The MGDO software library for Germanium neutrinoless double beta decay experiments

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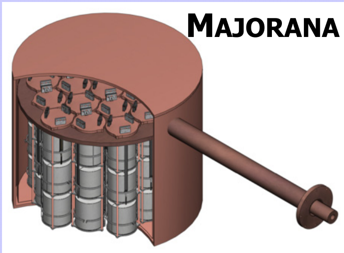
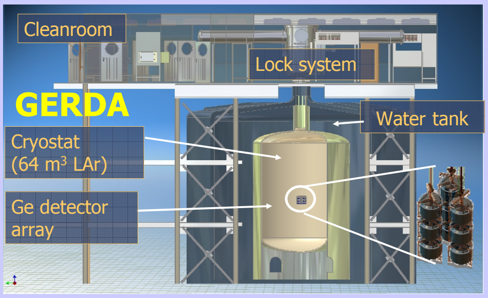
Neutrinoless double β decay (0νββ) experiments with HPGe detectors

The experiments **GERDA** and **MAJORANA** are designed to search for **0νββ-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 ^{enr}Ge detectors will be deployed. Additional 30 kg of ^{enr}Ge detectors in Phase II

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

Common requirements

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 mantained

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

<u>Idea</u>: 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 **FFTW3** 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

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

<u>Examples</u>: 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

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

<u>Examples</u>: 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

<u>Attributes</u>:
- sampling frequency
- time offset
- waveform type (charge, current, voltage)
- array of samples
- ID of the detector (for multi-channel analysis)

<u>Methods</u>
- 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**

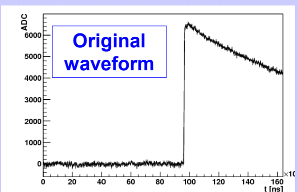
(3) In the **ROOTified** version, inherits from **TNamed**: ROOT attributes, ROOT I/O, interface to graphical tools

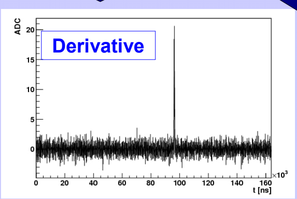
Used as a standardized format

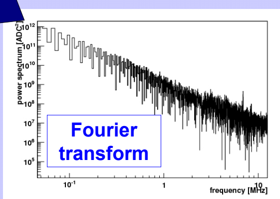
Experimental waveforms stored as MGWaveform objects; output of Monte Carlo simulations directly produced as MGWaveform → **real** and **simulated waveforms handled** in the **<u>same way</u>** by the **analysis**

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

An example of transform







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

<u>Transform output</u>
- 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**

<u>For instance</u>: Approximate Gaussian filter (used for amplitude reconstruction)

Moving window deconvolution **+** Moving window average (x *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 0νββ experiments: of potential interest of other low-background experiments