KIMS
(KOREA INVISIBLE MASS SEARCH)

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Sejong University

2013. 1.28-2.3
Closing in on Dark Matter, Aspen

Contents

Yangyang(Y2L) Underground Laboratory

(Upper Dam)

Korea Middleland Power Co.
Yangyang Pumped Storage Power Plant

(Power Plant)

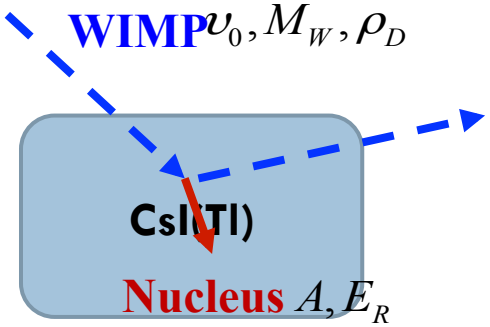
(Lower Dam

KIMS (Dark Matter Search)

AMoRE (Double Beta Decay Experiment)

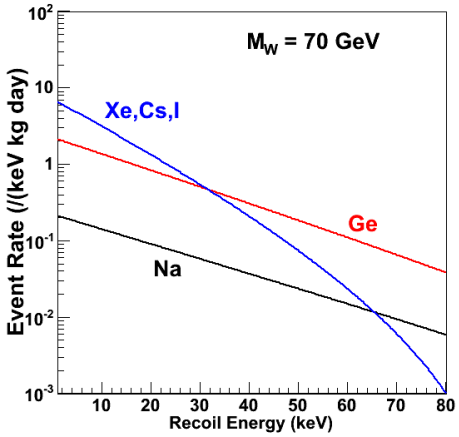
Minimum depth : 700 m / Access to the lab by car (~2km)

KIMS overview



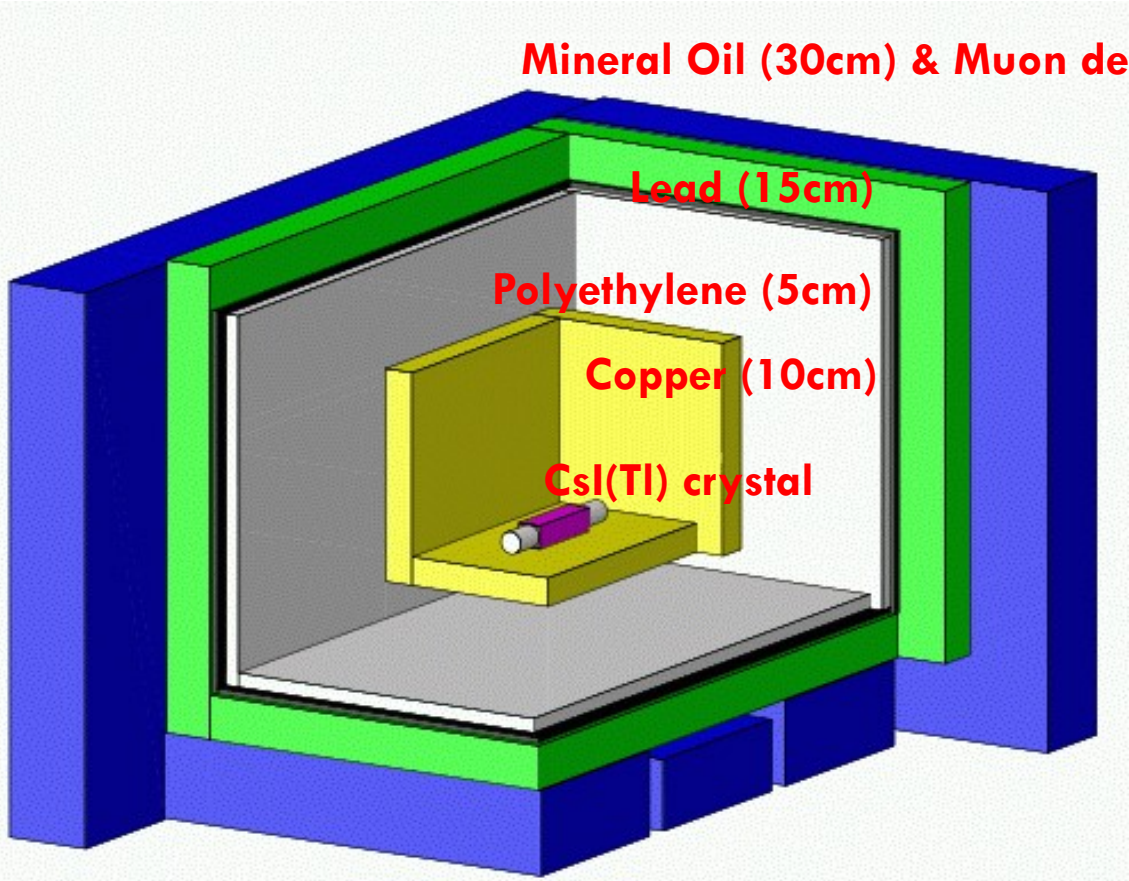
WIMP-Nucleus elastic scattering

- **Similar experiment to DAMA.**
- **Direct comparison to DAMA annual mo dulation signal is possible. Iodine is com mon to both exp.**

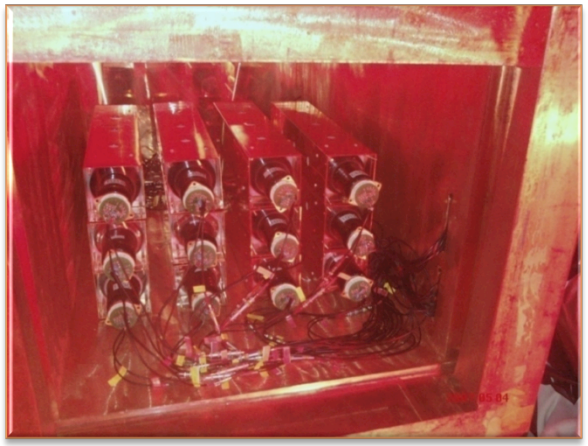


CsI(Tl) Crystal 8x8x30 cm^3

(8.7 kg) + 3" PMT (9269QA)

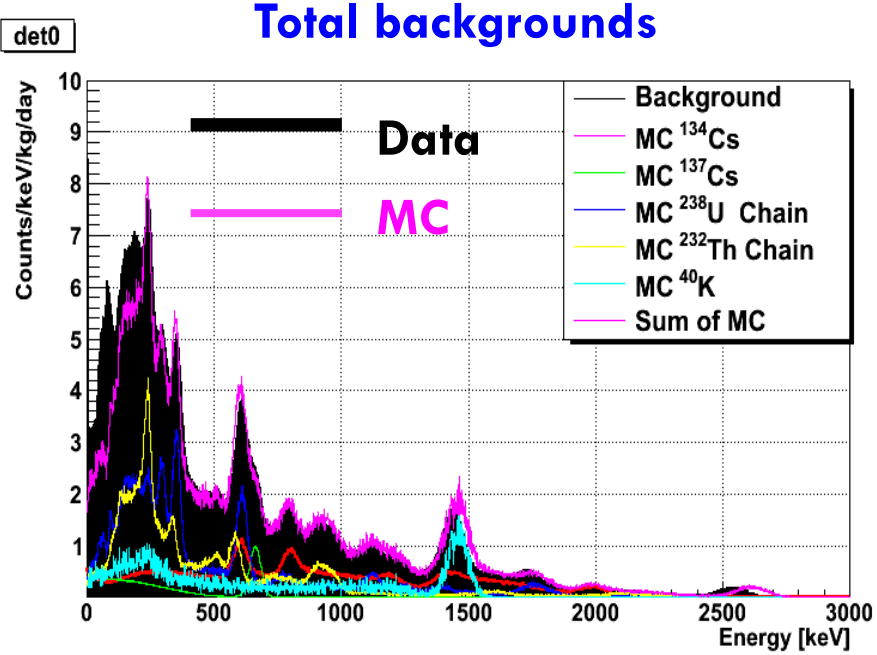


Data with 12 crystals

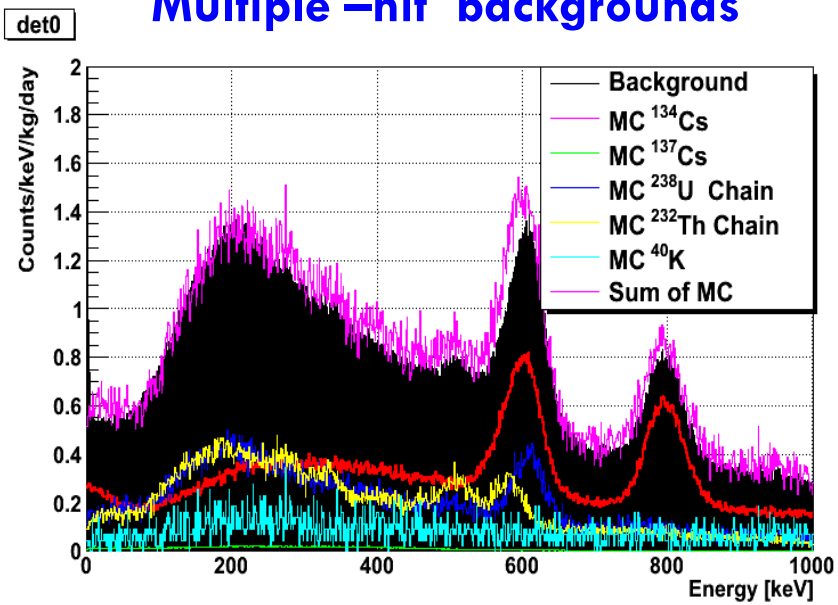


- 12 crystals (104.4kg) installed in the Cu shield.
- 2.5 year data (Sep. 2009 – Feb. 2012)
- Background Level : 2~3 cpd/kg/keV
- Source calibration with ^{55}Fe & ^{241}Am
- 1 year of data (Sep. 2009 – Aug. 2010) published with PSD analysis.
- Backgrounds are well understood.

Total backgrounds

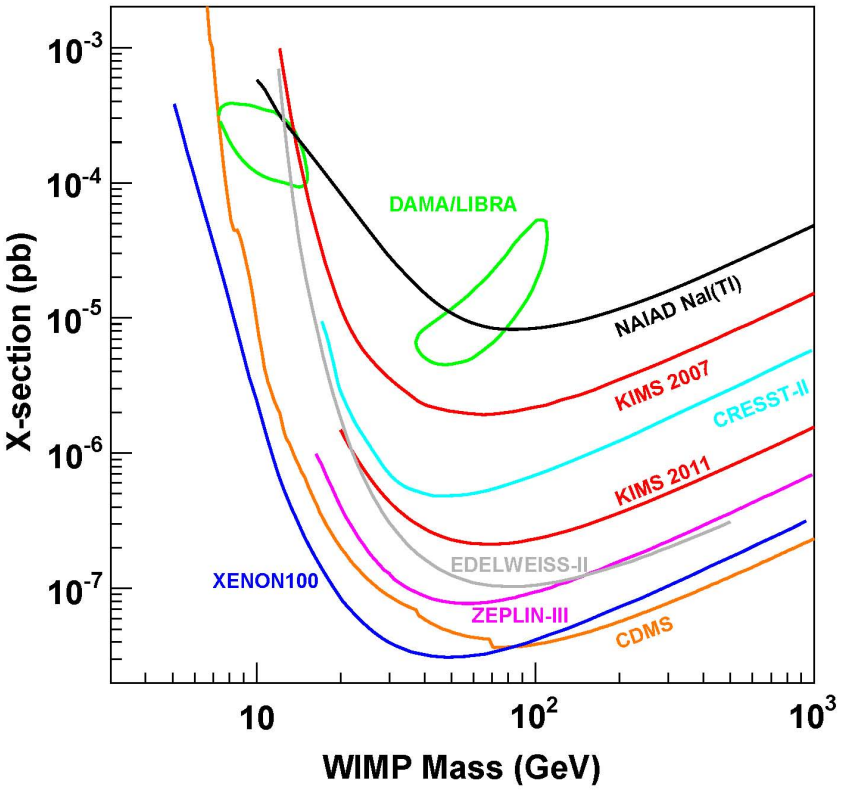


Multiple –hit backgrounds

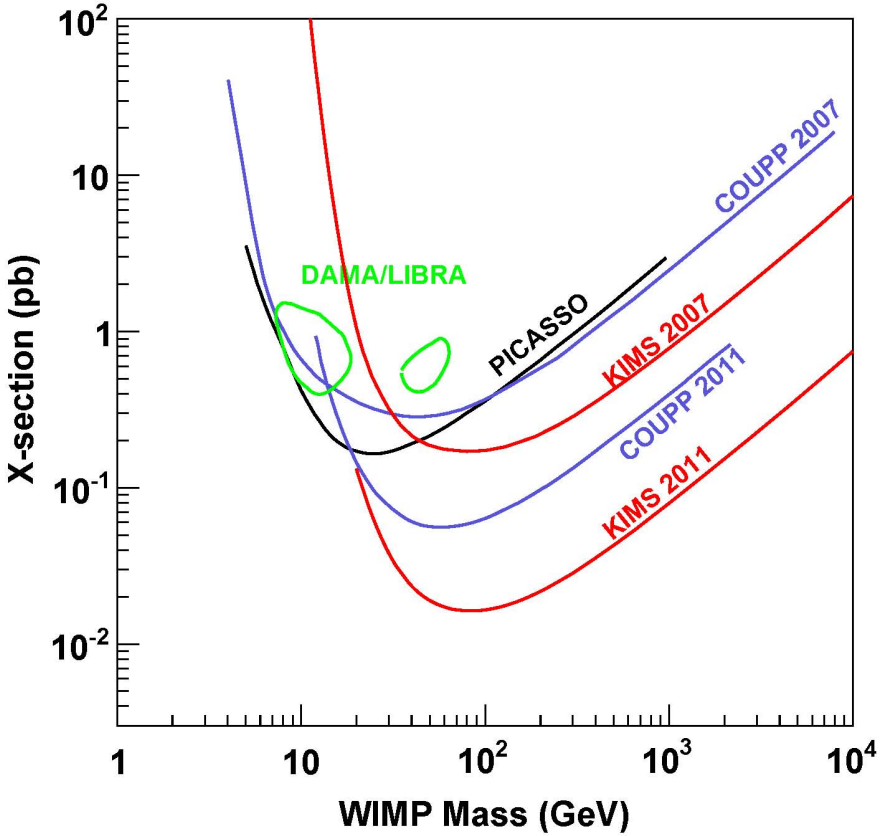


Cross Section Limits in 2012.

S.C. Kim et al., PRL 108 181301 (2012)

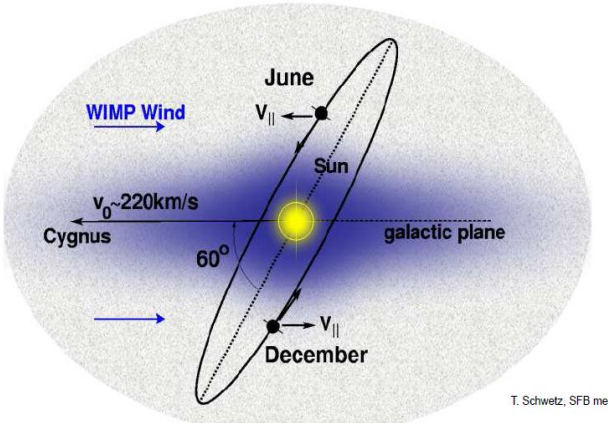


SI cross section limit

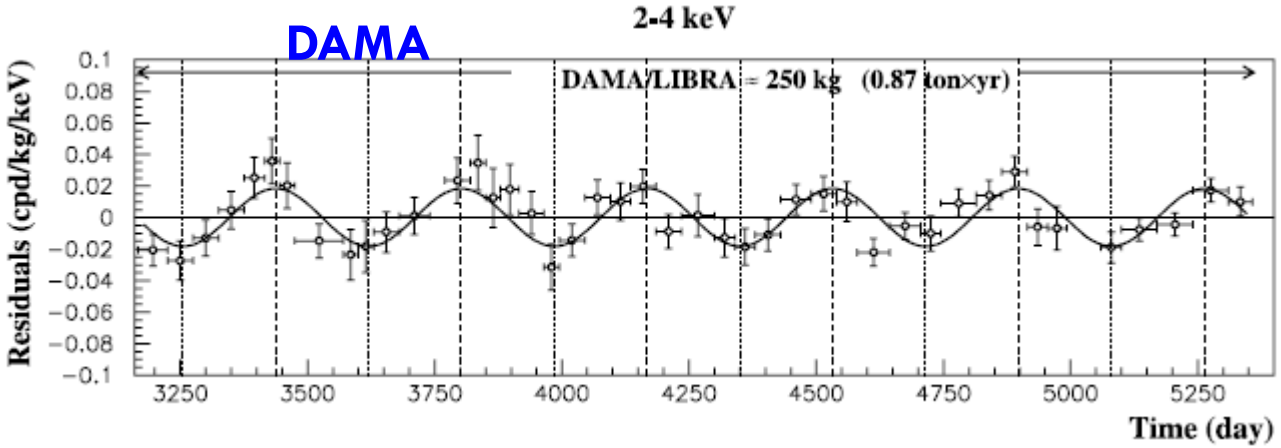


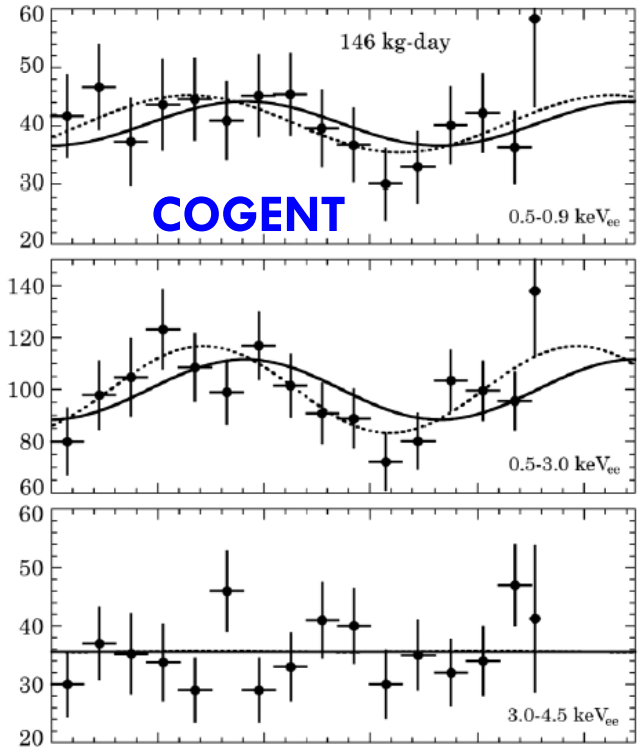
SD cross section limit

Annual Modulation Signals are (de)claimed.

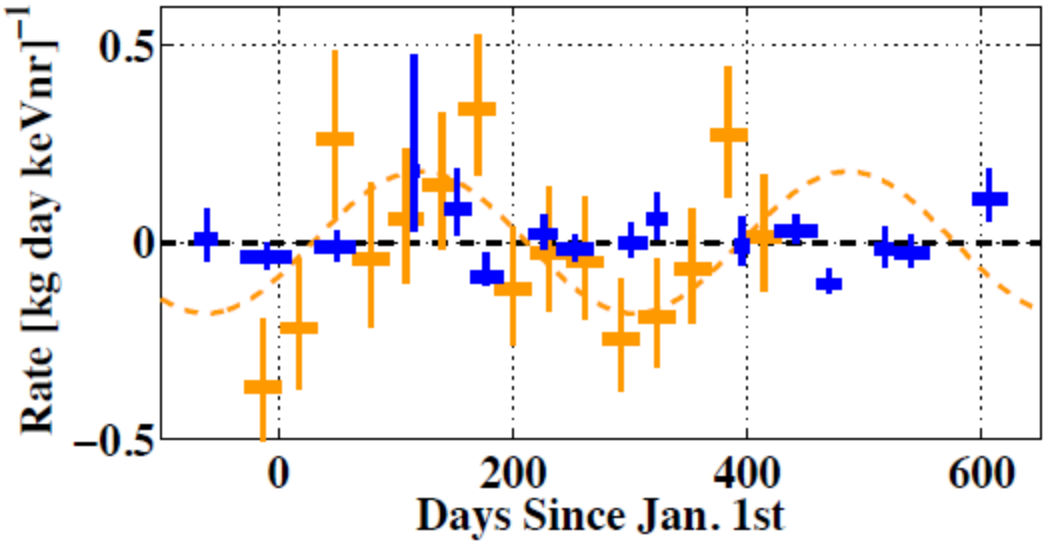


DAMA

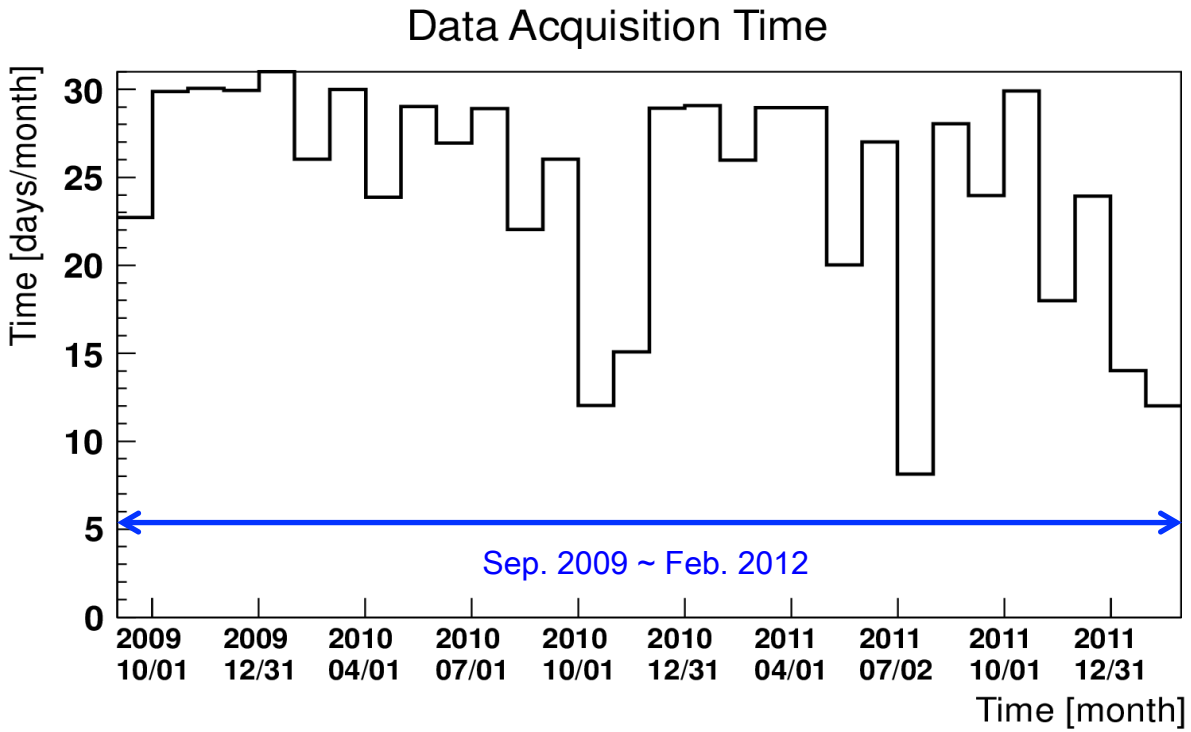




CDMS didn't see annual modulation.
arXiv:1203.1309

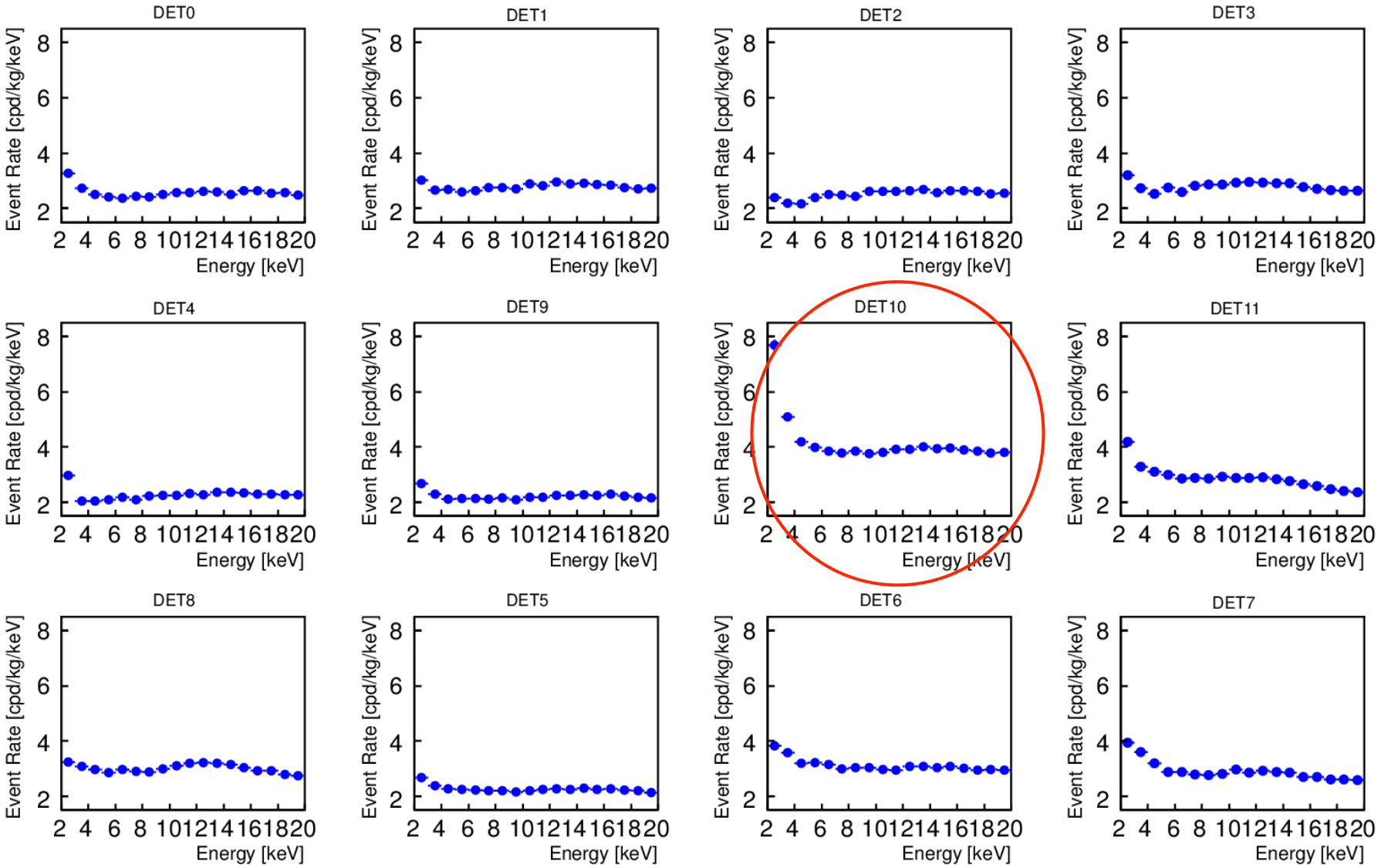


Annual Modulation Studies (w/o PSD)



- **Total DAQ rate is under 6Hz .**
- **2.5 year data to see annual modulation ; 75.53 ton·days**
- **The temperature of detector array is 20 - 21.6 ^{O}C depending on the position, and it is maintained stably with a maximum fluctuation of around 0.2 ^{O}C.**

Energy spectra w/ efficiency correction



Analysis was done by 11 detector except DET10 because of higher background rate

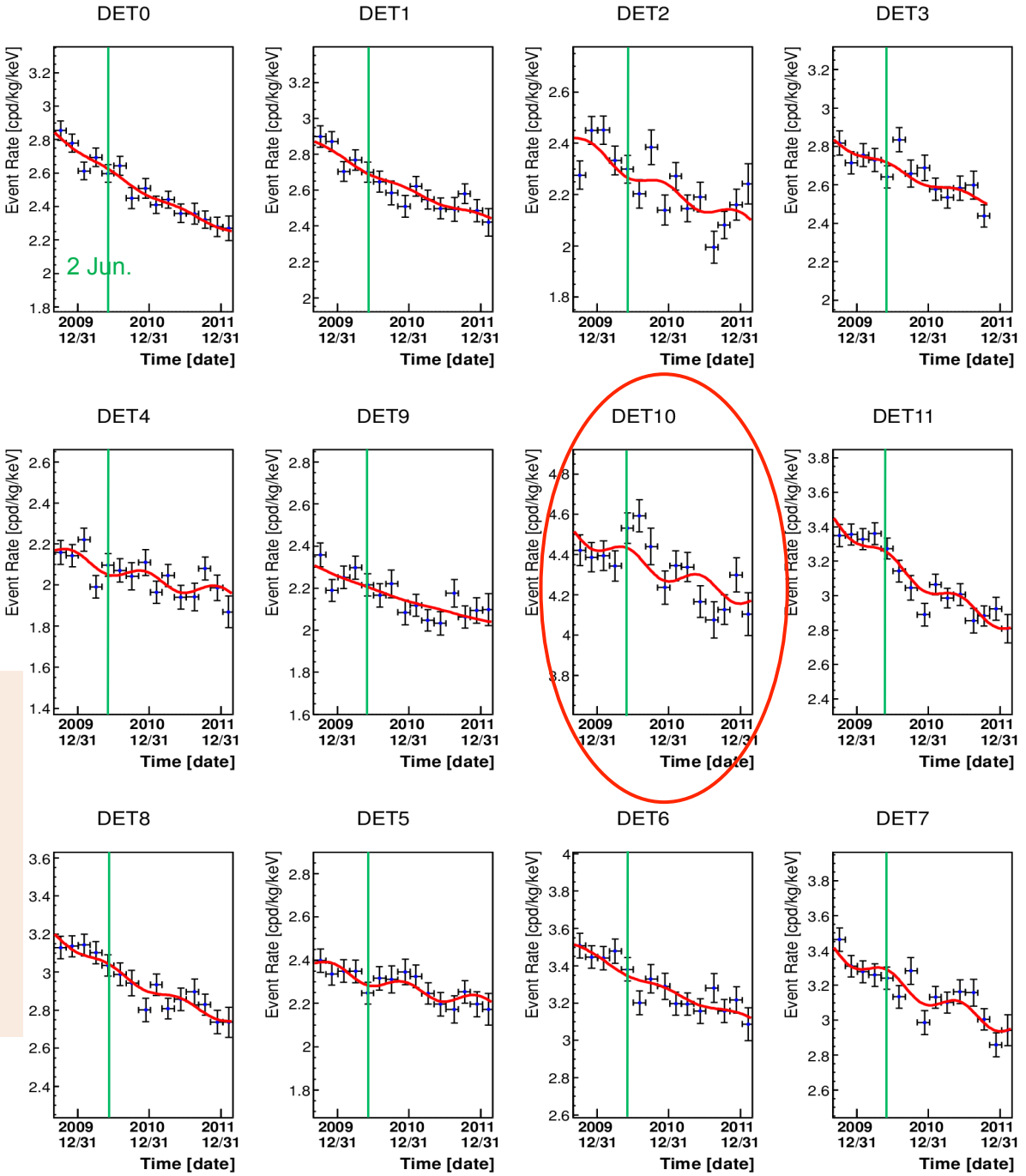
3-6 keV

$$R = A_{decay} e^{-\frac{t-t_0}{\tau}} + bkg + A\cos\frac{2\pi}{365}(t - t_{peak})$$

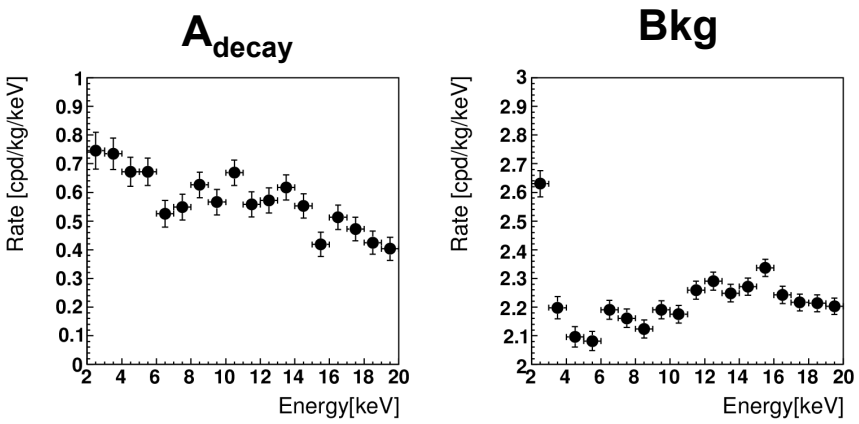
$$\tau = 2.980\,y,$$

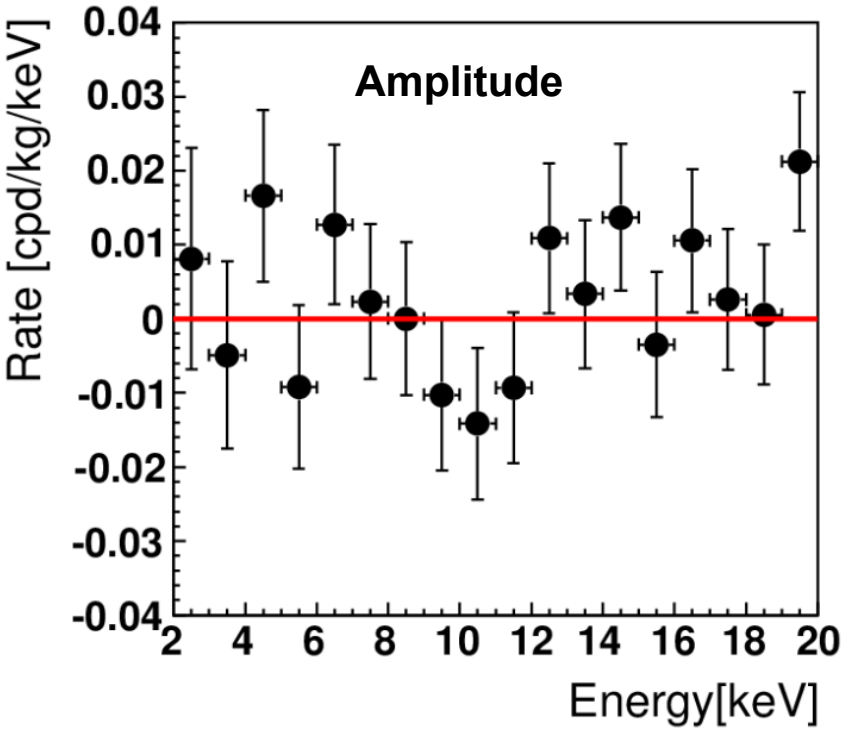
$$t_{peak} = 153(\text{June } 2)$$

- **Annual modulation amplitude is obtained including the exponential decay of ^{134}Cs.**
- **The mean amplitude from 3 keV to 6 keV is 0.0008±0.0068 cpd/kg/keV**



Fit results of 11 crystals (1 keV energy bin)





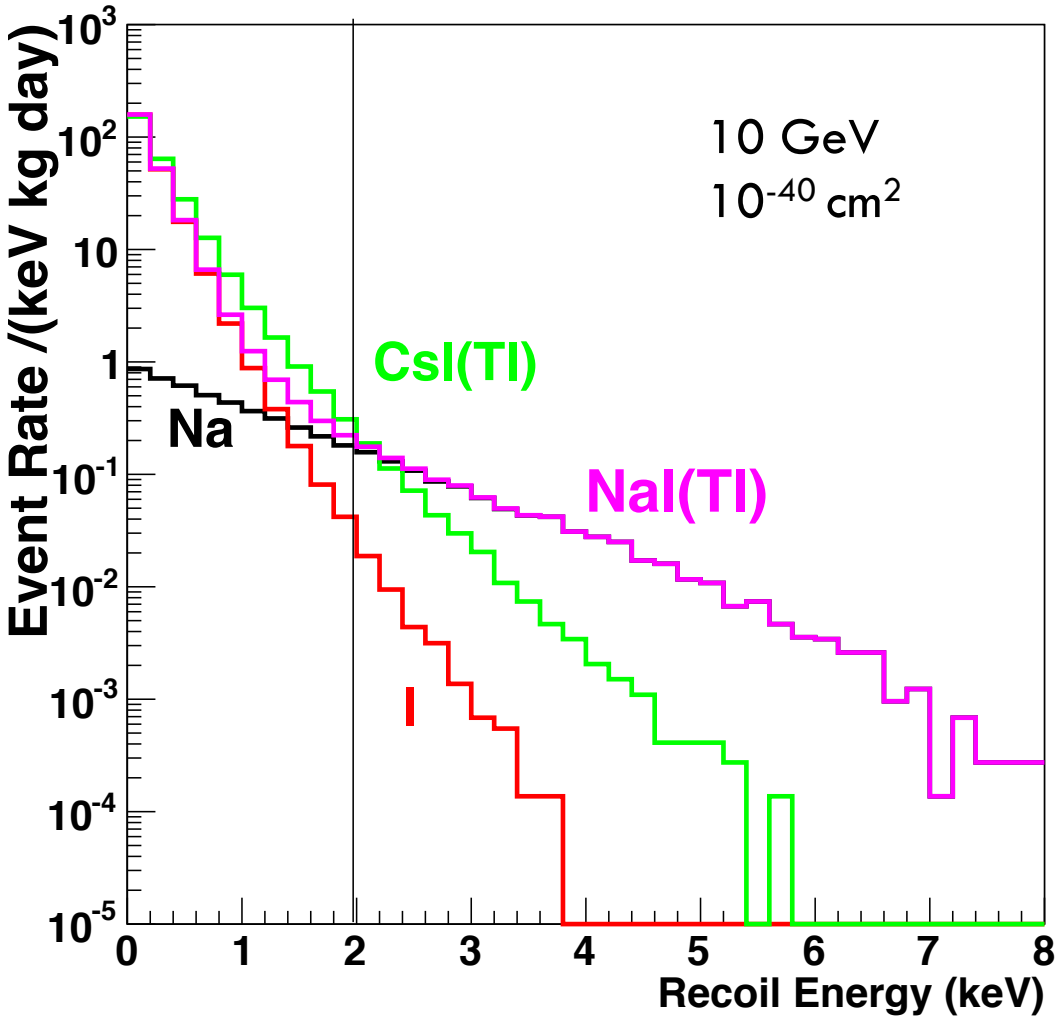
- A_{decay} is consistent with the beta spectrum of ^{134}Cs.
- The background rate of 2 ke V bin is relatively higher tha n other energy bins.
- The amplitude of annual mo dulation is consistent with N ULL.

Comparison with DAMA

Energy interval (keV)	DAMA/LIBRA (cpd/kg/keV)	DAMA/NaI & DAMA/LIBRA (cpd/kg/keV)
2–4	$A = (0.0170 \pm 0.0024)$	$A = (0.0183 \pm 0.0022)$
	$\chi^2/\text{d.o.f.} = 41.0/42$	$\chi^2/\text{d.o.f.} = 75.7/79 \rightarrow 8.3\sigma$ C.L.
2–5	$A = (0.0129 \pm 0.0018)$	$A = (0.0144 \pm 0.0016)$
	$\chi^2/\text{d.o.f.} = 30.7/42$	$\chi^2/\text{d.o.f.} = 56.6/79 \rightarrow 9.0\sigma$ C.L.
2–6	$A = (0.0097 \pm 0.0015)$	$A = (0.0114 \pm 0.0013)$
	$\chi^2/\text{d.o.f.} = 24.1/42$	$\chi^2/\text{d.o.f.} = 64.7/79 \rightarrow 8.8\sigma$ C.L.

- **2~4 keV of DAMA == 3.6~5.8 keV of KIMS.**
- **KIMS : Amplitude = 0.0008±0.0068 cpd/kg/keV (1σ; 3~6 keV)**
  - **→ Amplitude < 0.0119 cpd/kg/keV with 90% confidence level.**
  - **→ inconsistent with DAMA for modulation due to iodine.**

Low energy WIMP sensitivity of CsI(Tl)



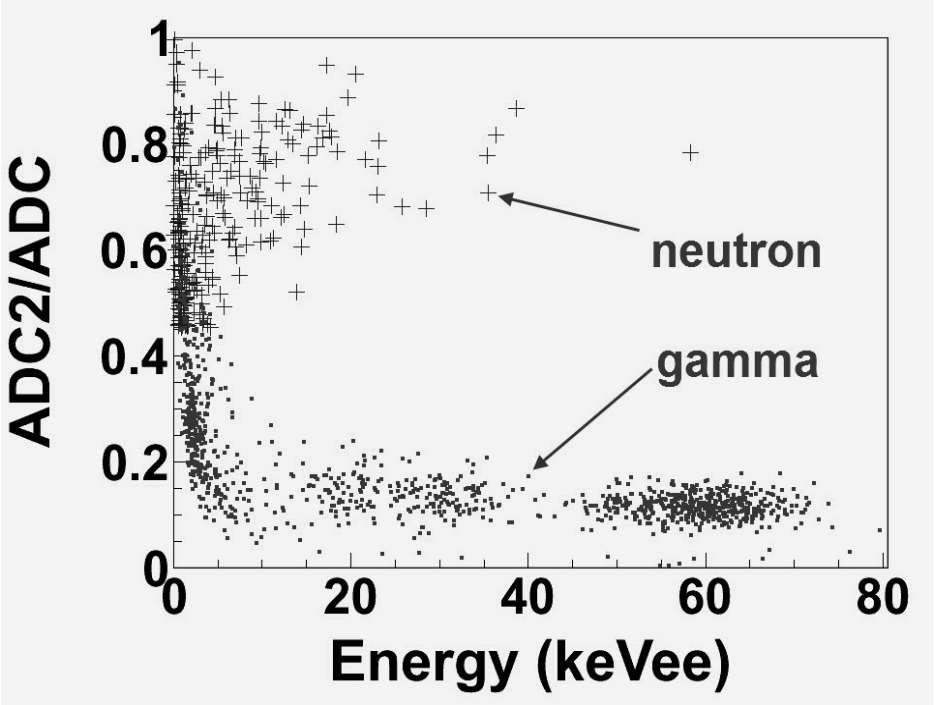
Due to the higher quenching fa ctor of I in CsI(Tl) than NaI(Tl), CsI(Tl) data has a sensitivity of low mass WIMP at the level o f DAMA data.

CsI(Na) : Strong PSD is claimed by Sun et al.

Very strong PSD power of CsI(Na) crystal is claimed by Sun et al., Nuclear Recoils are faster and well separated from slow gamma signals.

Define: ADC is the integration of the slow component 2us
ADC2 is the integration of the fast component 100ns

NIMA 642, 52 (2011)



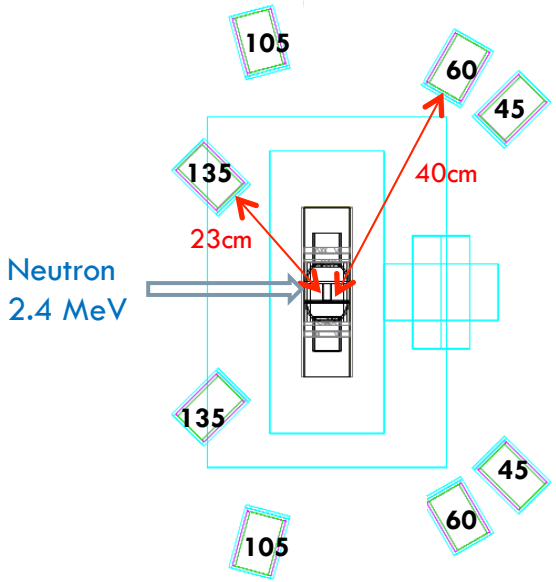
Scatter plot of ADC2/ADC versus energy for n and γ. Dot is γ-ray fro m ^{241}Am and plus is neutron

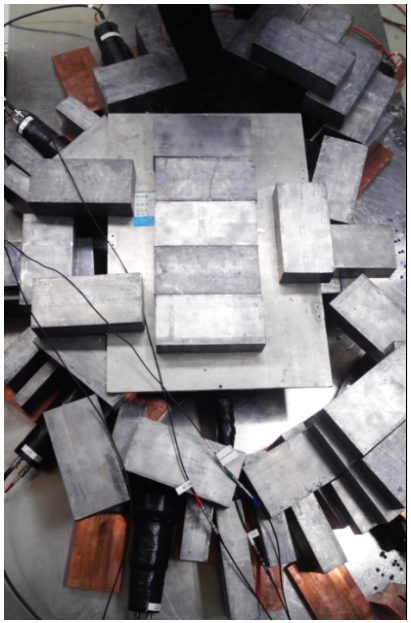
CsI(Na) nuclear recoil measurements at KIMS

- CsI(Na) – 0.019 mole% of Na^+ doping
- PMTs – 9269QA Green Extended.
- DAQ module – 10 bit, 400 MHz ADC with X100 preAmp.
- Energy calibration
  - ^{241}Am gammas, 59.54 keV, ^{55}Fe x-rays, 5.9 keV
  - Trigger : 2 μs width coincidence for >1 p.e. of each PMT
    200 ns width pulse for one of the PMTs
- Surface control
  - Grinding and polishing in the glove box w/ N_2 gas
  - Sometimes coting with BC600 or OP305 (~500 μm thickness)
- Neutron source.
  - 2.4 MeV neutrons from d-d collisions
  - For 10.9, 18.5, 45.7 and 62.9 keVnr
  - Trigger : 2μs width coincidence btw. trigger outs from CsI(Na) and a neutron detector (> 1 p.e.)

Nuclear recoil measured with neutron gun

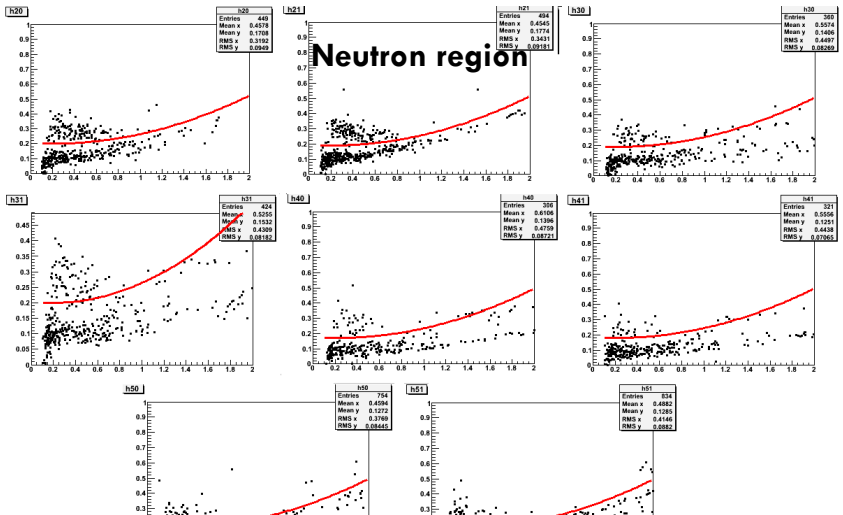
- Setup



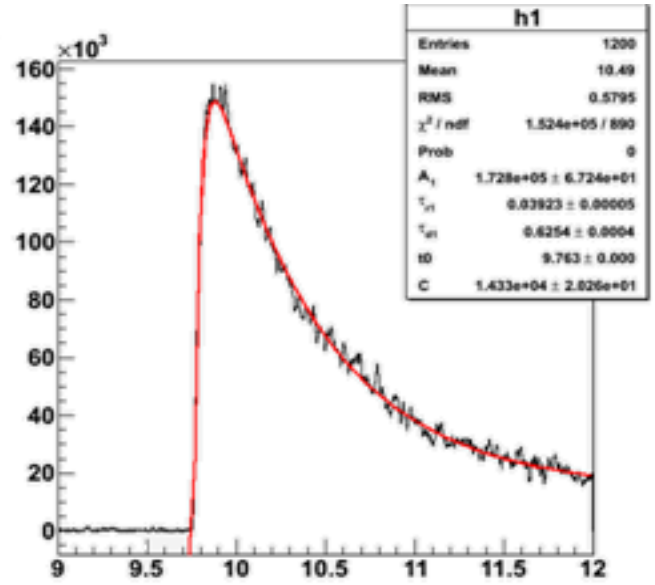


- Neutron detectors' PSD

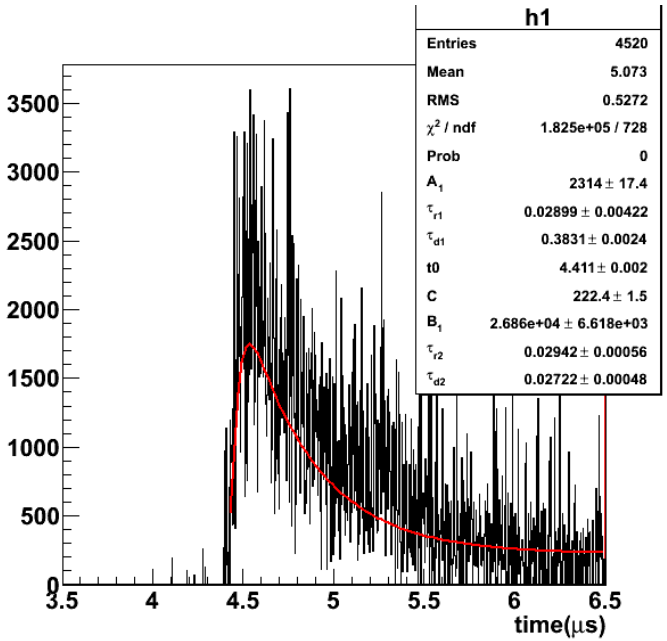
Accumulated Event shapes



Accumulated Event Shapes



Gammas : ^{241}Am ~ 30 keV

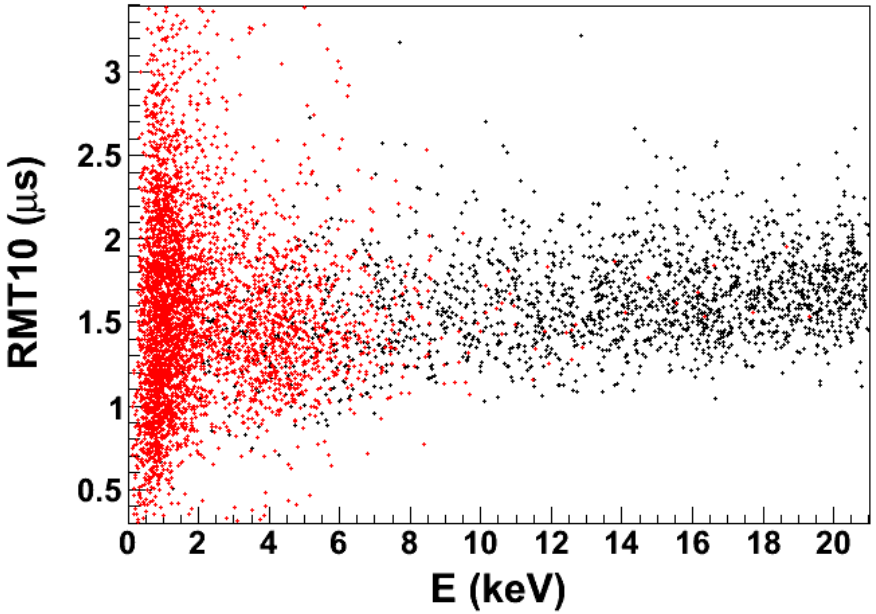


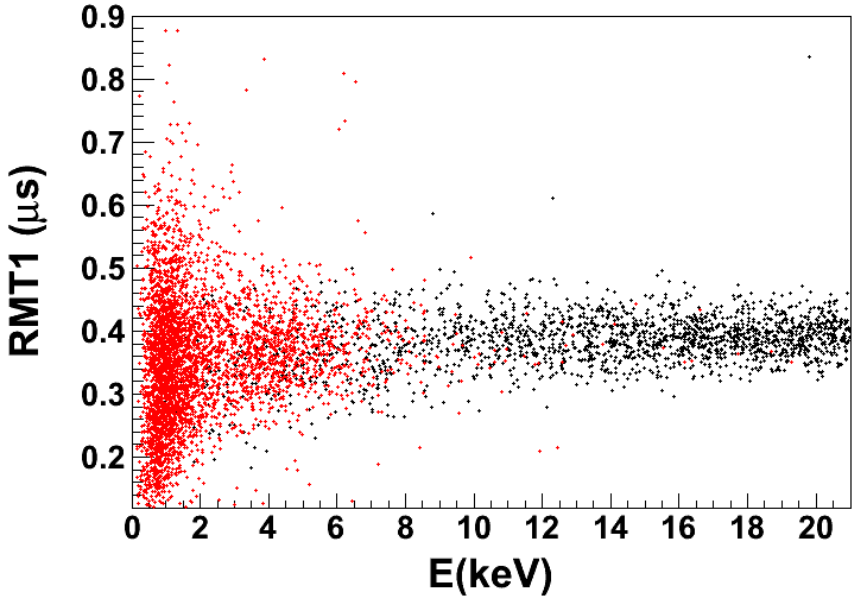
Nuclear Recoil from neutron scattering ~ 4keV

→ We didn't observe large diffe rence between electron and nucl ear recoil signals.

Comparison

- The scintillation decay time from nuclear recoil and electron recoil a re not much different.
- Surface events are much faster and peaked at the start of event.





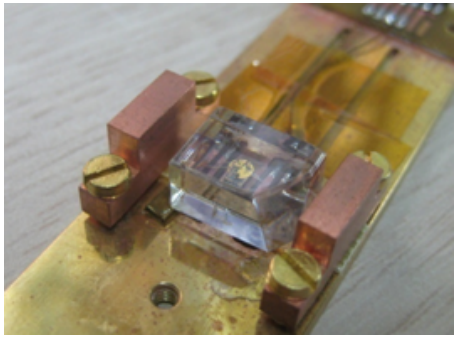
Nuclear recoils

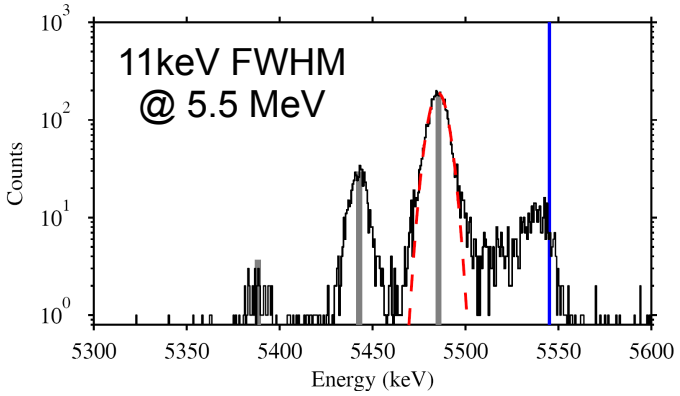
Electron recoils

Scintillating Bolometer with Molybdate crystal

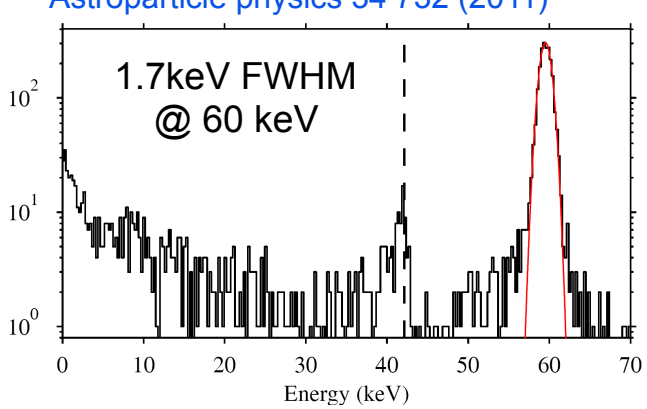
AMoRE(Advanced Mo based Rare process Experiment) for neutrinoless double bet a decay using molybdate crystal, such as CaMoO4, is proposed.

<0.6 cm^3>



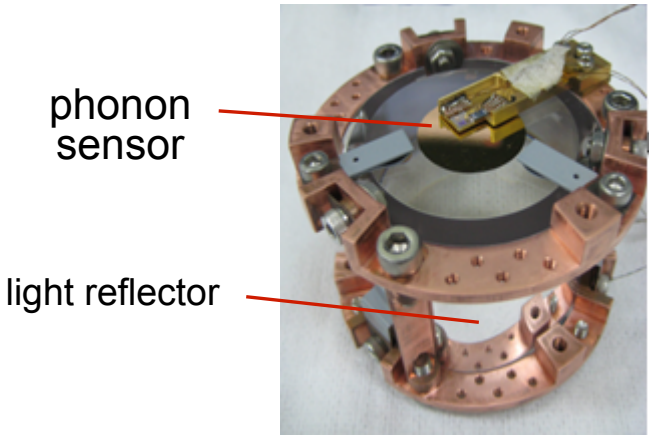


Astroparticle physics 34 732 (2011)

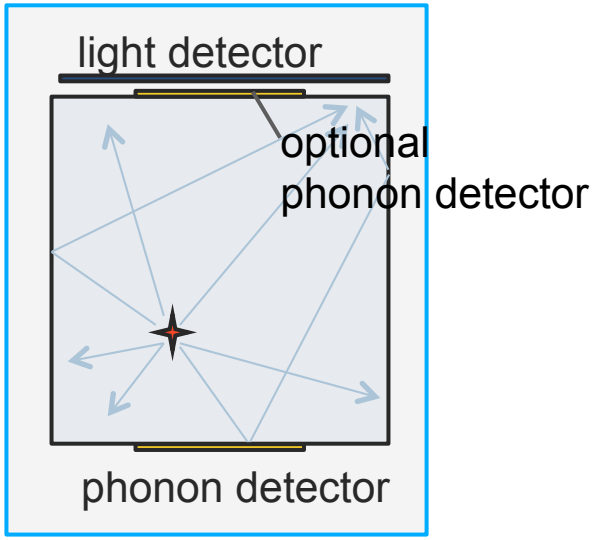


- **Production of AMoRE detectors**

  - 400 cells with 0.5 kg CMO

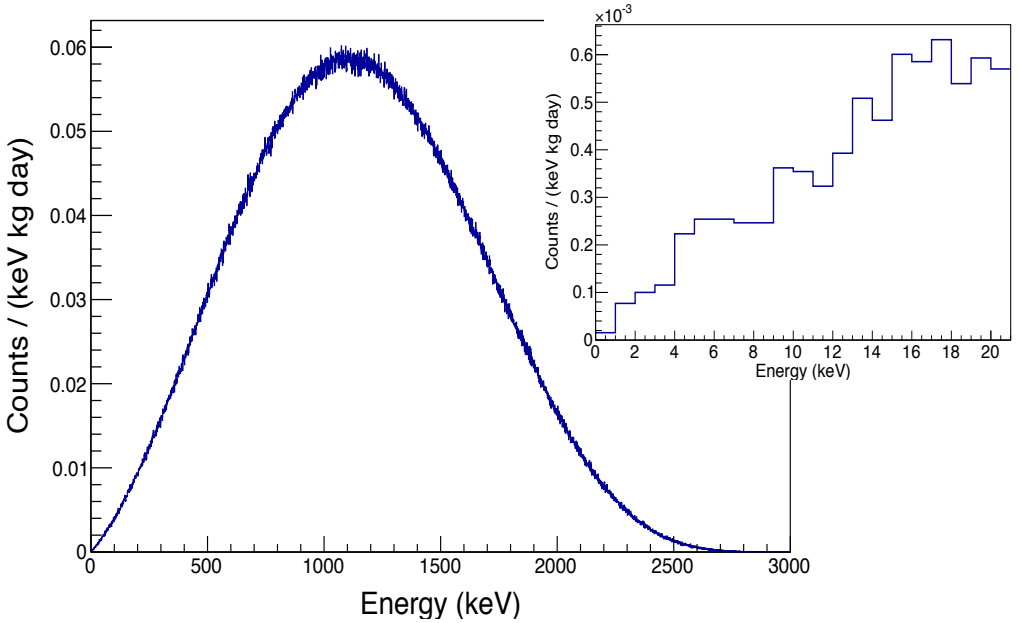


<Detector cell>

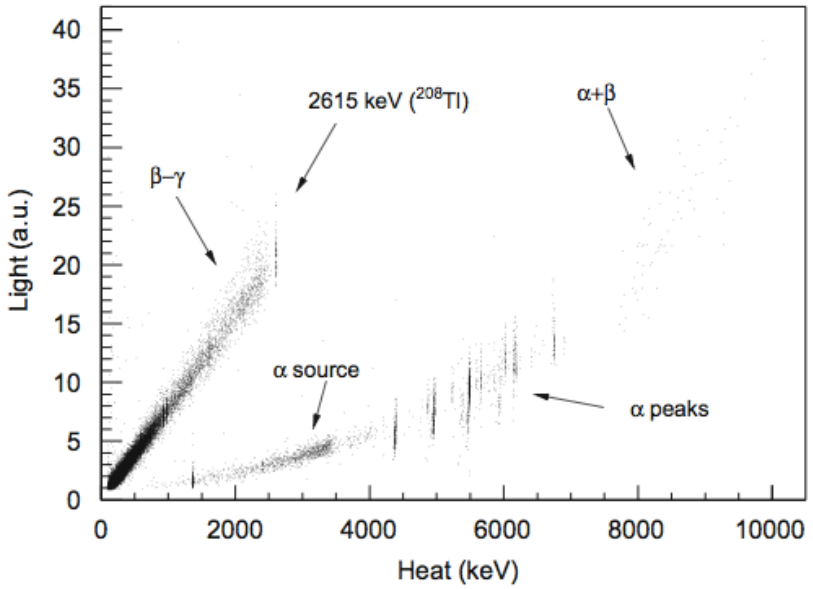


Backgrounds for AMoRE-DARK

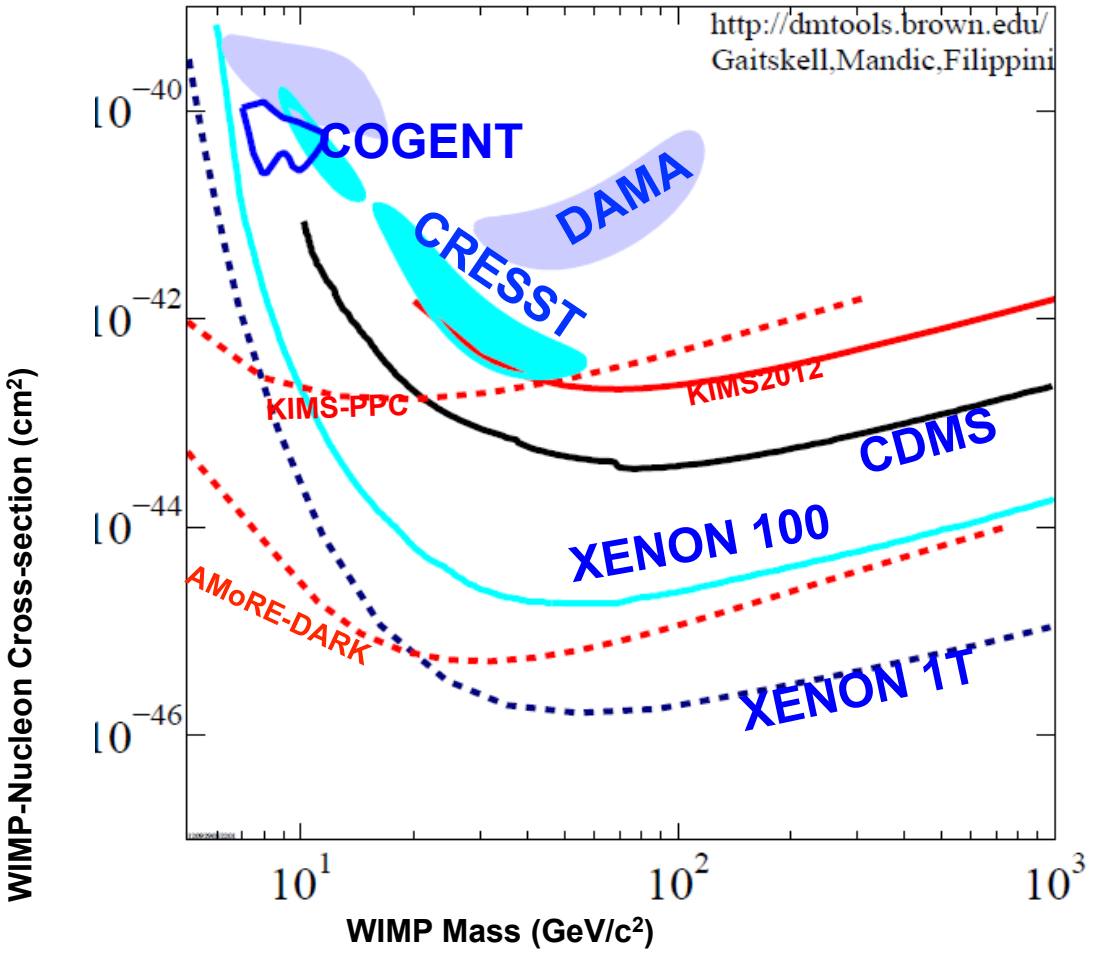
Natural CaMoO4 crystal in Bolometer can be used for Dark Matter Search.
^{100}Mo two neutrino decay will produce backgrounds ~ 0.0001 dru.

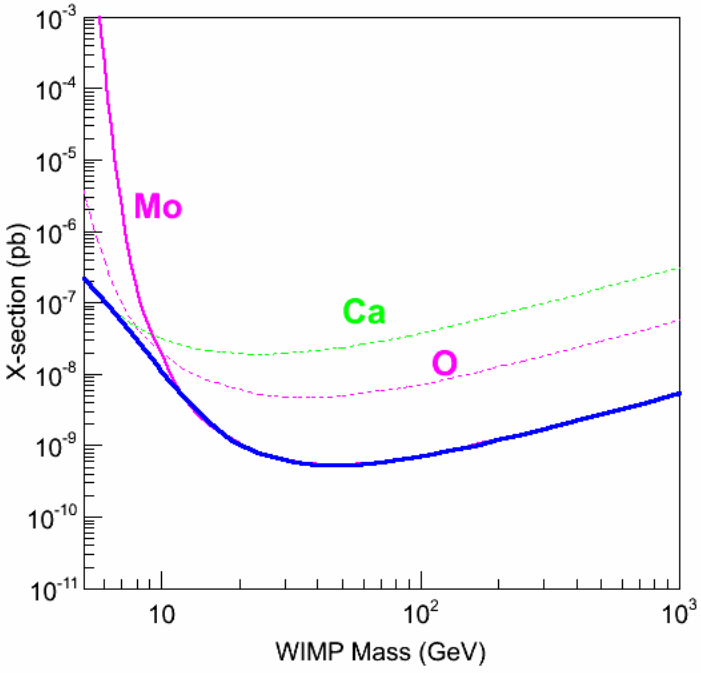


Gironi, NIMA 617, 478 (2010)



Sensitivity of CaMoO4 bolometer





10^{-5} /(keV kg day) with light sensor

5 keV threshold.

R&D on Low-background NaI(Tl) crystal

Crystal	Exp.	U (ppt)	Th (ppt)	K (ppb)	Background Level (/keV kg day)
NaI	DAMA	2-10	1-6	~ 20	
	LIBRA	0.7-10	0.5-7.5	13	
	ANAIS			400	>10
CsI	KIMS	0.75	0.38	<10	~3

- It is possible to add several NaI(Tl) crystals to KIMS.
- New low-K NaI crystal is under R&D (DM-ICE and KIMS).
- Trials with (HR)ICP-MASS failed.
- Single (~8kg) NaI crystal will be grown with new ultra-pure powder (K<10ppb) coupled with HPGe to confirm the low K contents.

Summary

- 2.5 year data is analyzed without PSD for annual modulation → Null modulation amplitude < 0.0119 cpd/kg/keV with 90% confidence level is inconsistent with DAMA's modulation amplitude due to Iodine.
- The proposed CsI(Na) PSD power is not confirmed.
- Upgrade plans with new NaI(Tl) experiments in South Pole and Y2L at the same time are promising.
- AMoRE-DARK plan for low mass WIMP.