



The MGDO software library for Germanium neutrinoless double beta decay experiments



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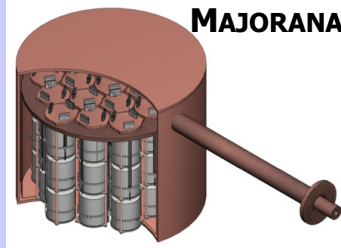
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Neutrinoless double β decay ($0\nu\beta\beta$) experiments with HPGe detectors

Common requirements

The experiments **GERDA** and **MAJORANA** are designed to search for **$0\nu\beta\beta$ -decay** of ^{76}Ge by using high purity **germanium detectors** (HPGe), enriched in ^{76}Ge .

The experiments differ for the basic approach and **shielding philosophy**: in GERDA detectors are operated **naked** and immersed in **liquid argon**, in MAJORANA they are operated in a (ultra-radio pure) **vacuum cryostat**



Construction of GERDA completed at the INFN Gran Sasso Laboratory, Italy. **Commissioning is ongoing**. In the Phase I, 15 kg of ^{76}Ge detectors will be deployed. Additional 30 kg of ^{76}Ge detectors in Phase II

MAJORANA plans to build a **demonstrator set-up** consisting of **two modules** (40 kg of ^{76}Ge and ^{nat}Ge detectors)

In spite of the two experiments' different shielding approaches, they **use the same materials** and have very **similar detector technologies**

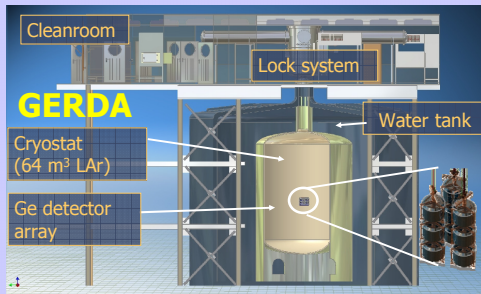
Since 2004 a **common Monte Carlo framework** based on Geant4 – called **MaGe** – has been jointly built, developed and maintained



Very successful project: clear advantage in **avoiding the duplication of coding** for the parts of common interest, easing the **comparison** between **simulations** and **experimental data**

Idea: to jointly **develop a set of objects, libraries and interfaces** to be used for **common tasks/issues in simulations and data analysis: MGDO (MAJORANA-GERDA Data Objects)**

Active development started in **2007**. Acceleration in the last two years under the **pressure of test/commissioning data**



Basic design and concept

Source code is **written in C++**, to exploit the **Object Oriented technology** and to make it open to other recent and **general-purpose projects** for scientific computing. MGDO depends on the **CLHEP** libraries and (optionally) on **FTW3** and **ROOT**

MGDO designed to be a **set of libraries** (= **no executable** provided), to be used in the **specific analysis softwares** of the experiments.

Two main kinds of tools available in MGDO

Containers

Encapsulation of complex data in the form of C++ objects

Pro's: Eases management and handling of data. Usable as **standardized format** → makes sharing of information/results easier. Possibility of **storage** within ROOT files.

Examples: waveforms, detector geometries, electric fields, cross-talk matrices

Transforms

General-purpose algorithms for digital data analysis. All algorithms act on the **MGDO object** which encapsulates a sampled waveform

Pro's: **avoid duplication** of basic and general algorithms. **Basic interface** provided to add new transforms

Examples: filters, smoothing, differentiation, extremum finding, Fourier transforms

An example of container

MGWaveform (or its "**ROOTified**" version, **MGTWaveform**) is the MGDO class used to **handle and store a digitized waveform** produced by any kind of detector (HPGe, PMT, etc.)

class MGWaveform

```
Attributes:
sampling frequency
time offset
waveform type (charge, current, voltage)
array of samples
ID of the detector (for multi-channel analysis)
Methods
I/O of the attributes or derived quantities
(e.g. sampling time from sampling frequency)
re-definition of operators (sum, product)
(waveform-waveform or waveform-scalar)
```

- (1) **Attributes** of the waveform (individual samples, but also others, as sampling frequency)
- (2) **Methods** for the attribute handling: several **i/o** options, many **operators**
- (3) In the **ROOTified** version, inherits from **TNamed**: ROOT attributes, ROOT I/O, interface to graphical tools

Used as a standardized format

Experimental waveforms stored as **MGWaveform objects**; output of Monte Carlo simulations directly produced as MGWaveform → **real and simulated waveforms handled in the same way** by the **analysis**

Many other **containers** in MGDO (e.g. MGTEvent → event information)

An example of transform

All transforms **inherit** from the **base virtual class MGWaveformTransformer** → interface defined, making **easy** to **implement new/customized transforms**

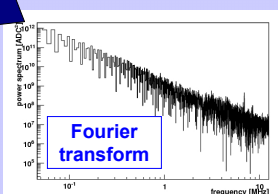
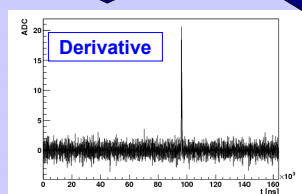
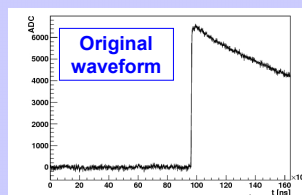
Transform output

- A **new waveform** (derivative, smoothing, etc.)
- A **scalar number** (rise time, maximum, etc.)
- Both**

Transforms can be used as **building blocks** for **complex analysis tasks** → **chain of individual transforms**

For instance: **Approximate Gaussian filter** (used for amplitude reconstruction)

Moving window deconvolution + Moving window average ($\times n$ times) + Maximum finder



Conclusions and perspectives

- MGDO** is a **set of libraries** developed jointly by the **MAJORANA** and **GERDA** Collaborations

- The **containers** provide a **standardized and convenient format** (events, waveforms, etc.) for **data handling, management and storage**

They ease the **MC-data comparison** and may act as **common format** to **exchange information** and data between different experiments

- Transforms** are **general-purpose algorithms** for **digital data processing**

They can be used as **building blocks** in the experiment-specific software to perform **complex analysis tasks**

- Design** based on **OO-technology** and very flexible

Possibility to **extend** and **customize** the components

- The **applicability** of MGDO can be of **more general** extent than Ge-based $0\nu\beta\beta$ experiments: of **potential interest** of other **low-background experiments**