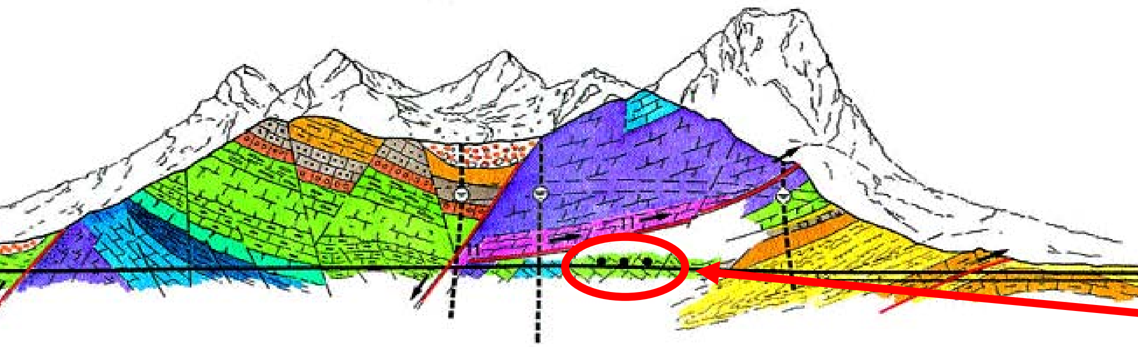
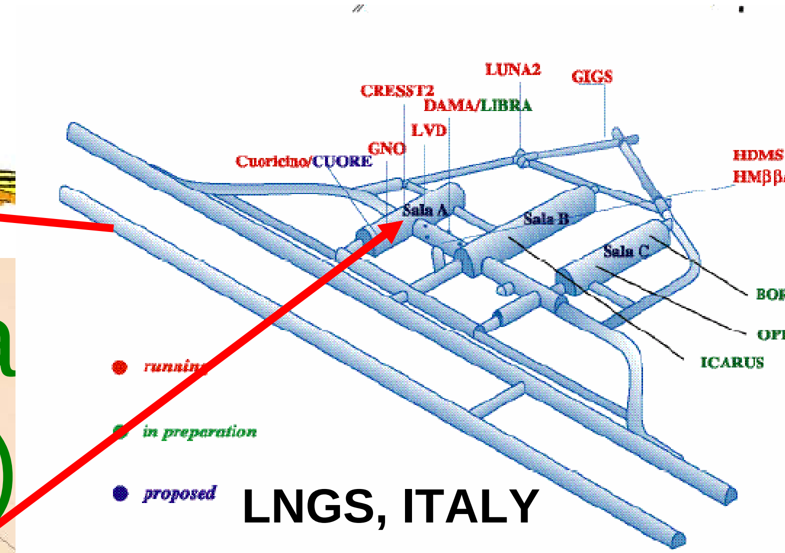
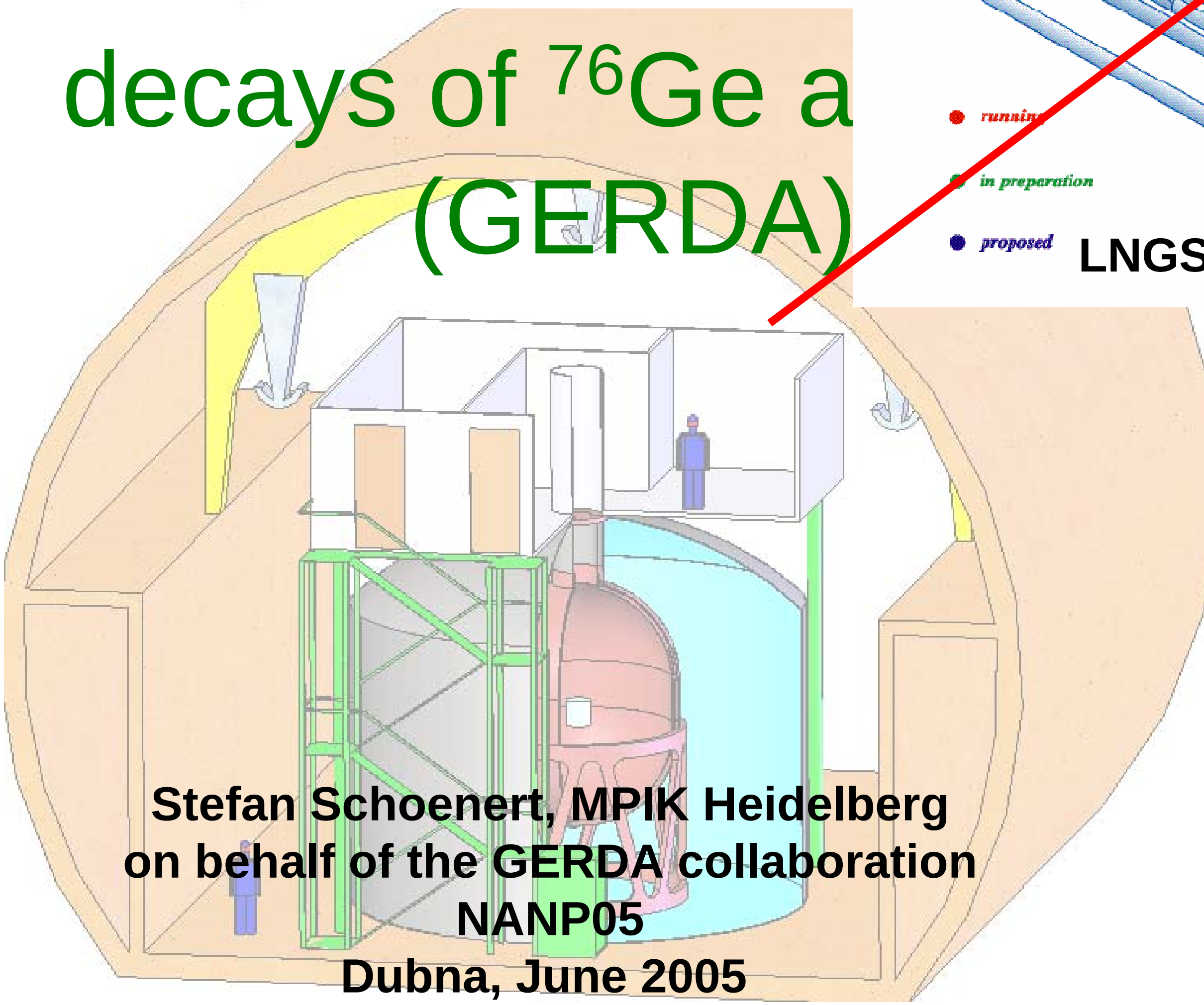


decays of ^{76}Ge a (GERDA)



LNGS, ITALY



Stefan Schoenert, MPIK Heidelberg
on behalf of the GERDA collaboration

NANP05

Dubna, June 2005

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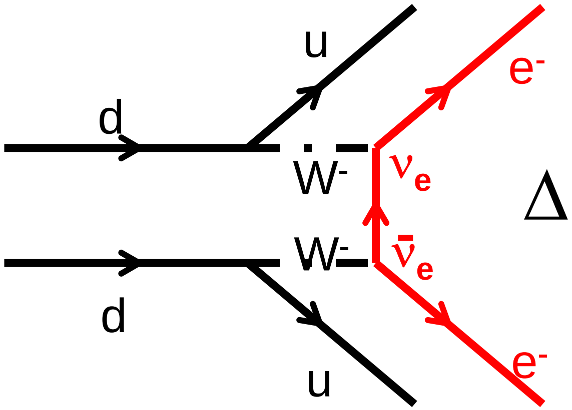
Physics goals of GERDA

Primary Objective:



$\Delta L=2$

$0\nu\beta\beta$: (A,Z) $\rightarrow$ (A,Z+2) + $2e^-$

$\Rightarrow$Majorana nature

$\Rightarrow$Effective mass: $1/\tau = G(Q,Z)\,|M_{nucl}|^2\, \mathbf{m_{ee}^2}$, (decay generated by (V-A) cc-interaction via exchange of light Majorana neutrinos)

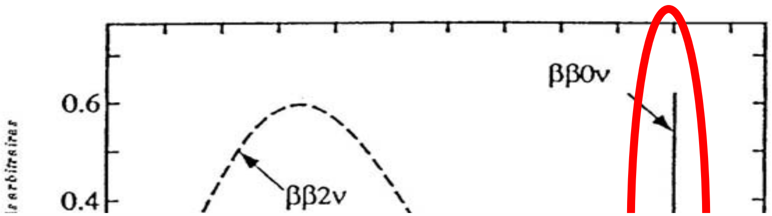
$$m_{ee} = |\sum_i U_{ei}^{\;2}\; m_i\,|$$

Other Physics: WIMP DM search

Method: Operation of HP Ge-diodes enriched in ^{76}Ge in (optional active) cryogenic fluid shield. Line search at $Q_{\beta\beta} = 2039$ keV

GERDA @ Gran Sasso: experimental concept

- HP Ge-diodes (86%^{76}Ge): **point-like** energy deposition at $Q_{\beta\beta}$ = 2039 keV

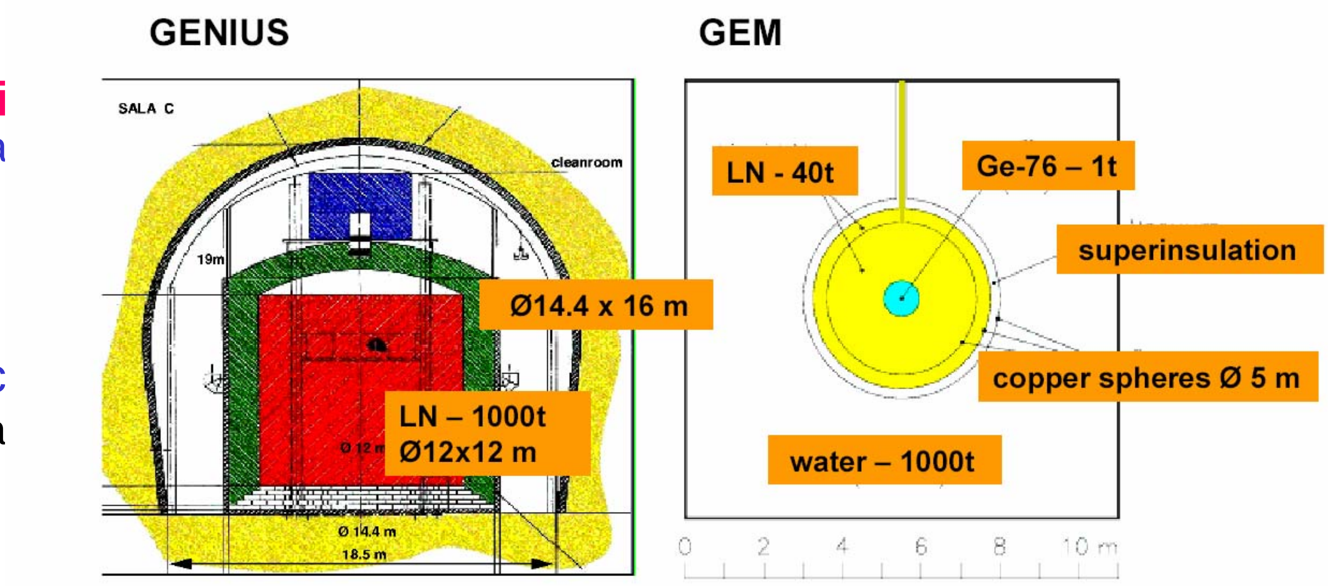


- Operation o… …r LAr **shield** (Heusser, Ann. Rev. Nucl. Part. S… …JS (H.V. Klapdor-Kleingrothaus et. al., hep-ph/9910205 (… …)

- **Baseli…** …nce with scintilla…

- Reduc…
  - Ha…
    -
    -

free!



Klapdor-Kleingrothaus., Baudis, Heusser, Majorovits, Päs, hep-ph/9910205

Zdesenko, Ponkratenko, Tretyak nucl-ex/0106021

Why Ge-76 ?

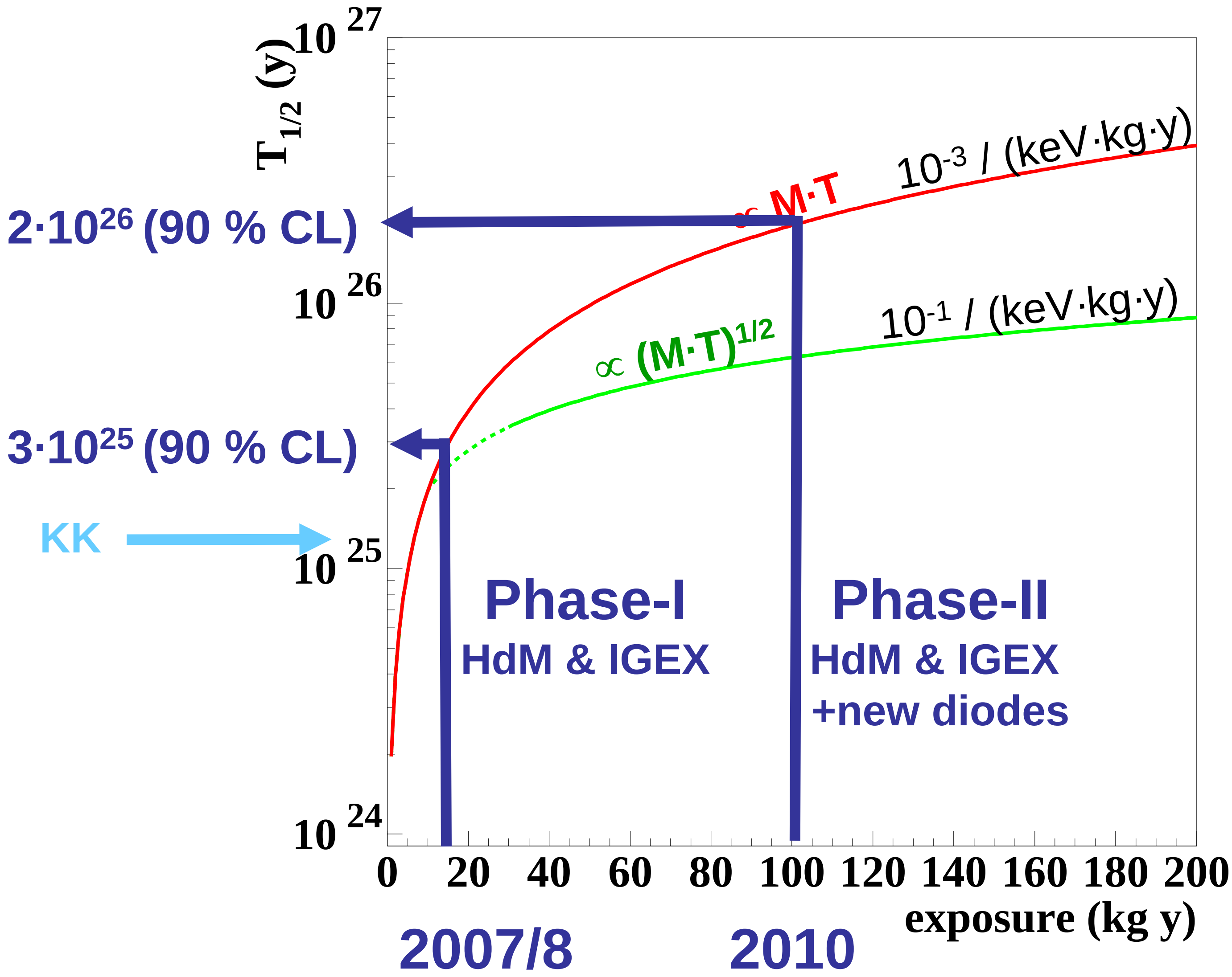
- High resolution (<4 keV @ $Q_{\beta\beta}$): no bgd from 2ν-mode
- Huge leap in sensitivity possible …

  …applying ultra-low background techniques

  …novel background / 0ν-$\beta\beta$ signal discrimination methods (ie. point-like vs. compton events)

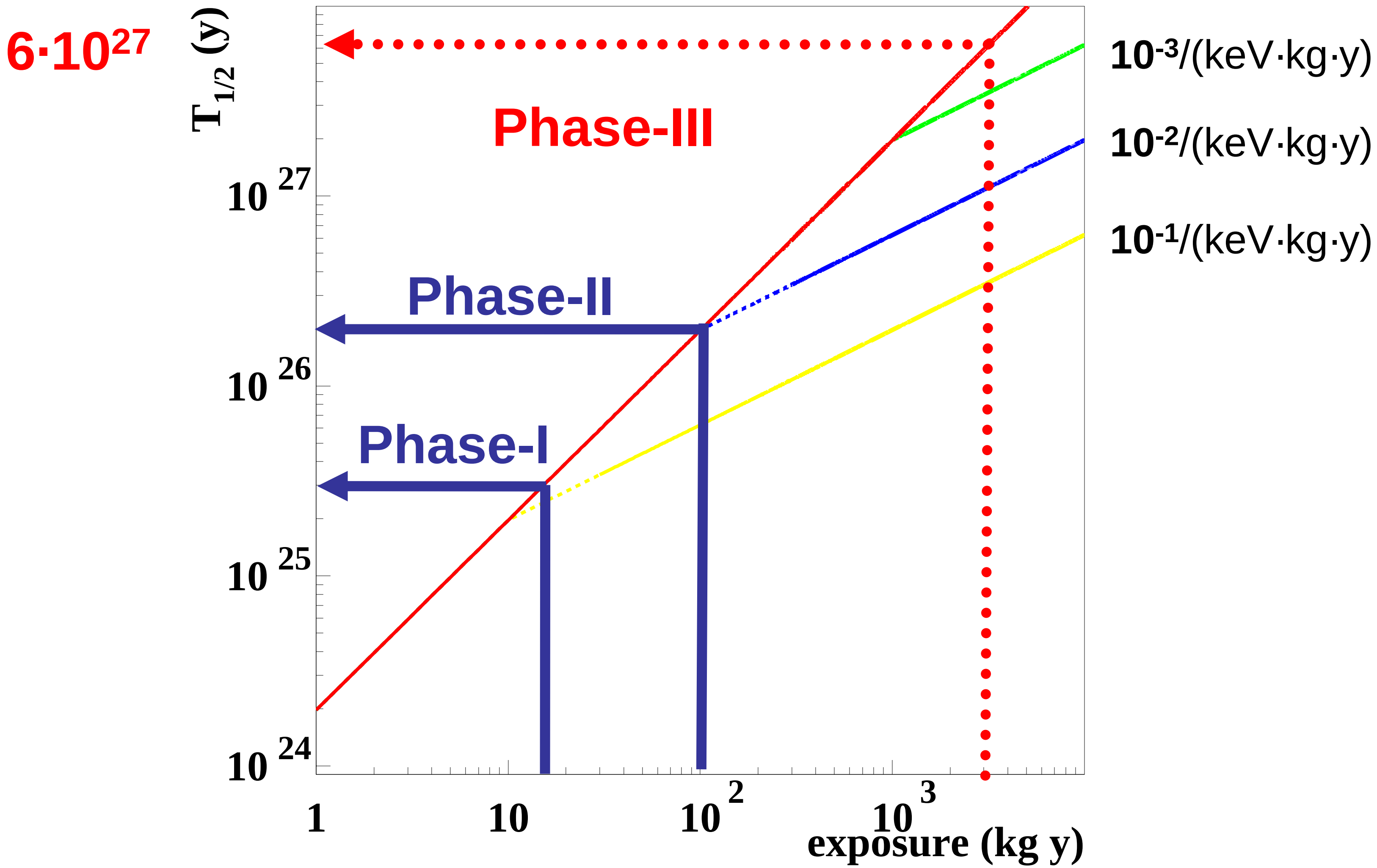
    - Segmentation & pulse shape (with true coaxial detectors)
    - Liquid argon scintillation read out
- Phased approach: increment of target mass
- Only method to scrutinize 0ν-DBD claim on short time scale: test $T_{1/2}$, not m_{ee} !

Phases and physics reach of GERDA

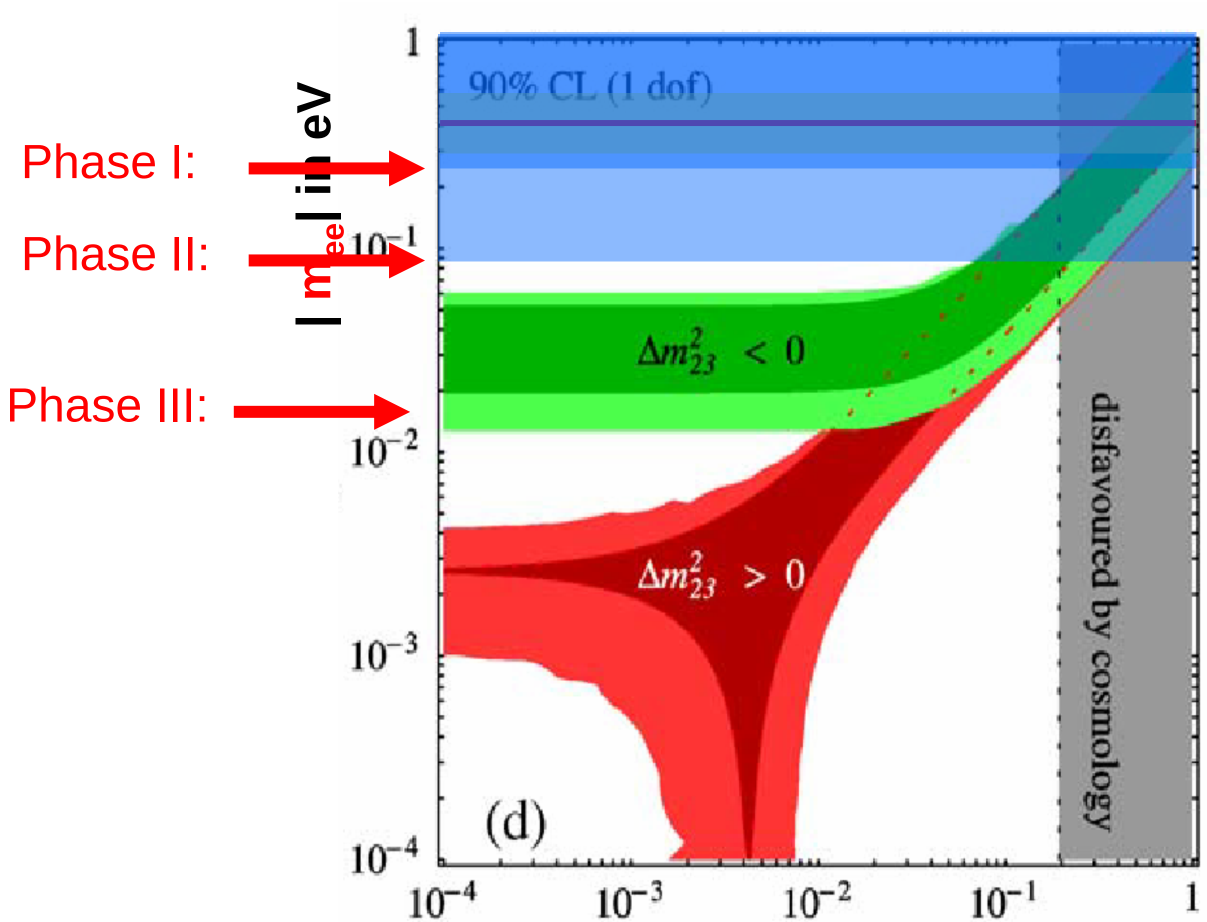


Phases and Physics reach of GERDA

world-wide collaboration for Phase-III; coop. with MAJORANA started



Phases and Physics reach of GERDA

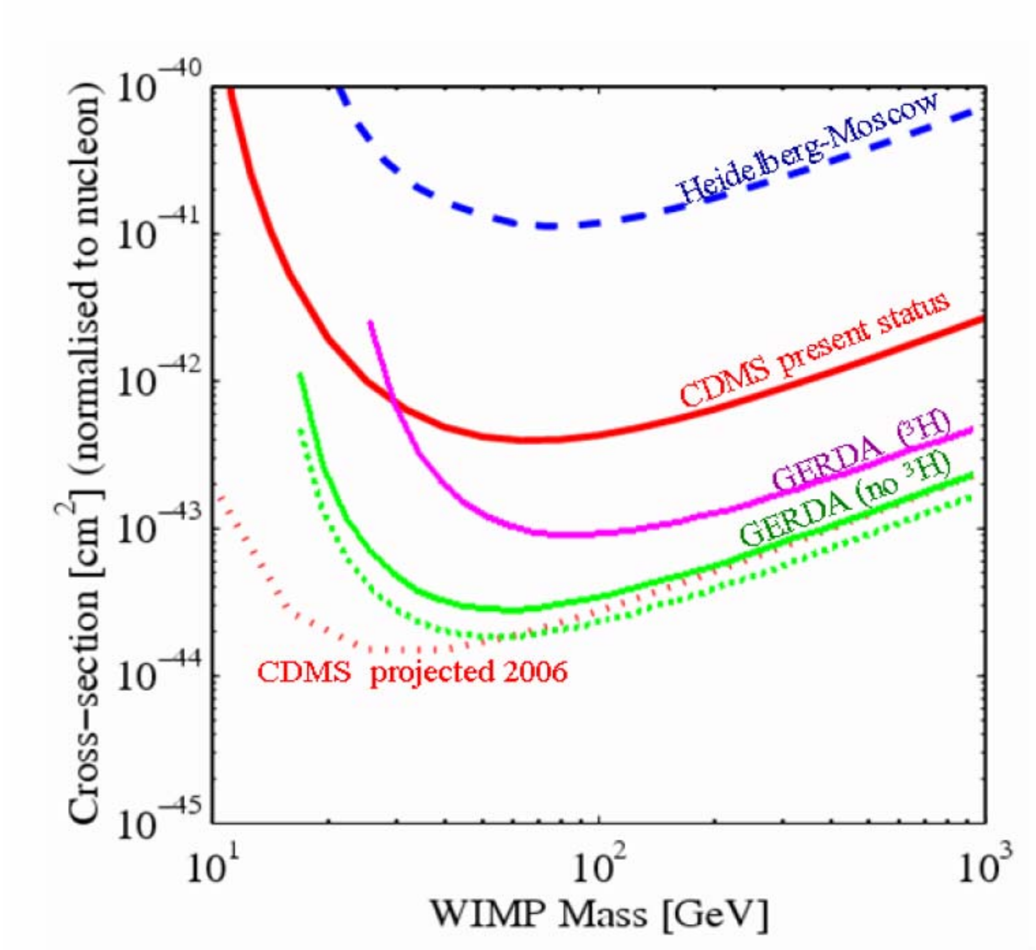


F.Feruglio, A. Strumia, F. Vissani, NPB 659

Lightest neutrino (m_1) in eV

Taking Faessler's ME (cf. his presentation this morning) : P-I: 0.31 eV, P-II: 0.12 eV; P-III: 0.02 eV

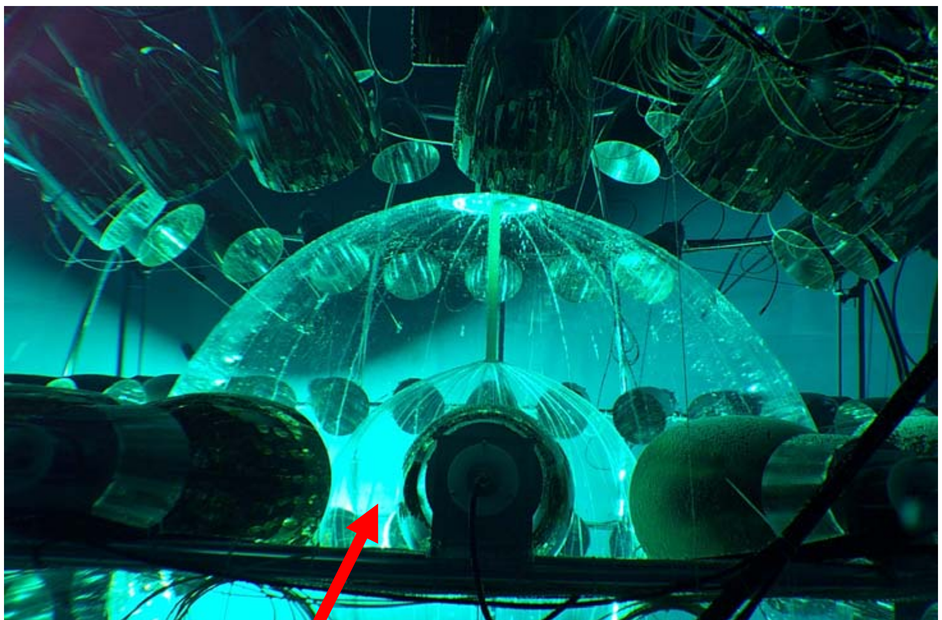
GERDA Dark Matter sensitivity



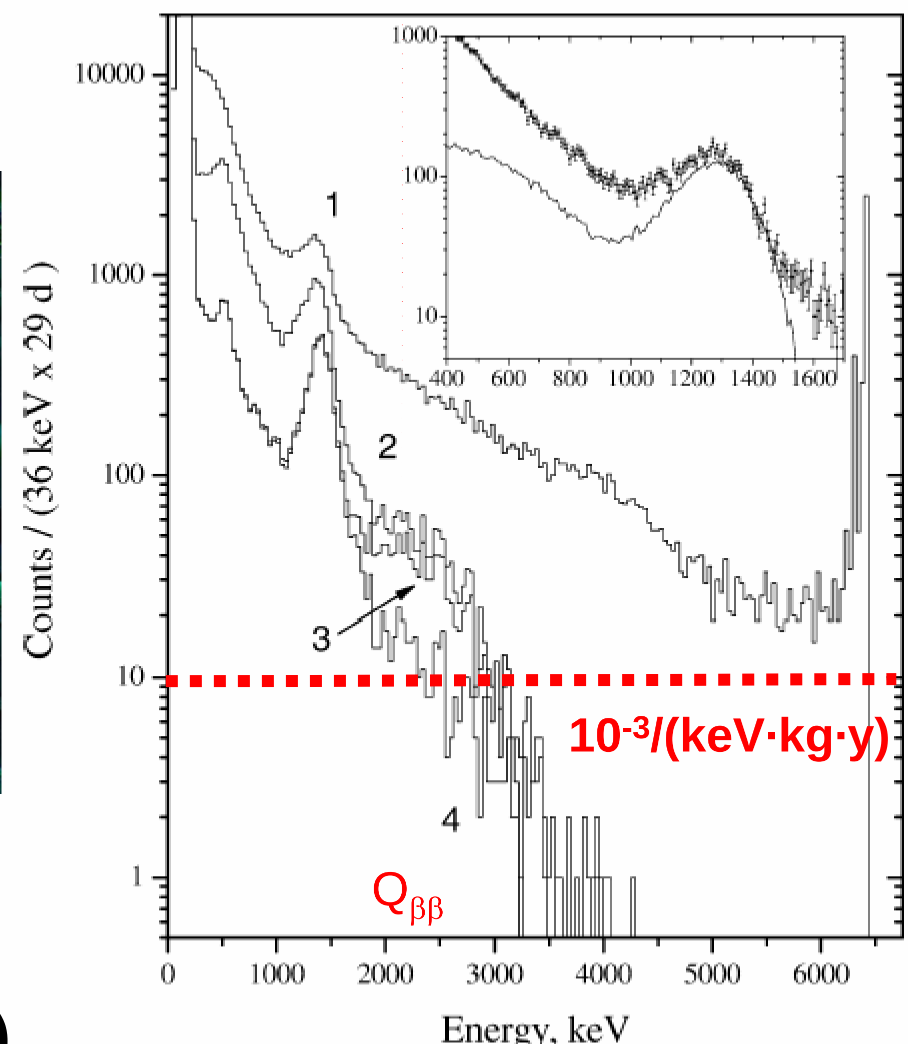
Assumptions: **background:** 0.05 cts/(keV$_{rec}$·kg·y);
threshold: 30 keV$_{rec}$(“no ^{3}H”) / 57 keV$_{rec}$(“^{3}H”)
exposure: 100 kg year (^{nat}Ge)

…how to reach $<10^{-3}$/(keV·kg·y)?

BOREXINO Counting Test Facility (CTF)
('world record')



Liquid scintillator target

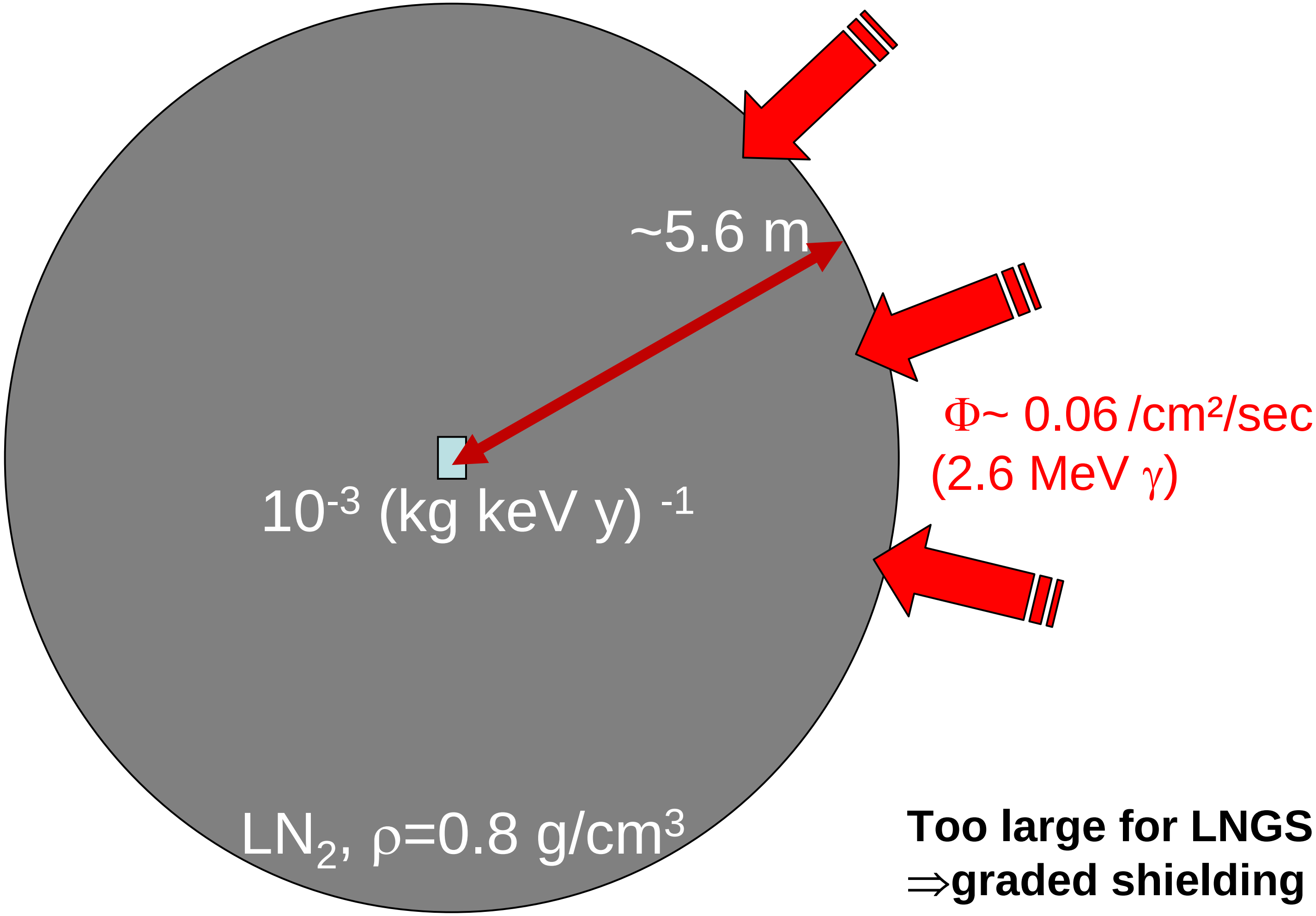


Borexino Collab. PLB 563 (2003)

BOREXINO ⇒~10^{-5}/(keV·kg·y)

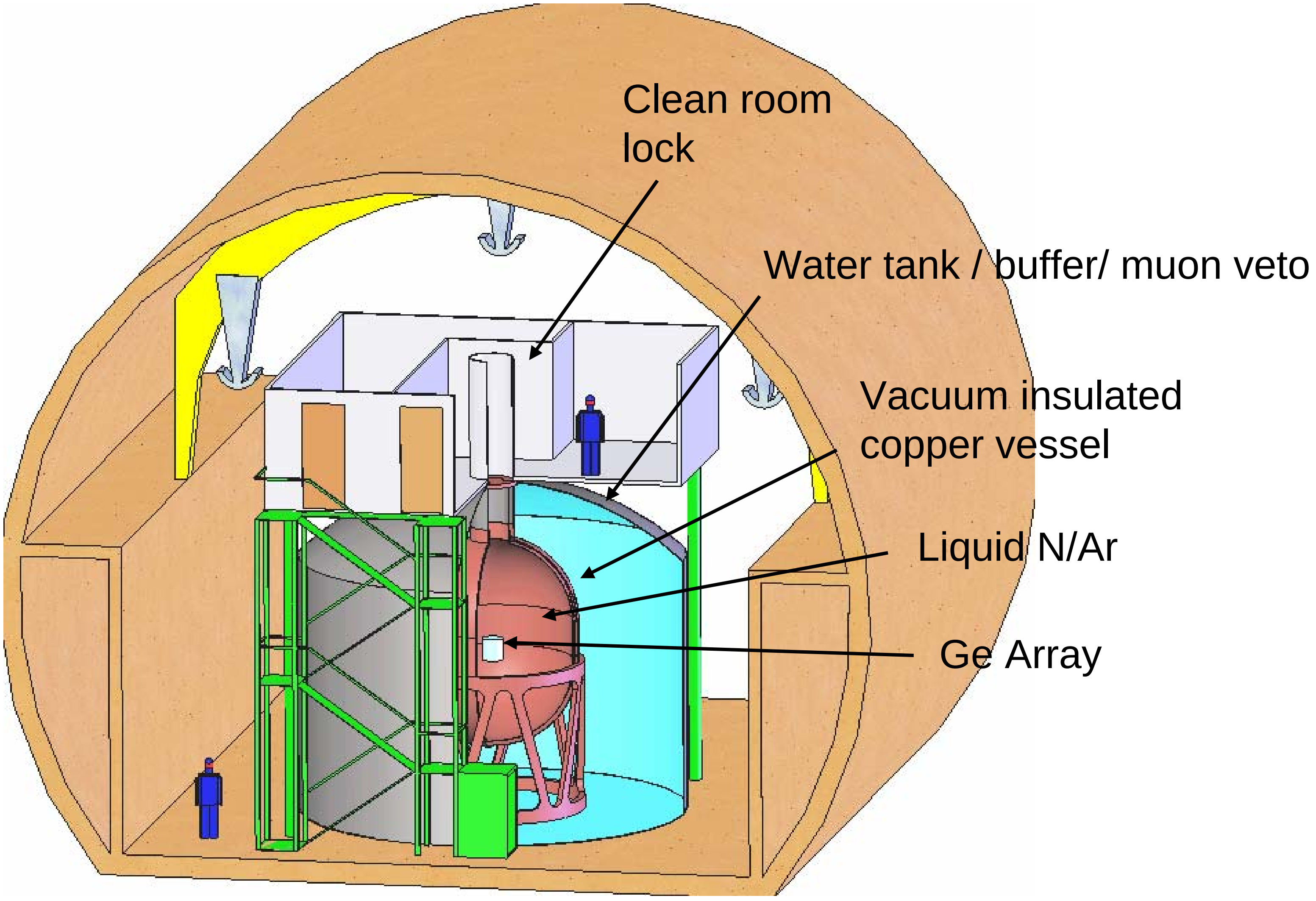
shielding against ext. γ's à la BOREXINO…

….but with high purity liquid N_2/Ar (**<0.3μBq ^{222}Rn / m^3(STP)**)



Too large for LNGS
⇒graded shielding (water buffer)

GERDA: Baseline design



Backgrounds in GERDA

Source	**B [10^{-3} cts/(keV kg y)]**
Ext. γ from ^{208}Tl (^{232}Th)	<1
Ext. neutrons	<0.05
Ext. muons (veto)	<0.03
Int. ^{68}Ge ($t_{1/2}$= 270 d)	**12**
Int. ^{60}Co ($t_{1/2}$= 5.27 y)	**2.5**
^{222}Rn in LN/LAr	<0.2
^{208}Tl, ^{238}U in holder	<1
Surface contam.	<0.6

derived from measurements and MC simulations

Muon veto

180 days exposure after enrichment + 180 days underground storage

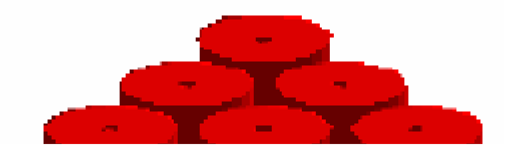
30 days exposure after crystal growing

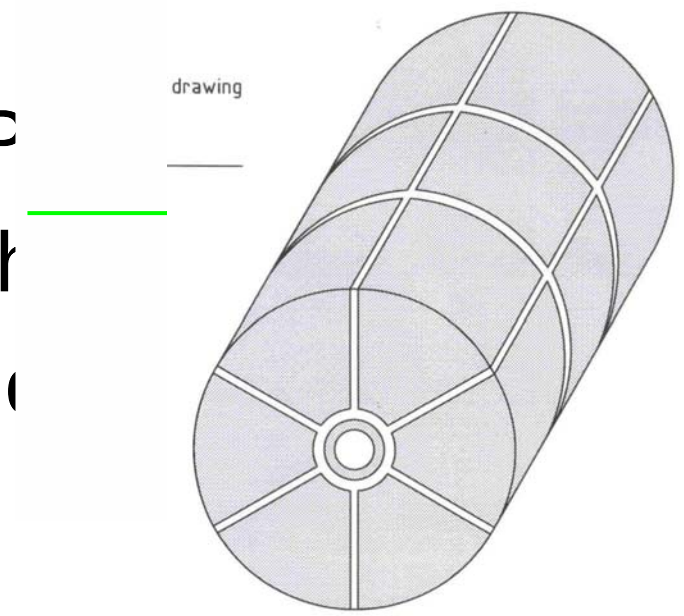
Target for phase II: B $\leq$ 10^{-3} cts/(keV kg y)

$\Rightarrow$ additional bgd. reduction techniques

Background reduction techniques

- Muon Veto
- Anti-coincidence between detectors
- Segmentation of readou
  (Phase II)
- Pulse shape analysis (P
- Coincidence in decay ch
- Scintillation light detecti



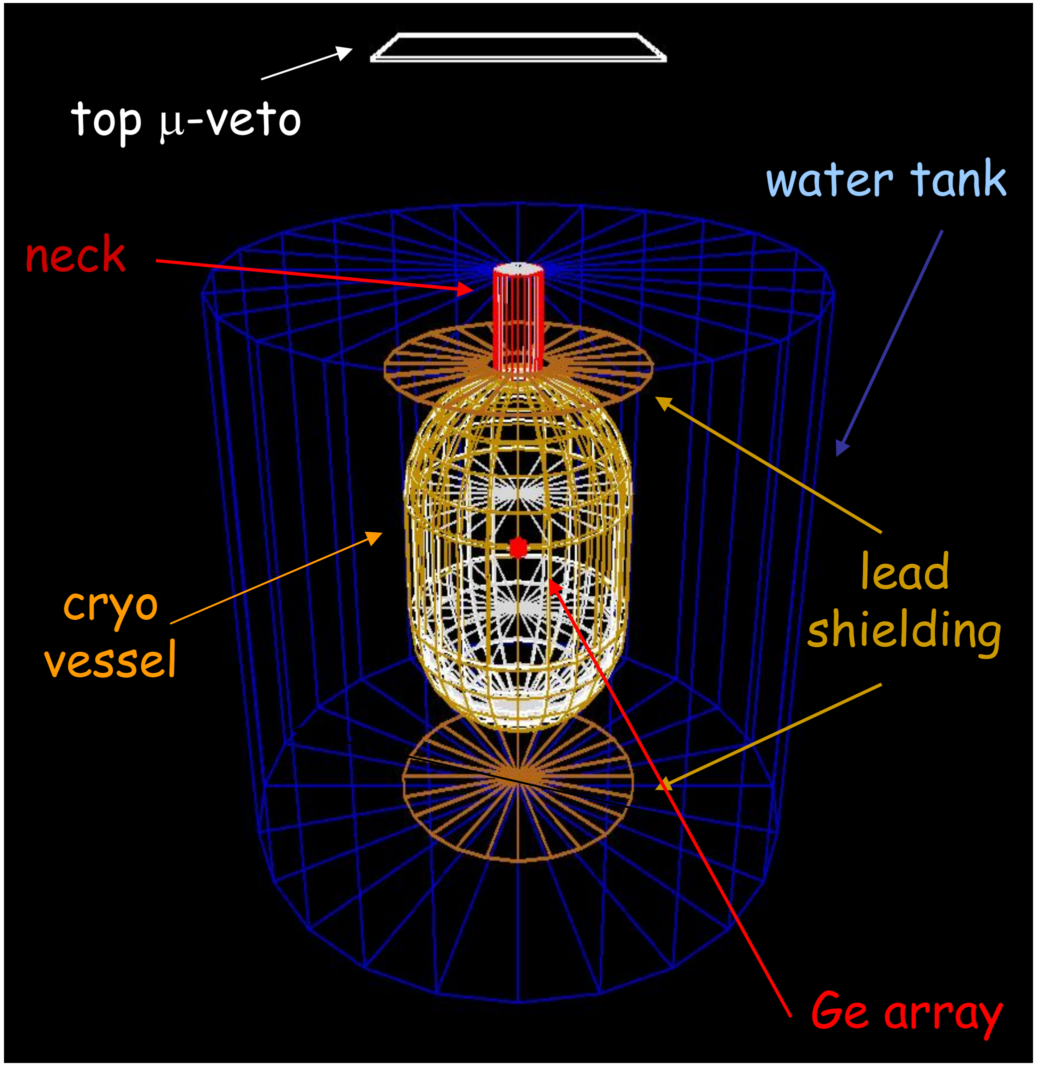


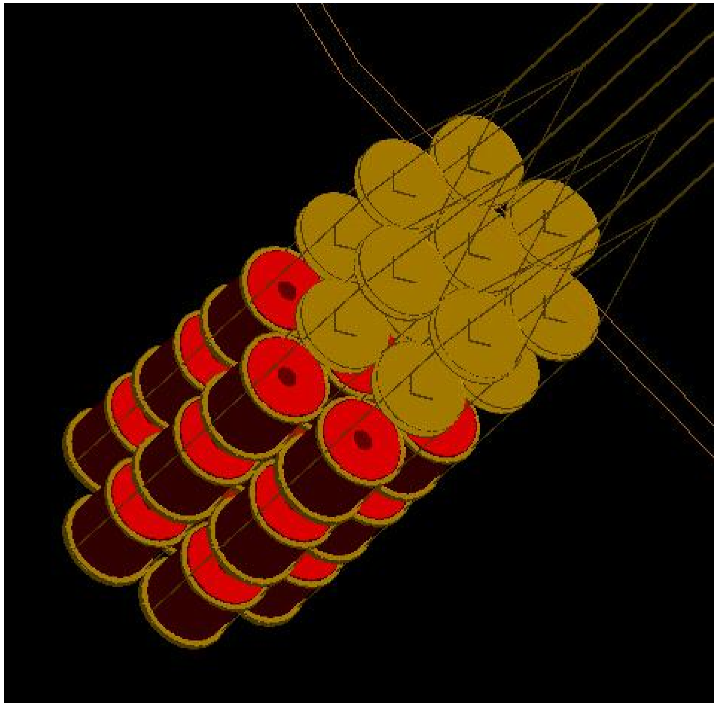
Background reduction techniques

- Muon veto
- Anti-coincidence between detectors
- Segmentation of readout electrodes (Phase II)
- Pulse shape analysis (Phase I+II)
- Coincidence in decay chain (Ge-68)
- Scintillation light detection (LArGe)

Background simulations with **MaGe**

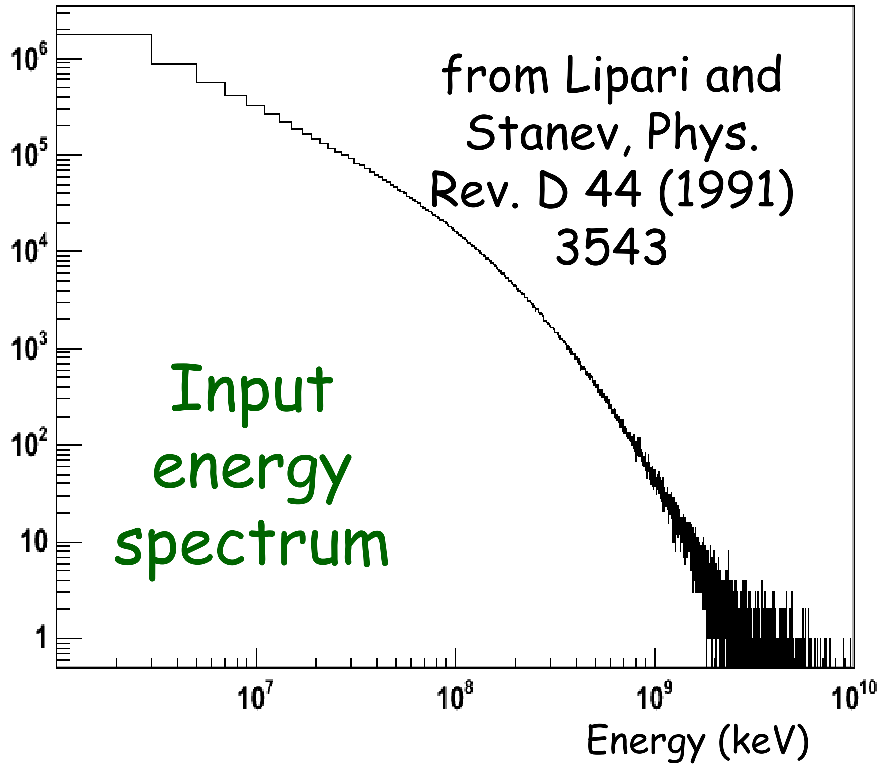
(common **Ma**jorana–**Ge**rda Geant4 MC framework)

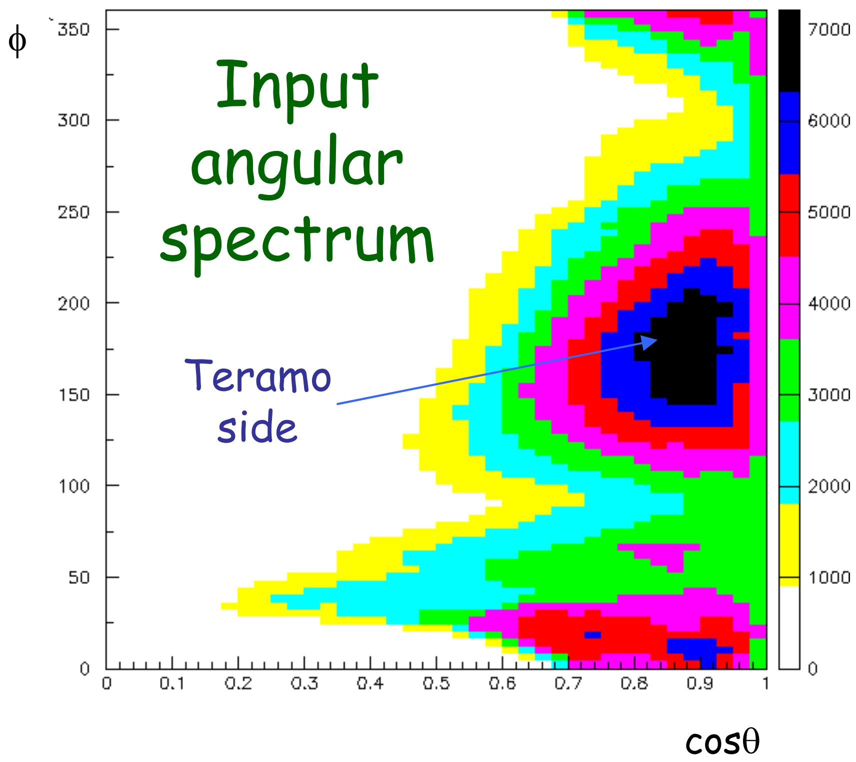




Description of the Gerda setup including shielding (water tank, Cu tank, liquid Nitrogen), crystals array and kapton cables

MaGe simulation of muons

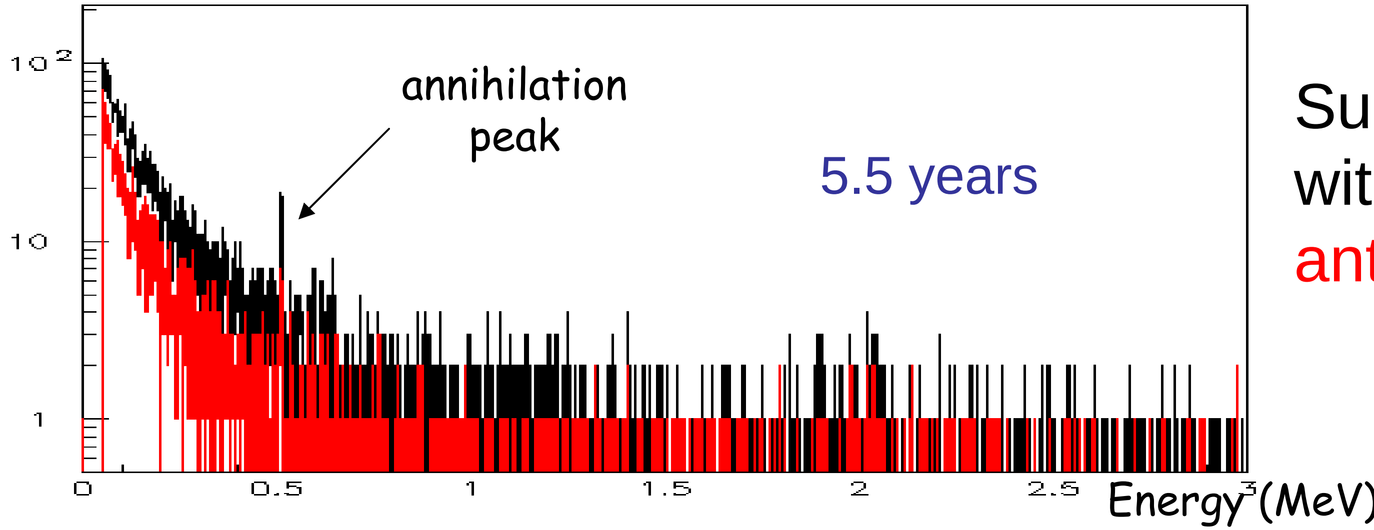




Flux at Gran Sasso: 1.1 μ/m^2 h (270 GeV)

MaGe: cosmic ray muons – Ge signal

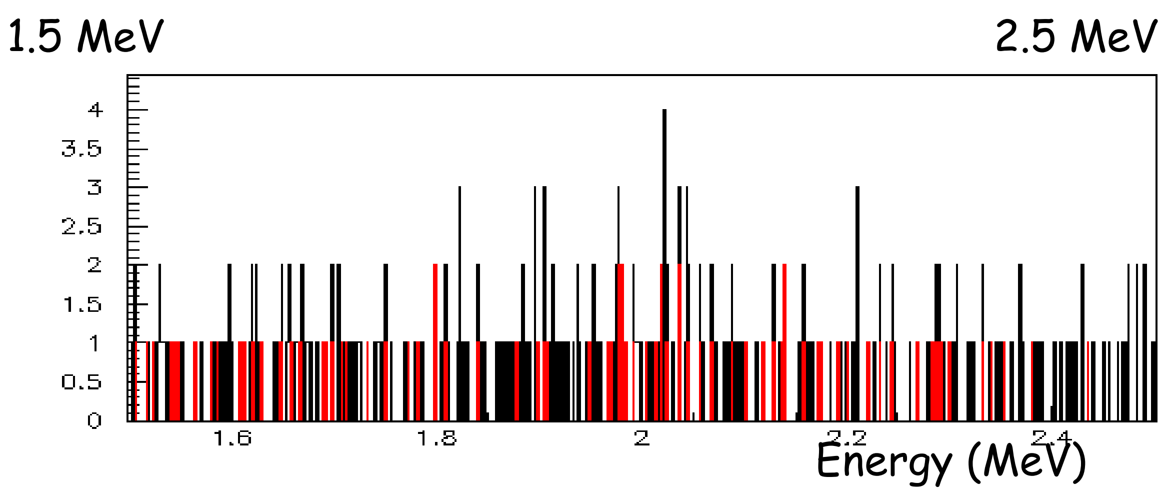
Phase I: 9 Ge crystals for a total mass of 19 kg; threshold: 50 keV



Sum spectrum without and with anticoincidence

(1.5 → 2.5 MeV): **3.3·10^{-3} counts/keV kg y**

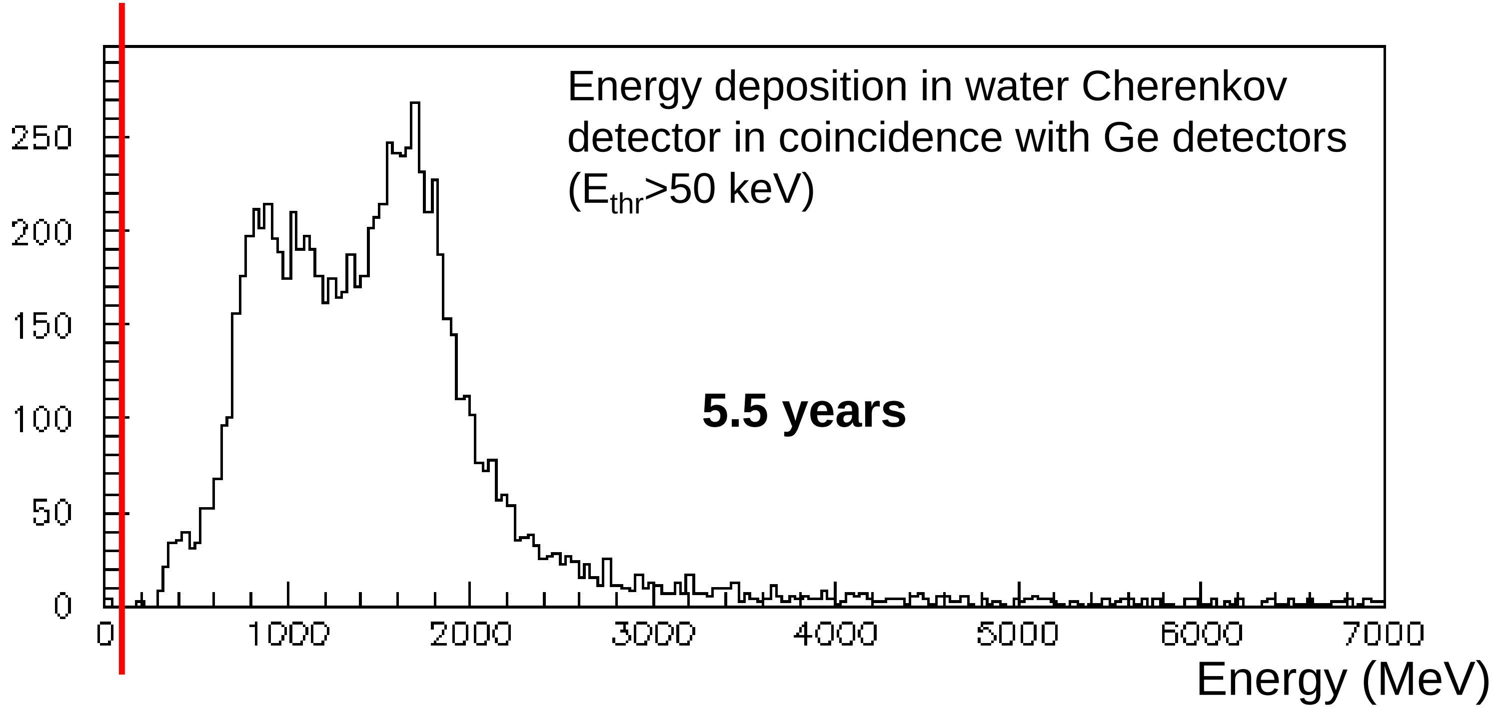
(~4·10^{-3} counts/keV kg y in H-M simul.) C. Doerr, NIM A 513 (2003) 596



anticoincidence between 9 crystals reduces background index by factor 3

⇒1.0 · 10^{-3} cts/keV kg y

MaGe: cosmic ray muons - muon veto

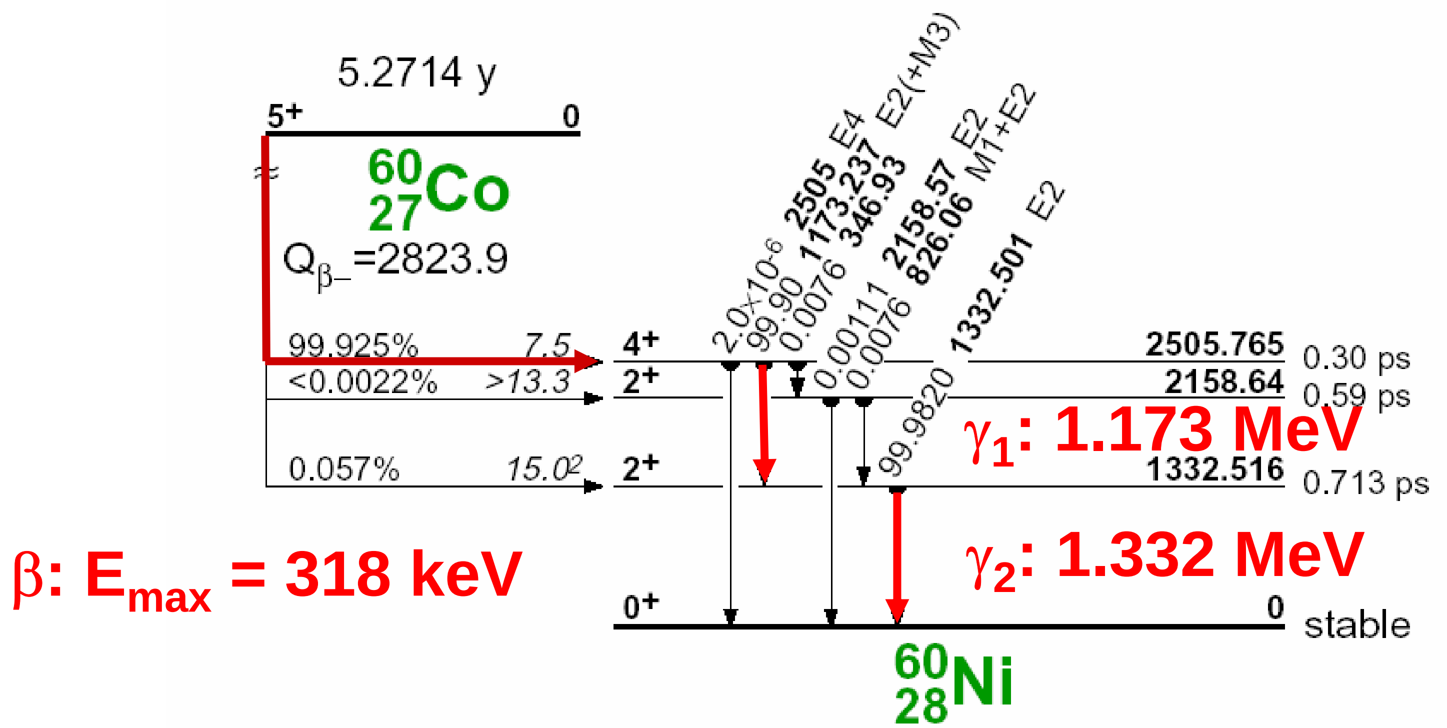


Threshold 120 MeV → all events cut but two

120MeV in water (~60 cm) → 30,000 ph. → 40 p.e. (0.5% coverage) → 80-90 PMTs

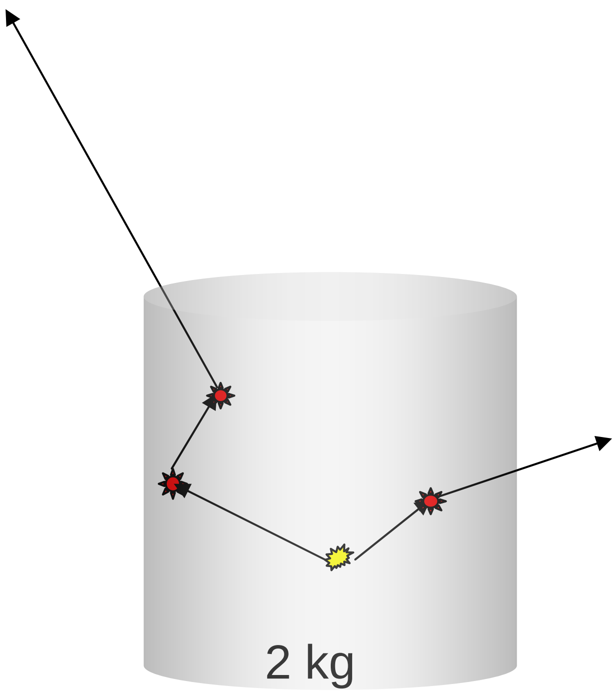
No cuts	$3.3 \cdot 10^{-3}$ (cts/keV kg y)
Ge anti-coincidence	$1.0 \cdot 10^{-3}$
Ge anti-coinc.+ Top μ-veto (plastic scint.)	$4.4 \cdot 10^{-4}$
Cerenkov μ-veto	**< $3 \cdot 10^{-5}$ (95% CL)**

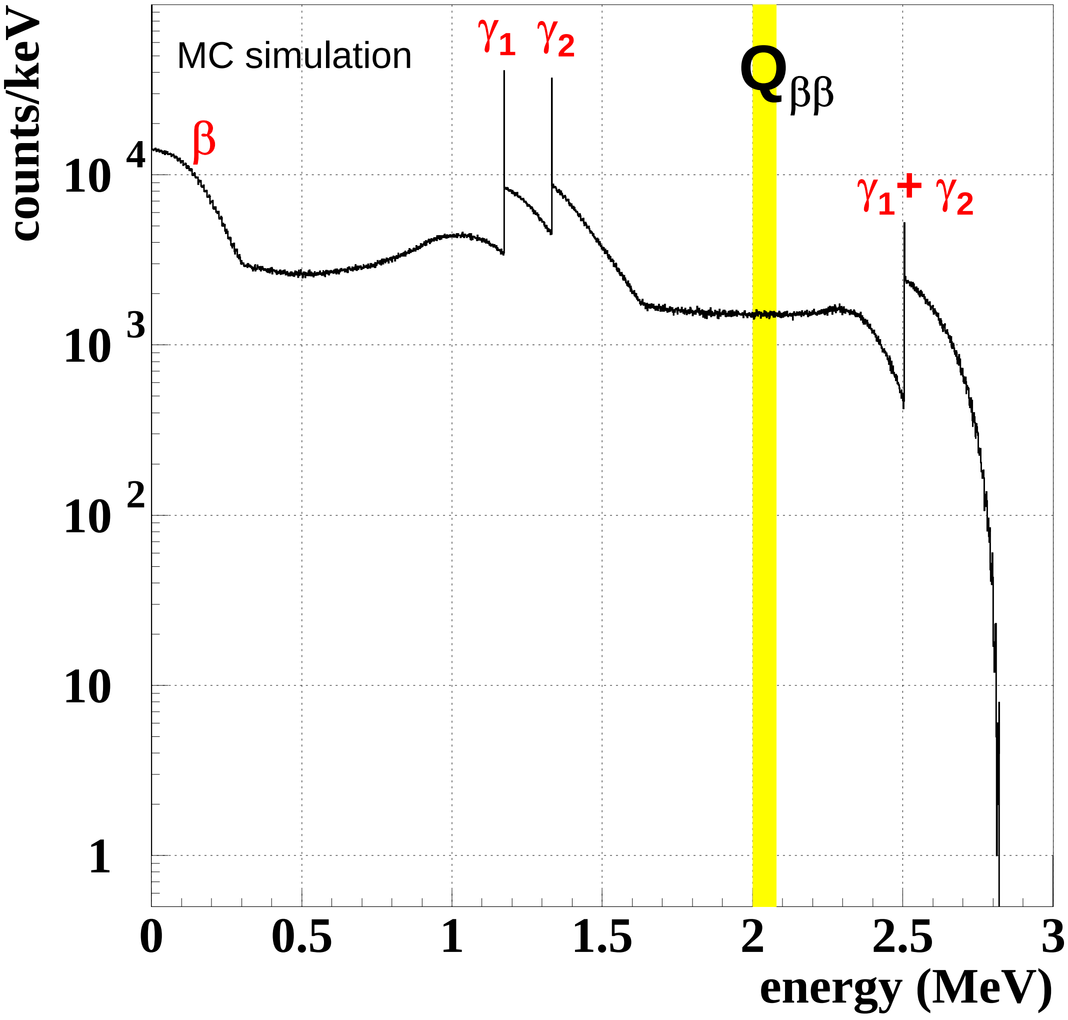
Example: Internal ^{60}Co



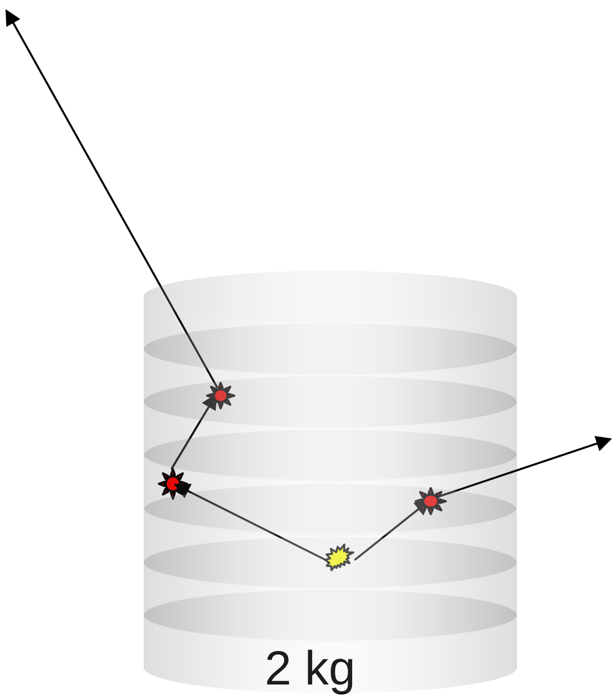
- T_0 : crystal growing
- 0.017 μBq/kg per day exposure
- Test: detector production in 7.4 days
- Assume 30 days ⇒ $2.5 \cdot 10^{-3}$ / (keV·kg·y)

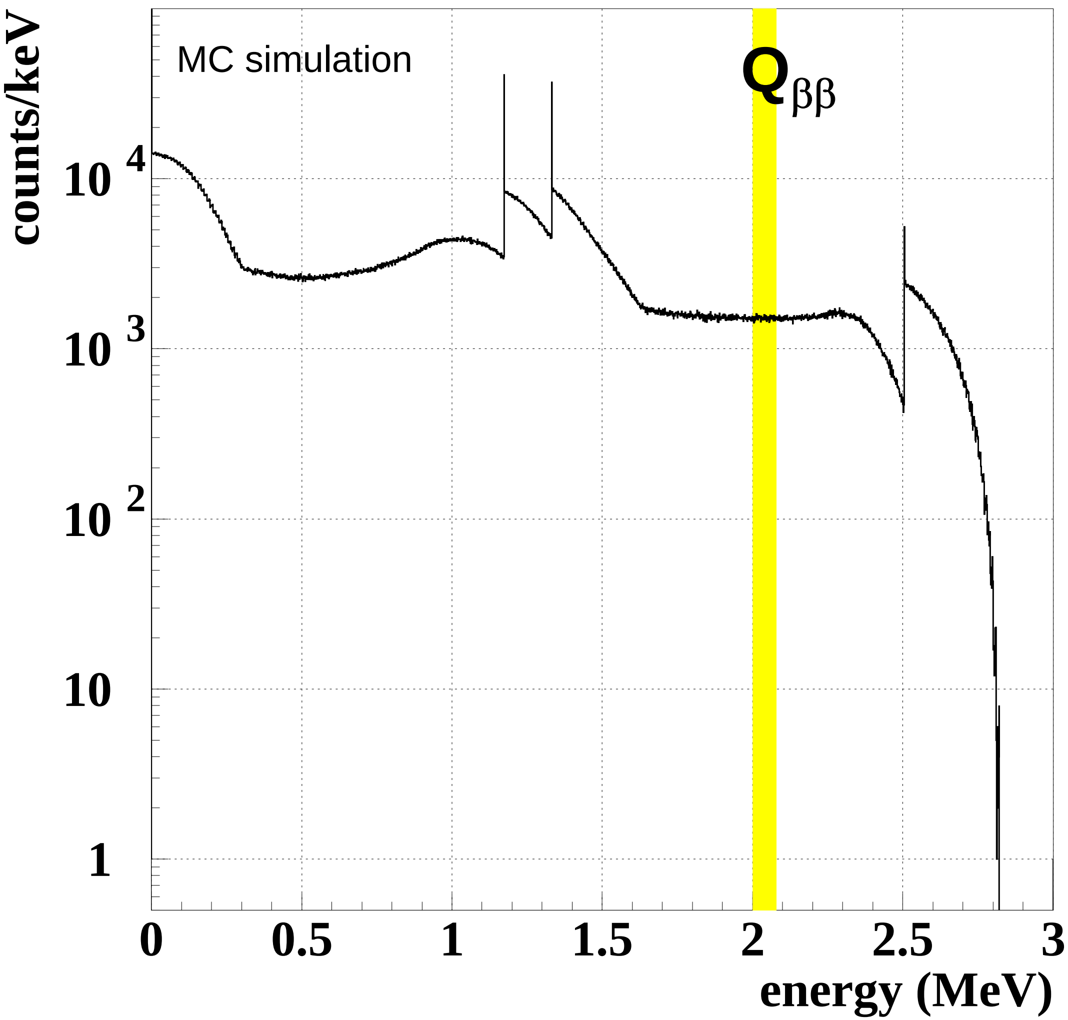
^{60}Co background spectrum



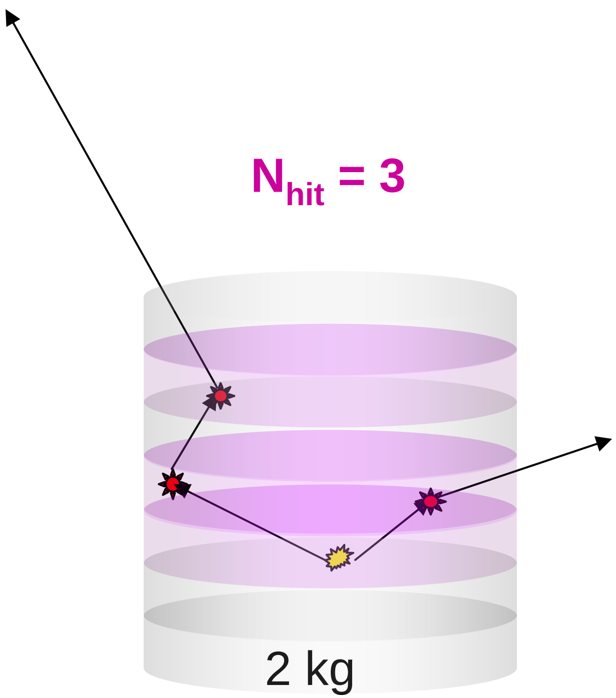


^{60}Co: suppression by segmentation





^{60}Co: suppression by segmentation



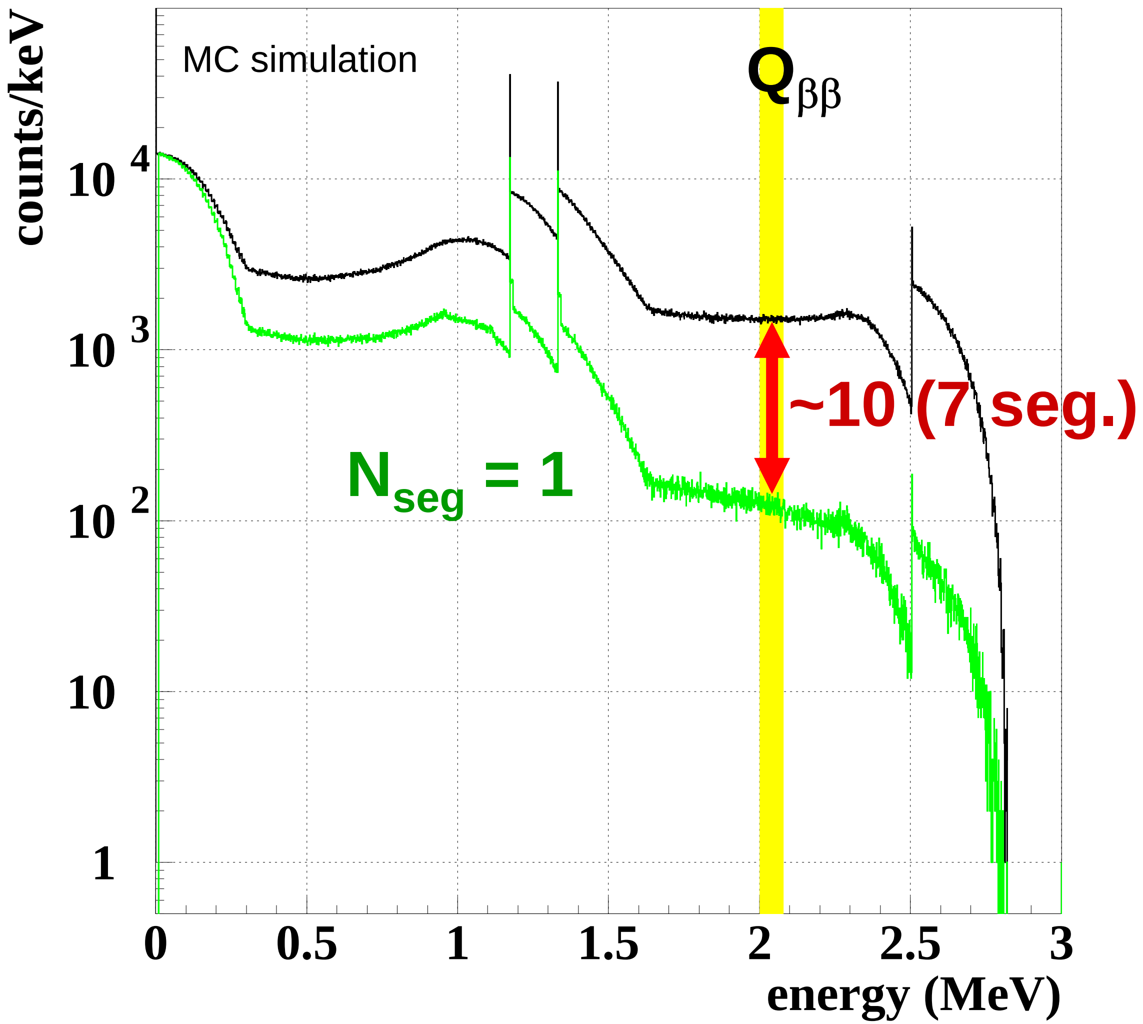
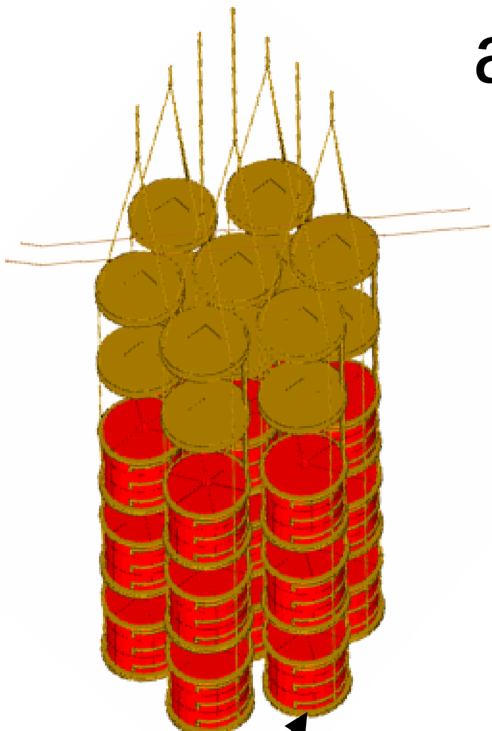
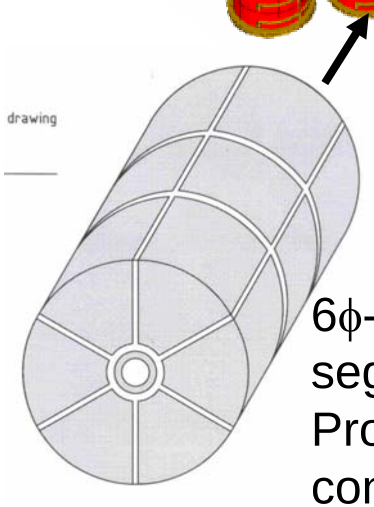


illustration:
Simple 7-fold segmentation

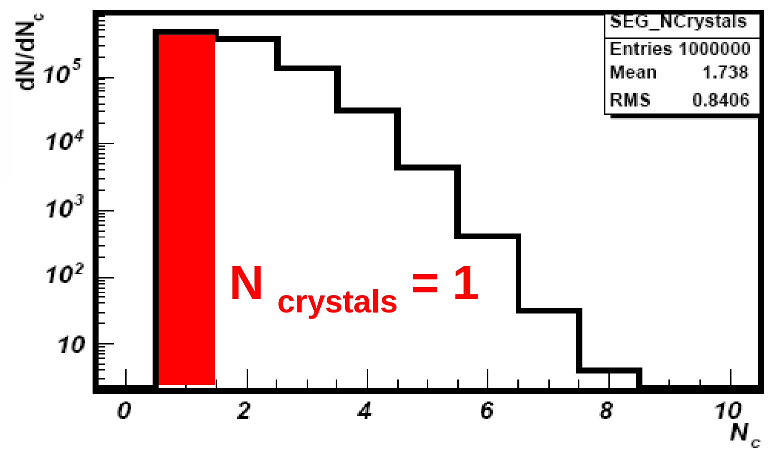
MaGe: ^{60}Co suppression by segmentation and anti-coincidence



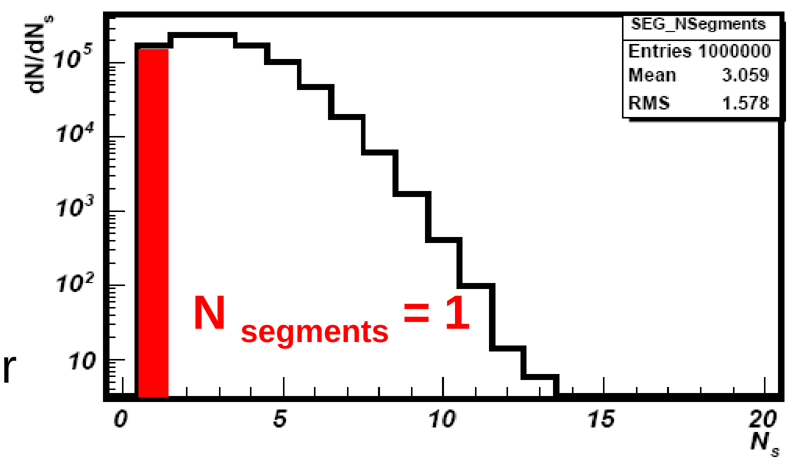


6ϕ-3z segmentation; Prototype under construction

Number of crystals



Number of segments

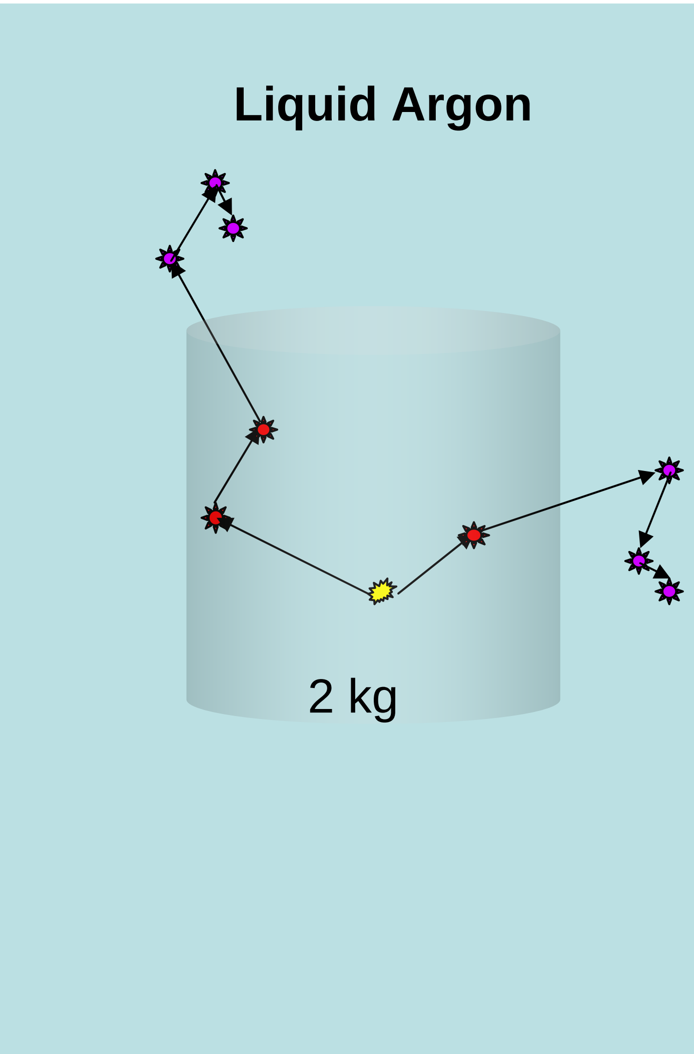


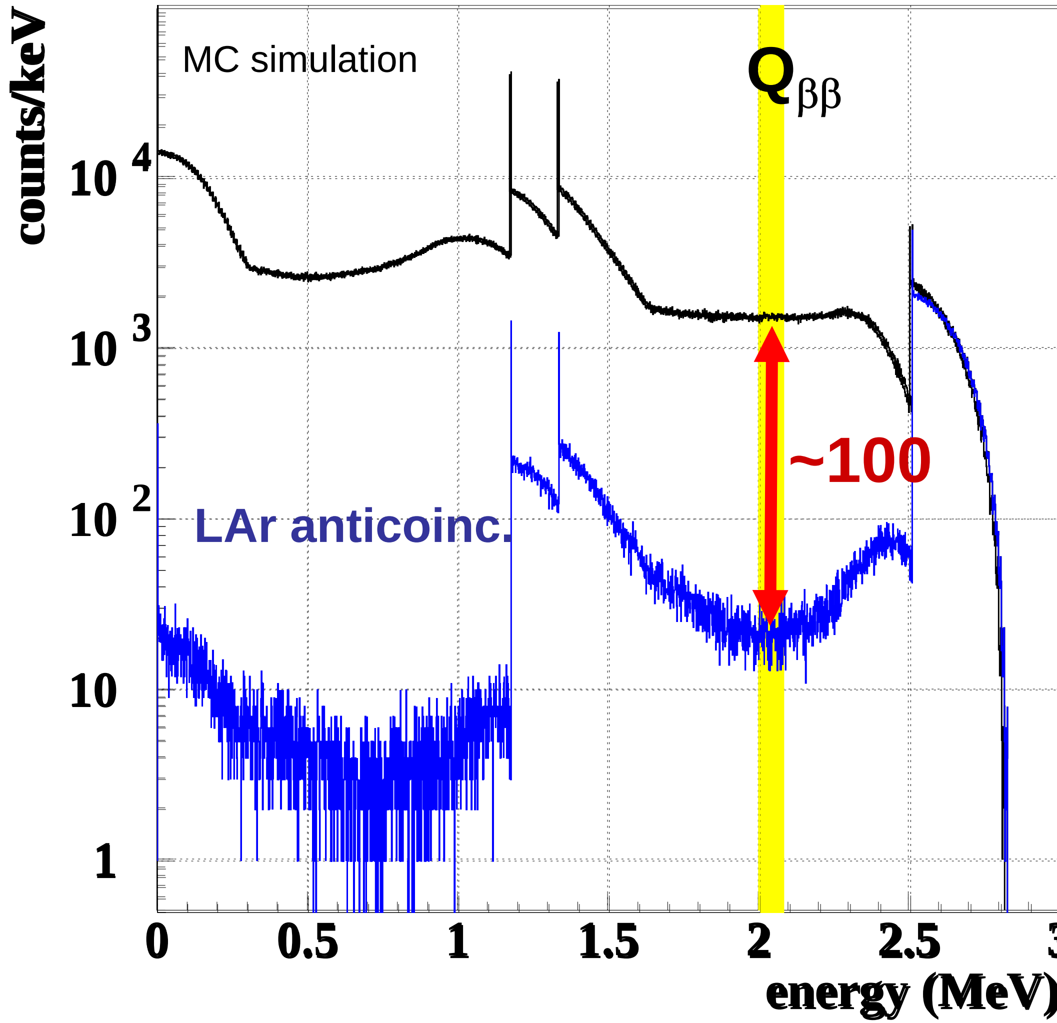
probability per decay to deposit energy within $Q_{\beta\beta}$ ROI per 1 keV energy bin after combined cuts: (18-fold segm.)

P = 4.7·10^-6/keV

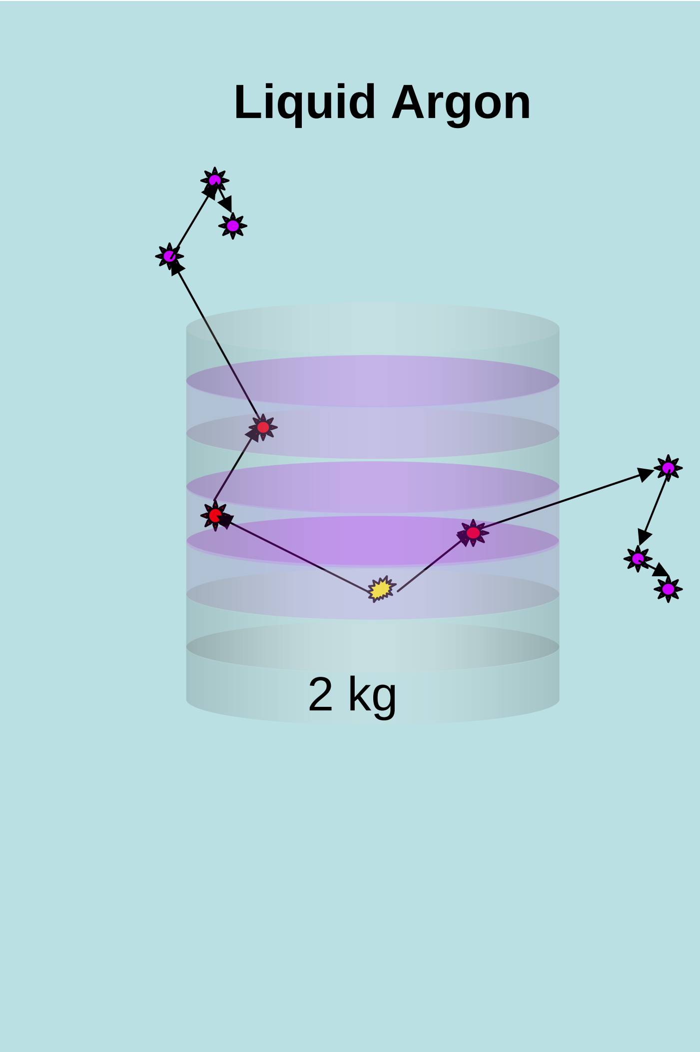
(factor ~35 reduction w/r to single unseg. detector)

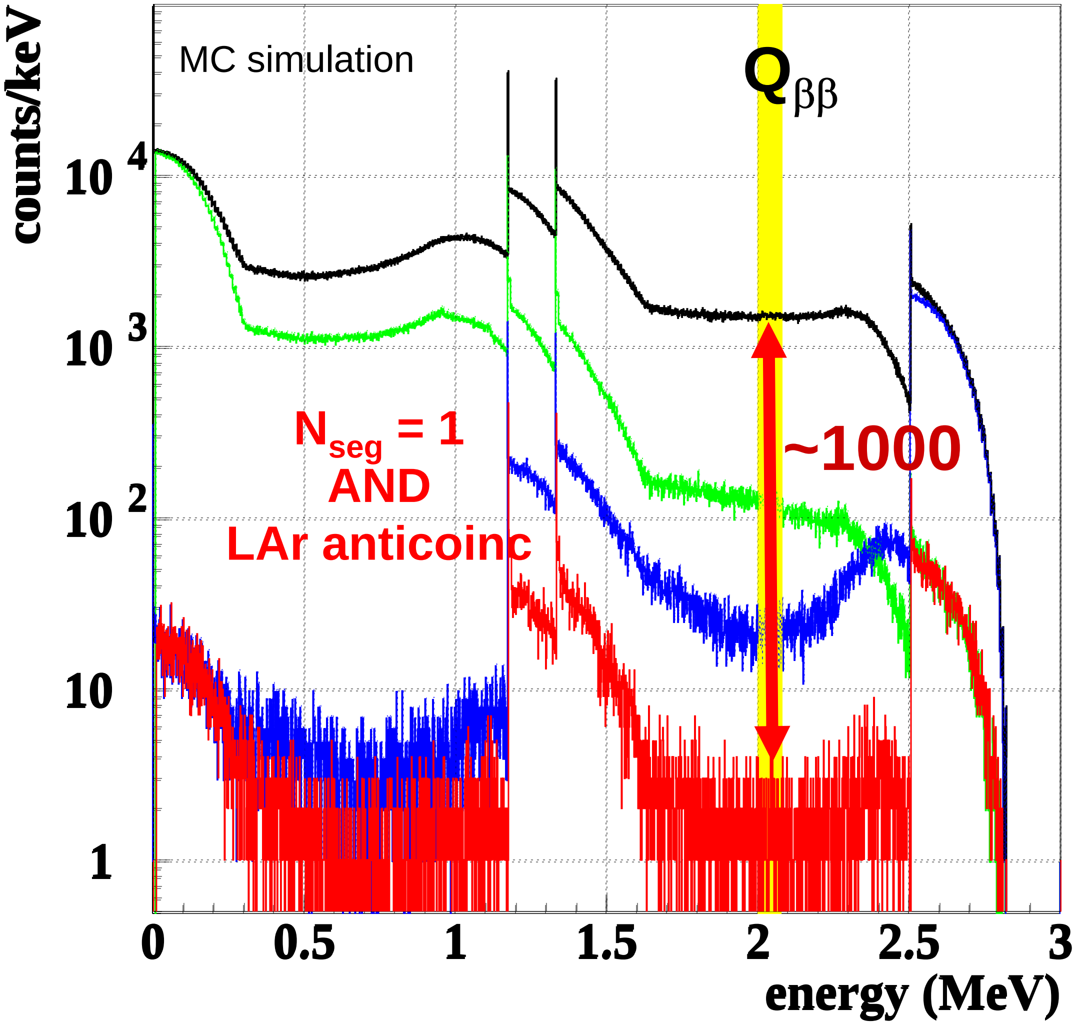
^{60}Co: suppression by LAr Ge-anticoinc.



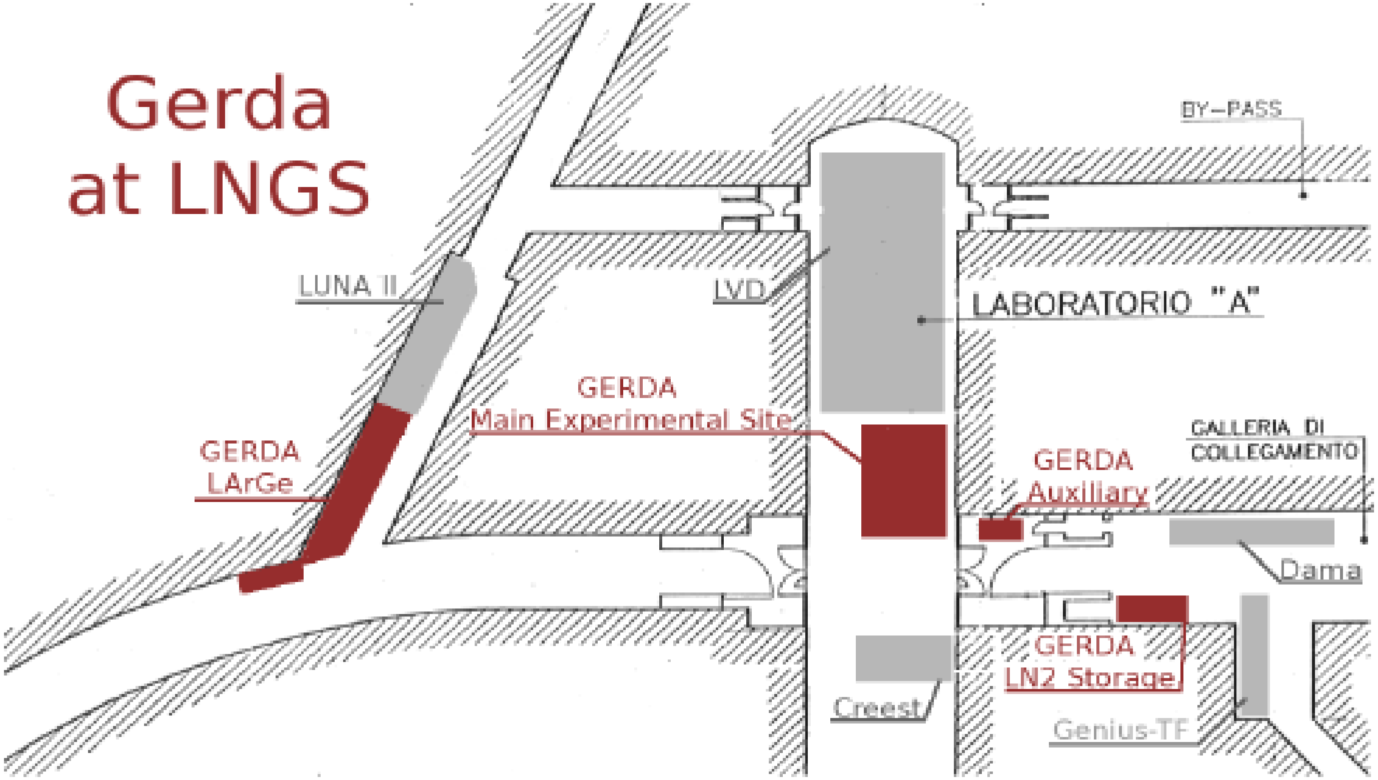


^{60}Co: segmentation and LAr Ge-anticoinc. are orthogonal suppression methods





Locations of GERDA



Hall A of LNGS

Infrastructures in HALL A

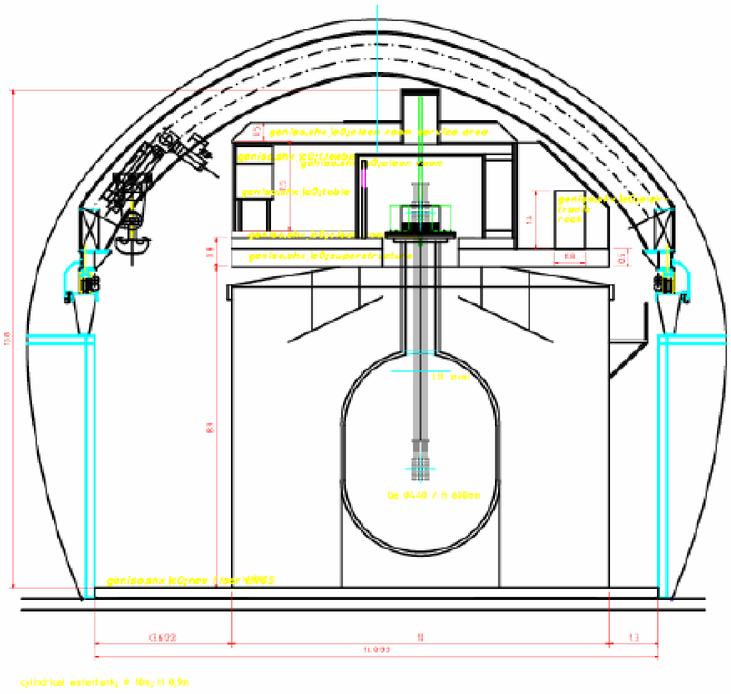


Figure 4: View of GERDA cross section from TIR tunnel. The shielding structure below the roof of the water tank might be not needed.

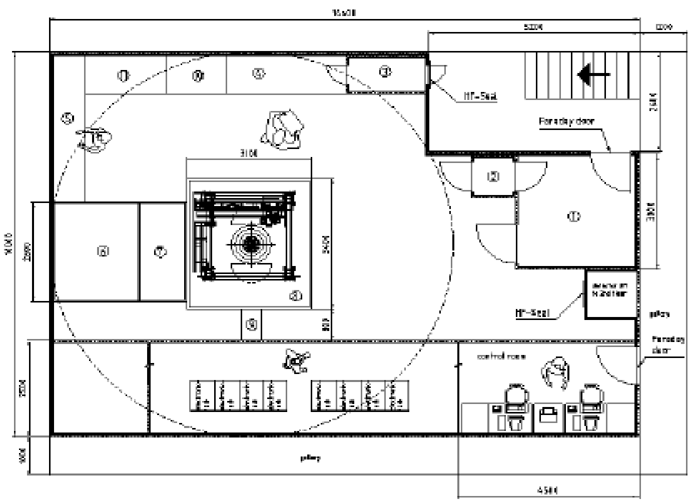
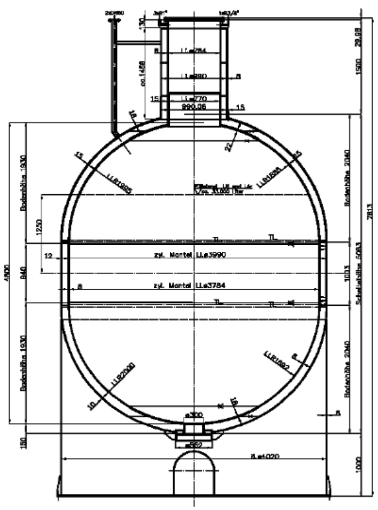
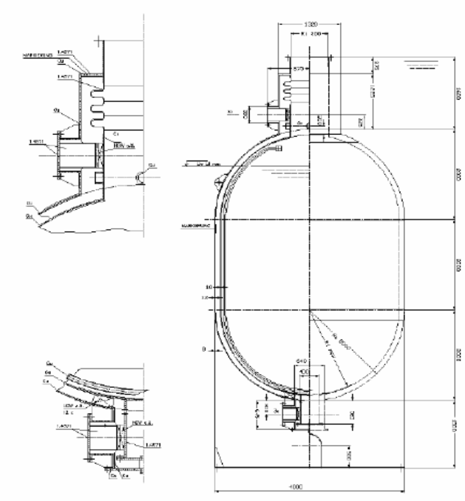


Figure 18: Layout of the penthouse [int.vers. 8] on top of the vessel with clean-room, lock system and the electronics-room. Numbered components are specified in subsection 5.3.

Infrastructures in Hall A: Super-insulated cryogenic vessel

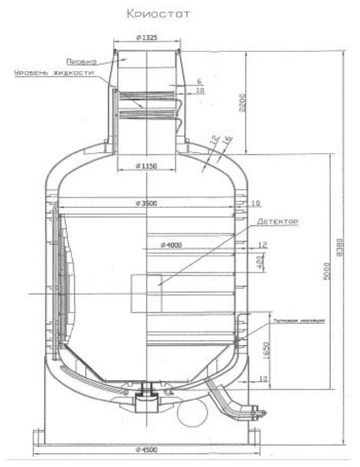




Two design studies for Cu-cryostat:

Cu-cryostat:
hanging from neck

Cu-cryostat:
resting on pads



Steel-cryostat:
with optimized
shielding

Decision taking Cu vs. steel cryostat: Cu-Steel welding tests and certification

Underground detector laboratory (LArGe-Facility)

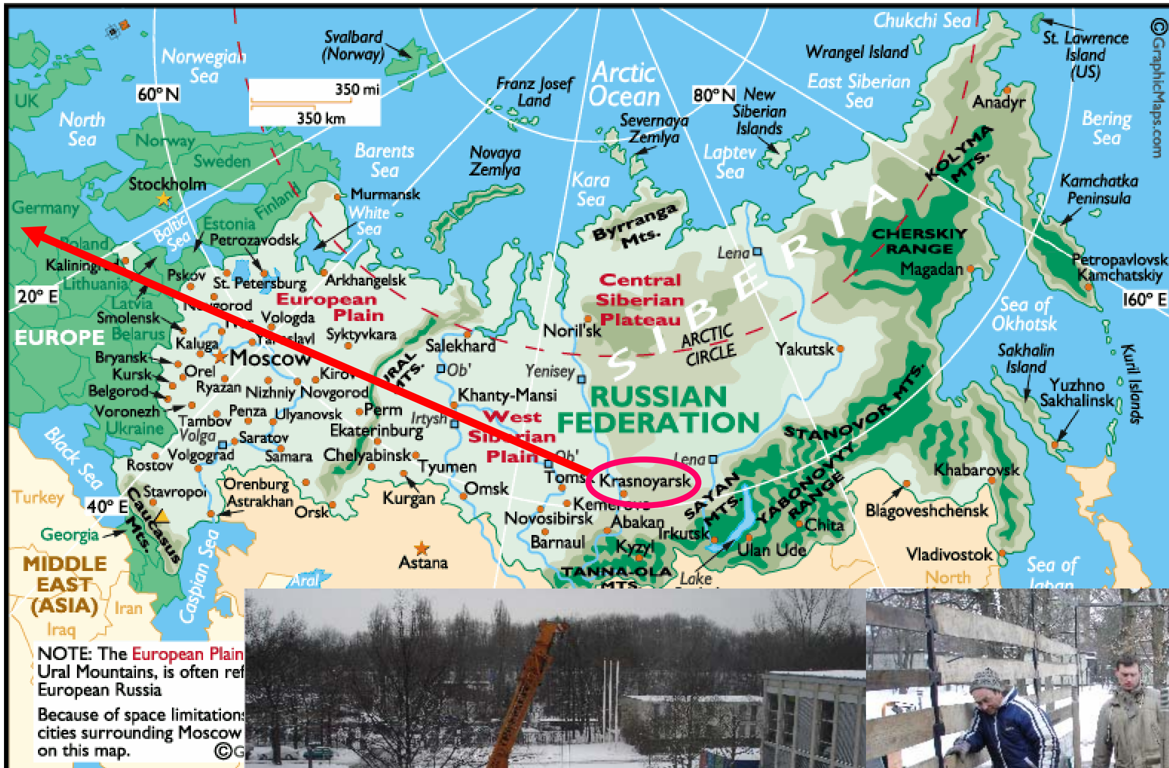
Washstand with high-purity water supply

Clean bench & Rn-free clean bench

Fume hood with charcoal filter

LArGe shield

New detectors for Phase II: Procurement of enriched Ge



1) procurement of 15 kg of natural Ge ('test run')
2) procurement of 30-35 kg of Ge-76 ('real run')

Specially designed protective steel container reduces activation by cosmic rays by factor 20

^{nat}Ge sample received March 7, 2005 ⇒ 30-35 kg of ^{76}Ge: Sept/Oct 2005

Status - Outlook

- GERDA approved by LNGS
- Substantial funding from MPI (Hd&Munich), Russia (in-kind), INFN, BMBF
- Start of construction end 2005
- Detector commissioning/start data taking 2006/7
- Co-operation with Majorana (MaGe, LArGe) very positive: mutual benefit!
- GERDA well on its way

GERDA