Developments of a new fastest readout system "HTS2"

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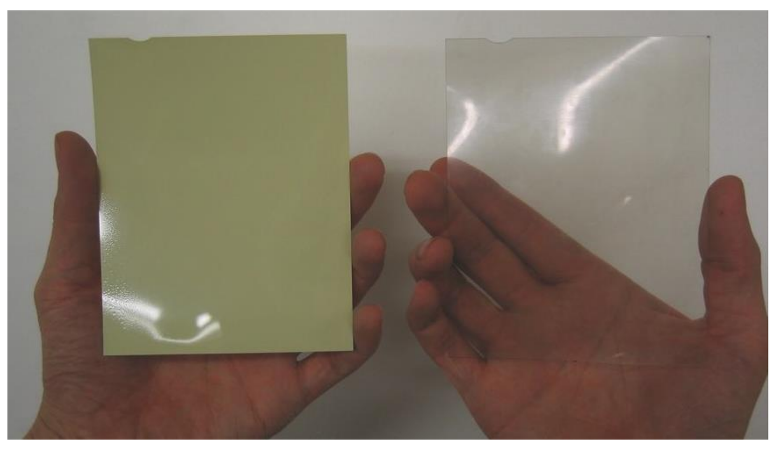
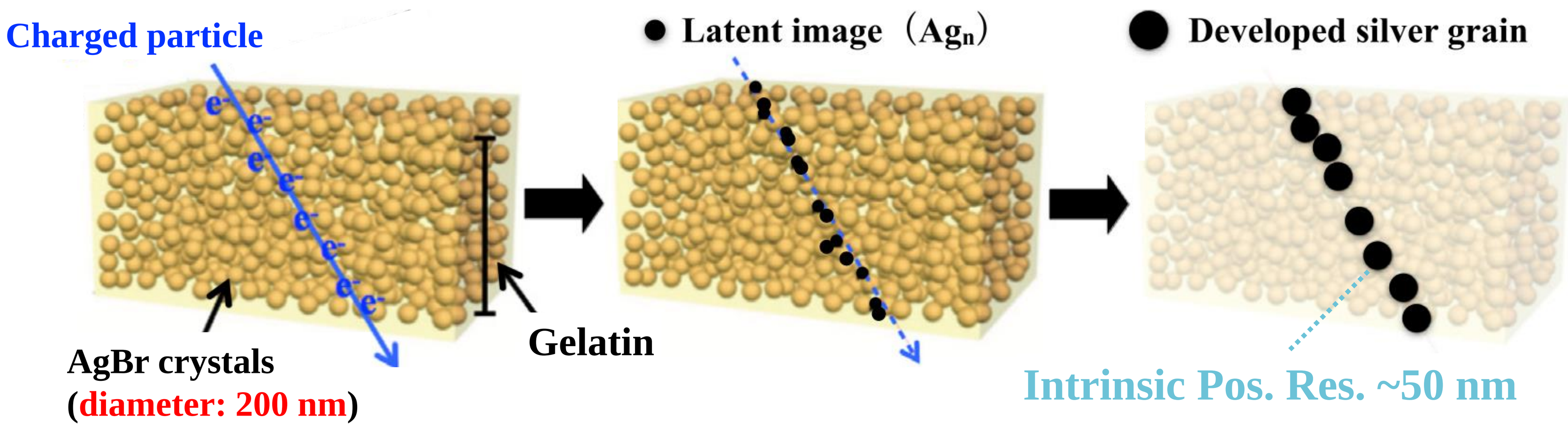
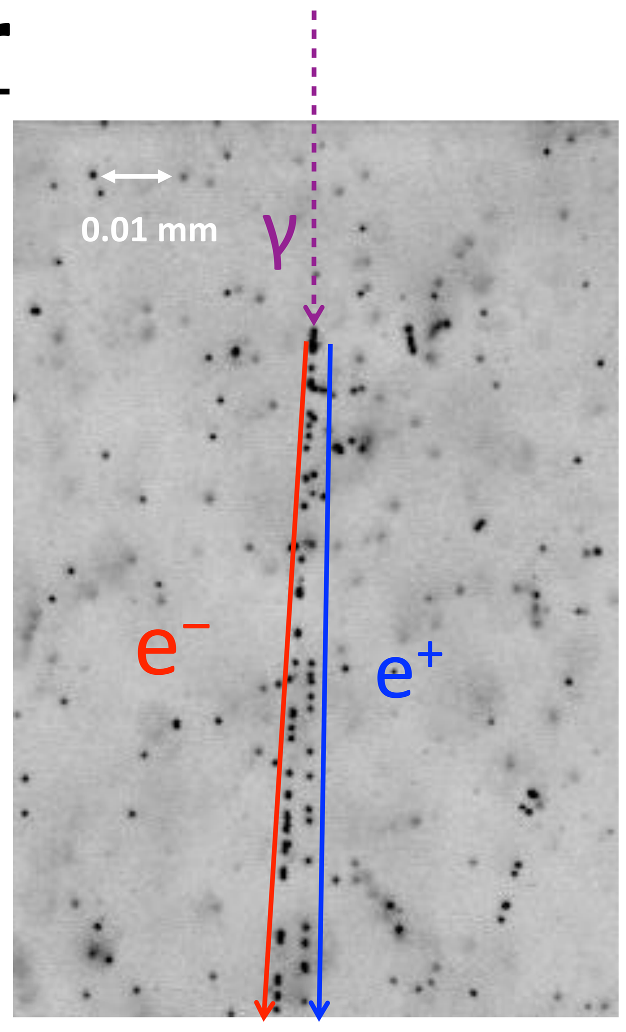
1. Nuclear Emulsion and Track Selector

Nuclear Emulsion is a photographic film that can record the trajectories of charged particles in 3D with high spatial resolution.
Today, its high spatial resolution is used for particle physics experiments, space astronomical observations, and non-destructive inspection of large-scale structures.



Left: nuclear emulsion before development.
Right: nuclear emulsion after development.

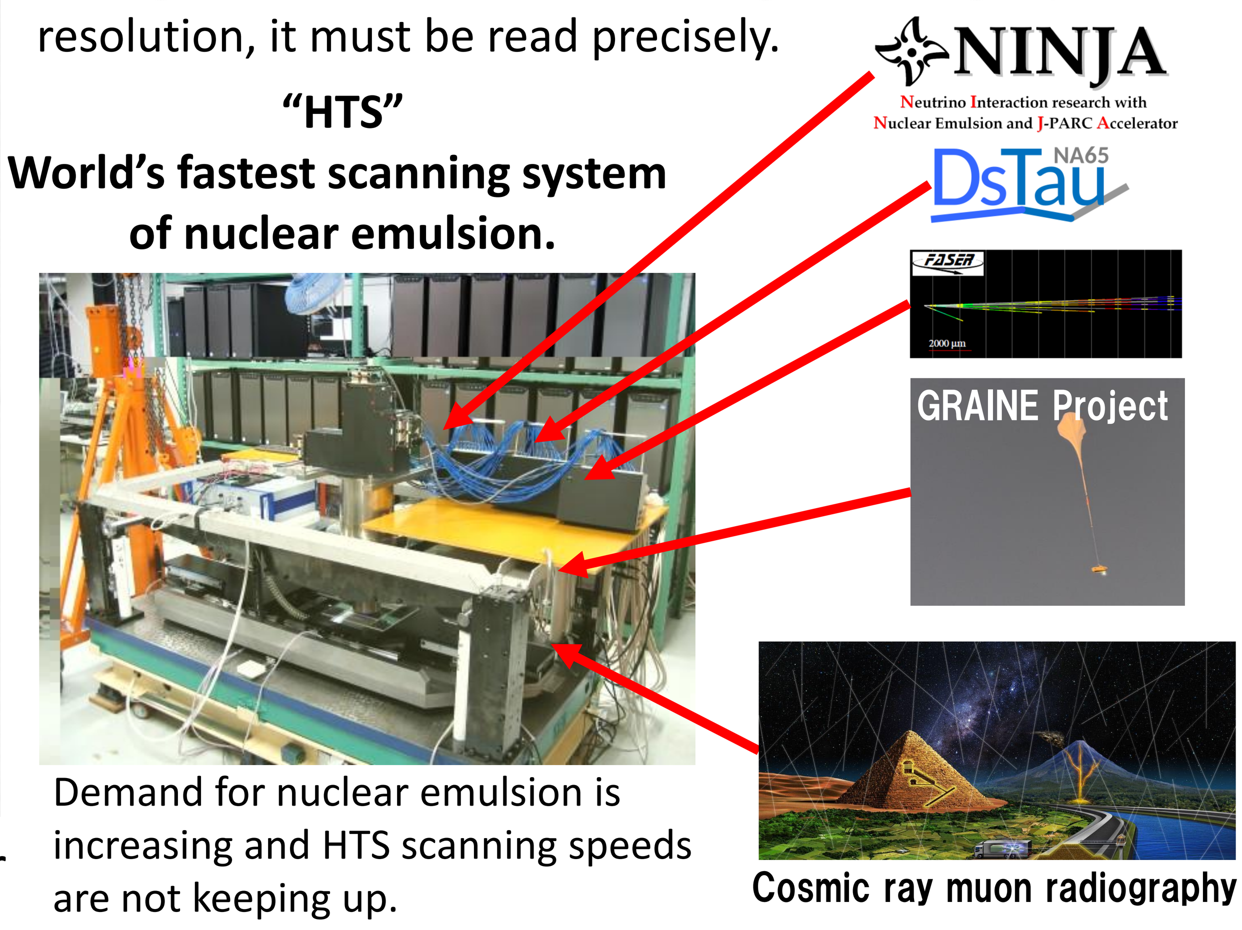




Microscope image of nuclear emulsion

The bottleneck in using nuclear emulsion is analysis. Because it is a photographic film, the data is stored in an analog format, and to take advantage of its high spatial resolution, it must be read precisely.

"HTS"
World's fastest scanning system of nuclear emulsion.



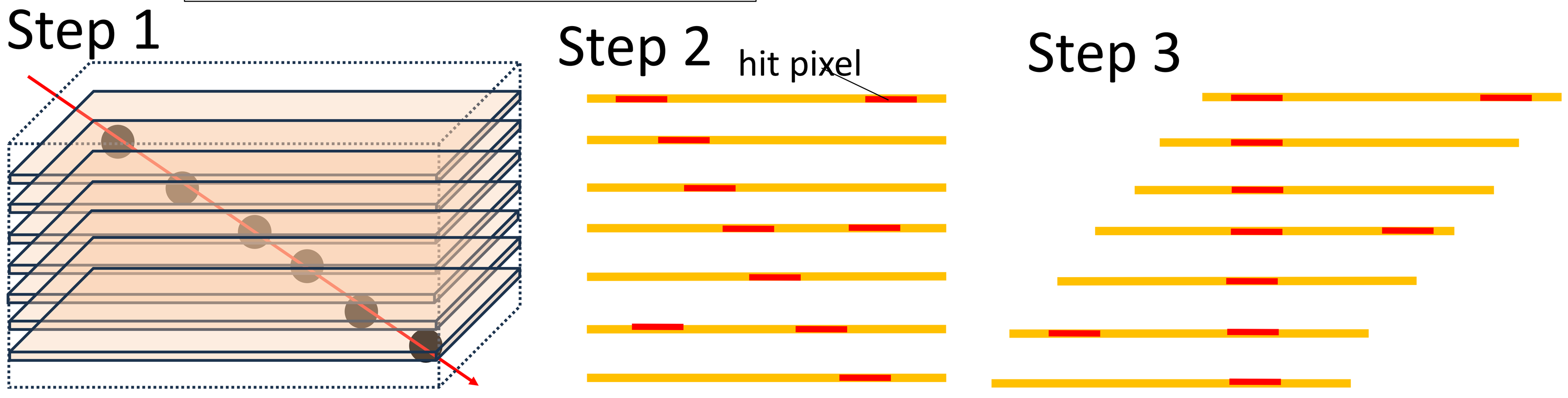
Demand for nuclear emulsion is increasing and HTS scanning speeds are not keeping up.

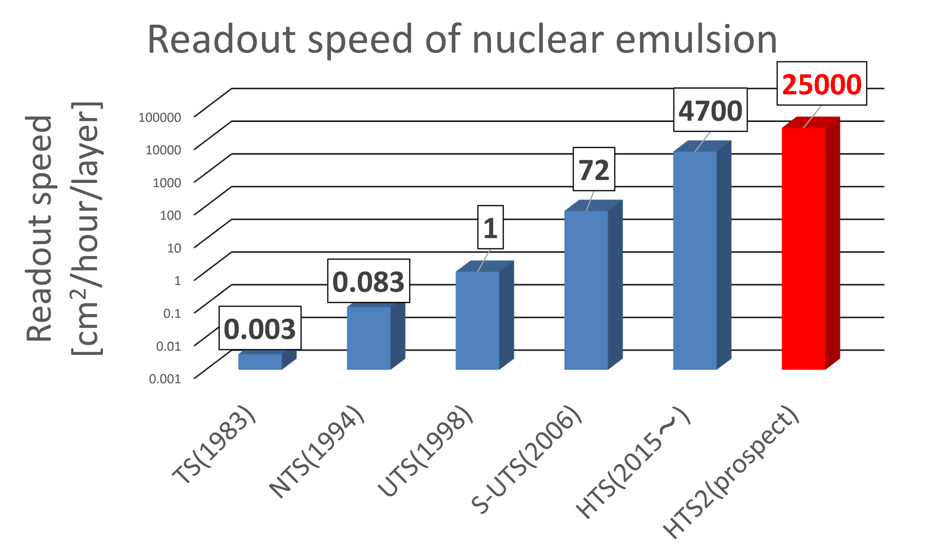
→ To develop faster scanning system is essential !

2. Overview of HTS2

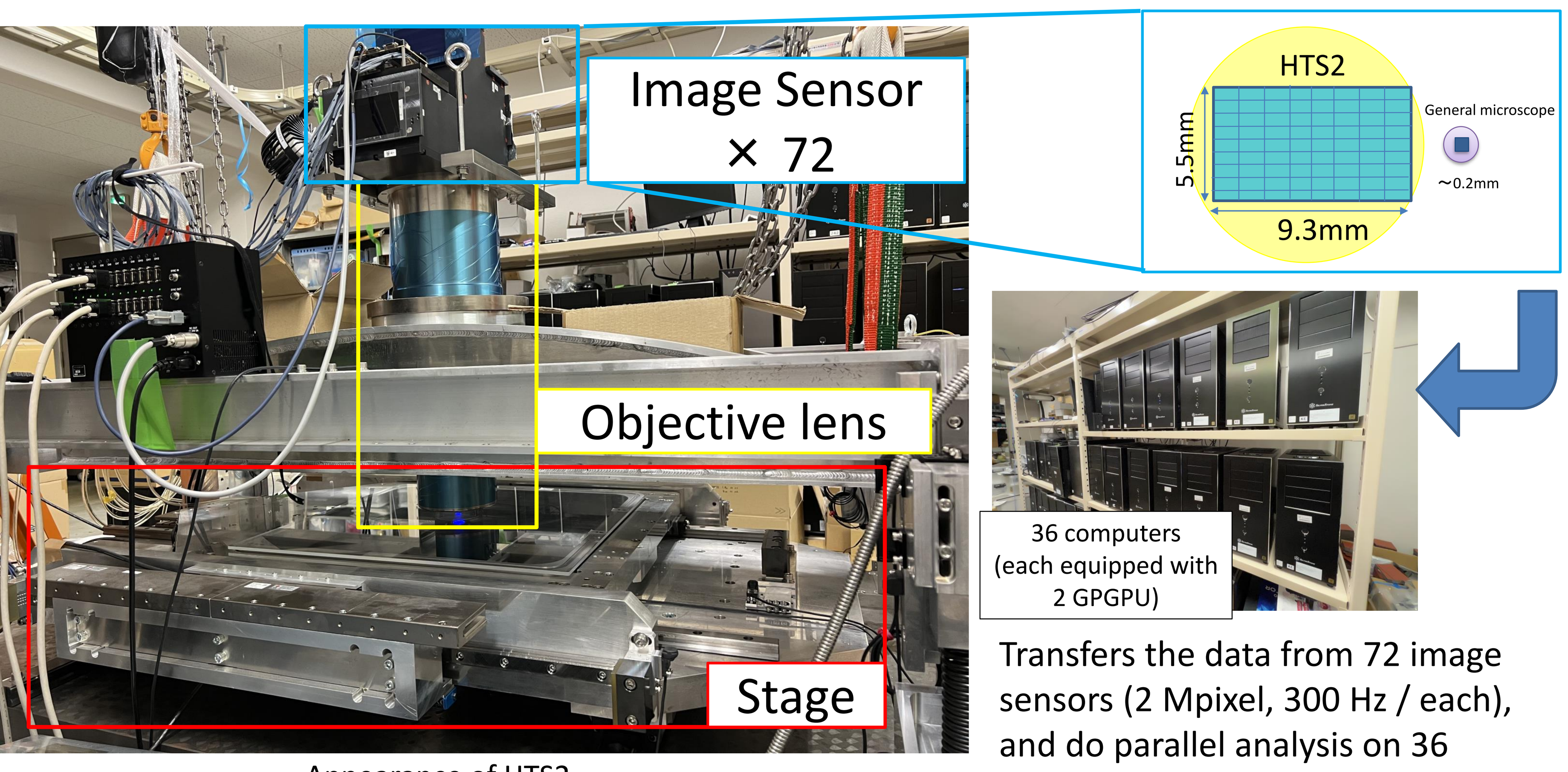
How to select tracks

1. Capture tomographic image
2. Apply image processing to detect Ag.
3. Select straight line from hit pixels





Since the world's first readout system Track Selector(TS) was developed in 1983, the readout speed has dramatically improved with each model change.
Hyper Track Selector (HTS2) is next-generation readout system of nuclear emulsion and aims to achieve a readout speed **25,000 cm²** (**5 times faster** than that of HTS which is world's fastest system currently).



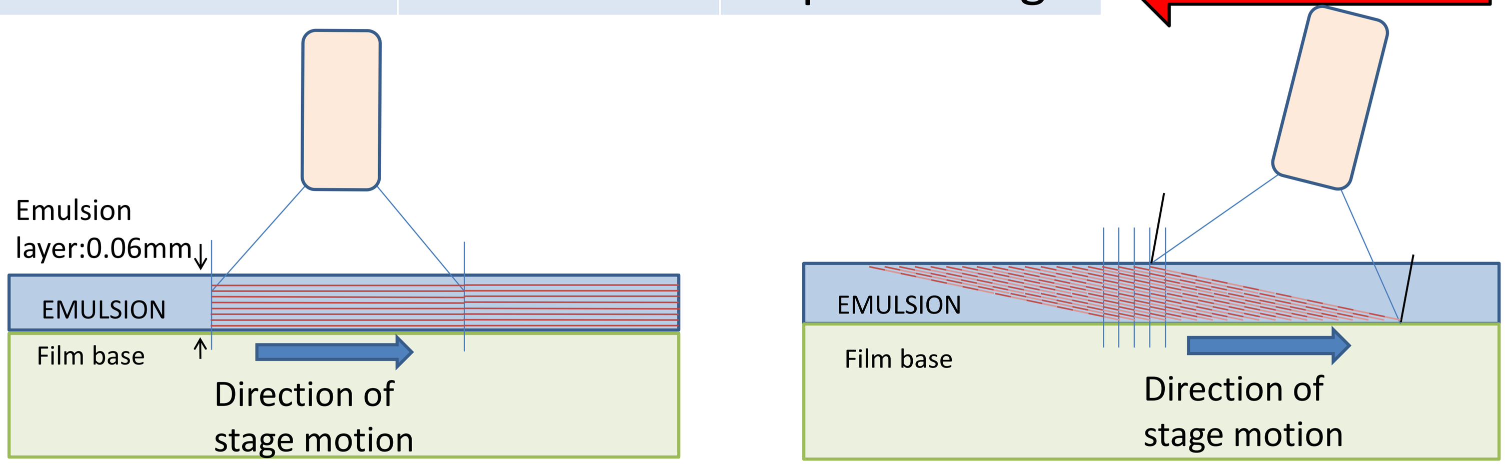
Appearance of HTS2

Transfers the data from 72 image sensors (2 Mpixel, 300 Hz / each), and do parallel analysis on 36 computers.

Different point in HTS and HTS2

	HTS	HTS2
Imaging area	5 × 5 mm²	9 × 5.5 mm²
Image capturing method	stop-and-go	Inclined non-stop scanning

2x with low magnification and wide area
2.5x with new method



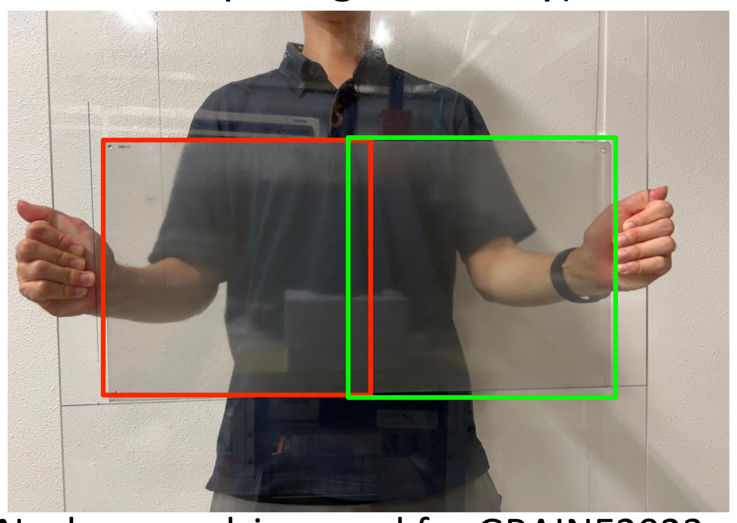
Currently method: stop-and-go

New method: Inclines non-stop scanning

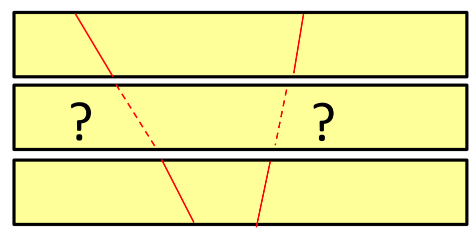
Compared to the HTS, the HTS2 has approximately **twice** the imaging area with a lower magnification. Furthermore, we aim to improve the drive speed by approximately **2.5 times** by innovating the conventional image capturing method.
Thereby, a total reading speed improvement about **5 times faster** than that of HTS.

3. Performance Study of HTS2

As a basic performance study, first, we determined detection efficiency using 24 sensors (one-third of the all sensors). Using film: Used GRAINE2023 experiment (the experiment for observe space gamma-ray). Scanning Method: "stop-and-go"



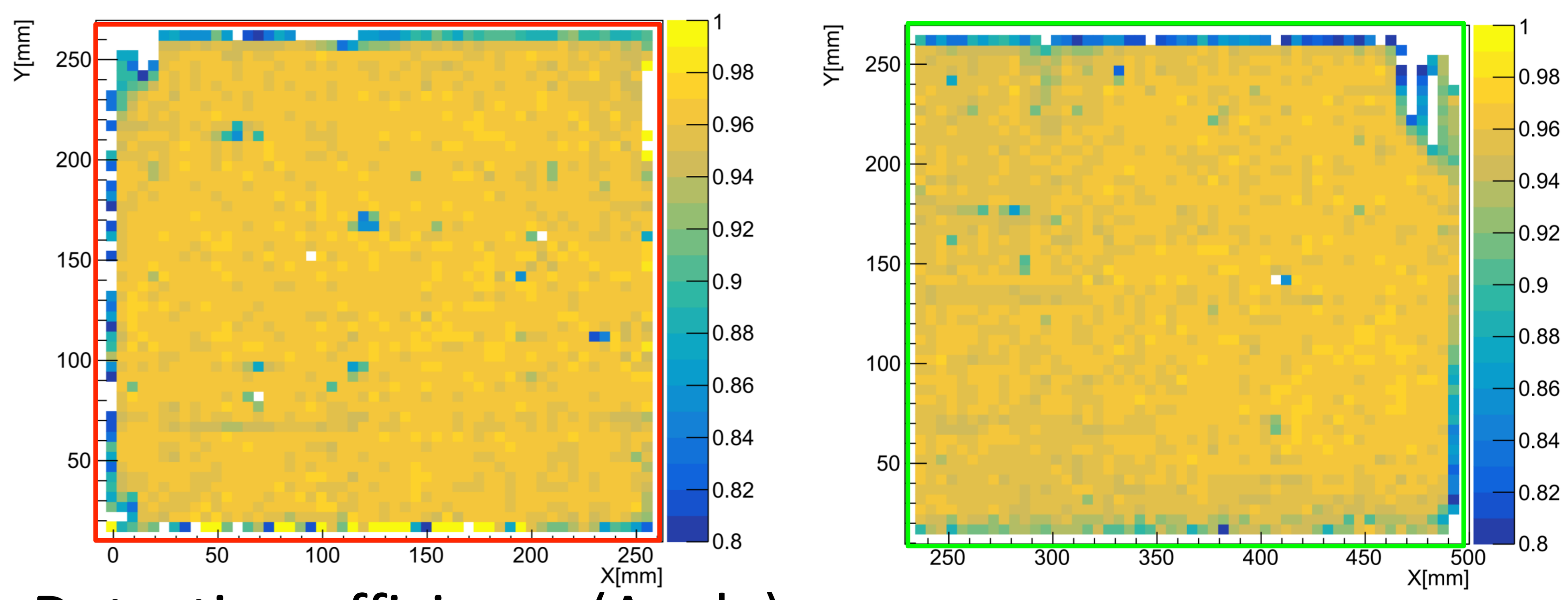
Nuclear emulsion used for GRAINE2023
It was scanned in two sections in the X direction because the film size is 50 cm.



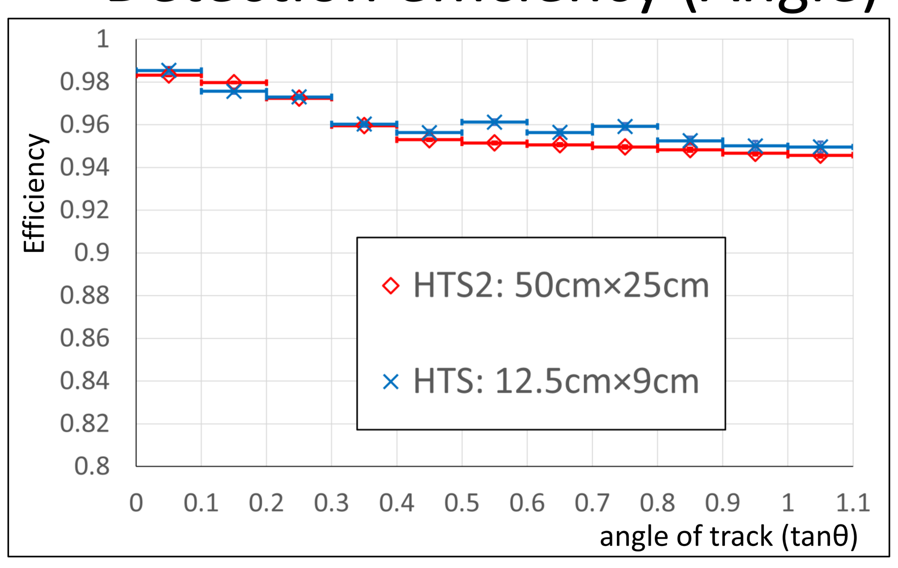
Detection efficiency = ①&②&③ / ①&③

The detection efficiency was calculated using three adjacent nuclear emulsion, with the number of tracks connected by the outer two nuclear emulsion as the denominator and the number of tracks connected by all three as the numerator.

Detection efficiency (Position)



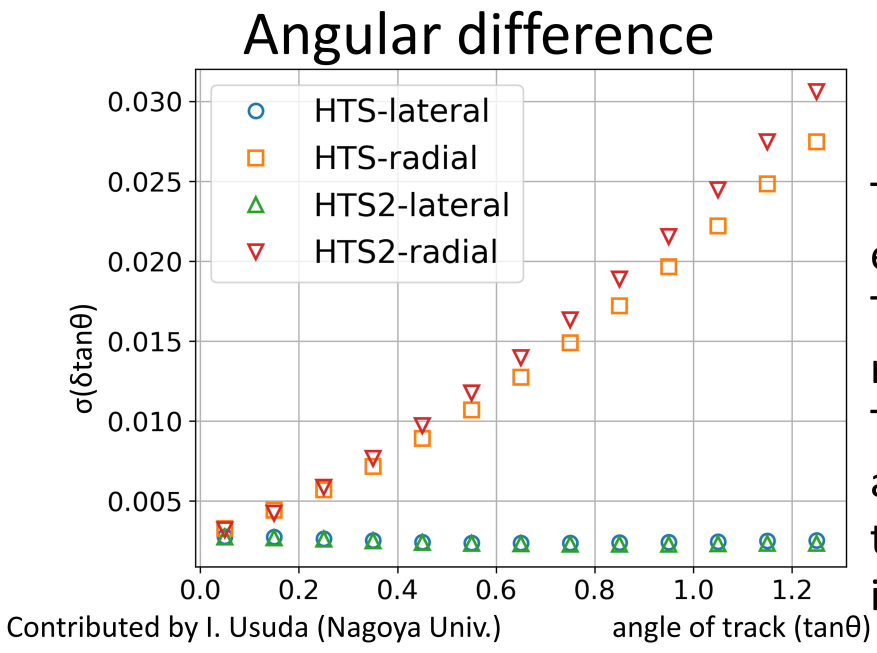
Detection efficiency (Angle)



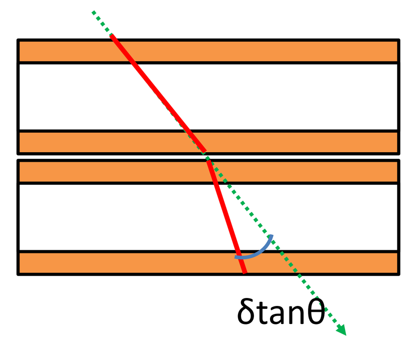
First, regarding the positional distribution of detection efficiency, high detection efficiency (>95%) is achieved almost of all area.
Next, we discuss the angular distribution of detection efficiency. To compare, a part of the same film was also scanned by HTS. At all angled, the difference in HTS/HTS2 detection efficiency was cured within 1%, confirming that the trails ware successfully read by HTS2.

Second, we determined angle accuracy. Some nuclear emulsion were scaand and the angular difference between the detected tracks was calculated.

Angular difference



Contributed by I. Usuda (Nagoya Univ.)



"Radial" is the axis parallel to the track, and "Lateral" is the axis perpendicular to the "Radial"

The results show that the lateral component is equally accurate when HTS and HTS2 are compared. This indicates that the lateral component depends mainly on positioning accuracy, which is equivalent. The radial component shows differences as the angle increases. This is due to the fact that the thickness recognition is not yet well. It will be improved by improving the algorithm in the future.

4. Future Prospect

The above results show that HTS2 can scan nuclear emulsion successfully using 24 sensors. The next goal is to implement the HTS2-beta mode, which is twice as fast as HTS by using all 72 image sensors. After that, we will establish an image analysis method when the imaging surface is tilted, and finally aim for a readout speed of 25,000 cm/h/layer, which is five times faster than HTS.