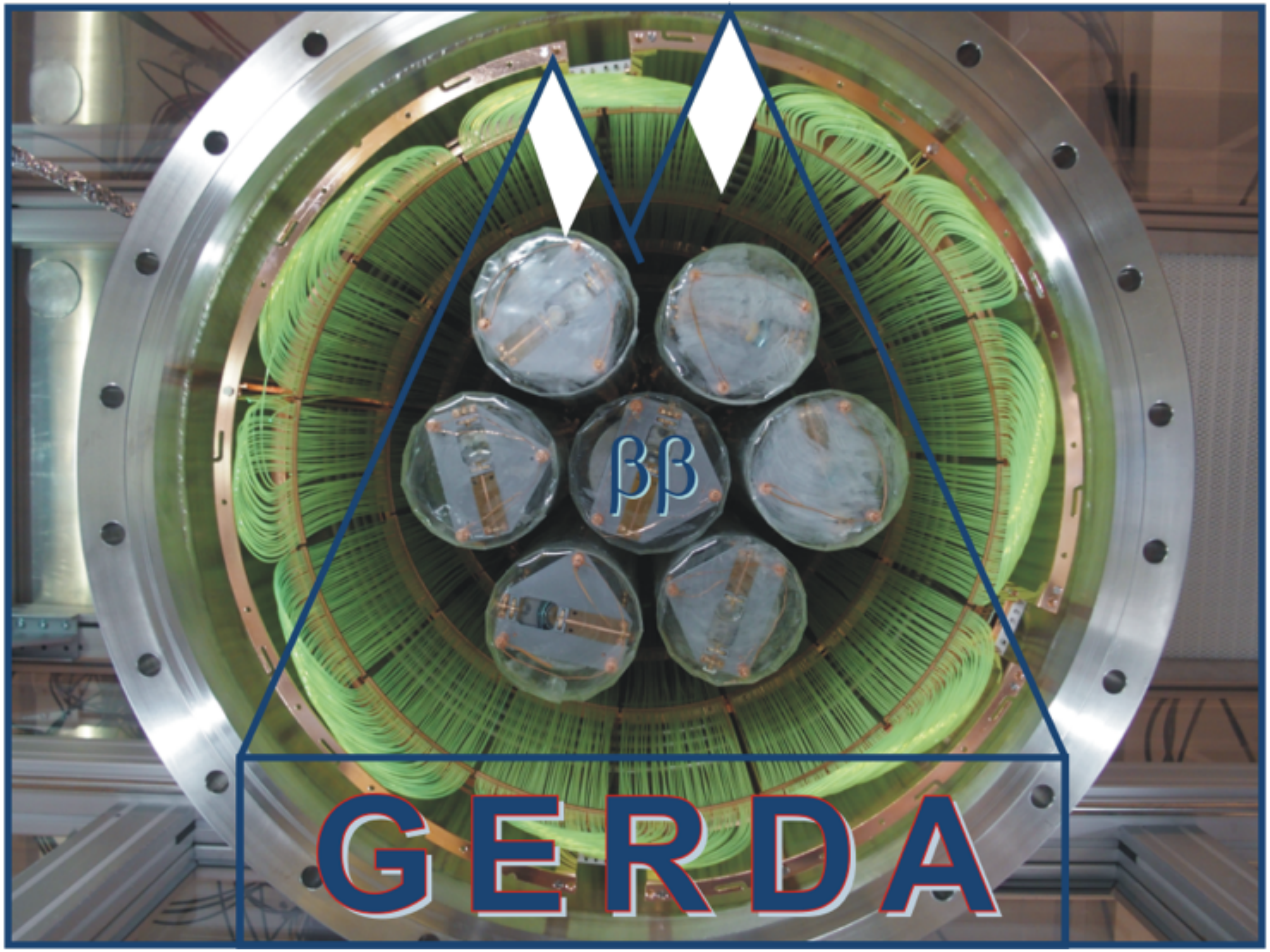
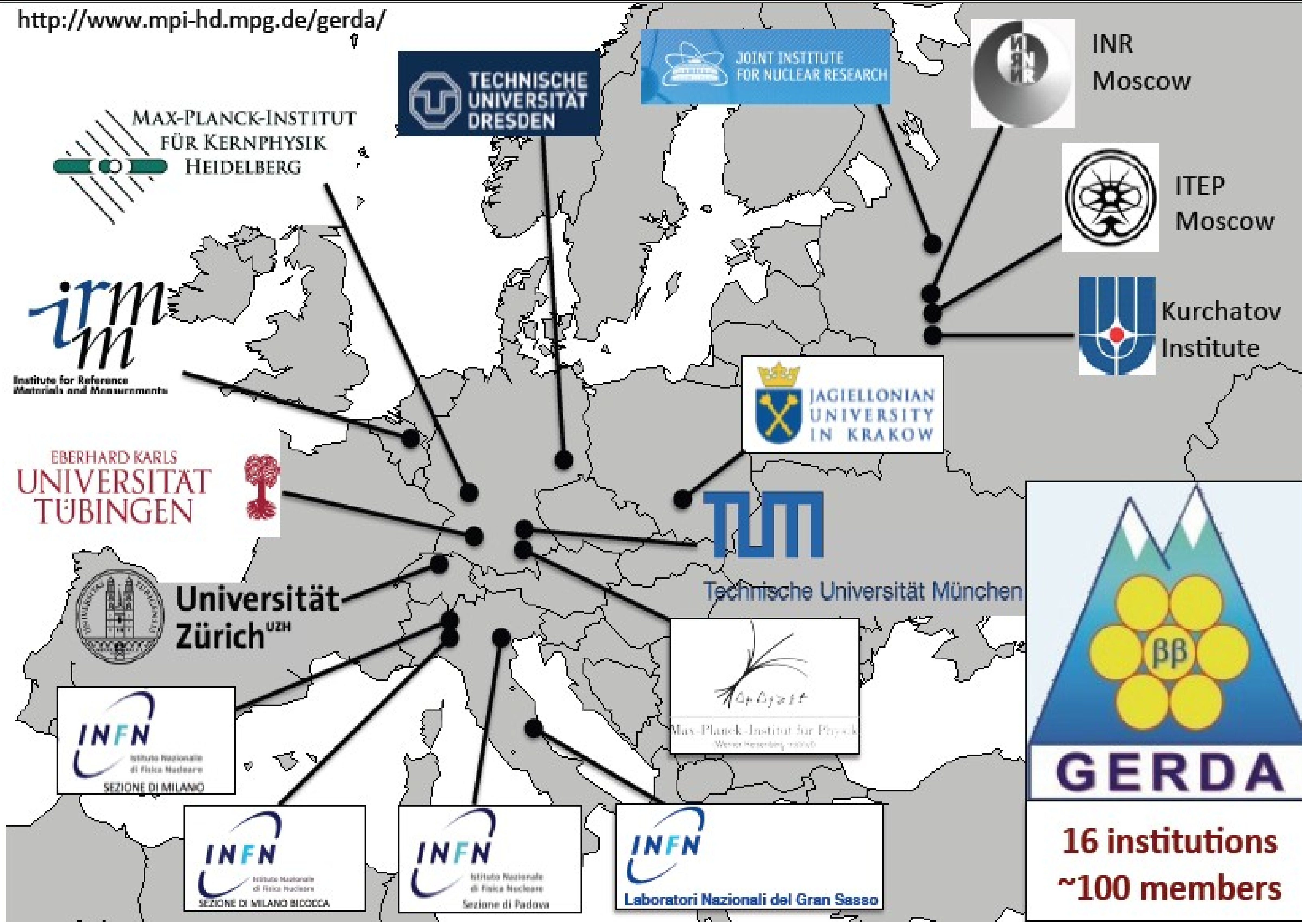


Phase II status

József Janicskó Csáthy for the GERDA collaboration

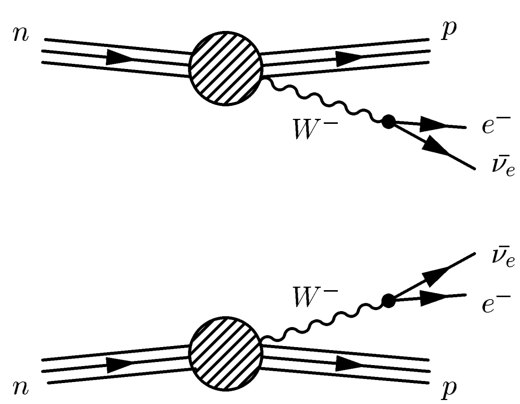
Technische Universität München

GERDA



Technische Universität München

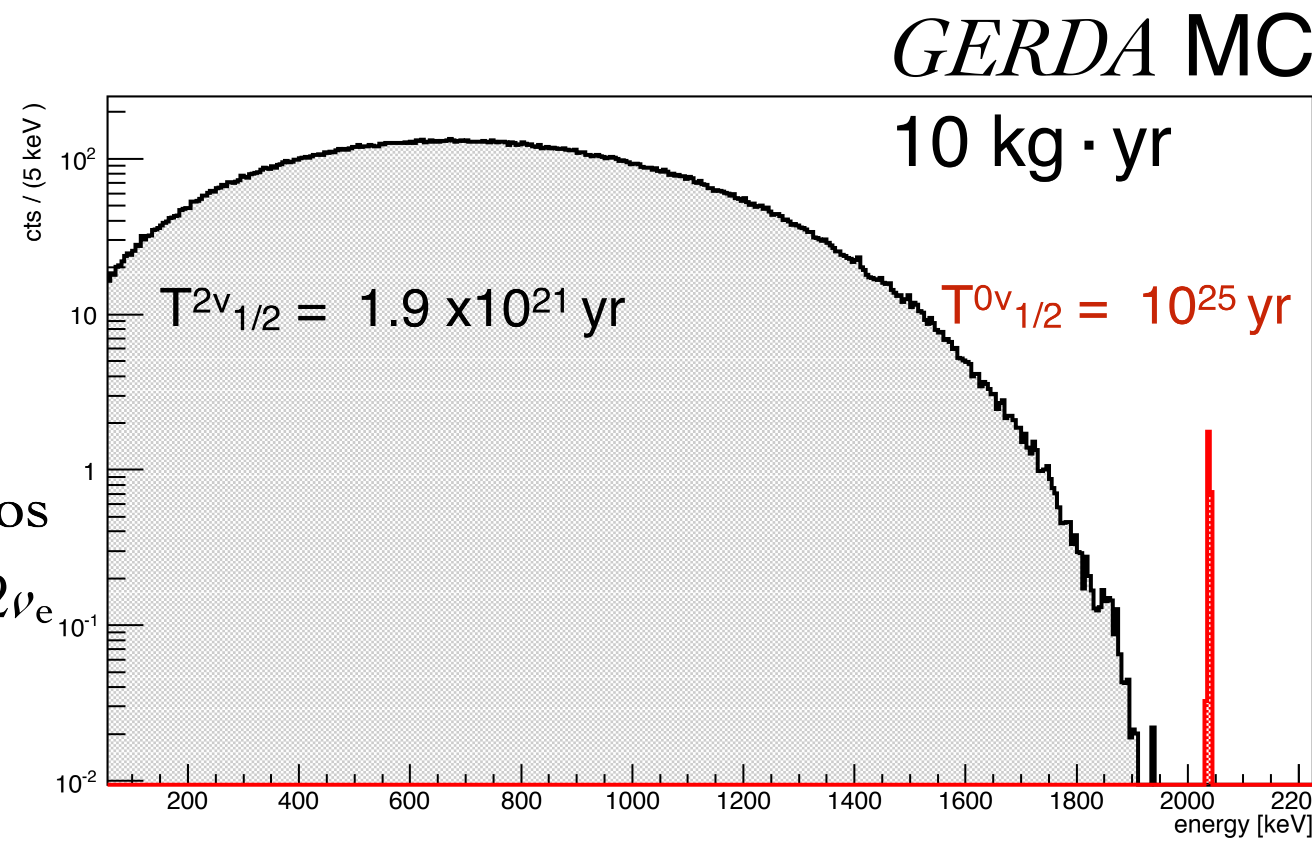
Double-beta decay

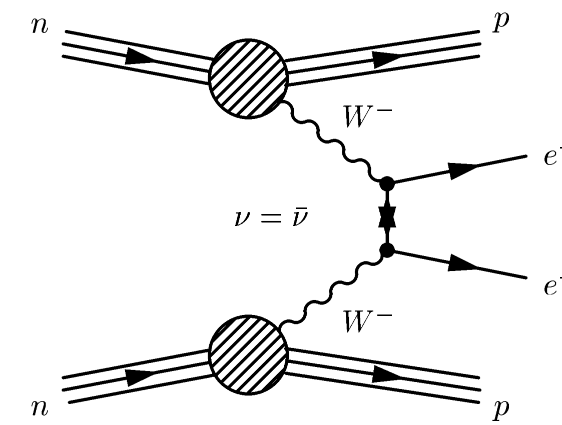


ββ decay with 2 neutrinos

(A,Z)→(A,Z+2) + 2e⁻ +2ν_e

allowed and observed





ββ decay with 0 neutrinos

(A,Z)→(A,Z+2) + 2e⁻

violates lepton number conservation

- If 0ν2β decay is observed neutrinos have a Majorana mass component
- The measured half life converts in neutrino mass

$$(T^{0\nu}_{1/2})^{-1} = F^{0\nu} \cdot |\mathcal{M}^{0\nu}|^2 \cdot \langle m_{\beta\beta} \rangle^2$$

$$\langle m_{\beta\beta} \rangle^2 = \left|\sum_i U_{ei}^2 m_{\nu i}\right|^2$$

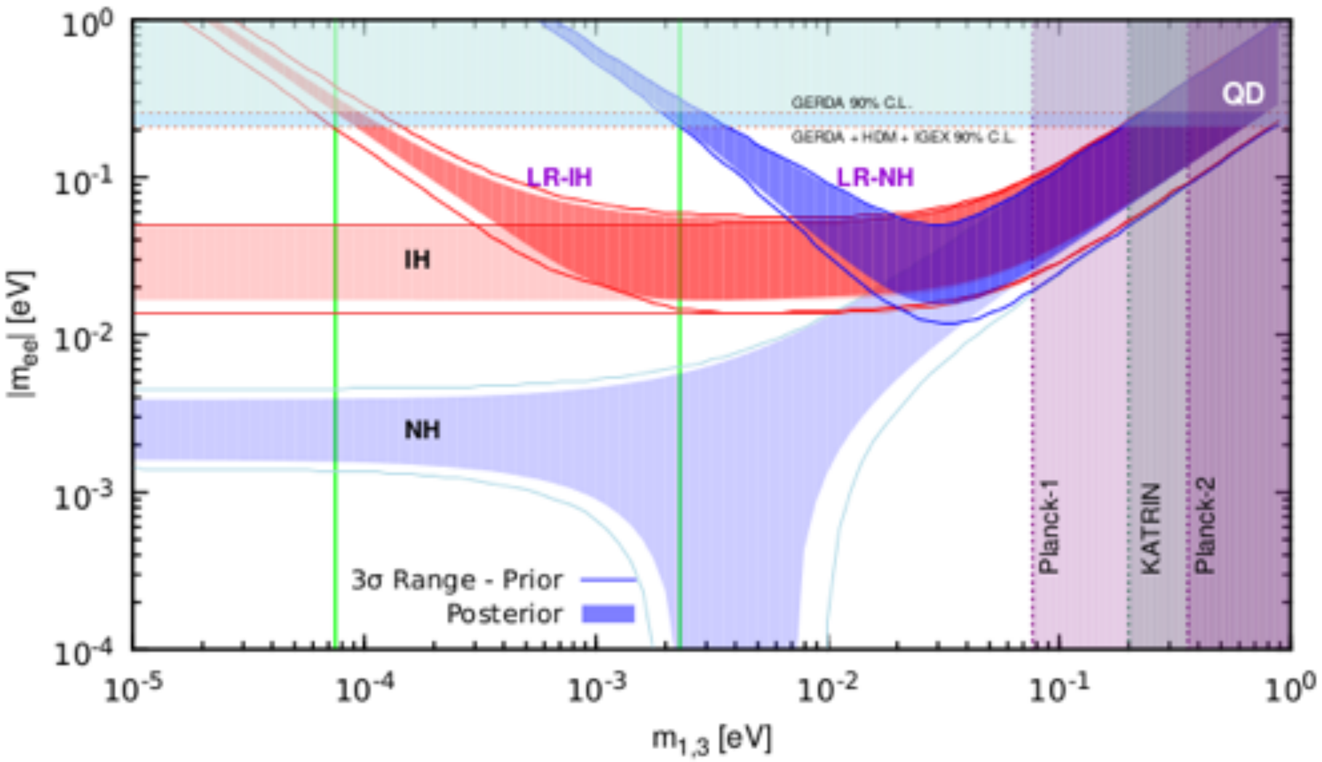
$M^{0\nu}$ - nuclear matrix element

$F^{0\nu}$ - phase space integral depends on the Q value

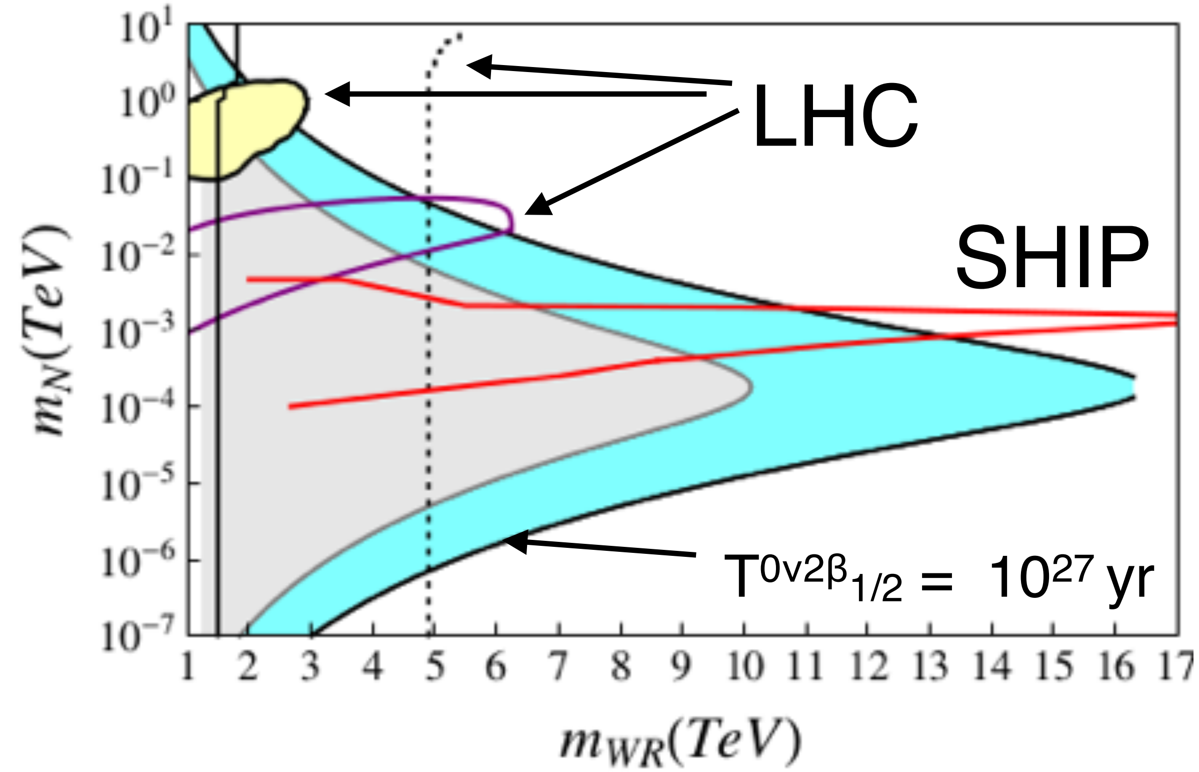
$\langle m_{\beta\beta} \rangle$ - effective neutrino mass

The Physics case

arXiv:1508.07286



arXiv:1509.00423



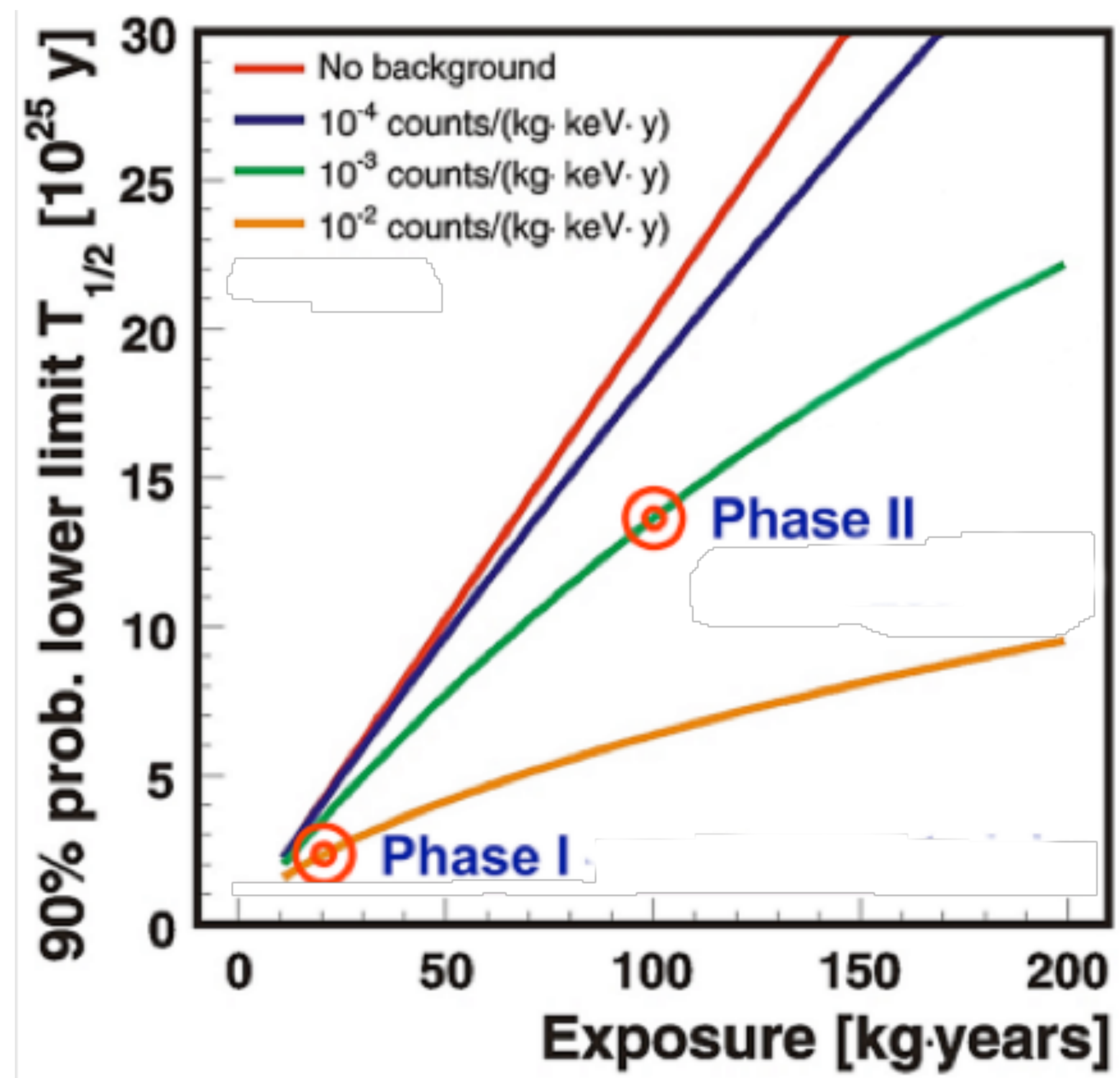
- $0\nu\beta\beta$ search probes physics beyond the SM
- LR symmetric models predict neutrino masses >10 meV even for NH
- Lepton number violation searches at LHC are focusing on heavy right-handed neutrino in the TeV range
- Most of the parameter space scrutinised at LHC is within the reach of next generation DBD experiments

Technische Universität München

GERDA status

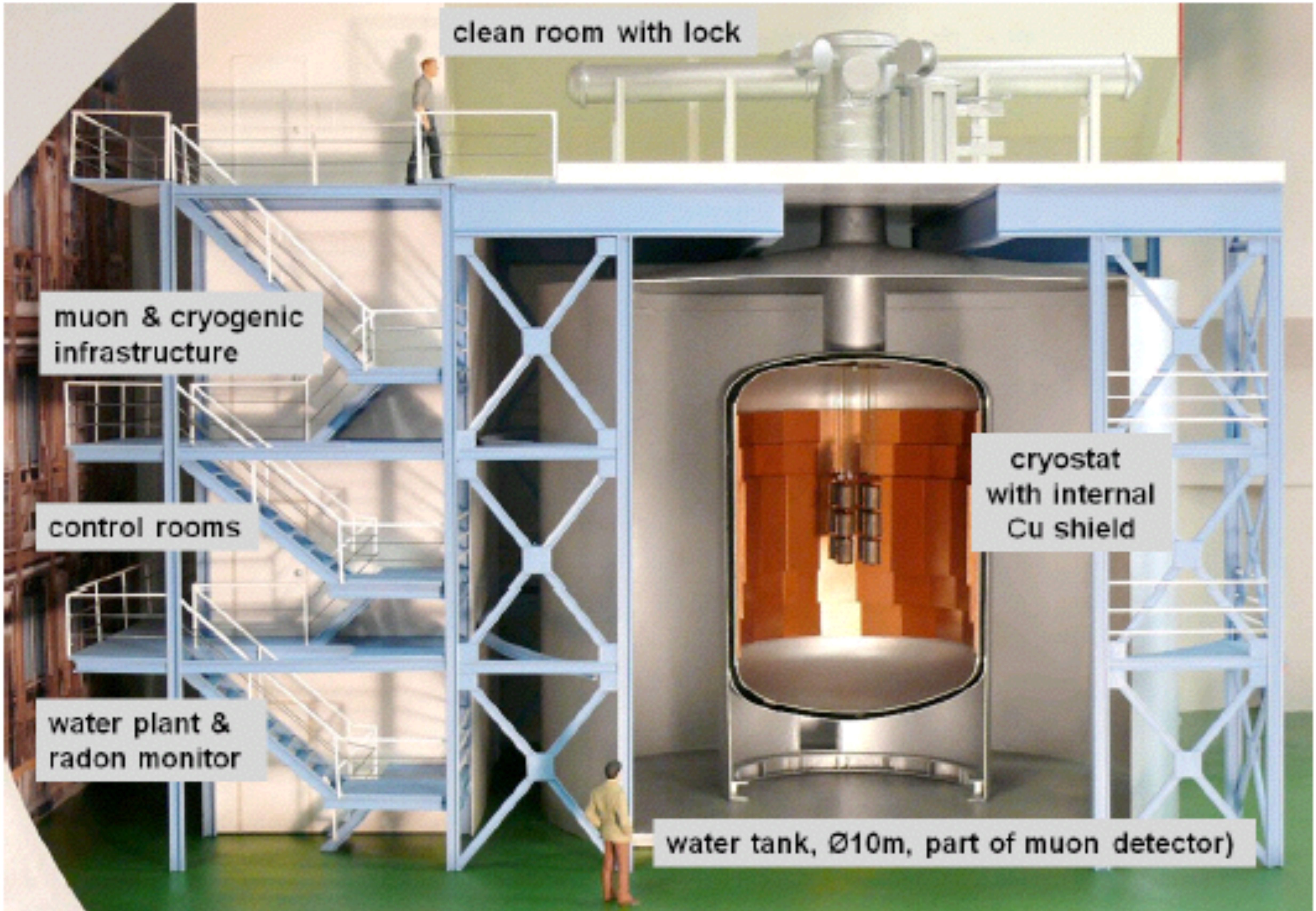
- GERDA is located at LNGS, under 3500 m w.e. overburden
- Construction finished in 2009, operational since then
- GERDA is using HPGe detectors from germanium enriched in ^{76}Ge. Source and detector is the same.

- *Status of Phase I*: data taking ended with 21.6 kg · yr exposure: run from Nov. 2011 to May 2013
- *Result of Phase I:* $T^{0\nu}_{1/2} > 2.1 \times 10^{25}$ yr
- *Goal of Phase II*: background level of 10^{-3} cts/(keV kg yr) and a half-life sensitivity of $\sim 10^{26}$ yr
- *Phase II strategy to reduce background:* LAr scintillation light readout + pulse shape discrimination
- *Phase II status:* data taking since 2015, first data release: June 2016



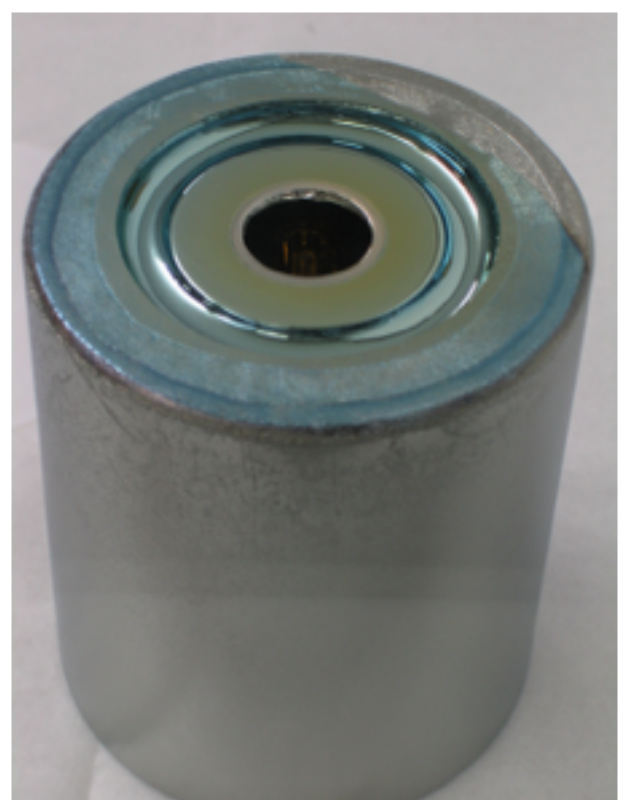
Technische Universität München

GERDA at Gran Sasso



Phase II setup

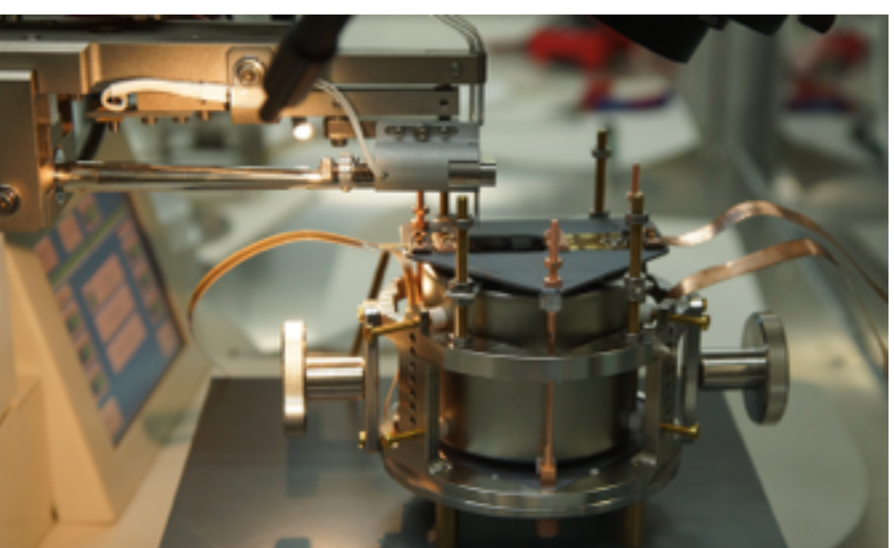
- 7 coaxial detectors, HdM and IGEX: 15.8 kg
- 30 new BEGe detectors, from new production total: 20 kg
- 3 natural coax: 7.6 kg
- Last integration test in Dec. 2015
- The experiment is alive since then

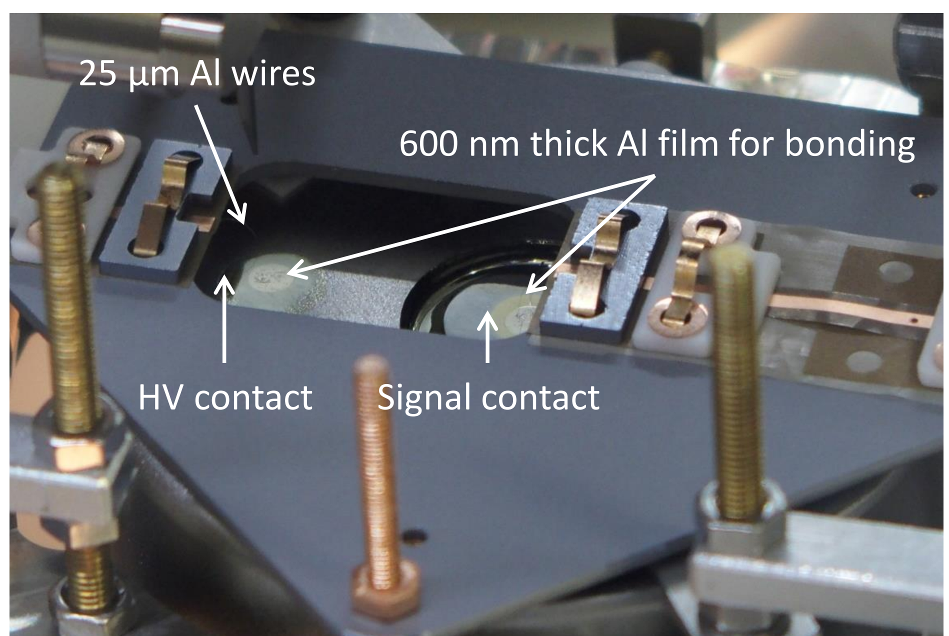


Technische Universität München

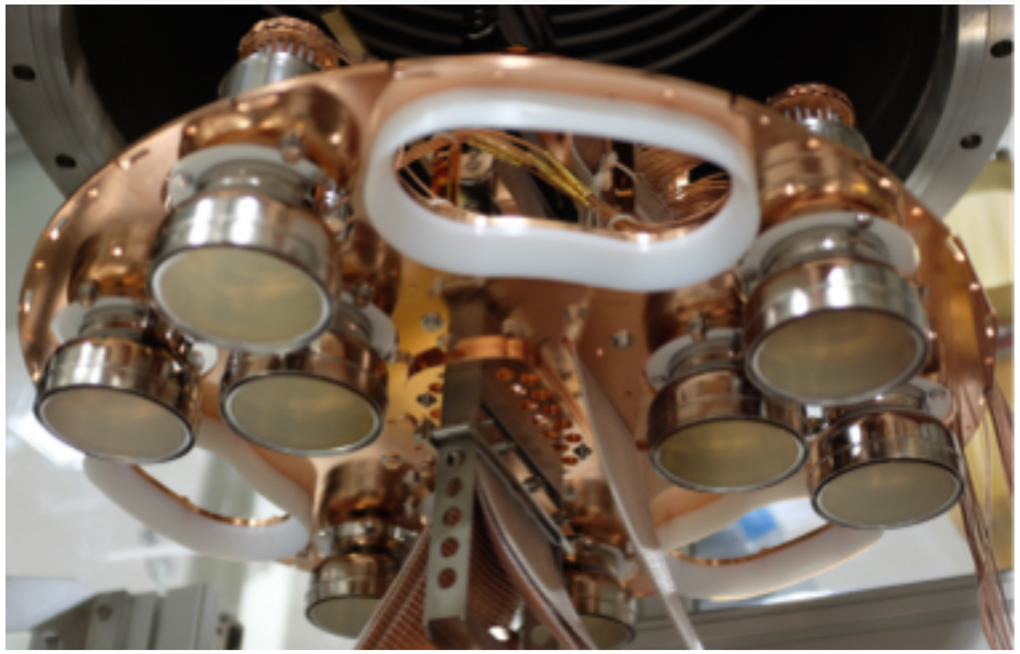
Upgrades for Phase II

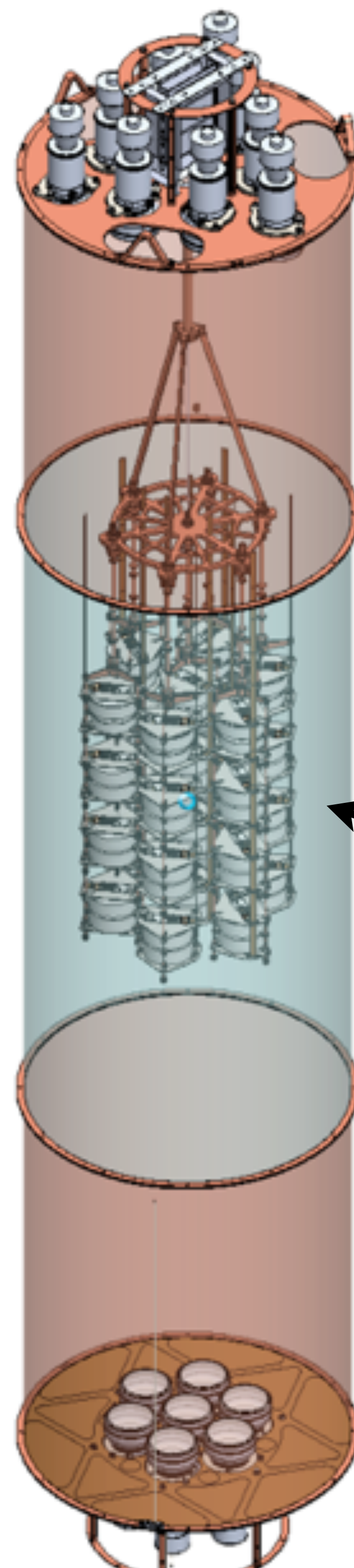
- 30 new BEGe detectors need new holders
- New holder made of silicon plates
  - Silicon is cleaner
  - 3x less copper than in the Phase I holder
- Detector contacting with wedge bonding
- String wrapped in WLS coated nylon
  - Reduces ^{42}K background



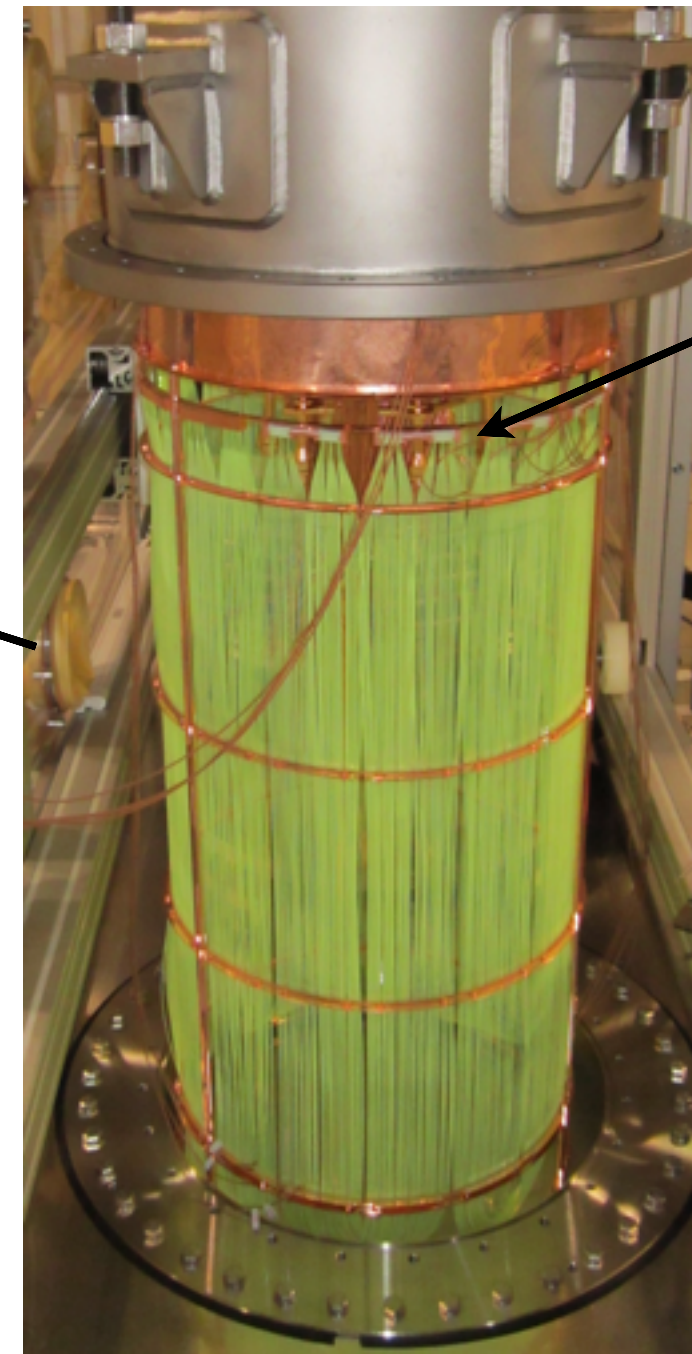


LAr - veto





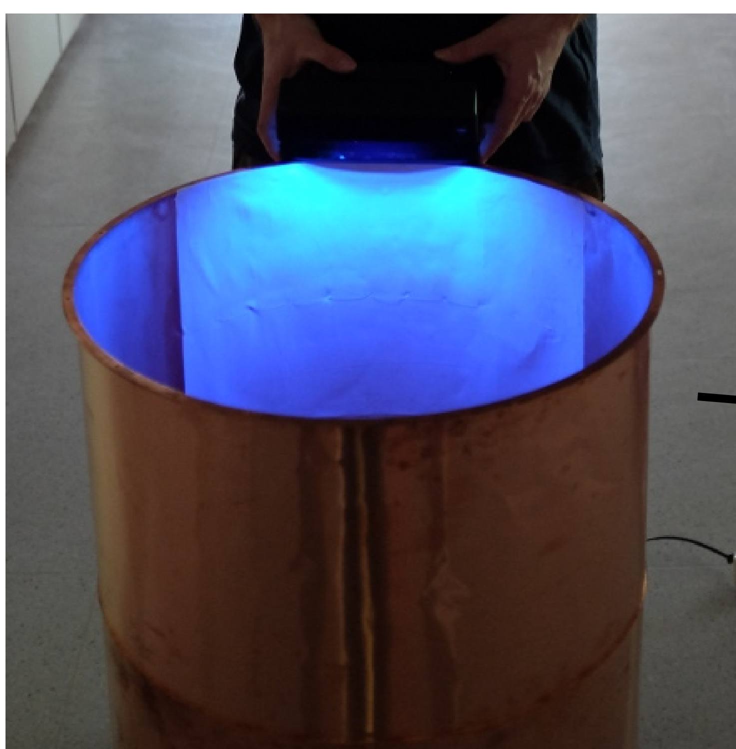
3” low-background PMT
Hamamatsu R11065-20



SiPMs

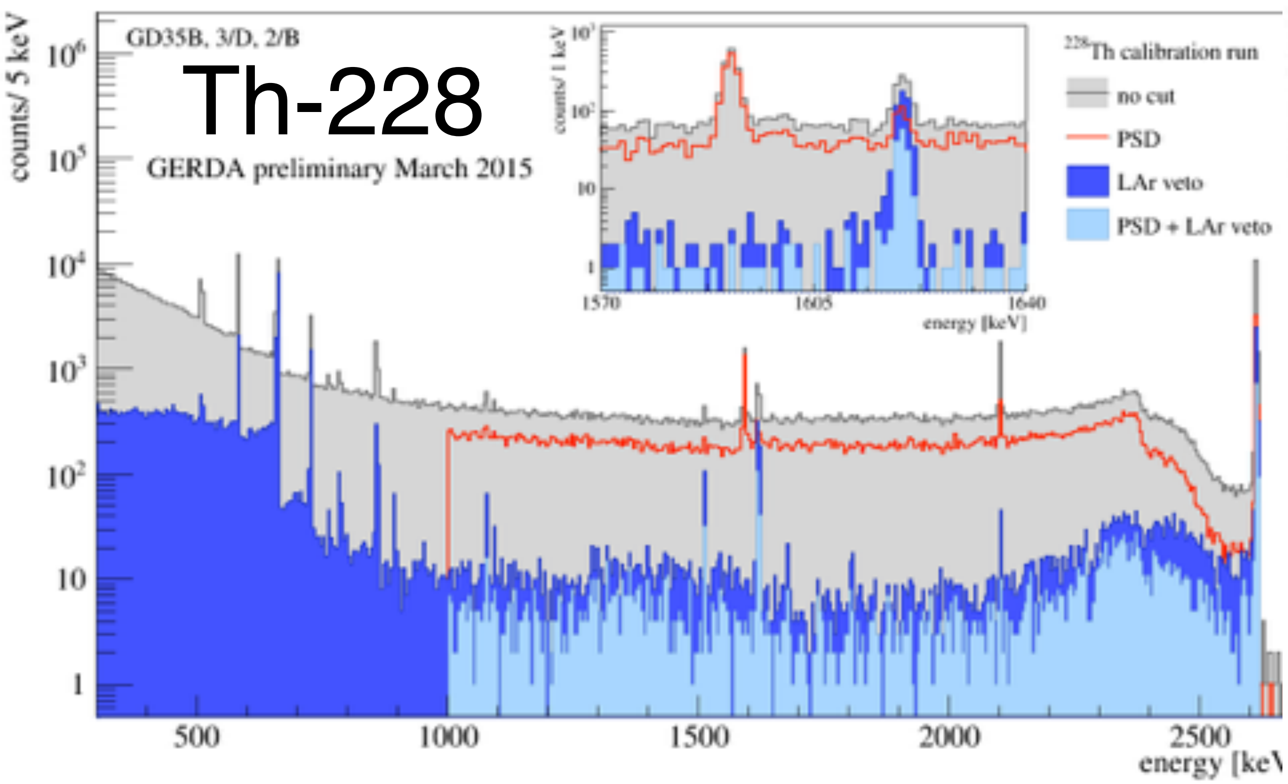
Fiber “shroud”
800 m WLS
fibre coated
with TPB

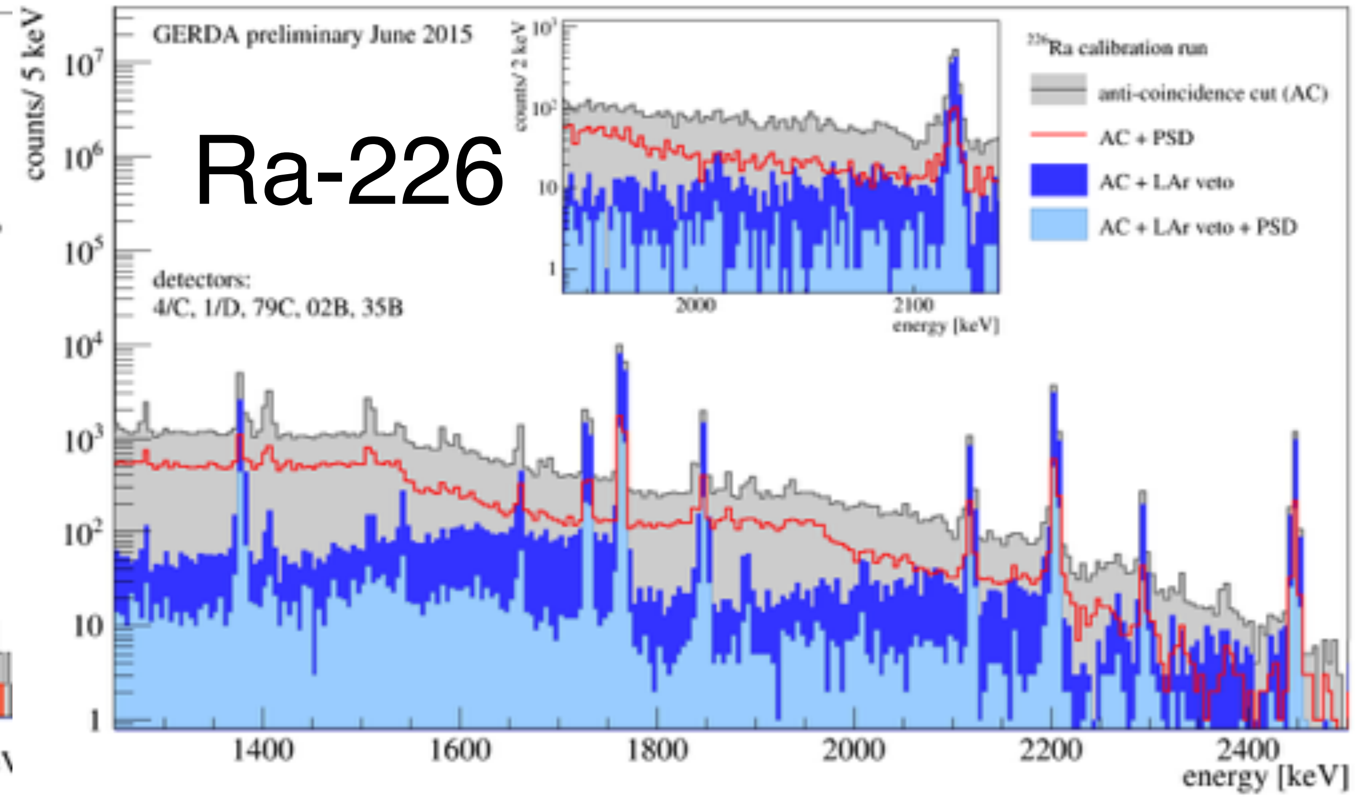
Copper “shroud” with
Tetratex reflector coated
with TPB



Technische Universität München

LAr veto commissioning



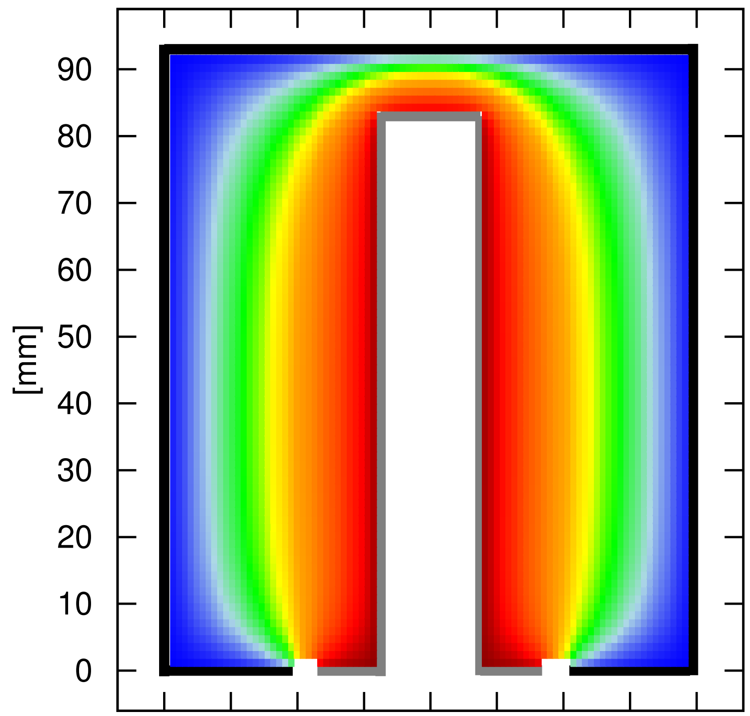


- LAr-veto mounted in Nov. 2014, several calibration runs.
- Trigger on single photoelectron, both PMTs and SiPMs
- Very effective for gamma background

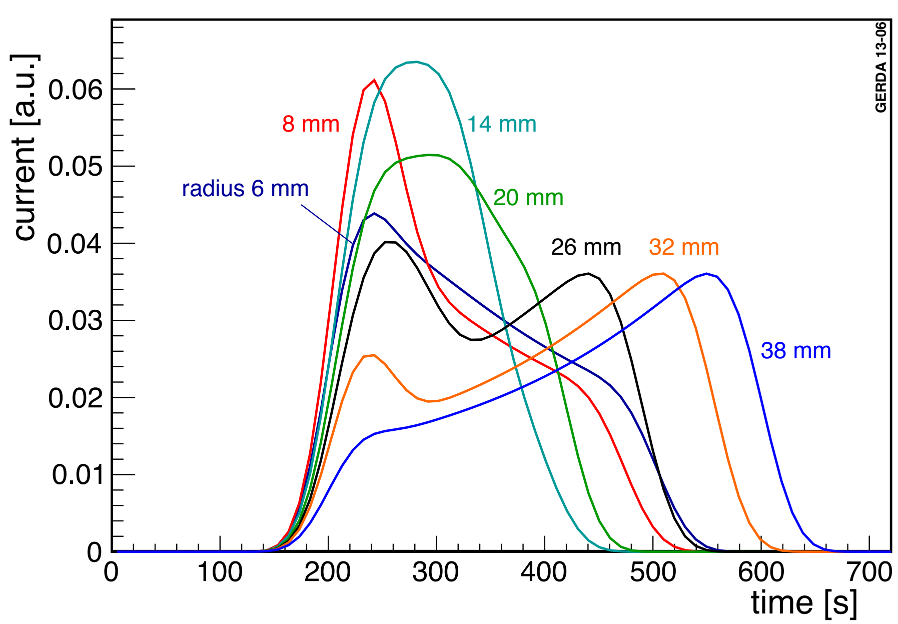
Suppression of:	Ge Anti-Coincidence	LAr-veto	PSD	LAr + PSD	Acceptance
^{228}Th	1.26 ± 0.01	97.9 ± 3.7	2.19 ± 0.01	344.6 ± 24.5	86.8%
^{226}Ra	1.26 ± 0.01	5.7 ± 0.2	2.98 ± 0.06	29.4 ± 2.5	89.9%

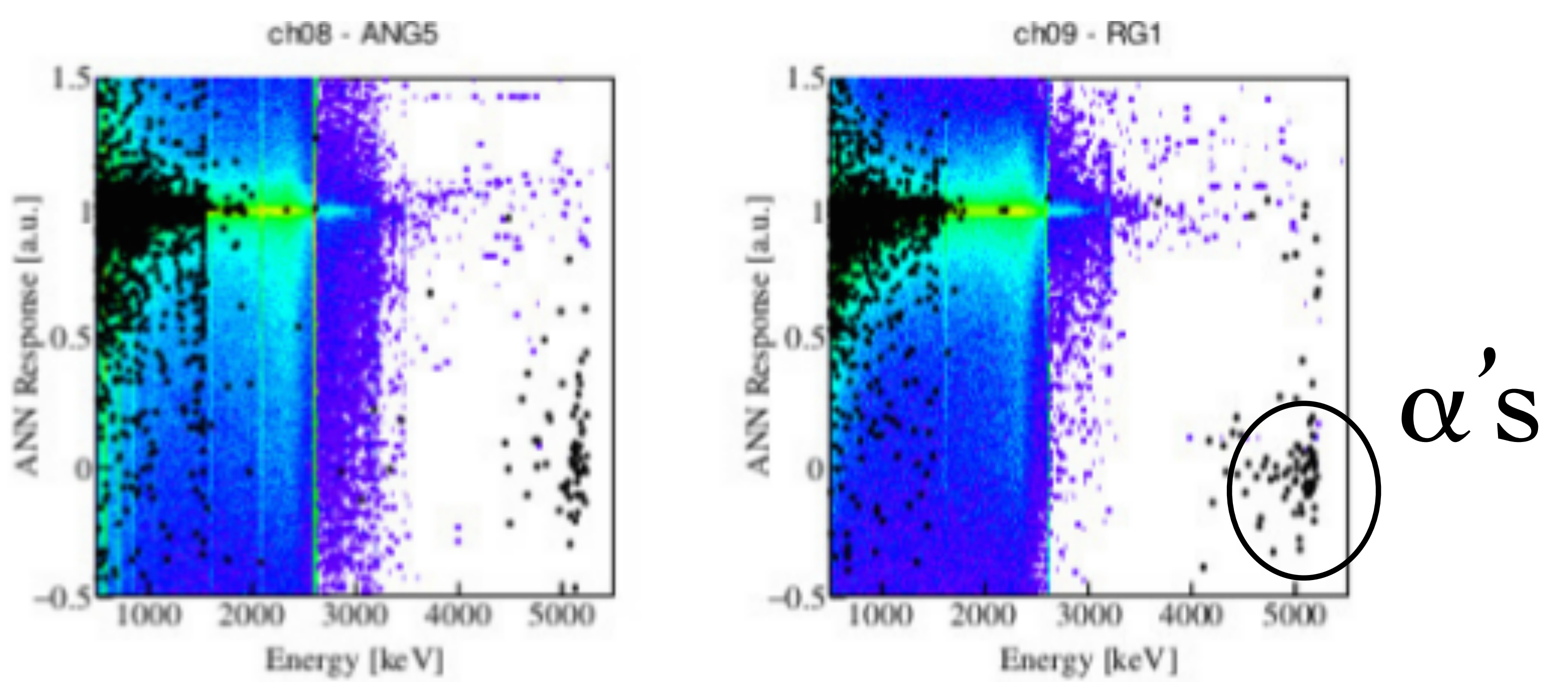
Technische Universität München

Pulse Shape Discrimination, Coax

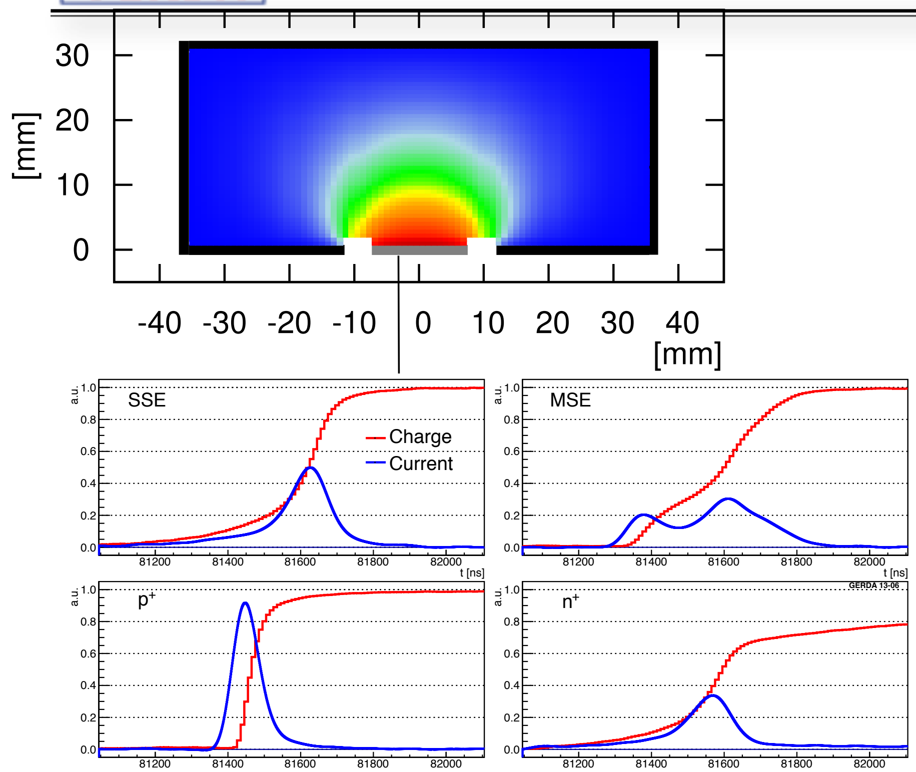


- **Signal:** Single Site Event, **Background:** Multi-Site Ev.
  - PSD can veto Multi-Site Events in HPGe detector
- Neural network trained with calibration data
- Achieved performance is similar to Phase I
- Tuned to 90% acceptance of the DEP of 2.6 MeV line (Tl-208)

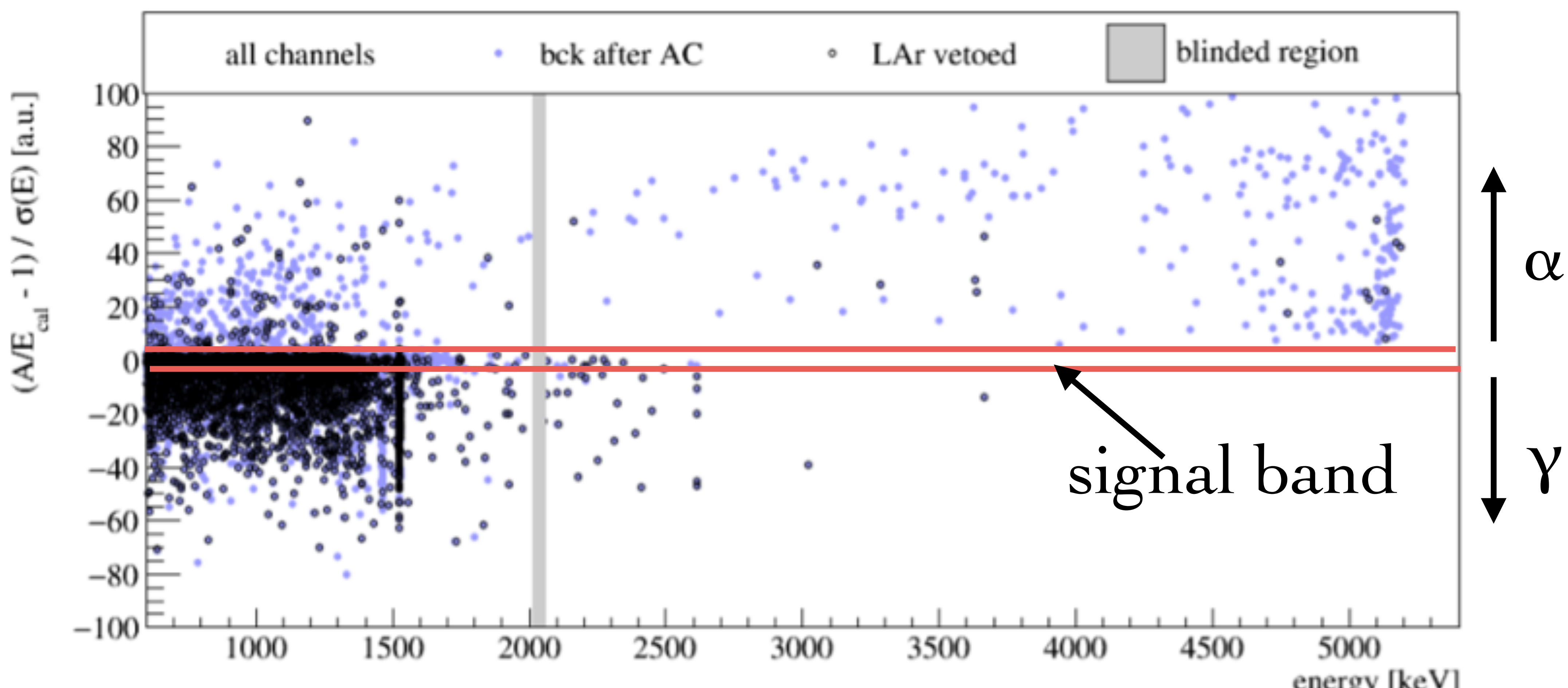




Pulse Shape Discrimination, BEGe

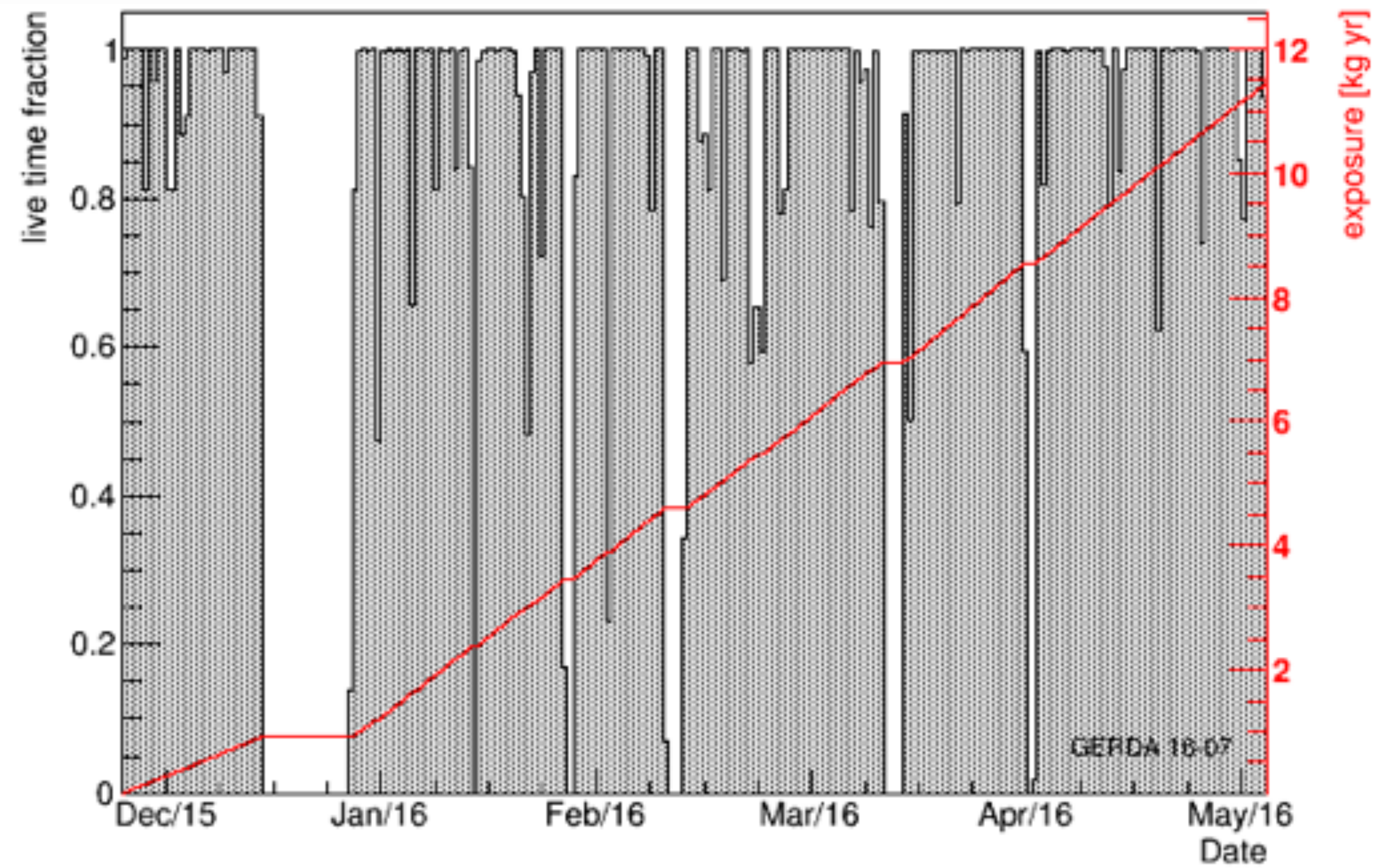


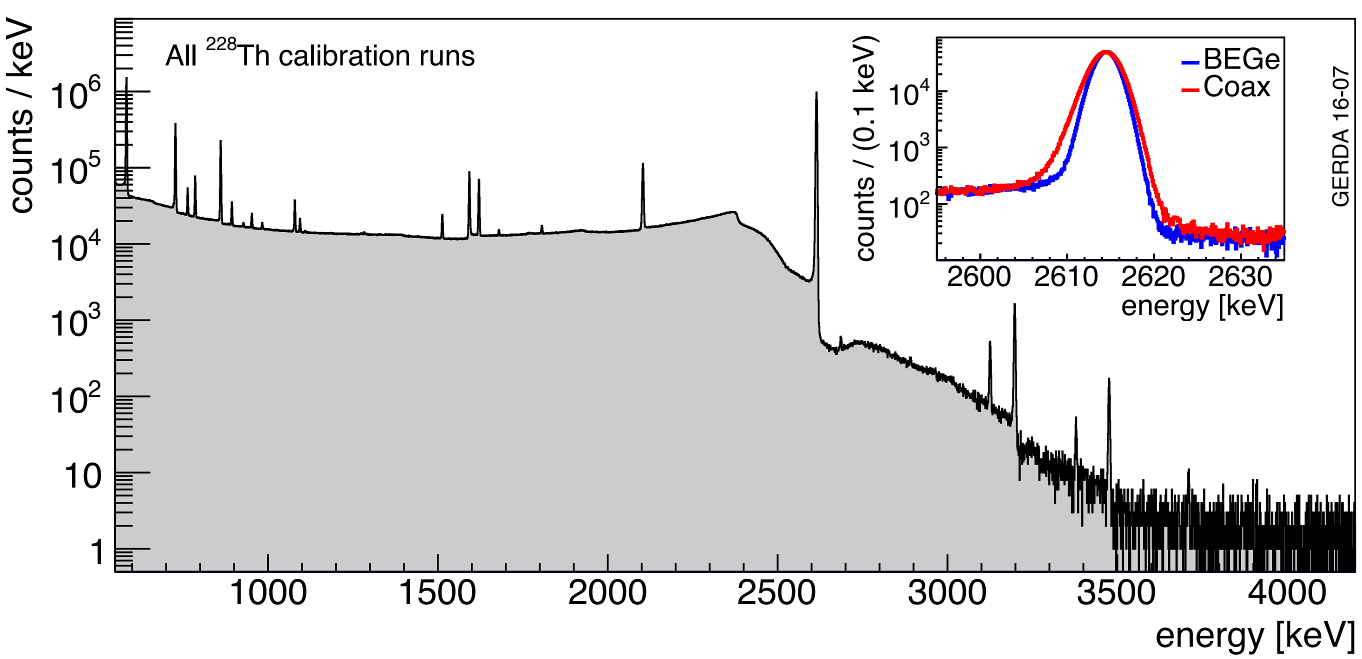
- BEGe detectors have a better PSD performance
- A/E single parameter cut is very efficient rejecting multisite events
- Tuned to 90% acceptance of the ^{208}Tl DEP peak
- ~85% acceptance for $2\nu2\beta$ in the background data



Phase II performance

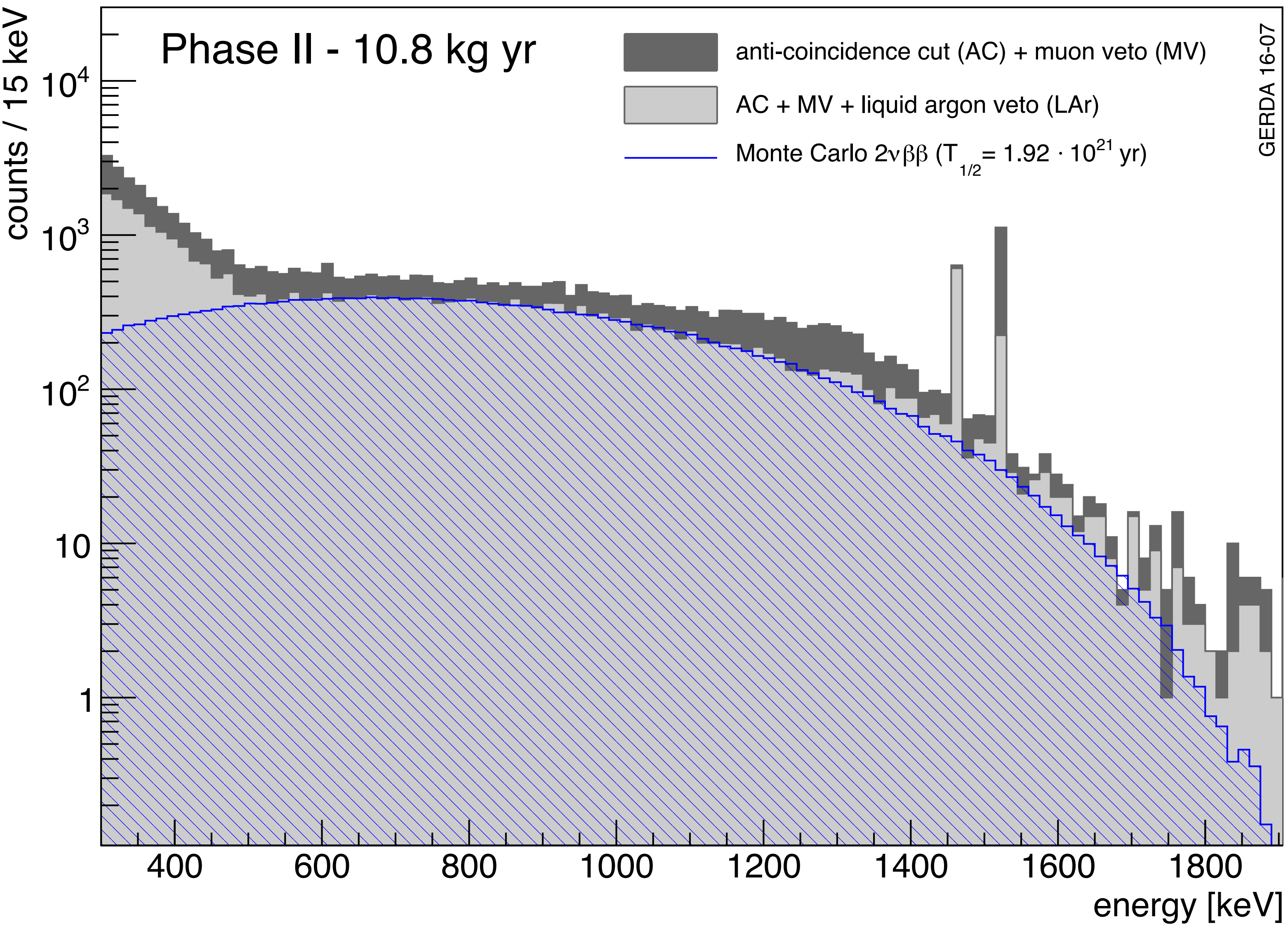
- Data released: Dec. 2015 - May 2016
- 85% duty cycle: Dec.2015 - May 2016
- Exposure BEGe 5.8 kg yr
- Exposure Coax. 5.0 kg yr

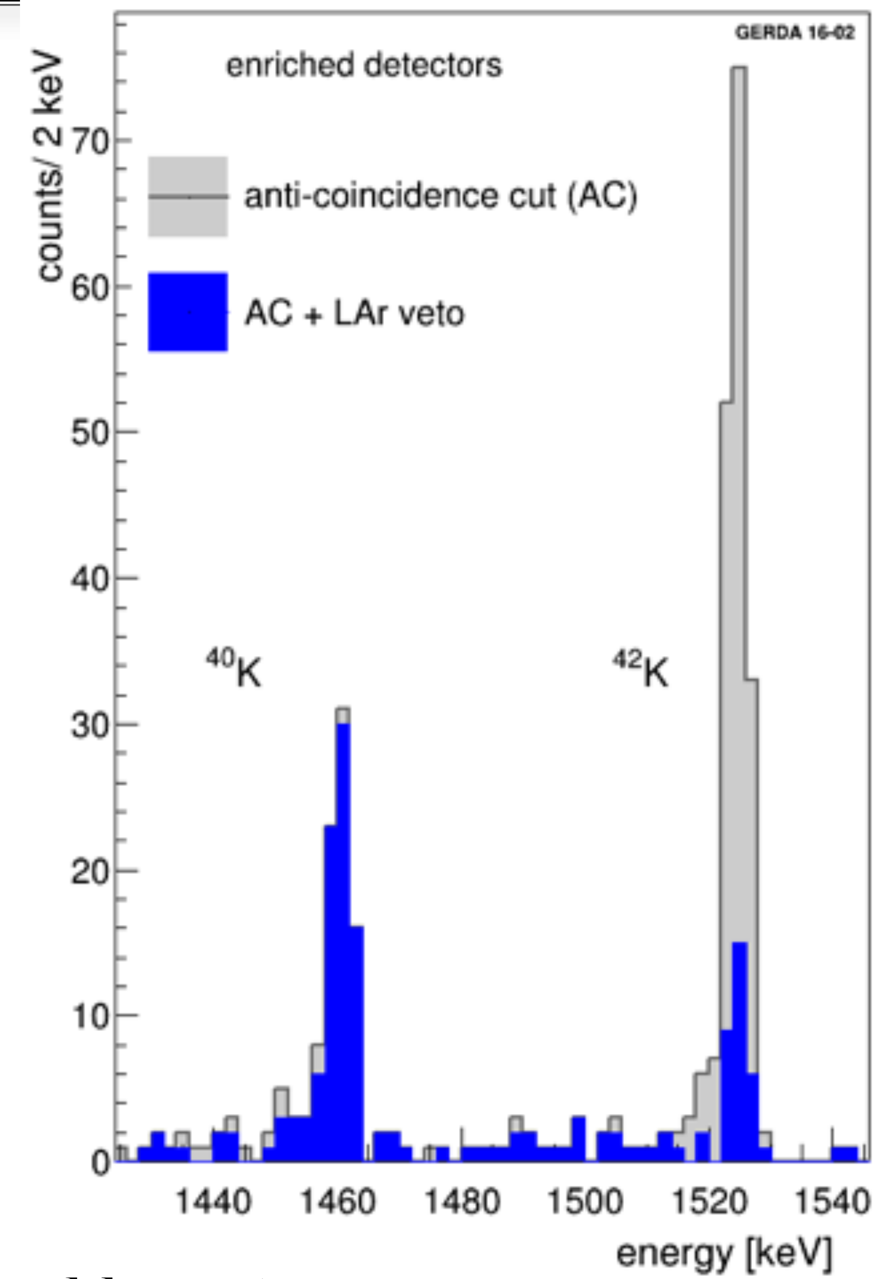




- weakly calibration runs with Th-232 source
- Resolution at 2.6 MeV, BEGe: 3.2 keV
- Resolution at 2.6 MeV, Coax.: 3.8 keV
- Background data blinded $Q_{\beta\beta}$ ± 25 keV

Phase II, first results

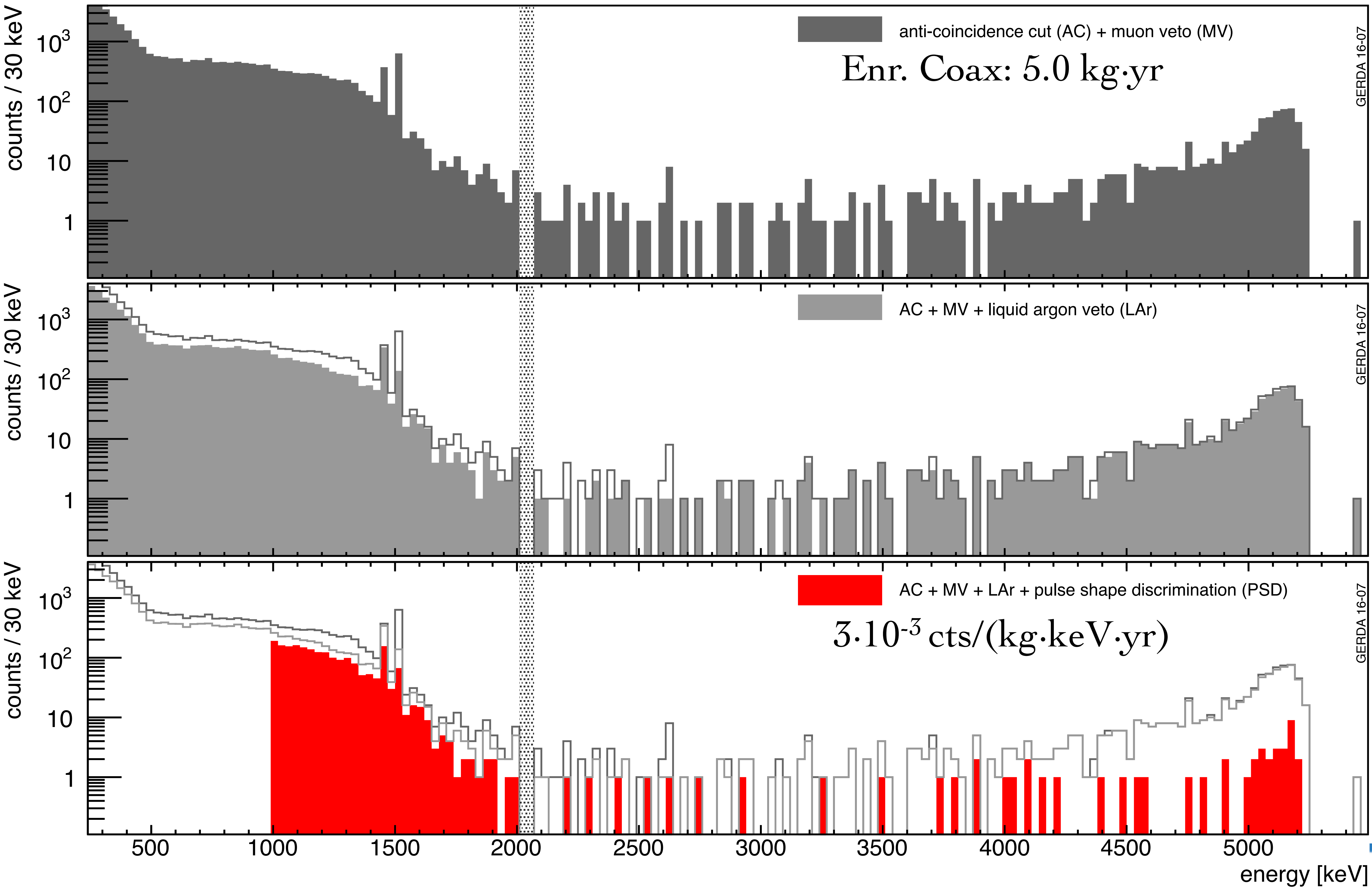




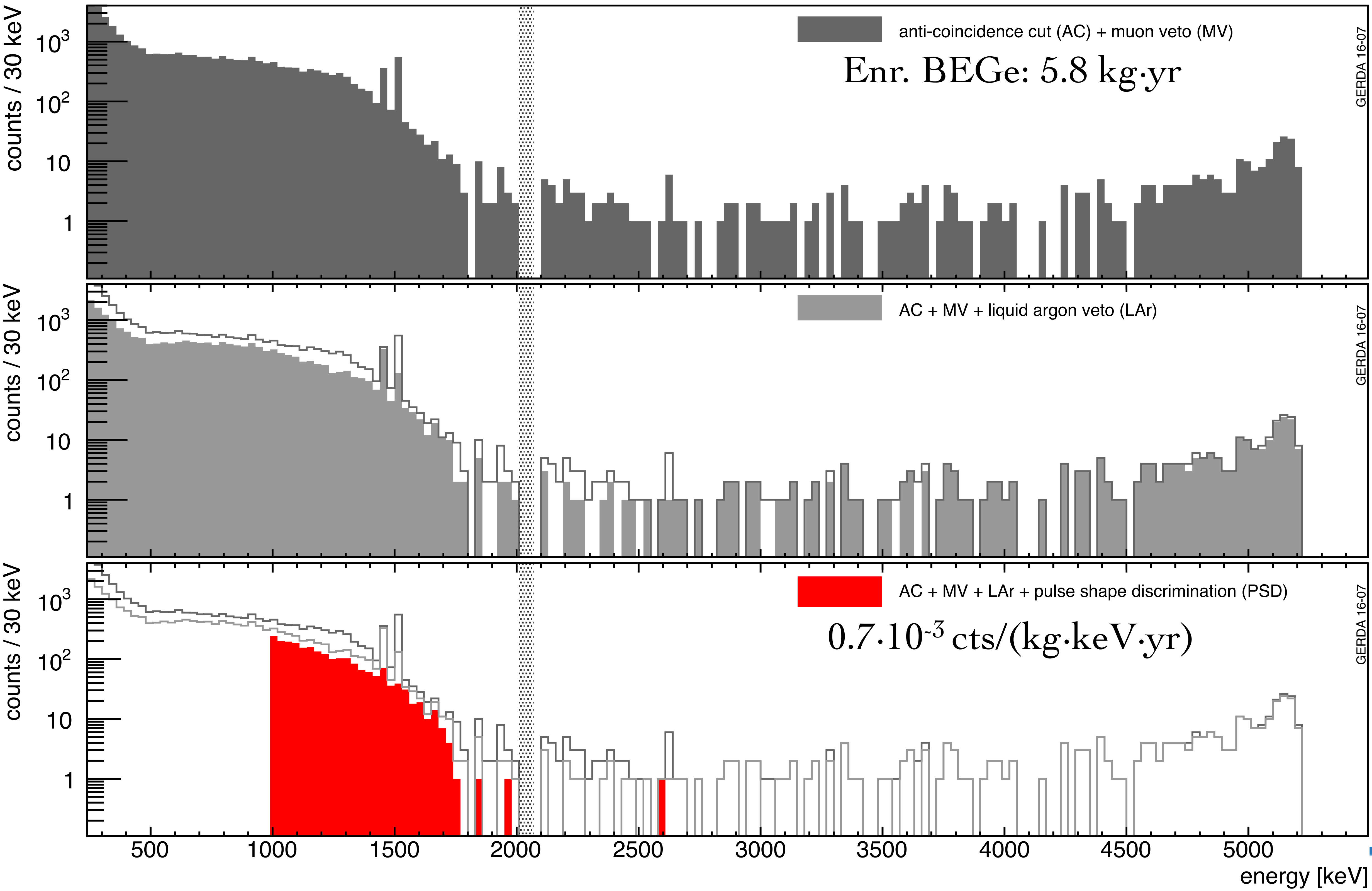
- LAr-veto works for background data as well
  - K^{40}/K^{42} Compton continuum strongly suppressed by LAr-veto
- Data agrees with $T_{1/2}(2\nu\beta\beta) = 1.9 \cdot 10^{21}$ yr from GERDA Phase I
- $2\nu\beta\beta$ events are used to validate PSD and active volume determination

Technische Universität München

Phase II, first results



Phase II, first results

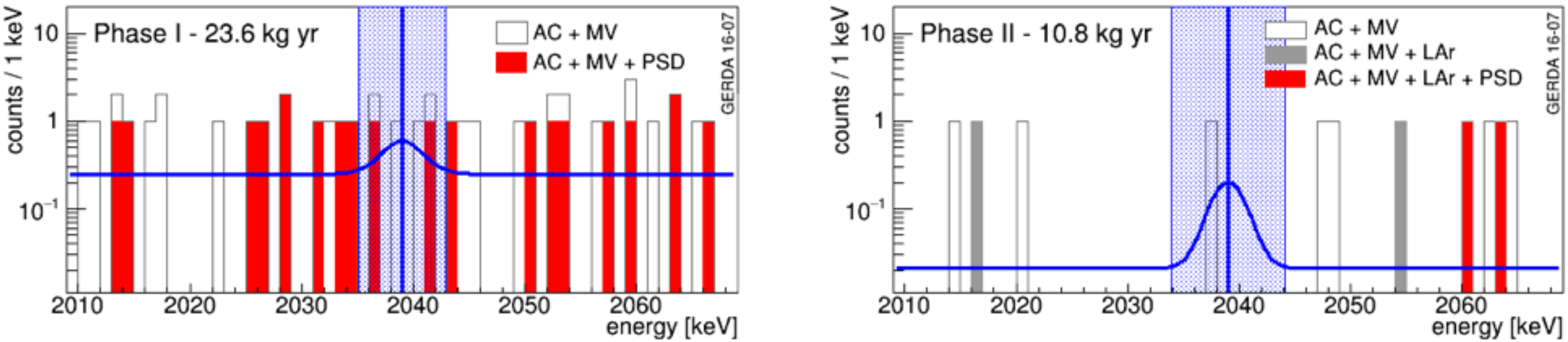


Phase II, first results

data set	exposure [kg yr]	FWHM [keV]	efficiency	final background [10^{-3} cnt/(keV kg yr)]
PI golden	17.9	4.27±0.13	0.57±0.03	11±2
PI silver	1.3	4.27±0.13	0.57±0.03	30±10
PI BEGe	2.4	2.74±0.20	0.66±0.02	5^{+4}_{-3}
PI extra	1.9	4.17±0.19	0.58±0.04	4^{+5}_{-2}
PII coax	5.0	4.0±0.2	0.51±0.07	3^{+3}_{-1}
PII BEGe	5.8	3.0±0.2	0.60±0.02	$0.7^{+1.2}_{-0.5}$

- Exposure is calculated with total mass
- Efficiency includes: enrichment, active volume, 0νββ signal efficiency, PSD efficiency, LAr-veto dead time
- GERDA Phase II reached it's background goal !

Phase II, first results

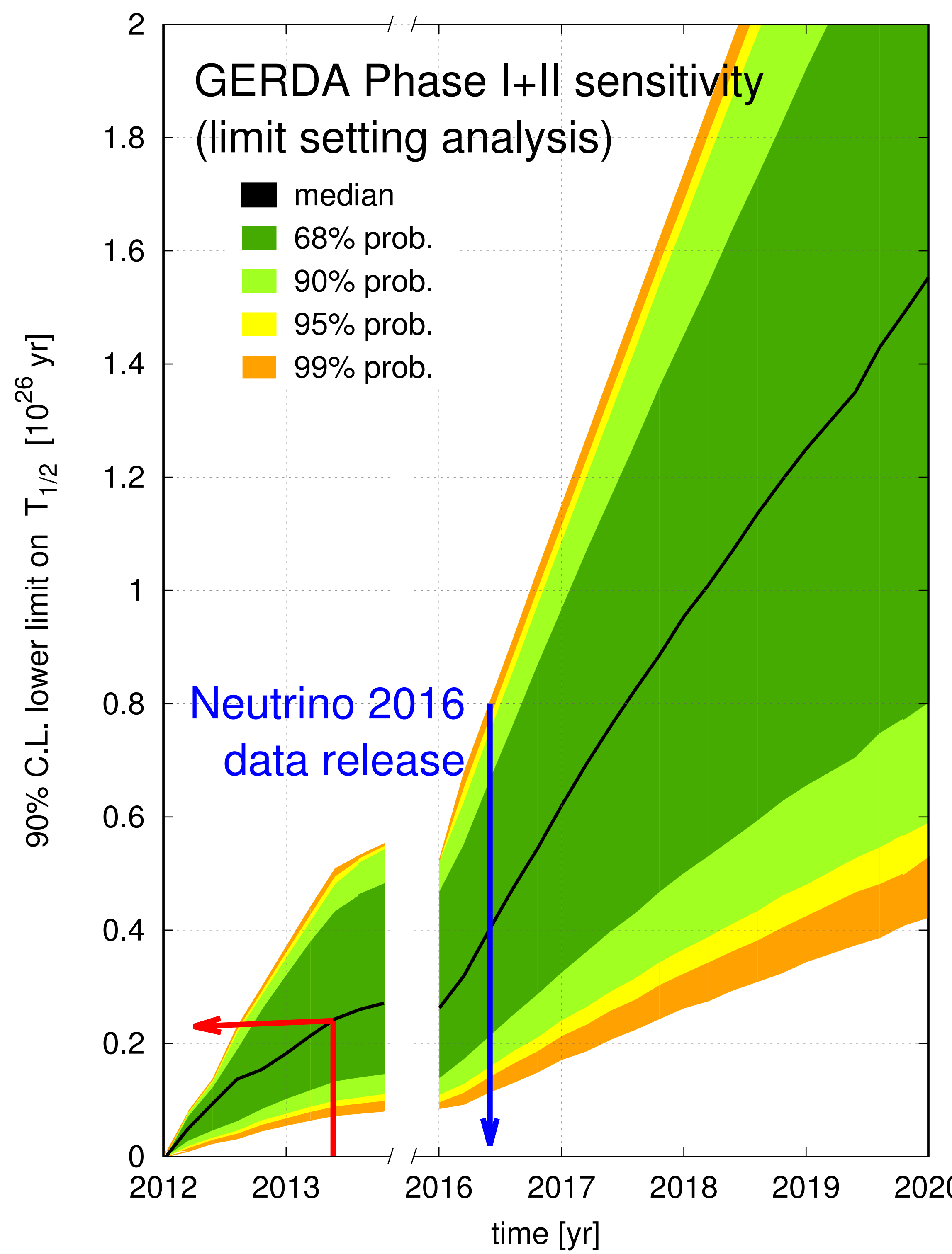


	profile likelihood 2-side test stat.	Bayesian flat prior on cts.
$0\nu\beta\beta$ cts. best fit value	0	0
$T_{1/2}(0\nu\beta\beta)$ lower limit [10^{25} yr]	> 5.2 (90% CL)	>3.5 (90% CI)
$T_{1/2}(0\nu\beta\beta)$ median sensitivity [10^{25} yr]	> 4.0 (90% CL)	>3.0(90% CI)

- Unbined profile likelihood: flat background + Gaussian signal

Summary

- GERDA Phase II is taking data with 35.8 kg enriched germanium detectors
- Phase II background goal reached: running practically background free:
    - $0.7{\cdot}10^{-3}$ cts/(keV·kg·yr) achieved for BEGe data set
    - lowest background level in [cts/ROI] among all $0\nu\beta\beta$ experiments (10x lower than any running experiment)
- New $T_{1/2}$ limit: Phase II + Phase I published + Phase I extra:
    - Profile likelihood fit gives a median sensitivity of $4.0 \cdot 10^{25}$ yr
    - and a half life limit of $5.2 \cdot 10^{25}$ yr



5

Technische Universität München