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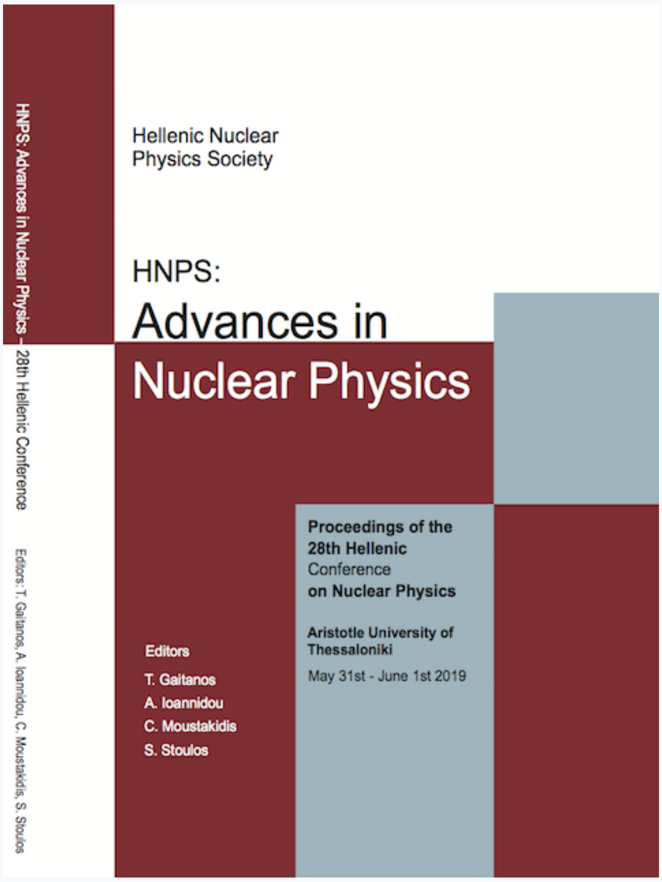

Geant4 Simulations of the gSPEC Experimental Apparatus

N. Maniatis, Theo J. Mertzimekis

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Geant4 Simulations of the gSPEC Experimental Apparatus

N. Maniatis and T.J. Mertzimekis

Department of Physics, National Kapodistrian University of Athens, Zografou Campus, Athens

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.*

Keywords *Geant4, Simulation, gSPEC, magnetic moments.*

Corresponding author: T.J. Mertzimekis (tmertzi@phys.uoa.gr) | *Published online:* May 1st, 2020

INTRODUCTION

Nuclear *g* factors are of the most accurate probes in modern nuclear physics investigations. Sensitive to the precise structure of the nuclear states, single–particle or collective nature is accessed directly by their measurement. The gSPEC collaboration aims at studying *g* factors of isomeric states along the entire nuclear chart. This work intends to help design an experimental apparatus to perform measurements of nuclear moments in exotic isotopes. The apparatus will install a large dipole magnet and a few DEGAS detectors, among other components. As the main focus is exotic nuclei with very low counting rates, it is important to know the absolute detection efficiency of the experimental apparatus during the designing phase.

Similar work has been done by members of GSI [1], regarding the efficiency of the DEGAS detectors in various nuclear spectroscopy configurations, also compared with experimental results. In the present work, no experimental data are available to compare with, however simulations can be very useful in providing insights beforehand.

gSPEC AT FAIR

Currently the international accelerator facility FAIR, one of the largest research projects worldwide, is being built in Darmstadt, Germany. FAIR will generate particle beams of a previously unparalleled intensity and quality. The variety of these particles will be unique: Ions of all the natural elements in the periodic table, as well as antiprotons, can be accelerated. The key component of FAIR is an underground ring accelerator with a circumference of 1’100 meters. Connected to this is a complex system of storage rings and experimental stations. The existing GSI accelerators will serve as the first acceleration stage. The facility consists of 20 accelerator and experiment buildings, laboratories and supply buildings while it spreads over an area of 150.000 m^2 (Fig. 1). The gSPEC Collaboration proposes the development of a dedicated setup after SuperFRS taking advantage of the unique exotic beams to be delivered by FAIR.

DEGAS AND THE APPARATUS GEOMETRY

The DESPEC Germanium Array Spectrometer (DEGAS) is a type of detector featuring multiple high–purity germanium crystal heads in compact geometry used for high–resolution spectroscopy of electromagnetic decays from exotic nuclear species.

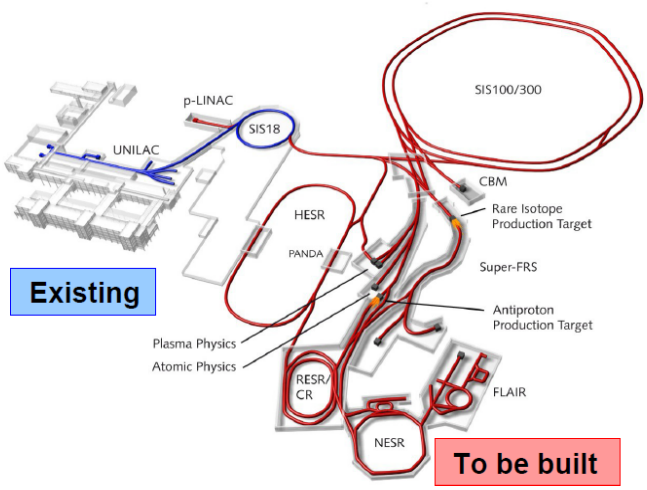

Figure 1. *Overview of the FAIR facility.*

Figure 2. *A photorealistic model of DEGAS detector.*

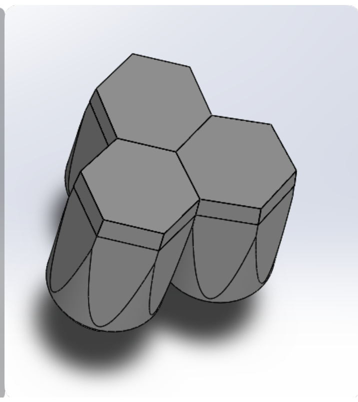

Figure 3. *The DEGAS detector without caps or electronics.*

An important characteristic of this type of detector is that it does not need liquid N_2, as it is electrically cooled. This feature offers some advantages when packed geometry in the apparatus is needed, in our case if the distance between the magnet poles has to be reduced to provide larger fields. It its complete form (Fig. 2), the DEGAS detector has a large number of components. The conversion of the CAD file to GDML, which can be directly imported to Geant4, so that a precise model can be incorporated for detailed simulation is nothing but trivial. Several attempts have been carried out (e.g. with code in [2]), but there is no software that works fully as desired. To avoid further complication, one needs to adopt a simplified model of the detector to simulate (Fig. 3). The simplified model of the detector will only provide approximate results, but it can be a first attempt towards providing a value of the absolute detection efficiency. In this work, the adopted model consists of three hexagonal section prisms with the same front face dimensions and overall length of the crystals.

The complete experimental apparatus (Fig. 4) is envisioned with four detectors, as well as two superconducting magnet poles necessary for the employment of the TDPAD technique, a target, the poles supporting the magnets, and the path in which the beam travels towards the target.

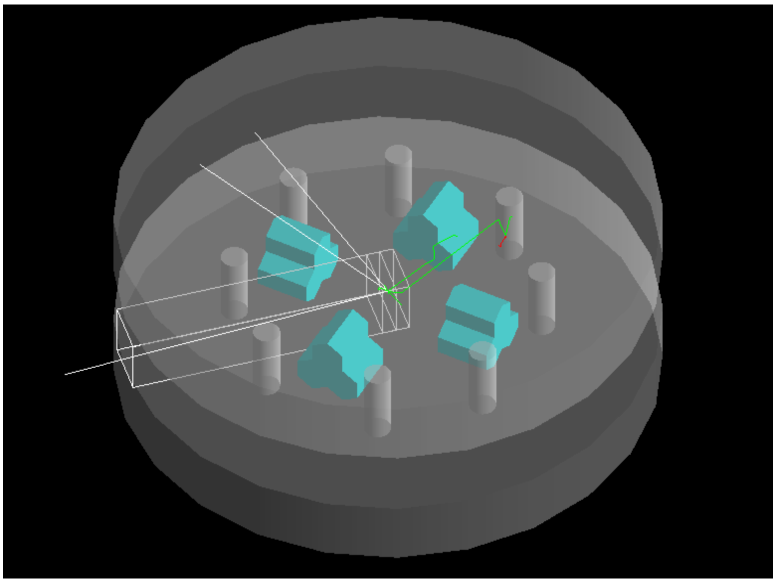

Figure 4. *The simulated experimental apparatus*

THE SIMULATION FRAMEWORK

The simulation framework profited from the Geant4 toolkit (v10.05), developed for the description of the passage of particles and radiation through matter. 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 spectra of the two sources used.

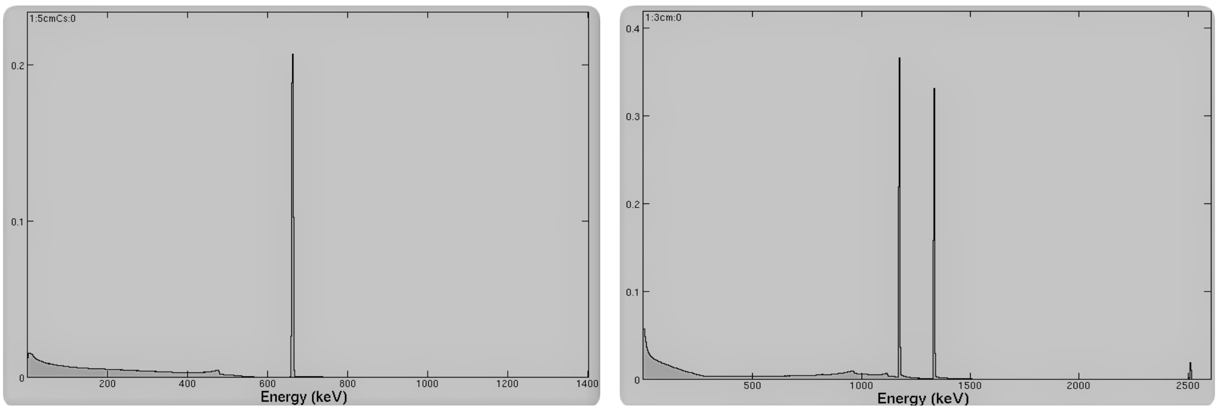

Figure 5. *A typical spectrum of a ^{137}Cs source (left) and a ^{60}Co source (right)*

The results in Fig. 6 and 7 show the absolute efficiency as a function of the detector – source distance. The number of simulated events is 10^8 for every distance value. As for ^{60}Co, two preliminary plots regarding the 1173 and 1332 keV photopeaks are presented, respectively. The summing peak is not studied as it is barely noticeable as the distance grows.

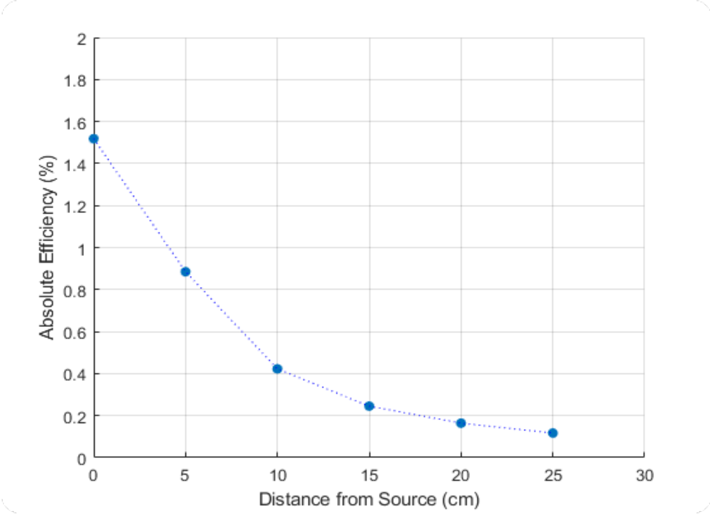

Figure 6. *Distance dependence plot. Radioactive source: ^{137}Cs (662 keV)*

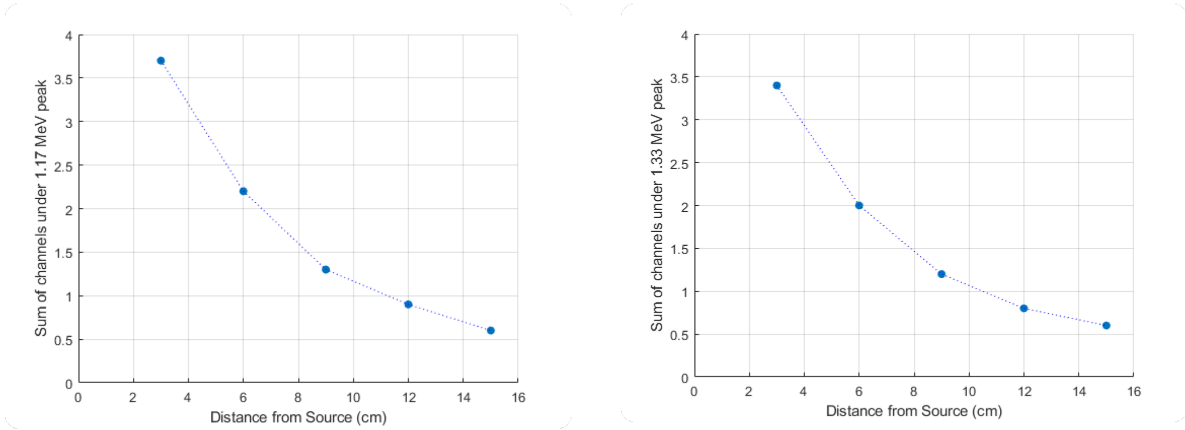

Figure 7. *Distance dependence of the 1173 keV (left) and 1332 keV (right) peak of ^{60}Co*

CONCLUSIONS

The performed simulations provided with some useful insights about how the DEGAS detector behaves in increasing distance from the source, and showed a 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.

References

[1] G.-S. Li et al. Nucl. Instrum. Meth. Phys. Res. A 890, 02 (2018)
[2] C.M. Poole et al., Austral. Phys. Eng. Sci. Med. 35, 329 (2012)