GERDA and GeDet Project Review 2010

Fabiana Cossavella for GERDA & GeDet groups

Max-Planck Institut für Physik, München

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Director: Allen Caldwell
Project leaders: Béla Majorovits (GERDA), Iris Abt (GeDet)
Postdoc: Fabiana Cossavella, Josef Janicsko, Xiang Liu (03/10), Christopher O'Shaughnessy
PhD: Neslihan Becerici-Schmidt, Sabine Dinter, Daniel Lenz (03/10), Oleksandr Volynets
Diplomand: Hossein Aghaei-Khozani (11/10), Florian Faulstich, Sabine Hemmer (09/10), Annika Vauth (10/10)
Group engineer: Hans Seitz, Franz Stelzer
Engineering: Karlheinz Ackermann, Sven Vogt

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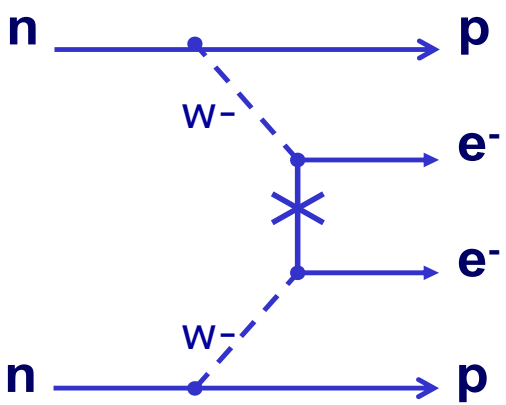
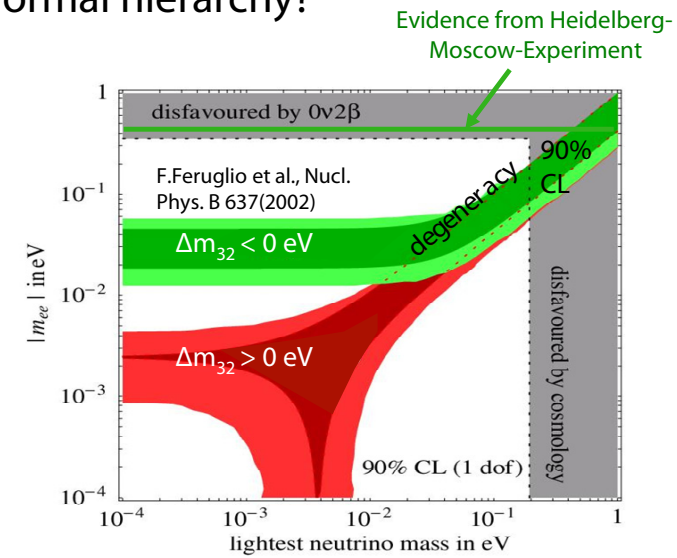
Search for $0\nu\beta\beta$ decay

Unknowns about Neutrinos:

- Nature of the Neutrino (Dirac - Majorana?)
- Absolute mass scale? Inverted/normal hierarchy?
- CP phases?



$\Delta L=2$, beyond SM



If neutrinoless double beta-decay is observed:

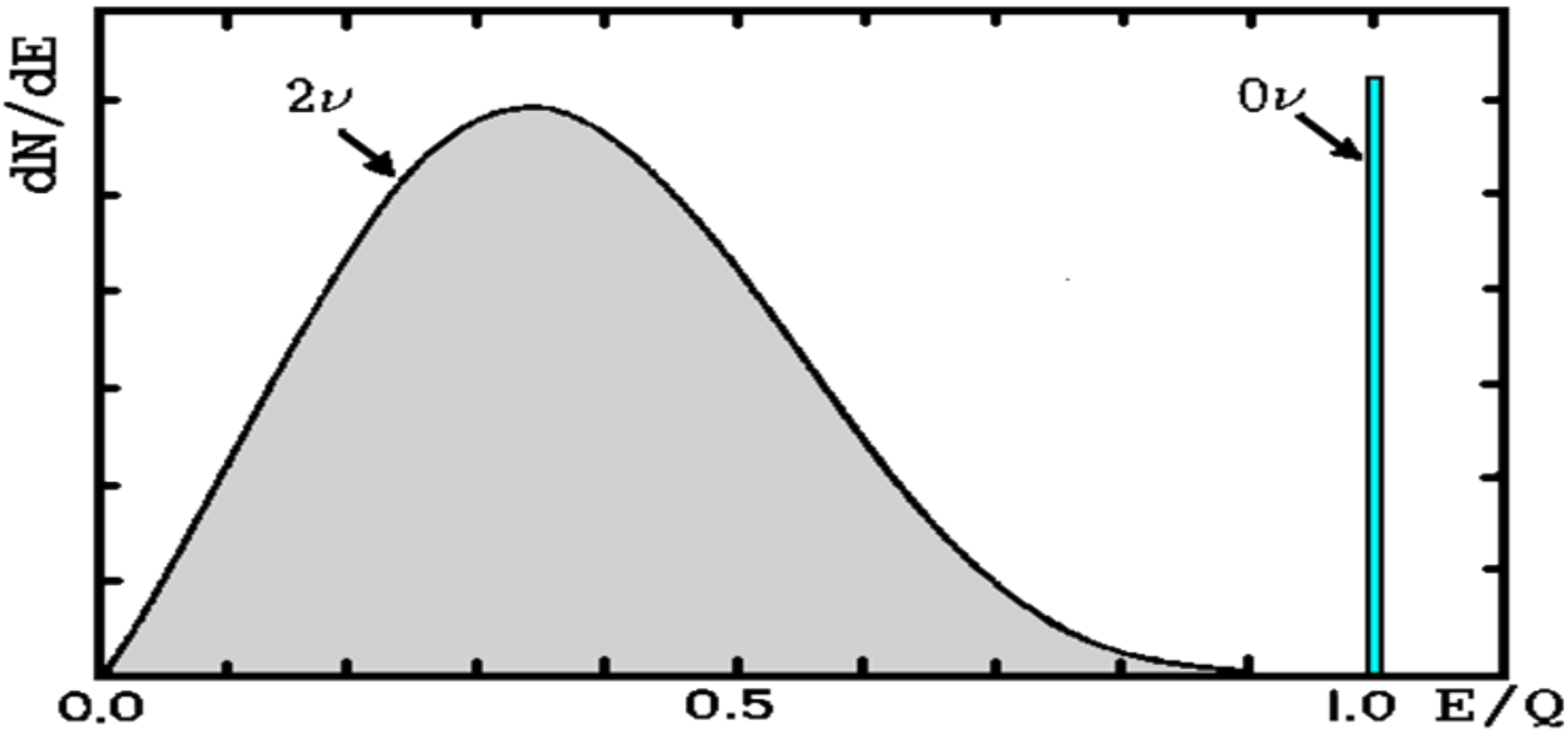
→Neutrino is a Majorana particle

→Information on absolute mass scale

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

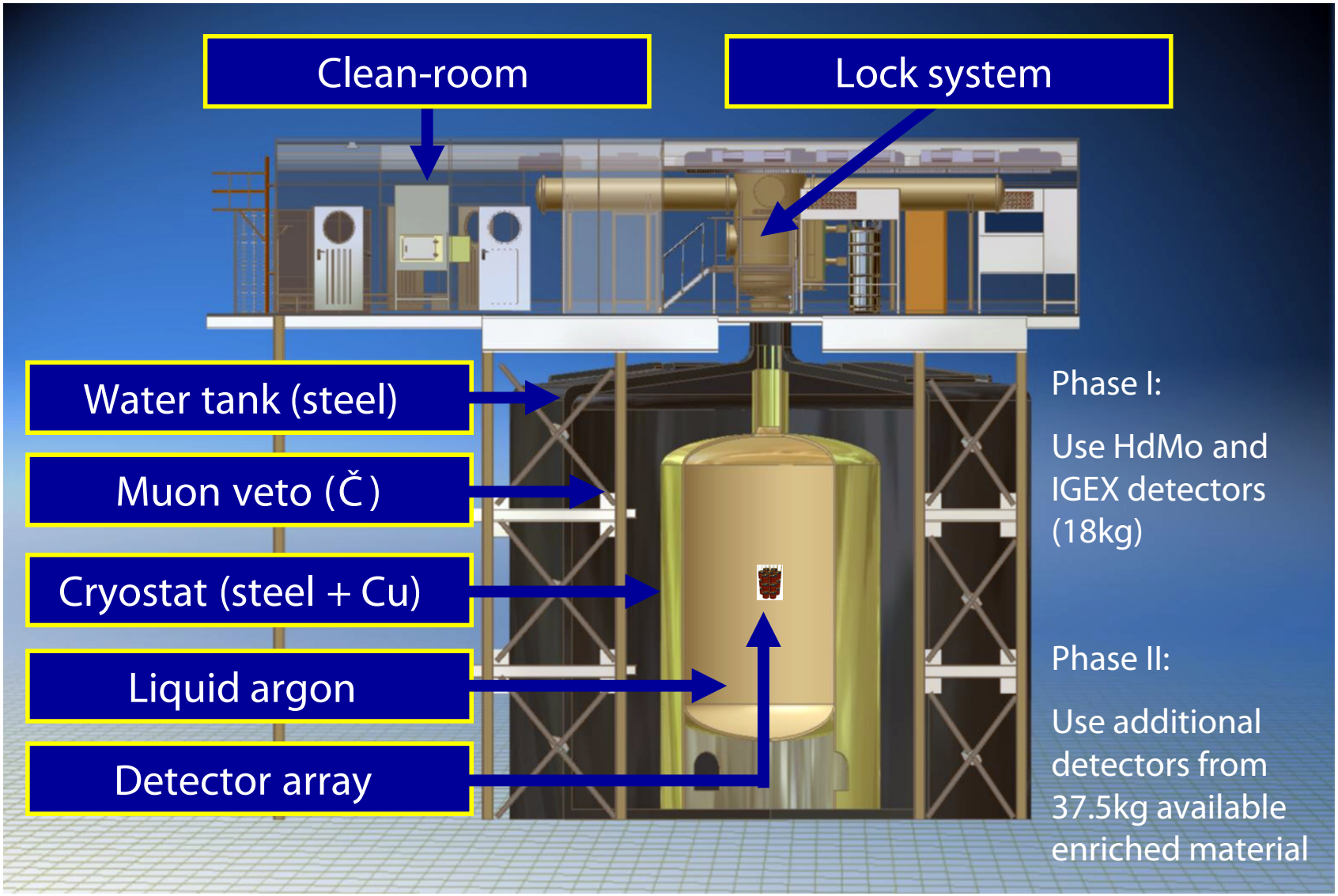
$0\nu\beta\beta$ Decay rate	Phase space factor	Matrix element	Effective Majorana Neutrino mass

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

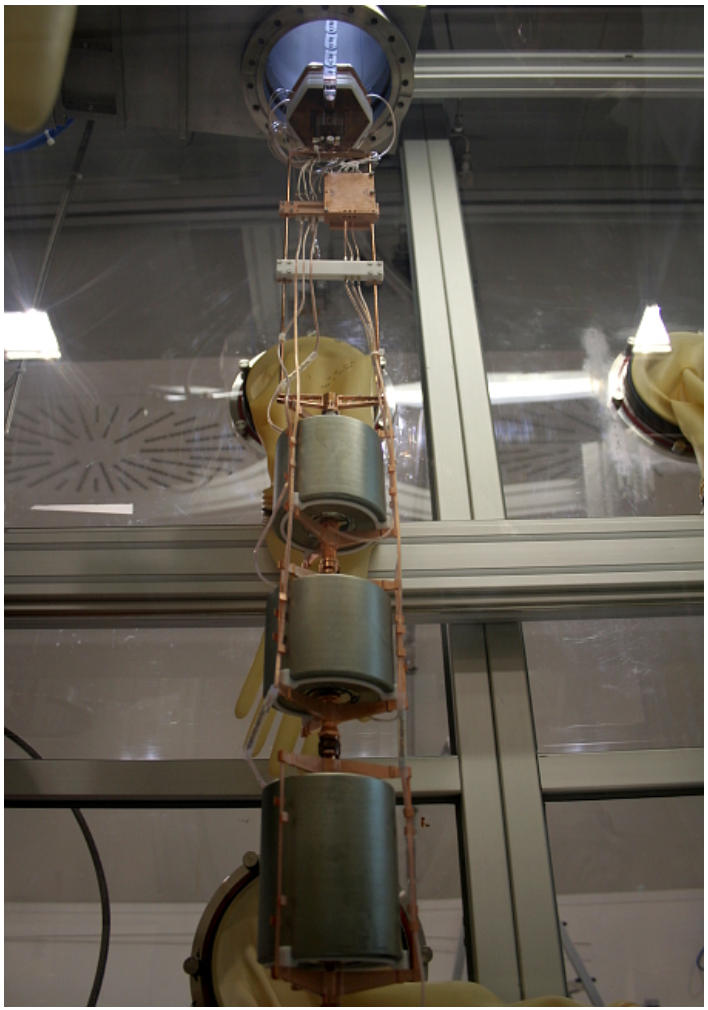


Signature: Sharp peak at Q-value of the decay (2039 keV for ^{76}Ge)

The GERmanium Detector Array



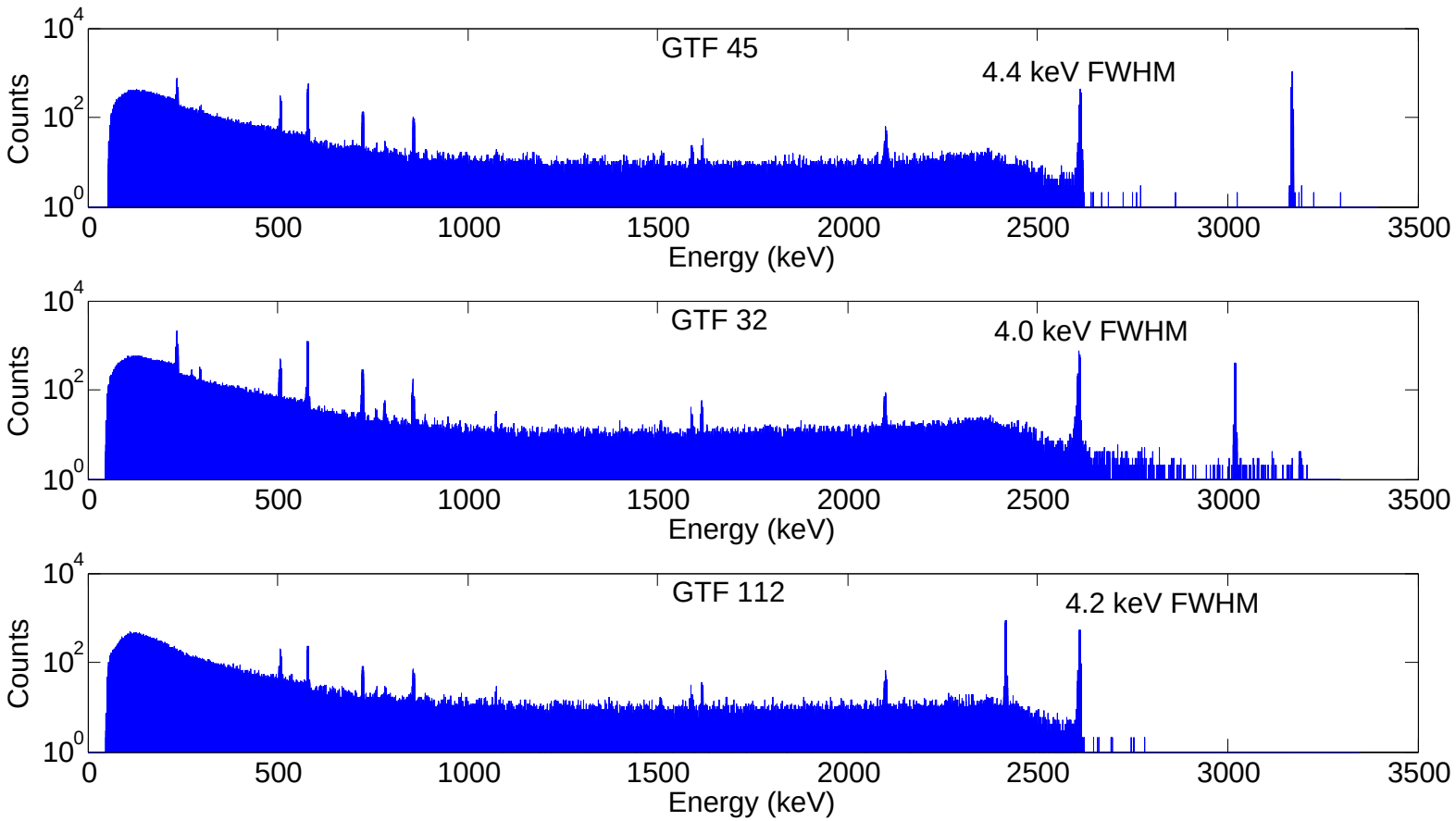
Deployment of 1st string



- infrastructure completed in May 2010
- 1st string of ^{nat}Ge installed in June 2010

background measurement ongoing since June 2010

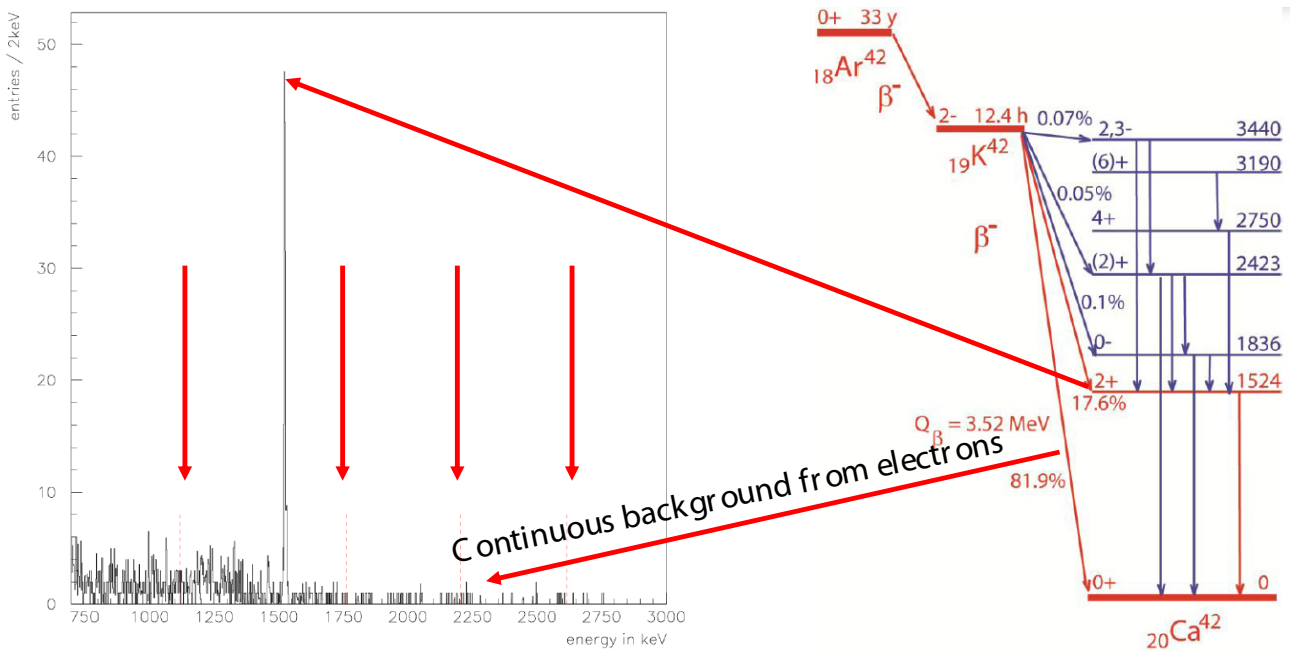
Deployment of 1st string



^{228}Th calibration spectrum

GERDA background

Distinct peak at 1525 keV

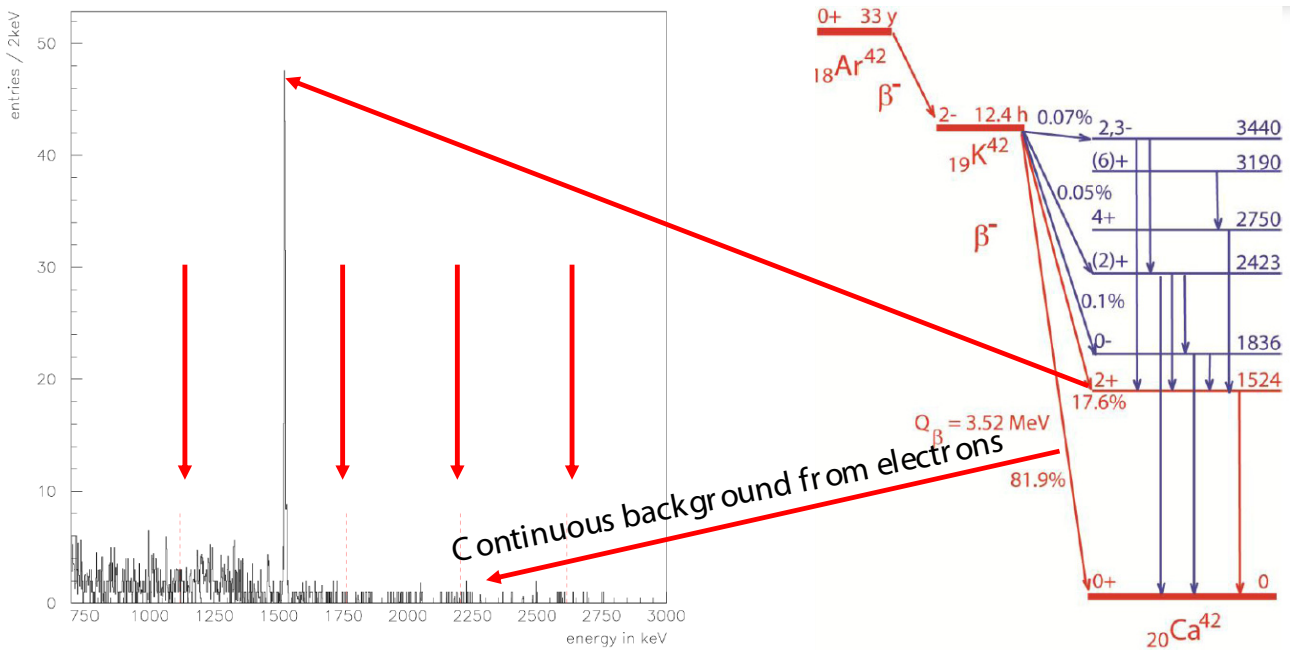


- background contributions due to ^{232}Th, ^{238}U:

$$< 1.2 \cdot 10^{-2} \mathrm{counts}/(\mathrm{kg\,keV\,y})$$

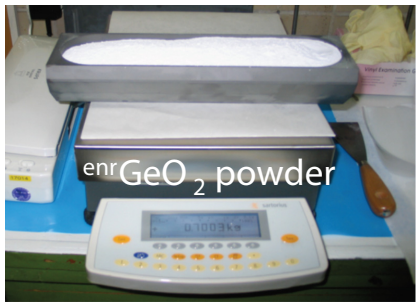
GERDA background

Distinct peak at 1525 keV

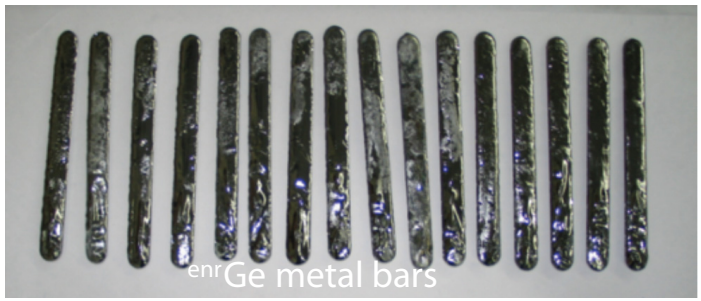


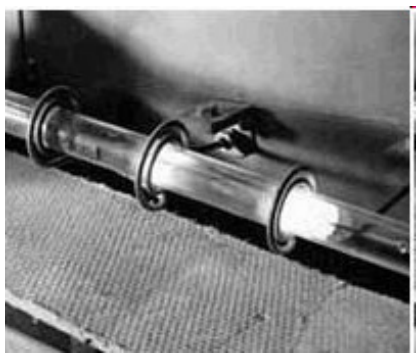
- $^{42}K^{+}$ drift in the electric field
- Changing field configuration changes intensities $\rightarrow$ best background: $8 \cdot 10^{-2} \mathrm{counts}/(\mathrm{kg\,keV\,y})$ at $Q_{\beta\beta}$
- further studies ongoing

GERDA enriched material

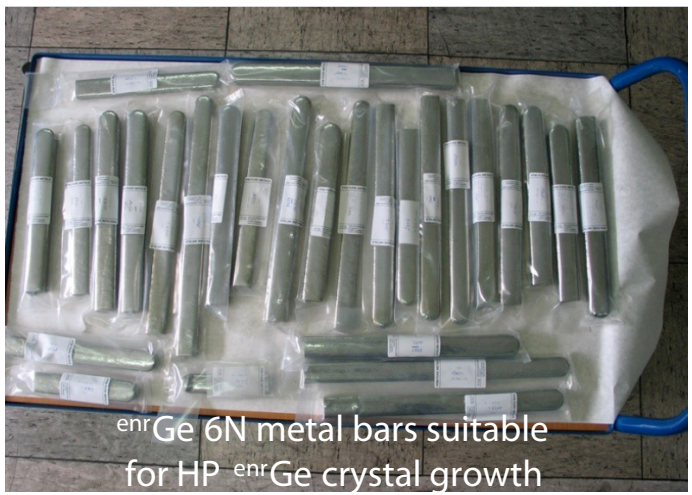


Reduction in H_2 atmosphere





Zone refinement



Reduction yield

98.5%

Zone refinement yield

95.3% , overall 93.9%

Material reduced and purified with yield $>$ 80% (target)

Crystal pulling for n-type HPGe detectors

Pulling HPGe crystals is not trivial!
Worlwide only three companies.

Cooperation with IKZ, Berlin:
Czochralski puller procured,
Refurbrished and electropolished.

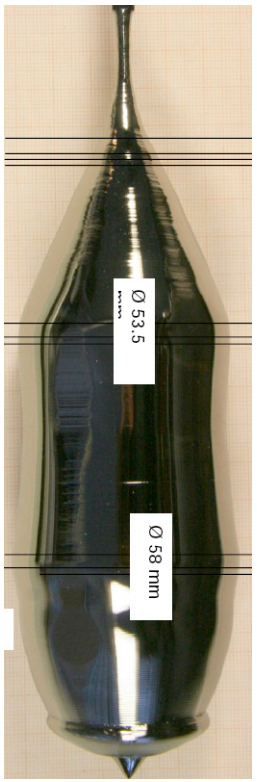
Many crystals grown.

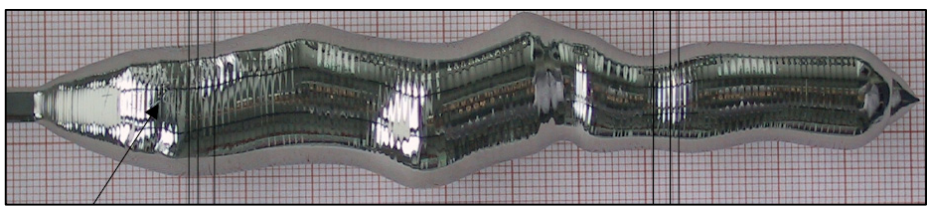
One crystal with few 10^{10} per cm^3

But most crystals with ~10^{11} per cm^3

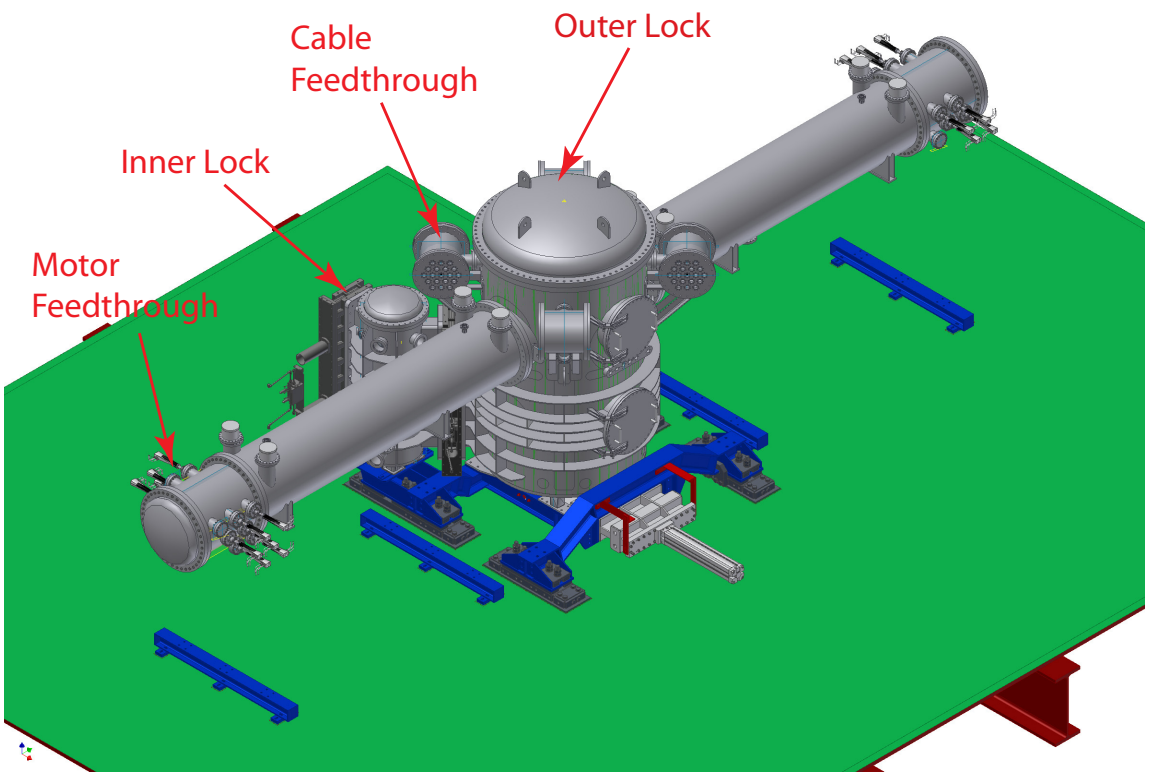
→ Still one order of magnitude too high

6N Material from PPM is already very clean





The final lock system



assembly starts after delivery of the 3-string arm of c-lock

GeDet Project

Development of segmented n-type Germaniun detectors for future applications

1 Ton initiative

- push further down sensitivity
- normal or inverted hierarchy?
- 1 Ton of ^{enr}Ge
- background index $= 10^{-5}$ cts keV^{-1}kg^{-1}y^{-1}

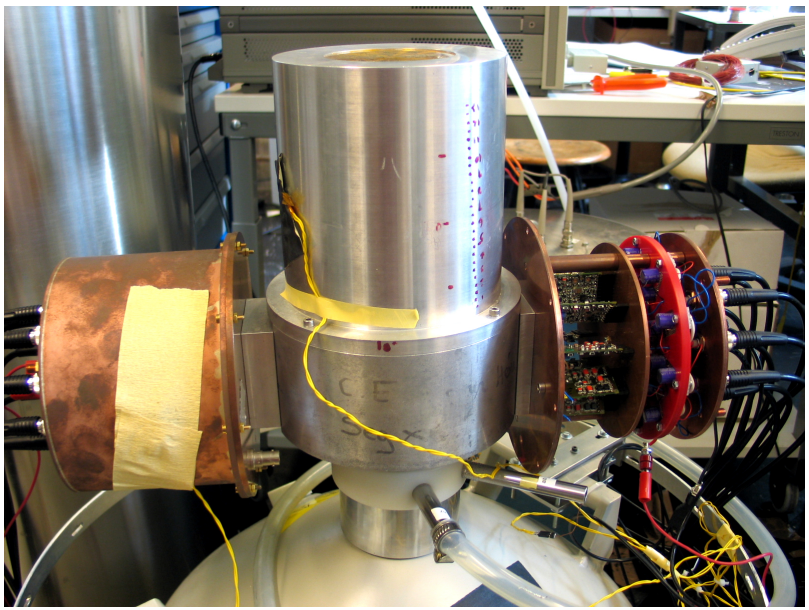
Properties of Ge detectors

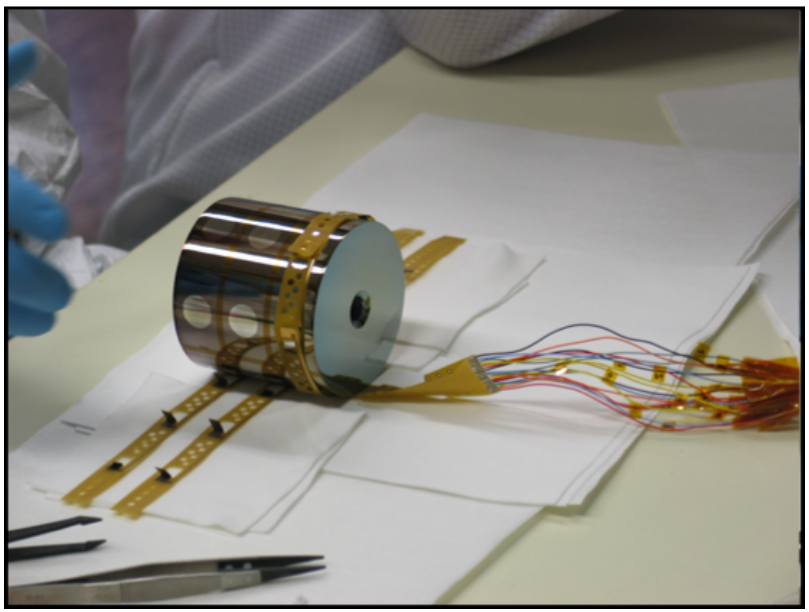
- study of surface events induced by α and β
- study of pulse shape details to identify surface events and multiple interaction $\rightarrow$ background reduction

Test Stands: detector characterization

K1 test stand:

detector operated in vacuum cryostat (T from 90 K to 120 K), γ scans only

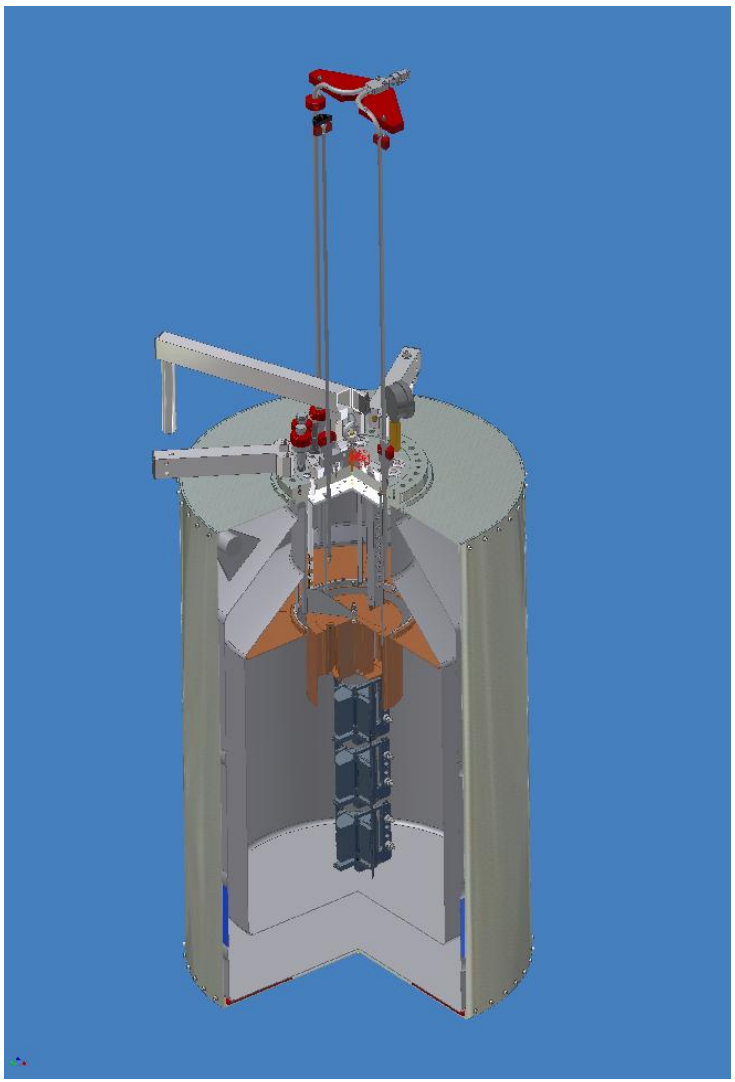


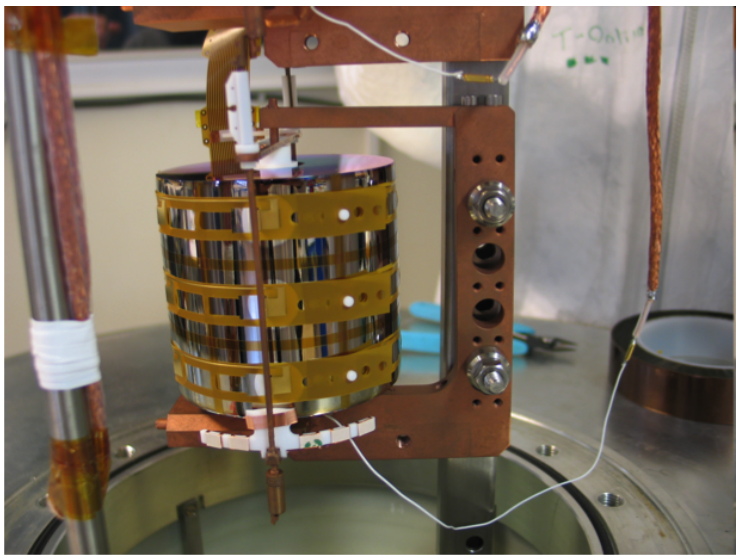


task completed $\rightarrow$ prototype detector for a GERDA scale experiment

"Characterization of the first true coaxial 18-fold segmented n-type prototype detector for the GERDA project", Iris Abt et al., Nucl.Instrum.Meth. A 577 (2007) 574

Test Stands: detector characterization





Gerdalinchen II

- able to handle 3 HPGe detectors in LN_2 or LAr
- operation at 77 K

"Operation of an 18-fold segmented n-type HPGe detector in liquid nitrogen", Iris Abt et al., J. Instrum. 4 (2009) p11008

Pulse Shape simulation

Development of a complete package to simulate pulses.
Shape of a pulse strongly influenced by:

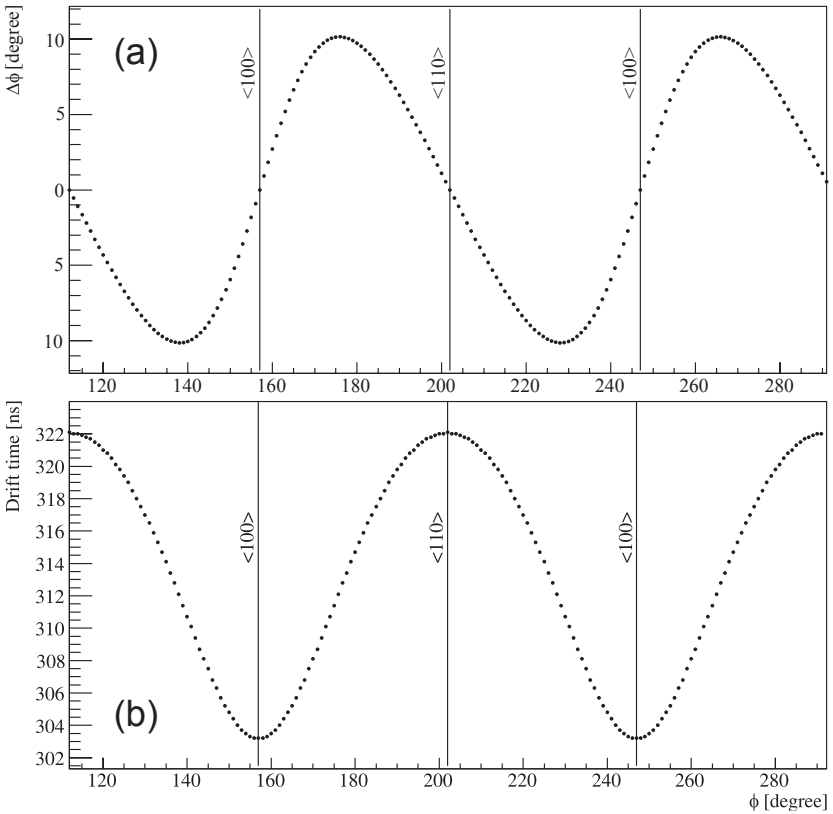
impurity of the crystal

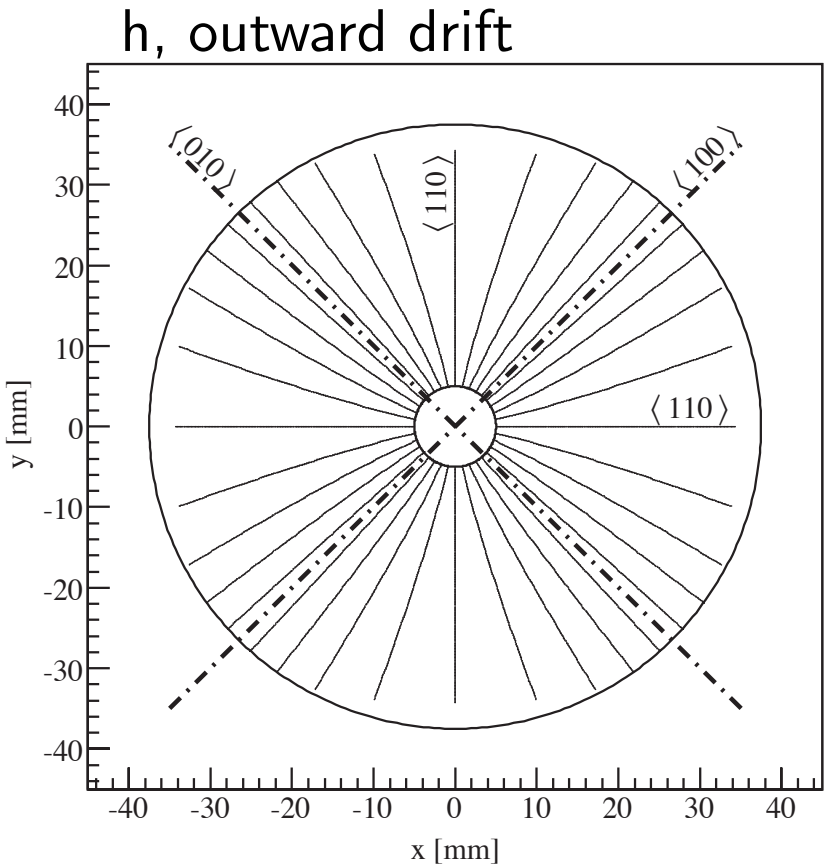
- impurities are not homogenous
- each crystal is individual
- uncertainty $\sim 20\% - 30\%$

mobility

- e^- reasonably well known
- holes $\rightarrow$ available measurements differ inside a factor 2

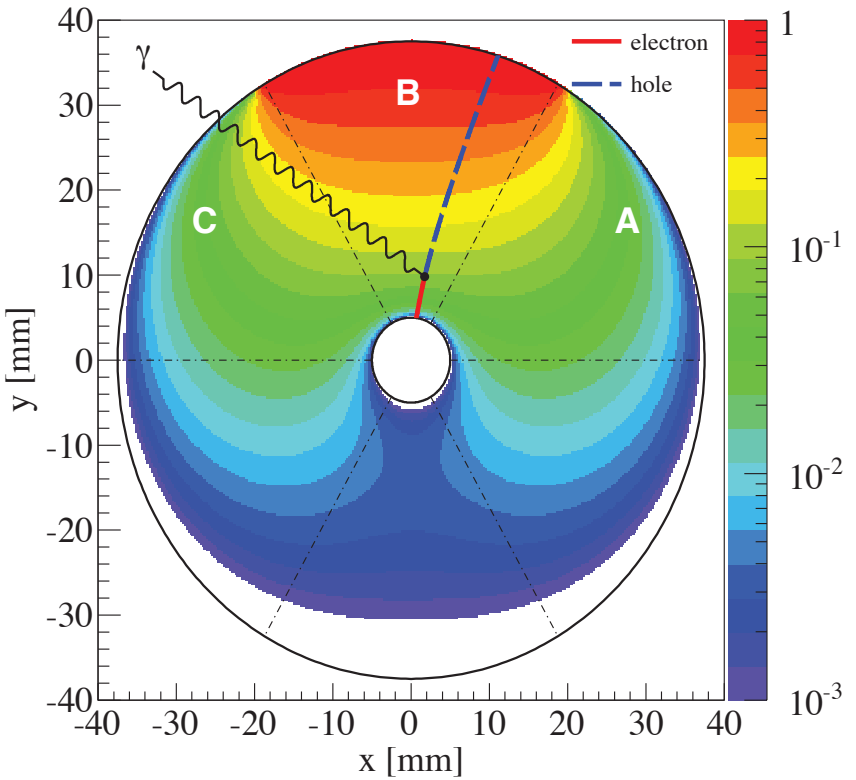
Pulse Shape simulation

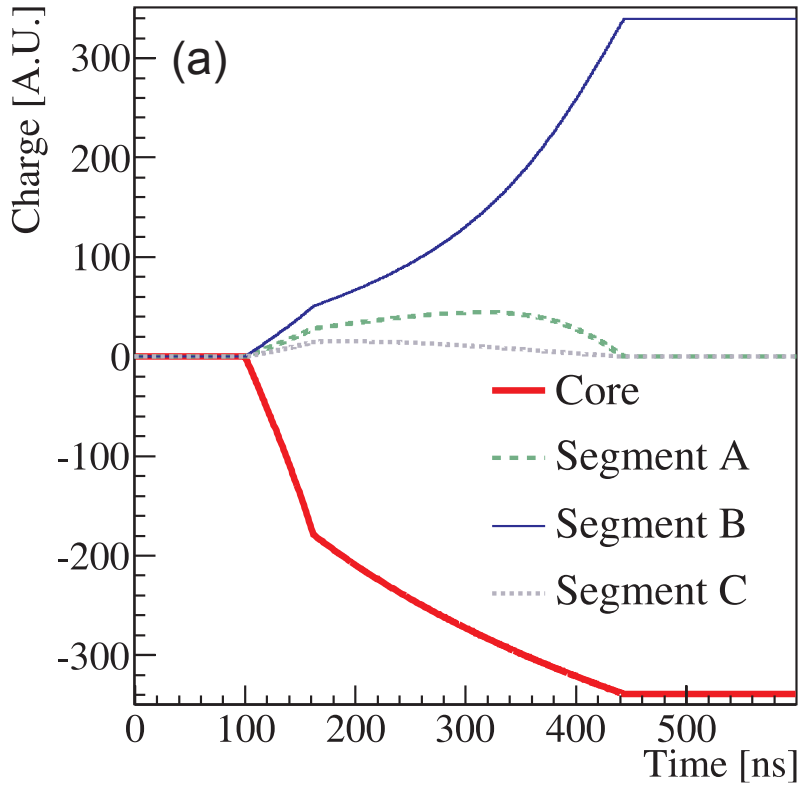




- trajectories are bent due to the crystal structure
- charge carries slower in the $< 110 >$ than in the $< 100 >$ direction $\longrightarrow$ very clear for the holes trajectories

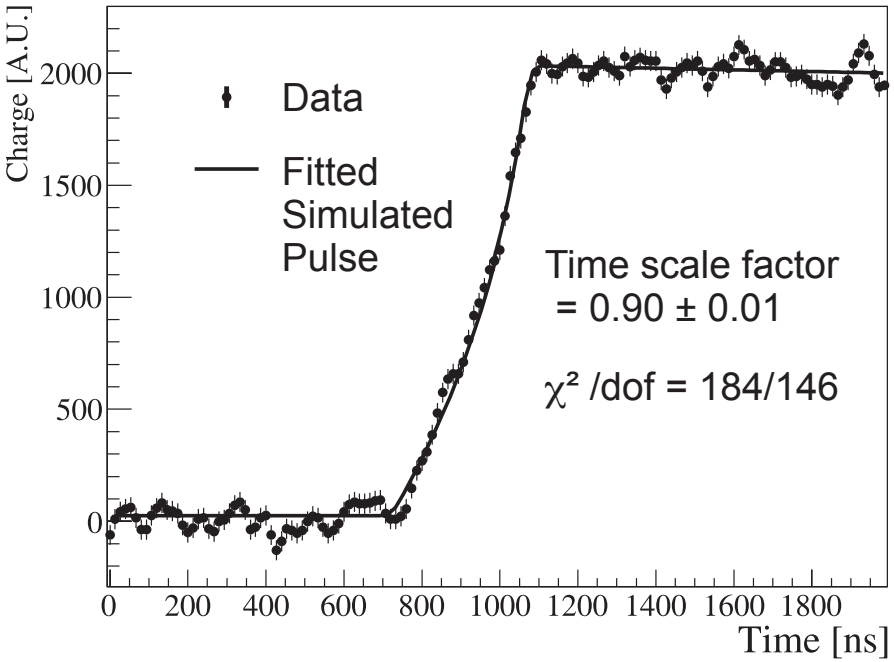
Pulse Shape simulation

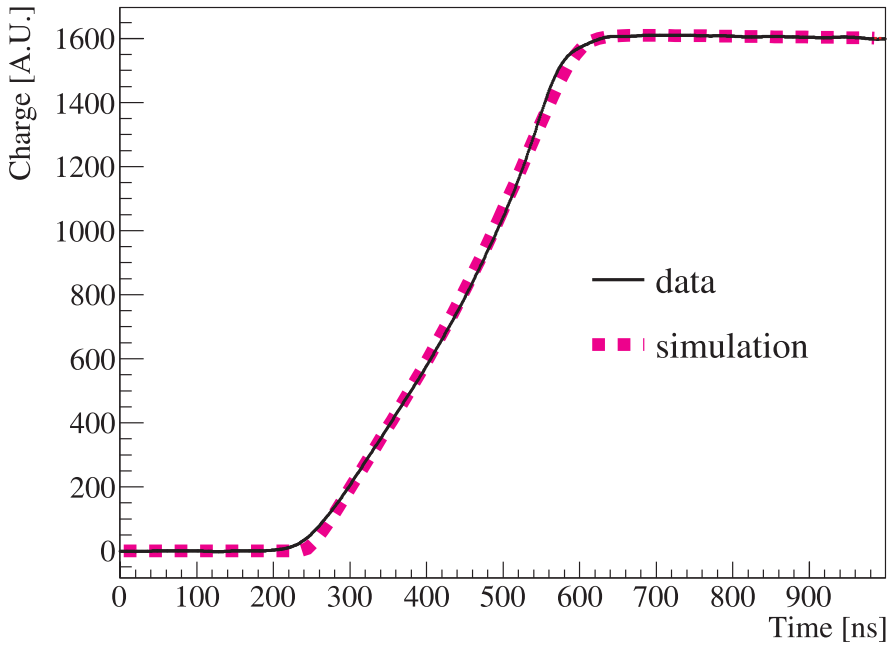




- electric signals induced on the electrodes by cumulative influence of moving electrons and holes
- pulse in segment B + mirror pulses in segments A and C
- kinks in core and segment B pulse when e^- reach the core

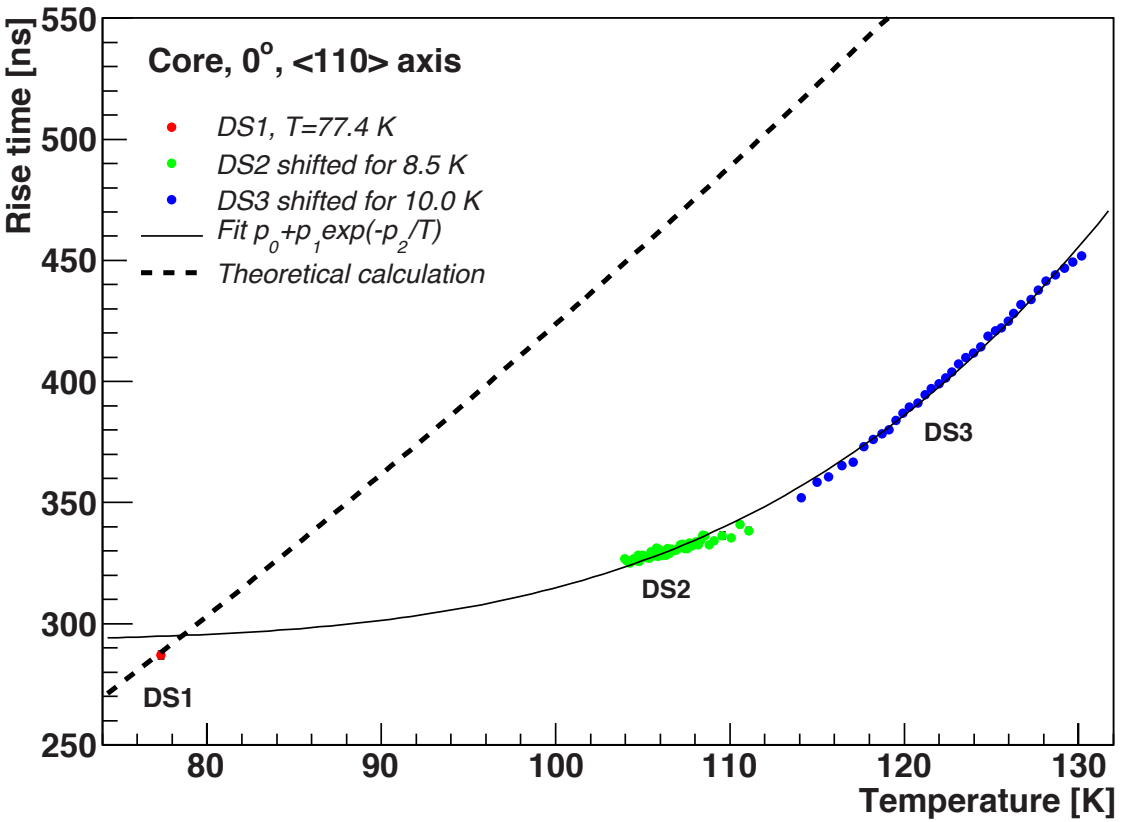
Pulse Shape simulation





- simulated core pulses fitted to measured pulses → simulation describe the general shape very well
- overall length of simulated pulse to be adjusted → ρ_{imp}, T, μ

Pulse lenght: T dependence



- $t_r{}^{core} = 290$ns, simulation
- $t_r{}^{core} = 287$ns, data

$\longrightarrow$

Expectation

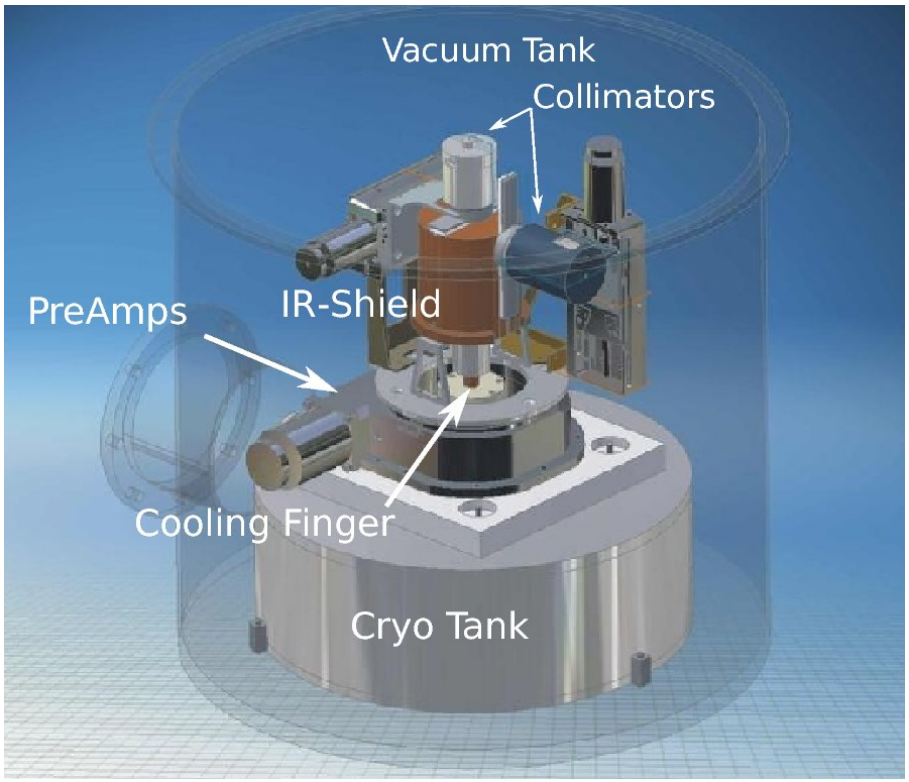
- if E $\sim$ const. $\longrightarrow$ $t_r \propto \mu_{eff}{}^{-1}$
- $\mu_{eff} \propto T^{-3/2}$

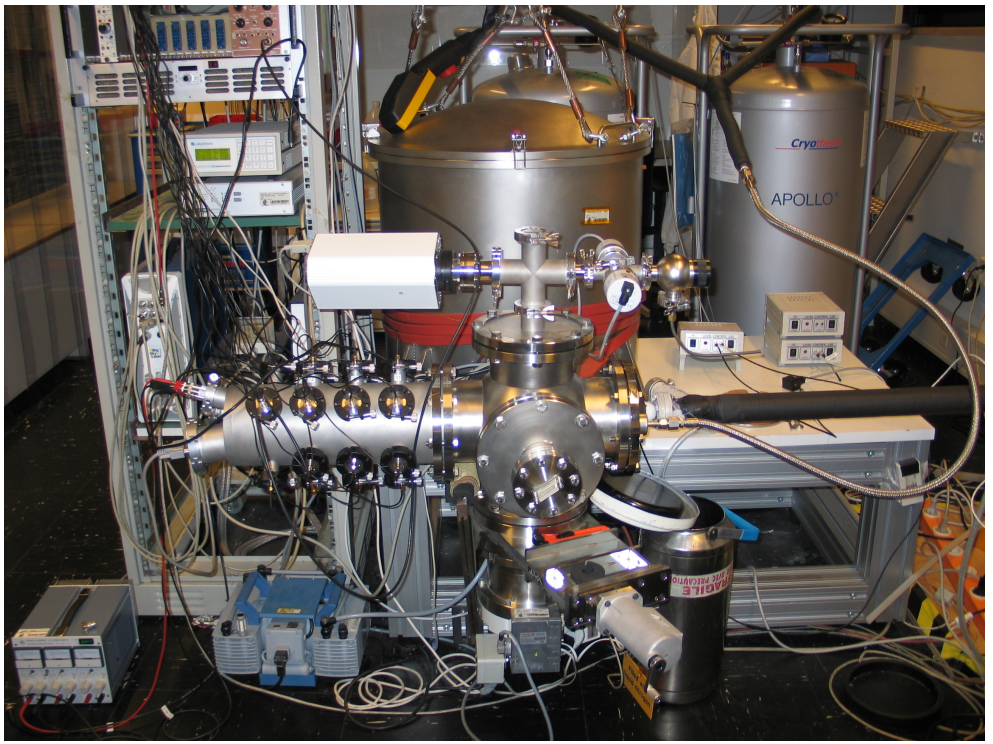
Data

- Boltzmann-like law: $t_r \propto e^{-k/T}$
- is something else T-dependent?

T dependence will be included in PS simulation package!

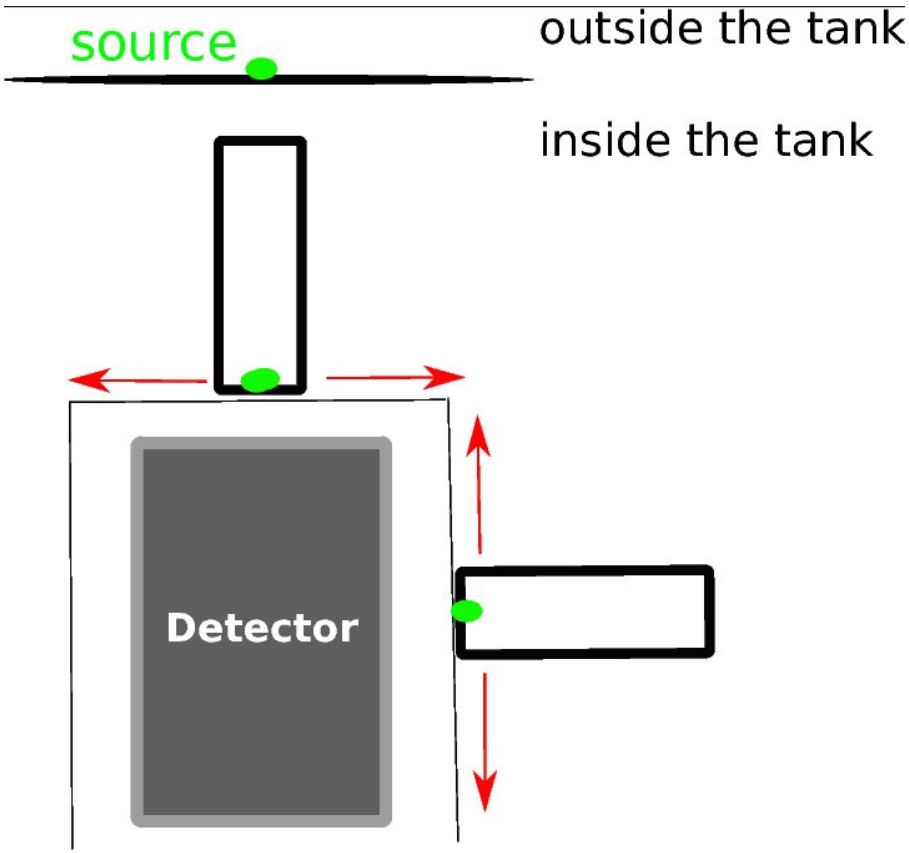
GALATEA





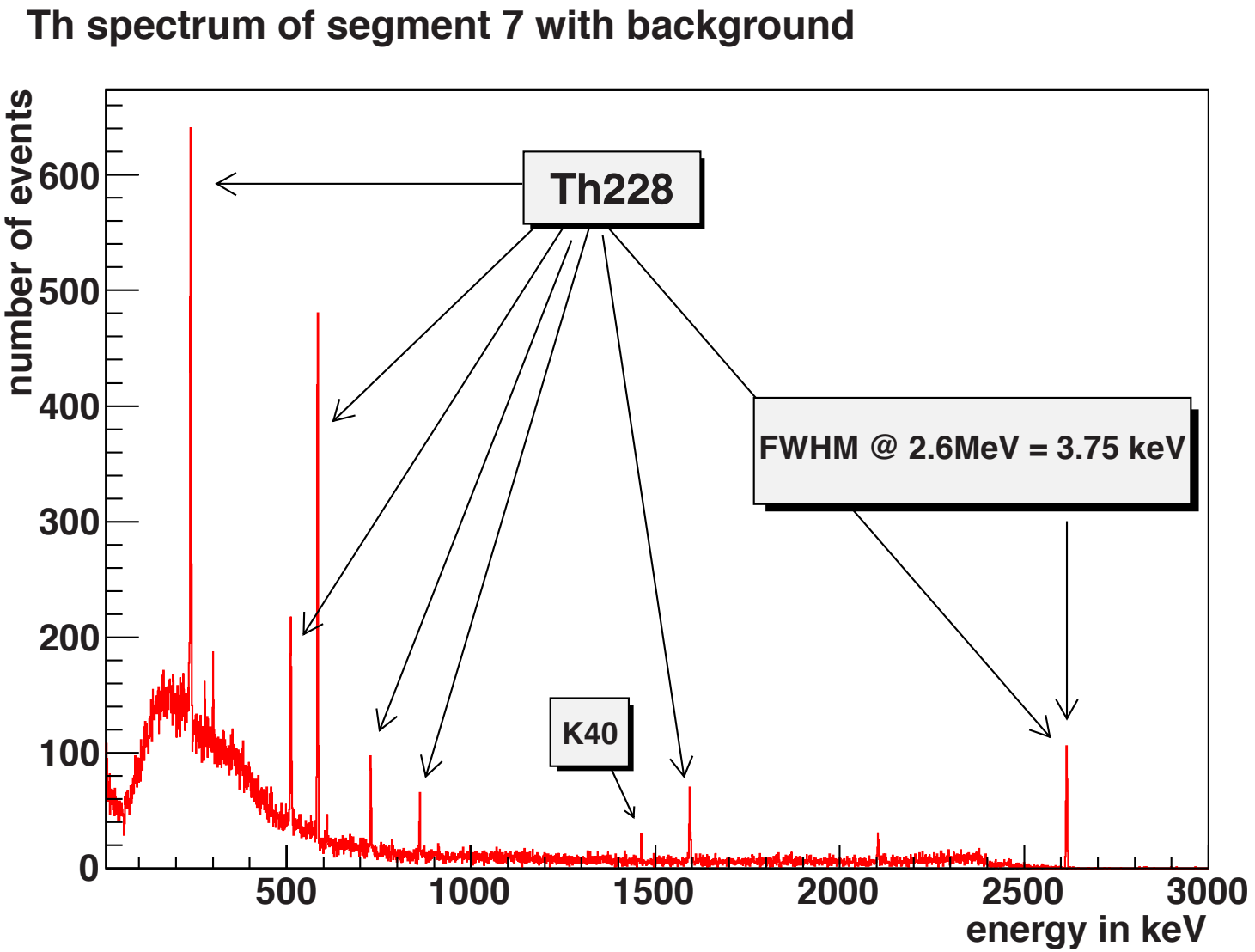
- analysis of surface effects with coaxial Ge detectors
- direct irradiation with α and β particles and IR laser

GALATEA first measurements

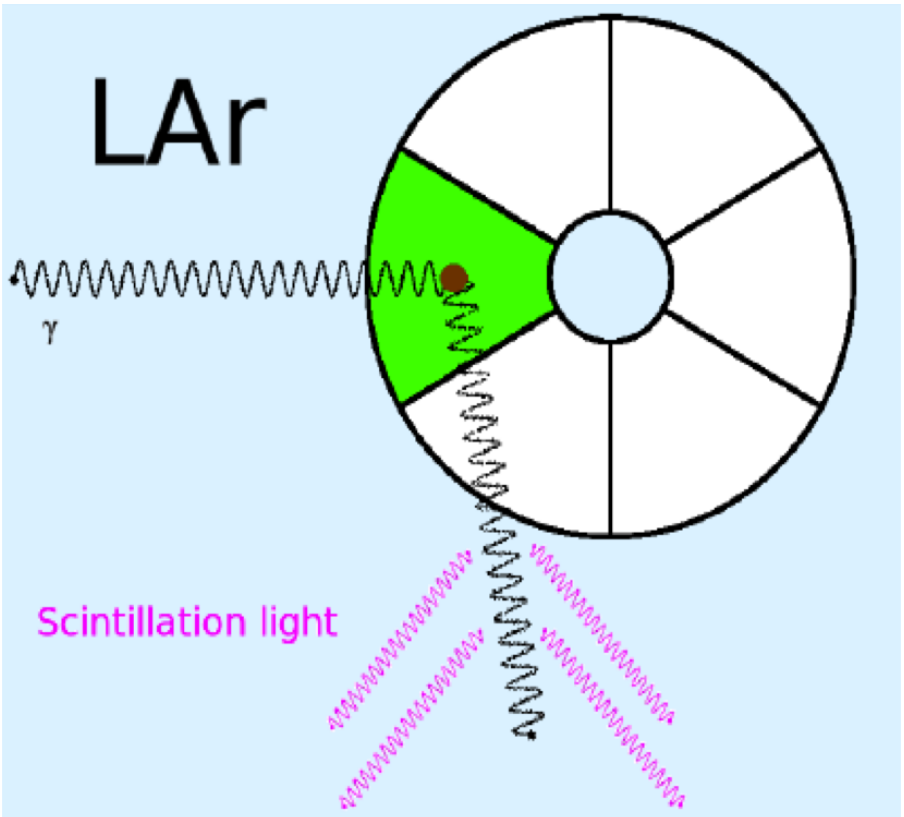


- ^{60}Co and ^{228}Th on top of the tank to test functionality
- alpha-(^{241}Am), beta-(^{90}Sr) and gamma sources inside the tank for precision measurements

GALATEA first measurements

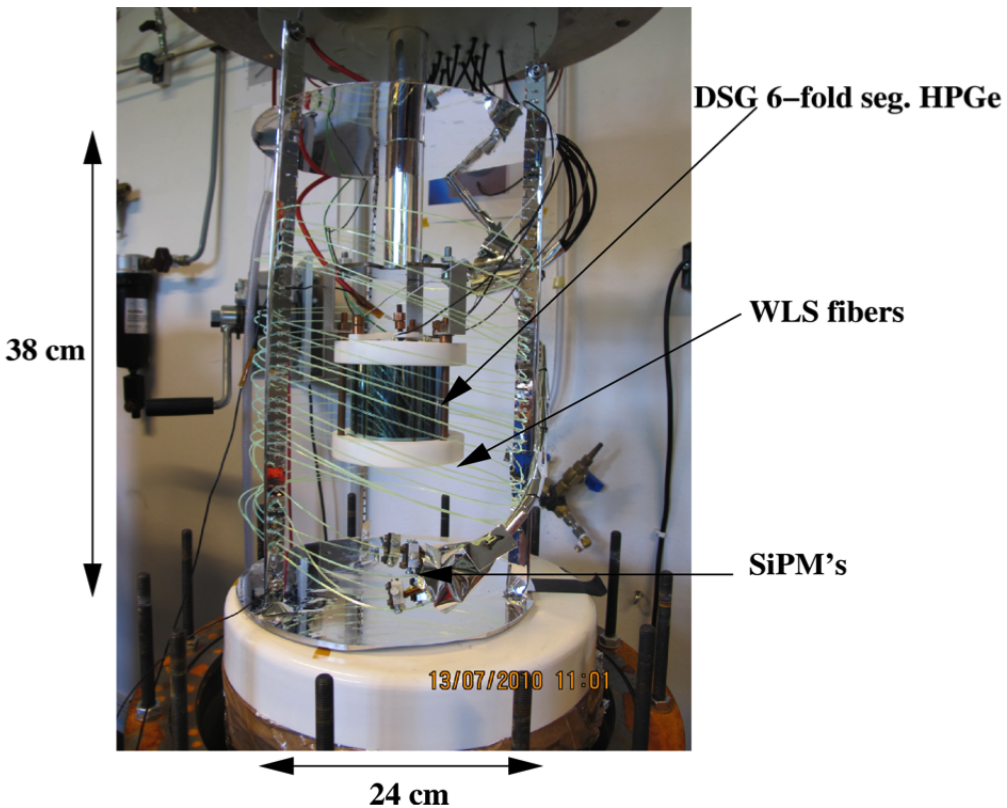


Background reduction R&D



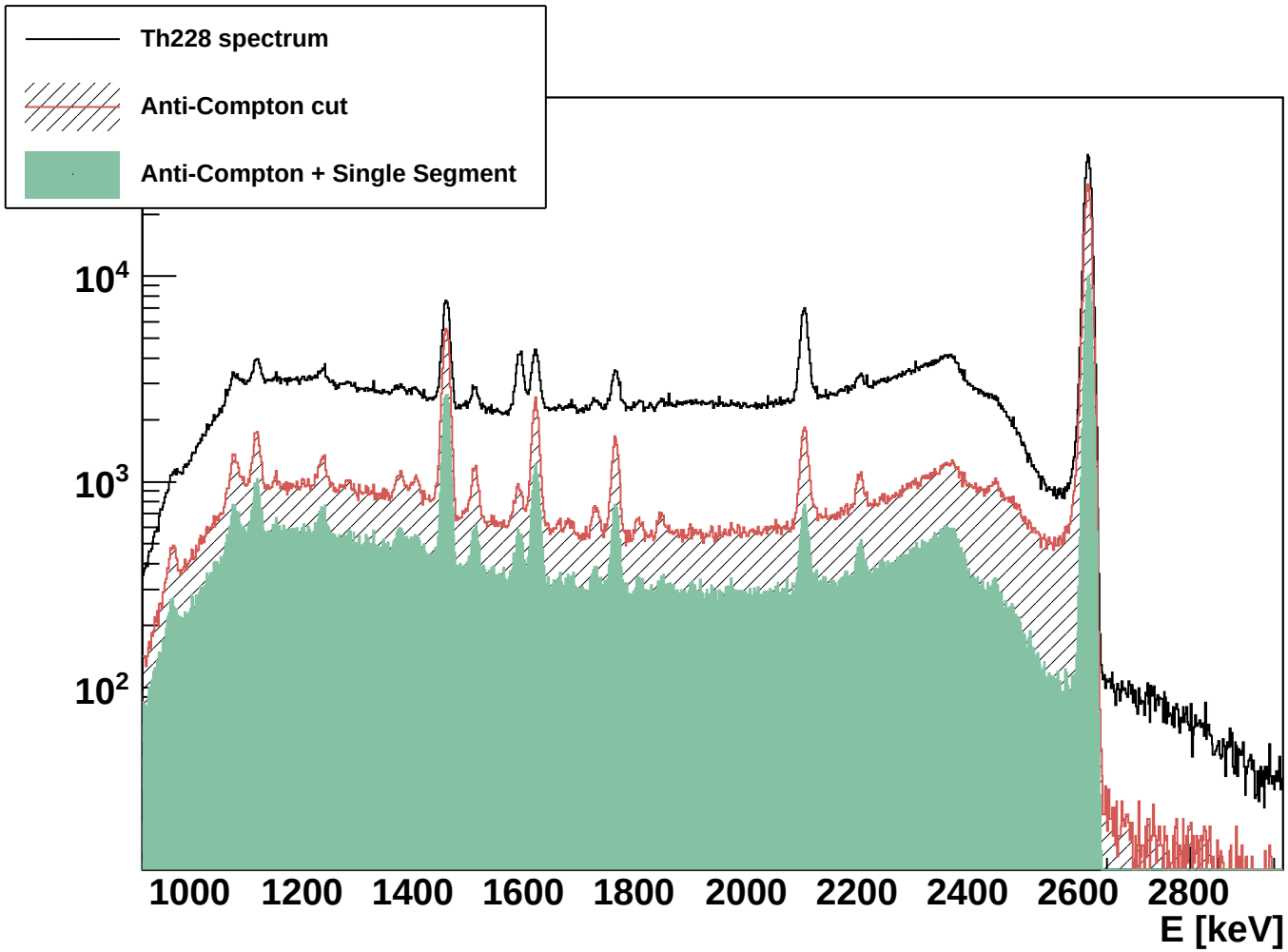
- singly Compton scattered γ_s escaping detector $\longrightarrow$ same event topology as signal-like events
- use scintillation light to identify event as background
- normal PMTs contribute to radioactive background!

Background reduction R&D



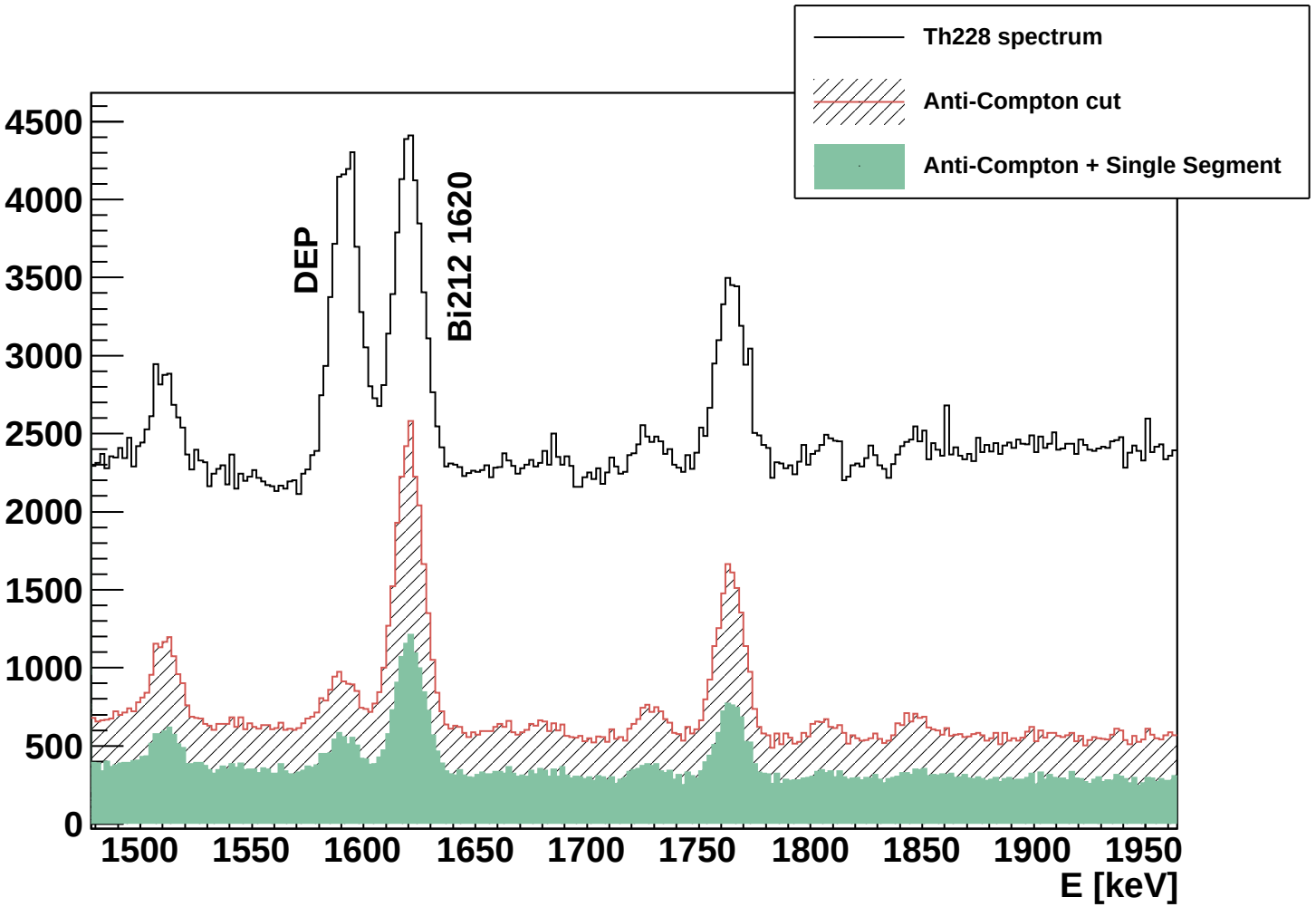
- 12 SiPMs + 15 m wavelength shifting fibers
- successfully operated in anticoincidence with 6-fold segmented HPGe detector
- detection efficiency $\approx$ 90 p.e./MeV energy deposit

Background reduction R&D



background suppression by factor 4.2 in the RoI (8.6 with segment anti-coincidence veto)

Background reduction R&D



background suppression of the DEP (1593 keV) by a factor 6.2 (9.3)

Summary: GERDA

- GERDA infrastructure finished, first commissioning detectors deployed
- ^{42}Ar background is being investigated
- Phase I start next year after delivery of 3-string arm and mitigation of the ^{42}Ar problems
- Enriched material has been purified with very high yield
- R&D on crystal pulling at IKZ is ongoing
- SiPM anti-compton veto looks promising

Summary: GeDet

- characterization of 18-fold segmented Ge detectors completed
- power to suppress background with segmentation cut andor PSA
- validation and improvement of the PS simulation package
- improvement of PSA package ongoing
- GALATEA test stand for 3D scan in operation!
- also ongoing: neutron screening studies for 1 Ton experiment