TG10 Status Report

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Outlook of TG10 activities

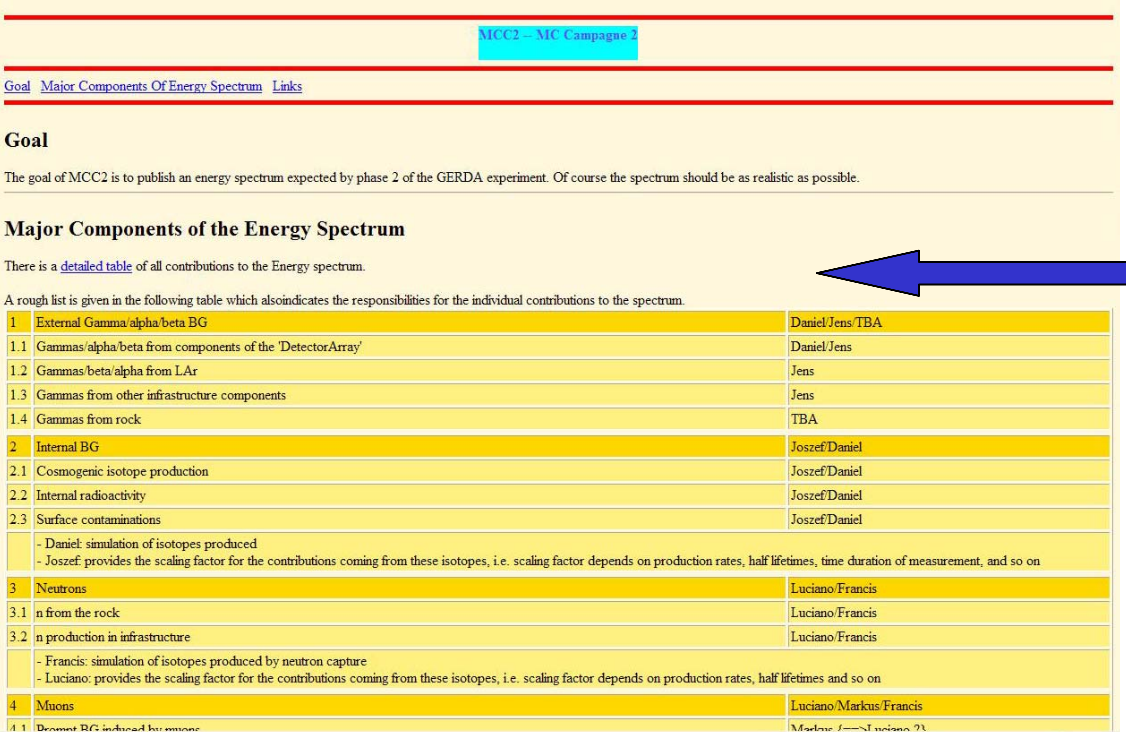
The main activities currently carried on by the TG10 group are:

- **Monte Carlo Campaign 2 (MCC2)** [LNGS, MPPMU, Tübingen, Zürich] for the estimate of a realistic background spectrum for GERDA. Simulations are based on MaGe. Major effort within TG10
- **Pulse shape simulation** [MPPMU] → dedicated talks by J. Liu and D. Lenz
- **Simulation** of **calibration sources** [Zürich] → dedicated talk by F. Froborg
- **Simulation** of **light response** from **MiniLArGe** [JINR], to help for interpretation of LAr scintillation data collected with the MiniLArGe prototype

MCC2 Monte Carlo Campaign

Monte Carlo Campaign **MCC2** for the evaluation of the full background spectrum (also below $Q_{\beta\beta}$) with a realistic GERDA geometry and updated numbers on radiopurity. Simulations are **based on Geant4 and MaGe**

Activity is **presently ongoing**



MCC2 -- MC Campagne 2

Goal Major Components Of Energy Spectrum Links

Goal

The goal of MCC2 is to publish an energy spectrum expected by phase 2 of the GERDA experiment. Of course the spectrum should be as realistic as possible.

Major Components of the Energy Spectrum

There is a detailed table of all contributions to the Energy spectrum.

A rough list is given in the following table which alsoindicates the responsibilities for the individual contributions to the spectrum.

1	External Gamma/alpha/beta BG	Daniel/Jens/TBA
1.1	Gammas/alpha/beta from components of the 'DetectorArray'	Daniel/Jens
1.2	Gammas/beta/alpha from LAr	Jens
1.3	Gammas from other infrastructure components	Jens
1.4	Gammas from rock	TBA
2	Internal BG	Joszef/Daniel
2.1	Cosmogenic isotope production	Joszef/Daniel
2.2	Internal radioactivity	Joszef/Daniel
2.3	Surface contaminations	Joszef/Daniel
	- Daniel: simulation of isotopes produced - Joszef: provides the scaling factor for the contributions coming from these isotopes, i.e. scaling factor depends on production rates, half lifetimes, time duration of measurement, and so on	
3	Neutrons	Luciano/Francis
3.1	n from the rock	Luciano/Francis
3.2	n production in infrastructure	Luciano/Francis
	- Francis: simulation of isotopes produced by neutron capture - Luciano: provides the scaling factor for the contributions coming from these isotopes, i.e. scaling factor depends on production rates, half lifetimes and so on	
4	Muons	Luciano/Markus/Francis
4.1	Prompt BG induced by muons	Markus (==>Luciano ?)

Available a dedidated webpage provided by Jens → **link from the GerdaWiki**
(http://wwwgerda.mppmu.mpg.de/~schubert/WORK/GERDA/MCC2)

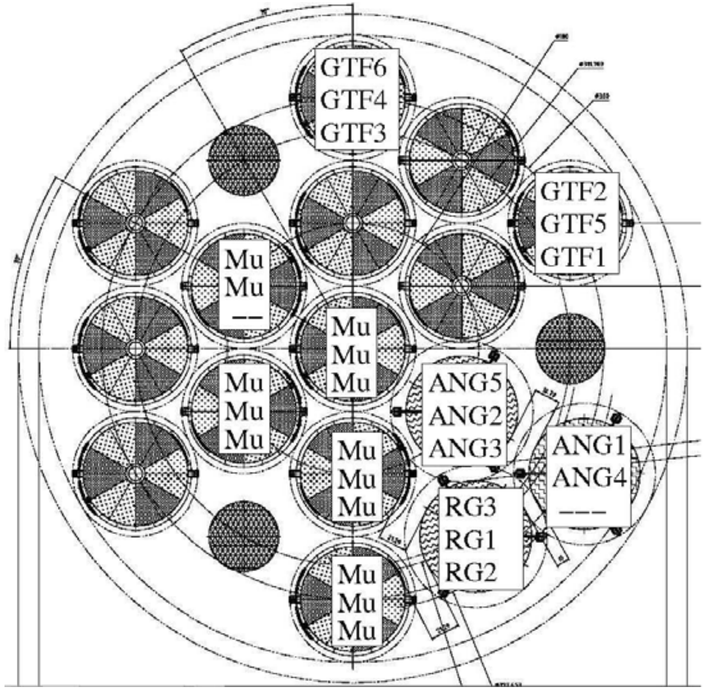
and a mailing list
(mcc2-gerda@lngs.infn.it)

MCC2 status and organization

- The reference MaGe release for MCC2 was tagged (MCC2-2008-10-15)
  → GERDA geometry has been frozen
- CPU-intensive jobs are running
  → MaGe-MCC2 successfully installed in Dresden (large cluster)
- Common scripts are available to allow for a uniform and consistent data treatment (e.g. "Ntuple→Histogram" conversion)
- All simulated BG histograms will be collected at one common place; the framework for assembling all histograms is in work
- Documentation of detailed list of elementary BG contributions (ElBaCo) is in progress, to contain all information on individual ElBaCos, i.e. description, parameters, scaling behavior, …

MCC2 Campaign

Simulations run for Phase I and Phase II arrangement



Phase II array contains: 8 $^{\mathrm{enr}}$Ge unsegmented detectors (HdM-IGEX), 14 $^{\mathrm{enr}}$Ge 18-fold segmented detectors and 8 $^{\mathrm{nat}}$Ge unsegmented detectors (GTF)

"tight" displacement scheme considered

(GSTR-08-014)

Phase I array has HdM-IGEX-GTF. Individual dimensions considered.

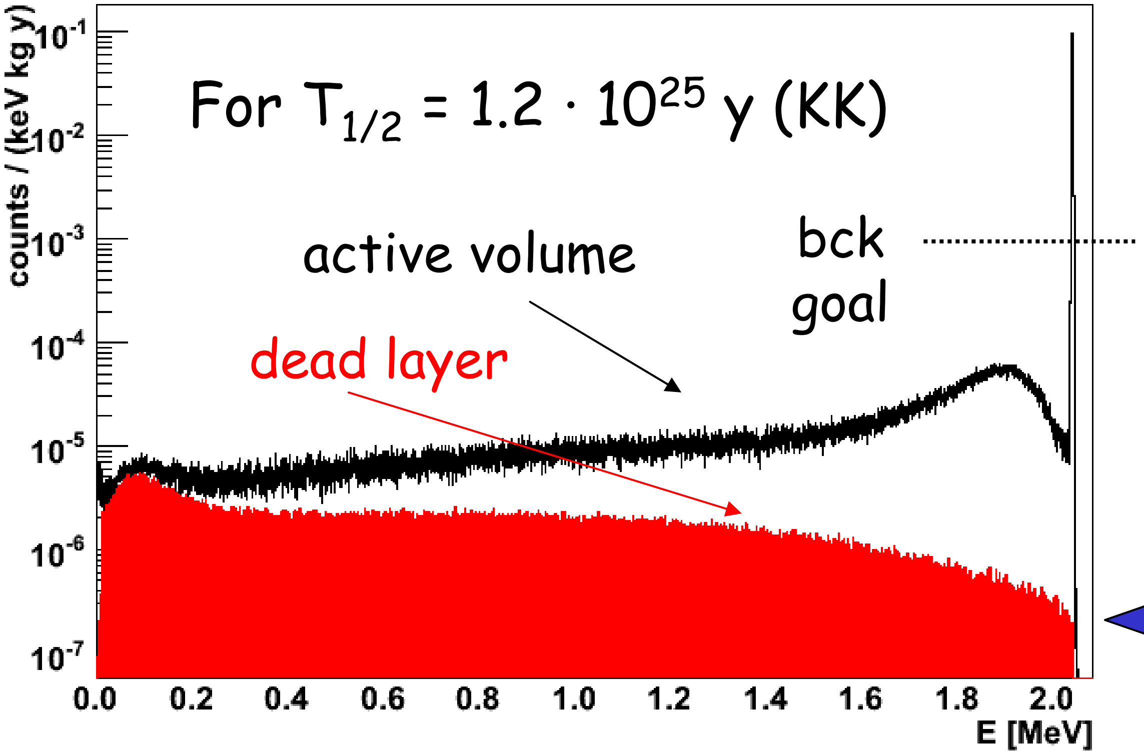
GTF detectors are considered **only for anti-coincidence** (not for the energy spectrum). Core and segment thresholds for anti-coincidence purposes assumed 10 keV. Resolution: 2.5 keV FWHM at 1.332 MeV.

Simulated spectra realistic for energy above ~100 keV

MCC2 – 0νββ decay

Simulated 0νββ decay of ^{76}Ge in the active volume and dead layer for Phase I and II arrays. Spectrum in the assumption of DBD mediated by massive Majorana neutrinos.

Dead layer: 0.8 mm for existing p-type detectors and negligible for n-type. Resolution: 2.5 keV FWHM at 1333 keV line.



Signal efficiency vs. anti-coincidence cuts (Phase II array)

No cuts: 92.0%

Det anti-coinc: 91.3%

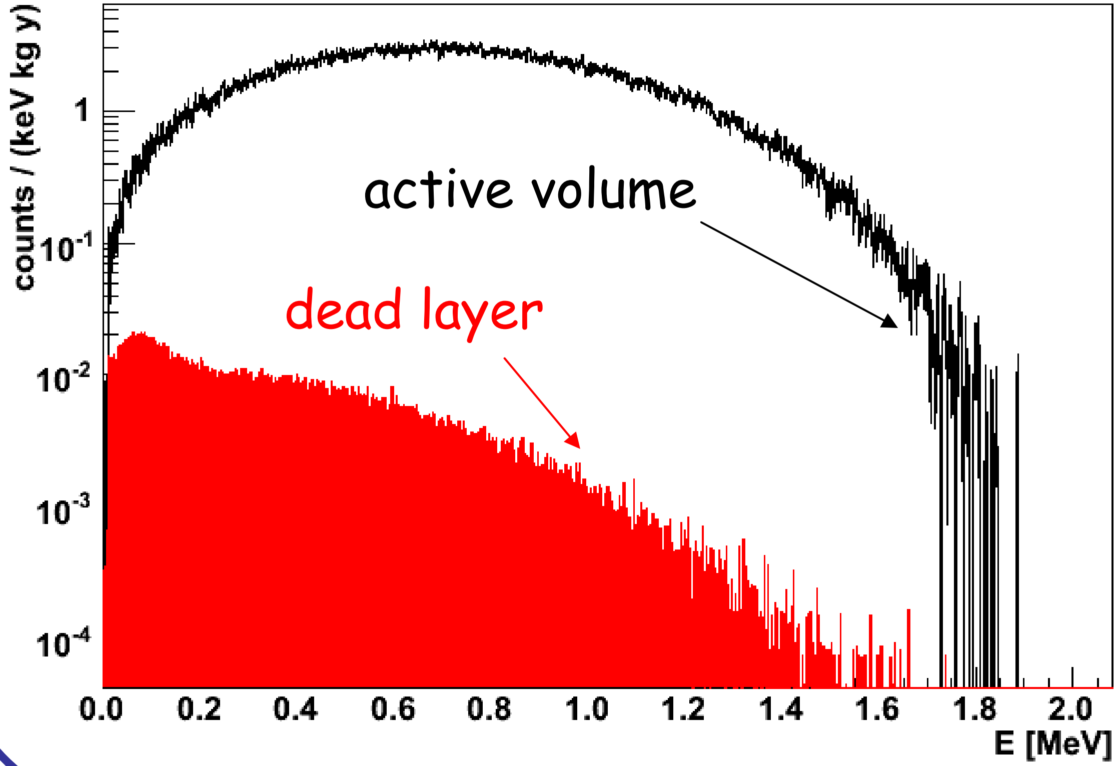
Seg anti-coinc: **87.2%**

(For PhaseI: 91.9% and 91.6%, TBC)

MCC2 – 2νββ decay

Simulated 2νββ decay of ^{76}Ge in the active volume and dead layer (Phase I and Phase II)

Used as **"reference"** for other background sources: sources giving background contribution « 2νββ (everywhere) will not be simulated explicitely



First round of simulations, to have a general "feeling". More statistics necessary for meaningful results at $Q_{\beta\beta}$

Phase II

Simulation of γ-rays produced far from the array

[GSTR-08-015]

Background from γ-rays produced by **distant sources** (e.g. cryostat, rock) is very difficult to estimate reliably → "pure" Monte Carlo methods are very **inefficient**

E.g. if one considers the inner wall of the cryostat: only **~0.3%** of the solid angle is covered by the detector array (→ only one γ out of 300 is interesting!)

It is possible to **save a lot of CPU time** by using appropriate techniques (suitable for many sources)

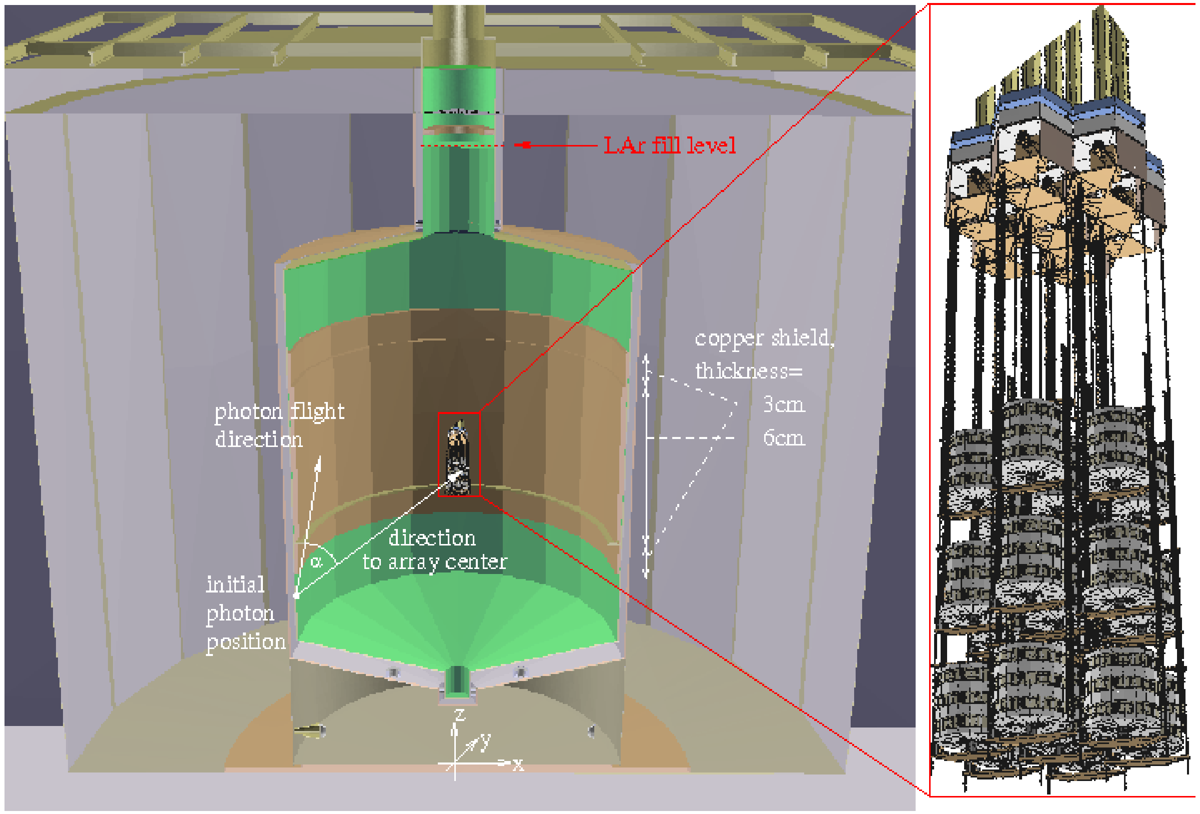
As a test: 2.6-MeV γ-rays (^{208}Tl) from the inner wall of the cryostat have been simulated to understand if it is possible to **gain CPU time** (and at which price) by **restricting** the initial direction of the γ-ray

2.6-MeV γ from the cryostat inner wall

Main goal: run a **full** simulation to understand **how** the **energy spectrum is affected** by **restricting** the **angle** α between the initial γ direction and the center of the array

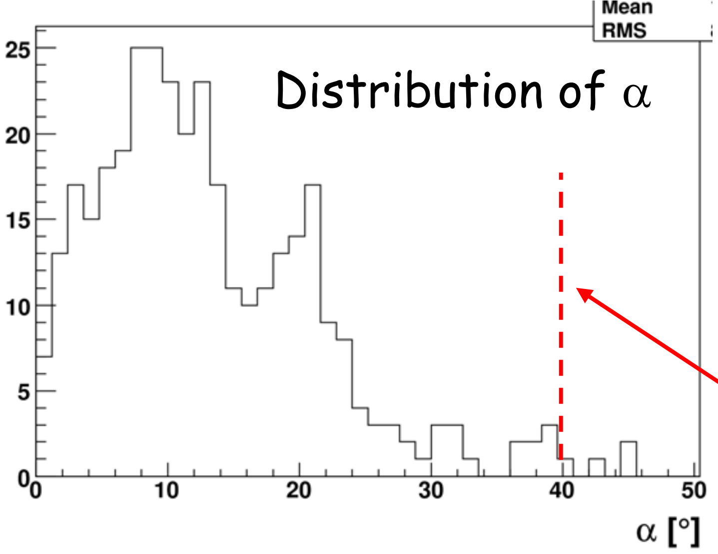
Considered an array of 21 segmented detectors in the reference GERDA geometry

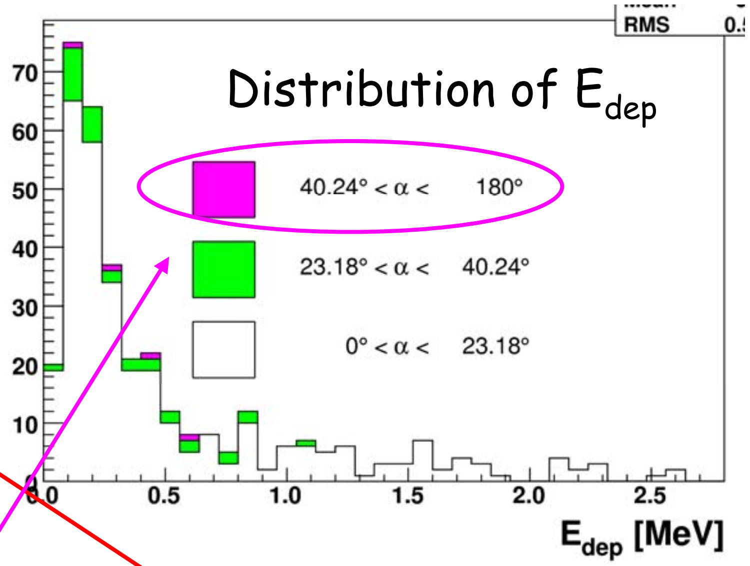
$3 \cdot 10^9$ photons have been generated uniformly from the cryowall



2.6-MeV γ from the cryostat inner wall

Only 364 events (out of $3\cdot10^9$) originate an energy deposition in the detector array (!)





γ-rays giving energy depositions in the detectors start with ⟨α⟩ = 13.5 deg. For all events $\alpha < 45$ deg

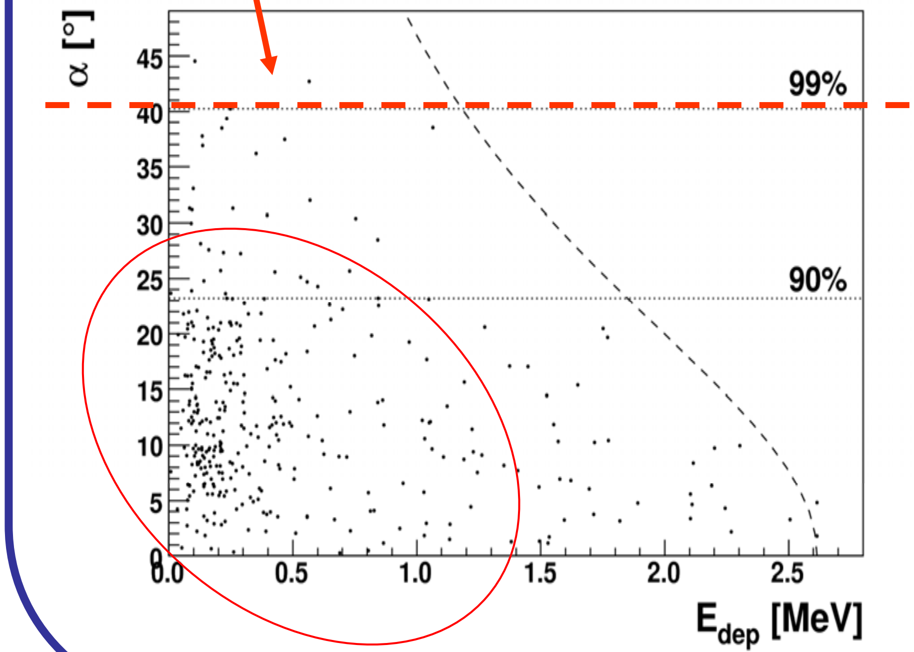
Restricting generation of primary γ-rays to **$\alpha < 40$ deg** saves 90% of the CPU time! E_{dep} is still correct down to some E_{min} (in the case on single Compton scattering, 40 deg → E_{min} 1.2 MeV)

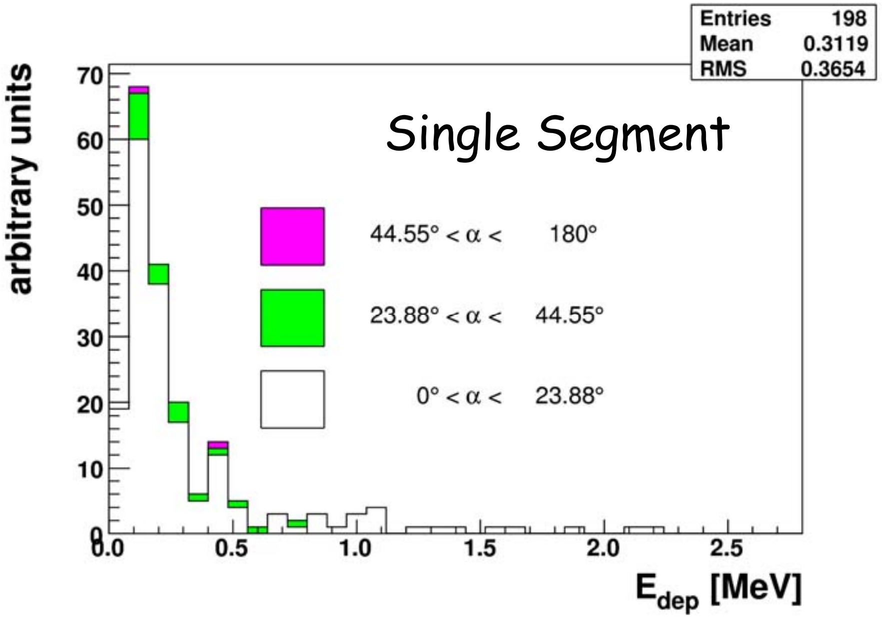
Same situation for events surviving the single-segment cut

2.6-MeV γ from the cryostat inner wall

Hence: the **restriction α<40°** saves **~90% CPU time** with only **marginal changes** in the energy spectrum

Viable solution for MC simulation of far sources

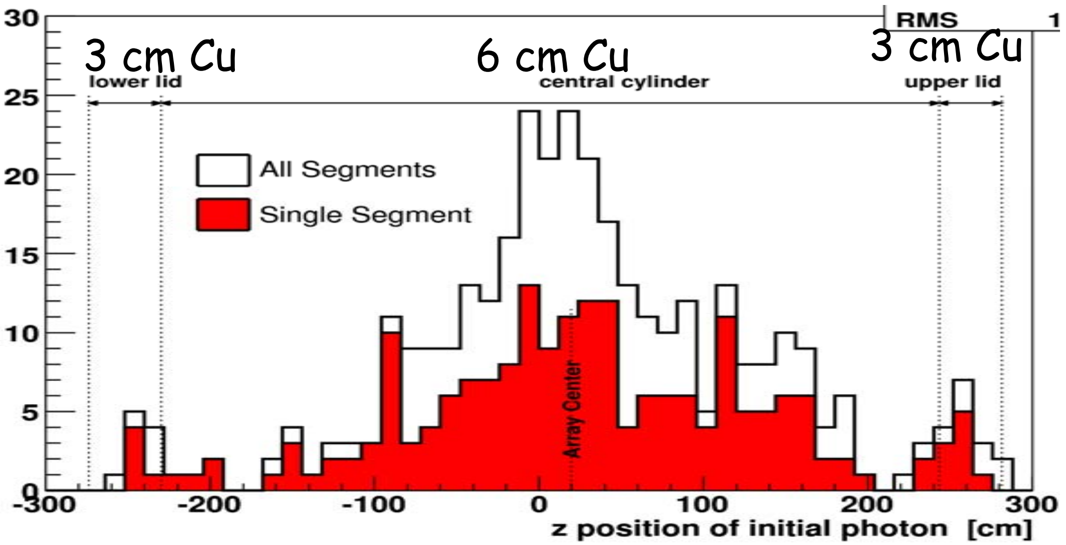




Similar approach had been adopted by the Russian groups to estimate external γ-ray background (but not using Geant4-MaGe)

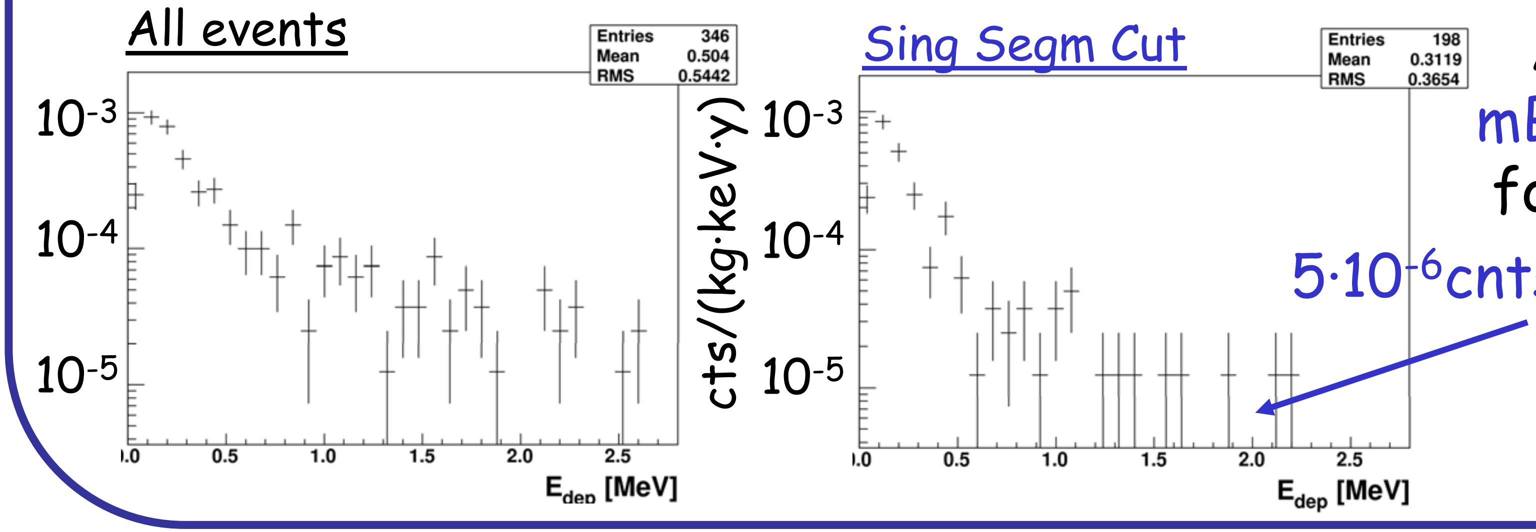
2.6-MeV γ from the cryostat inner wall

Distribution of the starting z coordinate for events reaching the detectors



The main contribution comes from z=0 (minimum distance between array and cryostat)

The thickness of the Cu layer vs. z could be optimized to further reduce the background (e.g. smooth change vs. z)



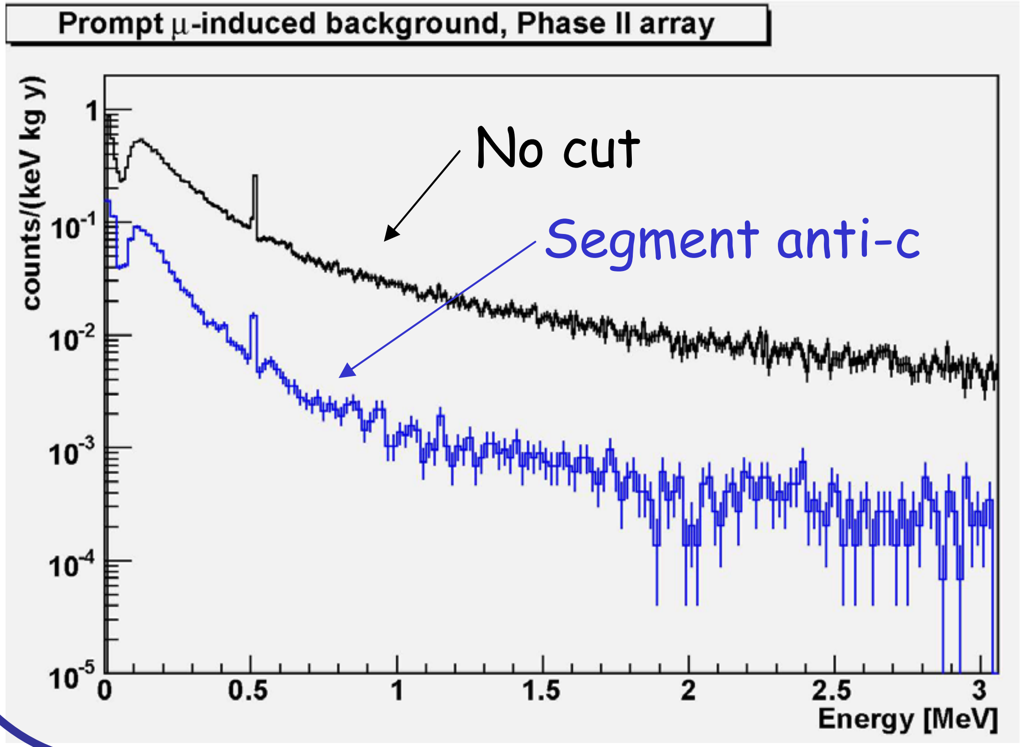
Assume 1 mBq/kg steel for ^{228}Th →

$5\cdot10^{-6}$ cnts/(kg·keV·y)

Prompt μ-induced background

Prompt μ-induced background simulated again with **MaGe** in the **MCC2** framework (Phase I & II). Derived info for new estimate of μ-induced delayed background (e.g. ^{77m}Ge, ^{38}Cl)

Notice: the previous simulation [NIM A 570 (2007) 149] run with *different geometry* (Cu cryostat, LN$_2$, array, etc.). Furthermore: used MUSUN code to simulate explicitely *energy-angle correlation*



Results qualititatively consistent with the previous work. For Phase II (at $Q_{\beta\beta}$):

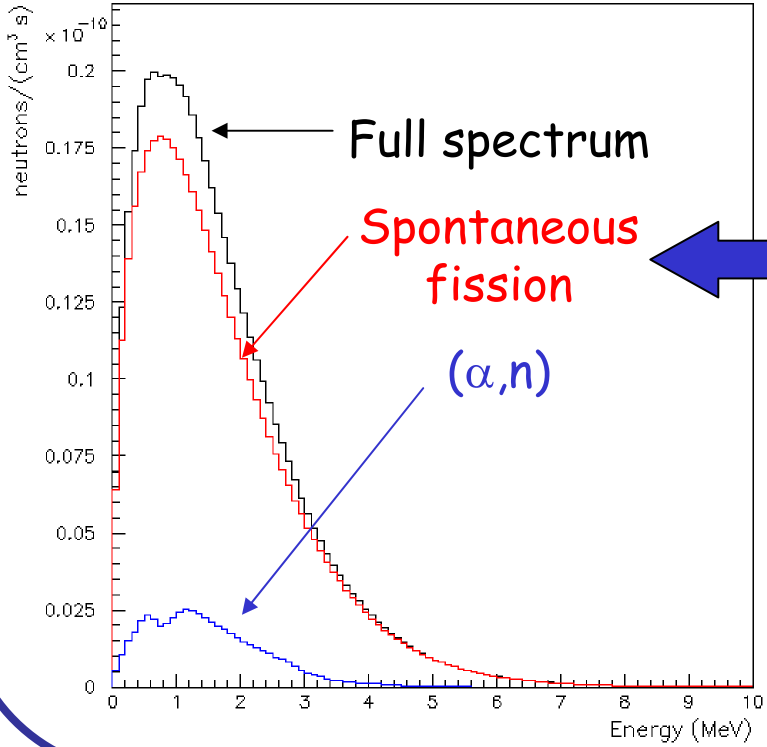
$9 \cdot 10^{-3}$ counts/(keV·kg·y) without cuts and $4 \cdot 10^{-4}$ counts/(keV·kg·y) with segment anti-coincidence.

Cherenkov veto needed and allows for < 10^{-5} counts/(keV·kg·y)

n-induced background

Water buffer absorbs effectively **all external neutrons**: main contribution comes from neutrons produced in the setup (specifically, the stainless-steel cryostat!)

The GERDA background due to *external* neutrons was estimated (but not simulated). Estimate of background due to "internal" neutrons never done in the past



Neutron production from **stainless steel** by spontaneous fission and (α,n) for: 1.7 mBq/kg (^{232}Th), 4 mBq/kg (^{226}Ra) and 50 mBq/kg (^{238}U)

Total neutron rate from the SS cryostat: **$1.86 \cdot 10^3$ n/(ton·y)**, with <E> = 1.62 MeV.

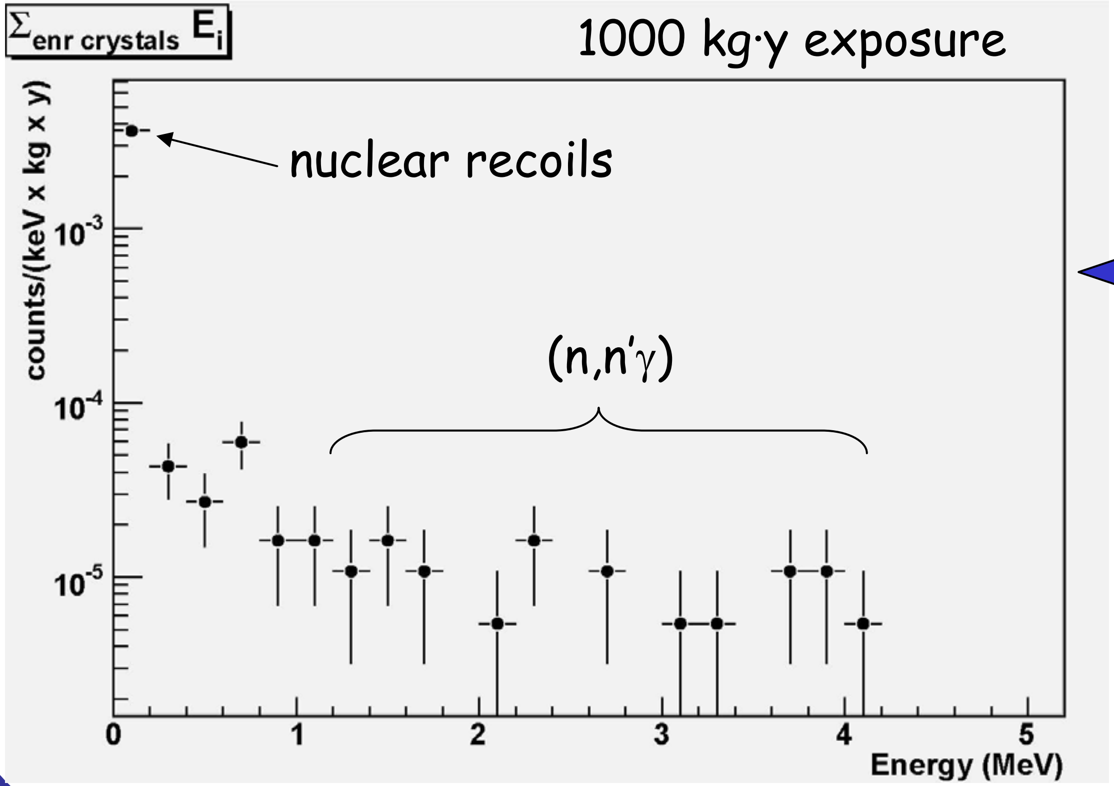
Neutrons tracked in the GERDA setup using MaGe-MCC2

(Prompt) background by neutrons

Contribution from external neutrons was partially simulated (for neutrons coming **close to neck**) and partially calculated.

No neutron will ever come through 2.5 m of water ($\lambda \sim 6$ cm): only possible close to neck (where water shield is smaller).

Global limit to bck from external neutrons: 10^{-7} cts/(keV·kg·y)



Spectrum due to interactions of n from cryostat

Prompt background at $Q_{\beta\beta}$: $7 \cdot 10^{-6}$ cts/(keV·kg·y) with no cut. Reduction by factor of 4 by segment anti-coincidence

Delayed background

Delayed baground is due to unstable isotopes produced by muon and neutron interactions (e.g. ^{77m}Ge, ^{41}Ar, ^{38}Cl)
→ previous simulations provide **production rates**

Relevant isotopes (a long list is available...) are simulated individually and spectra are re-scaled according to the total production rate → **work in progress**

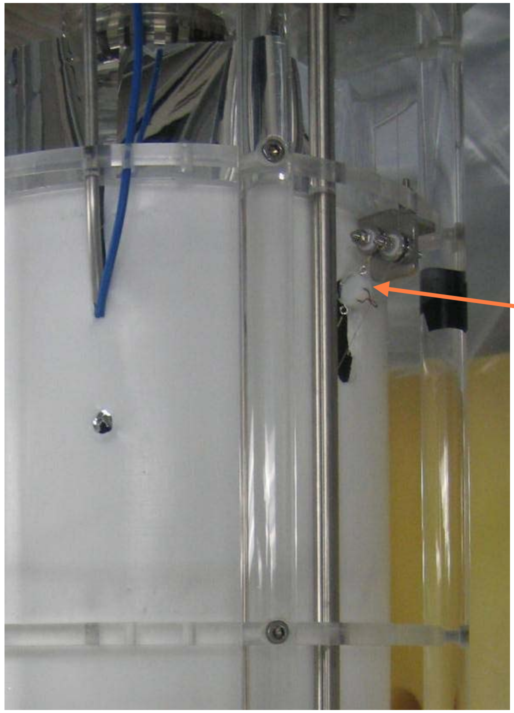
Such approach is valid if **$T_{1/2}$ < ~few weeks** so that production and decay rates are in equilibrium

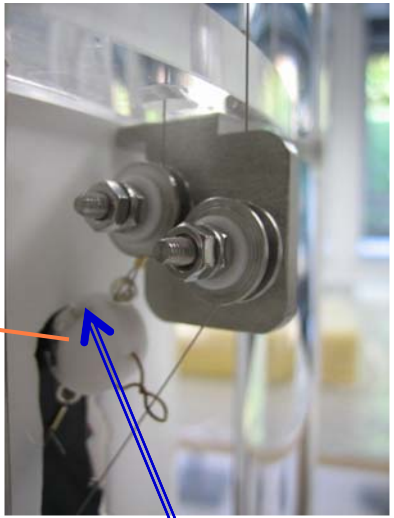
For longer half-lives, the decay rate is dominated by activation above ground and varies in time

Very short-lived isotopes (< 50 ms) can be rejected efficiently by the Cherenkov veto

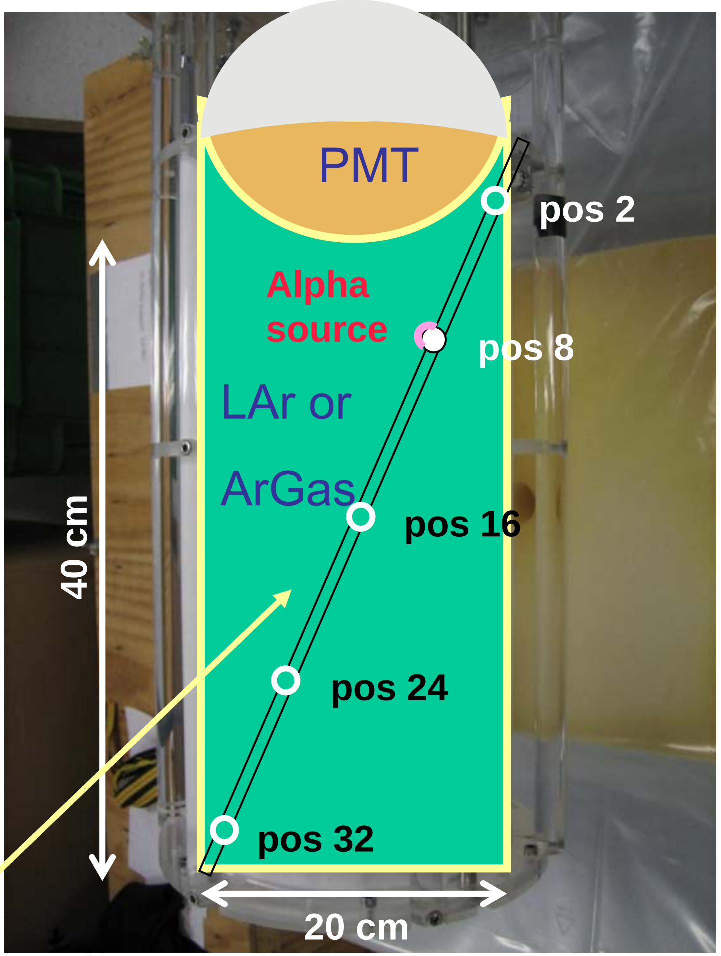
LAr scintillation studies

MaGe-based simulation developed to investigate response function and optical properties of LAr scintillation





Alpha source ^{148}Gd

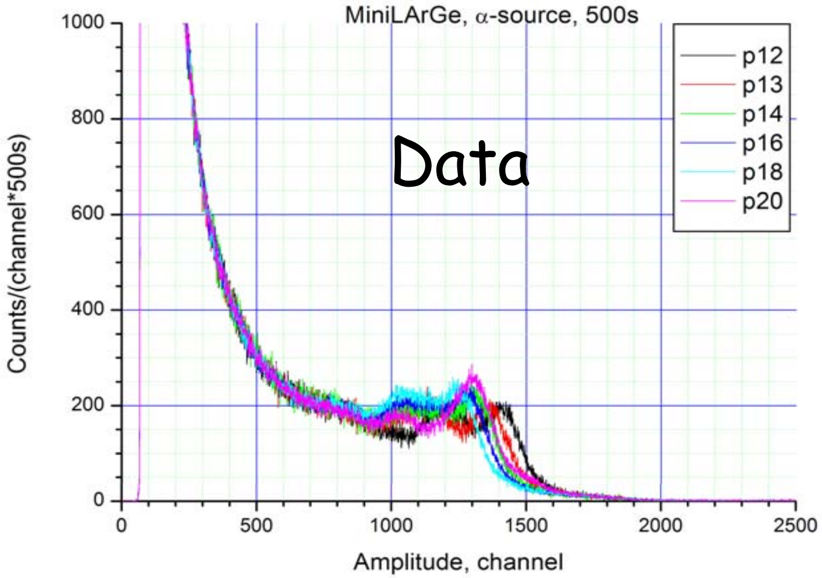


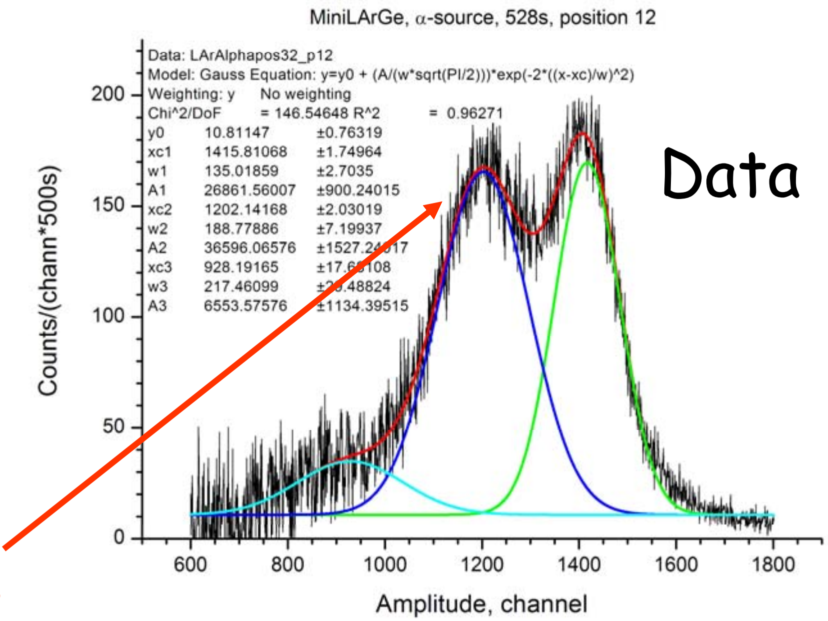
Simulations compared with **MiniLArGe data** (^{148}Gd α source) collected in different source positions

LAr scintillation studies

Simulation was used to **understand the experimental spectrum** and to **tune unknown optical properties** of the MiniLArGe system

A detailed model of the MiniLArGe setup (including optical properties) was modeled in Geant4-MaGe.





```
Data: LArAlphapos32_p12
Model: Gauss Equation: y=y0 + (A/(w*sqrt(PI/2)))*exp(-2*((x-xc)/w)^2)
Weighting: y     No weighting
Chi^2/DoF        = 146.54648 R^2         =  0.96271
y0        10.81147        ±0.76319
xc1       1415.81068      ±1.74964
w1        135.01859       ±2.7035
A1        26861.56007     ±900.24015
xc2       1202.14168      ±2.03019
w2        188.77886       ±7.19937
A2        36596.06576     ±1527.24[illegible]17
xc3       928.19165       ±17.6[illegible]108
w3        217.46099       ±2[illegible].48824
A3        6553.57576      ±1134.39515
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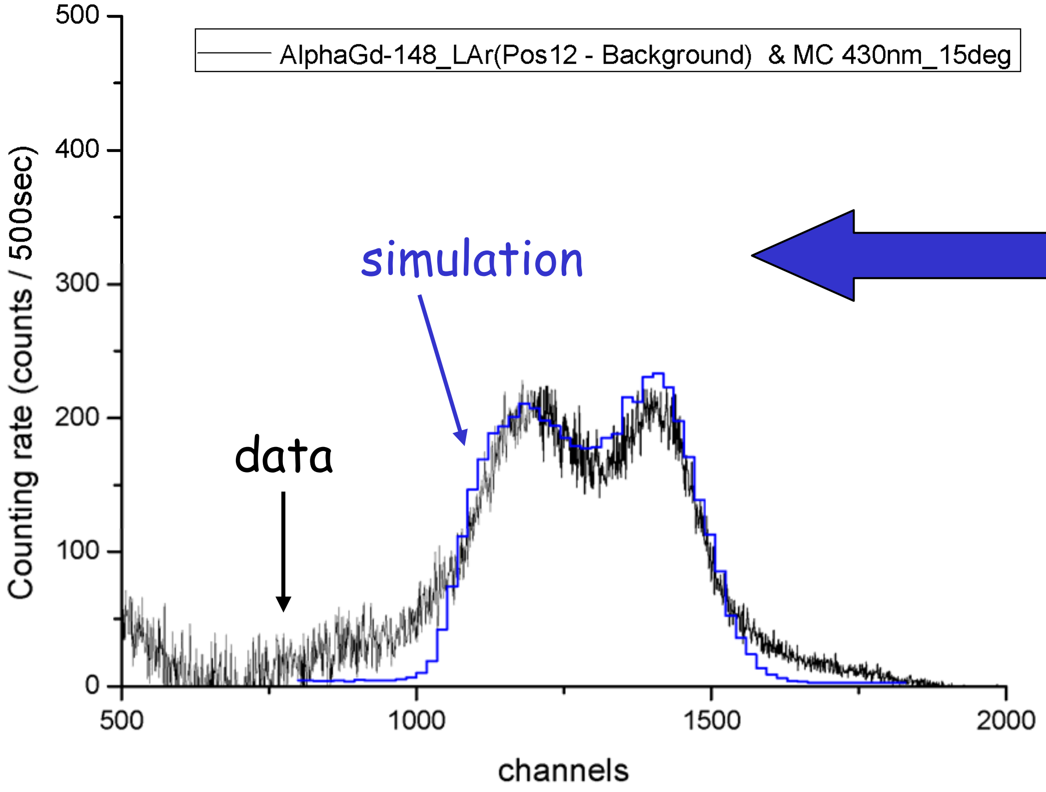
Open issue: why **two peaks** in the data for mono-E α?

LAr scintillation studies



Following the tuning of optical parameters, a **good qualitative agreement** was obtained for all source positions

The two-peak structure due to **reflection** of light from the α-source substrate (Al) → response may depend on the orientation of the source substrate

MC **crucial** for the interpretation of measurements

Conclusions

The **activity** of the Monte Carlo Working Group on simulations and background studies continues **regularly**

The **main effort** at the moment is the Monte Carlo Campaign 2 (**MCC2**), aiming to estimate a realistic background spectrum from GERDA (with updated geometry and radiopurities)

Simulations are based on MaGe. MaGe is regularly updated to include new tools needed for MCC2

Activity for the development of electric fields and **pulse shape simulation is going on**. It is interfaced to with MaGe, to have the full simulation chain

Other Monte Carlo activities are ongoing on **calibration sources** and **LAr scintillation properties**