WAGASCI
+ ND280 upgrades

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Introduction

- T2K's approved POT by J-PARC PAC is 7.8e21.
  - Current delivered POT is 1.1e21 (15%).
- T2K started a discussion to extend the T2K running up to 25e21 POT*.
  - T2K also started a discussion about the collaboration efforts equivalent to 1.5 times statistical increase. (Horn current optimization, new SK samples/fiducial volume, …)

A case study on expected POT projection

Year (20XX)	15	16	17	18	19	20	21	22	23	24	25	26	27	28
POT (e21)	1.4	2.3	3.1	3.9	5.4	7.1	9.0	11.1	13.3	15.7	18.1	20.6	23.1	25.5
Power (MW)	0.36	0.40	0.46	0.70	0.80	0.89	1.06	1.12	1.19	1.29	1.29	1.33	1.33	1.33

T2K T2K extension

*** Workshop for Neutrino Programs with facilities in Japan**
http://www-conf.kek.jp/ws_nu_prog_in_jp/

Current T2K systematic errors

2014 → 2015

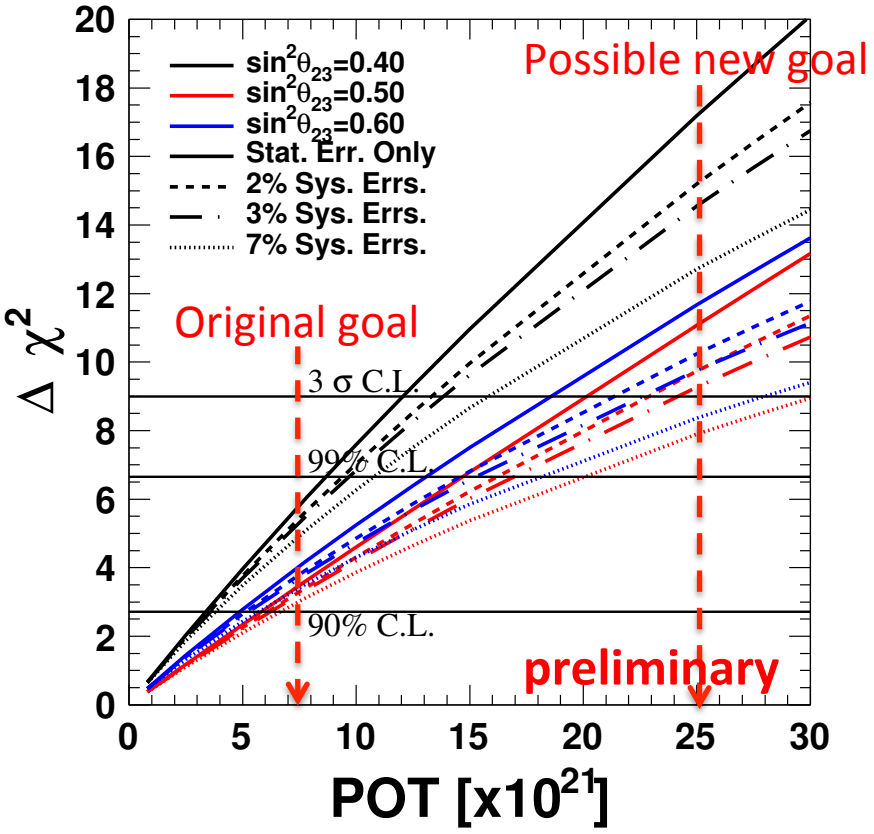
		ν_μ sample	ν_e sample	$\bar{\nu}_\mu$ sample	$\bar{\nu}_e$ sample
ν flux		16%	11%	7.1%	8%
ν flux and cross section	w/o ND measurement	21.8%	26.0%	9.2%	9.4%
	w/ ND measurement	2.7%	3.1%	3.4%	3.0%
ν cross section due to difference of nuclear target btw. near and far		5.0% *	4.7% *	10%	9.8%
Final or Secondary Hadronic Interaction		3.0%	2.4%	2.1%	2.2%
Super-K detector		4.0%	2.7%	3.8%	3.0%
total	w/o ND measurement	23.5%	26.8%	14.4%	13.5%
	w/ ND measurement	7.7%	6.8%	11.6%	11.0%

There are on-going efforts to reduce this nucleus-dependent errors with water target measurements in T2K near detectors.

* 2014 errors don't include the effect of multi-nucleon bound state at the neutrino interaction.

Effect of syst. errors for δ_{CP} measure.

$\Delta\chi^2$ for resolving $\sin\delta_{CP}\neq 0$ in T2K

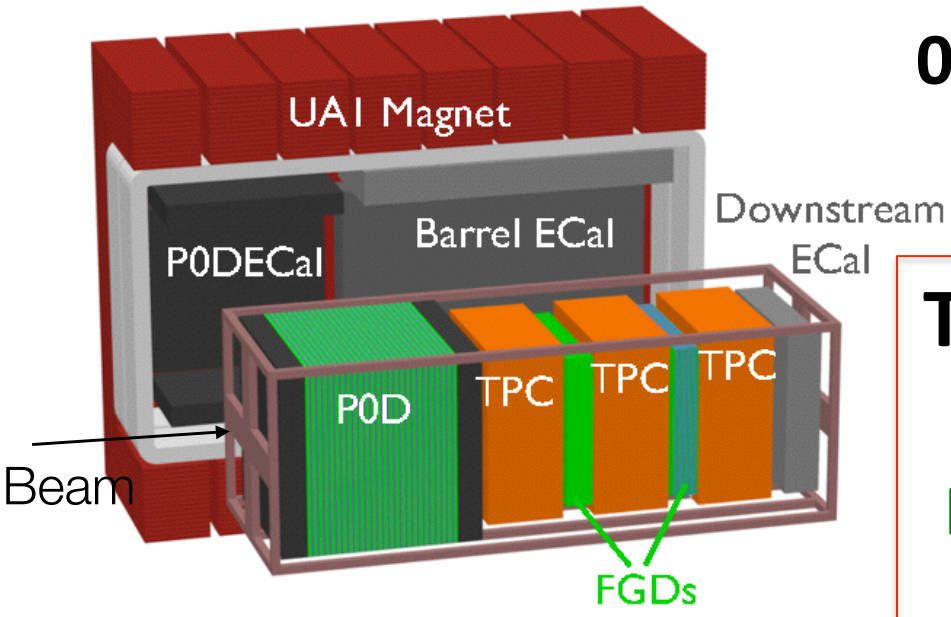


true $\delta_{CP} = -\pi/2$, true MH = NH
50% ν + 50% anti-ν mode

- At the goal of the T2K extension* (25e21 POT), reducing systematic errors from 7% to 2% is equivalent to 25% more data.
- Syst. errors should be reduced as much as possible to maximize the physics sensitivity.

* Discussion about the extension is ongoing. Nothing has been decided yet.

T2K near detectors (ND280)



0.2 T magnetic field

Surrounding ECALs

Tracker: Constrain signal/BG predictions for OA

Fine-Grained Detector (FGD)

active plastic scintillator target*
(+ passive water targets (FGD2))

TPCs

- particle/charge ID
- Momentum measure.

π^0 detector (P0D)

active plastic scintillator targets*
+ passive water targets
+ brass radiator layers

* active targets with segmented X/Y planes

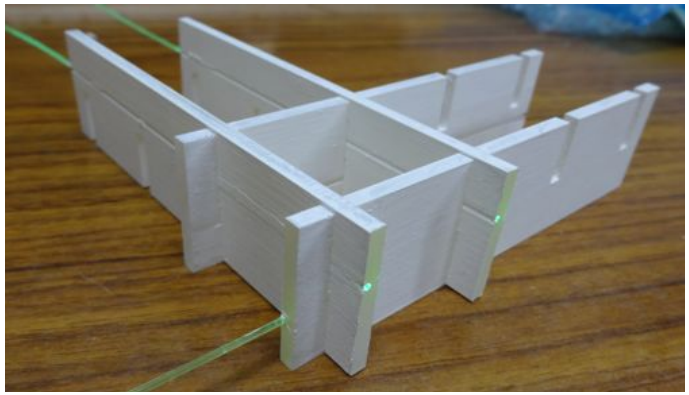
Limitation of the current T2K ND

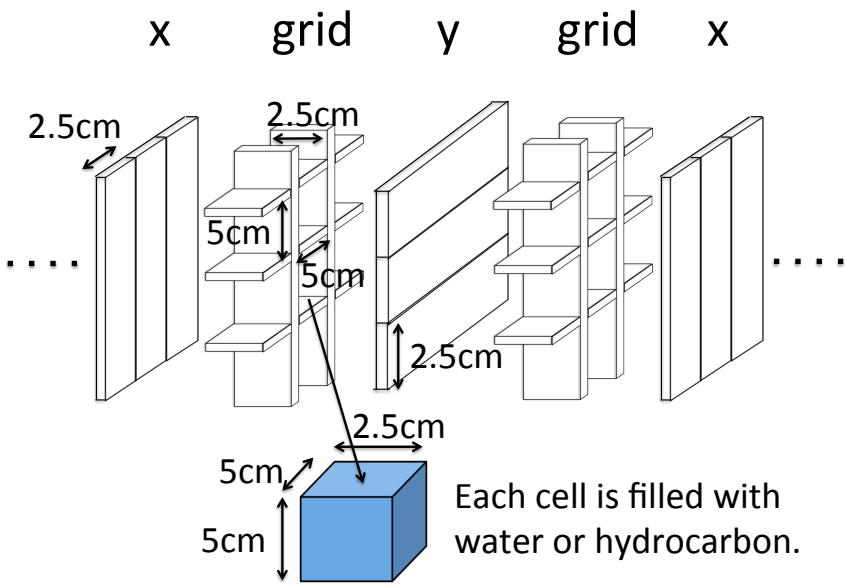
- **Detector acceptance**
  - Super-K: 4π, ND280: Low efficiency for large angle tracks
- **Mass fraction of water**
  - Super-K: 100%, ND280: 47%
- **Neutrino flux**
  - Super-K: point source, ND280: line source
- **Proton reconstruction**
  - Energy threshold/position resolution may not be sufficient to give definite answer for Multi-nucleon CCQE-like events.
- **ν_e measurement**
  - Statistics for $E_\nu < 1.2$ GeV is too low. (~10% stat. error @ 3.9e21 POT)

WAGASCI
(J-PARC T59)

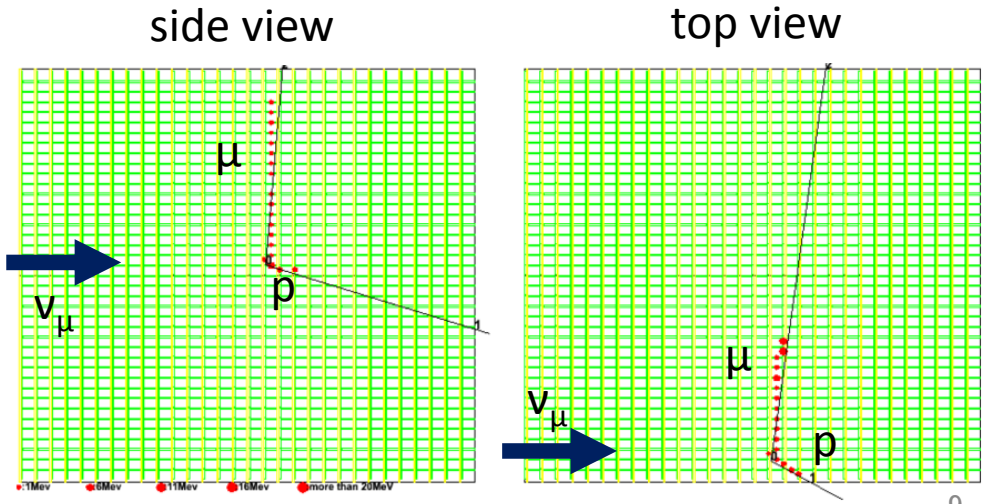
WAGASCI concept

- Plastic scinti. tracker with 3D grid-like structure
  - x + grid + y + grid + … layers
  - **4π angular acceptance**
  - **H_2O(signal):CH(BG) = 79:21**



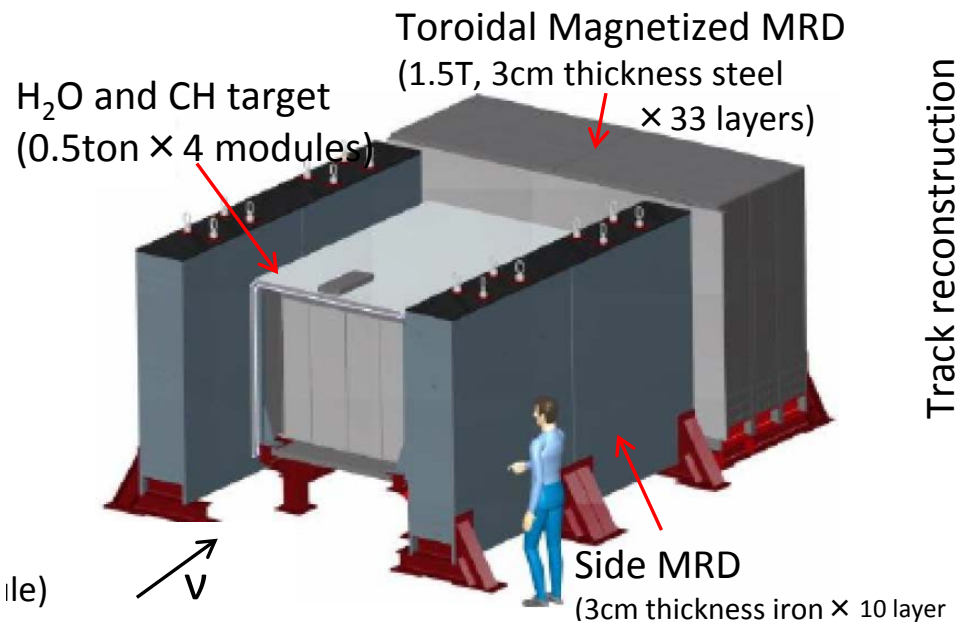


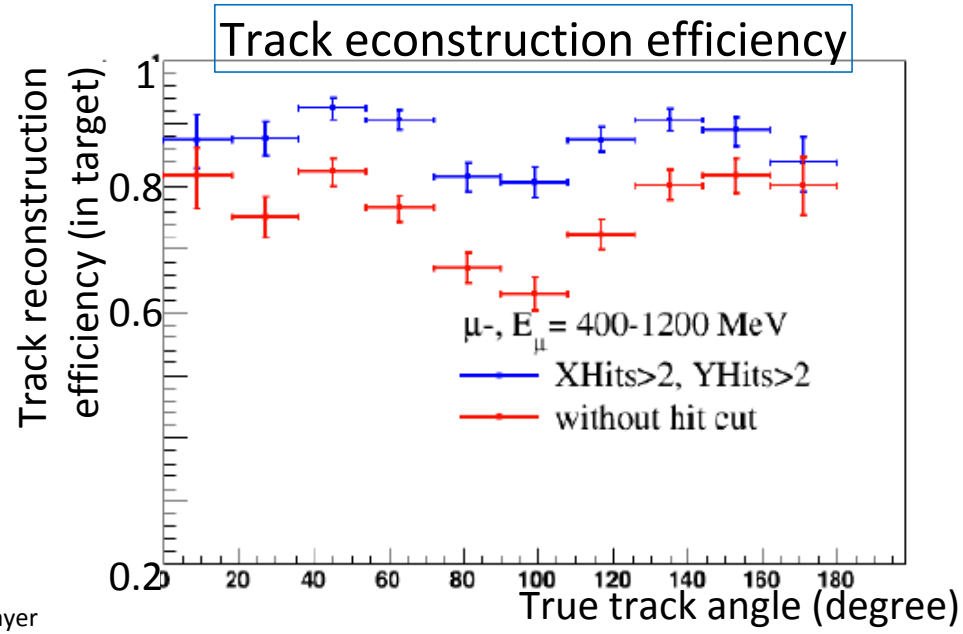
Event Display (MC)



WAGASCI (J-PARC T59)

- An approved test experiment by J-PARC PAC (T59).
- Goal: measure H_2O/CH charged-current cross-section ratio with 4π acceptance and 3% accuracy.

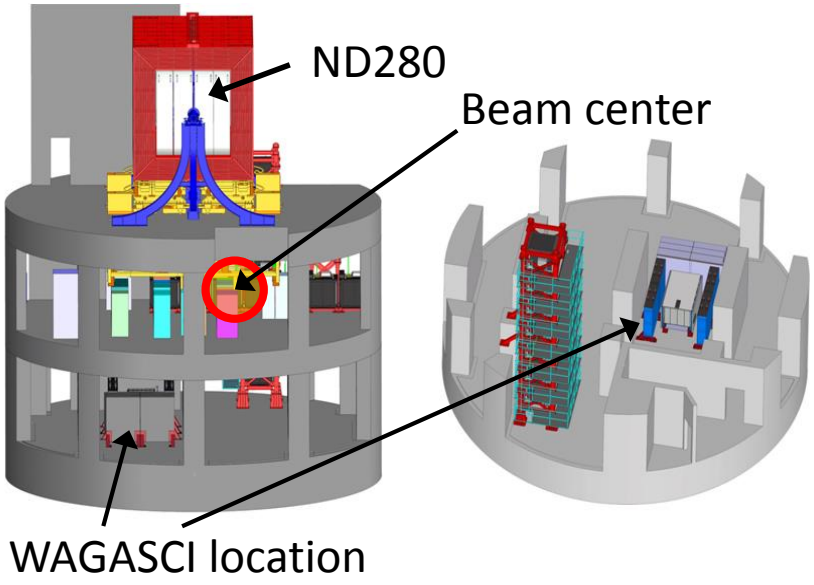


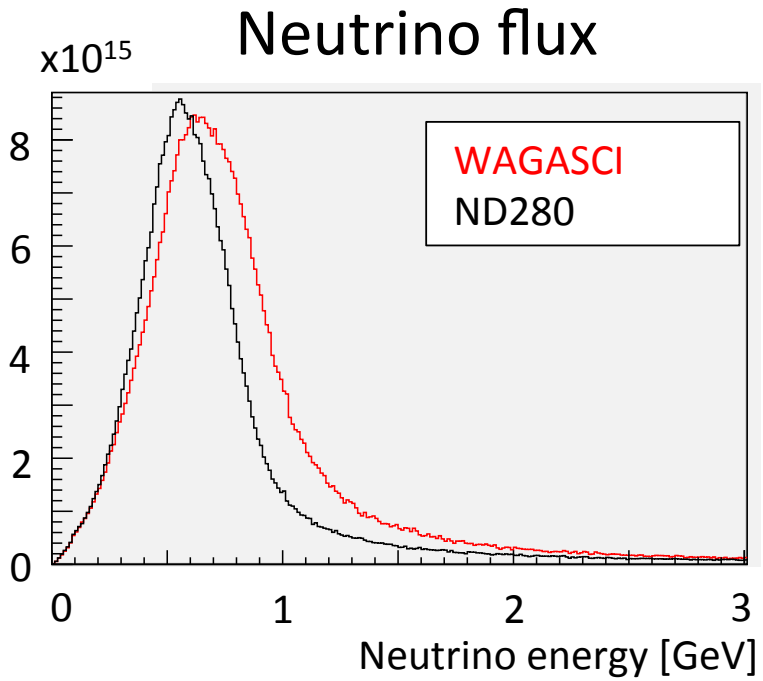


Reconstructed events on water	CC on Water	NC on Water	CC and NC on Scintillator	BG from outside detector
# of selected events /10^{21}POT /1 ton	23560 (73.2%)	848 (2.6%)	6102 (18.9%)	1640 (5.1%)

WAGASCI (J-PARC T59)

- Experimental site
  - B2 floor of ND280 pit (Off-axis angle = 1.6 deg.)

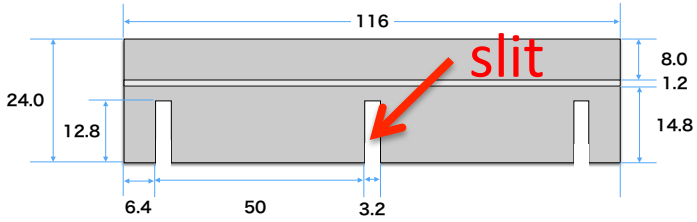


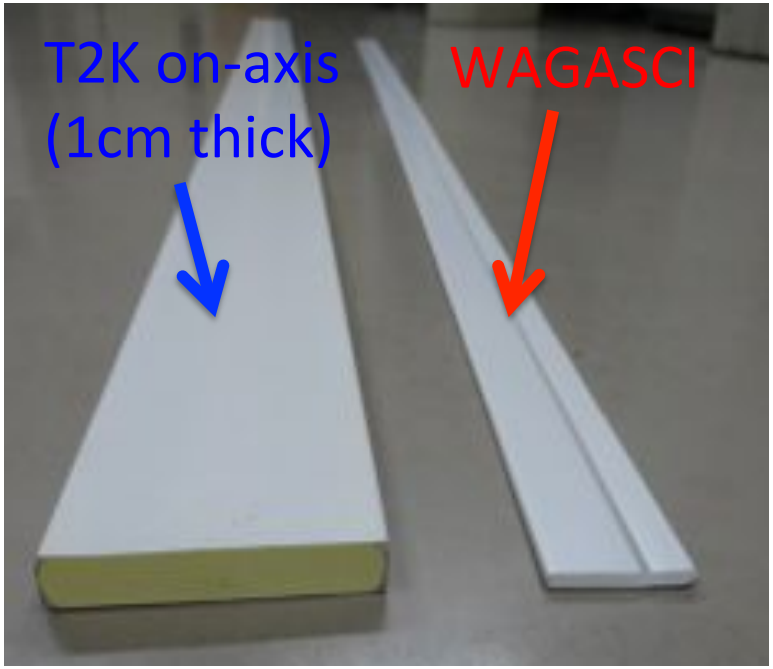


- Schedule
  - 2015-2017: Construction of detectors
  - 2017: Start beam measurement

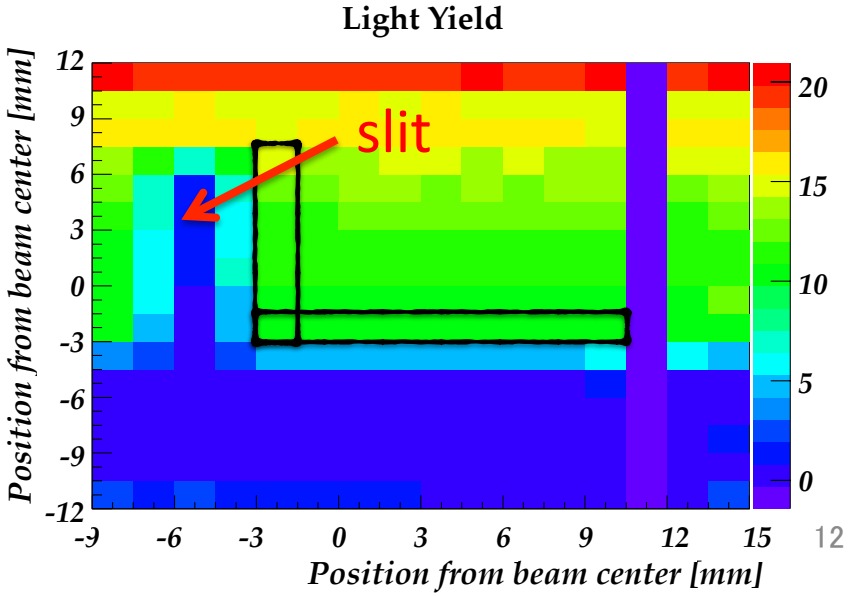
WAGASCI (T-59): Key technology (1)

- 3mm thick scintillator (made by Fermi-lab)
  - Light yield > 10 p.e. for MIP
  - Hit efficiency > 99.5% for MIP
  - Long-term stability in water: OK





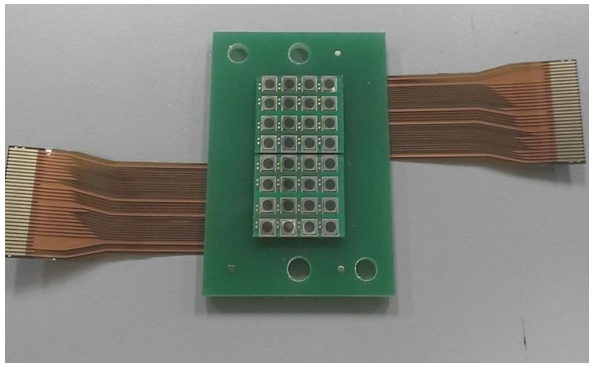
Light yield distribution
w/ positron beam

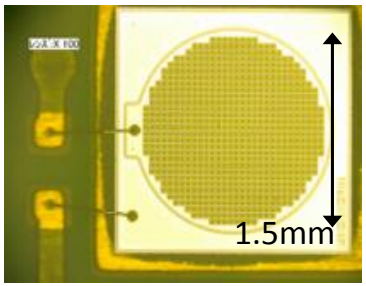


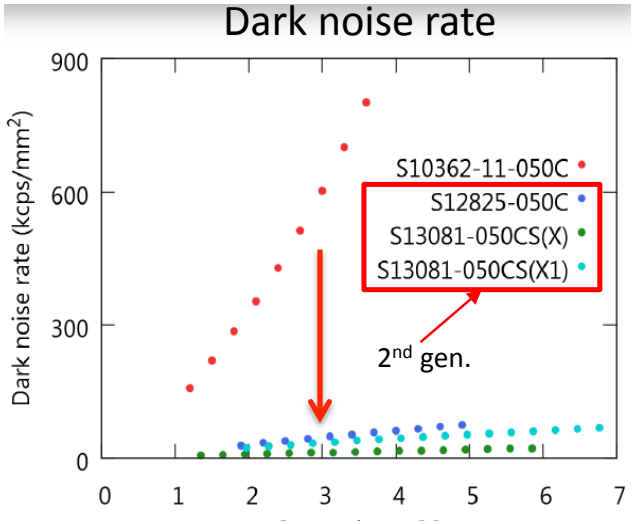
WAGASCI (T-59): Key technology (2)

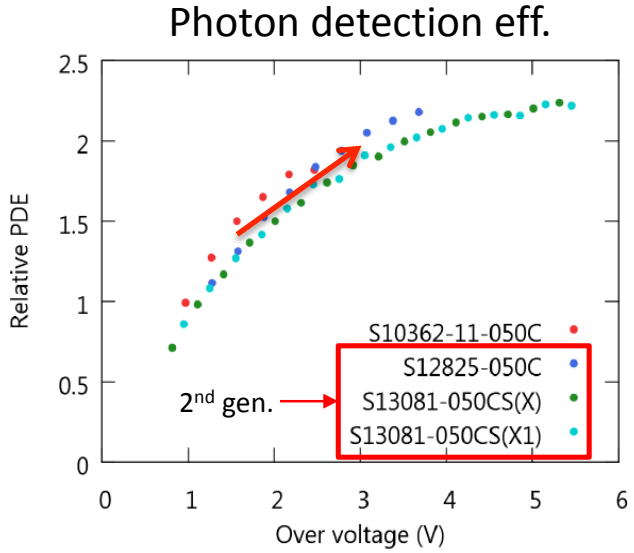
- 2nd generation MPPC (made by Hamamatsu)
  - Low dark noise
  - High photon detection efficiency (PDE)

32ch array type



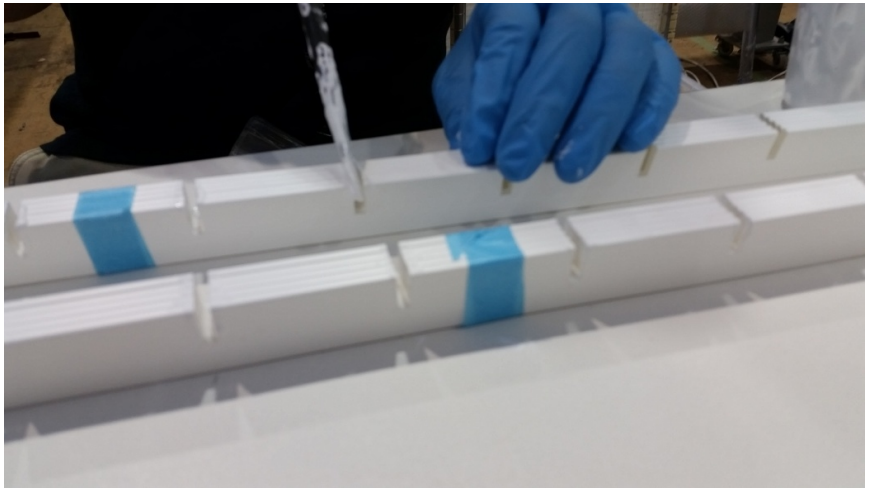


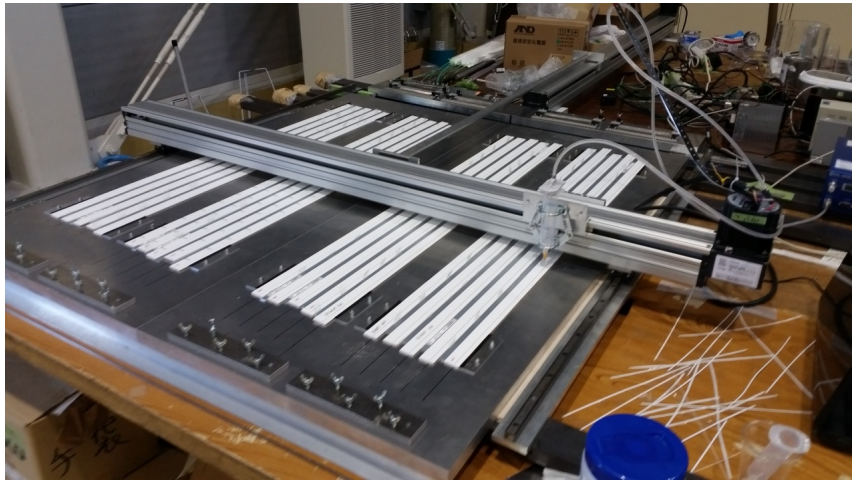


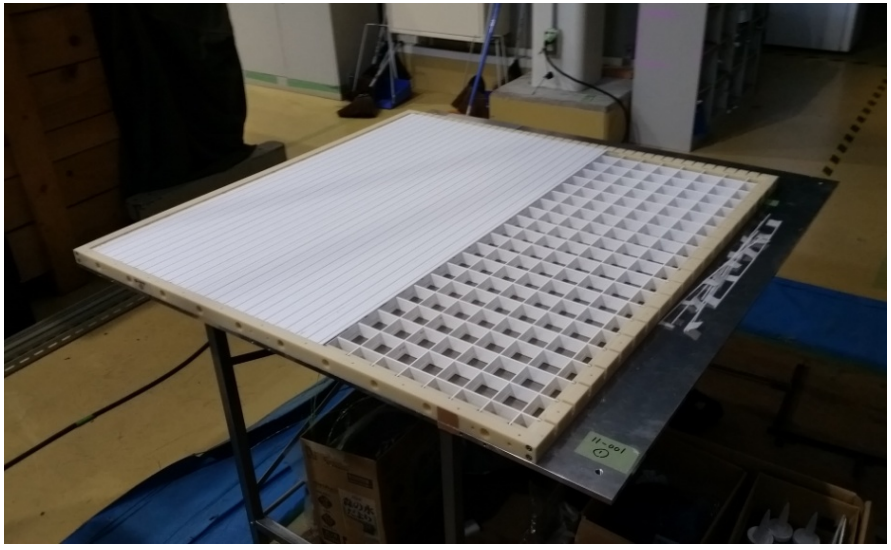


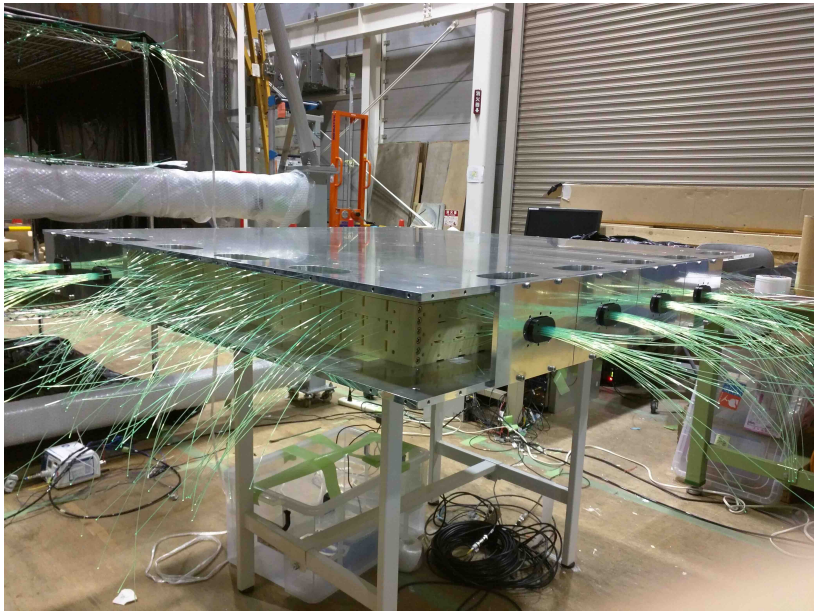
WAGASCI (J-PARC T59)

- Construction is ongoing.









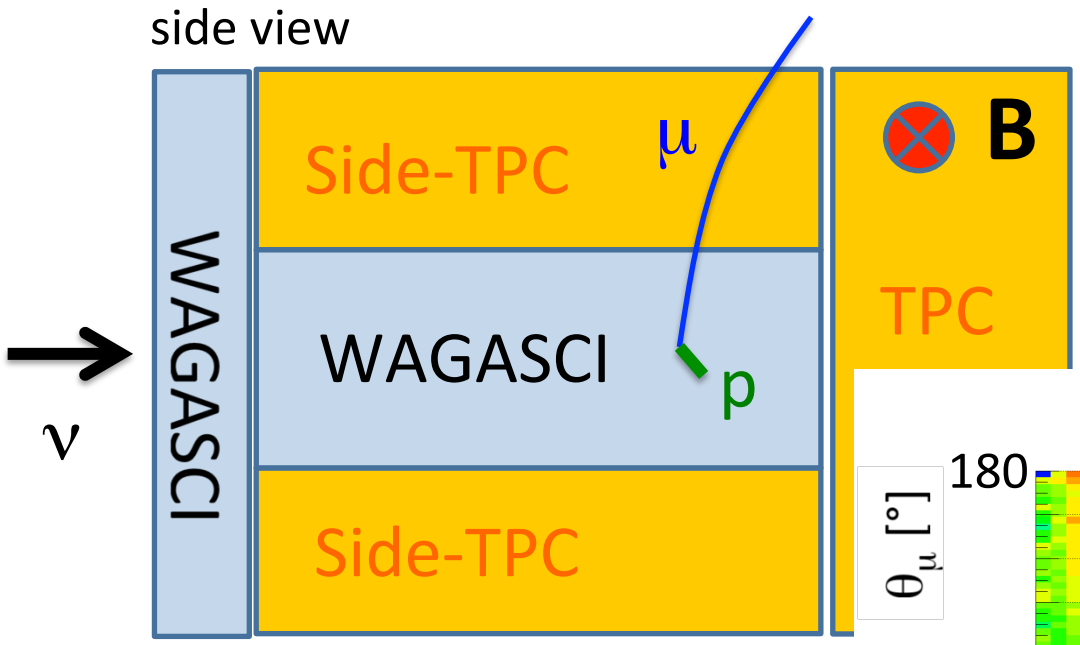
Candidate new ND280 detectors

1. 3D grid water detector, WAGASCI
2. High pressure TPC
3. Water based scintillator detector
4. Emulsion detector
5. …

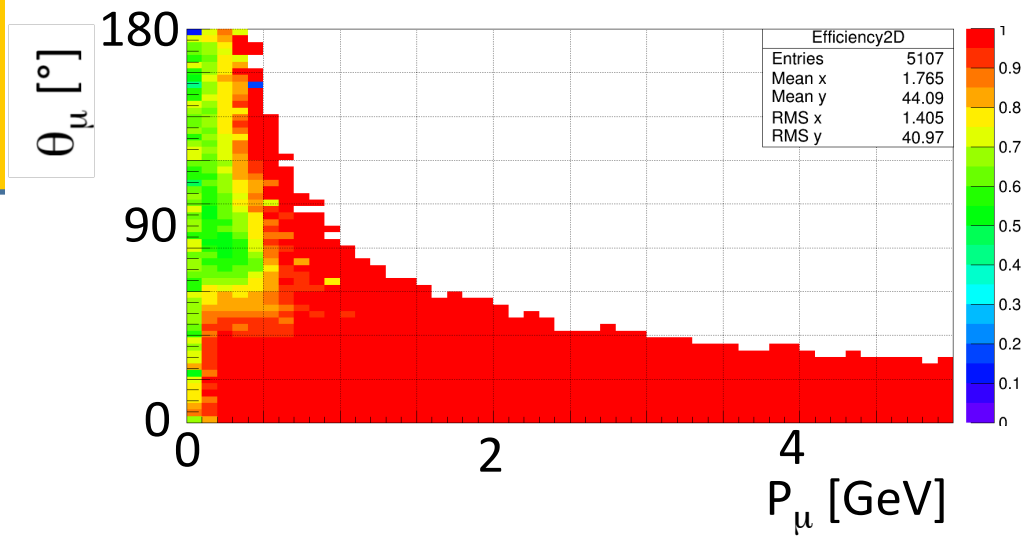
T2K ND280 upgrade task force is just formed.

- Fall 2016: Recommendation document
- ~2020: Installation of an upgraded detector

WAGASCI in ND280 magnet



Reconst. efficiency

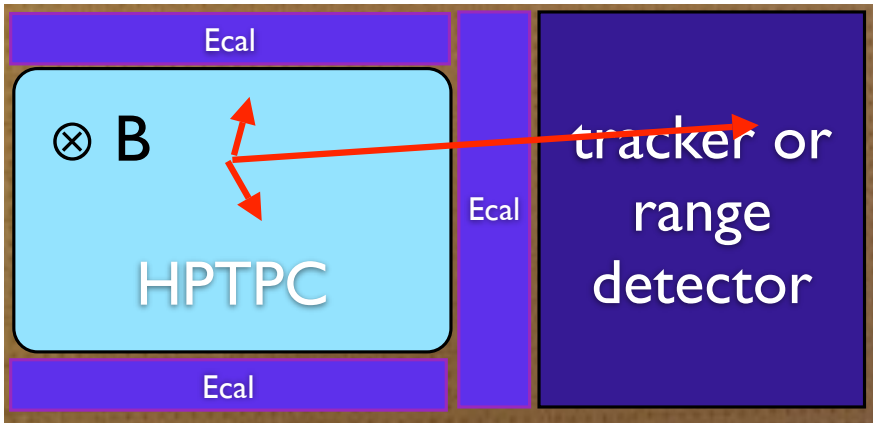


Side-TPCs enable excellent **charge/particle identification** and **momentum measurement** for large angle tracks.

High-pressure TPC

- High-pressure TPC
  - Low thresholds.
    ➔ Sensitive to hadronic final state.
  - excellent PID capabilities.
  - Momentum measurement.
  - Almost uniform 4π acceptance.

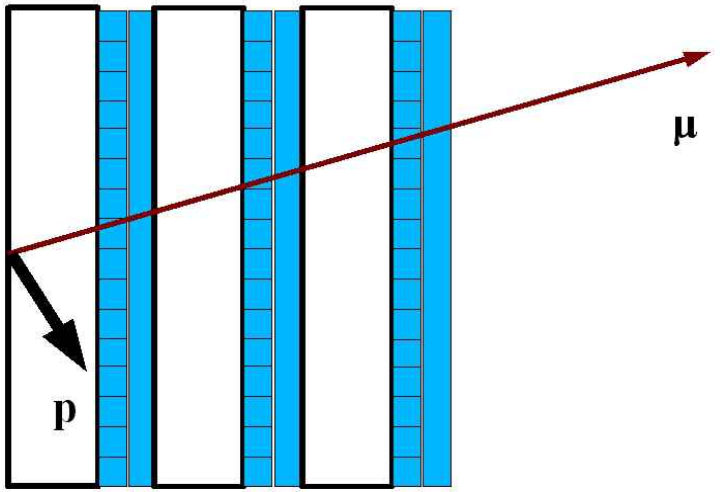
- Goals
  - Multi-nucleon modeling.
  - Multi-pion resonance.
  - Final state interaction.
  - Secondary interaction in detector.



# of CC events assuming full FV.

$2x2x2\ m^3$ 20°C	5 bars	10 bars
He	6.65 kg	13.3 kg
	520 evt/10^{21}pot	1040 evt/10^{21}pot
Ne	32.5 kg	67.1 kg
	2543 evt/10^{21}pot	5086 evt/10^{21}pot
Ar	66.5 kg	133 kg
	5203 evt/10^{21}pot	10406 evt/10^{21}pot
CF_4	146.3 kg	293 kg
	11450 evt/10^{21}pot	22893 evt/10^{21}pot

Water based scintillator cells in FGD/P0D

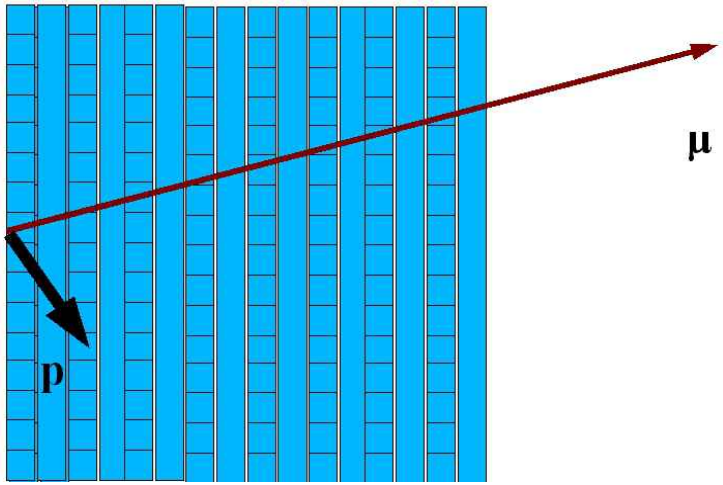


Present near detector:

Passive water layers between plastic scintillator layers

➔ Dead region.

➔ Low energy recoil protons in passive water produce no signal.



Active scintillating water:

Introduce water based scintillator cells (< 5mm cell size).

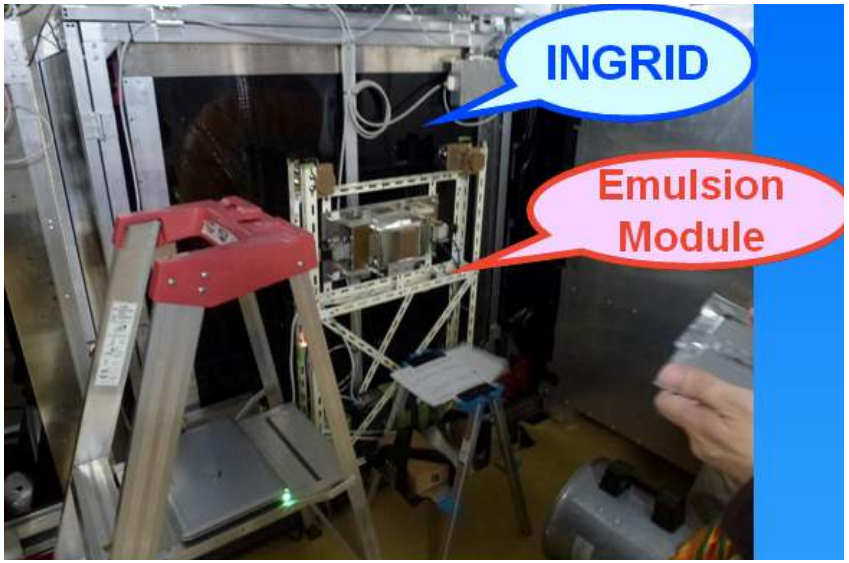
➔ No dead region.

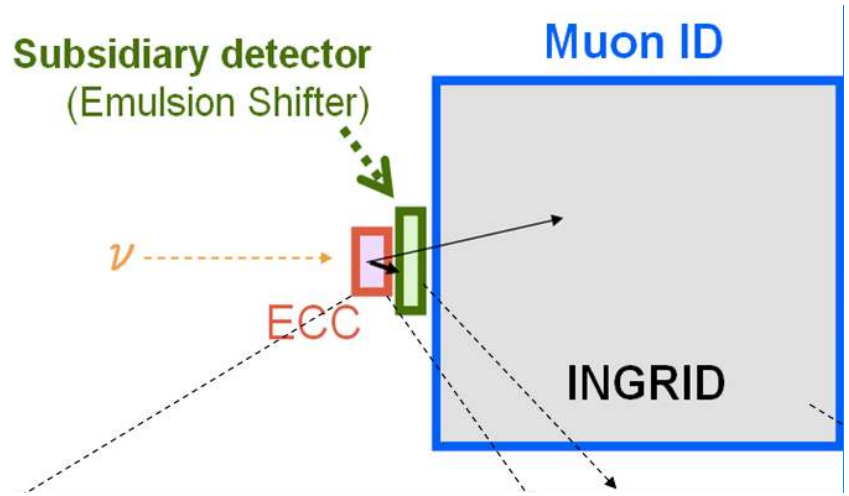
➔ All recoil particles detected.

<u>R&D is on-going.</u>

Emulsion detector (J-PARC T60)

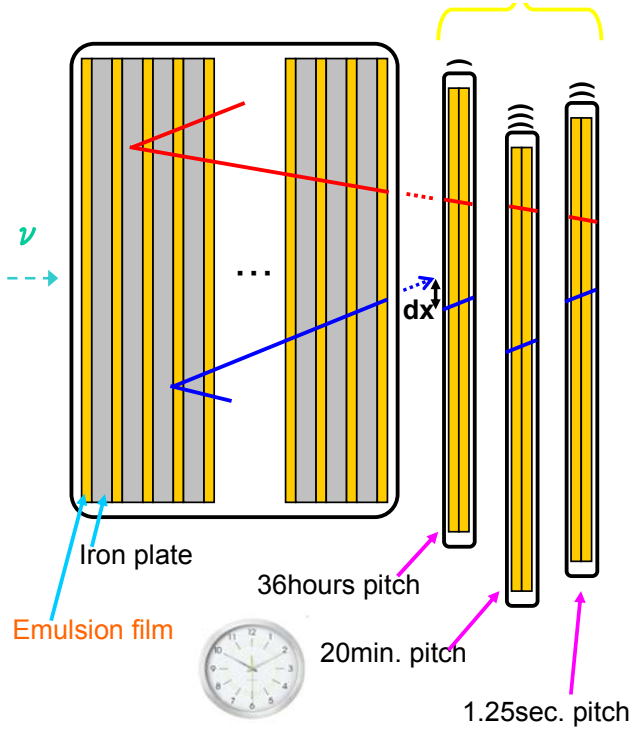
An approved test experiment by J-PARC PAC (T60).



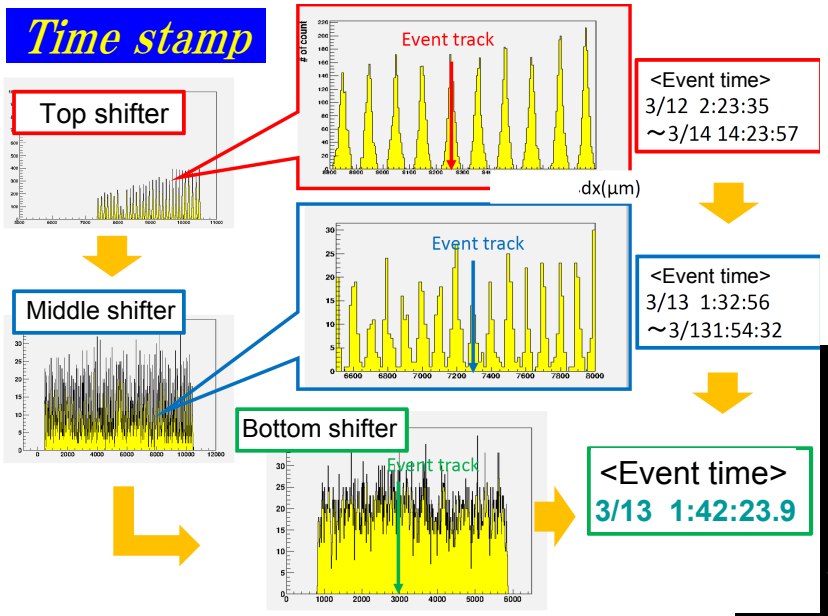


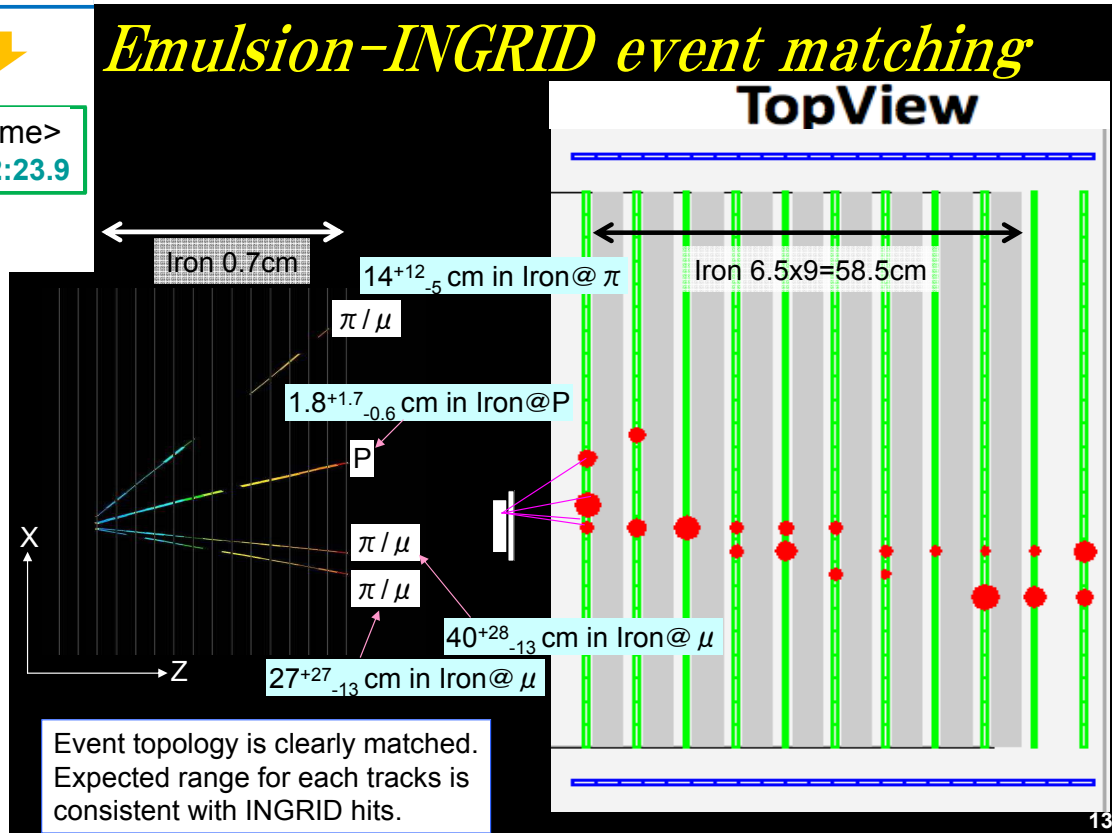
Emulsion shifter

- Time stamps for ν events
- Hybrid analysis with other near detectors



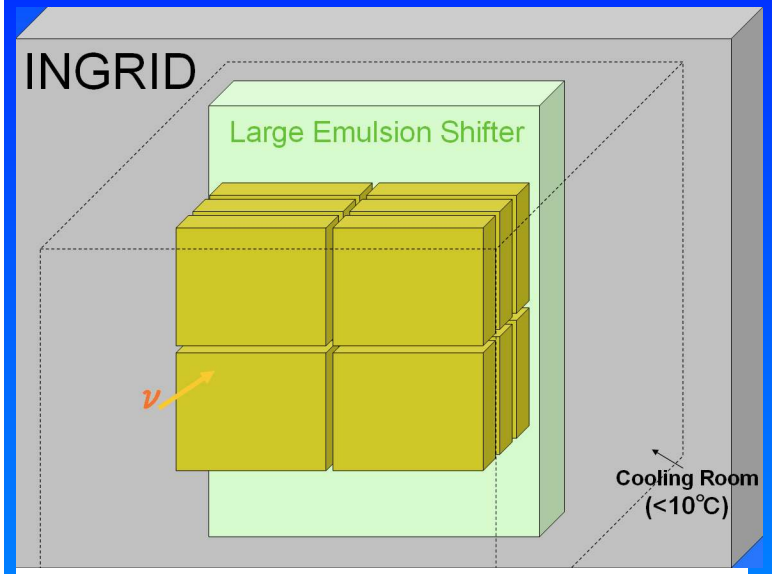
Emulsion detector (J-PARC T60)



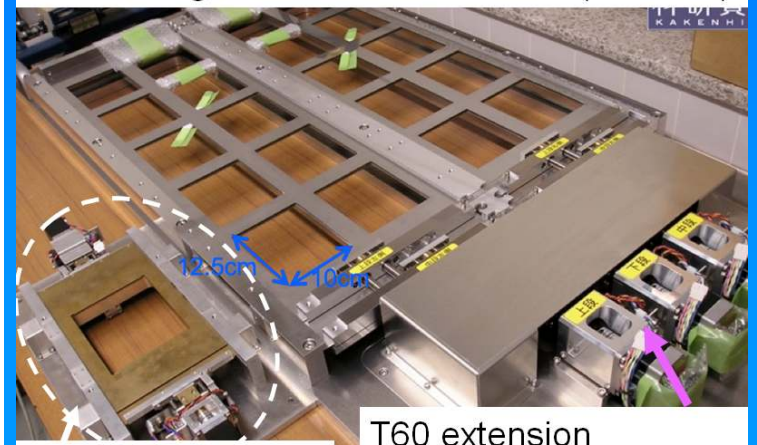


Emulsion detector (J-PARC T60)

We are planning next exposure as Detector Run from next Jan.



Large size Emulsion Shifter (Kobe U.)



T60:
GRAINE 2011 version

T60 extension
GRAINE 2015 version

- ν exposure : 2016 middle of Jan.
  → May or Jun.
- Iron target (total~60kg : 500 μm seg.)
- High statistics (3-6k ν_μ events)
- ν_e detection (20-40 ν_e CC events)

Emulsion film Production for T60 extension

1

Physics requirements vs. detectors (my personal view)

	ν_e cross section	H_2O target	4π accep.	Wrong sign BG	NC, Int. ν_e BG	Muon FS vs. Eν	Hadronic FS	# of neutron (Gd)	CCπ^0
Current ND280									
ND280 (WAGASCI)									
ND280 (HP-TPC)									
ND280 (WbLS)									
ND280 (Emulsion)									
νPRISM									
TITUS									

This talk

Next talk

= Good = OK = Not Good

Summary

- Reduction of systematic errors is getting more important in the era of T2K extension* to improve the sensitivity.
  - It becomes more important to constrain the errors with near detector measurements.
- T2K ND280 upgrade task force is just formed.
  - Fall 2016: Recommendation document
  - ~2020: Installation of an upgraded detector

* Discussion about the extension is ongoing. Nothing has been decided yet.