GERDA

The neutrinoless double beta decay in ^{76}Ge at GERDA

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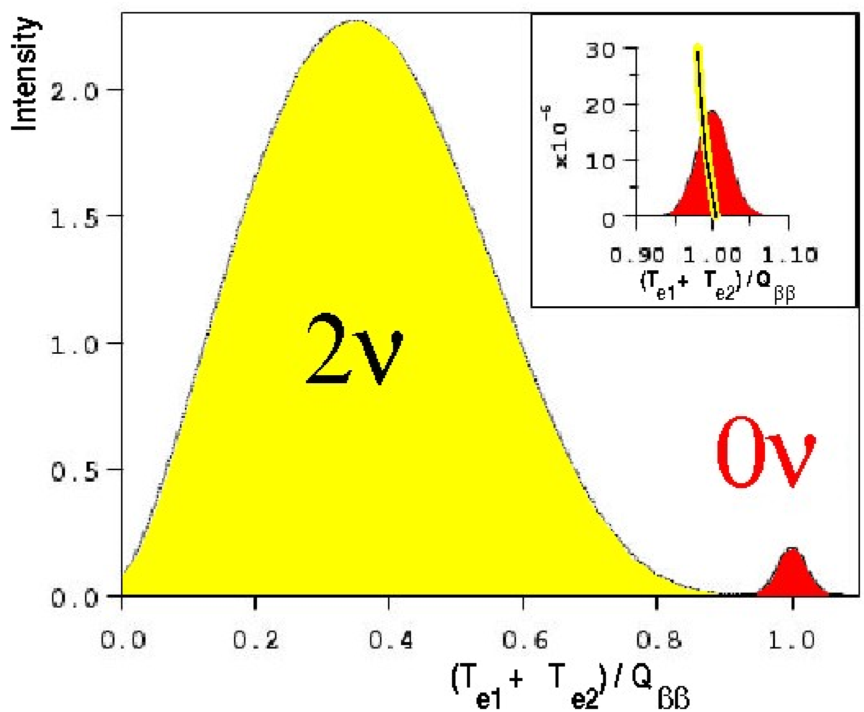
bmb+f - Förderschwerpunkt
Astroteilchenphysik
Großgeräte der physikalischen Grundlagenforschung

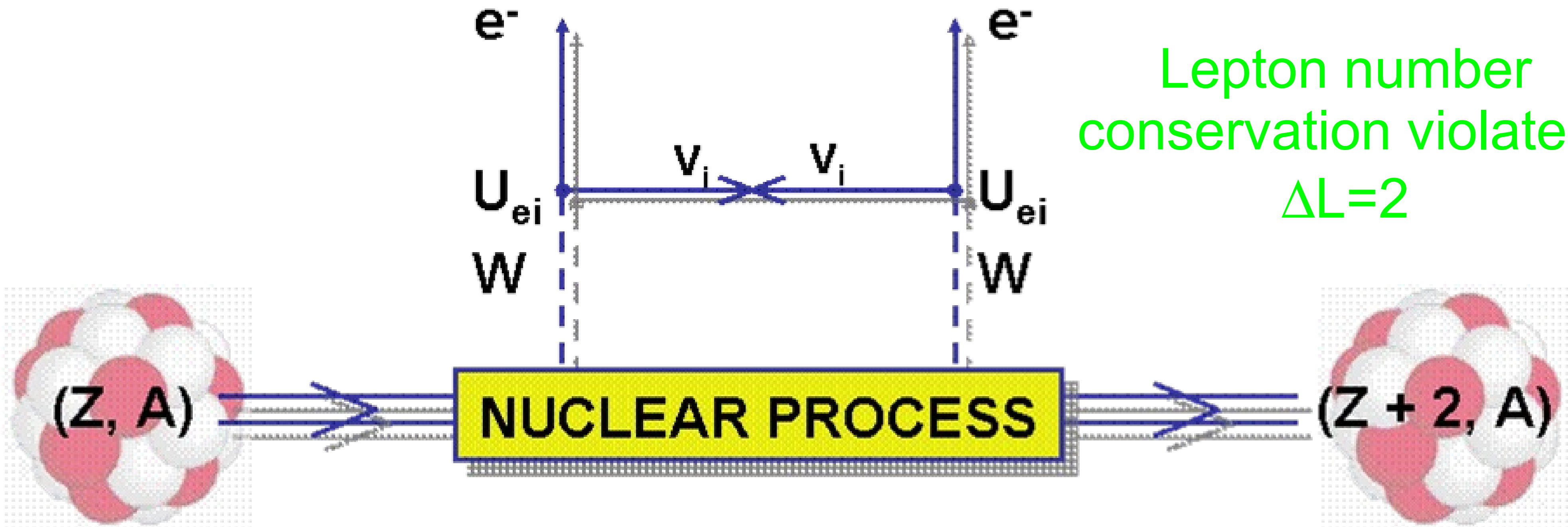
Content

- neutrinoless double beta decay
- consequences for neutrino properties
- ^{76}Ge experiments and GERDA
  - principle
  - background and sensitivity
  - setup and status
- Schedule and Outlook

Signature : peak @ $Q_{\beta\beta}$



Neutrinoless 2β decay



Lepton number conservation violated: $\Delta L=2$

0ν2β process possible only if:

- Neutrino has finite mass
- Neutrino == Anti-Neutrino (Majorana type)

rate: (exp.)

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

Phase space factor ($\sim Q^5$;choose (A,Z))

Nuclear matrix element (theory input)

Effective Majorana mass (hierachy)

Neutrino masses

Neutrino oscillations:

mass is finite

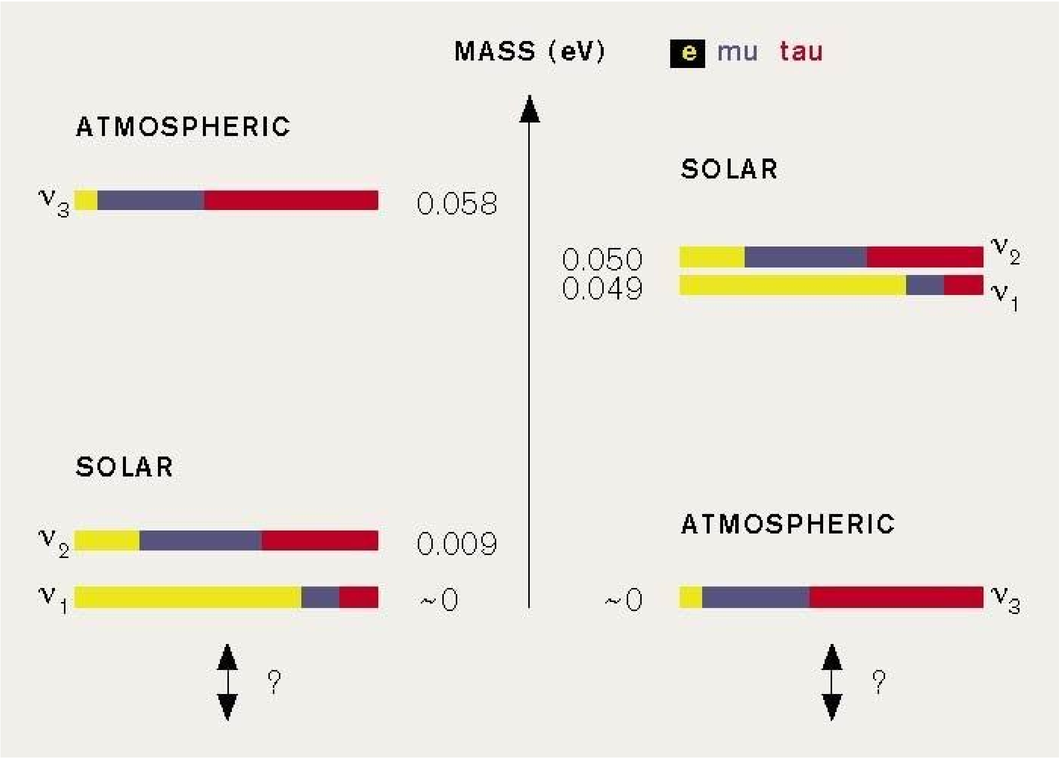
(Suzuki, INPC07)

$\Delta m^2_{solar} = 8{,}2\ 10^{-5}\ eV^2$

$\Delta m^2_{atm} = 2{,}7\ 10^{-3}\ eV^2$

$\Delta m^2_{23} > 0$ — normal

$\Delta m^2_{23} < 0$ — inverted



still need:

- absolute mass scale
- hierachy

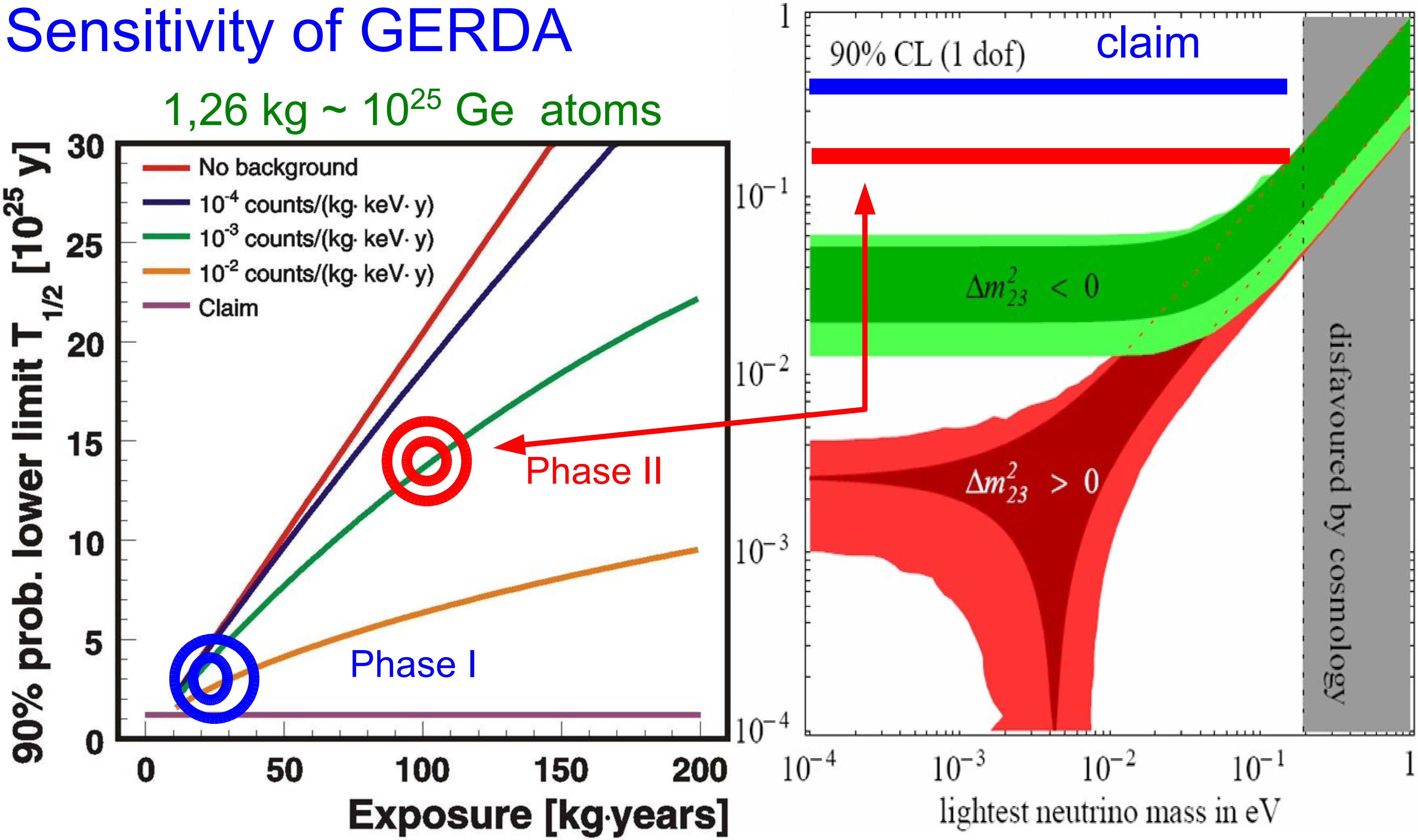
Tritium β decay : < 2,2 meV

Cosmology : < 1,0 meV

ββ decay : < 0,4 meV

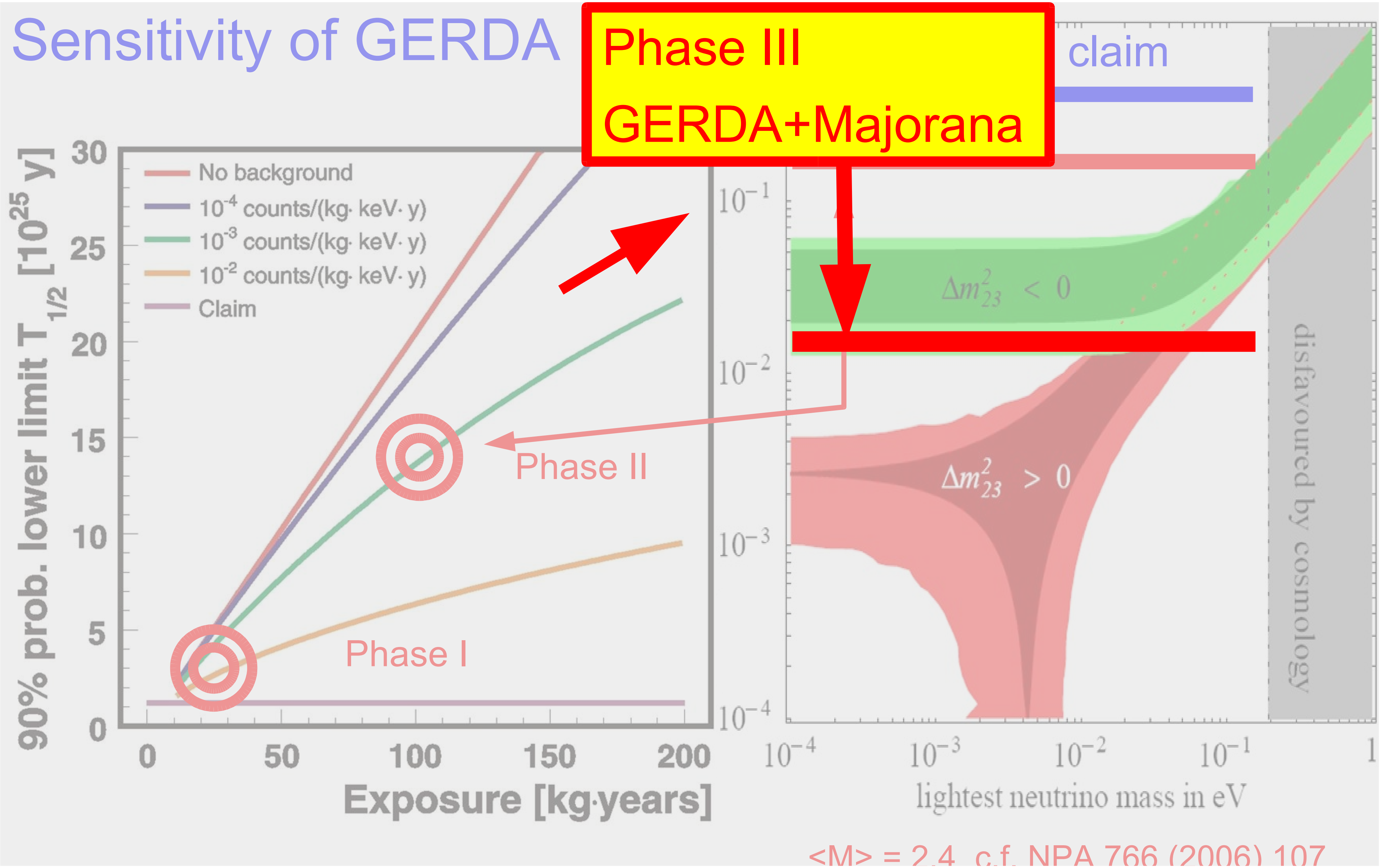
absolute mass scale

Sensitivity of GERDA



<M> = 2,4 c.f. NPA 766 (2006) 107

absolute mass scale



^{76}Ge experiments

previous experiments: HDM (5 det) and IGEX (3 det)

Klapdor-Kleingrothaus et al.
Phys Lett B586 (2004) 198

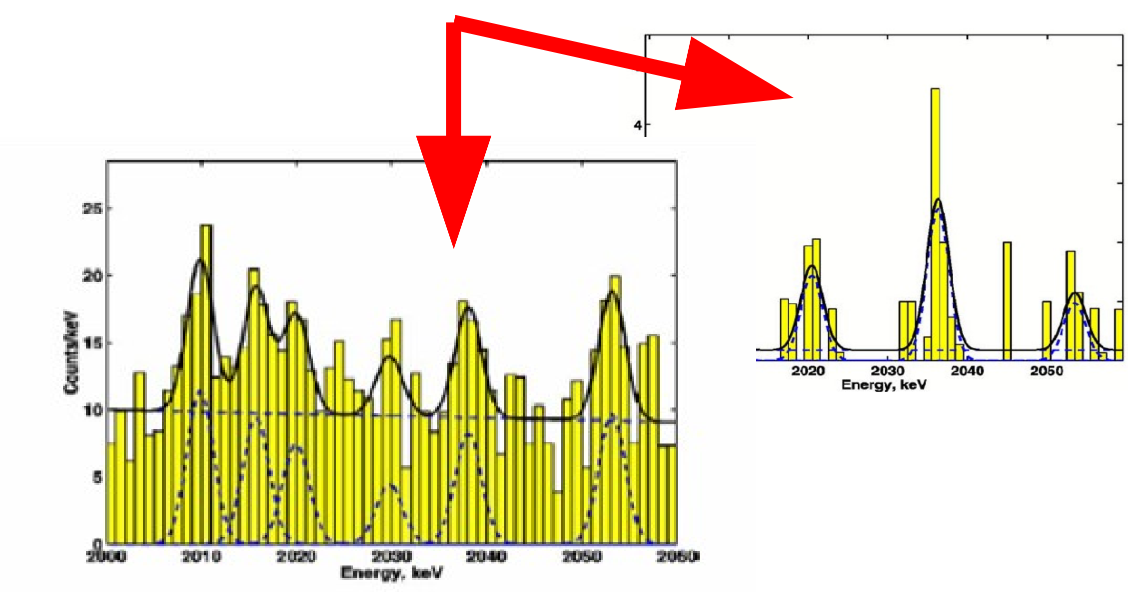
71,7 kg·y

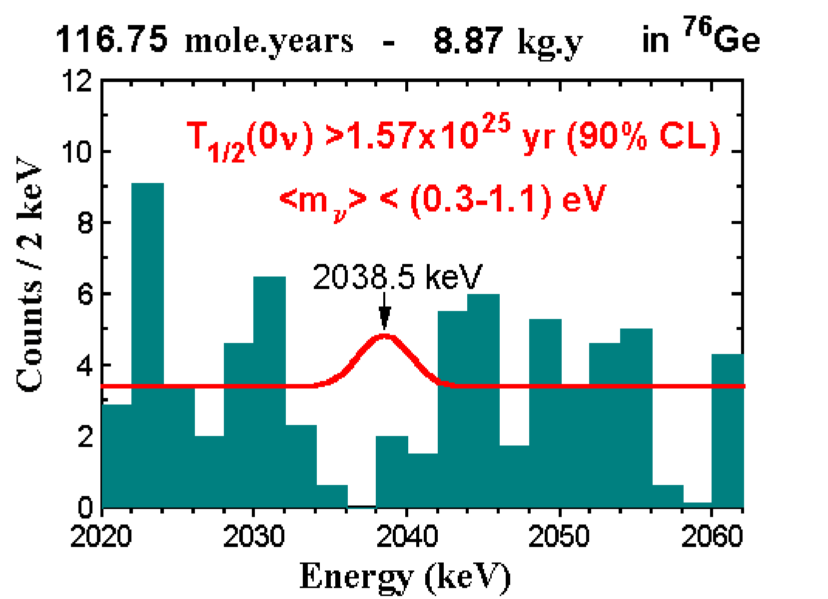
$T_{1/2} > 1{,}9 \cdot 10^{25}$ y (90%CL)
(0,69 - 4,18)

Aalseth et al.
Phys Rev D65 (2002) 092007

8,9 kg·y

$T_{1/2} > 1{,}6 \cdot 10^{25}$ y (90%CL)

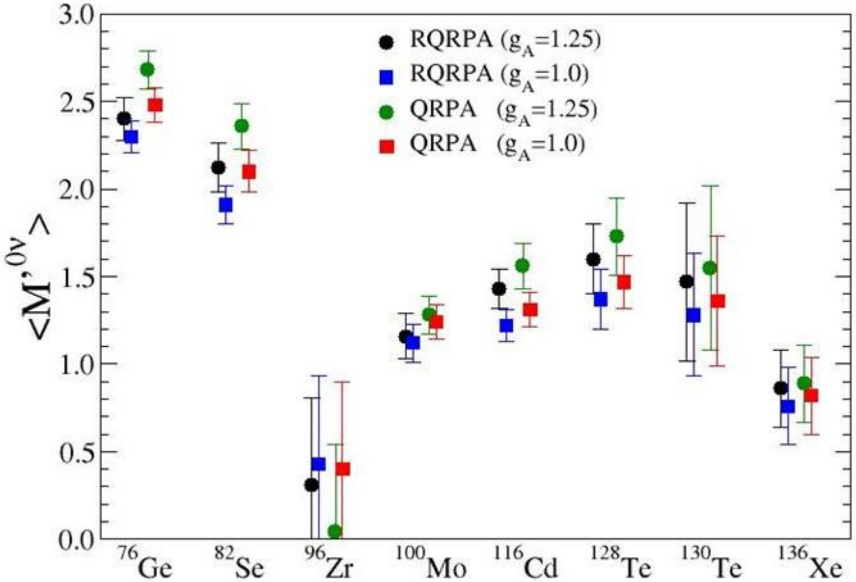


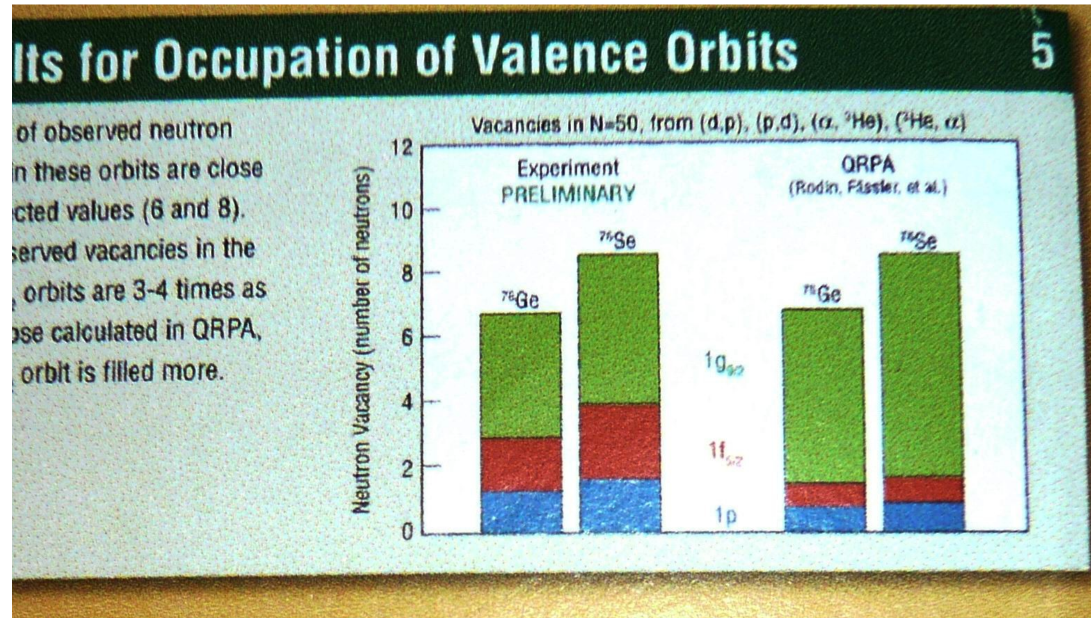


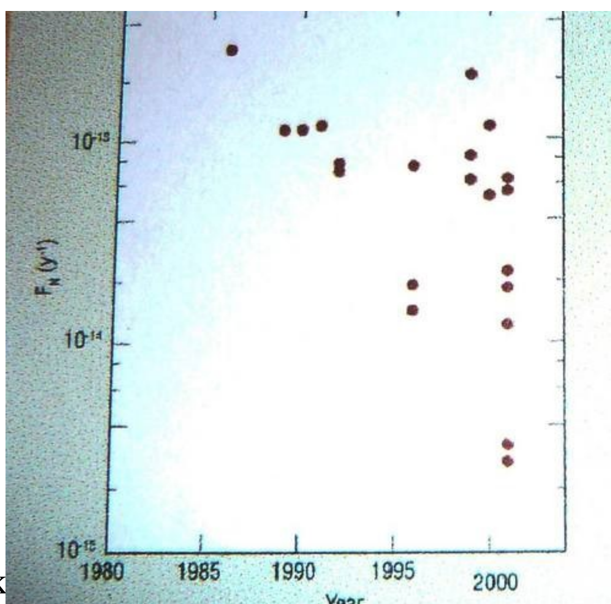
Matrixelements

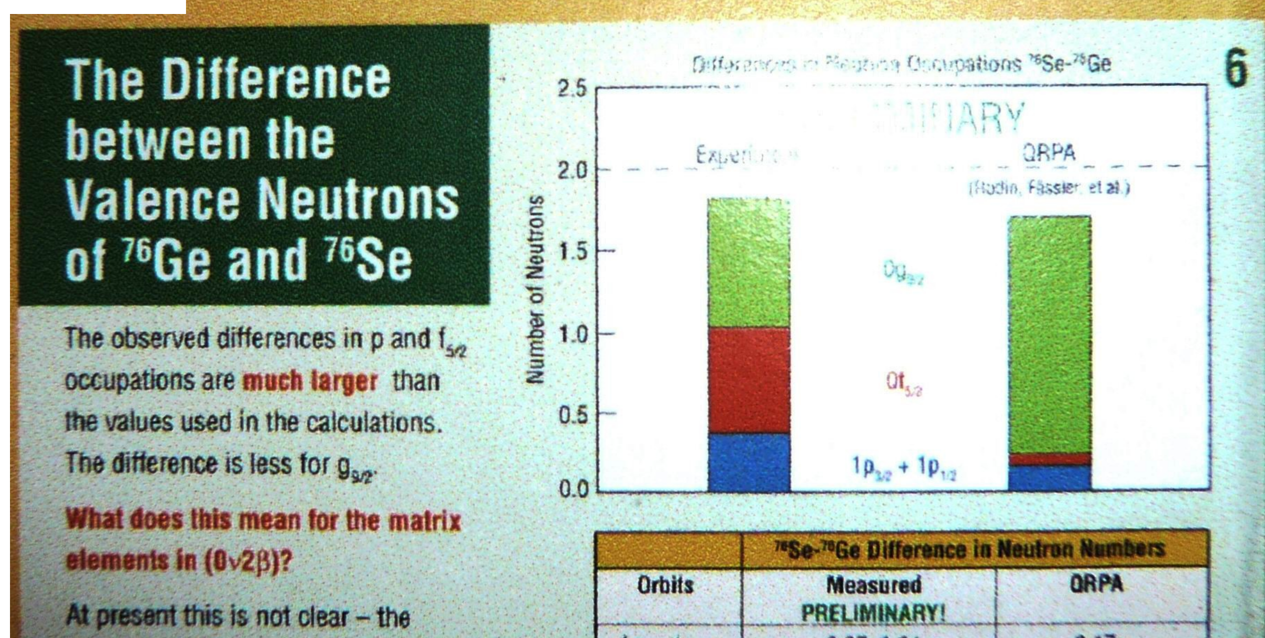
V.Rodin & A. Faessler (NPA)

J.P. Schiffer (INPC07)









^{76}Ge experiments

GERDA

^{76}Ge: Source == Detector

GERDA:

$Q_{\beta\beta}$ = 2039 keV

large mass of enriched material — 7,44% -> ~86%

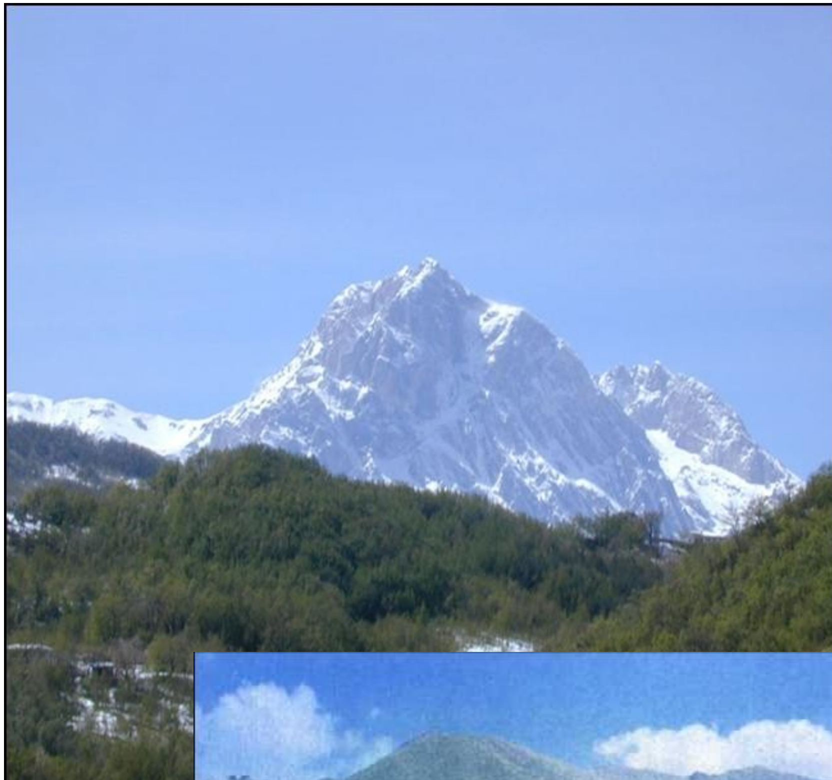
high energy resolution — <4 keV

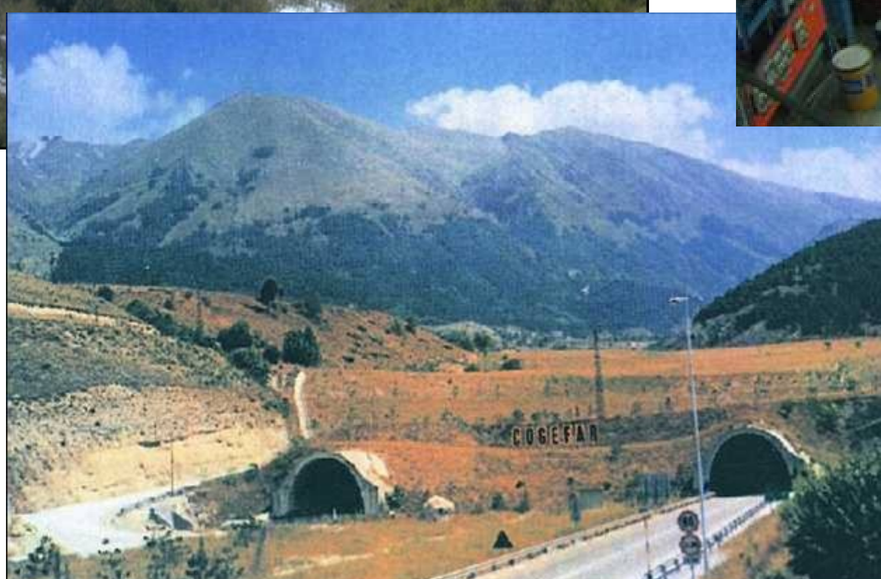
- separate $0\nu\beta\beta$ from $2\nu\beta\beta$
- set smaller ROI

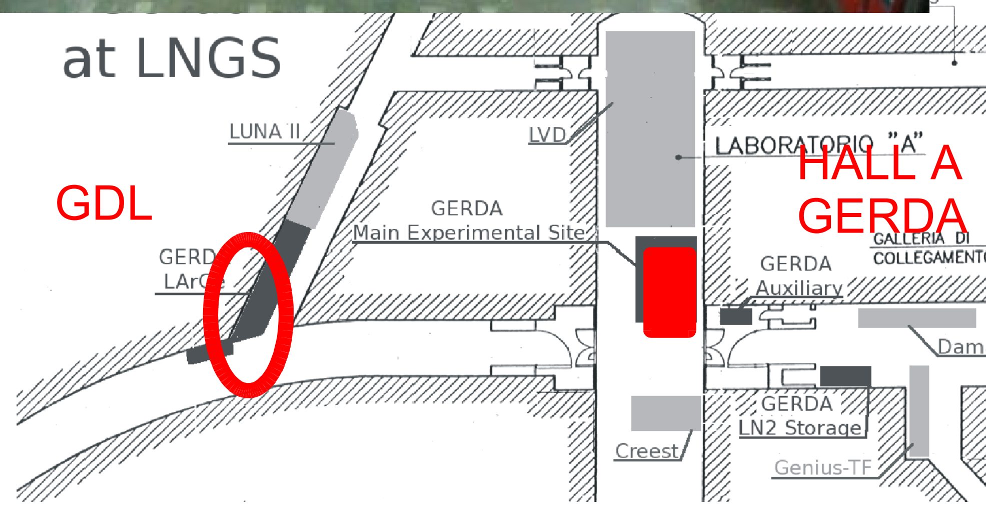
low background — $<10^{-3}$ cts/(kg·y·keV)

- passive : LNGS @ 3800 m.w.e. (reduce μ)
  - Watertank, LAr (avoid n,cosmogenic)
  - selection of material (reduce Th,U)
- active : Muon veto
  - segmentation, anti-coincidence
  - PSA

GERDA @ LNGS





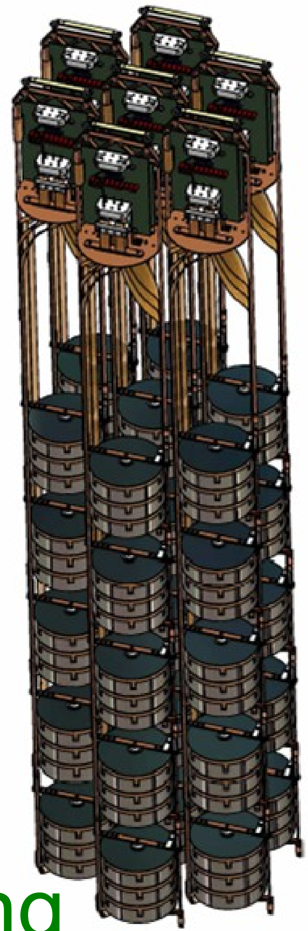

at LNGS
LUNA II
LVD
LABORATORIO "A"
HALL A
GERDA
GDL
GERDA
Main Experimental Site
GALLERIA DI
COLLEGAMENTO
GERDA
Auxiliary
Dama
GERDA
LN2 Storage
Creest
Genius-TF

GERDA – the schema

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

"...low Z material around detector..."
"...mount the Ge diodes directly in cryo-liquid"

reduced radioactivity of environment
less muon-induced background

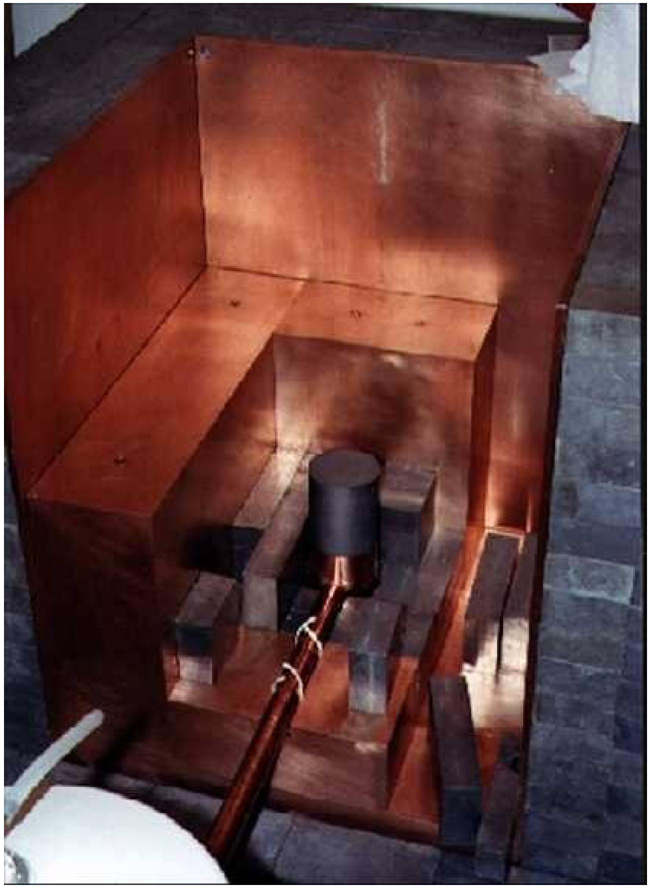


Ge diodes – enriched to 86%
liquid argon
stainless steel cryostat
water to moderate neutrons and
as muon veto (Cerenkov)

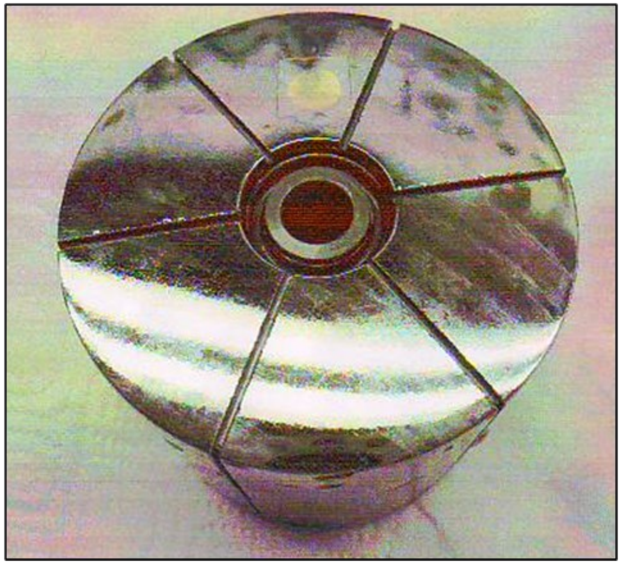
=>HdM, Majorana: closed compact shielding

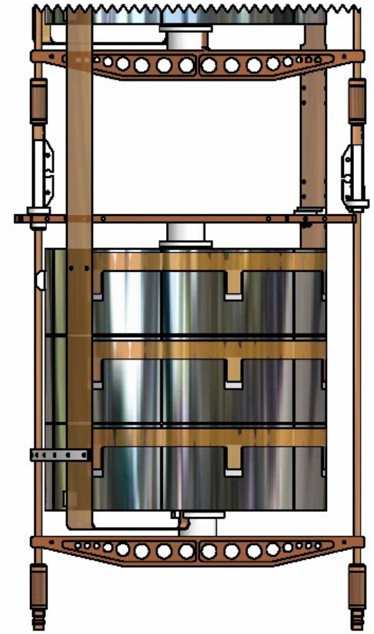
Setup: HdM versus GERDA

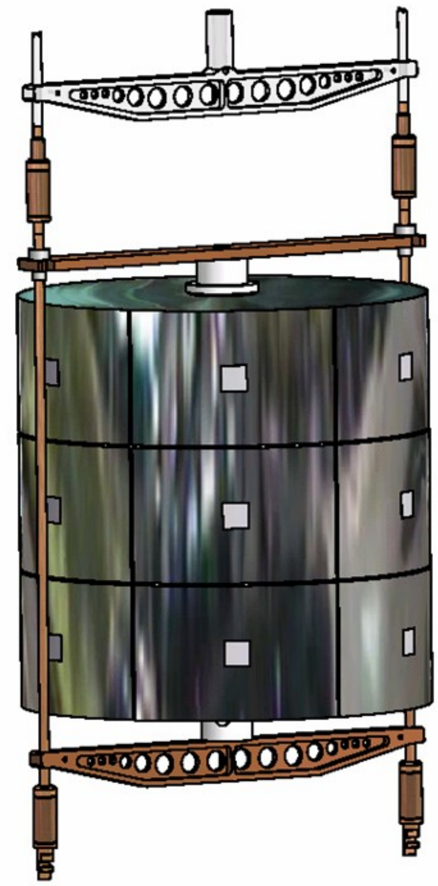
HdM



non-enriched prototype





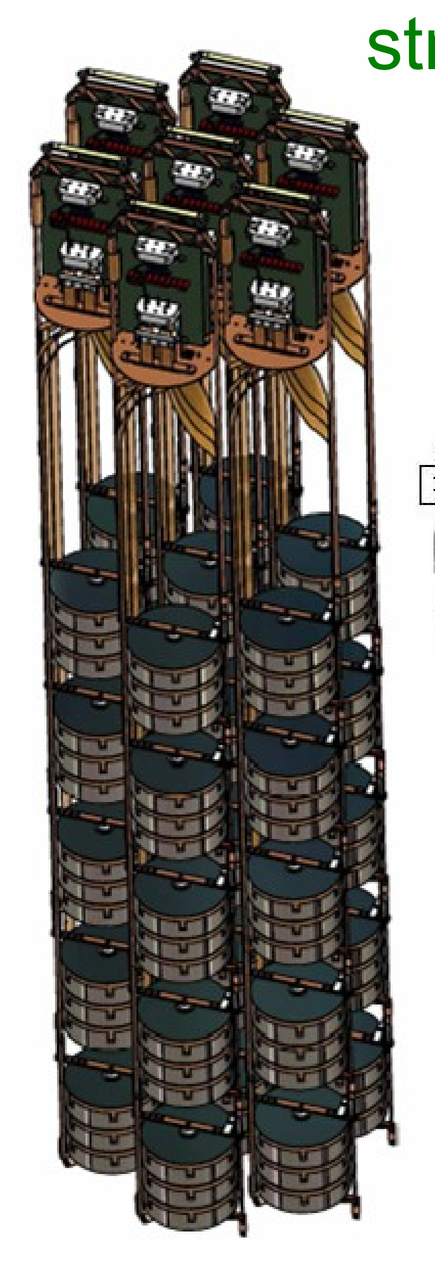


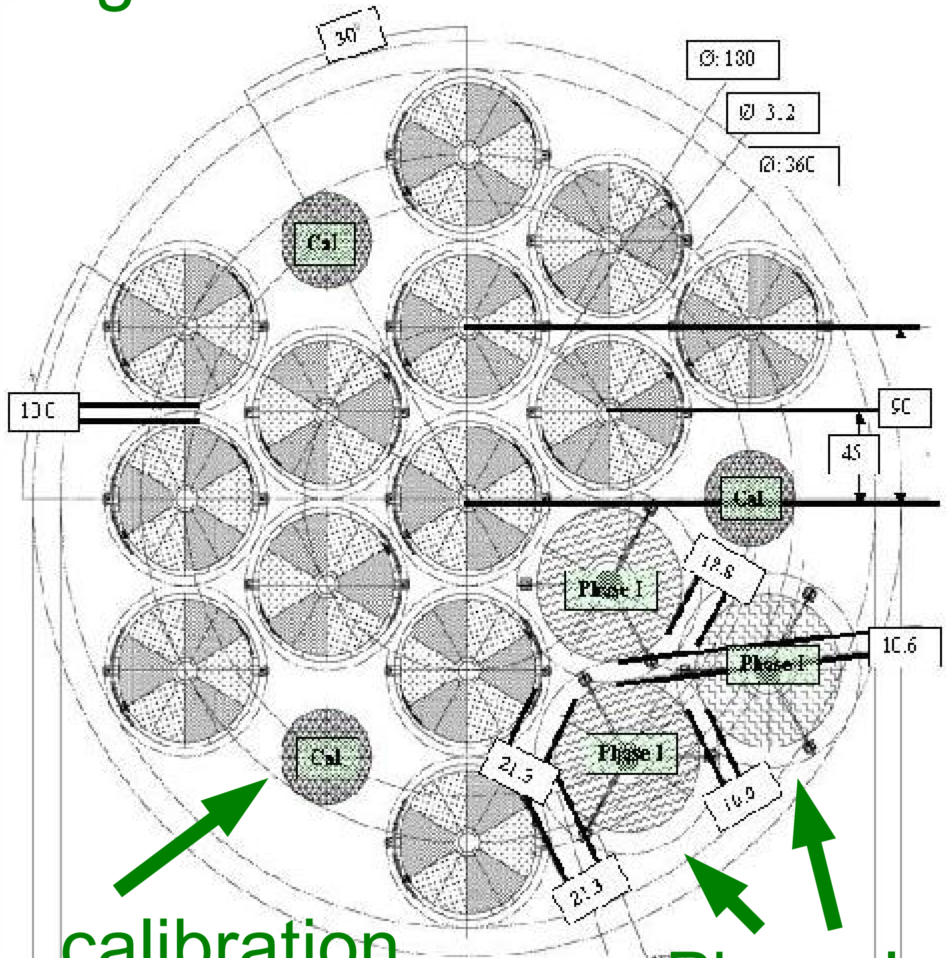
~ 12 g vs. ~ 2 kg

Setup: HdM versus GERDA

strings

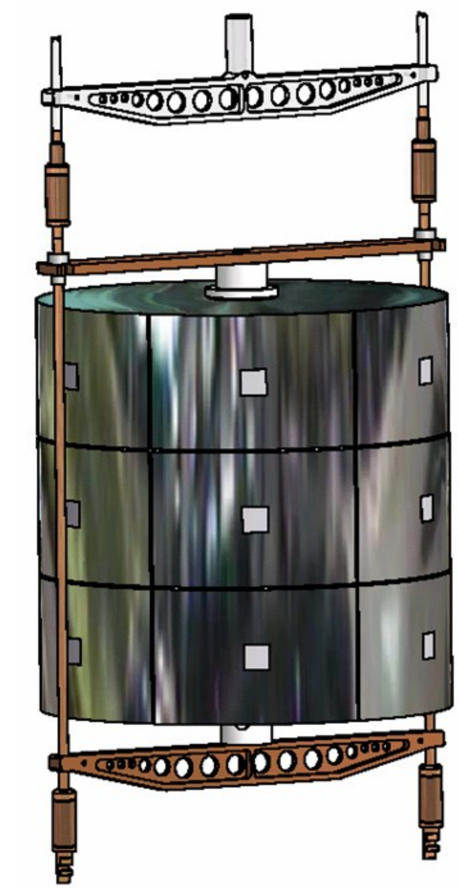
non-enriched prototype





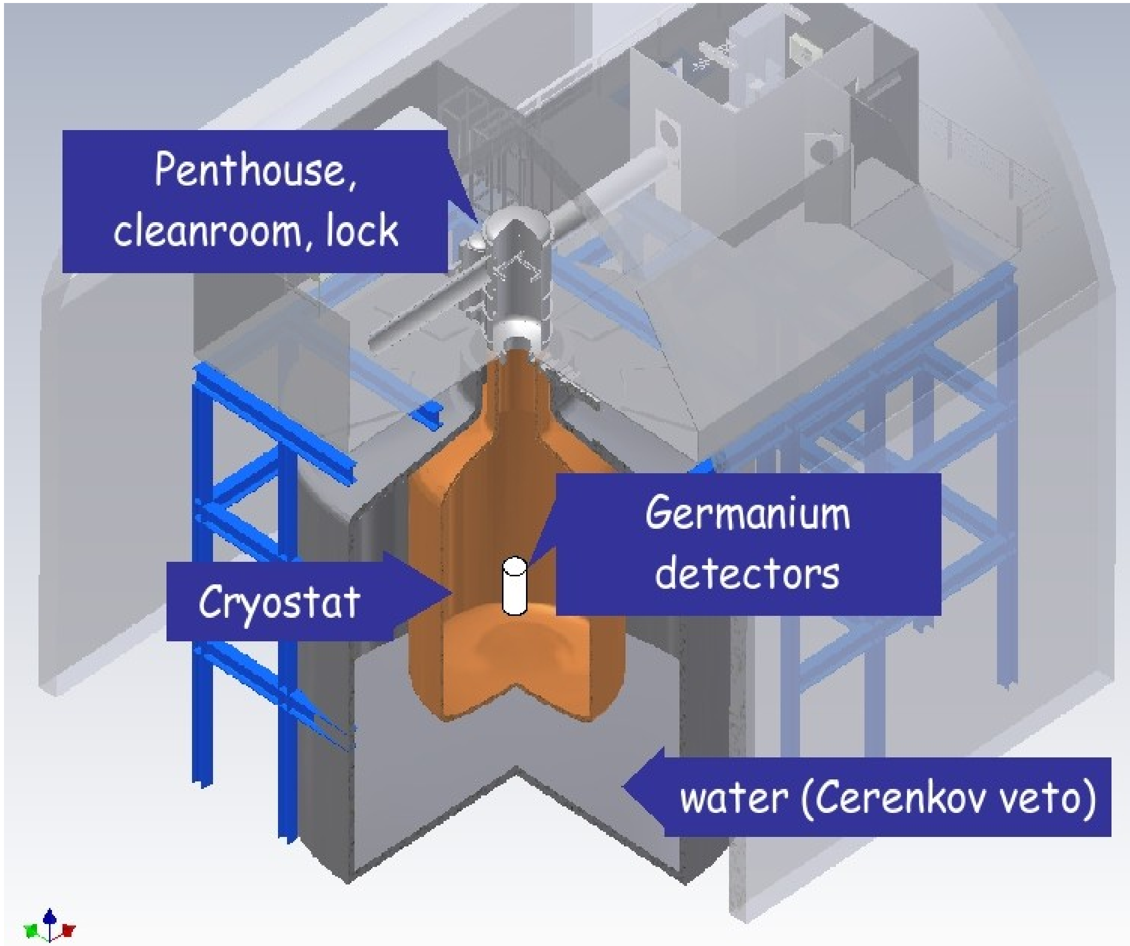
calibration source

Phase I

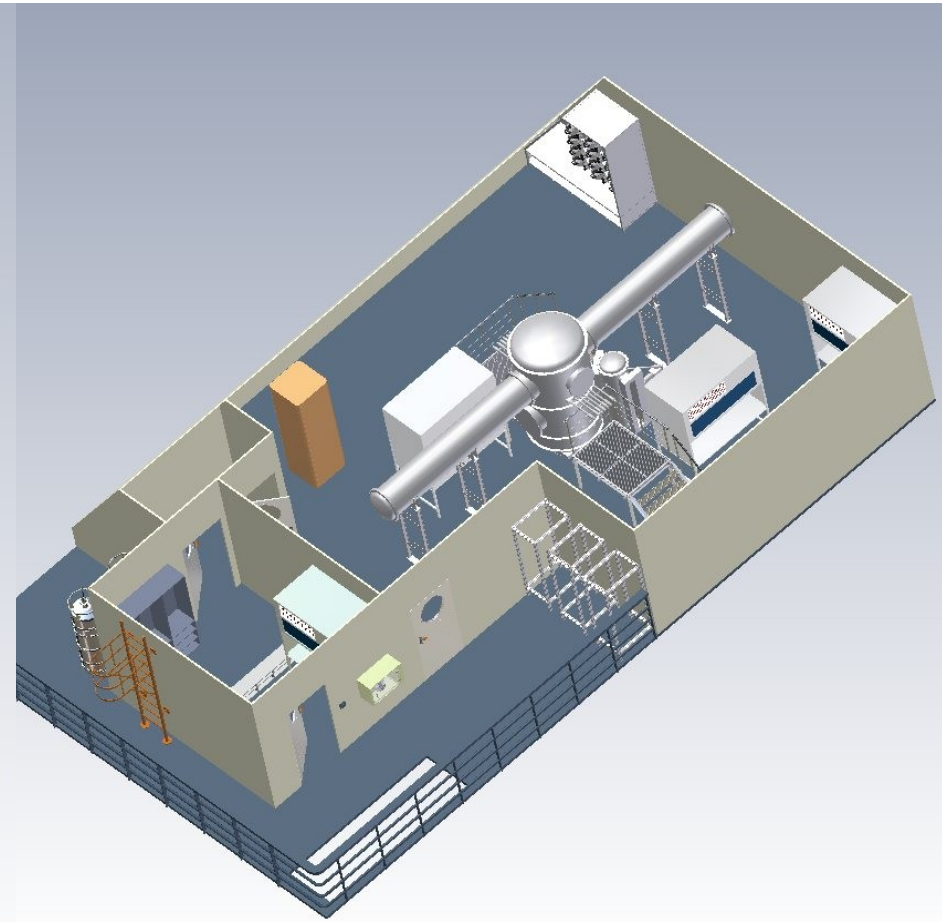


~ 12 g vs. ~ 2 kg

Super-structure and Watertank



Hall A @ LNGS

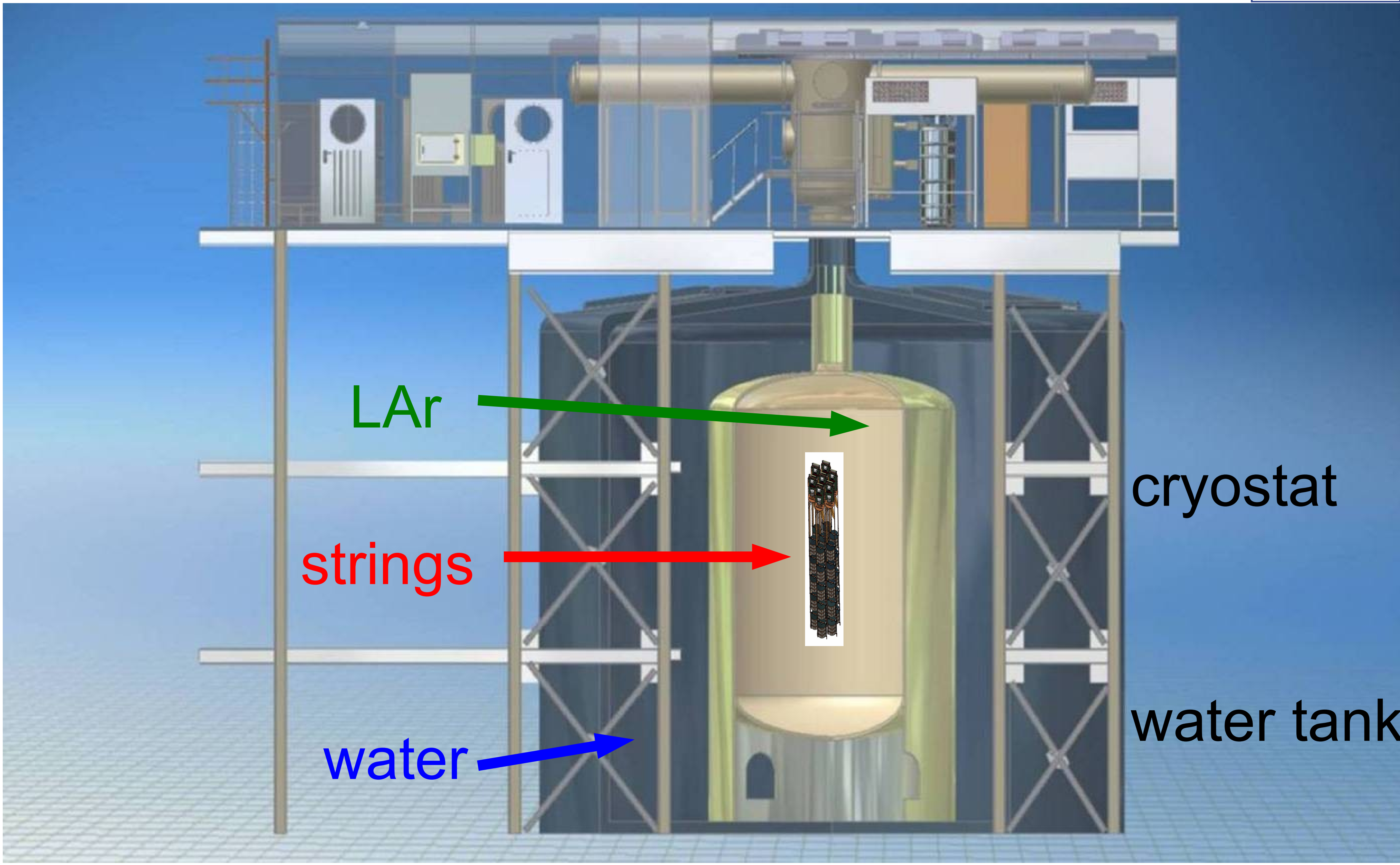


clean room on top

water tank as active muon veto (66 PMTs)

SS cryostat with copper shield, filled with LAr (~70m^3)

GERDA - experimental setup



GERDA – the collaboration

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39 FTE

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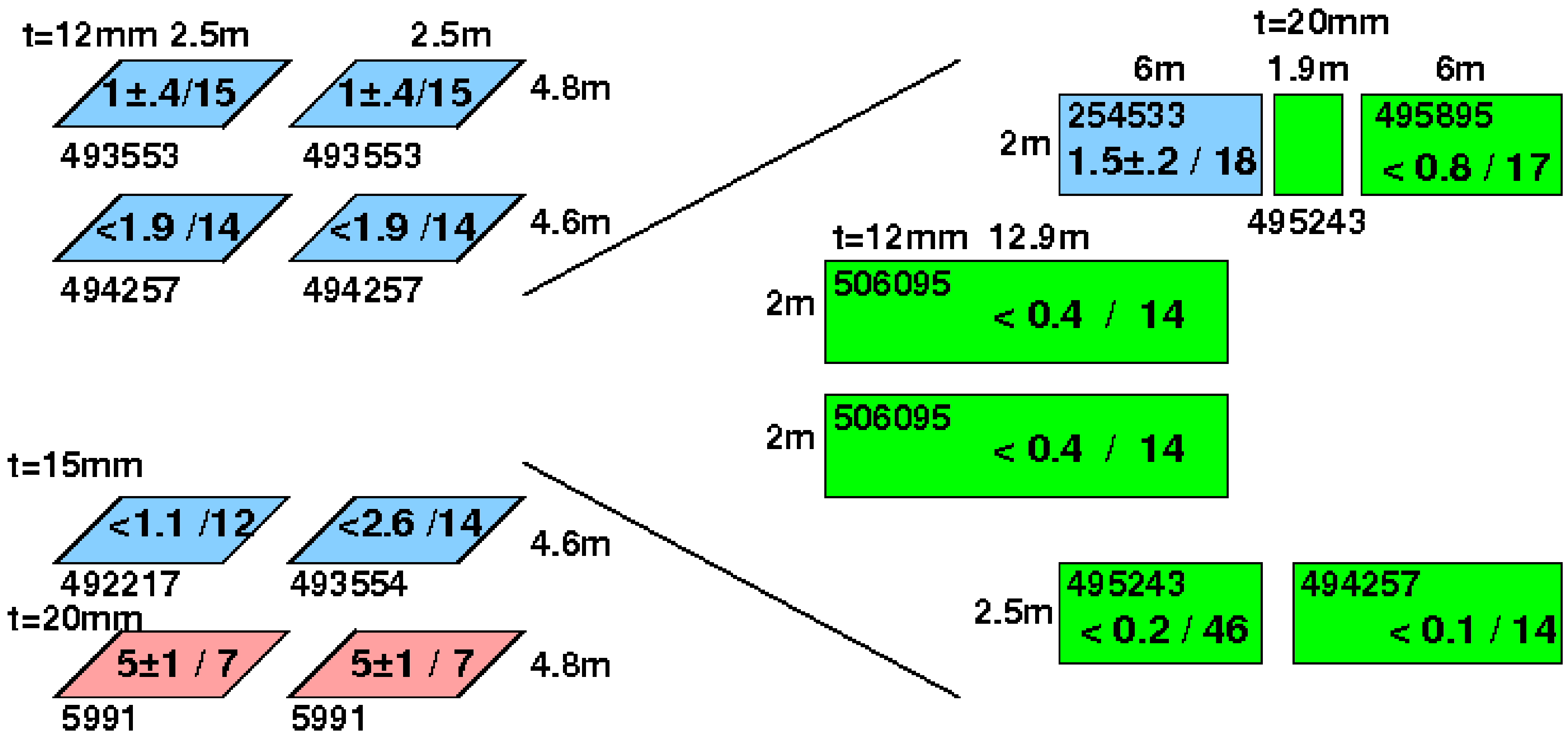
ITEP Moscow, Kurchatov Institute, MPI Physik München,
U. Padova, U. Tübingen, IRMM Geel

Stainless Steel Cryostat

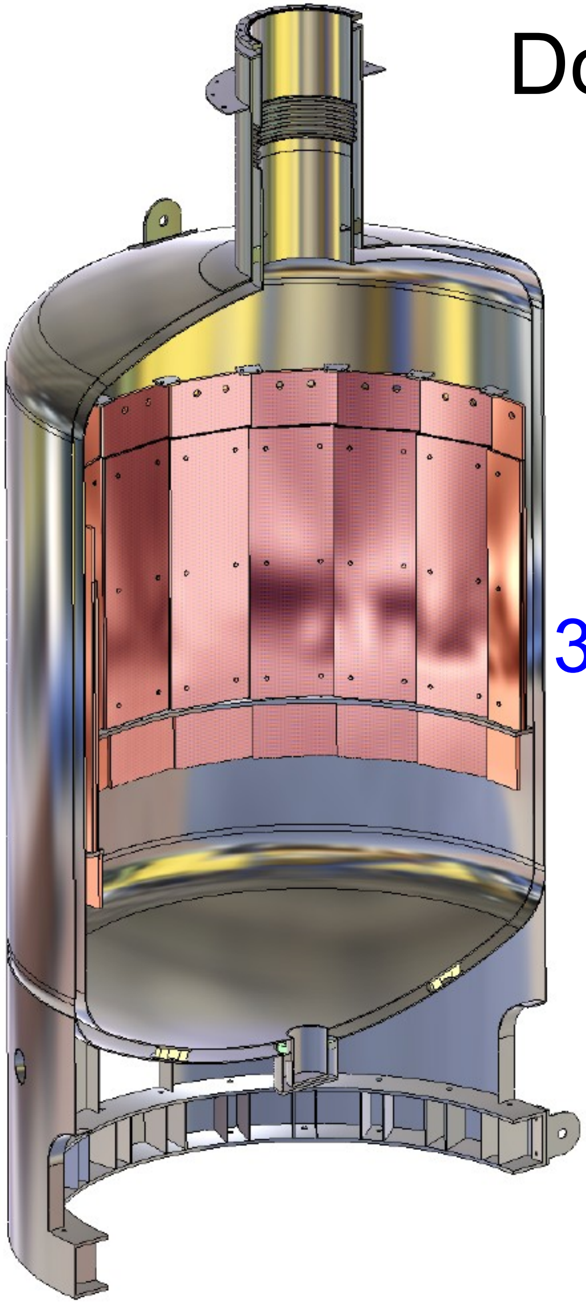
screening of SS sheets from different producers

(~ 27 tons of SS 1.4571)

units: mBq/kg for ^{228}Th and ^{60}Co



Stainless Steel Cryostat



Double walled SS container

reduce Cu shield from 40 to 16 t
(1t ~ 8000 €)

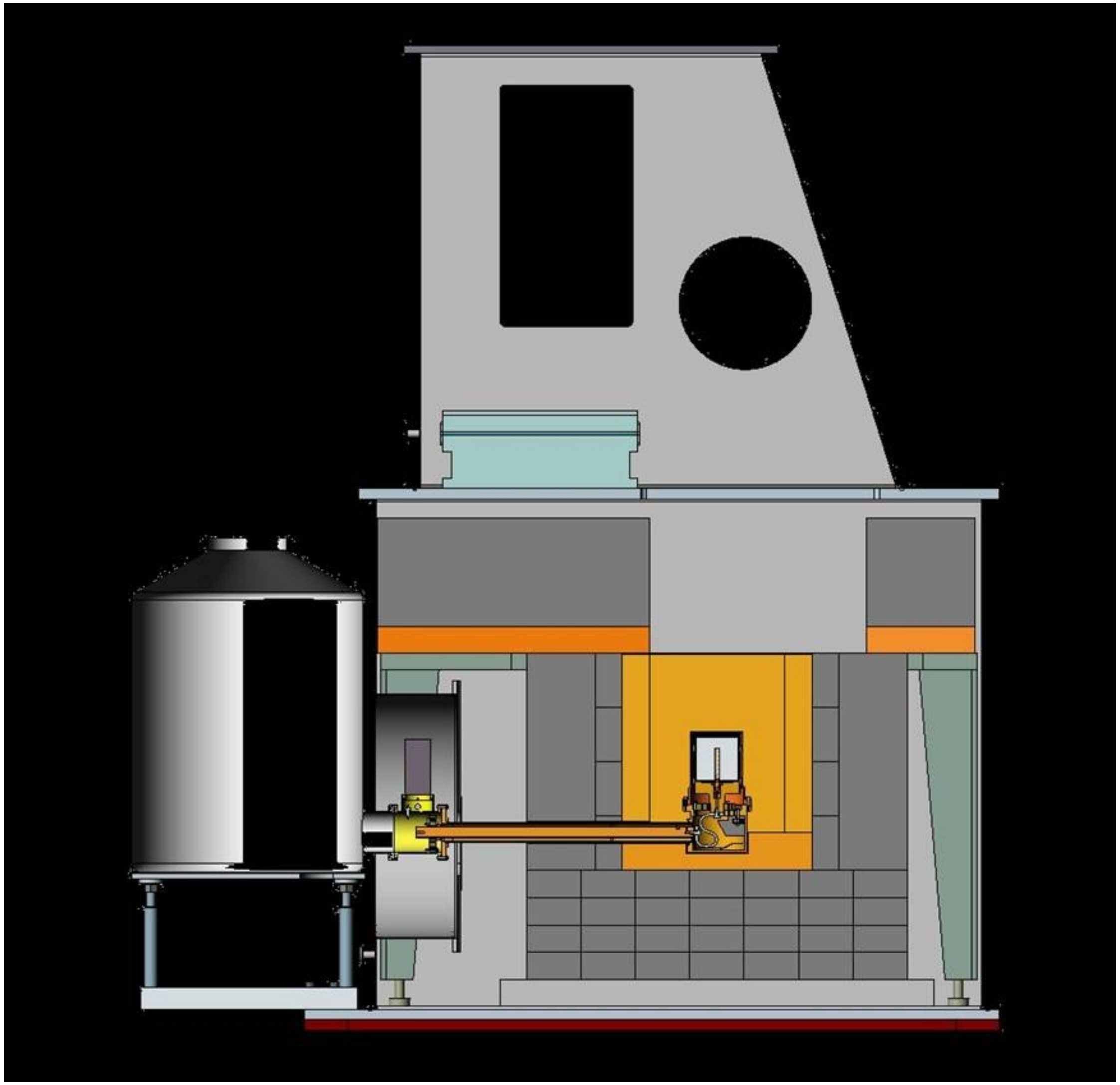
3 – 6cm Cu

Material screening

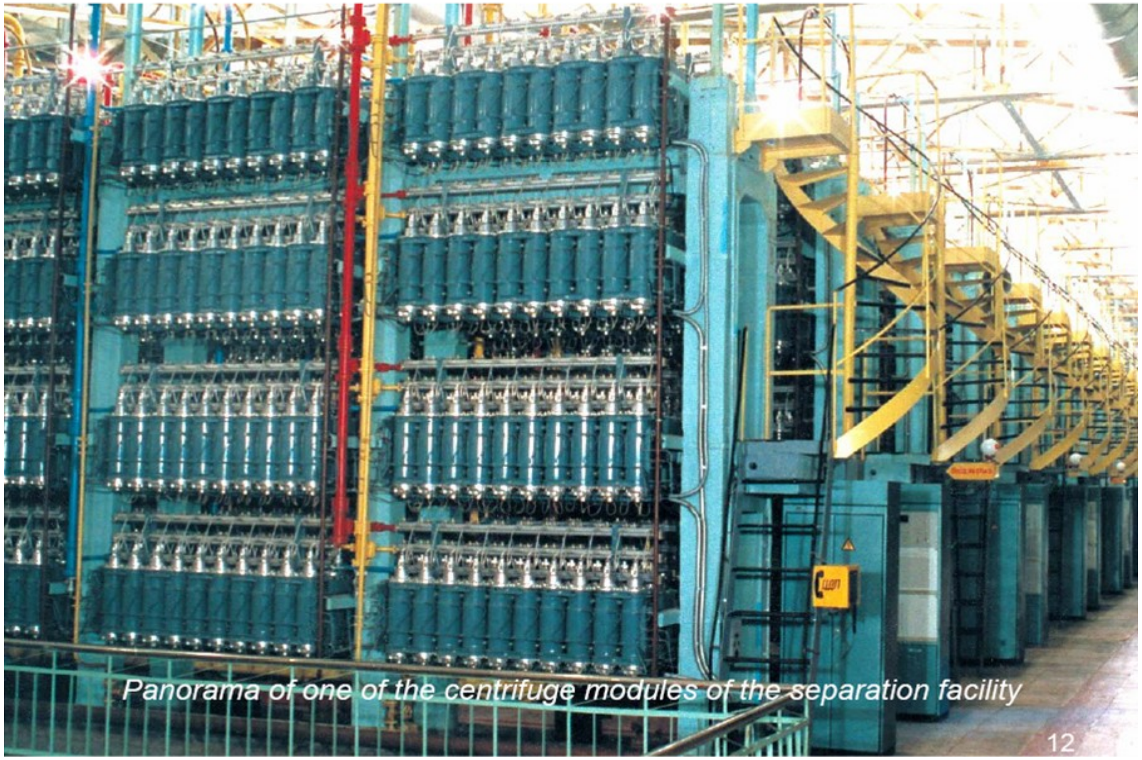
GeMPI
Corrado

several systems
at LNGS & MPI

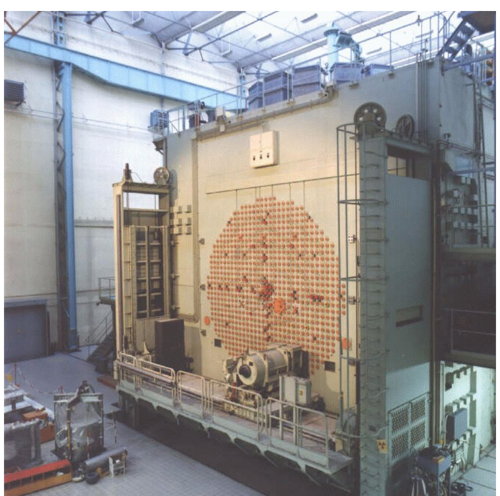
steel
Cuflon
preamps
O-rings



Enrichment and Transport



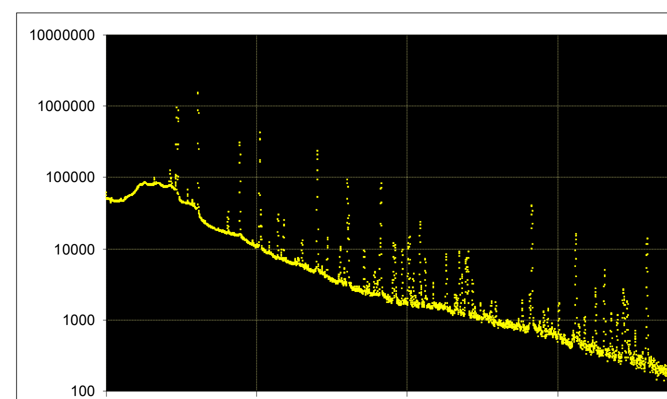
Krasnoyarsk (~Baykal)
37.5 kg enriched GeO_2



Geel, n activation

precise determination of abundance

zone refinement tested on depleted Ge

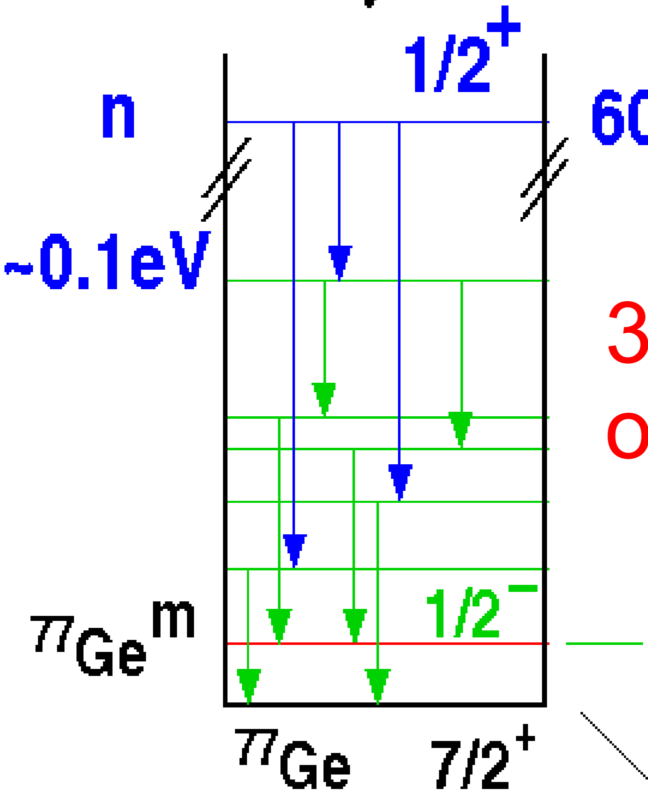


n-capture on ^{76}Ge

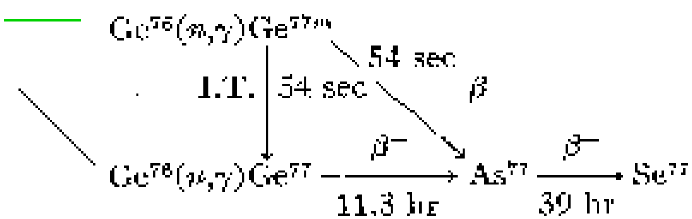
$^{76}Ge(n,\gamma)\,^{77}Ge$

σ = 10/100/140 mb

E_γ=2037.76 keV



36% known
out off >200%



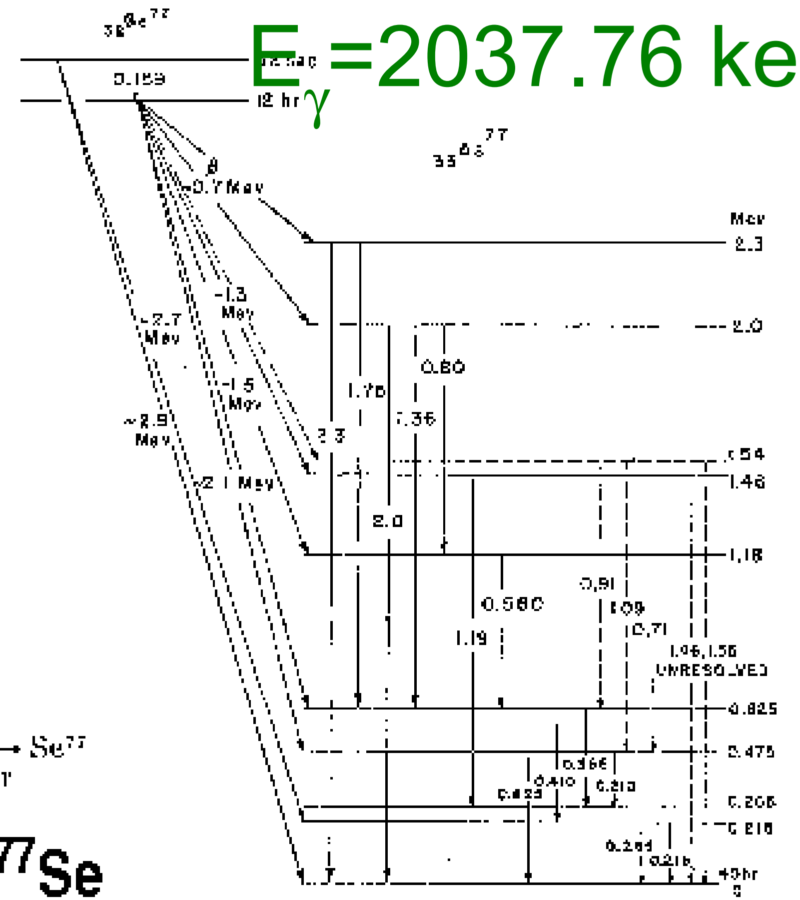


Fig. 6. Decay scheme of $_{32}Ge^{77}$.

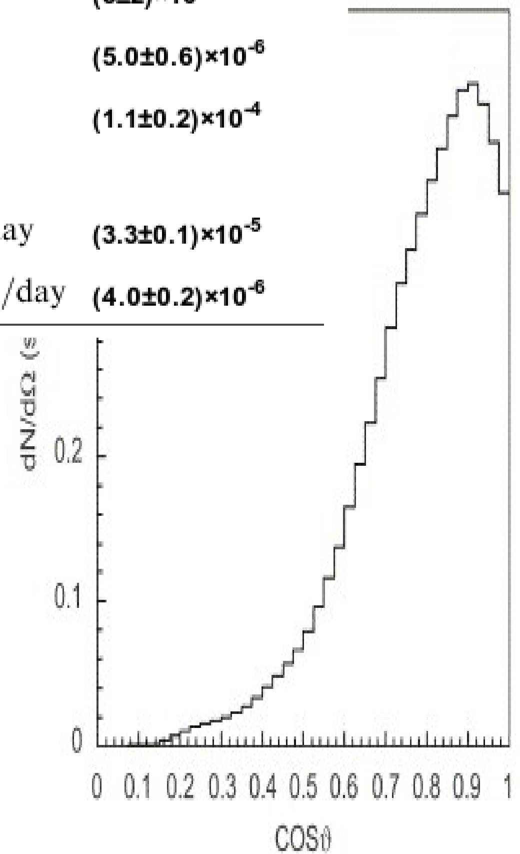
$^{77}Ge \xrightarrow{\beta} {}^{77}As \xrightarrow{\beta} {}^{77}Se$

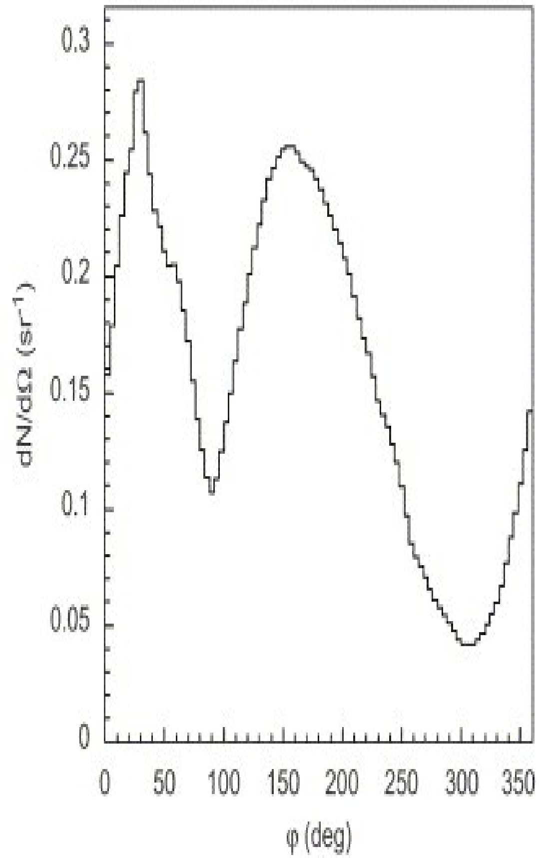
Q_β = 2703 690 keV

Muon induced backgrond

Muon-induced isotope production

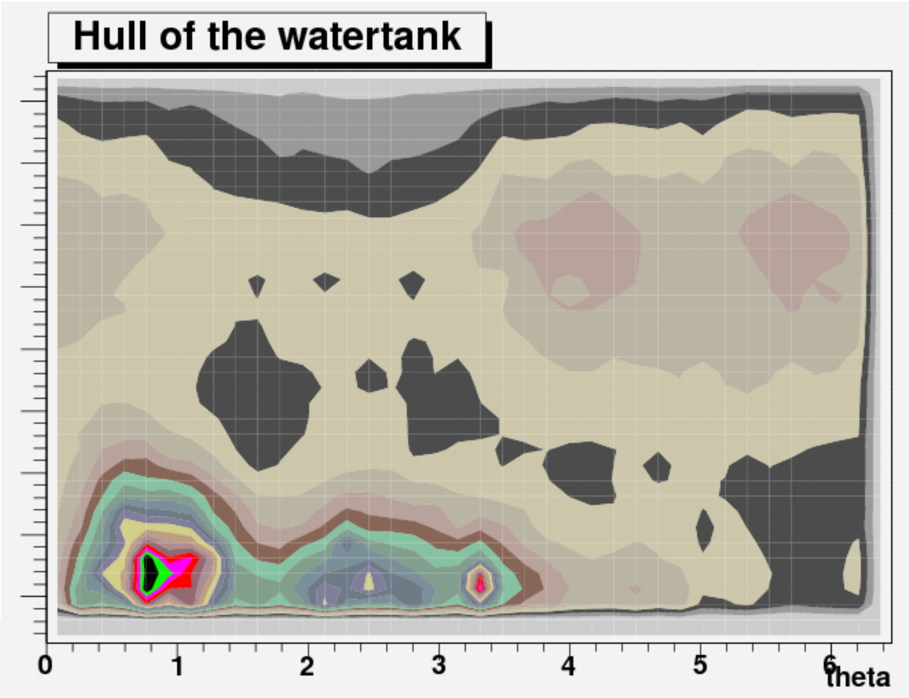
	Nitrogen		Argon	
	nuclei/(kg y)	counts/(kg keV y)	nuclei/(kg y)	counts/(kg keV y)
Isotopes produced in crystals				
$^{74}Ga/^{75}Ga/^{76}Ga$	**<0.08**	**$<3\times10^{-5}$**	**<0.1**	**$<4\times10^{-5}$**
^{68}Ge	**0.07±0.03**	**$(4\pm2)\times10^{-6}$**	**0.08±0.03**	**$(5\pm2)\times10^{-6}$**
^{69}Ge	**0.38±0.08**	**$(1.0\pm0.2)\times10^{-6}$**	**1.8±0.2**	**$(5.0\pm0.6)\times10^{-6}$**
$^{77}Ge/^{77m}Ge$	**0.05±0.03**	**$(1.0\pm0.6)\times10^{-5}$**	**0.51±0.09**	**$(1.1\pm0.2)\times10^{-4}$**
Isotopes produced in cryogenic liquid				
^{38}Cl	–	–	46 ± 1 nucl/day	**$(3.3\pm0.1)\times10^{-5}$**
^{40}Cl	–	–	2.7 ± 0.1 nucl/day	**$(4.0\pm0.2)\times10^{-6}$**

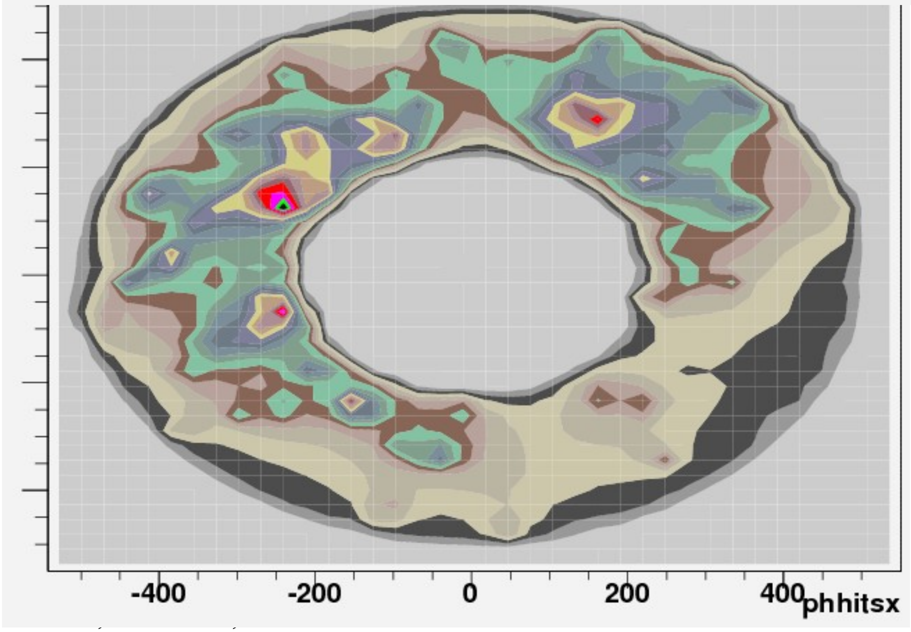




Muon veto necessary

Water Cerenkov veto



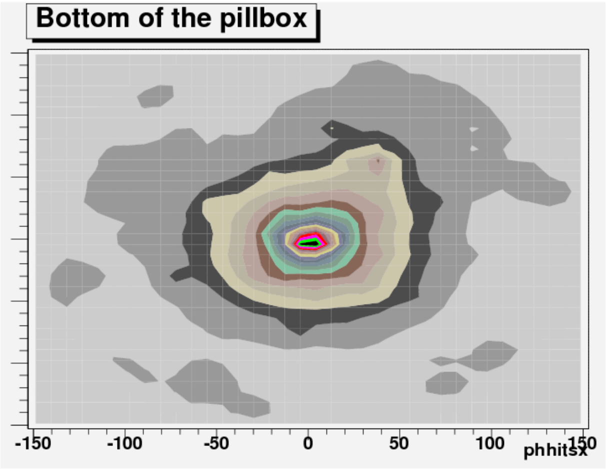


66 PMTs (ETL, 8")

VM2000

(3M,WLS+reflector)

3PMT @ 0,5 pe ~99%

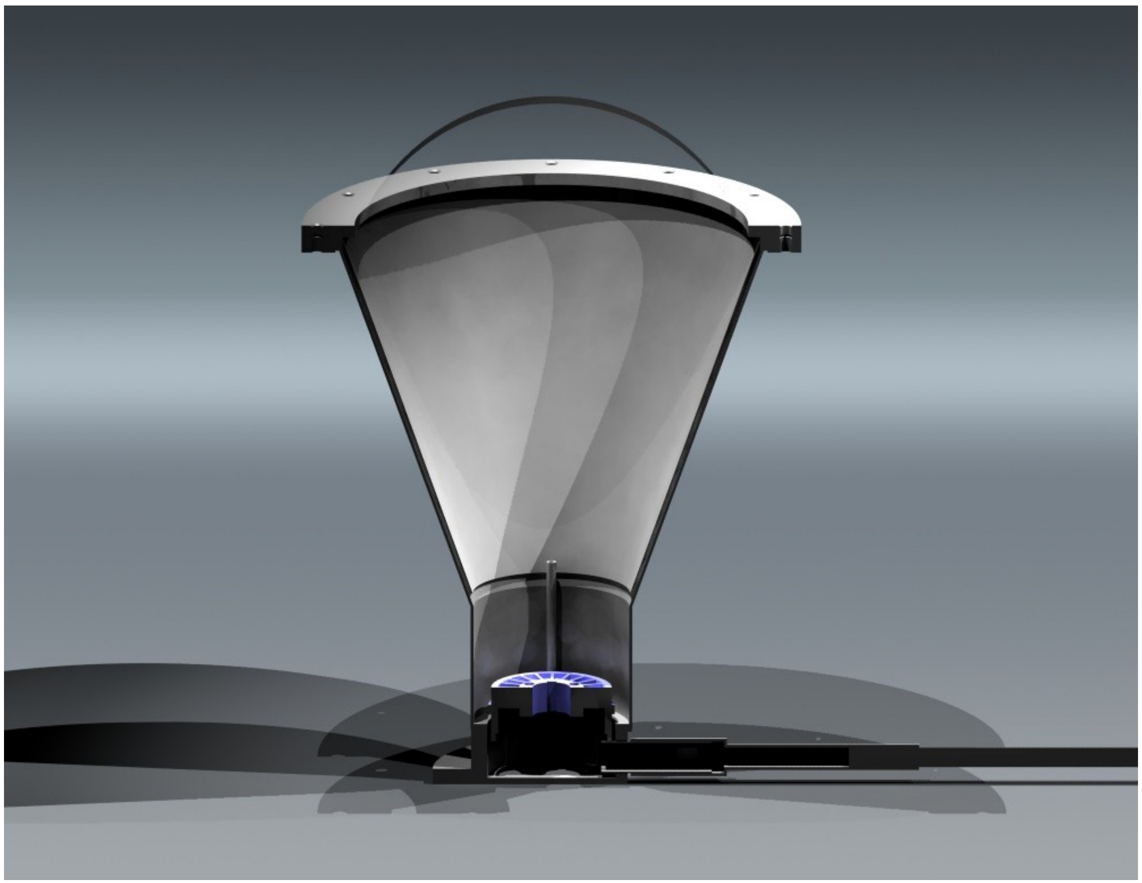


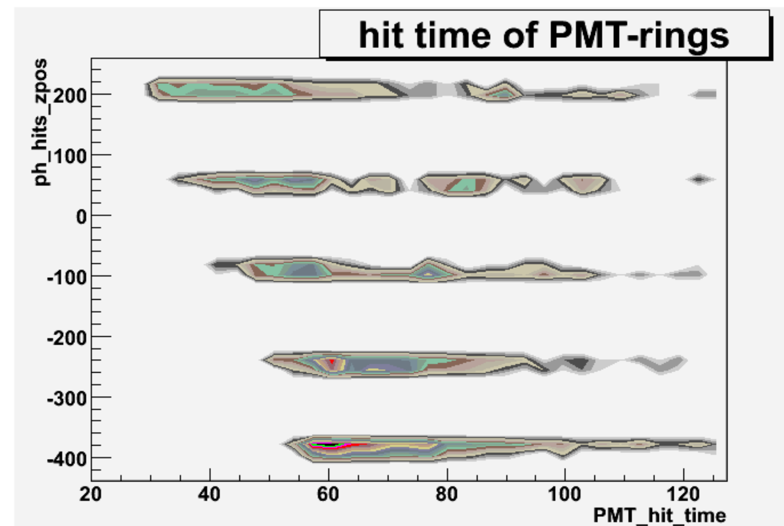
P. Grabmayr

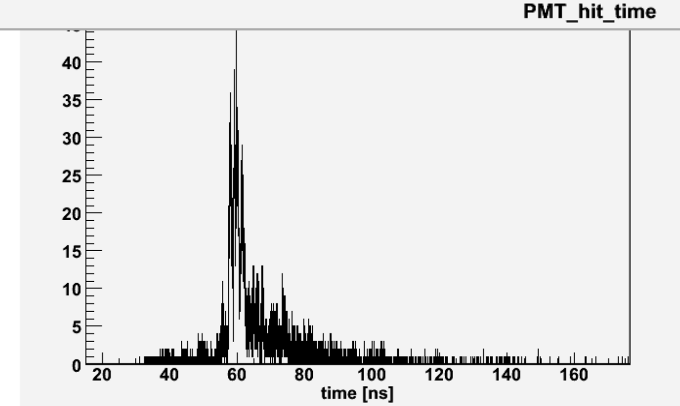
Cerenkov veto

ETL 8" inside capsule with oil

4 rings on wall
+ 2 rings on bottom
+ pillbox





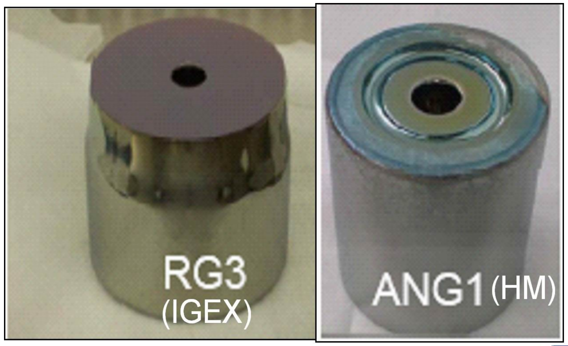


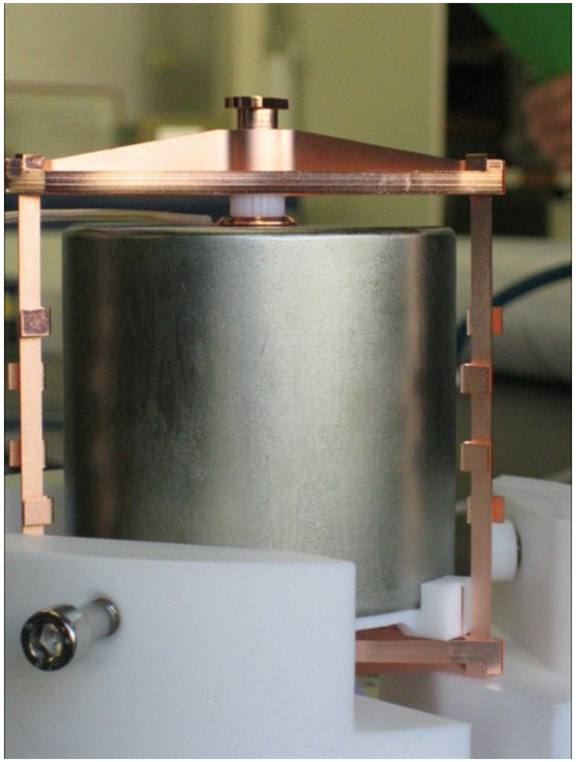
+2mm μ metal-shield

All HDM & IGEX detectors

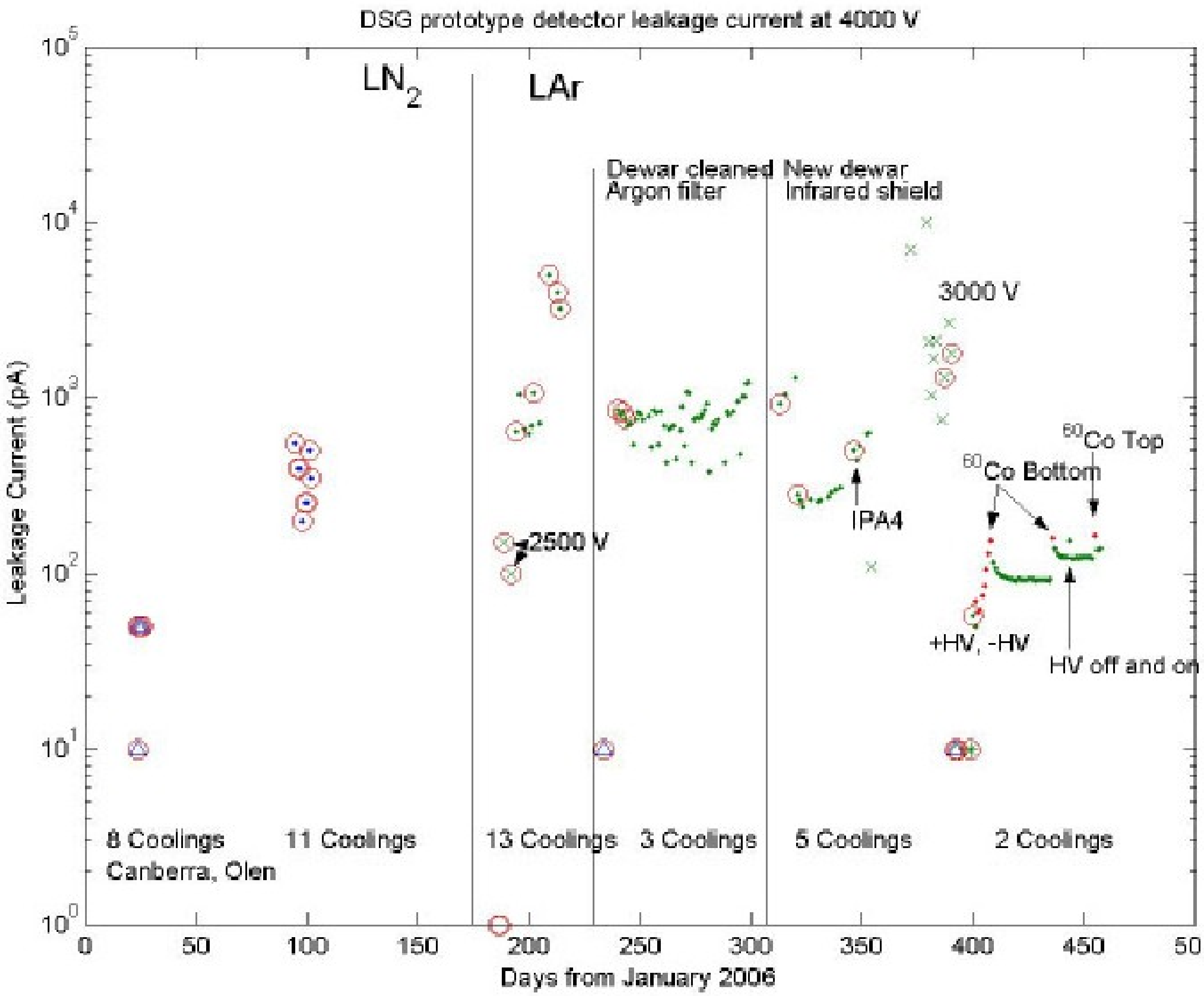
Refurbishing Ge diodes in GDL

GDL: Installation of clean room for diode preparation and tests in LAr





Prototype testing in LN & LAr

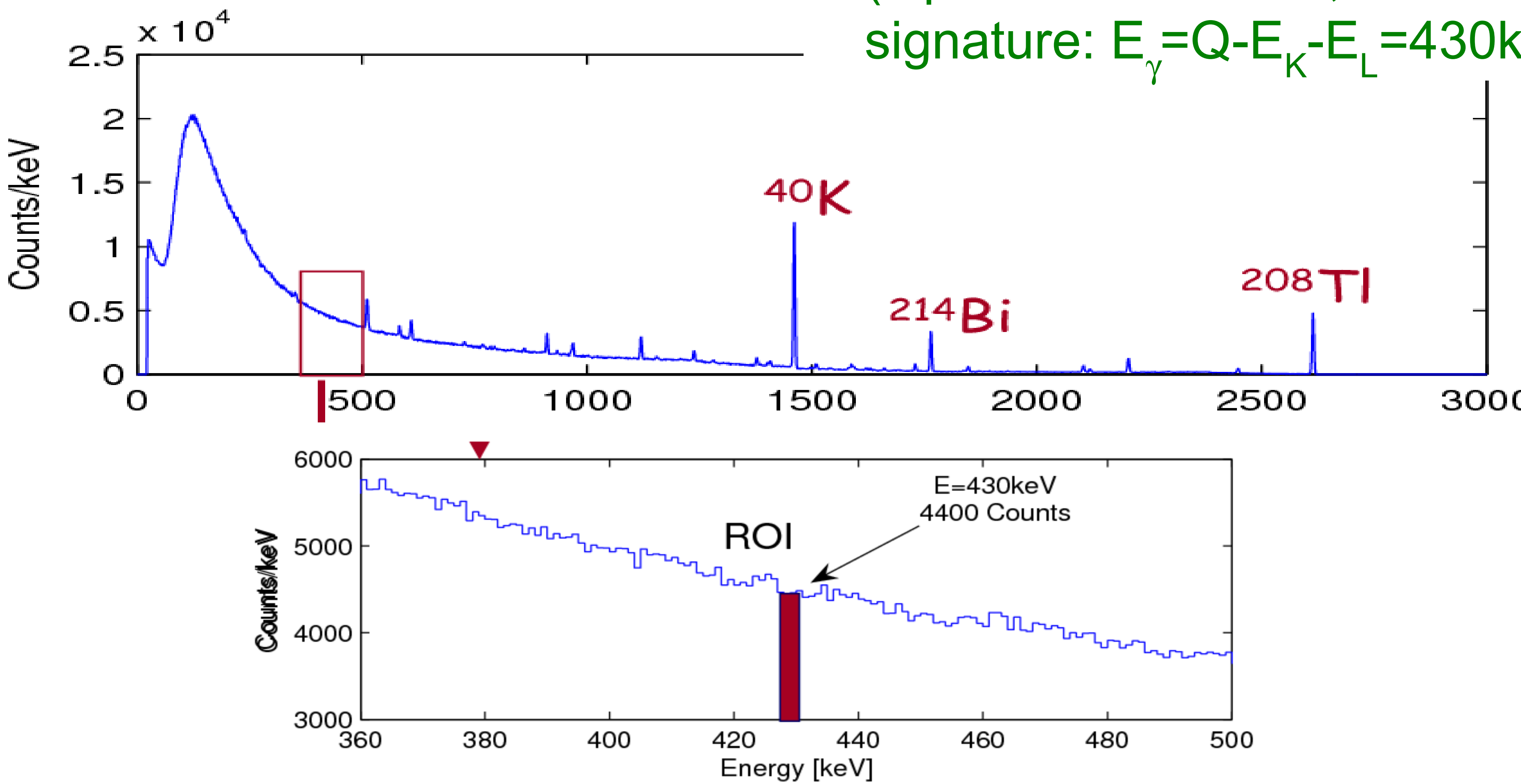


GERDA – LNGS SC meeting, April 18/19, 2007

Physics results in GDL

Within 10 days a limit for 0νECEC on ^{36}Ar:

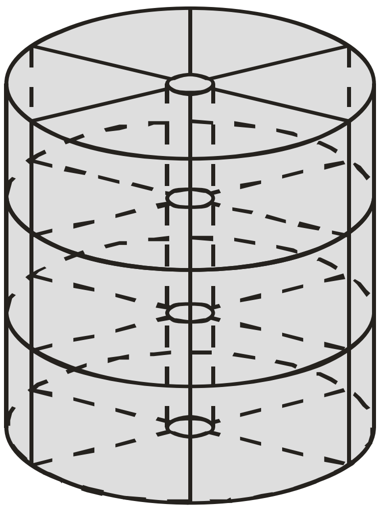
(liquid Ar contains 0,336% ^{36}Ar; signature: $E_{\gamma}=Q-E_K-E_L=430keV$)



$T_{1/2} > 1{,}9 \cdot 10^{18}$ y (68% C.L.) [==> 10^{23} y]

segmentation

Discriminate e/γ by event type: single- or multi-site

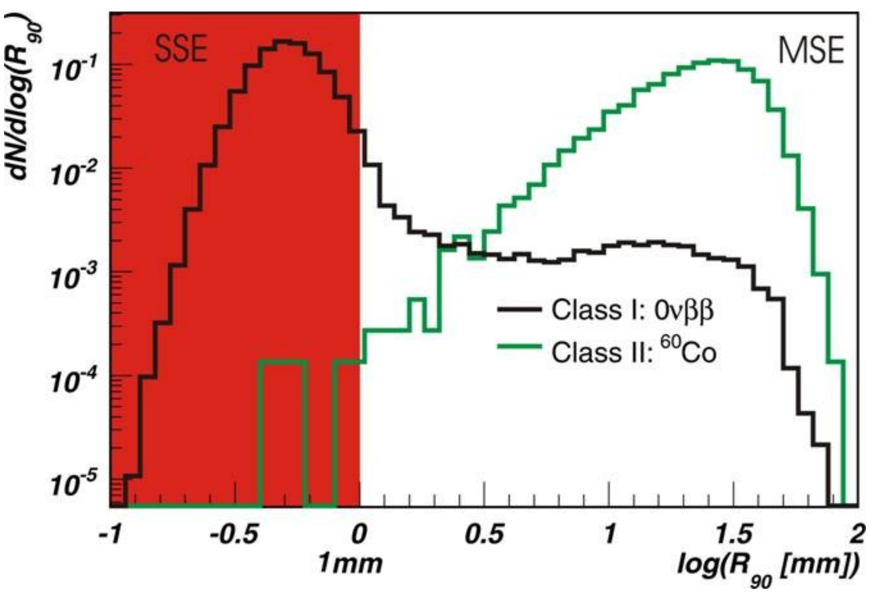


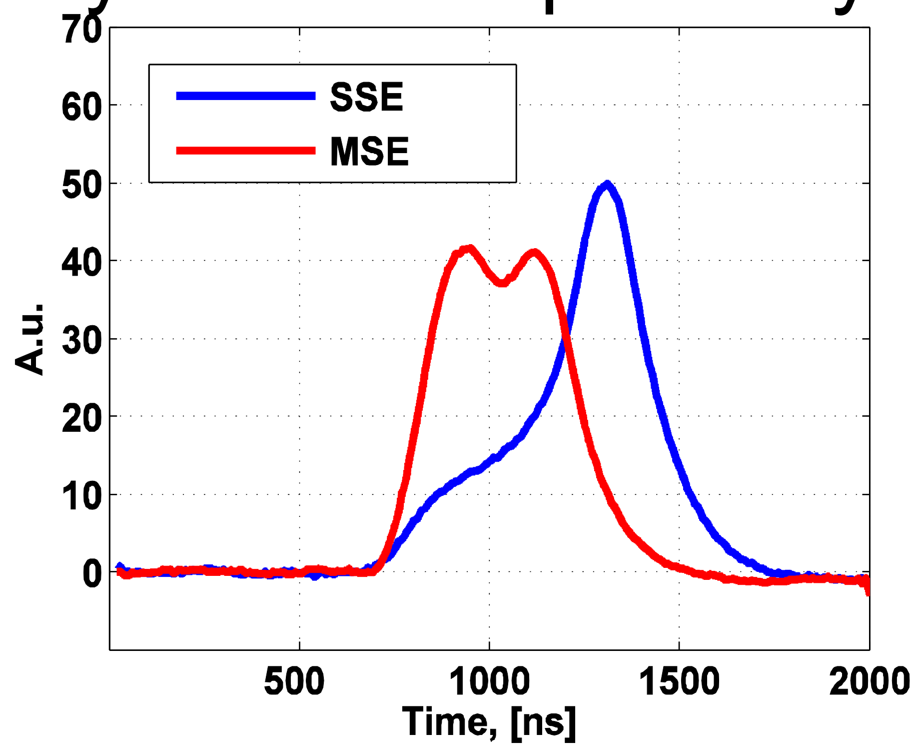
by anti-coincidence between diodes

& segments (6x3 fold)

by Pulse Shape Analysis

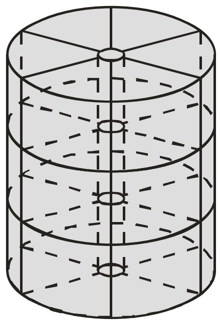
I.Abt et al., NIM A570 (2007) 479

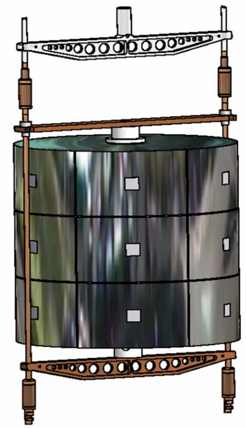


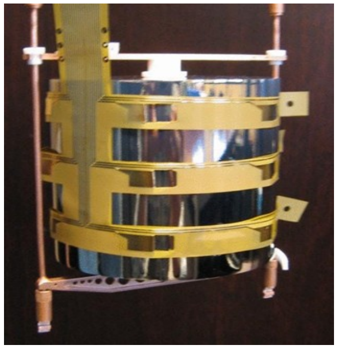


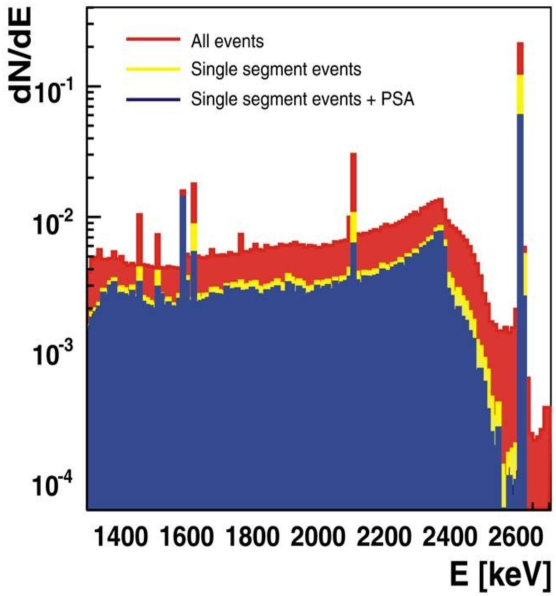
Segmentation

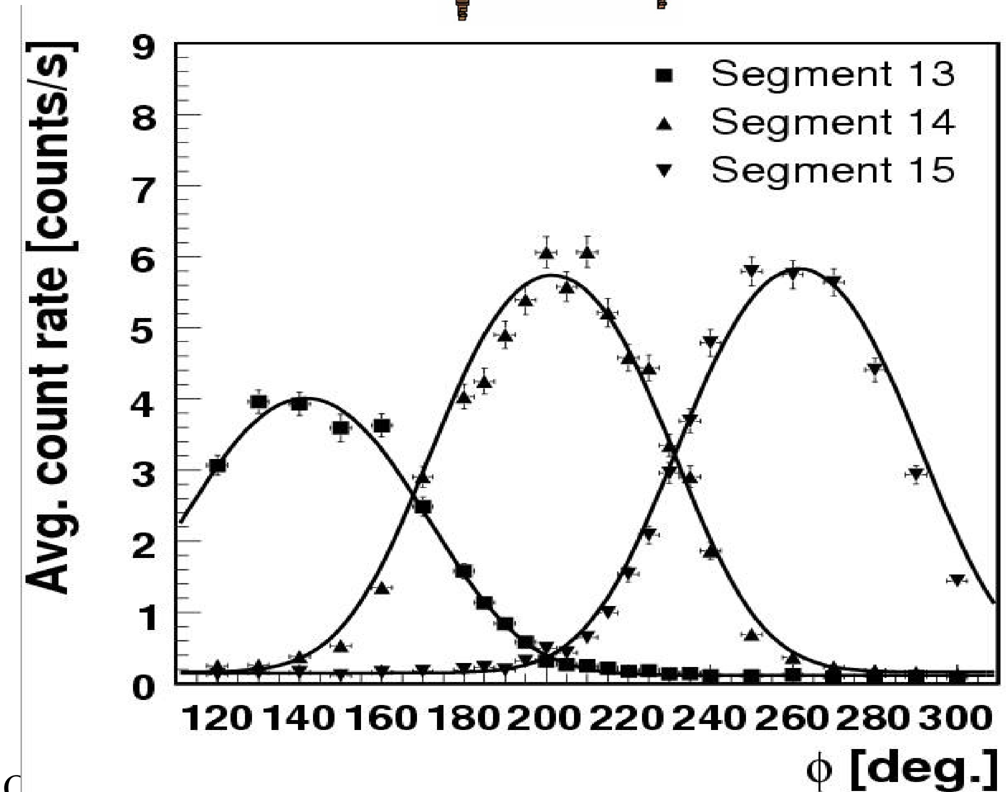
I. Abt et al., NIM A accepted

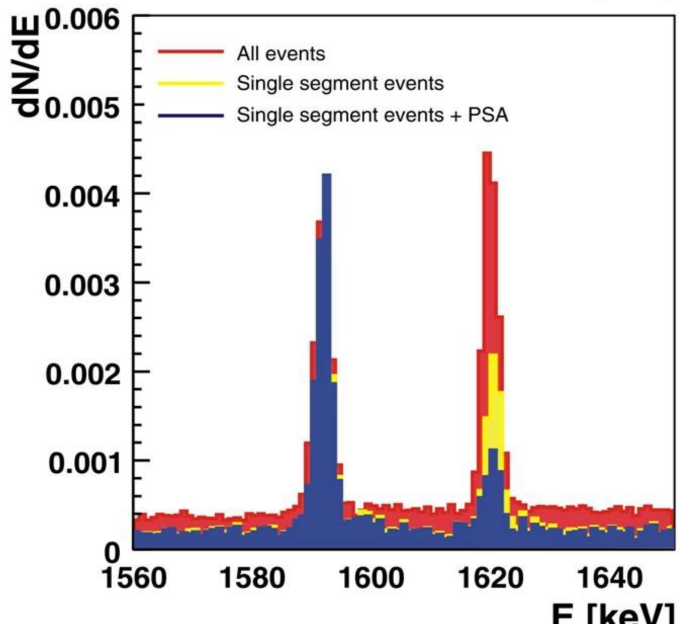










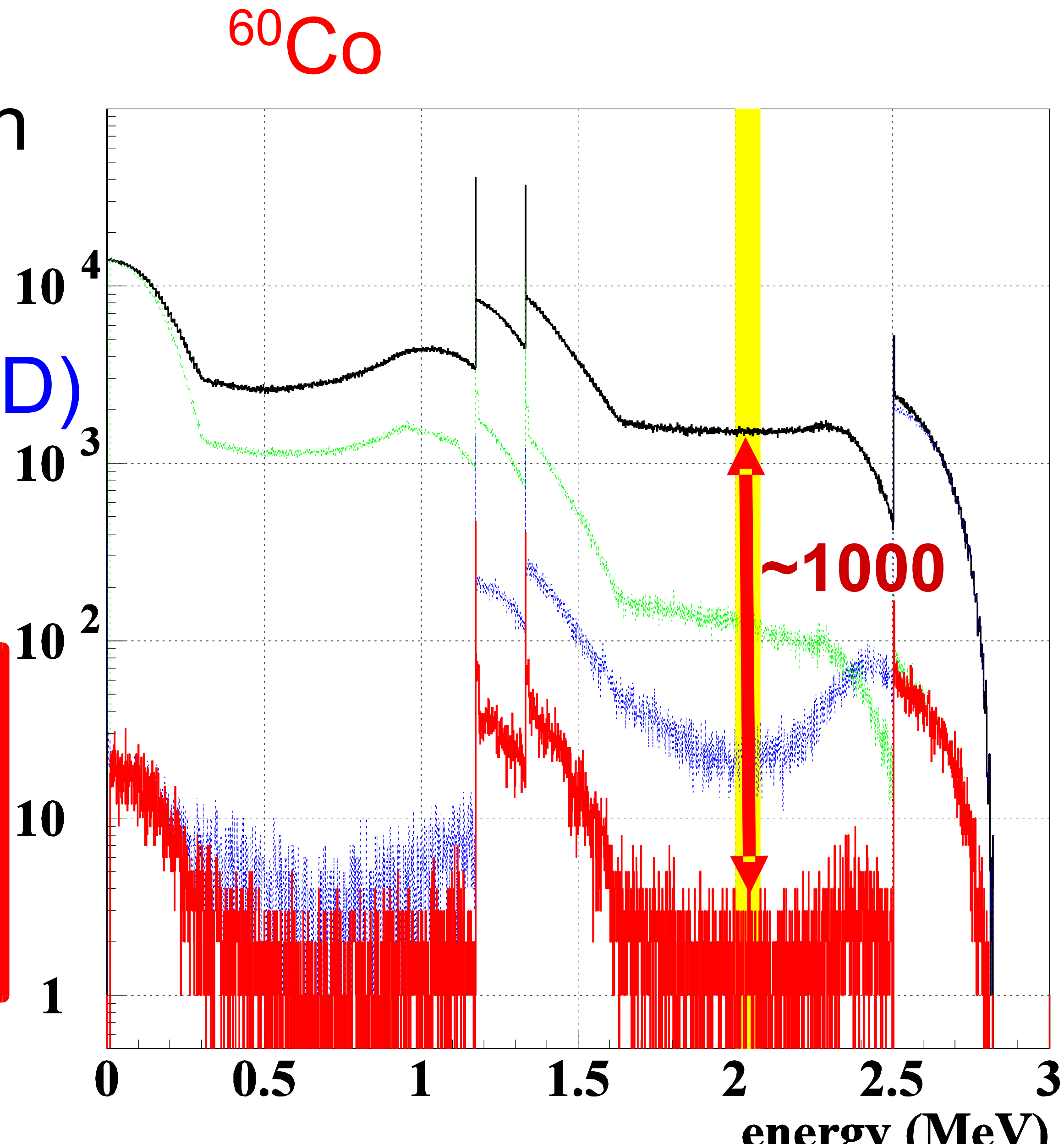


Veto through scintillation in LAr

MC simulation of background reduction through segmentation and scintillation in LAr (R&D) and the combination of both methods.

factor 1000

in ROI @ 2039 keV



Schedule and Outlook

GERDA was constituted in 2004
~80 persons, 39 FTE in 14 institutions

Refurbishment of Hall A complete

Safety concept accepted by LNGS

Watertank & Cryostat ordered in 2006
installation by end 2007,
(to be) complete in 2008

Muonveto: PMT capsules being tested

Lock,clean room and infrastructure being tendered

Prototypes of preamps and cables
available for Phase I
prototyping for Phase II

DAQ & slow control

Schedule and Outlook

detectors:

Phase I

enriched detectors (HDM & IGEX)
presently being refurbished (18.7 kg)
15 kg non enriched detectors available

Phase II

37.5 kg enriched GeO_2 procured
segmented prototype successfully tested
zone refinement for first 'depleted detector'

Schedule and Outlook

Finish setup by end of 2008

verify background level of
< 10^{-2} cts/(kg·y·keV)
for Phase I

count for one year with
17.9 kg ^{76}Ge for
first result on $0\nu2\beta\beta$
.... if he is right

meanwhile: first limit for 0νECEC on ^{36}Ar
$T_{1/2} > 1{,}9 \cdot 10^{18}$ y (68% C.L.)