A 3D grid-like neutrino near detector with a water target, WAGASCI

A. Minamino (Kyoto Univ.)

6^{th} Open Meeting for Hyper-K Project

Jan. 31, 2015 @ Kavli IPMU, Kashiwa

Motivation

- Unknowns in ν cross-sec. for Hyper-K/J-PARC
  - Good model of Initial nuclear state
    - "Simple relativistic Fermi-Gas model", "Spectral function", …
  - Existence of multi-nucleon ν scattering (MEC)
    - models: Martini, Nieves, …
  - Charged current 1π production
  - Final state interactions within the nucleus
  - Pions' secondary interactions in the detector

Appropriate real data, well-defined control sample, is need to test the above unknowns.

Motivation

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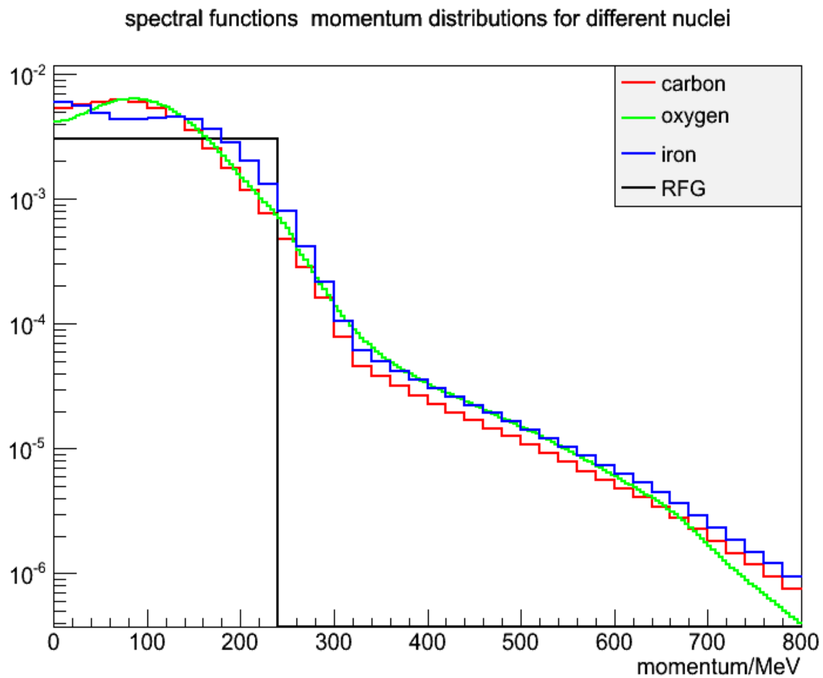

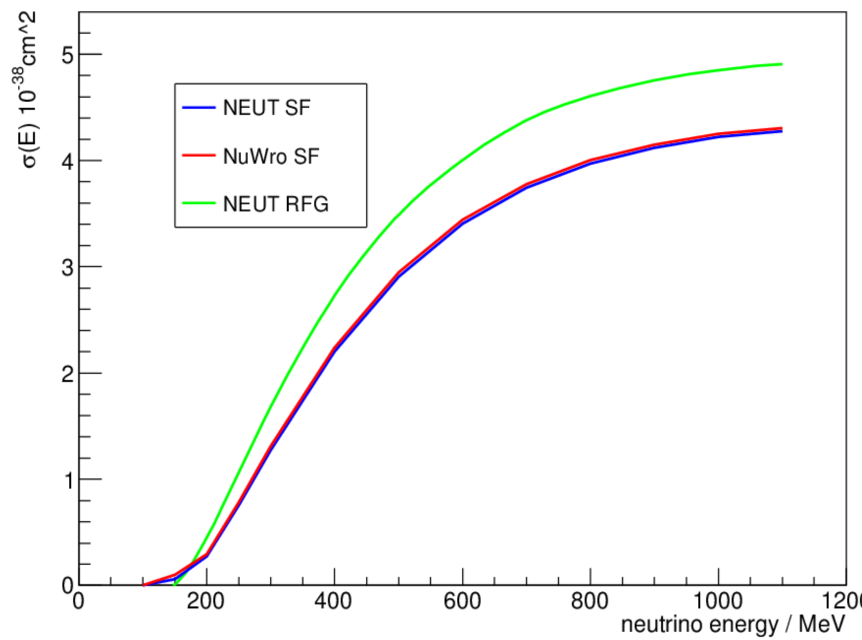

SF has better agreement with electron scattering data.

Motivation

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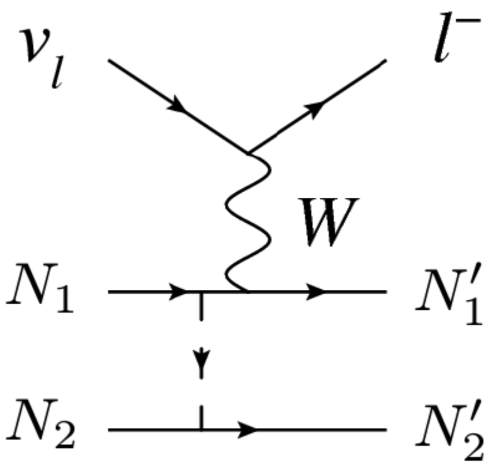
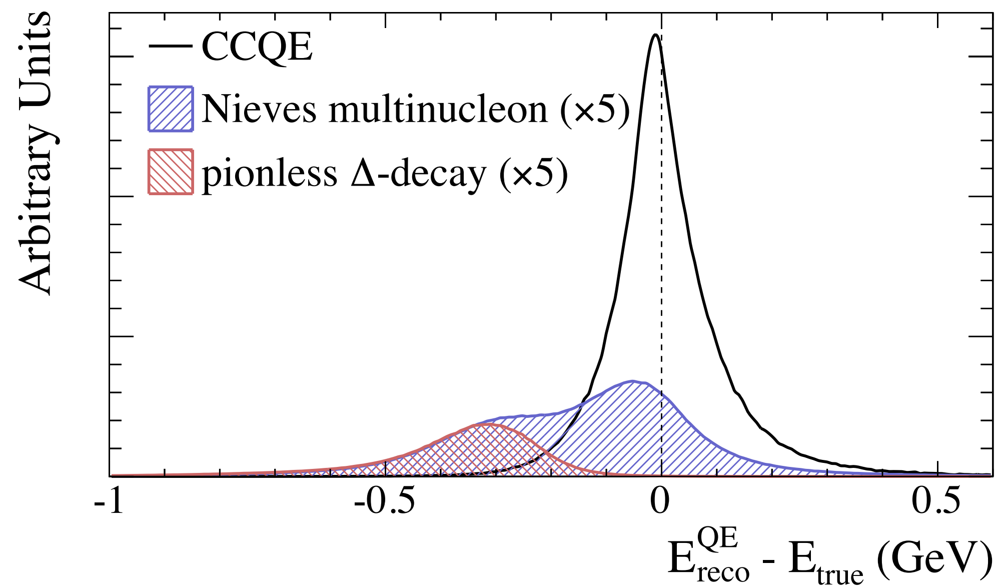


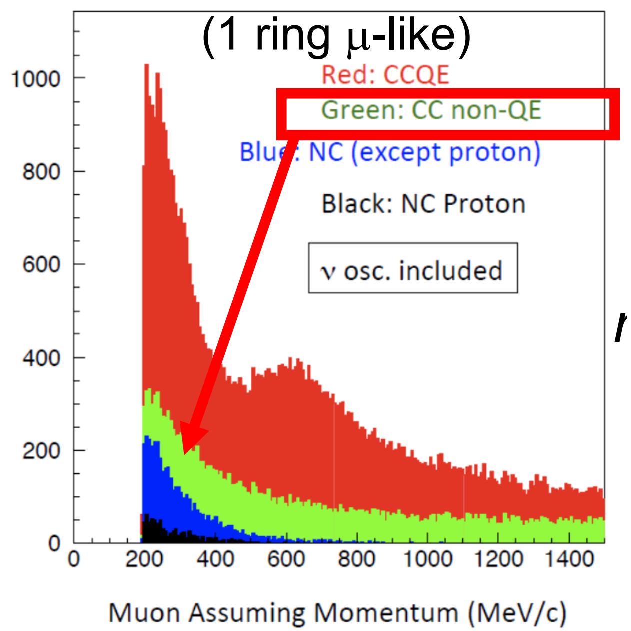


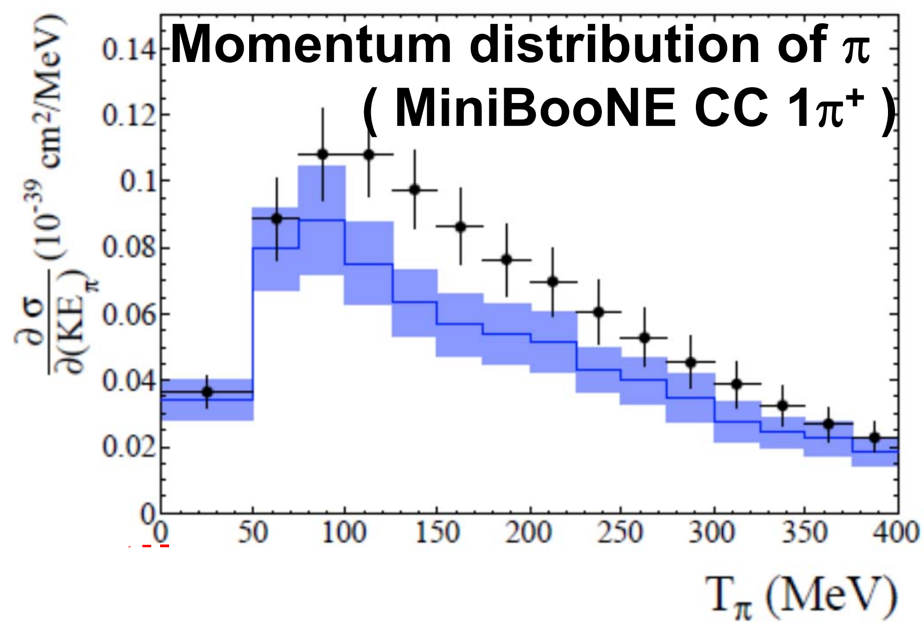
MEC models enhance the CCQE-like xsec around 1GeV.
-> MiniBooNE Ma = 1.35

Motivation

- Unknowns in ν cross-sec. for Hyper-K/J-PARC
  - Charged current 1π production

Reconstructed momentum



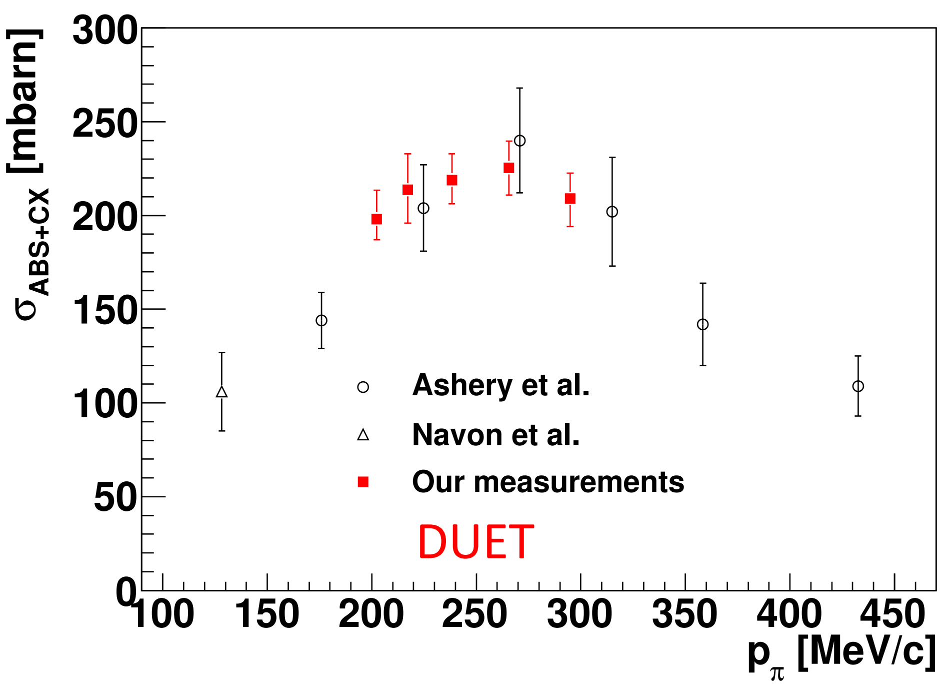


- μ is identified as μ-like ~ Invisible π
  - Absorption of π
  - π is below threshold
- π is identified as μ-like ~ Invisible μ
  - μ is below threshold

Motivation

- Unknowns in ν cross-sec. for Hyper-K/J-PARC
  – Final state interactions within the nucleus
  – Pions' secondary interactions in the detector

Pion cross section data on C



Motivation

- Hyper-K
  - Neutrino target: H_2O
  - 4π acceptance for charged particles
  - Charge ID is difficult
  - Cherenkov thresholds of charged particles in H_2O
    - Muon: 118 MeV
    - Charged pions: 157 MeV
    - Proton: 1GeV

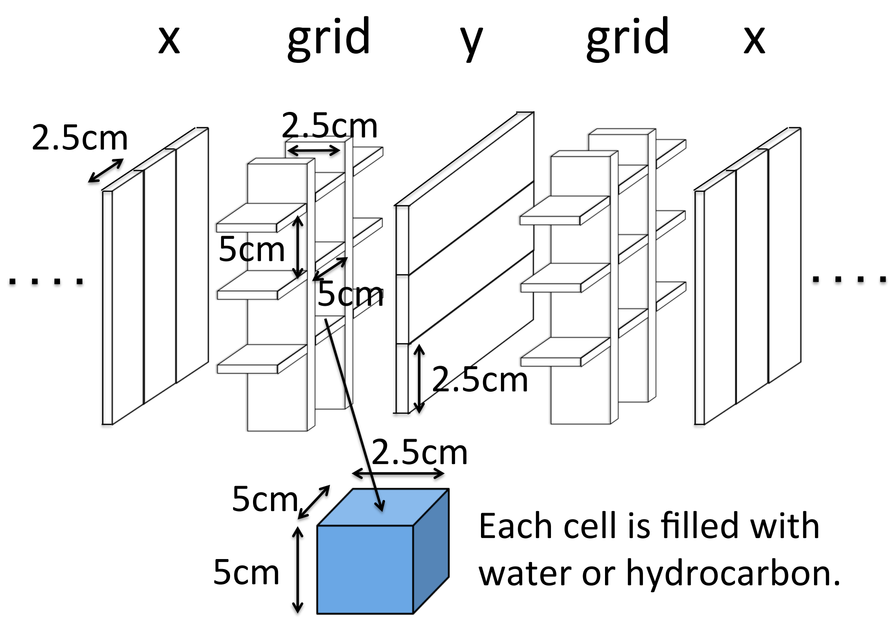
Our proposal

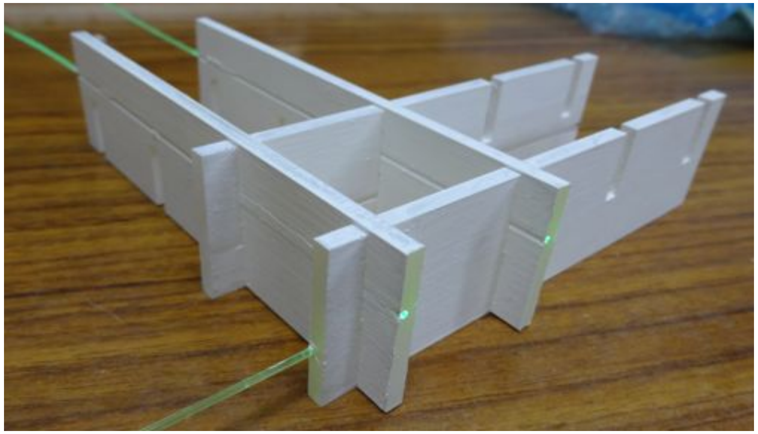
- New H_2O target near detector in UA1 magnet
  - H_2O target → Same target nucleus as Hyper-K
  - Same ν_μ flux as Hyper-K
  - 4π acceptance

    Same phase space as Hyper-K
  - Lower momentum thre. than Cherenkov det., HK
  - Charge ID is possible
  - Observables
    - Differential (Q^2 or (p_μ, θ_μ)) CC0π data w/ bin correlations
    - Differential (p_π) CC1π data for non-QE BG estimation

Our proposal

- 3D grid-like structure + H_2O target for HK ND
  - x + grid + y + grid + … layers
  - 4π angular acceptance for charged particles
  - Lower momentum thre. than Cherenkov detector
  - Charge identification is possible if operate in UA1 magnet
  - H_2O(signal):CH(BG) = 79:21 (= 46:54 -> T2K ND280)





Current status

Water Grid And SCIntillator detector
WAGASCI

H_2O/CH detector
(3D grid-like structure)

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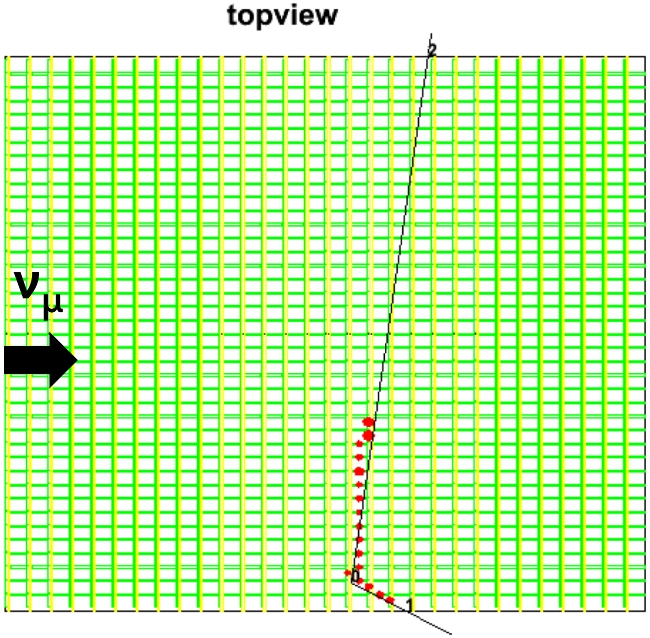
Box for
Japanese sweets (Wagashi)



The project starts on August, 2013.

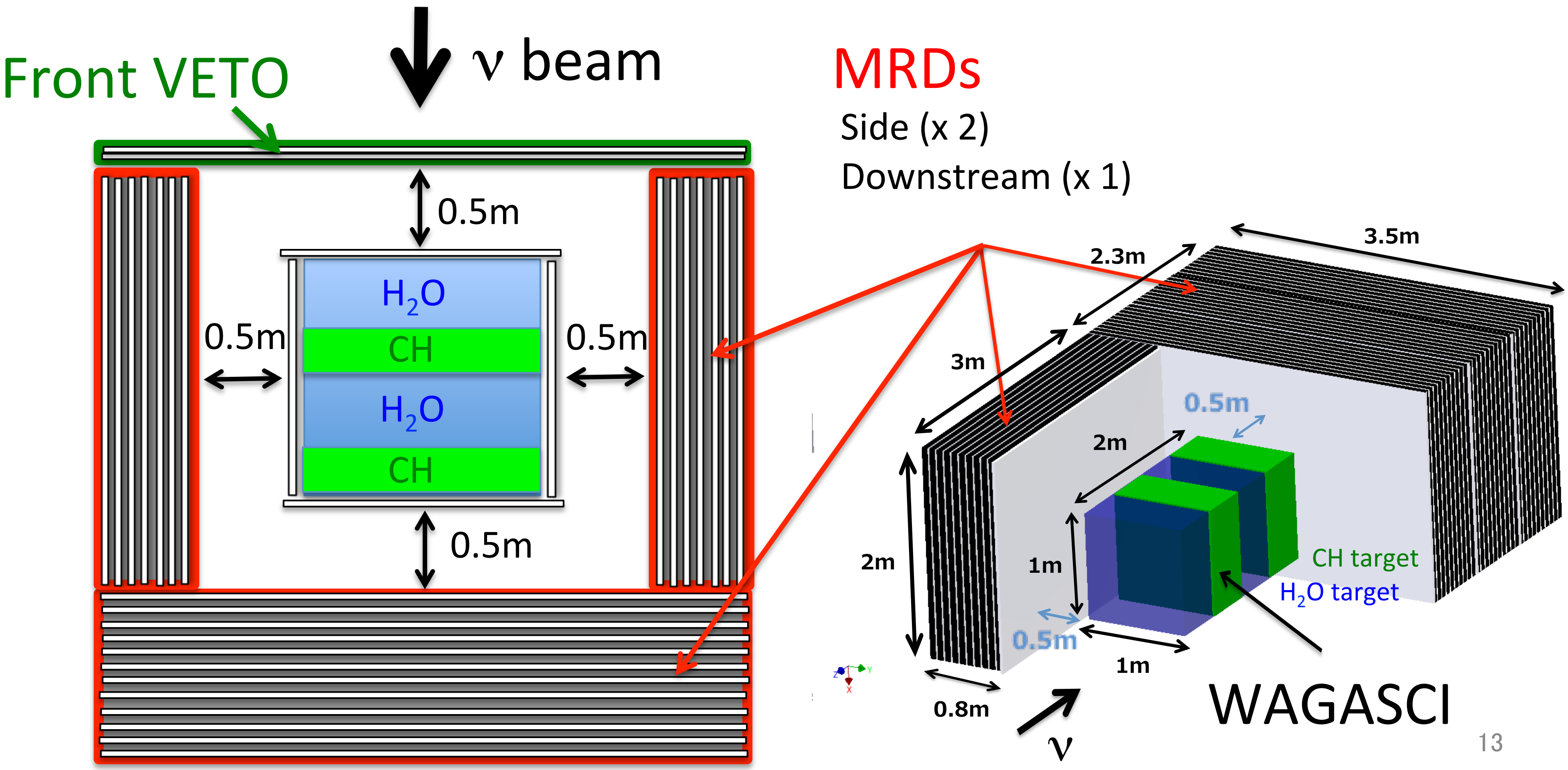
Approved as a test experiment, T-59, at J-PARC PAC.

Project members

- 8 institutes, 41 collaborators
  - **Institute for Nuclear Research of the Russian Academy of Science**
    - I. Ayzenberg, A. Izmaylov, I. Karpikov, M. Khabibullin, A. Khotjantsev, Y. Kudenko, S. Martynenko, A. Mefodiev, O. Mineev, T. Ovsjannikova, S. Suvorov, N. Yershov
  - **KEK**
    - T. Ishida, T. Kobayashi
  - **Kyoto University**
    - T. Hayashino, A.K. Ichikawa, A. Minamino, K. Nakamura, T. Nakaya, K. Yoshida
  - **Laboratoire Leprince-Ringuet, Ecole Polytechnique**
    - A. Bonnemaison, R. Cornat, O. Drapier, O. Ferreira, F. Gastaldi, M. Gonin, J. Imber, Th.A. Mueller, B. Quilain
  - **Osaka City University**
    - K. Kim, Y.Seiya, K. Wakamatsu, K. Yamamoto
  - **University of Geneva**
    - A. Blondel, E. N. Messomo, M. Rayner
  - **University of Tokyo**
    - N. Chikuma, F. Hosomi, T. Koga, M. Yokoyama
  - **Institute of Cosmic-Ray Research, University of Tokyo**
    - Y. Hayato

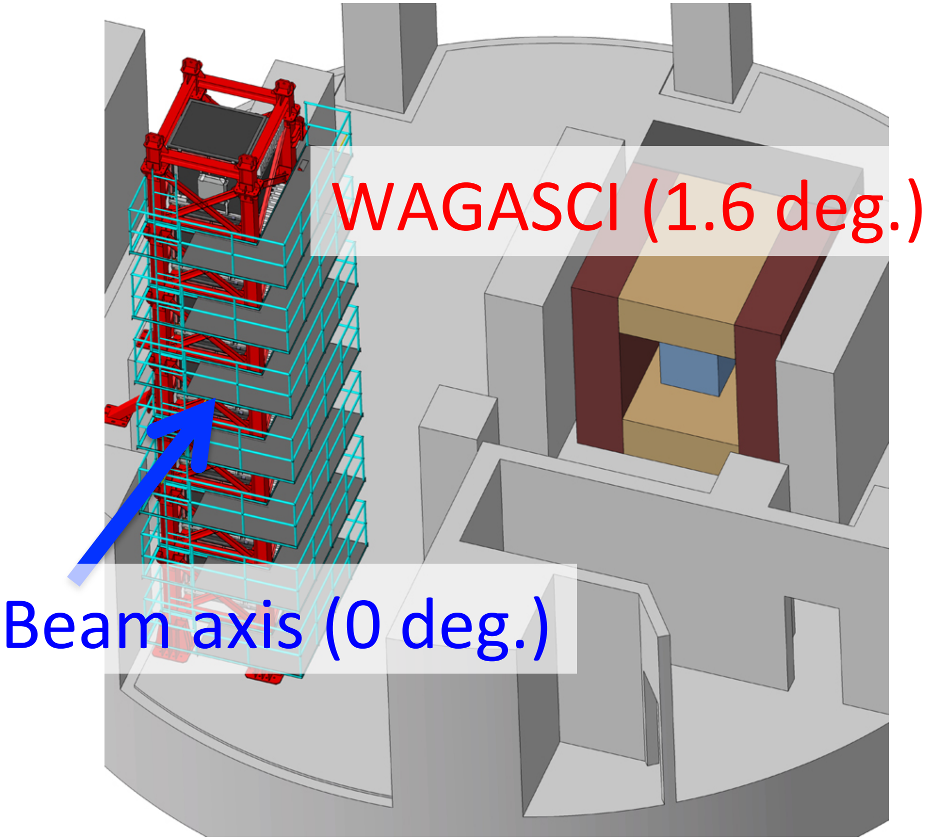
Detector configuration

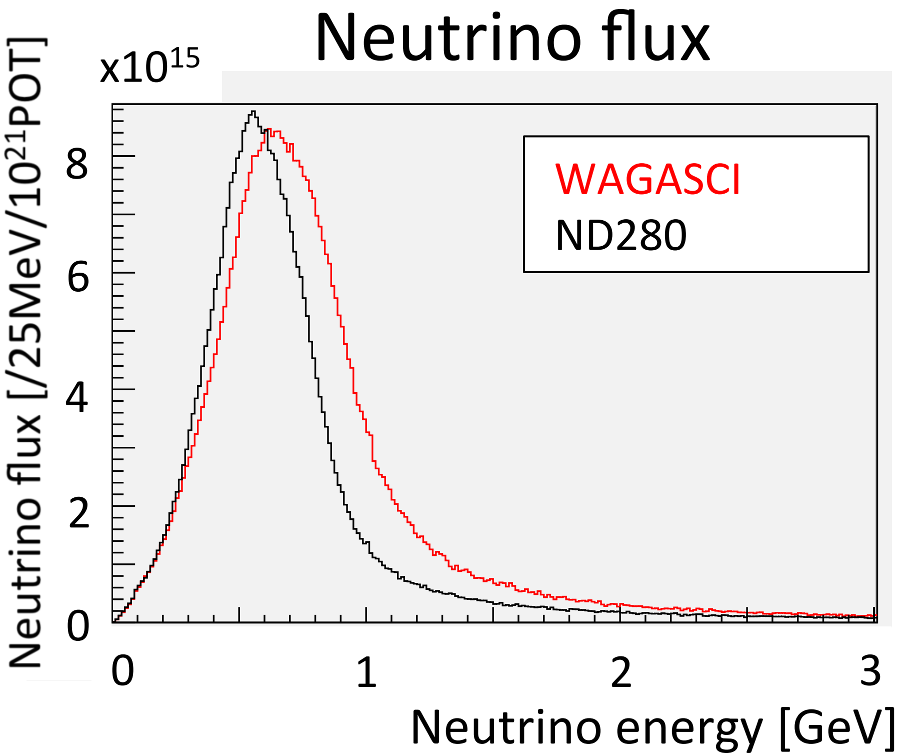
- WAGASCI + muon range detectors (MRDs)
  - MRDs are located 50cm away from the WAGASCI detector to identify the charged particle directions from TOF.



Site

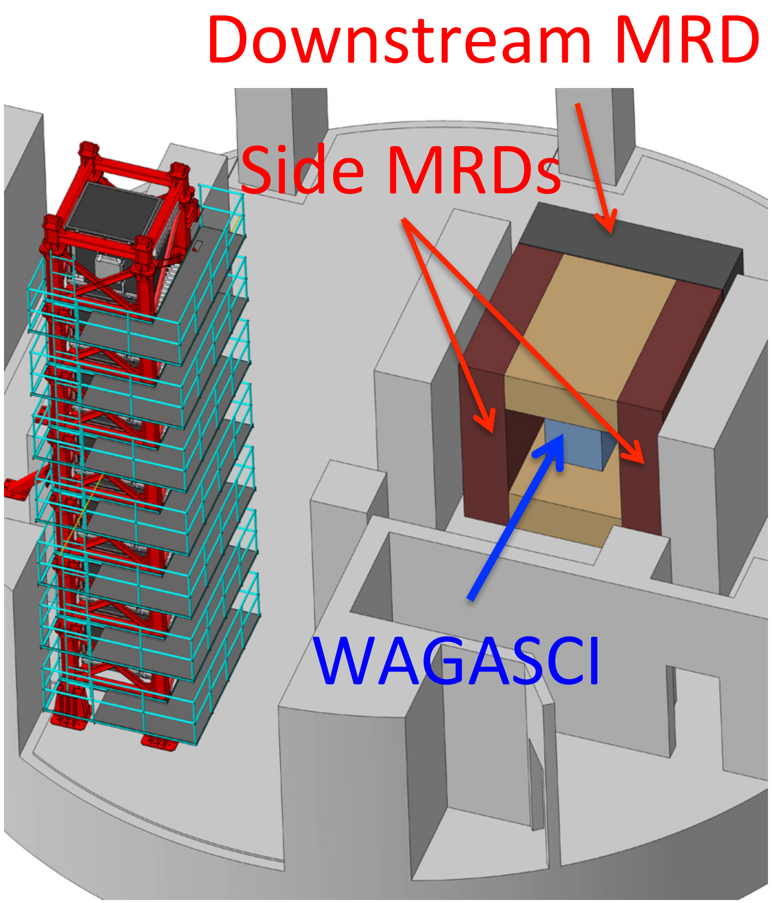
- B2 floor of ND hall
  - Off-axis angle = 1.6 deg.





MRDs

- Side MRDs (x 2)
  - tracking layers + steel plates
  - p_μ up to ~1 GeV/c
- Downstream MRD
  - tracking layers + steel plates
  - p_μ up to ~ 2 GeV/c
  - magnetized steel (optional)
    - μ charge ID for anti-ν run



Goals

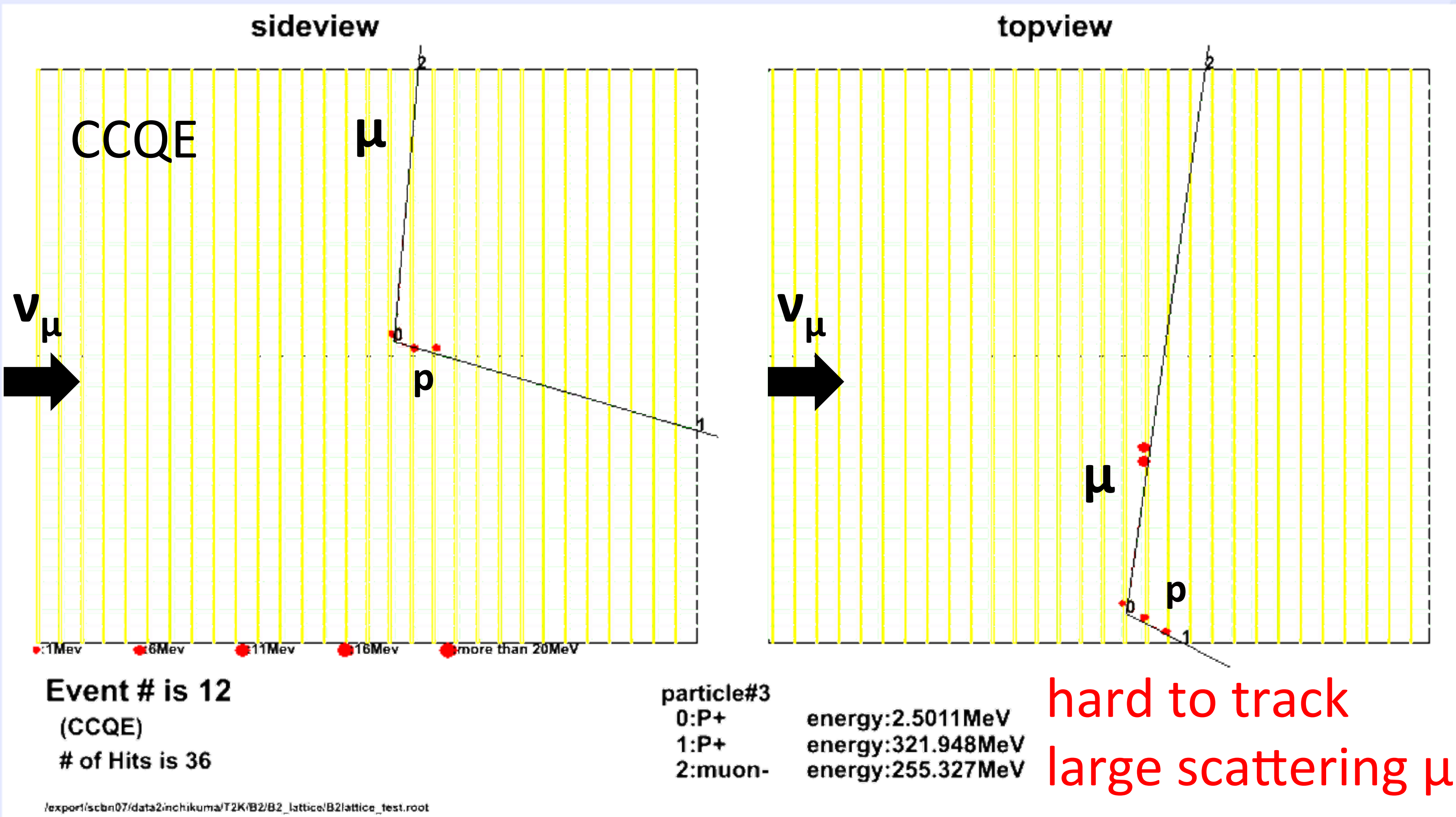
- **Basic performance test of 3-D grid-like detector**
  - Track recon. efficiency, PID capability, TOF cut for BG
- **Cross section ratio, H_2O/CH**
  - 4π acceptance
  - 3% accuracy -> Check if any anomaly exist
  - CC-inclusive channel, then, exclusive channels.
- **Absolute cross section on H_2O (and CH)**
  - 4π acceptance
  - 10% accuracy (Flux error is dominant.)
  - Double differential cross sections for (T_μ, $\cos\theta_\mu$)
  - CC-inclusive channel, then, exclusive channels.

MC study

Event display

T. Koga, N. Chikuma
(Univ. Tokyo)

w/o grid layer



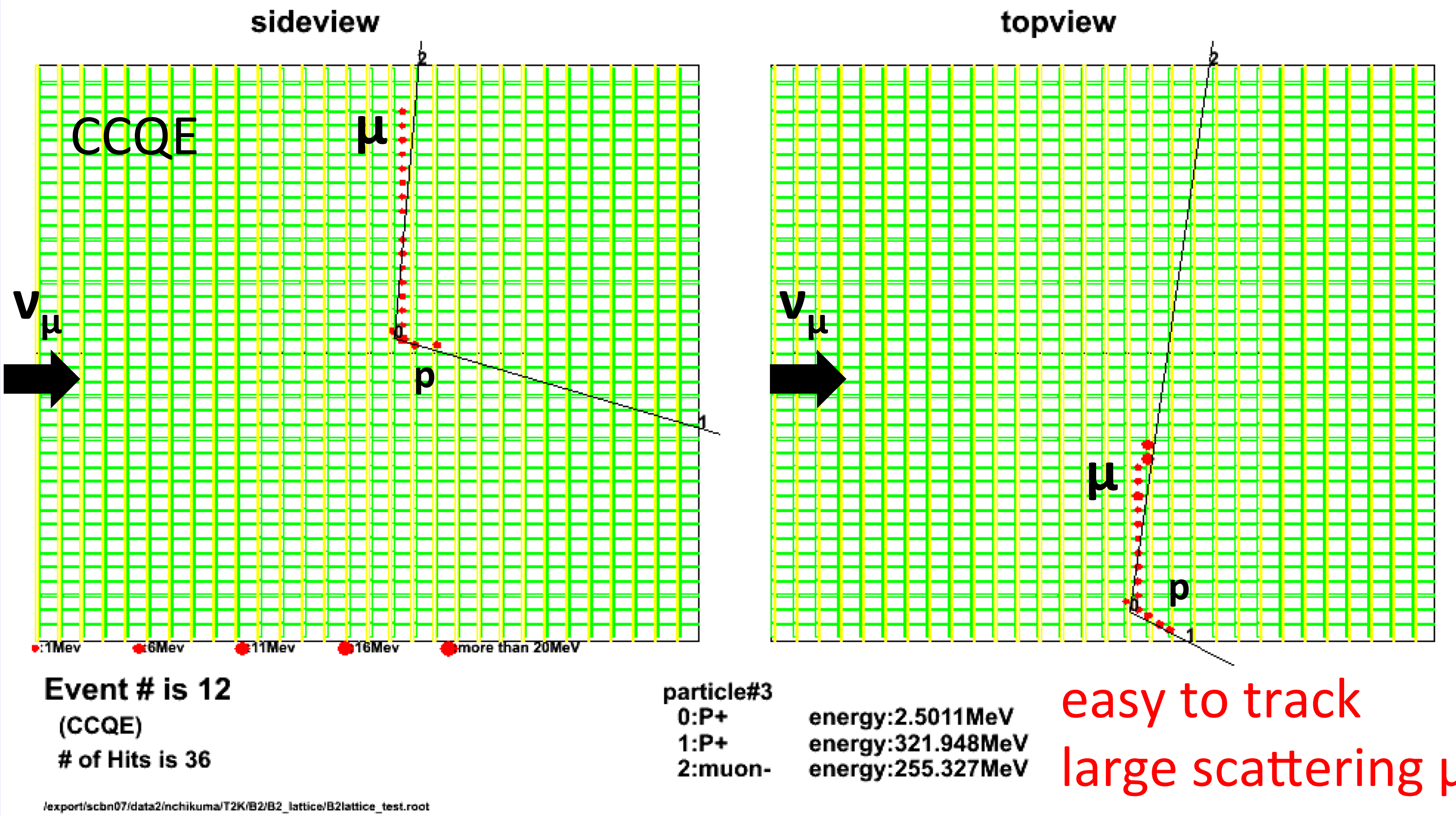
hard to track

large scattering μ

Event display

T. Koga, N. Chikuma
(Univ. Tokyo)

with grid layer

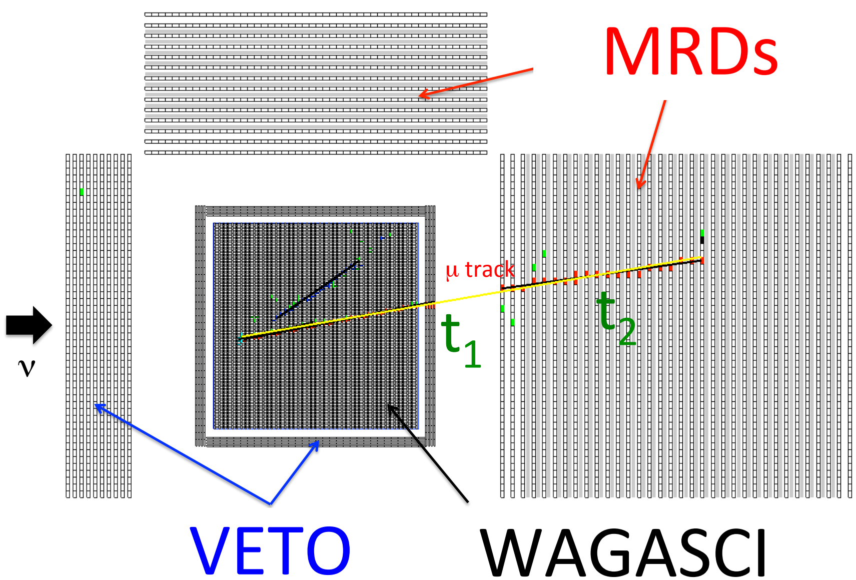


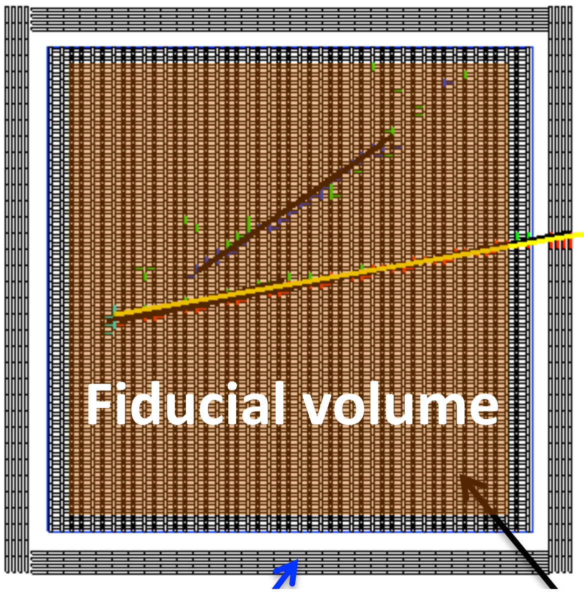
easy to track

large scattering μ

Event selection for CC-inclusive

- WAGASCI/MRD matched track, stopped in MRDs
  - Select a long muon track from CC interaction.
- TOF ($t_1 < t_2$) cut for charged particle BGs
- WAGASCI fiducial volume cut



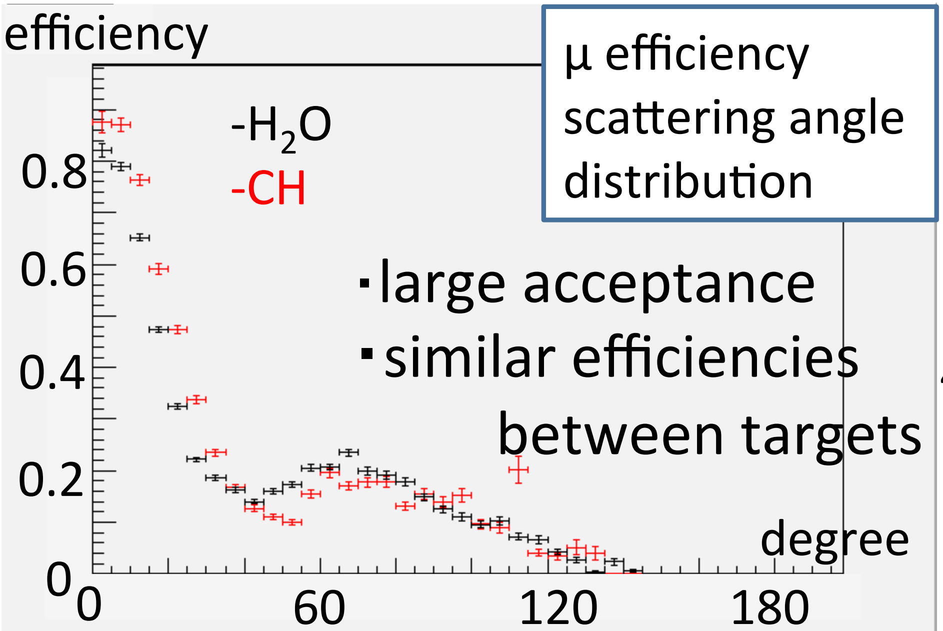


Performance for CC-inclusive (MC)

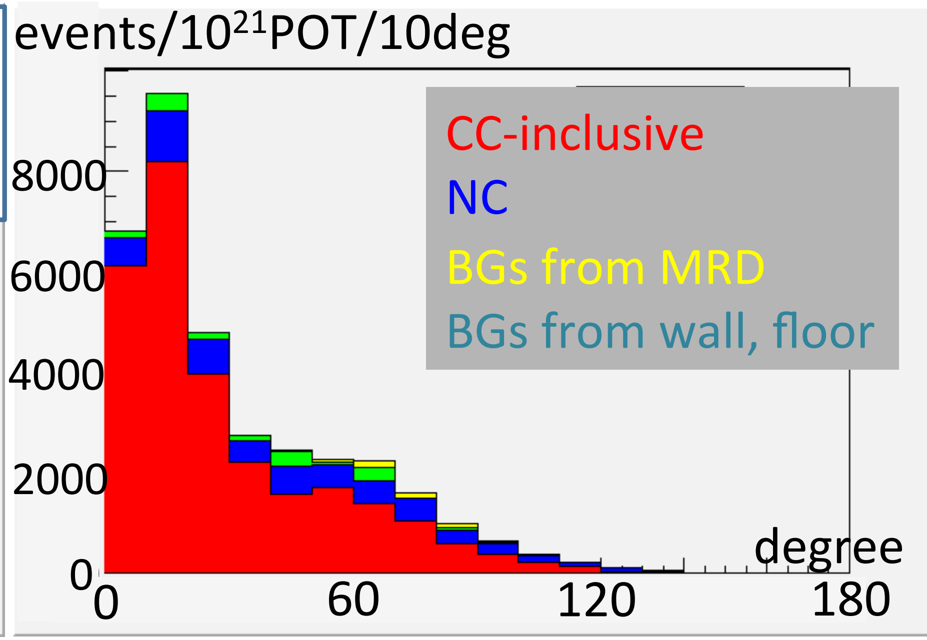
neutrino run

T. Koga (Univ. Tokyo)

μ efficiency scattering angle distribution



- large acceptance
- similar efficiencies between targets



	CC	NC	BG from outside	All
Events/10^{21}POT	31466	1608	1832	43440
Fraction	90.1%	4.7%	5.2%	100%

low BG

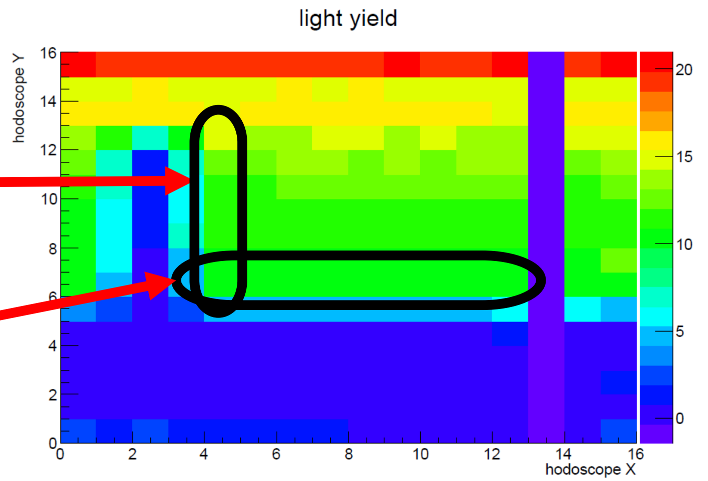
R&D
of detector components

3mm-thick scinti. for WAGASCI

- Positron beam test at Tohoku Univ. on Dec., 2014.

Scinti.: test production @ Fermi lab
2^{nd} gen. MPPC (ΔV=4.0V)

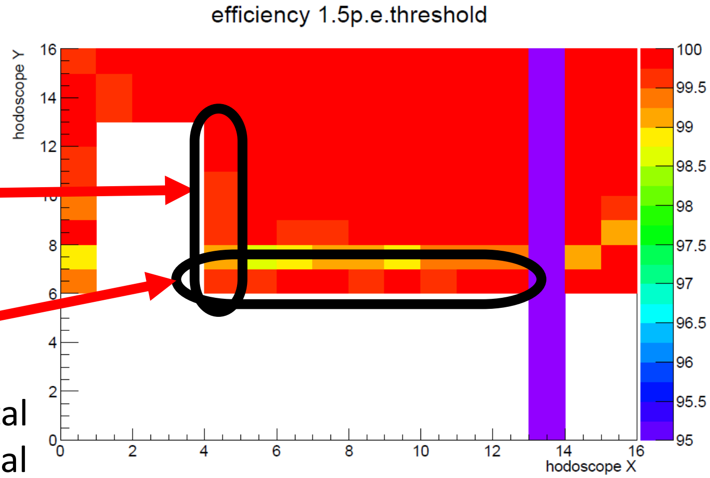
Light Yield



The average for these 7 bins at the edge*1 :
11.34 $\pm$ 0.11p.e.

The average for these 9 bins at the edge*2 :
10.41 $\pm$ 0.09p.e.

Efficiency



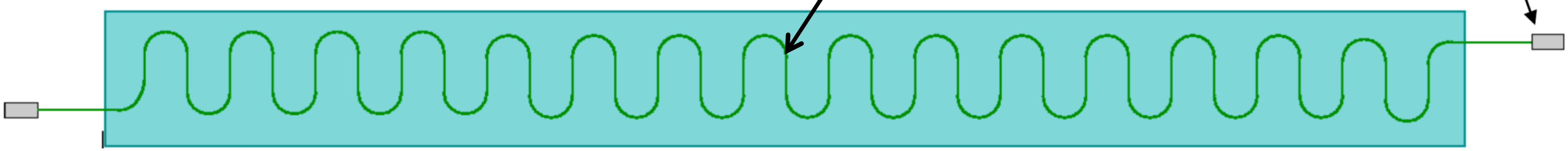
The average for these 7 bins at the edge*1 :
99.60 $\pm$ 0.94%

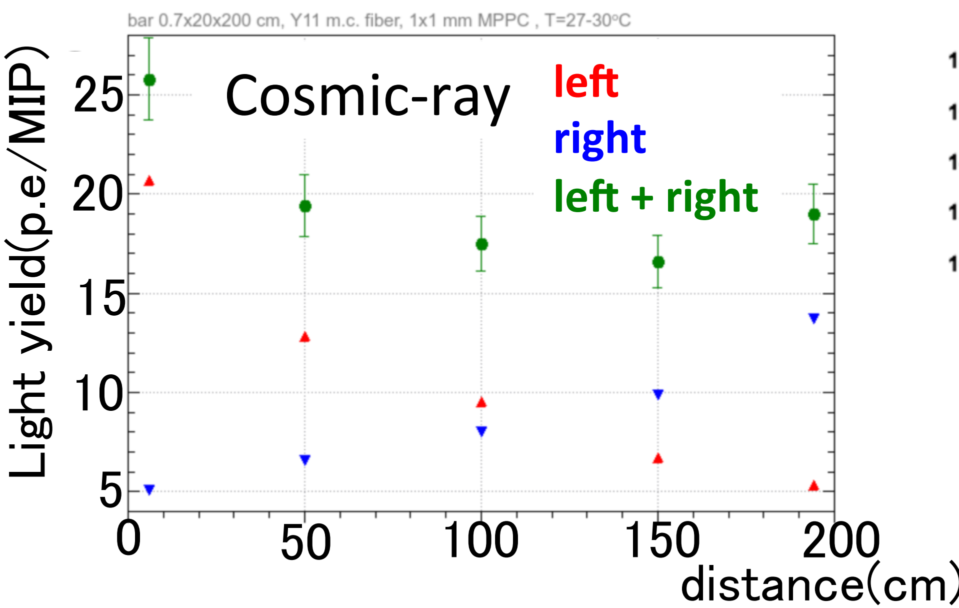
The average for these 9 bins at the edge*2 :
99.78 $\pm$ 0.91%

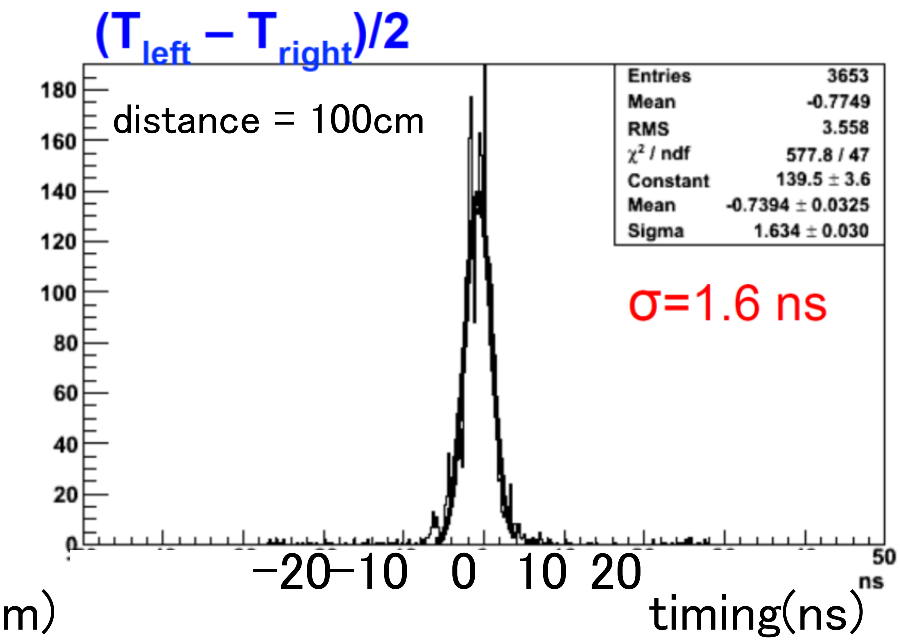
*1 ch # is 4 in vertical, 6~12 in horizontal
*2 ch # is 4~12 in vertical, 6 in horizontal

A. Izmaylov (INR)

MRD scintillator







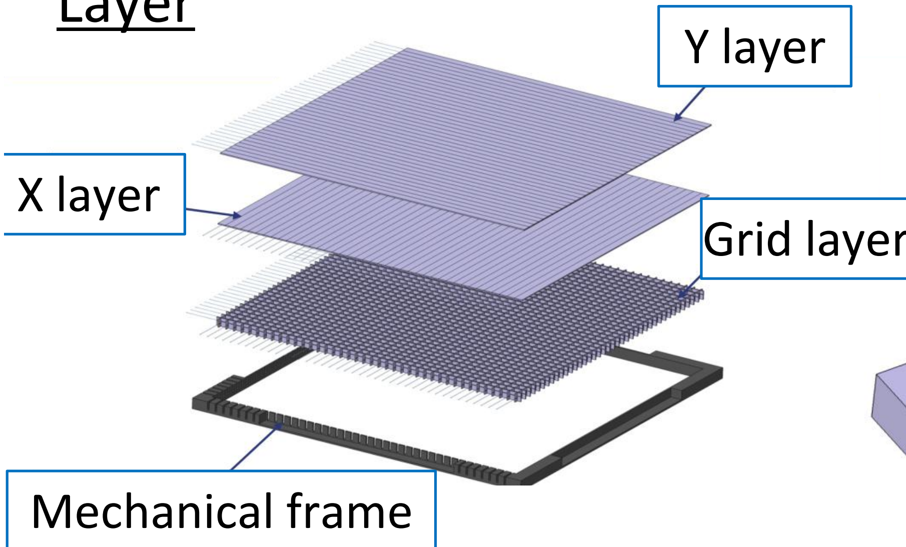
- -Light yield > 17 p.e/MIP.
- -Detection efficiency > 99.5% (5 p.e. thre.)
- -Timing resolution = 1.6 ns.

good performance!

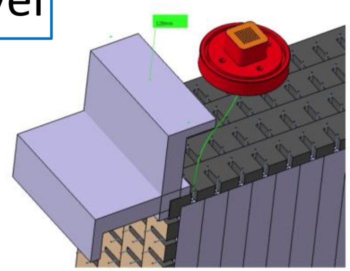
Mechanical design

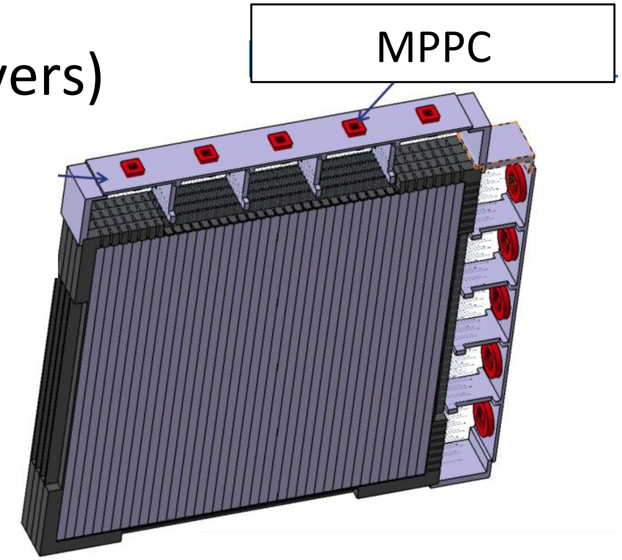
A. Bonnemaison/
O. Ferreira (LLR)

Layer

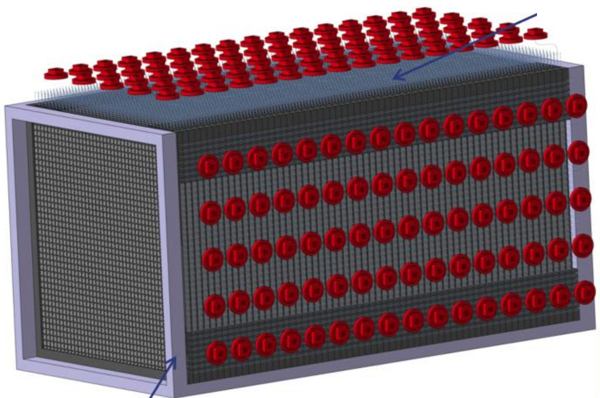


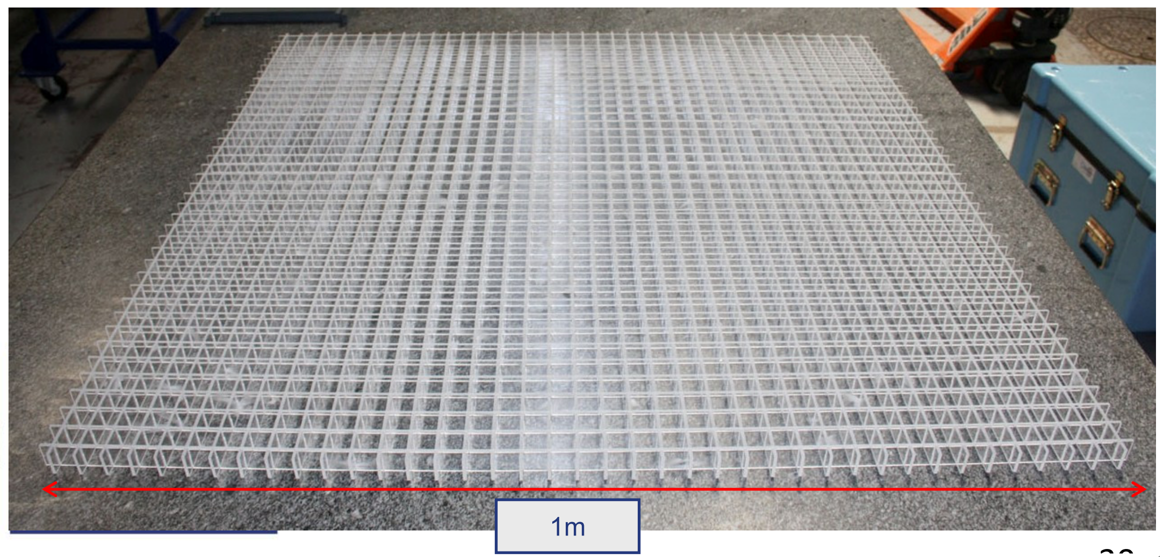
Module(4layers)





Detector(16modules)



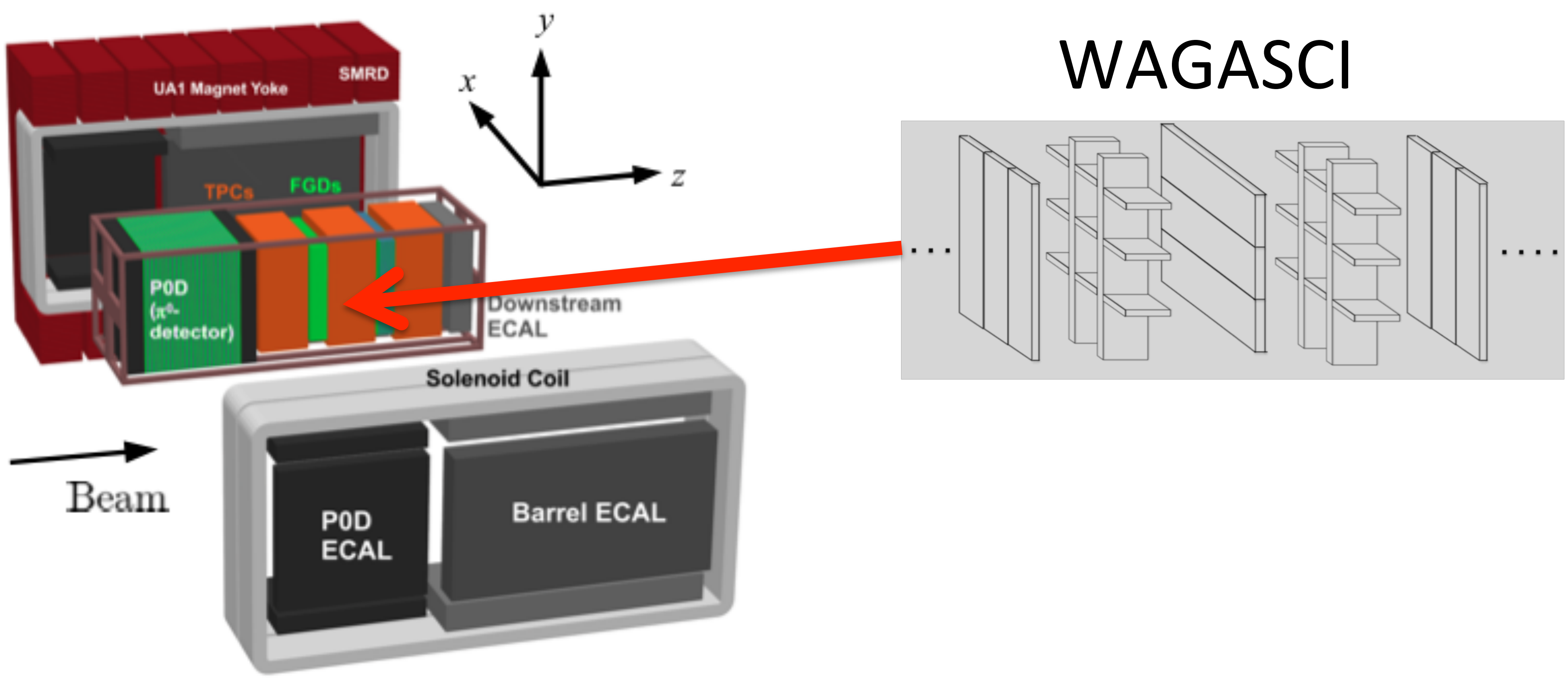


Schedule

- **WAGASCI**
  - May, 2015: Final mechanical drawing
  - Aug. – Nov., 2015: Construction
- **Side (Downstream) MRDs**
  - May, 2015 (Jul., 2015): Final mechanical drawing
  - Dec. – Feb., 2016 (Mar. – May, 2016): Construction
- **Installation/Commissioning @ ND hall**
  - Mar. –Sep., 2016
- **Start operation**
  - Oct., 2016

Possible upgrade

- Install an upgraded WAGASCI into ND280 magnet.
  - 4π-acceptance water-target near detector



Discussion is just getting started.

Summary

- We are developing a new water-target neutrino detector, WAGASCI.
- WAGASCI was approved by J-PARC PAC as a test experiment.
- Start operation on Oct. 2016.

- Possible upgrade: WAGASCI into ND280 magnet

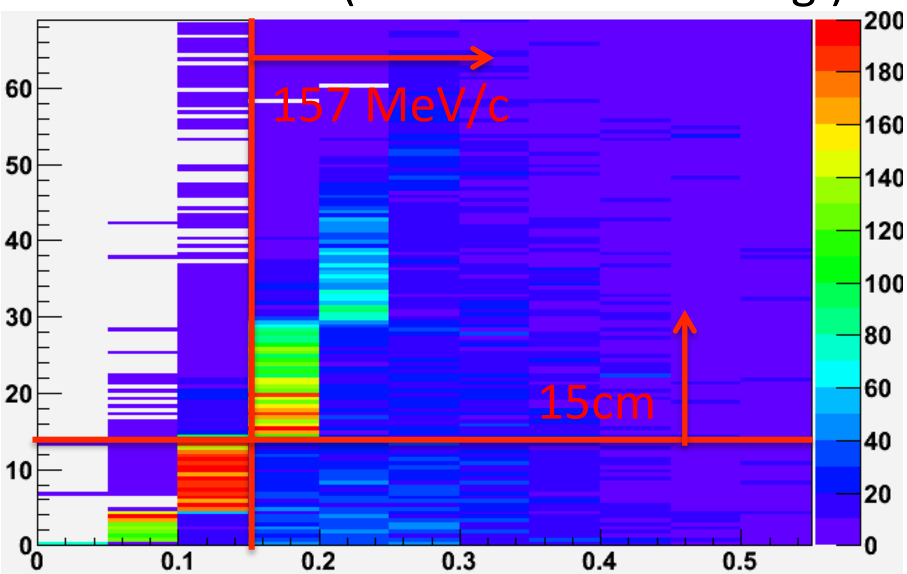
Backup

Motivation

- An ideal near detector for Hyper-K/J-PARC
  - Momentum thresholds of charged particles are lower than Cherenkov thresholds in H_2O

CC1π^+ events (T2K off-axis = 1.6 deg.)

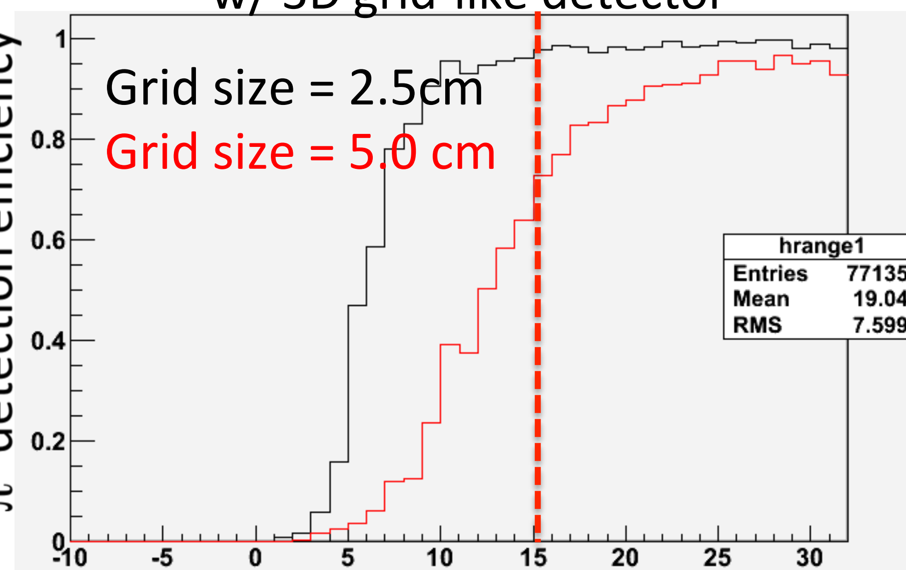
π^+ range in H2O (cm)



π^+ momentum (GeV/c)

π^+ detection efficiency w/ 3D grid-like detector

π^+ detection efficiency



π^+ range in H_2O (cm)