Deep-TITAND

5 Mt fid volume Water Cherenkov

Based on my talk at the WS on the 20th anniversary of SN1987A @Hawaii, 24-Feb, 2007

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Motivation for 5 Mt detector

- **Next generation detectors (～0.5Mt fid.)**
  - are a bit small to search for proton decay
  - do not have bread and butter science other than atmospheric neutrinos
  - may not produce significant scientific results, if θ_{13} is small
- **➔ 5 Mt**

  (List of subjects of my talk today)
  - big chance for discovery of proton decay
  - good (new) bread and butter science
  - varieties of approach for the long baseline experiment

Proton Decay

What is the required sensitivity

Theorists do not give us
any guarantee, but

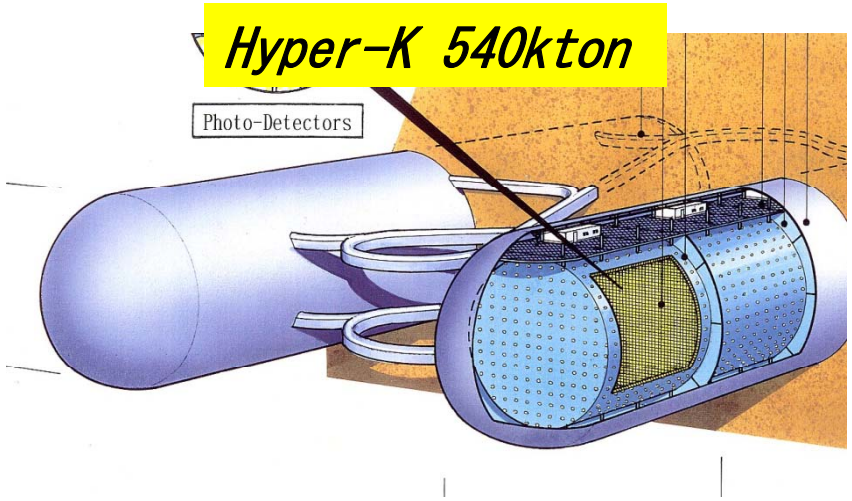
Theorists' best bets ???

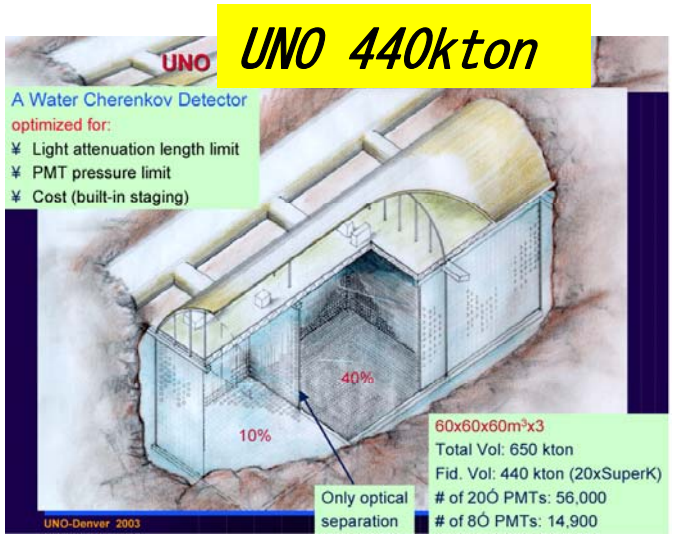
~ 10^{35} ~10^{36} yr for $e\pi^0$

< 10^{35} yr for νK, μK

The size requirement

- How much of the scale up is needed.
  - Super-Kamiokande (22.5kton) by 2020
    (~start time for UNO, HK,,,,,,)
    ➔ achieve ~0.5 Mty exposure (25yrs)
- ~ 0.5 Mt fid. detector : UNO, HK etc.

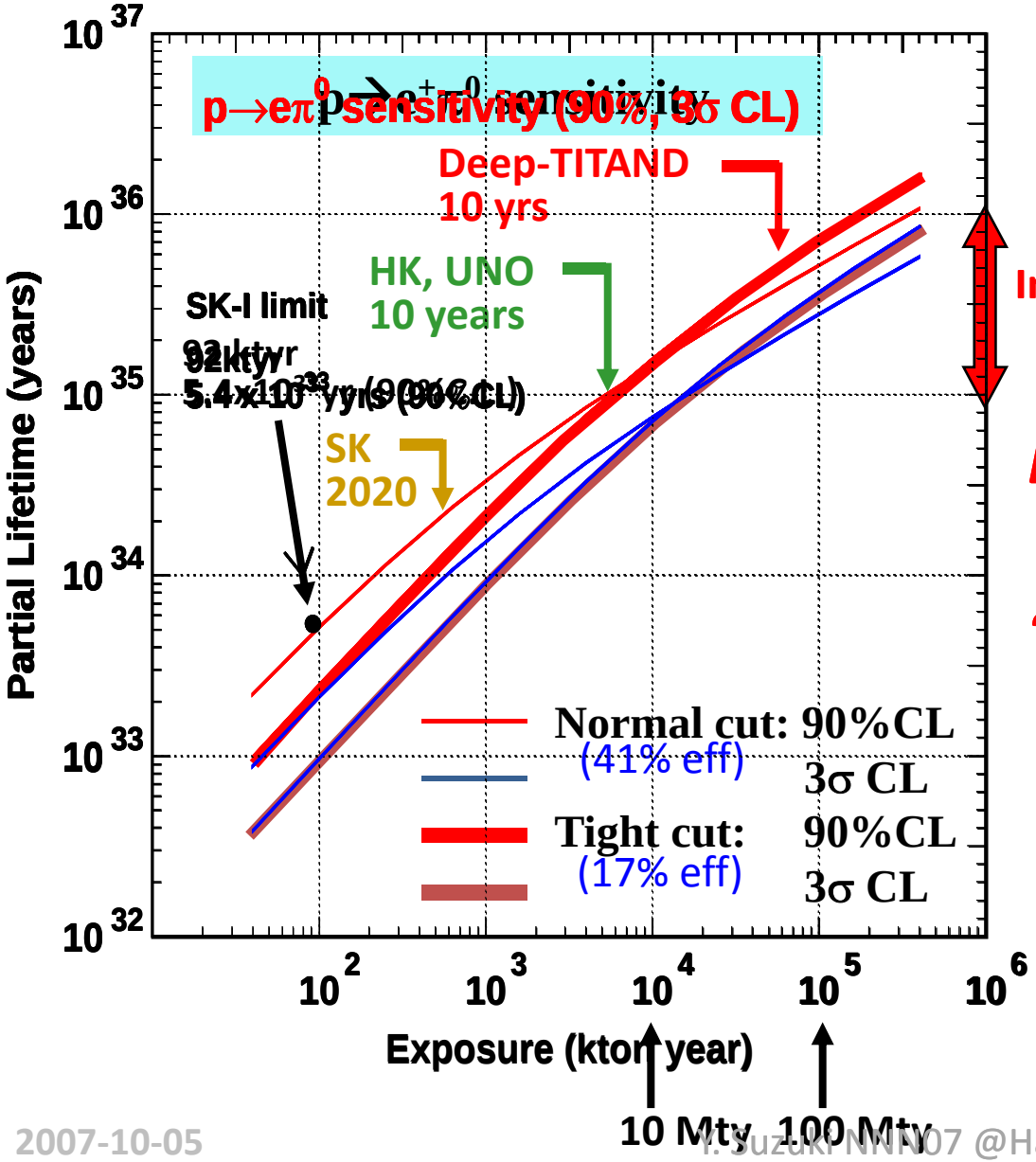




➔ Only factor 3=sqrt(10) improvement
(for 10 years operation: 2020 ~ 2030)

➔ "NEED" ~ 5 Mt fiducial mass for
factor 10=sqrt(100) improvement in 10 years

Sensitivity for $p \to e^+ \pi^0$



Tight cut is effective

Only for > 1Mt detector

Interested region

Deep-TITAND(5 Mt):10 yrs

➔

~ 7 x 10^{35} yrs @90% C.L.

HK, UNO (0.5Mt): 10yrs

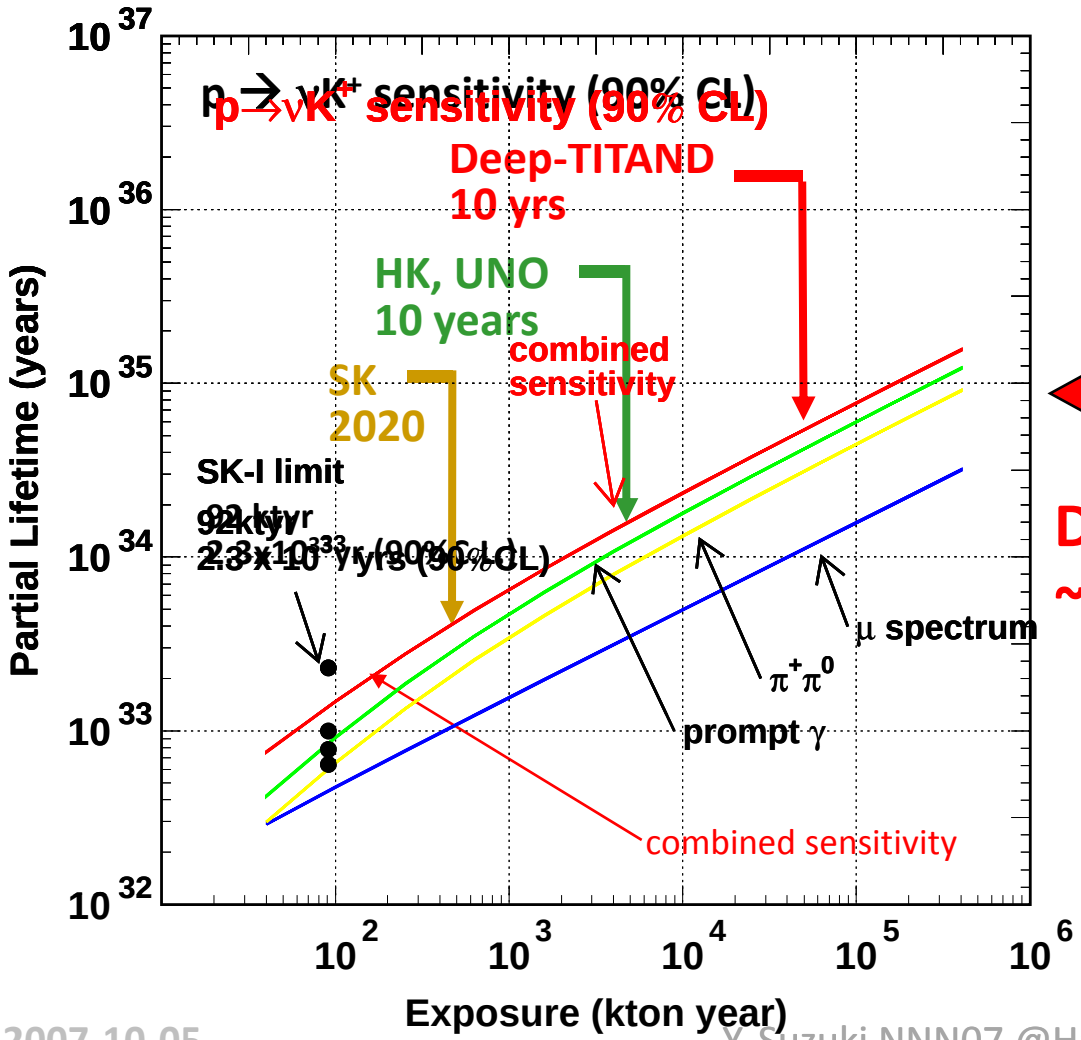
➔

~ 10^{35} yrs @90% C.L.

Sensitivity for $p \rightarrow \nu K^+$

- Assume; 40% coverage:

  Need more study for the 20% coverage



Interested point

Deep-TITAND (5 Mt): 10 yrs
~ 7 x 10^{34} yrs @90% C.L.

HK, UNO (0.5Mt): 10yrs
~ 2 x 10^{34} yrs @90% C.L.

For proton decay search,
we are able to step into a discovery region
by using 5 Mt detector

What is the bread and butter science
for the 5 Mt detector

Obs. ν-bursts from SN <u>every year</u>

Expected # of neutrino events from SNB

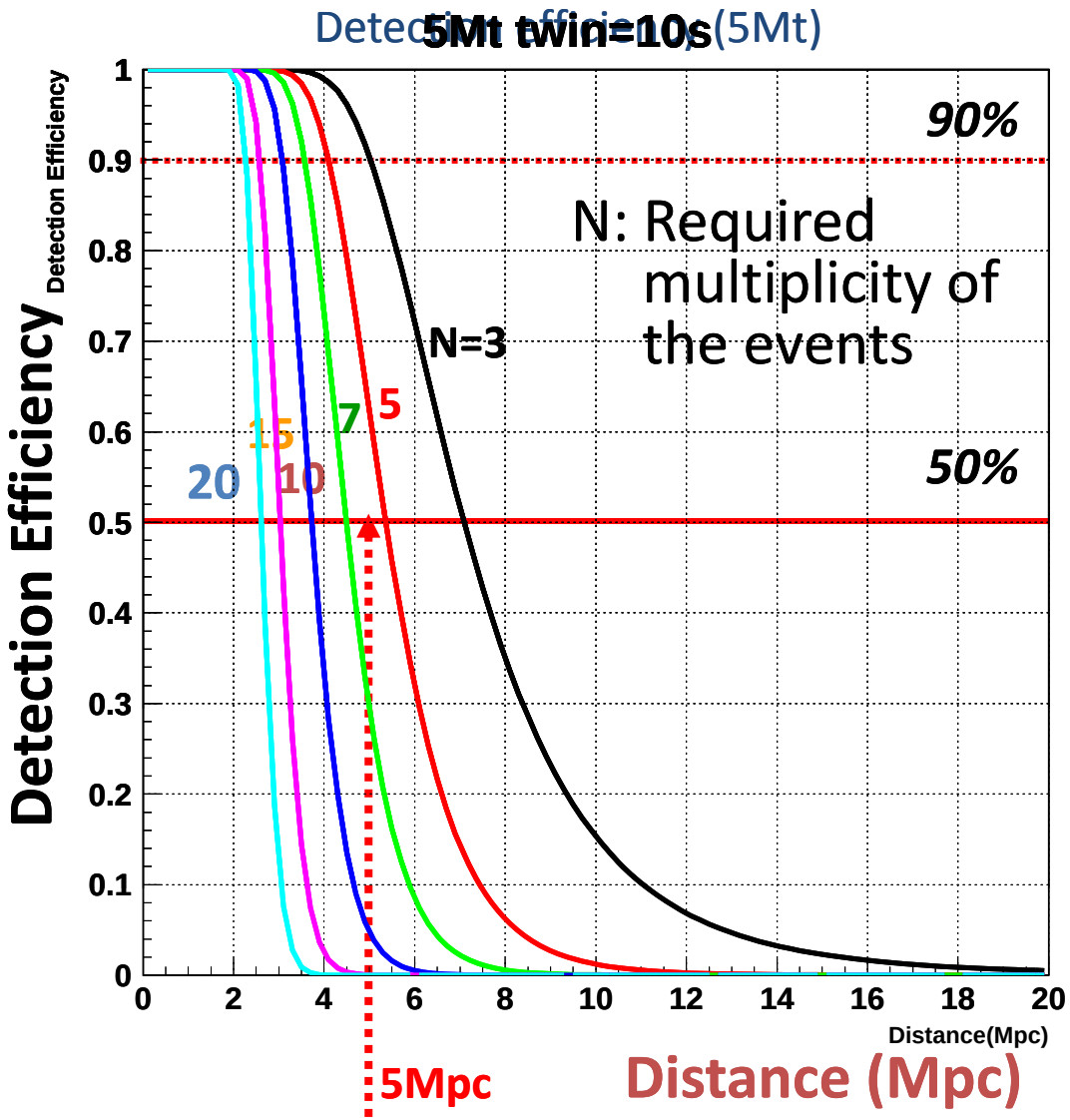
- Observation SN1987A
  - KMII, IMB, Baksan,.

prediction

	Observation for SN1987A	1Mpc 1Mt
Kamiokande 1987A	50kpc, ~2kt, 11 events (T=2.7 MeV)	14
IMB 1987A	50kpc, ~6kt, 8 events (T=4.0 MeV), ”24 KM-II”	32
Typical Simulation	Ref: Totani et al., astroph/9710203 J.F.Beacom hep-ph/9909231 and others	27

*For ‘standard’ SN: ~ **5** events @**5**Mpc for 5Mt detector*

Detection efficiency for distant SNe



Parameters:
Nint = 27ev. /Mton @1Mpc (scaled to 5Mt)
Time window ~ 10 sec

50% efficiency

Coincidence Multiplicity	Observable Distance
N=3	7.0 Mpc
5	5.4
7	4.6
10	3.8
15	3.1
20	2.7

Backgrounds determine the sensitivity

Most BG ← Accidental coincidence of time-uncorrelated events
→ Spatially uniform

- Random noise events
- Solar ν, atmospheric ν (depend on volume)
- **Spallation** (left 1 event) (depend on volume & depth)

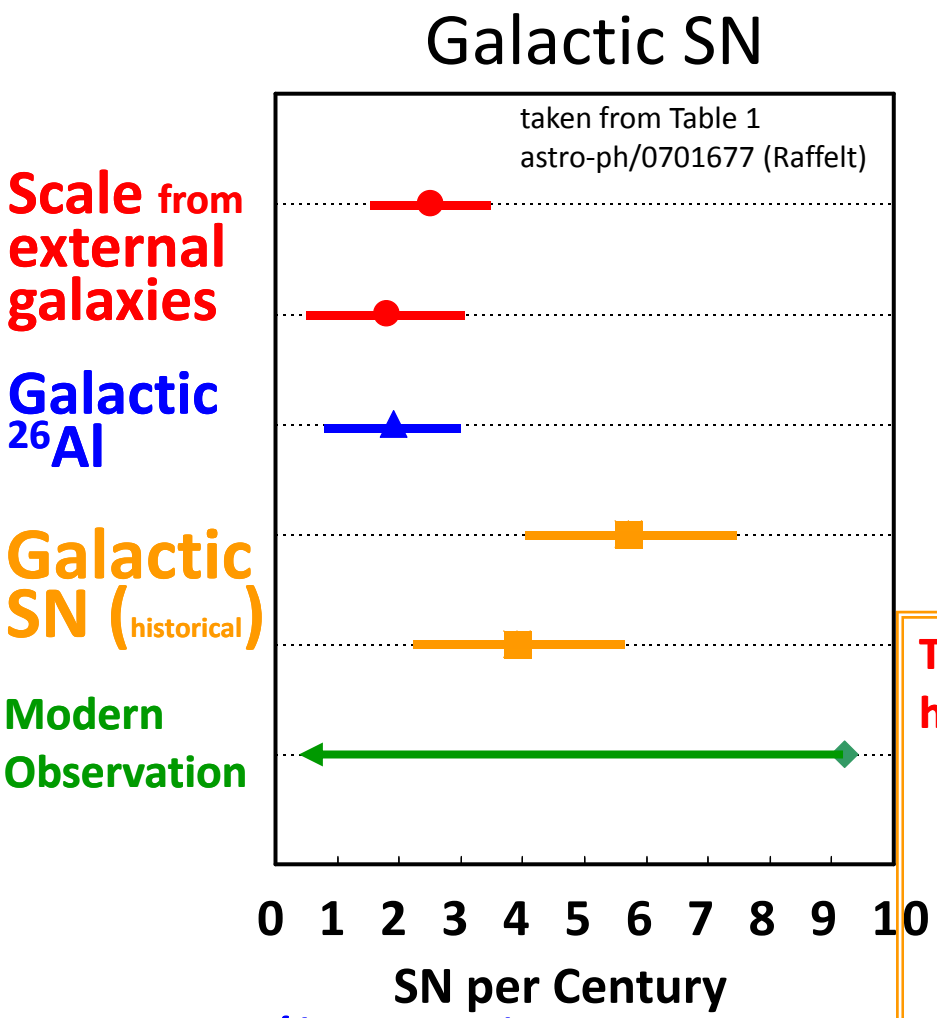
Reduce BG (spallation)

1. deeper depth ~ a few hundred m

2. higher event energy threshold

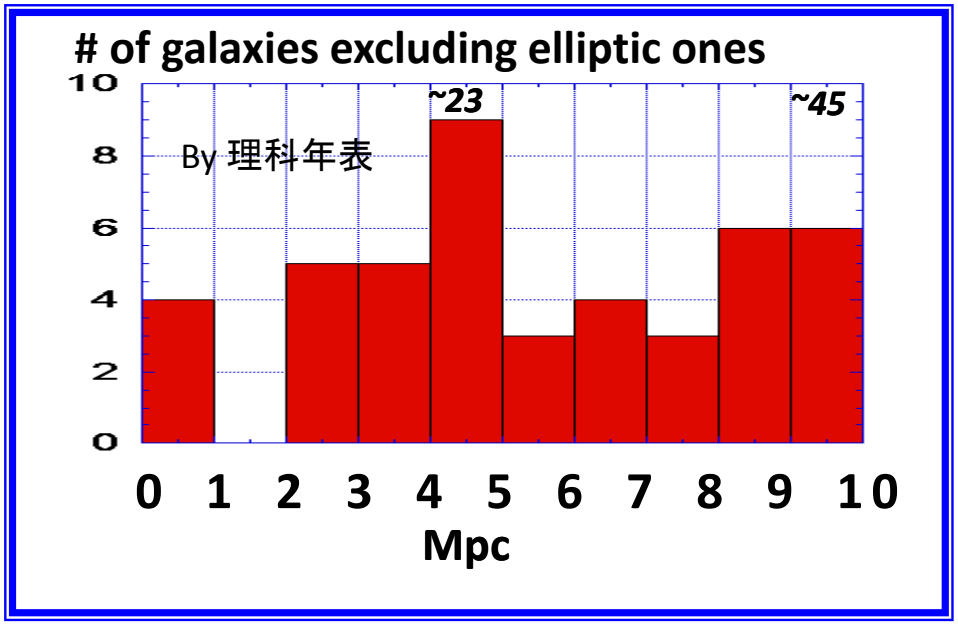
→Almost BG free without loosing efficiency largely (see my talk @ Hawaii)

SN rate



~1 SN/(30~50)yrs

in our Galaxy



There are Galaxies beyond ~3~5 Mpc where SNe have frequently happened (2～3 times more)

- **NGC6946 (5.9 Mpc)**
  1917A, 1939C, 1948B, 1968D, 1969P, 1980K, 2002hh, 2004et
- **M83 (4.3Mpc)**
  1923A,1945B, 1950B, 1957D, 1968L,1983N
- **NGC2403 (3.3Mpc)**
  1954J, 2002kg, 2004dj

4～5 Mpc! and beyond➔ ～1 SN /yr obs.

Sensitivity for Science (5 Mt detector)

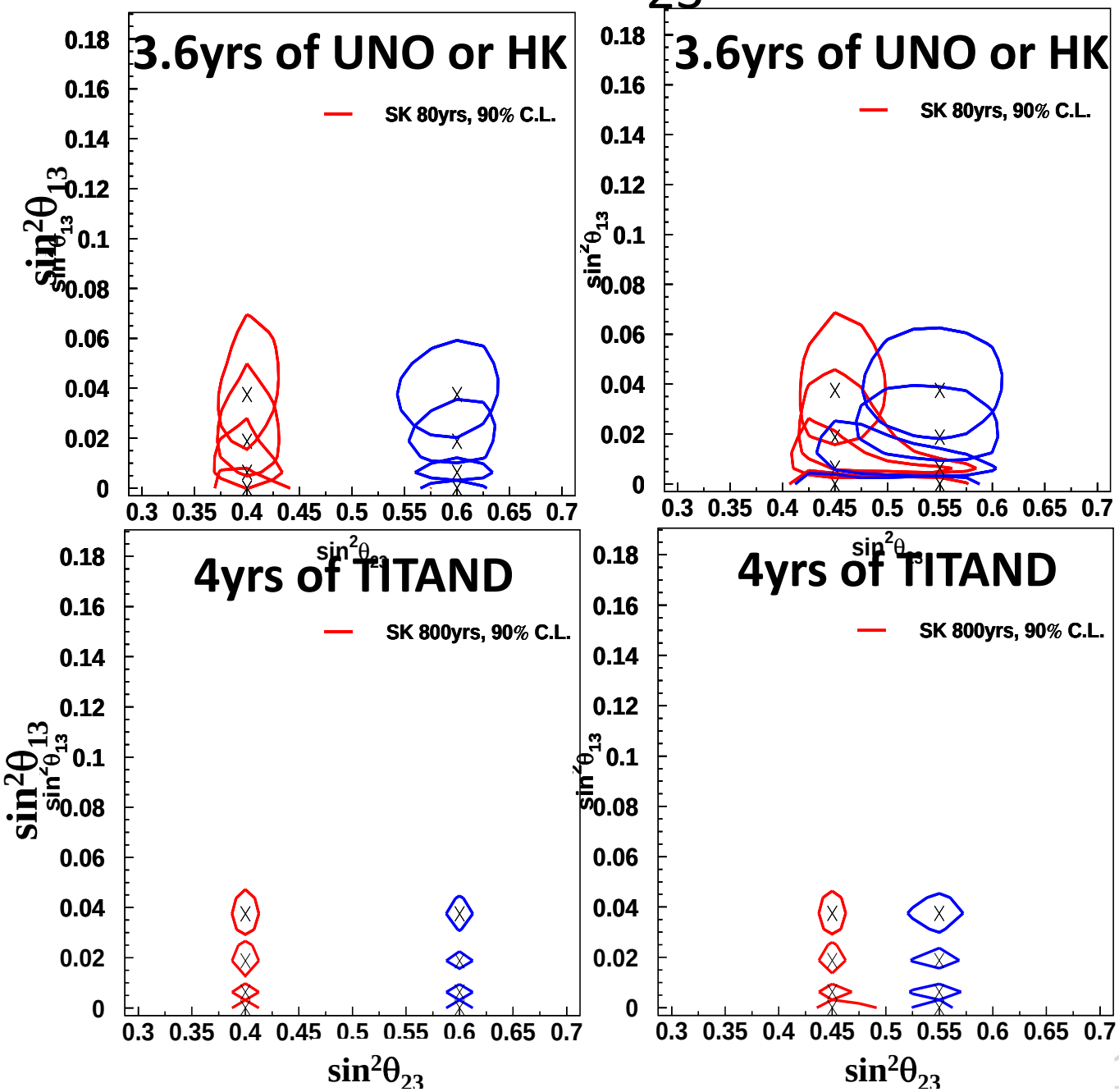
	Galactic (10kpc)	**M31** (650kpc)	Distant Supernova (1 Mpc)	(3 Mpc)	(5 Mpc)
# of events	**1,300k**	**310**	**140**	**15**	**5.4**
SN rate (integral) per year	<20kpc 0.03 SN/y	<650kp 0.1 SN/y	<1 Mpc 0.1 SN/y	<3Mpc 0.4 SN/y (x3 ?)	<5Mpc 1 SN/y (x3 ?)
precise spectrum	○	○	○	△	X
Oscillation study	○	○	○	△	X
Oscillation study (Neutronization B.)	○ ~2500 ev	X	X	X	X
Early Earning	○	○	○	○	○

(see my Hawaii Talk in details)

How about atmospheric neutrinos for 5 Mt detector

Octant of $\sin^2\theta_{23}$

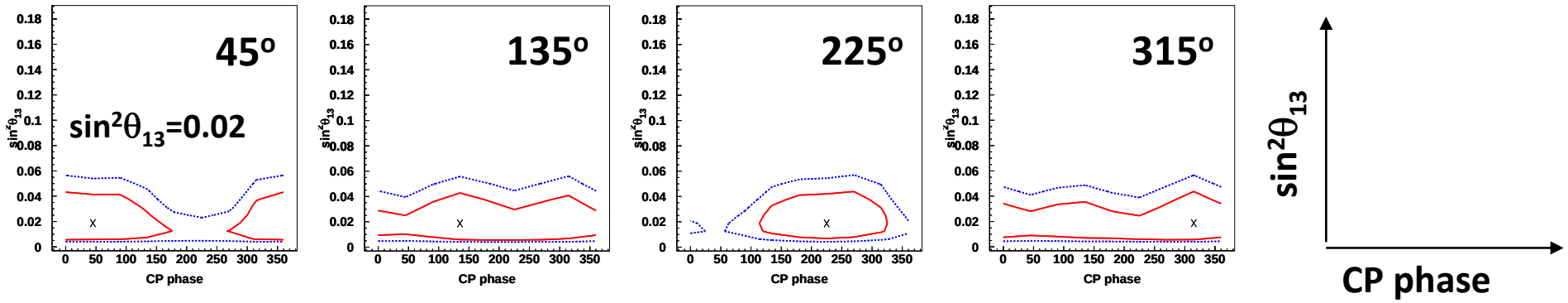
$s^2 2\theta_{12}=0.825$
$s^2\theta_{23}=0.40 \sim 0.60$
$s^2\theta_{13}=0.00\sim0.04$
$\delta cp=45^o$
$\Delta m^2_{12}=8.3\times10^{-5}$
$\Delta m^2_{23}=2.5\times10^{-3}$



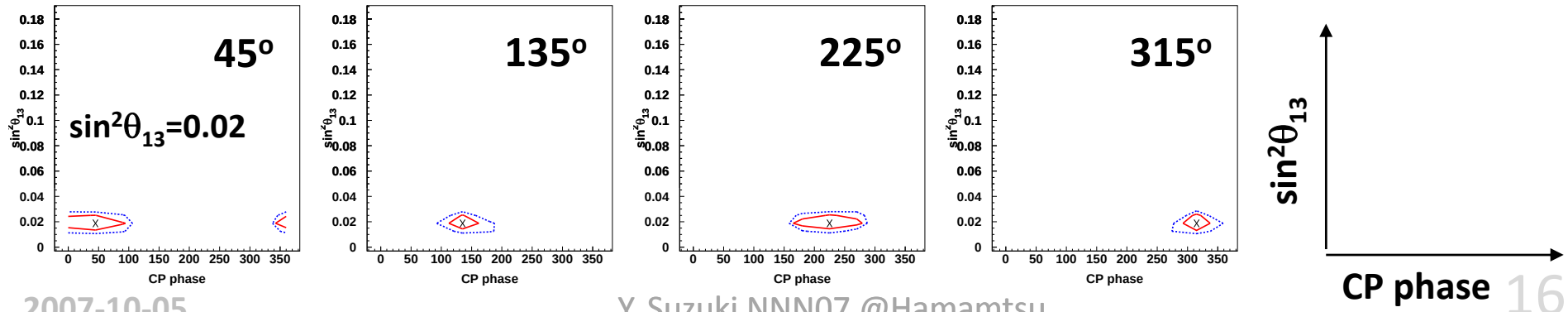
Atmospheric Neutrino Study (CPV)

$\sin^2 2\theta_{12}=0.825$
$\Delta m_{12}^2=8.3\times10^{-5}$
$\sin^2\theta_{23}=0.5$
$\Delta m_{23}^2=2.5\times10^{-3}$

CP phase (3.6yrs of UNO or HK)



CP phase (4 yrs of Deep-TITAND)

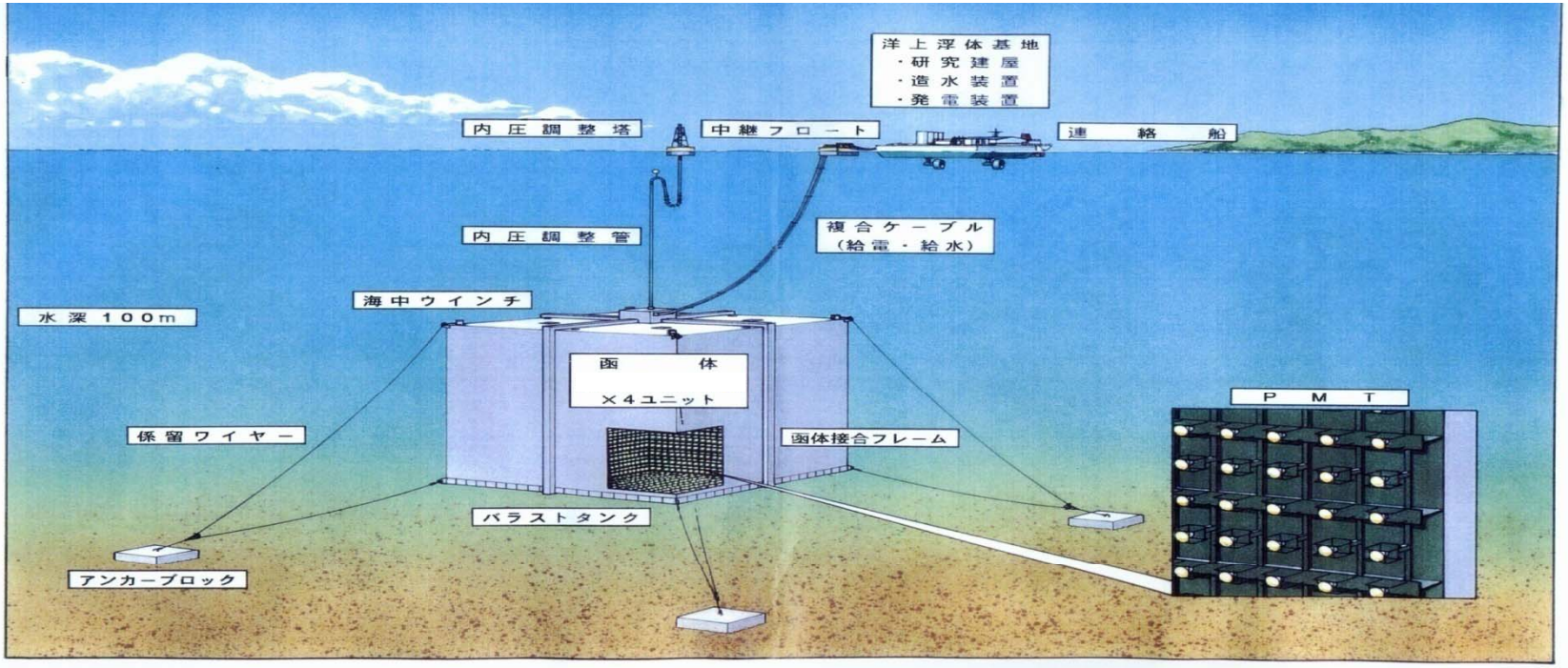


How does the detector look like?

Requirements for the detector

1) **Scalability: may start with 1 Mt but can be expandable to 5 Mt and beyond**
2) **Inexpensive!**
3) **Short construction time**
4) **Should be placed a few hundred meter (w.e.) depth.**

TITAND



浮沈式陽子崩壊実験装置イメージ図

TITAND-I

85m x 85m x 105m x 4 units = 3.03 Mt

(2.22 Mt fiducial : ~ SK x 100)

TITAND-II

2 module ➔ 4.4 Mt f.v. (SK x 200)

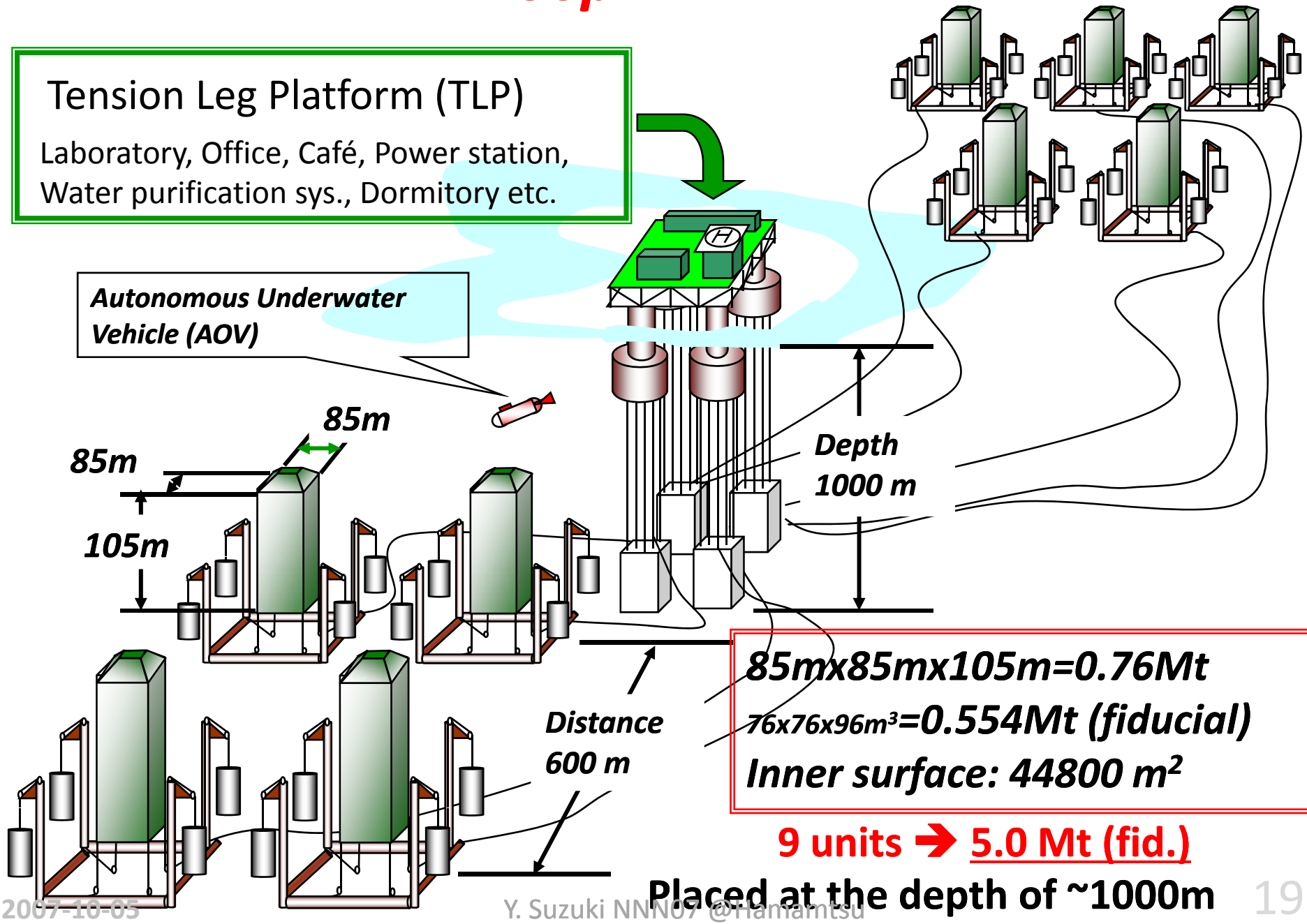
Ref:1) Y. Suzuki, hep-ex/0110005 (in 2001)
2) Y. Suzuki, in Proc. of Neutrino Oscillation in Venice, Feb, 2006

But this is shallow @100 m depth

Deep-TITAND

Tension Leg Platform (TLP)

Laboratory, Office, Café, Power station, Water purification sys., Dormitory etc.



85mx85mx105m=0.76Mt

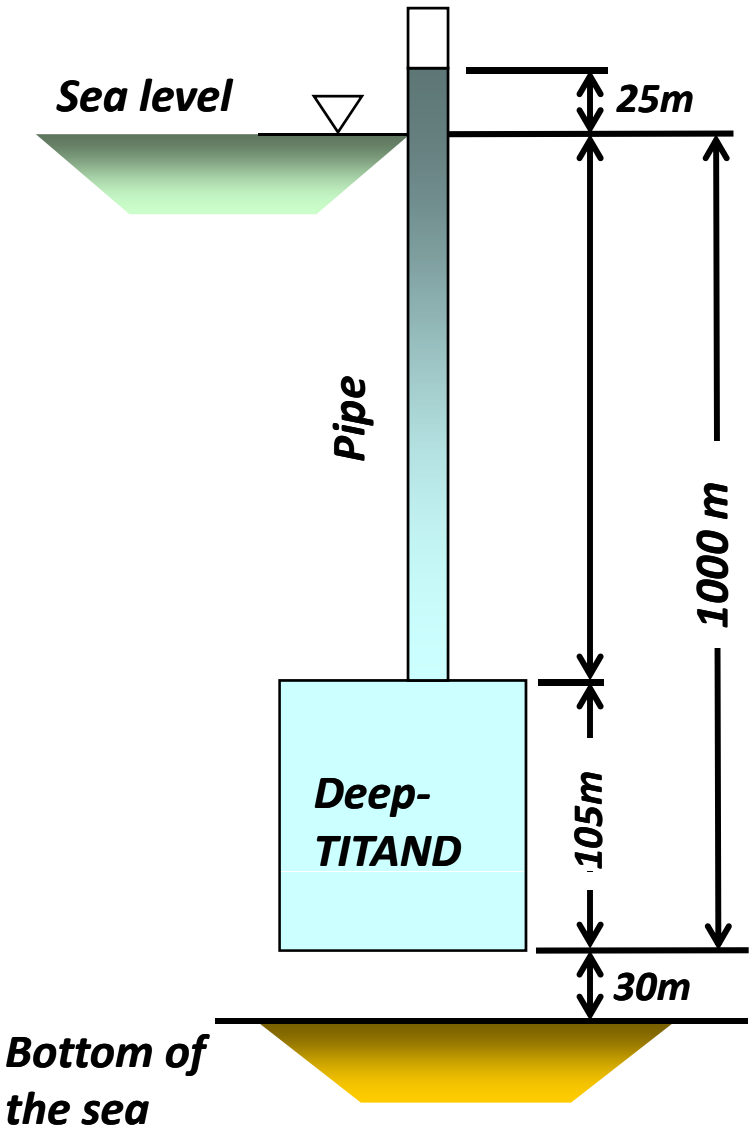
76x76x96m³=0.554Mt (fiducial)

Inner surface: 44800 m²

9 units → 5.0 Mt (fid.)

Placed at the depth of ~1000m

Pressure Head



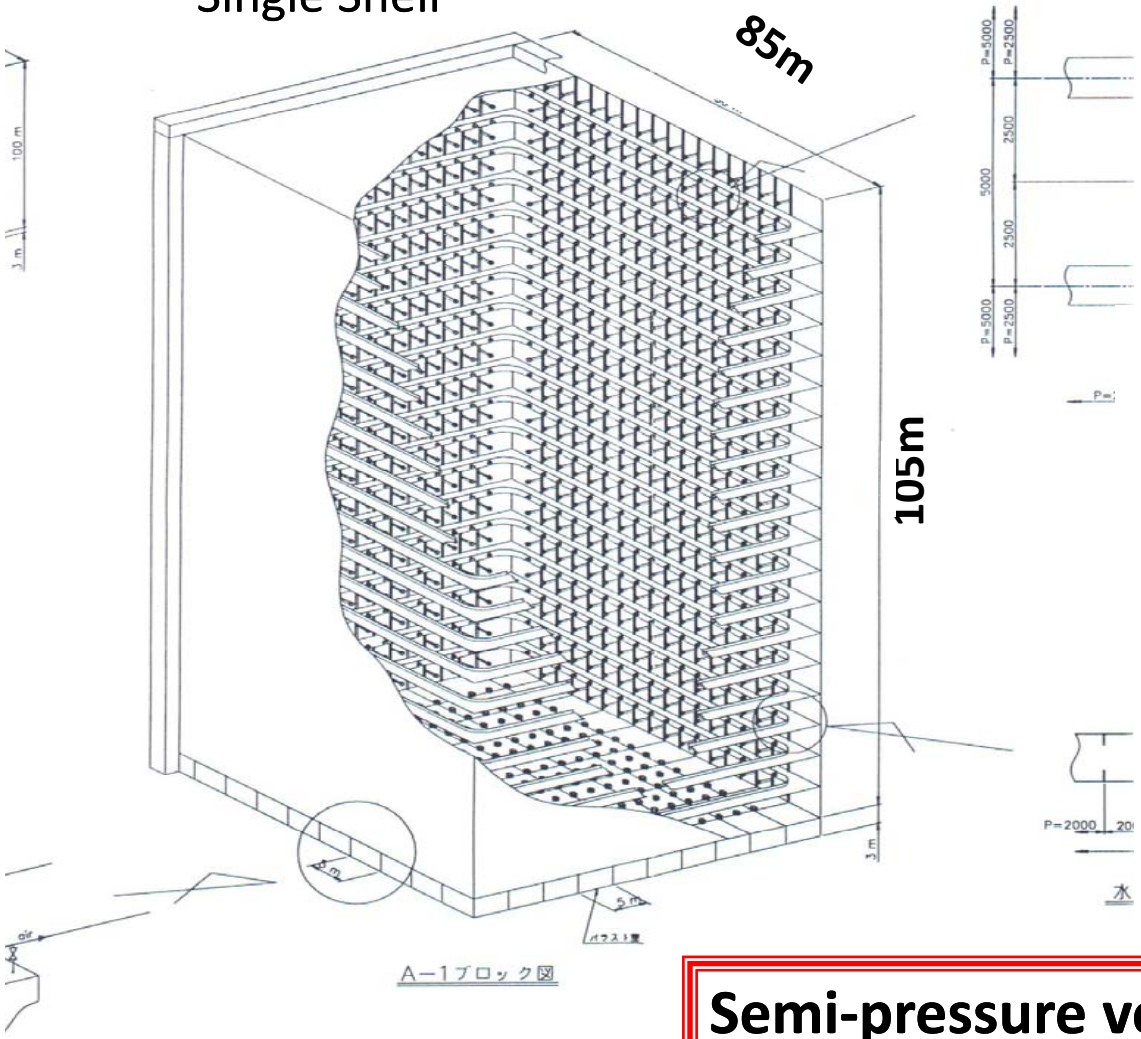
+ 2.5 atm

Must compensate the pressure difference due to the density difference between the salt water and the pure water by 2.5%

Pressure balance between Inside and outside

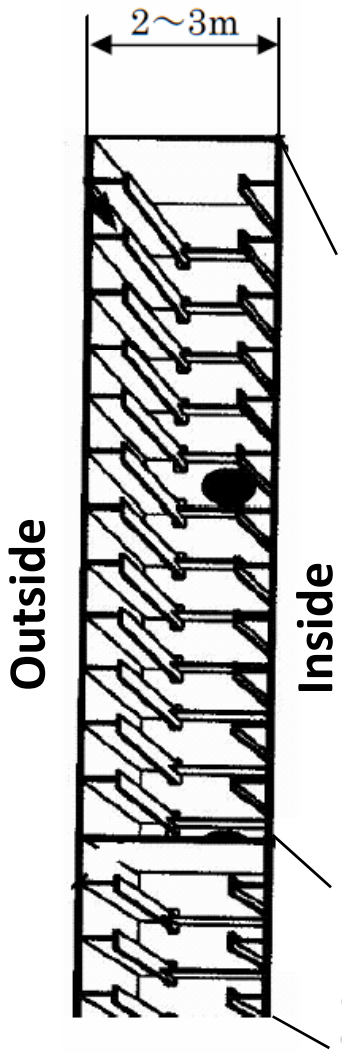
Structure

Single Shell



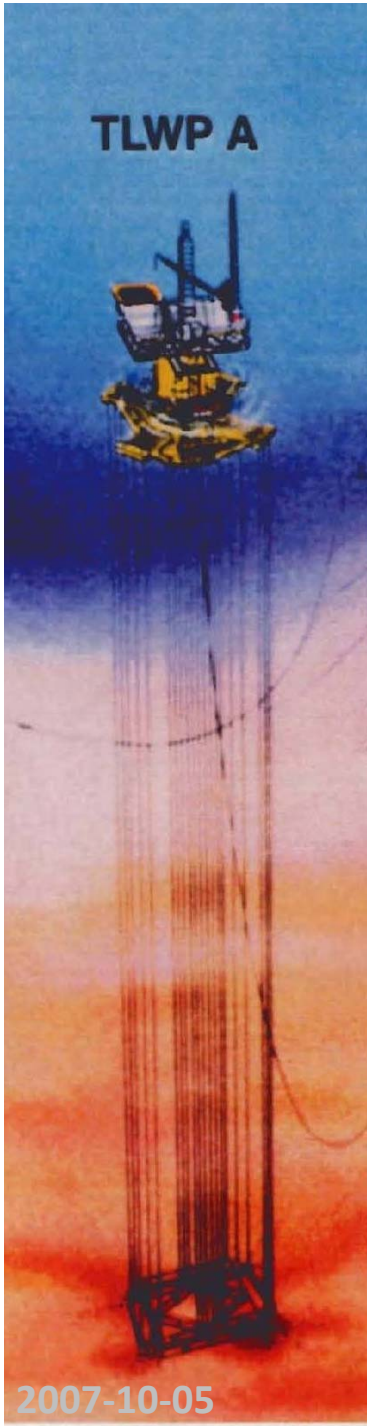
OR

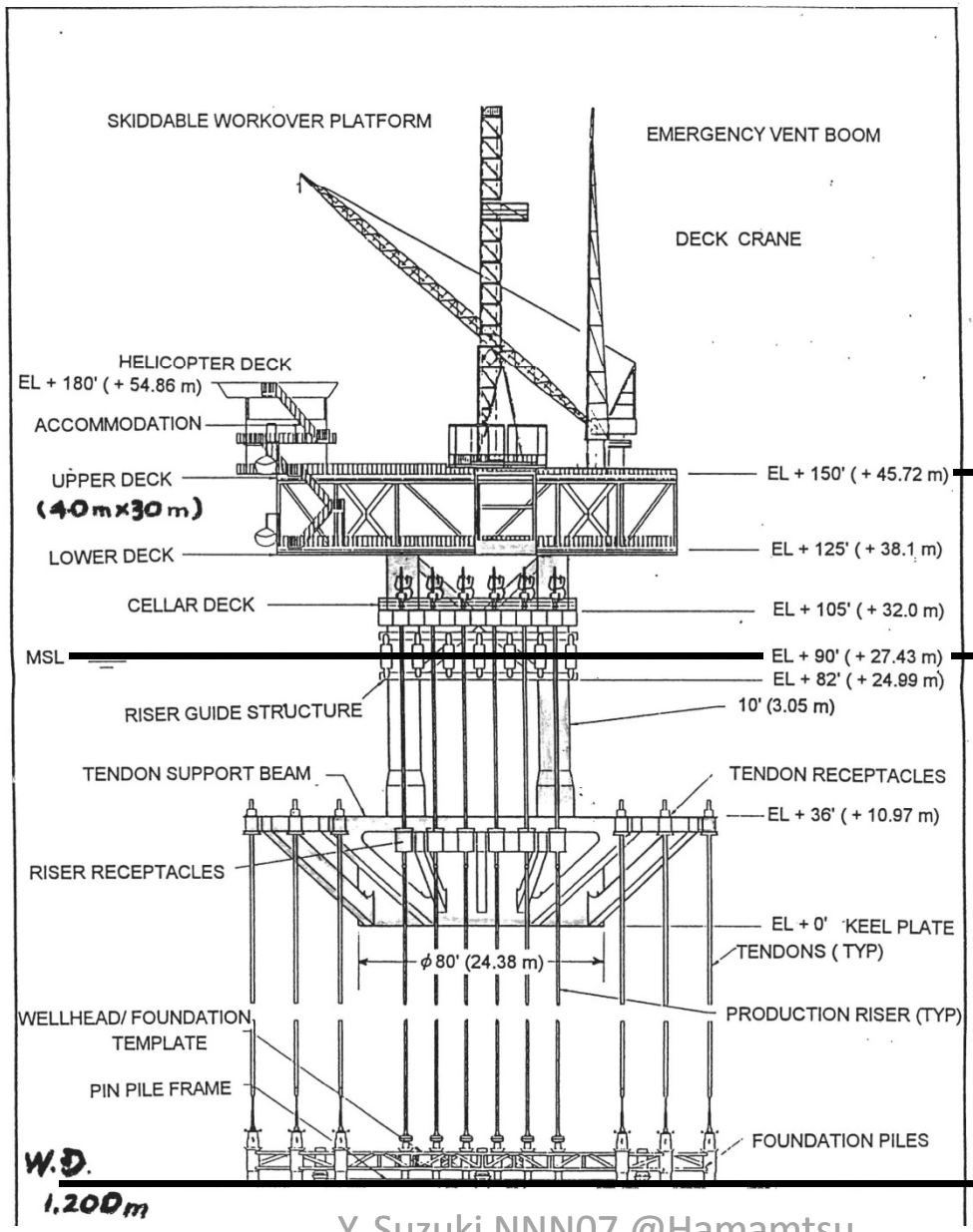
Double Shell Structure



Semi-pressure vessel upto >0.3 atm (in/out)

Tension Leg Platform





Power Generator
Desalination system
Water purification system
Research buildings
- ***Electronics & computer***
- ***Dormitory***
- ***Restaurant & Cafe***

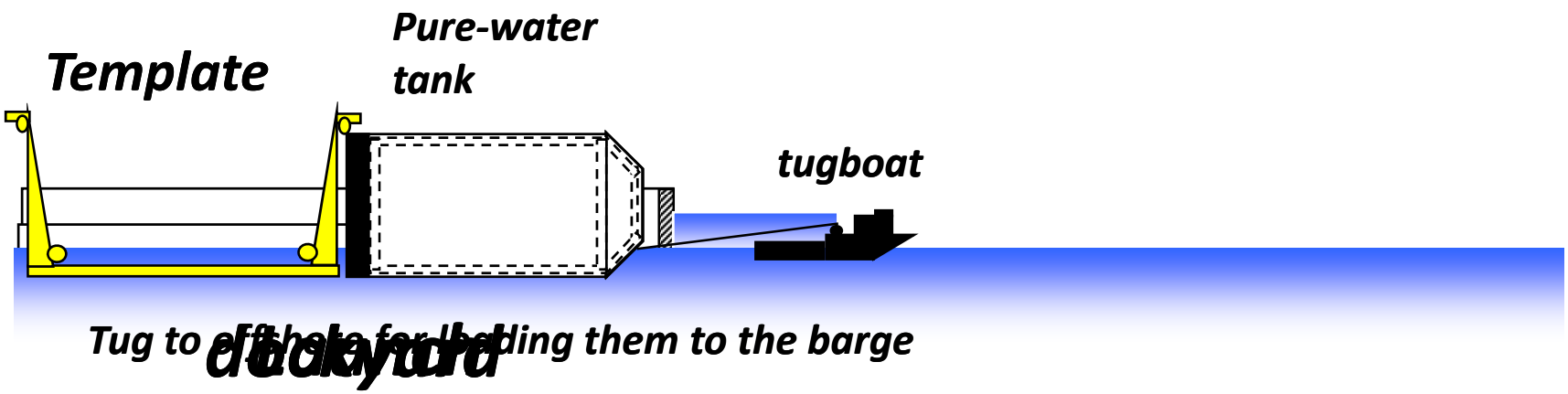
Upper Deck

~ 20m

Sea level

> 1,000 m

Bottom of The sea



How to construct

Construct steel container (unit) at the DOCK

85m x 85m x 105m

Maximum size of DOCK in the world

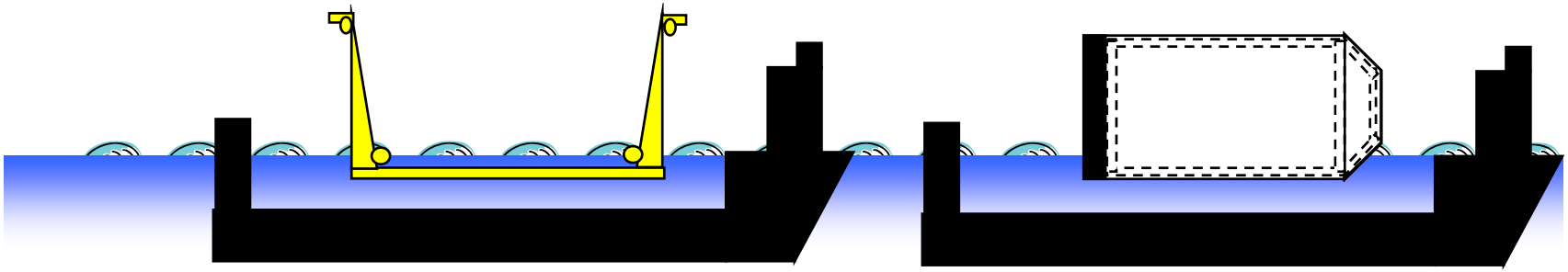
➔ width:108m x length: 480m

Install PMTs(or equivalent)

Number of PMTs

44,800 PMTs for one unit

(for 1/2 SK density)

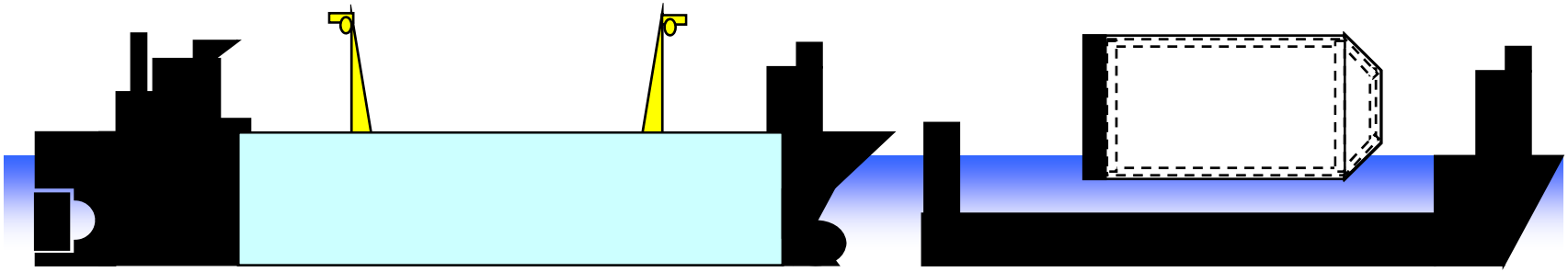


Sinking barge
(loading capacity:
20,000 ~ 30,000 tons)

Move to the installation site

Sinking barge

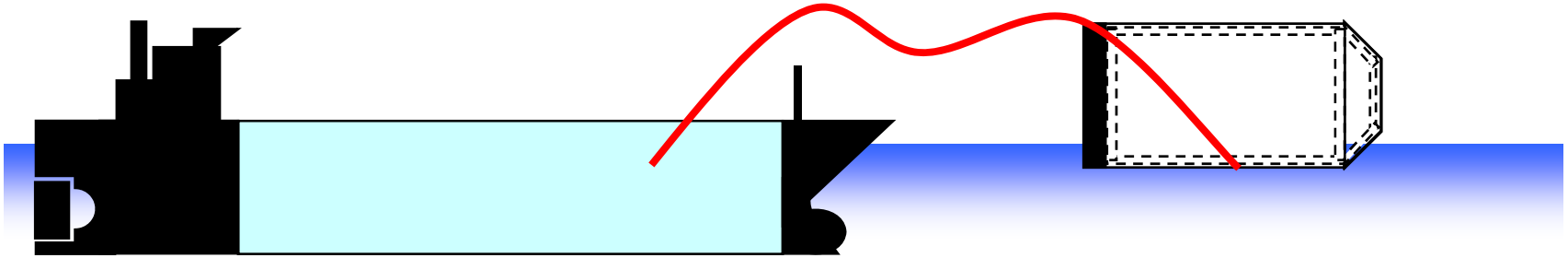
The installation site



Unload the template and the water tank

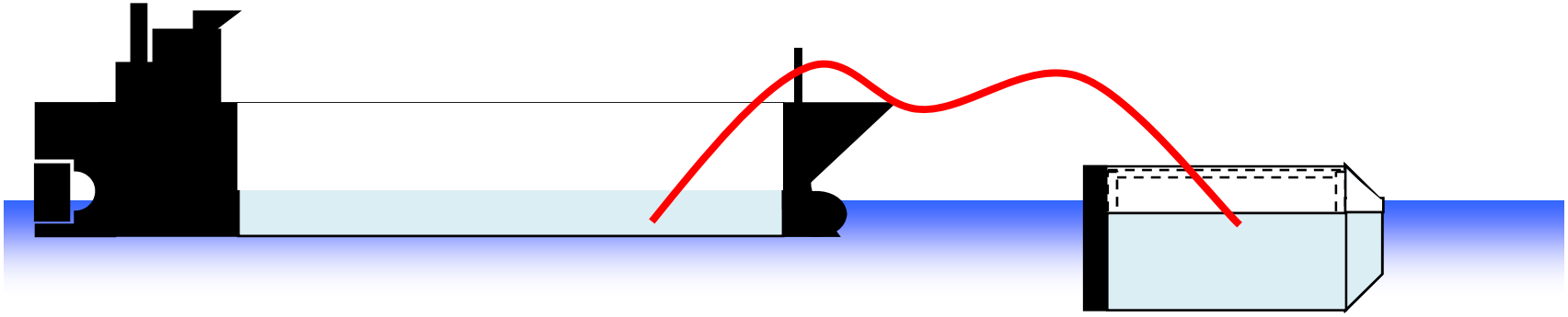
Bring a Ultra Large Crude Oil Carrier (ULCC)

which containes pure water

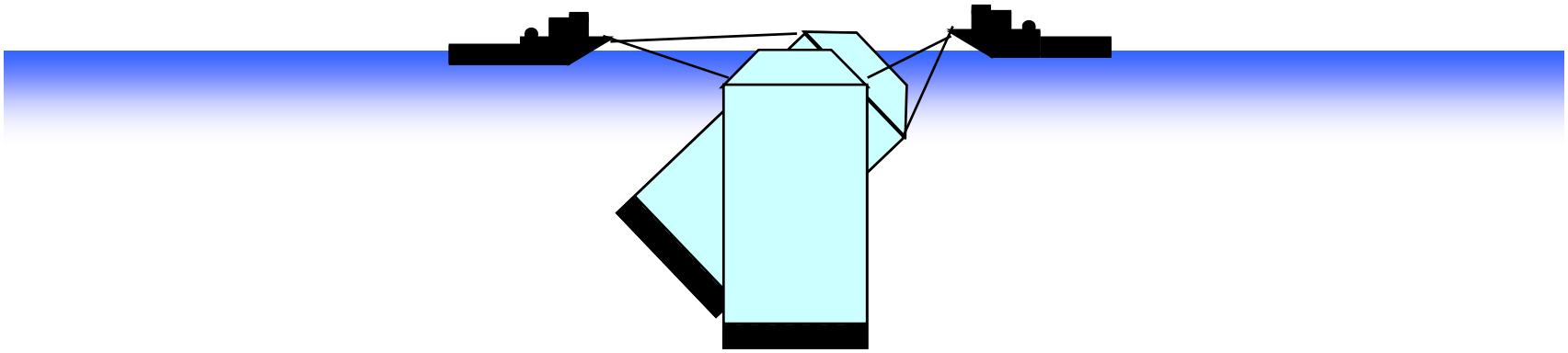


Bring a Ultra Large Crude Oil Carrier (ULCC) which contains pure water

ULCC: 300ktons x 3 ➔ 760ktons for one unit
Transfer speed 10ktons /hour (30 hours /ship)

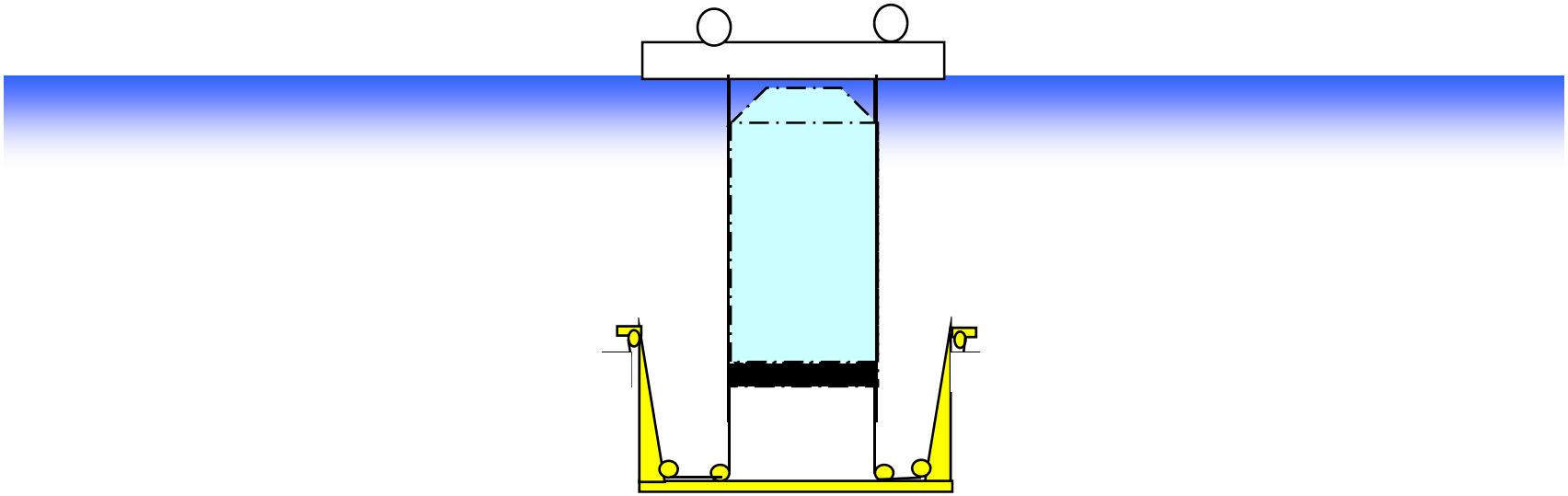


Water is poured into a tank



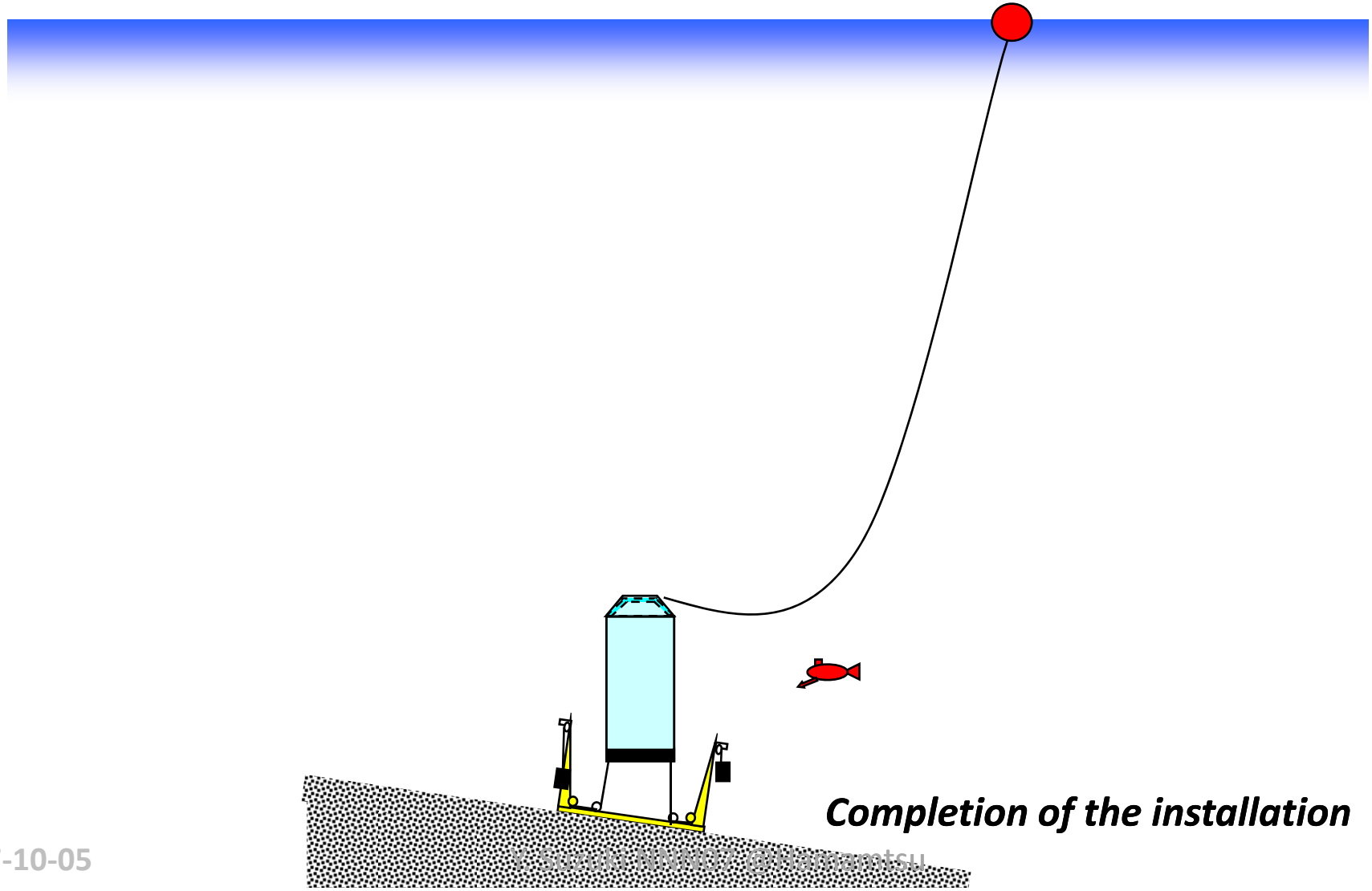
The water tank is rotated

Winch



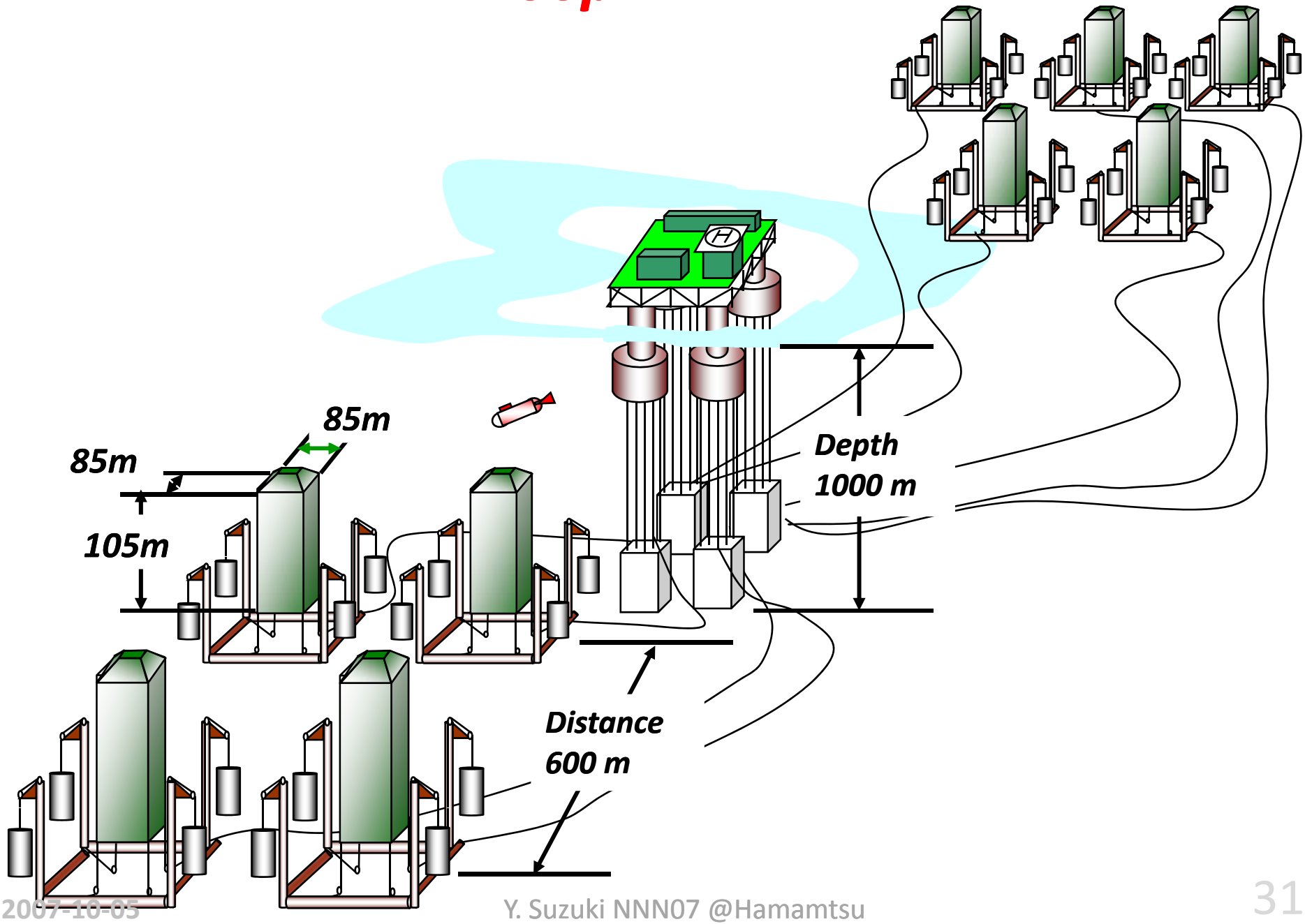
The template and the water tank is joint together

Bring the template and the water tank to the bottom of the sea



Completion of the installation

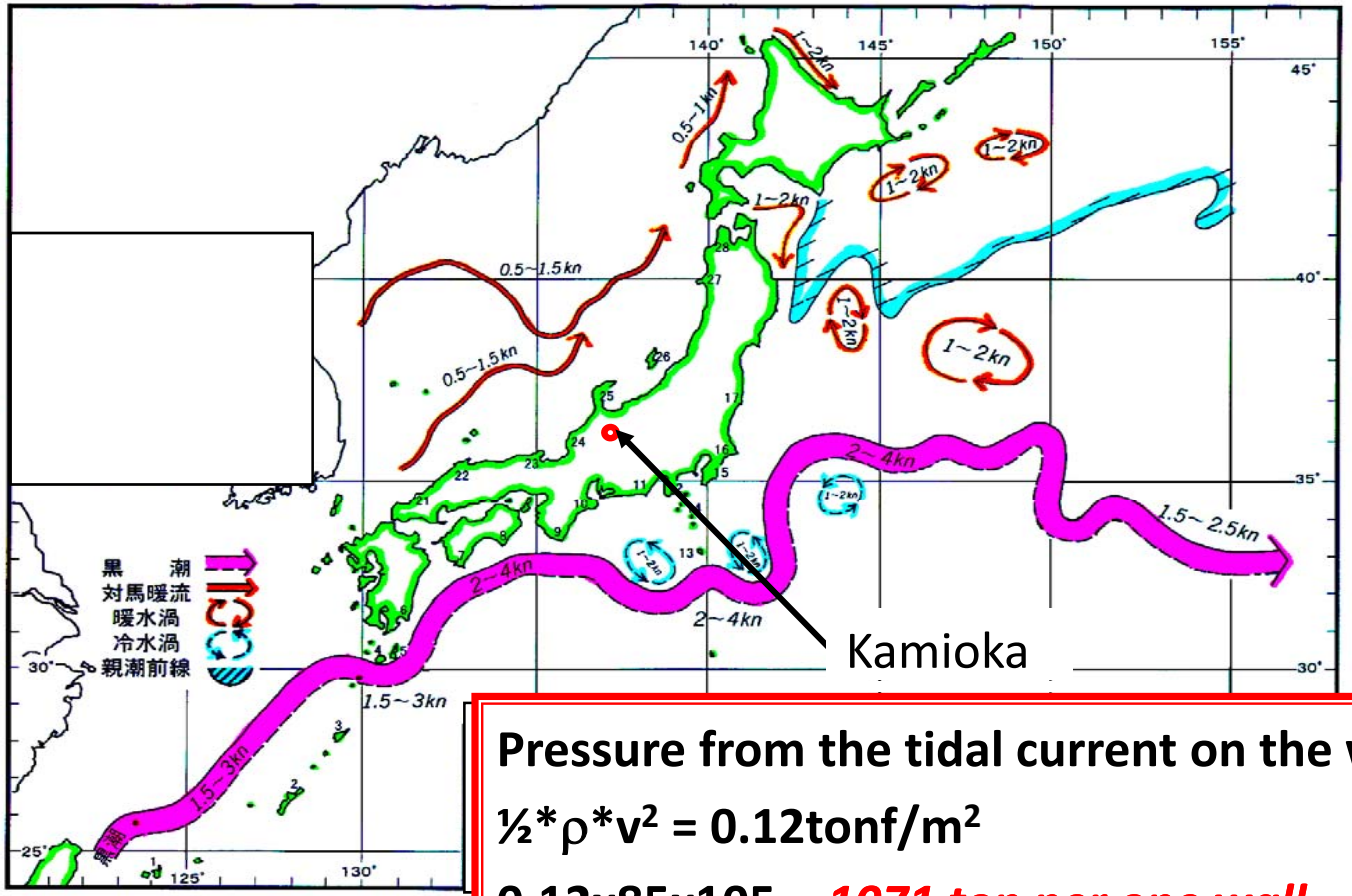
Deep-TITAND



Where we can place the detector?

Tidal current < 3 knot

~ 5.6km/hour (1.5m/s)



Pressure from the tidal current on the wall:

$\frac{1}{2}*\rho*v^2$ = 0.12tonf/m^2

0.12x85x105 = *1071 ton per one wall*

Comments for Long baseline experiments

Long baseline neutrino oscillation experiments

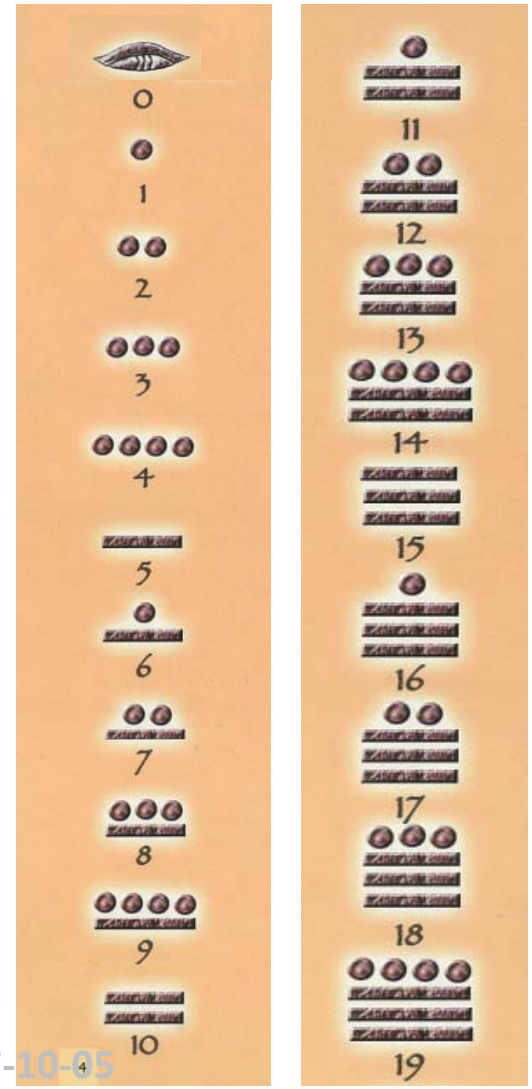
- Running time will become shorter
- Do not need to increase the accelerator power for the CPV experiments
  - Can put more money to the detector than the accelerator
- Movable detectors
- Variety of configuration

Quiz

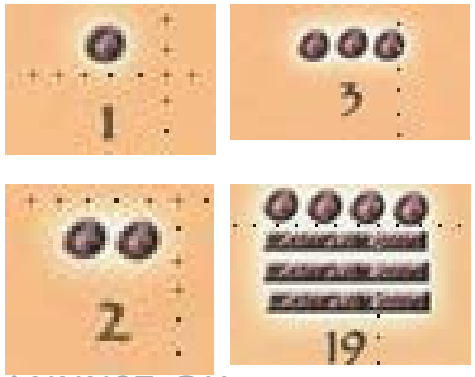
1, 20, 400, 8000, ・・・

Vigesimal calculation
base-20 numerical system

They have zero!

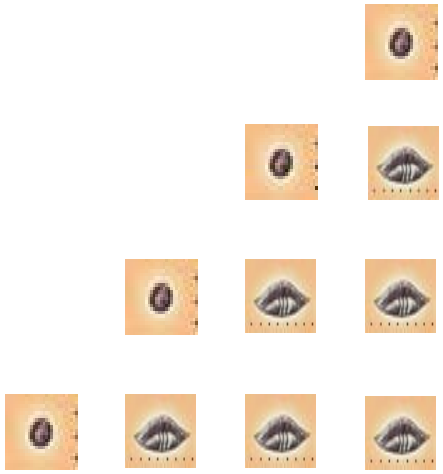


Maya used this Calculus



→ 23

→ 59



1 **Kt: Kamiokande**

20 **Kt: Super-Kamiokande**

400 Kt: HK, UNO, Memphis

8000 **Kt: ～TITAND**

Maya's prediction for the size of the Next-Next generation Neutrinos and Nucleon decay detector (NNNN)

8 Mega ton detector !?

Conclusion

1 kt Kamiokande was built for proton decay,

but, found the neutrino burst from SN1987A

20kt Super-Kamiokande has extended

the study on neutrinos

and discovered neutrino oscillations

8000 kt detector can be built for neutrino studies,

but, may find proton decay

Have a dream !!

END