Neutrino experiments with Nuclear Emulsion at J-PARC

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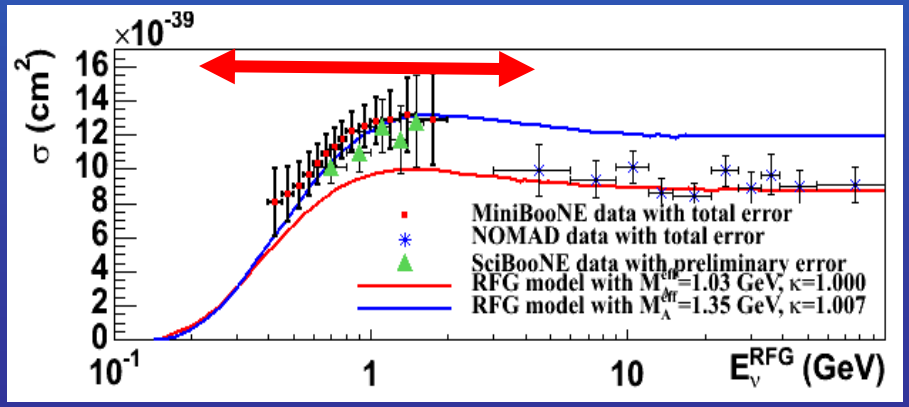
on behalf of J-PARC T60 group

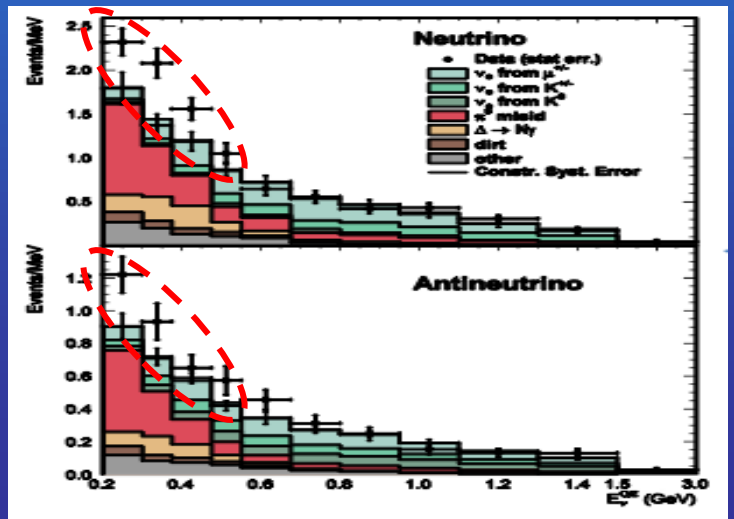
Neutrino Frontier Workshop 2014, 22nd Dec. 2014 @Fuji Calm

Introduction

- We are planning new experiments at J-PARC to study low energy neutrino interactions by introducing nuclear emulsion technique.
- The emulsion technique can provide good measurements with ultimate position resolution.
- Physics motivation is a detailed (exclusive) study of low energy neutrino – nucleus interactions for a variety of target (H_2O,Fe,C) and

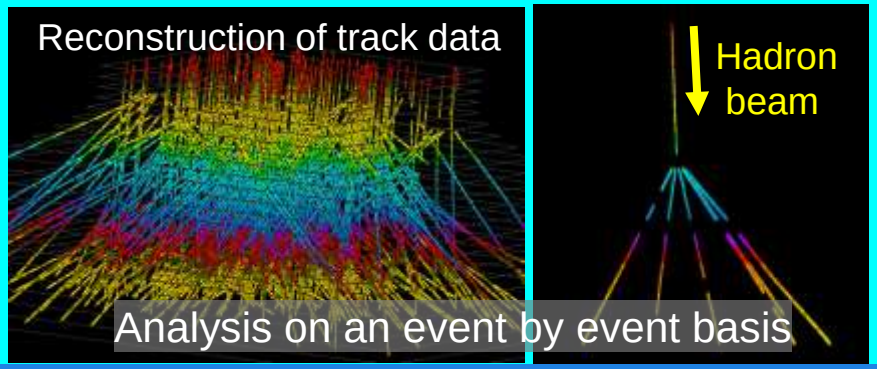
  cross section measurement of low energy ν_e interaction and the exploration of a sterile neutrino.

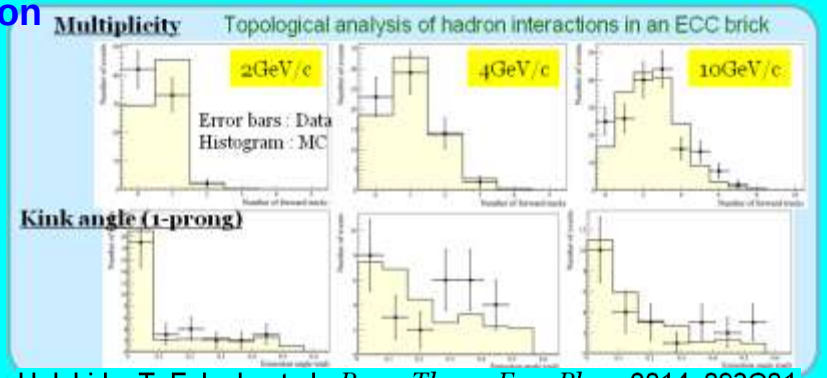




Advantage of Emulsion

Systematic analysis with sub-micron position resolution

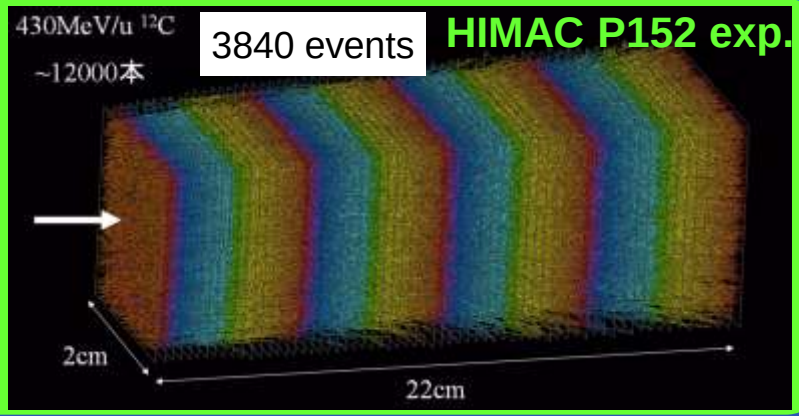




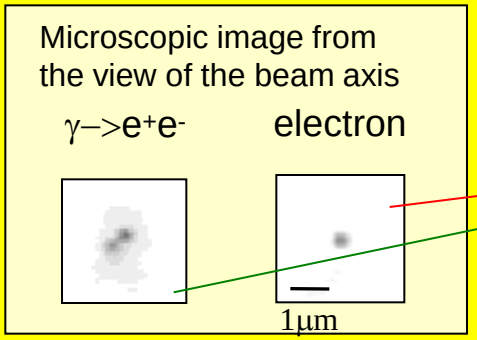
H. Ishida, T. Fukuda et al., *Prog. Theor. Exp. Phys.* 2014, 093C01

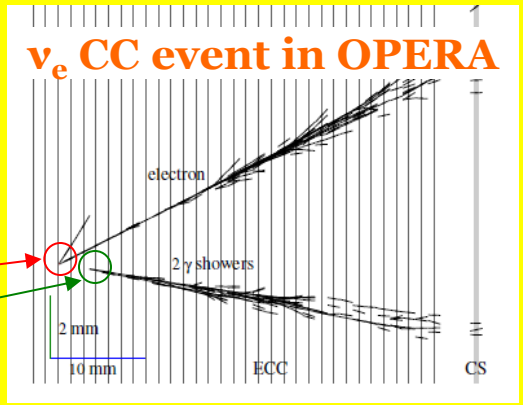
Flexibility for target material

A sandwich structure



γ/ electron ID





Low background from ν_μNCπ^0 production

Primary electron track is observed as a isolated track, not as a pair of tracks.

Roadmap

Preliminary measurements RUN — Feasibility study at J-PARC

J-PARC T60 experiment

Future plan

Detector RUN — Detector performance check

Target mass: 10- 30kg

Physics RUN Ⅰ — Neutrino-nucleus interaction study

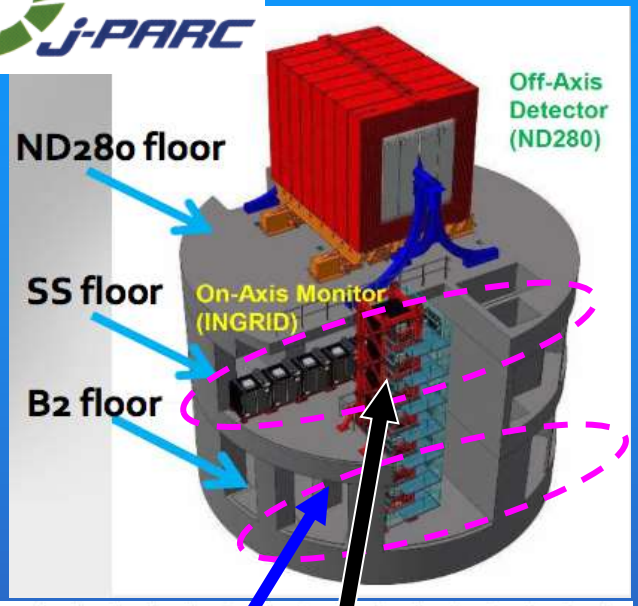
Target mass: 100- 300kg

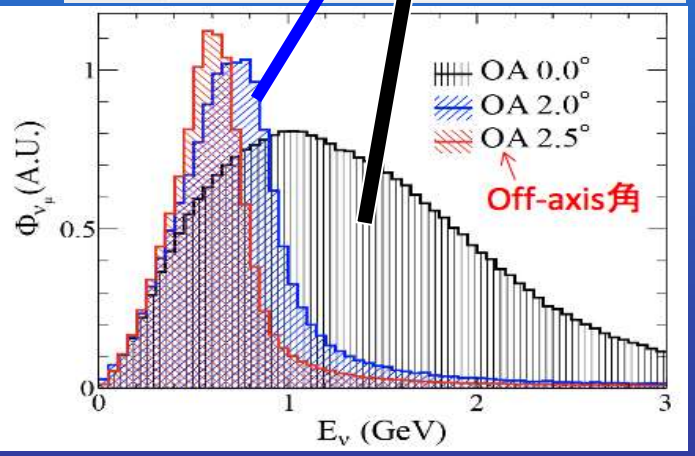
Physics RUN Ⅱ — Search for sterile neutrino

Target mass: 1- 3ton
Target mass: 6-10ton

- The aim of T60 is a feasibility study to make a future plan.
- We will expand the scale of detector gradually, step by step.

J-PARC T60 experiment



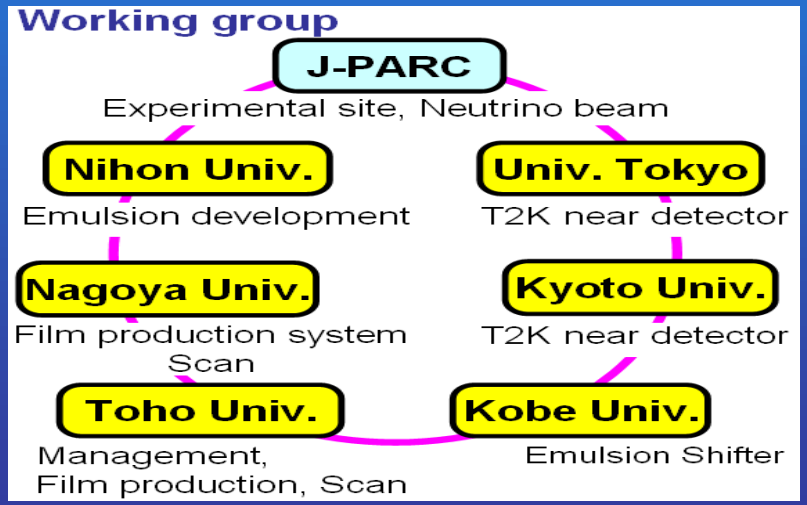


Proposal of an emulsion-based test experiment at J-PARC

Exclusive summary

A test experiment is proposed that equips Emulsion Cloud Chamber as a main detector in order to investigate environmental and beam associated background at the T2K near detector hall in J-PARC, optimal detector structure, and performance of newly developed nuclear emulsion gel. The aim of the experiment is a feasibility study to make a future experimental plan for the study of low energy neutrino-nucleus interactions and the exploration of a sterile neutrino.

- J-PARC PAC endorsed as a test experiment (T60).
  ν beam exposure: end of Oct. – end of Dec. 2014.

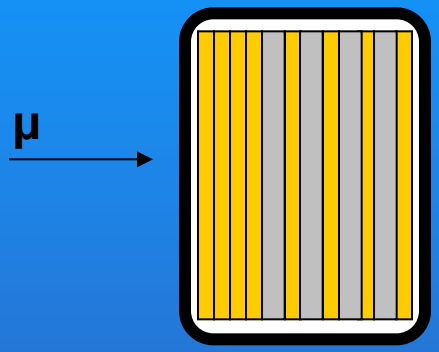


A collaborative project with some member of OPERA and T2K in this research program (Neutrino Frontier).

Detector setup in T60

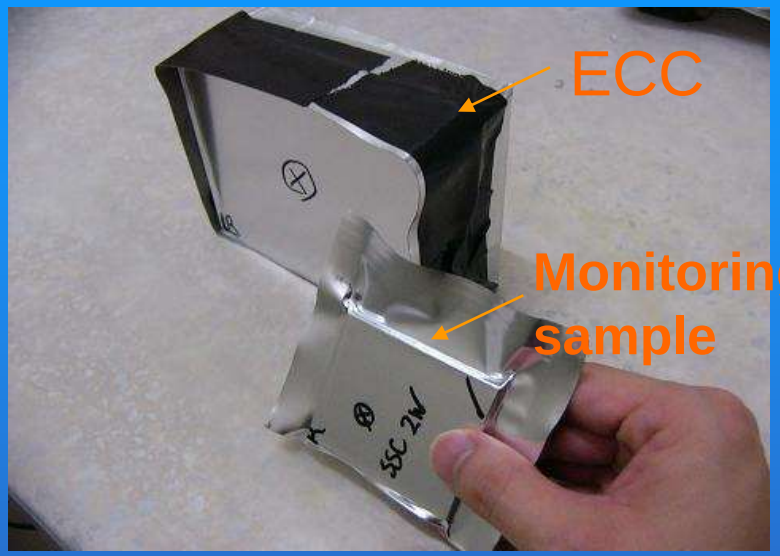
[i] Monitoring sample

Small size ECCs (5cm x 6cm x 0.5cm ; ~0.1kg)



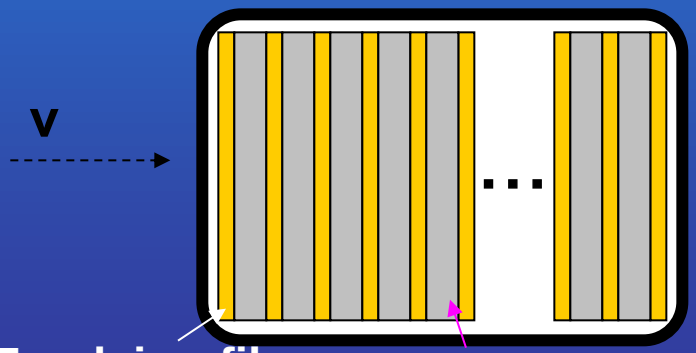
8 films
(~0.3mm thickness)
+
4 iron plate
(0.5mm thickness)

Check noise rate, film condition, etc



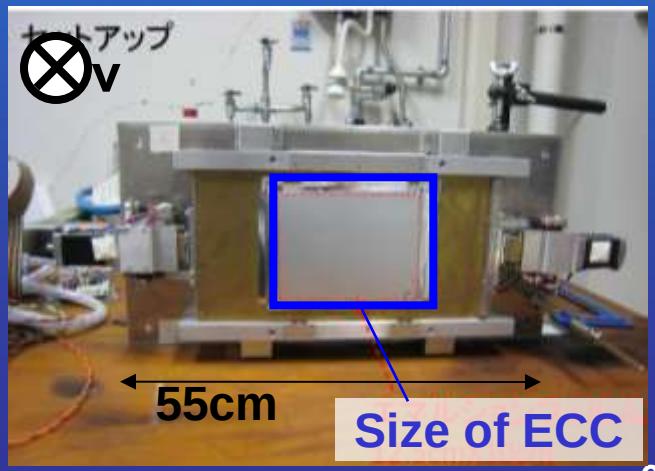
[ii] **E**mulsion **C**loud **C**hamber

A standard-size ECC (10cm x 13cm x 5cm ; ~3kg)



61 films
(~0.3mm thickness)
+
60 iron plates
(0.5mm thickness)

Multi stage emulsion shifter

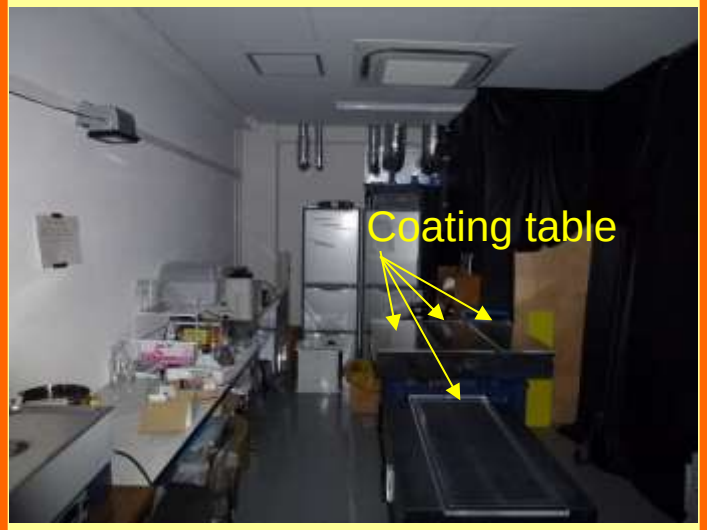


Preparation of emulsion films

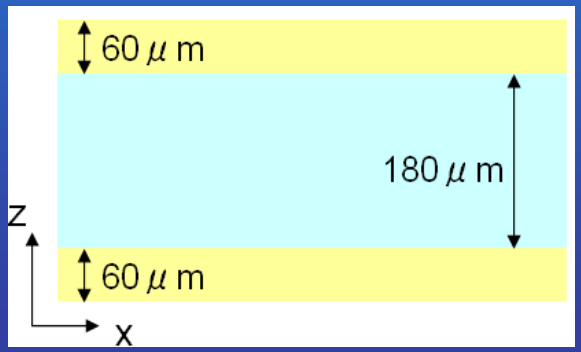
Nuclear emulsion gel production system at Nagoya Univ.

5 batch were produced.

Emulsion coating



6 sheets were produced.

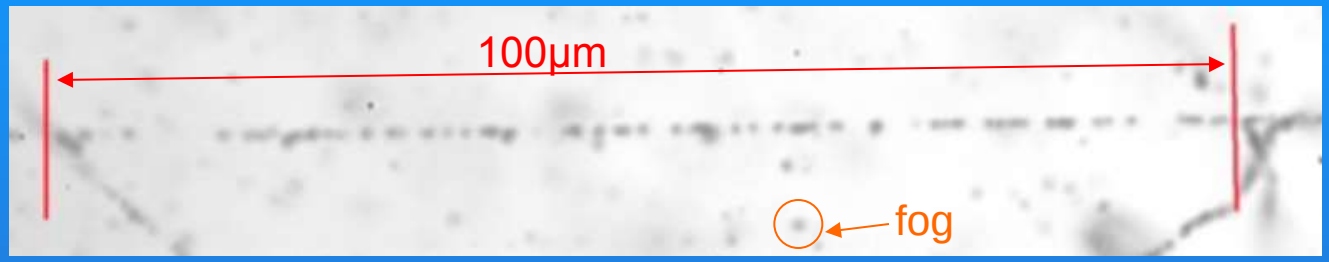


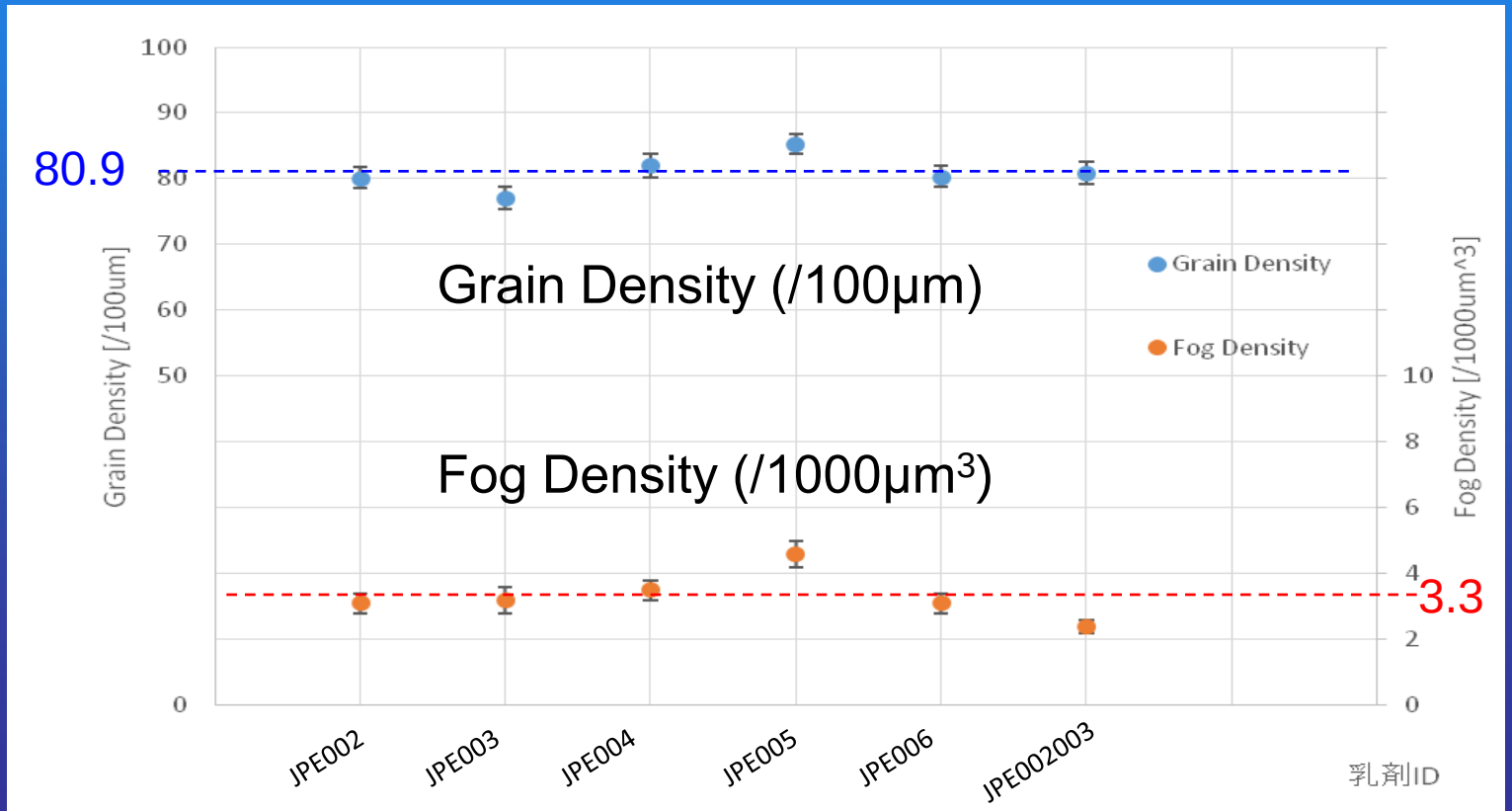
Emulsion coating:
Both sides of plastic base

Nagoya member were helped to produce emulsion films.
Thanks, H. Rokujo, N. Naganawa, H. Kawahara.

Nuclear emulsion films for T60

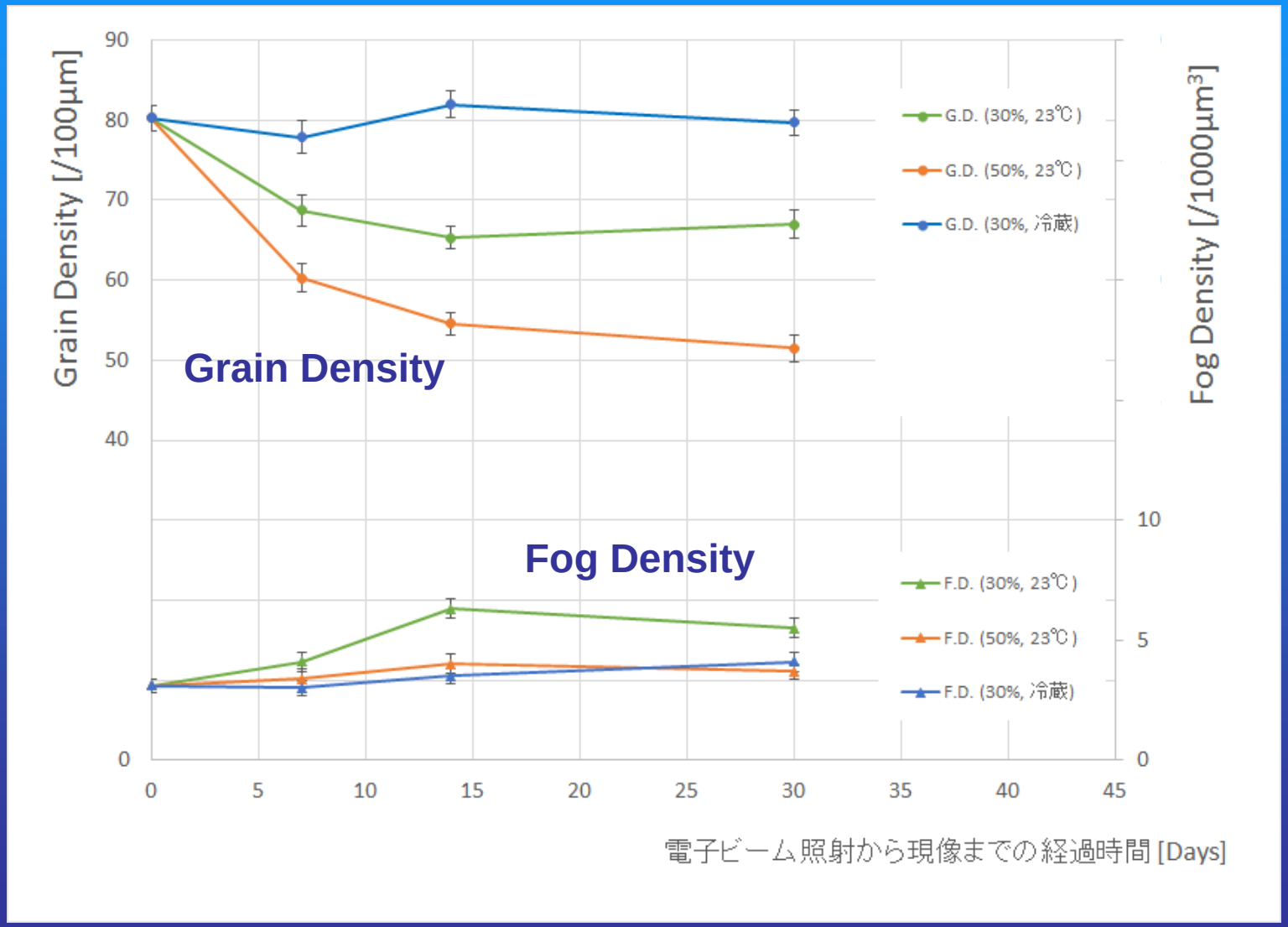
Initial performance:
efficiency and noise density measurement based on grain counting.





Nuclear emulsion films for T60

Aging characteristics (fading effect):
efficiency and noise density measurement based on grain counting.



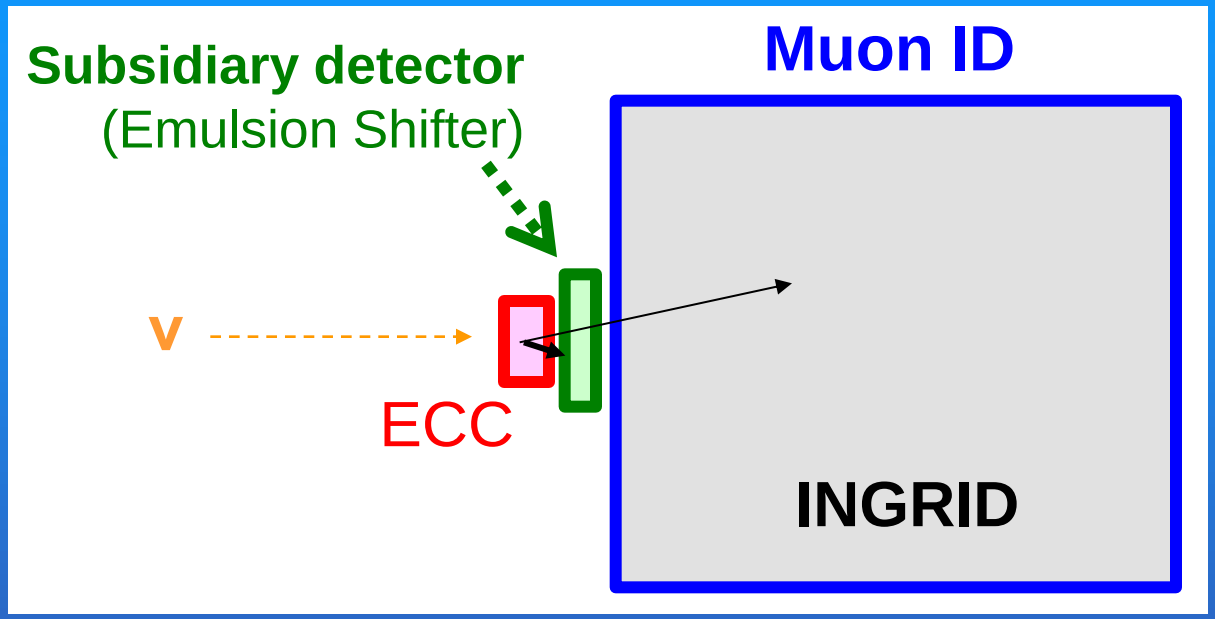
Preparations for experiment

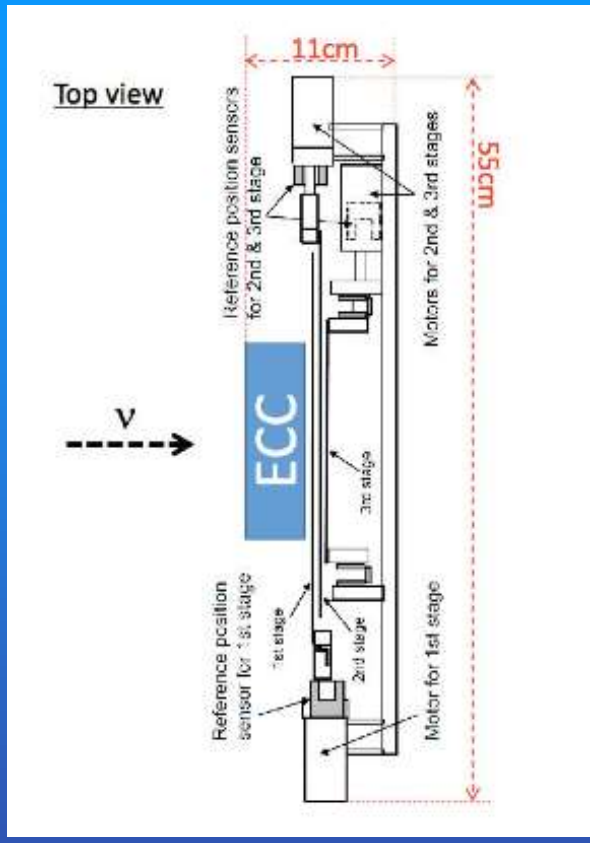
Dark room for development was prepared at Toho Univ.

Test development

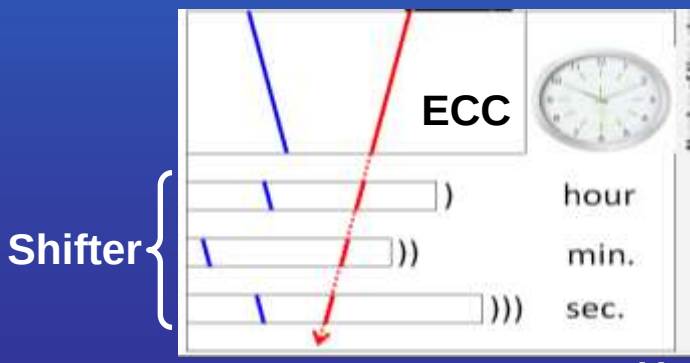
Emulsion – Counter hybrid method

Conceptual design



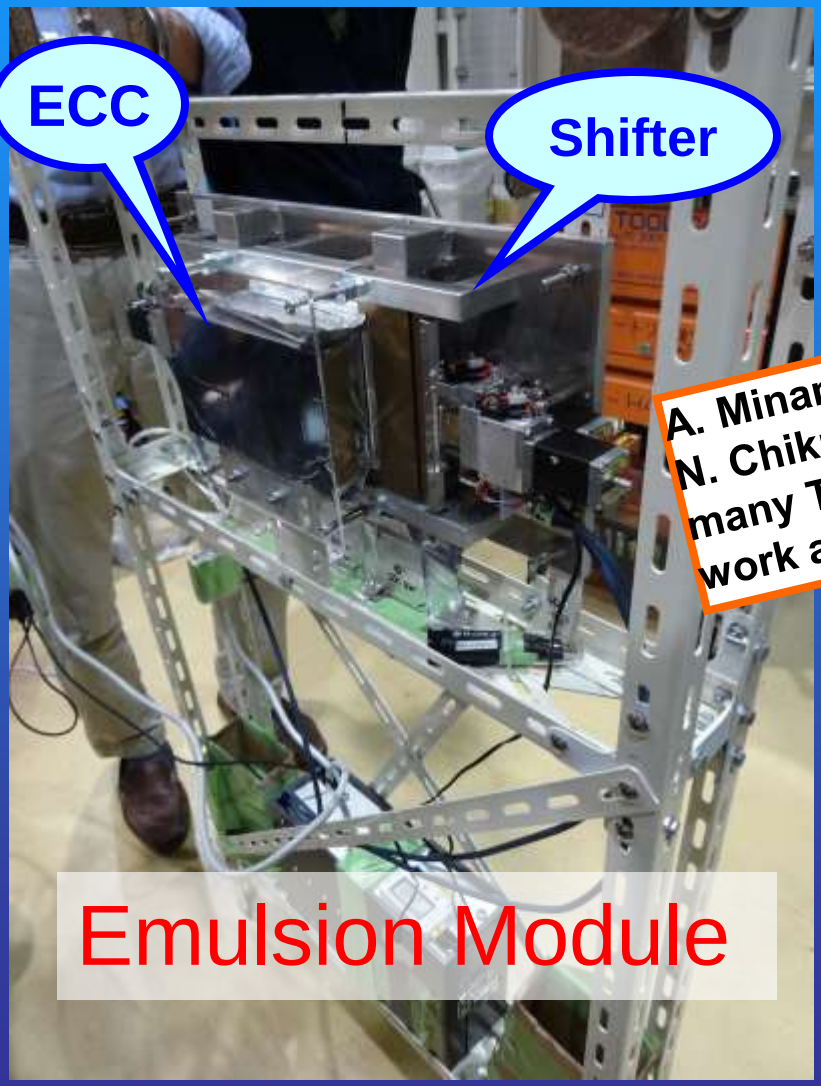


- ECC is placed in front of the INGRID module for muon ID. (T2K near detector)
- Emulsion Shifting system is placed between ECC and INGRID in T60.
- Emulsion Shifting system give a timing info. to emulsion tracks.
- Tracks in ECC is given muon ID from INGRID by timing matching method.

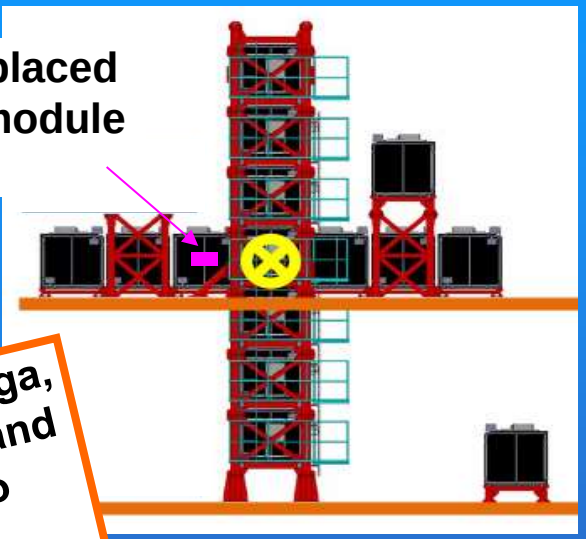


Detector install at J-PARC

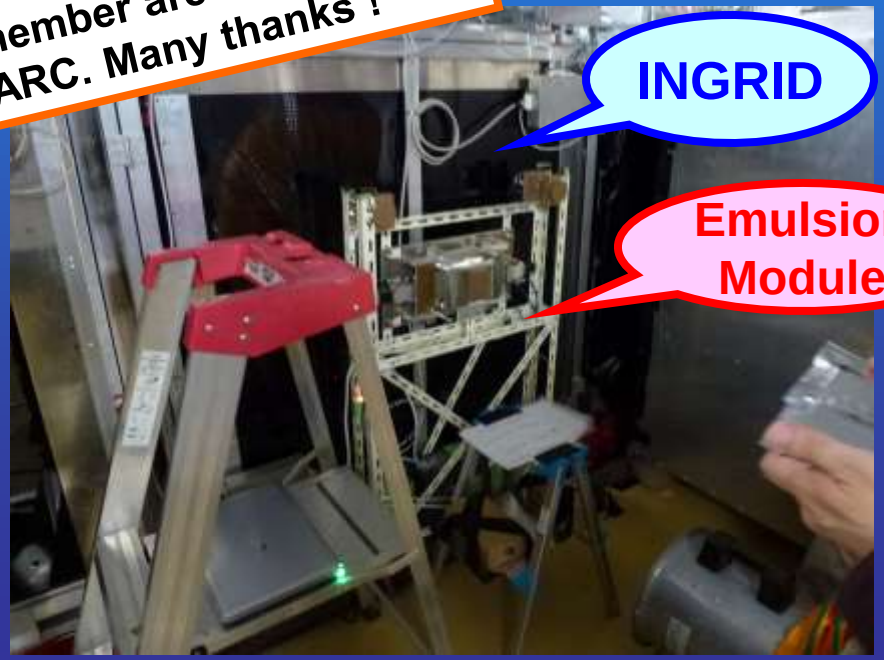
ECC and Shifter are installed in steel frame, so called the Emulsion Module.



Emulsion Module was placed in front of the INGRID module at SS floor.

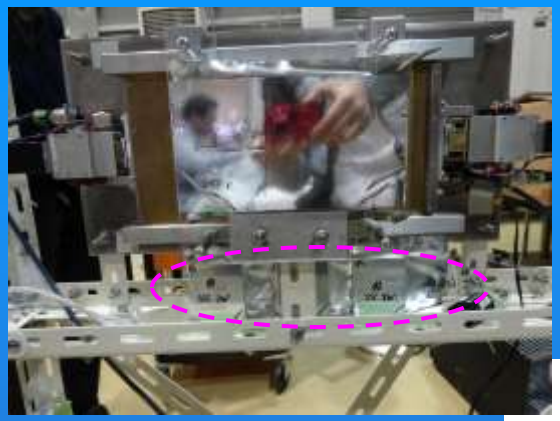


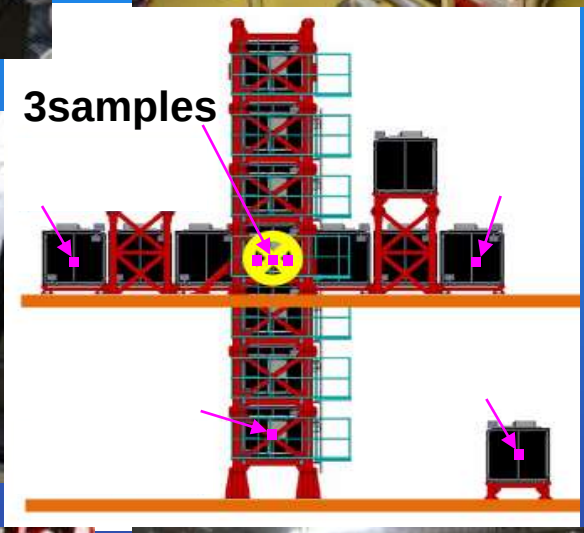
A. Minamino, T. Hayashino, T. Koga, N. Chikuma, F.Hoshomi, S. Cao and many T2K member are helped to work at J-PARC. Many thanks !



Detector install at J-PARC

Monitoring sample





7 monitoring samples were also placed in front of the INGRIDs.

3 samples at Center position at SS floor were uninstalled at different timing.

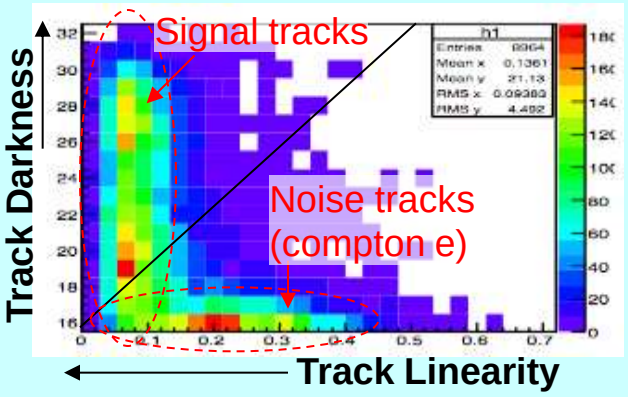
Another 1 sample was immediately developed without setting as a reference.

Analysis of monitoring sample

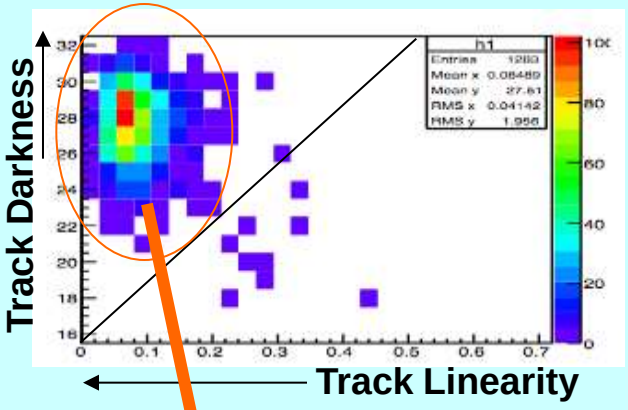
Preliminary

Reference sample

Track data of only one plate



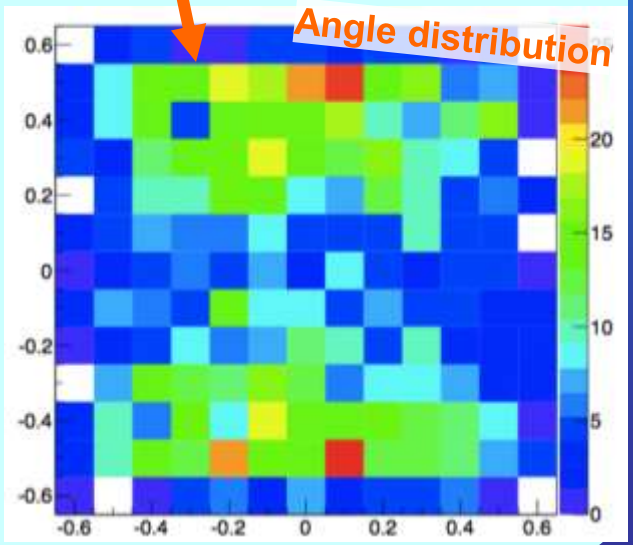
Connected track data



Bad linearity and thin tracks are chance coincidence of compton electrons.

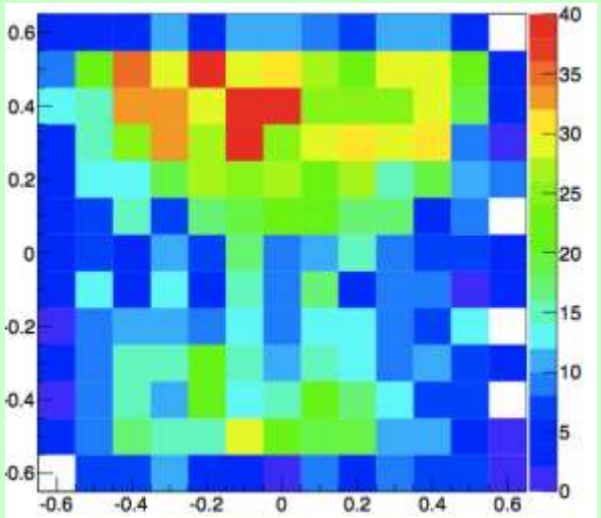
Good linearity and dark connected tracks are cosmic ray exposed in 3 days before development.

Good linearity and thin tracks are accumulated cosmic ray before final process (40℃, 50%) in film production.



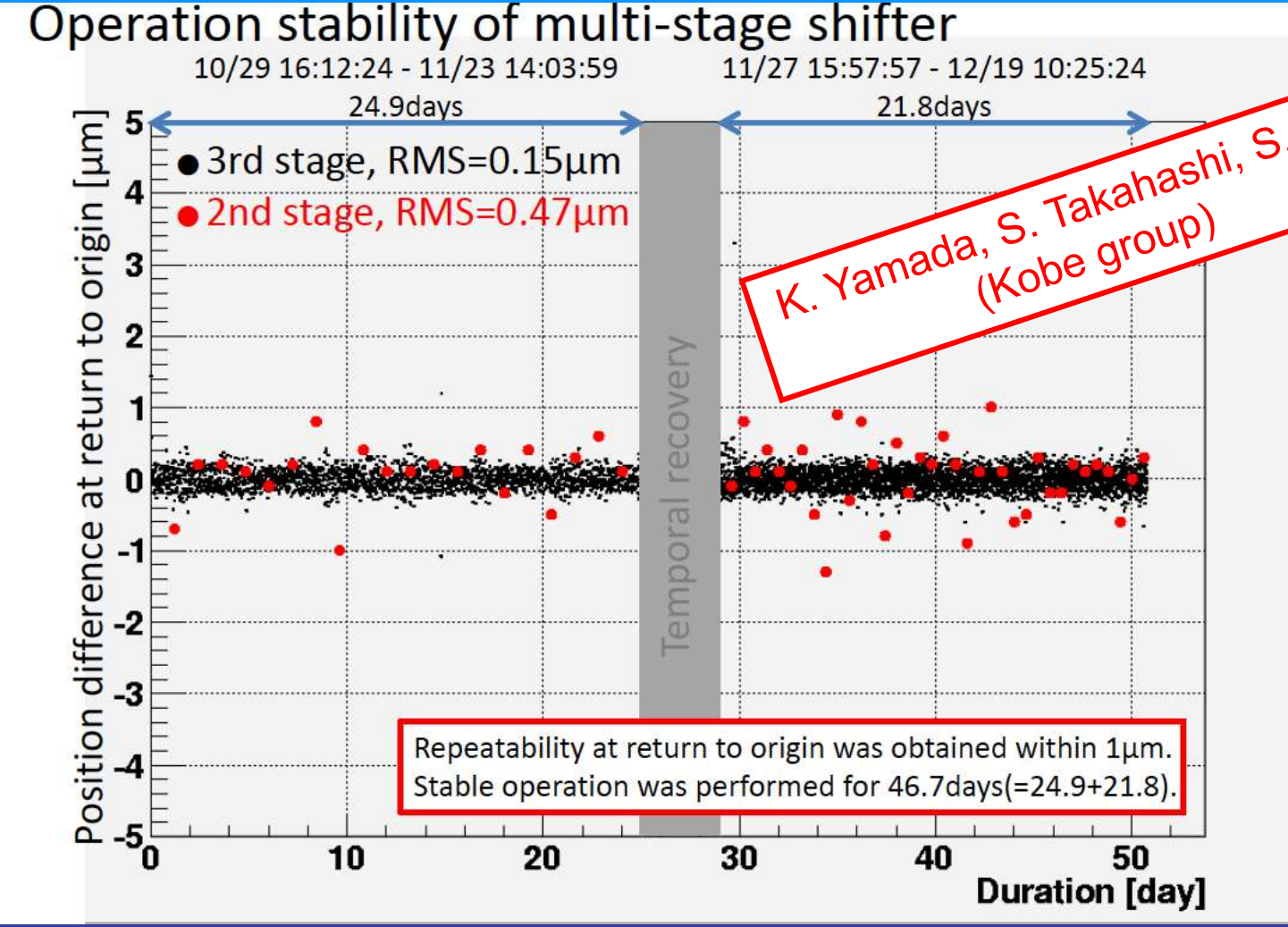
3 weeks sample

If we compare track data between reference and 3 weeks sample, We get beam and cosmic ray info. at the experimental hole in J-PARC statistically.



Angle distribution
3 weeks in the experimental hole

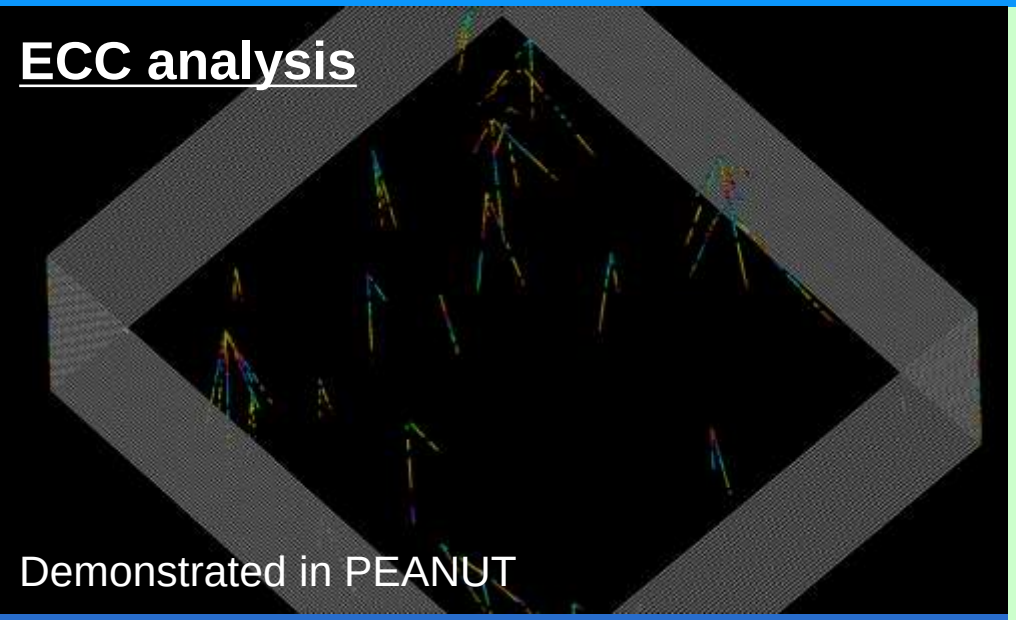
Working status of Emulsion Shifter



Emulsion Shifter is working very well.

Future analysis

ECC analysis



Oct. 30-Nov.25	vmode : 0.156 x 10^{19} p.o.t. $\overline{\text{v}}$mode : 5.536 x 10^{19} p.o.t.
Nov.29-Dec.11 (→ Dec.22)	$\overline{\text{v}}$mode : 3.567 x 10^{19} p.o.t.

➡ ~50 anti-neutrino interaction events are accumulated in ECC.

Full area scanning data in ECC is used to the neutrino event analysis.

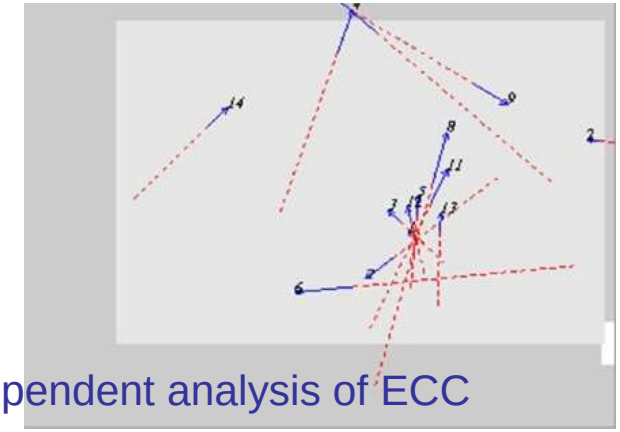
Shifter analysis

Shifter work as a interface detector between ECC and INGRID by its timing information.

1.Muon ID for tracks in ECC by matching with INGRID.

2. Muon flux and angle info. observed in Shifter will be available for beam study by comparing with INGRID tracks or beam p.o.t. info.

Direct VTX Hunting method
demonstrated in OPERA-CS analysis



Multi track vertices are found directly at low BG track situation.
→ cross-check on the ECC analysis

Schedule of T60

- 22nd Dec. : v beam finish.
- 24th Dec. : uninstall the Emulsion Module at J-PARC.
- 25th Dec. : emulsion films development at Toho Univ.
- 26th Dec. : emulsion films drying.
- 27th Dec. ~ : some basic check (thickness, fog density measurement …)
- Jan. 2015 ~ : emulsion films scanning and analysis start.
- Mar. 2015 : report first result.

Future prospects

Preliminary measurements (T60) **2014**

2015

Detector Run

Now we are discussing about some physics targets.
Advices for target physics are very welcome !

Air + magnetic field:
neutrino beam study, tech. R&D
($\nu_e/\overline{\nu_e}$ separation)

Water target:
neutrino – nucleus int. study

Nano Imaging Tracker target:
first observation
neutrino nucleus coherent scattering

Iron target:
Sterile neutrino search

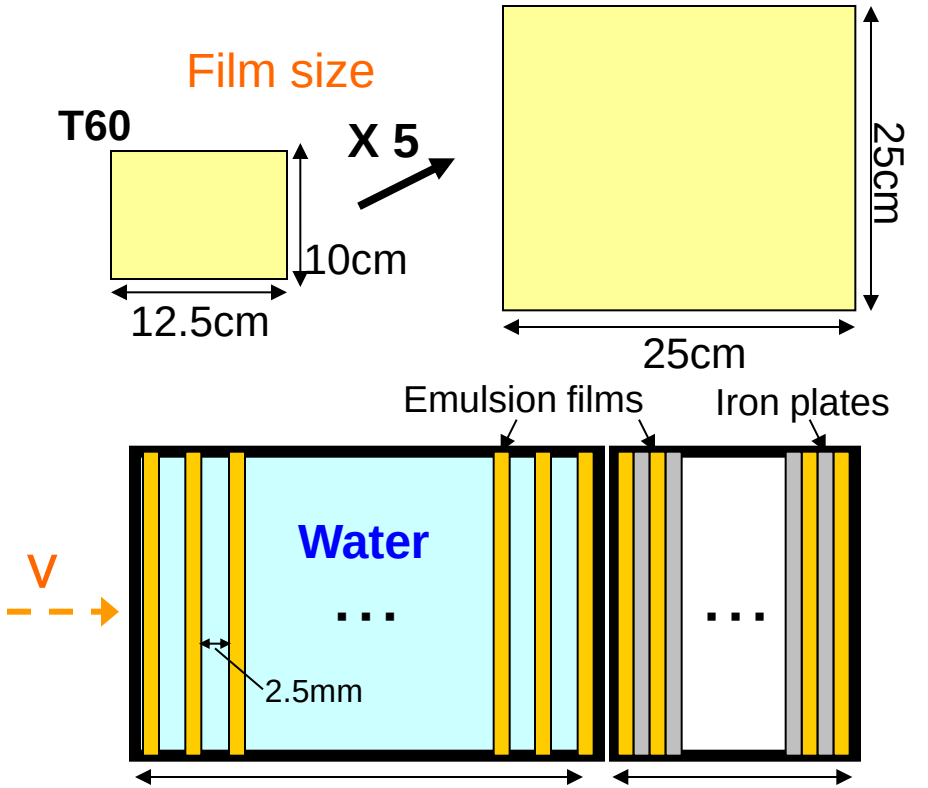
New idea !!
introduced by O. Sato today's evening

Consideration for Detector Run

We are planning the detector run as a next step.

2015 Oct. ~

Water target ECC



H_2O target mass: 15kg

Iron mass: 15kg
- **Momentum, Range dE/dX measurement**
- **Particle ID (p/π/e)**

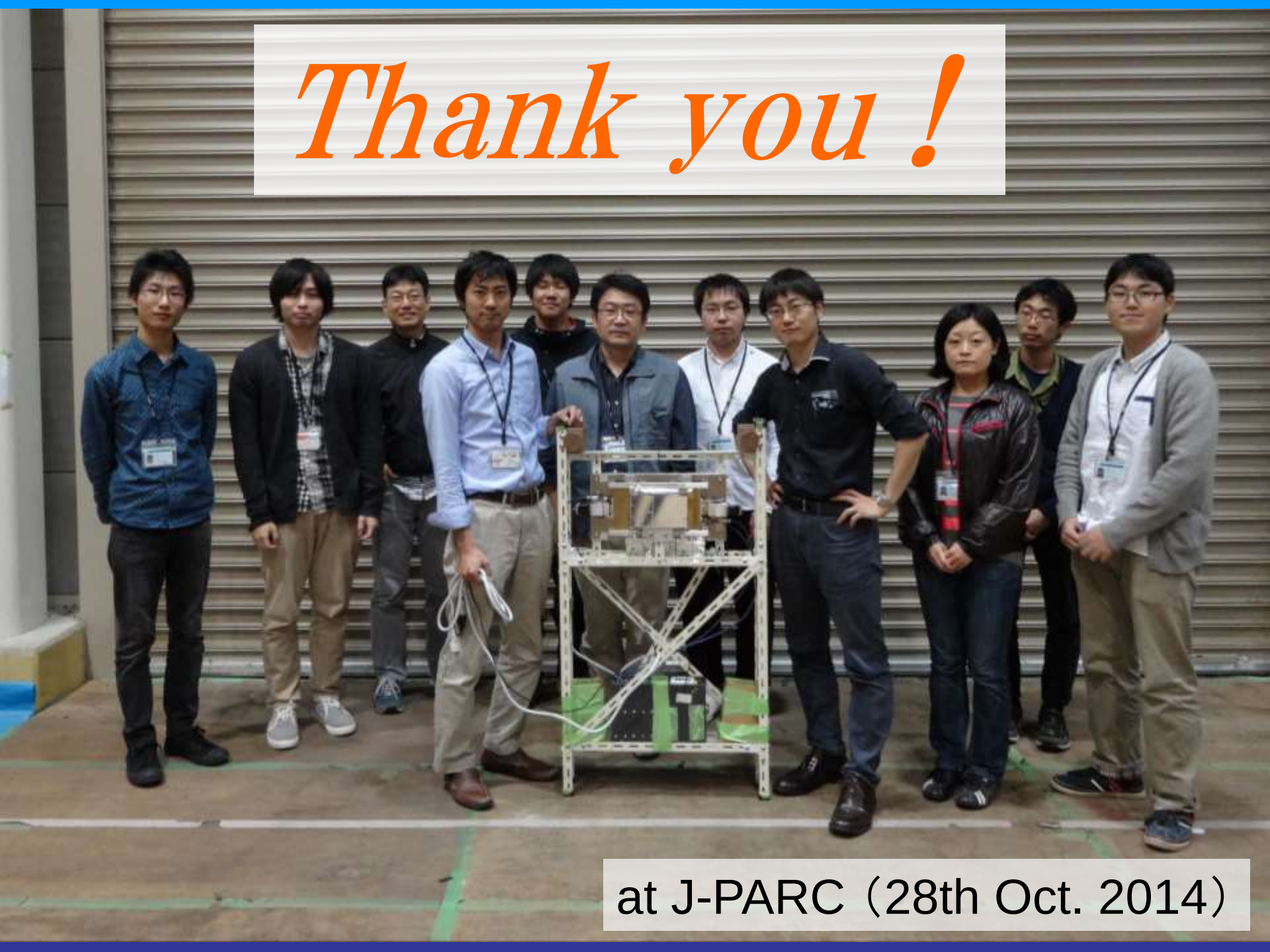
Large scale development facility

→ **Dark room at Nihon Univ.**

A whole lot of emulsion film development process is needed in physics run.
We will construct a large scale development facility at Nihon Univ. and develop automatic development system through the detector run.

Summary

- We are planning neutrino experiments at J-PARC to study low energy neutrino - nucleus interactions with nuclear emulsion.
- First of all, we carry out a test experiment at J-PARC (T60) for the feasibility study.
- We will expand the detector scale for the physics goal. As a next step, we are considering to proceed Detector Run (2015).
- We will modify and confirm the details of next run based on the analysis result of T60.


Thank you !
at J-PARC（28th Oct. 2014）

Supplements

Tentative schedule

2014. 11 — **Preliminary measurements RUN** start.
Measurements of vevent ・cosmic μ・rock μ・etc

T60:Nov.-Dec. 2014

2015. 4 — **Detector RUN** start.
Detector performance check
(Fe, C, CH, H_2O target ECC)

2016. 4

Physics RUN (200kg ?) start.
Total 200kg target detector
(Fe, C, CH, H_2O target ECC)
→ More than 10,000 ν_μ int.
More than 100 ν_e int. will be measured.

2017. 4

2018. 4

Sterile RUN-1 (1ton ?) start.
（＞2σ）

2019. 4

Schedule and detailed plan will be modified after each Run.

2020. 4

Sterile RUN-2 (8ton ?) start.
（＞5σ）

2021. 4

$|\tan\theta| \leq 2.0$

- Reference sample