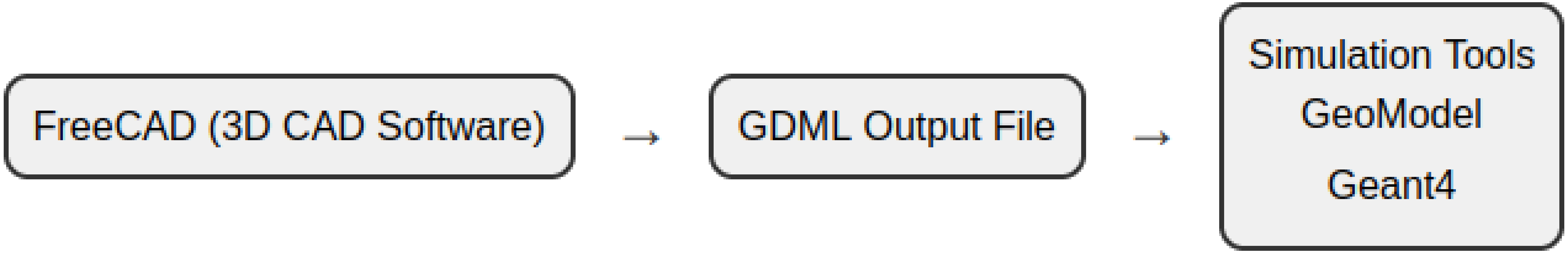


Figure 4: Workflow diagram

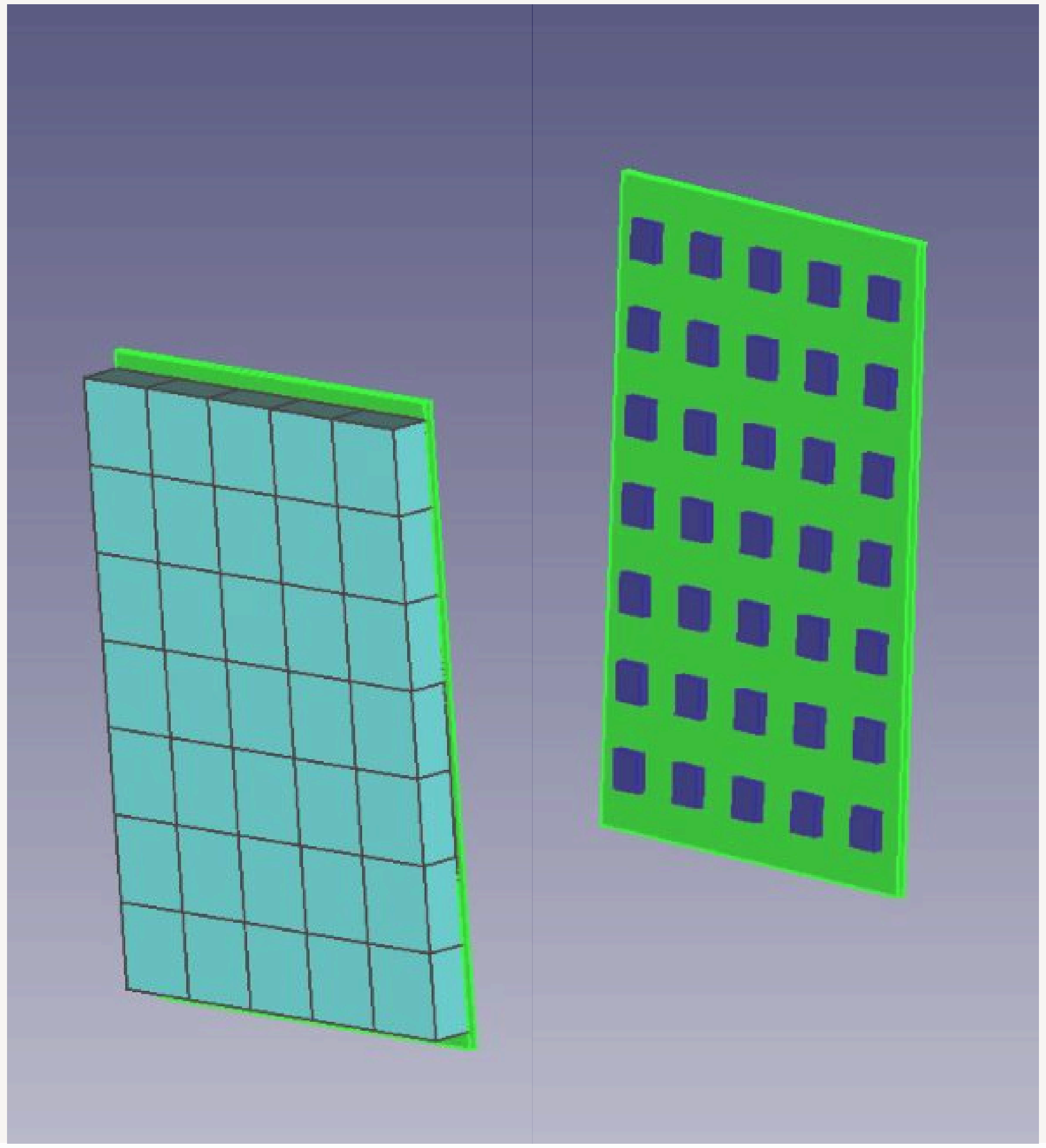


Figure 5: Left: Scintillator plate with PCB frame green. Right: PCB with SiPM detectors.

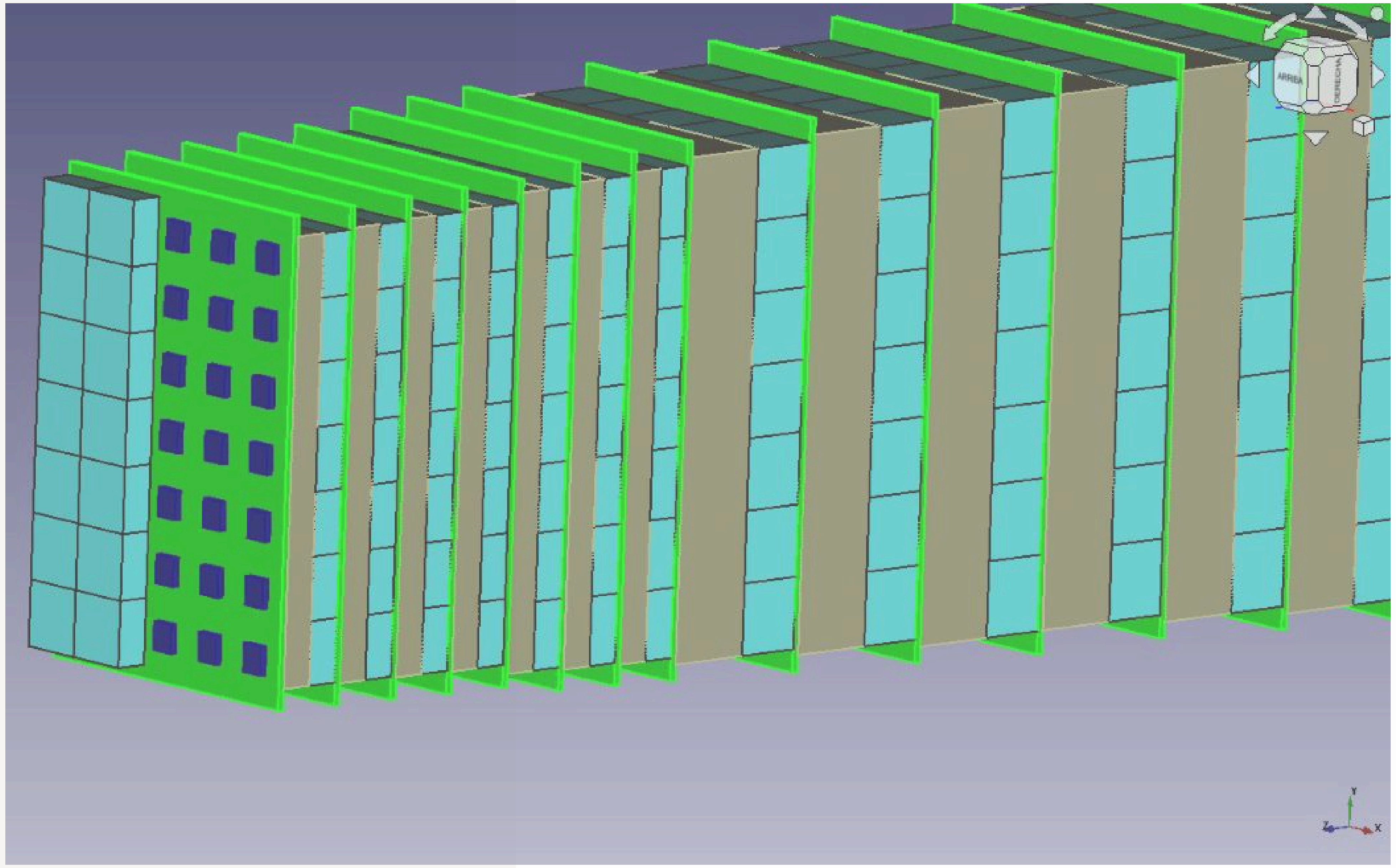


Figure 6: Assembly of individual planes: 3D model in FreeCAD

Parameters

Number of Layers:

- EM section: 8 layers
- HAD section: 22 layers

Absorber Plates:

- EM section: 7 absorbers
- HAD section: 22 absorbers

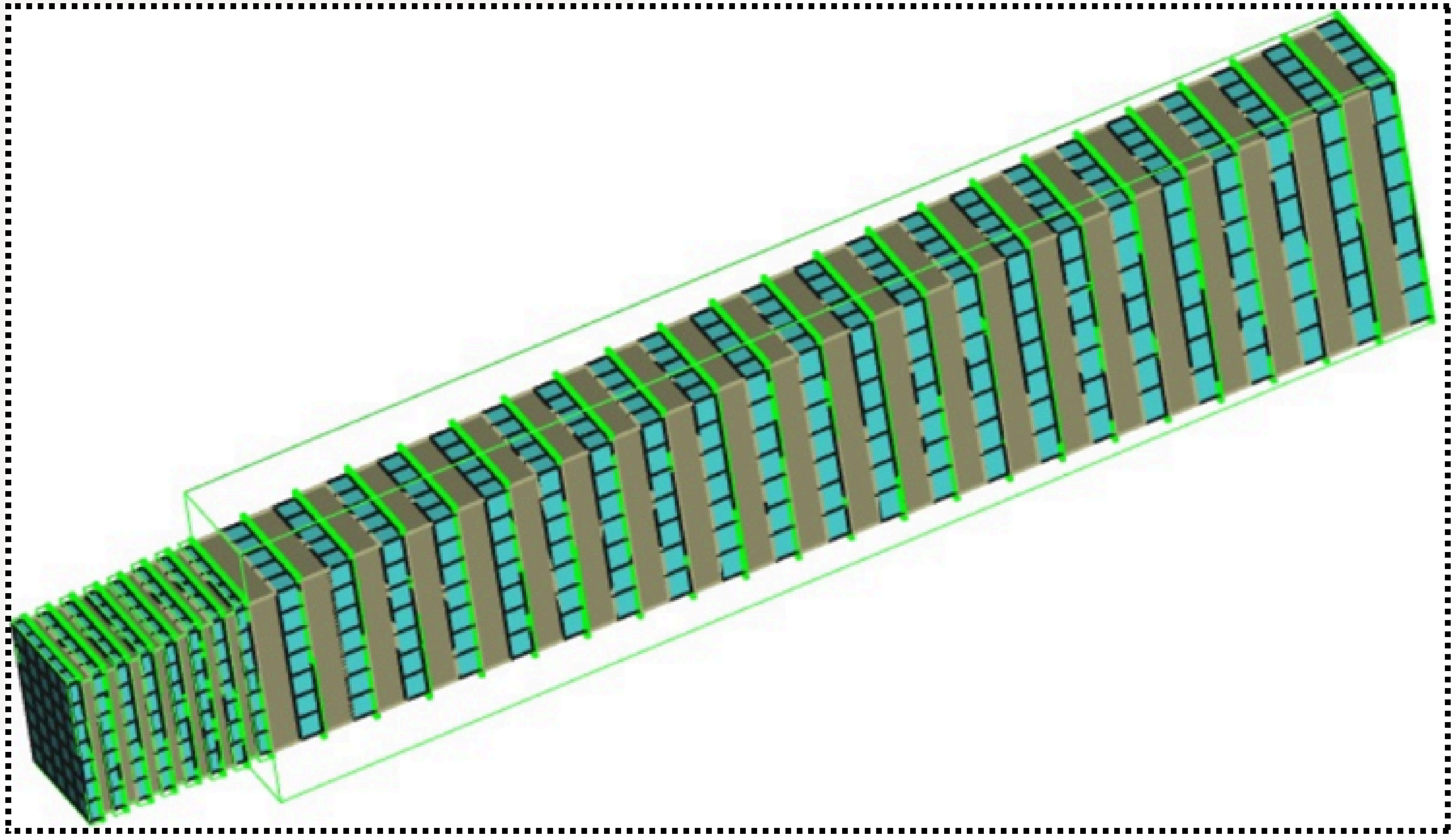


Figure 7: Integration of the calorimeter sections

Materials Selection

Scintillating Plastic
Composition: 97.49% C, 2.5% H, 0.01% O
Density: 1.05 g/cm³
Function: Conversion of energy into light signals

Tungsten (W)
Function: Primary absorber
Properties: Z=74, ρ=19.3 g/cm³
Advantage: Excellent for initiating particle cascades

FR-4 (PCB)
Composition: 43% C, 3% H, 54% O
Density: 1.85 g/cm³
Function: Structural support and electrical connections

SiPM
Simplified composition: 95% Si, 3% O, 2% Al
Density: 2.33 g/cm³
Function: Detection of light signals

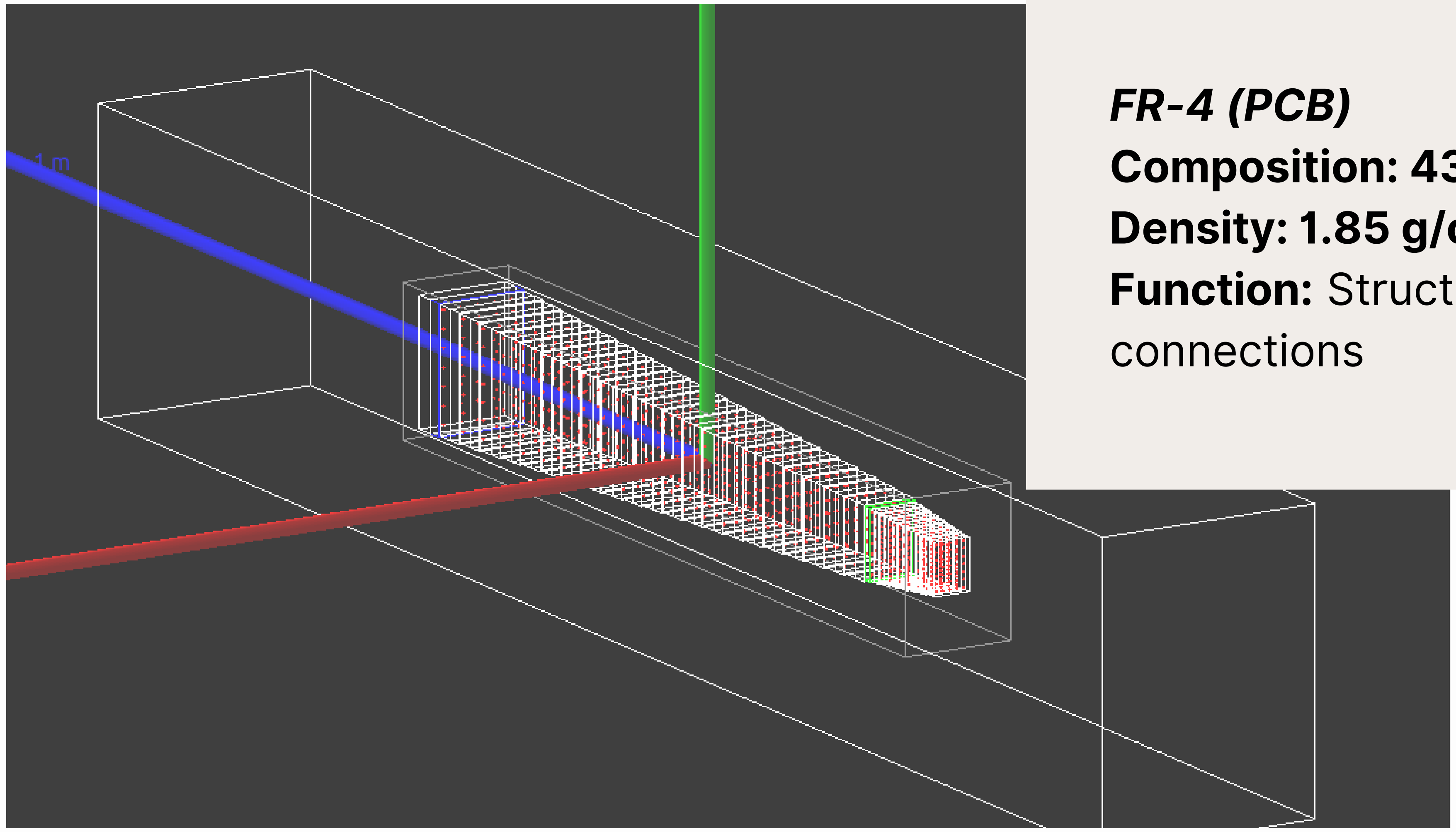


Figure 8: Geometry overview, simulated in Geant4.

Event Generation

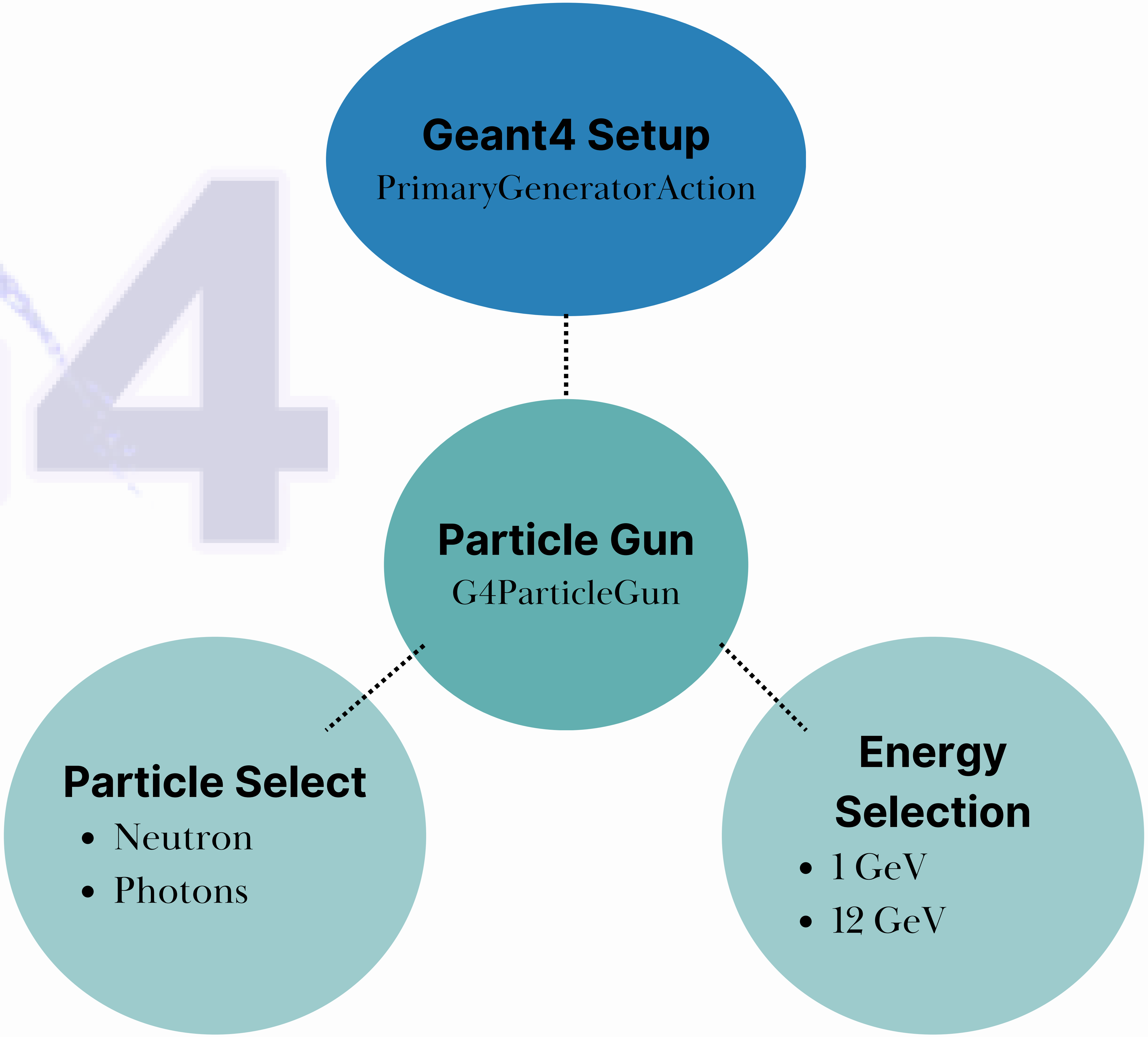


Figure 9: Event Generation Schematic

- The Geant4 simulation provides a customizable particle beam with a circular distribution, where the maximum radius is dynamically calculated based on the detector's dimensions.

- Particle starting positions are randomly sampled according with a uniform distribution, with the initial position in the calorimeter’s front face.

Detector Response Simulation

Energy Distribution per Layers

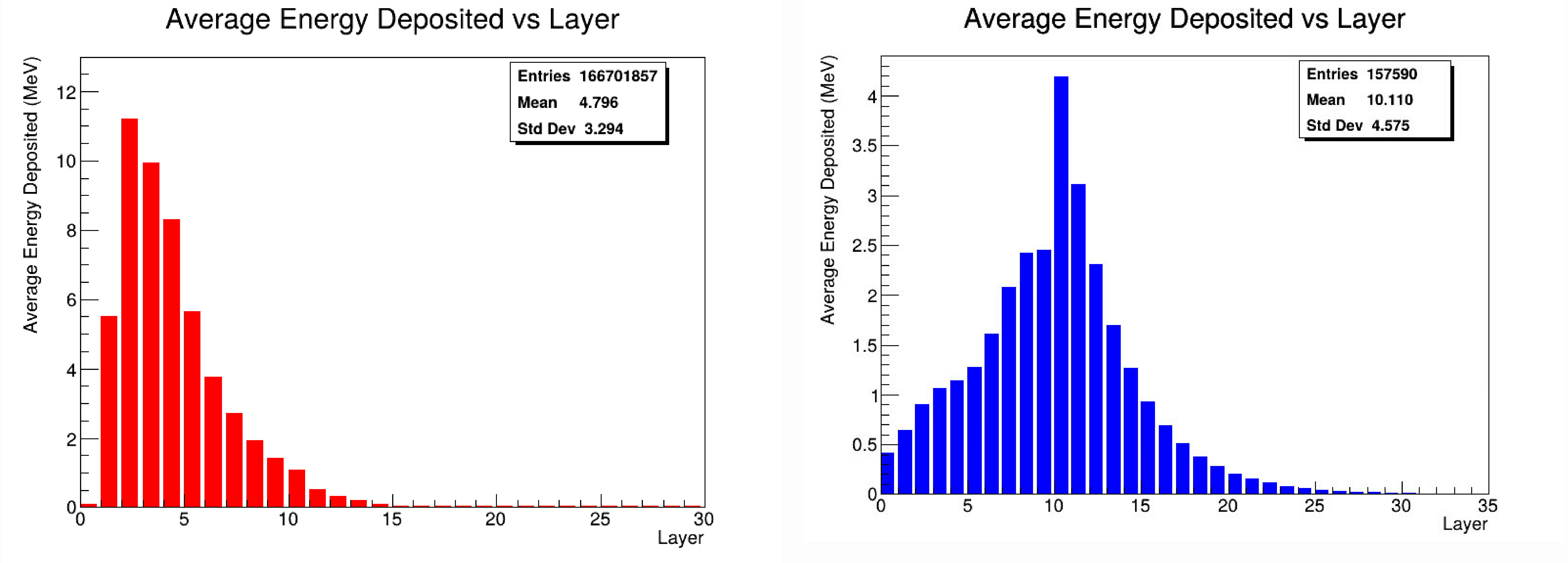
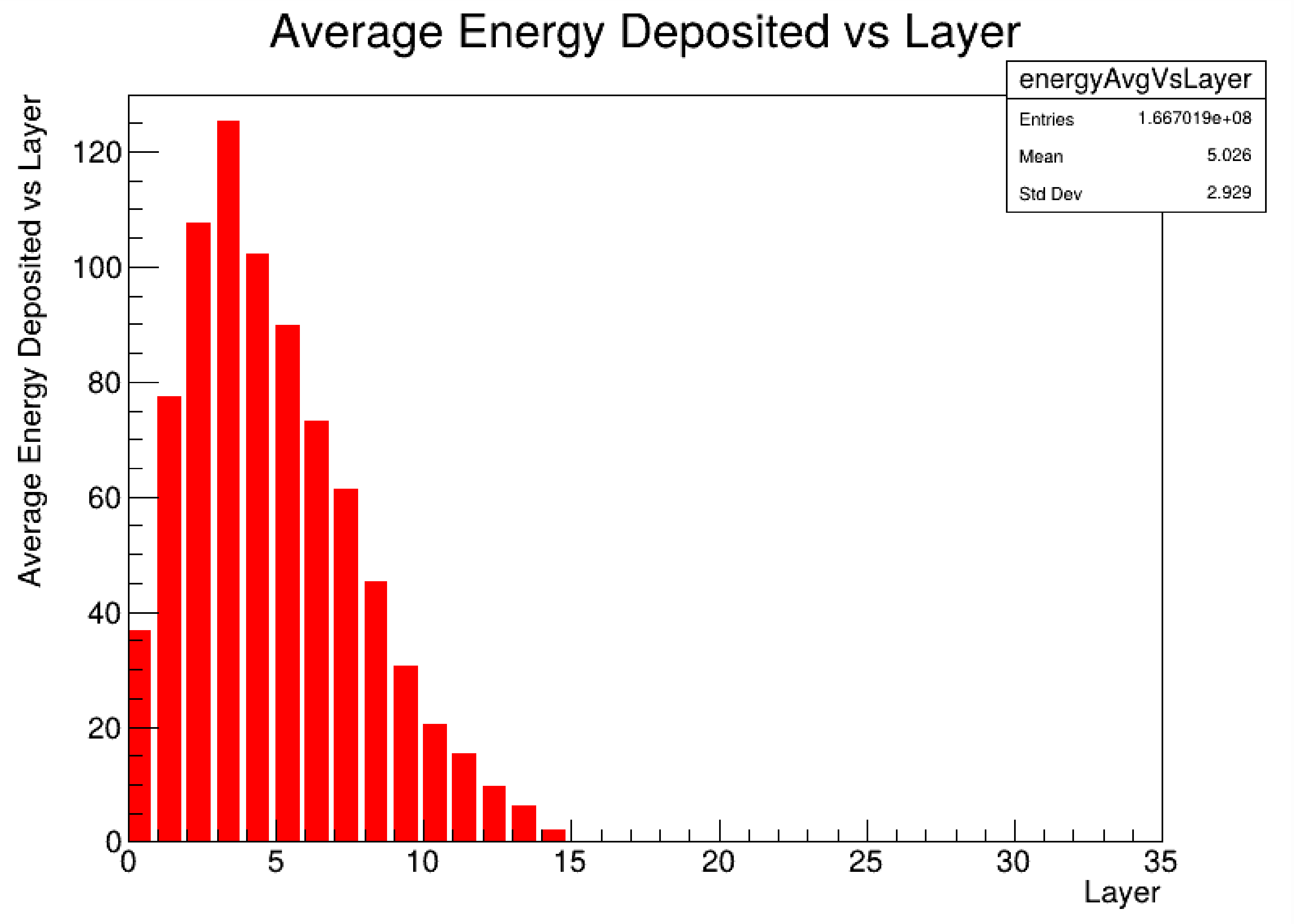


Figure 10: Average energy deposited vs. detector layer for gamma rays (red) and neutrons (blue) of 1 GeV.

Energy Distribution per Layers



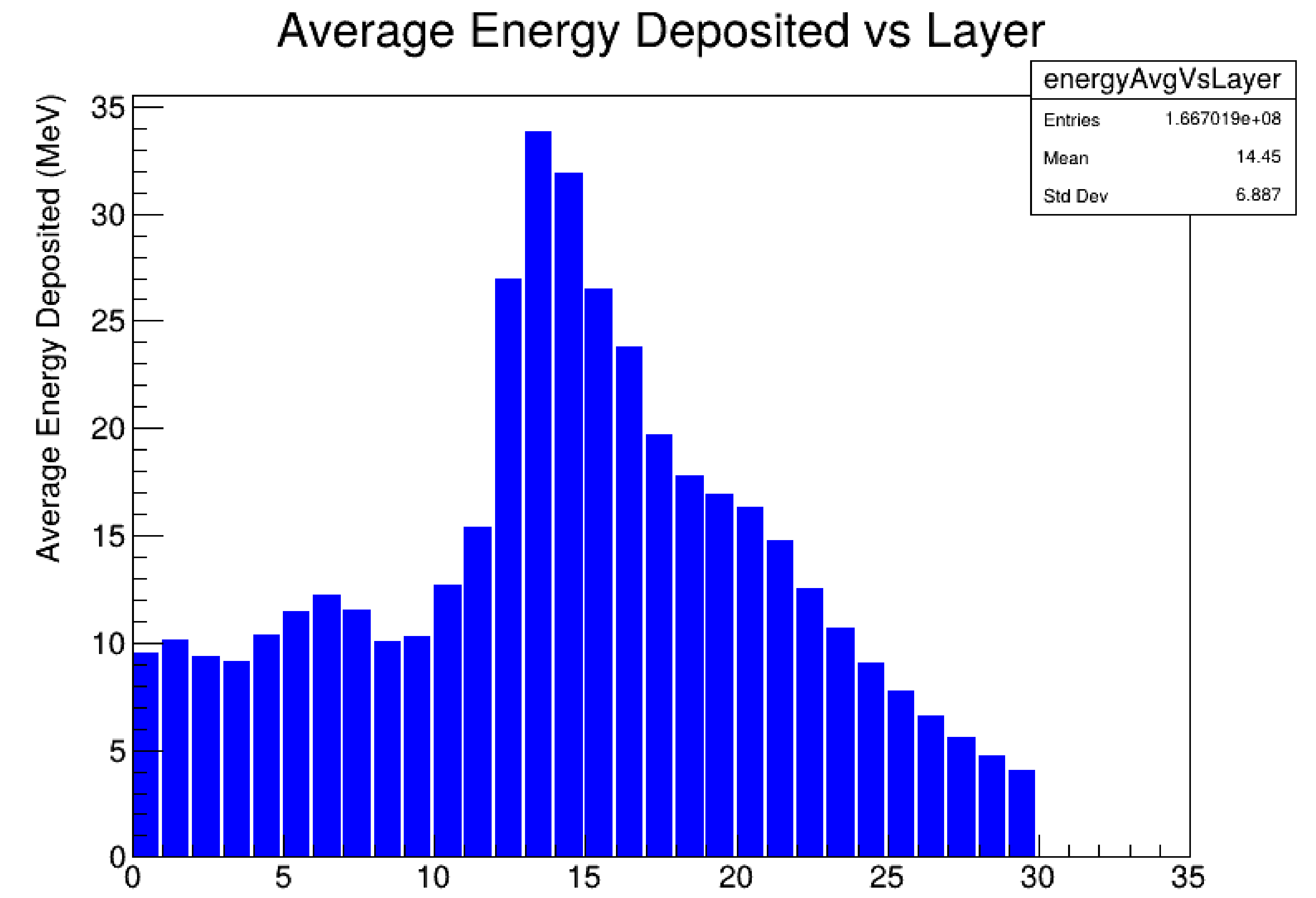


Figure 11: Average energy deposited vs. detector layer for gamma rays (red) and neutrons (blue) of 12 GeV.

Energy deposit vs. Total energy

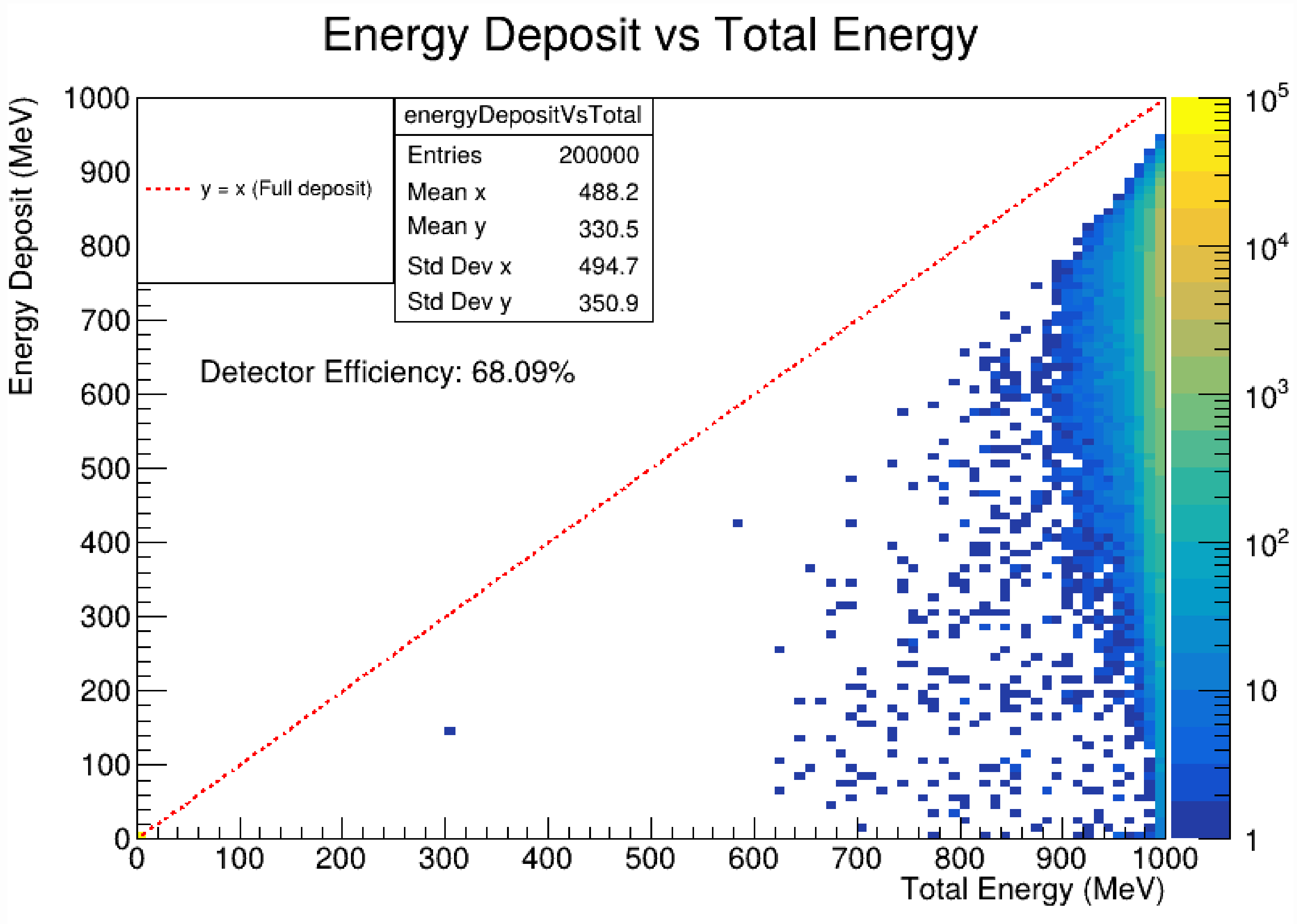


Figure 12: Response to 1GeV gamma.

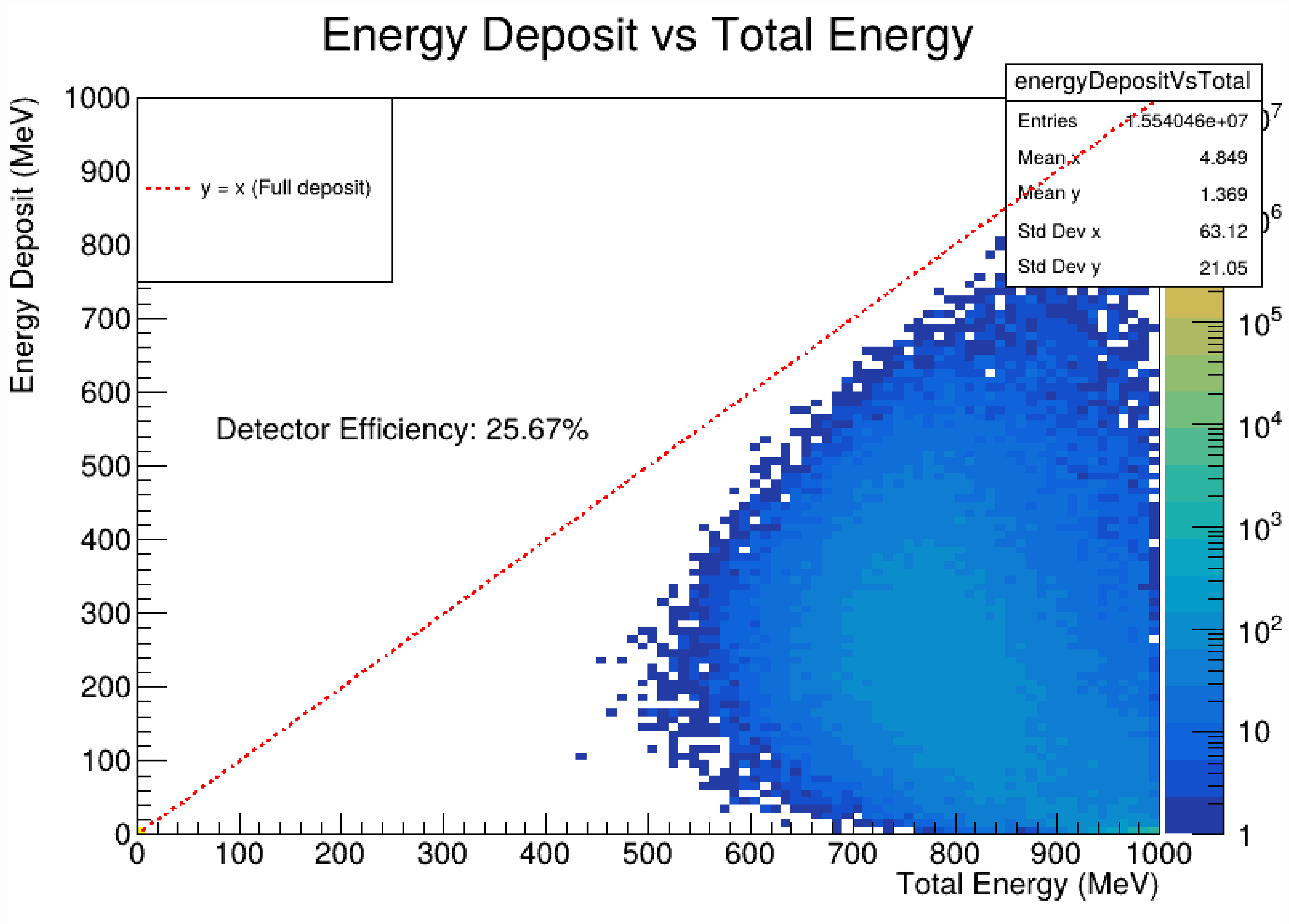


Figure 13: Response to 1GeV neutrons

An approximate efficiency of 68%

An approximate efficiency of 25%

Energy deposit vs. Total energy

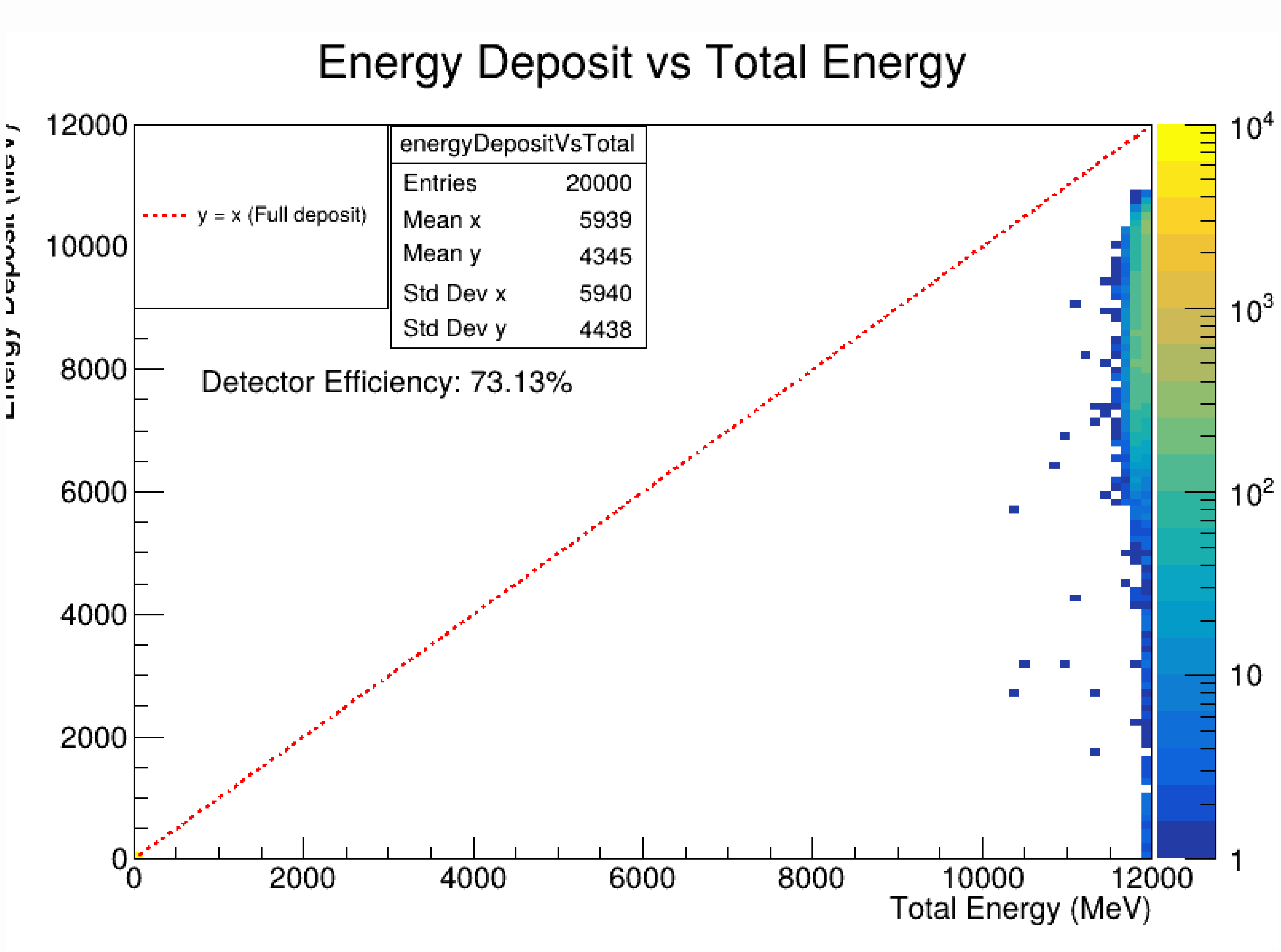


Figure 14: Response to 12GeV gamma.

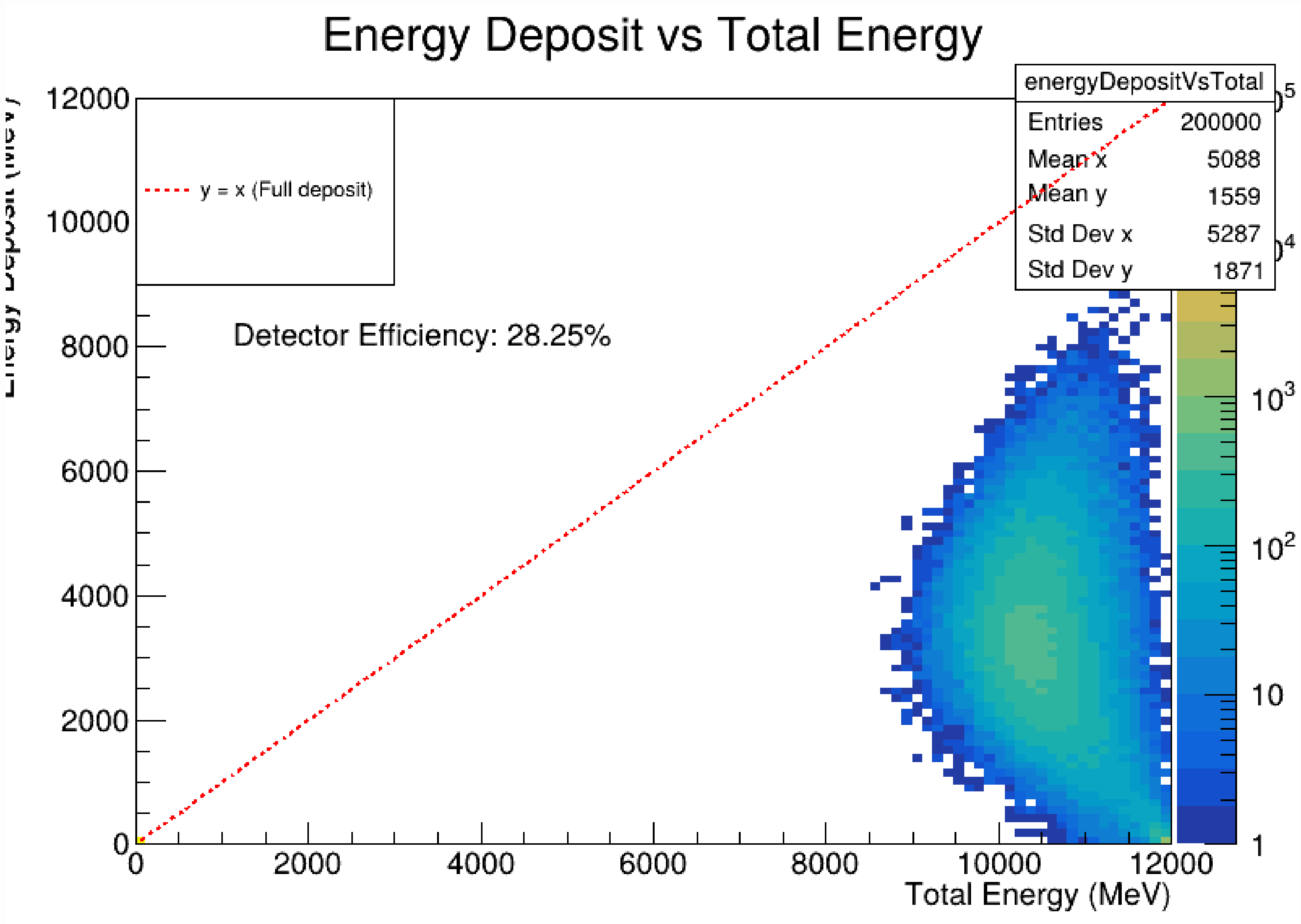


Figure 15: Response to 12GeV neutrons

An approximate efficiency of 73%

An approximate efficiency of 28%

Summary and Conclusions

- A detailed model of the ZDC geometry was created, using the geometry information from the Technical Report and the Conceptual Design Report of SPD.

- The use of the software FreeCAD significantly enhanced our understanding of its geometrical structure, composed by the electromagnetic and the hadronic modules.

- A precise ZDC geometry description was first created as a GDML solid in a FreeCAD workbench with the aim of being imported in Geant4.

- The detector response to photons and neutrons with two different energies was studied through a simulation with the version 11.3.0 of Geant4 toolkit.

- The different longitudinal energy distributions for neutrons and photons can be used for neutron/photon separation in future analyses.

- The energy efficiency is less than 74% for photons and less than 29% for neutrons.

- This is an early stage of a broader project, aimed to develop computational methods in order to build a modular approach of the ZDC geometry based on the G4/GeoModel integration and subsequently integrate it in the SpdRoot framework.

Thank you very much for your attention