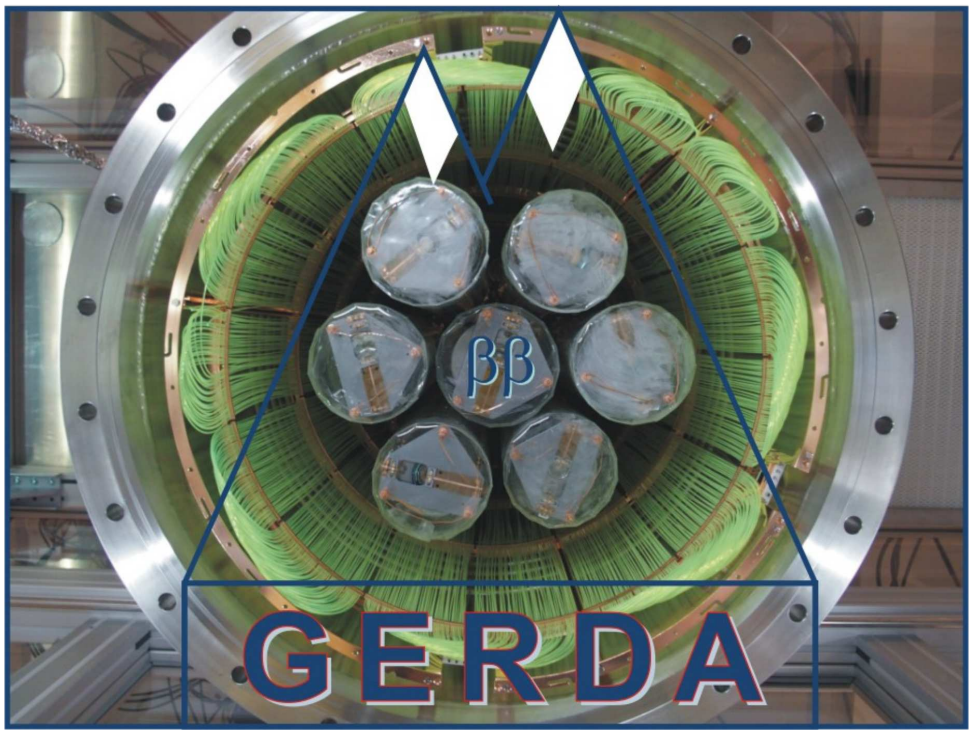
University of Zurich[UZH]

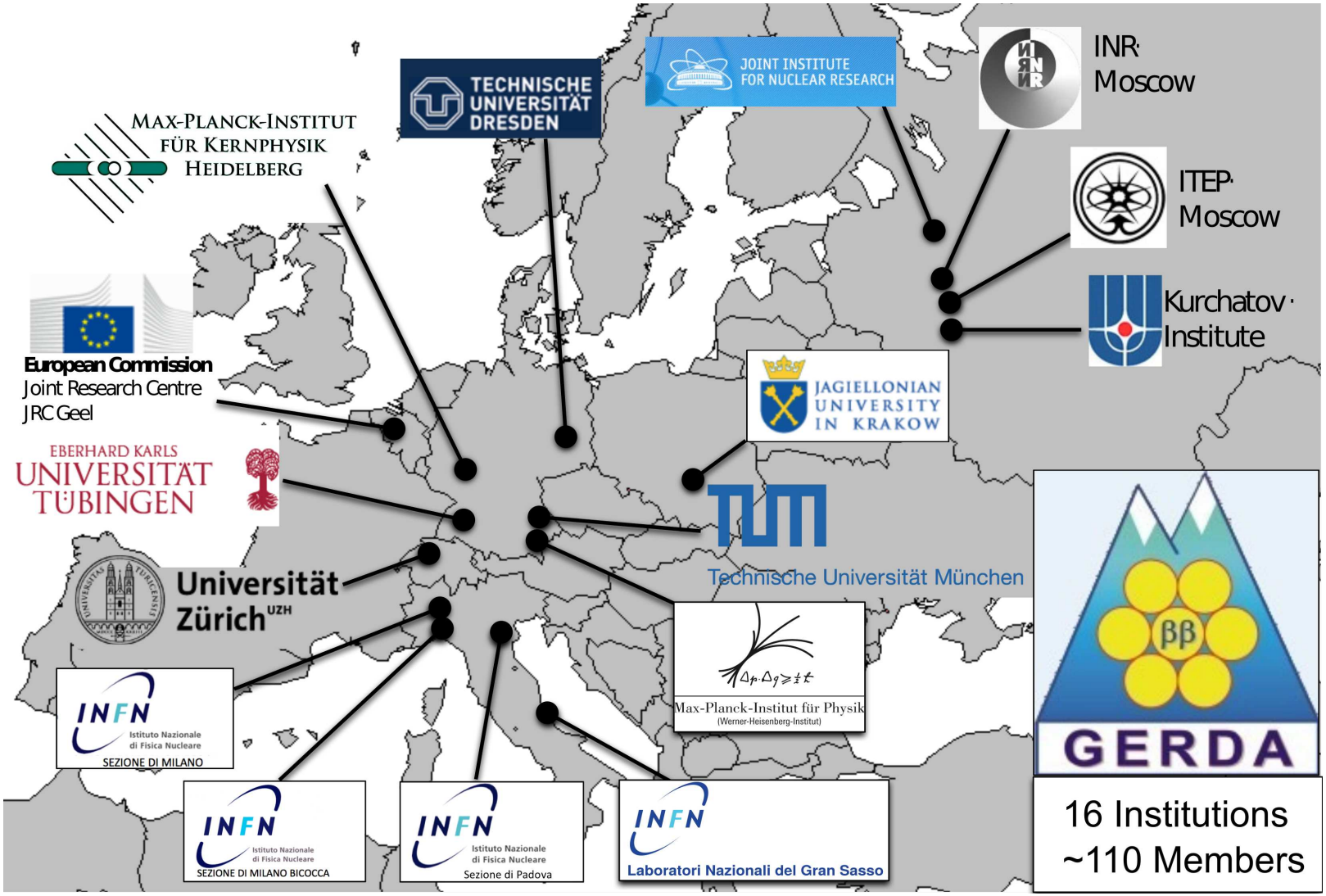
Physik-Institut

Status of GERDA Phase II

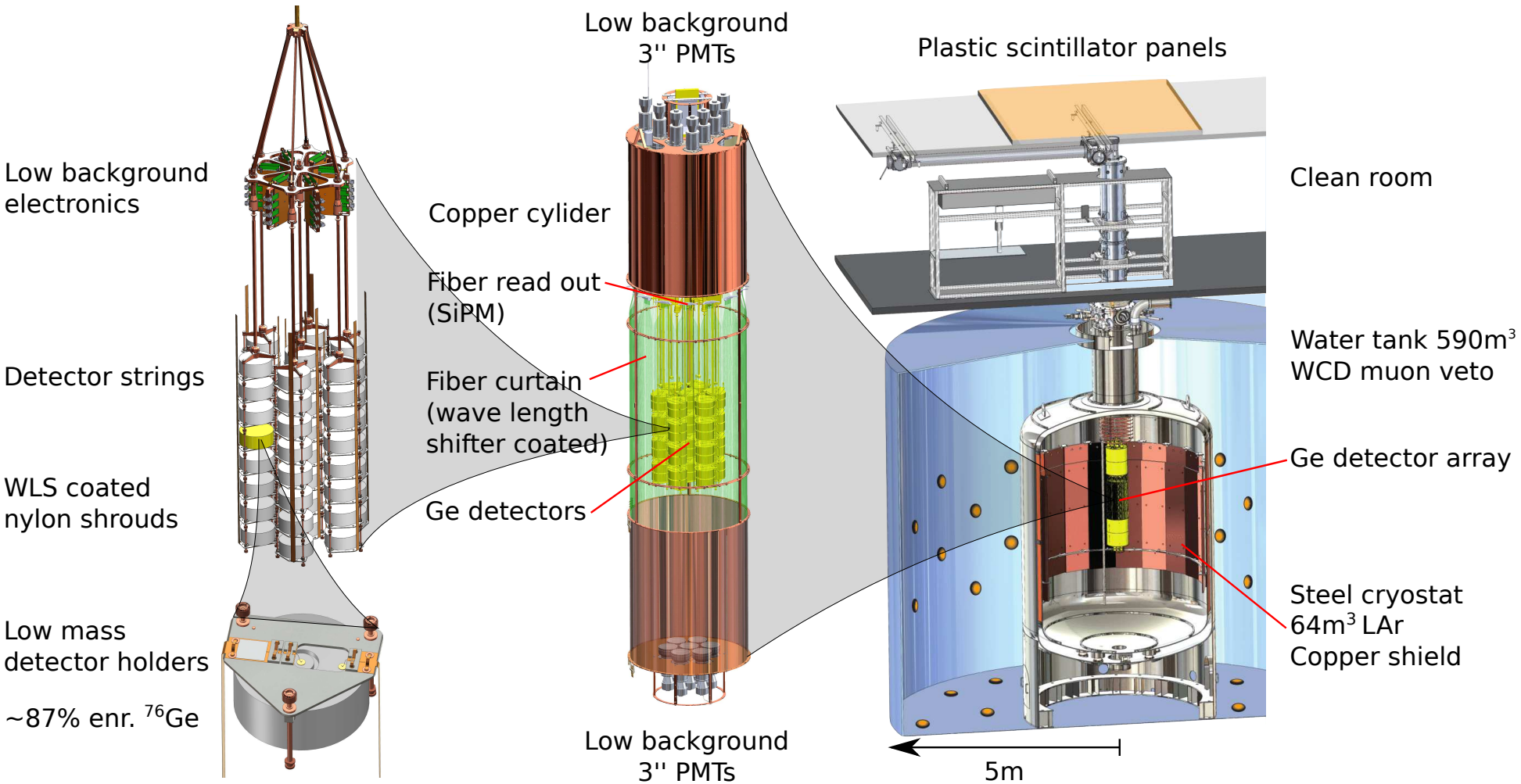
Roman Hiller for the GERDA collaboration



The GERDA collaboration



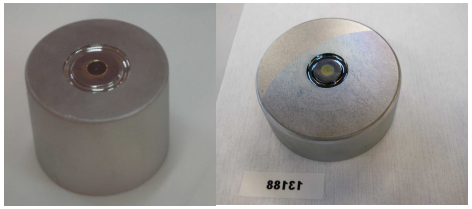
GERmanium Detector Array

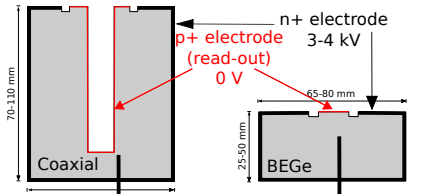


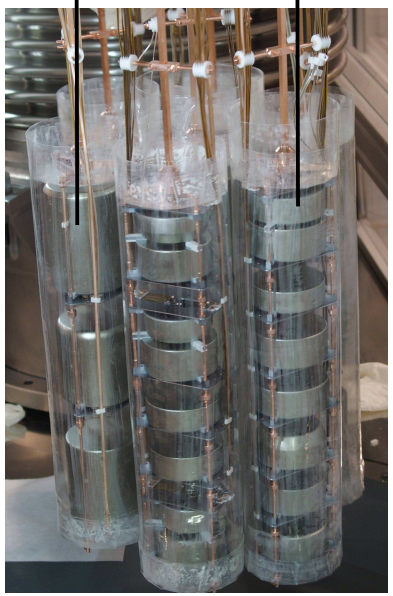
Detector array

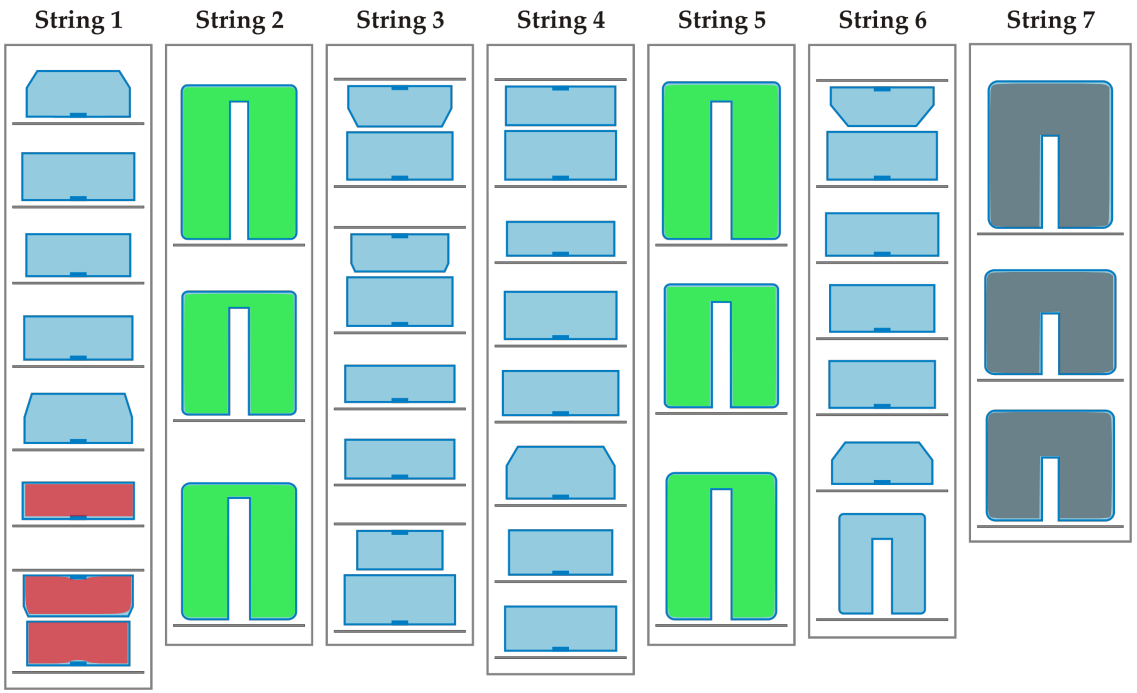
40 detectors in 7 strings:

- 7 enriched semi-coax (15.6 kg)
- 30 enriched BEGe (20.0 kg)
- 3 natural semi-coax (7.6 kg)
- 3 BEGe JFET dead (2 new)



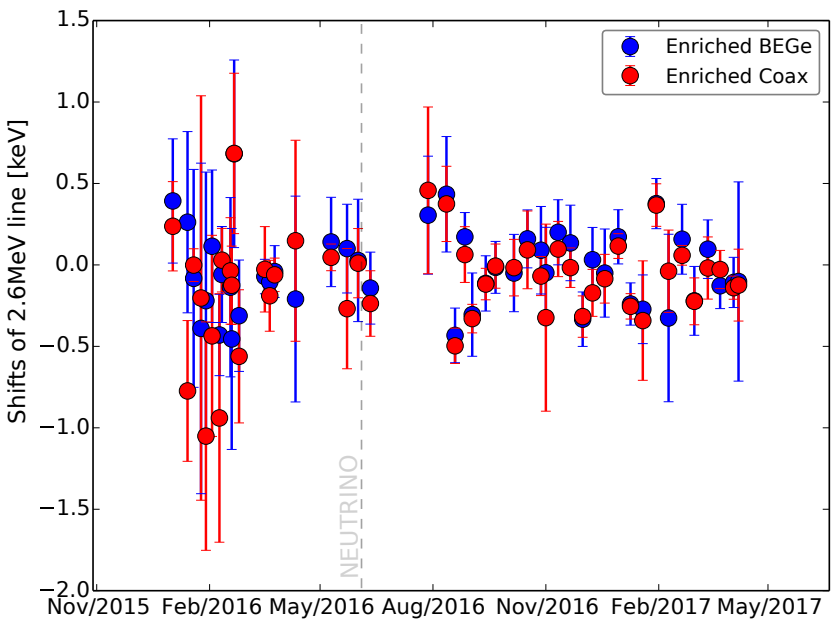


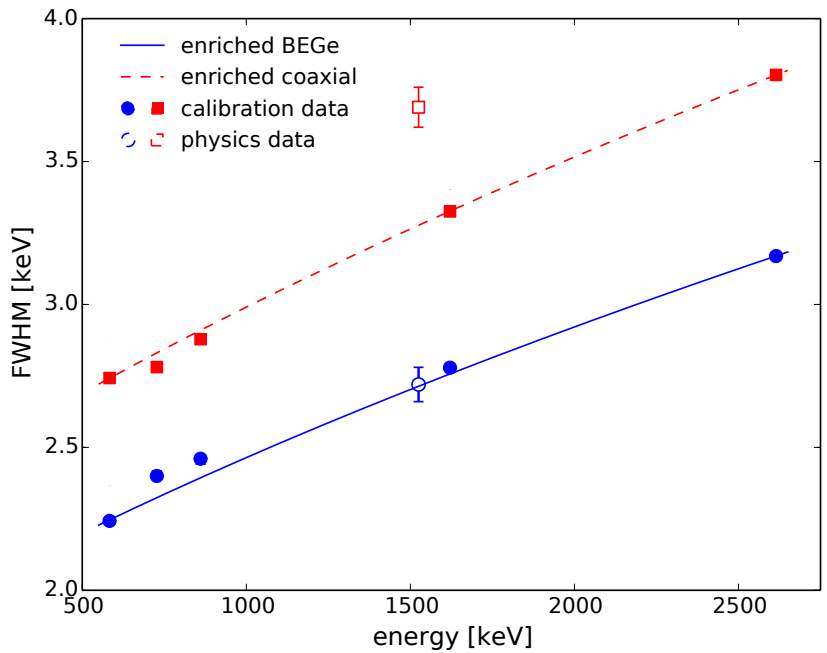




Energy scale stability and resolution

- Weekly calibrations with ^{228}Th
- Stability monitoring in between via pulser 50 mHz
- Shifts in energy scale typically 0.3 keV (systematic)
- Resolution at $Q_{\beta\beta}$ 2.9 keV BEGe, 3.9 keV Coax
- Correction to Coax resolution from physics data

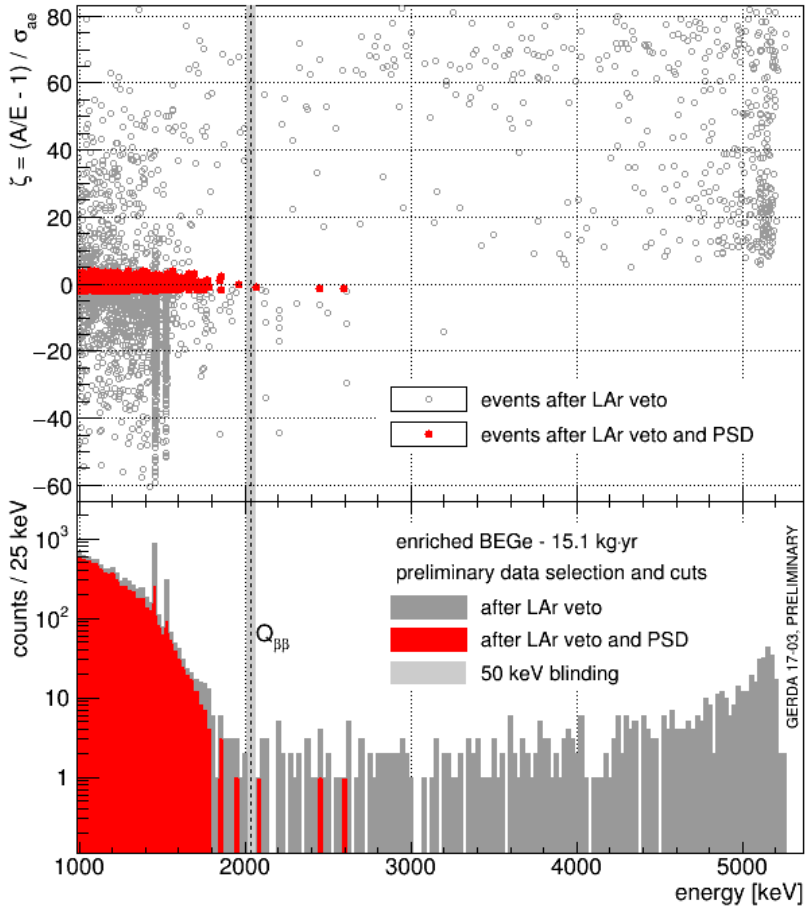




Pulse shape discrimination BEGe

- Pulse shape discrimination for BEGe with Current amp./energy
- 87% acceptance of single site events (e.g. $2\nu\beta\beta$, $0\nu\beta\beta$)
- 80-90% rejection of multi site events (gamma)
- all $\sim$500 alpha events so far rejected

Pulse shape parameter A/E vs. E



Phased approach of GERDA

Phase I (2011-2013):

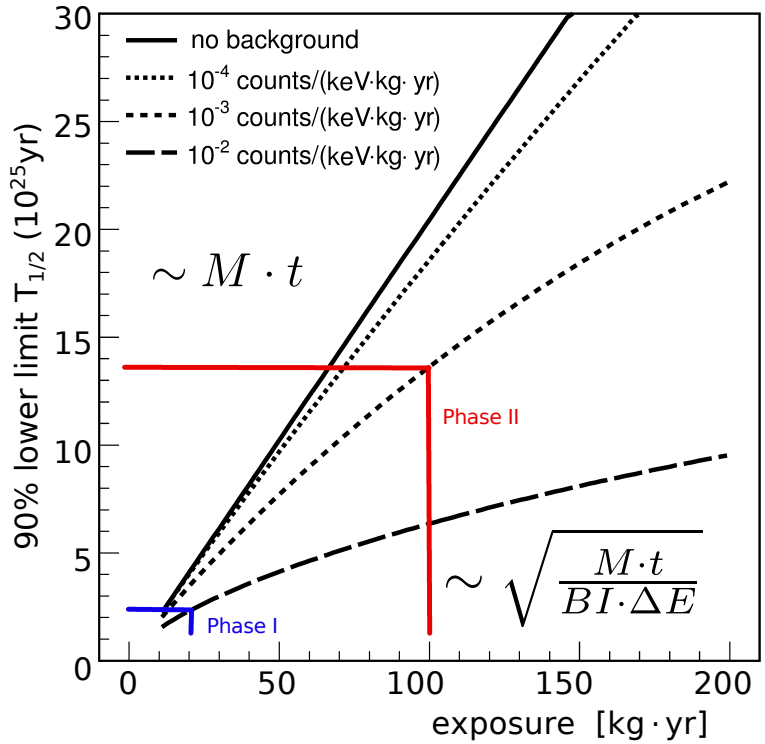
- Completed with 21 kg yr exposure
- 16 kg refurbished HdM+IGEX detectors
- Only passive LAr shield
- BI$\sim$0.01 $\frac{\mathrm{cts}}{\mathrm{keV\ kg\ yr}}$
- Blind analysis

Phase II (Dec 2015-present):

- Add BEGe detectors (20 kg)
- Readout LAr scintillation light
- Events at 2039$\pm$25 keV blinded
- Unblinding when certain exposure milestones reached after finalizing cuts

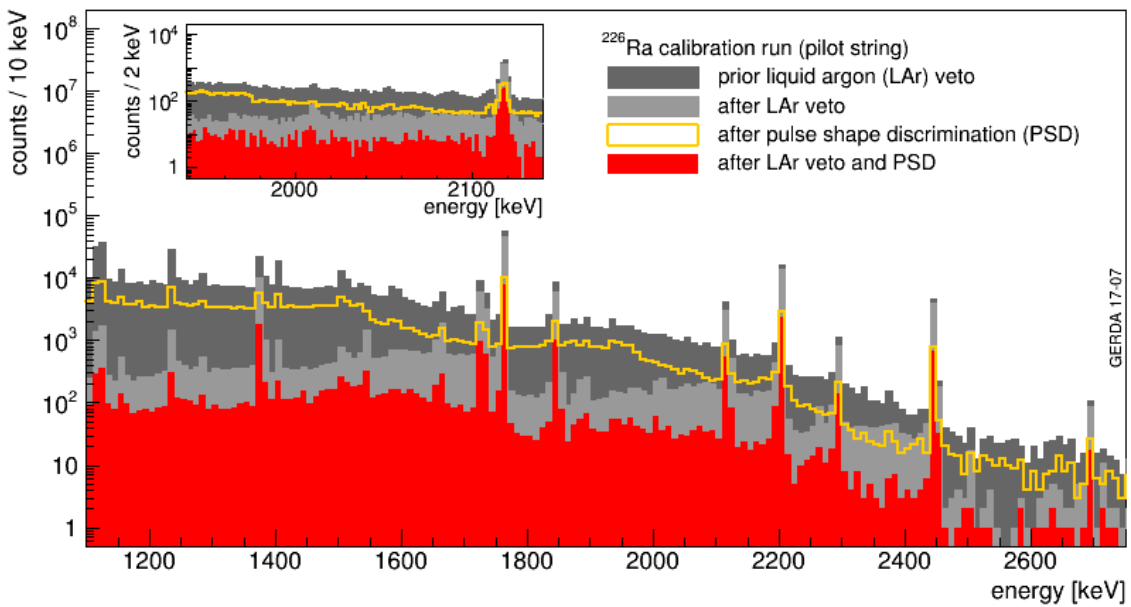
Goals:

- >10^{26} yr half life sensitivity
- 100 kg yr exposure
- BI$\sim$0.001 $\frac{\mathrm{cts}}{\mathrm{keV\ kg\ yr}}$



Background suppression

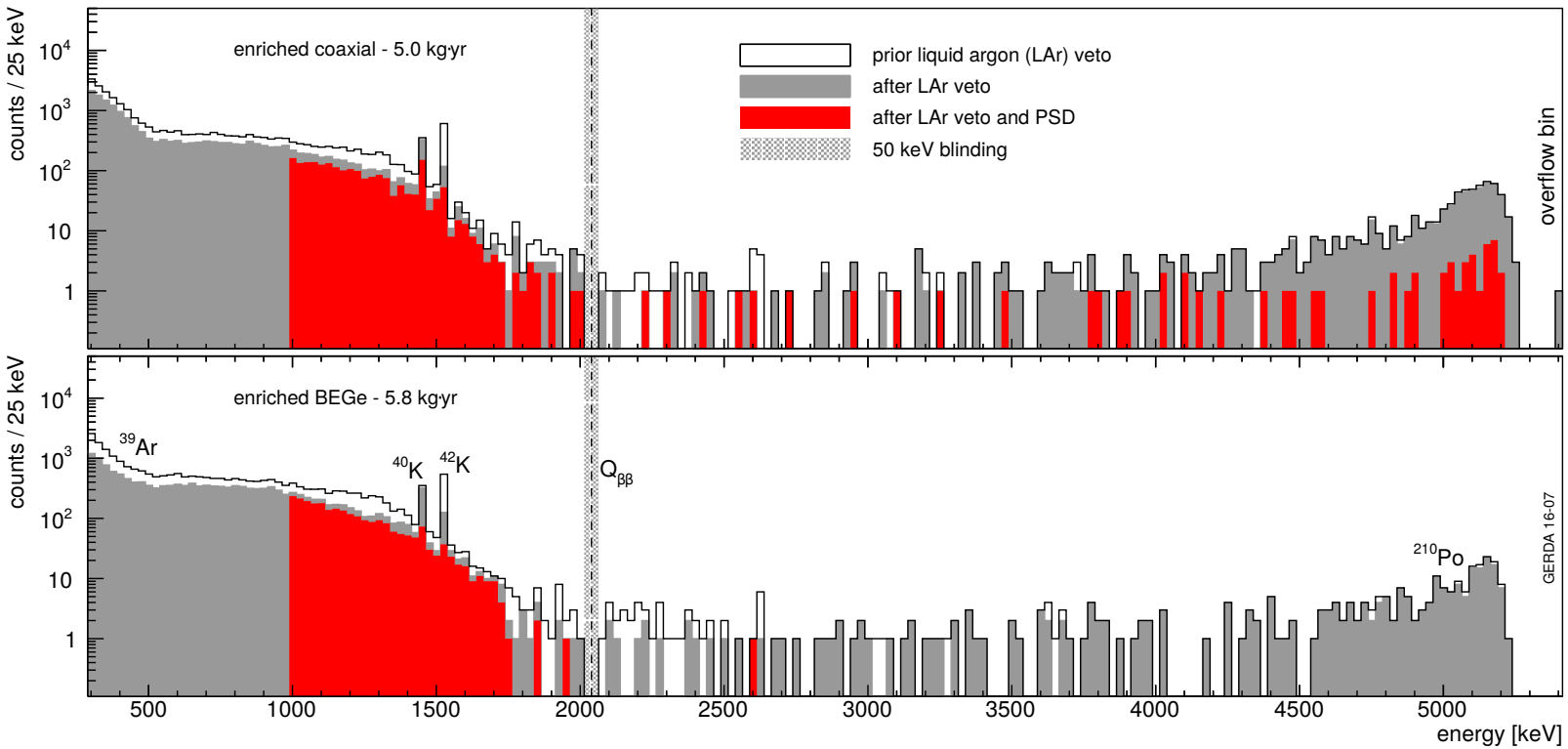
- Anti-coincidence
- Muon veto
- LAr veto
- Pulse shape discrimination
- Special calibration ^{226}Ra (^{228}Th):
  Suppression factor LAr 5.7 (98), LAr+PSD 29 (345)



Phase IIa release

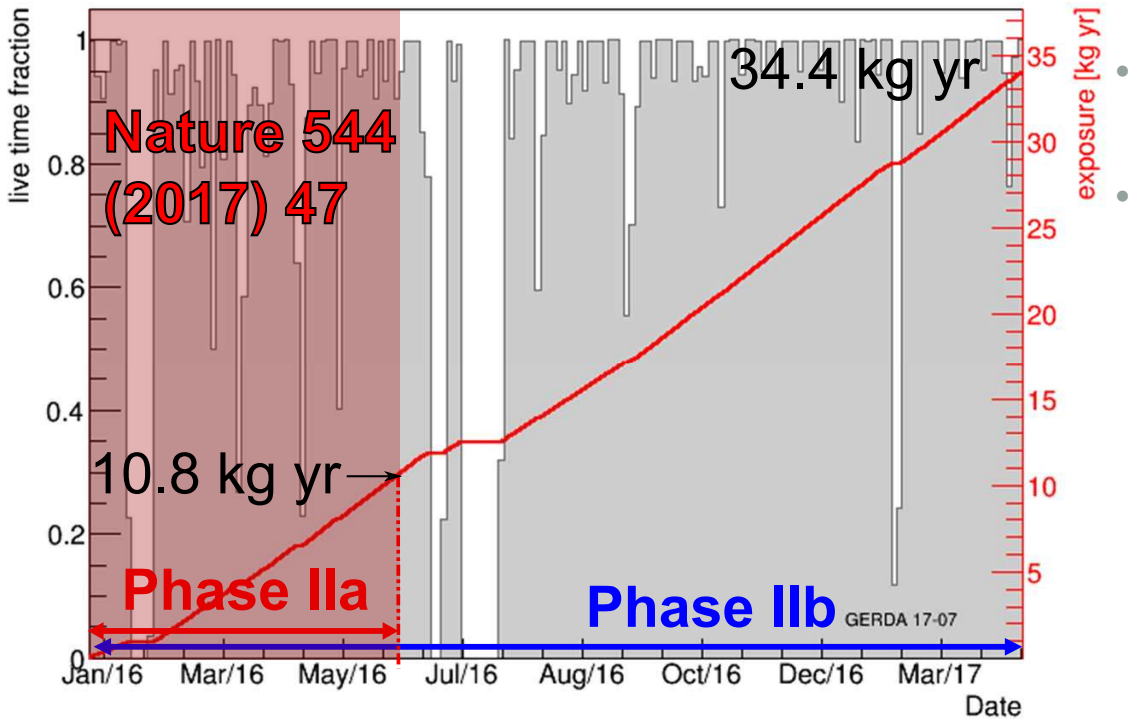
Phase IIa release June 2016 (Ringberg) 10.8 kg yr:

- Published in Nature 544, 47-52, 2017
- $BI_{Coax} = 3.5^{+2.1}_{-1.5} \cdot 10^{-3}$ cts/(keV kg yr)
- $BI_{BEGe} = 0.7^{+1.1}_{-0.5} \cdot 10^{-3}$ cts/(keV kg yr)
- $T_{1/2} > 5.3 \cdot 10^{25}$ yr@90% CL ($4.0 \cdot 10^{25}$ yr sensitivity)



Data taking since June 2016

- Phase IIb data set up to April 15th (up to water drainage incident)
- Few interruption:
  - June 2016: $\sim$ 1 week muon veto off after loss of UPS power
  - July 2016: $\sim$ 3 weeks test pulser + maintenance + special calibration
  - Feb. 2017: $\sim$ 1 week special calibration



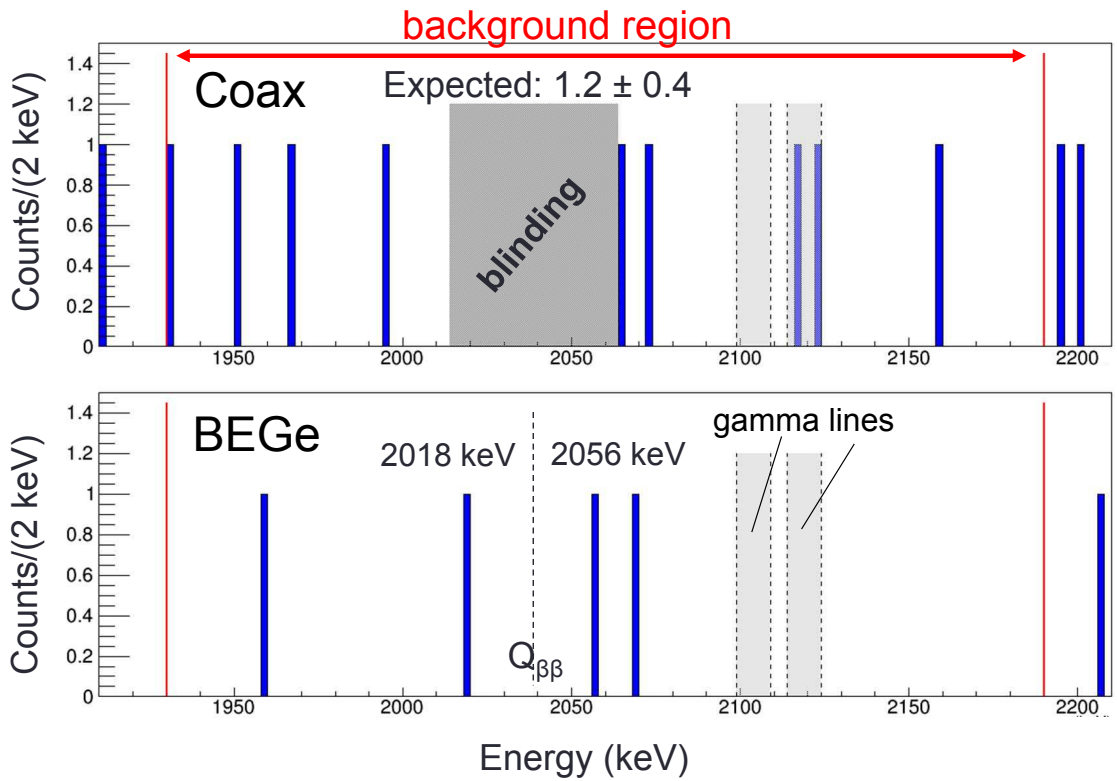
Phase IIb release (June 2017)

Unblinding at collab. meeting in Krakow:

- Cutoff date April 15th, before the water drainage incident
- 34.4 kg yr accumulated (23.6 kg yr new)
- 12.4 kg yr of new BEGe data released
- Left 11.2 kg yr of new Coax data blind:
  found recently that PSD can be further improved

Results Phase IIb

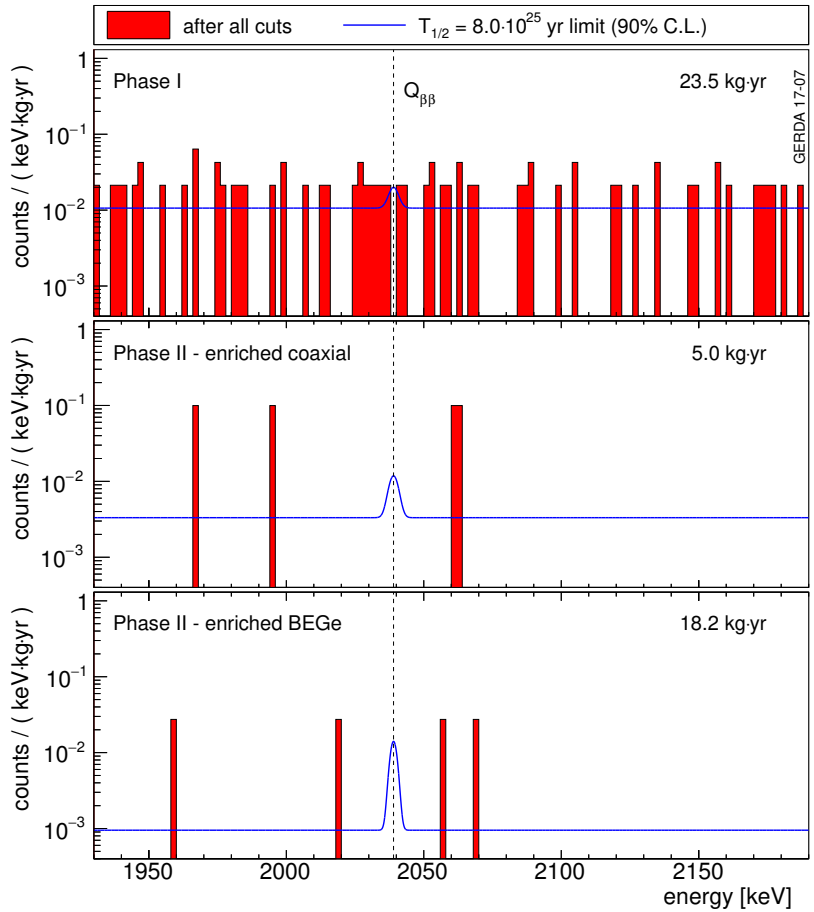
- Background estimated 1930-2190 keV
- excluding gamma lines 2104±5 keV and 2119±5 keV
- excluding blinded region for coax after Phase IIa
- $BI_{Coax} = 2.7^{+1.0}_{-0.0} \cdot 10^{-3}$ cts/(keV kg yr) (preliminary)
- $BI_{BEGe} = 1.0^{+0.6}_{-0.4} \cdot 10^{-3}$ cts/(keV kg yr)



ROI statistical analysis (preliminary)

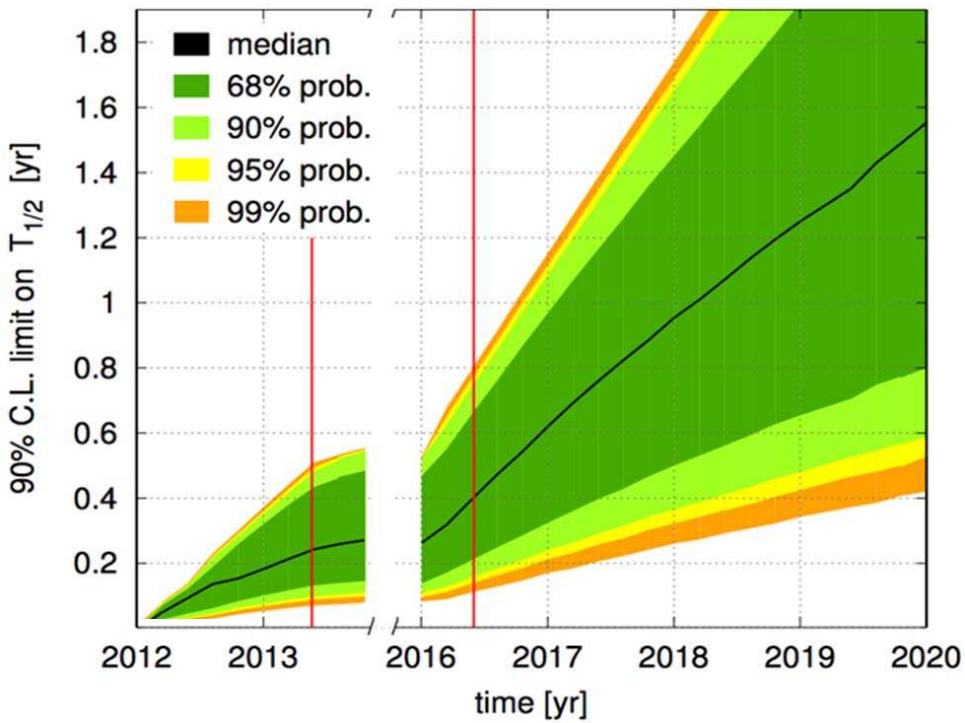
Combined unbin. max. likelihood fit of all data sets of GERDA (PI and PII), 46.7 kg yr

- **Frequentist**:
  Methods described in Nature 544, 47-52, 2017
  - Best fit $N_{0\nu} = 0$
  - $T_{1/2} > 8.0 \cdot 10^{25}$ yr @ 90% CL
  - Median sensitivity (limit) $5.8 \cdot 10^{25}$ yr
- **Bayesian**:
  Flat prior on $1/T_{1/2}$ between 0 and 10^{-24} yr
  - $T_{1/2} > 5.1 \cdot 10^{25}$ yr @ 90% CI
  - Median sensitivity $4.5 \cdot 10^{25}$ yr



Conclusion

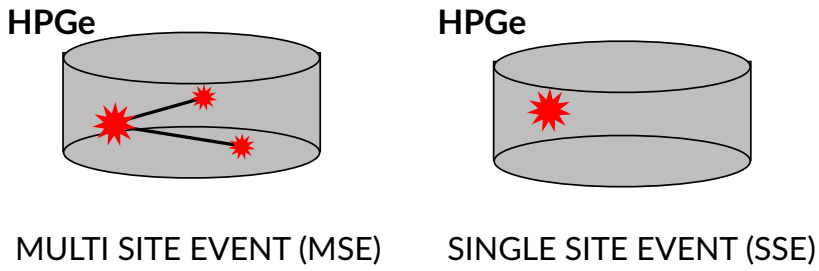
- GERDA Phase II works stably and accumulated already $\sim$45 kg yr exposure (23.2 kg yr released)
- Background at $Q_{\beta\beta}$ 2.7 (Coax) and 1.0 (BEGe) [10^{-3}cts/keV kg yr]
- "Background free" (<1 cts in 1 FWHM) up to 100 kg yr
- $T_{1/2} > 8.0 \cdot 10^{25}$ yr @ 90% CL
- Projected sensitivity 10^{26} yr (limit) spring-2018

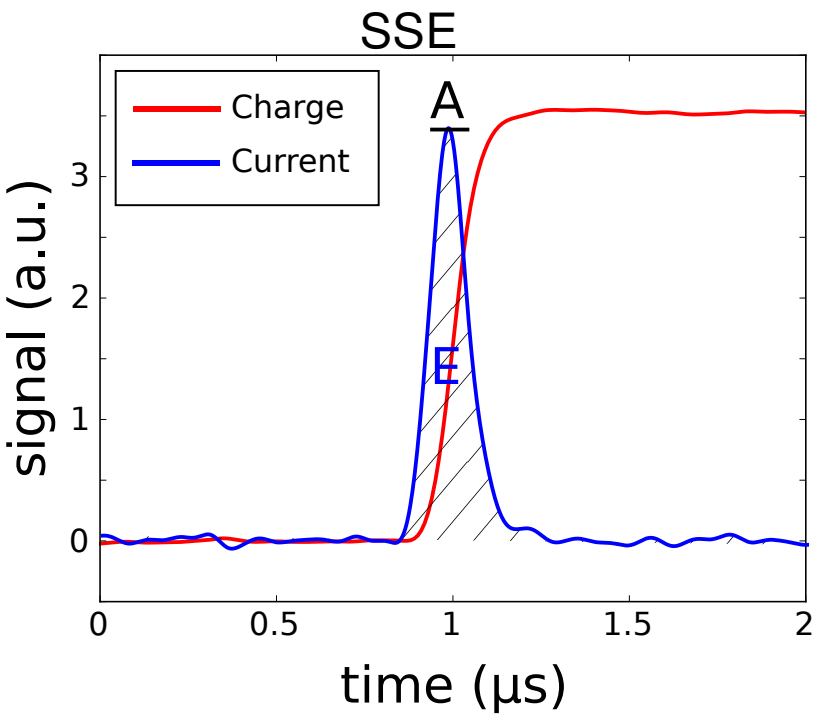


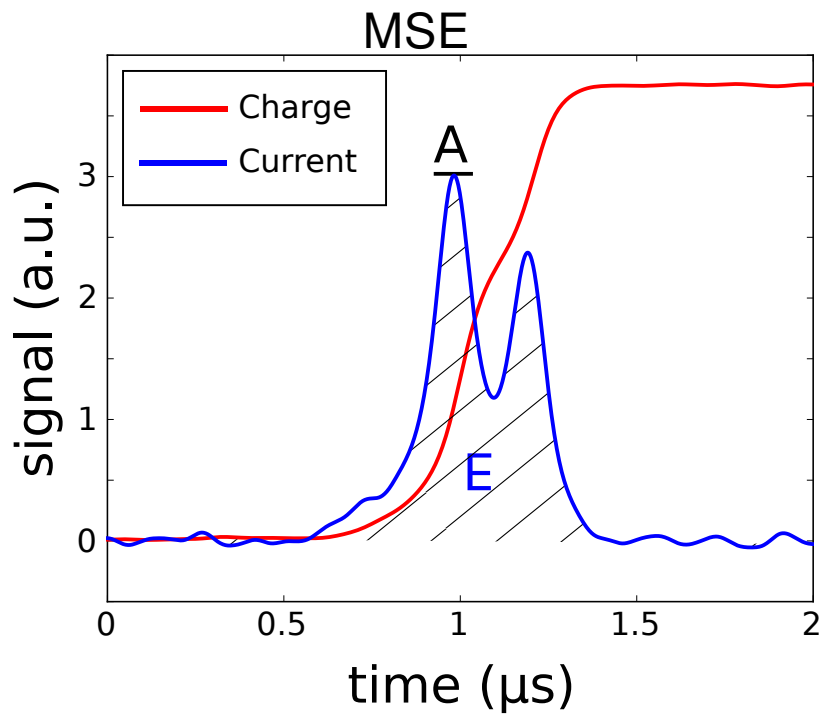
Backup

Pulse shape discrimination

- Discrimination of SSE/MSE, surface events
- Charge drift time → pulse shape
- Current trace amplitude/energy = amplitude/area

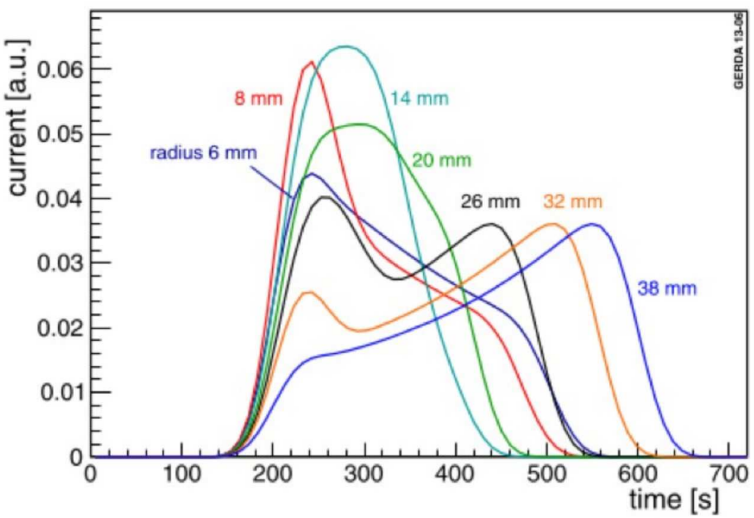


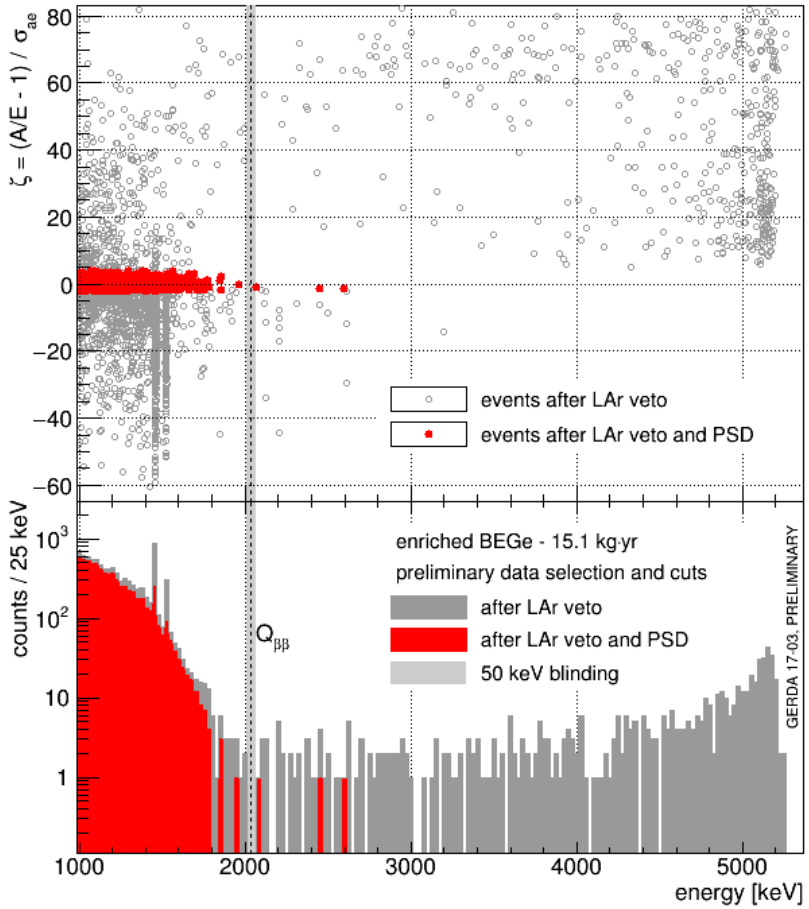




AoE vs. ANN

- Current amplitude/energy very efficient PSD parameter for BEGes
- For Coax waveform more dependent on hit position
  → artificial neural network, dedicated cut for MSE and alpha

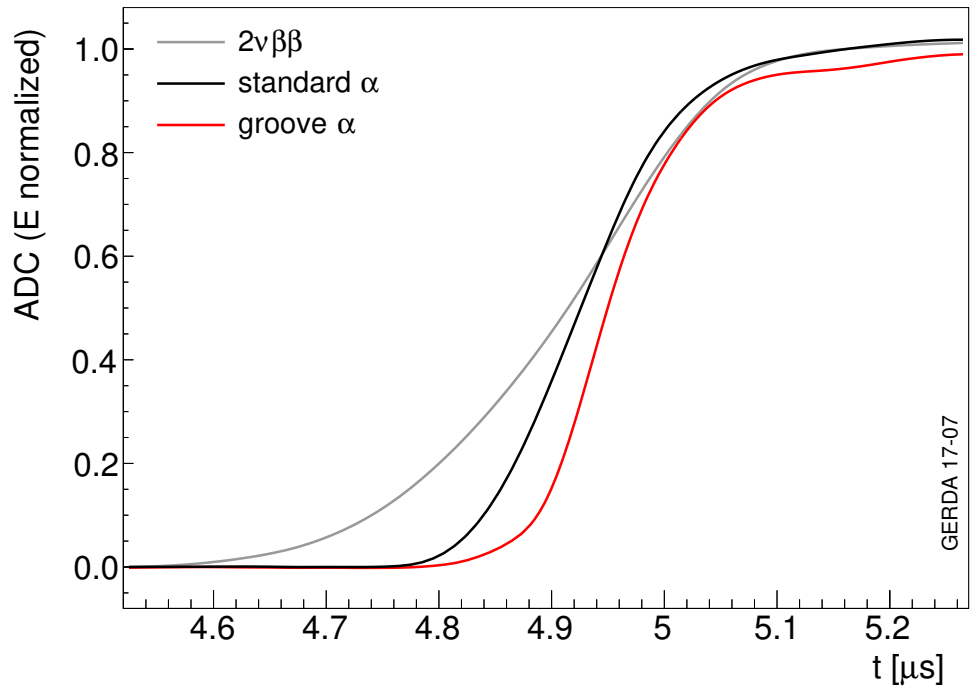




Groove events

Discovery between Phase IIa and b releases:

- Events with very fast rise time and delayed charge accumulation
- Consistent with events close to the groove/electrode interface
- A/E cut used for BEGe rejects them very efficiently
- Neural network for Coax detectors does not reject them (rare occurance in training data)
  $\rightarrow$ Coax background can be further reduced



Water drainage incident

- April 15th false alarm in a vacuum pressure sensor for cryostat
- Water tank drained
- Refill until June 4th via Xenon water plant $\rightarrow$ **many thanks**
- Continued data taking
  $\rightarrow \sim$3 kg yr with BG$\sim$4x higher before LAr and PSD