TG10
Monte Carlo Status Report

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on behalf of TG10

Max-Planck-Institut für Physik, München

GERDA Collaboration Meeting,
LNGS, 05-07 Nov. 2007

Overview

- Recently finished projects

  GDML, Neutrons, GDL Detectors

- Ongoing projects

  Screening Detector, Background Campaign, MaGe Paper,
  Pulse Shape Simulation

- Future projects

  Test + Benchmarks processes

Documentation

- Documentation: in cvs
  doc/GERDAUserGuide/userguide.tex

  - Major **Installation** chapter update:

    detailed description of:

Howto:
- get the source code
- install programs
- setup programs

  - several other small updates

Feedback and **contribution** welcome

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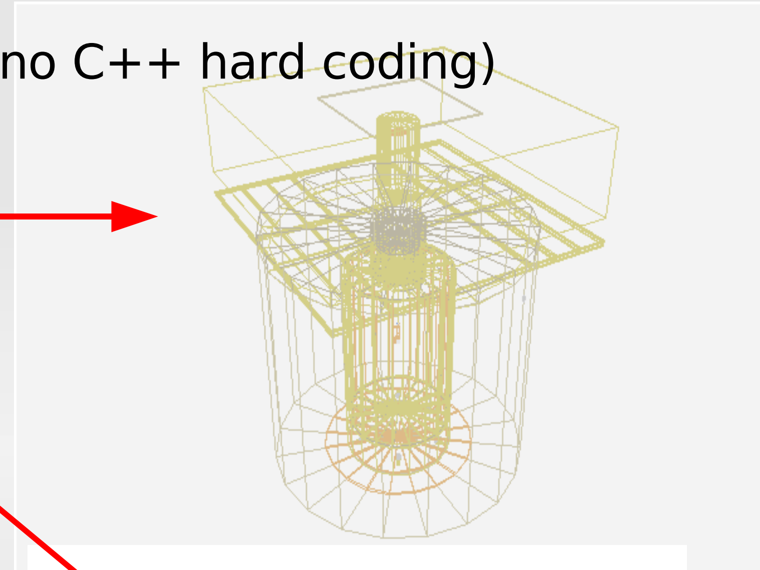
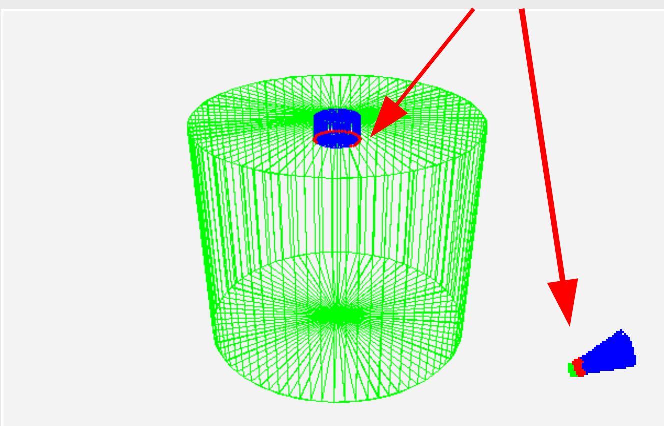
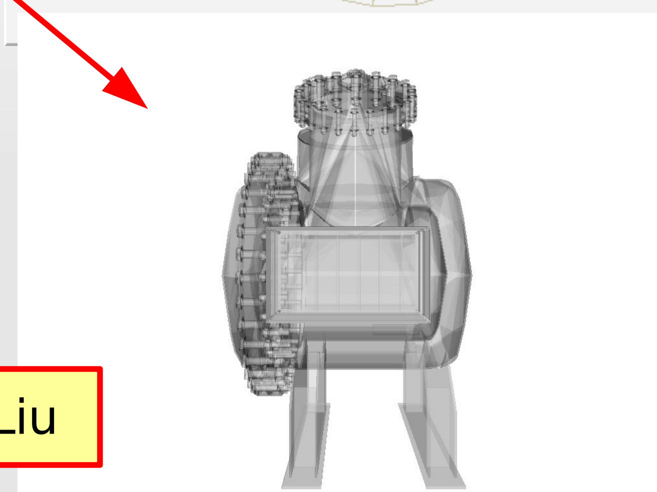
GDML

- General Description Markup Language (GDML)
- Easy description of geometry in XML format (no C++ hard coding)
- Bindings to GEANT4 and ROOT
- Interface to CAD via ST-Viewer possible
- Several nice features:
  i.e. easy check for overlaps possible



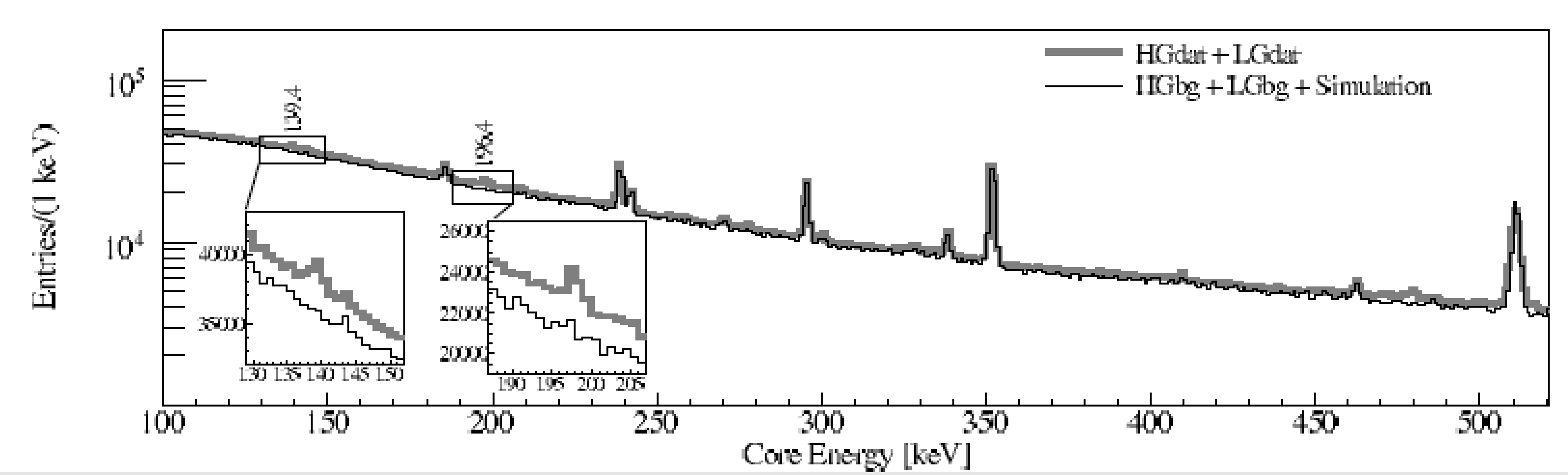




Talk: Jing Liu

Neutron Simulation

- Data taken with 18-fold segmented Detector and an AmBe source
- MC + Bkg describes most features of spectrum
- Metastable states of ^{75}Ge and ^{71}Ge are missing, no 139 keV and 196 keV photon peaks

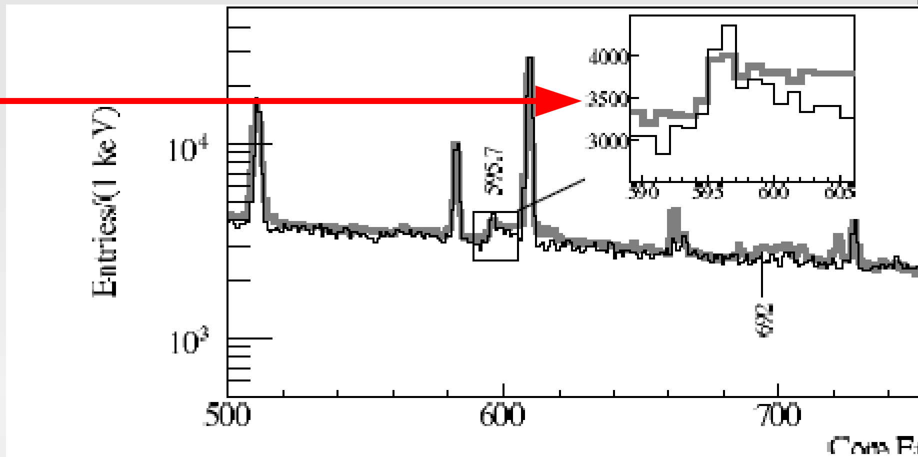


- Problem reported to Geant4 Problem Tracking System

Neutron Simulation II

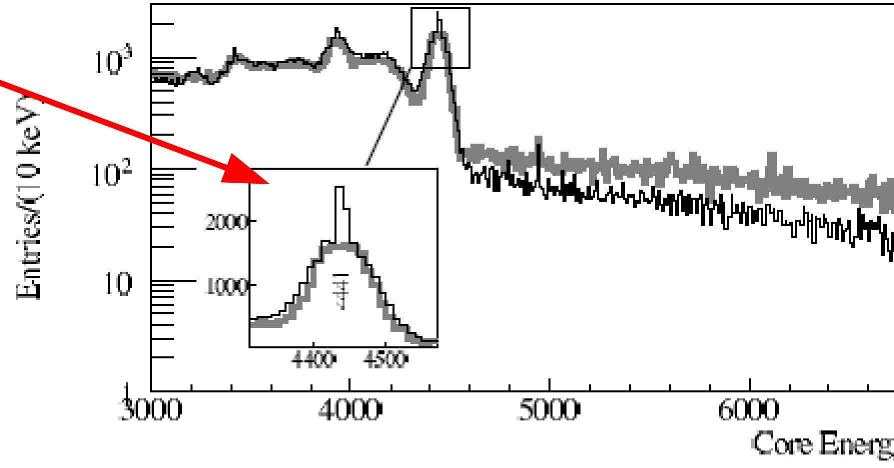
- Bug for neutron inelastic scattering:
  Secondary particles not boosted back from CMS ⇒ 2-fold problem

  - Simulated recoil energies wrong: 596 keV from ^{74}Ge(n,n'γ) long tail from nuclear recoil missing



  - Broad 4.4 MeV peak from ^{12}C* de-excitation

  - Narrow peak ^{12}C(n,n'γ) due to inelastic scattering: Doppler broadening missing

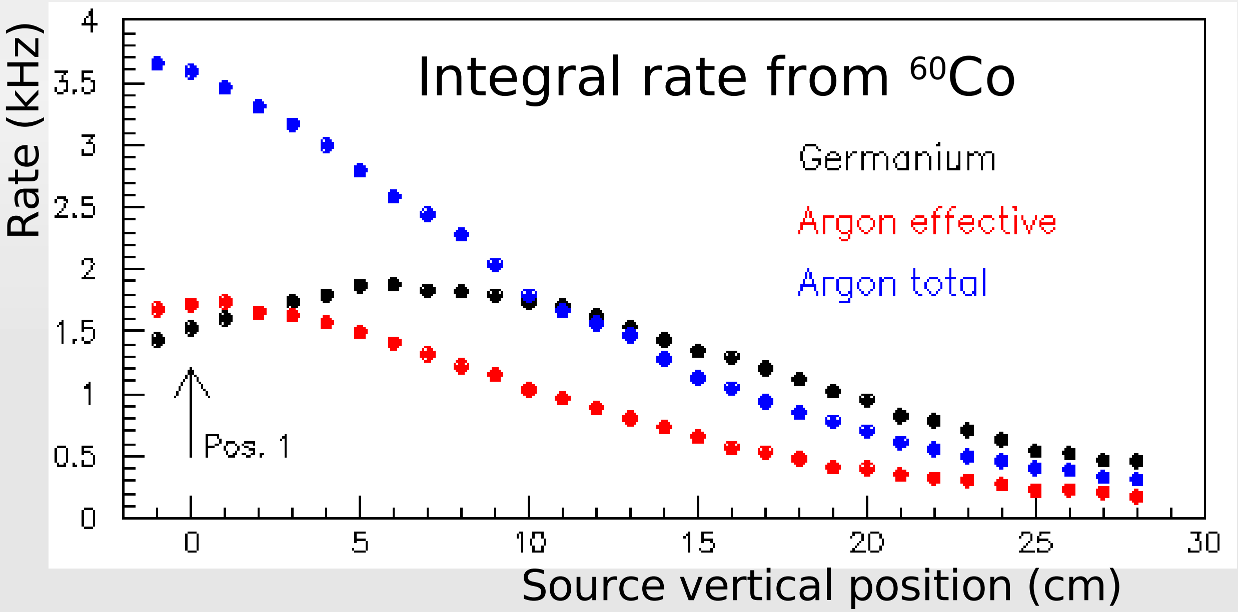


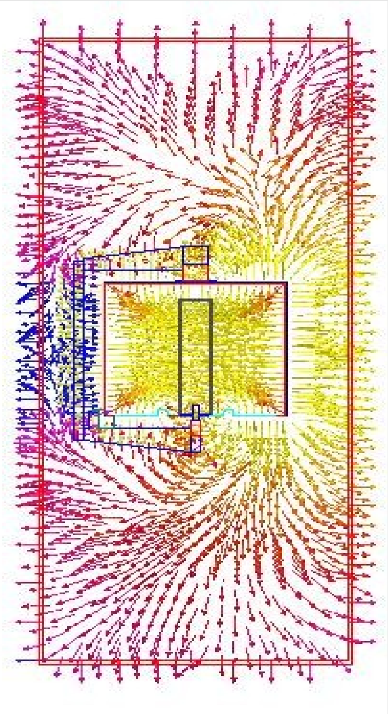
- Paper submitted to: European Physics Journal A

“Neutron Interactions as Seen by A Segmented Germanium Detector“

GDL Detector (TG1)

- MaGe is used for interpretation of the leakage current data in the GDL
  - Detailed test stand geometry has been implemented in MaGe
  - Full E-Field calculation performed with Maxwell-2D
  - Estimate of expected rate from ^{60}Co decay

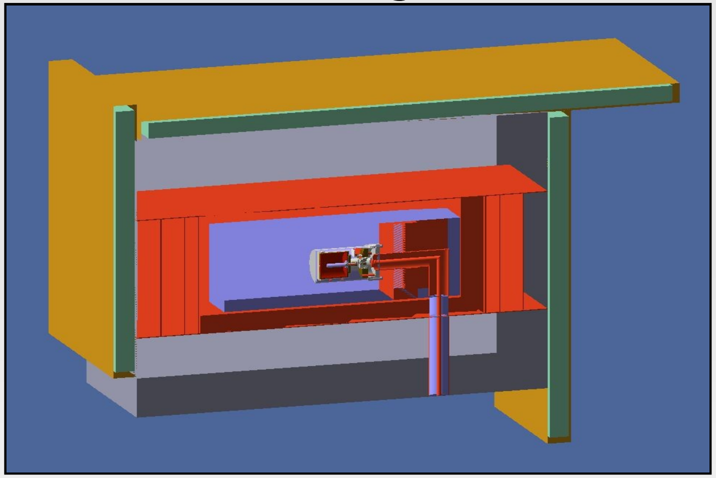




Screening Detectors (TG11)

- Three Heidelberg detectors modeled, MaGe used to determine efficiency

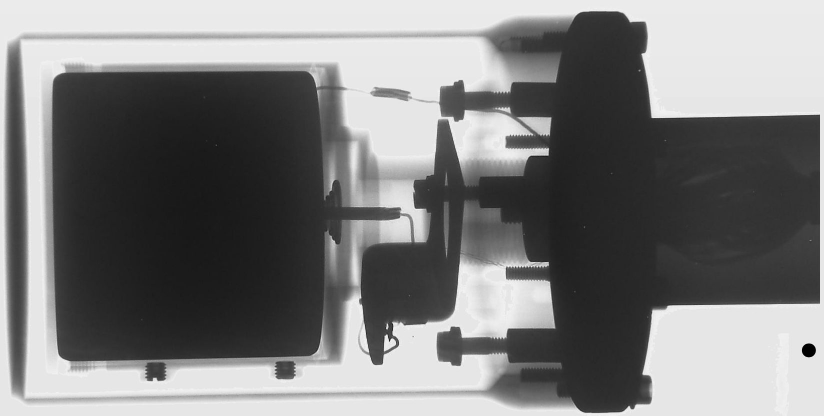
Corrado



- first measurements of standard sources and MC yielded differences on order of ~20% for Dario and Bruno detector (mentioned TG11, NPL2005)

  ⇒ optimize geometry in MC

- X-ray screening of Corrado detector, provided accurate dimensions, shape and position of the crystal



- optimization of DL and inner hole based mesurements of point like sources
- differences ~10% now, present biggest uncertainty: activity of used sources
- improvements of optimization ongoing

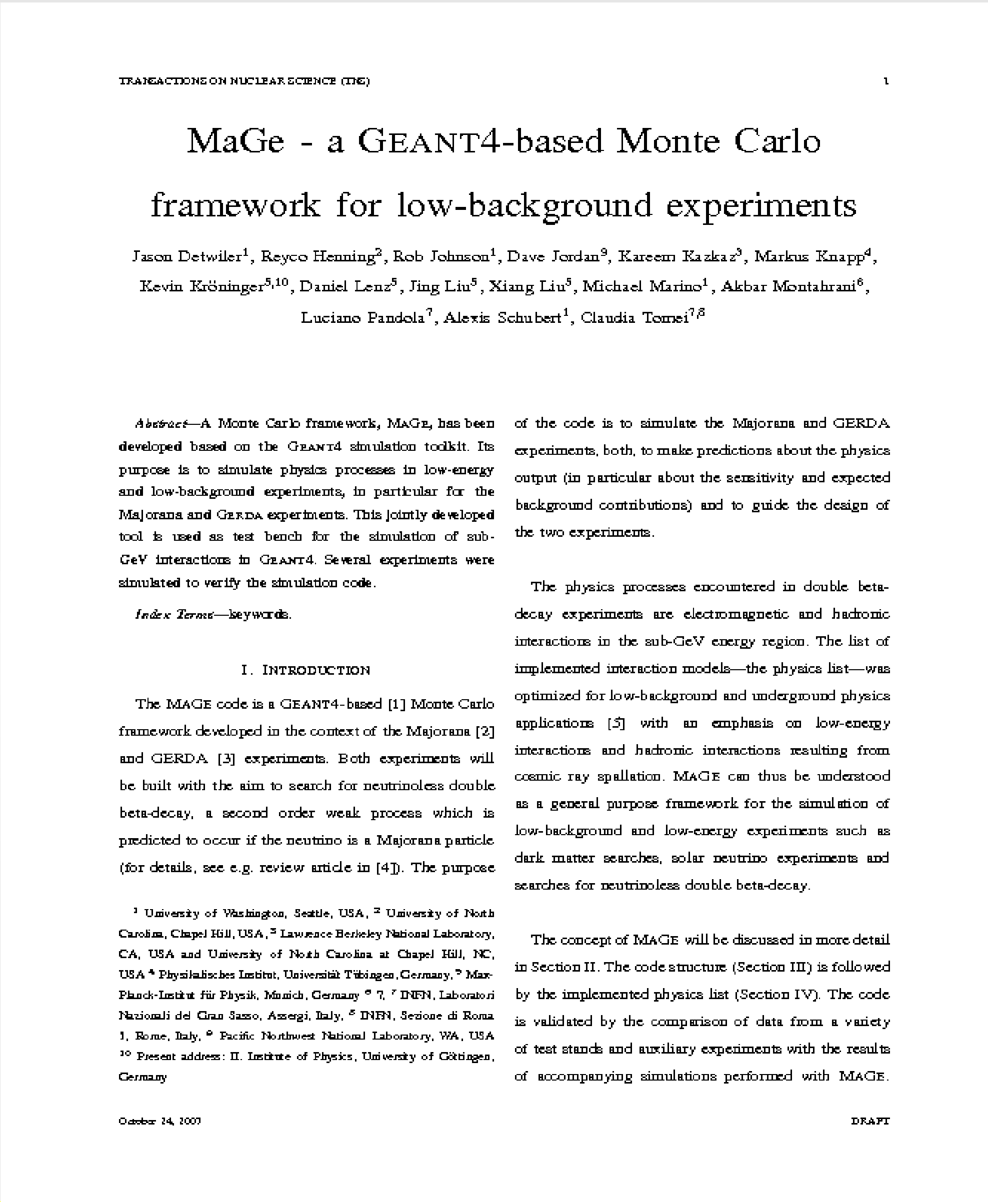
MaGe Paper

- Designed to be new reference paper

<u>Content:</u>
- Concept of MaGe
- Code structure
- Physics list
- Monte Carlo validation

- Close to completion
  - Authors review
  - Collab. EB review

- to be submitted to: IEEE (?)
- submission end this year



TRANSACTIONS ON NUCLEAR SCIENCE (TNS) 1

MaGe - a GEANT4-based Monte Carlo framework for low-background experiments

Jason Detwiler[1], Reyco Henning[2], Rob Johnson[1], Dave Jordan[9], Kareem Kazkaz[3], Markus Knapp[4], Kevin Kröninger[5,10], Daniel Lenz[5], Jing Liu[5], Xiang Liu[5], Michael Marino[1], Akbar Montahrani[6], Luciano Pandola[7], Alexis Schubert[1], Claudia Tomei[7,8]

Abstract—A Monte Carlo framework, MAGE, has been developed based on the GEANT4 simulation toolkit. Its purpose is to simulate physics processes in low-energy and low-background experiments, in particular for the Majorana and GERDA experiments. This jointly developed tool is used as test bench for the simulation of sub-GeV interactions in GEANT4. Several experiments were simulated to verify the simulation code.

Index Terms—keywords.

I. INTRODUCTION

The MAGE code is a GEANT4-based [1] Monte Carlo framework developed in the context of the Majorana [2] and GERDA [3] experiments. Both experiments will be built with the aim to search for neutrinoless double beta-decay, a second order weak process which is predicted to occur if the neutrino is a Majorana particle (for details, see e.g. review article in [4]). The purpose of the code is to simulate the Majorana and GERDA experiments, both, to make predictions about the physics output (in particular about the sensitivity and expected background contributions) and to guide the design of the two experiments.

The physics processes encountered in double beta-decay experiments are electromagnetic and hadronic interactions in the sub-GeV energy region. The list of implemented interaction models—the physics list—was optimized for low-background and underground physics applications [5] with an emphasis on low-energy interactions and hadronic interactions resulting from cosmic ray spallation. MAGE can thus be understood as a general purpose framework for the simulation of low-background and low-energy experiments such as dark matter searches, solar neutrino experiments and searches for neutrinoless double beta-decay.

The concept of MAGE will be discussed in more detail in Section II. The code structure (Section III) is followed by the implemented physics list (Section IV). The code is validated by the comparison of data from a variety of test stands and auxiliary experiments with the results of accompanying simulations performed with MAGE.

[1] University of Washington, Seattle, USA, [2] University of North Carolina, Chapel Hill, USA, [3] Lawrence Berkeley National Laboratory, CA, USA and University of North Carolina at Chapel Hill, NC, USA [4] Physikalisches Institut, Universität Tübingen, Germany, [5] Max-Planck-Institut für Physik, Munich, Germany [6] ?, [7] INFN, Laboratori Nazionali del Gran Sasso, Assergi, Italy, [8] INFN, Sezione di Roma 1, Rome, Italy, [9] Pacific Northwest National Laboratory, WA, USA [10] Present address: II. Institute of Physics, University of Göttingen, Germany

October 24, 2007 DRAFT

Monte Carlo Campaign II

- **Goal**: Estimate overall GERDA background,
  create reference bkg table + spectrum

- Complete evaluation of α, γ, n, μ-induced background

Steps taken:

- Major update of string design
- Update of infrastructure design
- Re-evaluation of activation due to cosmic rays
- Gather all known contamination of materials

First test jobs **running**

Monte Carlo Campaign II

- Preliminary simulations for muons (Geant4.8.2.p01) – Phase II*

	counts/(keV·kg·y)
No cut	$1.1 \cdot 10^{-2}$
Detector multiplicity	$8.9 \cdot 10^{-4}$
Segment multiplicity	$5.7 \cdot 10^{-4}$
Muon veto (ε = 95%)	$3 \cdot 10^{-5}$

*24 detectors: 15 segmented + 9 unsegmented

- Some differences with respect to old simulations with similar geometry (factor 2)
  - Old simulation: Geant4.6.2 results in higher background
  - Under investigation
- Update of simulation with updated geometry

Monte Carlo Campaign II

- Dedicated simulation to evaluate maximum ^{208}Tl rate in watertank
  - Generated γ-rays within 20 deg from crystal array (Compton $E_\gamma > Q_{\beta\beta}$)
    - 5 * 10^8 tracks generated (= 1.7 * 10^{10} primaries)
  - No energy deposit in crystal between 1.5 -2.5 MeV
    - Estimate is limited by statistics
      - Analytical approach described in GSTR 06-007

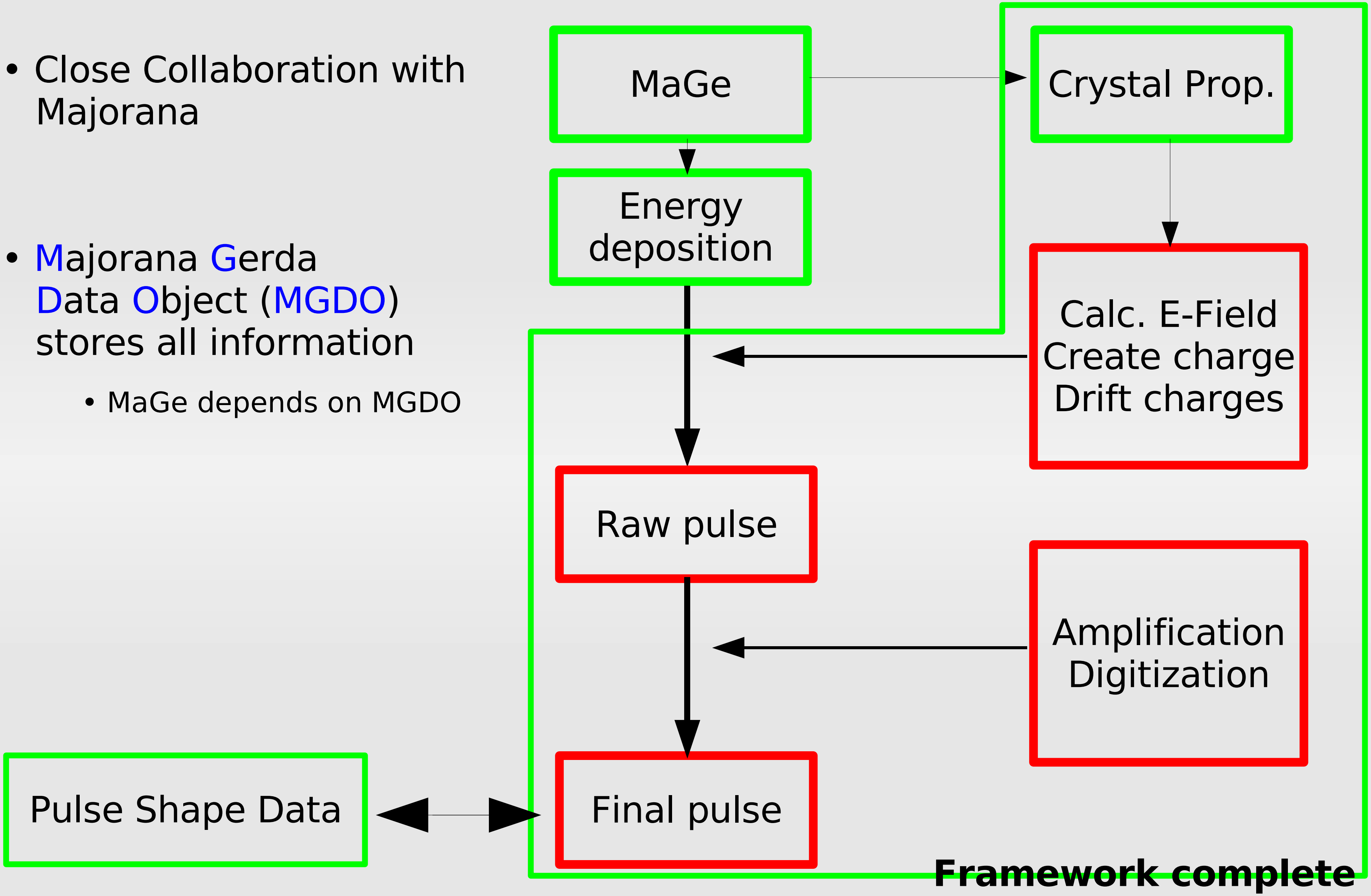
	Full Monte Carlo (for 1 mBq/kg)	Analytical calculation (for 1 mBq/kg)
Phase I	$< 4 \cdot 10^{-5}$ (90% CL)	$4 \cdot 10^{-6}$ (mult. cut) $6 \cdot 10^{-6}$ (no cut)
Phase II*	$< 2 \cdot 10^{-5}$ (90% CL)	$3 \cdot 10^{-6}$ (mult. cut) $6 \cdot 10^{-6}$ (no cut)

Max. ^{232}Th activity to reach $< 10^{-4}$ cts/(keV * kg * y):

- 15 mBq/kg without cut
- 20 mBq/kg Phase I (Single Crystal)
- 37 mBq/kg Phase II (Single Seg)

Pulse Shape Simulation

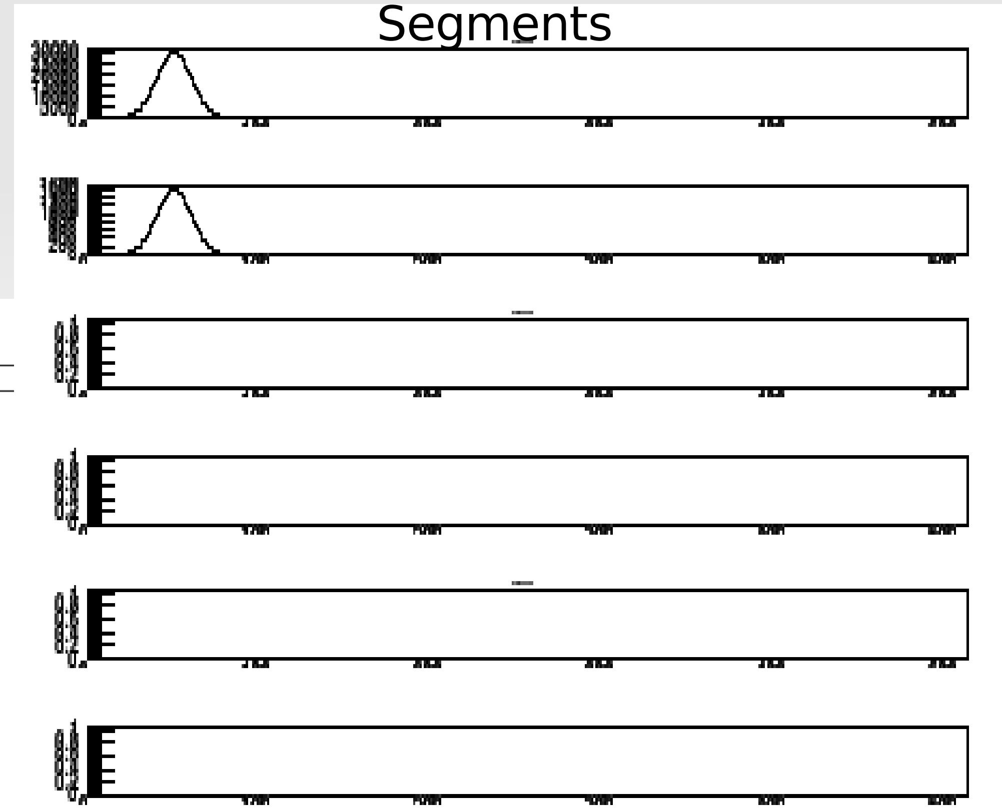
- Close Collaboration with Majorana
- Majorana Gerda Data Object (MGDO) stores all information
  - MaGe depends on MGDO

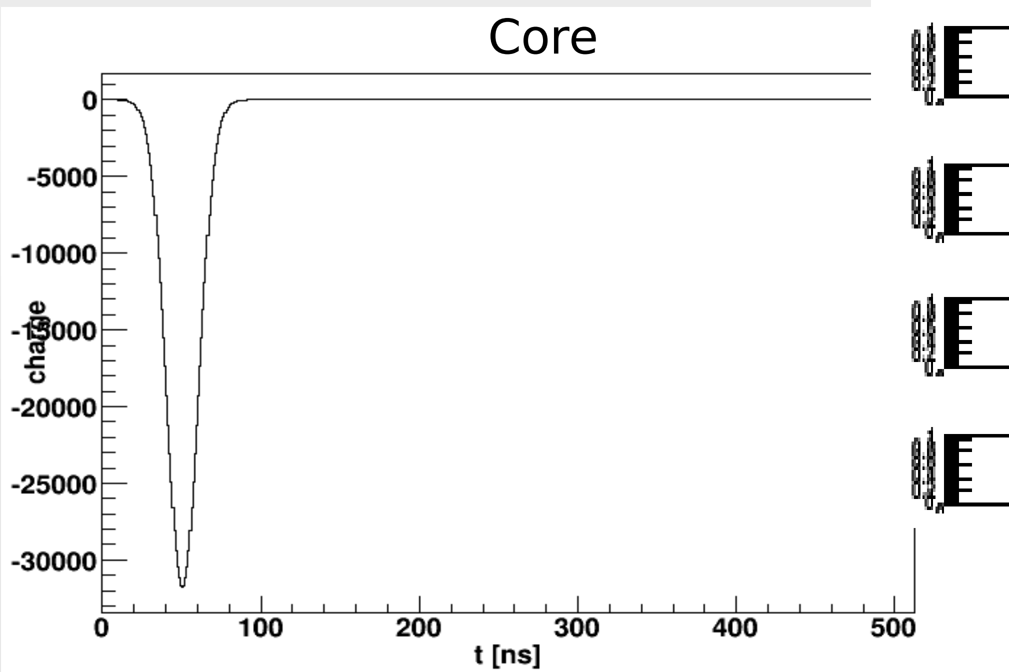


Pulse Shape Simulation

- Framework complete (running with little MaGe modification)

- Using dummy gaussian pulse shape generator:

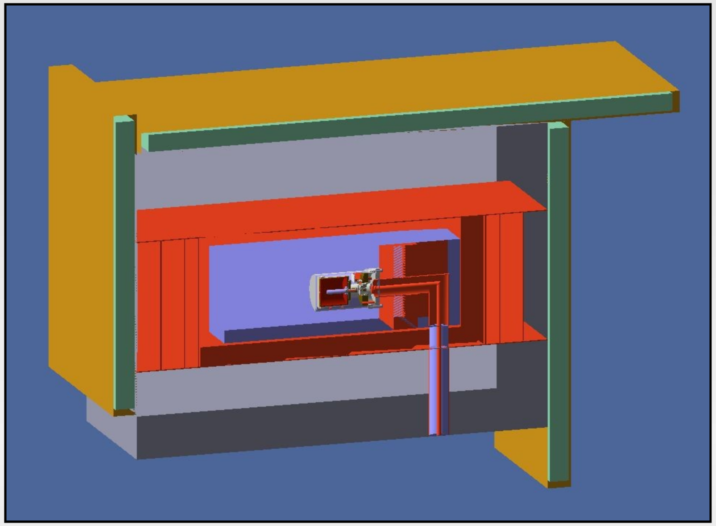




Tests

Using Corrado geometry:

Corrado



- test of MaGe-Geant4 radioactive decay module (branching ratios of γ-lines) → note GSTR-07-010

- **Three bugs** in Geant4 reported (#952, 968 and 970) internally fixed!

Example: ^{210}Pb decay

Energy (keV)	Table of Isotopes	Geant4	Geant4 + fix
115.18	0.59%	0.34%	0.58%
176.68	0.05%	1.74%	0.05%
300.09	3.28%	2.75%	3.27%
415.2	0.14%	0.67%	0.14%

Tests and Benchmarks

- Need test simulations,
  everyone can run to verify the correct setup

- Makes simulations comparable
  - Difference between 32bit ⇔ 64bit architecture reported

- First ideas available and macros are planned
  - Kolmogorov-Smirnov test
  - Residual distribution