Liquid-Xe Solar pp ^{7}Be neutrino detector

Y.Suzuki
Kamioka Obs.
ICRR, U.Tokyo

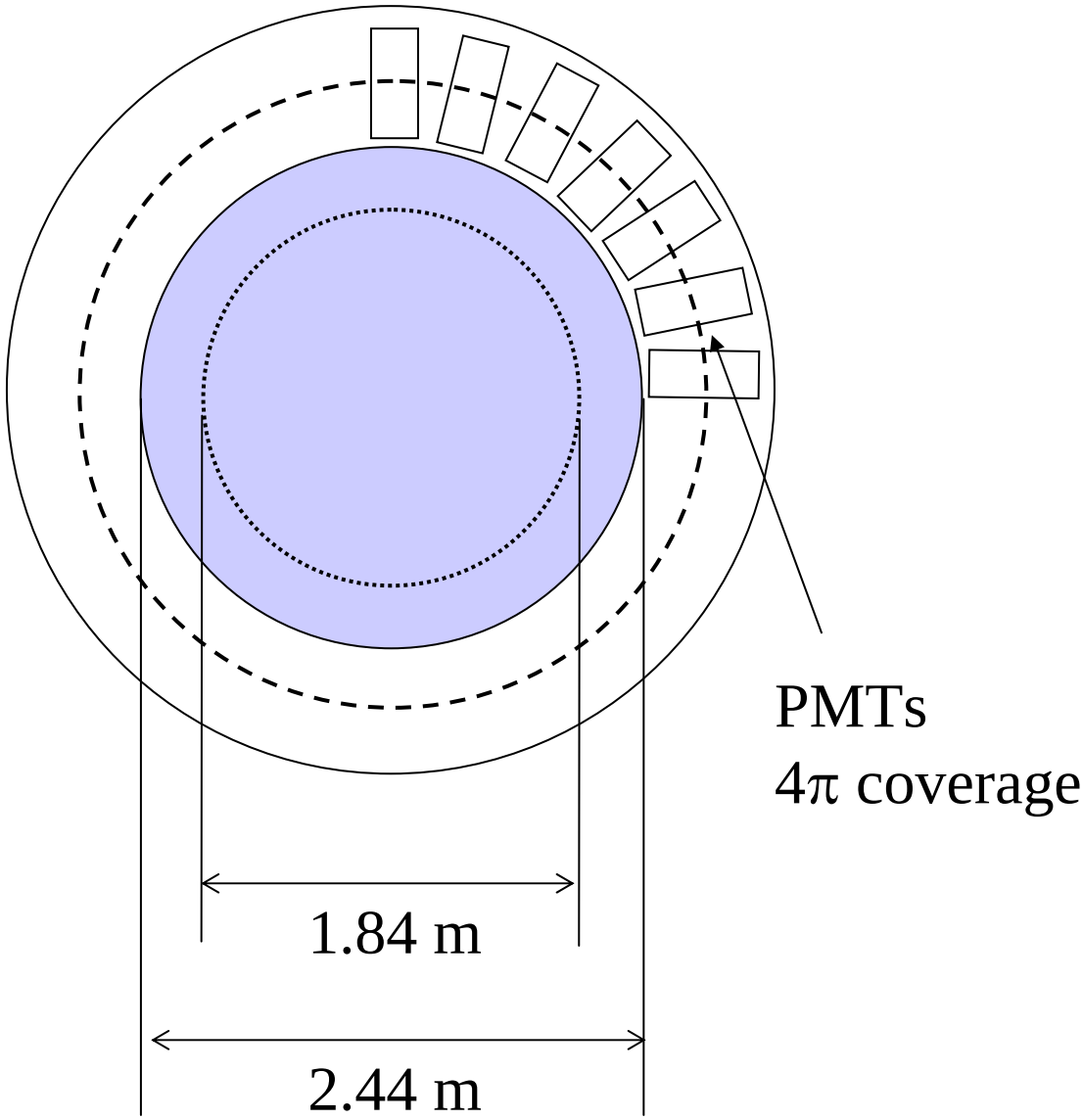
@LowNu

2000-06-15

Detector

1) **Liquid Xenon with 10 ton fiducial volume**
2) **Scintillation detector: 42,000 photons/MeV**
   similar amount of NaI
   (known very well)
3) **Emission: 173 nm**
   can be read by PMTs w/o wave length shifter
4) **Self-Shield (ρ=3.06g/cm^3, Z=54)**
   X_0=2.7cm (30 cm Xe ~ 4m of Water)
5) **Radius: 0.92 m for fid. volume of 10 tons**
   and 1.22m for entire volume of 23 tons
6) **For 40% coverage**
   needs 1692 PMTs (3 inch)
7) **PMT needs quarts (or MgF_2) window**
   (can be placed inside or outside of liq-Xe)

Detector

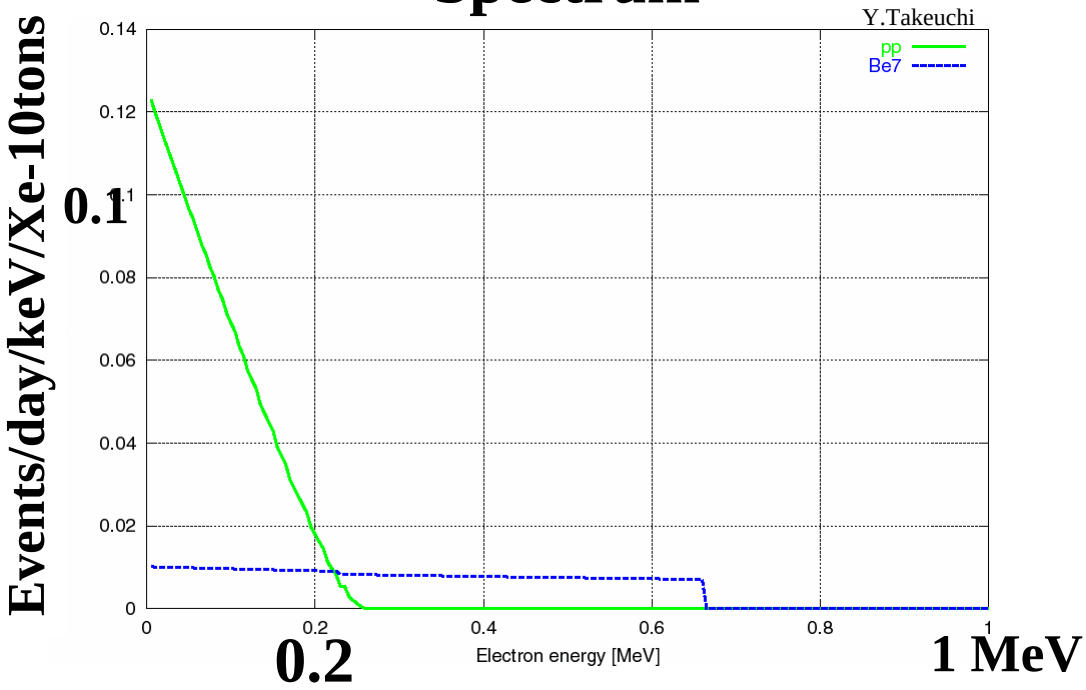


Signal (high rate) $\nu_e + e \rightarrow \nu_e + e$ scattering

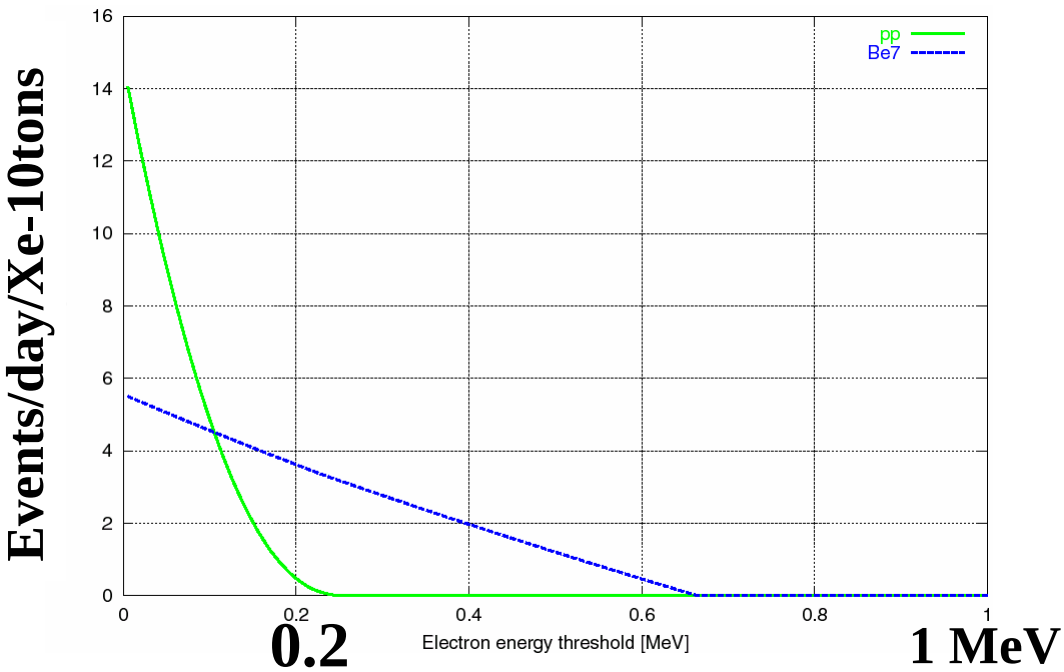
10 pp and 5 ^{7}Be events/day/10ton (> 50 keV)

←→ SK : 13 events/ day

Spectrum



Event Rate above threshold



Other Characteristics

1) 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

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

3) By products

0ν ββ (energy resolution ok?)

(2ν ββ → serious backgrounds: discussed later)

Dark Matter Search

4) Possibility to scale up

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 < 1decay/day for 10tons)

^{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

(for < 1decay/day for 10tons)

U/Th

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

Further reduction backgrounds from U/Th-chain

α identification

PSD

Recombination time

electron events: ~ 40ns

nuclear recoil

or α : ~ 3ns

TWO Phase detector →

Electric field → ionized electrons only from electron events DRIFT

In gas phase → proportional scintillation

ION SWEEPER

Assumption:

ionization of all the daughters

ion life time – long enough to drift away

Newly produced daughters → all swept away

Original U/Th products (accumulated before):

Short lived → decay out in a few months

Long lived → Most: α-decay ← identified

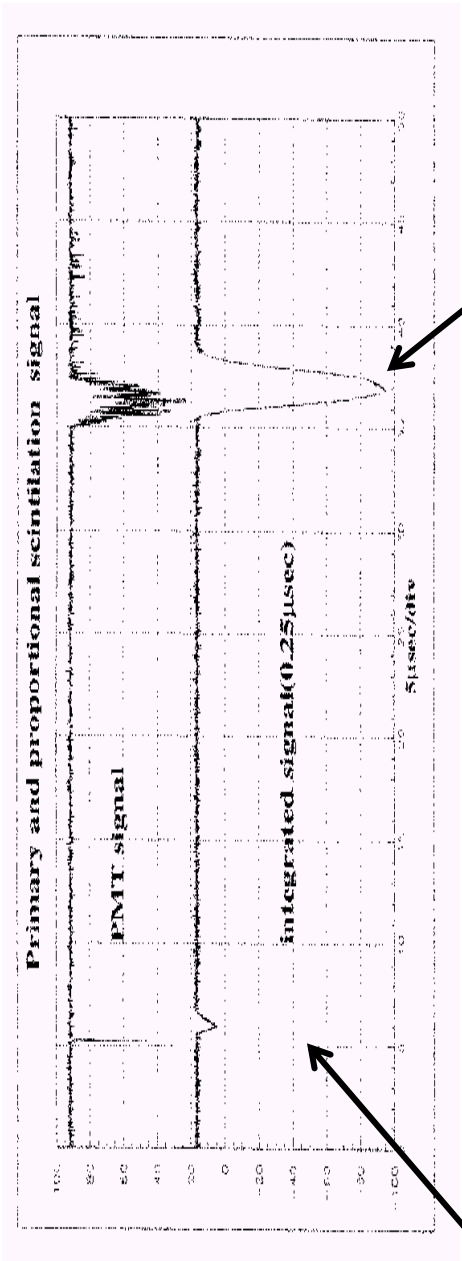
but, β/γ: ^{228}Ra(5.75y) 45keV

^{210}Pb(22.3y) 63keV

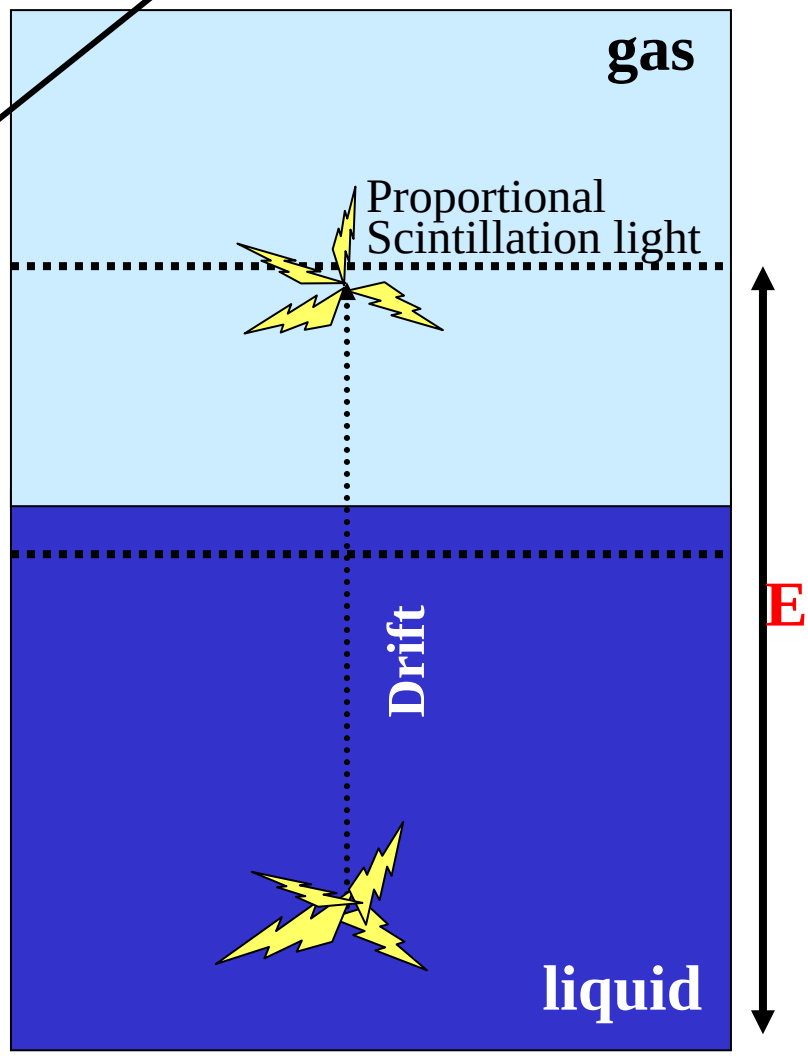
→ may determine energy threshold

→ **may not be necessary to go down to 10^{-16}g/g level**

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.
……

Purification

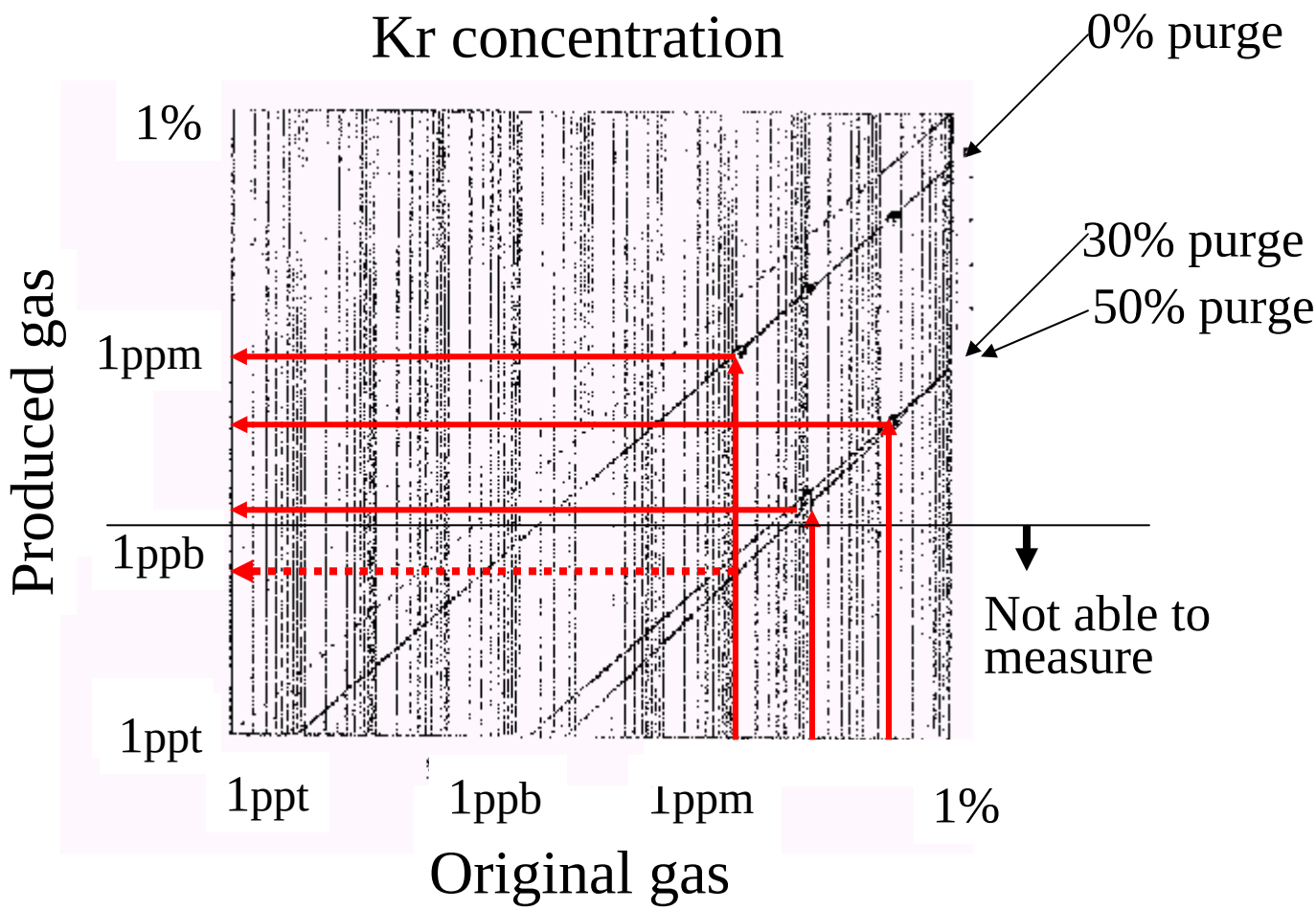
3 phases (gas, liquid, solid)

- **distillation**
- **bubbling**
- **centrifugal**
- **absorption column →**

can be done even during the experiment

New development

Absorption column: **→ "Kr free" Xe**



Spallation backgrounds

250μ/day at Kamioka site

assume: most cross sections →(Z, A-1), (Z, A-2)

^{136}Xe(8.87 %) → ^{135}Xe :9.1h Q_β=1.16MeV

^{134}Xe(10.44%) → ^{133}Xe :5.3d Q_β=0.43MeV

^{128}Xe(1.919%) → ^{127}Xe : small abundance

^{126}Xe(0.089%) → ^{125}Xe : small abundance

^{124}Xe(0.096%) → ^{123}Xe : small abundance

^{129}Xe(26.4 %) → ^{127}Xe : EC(664keV)

^{133}Xe: β/γ (81keV: 6ns) coincidence?

^{135}Xe: 96% β/γ (249keV) ≳ pp-ν

assuming 10 mb on ^{136}Xe and ^{134}Xe

→ 2 events /day x ??

short lived

← correlation with muons

long lived

← ion sweeper ?? or circulation

go deeper

External Backgrounds

+30 cm self-shields (10tons → 23 tons)

Need MC study: underway

^{136}Xe 2ν ββ decay BACKGROUND

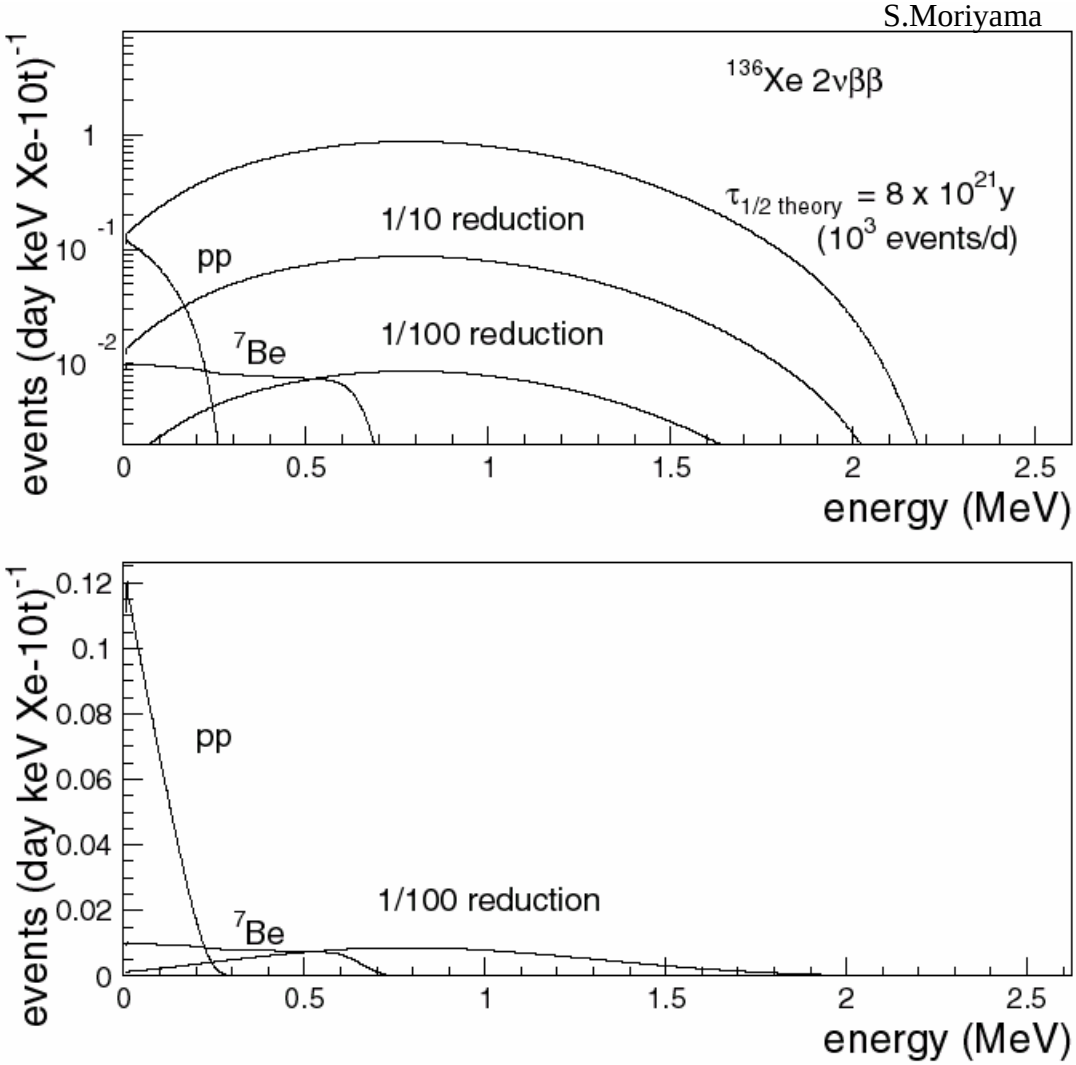
Q=2.476±8 MeV

~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

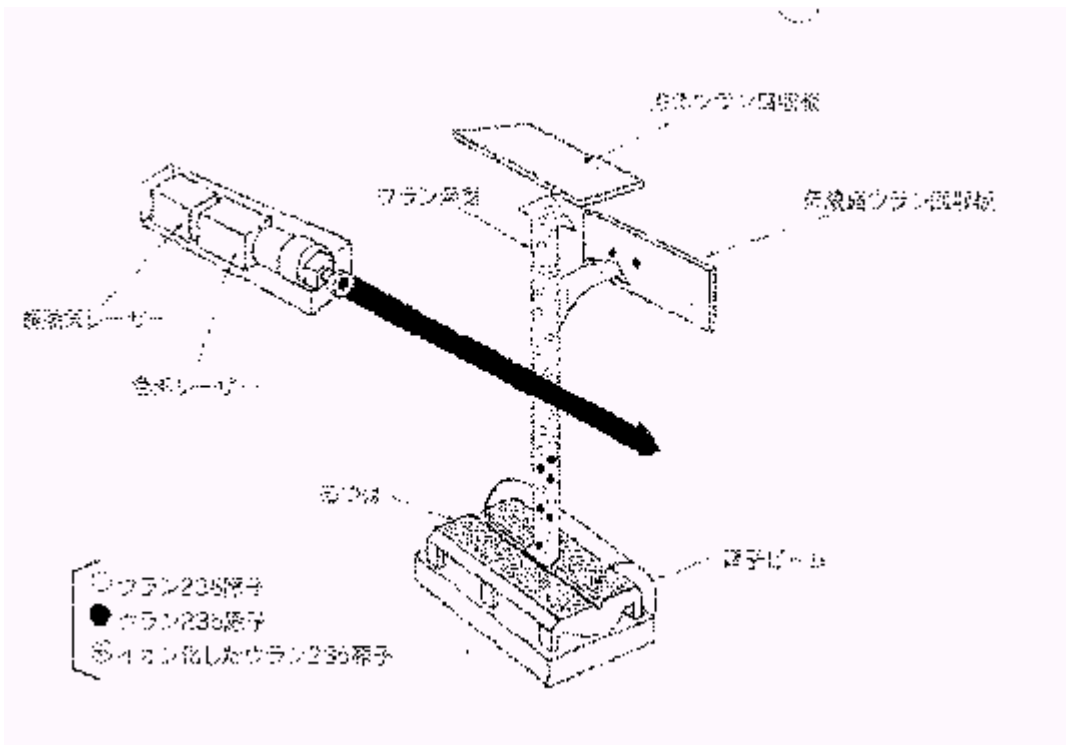
If $\tau_{1/2}$ <(10~100) x (8x10^{21}y)

➔ Isotope Separation

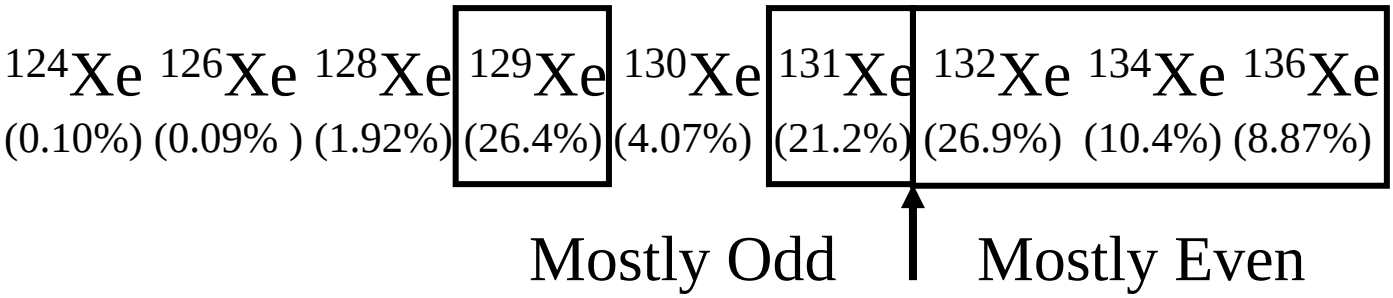
Isotope Separation

Ex. for U

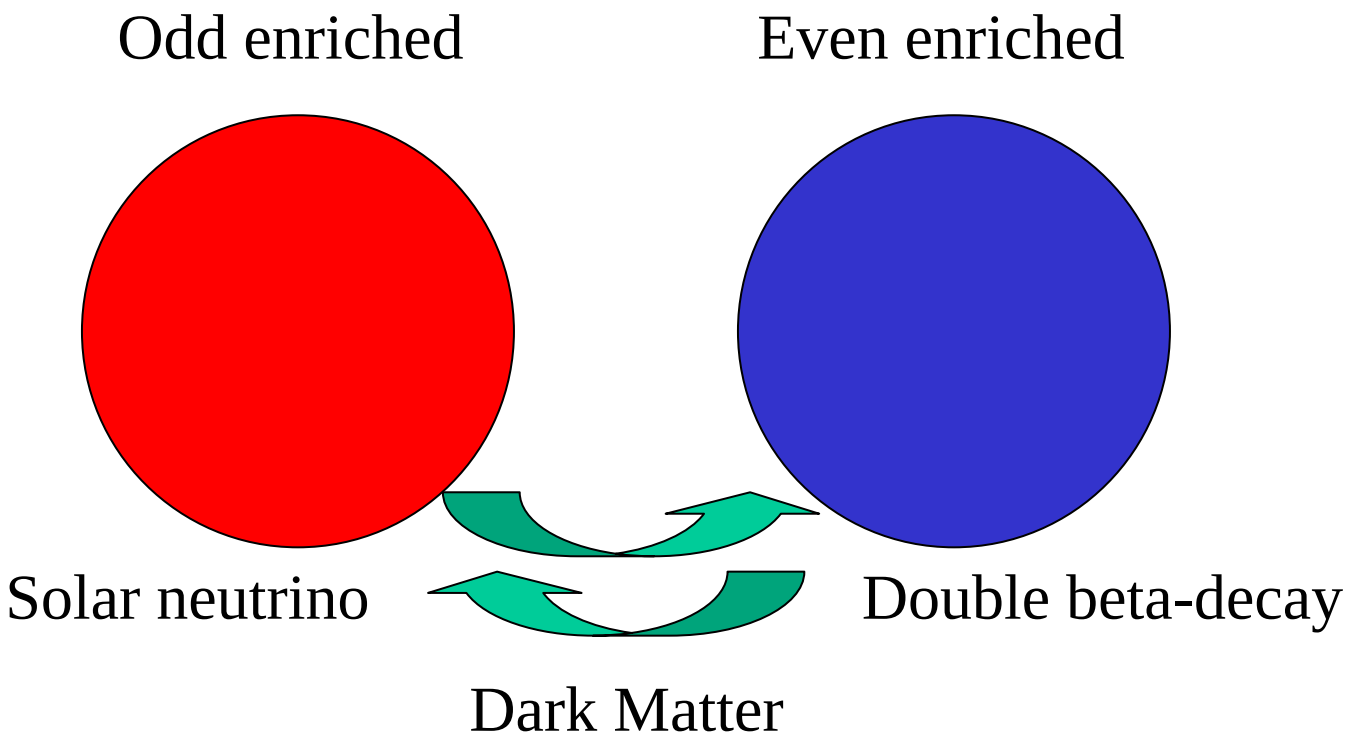
	Sep. co-eff.	Steps
centrifugal	**~1.4**	**10**
chemical	**~1.001**	**1,000**
gas diffusion	**~1.003**	**1,000**
laser	**~10**	**1**



Isotope Separation and Dark Matter Search



Positive identification may be possible by measuring separately with ODD and EVEN nuclei



Cost (in M$)

Liq-Xe	20
PMT	4
Electronics	0.2
Cavity	2
Container	1
Cryogenics	1
Isotope Sep.	10 (?)
	~40 ⟷ ~100 (SK)

Schedule

2000 **Basic test by 1 litter chamber (exists)**
(move to Kamioka this autumn)
---- Background study
---- Use of "Kr-free" Xe
R &D of purification

2001 **Measurement of Spallation (@CERN)**
33 litter (100kg) chamber
(low background container)
----Measurements of $2\nu\beta\beta$ rate
----Background study
----Feasibility of Ion Sweeper
R &D Isotope Separation

2002 **Proto-type & Proposal for the experiment**