Muon-induced Neutrons in GERDA

DPG-Frühjahrstagung Münster, 2017

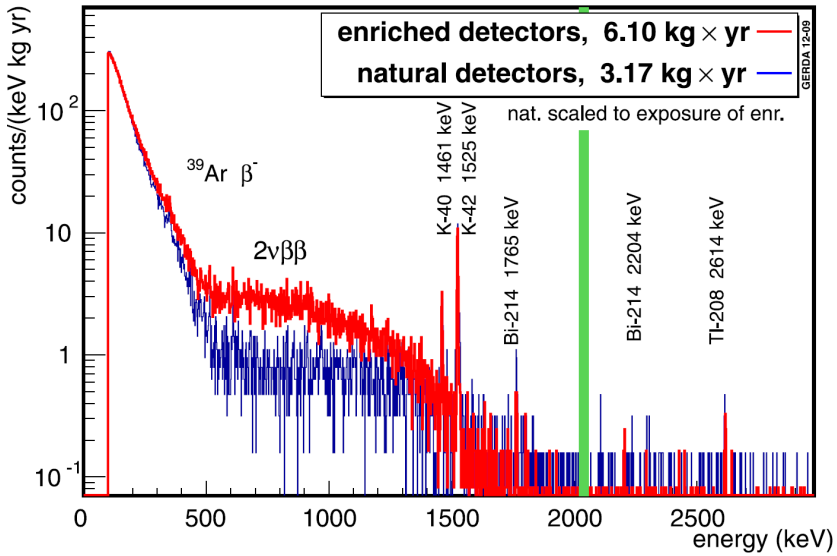
Laura Vanhoefer

Max-Planck-Institut für Physik
München

March 28, 2017

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

Eur. Phys. J. C (2013) 73:2330



Phase I :

- 11/ 14 detectors
- muon veto

Phase II:

- 40 detectors
- muon + LAr veto

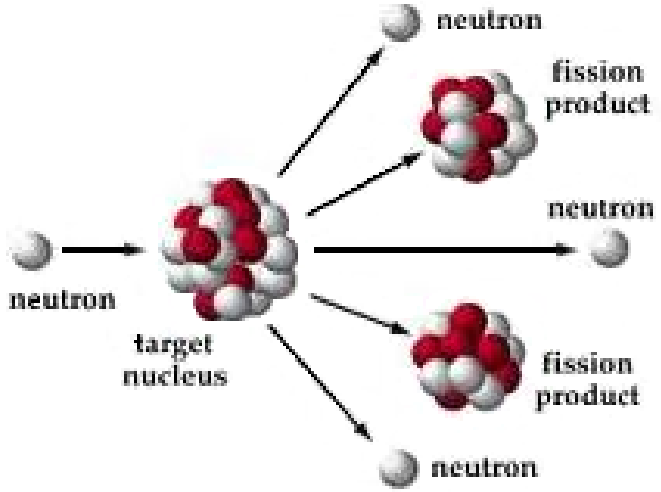
Background: Any energy deposition near or above the Q-value (^{76}Ge: $Q_{\beta\beta} = 2039\,\text{keV}$)

Neutron-induced Background

Background: Any energy deposition near or above $Q_{\beta\beta}$

Neutrons can produce radioisotopes via

- Neutron capture: e.g. $^{76}\mathrm{Ge}+\mathrm{n}\rightarrow{}^{77}\mathrm{Ge}$
- (n,p) reaction: e.g. $^{76}\mathrm{Ge}(\mathrm{n,p})^{76}\mathrm{Ga}$
- Spallation

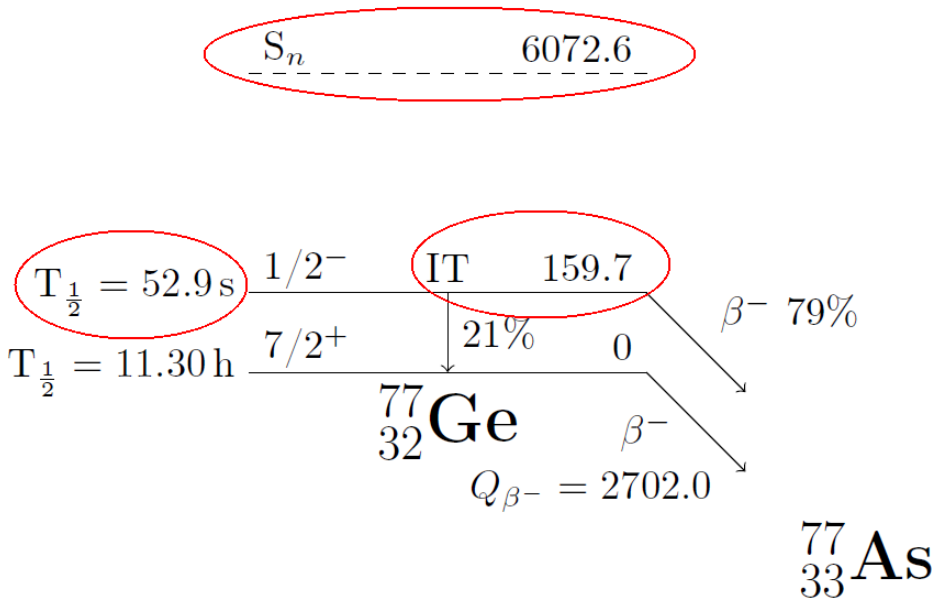


http://skmclasses.weebly.com/uploads/3/39174177/3615134_orig.jpg

Inelastic scattering (n,n'γ) can activate the nucleus putting it into an excited state

$\longrightarrow$ Goal: estimate neutron flux inside Gerda

Neutron Capture on Germanium



- Neutron capture detection: $E > E_{cut}$ in one detector
- IT detection: energy deposition of $E_{IT} \pm \Delta E$ within $t < t_{cut}$

$$\epsilon = \epsilon_{ncap,det} \cdot \epsilon_{IT} \cdot \epsilon_{IT,det} = \epsilon_{det} \cdot \epsilon_{IT}$$

Data set: Phase I, Run 35 – 46, 14 detectors

Signal

Decays per time interval after muon has passed:

$$A(t) = -\frac{dN}{dt} = N_0 \cdot \lambda \cdot e^{-\lambda t} \qquad \text{with} \quad \lambda = \frac{\ln 2}{T_{\frac{1}{2}}}$$

substitute with $t = x \cdot T_{\frac{1}{2}}$

$$\longrightarrow A(x) = \ln 2 \cdot N_0 \cdot e^{-\ln 2 \cdot x} = \ln 2 \cdot N_0 \cdot \frac{1}{2}^x = A_0 \cdot \frac{1}{2}^x$$

with number of decays:

$$N_0 = \frac{A_0}{\ln 2}$$

BAT Analysis

Models:

- Signal + Background: $f(x) = A_{capt} \cdot \frac{1}{2}^{x} + A_{bkg}$
- Only Background: $f(x) = A_{bkg}$

Flat prior P_0 for all parameters

Table : Results model Signal + Background. Best fit and quantiles.

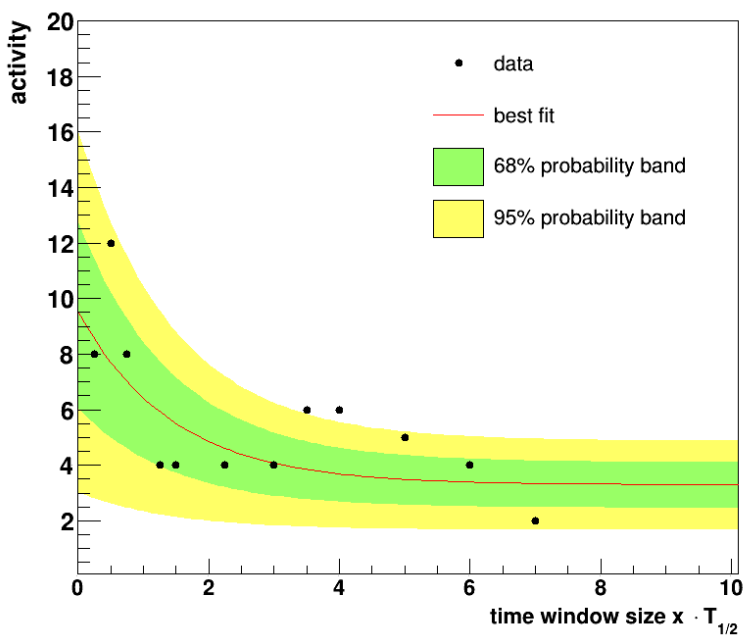
Parameter	Best fit (global)	5%	16%	84%	95%
A_{capt}	6.25 ± 0.14	2.06	3.62	8.71	10.39
A_{bkg}	3.30 ± 0.06	1.92	2.46	4.09	4.61

Table : Results model Signal + Background. Best fit and quantiles.

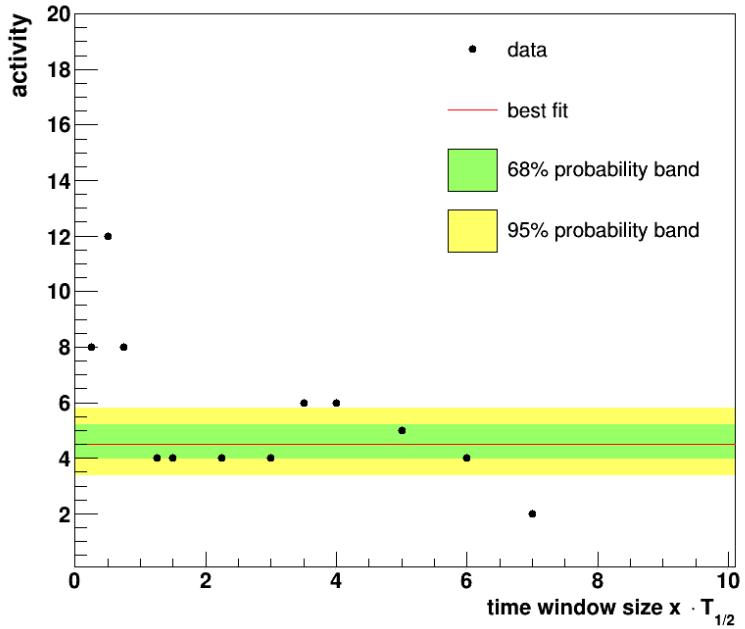
Parameter	Best fit (global)	5%	16%	84%	95%
A_{bkg}	4.50 ± 0.06	3.57	3.97	5.20	5.60

Model Comparison

Model: Signal + Background



Model: Only Background

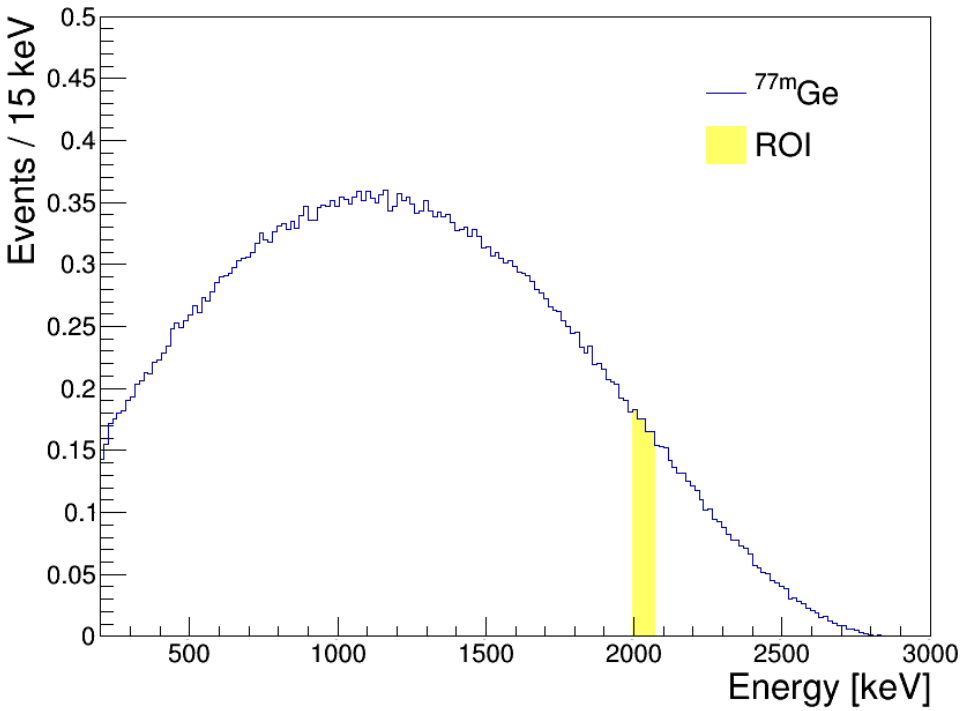


Bayes Factor:

$$K = \frac{P(D|M_{sgn+bkg})}{P(D|M_{bkg})} = 50$$

$\longrightarrow$ **Model Signal + Background** describes data better

^{77m}Ge in ROI



Q : 2039 keV

ROI: (2019 – 2059) keV

Time: 302.136 d

Mass: 24.251 kg

Seen ^{77m}Ge signals: 9.02 ± 0.20

$\longrightarrow$

Neutron captures: (70.47 ± 1.56)

^{77m}Ge isotopes: (50.0 ± 1.1)

^{77m}Ge β^- decays: (40.53 ± 0.90)

Counts in 2010 – 2055 keV: 0.516 ± 0.011

Count rate: $(5.716 \pm 0.127)\, 10^{-4}\ (\mathrm{kg\,keV\,y})^{-1}$

Summary

- Neutrons can produce long-lived radioisotopes $\longrightarrow$ background
- Used neutron capture on ^{76}Ge to determine number of produced ^{77m}Ge
- Phase I data (Run 35 – 46, 14 detectors):
  (50.0 ± 1.1) ^{77m}Ge isotopes
- Muon-induced neutrons $\longrightarrow$ background in ROI

  (without muon anti-coincidence)

  ^{77m}Ge β^- decays in ROI: $(5.716 \pm 0.127)\,10^{-4}$ $(\mathrm{kg\,keV\,y})^{-1}$