WAGASCI update
~MC simulation for dMRD with magnet~

Naruhiro CHIKUMA
The University of Tokyo
竹馬 匠泰
東京大学

Baby MIND update meeting

Wednesday, 29th July 2015

Physics Motivation

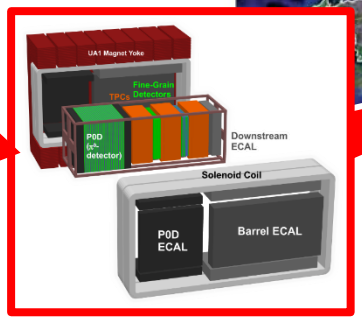
Far Detector (SK)
- Target : **Water(H_2O)**
- Acceptance : **4π**

Super-Kamiokande
(ICRR, Univ. Tokyo)

T2K

J-PARC Main Ring
(KEK-JAEA, Tokai)

Near Detector (ND)
- Target : **plastic(CH)**
- Acceptance : **forward scattering**



ND280 (Tokai)

The differences in target & acceptance b/w SK and ND.

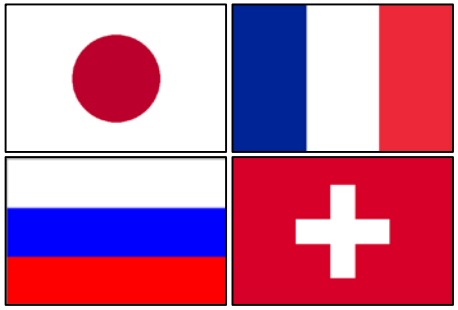
- ✓ ν_μ beam produced at J-PARC.
- ✓ Two modes of **neutrino oscillation**.
  - ν_e appearance : $\nu_\mu \rightarrow \nu_e$
  - ν_μ disappearance : $\nu_\mu \rightarrow \nu_{not\ \mu}$

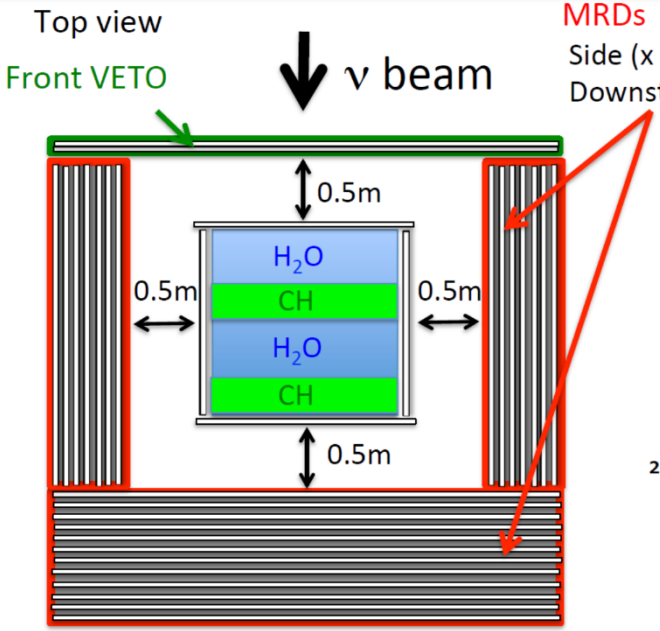
Systematic Error Sources	ν_e	ν_μ
ν flux & cross section (constrained by ND280)	3.2%	2.7%
ν flux & cross section (not constrained by ND280)	**4.7%**	**5.0%**
Super-K etc.	3.7%	5.0%
Total	6.8%	7.7%

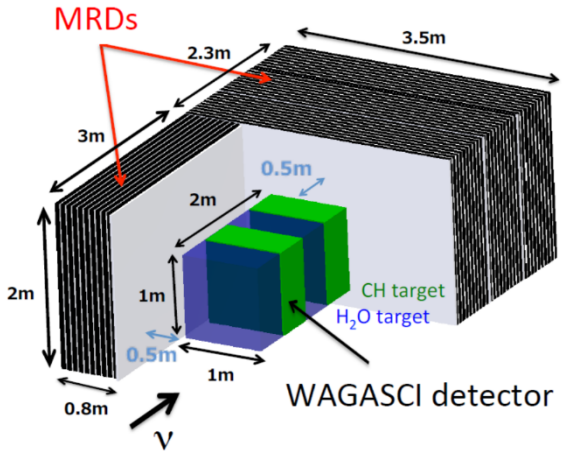
The measurement of the H_2O/CH cross section ratio with large acceptance.

WAGASCI experiment.

WAGASCI experiment







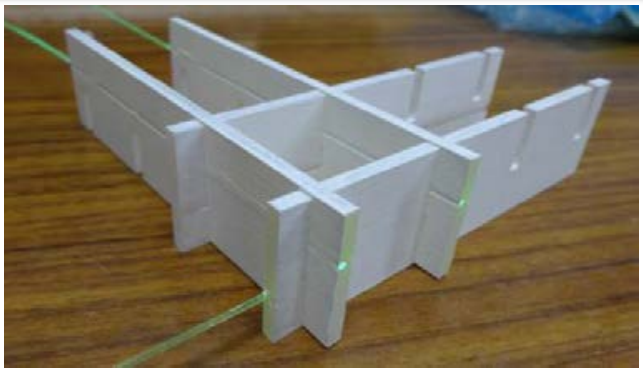
- Goal
  1. Measure the cross section ratio of charged current neutrino interaction on nucleus between H_2O/CH with 3% accuracy.
  2. Measure the differential cross section(T_μ, θ_μ) with large phase space acceptance.
- Location
  - J-Parc neutrino near detector hall. (at B2 floor)
  - Use the **similar off-axis angle to T2K ND280 and SK**. ($\sim 1.6^\circ$)
- Design
  - Little difference in flux and detection efficiency between H2O/CH targets.
    ⇒ Taking cross section ratio **cancels systematic error in beam flux**.
  - Background is rejected by time information and veto planes.

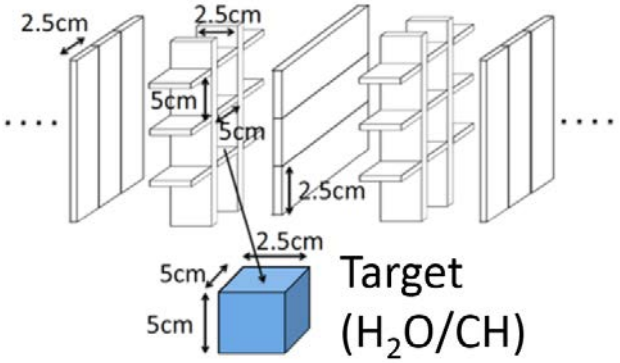
WAGASCI Detector

- Target

  H_2O : *1ton*, CH : *1ton.*

- 3D grid-like scintillator detector.
  - ✓ Use **3-mm-thick plastic scintillator with slits**.
  - ✓ Each cell of 3D-grid is filled with target(H_2O/CH).





○*Merit*

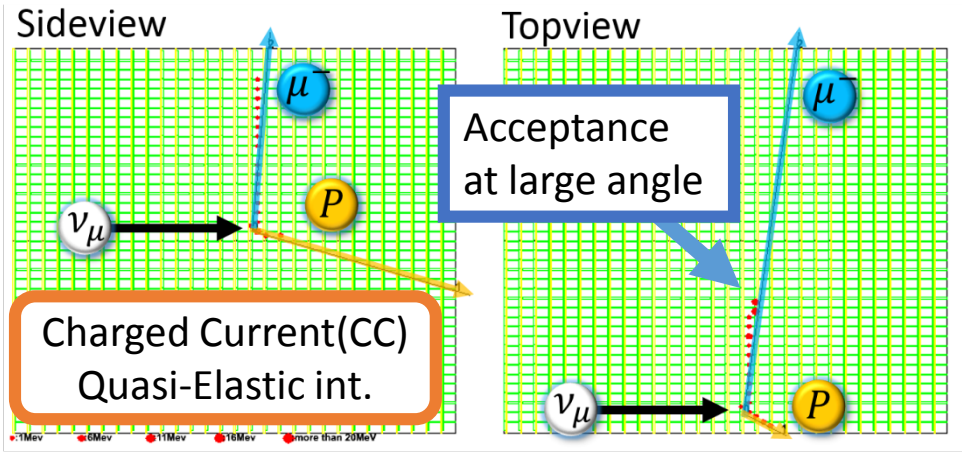
1. **80% target region** in the detector.
   ⇒ Reduce the ν interaction on scintillators.
2. Almost **4π acceptance**.
   ⇒ Improve neutrino interaction model.

- Expected Performance

	CC	NC	Ext. BG	All
Events	**31466**	1608	1832	43440
Ratio	**90.1%**	4.7%	5.2%	100%

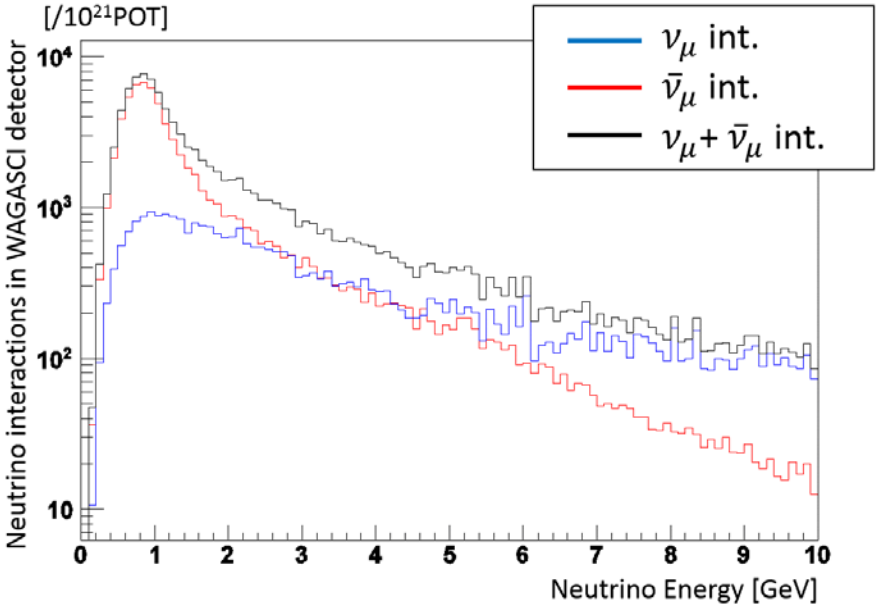
*Expected number of event with 10^{21} POT.

- **High Statistics.**
- **Low Background.**
- **High purity of CC interaction.**



Motivation to Install Magnetized Module

- In anti-neutrino beam mode, large contamination of ν_μ BG.
  - All CC interactions in WAGSCI detector(2ton target in total.)



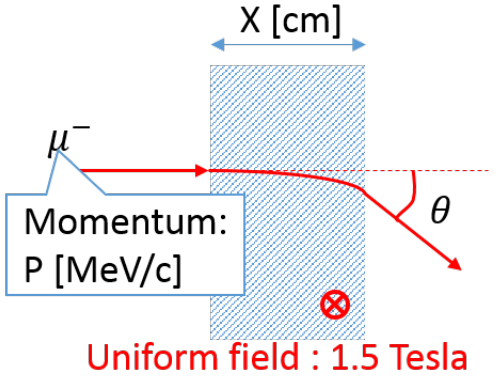
- Baby-MIND
  - Developed by Geneva Univ. and CERN.
  - Some components will be optimized to WAGACI.

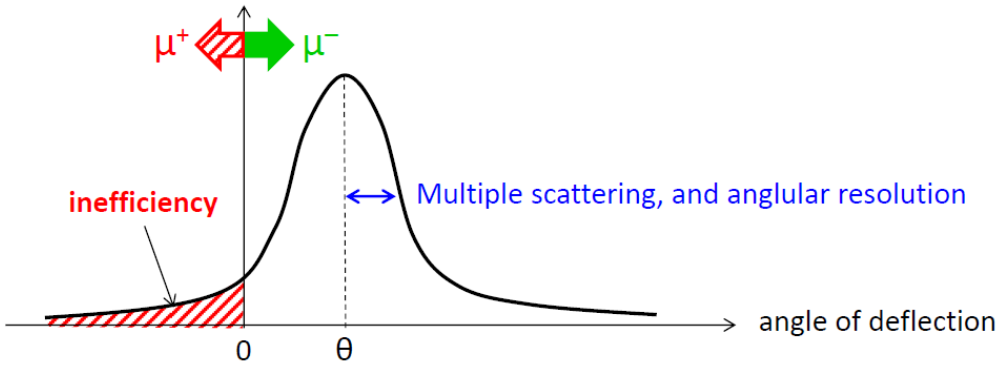
	(up to 10 GeV)			(up to 2 GeV)		
	$\bar{\nu}_\mu$	ν_μ	total	$\bar{\nu}_\mu$	ν_μ	total
The number of interactions	67993	29865	97858	53529	12367	65896
	69.5%	30.5%	100%	81.2%	18.8%	100%

Table 1 The number of interactions expected at the place for the WAGASCI detector to be placed.

Approach

- Identify the charge of particles by magnetic field.

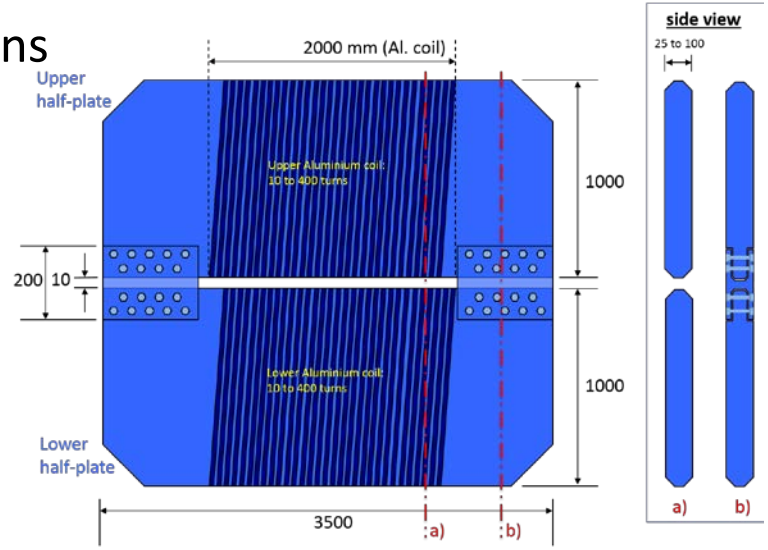


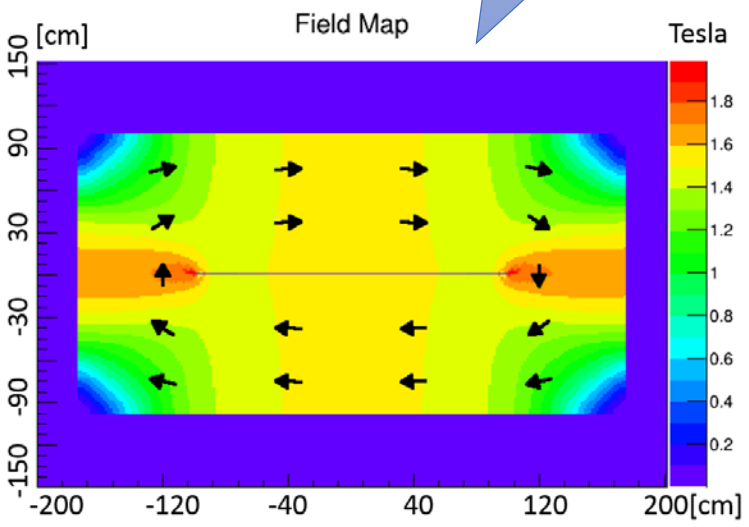


- Magnetized module
  - Fe plate with Al coils.
    - ✓ ~a few A. electric current
    - ✓ ~400 turns
    - ✓ ~1.0kW
    - ✓ 1.5 Tesla

Some options how to configure the module

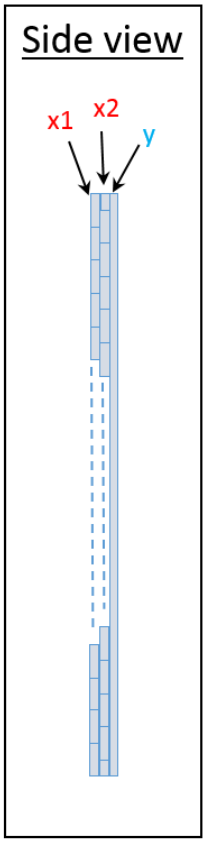
Now being updated

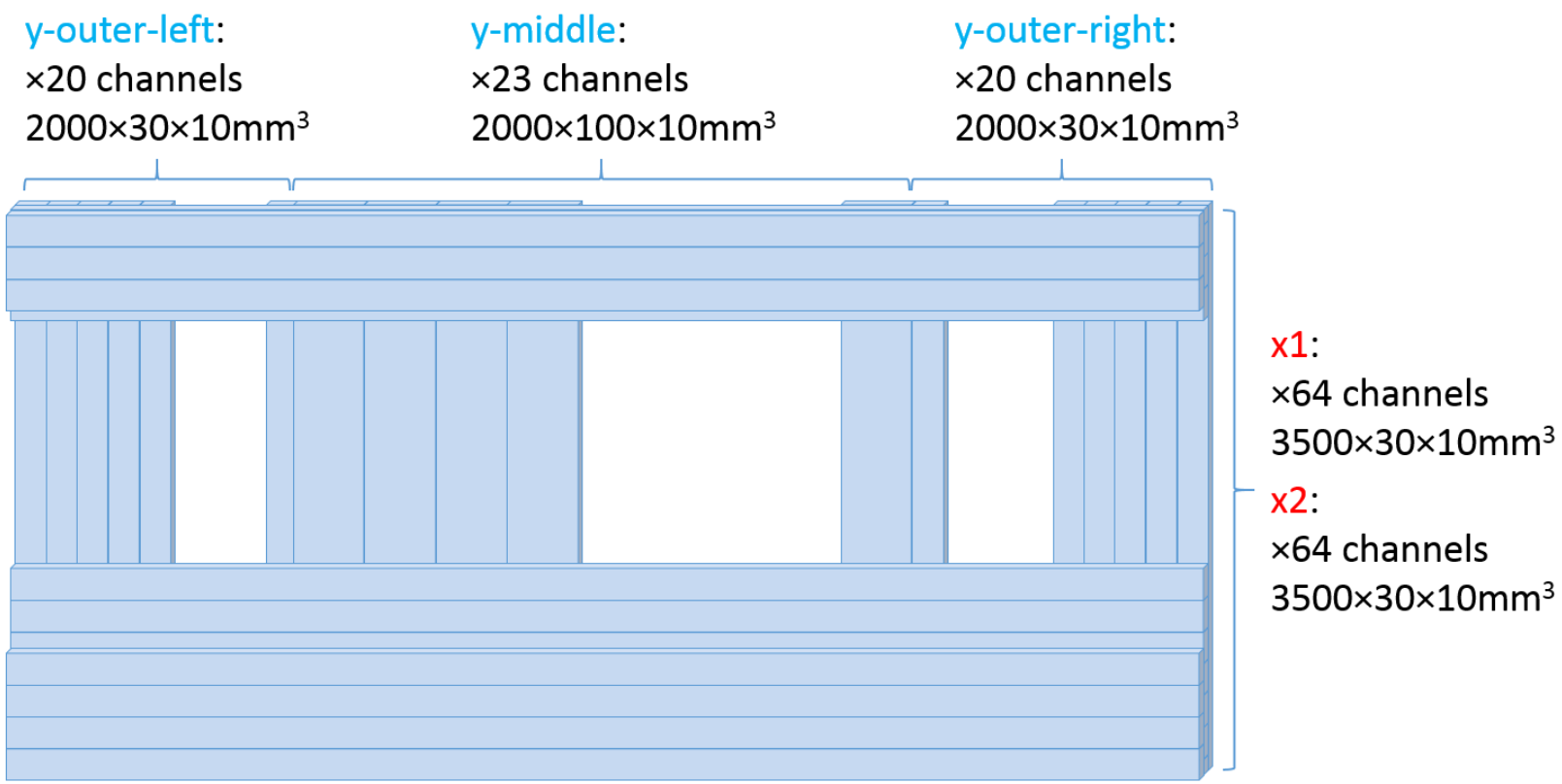




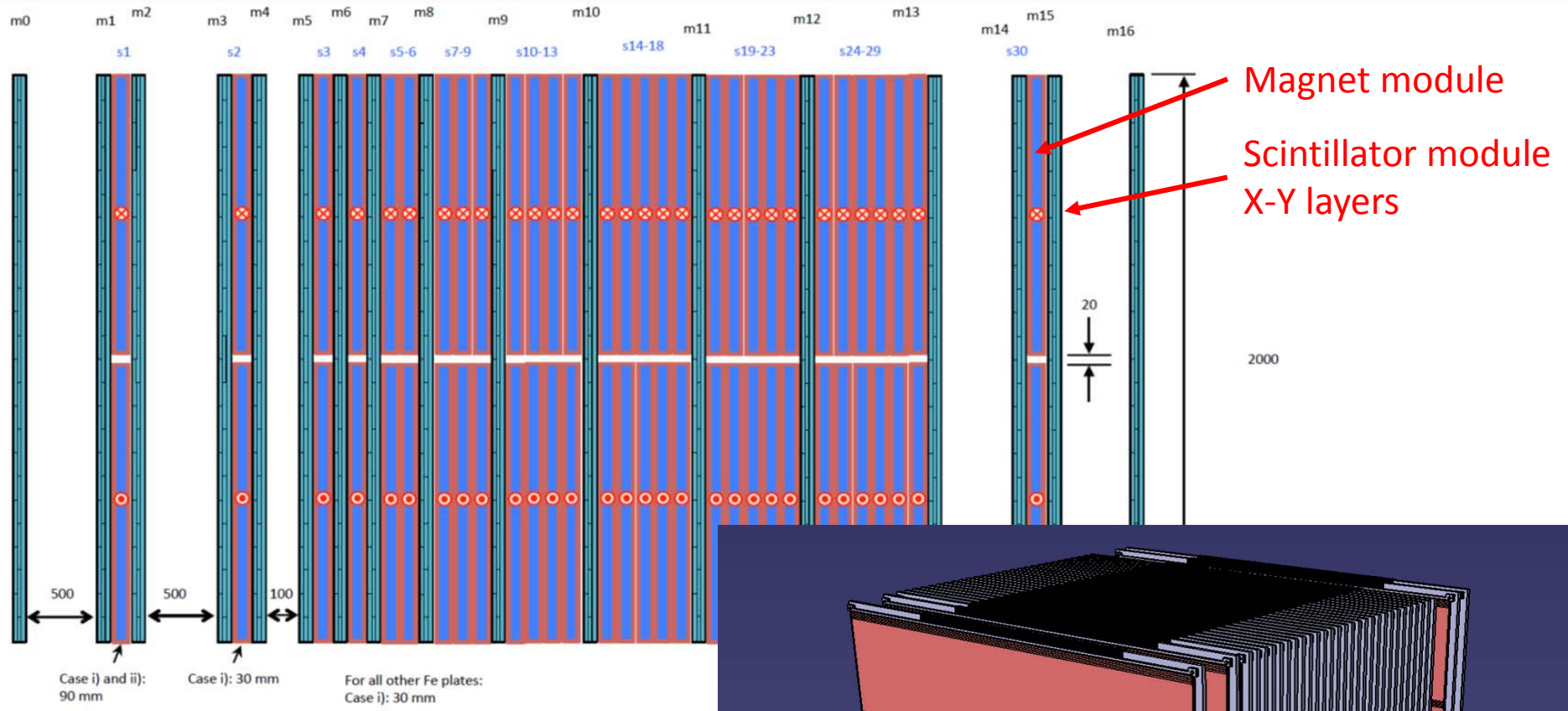
Scintillator Module

- Tentative configuration
  - Could be optimized

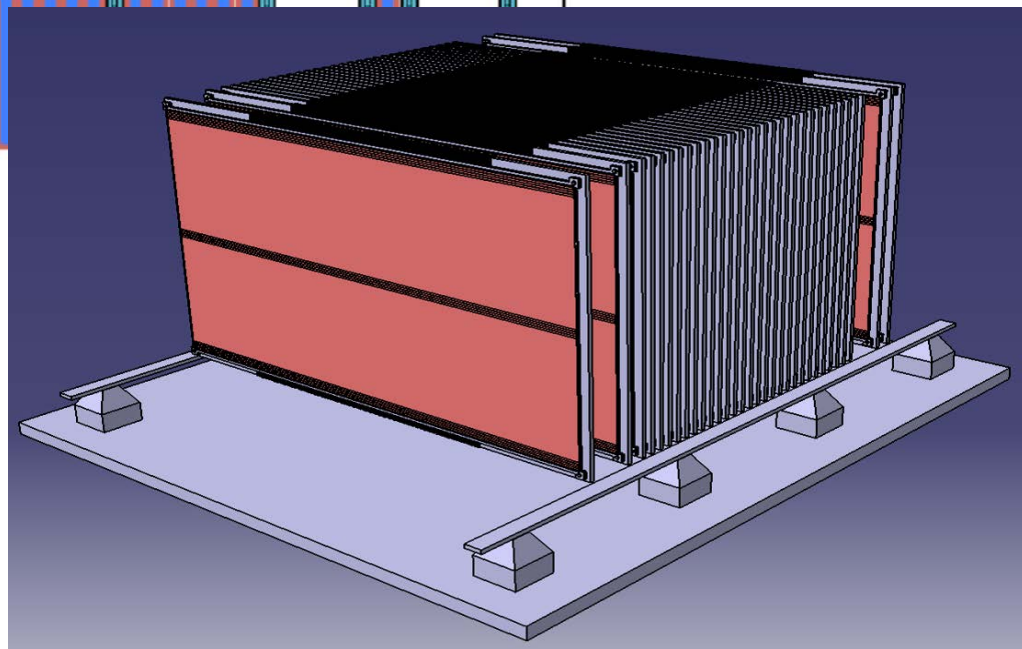




Magnetized Downstream MRD Module



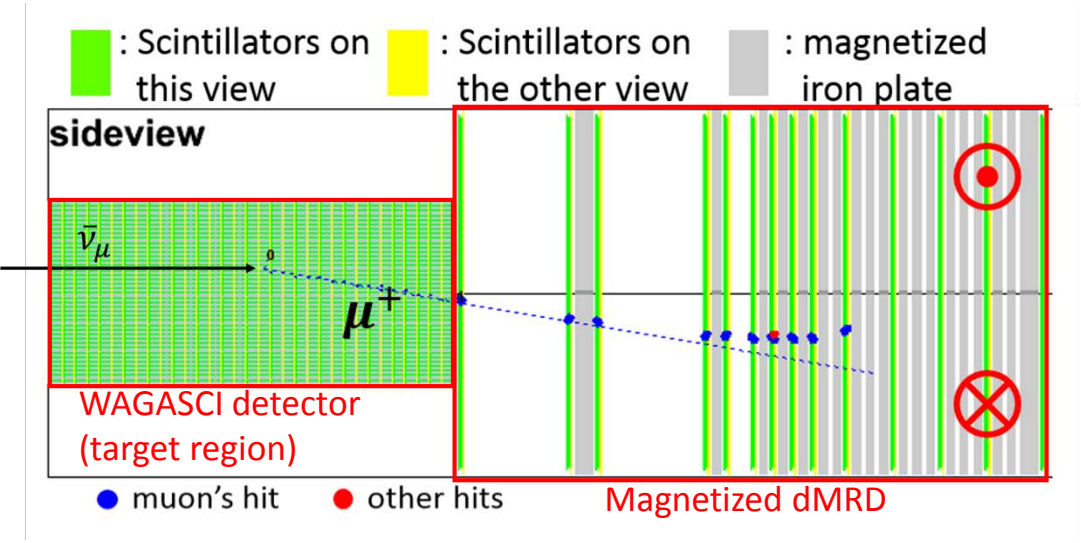
- Not fixed yet
  - 9 or 3-cm-thick Iron plate
    - ✓ The total thickness of iron : 102cm
  - Thickness of Al coils : 4~5mm

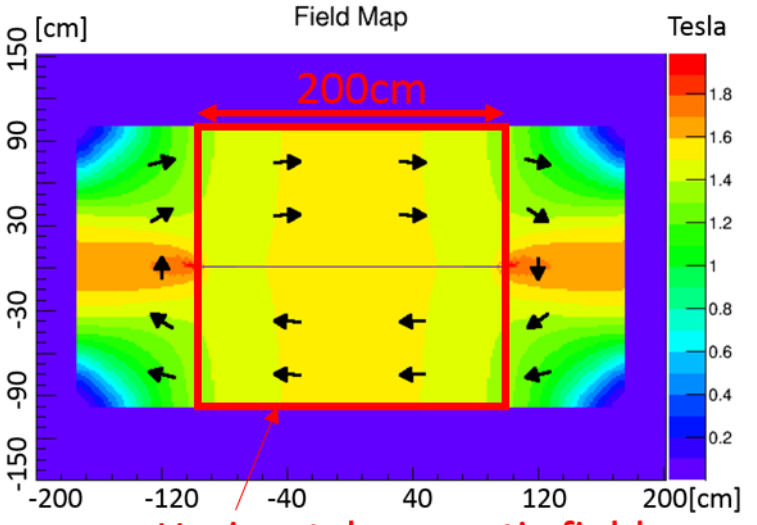


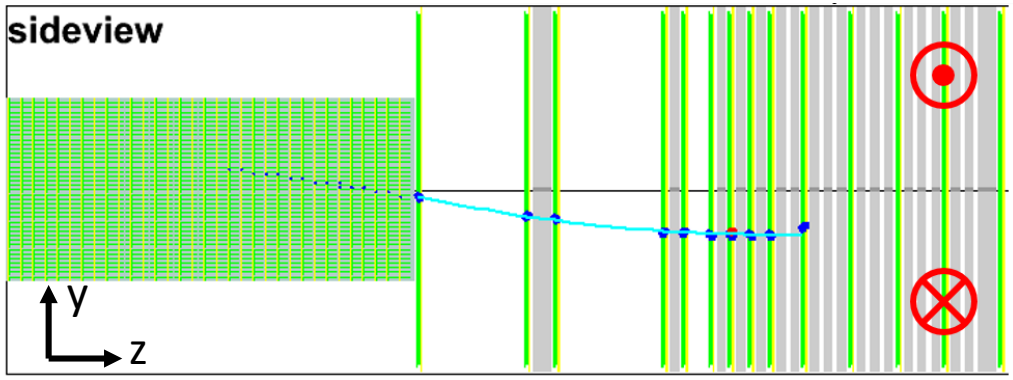
Evaluation of Performance to ChargeID

GEANT4-base simulation

- 2ton target(simply water only.)







Fitting hits' position with quadratic func. (to be simplified)

- $y=a*z^2+b*z+c$
- Tell the charge's sign by the coefficient "a".

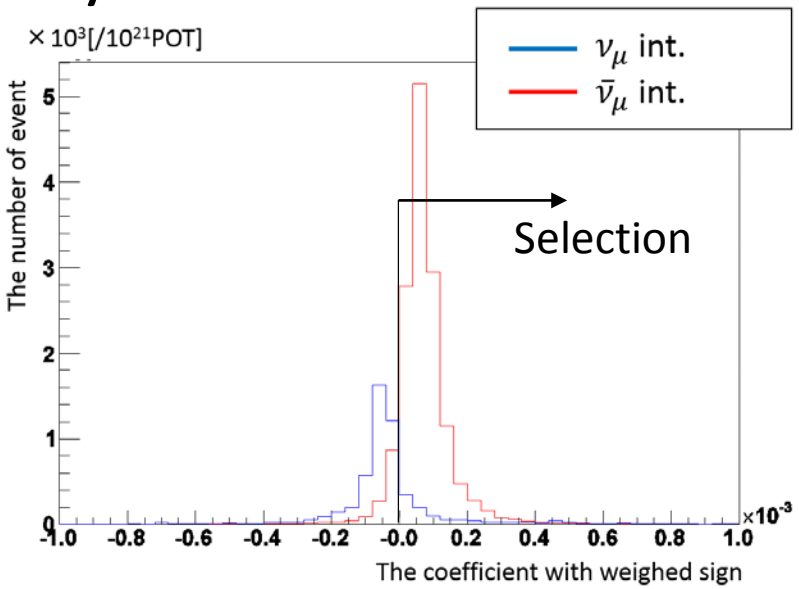
Results

Efficiency to identify charge correctly.

- Event selection :

  charge ID : the coefficient "a" > 0

  - ✓ 9cm iron plate penetrated.
  - ✓ Stop within 102cm iron plates.
  - ✓ Edge cutting (10cm away from dMRD surface.)
  - ✓ Fiducial volume (5cm away from WAGASCI surface)
- Achieved **89% in total**.



Contamination of Neutrino BG

- **Decreased down to 2.9%** (from 30.5% for all CC int.)

*After the event selections (not perfect…)

	anti-neutrino events	neutrino events	neutrino contamination
1. All charged current interactions	67993	29865	30.5%
2. Muons to stop within dMRD (true info.)	24133	2616	9.8%
3. Reconstructed muon's track in dMRD	16445	3238	16.1%
4. After charge identification	14620	435	2.9%
*Efficiency to reconstruct charge(4./3.)	88.9%	13.4%(mis-ID)	

Table 5 The efficiency to reconstruct particle charge and the contamination of neutrino background.

Plans

Configuration of dMRD

- Optimize due to MC simulation
- In accordance with the method to construct magnet module.
- ~ Autumn 2015
- Probably, ND280 method will also be implemented.

Summary of MC study

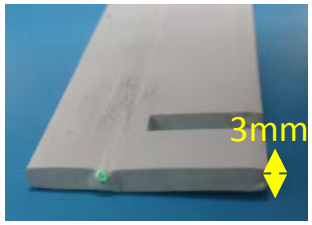
- http://hep.phys.s.u-tokyo.ac.jp/~nchikuma/doc/magnet_WAGASCI.pdf
- Not completed yet.
- Will be added into master thesis.

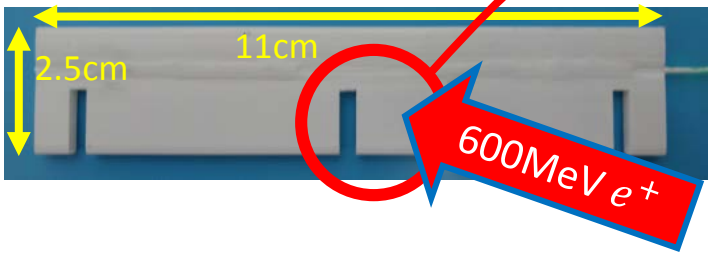
Backup

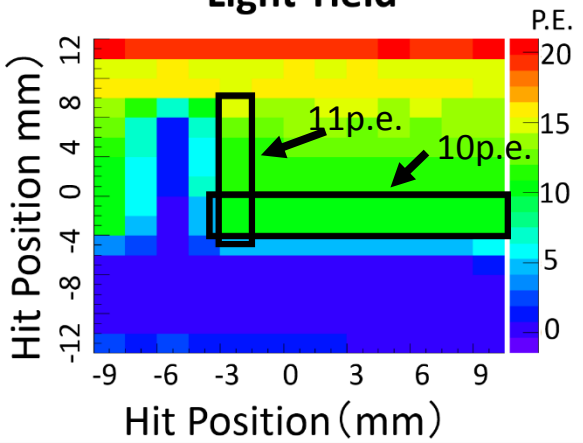
Components

Performance test of 3mm thin plastic scintillator

- ✓ Positron beam produced by the accelerator at Tohoku Univ.
- ✓ Readout : WLS fiber ⇒ MPPC.
- ✓ 1.5mm segmentation hodoscope.



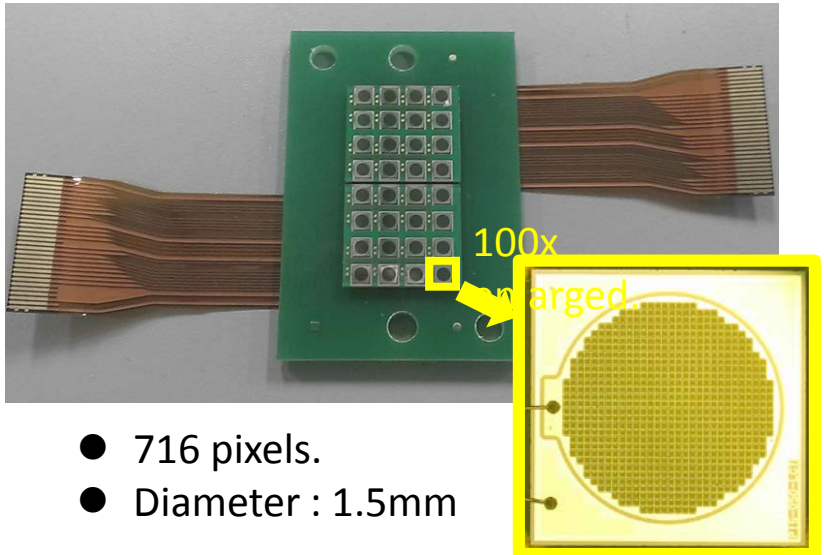




Result: (1.5p.e. threshold)

99% detection efficiency

32ch arrayed MPPC



- 716 pixels.
- Diameter : 1.5mm

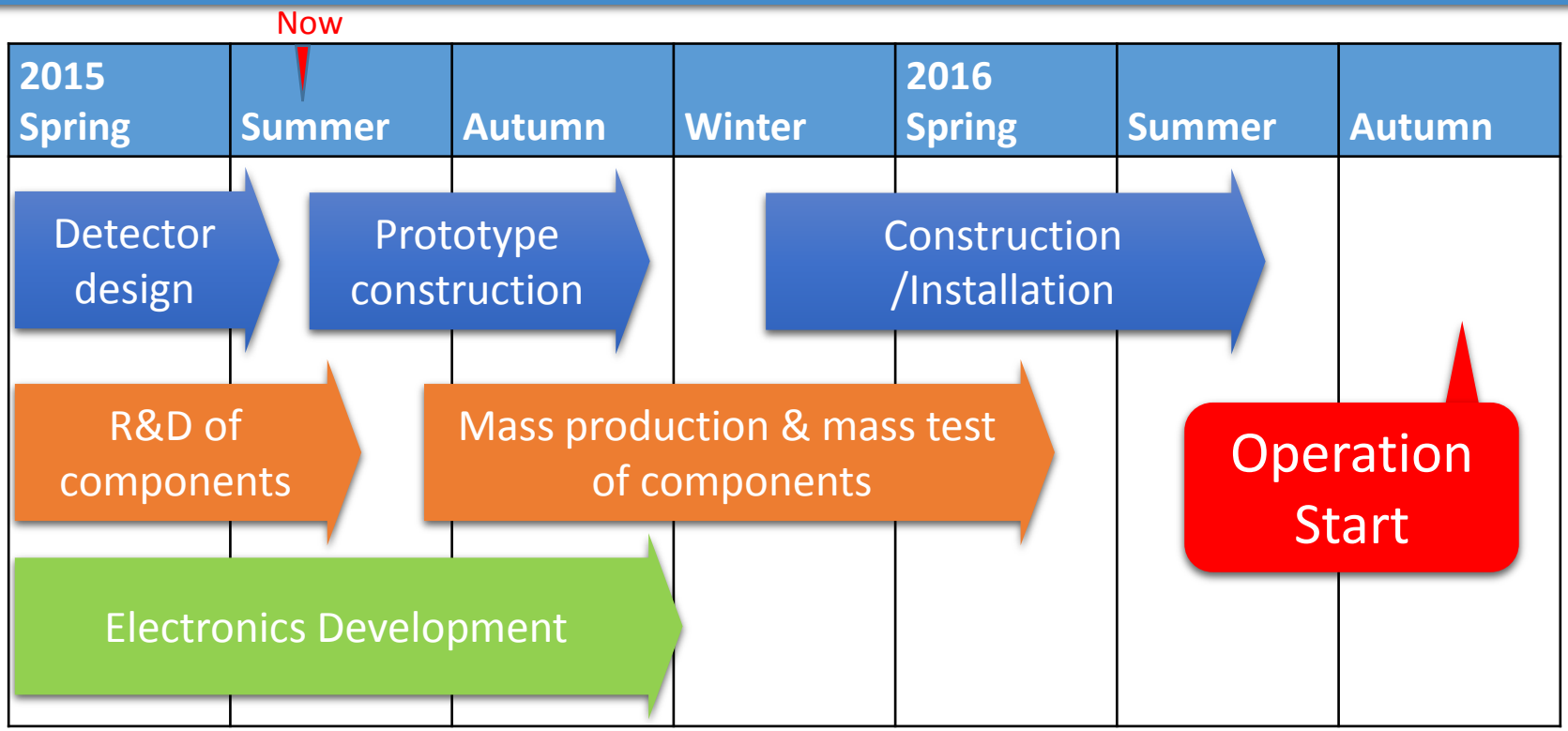
Performance of new MPPCs developed by Hamamatsu

- ✓ Low noise(~1/10 compared to T2K ver.)
- ✓ Much less after pulse
- ✓ Wider operation voltage
- ✓ Low cross-talk

- Performance test of MPPC
- Development of electronics

On going

WAGASCI Schedule



- ✓ We plan to construct a new detector, named WAGASCI, for precise neutrino oscillation measurement.
- ✓ Measure **the CC neutrino cross section ratio** on H_2O/CH with 3% accuracy.
- ✓ **3D grid-like scintillator** will be used for large acceptance.
- ✓ MC studies and R&D of components have almost been done.
- ✓ An Option to install **magnet module at downstream**.
- ✓ Start operation at Oct. 2016.