The MaGe Simulation Package for the Majorana and Gerda Experiments

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The Majorana experiment[1] is a proposed 500-kg enriched, segmented, HPGe detector array that will primarily search for neutrinoless double-beta ($0\nu\beta\beta$) decay and dark matter. It will rely on pulse-shape discrimination and segmentation to suppress remnant backgrounds following careful materials selection. The projected sensitivity of Majorana to $0\nu\beta\beta$ decay is 4×10^{27} years.

A unified simulation framework meeting the requirements of the Majorana collaboration has been implemented. The primary goals and requirements of the framework are:

1. To use modern simulation tools to produce an easily adaptable and flexible platform with appropriate verification and anticipated longevity.
2. To provide the collaboration with a physics simulation package to aid in the optimal design, operation and analysis of data from the Majorana experiment. The physics generators will concentrate on radioactive decays of background sources.
3. The package must be well maintained, documented, and robust.
4. It must accurately reflect detector response and resolution.
5. The numerous physics processes (radioactive decay, signal generation, energy deposit, pulse formation and electronic response), normally modeled by separate software packages, must be integrated into a single framework.
6. Simulations of existing detectors must be performed and documented to verify the performance of the simulation software.

In order to achieve these goals, a unified framework was developed using professional programming techniques in consultation with collaborators from the National Energy Research Scientific Computing Center (NERSC) at LBNL. In October 2004, it was also decided to combine simulation efforts with the Gerda collaboration. The resulting joint simulation package, dubbed "MaGe," can be summarized as follows:

- MaGe is a single C++ program that allows easy integration of different detector geometries and data formats into a framework of common tools, such as radioactive decays generators, materials databases, particle tracking through detector geometries, etc. It makes full use of C++'s powerful object-oriented and abstraction capabilities.
- MaGe is based on Geant 4, a commonly used simulation tool for high-energy and nuclear physics detectors with a large, active international user's community.
- The DOxygen package generates reference documentation, and Docbooks parses Standard Generalized Markup Language (SGML) source text into the User's Guide.
- A modified Taligent naming convention has been adopted to maintain a consistent naming scheme for variables and classes.
- ROOT is used for output and analysis, although other formats (such as AIDA) are also implemented.
- An interface to a PostgreSQL database has been implemented. The database is used to store calibration constant, materials definitions, geometry information, etc.

The package is hosted for the collaboration by LBNL at the NERSC Parallel Distributed Systems Facility (PDSF). A version for remote operation has been created to permit small scale running of the code (for example, on a single PC).

Numerous simulation projects are currently being pursued within the MaGe framework and many of their results have been used in other parts of this proposal. These projects are:

- A detailed study of background contamination in a realistic, fifty-seven 1-kg crystal detector array that has been used in the background budget. A simulation of a higher-granularity detector consisting of 300g crystals is underway.
- A detailed simulation of a Canberra Clover detector at Los Alamos to provide simulation data to compare to a known and understood detector.
- A simulation of a Clover Detector at the TUNL free-electron laser source to study the efficiency of generating a sample of pure single site events for segmentation and pulse shape analysis studies.
- A simulation of a highly segmented Ge detector for pulse-shape and segmentation studies.
- A simulation of the LArGe scintillating-liquid-argon-bath Ge detector is under development.
- All the simulated Gerda geometries and tools are also part of this package.

In addition to the Monte Carlo framework, an analysis software framework proposal is in preparation. The goal of this framework is to combine all data analysis and processing tools into a unified framework, most likely ROOT-based. By testing and developing it in parallel with the Monte Carlo framework, Majorana will be in excellent position to use trusted and understood software for analysis as soon as data taking begins.

REFERENCES

[1] The Majorana Zero-Neutrino Double-Beta Decay Experiment White Paper. nucl-ex/0311013.