非加速器物理実験の将来

Future of non-accelerator experiments

(Personal View)

Y.Suzuki （Kamioka Obs.）
@高エネルギー宇宙の総合理解

(1) Atmospheric ν --- established

⇒ accelerator based long baseline experiments

JHF, ν-factory,…

θ_{13}, matter effect, CP violation etc.

(2) Solar ν --- ???

⇒ Need smoking gun evidence?

SK (^{8}B: effect is small), NC (SNO)

KamLAND (LMA)

⇒ **^{7}Be & pp**

(3) Absolute mass

(4) **0νββ**

(5) **Dark matter**

Liq. Xenon Detector

(6) **Proton decay**

(7) …..

Multi-Megaton
Water Cherenkov Detector

Liquid-Xenon detector

pp-^{7}Be Solar Neutrinos, Dark Matter, 0νββ

1) **Scintillation/Ionization detector:**
   - **Scintillation: 42,000 photons/MeV**
     similar amount of NaI (known very well)
   - **Proportional scintillation in gas phase**
     (amplification in the high E-fields)
   - **Two phase detector (S.Suzuki et al….)**
   - **Ionization:**
     - **Proportional chamber,**
     - **TPC (gas & liquid)**

Variety of techniques → Particle Id……

Limit to the scintillation technology for simplicity

2) **Emission: 175 nm**
   can be read by PMTs w/o wave length shifter
3) **Self-Shield (ρ=3.06g/cm^3, Z=54)**
   X_0=2.7cm (30 cm Xe ~ 4m of Water)
4) **Radius: 0.92 m for fid. volume of 10 tons and 1.22m for entire volume of 23 tons**
5) **For 40% coverage**
   needs 1692 PMTs (3 inch)
6) **PMT needs quarts (or MgF_2) window (can be placed inside or outside of liq-Xe)**

7) High operating temperature: ~165^{o}K

←→ **He (4^{o}K), Ne(27^{o}K)**

can use liq.-N_2 to liquefy Xe

can use acrylic matterial

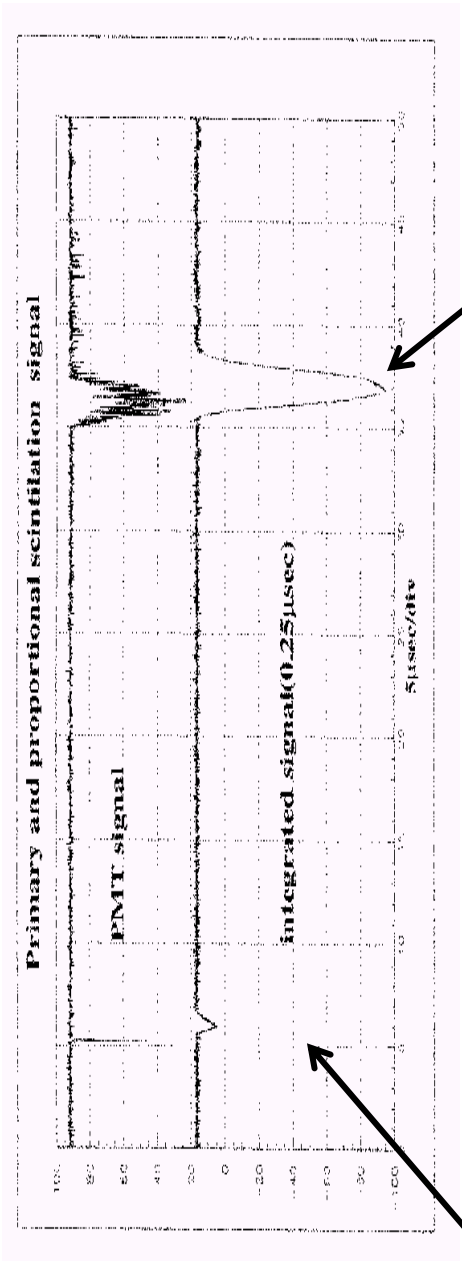
8) Absorption > 1m(?), scattering > 30cm

9) Possibility and easiness to upgrade and scale up

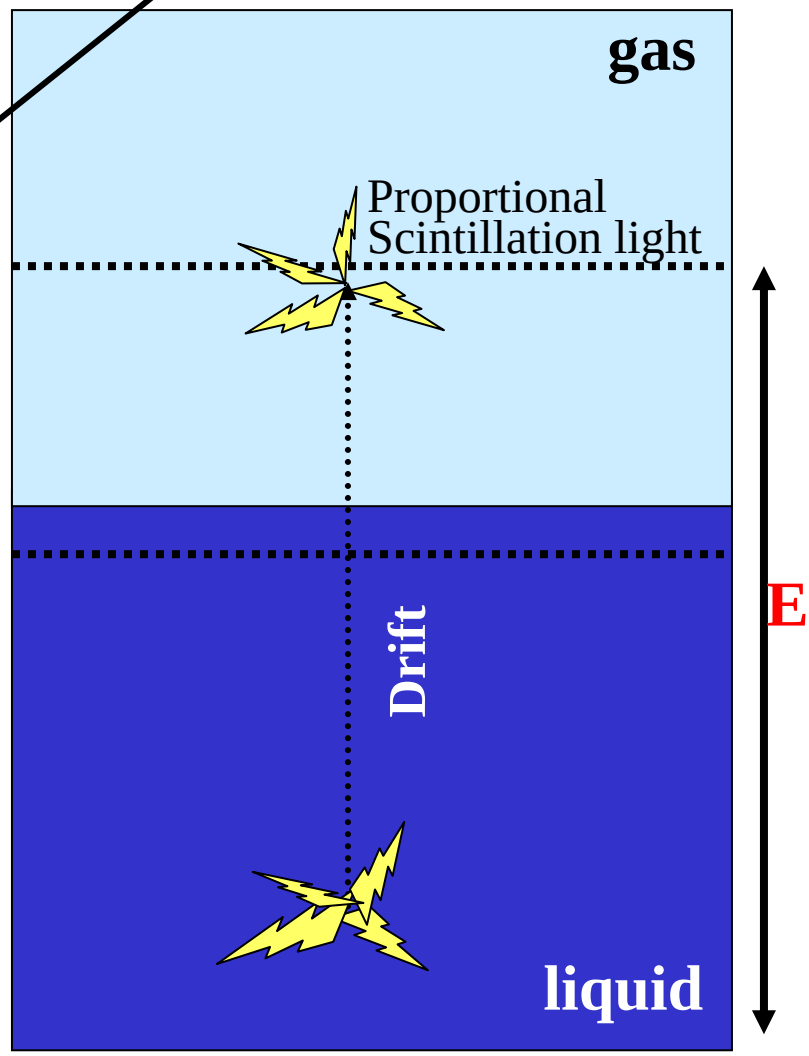
Purification even during the experiment

Able to change the chamber (detector technology) very easily and quickly

Two phase detector



Signals from
electron/γ events

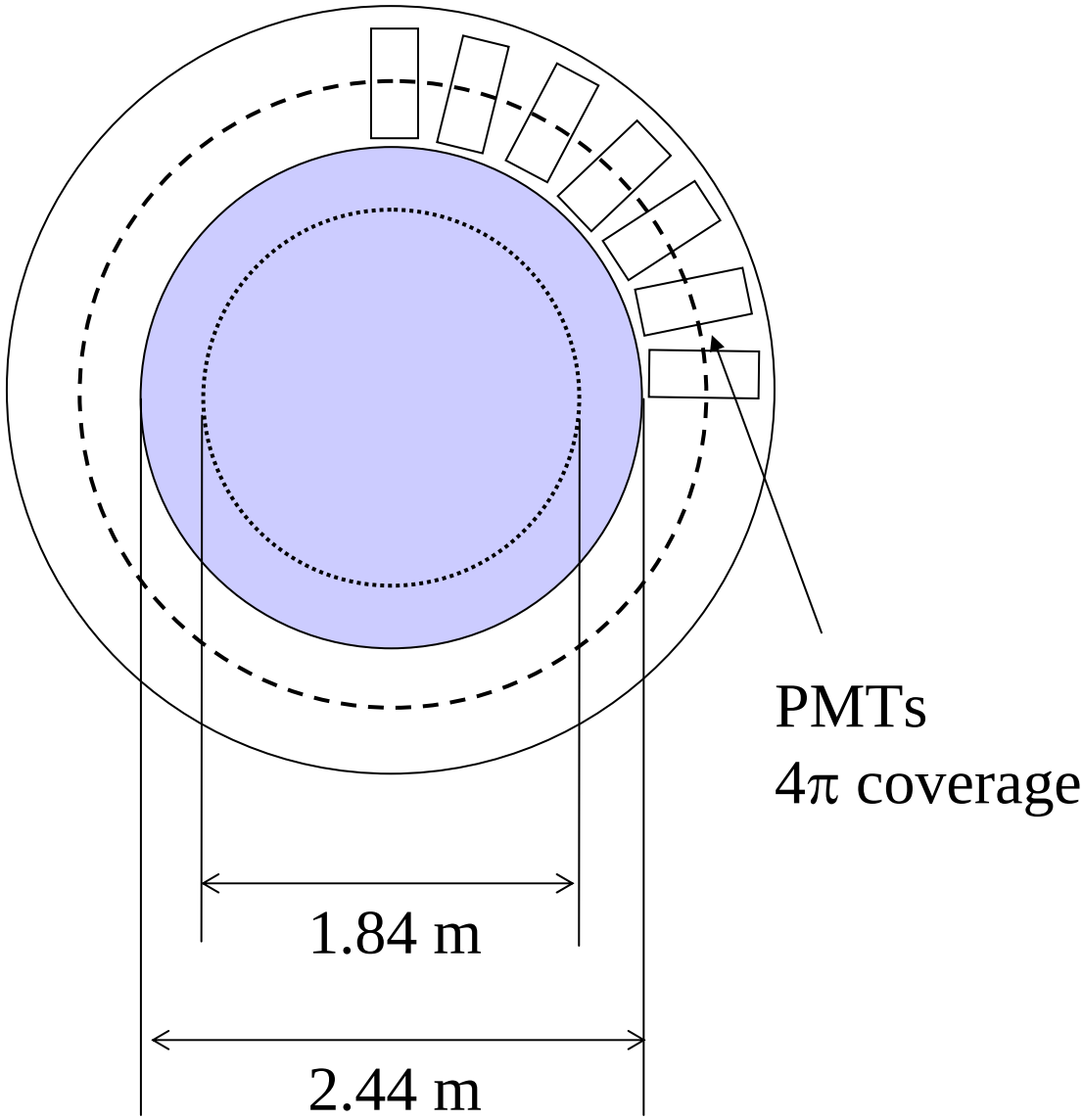


Signals from
Nuclear recoils or α particles

(short recombination time:
no ionized electrons left over)

Ref) ICURUS Group;
N.J.Smith et al. 1999 (ZEPLIN);
S.Suzuki et al.
……

Detector



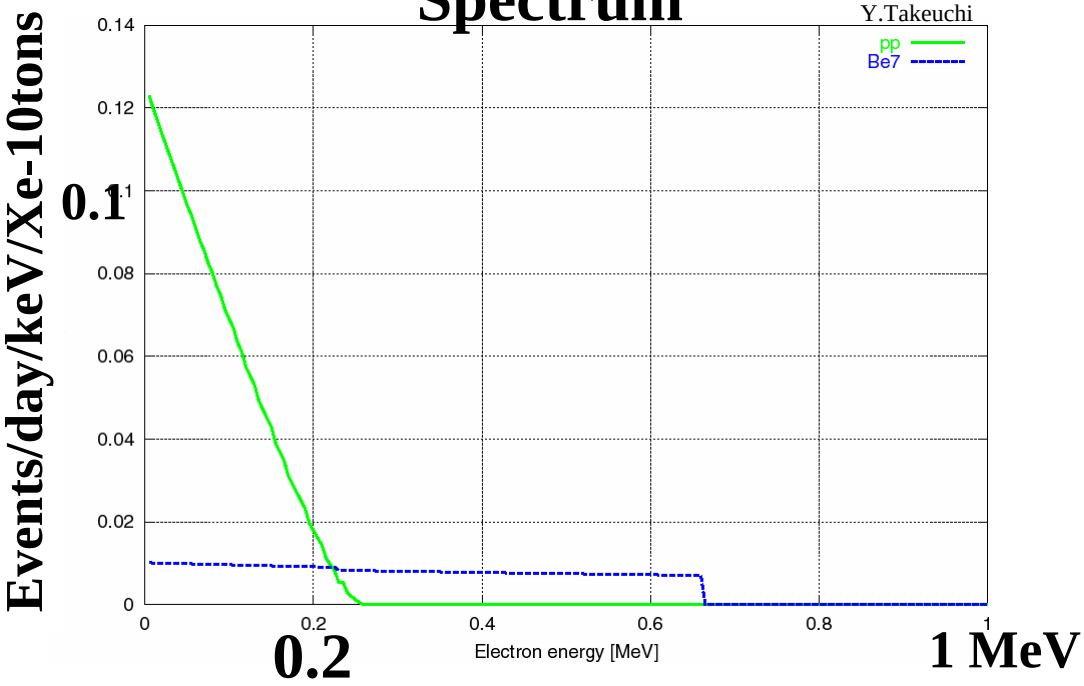
Solar Neutrino Measurements w/ 10 ton mass

Signal (high rate) $\nu_e + e \rightarrow \nu_e + e$ **scattering**

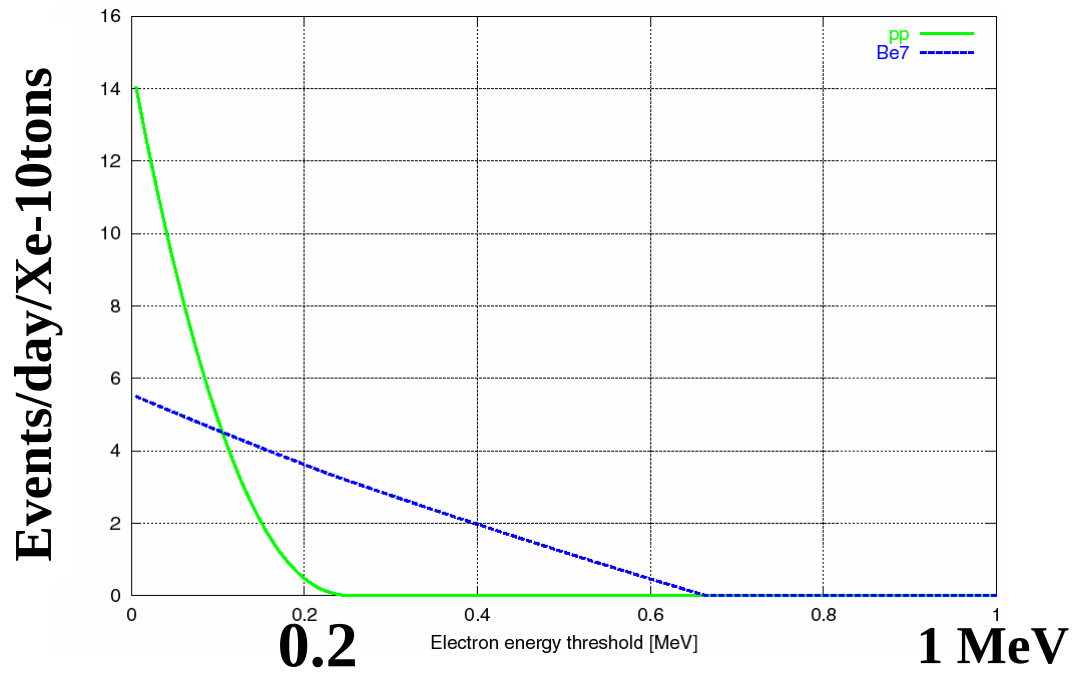
10 pp and 5 ^{7}Be events/day/10ton (> 50 keV)

←→ SK : 13 events/ day

Spectrum



Event Rate above threshold



Challenge---Backgrounds

Internal Backgrounds

Cosmogenics

Xe: no long-life isotopes

longest: $\tau_{1/2}(^{127}Xe)$=36.4 days

^{85}Kr ($\tau_{1/2}$=10.7y): $^{85}Kr/Kr \sim 2\times10^{-11}$

1Bq/m^3 in air

10Hz ^{85}Kr decays in 1 l liq-Xe

(if 10 ppm contamination)

need < 4×10^{-15}g/g for Kr/Xe(for < 1BG/day)

^{42}Ar ($\tau_{1/2}$=33y): $^{42}Ar/Ar=7\times10^{-15}$

1Bq/m^3 in air

need < 2×10^{-11}g/g for Ar/Xe

U/Th

should be < 10^{-16}g/g (for < 1BG/day)

Spallation (250μ/day at Kamioka site)

assuming 10 mb on each Xe isotope

→ 2 events /day x ??

External Backgrounds

+30 cm self-shields

Need MC study: underway

γ-ray backgrounds from outside

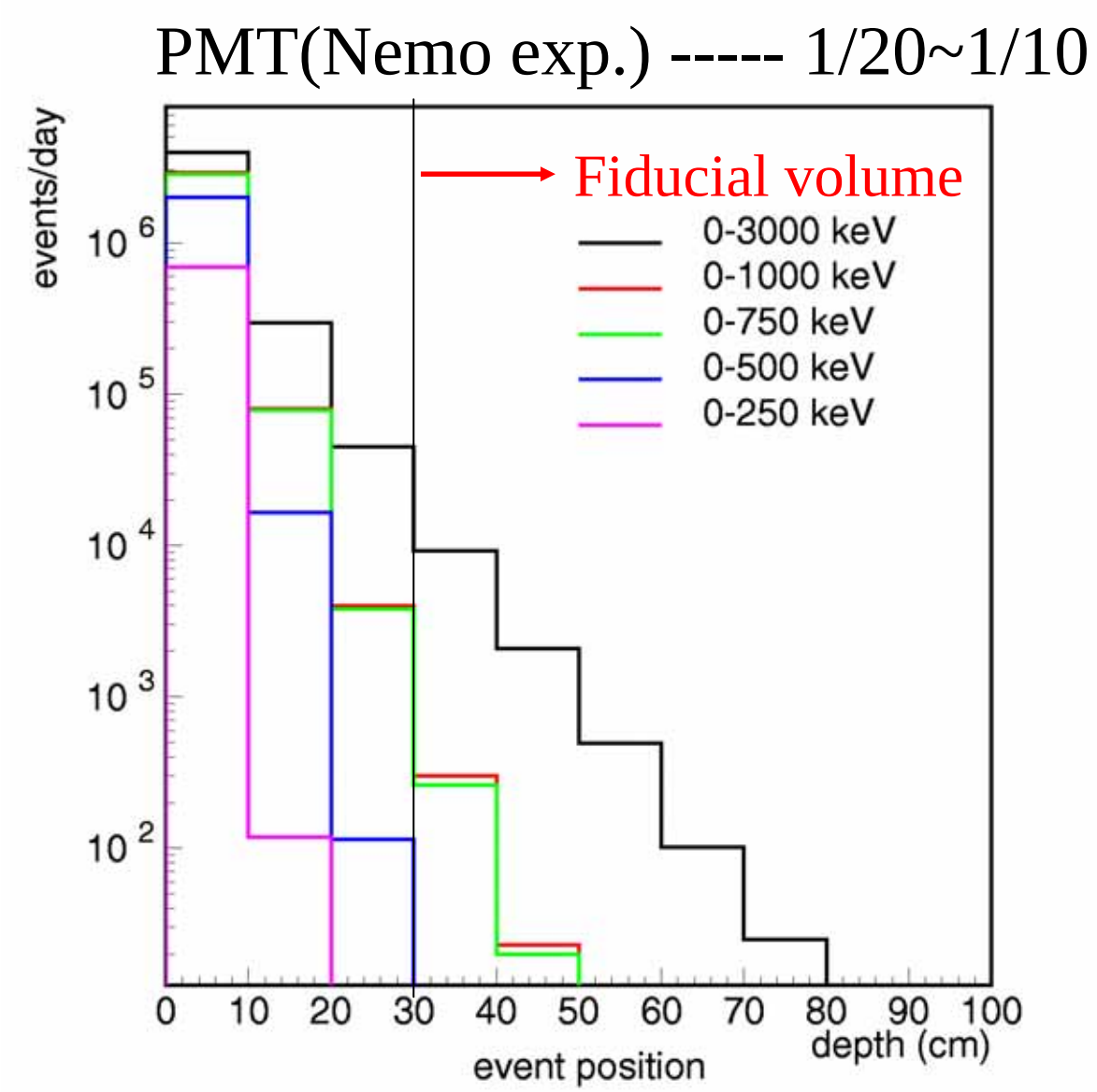
Assume

Pb&OFHC: U/Th 1ppb (inc. ^{210}Pb)

Breeder (0.18Bq(40K),0.068Bq(Th),0.10Bq(U))

---------- largest BG

PMT(Nemo exp.) ----- 1/20~1/10



BG is small less than 500 keV

Most serious Backgrounds
$2\nu\ \beta\beta$ decay

^{136}Xe 2ν ββ decay BACKGROUND

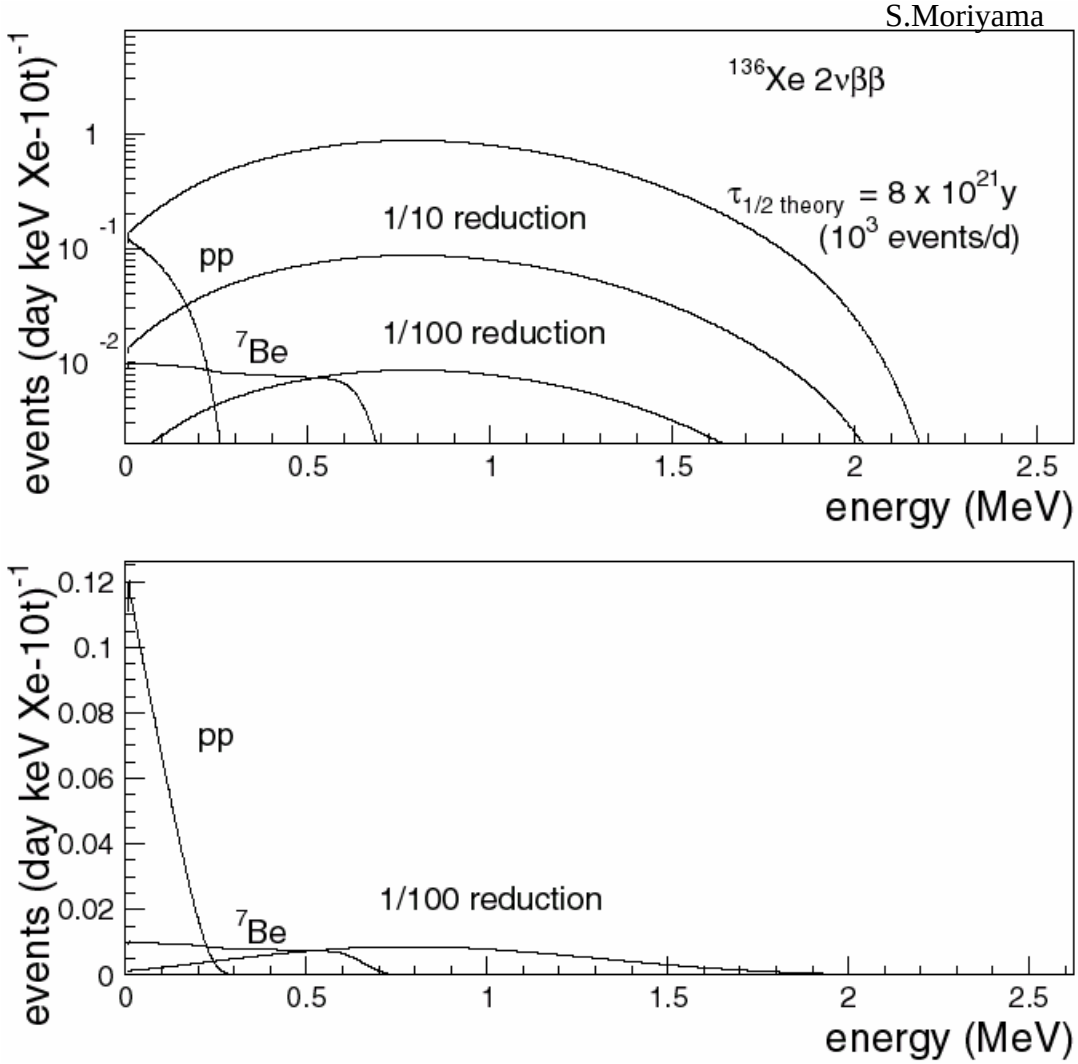
Q=2.476±8 MeV

~1000 events /day for 8x10^{21}yr.

(exp. > 0.5x10^{21}yr)

Rate of ^{136}Xe 2ν ββ decay

S.Moriyama



Need life time measurement

If $\tau_{1/2}$ <(10~100) x (8x10^{21}y)

➔ Isotope Separation

What is the 'best Isotope Separation' for solar neutrino, dark matter and 0νββ

ββ-nucleus

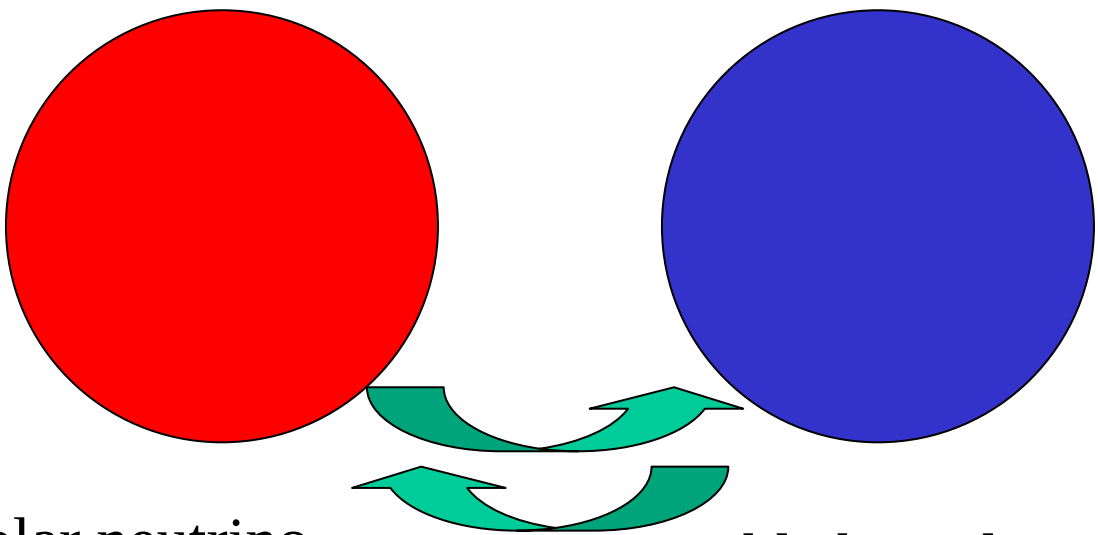
^{124}Xe	^{126}Xe	^{128}Xe	^{129}Xe	^{130}Xe	^{131}Xe	^{132}Xe	^{134}Xe	^{136}Xe
(0.10%)	(0.09%)	(1.92%)	(26.4%)	(4.07%)	(21.2%)	(26.9%)	(10.4%)	(8.87%)

Mostly Odd | Mostly Even

Separate here

Odd enriched

Even enriched: containing ^{136}Xe



Solar neutrino

Dark Matter

Spin dependent

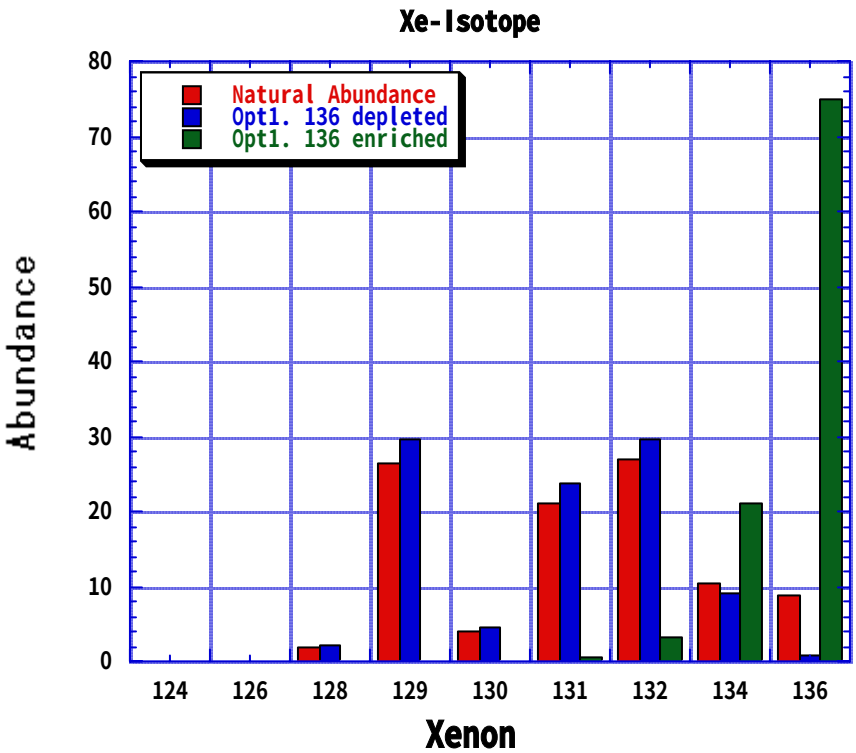
Double beta-decay

Dark Matter

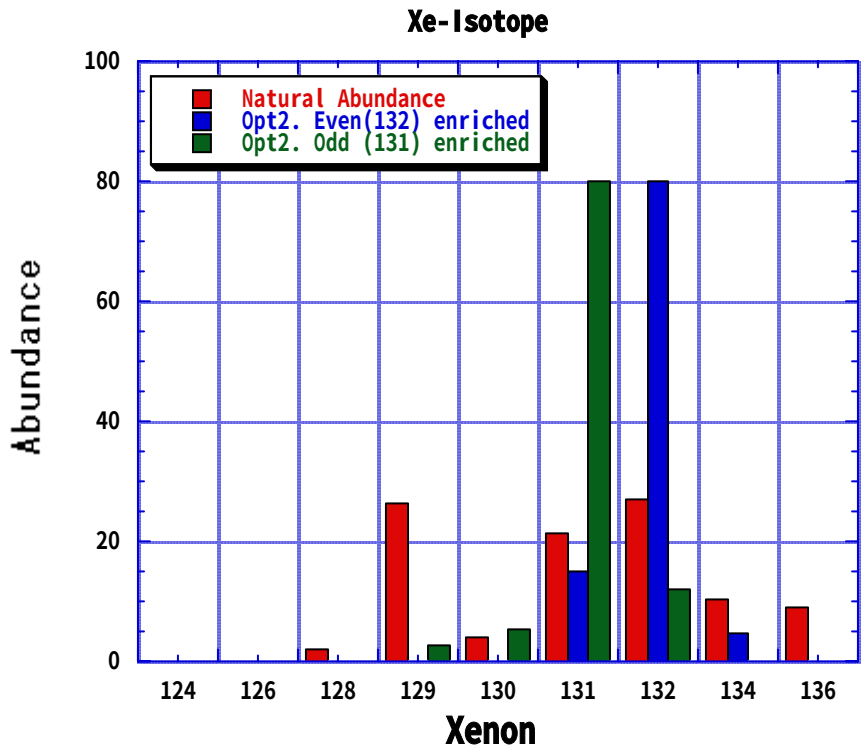
Spin dependent

Spin independent

Xe-Isotope separation Opt. I



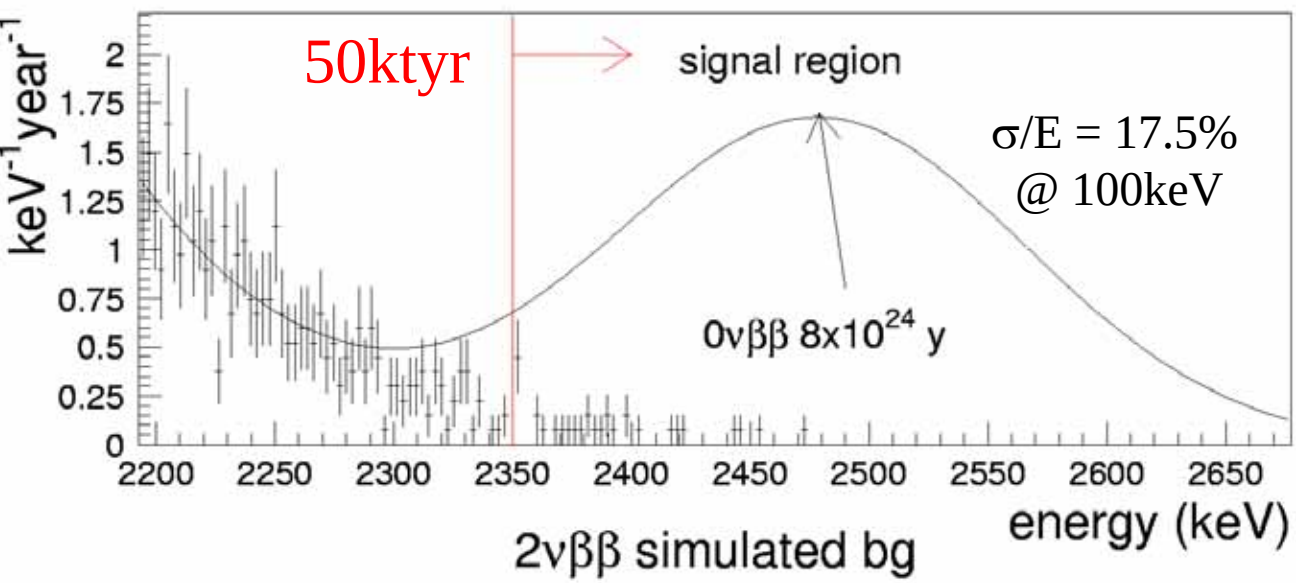
Xe-Isotope separation Opt. II



Sensitivity of 0νββ decay

Assumption：BG only from 2νββ

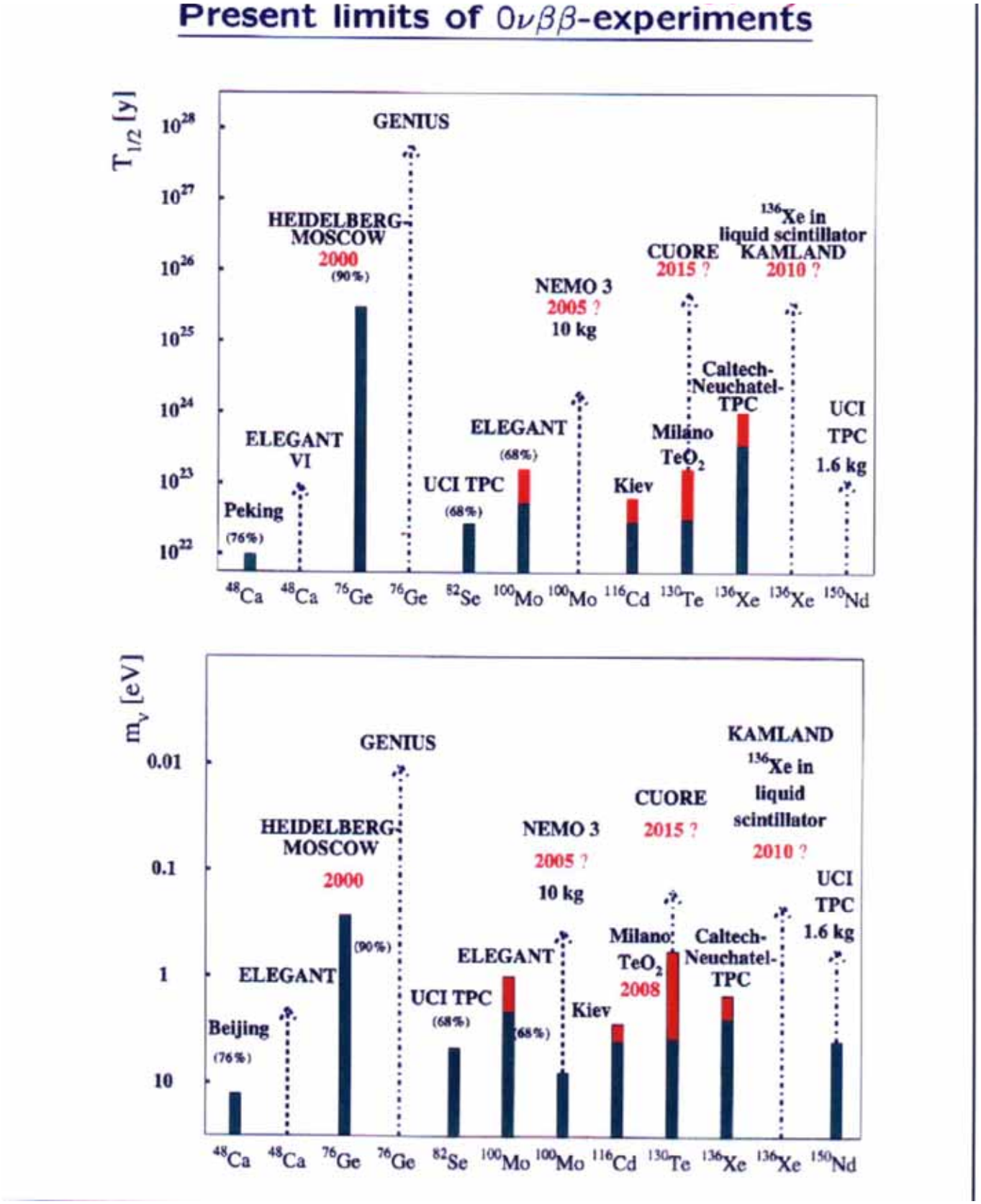
Natural Xenon



Sensitivity ~3.3×10^{26} yr (5yr)

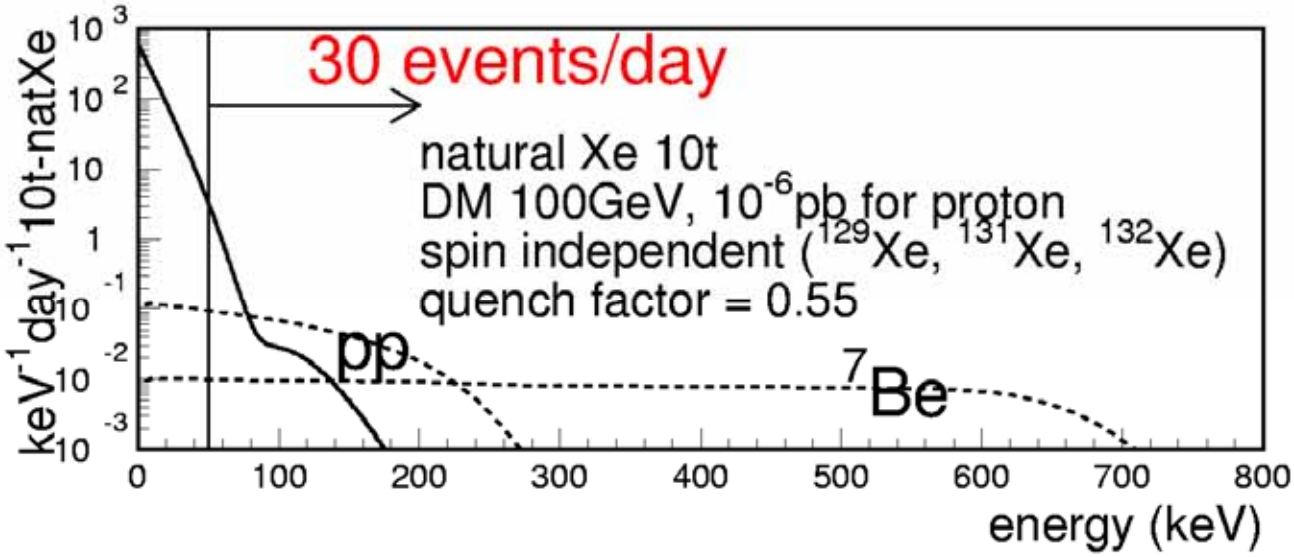
→ $\langle m_\nu \rangle$ < 0.06-0.09 eV

Status of the double beta decay experiments



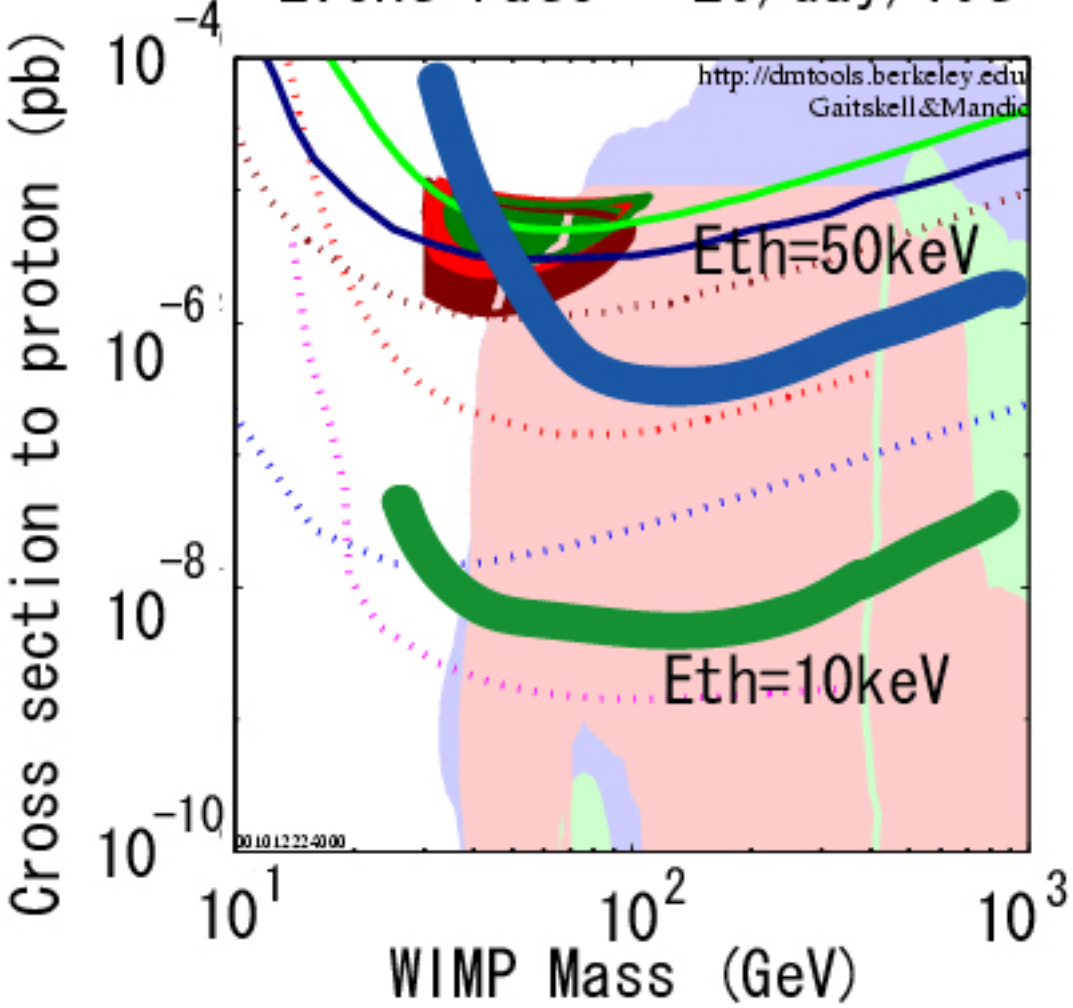
Double beta decay and solar neutrino solutions

Sensitivity to Dark matter search



Sensitivity to DAMA's allowed region

Spin independent case



DATA listed top to bottom on plot

DAMA 1996 Exclusion Region (90%CL)

CDMS Feb. 2000 ver. sub. to PRL

DAMA 1998 20k kg–days NaI Ann. Mod. 2sigma

DAMA 2000 58k kg–days NaI Ann.Mod. 3sigma,w/o DAMA 1996 limit

DAMA 2000 58k kg–days NaI Ann. Mod. 3sigma w/DAMA 1996

Heidelberg DMS, projected

Genino projected exclusion limit, DM2000

CDMS, projected at Soudan mine

Heidelberg – Genius, projected

Cosetti & Nath, mSUGRA predictions

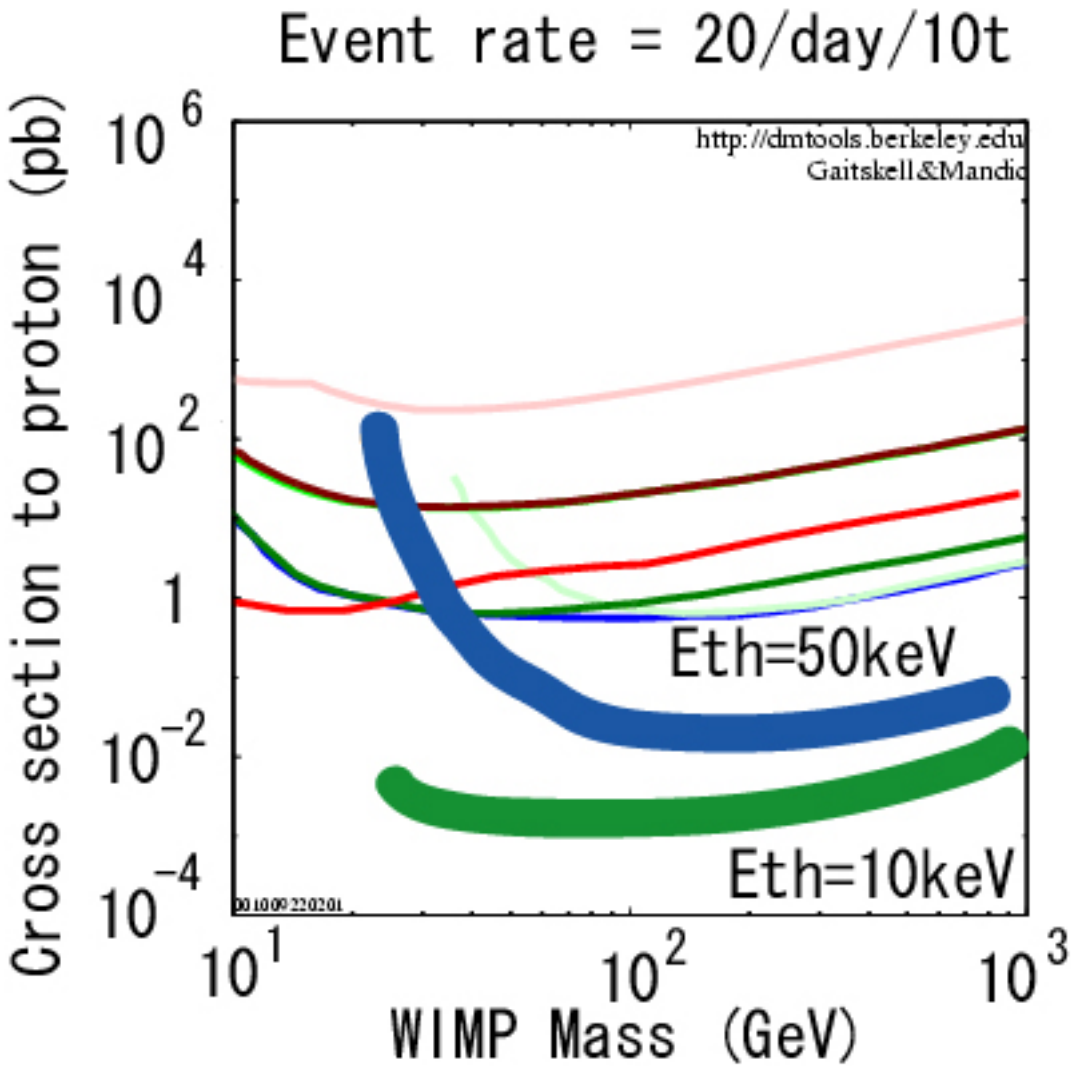
Gondolo et al. SUSY (Gaugino–like Models)

Gondolo et al. SUSY (Higgsino–like Models)

Gondolo et al. SUSY (Mixed Models)

00101222400.0

Spin dependent case



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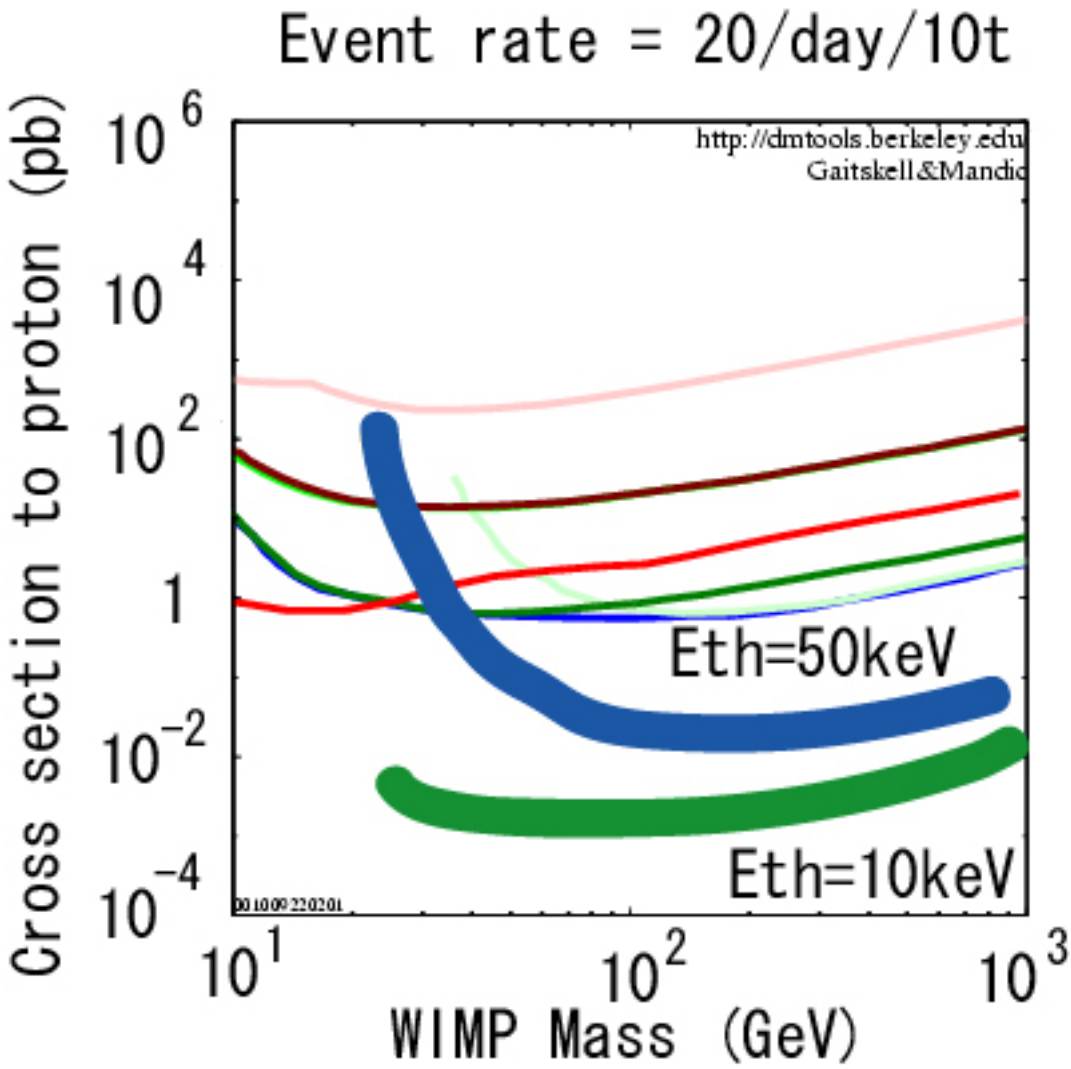
- Edelweiss Al2O3
- Modane NaI
- Saclay
- ELEGANT spin dep. exclusion limit (OTO COSMO Observatory)
- UKDMC NaI, from Na data
- UKDMC NaI, from I data
- UKDMC NaI, from combined Na and I data

001009220201

Spin dependent case



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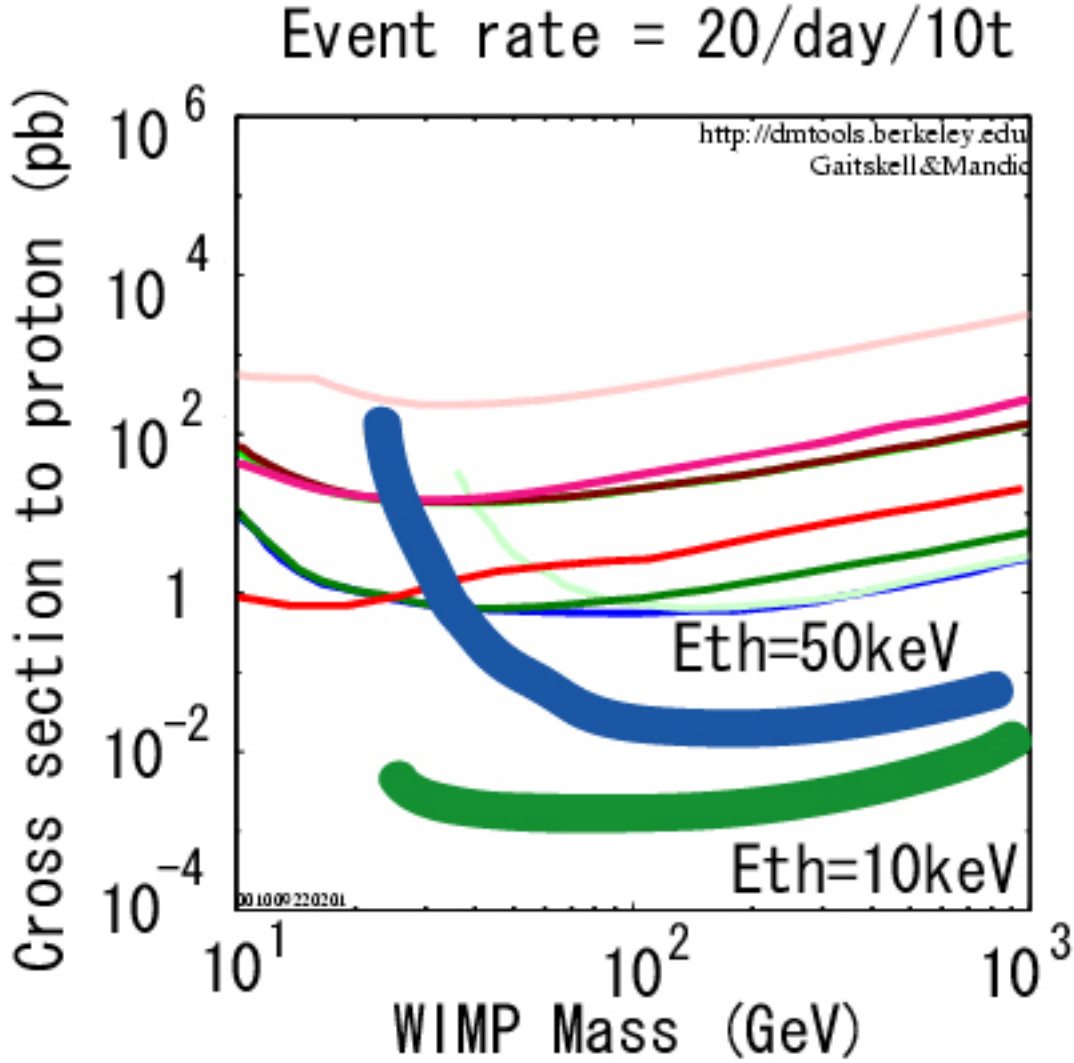

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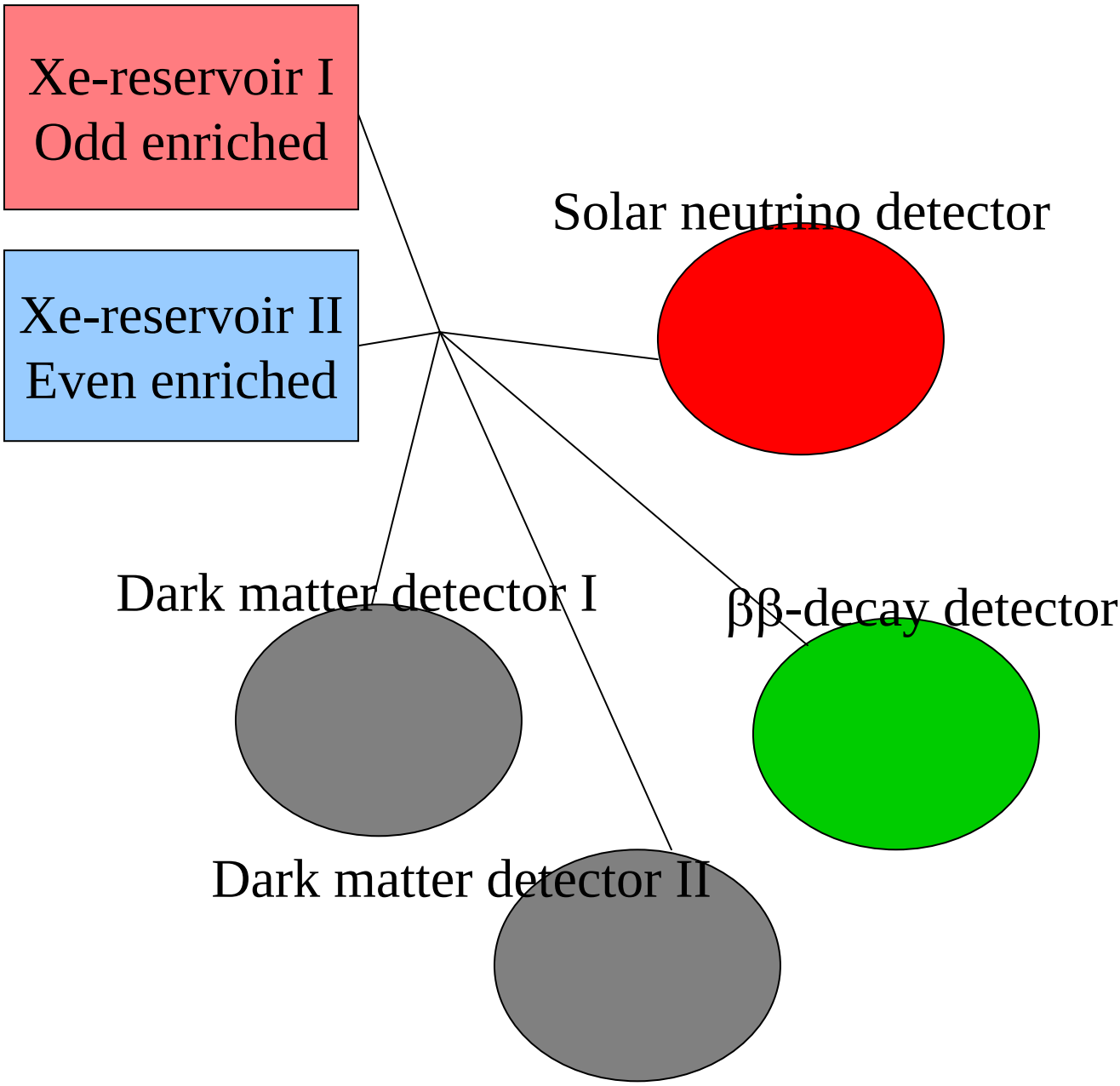
- Tokyo Kamioka (LiF)

Xe-complex

Xe: very easy to transfer Xe from one detector to the other.



TITANIC

Totally Immersible Tank Assaying Nucleon
Immortality Cost-effectively

Multi-Megaton Water Cherenkov Detector (MMWaC)

Totally **I**mmersed **T**ank
Assesing **N**ucleon **I**mmortality **C**ost-effectively
(TITANIC)

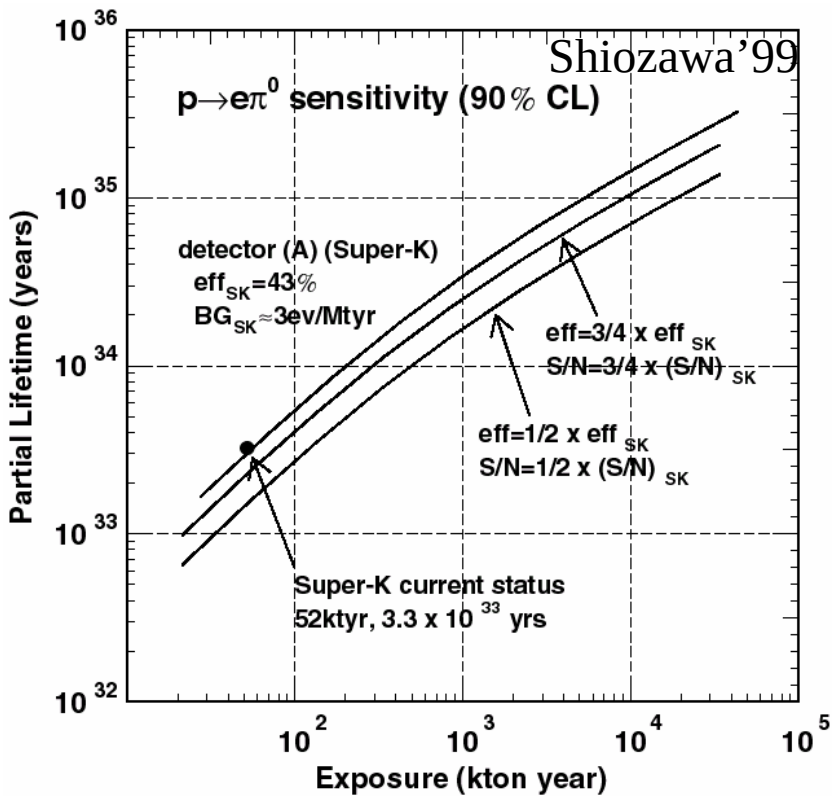
Why multi-megaton?

Theorists`s best bets :

10^{35}〜10^{36} yr for $e\pi^0$ (10^{37}~10^{38} : guaranteed?)

$5x10^{34}$ yr for μK, νK ($1x10^{36}$: guaranteed?)

1Mt →~$1x10^{35}$ yr ($e\pi^0$) for 10 yrs' operation



1Mt is not big enough!

Characteristics of the detector

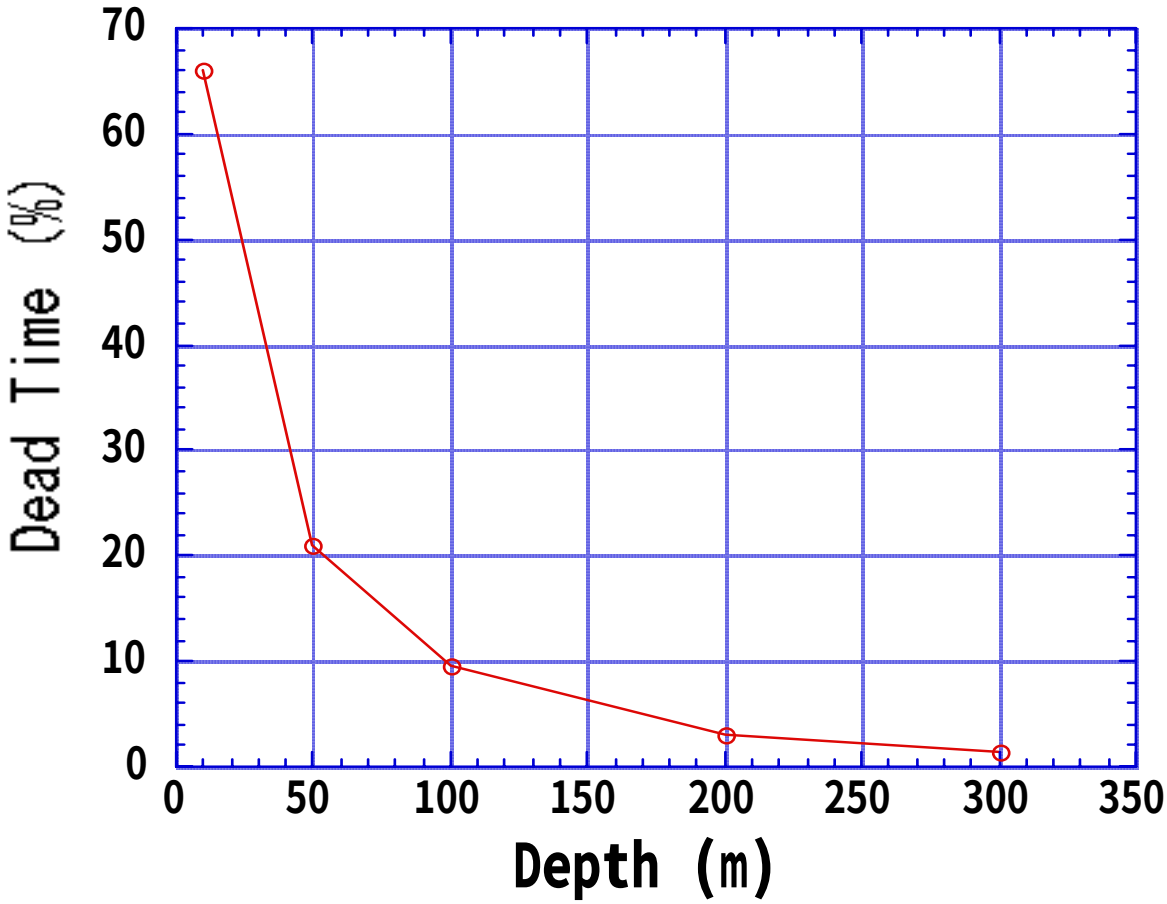
1) Expandability: May start with 1 Mton,
   but can be expandable.
2) Low cost
3) Short construction time

Disadvantage

1) No solar neutrino measurements
2) May not have high sensitivity to νK mode
   → under study
3) Cosmic Ray backgrounds
   → create dead time

Cosmic Ray background and dead time

Vertical flux
1μsec dead time for CR events
→ over estimate



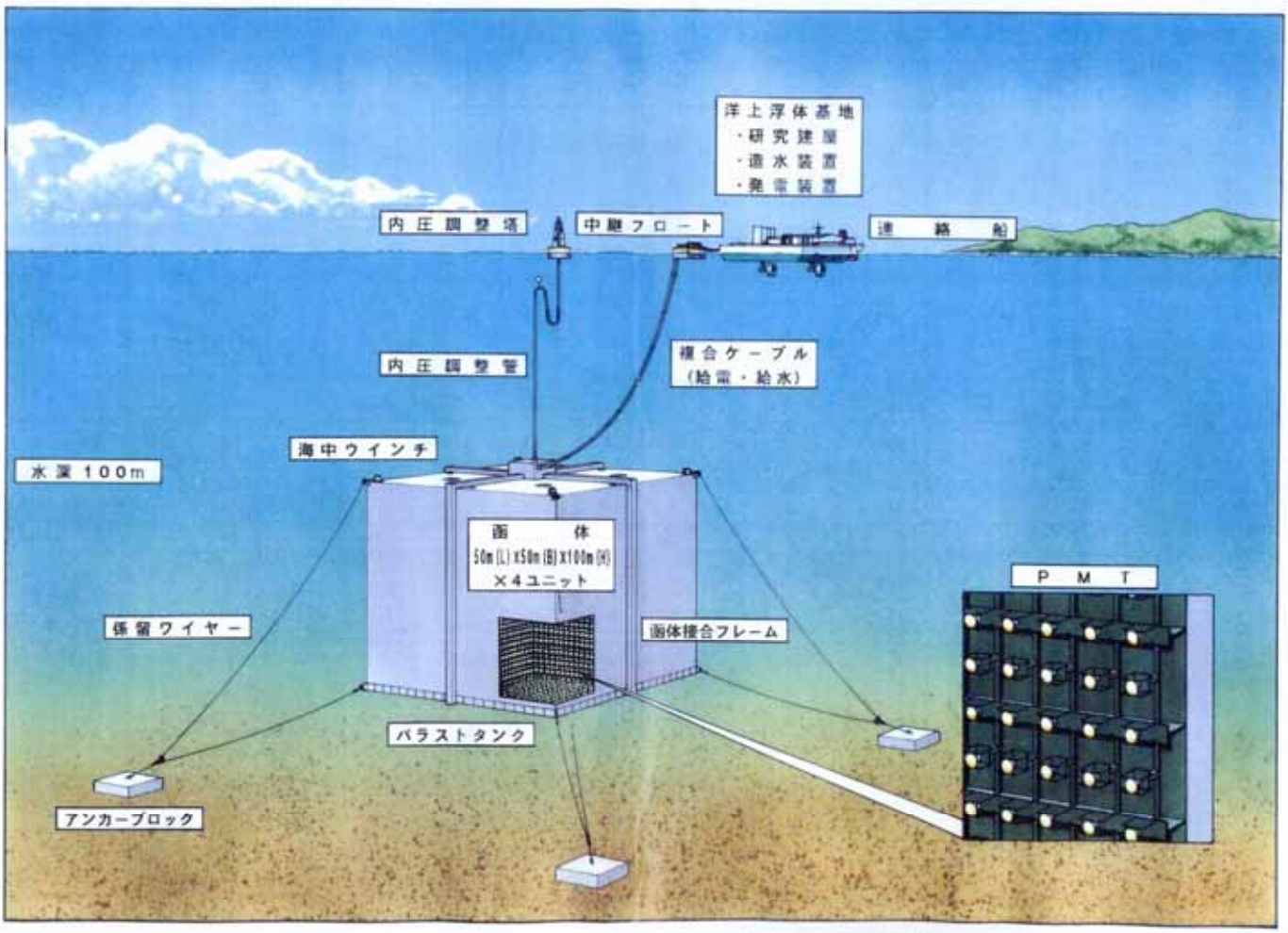
Dead time < 10%

→ go deeper than 100m w.e.
(conservative)

(Depend on the segmentation)

Detector

1) 50m x 50m x 100m x 4 units = 1.0 Mton
(0.813 Mton fiducial : SK x 36)
2) 70m x 70m x 100m x 4 units = 1.96 Mton
(1.673 Mton fiducial : SK x 74)
→ close to the maximum size
→ add one more module → ~ 4Mton



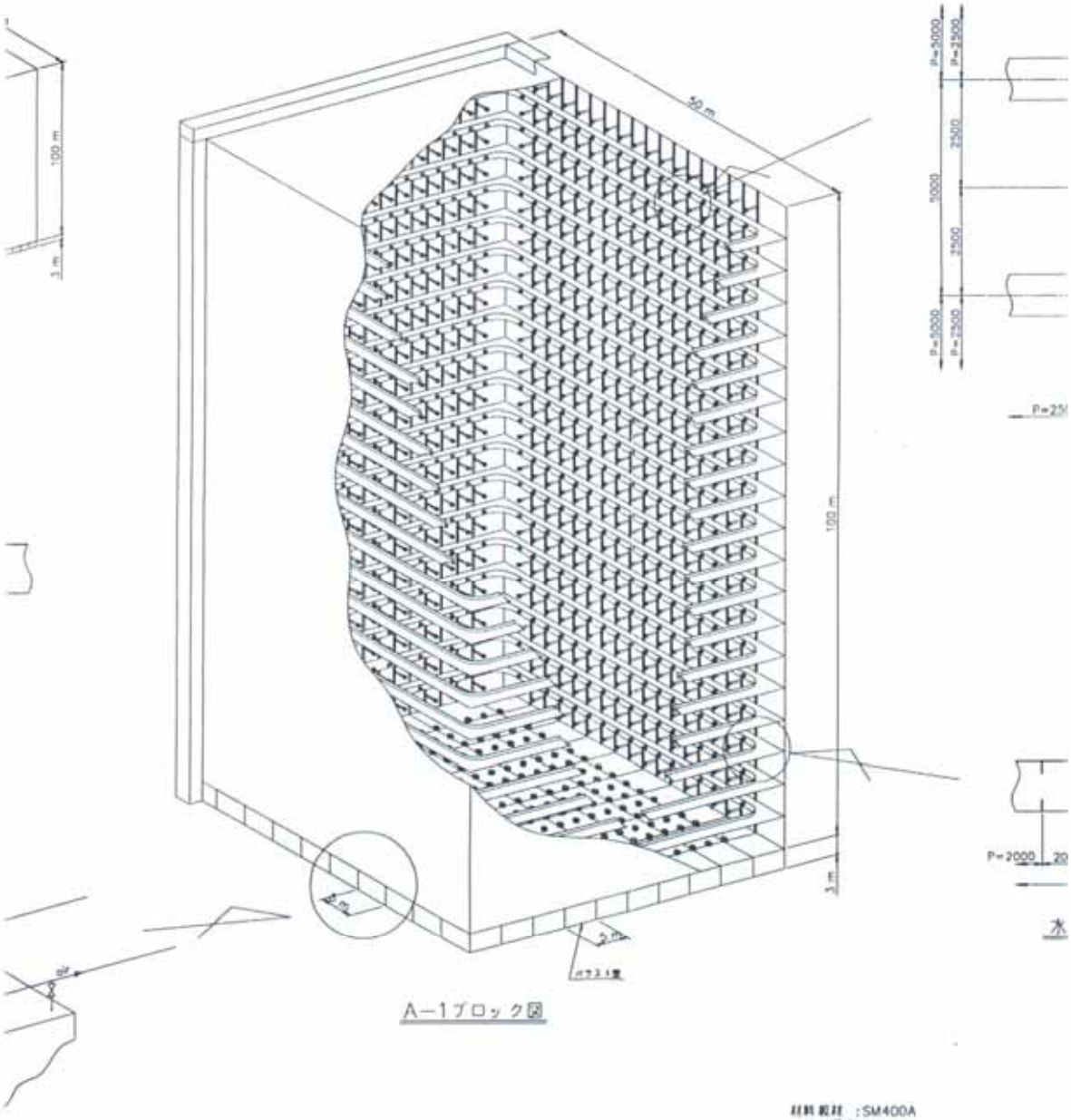
浮沈式陽子崩壊実験装置イメージ図

For 1 Mton module

Steel + epoxy lining
29,000 tons
4 units

→ **Balance to the buoyancy force**

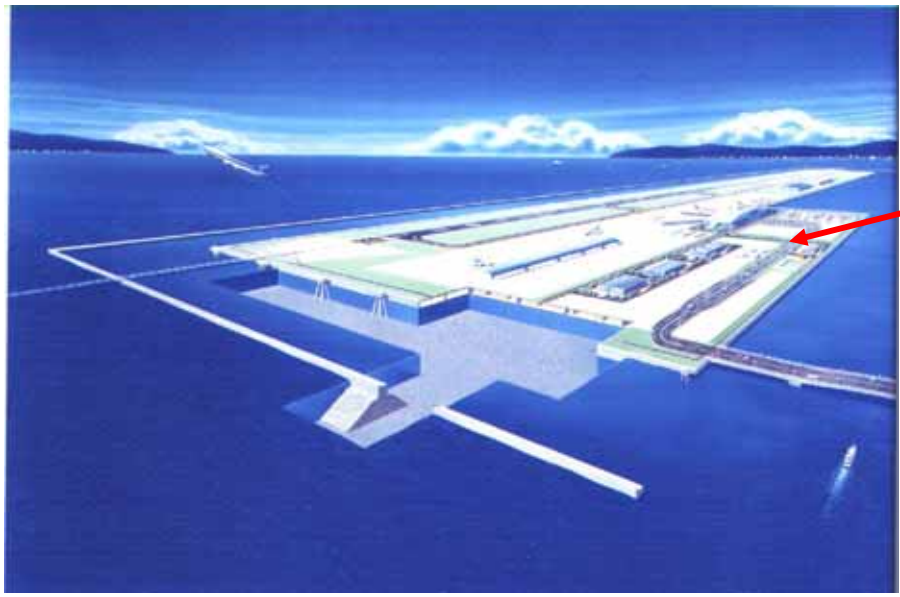
Structure


50 m
120 m
A－1ブロック図
材料 鋼材 ：SM400A
付属品：SUS304
塗装 内面 ：ガラスフレークコーティング
外面 ：船舶用塗装標準＋電気防食
付属品：なし

Floating bulge for the facility

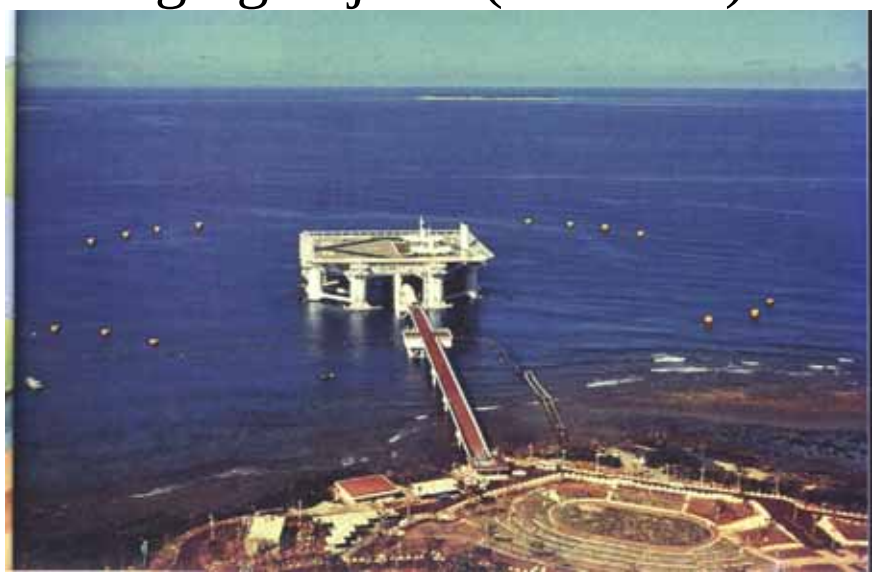
(30m x 40m : steel + epoxy lining)

Mega-float (Japanese project)



ex. floating airport

sub-merging objects (can float)



1) Generator → 1.5 MW
2) Desalination system
3) Water purification system
4) Research buildings

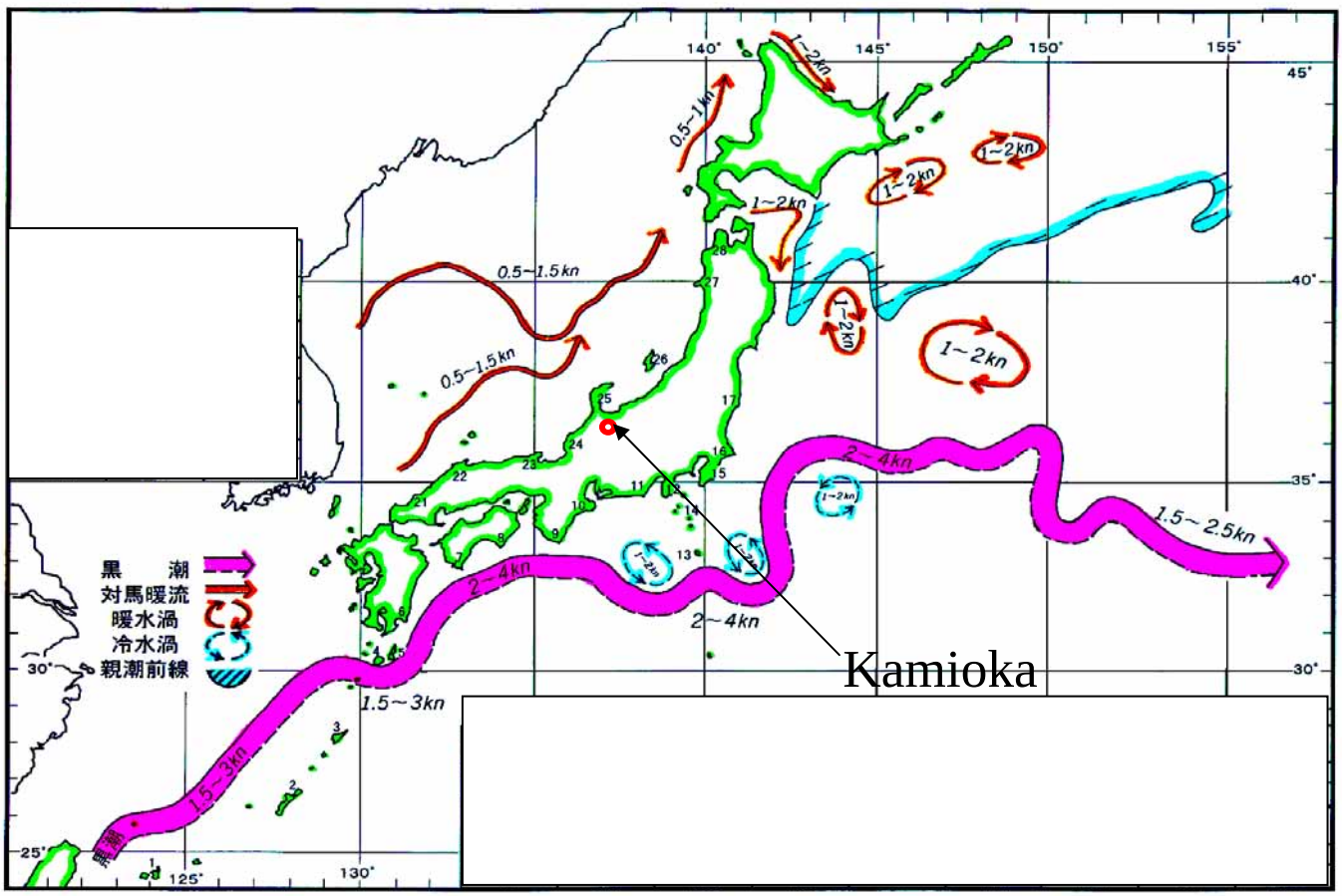
Water desalination system

10k tons /day (2 system)

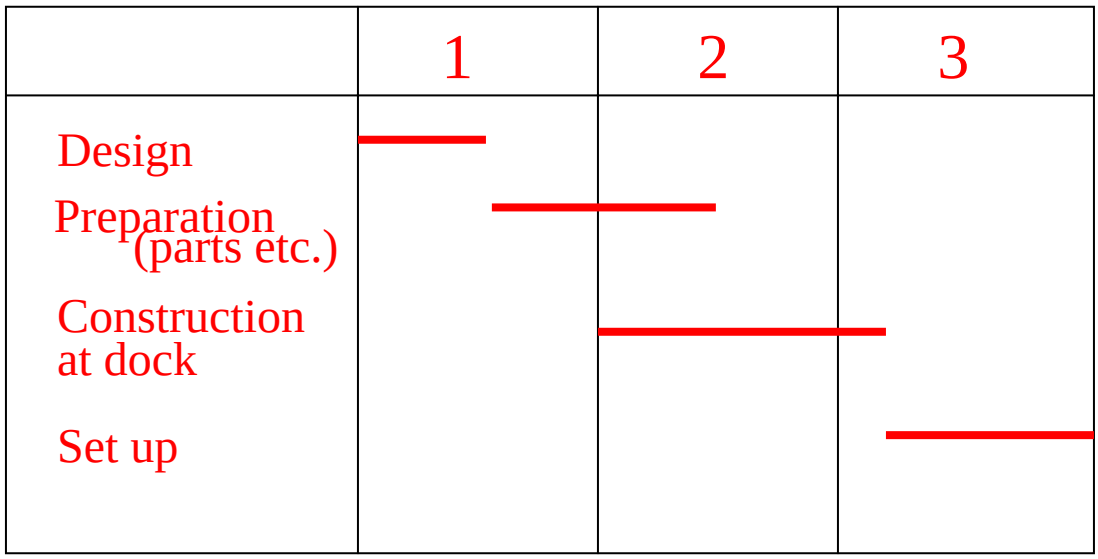
100 days for 1Mton

Where we can place the detector?

Tidal current < 3 kn !!
(knot)



Construction periods



2~3 years:

very short

Cost
80% of the initial quotation

Total volume (Mega ton)	1.00 (100x100x100m^3)	1.96 (140x140x100m^3)
Fiducial volume (Mega ton)	0.813 **(36xSK)**	1.673 **(74xSK)**
Container	71.0 M$	107.4 M$ ↓
set up	25.0	25.0 ↓
light sensor and electronics (assume 1k$/each channel) PMT density = SK x (1/4)	43.8 (43792PMTs)	68.1 ↓ (68112PMTs)
others	10.0	10.0
floating bulge	8.6	8.6
generator	5.0	5.0
desalination plant	32.0	32.0
total	195.4 M$	256.1 M$

Need to develop a low cost light sensor!!