Geant4 Simulations of the gSPEC Experimental Apparatus

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Abstract

A new setup (gSPEC) for the measurements of magnetic moments in exotic species is proposed for development at FAIR, the international nuclear facility currently under construction in Darmstadt, Germany. The experimental setup will use a few of the state-of-the-art segmented DEGAS detectors available at GSI, acquire a new large dipole magnet to induce external magnetic fields required for the application of the Time-Differential Perturbed Angular Distribution (TDPAD) technique and integrate ancillary detection systems as part of a research plan to study the properties of exotic species that will made available at FAIR.

At the current stage, the envisioned gSPEC setup is still in R&D. Several configurations of the detectors are considered, but optimization relies on detailed simulations of the total efficiency in various geometries. In this work, DEGAS detectors and a split-pole superconducting magnet are studied using the latest GEANT4 simulation package. The simulations aim to offer insight on the detector setup performance before gSPEC is actually constructed.

FAIR Facility

- 20 accelerator and experiment buildings, laboratories and supply buildings.
- Underground accelerator ring of circumference of 1.100 m.
- About 150.000 m² of total area.

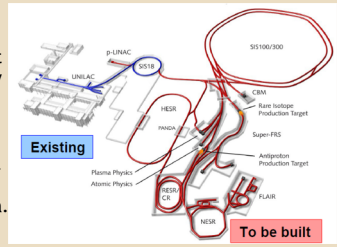

Fig. 1 Overview of the FAIR facility.

Geometry

The DESPEC Germanium Array Spectrometer (DEGAS) is a high-purity germanium γ-detector array for high-resolution spectroscopy of electromagnetic decays from exotic nuclear species

Fig. 2 The DEGAS detector (complete)

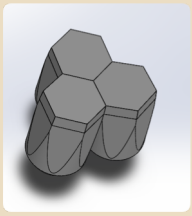

Fig. 3 The DEGAS detector without caps or electronics.

The simulated geometry consists of 4 simplified DEGAS-type detectors (Fig. 3), 2 magnets with 8 poles supporting them, and the path in which the beam travels towards the target.

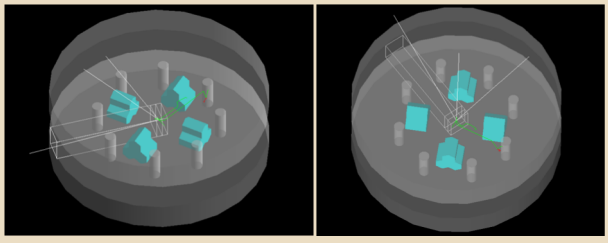

Fig. 4 The simulated experimental apparatus

References:

[1] Guang-Shun Li et al., Simulated characteristics of the DEGAS γ -detector array, https://doi.org/10.1016/j.nima.2018.02.062.

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The Simulation Framework

- The simulation framework profited from the Geant4 toolkit (v10.05), developed for the simulation of the passage of particles through matter.
- This model was developed using the radioactive decay Geant4 example from the extended set of examples.
- The detector resolution was incorporated in the simulation result by redistributing the simulated data of each event with a random variable biased on a Gaussian distribution of standard deviation corresponding to a FWHM of 0.3%.
- Two different isotopes were used as radioactive sources, ^{137}Cs and ^{60}Co.

Simulation Results

The distance dependence of a single DEGAS detector is studied. The figures below show the typical spectrums of the two sources used.

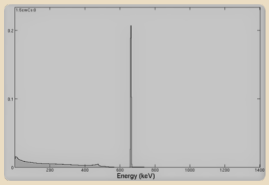

Fig. 5 A typical spectrum of a ^{137}Cs radioactive source.

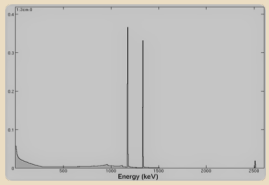

Fig. 6 A typical spectrum of a ^{60}Co radioactive source.

The results below show the absolute efficiency as a function of the detector – source distance. The number of simulated events is 10^8 for every distance value.

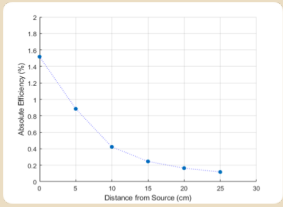

Fig. 7 Distance Dependence plot. Radioactive source: ^{137}Cs (662 keV)

As for ^{60}Co, we present two preliminary plots regarding the 1.17 and 1.33 MeV peaks respectively. The sum peak is not studied as it is barely noticeable as the distance grows.

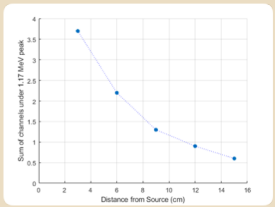

Fig. 8 Distance Dependence of the 1173 keV peak of ^{60}Co.

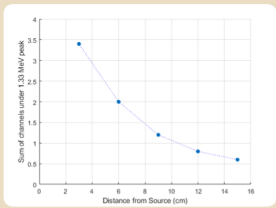

Fig. 9 Distance Dependence of the 1332 keV peak of ^{60}Co.

Conclusions

The simulations provided us with some useful insight in how the DEGAS detector behaves in increasing distance from the source, and showed an decreasing exponential behavior in the absolute efficiency.
More simulations are currently in progress in order to study the efficiency of the experimental apparatus regarding the number and positioning of the detectors, as well as its overall optimization inside the strong dipole magnet.