MAX-PLANCK-GESELLSCHAFT

GERDA

GERDA commissioning results and summary of double beta decay projects

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OUTLINE:

- motivation
- current status: the GERDA experiment and overview of other $0\nu\beta\beta$ decay experiments

Neutrino Properties

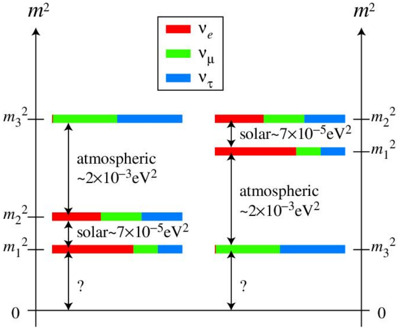
Neutrino mass $\neq 0 \rightarrow$ oscillation experiments

- $m_2^2 - m_1^2 = \Delta m_\odot^2$
- $|m_2^2 - m_3^2| = \Delta m_{atm}^2$

- $\theta_{12} = \theta_\odot$ and $\theta_{23} = \theta_{atm}$

and an upper limit on θ_{13}

Normal hierarchy $\Delta m_{32} > 0$ **eV** **Inverted hierarchy** $\Delta m_{32} < 0$ **eV**

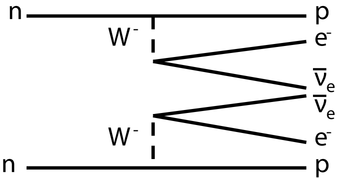


Still Missing

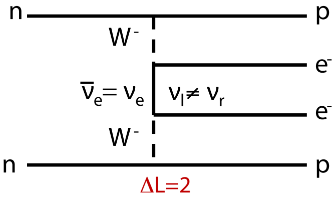
- Nature of the neutrino (Majorana or Dirac)
- Absolute mass scale
- Mass hierarchy
- Value of the third mixing angle
- CP violating phases

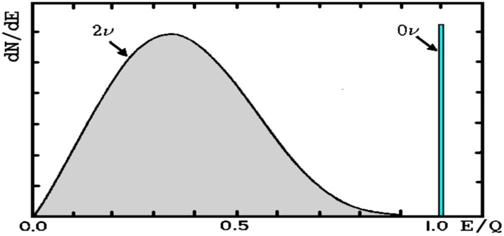
Search for $0\nu\beta\beta$ decay

Neutrino accompanied Double-Beta Decay:



Neutrinoless Double-Beta Decay:

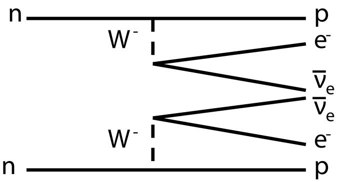




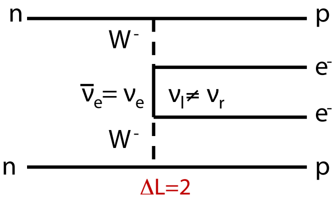
Signature: Sharp peak at Q-value of the decay (2039 keV for ^{76}Ge)

Search for $0\nu\beta\beta$ *decay*

Neutrino accompanied Double-Beta Decay:



Neutrinoless Double-Beta Decay:



If neutrinoless double beta-decay is observed:

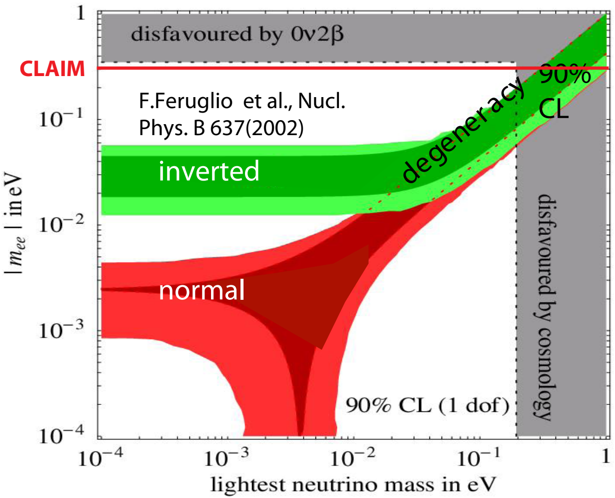
- neutrino is a Majorana particle
- information on absolute mass scale

$$1/\tau = G(Q,Z) \; |M_{nucl}|^2 \; \langle m_{ee} \rangle^2$$

$0\nu\beta\beta$ Decay rate	Phase space factor	Matrix element	Effective Majorana Neutrino mass

$$\langle m_{ee} \rangle = \left|\sum_i |U_{ei}|^2 e^{i\beta_i} m_i\right|$$

Search for $0\nu\beta\beta$ decay



Previous $0\nu\beta\beta$ decay experiments

Experiment	Underground Laboratory	Isotope	Technology	$T_{1/2}$ [10^{24} y]	<m_{ee}> [eV]
Heidelberg-Moscow	LNGS (Italy)	^{76}Ge	HPGe	>19 claim: $22.3^{+4.4}_{-3.1}$	< 0.35 - 1.2 $0.32^{+0.03}_{-0.03}$
IGEX	LSC (Spain)	^{76}Ge	HPGe	> 16	< 0.3 - 1.35
NEMO-III	LSM (France)	^{82}Se	Foils btw.	> 0.36	< 0.89 - 2.43
NEMO-III		^{100}Mo	tracker	> 1.1	< 0.45 - 0.93
$CdWO_4$	Solotvina (Ukrain)	^{116}Cd	Scintillator	> 0.17	< 1.5 - 1.7
Cuoricino	Gran Sasso	^{130}Te	Bolometry	> 3.0	< 0.19 – 0.68

Different isotopes choice...

(Only few past experiment presented, list is incomplete!)

The experimental challenge

... about 30 isotopes available, but:

$$\text{sensitivity on } T_{1/2} \propto \epsilon \cdot A \cdot \sqrt{\frac{M \cdot T}{b \cdot \Delta E}}$$

ϵ	detection efficiency	$\sim$ 85% if detector=source
A	isotopic abundance	high natural i.a. or enrichment!
M	active target mass	increase mass
T	measuring time	
b	background rate (cts/(keV kg y))	minimize & select radiopure material
ΔE	energy resolution	use high resolution spectroscopy

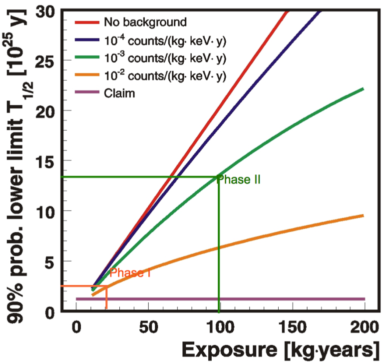
Experimental approach: improve exposure (M·T) and reduce background.

The GERmanium Detector Array

Phase I:

- operate existing HP^{76}Ge detectors from HdM and IGEX + ^{nat}Ge diodes
- reach background of 10^{-2} cts/(keV kg y)
- exposure of $\sim$ 15 kg y $\rightarrow$ check claim within 1 y data taking

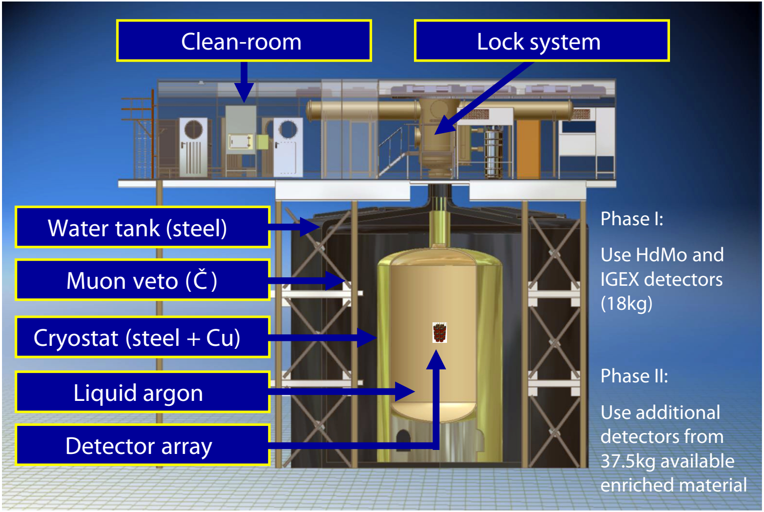
Phys. Rev. D 092003 (2006)



Phase II:

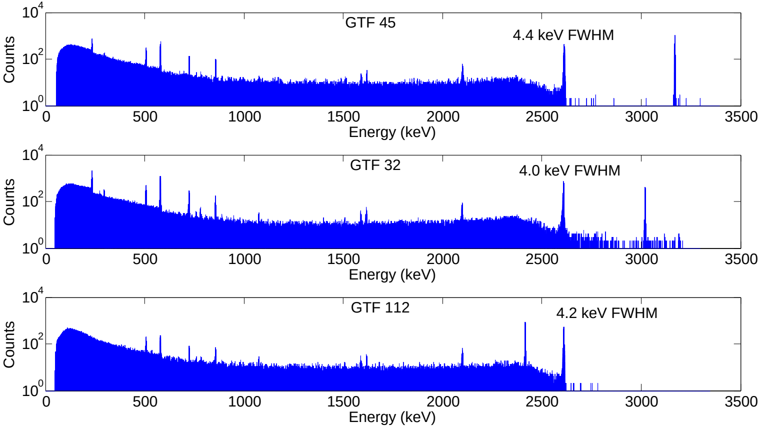
- operate additional new ^{76}Ge detectors for a total of 40 kg
- reach background of 10^{-3} cts/(keV kg y)
- exposure of $\sim$ 100 kg y $\rightarrow$ ${T_{1/2}}^{0\nu} \geq 1.35 \cdot 10^{26}$ y

The GERmanium Detector Array



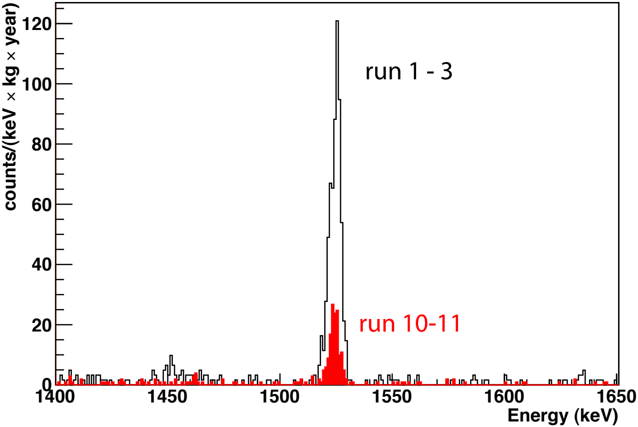
Infrastructure completed in May 2010

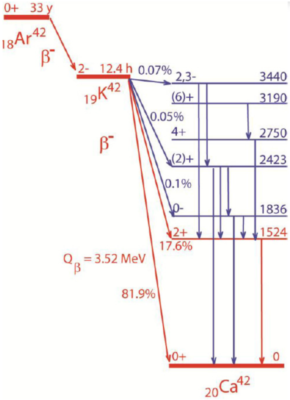
First Deployment of the first string: June 2010



3 ^{nat}Ge detector, ^{228}Th calibration spectrum

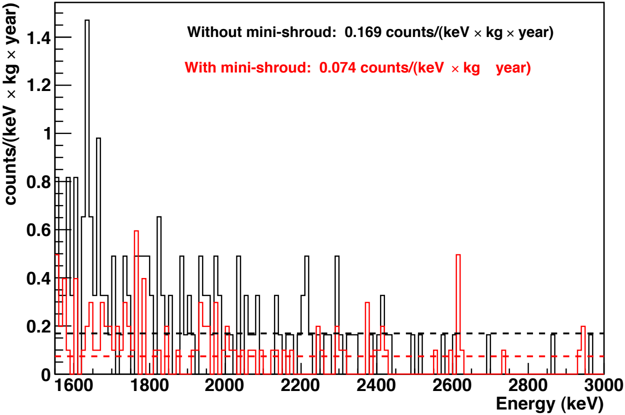
GERDA background





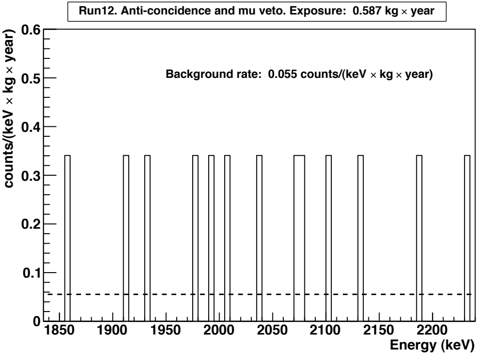
- $^{42}K^{+}$ drift in the electric field
- Changing field configuration changes intensities

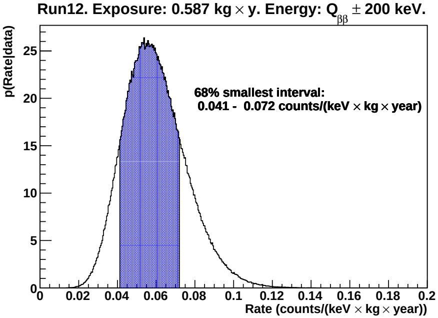
GERDA background



- background index from 0.169 $\mathrm{cts}/(\mathrm{keV\,kg\,y})$ to 0.074 $\mathrm{cts}/(\mathrm{keV\,kg\,y})$

GERDA background





- 12 runs with different detectors, E-field configurations and read-out schemes
- current background index (E-field free): $0.055\,\mathrm{cts/(keV\,kg\,y)}$
- 68% smallest interval: $0.041 - 0.072\,\mathrm{cts/(keV\,kg\,y)}$

Other $0\nu\beta\beta$ experiments: small selection

Experiment	Isotope	Target Mass	Technology	FWHM	BI [cts/(keV kg y)]	Exp. Sens.[meV]	Start
GERDA I GERDA II	^{76}Ge	18 kg 40 kg	HPGe	0.2%	0.055 (0.01) 0.001	230 - 390 90 - 150	2011 2012
Majorana	^{76}Ge	~20 kg 40 kg	HPGe	0.2%	0.01	<140	2013 2014
CUORE0 CUORE	^{130}Te	10 kg 200kg	$^{130}TeO_2$ bolometer	0.25%	0.12 <0.01	168 - 391 41 – 96	2011 2013
EXO-200	^{136}Xe	200kg	LXe TPC	3.7%	~0.002	109 - 135	2011

Majorana (Sanford lab)

- HPGe detectors in low background cryostat
- detector with very good PSA capabilities
- 2012: commissioning of prototype cryostat
- 2013: 3 strings ^{enr}Ge detectors + 4 strings ^{nat}Ge detector
- 2014: +7 strings ^{enr}Ge detectors

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CUORE (LNGS)

- Low Temperature bolometers: TeO_2 crystals
- ^{130}Te: i.a. 33.4%, good energy resolution, slow $\tau \sim 1 - 10^3$ms
- CUORE-0: Cuoricino cryostat + CUORE-like tower
- CUORE: 200 kg ^{130}T, new cryostat with improved radiopurity

E.Previtali, WIN2011

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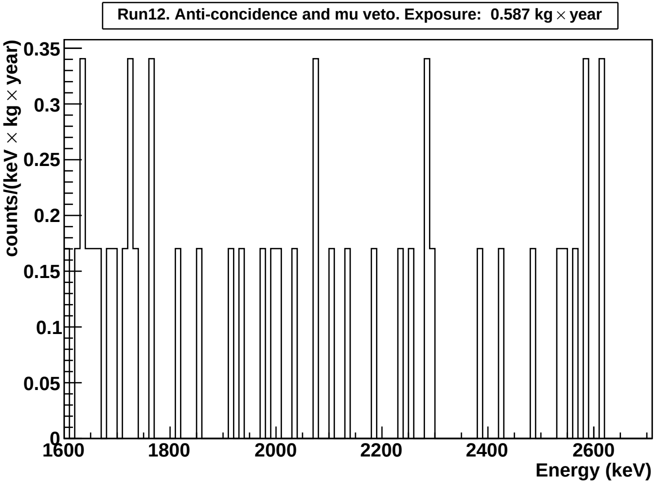
EXO (WIPP, New Mexico)

- liquid Xe TPC: measures scintillation light AND ionization
- EXO-200 filled with 200 kg ^{nat}Xe in fall 2010 + engineering runs: analysis ongoing
- early 2011: refilling after lead shield and radon enclosure mounting + begin of low-background data taking

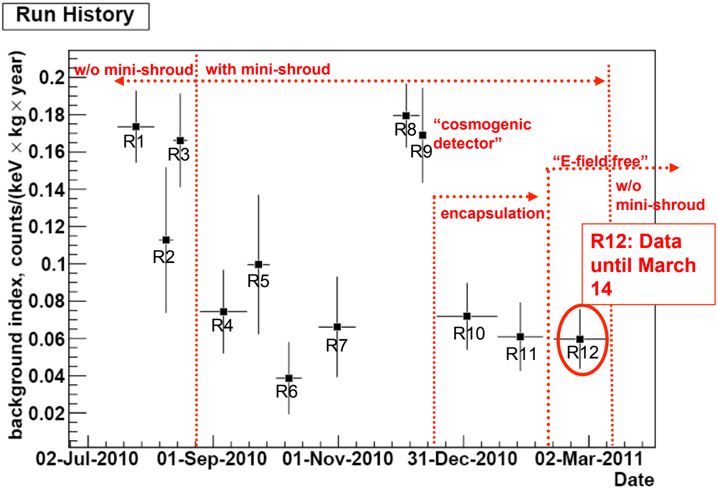
Conclusions

- $0\nu\beta\beta$ decay is the only practical way to test the neutrino nature
- claim of evidence for observation in only 1 of the past experiments...need independent confirmation
- GERDA infrastructure finished in spring 2010
- GERDA background runs nearing completion, current background index: 0.055 $\mathrm{cts/(keV\,kg\,y)}$
- GERDA Phase I to be started soon
- other experiment with different isotopes are also commissioning...

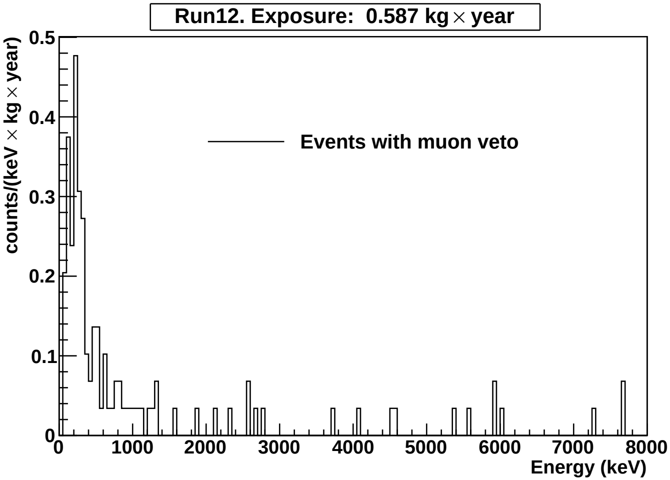
Backup Gerda



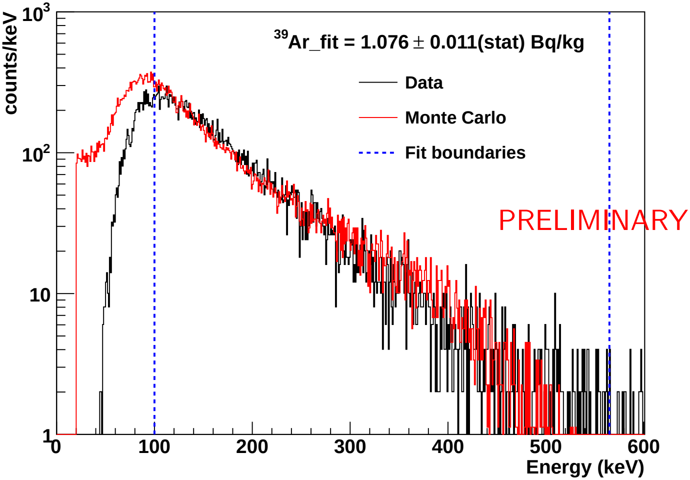
Backup Gerda



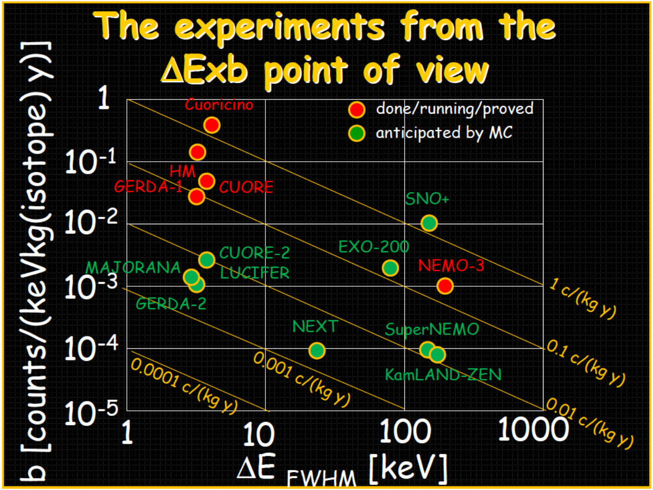
Backup Gerda



Backup Gerda



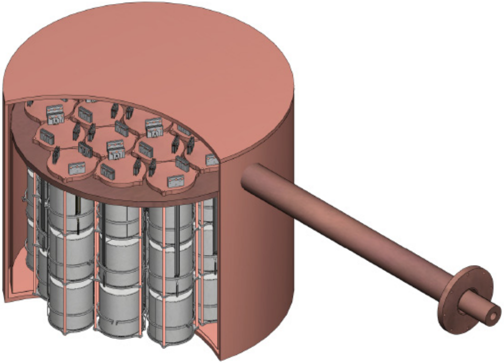
Backup Gerda



A.Giuliani, International Student Workshop on Neutrinoless Double Beta Decay, LNGS, Nov 2010

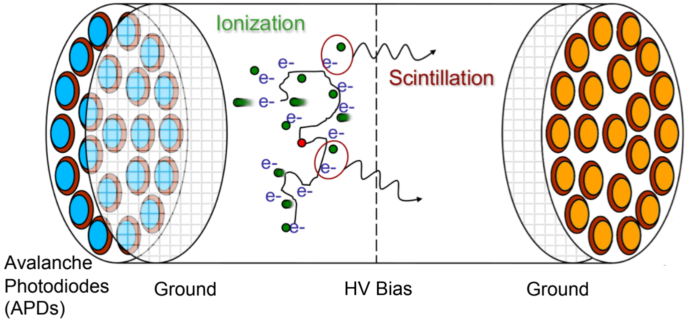
Backup others

Majorana:



Backup others

EXO Detector Schematic



APDs and wires collect light and charge, respectively, and are installed on each side of the detector cylinder.

Backup others

CUORE: