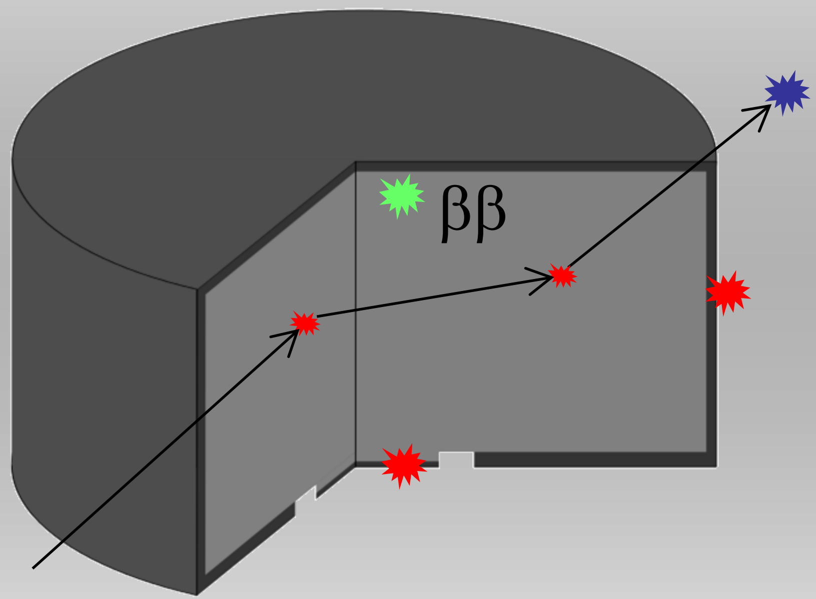
Background suppression in GERDA Phase II

and its study in the LArGe low background set-up



Dušan Budjáš
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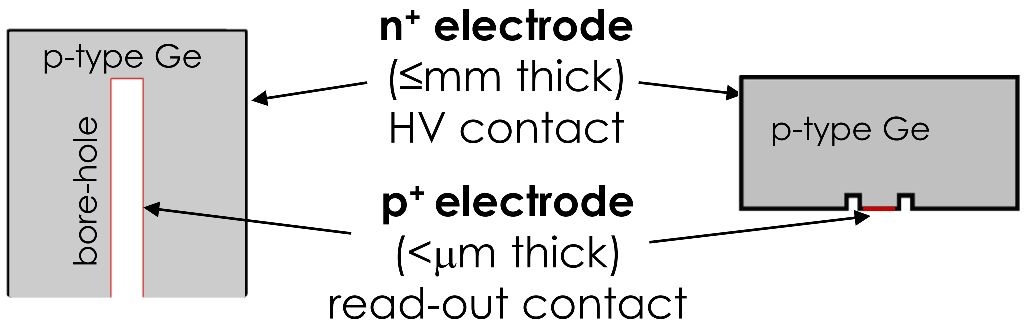
for the GERDA collaboration
http://www.mpi-hd.mpg.de/GERDA

E15

Modified Broad-Energy Ge detectors

GERDA Phase I: semi-coaxial Ge detector

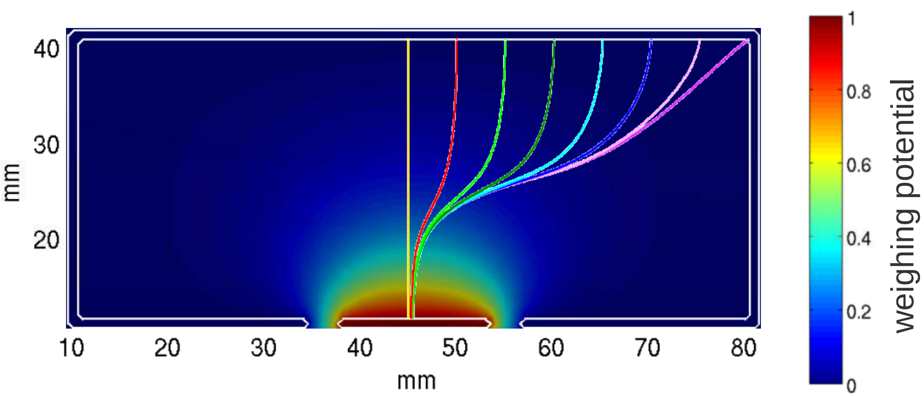


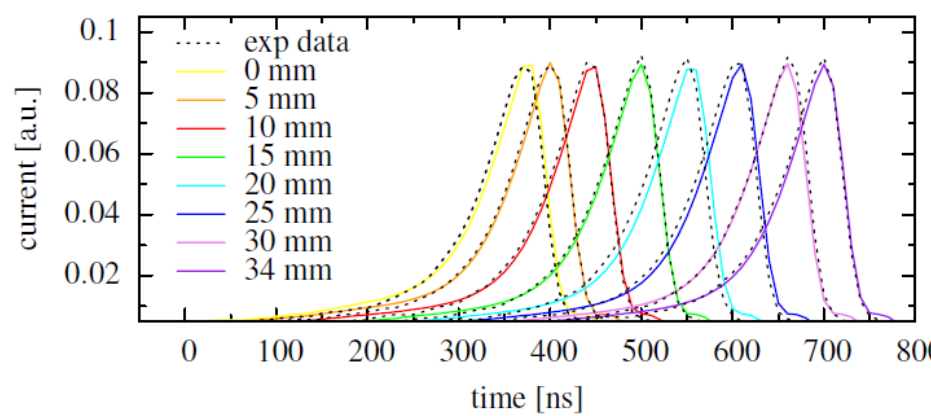
GERDA Phase 2: **modified BEGe detector**

BEGe advantages:

1) smaller p+ electrode ⇒ less capacitance ⇒ **less noise** ⇒ **better energy resolution** ⇓

2) favourable internal electric field distribution ⇒ **powerful PSD capability**





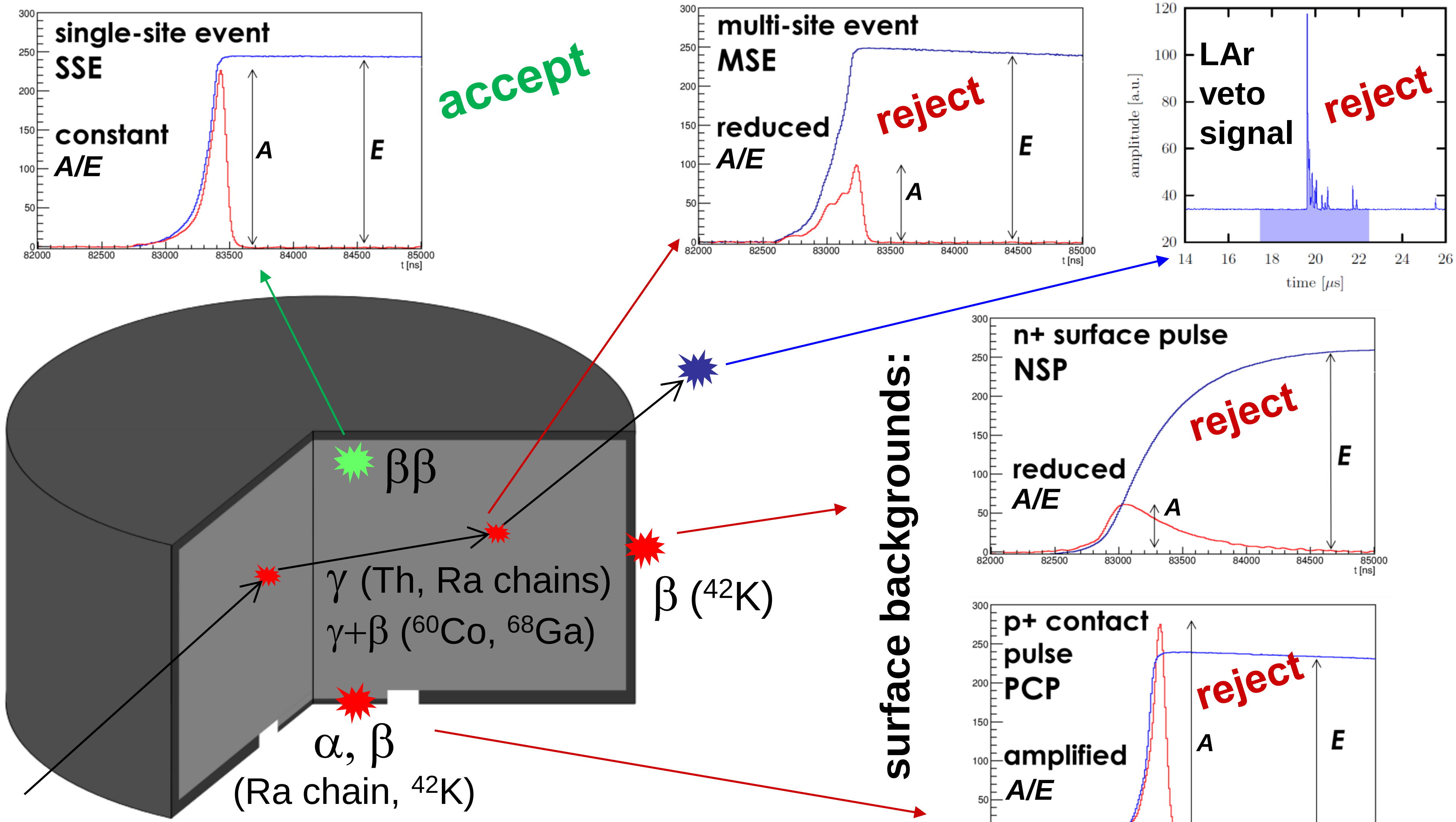
- narrow peak in current signal
- signal shape independent of interaction position (same final trajectory)
- current amplitude depends only on energy of interaction (~95% of volume)

 [D. Budjáš et al., JINST 4:P10007,2009] [M. Agostini et al., JINST 6:P03005, 2011]

GERDA Phase II background identification tools

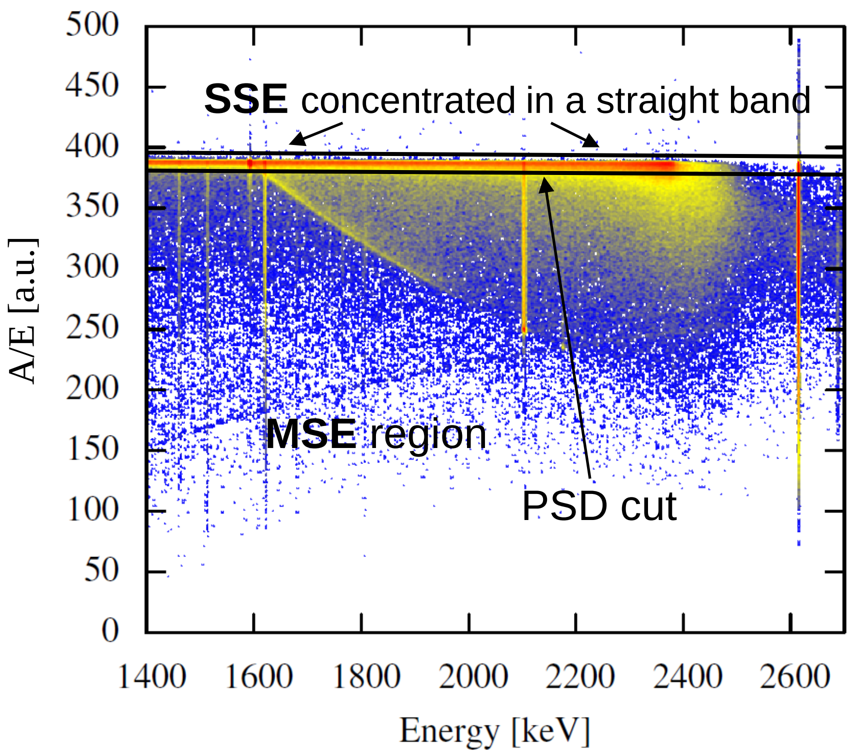
- identification and discrimination of events by **PSD** and **LAr veto**:

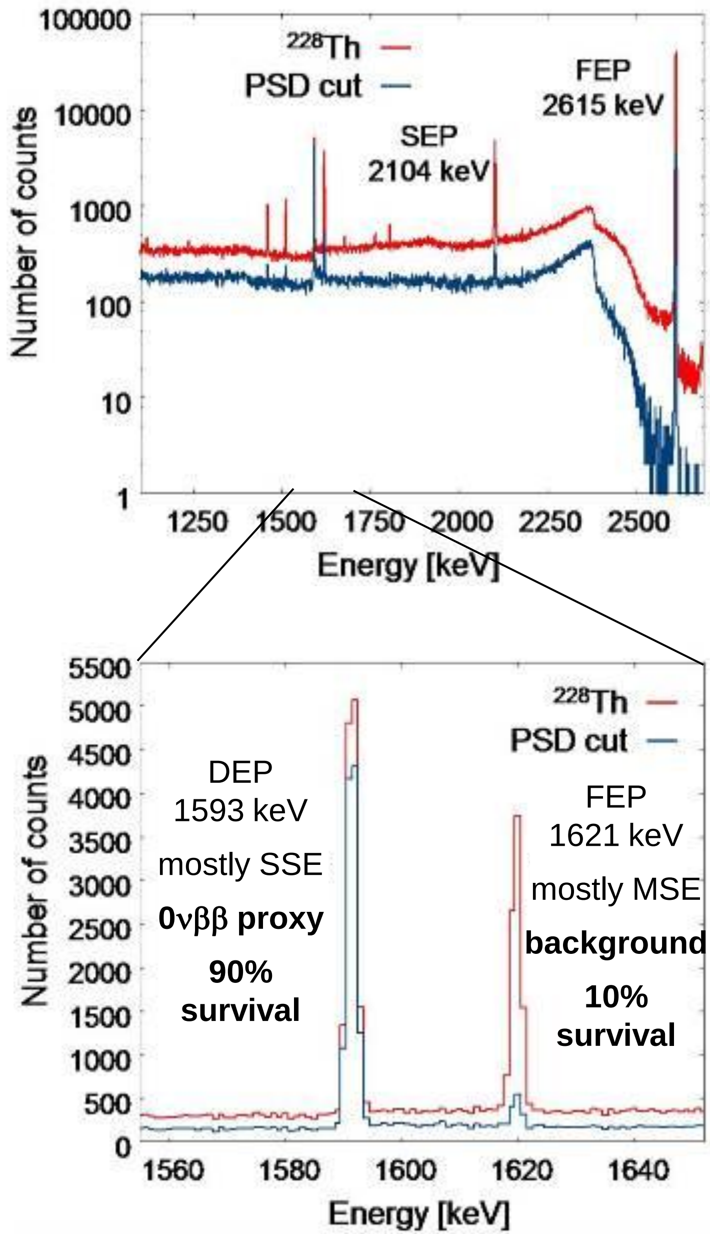
ββ-decay: β range in Ge ~mm **γ-ray backgrounds:** range in Ge ~cm



Background rejection using A/E cut with BEGes

A/E distribution from ^{228}Th source

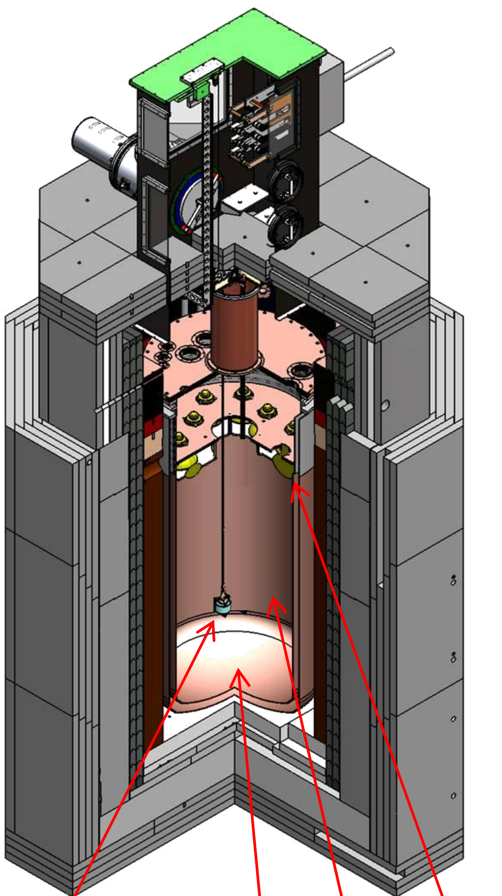


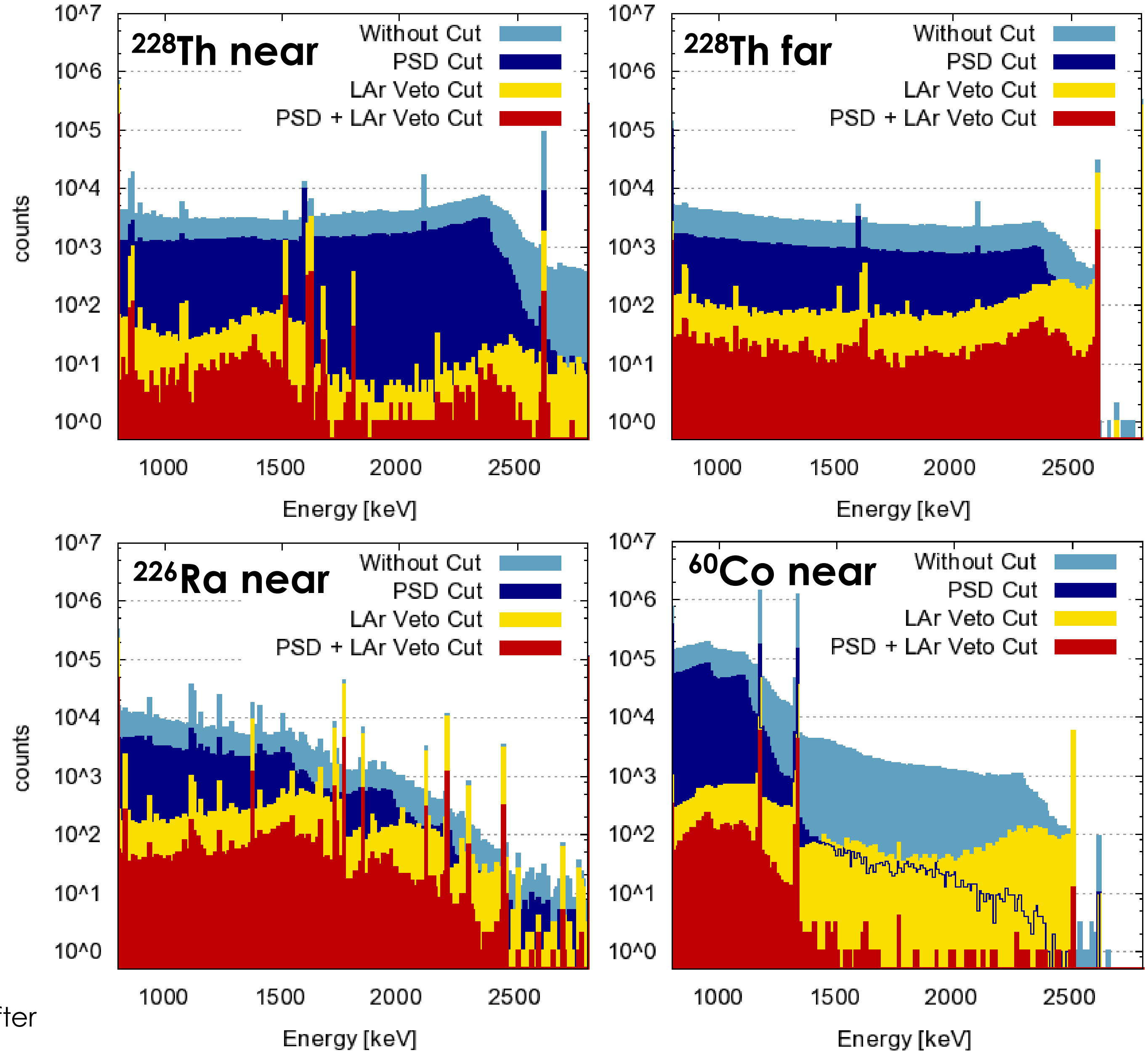


[D. Budjáš et al., JINST 4:P10007,2009]
[M. Agostini et al., JINST 6:P03005, 2011]

PSD and LAr veto studies in LARGE

Low background test facility GERDA-LARGE at LNGS:

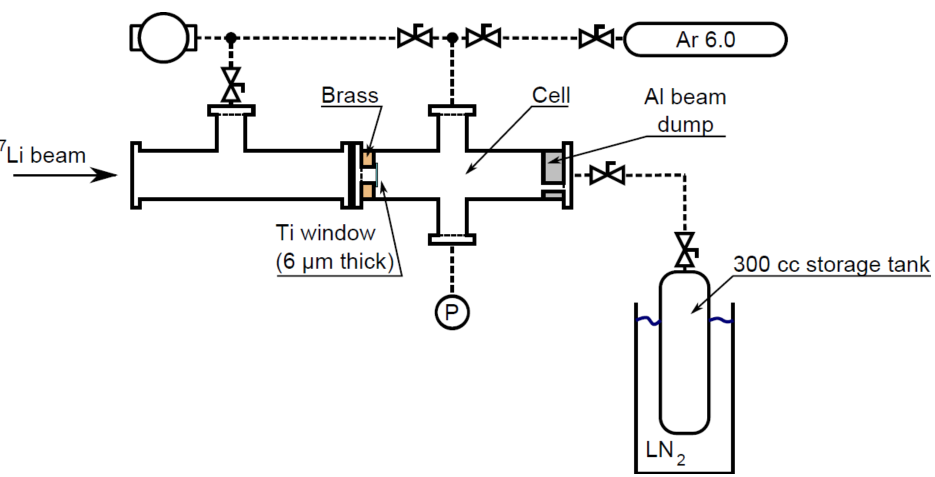




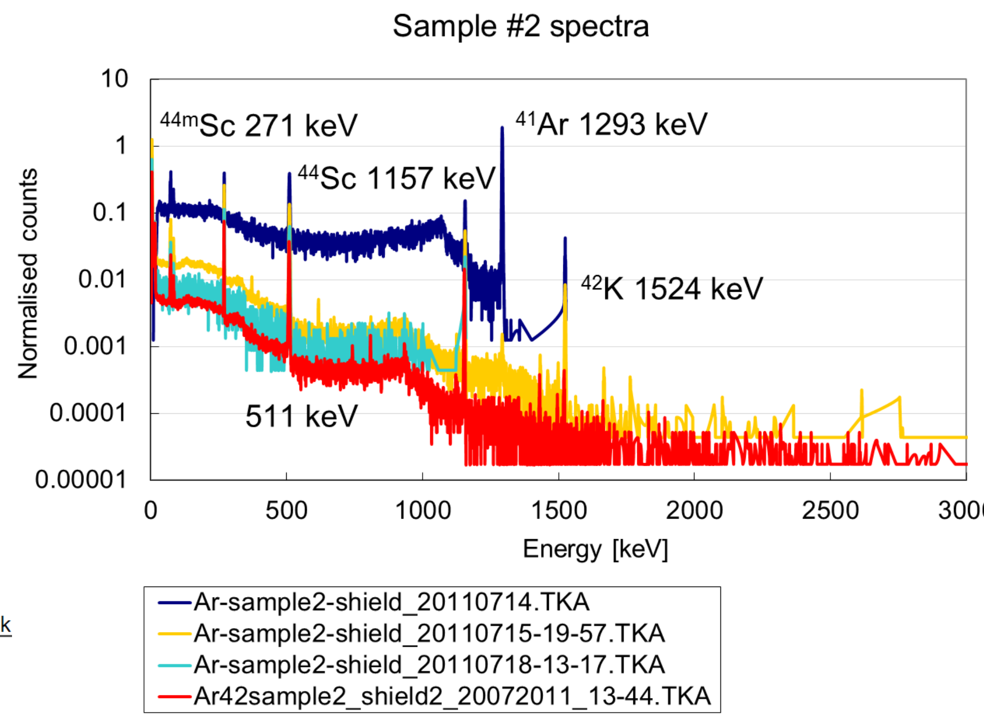
[M. Heisel, Dissertation, University of Heidelberg (2011)]

Production of ^{42}Ar for studying ^{42}K background

Tandem accelerator MLL Garching



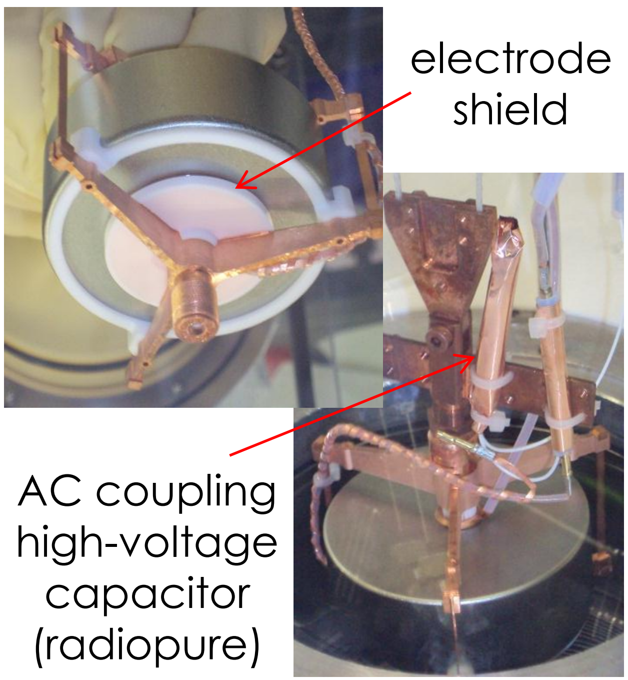
- $^{7}Li^{3+}$ irradiation; reaction: $^{40}Ar(^{7}Li,\alpha\ p)^{42}Ar$
- target cell with 500 mbar Ar gas
- activated Ar inserted into LArGe



^{42}K suppression methods studied in LARGE

Step1: preventing ^{42}K ions collection at detector surfaces

AC-coupled read-out ⇒ outer electrode grounded, inner electrode shielded ⇒ “field-free”

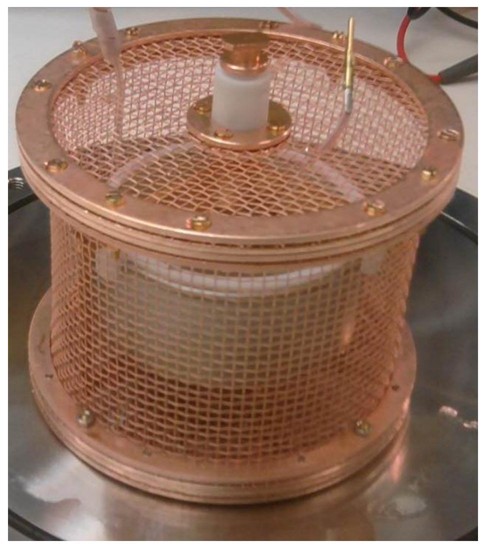


electrode shield

AC coupling high-voltage capacitor (radiopure)

suppression by factor 8

Electrostatic shielding (mesh on HV potential) ⇒ repelling ions and collecting them away from detector



prototype (final version will be low-mass optimised)

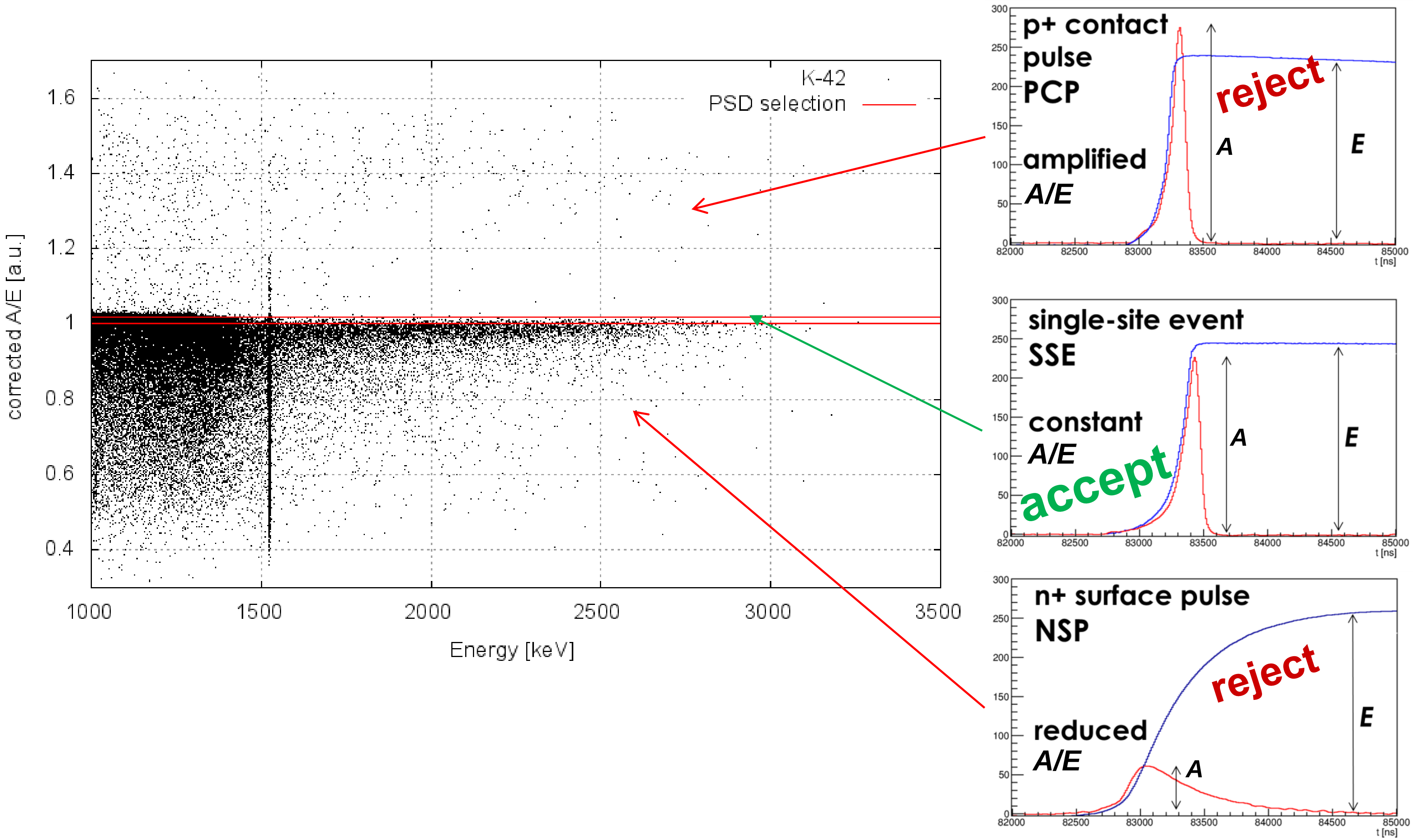
suppression by factor ~10

Hermetic shroud (transparent to XUV for LAr scintillation veto) ⇒ block ions from reaching detector

measurement ongoing

^{42}K suppression methods studied in LArGe

Step2: reject the remaining ^{42}K background via PSD



GERDA Phase II background summary

Background goal: < 10^{-3} cts/(keV·kg·yr)

background	without cuts [cts/(keV·kg·yr)]	PSD survival	LAr veto survival	after cuts [cts/(keV·kg·yr)]
^{208}Tl (γ)	≤ 0.01	0.43	≤ $7.9 \cdot 10^{-3}$	≤ $3.4 \cdot 10^{-5}$
^{214}Bi (γ)	≤ 0.0037	0.33	≤ 0.012 *	≤ $4.5 \cdot 10^{-5}$
^{214}Bi (β on p+)	≤ 0.0098	< 0.003	0.21	< $5.2 \cdot 10^{-6}$
^{60}Co (γ)	≤ $4 \cdot 10^{-4}$	0.02	0.066	≤ $5.2 \cdot 10^{-7}$
^{60}Co (γ+β in Ge)	$3 \cdot 10^{-4}$	0.02	0.066	$4.0 \cdot 10^{-7}$
^{68}Ga (γ+β in Ge)	$2.3 \cdot 10^{-3}$	0.09	0.2	$4.1 \cdot 10^{-5}$
Ra-chain α on p+	≤ $0.8 \cdot 10^{-3}$	< 0.003	–	< $2.4 \cdot 10^{-6}$
^{42}K (surface β)	several solutions under investigation			goal: < $3 \cdot 10^{-4}$

PRELIMINARY PRELIMINARY PRELIMINARY PRELIMINARY

PSD and veto combined acceptance of $0\nu\beta\beta$-decay events: 75% - 85% (depending on signal read-out noise performance)

* mean value for several different contributions

Thank you for your attention

The GERDA Collaboration :

1. INFN Laboratori Nazionali del Gran Sasso, Assergi, Italy
2. Joint Institute for Nuclear Research, Dubna, Russia
3. Max-Planck-Institut für Kernphysik, Heidelberg, Germany
4. Institute of Physics, Jagiellonian University, Krakow, Poland
5. Università di Milano Bicocca e INFN Milano, Milano, Italy
6. Institute for Nuclear Research of the Russian Academy of Sciences, Moscow, Russia
7. Institute for Theoretical and Experimental Physics, Moscow, Russia
8. Russian Research Center Kurchatov Institute, Moscow, Russia
9. Max-Planck-Institut für Physik, München, Germany
10. Dipartimento di Fisica dell'Università di Padova e INFN Padova, Padova, Italy
11. Physikalisches Institut, Universität Tübingen, Germany
12. Institute for Reference Materials and Measurements, Geel, Belgium
13. Institut für Kern- und Teilchenphysik, Technische Universität Dresden, Germany
14. Physik Institut der Universität Zürich, Switzerland
15. Physik Department E15, Technische Universität München, Germany

Other GERDA talks at DPG:

GERDA overview:
M. Heisel, HK 43.2, Tuesday 17:15
M. Agostini, T 103.1, Thursday 16:45

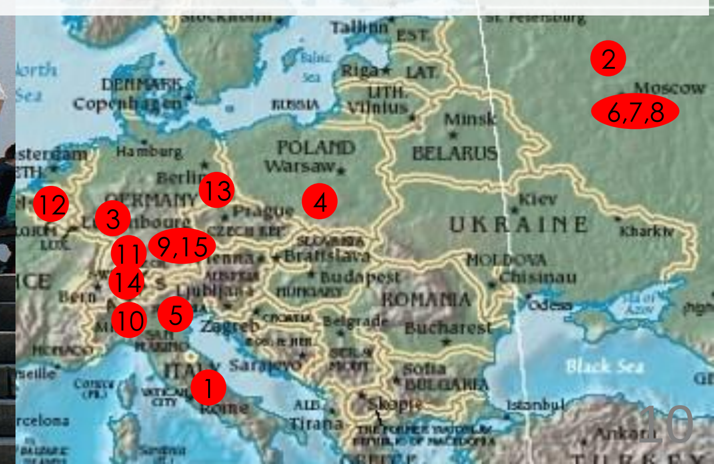
GERDA Phase I background:
N. Becerici-Schmidt, T 103.4, Thursday 17:40

GERDA Phase II K-42 background:
A. Lubashevskiy, HK66.7, Thursday 15:45

GERDA Phase II PSA:
A. Lazzaro, HK 66.6, Thursday 15:30
V. Wagner, T 110.2, Tuesday 17:05

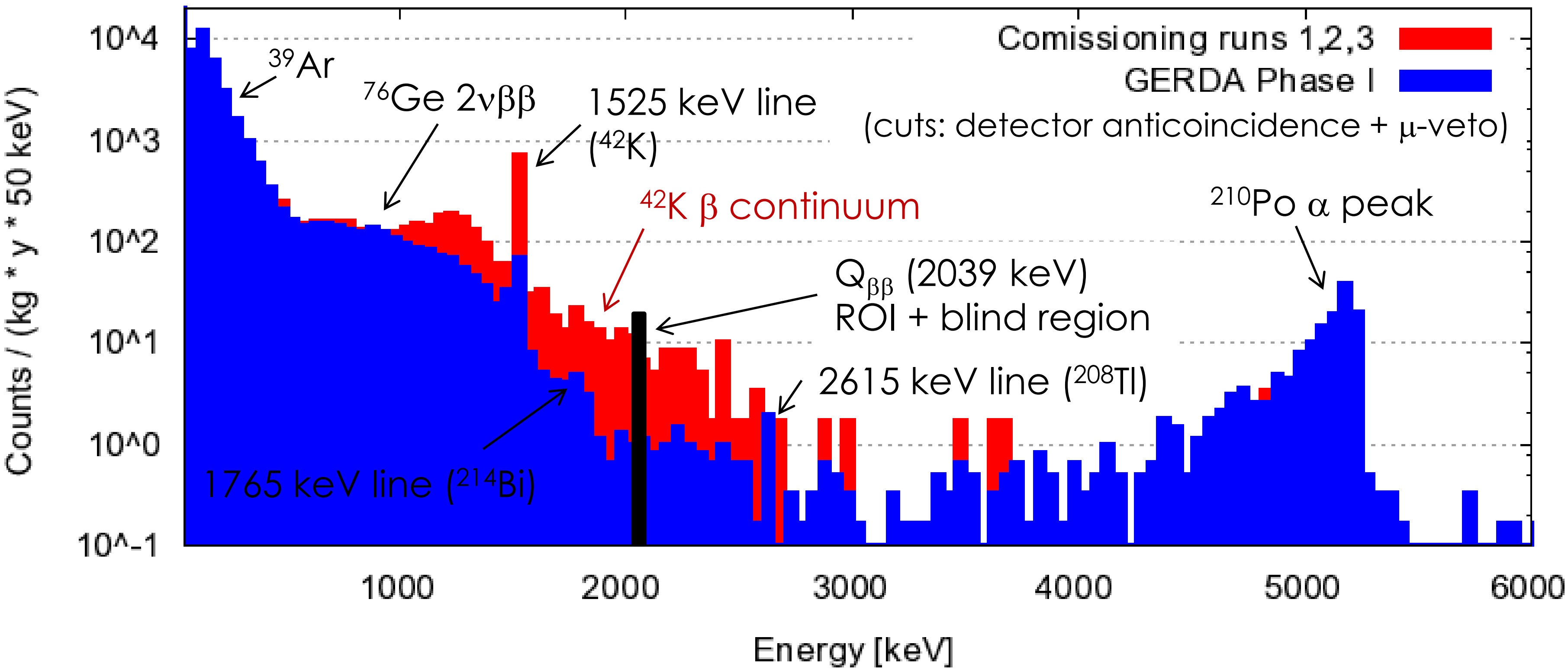
GERDA Phase II detectors:
R. Falkenstein, T 110.1, Tuesday 16:45
B. Lehnert, T 110.3, Tuesday 17:20

GERDA Phase II LAr veto:
M. Walter, HK 46.8, Tuesday 18:30



Back-up

Backgrounds in GERDA



Backgrounds observed in Phase I:

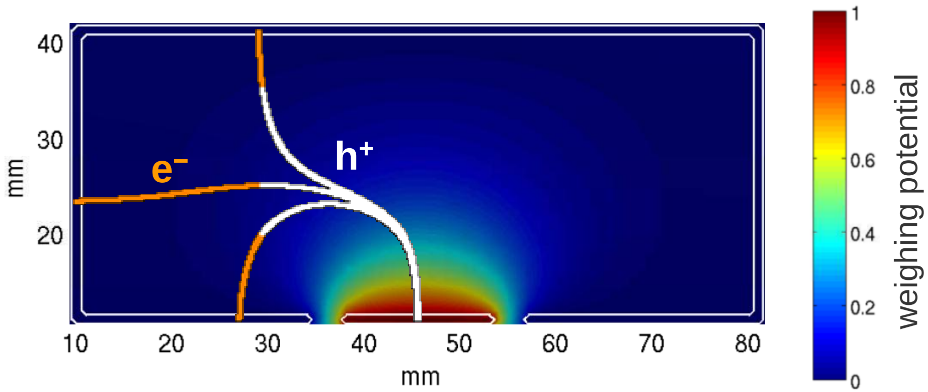
- surface α from ^{226}Ra chain
- surface β from ^{42}K (from ^{42}Ar in LAr)
- γ from Th and Ra decay chains

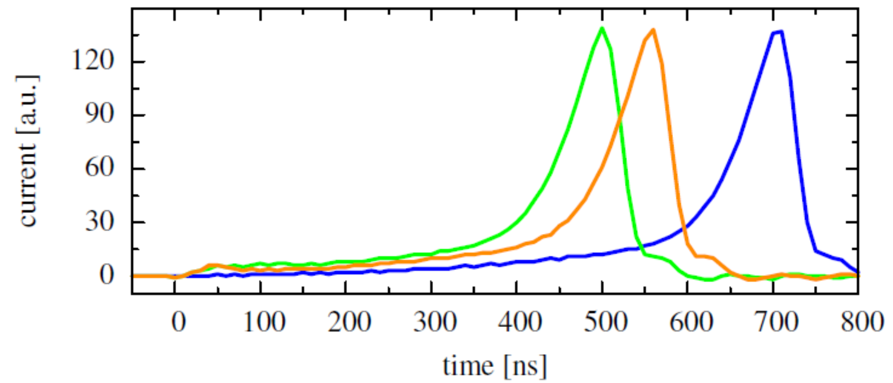
→ see talk by:
N. Becerici-Schmidt, T 103.4, Do 17:40

Additional bkg expected in Phase II:

- β/γ decays of ^{60}Co and ^{68}Ga from cosmogenic activation of Ge

Pulse shape discrimination with BEGe





Ramo's theorem:
(current signal)

$$I(t) = q \cdot \nabla \phi_W(\vec{r}(t)) \cdot \vec{v}$$

q, r, v – charge, position and velocity of charge cluster
$\boldsymbol{\phi_W}$ – weighing potential

- ~95% volumetric efficiency of **A/E position independence**
- **separation sensitivity**: <10 ns (current peaks) ⇒ **<1.2 mm** (interactions; 1D)*
- I_{max}/E resolution ≈ 0.6% ⇒ **~15 keV sensitivity for 2nd interaction** in a 2 MeV MSE

* using $12 \cdot 10^{-6}$ cm/s hole drift velocity [Bruyneel et al., NIM A 569 (2006) 764]

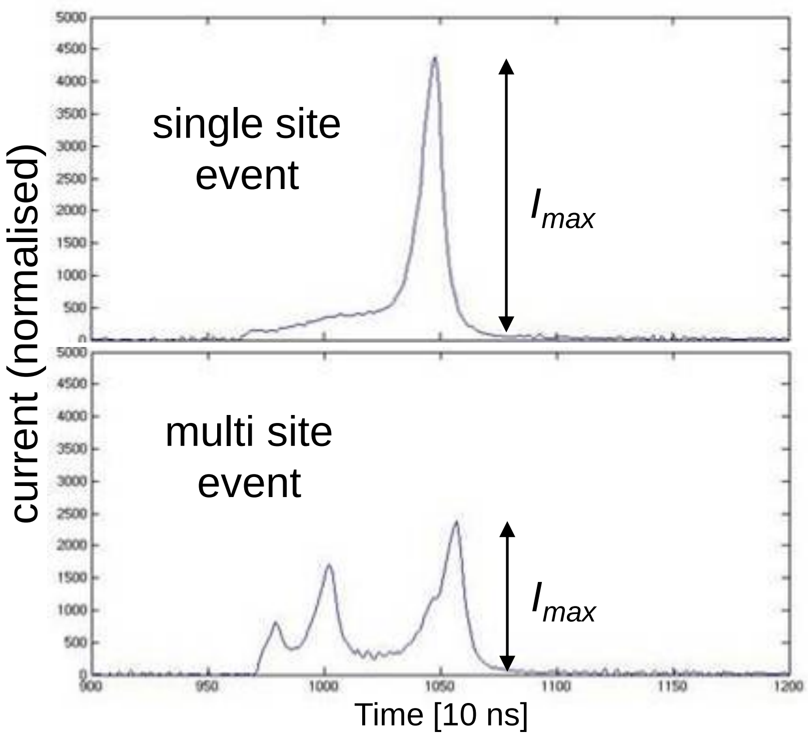
Pulse shape discrimination with BEGe

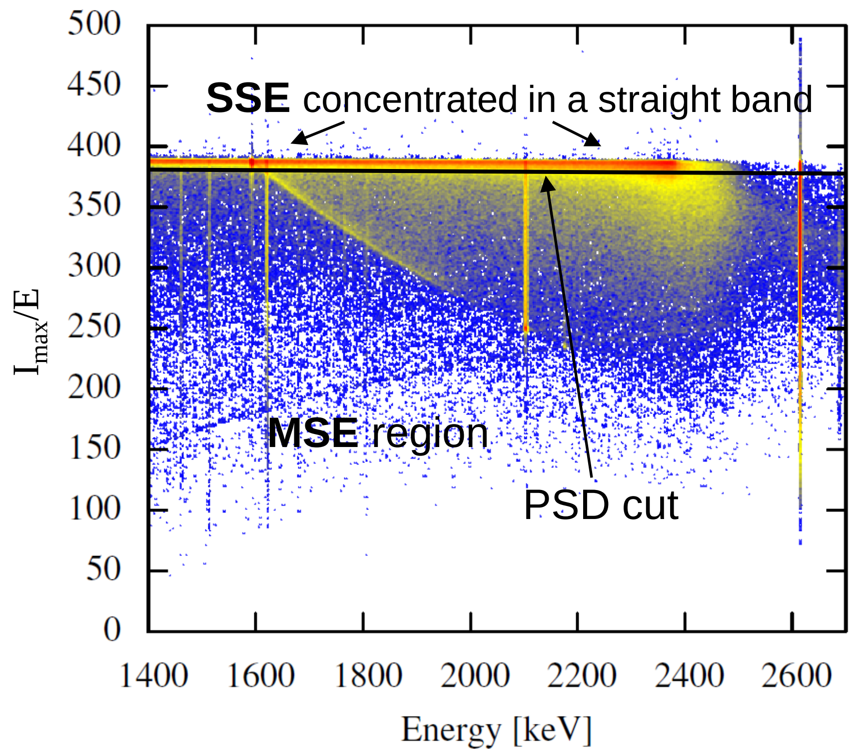
$I_{max}/E \Rightarrow$ discrimination parameter E=total event energy

$$I_{\max} \propto q \Rightarrow$$

SSE: single charge cluster: **$q \propto E \Rightarrow (I_{max}/E)_{SSE} \approx$ const.**

MSE: several charge clusters: **$q_i < E \Rightarrow (I_{max}/E)_{MSE} < (I_{max}/E)_{SSE}$**

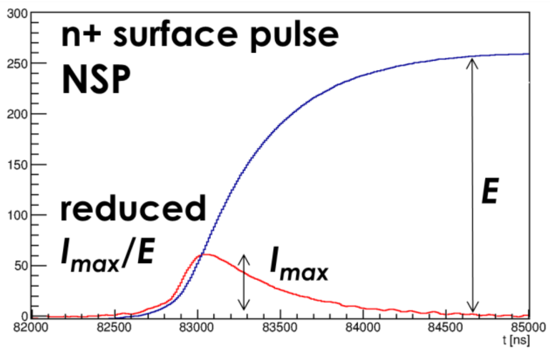




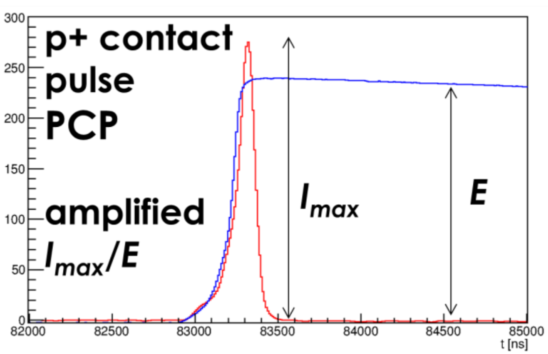
D. Budjáš et al., JINST 4:P10007,2009
M. Agostini et al., JINST 6:P03005, 2011

BEGe performance studies: Surface events

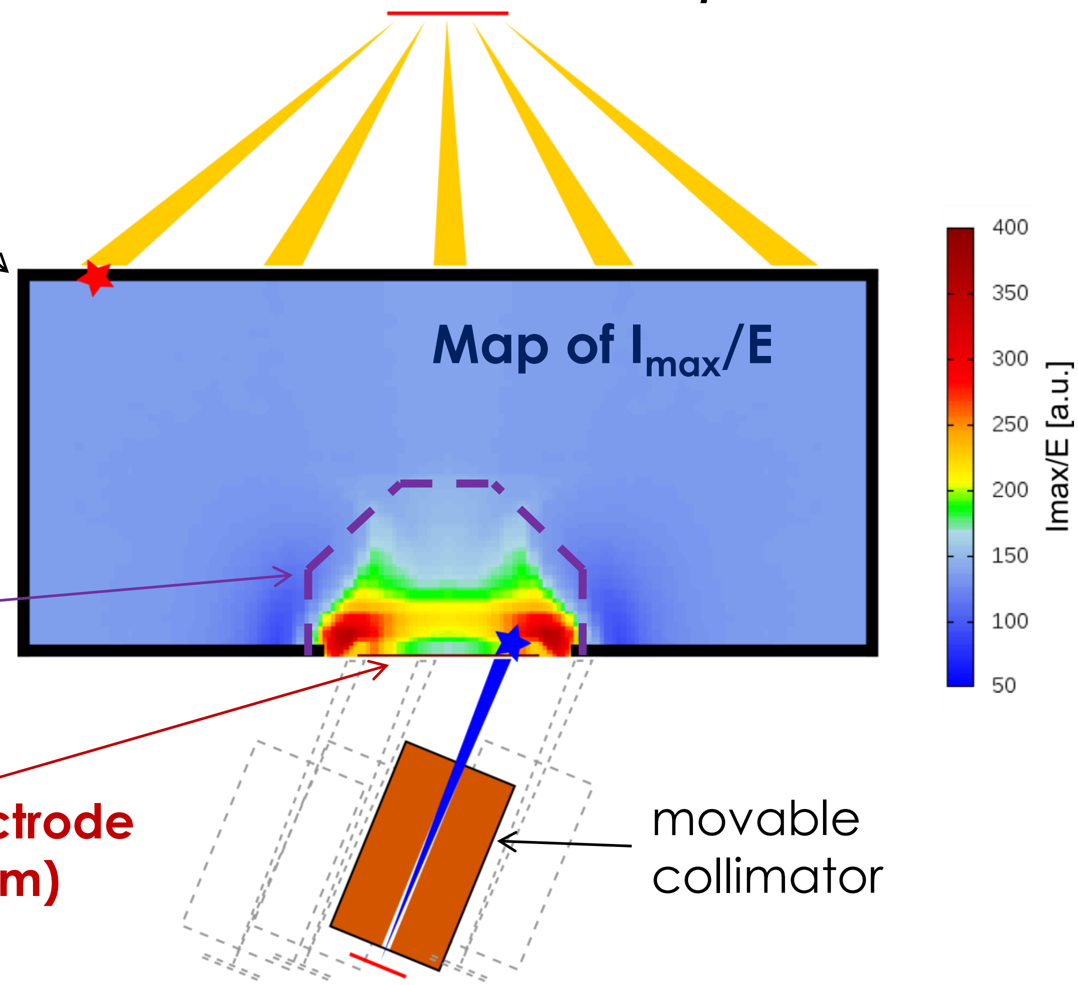
n+ electrode (≲ mm)
→ n+ surface pulses (NSP) occurrence



region of p+ contact pulses (PCP) occurrence



Irradiation with ^{90}Sr and ^{106}Ru β sources

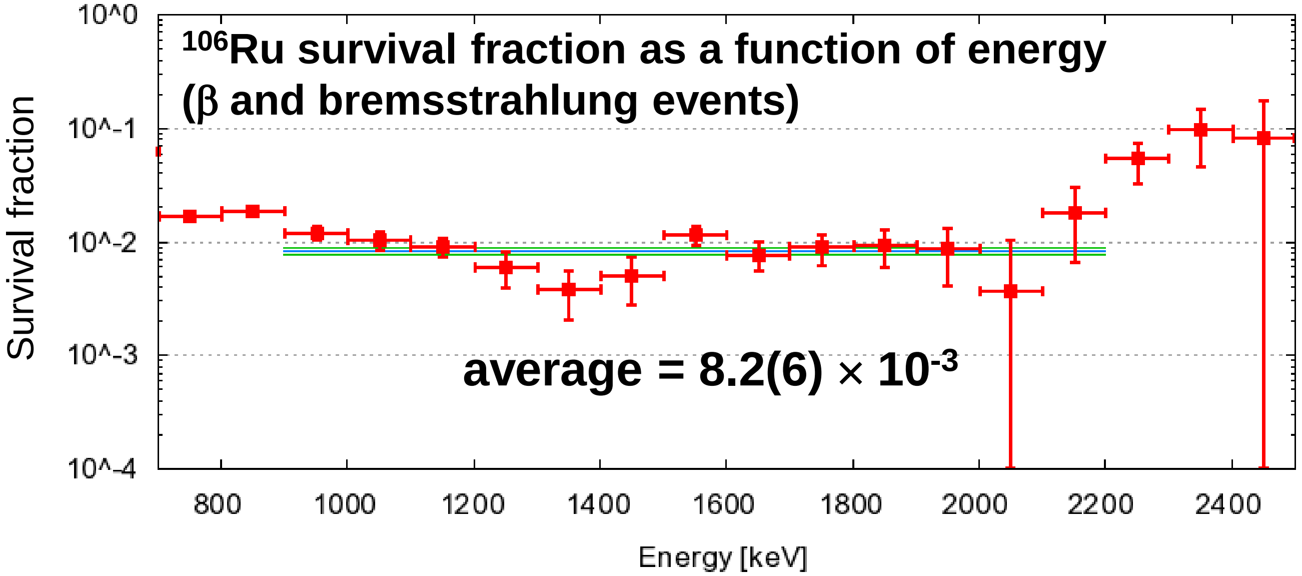


p+ electrode (< µm)

movable collimator

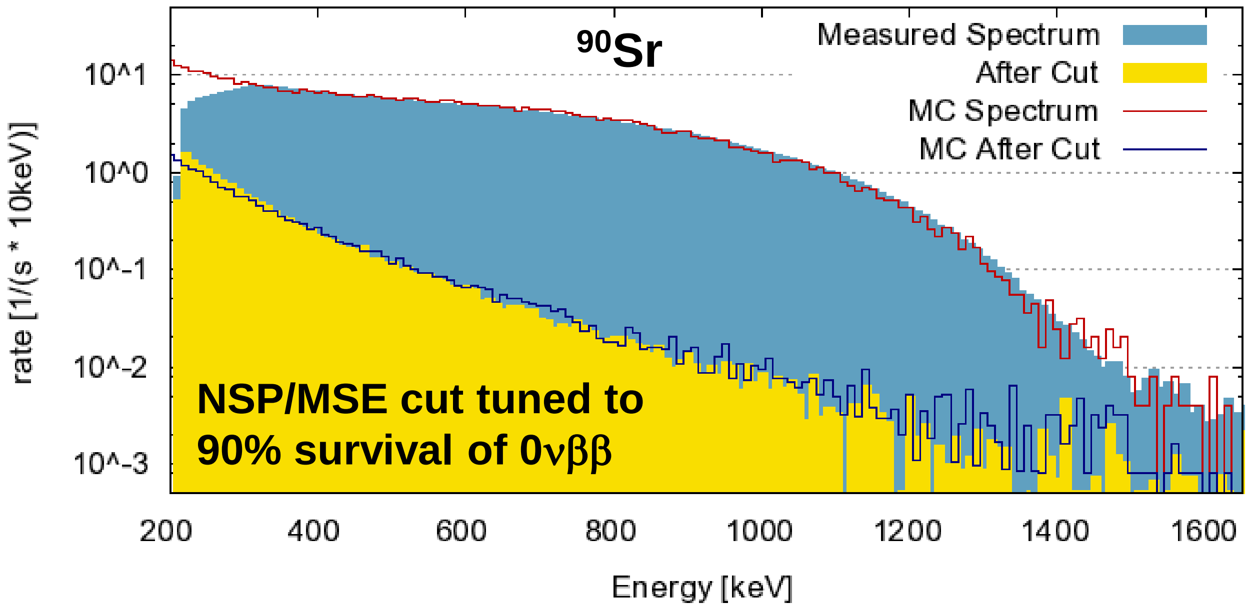
Scanning of p+ contact with ^{241}Am α source and ^{90}Sr β source

Performance studies: ^{90}Sr and ^{106}Ru n+ surface β events



n+ surface β event PSD rejection power demonstrated stable in region 1 - 2 MeV

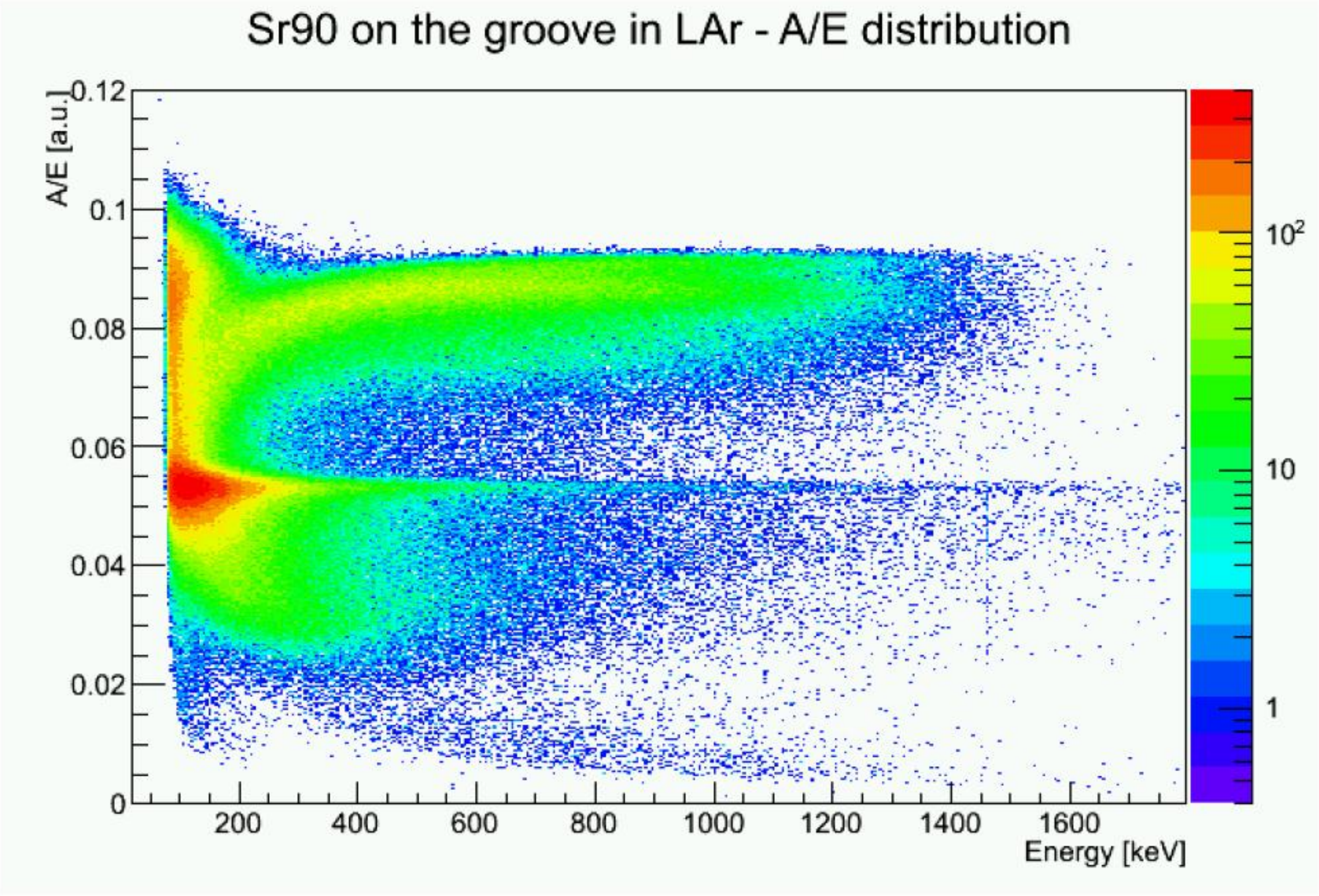
NSP/MSE cut tuned to 90% survival of 0νββ



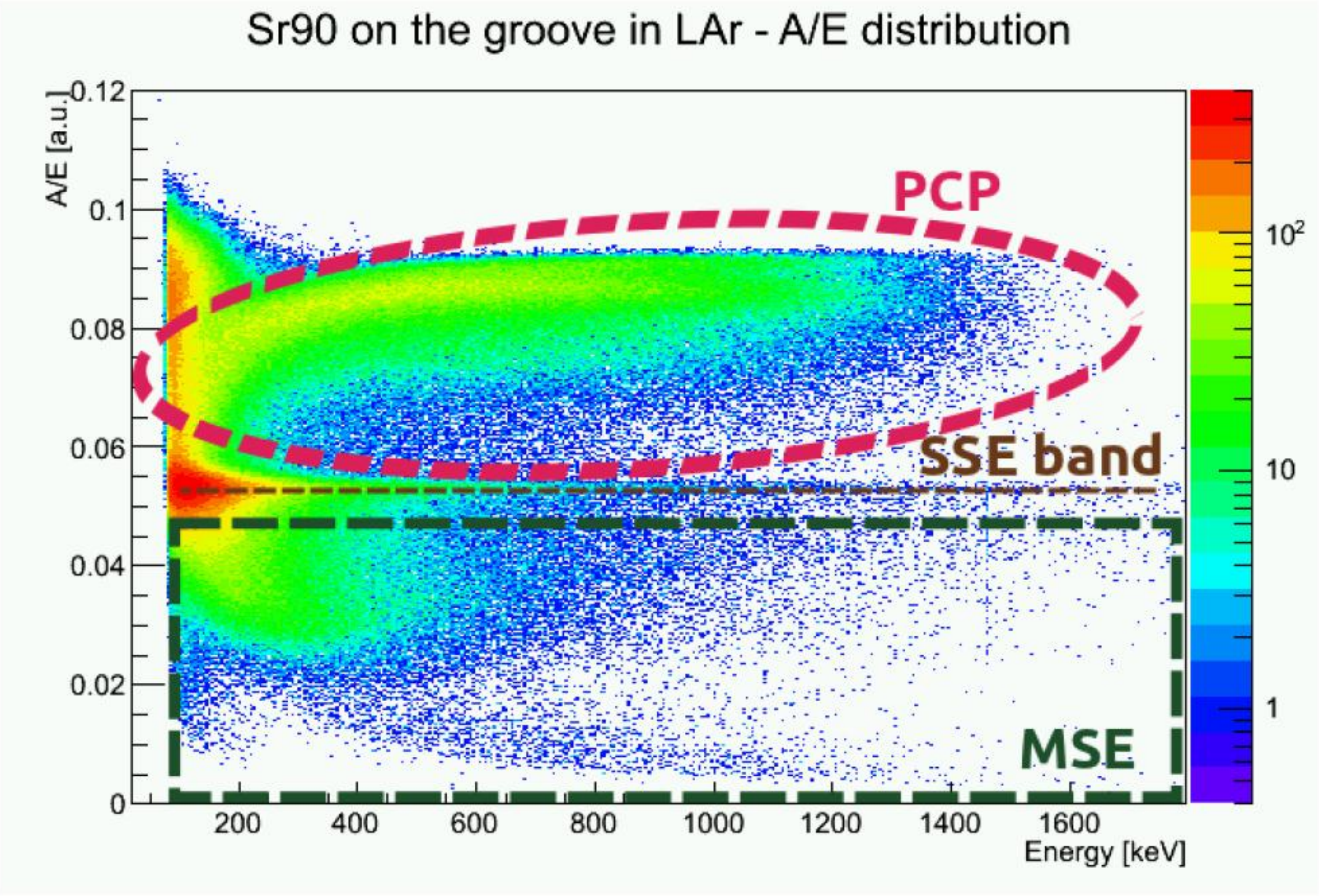
MC cut set to 0.1% survival of β-like events and 20% survival of γ-like (bremsstrahlung) events.

good quantitative agreement of simulated suppression with measurement

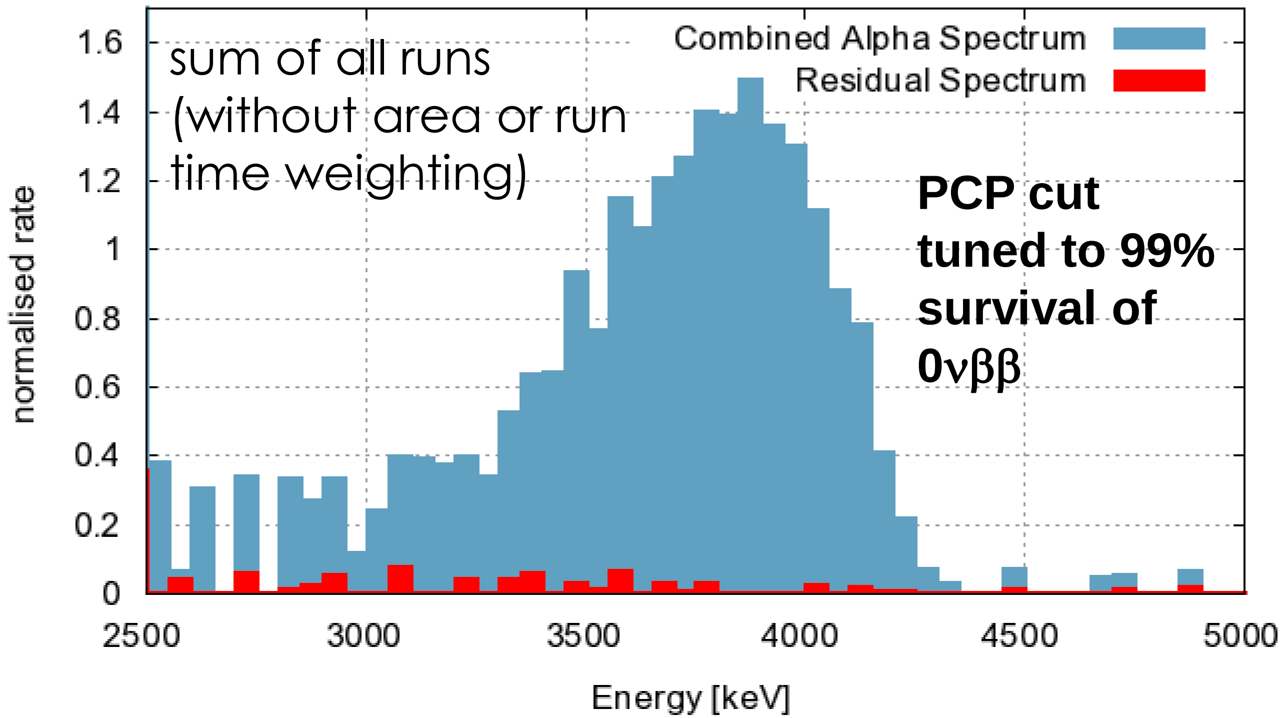
A over E distributions



A over E distributions



Performance studies: ^{241}Am p+ contact α events



surface	p+ contact	groove inner	groove bottom	groove outer
survival fraction *	< 1.1%	< 12%	< 1.0%	< 1.2%

* 90% confidence-level upper limits
results limited by background in test setup; improved measurement analysis under way