

Nagoya University
Nuclear Emulsion Facility
:Recent Activities and Prospects of
Film Production

Hiroki ROKUJO
(Nagoya Univ.)

Contents

- Nagoya University Nuclear Emulsion Facility
(**NUNEF**)
 - Mission of NUNEF
 - Progress of mass production in recent 5 years.
- Latest R&Ds to improve the film production.

Why do we use emulsion?

A: One and Only Vertex detector

ν , had., e^{+-} , Nucl.

Cross section
(Electron microscopic view)

~60-70 μm Emulsion

~200 μm Plastic

~60-70 μm Emulsion



Why do we use emulsion?

A: One and Only Vertex detector

Cross section
(Electron microscopic view)

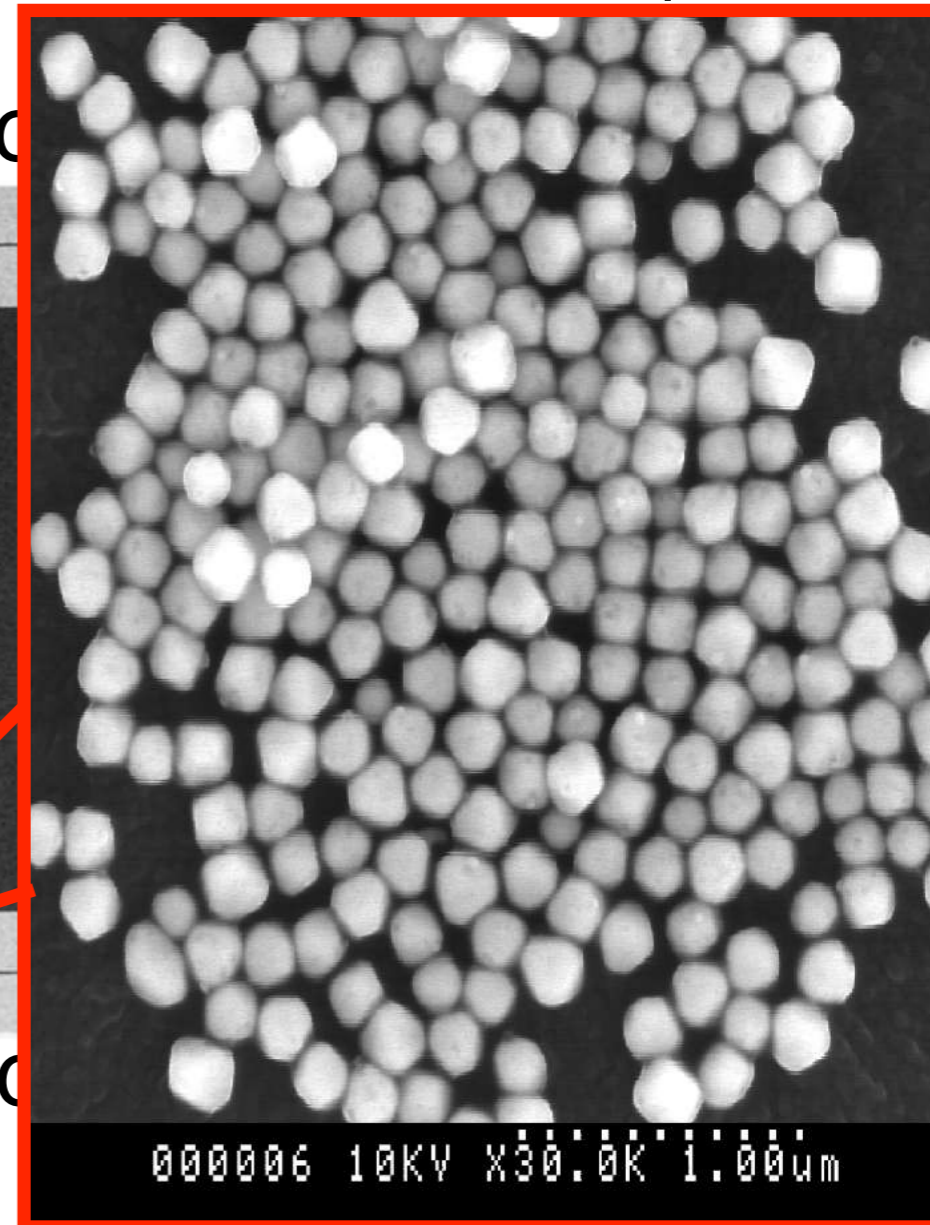
Electron microscopic view



~60-70 μm Emulsion

~200 μm Plastic

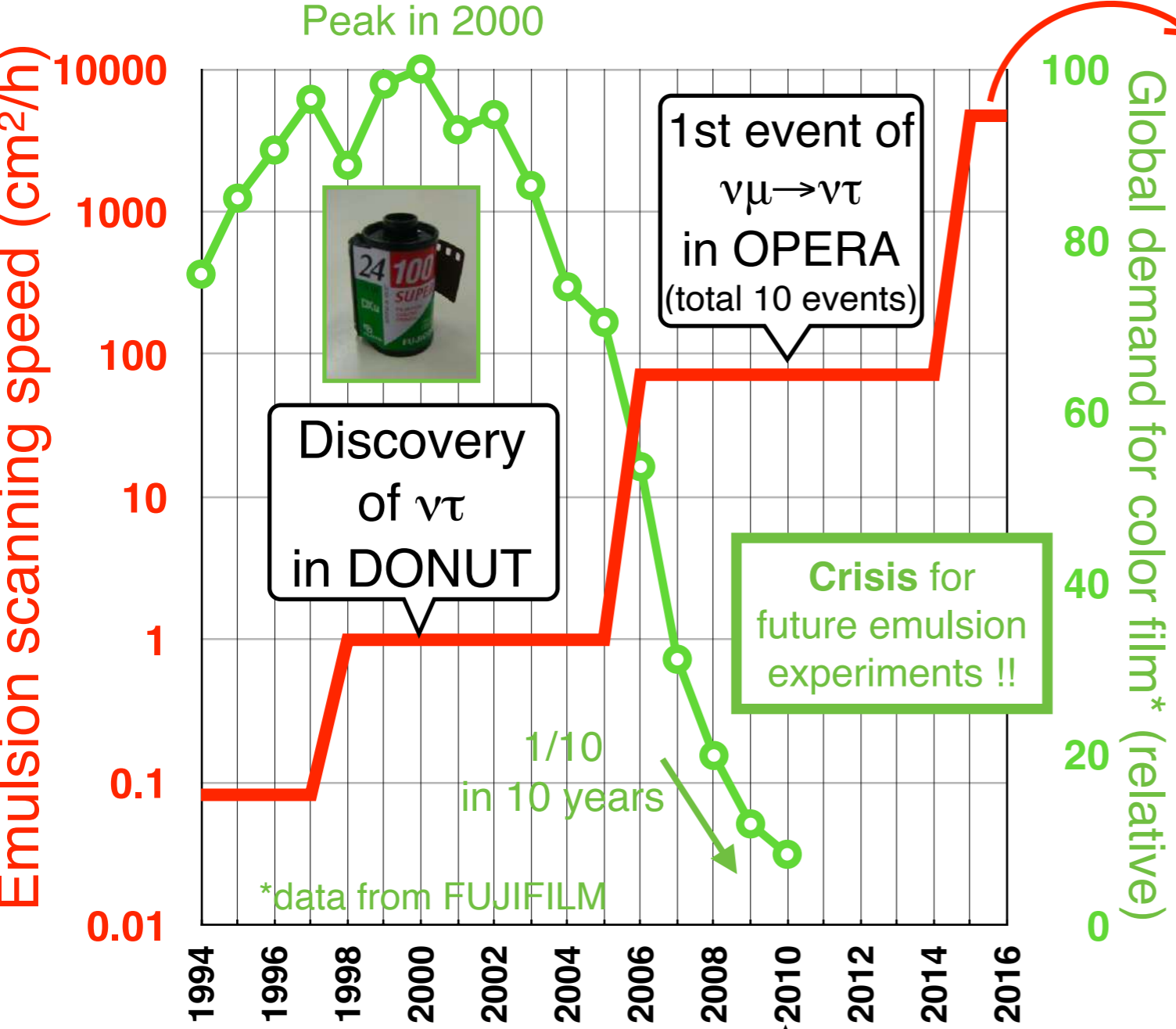
~60-70 μm Emulsion



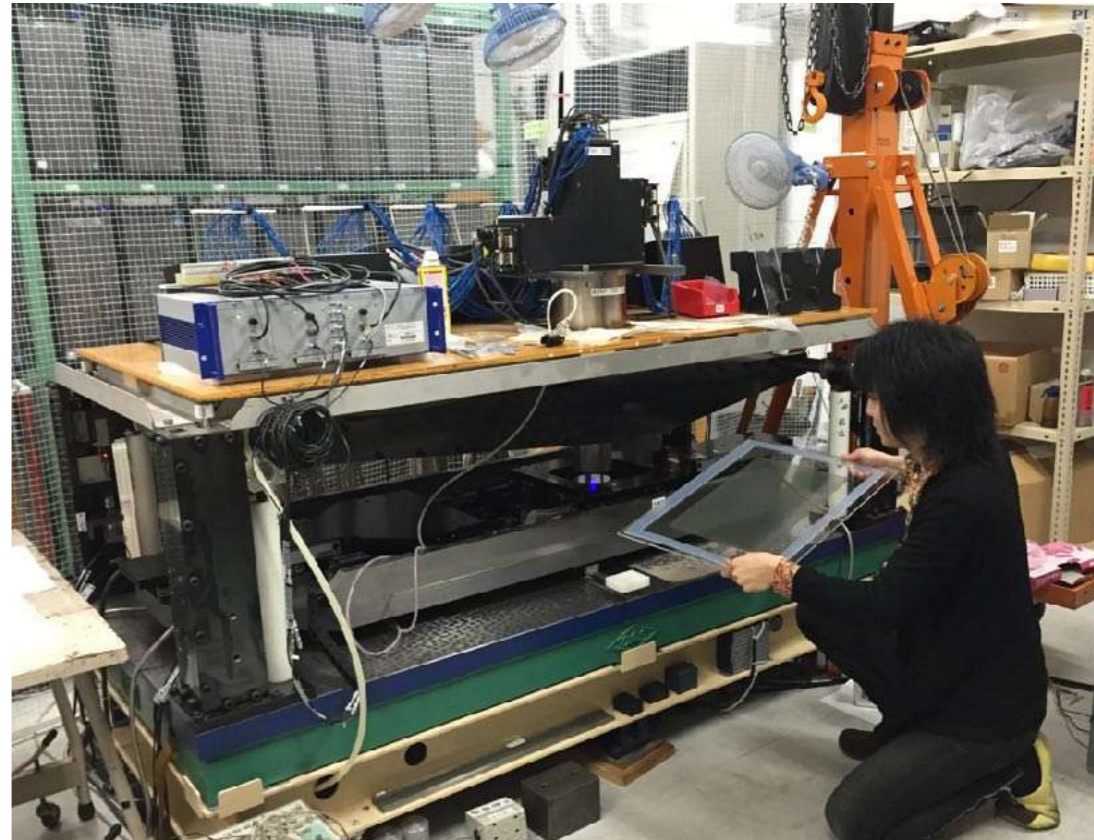
0.2 μm -diameter AgBr crystals in gelatine
function as 3-D position sensors.

Intrinsic resolution: ~ 50 nm

Evolution of Emulsion Scanning Speed and Decline of Photographic Film Industry



Current system "HTS" 5000 cm²/h



→ New system "HTS-II" (developing) will be 25000 cm²/h (x5 faster)

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

Conception of Nagoya University Nuclear Emulsion Facility (NUNEF) since 2010

Offline Analysis

illustrated by M.Nakamura

Emulsion Gel

Rokujo's talk

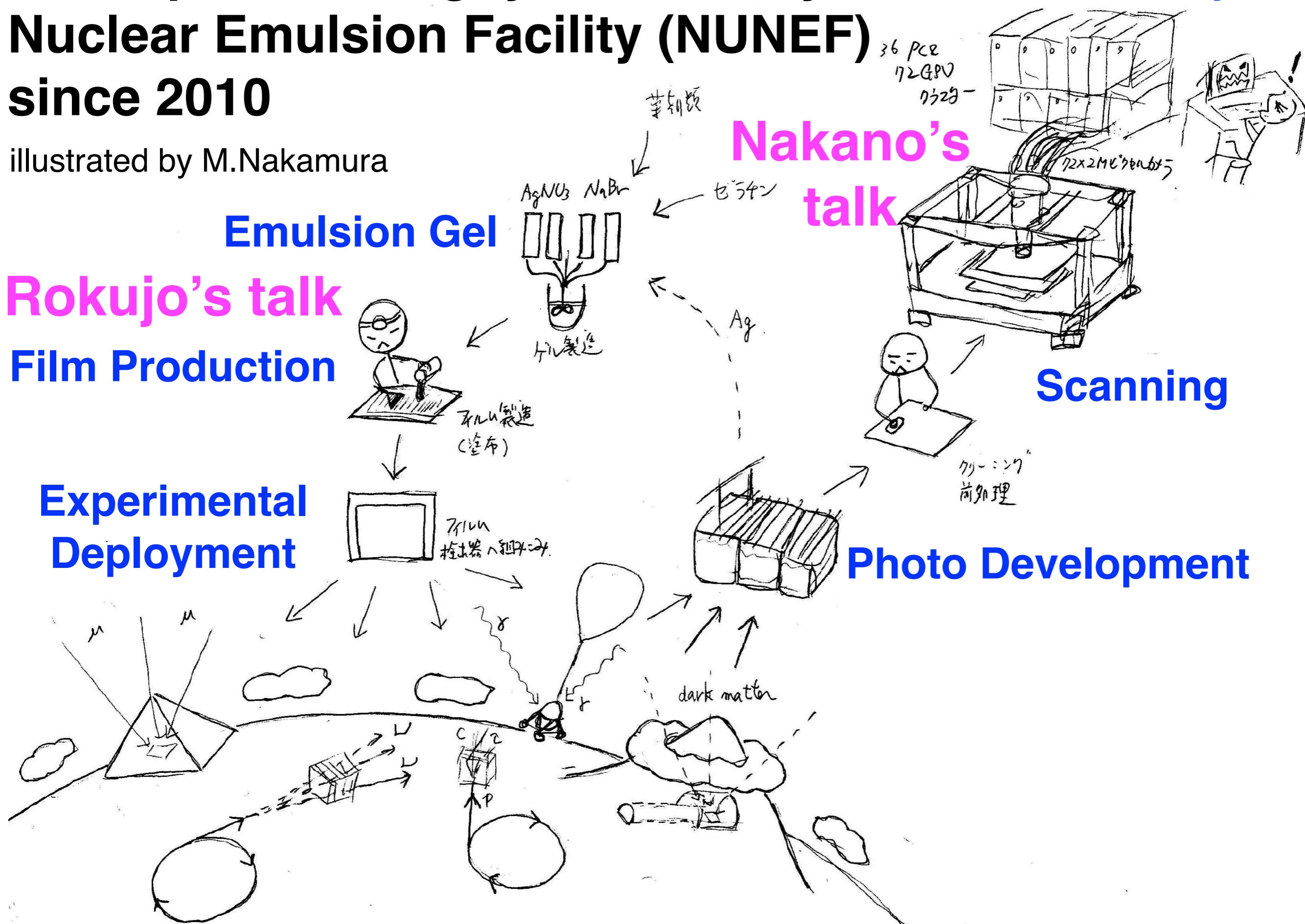
Film Production

Experimental
Deployment

Nakano's
talk

Scanning

Photo Development



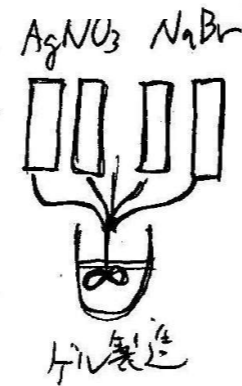
Conception of Nagoya University Nuclear Emulsion Facility (NUNEF) since 2010

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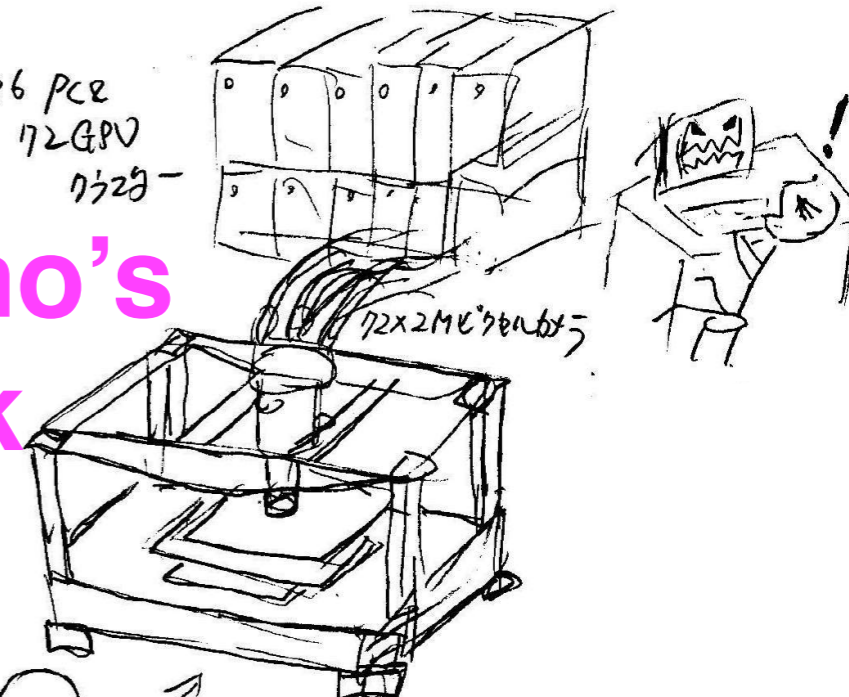
Rokujo's talk
Film Production



Experimental
Deployment



Nakano's
talk



Scanning

クリーニング
前処理
Photo Development

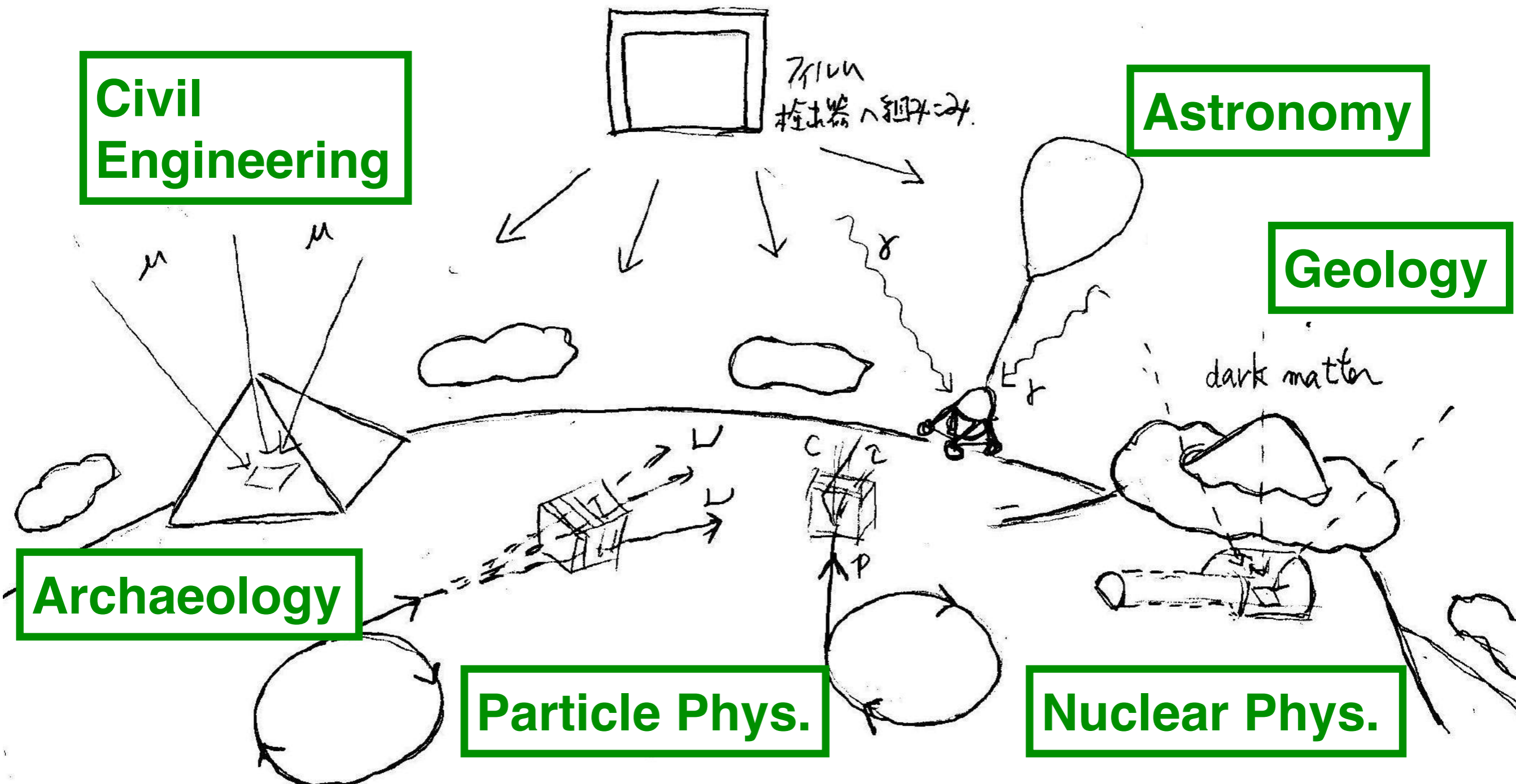
NUNEF aims at

- Build-up and maintenance of a total system for emulsion exp.
- Function as the world's hosting center for emulsion technology

Conception of Nagoya University Nuclear Emulsion Facility (NUNEF) since 2010

illustrated by M.Nakamura

Emulsions will be widely utilized
in a variety of fields.



We welcome to use NUNEF to advance your research!!

Early situation

In 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.

Early situation (2013)

Upgrade of Film Production

Conventional method (手塗り)

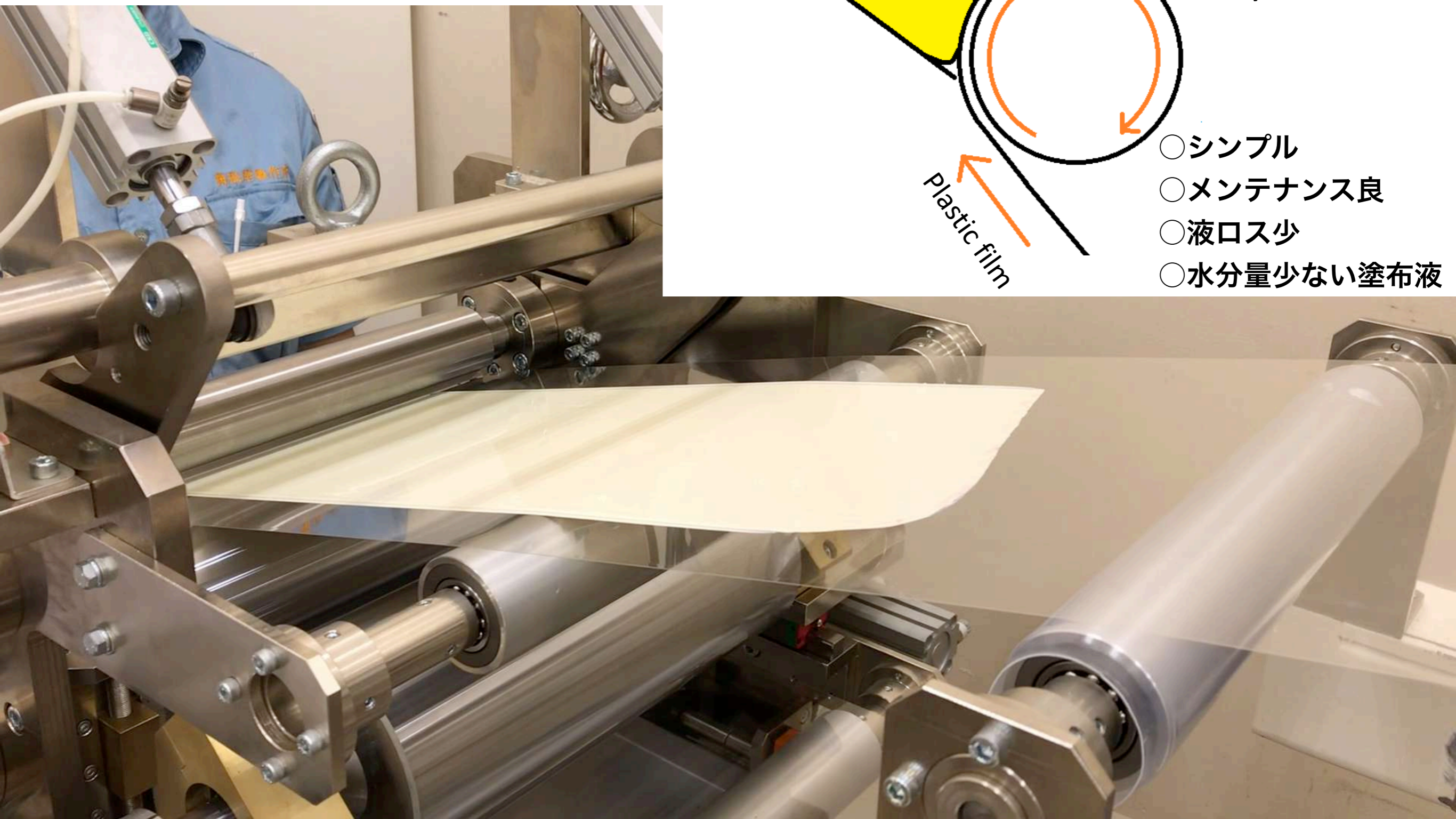
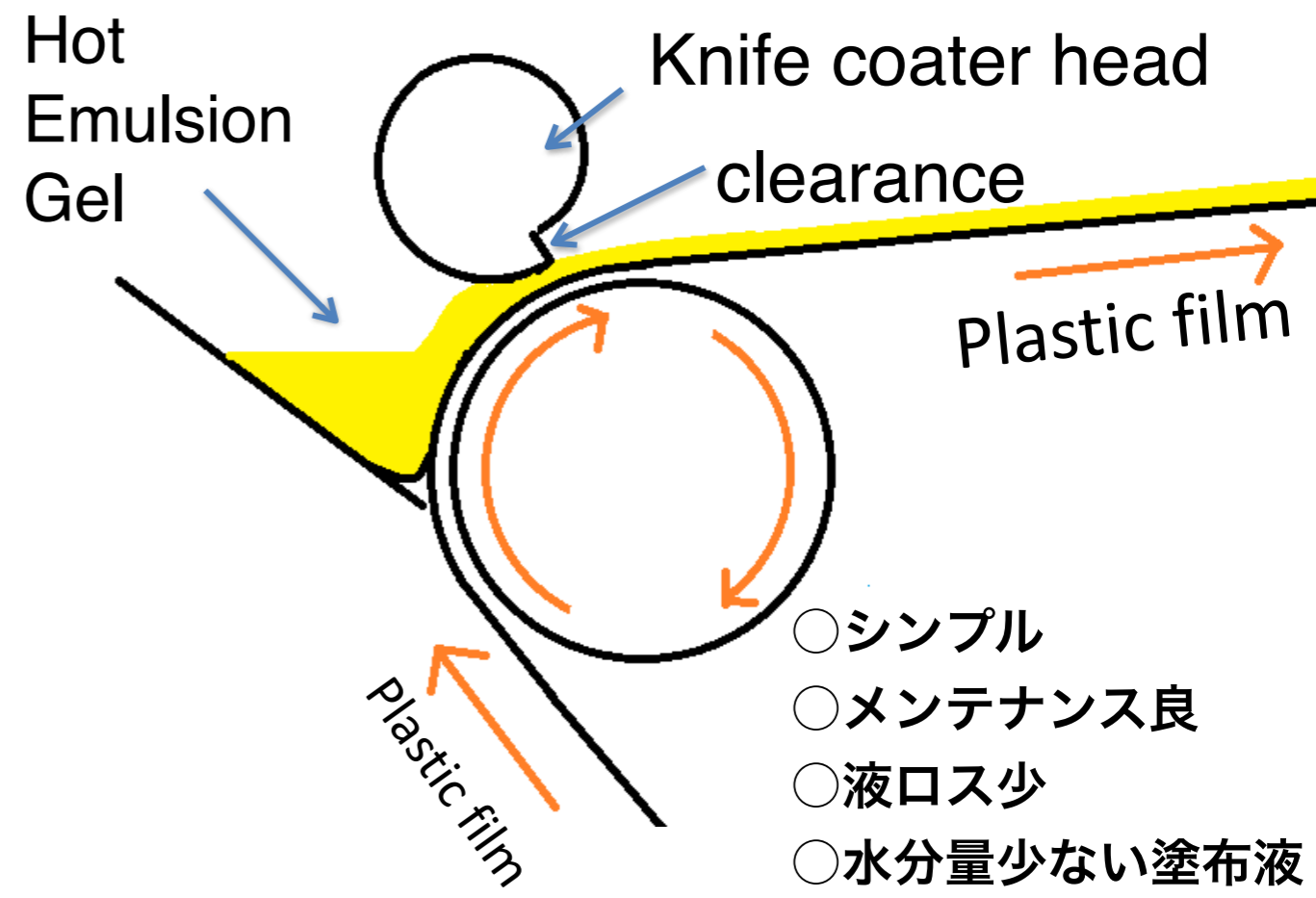


several 100 m² / year

Recent progress

Development of Automatic Coat Method

- Knife Coater Method -



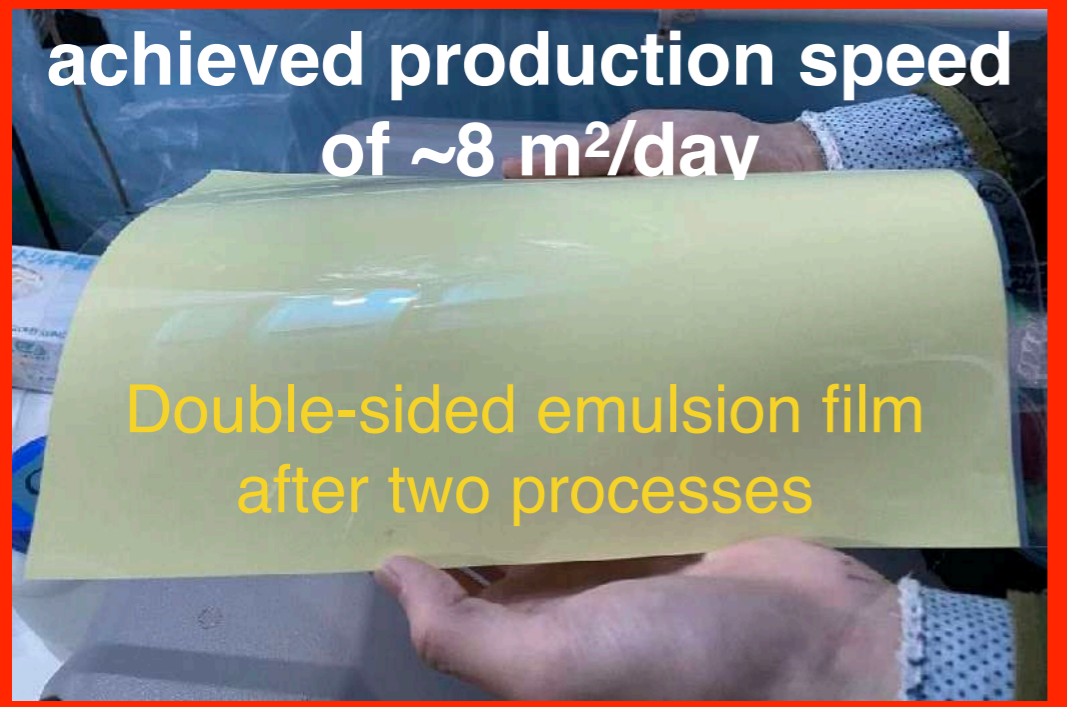
2021 May.- **Recent progress**
Roll-to-roll emulsion film coating facility
started practical operation
(Real production in the dark)

Coating

Drying

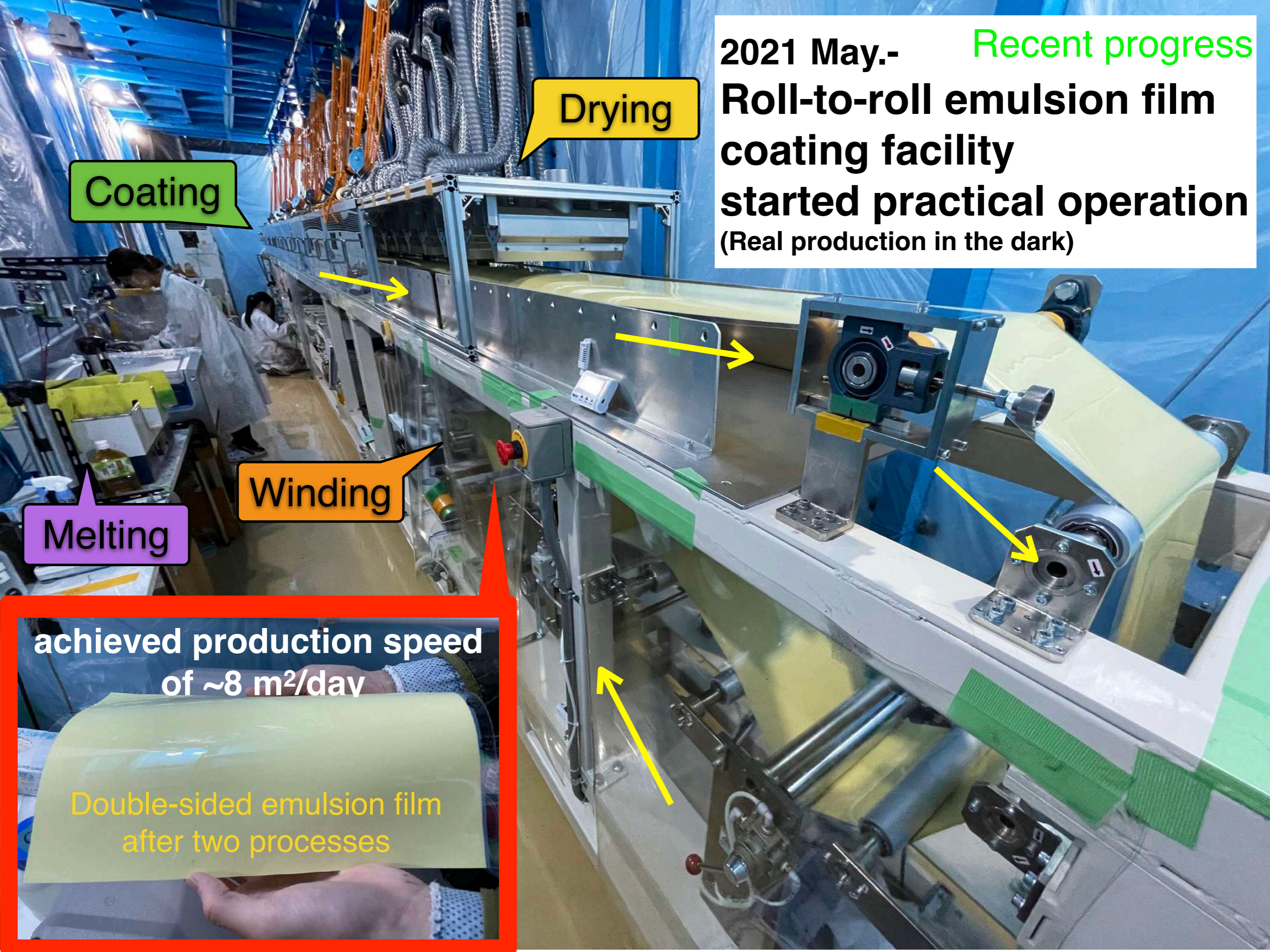
Winding

Melting



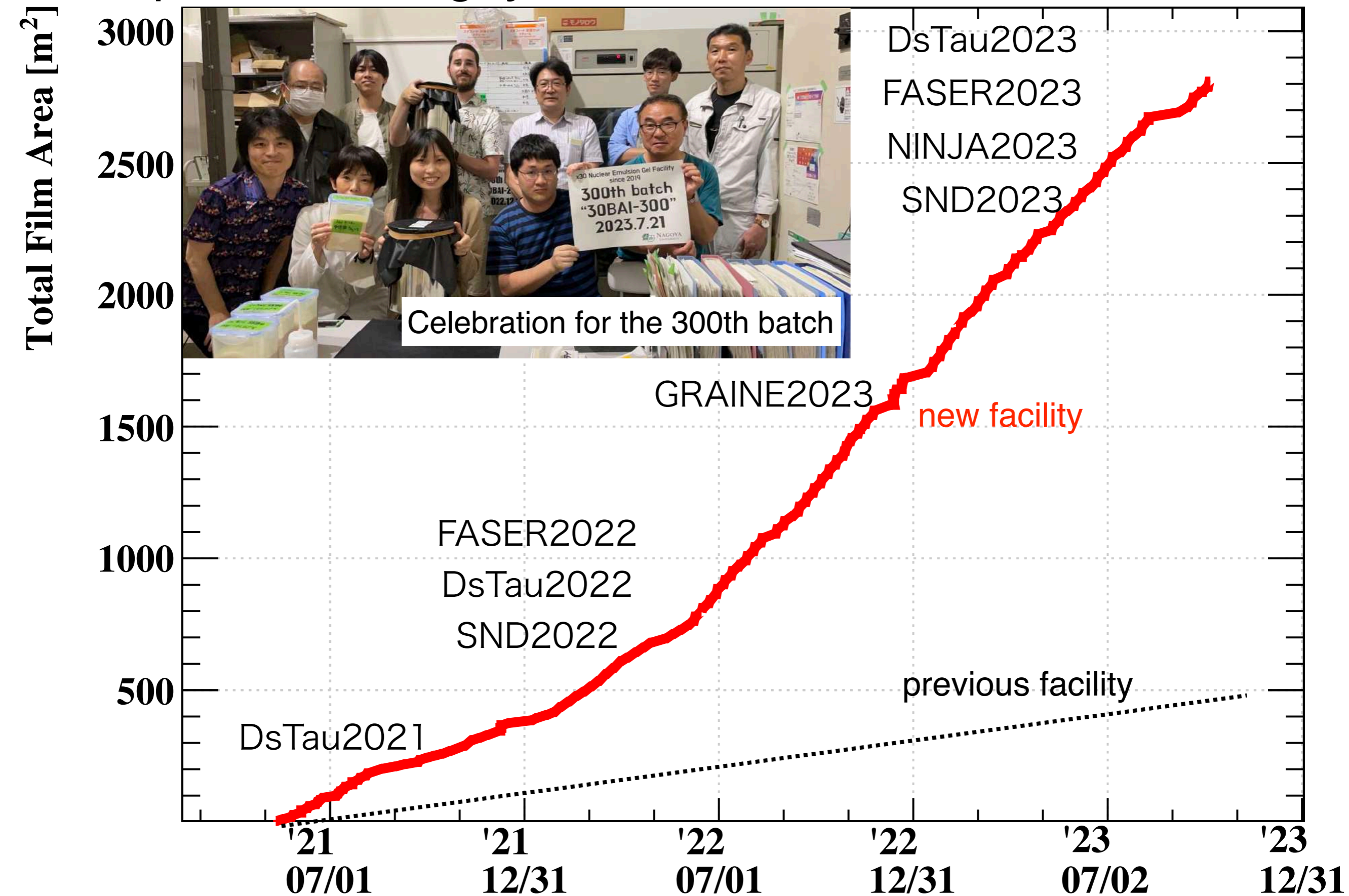
achieved production speed
of $\sim 8 \text{ m}^2/\text{day}$

Double-sided emulsion film
after two processes



Recent progress

We produced Nagoya emulsion film of ~ 3000 m² in total.



Recent R&Ds for Improvements of Emulsion/Film production

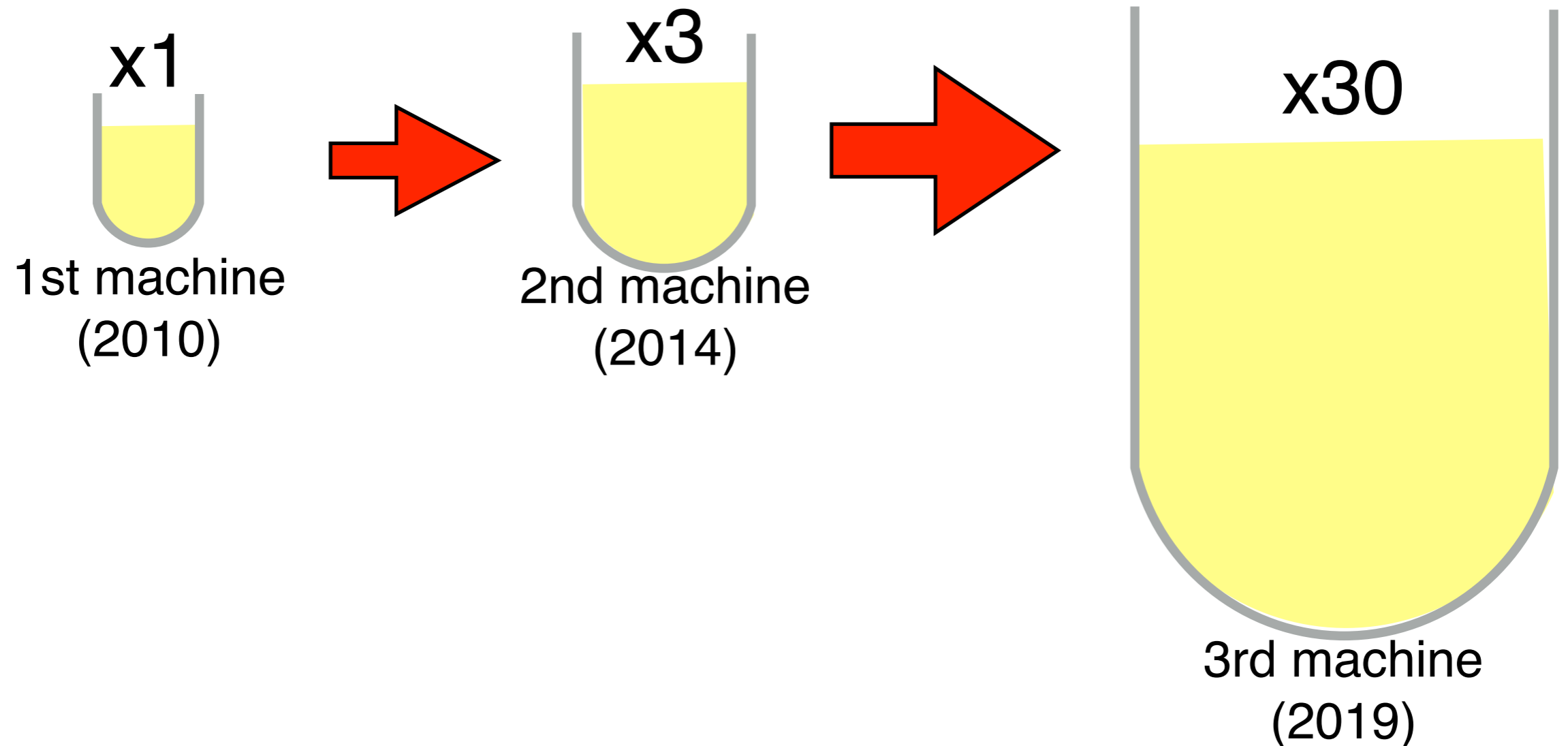
Studies on

- (1) increasing the gel production capacity
- (2) size-up of developing silver grains
- (3) new developer for size-up
- (4) improvement of R-to-R coating
- (5) protection layer coating

(1) Study on increasing gel production capacity

Current Nagoya-gel recipe (2010)

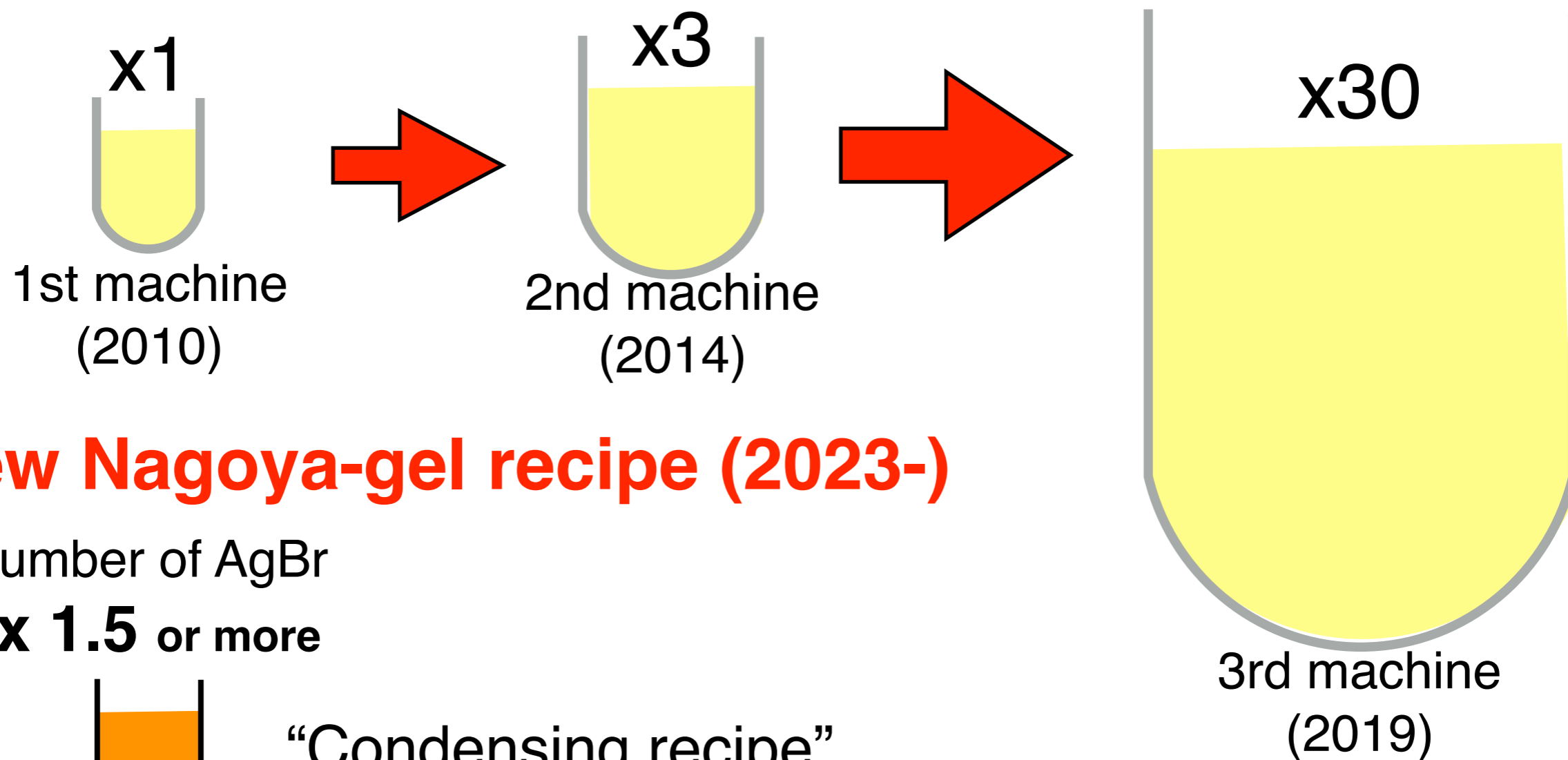
was standardized by Kuwabara, Naganawa et al.
based on the results of OPERA film.



(1) Study on increasing gel production capacity

Current Nagoya-gel recipe (2010)

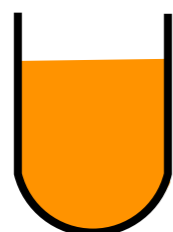
was standardized by Kuwabara, Naganawa et al. based on the results of OPERA film.



New Nagoya-gel recipe (2023-)

number of AgBr

x 1.5 or more

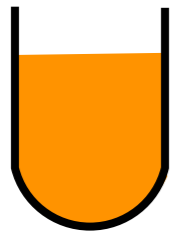


“Condensing recipe”

1st machine

Development of new recipe

Number of AgBr
x 1.5



1st machine

✓ Crystal Formation(MT)

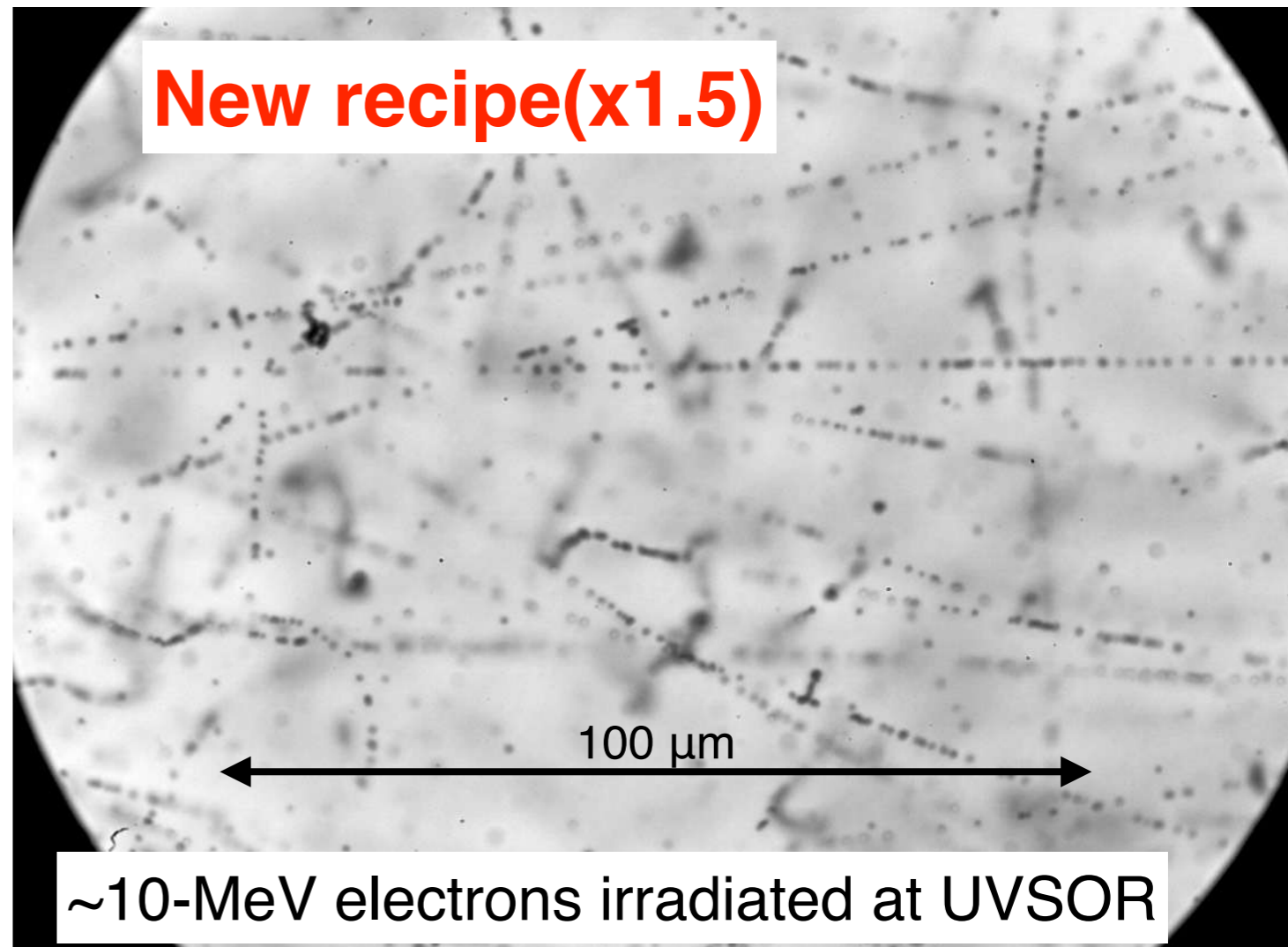
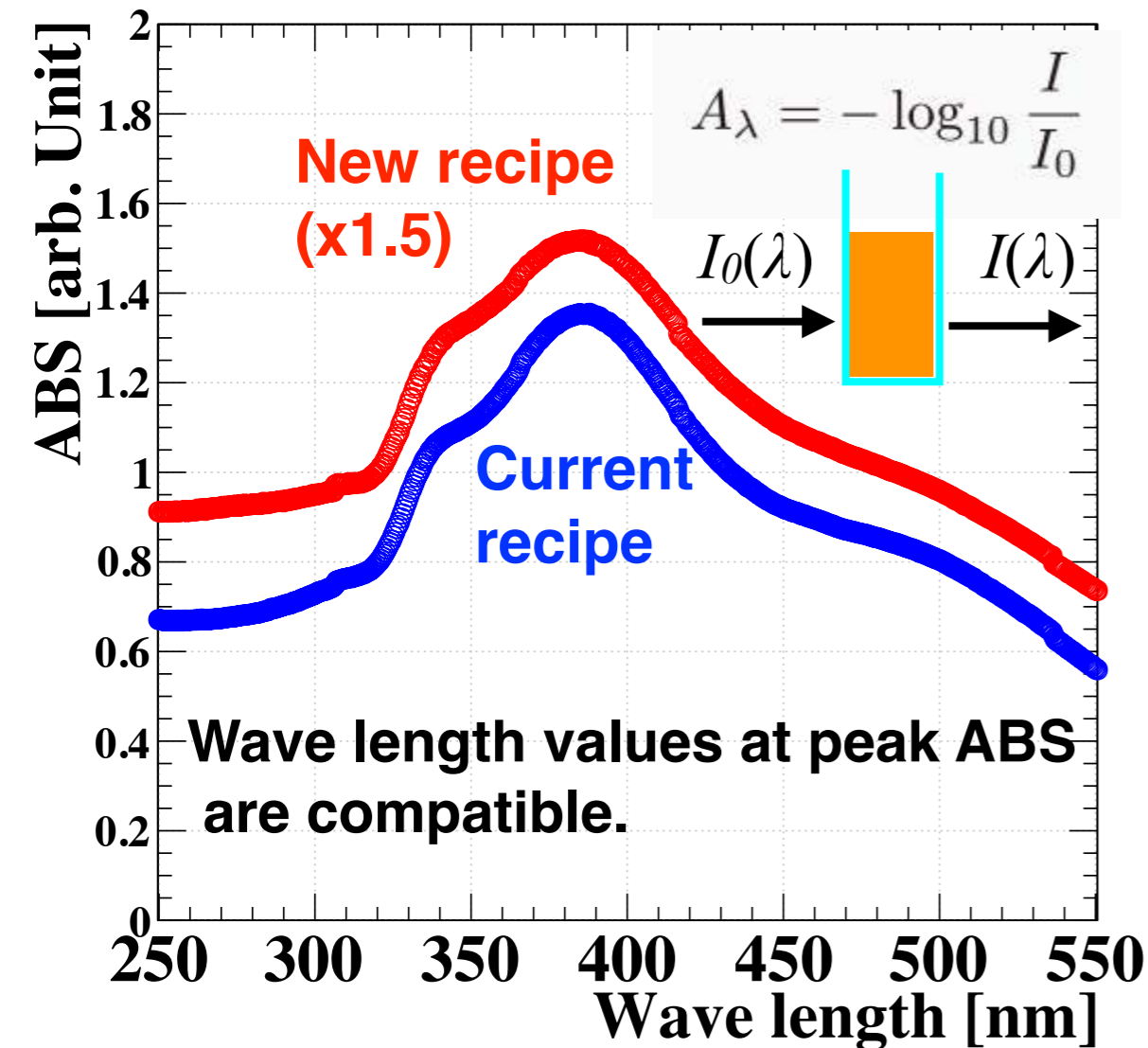
✓ Deionization (WT)

✓ Sensitization (ART)

← ✓ Dilution with gelatin

by Ohzeki et al.

OZE-047

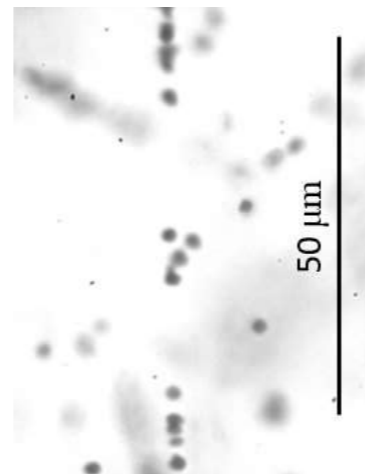
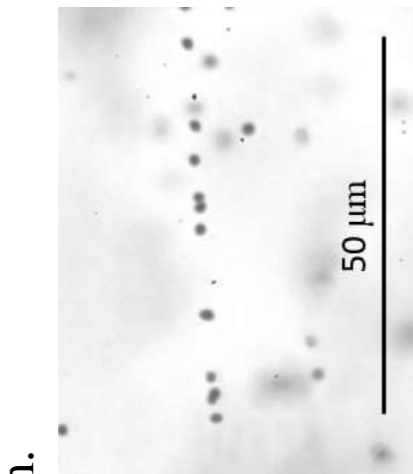
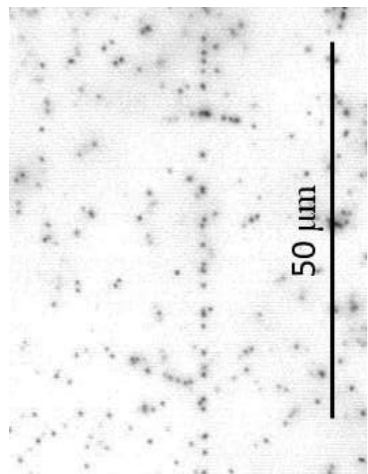


Gel production capacity could increase by a factor of 1.5 or more in the future.

(2) Study on size-up of developing silver grains

One of the directions to achieve faster scanning speeds is to **increase the size of silver grains.**

Larger silver grains



- increase the effective pixel size
- larger field of view (lower magnification)
- **Faster scanning**

T. Ariga et al JINST 11 P03003 (2016).



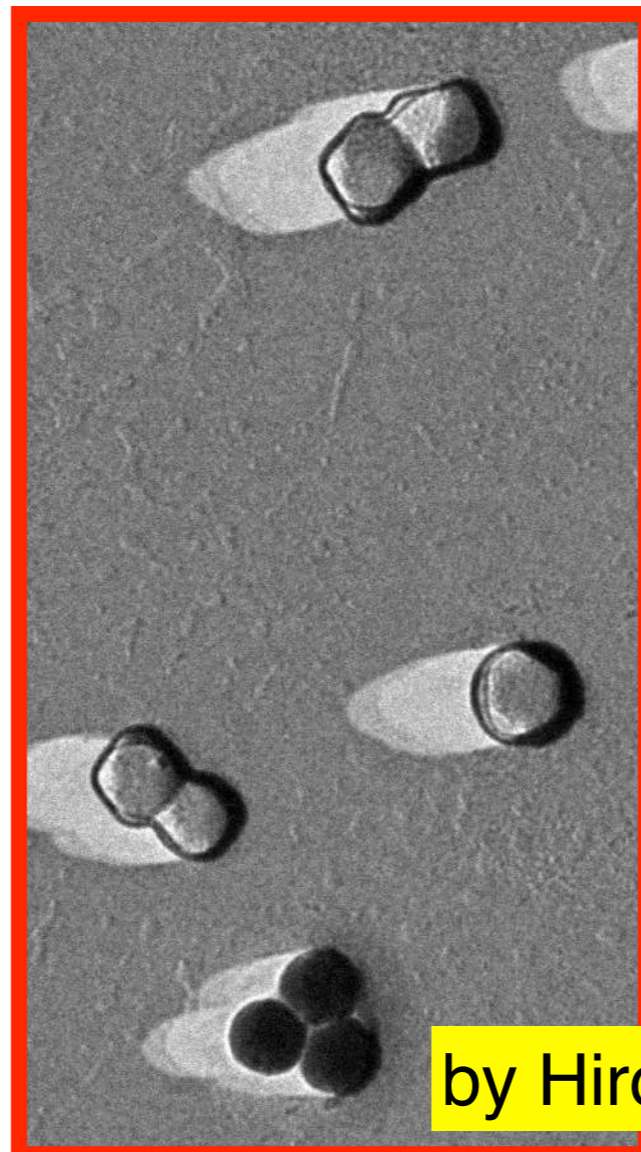
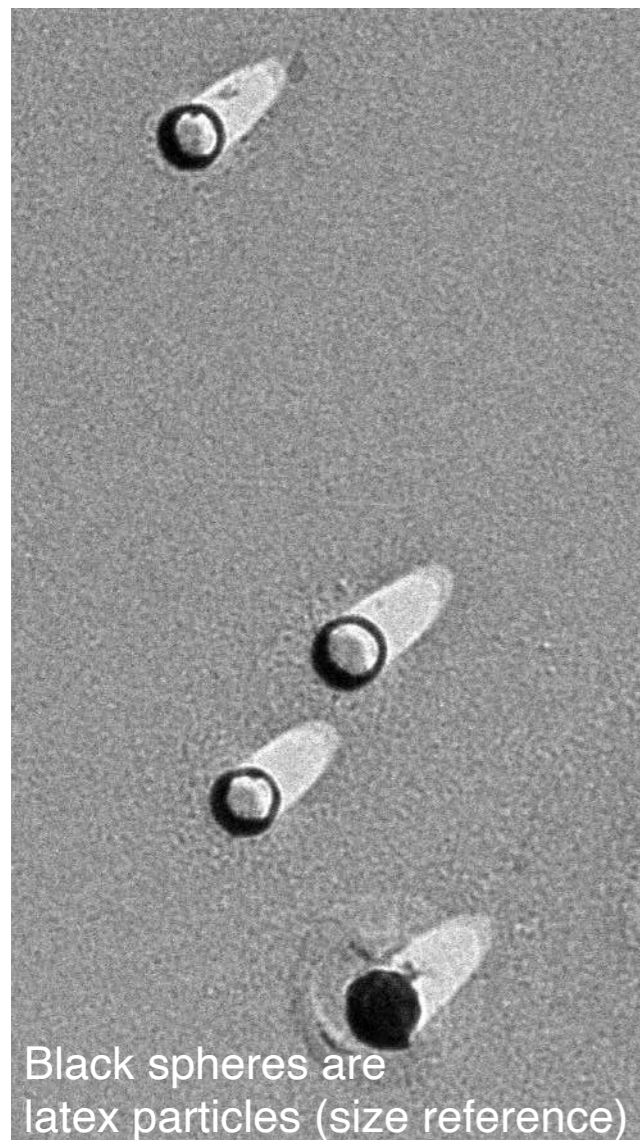
FoV increases by x2
(9.3cm x 5.2cm) with lower mag.

Mass Production of Large-crystal emulsion films in NUNEF

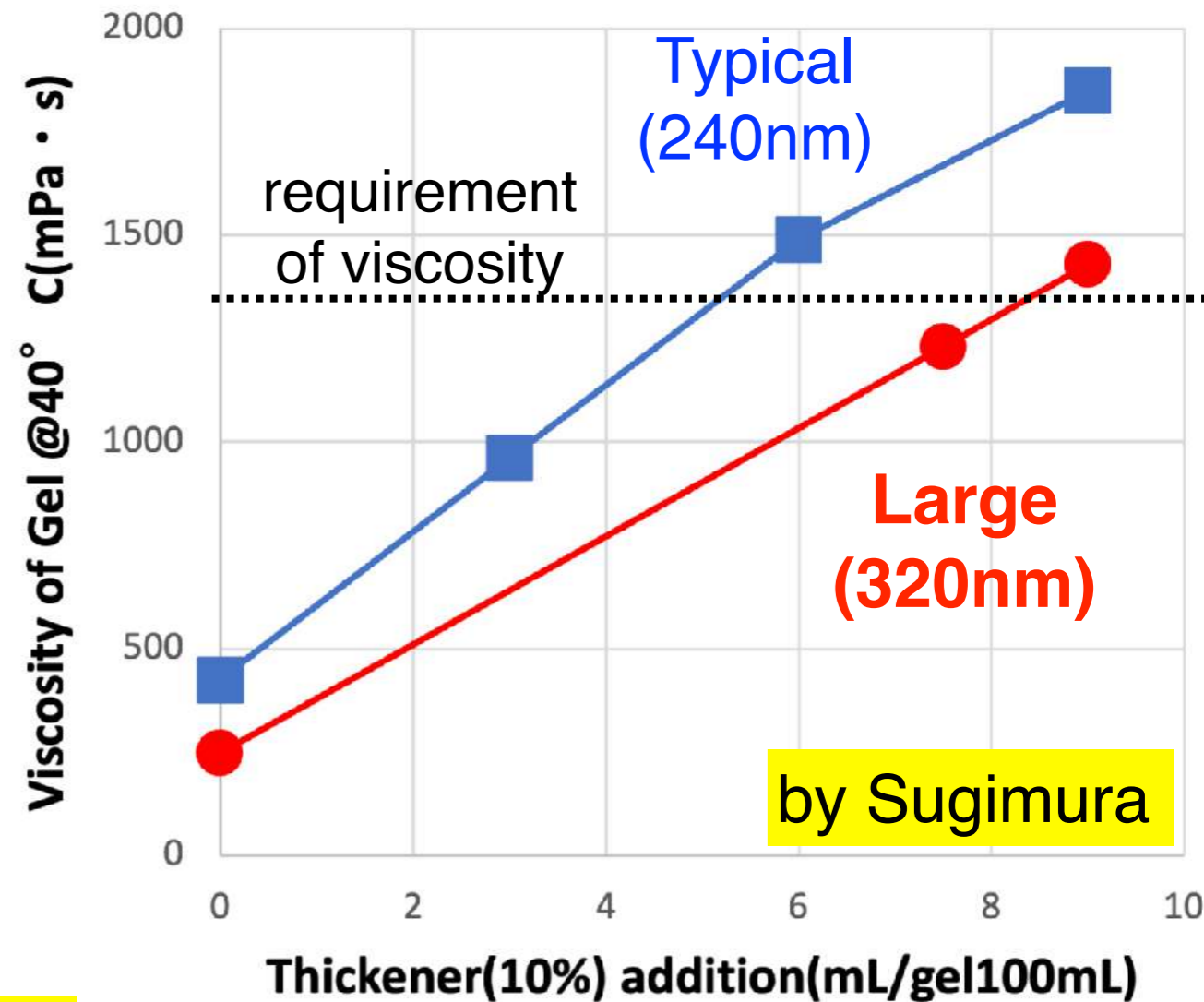
Changing and tuning the conditions of temperature in the crystals formation process, and sedimentation(沈降) in deionizing process

Typical (240nm)

Large(320nm)

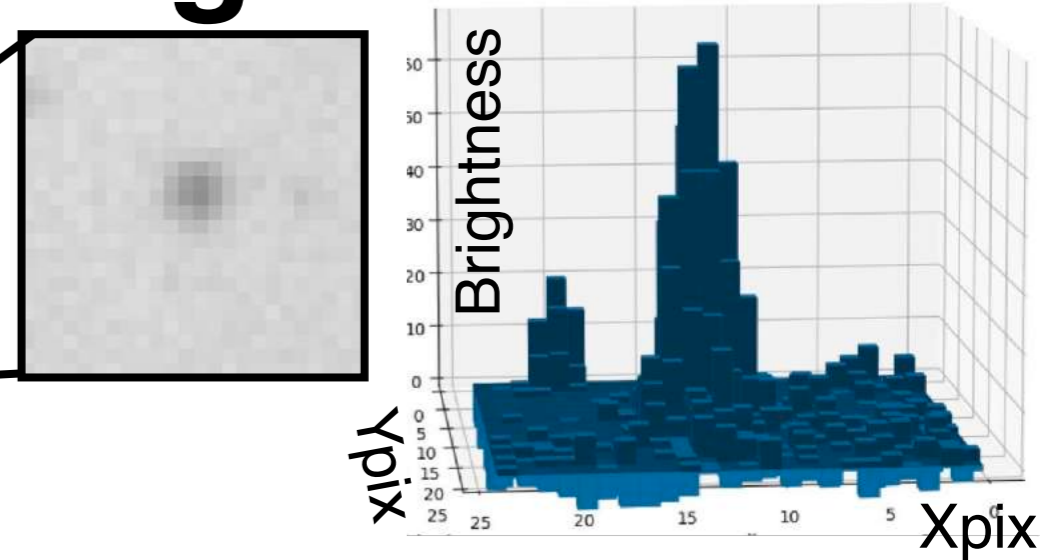
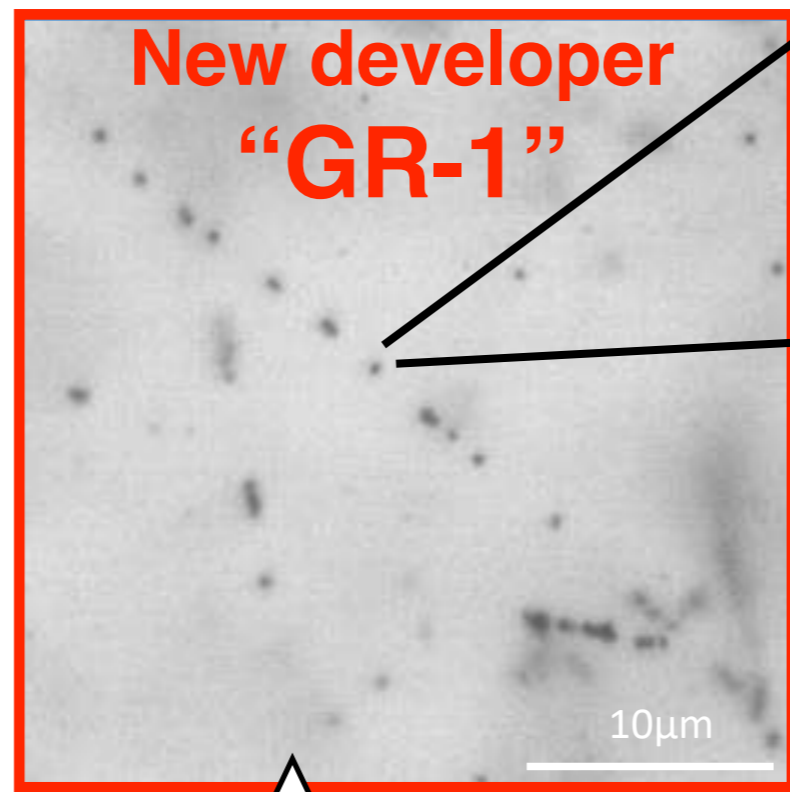
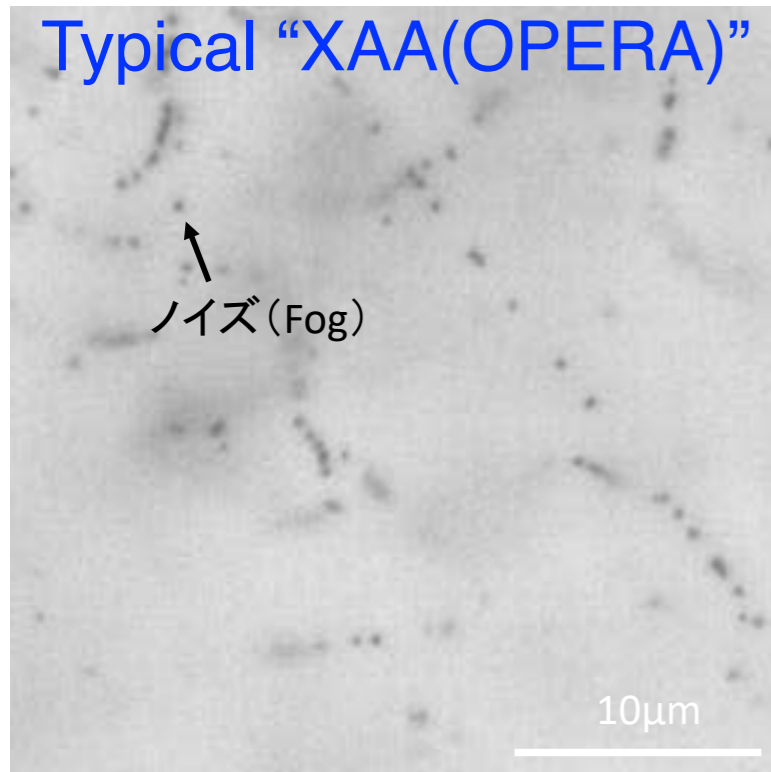


Tuning viscosity with the addition of thickener for adapting to R-to-R coating

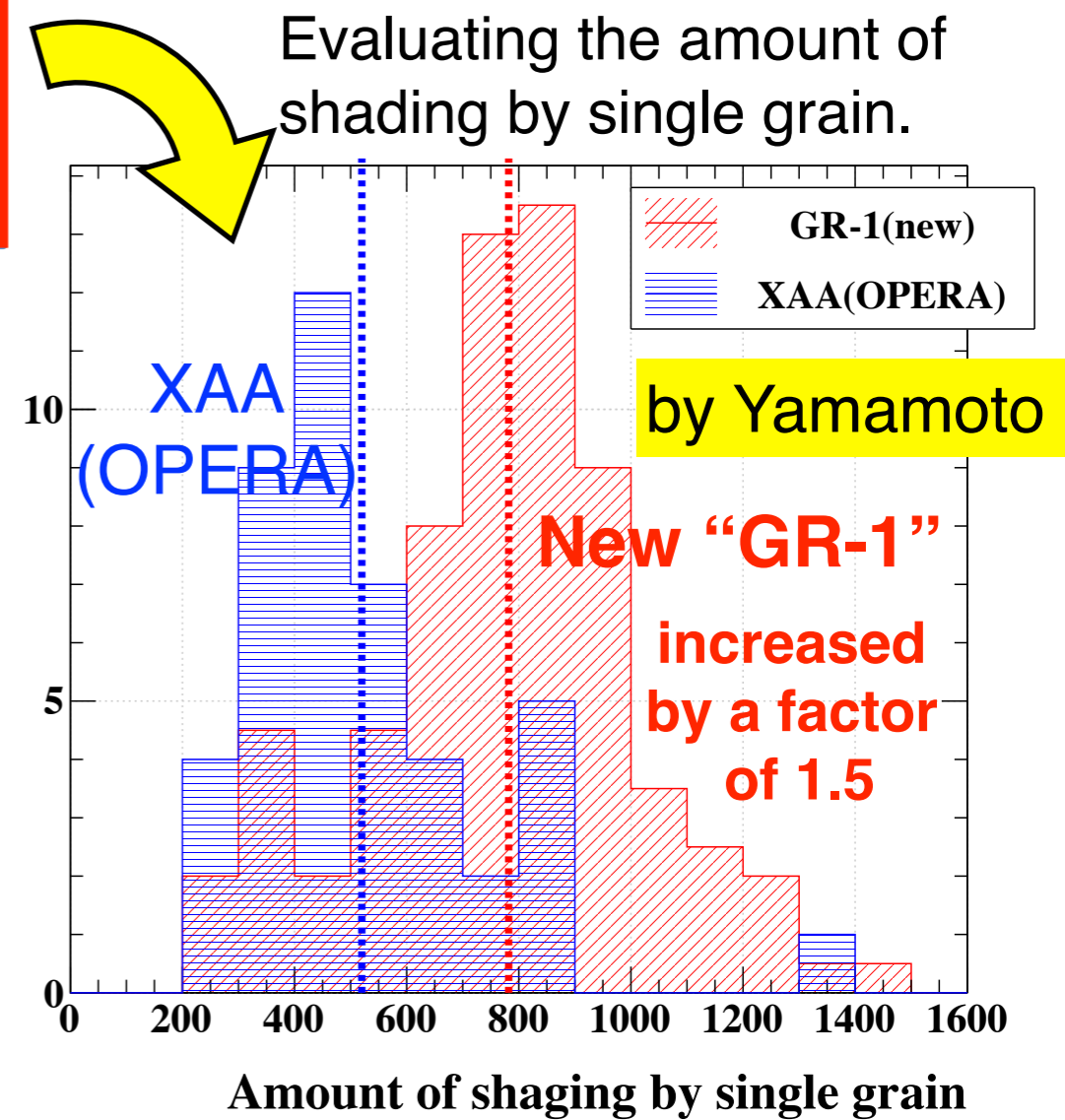


NUNEF achieved the stable mass production of large crystal emulsion films(~500 m²) for NINJA 2023 run.

(3) Study on new developer for size-up of silver grains



The silver grains are captured in a larger and denser image w/o fog up.



	XAA(OPERA) (g/L)	New "GR-1" (g/L)
Developing agent	Phenidone 3	Phenidone 1.5
	ascorbic acid 15	hydroquinone PQ dev. 20
Preservative	sodium sulfite 5	sodium sulfite 30
Accelerator	potassium carbonate 17.5	potassium carbonate 12
	sodium carbonate 10	
Untifoggant	potassium bromide 5	potassium bromide 2.5
		potassium iodide 0.002
		potassium thiocyanate 1.2

Solvent

→ Solution Physical Development

GRAINE 2023 Balloon Experiment

Photo Development of Recovered Films in JPN

Facility in Gifu University

“GR-1”

Developer

390L、 $15\pm 0.2^{\circ}\text{C}$

Wash

Stopper

Fixer

250 m²
in total

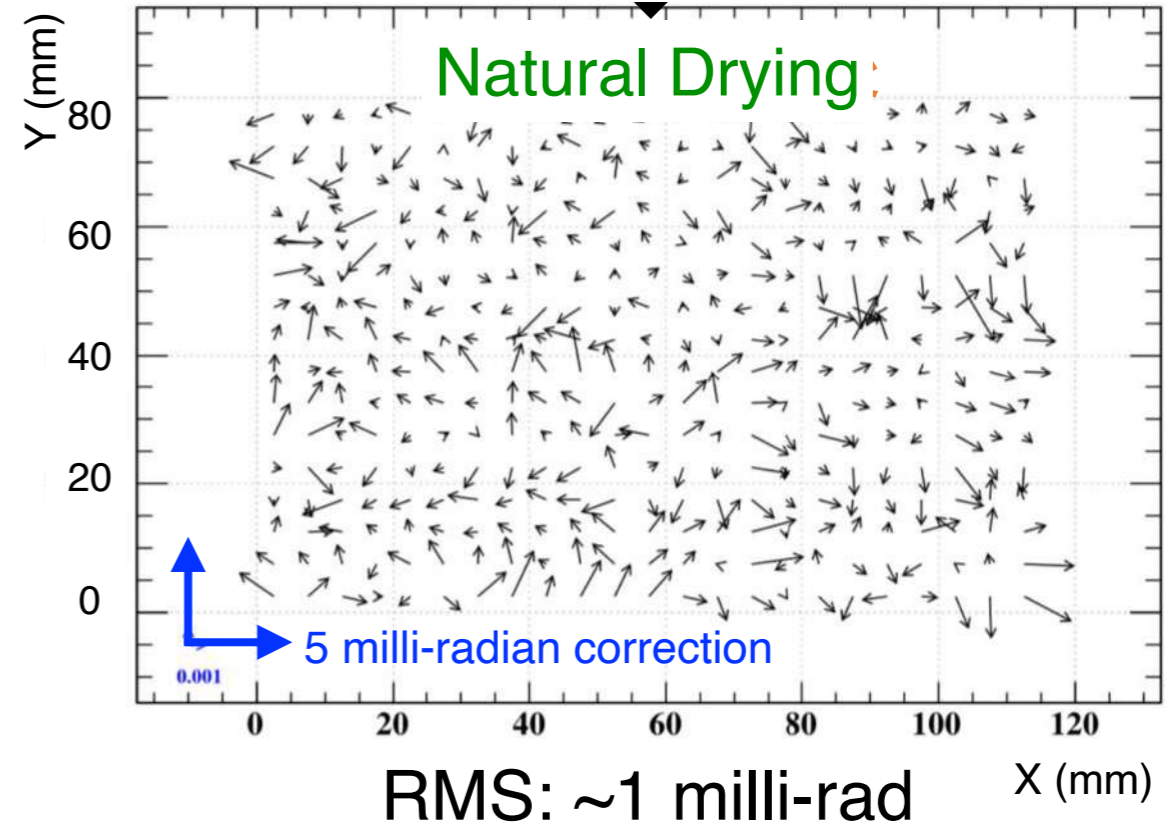
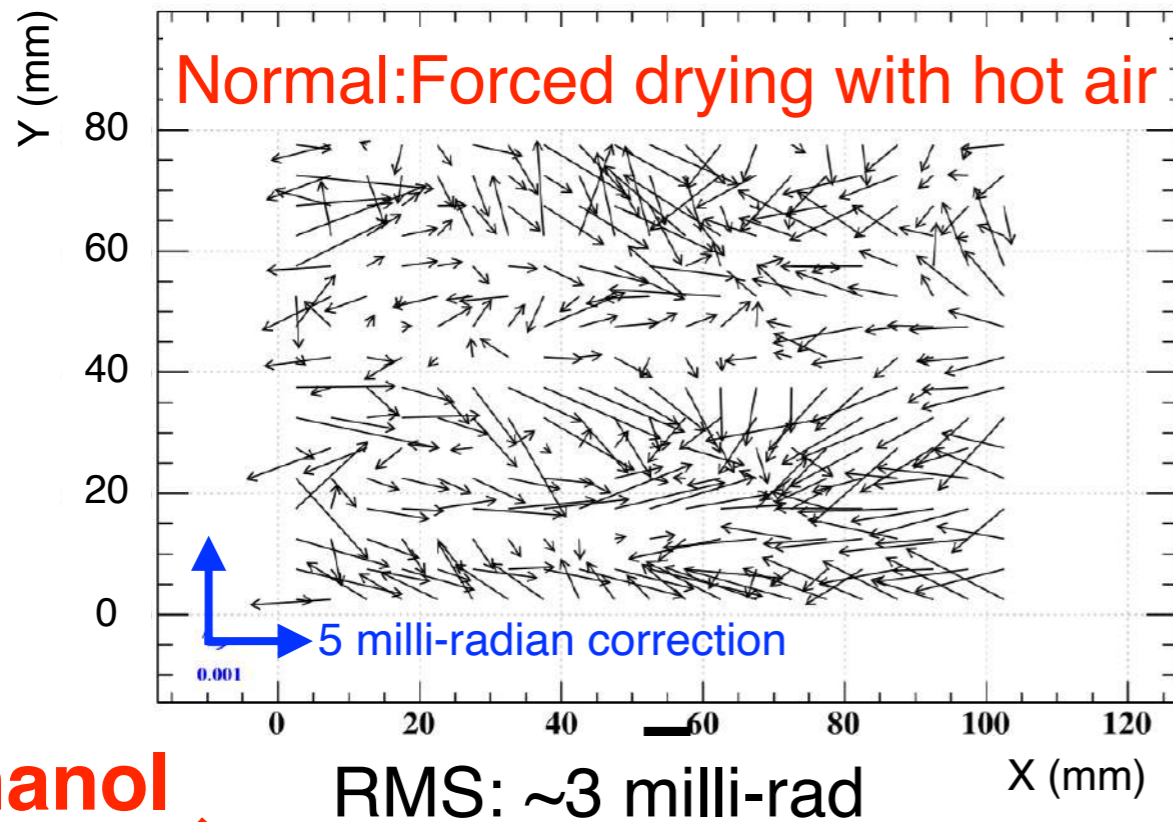
Scan data using HTS-2
is shown in posters
by Usuda and Minami

Development of all films
completed in about one month

(4) Study on improvement of R-to-R coating

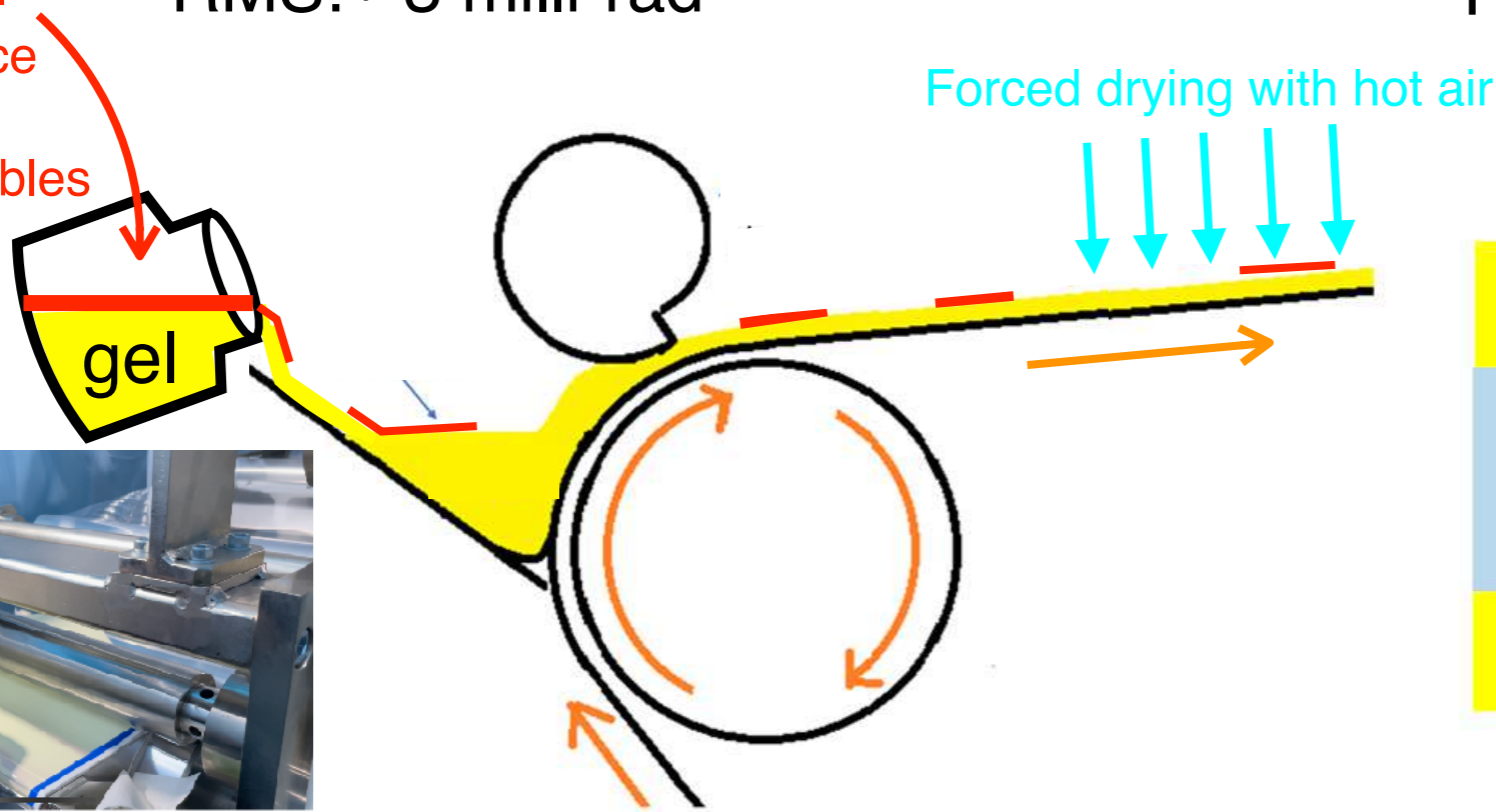
Current issue: Angular accuracy becomes worse due to distortion.

Angular correction maps of alignment btw two films by T.Nakamura

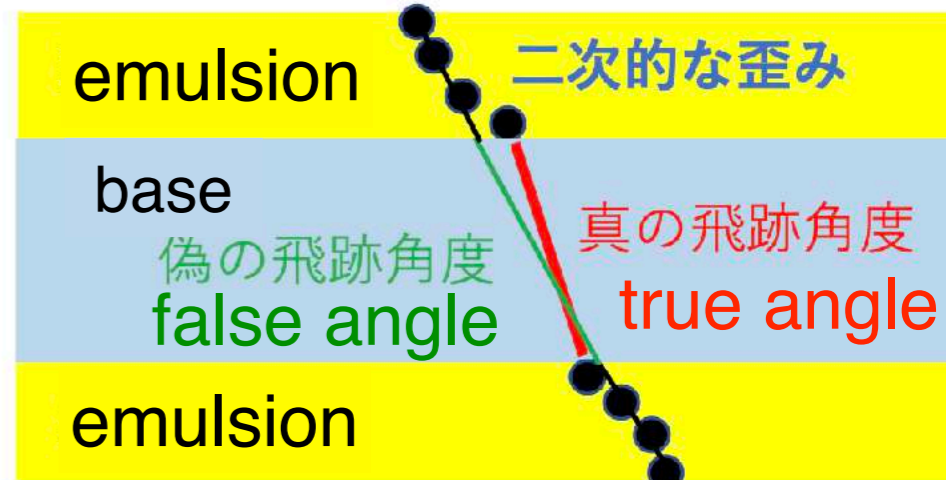


Ethanol

on the surface of the gel to break bubbles



Strong distortion

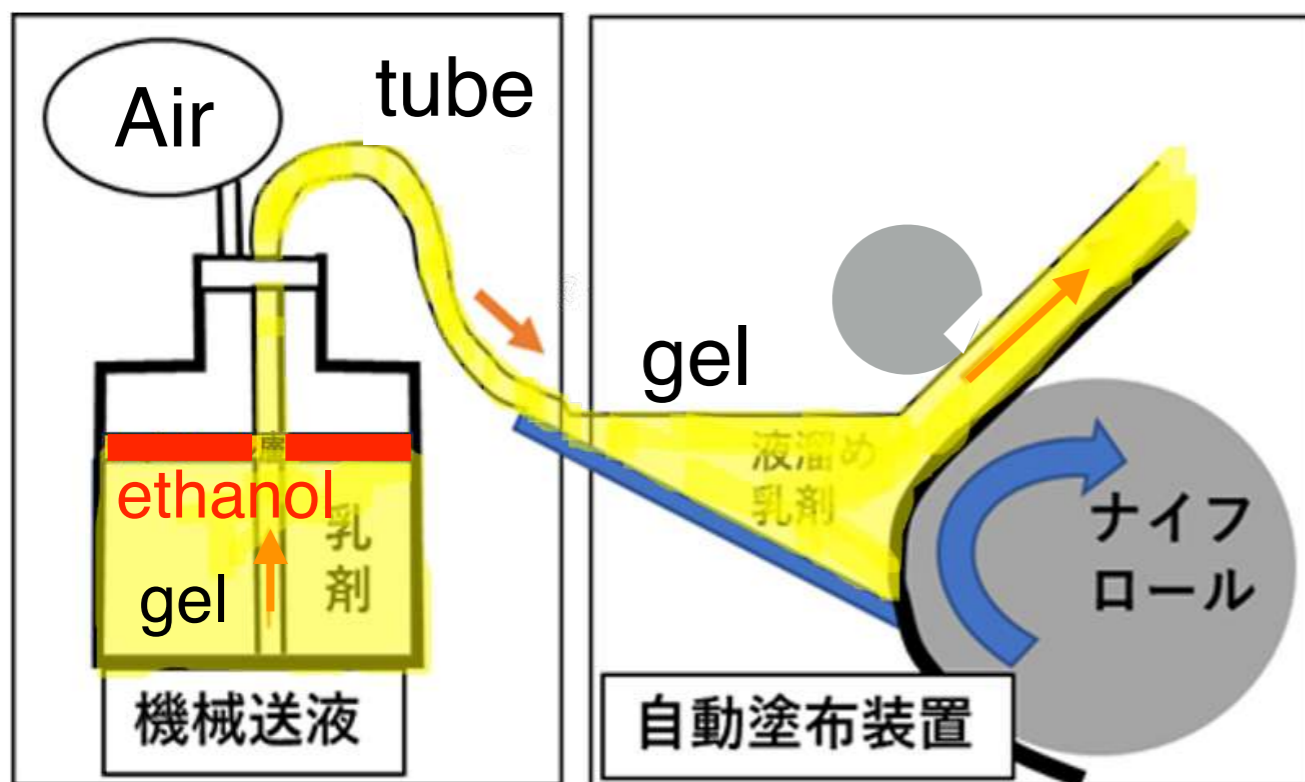


(4) Study on improvement of R-to-R coating

Pumping gel by air pump

by Iwamoto et al.

To avoid ethanol contamination, placing a tube in the bottom of a bottle, pressurizing it with an air pump, and pumping the gel to the knife coater

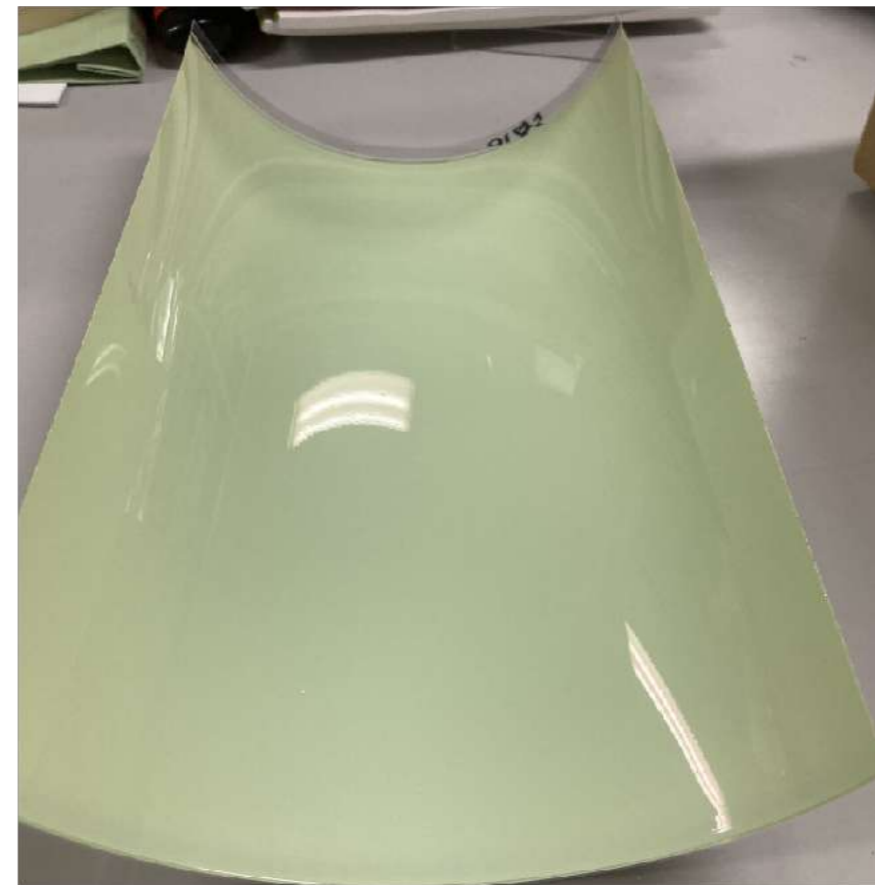


→ Improved the flatness of surface

Addition of antifoam

by Sugimura et al.

Mixing antifoam (DAWSIL™ FS Antifoam 93) into emulsion gel **without ethanol**.



→ Improved the flatness of surface
→ suppressing the bubble contamination
Chemical reaction test of antifoam is under studying

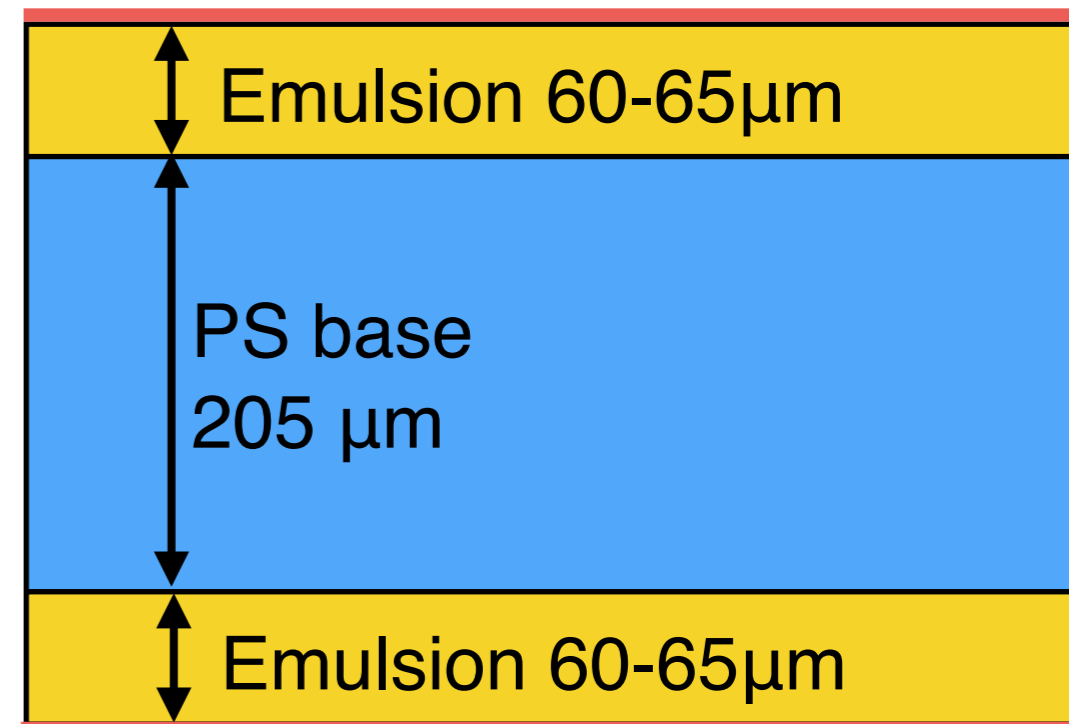
These methods expected to be improve the distortion of emulsion layers.
(would be evaluated.)

(5) Study on Protection-layer Coating (PC)

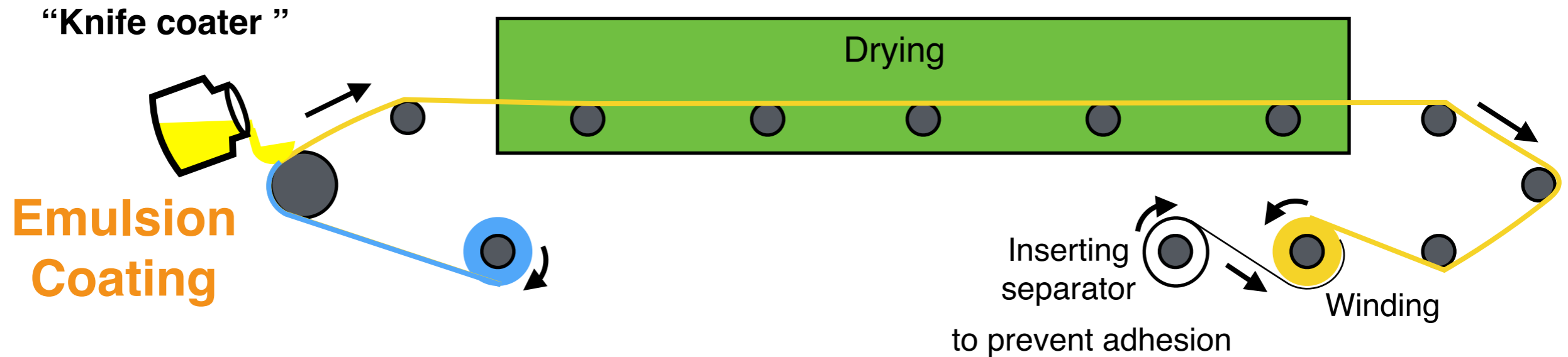
Aim: To cut/reduce labor of removing surface silver.



PC: Gelatin layers $\sim 1 \mu\text{m}$

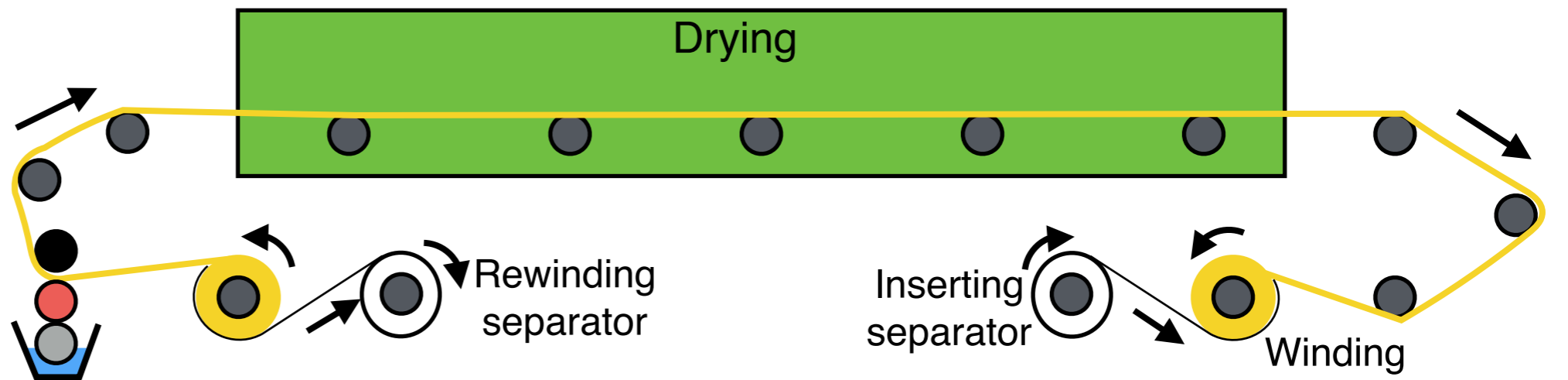


How to Make Film with PC



Additional operation for PC

“Gravure coater ”



Many try & errors to search for good conditions

- Gelatin solution (amount, concentration, temperature, additives)
- Drying condition (temperature, duration)
- Separator (material, insert/rewind method)

Emulsion Coat(A) → Protection Coat(A) → Emulsion Coat(B) → Protection Coat(B)

“Quadruple-pass coating”

Results of “Quadruple-pass coating”



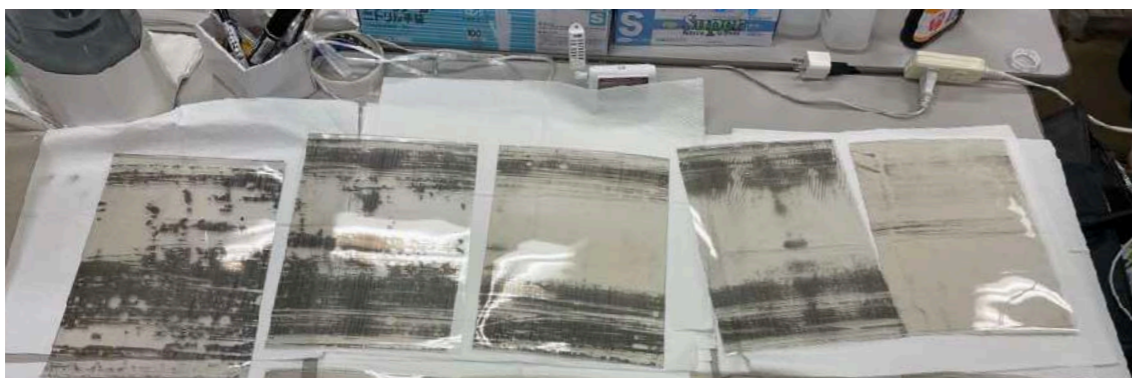
Succeeded in significantly preventing surface silver
Removed fractions are
86% and 95% for surf A and B.

by Shimizu et al.

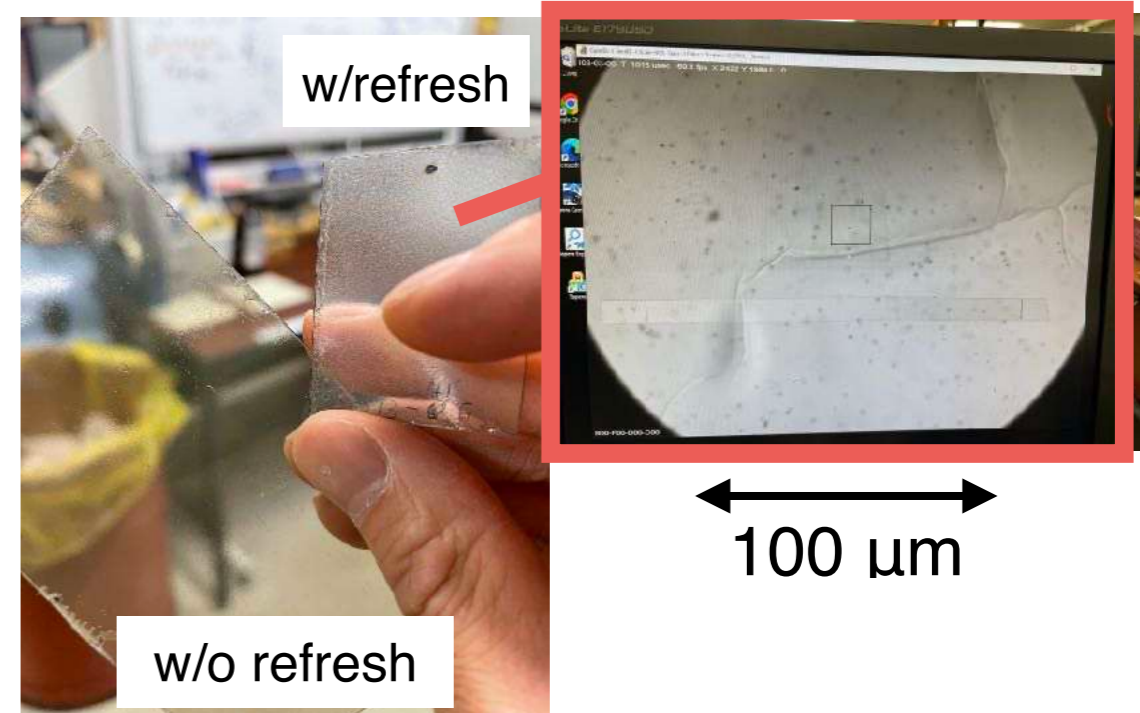
However, there are still many troubles and difficulties in this process...

- “**Reproducibility**” Difficulty in stable coating & drying conditions

- Strong silver appeared on surface.



- “**Reticulation**” structure after refreshing



- “**Adhesion problems**”
(agent for separation マット剤 required)

Further study is needed for PC!!

Summary

- **Nagoya University Nuclear Emulsion Facility (NUNEF)**
 - is aiming at;
 - Build-up and maintenance of a total system of emulsions
 - Function as the world's hosting center for emulsion technology
- **Production capacity have been greatly upgraded in recent 5 y.**
 - gel production and RtR coater
- **Recent R&Ds**
 - (1) increasing the gel production capacity
 - (2) size-up of developing silver grains
 - (3) new developer for size-up
 - (4) improvement of R-to-R coating
 - (5) protection layer coating
- **We welcome to use NUNEF to advance your research!!**