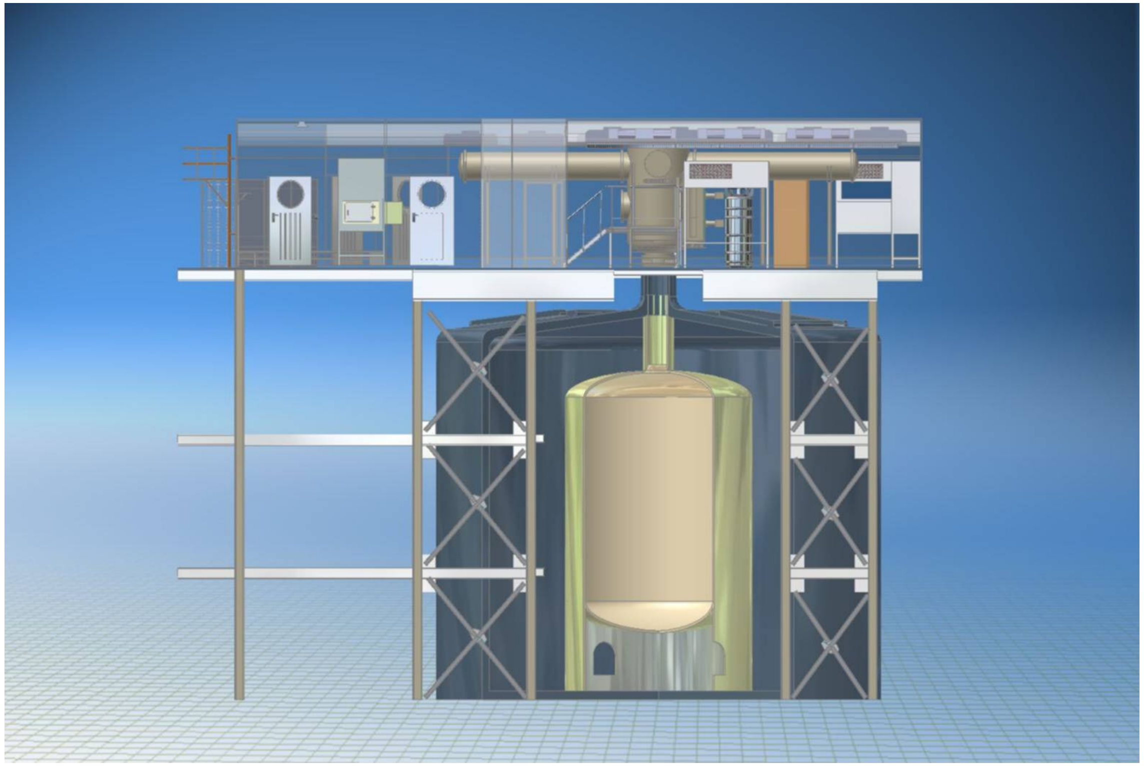
The GERDA experiment



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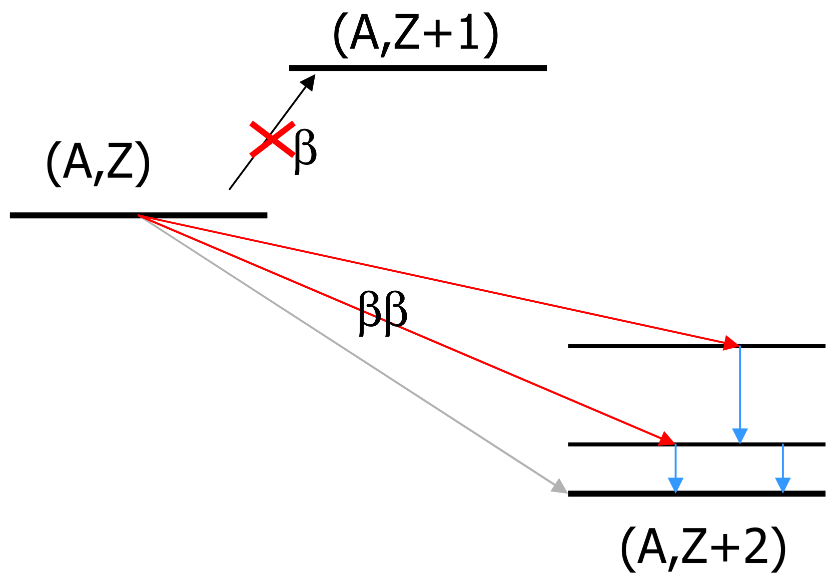
for the GERDA Collaboration

WIN2009, Perugia, September 17th 2009

2ν2β and 0ν2β decay

2ν2β decay:

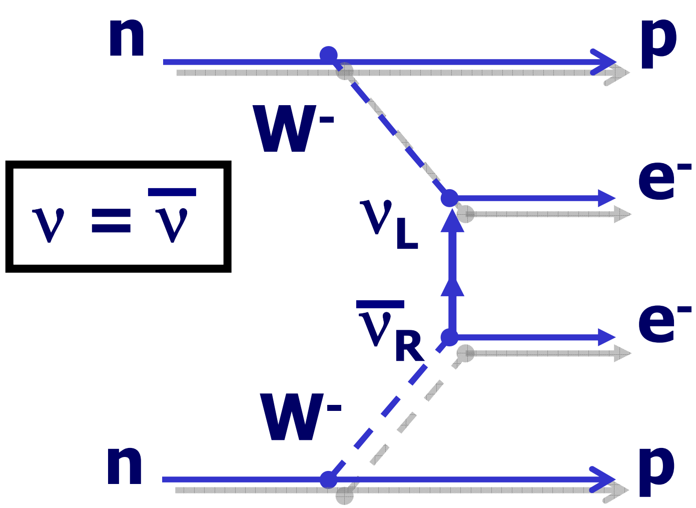
$(A,Z) \rightarrow (A,Z+2) + 2e^- + 2\bar{\nu}$



SM allowed & observed on several isotopes with forbidden single-β. Conserves lepton number, but long half-life because 2nd order ($10^{19} \div 10^{21}$ y)

0ν2β decay:

$(A,Z) \rightarrow (A,Z+2) + 2e^-$



Violates lepton number by two units. Possible **only** if νs Majorana & $\langle m_{\beta\beta} \rangle > 0$.

0ν2β decay

If mediated by the exchange of massive Majorana neutrinos:

$$1/\tau = G(Q,Z)\ |M_{nucl}|^2\ <m_{\beta\beta}>^2$$

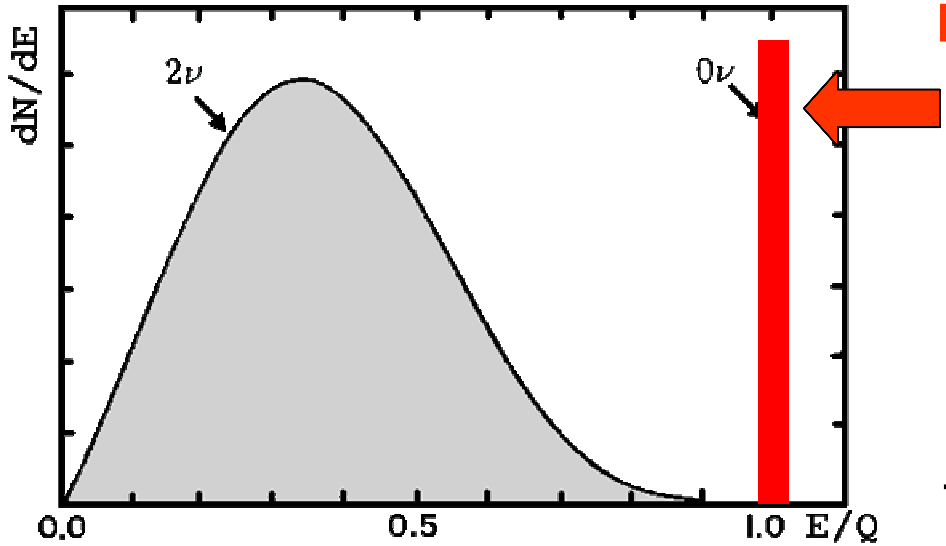
$\rightarrow$ $|\Sigma_i\ U_{ei}^2\ m_i\ |$

0νββ Decay rate

Phase space (~Q^5)

Nuclear matrix element (NME)

Majorana neutrino mass



Signature of 0ν2β:

mono-energetic line at the $Q_{\beta\beta}$ (2039 keV for ^{76}Ge)

Furthermore: e^- events rather than γ-rays (different topology → energy released in a smaller volume)

Why choose ^{76}Ge?

sensitivity on $T_{1/2} \propto \varepsilon \bullet A \bullet \sqrt{\frac{M \bullet T}{b \bullet \sigma}}$

$T_{1/2} \propto \varepsilon MTA \text{ if } b = 0$

challenge	^{76}Ge advantage
large amount isotope **M** long exposure **T**	existing detectors from past experiments IGEX & Heidelberg-Moscow
high signal efficiency ε	source=detector, 85~95% ε
extremely low level background rate b: background rate σ: energy resolution	Ultra-pure material (HPGe) excellent energy resolution → FWHM ~3keV at 2MeV, small search window → reduce background, including 2νββ new development → segmentation, new type of Ge detector etc…

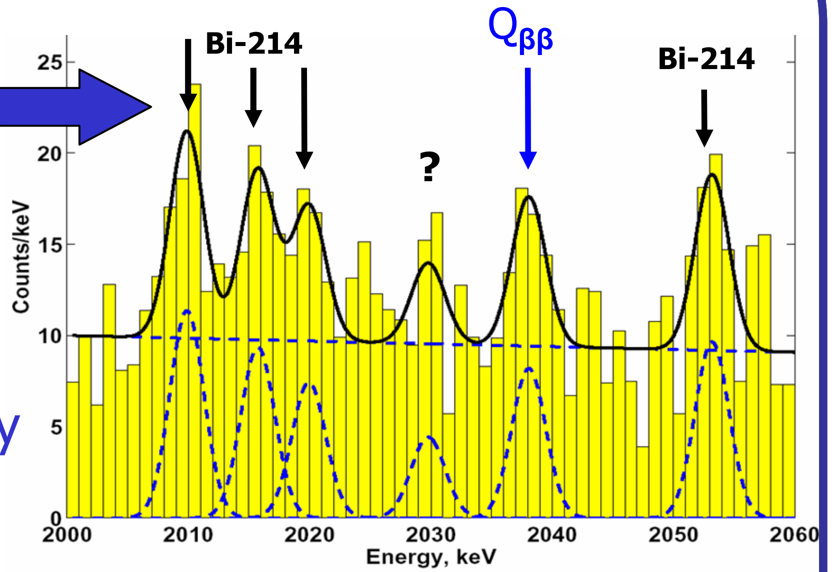
☹ need enrichment (A=7.6%, most backgrounds scale with target mass)

☹ $Q_{\beta\beta}$=2039 keV (< 2614 keV from ^{208}Tl)

The present situation with ^{76}Ge

Claim for evidence of $0\nu2\beta$ of ^{76}Ge based on the data of Heidelberg-Moscow

H.V. Klapdor-Kleingrothaus et al. Phys. Lett. B **586** (2004) 198



5 enriched ^{76}Ge diodes; exposure: 71.7 kg·y

background at $Q_{\beta\beta}$: 0.1 counts/(keV·kg·y)

$T_{1/2} = 1.19 \cdot 10^{25}$ y (3σ range: $0.69\text{-}4.18 \cdot 10^{25}$ y)

No evidence (upper limit only) from IGEX

D. Gonzalez et al. Nucl Phys B (Proc. Suppl.) **87** (2000) 278

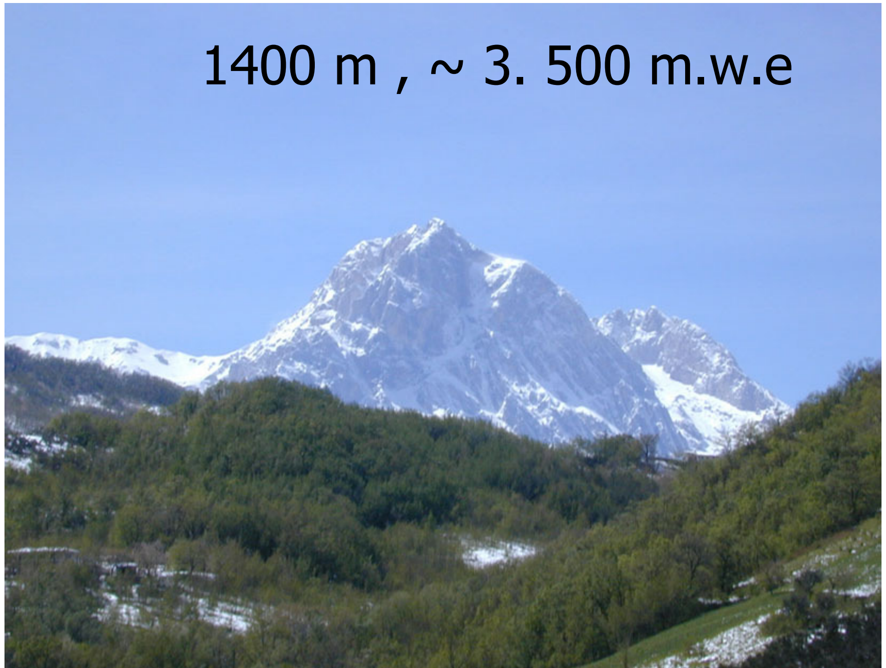
3 ^{enr}Ge diodes; exposure (8.87 kg·y)

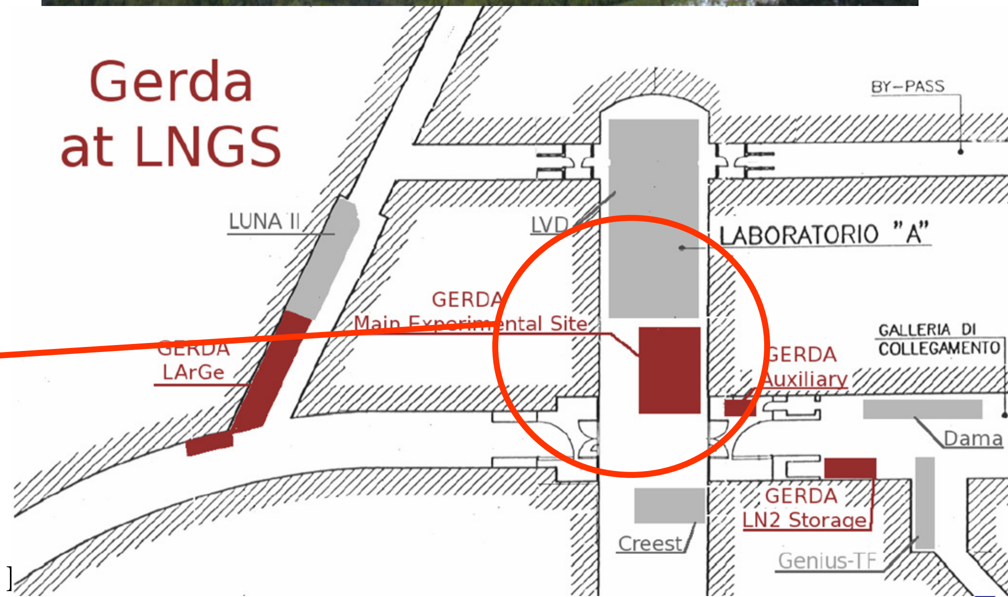
$T_{1/2} > 1.57 \cdot 10^{25}$ y (90% CL)

Scrutinize claim using the **same** isotope (no NME uncertainties)

→ reduce background by a factor of 100, or more

The GERDA experiment at LNGS

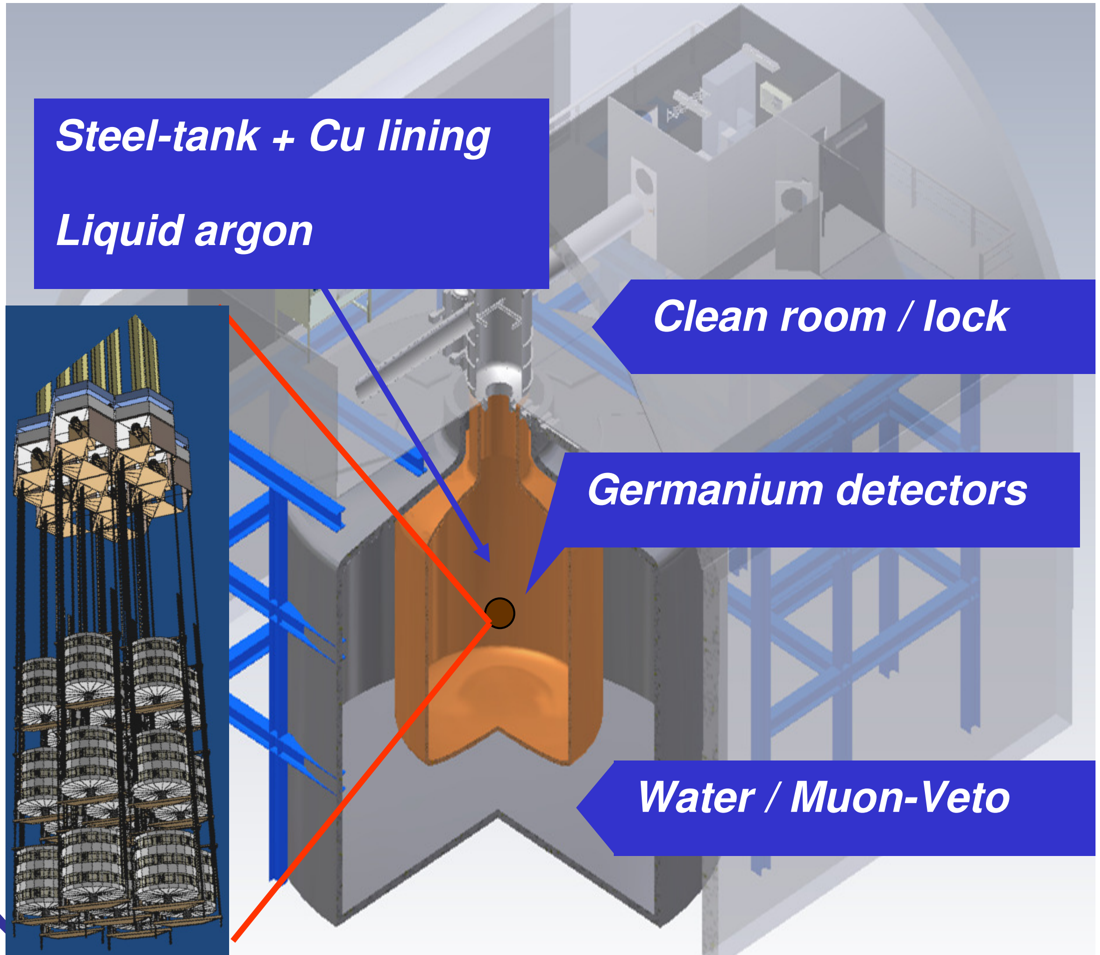




The GERDA concept

Use cryogenic liquid (liquid argon) as cooling medium and shield simultaneously → array of naked detectors

G. Heusser, Ann. Rev. Nucl. Part. Sci. **45** (1995) 543



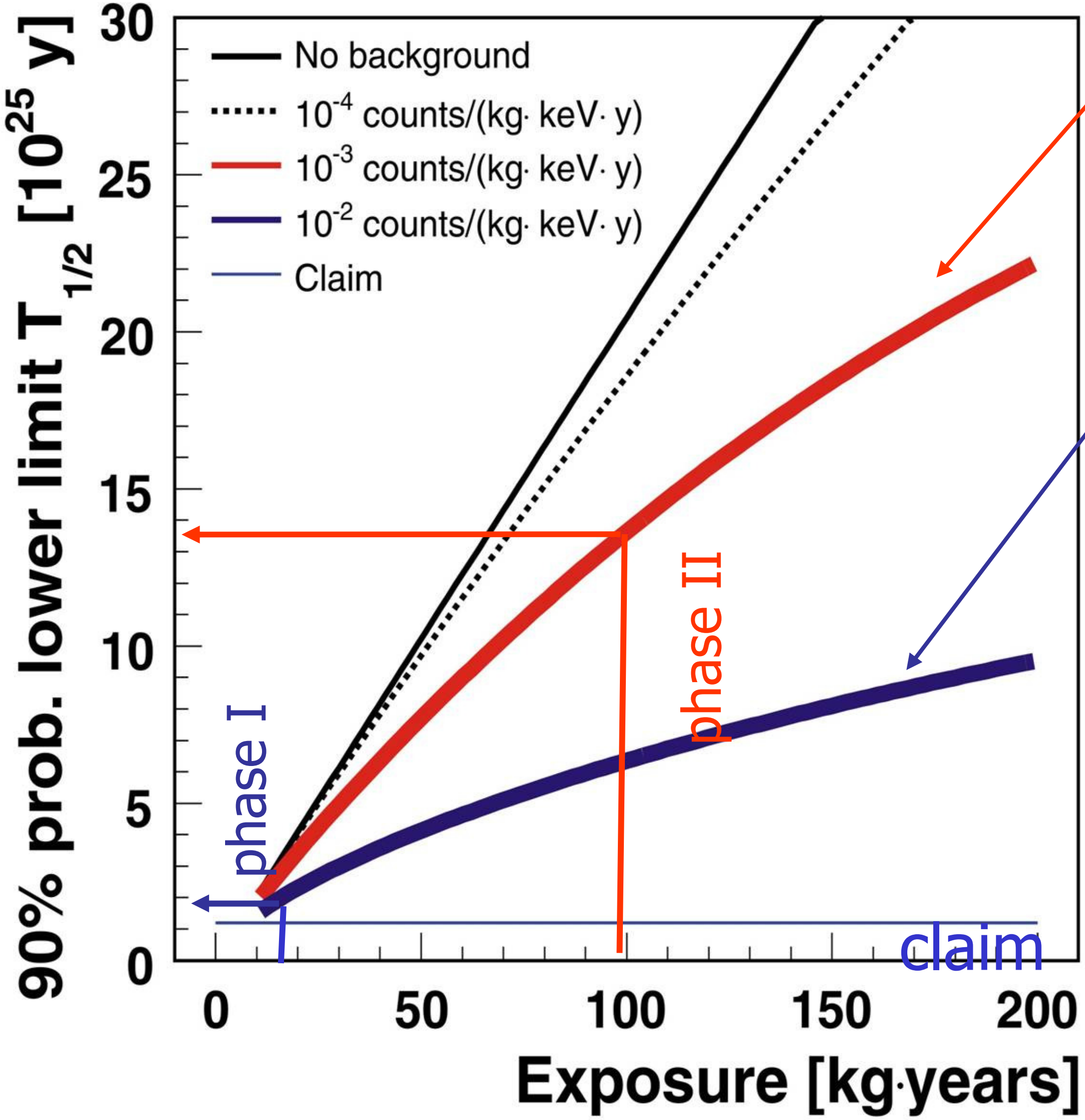
Additional water shielding:

- cheap and safe
- neutron moderator
- Cherenkov medium for 4π muon veto

LAr required to shield γ **radiation** from the **stainless steel cryostat** and from the rock

→ **external** background from γ, μ and n < 10^{-4} counts/(keV·kg·y)

GERDA goals and sensitivity



GERDA goal: 10^{-3} counts/(keV kg y)

improvement of a **factor 100** with respect of H-M

Phase I: **test claim**

crystals from HM and IGEX

exposure: 15 kg·y

bck: **10^{-2}** counts/(keV kg y) (internal ^{60}Co contamination)

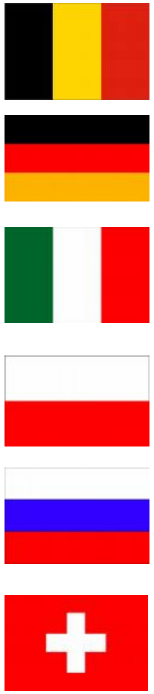
Phase II: **measure** $T_{1/2}$ or **improve** limit

new better ^{enr}Ge detectors (bought 40 kg of raw material)

exposure: 100 kg·y

bck: 10^{-3} counts/(keV kg y)

GERDA Collaboration



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Max-Planck-Institut für Kernphysik, Heidelberg, Germany
Max-Planck-Institut für Physik (Werner-Heisenberg-Insititut), München, Germany
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Jagiellonian University, Cracow, Poland
Institute for Nuclear Research of the Russian Academy of Sciences, Moscow, Russia
Institute for Theoretical and Experimental Physics, Moscow, Russia
Joint Institute for Nuclear Research, Dubna, Russia
Russian Research Center Kurchatov Institute, Moscow, Russia
University Zurich, Switzerland

Cryotank and water tank constructed

cryostat (Mar. 2008)

water tank (Aug. 2008)

Clean room and infrastructure ok

cryogenic infrastructure is being constructed

clean room, May 2009

PMTs in water tank

mounting PMTs in watertank completed

August 2009

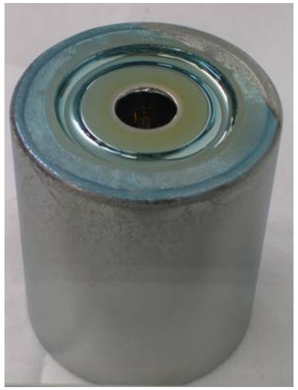
Phase I detectors: status

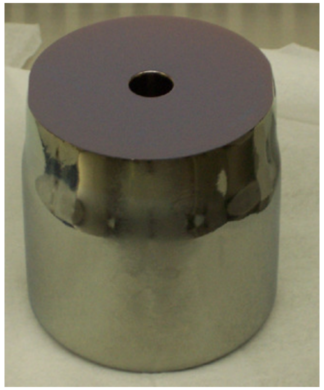
Phase I: 3 IGEX & 5 Hd-Moscow detectors, **17.9 kg**
30g Cu, 6.3g PTFE, 1g Si per detector
all of them stored **underground** (no activation)

	ANG1	ANG2	ANG3	ANG4	ANG5	RG1	RG2	RG3
FWHM [keV]	2.54	2.29	2.93	2.47	2.59	2.21	2.31	2.26
Mass [kg]	0.980	2.906	2.446	2.400	2.781	2.150	2.194	2.121

(at 1.3 MeV)

Heidelberg-Moscow & IGEX (before reprocessing)





reprocessed detectors tested in LAr

All detectors reprocessed and tested in liquid Argon
FWHM **~2.5keV** (at 1332keV), leakage current (LC) stable

Phase I detectors: long-term stability

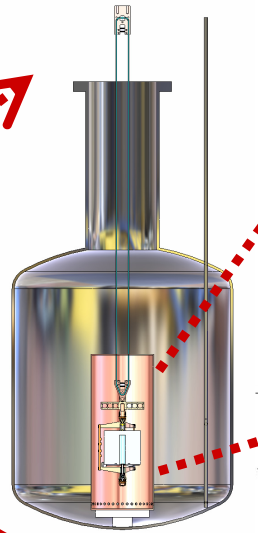
Tested procedure for handling detectors defined

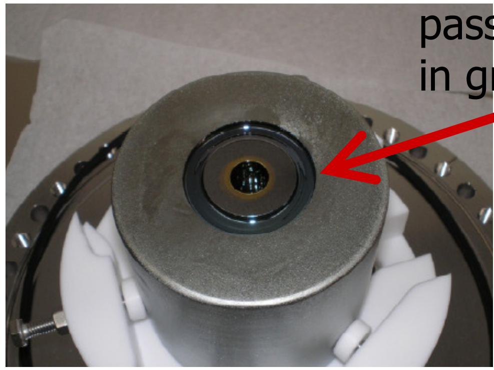
Observed increase of leakage current well understood

→ **charge trapping** above passivation layer (PL)

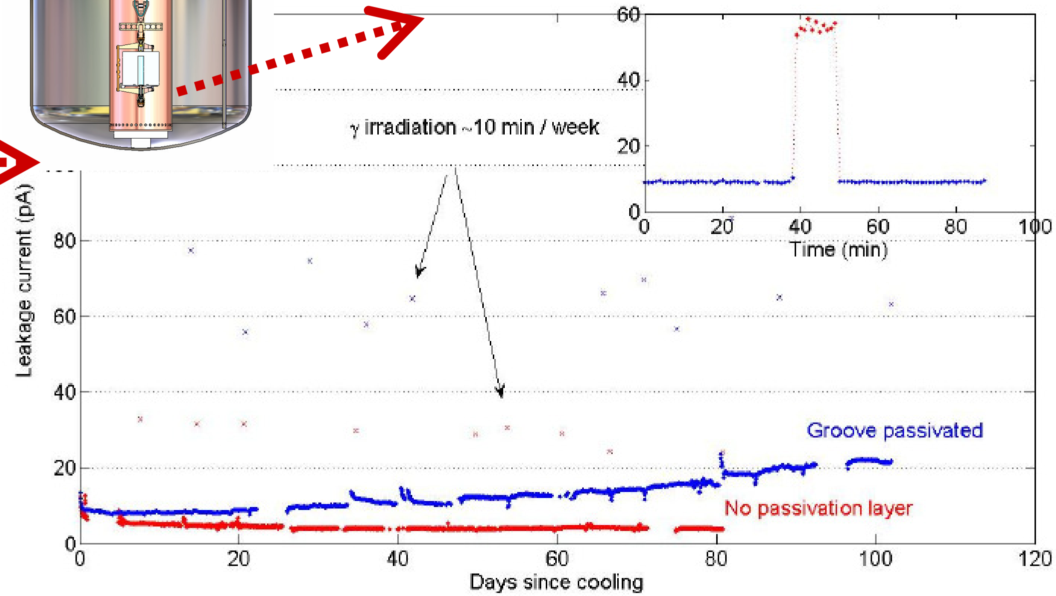
Detector without PL inside groove, long term performance **stable**

detector test bench





passivation layer in groove



detector leakage current with & without PL

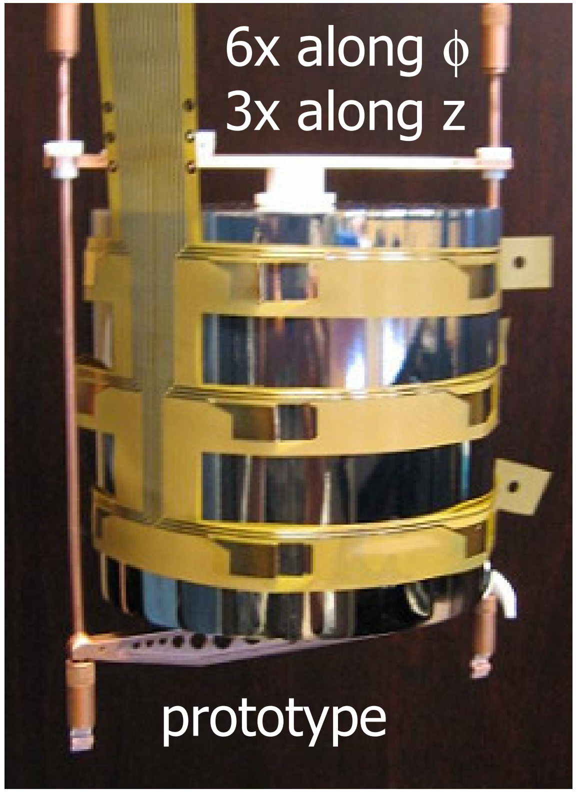
Phase II detector candidate

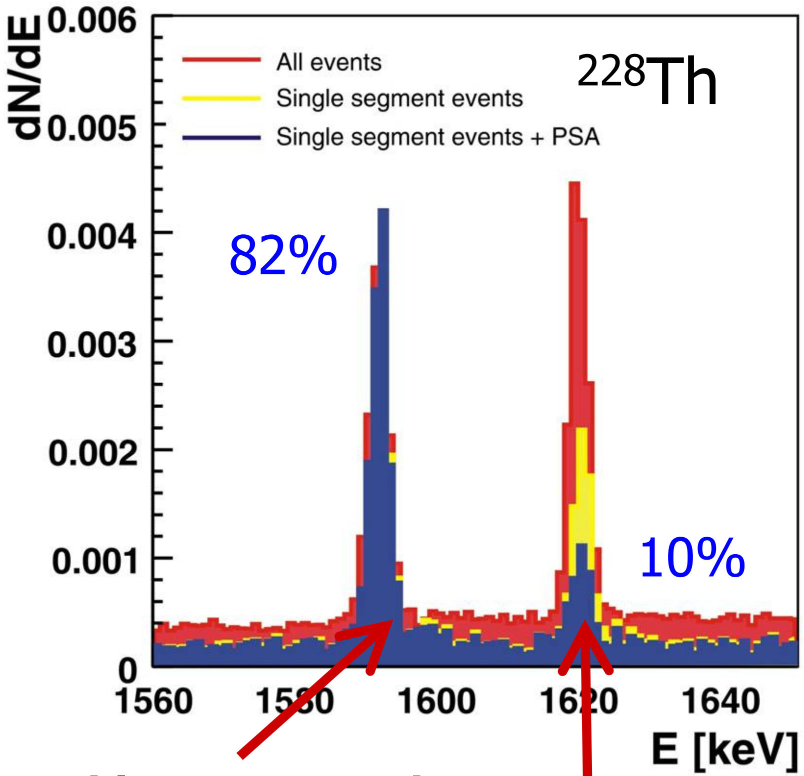
18-fold segmented detector

Prototype available in Munich and **extensively tested** → data used to validate MC and test rejection power by segment anti-coincidence

- novel "snap contact"
- small amount of extra material

Abt et al. Eur.J.Phys. C**52** (2007) 19





Double-escape peak
(single-site dominant)

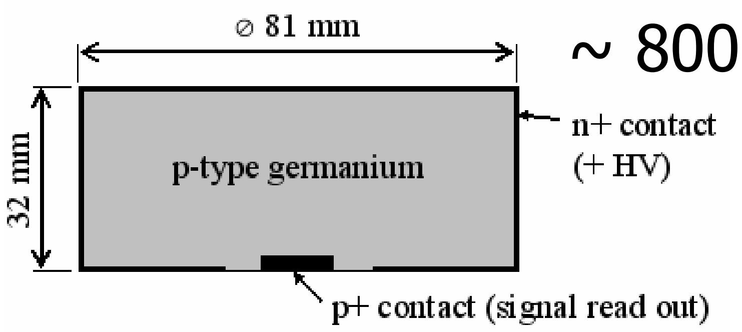
1620 keV ^{212}Bi
(multi-site dominant)

Phase II detector candidate

point contact detector

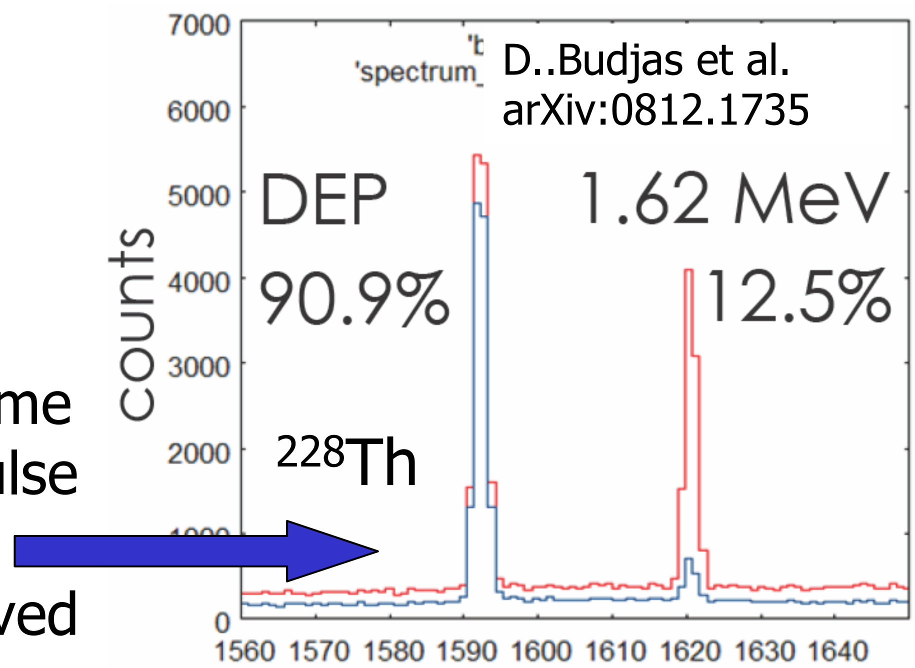
prototypes available in Heidelberg, LNGS, Zurich, Hades

- not segmented but **powerful pulse shape** → less DAQ channels



~ 800 g

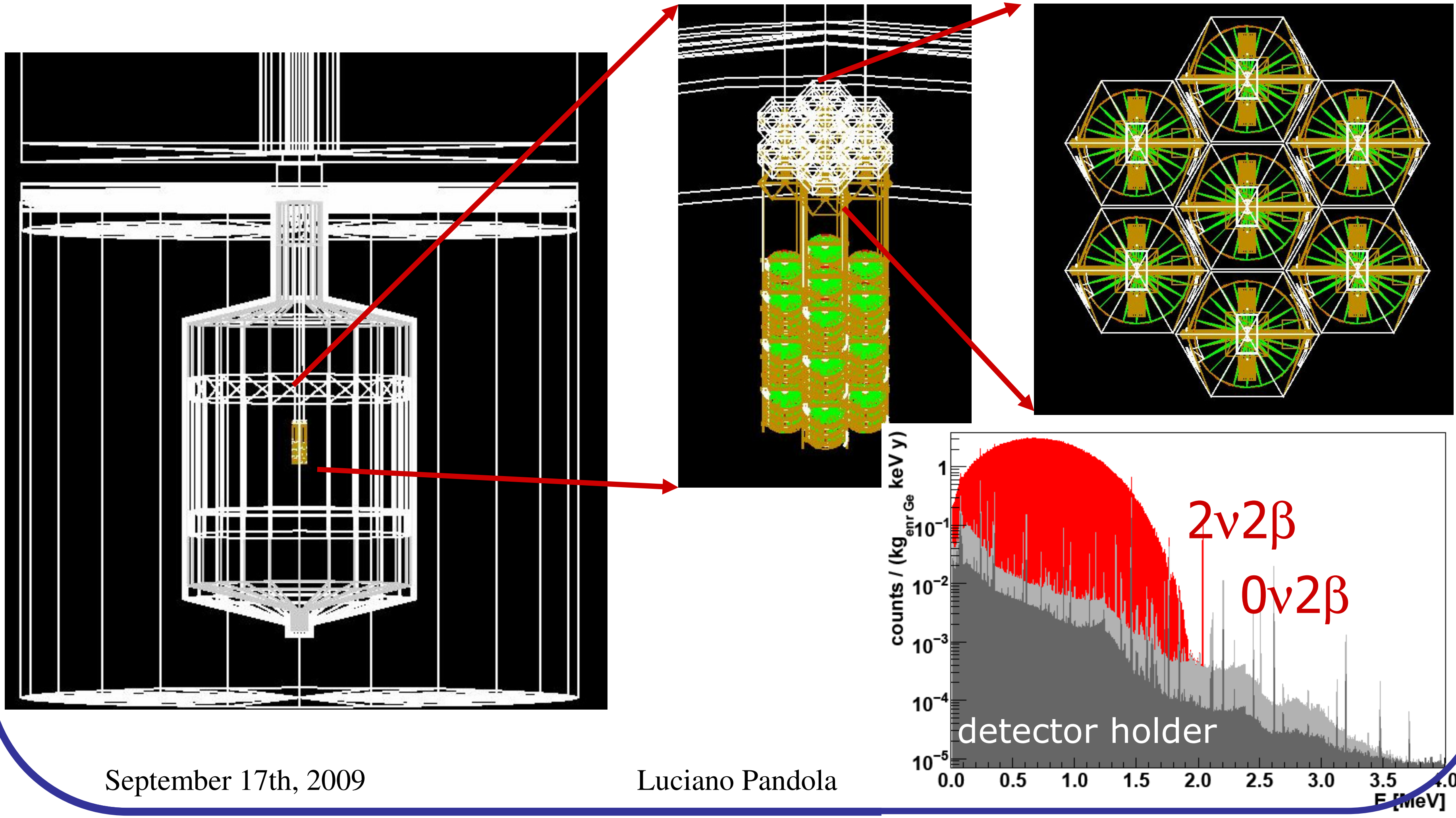
→ Observed complete charge collection from full detector volume
→ No position dependence of pulse height and resolution
→ Similar reduction factor achieved



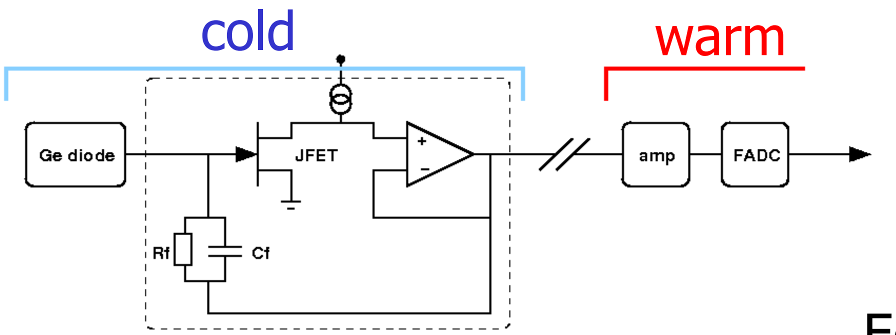
Production yield under investigation. Very interesting candidate if mass production feasible

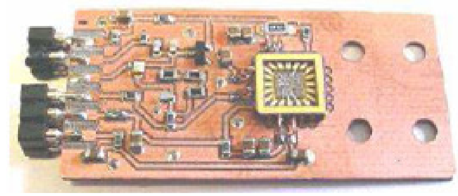
Monte Carlo package MaGe

Geant4-based, developed together with **Majorana**
Flexible and optimized for low energy & low background MC
Code sharing & physics verification



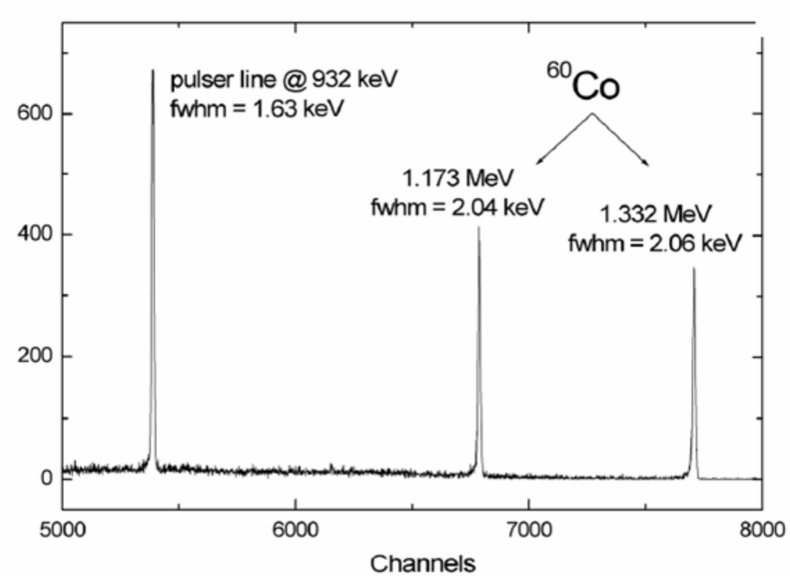
R&D: preAmplifier working at 77 K



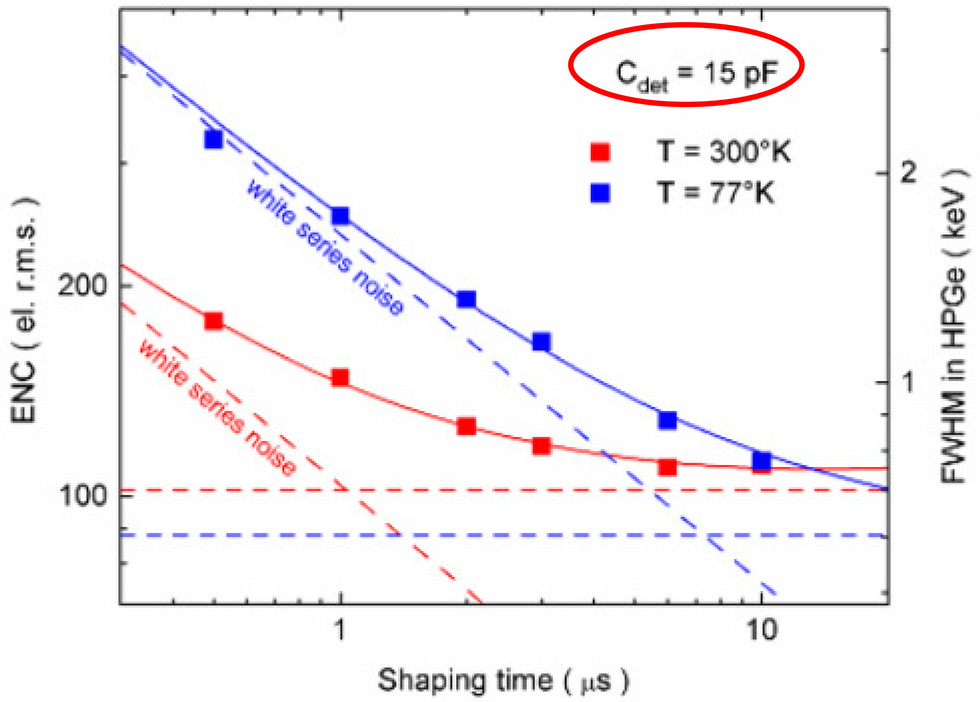


PZ-0

measured spectrum at 77K



Equivalent noise charge at 77 K (300 K)



15 ns rise time driving a 10-m coaxial cable

Outlook

Experiment approved in 2005 by LNGS with its location in the Hall A

Construction started (almost completed) in LNGS Hall A

All phase I detectors (8 detectors, ~18 kg) refurbished & ready → scrutinize present claim with 1 year of data

Parallel R&D for the definition of phase II detectors

Cold front-end electronics meets specifications (R&D)

Joint Monte Carlo activity with Majorana (MoU)

End of installation and **start of commissioning** within **2009**