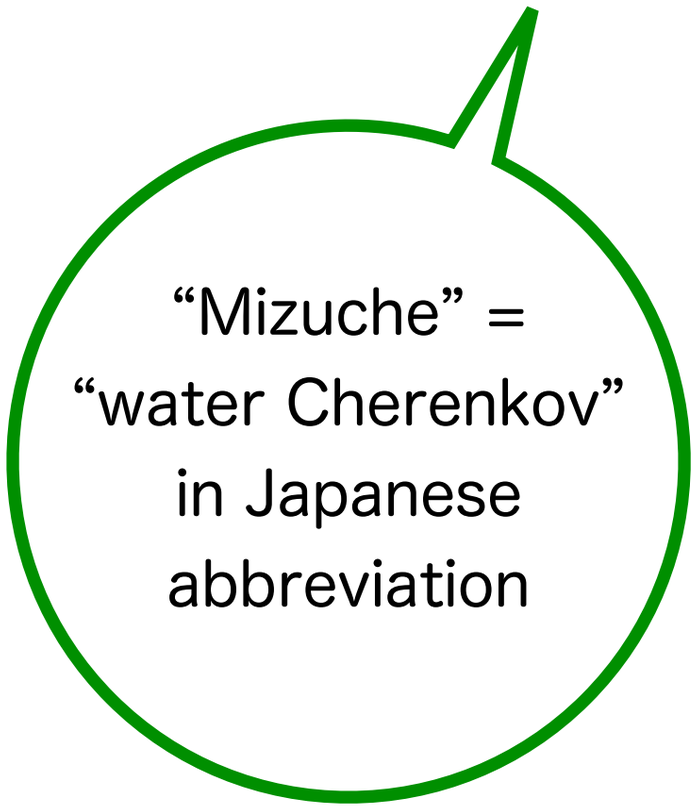
Mizuche Experiment



Shota Takahashi,
Akira Murakami,
Ken Sakashita[A],
Atsuko K. Ichikawa,
Takashi Kobayashi[A],
Tsuyoshi Nakaya,
Akihiro Minamino
Kyoto University, KEK[A]

Contents

- Motivation
- Experimental principle
- Current status
- Study with Monte Carlo simulation
  - Signal event MC
  - Background event MC
- Key issue
- Schedule
- Request for support

Motivation

Ultimate goal : Predict # of ν interaction in SK with 2% precision

- Predict N_{SK}

$$N_{SK}^{exp} = \frac{N_{SK}^{MC}}{N_{Miz}^{MC}} \times N_{Miz}^{obs} \times \frac{\sum \Phi_{SK}^{MC} \times \sigma_{SK} \times \varepsilon_{SK}}{\sum \Phi_{Miz}^{MC} \times \sigma_{Miz} \times \varepsilon_{Miz}}$$

cancel uncertainty in cross-section

cancel uncertainty of detector efficiency

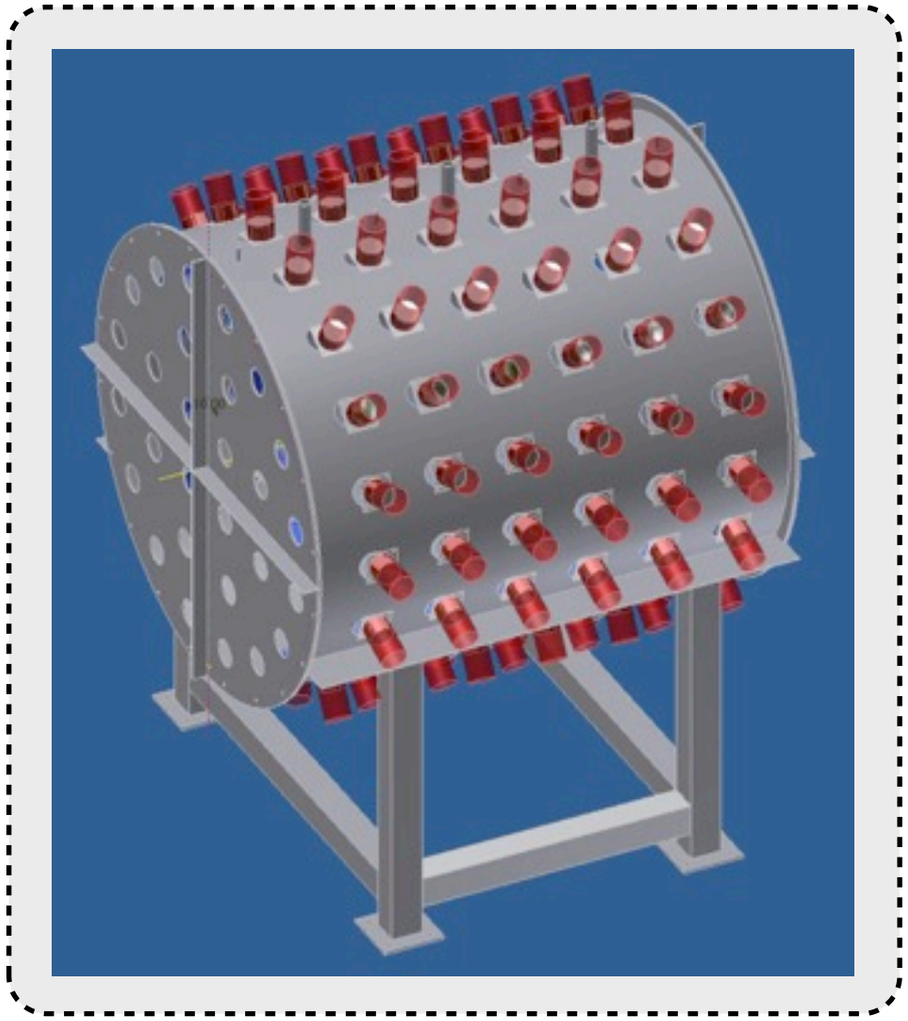
reduce systematic error

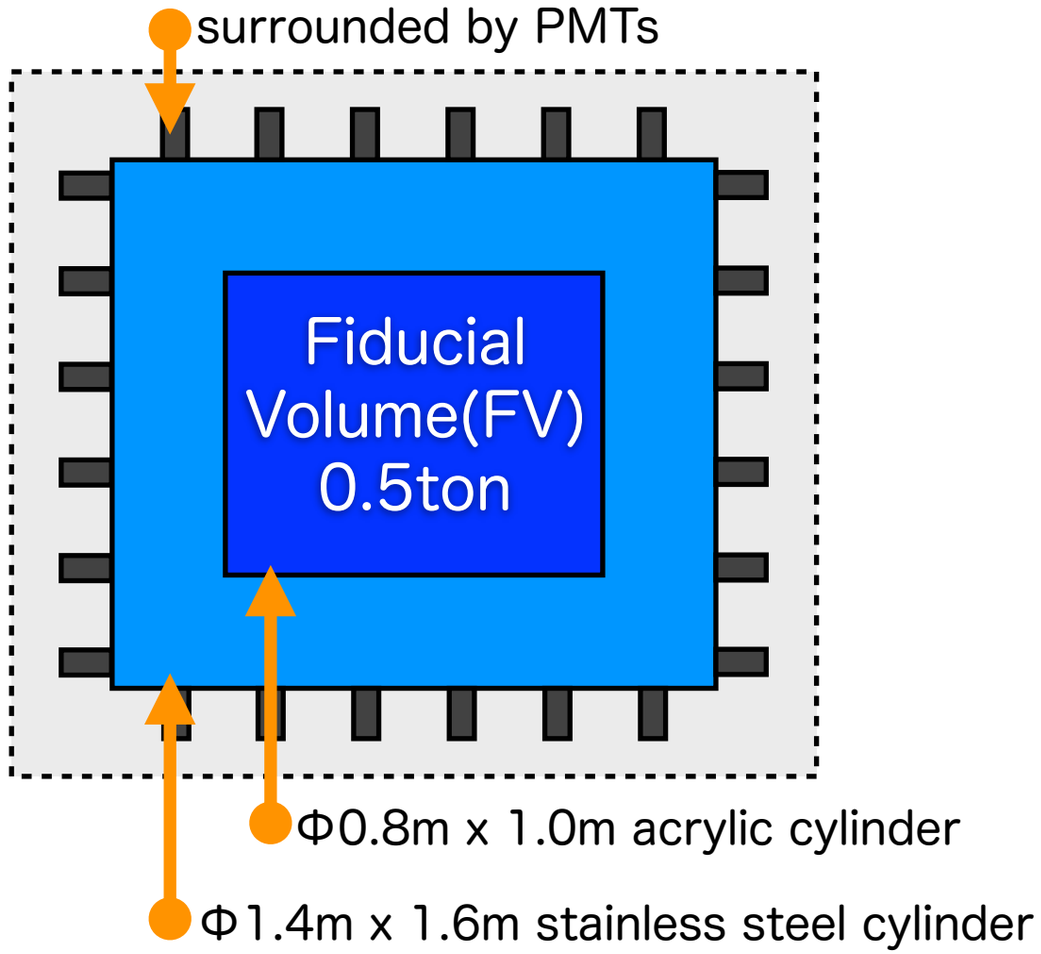
- "Mizuche" detector
  - "water" target
  - detect "Cherenkov light"

- **1st phase** : test experiment to prove feasibility of small water Cherenkov detector for high intensity neutrino beam counting
- **2nd phase** : measure with 2% precision and contribute to T2K physics

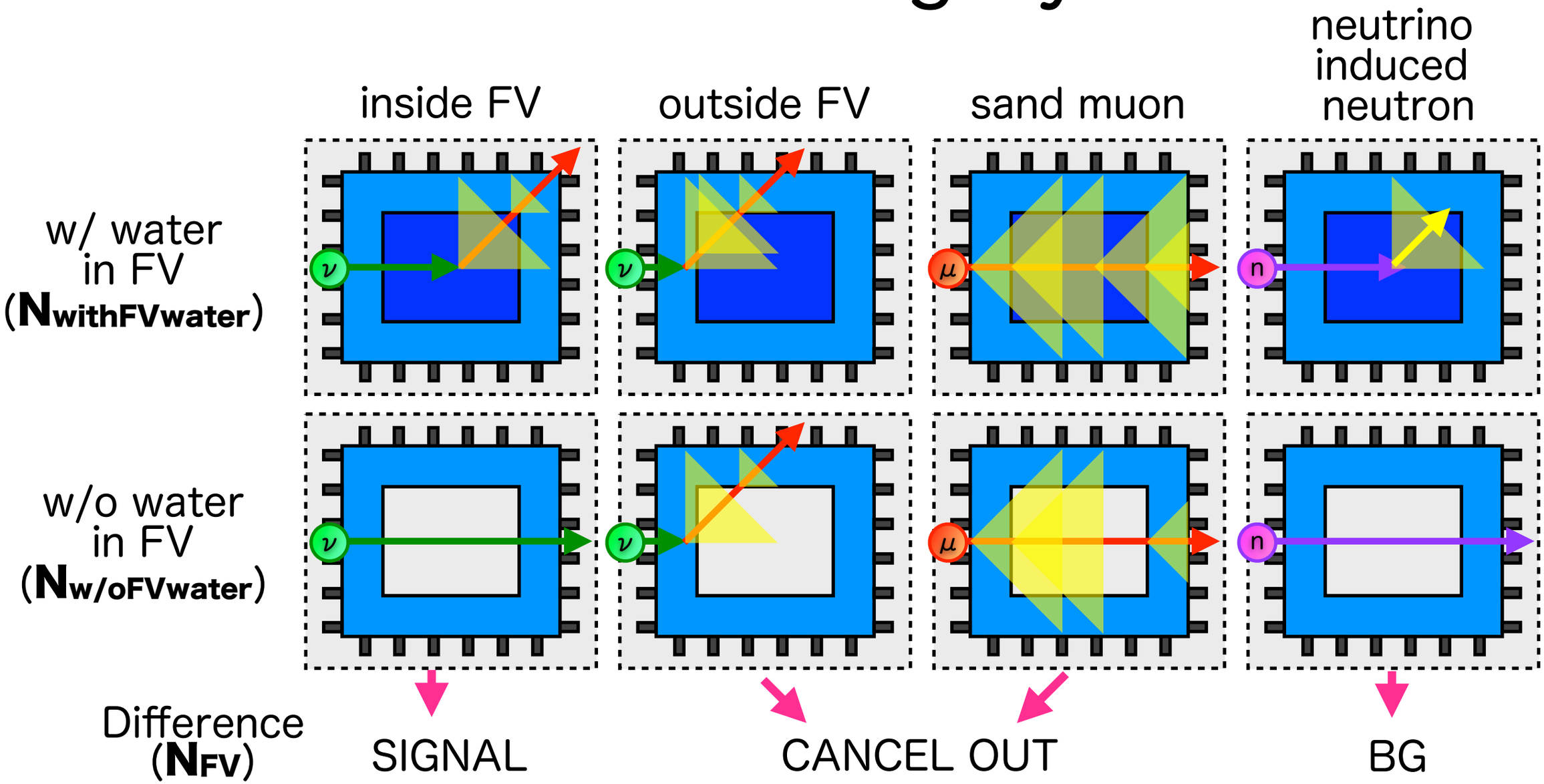
Experimental principle

- Count # of ν interaction **with** and **w/o** water in Fiducial Volume (FV)
- **Difference = # of ν interaction in FV**



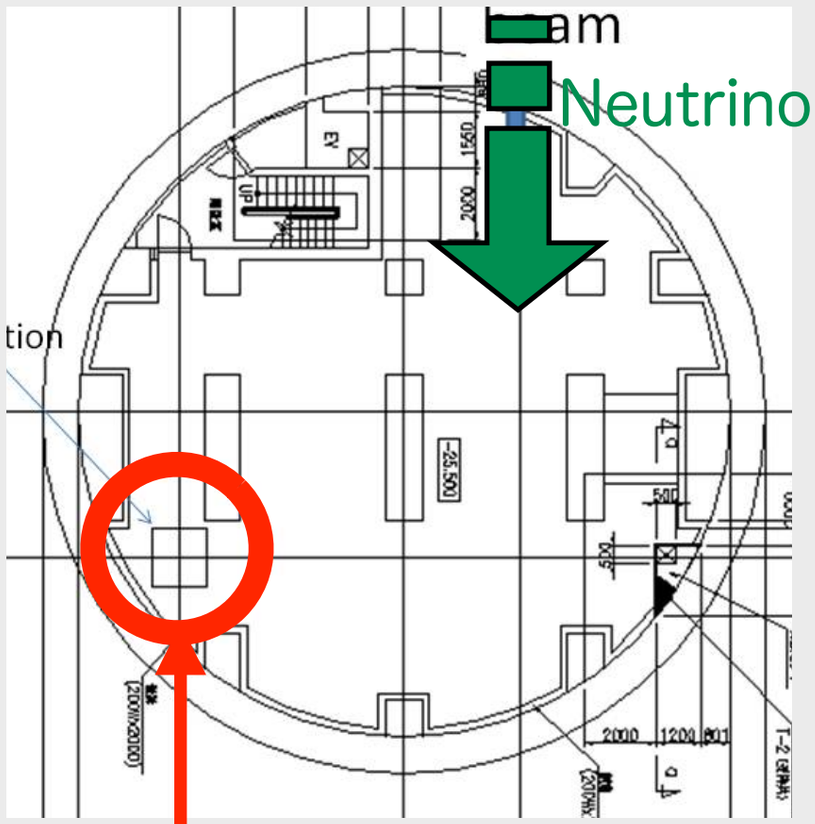


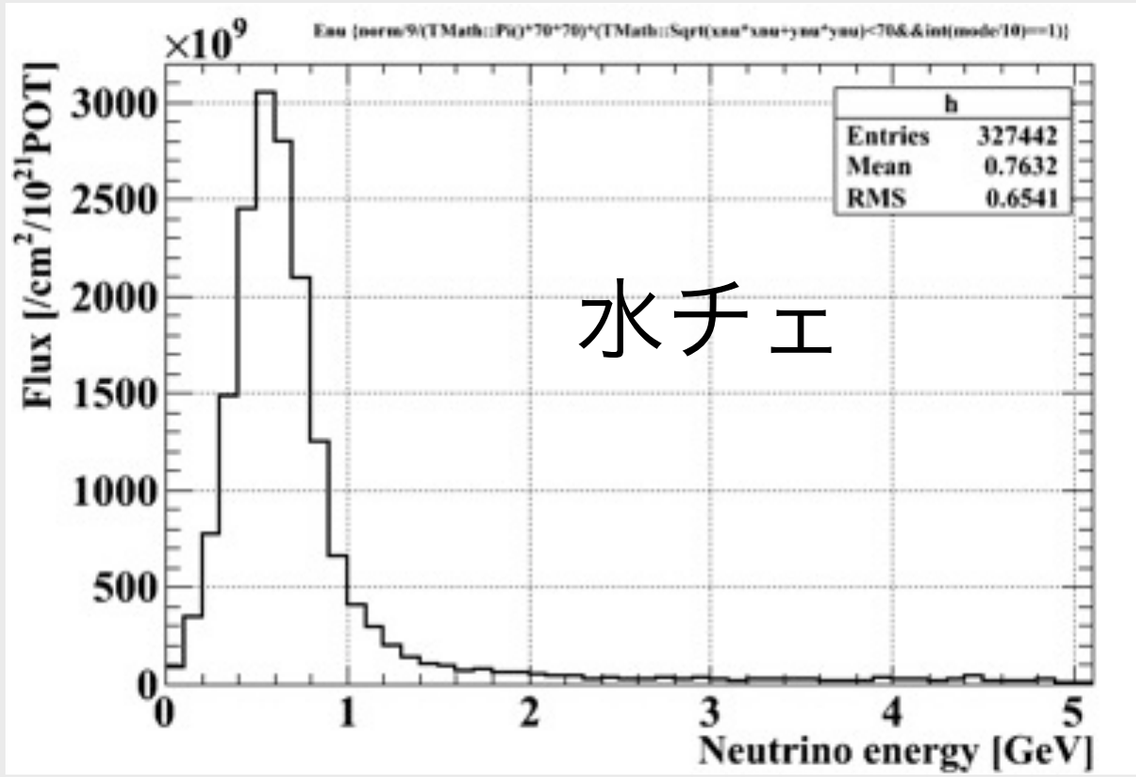
Event category



- **$N_{FV} = N_{withFVwater} - N_{w/oFVwater}$**
  - Normalize by delivered POT before subtraction

Detector position & flux

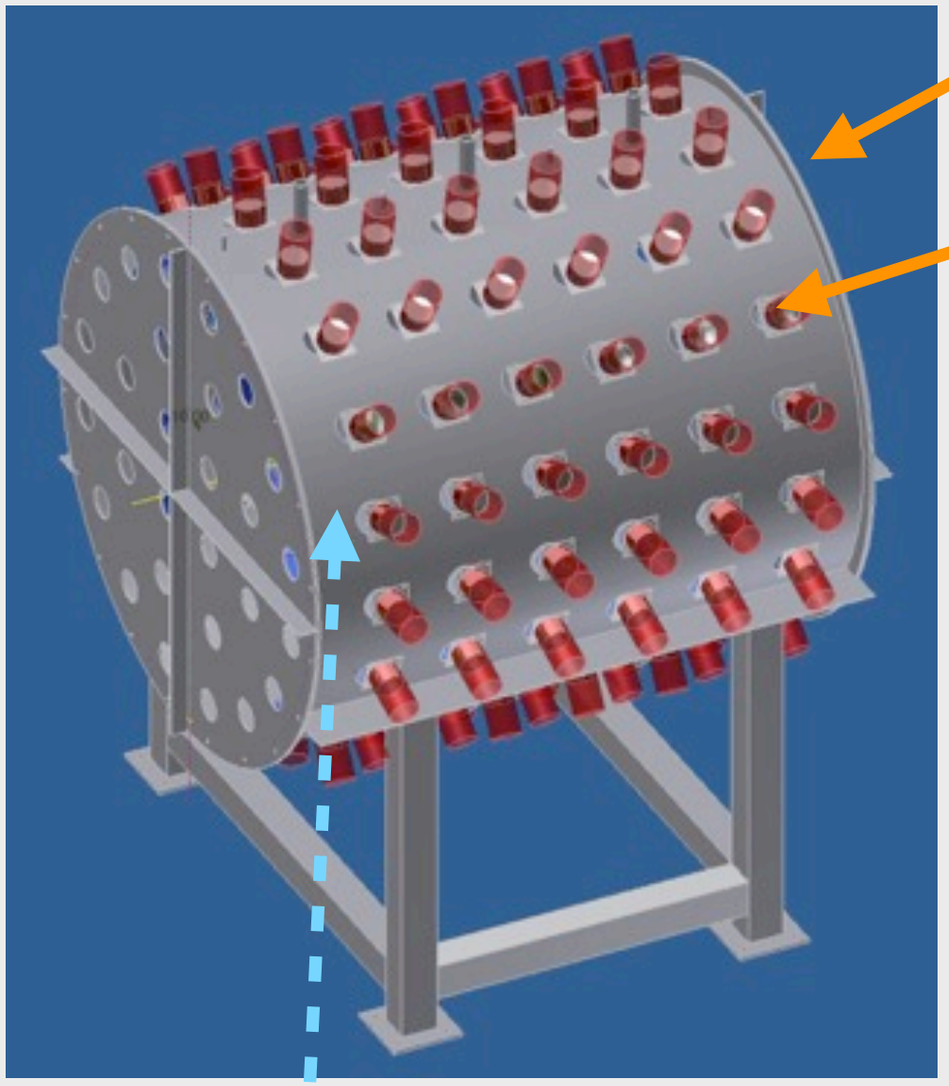




Neutrino flux @ detector position

- Set on B2 floor of Neutrino Monitor building (NM)
- Almost same off-axis angle as ND280 off-axis detector

Detector setup

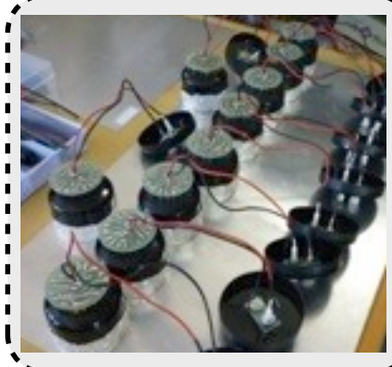


Tank

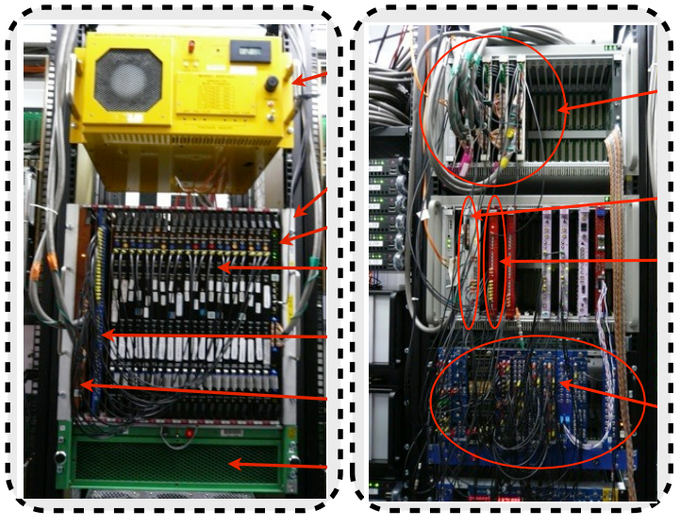
- Φ1.4m x 1.6m stainless tank

PMT

- 3in. PMT x 164
- 7.2% coverage



- **Read out electronics**
  - NIM, VME, TKO crate
  - ATM, GONG, SCH, etc
    - Old SK electronics

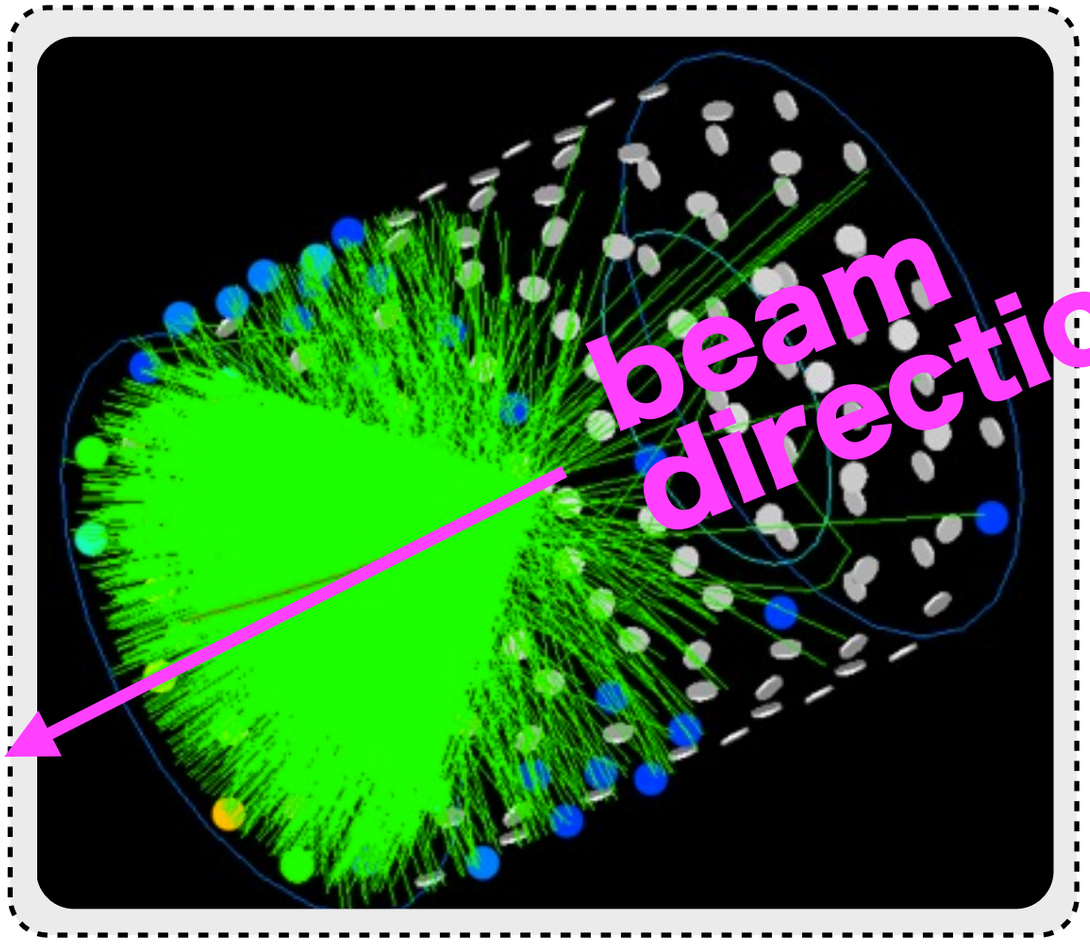


※ TKO crate & modules @ XMASS

- **Fiducial Volume (0.5 ton)**
  - Φ0.8m x 1.0m acrylic tank
- **Circulate water**
  - purify with ion exchange filter

Event rate estimation in FV

- @100 kW operation
  - with water in FV : 202 events/day
  - w/o water in FV : 127 events/day

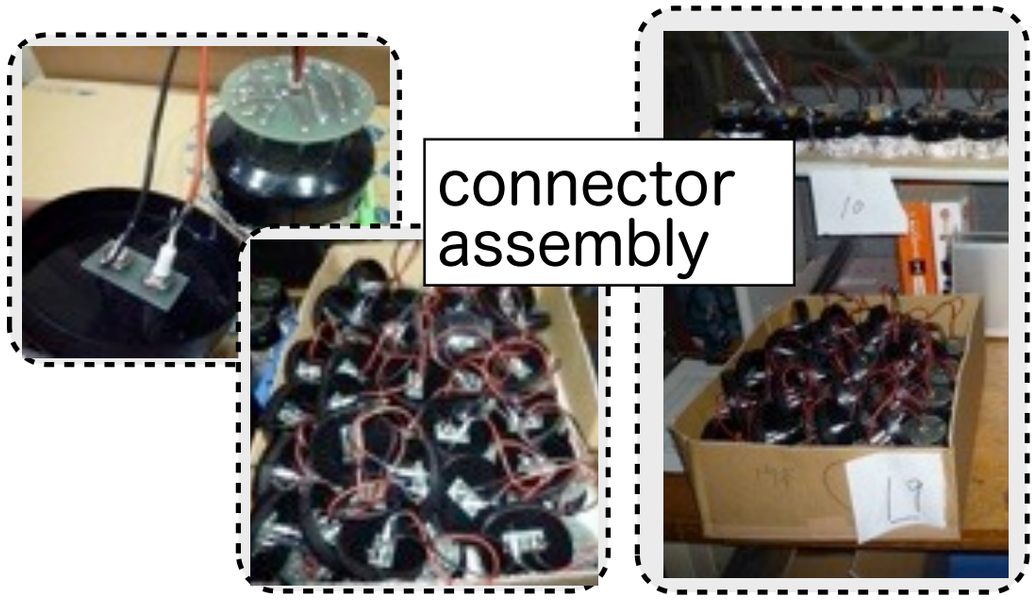


typical event display

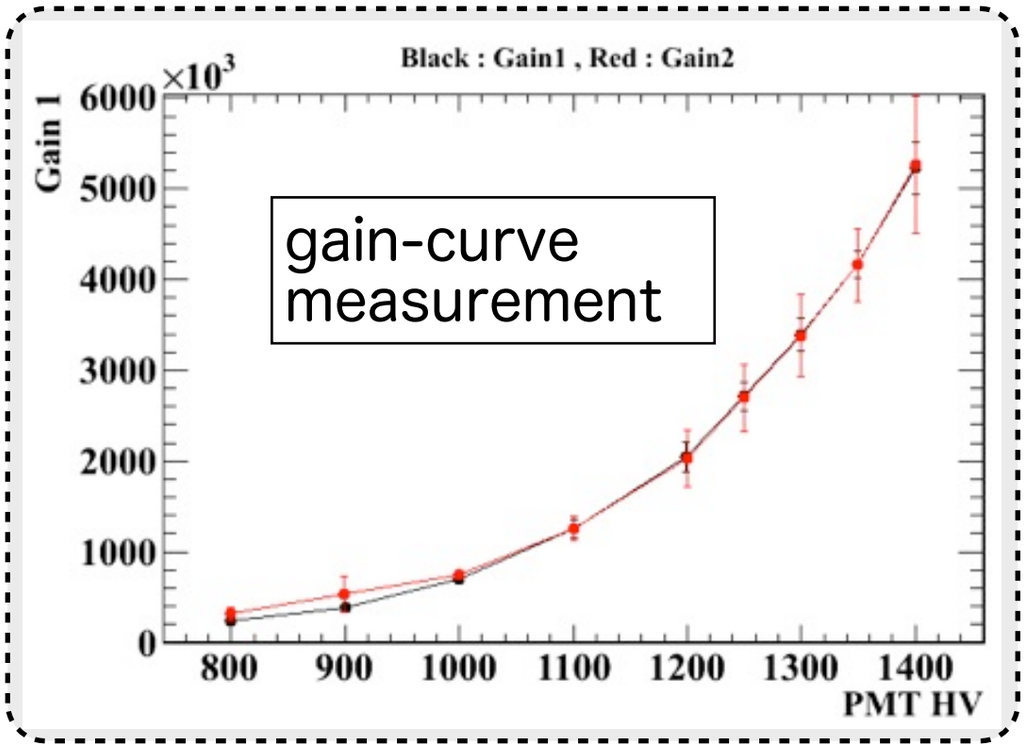
(muon : E=300 MeV)

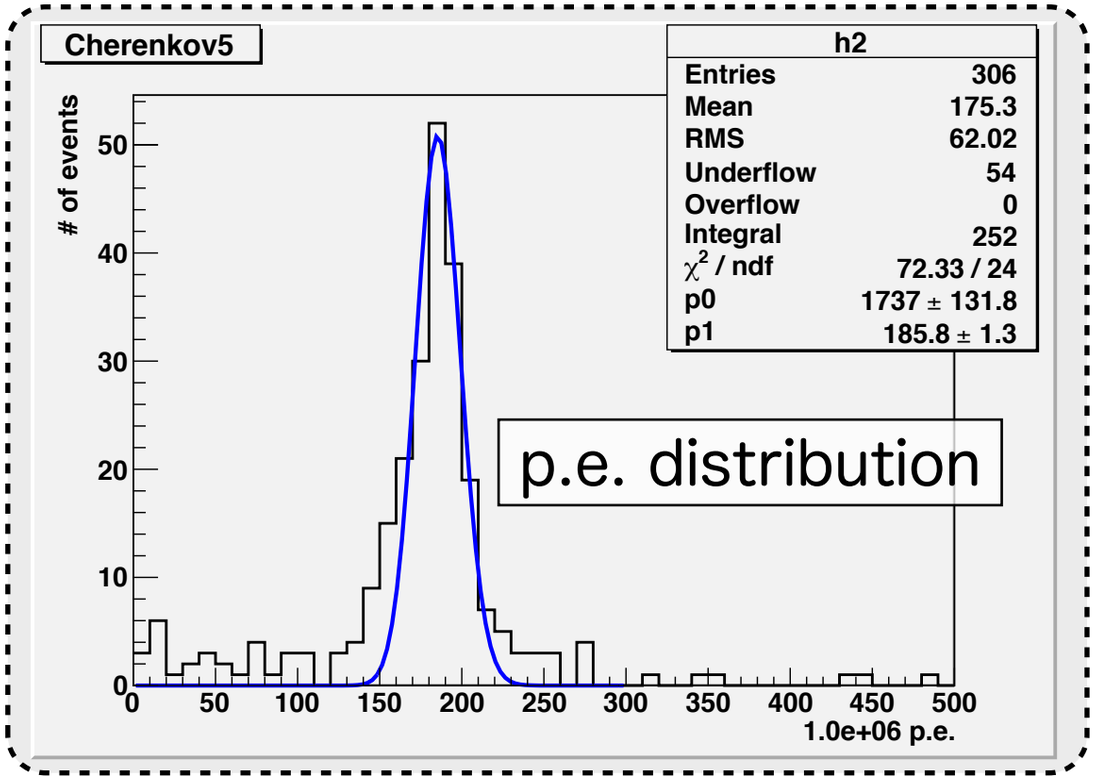
Current status (1)

- Preparation of PMT



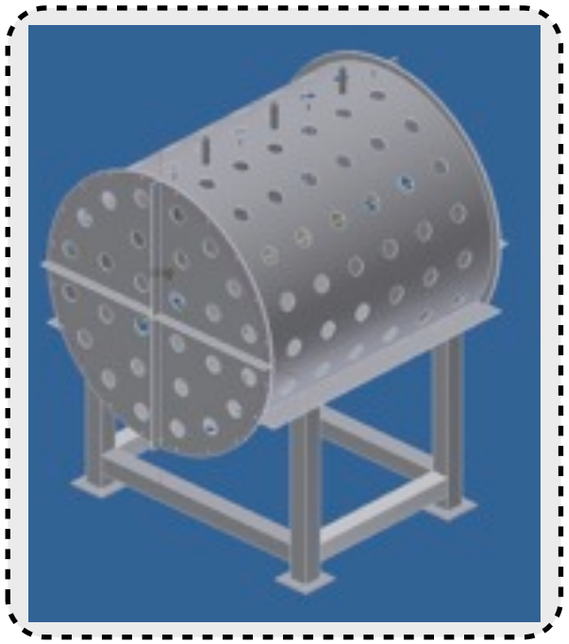
- Measurement of Cherenkov light using cosmic muon

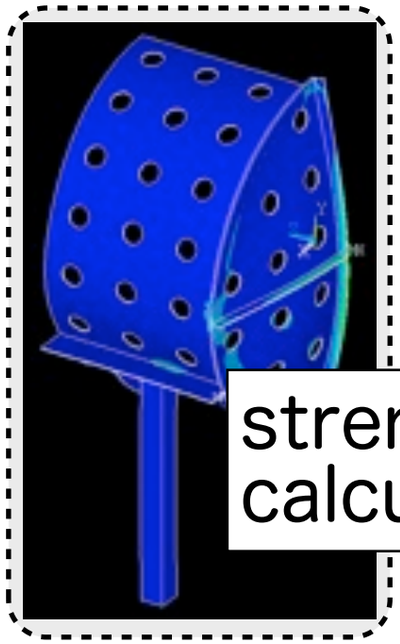




Current status (2)

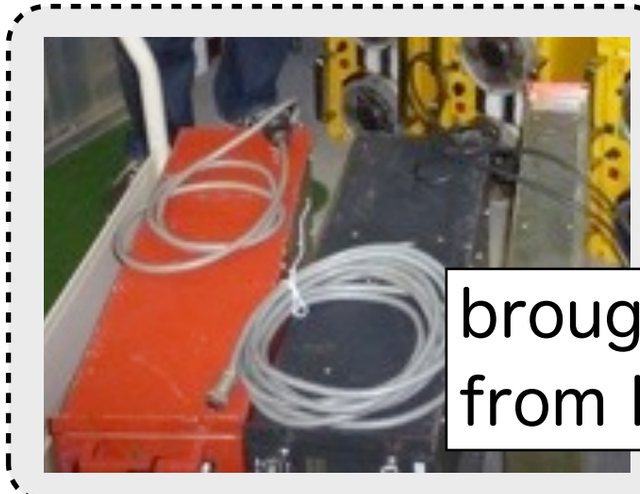
- Design tank



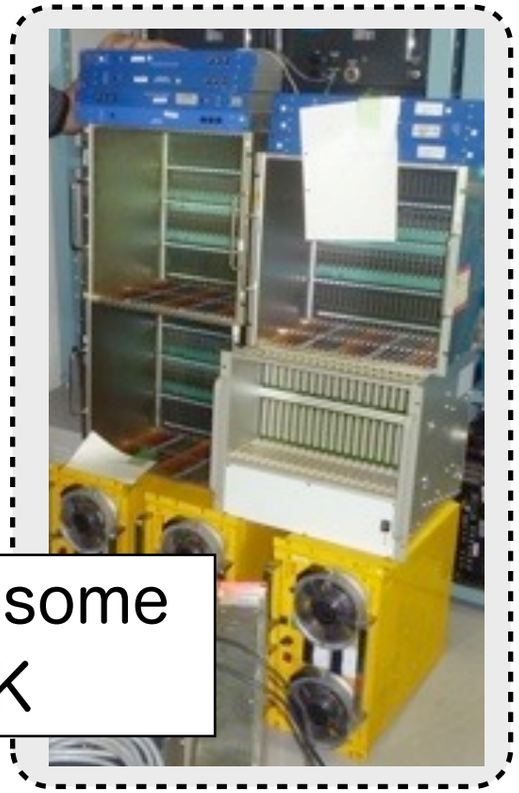


strength calculation

- Preparation of electronics



brought some from KEK



Study with MC simulation

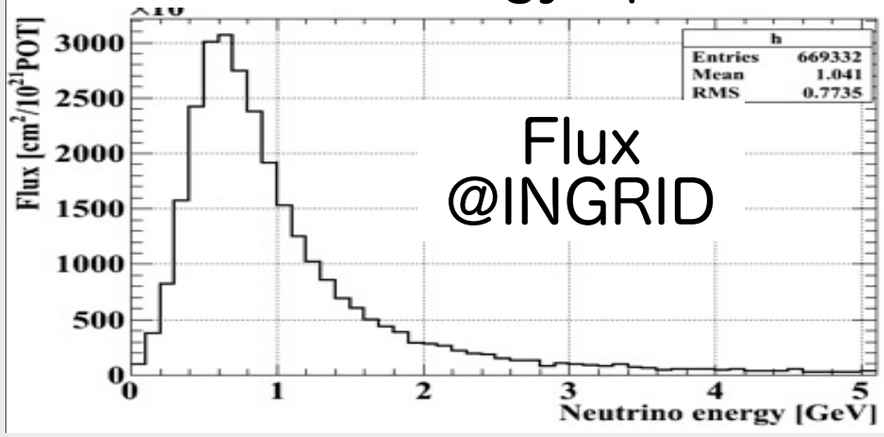
- Signal event MC
- Background event MC

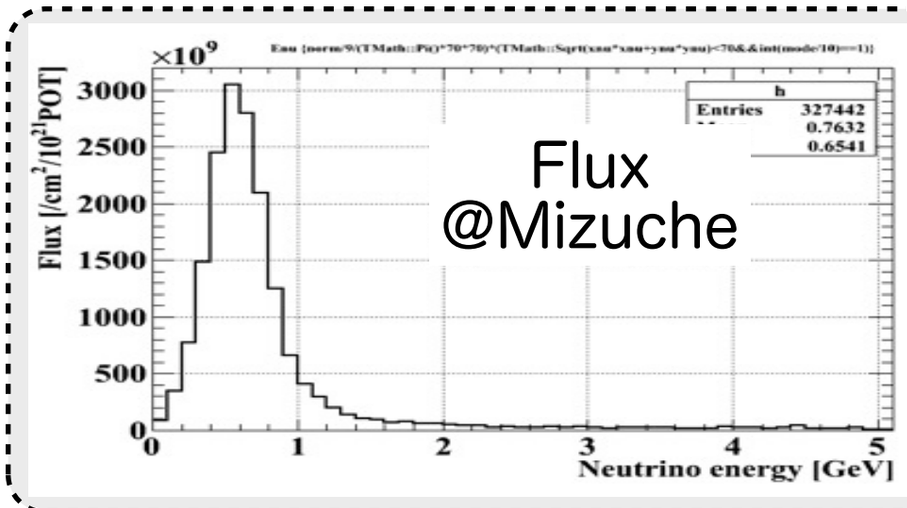
Signal MC (1)

Estimation of neutrino energy @ Mizuche

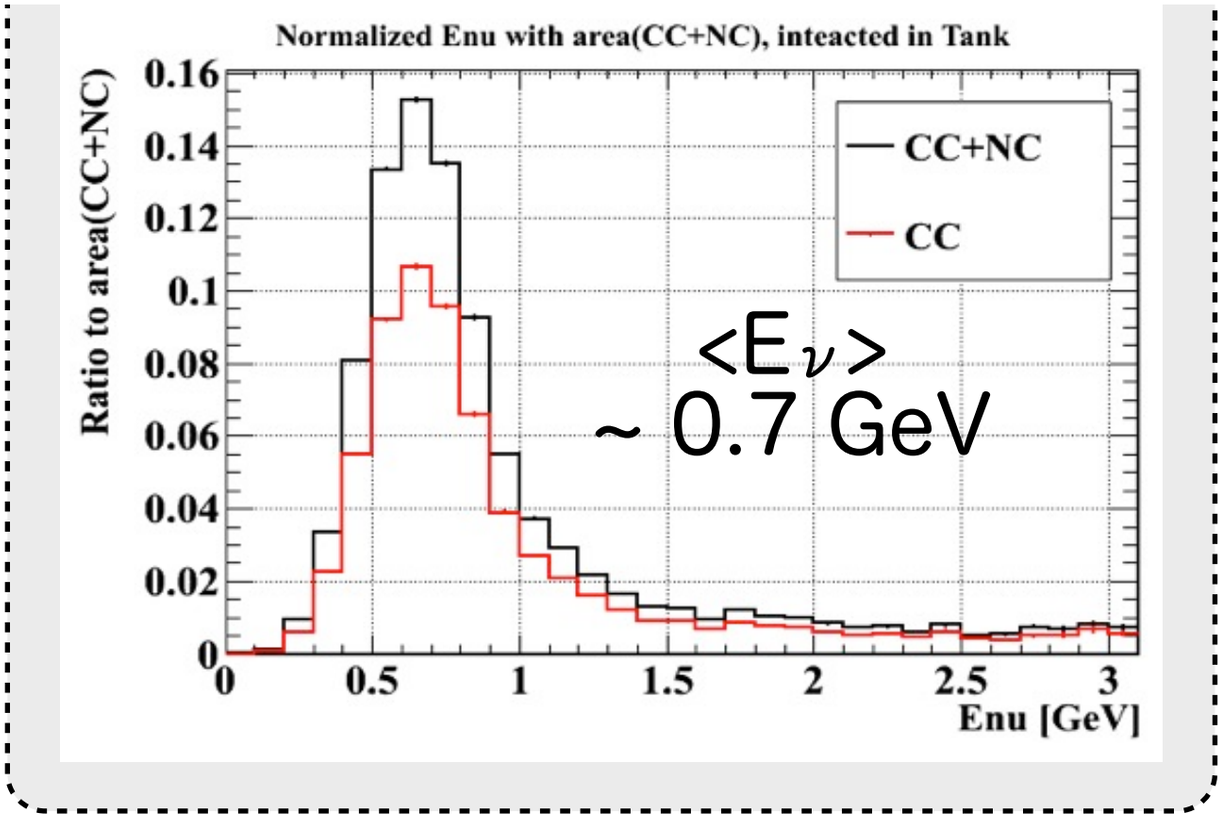
- NEUT (ν +scintillator) → Neutrino energy at INGRID
- Re-weighted the Flux by factor $\Phi_{Mizu}/\Phi_{INGRID}$ → Neutrino energy interacted at Mizuche.

Neutrion energy spectrum





Interacted Neutrino at Mizuche
(area normalized)

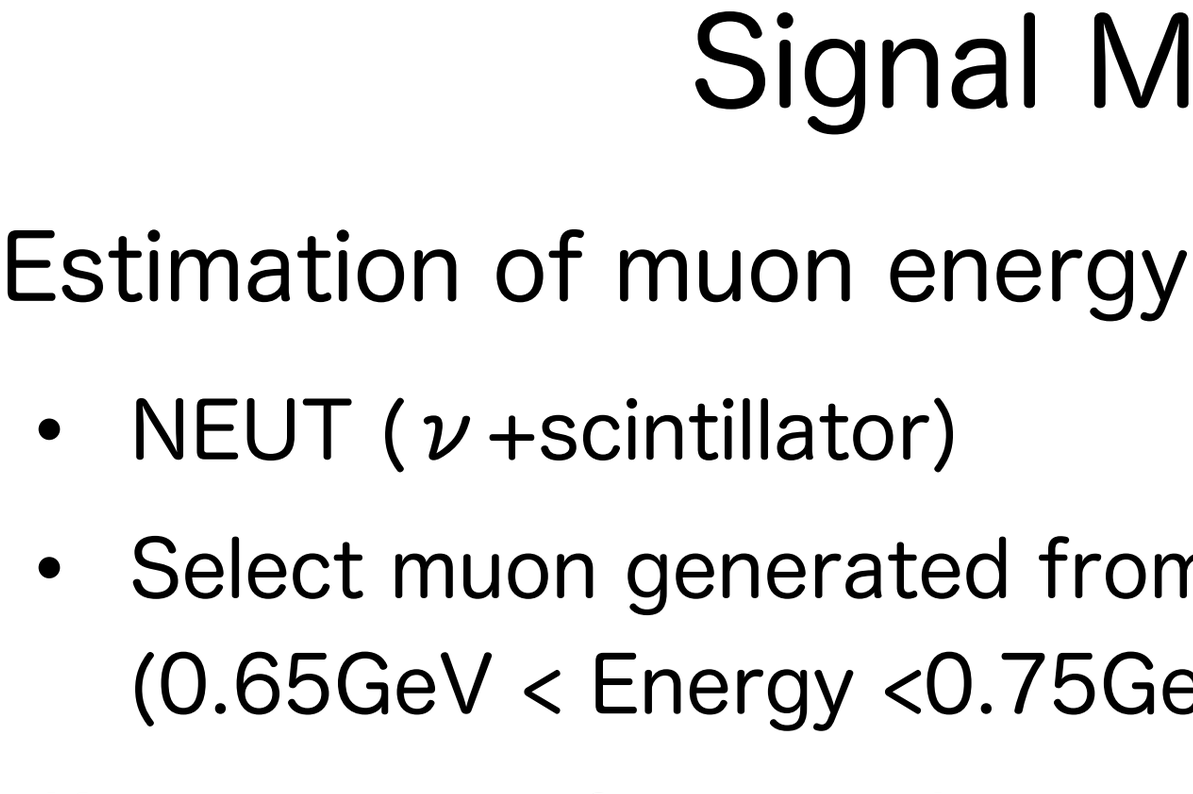


Signal MC (2)

Estimation of muon energy generated at Mizuche

- NEUT (ν +scintillator)
- Select muon generated from neutrino around 0.70GeV (0.65GeV < Energy <0.75GeV)

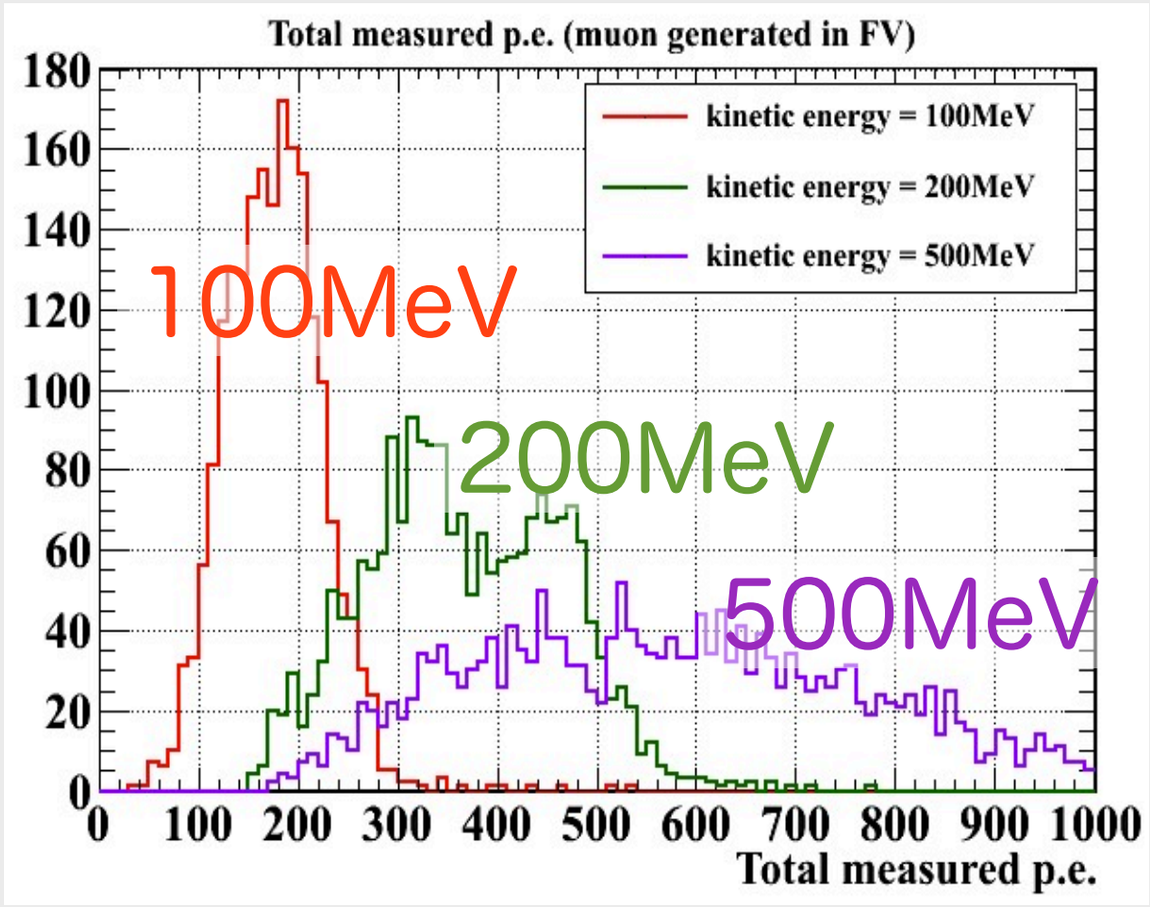
Kinetic energy of generated muon (0.65<Enu<0.75)

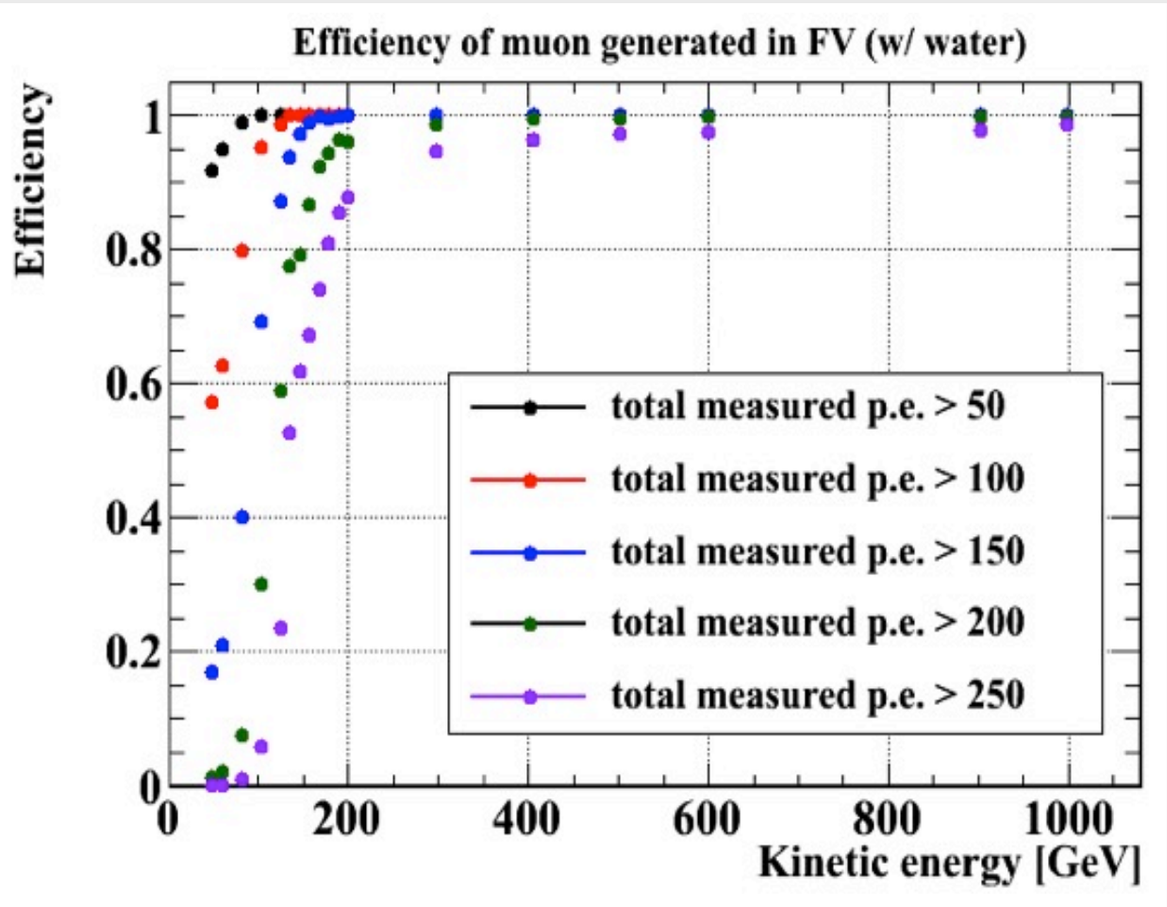


Muon kinetic energy:
0 ~ 600MeV
→ Mean kinetic energy
~ 325MeV

Signal MC (3)

- Estimate the efficiency to muon with Geant4
- Injected muon
  - Kinetic energy : 0 ~ 1 GeV
  - vertex : uniform inside FV
  - direction : uniform



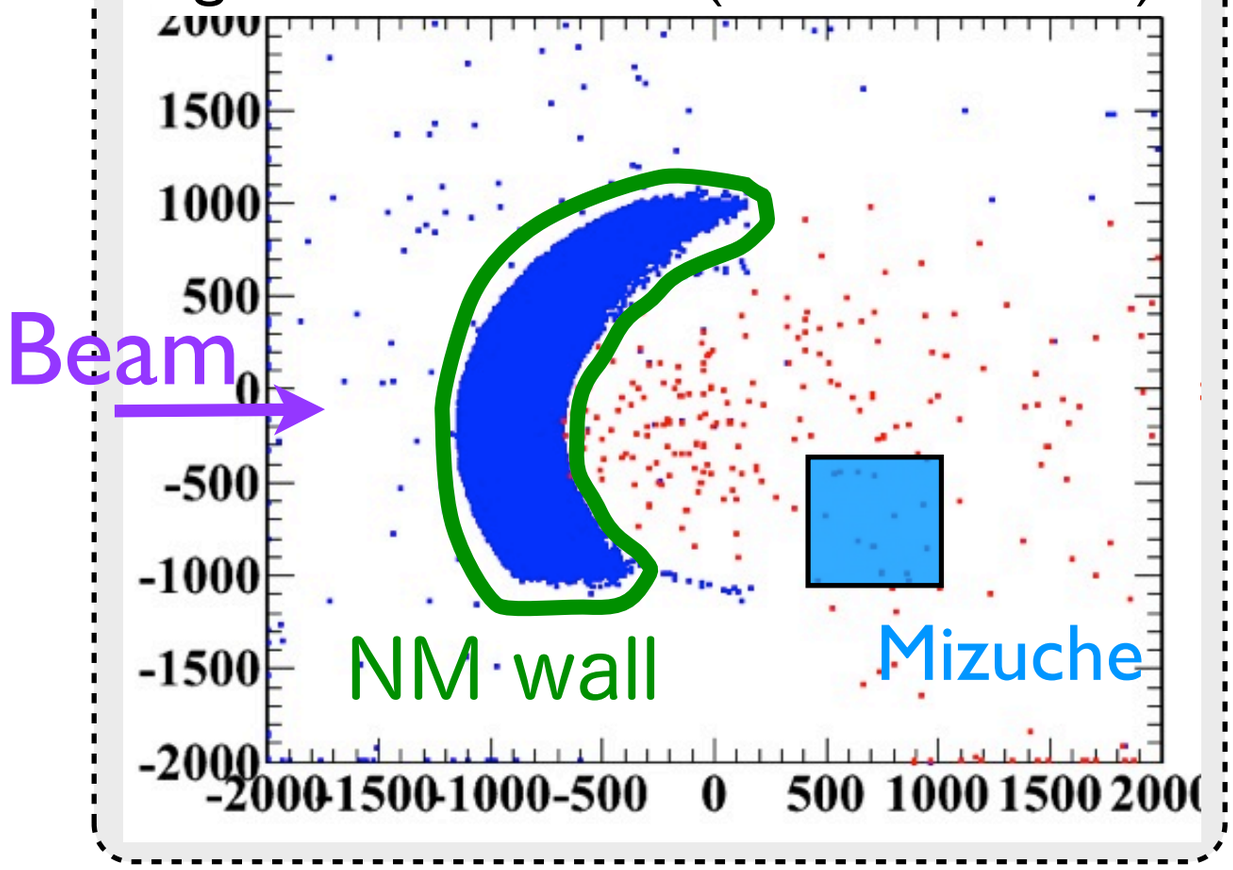


Background MC (1)

Estimation of # of neutron into Mizuche

- NEUT with Neutrino Monitor wall (2360m^3, 5.19kton)
  - interaction in scintillator nucleus

Stop point distribution of neutron generated in Hall (overhead view)



Blue point : generated neutrons

Red point : injected from Hall

# of Neutrino interaction in Hall :

1.4 x 10^9 / Hall / 10^{21}POT

→ # of generated neutron :

2.9 x 10^8 neutrons / 10^{21}POT

→ # of inject from Hall :

3.9 x 10^6 neutrons / 10^{21}POT

Estimated # of neutron inject into Mizuche :

6.6 x 10^{-4} neutrons / spill

(Normalized by 100kW ~ 4.4×10^{13}POT/spill)

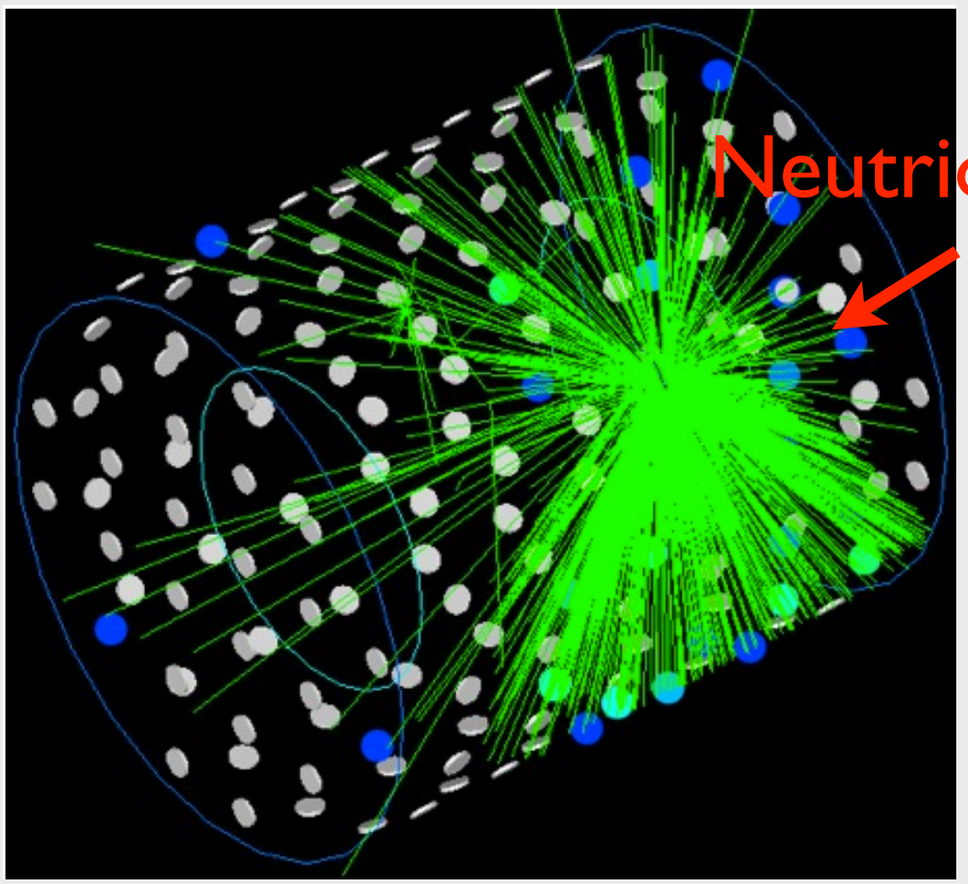
Background MC (2)

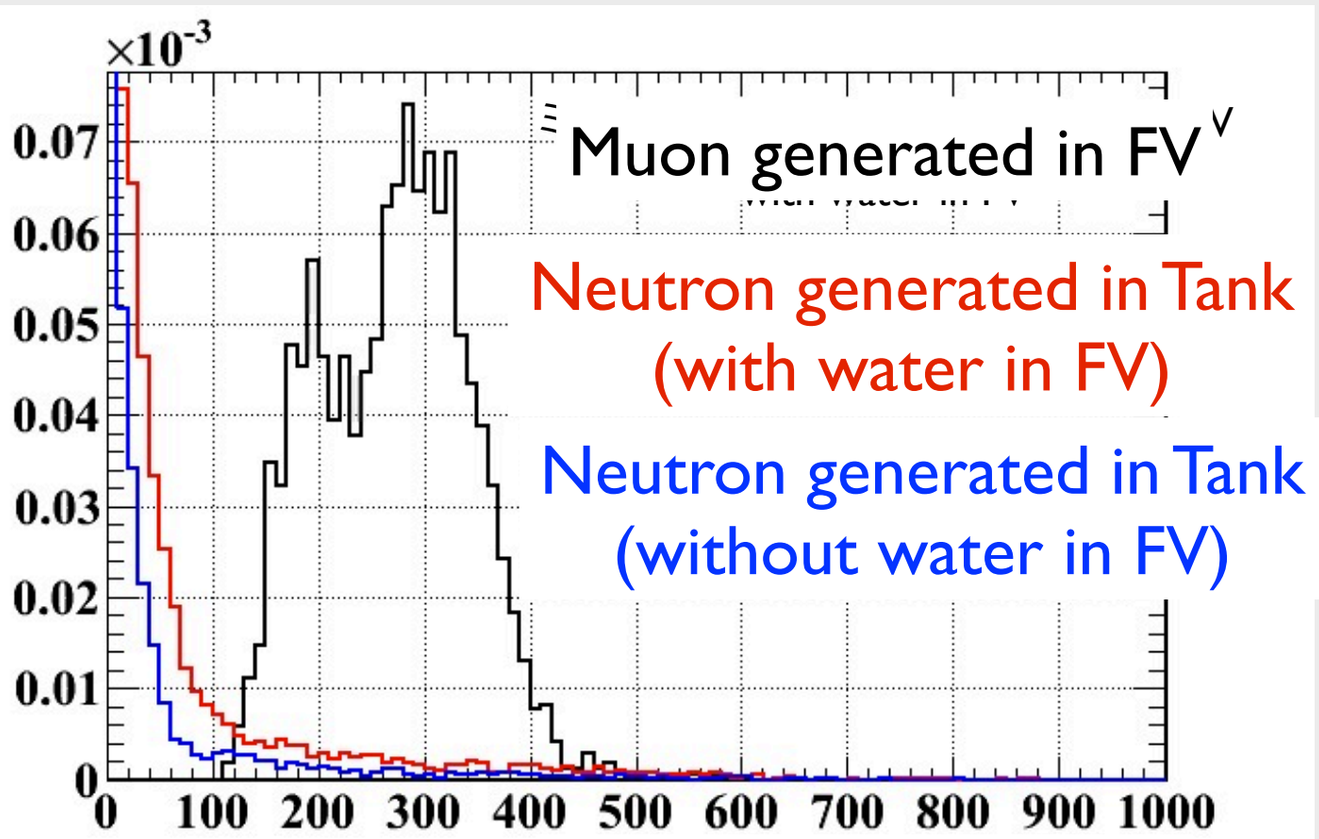
Estimate the event of neutron back ground

- Use Geant4
- Injected neutron
  - Kinetic energy ~ 400 MeV
  - Normalization ~ 6.6×10^{-4} neutrons/spill

cf) muon generated in FV

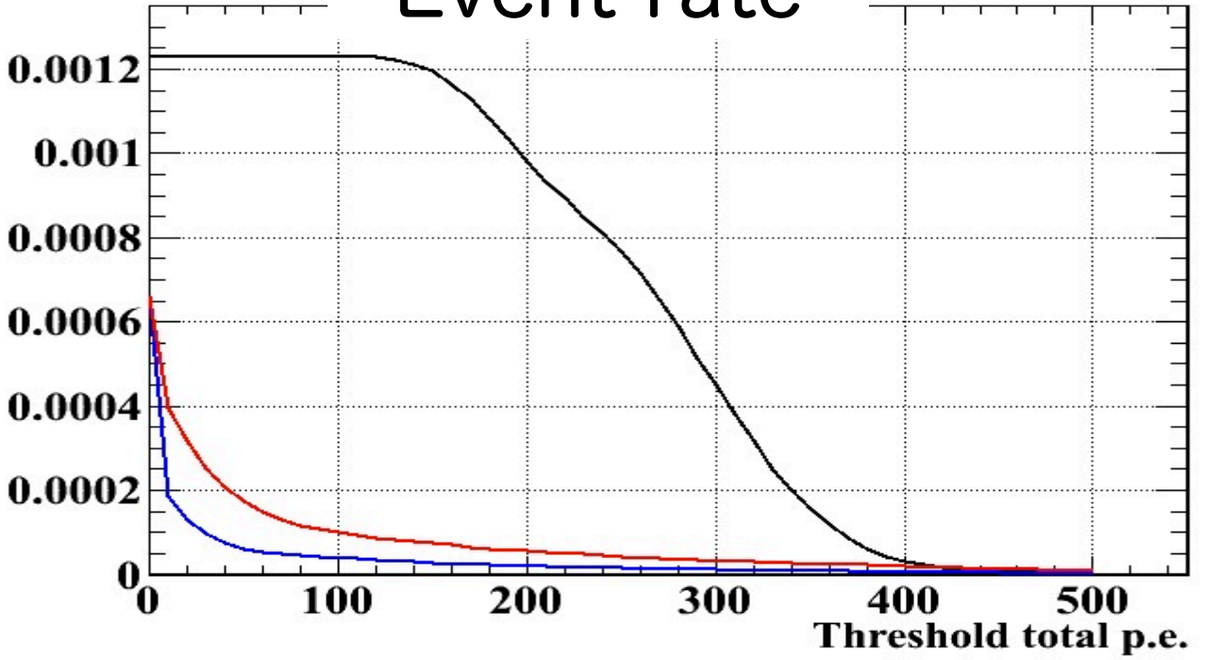
- Kinetic energy : 150 MeV
- Normalization : 1.23×10^{-3} particles/spill in FV ~ # of CC int./spill in FV

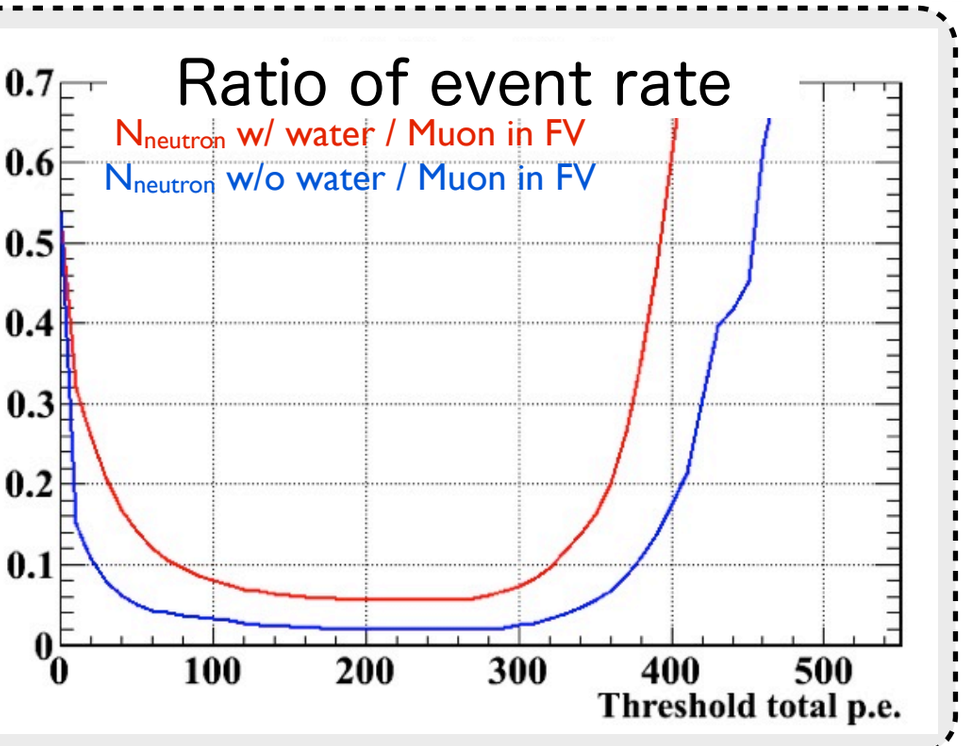




Background MC (3)

Comparison between # of neutron and muon after event cut





Muons generated in FV
(Kinetic energy = 150 MeV)

Neutron with FV water
($0.35 < E_{kin} < 0.45$ GeV)

Neutron w/o FV water
($0.35 < E_{kin} < 0.45$ GeV)

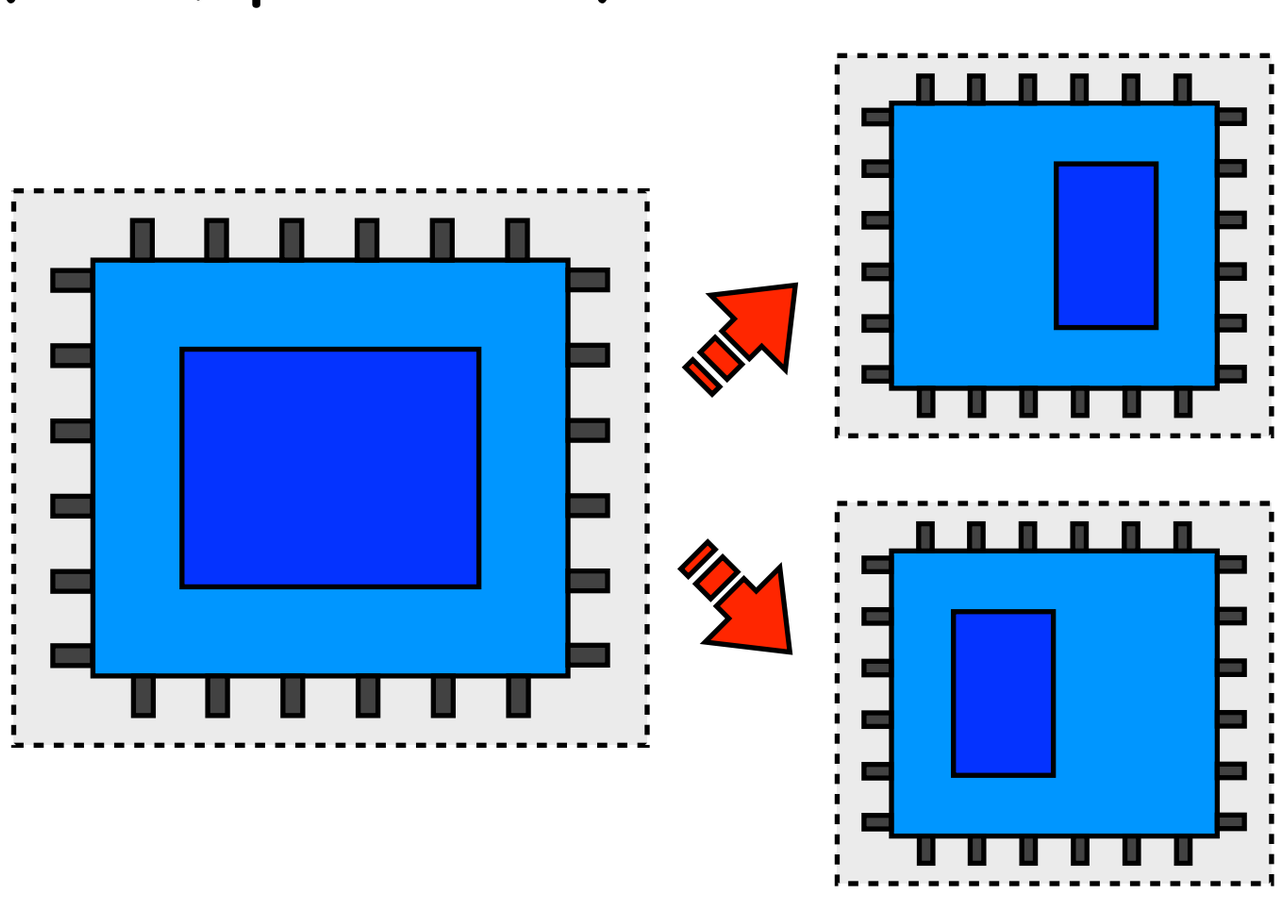
- Event selection : total p.e. > 200 p.e.
  - w/ water in FV : $N_n^{inTank} / N_{cc}^{inFV}$ ~6%
  - w/o water in FV: $N_n^{inTank} / N_{cc}^{inFV}$~2%

➡Remaining : **$N_n^{inTank} / N_{cc}^{inFV}$~4%**

How to ecaluate the systematic error ?

→ one possibility

- Change the size and position of FV
  - ⇒ see correlation btw # of ν interaction and FV(size, position)

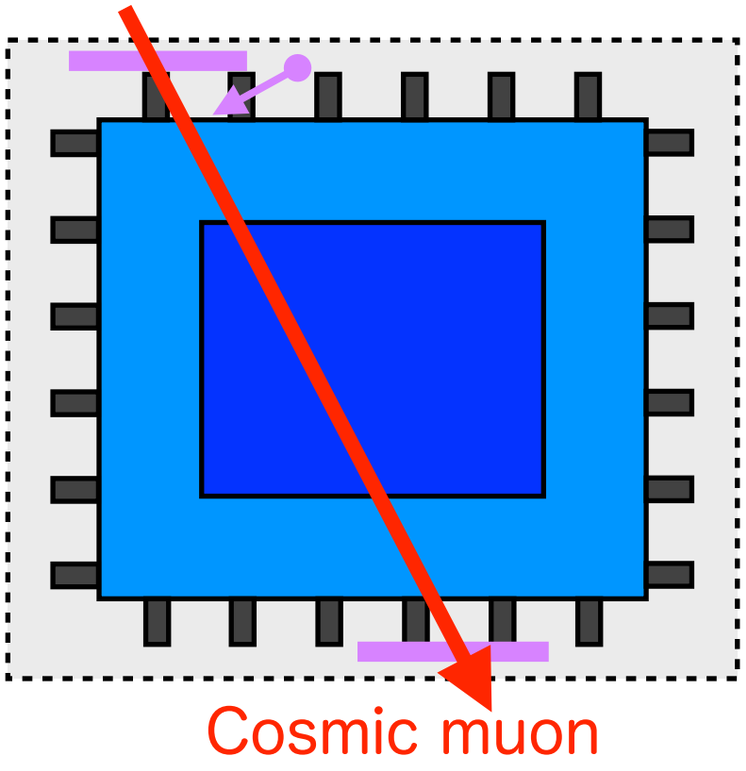


Detector calibration

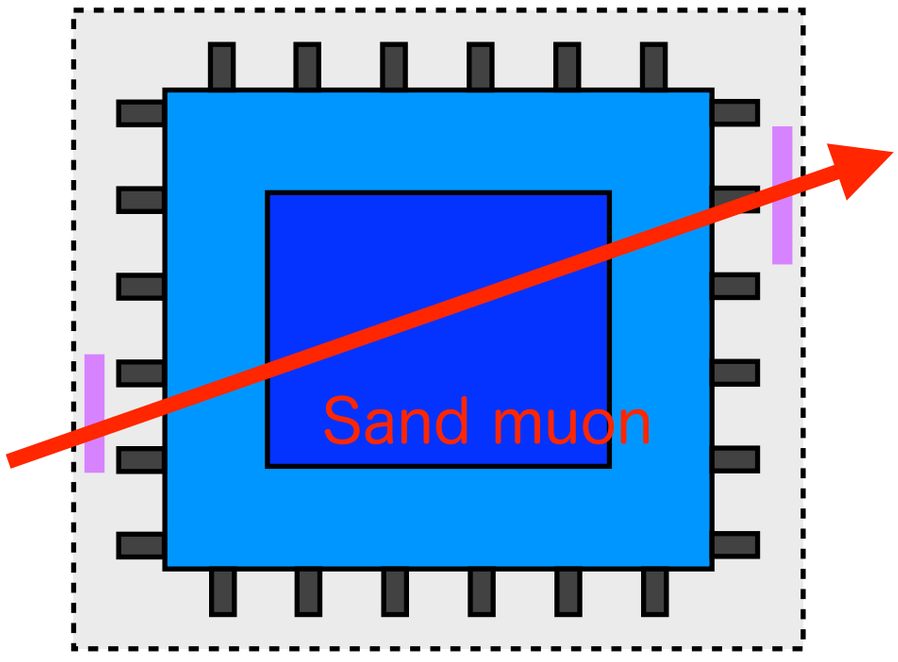
Consider three calibration source

Cosmic muon

trigger scintillator

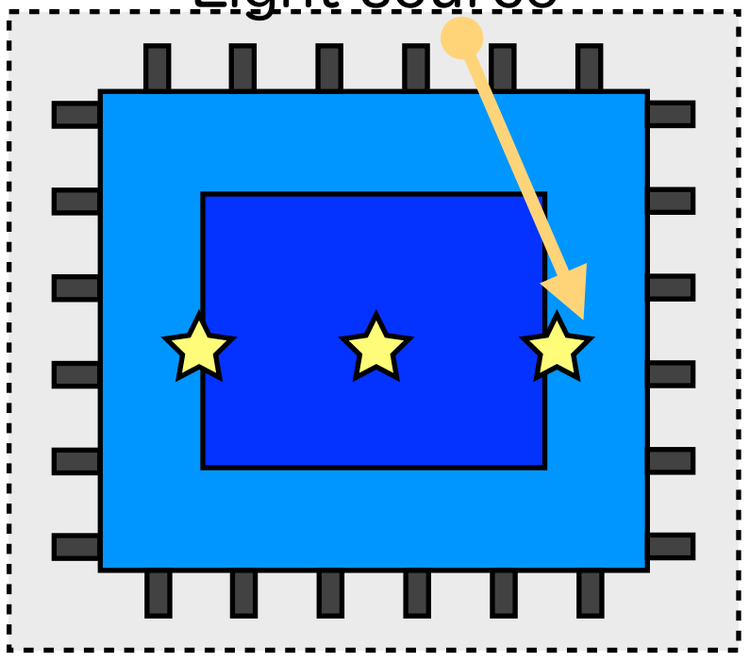


Sand muon



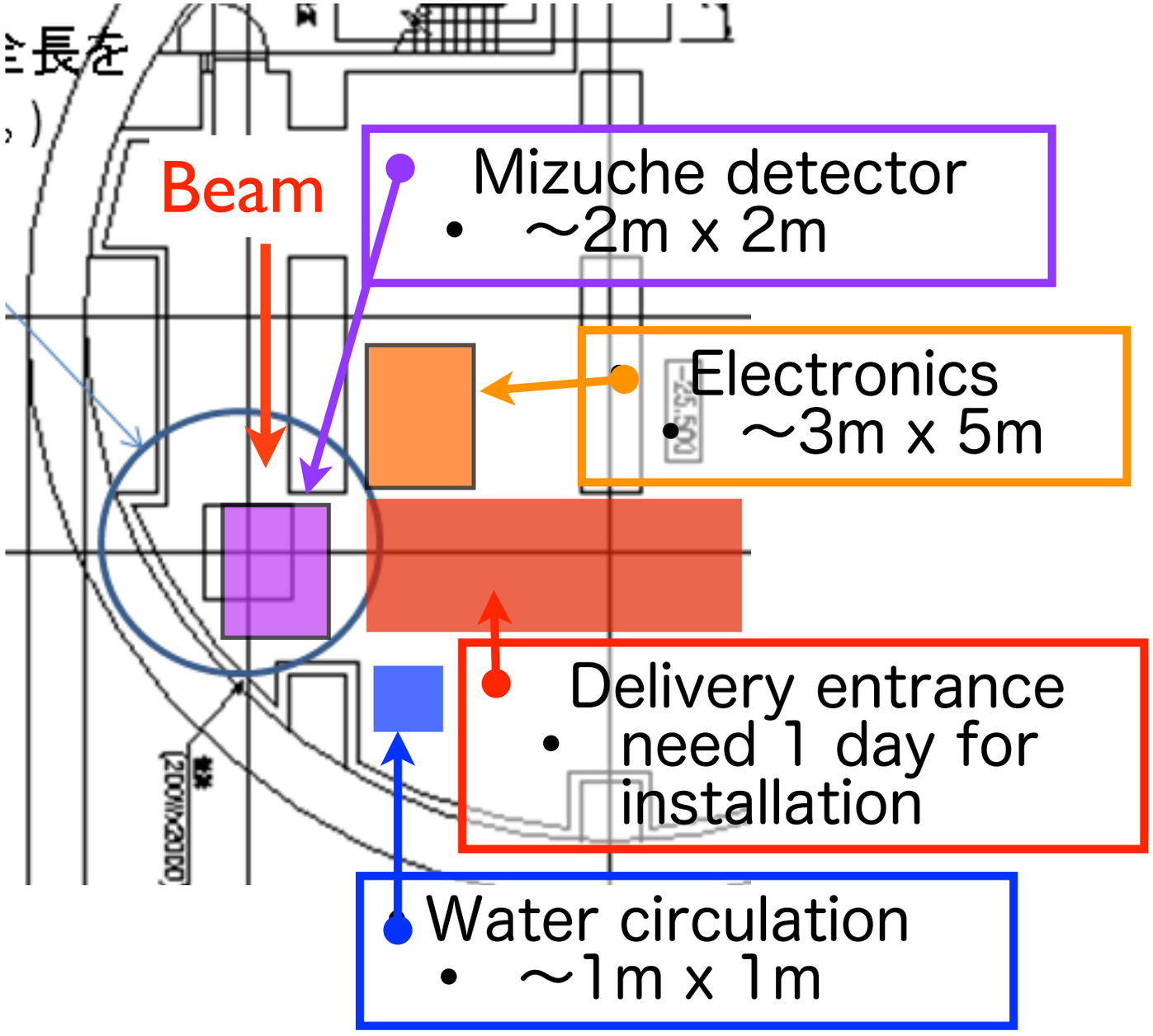
External light source

Light source



Request for support

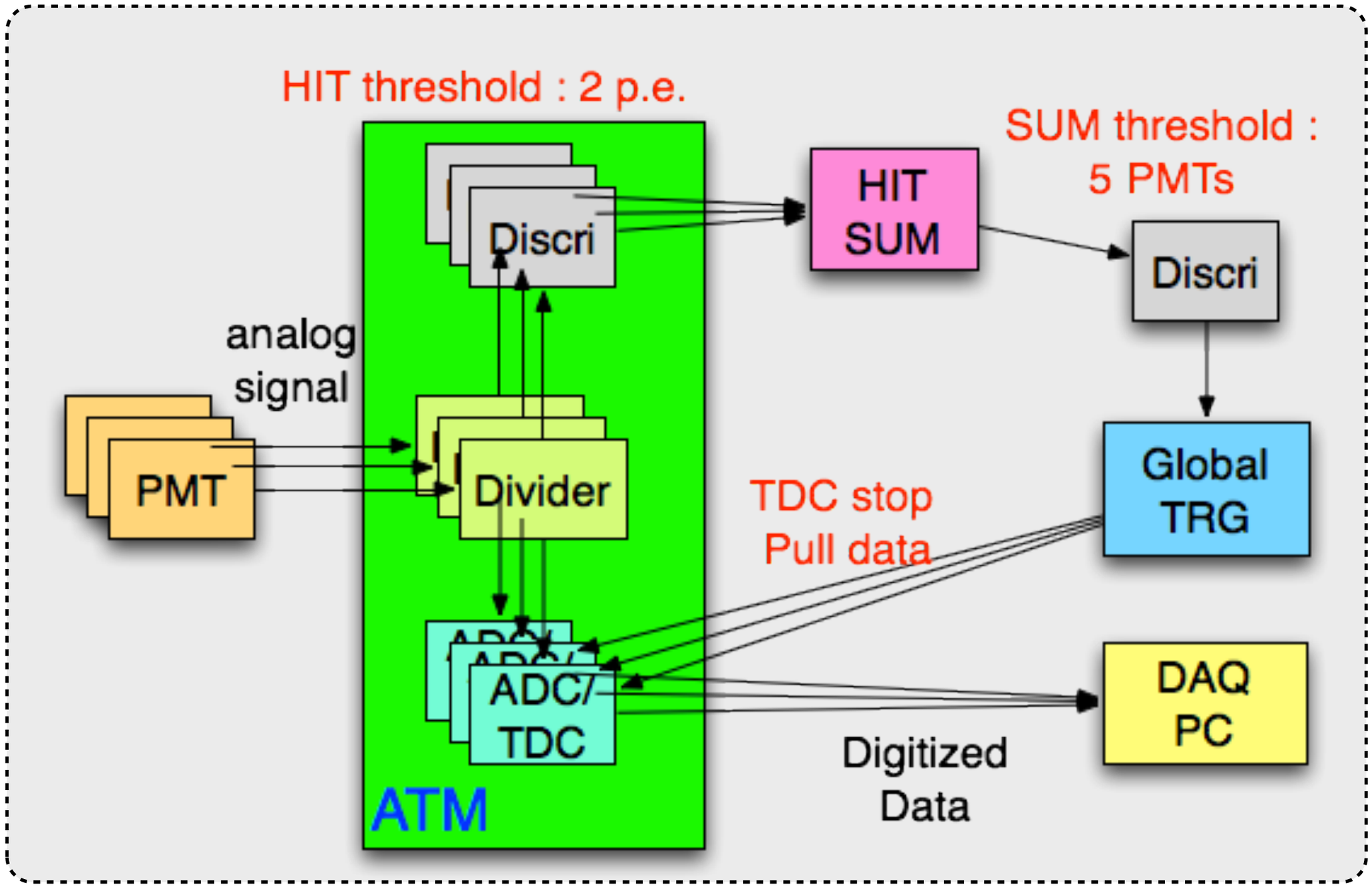
- Place
  - Neutrino Monitor building
  - B2 floor



- Power supply
  - 10kW
- DAQ in local network
  - JLAN for data transportation
- Beam timing
  - Existing optical cable from NU1

Backups

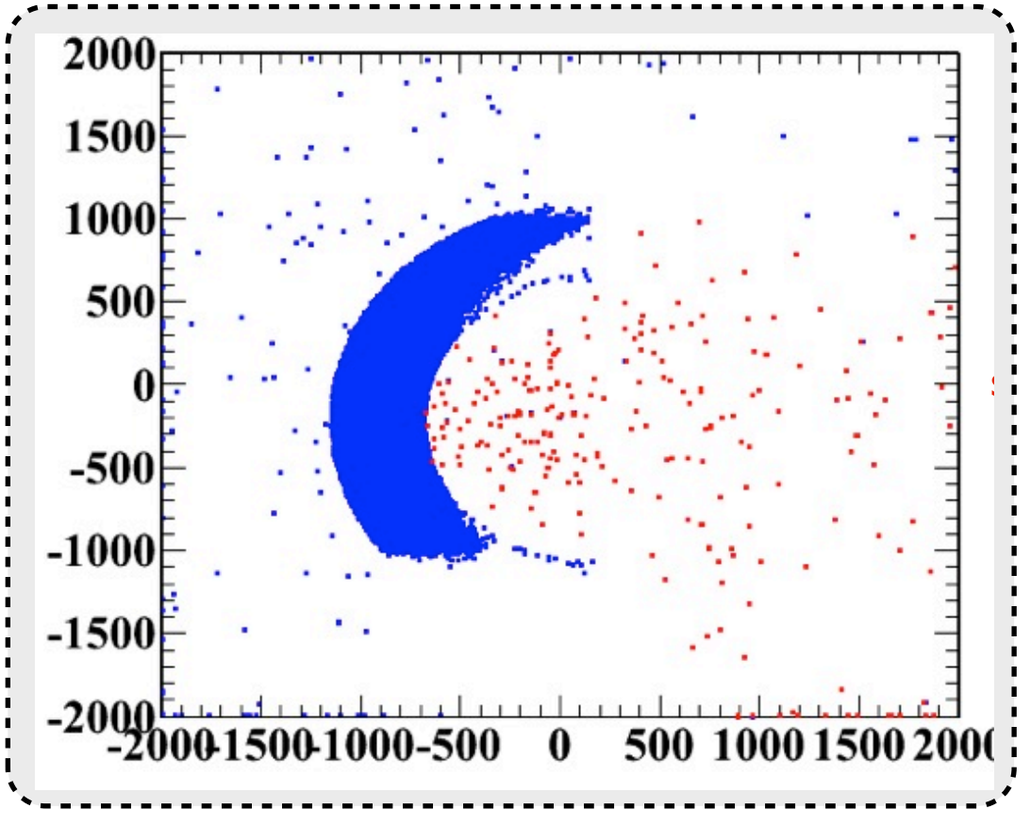
DAQ Logic


HIT threshold : 2 p.e.
SUM threshold :
5 PMTs
HIT
SUM
Discri
Discri
analog
signal
PMT
Divider
Global
TRG
TDC stop
Pull data
ADC/
TDC
DAQ
PC
Digitized
Data
ATM

Background

of neutron inject to Mizuche tank

- MC setting
  - INGRID NEUT



Geometry of NM Hall
- 2360 m3
- 5192 ton
- 3.13e+33 nucleon

# of Neutrino interaction
- with Hall : 1.4 x 10^{9} / Hall / 10^{21}spill

# of stopped point of neutron
- all : 2.9 x 10^{8} / Hall / 10^{21}spill
- selected : 3.9 x 10^{6} / Hall / 10^{21}spill

# of neutron inject into Mizuche
- 1.5 x 10^{4} / 10^{21}POT

@100kW ～ 4.4 x 10^{13} POT/spill
- 6.6 x 10^{-4} / spill