Development of nuclear emulsion readout system HTS (Hyper Track Selector) and an application to muon tomography

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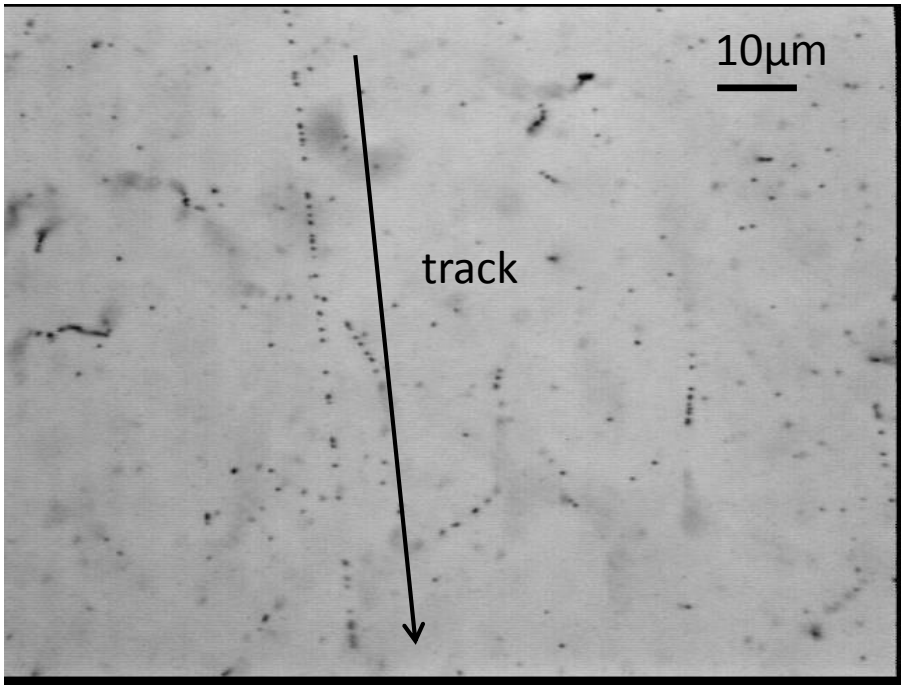
Nuclear emulsion

Nuclear Emulsion plate is a 3D tracking detector.

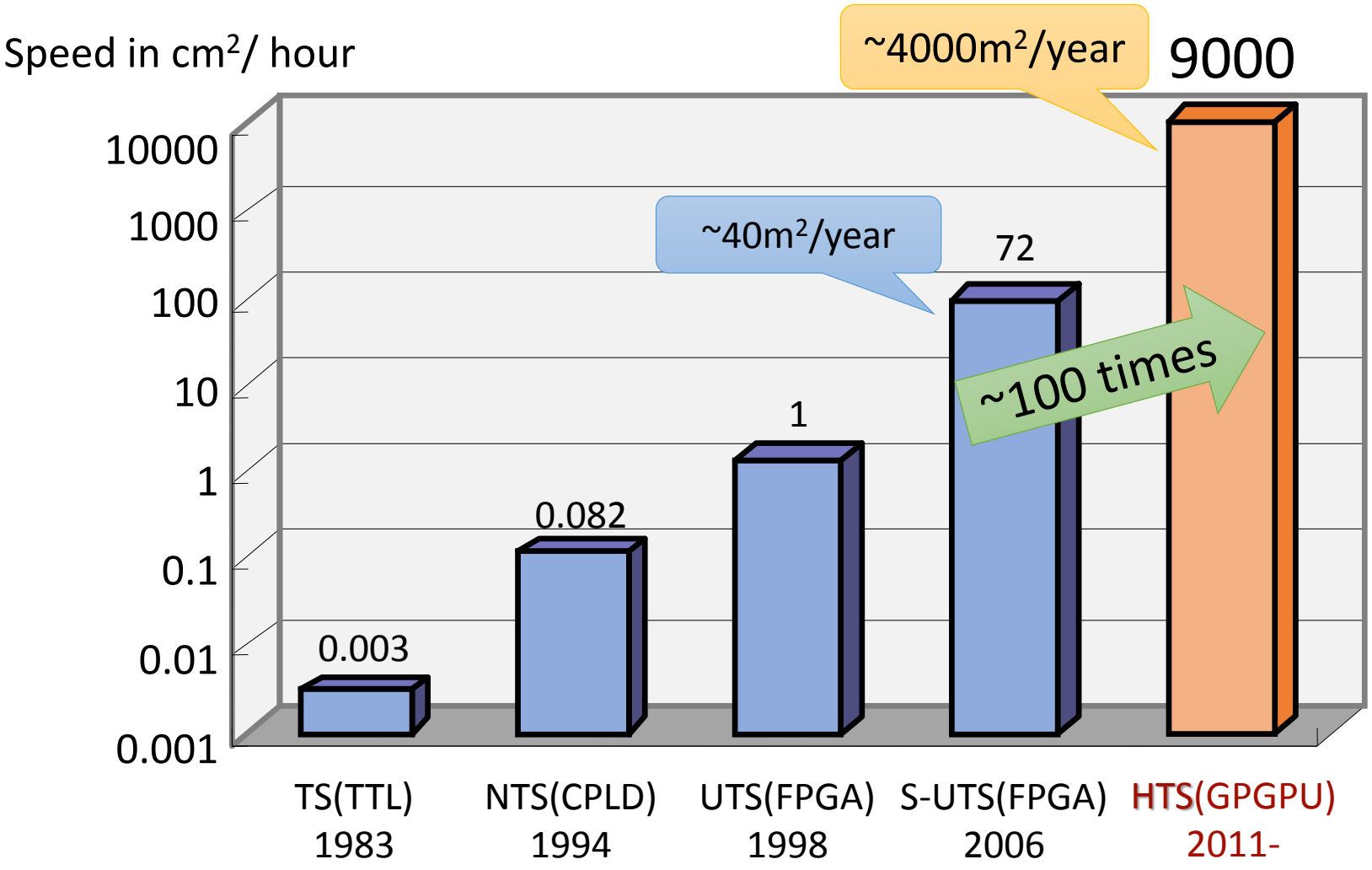
- ✓High spatial resolution (more than 1μm)
- ✓Possible to record muon tracks
- ✓Light weight and compact
- ✓Without power supply
- ✓No dead time
- ✓Without time resolution by itself
- ✓Low cost and large area

3mrad = 0.17°
(300μm thickness)

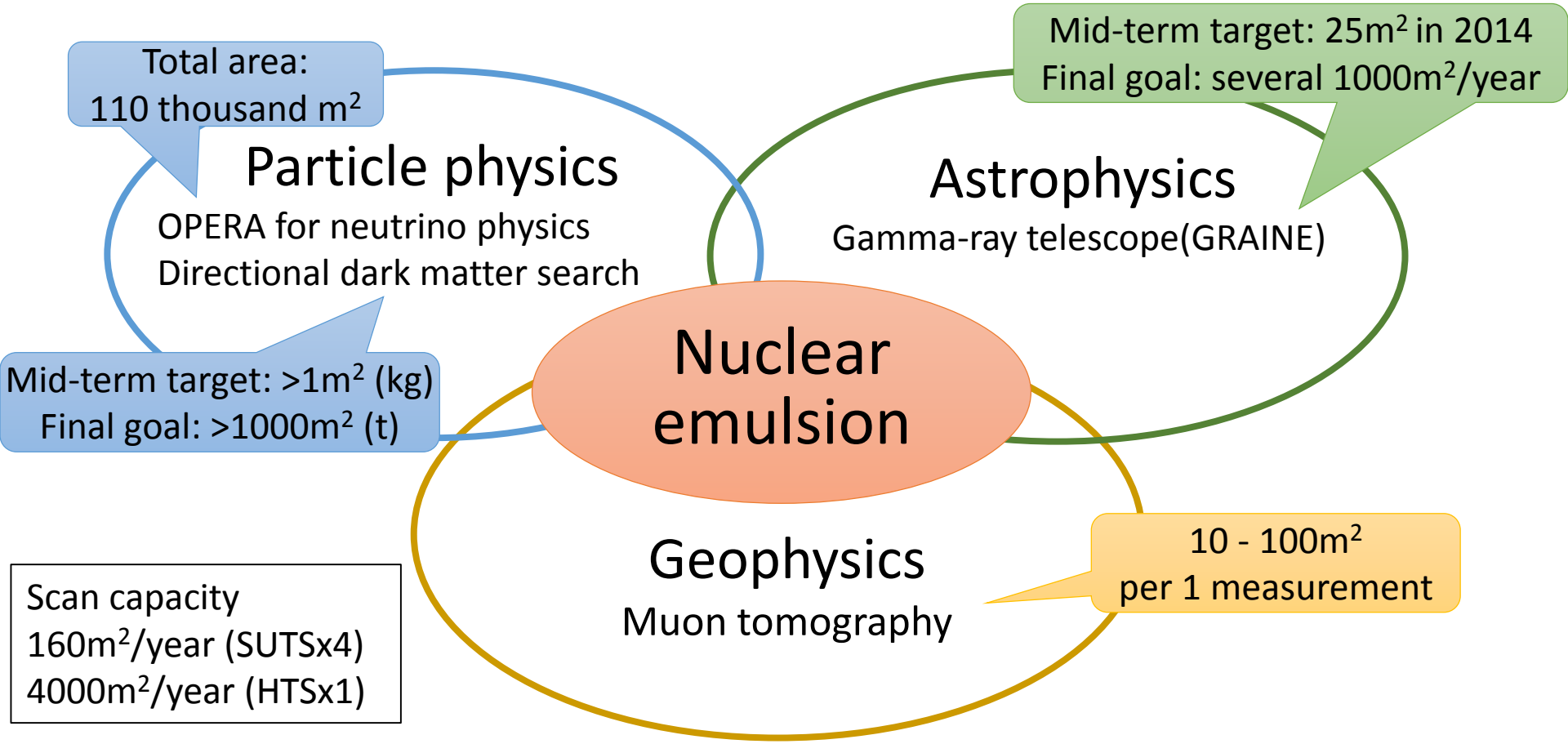


Microscope image

Progress of readout speed

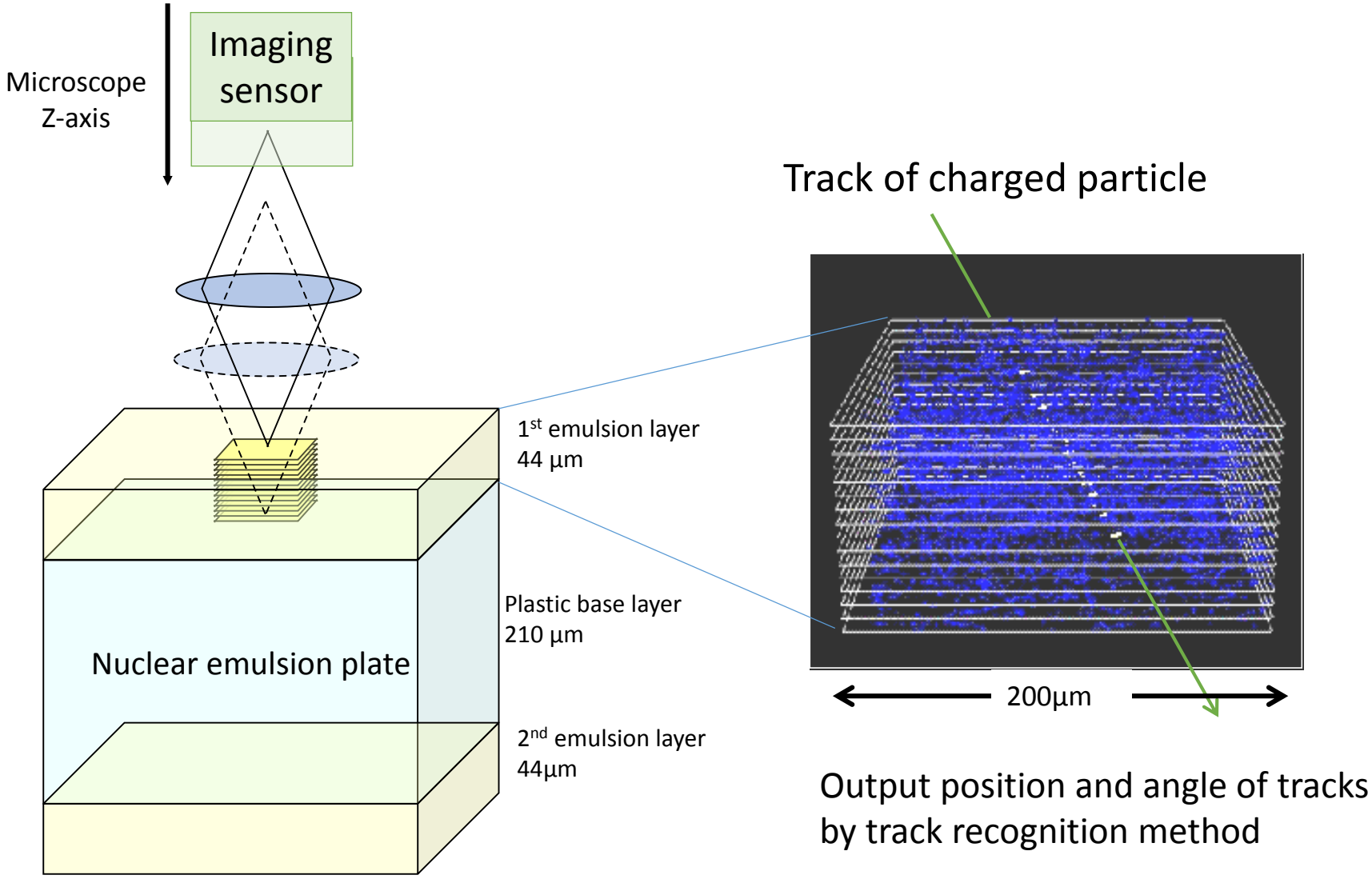


Applications



Large area readout is required for the next applications

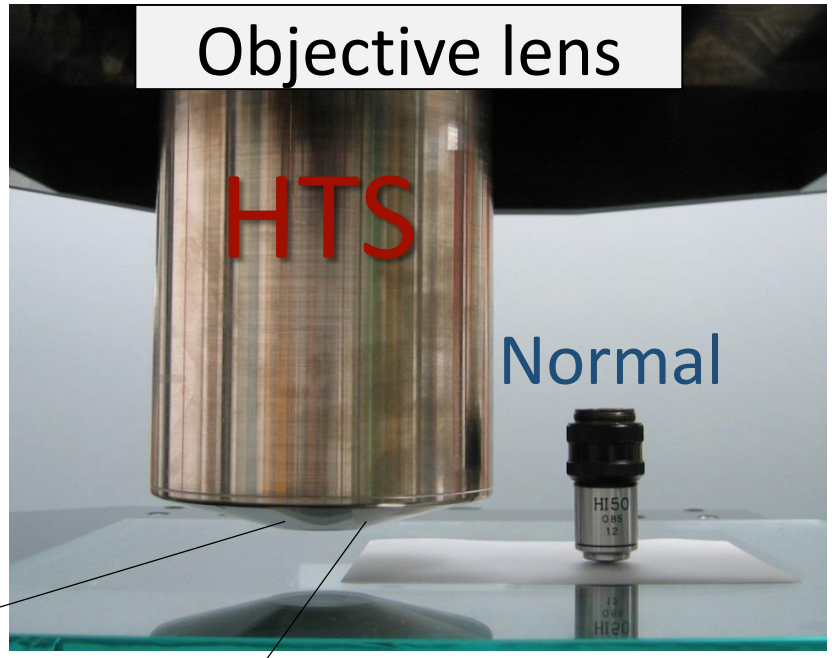
Tracking in the nuclear emulsion plate

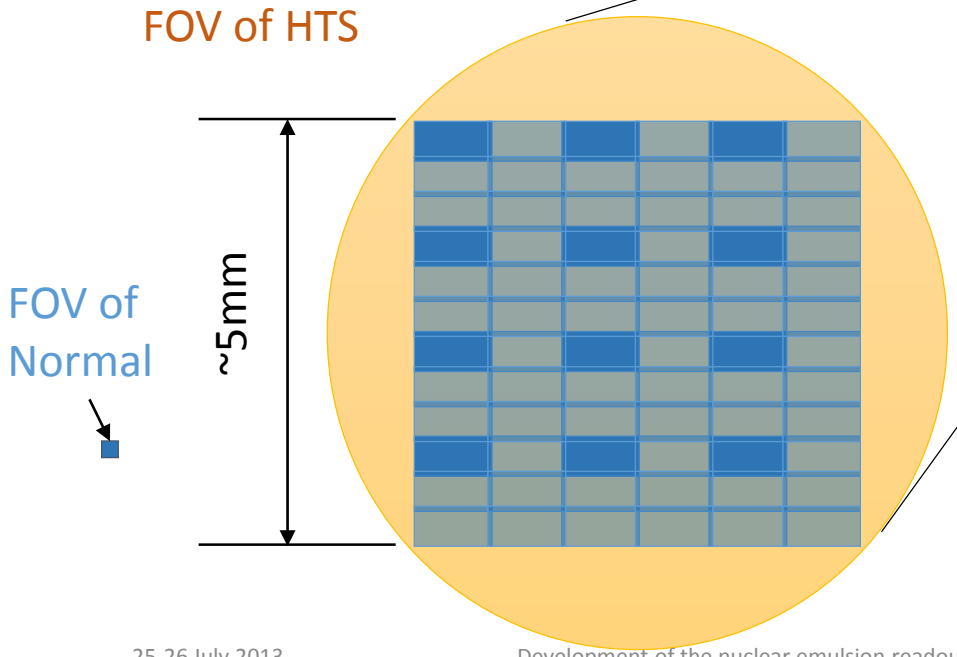


Output position and angle of tracks by track recognition method

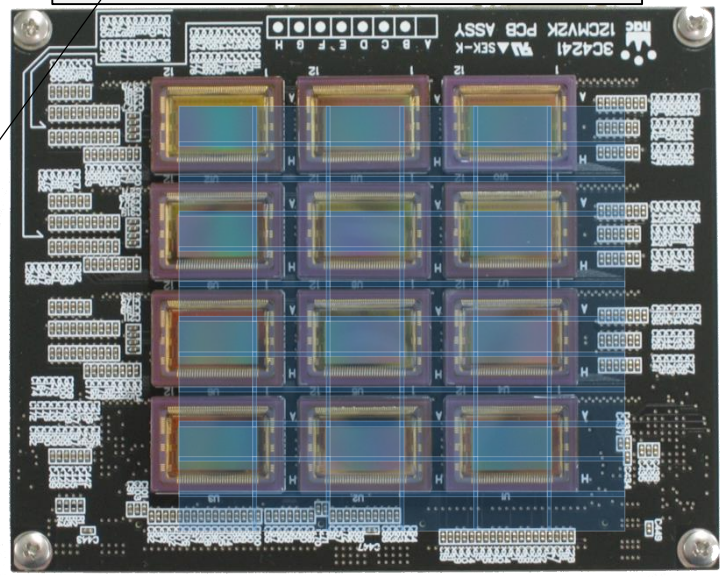
Concept of HTS

- Large field of view
- High-speed precision stage
- GPGPU for track recognition





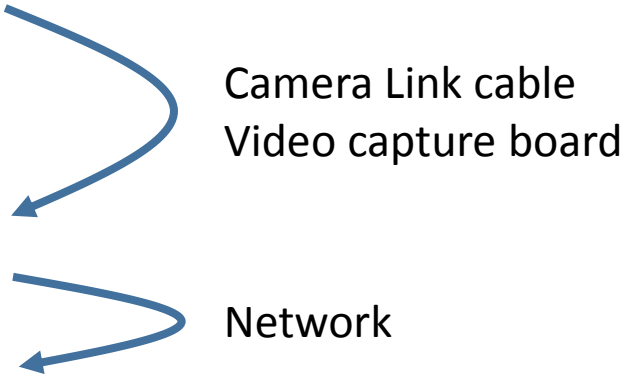
Mosaic Camera



Using 6 cameras to fill in the gaps

Requirements for emulsion readout system

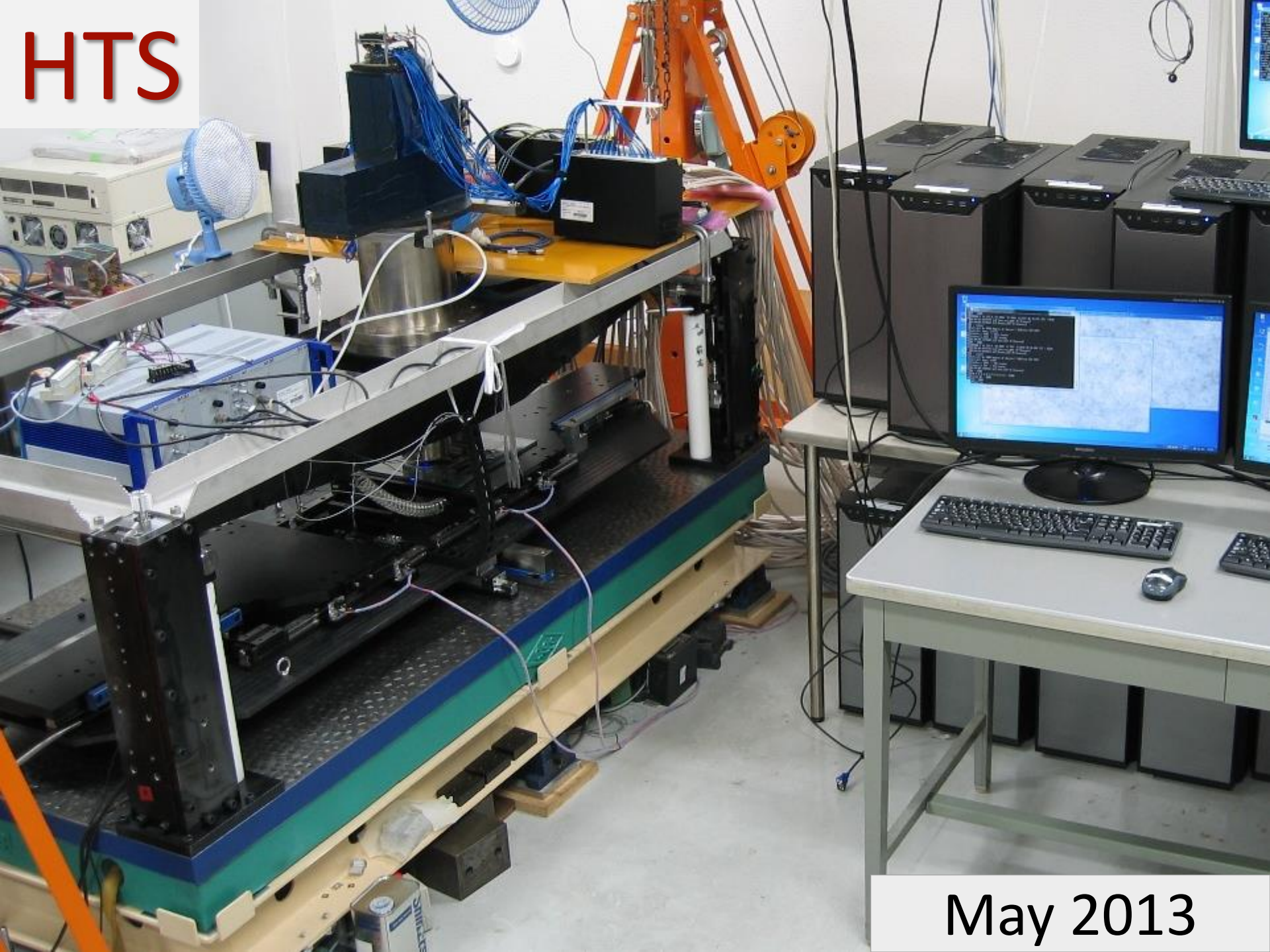
- Stage:
  - Positioning accuracy : <0.2μm (1σ)
  - Acceptable vibration: <0.2μm (1σ)
- Objective lens:
  - Spatial resolution: 0.40μm
  - Working distance: ~1mm (depend on emulsion thickness)
- Camera:
  - Pixel pitch: 5.5μm
  - (0.45μm for x12.2)
- Processer:
  - GPU and CPU
- Storage server:



HTS

August 2011

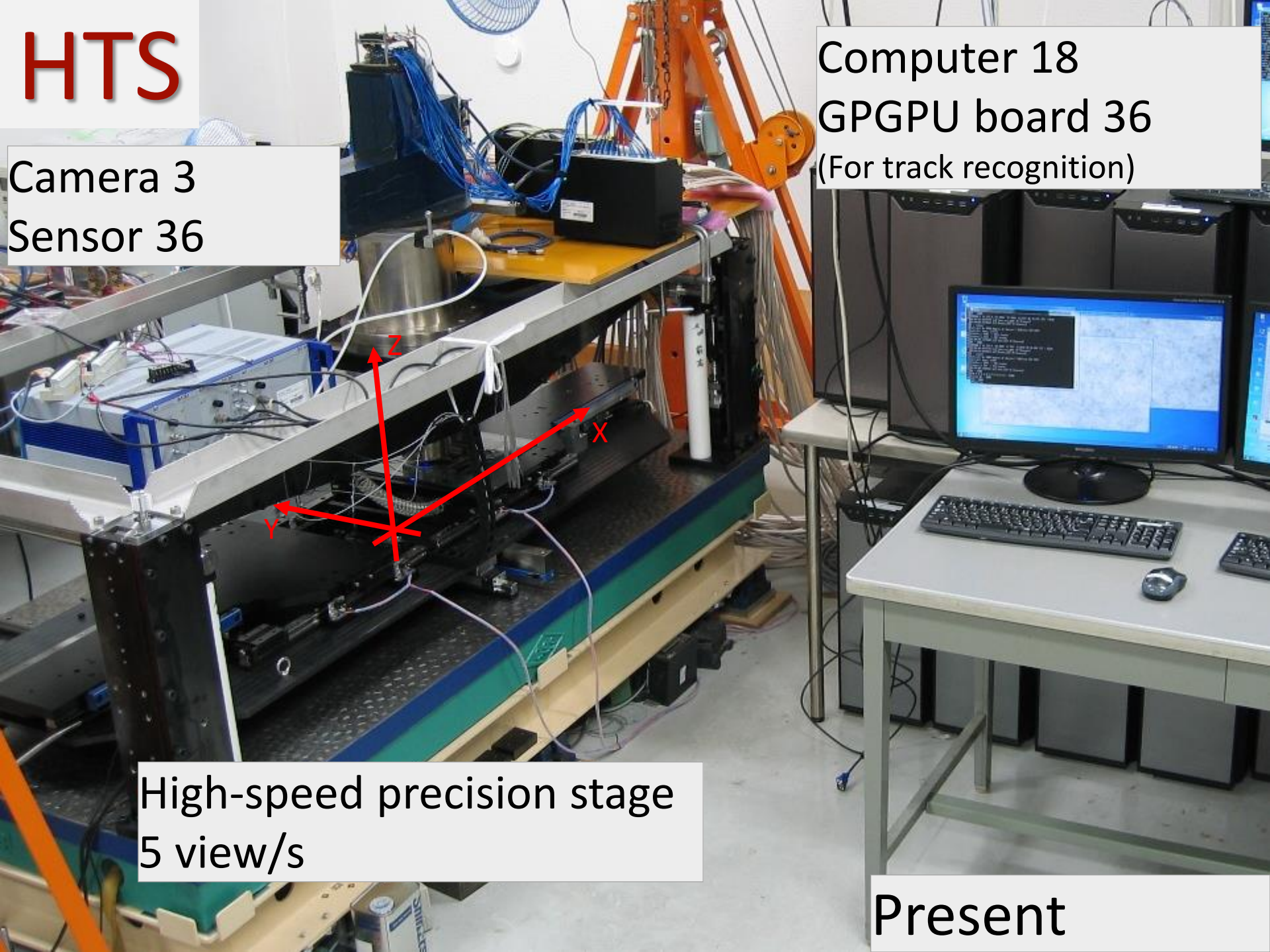
HTS



May 2013

HTS

Camera 3
Sensor 36



Computer 18
GPGPU board 36
(For track recognition)

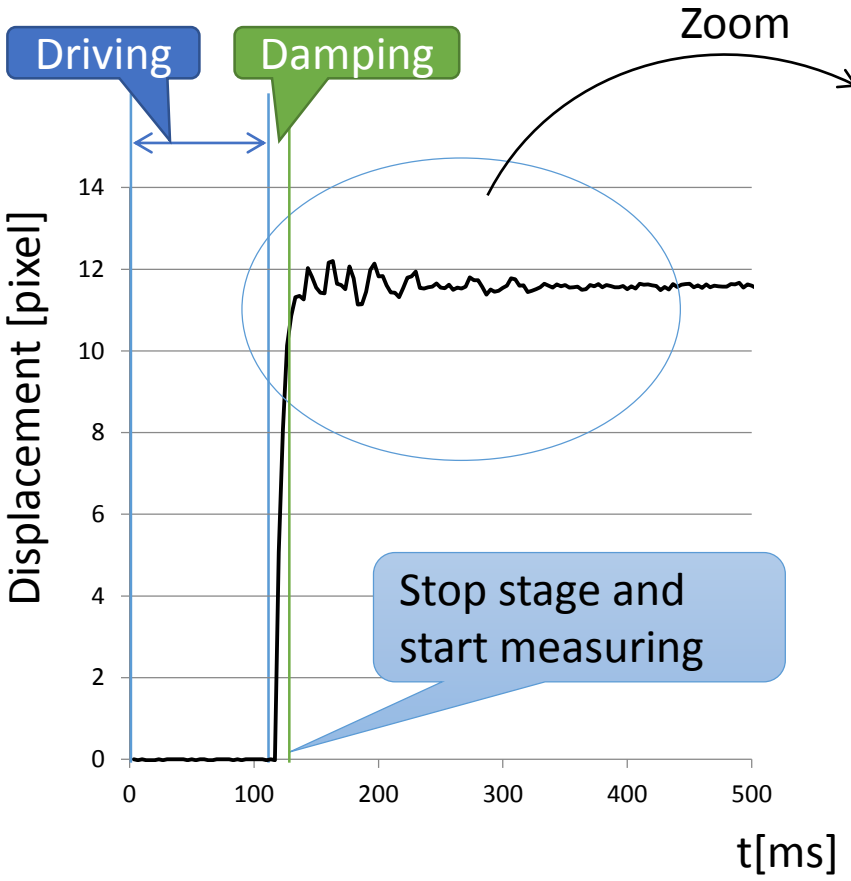
High-speed precision stage
5 view/s

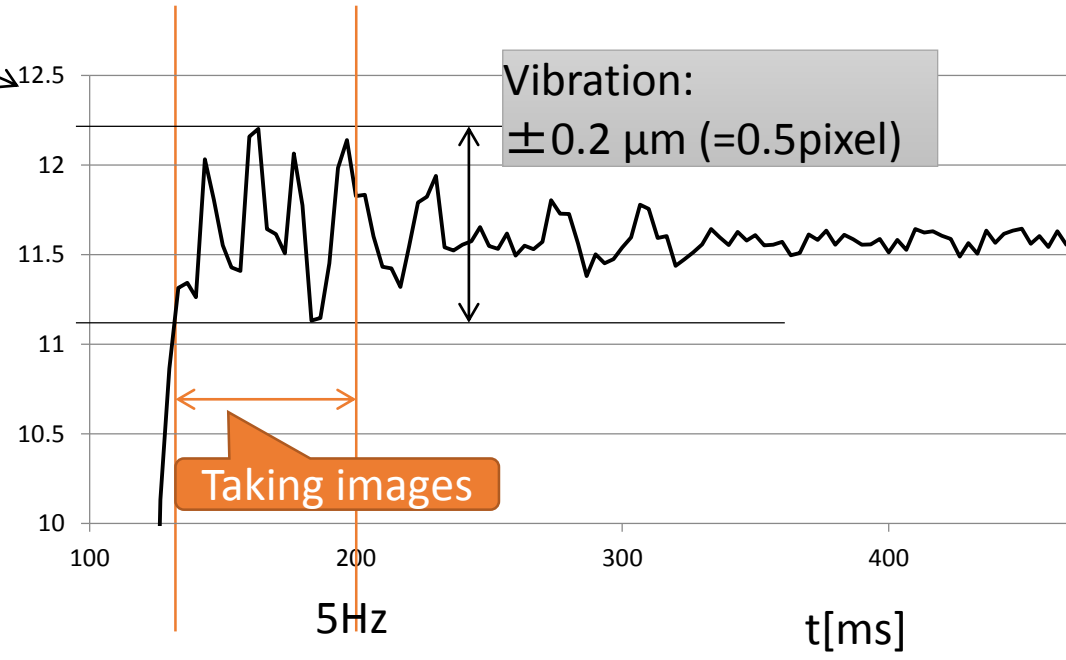
Present

Vibration

Driving stage causes vibration of the whole stage.

Following result was measured with images by pattern matching.





By optimizing the acceleration, both high-speed and less vibration were achieved. 5view/s is half speed.

Track reproducibility and Position displacement(HTS-SUTS)

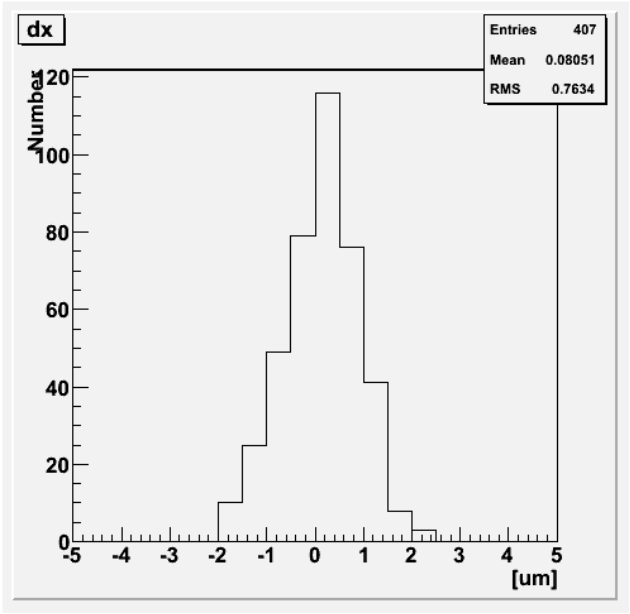
- 500 tracks was scanned with 12 sensors at HTS. These tracks have been analyzed at the other stage (SUTS).

Sensor No. 1

<u>Track reproducibility rate 94.2%</u>

cf. SUTS-SUTS 95%

Sensor No. 1



dx	0.76μm (1σ)

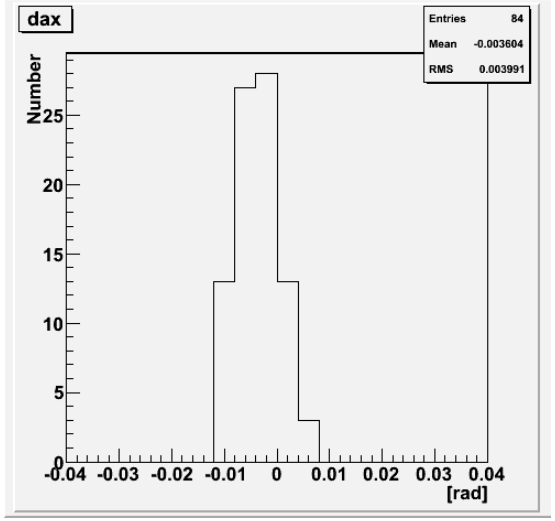
cf. SUTS-SUTS

dx	0.85μm

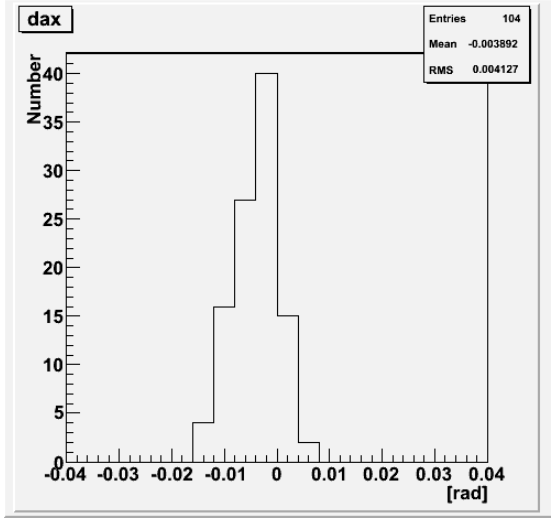
Angle displacement (HTS-SUTS)

Sensor No. 1

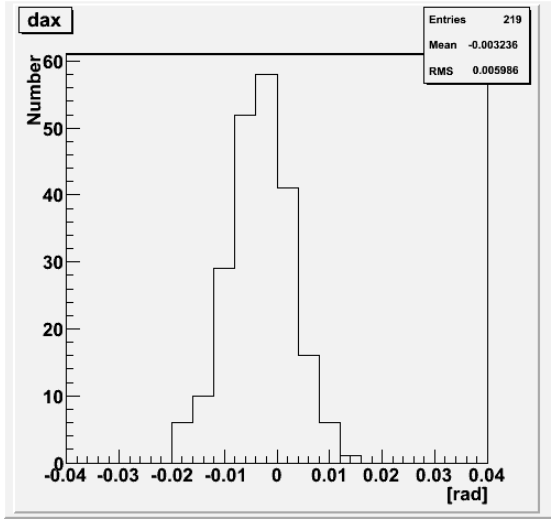
0 – 100 [mrad]



200 – 500 [mrad]



100 – 200 [mrad]



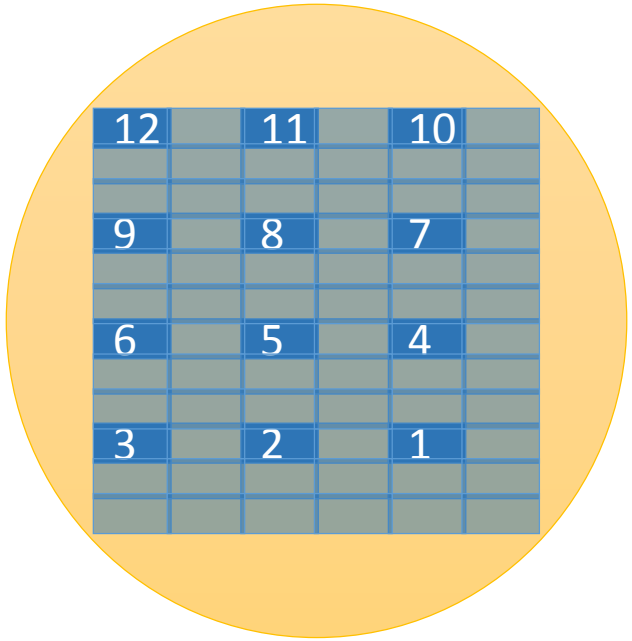
dax	0 – 100	4.0mrad (1σ)
	100 – 200	4.1mrad
	200 – 500	6.0mrad

cf. SUTS-SUTS

0 – 100	3.5mrad
100 – 200	3.6mrad
200 – 500	5.6mrad

Results of 12 sensors

Sensor No.	Reproducibility [%]	Position dx [μm]	Angle dax [mrad]
1	94.2	0.76	5.2
2	95.2	0.86	5.5
3	93.6	0.80	5.2
4	93.6	0.79	5.6
5	94.6	0.78	5.5
6	93.6	0.87	5.3
7	93.0	0.82	5.9
8	93.8	0.83	5.3
9	94.8	0.78	5.2
10	92.6	0.81	5.5
11	95.0	0.83	5.6
12	93.0	0.82	5.6
Aver.	**93.8**	**0.81**	**5.5**



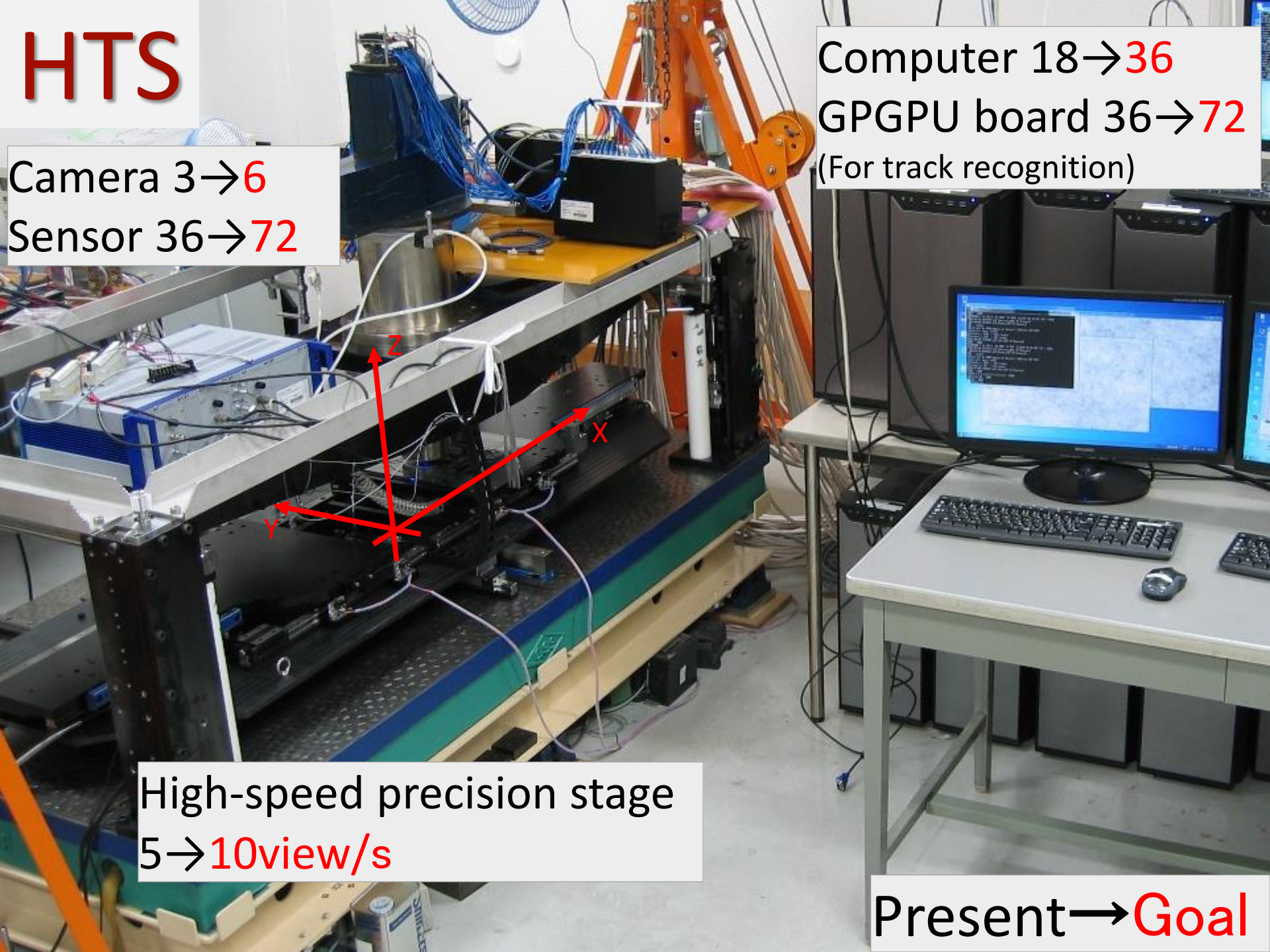
- These results doesn't depend on the location of each sensor.
- The position and angle accuracy are enough to take muon tomography.

0.32°

HTS

Camera 3→6
Sensor 36→72

Computer 18→36
GPGPU board 36→72
(For track recognition)



High-speed precision stage
5→10view/s

Present→Goal

Schedule

Present

Limit speed of stage

Rate[%]	Mar. 2013	Sep. 2013	~Mar. 2014	~end of 2014
Camera and Stage speed	1/4 (25%)	1/4 (25%) (already achieved)	1/2 (50%)	1/1 (100%)
Track recognition speed	1/6 (13%)	1/2 (50%) (already achieved)	1/1 (100%)	1/1 (100%)
Scanning tested done	1/12 (9%)	1/4 (25%)	1/1 (100%)	1/1 (100%)
		Quarter 2250cm^2/h	Half 4500cm^2/h	Full 9000cm^2/h

Analysis target

- 10 - 100m^2 : Muon tomography / 1 measurement.
- 25m^2 : Gamma-ray telescope (GRAINE) in 2014.

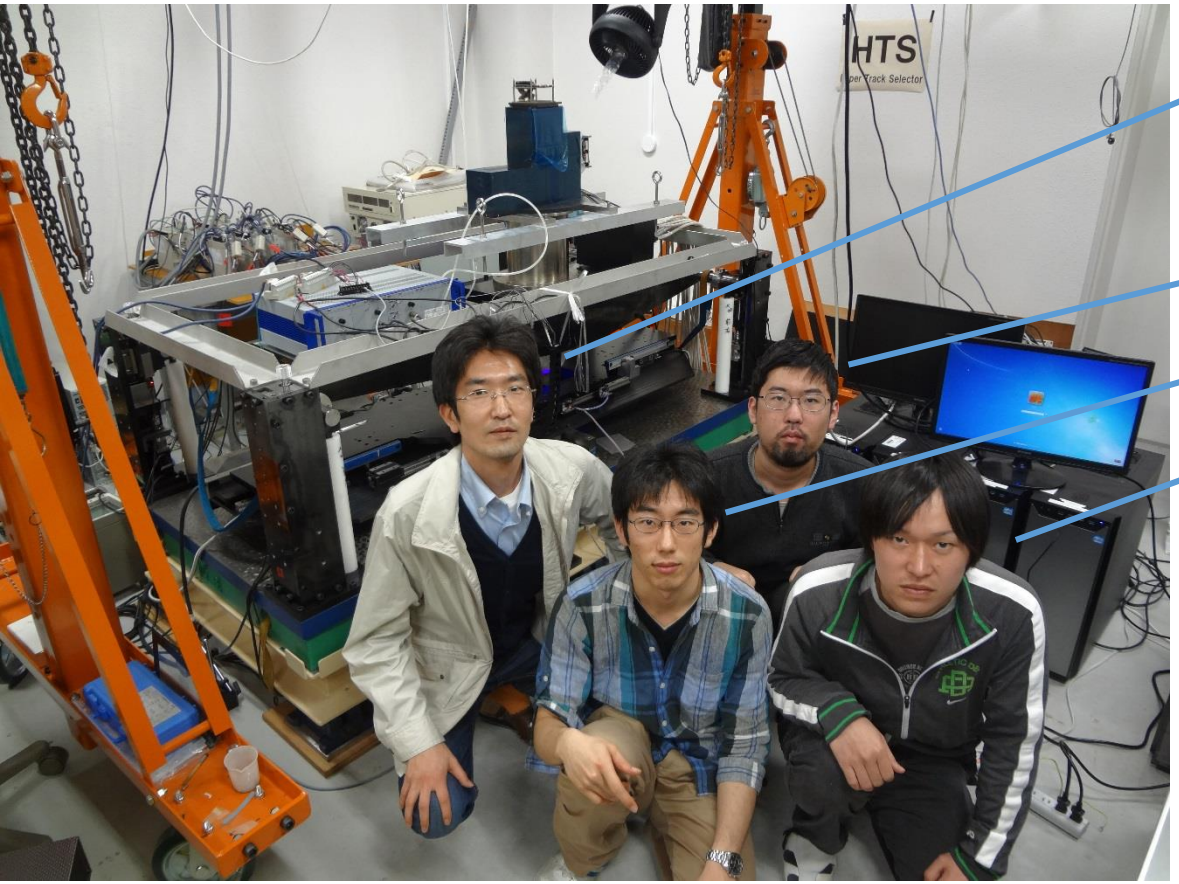
Welcome to the use of your measurements.

Summary

- Parameter adjustment made it possible to drive stage at 5view/s.
- The performance of optical system was checked.
- Track reproducibility is 93.8% and angle repro. is 5.5mrad (0.32°).

- Half of the total cameras is installed and speed of the stage is a half. Total throughput is quarter at the present moment.
- Scan speed will be 4500cm^2/hour (half) this fiscal year by installing full image sensors.

Thank you for your attention.



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