The GERDA Experiment: Status and Perspectives

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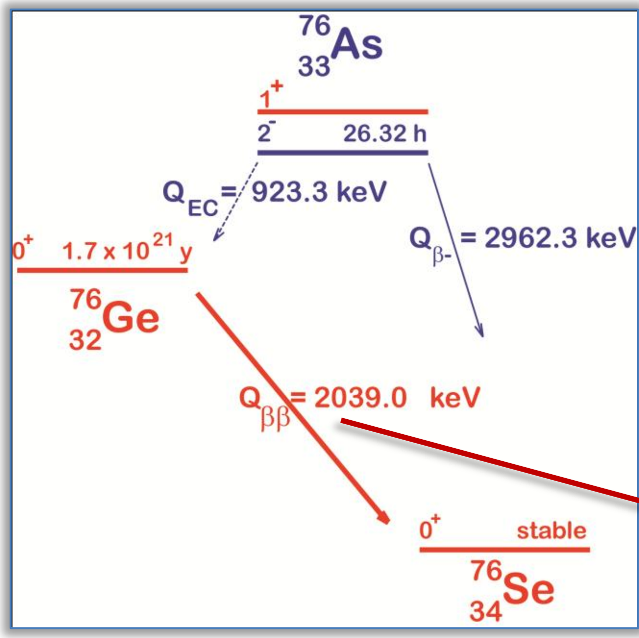
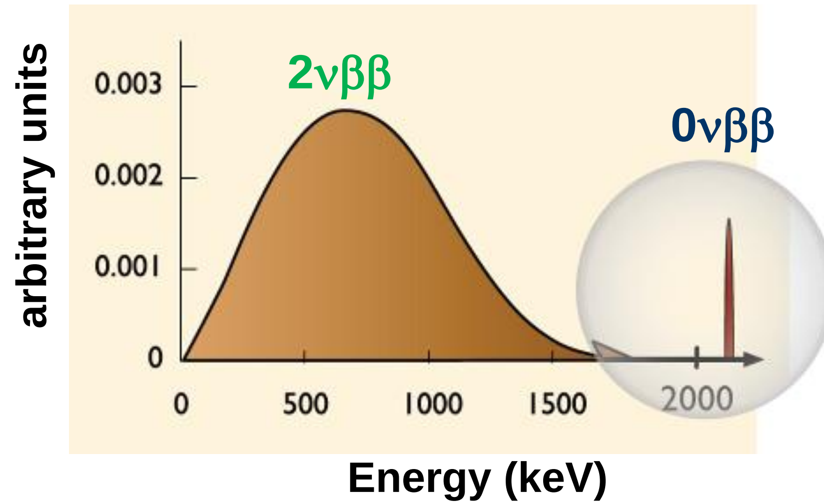
Outline

1. The GERDA experiment
   - short introduction
2. Status of Phase I
   - installation
   - first measurements
3. Perspectives for Phase II
   - the detectors
   - R&D

Physics of the GERDA Experiment

Search for the half-life of the $0\nu\beta\beta$–decay of ^{76}Ge





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

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

Majorana nature
Physics beyond SM
Absolute mass scale

- Hierarchy: degenerate, inverted or normal
- (effective) neutrino mass

Best limits on $0\nu\beta\beta$-decay used ^{76}Ge (86%) (IGEX & Heidelberg-Moscow):

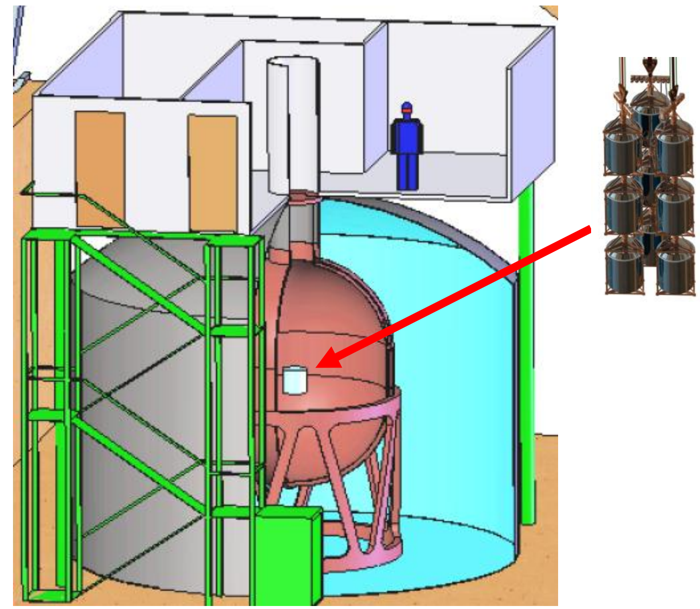
$T_{1/2} > 1.9 \times 10^{25}$y (90%CL)
(& 6σ claim for evidence)

Sensitivity of the GERDA Experiment

$$T_{1/2}^{0\nu}(y) > \frac{\log 2 \cdot N_A}{k_{CL}} \cdot \frac{\varepsilon \cdot k_{enr}}{A} \cdot \sqrt{\frac{M \cdot t}{B \cdot \Delta E}}$$

- well established enrichment technique (reasonable cost for > 80%)
  - ⇒ enrichment k_{enr} = 86% ^{76}Ge
- established detector technologies
  - ⇒ large total mass M (expandable)
- very good energy resolution:
  - ⇒ small ΔE ~ 2-3 keV
- very good detection efficiency because detectors made of source material
  - ⇒ ε ~ 1
- detector-grade semiconductors are high-purity materials (low background)
  - ⇒ small direct contribution to the bckg. index B

<u>Optimize the parameters</u>



- Bare ^{enr}Ge-diodes array in LAr

+

- Shield: high-purity LAr/H_2O

Background Sources in the GERDA Experiment

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 LAr	<0.2
^{208}Tl, ^{238}U in holder	<1
Surface contamination	<0.6

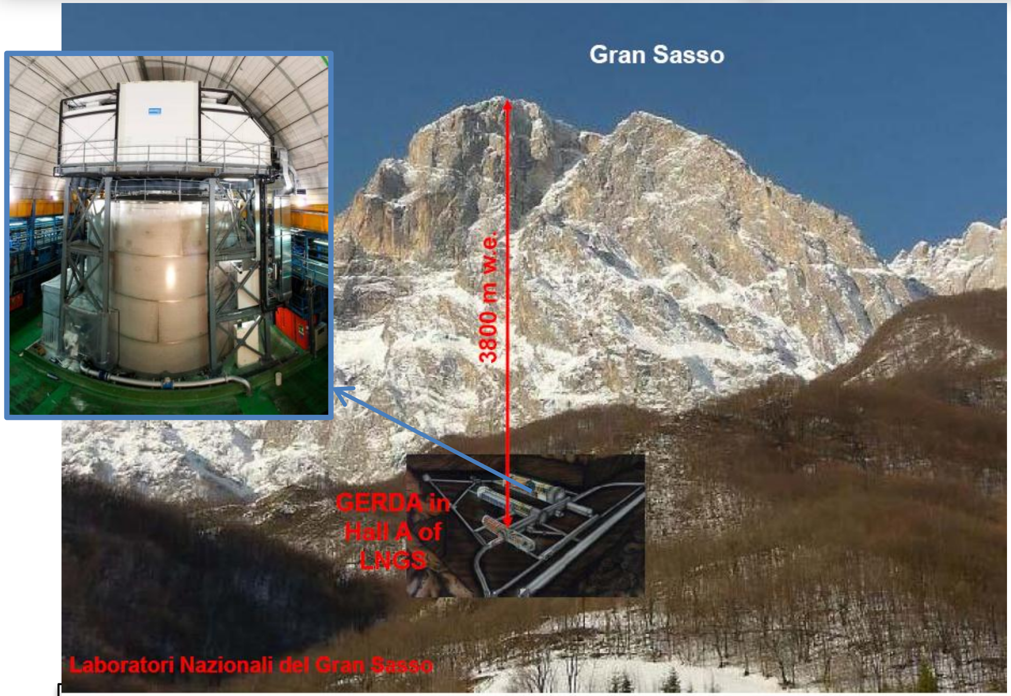
Muon veto

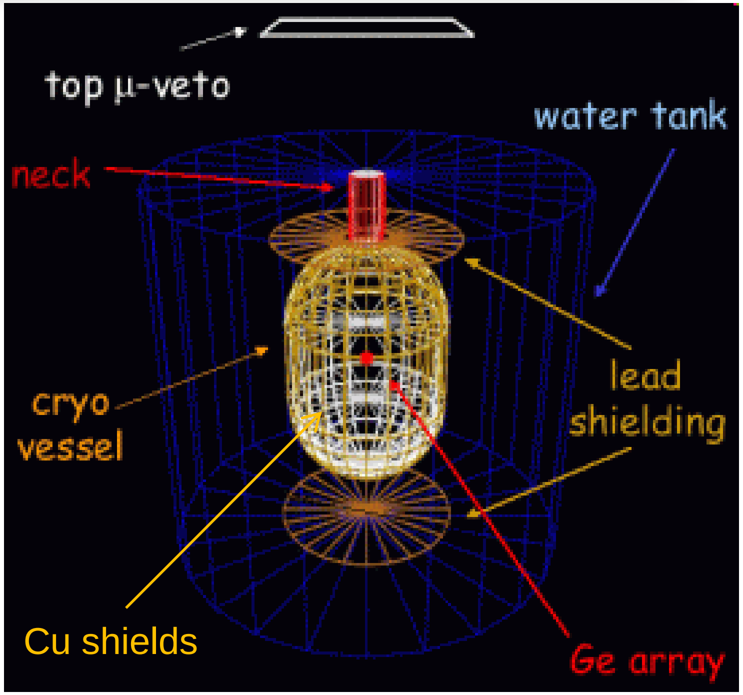
180 days exposure after enrichment + 180 days underground storage

30 days exposure after crystal growing

Target values: Phase I: B < 10^{-2} cts/(keV· kg· y)
Phase II: B < 10^{-3} cts/(keV· kg· y)

Background Reduction in the GERDA Experiment





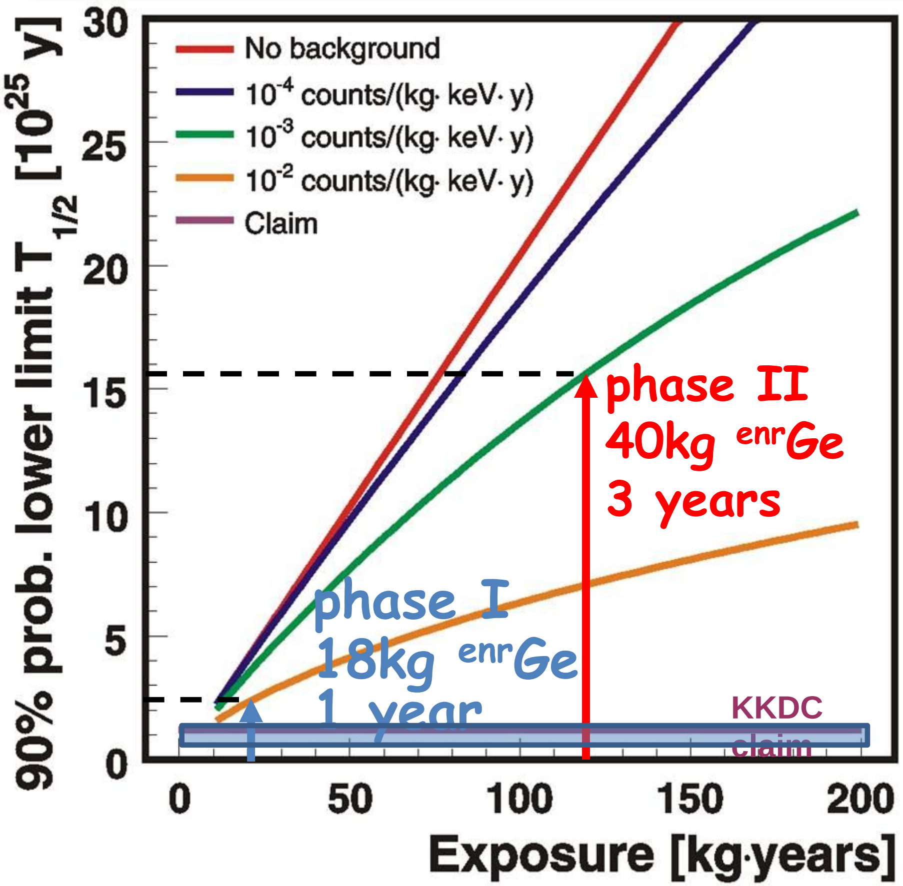
Suppression of μ-flux > 10^6

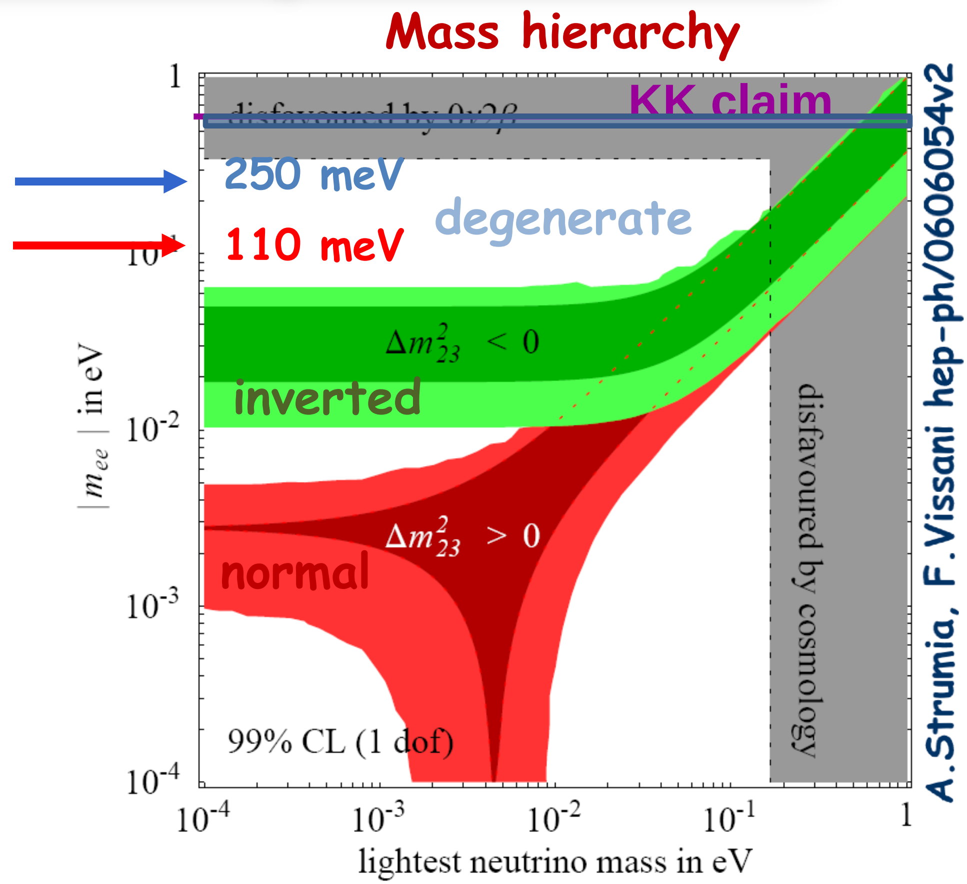
Background reduction methods

- Underground laboratory
- Material cleaning
- Passive shield (Cu&Pb&LAr)
- Muon veto

- Pulse shape analysis vs. detector segmentation
- Detector anti-coincidence
- R&D: LAr scintillation

Phases of the GERDA Experiment

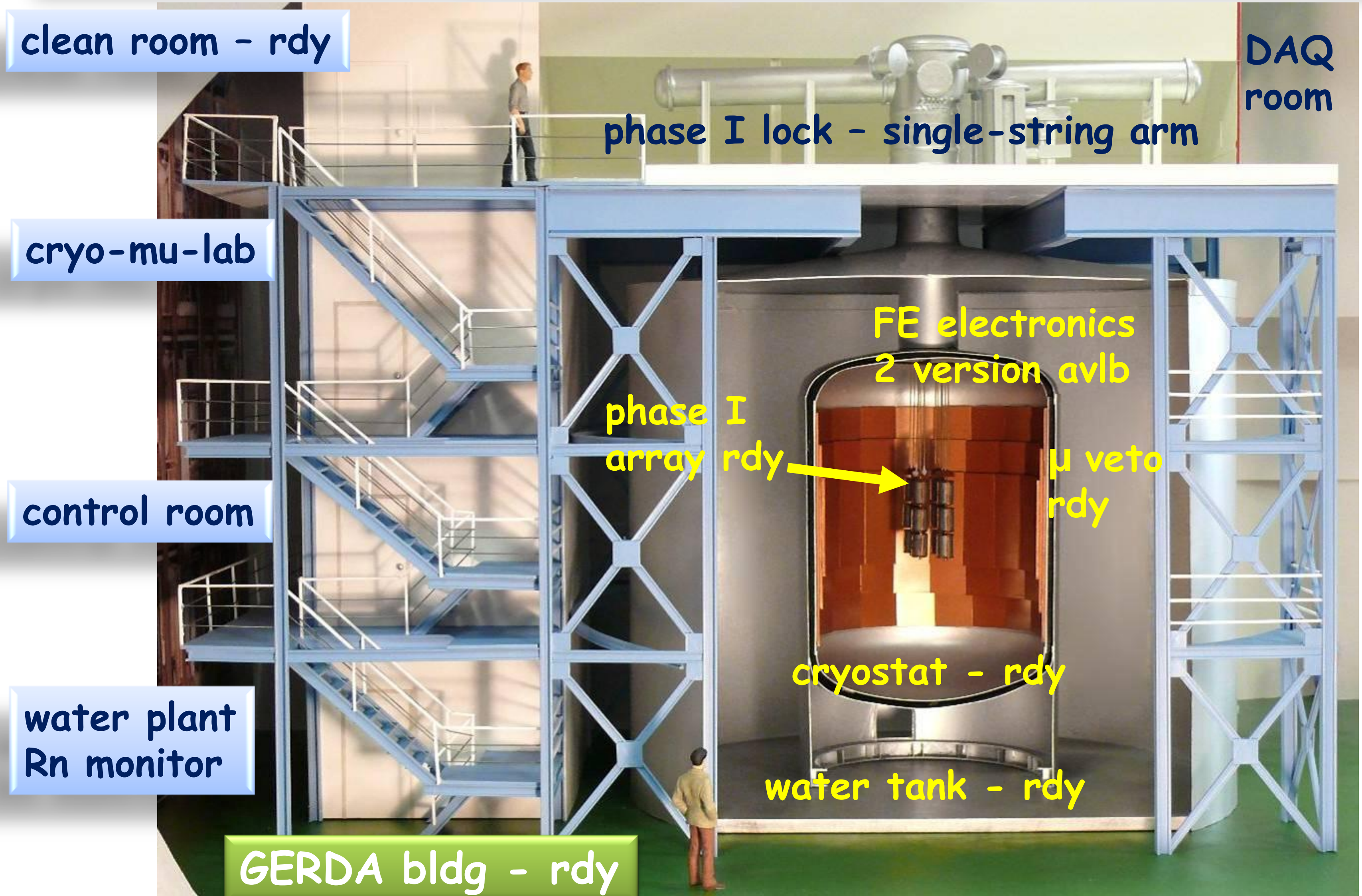




GERDA Phase I – after 1 year able to verify the KK claim

Phase III (GERDA+Majorana) – 1 ton exp. → ~50 meV

Status of Phase I



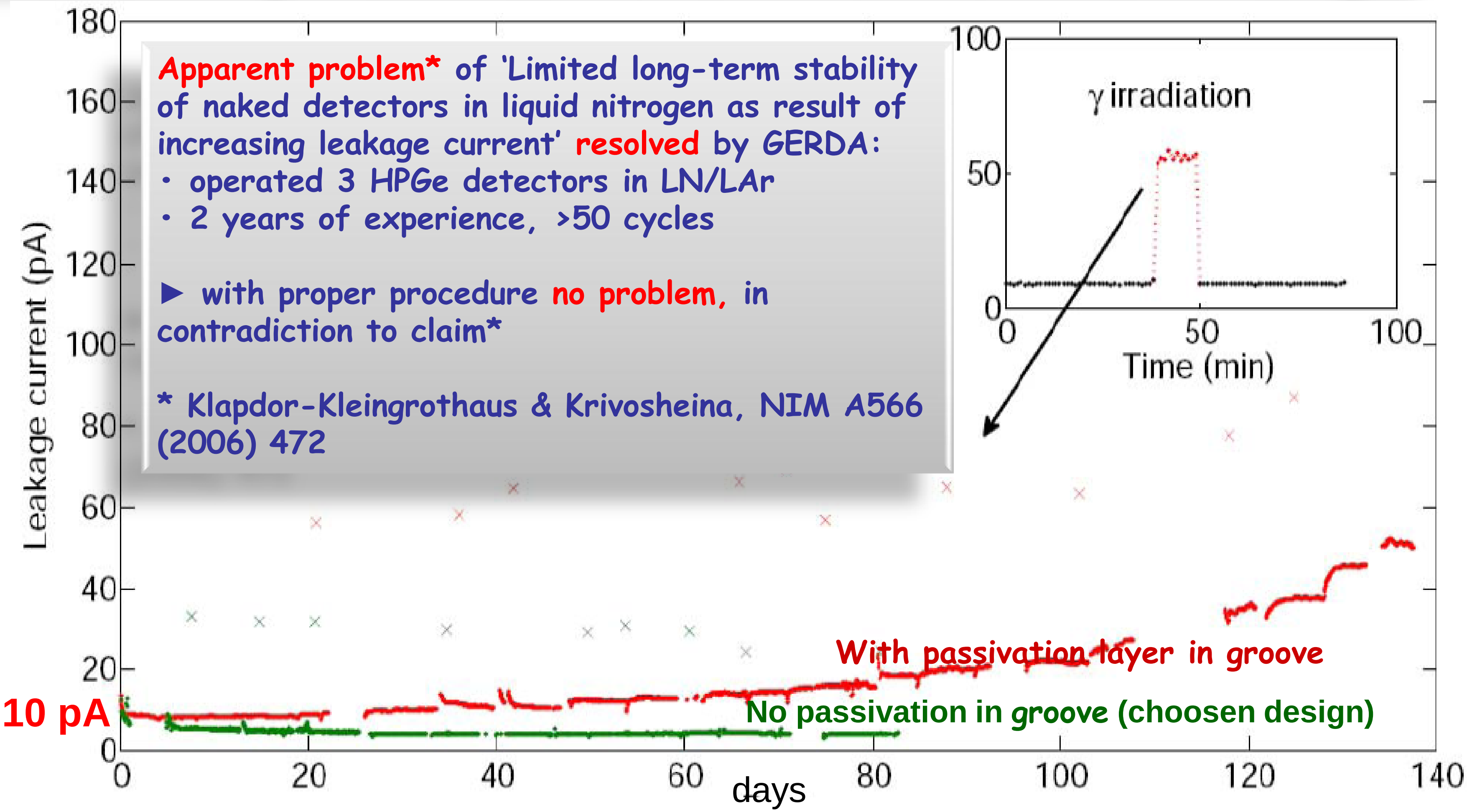
Mounting of GERDA

Phase I Detectors

Detector	Total mass	HV
	(g)	(V)
ANG 1	958	3500
ANG 2	2833	4000
ANG 3	2391	3000
ANG 4	2372	3000
ANG 5	2746	1800
RG 1	2110	4500
RG 2	2166	4000
RG 3	2087	3500
GTF 32	2321	3200
GTF 42	2467	3000
GTF 44	2465	3500
GTF 45	2332	1500
GTF 110	3046	3000
GTF 112	2965	2500
Prototype	1560	3000

- 8 ^{enr}Ge (HdM&IGEX) + 6 ^{nat}Ge (GTF) p-type coaxial Ge detector refurbished
- ^{enr}Ge mass:1-3 kg (total 17.9 kg)
- C_{det} = 30-40 pF
- deployed in strings of 3 dets.
- mounted in low-mass Cu holders
- HV contact: on Li surface by pressure
- readout contact: in borehole spring-loaded
- all the detectors have been tested naked in LAr and perform well (I-V & R < 3 keV @ 1.332 MeV).
- Long term stability experimentally proved

Stability of Phase I Detectors in LAr/LN_2



no deterioration after 1 year of operation in LAr

M. Barnabé-Heider, PhD thesis '09

Commissioning with ^{nat}Ge Det.–Running NOW

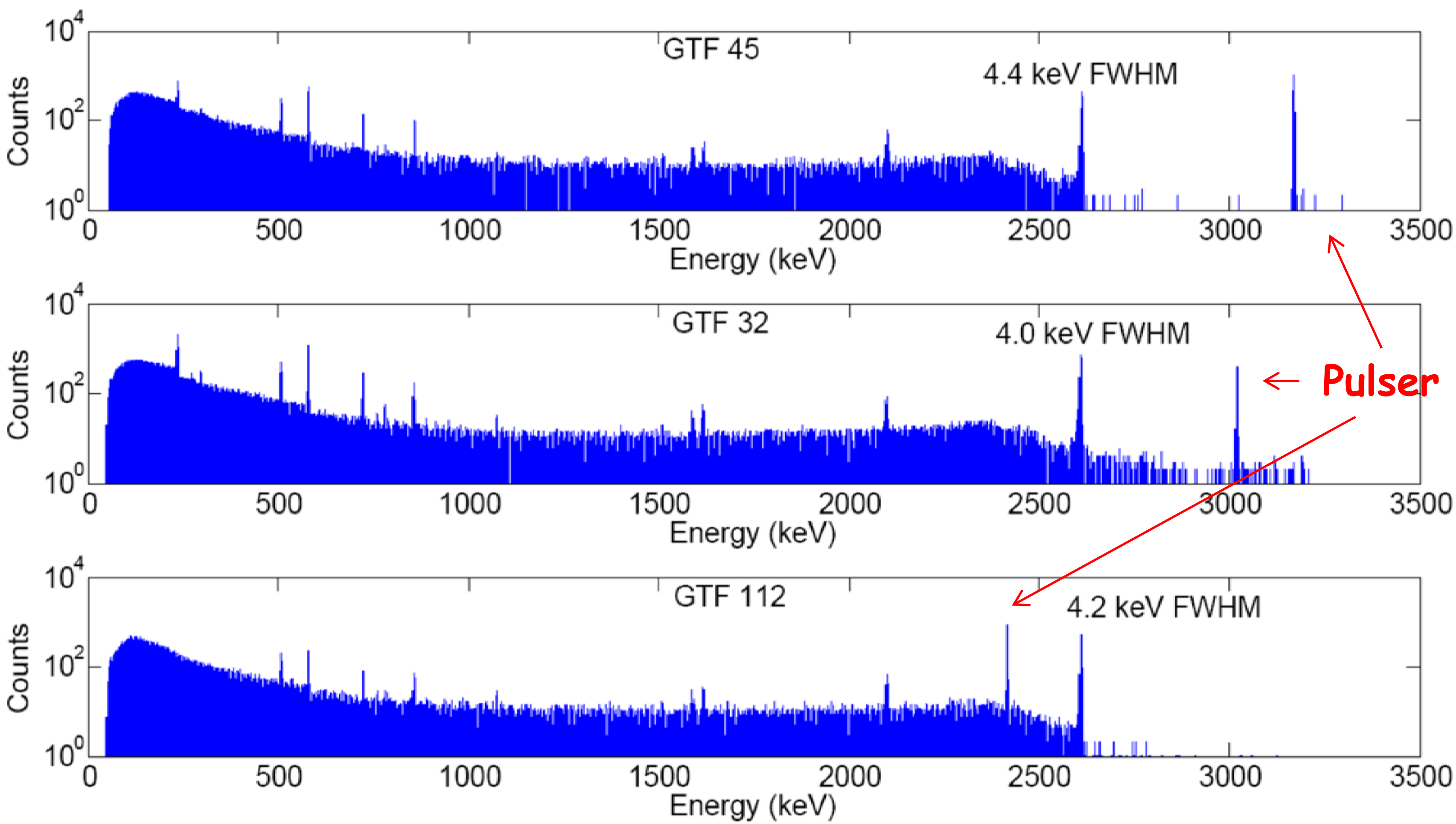
- Summer/autumn 2009: integration test of phase I detectors, FE, lock, DAQ, LAr dewar

  ⇒ energy resolution ~ 2.7 keV @ 1332 keV

- Apr/May 2010: Installation of single-string lock in the GERDA cleanroom
- May 2010: Deployment of FE & detector mock-up, followed by first deployment of a of non-enriched det.
- June 2010: Water tank filling

- June 2010: Commissioning run with 3 ^{nat}Ge detectors
- four cooling cycles made until now
- grounding problems
- characterization runs with Th source
- optimizing energy reconstruction algorithms from digital data
- long-term background measurement are in progress

^{nat}Ge Detectors in LAr - ^{228}Th source



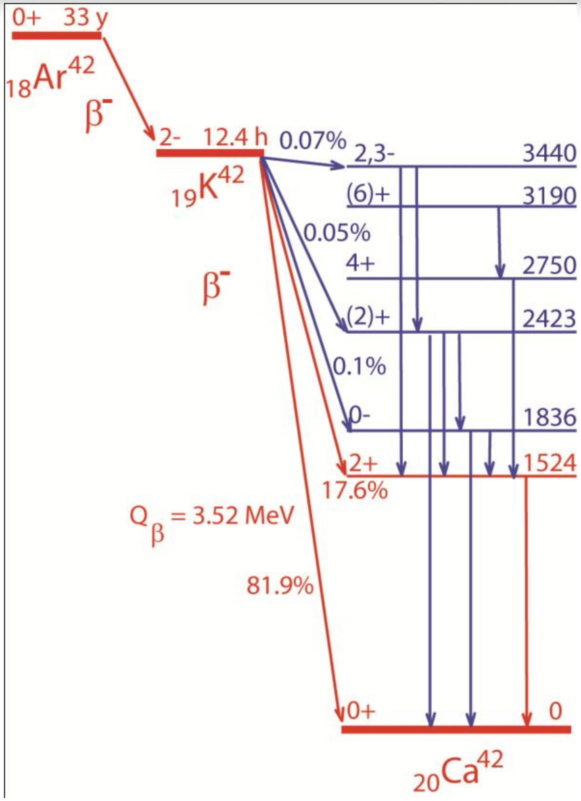
Operation of the 3 ^{nat}Ge Detectors String

Date	Detector	Signal cable length	FWHM [keV]	
			Pulser	γ-ray of 2.6 MeV
11/07/2010	GTF 45	~35 cm	2.8	4.4
	GTF32	~50 cm	2.9	4.0
	GTF112	~65 cm	3.1	4.2

- July 16 start of background measurement with Flash ADC (FWHM ~ 5 keV)
- pulser at 0.1 Hz
- Muon veto signal recorded with the Flash ADC

- No indication of background from U/Th/Co
- Clear peak at 1524 keV (line from 42Ca)

^{42}Ar Background '*Dilema*'



A.S.Barabash,
Proc. Int. Workshop on Technique and Application of Xenon Detectors 2002
42Ar/Ar = 3 x 10^{-21}

Measurements in LArGe with BEGe
- 10 times more 42Ar activity

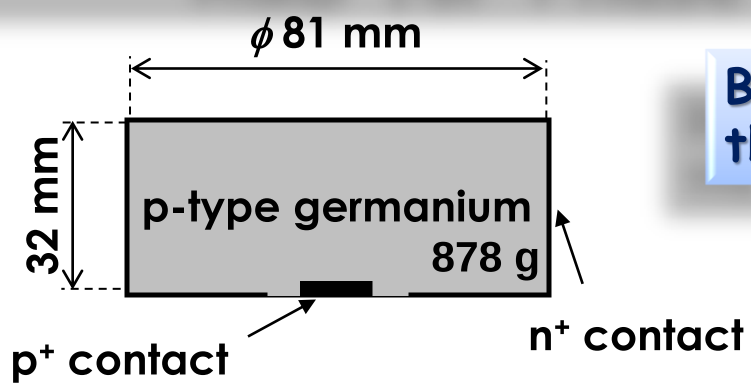
with GTF (in GERDA and LArGe setups)
- even more

Study of the problem:
- origin of the effect
- possible solutions to reduce it

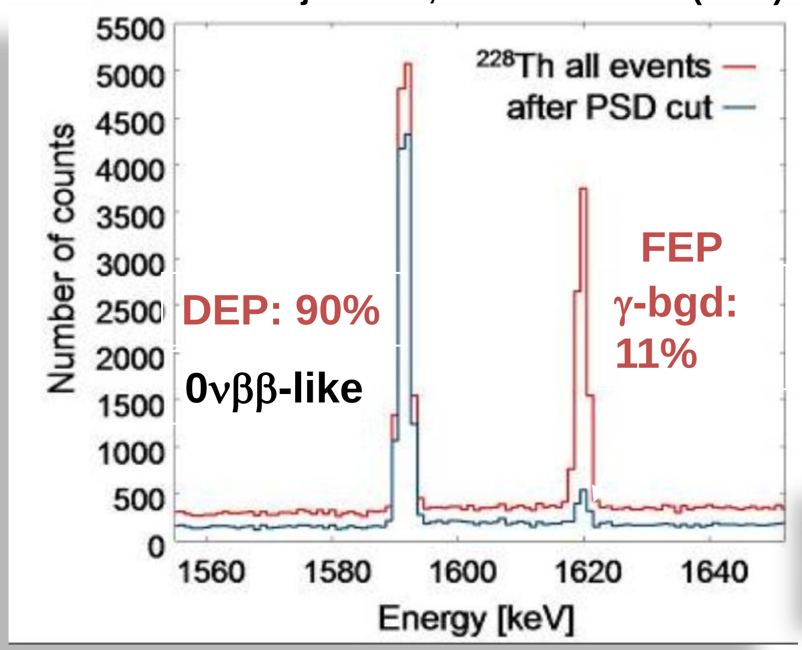
Mounted a mini-shround around the 3 detectors in the GERDA setup
- reduction of the effect

More work needed with both setups: LArGe and GERDA

R&D for Phase II Detectors



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

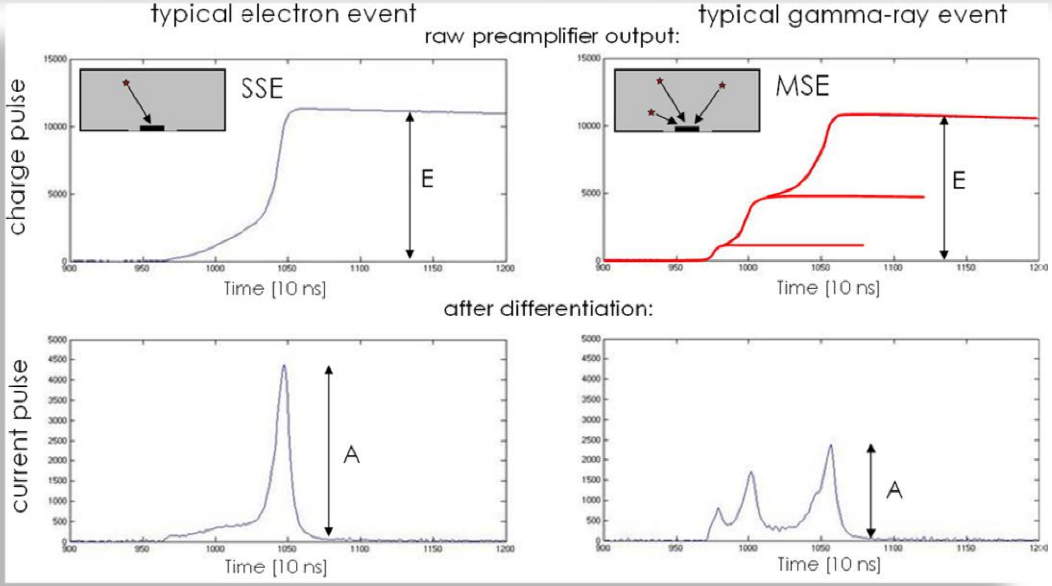


BEGe type detectors were chosen for the Phase II of the GERDA experiment

- good energy resolution and noise characteristics
- excellent rejection capability of discrimination between single-site and multiple-site events based on PSD analysis
- simpler electronic configuration as compared to segmented detectors / less background due to the reduced number of FE electronics channels and less cables

Presently tests are run with 2 ^{depl}Ge and 3 ^{nat}Ge BEGe detectors

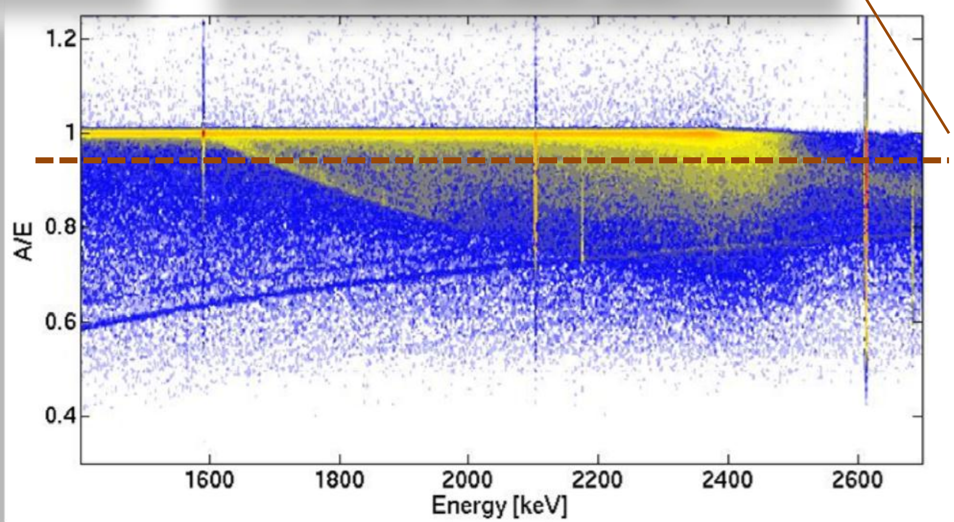
Discrimination based on A/E Parameter



A = maximal current signal amplitude

E = energy of the event

PSD cut – 90% of the ^{208}Tl 2614 keV DEP

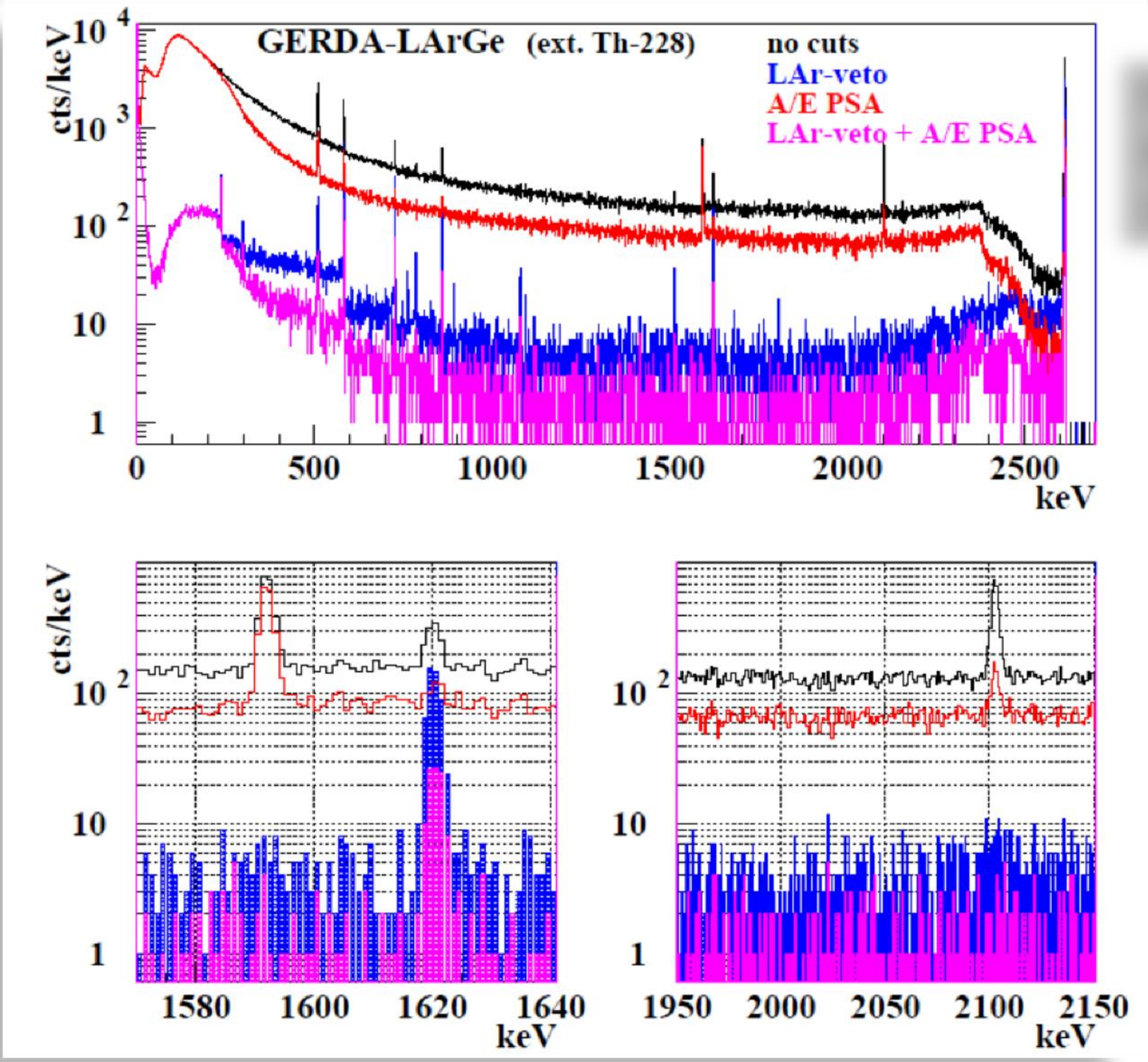


A/E for SSE is independent of the energy and the interaction location inside the crystal volume.

A/E for MSE is smaller

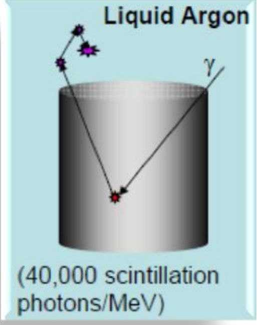
D. Budjas et al., JINST 4 P10007 (2009)
M. Agostini et al., to be published

Test of BEGe performance in LArGe



First test of a naked BEGe detector in LAr (LArGe test bench)

- mantains its spectroscopic characteristics
- good PSA
- importance of the LAr veto for the reduction of the γ–ray backg. (R&D needed for Phase III)



Outlook

- Construction of GERDA is concluded
- The cryostat and the water tank were filled
- Since June 2nd commissioning runs with Phase I ^{nat}Ge detectors and the single-string arm are in progress
- Long-term background measurements are presently running with ^{nat}Ge GTF detectors
- By November the 3-strings lock will be installed and it will be tested with mockup and ^{nat}Ge detectors
- Mounting of the enriched detectors depends on the results from these measurements
- Presumably first results from Phase I will be available in 2011
- The R&D for the Phase II BEGe detectors development is running in parallel with the preparation of Phase I
- The BEGe detector was chosen for the Phase II due to its excellent noise and PSD characteristics

GERDA

Collaboration

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