GERDA

Phase II status report

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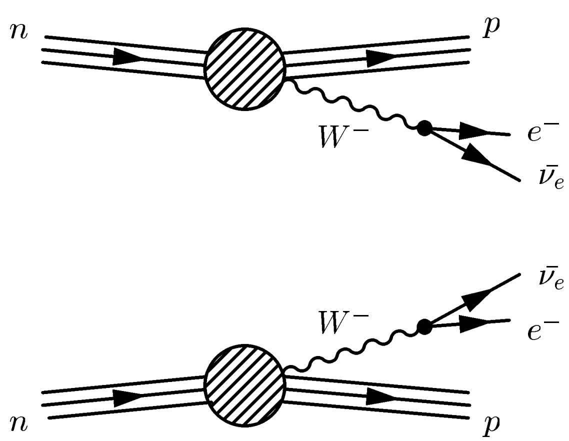
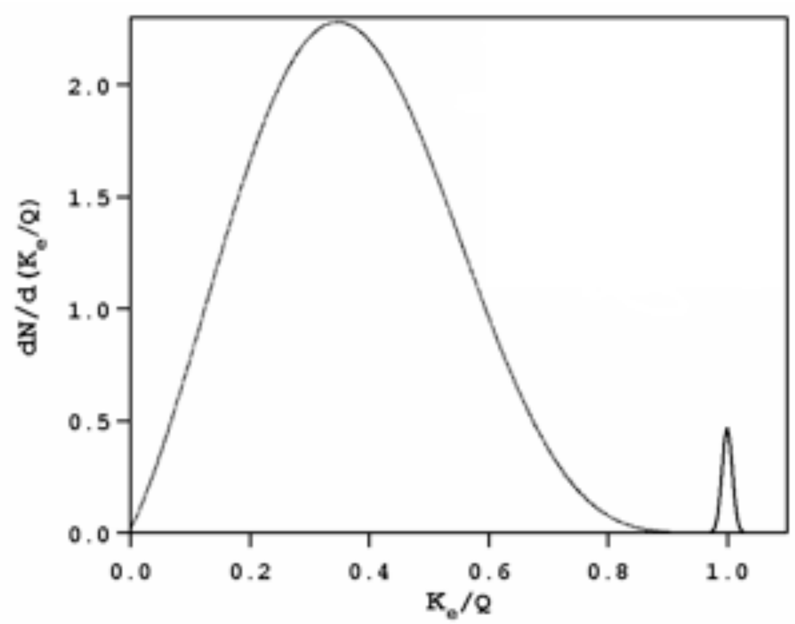
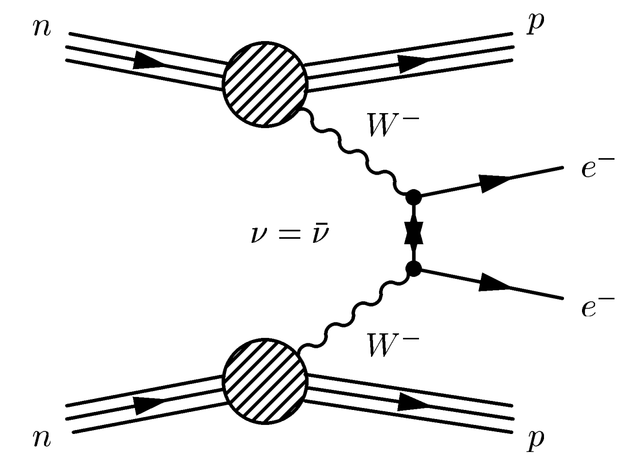
0νββ decay



2β decay with 2 neutrinos





2β decay with 0 neutrinos

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

allowed and observed

(A,Z)→(A,Z+2) + 2e$^-$

violates lepton number conservation

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

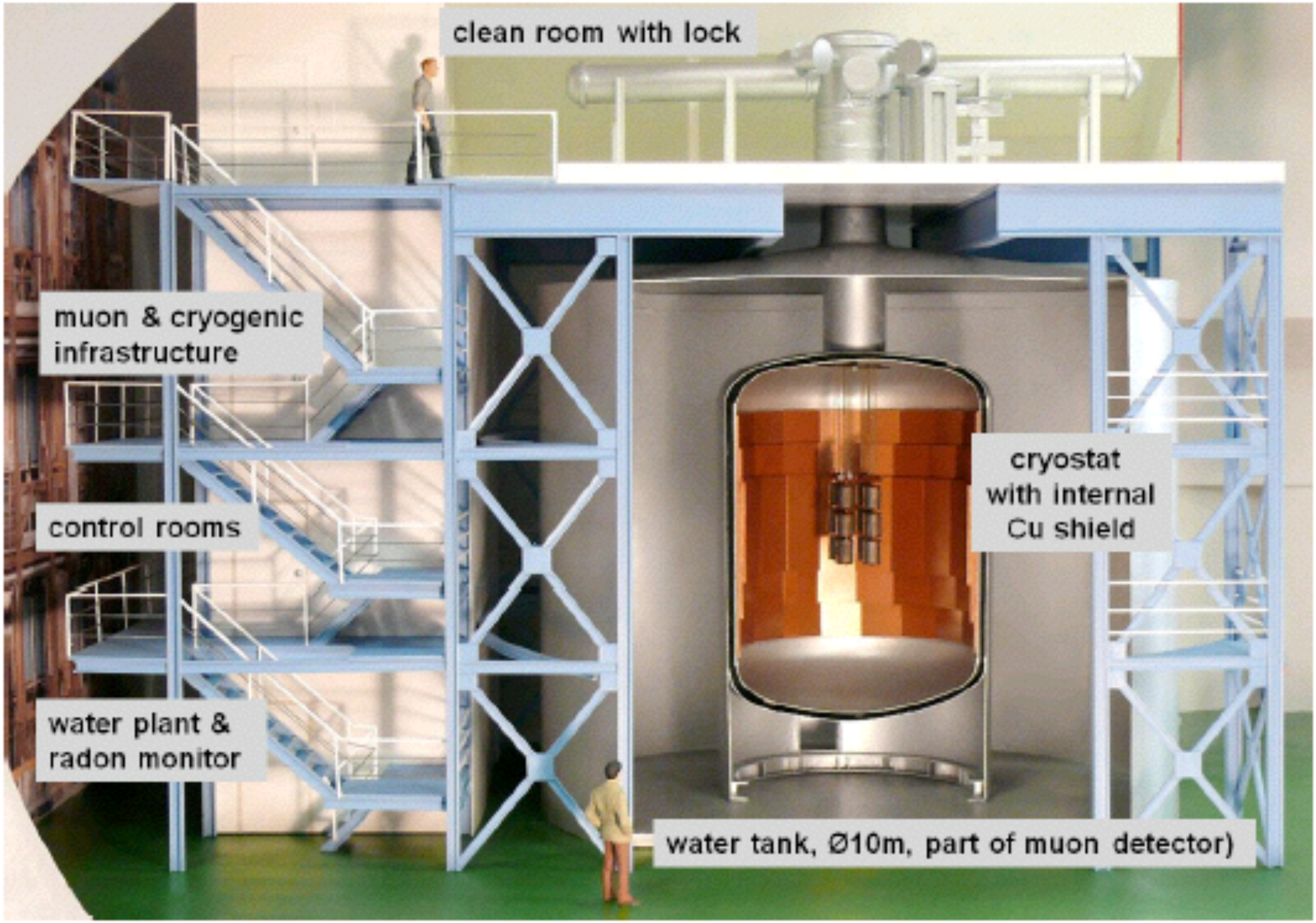
$$\langle m_{\beta\beta}\rangle^2 = \left|\sum_i U^2_{ei} m_{\nu i}\right|^2$$

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

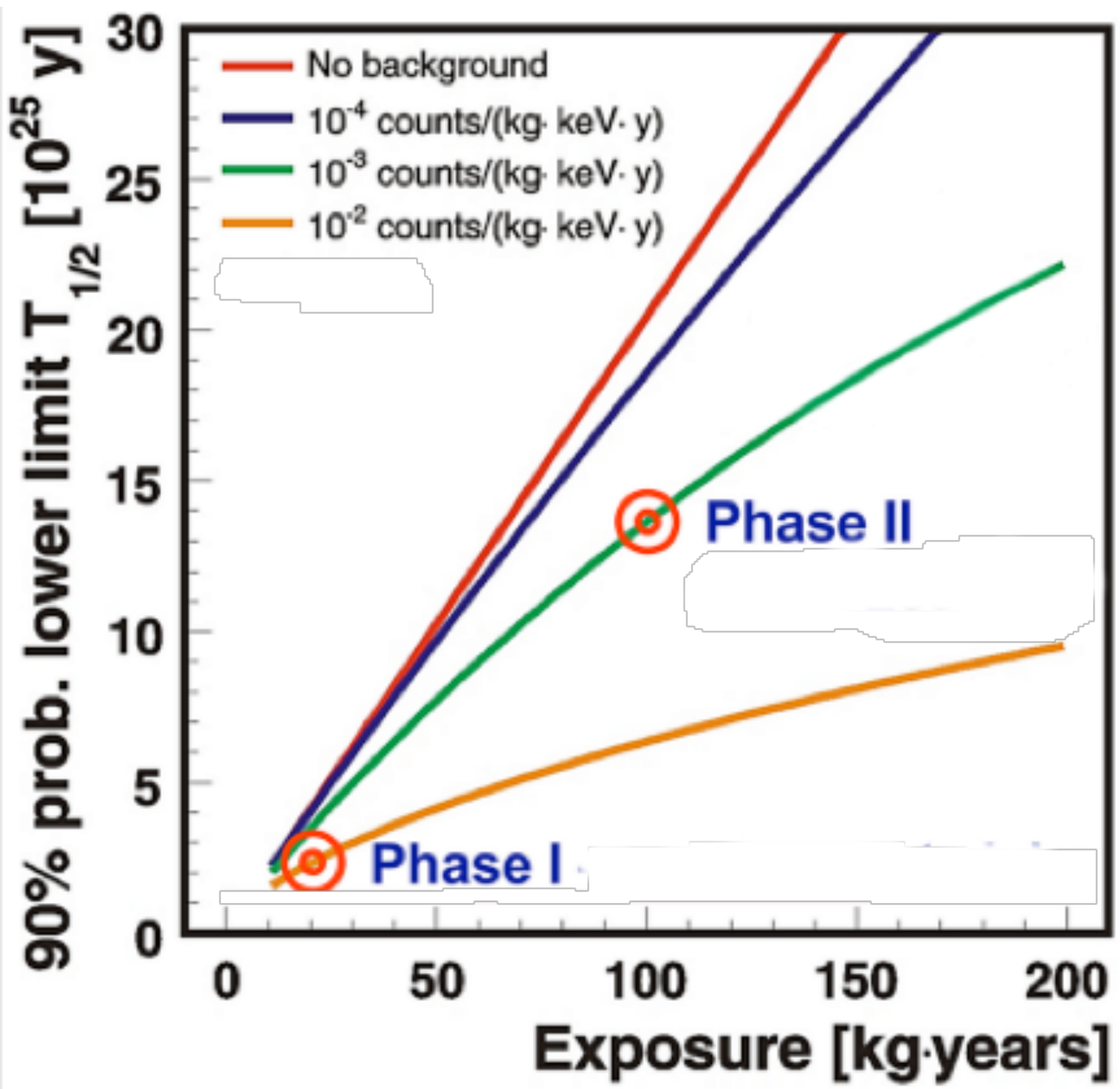
$F^{0\nu}$ - phase space integral depends on the Q value

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

GERDA at Gran Sasso



GERDA status



- *Status of Phase I*: data taking ended with 21.6 kg · yr exposure: 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 0.001 cts/(keV kg yr) and 100 kg yr exposure
- *Phase II strategy to reduce background:* LAr scintillation light readout + pulse shape discrimination
- *Phase II status:* is in commissioning phase right now

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GERDA Publications in 2015

- Still publishing *Phase I* results
- 6 articles + conference proceedings, ~4 more in the pipeline

LArGe: active background suppression using argon scintillation for the Gerda 0νββ-experiment
Eur. Phys. J. C 75 (2015) 506

2νββ decay of 76Ge into excited states with GERDA Phase I
J. Phys. G: Nucl. Part. Phys. 42 (2015) 115201

Results on ββ decay with emission of two neutrinos or Majorons in 76Ge from GERDA Phase I
Eur. Phys. J. C 75 (2015) 416

Enhancement of light yield and stability of radio-pure tetraphenyl-butadiene based coatings for VUV light detection in cryogenic environments
JINST 10 (2015) P09009

Improvement of the energy resolution via an optimized digital signal processing in GERDA Phase I
Eur. J. Phys. C 75 (2015) 255

Production, characterization and operation of 76Ge enriched BEGe detectors in GERDA
EPJC 75 (2015) 39

2νββ decay into excited states

J. Phys. G: Nucl. Part. Phys. 42 (2015) 115201 (18pp)

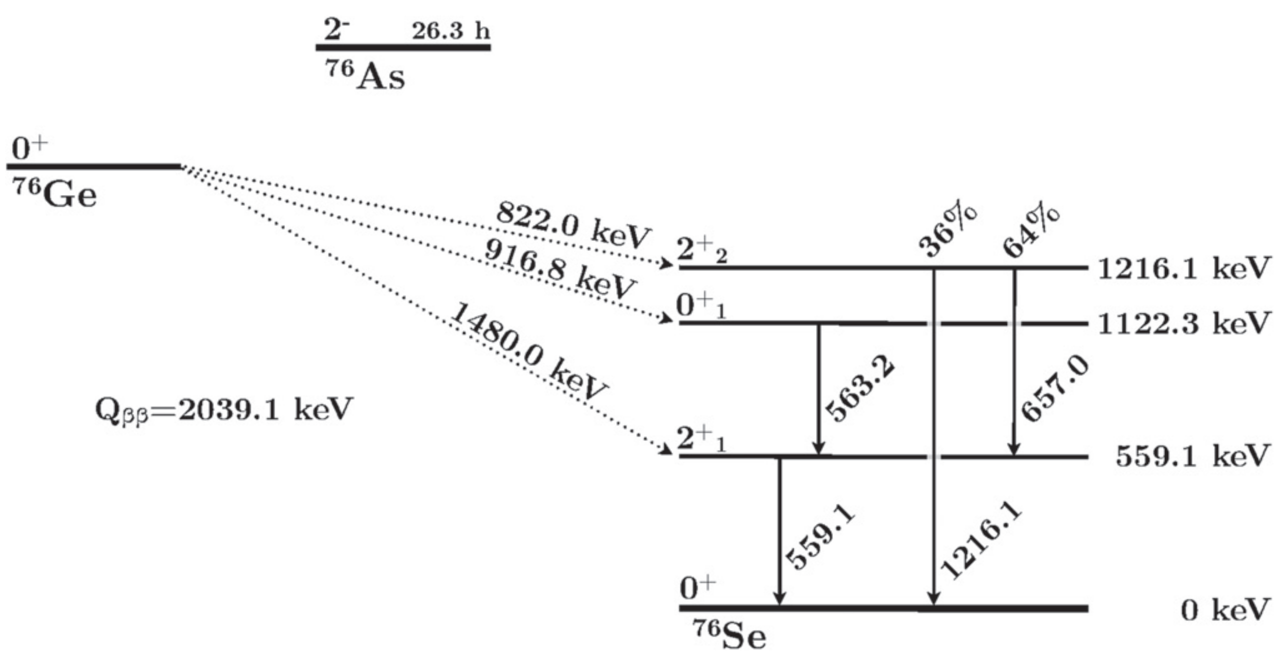
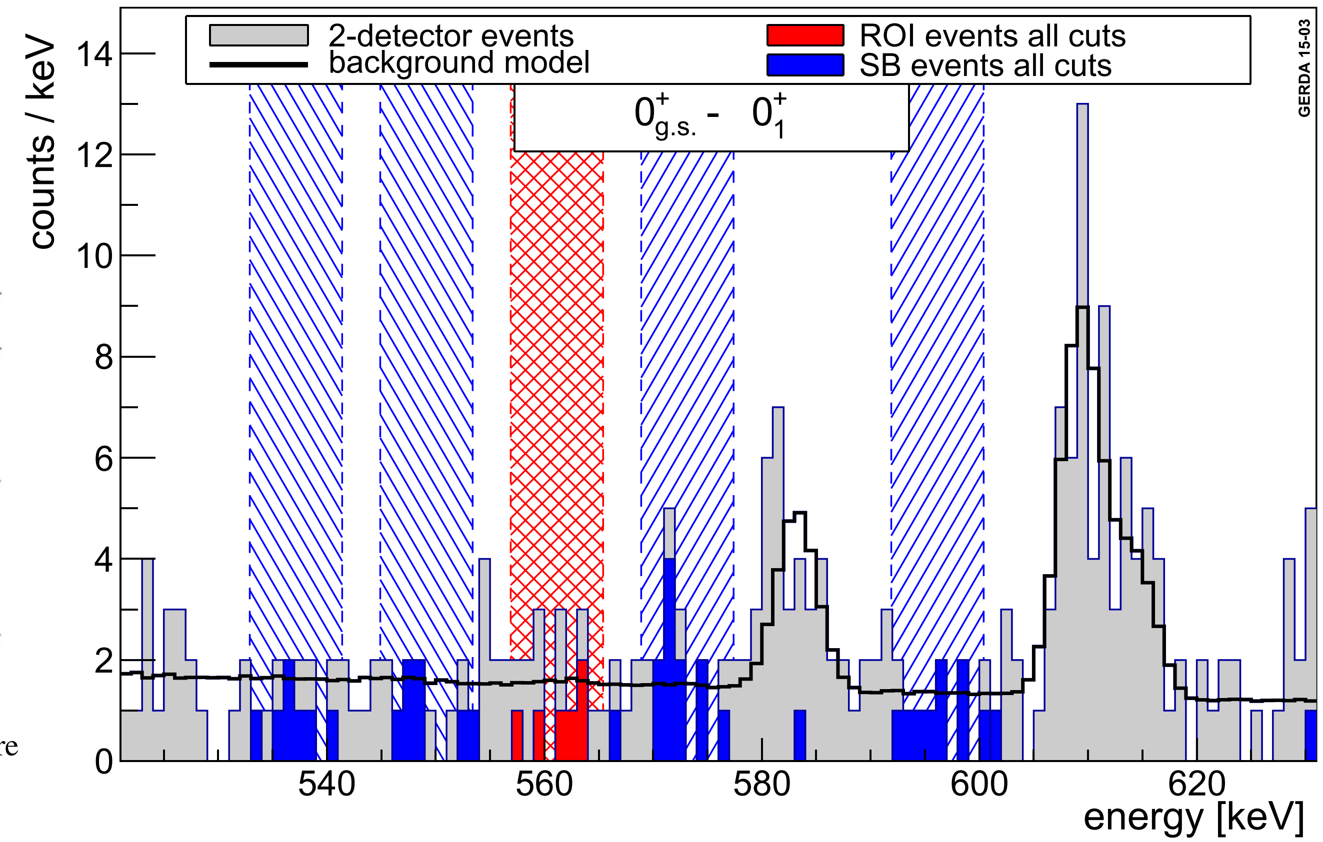


Figure 1. Possible double beta decay modes of ^{76}Ge to excited states of ^{76}Se that are investigated in this work.



- $2\nu\beta\beta + \gamma$: Coincidence between HPGe detectors
- $T_{1/2}(0^+ \rightarrow 0^+_1) > 3.7 \cdot 10^{23}$ yr. About 20 times better limits than in previous experiments
- Image of the week in September on IOPScience: http://jphysplus.iop.org/2015/09/28/image-of-the-week-the-thrill-of-the-chase/

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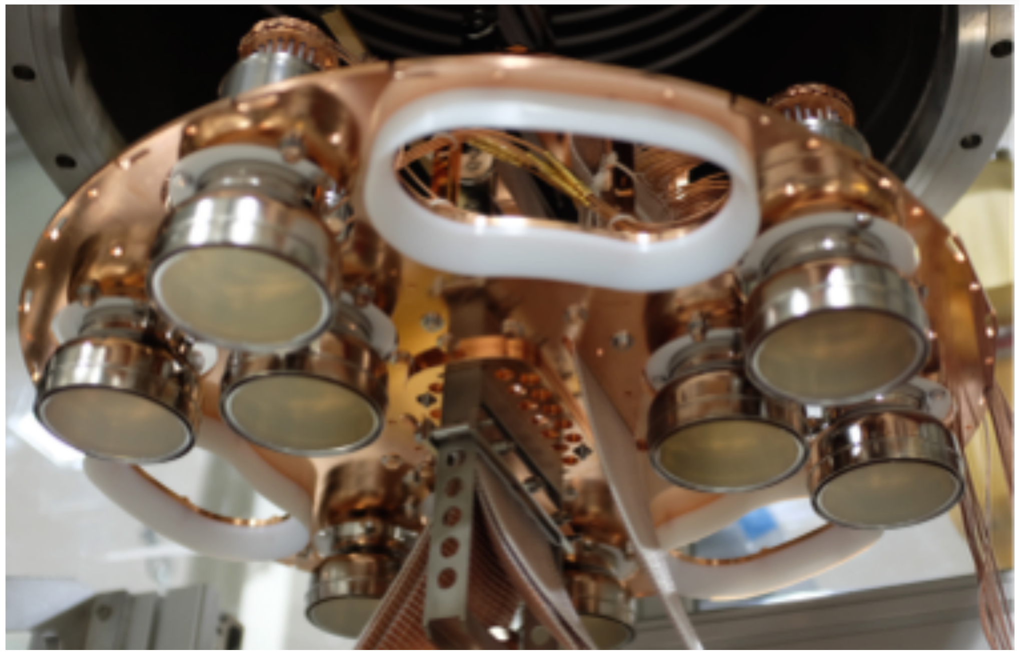
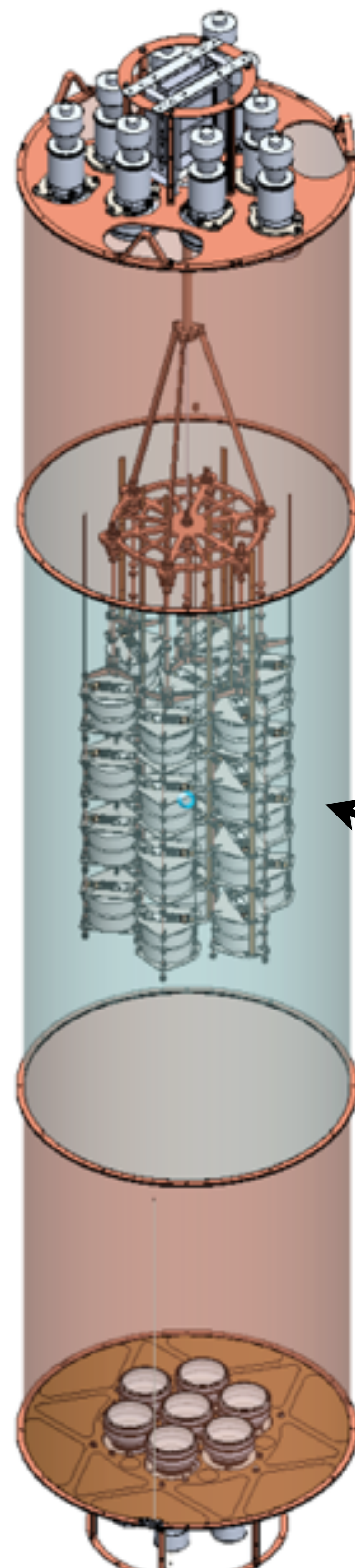
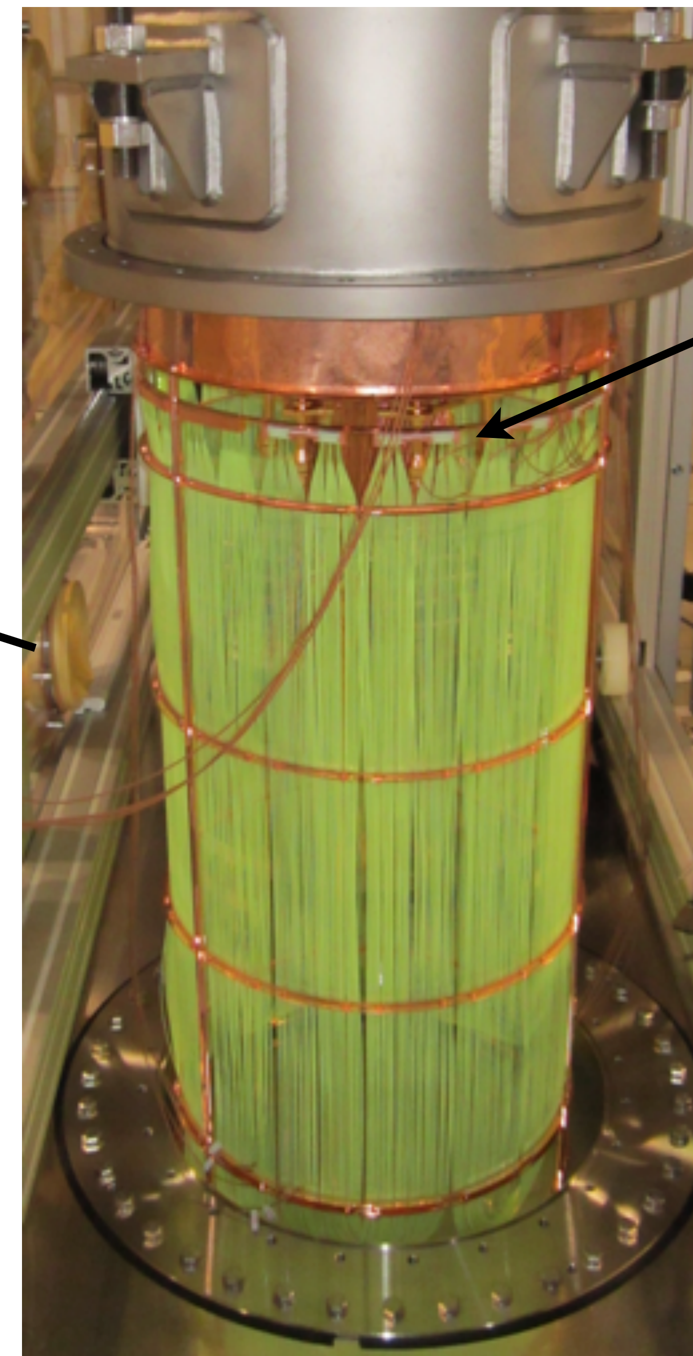
LAr - veto





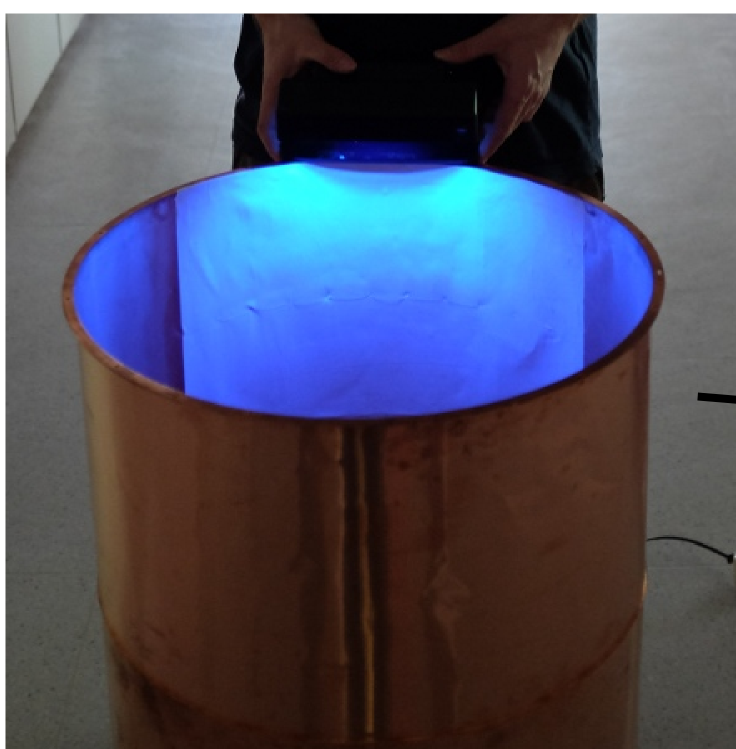
3" low-background PMT
Hamamatsu R11065-20

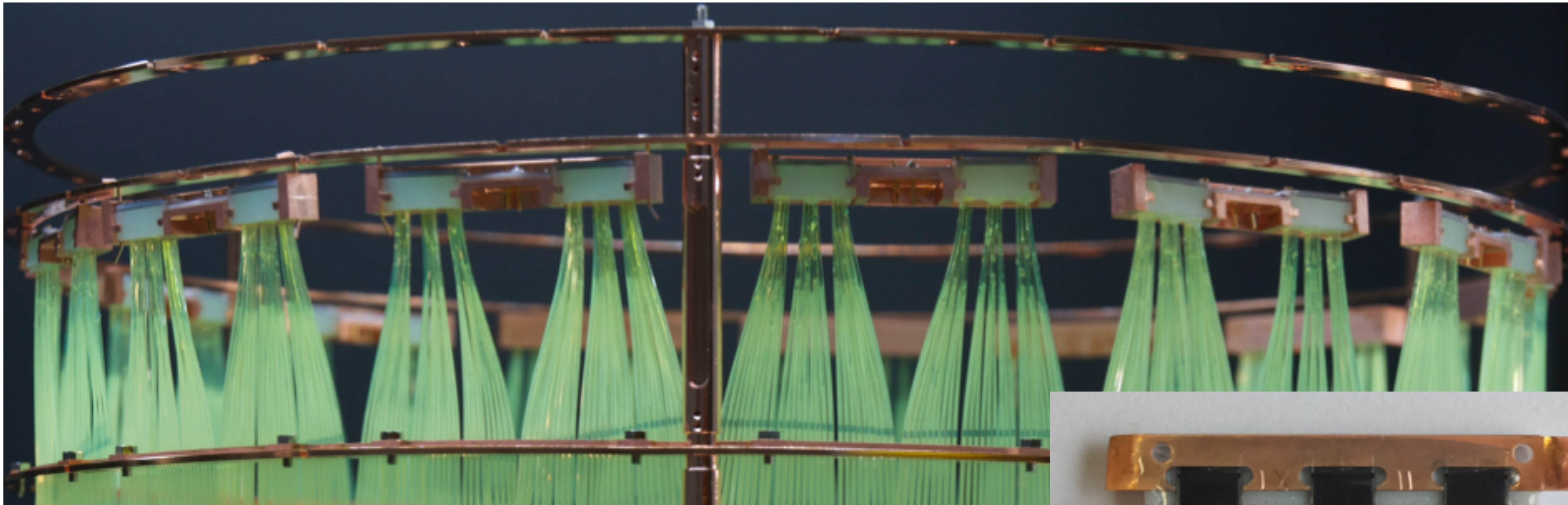
SiPMs

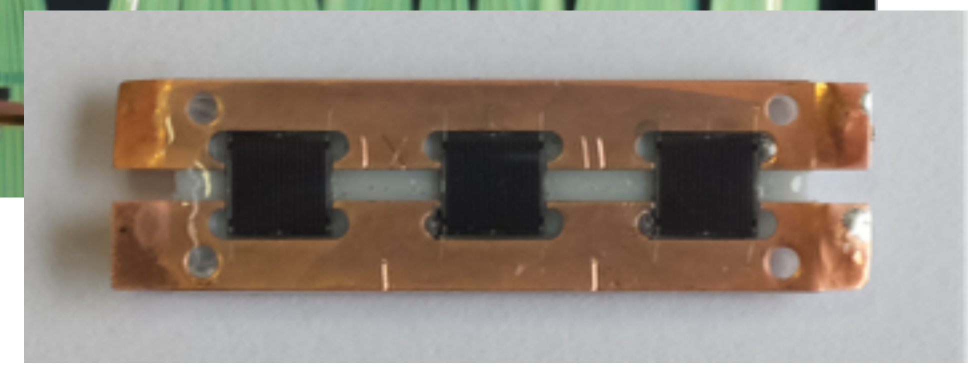


Fiber "shroud"
800 m WLS
fibre coated
with TPB

Copper "shroud" with
Tetratex reflector coated
with TPB







- Production and installation in 2014
- PMT developments done by MPIK in close contact with Hamamatsu
  - some replaced in September 2015 - All channels are working
- Low background SiPMs packaging done at TUM, SiPMs in die from Ketek GmbH.
  - After some difficulties - All channels are working

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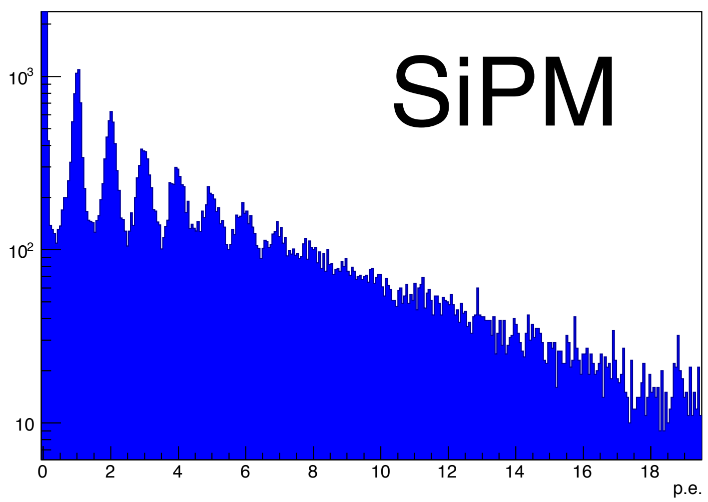
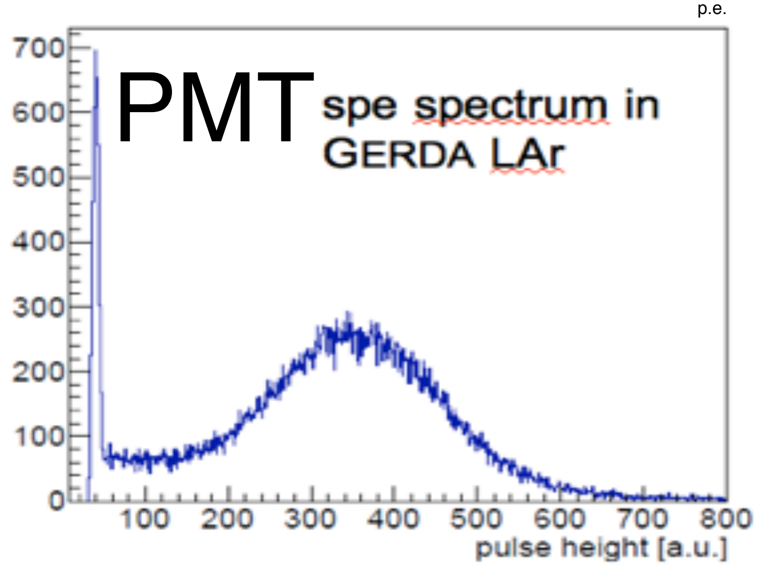
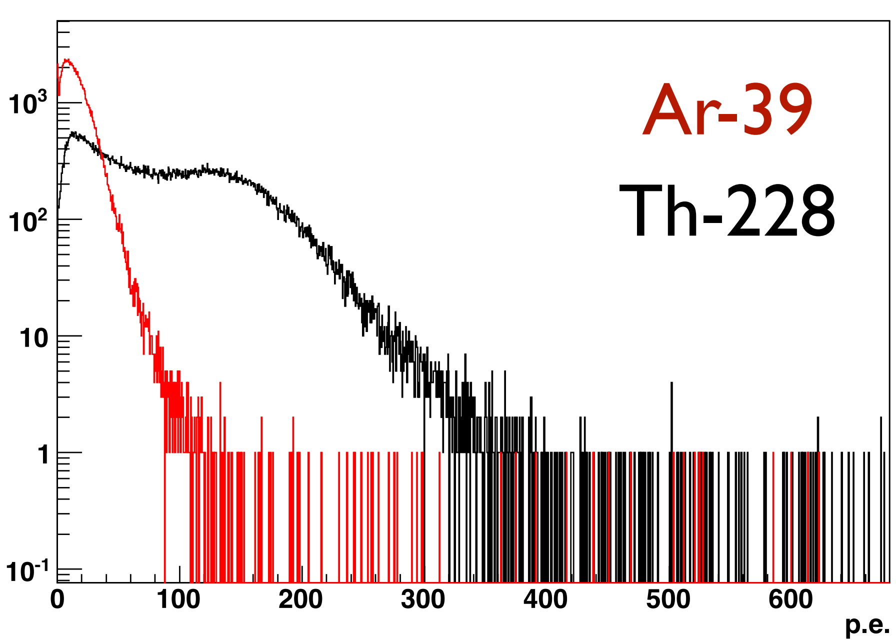
LAr veto commissioning

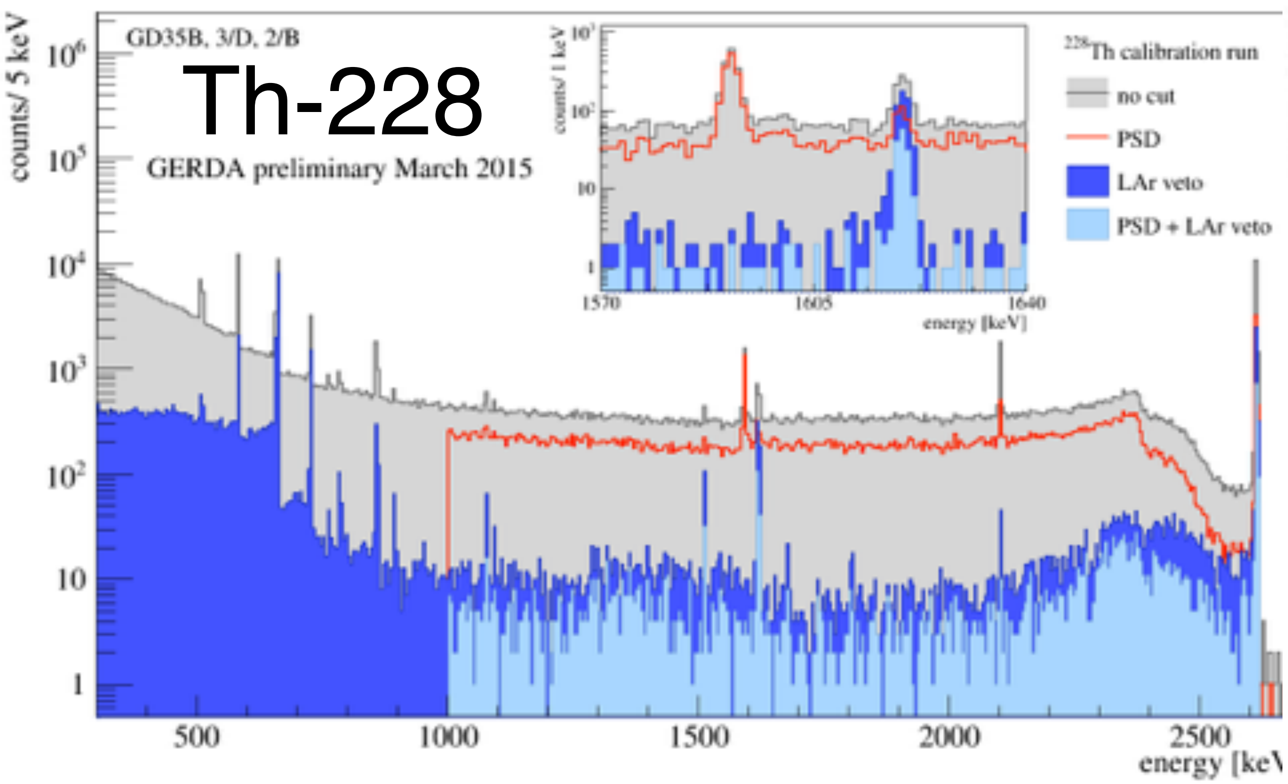


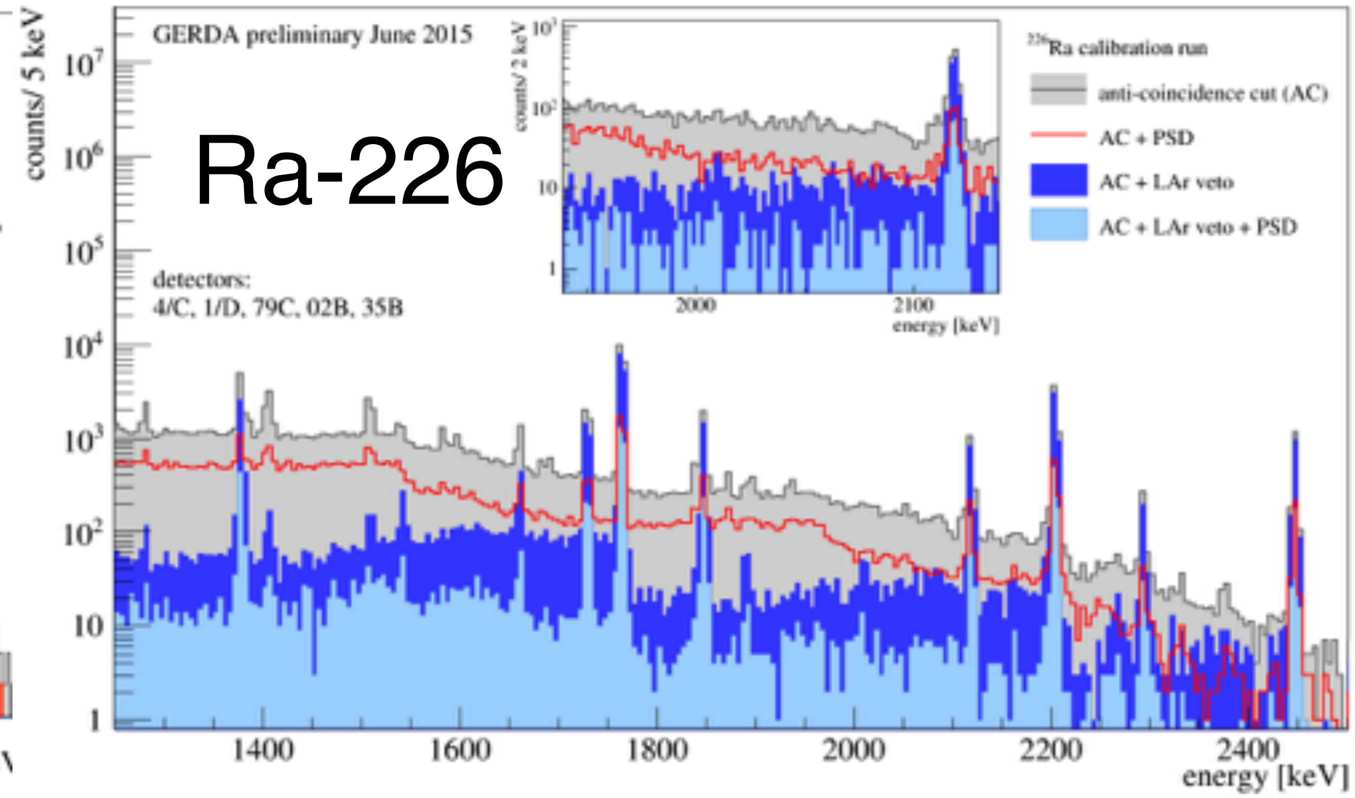




- "Photo-electron" peaks recognisable in the amplitude spectrum - in both SiPMs and PMTs spectra
- Veto on one photo-electron in any channel
- After single channels calibrated and summed up: light yield: 50 - 60 p.e./MeV - with ^{228}Th source
- Count rate dominated by ^{39}Ar
- LAr -veto Suppression Factor tested with one detector string with ^{228}Th and ^{226}Ra sources

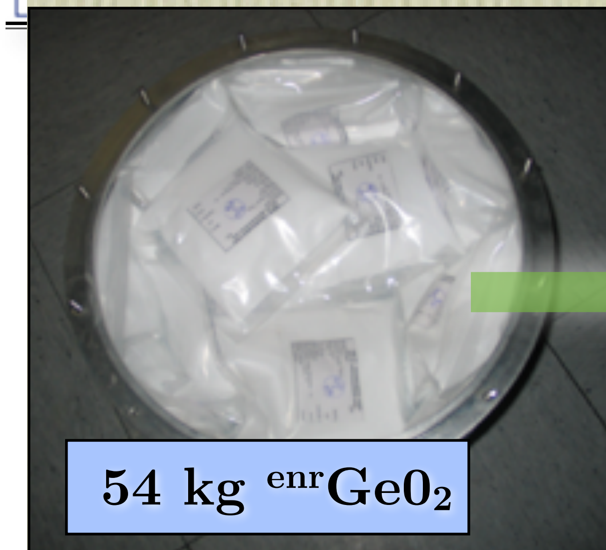
LAr veto commissioning





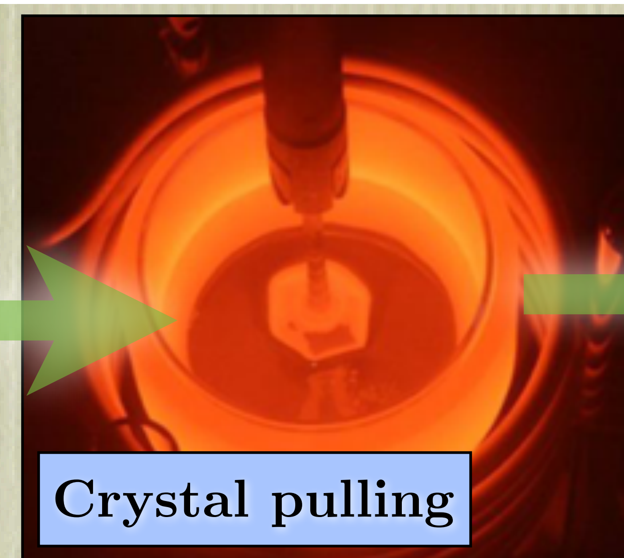
Suppression of:	Ge Anti-Coincidence	LAr-veto	PSD	LAr + PSD	Acceptance
^{228}Th	1.26 ± 0.01	97.9 ± 3.7	2.19 ± 0.01	344.6 ± 24.5	86.8%
^{226}Ra	1.26 ± 0.01	5.7 ± 0.2	2.98 ± 0.06	29.4 ± 2.5	89.9%

Detector Production



54 kg $^{enr}GeO_2$

35.5 kg 6N ^{enr}Ge

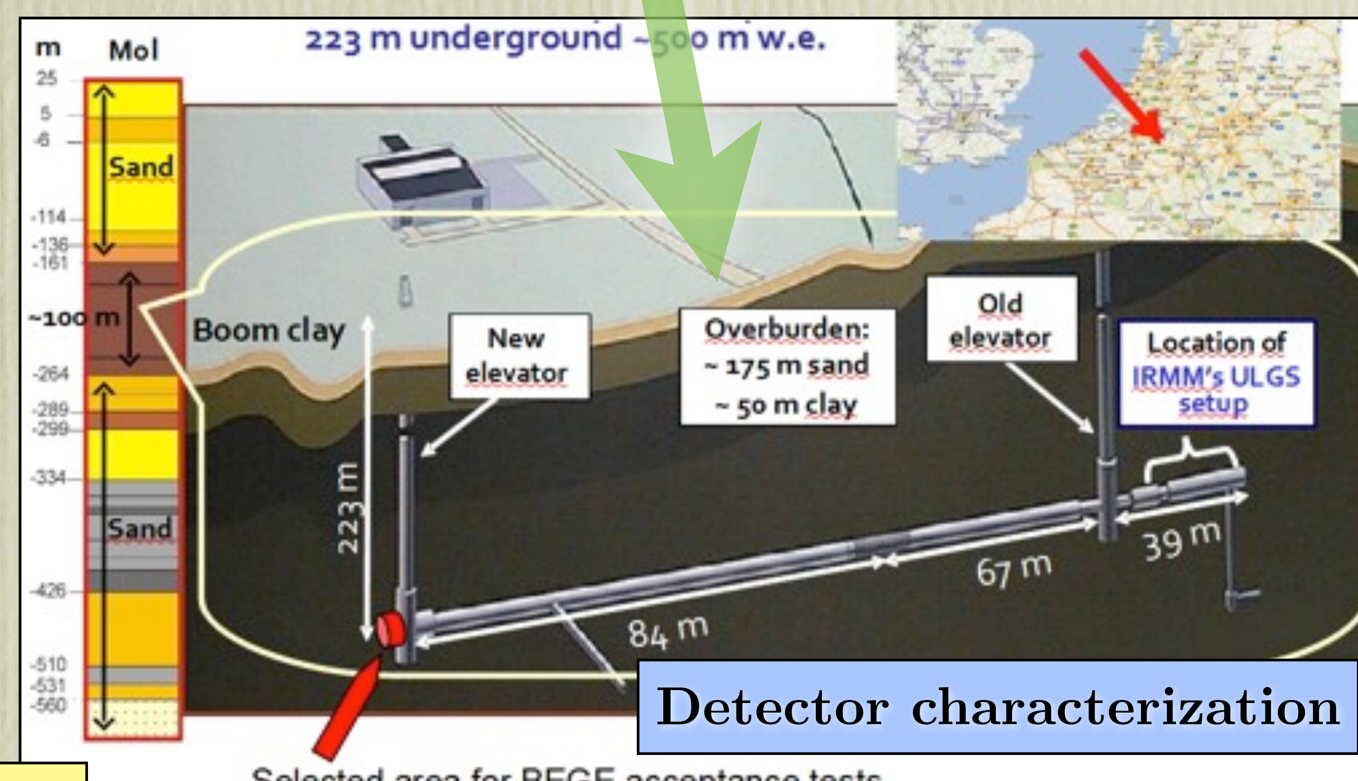


Crystal pulling

7 crystals

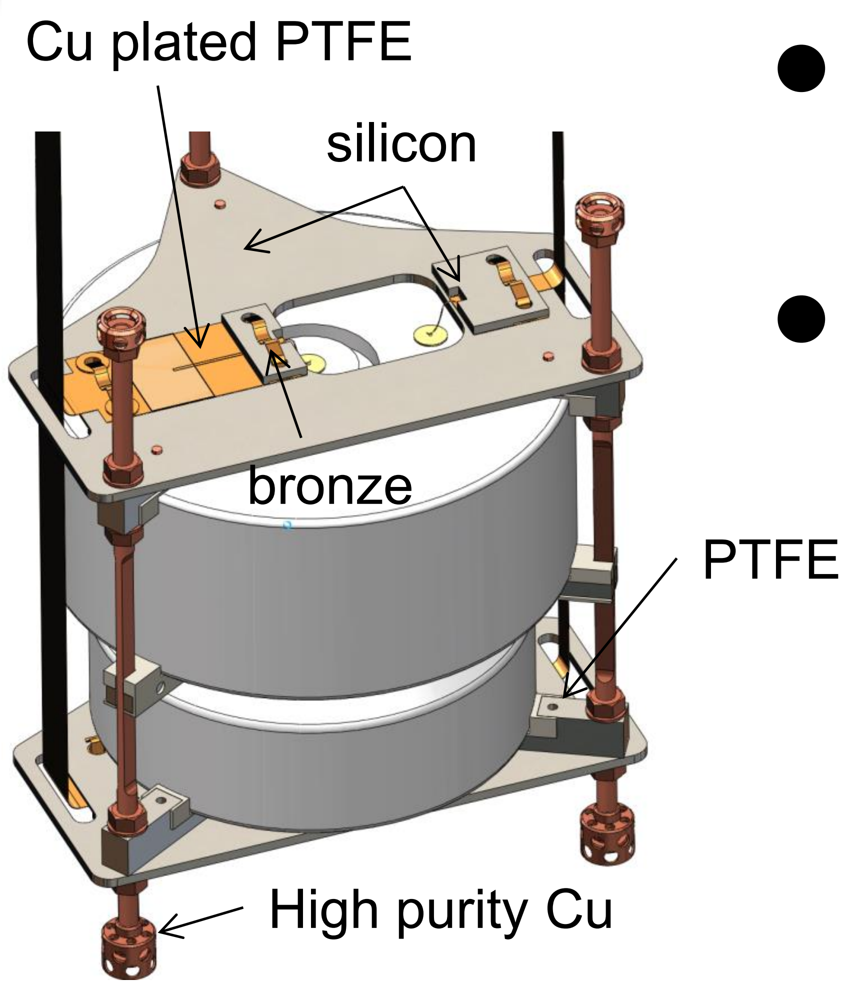
30 BEGe detectors

- Whole production chain from $^{enr}GeO_2$ to BEGe diode organized by GERDA and tested with ^{dep}Ge (JINST 8 P04018 2013)
- Total gain 30 BEGes with 20.5 kg (58 % yield)
- Detector characterization in HADES underground facility, Belgium
- Exposure to cosmic rays reduced as much as possible:
  - Transport in shielded container
  - Storage and testing underground

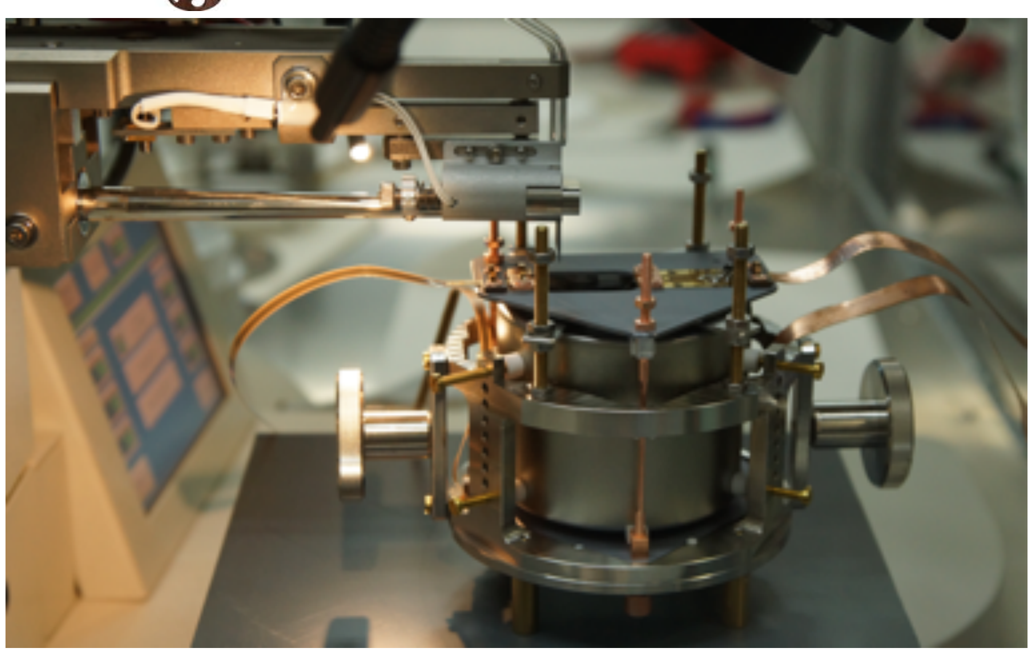


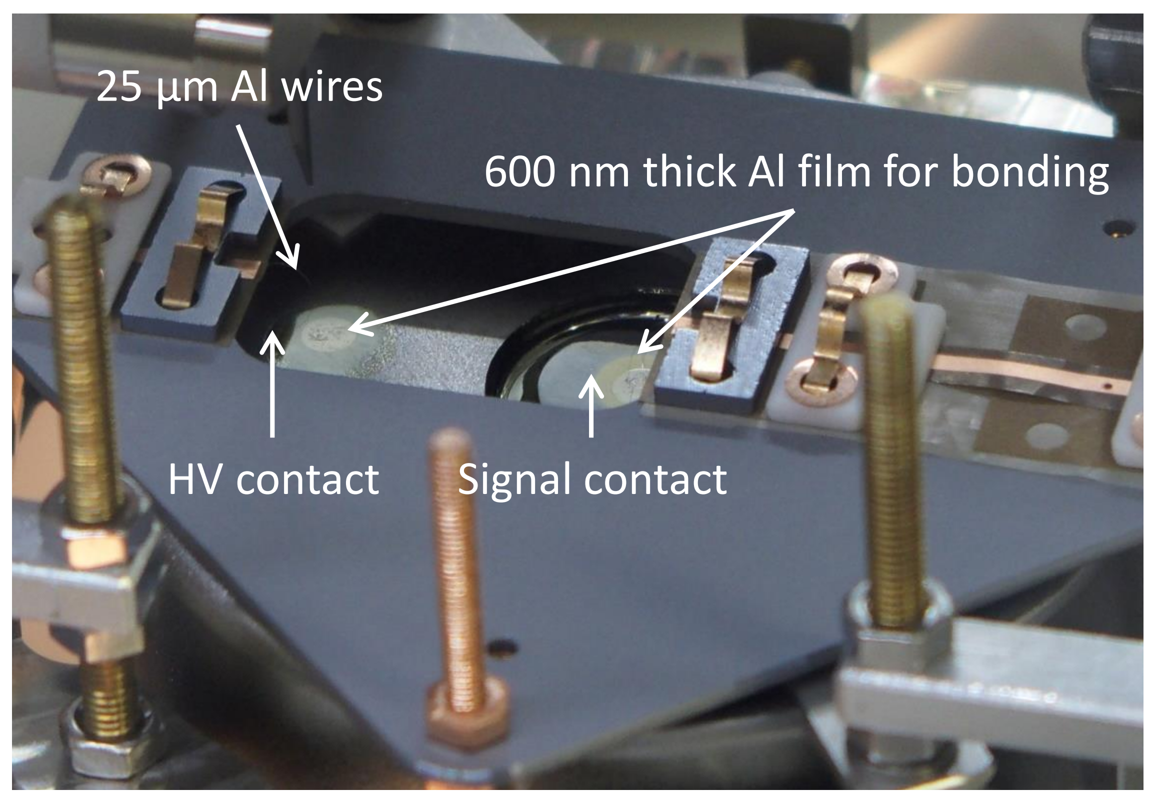
Detector characterization

Phase II detector holders



- 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

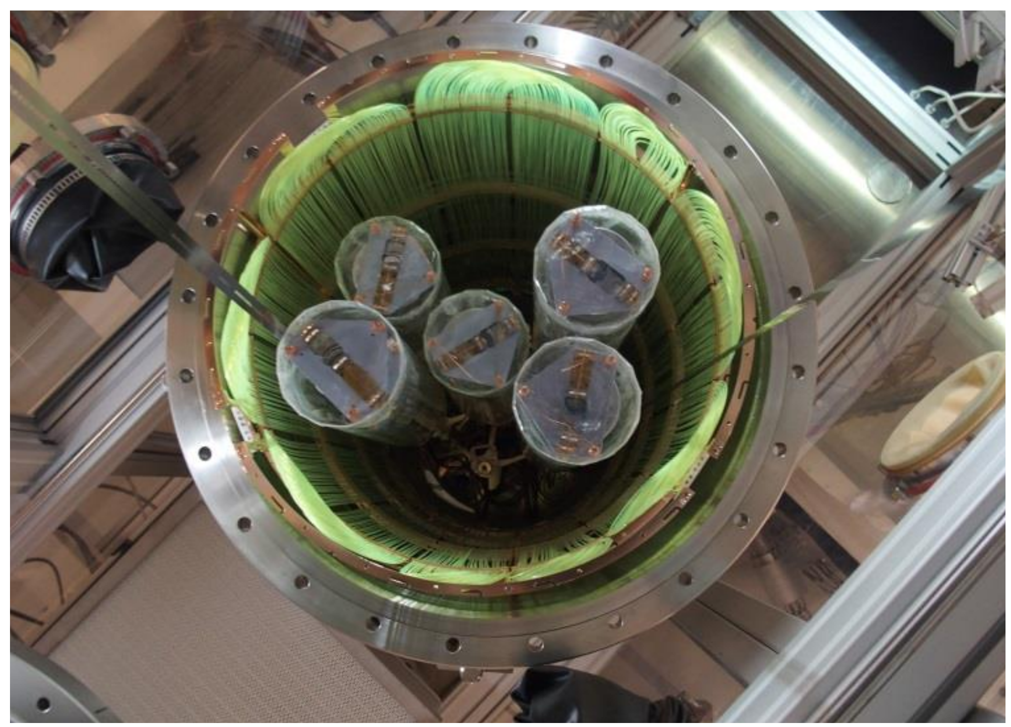




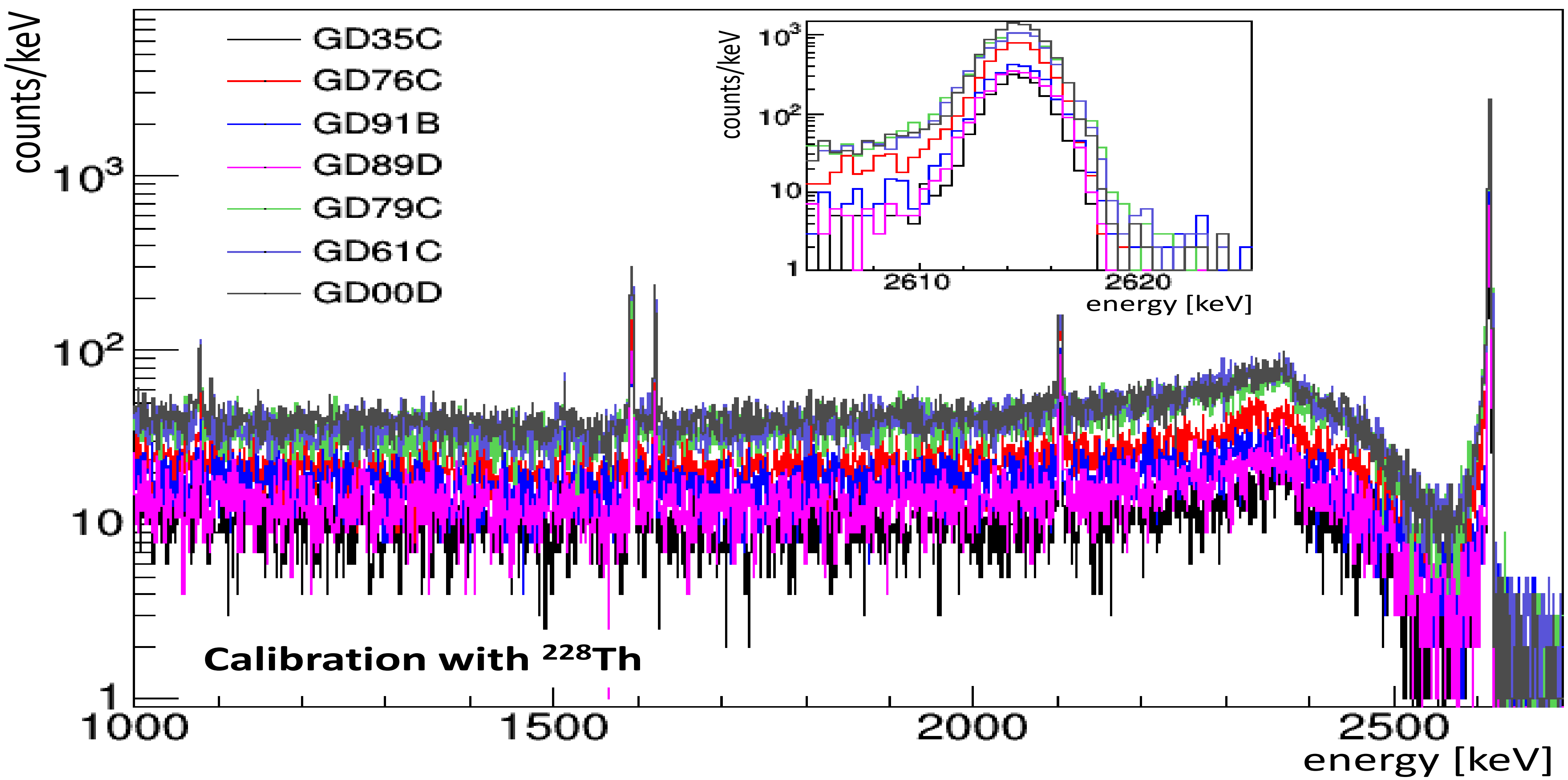
Integration test July 2015

- In July 22 BEGe and 5 coaxial detectors mounted in 5 strings
- ~20 kg Germanium in GERDA
  - 15 BEGe + 4 coax was working: leakage current, contact problems
- Detector strings surrounded by nylon Mini-Shrouds coated with TPB
  - Reduces ^{42}K background
- 6 weeks of data recorded
  - ~1 kg/yr exposure & first background spectrum

Integration test July 2015



Commissioning with 5 strings



Calibration spectrum from detectors in one string

- Energy resolution of the BEGe detectors: 2.6 - 3.2 keV (at 2.6 MeV)

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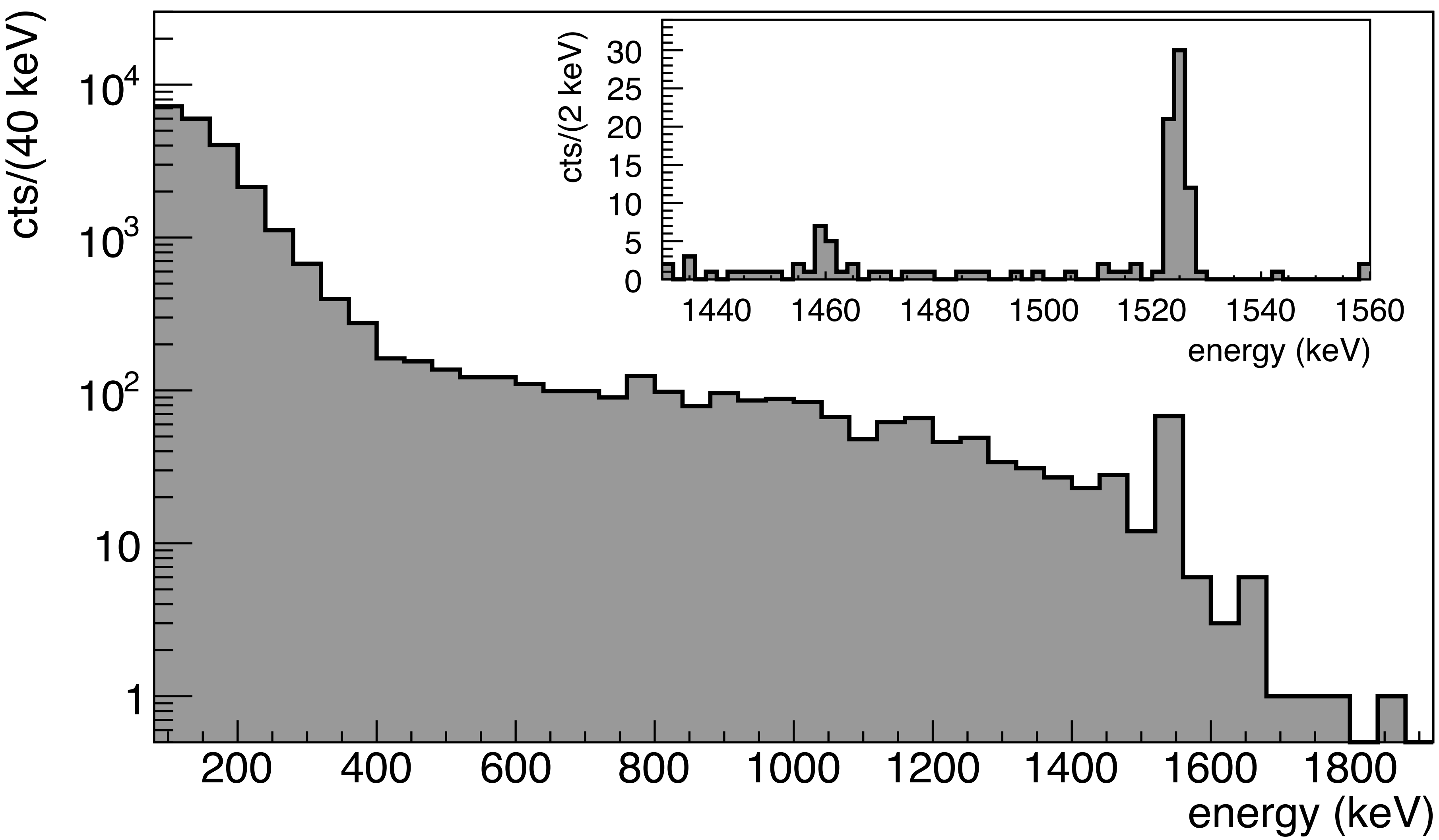
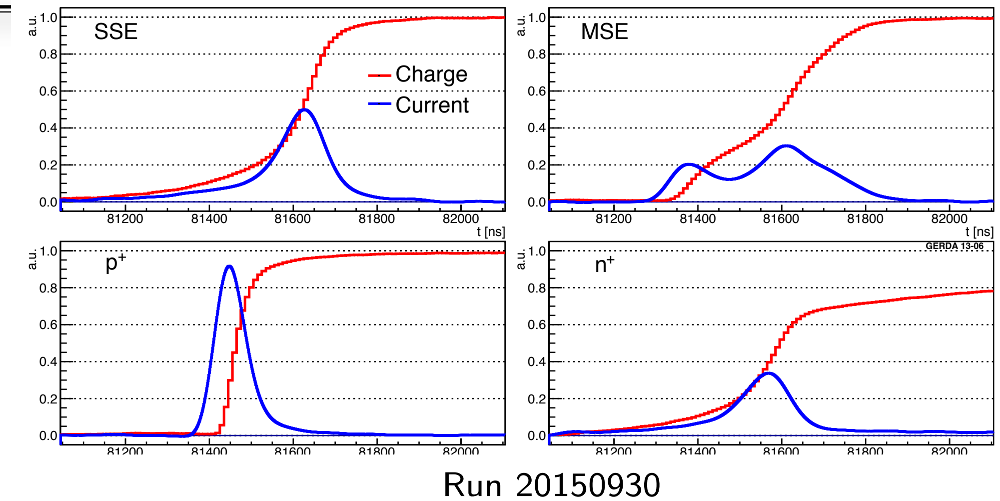
Commissioning with 5 strings

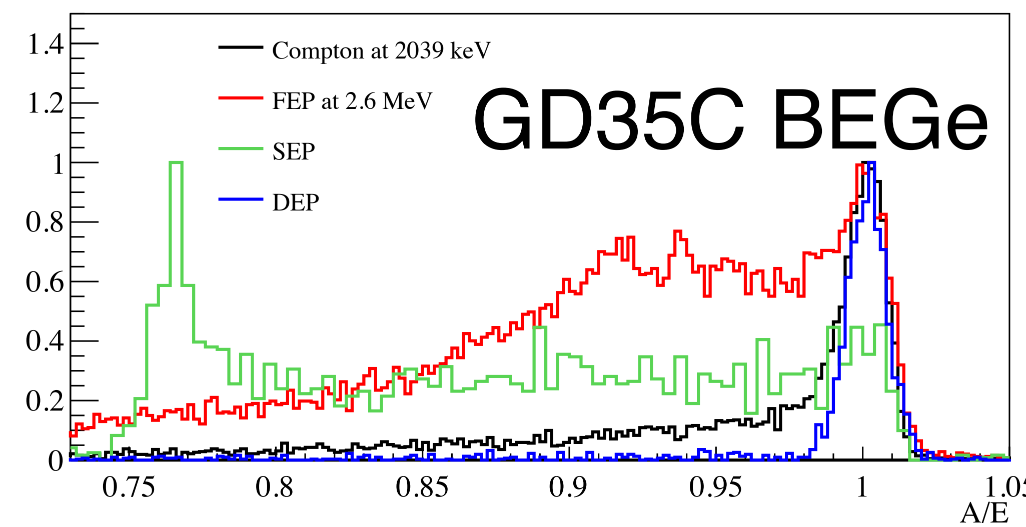


- $2\nu\beta\beta$ spectrum visible after only a month of data taking
- ^{42}K line is the strongest γ-line, count rate like in *Phase I*
- ^{39}Ar background dominant below 500 keV
- Background is within the expectations

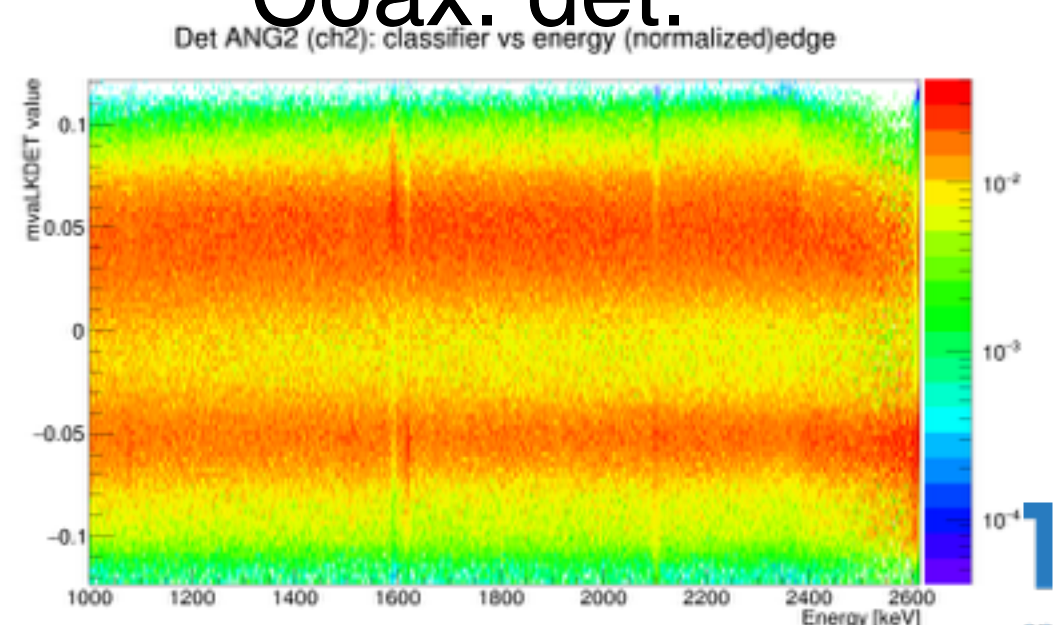
Pulse Shape Discrimination

- Special calibration runs for PSD with strong sources (high stat.)
- PSD performed for both Coax. and BEGe detectors
- Achieved performance is similar to Phase I
- NN can be trained with events selected in coincidence with LAr-veto



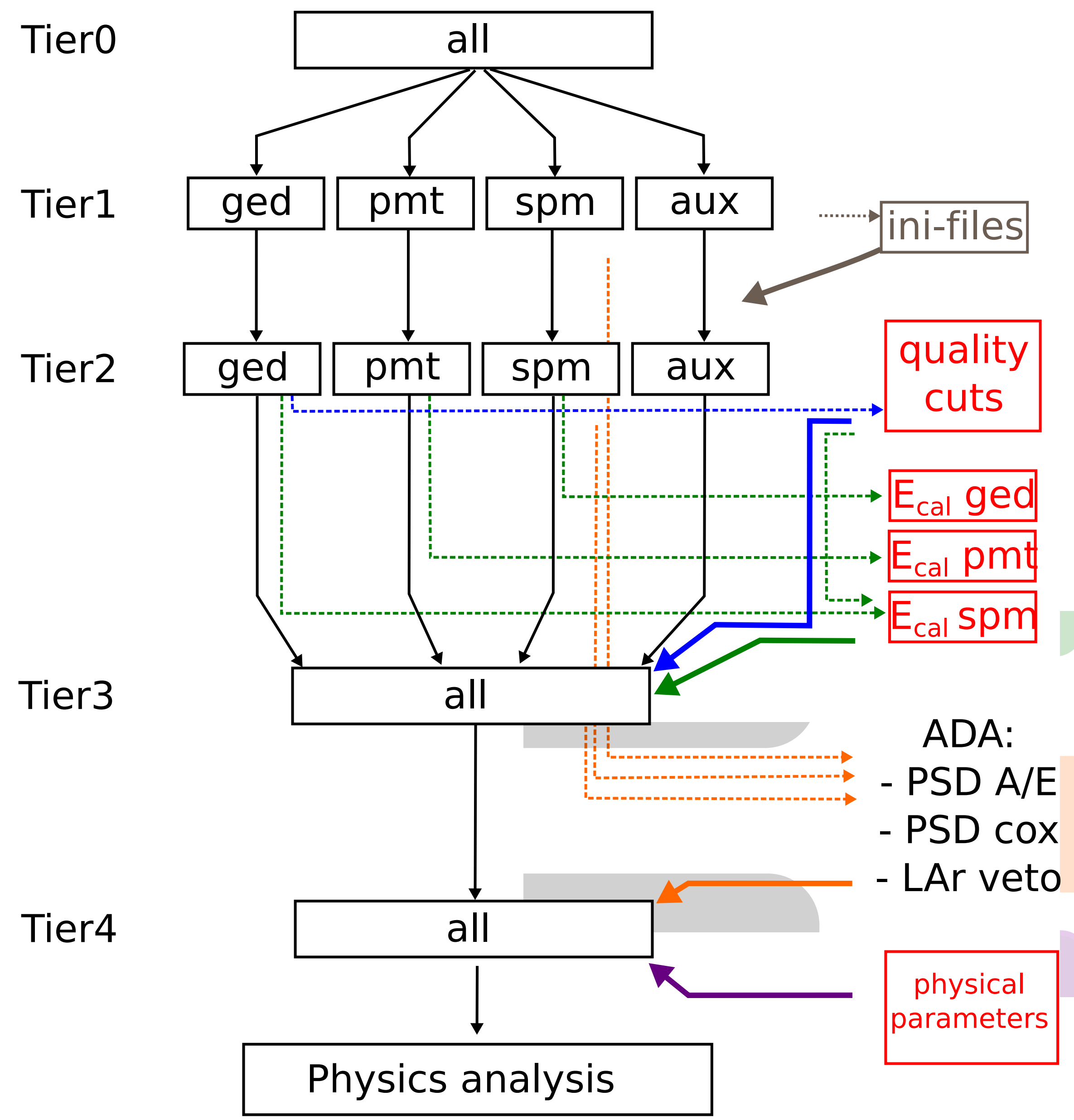


Coax. det.



Software

- LAr-veto and PSA included
- Tier3 OK, Tier4 being finalised
- First full production with the first background data
- Data production / monitoring performed in real time
- Blinding procedure at tier0 level was worked out



Ready for Phase II

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Detector reprocessing

- 15 out of 30 BEGe detectors sent back to producer:
  - leakage current problems discovered in GS,
  - 12 are working in GERDA, 3 waiting for Al evaporation
- 5 out of 7 coax detectors had Al bonding pads evaporated on
  - 5 enriched + 1 natural Ge are working in GERDA
  - 2 enriched + 2 natural Ge coax waiting for evaporation
- Further delays caused by the Al evaporator
  - Since a few days is working again

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Outlook

- Two commissioning runs resulted in about 2 kg · yr background data
    - background is good enough to start a physics run
- performance of the detectors is within the expectations
- performance of the LAr-veto is good
- preparation of the analysis is almost finished

- New commissioning run started with 7 strings - this week !
    - 28 detectors mounted and working !
- arrival of additional detectors this year (7)
- we expect to collect physics data in 2016