JOINT INSTITUTE FOR NUCLEAR RESEARCH

First results from **Phase II** of the **GERDA** experiment

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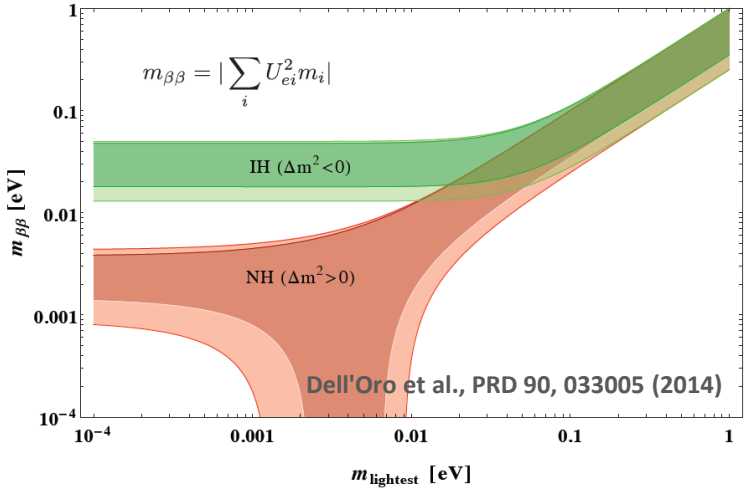
INPC 2016

11-16 September 2016 – Adelaide – Australia

NATIONAL RESEARCH CENTRE
"KURCHATOV INSTITUTE"

0νββ-decay

- ! violates lepton number ↔ forbidden in the SM
- ! only if ν has Majorana mass component or other new ΔL = 2 operators exist



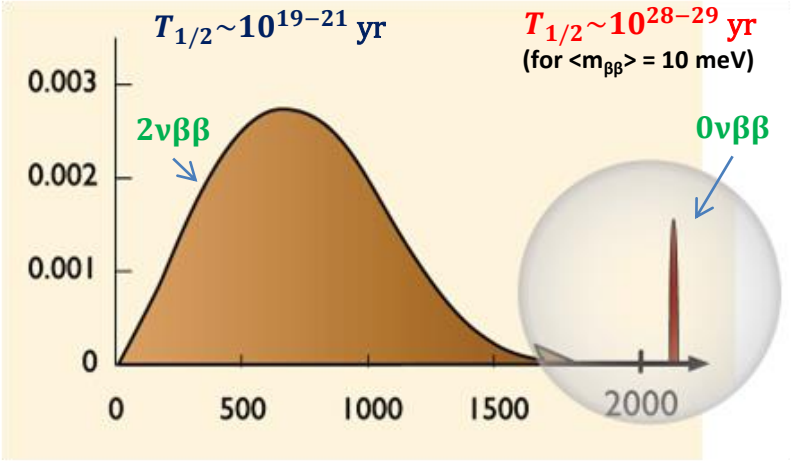
$$\frac{1}{T_{1/2}^{0\nu}} = G^{0\nu}|M^{0\nu}|^2\langle m_{\beta\beta}\rangle^2$$

$T_{1/2}^{0\nu} \propto M\,t$, if background = 0

$T_{1/2}^{0\nu} \propto \sqrt{\frac{M\,t}{\Delta E\;BI}}$, if bkg ≠ 0

$M\,t$ - exposure (kg yr)
ΔE - energy resolution (keV)
BI - background index (counts/keV kg yr)

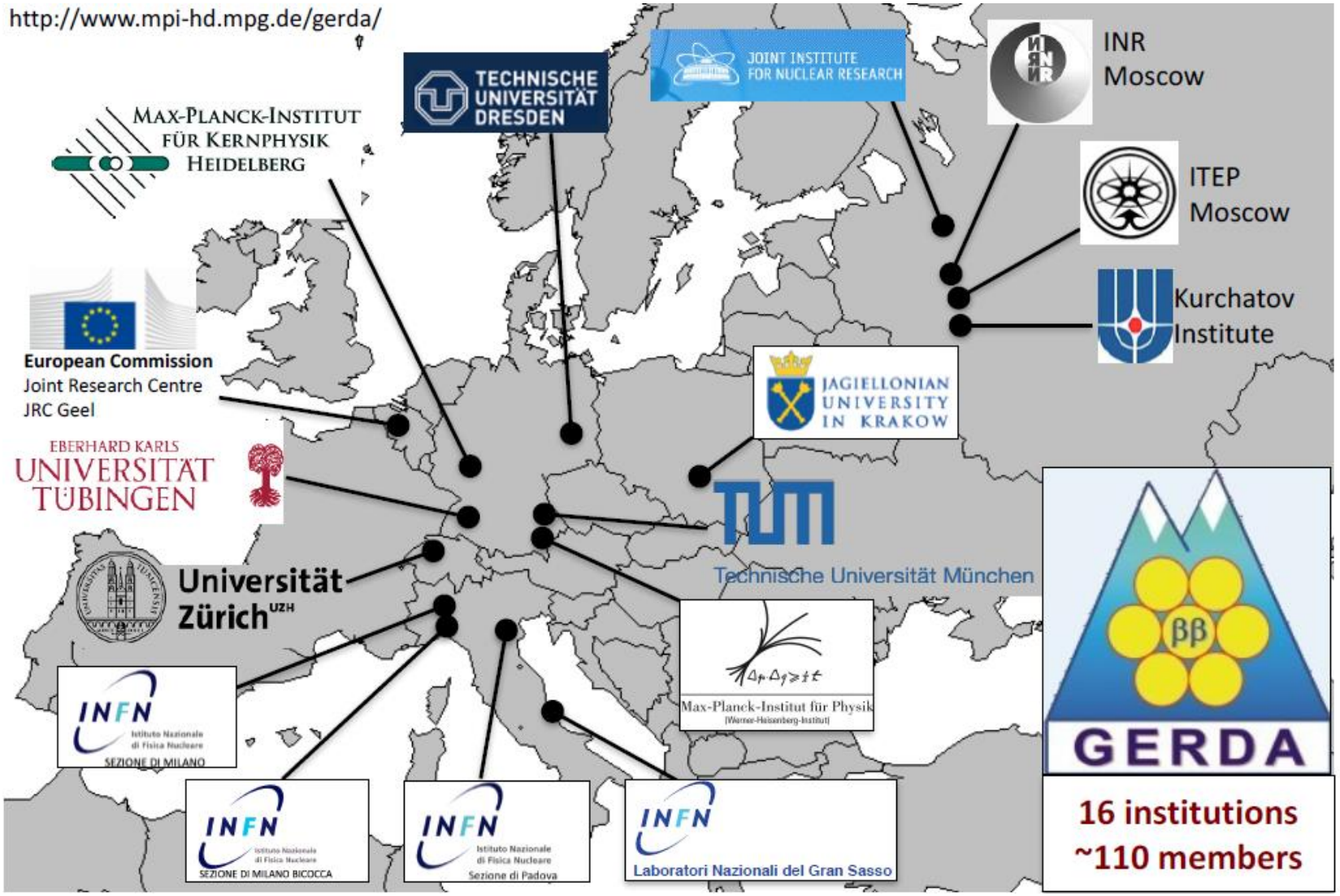
- ✓ No preferred isotope from Nuclear Physics (G*M)
- ✓ Target mass and detector efficiency as high as possible
- ✓ "Zero-background" regime if possible
- ✓ Resolution remains important due to 2νββ and background reduction



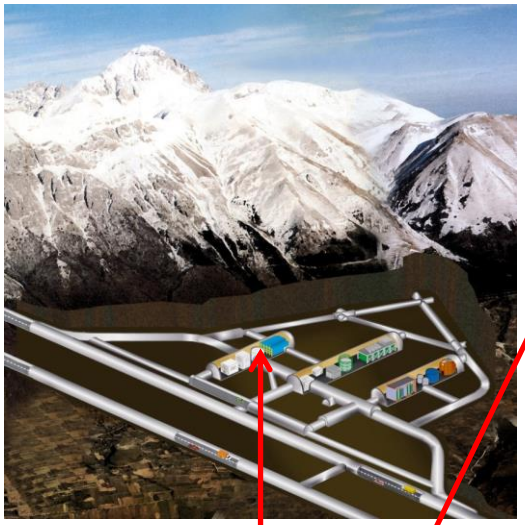
GERDA:

the Collaboration

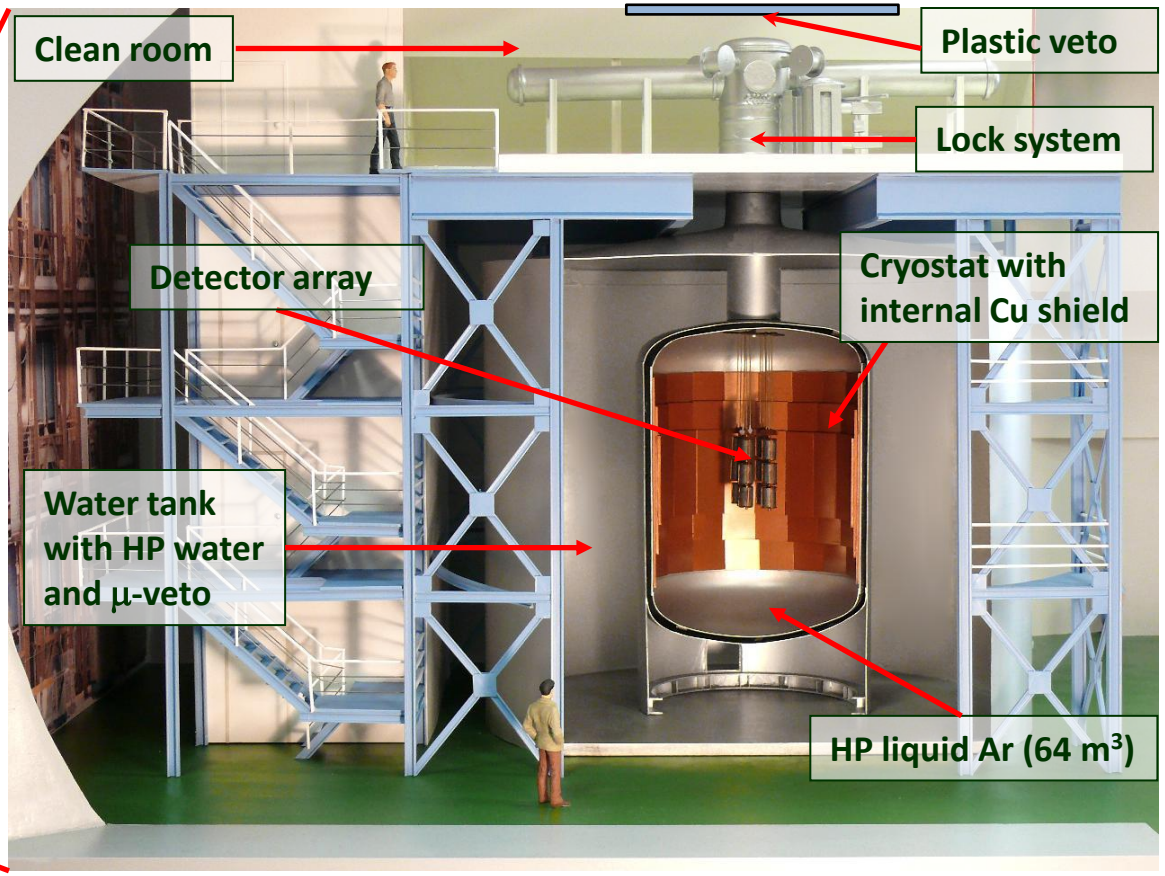
http://www.mpi-hd.mpg.de/gerda/



GERDA:
location



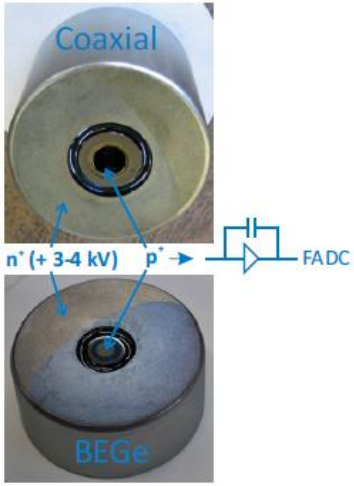
- bare HPGe detectors in LAr
- water and LAr – shield against external radiation
- deep underground – Hall A of **LNGS**, Italy (3500 m.w.e)



GERDA Phase I & Phase II

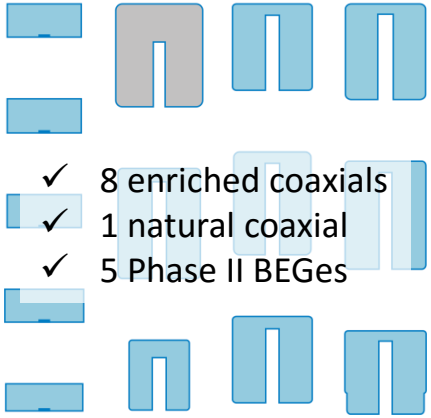
HPGe detectors enriched in ^{76}Ge (86%)

Coaxials:
- from HdM and IGEX
- reprocessed by Canberra
- total mass ~ 18 kg
- average FWHM 4.8 keV at $Q_{\beta\beta}$



BEGes:
- novel Ge detectors
- produced by Canberra
- total mass ~ 20 kg
- better **PSD** and **FWHM** (3.2 keV at $Q_{\beta\beta}$ in Phase I)

Phase I



✓ 8 enriched coaxials
✓ 1 natural coaxial
✓ 5 Phase II BEGes

Total exposure:
21.6 kg yr (11.2011 – 05.2013)

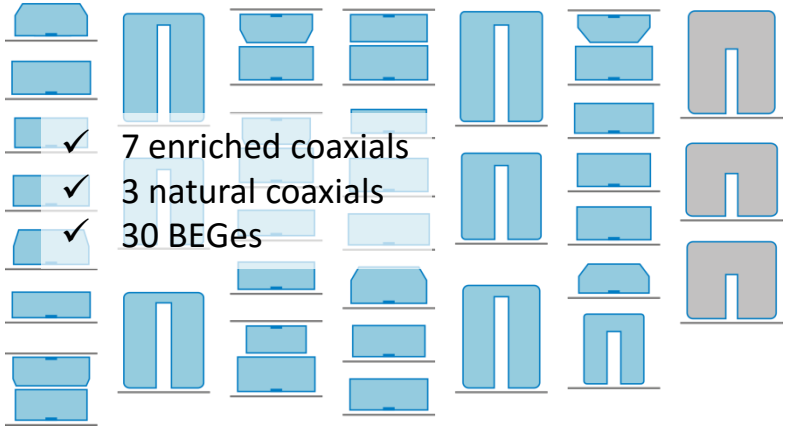
Background after PSD:
10^{-2} counts / (keV kg yr)

Limit on the half-life:
$T_{1/2}^{0\nu} > 2.1\ 10^{25}$ yr (90% CL)

Phase I & Phase II

! Naked Ge detectors in LAr – first time ever
! Blind analysis – first time in the field
! Pulse shape discrimination (PSD)

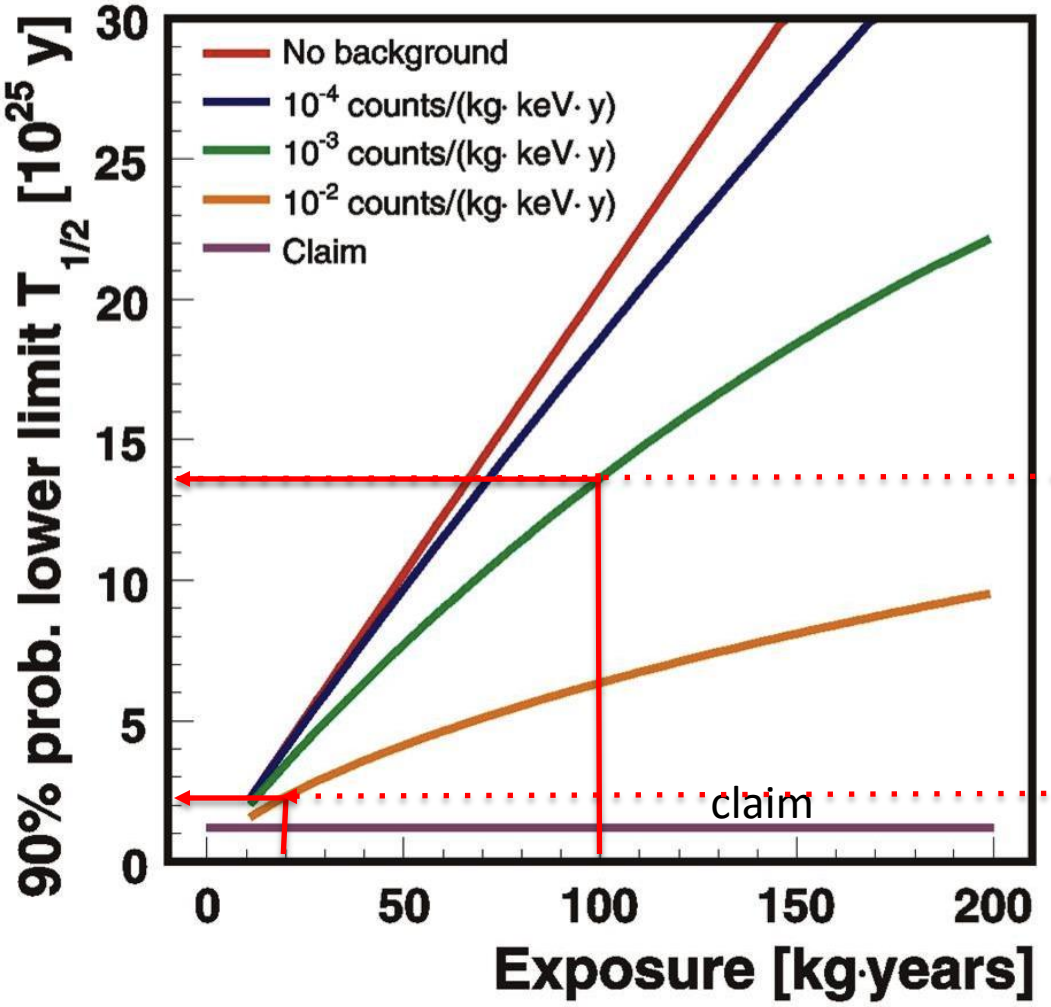
Phase II



✓ 7 enriched coaxials
✓ 3 natural coaxials
✓ 30 BEGes

GERDA:

Phase II upgrade



Phase II:

Add new BEGe detectors (20 kg)

BI ≈ 0.001 cts / (keV kg yr)

Sensitivity after 100 kg yr

Phase I:

Use refurbished HdM & IGEX (18 kg)

BI ≈ 0.01 cts / (keV kg yr)

Sensitivity after 20 kg yr

$$T_{1/2}^{0\nu} > 2.1 \times 10^{25}\ \text{yr}\ (90\%\ \text{CL})$$

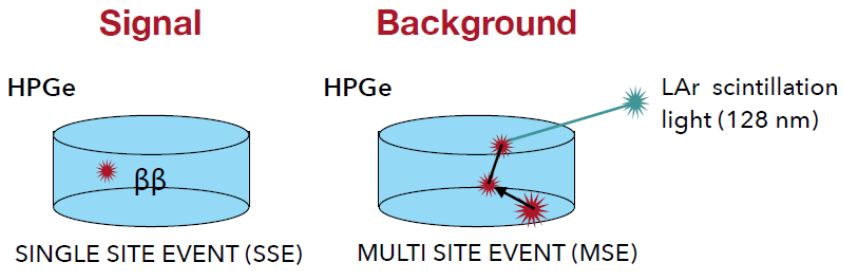
(PRL 111 (2013) 122503)

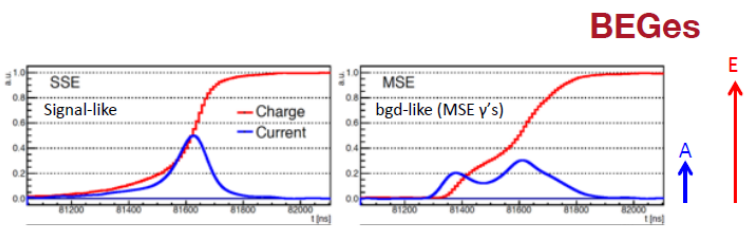
GERDA:

Phase II upgrade

! Background had to be reduced by one order of magnitude vs Phase I

- **New** in Phase II:
  - ✓ lock
  - ✓ holders
  - ✓ HV and signal cables
  - ✓ more BEGe detectors – PSD more effective!
  - ✓ read out of liquid argon light for veto!!!

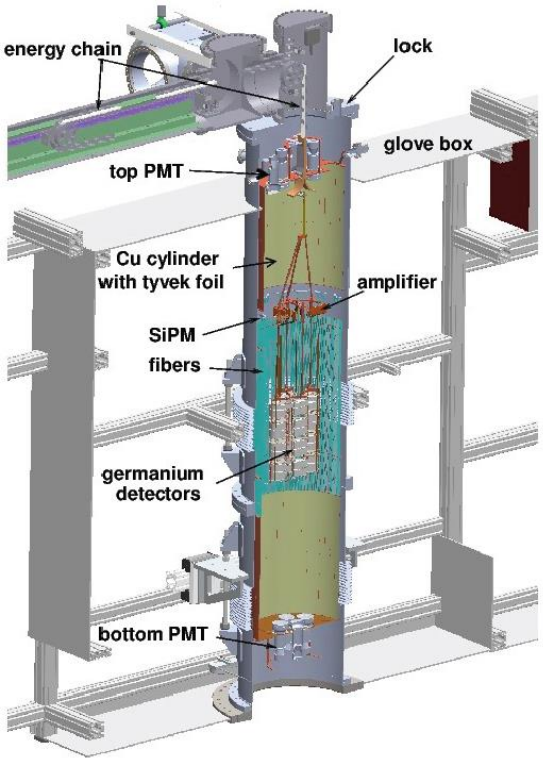


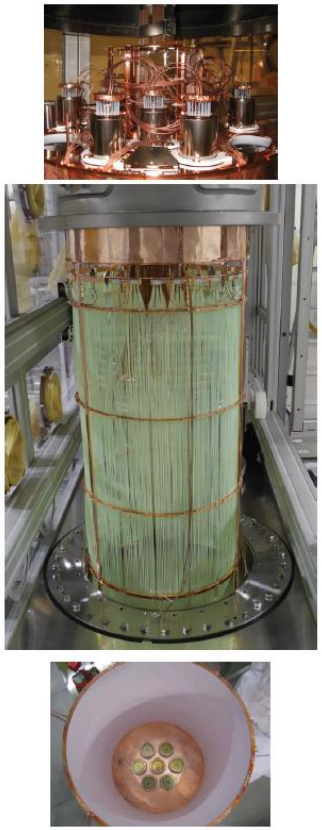


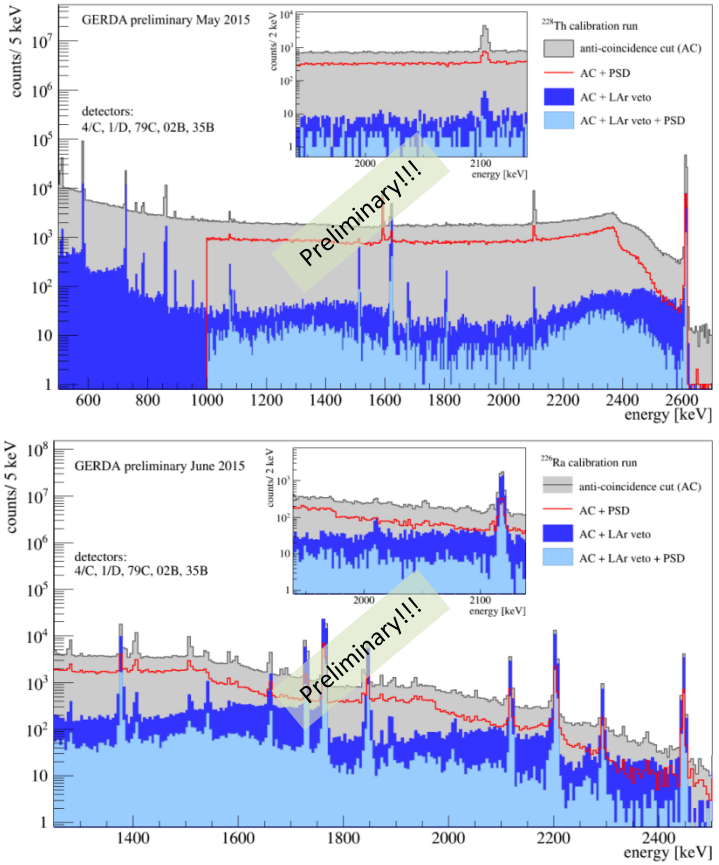
Pulse shape parameter for BEGes is

$$A/E = \frac{\text{amplitude of Current pulse}}{\text{amplitude of Charge pulse}}$$

Phase II upgrade:
LAr veto

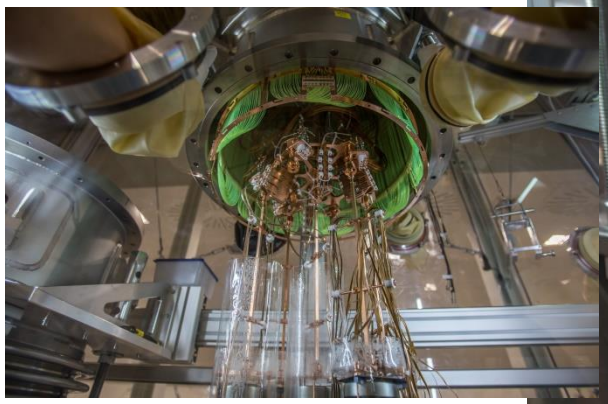


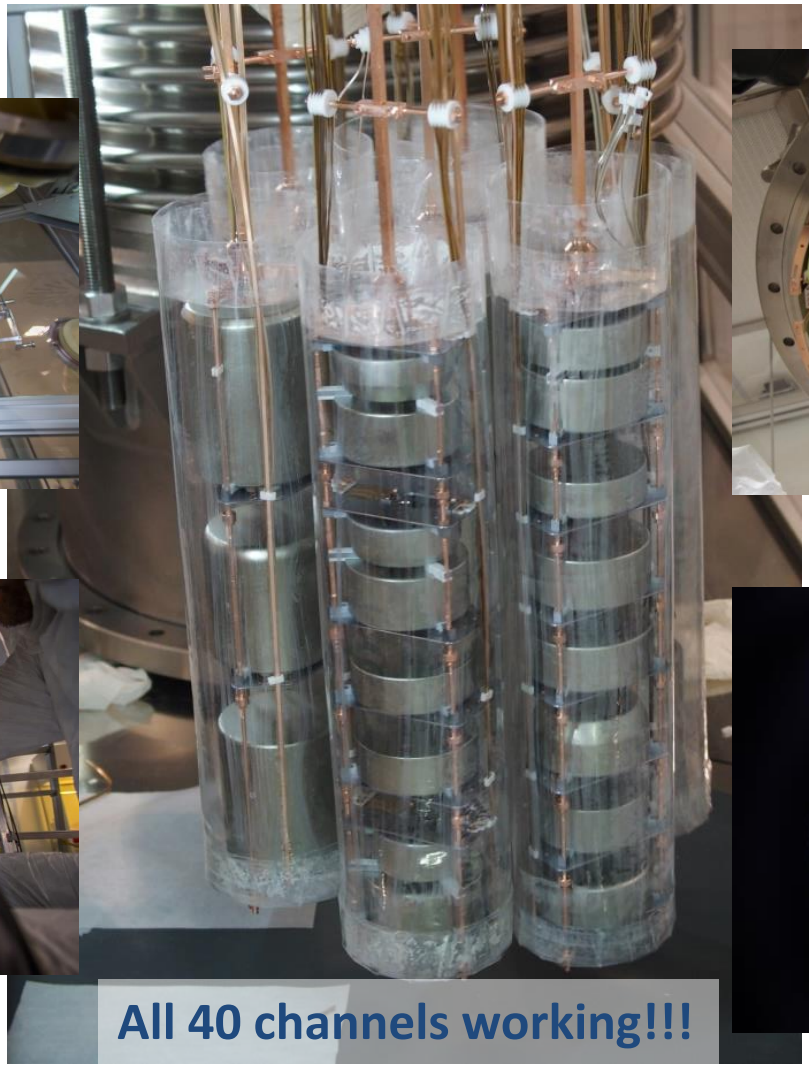


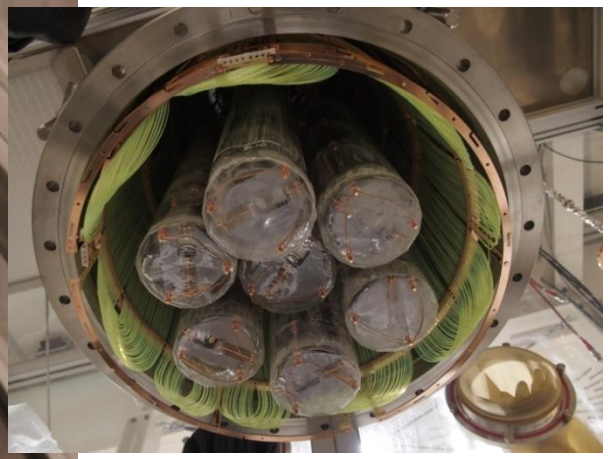


- ✓ works well
- ✓ suppression factors depend on isotope, location and detector configuration

Phase II upgrade :
Final integration (Dec 2015)



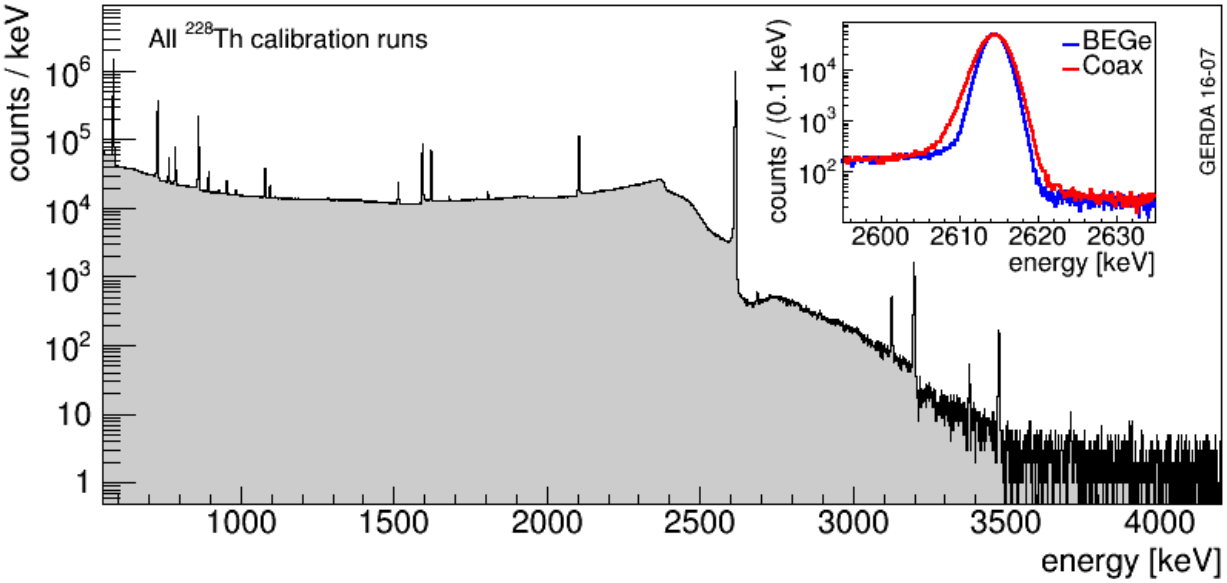


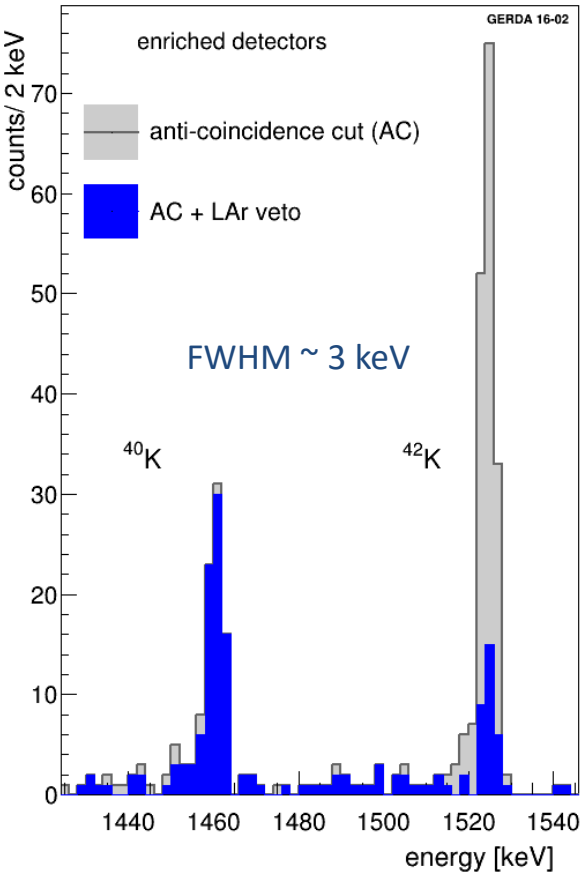


All 40 channels working!!!

Phase II:
Performance

Phase II started on December 20, 2015

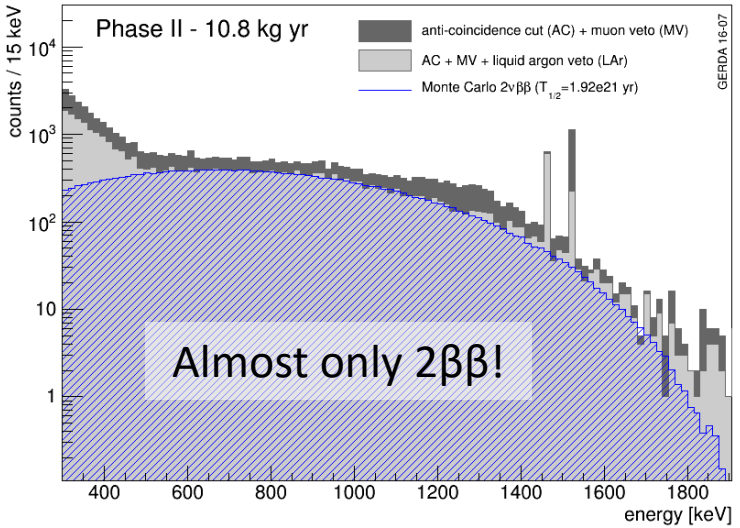




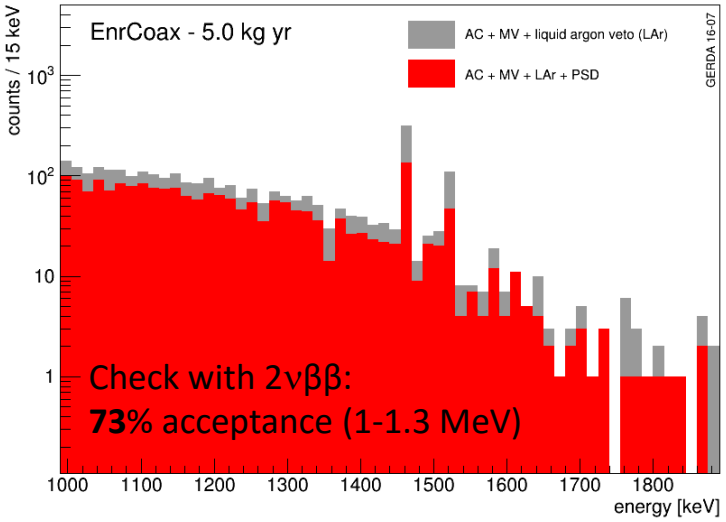
- ✓ Data released: Dec 2015 – May 2016
- ✓ 82 % average duty cycle
- ✓ Weekly calibration with ^{228}Th
- ✓ FWHM at 2.6 MeV: ~ 3.2 keV for BEGe, ~ 3.8 keV for coaxial
- ✓ LAr-veto works also for background data

Phase II: Performance

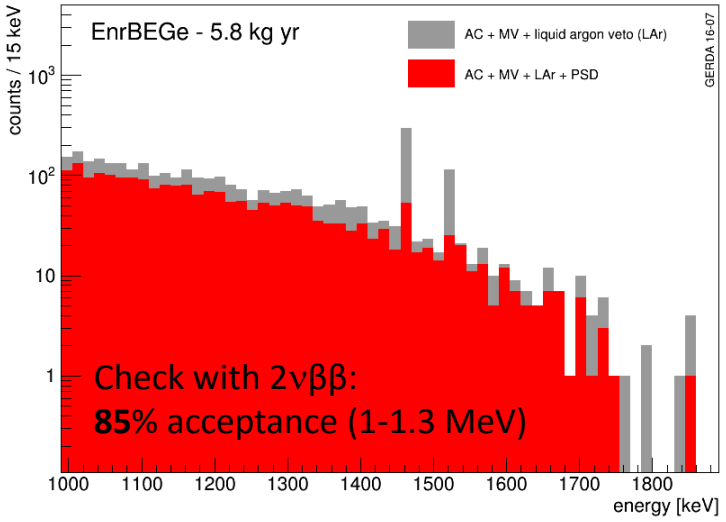
- ✓ Total enriched coaxial exposure: 5.0 kg yr
- ✓ Total enriched BEGe exposure: 5.8 kg yr
- ✓ Blinding window $Q_{\beta\beta}$ ± 25 keV
- ✓ K^{40}/K^{42} Compton continuum strongly suppressed by LAr-veto
- ✓ PSD works



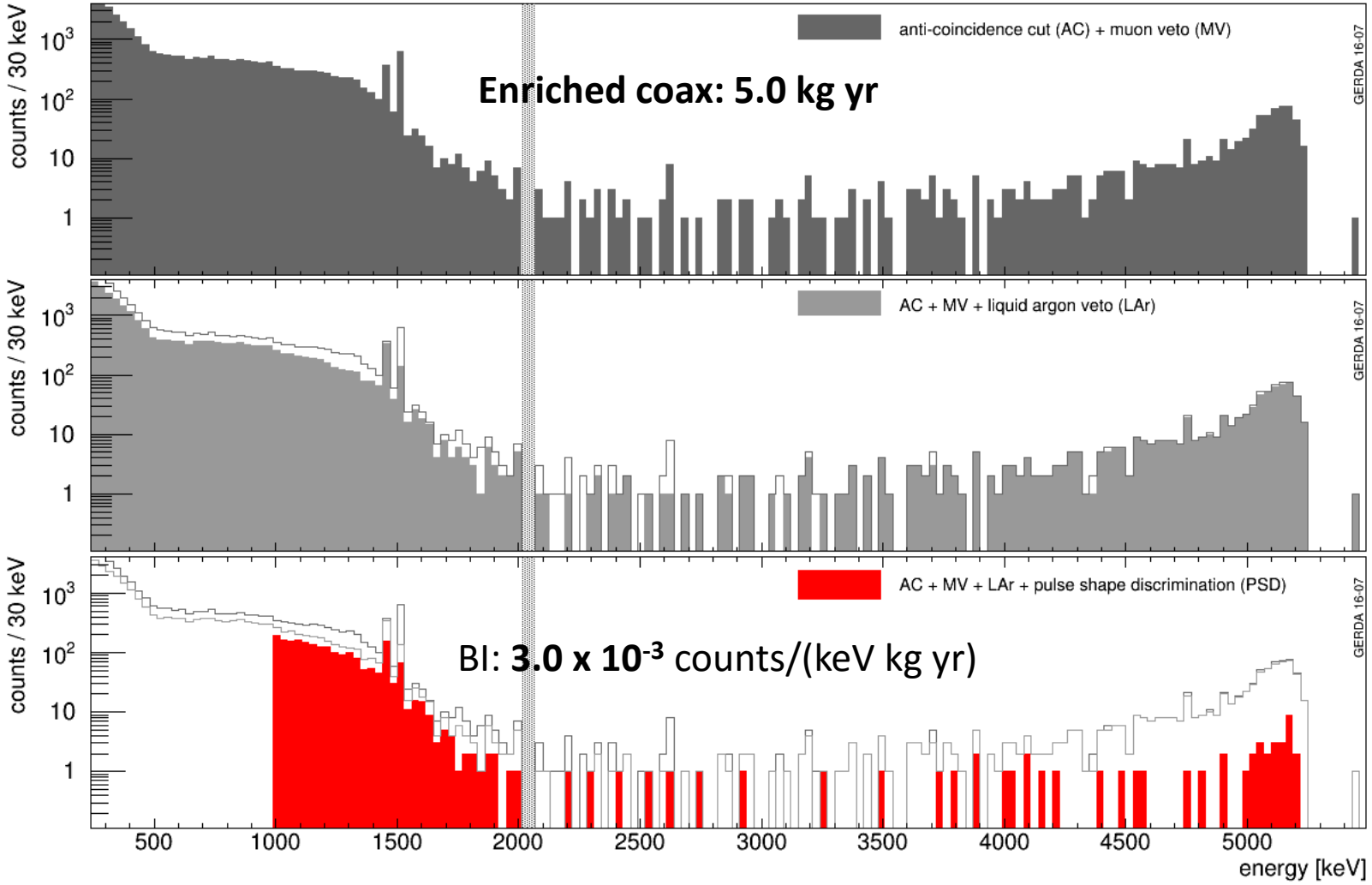
PSD for **coaxial**:
0νββ acceptance: (**76**±7)% (preliminary)



PSD for **BEGe**:
0νββ acceptance: (**87.3**±0.9)%

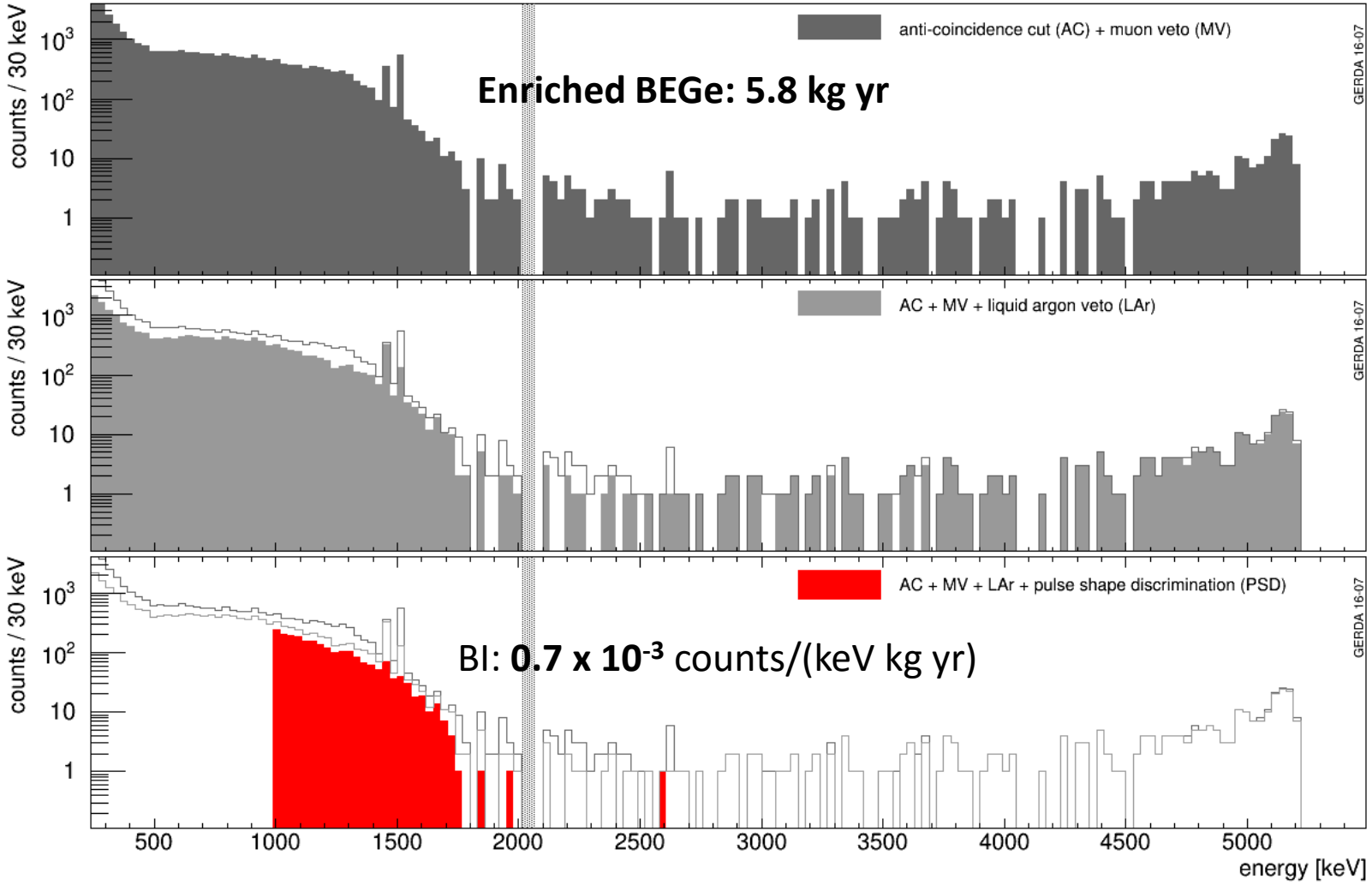


Phase II:
First results

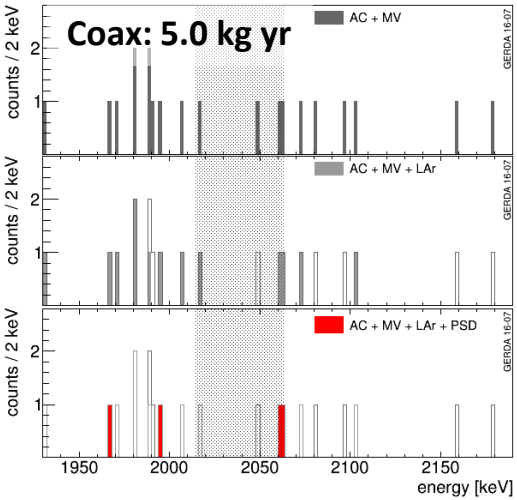


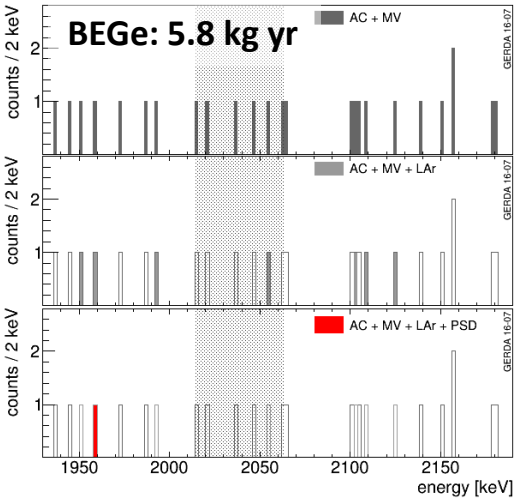
Phase II:

First results



Phase II first results:
Unblinding





Phase II first results:

New limit

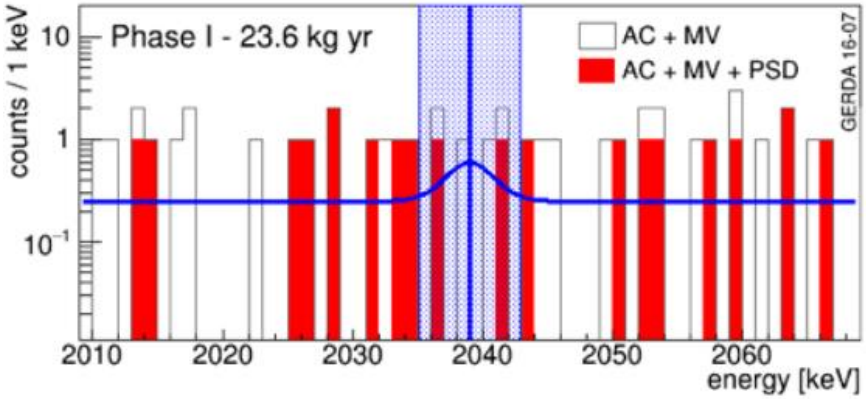
data set		exposure [kg·yr]	signal eff	background [cts/(keV·kg·yr)]	resolution [FWHM]
Phase I	golden	17.9	0.57 (3)	$11 \pm 2 \cdot 10^{-3}$	4.3 (1)
Phase I	silver	1.3	0.57 (3)	$30 \pm 10 \cdot 10^{-3}$	4.3 (1)
Phase I	BEGe	2.4	0.66 (2)	$5^{+4}_{-3} \cdot 10^{-3}$	2.7 (2)
Phase I	extra	1.9	0.58 (4)	$5^{+4}_{-3} \cdot 10^{-3}$	4.2 (2)
Phase II	coaxial	5.0	0.51 (7)	$35^{+21}_{-15} \cdot 10^{-4}$	4.0 (2)
Phase II	BEGe	5.8	0.60 (2)	$7^{+11}_{-5} \cdot 10^{-4}$	3.0 (2)

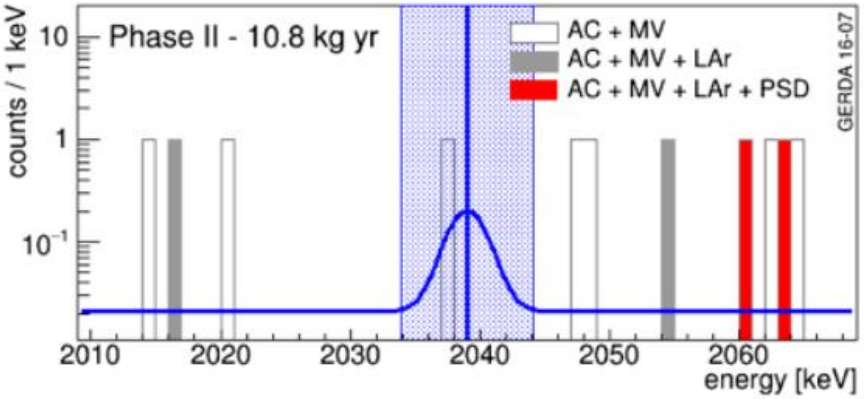
- ✓ Phase I & Phase II data were used to set the new limit
- ✓ Phase I resolution improved with new energy reconstruction [EPJ C75 (2015)]
- ✓ "Phase I extra" has been unblinded together with Phase II data

- ✓ Phase II background goal reached!!!

Phase II first results:

New limit





	Profile likelihood 2-side test stat.	Bayesian flat prior on cts
0νββ cts best fit value (cts)	0	0
$T_{1/2}^{0\nu\beta\beta}$ lower limit ($\times 10^{25}$yr)	> 5.2 (90% CL)	> 3.5 (90% CL)
$T_{1/2}^{0\nu\beta\beta}$ median sensitivity ($\times 10^{25}$yr)	4.0 (90% CL)	3.0 (90% CL)

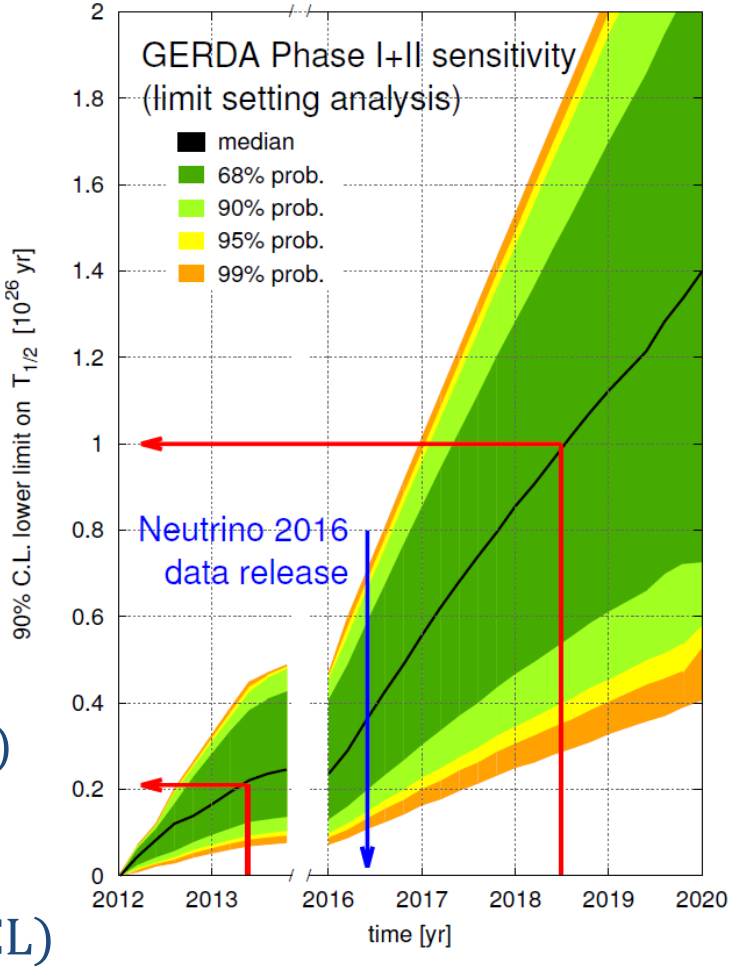
GERDA Phase II:

Status

- Phase II data taking successfully started in **December 2015**!
- 7 strings of HPGe detectors deployed:
  - 37 detectors enriched in ^{76}Ge (**35.8 kg**)
  - 3 natural detectors (7.6 kg)
- all 40 detectors and LAr veto work well

- first Phase II data released
  - ✓ BI for BEGe – **10^{-3}** counts/(keV kg yr)
  - ! best BI ever achieved!

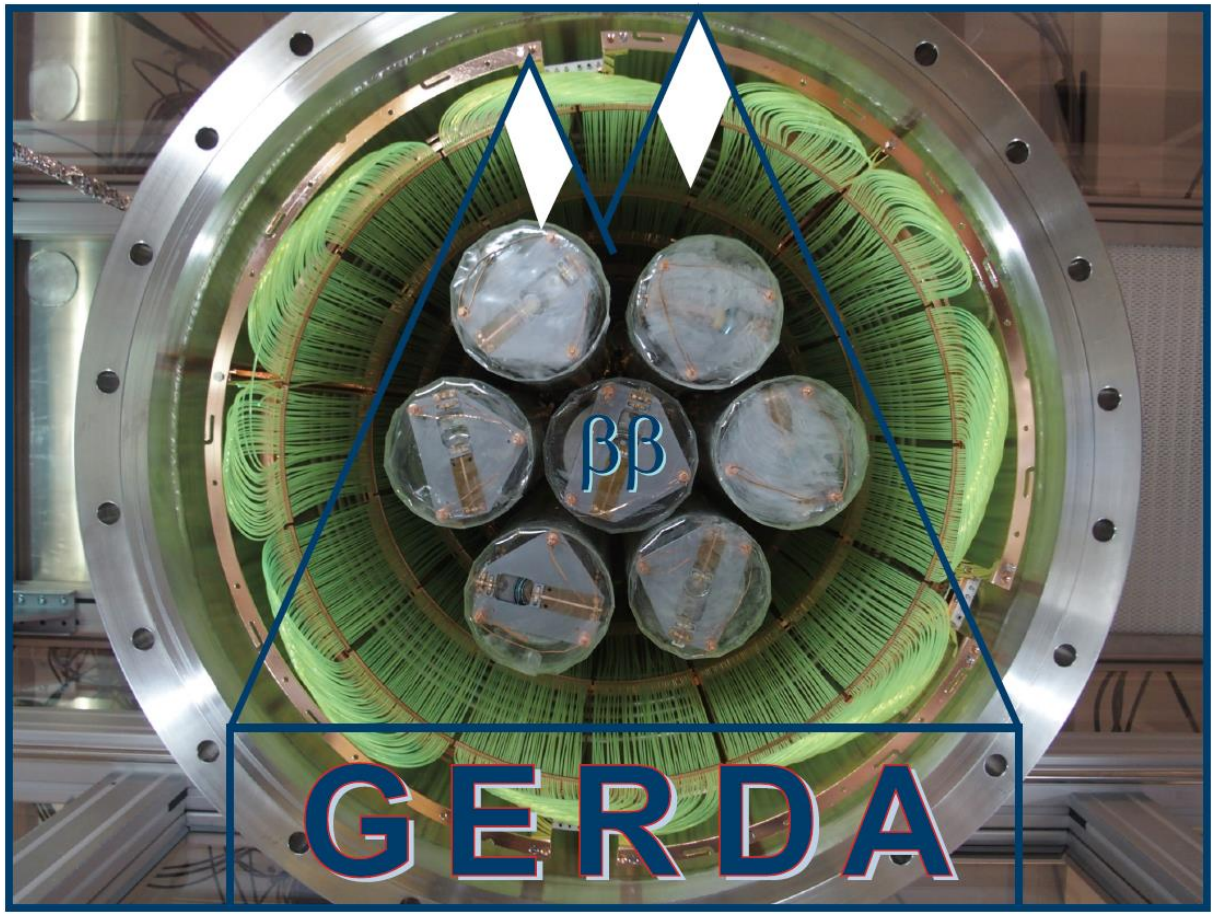
- New $T_{1/2}^{0\nu\beta\beta}$ limit from Phase I & Phase II data:
  - ✓ Sensitivity: $T_{1/2}^{0\nu} > 4 \times 10^{25}\text{yr (90\% CL)}$
    (similar to KamLAND-Zen)
  - ✓ Limit: $T_{1/2}^{0\nu} > 5.2 \times 10^{25}\text{yr (90\% CL)}$



GERDA Phase II:

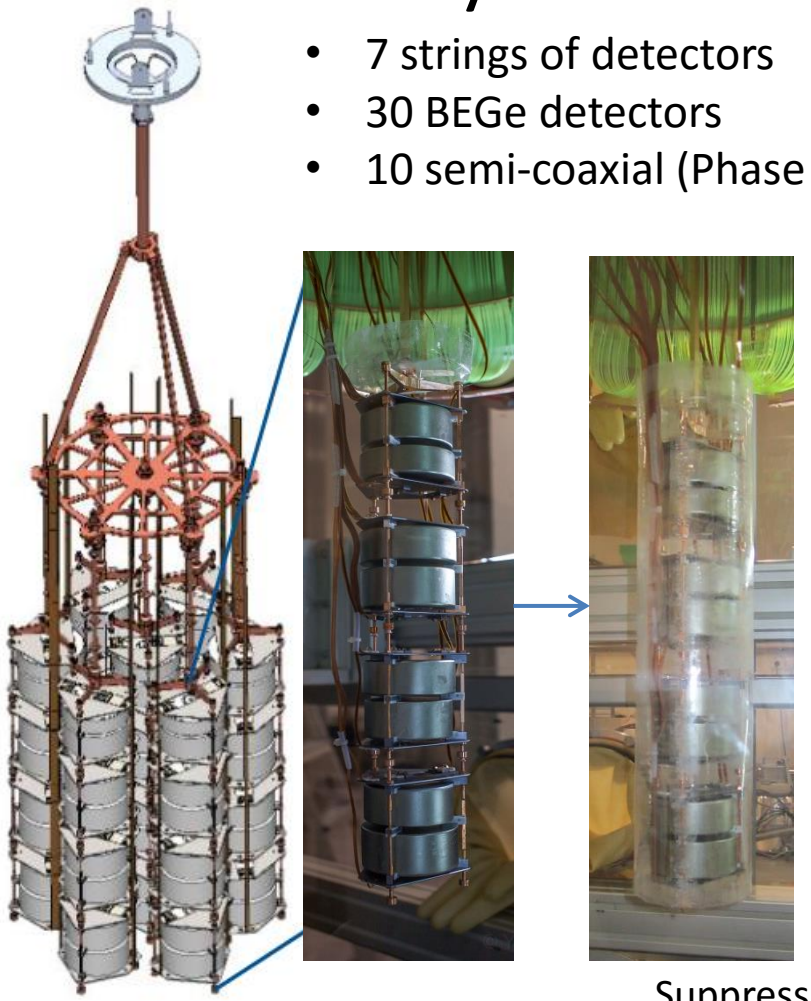
Status

GERDA Phase II is the first background free double beta experiment



Additional slides

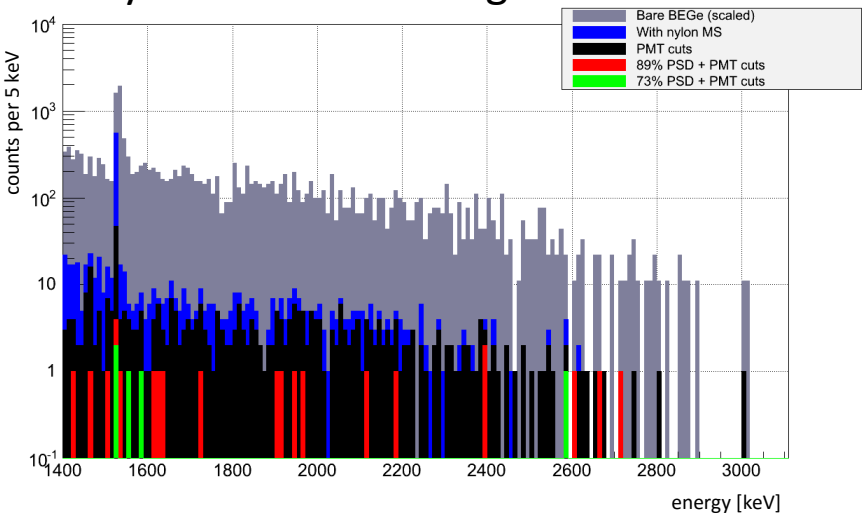
Phase II:
detector array



- 7 strings of detectors
- 30 BEGe detectors
- 10 semi-coaxial (Phase I) detectors: 7 enriched + 3 non-enriched

✓ Dense packing of detectors allows better anti-coincidence cut

✓ Each string enclosed by transparent nylon mini-shroud against ^{42}K-ions:



Suppression factor > 1000 for ^{42}K bkg has been demonstrated in LArGe test facility (nylon mini-shroud + PSD + LAr veto)

GERDA:

PSD for BEGe detectors