PICO-LON
DARK MATTER SEARCH

KamLAND-PICO Collaboration

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1. Aim of PICO-LON
2. PICO-LON Concept
3. Performance of PICO-LON Module
4. KamLAND-PICO Project

WIMPs search by NaI(Tl)

- Annual modulation
- Complementary work for directional measurement
- Limited work using NaI(Tl)
- DAMA, DM-Ice and PICO-LON

- PICO-LON in northern hemisphere
- However ...
- Highly radiopure NaI(Tl) is needed.
- Who makes the best NaI(Tl) in the world?
- In Japan, we restarted to make the best NaI(Tl)

Previous result by Japanese NaI(Tl) maker

	DAMA	DM-Ice	Horiba	Goal of PICO-LON
^{nat}K	<20ppb	500ppb	<200ppb	<20ppb
^{232}Th	0.5-0.7ppt	50ppt	0.6ppt	<1ppt
^{238}U	0.7-10ppt	7.5ppt	1.07ppt	<1ppt
^{210}Pb	5-30μBq/kg	2mBq/kg	6mBq/kg	<100μBq/kg

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

PICO-LON for WIMPs search

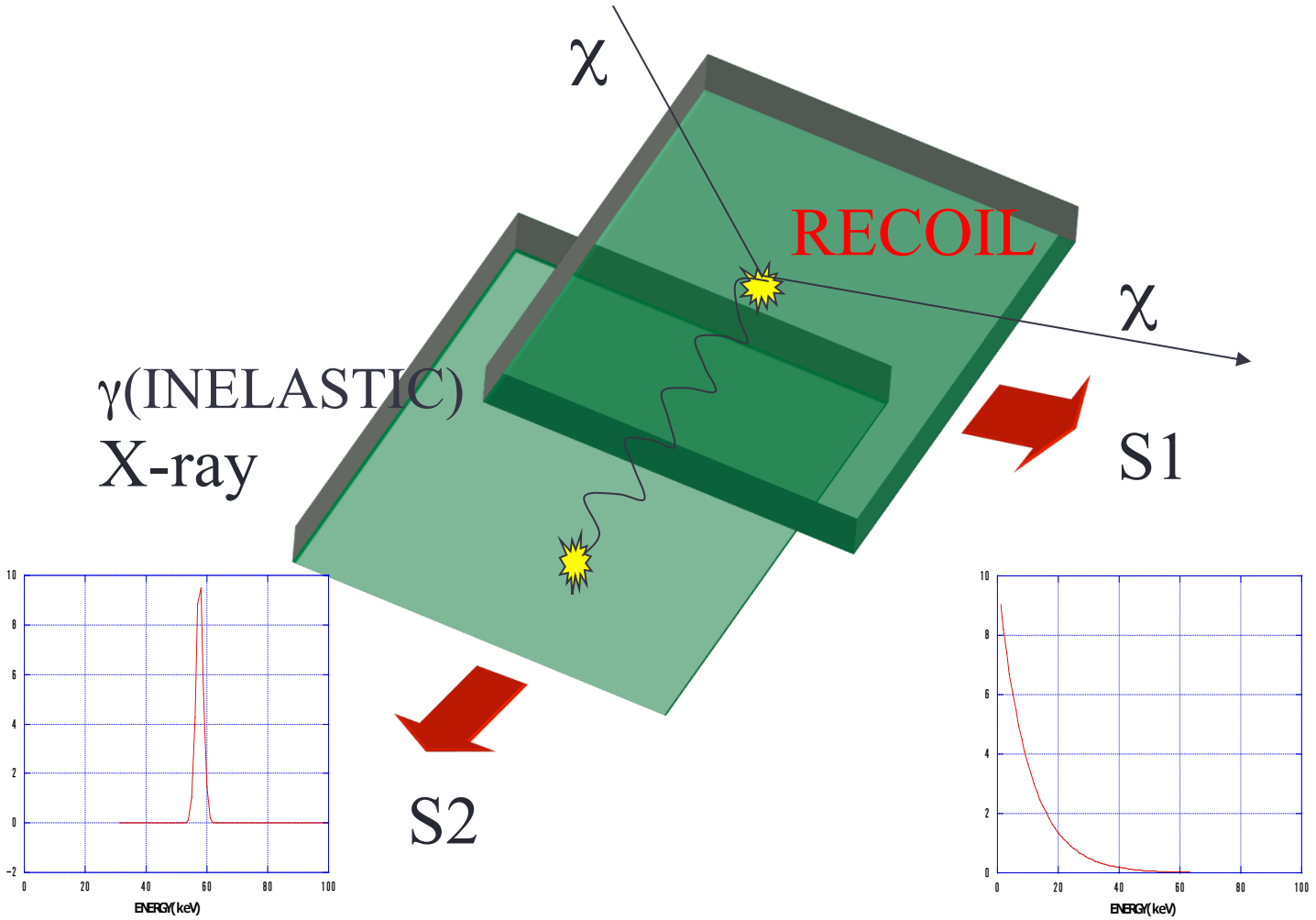
- Planar
- Inorganic
- Crystal
- Observatory for
- LOw-background
- Neutr(al)ino

- High selectivity
- Background reduction

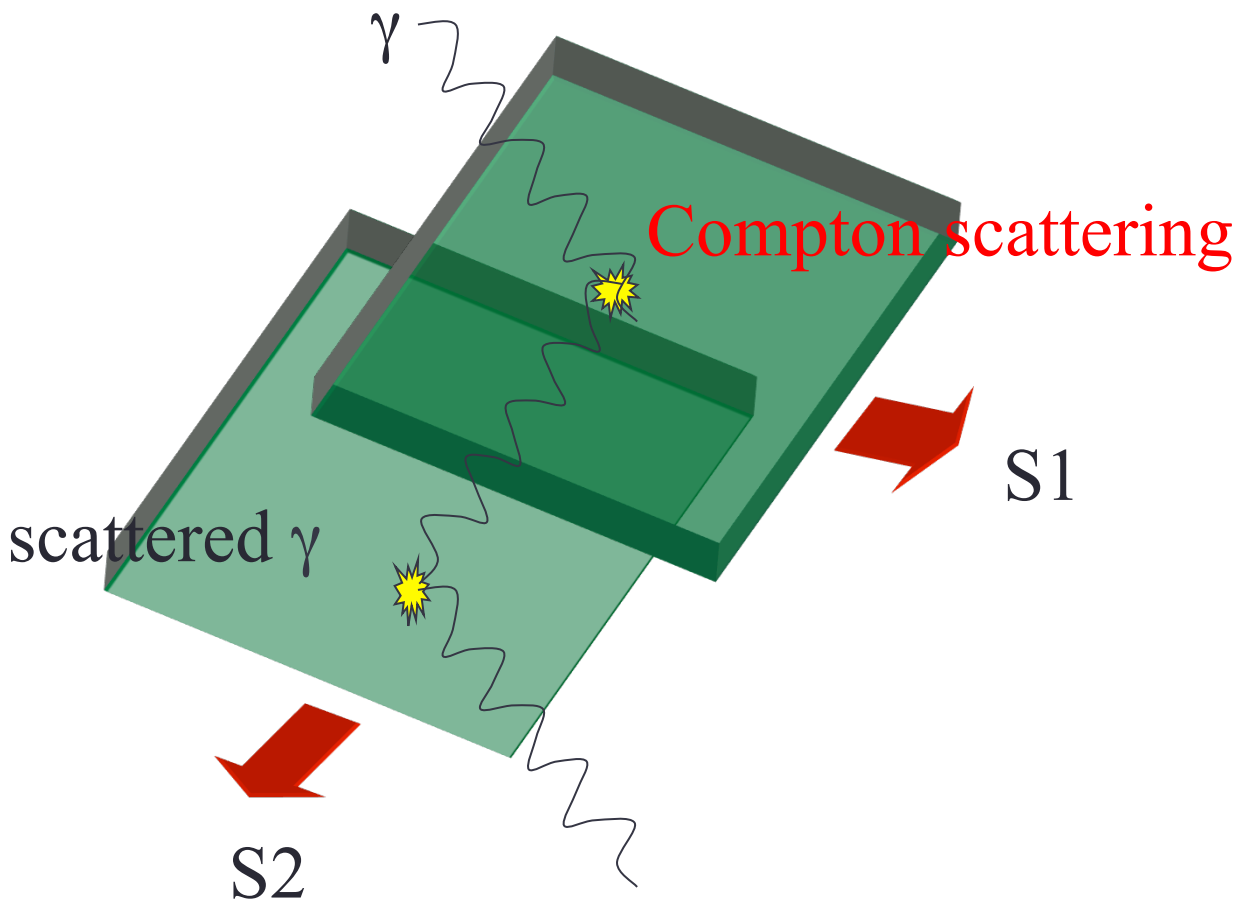
- Sensitive to
- Elastic scattering (SI+SD)
- Inelastic scattering (SD)

- Study the interaction type of WIMPs

Concept of PICO-LON detector



Background reduction



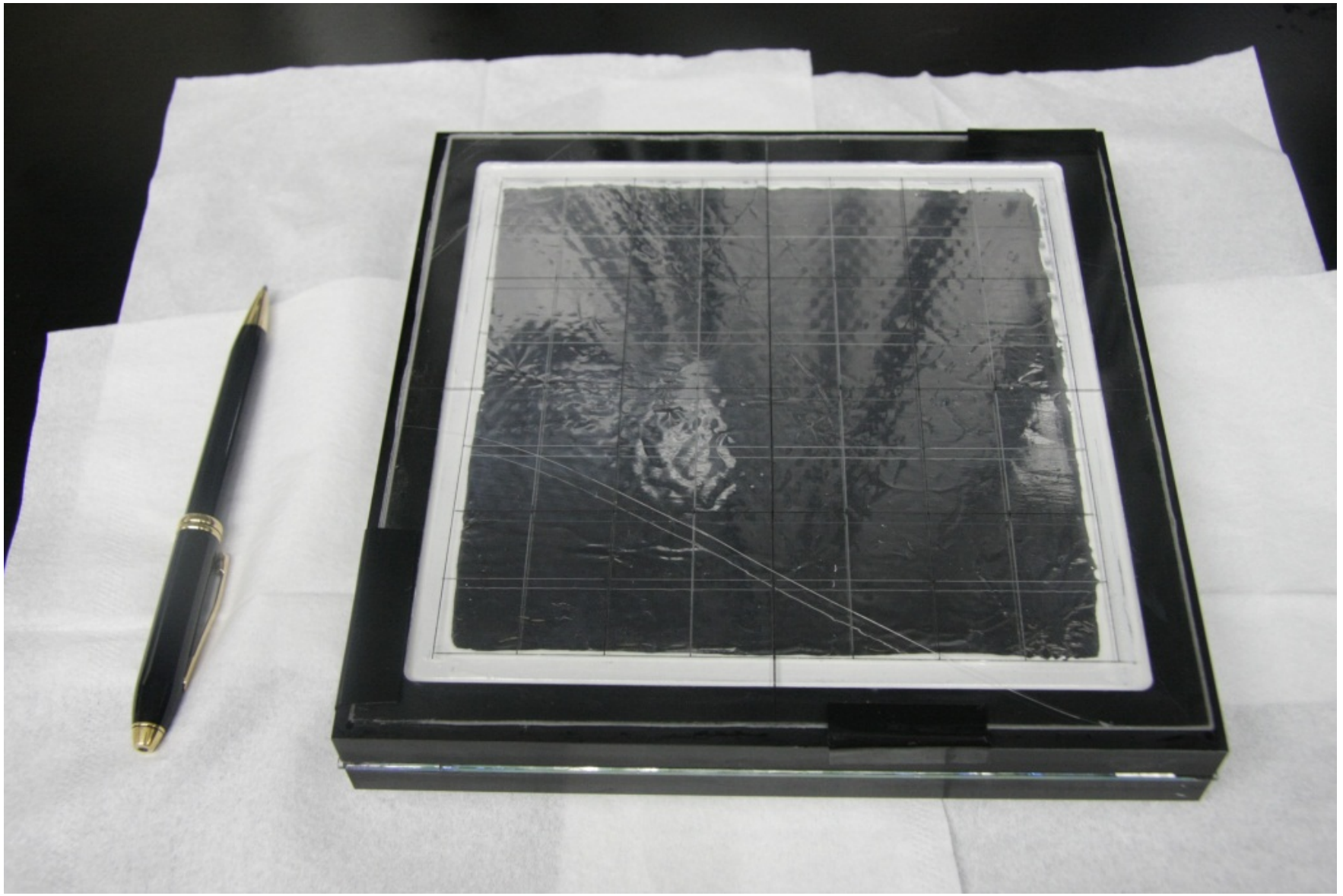
Segmented detector → Remove Compton scattering

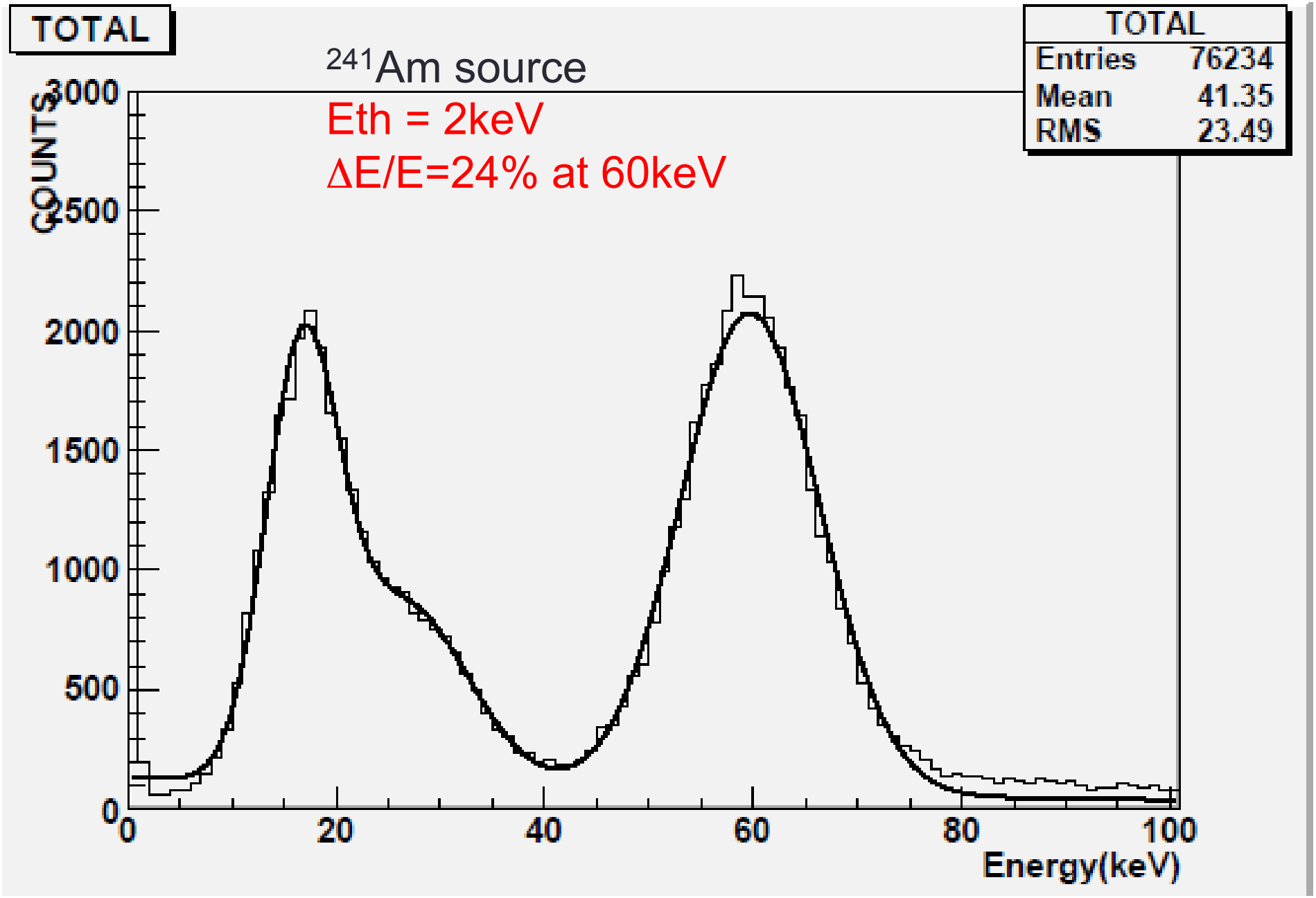
Design of PICO-LON

- Requirements

- Coincidence measurement of ^{127}I gamma ray
  - Thin NaI(Tl) crystal 0.1cm
- Low energy threshold
  - Low energy WIMPs signal $E_{ee} < 5\mathrm{keV}$
- Good energy resolution
  - Background by ^{210}Pb at 46.5keV $\Delta E_{ee} = 12\mathrm{keV}$
- Large acceptance
  - Wide area crystal 10cm square ~ 18cm square
  - Pile up modular detectors

PICO-LON single layer module

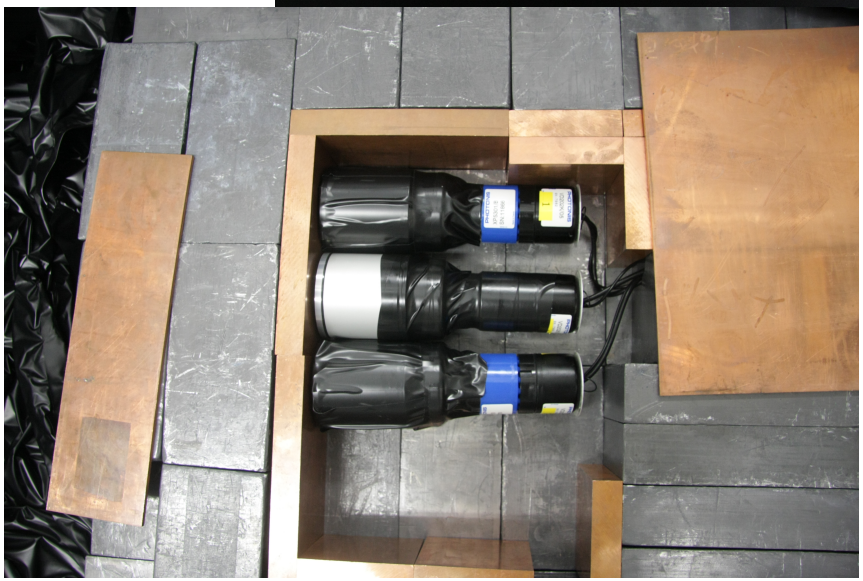



TOTAL
^{241}Am source
Eth = 2keV
ΔE/E=24% at 60keV
TOTAL
Entries 76234
Mean 41.35
RMS 23.49
COUNTS
3000
2500
2000
1500
1000
500
0
0
20
40
60
80
100
Energy(keV)

R&D for pure NaI(Tl) production

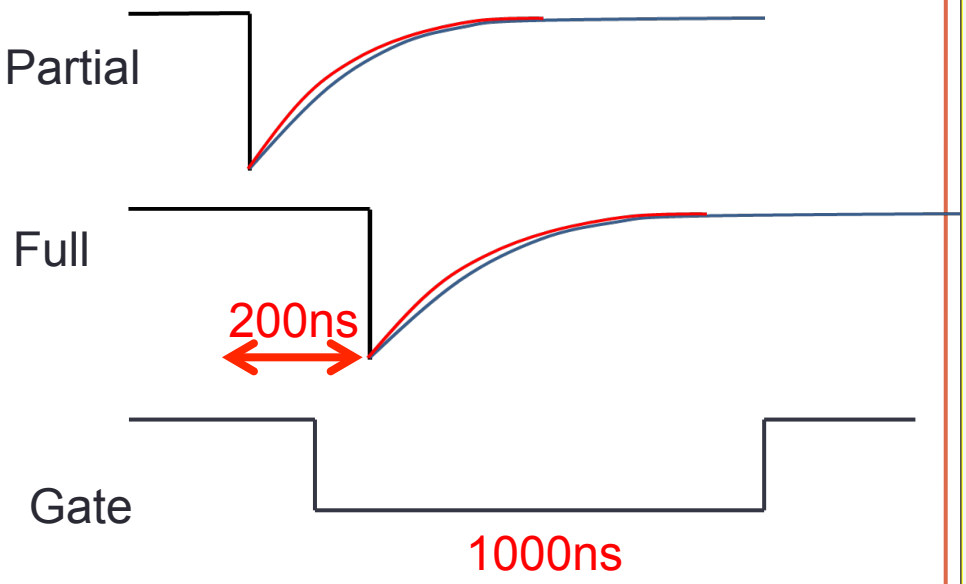
- Crucible selection
- Raw material of NaI selection
- Surroundings of a plant

- 3.0”ϕX3.0” NaI(Tl)
- Three different conditions

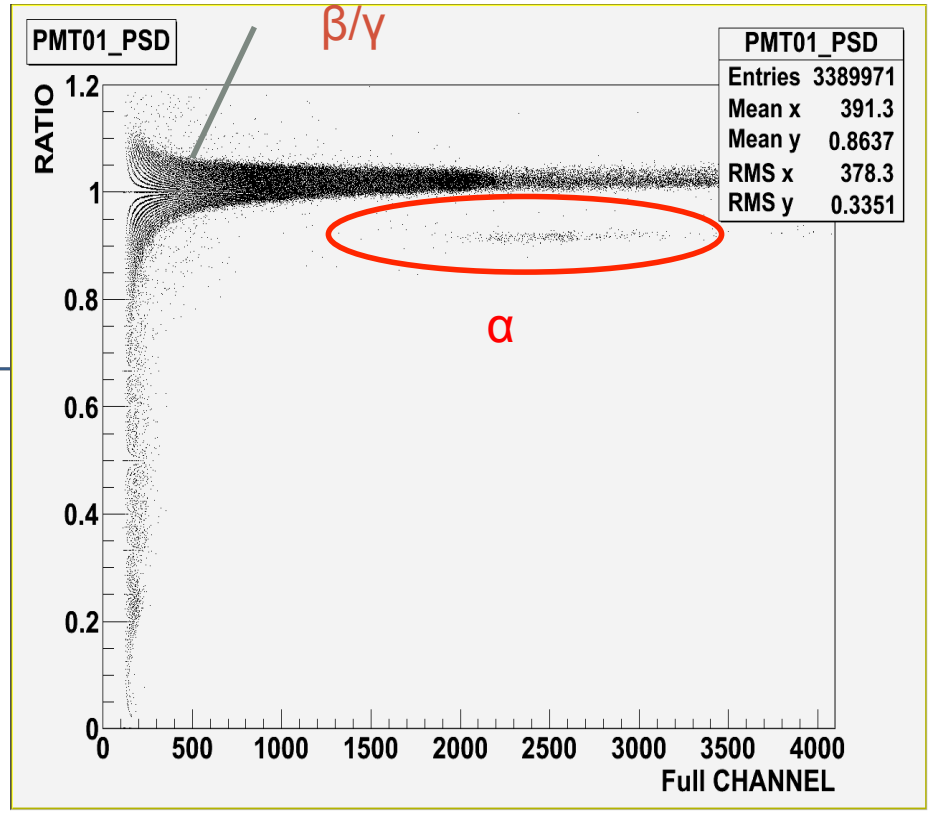


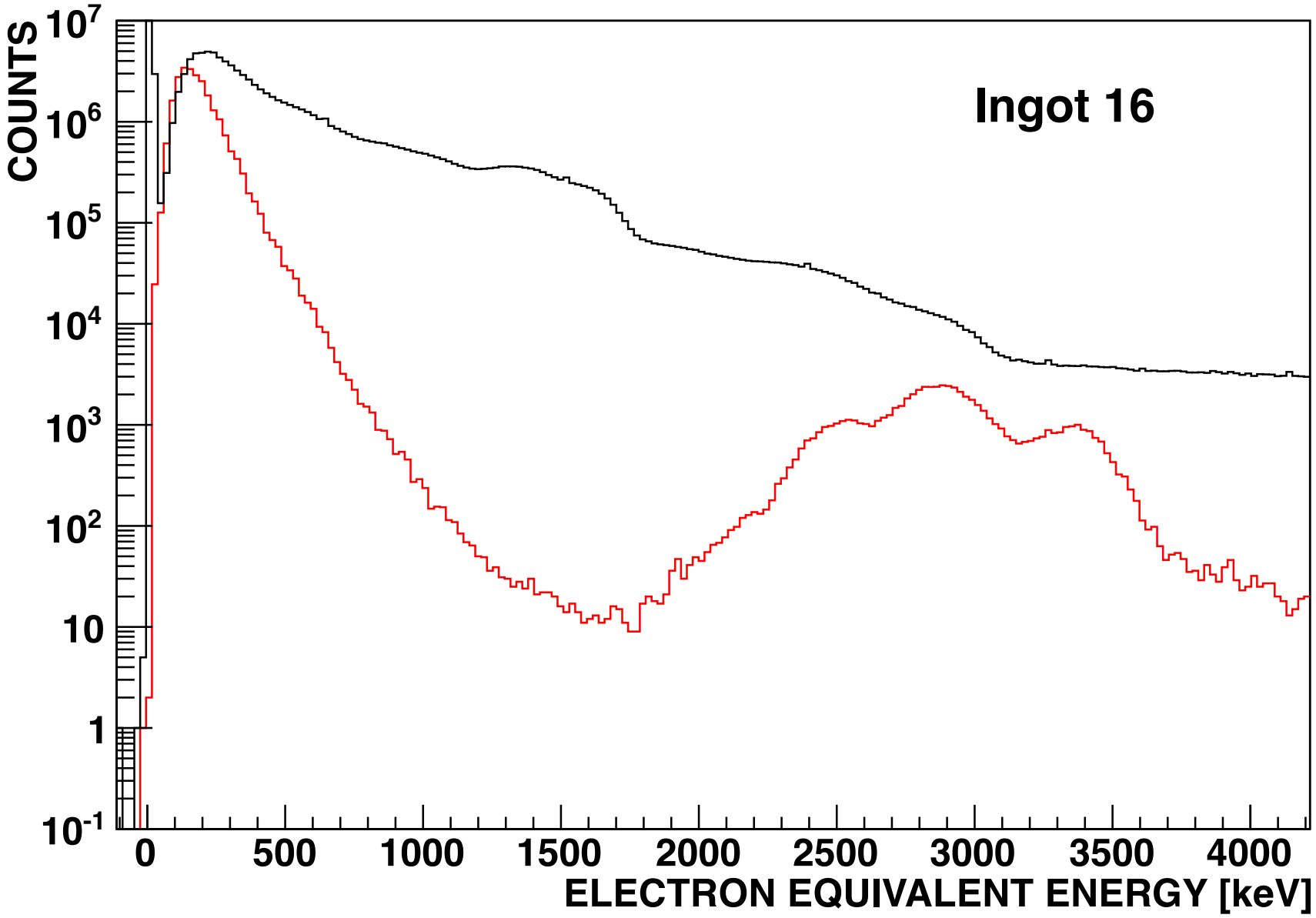
Pulse shape discrimination for alpha/beta selection

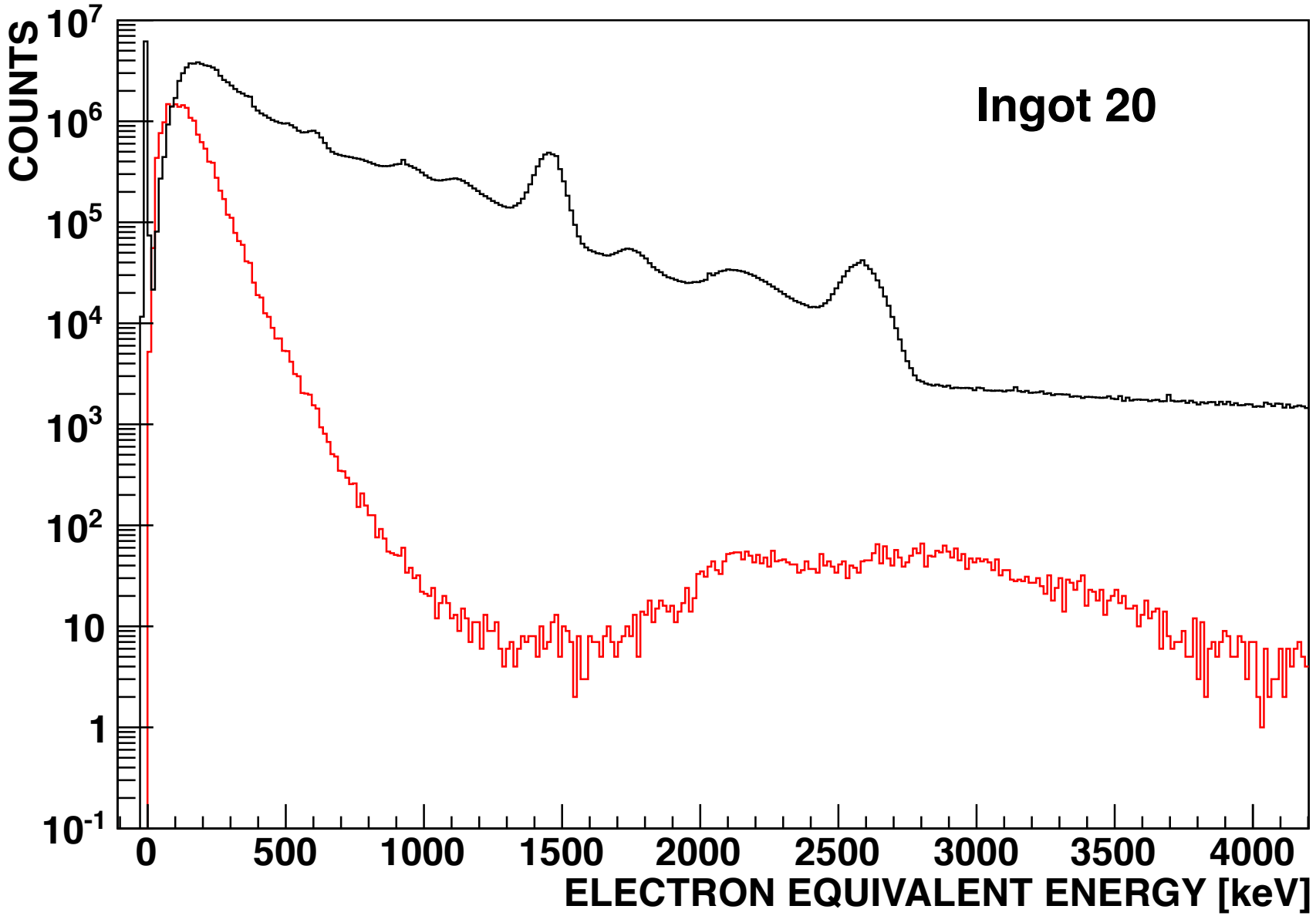
Small difference of pulse shape

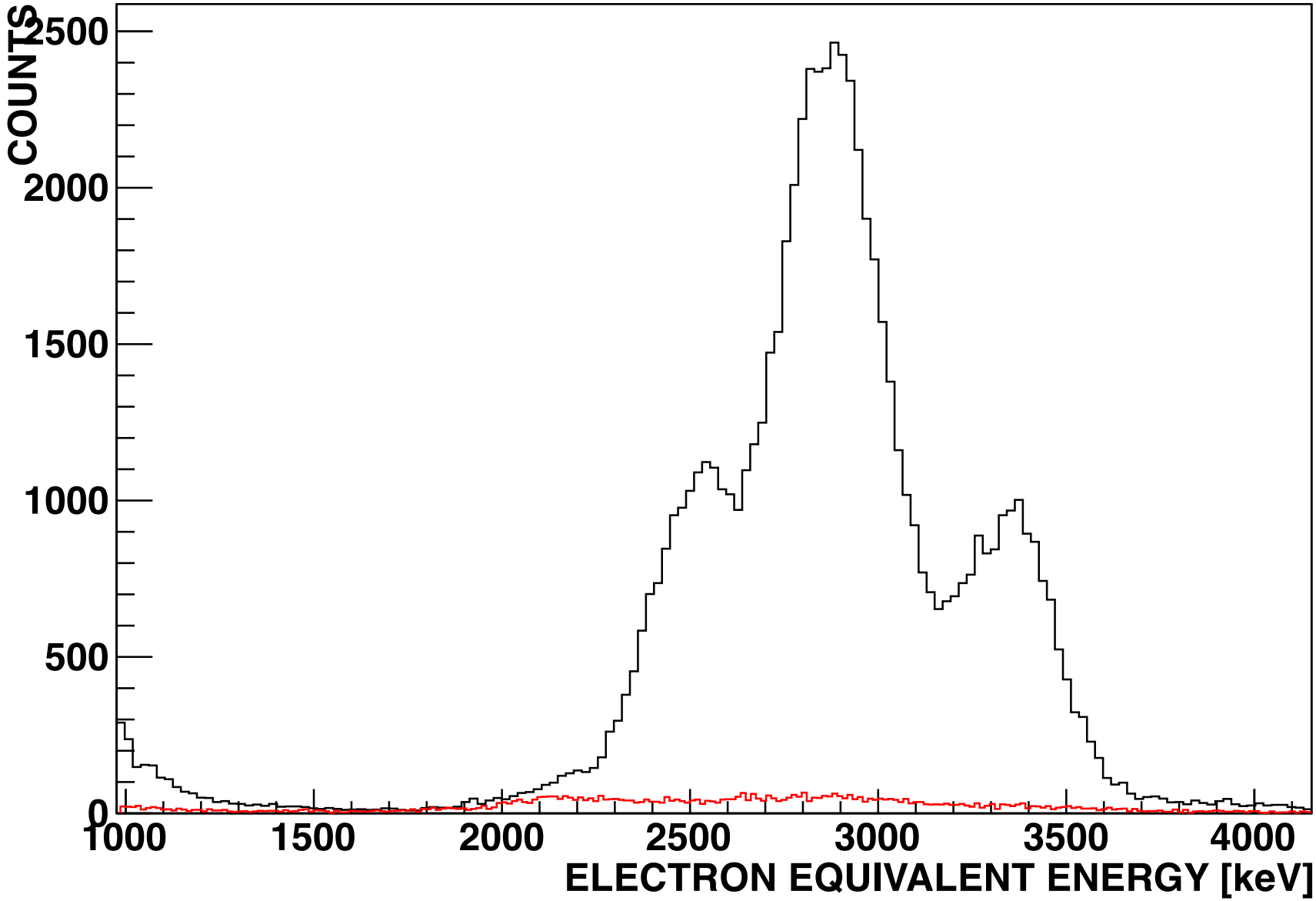


Decay time	
α	190ns
β/γ	230ns

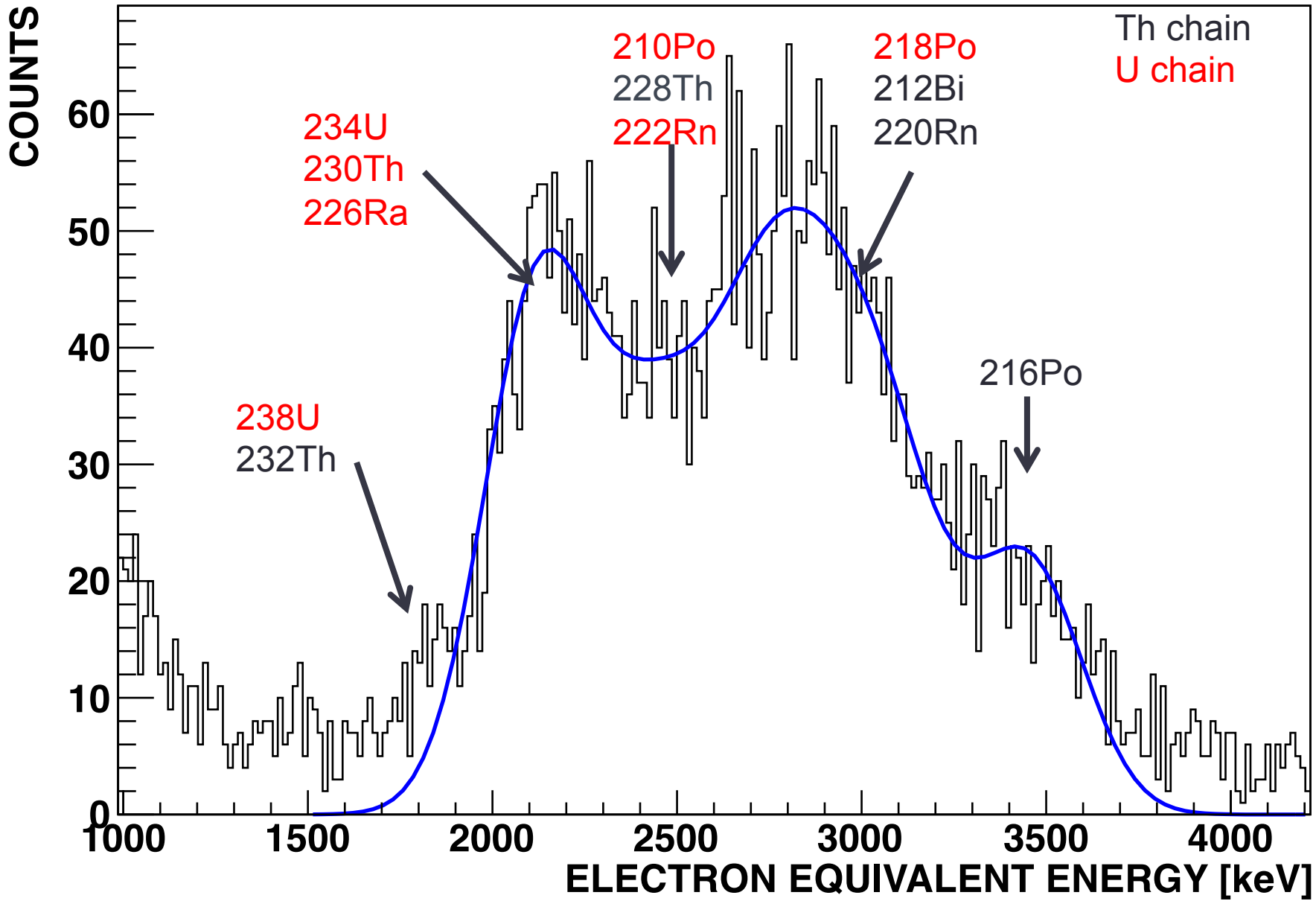



Ingot 16
COUNTS
10^7
10^6
10^5
10^4
10^3
10^2
10
1
10^{-1}
0
500
1000
1500
2000
2500
3000
3500
4000
ELECTRON EQUIVALENT ENERGY [keV]


Ingot 20
COUNTS
10^7
10^6
10^5
10^4
10^3
10^2
10
1
10^{-1}
0
500
1000
1500
2000
2500
3000
3500
4000
ELECTRON EQUIVALENT ENERGY [keV]


COUNTS
2500
2000
1500
1000
500
0
1000
1500
2000
2500
3000
3500
4000
ELECTRON EQUIVALENT ENERGY [keV]

NaI(Tl) ingot #20 Live time 28 days



Preliminary Result (μBq/kg)

α source		Ingot 16	Ingot 18	Ingot 20 (Preliminary)
U chain	^{210}Po	9600±100	1825± 45	306±23
	^{226}Ra	4510±60	308± 26	126±15
	^{234}U +^{230}Th	520±73	1161±38	243±20
Th chain	^{228}Th	243± 11	255± 12	67±6

Contamination depends on the purity of crucible.

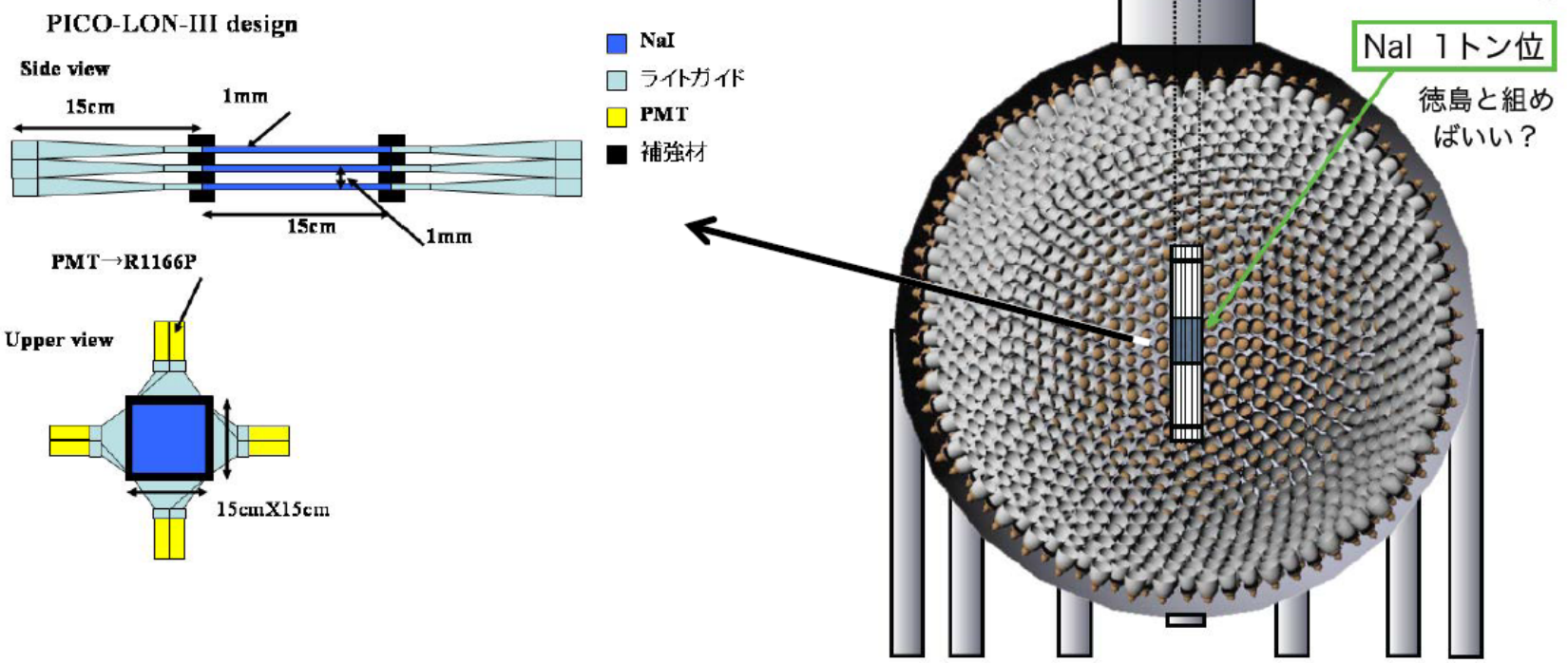
Low density for ^{210}Pb = 300μBq/kg

Results for performance

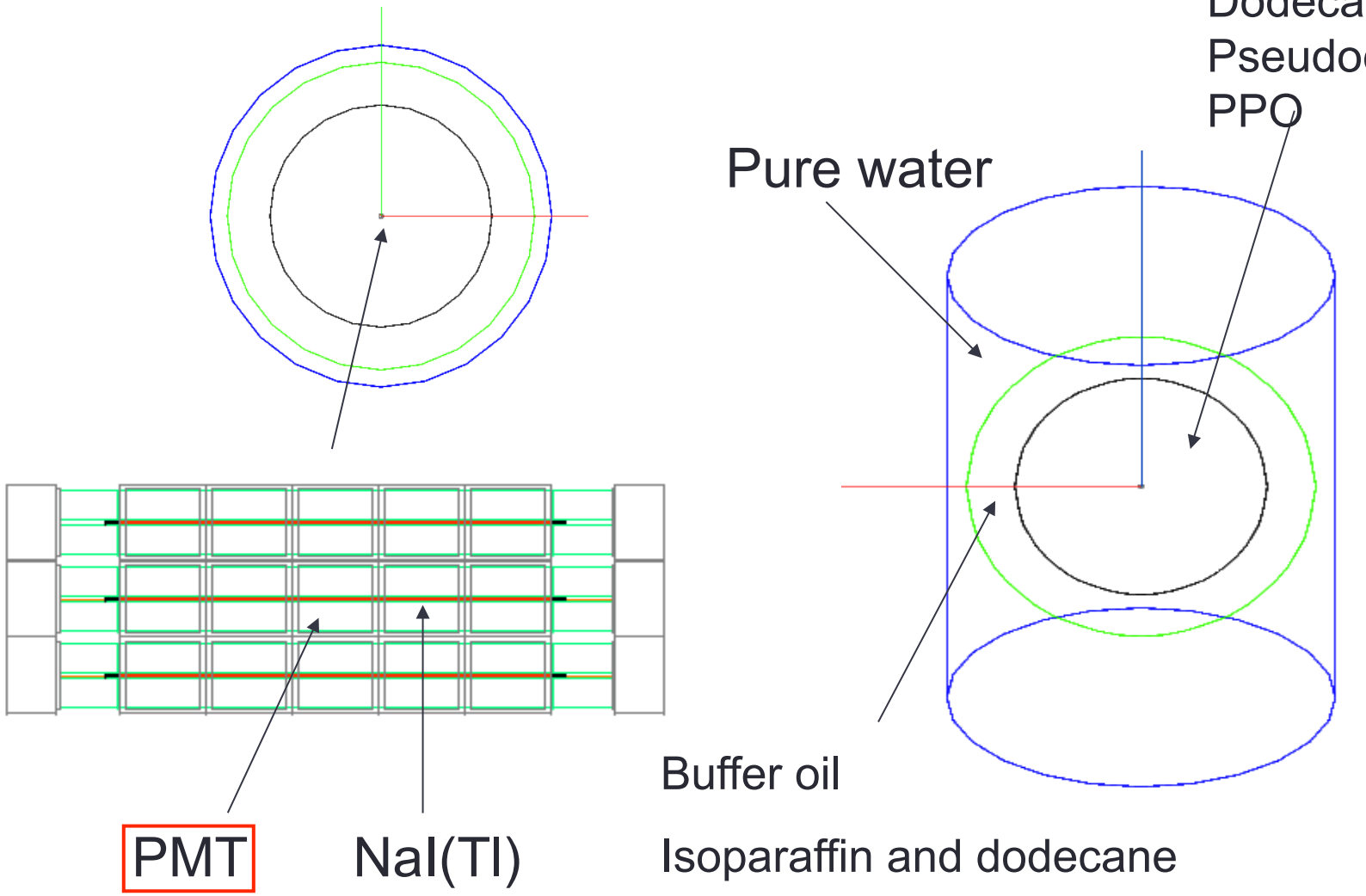
- Good energy threshold
  - Lower than 2keV electron equivalent.
- NaI purification
  - R&D in progress
  - ^{210}Pb was effectively reduced

KamLAND-PICO

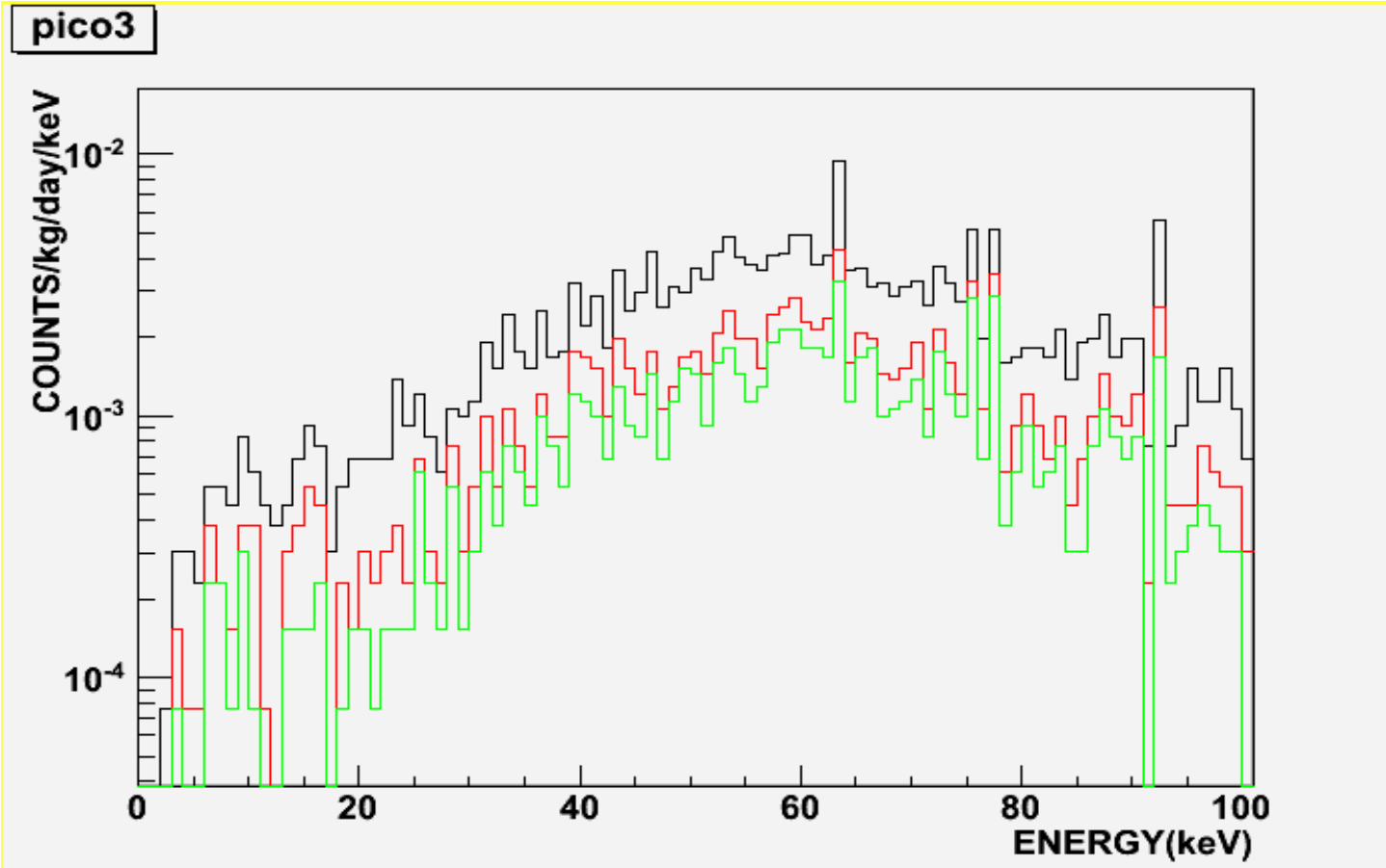
- Install PICO-LON detector into KamLAND
- KamLAND is an ideal active shield.



BG Simulation of KamLAND-PICO



Low energy region ^{214}Bi in NaI(Tl)



Energy threshold of KamLAND

100keV 180keV 400keV

6.Estimated background (Preliminary!!)

events/kg/day/keV	
^{40}K PMT glass	5.3×10^{-5}
^{232}Th PMT glass	2.7×10^{-4}
^{40}K PMTcase	2.7×10^{-4}
^{210}Pb NaI(Tl)	6×10^{-2}
^{212}Pb NaI(Tl)	1×10^{-4}
^{40}K NaI(Tl)	3×10^{-1}
^{40}K light guide	9×10^{-2}
^{232}Th light guide	2.7×10^{-7}
^{40}K reinforcement	5×10^{-2}
^{232}Th reinforcement	5.5×10^{-7}

DAMA

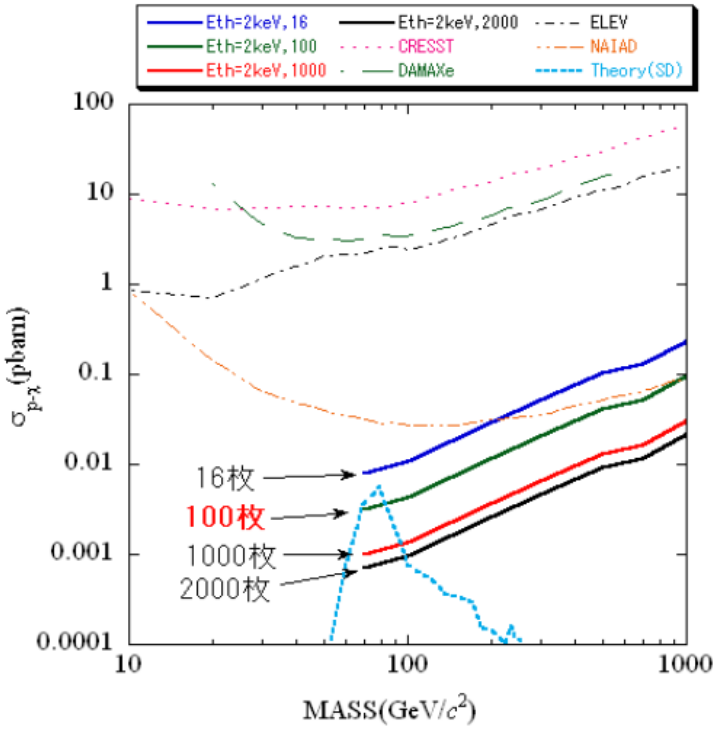
BG~1/kg/day/keV

KamLAND-PICO (E_{th}=100keV)

BG ~ 0.5/kg/day/keV

Summary

- PICO-LON for WIMPs search
- High sensitivity to all the types of interaction.
  - Elastic scattering for SD+SI
  - Inelastic scattering for SD
- Good performance for WIMPs search
- KamLAND-PICO has been funded.
  - 15Myen/4year
  - Low background study for NaI(Tl) with 4π active shield.



Expected sensitivity (Elastic, 1ton*yr)
0.5/day/kg/keV Eth=2keV