The GERmanium Detector Array for the search of neutrino-less double beta decay of Ge-76

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~ 70 physicists
13 institutions
5 countrys

Outline

Introduction & Motivation

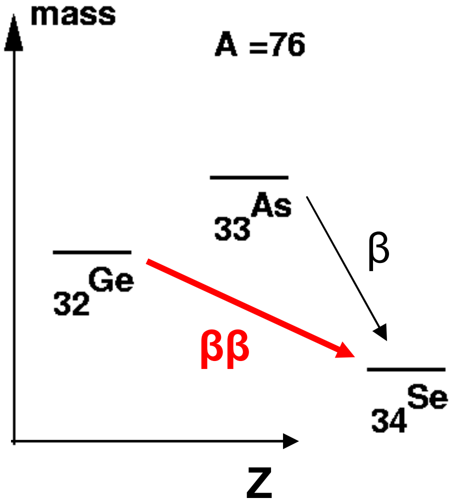
Goal

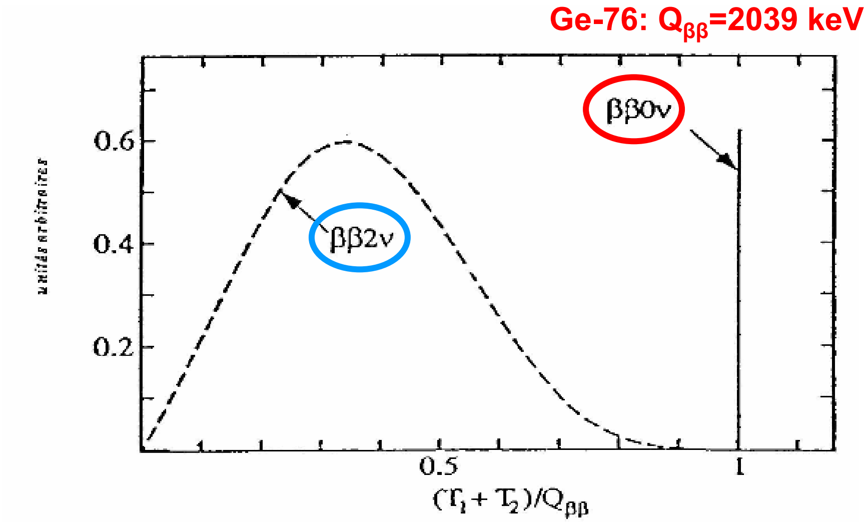
Experimental Layout

R&D

Status & Schedule

Summary

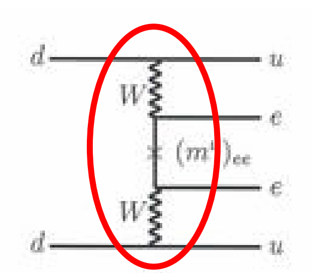




2νββ : $(A, Z) \rightarrow (A, Z+2) + 2e^- + 2\bar{\nu}_e$

2nd order process, observed, $T_{1/2} \sim 10^{19}$-10^{21} yrs

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



physics beyond SM
if observed ($T_{1/2} > 10^{25}$ yrs) :

- $\nu = \bar{\nu}$: Majorana particle
- ν massive
- $\Delta L = 2$

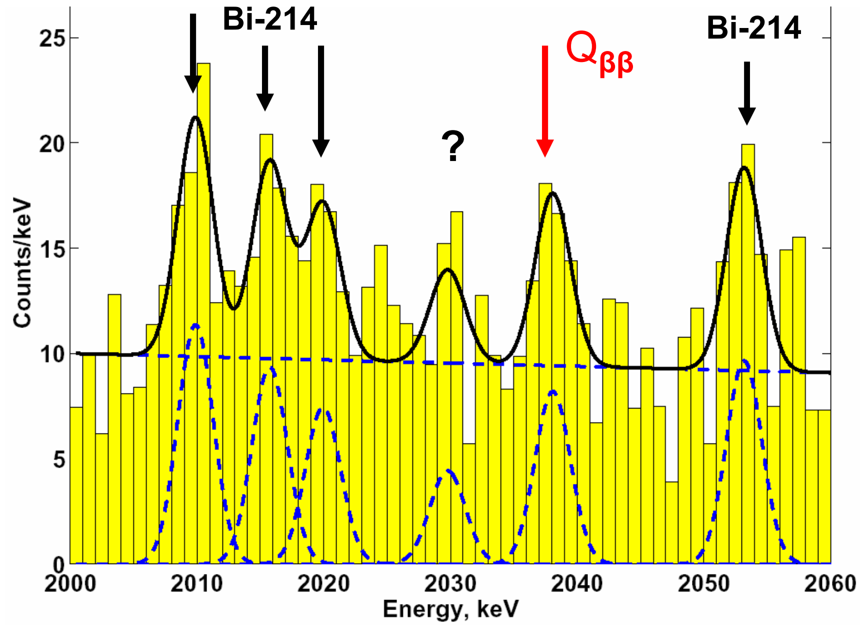
$$T^{0\nu}_{1/2} = 1 / [\ \Gamma(Q_{\beta\beta}^5)\ |M_{nucl}|^2 \ \langle m_{ee} \rangle^2\ ]$$

phase space factor
nuclear matrix element

$$\langle m_{ee} \rangle = |\ \Sigma_i\ U_{ei}^2 m_i\ |$$

$<m_{ee}>$ best limits / value

KKDC: H.V.Klapdor-Kleingrothaus, I.V.Krivoshina, A.Dietz, O.Chkvorets, Phys.Lett. B586 (2004) 198

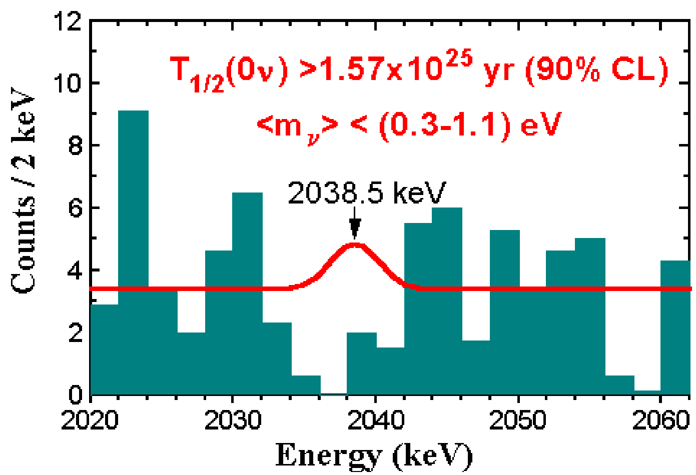


5 enriched Ge-76 diodes (10.9 kg / 71.7 kg·y)
B = ~0.1 cts / (keV·kg·y)

$T^{0\nu}_{1/2}$ = (0.69 - 4.18)·10^{25} y (3σ range)

$<m_{ee}>$ = 0.2 – 0.6 eV (99.73% C.L.)
= 0.1 – 0.9 eV (nucl. m.e. depend.)

IGEX : **Gonzales et al., NP B87(2000)278**



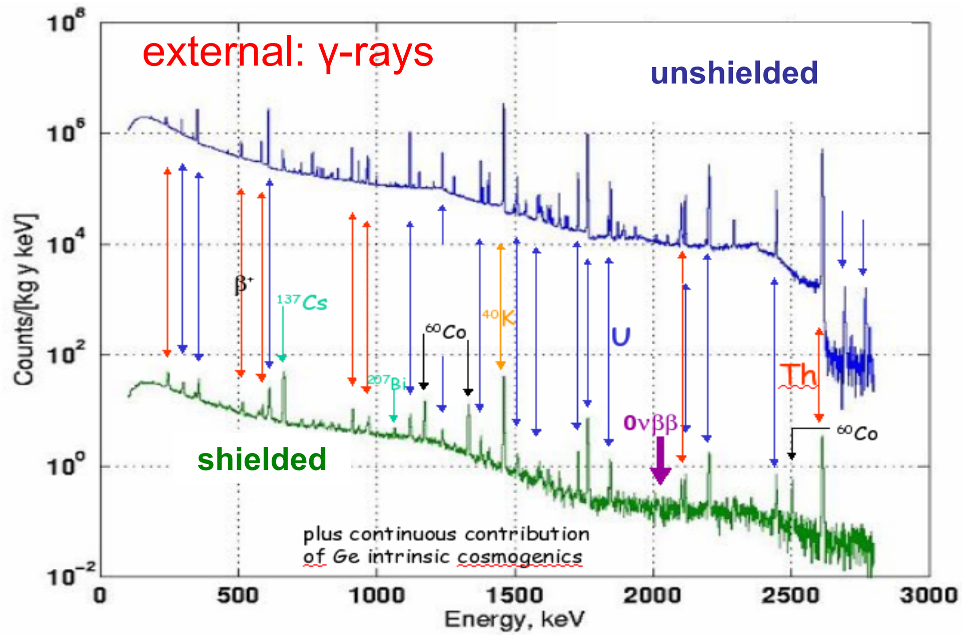
► confirmation needed with same & different isotopes
key: reduce background by *O*(100) for better sensitivity

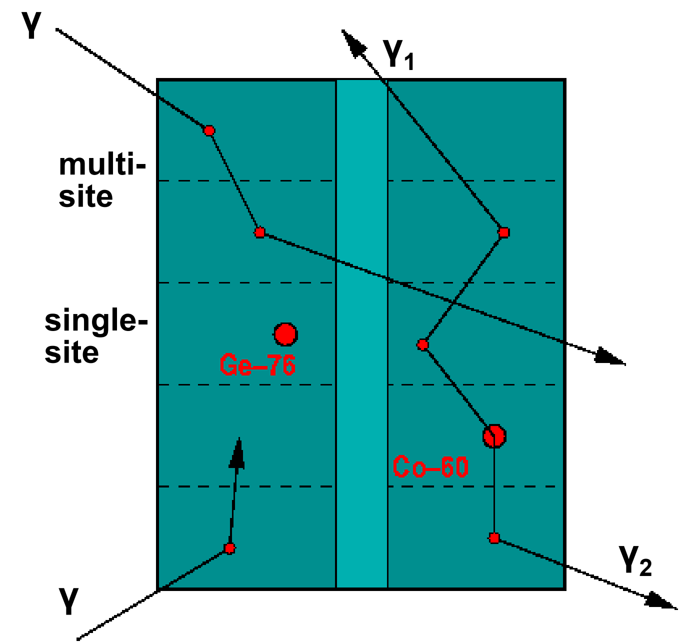
GERDA strategy & goals

- reduce all impure materials close to Ge diodes as much as possible
- operate Ge-diodes in ultra clean environment and (active) shield
  ► LN/Ar best solution (G.Heusser, Ann.Rev.NPS 45(1995) 543)
- reject intrinsic backgrounds by fully exploiting difference between single site (ββ) and multi site events

GERDA's goal : reach background at $Q_{\beta\beta}$ = 2039 keV of 0.001 cts / (keV·kg·y)

- phase I : use existing Ge-76 diodes of Heidelberg-Moscow experiment & IGEX (~15 kg)
  ~0.01 cts / (keV·kg·y) intrinsic background expected
  KKDC: 28.8±6.9 events in 71.7 kg·y
  ► GERDA expects 6±1.5 counts above background of 0.5 counts in 1 y
  for ≤1 event the ββ signal is excluded at 98% CL.
- phase II : add new enriched Ge-76 detectors (~20 kg)
  ► 3 y·35 kg : $T^{0\nu}_{1/2} > 2 \cdot 10^{26}$ y , $\langle m_{ee} \rangle < 0.09 – 0.29$ eV
- phase III: depending on results worldwide collaboration for real big experiment
  close contacts & MoU with MAJORANA collaboration established



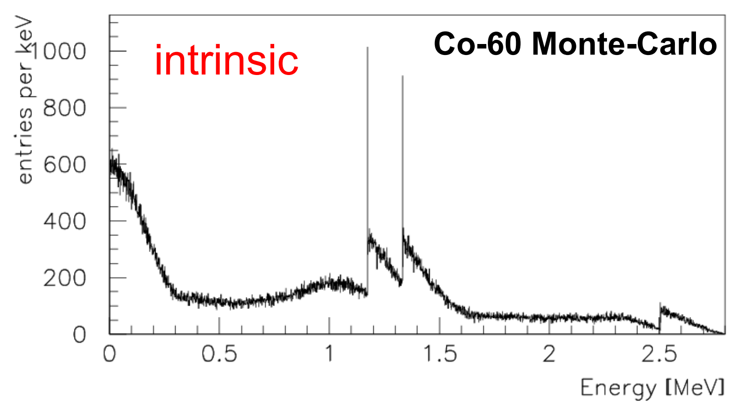


external backgrounds:

- γ-rays from primordial decay chains
  ►2.615 MeV Tl-208
- neutrons from fission, (α,n) reactions in rock, and μ-induced reactions
- muons from cosmic showers

intrinsic backgrounds:

- cosmogenic isotopes (Ge-68, Co-60) due to spallation reactions above ground and $T_{1/2}$~yrs.



reduction of intrinsic background

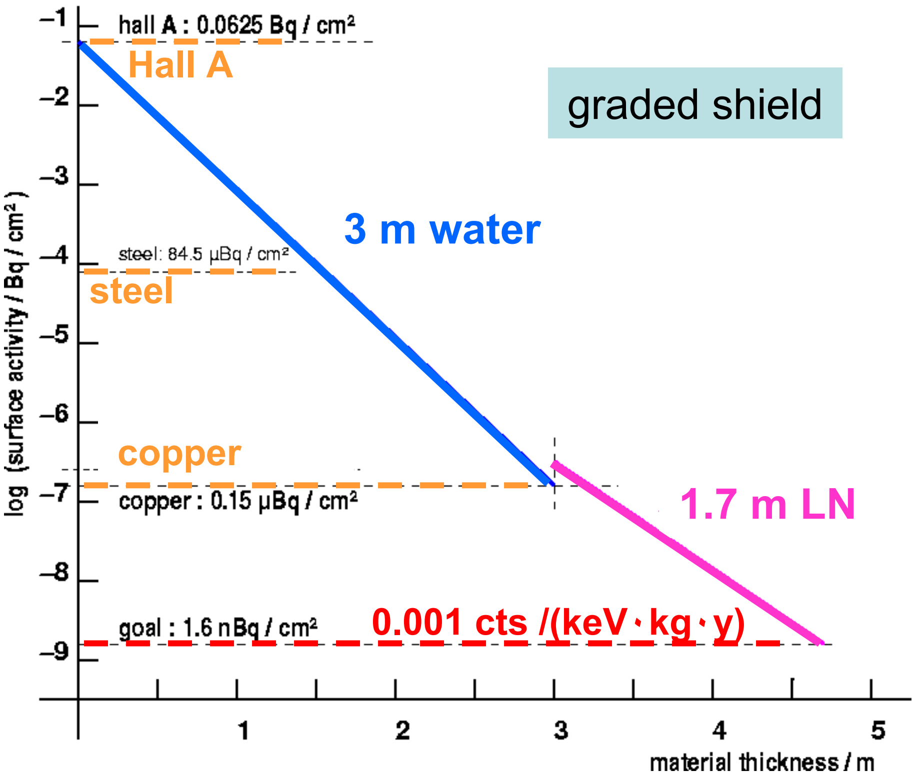
mostly for phase II :

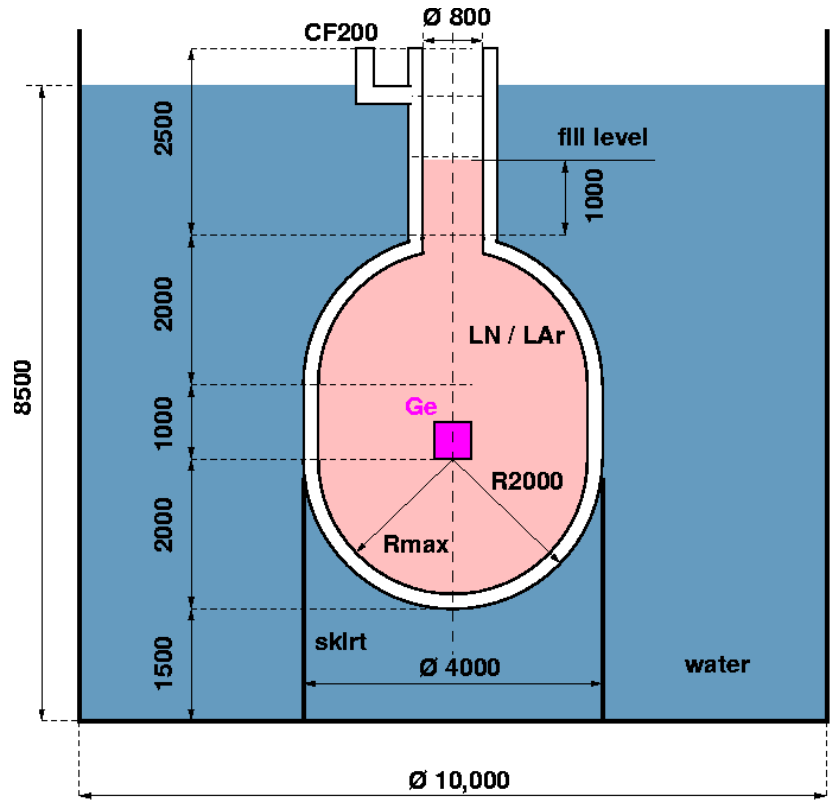
- carefully screen production of enriched material
- avoid production of cosmogenic isotopes in Ge-76 by short exposure to cosmic rays

- veto multi-site signals by anti-coincidences of detectors – phase I
- veto multi-site signals by anti-coincidences of detector segments
- differentiate single- and multi-site events by pulse shape discrimination (phase I)
- locate/track event within detector by pulse shape analysis

Activity of Tl-208	(μBq/kg)
rock, concrete	3000000
Cu(NOSV), Pb	<20
water, purified	< 1
LN, LAr	~ 0

Shield against 1) Tl-208 2.6 MeV γ-rays,
2) neutrons, 3) muons !

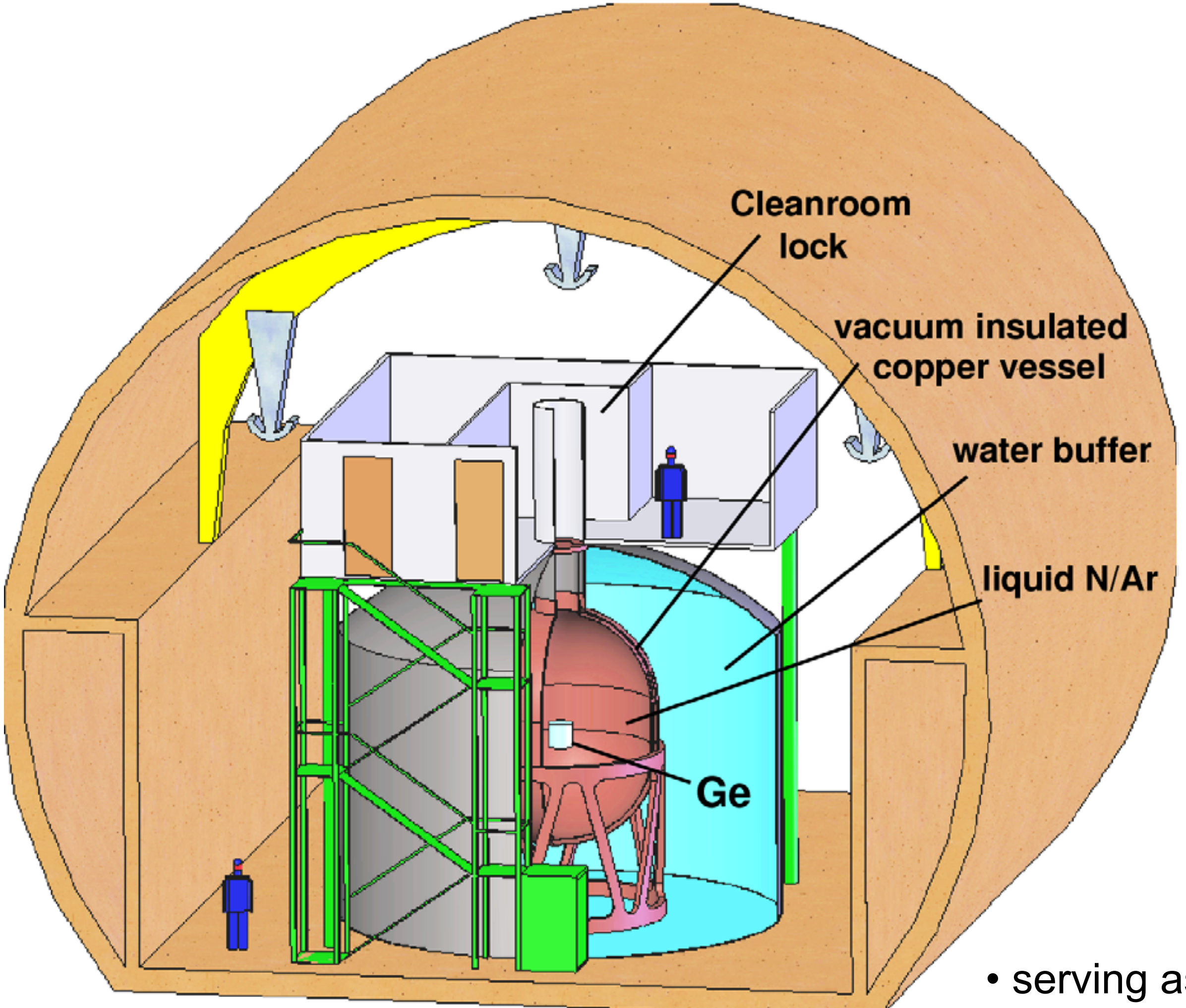




very similar to GEM design

Yu.G.Zdesenko, O.A.Ponkratenko,V.I.Tretyak
J.Phys. G, Nucl.Part.Phys. 27 (2001) 2129

proposed GERDA installation in LNGS Hall A



Ø 10 m water vessel
Ø 4 m Cu cryostat

45 m^3 of LN (LAr)
650 m^3 of water

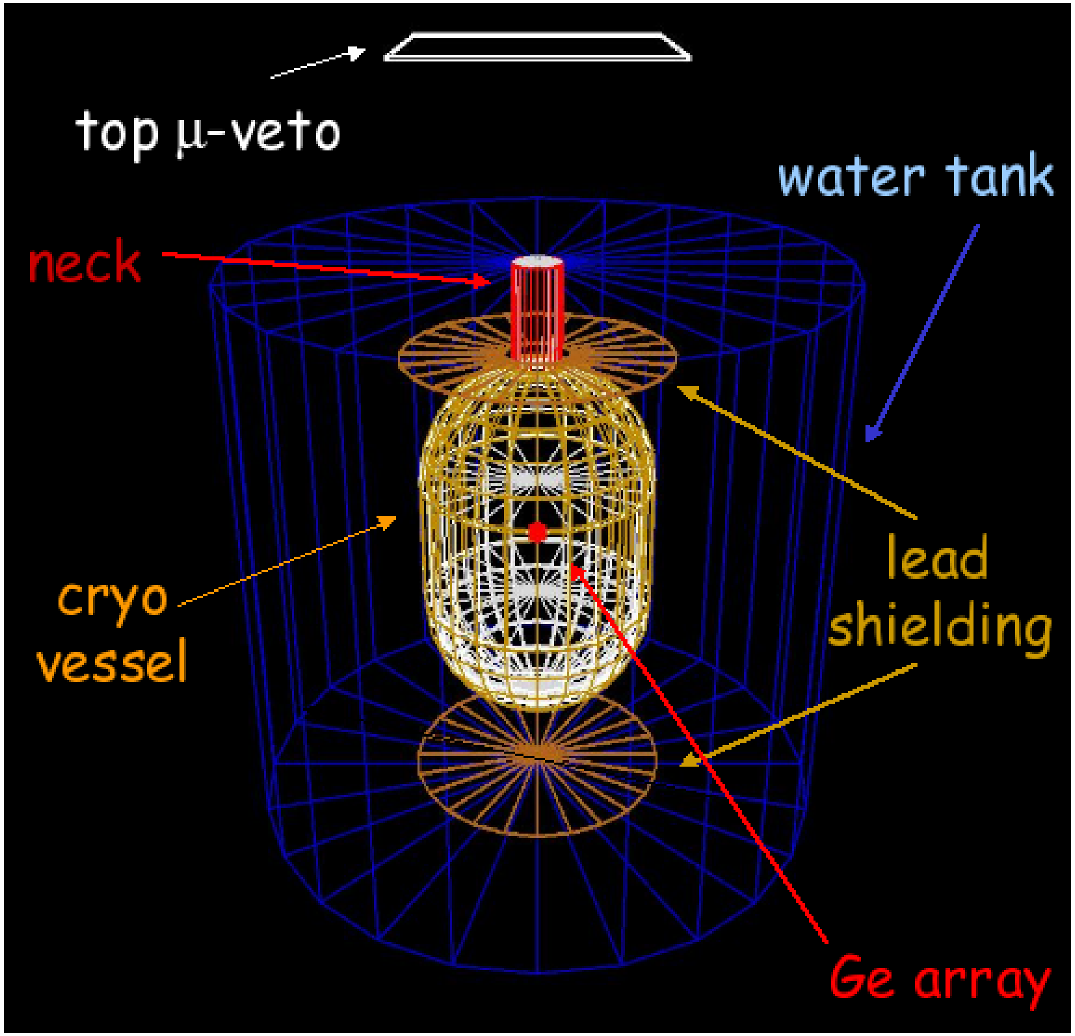
designed for
external γ,n,μ background
< 0.001 cts /(keV·kg·y)

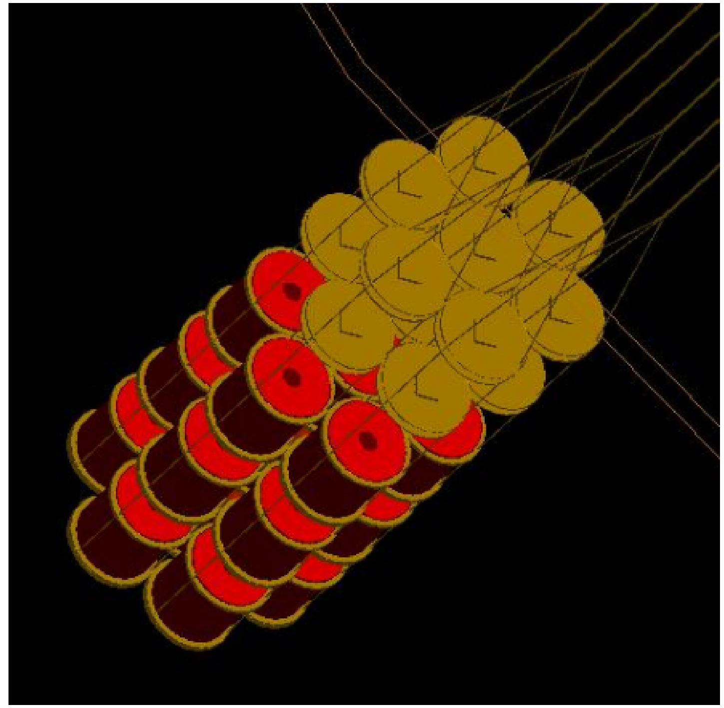
factor 10 smaller for LAr

water:
- acting as neutron moderator
- serving as Čerenkov medium for μ veto
- cheaper, safer, more effective than liquid N

MaGe Monte Carlo for GERDA

MC framework shared with MAJORANA collaboration



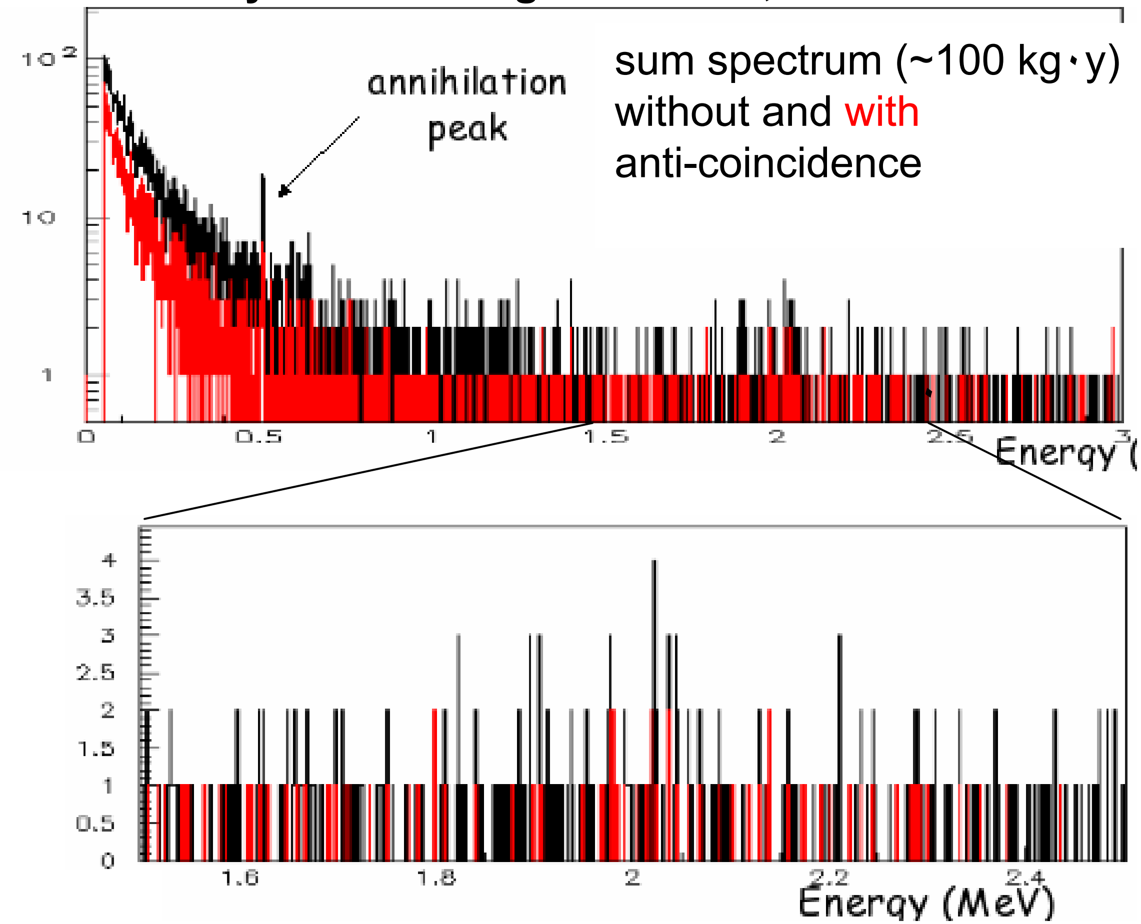


- diodes arranged in strings
- insertion / removal of diodes via respective string
- same scheme for calibration sources

μ background simulated within MaGe

μ flux at LNGS: ~1 μ / (m²·h) , (270 GeV) , laterally anistropic – total of 88 events / (kg·y)

9 Ge crystals of 19 kg total mass, 50 keV threshold



ave. background [cts/(keV·kg·y) within in 1.5 < Eγ < 2.5 MeV

no cuts	$3.3 \cdot 10^{-3}$
Ge anti-coinc.	$1.0 \cdot 10^{-3}$
+ top μ veto	$0.9 \cdot 10^{-3}$
dto. optimized	$0.4 \cdot 10^{-3}$
+ water Č. μ veto	$<3 \cdot 10^{-5}$

Ge γ spectrometers

- Baksan 600 m w.e. (soon → 4900 m w.e.) 4-fold spectrometer
- Hades 500 m w.e. Ge-2 – Ge-9
- MPI-K 15 m w.e. 3 diodes
- LNGS 3500 m w.e. GeMPI 1,2,(3) S : ~ *O*(10[100]) µBq/kg for heavy [light] samples

Rn-222 diagnostics / monitoring

- emanation technique S : 0.5 µBq / m^2 , 10 µBq / kg
- gas purity analysis
- electrostatic chamber : 0.1 – 1 mBq / m^3

α spectrometer

- Baksan (ionization chamber) S : 10 Bq/m^3 (quick), background: 0.002 / ($cm^2 \cdot h$)
- Krakow

ICPMS **(inductively coupled plasma mass spectrometry)**

- Frankfurt U S : U/Th ~ 1 µBq / kg > secular equilibrium? <

(measured materials: Kapton, Teflon, Torlon, MLI, PMT glass, Cu, steel, Cu/P granulate)

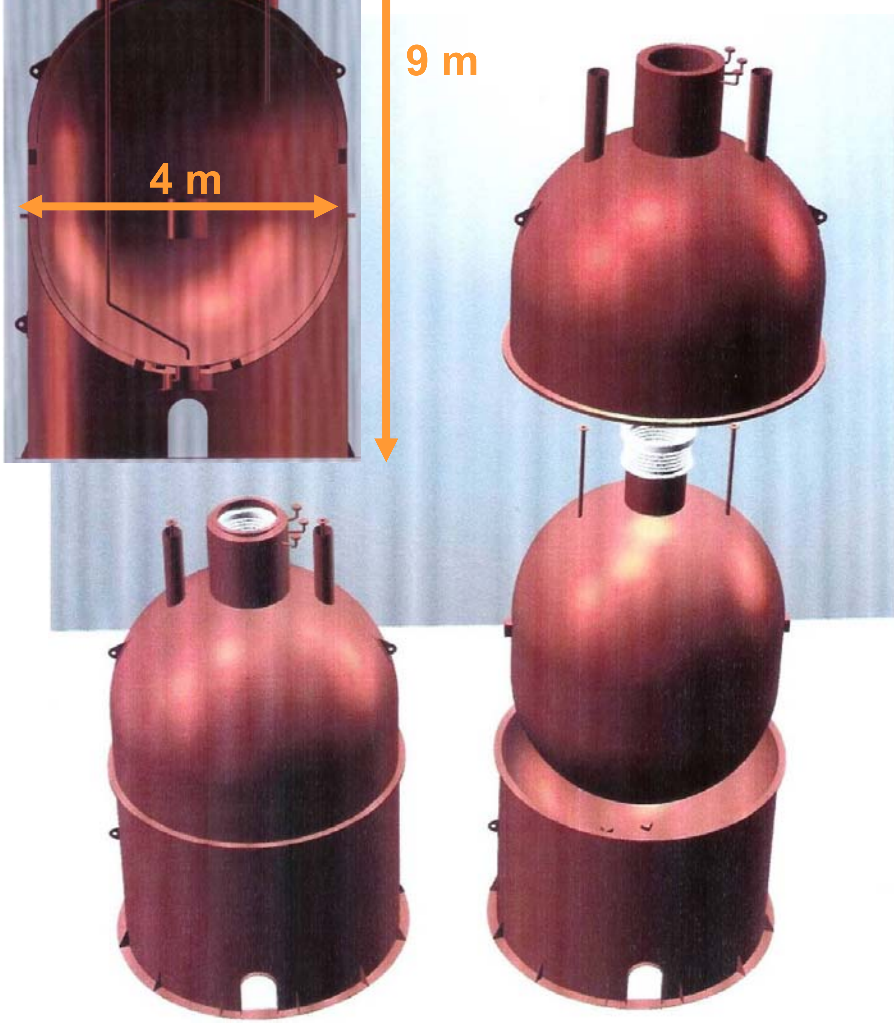
►Challenge: screening of plastics at required Th sensitivity of < 10 µBq / kg not (yet) possible !
Large samples (~100 kg)needed for best sensitivity !

Cu surface purification studies **(cryostat > 100 m^2)**

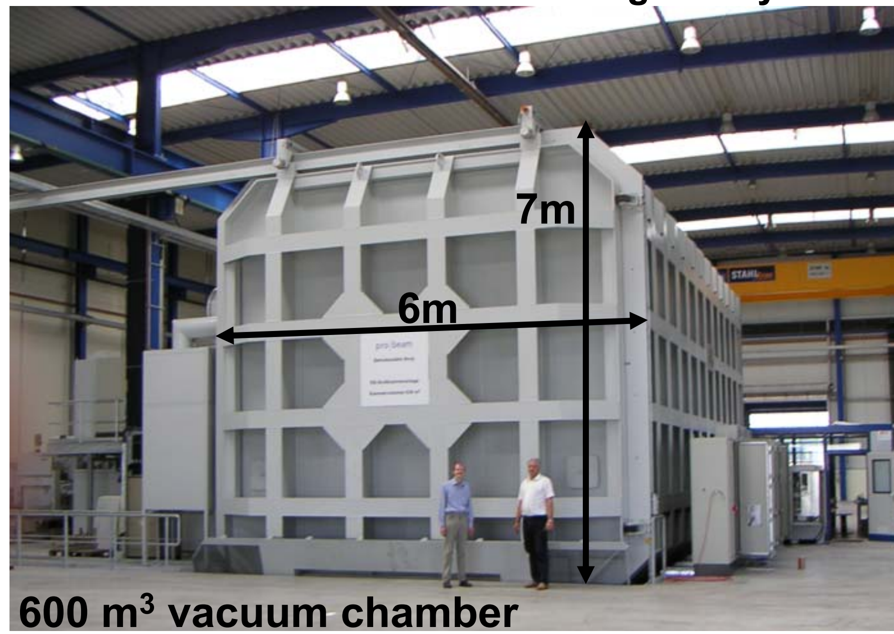
- Cu disks radiated with strong Rn source S : 1 µBq / m^2

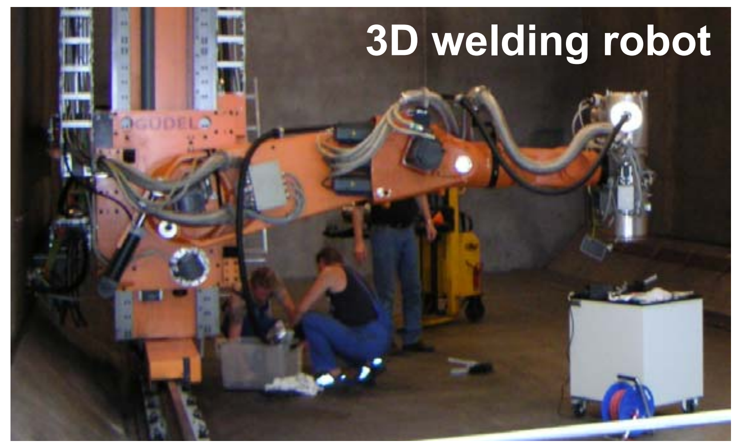
clean welding of copper cryostat

Before, ca. 130m^2 Cu surface to be cleaned!



‘pro-beam AG’ electron beam welding facility at Burg

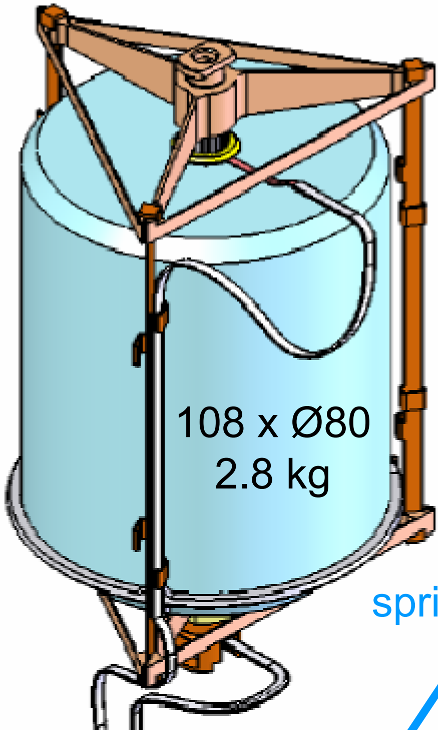


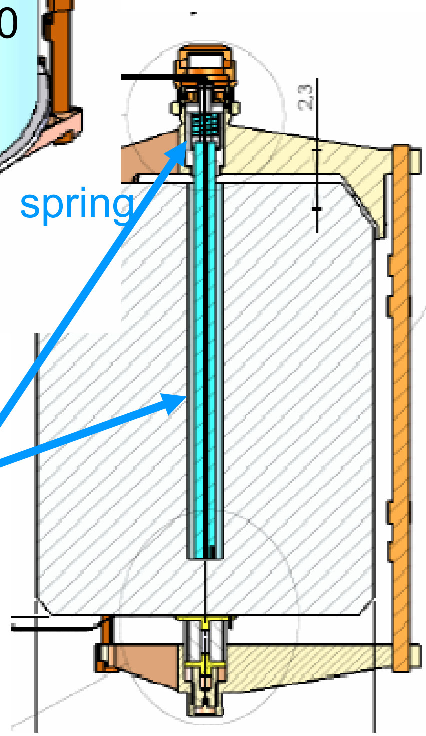


low mass diode supports and contacts

Phase I

HdM & IGEX
p-type Ge diodes

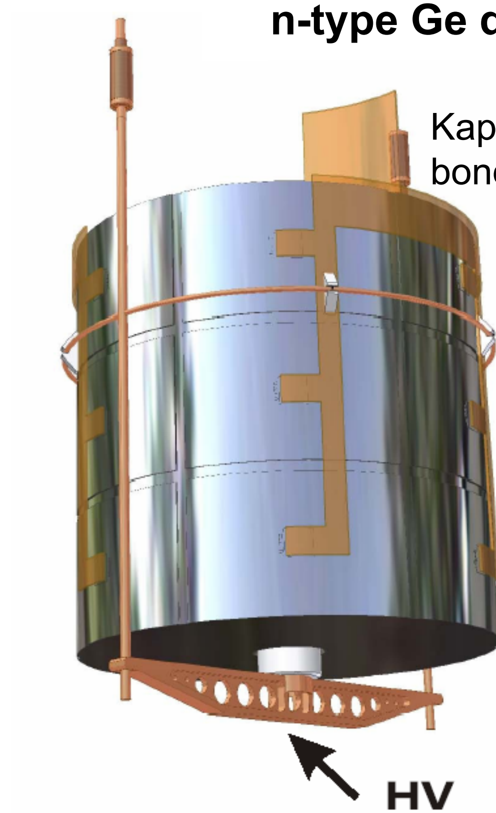




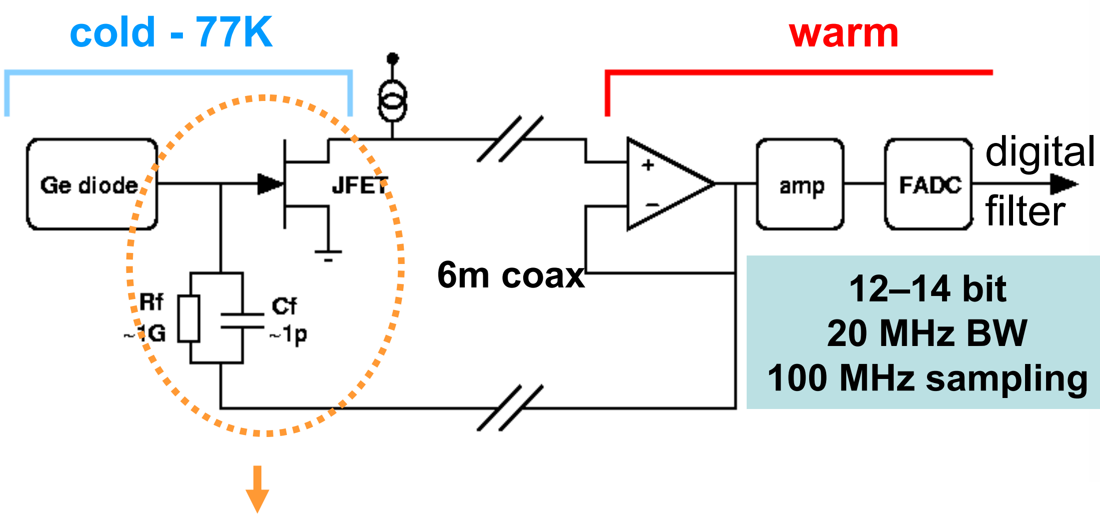
Cu	80.8 g
Si	4.5 g
PTFE	6.4 g

Phase II

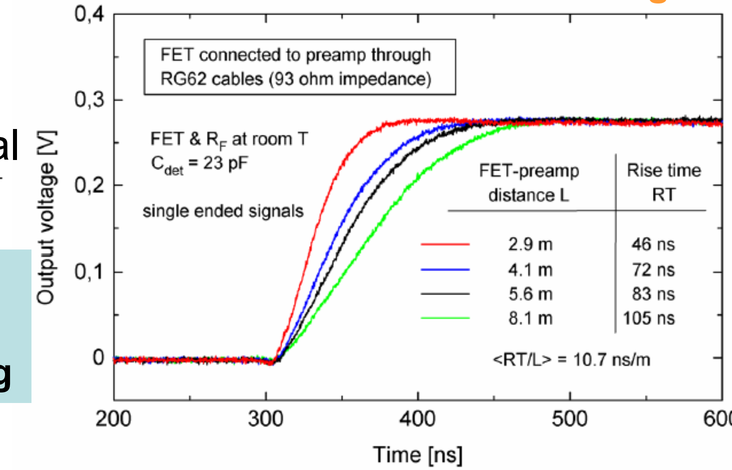
true-coaxial 3x6 segmented
n-type Ge diode



total of ~30g mounting material

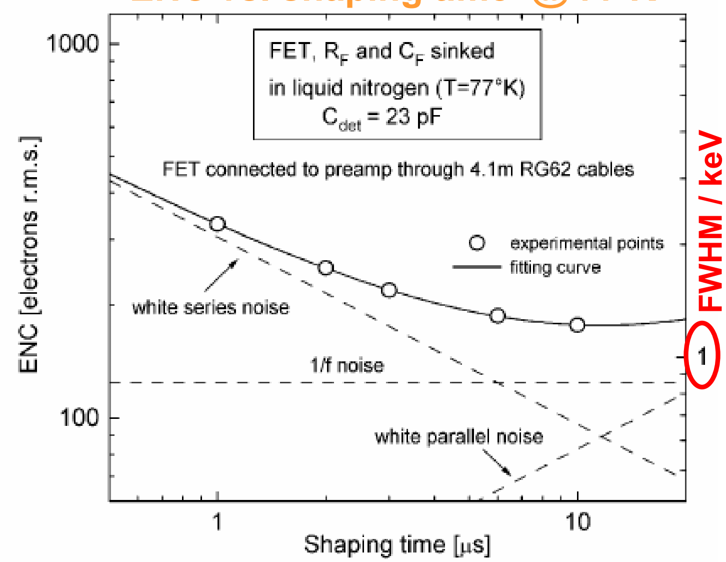


rise times for various coax lengths



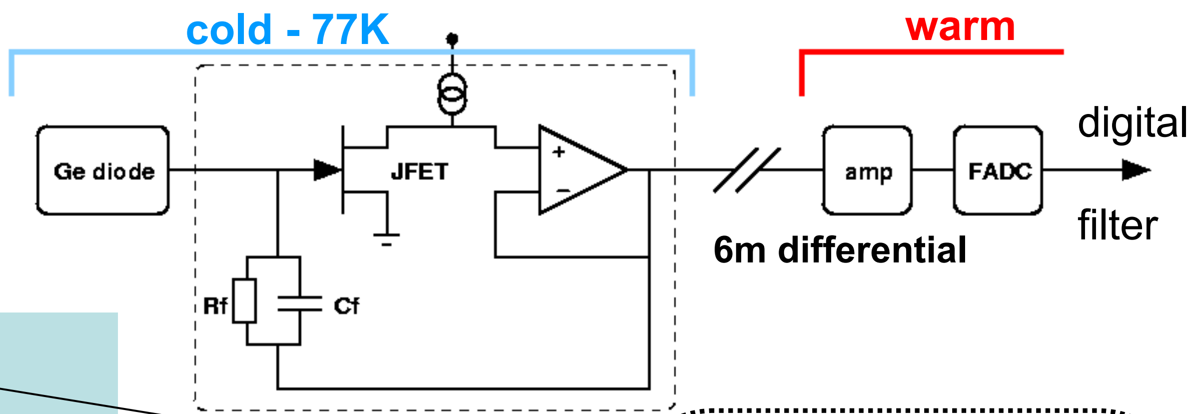
+ available & working
  ► phase I
- increased rise time
- potential for noise pickup

ENC vs. shaping time @ 77 K



JFET: BF862, IF1331, Agata preamp

Preamp 'on the chip', 'ASIC', indispensable for phase II with segmented detectors!

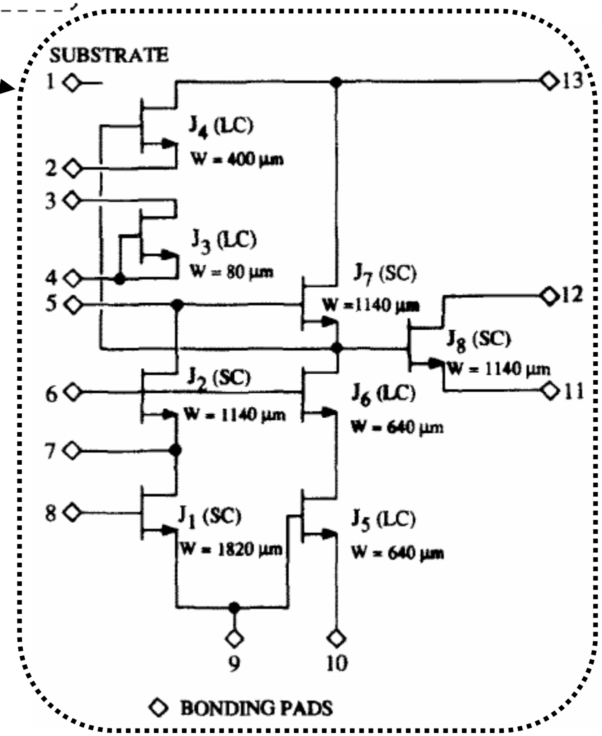


► monolithic JFET preamp
(P.F.Manfredi, V.Re, V.Speziali, NIM A380 (1996) 308)
tests in progress – phase I ?
+ available from InterFET
+ excellent noise performance at RT
o to be optimized for C_{inp} = 30 pF
- needs external bias supplies
- Rf, Cf not integrated

77K ASIC Wanted :

gain	200mV/MeV
dyn. range	2000
BW	20-30 MHz
ENC	<100e @ 30 pF
output	differential

FET, Rf, Cf, bias,analog test pulse integrated .



► ASIC development in CMOS – challenge 1/f noise of FET
two approaches – phase II
i) ASIC in 0.8µ AMS process, w / wo integrated input FET, Rf and Cf not integrated, submitted, chips ► Oct 05.
ii) ASIC in 0.6µ X-Fab process, w / wo integrated input FET, integrated Rf, Cf and bias supplies, submission ► Nov 05.

phase II: procurement of enriched Ge-76

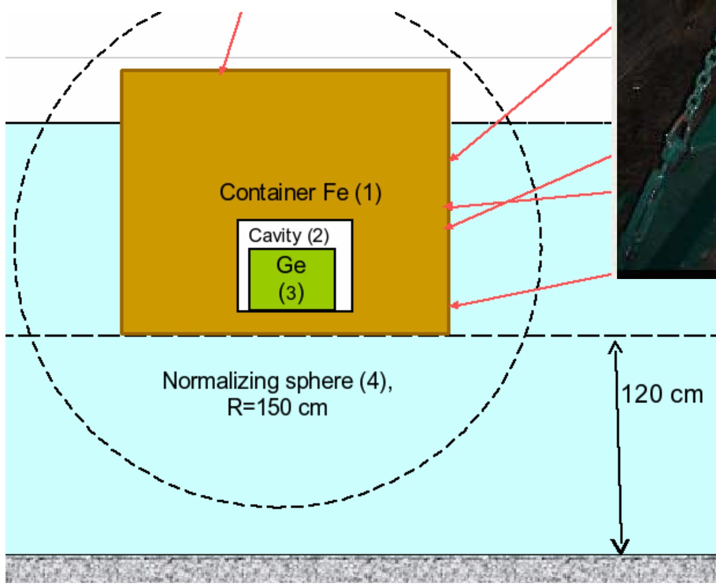
Shielding container designed and fabricated to shield Ge-76 from cosmogenic neutrons and protons

attenuation factor for production of

		μ	
Ge-68	**10**	→	**8**
Co-60	**15-20**	→	**12-15**

Delivery procedure tested by shipment of 15 kg Ge-nat in shielding container from Siberia to Munich.

22 kg enriched Ge-76 already produced!



more ongoing R&D for phase II

- optimization of purification of enriched Ge-76 oxide to 6N grade metal
- optimization of production of new enriched Ge-76 diodes
- commissioning of test stands for the characterization of Ge-diodes
- study of segmented n- and p-type true-coaxial Ge-diodes
- study of active LAr shield
- ....

2004

• Feb	Letter of Intent to LNGS, **hep-ex/0404039**
• Sep	formation of collaboration
• Oct	funding requests approved by MPG
• Oct	Proposal to LNGS, **www.mpi-hd.mpg.de/GERDA/proposal.pdf**

2005

• Jan	`prior information notice' about cryostat tendering in SIMAP
• Feb	GERDA approved by LNGS, location in Hall A in front of LVD
• Mar	Technical Proposal to LNGS, 30 kg of enriched Ge-76 ordered
• May	funding requests approved by INFN
• Jun	funding request approved by BMBF
• Jul	Ge-76 order enlarged to 37.5 kg
• Jul	FMECA & HAZOP safety study for cryostat submitted to LNGS ('safe if designed & fabricated according to the rules')
• Aug	► decision by LNGS about system safety – if OK then
• Sep	tendering for water tank, first orders for cryostat

2006

• Jun	start of construction of water tank in Hall A
• ...	installation of cryostat, clean room & lock, μ veto, lab rooms

2007

• spring	commissioning, start of physics run

Summary

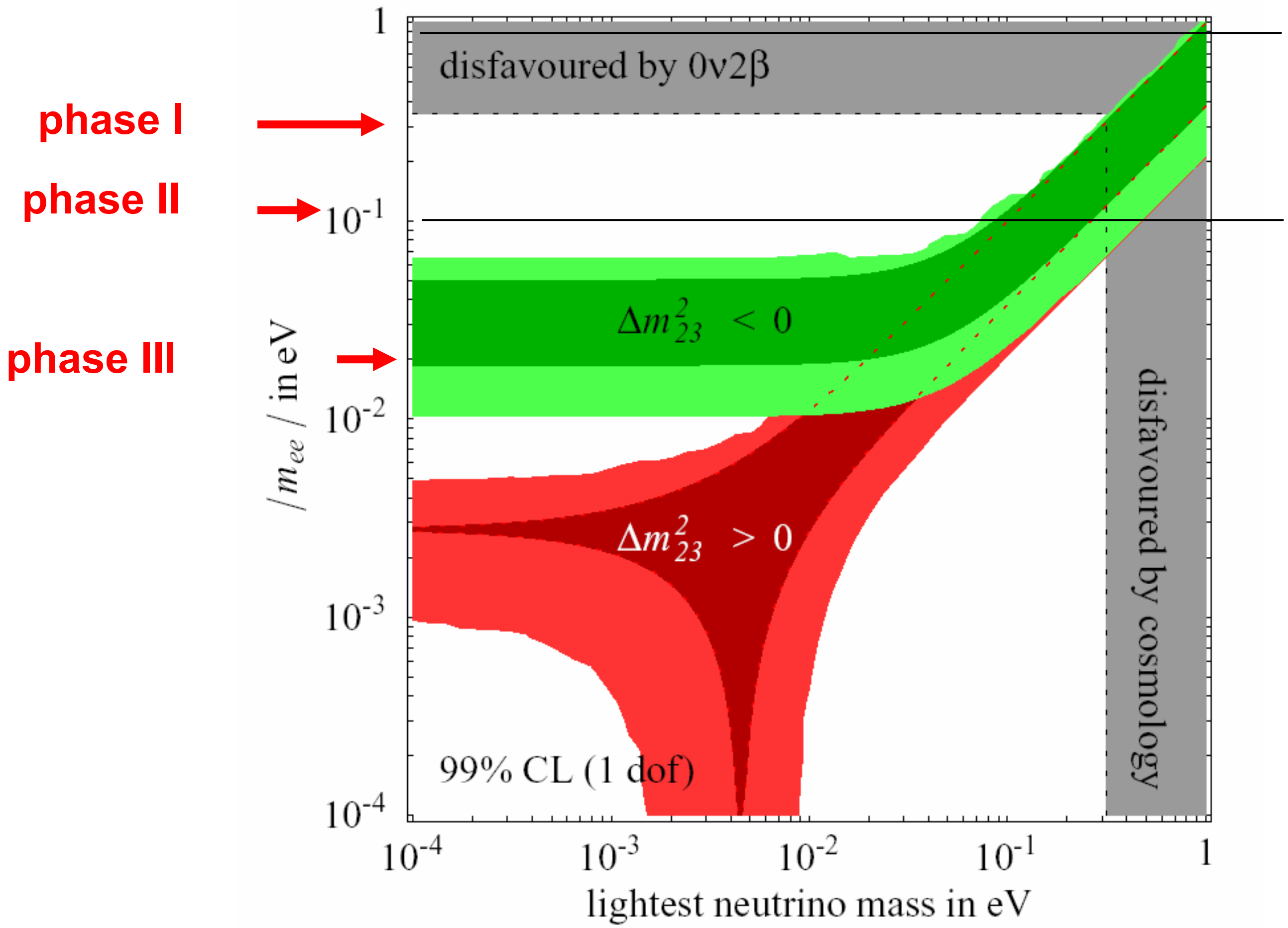
- approved by LNGS with location in Hall A,
- substantially funded by BMBF, INFN, MPG, and Russia in kind
- construction to start in LNGS Hall A in June 2006
- parallel and fast R&D for phase II
- start of data taking in 2007

goal: phase I : background 0.01 cts / $(kg \cdot keV \cdot y)$

► scrutinize KKDC result within 1 year

phase II : background 0.001 cts / $(kg \cdot keV \cdot y)$

► $T_{1/2} > 2 \cdot 10^{26}$ y , $\langle m_{ee} \rangle < 0.09 – 0.29$ eV



A.Strumia & F.Vissani, hep-ph / 0503246

clean room with lock on top of vessel