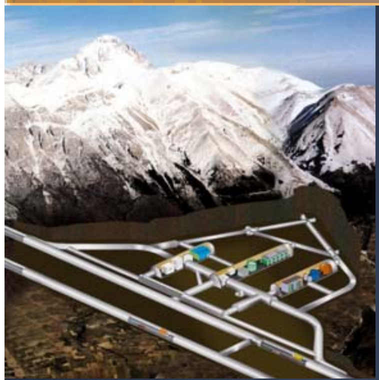

LATEST GERDA RESULTS ON $0\nu\beta\beta$ OF ^{76}Ge

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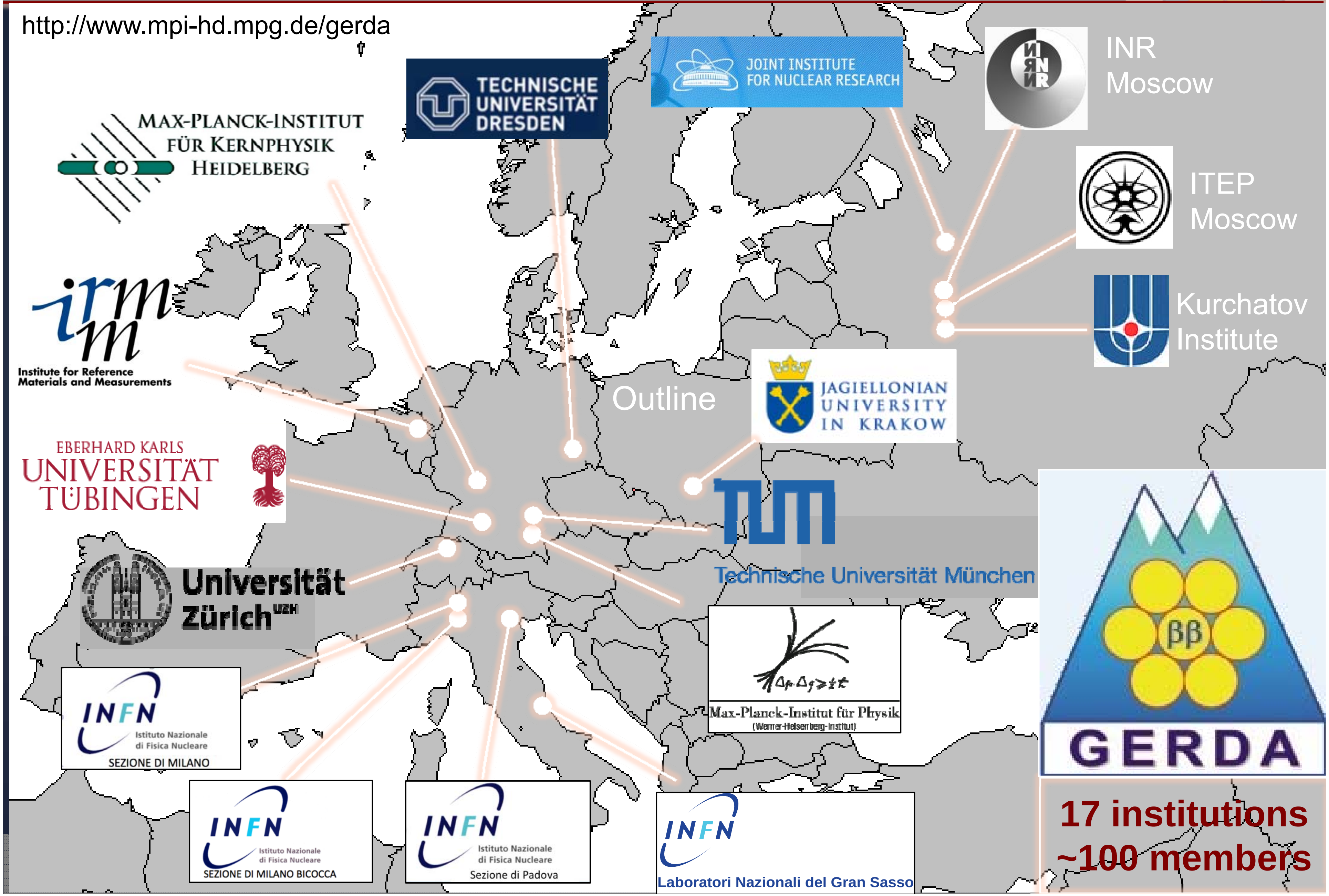
INFN Milano Bicocca
on behalf of the GERDA Collaboration

CPAN 2013, Santiago de Compostela (ES)
25-27 November 2013

Greetings from Dubna!

The GERDA Collaboration



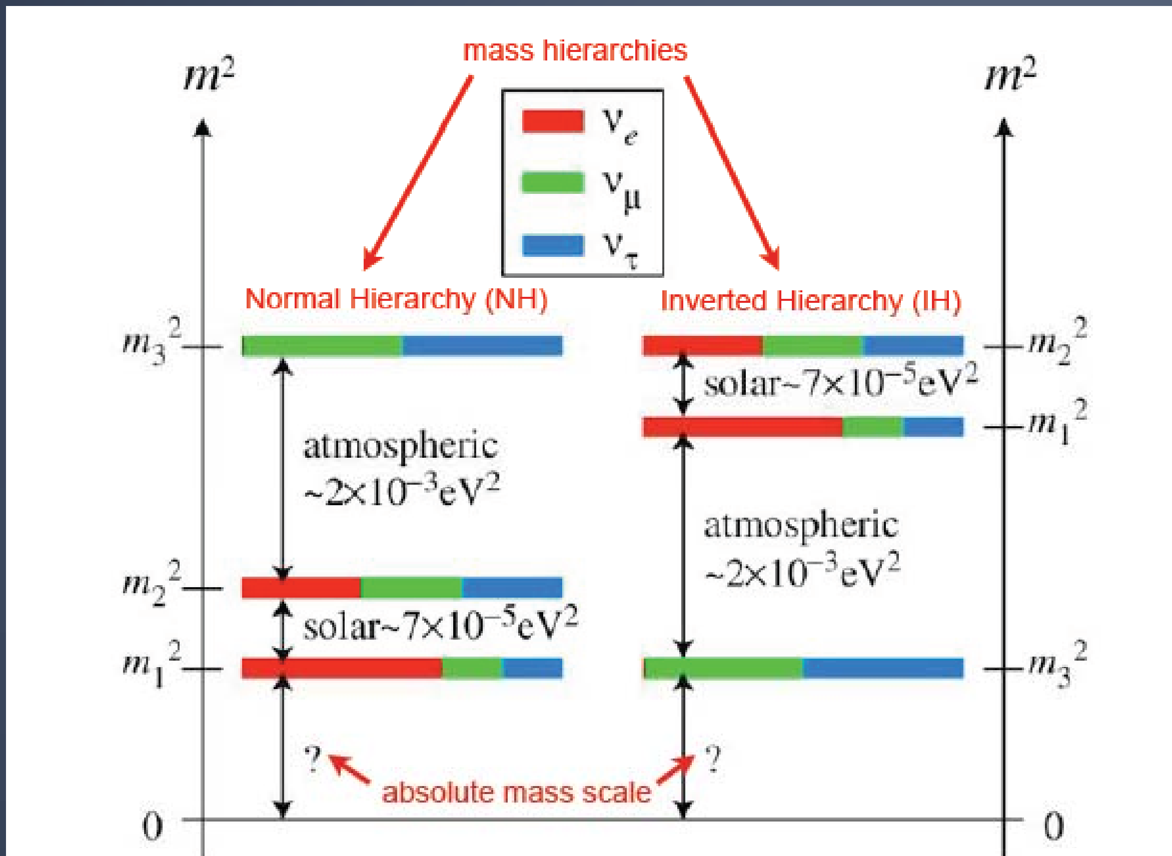
Outline

- ❑ Neutrino masses and DBD
- ❑ The GERDA experiment
- ❑ Data Treatment
  - The Energy scale and FWHM
  - Analysis cuts
  - The Pulse shape discrimination
  - Data sets
- ❑ Background in GERDA
- ❑ ………….results
- ❑ Conclusion

Neutrino Mass Question

In the present neutrino scenario, two open issues refer to neutrino masses

1. Absolute mass scale: i.e. mass of the lightest ν
2. Hierarchy ($m_1 \ll m_2 < m_3$ or $m_3 \ll m_1 < m_2$) or degeneracy ($m_1 \approx m_2 \approx m$



Forthcoming Neutrino Oscillation Experiment (Daya Bay II, Reno II, T2K, Nova, LBNO,LBNE,Pingu,ORCA), cannot address point 1. but can solve point 2.

0νββ rate and the effective neutrino mass

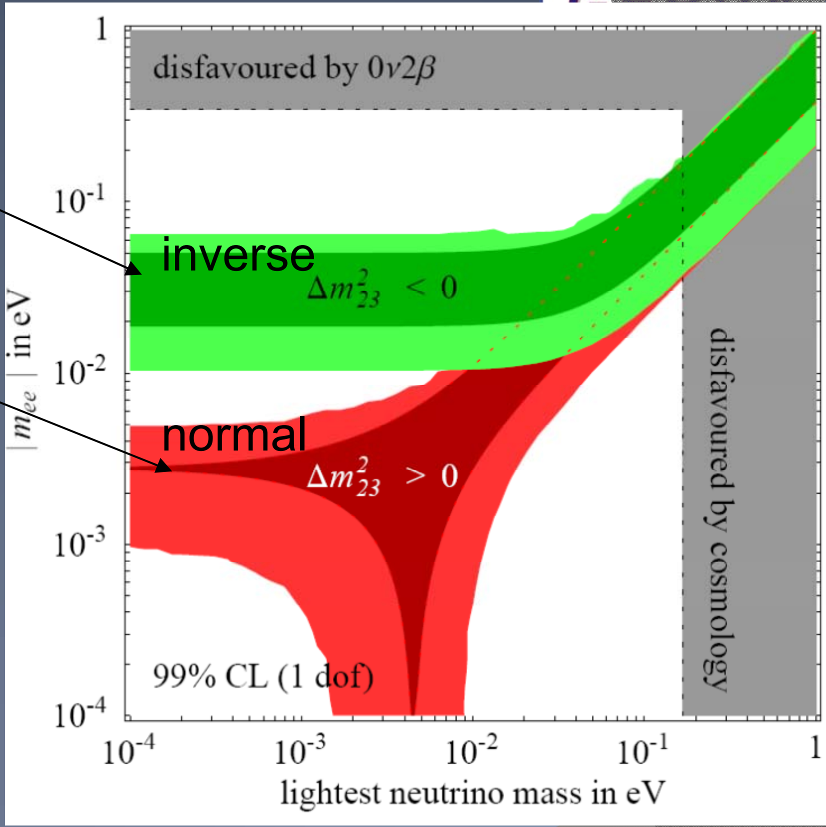
0νββ rate ~ (effective Majorana neutrino mass)²

From Vissani, Strumia hep-ph/0606054v2

$$< m_\nu > \cong \sqrt{m_1^2 + \Delta m_{atm}^2} \left| \left|U_{e1}^L\right|^2 e^{i\phi 2} + \left|U_{e2}^L\right|^2 e^{i\phi 3} \right|$$

$$< m_\nu > \cong m_1 \left| \left|U_{e1}^L\right|^2 + \left|U_{e2}^L\right|^2 e^{i\phi 2} (1 + \frac{\delta m_{solar}^2}{2m_1}) \right|$$

$$\Delta m_{atm} = m_3 - \frac{(m_2^2 + m_1^2)}{2}$$

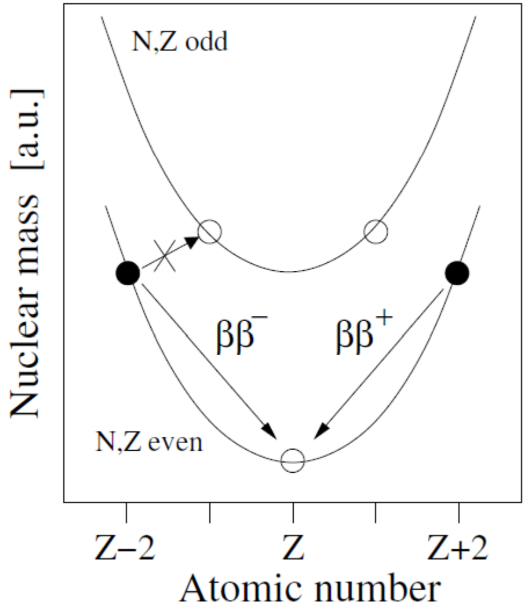


DBD can address both point (but Nuclear Model dependent)

1. Absolute mass scale: i.e. mass of the lightest ν
2. Hierarchy ($m_1 \ll m_2 < m_3$ or $m_3 \ll m_1 < m_2$) or degeneracy ($m_1 \approx m_2 \approx m_3$)

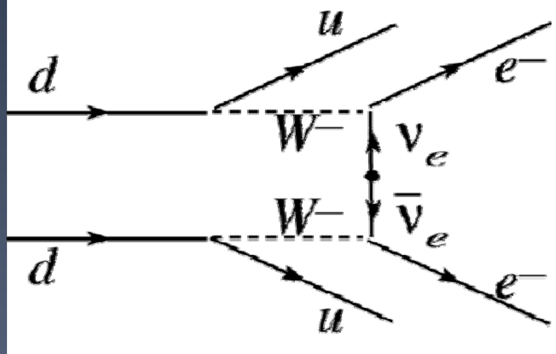
$$(T_{1/2}^{0\nu})^{-1} \sim 5 \times 10^{-17} \, [y^{-1}] \, F_{0\nu} (Q,Z) \, |M_{0\nu}|^2 \, m_\nu^2 / m_e^2$$

0νββ half-life	Phase space…	Nuclear Matrix Elements	Effective Majorana neutrino mass



ββ Decay

2ν 0ν



Proposed by Majorana (and Racah) in 1937:

A ν is exchanged between two neutrons

It is a forbidden process in SM and requires

- Lepton number violation $\Delta L = 2$ $\nu_e = \overline{\nu}_e$
- Can be mediated by a light Majorana ν finite mass $< m_\nu > \neq 0$

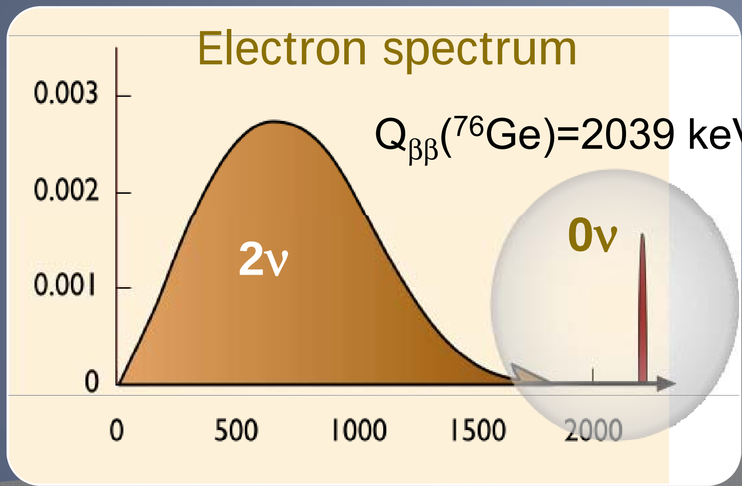
$$\frac{1}{T_{1/2}^{0\nu}} \propto G_{0\nu} |M_\nu|^2 \frac{< m_{ee} >^2}{m_e}$$

$< m_{ee} > = effective\ \nu\ mass$

$M_\nu = Nuclear\ Matrix\ Element$

$G_{0\nu} = Phase\ Space\ Factor$

$< m_{ee} > = \left| \sum_i U_{ei}^2 m_i \right|$

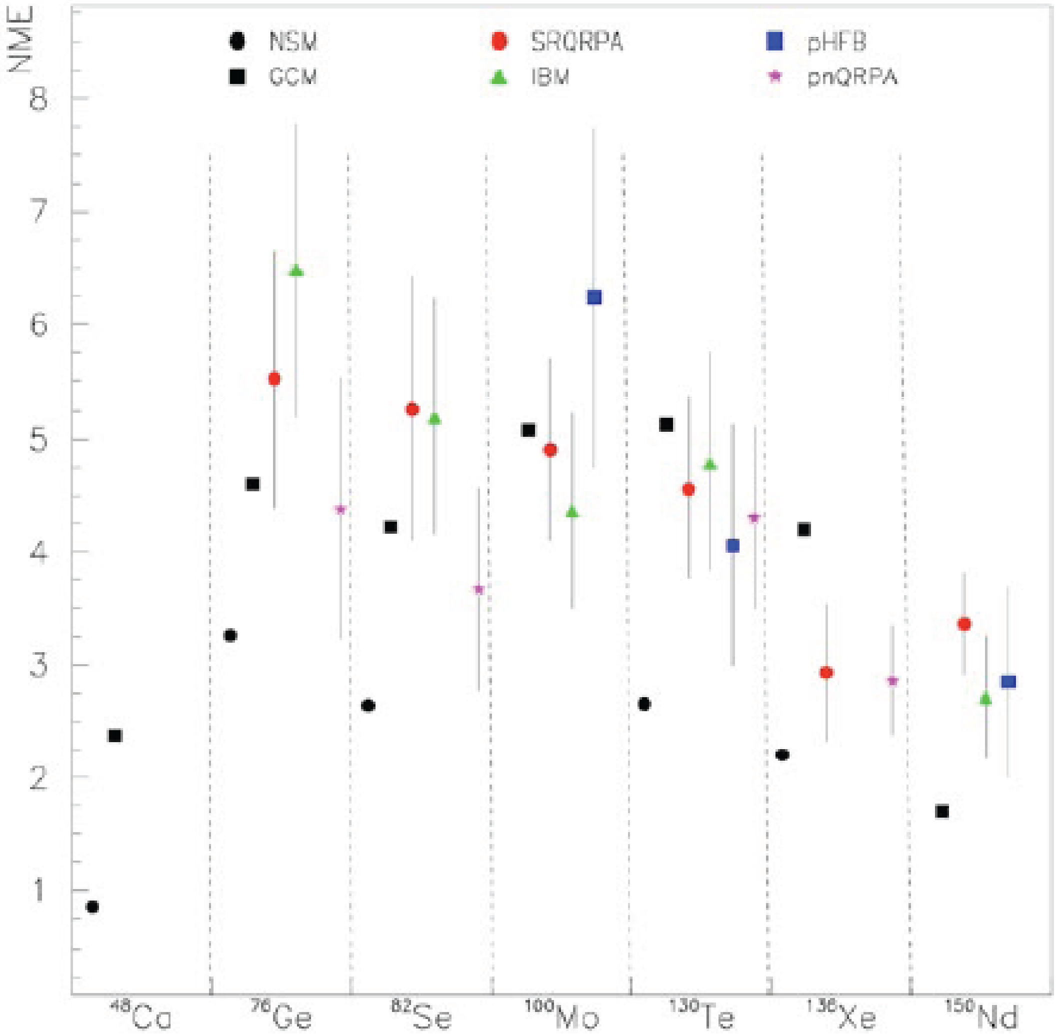


Nuclear Matrix Elements Jungle

Nuclear matrix elements (NME) are calculated according to various models:
QRPA (RQRPA, SQRPA, …….), Shell model, IBM2 ...
Calculation discrepancies are one of the largest sources of uncertainties

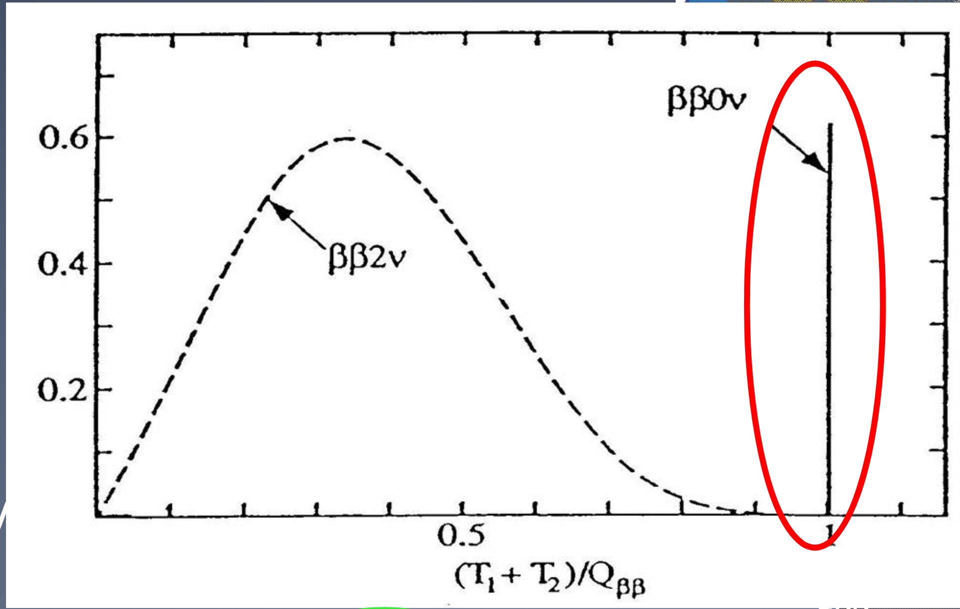
NSM nuclear shell model, Nucl. Phys. A 818 (2009) 139.Phys. Rev. C80 (2009) 048501(1)
SRQRPA self-consistent renormalized quasiparticle random phase approx.(2), Phys Rev D83 (2011) 113015, Phys Rev C79 (2009) 055501(1), Phys Rev C83 (2011) 034320
pnQRPA proton-neutron QRPA, Nucl Phys A847 (2010) 207
GCM generating coordinate method Phys. Rev. Lett. 105 (2010) 252503.
IBM interacting boson model(3), Phys Rev C79 (2009) 044301
pHFB projected Hartree-Fock-Bogoliubov Phys Rev C82 (2010) 064310

- more groups calculate NME with different methods
- NSM lower than other calculations
- NME vary by factor 2-3 for a given nucleus
- "errors" on NME calculations largely correlated for different A
- difference between QRPA calculations small
- **no** "super" element from NME point-of-view



Signatures of ββ decay and experimental sensitivity

ε= detection efficiency
A= Atomic weight
i.a.= isotopic abundance
a = ββ isotope Number of Moles → enrichment
M = mass of detector in kg
T = data taking time [y]
B = background index in cts/(keV kg y
Δ = energy resolution at $Q_{\beta\beta}$ [keV]



With bck →

$$T_{1/2}^{0\nu} \propto \varepsilon \frac{i.a.}{A}\sqrt{\frac{MT}{B\Delta}} = \sqrt{\frac{\varepsilon i.a. \cdot MT}{A}\frac{\varepsilon i.a}{A\,B}\frac{}{\Delta}}$$

a' B'

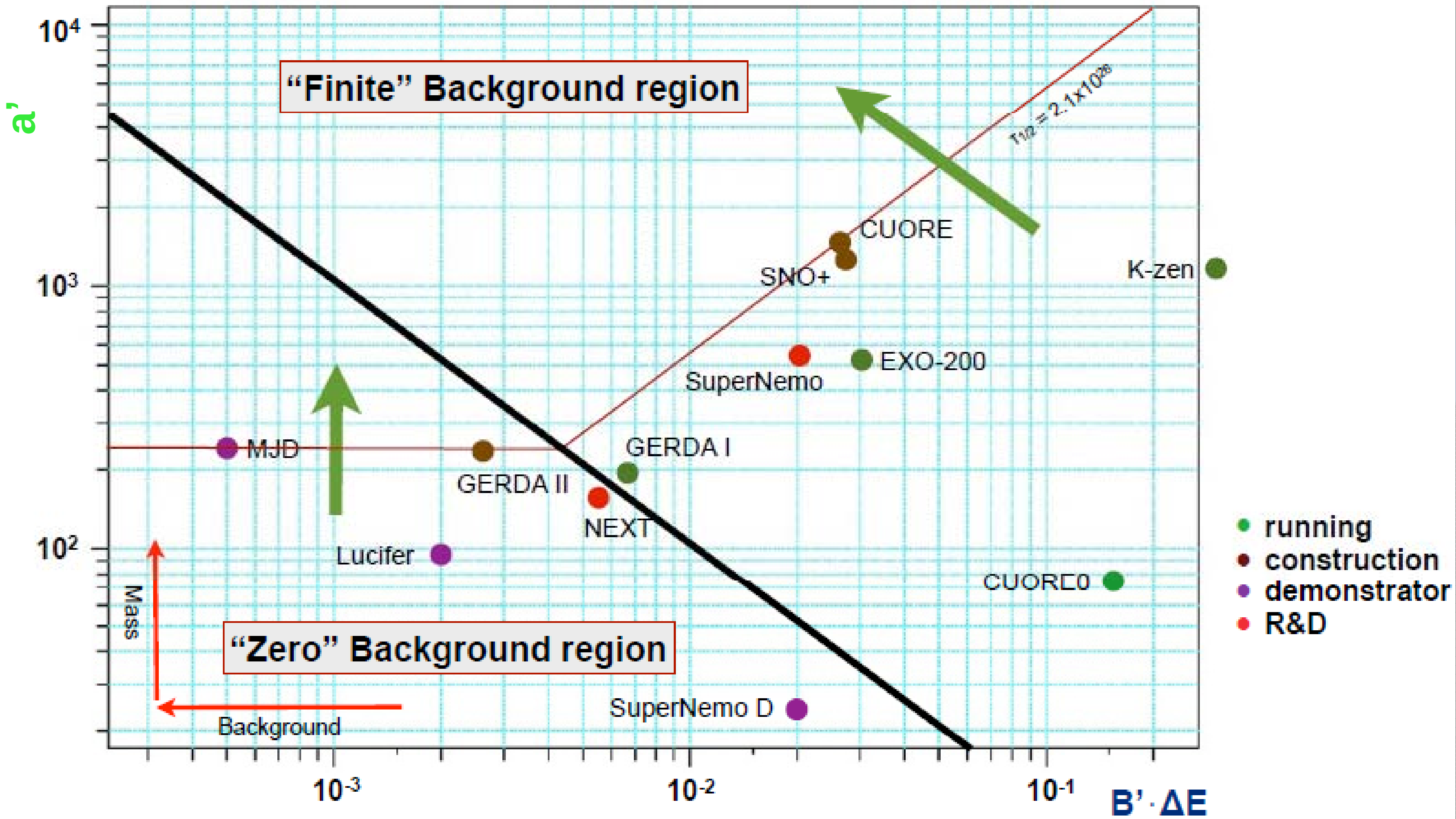
$$\frac{i.a.\ M}{A} = \mathrm{a} = \text{Number of isotope moles}$$

$$T_{1/2}^{0\nu} \propto \mathrm{a}\,\varepsilon MT$$

← Bck free

Comparison of experiments

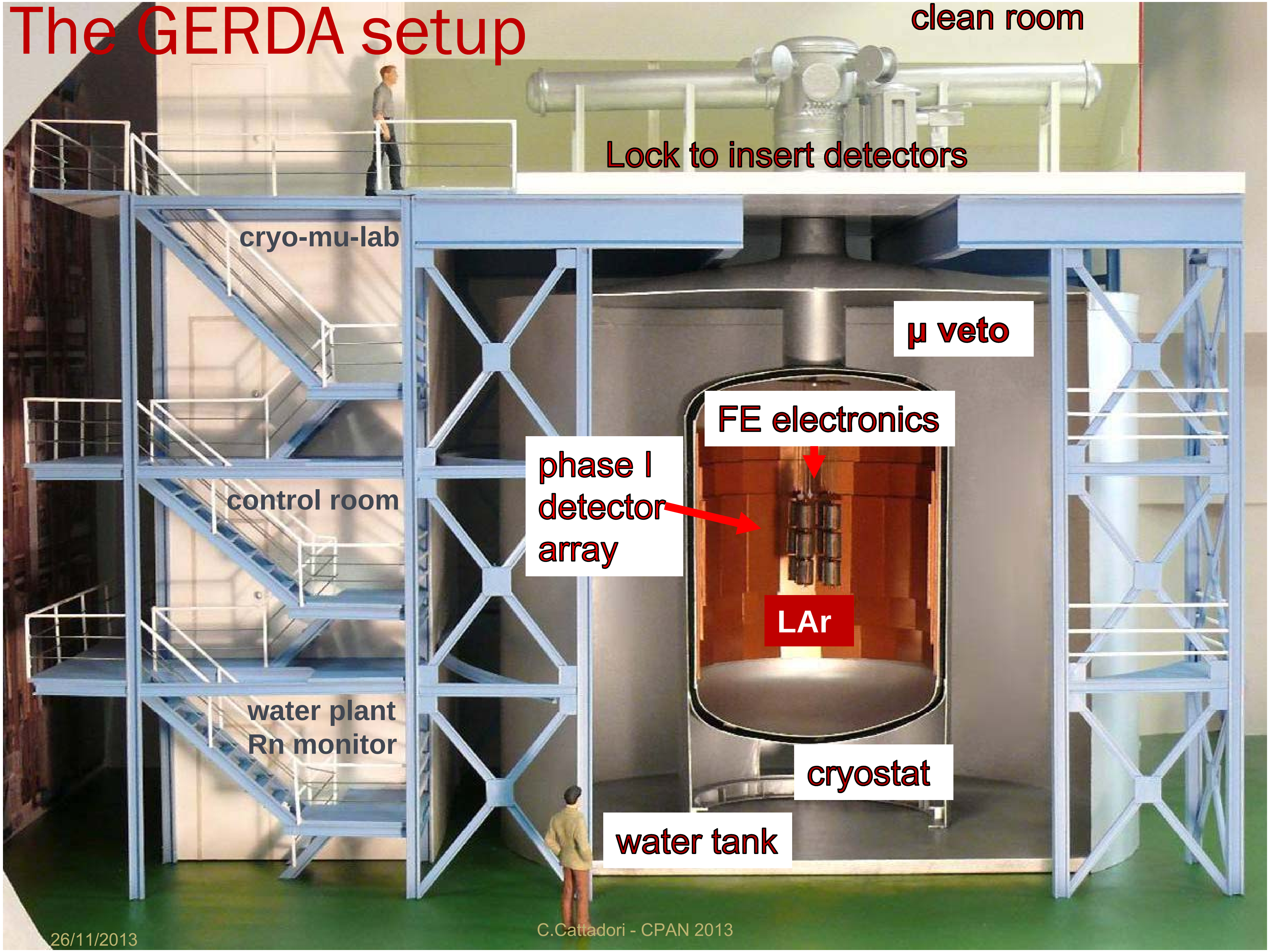
a' = number of "effective" isotope moles **B'**= cts/(keV a' y)



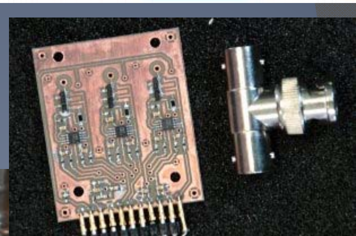
DBD experiments summary

Experiment	Isotope	Technique	Mass ββ(0ν) isotope	Status
CANDLES	48Ca	305 kg of CaF2 crystals - liq. scint	0.3 kg	Construction
CARVEL	48Ca	48CaWO4 crystal scint.	~ tonne	R&D
GERDA I	76Ge	Ge diodes in LAr	18 kg	Operating
GERDA II	76Ge	Point contact Ge in LAr	18+21 kg	Construction
Majorana D	76Ge	Point contact Ge	30 kg	Construction
1TGe (GERDA +MJ)	76Ge	Best technology from GERDA and MAJORANA	~ tonne	R&D
NEMO3	100Mo/ 82Se	Foils with tracking	6.9/0.9 kg	Complete
SuperNEMO D	82Se	Foils with tracking	7 kg	Construction
SuperNEMO	82Se	Foils with tracking	100 kg	R&D
LUCIFER	82Se	ZnSe scint. bolometer	18 kg	R&D
AMoRE	100Mo	CaMoO4 scint. bolometer	50 kg	R&D
MOON	100Mo	Mo sheets	200 kg	R&D
COBRA	116Cd	CdZnTe detectors	10 kg/183 kg	R&D
CUORICINO	130Te	TeO2 Bolometer	10 kg	Complete
CUORE-0	130Te	TeO2 Bolometer	11 kg	Operating
CUORE	130Te	TeO2 Bolometer	206 kg	Construction
SNO+	130Te	0.1% natNd suspended in Scint	55 kg	Construction
KamLAND-ZEN	136Xe	2.7% in liquid scint.	380 kg	Operating
NEXT-100	136Xe	High pressure Xe TPC	80 kg	Construction
EXO200	136Xe	Xe liquid TPC	160 kg	Operating
nEXO	136Xe	Xe liquid TPC	~ tonne	R&D
DCBA	150Nd	Nd foils & tracking chambers	20 kg	R&D

The GERDA setup

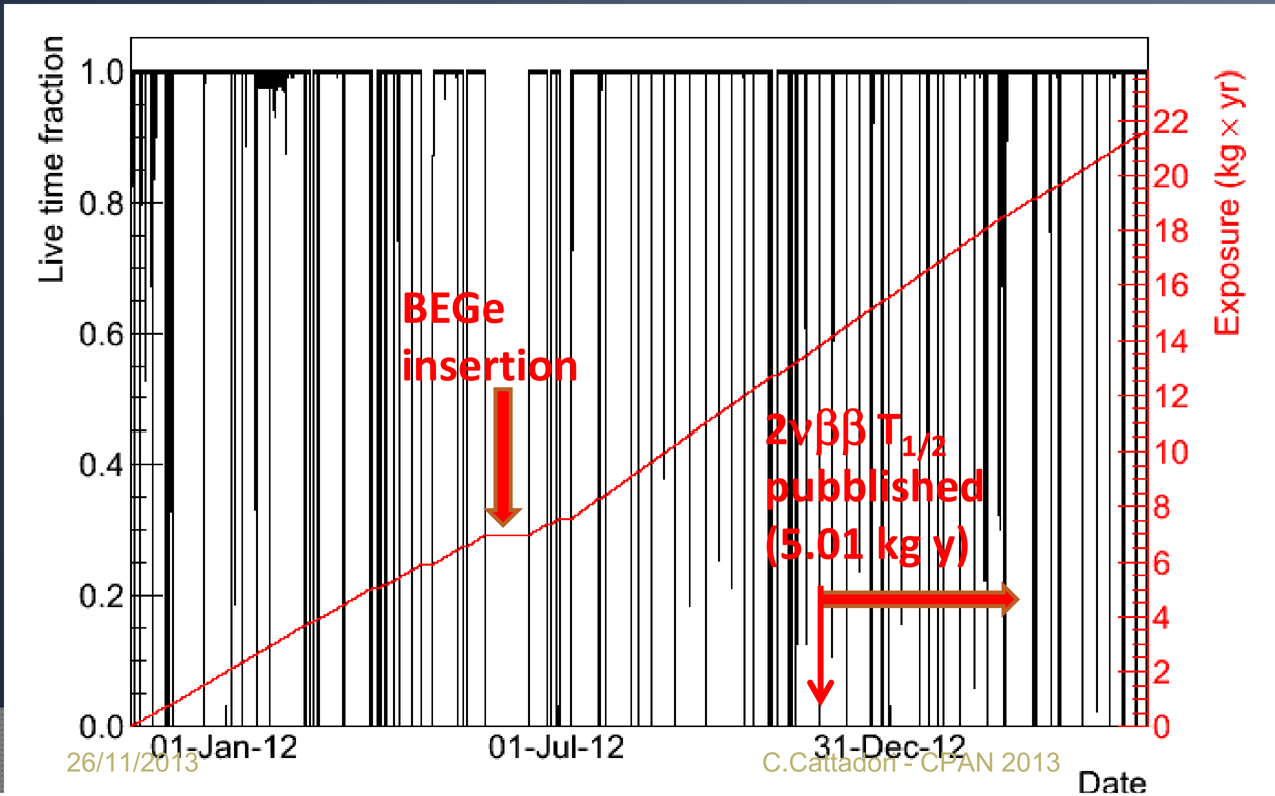


A tour in GERDA



Building the exposure up.....

- Total of 21.6 kg y: from 6 November 2011 to 3rd May 2013
- 6 of 8 Semi-Coaxial ^{enr}Ge detectors of the former IGEX and HdM in the $0\nu\beta\beta$ data sets (2 diodes high LC)
- 1 ^{nat}Ge semi-coaxial detector (not in the $0\nu\beta\beta$ data set)
- June 2012: 5 new $^{enr}BEGe$ detectors deployed to compensate the lost of two coax.



The energy scale is monitored by:
- Weekly ^{228}Th calibrations

Electronics Stability monitored by: Pulser

Prior detector deployment, Mass, isotope fraction accurately remeasured: related errors considered

arXiv: 1306.5084v1

- 21.6 kg y→ 215.2 ±7.6 moles of ^{76}Ge

Accuarte weight

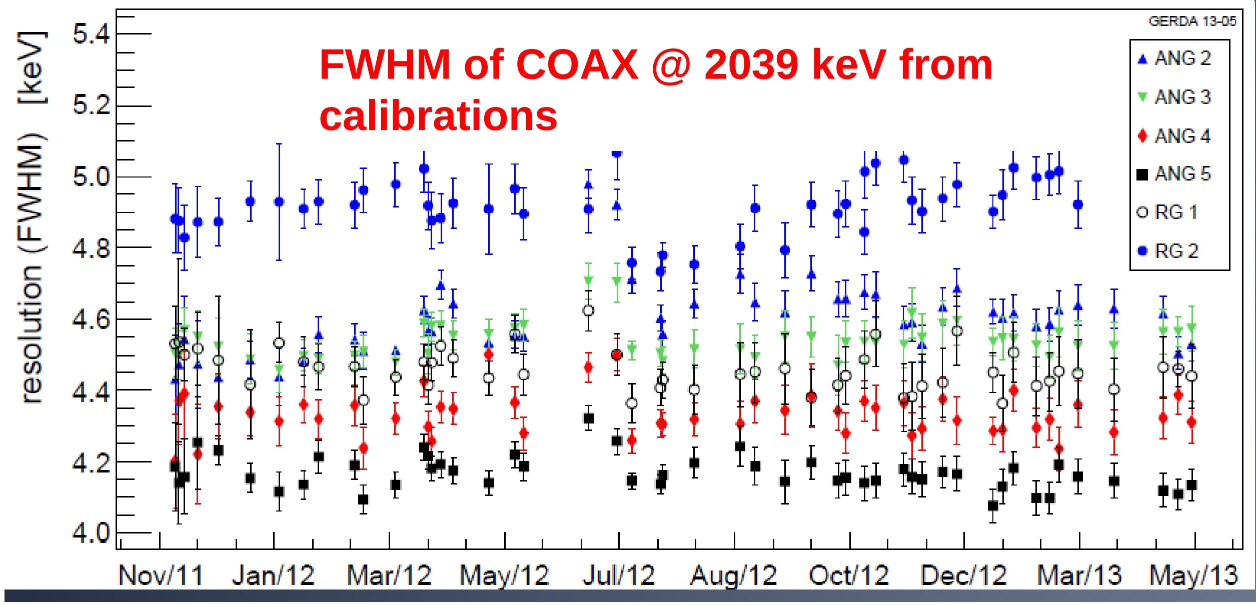
ICPMS

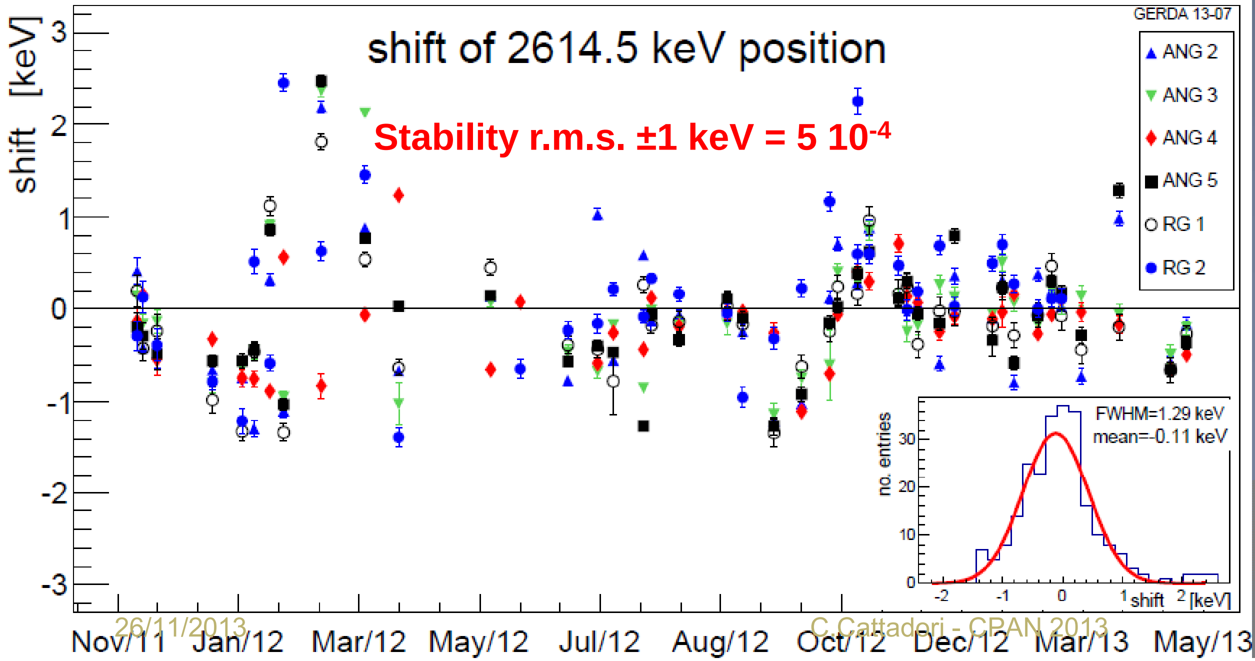
Low E γ-sources

detector	f_{76}	M g	$M_{act}(\Delta M_{act})$ g	$f_{av}(\Delta f_{av_t})$	d_{dl} mm
enriched coaxial detectors					
ANG 1 †)	0.859(29)	958	795(50)	0.830(52)	1.8(5)
ANG 2	0.866(25)	2833	2468(145)	0.871(51)	2.3(7)
ANG 3	0.883(26)	2391	2070(136)	0.866(57)	1.9(7)
ANG 4	0.863(13)	2372	2136(135)	0.901(57)	1.4(7)
ANG 5	0.856(13)	2746	2281(132)	0.831(48)	2.6(6)
RG 1	0.855(15)	2110	1908(125)	0.904(59)	1.5(7)
RG 2	0.855(15)	2166	1800(115)	0.831(53)	2.3(7)
RG 3 †)	0.855(15)	2087	1868(113)	0.895(54)	1.4(7)
enriched BEGe detectors					
GD32B	0.877(13)	717	638(19)	0.890(27)	1.0(2)
GD32C	0.877(13)	743	677(22)	0.911(30)	0.8(3)
GD32D	0.877(13)	723	667(19)	0.923(26)	0.7(2)
GD35B	0.877(13)	812	742(24)	0.914(29)	0.8(3)
GD35C †)	0.877(13)	635	575(20)	0.906(32)	0.8(3)
natural coaxial detectors					
GTF 32 †)	0.078(1)	2321	2251(116)	0.97(5)	0.4(8)
GTF 45 †)	0.078(1)	2312			
GTF 112	0.078(1)	2965			

The Energy Scale over data taking: COAX

arXiv: 1306.5084v1





From 1525 keV ^{42}K γ-line summed COAX spectra

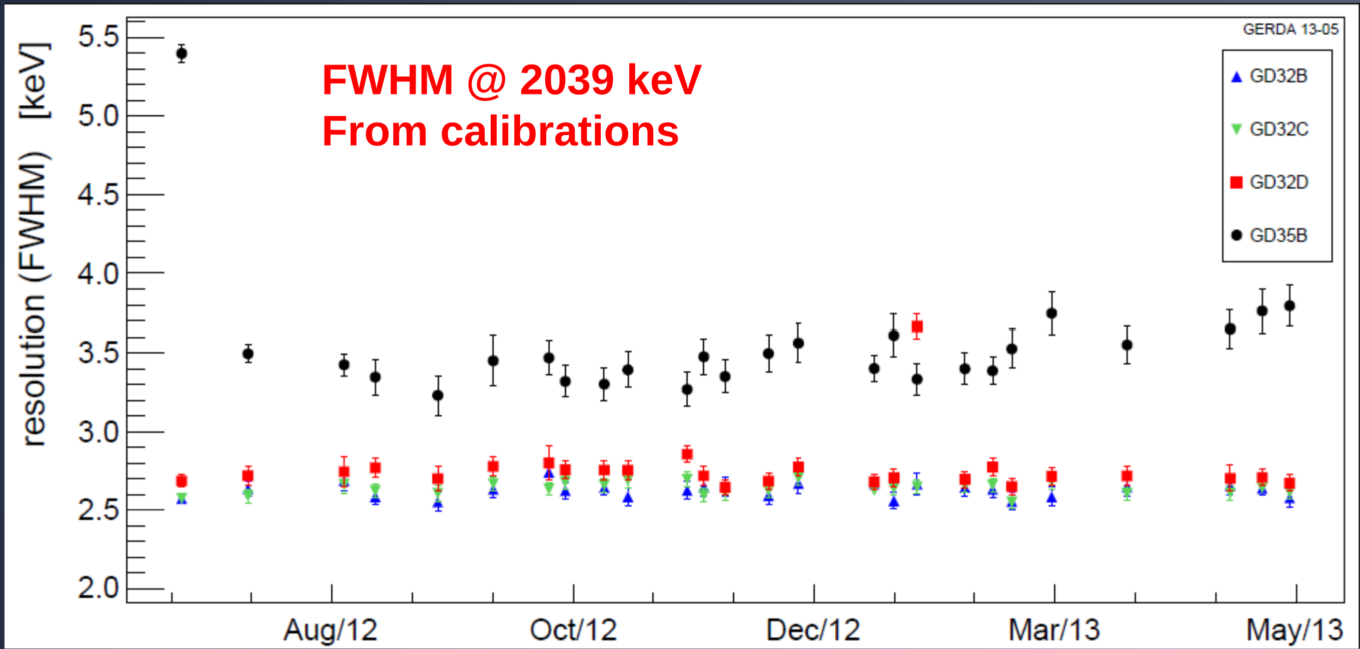
detector	FWHM @ 2039 keV
ANG2	5.8 ± 0.3
ANG3	4.5 ± 0.1
ANG4	4.9 ± 0.3
ANG5	4.2 ± 0.1
RG1	4.5 ± 0.3
RG2	4.9 ± 0.3
Mean COAX	4.8 ± 0.2

Energy :
From semi-gaussian DSP of the acquired waveforms

DAQ facts:
14 bit, 100 MHz continuos running ADC.
TRG thrsd:40-100 keV

arXiv: 1306.5084v1

The Energy Scale: BEGEs



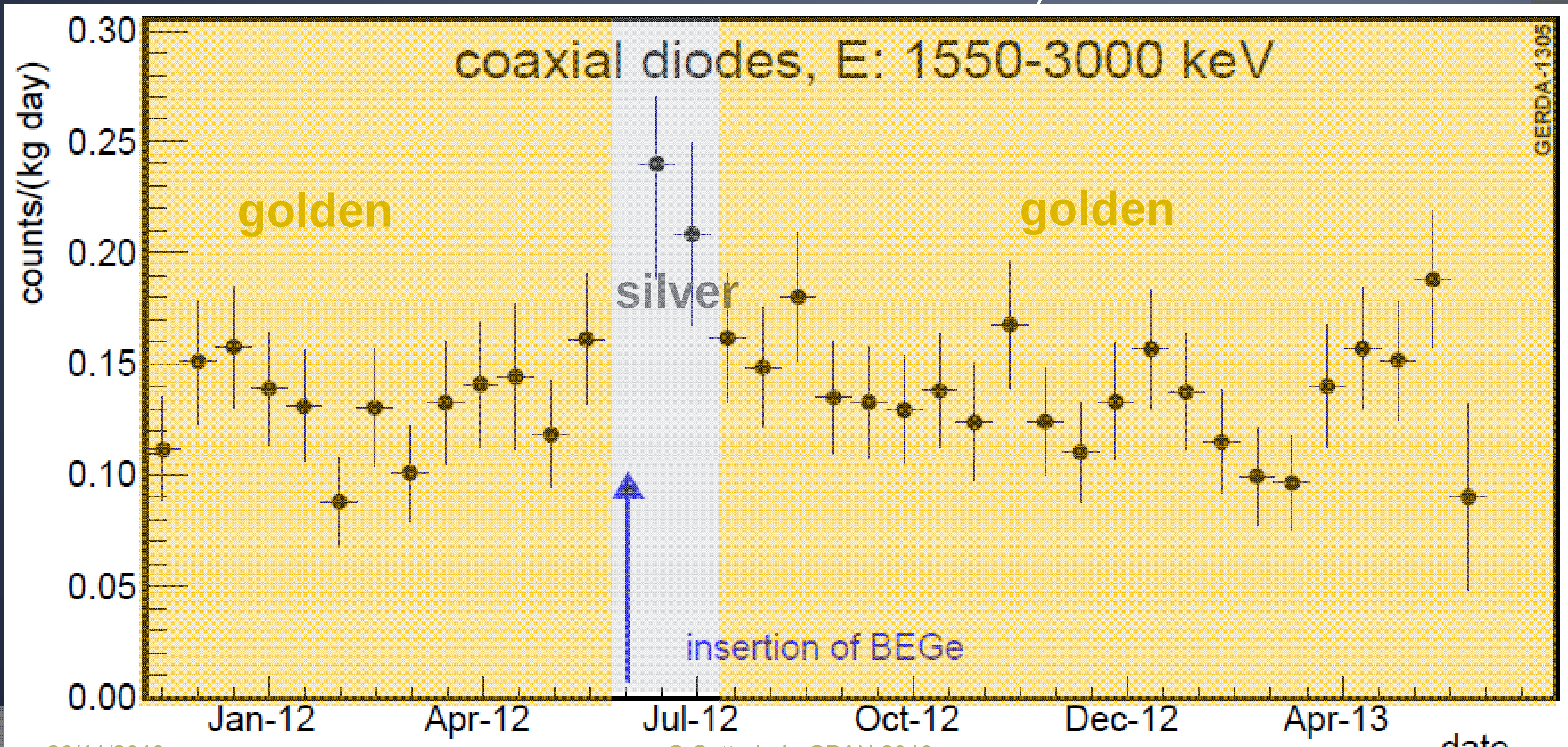
From 1525 keV ^{42}K γ-line summed BEGe spectra

detector	FWHM @ 2039 keV
GD32B	2.6 ± 0.1
GD32C	2.6 ± 0.1
GD32D	3.7 ± 0.5
GD35B	4.0 ± 0.1
Mean BEGE	3.2 ± 0.2

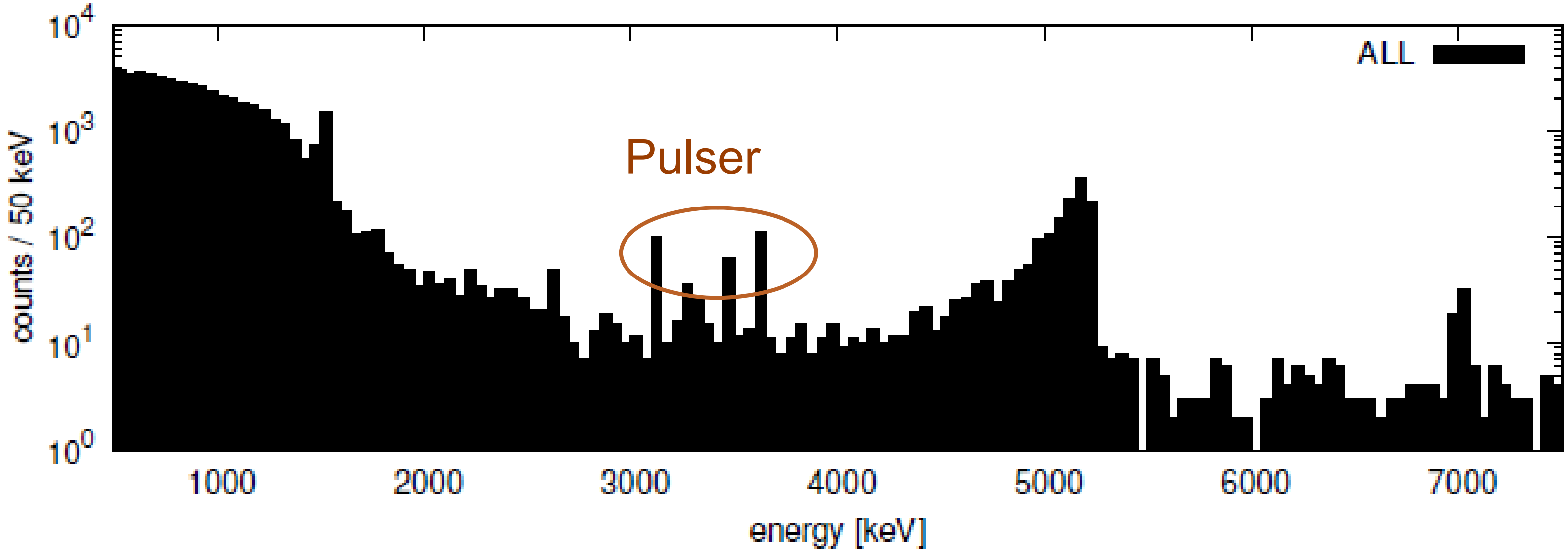
1 ^{enr}BEGe not used in the 0νββ data sets because of instabilities

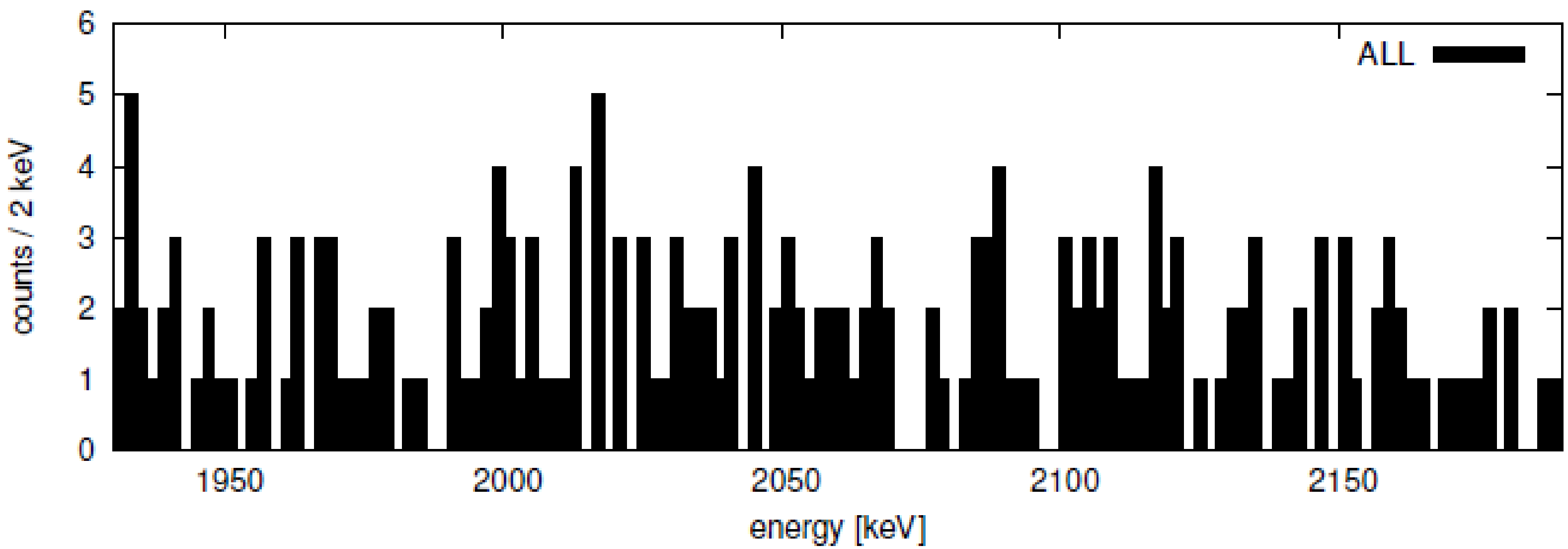
GERDA Data Sets

- Golden coax: all the coax runs apart from 30 days just after the BEGe insertion in june 2012
- Silver coax: The coax data collected in the 30 days following the BEGe insertion
- BEGe: Treated separately because of intrinsic differences (better FWHM, intrinsic PSD, lower alfa contamination)

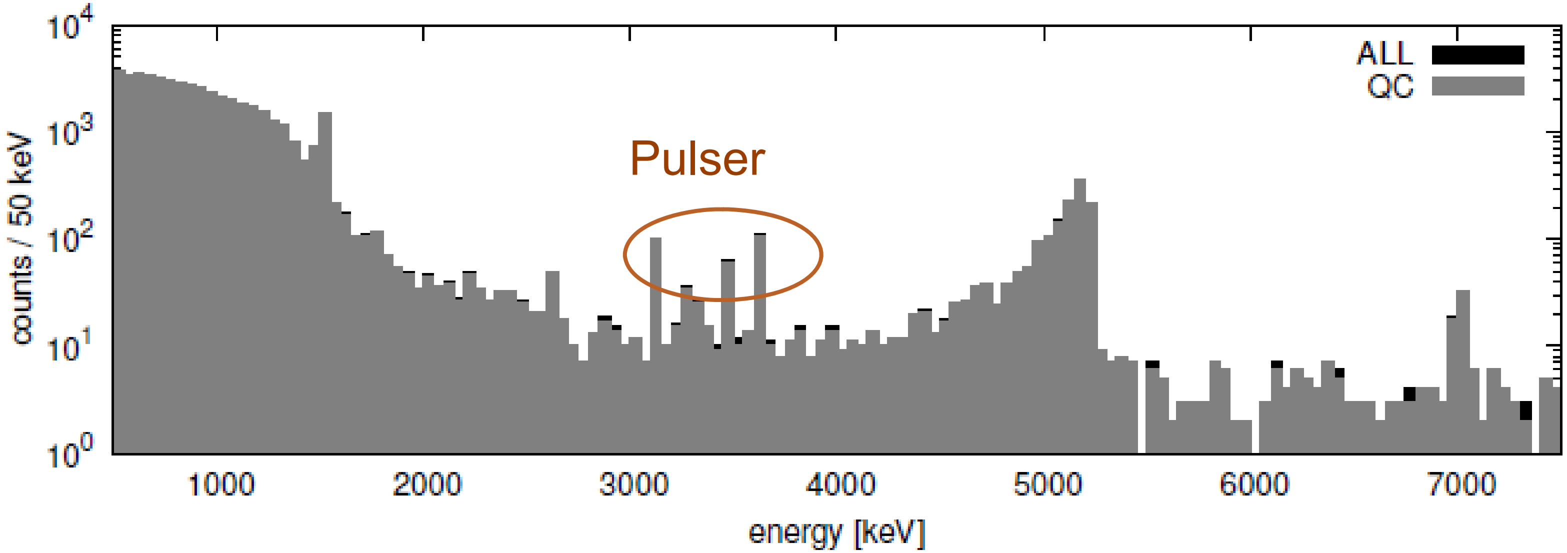


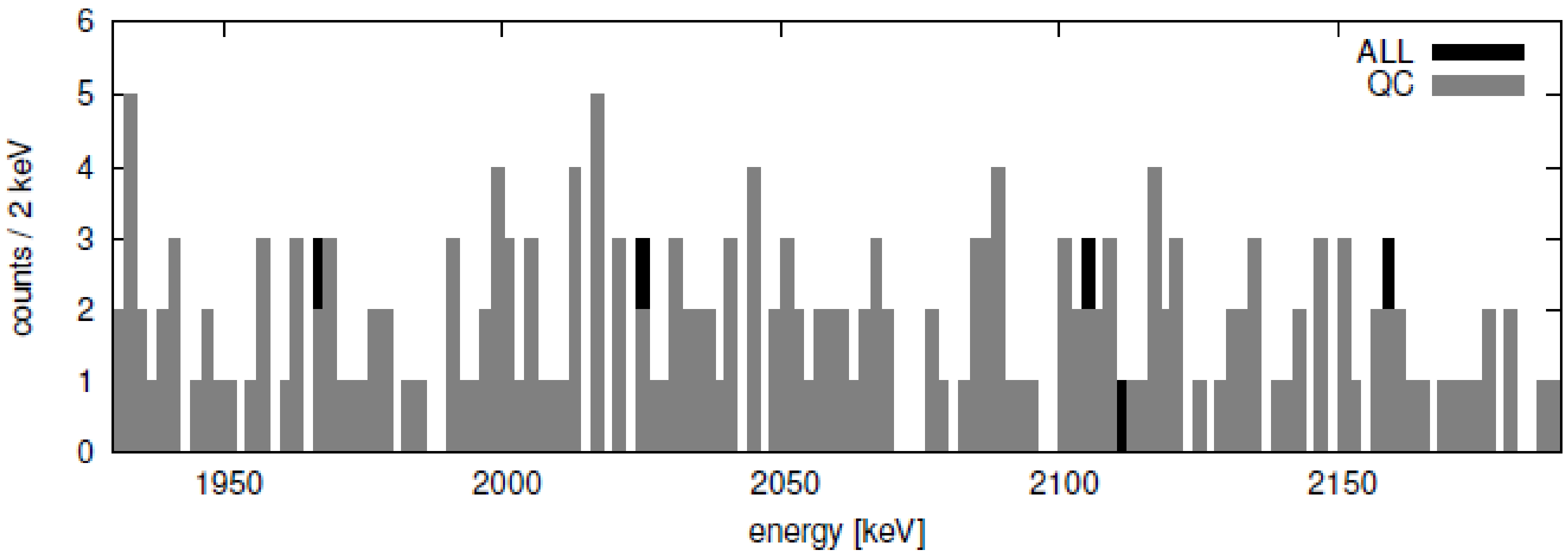
Events accepted by the analysis cut 50 keV binning



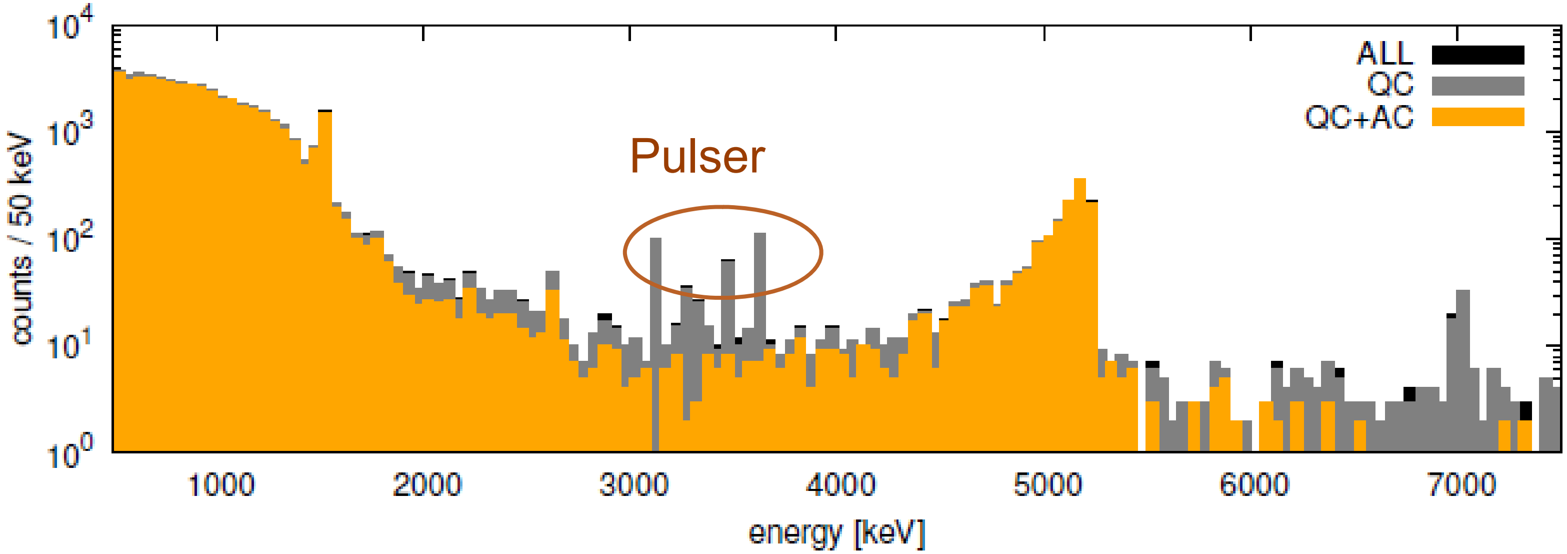


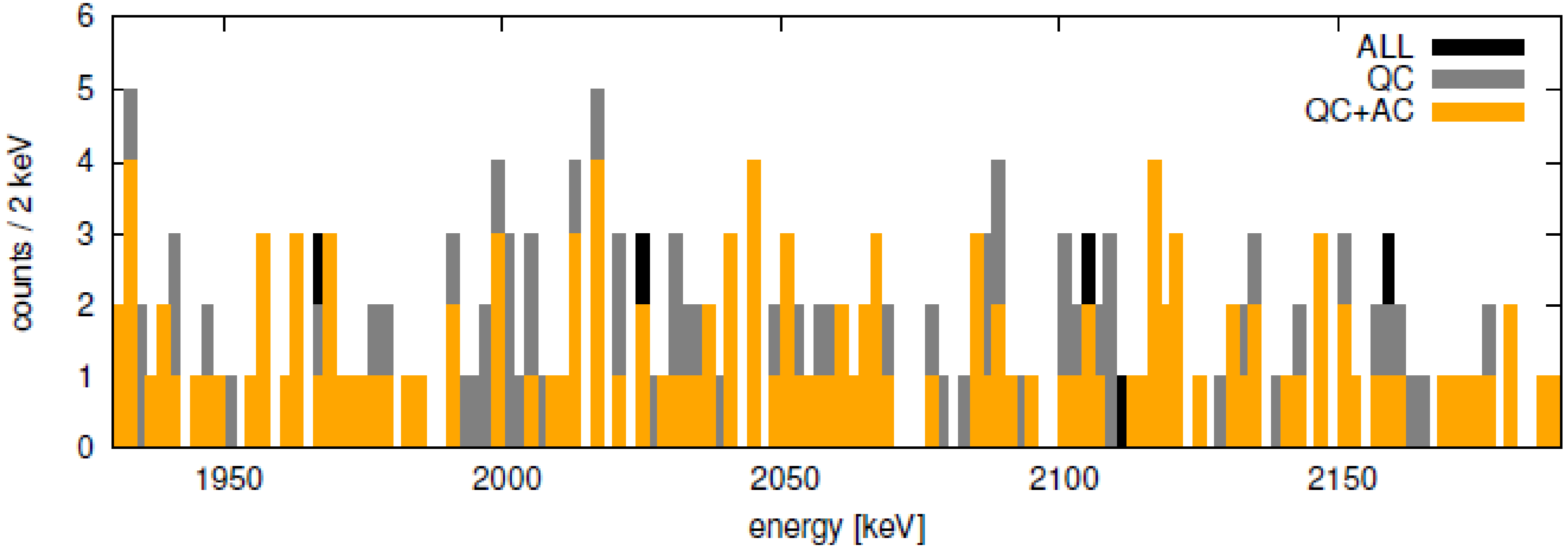
Events accepted by the analysis cut 50 keV binning



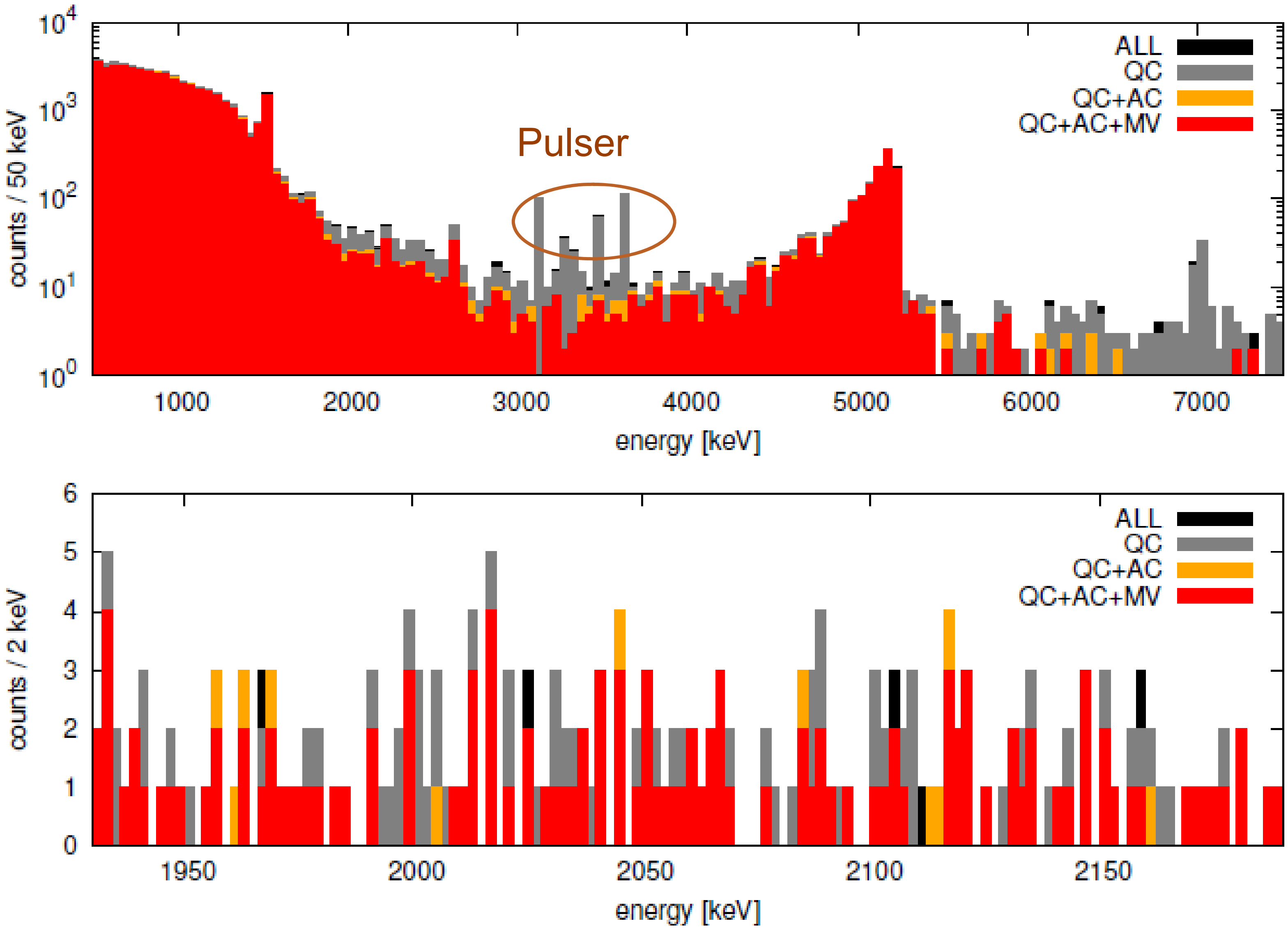


Events accepted by the analysis cut 50 keV binning

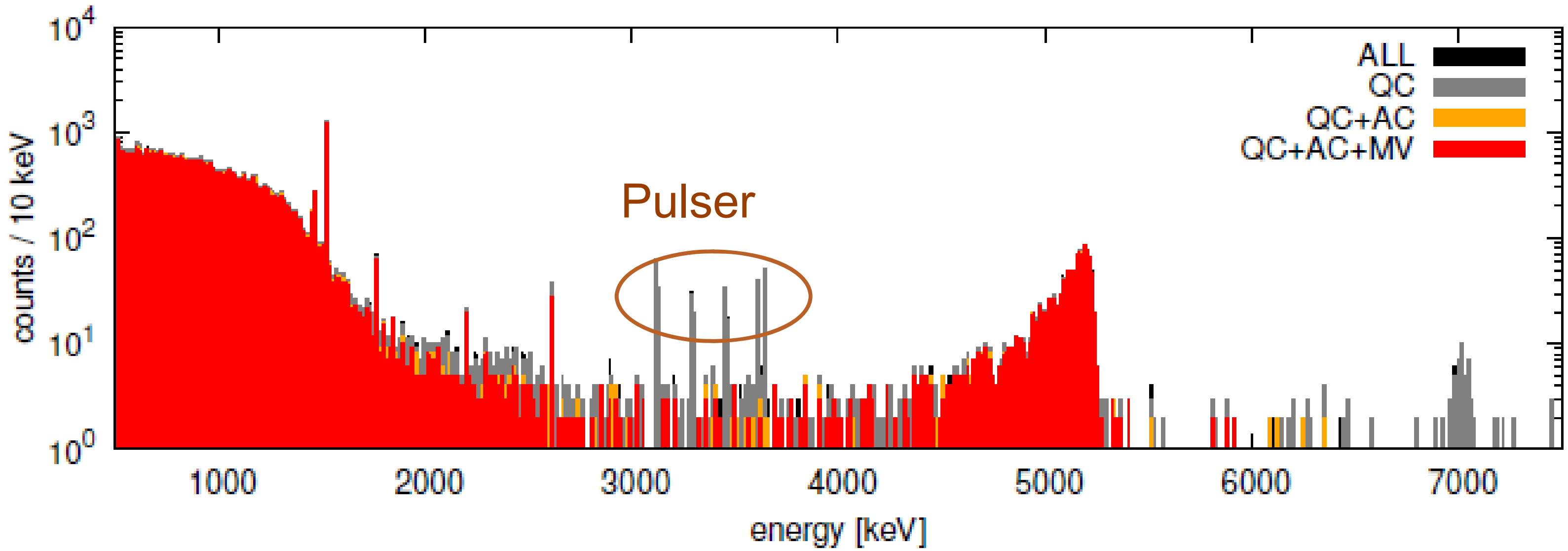


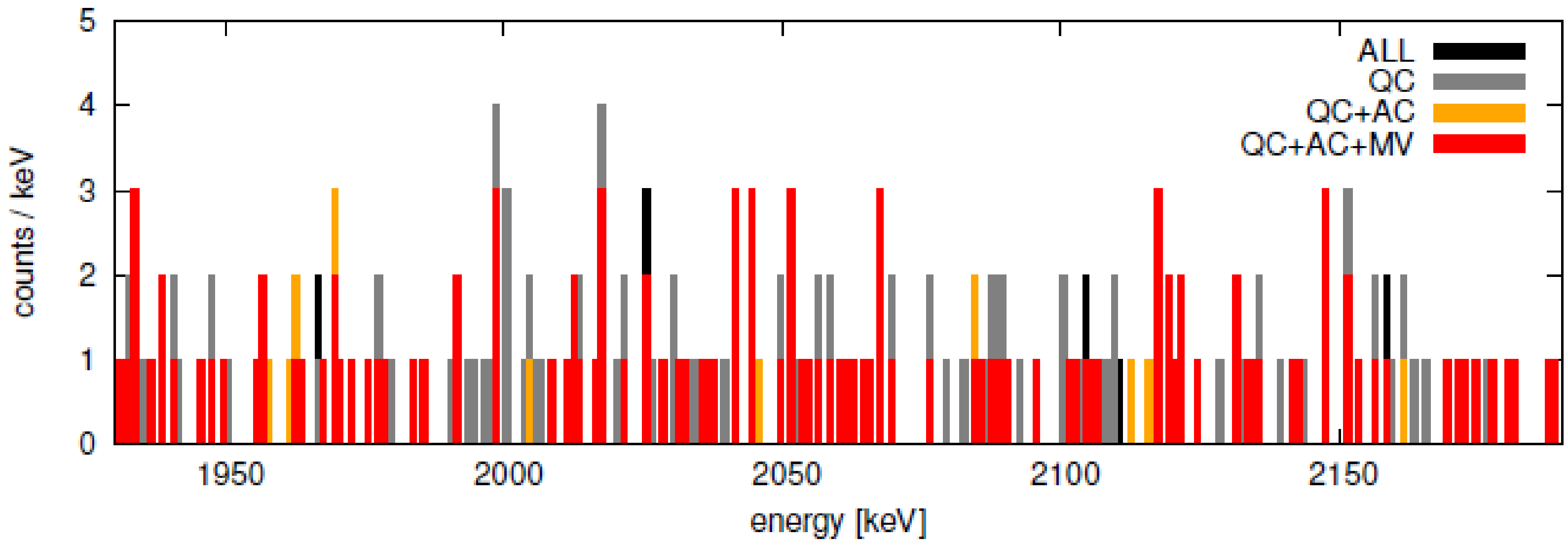


Events accepted by the analysis cut 50 keV binning



Events accepted by the analysis cut 10 keV binning



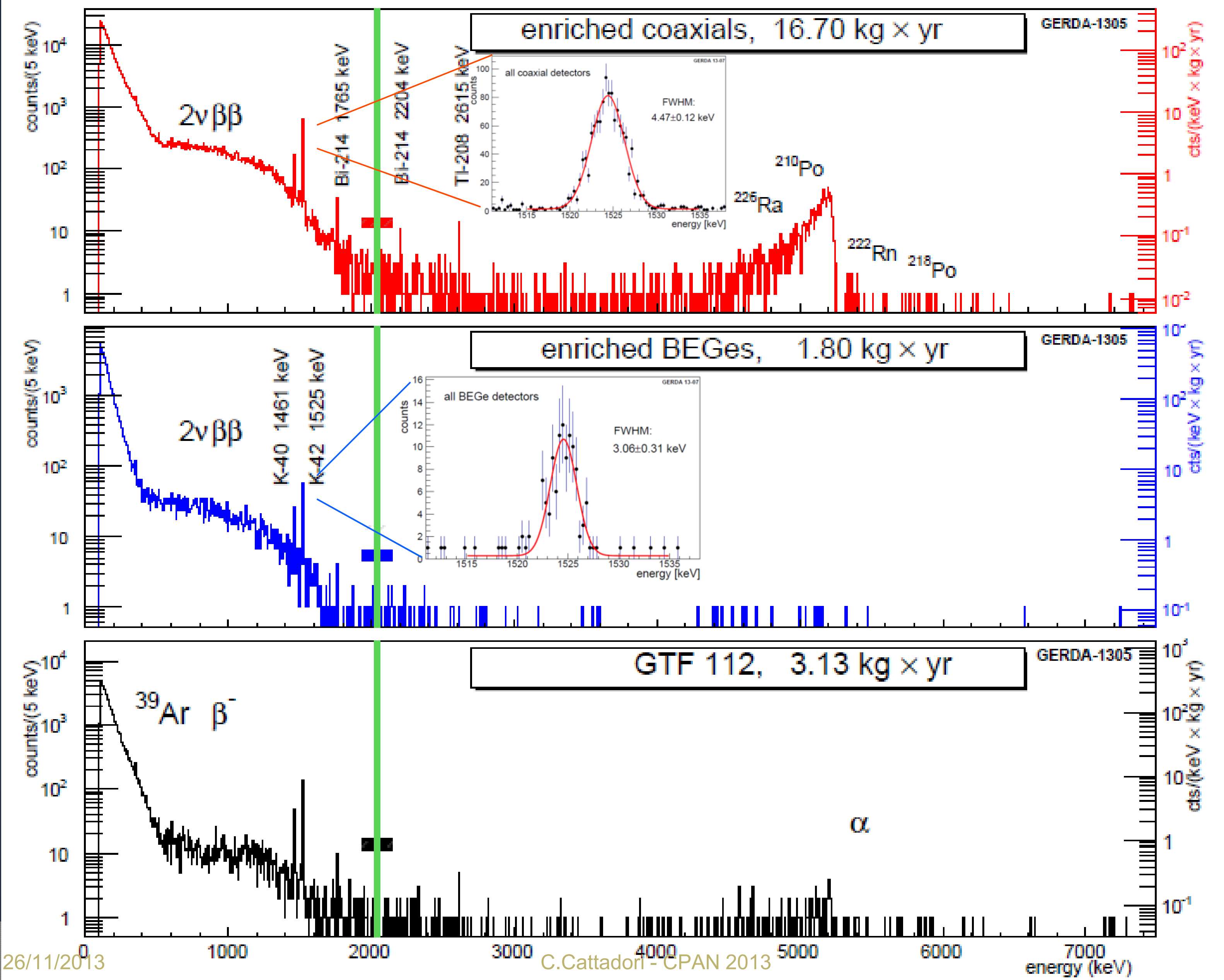


Acceptance of the cuts used in $0\nu\beta\beta$ analysis

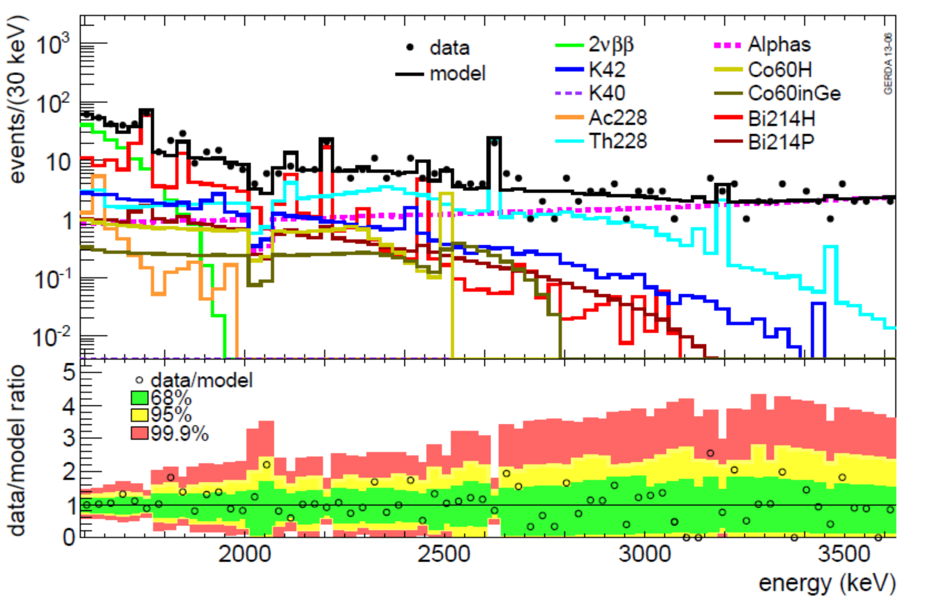
QC:	quality cuts	single physical pulse in the waveform
AC:	detector anti-coincidence	only events with a single pulse
MV:	muon-veto	no time-coincidence with muon-veto signals

	acceptance of the raw number of events	
cuts	E> 500 keV	1930<E<2190 keV
QC	(99.7±0.6)%	(98±10)%
QC+AC	(94.5±0.6)%	(66±7)%
QC+AC+MV	(93.7±0.6)%	(60±7)%

The energy spectra: events falling in ±20 keV around $Q_{\beta\beta}$ not reconstructed (blinded)

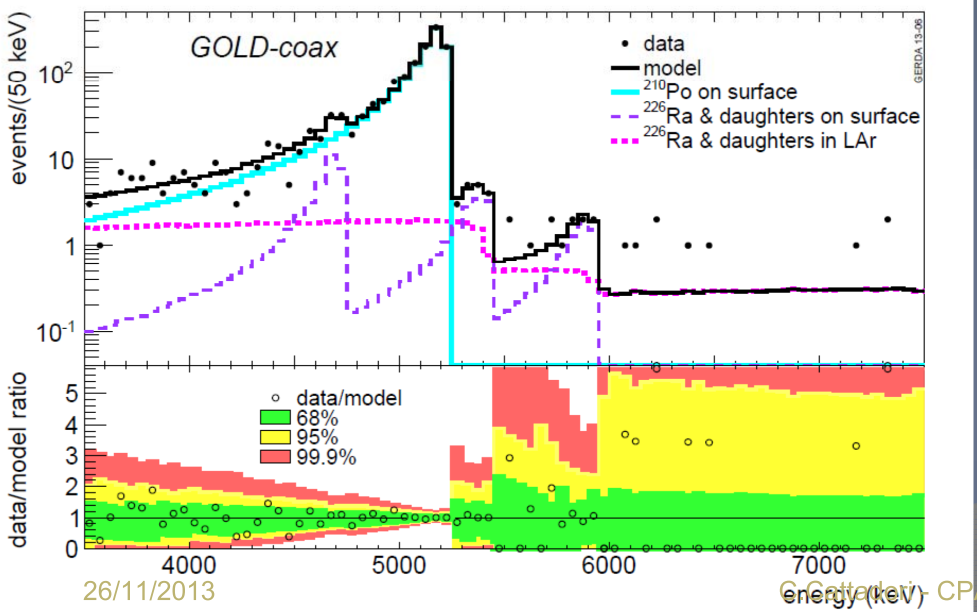


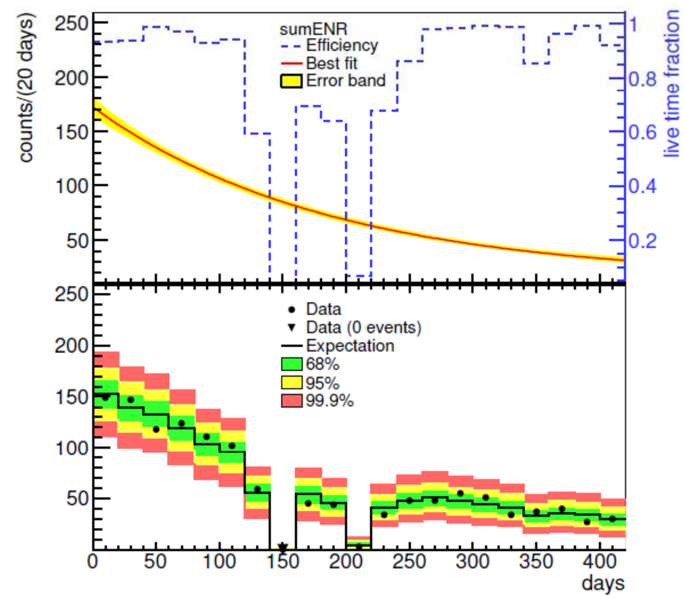
Identification of Background Components



arXiv: 1306.5084v2

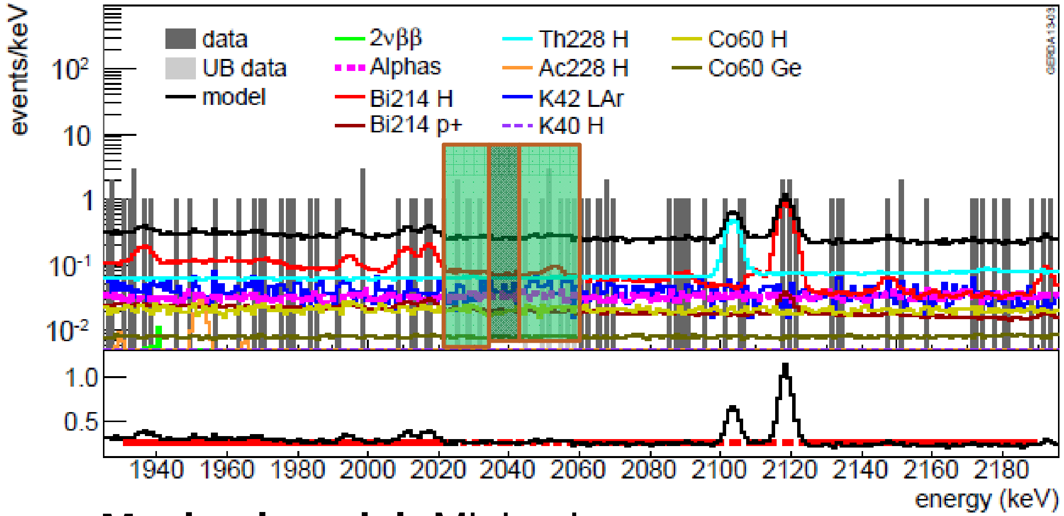
- α contamination from ^{210}Po.
- contamination at time of refurbishment mostly on thin p+ contact
- ^{210}Po decaying away ($t_{1/2}$=138 d)
- Large differences among detectors
- BEGes much cleaner (> factor 10)



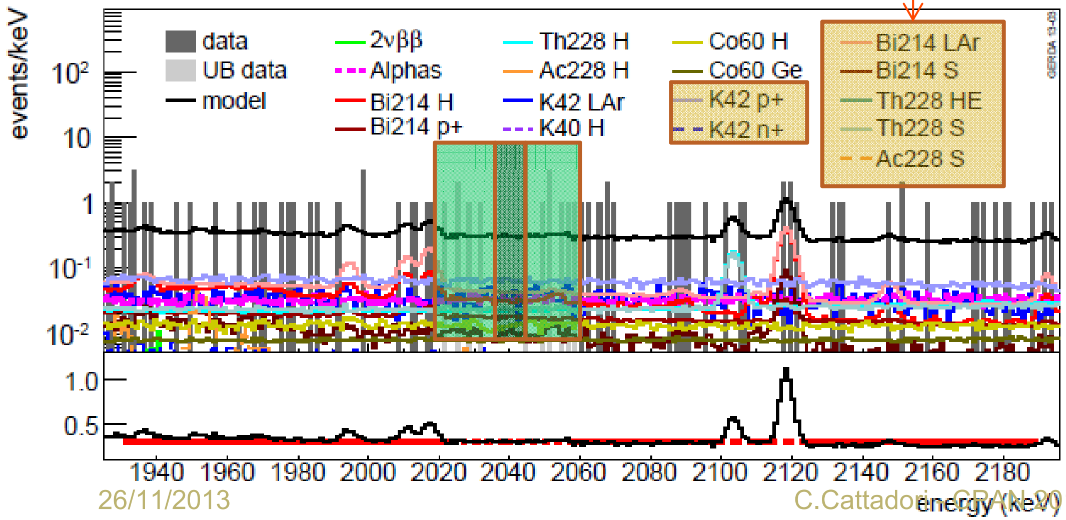


Background model predictions vs data in 260 keV range around Q_ββ

Minimal model



Maximal model: Minimal +



- The model reproduces a flat bckgrd around Q_ββ
- No γ-lines visible in the 30 keV around the Q_ββ

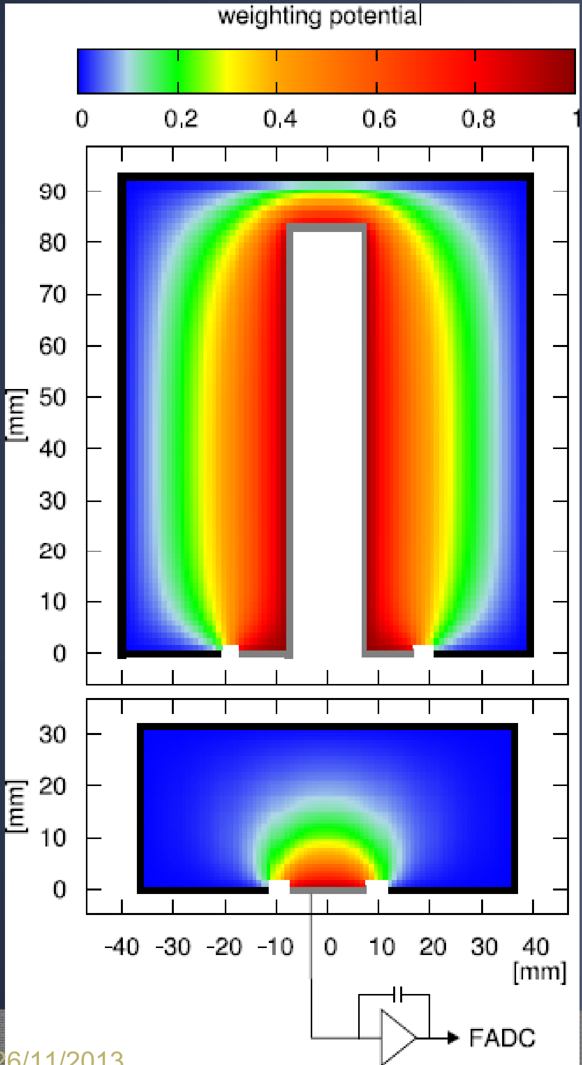
→ spectra can be fitted with a flat background apart from ^{214}Bi lines @ 2104 keV and 2119 keV

arXiv: 1306.5084v2

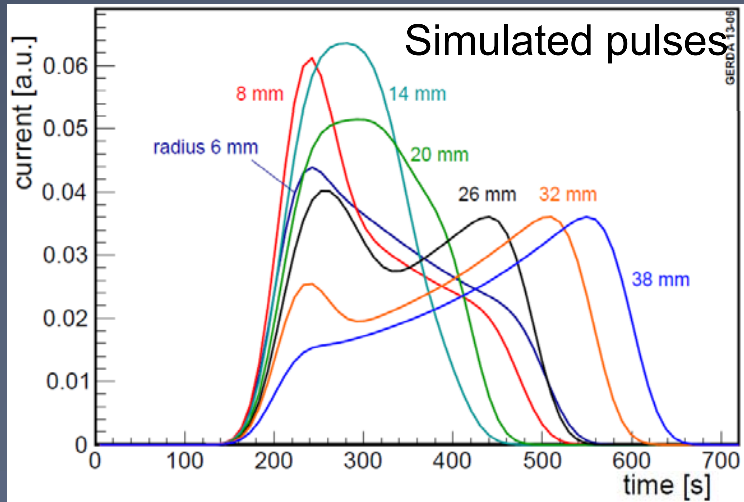
PSD to discriminate ββ-like (SSE) to γ-like (MSE) events

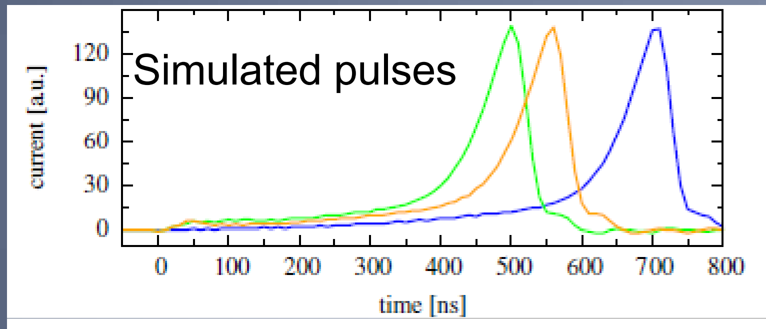
EPJC 73(2013) 2583

Different weighting potentials for Coax and BEGe



COAX: Artificial Neural Network (ANN) estimator used as PSD parameter





BEGe: Amplitude of Current/Amplitude of Charge Pulse (A/E) is the PSD parameter

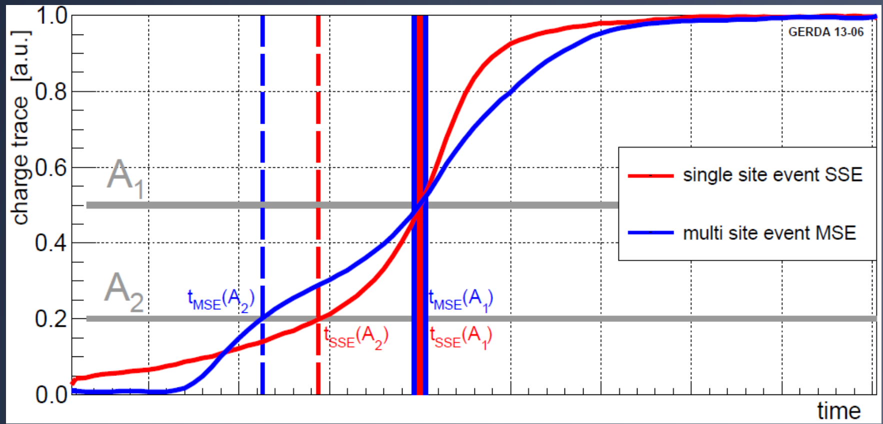
PSD for coax

EPJC 73(2013) 2583

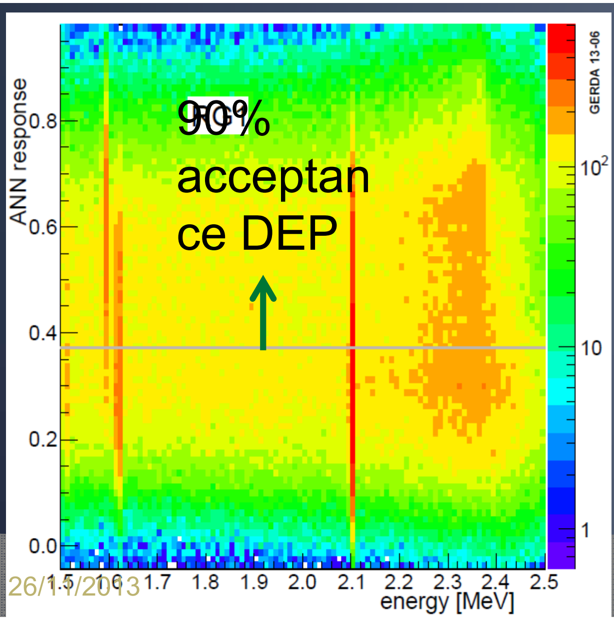
ANN trained on

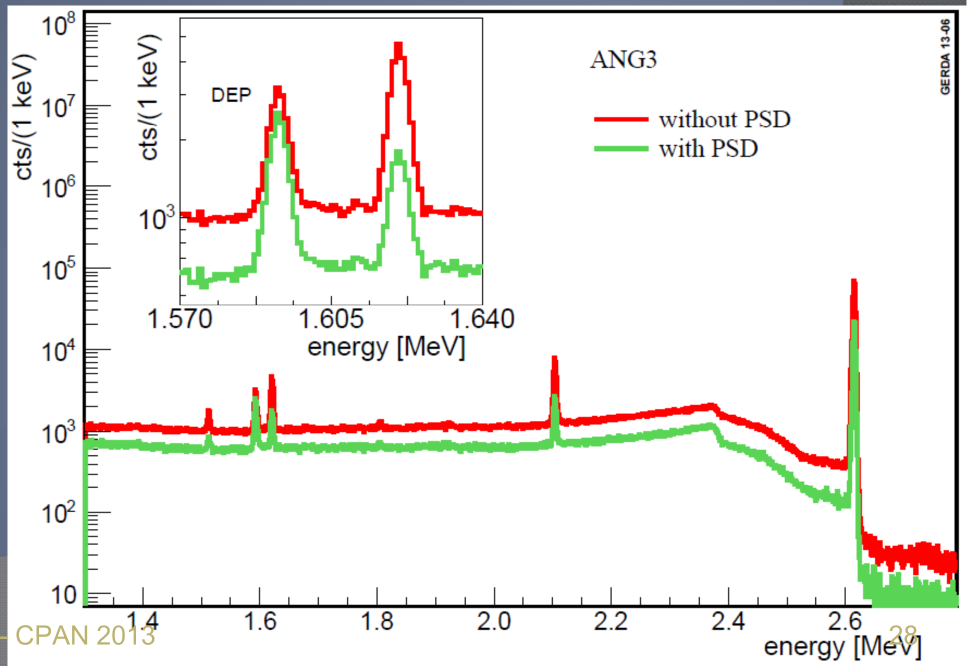
SIGNAL (SSE) : ^{208}Tl (2614 keV) Double Escape Peak (DEP) @ 1592 keV line

BACKGROUND (MSE): ^{212}Bi @ 1620 keV γ-line



- Required 90% acceptance of DEP
- ε for other classes of events derived
- acceptance of SSE verified on Compton edges (CE) and 2νββ





..to conclude PSD efficiencies and their systematics are evaluated

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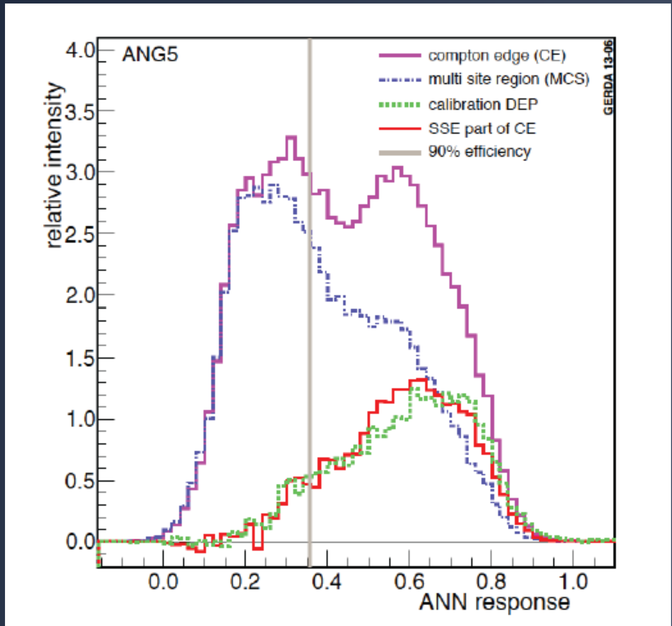
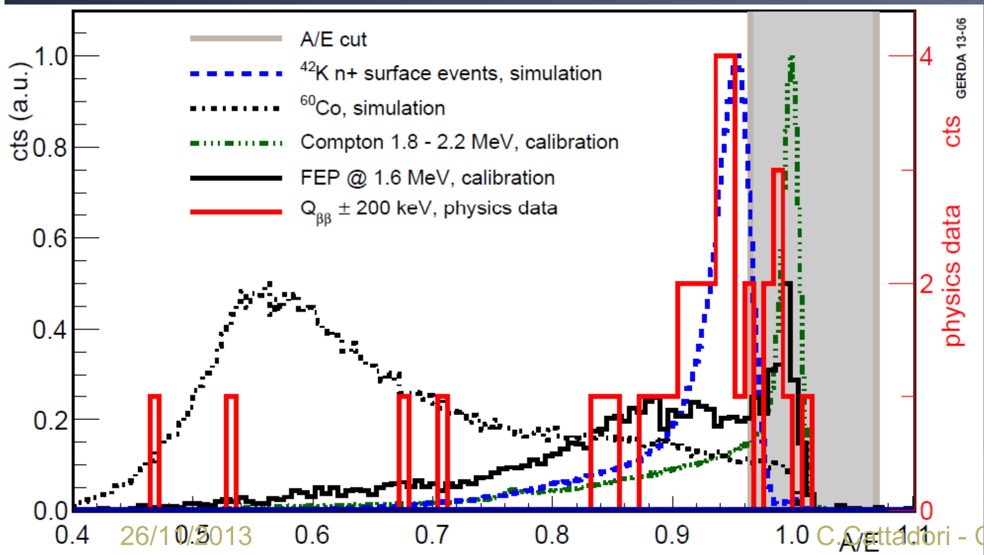


	$\varepsilon_{2\nu\beta\beta}$	$\varepsilon_{0\nu\beta\beta}$
Coax	0.85 ± 0.02	0.90 ± 0.1
BEGe	0.91 ± 0.05	0.92 ± 0.02



Bckgrd rejection= 33 of 40 events rejected in ±200 keV range.

BI_{PSD} = 0.7 10^{-2} cts/(keV kg y)

Summary of parameters and systematics relevant to $T_{1/2}^{0\nu}$

Energy Windows at $Q_{\beta\beta}$=2039 keV

76Ge fraction

Active volume fraction

ββ FEP efficiency

PSD efficiency

Total efficiency

Data set	FWHM [keV]	ROI [keV]	$\langle f_{76} \rangle$	$\langle f_{av} \rangle$	$\langle \varepsilon_{fep} \rangle$	$\langle \varepsilon_{PSD} \rangle$	$\langle \varepsilon \rangle$
Coax	4.8 ± 0.2	± 5	0.86	0.87	0.92	$0.90^{+0.05}_{-0.09}$	$0.619^{+0.044}_{-0.070}$
BEGe	3.2 ± 0.2	± 4	0.88	0.92	0.90	0.92 ± 0.02	0.663 ± 0.022

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The blinded/unblinded data

- Data blinded since january 2012:

Events in ± 20 keV around $Q_{\beta\beta}$ removed from Tier1

- Unblinding in two steps:
  - May 2013: Unblinded ± 15 keV around still blinded ± 5 keV @ $Q_{\beta\beta}$
  - 17 June 2013 @ GERDA Plenary meeting in Dubna (RU):

    Unblinded the ± 5 keV region @ $Q_{\beta\beta}$

Table 1: List of all events within $Q_{\beta\beta} \pm 5$ keV

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data set	detector	energy [keV]	date	PSD passed	ANN	A/E	Cut Threshold
golden	ANG 5	2041.8	18-Nov-2011 22:52	no	0.344		0.366
silver	ANG 5	2036.9	23-Jun-2012 23:02	yes	0.518		0.366
golden	RG 2	2041.3	16-Dec-2012 00:09	yes	0.682		0.364
BEGe	GD32B	2036.6	28-Dec-2012 09:50	no		0.750	0.965÷1.070
golden	RG 1	2035.5	29-Jan-2013 03:35	yes	0.713		0.372
golden	ANG 3	2037.4	02-Mar-2013 08:08	no	0.205		0.345
golden	RG 1	2041.7	27-Apr-2013 22:21	no	0.369		0.372

The unblinded spectrum @ Q_bb

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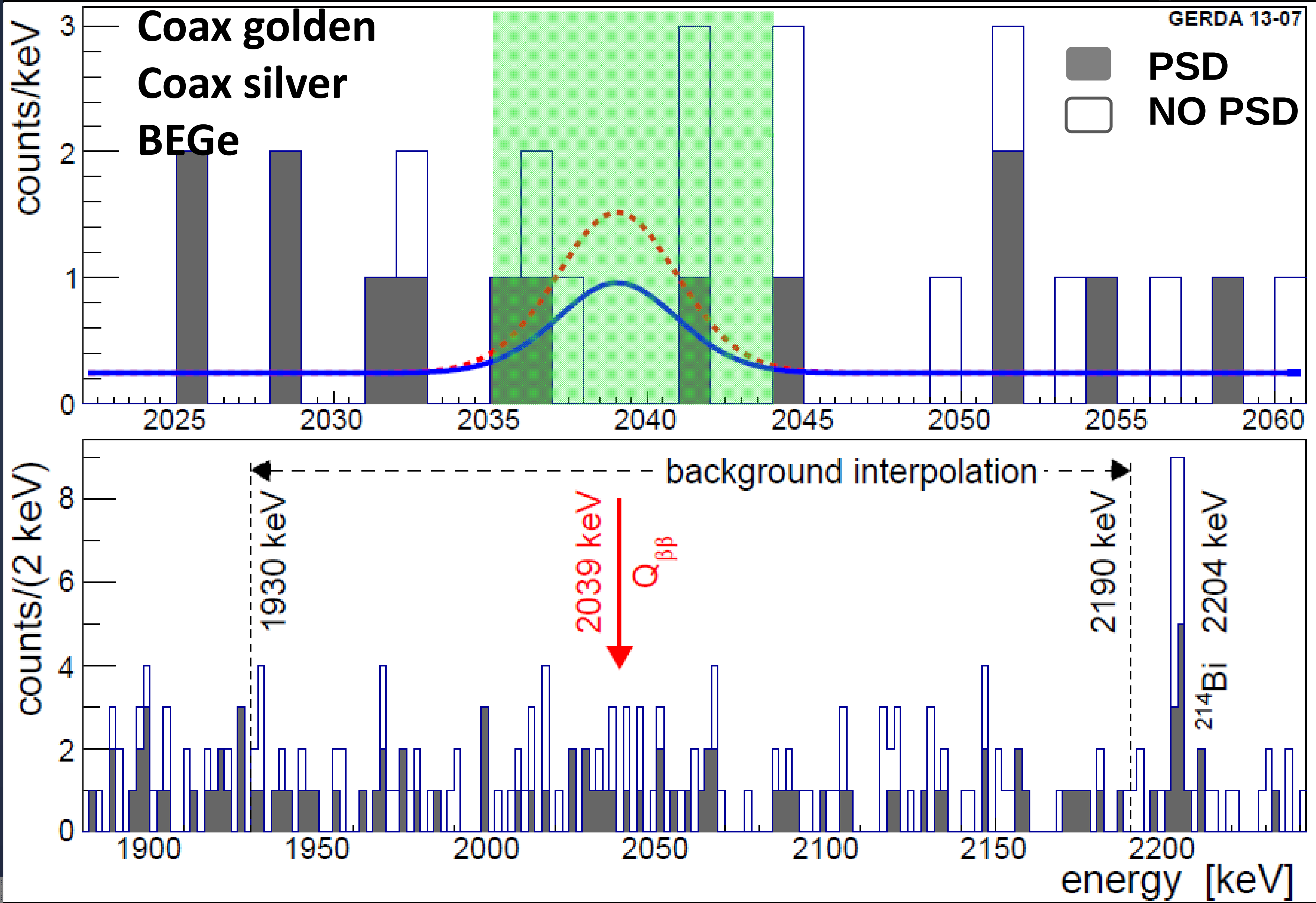

From counts to $T_{1/2}^{0\nu}$: the relevant numbers

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GERDA

$$T_{1/2}^{0\nu} = \frac{\ln 2 \cdot N_A}{m_{enr} \cdot N^{0\nu}} \cdot \mathcal{E} \cdot \epsilon$$

$$\epsilon = f_{76} \cdot f_{av} \cdot \varepsilon_{fep} \cdot \varepsilon_{psd}$$

In 230 keV @$Q_{\beta\beta}$

In ± 5 keV @ $Q_{\beta\beta}$

Expected bckgd only

data set	$\mathcal{E}$[kg·yr]	$\langle\epsilon\rangle$	bkg	BI †)	cts	Expected bckgd only
without PSD						
golden	17.9	0.688 ± 0.031	76	18 ± 2	5	5.1
silver	1.3	0.688 ± 0.031	19	63^{+16}_{-14}	1	
BEGe	2.4	0.720 ± 0.018	23	42^{+10}_{-8}	1	
with PSD						
golden	17.9	$0.619^{+0.044}_{-0.070}$	45	11 ± 2	2	2.5
silver	1.3	$0.619^{+0.044}_{-0.070}$	9	30^{+11}_{-9}	1	
BEGe	2.4	0.663 ± 0.022	3	5^{+4}_{-3}	0	

†) in units of 10^{-3} cts/(keV·kg·yr).

BI Rej $_{PSD}$ ^{Coax} ~ 43%

BI Rej $_{PSD}$ ^{BEGe} ~ 87%

$T_{1/2}^{0\nu}$ from GERDA data sets

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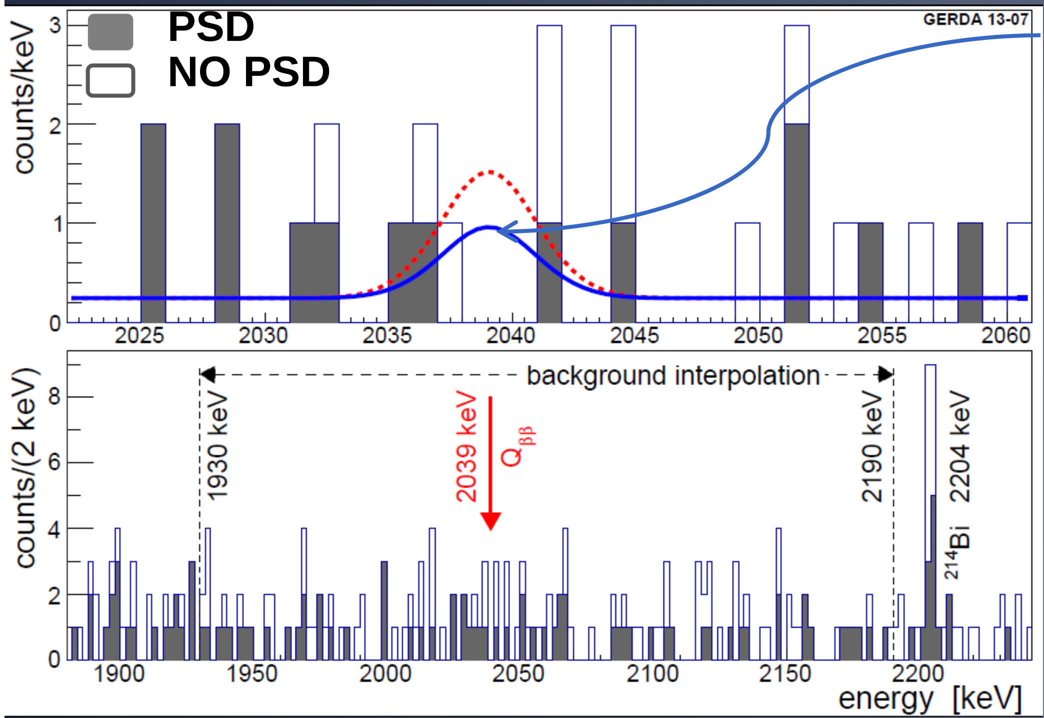
Performed Profile Likelihood fit of the 3 data sets

- B+S: described by constant term + Gaus($Q_{\beta\beta}$,σ_E)
- 4 free parameters in the fit B_{gold}, B_{silv},B_{BEGe},$1/ T_{1/2}^{0\nu}$
- Systematics folded in



Frequentist approach

Best fit: $N^{0\nu} = 0$

$N^{0\nu}$ < 3.5 cts @ 90% C.L.

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

Bayesian approach

Flat prior for $1 / T_{1/2}^{0\nu}$

Best fit: $N^{0\nu} = 0$

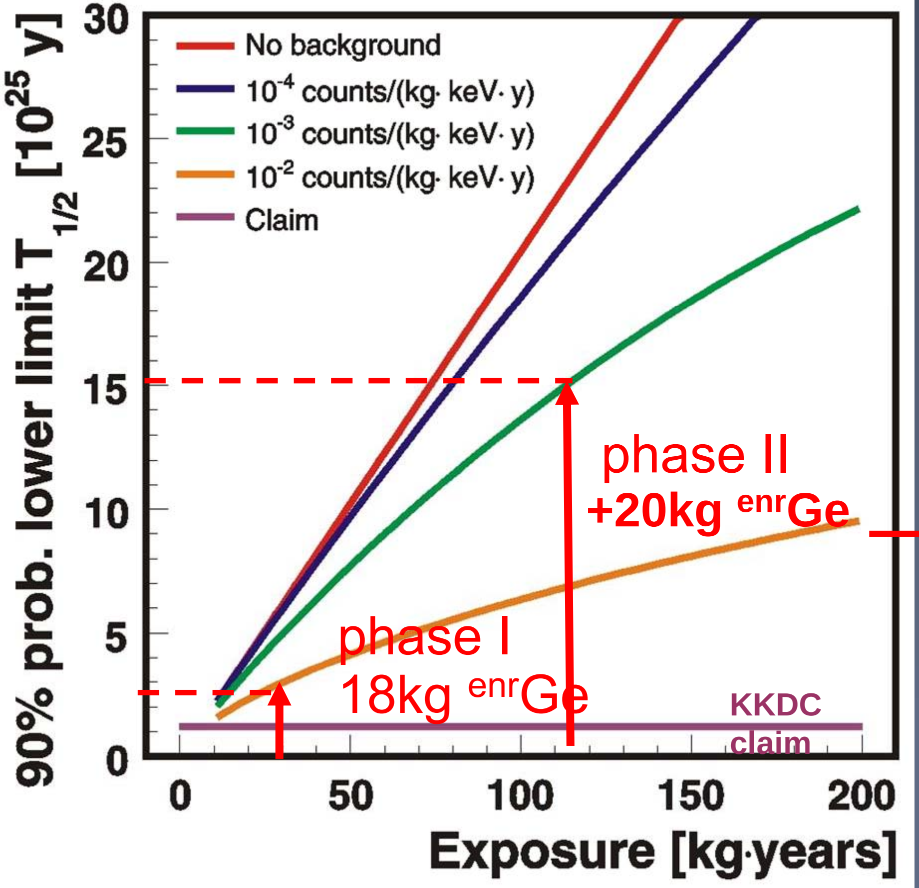
$T_{1/2}^{0\nu} > 1.9 \times 10^{25}$ yr @ 90% CI

Median sensitivity:

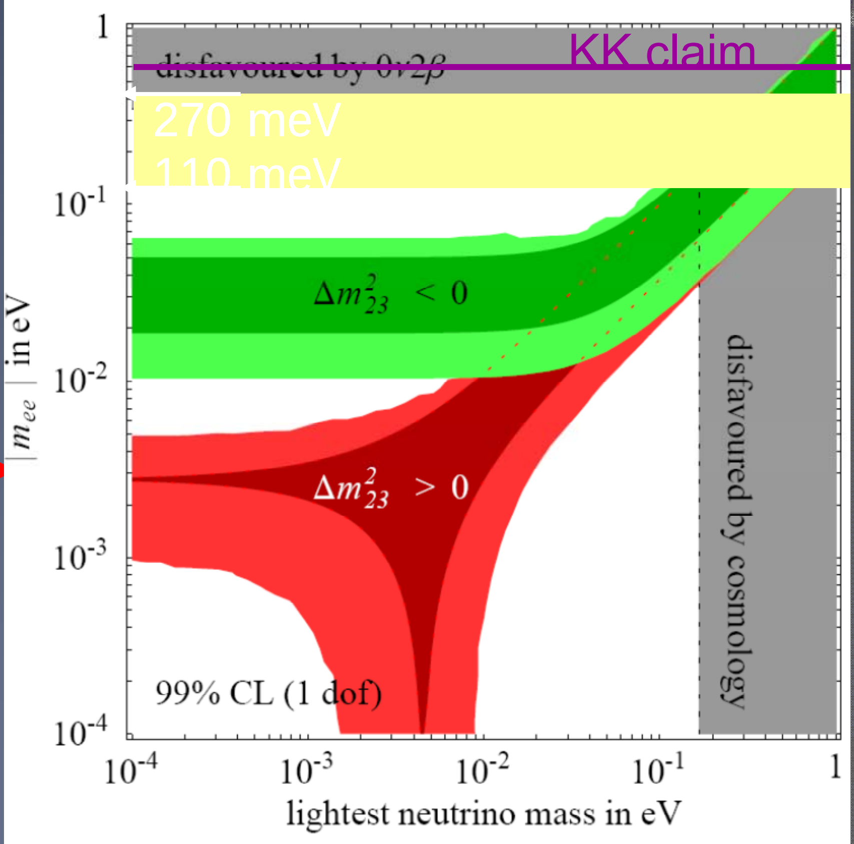
$T_{1/2}^{0\nu} > 2.1 \times 10^{25}$ yr

Comparison w. the stated Sensitivity

Assumed E resolution: ΔE = 4 keV



From Vissani, Strumia hep-ph/0606054v2



GERDA I→ scrutinize in ~ 1 year data taking (assuming 18 kg y exposure) the KK claim: if true ββ decay GERDA will have 7 cts, above bckg of 0.5 cts → probability that bckg simulate signal ~ 10^{-5}

GERDA (all data sets) vs KK (2004) claim

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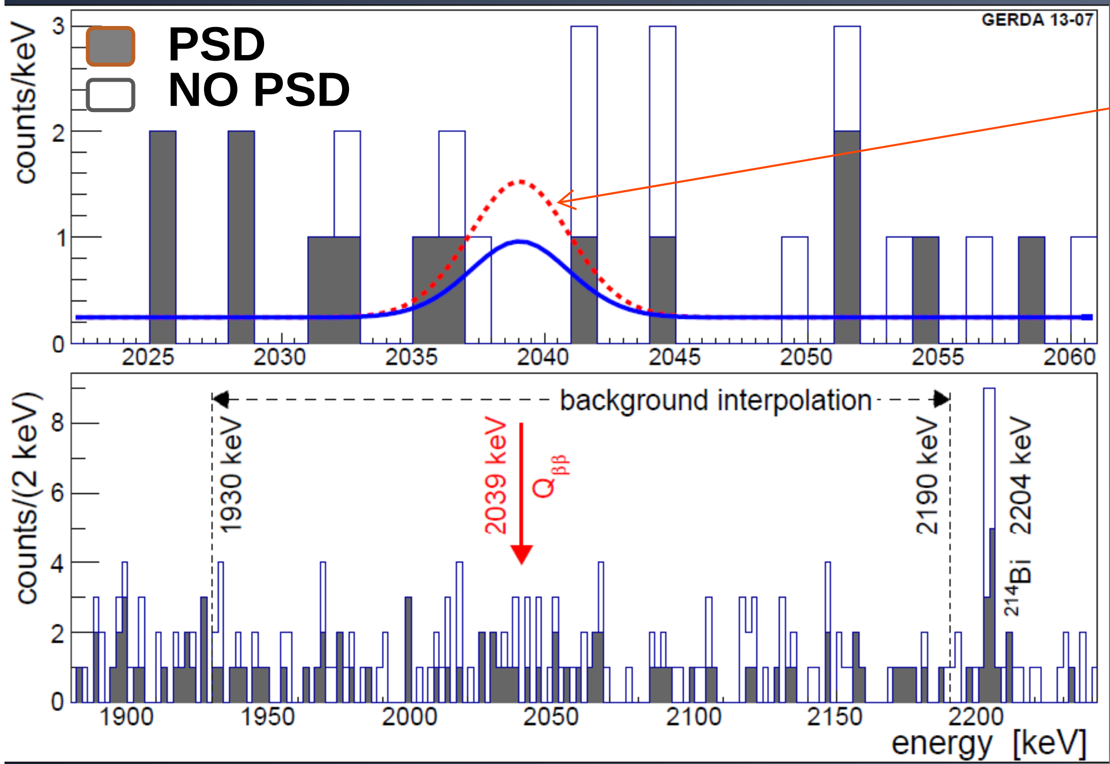
For $T_{1/2}^{0\nu} = 1.19 \times 10^{25}$ yr

Expected Signal (after PSD): 5.9 ± 1.4 cts in ±2σ

Expected Bckgd (after PSD): 2.0 ± 0.3 cts in ±2σ

Observed: 3.0 (0 in ±1σ)



From profile likelihood
Assuming H1,
P ($N^{0\nu}$=0 for H1)=1%

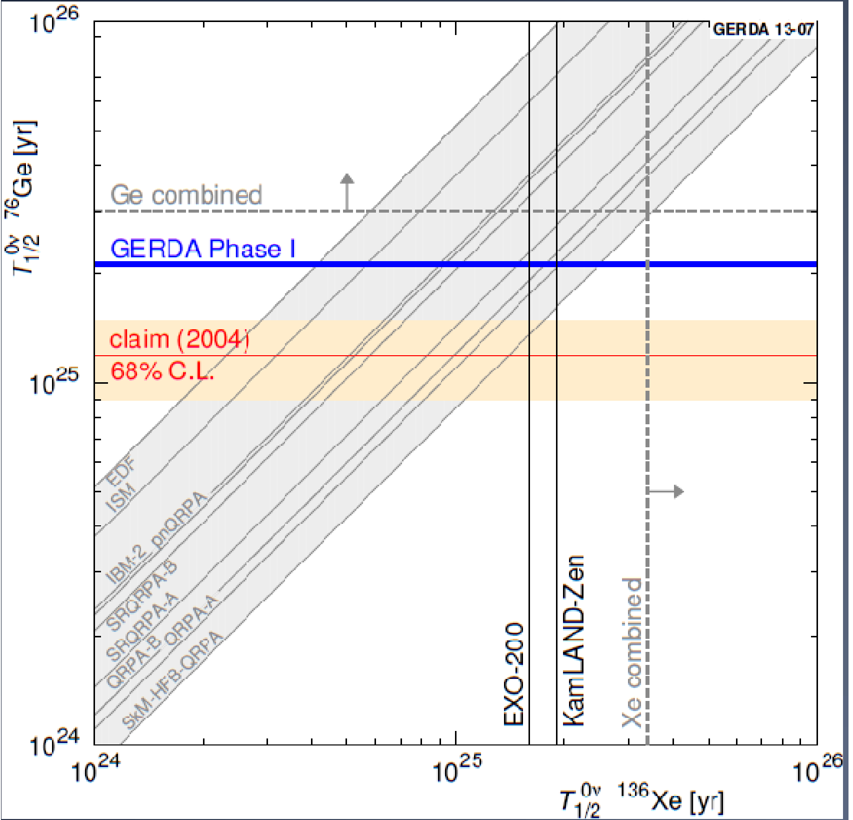
Comparing
H1: Claimed signal
H0: Background only

Bayes factor
P(H1)/P(H0)=0.024
(uncertainties on claim included)

Claim poorly credible

Combining GERDA, HdM, IGEX & Xe

arXiv: 1307.2610



H1: signal with $T_{1/2}^{0\nu} = 1.19\times10^{25}$ yr

H0: background only

	Isotope	$P(H_1)/P(H_0)$	Comment
GERDA	^{76}Ge	0.024	Model independent
GERDA +HdM+IGEX	^{76}Ge	0.0002	Model independent
KamLAND-Zen*	^{136}Xe	0.40	Model dependent: NME, leading term
EXO-200*	^{136}Xe	0.23	Model dependent: NME, leading term
GERDA+KLZ* +EXO*	^{76}Ge + ^{136}Xe	0.002	Model dependent: NME, leading term

*:with conservative NME ratio $M_{0\nu}(^{136}Xe)/M_{0\nu}(^{76}Ge) \approx 0.4$ from:

NME from P.S. Bhupal DeV et al (2103), arXiV:1305.0056

Combining GERDA, HdM,IGEX

3 GERDA Data sets, 1 HdM, 1 IGEX

Profile likelihood function w. 5 independent bckgds

$T_{1/2}^{0\nu} > 3.0 \times 10^{25}$ yr @ 90% CL

Conclusions

- GERDA achieved its design goals
  - Phase I Exposure: 21.6 kg yr → 215.2 ±7.6 moles of ^{76}Ge
  - Background Index: ~10^{-2} cts / (Kev kg y) Unprecedent value!
  - Scrutinized the KK claim in 1.5 yr data taking
- No excess of counts above background is found @ $Q_{\beta\beta}$ after unblinding: 7 (3 after PSD) cts in ± 5keV region

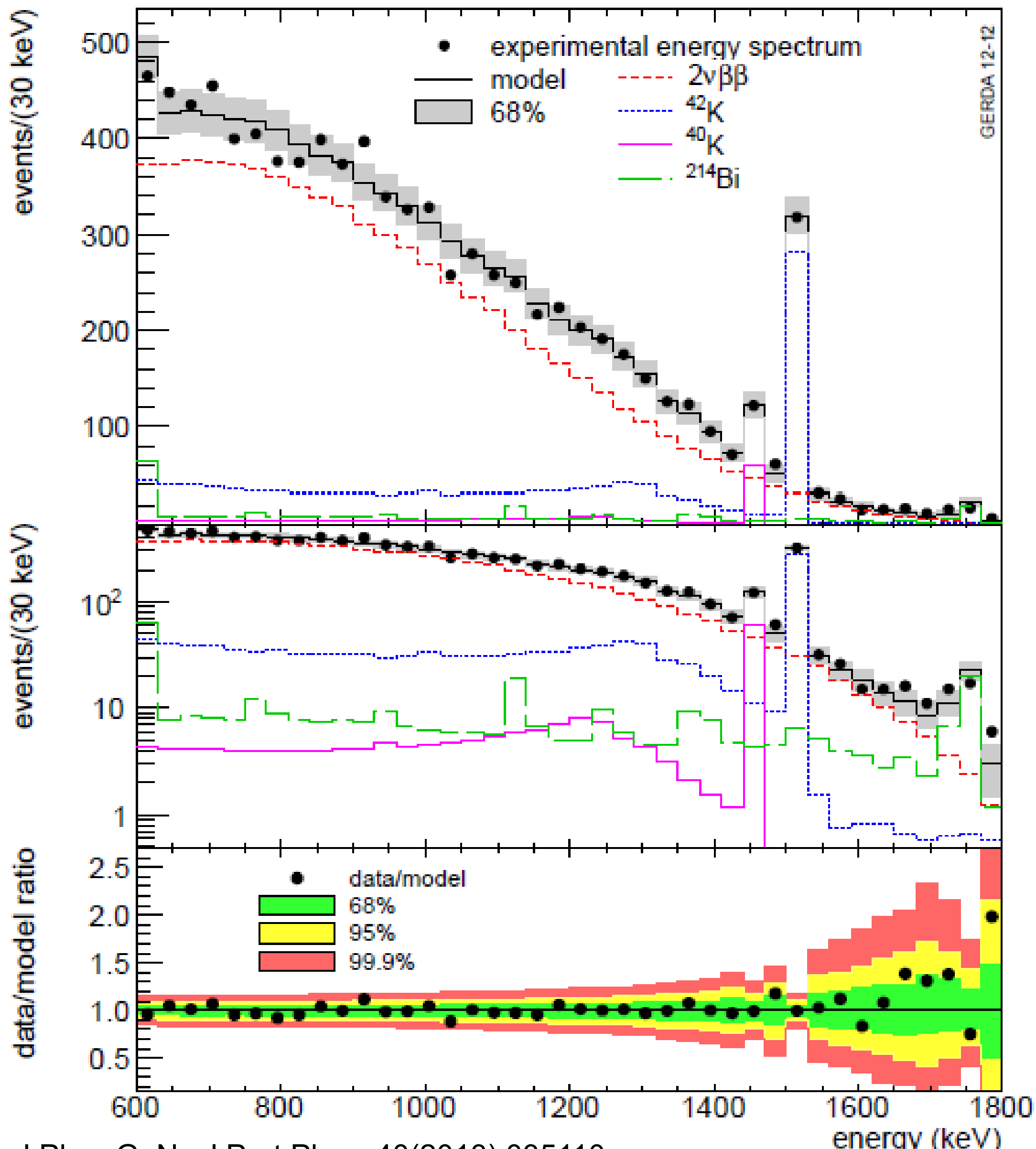
- GERDA : $T_{1/2}^{0\nu} > 2.1 \times 10^{25}$ yr @ 90% CL
- GERDA combined w. IGEX & HdM $T_{1/2}^{0\nu} > 3.0 \times 10^{25}$ yr @ 90% CL
- $m_{\beta\beta} < (0.2 – 0.4)$ eV depending on NME and Phase Space Factors

- PSD works well mainly for BEGEs

Ongoing activities and outlooks

- Phase I
  - Data taking stopped since end september 2013
  - Detectors already out of the cryostat to reprocessing
  - Lost calibration ^{228}Th source is being “fished” out of the cryostat in these days
- Phase II (see talk of. Bela Majorovitz at TAUP 2013)
  - New contacting technology of BEGe detectors defined and tested: wire-bonding contacts instead of spring loaded (Phase I)
  - New lock, cabling etc. equipped to host ~ 50 detectors in preparation
  - New ^{enr}Ge BEGe detectors already at LNGS (since 5 November 2013) with Al evaporated pads to wire-bond
  - New Si –holders in final phase of preparation
  - New FE electronics in preparation
  - LAr veto read-out in preparation
    - 18 PMTs &, if performances adequate, an inner veto of Fibers, read-out by SiPMs.
- Phase II challenge: achieve another factor 10 in BI and sensitivity.

EXTRA slides



J.Phys.G: Nucl.Part.Phys. 40(2013) 035110

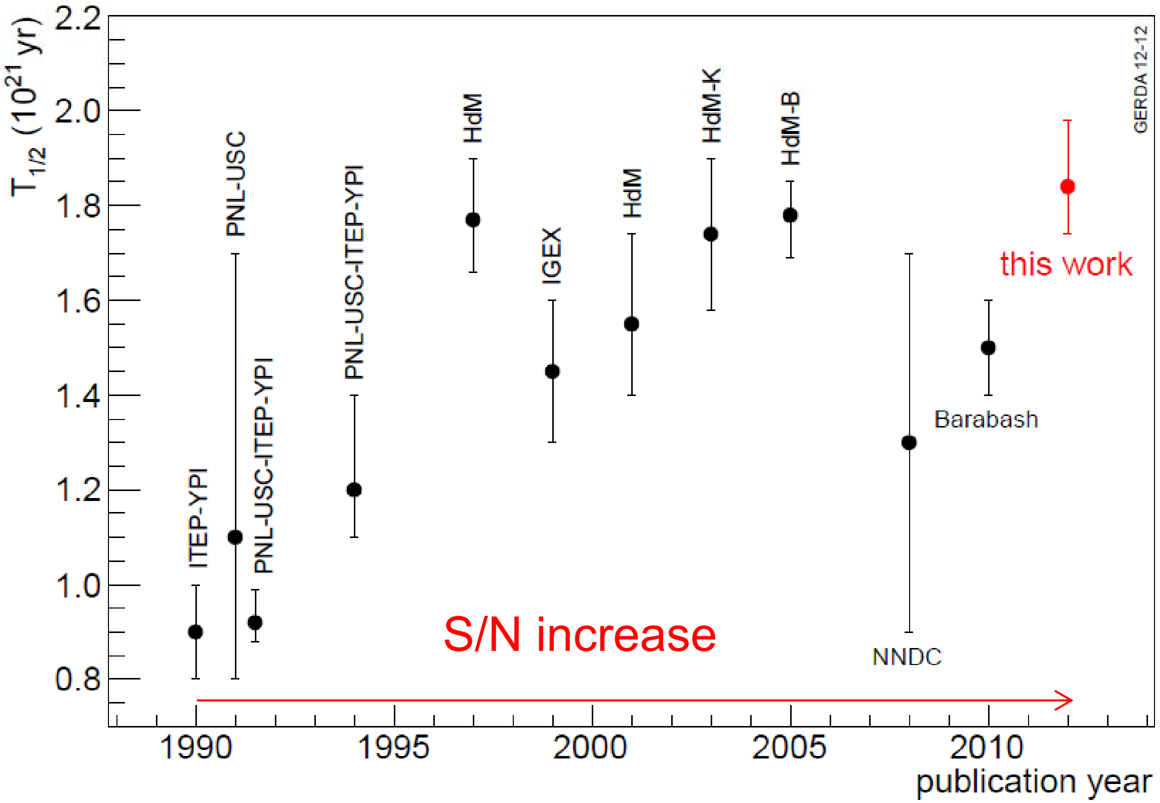
- 2νββ spectrum generated by DECAY0 (V.Tetryak)
- 6 independent models for the 6 detectors (5 x 6=30 detector parameters)
- $T^{2\nu}_{1/2}$ common in 6 detectors
- Background from 3 sources: ^{42}K, ^{40}K, ^{214}Bi (γ-lines used for normalization)
  - ^{42}K: homogeneusly distributed
  - ^{40}K & ^{214}Bi: close sources
- Detectors active masses and enr. factors are nuisance parameters in the fit.
- $T^{2\nu}_{1/2}$ *pdf is quasi-gaussan*

ββ spectrum: 8796 events:

Model of the residual background: 80% 2νββ, 14% ^{42}K, 3.8% ^{214}Bi, 2% ^{40}K, J.Phys.G: Nucl.Part.Phys. 40(2013) 035110

GERDA vs previous measurements of $T^{2\nu}_{1/2}$

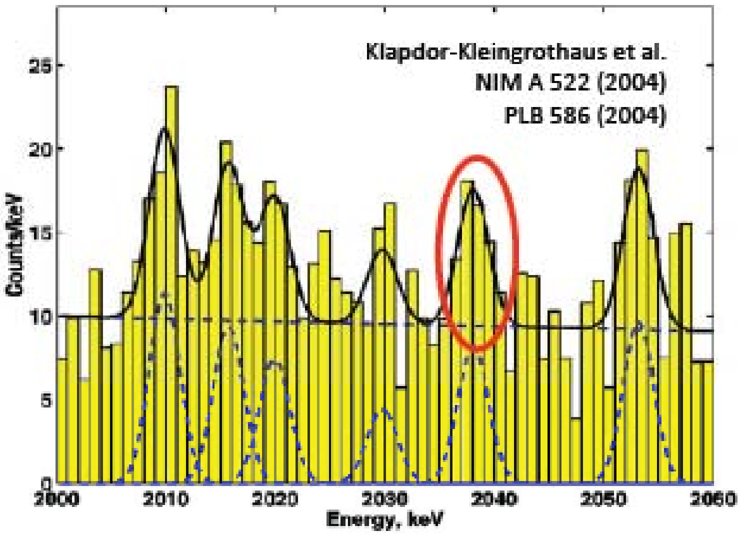
$$T^{2\nu}_{1/2} = (1.84^{+0.09}_{-0.08\ \mathrm{fit}}\ {}^{+0.11}_{-0.06\ \mathrm{syst}}) \cdot 10^{21}\ \mathrm{yr} = (1.84^{+0.14}_{-0.10}) \cdot 10^{21}\ \mathrm{yr}, \quad (2)$$

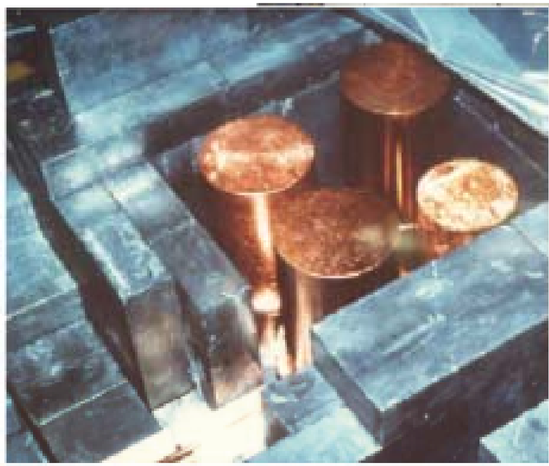


- GERDA is consistent with HdM $T^{2\nu}_{1/2} = 1.78^{+0.07}_{-0.09}$
- Thanks to our BI comparable σ_{stat} with ~1/10 exposure
- GERDA results can improve by
  - New measurement of coax active volumes

    &
  - Increased statistics (already available)

The KK 2006 claim





Klapdor-Kleingrothaus et al., NIM A 522 (2004), PLB 586 (2004):

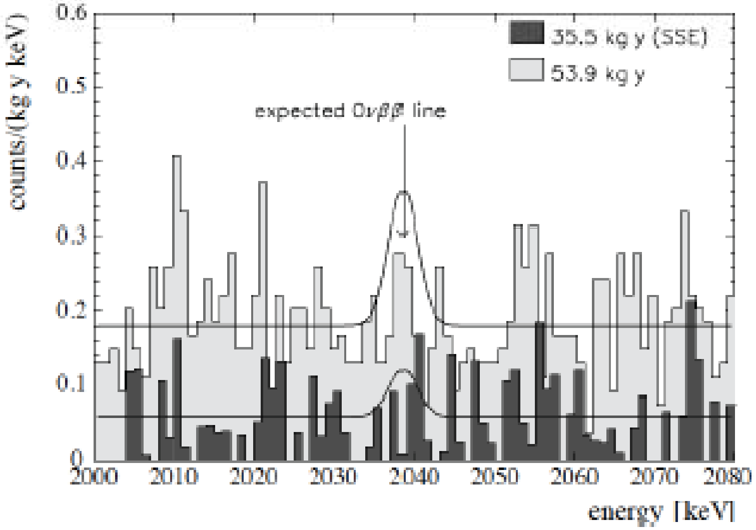
- 71.7 kg year - Bgd 0.17 / (kg yr keV)
- 28.75 ± 6.87 events (bgd:~60)
- Claim: 4.2σ evidence for 0νββ
- reported $T_{1/2}^{0\nu}$ = 1.19 x10^{25} yr

N.B. Half-life $T_{1/2}^{0\nu}$ = 2.23 x10^{25} yr $T_{1/}$after PSD analysis (Mod. Phys. Lett. A 21, 1547 (2006).) is not considered because:

- reported half-life can be reconstructed only (Ref. 1) with ε_{psd} = 1 (previous similar analysis $\varepsilon_{psd} \approx 0.6$)
- ε_{fep} = 1 (also in NIM A 522, PLB 586 (2004) (GERDA value for same detectors: ε_{fep} = 0.9)

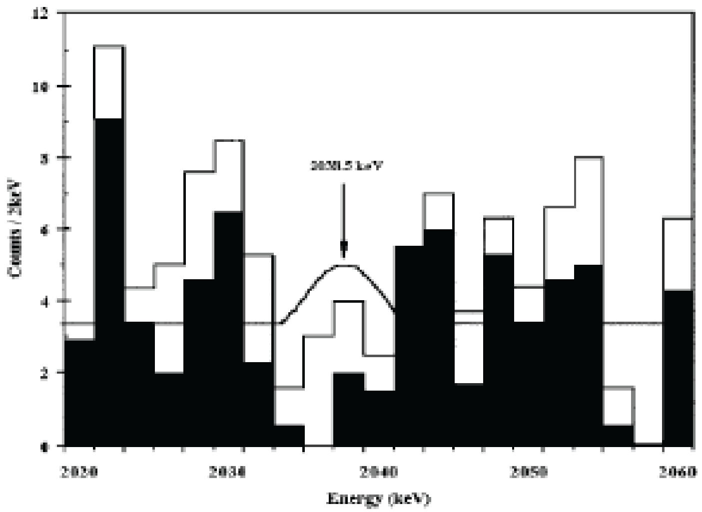
(1) B. Schwingenheuer in Ann. Phys. 525, 269 (2013):

Precursor Ge experiments



Heidelberg-Moscow
(H.V. Klapdor-Kleingrothaus et al.)
(Eur. Phys. J. A 12, 147-154 (2001)):

53.9 kg y (35.5 kg y): $T_{1/2}^{0\nu} > 1.3 \times 10^{25}$ yr (1.9×10^{25} yr)
(90% C.L.)



IGEX
(Aalseth et al.)
Phys. Rev. D 65 (2002) 092007

8.8 kg y: $T_{1/2}^{0\nu} > 1.6 \times 10^{25}$ yr (90%C.L.)

	Golden Coax	BEGe
	BI[10^{-3}] in 10 keV	BI[10^{-3}] in 10 keV
Interpolation	17.5 [15-20]	36.1 [26-49]
Minimal	18.5 [17.6- 19.3]	38.1 [37.5 – 38.7]
Maximal	21.9 [20.7– 23.8]	
	Cts in 40 keV	Cts in 32 keV
data	13	
Minimal	8.6 [8.2-9.1]	2.2 [2.1 – 2.2]
Maximal	10.3 [9.7-11.1]	

The background index evaluated in the 230 keV region centered at Q_bb

Table 10 The total background index and individual contributions in 10 keV (8 keV for BEGes) energy window around $Q_{\beta\beta}$ for different models and data sets. Given are the values due to the global mode together with the uncertainty intervals [upper,lower limit] obtained as the smallest 68 % interval (90 %/10 % quantile for limit setting) of the marginalized distributions.

component	location	*GOLD-coax* minimum model		*GOLD-coax* maximum model		*GOLD-nat* minimum model		*SUM-bege* minimum + n^+	
		BI 10^{-3} cts/(keV·kg·yr)							
Total		18.5	[17.6,19.3]	21.9	[20.7,23.8]	29.6	[27.1,32.7]	38.1	[37.5,38.7]
^{42}K	LAr homogeneous	3.0	[2.9,3.1]	2.6	[2.0,2.8]	2.9	[2.7,3.2]	2.0	[1.8,2.3]
^{42}K	p^+ surface			4.6	[1.2,7.4]				
^{42}K	n^+ surface			0.2	[0.1,0.4]			20.8	[6.8,23.7]
^{60}Co	det. assembly	1.4	[0.9,2.1]	0.9	[0.3,1.4]	1.1	[0.0,2.5]		<4.7
^{60}Co	germanium	0.6	>0.1 †)	0.6	>0.1 †)	9.2	[4.5,12.9]	1.0	[0.3,1.0]
^{68}Ge	germanium								1.5 (<6.7)
^{214}Bi	det. assembly	5.2	[4.7,5.9]	2.2	[0.5,3.1]	4.9	[3.9,6.1]	5.1	[3.1,6.9]
^{214}Bi	LAr close to p^+			3.1	<4.7				
^{214}Bi	p^+ surface	1.4	[1.0,1.8] †)	1.3	[0.9,1.8] †)	3.7	[2.7,4.8] †)	0.7	[0.1,1.3] †)
^{214}Bi	radon shroud			0.7	<3.5				
^{228}Th	det. assembly	4.5	[3.9,5.4]	1.6	[0.4,2.5]	4.0	[2.5,6.3]	4.2	[1.8,8.4]
^{228}Th	radon shroud			1.7	<2.9				
α model	p^+ surface	2.4	[2.4,2.5]	2.4	[2.3,2.5]	3.8	[3.5,4.2]	1.5	[1.2,1.8]

†) prior: discussed in sec. 5