Results of the commissioning phase of GERDA

and short status report on neutrino-less double beta decay experiments

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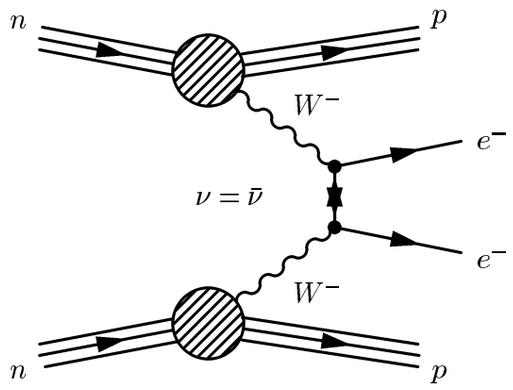
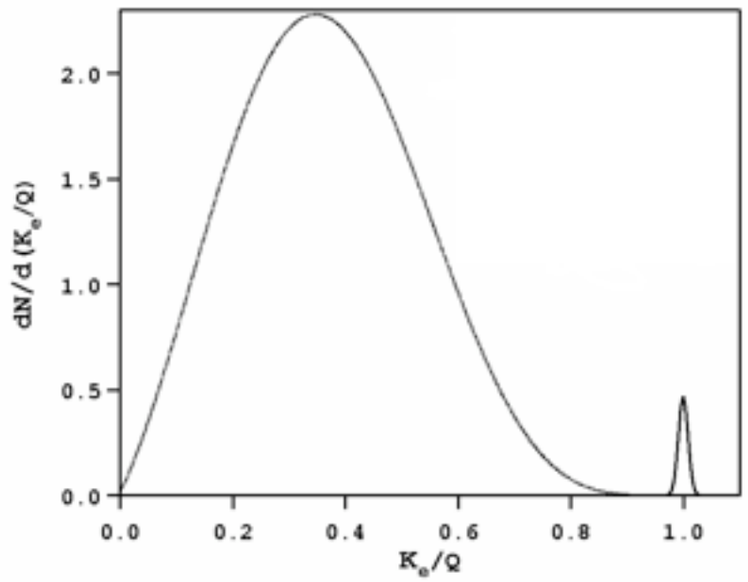
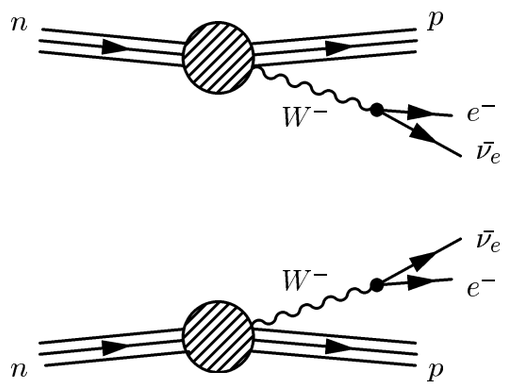
for the GERDA collaboration

2β decay



2β decay with 2 neutrinos





2β decay with 0 neutrinos

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

allowed and observed

$(A,Z) \rightarrow (A,Z+2) + 2e^-$

violates lepton number conservation

$$\left(T^{0\nu}_{1/2}\right)^{-1} = F^{0\nu} \cdot \left|\mathcal{M}^{0\nu}\right|^2 \cdot m^2_{\beta\beta}$$

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

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

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

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

Present status

$$T^{0\nu}_{1/2} \sim \sqrt{\frac{M \cdot t}{B \cdot \Delta E}} \; [y]$$

This is what we measure

M - mass of the isotope
t - time

B - background
ΔE - resolution

For a better limit we need:
- more mass
- lower background
- better energy resolution
- measure longer ??

Isotope	2nu T1/2	0nu T1/2	Q(MeV)
^{48}Ca	4.4x10^{19} (NEMO3)	>1.3x10^{22} (NEMO3)	4.77
^{76}Ge	1.78x10^{21} (HdM)	1.19x10^{25} ? (HdM)	2.04
^{82}Se	9.6x10^{19} (NEMO3)	>2.1x10^{23} (NEMO3)	2.29
^{96}Zr	2.3x10^{19} (NEMO3)	>8.6x10^{21}(NEMO3)	3.35
^{100}Mo	7.1x10^{18} (NEMO3)	>5.8x10^{23} (NEMO3)	3.03
^{116}Cd	2.8x10^{19} (NEMO3)	>1.18x10^{19} (COBRA)	2.81
^{130}Te	7.6x10^{20} (NEMO3)	>2.8x10^{24}(Cuoricino)	2.53
^{136}Xe	>8.5x10^{21} (Baksan)	>3.1x10^{23} (Baksan)	2.46
^{150}Nd	9.11x10^{18} (NEMO3)	>1.8x10^{22} (NEMO3)	3.36

Not so Near future expectations

Future experiments, R&D projects and proposals, (without completeness)

Experiment	Isotope	Mass	T1/2	$m_{\beta\beta}$ (meV)
CANDLES	^{48}Ca	~ton	$>10^{26}$ y	~30
GERDA Ph I	^{76}Ge	~15 kg	$>2.2\times10^{25}$ y	230 - 390
GERDA Ph II	^{76}Ge	~40 kg	$>1.5\times10^{26}$ y	< 150
MAJORANA	^{76}Ge	~120 kg	$>5.5\times10^{26}$ y	< 100
GERDA +MAJORANA	^{76}Ge	~ ton	$> 10^{27}$ y	< 50
superNEMO	^{82}Se	>100 kg	$>10^{26}$ y	40 - 110
MOON	^{100}Mo	~ton	10^{26} y	~30
LUCIFER	^{116}Cd,	~10 kg	$>2\times10^{26}$ y	50 - 100
COBRA	^{116}Cd, ^{130}Te	400 kg	$> 10^{26}$ y	50
CUORE	^{130}Te	203 kg	$>2\times10^{26}$ y	20 - 160
EXO-200	^{136}Xe	200 kg	$>6.4\times10^{25}$ y	133 - 186
NEXT	^{136}Xe	100 kg	10^{26} y	~ 100
KamLAND-Zen	^{136}Xe	400 kg	$>4\times10^{26}$	40-80
SNO+	^{150}Nd	44 kg	$>10^{25}$ y	100 - 250
DCBA	^{150}Nd	330 kg	$>10^{25}$ y	~30

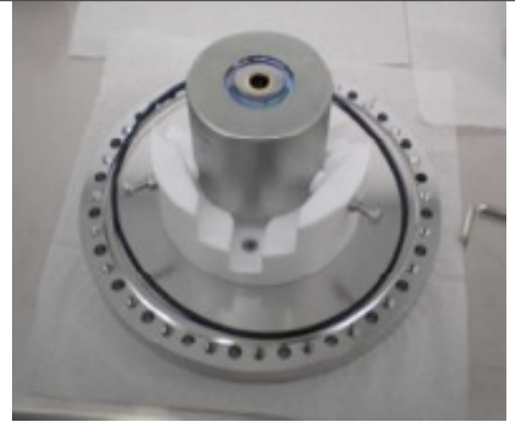
*Data collected from proposals and public presentations

The goal of every future experiment is to reach at least 50 meV, but 10 meV needed to exclude inverted hierarchy

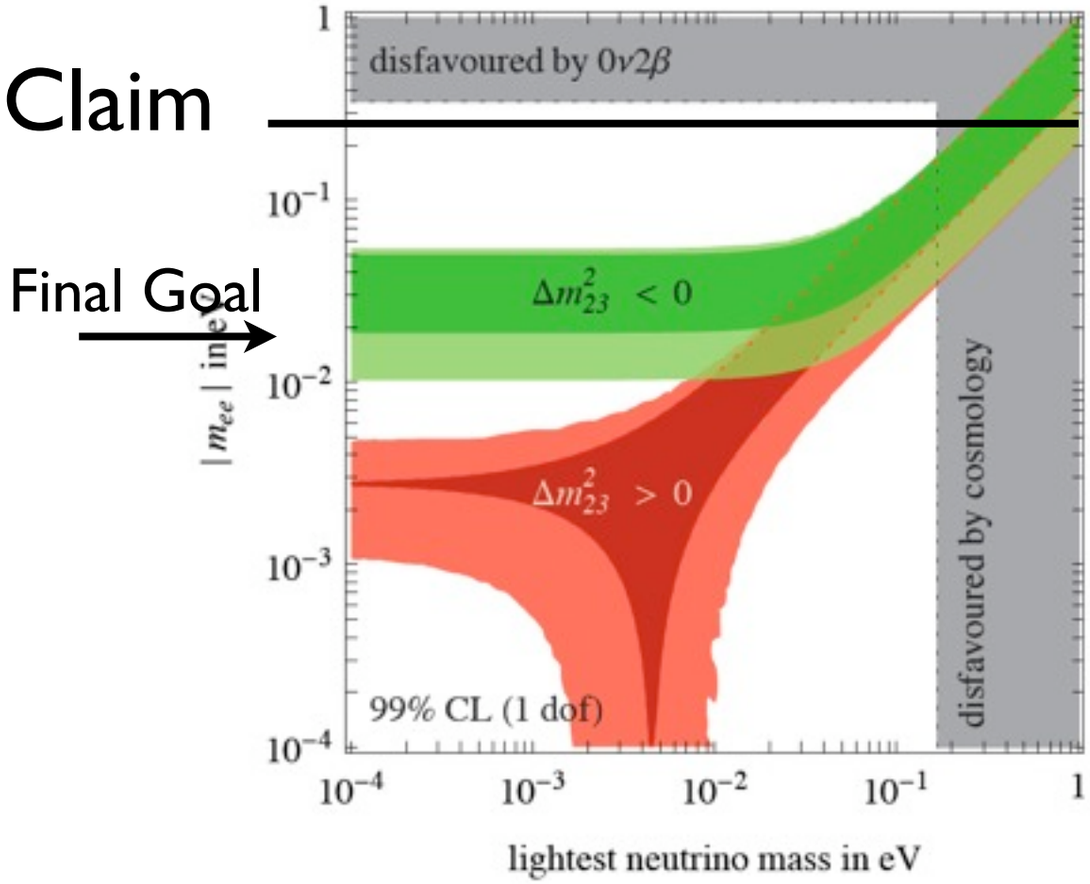
Missing from the table: timescale and cost

We got competitors !

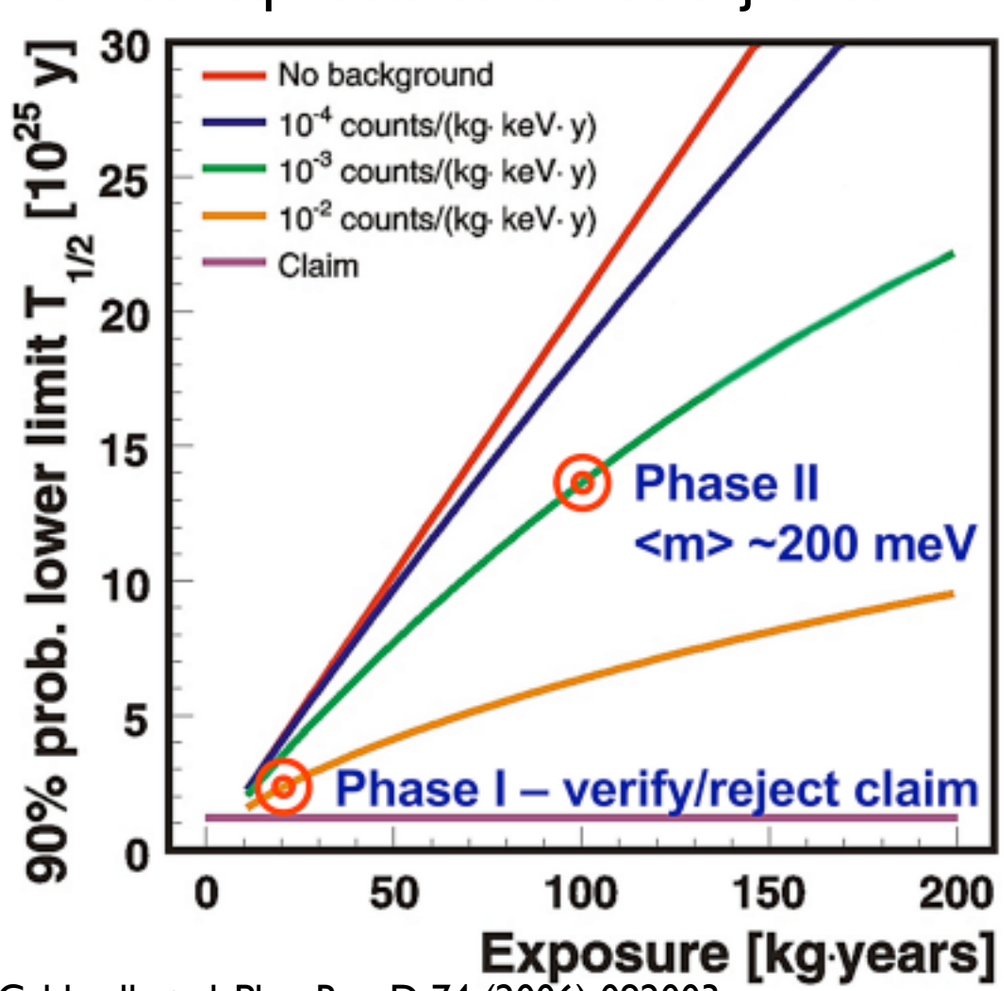
GERDA



- GERDA will test the **Claim**
- Phase I: HdM and IGEX detectors will be redeployed. total mass 17.66 kg with a projected background level of 10^{-2} cts/(keV kg y)
- Phase II: 37 kg additional enriched ^{76}Ge is available for detector production. Projected background level 10^{-3} cts/(keV kg y)
- GERDA is also an R&D project for a future 1 ton experiment with Majorana

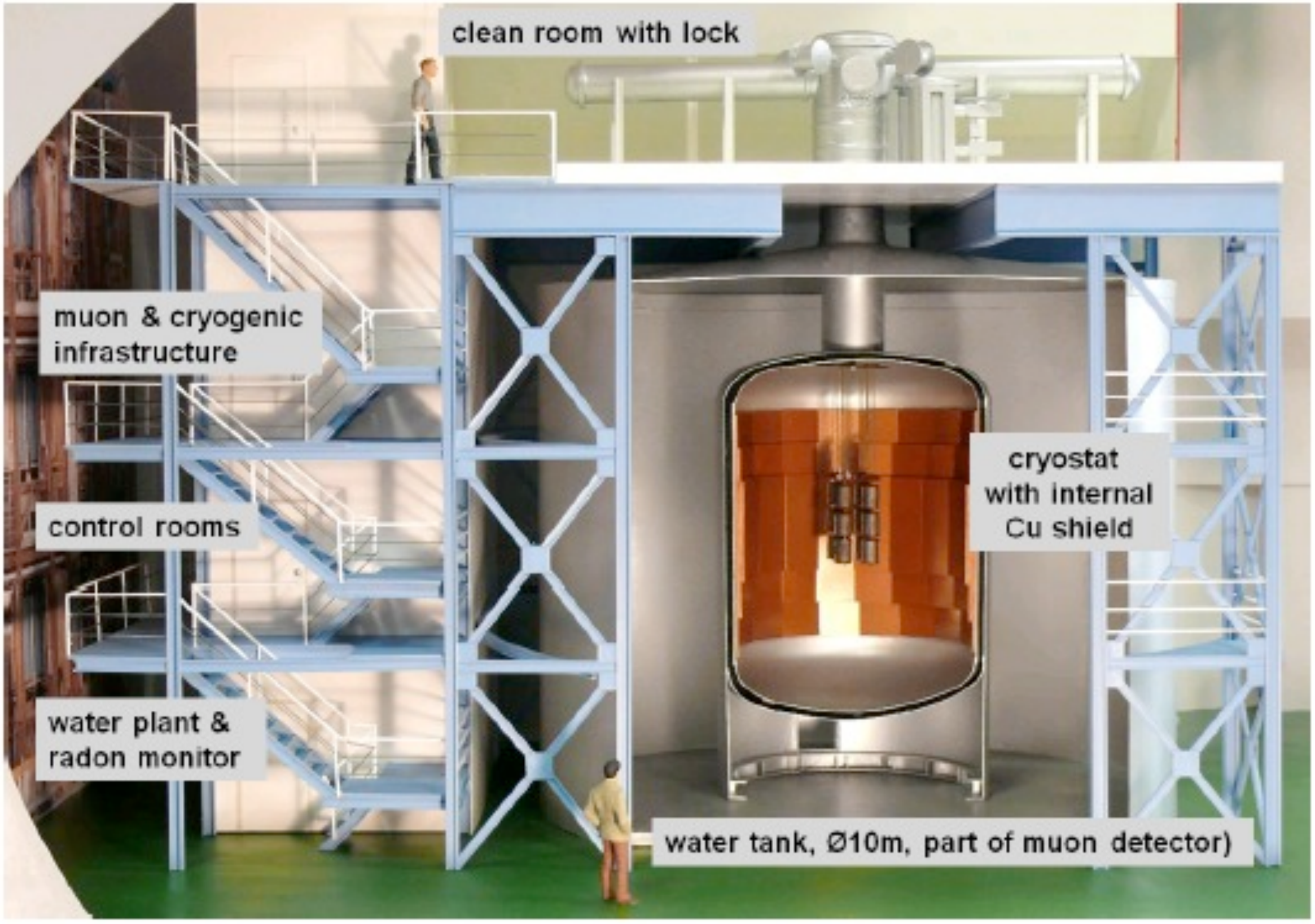


F.Feruglio et al. Nucl.Phys.B 637 (2002)



A. Caldwell et al. Phys.Rev. D 74 (2006) 092003

GERDA at Gran Sasso



GERDA Milestones

Cryostat delivered March 2008

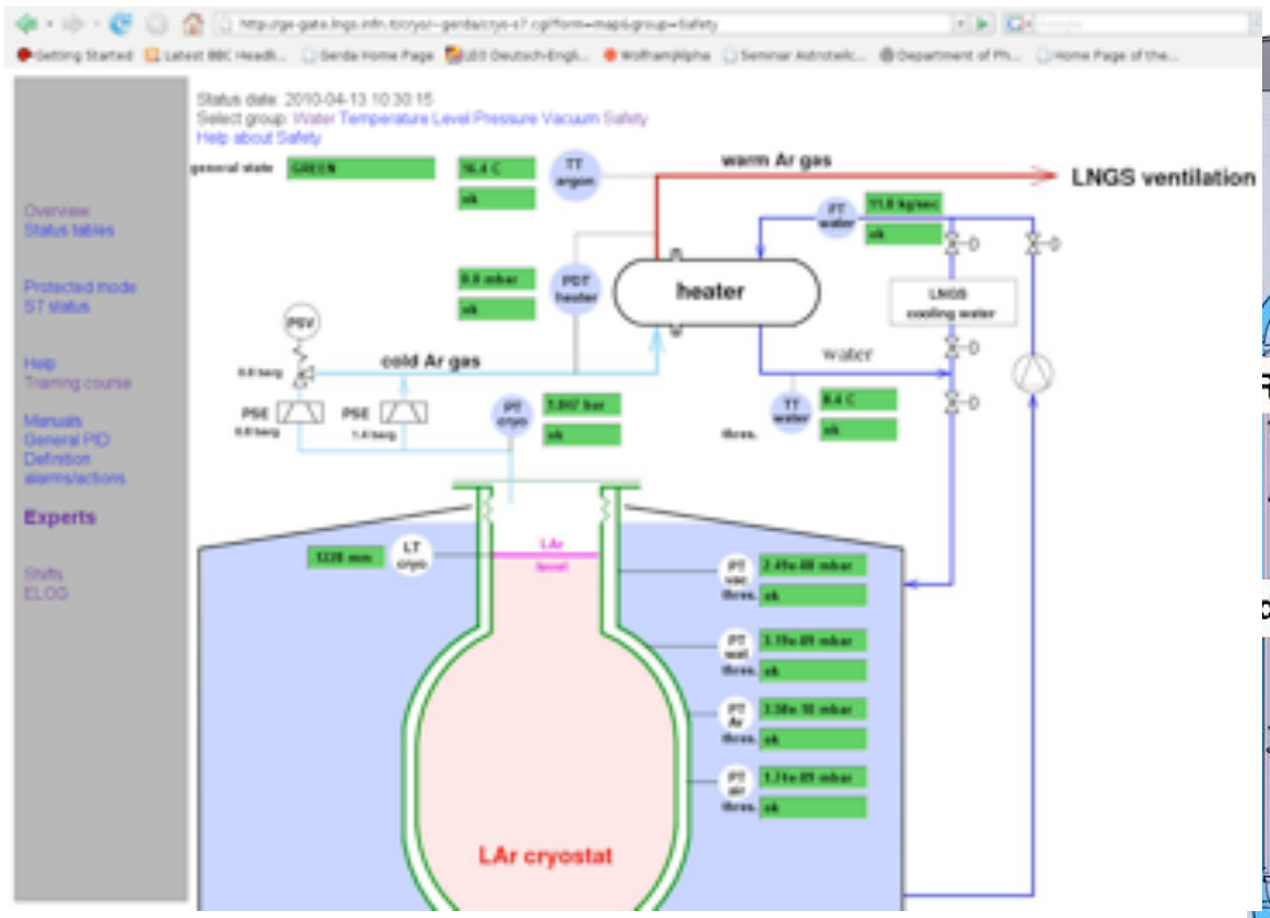
Water tank completed May 2008

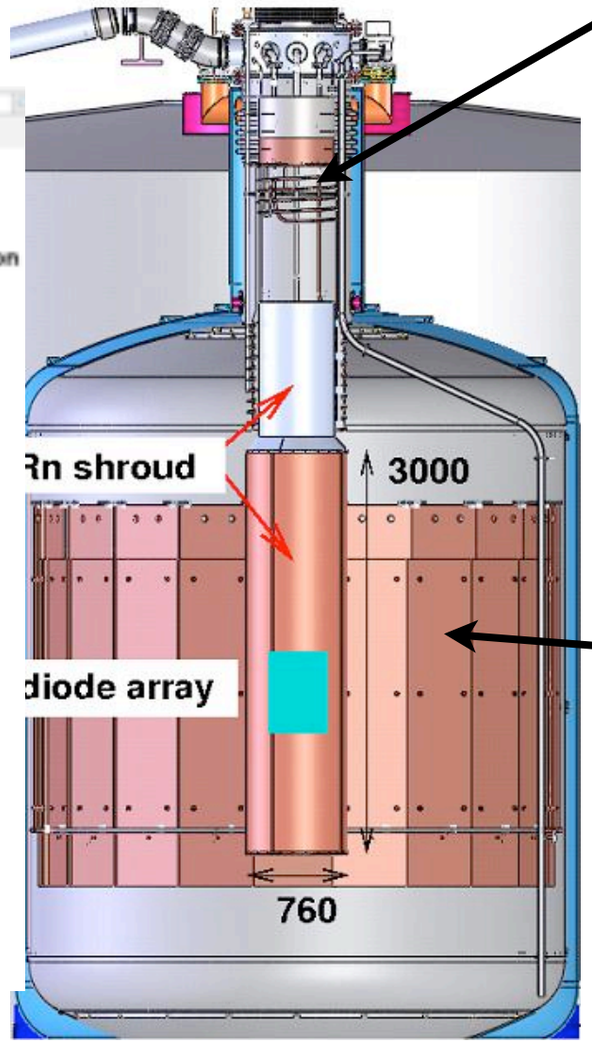
2009 April Clean Room built up

2009 construction completed:
In Nov. 2009 started filling with LAr

Cryogenic Infrastructure

- LAr level stable, no evaporation losses: active cooling with LN
- Slow control with web interface
- Operating since 2009, Nov





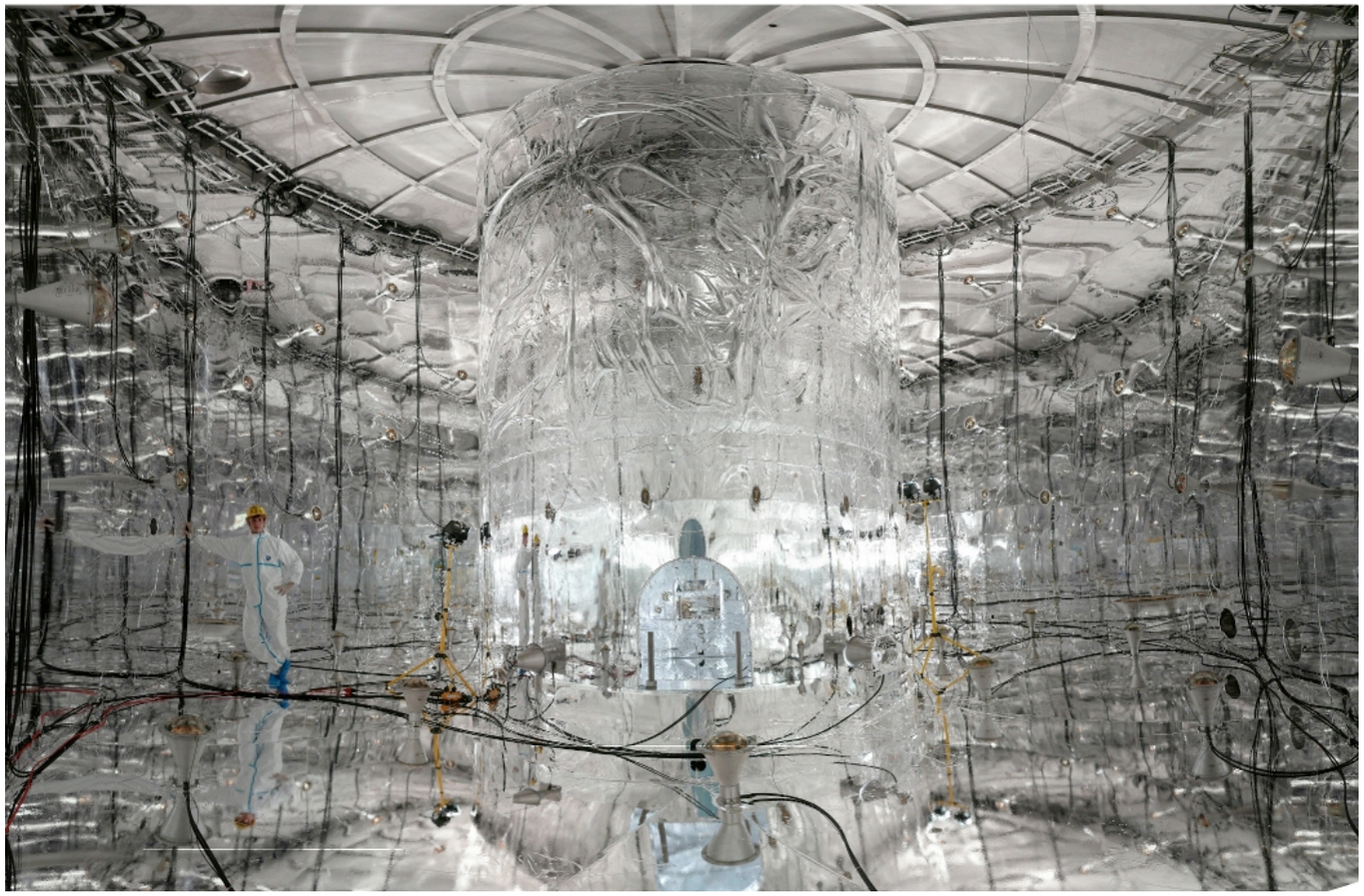
Cooling circuit

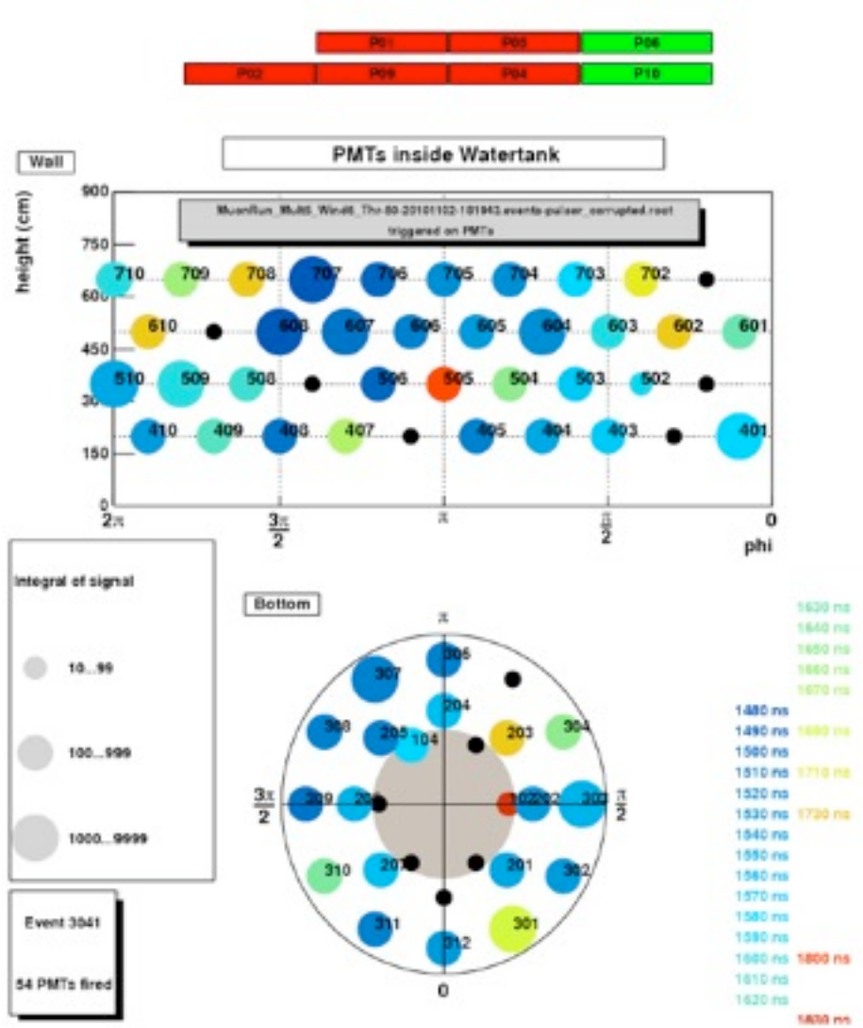
Cu shield

Vacuum insulated steel cryostat

Muon veto

- 580 t of water instrumented with 66 PMTs
- 4 m^2 plastic scintillator panels on the top
- Completed in 2010, fully functional





Detector handling

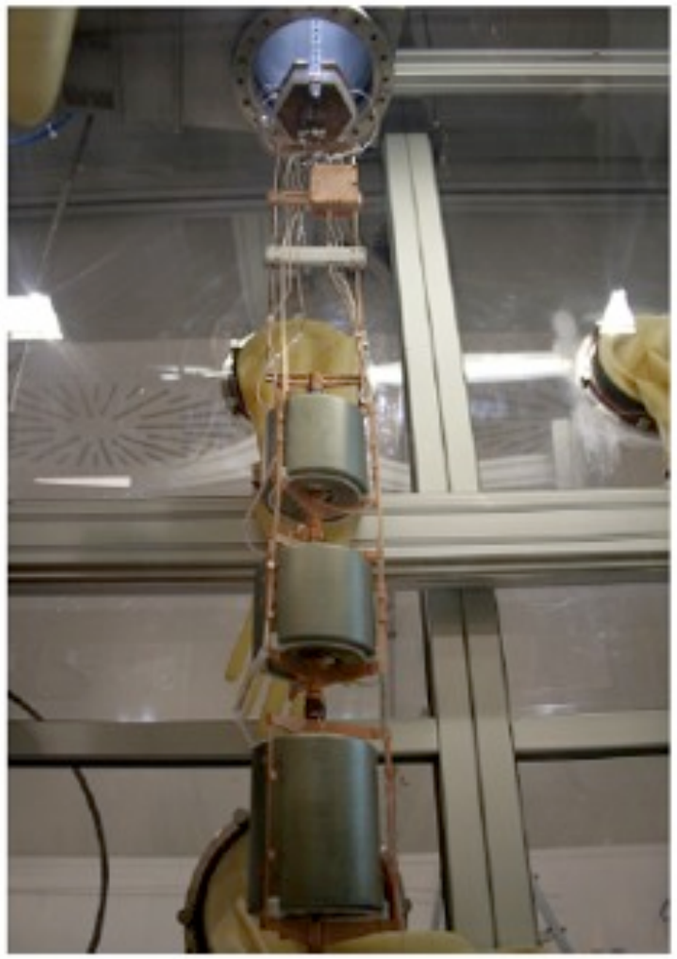
- Class 10000 clean room with a class 100 flow box inside for detector handling
- HPGe detectors never come in contact with air:
  - ★ Stored in vacuum
  - ★ Mounted in flow box in N_2

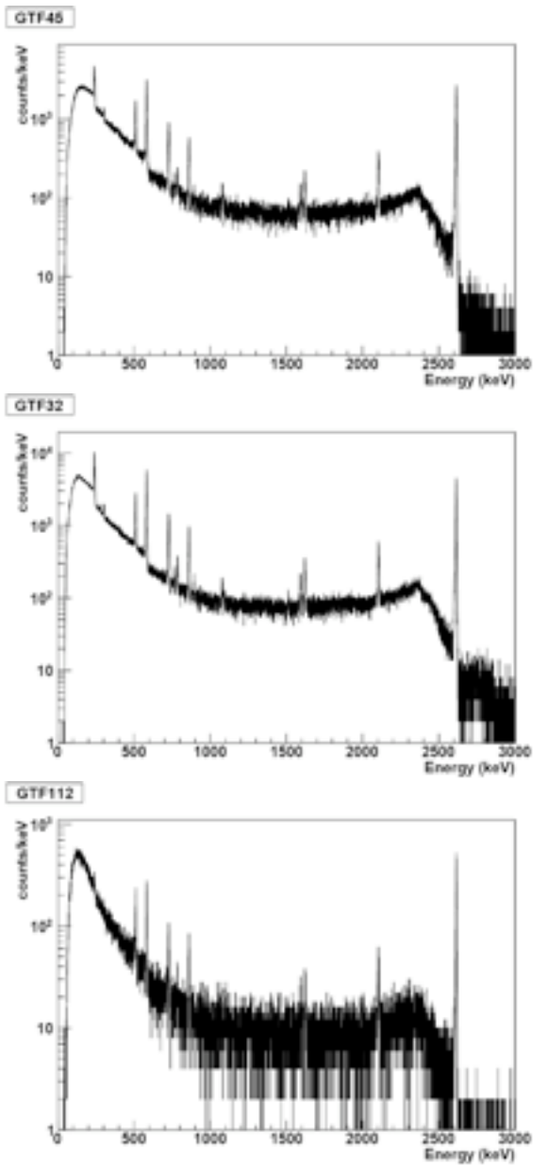
Read-out chain

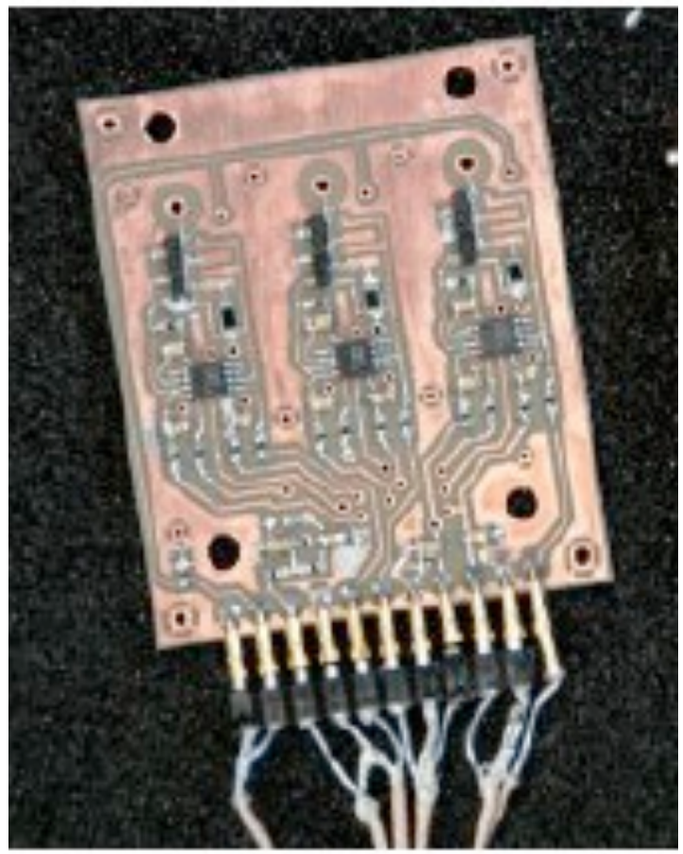
- DAQ with FADCs
- Amplifiers have to be close to the HPGe

★Cryogenic **low activity** front-end

All up and running

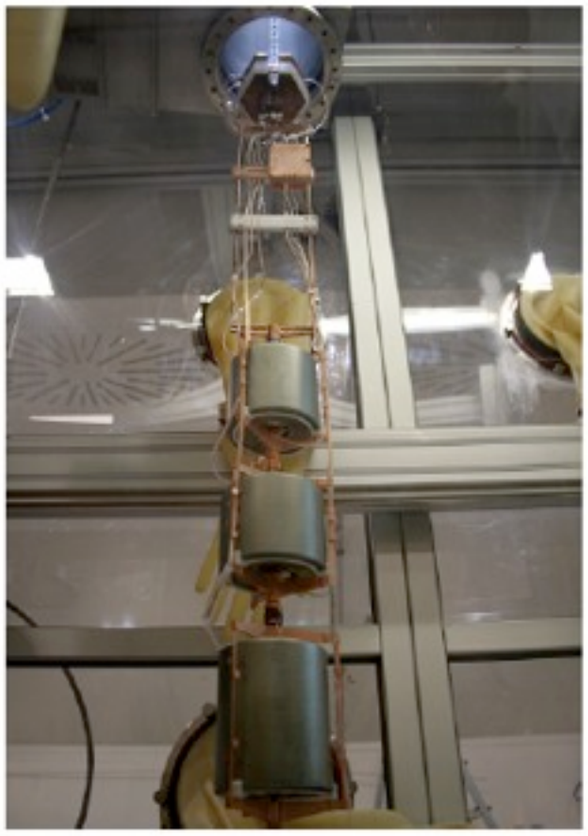




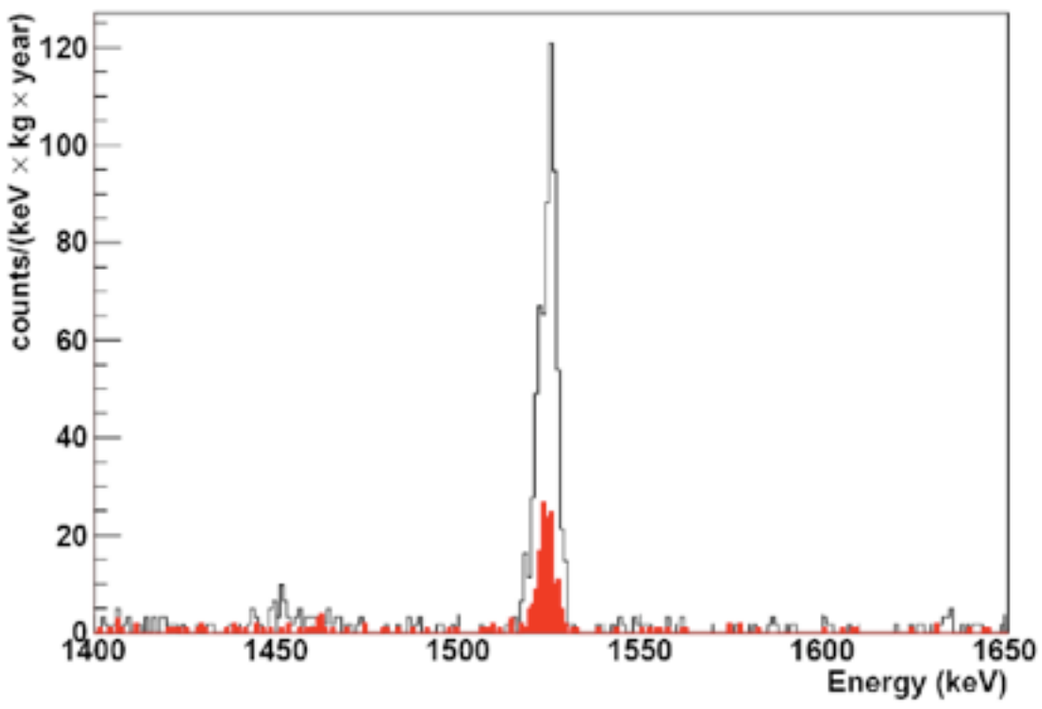


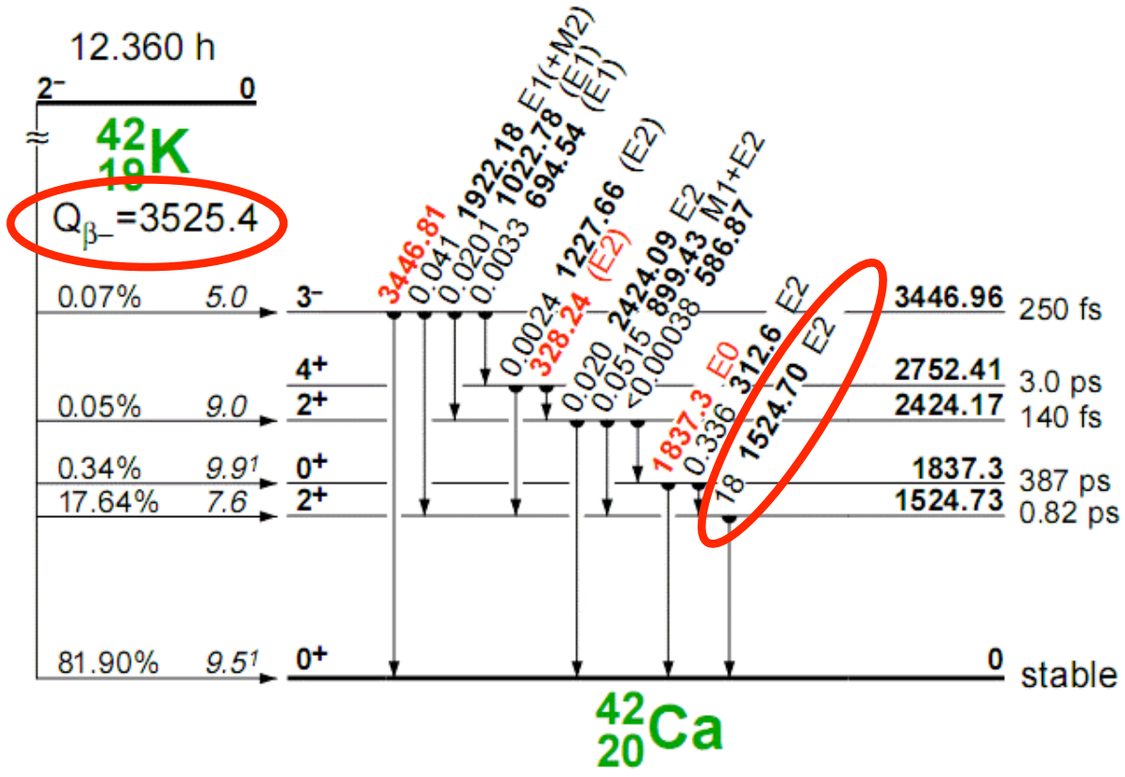
Calibration Spectra with ^{228}Th source

Commissioning runs

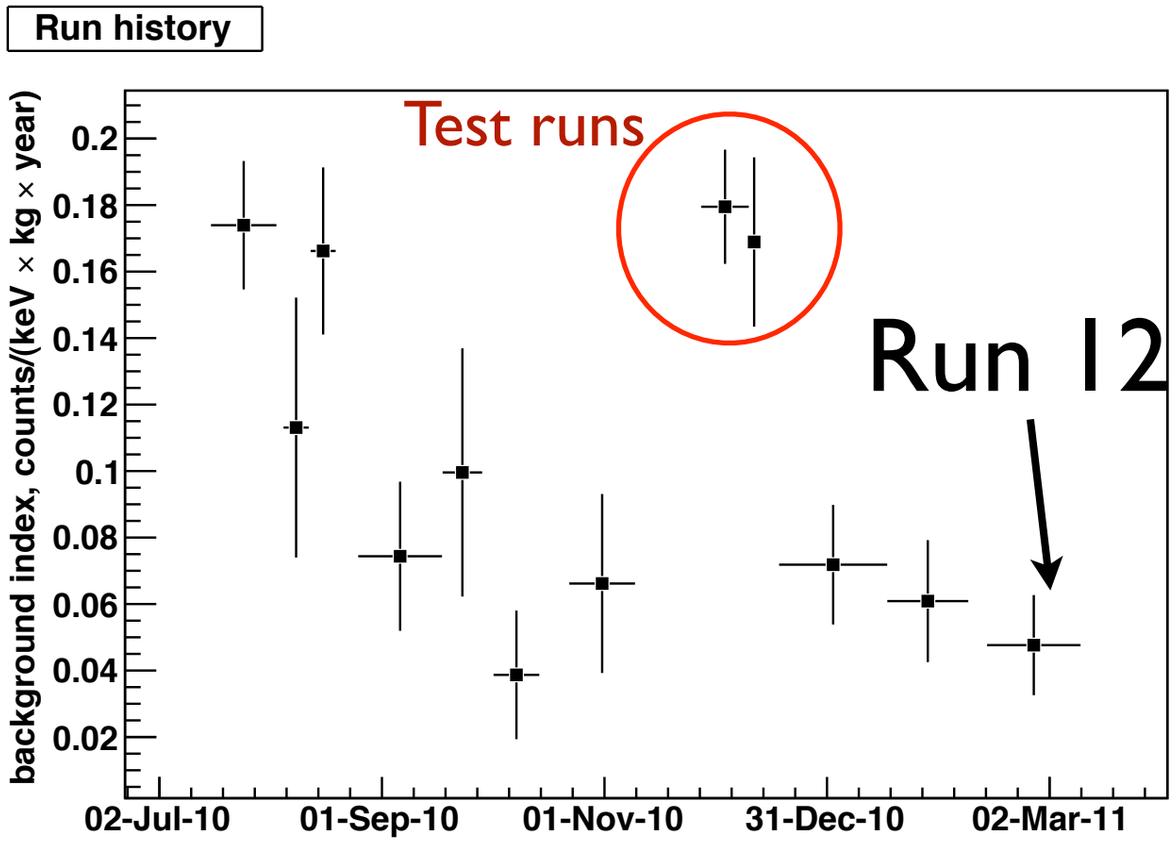


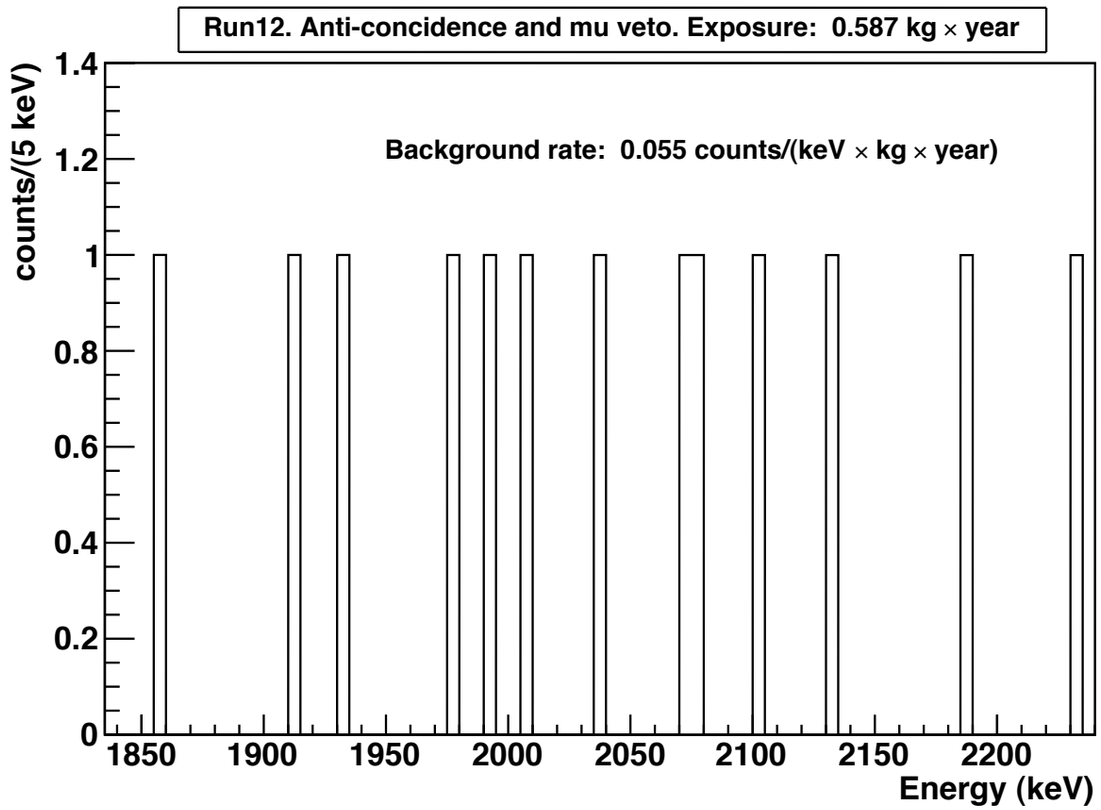
- One string operated with 3 natural Ge detectors
- Taking data since June 2010
- 1.7 kg/y data collected with non-enriched detectors
- Background level already better than in the HdM experiment
- First surprise: main background source $^{42}Ar/^{42}K$
  - In the ROI background from ~3 MeV β's
  - Sensitive to E-field, we hope to reduce it





Commissioning runs

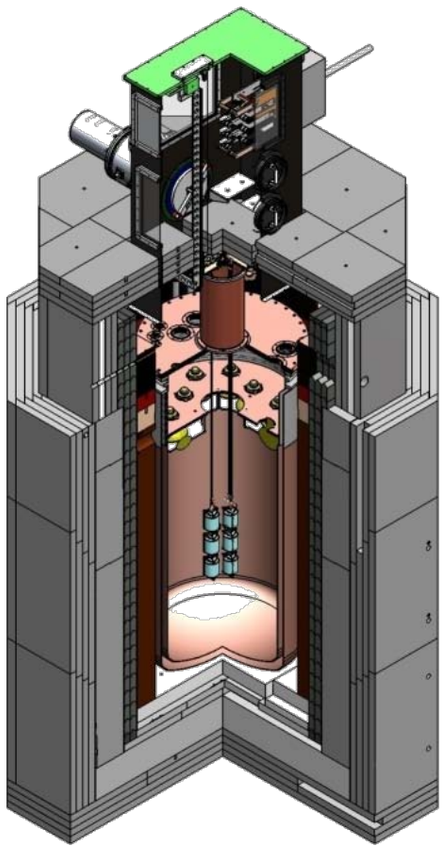




- Background level of 0.055 ± 0.023 cts/(keV kg y) reached.
- Commissioning will take some time because we need weeks to see a few counts

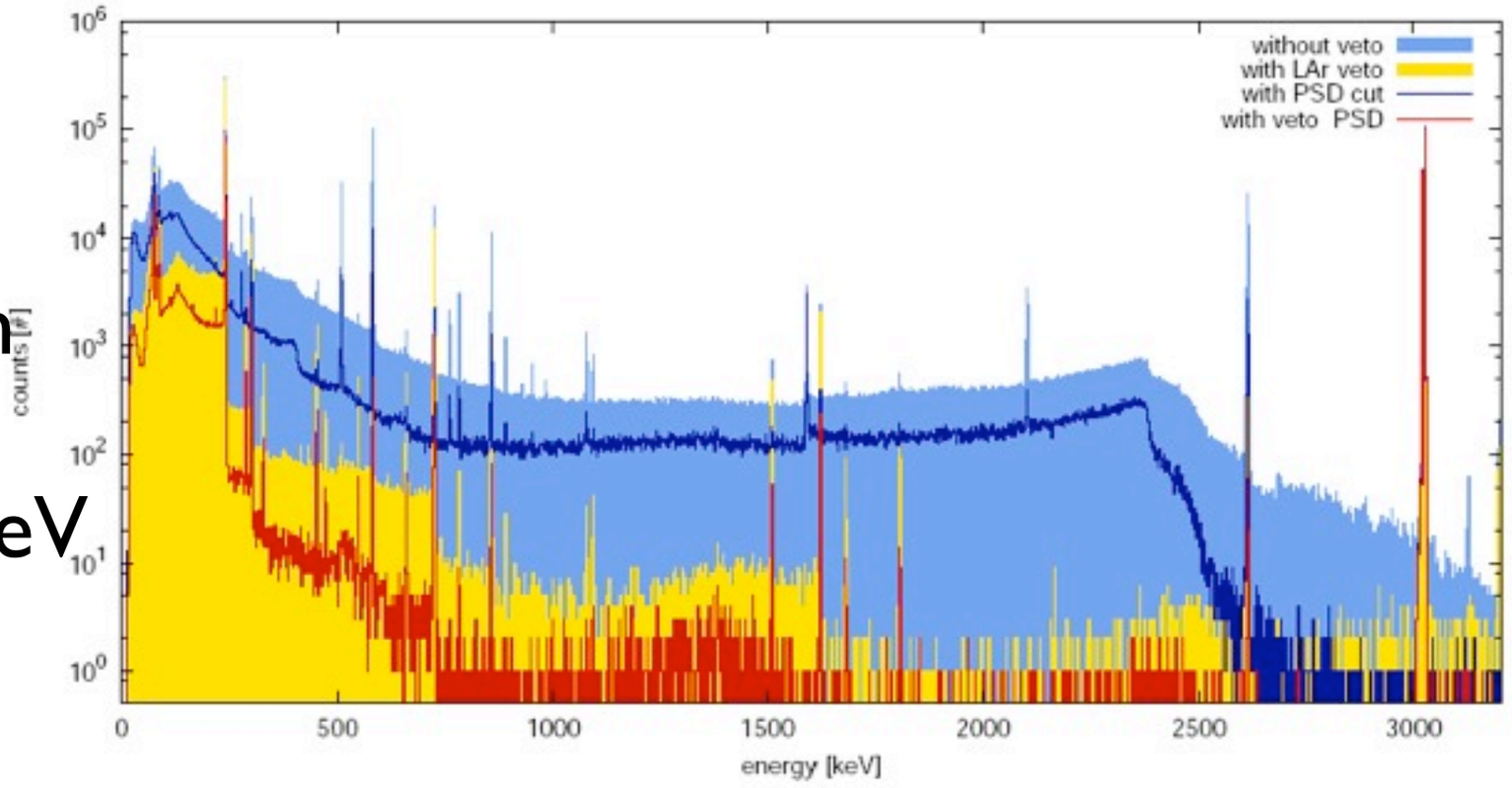
R&D for Phase II

LArGe facility at LNGS



- R&D project for LAr instrumentation
- 1t LAr low background cryostat at LNGS
- LAr scintillation light read out with 9 PMTs
- + low background HPGe detectors

Spectacular suppression of the Compton background around 2MeV



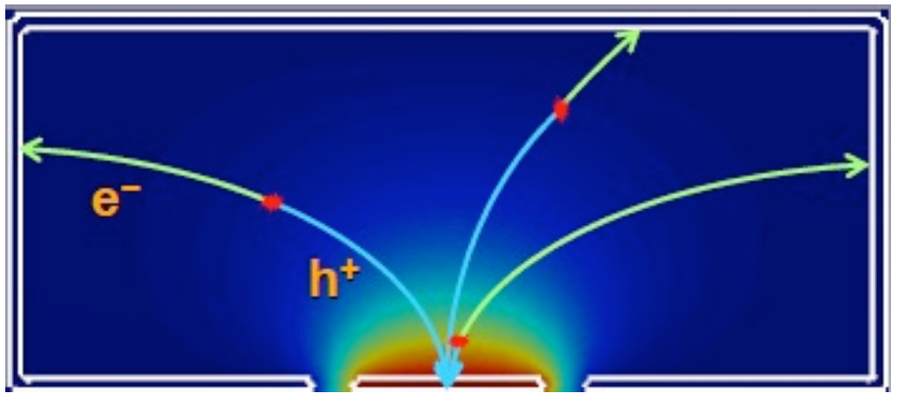
^{76}Ge for Phase II

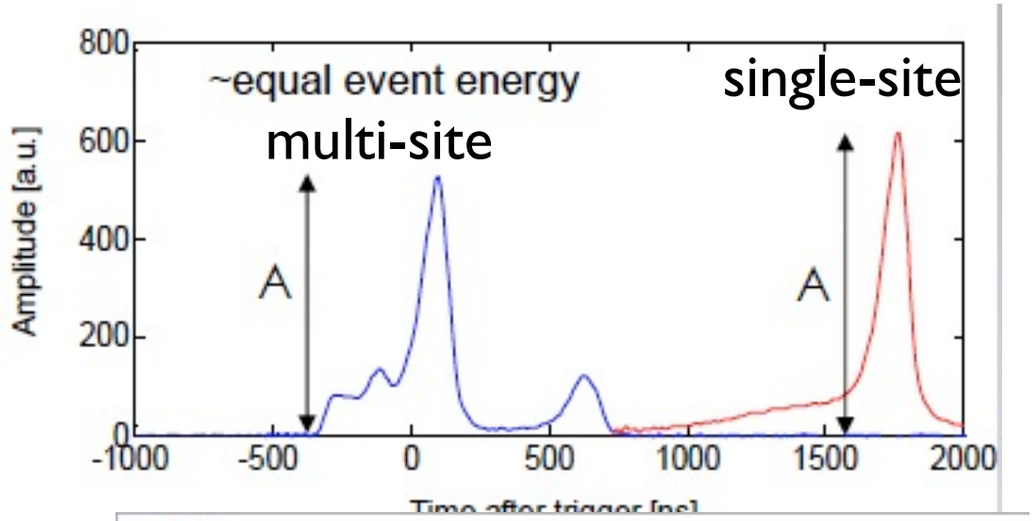
- 53 kg of enriched GeO_2 bought from ECP reduced and purified
- 36.6 kg Ge metal produced out of which 35.4 kg is 6N purity and is available for detector production
- Stored underground in the Rammelsberg mining museum, Goslar

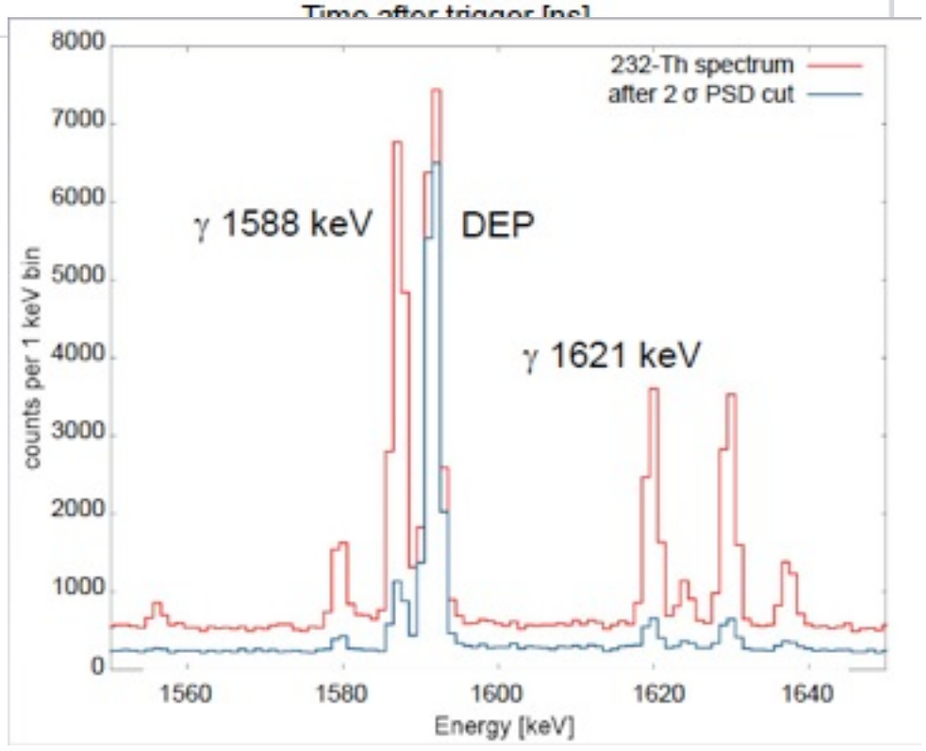
- Cosmogenic ^{68}Ge and ^{60}Co two orders of magnitude less than in equilibrium

R&D for Phase II

- BeGe's are the preferred candidates for Phase II
- Good Pulse Shape Discrimination capabilities and commercially available
- BeGe prototype detectors already produced from depleted Ge

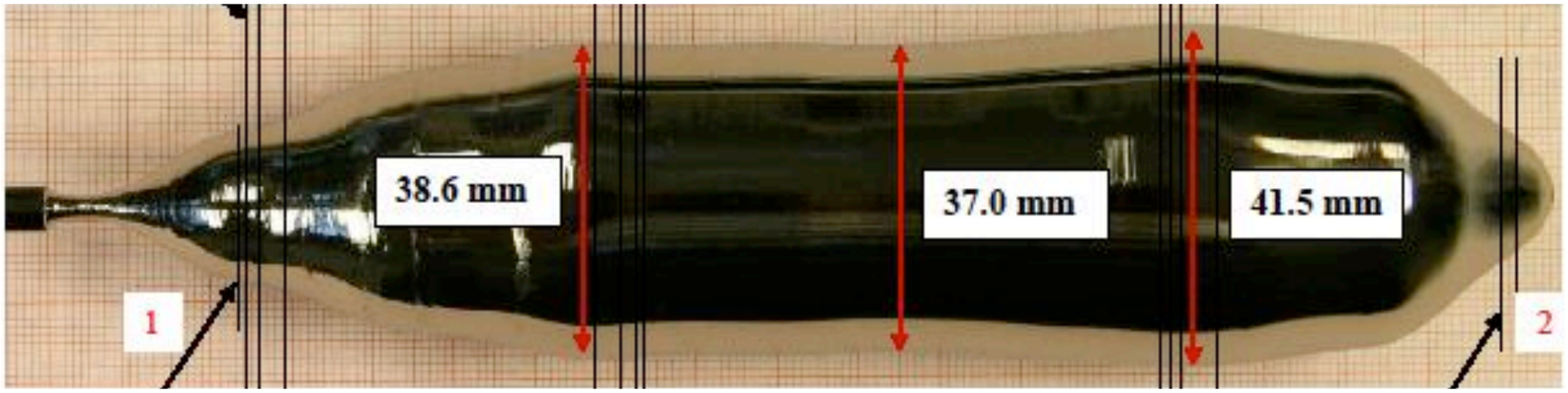


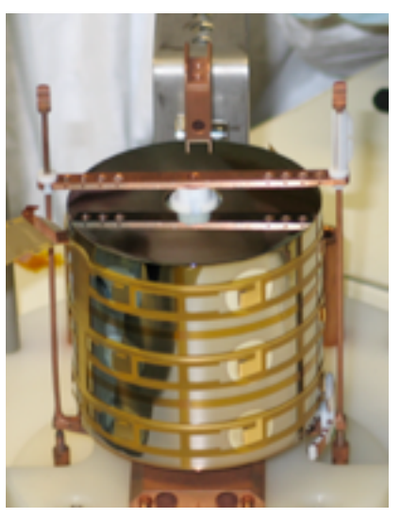




R&D for Phase II and beyond

- Crystal pulling R&D at Institute für Kristallzüchtung (IKZ) continues
- The best crystal produced has the imp. conc. 4×10^{10} / cm^3
  - A test-diode is being produced now





- Segmented detector R&D is still continuing

Conclusion

- Construction of GERDA is finished
- We are taking data with natural Ge detectors
- Background level already lower than in the HdM experiment
- Enriched detectors will be deployed soon
- The preparation of Phase II is progressing fast

The Collaboration

- about 100 members
- 19 institutions from 6 countries

M. Agostini [n], M. Allardt [c], E. Andreotti [e], A.M. Bakalyarov [l], M. Balata [a], I. Barabanov [j], M. Barnabe-Heider [f], L. Baudis [s], C. Bauer [f], N. Becerici-Schmid [m], E. Bellotti [g,h], S. Belogurov [k,j], S.T. Belyaev [l], G. Benato [o,p], A. Bettini [o,p], L. Bezrukov [j], T. Bruch [s], V. Brudanin [d], R. Brugnera [o,p], D. Budjas [n], A. Caldwell [m], C. Cattadori [g,h], F. Cossavella [m], E.V. Demidova [k], A. Denisov [j], S. Dinter [m], A. Domula [c], V. Egorov [d], F. Faulstich [m], A. Ferella [s], K. Freund [r], F. Froborg [s], N. Frodyma [b], A. Gangapshev [j], A. Garfagnini [o,p], S. Gazzana [l,d], P. Grabmayr [r], V. Gurentsov [j], K.N. Gusev [l,d], W. Hampel [f], A. Hegai [r], M. Heisel [f], S. Hemmer [o,p], G. Heusser [f], W. Hofmann [f], M. Hult [e], L. Ianucci [a], L.V. Inzhechik [j], J. Janicsko [n], J. Jochum [r], M. Junker [a], S. Kianovsky [j], I.V. Kirpichnikov [k], A. Kirsch [f], A. Klimenko [d,j], K-T. Knoepfle [f], O. Kochetov [d], V.N. Kornoukhov [k,j], V. Kusminov [j], M. Laubenstein [a], V.I. Lebedev [l], B. Lehnert [c], S. Lindemann [f], M. Lindner [f], X. Liu [q], A. Lubashevskiy [f], B. Lubsandorzhiev [j], A.A. Machado [f], B. Majorovits [m], G. Marissens [e], G. Meierhofer [r], I. Nemchenok [d], S. Nisi [a], C. O'Shaughnessy [m], L. Pandola [a], K. Pelczar [b], F. Potenza [a], A. Pullia [i], M. Reissfelder [f], S. Riboldi [i], F. Ritter [r], C. Sada [o,p], J. Schreiner [f], U. Schwan [f], B. Schwingenheuer [f], S. Schönert [n], H. Seitz [m], M. Shirchenko [l,d], H. Simgen [f], A. Smolnikov [f], L. Stanco [p], F. Stelzer [m], H. Strecker [f], M. Tarka [s], A.V. Tikhomirov [l], C.A. Ur [p], A.A. Vasenko [k], O. Volynets [m], M. Wojcik [b], E. Yanovich [j], P. Zavarise [a], S.V. Zhukov [l], D. Zinatulina [d], F. Zocca [i], K. Zuber [c], and G. Zuzel [b].

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