MaGe: a Monte Carlo framework for the Gerda and Majorana double beta decay experiments


What is MaGe?

MaGe is a Monte Carlo simulation package dedicated to experiments searching for 0v2β decay in 76Ge. Created by the Majorana collaboration, MaGe is now developed jointly by the Majorana and GERDA simulation groups. MaGe is based on GEANT4, a software well established and widely used in experimental physics.

The idea of MaGe is to share a common simulation framework with an abstract set of interfaces, while each experiment adds its concrete implementations (geometry, output, etc.).

MuGe

The whole package can be configured and tuned by macro without accessing the code accessible to new users and non-experts of C++

Majorana geometry

No constraints to both sides (geometry, physics, etc.) each component can be independently rewritten

MJ output

GERDA geometry

Event generators, description of physics processes, properties of the materials, management

GERDA output

Present status of MaGe

A common CVS repository is hosted at Munich, allowing people from both groups to easily commit new contributions to the code and keep their version of MaGe always up to date.

A discussion forum is hosted at Berkeley to periodically exchange ideas and suggestions for the development of the package and to keep both sides informed about recent implementations and results.

Why MaGe?

✓ avoids duplication of the work for the common parts of the simulators (generators, physics, materials, management)
✓ provides the complete simulation chain
✓ allows more extensive validation of the simulation with experimental data coming from both experiments
✓ can be run by script and is flexible for experiment-specific implementation of geometry and output;
✓ is suitable for the distributed development

The Gerda 76Ge Ov2β experiment

GERDA is a new experiment for the search of 76Ge neutrinoless double-β decay at the Gran Sasso Laboratory (LNGS). The basic principle is to operate Ge detectors made out of isotopically enriched material inside a cryogenic fluid shield.

MaGe simulation of the GERDA geometry including the detectors and the shielding

GERDA will be located in Hall B of LNGS. The main goals of the experiment are:

● to probe the neutrinoless double-beta decay of 76Ge with a sensitivity of $T_{1/2} > 2.10^{26}$ y at 90% Cl, corresponding to a range of effective neutrino mass $0.09 - 0.20$ eV within 3 years.
● to be a pioneering low-level facility demonstrating the possibility of cutting through backgrounds by 2-3 orders of magnitude below the current state-of-the-art.

Muon background Study @ LNGS

The MaGe simulation package has been used to study the background induced by cosmic muons in the GERDA experiment and to optimize the design of the muon veto (plastic scintillators and Ceravolo p-veps).

Simulation of muon-induced spectrum in germanium

Phases I: 6 Ge crystals for a total mass of 10 kg. The threshold for 64 crystals is 50 keV

Sum spectrum without and with anticoincidence

Energy (MeV)

Reduction of more than a factor 4 by means of the anticoincidence

Radioactive bck Study @ MPI Munich

Background events from decays of radioactive elements (137Cs, 134Cs, 137mBa, 140Ba) inside crystals, support and electronic cables are studied.

Most background events come from photons, depositing energy in several crystal segments, while signal events have electrons depositing energy locally.

Segment anticoincidence cut background < 10⁻³ cts/keV/kg

Signal efficiency > 85%

Pulse-shape under study, will further reject background.

The Majorana 76Ge Ov2β experiment

Majorana is US, Canadian, Russian, and Japanese Collaboration, about 50 scientists are involved.

The initial, proposed deployment consists of 380 kg of crystals, scalable to 500kg.

The expected sensitivity is $T_{1/2} > 5 x 10^{25}$ y within 3 years.

The shielding consists of ultra-pure copper, lead and active muon veto.

Majorana uses careful material selection. Crystal-to-crystal veto, segmentation, pulse-shape discrimination, deep site location, and other techniques are used to reduce backgrounds.

Background Model for Proposal

Vacuum Jockey Cold Plate Cold Finger 1.1 kg Crystal Thermal Shroud Bottom Closure

1 of 10 crystal stacks

Proposed Geometry

Ionization Energy Distribution

Selected Majorana Studies with MaGe

Segmentation Studies

Crystal 148 148 GEM40 GEM70

PbWO4

* First year only