

# Survey of the SuperKEKB main ring after the Great East Japan Earthquake

M. Masuzawa, H. Iinuma, T. Kawamoto, Y. Ohsawa  
and R. Sugahara , KEK, Tsukuba, Japan

N. Abe, T. Ariyama and K. Mishima, PASCO Corp.,  
Tokyo, Japan

# Contents

## 1. Introduction

- SuperKEKB overview
- Preparation for SuperKEKB magnet alignment

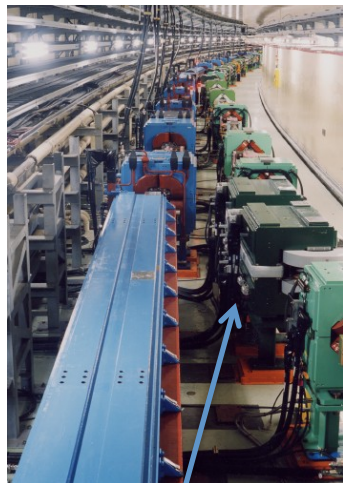
## 2. After the earthquake

- Damage
  - Tunnel structure (Main ring)
  - Beam line deformation
    - Survey by laser trackers
    - Level survey by N3
    - Survey 2012

## 3. Summary

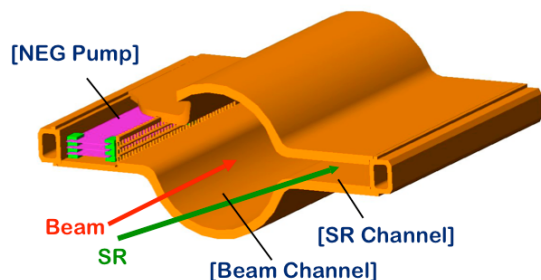
# 1. Introduction

- SuperKEKB overview
- Preparation for SuperKEKB magnet alignment

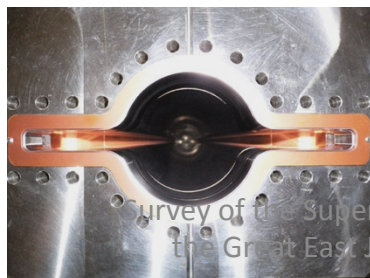
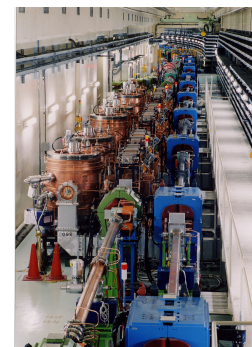
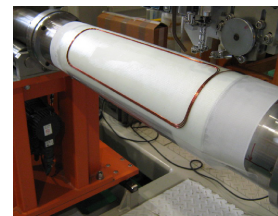
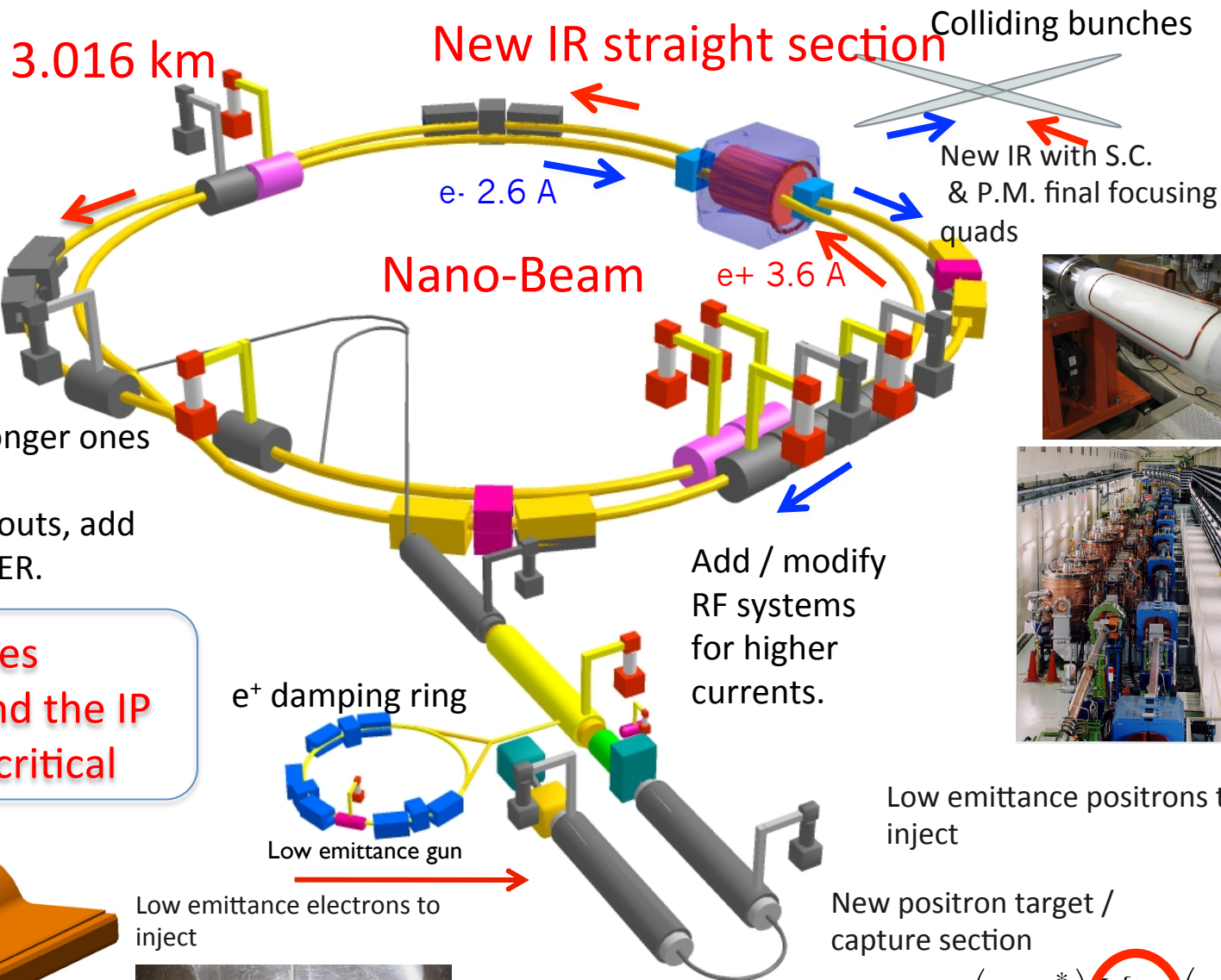


Replace dipoles with longer ones (LER).  
Change the wiggler layouts, add more wigglers LER & HER.

**Tighter tolerances  
alignment around the IP  
Vibration more critical**



TiN coated beam pipe  
with antechambers



$$L = \frac{\gamma_{\pm}}{2e r_e} \left( 1 + \frac{\sigma_y^*}{\sigma_x^*} \right) \frac{I_{\pm} \xi_{\pm y}}{\beta_y^*} \left( \frac{R_L}{R_y} \right)^{\frac{1}{2}}$$

~40 times gain in luminosity



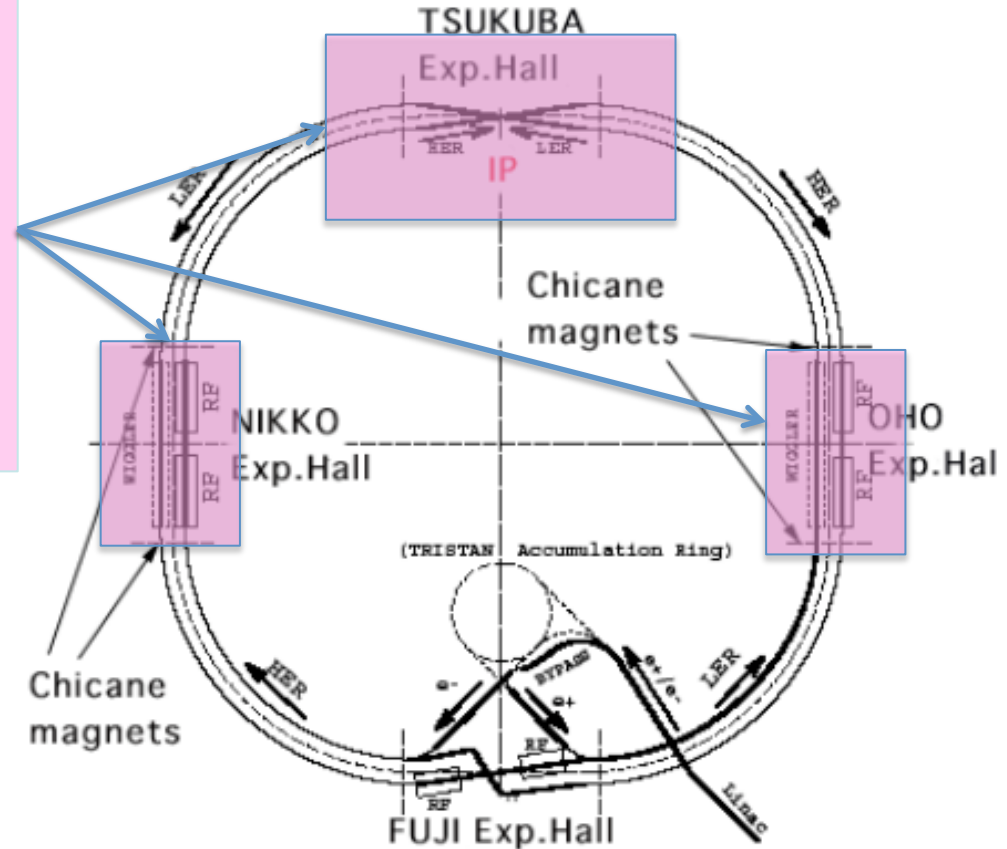
# 1. Introduction

- SuperKEKB overview
- Preparation for SuperKEKB magnet alignment

Sections with totally different magnet layouts (IR & straight sections)

➔ removal of the KEKB magnets & installation of the new magnets.

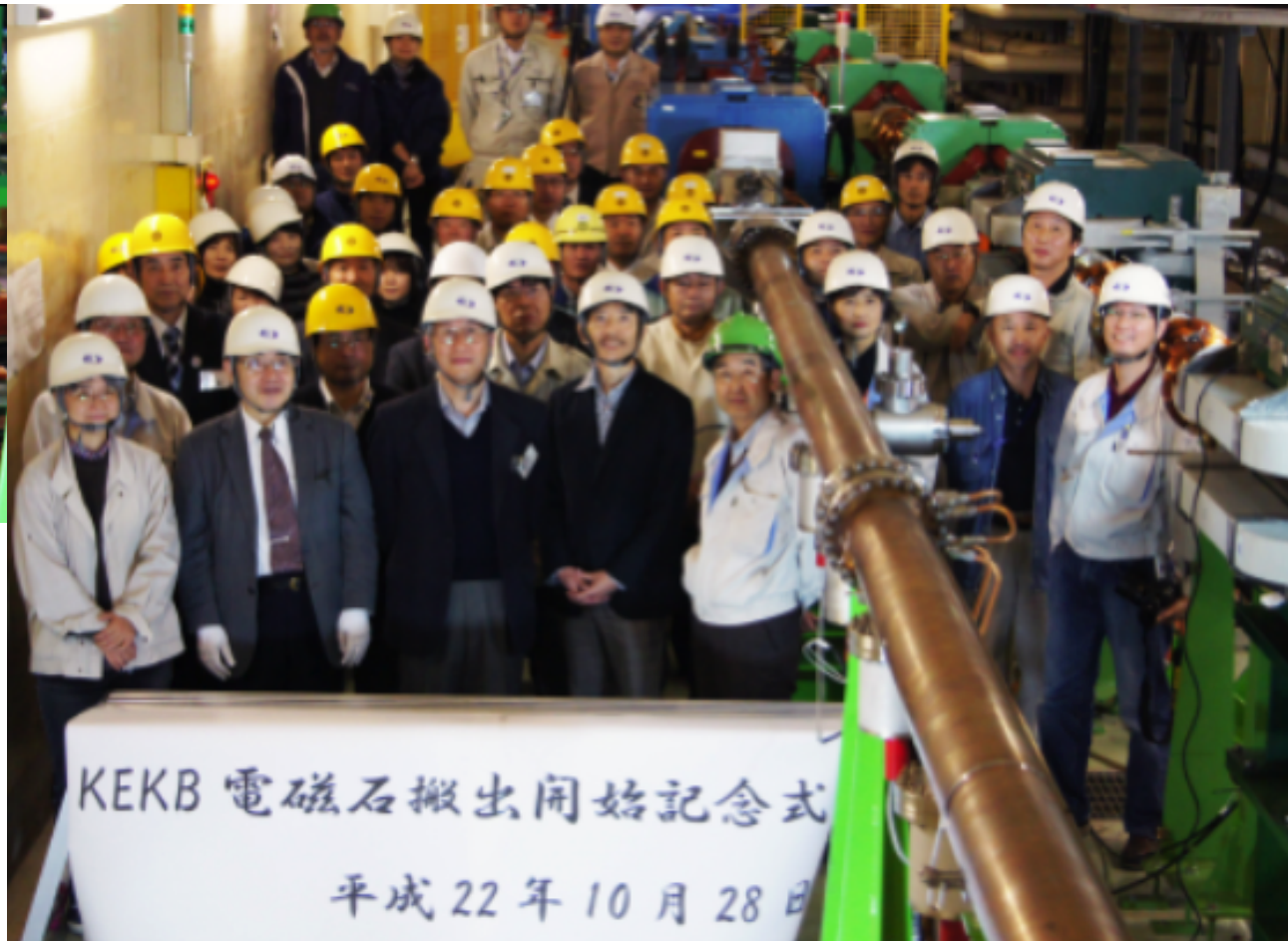
The rest of the magnets, about 2/3 of 2000 magnets, mainly in the arc sections, were planned to be used as good and reliable reference points of the network.



LER arc sections dipole magnets (~100) replaced by larger (~4m) ones.

Oct. 28, 2010 Dismantling KEKB LER dipole started

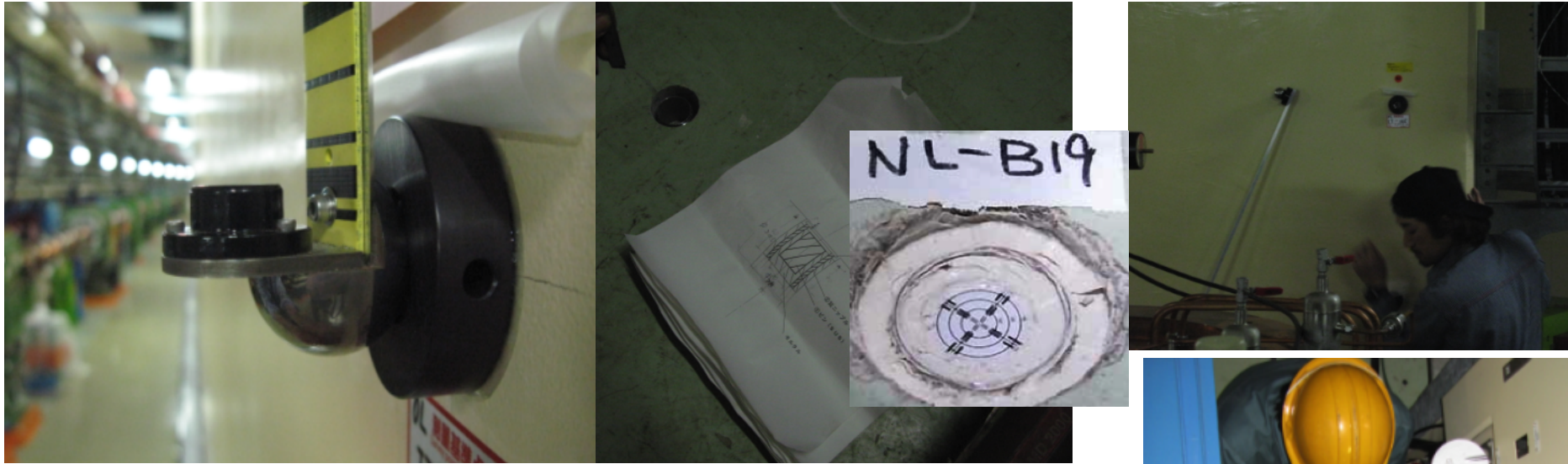
Director general A.Suzuki, director K.Oide etc., untightened the bolts.



# Preparation for SuperKEKB magnet alignment

## Improving the survey network

IWAA10



Our tunnel is ~3 decades old.  
It has served two generations of accelerators,  
TRISTAN (single ring) & KEKB (double ring, more crowded).  
Lots of junk (cables, pipes,...) → not much space, especially  
on the cable rack side.  
Very difficult to find space for stable monuments.

New monuments installed on wall and floor.

Survey of the SuperKEKB main ring after  
the Great East Japan Earthquake

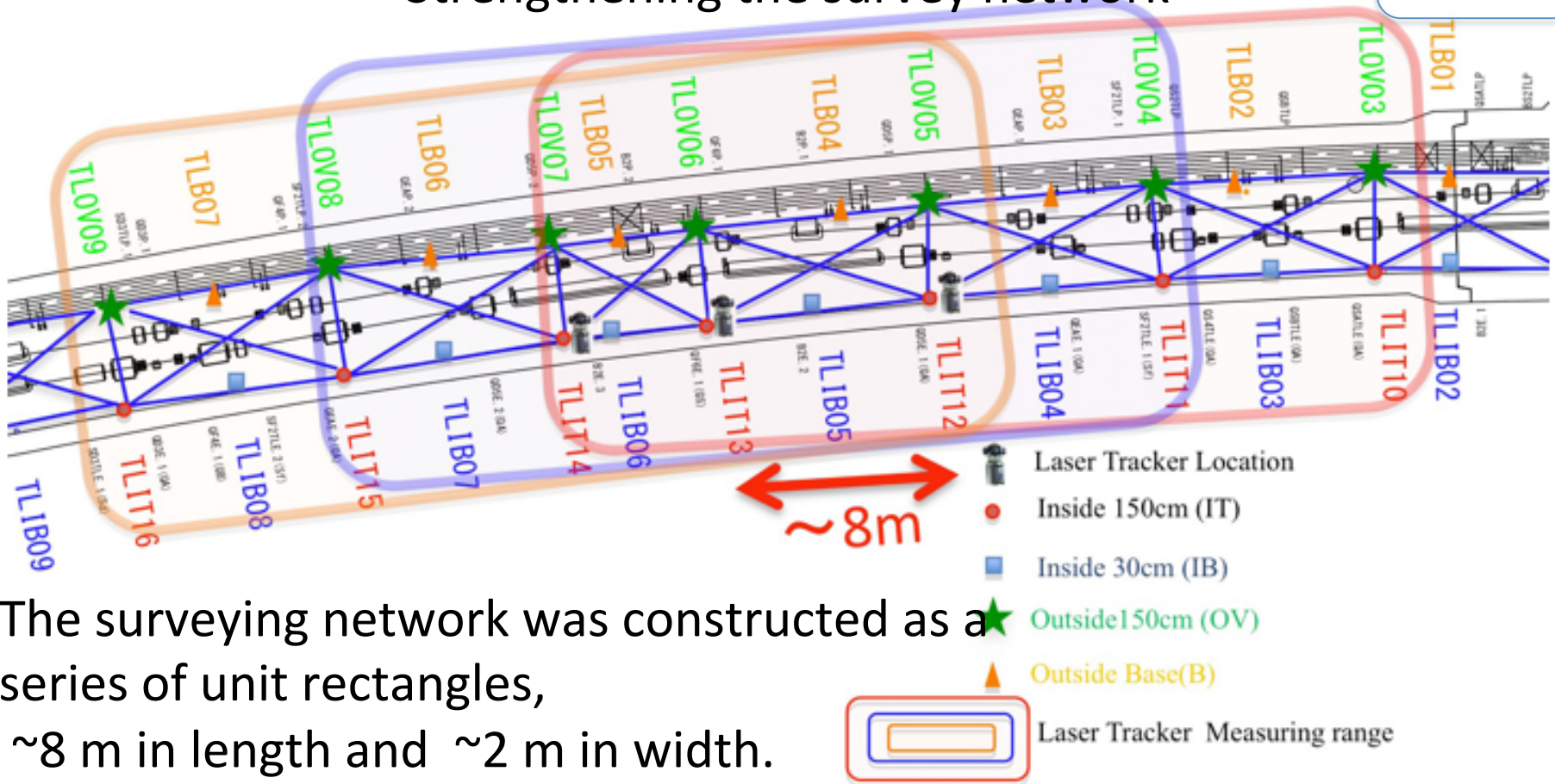




# Preparation for SuperKEKB magnet alignment

## Strengthening the survey network

IWAA10

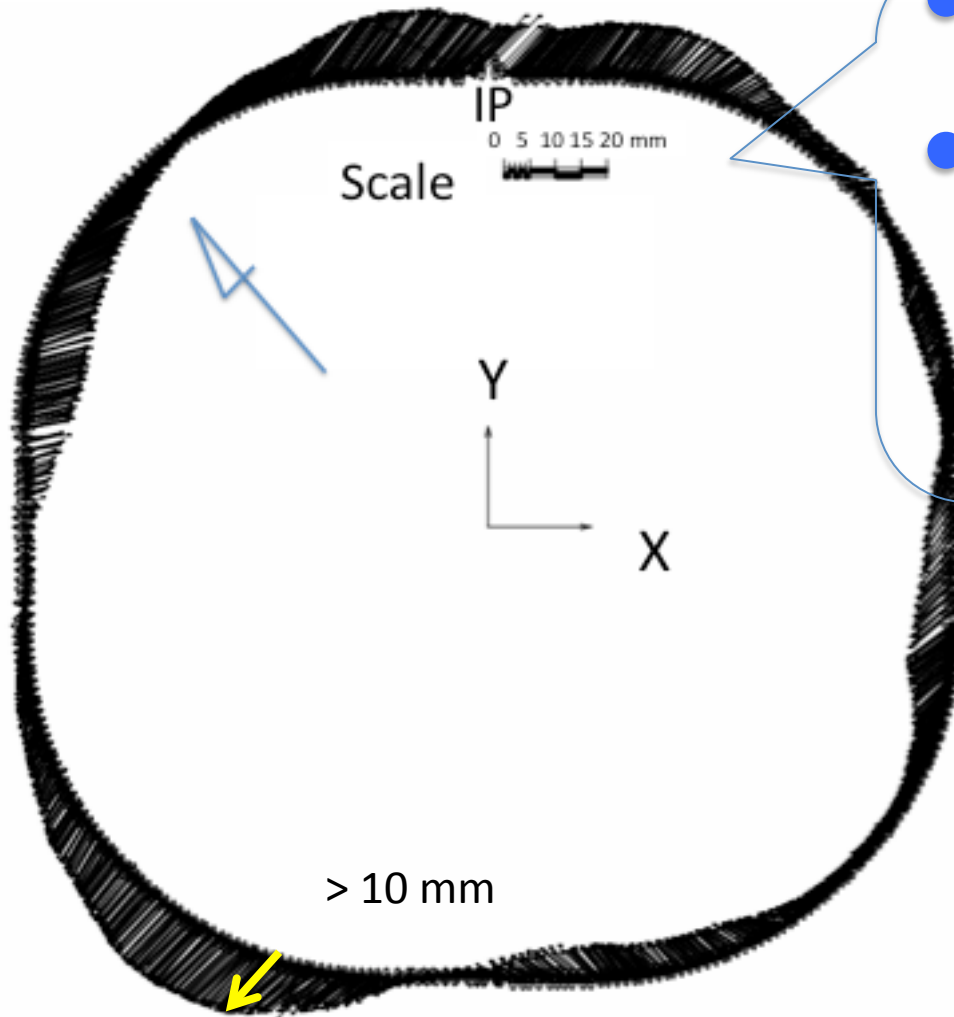


The surveying network was constructed as a series of unit rectangles, ~8 m in length and ~2 m in width. One ~32 m-long area (4 unit rectangles) was covered by one tracker setup (station). More than 400 setups to survey the 3 km tunnel.

Survey of the SuperKEKB main ring after the Great East Japan Earthquake

# Preparation for SuperKEKB magnet alignment Comparison with the design (magnet positions)

IWAA10

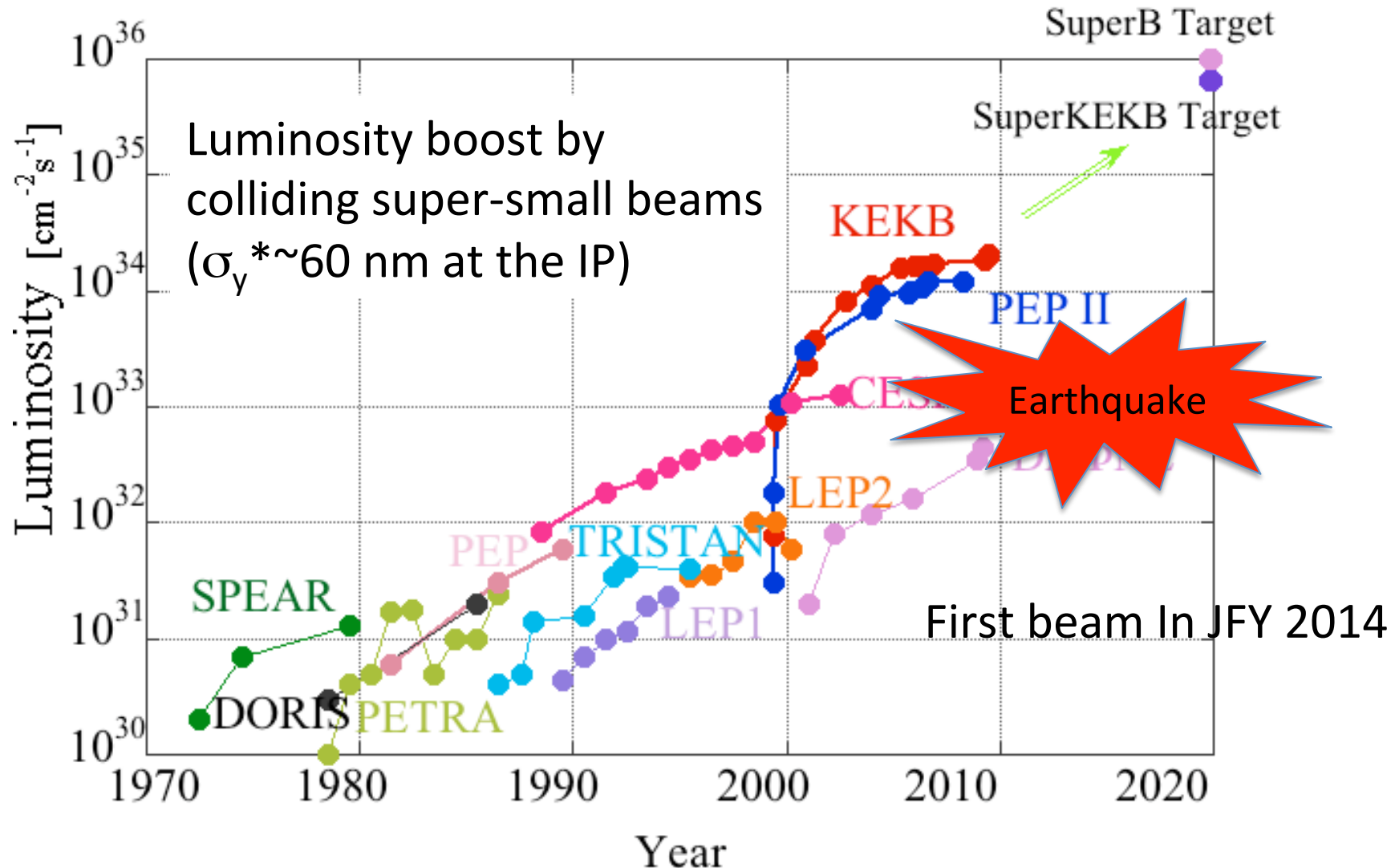


- The 3 km tunnel was found to be deformed.
- This was not a serious problem for KEKB, the preceding project, as the “wavelength” of the deformation is larger than those of the beta functions.

All monuments (new and old) were surveyed to establish their positions, which we were going to use for aligning the new magnets for SuperKEKB. **BUT...**

Survey of the SuperKEKB main ring after the Great East Japan Earthquake

## Peak luminosity trends (e+e- colliders)



Survey of the SuperKEKB main ring after  
the Great East Japan Earthquake

**Date** Friday, 11 March 2011

**Origin time** 14:46:23 JST (UTC+09:00)

**Duration** 6 minutes<sup>[1]</sup>

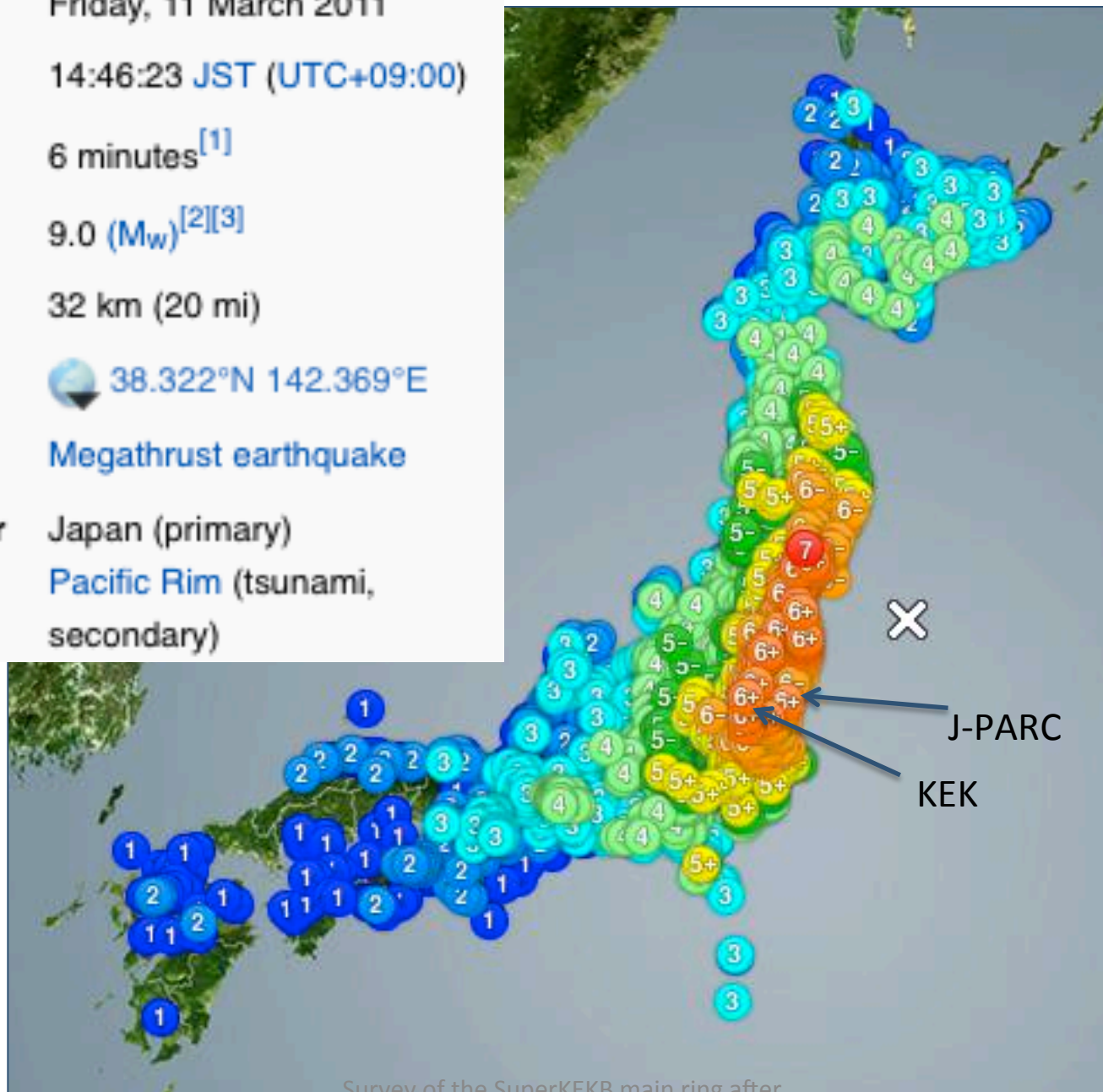
**Magnitude** 9.0 ( $M_w$ )<sup>[2][3]</sup>

**Depth** 32 km (20 mi)

**Epicenter**  38.322°N 142.369°E

**Type** Megathrust earthquake

**Countries or regions** Japan (primary)  
Pacific Rim (tsunami, secondary)



Survey of the SuperKEKB main ring after  
the Great East Japan Earthquake

## 2. After the earthquake

### 1. After the earthquake

- Damage
  - Tunnel structure (Main ring)
  - Beam line deformation
    - Survey by laser trackers
    - Level survey by N3



# A few weeks after March 11<sup>th</sup>

We were not allowed to go in the tunnel for about a week.

We were ordered to stay at home.

Some of us did not even have water, lights for a few days.

This is nothing compared to what people in the Tohoku area experienced.

The KEK computer system went down and was unusable for a very long time.

We went into the tunnel and did the tunnel level survey and the magnet tilt measurements first, using flashlights at the end of March.

There was also a severe electricity shortage due to the Fukushima nuclear power plant accidents...

Photo of the SuperKEKB main ring after  
the Great East Japan Earthquake

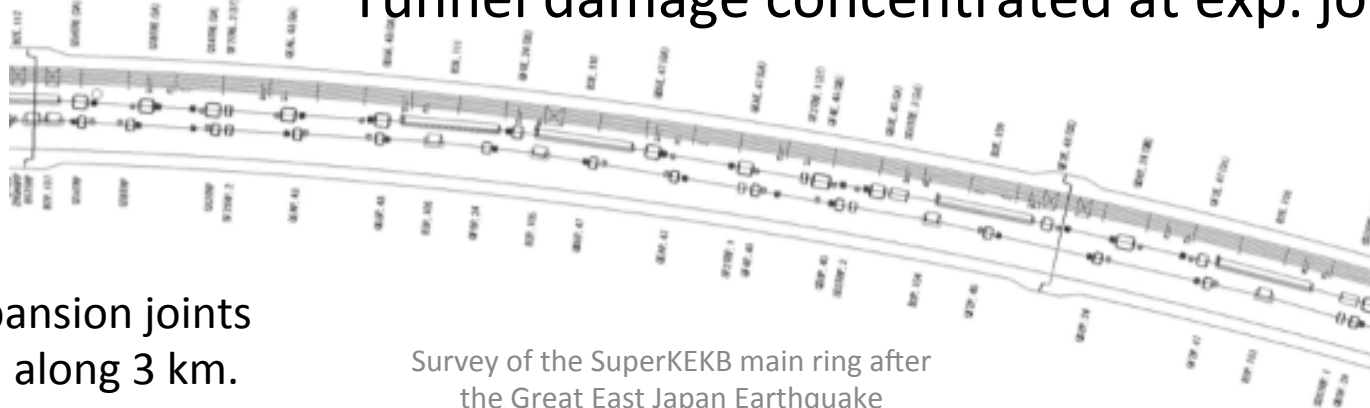


Visible structural damage



2011/03/22

Tunnel damage concentrated at exp. joints.



Thermal expansion joints  
every ~70 m along 3 km.

Survey of the SuperKEKB main ring after  
the Great East Japan Earthquake

Visible structural damage



2011/03/31

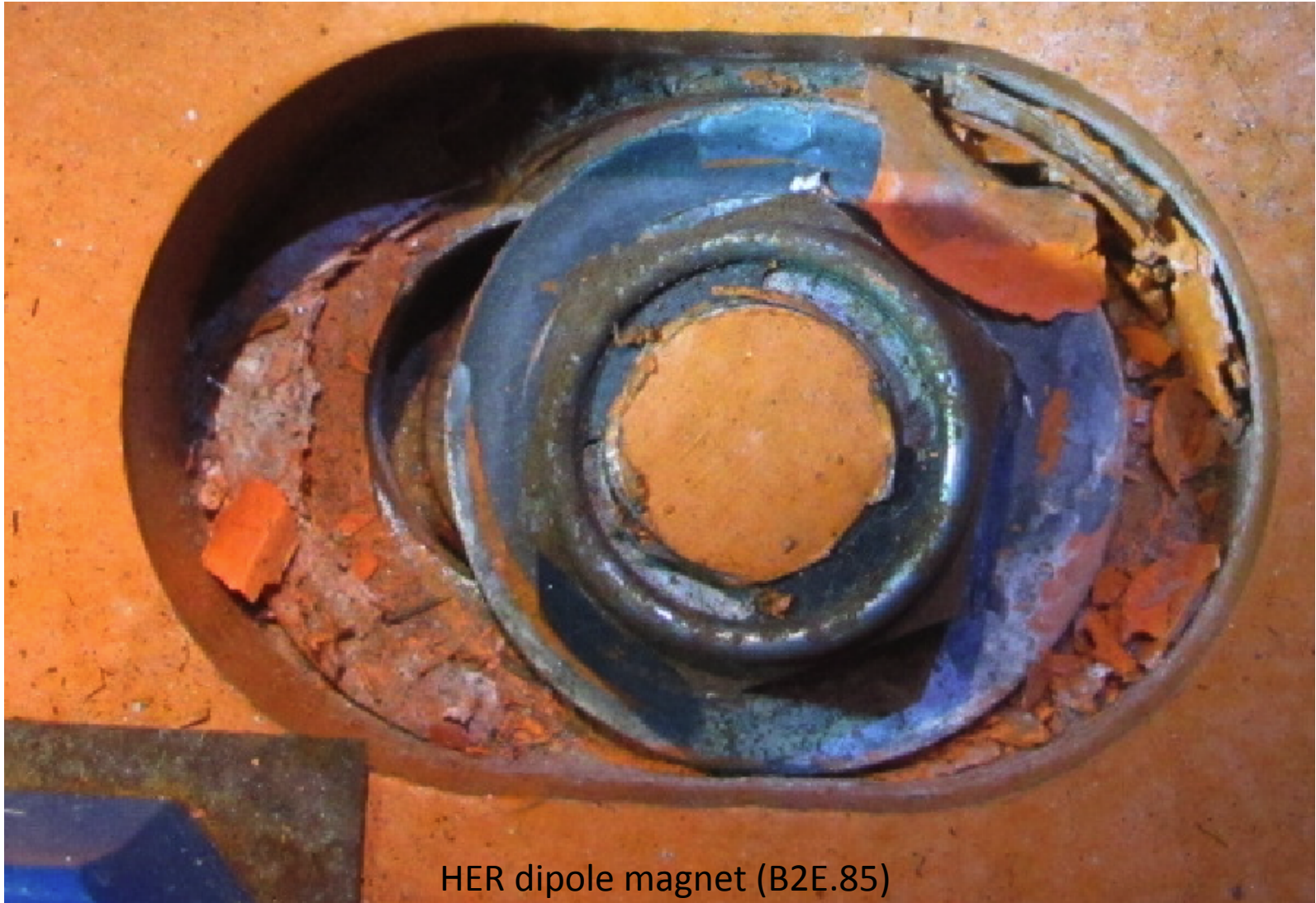
Underground water leaks found in many locations.

Survey of the SuperKEKB main ring after  
the Great East Japan Earthquake



Evidence that magnets moved.

The magnets, which we had planned to use as reliable survey reference points, had moved... sigh.



HER dipole magnet (B2E.85)

## Visible structural damage

Liquefaction of the ground caused by earthquake?

Is the foundation strong enough for a nano-beam collider?

→ Talk by H. Yamaoka this afternoon.

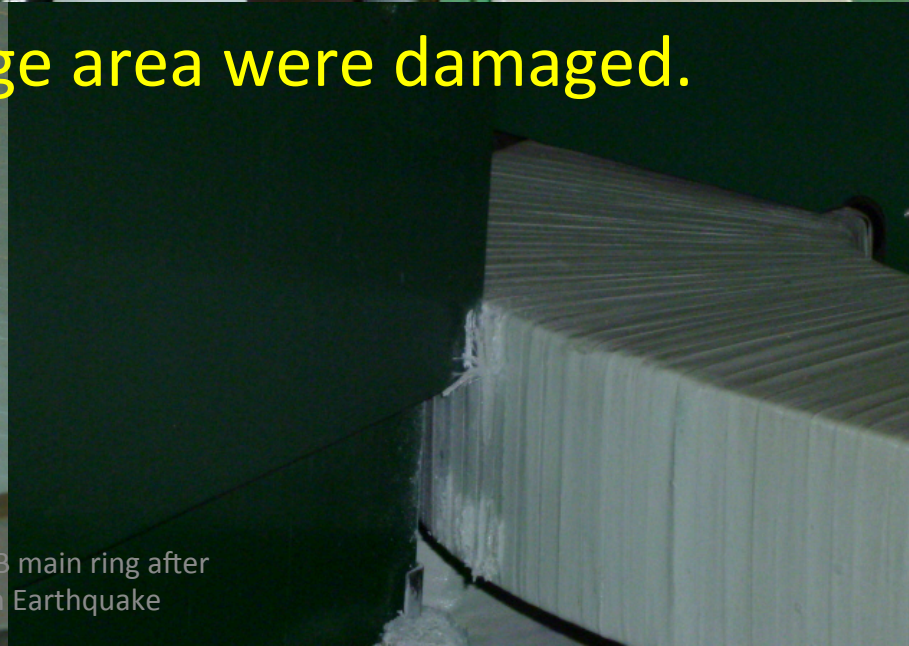


The ground above the south arc section of the tunnel.  
Not as bad as at J-PARC, but still...





Some magnets in the storage area were damaged.



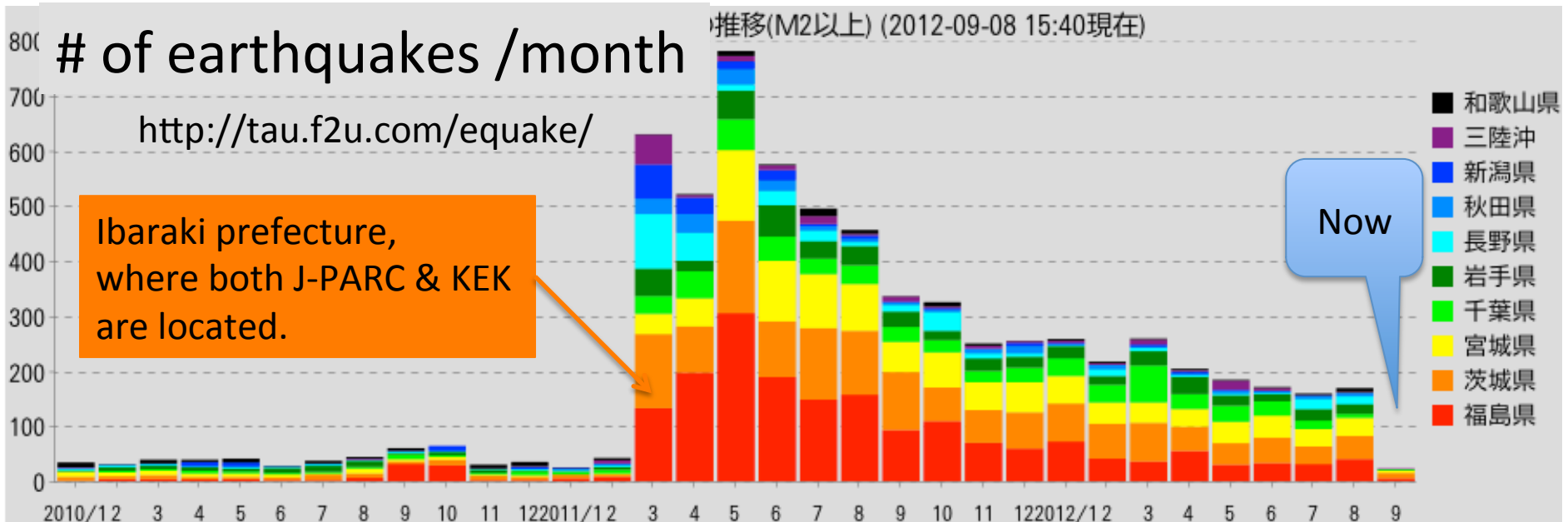
Survey of the SuperKEKB main ring after  
the Great East Japan Earthquake

## 2. After the earthquake

### 1. After the earthquake

- Damage
  - Tunnel structure (Main ring)
- Beam line deformation
  - Survey by laser trackers
  - Level survey by N3

# Survey work in presence of thousands of aftershocks



Not quiet yet.

SuperKEKB construction must resume.

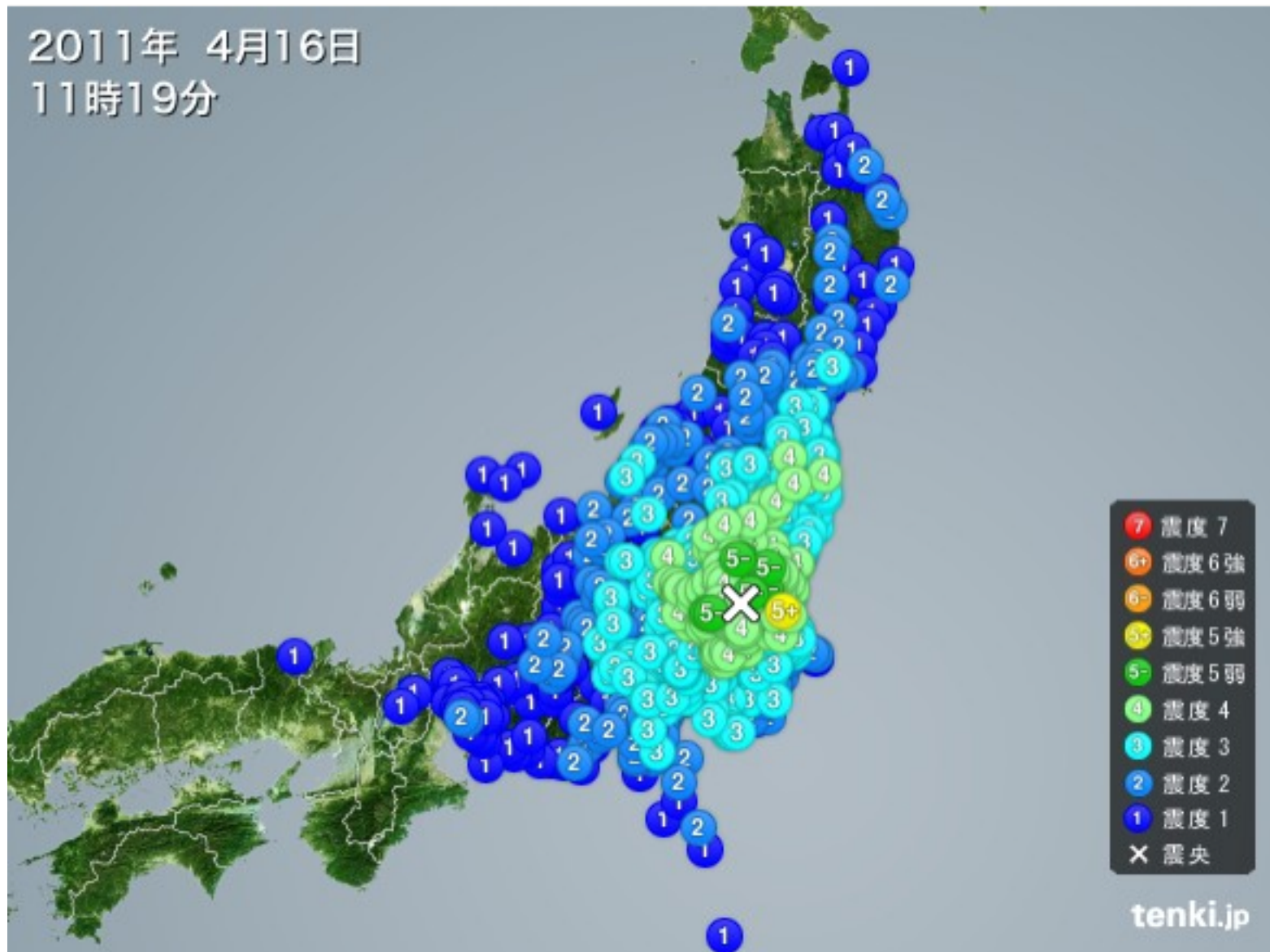
A quick survey of part of the tunnel done in June 2011, while still shaky, to get some idea of the extent of tunnel (beam line) deformation.

Re-Survey started in April 2012, to re-construct the survey network.

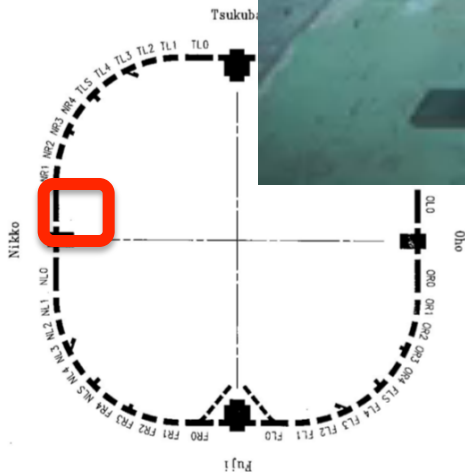
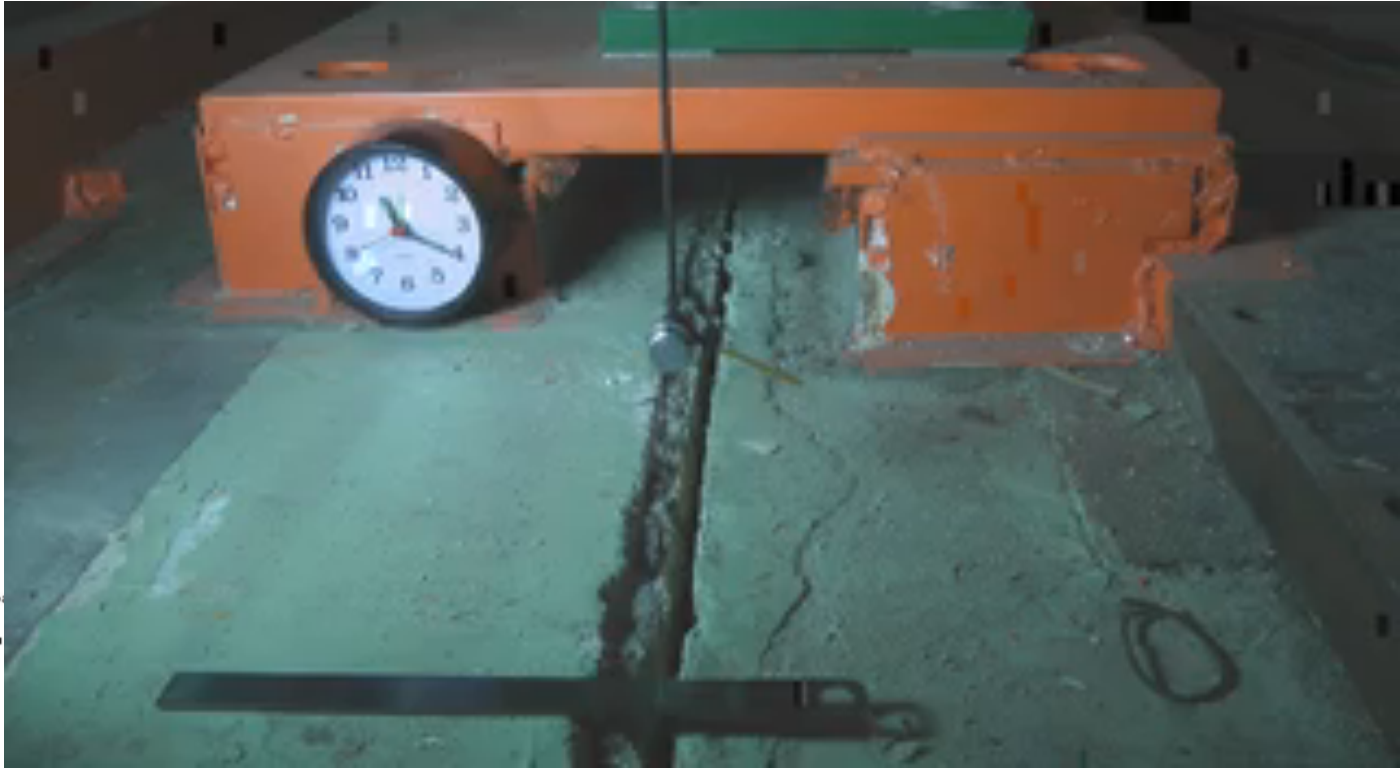
Survey of the SuperKEKB main ring after the Great East Japan Earthquake



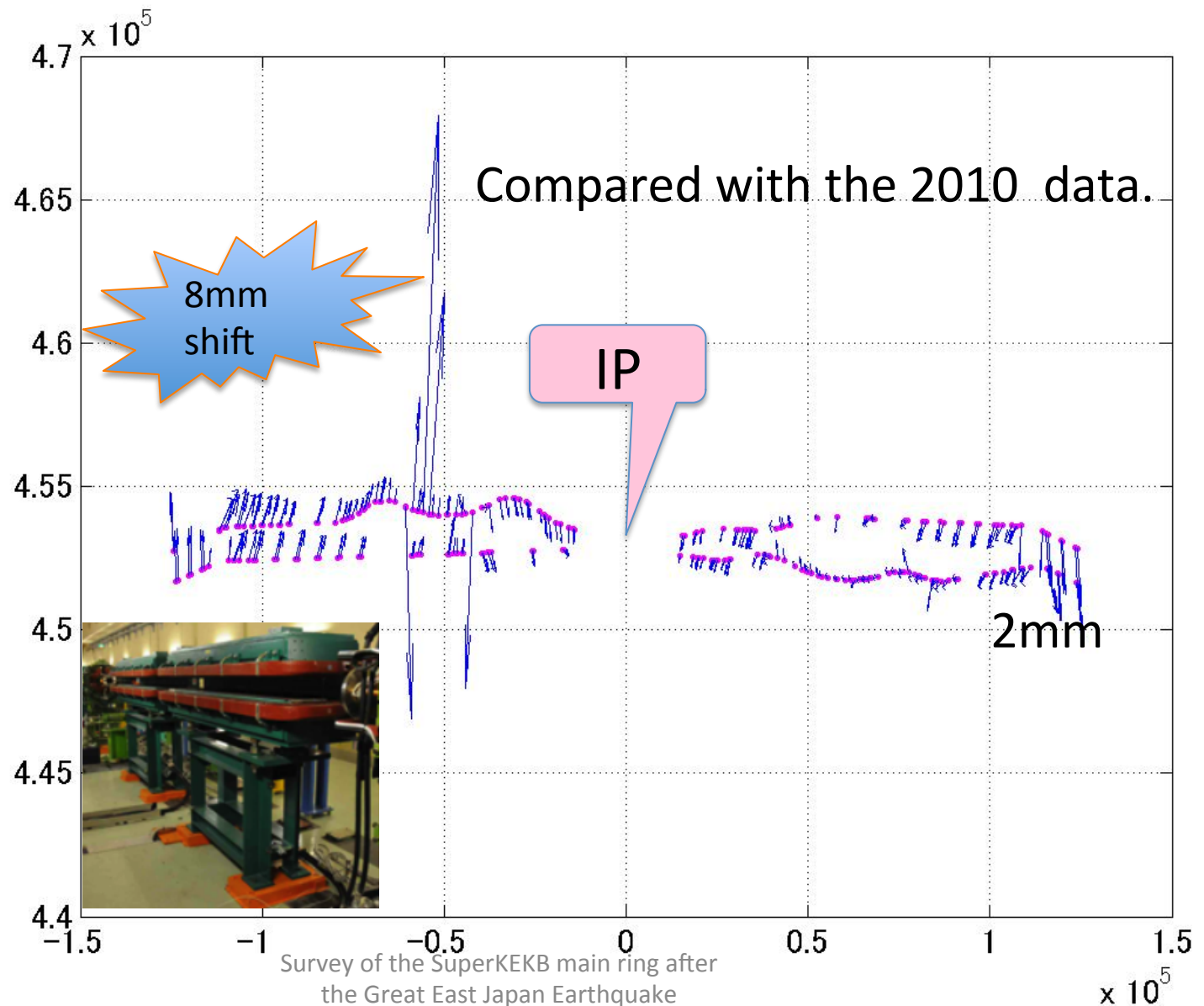
Aftershock captured by our camera on April 16<sup>th</sup>.  
Not a big one, but...

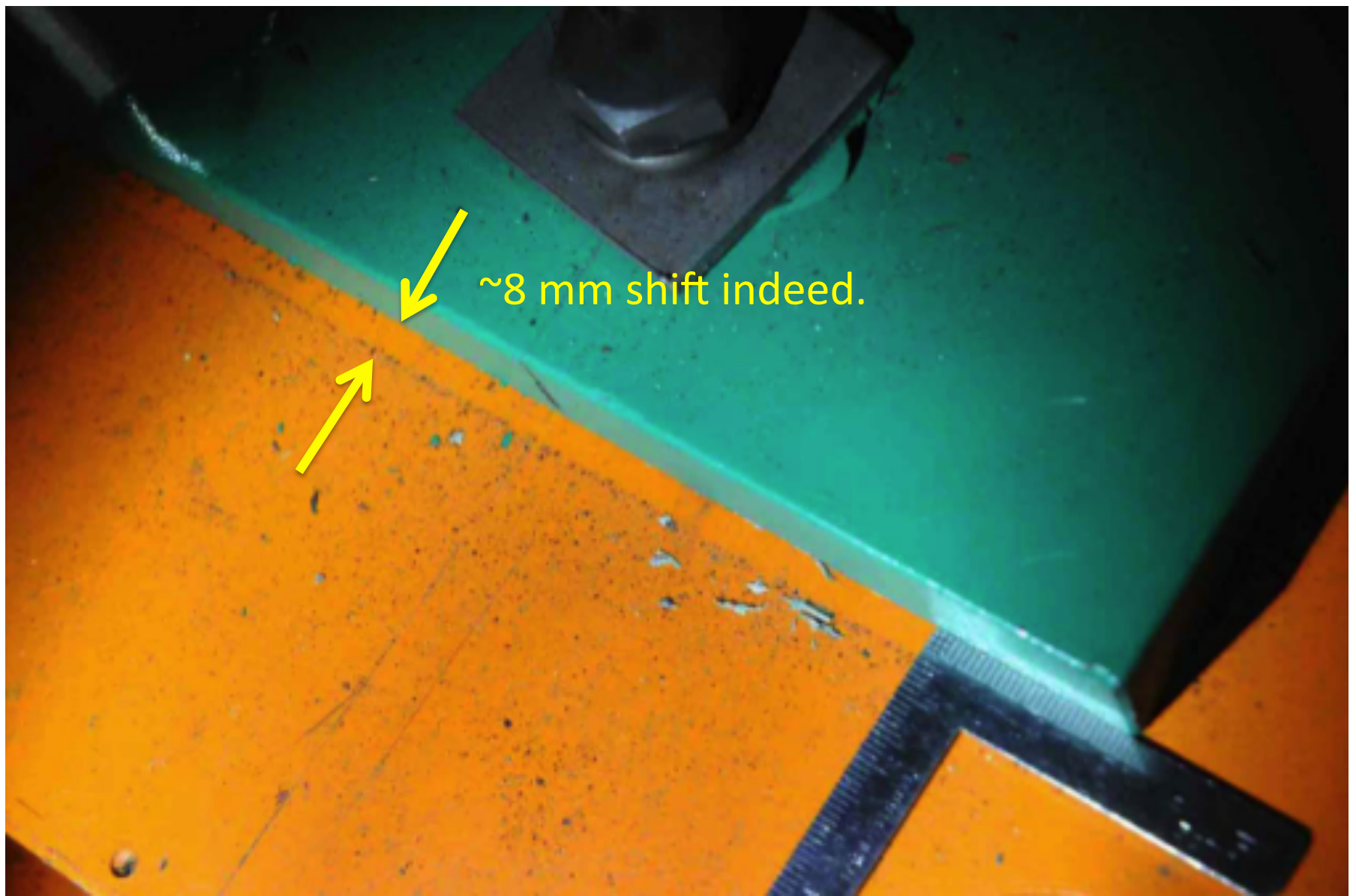


Aftershock captured:  
See how the tunnel sections shake  
and hear the noise.



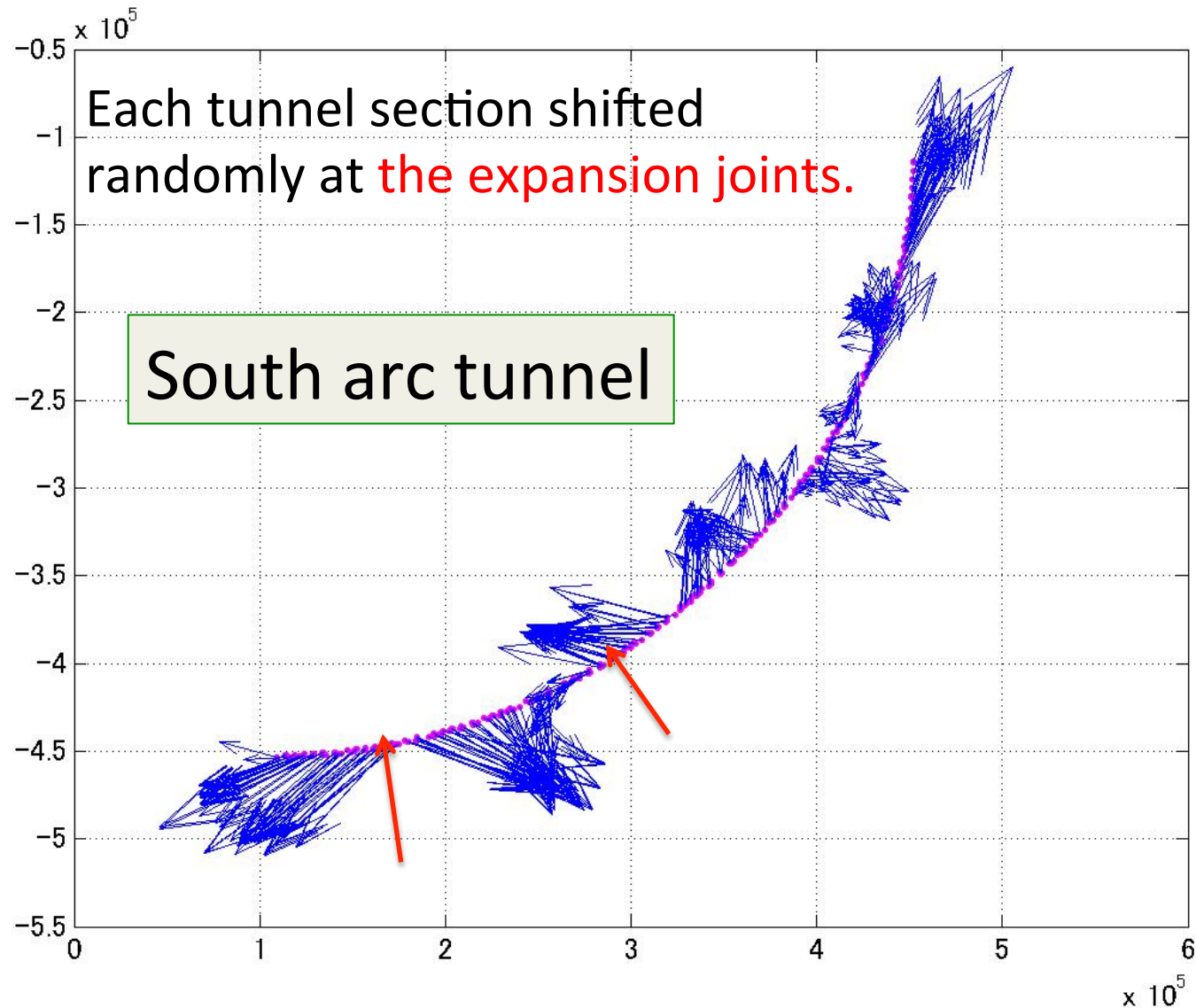
# A quick survey around the IP & the south arc tunnel in June, 2011





Survey of the SuperKEKB main ring after  
the Great East Japan Earthquake

# A quick survey around the IP & the south arc tunnel in June, 2011





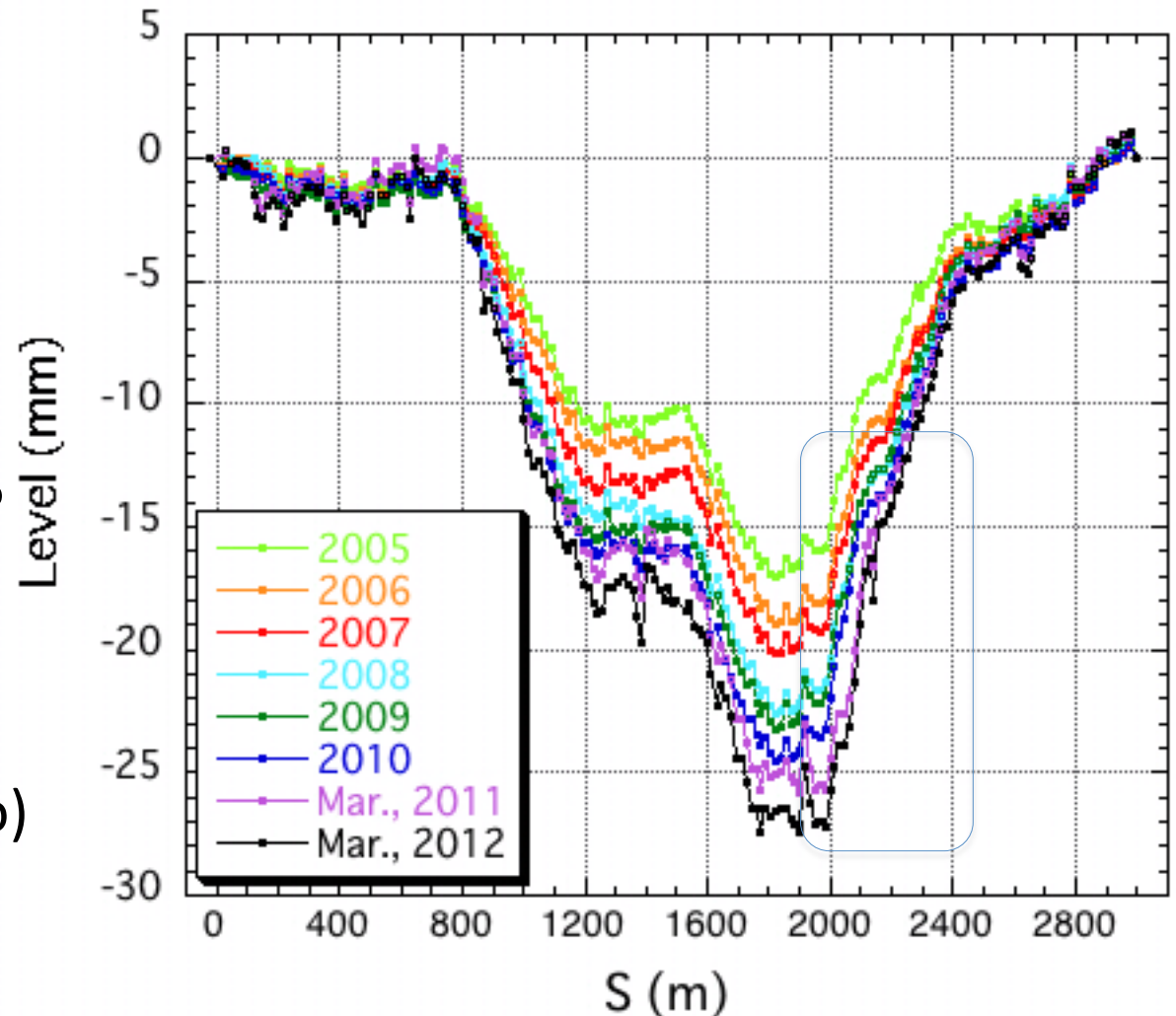
# Level survey by N3

South arc keeps sinking  
(or is it the IP keeps  
rising??).

Will the sinking  
accelerate  
due to the earthquake?

➔ Level monitor is  
needed.

➔ HLS (by T. Kawamoto)



Survey of the SuperKEKB main ring after  
the Great East Japan Earthquake

# Survey 2012

## Re-survey of the entire tunnel a year after the earthquake

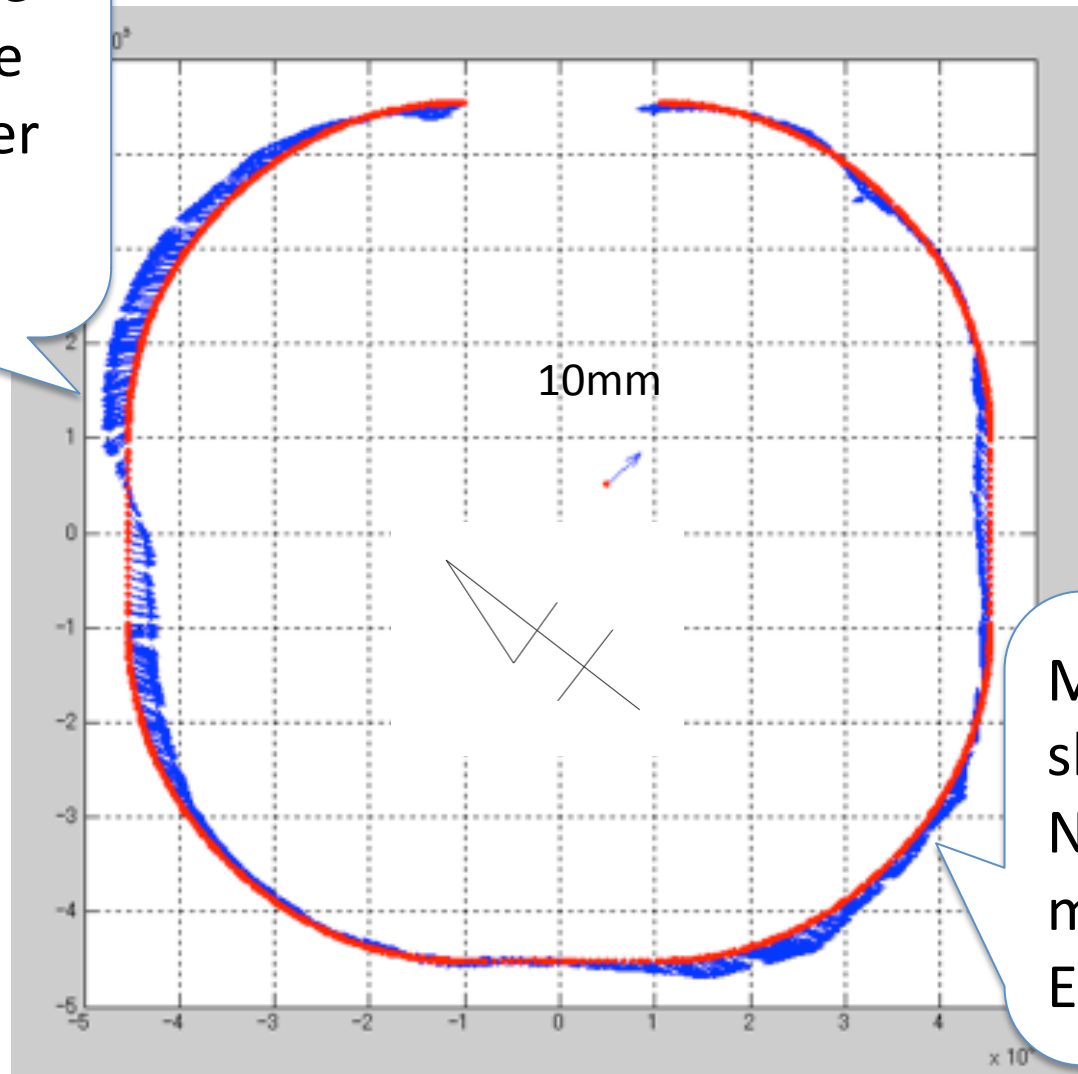
Is the tunnel still moving?

When will the tunnel settle?

# Surveyed magnet position comparison before (2010) and after the earthquake (2012)

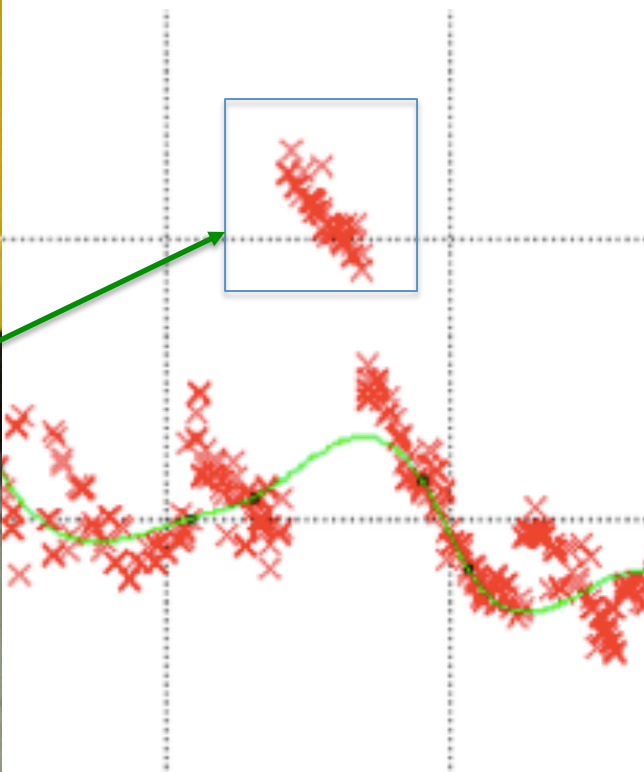
Circumference  
seems to have  
become longer  
due to the  
earthquake.

2012Survey-2010Survey



Magnets  
shifted in the  
NS direction  
more than in  
EW direction

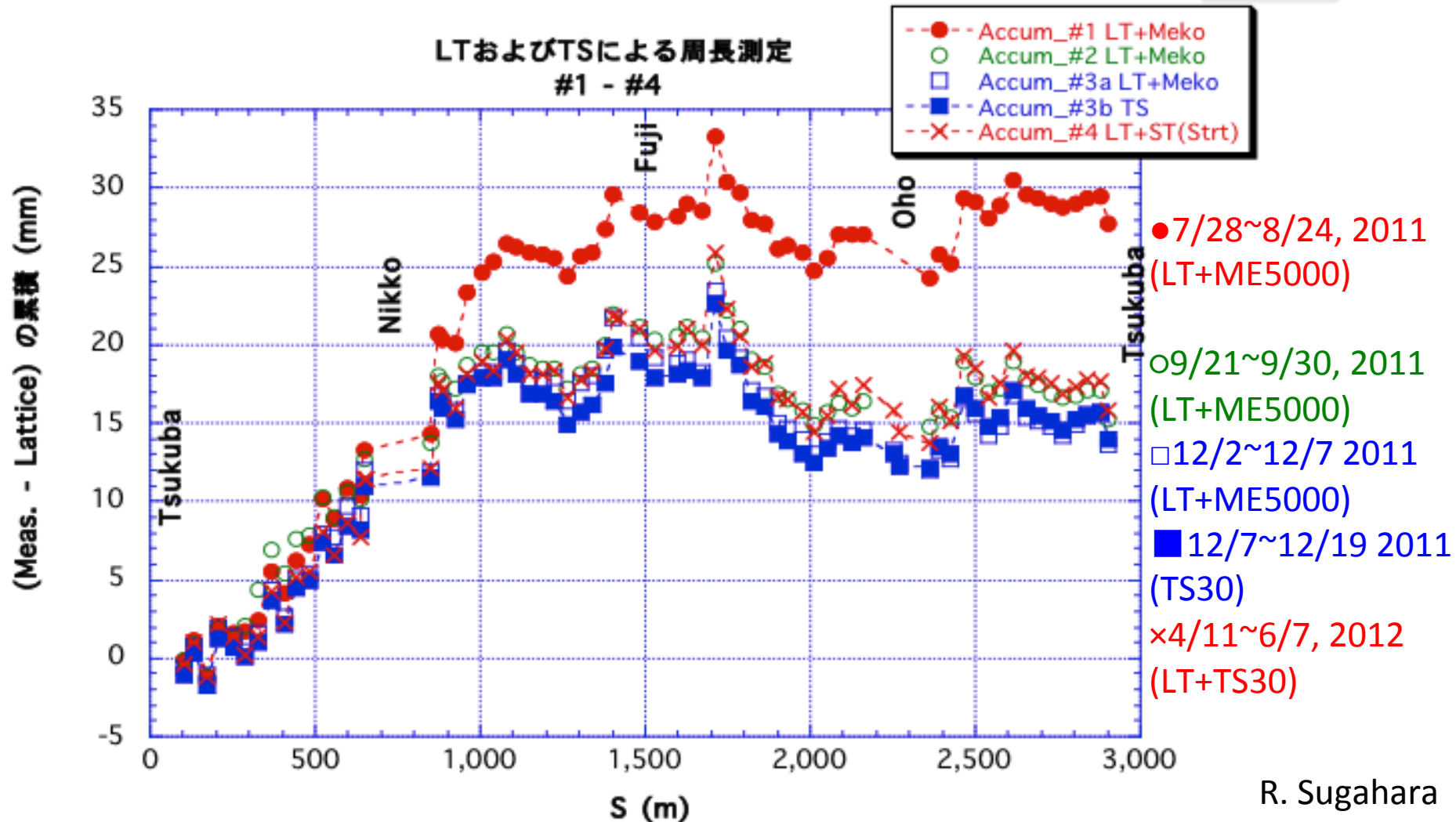
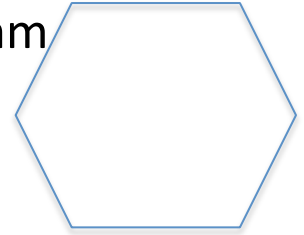


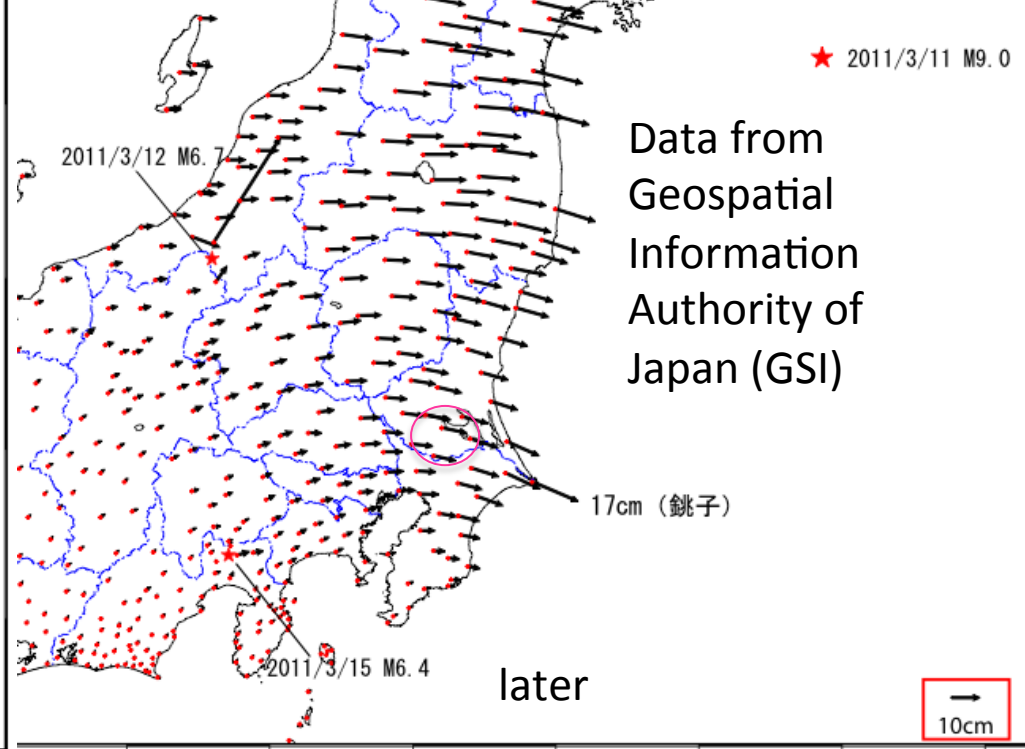
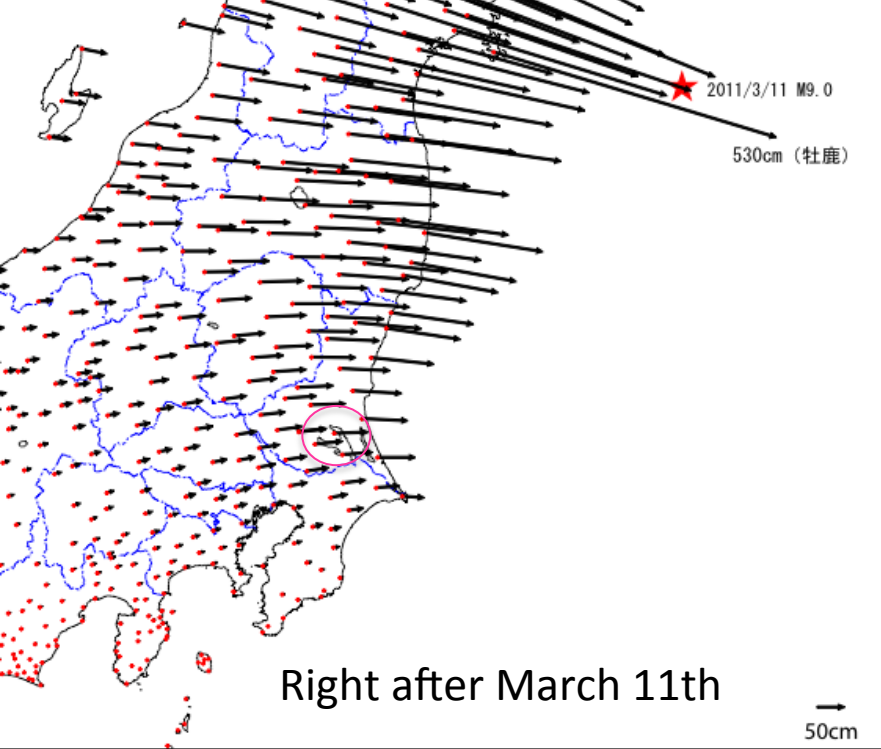


Local deviations of the magnets from the design positions are large at the expansion joints between the straight sections, which have pile foundation, and the arc sections, which do not have piles. These types of local deviations need to be fixed.

Circumference estimated by measuring the distances between quadrupole magnets using TS30, ME5000 and LT.

The tunnel did seem to have been expanded in July 2011,  $\Delta \sim 30$  mm  
But is now settling to a level of about  $\Delta \sim 15$  mm





Data from  
Geospatial  
Information  
Authority of  
Japan (GSI)

速報解 比較: Q3迅速解]

☆固定局: 三隅 (950388)

国土地理院

H V

県	市町村		水平 変化量 (m)	高さの 変化量 (m)	電子基準点名
茨城県	水戸市	元吉田町	0.88	-0.24	水戸
茨城県	日立市	金沢町	1.13	-0.33	日立
茨城県	古河市	大字諸川字西浦	0.45	-0.05	三和
茨城県	石岡市	小屋	0.63	-0.12	八郷
茨城県	常総市	鴻野山	0.46	-0.07	石下
茨城県	常陸太田市	大中町	1.18	-0.25	里美
茨城県	高萩市	高浜町	1.35	-0.41	S高萩
茨城県	北茨城市	磯原町磯原	1.49	-0.46	北茨城
茨城県	つくば市	北郷	0.51	-0.10	つくば1

GPS point  
Near KEK



# Survey network above ground: First attempt by KEKB



TS30 would be good but there are trees and buildings everywhere, and It can only be partially used.

GPS network has been installed.

Survey of the SuperKEKB main ring after the Great East Japan Earthquake

➔Poster by H. Iinuma

- Eight GPS antennas are mounted on the roofs of the access buildings of the SuperKEKB main ring (3C, 6C, ....) which can access the KEKB tunnel.
- As a fixed point, we use one of the GPS-based control stations (Tsukuba-1) of the Geospatial Information Authority of JAPAN (GSI).
- Distance between Tsukuba-1 and KEKB is 5 km.
- Stability of slope distances between GPS antennas reaches the sub-millimeter level.
- Preliminary analysis indicates good agreement between the GPS network and the underground tunnel network (within 3 mm).

GPS: Leica Geosystems (GS10) L1 , L2  
Position accuracy: horizontal <3mm,  
vertical <6mm (from the spec sheet)

Survey of the SuperKEKB main ring after  
the Great East Japan Earthquake



# 3. Summary

- The survey network that we prepared in 2010 for the new project, SuperKEKB, was destroyed by the March 11<sup>th</sup> earthquake.
- Damage is concentrated at the tunnel expansion joints.
- The tunnel kept moving for a while but it seems to be settling.
  
- We added more HLS in the south section of the tunnel, which we know has continued sinking over many years.
- A GPS network was installed and has started operating, in order to compare with the underground survey results by LT, and to monitor the tunnel deformation.
- We have to realign ~2000 magnets in the tunnel...
  - We do not need to realign the majority of the magnets exactly to the design positions.
  - We do need to smooth out the local deviations.
  - The interaction region, though, need more precise alignment.
  - Vibration issues to be solved at the IR (poster by H.Yamaoka)

We thank you for all the concern and encouragement after the earthquake.

Any advice/help (sensors) is (are) appreciated.