Development of the new nuclear emulsion detector for muon tomography

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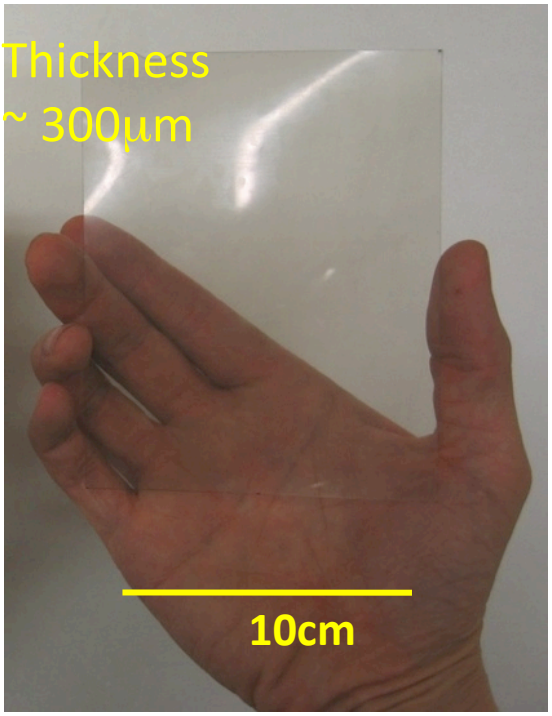
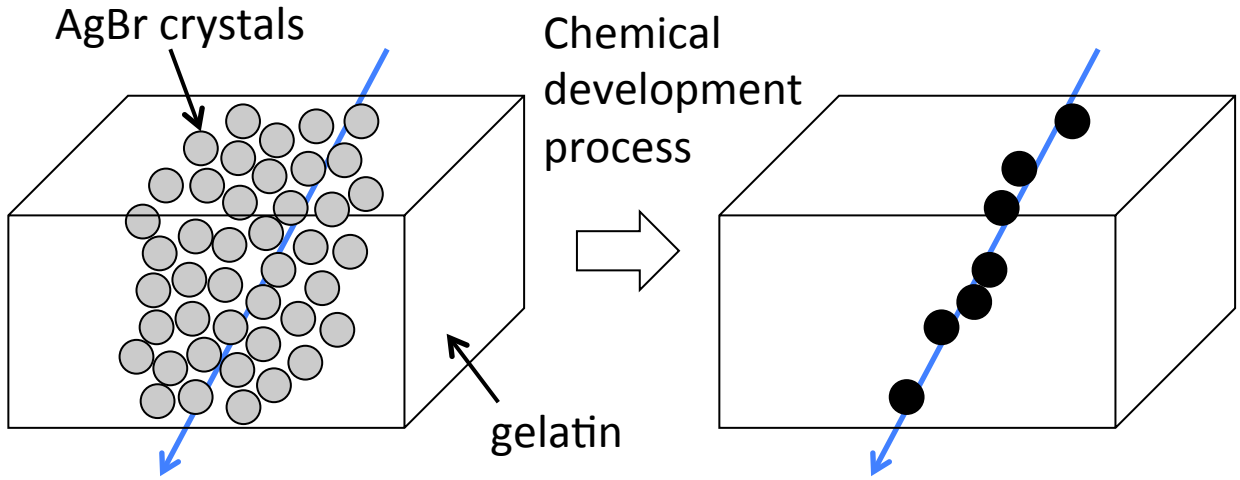
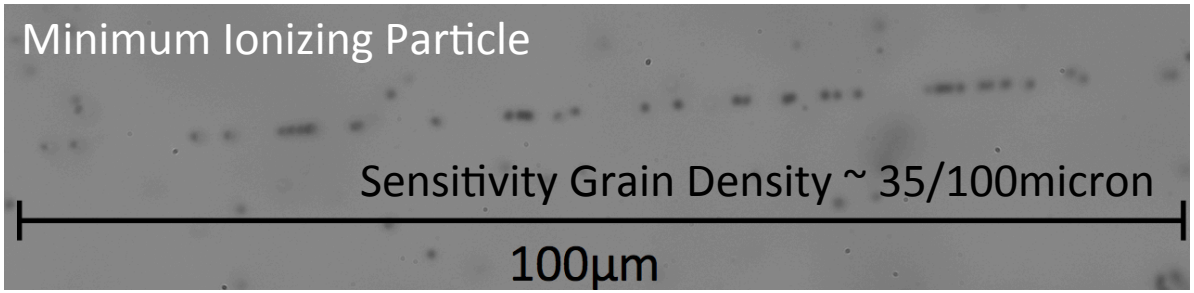
Nuclear Emulsion



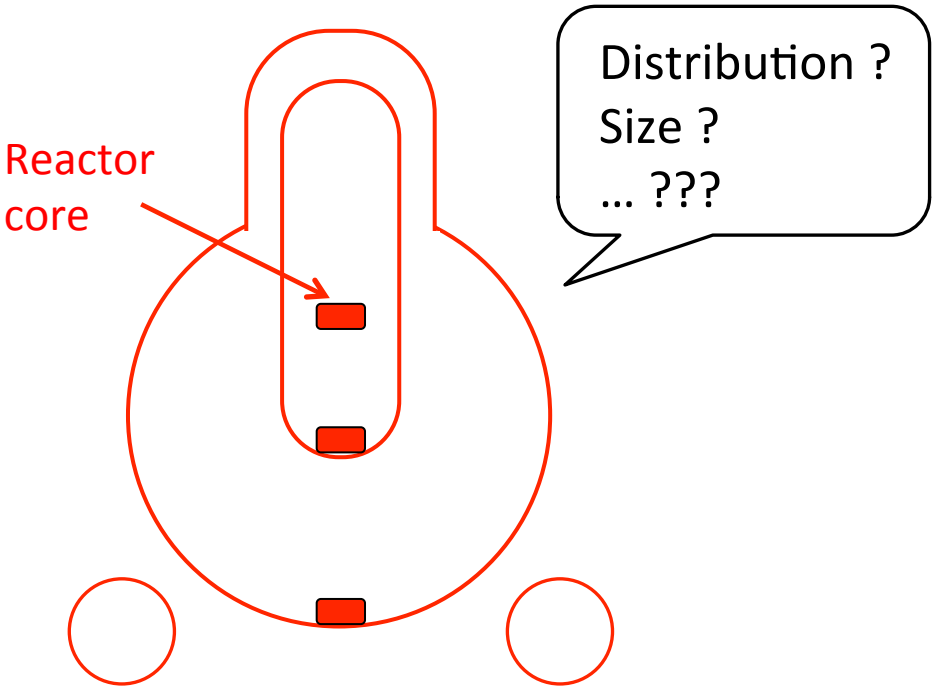




- 3 dimensional tracking detector
- High spatial resolution (< silver grain size)
- Solid state detector, No power supply
- flexible shape and size($1cm^2$-$100m^2$), light weight ($300g/m^2$)

These properties have advantage in field observation

The present situation expected in Fukushima Daiichi nuclear power plant



- High radioactivity → shielding material

- Power supply
- Space

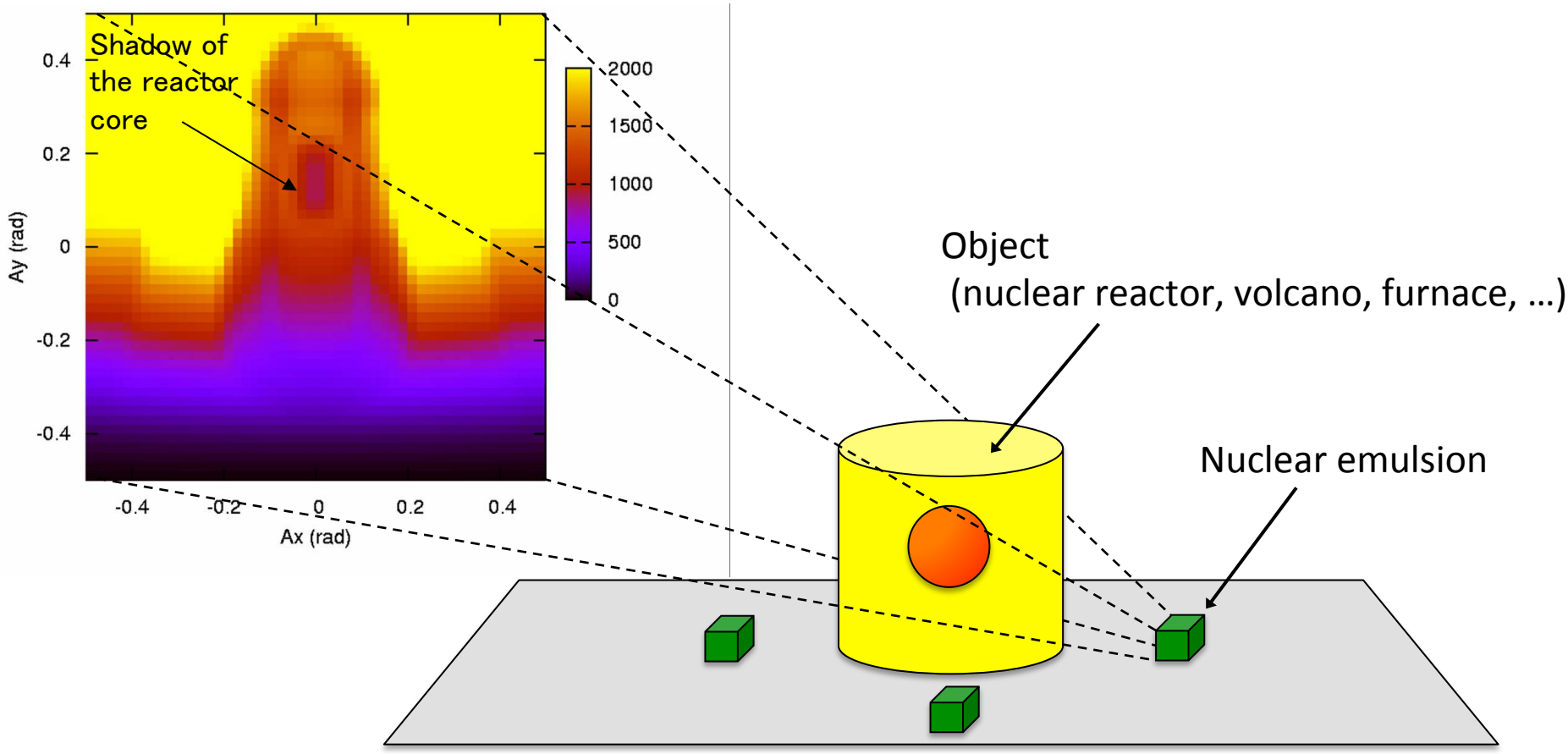
Advantages of nuclear emulsion as muon detector

- Compact, light weight
- No need of power supply
- High spatial resolution

Muon Tomography

Ex. Fukushima Nuclear Reactor

Exposure required 10m^{2}day



Requirements :

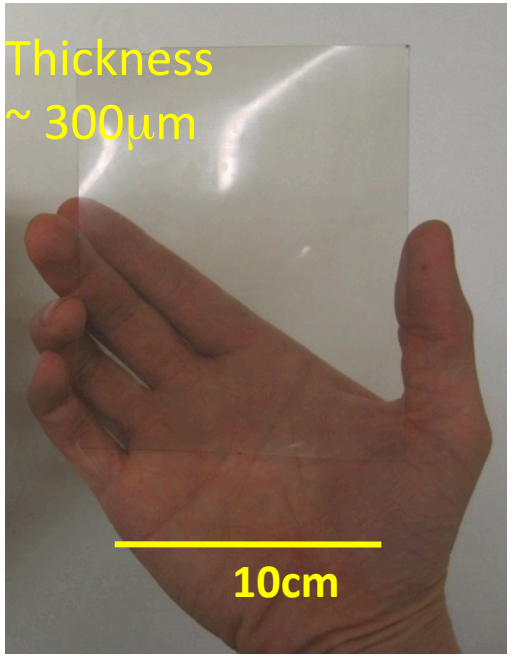
high resolution -> large area detector (>1m^2)

3D mass distribution -> multi detectors

<u>Development of nuclear emulsion</u>

Development of scanning system

Present situation of Nuclear Emulsion Detector



OPERA film

Manufacturing products by Fuji Corporation for the OPERA neutrino oscillation experiment

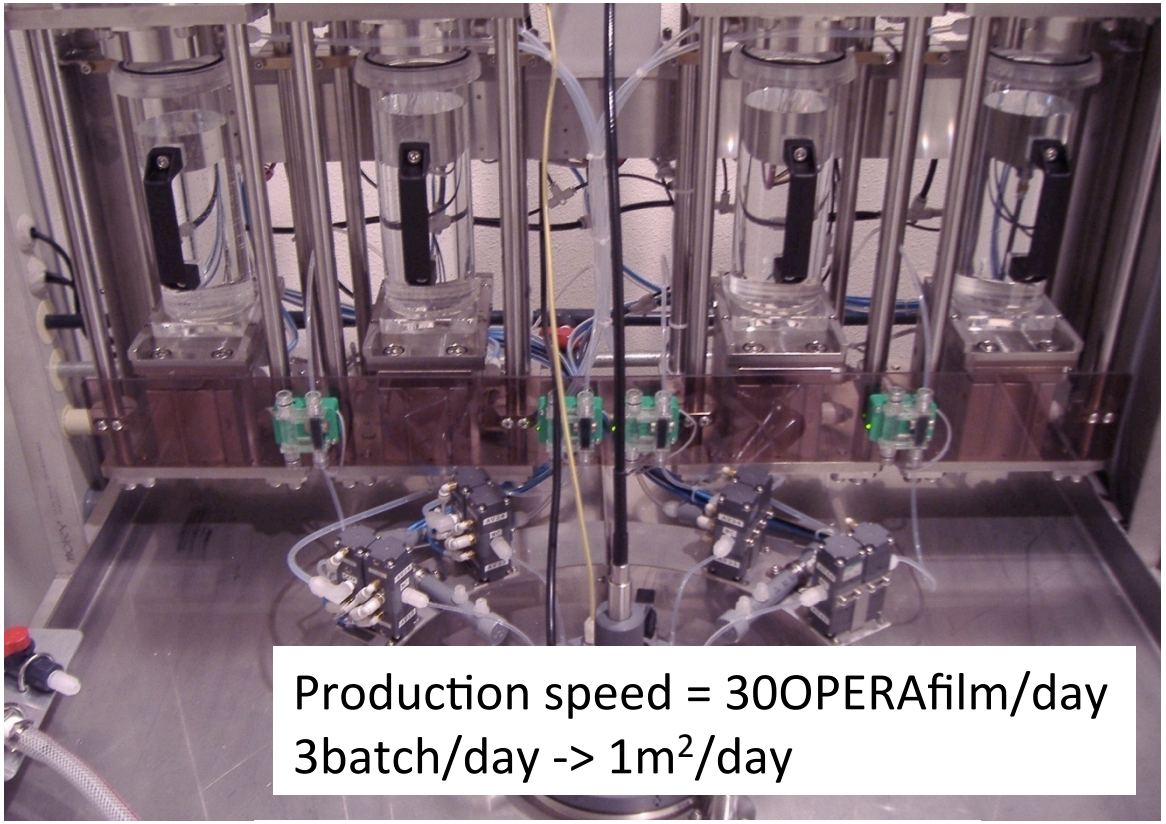
- discontinued product
- noise accumulated
- not enough sensitivity for MIP

Development of higher performance emulsion and its production technologies

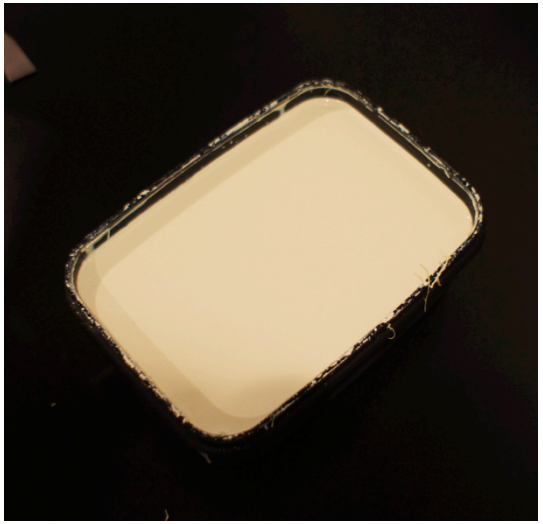
Development items

- Emulsion gel production technology
- Emulsion gel pouring technology
- Production speed

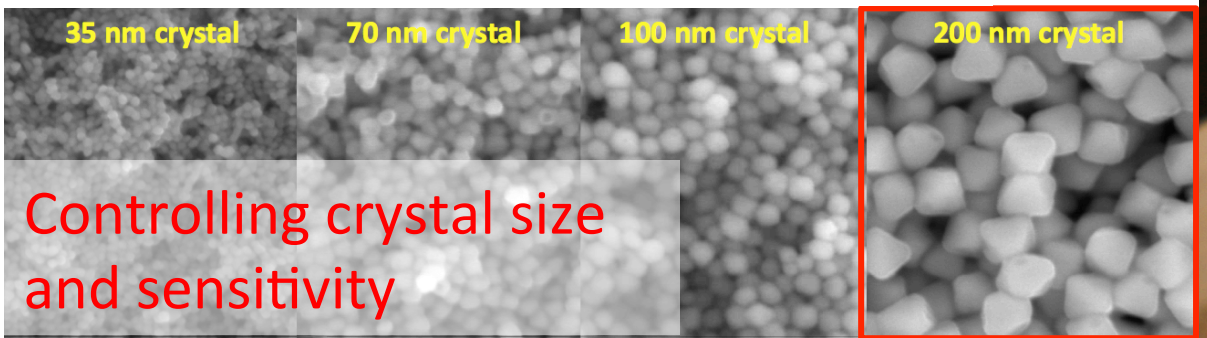
Gel Production Machine



Production speed = 30OPERAfilm/day
3batch/day -> 1m^2/day



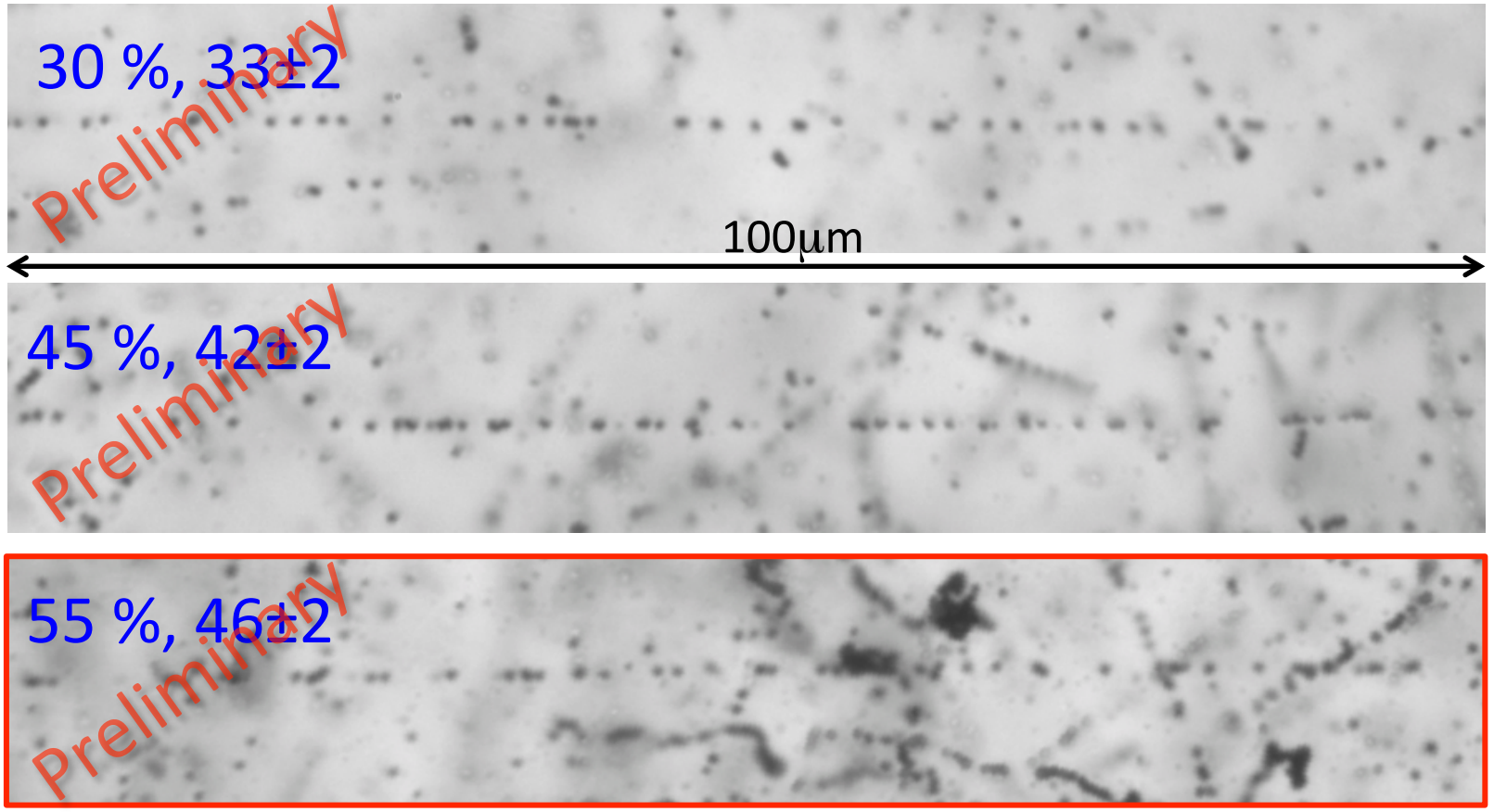
$AgNO_3 + KBr \rightarrow AgBr\downarrow + KNO_3$



Controlling crystal size and sensitivity

Performance of New Nuclear Emulsion Gel

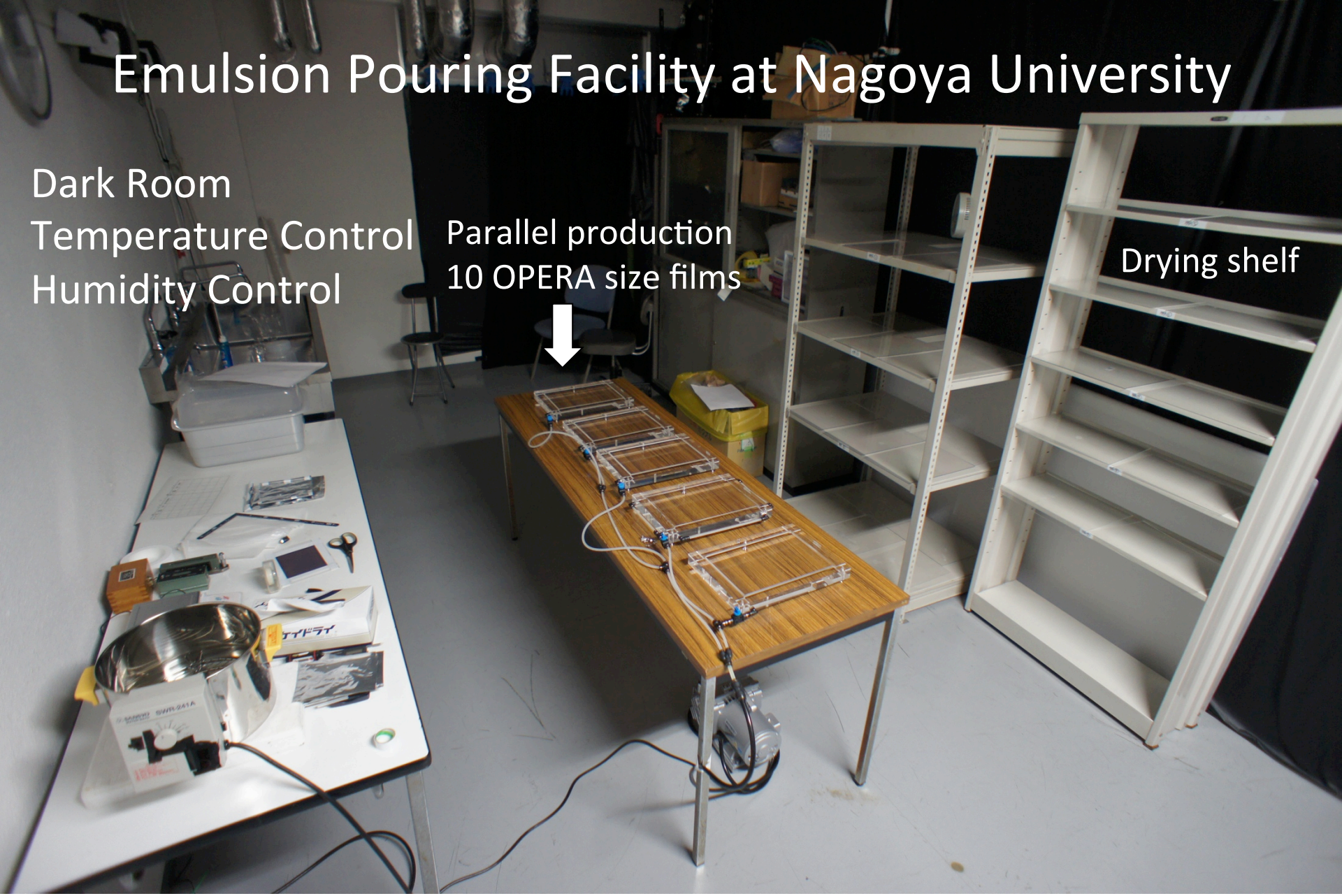
Volume occupancy of AgBr crystals, Grain density(/100μm)



*OPERA film, Volume occupancy ~30%, Grain Density ~35

We achieved 1.5 times higher sensitivity than OPERA film by increasing the filling rate of AgBr crystal.

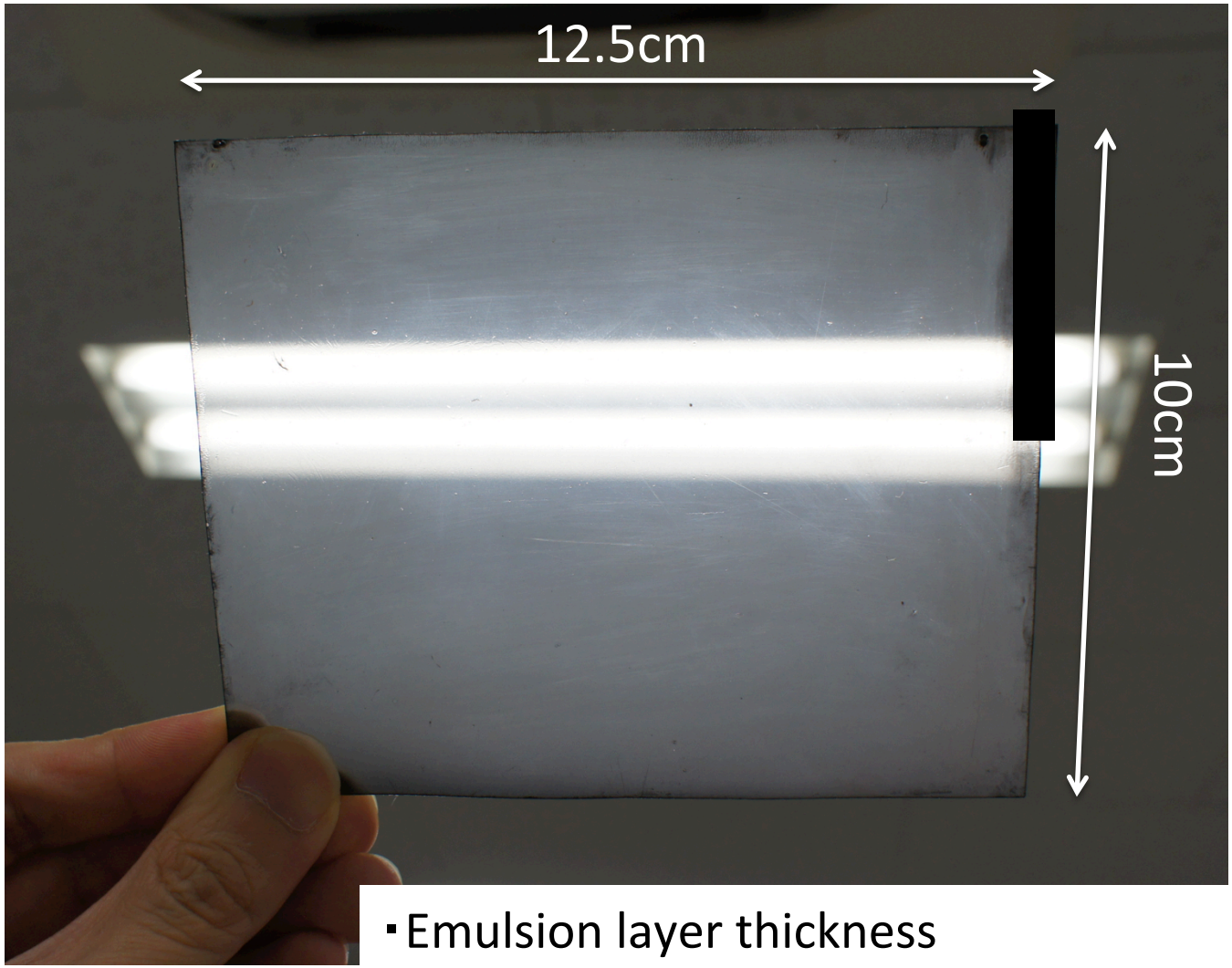
Emulsion Pouring Facility at Nagoya University



Production speed : 1m^2/4days

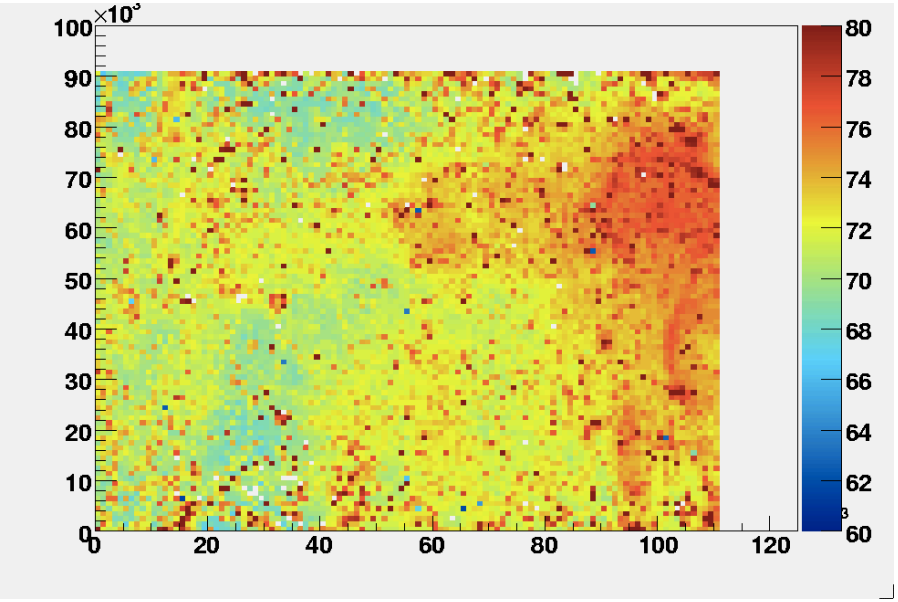
We are planning to increase the speed of 1m^2/day

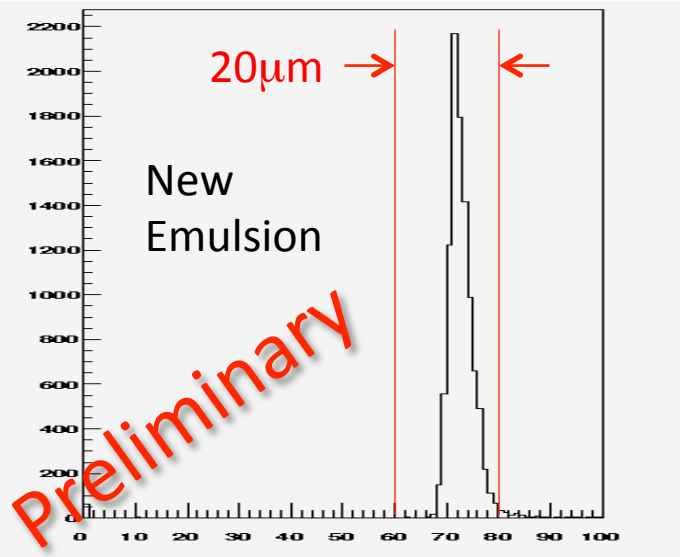
New Nuclear Emulsion (OPERA film size)



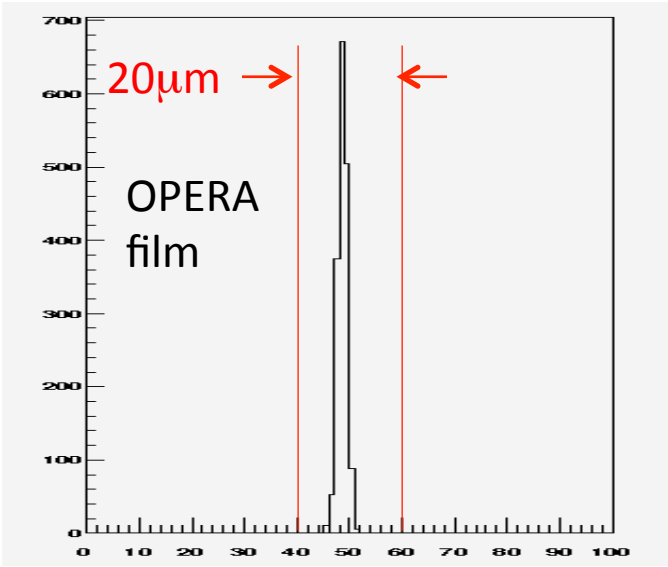
- Emulsion layer thickness
- Emulsion distortion
- Improvement of sensitivity and signal noise ratio

Thickness Distribution of Emulsion Layer



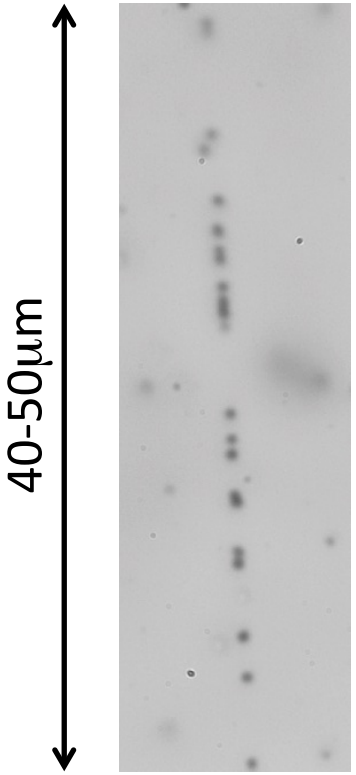


The un-uniformity of the thickness of 10μm per 10mm is 1mrad

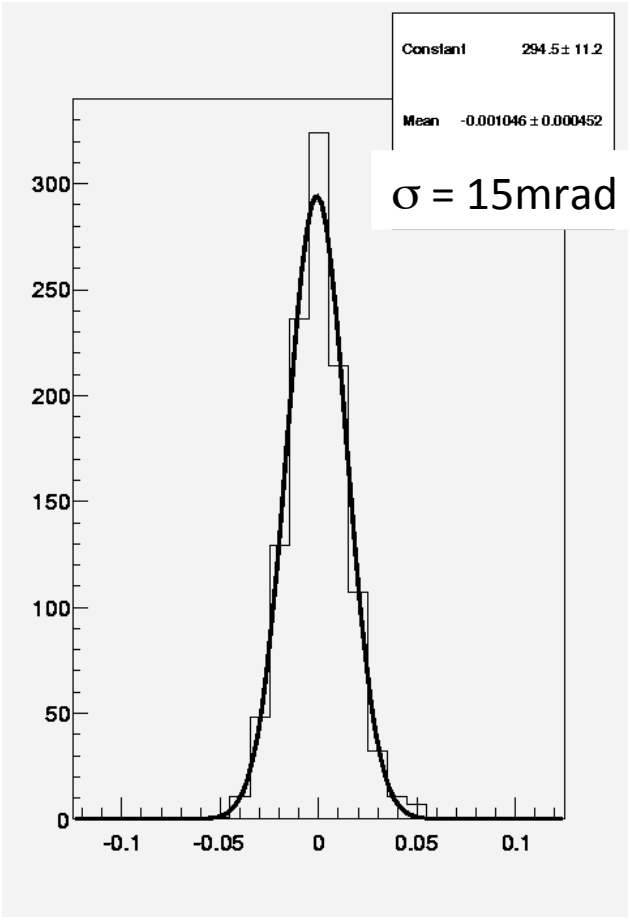


Enough performance for muon tomography

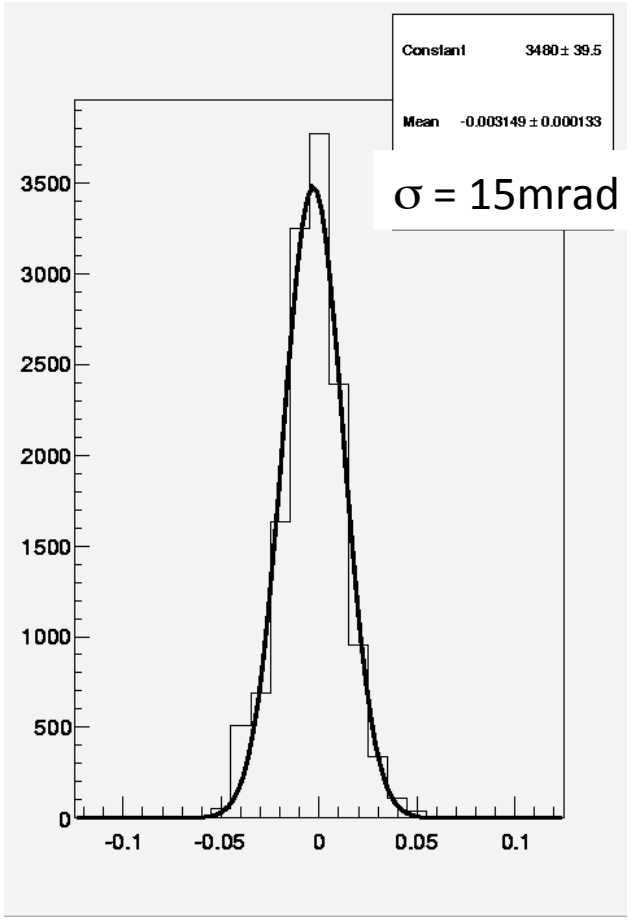
Track measurement accuracy in emulsion layer



OPERA film



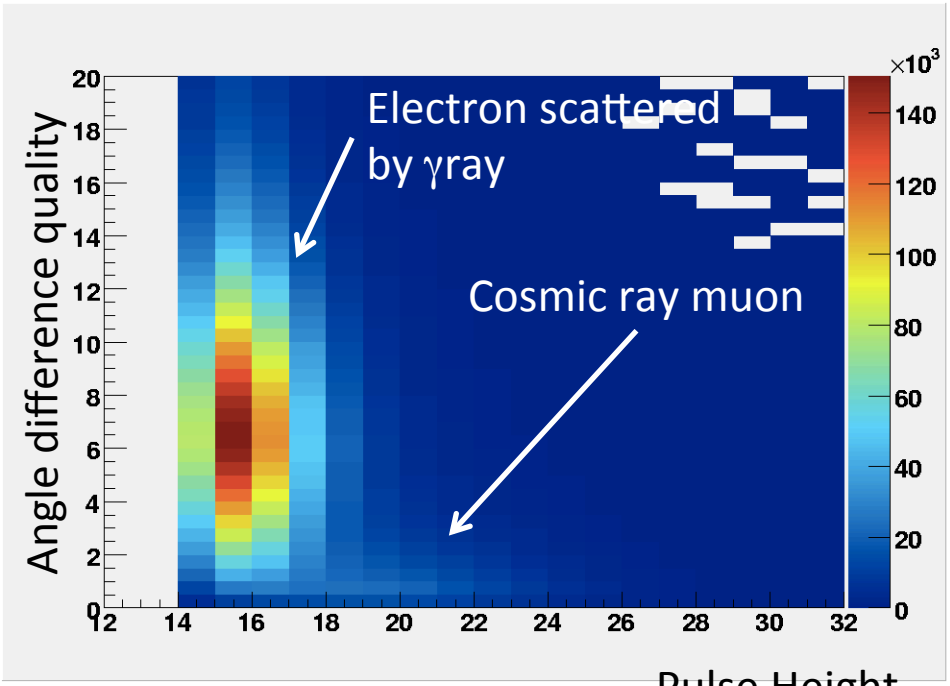
New emulsion



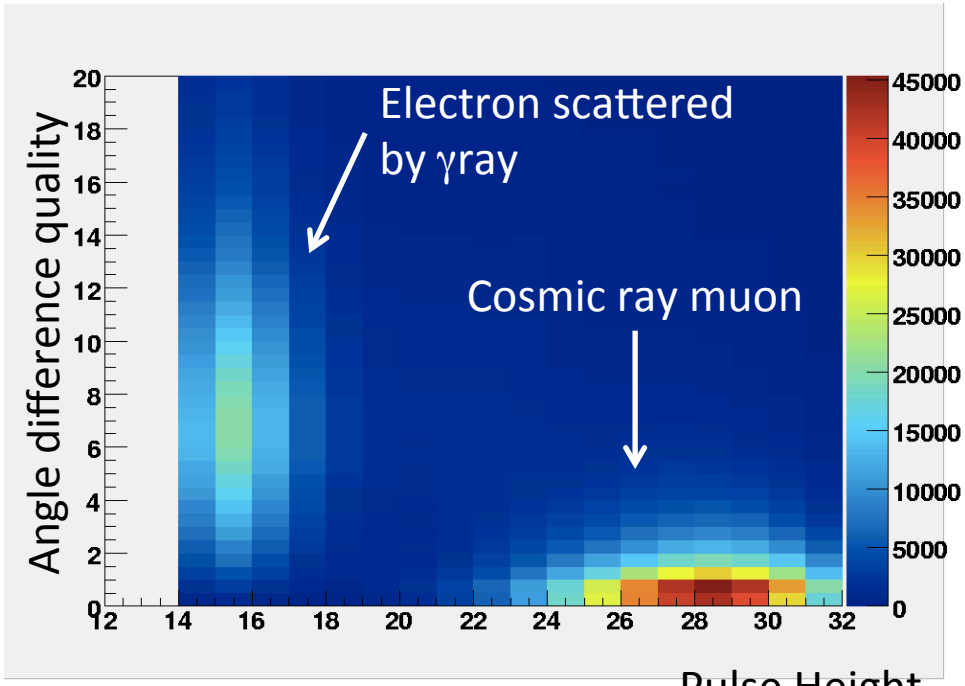
New Emulsion distortion is equivalent value to OPERA film

Performance of discrimination from Noise tracks

OPERA film (Grain density ~35)

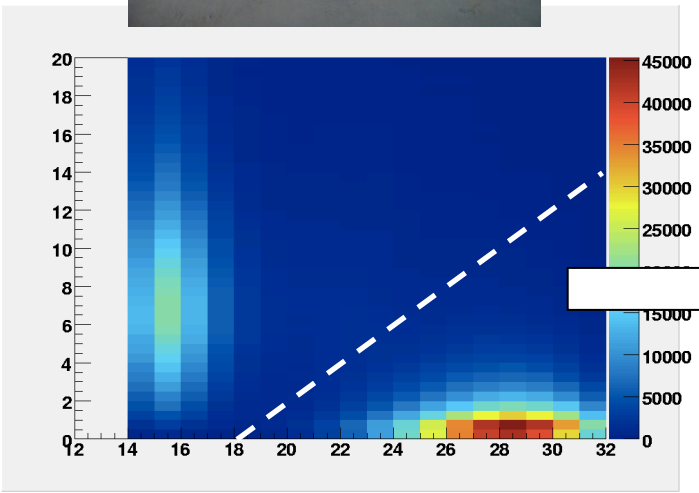


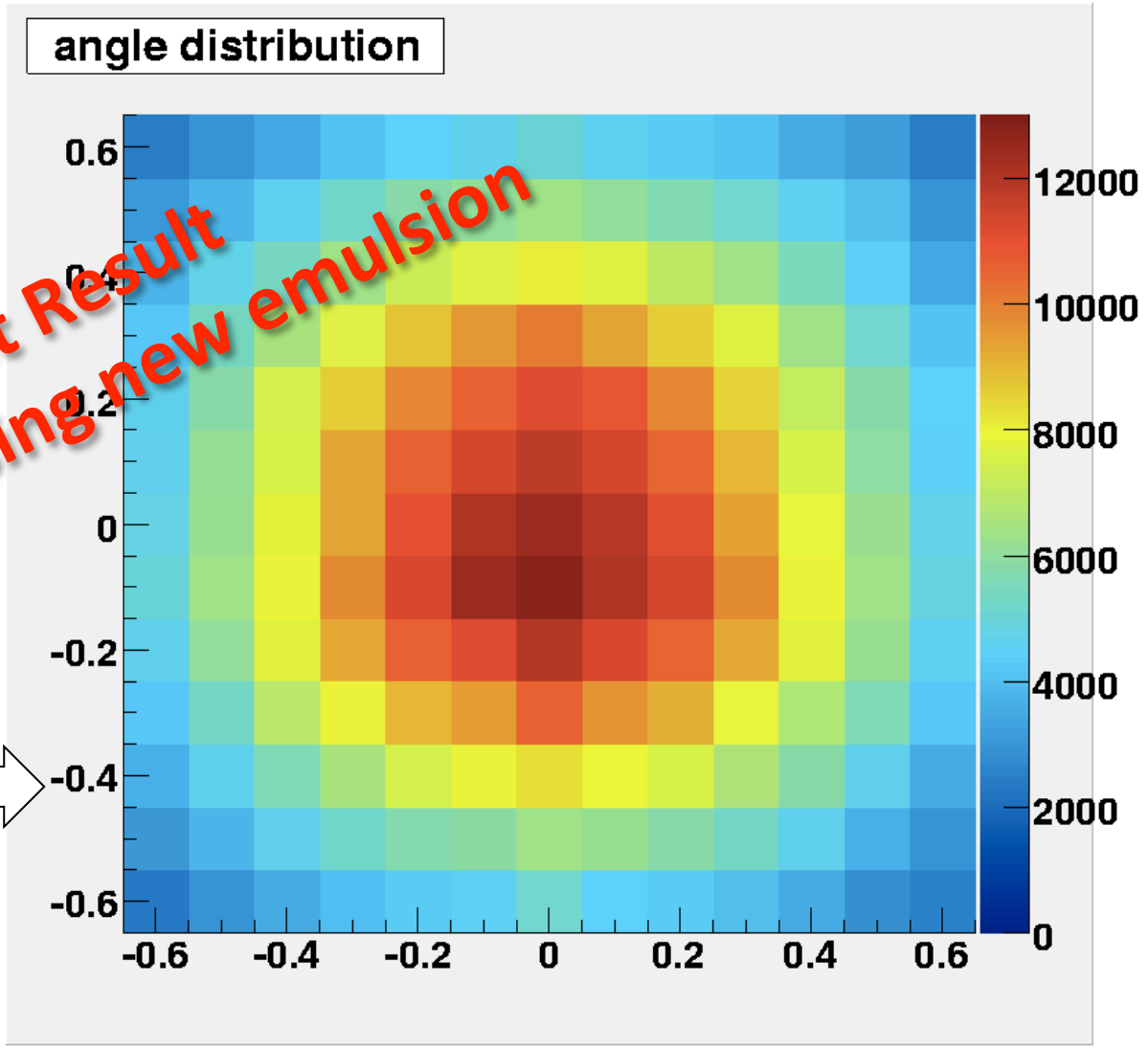
New Emulsion (Grain Density ~46)



Cosmic ray muon angular distribution achieved by using one new emulsion plate

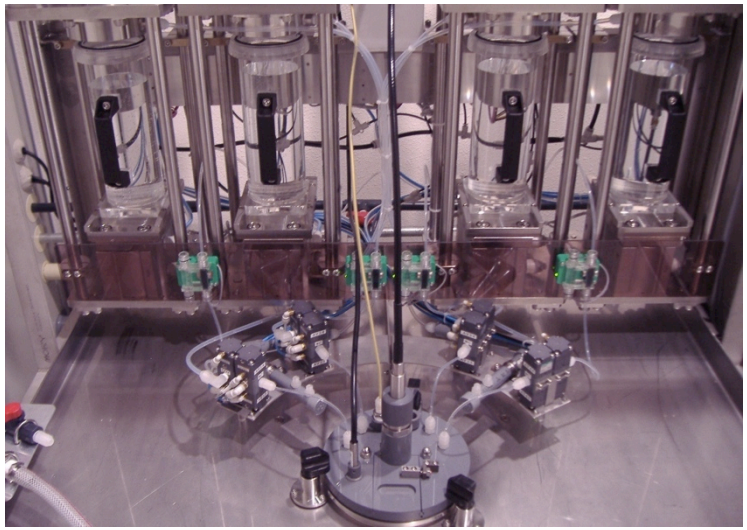
Measured on the rooftop of the building at Nagoya University





Future prospects

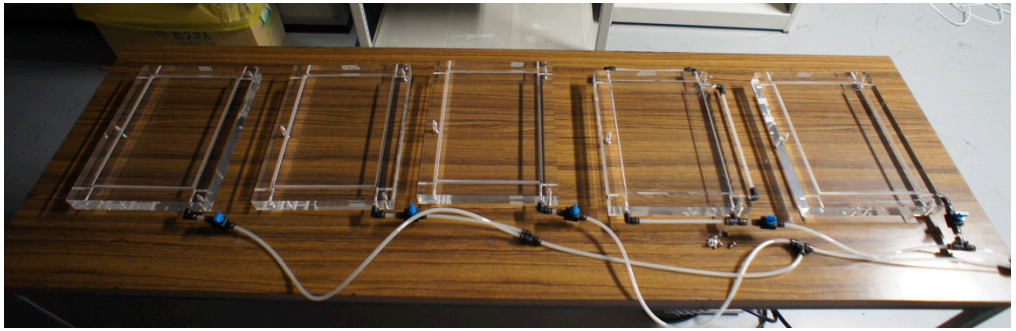
Emulsion gel production



Threefold scale emulsion gel production machine

Speed ~ 1m^2/batch

Emulsion pouring



Automated emulsion pouring machine

Speed ~ 10m^2/day

These machines are in designing

Conclusions

- Several 10m^2 nuclear emulsion area detector is needed for muon tomography
- We are developing nuclear emulsion production techniques
  - Gel production
  - Gel Pouring
- We achieved enough performance (flatness, distortion) and higher performance (noise discrimination) for cosmic ray muon tomography at the production speed of 1m^2/4days
- We can start 1m^2 area detector experiment with high sensitive new nuclear emulsion soon !
- If you are interested in usage of our new emulsion, please contact me.