THE STATUS OF KIMS
(KOREA INVISIBLE MASS SEARCH)

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ICHEP 2012, Melbourne

Yangyang(Y2L) Underground Laboratory

(Upper Dam)

Korea Middleland Power Co.
Yangyang Pumped Storage Power Plant

(Power Plant)

양양양수발전소

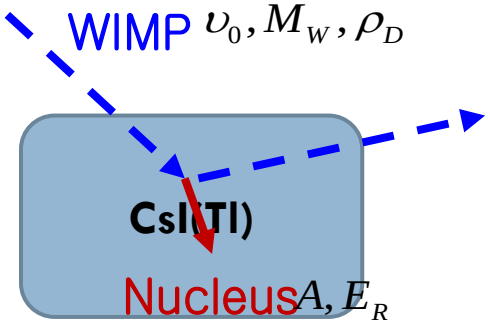
(Lower Dam

KIMS (Dark Matter Search)

AMoRE (Double Beta Decay Experiment)

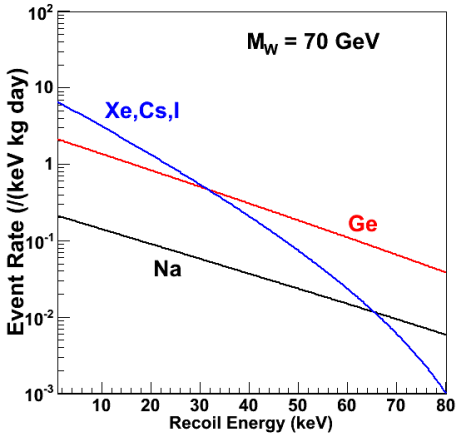
Minimum depth : 700 m / Access to the lab by car (~2km)

KIMS overview



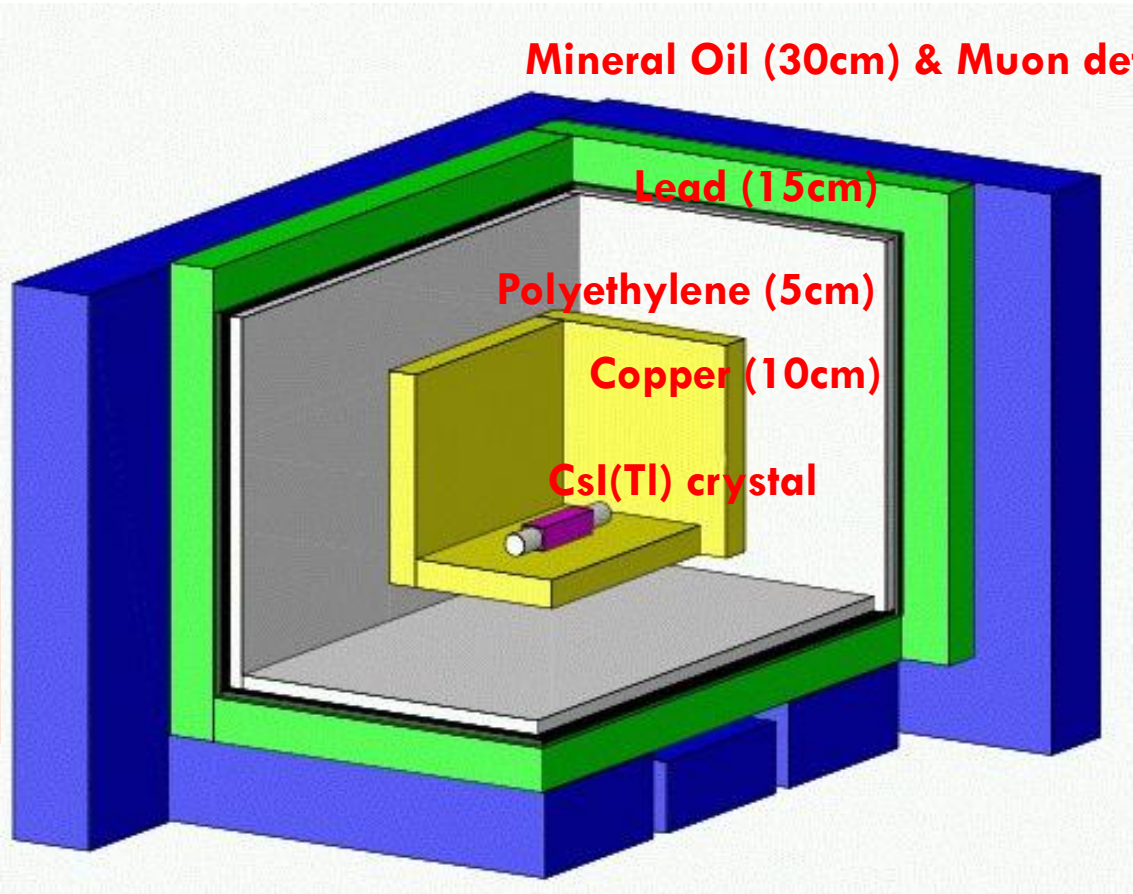
WIMP–Nucleus elastic scattering

- **Similar experiment to DAMA.**
- **Direct comparison to DAMA annual modulation signal is possible. Iodine is common to both exp.**



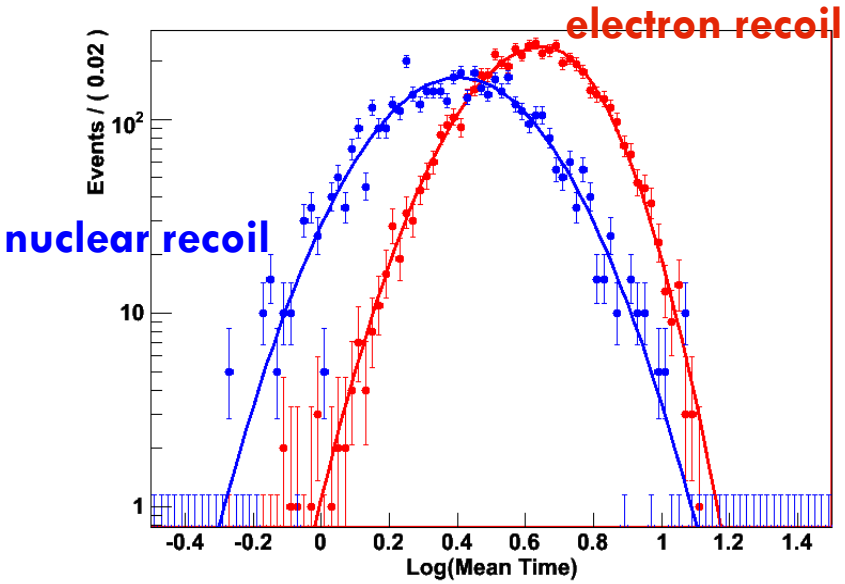
CsI(Tl) Crystal 8x8x30 cm^3

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



Characteristics of CsI(Tl) for WIMP Search

- High light yield ~5 photoelectrons/keV
  Pulse shape discrimination (PSD) ➔ Background discrimination.
- ^{133}Cs, ^{127}I (SI cross section ~ A^2)
  Both ^{133}Cs, ^{127}I are sensitive to SD interaction
- Notorious ^{137}Cs contaminations are controlled. (not dominant background anymore !) – Ultrapure CsI powders are developed and available from Chemetall company.

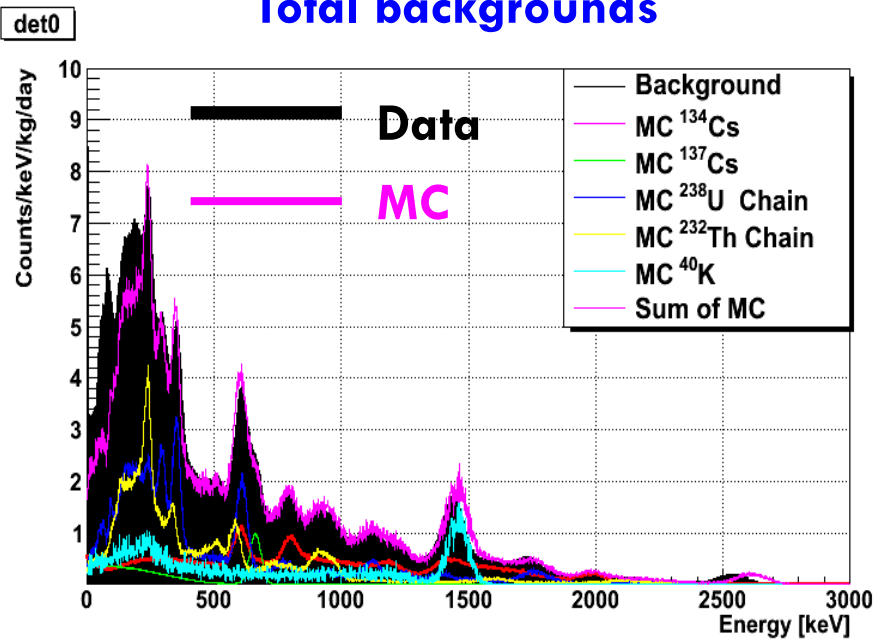


Isotope	J	Abun	<Sp>	<Sn>
^{133}Cs	7/2	100%	-0.370	0.003
^{127}I	5/2	100%	0.309	0.075
^{73}Ge	9/2	7.8%	0.03	0.38
^{129}Xe	1/2	26%	0.028	0.359
^{131}Xe	3/2	21%	-0.009	-0.227

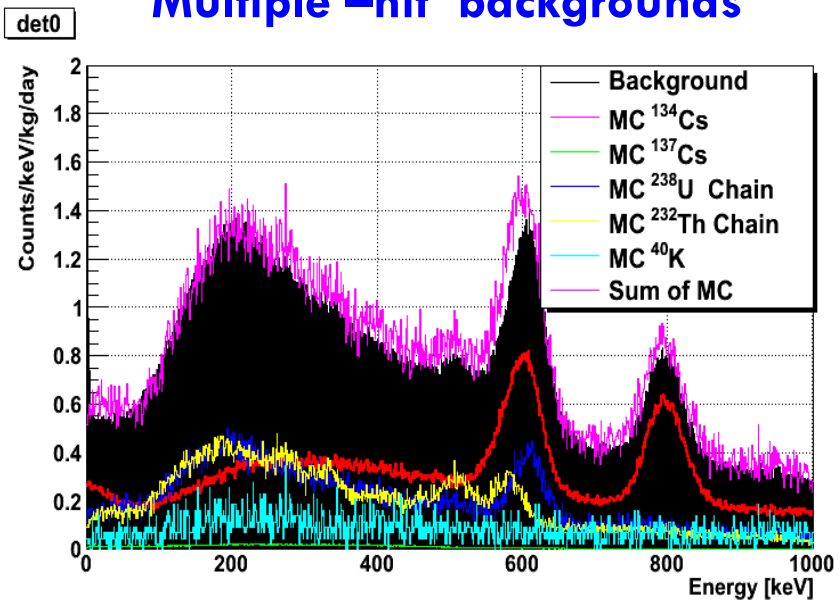
Data with 12 crystals

- 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



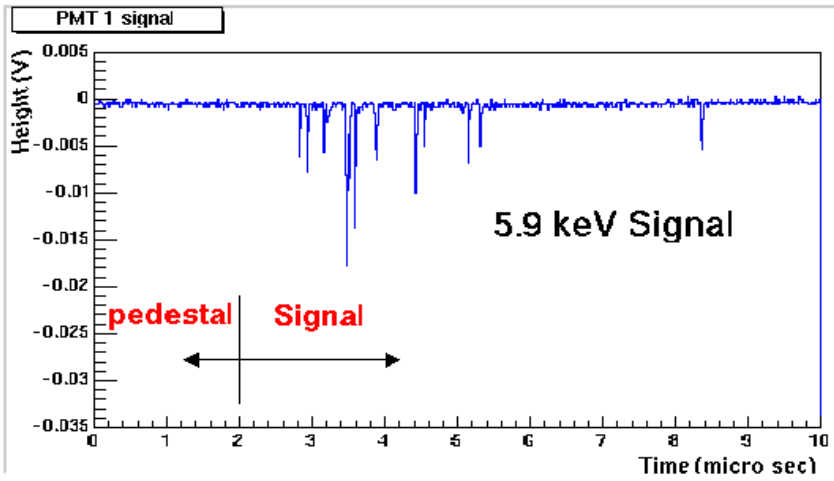
Multiple –hit backgrounds

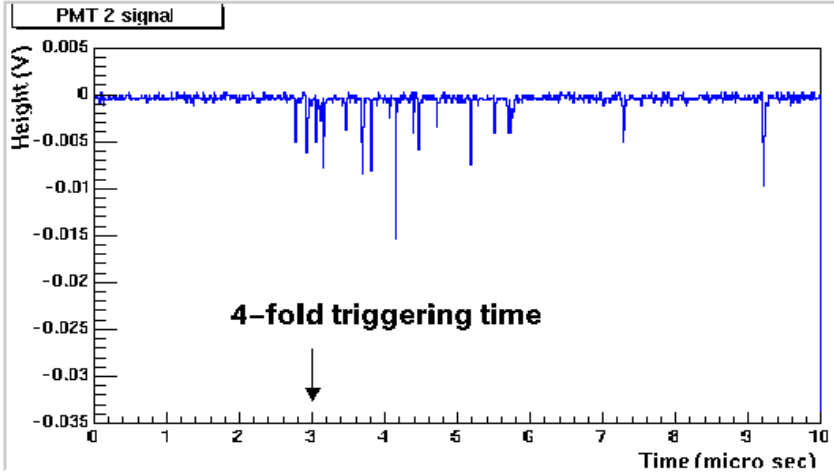


Analysis with PSD

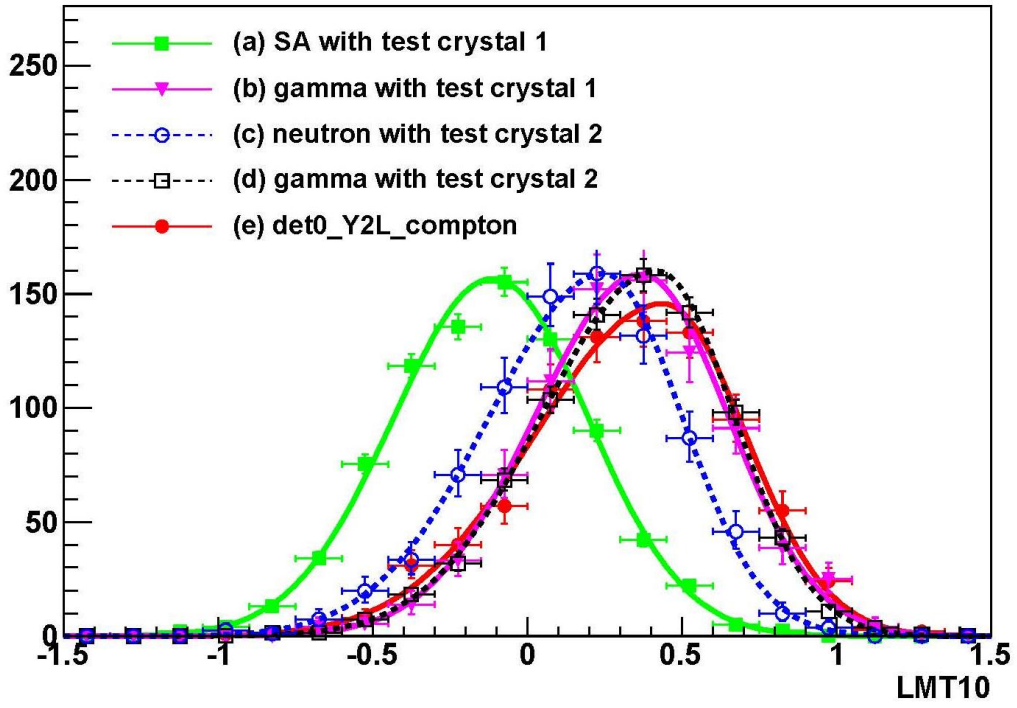
We calculate the mean time of FADC signal, and take logarithm of it.

$$\langle t \rangle = \frac{\sum A_i t_i}{\sum A_i}, \quad \text{LMT10} = \log_e\left(\langle t \rangle\right)$$



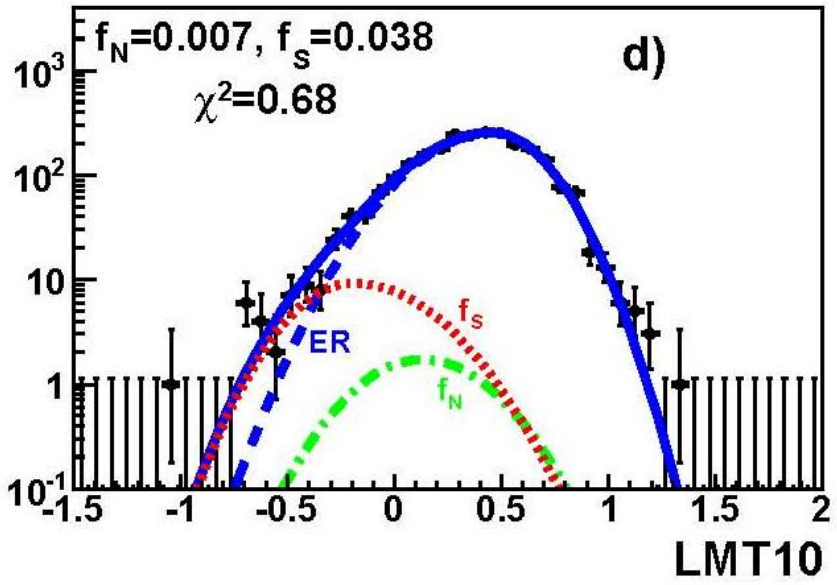


Our PSD parameter



Limits on nuclear recoil rates

$$Pdf = f0 \times F_{NR} + f1 \times F_{SA} + (1-f0-f1) \times F_{gamma}$$



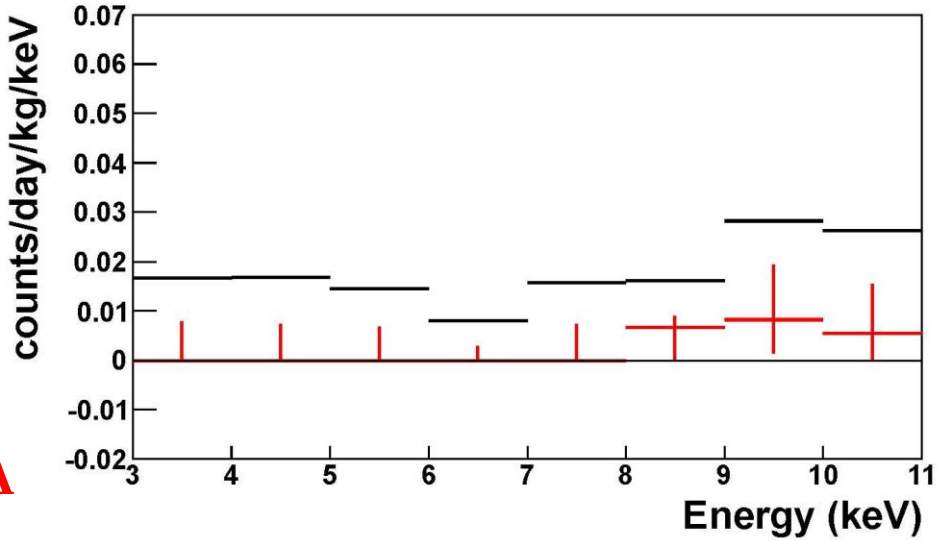
Bayesian method was used to estimate the NR rates.

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

Example : 6 keV bin, DET09

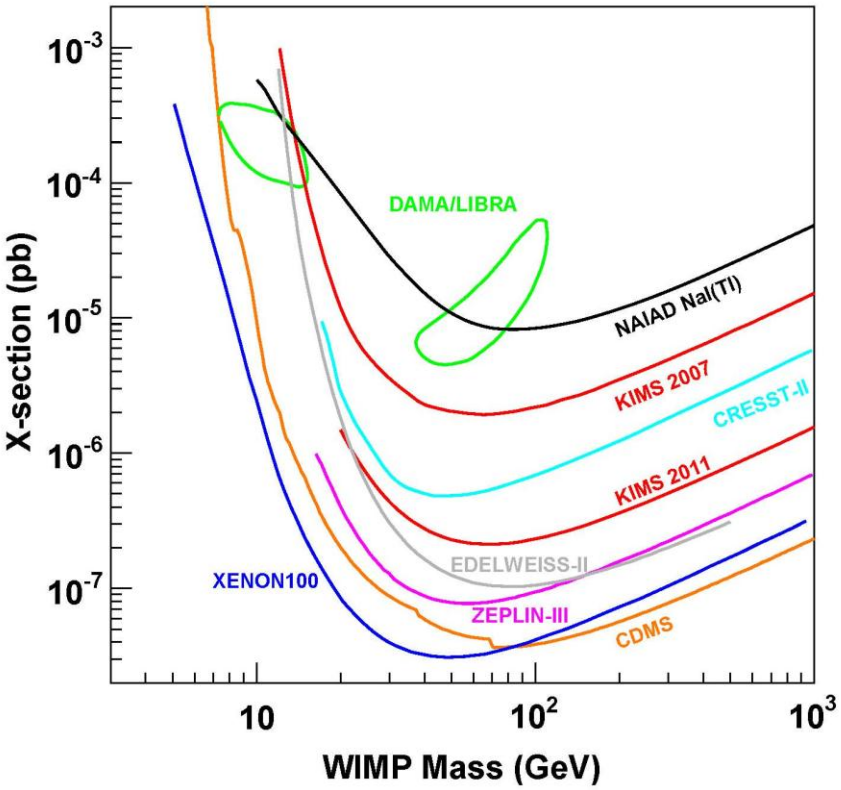
Total weighted limits for 1keV bin.
RED : 1 sigma limit
BLACK : 90% CL limit

3.6-5.8 keV (2-4 keV in DAMA)
90% CL limit is 0.0098 cpd/kg/keV
< 0.0183 cpd/kg/keV signal of DAMA

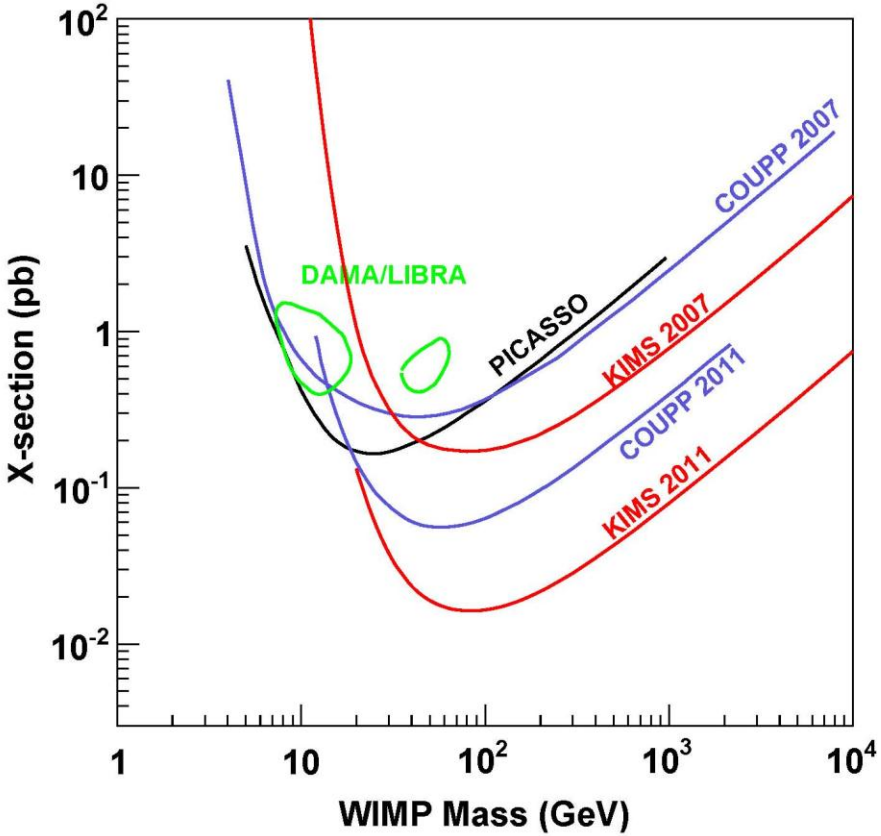


Cross Section Limits

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

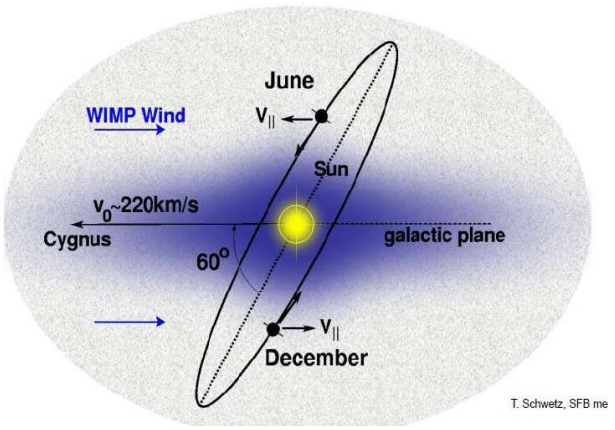


SI cross section limit

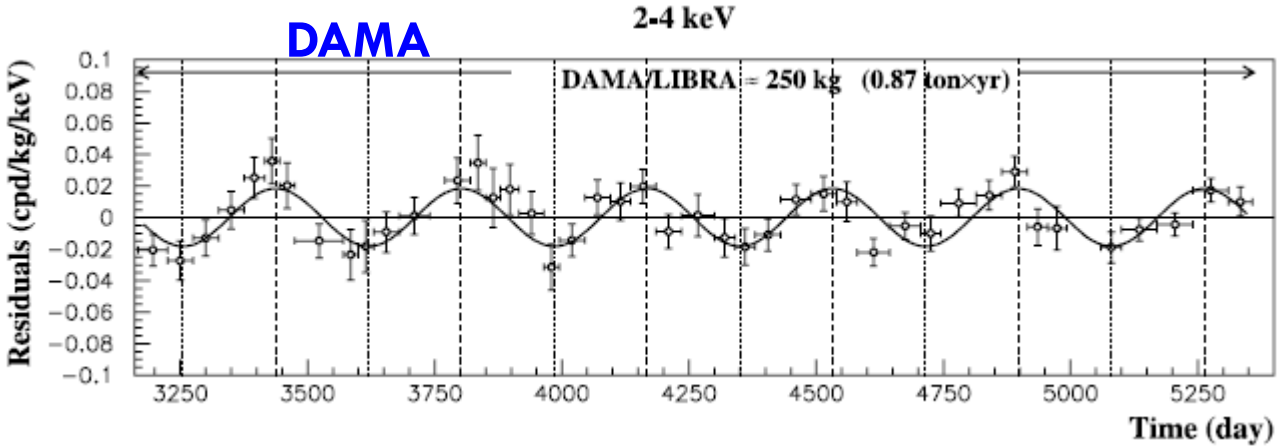


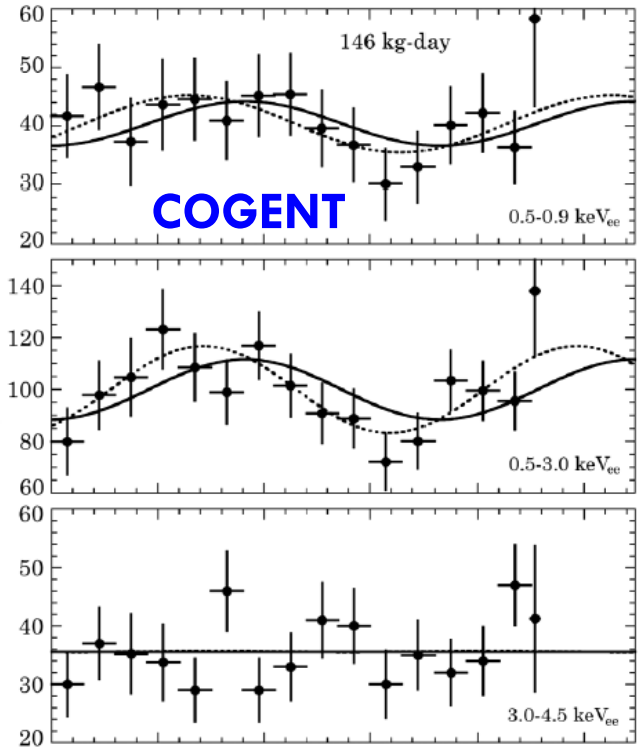
SD cross section limit

Annual Modulation Signals are (de)claimed.

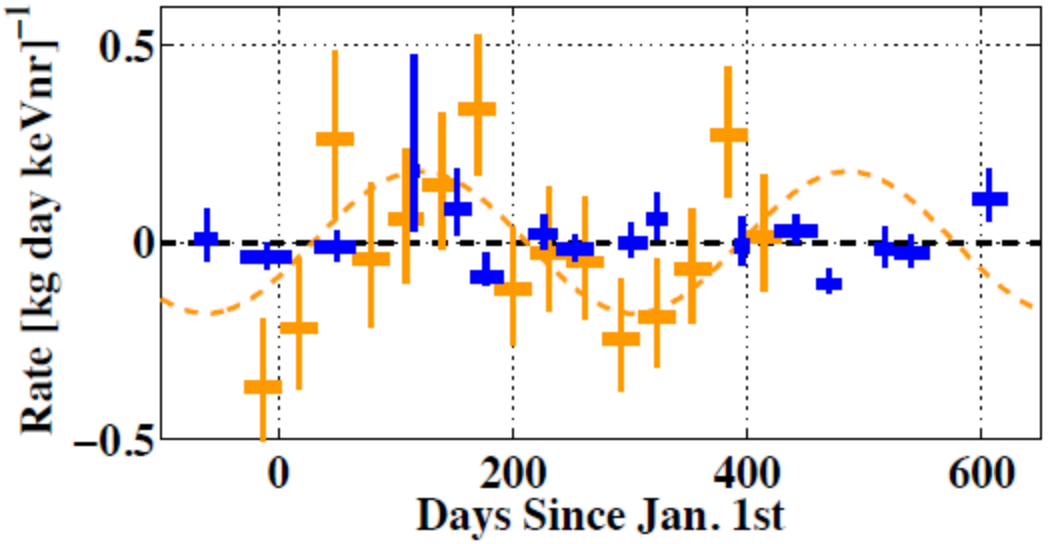


DAMA

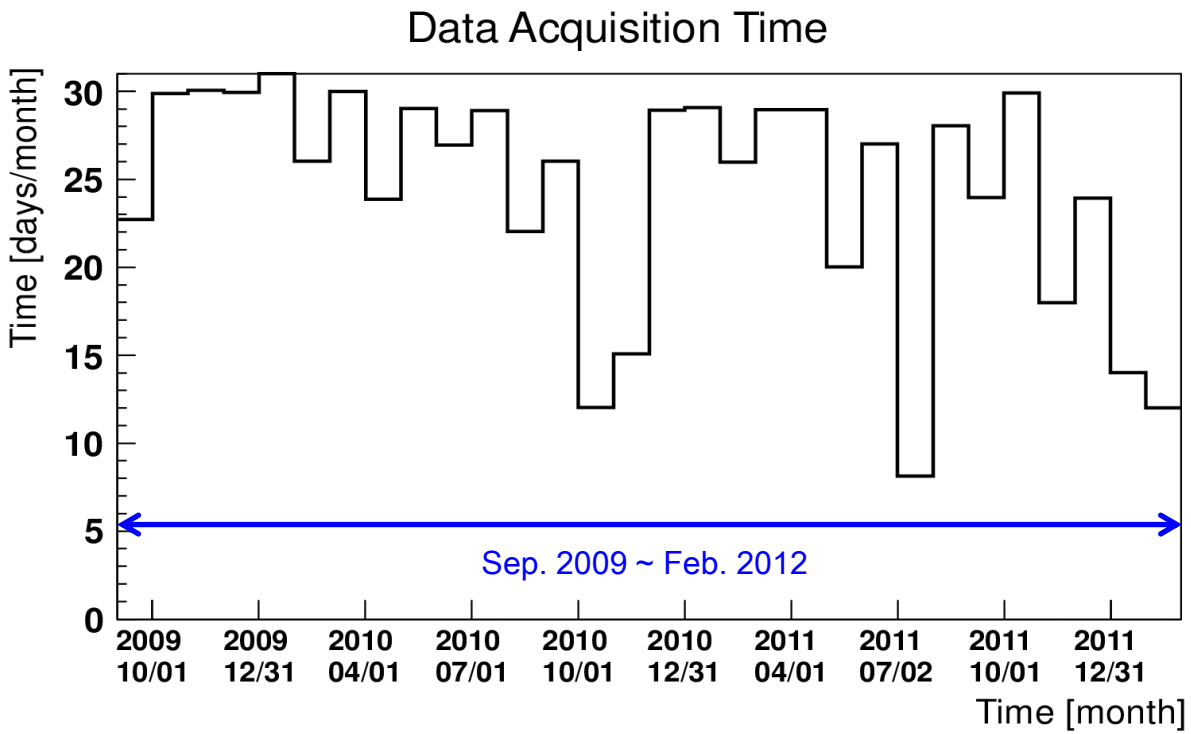




CDMS didn't see annual modulation.
arXiv:1203.1309



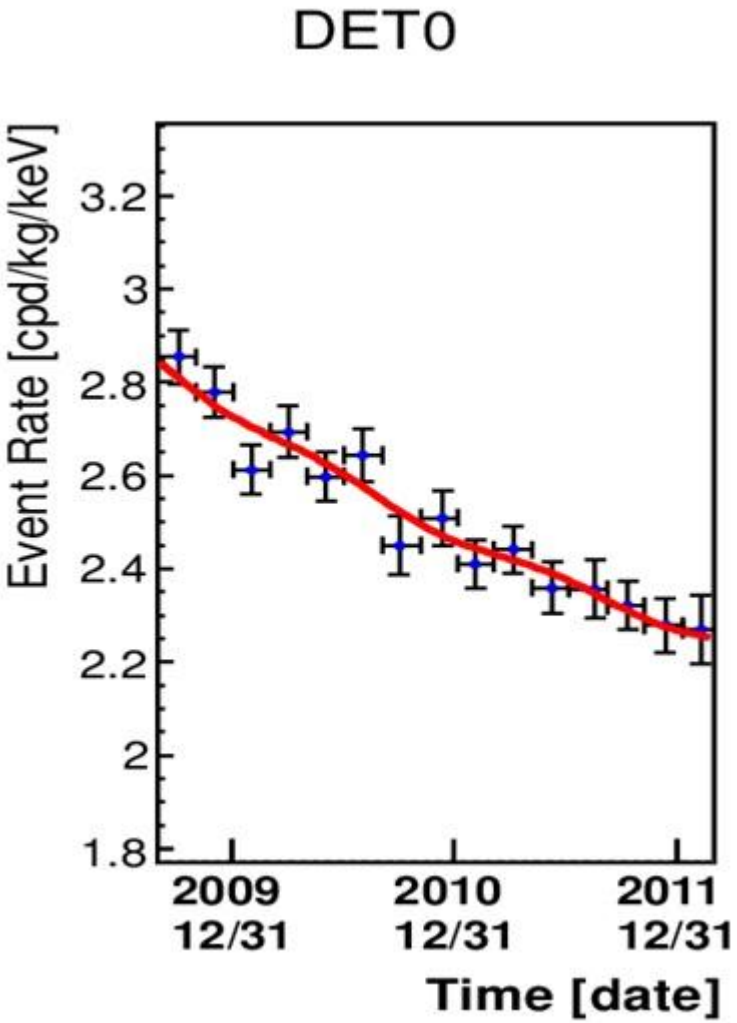
Annual Modulation Studies (w/o PSD)



- **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.**

3-6 keV

$$R = N_0 e^{-\frac{t-t_0}{\tau}} + b_0 + A\cos\frac{2\pi}{365}(t - t_{peak}), \quad \tau = 2.980y, \quad t_{peak} = 153(\text{June 2})$$



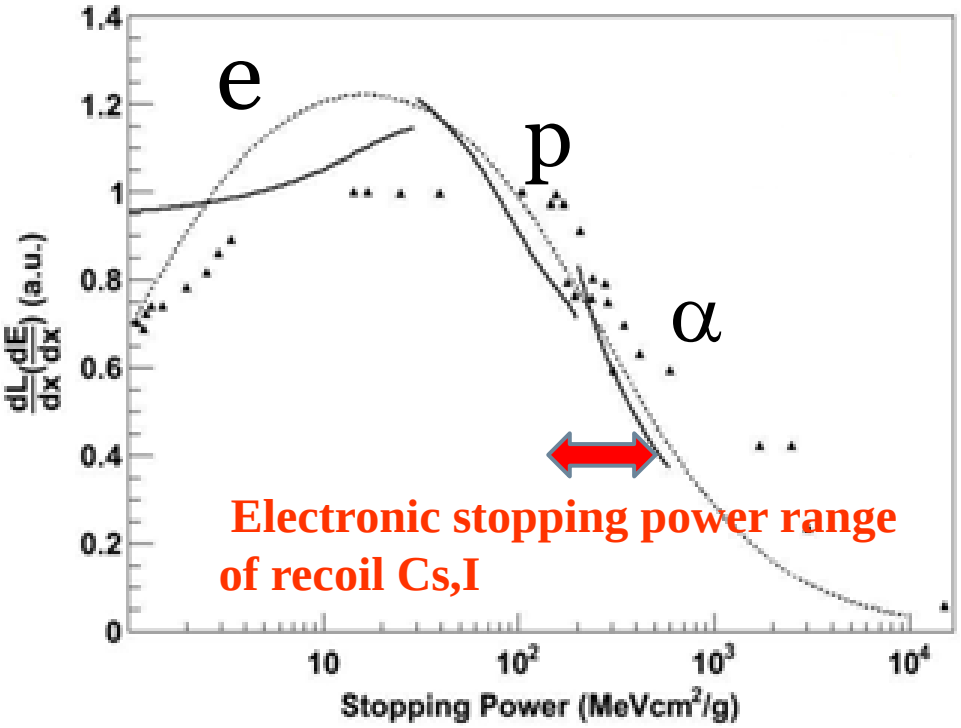
- **Annual modulation amplitude is obtained including the exponential decay of ^{134}Cs.**
- **Annual modulation amplitude is consistent with null.**
- **The 90% upper limit of the amplitude is comparable to DAMA's annual modulation signal (0.0189 cpd/kg/keV)**
- **We are trying to give final numbers shortly in this summer.**

Studies on Quenching

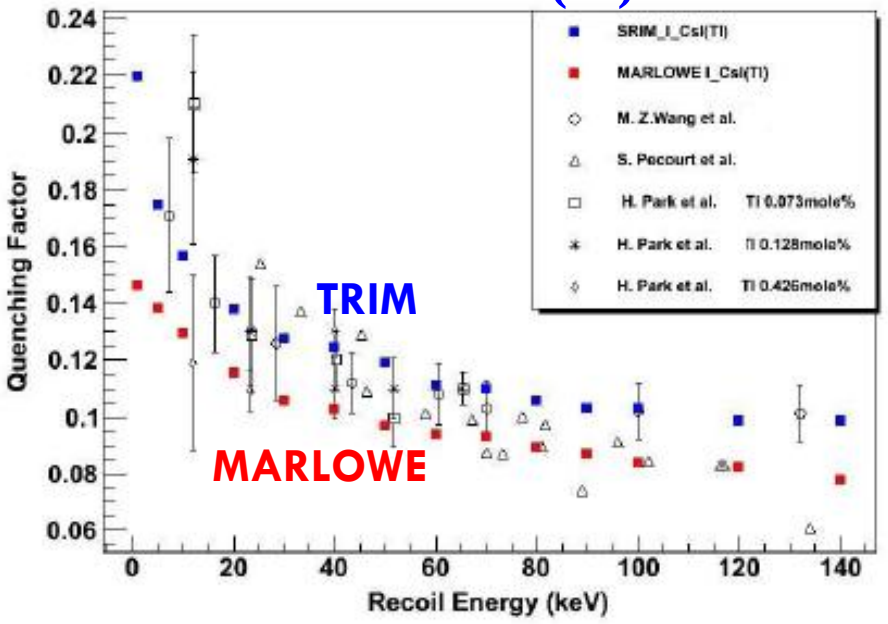
- Stopping power of ions : **TRIM, MARLOWE**
- Scintillation efficiency : measured with alphas.

Since electronic stopping power of WIMP nuclear recoil has similar values of alpha (electronic) stopping power, we can use these data. No parameter adjusted.

Recent claim of Chicago group on low quenching factor will be tested.



Cs/I in CsI(Tl)

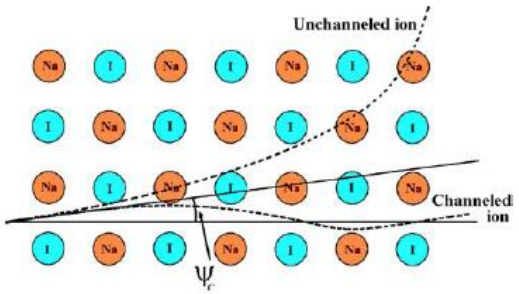


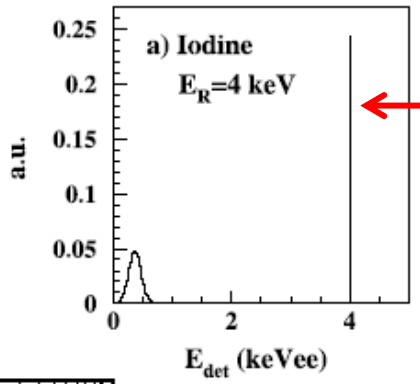
J.H. Lee IEEE (in print)

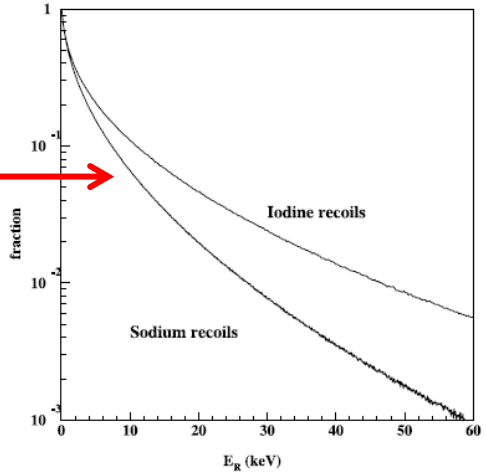
Studies on Channeling

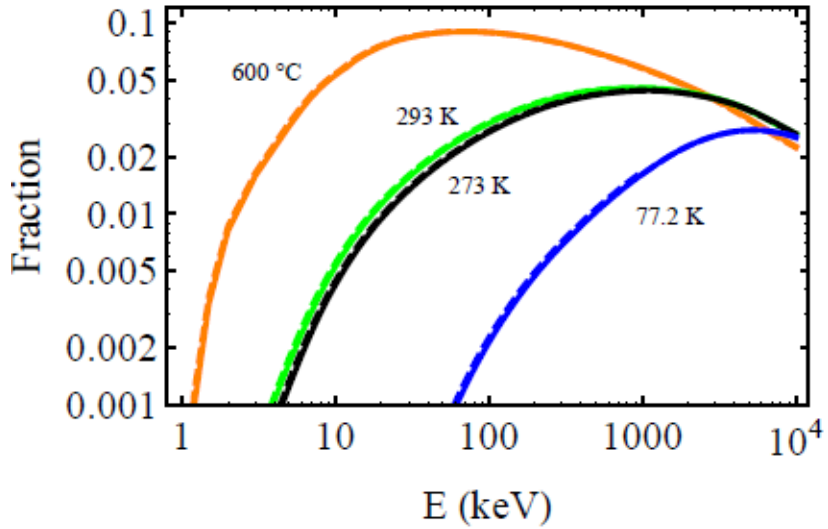
Motivated by DAMA's initial studies on channeling.

KIMS may lose some nuclear recoil events by PSD cut due to channeling effect -**Eur. Phys. J. C. 53, 205 (2008)**







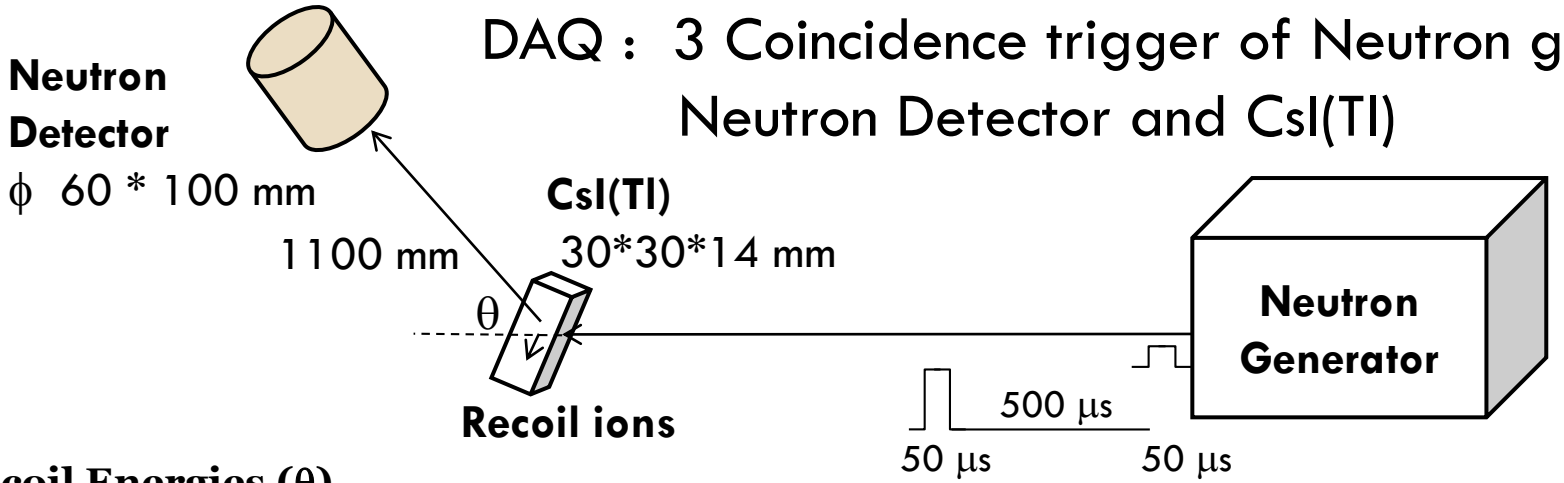


Bozorgnia et al., JCAP11, 029(2010)

Due to the blocking of recoil ions, channeling fraction in CsI(Tl) < 2%.

Experimental Setup

DAQ : 3 Coincidence trigger of Neutron generator, Neutron Detector and CsI(Tl)



Recoil Energies (θ)

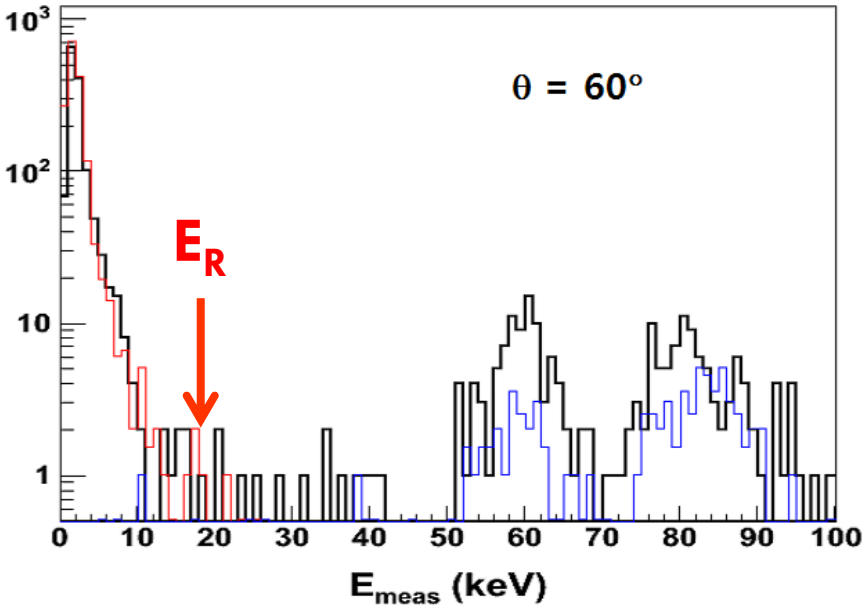
θ(°)	45	60	75	90	105	120	135
E_{recoil} (keV)	10.8	18.4	27.2	36.6	46	54.8	62.2

2.4 MeV Monoenergetic n

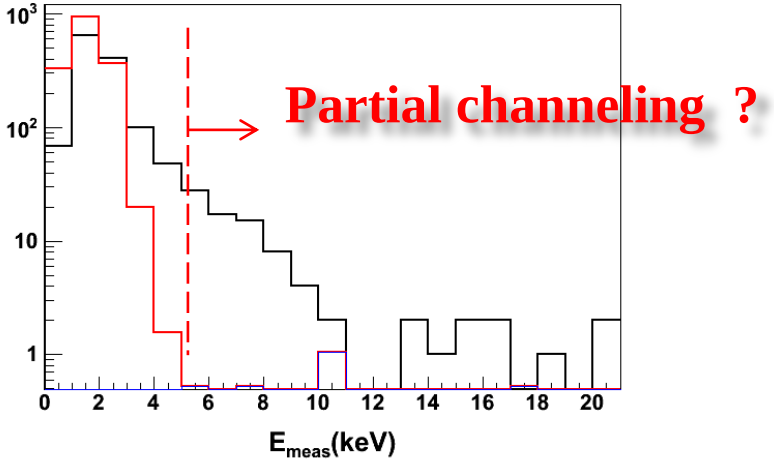
Figure 3.17: Neutron generator inside the shielding box

Simulation & Measurements

A single crystal is aligned. Very little channeling (<<1%) is observed.



Preliminary



Black **data**

Red **Nuclear recoil events in GEANT4+Malowe**

Blue **Gamma contaminated events in GEANT4+Malowe**

Due to very low event rate, we need more statistics to compare spectra of different recoil angle tagged by each neutron detector.

Upgrades I : Low Radioactive PMTs

PMT : 0.4-0.9 cpd **Cf. Internal : 0.7-1.2 cpd**

U, : 0.2-0.4 ^{137}Cs : 0.3-0.5

Th : 0.1-0.25 ^{134}Cs : 0.05-0.3 → will be less

K : 0.15-0.25 U,Th : 0.01

	U	Th	K
Present (9269QA)	83	48	1866
Plan (R11065)	33	1.9	32

Unit: mBq/PMT

- High K content in the PMT is at the coupling of Quartz and Borosilicate glasses at the center of PMT body.
- The Cherenkov lights from ^{40}K decay in the glass or weak glass scintillation may be the origin of the PMT noise.
- With new PMT, we can reduce ~ 1cpd/kg/keV

Upgrade II - Pure 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.
- We try to develop low background NaI(Tl) crystals from scratch in collaboration with Sigma-Aldrich company & DM-ICE group.
- Sigma-Aldrich company made first low-K NaI powder in June 2012. Both DM-ICE and KIMS will measure the powders. Normal powder : ~ 0.3 ppm of K.

Summary

- 1 year data with 100 kg CsI(Tl) data analyzed with PSD method. DAMA Iodine region is inconsistent with KIMS NR rate limit.
- Stringent limit of spin-dependent proton cross section is given.
- 2.5 year data is analyzed without PSD for annual modulation → null modulation limit comparable to the level of DAMA's modulation amplitude : final numbers are underway.
- Channeling & quenching factor studies generates first data.
- Upgrade plans show further reduction of backgrounds.

Backup Slides

KIMS (Korea Invisible Mass Search)

Seoul National University: H.C.Bhang, J.H.Choi, S.H. Choi, K.W.Kim, S.C.Kim, S.K.Kim, J.H.Lee, J.I.Lee , J.K.Lee, M.J.Lee, S.J.Lee, J.Li, X.Li, S.S.Myung,S.L.Olsen, I.S.Seong

Sejong University: U.G.Kang, Y.D.Kim

Kyungpook National University: H.J.Kim, J.H.So, S.C.Yang

Yonsei University: M.J.Hwang, Y.J.Kwon

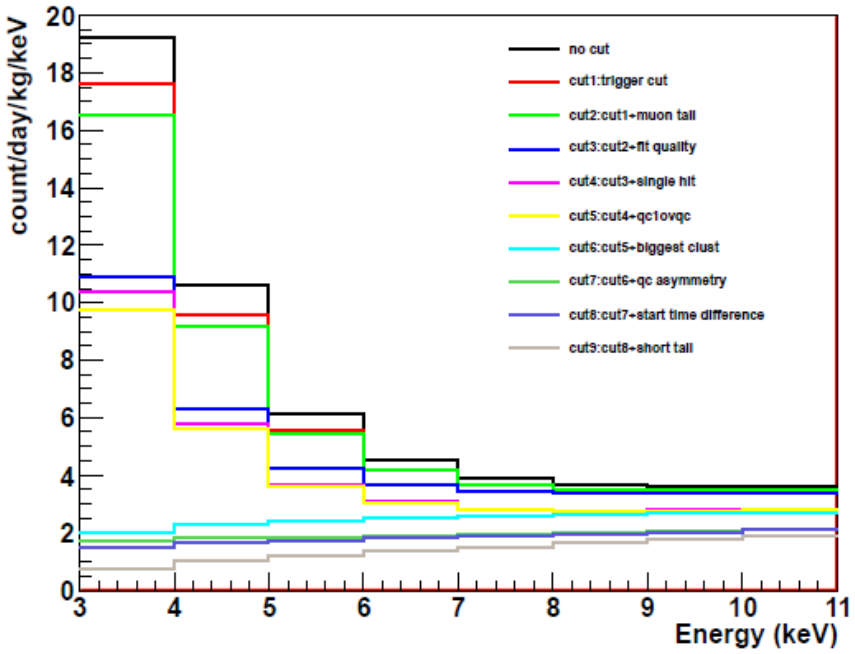
Ewha Womans University: I.S.Hahn

Seoul City University : Douglas Leonard

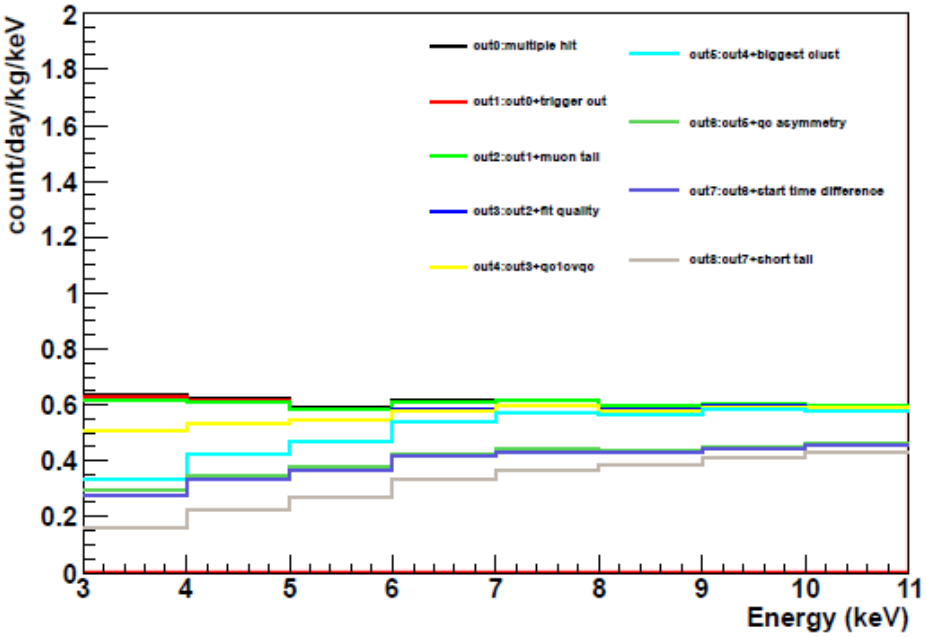
Korea Research Institute of Standard Sciences : Y.H.Kim, K.B.Lee, M. Lee

Tsinghua University : Y.Li, Q.Yue, J. Li

Background spectra



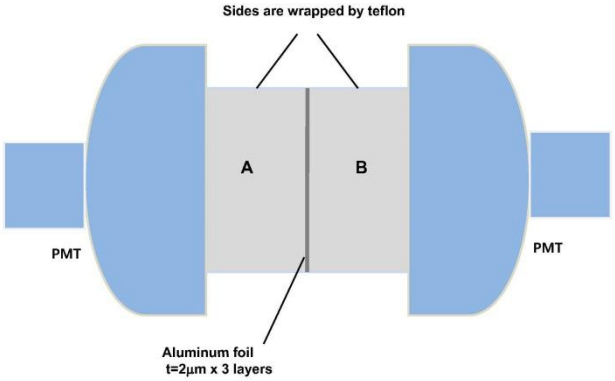
Raw Single rates



Multiple compton event rates

Surface alphas

- Surface alpha response studied with intentional Rn contamination.
- Measured low energy events of contaminated crystal tagged by alphas of the other crystals.

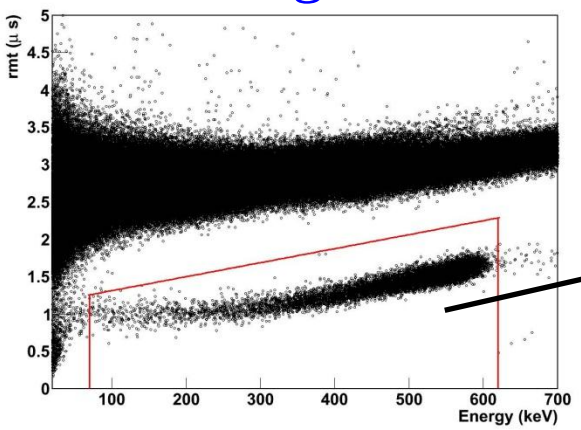


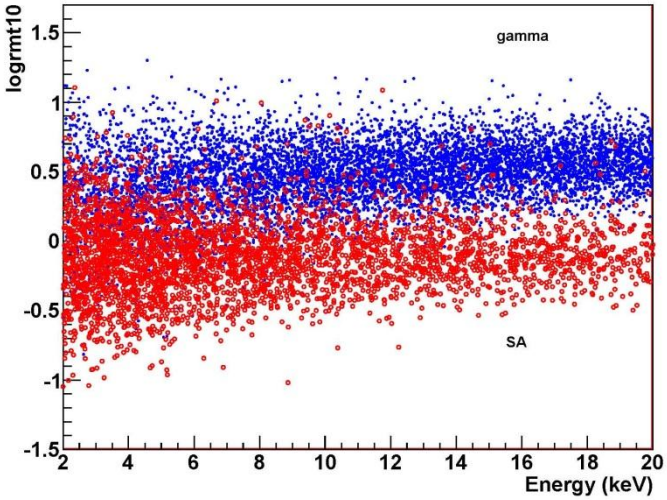
A is a crystal contaminated w/ Rn.
B is a clean crystal.

A

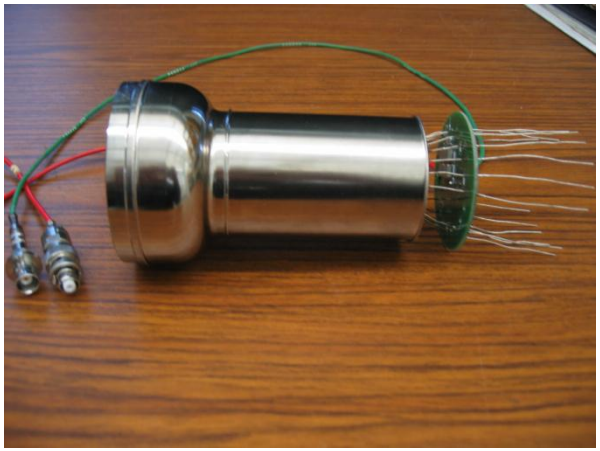
A:CsI(Tℓ), Rn progeny contaminated
B:CsI(Tℓ), clean

B signal

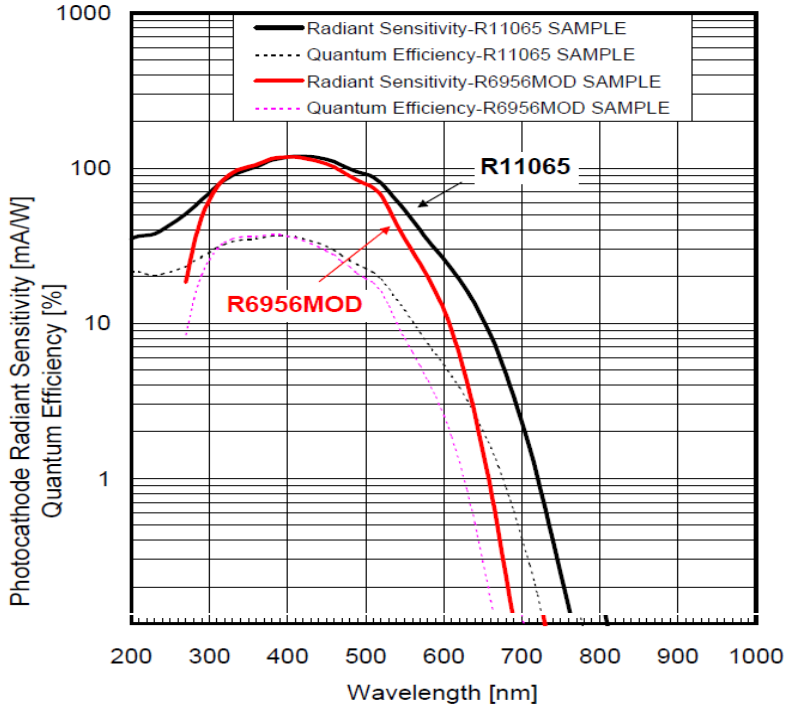


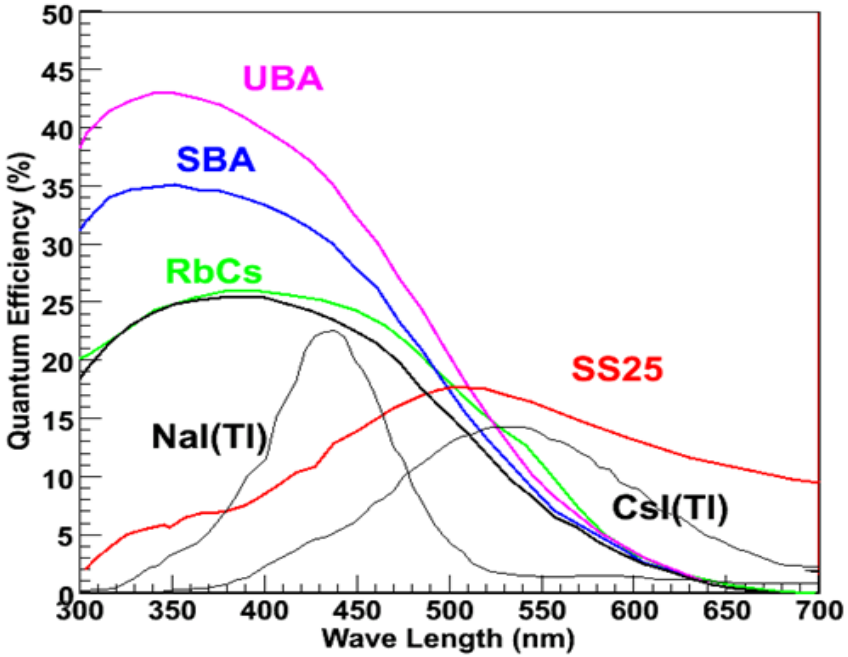


Upgrade I : PMT



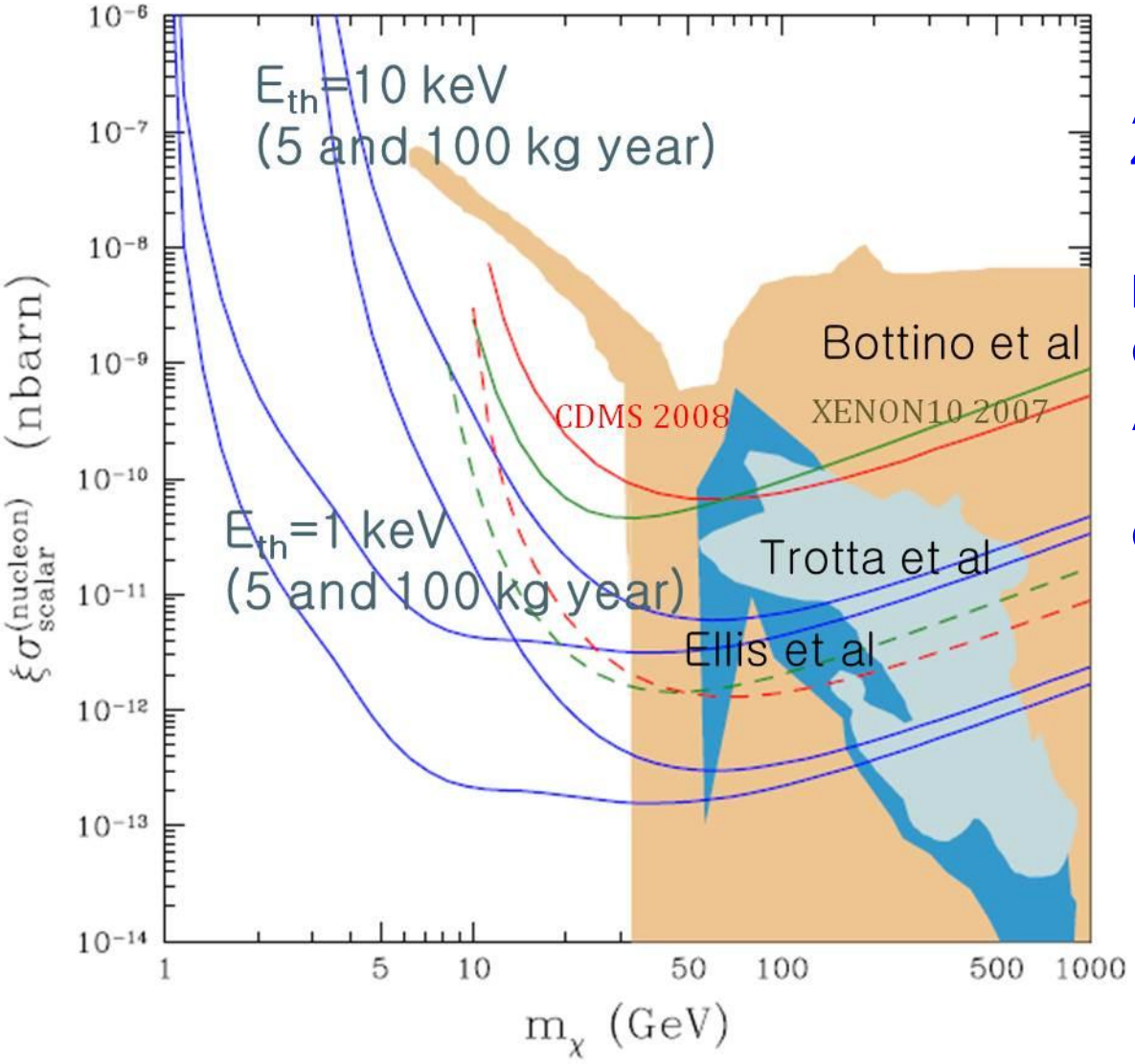
PMT noise is serious problem for WIMP search.
3” Metal + Quartz window PMT.
High Quantum efficiency.
Two PMTs will be delivered in June 2012.
Disadvantage : Expensive.





QE is similar to RbCs & SBA for CsI

Upgrade III : AMoRE-DARK



AMoRE is a project of 100 kg $^{40}Ca^{100}MoO_4$ bolometer.

For Dark Matter, $^{40}Ca^{nat}MoO_4$ Can be run simultaneously in AMoRE.

Cf. CRESST – $CaWO_4$