GERDA STATUS REPORT
SEARCH OF ^{76}GE $0\nu\beta\beta$ DECAY

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on behalf of GERDA collaboration

The GERDA setup
in Hall A of LNGS

Outline

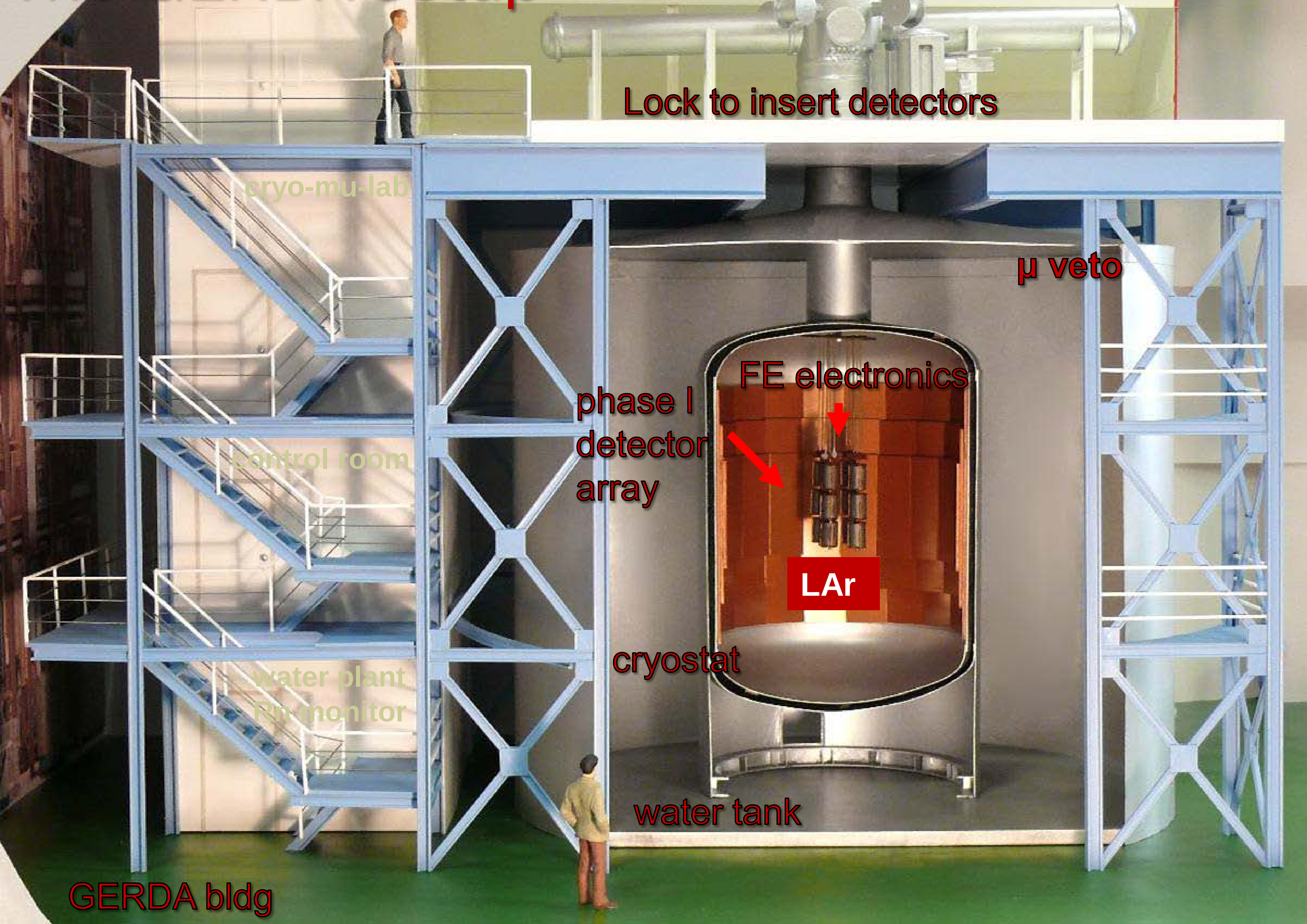
- GERDA
  - Setup
  - Sensitivity
- Results from the first year of data taking
  - Results on ^{42}Ar
  - Background from Th,U,K,Co
  - The spectrum of ^{76}Ge $2\nu\beta\beta$
  - Plans for forthcoming operations
- Status of Phase II preparation
  - Detectors
  - LAr instrumentation
- Conclusions

The Collaboration

~ 95 physicists
17 institutions
7 countries
(Germany, Italy, Russia,
Poland,Belgium,Switzerland, China)

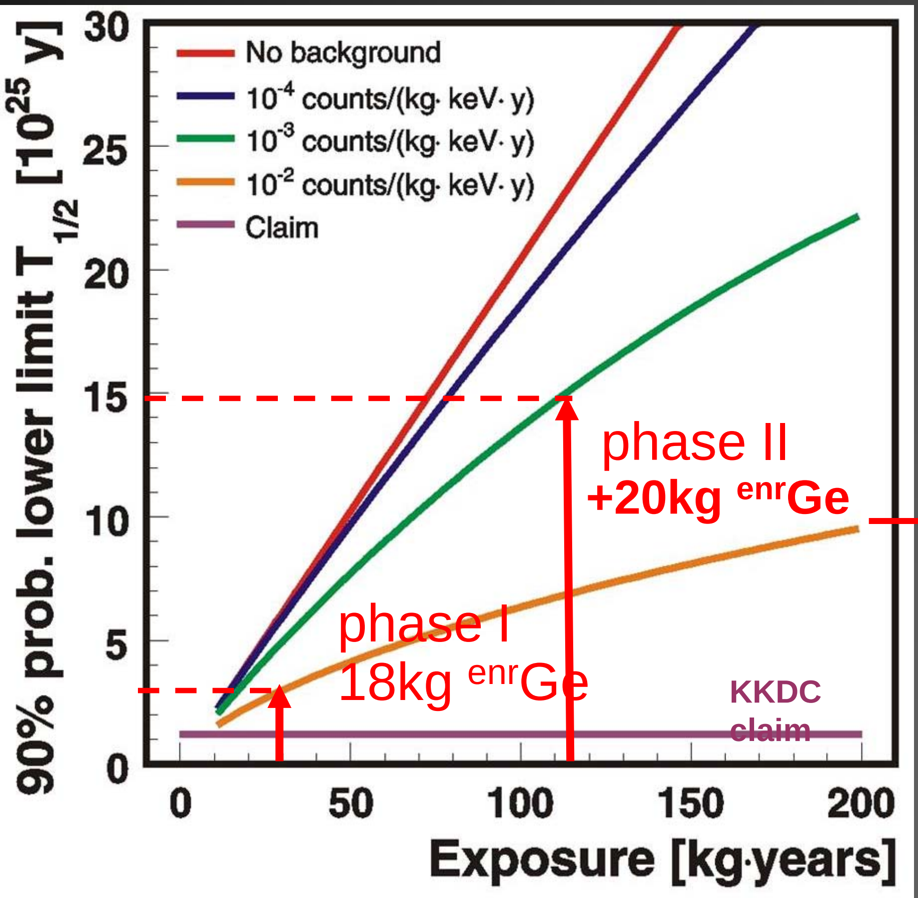
GERDA collaboration picture,
GERDA meeting; Zurich- June 2011

The GERDA setup

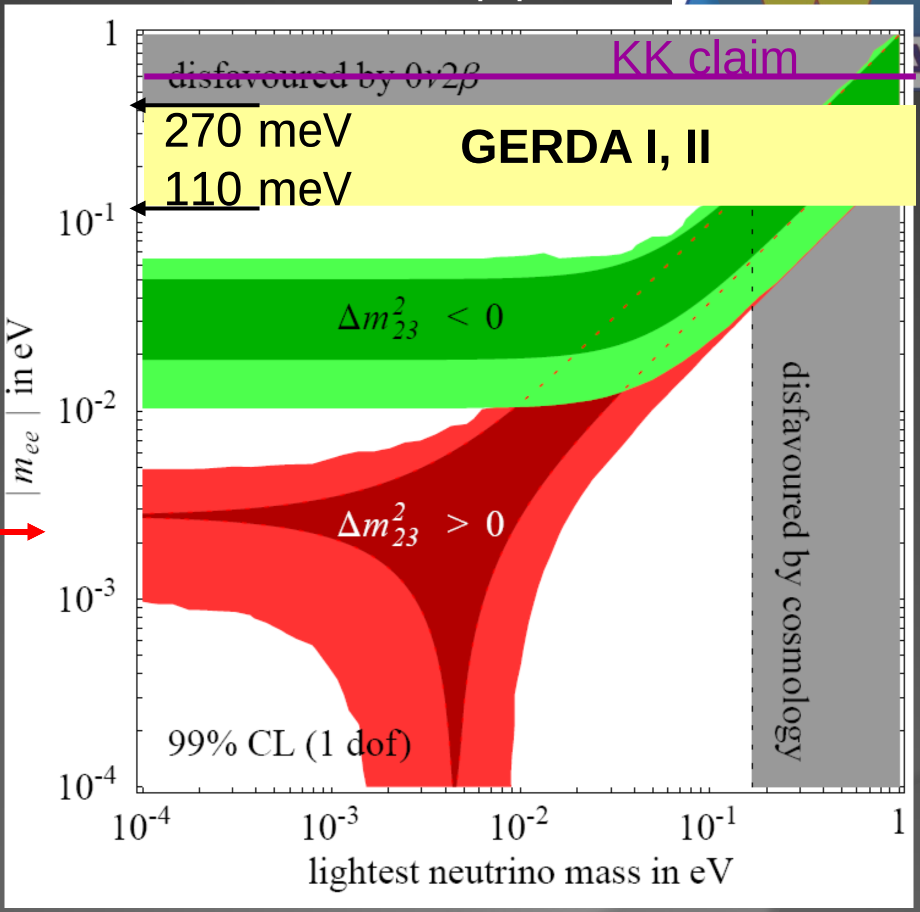


GERDA: Sensitivity

Assumed E resolution: ΔE = 4 keV



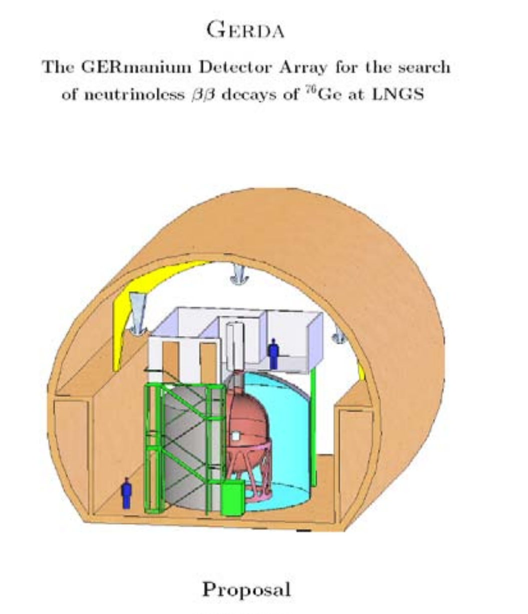
From Vissani, Strumia hep-ph/0606054v2

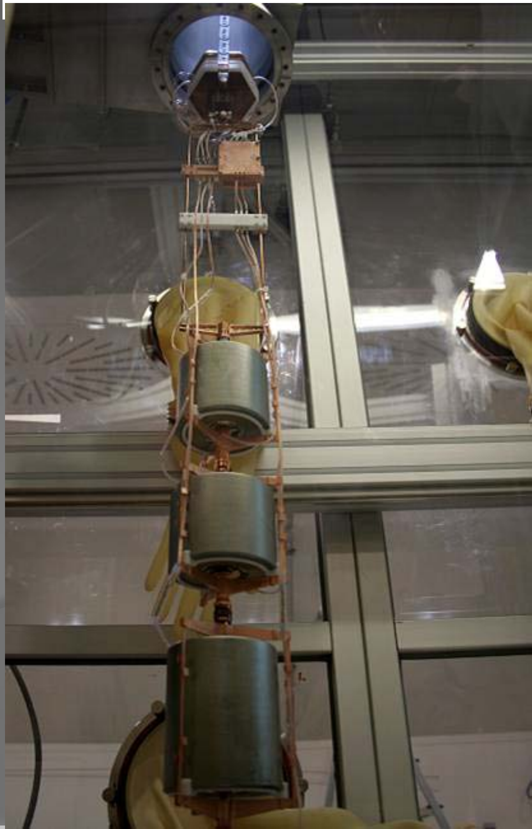


GERDA I: scrutinize in ~ 1 year data taking (assuming 18 kg y exposure) the KK claim: if true ββ decay GERDA will have 7 cts, above bckg of 0.5 cts → probability that bckg simulate signal ~ 10^{-5}

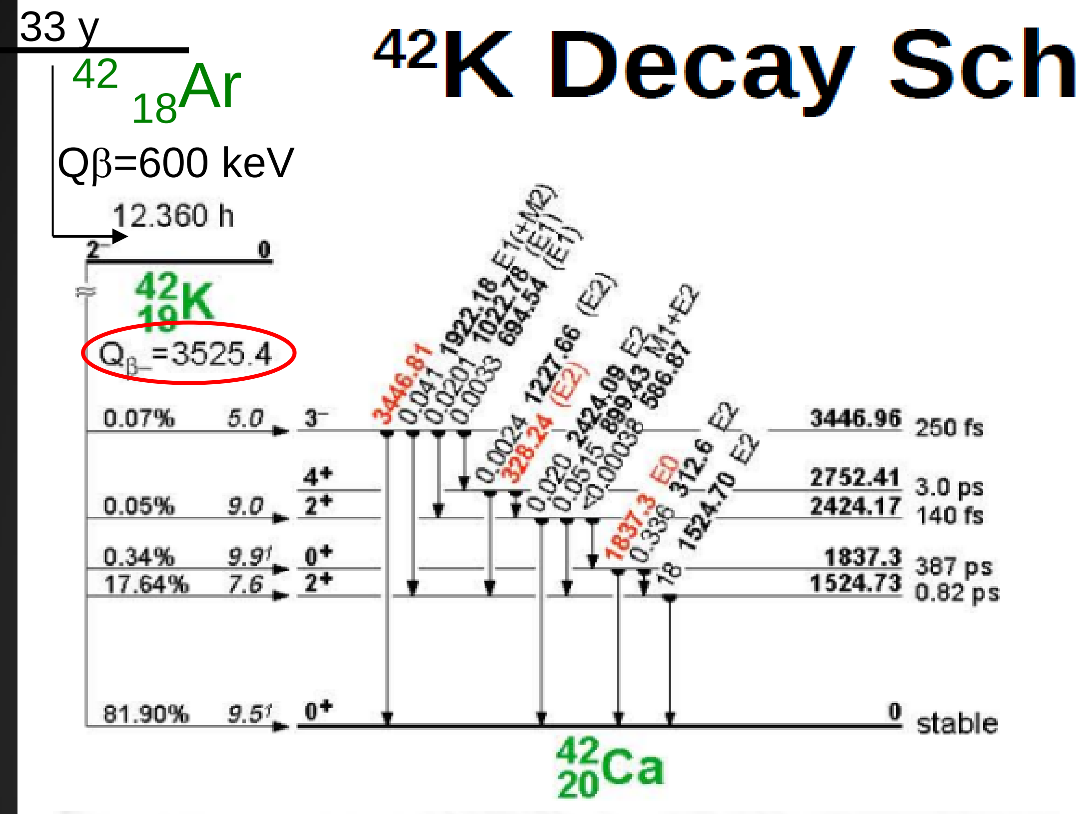
GERDA milestones

- Proposed, funded,designed, constructed: 2005-2010
- June 2010: start of commissioning runs with one string of 3 ^{nat}Ge detectors (7.6 kg) to investigate the setup background .
- June 2010- June 2011: investigated
  - background sources → ^{42}Ar- ^{42}K
  - the ^{42}Ar background mitigation strategies
- June 2011: deployed the first string of ^{enr}Ge (6.7 kg) detectors, in the best configuration found so far, while continuing the data taking with ^{nat}Ge detector strings on the second string arm





^{42}K Decay Scheme



- $T_{1/2}$ = 12.36 h
- Q = 3525.4 keV
- Mostly a pure β emitter
  - Most intense γ ray at 1524.73 keV (18.1%)

γ(^{42}Ca) from ^{42}K (12.360 h) β^- decay <for Iγ% multiply by 0.1808 9>

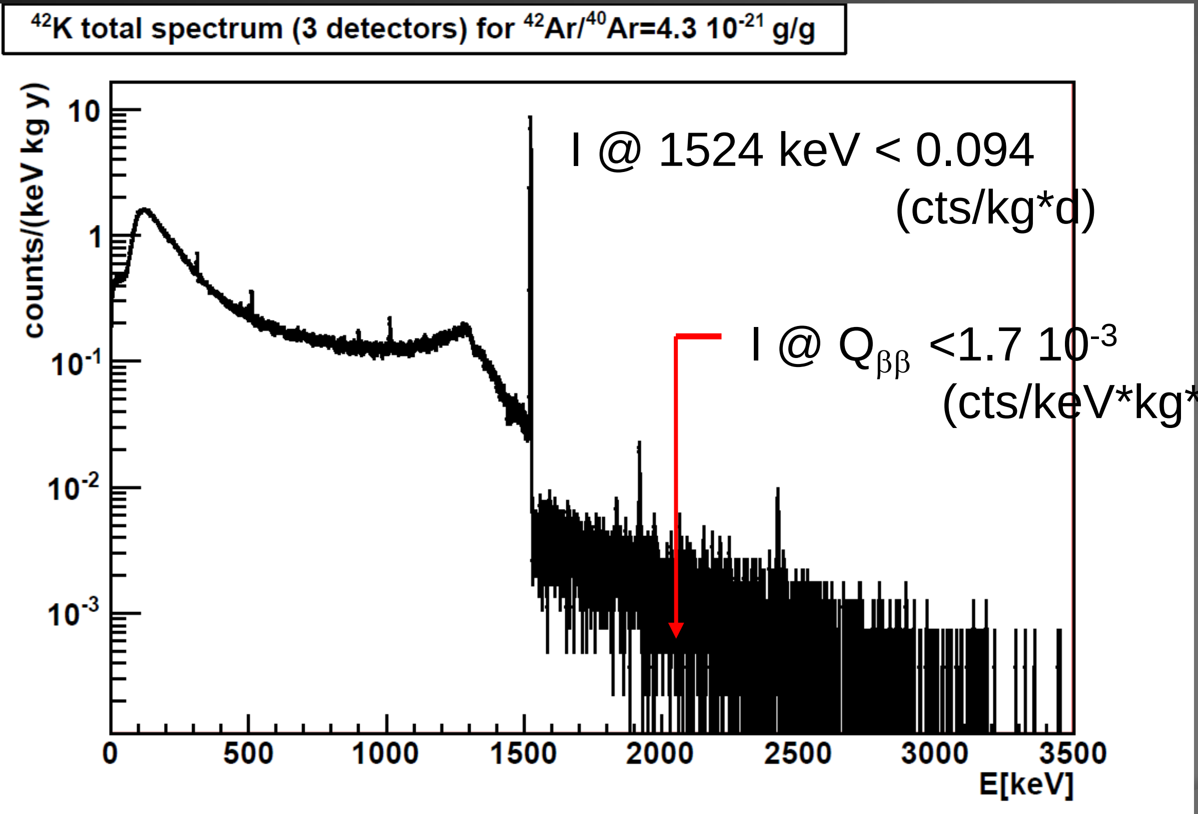
312.6 (I_γ 1.86 11) E2
586.87 (I_γ <0.0021)
694.54 (I_γ 0.018 4) (E1)
899.43 (I_γ 0.285 14) M1+E2: δ= −0.18 2
1022.78 (I_γ 0.111 8) (E1)
1227.66 (I_γ 0.013 6) (E2)
1524.70 (I_γ 100) E2
1922.18 (I_γ 0.228 22) E1(+M2): δ=+0.02 7
2424.09 (I_γ 0.110 16) E2

Background at $Q_{\beta\beta}$ by:

β, bremsstrahlung from β and 2424 keV γ-ray

The expected ^{42}Ar background

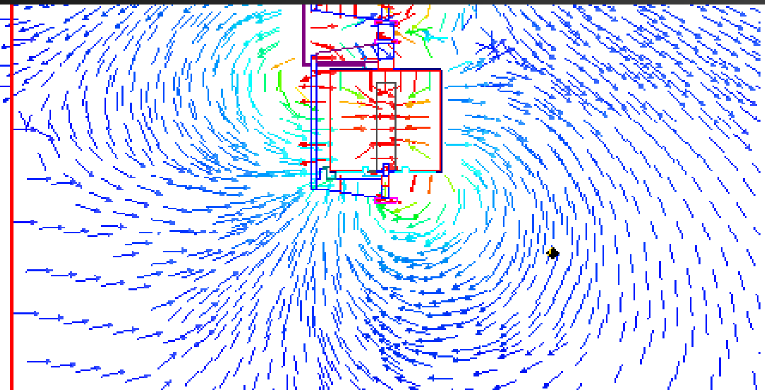
- ^{42}Ar production: ^{40}Ar(α,2p)^{42}Ar reaction in atmosphere and fall-out from atmospheric nuclear explosions
- ^{42}Ar concentration: measured < 40-60 μBq/l → < 0.1 cts/(kg day) in GERDA geometry, for an homogeneous distribution around the detectors.



Bckgrd @ $Q_{\beta\beta}$

- From ^{42}K β decay in the detector borehole or @ Li layer
- Hard bremssthralung of > 2 MeV βs in LAr

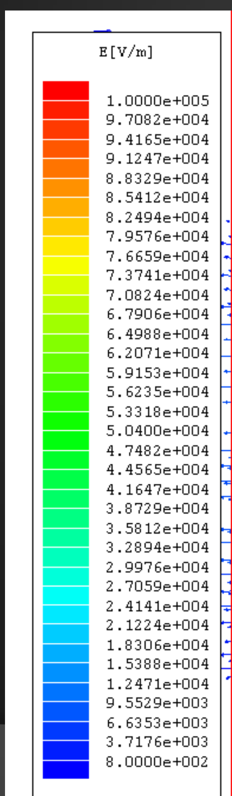
Results on ^{42}Ar-^{42}K from the first year of data taking



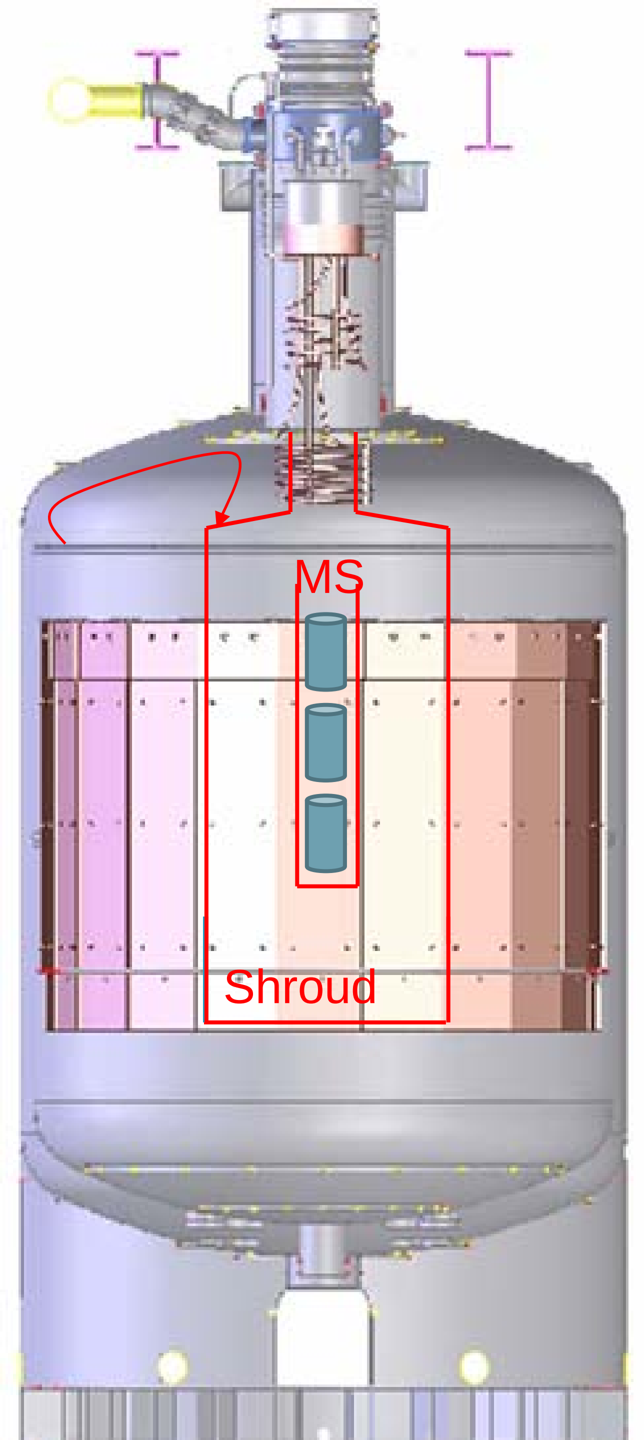
In the first run

$$I_{1524}^{meas} > 20\ I_{1524}^{expected}$$

Soon we understood that ^{42}K, generated positively charged by the ^{42}Ar β decay:



- ❑ can be drifted by moderate E_{field} as the ones dispersed in LAr by the diodes bias
- ❑ The starting ^{42}K homogeneous distribution changes to a new one → enhancement / reduction of cts rate @ the γ-line.
- ❑ While drifting or when reaching metallic surfaces it can be neutralized (τ_{neutr} 20 - 40 min), and/or decay (τ_{decay} 12 h).
- ❑ The ^{42}K β decay at the detector surface (mainly in borehole) gives events at the $Q_{\beta\beta}$



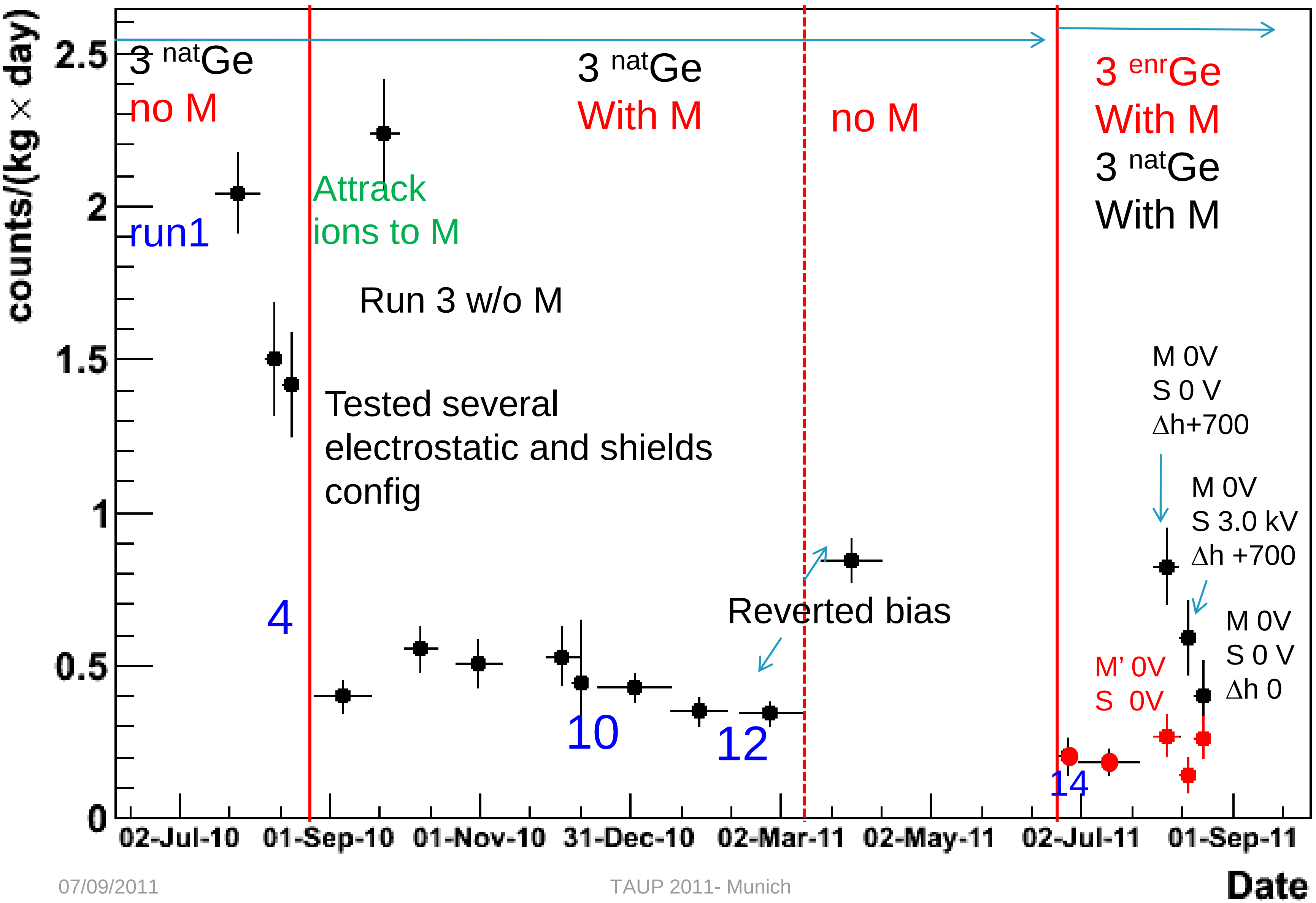
The Mini-Shroud

Deployed a Cu shield called minishroud (MS) to

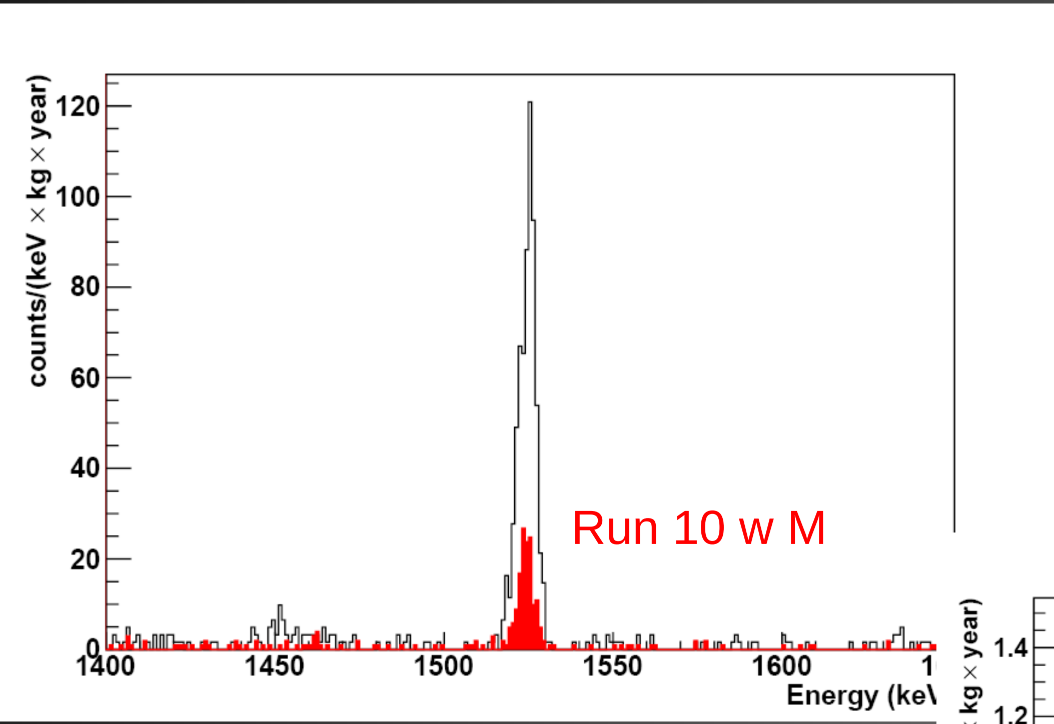
- Physically separate the LAr bath in two volumes: the smallest (3 l) surrounding the detectors, and the largest, outside it.
- Prevent that the dispersed E_{field} pumps ions from the largest fraction of the LAr bath (an infinite ^{42}K reservoir)
- Prevent that the sucked ions reach the detector surfaces

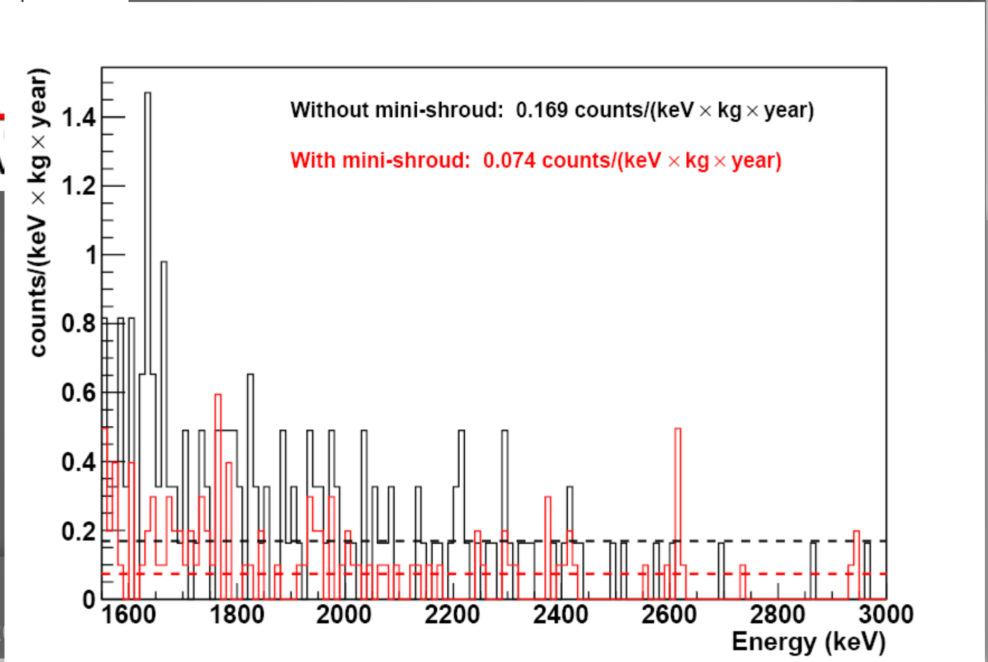
History ofCount rate at the 1525 keV γ-line

S= outer shroud (diameter 760 mm), M = mini-shroud (diameter 115 mm)

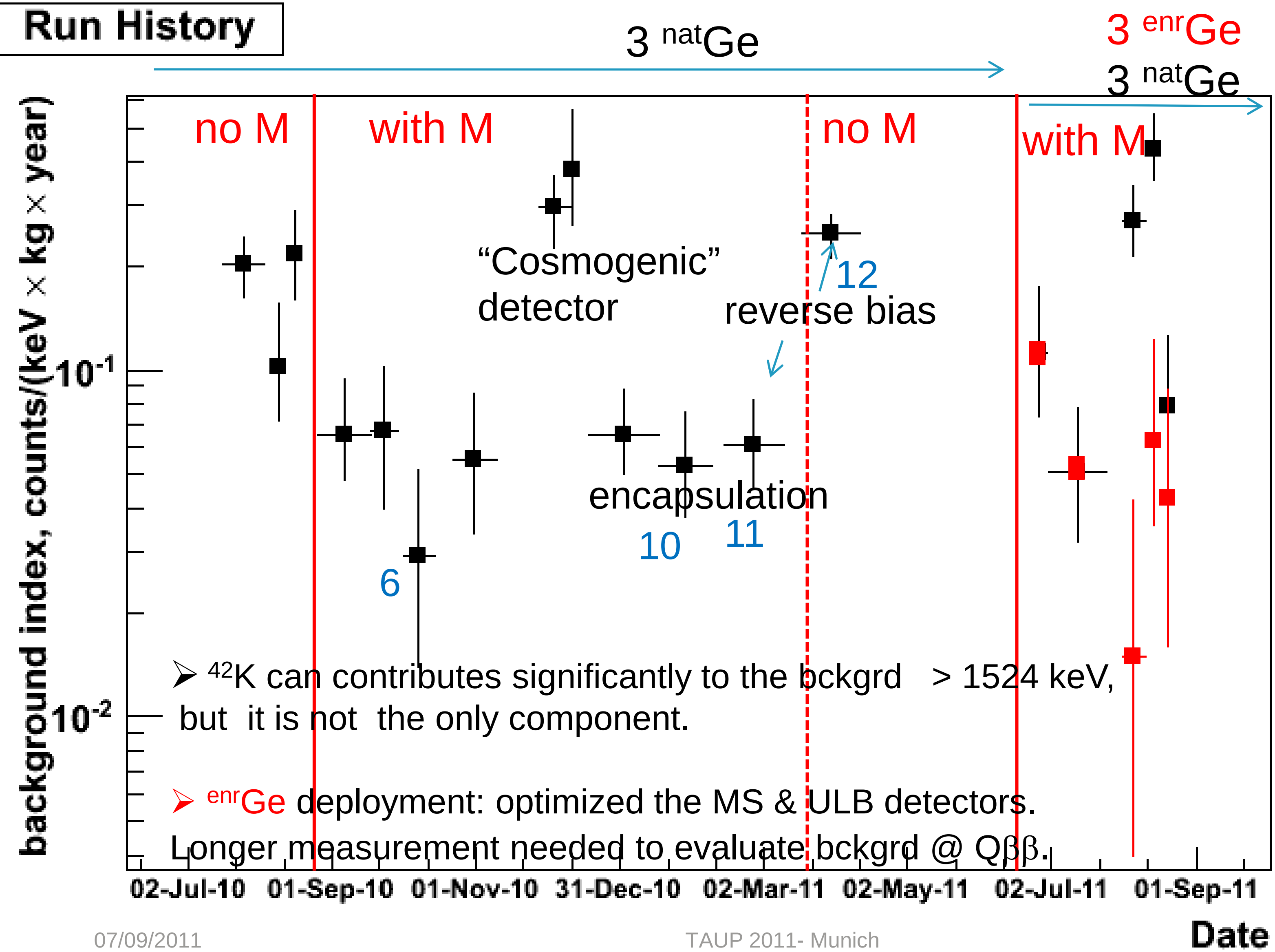


Effect of MS on the collected spectrum





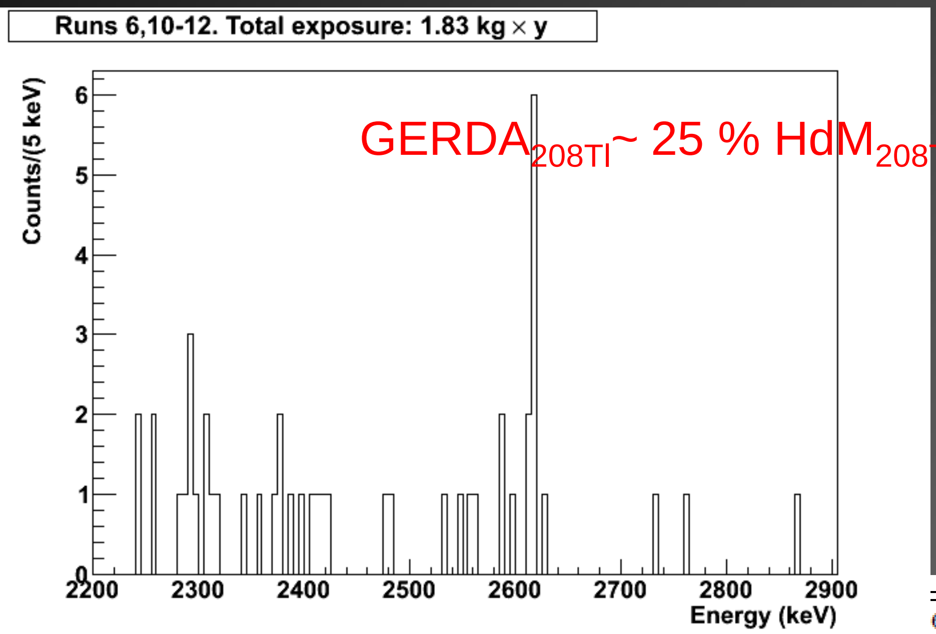
History of count rate at $Q_{\beta\beta}$ in ^{nat}Ge detectors (1839 keV – 2239 keV)



➢ ^{42}K can contributes significantly to the bckgrd > 1524 keV, but it is not the only component.

➢ ^{enr}Ge deployment: optimized the MS & ULB detectors. Longer measurement needed to evaluate bckgrd @ $Q_{\beta\beta}$.

Background from other isotopes in the ^{nat}Ge



Conservative estimate (not from best runs)

Rate@2614 keV= 4.83 cts/(kg y)

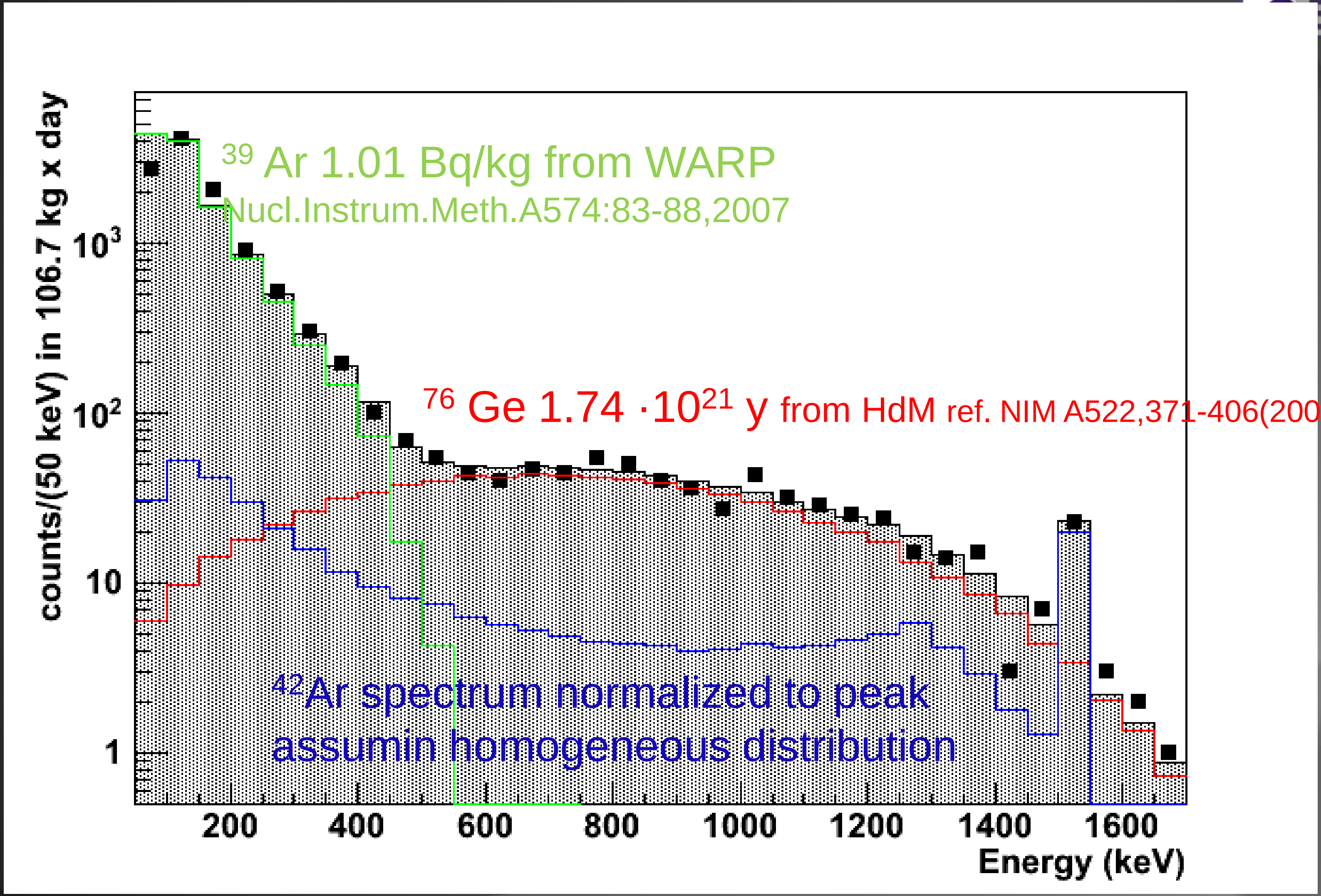
Extimated cts rate @ $Q_{\beta\beta}$= 2.2 10^{-2} cts/(kg KeV y)

HdM bckgrd Rate@2614 keV= 26 cts/(kg y)

Ratio (R) of the bckgrd in GERDA (G) and in previous HdM experiment. HdM data.

	energy [keV]	I_{HdM} [cnts] original	I_{HdM} [cnts] normalized	I_G [cnts]	R
^{40}K	1460.8	13010 ± 134	287 ± 3	14.6 ± 5.8	19.7 ± 7.9
^{60}Co	1173.2	3955 ± 88	87 ± 2	12.8 ± 5.8	6.8 ± 3.1
	1332.3	3690 ± 90	81 ± 2	< 7.9	> 10
^{137}Cs	661.6	20201 ± 164	445 ± 4	<2.5	> 180
^{208}Tl	583.1	2566 ± 228	57 ± 5	9.9 ± 5.8	5.7 ± 3.4
	2614.5	1184 ± 36	26 ± 1	$7.0^{+3.8}_{-2.6}$	$3.7^{+2.0}_{-1.4}$
^{214}Bi	609.3	7552 ± 96	167 ± 2	36.7 ± 8.1	4.6 ± 0.8
	1120.3	1926 ± 86	43 ± 2	12.2 ± 5.5	3.5 ± 1.6
	1764.5	2204 ± 51	49 ± 1	$7.0^{+3.8}_{-2.6}$	$6.9^{+3.8}_{-2.6}$
^{228}Ac	910.8	2135 ± 115	47 ± 3	<7.7	> 6
	968.9	1259 ± 82	28 ± 2	<6.4	> 4.8

NEW: First spectrum of 2νββ decay from the ^{enr}Ge string data taking (Run 15)



Ongoing and forthcoming activities

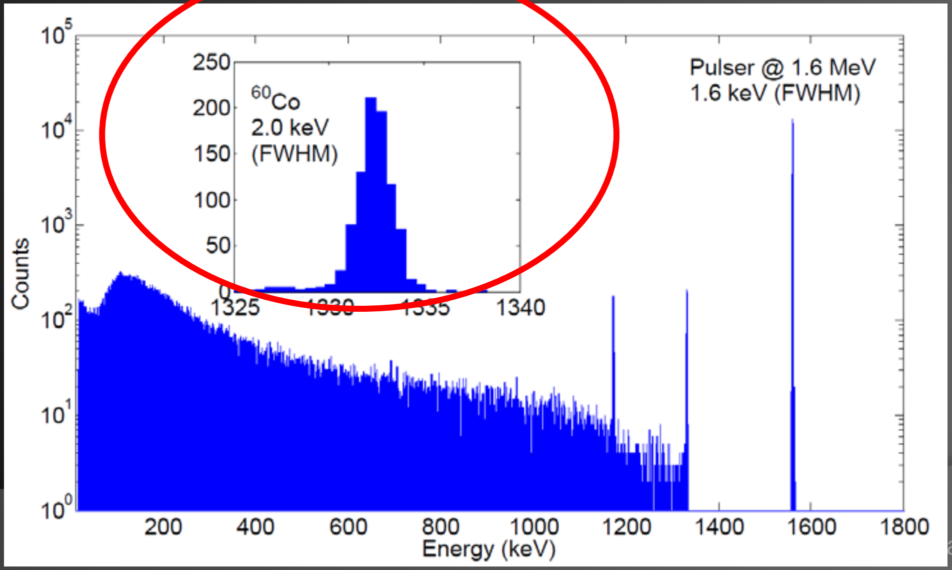
- Measurement in a field free configuration of [^{42}Ar] with ^{nat}Ge
- Long term background measurement with ^{enr}Ge

Present schedule

- Commissioning runs will end in autumn.
- By end of 2011: deploy all the ^{enr}Ge detectors in the 3 string arm
- Start Phase I data taking

Preparation of GERDA PHASE II: choice of detectors allowing enhanced PSD.

P-type thick window BEGe detector (80 x 40 mm) tested naked in Lar with cold front-end



The GERDA Phase II detector baseline is the Broad-Energy Germanium (BEGe) detector. The small size of its signal electrode results in :

1. Low capacitance → high energy resolution. En Res 1.6 keV @ 1.332 MeV

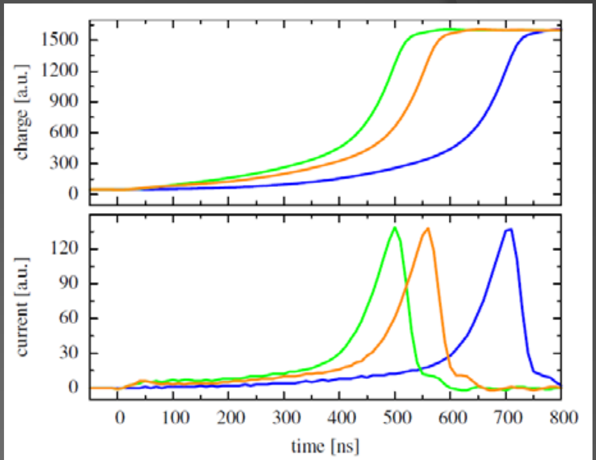
Preparation of GERDA PHASE II: BEGe detectors with enhanced PSD.

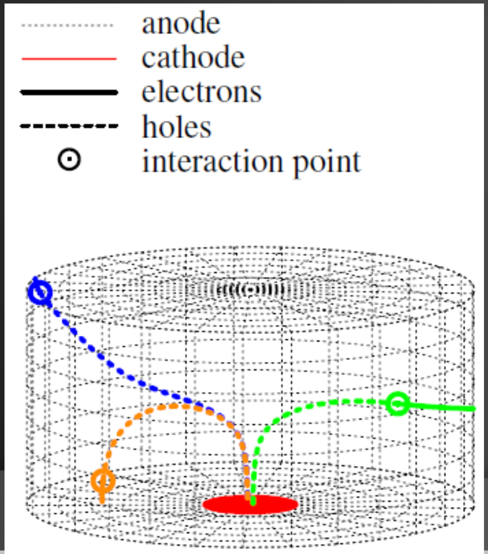
2. Increased field near electrode → improved S/bckgrd rejection capability by ID event topologies

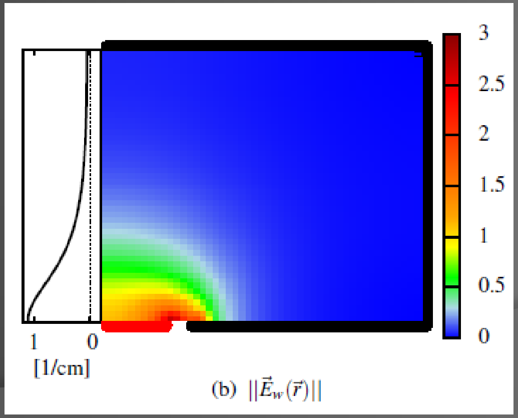
- Pulse Shape cuts accepting 90% of ^{232}Th DEP (mostly Single Site Events → $0\nu\beta\beta$-like)

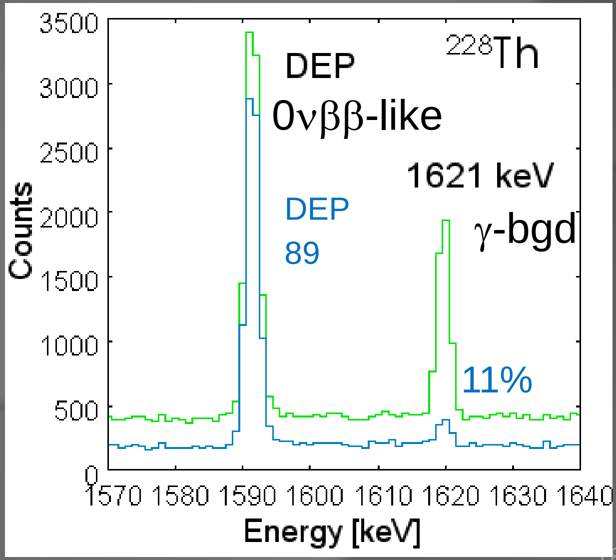
⇩

~10% survival of the γ-line ^{212}Bi line (mostly Multi-Site Events → γ-like)



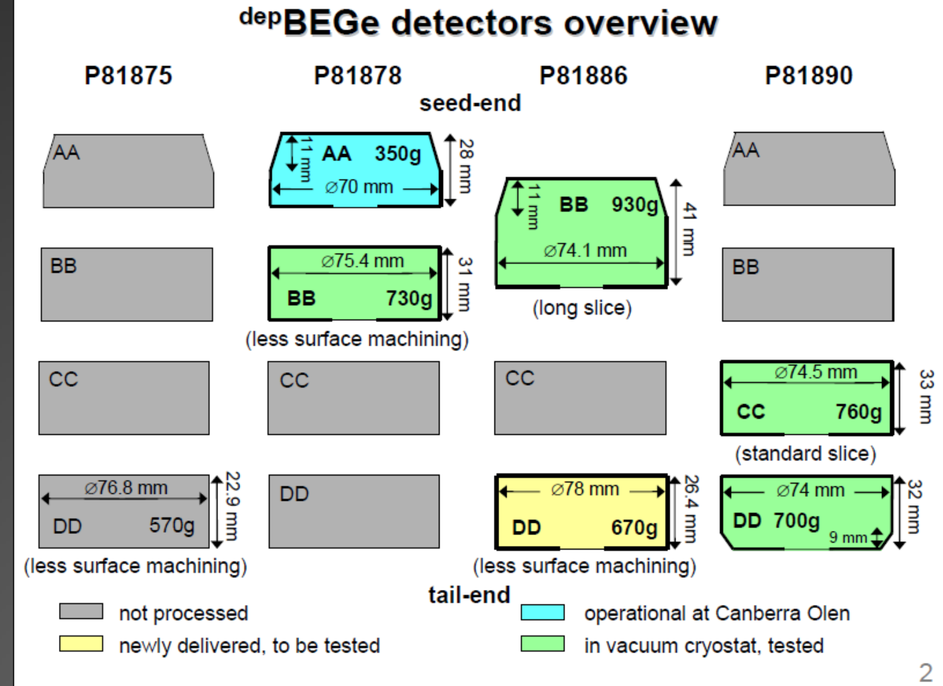


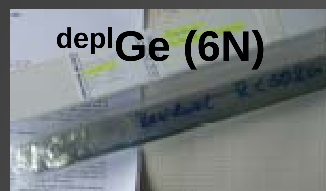




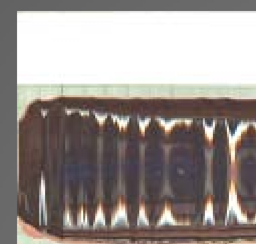
The ^{depl}BEGe production

- In years 2009-2010 performed a pilot production of BEGe diodes starting from ^{depl}Ge of same origin and processing history of the ^{enr}Ge.

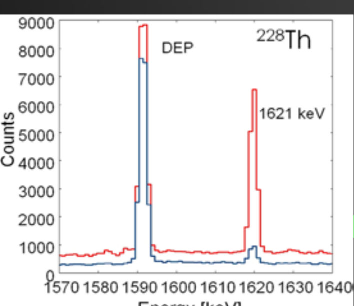




Test a modified production process aiming to improve the production mass efficiency of working detectors vs input Ge material



crystal slice



Test in vacuum cryostat

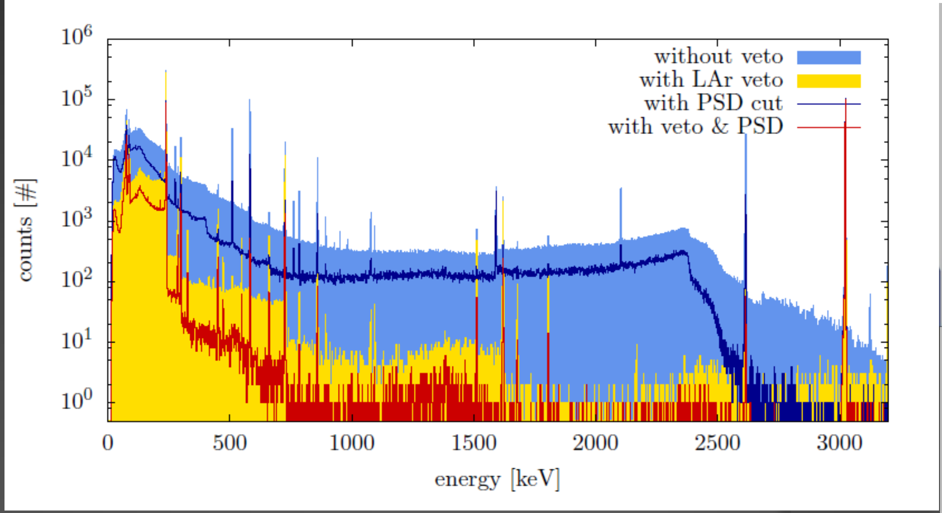
- 3 ^{nat}Ge + 4 (5) ^{depl}Ge BEGe detectors tested so far in vacuum cryostat: all show excellent resolution (1.6 keV @ 1332 keV) and Pulse Shape discrimination performances

The preparation of GERDA Phase II: ^{enr}Ge processing and diodes production

- ✓ 36.6 kg >50 Ohm material produced.
- ✓ 97% of the 37.5 kg available ^{enr}Ge is now 6N material.The integrated CR exposure: 5.2 days
- ✓ All the material is stocked underground ready to be sent to our industrial partner
- ✓ Contract with the industrial partner to grow ^{enr}Ge crystals & produce BEGe diodes following the process of ^{depl}BEGe: signed
- ❑ Current schedule: Phase II detector produced and tested by summer 2013

LAr instrumentation

❑ LAr readout is a powerful tool to further reduce background, (condition: should not introduce new bckgrd sources).



- **Measured** suppression factor at $Q_{\beta\beta}$: **~$0.5 \cdot 10^4$** for a ^{228}Th calibration source

- Triplet halflife in GERDA has been recently measured to be 920 ns ± 20: the lock and glove box system work very well in GERDA.

  look at M. Heisel poster (P27) in Poster session

- After 1 y of operation the LAr purity is preserved.

- Work in progress to implement the LAr readout the by new low background PMTs (Hamamatsu, few mBq Th) or by SiPM/APD coupled with fibers, or direct readout sticked @ MS wall

Conclusions & Outlook Phase I

- GERDA is taking data since june 2010. All the parts of the setup works well and allows a smooth data taking

- Phase I Detectors perform satisfactory:
  - Leakage current< 50 pA independent on length and number of calibrations
  - Energy resolution @ 2.614 keV 208Tl: 3.6 keV ÷ 6.0 keV

- Background:
  - Encountered ^{42}Ar - ^{42}K unexpected intensity. The ^{42}K β–γ decay is responsible for background < 2.0 MeV (1524 keV γ–line), and > 2.0 MeV if the ^{42}K β-decay happens in the borehole or at surface
  - ^{42}K is produced charged and we learned how to move it in the LAr by applying Efield
  - Background from Th and U is much lower (~ 1/4) than in previous experiments (HdM & IGEX): GERDA technique validated.

Conclusions & Outlook Phase I

- The background of the ^{nat}Ge string i@ $Q_{\beta\beta}$ (1839- 2239 keV range)
  0.06 ± 0.02 cts/(kg·keV·y)
  Most likely from a combination of Compton continuum from Th/U, residual ^{42}K, degraded α, bckgrd from cosmogenic isotopes

- In June 2011 deployed first string of ^{enr}Ge in the best electrostatic and shielding configuration found so far

  - $2\nu\beta\beta$ spectrum well visible in an exposure of
    107 kg·y (=6.6 kg·16 d) of ^{enr}Ge detectors:
    Spectrum well reproduced by overlapping of ^{39}Ar, $2\nu\beta\beta$ ^{76}Ge, ^{42}Ar

  - Indications of background improvement:
    In ^{enr}Ge run @ $Q_{\beta\beta}$ < 0.06 cts/(kg·keV·y) @ 90% CL
  - Needs confirmation (more statistics).

- By end of 2011 all the 8 ^{enr}Ge Phase I detectors will be deployed.

Conclusions & Outlook Phase II

- Phase II in advanced Phase of preparation.
- Tools to enhance the S/Background prove to work
  - BEGe detector with enhanced PSD feature to recognize event topology
  - Veto of external γs and internal cosmogenic isotopes (^{68}Ge,^{60}Co…) by LAr scintillation light works: LAr readout with PMTs successfull (LARGe), test with SiPM with/wo optical fibers ongoing.
  - Triplet half-life of LAr scintillation light measured in GERDA setup (no purification) 920 ns.