PICO-LON Project for Dark Matter Search

Ken-Ichi Fushimi for PICO-LON Project

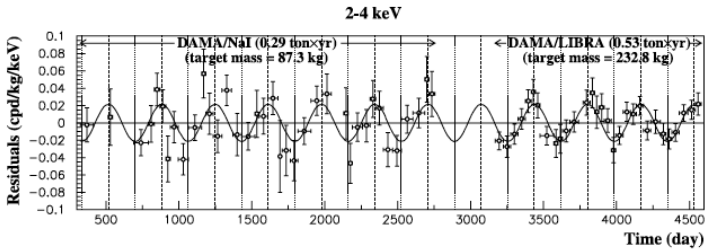
1. Aim of PICO-LON
2. Merit of PICO-LON
3. Performance of PICO-LON
4. Plan
5. Prospects

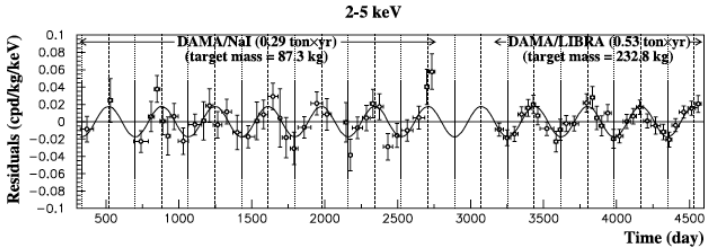
Aim of PICO-LON

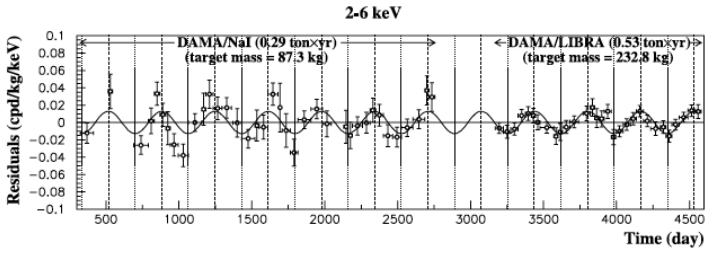
- WIMPs Search by highly segmented scintillator
- 30,000 layers of NaI(Tl) plate
- High sensitivity
- Both elastic and inelastic scattering
  - The same target of DAMA
  - The different analysis of DAMA

DAMA (250kg NaI(Tl))

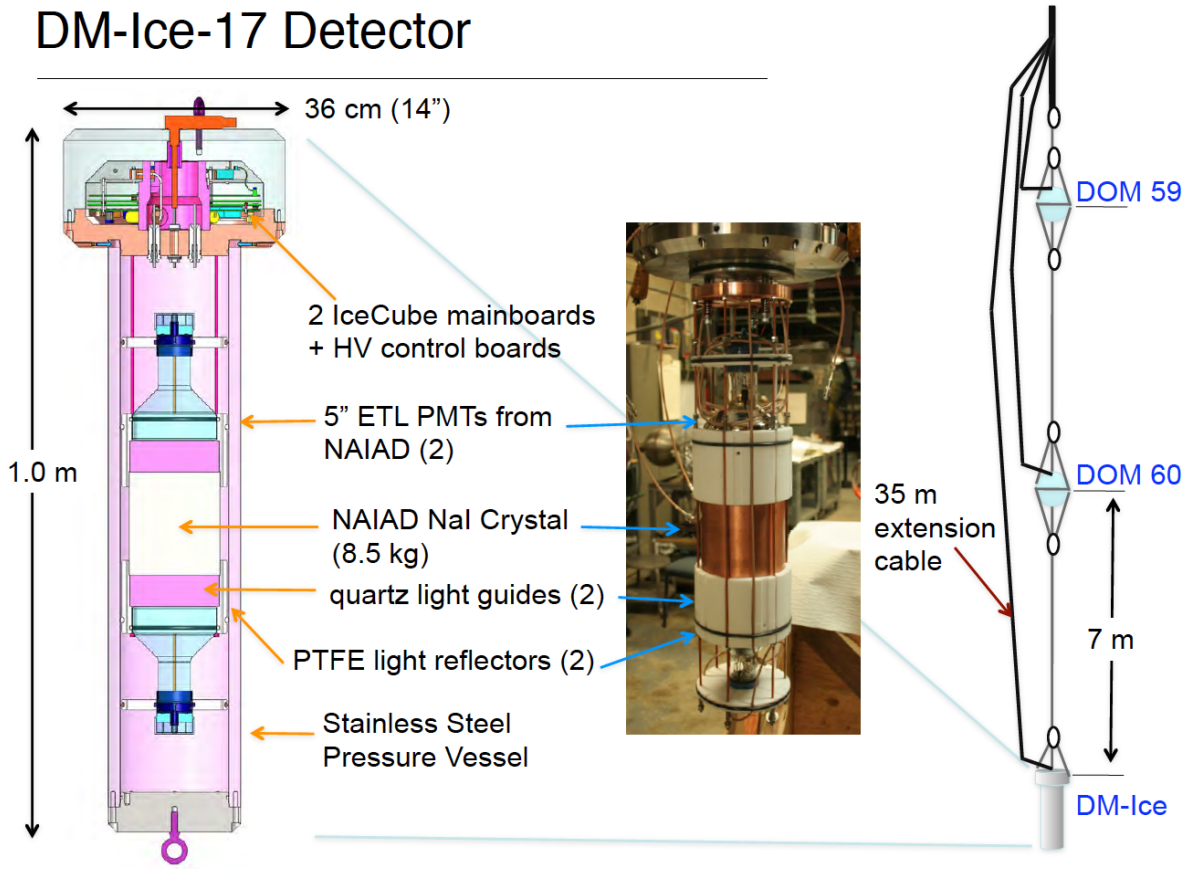
Eur. Phys. J. C56(2008)333







DM-Ice-17 Detector



J.Cherwinka et al., Astrop. Phys. 35(2012)749

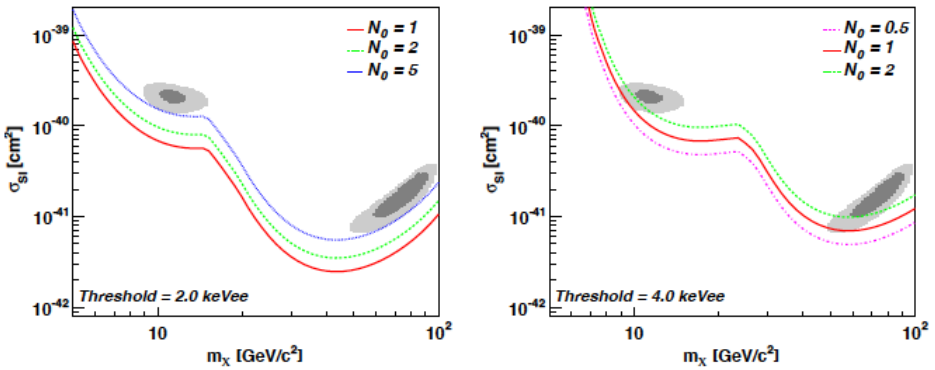
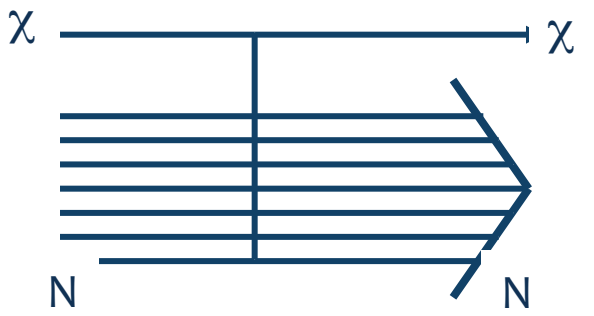


Figure 3: The curves show the sensitivity of hypothetical 500 kg-year exposures with varying total event rates (in cpd/kg/keV$_{ee}$). Shown are two energy threshold scenarios. The left plot shows sensitivities with a 2 keV$_{ee}$ experimental threshold. The right plot shows sensitivity with a 4 keV$_{ee}$ threshold. The gray regions show the 90% (dark) and 99.7% (light) DAMA/LIBRA allowed regions for interactions with Na (masses of ~10 GeV/c^2) and I (masses of ~100 GeV/c^2). DAMA/LIBRA allowed regions are calculated without channeling.

Interactions between WIMPs and nucleus

H.Ejiri K.Fushimi and H.Ohsumi,
Phys. Lett B317(1993)14

SI

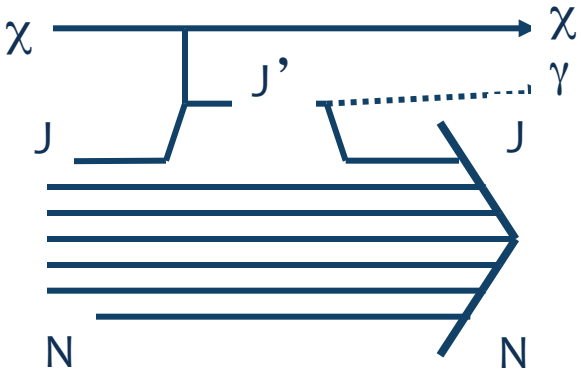


$$\sigma \propto A^2$$

SD

$$\sigma \propto C\lambda^2 J(J+1)$$

EX

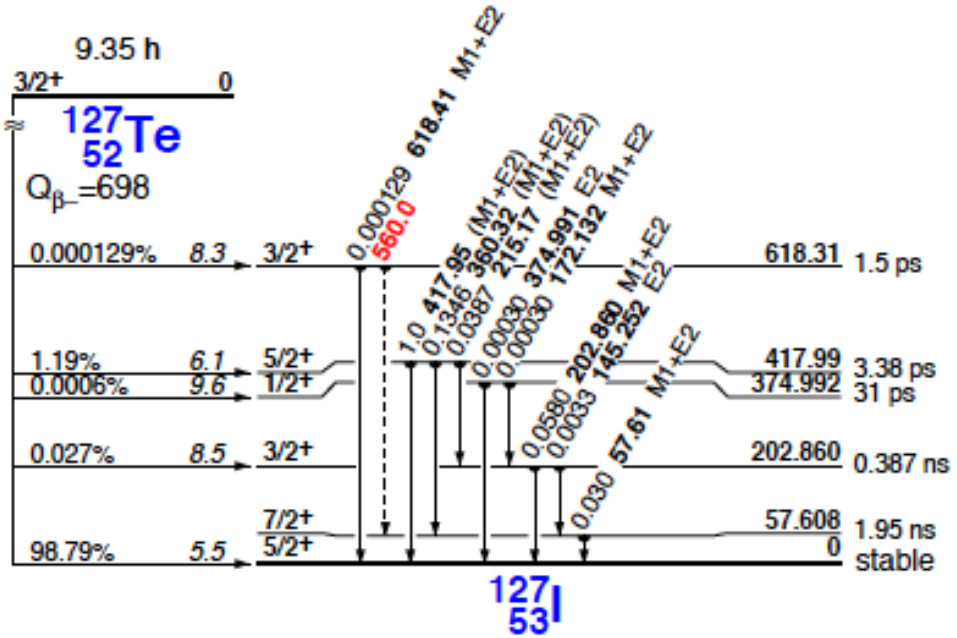


$$\sigma \propto \sqrt{\frac{2J'+1}{2J+1}}\frac{1}{g_M}\langle A|M1|A^*\rangle$$

We planned to study all the types of interaction!!

Merit of PICO-LON
Why NaI(Tl) ?

- ^{23}Na & ^{127}I
  - Sensitive to SD and SI
  - 100% natural abundance of finite spin nuclei
- ^{127}I
  - Sensitive to EX
  - Low energy excited state



Experimentally obtained

$$\left|M_{M1}\right|^2 = 0.1$$

- Expect: 3.60×10^{-3}/day/kg (Higgsino) J.Ellis et al., PLB212(88)375
- Limit: 4.98×10^{-2}/day/kg (ELE V NaI)

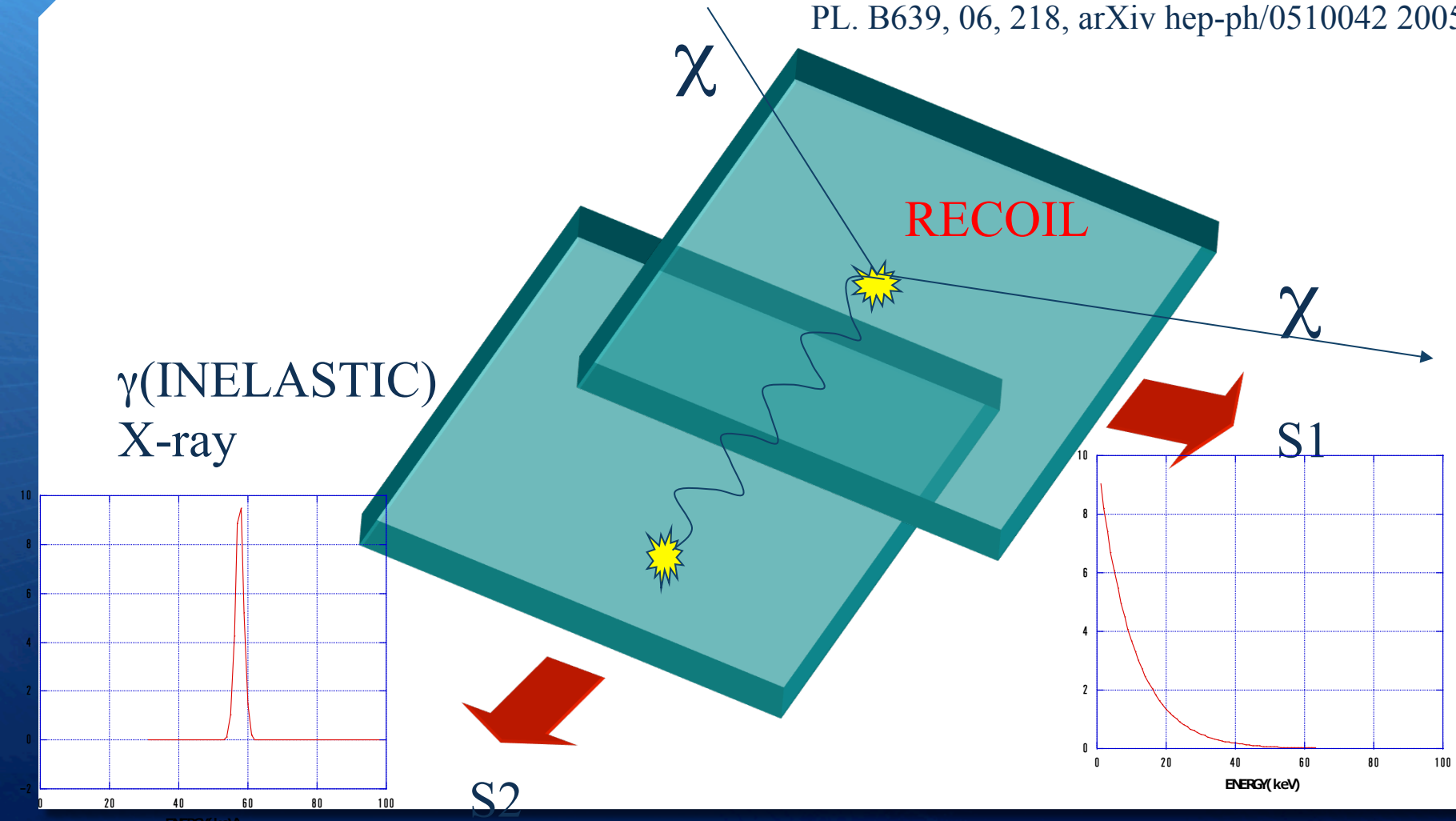
K.Fushimi et al., Nucl. Phys. B(Proc. Suppl.) 48 (1996) 70

Signal selection by Spatial and Timing Correlation (SSSTC)

- Signal Selection by Spatial Correlation
  - Signal → 57.6keV γ + Low energy recoil
  - Localized event in space and time
  - Background → U,Th chain, ^{40}K etc.
  - Diffused event in space and time
- Signal Selection by Timing Correlation
  - Signal → No following events
  - Background → Time-correlated events by decay chain (^{210}Pb)

Signal Identification by Segmentation

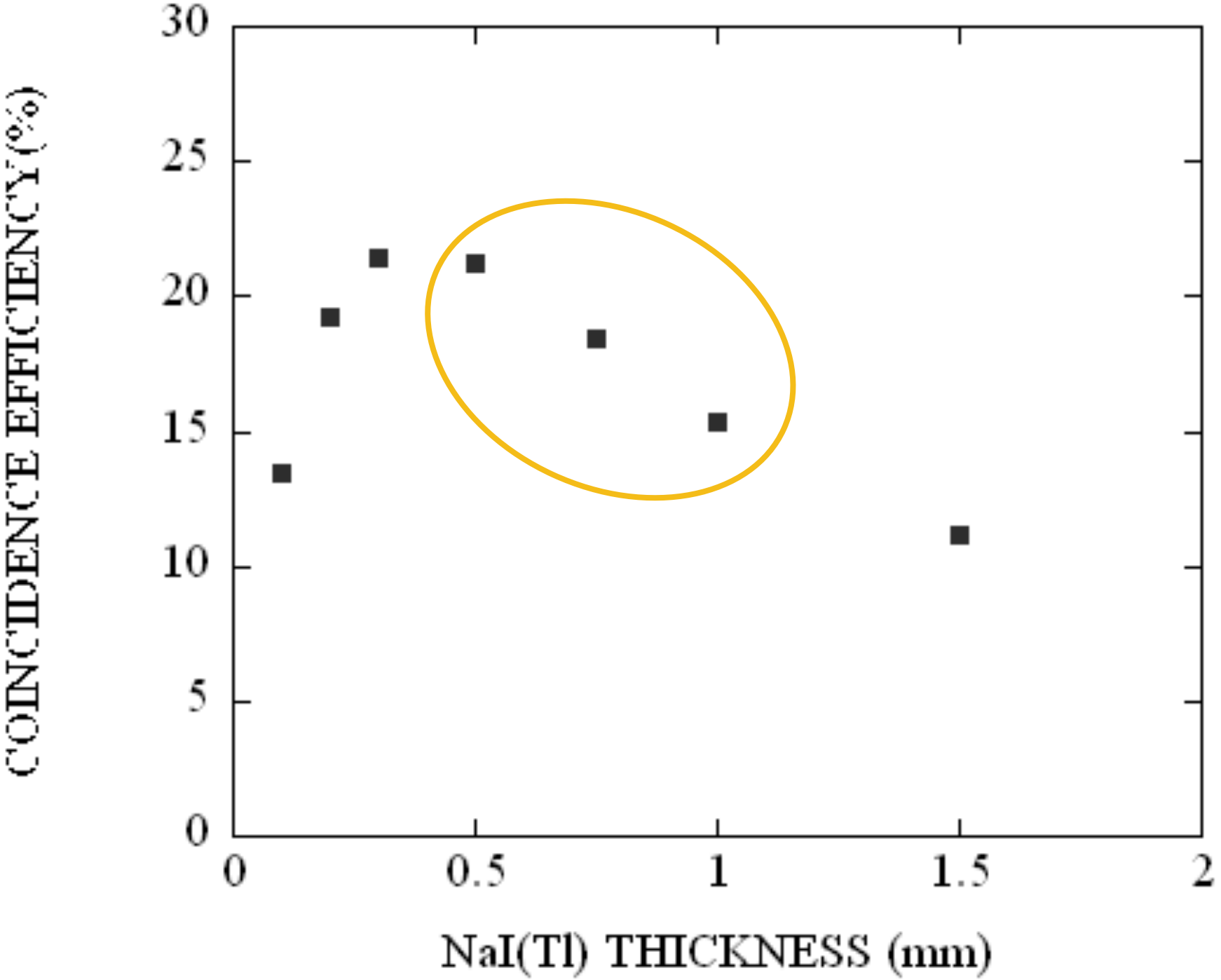
K.Fushimi et al., JPSJ74(2005)3117
astro-ph/0506329
H. Ejiri, Ch. C. Moustakidis, J.D. Vergados,
PL. B639, 06, 218, arXiv hep-ph/0510042 2005.



Estimation of signal selectivity

- Monte Carlo simulation (GEANT4)
- 57.6keV g ray ($^{127}I^{*} \rightarrow {}^{127}I$) from one module
- g is detected the another module
- Next module to the emitter module

The fraction which is detected both sides of emitter


COINCIDENCE EFFICIENCY (%)
30
25
20
15
10
5
0
0
0.5
1
1.5
2
NaI(Tl) THICKNESS (mm)

Specification of thin NaI array (PICO-LON)

- 0.1cmX10cmX10cm NaI(Tl)
- 0.1cmX11cmX0.5cm Acrylic Light Guide
- ESR™ reflector
- 3plates (PICO-LON-III)
- 100plates (PICO-LON-100)
- 1000→2000→30000 (Future)

Estimation of sensitivity

- Radioactive contamination
  - Uniformly contaminated in NaI(Tl) crystal
  - ^{210}Pb 0.1mBq/kg (1/3 of present value)
  - ^{214}Pb, ^{214}Bi 10μBq/kg
- Monte Carlo Simulation
  - GEANT4

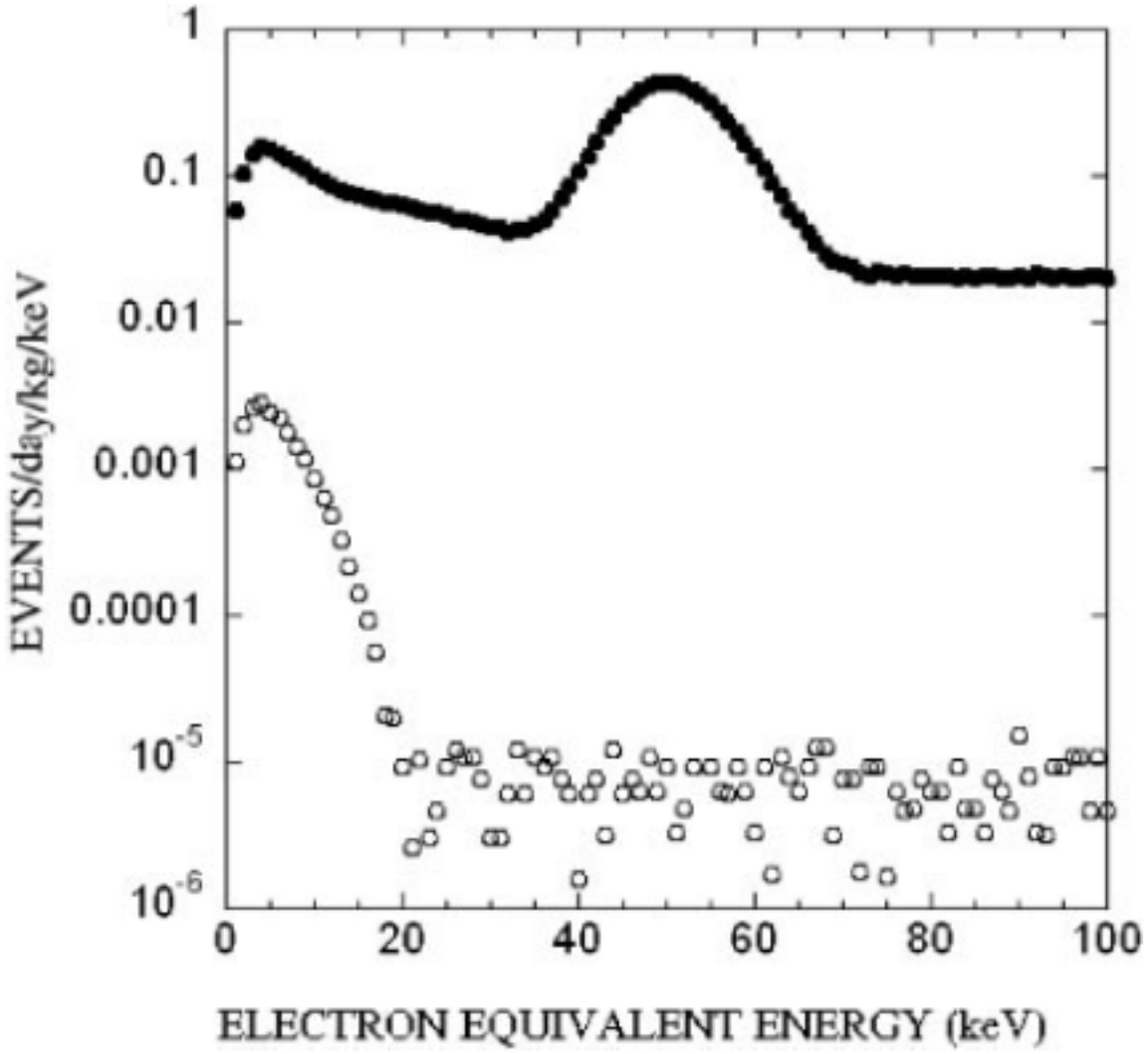
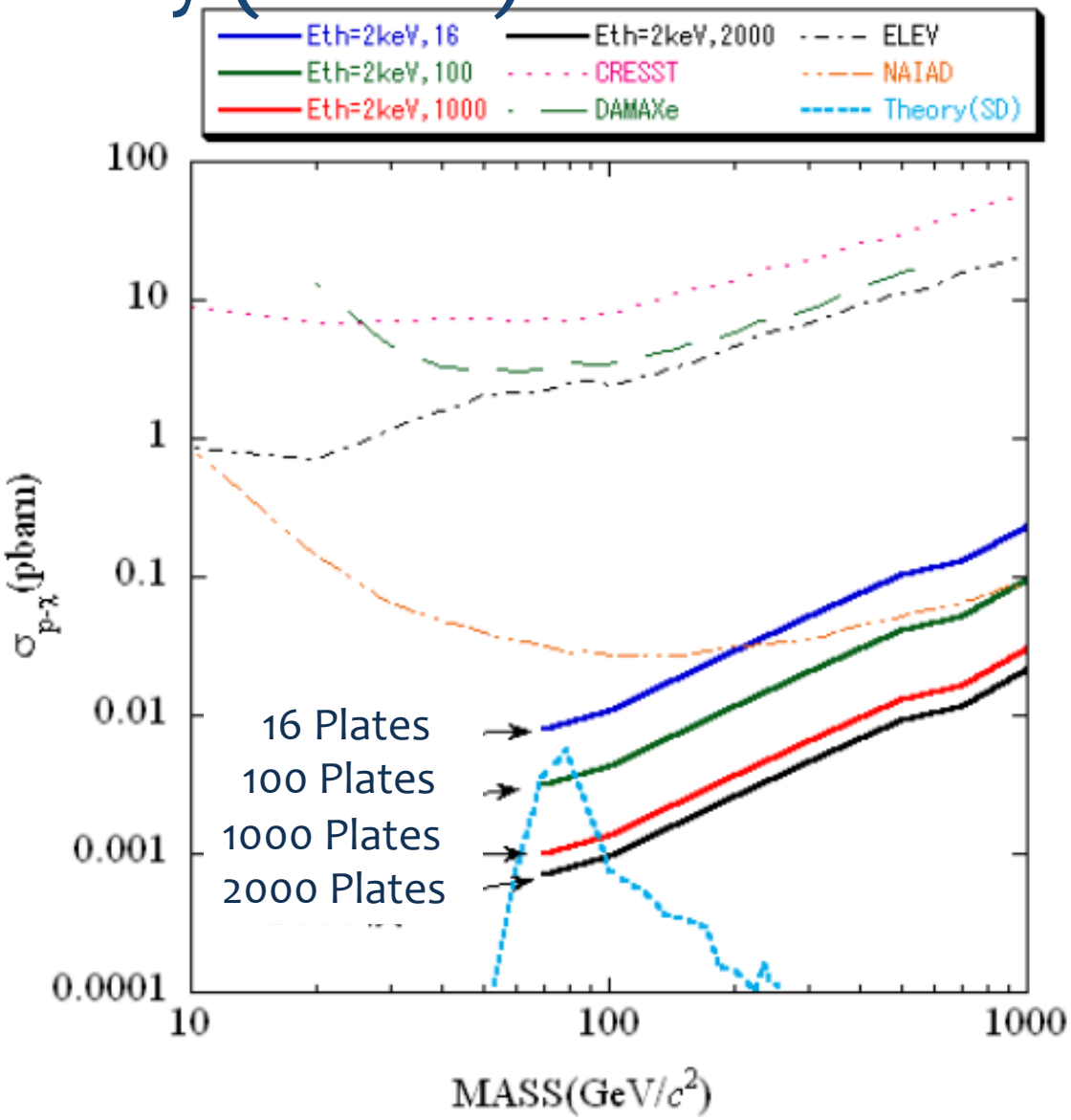


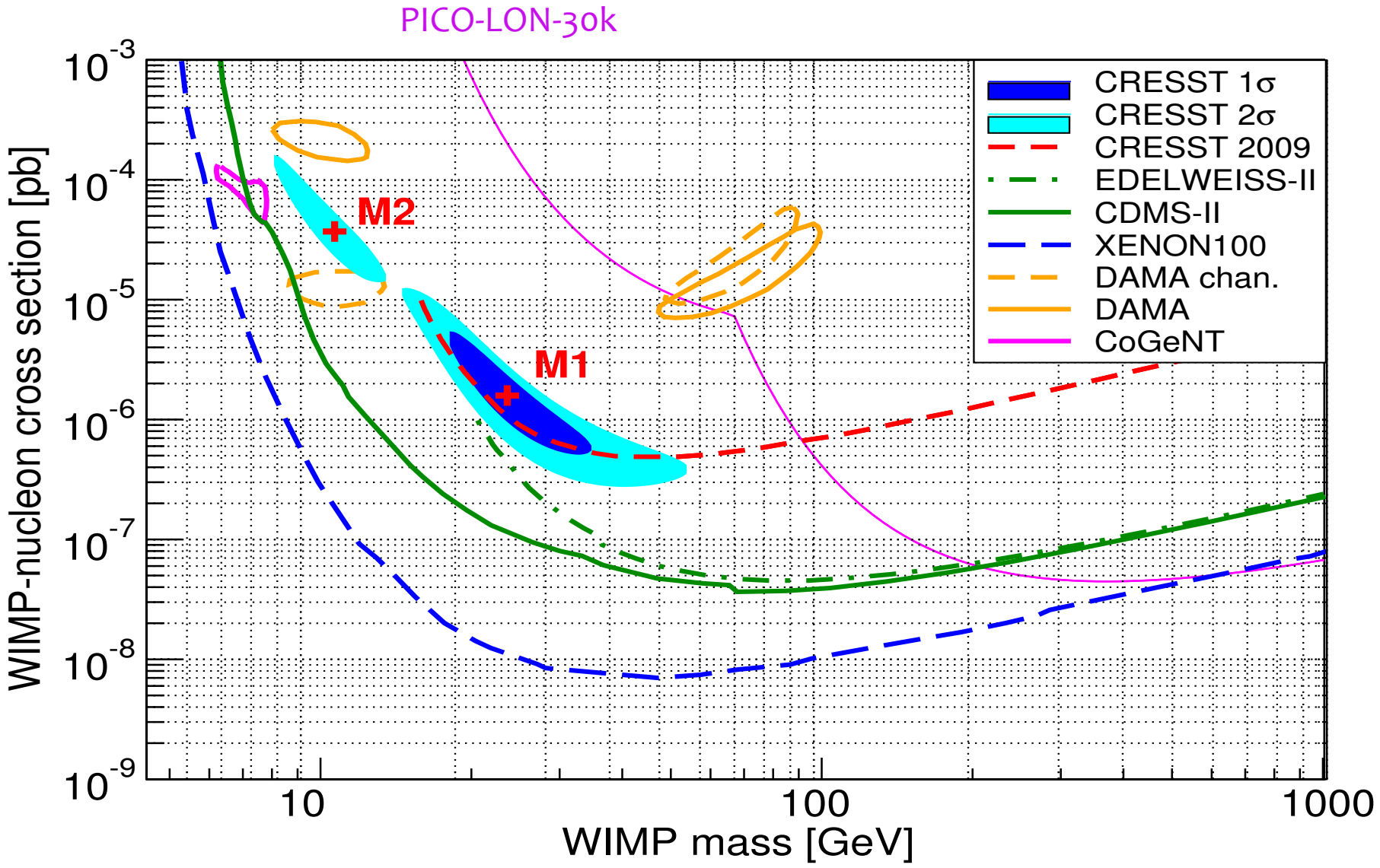
Fig. 4. The expected background energy spectrum. The closed circles and open circles mean the singles event rate and the event rate after performing the SSSTC analysis. The analysis process is described in text.

Expected sensitivity (EX-SD)

10cmX10cmX0.1cm
NaI(Tl) system

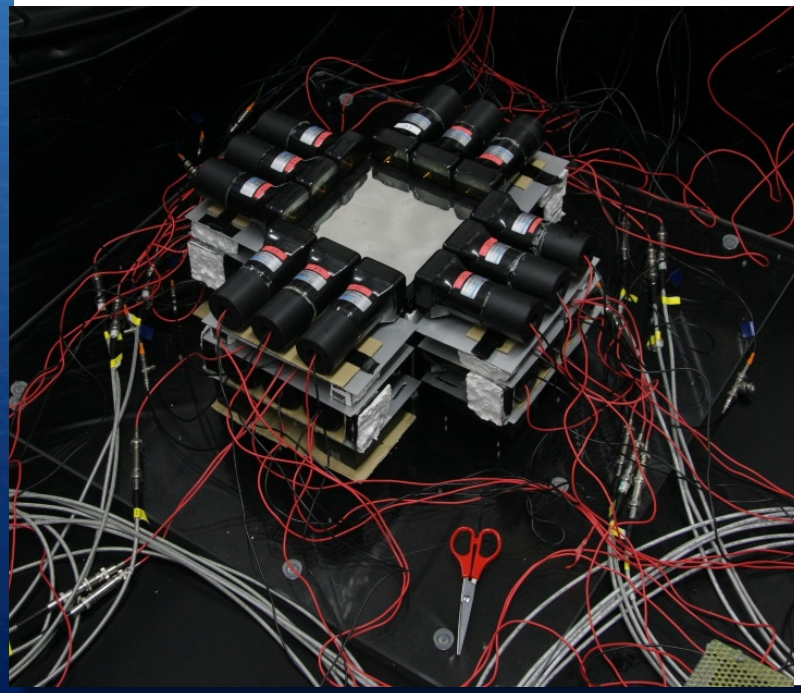


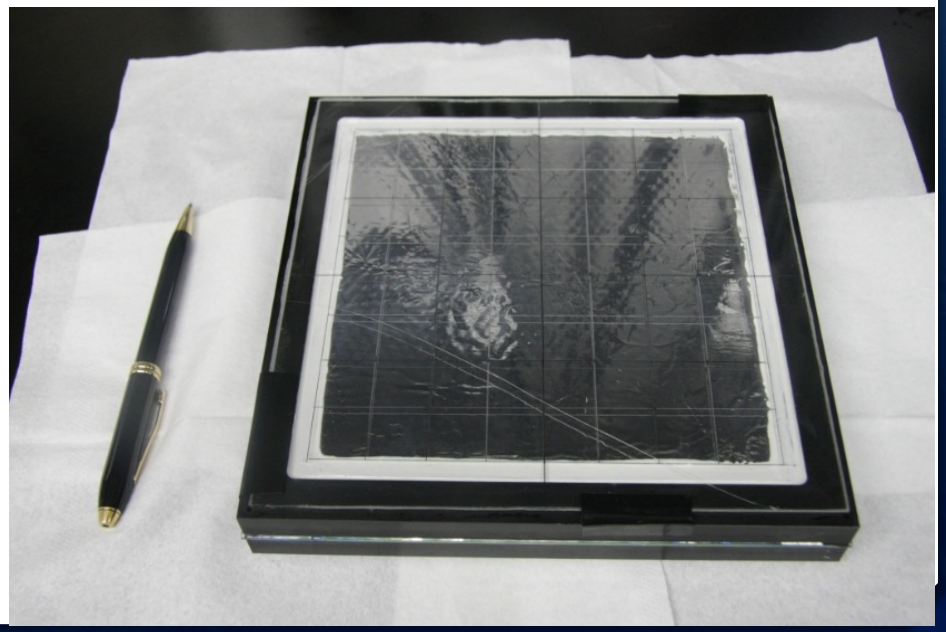
Expected sensitivity (Elastic, 1ton*yr)



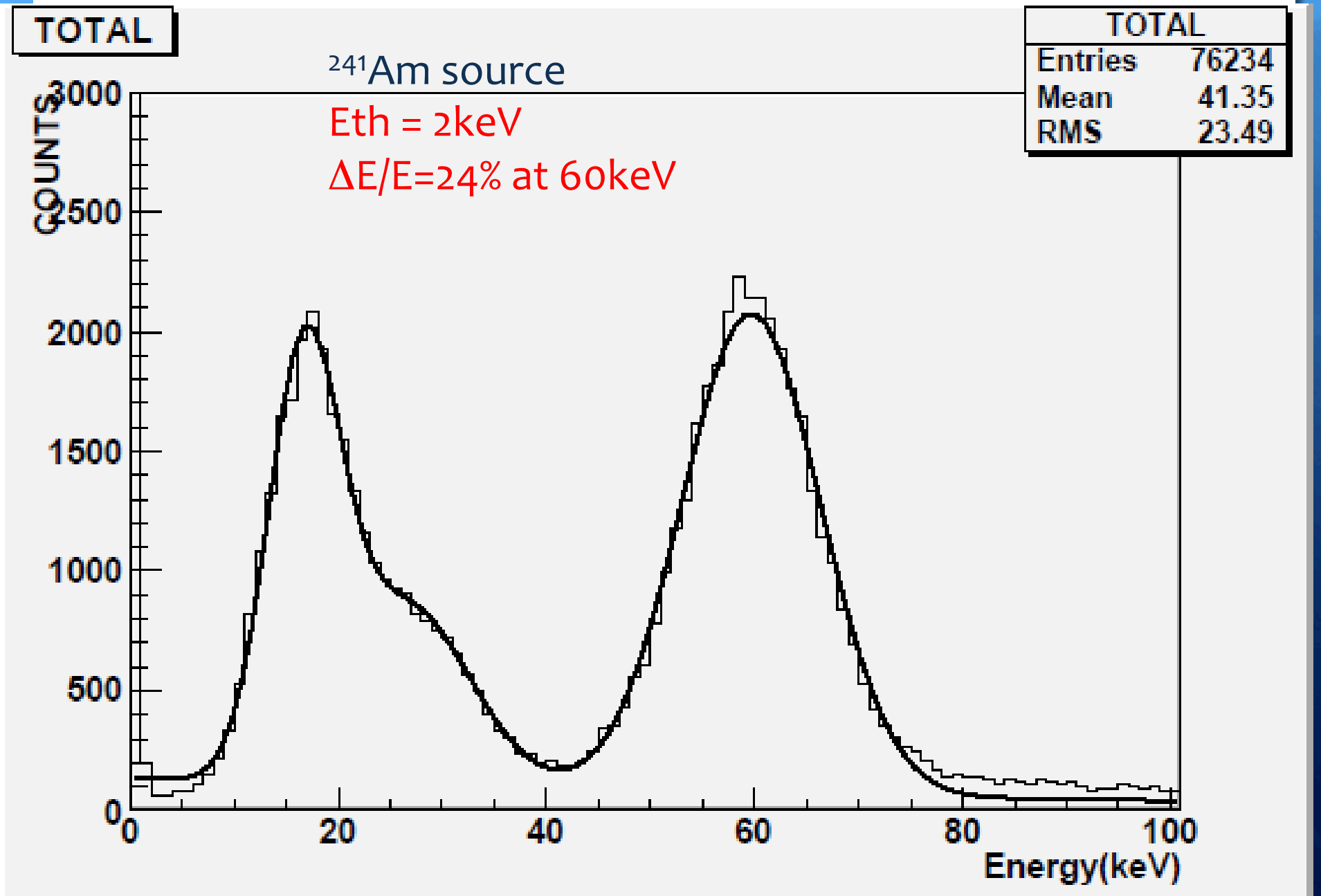
PICO-LON-III project

- Larger area 15cmX15cmX0.1cm
- Normal PMTs (Ultra bialcali)

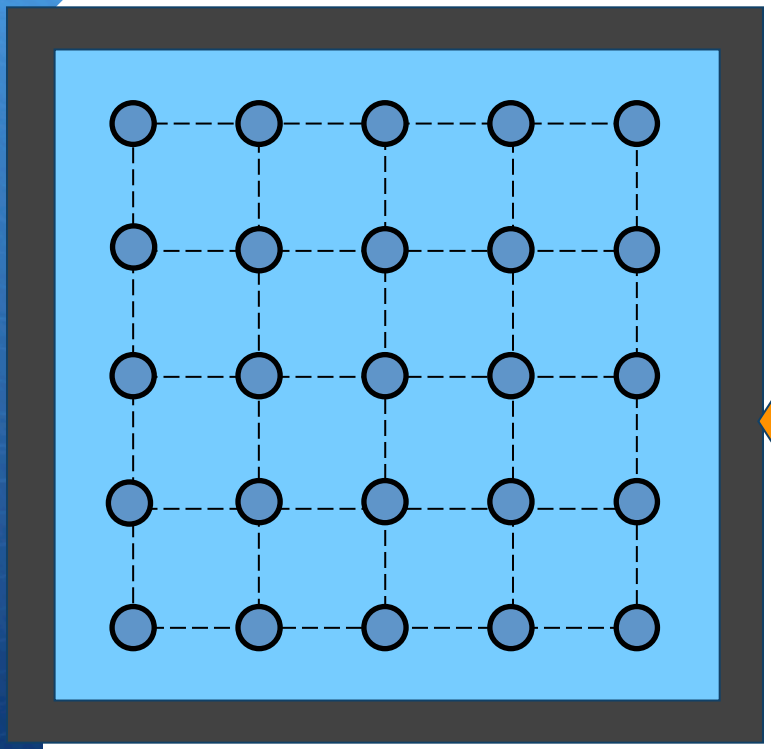


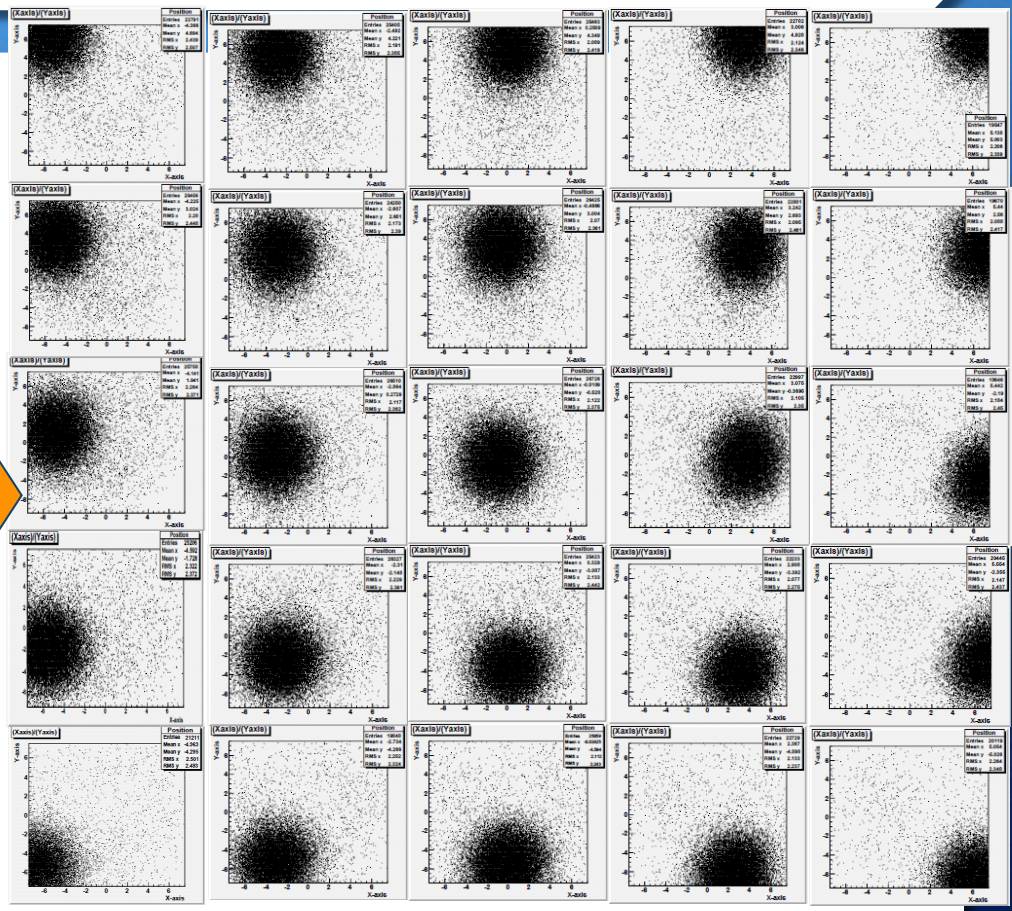


K.Fushimi, K,Harada in praparation



Position resolution = 30% FWHM





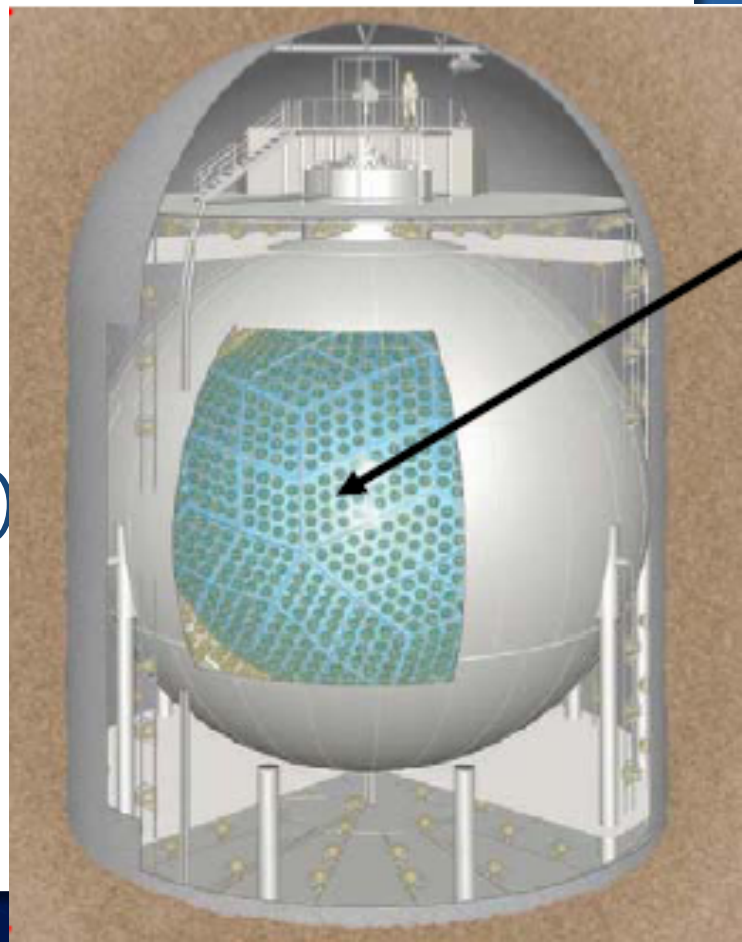
= Source postion

KamLAND-PICO Project

- Install NaI(Tl) scintillator into KamLAND
- Advantages
  - High sensitivity for WIMPs
  - Low background
  - 4π active shield
- 2012 FY~JSPS KAKENHI Grant (B)

  No. 24340055 was approved

  15Myen/4years

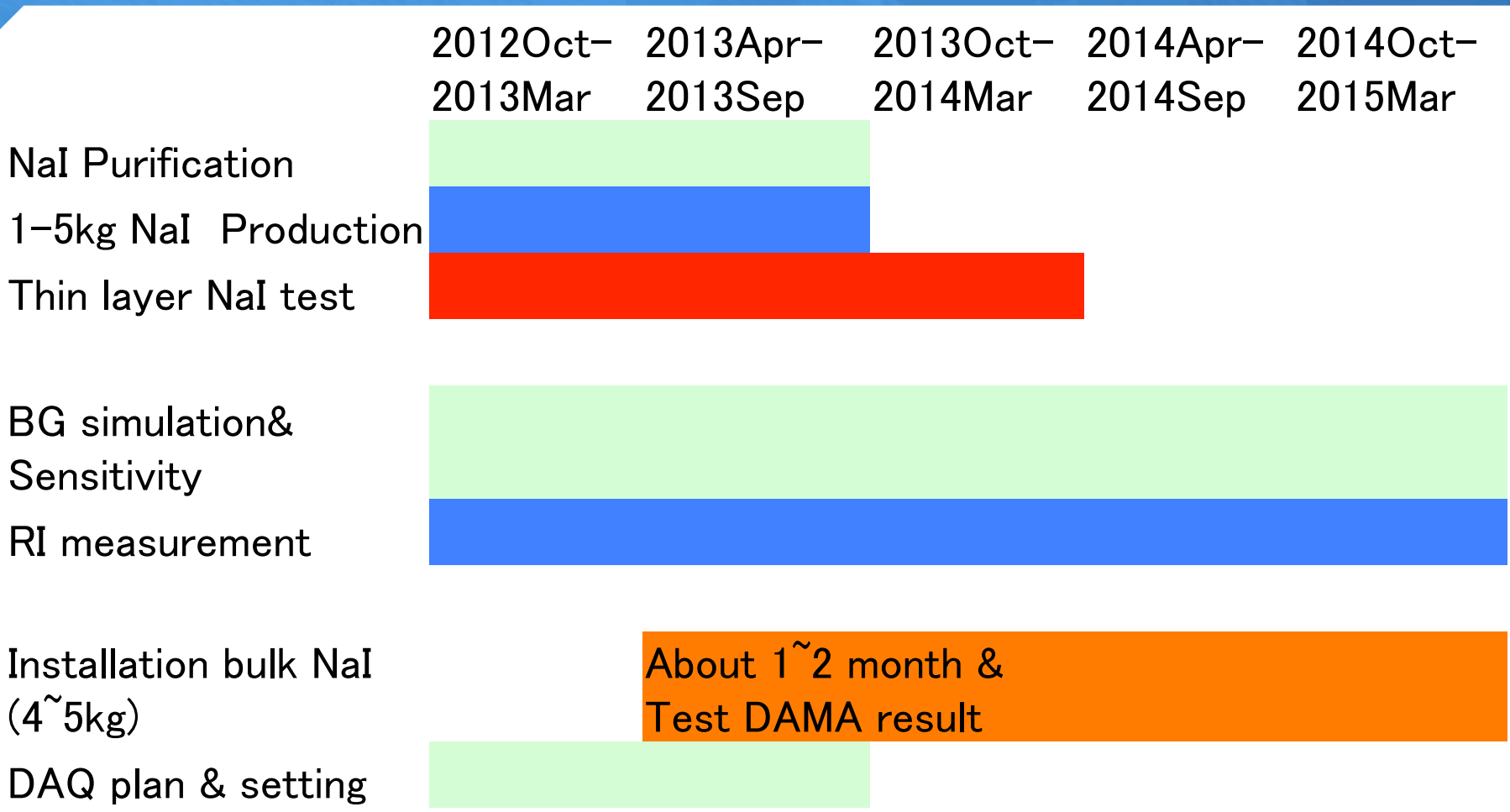


科研費
KAKENHI

Issues for PICO-LON 2k-30k

- PICO-LON module
  - Long-term stability → Test in 2013~2015
- Photon sensor
  - PMT square PMT → Low noise but limit on layout
  - SiPM or MPPC → Free layout but high dark current
  - R&D 2013~2015
- Experimental site
  - PICO-LON 100 → Small site
  - More than 1000 modules → Larger site is needed

Schedule (Short term)



Schedule (Long term)

		2013年度	2014年度	2015年度	2016年度	2017年度	2018年度	2019年度	2020年度	2021年度	2022年度	
プロジェクト名：PICO-LON	高純度NaI(Tl)開発	坩堝購入・製造・測定										
	経費	0.02										0.02
	人数	2										
	低バックグラウンド測定のテスト	KamLANDで測定（1～2ヶ月）	KamLANDで測定（1～2ヶ月）									基盤(B)~2015を短縮
	経費	0.02	0.01									0.03
	人数	3	3									
	3枚積層でテスト	PICO-LON-III										
	経費	0.02										0.02
	人数	2										
	PICO-LON 100	光センサーの検討・PICO-LONモジュールの設計	PICO-LONモジュールの設計・PICO-LON組立	PICO-LON組立・測定	PICO-LON組立・測定（弾性散乱・非弾性散乱）	測定（季節変化の感度評価）	測定（季節変化の感度評価）					三菱財団申請中・基盤(A)申請予定
	経費	0.1	0.5	0.5	0.5	0.2	0.2					2.00
	人数	1	2	4	4	2	2					
	PICO-LON 2k	場所の選定	場所の選定	建設地の決定・設計	設計・NaI(Tl)製作・PICO-LON組立	設計・NaI(Tl)製作・PICO-LON組立	建設	建設・測定（弾性散乱・非弾性散乱）	建設・測定（弾性散乱・非弾性散乱）	測定（季節変化）		基盤(S)または特別推進
	経費	0	0.01	0.01	3	4	4	1	0.7	0.5		13.22
	人数	2	2	2	2	2	2	5	5	5		
	PICO-LON 30k	場所の選定	場所の選定・設計	場所の選定・設計	場所の選定・設計	最終案の決定	NaI(Tl)製作・PICO-LON組立・建設	NaI(Tl)製作・PICO-LON組立・建設・測定	NaI(Tl)製作・PICO-LON組立・建設・測定	NaI(Tl)製作・PICO-LON組立・建設・測定	季節変化の測定	概算要求
	経費	0	0.01	0.01	0.01	0.01	10	15	15	20	5	65.04
	人数	2	2	2	2	2	4	7	7	7	7	
	必要経費(億円)	0.16	0.53	0.52	3.51	4.21	14.2	16	15.7	20.5	5	予算計（億円） 80.33
	必要人数	10	9	8	8	6	8	12	12	12	7	
	既存人数	7	6	6	6	6	6	6	6	6	6	
	不足人数	3	3	2	2	0	2	6	6	6	1	