PICO-LON dark matter search project

Ken-Ichi Fushimi

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科研費
KAKENHI

PICO-LON Collaboration

- Tokushima University
  - K.Fushimi, G.Kanzaki, R.Orito
- Osaka University
  - H.Ejiri, T.Shima, S.Umehara, S.Yoshida
- Osaka Sangyo University
  - R.Hazama
- Kavli IPMU Tokyo University (WPI)
  - A.Kozlov, Y.Takemoto
- Tohoku University
  - K.Inoue, H.Ikeda, Y.Teraoka
- I.S.C. Lab.
  - K.Imagawa, K.Yasuda

PICO-LON for WIMPs search

- Pure
- Inorganic
- Crystal
- Observatory for
- LOw-background
- Neutr(al)ino

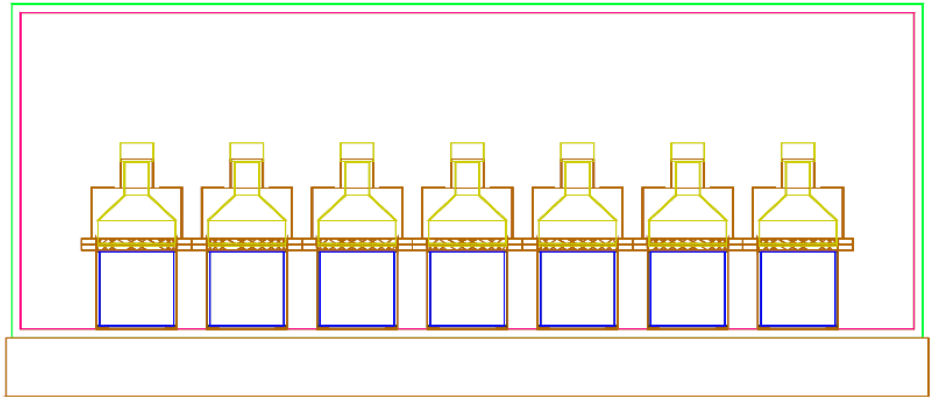
- High selectivity
- Background reduction

- Sensitive to
- Elastic scattering (SI+SD)
- Inelastic scattering (SD)

- Study the interaction type of WIMPs

Outline of PICO-LON project

- Search for dark matter by 250 kg NaI(Tl)
  - Test the annual modulation signal (DAMA/LIBRA)
  - Detection of dark matter candidates
  - 42 modules of 5 inchϕ×5 inch NaI(Tl)
  - Simple detector design



- Present status
  - Performance test of single module
  - Purification of NaI powder
  - Low BG measurement by single module
  - Material selection

NaI(Tl) purification

	DAMA	DM-Ice	Ingot 23 (2013)	Goal of PICO-LON
^{nat}K (ppb)	<20	660	Not yet (<100)	<20
^{232}Th(ppt)	0.5-0.7	2.5	3.3±2.0	<4
^{238}U(ppt)	0.7-10	1.4	5.4±0.9	<10
^{210}Pb (μBq/kg)	5-30	1470	58±26	< 5

- U-chain: 1ppt= 12.3μBq/kg
- Th-chain: 1ppt= 4.0μBq/kg
- ^{210}Pb: 1ppt=2.5kBq/kg

DAMA: NIM A592 (2008) 297.

DM-ICE: Phys. Rev. D90 (2014) 092005.

Purification of NaI powder

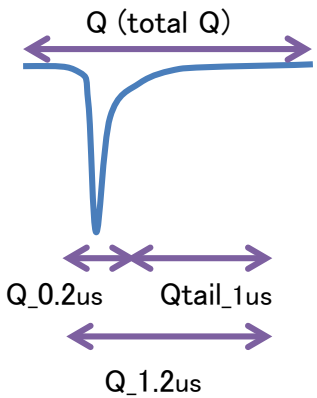
- Purification of NaI powder
  - Selection of cation exchange resin
  - Cation exchange resin for Pb reduction
  - Optimization of purification condition

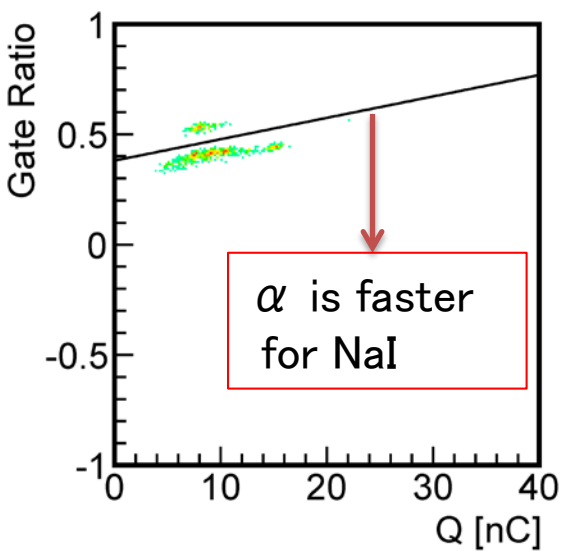
- Low BG measurement
  - Selection of surrounding materials
  - Measurement in Kamioka Underground Laboratory

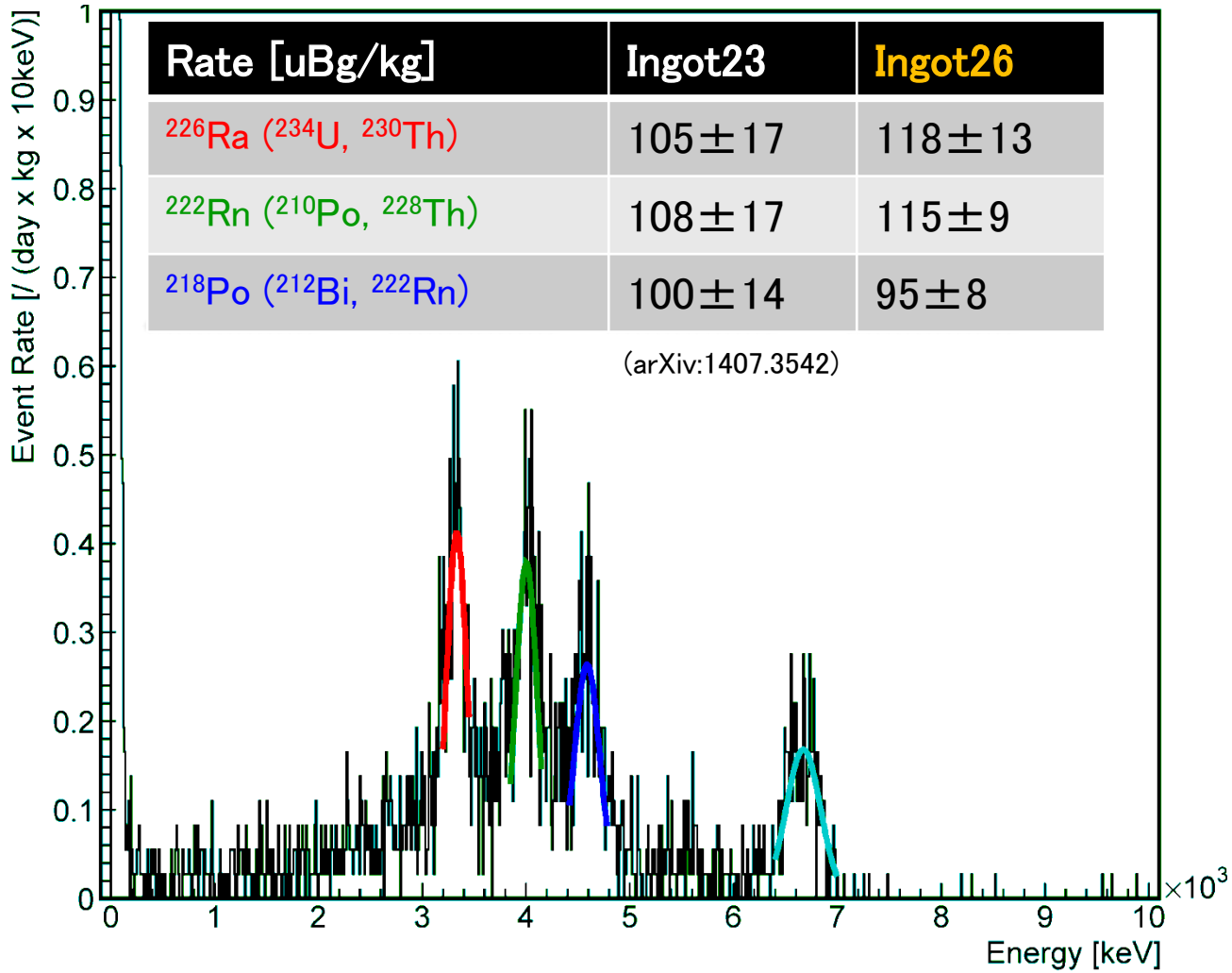
Alpha ray intensity ^{210}Pb was removed!

Double-Gate PSD is applied

Gate Ratio = Qtail_1us /Q_1.2us



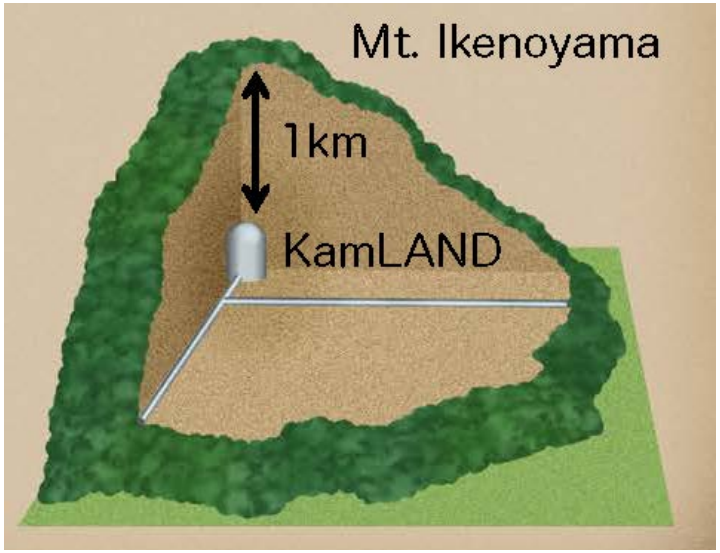


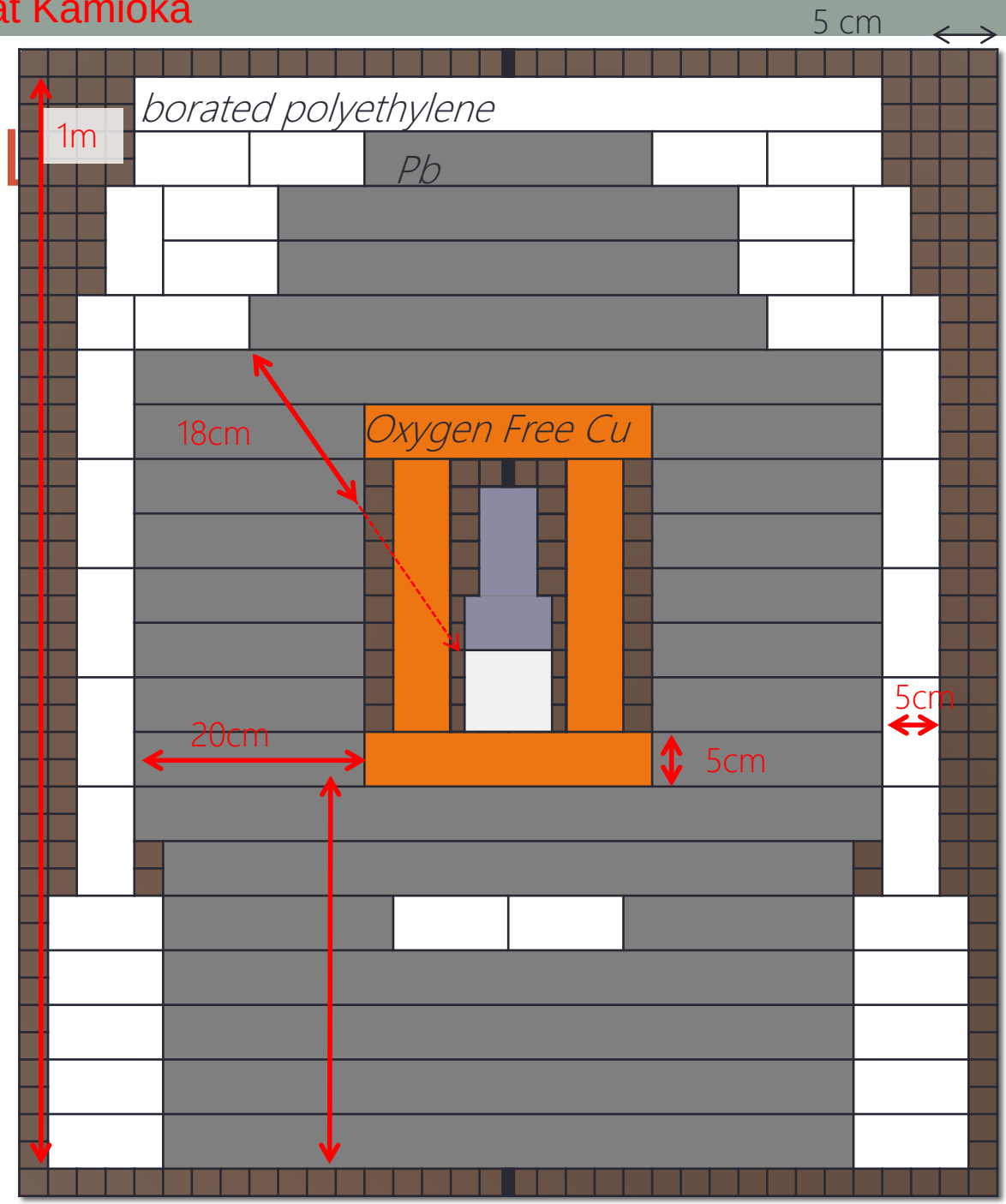


Rate [uBg/kg]	Ingot23	Ingot26
^{226}Ra (^{234}U, ^{230}Th)	105±17	118±13
^{222}Rn (^{210}Po, ^{228}Th)	108±17	115±9
^{218}Po (^{212}Bi, ^{222}Rn)	100±14	95±8

α background rate is consistent to Ingot23.
A reduction method is under investigation.

Low BG measurement at Kamioka

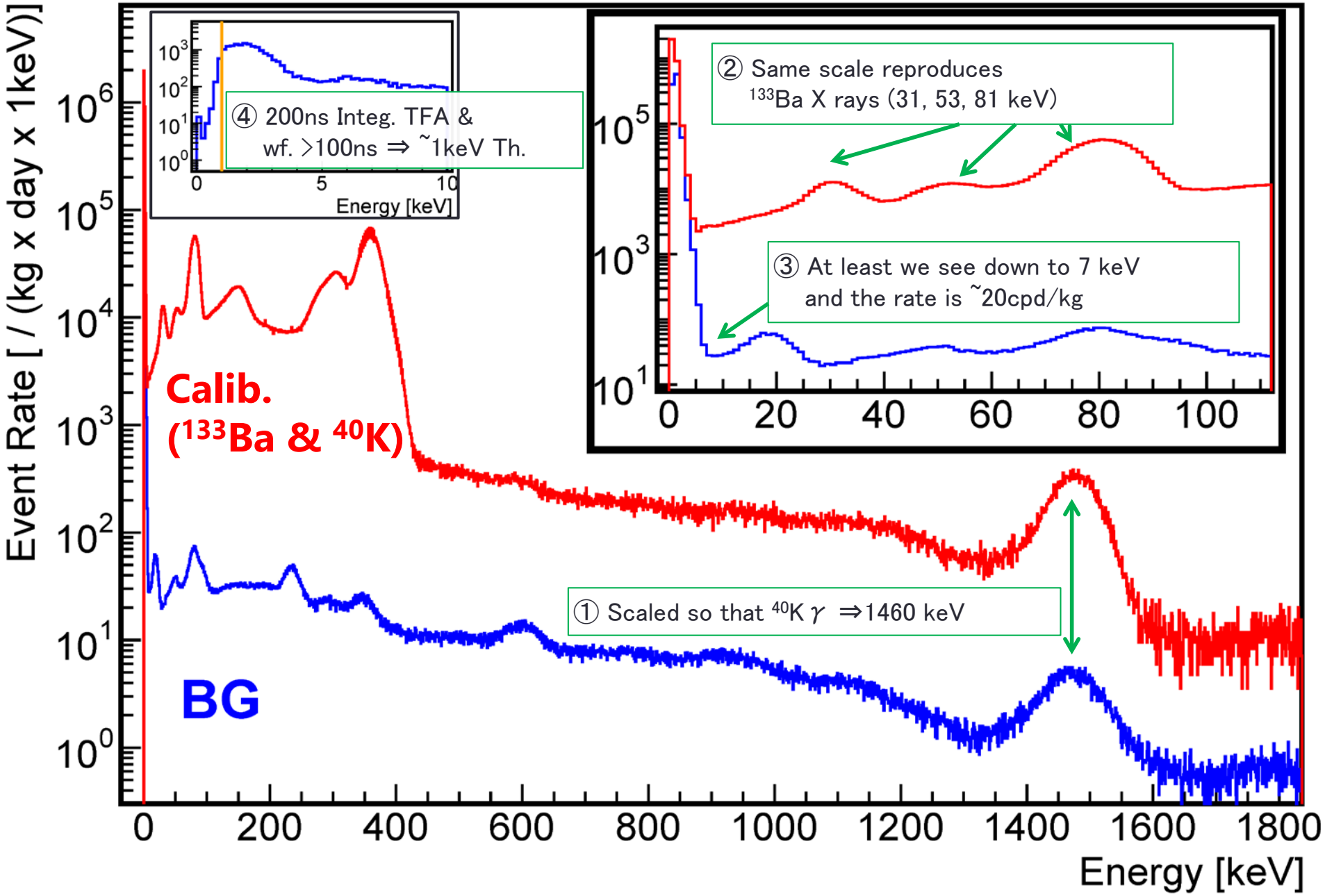




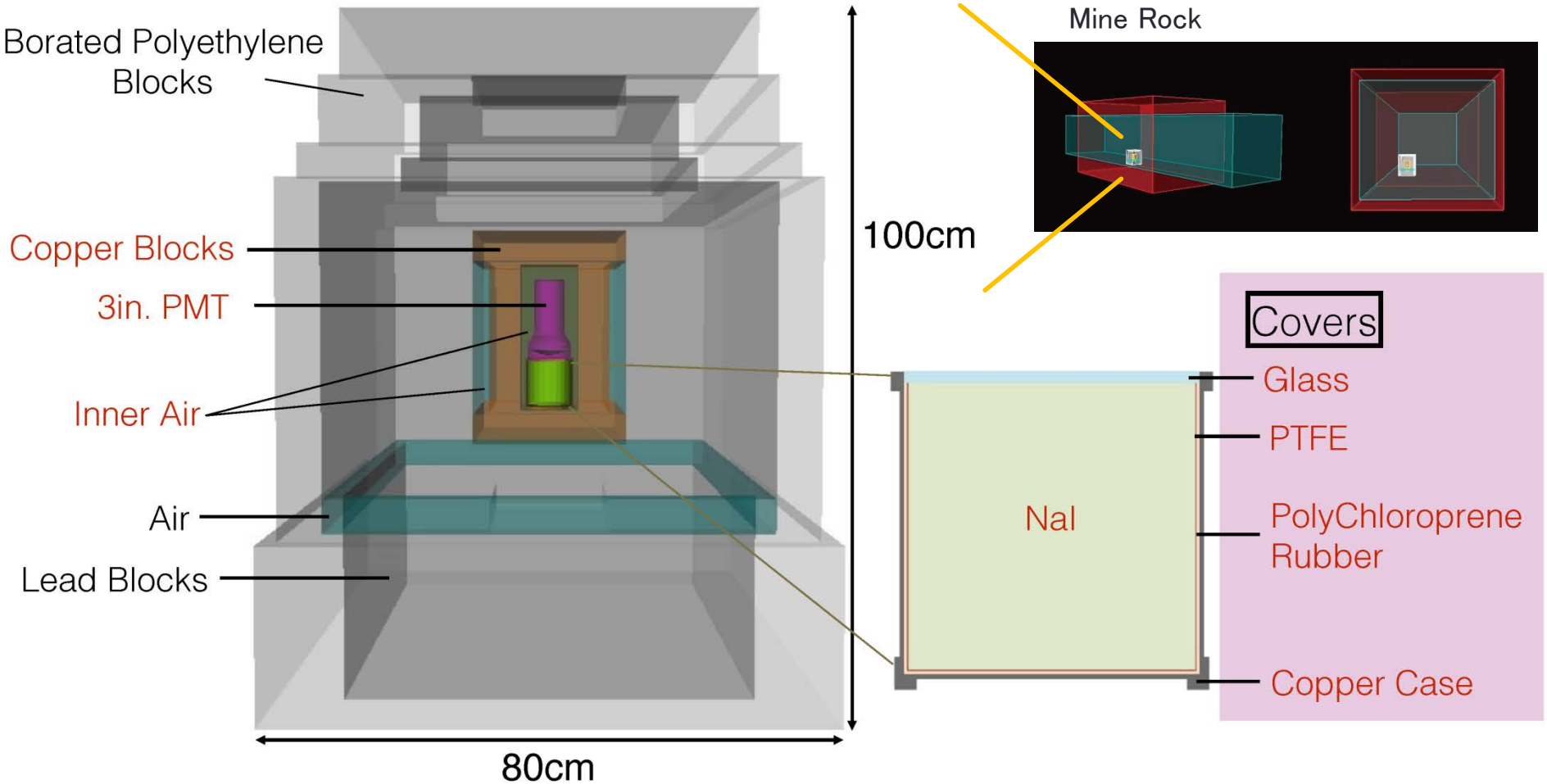
- Shielding
  - 2700m.w.e rock
    - Cosmic ray, 10^{-5}
  - 5cm+ B-PE
    - Neutrons
  - 18cm+ High purity Pb
    - External γ
  - ➢ 5cm+ OFC (8 yr. UG)
    - ➢ γ from Pb
- Rn purge
  - G1 GN2 2l/min in the most inner region

Preliminary result.

~25.2days x1.2kg exposure



Monte Carlo simulation for low BG measurement



For each, 6 chains are simulated.

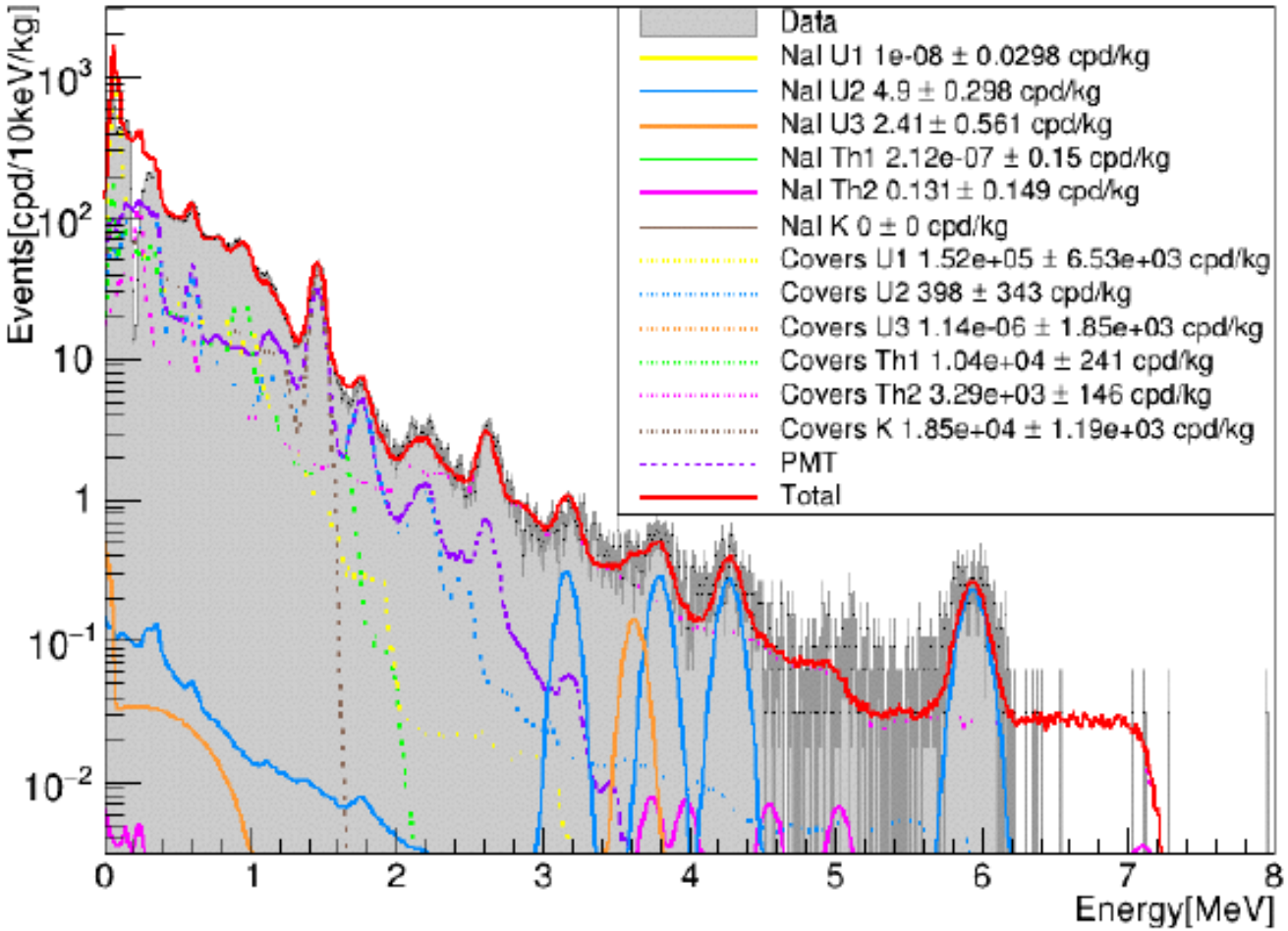
- U1: ^{238}U –^{226}Ra
- U2: ^{226}Ra–^{210}Pb
- U3: ^{210}Pb–^{206}Pb
- Th1: ^{232}Th–^{228}Th
- Th2: ^{228}Th–^{208}Pb
- K : ^{40}K

Known Rate

PMT (Ge)
- K : 819±38 mBq
- U2–3: 23.7±2.8 mBq
- Th2 : 22.8±4.8 mBq

Rock (NaI)
- K : 1.56ppm
- U2–3: 3.13ppm
- Th2 : 5.69ppm

NaI vs Ingot26



Impurities in NaI(Tl) detector

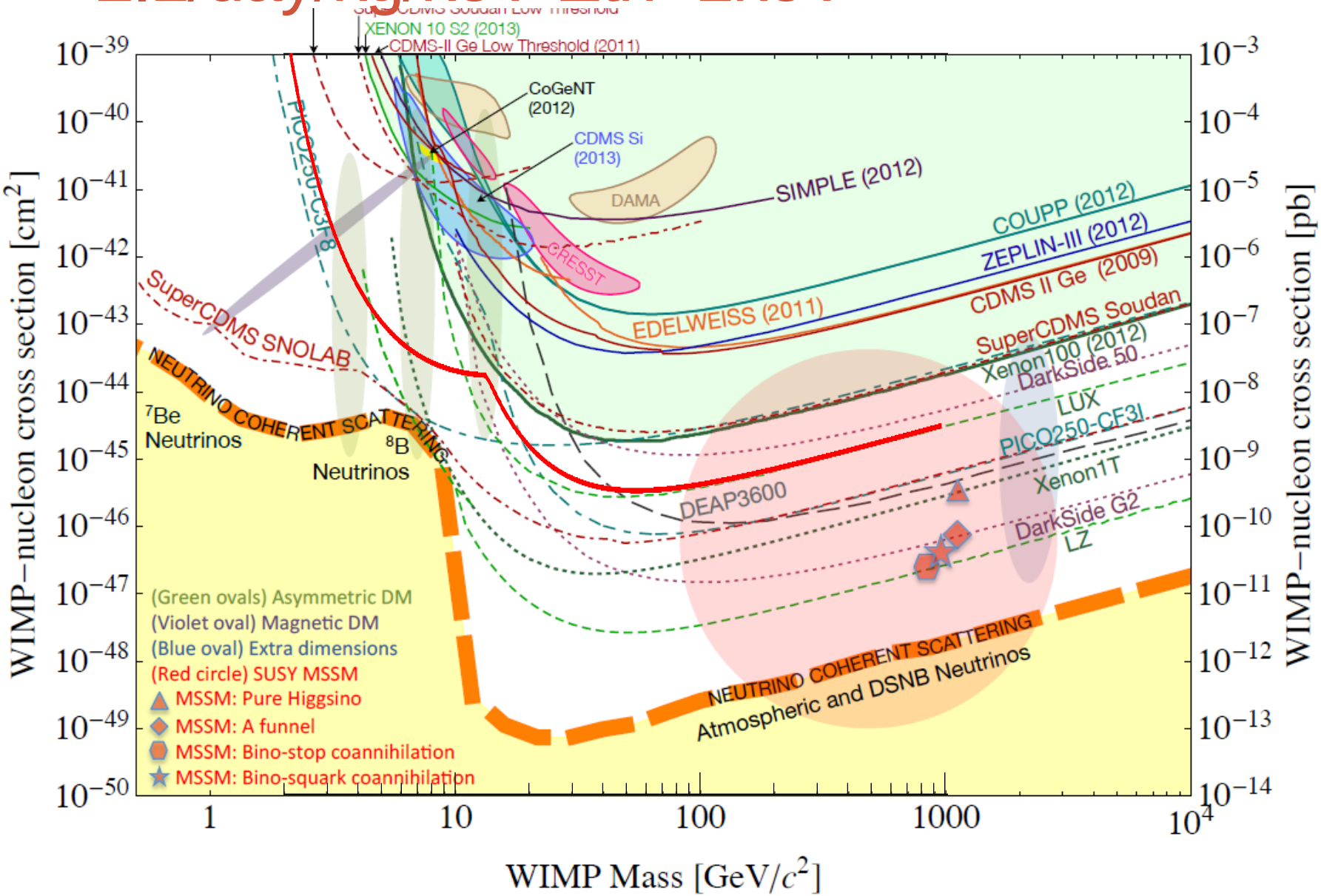
	Best Fit (μBq/kg)	NaI K=0 (μBq/kg)
NaI U2(^{226}Ra)	57.8±3.5	56.8±3.4
NaI U3(^{210}Pb)	29.4±6.6	27.9±6.5
NaI Th2(^{228}Th)	1.46±1.85	1.52±1.72
NaI K	$(1.10\pm0.03)\times10^{5}$	0
Cu case K	$(5.19\pm0.97)\times10^{5}$	$(0.2\pm10.7)\times10^{3}$
Rubber K	0±731	$(2.14\pm0.86)\times10^{5}$
Cover K	5.19×10^{5}	2.14×10^{5}
PMT K	6.42×10^{5}	$(1.78\pm0.043)\times10^{6}$

No significant signal from NaI(Tl) measured by Ge

Summary

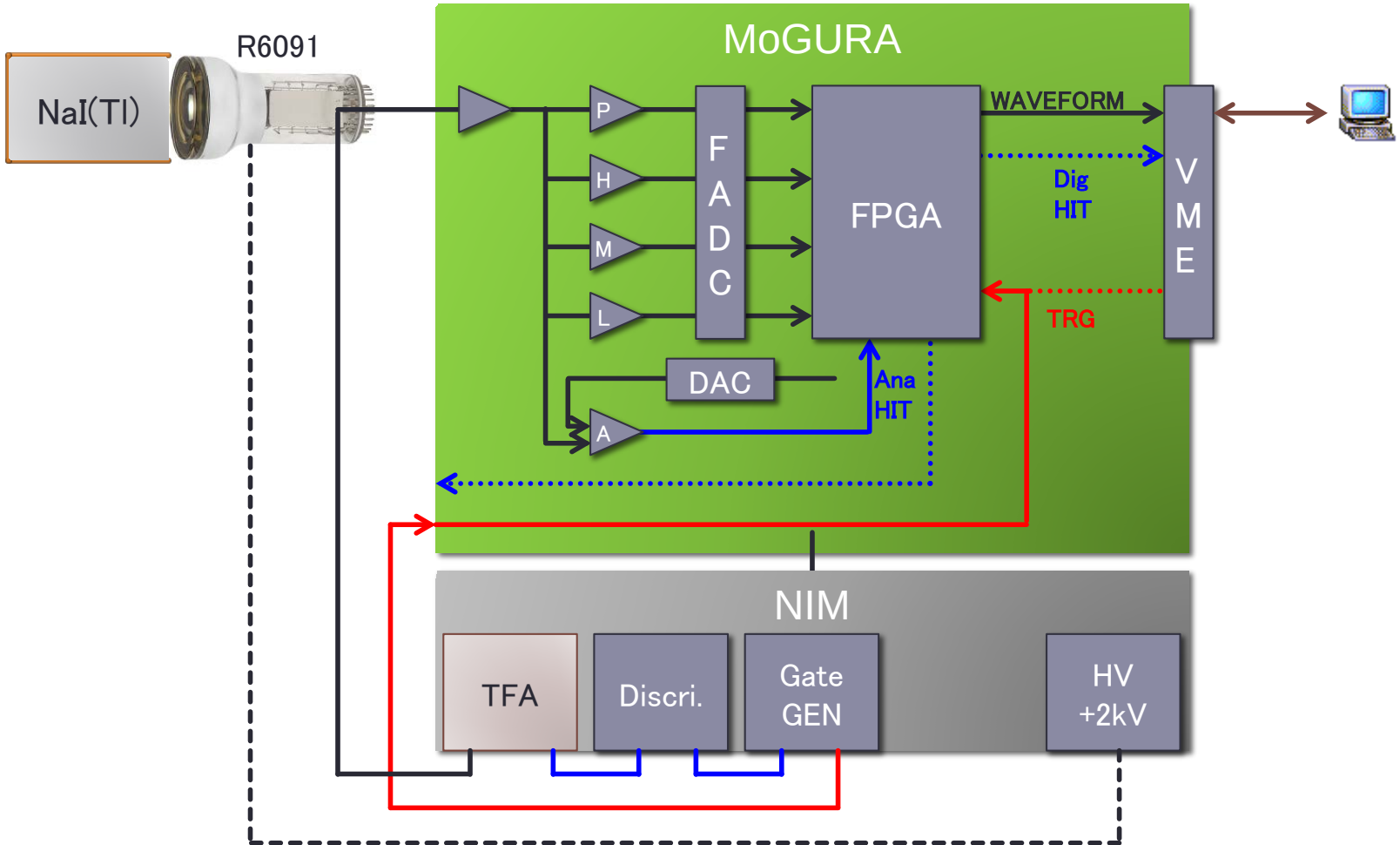
- Reduction of RI impurities in NaI has been achieved
  - To the same level as DAMA/LIBRA
- Low BG test has been performed
  - ~20 /day/keV/kg @ 7 keV_{ee}
  - This background rate is mainly due to PMT and Spacer
  - Refurbished NaI(Tl) is now in Kamioka
- Future
  - Further purification of NaI powder
  - Material selection (In collaboration with XMASS)
  - 5 inchϕ × 5 inch NaI(Tl) (PICO-LON module) in 2016
  - 250 kg NaI(Tl) : 42 modules of PICO-LON

Expected sensitivity (Elastic, 250 kg*yr) 2.1/day/kg/keV Eth=1keV

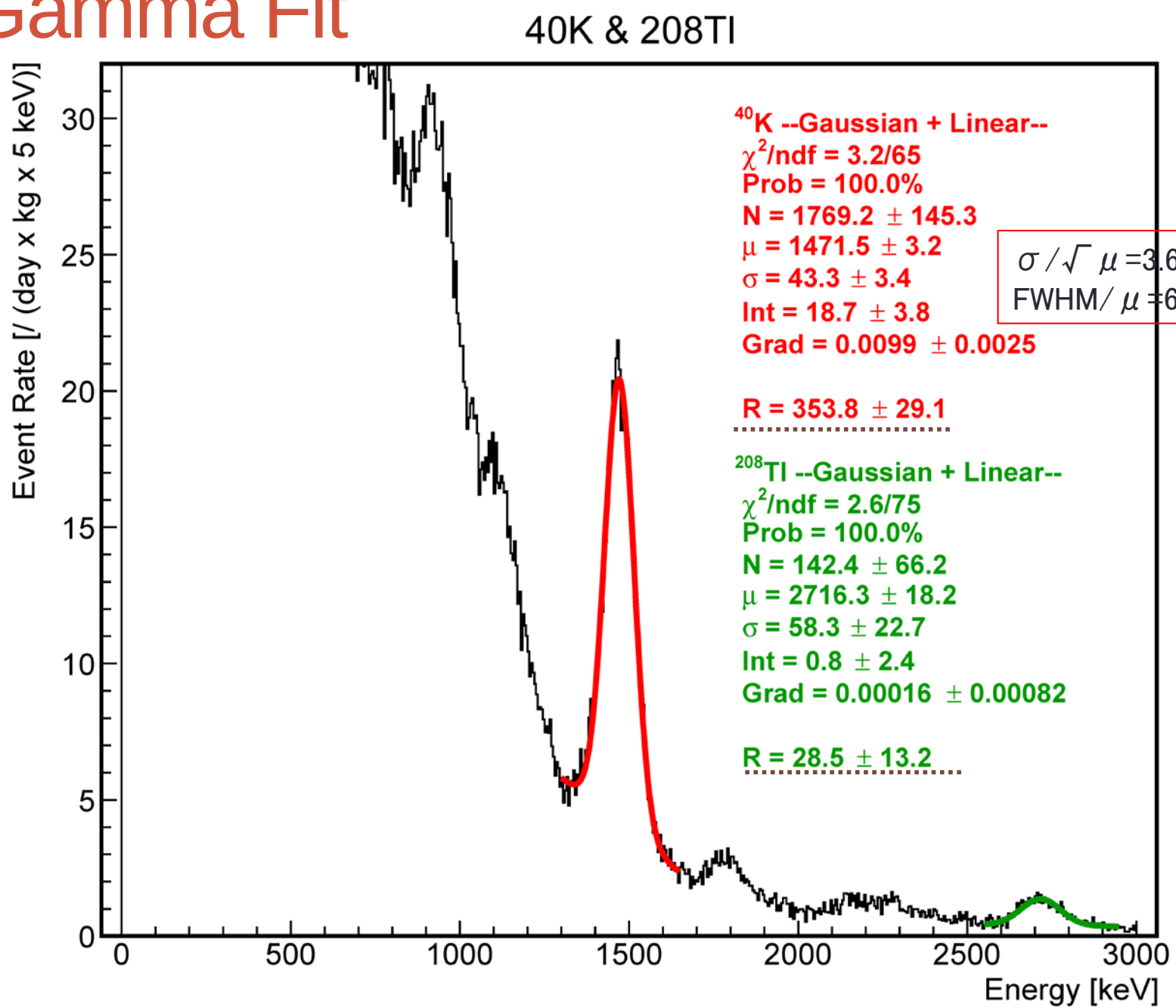


Back up slides

TFA Installation & Energy Threshold

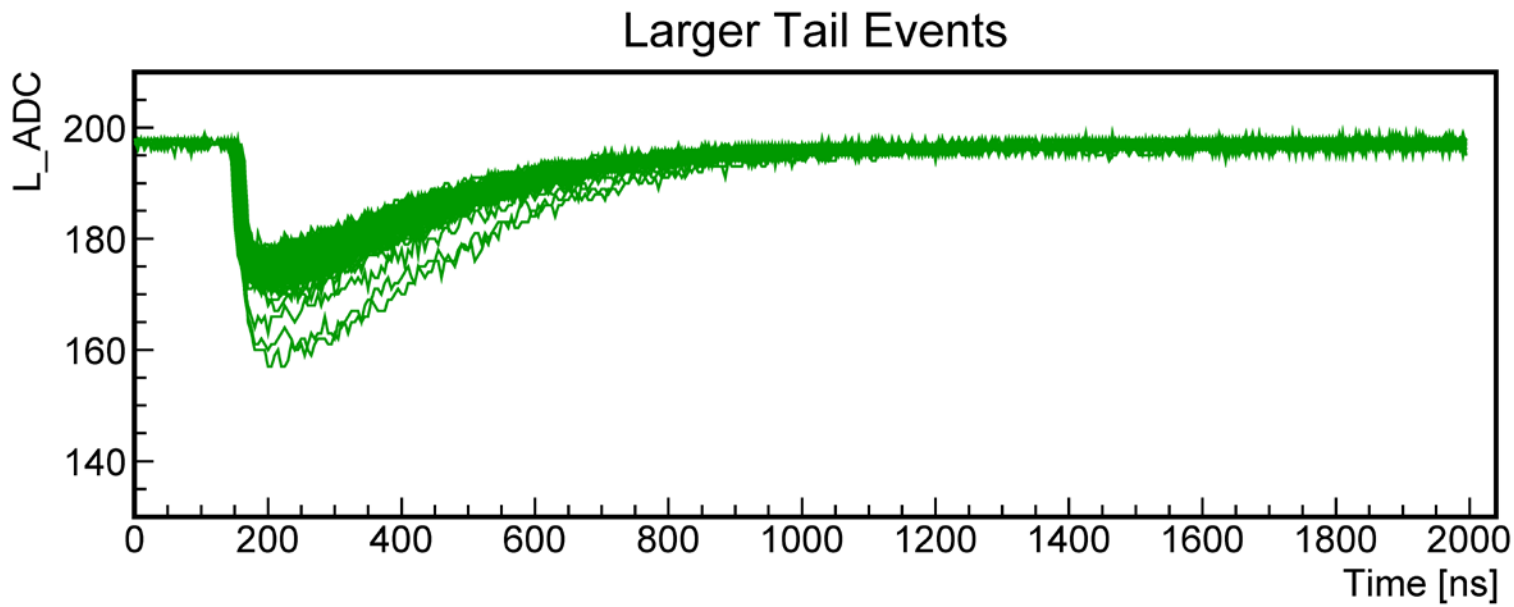


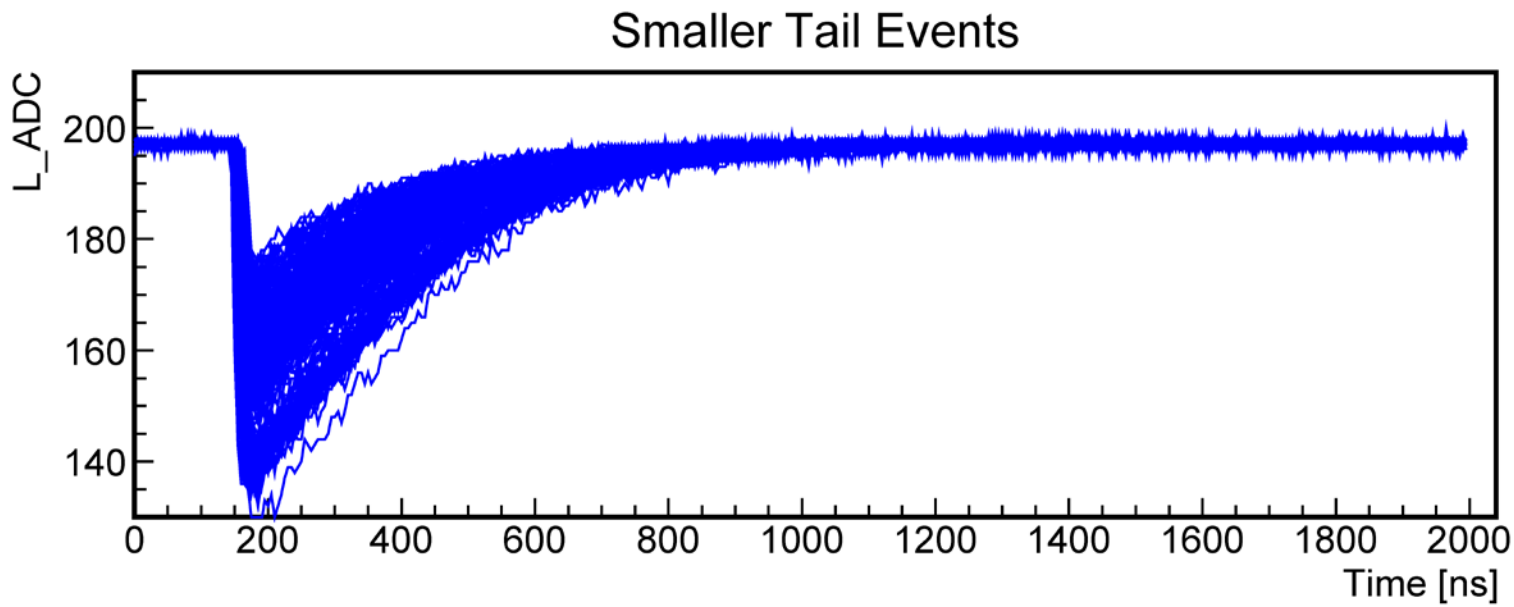
Gamma Fit



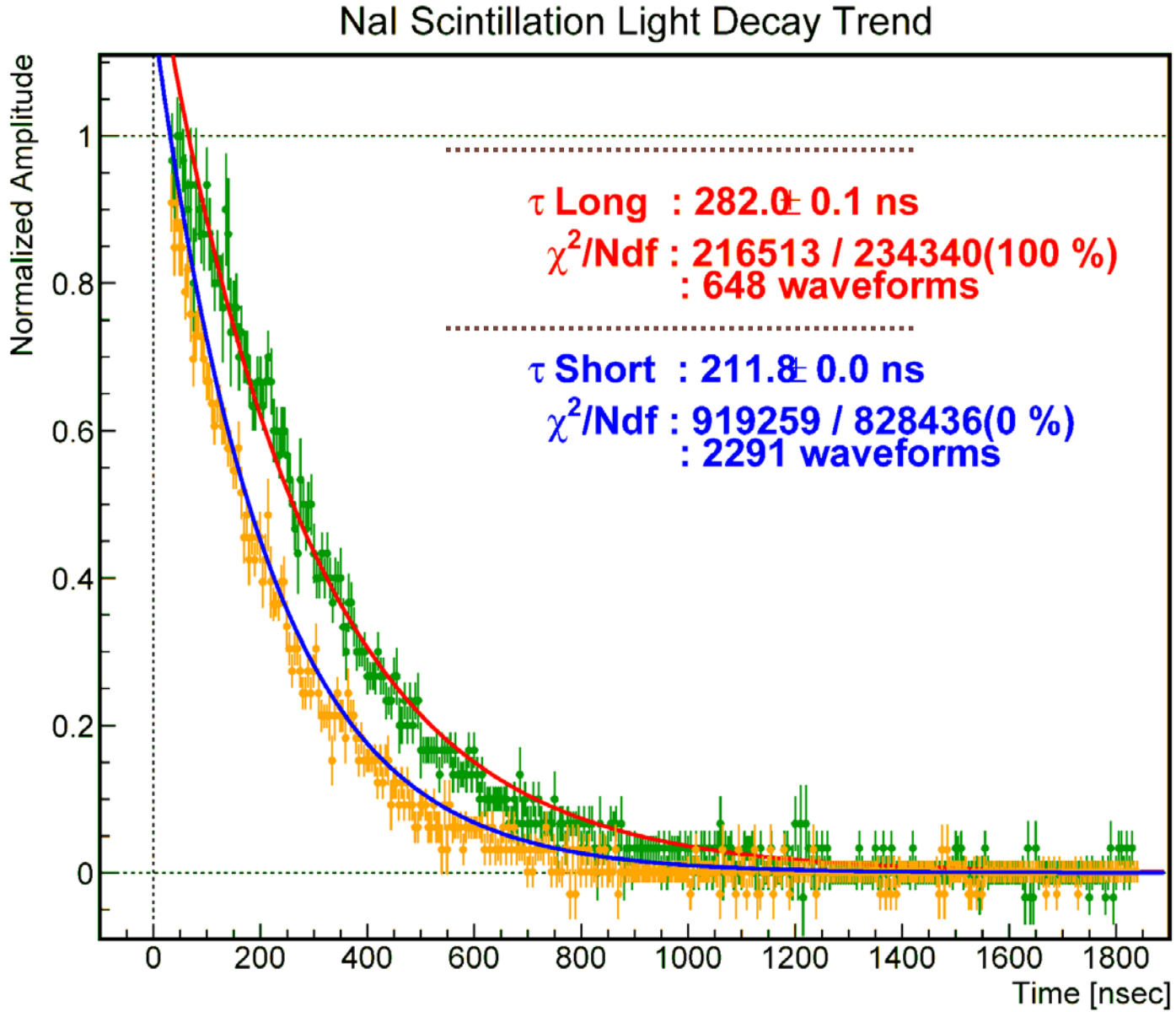
$\sigma/\sqrt{\mu}$ =3.6%/$\sqrt{\text{MeV}}$
FWHM/ μ =6.9%

Original NaI scintillation light in L-Gain



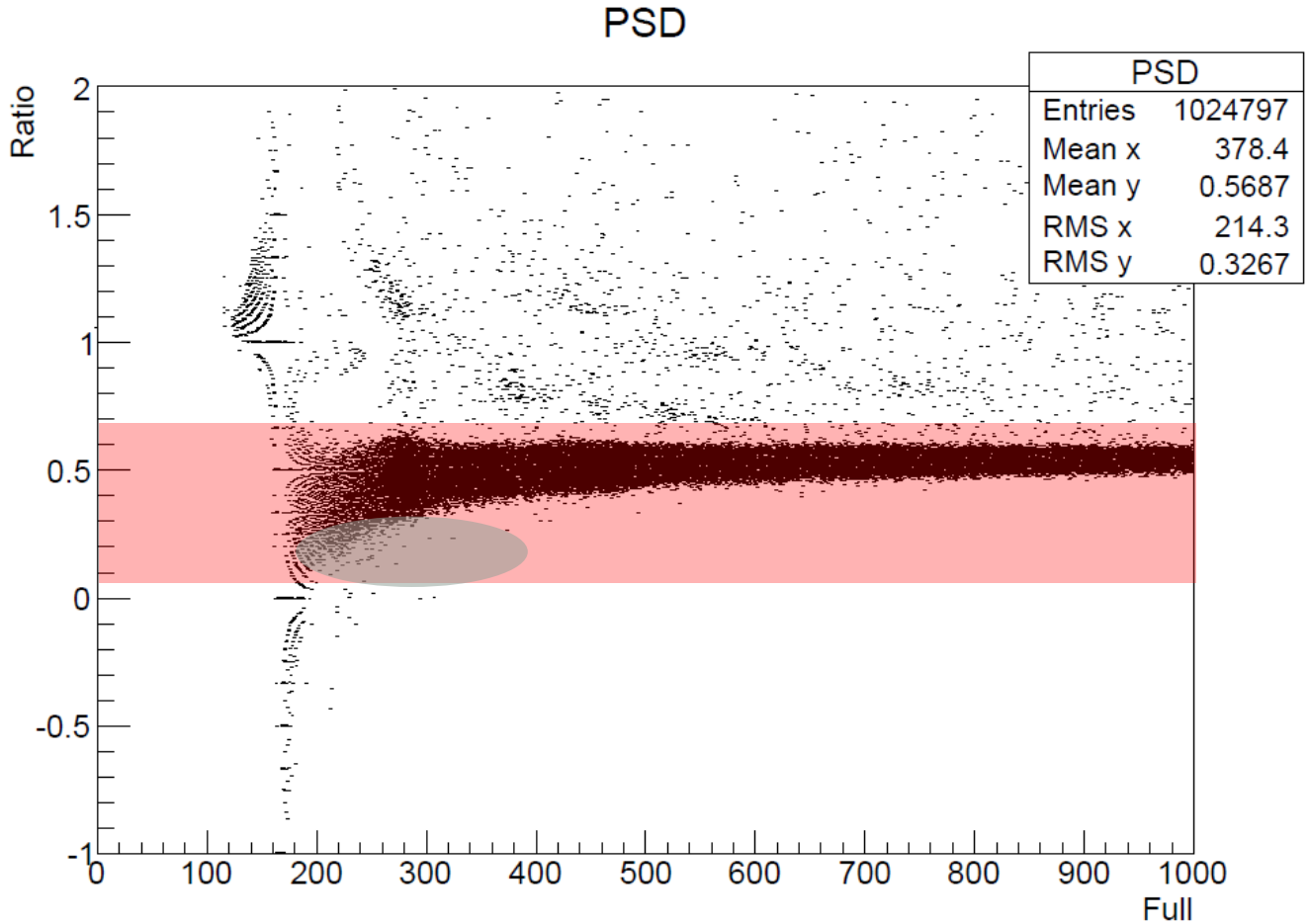


Decay constant of NaI scintillation light

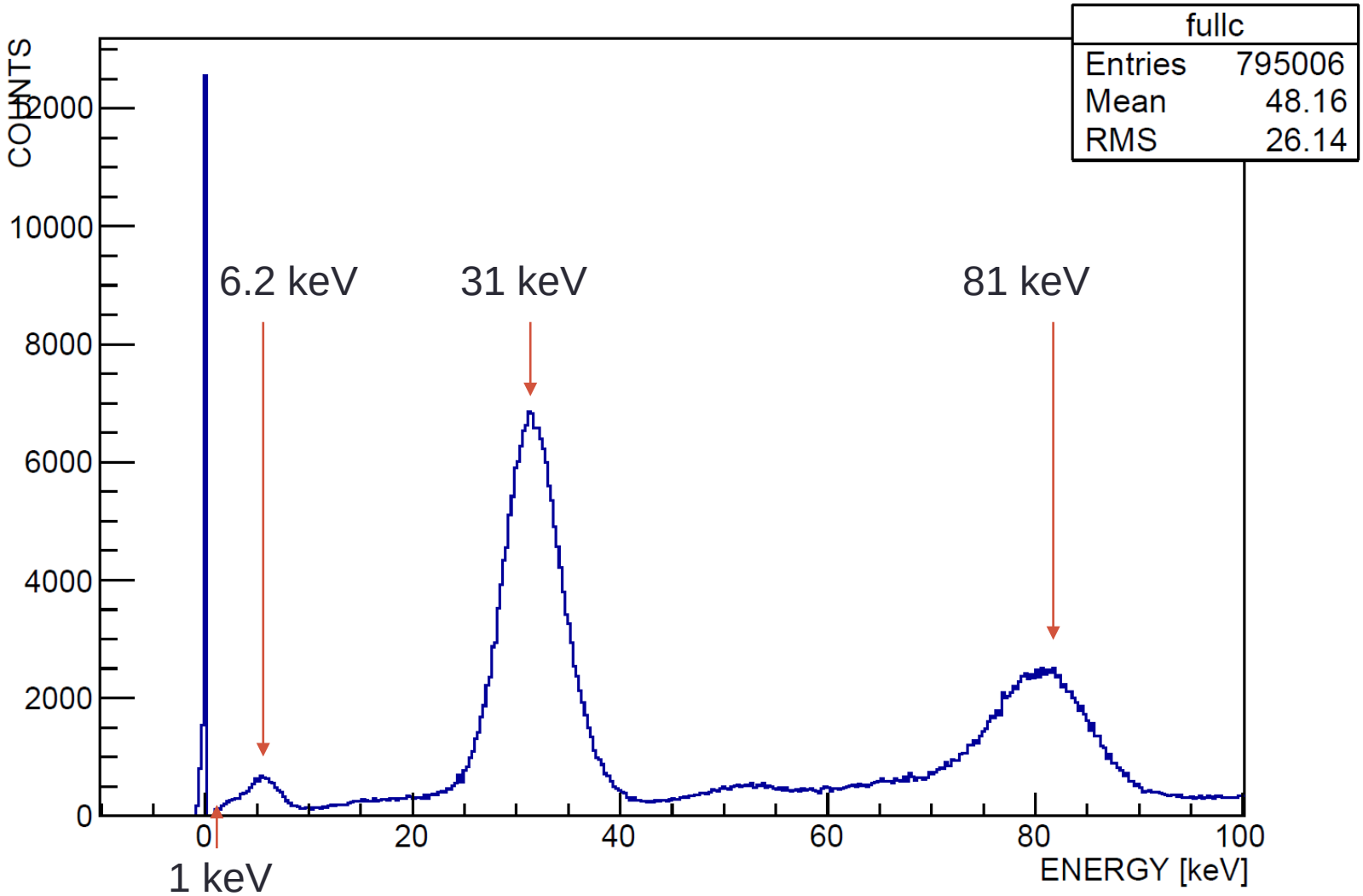


Low energy threshold (Noise reduction)

- Fast PMT dark noise was rejected by Timing filter AMP.
- Pulse shape discrimination → Rejects pile-up events



- 1 keV Energy threshold has been established



Ingot 23 results (26 days live time)