GERDA

Status and Perspectives

K.T.Knöpfle for the GERDA collaboration
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About 100 members, 19 institutions, 7 countries

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INTRODUCTION
- Motivation
- Goals

STATUS
- Experimental setup
- Preliminary results from Phase I

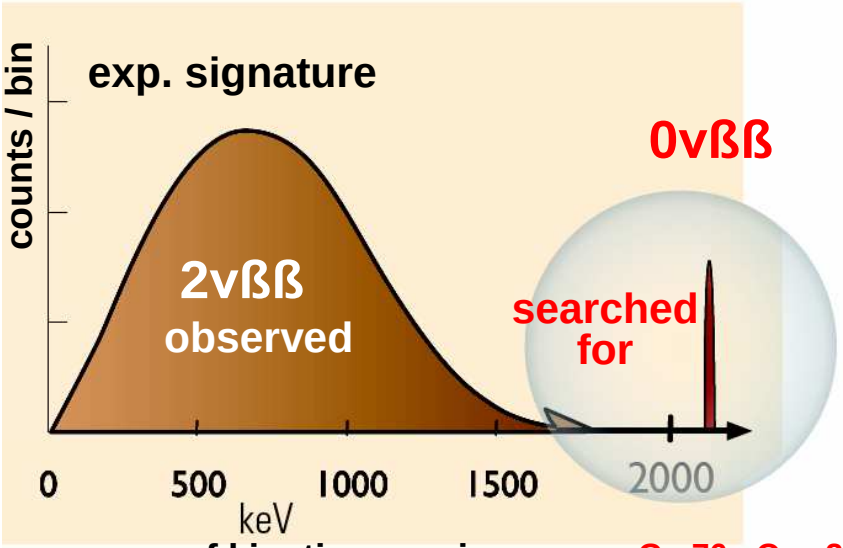
PERSPECTIVES / PHASE II
- Enriched BeGe detectors, improved holders
- LAr scintillation veto

CONCLUSION

Discovery of neutrinoless double beta decay would imply:

- **Lepton number violation ΔL = 2**
- **Neutrino is its own anti-particle, has Majorana mass**
- **Access to absolute neutrino mass scale**
- **Further new physics beyond the standard model**

Until recently (EXO:), best limits for neutrinoless double beta decay from Ge-76 experiments, IGEX and Heidelberg-Moscow (HdM),
$T_{1/2} > 1.9 \cdot 10^{25}$ yr at 90% confidence limit,
as well as claim for evidence by part of HdM collaboration
KKDC, PL B586 (04) 198 (71.7 kg·yr, BI ~ 0.11 cts/(keV·kg·yr)



Ge-76 : $Q_{\beta\beta}$=2039 keV

$$(T_{1/2}^{0\nu})^{-1} = G^{0\nu}(Q,Z)\,|M^{0\nu}|^2\,\langle m_{ee}\rangle^2$$

measured — phase space — nuclear matrix element — deduced

sensitivity*

$$T_{1/2}^{0\nu}(n_\sigma) = \frac{4.16 \times 10^{26} y}{n_\sigma} \left(\frac{\varepsilon a}{W}\right) \sqrt{\frac{Mt}{b\Delta(E)}}$$

detection efficiency (=1 if source=detector)

86%

72 kg yr
exposure [kg yr]

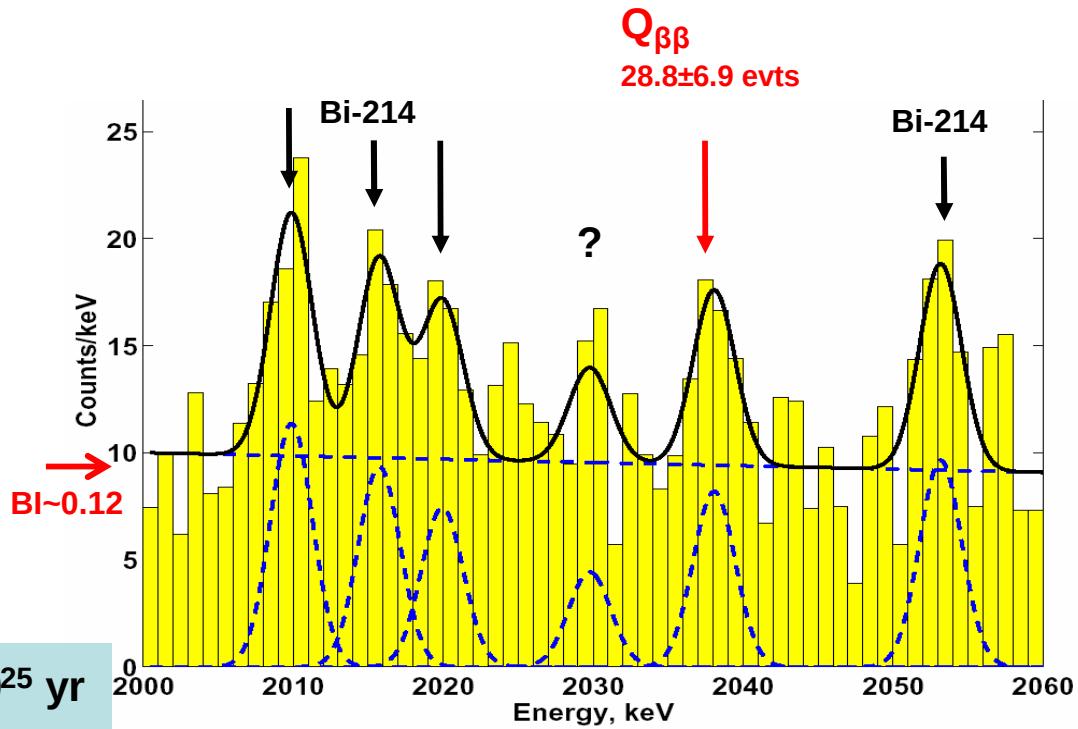
achieved with ^{76}Ge

~3.6 keV
instrumental spectral width

molecular weight
of source

background index (BI) [cts/(keV·kg·yr)]
~0.1

*RevModPhys 80(08)481



KKDC: 71.7 kg·yr: $T_{1/2} = 1.2(0.7\text{-}4.2)\cdot10^{25}$ yr
$\langle m_{\beta\beta} \rangle$ = 0.44 (0.24 – 0.58) eV (3σ)

detection efficiency (=1 if source=detector) (0.71)

86% (81)

72 kg yr (32.5)
exposure [kg yr]

sensitivity*

$$T_{1/2}^{0\nu}(n_\sigma) = \frac{4.16 \times 10^{26} y}{n_\sigma} \left(\frac{\varepsilon a}{W}\right) \sqrt{\frac{Mt}{b\Delta(E)}}$$

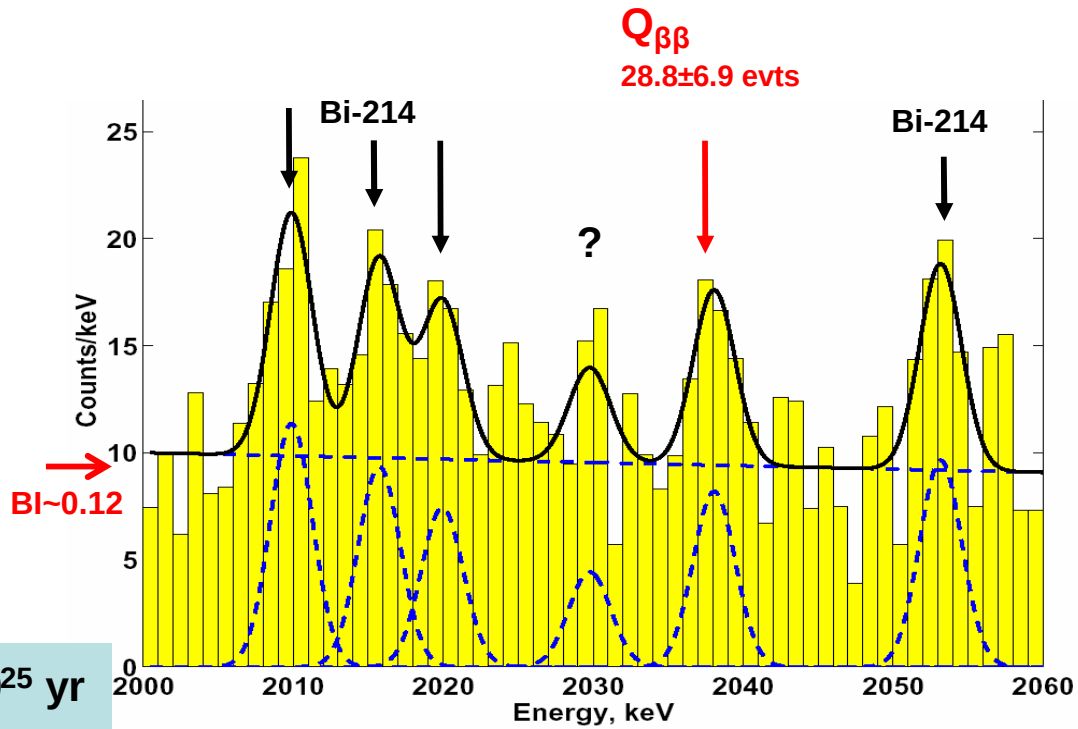
achieved with ^{76}Ge (^{136}Xe)

~3.6 keV (96)
instrumental spectral width

molecular weight
of source

background index (BI) [cts/(keV·kg·yr)]
~0.1 (0.0015)

*RevModPhys 80(08)481



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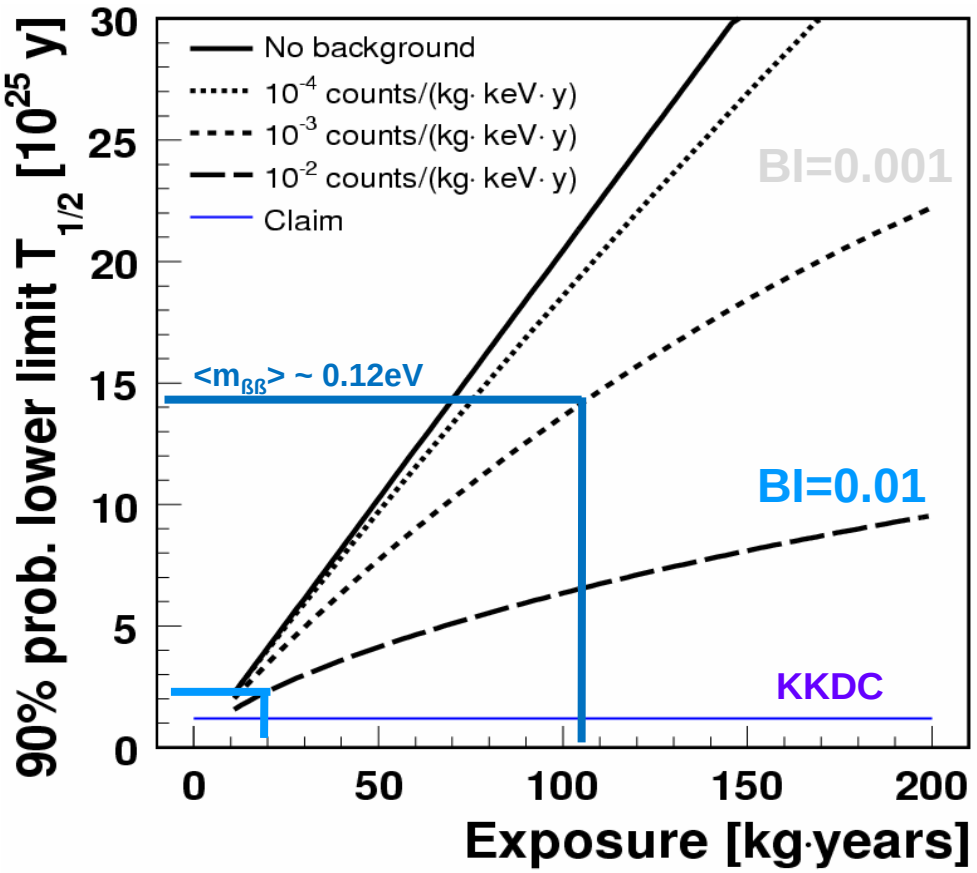
Reach background index (BI) at $Q_{\beta\beta}$ = 2039 keV of 0.01 / 0.001 cts / (keV·kg·yr) !



phase II :
add new enriched Ge-76 detectors, 20 kg
BI ~ 0.001 cts / (keV·kg·yr)
► 37.5 kg enriched Ge-76 bought
35 kg · 3 yr exposure

phase I :
use Ge-76 diodes of HD-Moscow & IGEX
~18 kg
BI ~ 0.01 cts / (keV·kg·yr)
intrinsic background expected

phase III: depending on results worldwide collaboration for real big experiment
close contacts & MoU with MAJORANA collaboration

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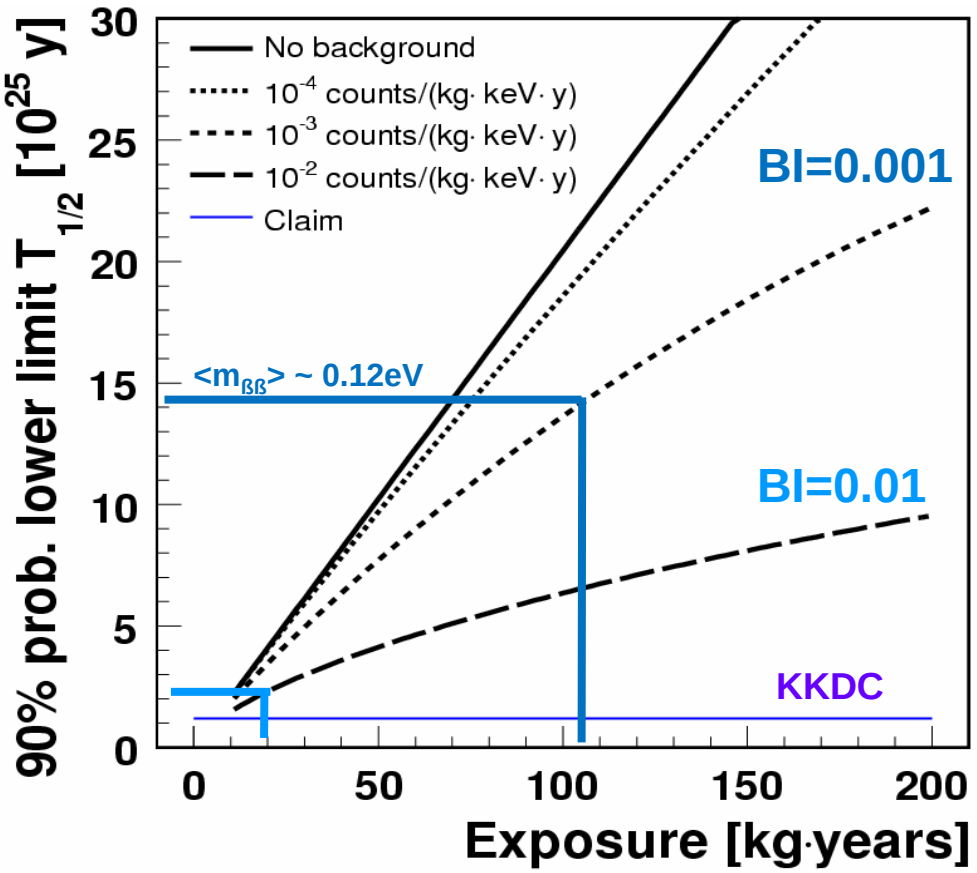

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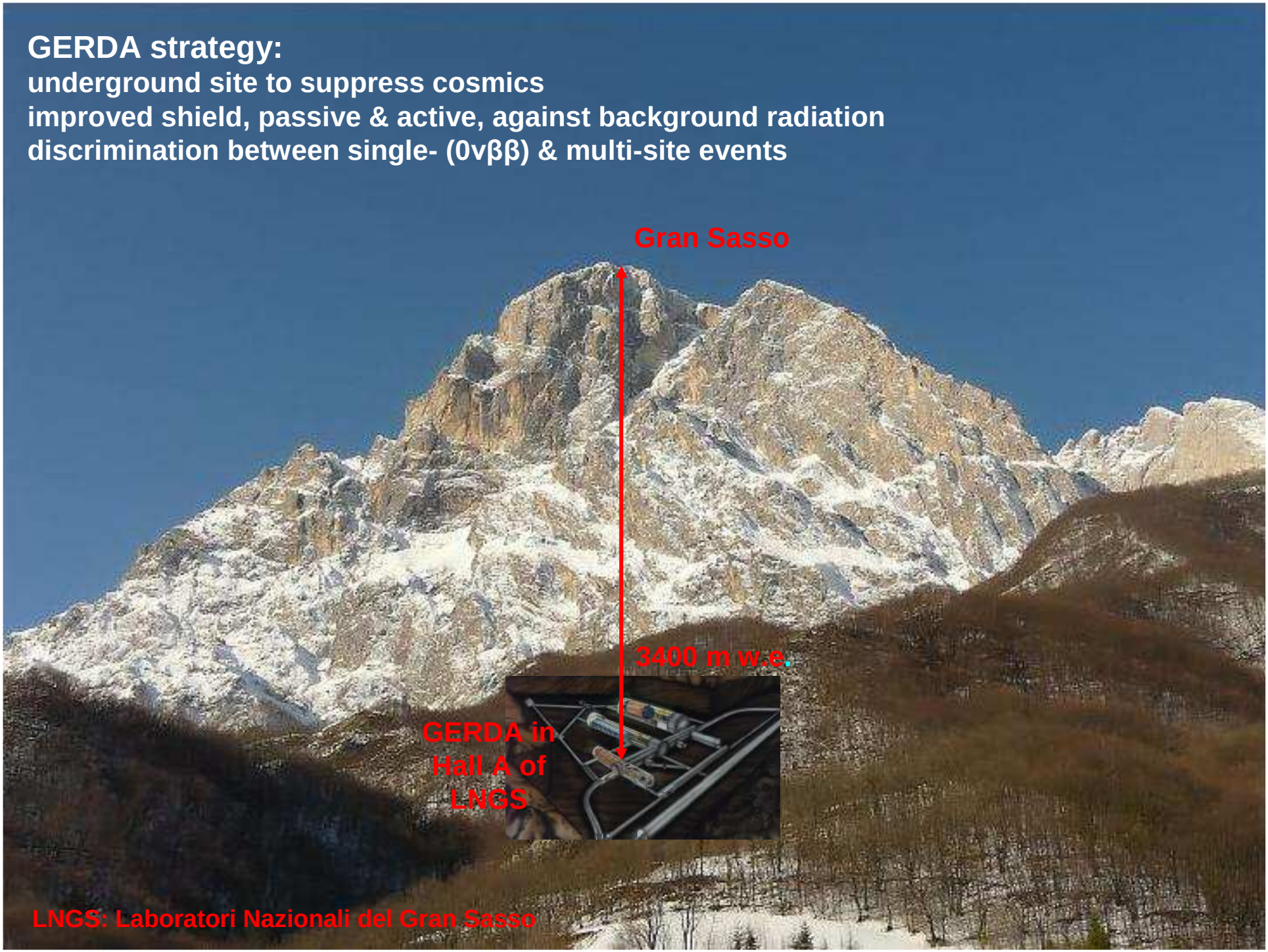
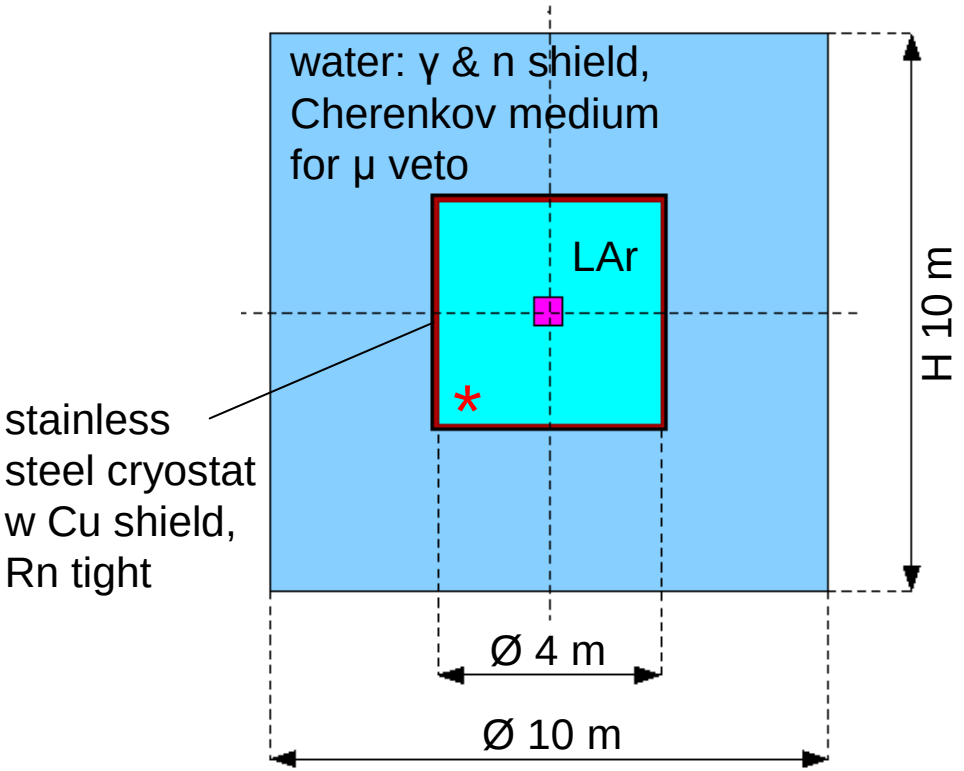
GERDA strategy:
underground site to suppress cosmics
improved shield, passive & active, against background radiation
discrimination between single- (0νββ) & multi-site events



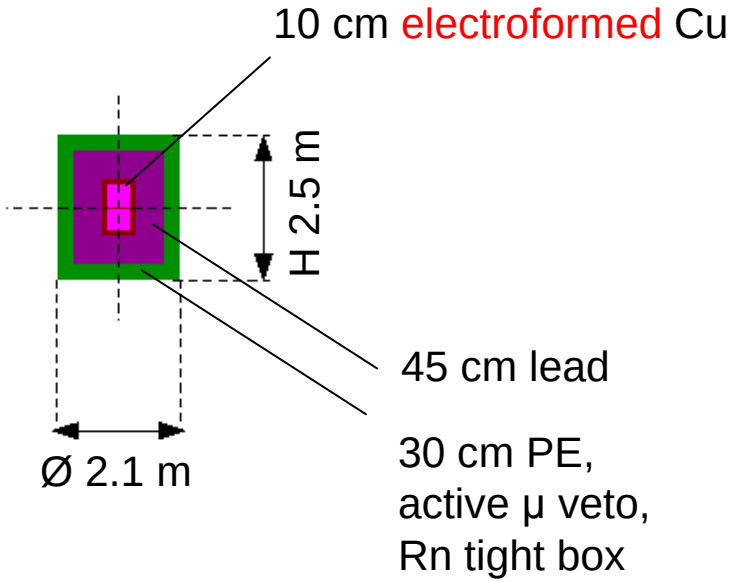
generic shields against background

GERDA: low Z shield, underground
bare Ge diodes in high-purity LAr



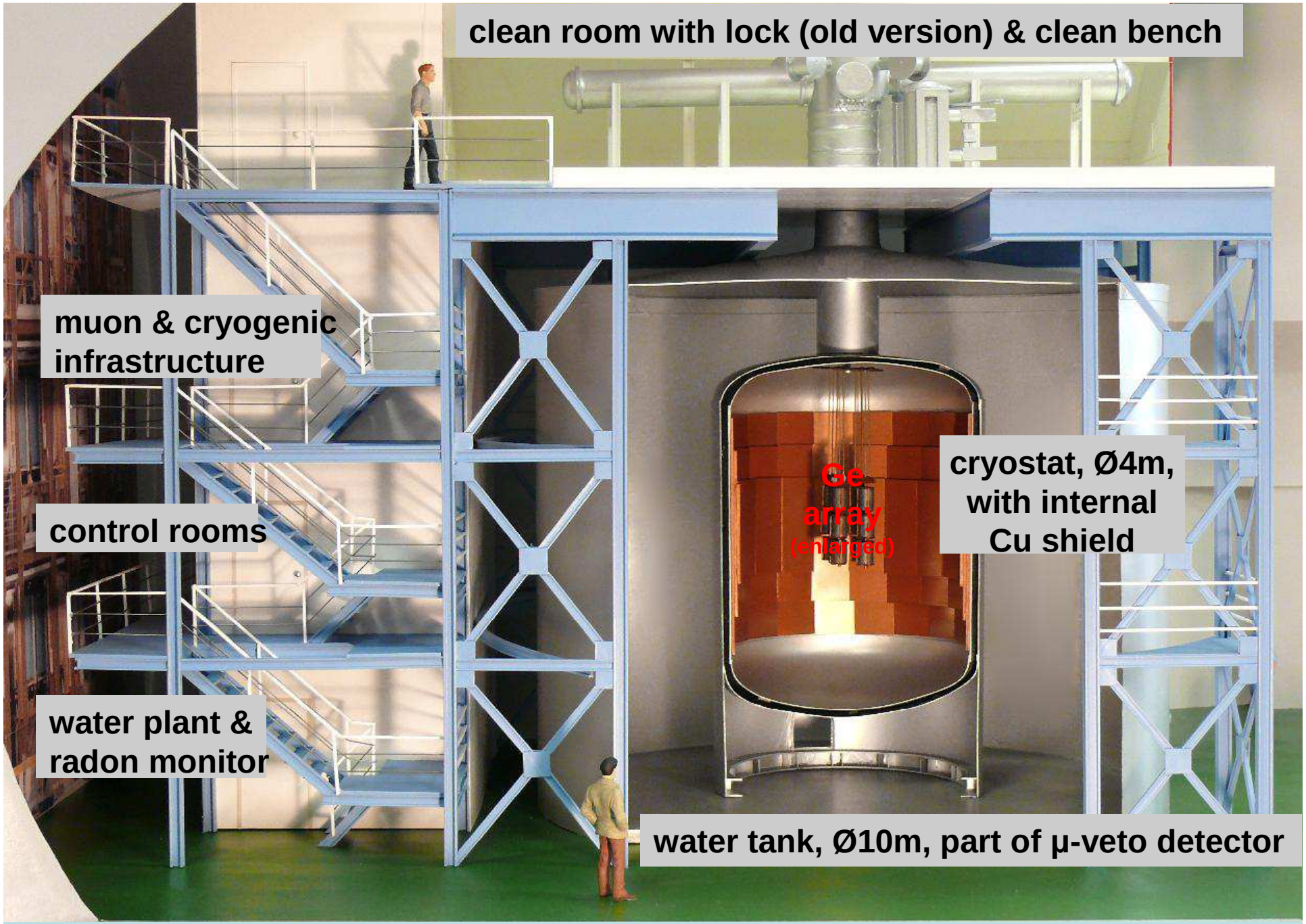
* LAr can be also active shield!

MAJORANA: high Z, deep underground
Ge diodes housed in vacuum cryostat,
ultra-high-purity electroformed Cu shield



α(LAr) = 0.050/cm α(Cu) = 0.34/cm
α(H_2O) = 0.043/cm α(Pb) = 0.48/cm

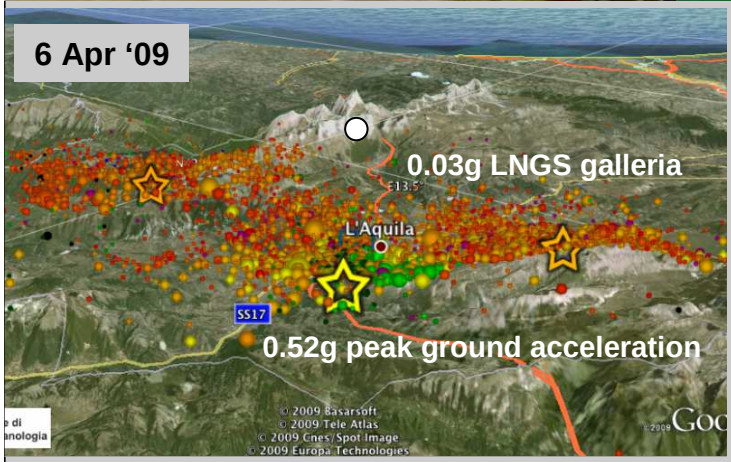
GERDA Setup

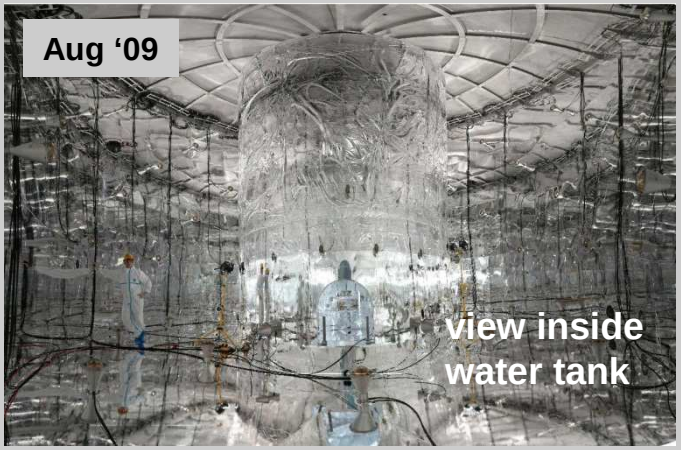

clean room with lock (old version) & clean bench
muon & cryogenic infrastructure
control rooms
water plant & radon monitor
Ge array (enlarged)
cryostat, Ø4m, with internal Cu shield
water tank, Ø10m, part of μ-veto detector

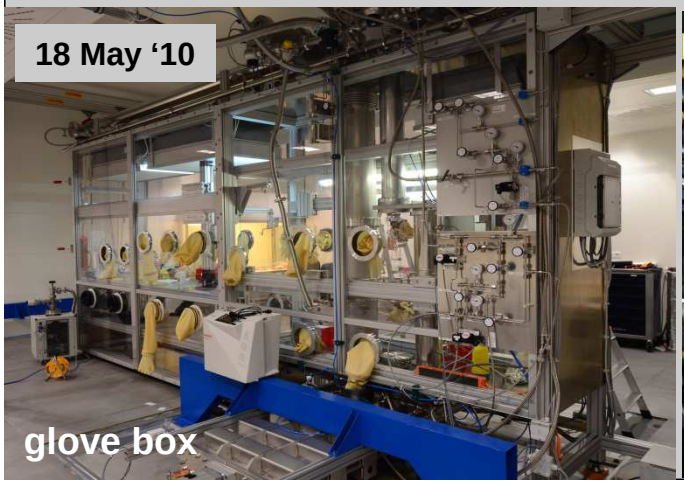
6 Mar ‘08

5 May ‘08

29 feb ‘09





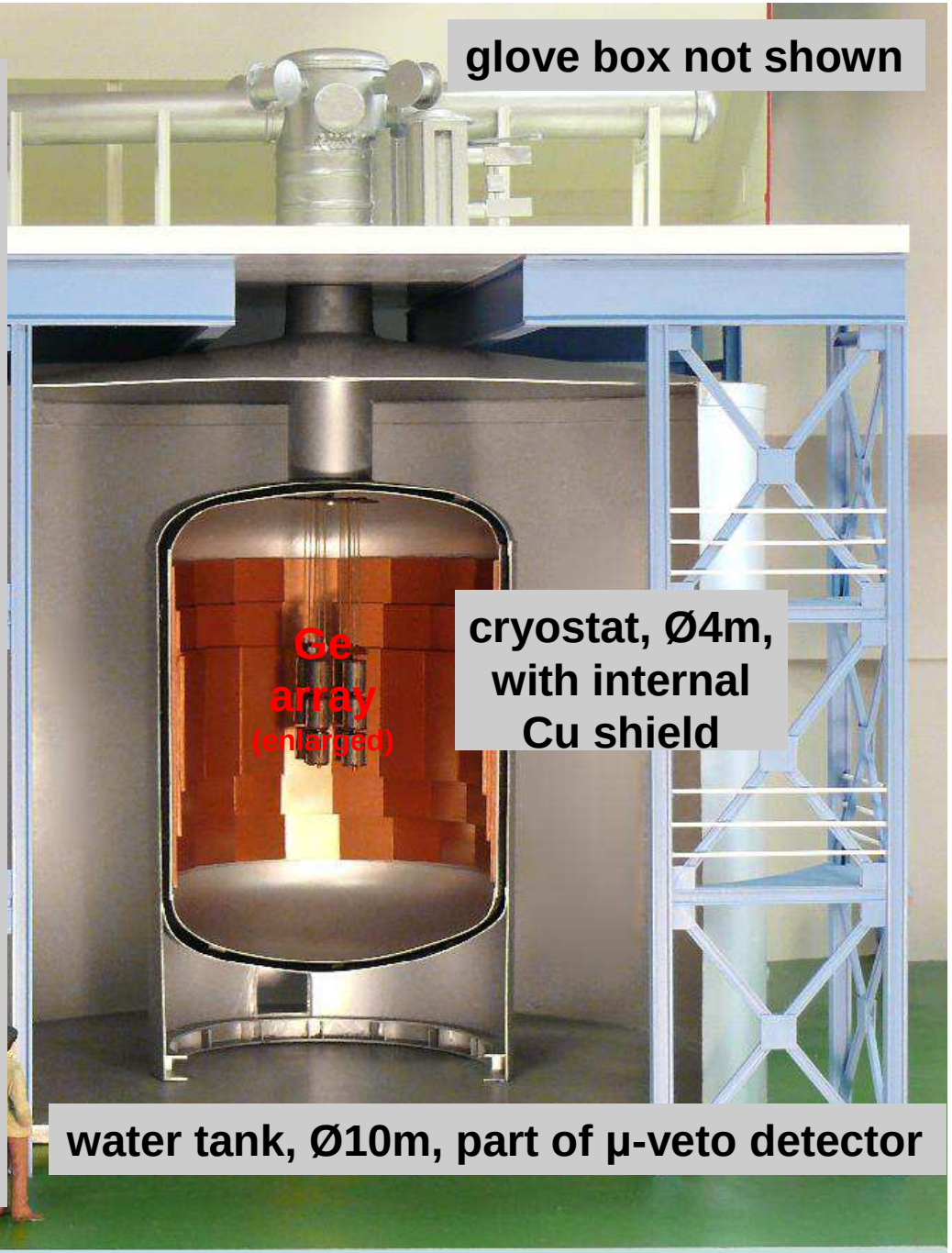


Cryostat filled since December 2009

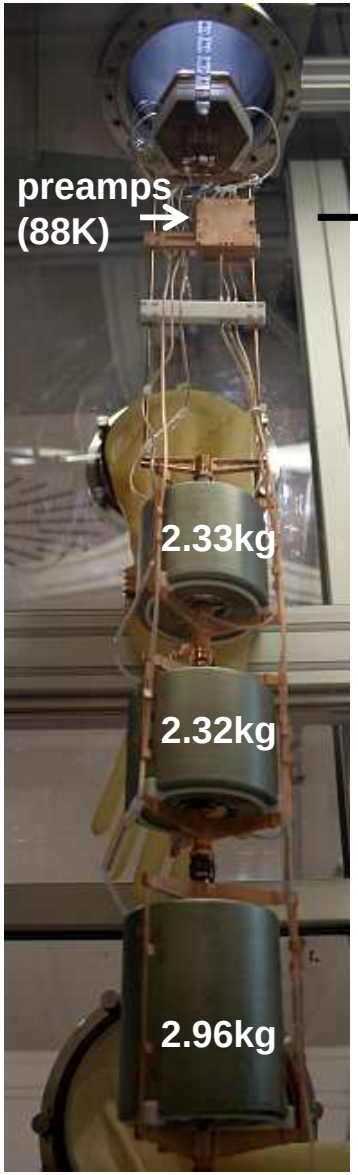
More on infrastructure:

- **Glove box around lock**
  - for detector handling in dry nitrogen
- **μ-veto system (ε > 97%)**
  - 66 8”PMTs in water tank,
  - 2x2 m^2 scintillator panels, 3x 3cm thick on roof of clean room, dedicated DAQ
- **Cryogenics**
  - LAr & LN storage tanks, valve box, active cooling, pressure control, safety valves, exhaust gas heater, insulation vacuum system, dedicated PLC
- **Water plant**
  - filter maintain water purity, ~0.8MΩ·cm
- **Calibration system**
  - allows to lower 3 Th-228 sources, ~20 kBq each, close to the Ge array
- **Safety & slow control system**
  - high redundancy, fast water drainage

All systems commissioned in 2009/10 – smoothly running since.

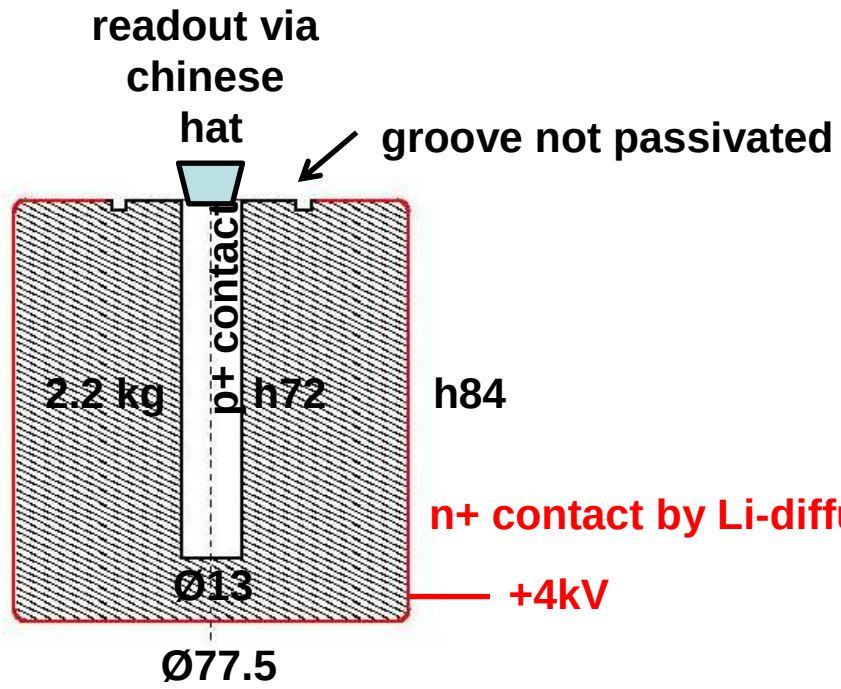


single string for commissioning – started June 2010



~20m coax-cable ► shaper (r.t.) ►2m coax-cable ► FADC

using 3 refurbished Genius-TF ^{nat}Ge-diodes (7.61 kg)
► p-type / coaxial ► 'low background' diodes
> same type as enriched detectors <



typical dimensions [mm]

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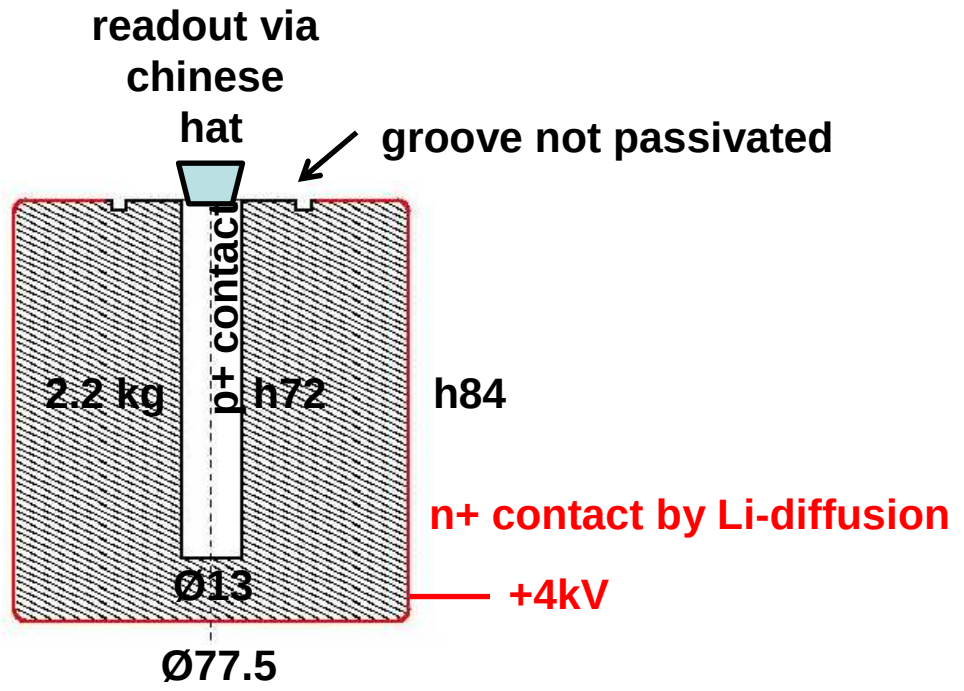

minishroud (60µm Cu)
to shield electrical field

typical dimensions [mm]

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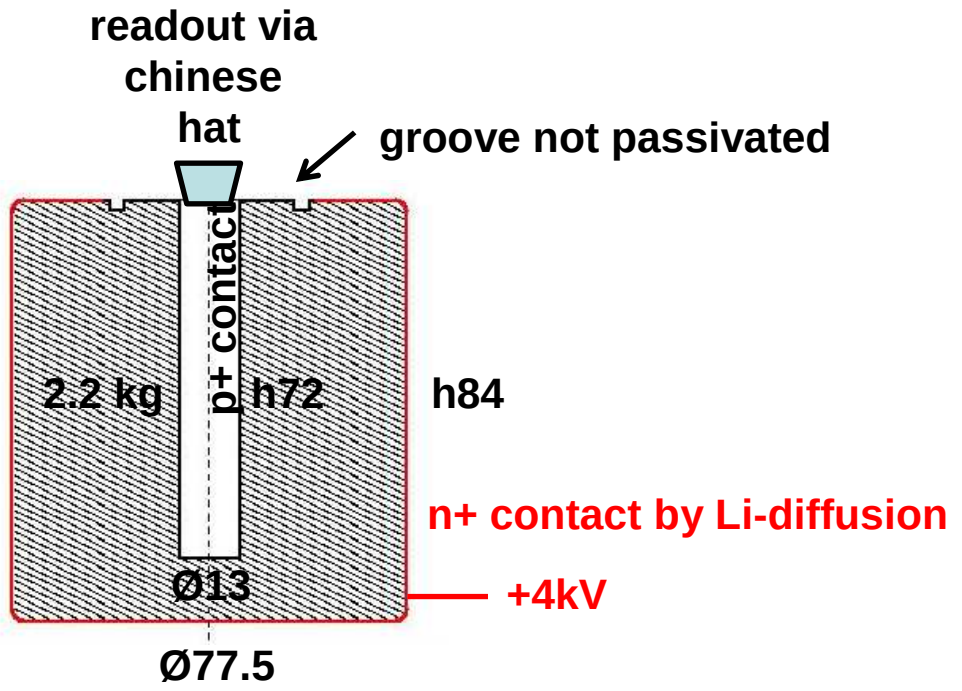
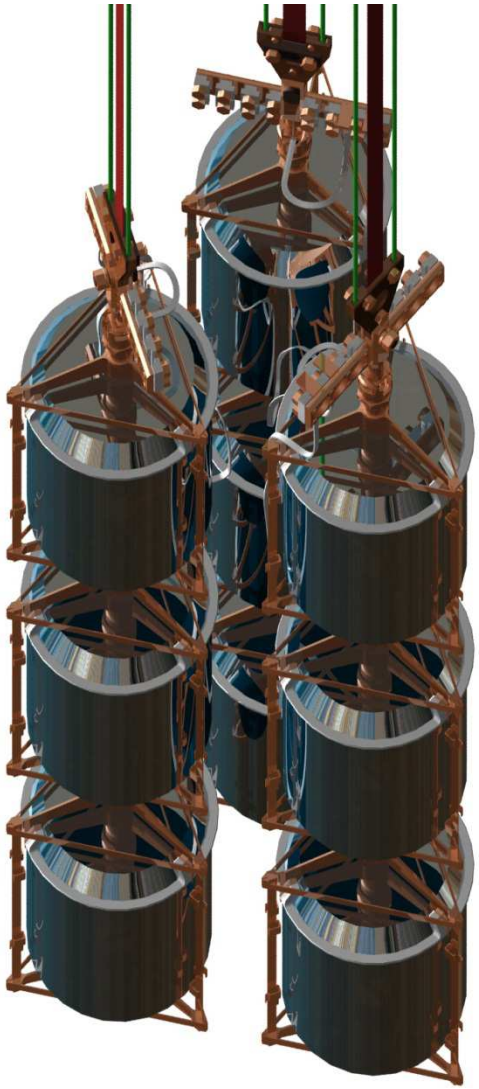


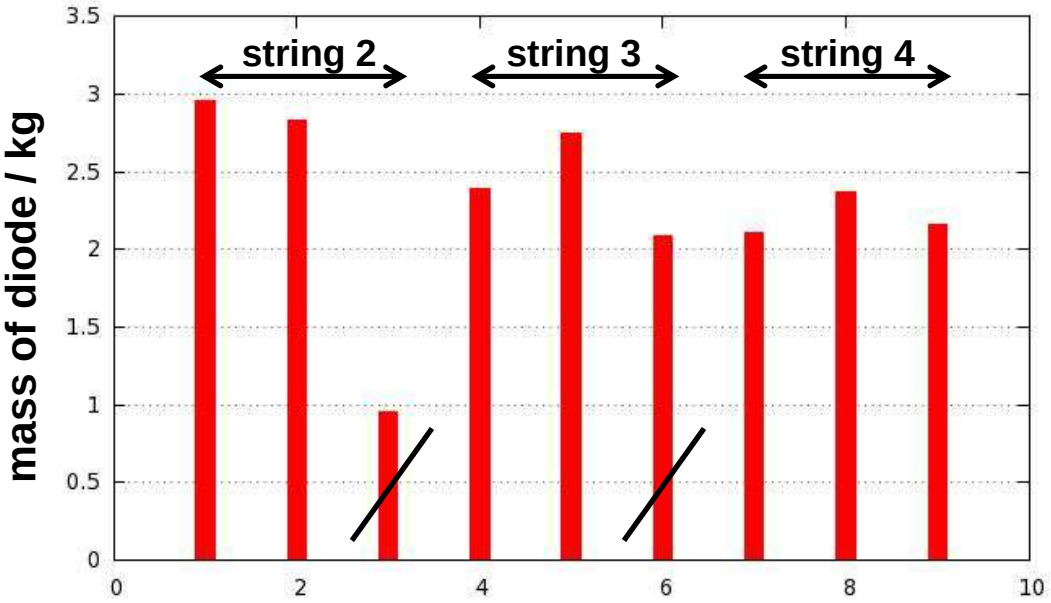
typical dimensions [mm]

3-string assembly for phase I run – started Nov 2011



8 refurbished enriched diodes from HdM & IGEX
- **86% isotopically enriched in Ge-76**
- **17.66 kg total mass**

plus 1 natural Ge diode from GTF



Diode #1 is natural GTF diode; #3 and #6 shut off because leakage current too high;
► total enriched mass 14.6 kg.

3-string assembly for phase I run – started 1 Nov 2011

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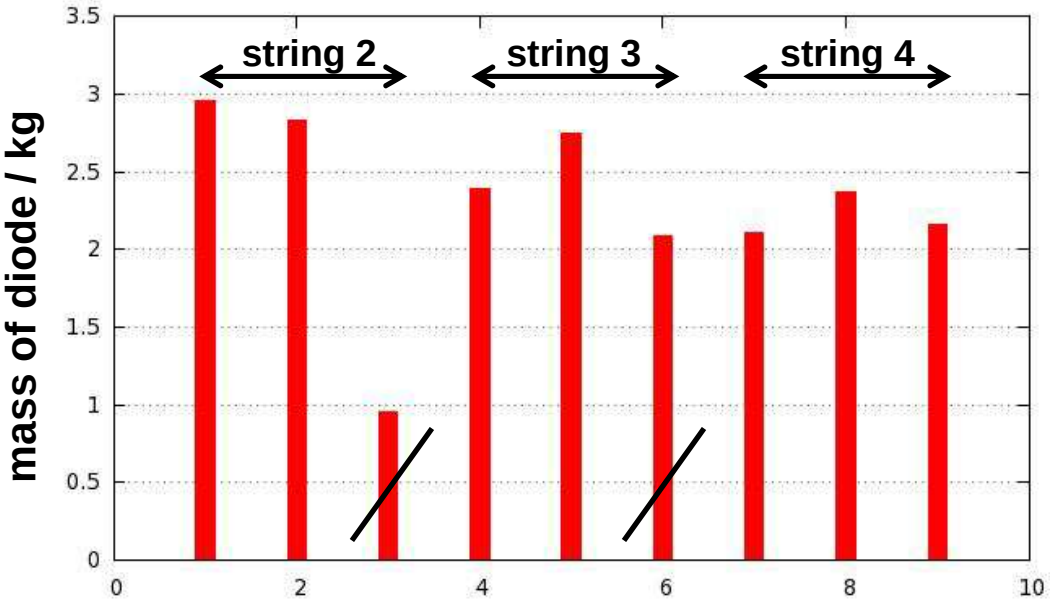

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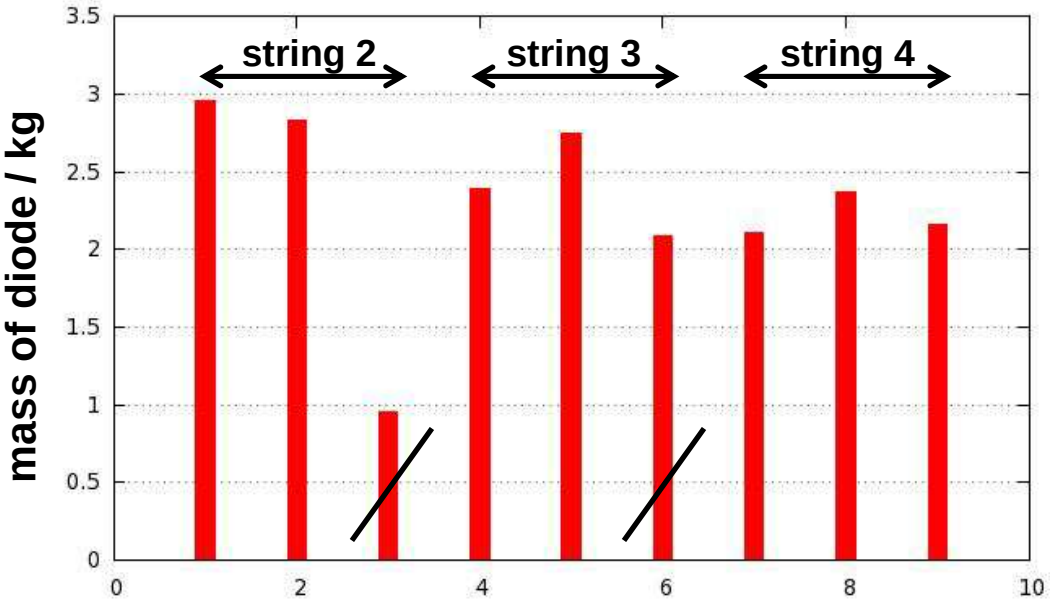

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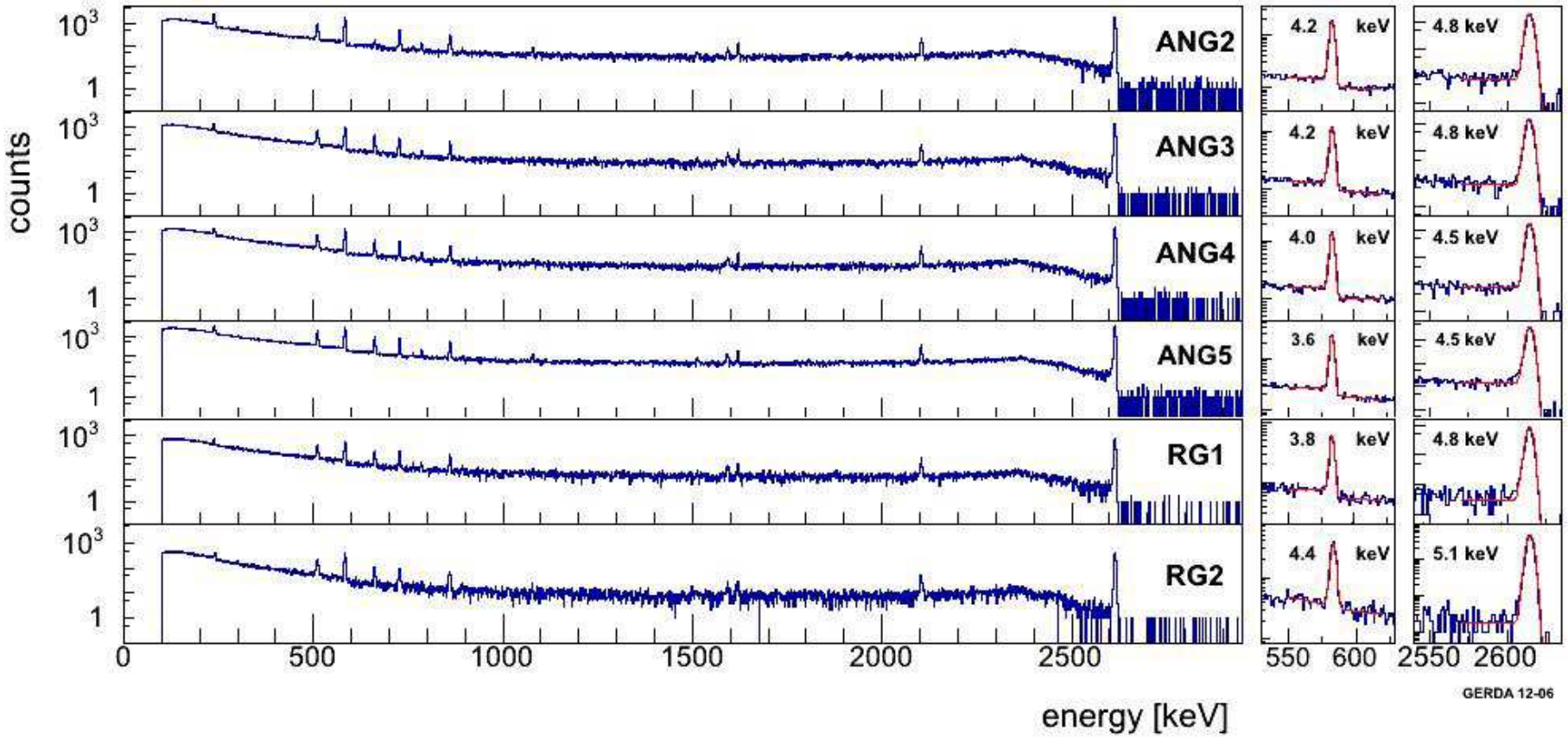
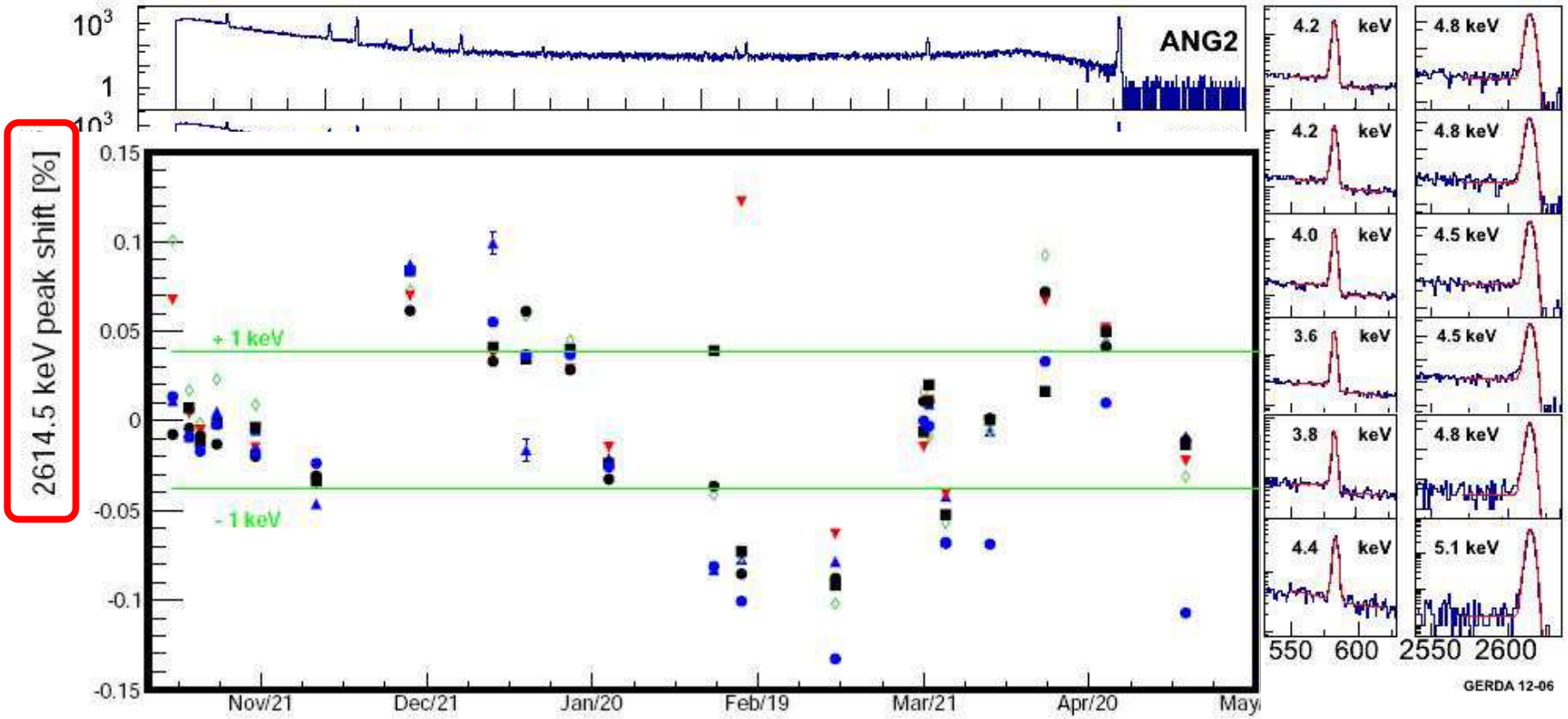
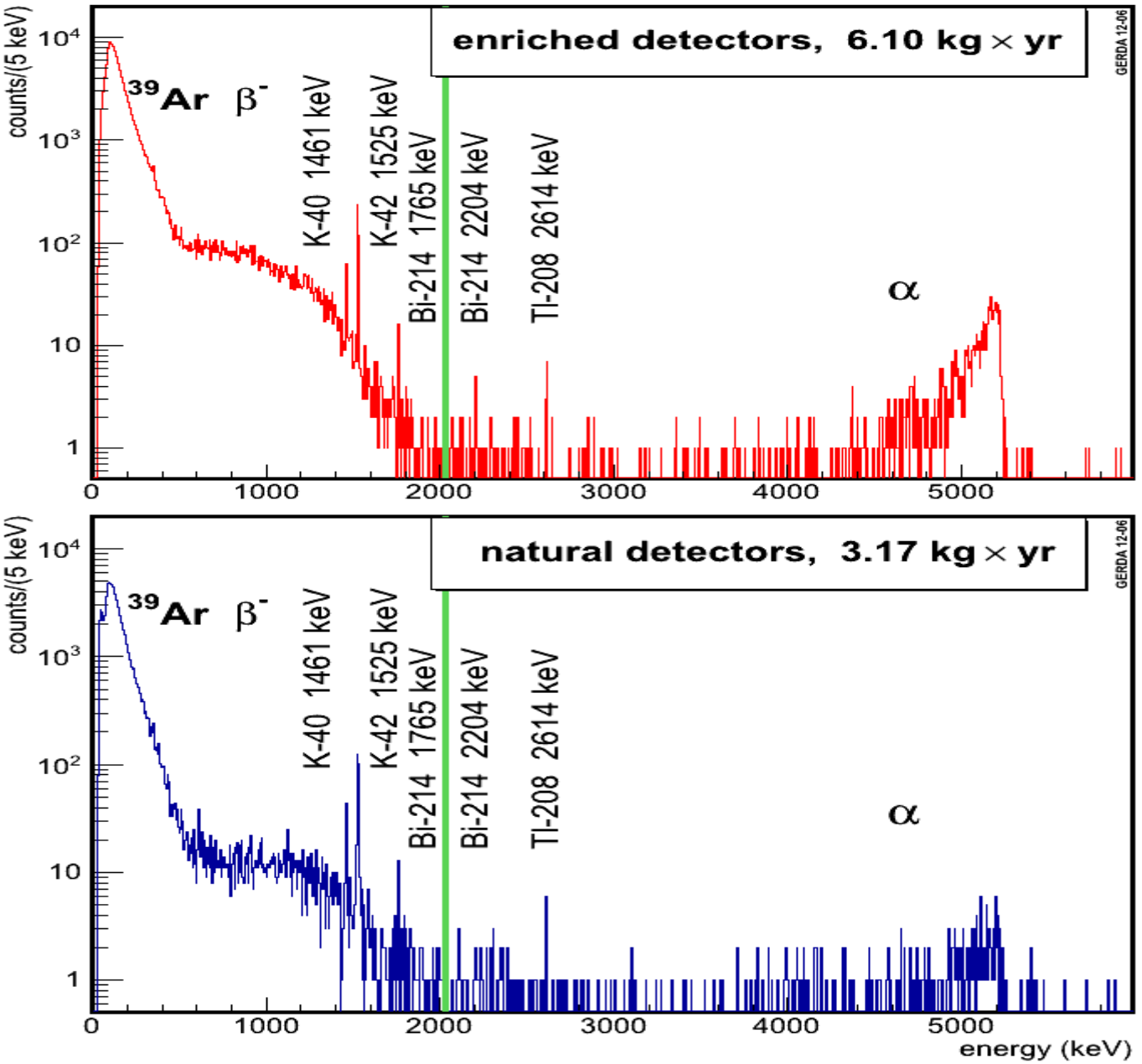
Preliminary results



Th-228 calibration spectra taken regularly, typ. 1 per week.



Th-228 calibration spectra taken regularly, typ. 1 per week.
Fair stability from run to run.

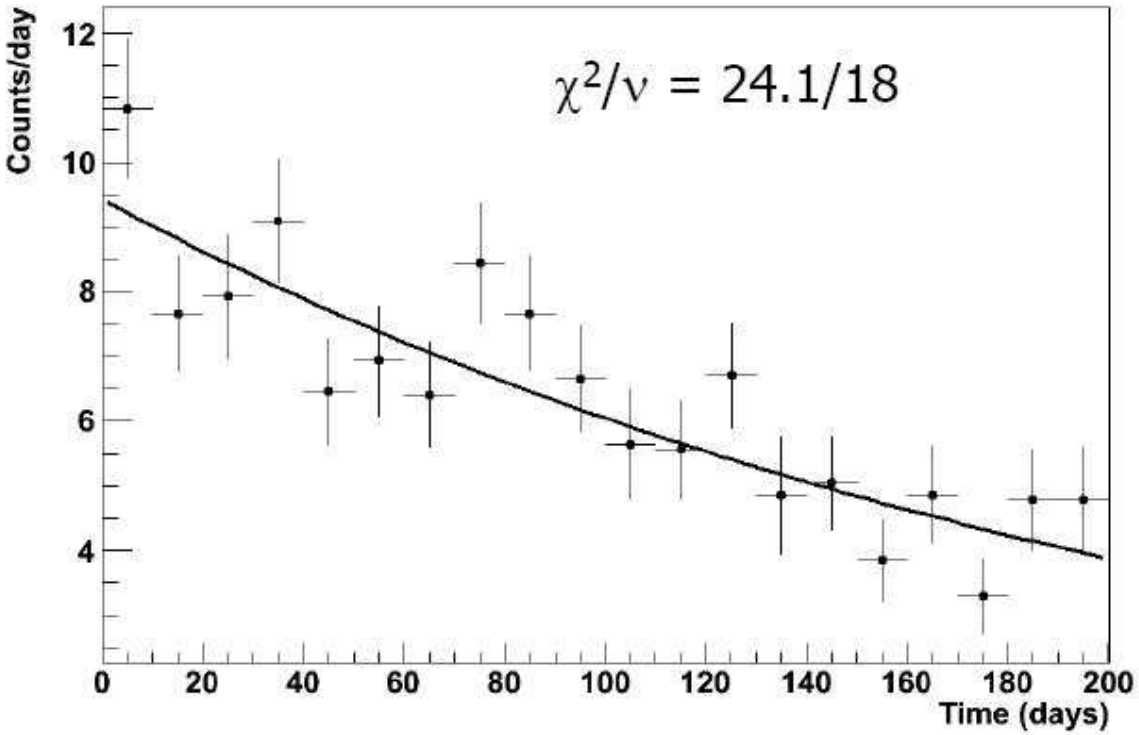


muon veto & Ge-Ge anti-coincidences applied

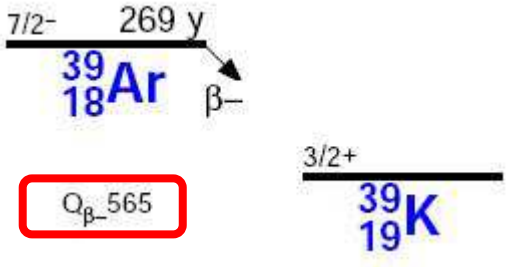
Blinded region of ($Q_{\beta\beta}$ ± 20) keV

Obvious components:
- **Ar-39**
- **Alphas**
- **Indicated isotopes**
  - ► **K42 – 1525 keV**
- **2v2β decay of Ge76**

Alpha rate not evenly distributed: one diode counts more than all the others (45%).
Evidence for decreasing alpha count rate with time.

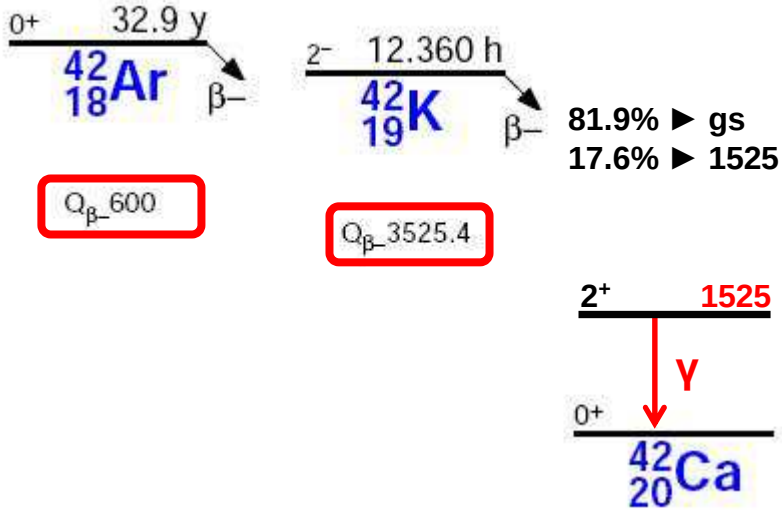


Tentative fit yields τ = (225±30) d; consistent with Po-210 (199 d), dto. energy.
Some indication that Po-210 was introduced in one refurbishing period.



Published activity of (1.01±0.08) Bq/kg (Benetti et al., NIM A574 (2007) 83) fully compatible with our data.

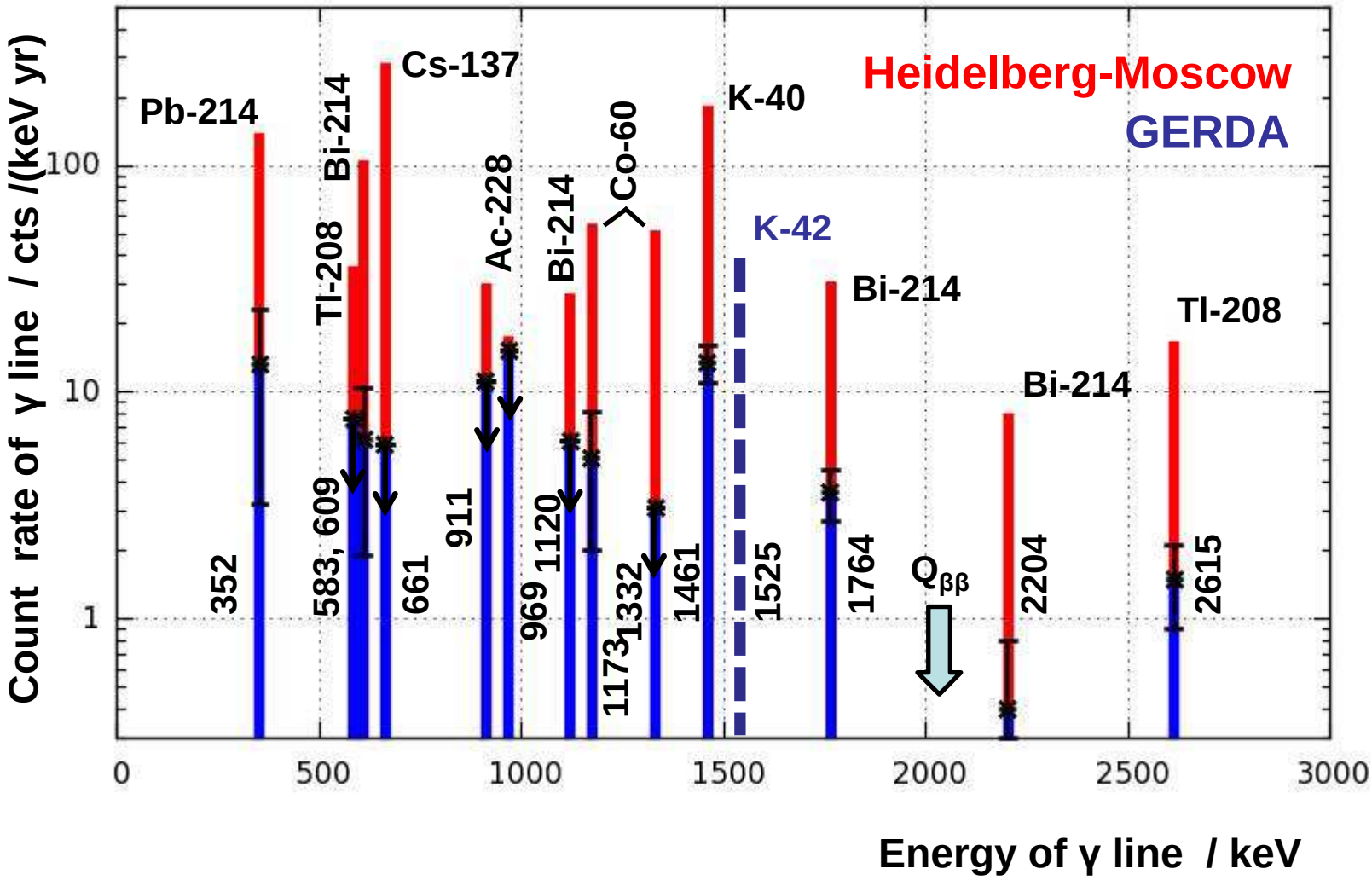
not relevant for BI at $Q_{\beta\beta}$



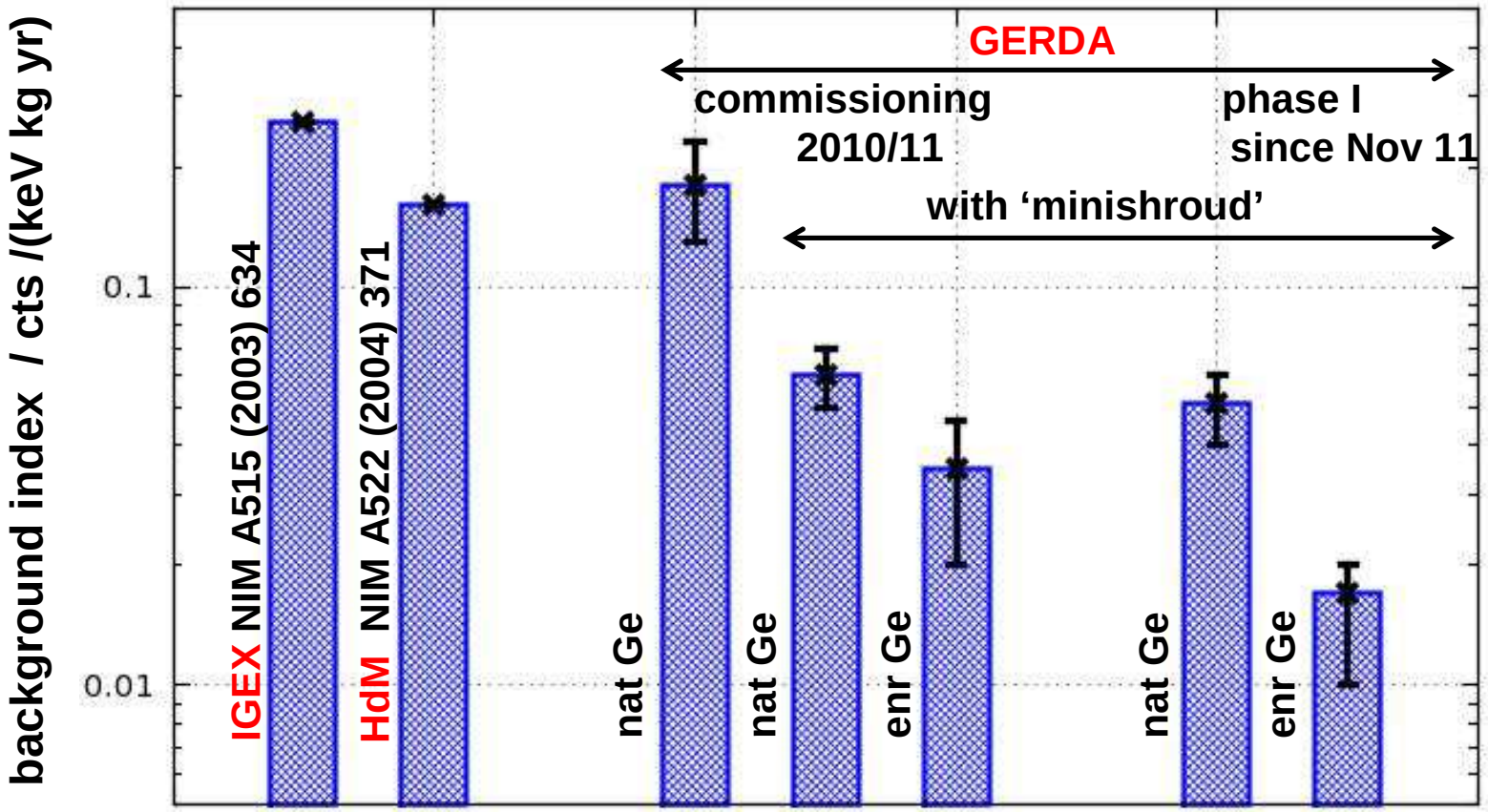
Lower limit of 41 µBq/kg (90% CL) (Ashitkov et al.,arXiV:nucl-ex/0309001) NOT compatible with our data.

Convincing evidence that charged K-42 ions drift in electric field of Ge-diodes. ► minishroud as shield against E-field.

Intensity of 1525 keV line, in E-field free setup - indicates Ar-42 activity to be more than twice the value of above LL..



GERDA / HdM intensity ratio typically 1 / 10



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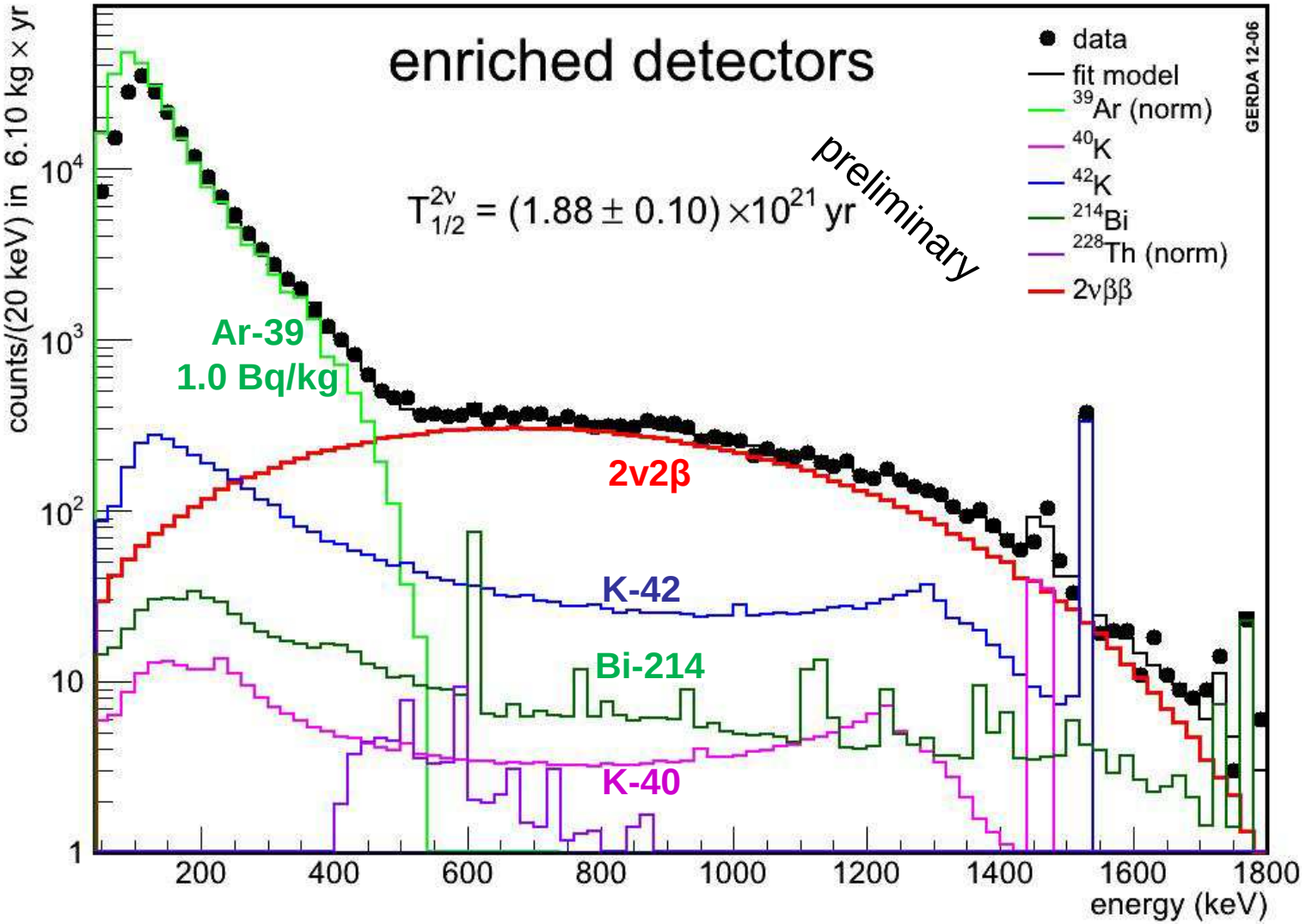
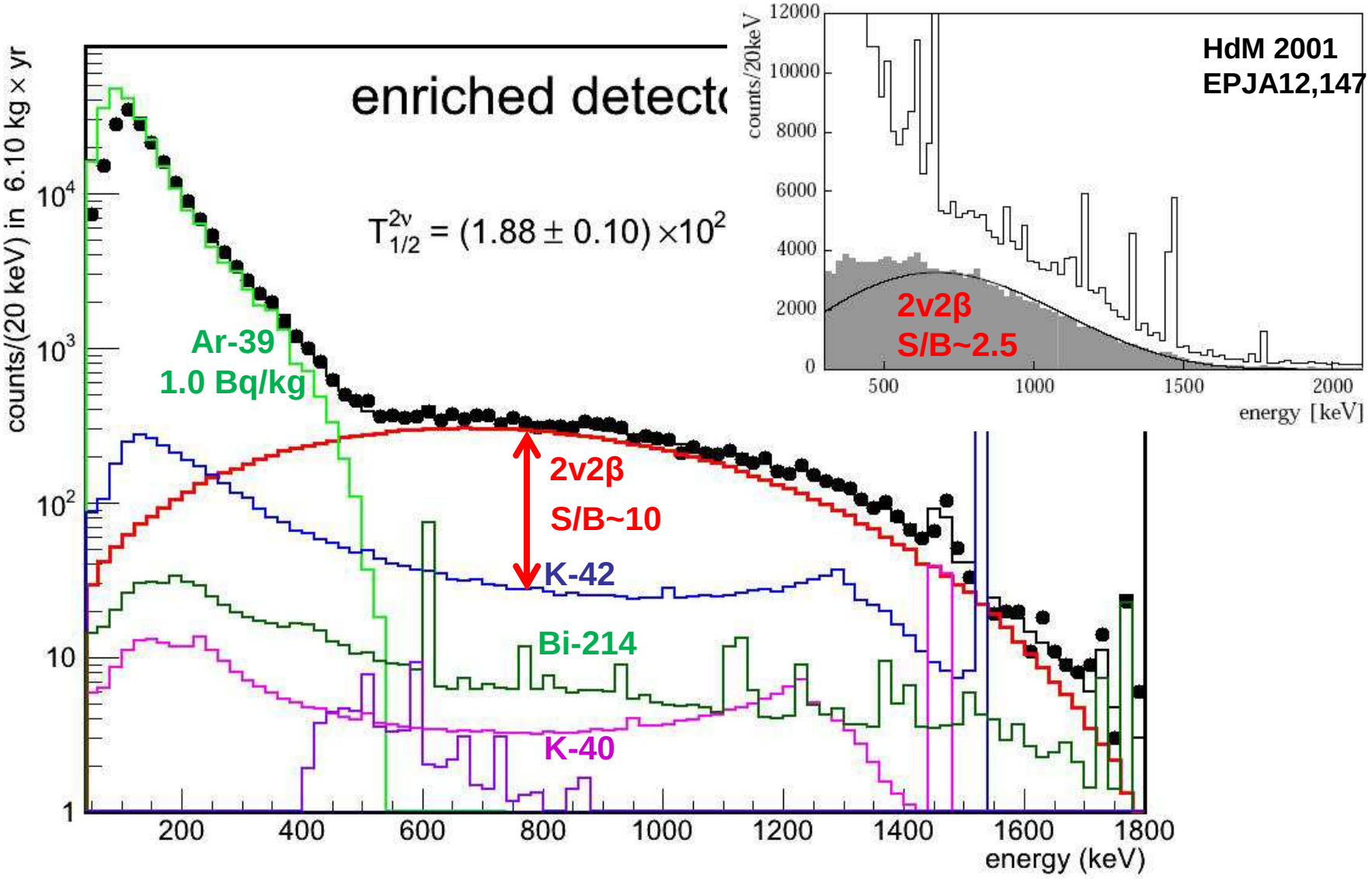
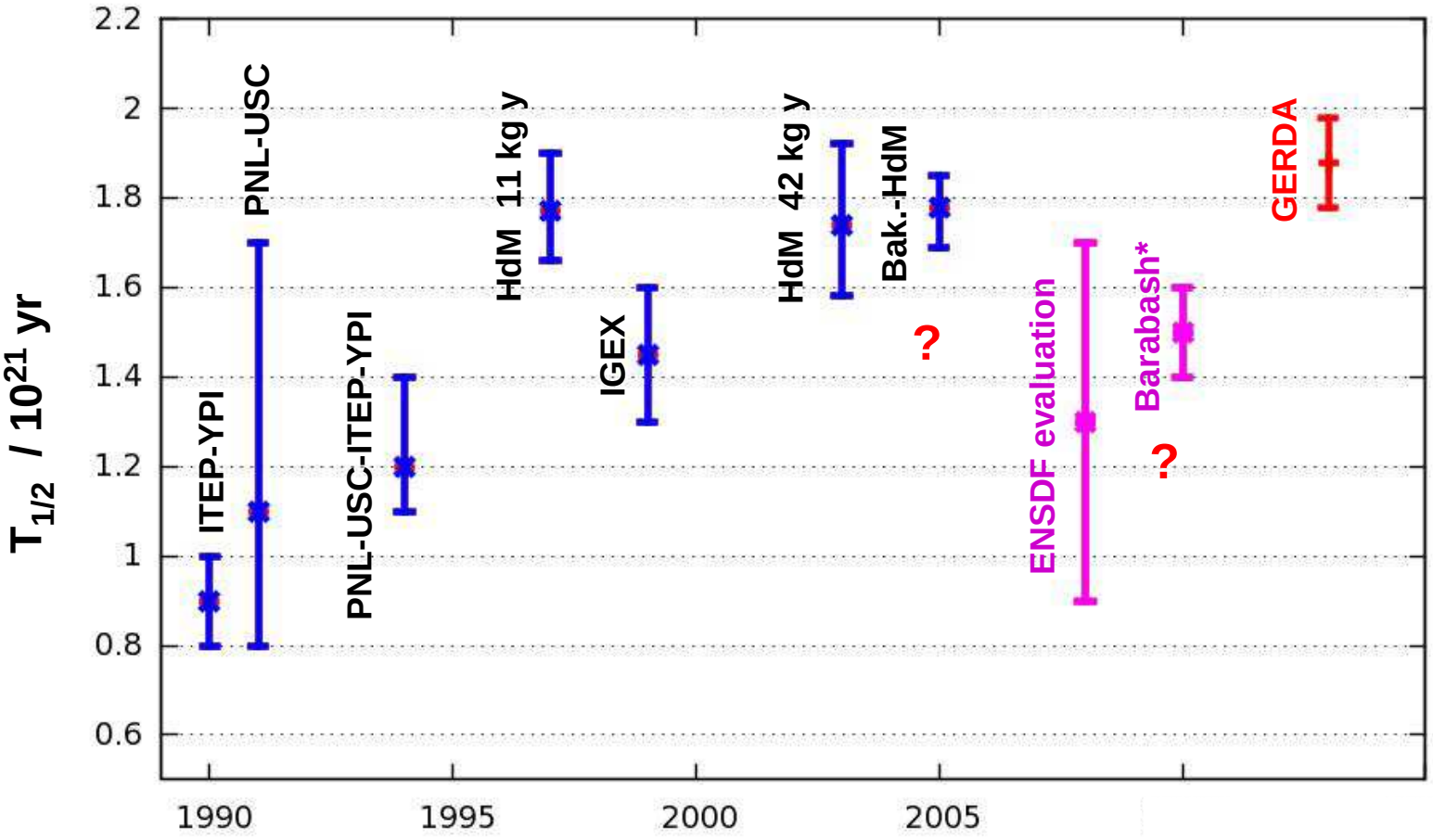

enriched detectors
$T^{2\nu}_{1/2} = (1.88 \pm 0.10) \times 10^{21}$ yr
preliminary
data
fit model
^{39}Ar (norm)
^{40}K
^{42}K
^{214}Bi
^{228}Th (norm)
2νββ
GERDA 12-06
Ar-39
1.0 Bq/kg
2v2β
K-42
Bi-214
K-40
counts/(20 keV) in 6.10 kg × yr
energy (keV)



Significant improvement in S/B ratio – less systematic uncertainties!



GERDA value most precise value – valuable input for 2β decay calculations.

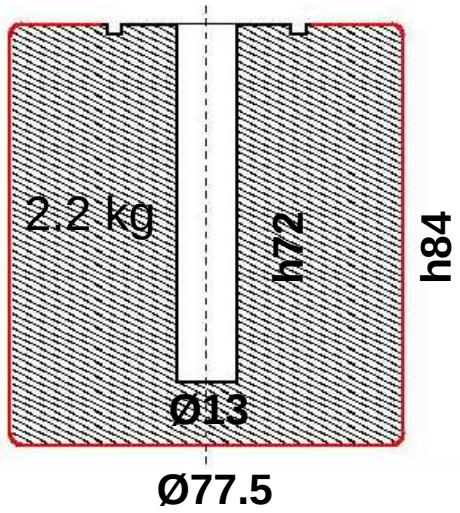
*** Evaluation by Barabash PR C81 (2010) 035501**

Phase II / Perspectives

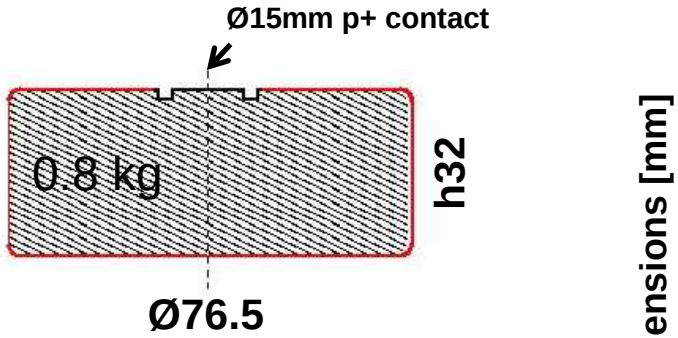
BEGe (point-contact like) type of diode selected for Phase II

Addition of up to 30 enriched BEGe diodes (~20 kg)

- **~36 kg of enriched & purified 6N material acquired**
- **9 crystals pulled thereof**
- **1st batch of 7 BEGe diodes produced and tested**
  1.7 keV FWHM at 1.3 MeV
- **Up to 23 more BEGe's to be available by the end of 2012**



present coaxial diode

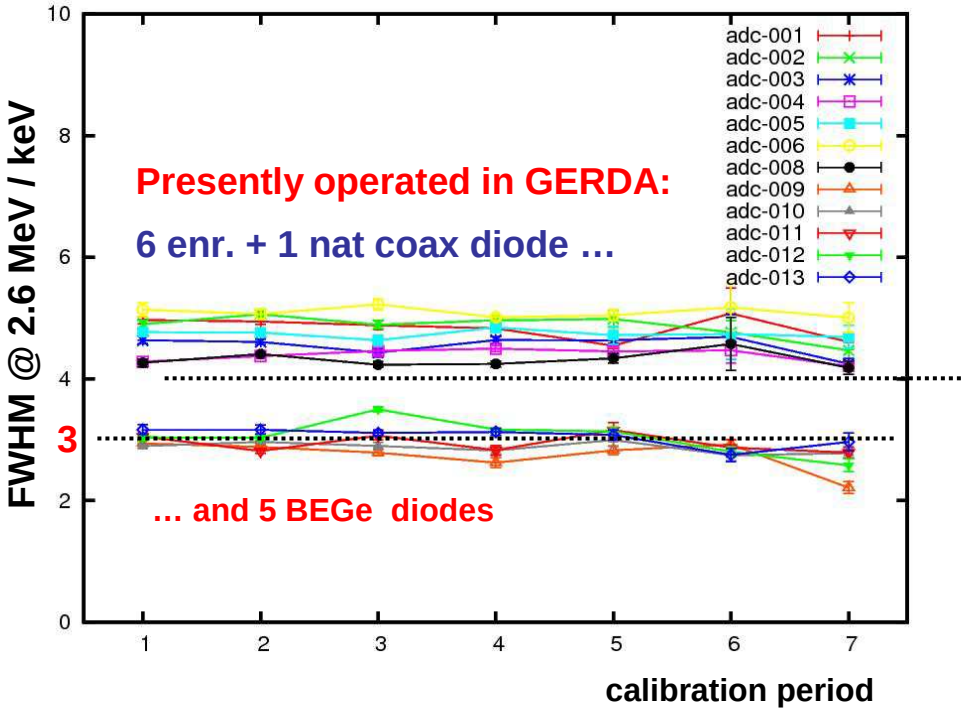


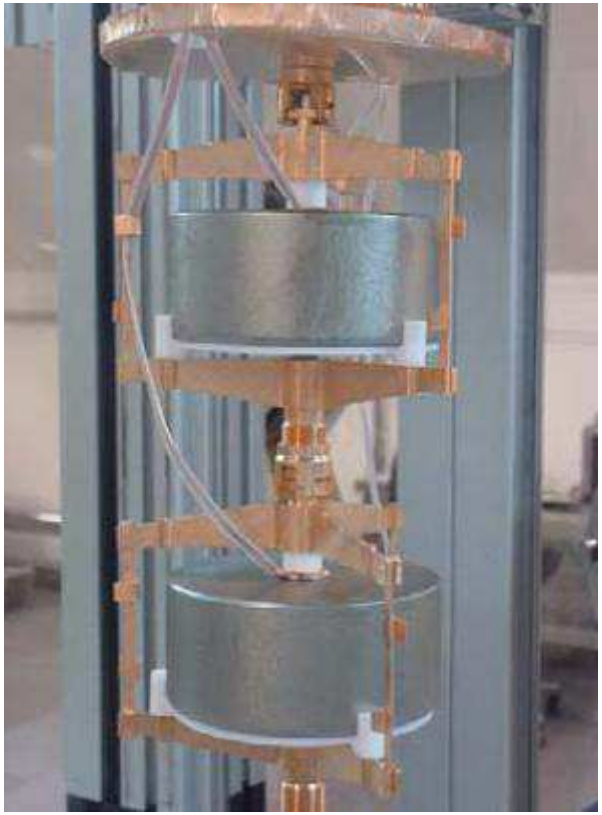
new BEGe diode
p-type, no bore hole,
thick n+ contact, K-42!

typical dimensions [mm]

Smaller, but beautiful performance ►

phase II perspectives BEGe diodes performance





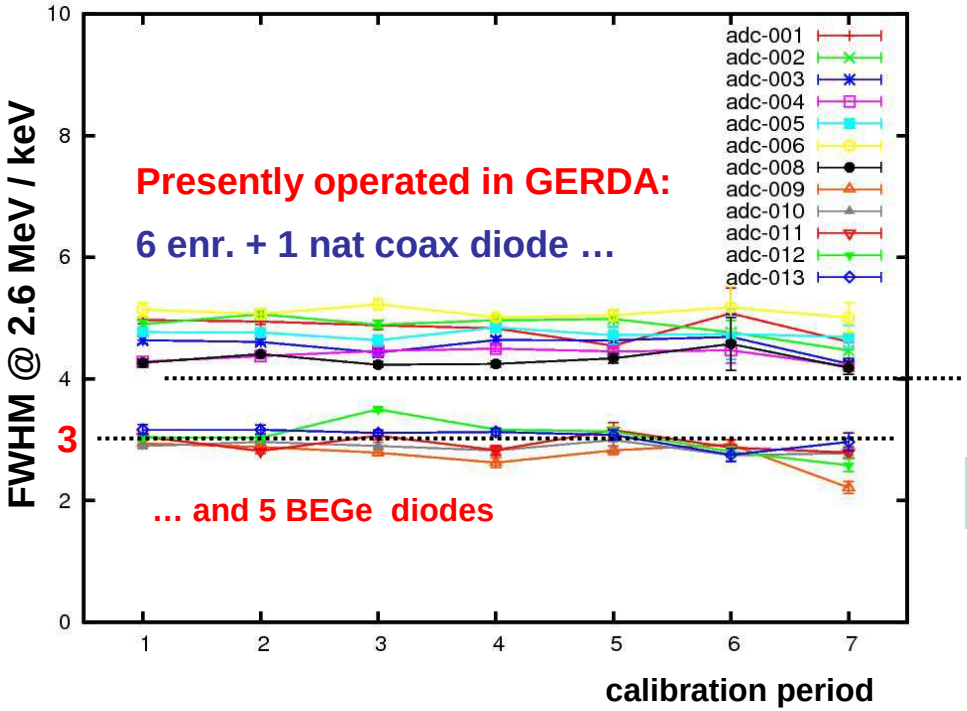
2 of the 5 BEGe diodes deployed in GERDA.

Superior energy resolution – verified in GERDA with non-optimized phase I readout!

Work in progress for phase II includes major reduction of mass of holders, substitution of Cu by Si, and better contacts by bonding.

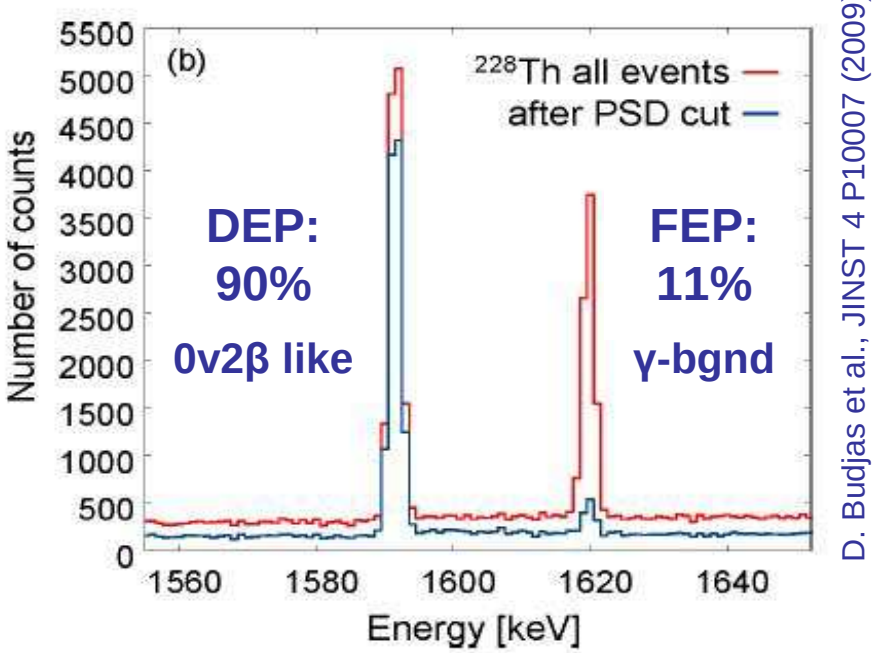
phase II perspectives

BEGe diodes performance

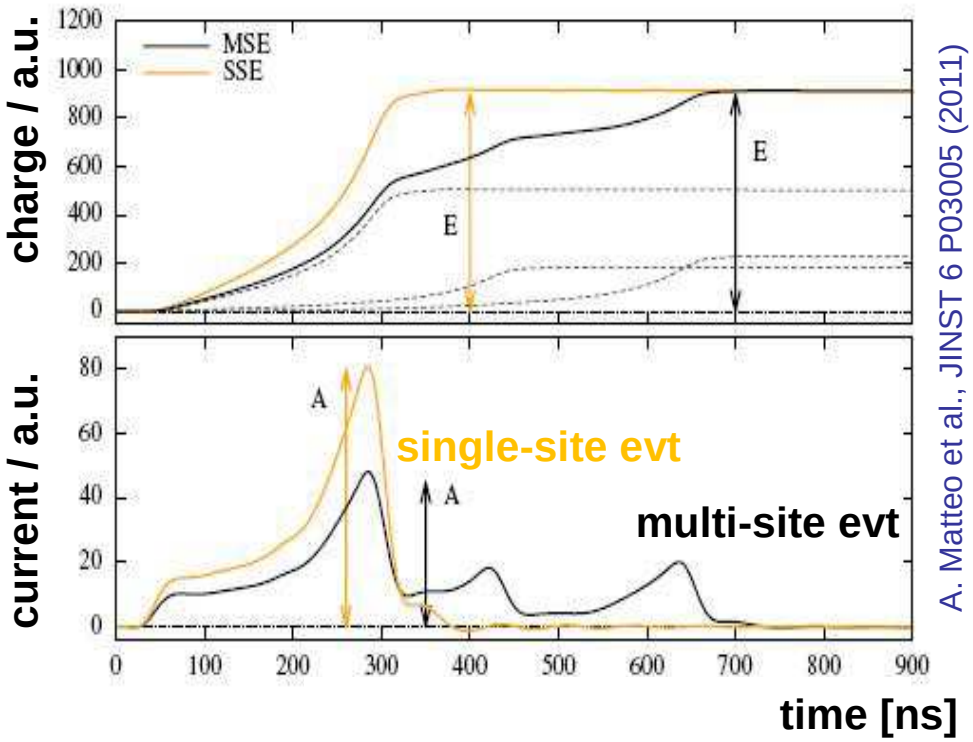


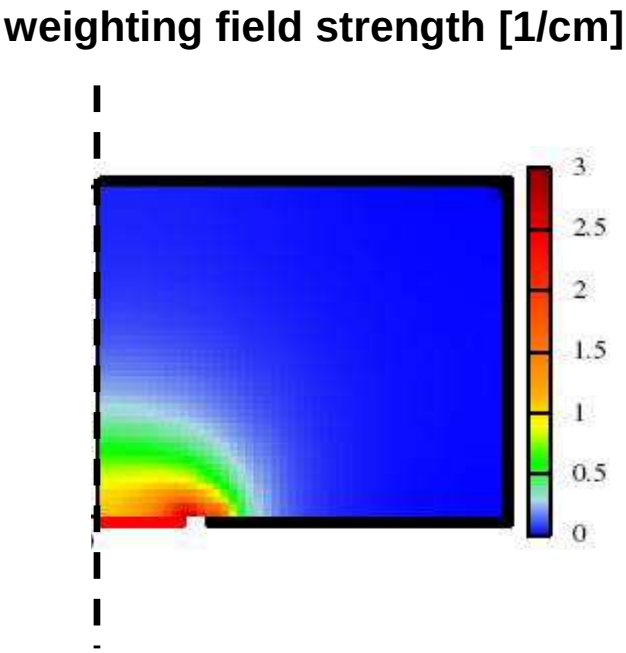
Superior energy resolution – verified in GERDA with non-optimized readout!

Superior pulse shape discrimination power



D. Budjas et al., JINST 4 P10007 (2009)

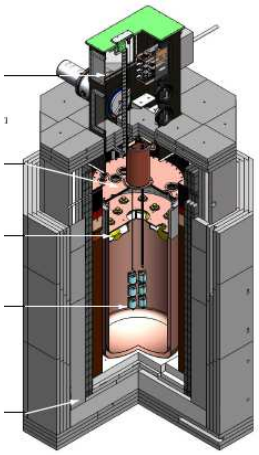




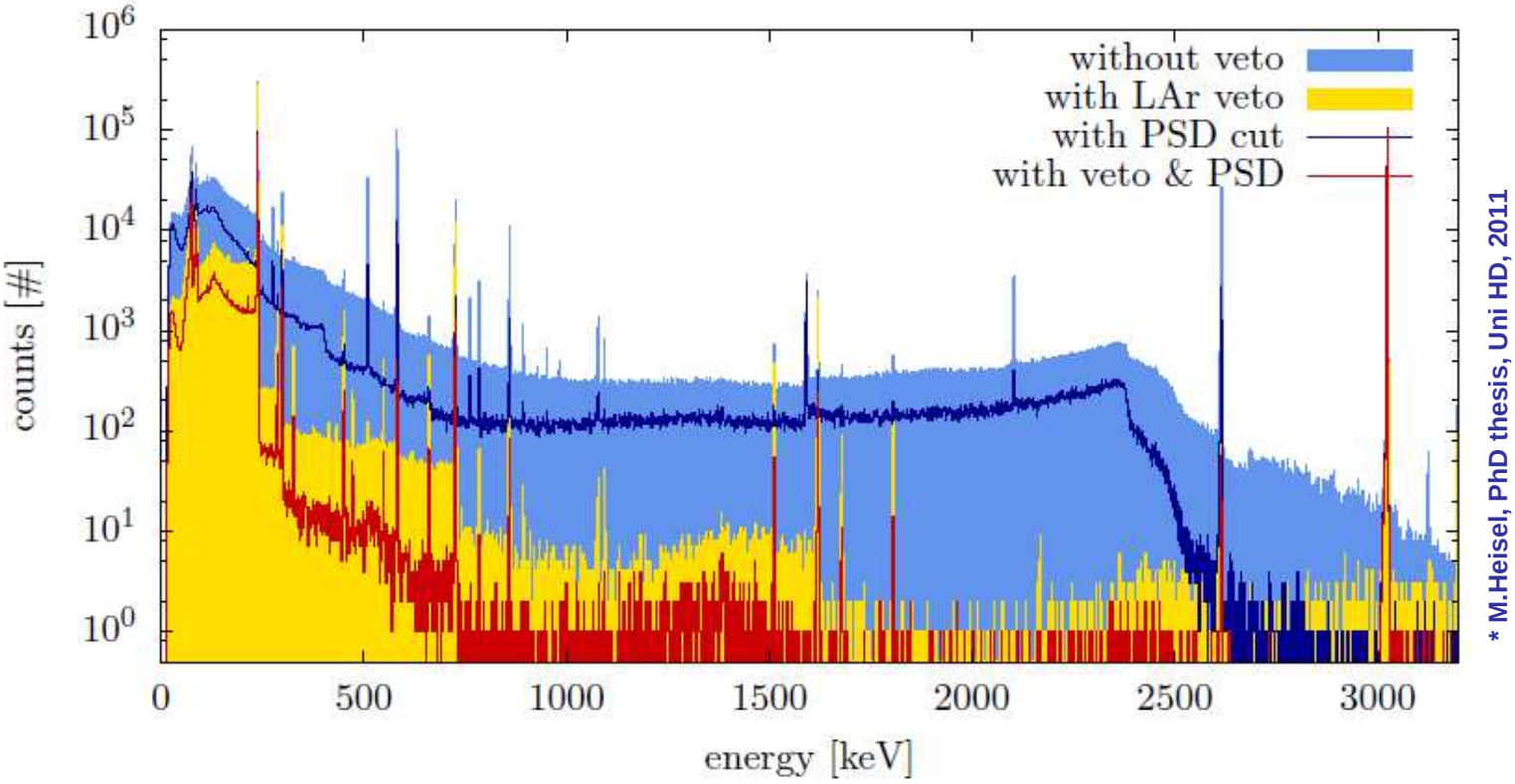
discrimination of single- and multi-site events by A / E ratio

R&D for LAr scintillation veto

9x8" PMTs

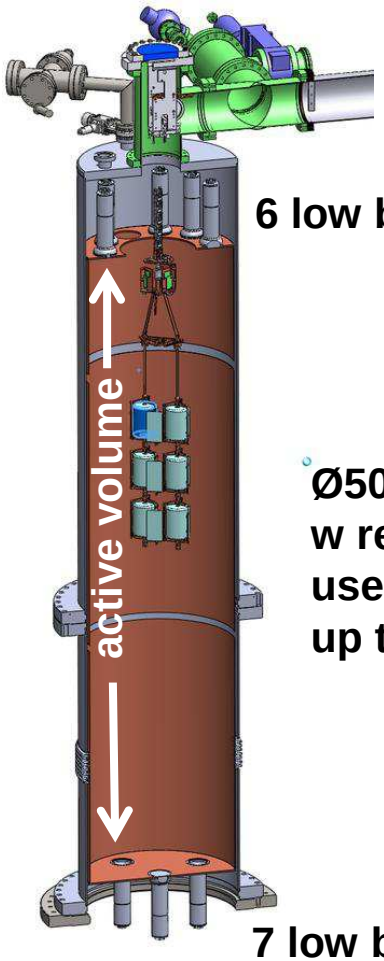


LArGe*



* M.Heisel, PhD thesis, Uni HD, 2011

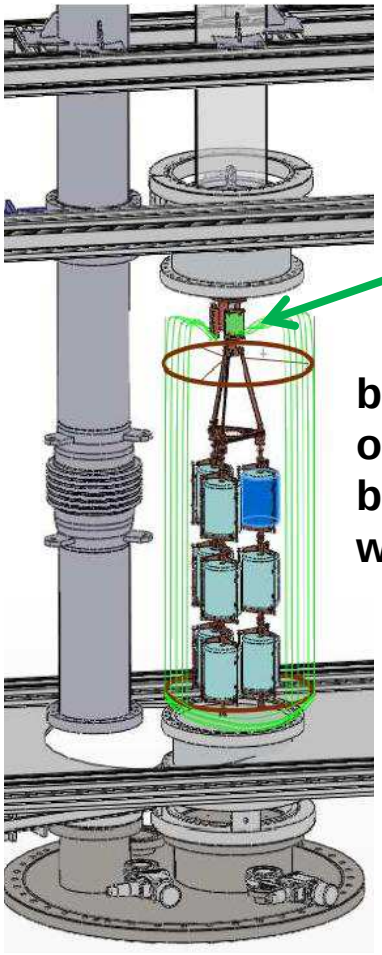
Suppression factor at $Q_{\beta\beta}$ of ~5000 measured with Th-228 calibration source.
Alternative to scintillation light readout by PMTs: fibers coupled to SiPMs, APDs



6 low background 3”PMTs R11065-20

Ø500 Cu shroud, h~2.8m, w reflector & WLS (TPB) - uses phase II lock for up to 7 detector strings

7 low background 3” PMTs



3x3 mm^2 SiPMs and preamps

bundle of 1x1mm^2 fibers on Ø250 mm - readout at both ends – compatible with phase I twin lock

active LAr volume not confined by fibers

Both setups mountable w/o drainage of LAr - hybrid version for phase II lock under study.

- **First realization of a novel shielding scheme: cryogenic shield within large water volume.**
- **All subsystems commissioned and running smoothly; GERDA commissioned with natural and enriched detectors.**
- **Phase I physics run started 15 Nov 2011 for exposure of 15 kg yr; region of interest, ($Q_{\beta\beta}$ ± 20) keV, blinded; BEGe string since July.**

Preliminary findings with ~6 kg·yr exposure:

- ► **^{42}Ar isotopic abundance factor of >2 larger than 90% limit reported previously – serious background for phase II.**
- ► **Best value for 2v2β decay of Ge-76 to be published soon.**
- ► **Best background index at $Q_{\beta\beta}$ of all Ge experiments so far, BI ~ 0.02 cts / (keV·kg·yr) without pulse shape analysis; goal: 0.01 cts / (keV·kg·yr), scrutinize KKDC result within ~1yr.**

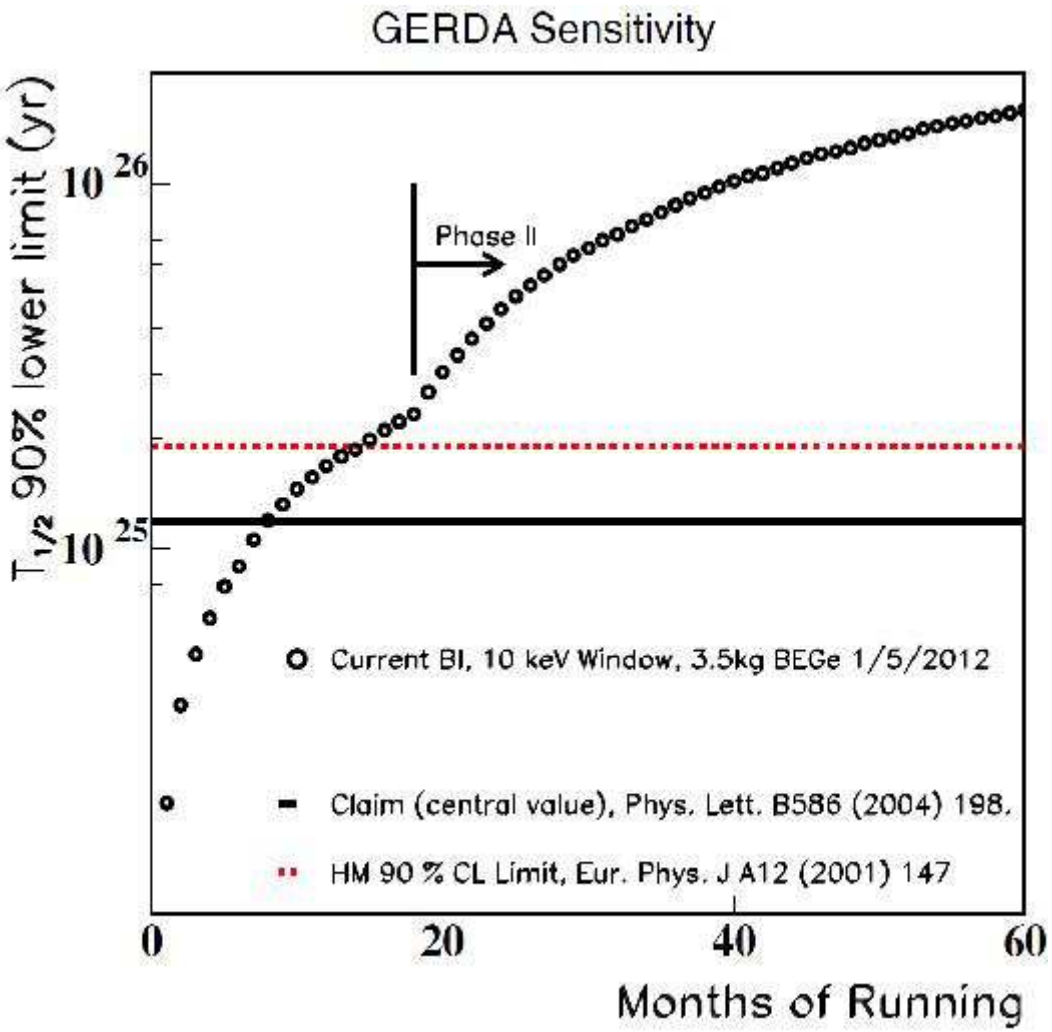
Perspectives for Phase II – start by spring of next year

- **New enriched Ge diodes of BEGe type, ~20 kg or ~30 pcs., will be produced by the end of the year; superior properties for PSA;**
- **Active LAr scintillation veto to further reduce background.**
- **Goal BI ~ 0.001 cts / (keV·kg·yr)**

► **$T_{1/2} > 1.5 \cdot 10^{26}$ yr , $0.09 < \langle m_{ee} \rangle < 0.15$ eV ***

*** PR C81(10)028502**

End / Backup


GERDA Sensitivity
$T_{1/2}$ 90% lower limit (yr)
10^{26}
10^{25}
Phase II
Current BI, 10 keV Window, 3.5kg BEGe 1/5/2012
Claim (central value), Phys. Lett. B586 (2004) 198.
HM 90 % CL Limit, Eur. Phys. J A12 (2001) 147
0
20
40
60
Months of Running

EXO-200 collaboration, PRL 109 (2012) 032505