Injector alignment

KEKB Accelerator Review Committee

14 June, 2016

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   - –Laser PD and tracker
2. Initial alignment
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5. Conclusion

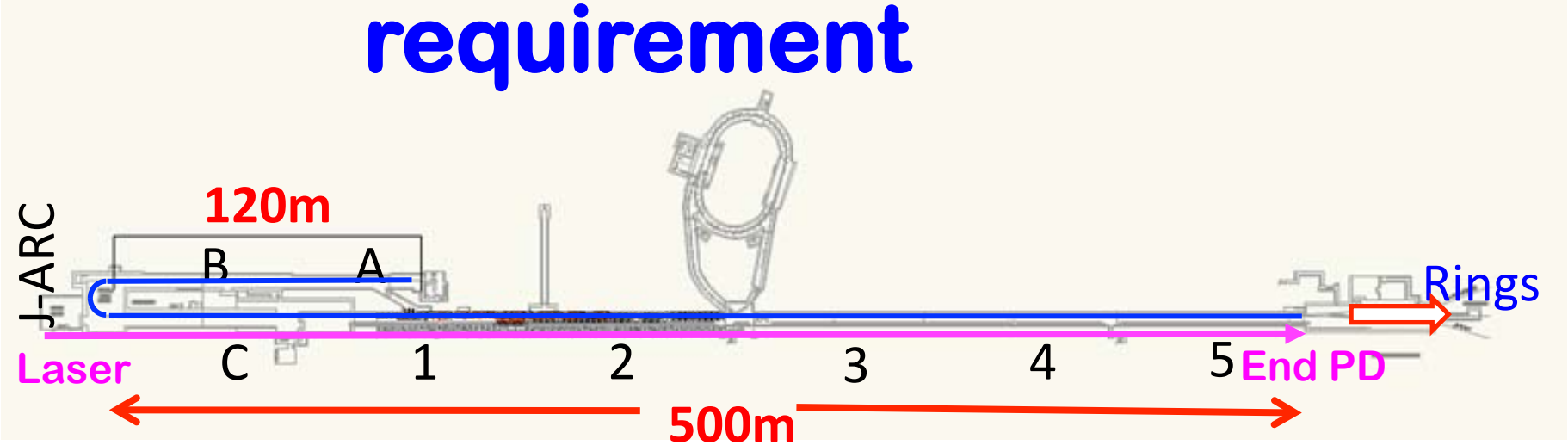
Who are contributing

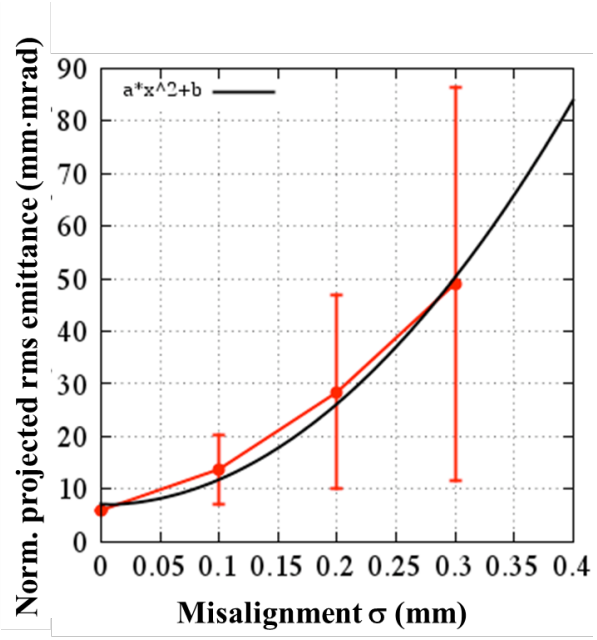
- Accelerator group
  - Enomoto, Higo, Kakihara, Tanaka, …..
- Control group
  - Mikawa, Satoh, Seimiya, Suwada, ……
- Injector group
  - Yoshida,
- Mitsubishi Electric.
  - Mizukawa, Kimura, Kudo, Kusano, Suzuki, Toyotomi, Ushimoto, ….
- Outside company
  - Nishitani, Chiyokura, …
- Magnet group of KEKB ring
  - Masuzawa, Sugawara, ….. but still loose coupling

Requirement and strategy

- Requirement
- Strategy
- Laser PD measurement
- Initial alignment of girder
- Hard ware alignment on girder

Linac layout and alignment requirement





σ < 0.1 mm→ βγε 20 mm·mrad almost kept.

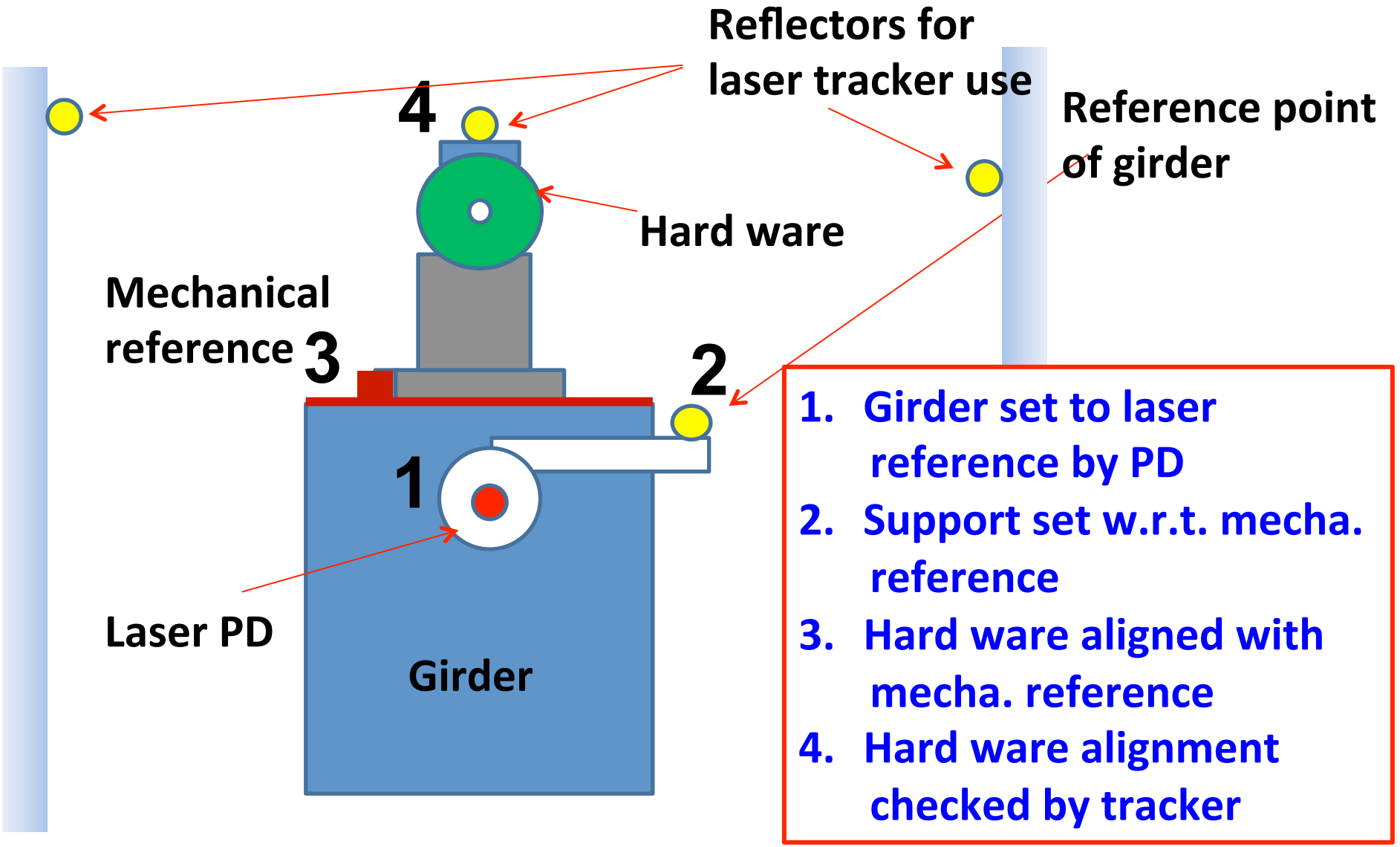
σ > 0.1 mm→ emittance preservation required.

Requirement

Local σ < 0.1mm

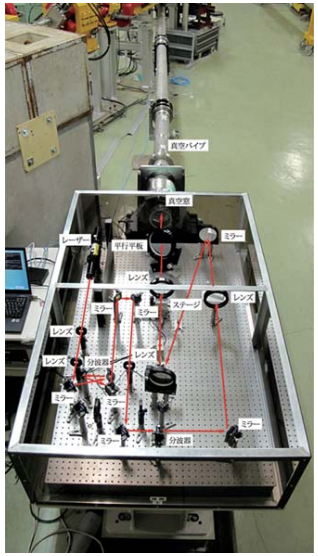
Global σ < 0.3mm

Alignment scheme



1. Girder set to laser reference by PD
2. Support set w.r.t. mecha. reference
3. Hard ware aligned with mecha. reference
4. Hard ware alignment checked by tracker

500m straight reference line by laser



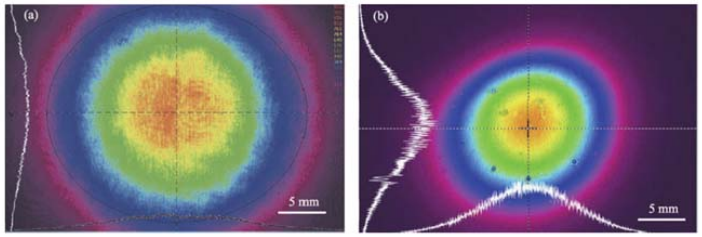
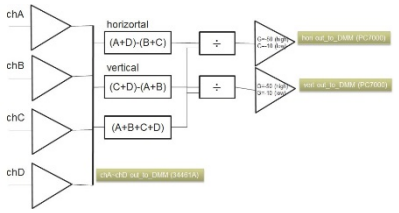
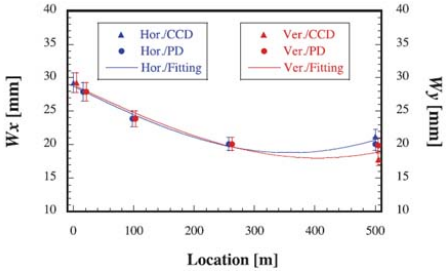
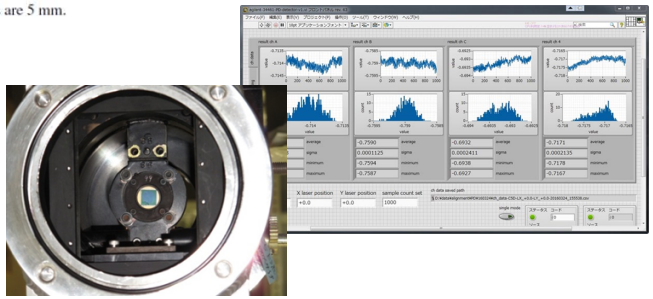


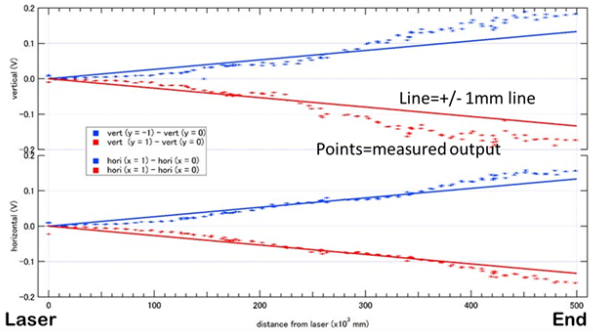
FIG. 5. Intensity profiles of the laser beam at (a) $z = 0$ m and (b) $z = 500$ m. Scale bars are 5 mm.







$$W_x(z) = W_{x0}\sqrt{1 + \left(\frac{z - z_{x0}}{z_{Rx}}\right)^2}$$

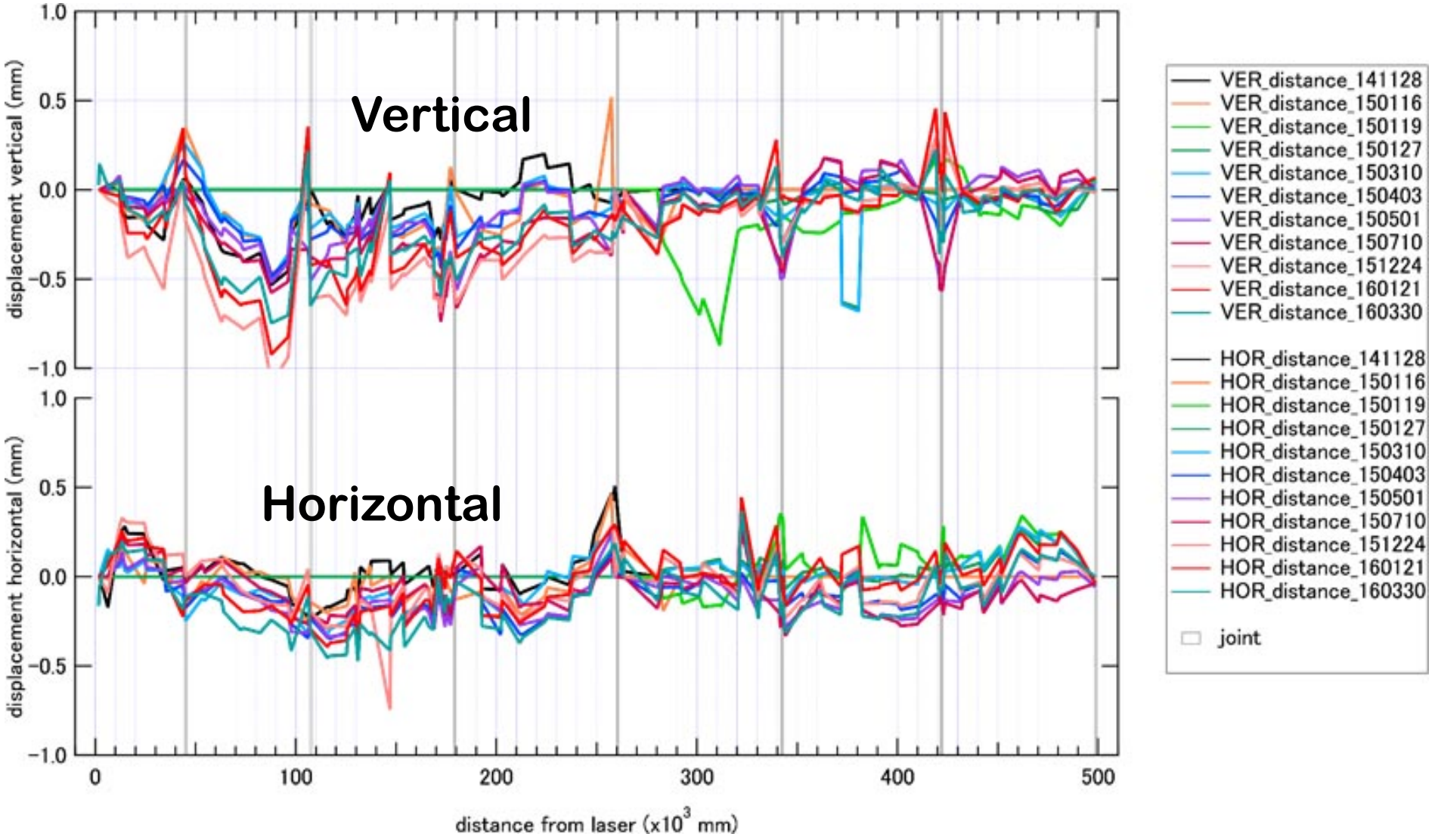


- 500m laser line stabilized by laser passage tilt.
- Improved data reliability with robust measurement.
- Sensitivity calibration done with laser tilting
- Some sensors automatically and continuously measuring now
- Started PD radiation damage evaluation

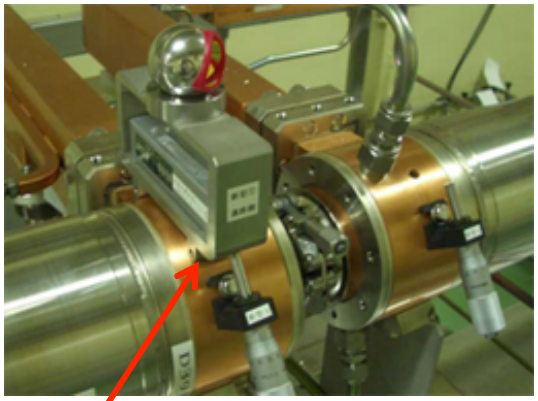
Initial alignment of girders

1. Girders in sectors 3—5 were quickly aligned in 2011 after the earthquake.
2. Positron generation section was installed by summer 2014.
3. By late Jan. 2015, all units in 3—5 sectors were aligned straight.
4. These alignment reading is better than 0.1mm at the timing of installation.
5. Alignment has been measured from time to time without further re-alignment.

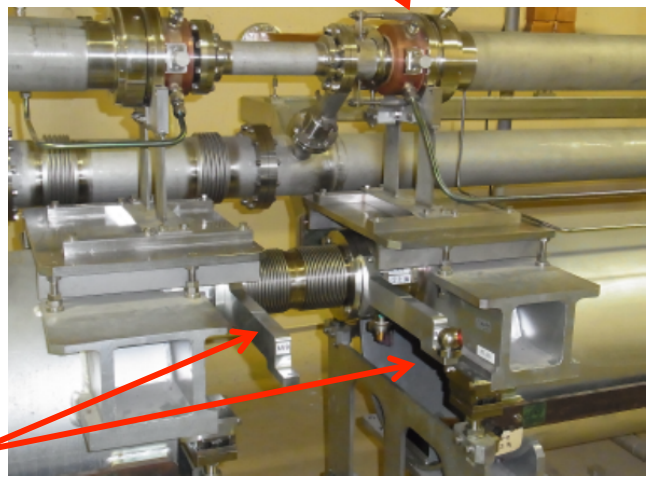
Measurement 141128 -- 160330



Mounting tracker reflector on each hard ware



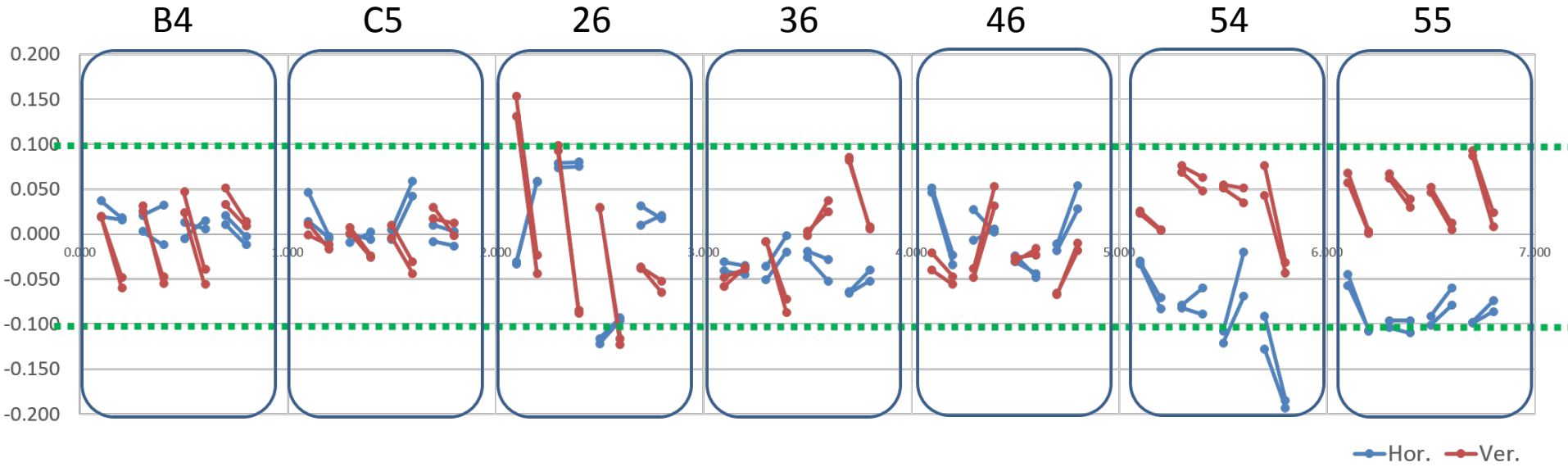
Mounted on coupler OD

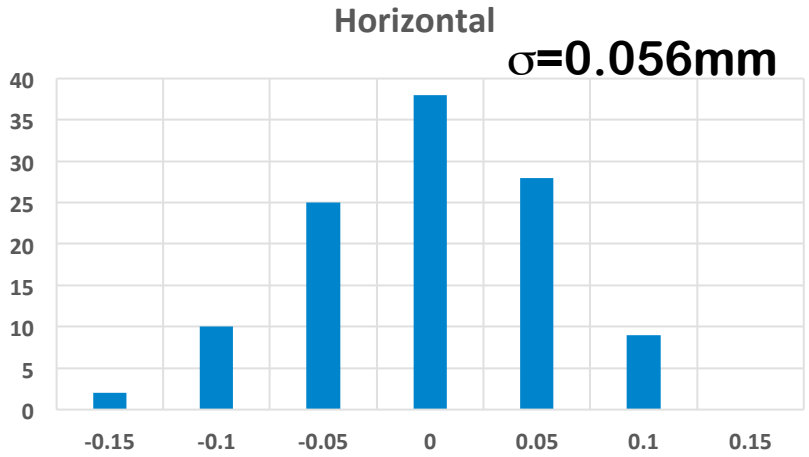


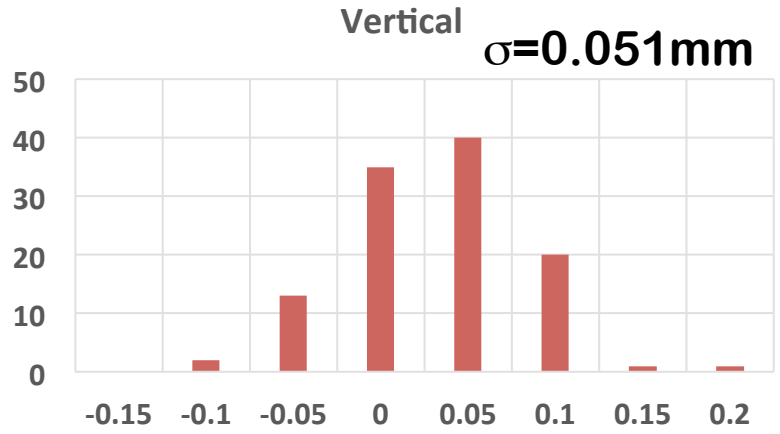
Arm from PD to reflector

Reflectors for old Q-magnet

Hard ware alignment on each girder measured in Jan. 2016

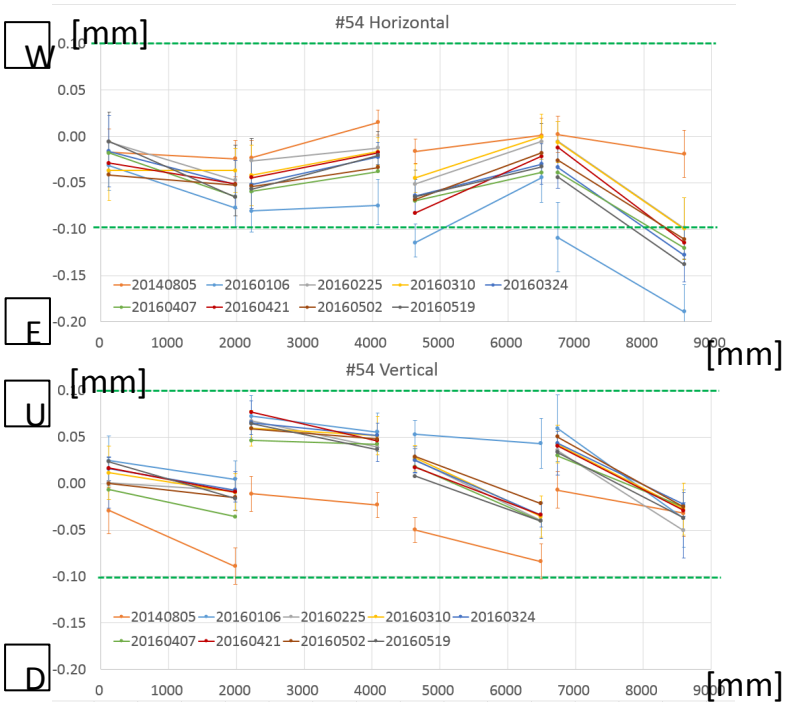




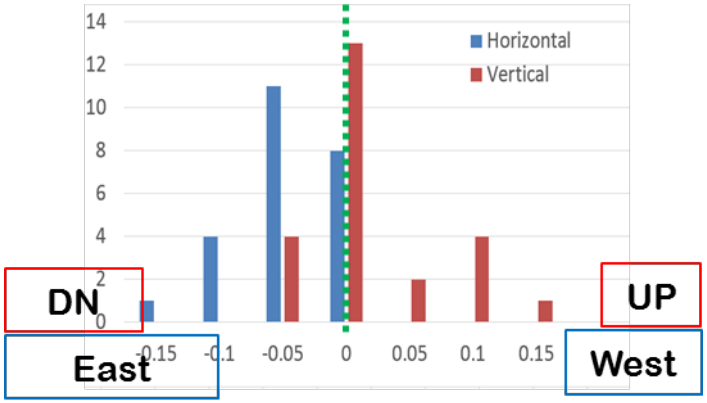


Accelerator position on girder unit 54
from August 2014 to May 2016

Unit 54 in nearly 2 years from Aug. 2014 to May 2016



Movement in 1.5 year between July 2014 and January 2016



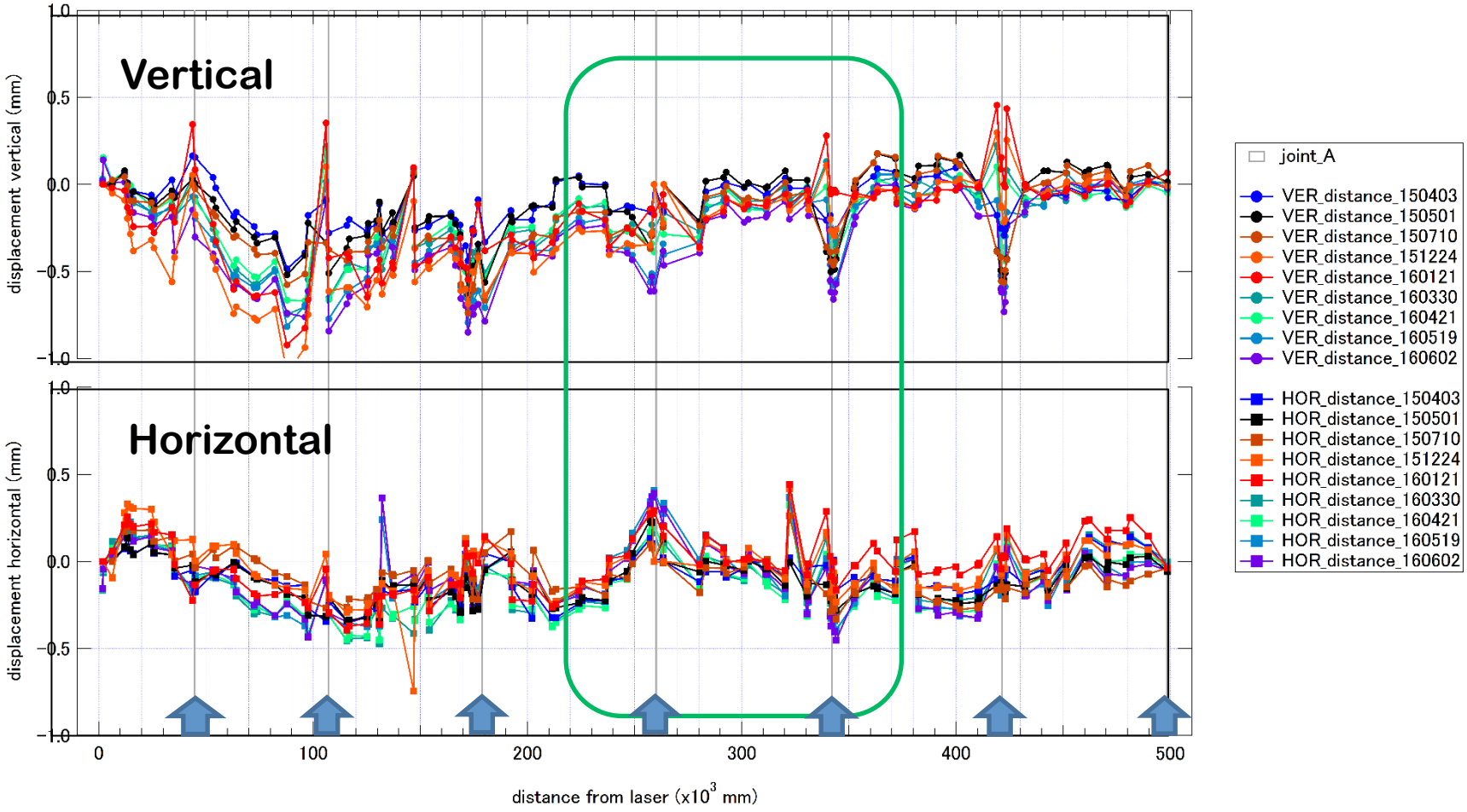
ACC's can be aligned on each girder within below +/-0.1mm.

It is speculated to be stable within +/-0.05mm.
This should be confirmed or realized.

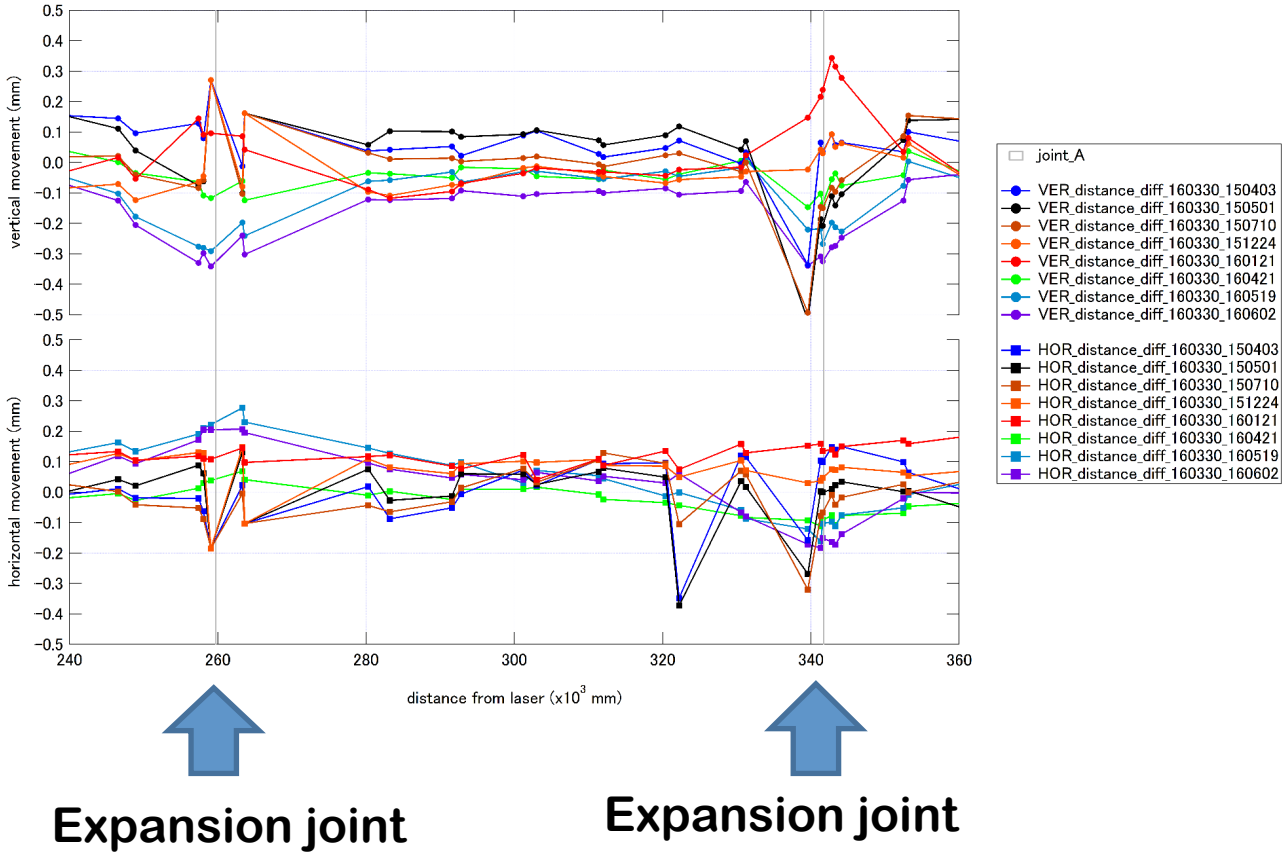
Floor movement

- Laser PD measurement showed movement of larger than a millimeter
- Severe at expansion joints
- Started continuous measurement over 500m
- Will start detailed 40m evaluation across a joint

Floor moves by fraction of 1 mm
example in more than a year (2015/4/3~2016/6/2)



Floor movement
close-up w.r.t. 2016/3/30

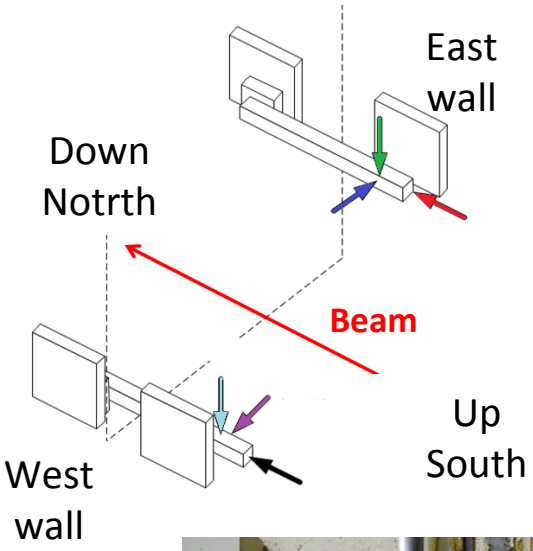


Expansion joint **Expansion joint**

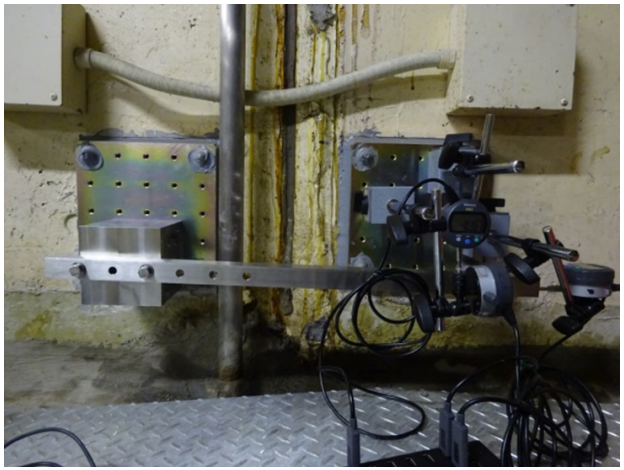
~20m from expansion joint is mostly moved.

Expansion joint and evaluation

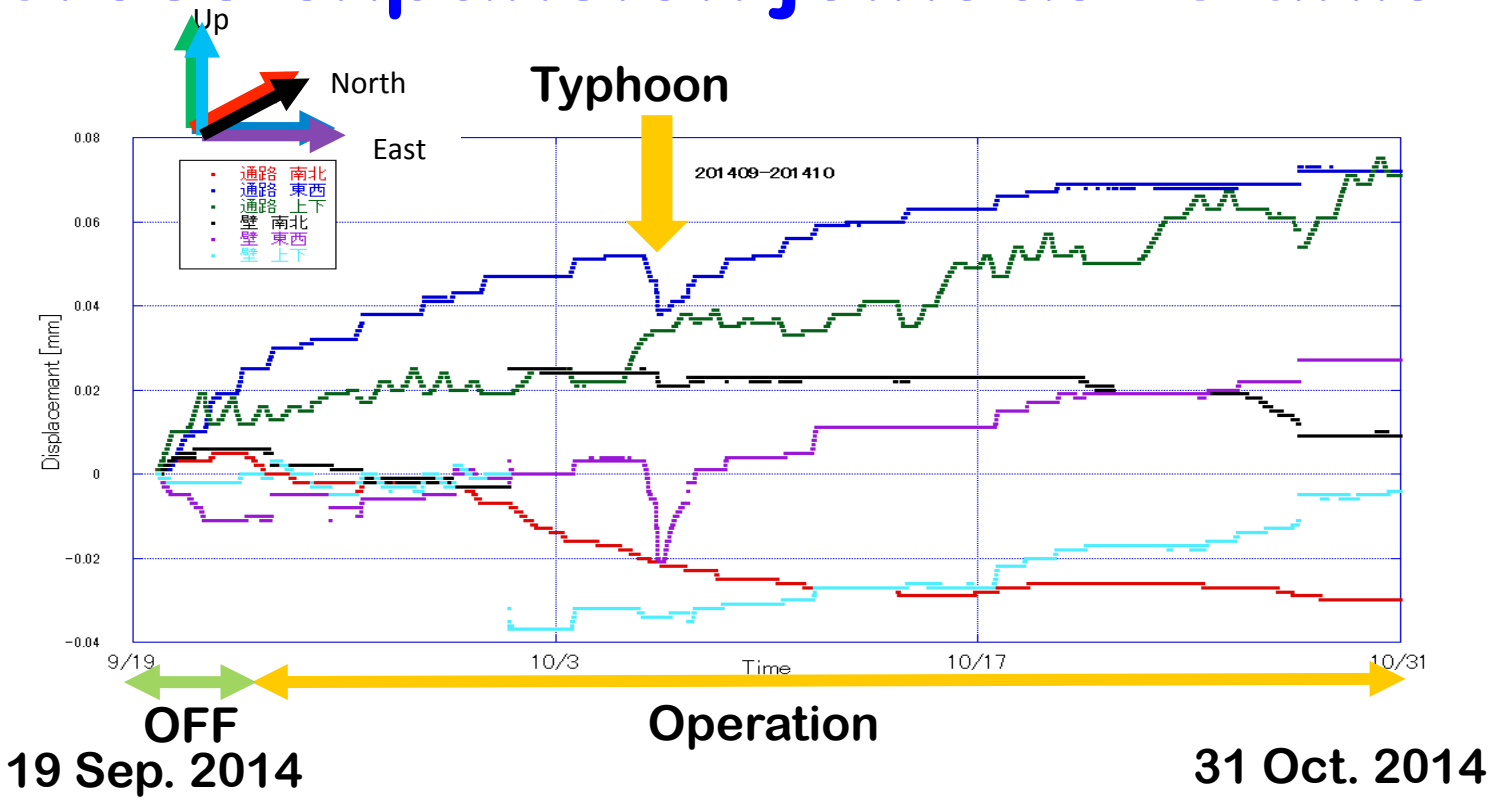
Expansion joint



Dial gauges

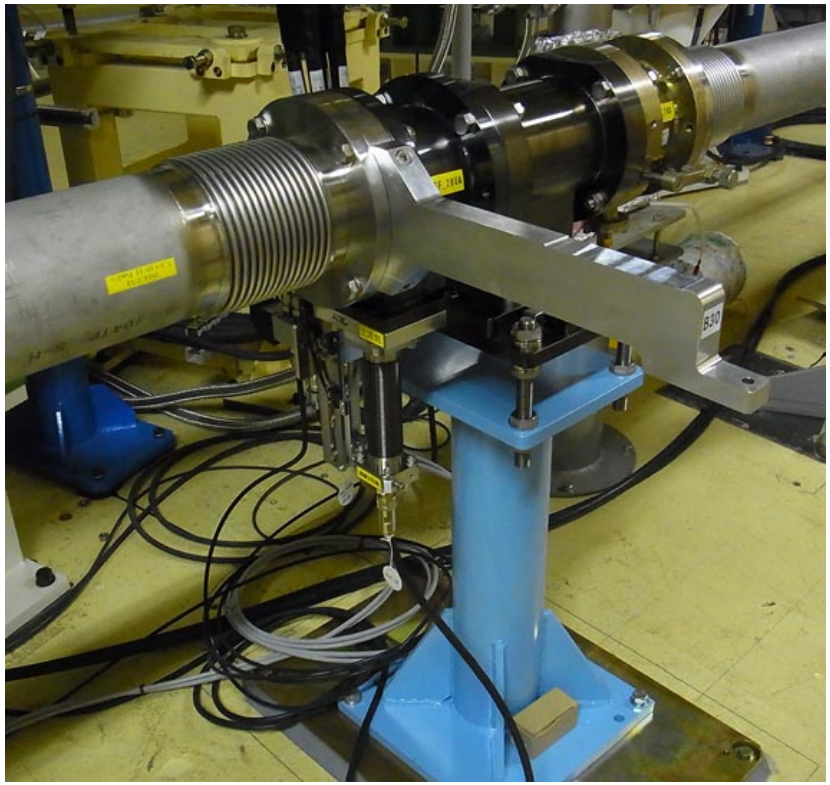


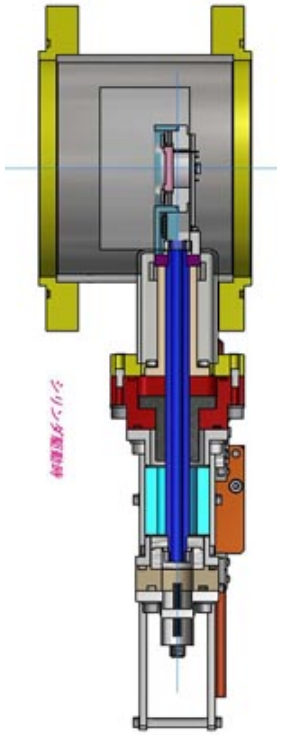
Relative movement across expansion joint at 28 unit



- Daily regular motion exists
- Gradual drift over a month after operation starts
- Sensitive on tunnel temperature
- Big perturbation due to typhoon
- Show a year cycling.

PD measurement automatic and continuous

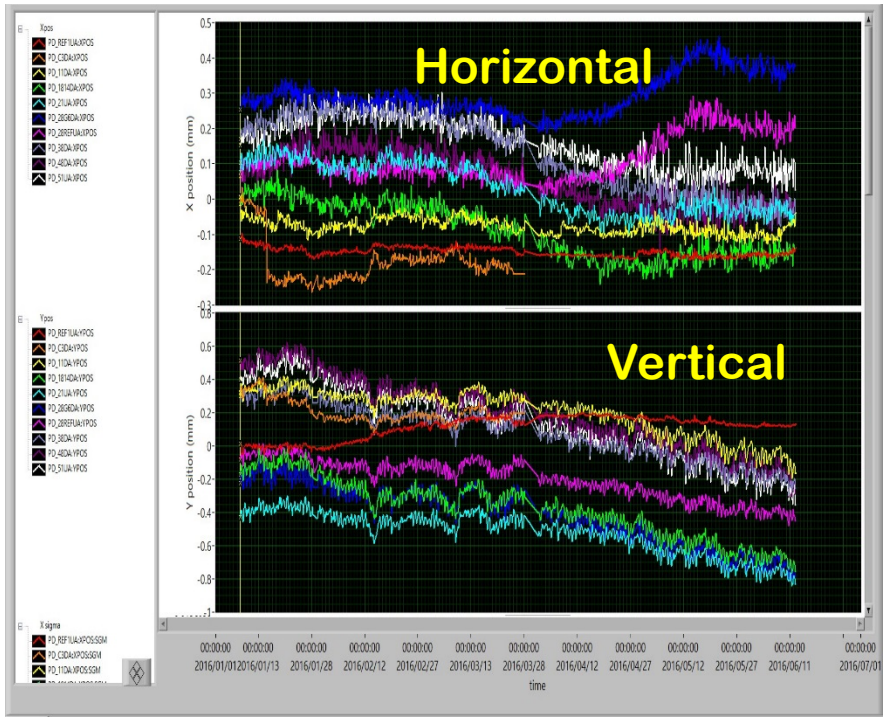


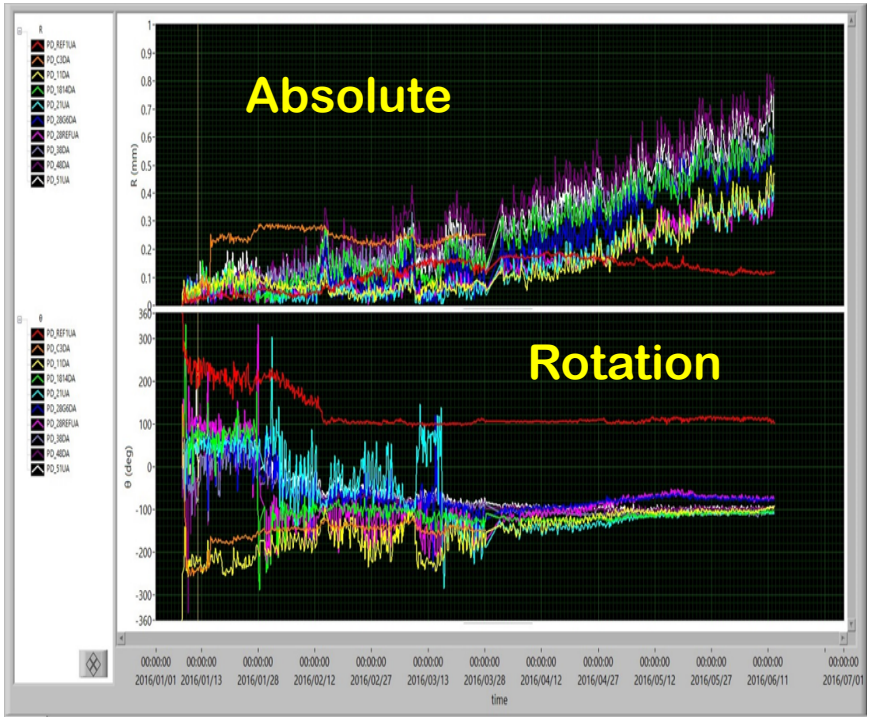


Measurement in every 4 hours

Automatic measurement in every 4 hours at 10 locations for half a year

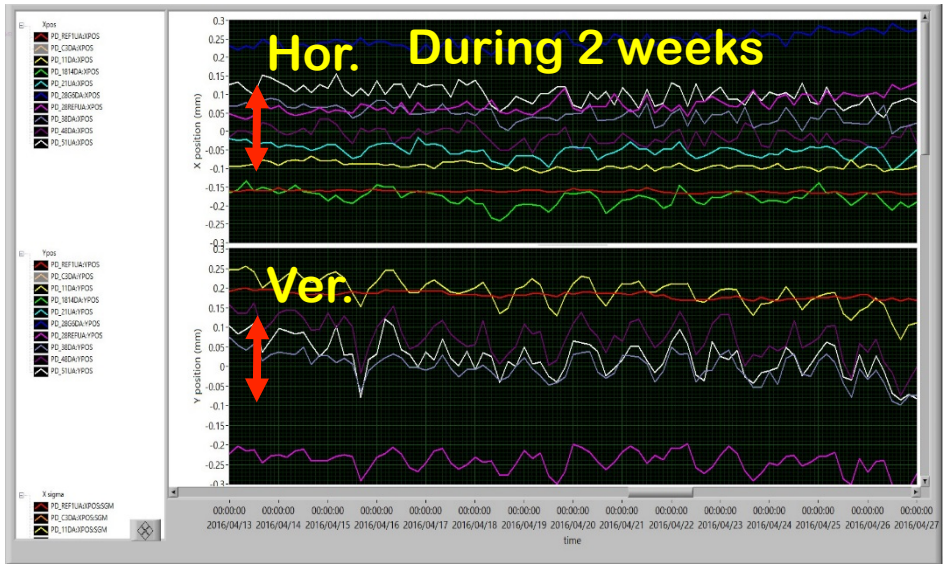
from January to June in 2016

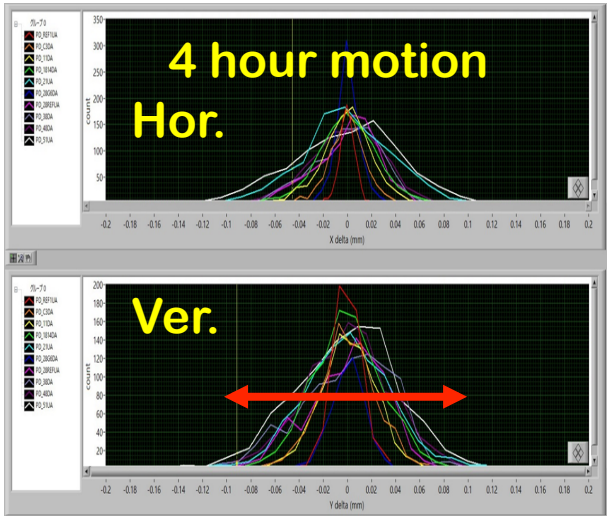


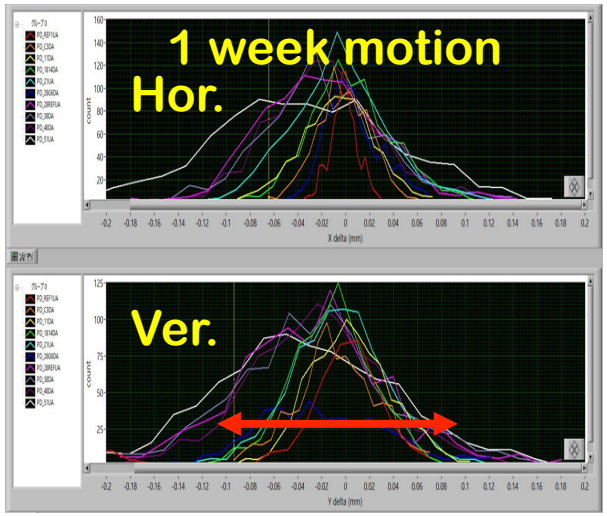


Daily motion
Movement in 4 hours or those in a week

Red arrow = +/- 0.1mm band

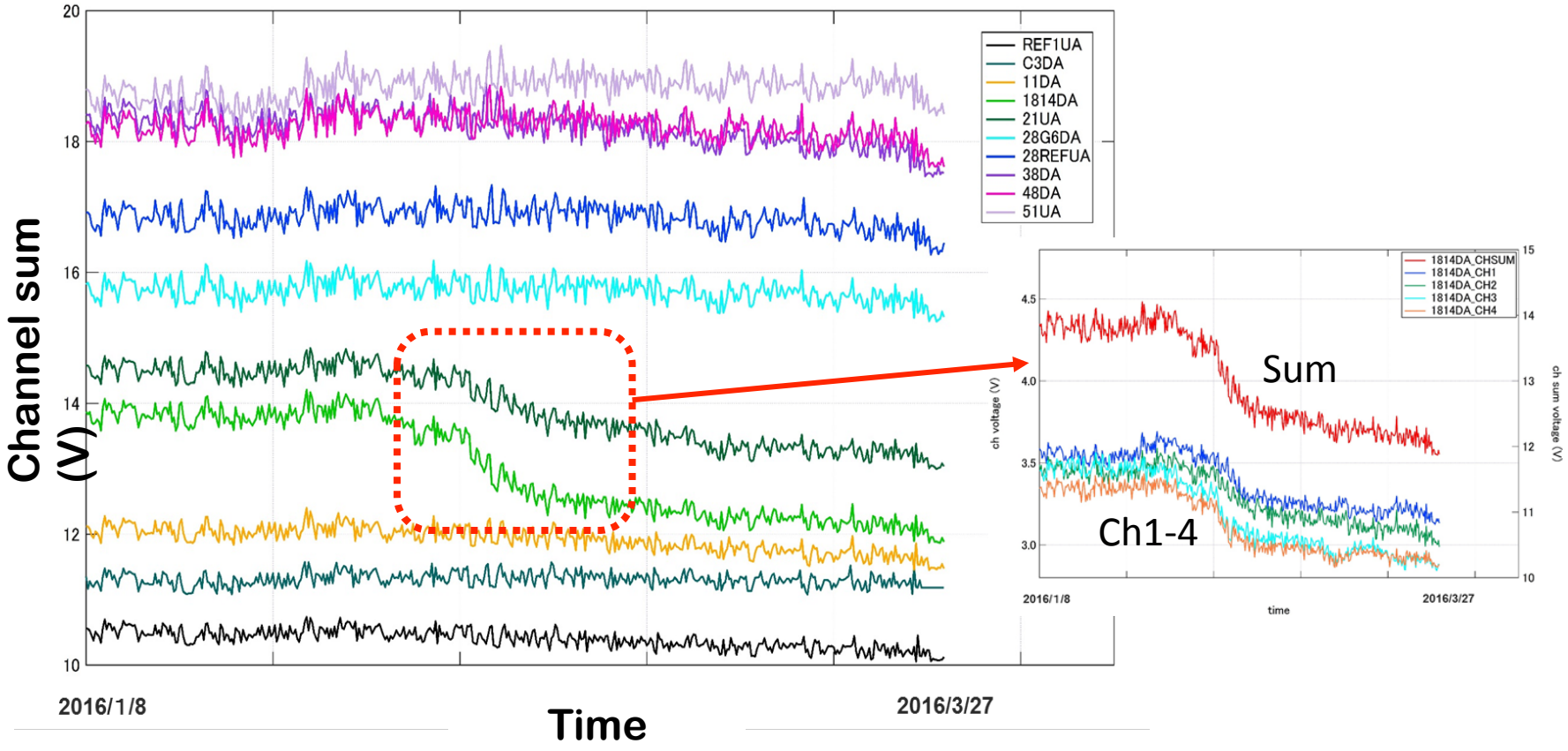






Daily motion full ~ 0.1mm
Motion in 4 hours ~ 1 week +/- 0.1mm

A concern
PD deterioration due to radiation



Deterioration observed during phase-1 operation for those at collimator.
How to use the PD information needs to be studied.

Simulation and cures

- SAD simulation started
- Possible cure methods are under consideration.

- How to stabilize position to keep alignment?
  - Studies should be made how to compensate the floor movement
  - Do we need other tool to evaluate the floor motion? i.e. HLS or WPS
  - How to implement beam information into feedback

- Compensation algorithm
  - ~~One-to-one steering~~ → Minimize residual error^2
  - DF or WF steering
  - How fast can we and how frequent should we apply offset injection?

SAD simulation on emittance growth along 500m straight section

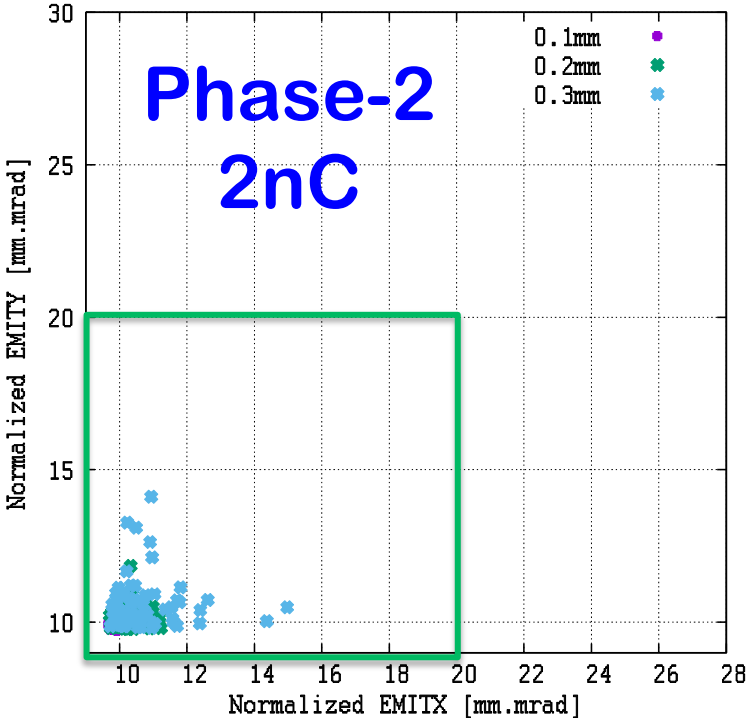
Assumption

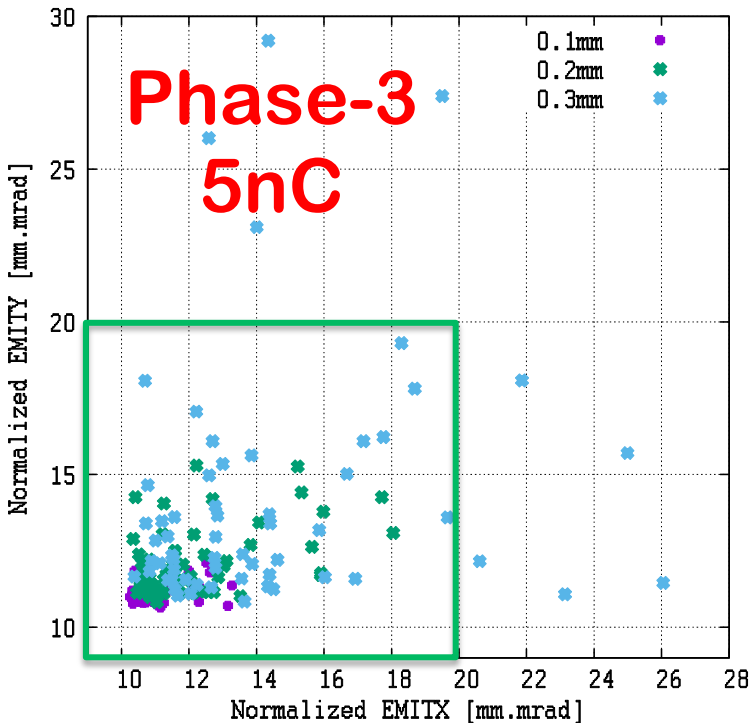
- Sector C~5 over 500m
- ε_{inj} = 10 μm
- σ_z = 10ps / 2.35
- δ_e = 0.4%
- σ_Q = 0.2mm (3σ cut)
- X_{ACC}, Y_{ACC} = Girder(measured)
- $2a_{ACC}$ = 20mm (diam.) for wake calc.
- W_t = Yokoya formula

Procedure

1. Orbit correction at BPM without wake field
2. Offset injection (x, x', y, y') at the front of sector C with wake field ON
3. Add variation in misalignment of ACC and Q
4. Add jitter in ST and Q
5. Check response to beam injection jitter

60 seeds of misalignments





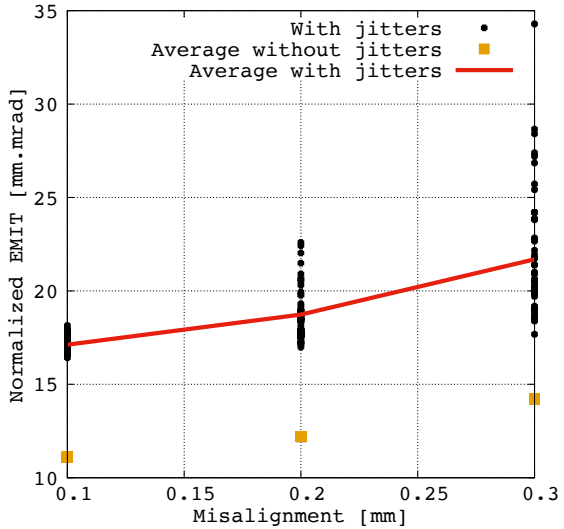
60 seeds of misalignments + perturbation unable to be compensated

K-value jitter

ST: K jitter = Peak K value X 0.08% (P-P)

Q: K jitter = Peak K value X 0.32% (P-P)

Injected beam: No jitter



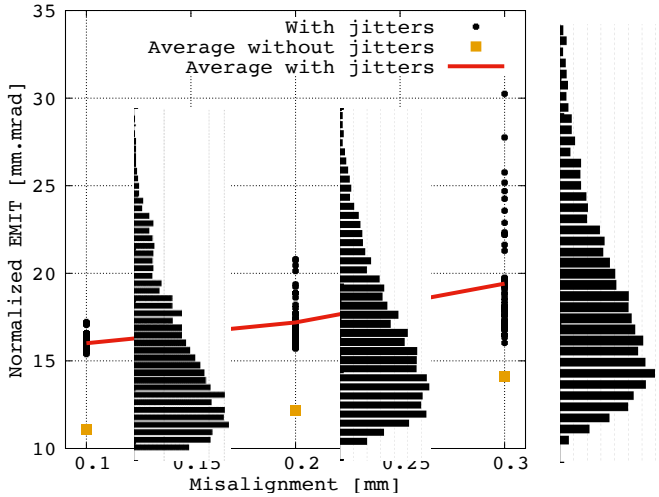
Mainly due to ST-K jitter

Injection jitter

ST, Q: K jitter = Operation K value X 0.2% (P-P)

Injected beam position jitter ~ beam size:

Sigma 0.1mm Gaussian in 100 seeds

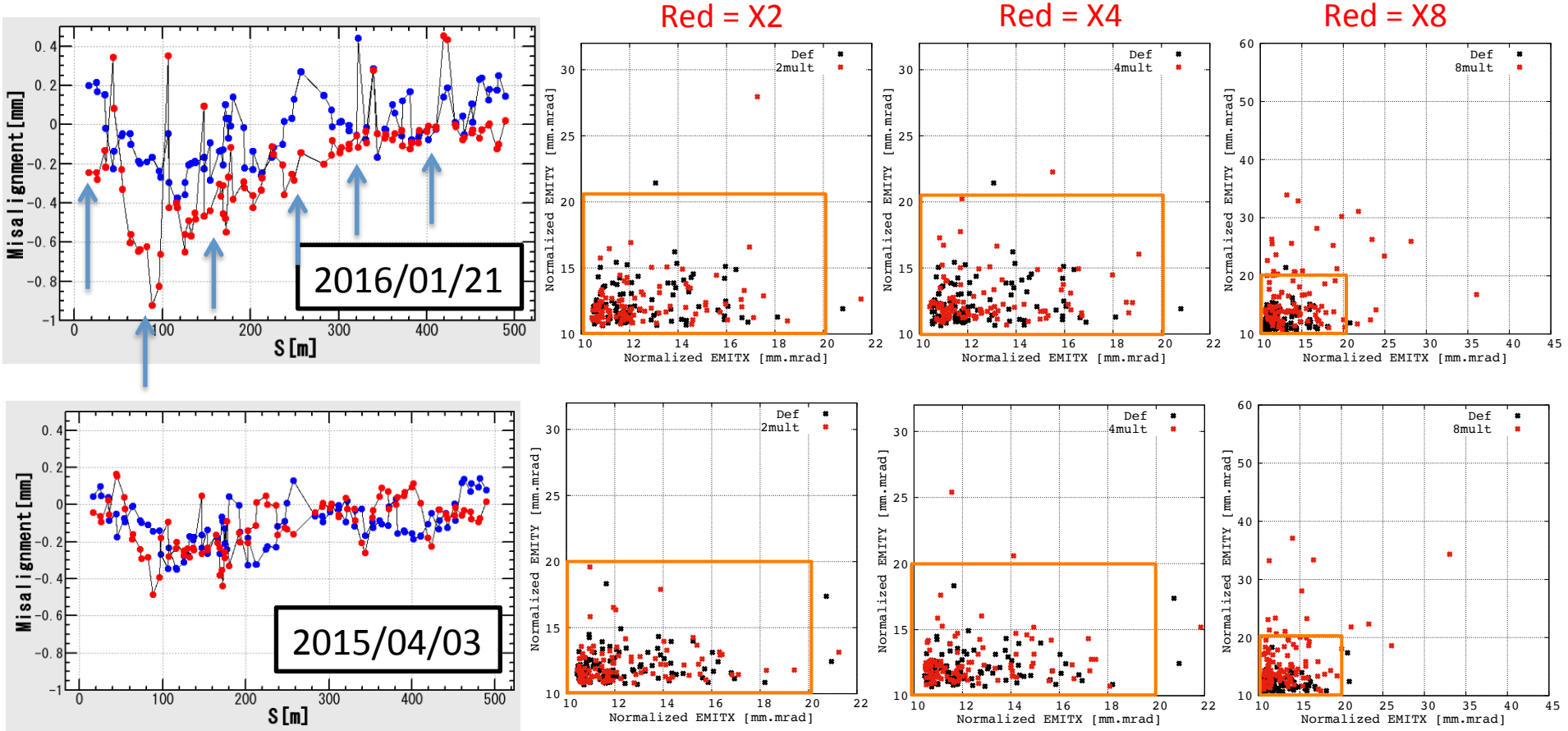


Mainly due to injection jitter

Jitter should be less than beam size

Emittance growth under measured misalignment + random movement not to be compensated

Black: σ_{ACC}=0.1mm, σ_Q=0.2mm



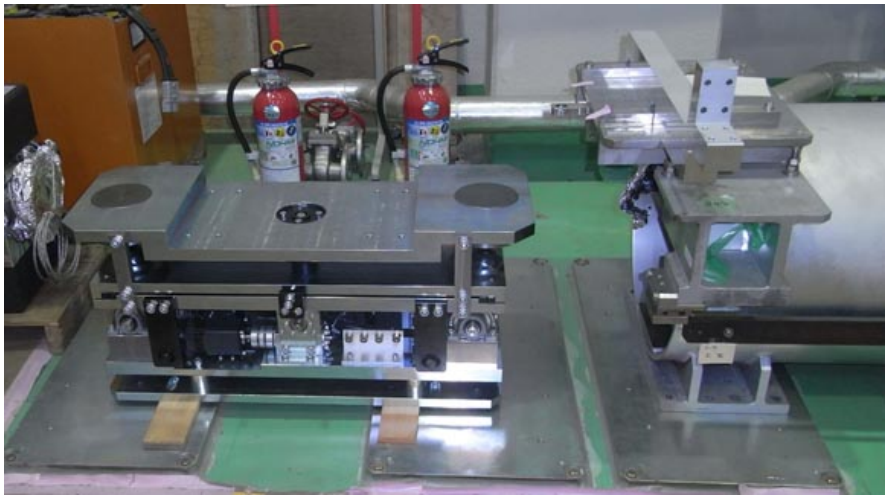
Uncompensated random movement of 0.4mm in sigma is marginal?

Floor movement to be compensated

Unit mm

	Horizontal	Vertical
Daily	0.1	0.1
Week	0.1	0.1
Year	0.5	1
Speed	0.01mm/hr	0.01mm/hr

Movers under study



Mover tests for accelerator girder

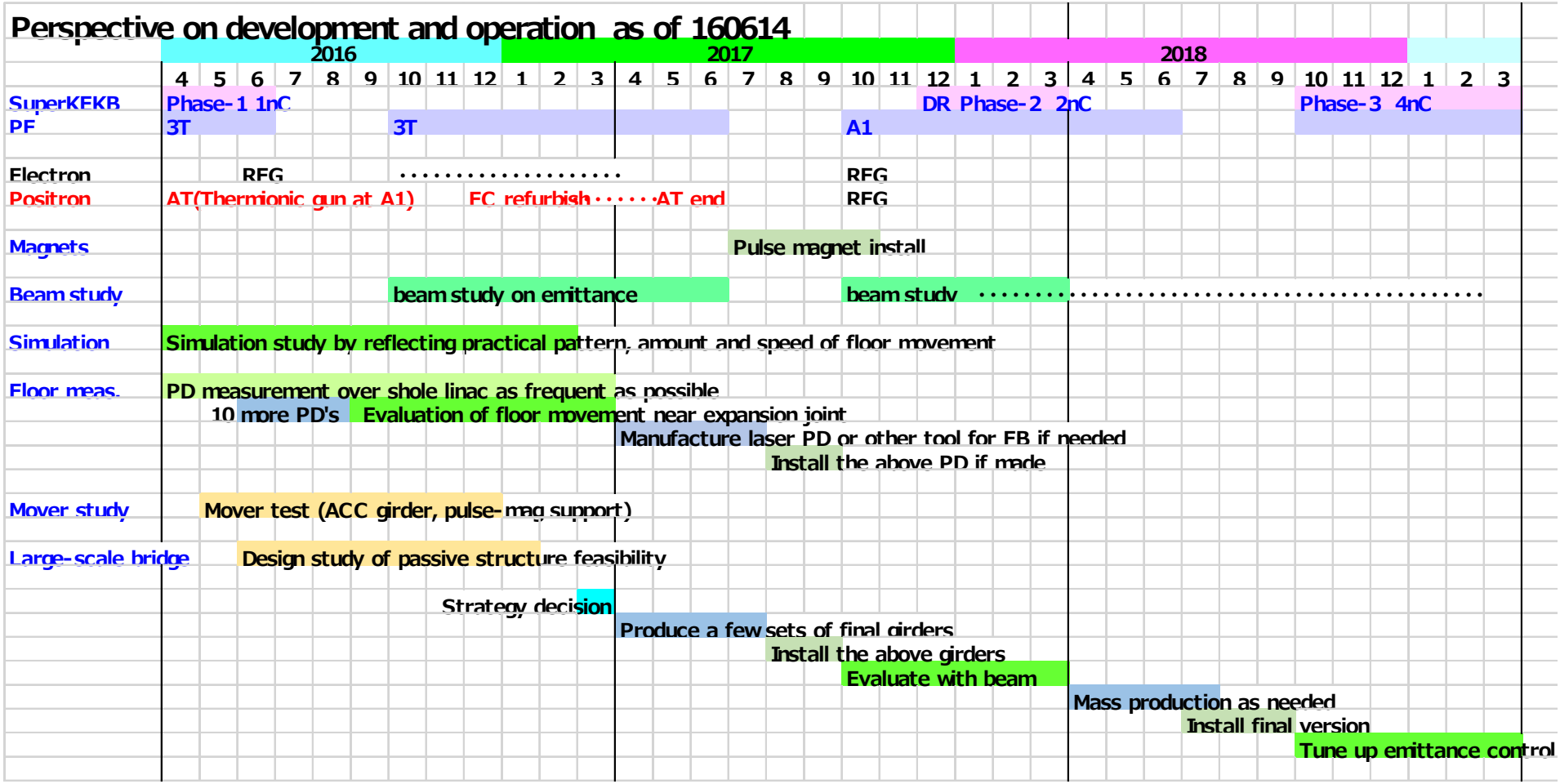
Support structure being developed for pulse magnets

Requirements and strategy against floor movement

- **In phase-2 timeframe**
  - Alignment as is with trial cures at some points
  - Confirm overall and year-scale floor movement
  - Evaluate distance scale from joint
  - Try to detect movement with beam
  - Investigate the cure algorithm with simulation
  - Study feasibility of mover or passive bridge
- **Development for phase-3**
  - Alignment corrected once more and stabilized with movers or suppression mechanism near relevant expansion joints
  - Beam manipulation to keep golden orbit
  - Compensation such as offset injection is developed

Concluding remarks

Development toward Phase-3



Concluding remark

1. **Initial girder alignment in 2014**
   - Done with residual ~0.3mm in sigma over 500m line.
2. **Hard wares alignment on girder improved**
   - Done with errors 0.05mm in sigma
   - Kept for in a year scale
3. **Floor continuous measurement**
   - Movement mostly near expansion joints
   - Daily motion ~0.1mm to yearly ~1mm
4. **Floor sophisticated evaluation**
   - Will explore near expansion joint
   - Will design compensation mechanism
5. **Compensation mechanism**
   - Basic study of movers is under way
   - Passive structure design study to be made

Concluding remark (cont.)

6. Tools to identify the movement

- Radiation resistive PD is being searched
- Pending now to develop other evaluation tools
- Should study how to use which beam information

7. Beam study

- Should study beam emittance on floor movement
- Study offset injection

9. Test girder

- Installation in mid 2017
- Should study effectiveness during phase-2

10. Full scale cures

- Installation by Phase-3
- Sophistication in parallel to phase-3 operation