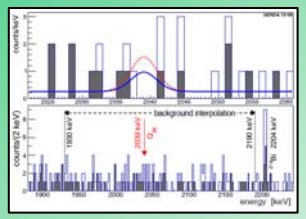
Reaching higher sensitivities for 0νββ decay with GERDA phase II

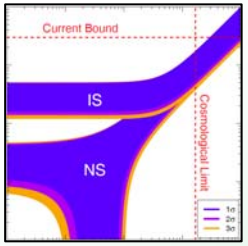
Béla Majorovits (MPI für Physik, Munich)
for the GERDA collaboration

TAUP, Sept. 9., Asilomar, California USA

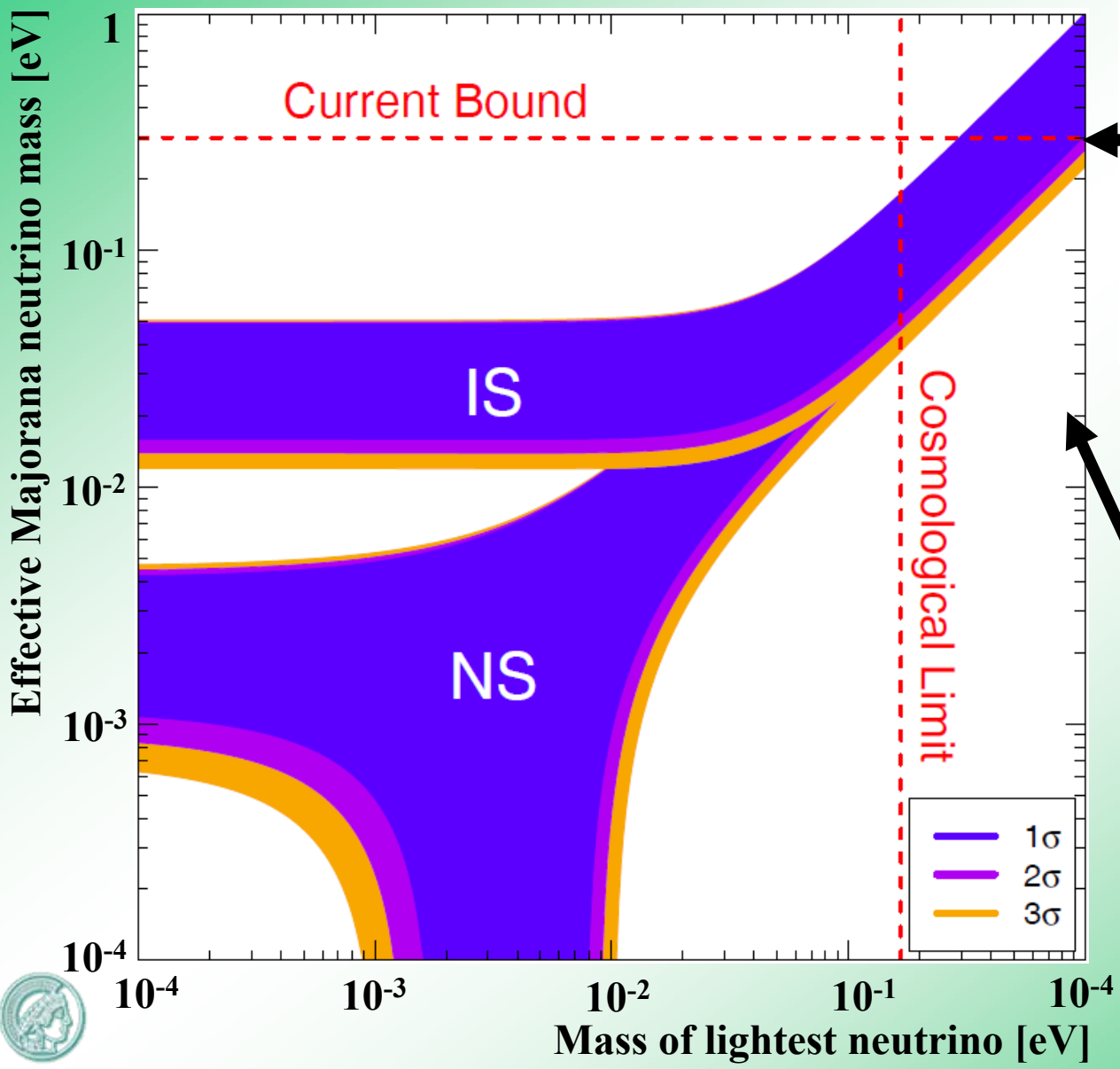
O U T L I N E :

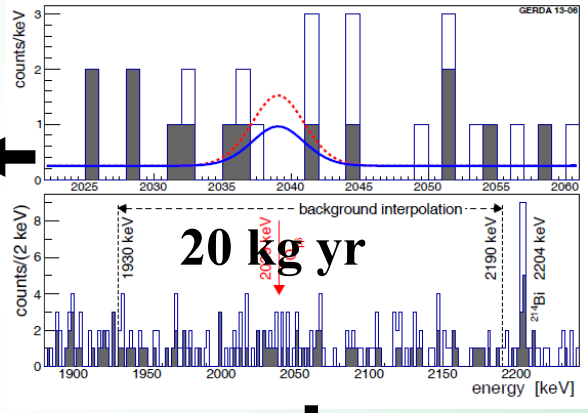


- Introduction: The case for higher sensitivity
- GERDA phase II principles: BEGe detectors and LAr readout
- Production and characterization of BEGes
- LAr instrumentation: simulations and hardware status
- Status of hardware preparations
- Background expectations for GERDA phase II

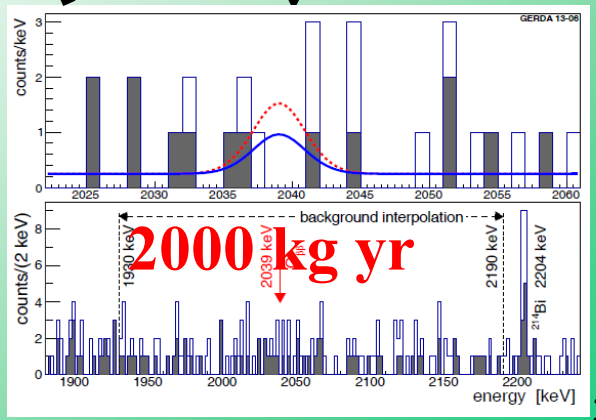


The case for higher sensitivity





Need to improve background, need to increase exposure



The case for higher sensitivity

→Improve background recognition: „intelligent detectors“

→Understand possible background sources

→Reduce radiation sources in surrounding of detectors

→ Increase target mass

GERDA Phase II strategy:

→Use BEGes with enhanced background recognition efficiencies

→Instrumentation of LAr surrounding

→Minimization of material in array surrounding & special care during crystal production

GERDA Phase II goal:

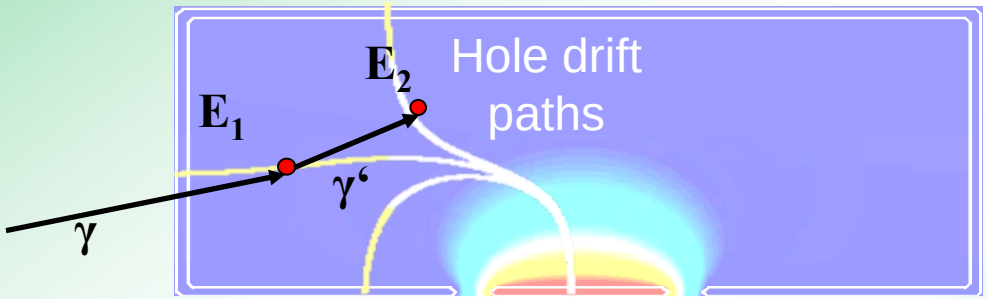
→BI 10^{-3} cts/(kg yr keV), Exposure: 100 kg yr

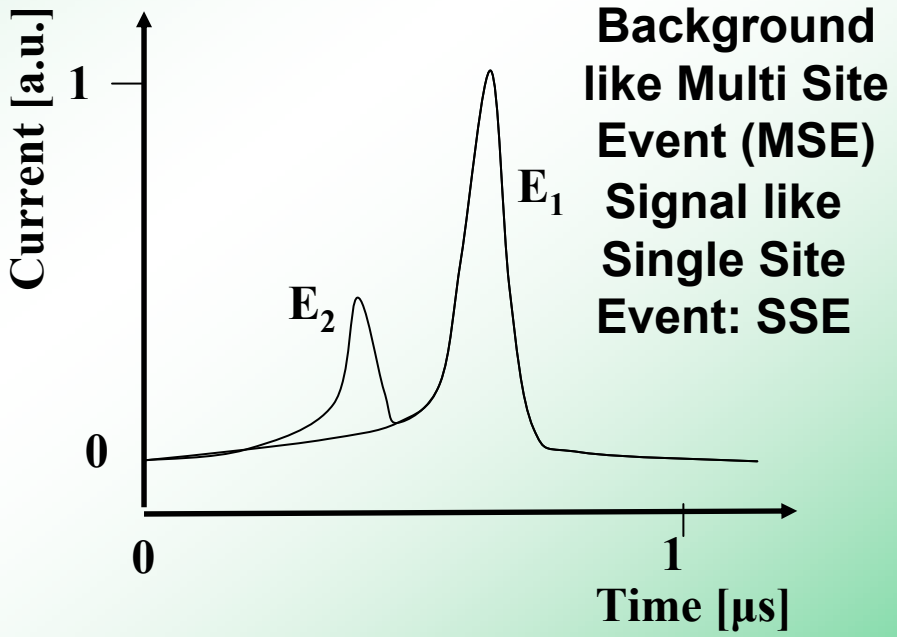
→Improve sensitivity to reach ${}^{0\nu\beta\beta}T_{1/2}=10^{26}$ yr

→Understand whether technology is suitable for ton scale

GERDA phase II principles: BEGe detectors

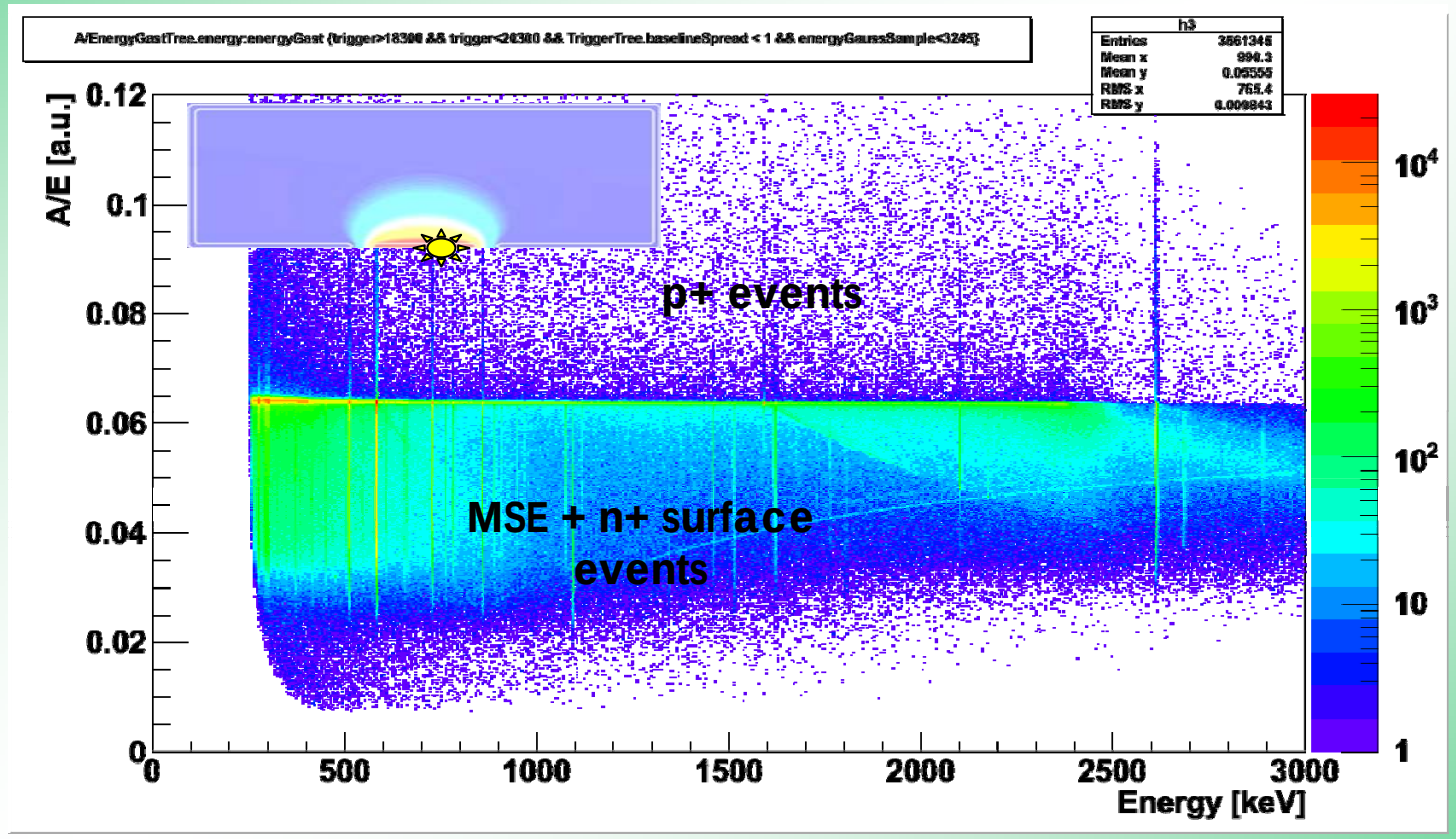
BEGe detectors with point like contact:

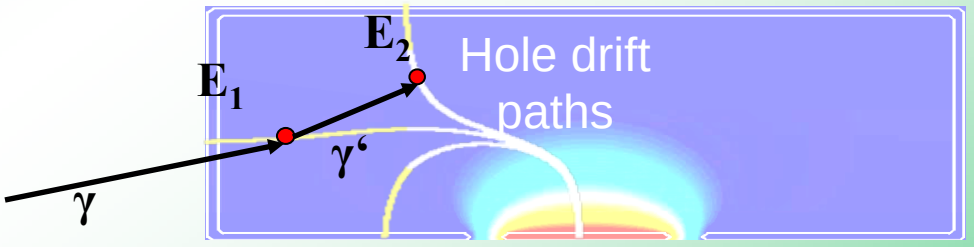




GERDA phase II principles: BEGe detectors

"Intelligent detectors": Recognize surface & MSE events:





D. Budjas et al., JINST 4 P10007 (2009)

M. Agostini et al., JINST 6P03005 (2011)

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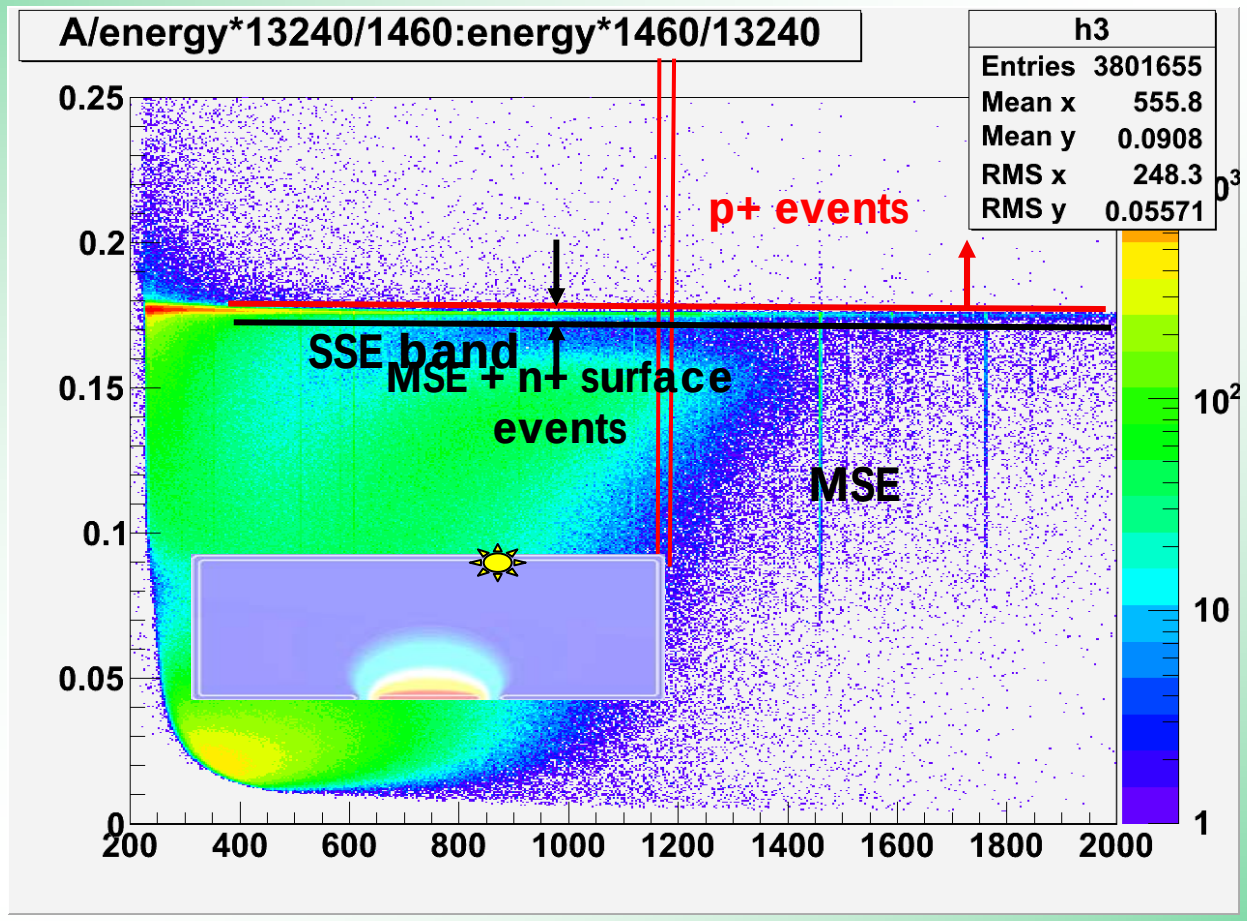

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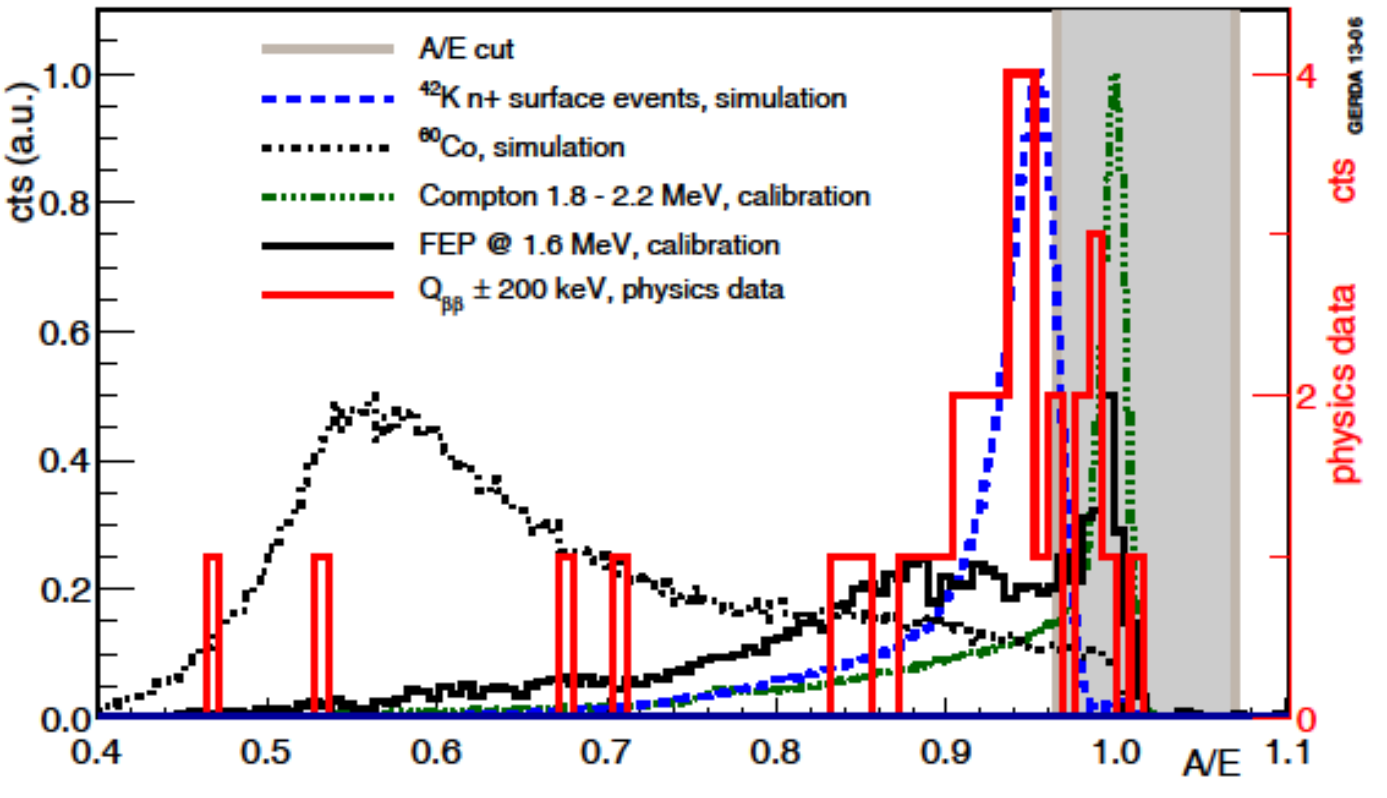
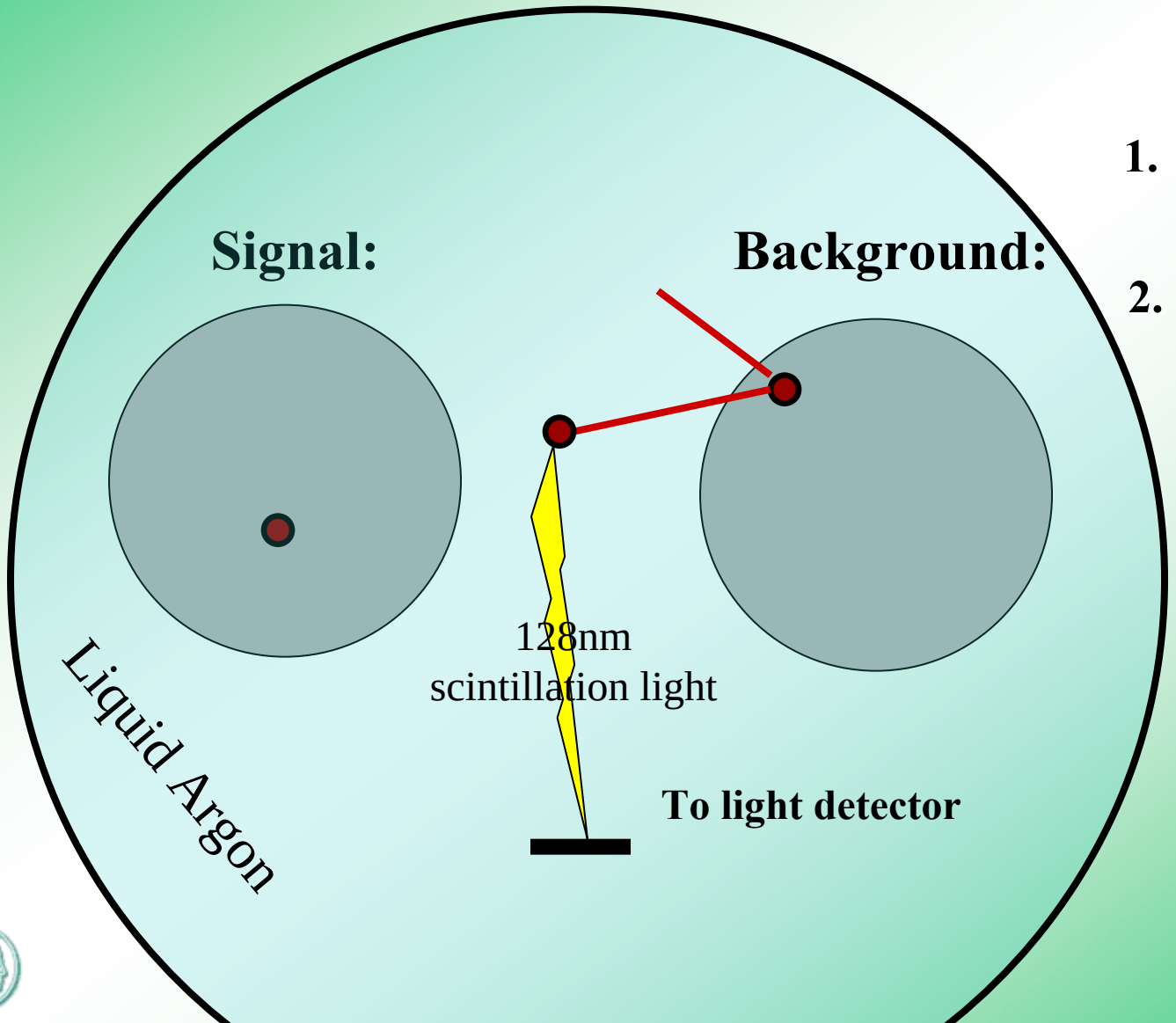


Experimental verification of 42K n+ surface event recognition by GERDA phase I data

arXiv:1307.2610

LAr instrumentation

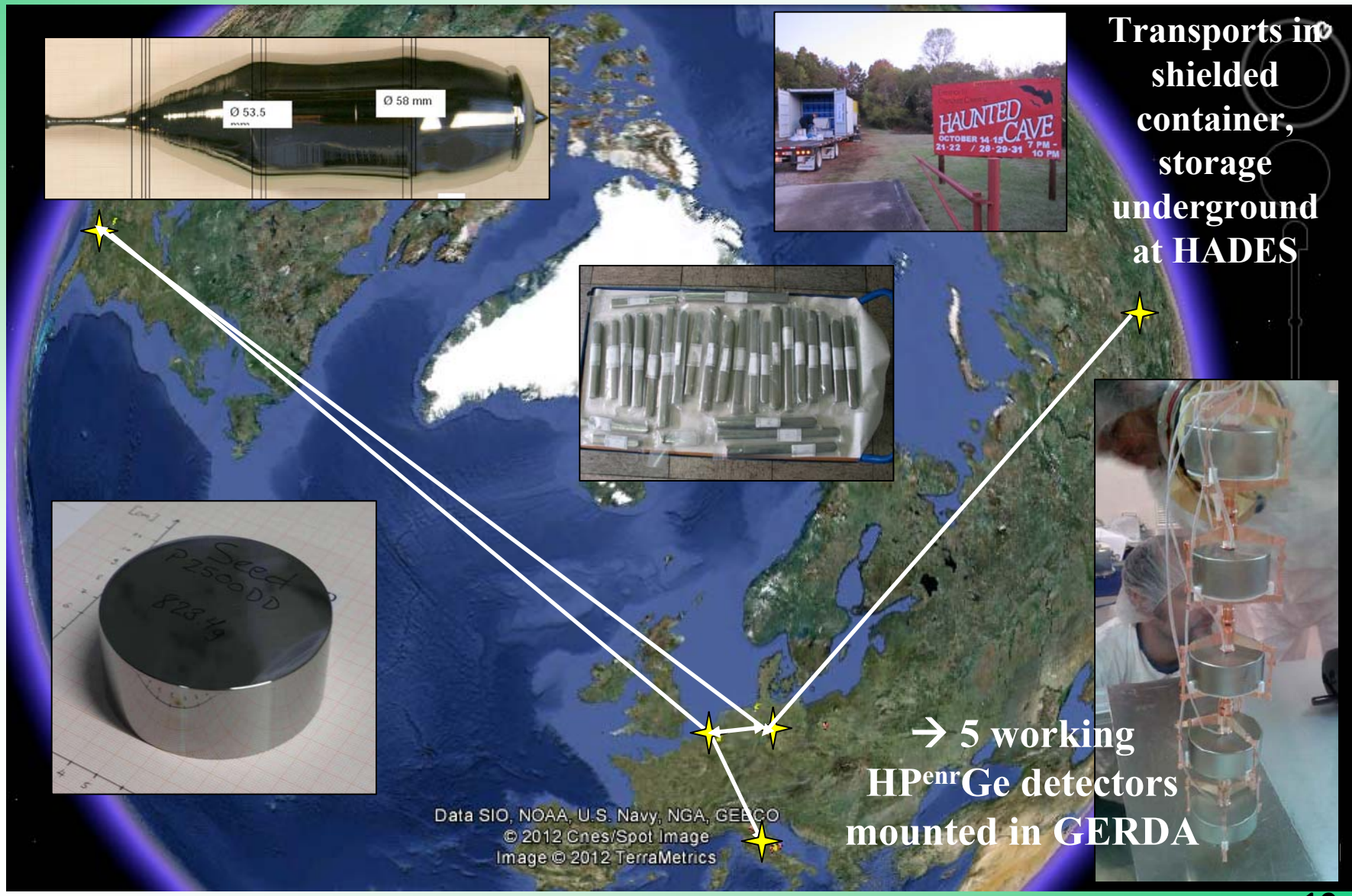
Background rejection by detection of LAr scintillation light



Two options:

1. **PMTs on top and bottom of array**
2. **SiPMs with fibre curtain**

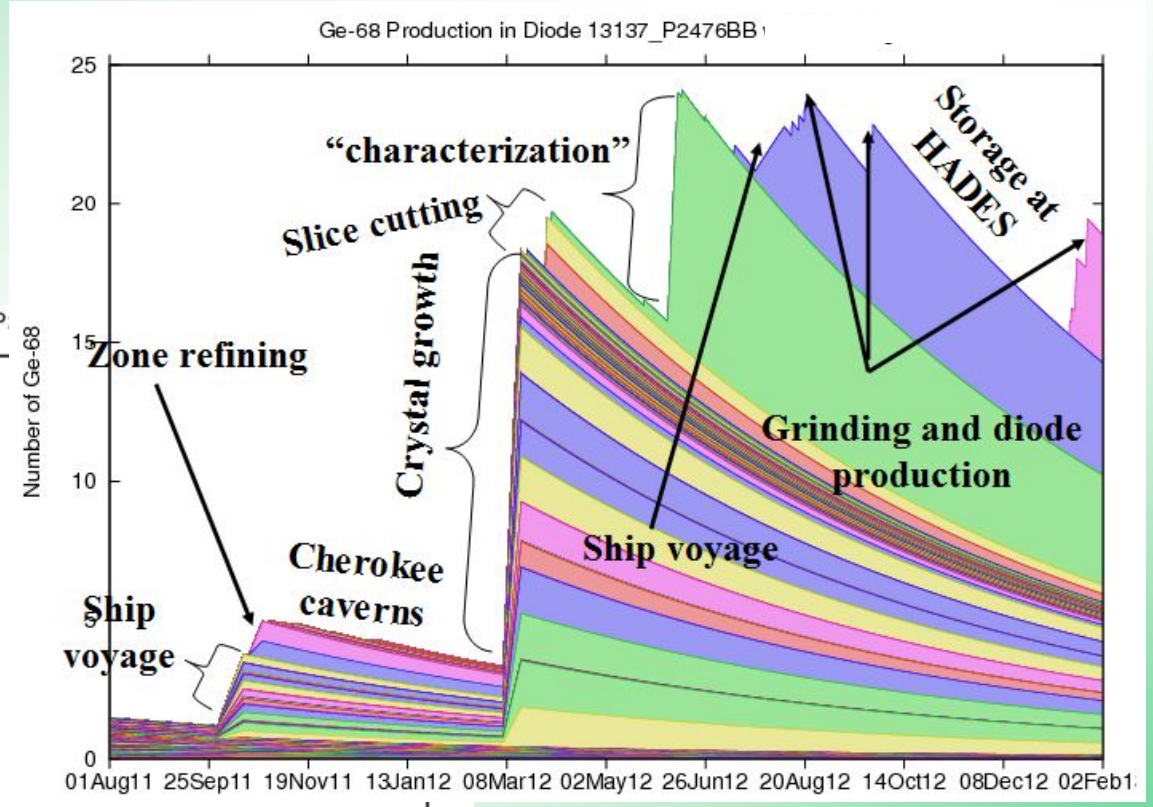
Production and characterization of BEGes

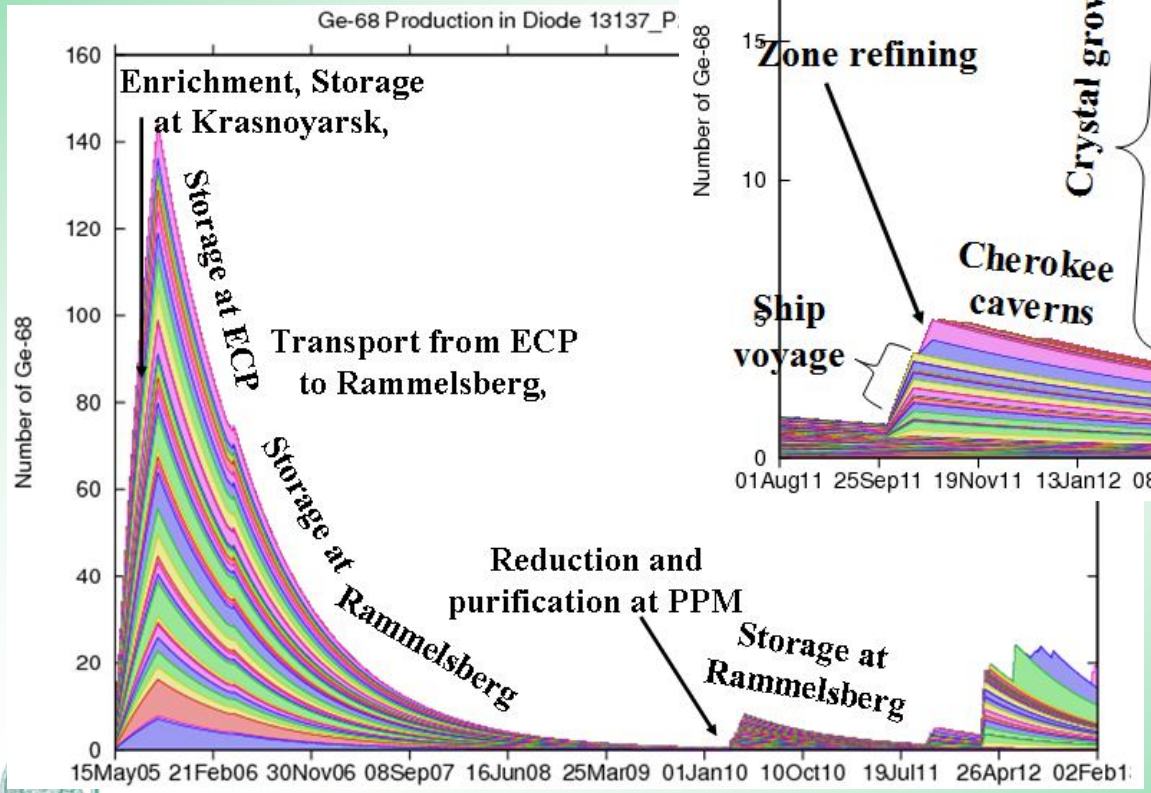


Production and characterization of BEGes

Monitoring of exposure to cosmic rays: Production history

Saturation concentration in ^{enr}Ge:
~1600 ^{68}Ge kg^{-1},
~10.000 ^{60}Co kg^{-1}

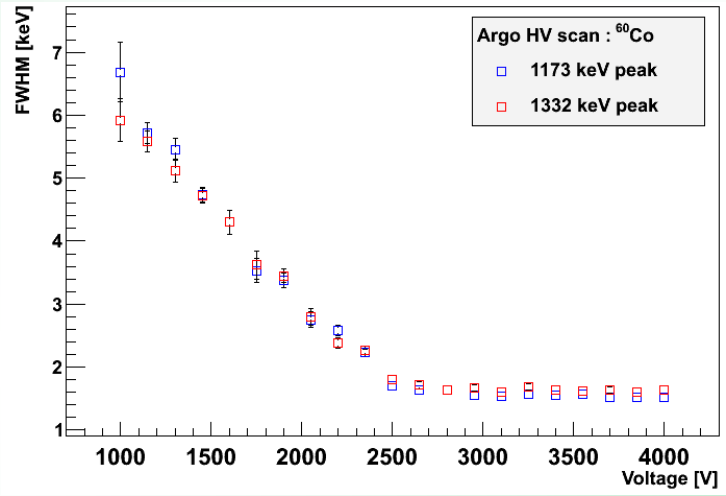




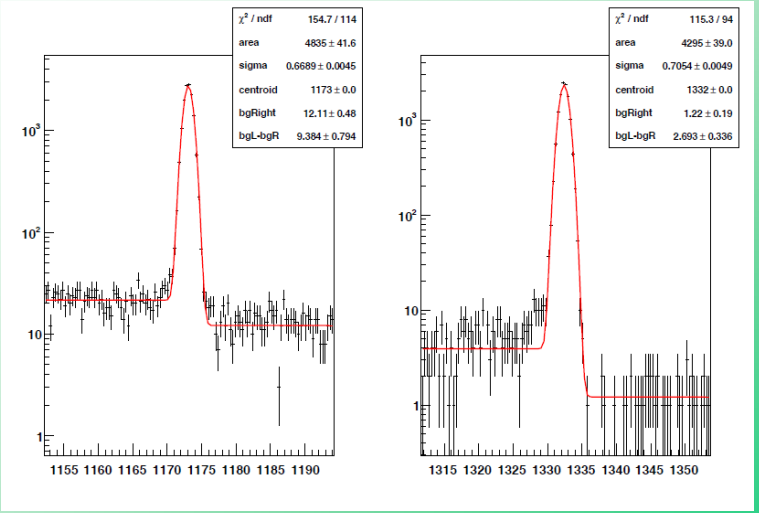
Expected (June 2013):
^{68}Ge activity: 35.3 kg^{-1}
^{60}Co activity: 26.7 kg^{-1}

Production and characterization of BEGes

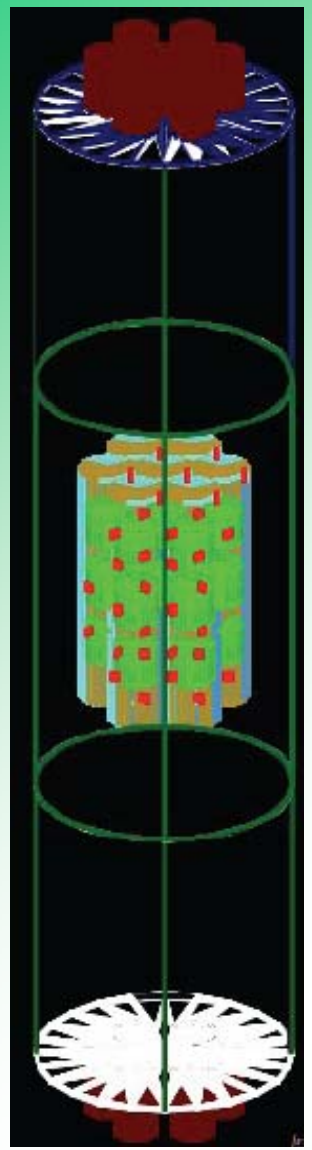
All 30 BEGe detectors according to specifications: Bias voltage < 5000kV, E-resolution @ 1.3MeV (FWHM) < 1.9 keV (0.14%)



Measured main operational paramters, active volumes, dead layers and pulse shape parameters for all 30 BEGe detectors at HADES underground facility in Belgium

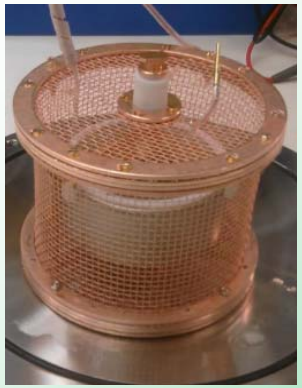


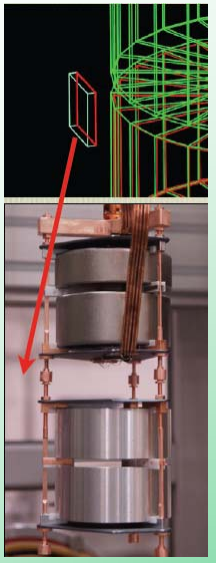
Simulations for LAr instrumentations

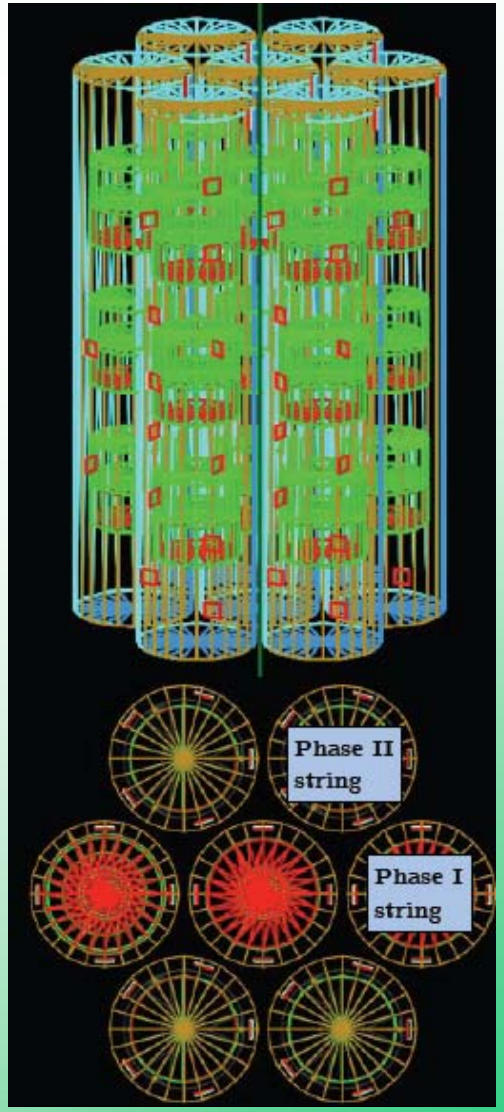


Different possibilities simulated:

- SiPM fibre
- PMTs
- „Hybrid“ solution
- Meshed copper shroud around strings
- Transparent mini shrouds
- VM2000 coated mini shroud with large area SiPMs between detectors







Simulations for LAr instrumentations

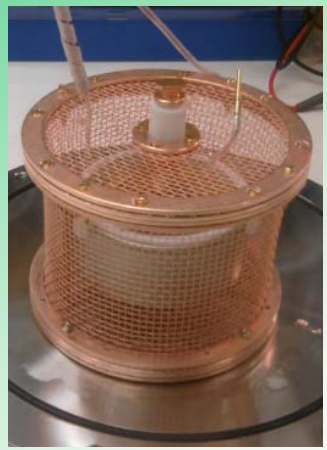
Simulated suppression factors:

Background	Super-Hybrid	Nylon-Hybrid	MMS-I Hybrid	Hybrid (wo MS)	SMS-Hybrid
^{214}Bi Holders	8.16 ±0.43	9.86 ±0.38	9.1 ±0.2 (Nuno, Feb13 p.7)	9.1 ±0.2 (Nuno, Feb13 p.7)	2.38 ±0.08 (SH wo SiPM) 2.4 ±0.1 (Nuno, Feb13 p.7)
^{214}Bi Surface	3.34 ±0.02	3.38 ±0.18	---	3.48 ±0.1 (Nuno, Oct12 p.23)	1.80±0.01 (SH wo SiPM)
^{214}Bi Homogeneous	24.86 ±2.11	38.20 ±2.73	---	54.79 ±7.9 (Nuno, Oct12 p.23)	5.29 ± 0.25 (SH wo SiPM)
^{42}K Surface	1.13 ±0.01	---	---	---	1.06 ±0.01 (SH wo SiPM)
^{42}K Homogeneous	3.61 ±0.28	9.56 ±4.22	---	5.31 ±0.60	1.16 ±0.06 (SH wo SiPM)

Choice of configuration for phase II decoupled from remaining hardware

LAr instrumentation measurements

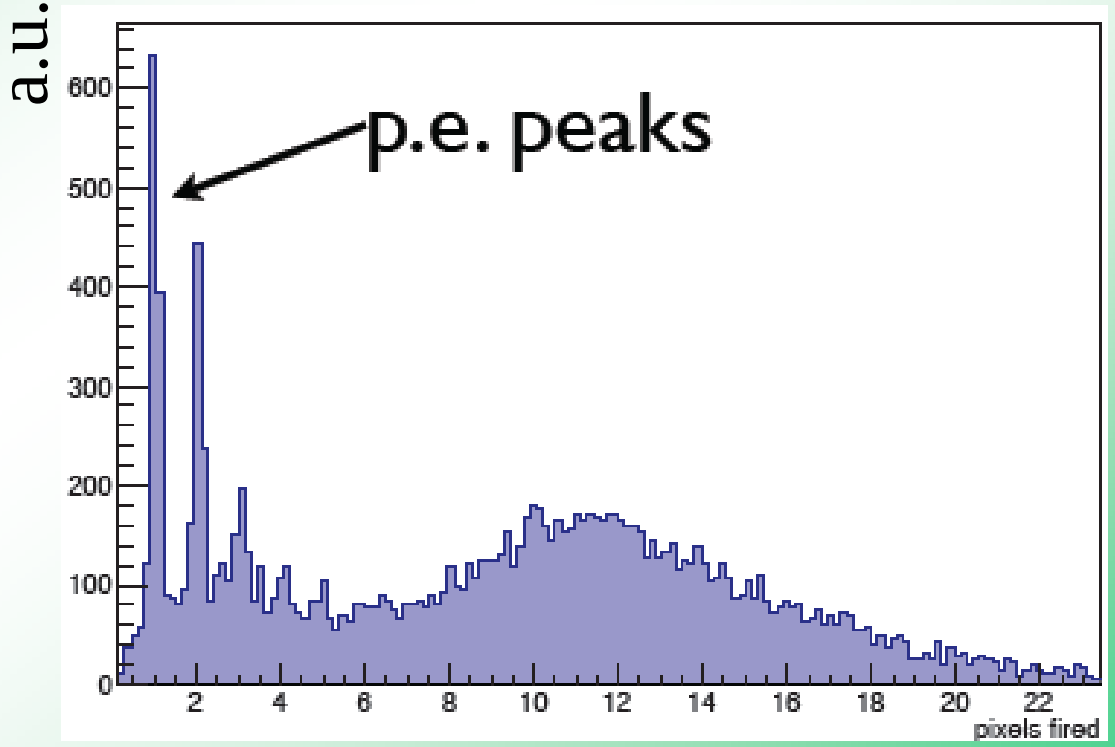
First measurements with different configurations in LArGe show:



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

Hardware status of LAr instrumentations

Test SiPM fibre setup:
Spectrum recorded using contaminated LAr (low light yield)

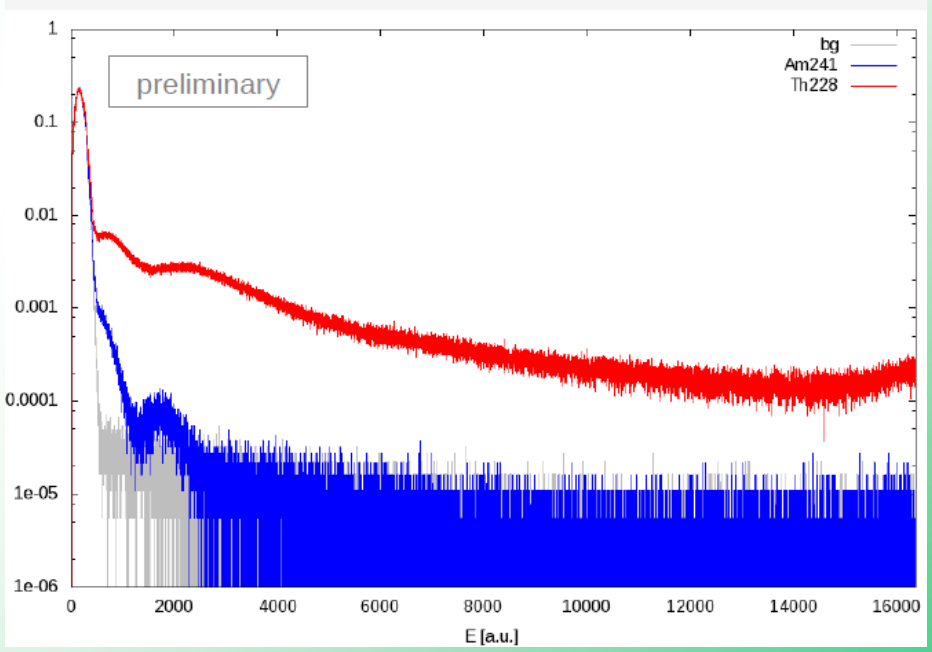


Hardware for integration to GERDA phase II being produced

Hardware status of LAr instrumentations

Test PMT setup :
Spectra recorded

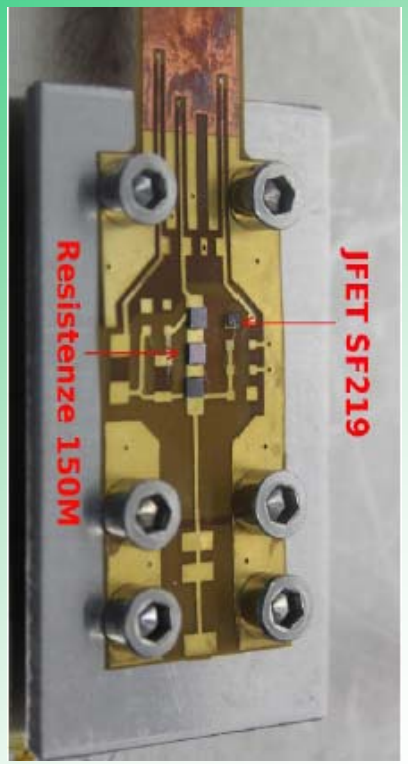
Low background PMTs being commissioned



Hardware for integration to GERDA phase II being produced

Status of hardware preparations:

integration including front end



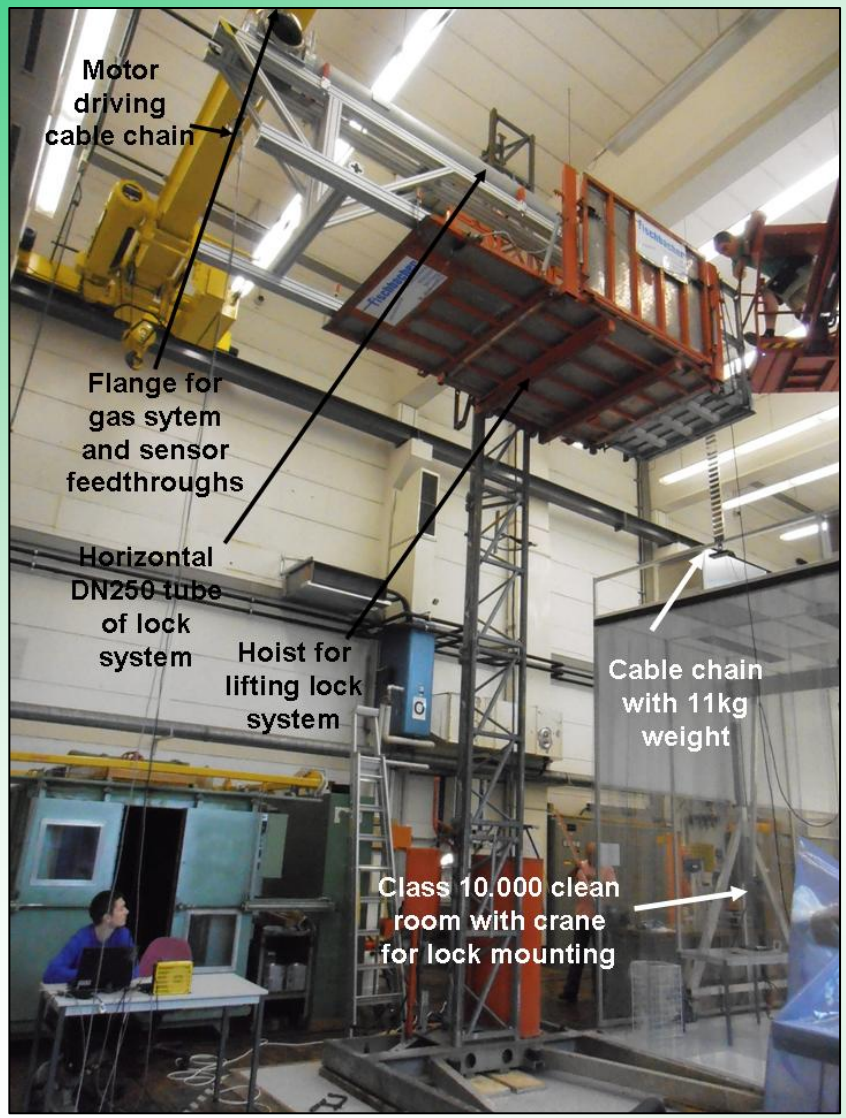
VFE 50 µm Cuflon cables (3g) and preamps being down selected

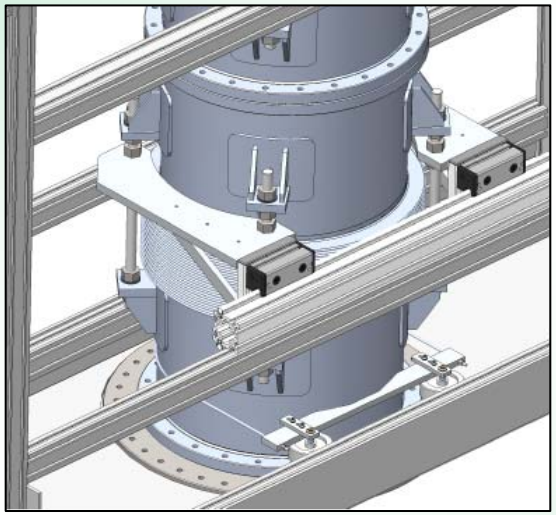
Integration tests of VFE electronics holder system ongoing.

Bonding of VFE electronics to detectors without problem

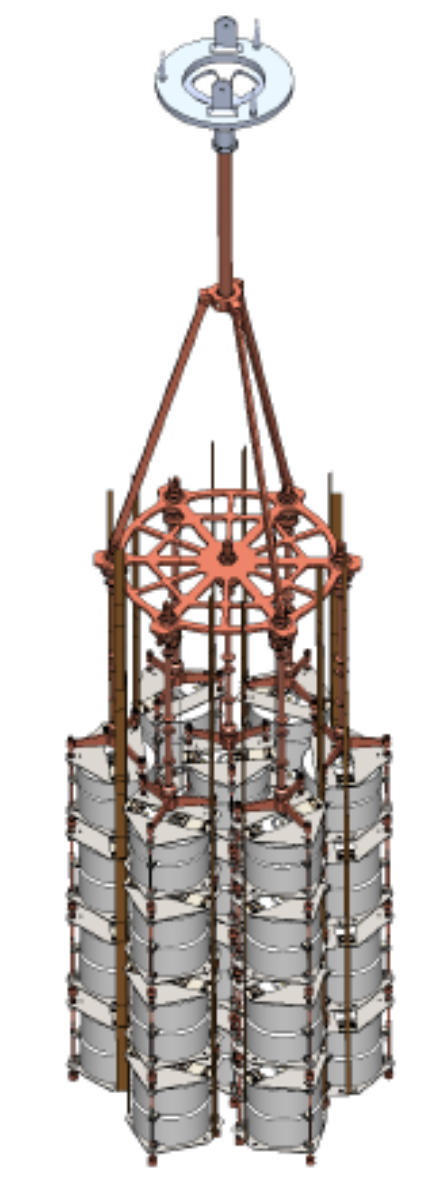
Performance of VFE prototype with test BEGe:
A/E resolution (FWHM): 1%
Energy resolution @ 2.6 MeV (over 4 hours: 1.6 keV)

Status of hardware preparations:





GERDA phase II lock system under construction. First assembly test successful. Completion of lock system until October 2013

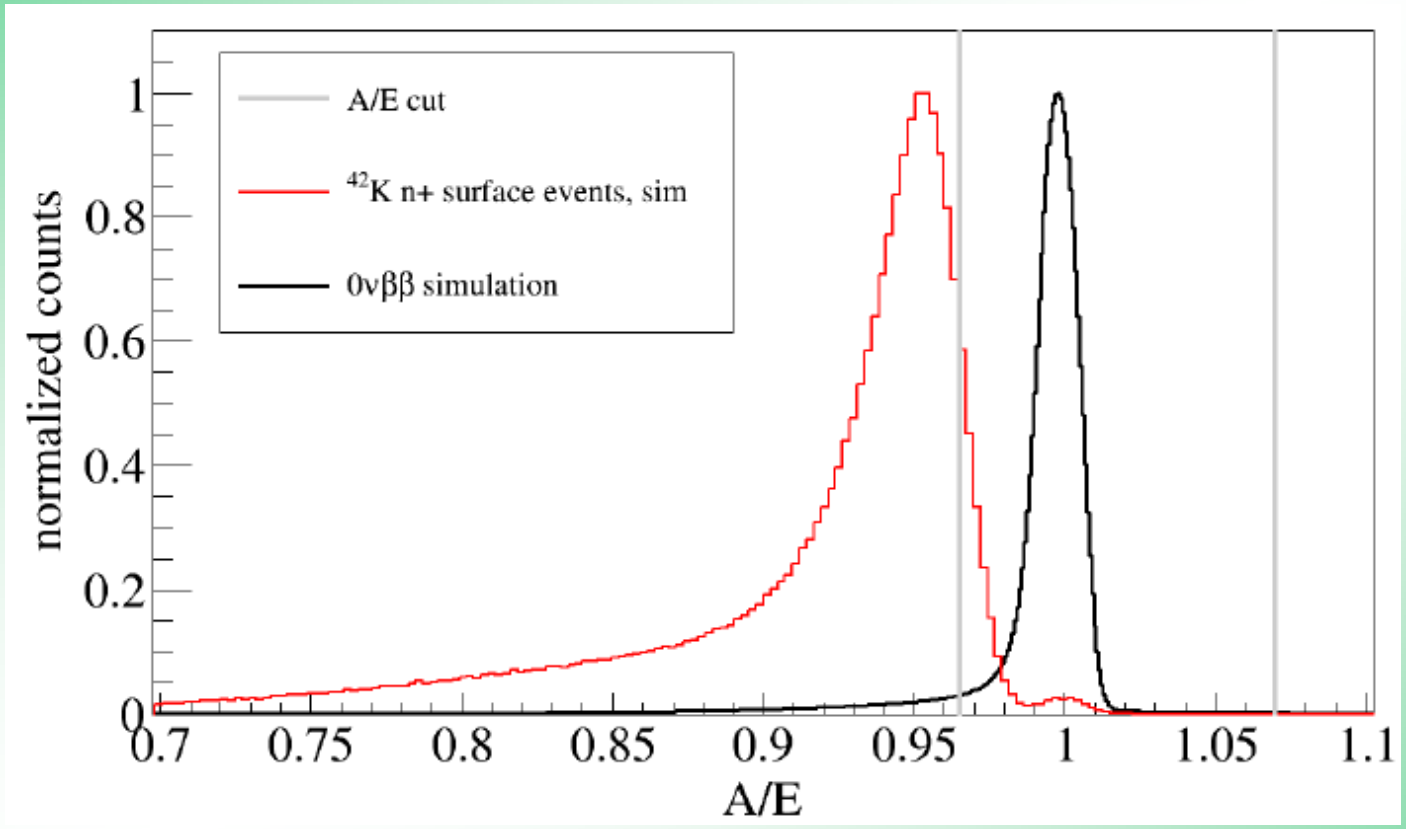


Background expectations for GERDA phase II

background [10^{-3} cts/(keV·kg·yr)]	without cuts	after PSD cuts	after PSD & veto († opaque MS)
^{228}Th (near)	≤ 5 *	≤ 2.3	≤ 0.01
^{228}Th (1 m away)	< 3	< 1.3	< 0.01
^{228}Th (distant)	< 3 ?	< 1.2 ?	< 0.1 ?
^{214}Bi (holder/MS)	≤ 5 *	≤ 1.7	≤ 0.13 († 0.5)
^{214}Bi (near p+)	< 6	< 0.13	< 0.03 († 0.07)
^{214}Bi (n+)	< 7 ?	< 0.7 ?	< 0.15 († 0.4)
^{214}Bi (1 m away)	< 3	< 1	< 0.08 († 0.2)
^{60}Co (near)	1	0.02	0.001
^{60}Co (in Ge)	≤ 0.3	≤ 0.006	≤ 0.0004
^{68}Ga (in Ge)	≤ 2.3	≤ 0.21	≤ 0.04
^{226}Ra (α near p+)	1.5	< 0.03	< 0.03
^{42}K (β on n+)	~ 20	< 1	< 0.86
unknown (n?)	?	?	?

→ **Most critical: ^{42}K on n+ surface**

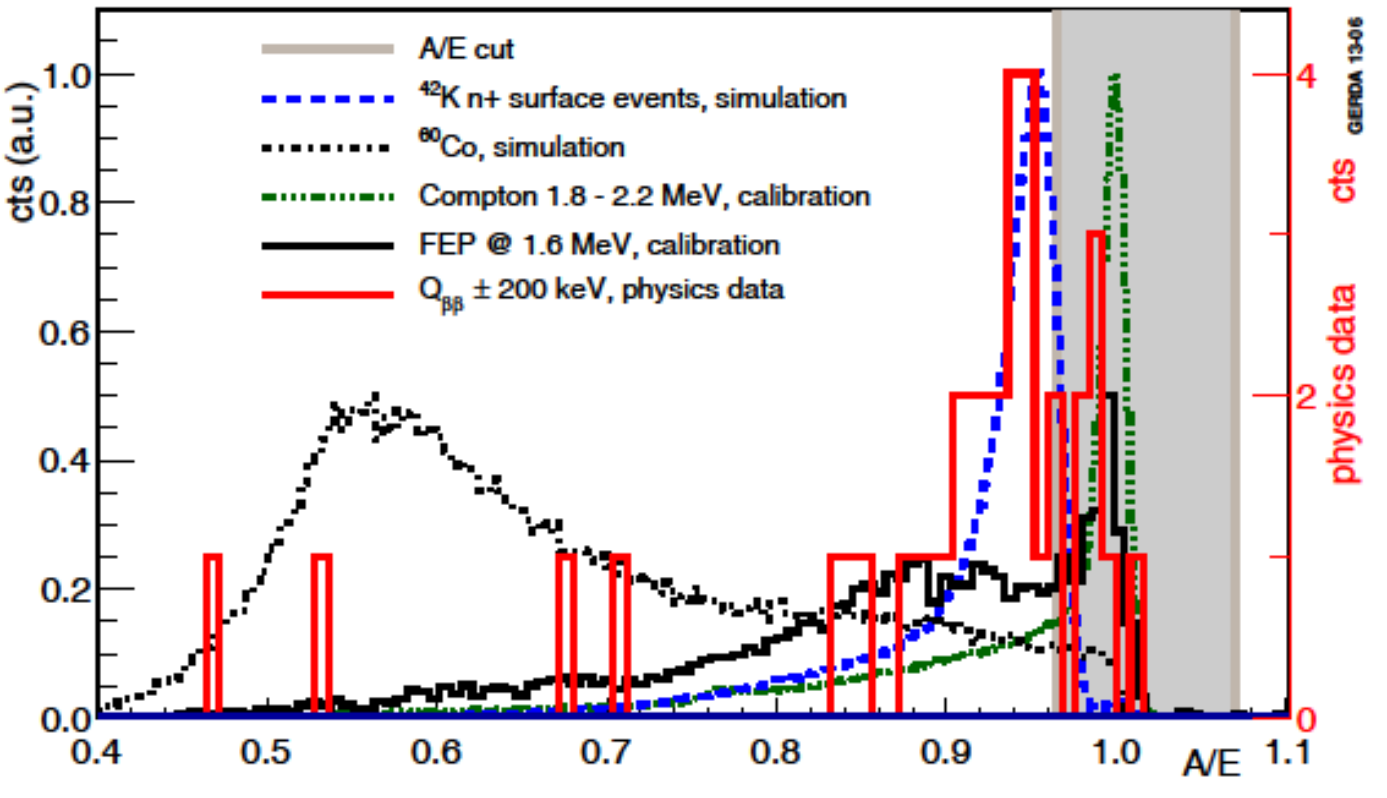
Background expectations for GERDA phase II



We are confident to reach 0.001 cts/(kg yr keV) given no ADDITIONAL bkg. components

Background expectations for GERDA phase II

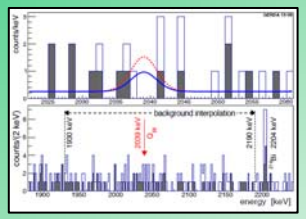
arXiv:1307.2610



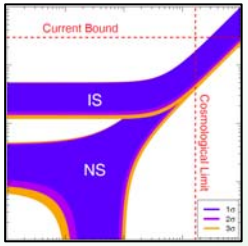
We are confident to reach 0.001 cts/(kg yr keV) given no ADDITIONAL bkg. components

→ 42K on n+ surfae recognition efficiency verified experimentally!

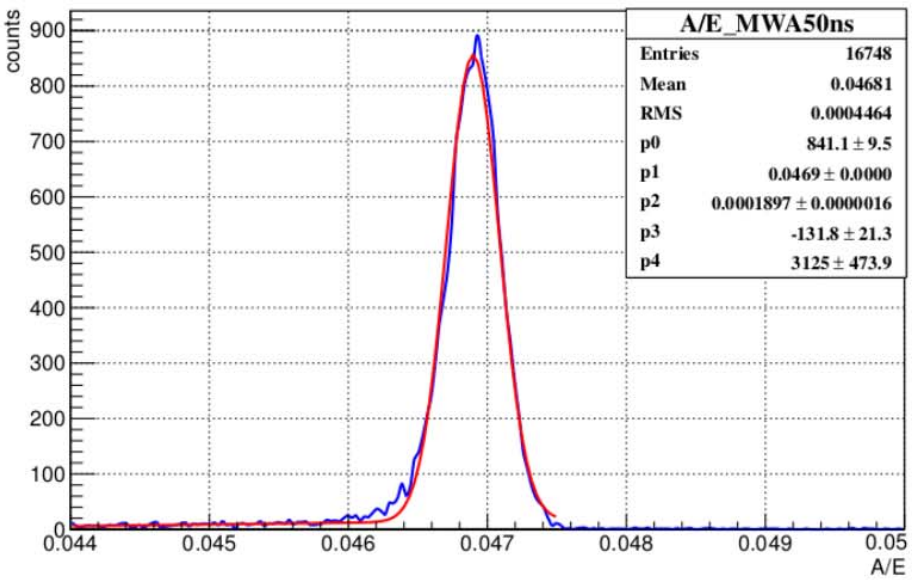
CONCLUSIONS:

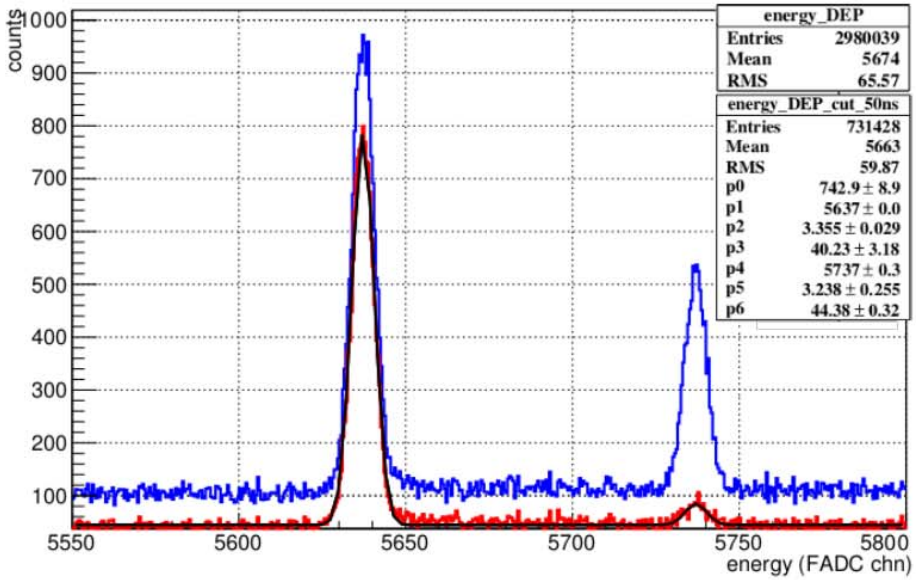


- The show must go on: is the neutrino a Majorana particle?
- Additional BEGe detectors and LAr readout improve sensitivity
- 30 BEGes produced and characterized
- LAr instrumentation should be efficient
- Hardware for phase II is close to completion
- Applying new methods: BI of 0.001 cts/(keV kg yr) should be reachable at RoI



PSD in Phase II





A/E resolution (FWHM): < 1%

Acceptance: ~ 90% at DEP of 2614 keV ^{208}Tl line

~11% at 1620 keV ^{212}Bi line