Neutrinoless double-beta decay in the GERDA Phase II

Carla Macolino per la collaborazione GERDA

INFN, Laboratori Nazionali del Gran Sasso

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Outline

- Science motivation for Phase II
- On the way to GERDA Phase II
- Pulse-Shape Discrimination (PSD) Analysis for BEGes
- LAr instrumentation

Science motivation

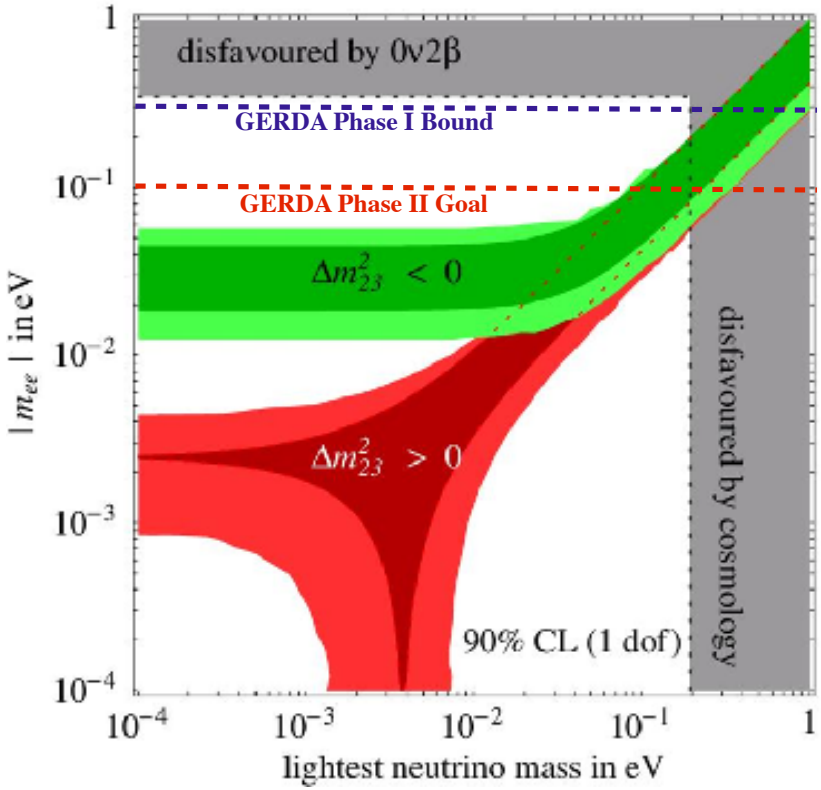
$$(T^{0\nu}_{1/2})^{-1} = G^{0\nu}|M^{0\nu}|^2 \frac{\langle m_{\beta\beta}\rangle^2}{m_e^2}$$

with $\langle m_{\beta\beta}\rangle$ = effective electron neutrino mass

$$\langle m_{\beta\beta}\rangle \equiv |U_{e1}|^2 m_1 + |U_{e2}|^2 m_2 e^{i\phi\ 2} + |U_{e3}|^2 m_3 e^{i\phi_3}$$

m_i=masses of the neutrino mass eigenstates
U_{ei}=elements of the neutrino mixing matrix
$e^{i\phi_2}$ and $e^{i\phi_2}$ the relative CP phases

→ information on the absolute mass scale!



- **Phase I result**: BI $\sim 10^{-2}$ cts/(keV kg yr) and $\sim$ 20 kg yr exposure
  → limit on $\langle m_{ee}\rangle$ between 0.2 and 0.4 eV
- **Phase II goal**: BI $\sim 10^{-3}$ cts/(keV kg yr) and 100 kg yr exposure
  → sensitivity on $\langle m_{ee}\rangle \sim$ 100 meV

On the way to GERDA Phase II

How to get a higher sensitivity for the Phase II:

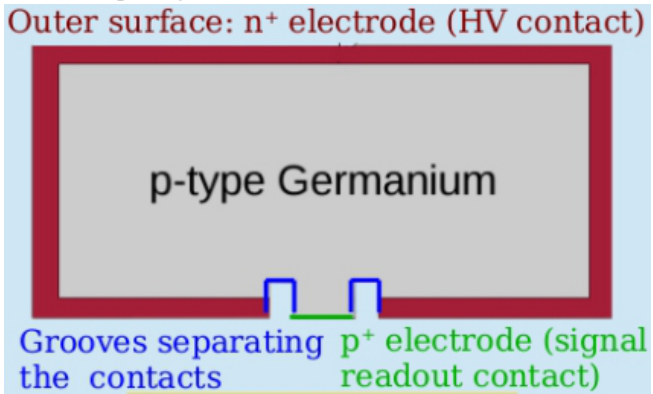
- Understand background sources and reduce radiation sources
- Improve background rejection
- Increase mass

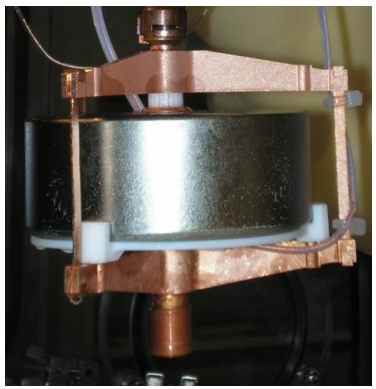
Strategy:

- Transition currently ongoing at LNGS
- Increase mass: additional 30 enriched BEGe detectors (about 20 kg)
- Suppress background contamination by a factor of 10 w.r.t. GERDA Phase I:
  - Use BEGes with Pulse-Shape Analysis for high background recognition efficiency
  - Use LAr scintillation light for background recognition and rejection
  - Use lower background Signal and HV cables w.r.t. Phase I
  - Use lower background Very Front End electronics w.r.t. Phase I
- Minimize material around sources and special care in crystal production
- Start commissioning in Autumn 2013 - Spring 2014

Phase II BEGe detectors

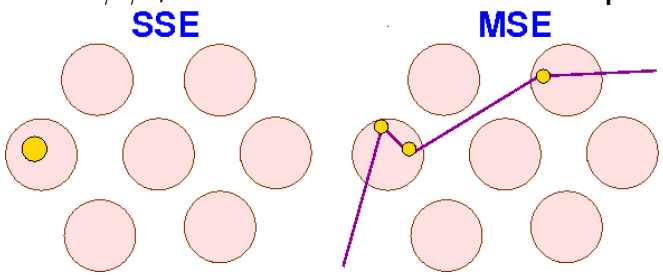
Broad Energy Germanium detectors allow a highly efficient discrimination of the background:





Discriminate between Single-site and Multi-site events

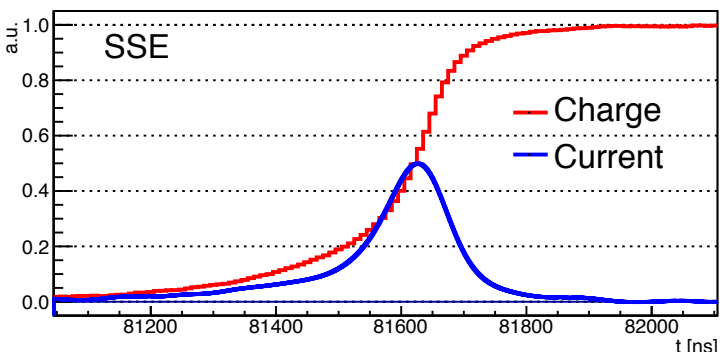
SSE: $\beta\beta$, DEP MSE: Compton

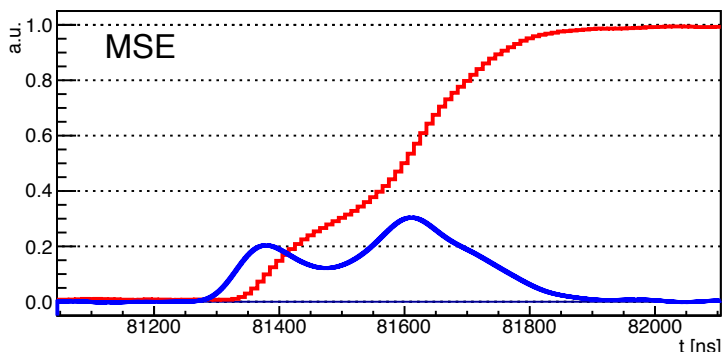


Pulse-shape analysis

e signal: single site energy deposition

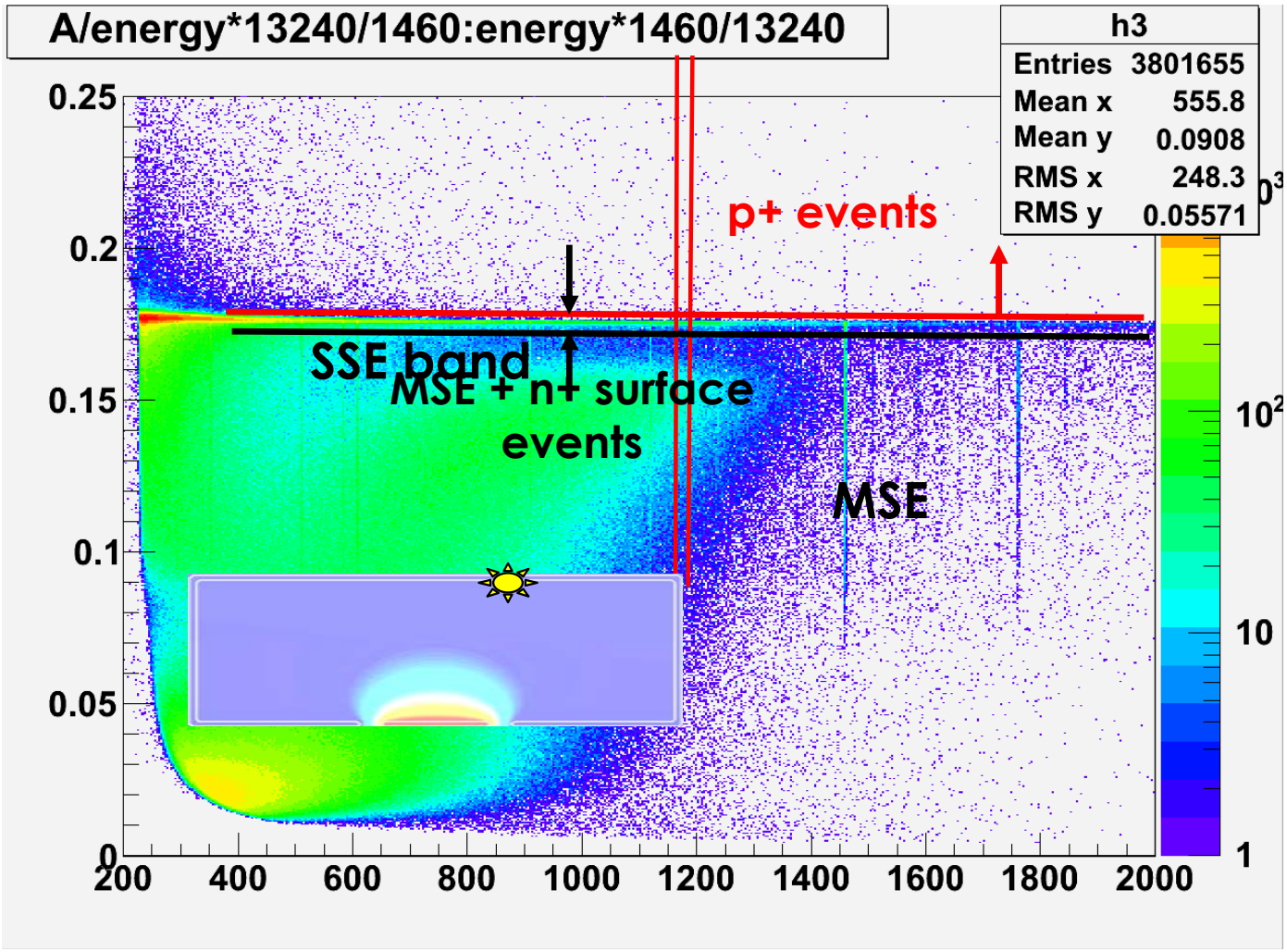
γ signal: multiple site energy deposition

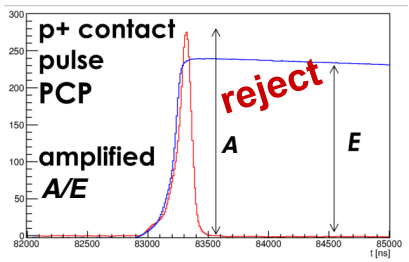


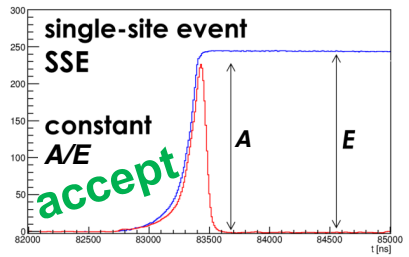


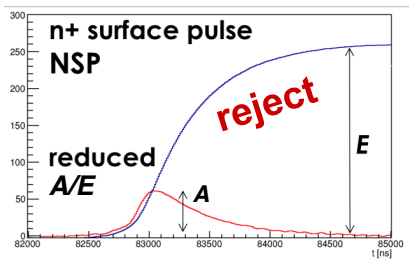
PSD on Phase II BEGe detectors

A/E parameter allows to separate SSE events from MSE, n^+ and p^+ events





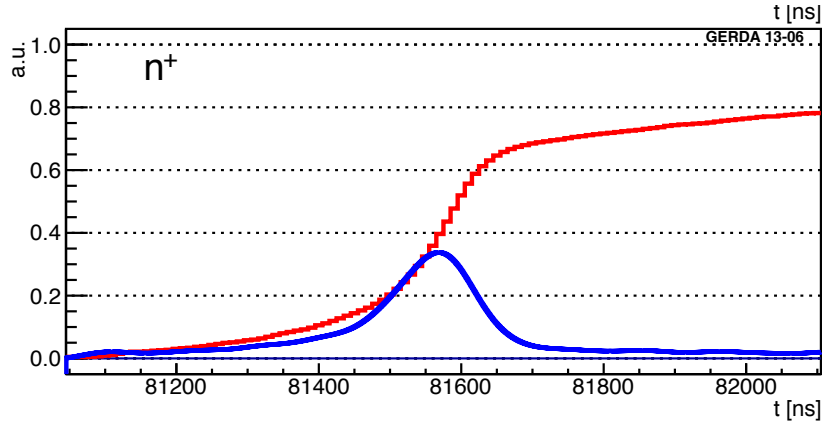


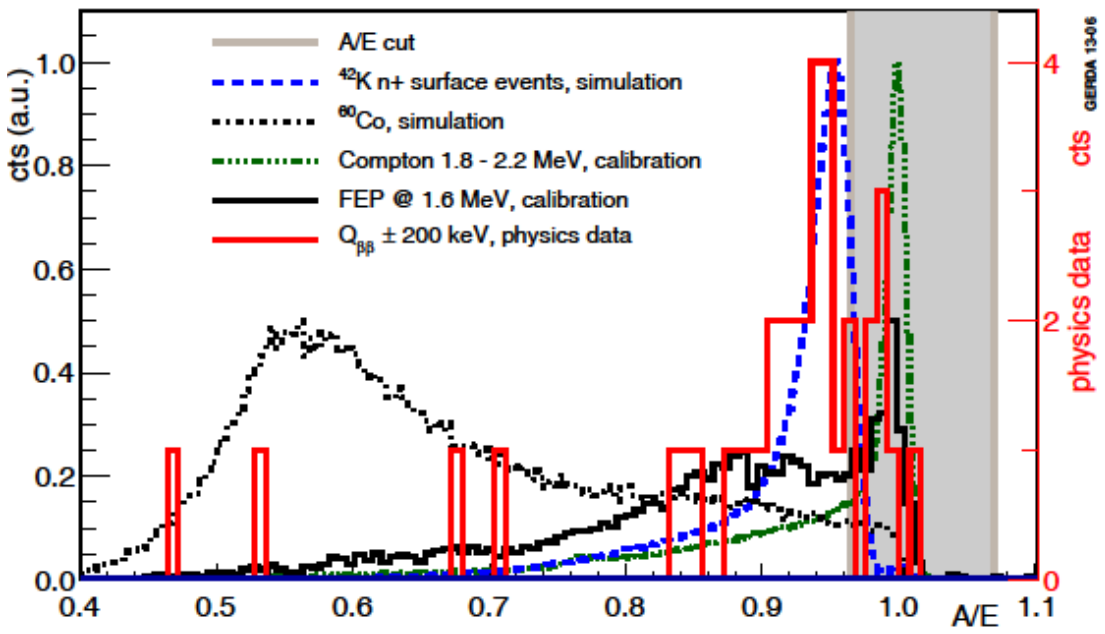


D. Budjas et al, JINST 4 P10007 (2009)
M. Agostini et al., JINST 6P03005 (2011)

PSD on Phase II BEGe detectors

Most dominant background from ^{42}K near n^{+} contact (different pulses with low A/E)





Experimental evidence of efficient ^{42}K rejection by PSD on GERDA Phase I data

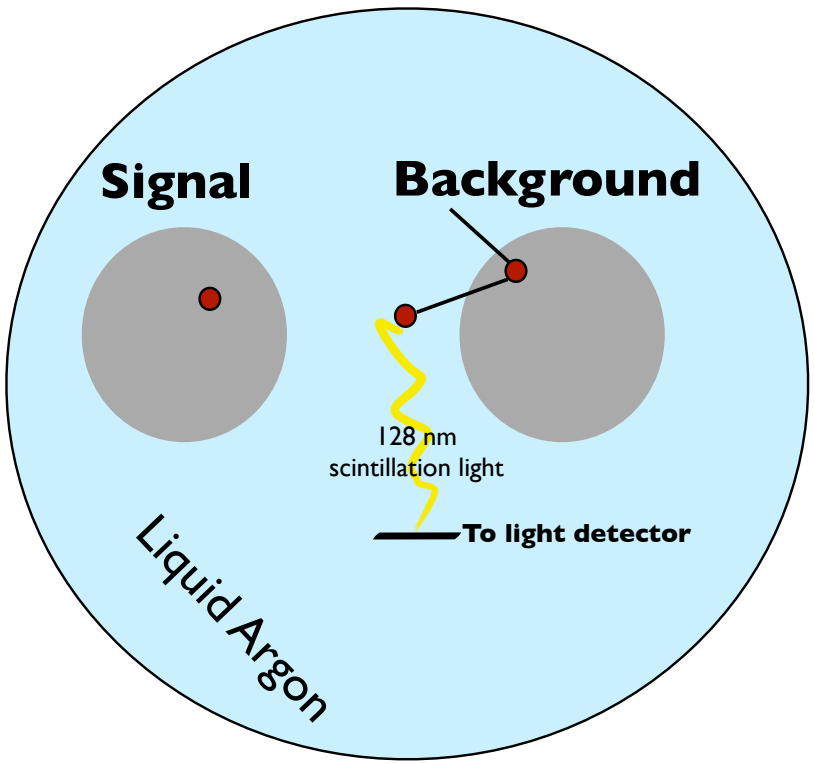
The GERDA Collaboration, The European Physics Journal C, *in press*

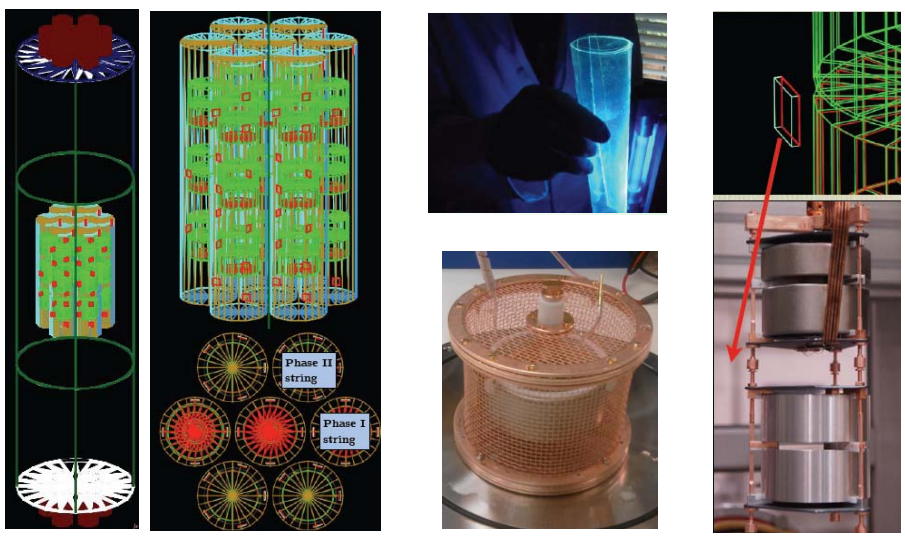
Liquid Argon instrumentation for Phase II

PMT LAr instrumentation studies for Phase II in LArGe (a smaller GERDA facility)

Different possible hardware configurations:

- SiPM fiber curtain
- PMTs on top and bottom of the array
- Hybrid solution
- Meshed copper shroud around strings
- Transparent mini-shroud
- VM2000 coated mini-shroud with large area SiPMs between detectors





Background for GERDA Phase II

Background suppression measurements with PMT veto and different possible configurations

Experimental condition	1540-3000 keV[1] cts/(kg d)	Suppression to bare BEGe
Bare BEGe, PMTs off	514(18)	1
MMS, HV = 0, PMTs off	552(16)	0.9
MMS, HV = 0, PMTs on	154(9)	3.3
MMS, HV = +4kV, PMTs on	58(8)	8.9
Nylon MS, PMTs off	203(10)	2.5
Nylon MS, PMTs on	64(3)	8.0
Nylon MS, PMTs on[2]	60(6)	8.6
Nylon MS, PMTs off	58(4)	8.9
Foil MS + SiPM, PMTs off	69(4)	7.5
Foil MS + SiPM, PMTs off	61(3)	8.4
Foil MS + SiPM, PMTs on	49(4)	10.5
LAr refilling		
Foil MS + SiPM, PMTs off	k*81(4)	~ 5.8
Glued Nylon MS, PMTs off	K*28(2)	~ 17

Conclusions

- GERDA Phase I/Phase II transition currently ongoing
- On the way to improve GERDA sensitivity:
  - **Increase mass**:
    - 30 additional BEGes ($\sim$ 20 kg)
    - already produced and completely tested in Hades (Belgium)
    - BEGe detectors already tested in the real environment in the Phase I
  - **Suppress background by a factor of 10 w.r.t. Phase I**:
    - Very efficient Pulse-Shape Discrimination for background recognition
    - Liquid Argon veto by detecting scintillation light
    - HV cable and VFE electronics with lower background
  - New lock system for the detector deployment into the cryostat
- Many important contributions from the GERDA Italian groups (Padova, Milano Bicocca and LNGS) on BEGe characterization, VFE electronics, data processing, MC simulations, data analysis
- Commissioning foreseen in **Autumn 2013 - Spring 2014**