

# Prospects of Emulsion Film Production for FASERnu2



**Hiroki ROKUJO**  
(Nagoya Univ.)

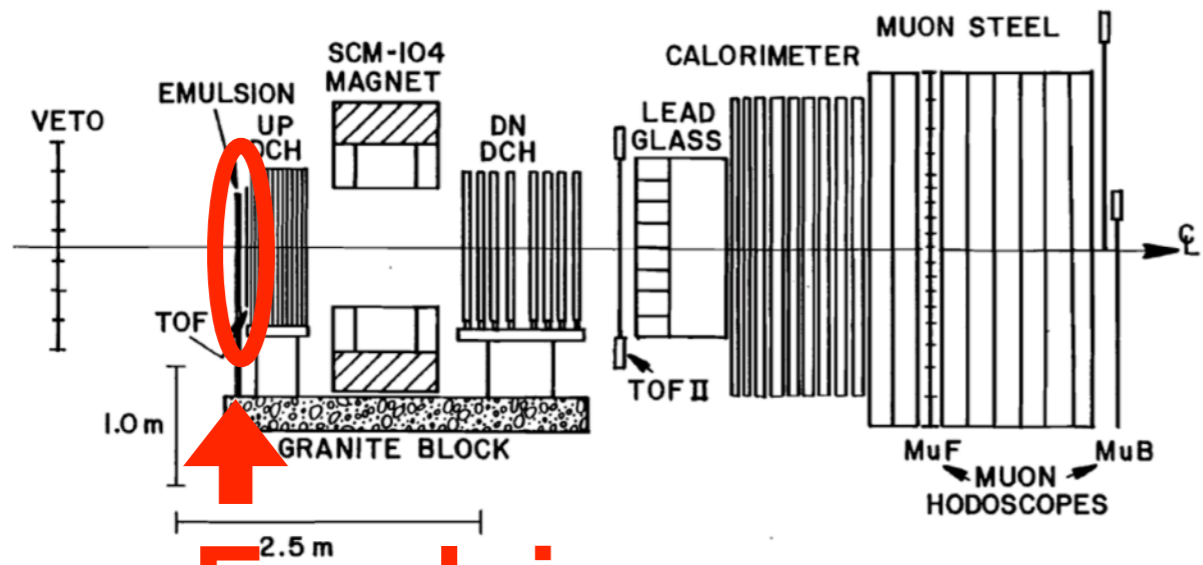
- Intro. Nuclear Emulsion in Neutrino Physics
- Status of Emulsion Film Facility in Nagoya
- Production for FASERnu in 2022 and Plan towards FASERnu2

1979-

# Fermilab E531

Neutrino Charm Production

$\nu_\mu \rightarrow \nu_\tau$  Oscillation Search



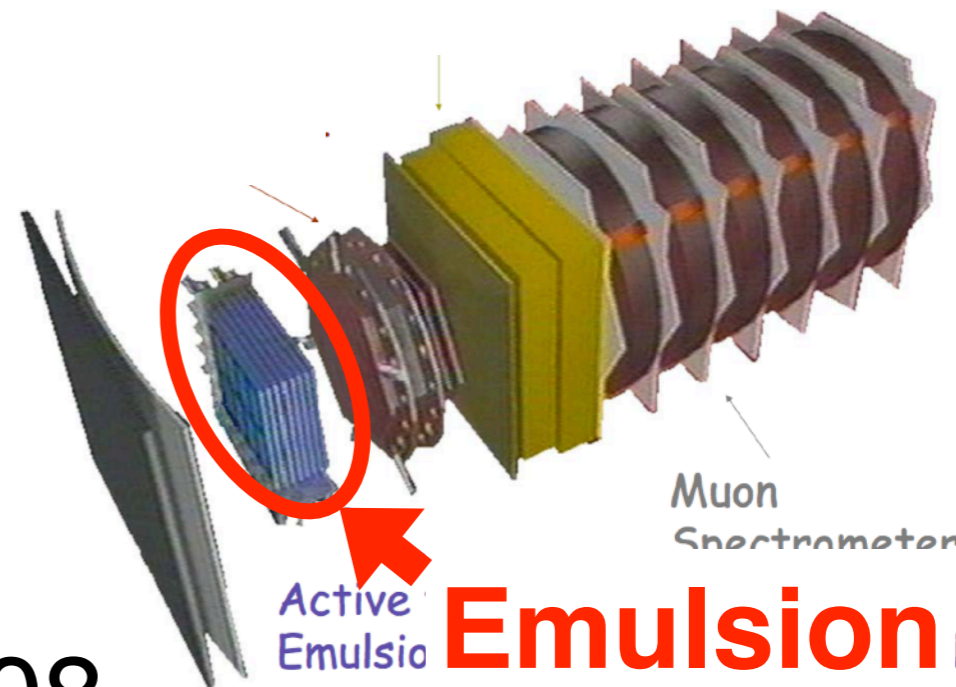
**Emulsion**

1994-

# CERN WA95 CHORUS

CERN Hybrid Oscillation Research Apparatus

$\nu_\mu \rightarrow \nu_\tau$  Oscillation Search



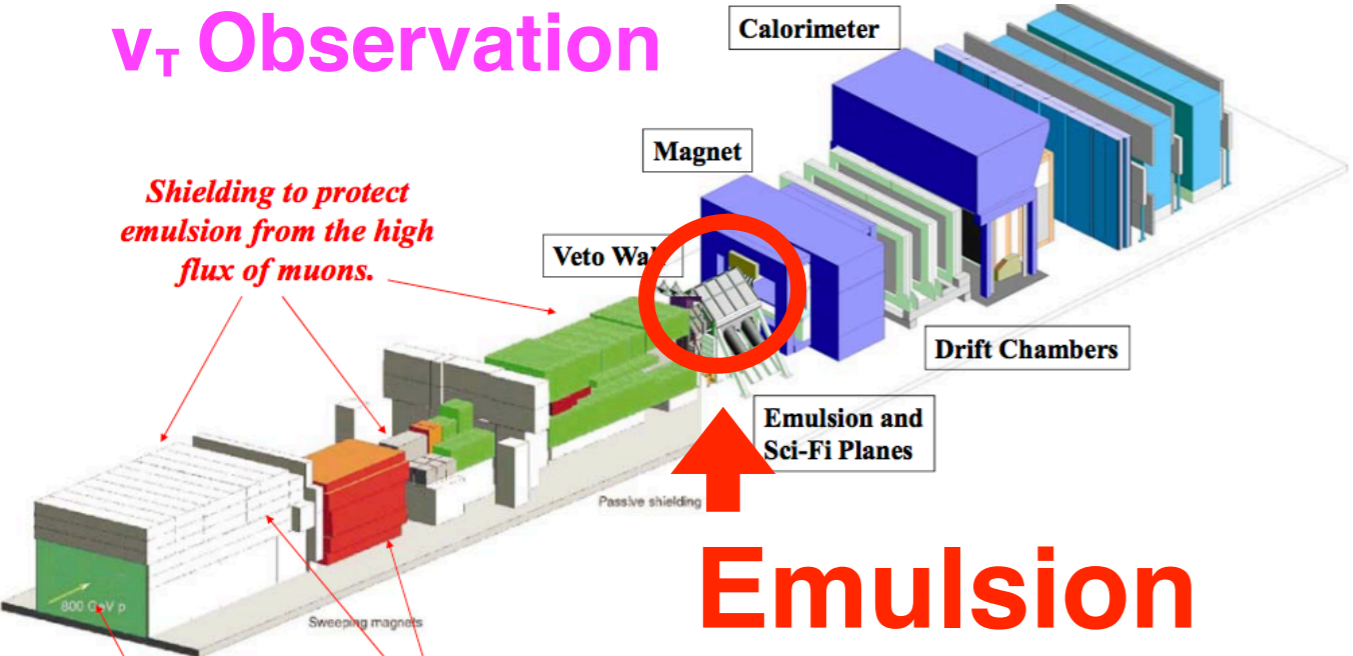
**Emulsion**

1997-

# Fermilab E872 DONUT

Direct Observation of  $\nu_\tau$

$\nu_\tau$  Observation



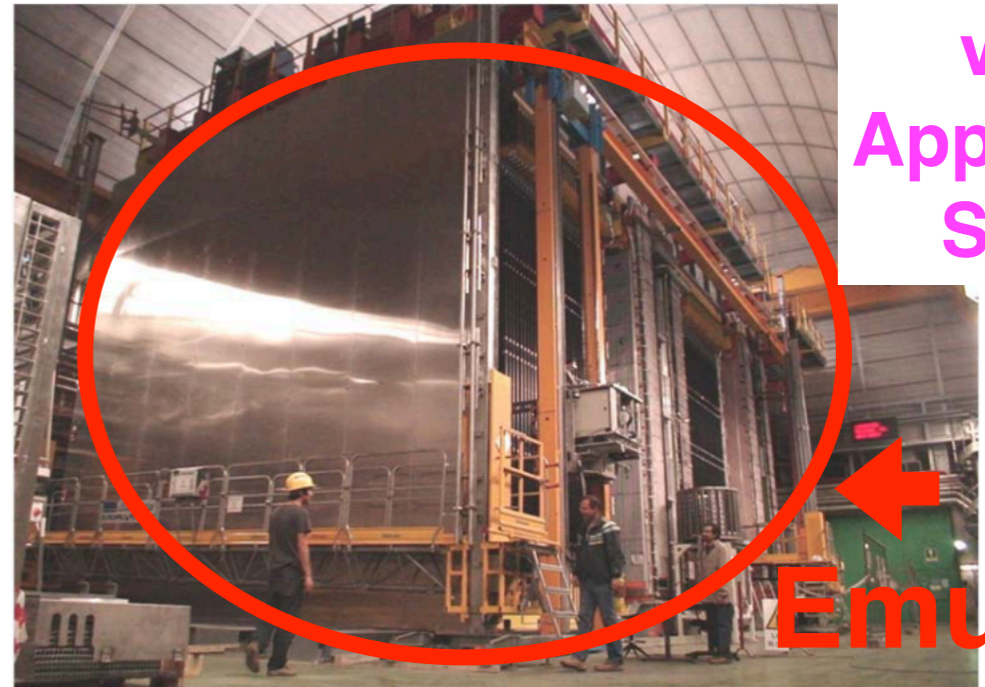
**Emulsion**

2008-

# CERN CNGS1 OPERA

Oscillation Project with Emulsion Tracking Apparatus

$\nu_\mu \rightarrow \nu_\tau$  Appearance Search



**Emulsion**

# Why do we use emulsion?

**A: One and Only Vertex detector**

Cross section  
(Electron microscopic view)

~60  $\mu\text{m}$  Emulsion

~200  $\mu\text{m}$  Plastic

~60  $\mu\text{m}$  Emulsion



# Why do we use emulsion?

## A: One and Only Vertex detector

Cross section  
(Electron microscopic view)

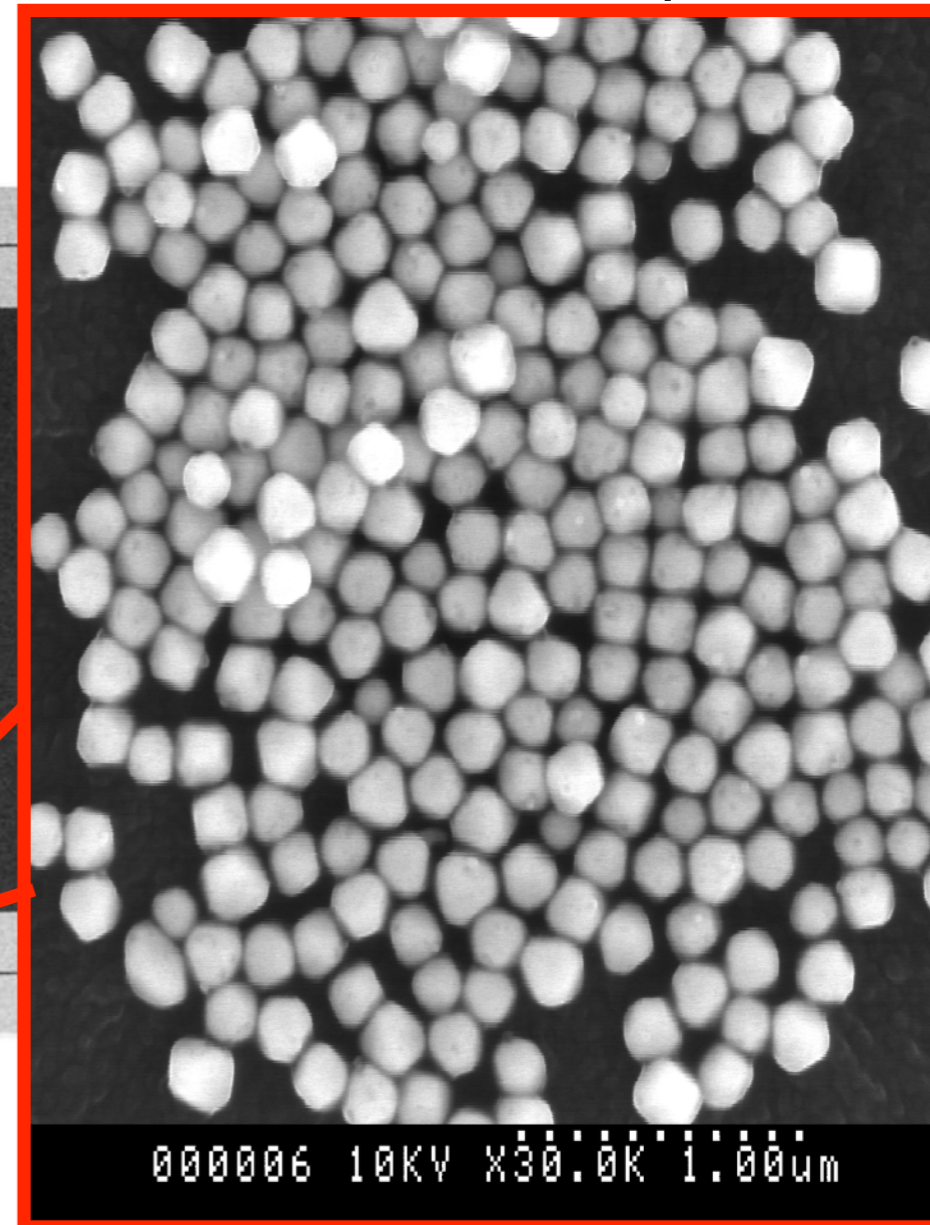
Electron microscopic view



~60  $\mu\text{m}$  Emulsion

~200  $\mu\text{m}$  Plastic

~60  $\mu\text{m}$  Emulsion



0.2  $\mu\text{m}$ -diameter AgBr crystals in gelatine  
function as 3-D position sensors.

**Intrinsic resolution: ~ 50 nm**

# Why do we use emulsion?

**A: One and Only Vertex detector**

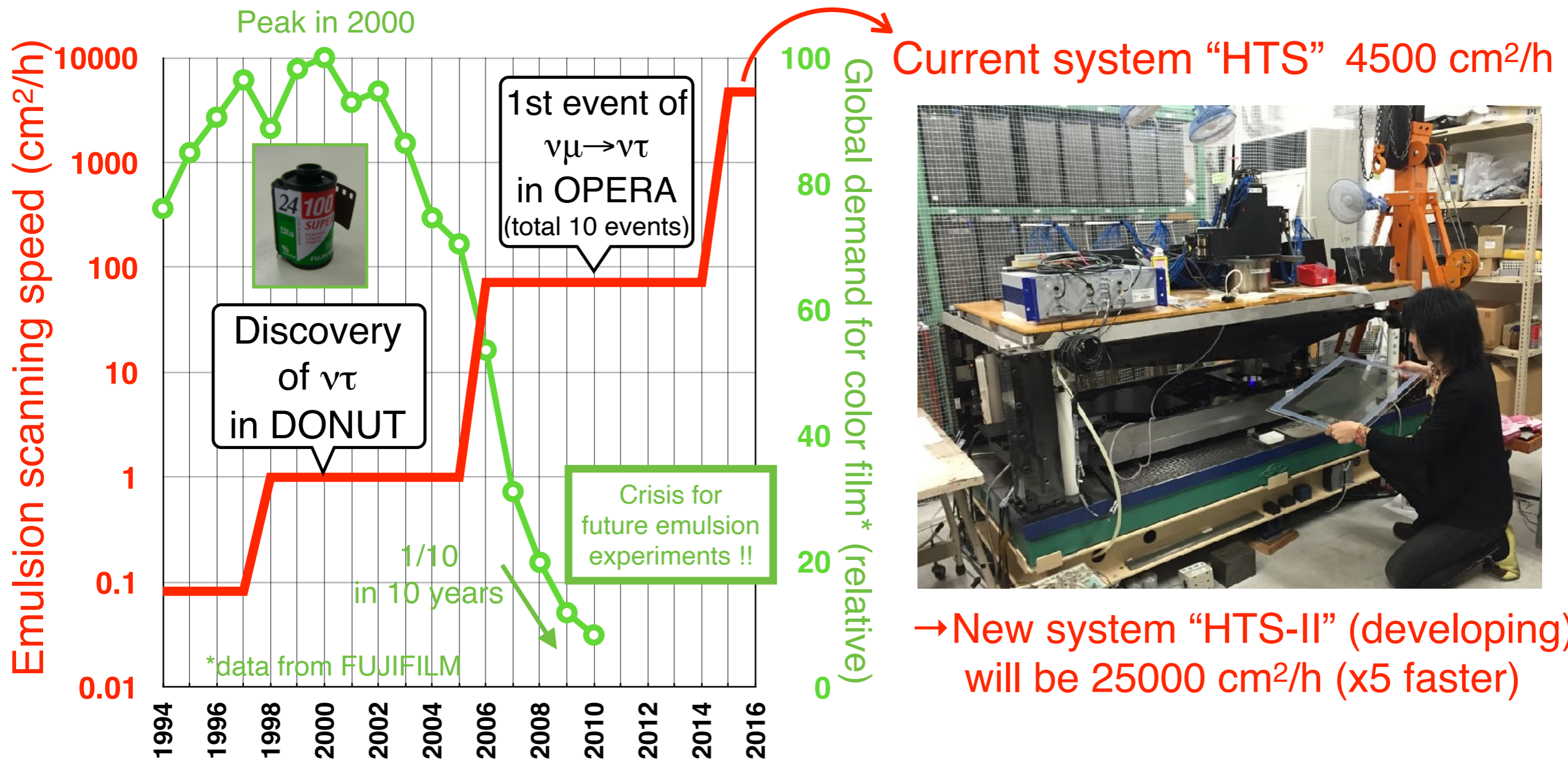
After chemical development

100  $\mu\text{m}$  (micro scopes view)

exposed to Ion beam

- ⊙ **Observation of short-lived particles ( $c$ ,  $\tau$ )**
- ⊙ **Precise 3D measurement of topology at VTX**

# Evolution of Emulsion Scanning Speed and Decline of Photographic Film Industry



We started the development and supply of Nuclear Emulsion itself in our laboratory (2010–)

# Introduction of Emulsion Gel Production System

in cooperation with former members of Fuji Film



Developing self-produced nuclear emulsion that satisfies our own research requirement.

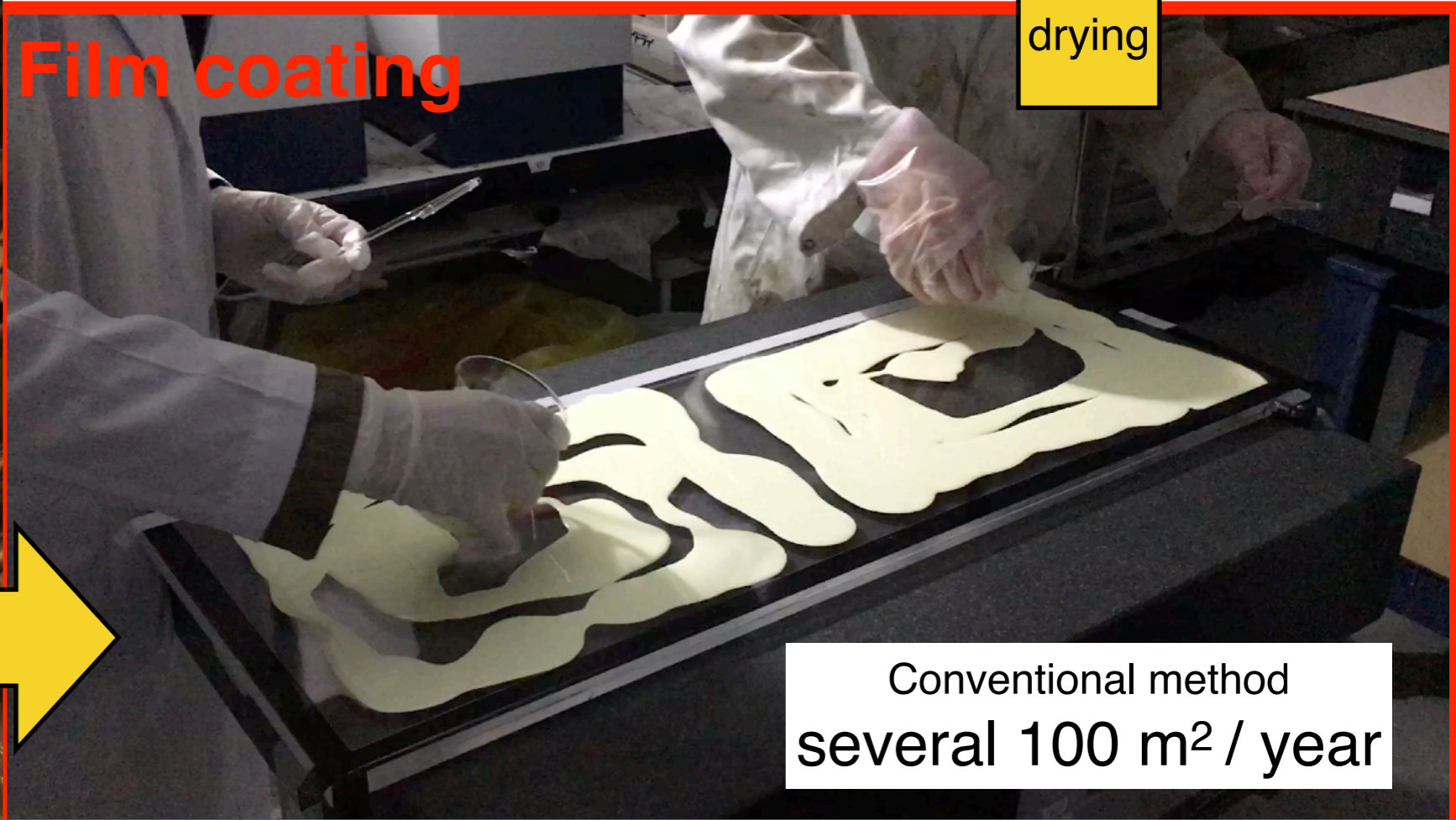
# Nagoya-made Nuclear Emulsion Film was born



Gel Production



Film coating

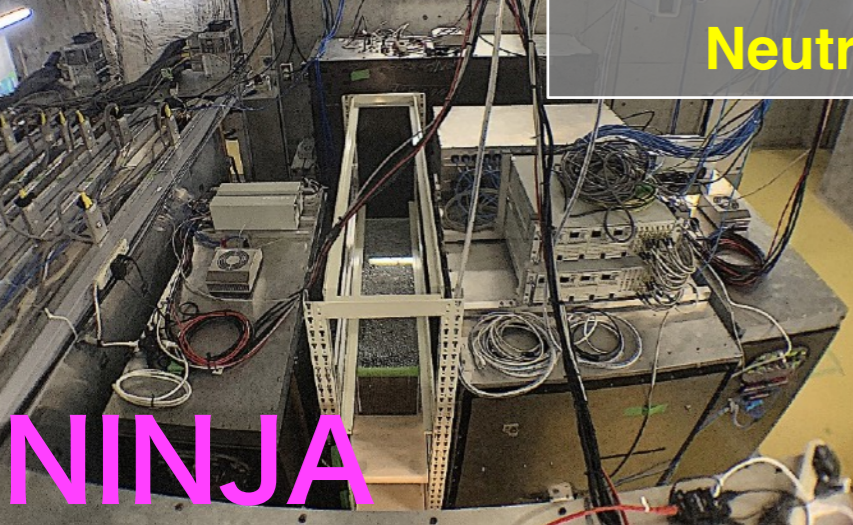


After drying

Conventional method  
several 100 m<sup>2</sup> / year

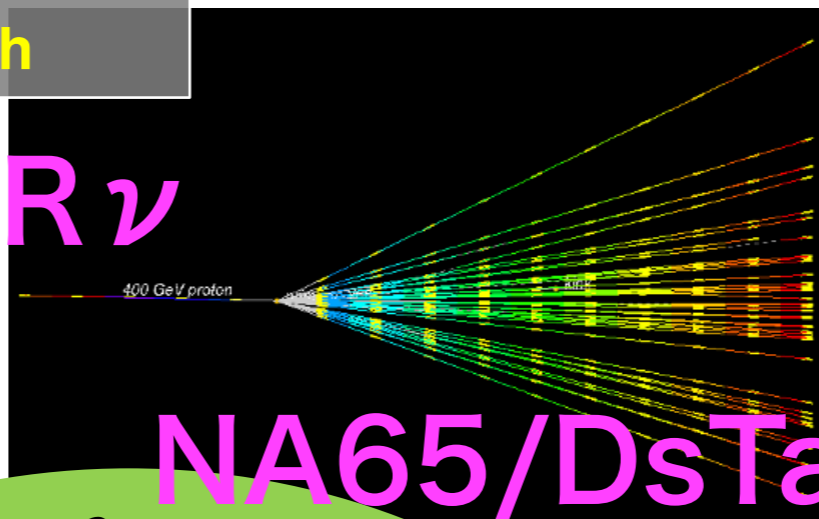


Neutrino research



NINJA

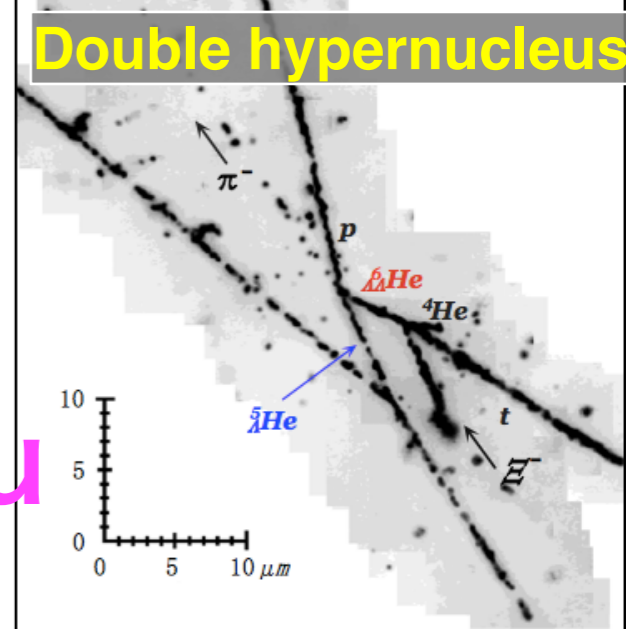
FASER $\nu$



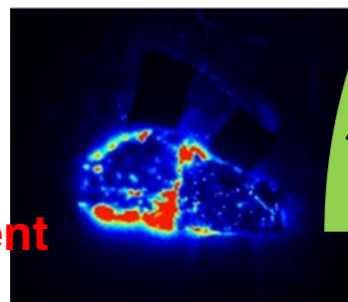
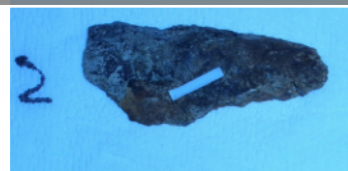
SND

NA65/DsTau

Double hypernucleus



Radiation education

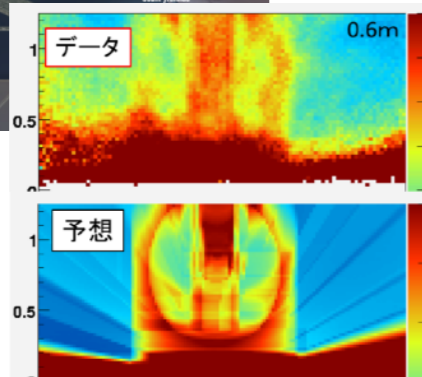


Radiation measurement from rocks

Cosmic-ray imaging

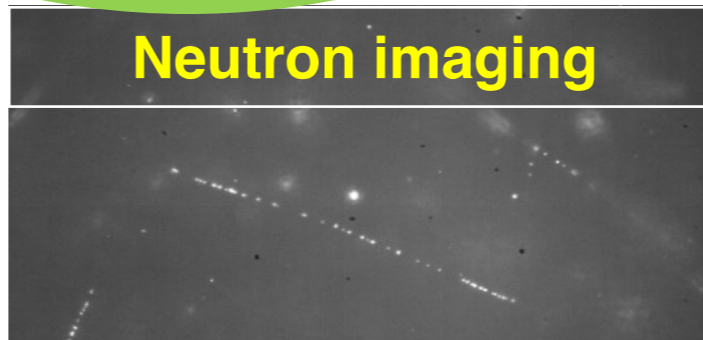


Pyramids

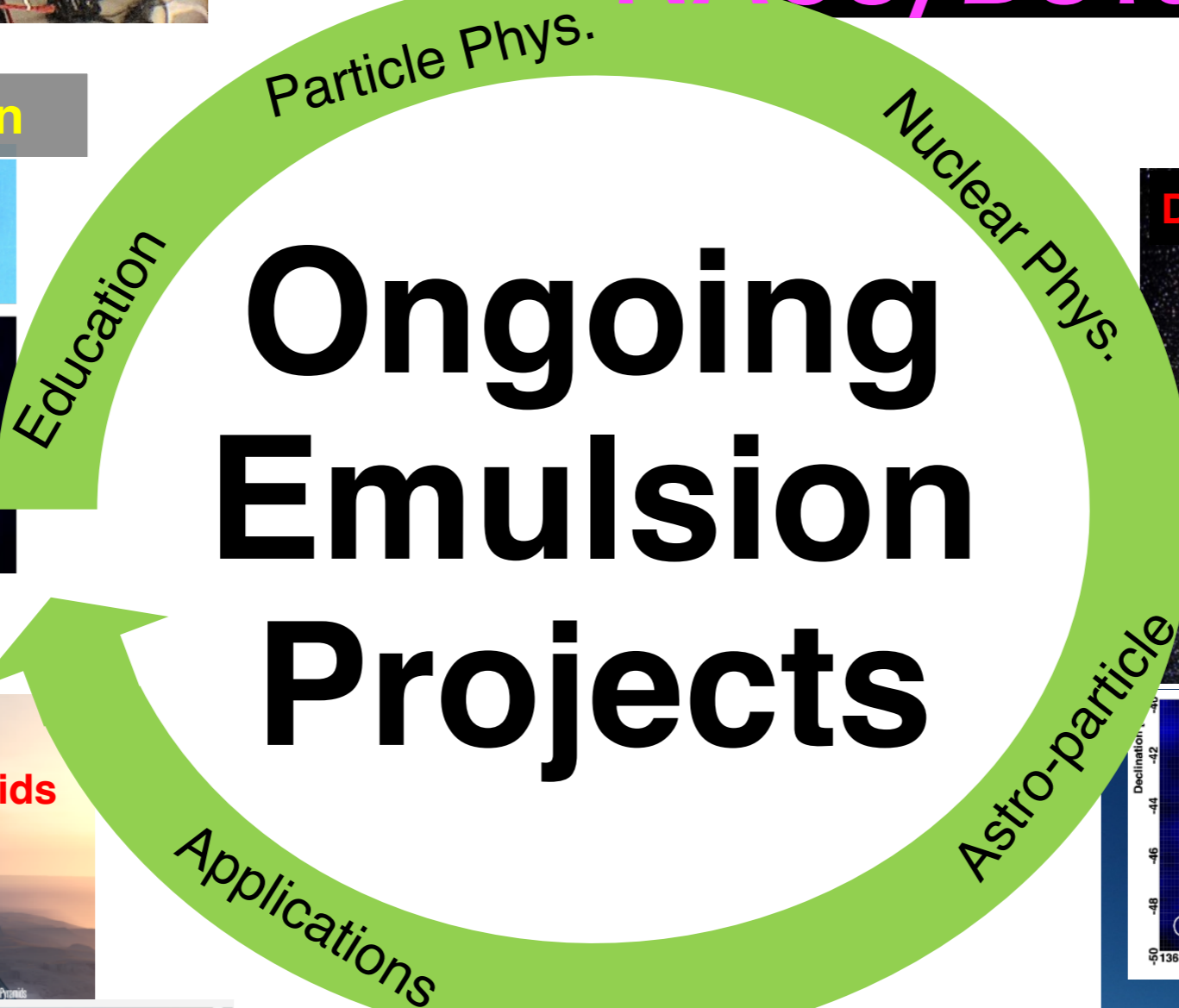


Reactor

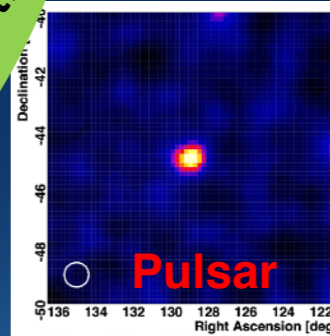
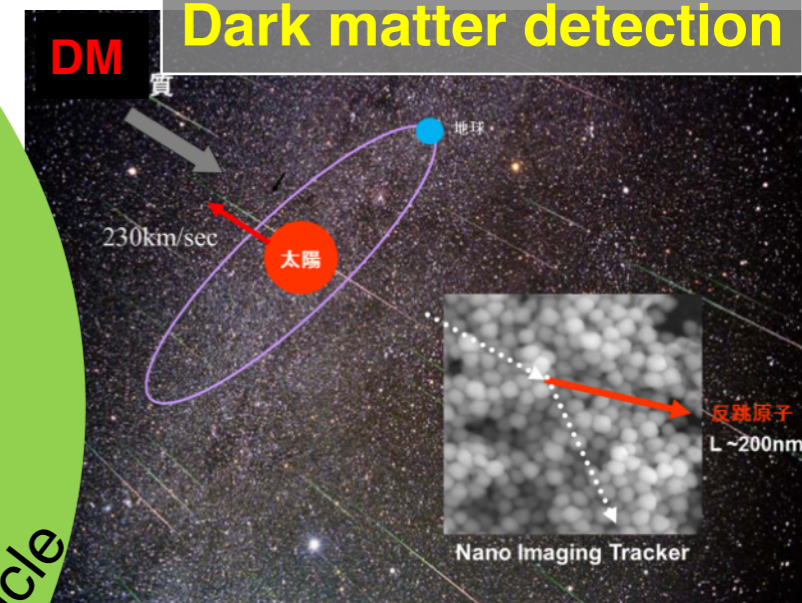
Neutron imaging



# Ongoing Emulsion Projects

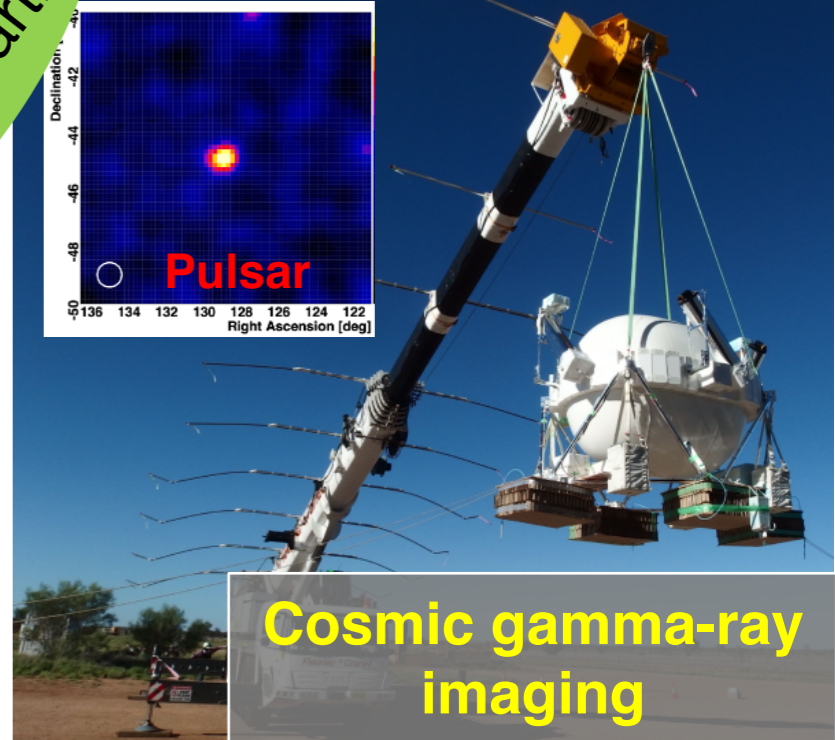


Dark matter detection



Pulsar

Cosmic gamma-ray imaging



# Development of Automatic Coat Method

## - Knife Coater Method-

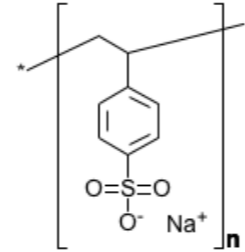
Hot Emulsion Gel

Knife coater head

clearance

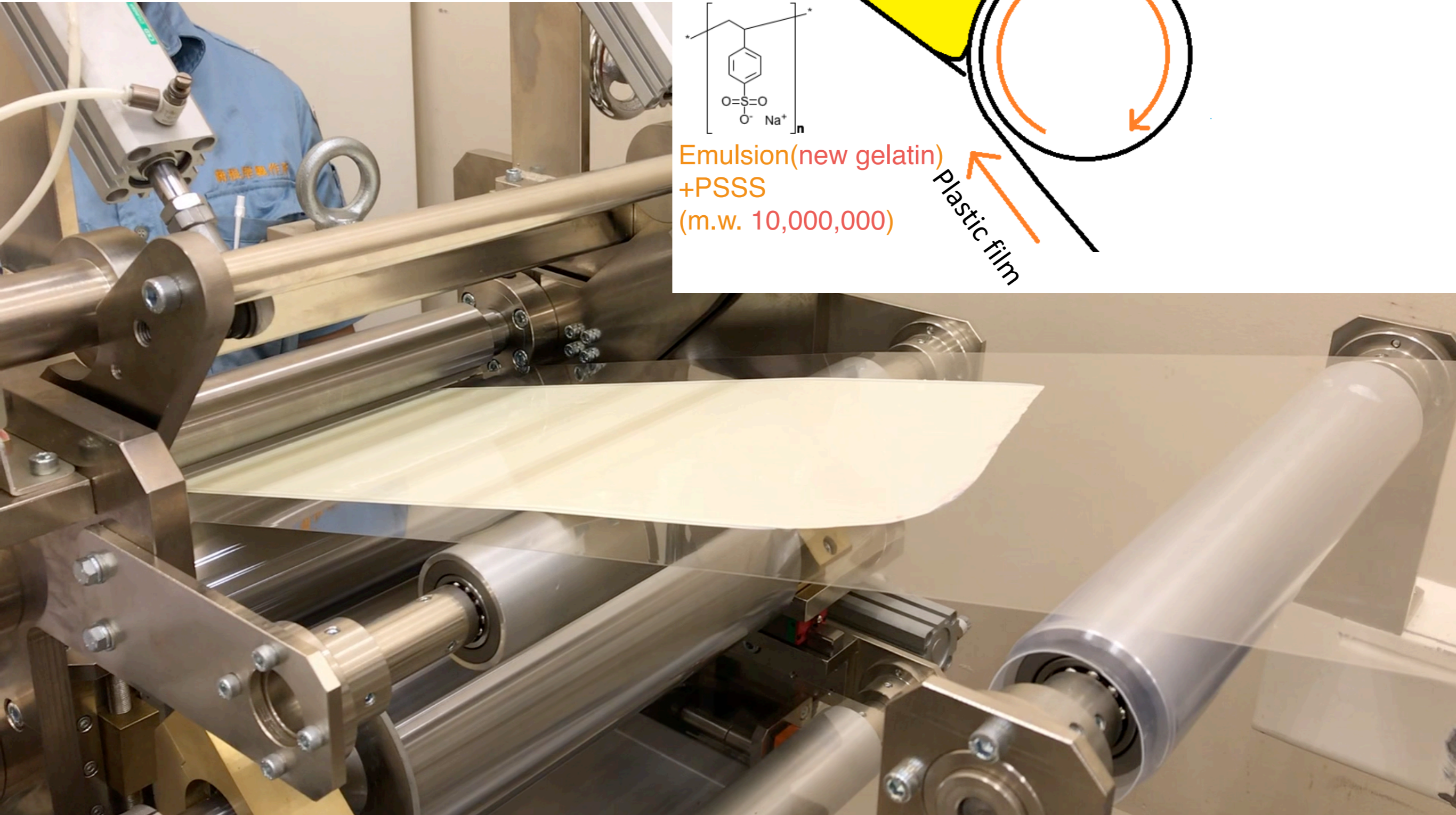
Plastic film

Viscosity Tuning

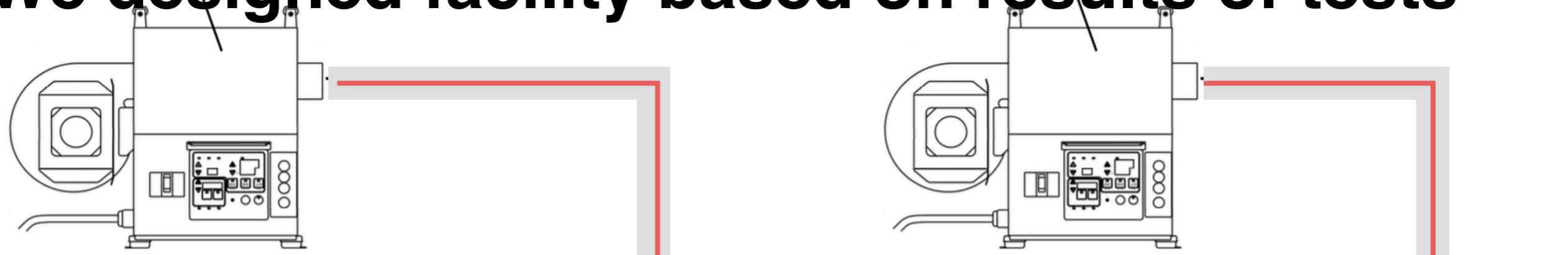


Emulsion(new gelatin)  
+PSSS  
(m.w. 10,000,000)

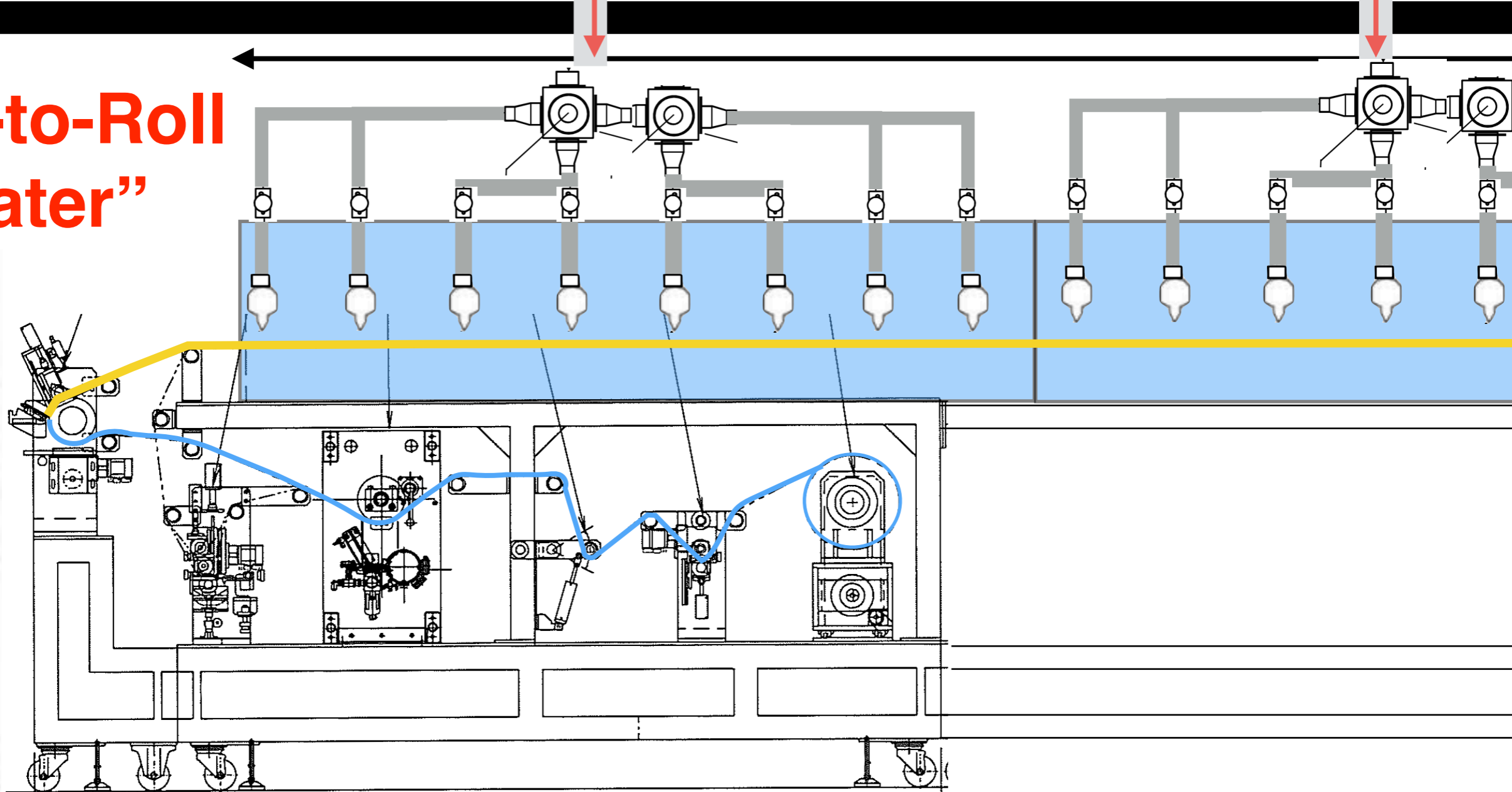
Plastic film



# We designed facility based on results of tests



**“Roll-to-Roll  
Coater”**



**2021 May.-  
Roll-to-roll emulsion film  
coating facility  
started practical operation  
(Real production in the dark)**

**Coating**

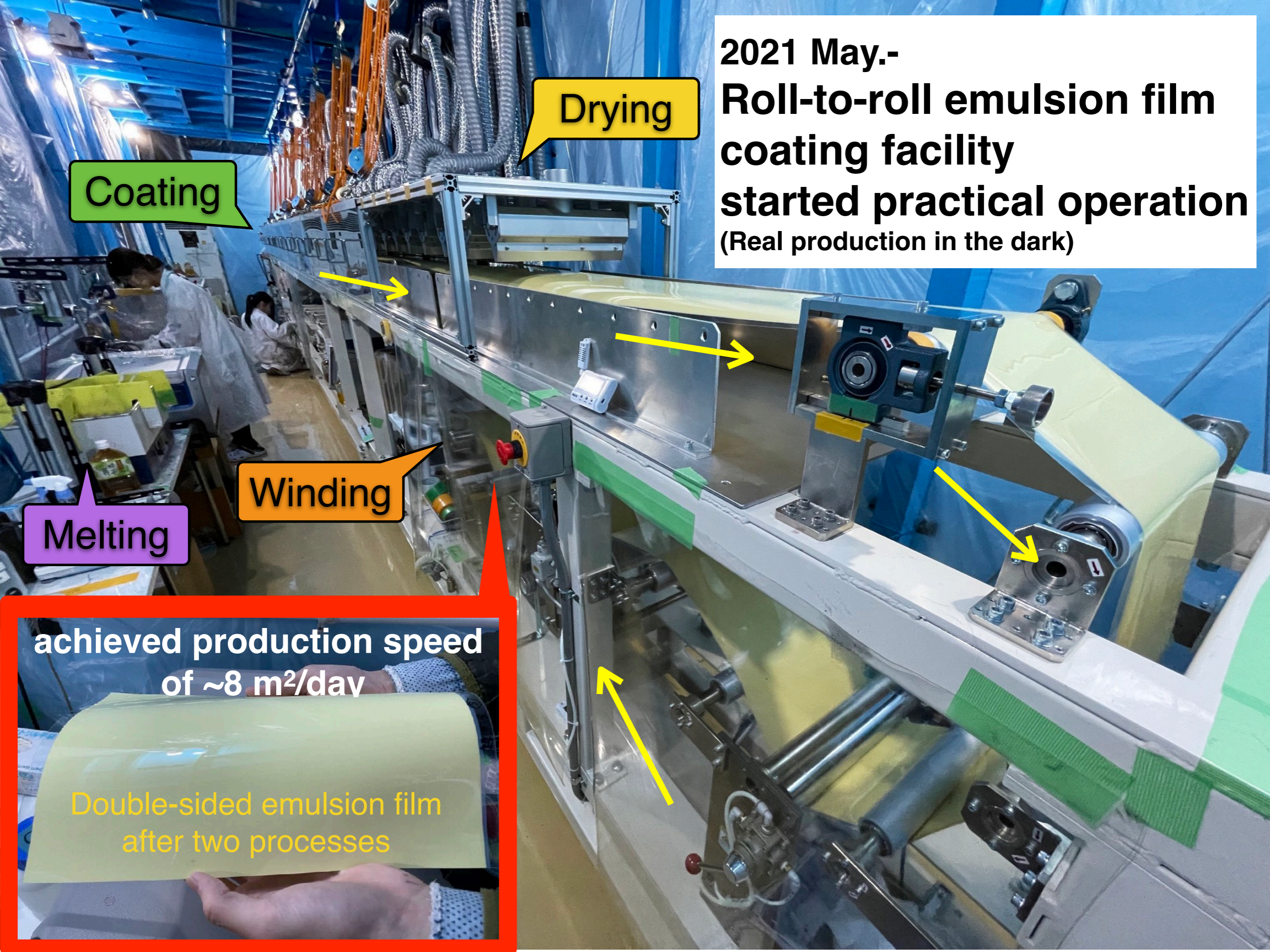
**Drying**

**Winding**

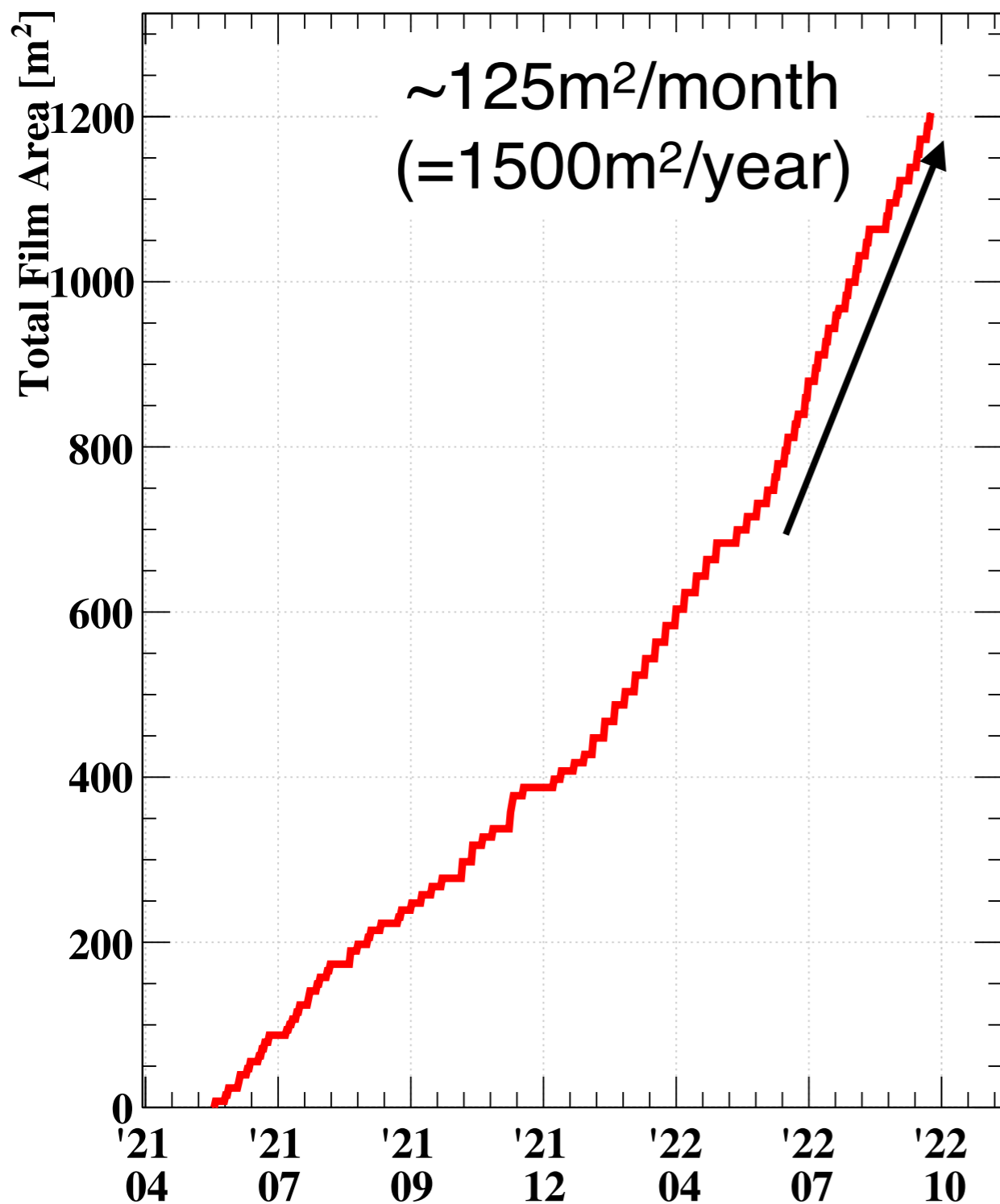
**Melting**

**achieved production speed  
of  $\sim 8 \text{ m}^2/\text{day}$**

**Double-sided emulsion film  
after two processes**



# Result of Mass Production in the new facility



celebration for the 100th batch in the new facility

Started supply for  
DsTau (2021&2022 run)  
FASER-nu (2022 run)  
SND (2022 run)  
GRAINE R&D  
Proton radiography R&D

In June 2022,  
Full speed operation for  
GRAINE (Balloon experiment)  
NINJA (2023run)  
...etc.

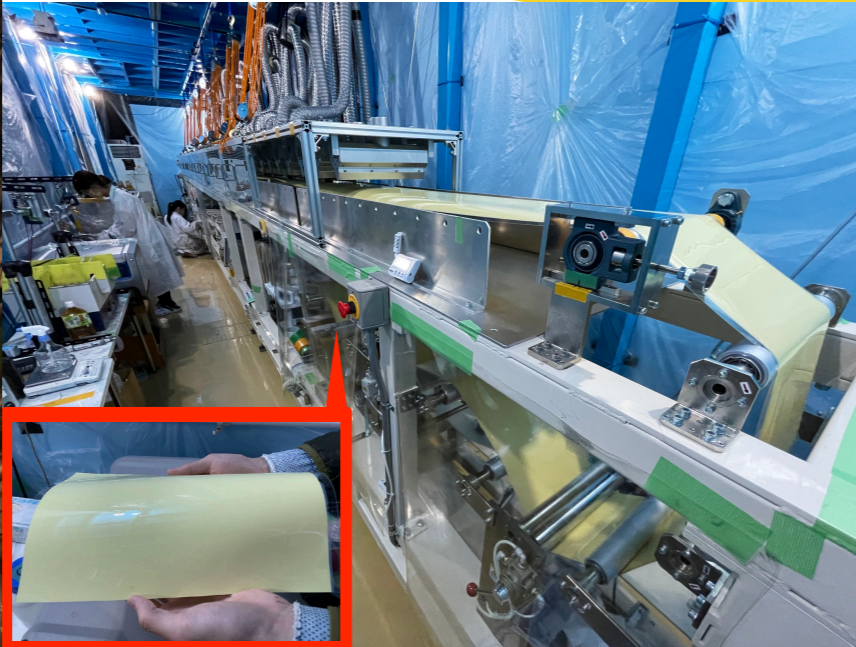
# Film Production for

# FASER-nu 2022 run

Gel Production



Gel-to-Film (coating & drying)



Cutting into Sheet (250 x 300 mm<sup>2</sup>)



**Provided 150 m<sup>2</sup>  
Emulsion Film in total.**



- ✓ Installation in Mar.
- ✓ Installation in Jul.
- ✓ Installation in Sep.

Resetting process  
(humidity control)

Shipping to CERN

# Emulsion Film for FASERnu2

The amount of emulsion films per year:

40×40 cm<sup>2</sup>×3300 films or 20×40 cm<sup>2</sup>×6600 films (total ~550 m<sup>2</sup>)

year		Emulsion film production for FASER <sub>v2</sub>
2031	year-1	~550 m <sup>2</sup>
2032	year-2	~550 m <sup>2</sup>
...	year-3	~550 m <sup>2</sup>
...	year-4	~550 m <sup>2</sup>
...	year-5	~550 m <sup>2</sup>
...	year-6	if funded
...	year-7	if funded
...	year-8	if funded
...	year-9	if funded
...	year-10	if funded

Film of 550m<sup>2</sup>/year will be available with Nagoya Facility  
(We plan to upgrade facility to increase capacity by a factor of 2-3 in a few years)

# Summary

- **Nuclear emulsion is a key technology for investigating interaction at the VTX**
- **Emulsion Film Facility in Nagoya started mass production from 2021.**
- **Current capacity: 1500 m<sup>2</sup>/year**
- **150m<sup>2</sup> emulsion films were provided for FASERnu in 2022.**
- **Film of ~550m<sup>2</sup>/year for FASERnu2 will be available with Nagoya Facility.**