CDEX-1A Data Analysis

- CDEX-1A Experimental Setup
- Data Analysis
- Summary & Prospect

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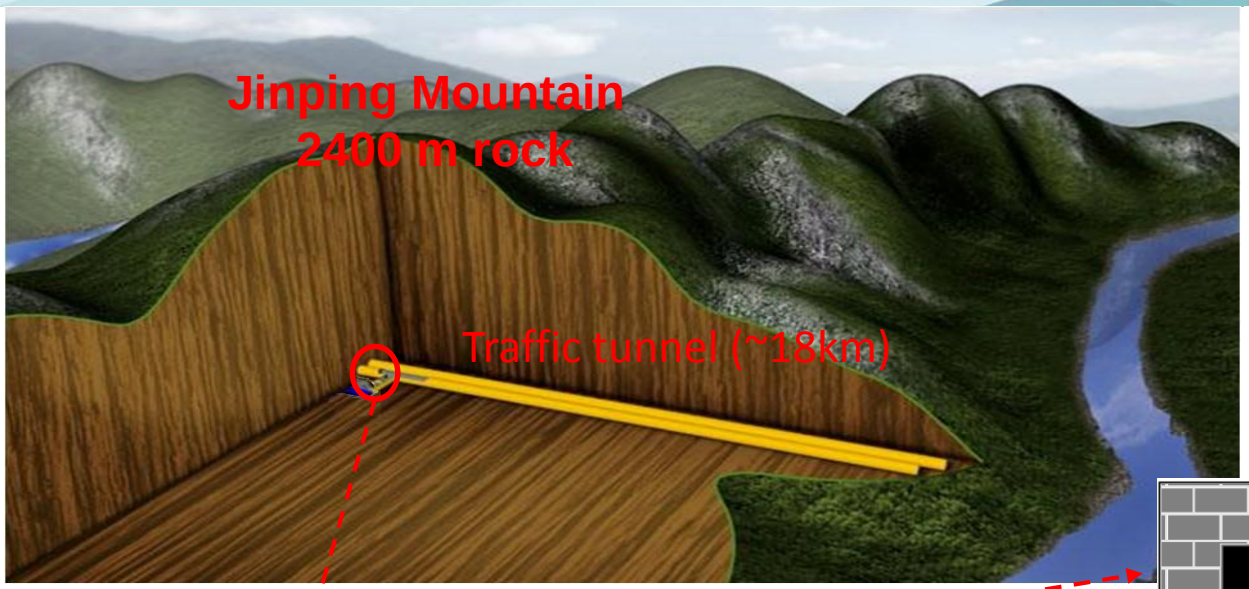
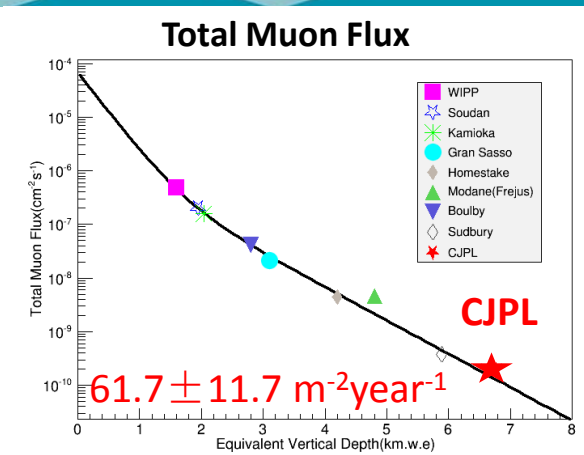
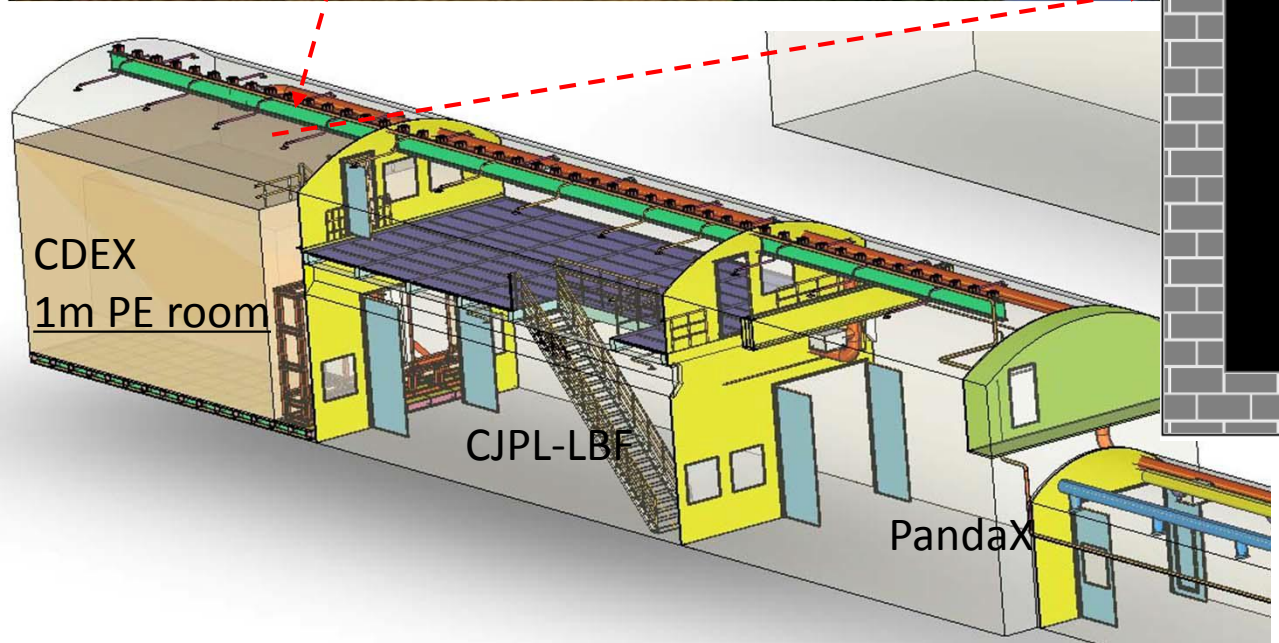
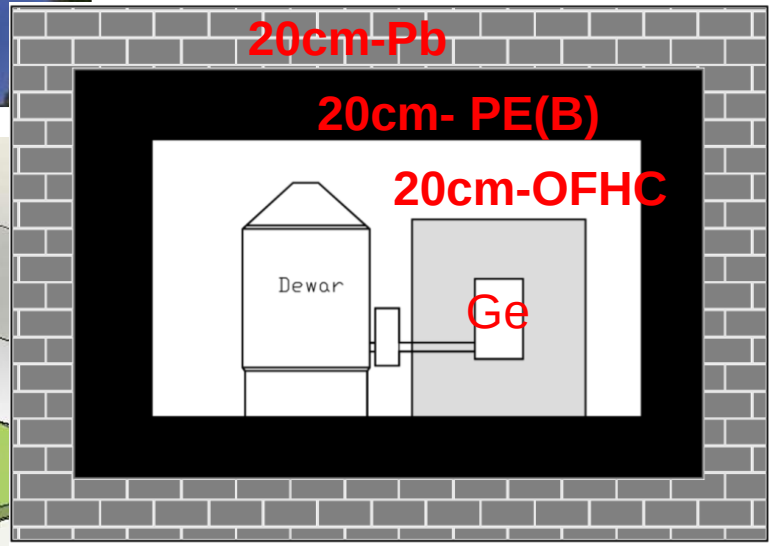
Experimental Setup: Shielding









K. J. Kang et al., Chin. Phys. C 37, 126002 (2013)
Y. C. Wu et al., Chin. Phys. C 37, 086001 (2013)

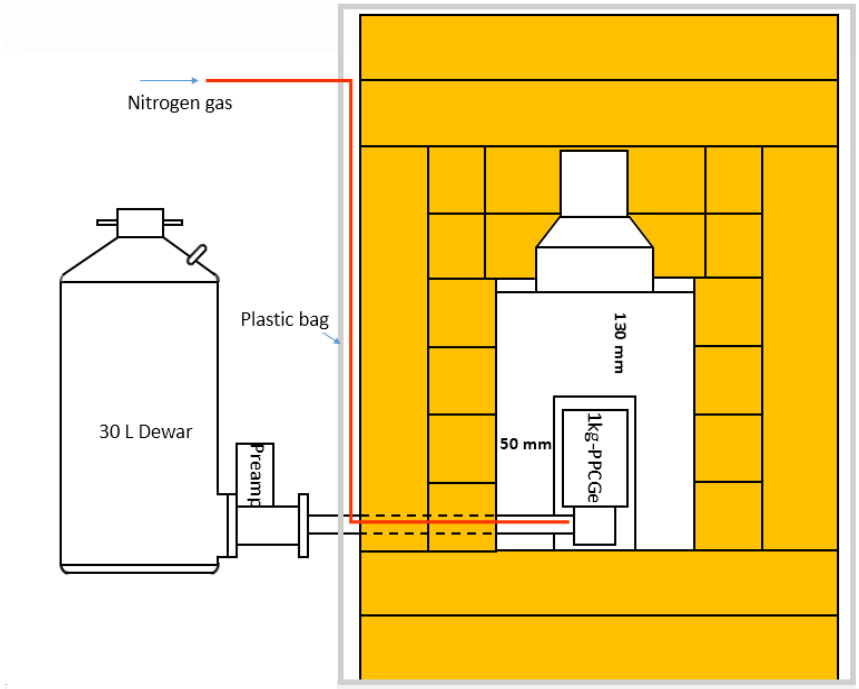
Experimental Setup: Detectors

1. HPGe technology

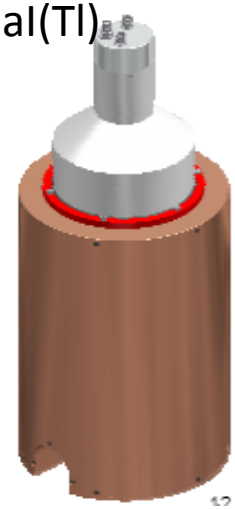
- 1kg-scale p-type point-contact Ge detector (1kg-PPCGe)
  Large-mass "prototype" (994 g)
  Low energy threshold (< 500 eVee)

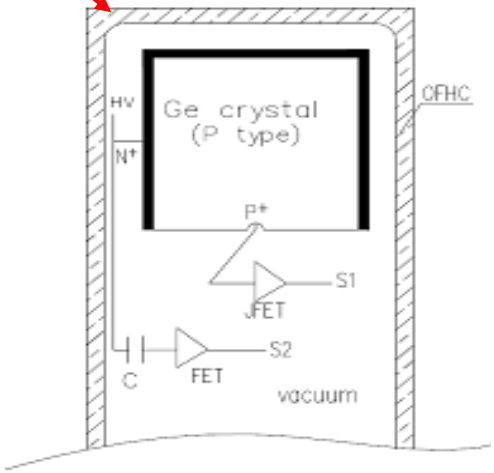
2. Active shielding technology

- NaI(Tl) used as anti-Compton detector
  low energy threshold (~ 10 keV)
  "bucket"-like: enclosed the cryostat of PPCGe



NaI(Tl)

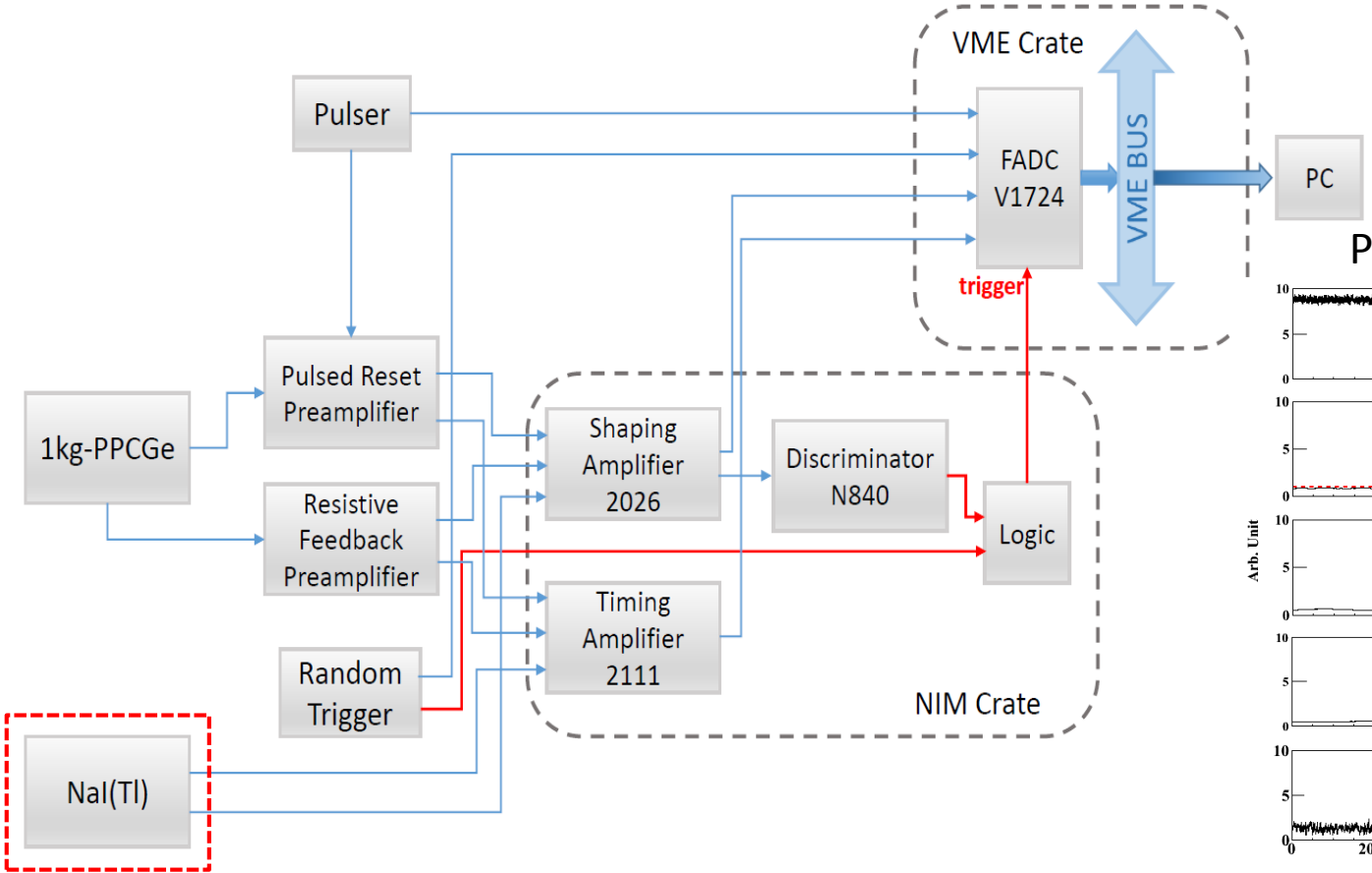




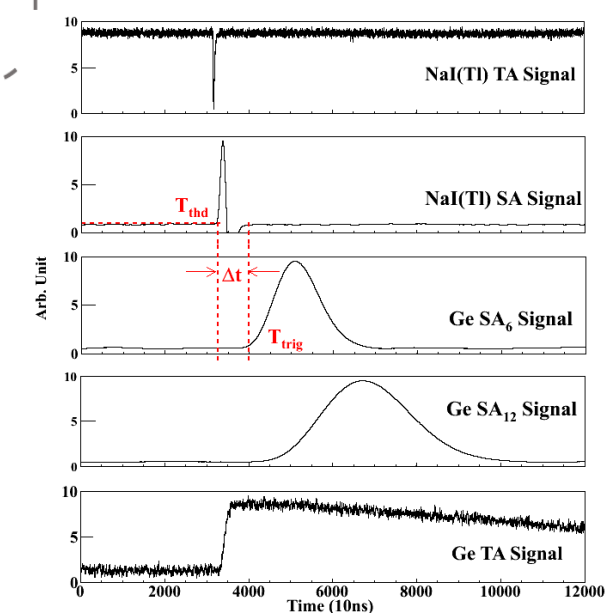
Experimental Setup: DAQ

Would NaI-AC detector introduce more background or suppress background?

- phase I: 1kg-PPCGe *Aug. – Sep., 2012*
- phase II: 1kg-PPCGe + NaI(Tl) *Aug.2013 - now*



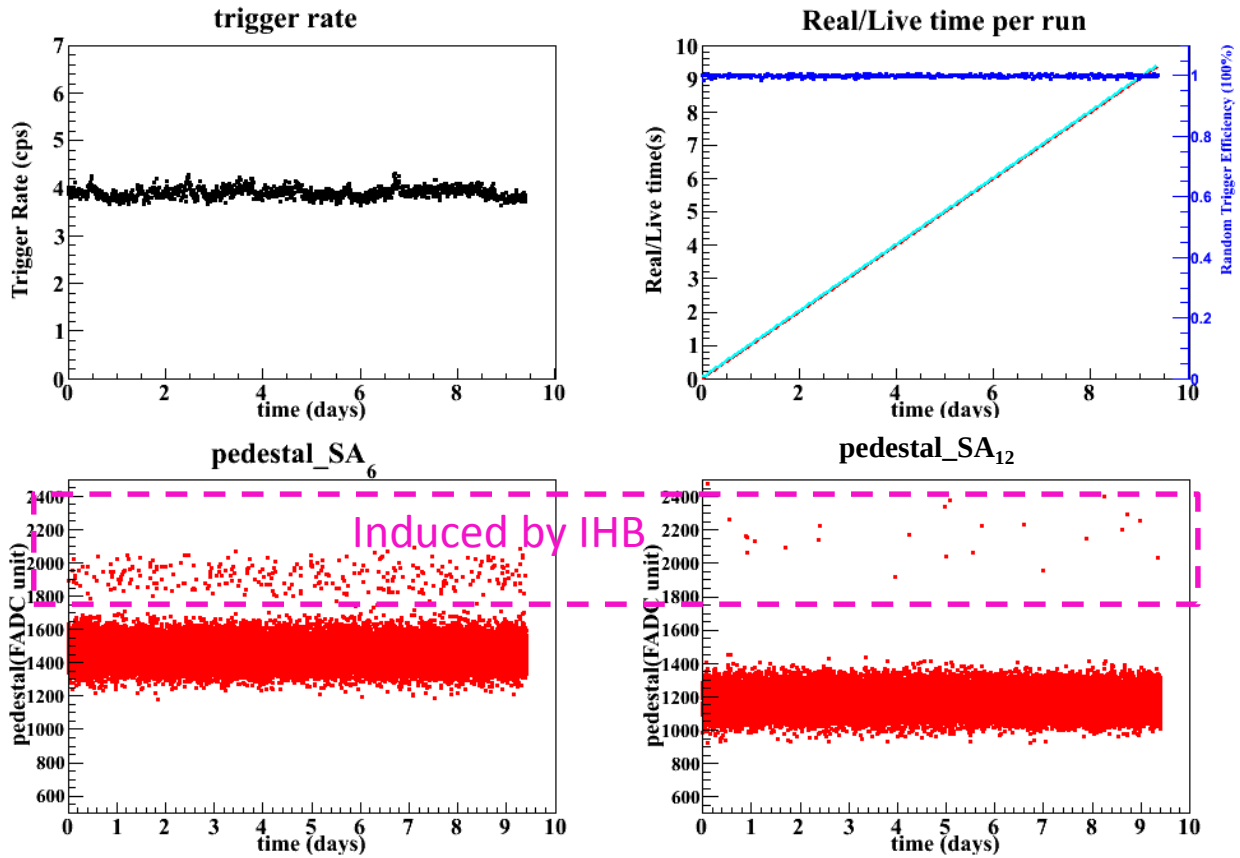
Pulses from Phase II



Data Analysis: Data Quality Monitoring

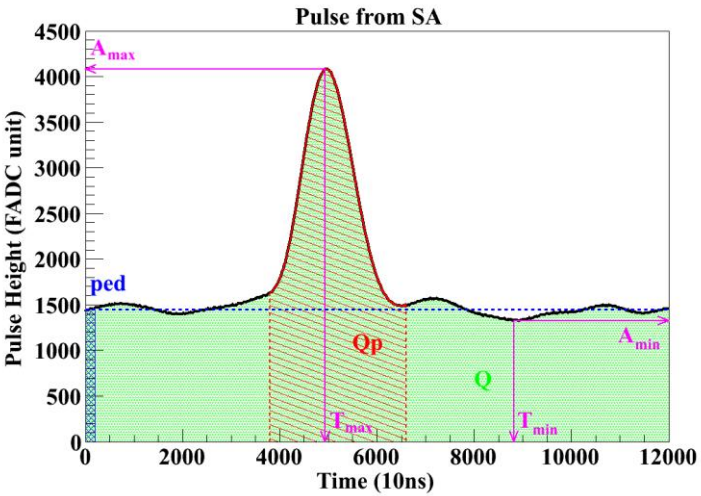
Step 1:
Check data quality of the datasets:

- Trigger rate
- Trigger efficiency
- Ratio of Real time to live time
- Noise level→ dispersion of the baselines of $SA_{6,12}$

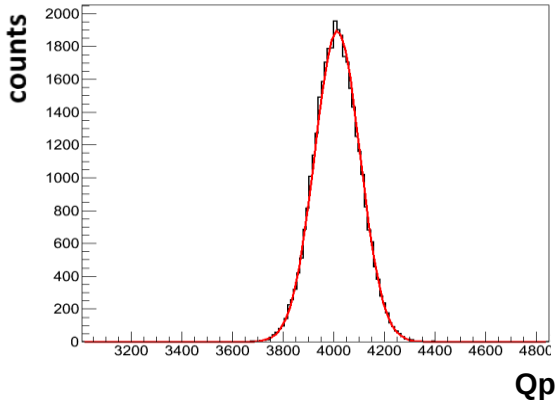


Data Analysis: Energy Calibration

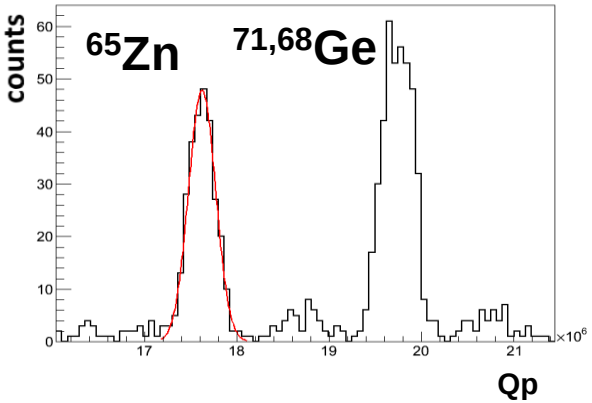
Step 2: energy calibration → Q_p of SA_6



random trigger : 0

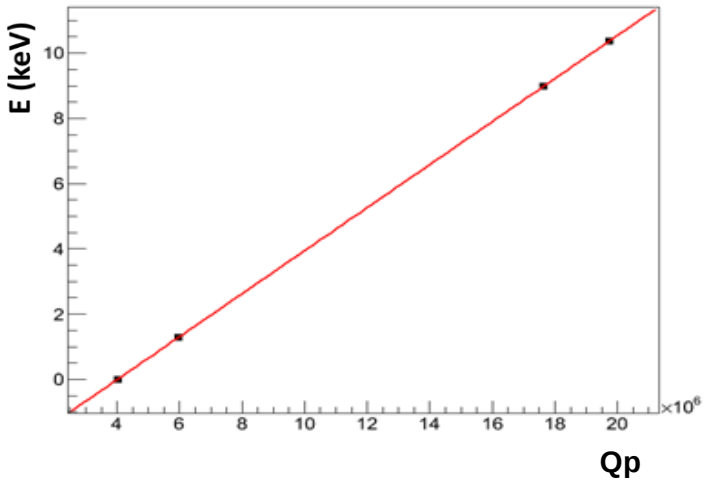


cosmogenic nuclides: X-rays

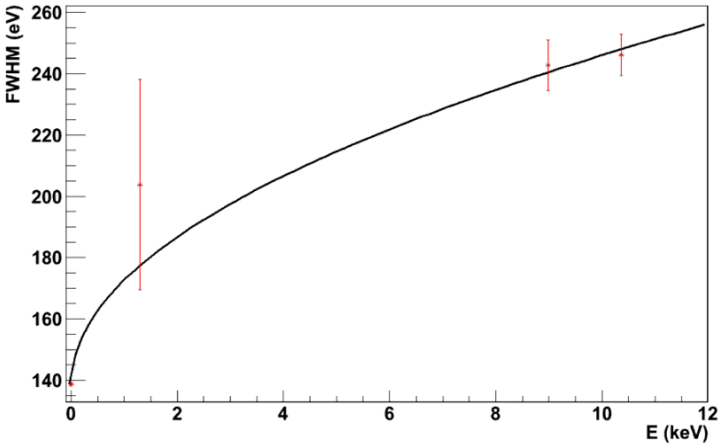


X-ray	Energy (keV)
RT	0
^{68,71}Ge	1.2977(LX)
^{65}Zn	8.98(KX)
^{68,71}Ge	10.37(KX)

Energy calibration



Energy resolution



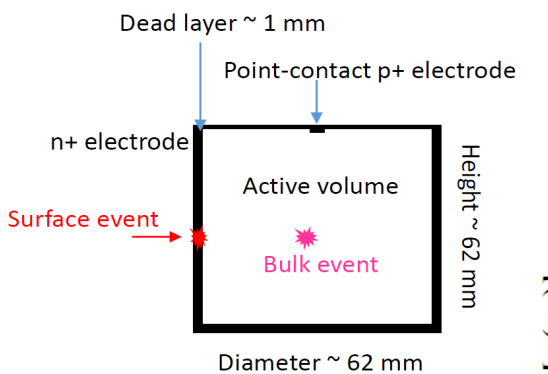
Data Analysis: Data Selection

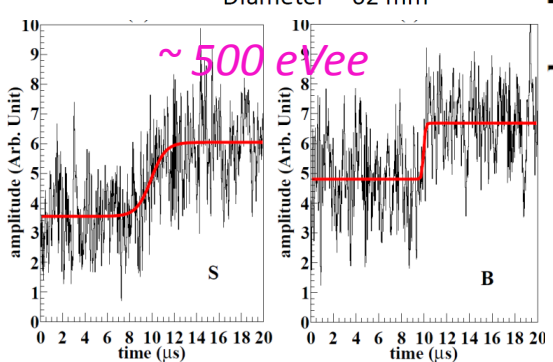
Step 3: data selection to find out WIMPs candidates

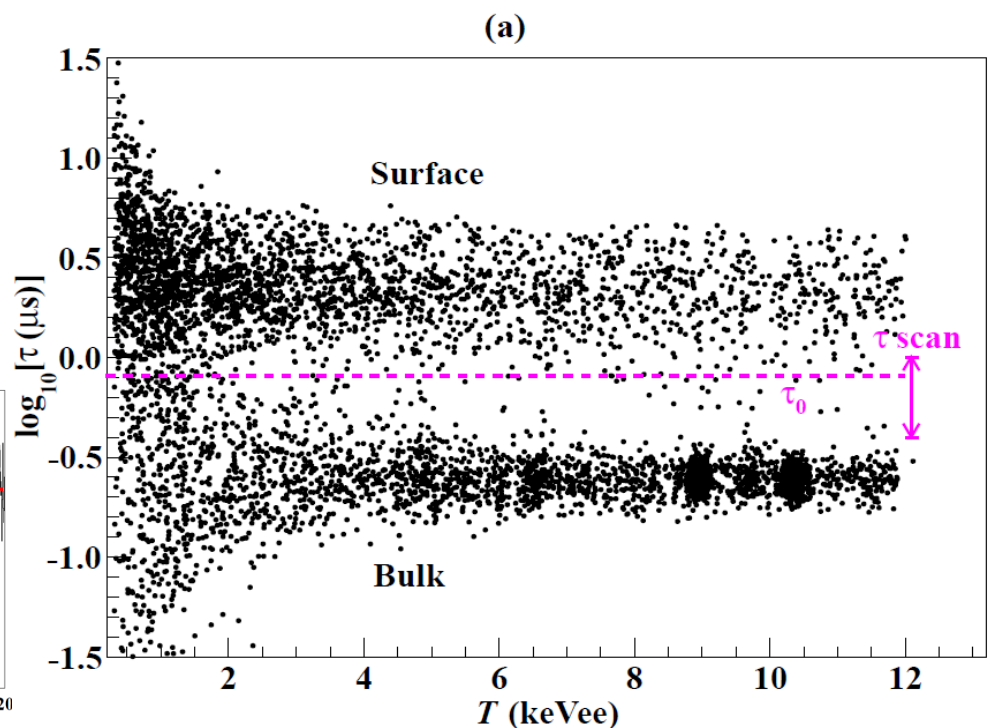
- Basic Cuts: physical events ***vs*** electronic noise & spurious signals
  - *(i) timing information: TT Cut*
  - *(ii) pulse shape: energy-independent & energy-dependent Cuts*

Ped Cut *PSD Cut*

- AC Cut: AC^- ***vs*** AC^+ (Compton scattering) events
- BS Cut: Bulk/Surface events discrimination







Data Analysis: Efficiency Corrections

Step 4: correct the efficiencies to get real spectrum

- ✓ Trigger efficiency:

  Source or background or pulser-simulation events

  ~ 100% @ T>320 eVee;

- ✓ Energy-independent selection:

  TT, Ped, AC Cuts: Random Trigger events (T=0)

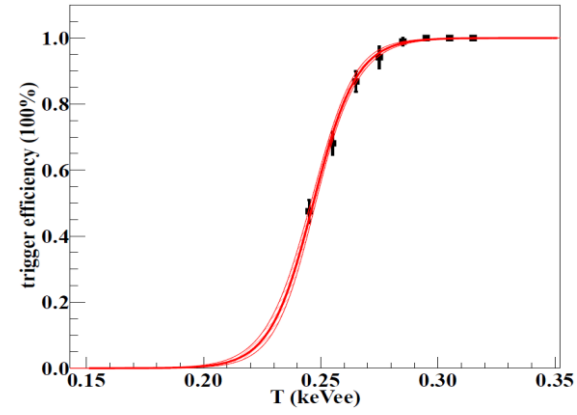
- ✓ Energy-dependent selection: PSD Cut

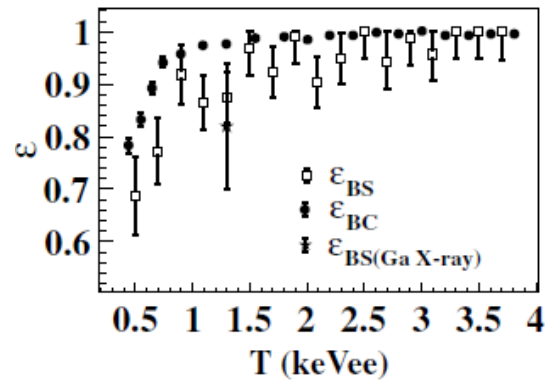
  Source AC⁺ events (ε = F(T))

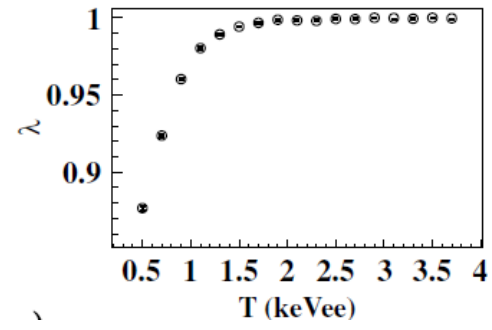
- ✓ Energy-dependent selection – B/S Cut

  surface richer: ^{241}Am(60keV),^{57}Co(122keV),

  bulk richer: ^{137}Cs(662keV), ^{60}Co(1173,1332)



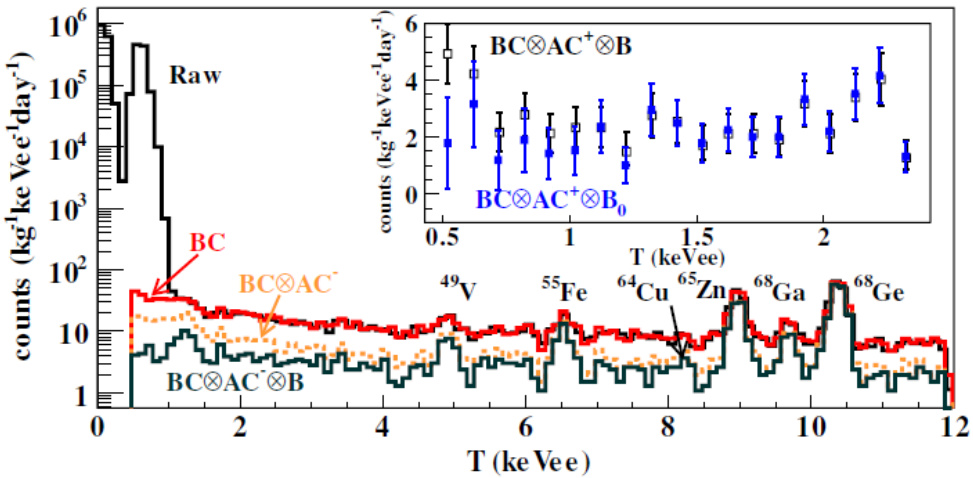




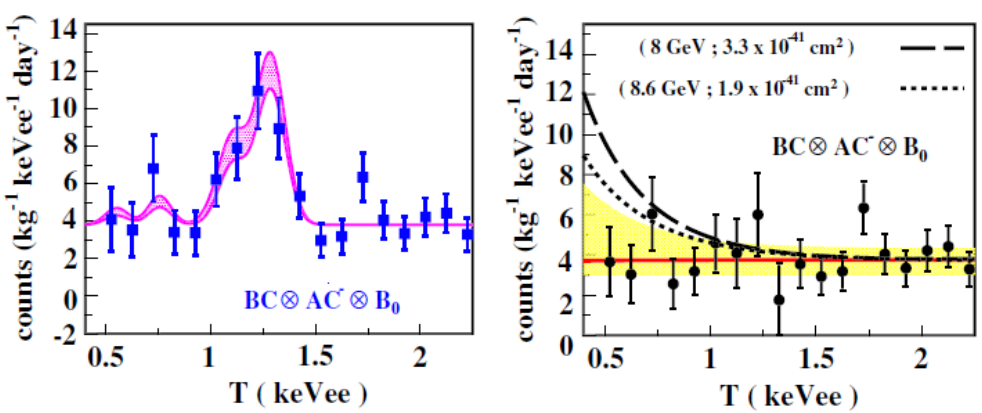
Q. Yue et al., Phys. Rev. D 90, 091701(R) (2014)

Data Analysis: Limits on WIMPs

Step 5: subtract known backgrounds and set limits on WIMPs

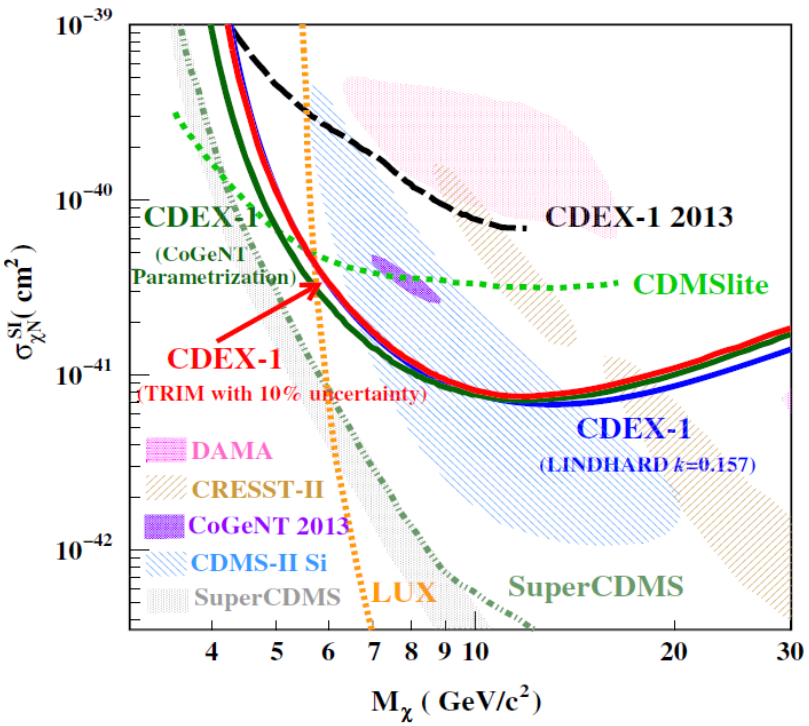


(a)



(b)

- Dataset: 53.9 kg.day
- Backgrounds @ ROI (0.5-2.3 keVee)
  - ✓ *Internal L-shell x-rays; (K-shell x-rays)*
  - ✓ *High energy gamma background*



Q. Yue et al., Phys. Rev. D 90, 091701(R) (2014)

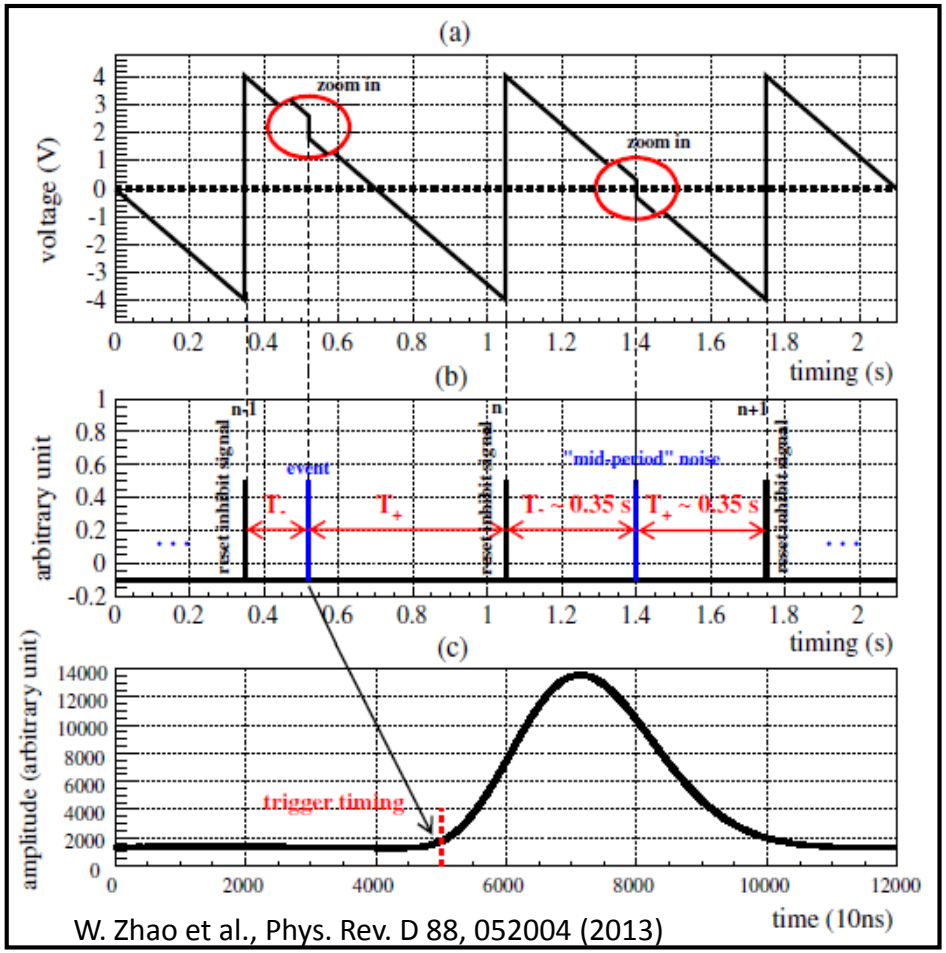
Summary & Prospect

- Improve an order of magnitude in the sensitivities compare to CDEX-1 2013;
- Part of the allowed regions at WIMP mass of 6 - 20 GeV are probed and excluded;
- Accumulated more than 1 kg.year data, deeply understanding background sources is on-going and "annual modulation" of this dataset is processing.

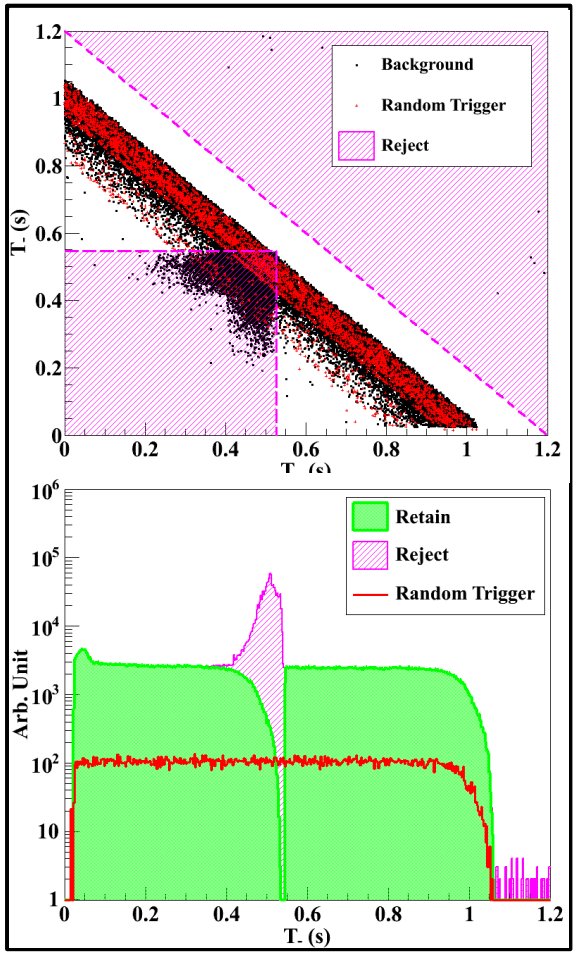
Thank you / 谢谢 !

Appendix I: Cuts

- Basic Cuts: physical events ***vs*** electronic noise & spurious signals
  - (i) timing information: TT Cut
  - (ii) pulse shape: energy-independent & energy-dependent Cuts



W. Zhao et al., Phys. Rev. D 88, 052004 (2013)



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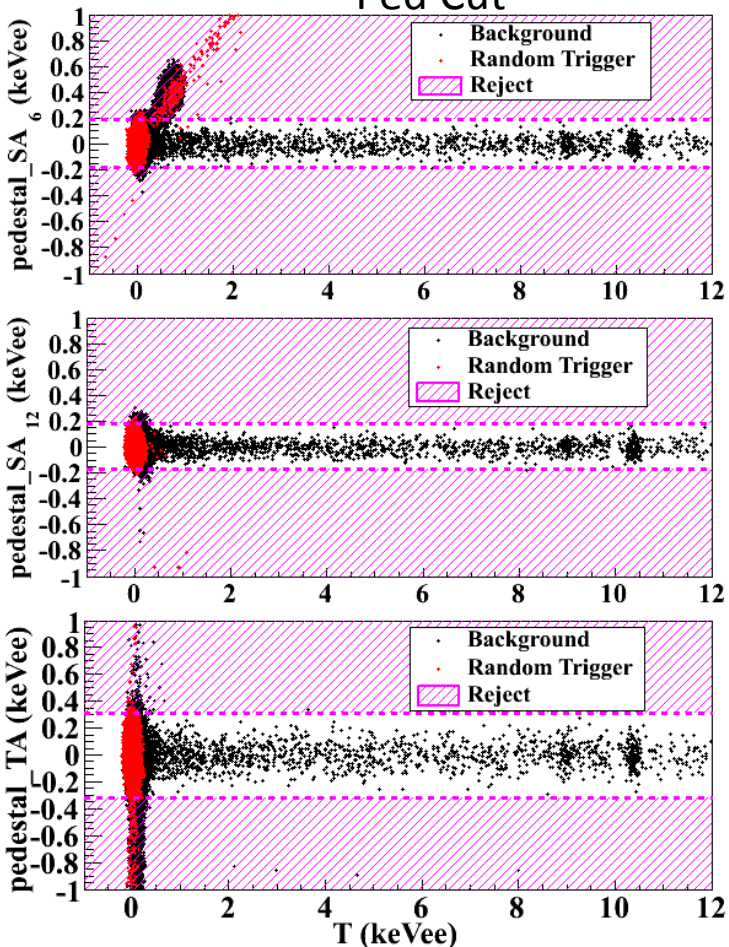
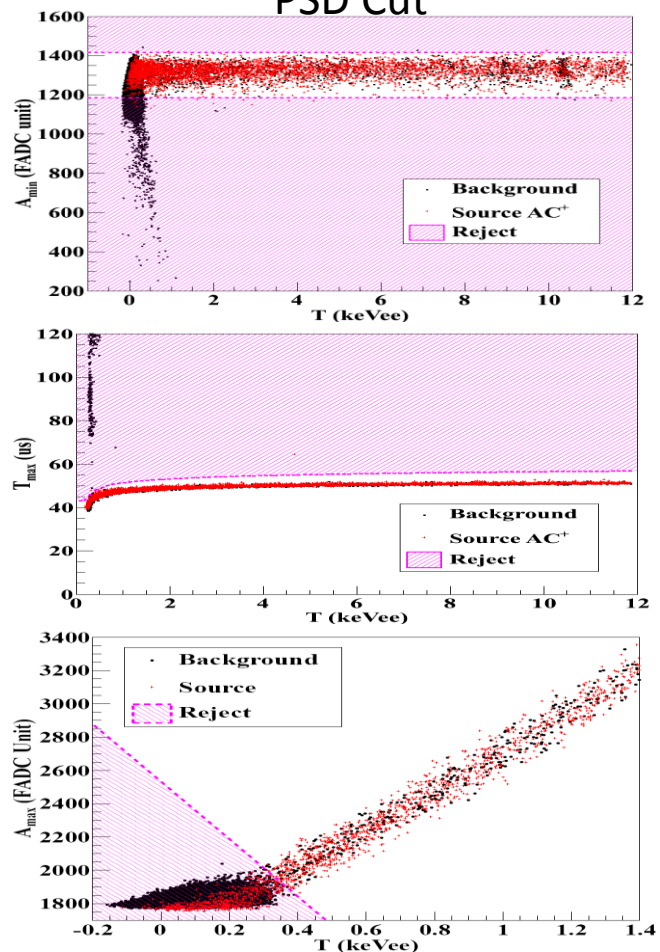
Ped Cut

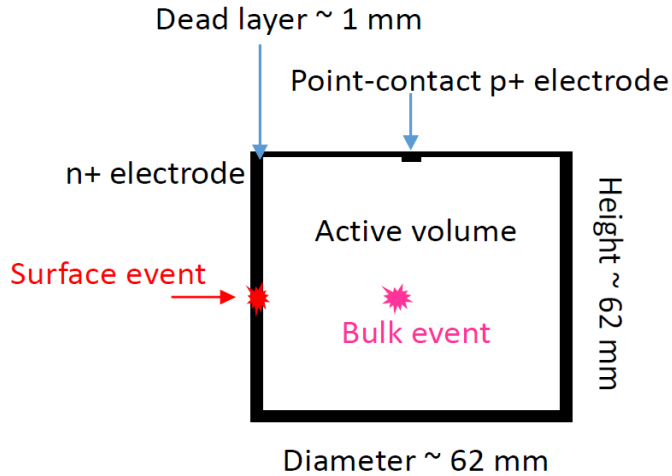


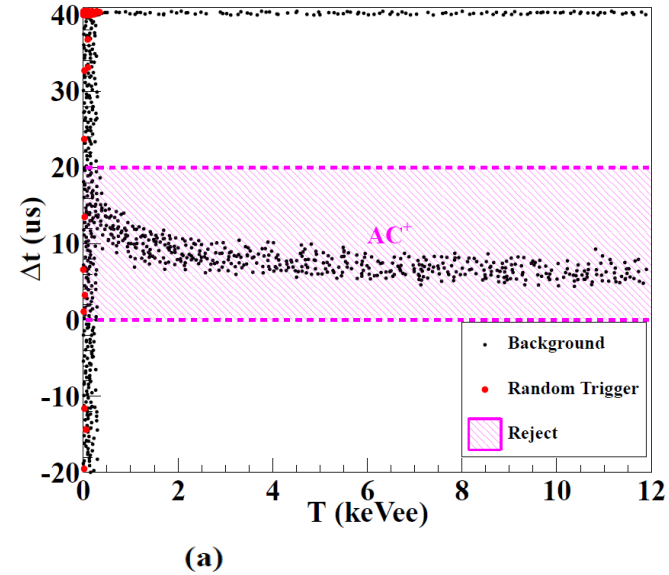
PSD Cut

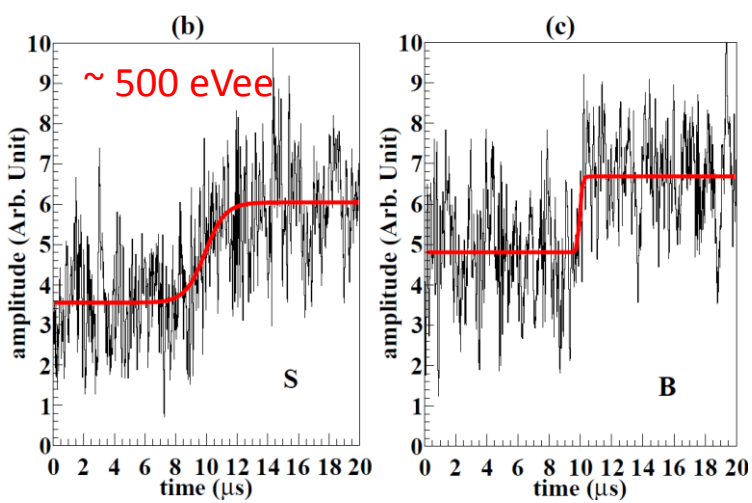


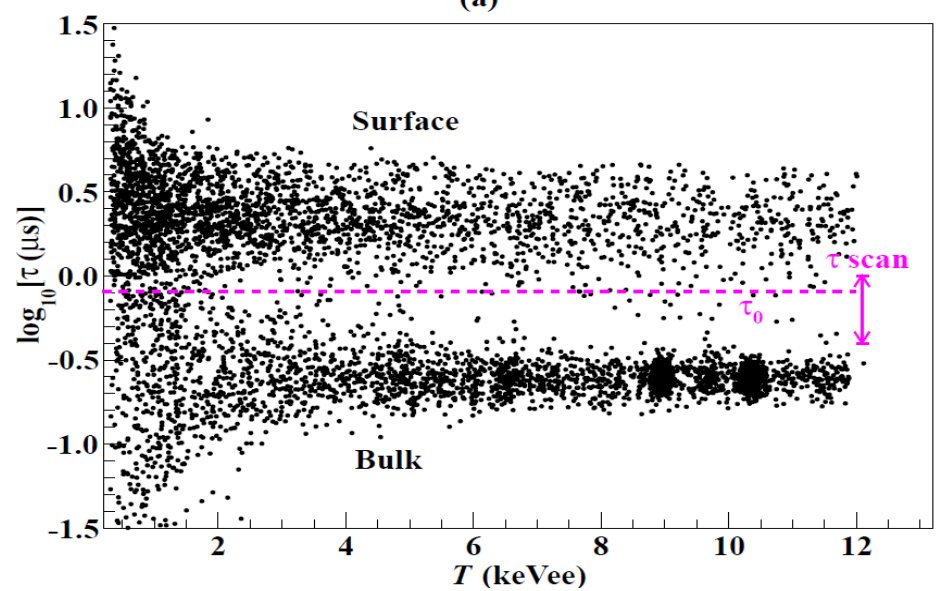
Appendix I: Cuts

- AC Cut: AC^- ***vs*** AC^+ (Compton scattering) events
- BS Cut: Bulk/Surface events discrimination









Appendix II: B/S efficiency

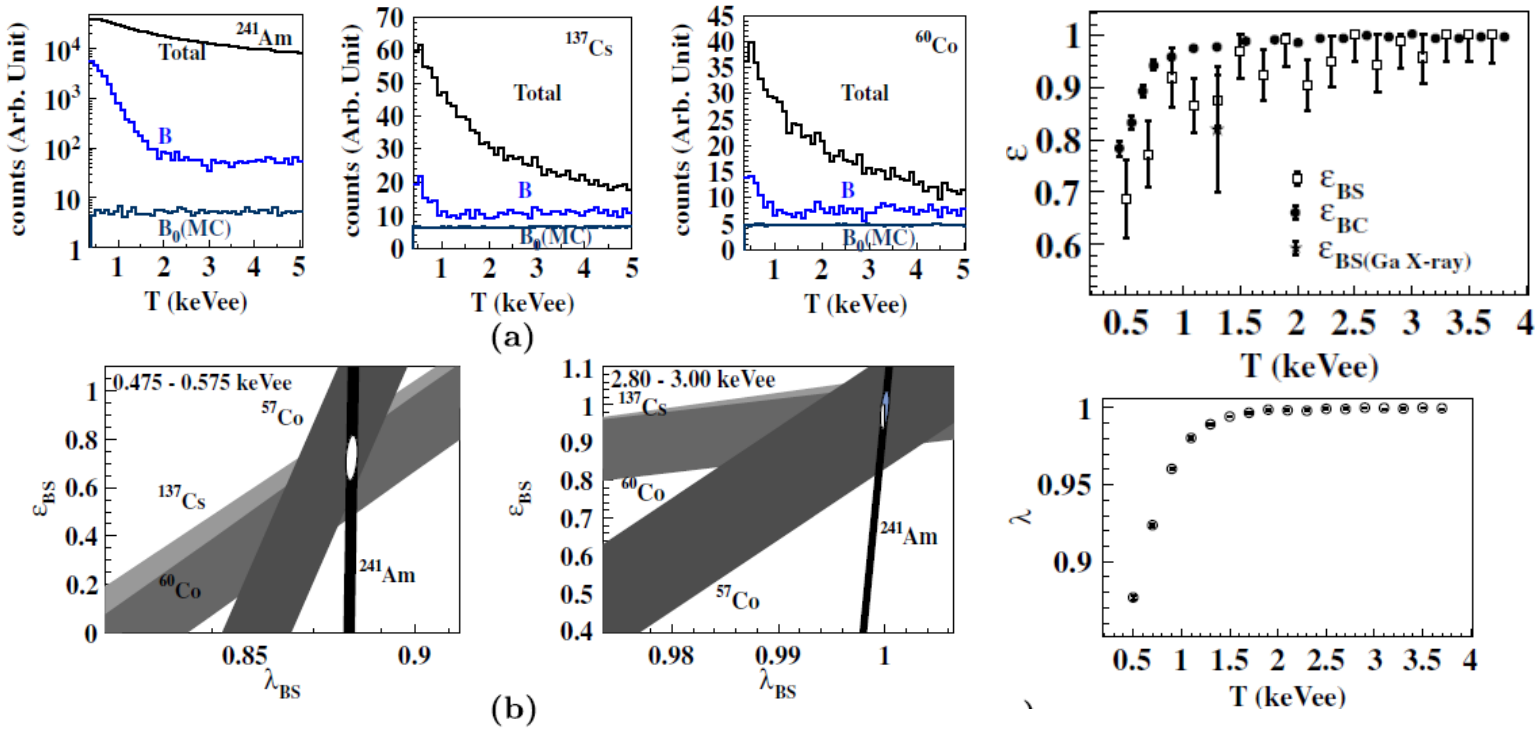
(1). B/S selection efficiency (ε_{BS}, λ_{BS})

$$B = \varepsilon_{BS} \cdot B_0 + (1 - \lambda_{BS}) \cdot S_0$$
$$S = (1 - \varepsilon_{BS}) \cdot B_0 + \lambda_{BS} \cdot S_0.$$

$$B_0 = \frac{\lambda_{BS}}{\epsilon_{BS} + \lambda_{BS} - 1} \cdot B + \frac{\lambda_{BS} - 1}{\epsilon_{BS} + \lambda_{BS} - 1} \cdot S$$
$$S_0 = \frac{\epsilon_{BS} - 1}{\epsilon_{BS} + \lambda_{BS} - 1} \cdot B + \frac{\epsilon_{BS}}{\epsilon_{BS} + \lambda_{BS} - 1} \cdot S.$$

calibrated by various gamma sources:

^{241}Am(59.5 keV), ^{57}Co(122keV), ^{137}Cs(662keV), ^{60}Co(1173keV, 1132keV)



Appendix II: B/S efficiency

(2). (ε_{BS}, λ_{BS}) induced systematic uncertainties:

TABLE I. The various contributions to the total error of $AC^- \otimes B_0$ at threshold and at a typical high energy bin.

Energy bin	0.475–0.575 keVee	1.975–2.075 keVee
$AC^- \otimes B_0$ and errors (kg^{-1} $keVee^{-1}$ day^{-1})	$4.09 \pm 1.47[stat] \pm 0.87[sys] = 4.09 \pm 1.71$	$4.22 \pm 0.97[stat] \pm 0.27[sys] = 4.22 \pm 1.01$
(I) Statistical uncertainties (combined):	1.47	0.97
(i) Uncertainties on calibration $(\varepsilon_{BS}, \lambda_{BS})$:	0.32	0.08
(ii) Derivation of $(\varepsilon_{BS}, \lambda_{BS})$-corrected bulk rates:	1.43	0.97
(II) Systematic uncertainties (combined):	0.87	0.27
(i) Rise-time cut value τ_0	0.27	0.12
(ii) Fiducial mass	0.05	0.05
(iii) Normalization range (3–5 keVee)	0.07	0.01
(iv) $(B_0, S_0) = (B, S)$ at normalization	0.10	0.10
(v) Choice of discard region	0.30	0.06
(vi) Source location	0.28	0.19
(vii) Source energy range and spectra	0.72	0.12

Appendix III

Quenching Factor (QF)