T2K & VN-neutrino

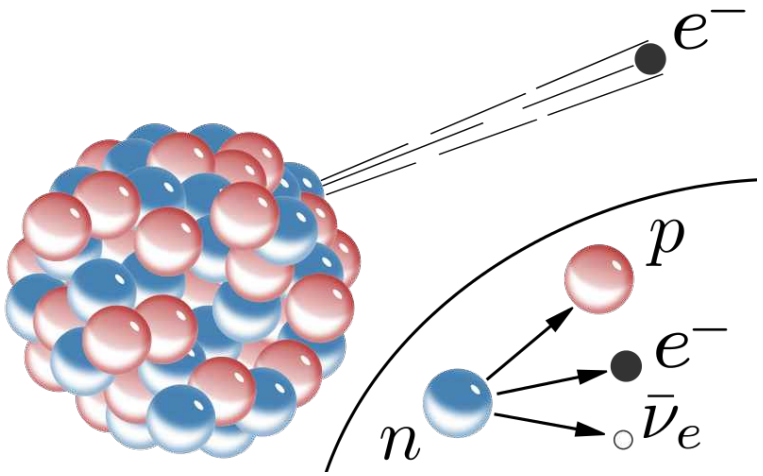
Nguyen Minh Truong

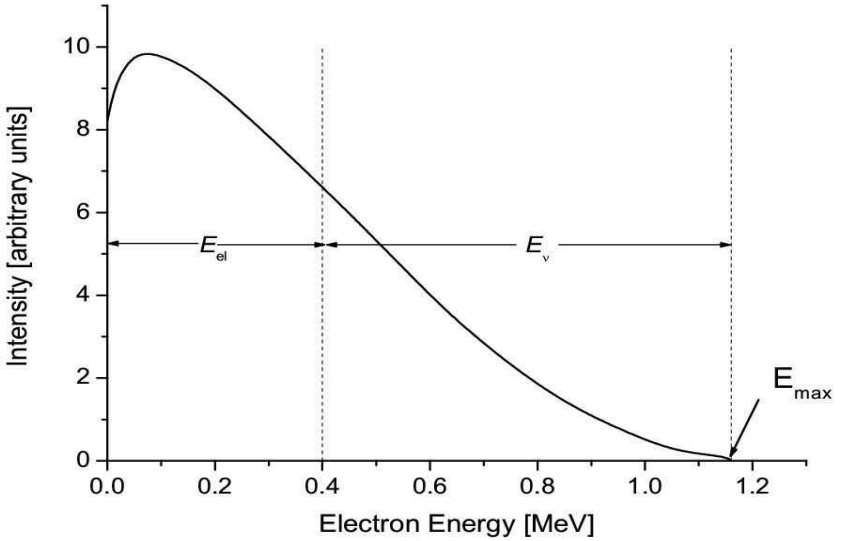
HCM – Nov 21, 2017

Content

- Neutrino
- CP violation
- T2K
- VN-neutrino group

Neutrino





° 1914~1930, energy conservation in β decays went crisis
° 1930, W. Pauli postulated a new *"invisible"* particle

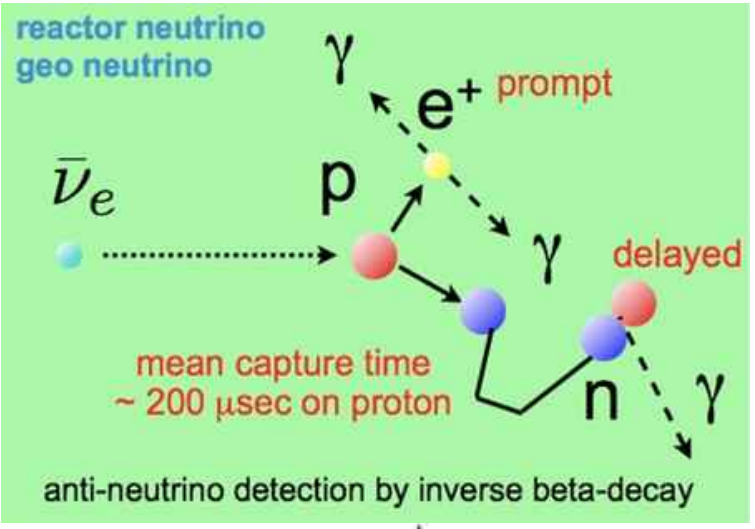
"I have done a terrible thing. I invented a particle that cannot be detected"

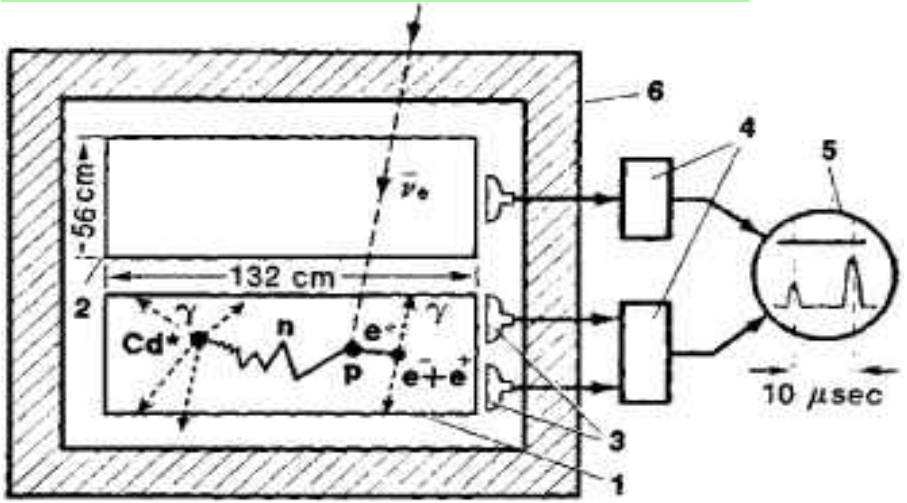
– W. Pauli

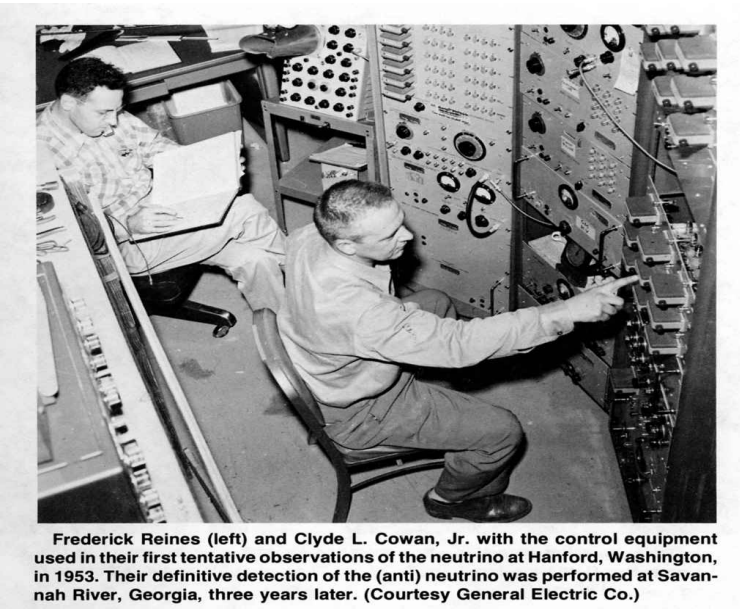
Neutrino

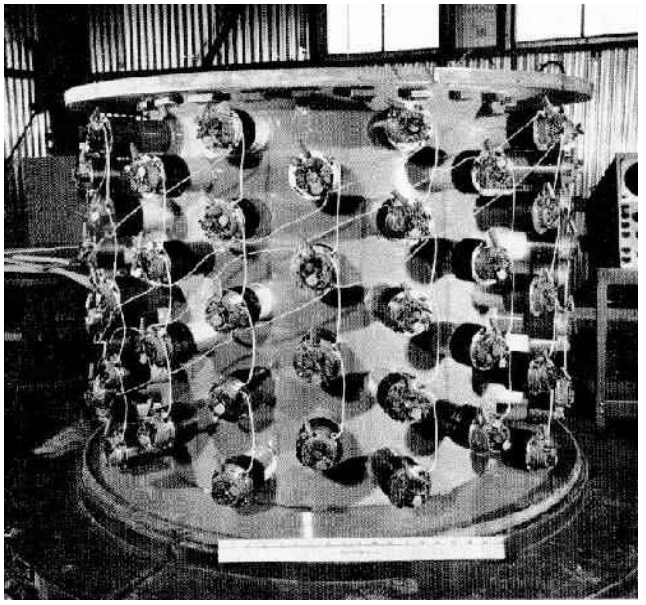
° 1933, E. Fermi built weak interaction theory of neutrinos

° 1956, Reines & Cowan, first detected (anti-)neutrino experimentally
→ Nobel prize in 1995



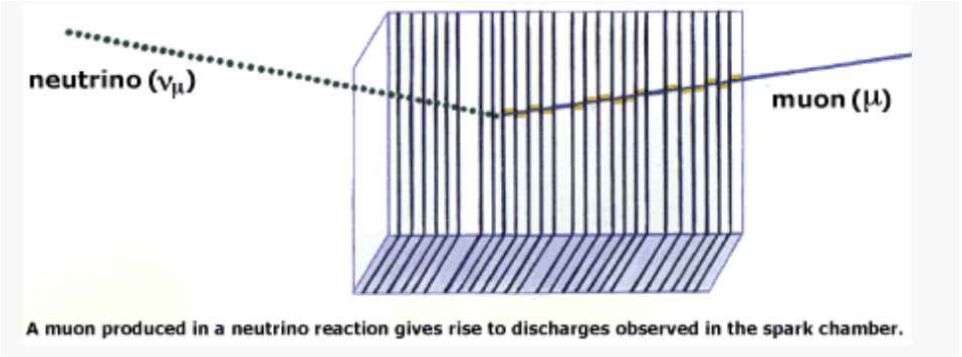



Frederick Reines (left) and Clyde L. Cowan, Jr. with the control equipment used in their first tentative observations of the neutrino at Hanford, Washington, in 1953. Their definitive detection of the (anti) neutrino was performed at Savannah River, Georgia, three years later. (Courtesy General Electric Co.)

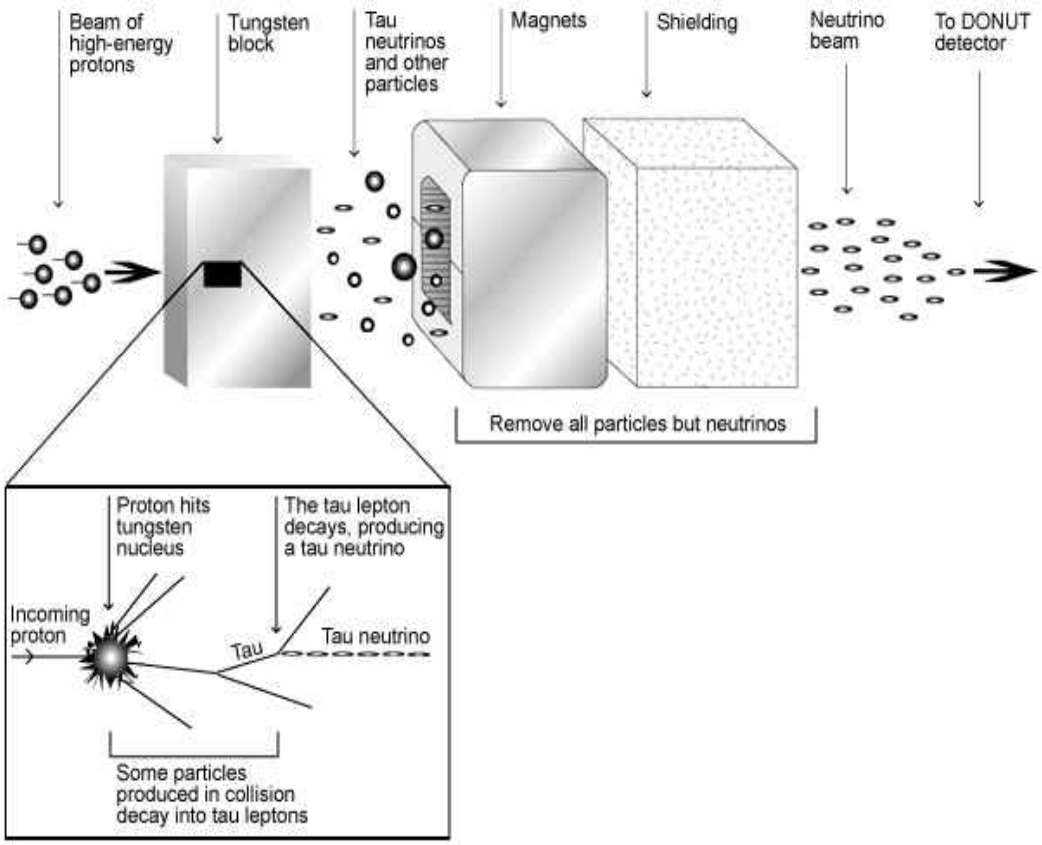


Three Types of Neutrino

Muon neutrino (ν_μ)



Tau neutrino (ν_τ)



Neutrino: undetect particle → detectable

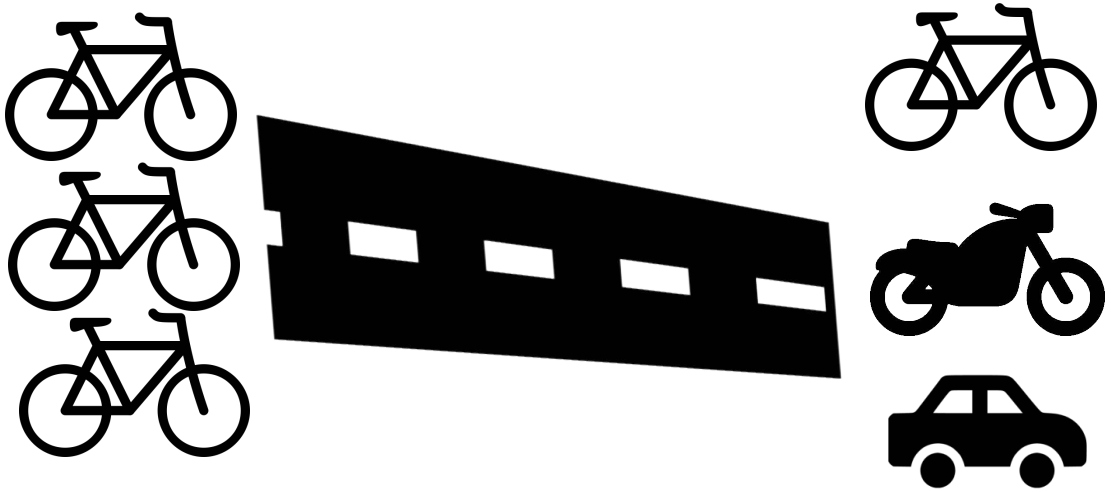
Neutrino Oscillation

a quantum mechanical phenomenon whereby a neutrino created with a specific lepton flavor (electron, muon, or tau) can later be measured to have different flavor

$$c_{ij} = \cos\theta_{ij}, \;\; s_{ij} = \sin\theta_{ij}$$

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & 0 & s_{13}e^{-i\delta_{\rm CP}} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta_{\rm CP}} & 0 & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

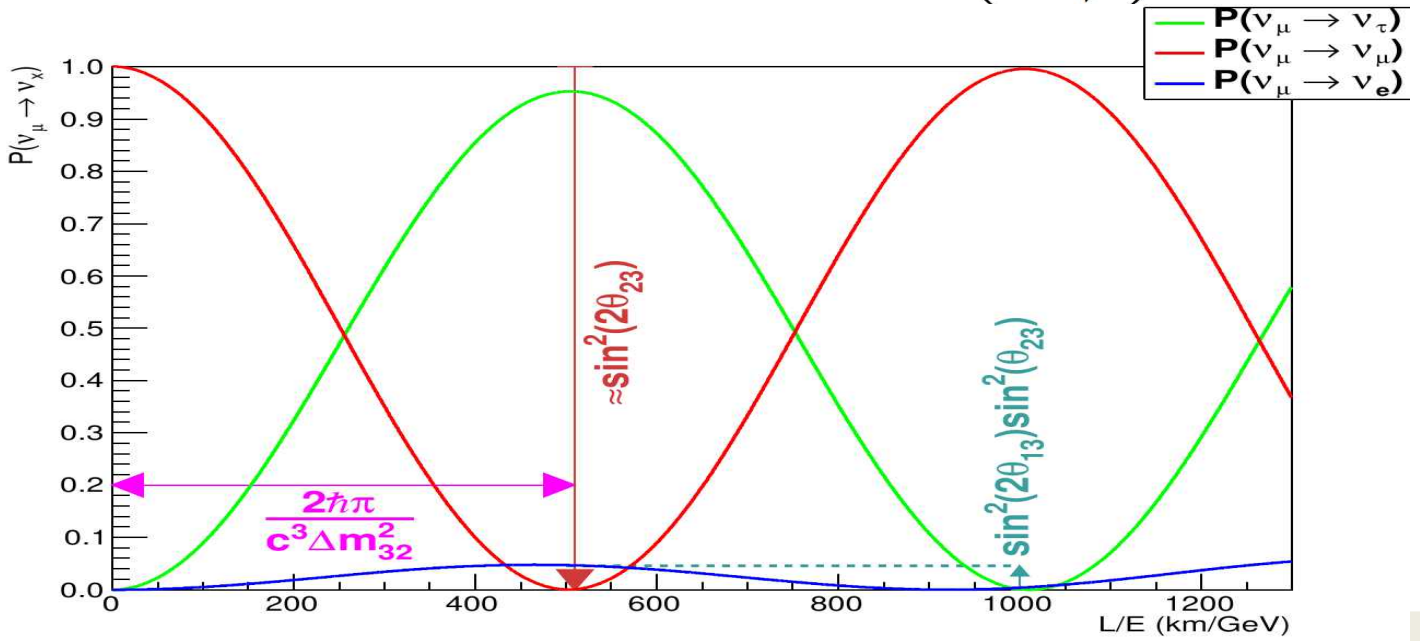
Atmospherics / Accelerators — Reactors / accelerator — s — Solar / reactors



- Indicate massive neutrinos
- Mix flavor and mass eigenstates
- Beyond Standard Model

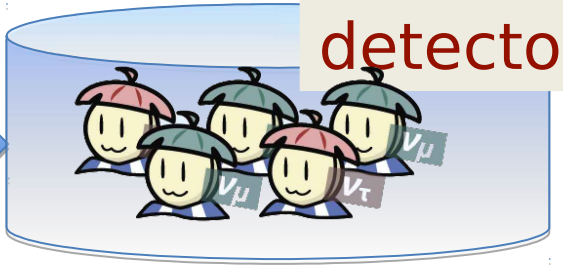
Neutrino Oscillation

$$P_{\mu\to x} \approx 1-\left(\cos^4\theta_{13}\cdot\sin^2 2\theta_{23}+\sin^2\theta_{23}\cdot\sin^2 2\theta_{13}\right)\sin^2\left(\frac{\Delta m^2 L}{4E_\nu}\right)$$



ν source

Defined baseline

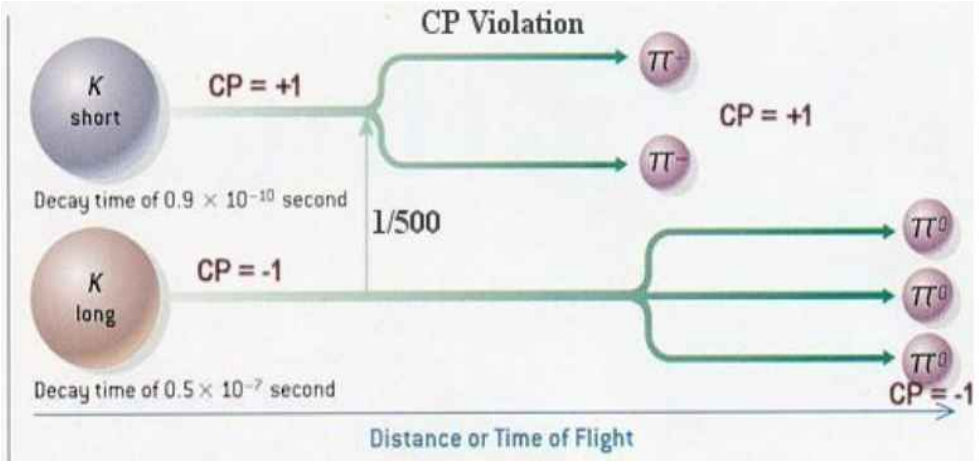


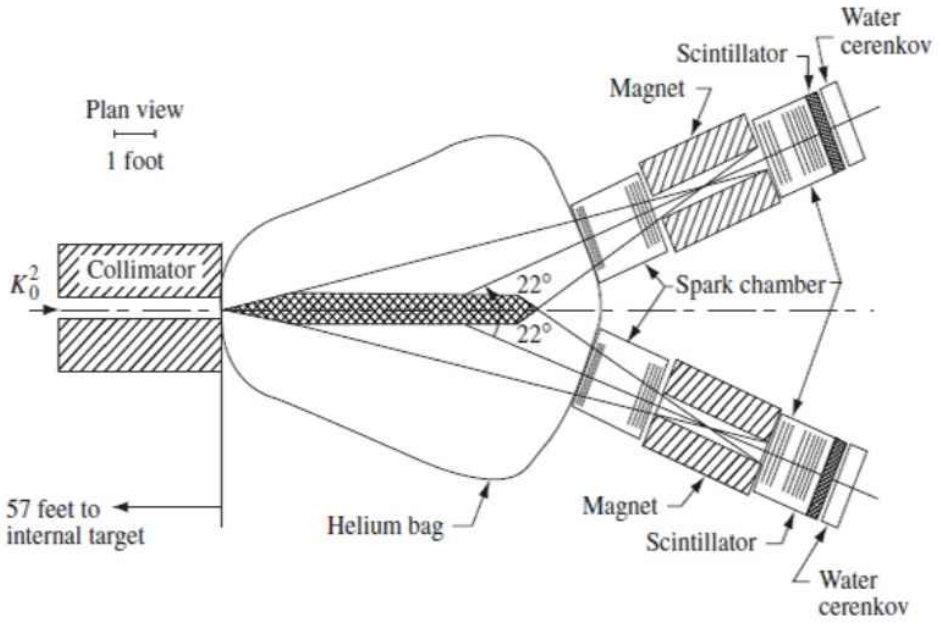
ν detector

CP Violation

CP violation: a violation of C-symmetry and P-symmetry

1964: first discovery of CP violation in the decay of neutral kaons





CP Violation & Neutrino

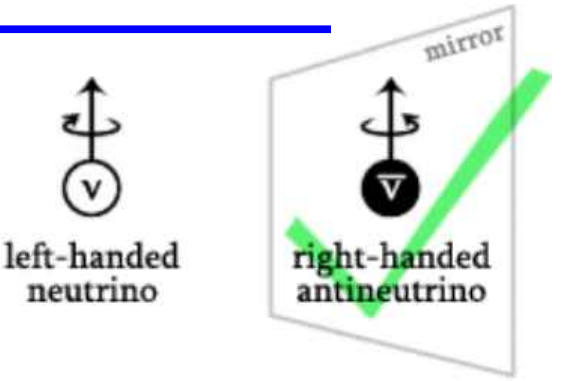
Theory: Baryon Asymmetry' is one of the unsolved problems.

Hypothesis explains: come from the violation of the CP symmetry on neutrinos

- CP Violation has already been observed in quark oscillations and incorporated into quark mixing theory

→ more CP violation must be observed in order to explain the universe's matter dominance

- neutrino in the CP symmetry



- If CP violation occurs in neutrinos, it will manifest itself as a difference in the oscillation probabilities of neutrinos and antineutrinos

$P(\nu_\mu \rightarrow \nu_e)$ exp > $P(\nu_\mu \rightarrow \nu_e)$ theory

T2K Experiment

http://t2k-experiment.org/

- search for CP violation in neutrino sector
- the discovery of $\nu_\mu \rightarrow \nu_e$ (i.e. the confirmation that $\theta_{13} > 0$)
- precision measurements of oscillation parameters in ν_μ disappearance
- a search for sterile components in ν_μ disappearance by observation of neutral-current events
- world-leading contributions to neutrino-nucleus cross-section measurements

OVERVIEW OF T2K EXPERIMENT

30 GeV proton beam

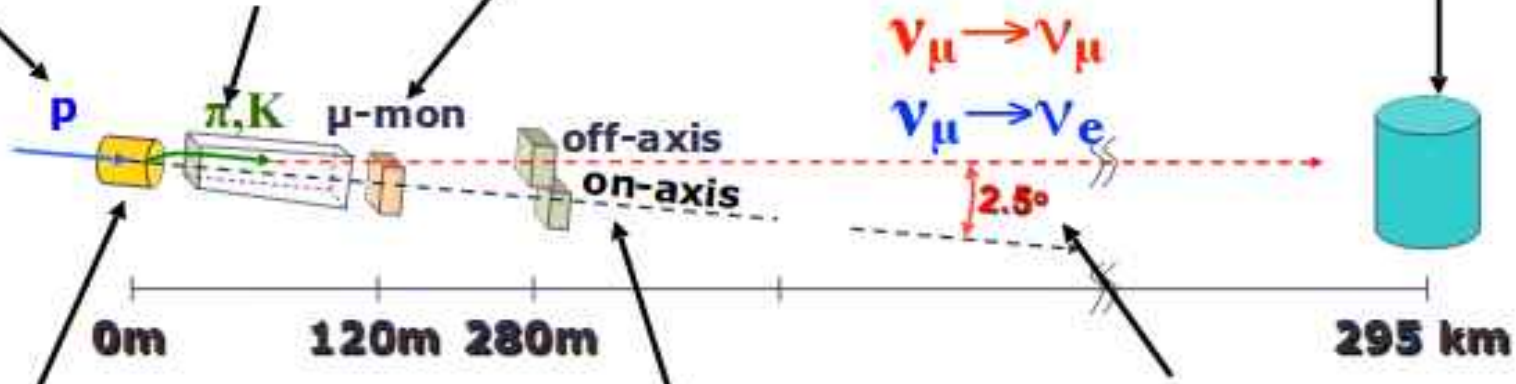
Decay volume:

$\pi^+ \rightarrow \mu^+ + \nu_\mu$

$\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$

MUMON measures muons from pion decay

Off-axis **far detector** at 295 km: SK Cherenkov detector measures event rates after oscillations



Off-axis = narrow band beam

Beam on graphite target

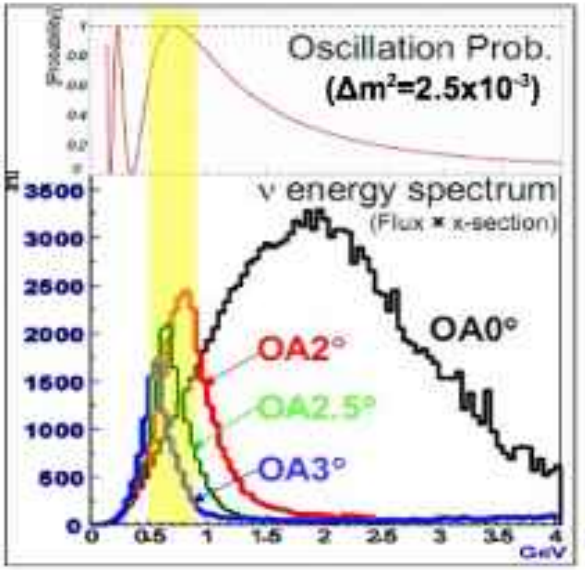
3 magnetic horns focus:

π^+ for neutrino mode

π^- for antineutrino mode

Off-axis **near detector**: ND280 detector measures spectra interactions

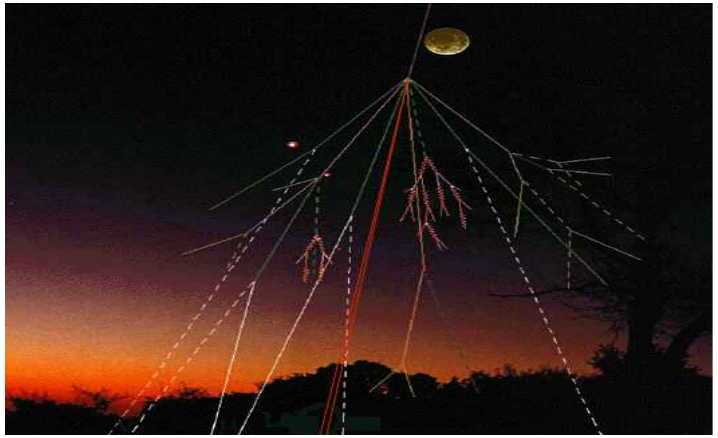
INGRID on-axis detector monitors beam direction and neutrino rate



How To Detect Neutrino

- Neutrino interaction is very weak
→ need very big detector and/or powerful neutrino beam to study

100 events interactions, in 1 tons of water → need ~ 5x 10^{10} neutrino

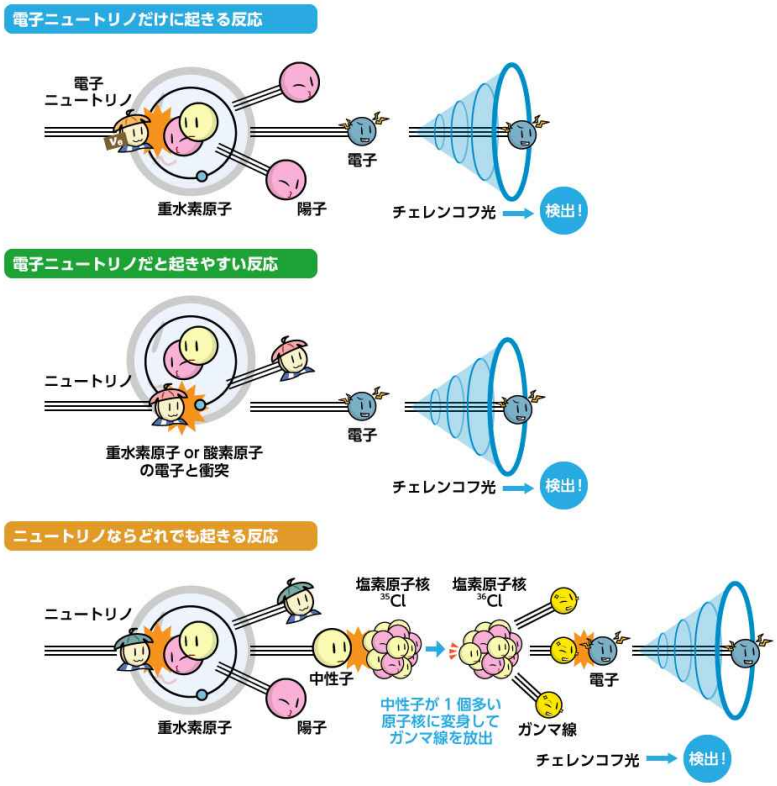


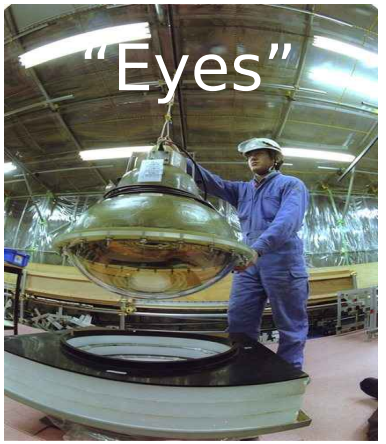
Also need to put underground to reduce the noise

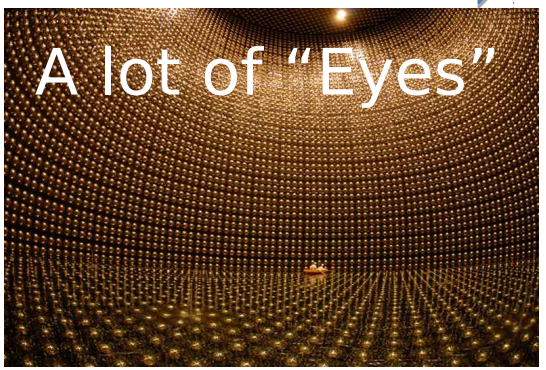
How To Detect Neutrino

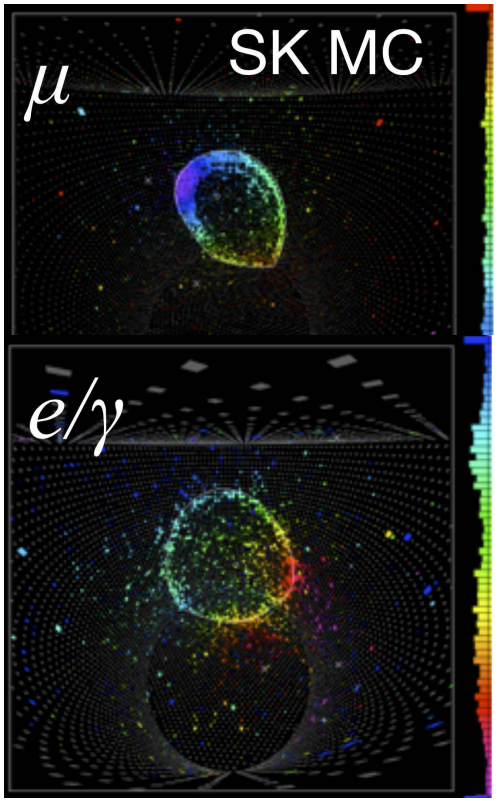
Can't directly detect/see neutrinos.

→ Look at their trace when they interact w/ nuclear instead



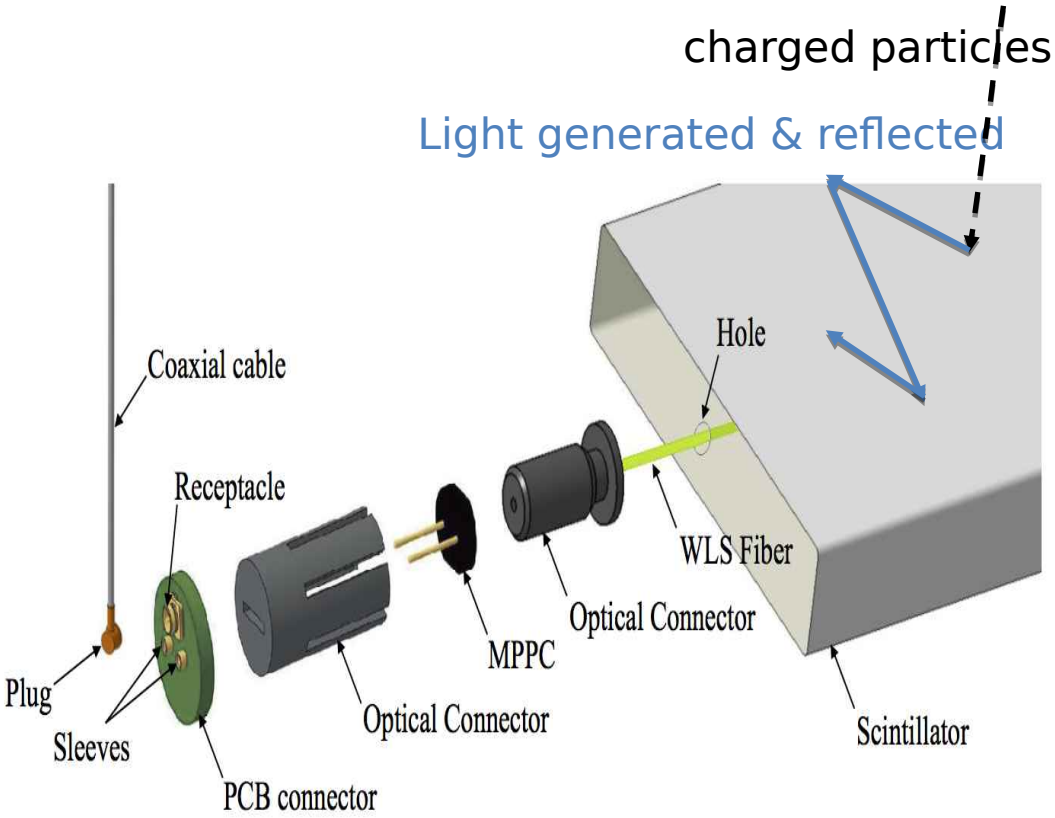


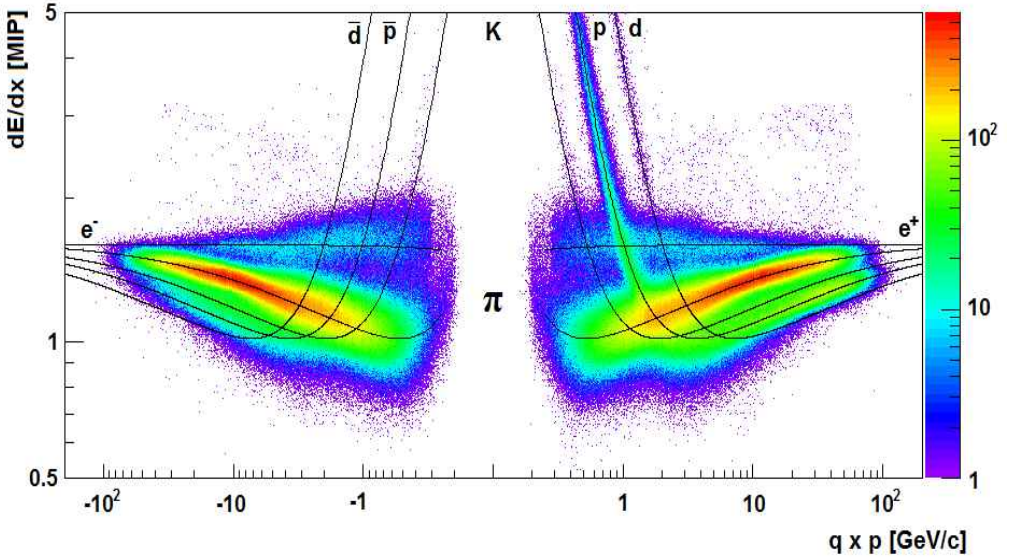




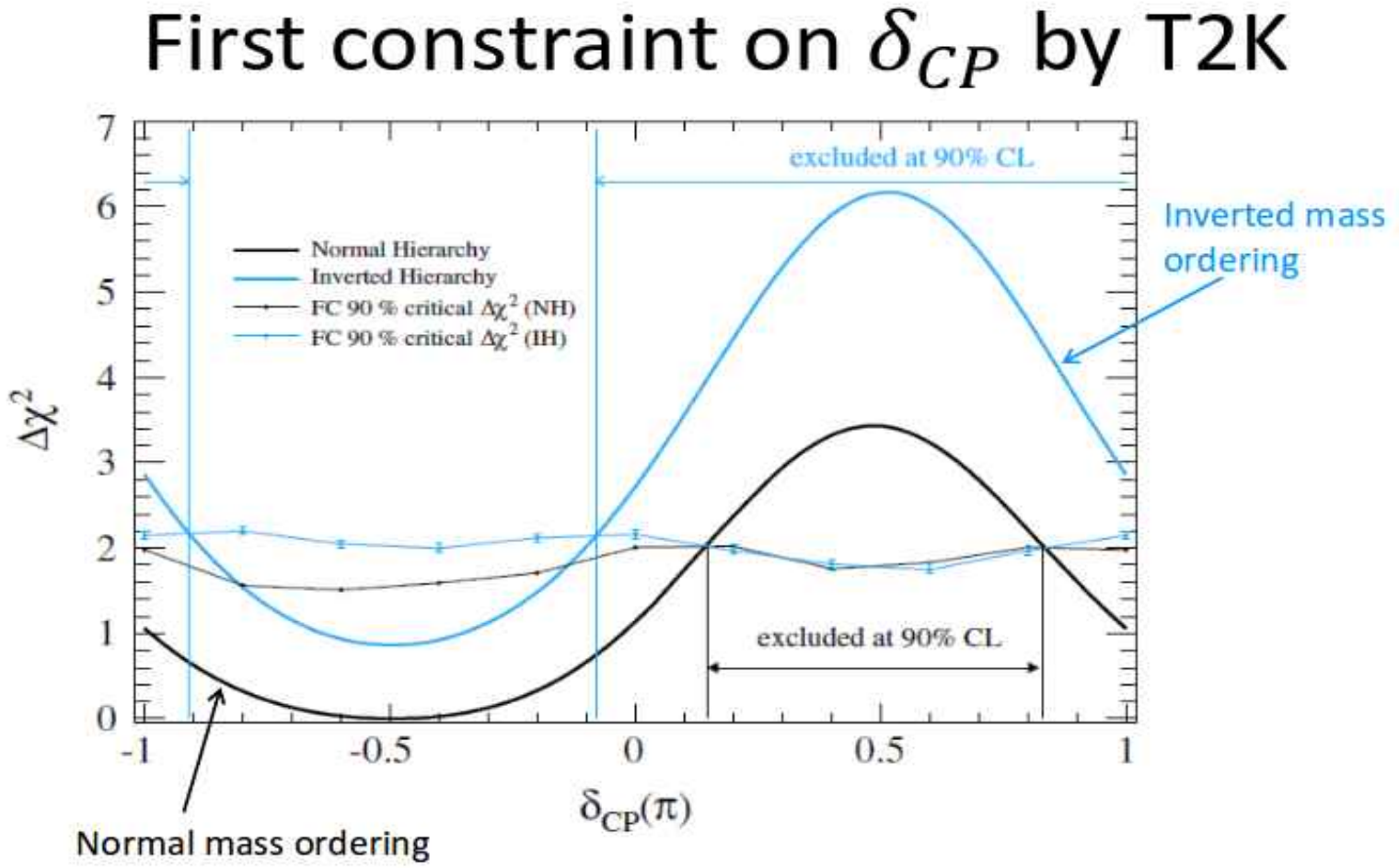
How To Detect Neutrino

Or use ionization to track charged particle





Results:δ_{CP}



T2K data: $\delta_{CP} = 0$ is excluded at 2σ CL.

T2K is about to release new result w/ double statistics

T2K Upgrade

- Aim for 3σ CP violation sensitivity by 2026

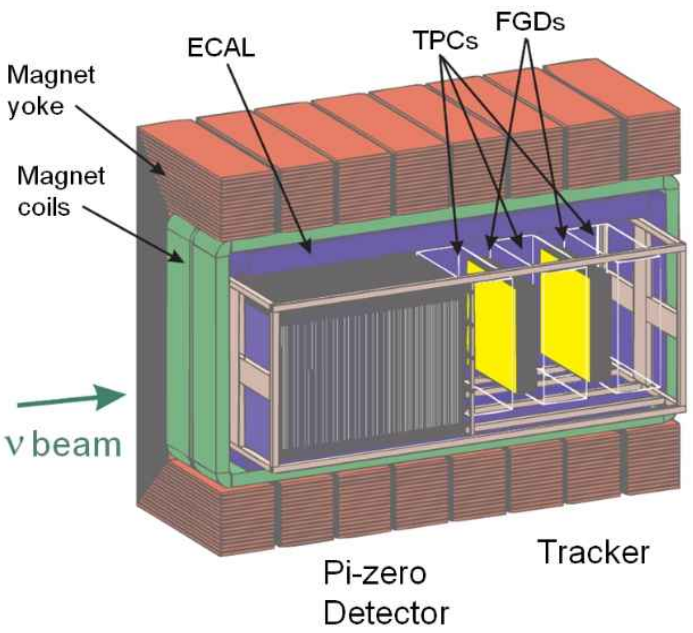
by accumulating 2×10^{22} POT with upgraded J-PARC (1.3MW)

- Goal of systematics: 4% in total for number of ν_e (~400evts expected)

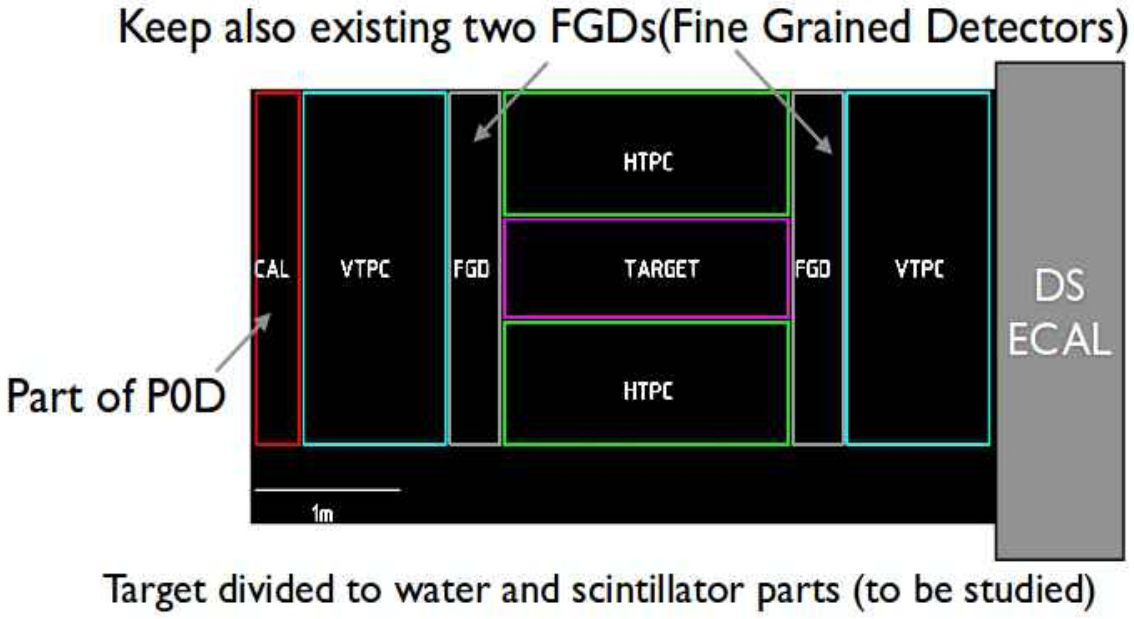
→ Near Detector measurement is a key!

- Upgrade of Near Detector (ND280) is under discussion inside T2K ~2020

Current design



Alternative design



T2K Upgrade

Schedule

- 2017: detailed design of the detectors/setting up the project and the funding, proposal to SPSC
- 2018-2019: construction of new detectors, possible beam test
- 2020: shipment, installation, and commissioning

Vietnam is now member of T2K – VN-neutrino group

The T2K Collaboration

~500 members, 64 Institutes, 12 countries

Canada
TRIUMF
U. B. Columbia
U. Regina
U. Toronto
U. Victoria
U. Winnipeg
York U.

France
CEA Saclay
LLR E. Poly.
LPNHE Paris

Germany
Aachen

Italy
INFN, U. Bari
INFN, U. Napoli
INFN, U. Padova
INFN, U. Roma

Japan
ICRR Kamioka
ICRR RCCN
Kavli IPMU
KEK
Kobe U.
Kyoto U.
Miyagi U. Edu.
Okayama U.
Osaka City U.
Tokyo Institute Tech
Tokyo Metropolitan U.
U. Tokyo
Tokyo U of Science
Yokohama National U.

Poland
IFJ PAN, Cracow
NCBJ, Warsaw
U. Silesia, Katowice
U. Warsaw
Warsaw U. T.
Wroclaw U.

Russia
INR

Spain
IFAE, Barcelona
IFIC, Valencia
U. Autonoma Madrid

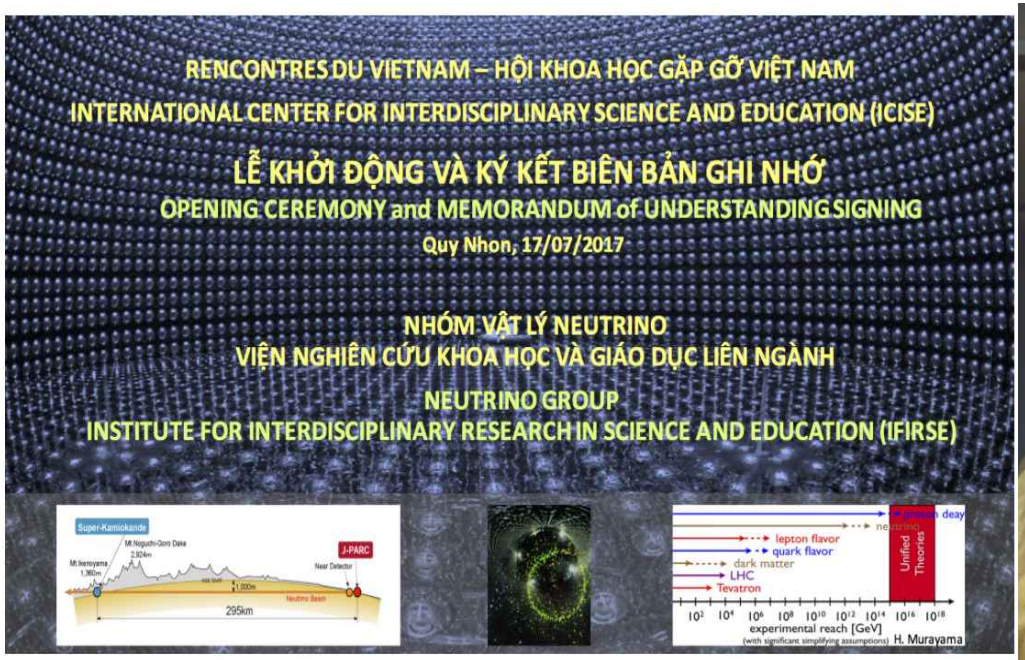
Switzerland
ETH Zurich
U. Bern
U. Geneva

United Kingdom
Imperial C. London
Lancaster U.
Oxford U.
Queen Mary U. L.
Royal Holloway U.L.
STFC/Daresbury
STFC/RAL
U. Liverpool
U. Sheffield
U. Warwick

USA
Boston U.
Colorado S. U.
Duke U.
Louisiana State U.
Michigan S.U.
Stony Brook U.
U. C. Irvine
U. Colorado
U. Pittsburgh
U. Rochester
U. Washington

Vietnam
IFIRSE
IOP, VAST

Vietnam is now member of T2K – VN-neutrino group



On July 17th 2017, Neutrino Group at IFIRSE is officially formed with the MoU signing between Japanese Professors and Rencontres Du Vietnam at ICISE center.

More detail can be found at
http://ifirse.icise.vn/nugroup/OpenMoU.html

VN-neutrino group

- Leader: Tsuyoshi Nakaya (Kyoto Univ.)
- Member: Van Nguyen (IFIRSE & IOP)
- Affiliated member:
  - Yuichi Oyama (IPNS, KEK);
  - Makoto Miura (ICRR, Univ. of Tokyo);
  - Atsumu Suzuki (Kobe Univ.);
  - Son Cao (IPNS, KEK);
  - Trung Le (Tufts Univ.),
  - Minh Truong (Danang Univ. of Science & Tech.)
  - Nhu Le (Hue Univ.)
  - Le Thi Que (VNUHCM-International University)
- Students:
  - Tran Van Ngoc (Ph.D candiadate),
  - Nguyen Thi Kim Ha (B4)

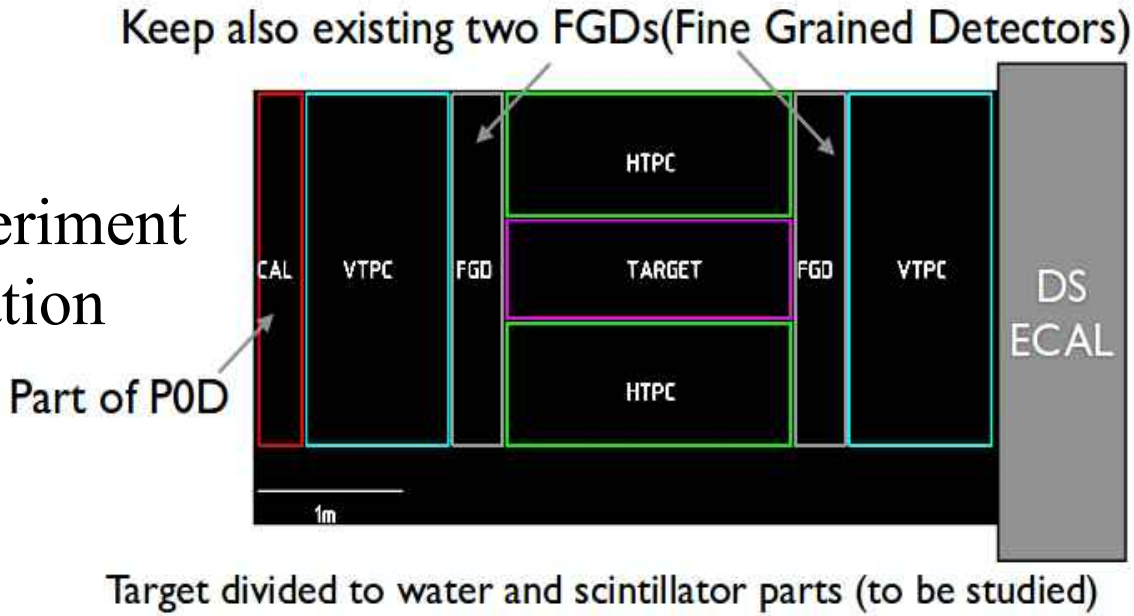
Need master student

We organized Vietnam School on Neutrinos & enrolling students a

http://ifirse.icise.vn/nugroup/

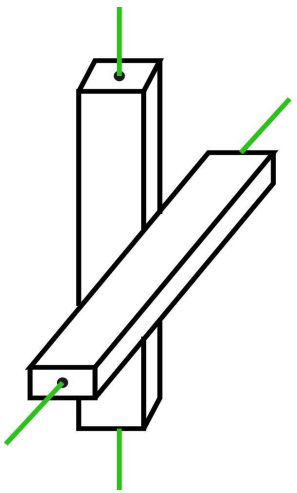
VN-neutrino group

- What will we do ?
  - Simulation with NEUT
  - Analysis in WAGASIC experiment
  - MPPC study with 3rd generation
  - ….

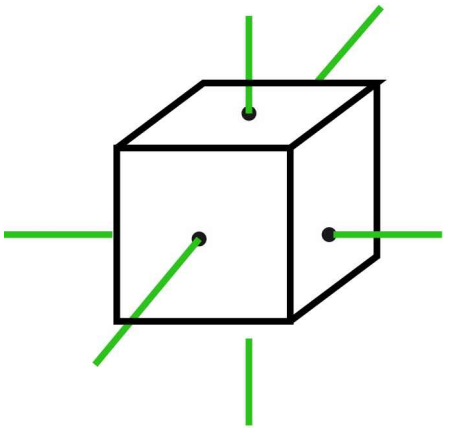


Target divided to water and scintillator parts (to be studied)

FGD => superFGD



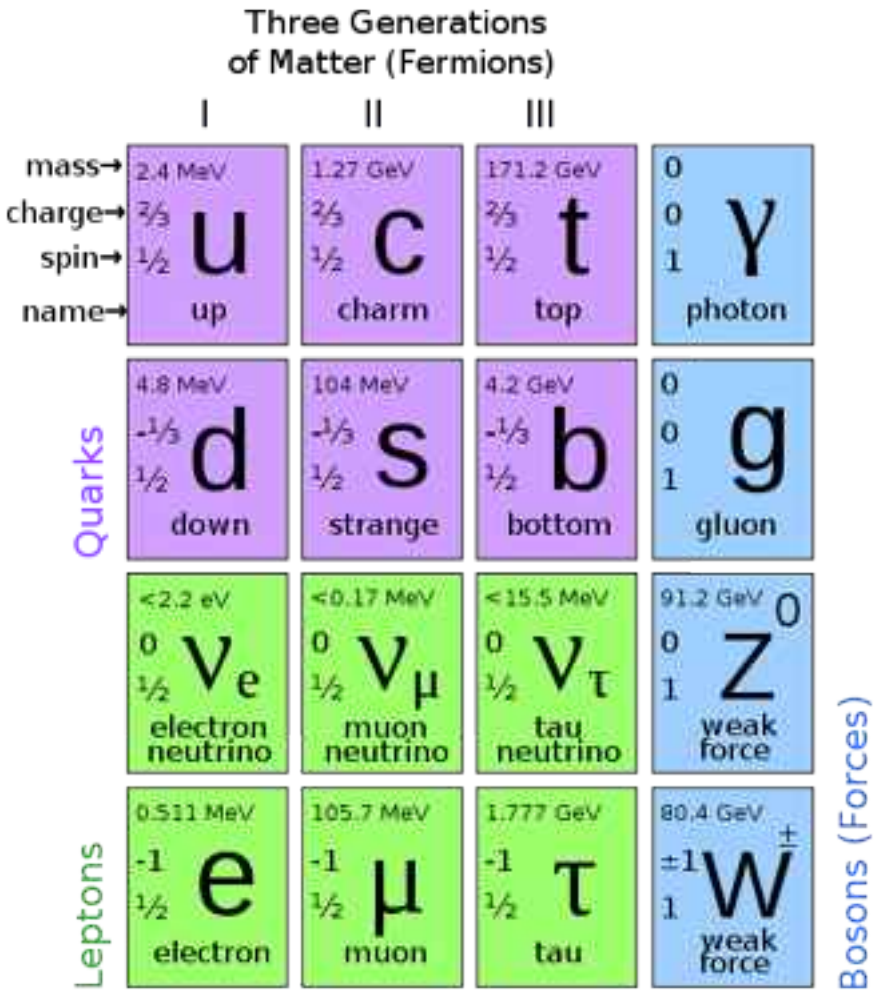
Scintillator bars



Scintillator cube

Thanks for your attention

Backup


Three Generations
of Matter (Fermions)
I
II
III
mass→
charge→
spin→
name→
2.4 MeV
2/3
1/2
u
up
1.27 GeV
2/3
1/2
c
charm
171.2 GeV
2/3
1/2
t
top
0
0
1
γ
photon
Quarks
4.8 MeV
-1/3
1/2
d
down
104 MeV
-1/3
1/2
s
strange
4.2 GeV
-1/3
1/2
b
bottom
0
0
1
g
gluon
<2.2 eV
0
1/2
νe
electron neutrino
<0.17 MeV
0
1/2
νμ
muon neutrino
<15.5 MeV
0
1/2
ντ
tau neutrino
91.2 GeV
0
0
1
Z0
weak force
Leptons
0.511 MeV
-1
1/2
e
electron
105.7 MeV
-1
1/2
μ
muon
1.777 GeV
-1
1/2
τ
tau
80.4 GeV
±1
1
W±
weak force
Bosons (Forces)