Background reduction at low energies with BEGe detector

operated in liquid argon using the GERDA-LARGE facility

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

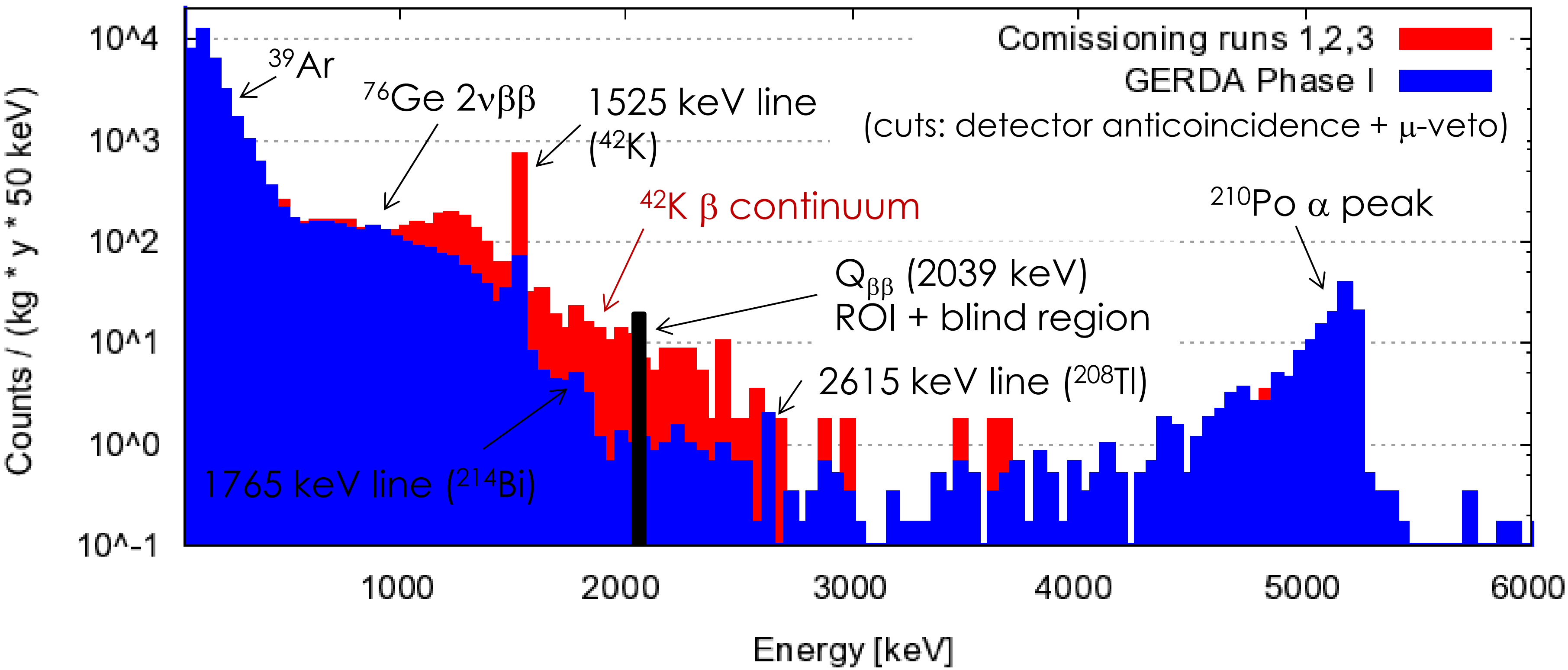
Outline

1. Backgrounds in GERDA Phase I and II
2. Background suppression tools in GERDA
3. Low background test facility GERDA-LArGe
4. Background suppression at low energies

Outline

1. **Backgrounds in GERDA Phase I and II**
2. **Background suppression tools in GERDA**
3. **Low background test facility GERDA-LArGe**
4. **Background suppression at low energies**

Backgrounds in GERDA



Backgrounds observed in Phase I:

- surface α from ^{210}Po
- surface β from ^{42}K (from ^{42}Ar in LAr)
- γ from Th and Ra decay chains, ^{60}Co
- prompt μ-induced events

Additional bkg expected in Phase II:

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

Main background at low-energy: ^{39}Ar

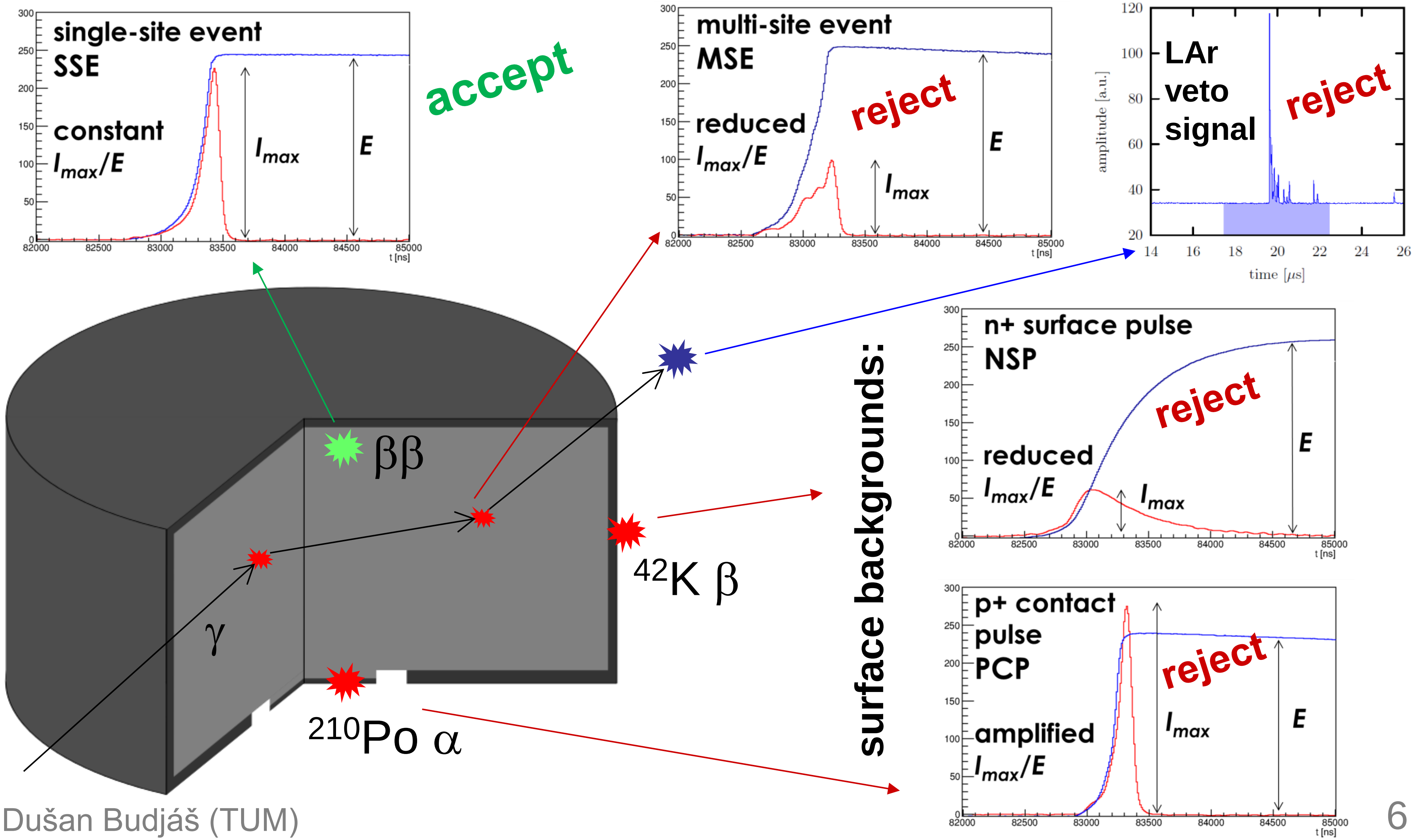
Outline

1. Backgrounds in GERDA Phase I and II
2. **Background suppression tools in GERDA**
3. Low background test facility GERDA-LArGe
4. Background suppression at low energies

Background suppression tools in GERDA

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

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



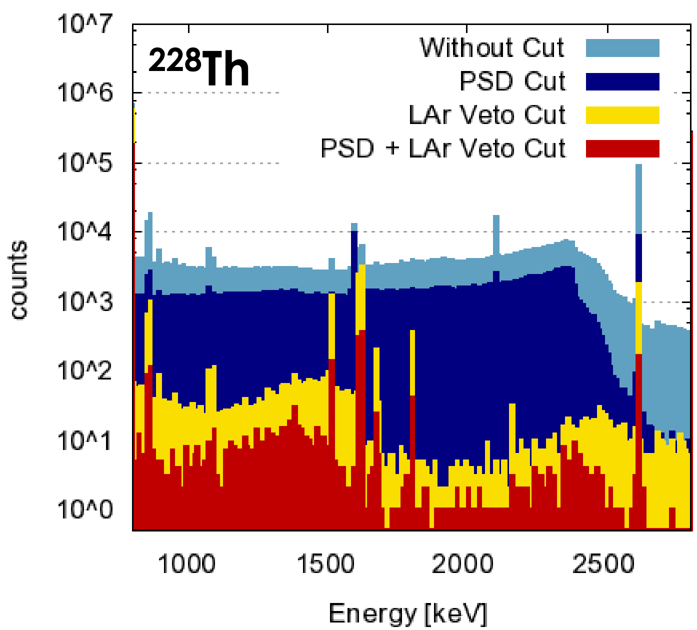
Outline

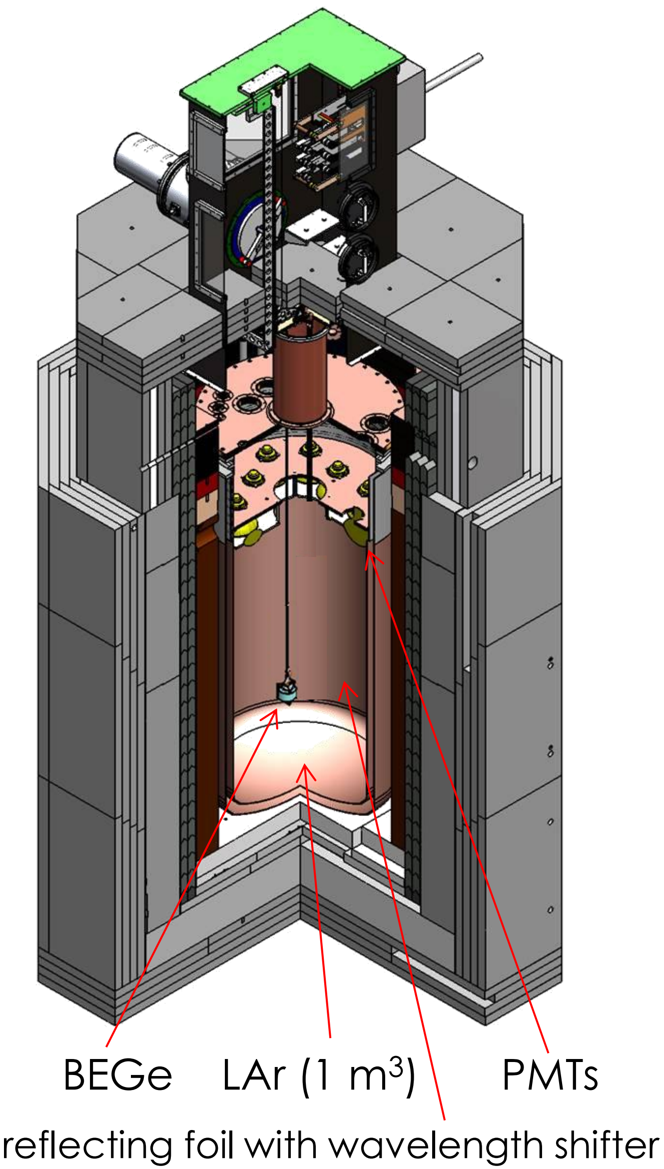
1. Backgrounds in GERDA Phase I and II
2. Background suppression tools in GERDA
3. **Low background test facility GERDA-LArGe**
4. Background suppression at low energies

Studies of background suppression by LAr veto and PSD

Low background test facility
GERDA-LArGe at LNGS

- LAr scintillation detected by PMTs
  ⇒ anti-coincidence veto
- PSD analysis cut on Ge signals
  applied in parallel



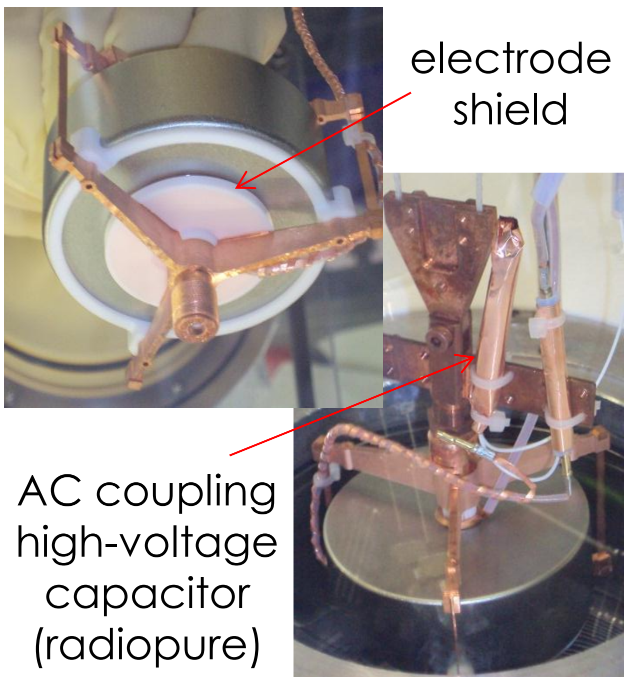


[M. Heisel, Dissertation, University of Heidelberg (2011)]

^{42}K suppression methods studied in LArGe

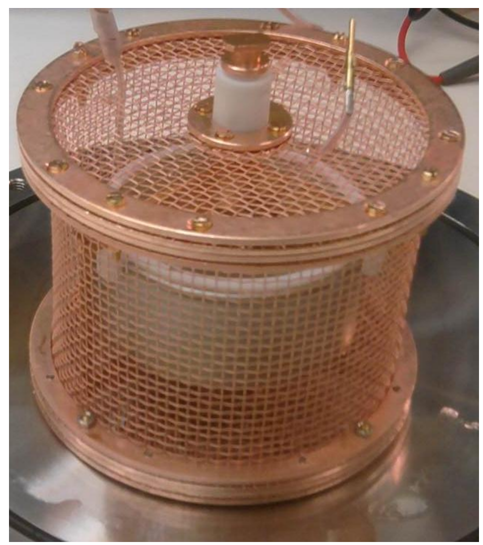
Step1: preventing ^{42}K ions collection at detector surfaces

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



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)

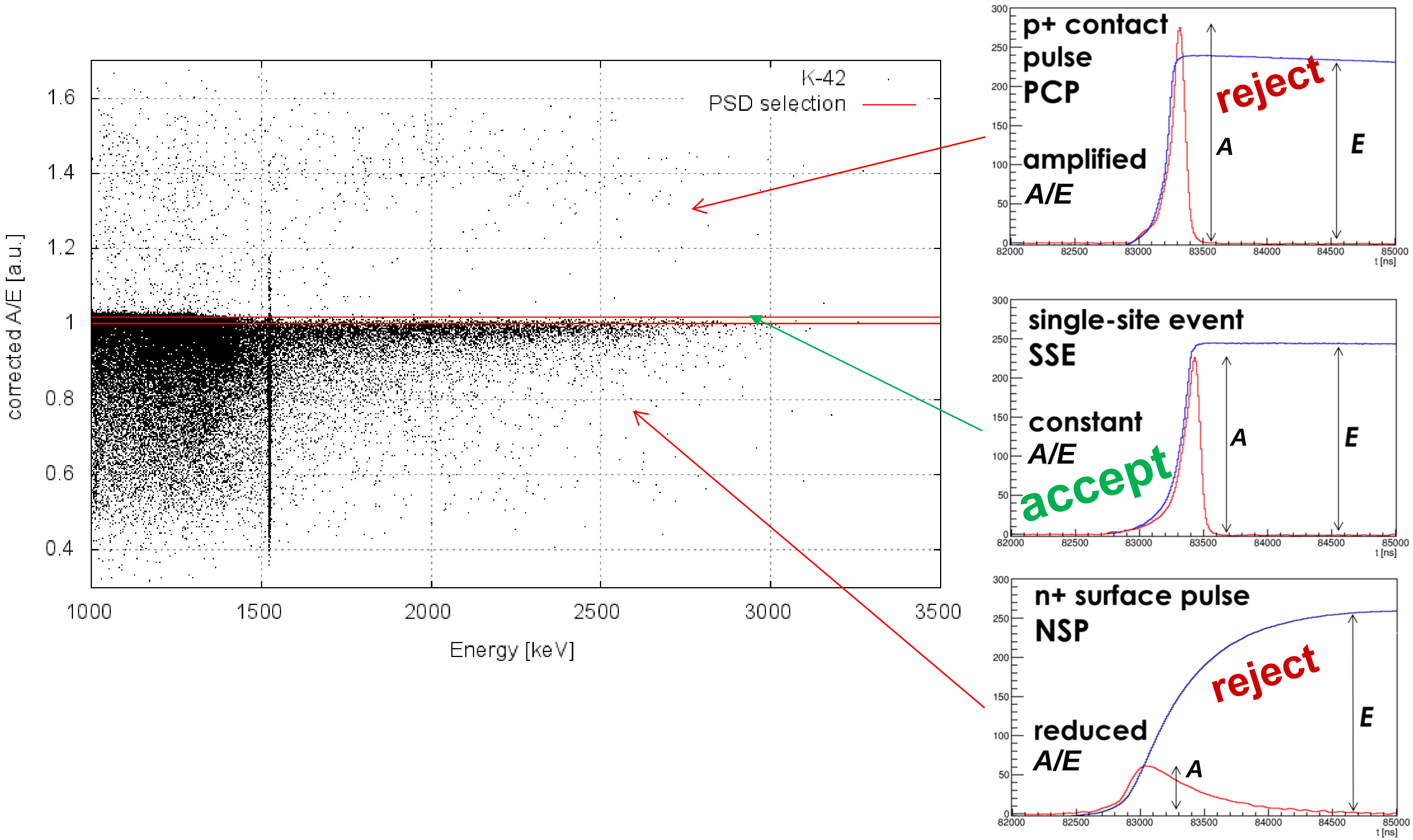
suppression by factor ~10

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

measurement ongoing

^{42}K suppression methods studied in LArGe

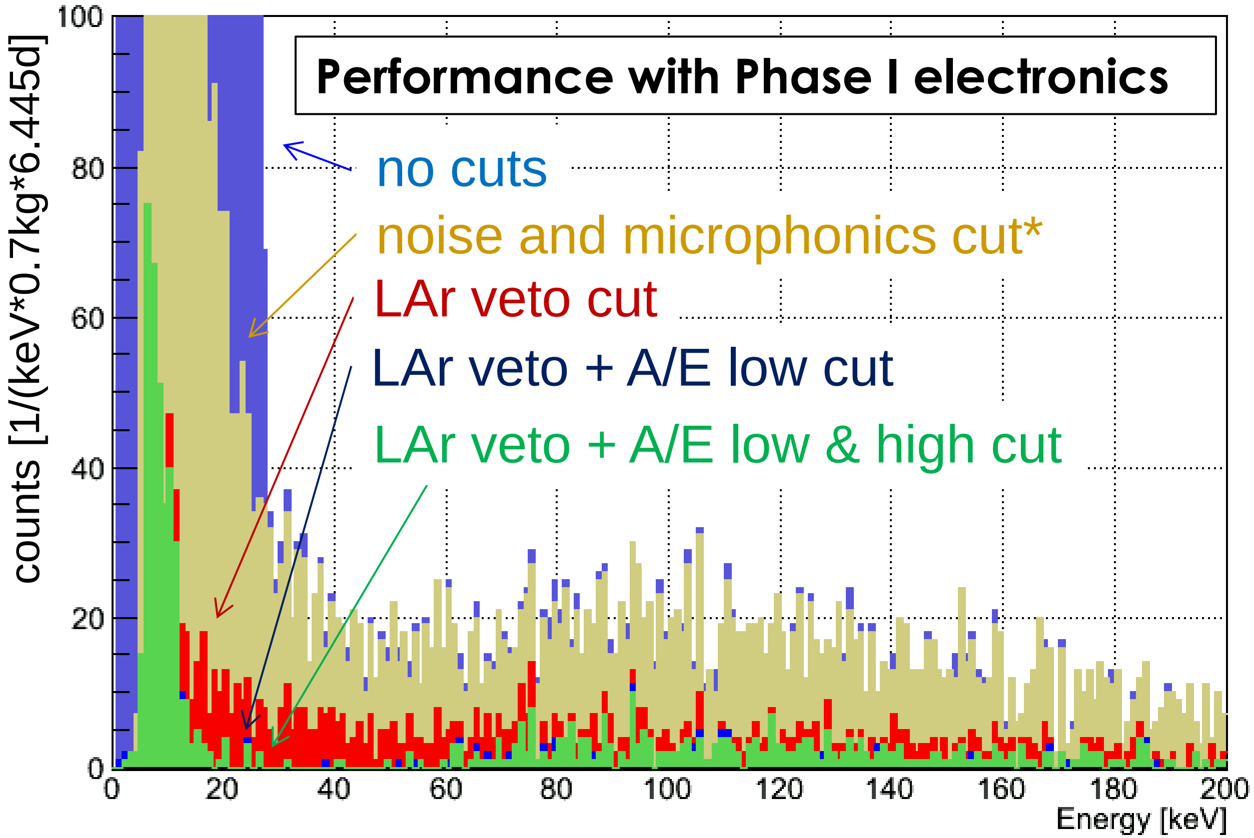
Step2: reject the remaining ^{42}K background via PSD



Outline

1. Backgrounds in GERDA Phase I and II
2. Background suppression tools in GERDA
3. Low background test facility GERDA-LArGe
4. **Background suppression at low energies**

Removal of ^{39}Ar background at low energies

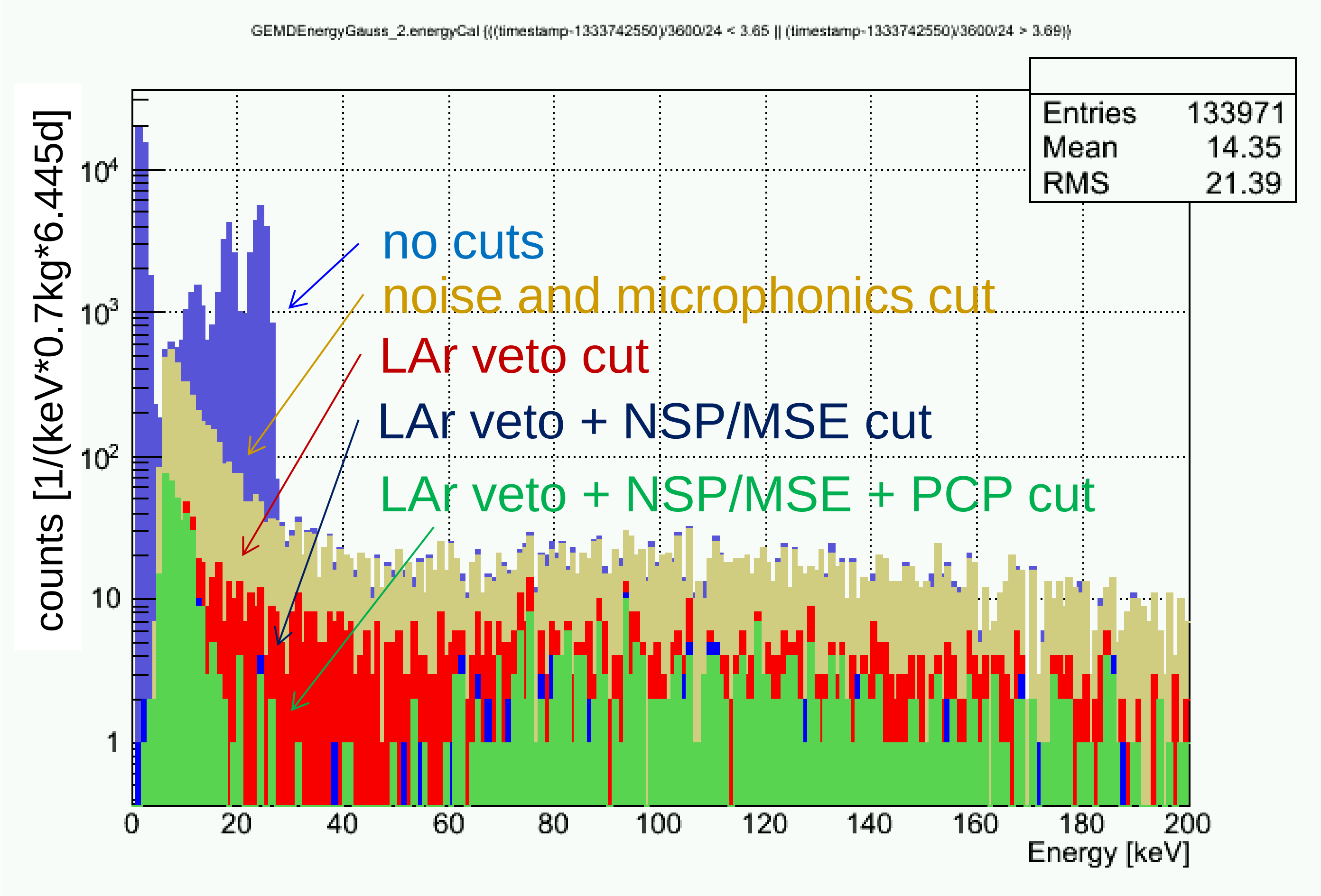


* ratio of E(shaping1)/E(shaping2) and other cuts to remove unphysical events

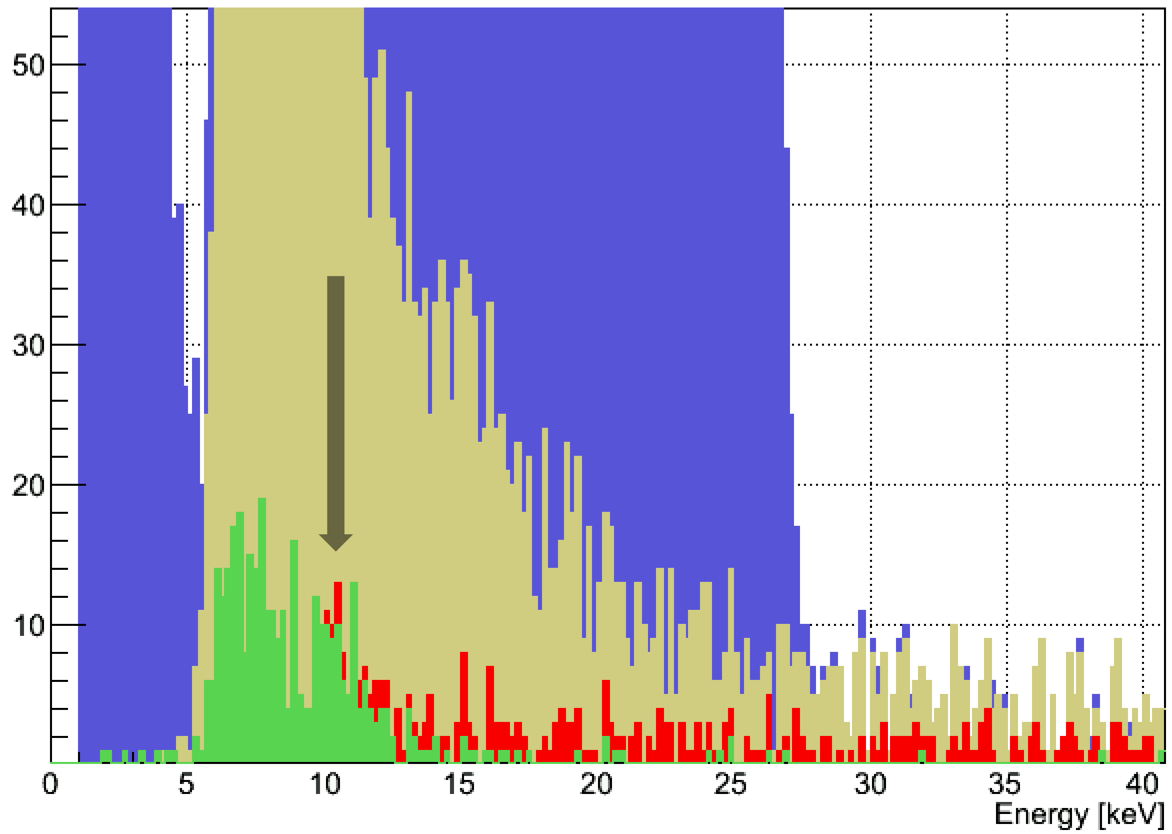
Energy threshold: ~7 keV (pulser FWHM: 1.8 keV)
PSD threshold: ~20 keV

rate after all cuts in region 30 – 50 keV: 0.04 cts/(keV.kg.d)

Removal of ^{39}Ar background at low energies



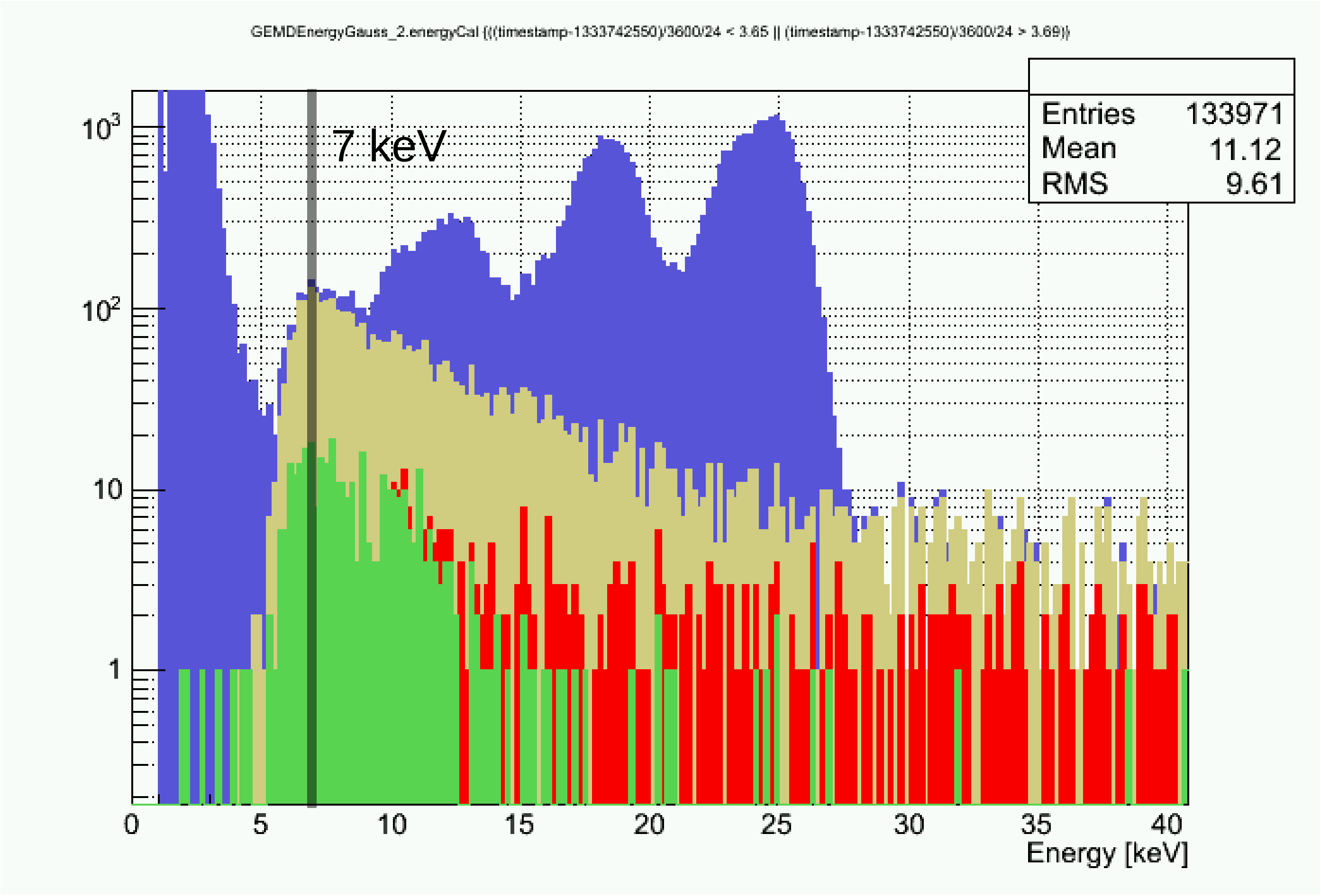
Spectrum near threshold



Ge-68 rate from 2010 run with BEGe in GERDA estimated ~20.5 decays/day

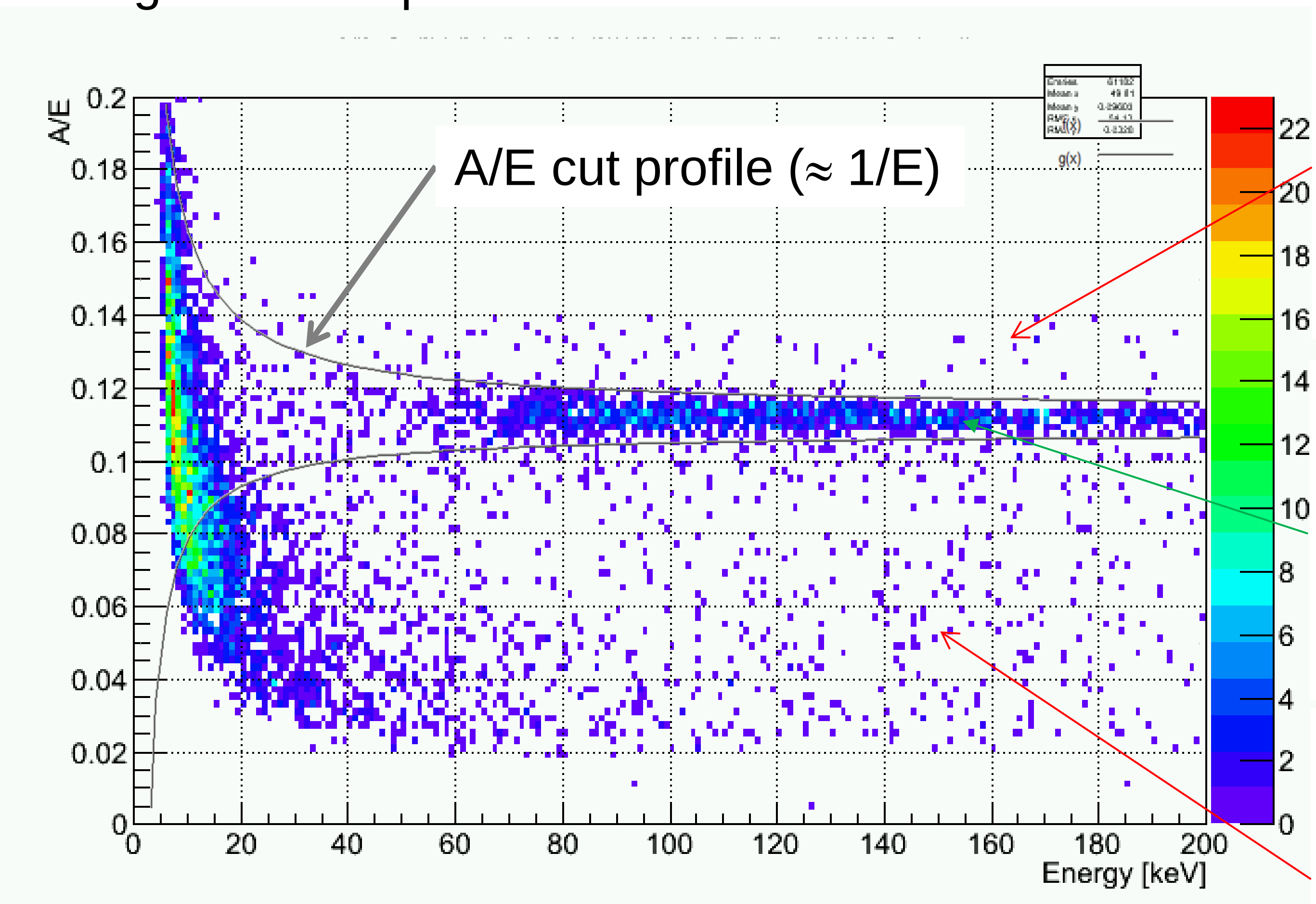
⇒ 6 decays/day in 2011 ⇒ expect about 25 counts (incl. efficiency correction)

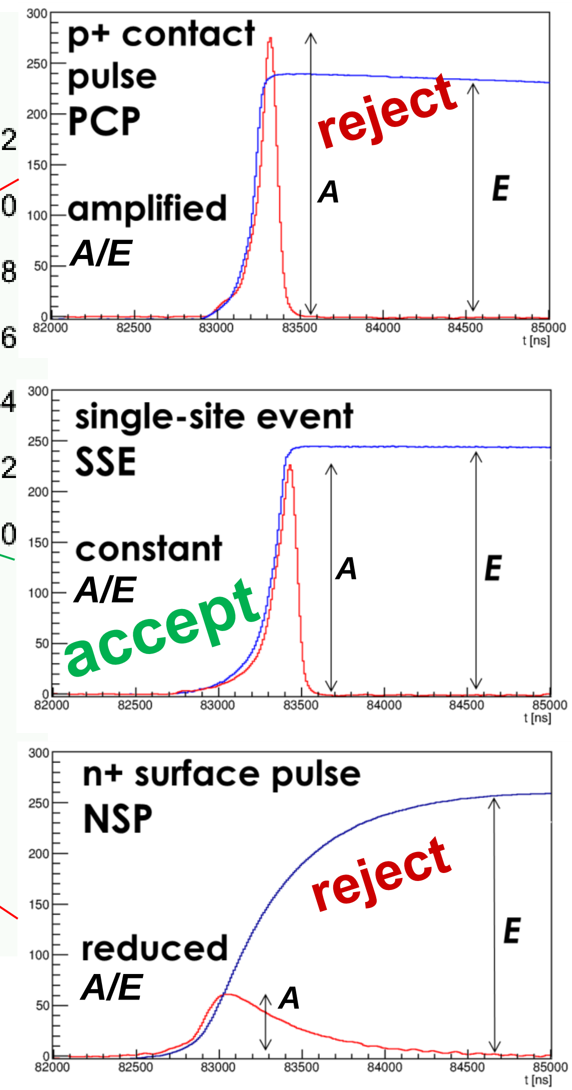
Background at low energies



Background at low energies

Background A/E plot:



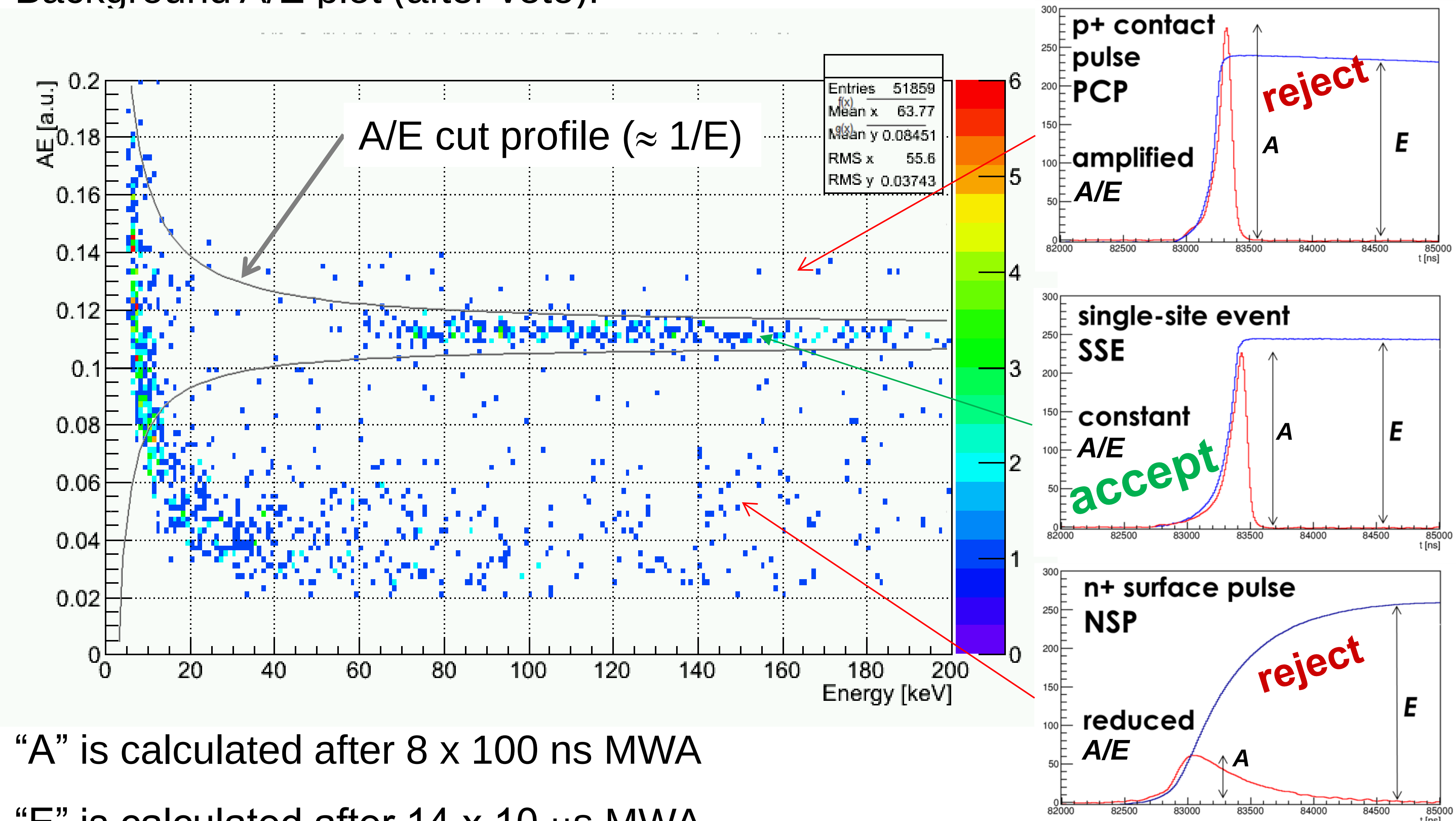


"A" is calculated after 8 x 100 ns MWA

"E" is calculated after 14 x 10 μs MWA

Background at low energies

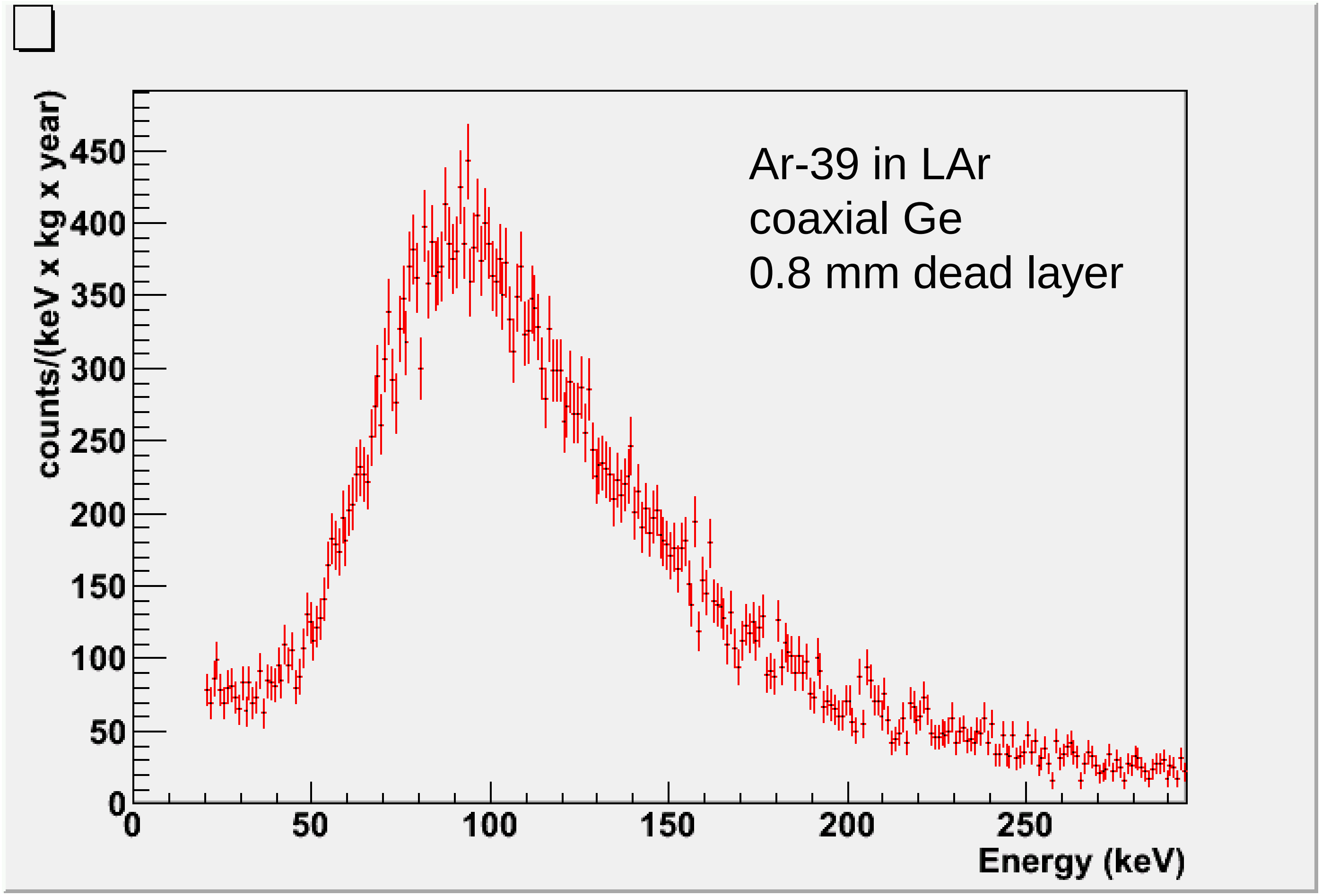
Background A/E plot (after veto):



“A” is calculated after 8 x 100 ns MWA

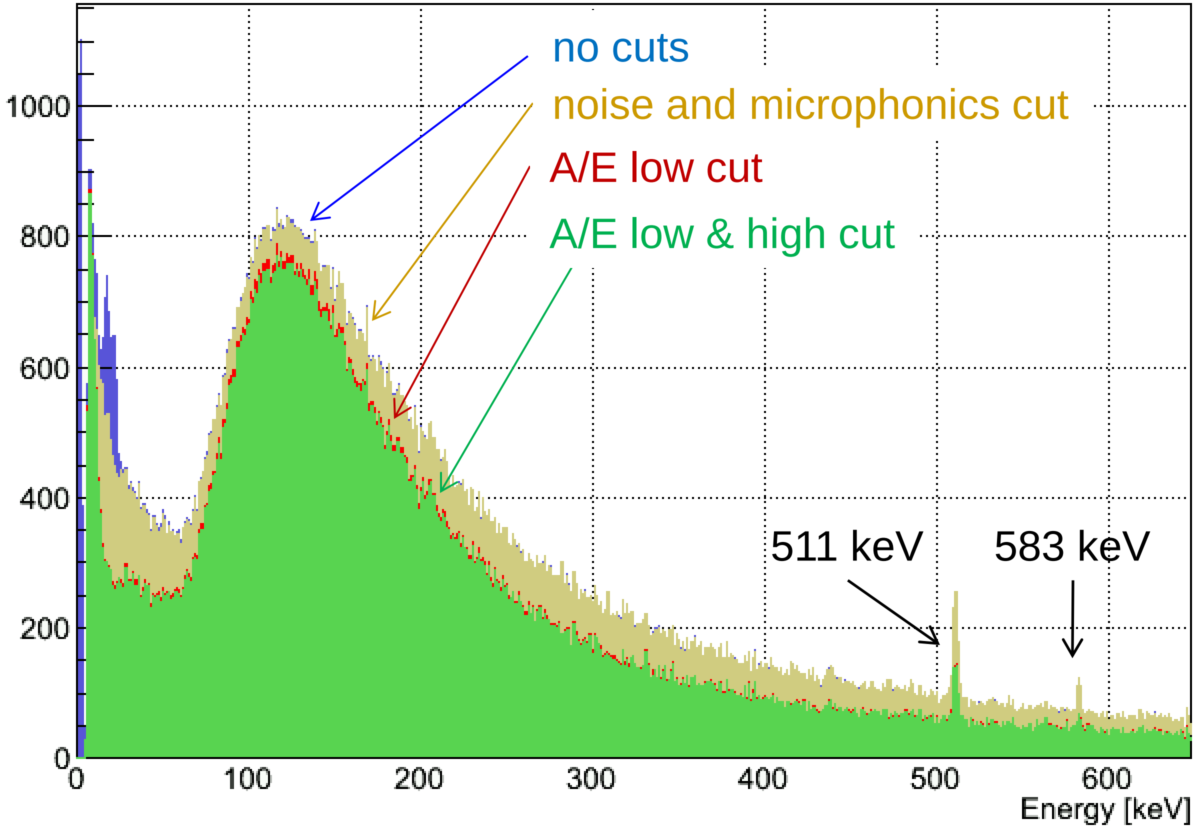
“E” is calculated after 14 x 10 μs MWA

Background at low energies



A/E cut at low energies

A/E cut on Th-228 calibration spectrum (no LAr veto):

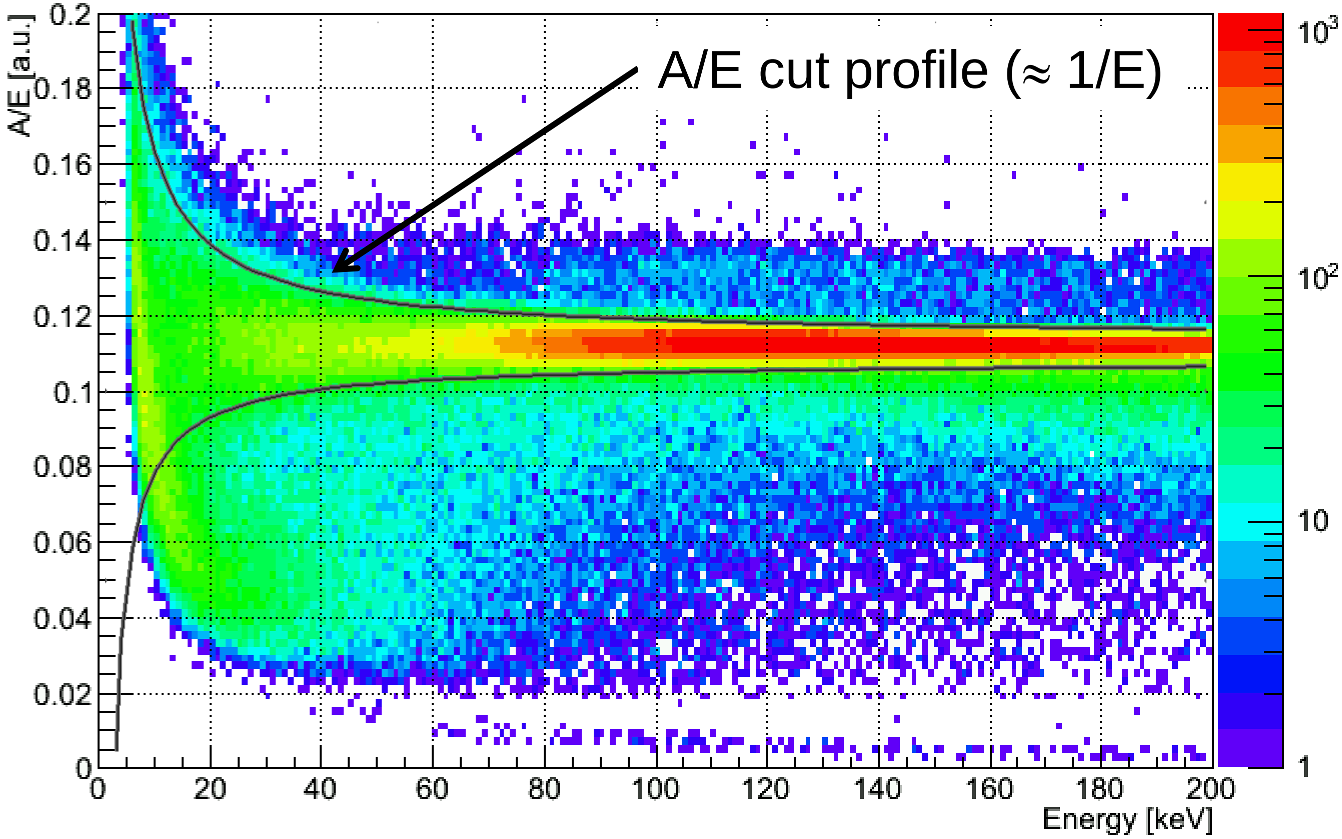


~90% acceptance in the continuum (low energy γ-rays, mostly SSE)

(optimised only below ~200 keV)

A/E cut at low energies

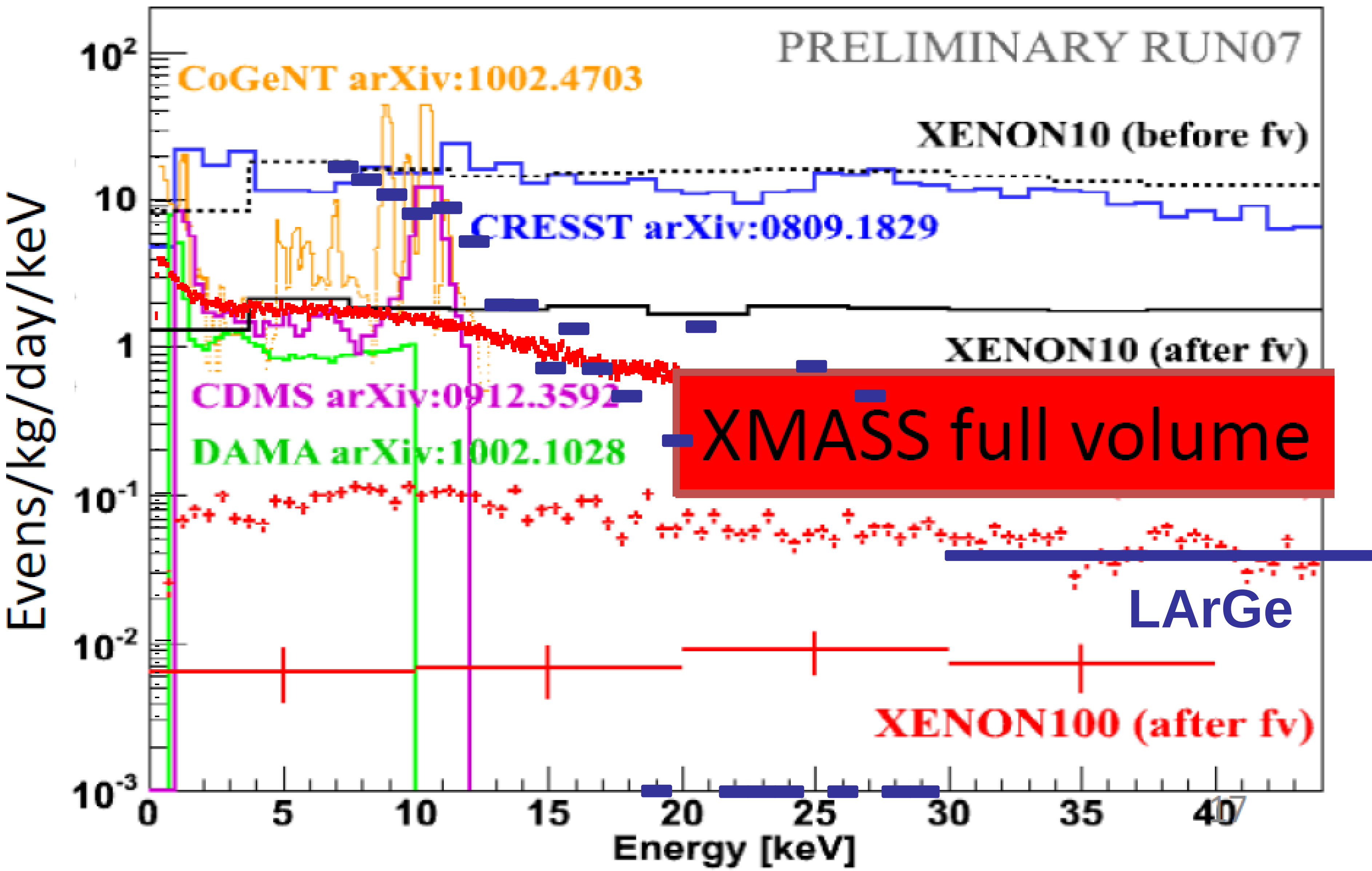
Th-228 calibration A/E plot:



“A” is calculated after 8 x 100 ns MWA

“E” is calculated after 14 x 10 μs MWA

Background at low energies



from S. Moriyama (XMASS, University of Tokyo)

Summary

- GERDA Phase II will use enhanced **pulse-shape discrimination** with modified **BEGe** detectors and **LAr veto** to reduce background to identify backgrounds: multi-site (γ), p+ (α) and n+ (β) surface events

- preliminary study of low energy background at GERDA-LArGe test facility provided an encouraging result: **^{39}Ar continuum removed**

Outlook

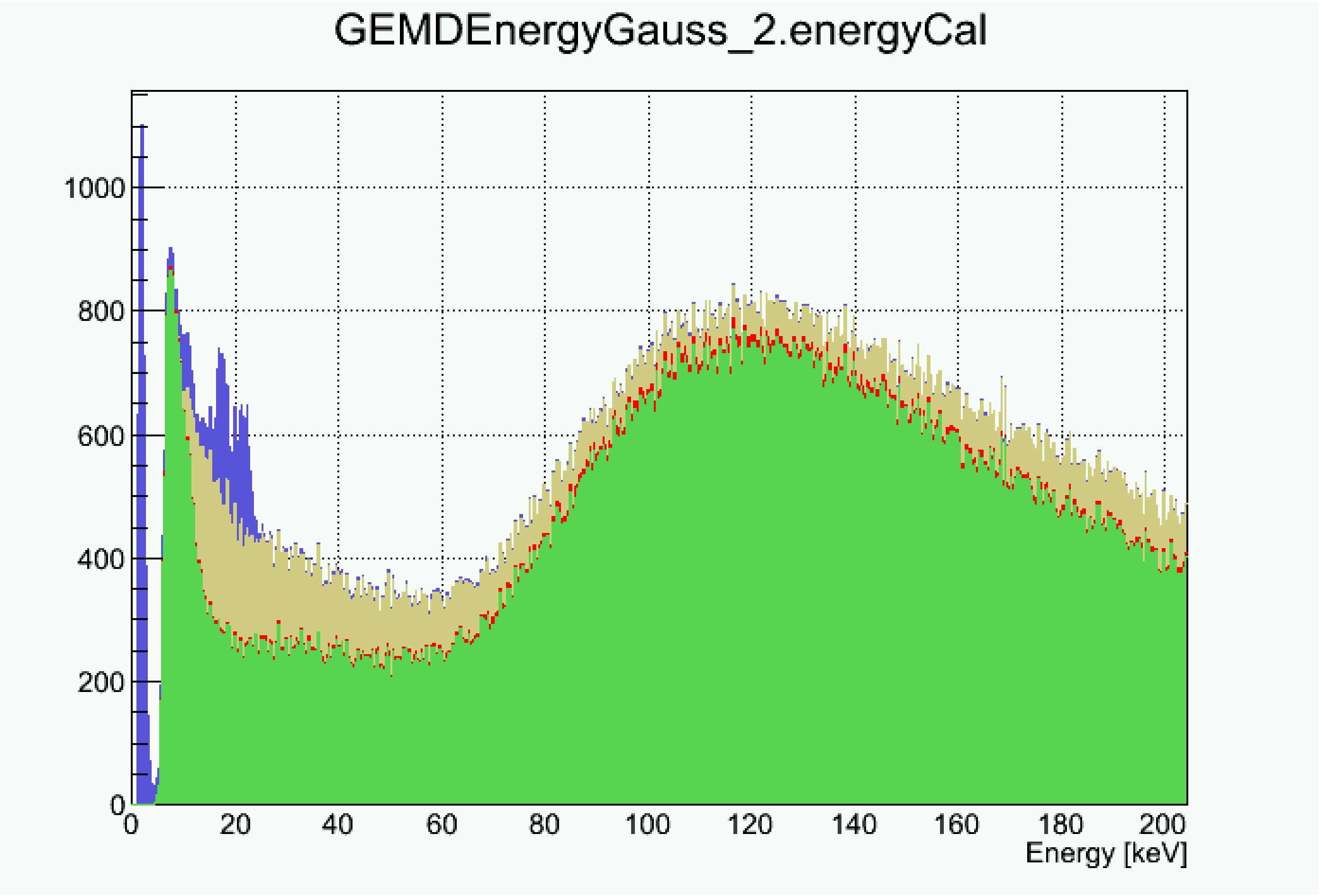
- background level can be probably lowered further (the used detector is not an ultra-low background one, and GERDA has lower background rate than LArGe)

- what can be done in near term:
  - improved signal filtering for better PSA (e.g. wavelet denoising)
  - pulser scan to check trigger efficiency
  - MC simulations to compare data with expected background spectrum shape

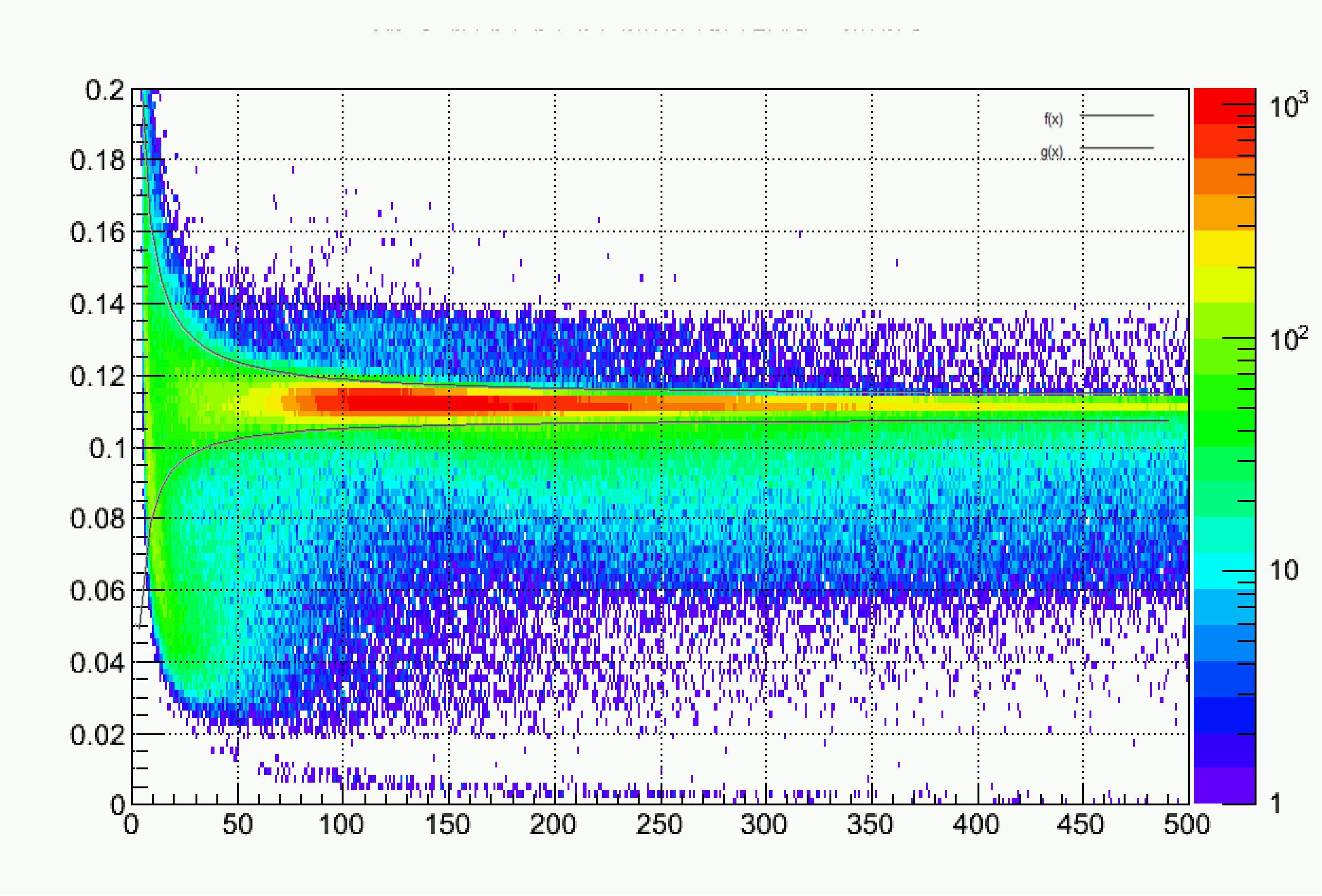
- on longer term: reducing noise in signal read-out electronic chain would have big impact on low energy threshold and PSA

Back-up

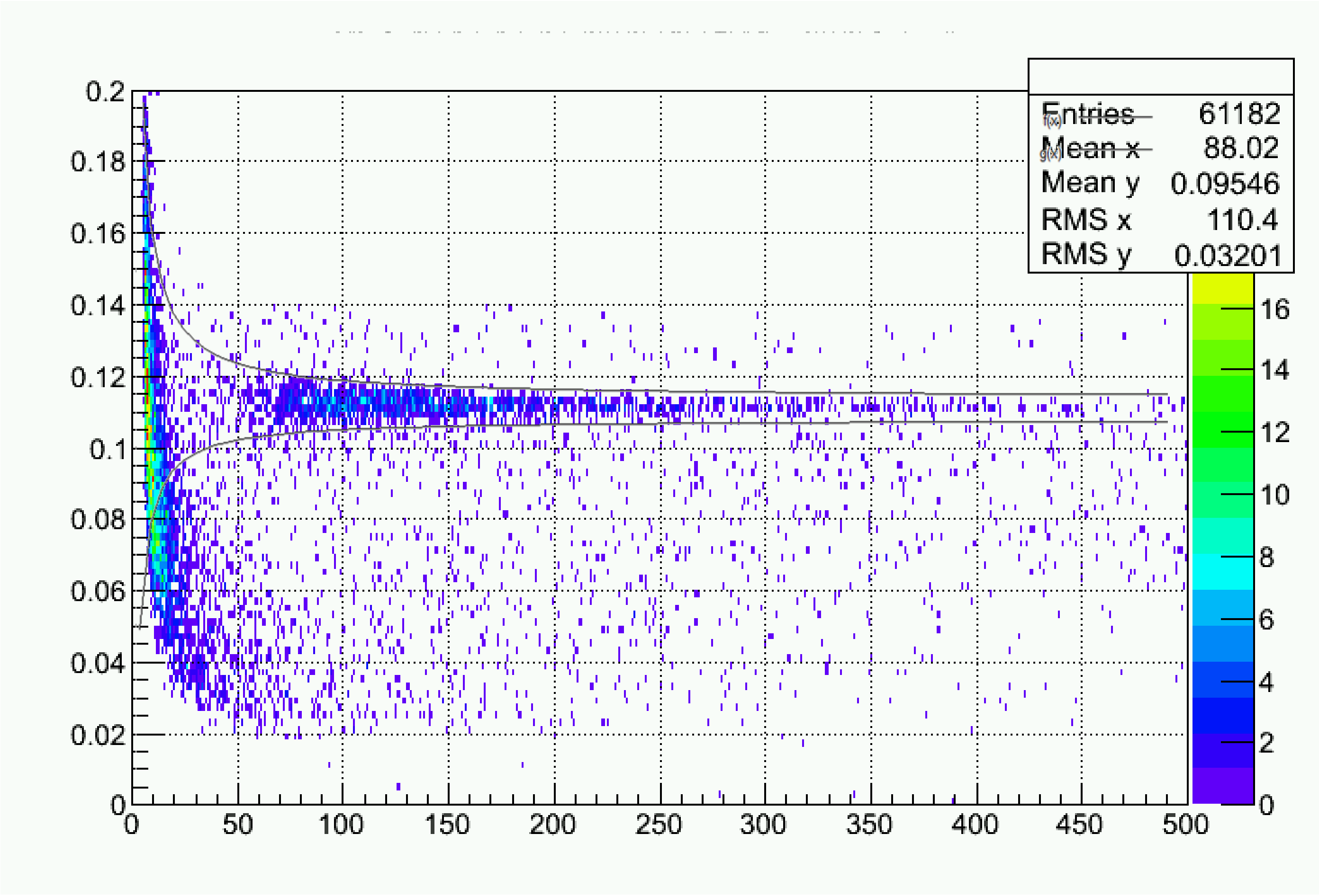
Background at low energies



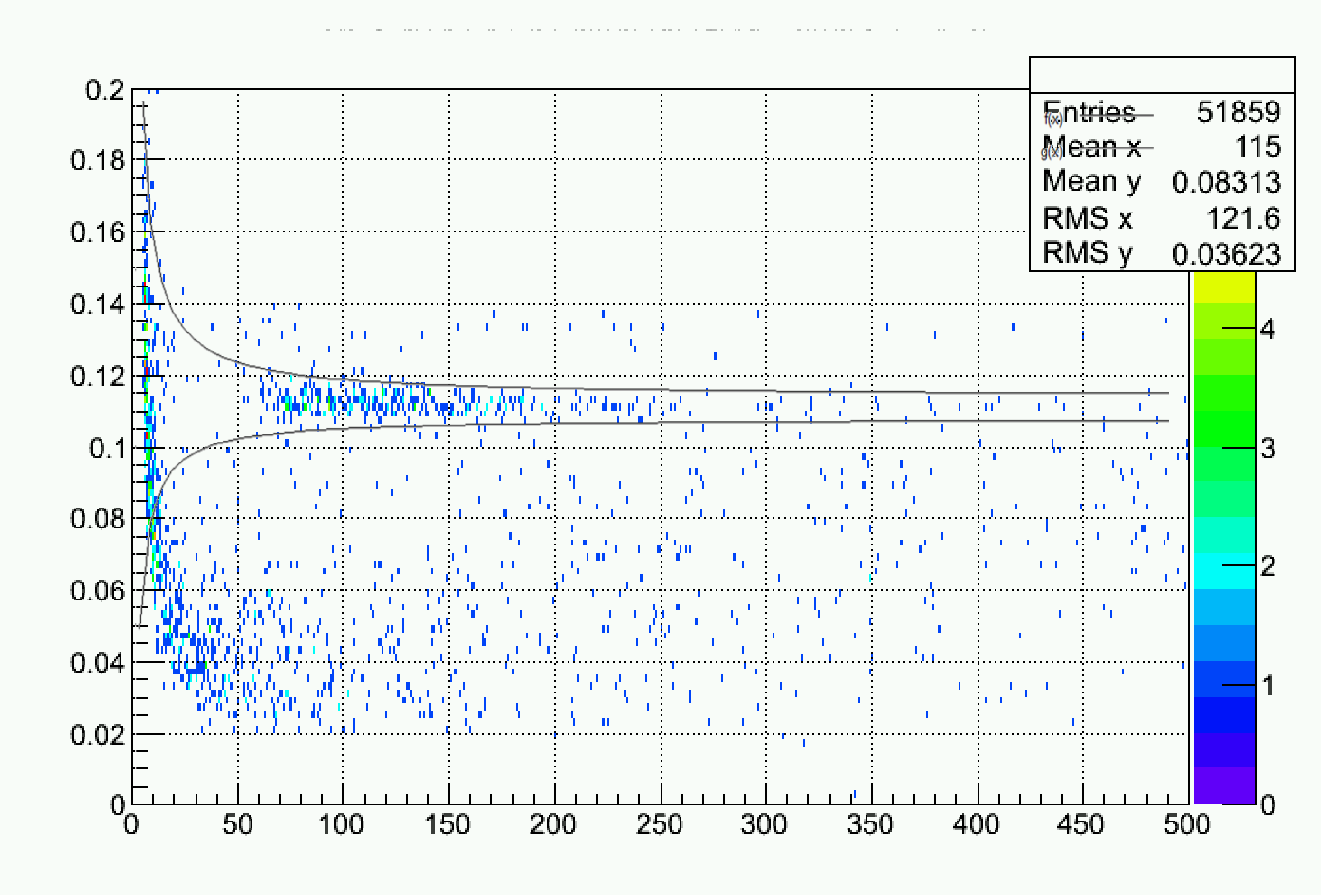
Background at low energies



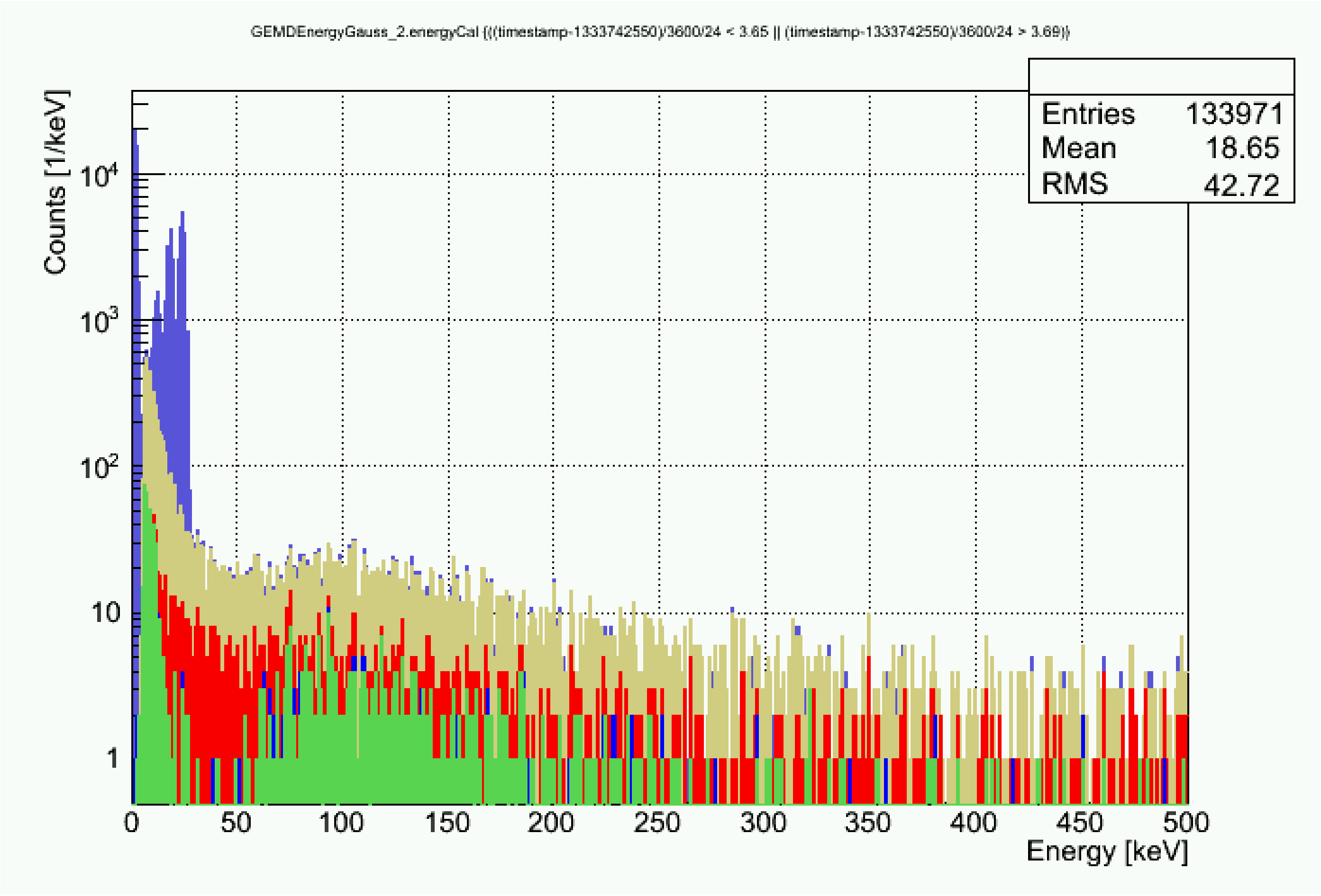
Background at low energies



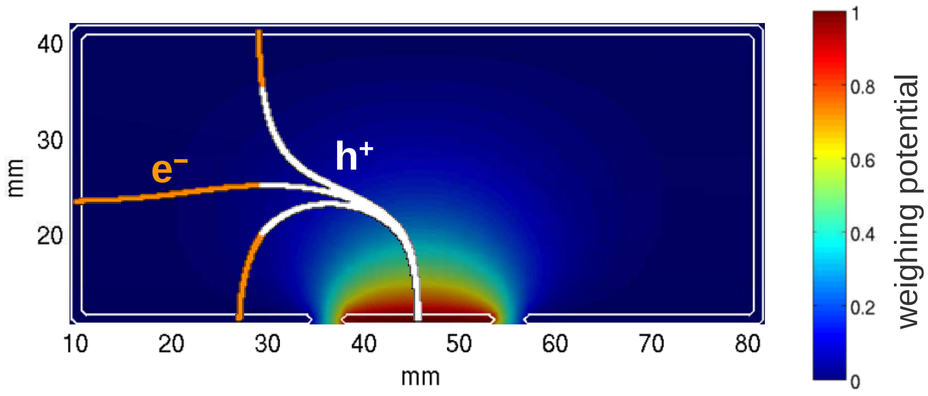
Background at low energies

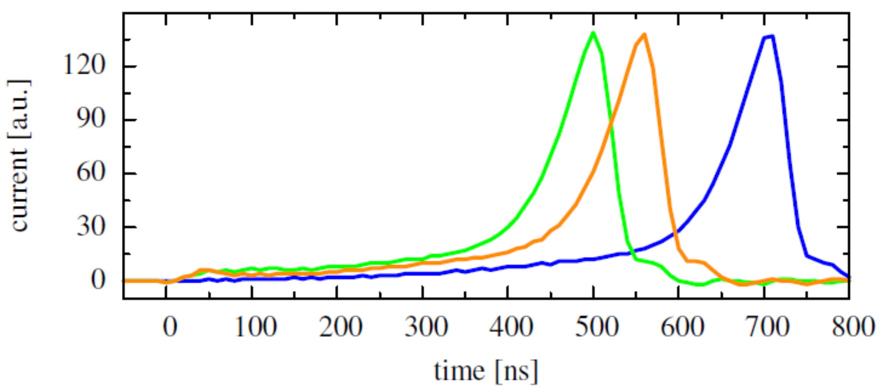


Background at low energies



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

ϕ_W – weighing potential

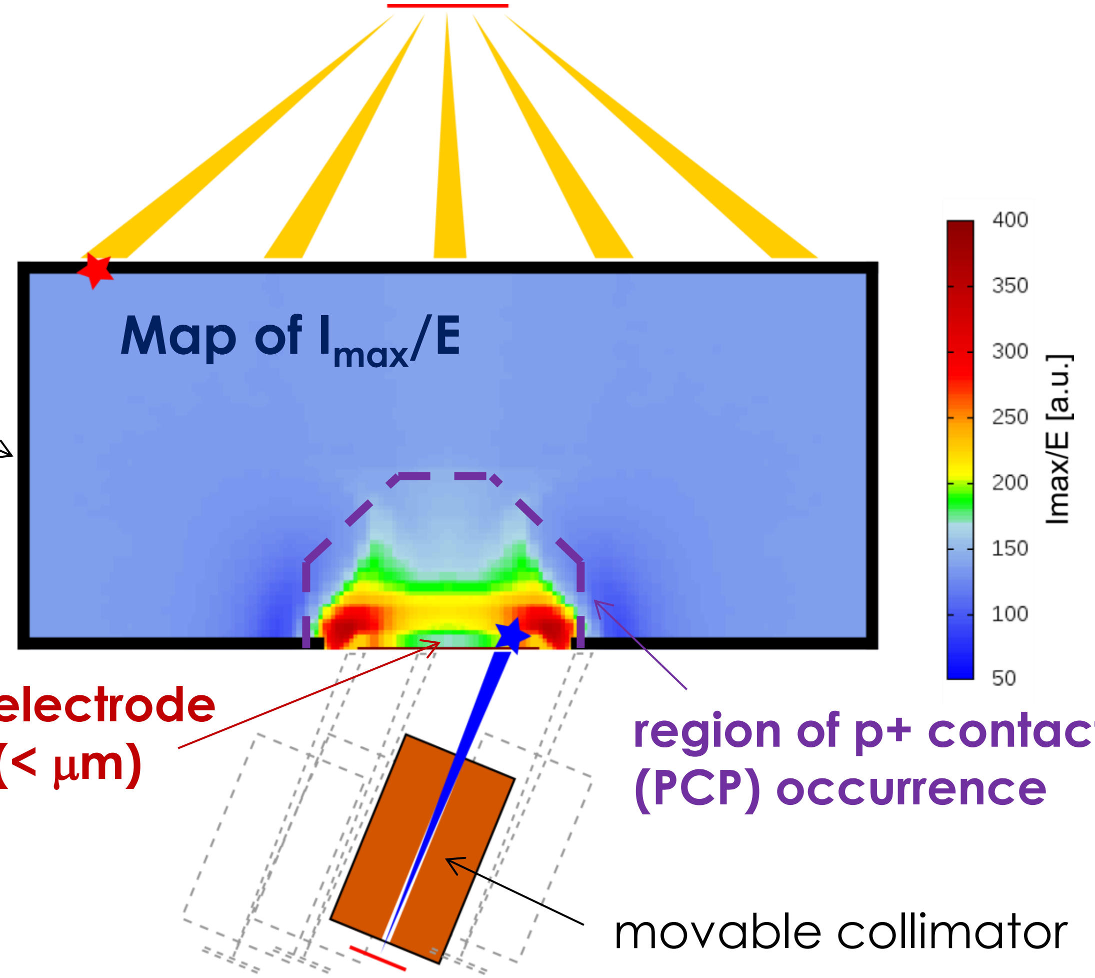
- ~95% volumetric efficiency of **A/E position independence**
- **separation sensitivity**: <10 ns (current peaks) ⇒ **<1.2 mm** (interactions; 1D)*
- I_{max}/E resolution ≈ 0.6% ⇒ **~15 keV sensitivity for 2nd interaction** in a 2 MeV MSE

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

Performance studies: Surface events

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

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



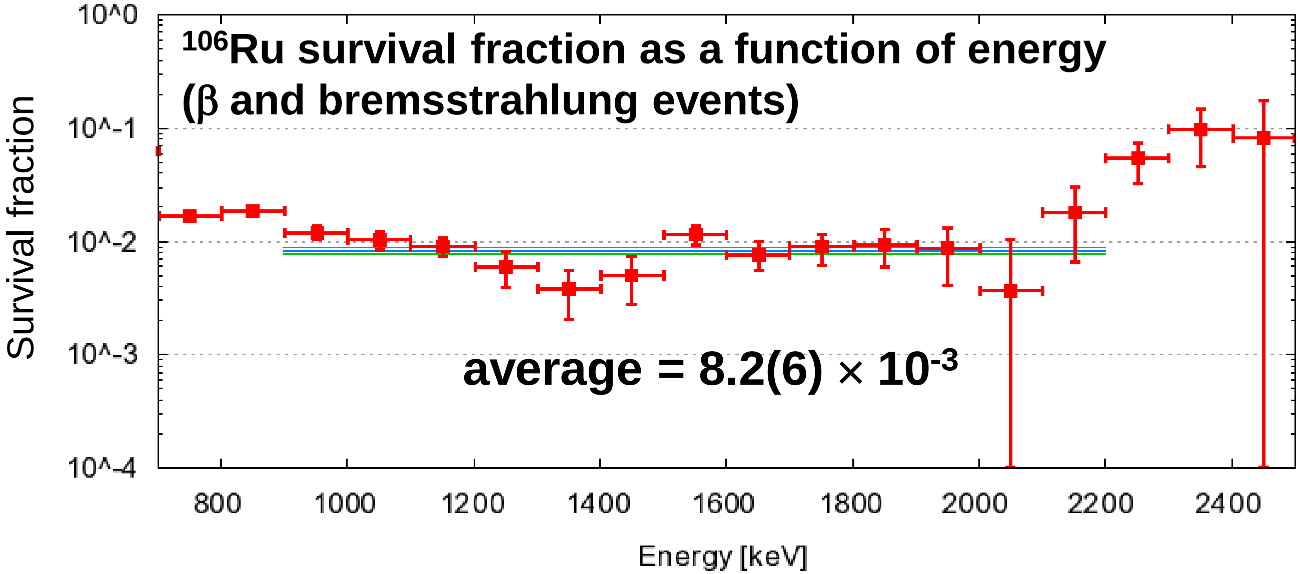
p+ electrode (< μm)

region of p+ contact pulses (PCP) occurrence

movable collimator

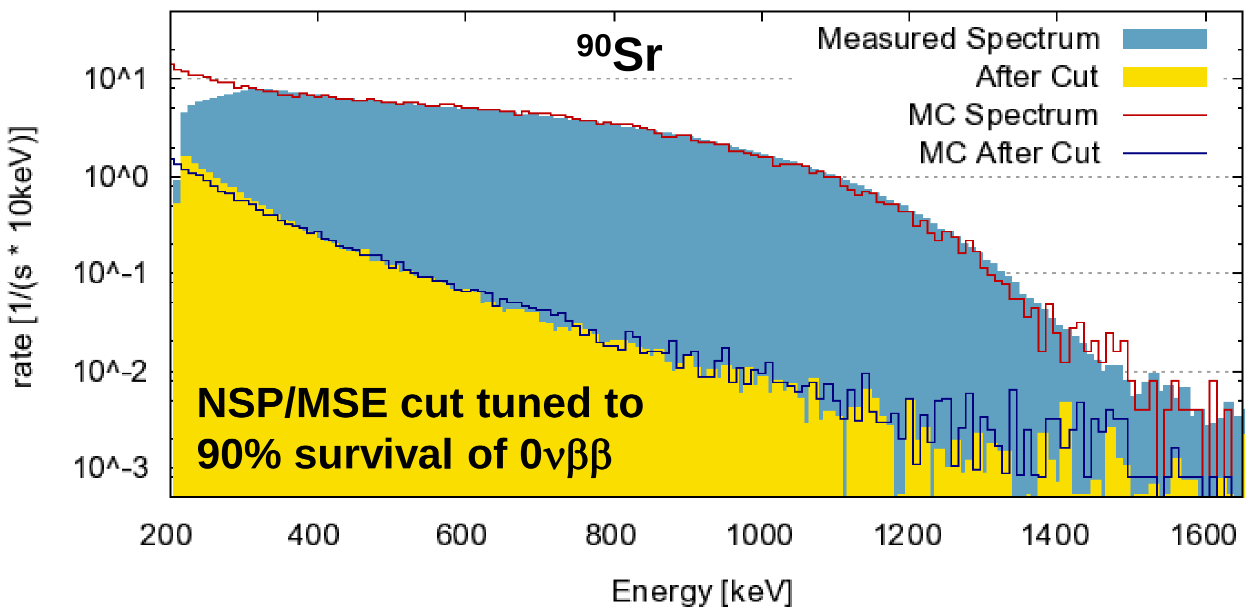
Scanning of p+ contact with ^{241}Am α source

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

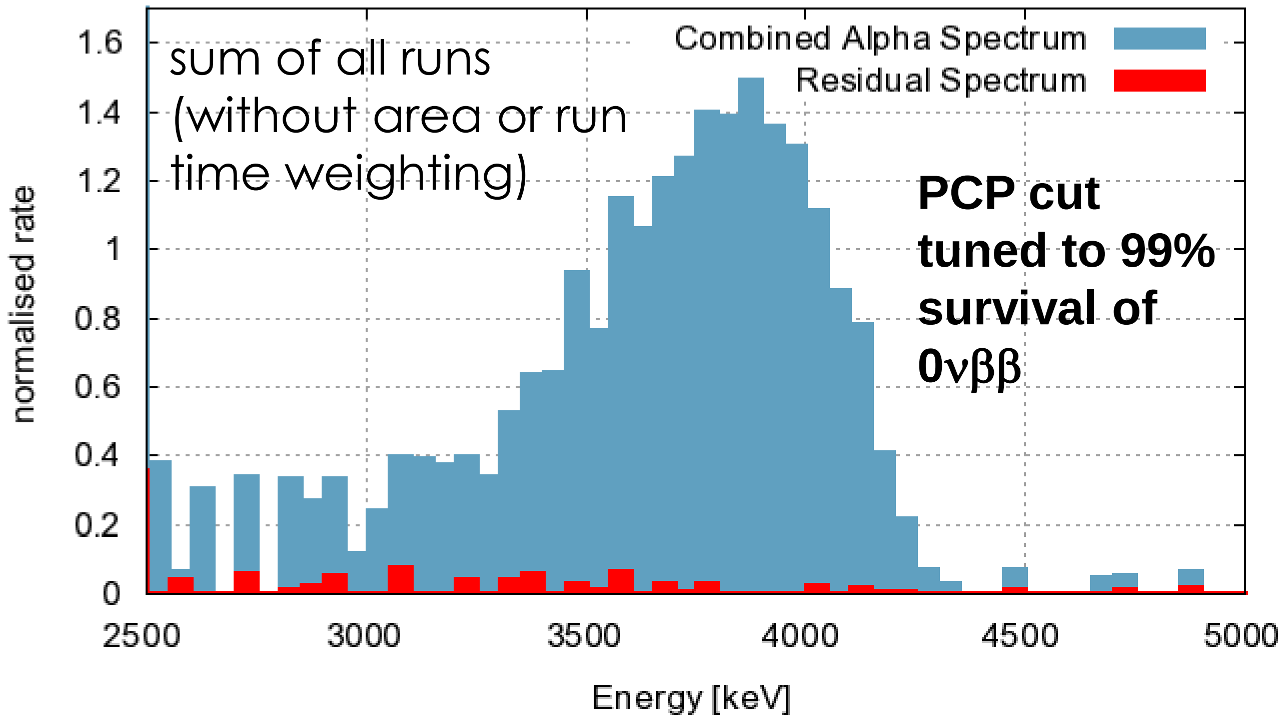
NSP/MSE cut tuned to 90% survival of 0νββ



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

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

Phase II background summary: $Q_{\beta\beta}$

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

background	without cuts [cts/(keV·kg·yr)]	PSD survival	LAr veto survival	after cuts [cts/(keV·kg·yr)]
^{208}Tl	≤ 0.01	0.4	$4 \cdot 10^{-3}$	≤ $1.6 \cdot 10^{-5}$
^{214}Bi	≤ 0.01	0.25	0.3	≤ $7.5 \cdot 10^{-4}$
^{60}Co	≤ $4 \cdot 10^{-4}$	0.01	0.02	≤ $8 \cdot 10^{-8}$
^{60}Co (in Ge)	≤ $4 \cdot 10^{-4}$	0.01	0.02	≤ $8 \cdot 10^{-8}$
^{68}Ga (in Ge)	≤ 0.015	0.05	0.2	≤ $3 \cdot 10^{-5}$
^{226}Ra (α on p+)	≤ $1.5 \cdot 10^{-3}$	< 0.03	–	< $3 \cdot 10^{-5}$
^{42}K (β on n+)	~0.2	< 0.05	0.68	< $0.86 \cdot 10^{-3}$

PSD and veto combined acceptance of $0\nu\beta\beta$-decay events is ~86%