AAP 2010, 仙台♪

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Current Status of RENO and Its Future Applications

RENO = Reactor Experiment for Neutrino Oscillation

(On behalf of the RENO collaboration)

- Introduction
- RENO Facility
- Current status of the RENO
- Location of the RENO detector
- Summary

KNRC Korea Neutrino Research Center

RENO

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Chonnam National University

October 3, 2010

❑ Introduction

- We had proposed RENO project in 2005.

– The project had been approved and started in 2006.

-We had started to construct the civil facility and finished it in the south western area between year 2008 and 2009.

-We had started to construct the detector 2009, and we will reach final line in this year.

– The goal of this experiment is to search the θ_{13} parameter in more definte limit.

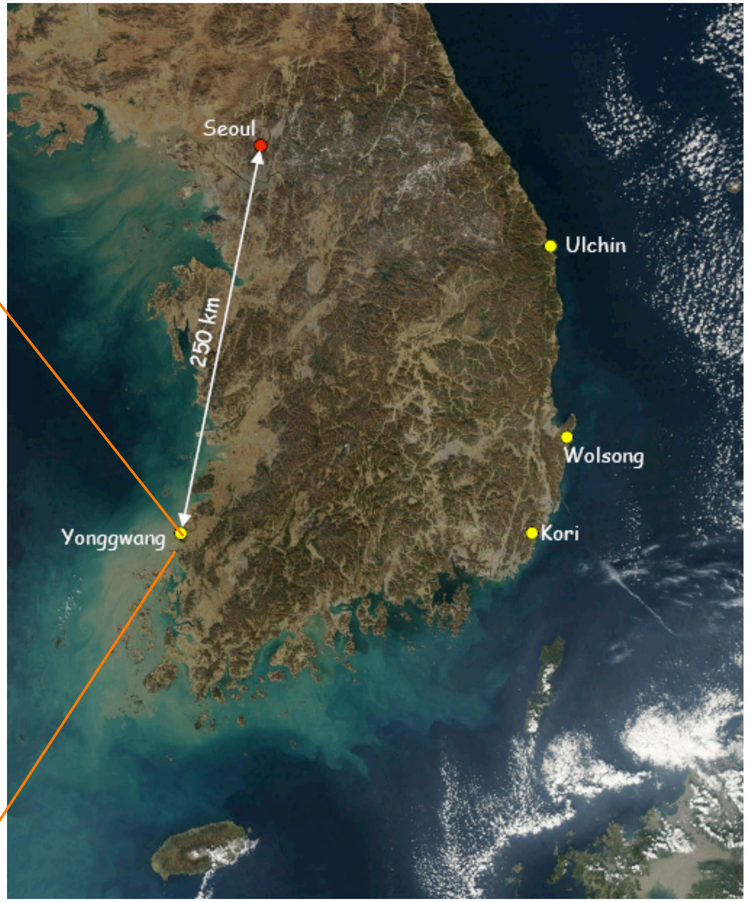
❑ RENO Facility

-I had been focused on the facility till now. So I will review the pr
ocess of the construction in some pages.
- We had been to be difficult to start constructing because of
  anti-nuclear-societies.
  many officer in charge.
  many document and agreement in relation.
 But we could had done something!

- Civil constuction
- Detector design

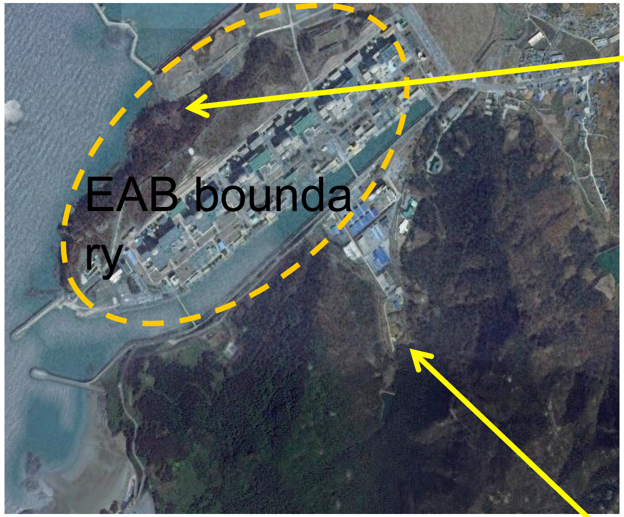
YongGwang Nuclear Power Plant

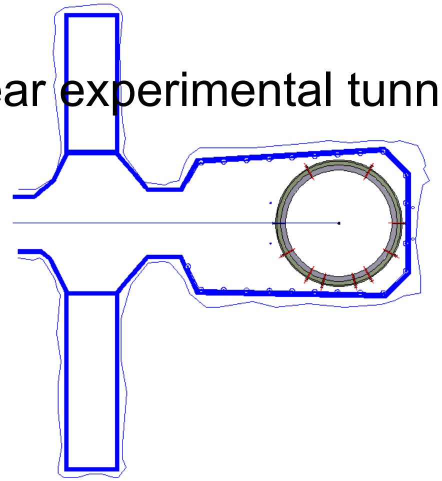
- ❒ Located in the west coast of southern part of Korea
(全羅南道 靈光郡 弘農邑 (株)韓國水力原子力 附近地域)
- ❒ ~400km from Seoul
- ❒ 6 reactors are lined up in roughly equal distances and span ~1.3 km
- ❒ Total average thermal output ~16.4GW_{th}
(2nd largest in the world)

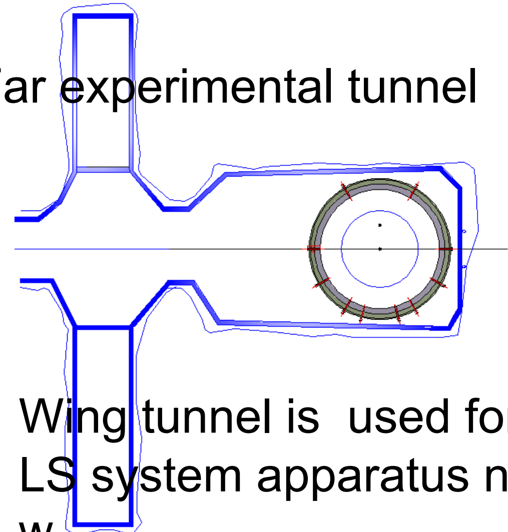


Civil construction(overburden)

Near tunnel is nonfree to enterance
(Inside of EAB boundary)







Far tunnel is free to enter
(Outside of EAB boundary)

Civil construction(Geological survey)

The rock quality and tunnel safety in the RENO underground facility

The physical characteristics of rock around the tunnel had been measured through preliminary drilling prior to constructing the underground facility for detecting neutrino. The stability of the tunnel during excavation and the long term stability had been confirmed on the basis of physical characteristics on the rock around the tunnel.

I. THE GEOLOGICAL CHARACTERISTIC AND THE ROCK IN Y.G AREA

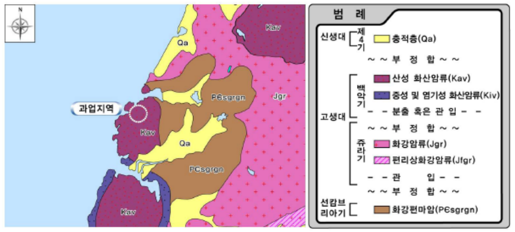


FIG. 1: The geological characteristic around the unground facility site in Yonggwang area.

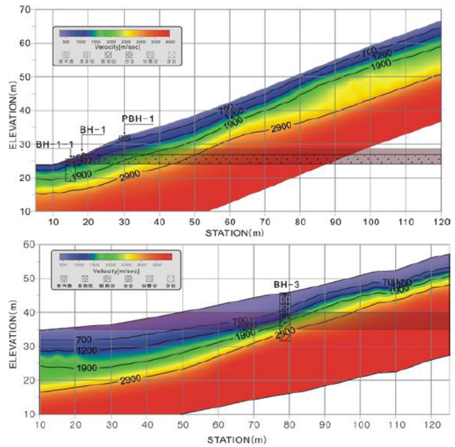


FIG. 3: The electric seismic plots along the survey line parallel with the access tunnel.(top)the plot in the near site, (bottom)the plot in the far site.

II. THE ROCK QUALITY

FIG. 2: Borehole rock samples from the near and far detector sites. (top)the sample in the near site entrance, (bottom)the sample in the far site.

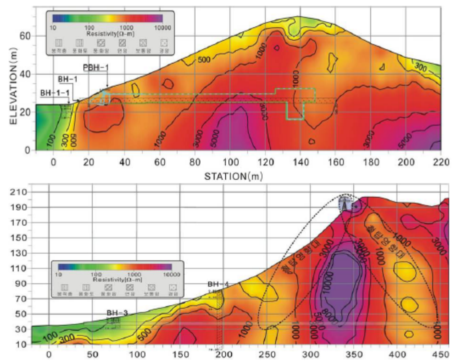


FIG. 4: The electric resitivity plots along the survey line parallel with the access tunnel. (top)the plot in the near site, (bottom)the plot in the far site.

By these surveys♪

Civil construction(Rock quality and tunnel safety)

TABLE I: Physical parameters in the rock

Tunnel	Pysical quantity	Magnitude	Unit
Near	Elastic velocity in Rock	1200	m/s
	Compression strength	143.5	MPa
	Deformation parameter	10395	MPa
	Elastic modulus	16353	MPa
Far	Elastic velocity in Rock	1000	m/s
	Compression strength	143.5	MPa
	Deformation parameter	10395	MPa
	Elastic modulus	16353	MPa

We could have had good rock to excavate♪

FIG. 5: The rock mass rating(RMR) in the tunnel site.(Top) in the near tunnel,(bottom)in the far tunnel.

III. TUNNEL SAFETY

Rock Load P_r by RMR

$$P_r = \frac{100 - RMR}{100} \cdot \gamma \cdot B \qquad (1)$$

In here, γ: unit weight, B: width of tunnel
Pressure of shotcrete(P_{sc})

$$P_{sc} = \frac{f_c}{2}[1 - \frac{(r_i - t_c)^2}{r_i^2}] \qquad (2)$$

Pressure of rockbolt(P_{sb})

$$P_{sb} = \frac{T_{bf}}{S_c \cdot S_l} \qquad (3)$$

In here, $P_t = P_{sc} + P_{sb}$, then

$$Safety\ ratio = \frac{P_t}{P_r} \qquad (4)$$

support pattern	Shotcret (MPa)	Rockbolt (MPa)	Totalpressure of supporting (MPa)	Load of the rock (MPa)	Safety ratio
PS-1	0.171	0.010	0.181	0.012	15.08
PS-2	0.271	0.012	0.283	0.034	8.32

Safety ratio is about 10 in RENO tunnel

TABLE II: Results of the physical parameter in the rock.

RENO detector(construction)

The basic design of RENO underground facility and veto detector

We had constructed the underground facility for the RENO experiment Feb. 25. 2009. NATM method was used to construct the tunnel considering financial and physical condition of tunnel construction. In this page, we will describe the basic scheme including the mechanical condition of the veto detector and the buoyance of the detector.

I. DETECTOR

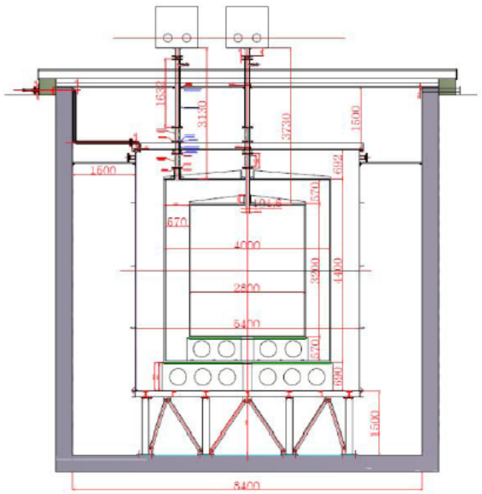


FIG. 1: The feature of the RENO detector.

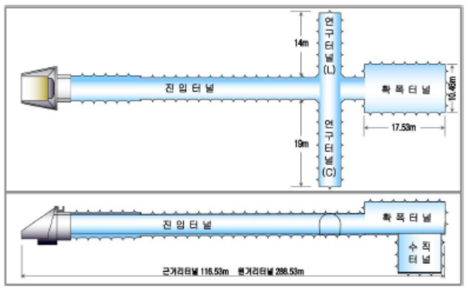


FIG. 2: The plan and the section view in the tunnel.

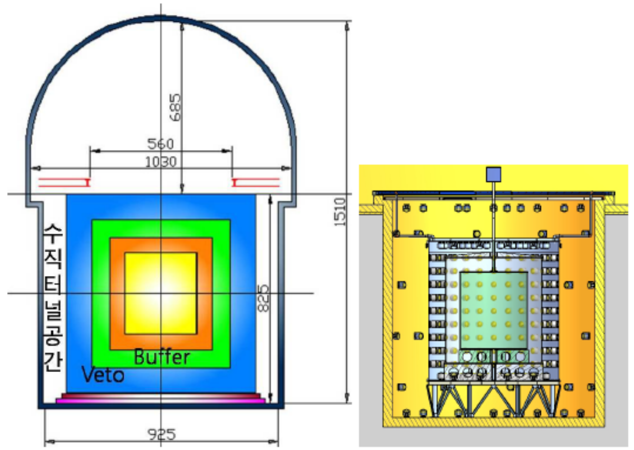


FIG. 3: Detector design in early times(left side). Final design of detector(right side)

FIG. 4: The anchorbolt assembly in the bottom of veto(left) and the concrete tank(right) under construction in last year.

II. BUYOANCE

RENO detector(Buoyancy of the Detector)

TABLE I: Measured result of the volume and buoyancy effect

	volume(cm^2)	density	mass(kg)	buyoancy(N)
Taget LS	18710.0	.86	16090.6	
Target vessel	932.7	1.19	1109.91	
sum	19642.7		17210	317.3
Gamma LS	33267.3	0.86	28609.9	
Gamma vessel	2270.0	1.19	2720	
sum	35537.3		31329.9	1478.5
Buffer oil	76620.0	0.84	64360.8	
Buffer Lid	246.6	8.05	1985.1	
Buffer barrel	969.6	8.05	7805.2	
Buffer supporter	383.0	7.805	2989.3	
sum	78219.2		77117.8	1078.7
veto mass	354028.8	1	354028.8	

small♪
weight!♪

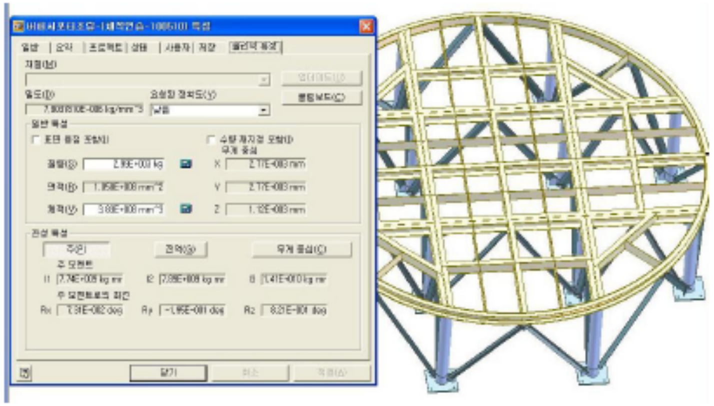


FIG. 6: Measured volume and mass of the buffer supporter by 3D inventor

If the detector will be filled with liquid material,
Buoyancy will be balanced by structure material slightl
y♪

FIG. 5: The feature of the veto tank(left) and the buffer tank filled with water(right).

❑ RENO status

-In order to reach final, all part is bei ng gathering and assembling in the near and far tunnel.

-Working in now
-Electronics
-Electronics and DQA
-Gd Loaded Liquid Scintillator
-RENO Event Display
-Constructing the Veto Tyvec Frame
-PMT setup

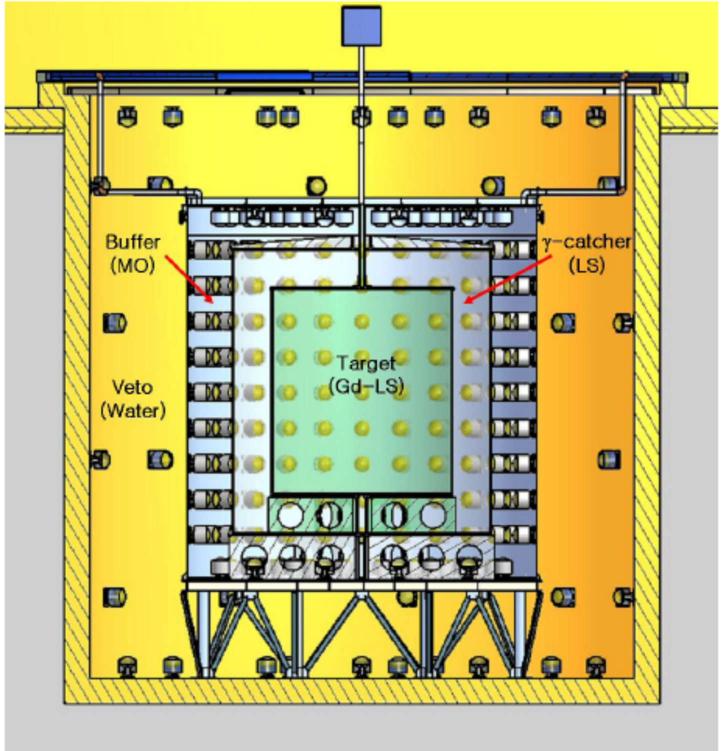


Figure 1.9: A schematic view of RENO detector. A neutrino target of 18.7 m^3 Linear Alkyl Benzene (LAB) based liquid scintillator doped with Gd is contained in a transparent acrylic vessel, and surrounded by 33.2 m^3 unloaded liquid scintillator of gamma catcher and 76.5 m^3 non-scintillating buffer. There are 354 and 67 10-inch PMTs mounted on buffer and veto vessel walls, respectively.

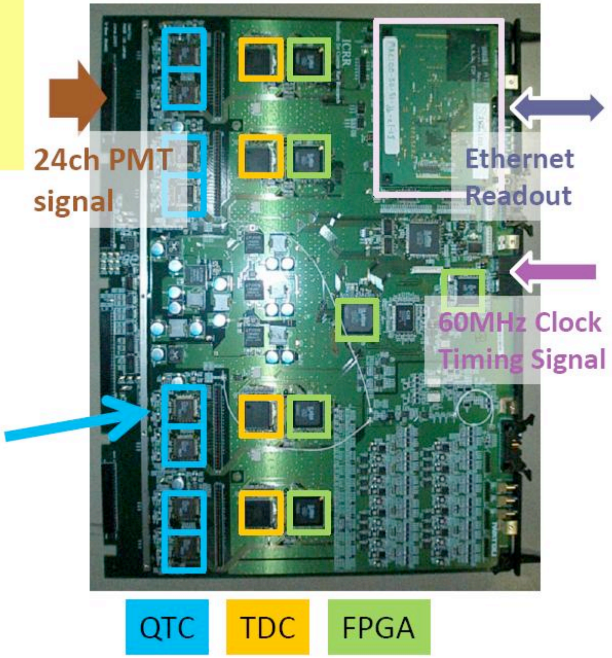
Working in now ♪

- PMT setup(holder assembly, mounting, cable running)
- VETO Tyvek setup (frame constuction, Tyvek frame setup)
- Gd Loaded Liquid Scintillator
  (Arclyic mixing tank fabrication, Gd-LS production)
- LS mixing and storage tank
  (Fabricating Stainless/Arclyic storage tank and setup)
- Electronics Hut & Control Room
  Electronics setup
  DAQ(computer, harddisk, networking, Run Control setup)
- Calibration system
  (PMT T & Q, energy calibration, pedestal, PMT gain & uniformity,
  vertex resolution, ...)
  - Glove Box
  - 3D robot arm
  - 1D calibration system
  - Laser calibration system
- Monitoring system
  (PMT performance, trigger rate, data stream, HV, temperature, pedestal
  data...)

Electronics

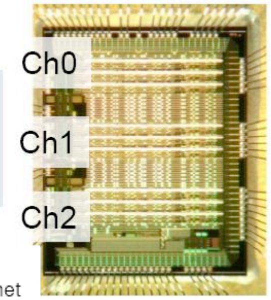
We have developed new elec.
- stable DAQ for next 10~20 yrs
- wider dynamic range
- hi speed & dead-time-less

QBEE (QTC-Based Electronics with Ethernet)

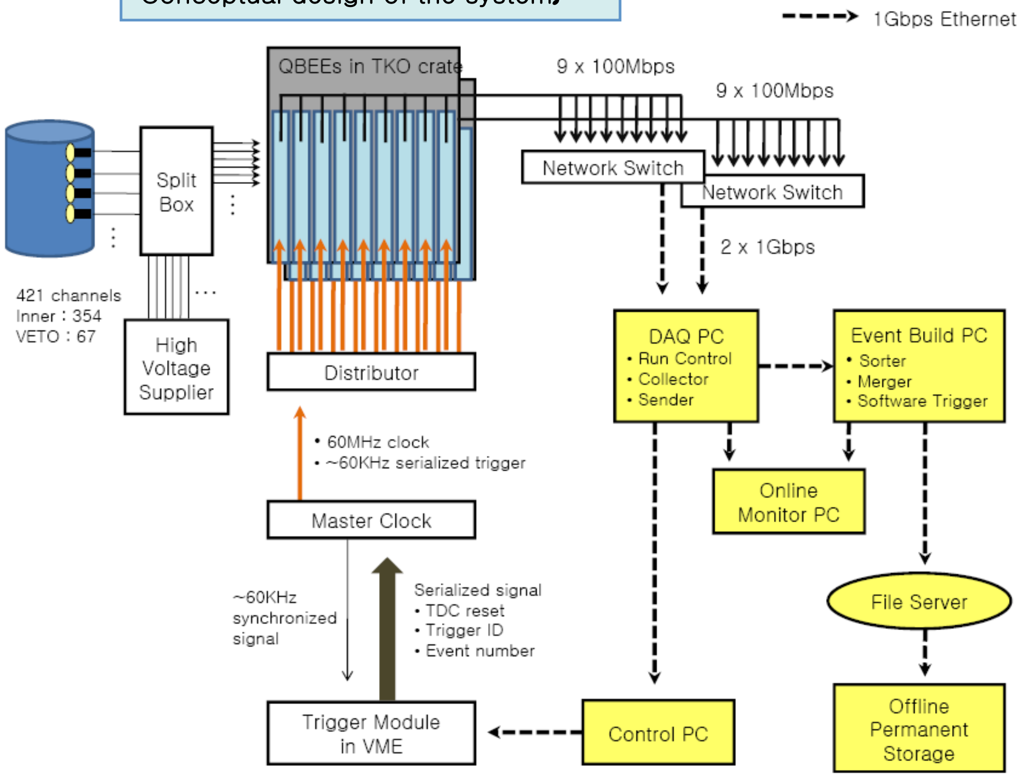


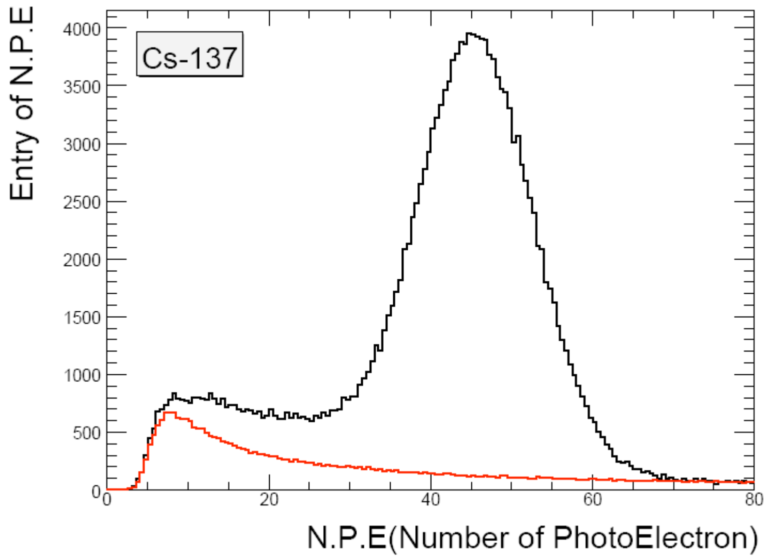
- We use SK new electronics♪ (all hardwares are ready)♪

Custom ASIC QTC
3 ch x 3 gain
0.35um CMOS



Conceptual design of the system♪





Electronics and DAQ

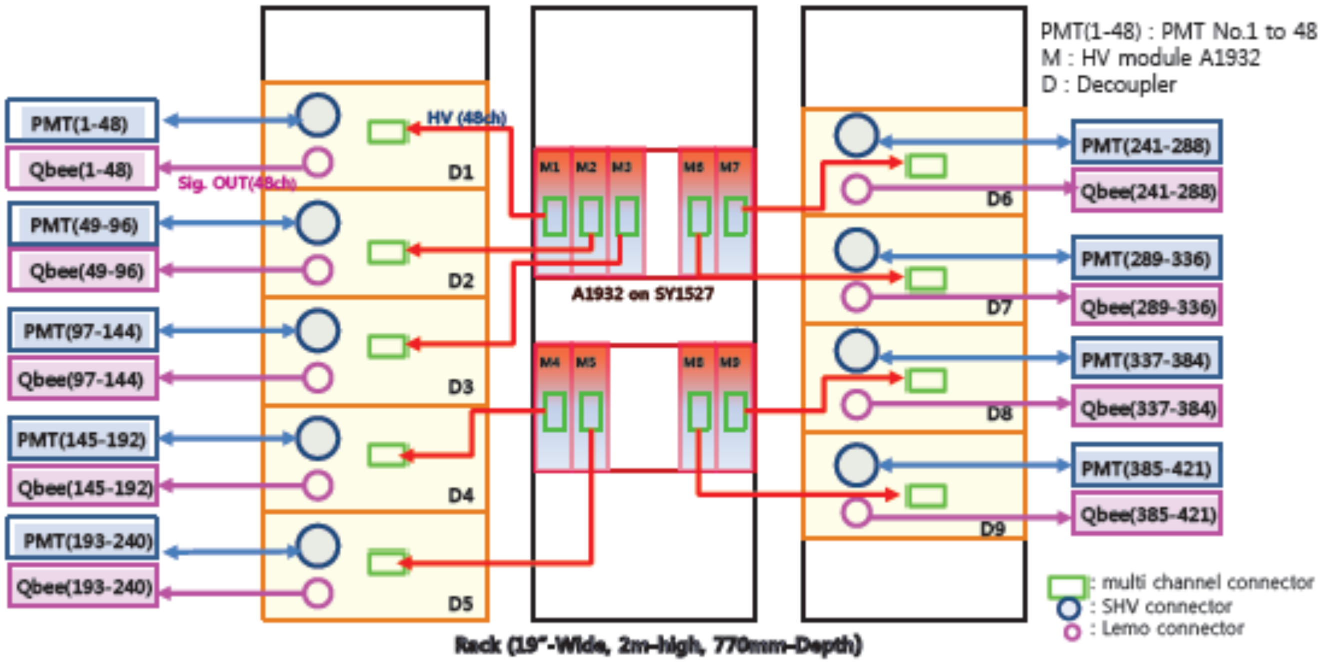
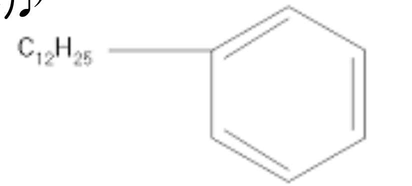


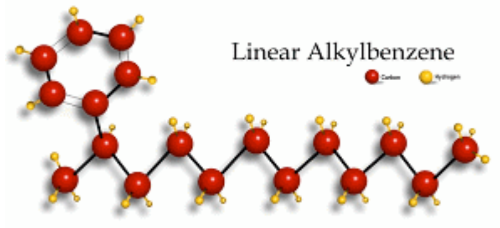
Figure 3.12: HV supplying and decoupling system for a detector of 421 PMTs. Each group consists of one A1932 48 channel HV supplying module and 48 channel decoupler box.

Gd Loaded Liquid Scintillator

$C_nH_{2n+1}-C_6H_5$ (n=10~14)♪



Linear Alkyl Benzene (LAB)

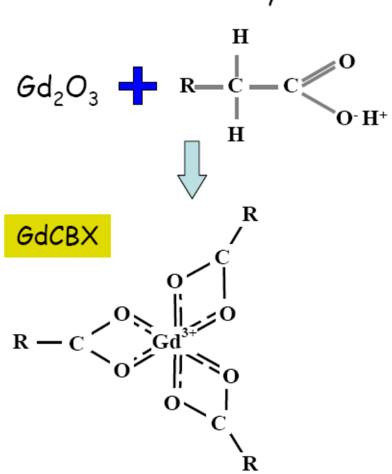


❑ Recipe of Liquid Scintillator

Aromatic Solvent	WLS	Gd-compound
LAB	PPO + Bis-MSB	0.1% Gd+TMHA (trimethylhexanoic acid)

♪

- High Light Yield : not likely Mineral oil(MO)
- replace MO and even Pseudocume(PC)
- Good transparency (better than PC)
- High Flash point : 147°C (PC : 48°C)
- Environmentally friendly (PC : toxic)
- Components well known (MO : not well known)
- Domestically available: Isu Chemical Ltd. (이수화학)

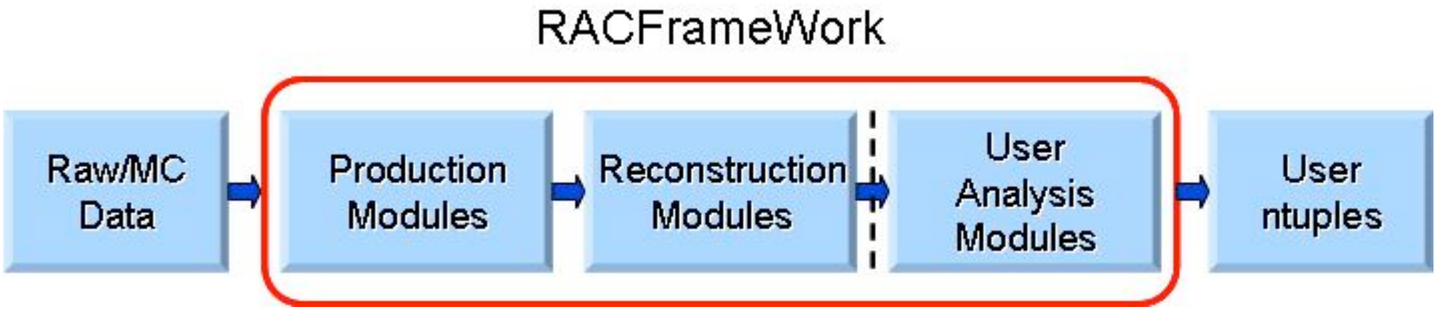


❑ 0.1% Gd compounds with CBX (Carboxylic acids; R-COOH)

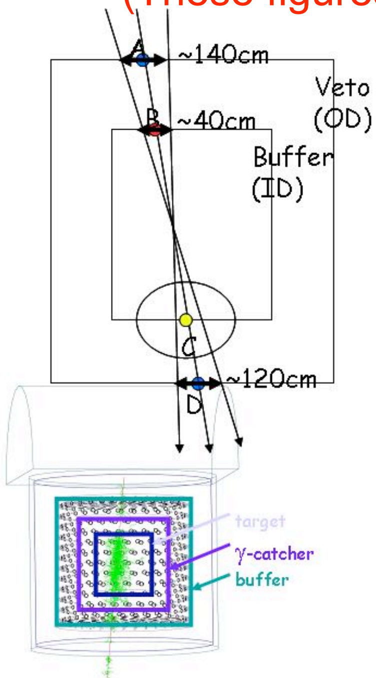
- CBX : MVA (2-methylvaleric acid), TMHA (trimethylhexanoic acid)

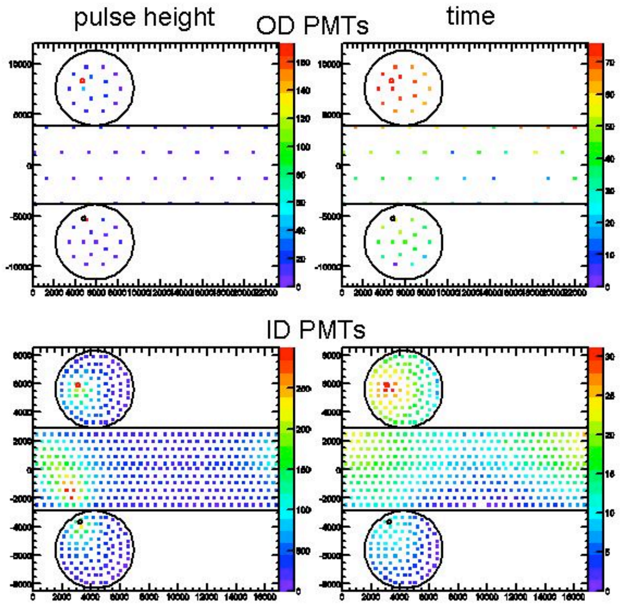
RENO Event Display

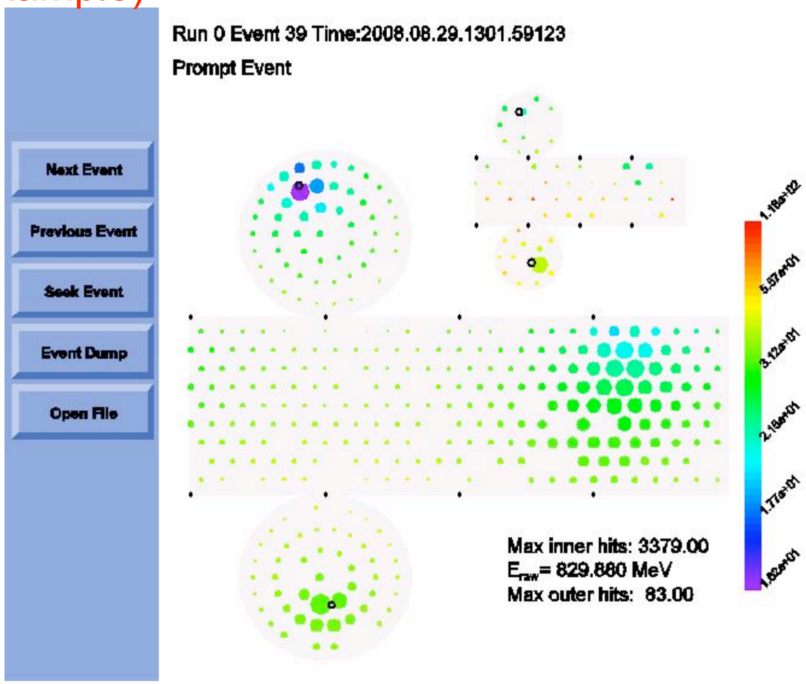
❑ *R*ENO *A*nalysis *C*ontrol



(These figures are about muon tagging as GUI example)

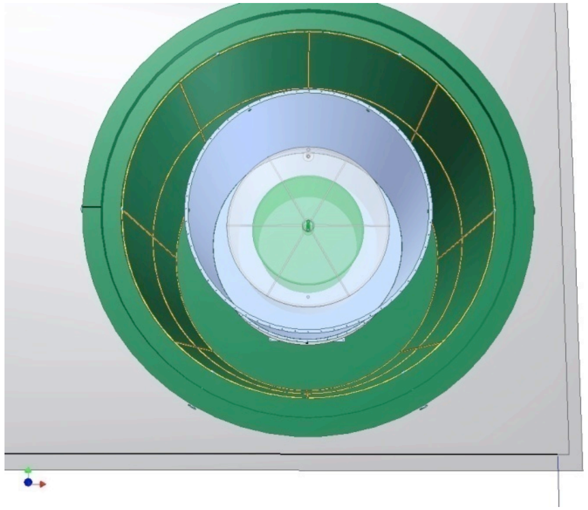




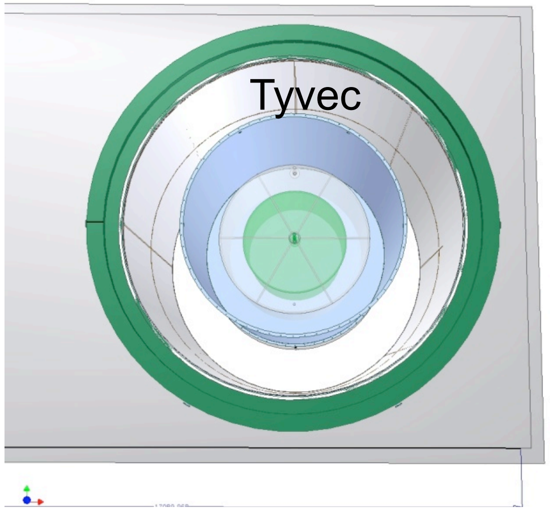


Constructing the Veto Tyvec Frame(last weeks July, 2010)

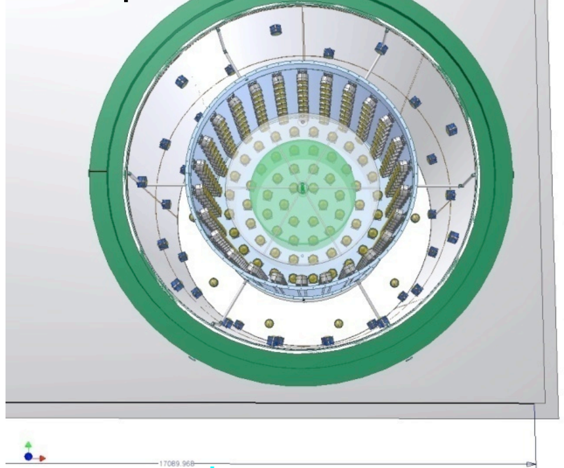
Tyvec frame install

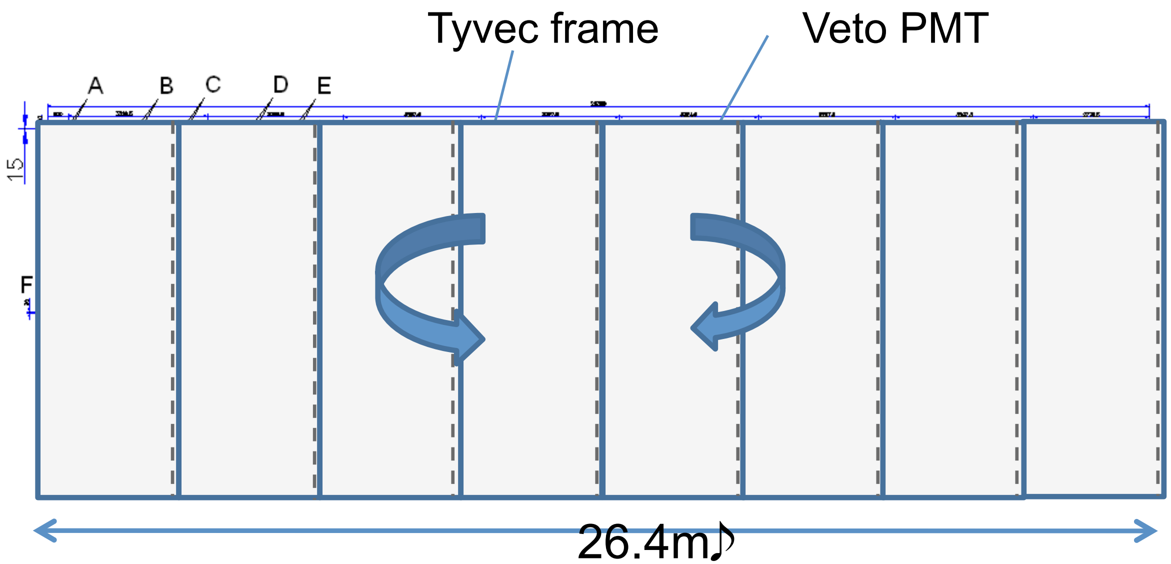


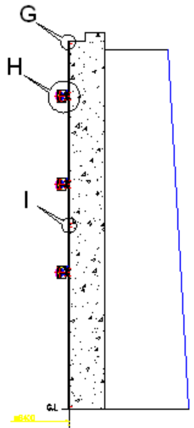
Will set up veto Tyvec in late season



Will set up veto PMT in late season



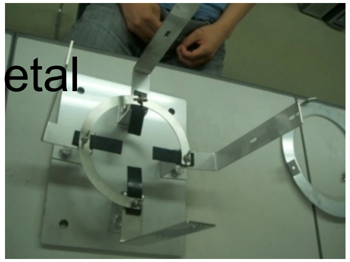
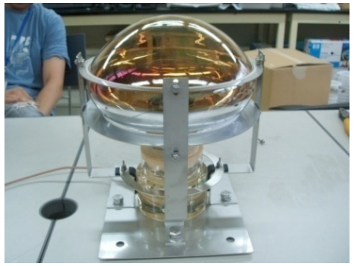
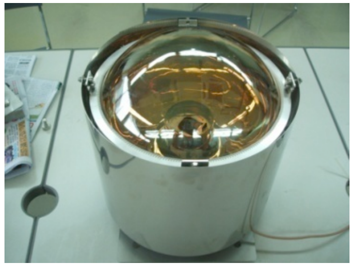




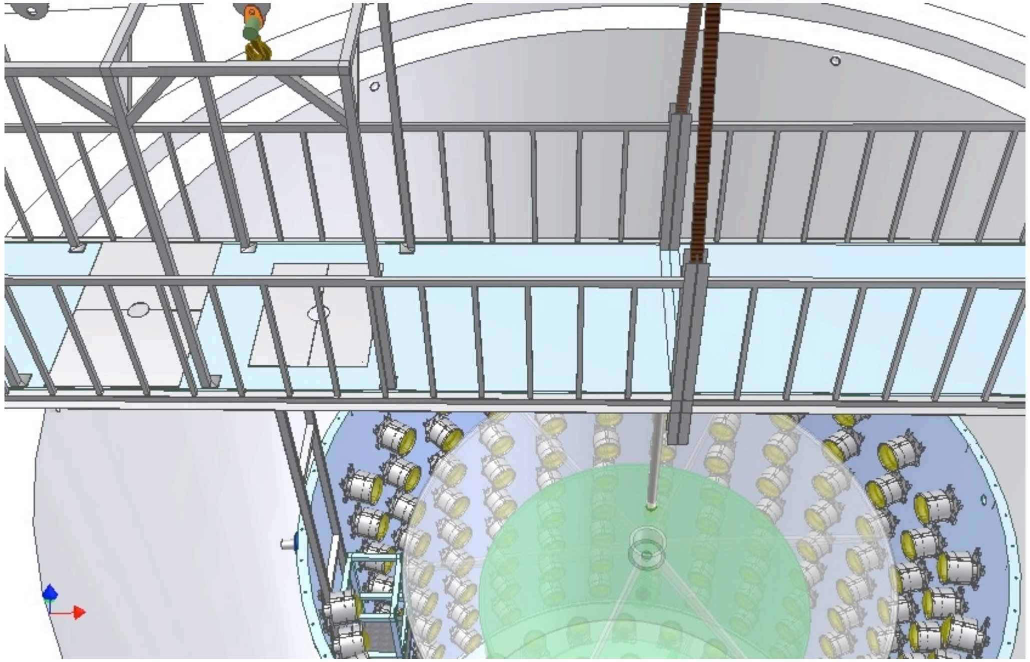
We will prepare many piece of Tyvec 26.4m in wide. And we will do very fine stitching)

PMT setup(3rd, 4th weeks, Aug, 2010)

Assembling PMT holder with mu-metal
Near 354 ea, Far 354 ea

Using the bridge for setting up
Two weeks needed



A kind of elevator and
Easy to access in buffer and veto
Effective to setup a round type detector

❑ Location of the RENO detector

-We must get detailed relative coordinate.
- I will present some coordinate, and we try to…

- I have received interesting proposal for presenting the north korean nuclear explosion from Prof. Suekane (Detecting potential by RENO).

- I did considered the problem simply.

The position of the RENO detector for Yonggwang reactors

The RENO's underground facility with a cavity, exit tunnel and research tunnel was constructed at the near site(~290 m) and far site(~1.4 km). The center coordinate of detectors had been determined during tunnel construction's period automatically. In this page, we consider the relative position between detectors and reactors.

I. THE COORDINATES OF THE RENO DETECTOR FOR THE NATIONAL BASE POINT

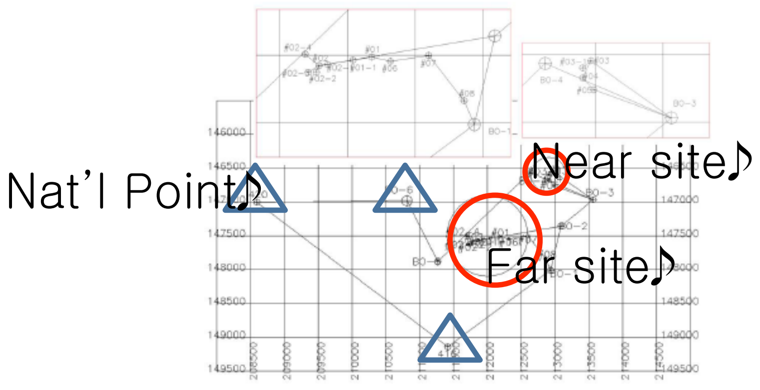


FIG. 1: The combined traverse on the basis of the national triangular point.

Precision in measuring
25cm/9.3 km 2.69 x 10^{-5} =0.00026%

TABLE I: The result of the combined traverse in the position measurement.

Measured line	X	Y	Measured point
420 ← 416	211412.86	149143.82	416
416 → B1	212934.505	148011.410	B1
B1 → B2	·	·	B2
B2 → B3	·	·	B3
B3 → B4	·	·	B4
B4 → B5	·	·	B5
B5 → B6	208592.178	147003.783	B6
B6 → 420	·	·	420
Tot		Difference on the traverse =0.258213	Ratio =1/36091

II. RELATIVE DETECTOR POSITION FROM REACTORS

$$\sigma_{tot_1} = \sigma_{tr} + \sigma_{Near} + \sigma_{Far}$$

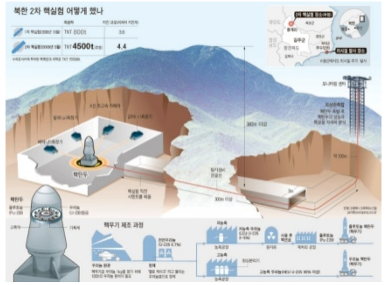
By combined traverse

TABLE II: Distances of reactor's cores from near and far detectors.

Reactor No.	X-coord	Y-coord	Z-coord
Reactor ♯1	~ 600	0.00	0.00
Reactor ♯2	·	·	0.00
Reactor ♯3	·	·	0.00
Center point	0.00	0.00	0.00
Reactor ♯4	·	·	0.00
Reactor ♯5	·	·	0.00
Reactor ♯6	~ 600	0.00	0.00
Near Dectector	-39.13	291.59	20
Far Detector	79.06	-1380.48	32

-We could not approach to the position informatio n of reactors untill now.
-Reactor position is controlled by NIS(National Intelligence Service, 國家情報院).
it is difficult to get information!
-But we will try to approach to the information as soon as possible.

Nuclear weapon's test of North Korea♪

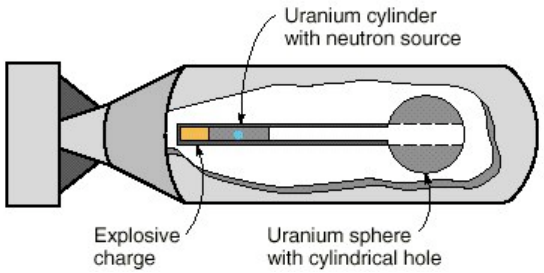


First test(2006
)   0.8 kt

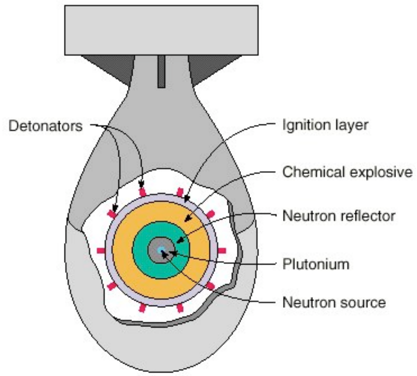
→ Second test(2009)

~4.6 kt : guessed by a korean news agency
~ 20 kt: guessed by a foreign news agency
In here, we assume half value
12.5 kt: same with Hirosima's value

Hirosima's Little boy(12.5kt)



Nakasaki's Fatman(20kt)



$$E = \frac{(12.5kt)(4.18\times10^{12}\,J/kt)}{(1.6\times10^{-19}\,J/eV)(10^{6}\,eV)} = 3.27\times10^{26}\,MeV$$

$$Number\,of\;neutrino = \frac{3.27\times10^{26}\,MeV\times 6n_{ve}/\,fission}{200\,MeV/\,fission} \approx 10^{25}\,n_{ve}$$

Approximation flux from explosion♪

We calculate all value roughly

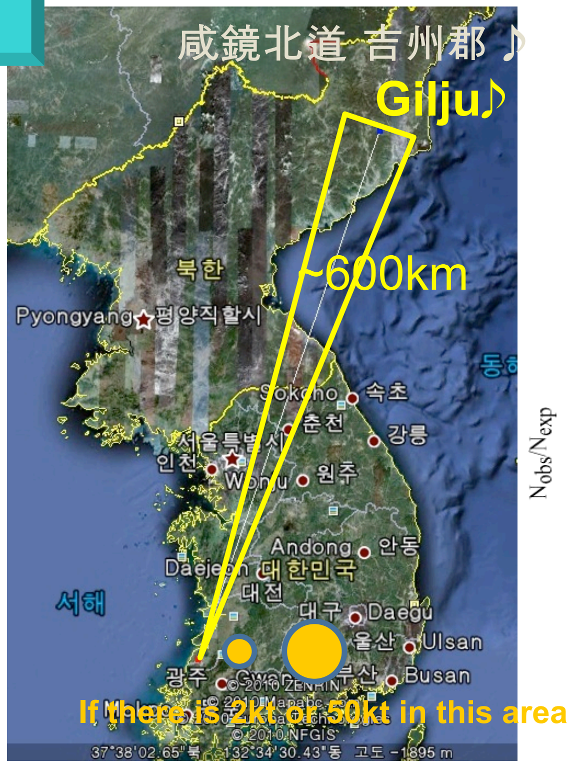
Number of Neutrino: $10^{25} n_{ve}$

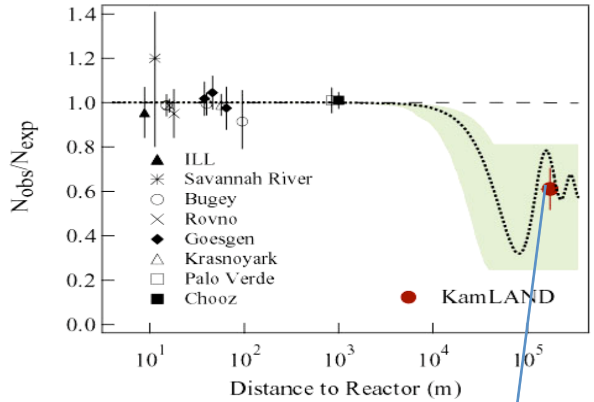
Distantace: from Gilju to YongGwang: 600km

Acceptance: target area/r^2
target area of 16t → 9m^2
target area of 2kt → 270m^2
target area of 50kt → 1400m^2

Cross section: 1.00E−46 **m^2 in 3MeV**

Approximation♪





	Number of Neutrino	Distance	Acceptance	flux	Number of Proton	Cross section	Number of Event	
RENO16ton (same with RENO Target)	1.00E+25	6.00E+05	1.99E-12	1.99045E+13	1.00E+30	1.00E-46	0.00199045	
2kt	1.00E+25	6.00E+05	5.97E-11	5.97134E+14	1.25E+32	1.00E-46	7.46417197	~4
50kt (same with SK)♪	1.00E+25	6.00E+05	3.36E-10	3.36164E+15	1.00E+33	1.00E-46	336.16419	~115

RENO detector size is too small to detect north korea nuclear explosion!

−Explosion of 14 kg U^{235} happen during 990ns ♪
−We must discriminate the signal of the events ♪

Signal discrimination

Nutron Generation eq. in nuclear fission is as follow

$$N = \frac{k^{n+1} - 1}{k - 1} \quad (1)$$

In here, N: Number of fission, k: multiplation factor, n: n^{th} generation.

We suppose that U^235 have super critical mass of k=1.8. Generation time *tau* between fissions is 10 ns.

$$N = \frac{14kg}{(235u/nucl.)(1.66 \times 10^{-27}kg/u)} = 3.59 \times 10^{25} nucl \quad (2)$$

And eq.[1] could be as follows

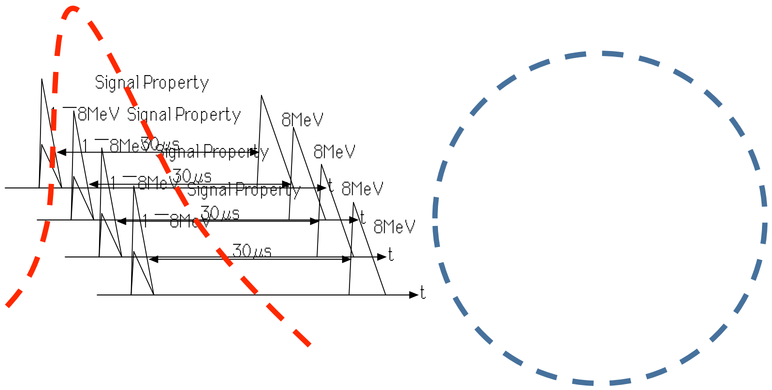
$$k^{n+1} = N(k-1) + 1 \quad (3)$$

Then $N \sim 10^{25}$, if we ignore +1

$$(n+1)lnk = ln[N(k-1)] \quad (4)$$

$$n = \frac{ln[N(k-1)]}{lnk} - 1 = 99 \quad (5)$$

Therefore, total generation time is 990ns



?

990ns
(explosion time)

- Positron signal is expected to be appear simultaneously
- Delayed signal is ?

- If we want to detect the signal, we need more definite study (In more larger detector size!!)

❑Summary

- RENO is suitable for measuring q_{13} ($\sin^2(2q_{13}) > 0.02$)
- Target and Gamma catcher were installed.
- RENO is under assembling phase.
- Data–taking is expected to start in end 2010
- International collaborators are being invited.
- We also wish to do some research in the field of the AAP in Korea.

서울대 김수봉 교수가 이끄는 RENO 실험팀. 30여년간 관측에 실패한 마지막 중성미자 변환상수를 밝히기 위해 프랑스 중국과 치열한 경주를 벌이고 있다.

Thank you for listening!