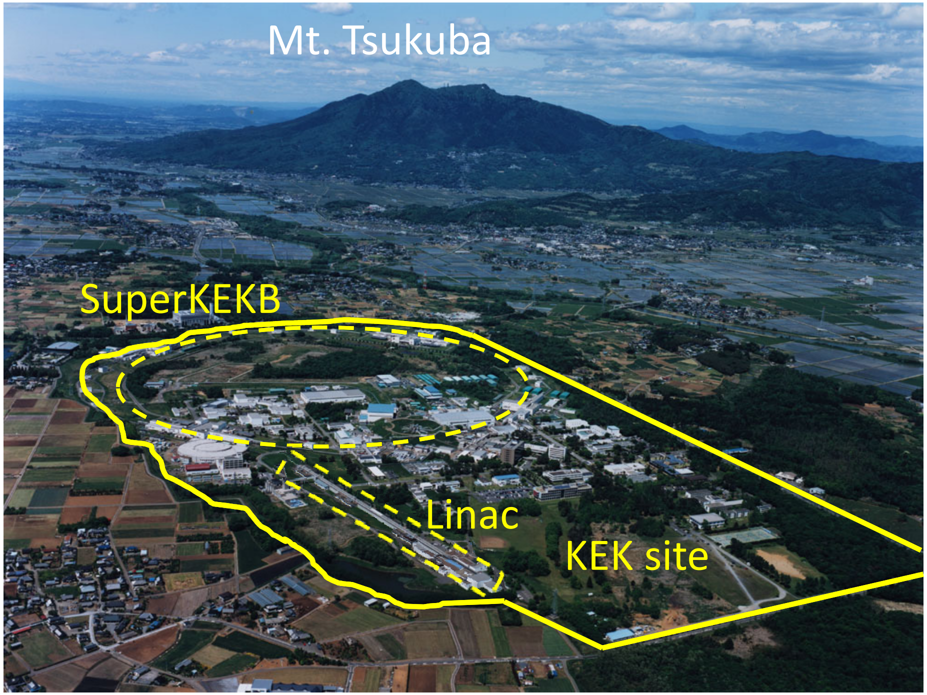
Status and schedule of SuperKEKB



2011.07.23 EPS-HEP2011 Accelerator Session

Kyo Shibata (on behalf of KEKB Group)

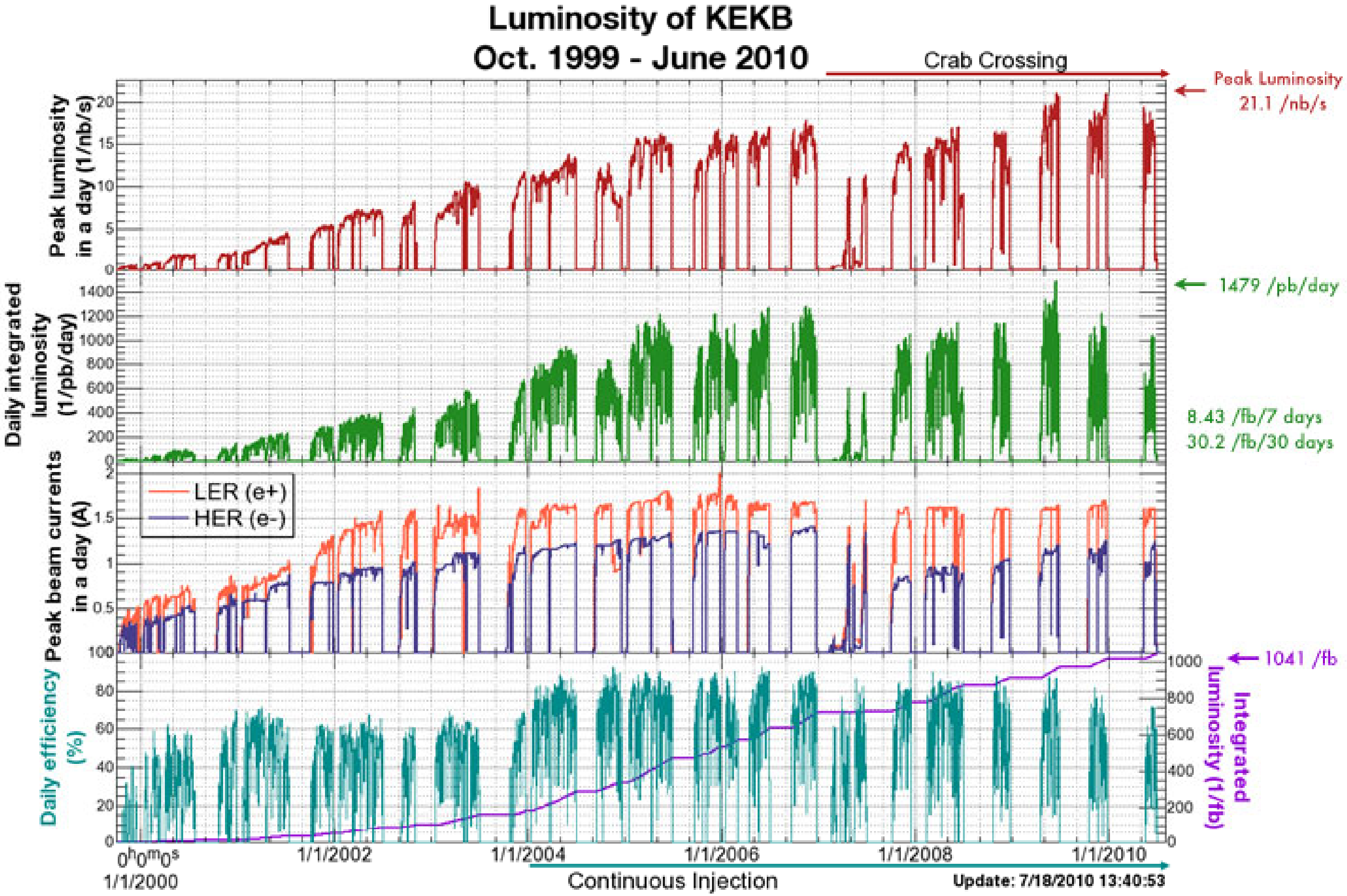
KEKB was shut down on Jun 30th 2010, and Upgrade of KEKB Has Started.

- KEKB B-factory
  - Electron-positron collider with asymmetric energies of 8 GeV (e-) and 3.5 GeV (e+)
  - Operating period : 1998 to 2010
  - Total integrated luminosity : 1040 /fb
  - Made a great contribution to confirm CP violation in the neutral B meson system.

Shut down ceremony (Jun 30th 2010, AM9:00 @ KEKB control room)

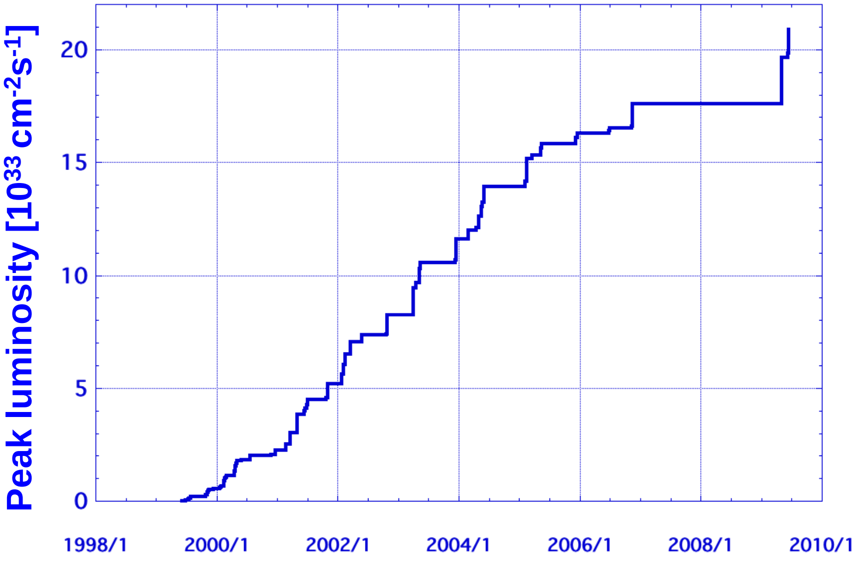
Prof. Suzuki (Director General of KEK) pressed the beam abort switch of KEKB.

History of KEKB Operation

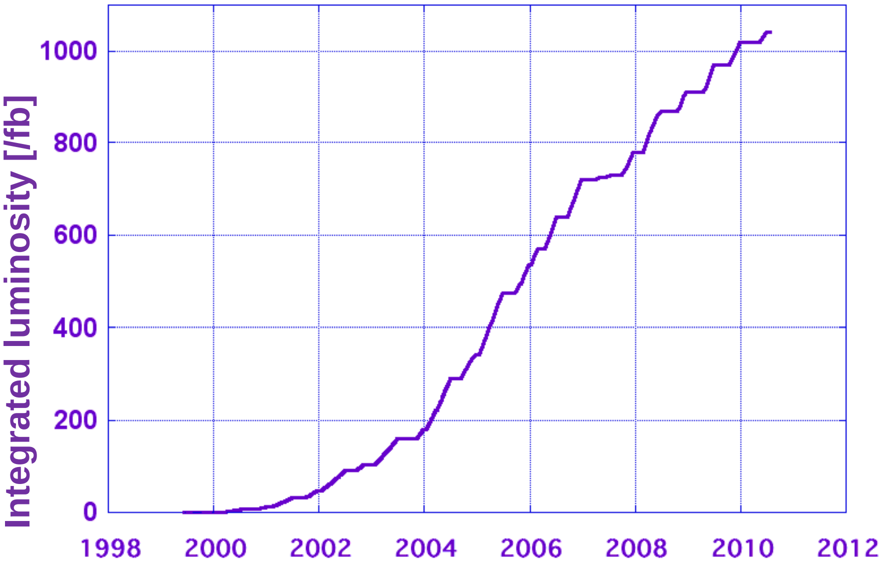


History of Peak & Integrated Luminosity

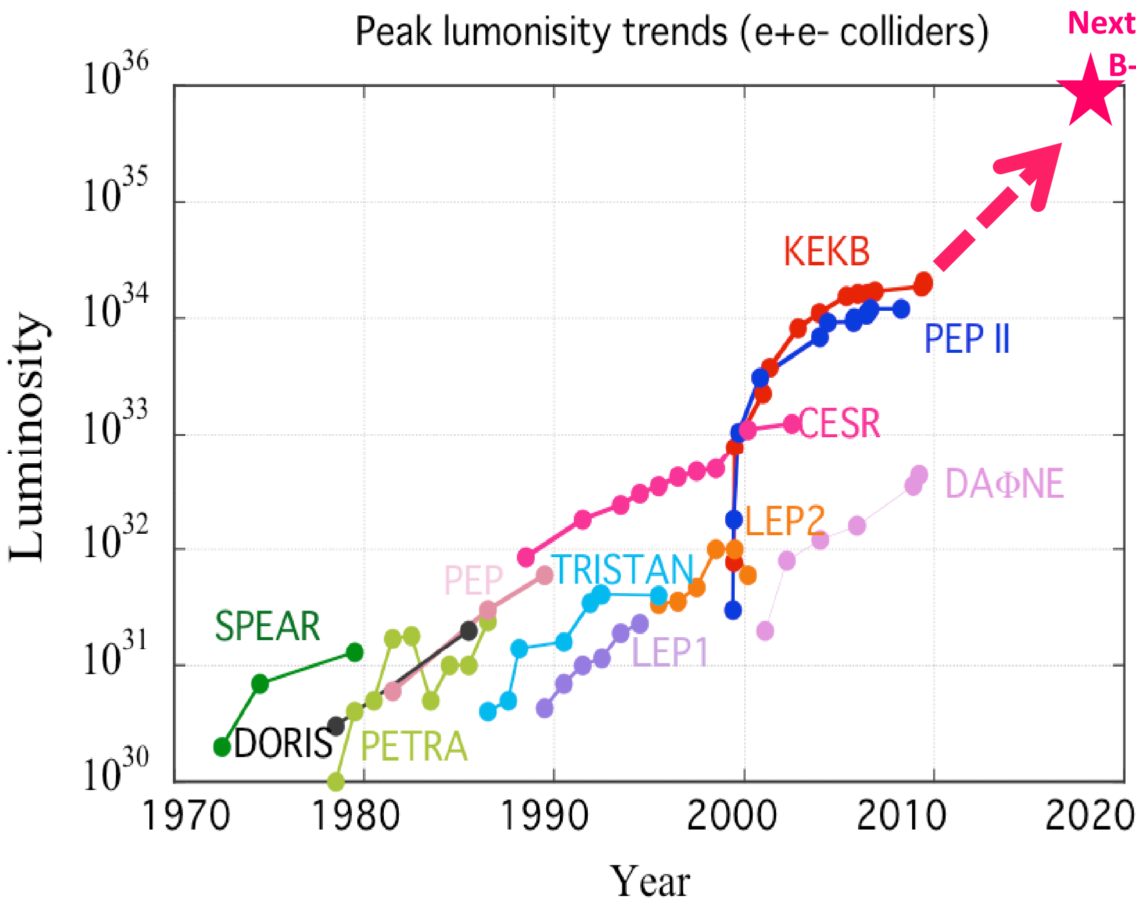
Trend of Peak Luminosity [10^{33} /cm^2/s]



Integrated Luminosity [/fb]



Mission of SuperKEKB



- Design Luminosity of SuperKEKB is 8×10^{35} /cm^2/s, which is 40 times larger than the KEKB's record.
- 50 /ab can be accumulated within several years.

Design Concept of SuperKEKB 1
To Increase Luminosity by 40 Times

- β_y^* at IP : 5.9 -> 0.27/0.30 mm (e+/e-)
  - Nano-beam scheme (first proposed for SuperB by P. Raimondi)
  - Luminosity gain : ×20
- Beam current : 1.7/1.4 A -> 3.6/2.6 A (e+/e-)
  - Luminosity gain : ×2
- Beam-beam parameter : 0.09 -> 0.09
  - Luminosity gain : ×1
- Total Luminosity Gain : 20 × 2 × 1 = 40

Lorentz factor

Beam current

Beam-Beam parameter

$$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\frac{I_\pm \xi_{y\pm}}{\beta_{y\pm}^*}\left(\frac{R_L}{R_{\xi_y}}\right)$$

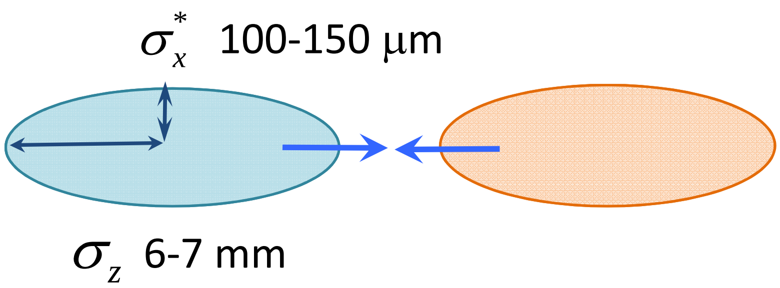
Geometrical reduction factors (crossing angle, hourglass effect)

Beam aspect ratio at IP

Vertical beta function at IP

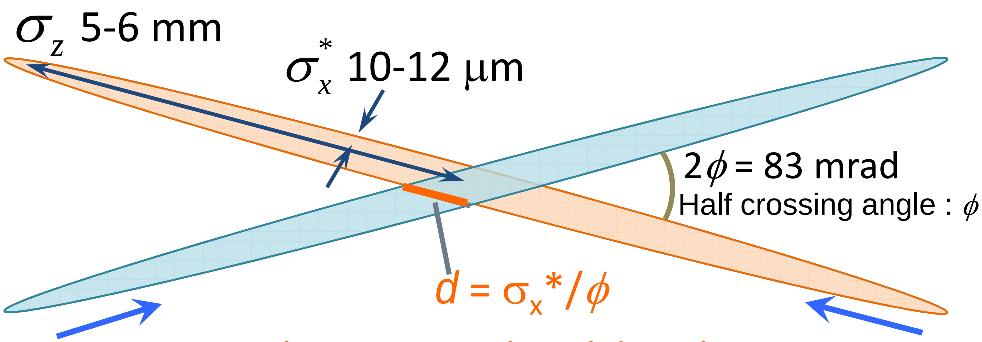
Collision Scheme (Nano Beam Scheme)

KEKB
Head-on (crab crossing)



overlap region = bunch length

SuperKEKB
Nano Beam scheme



overlap region << bunch length

Hourglass requirement

$\beta_y^* \geq \sigma_z \approx 6$ mm

$\beta_y^* \geq \sigma_x^*/\phi \approx 300$ μm

In nano-beam scheme:

Vertical beta function at IP can be squeezed to ~300 μm.
Small horizontal beam size at IP is necessary.

⇒ Low emittance, small horizontal beta function at IP

Design Concept of SuperKEKB 2

- To reduce the construction costs
  - ➢ Use the KEKB tunnel
  - ➢ Use the components of KEKB as much as possible.
    - ✓ Preserve the present cells in HER.
    - ✓ Replace dipole magnets keeping other main magnets in LER arcs.

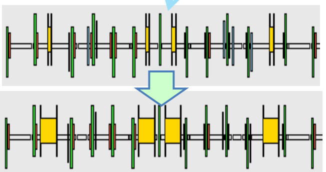
- Other features
  - ➢ No option for polarization at present.
  - ➢ Changing beam energy: 3.5/8.0 -> 4.0/7.0 GeV   (e+/e-)
    - ✓ LER : Longer Touschek lifetime and mitigation of emittance growth due to the intra-beam scattering
    - ✓ HER : Lower emittance and lower SR power

Comparison of Parameters between KEKB and SuperKEKB

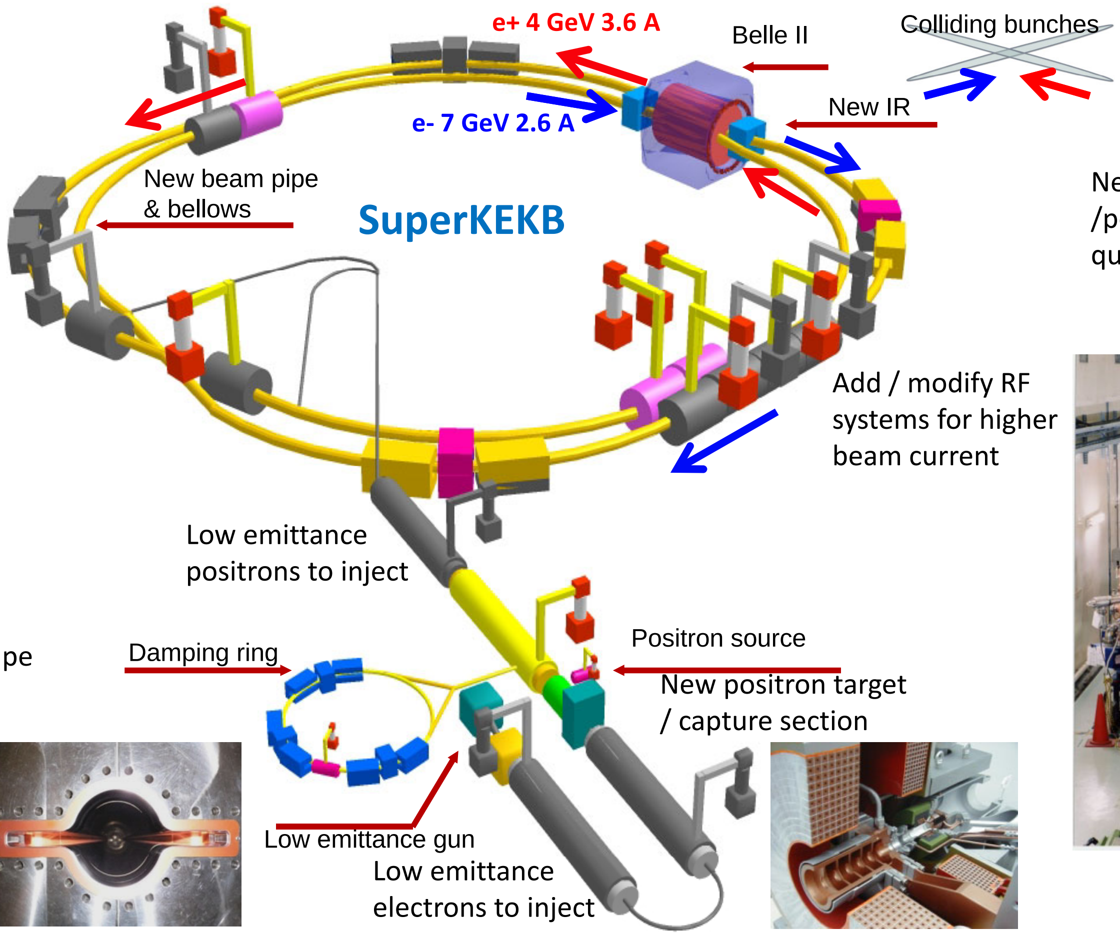
	KEKB Design	KEKB Achieved : with crab	SuperKEKB Nano-Beam
Energy (GeV) (LER/HER)	3.5/8.0	3.5/8.0	4.0/7.0
β_y^* (mm)	10/10	5.9/5.9	0.27/0.30
β_x^* (mm)	330/330	1200/1200	32/25
ε_x (nm)	18/18	18/24	3.2/5.3
$\varepsilon_y/\varepsilon_x$ (%)	1	0.85/0.64	0.27/0.24
σ_y(μm)	1.9	0.94	0.048/0.062
ξ_y	0.052	0.129/0.090	0.09/0.081
σ_z (mm)	4	6 - 7	6/5
I_{beam} (A)	2.6/1.1	1.64/1.19	3.6/2.6
$N_{bunches}$	5000	1584	2500
Luminosity (10^{34} cm^{-2} s^{-1})	1	2.11	**80**

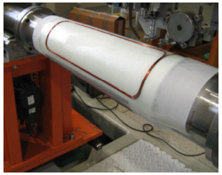
Outline of Upgrade to SuperKEKB

Replace short dipoles with longer ones (LER)



Redesign the lattices of both rings to reduce the emittance

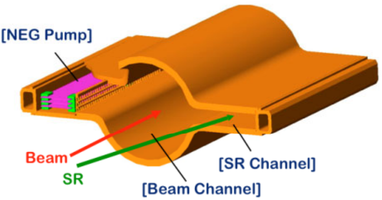




New superconducting /permanent final focusing quads near the IP

Add / modify RF systems for higher beam current

TiN-coated beam pipe with antechambers



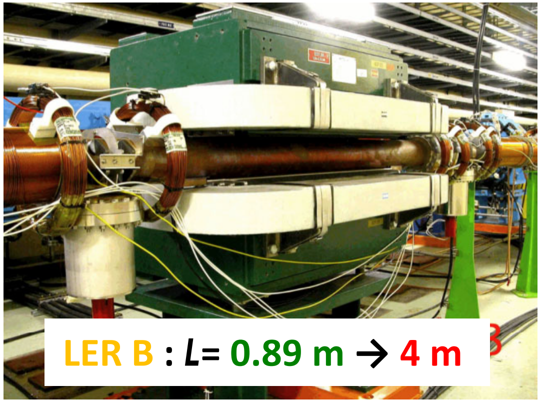
Major Items for Construction 1
Magnet

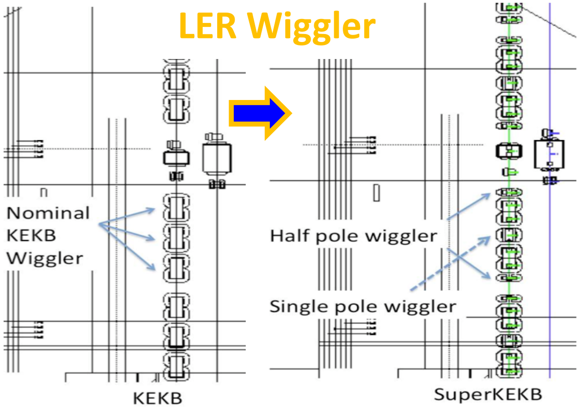
- In order to reduce the horizontal emittance of both beams to 1/5 ~1/10 of KEKB's values, a large number of magnets need to be rearranged, replaced and added.

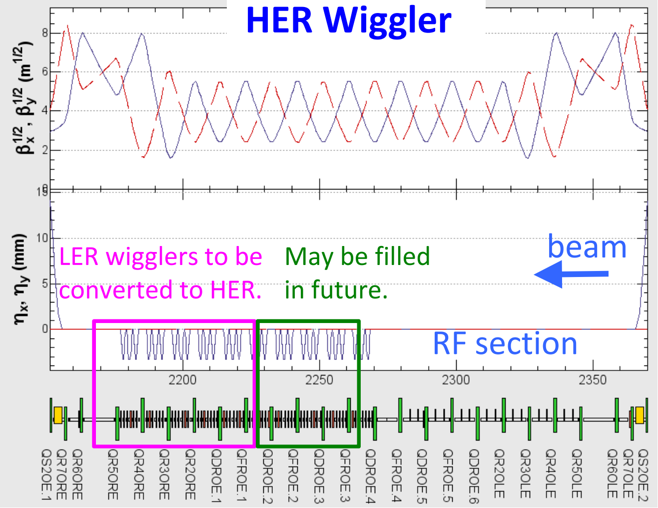
➢ LER arc section:
  ✓Replace bending magnets (~100) with new longer ones.

➢ LER wiggler section:
  ✓New 56 single pole wigglers and 112 half pole wigglers will be added to the existing normal ones to double the wiggler cycles.

➢ HER wiggler section:
  ✓Wiggler magnets will be installed.
  ✓For 6 wiggler sections among 10, present LER wiggler magnets will be reused.

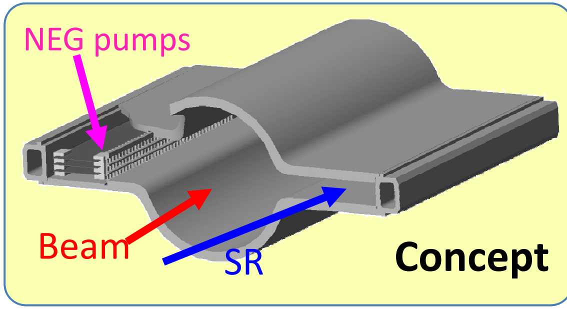






Major Items for Construction 2
Beam pipe

- To cope with the electron cloud issues and heating problems, ante-chamber type beam pipes are adopted with a combination of TiN coatings, grooved shape surfaces and clearing electrodes.

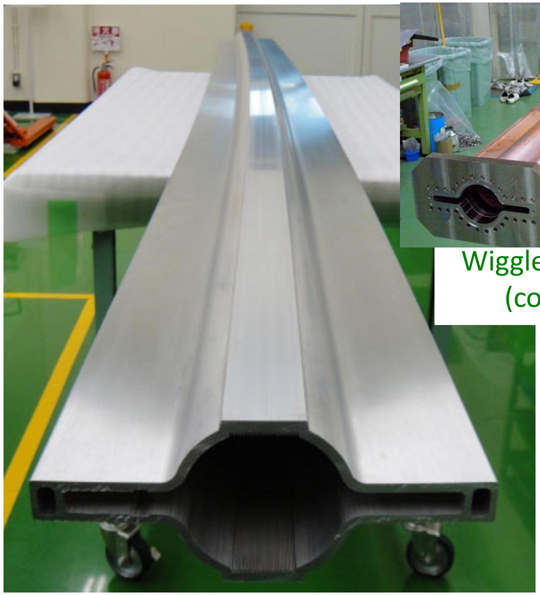


➢ LER arc section:
  - ✓Beam pipes are replaced with new aluminum-alloy pipes with antechambers. (~2000 m)

➢ HER arc section:
  - ✓Present copper beam pipes are reused.
  - ✓Since the HER energy is reduced from 8.0 to 7.0 GeV, SR power at normal arc section is more or less the same as KEKB.

➢ Wiggler section (both ring):
  - ✓Copper beam pipes with antechambers are used.

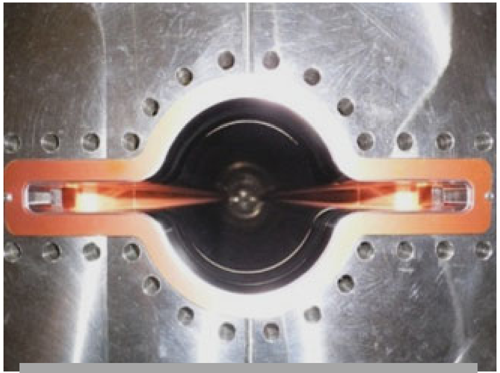
Wiggler section (copper)



Arc section (aluminum)

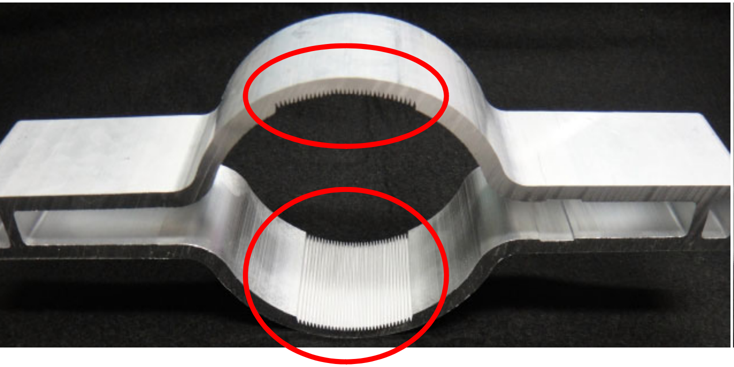
Major Items for Construction 3
Countermeasure against E-cloud

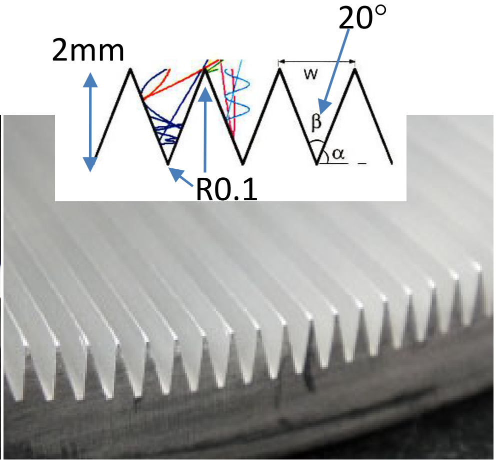
- **Wiggler section:**
  - ✓Electrons are attracted by the clearing electrode, which is mounted on the inner surface of beam pipe.
- **In bending magnet (Arc section):**
  - ✓Effective SEY is structurally reduced by the groove surface with TiN coating on top and bottom of beam channel.
- **Drift space:**
  - ✓Electron cloud is mitigated by TiN coating and solenoid field.

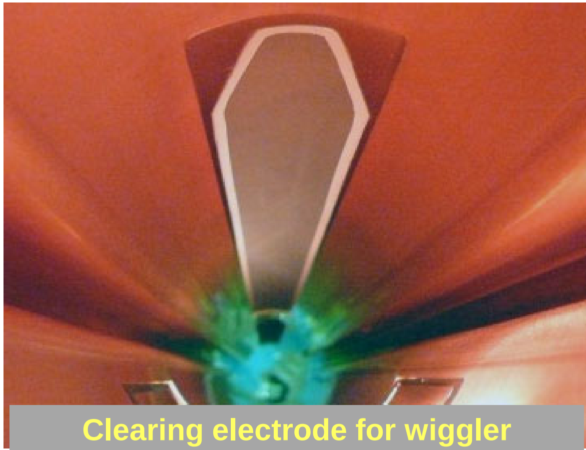


TiN coating on copper duct

Groove surface of beam pipe in bending magnet. (w/o TiN coating)



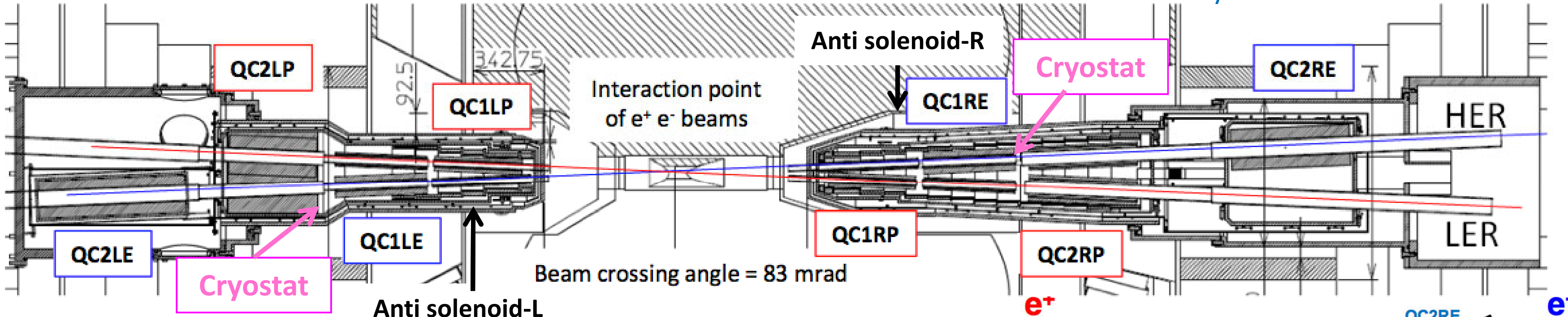




Clearing electrode for wiggler section (Inside view)

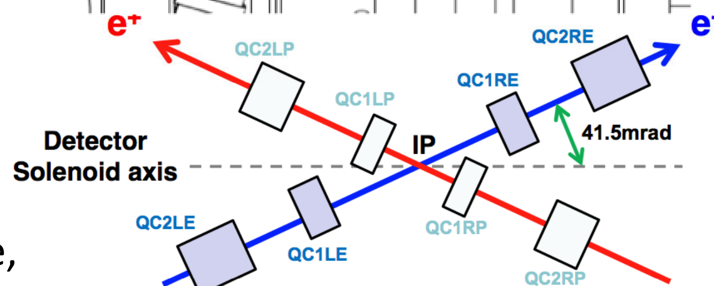
Major Items for Construction 4
Interaction Region

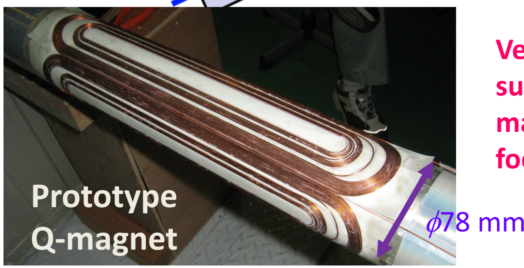
- A new final focus magnet system is being designed to squeeze β_y^*.



➢ Final SC quads are located as close to the IP as possible.
  ✓ Independent magnets in LER and HER are used.

➢ IR design needs to be fixed until the autumn this year.
  ✓ Optics design, local chromaticity correction scheme, hardware design (QCS, beam pipe, monitors and supports) and assembly procedure are under discussion now.
  ✓ Evaluation of B.G. issues are under way, too.





Very compact superconducting magnets for final focusing system

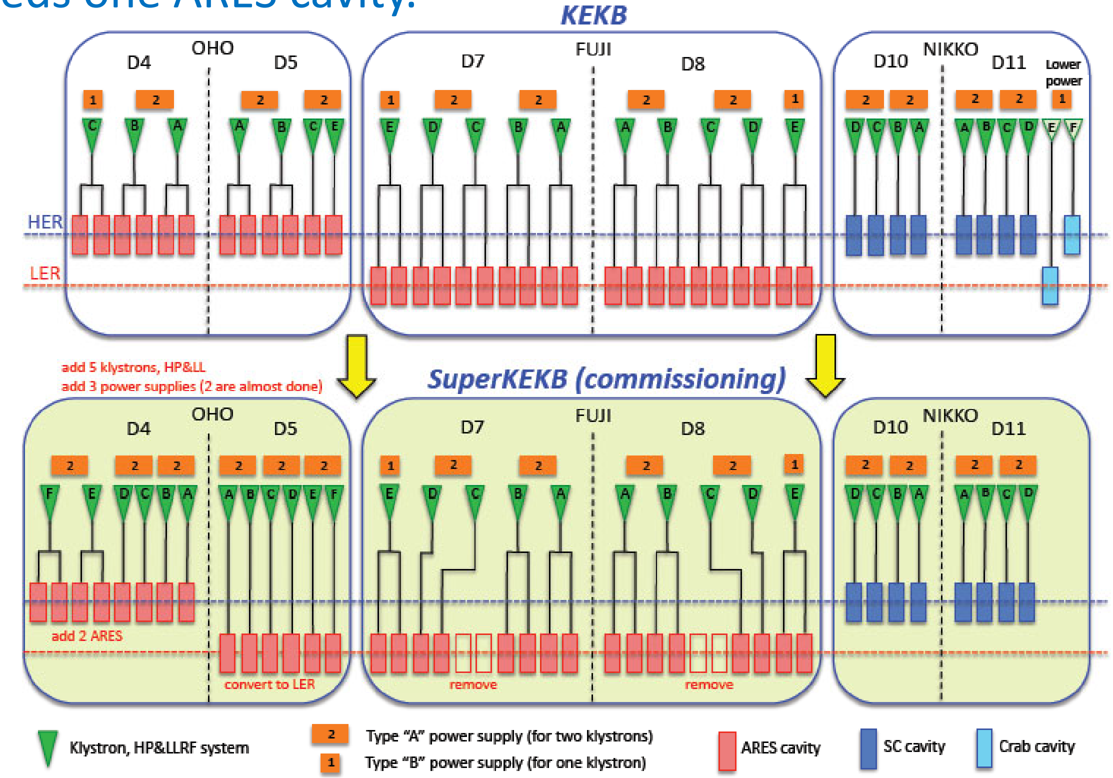
Major Items for Construction 5
RF system

- Beam powers required for HER and LER are 1.5 and 2.5 times higher than KEKB.
- It is necessary to increase the beam power per cavity and the number of RF stations where one klystron feeds one ARES cavity.

➢ ARES cavity (normal conducting cavity):
  - ✓ Add HP&LL RF system and rearrange ARES cavities.
  - ✓ Change ARES input couplers to larger coupling ones.
  - ✓ Improve HOM dampers.

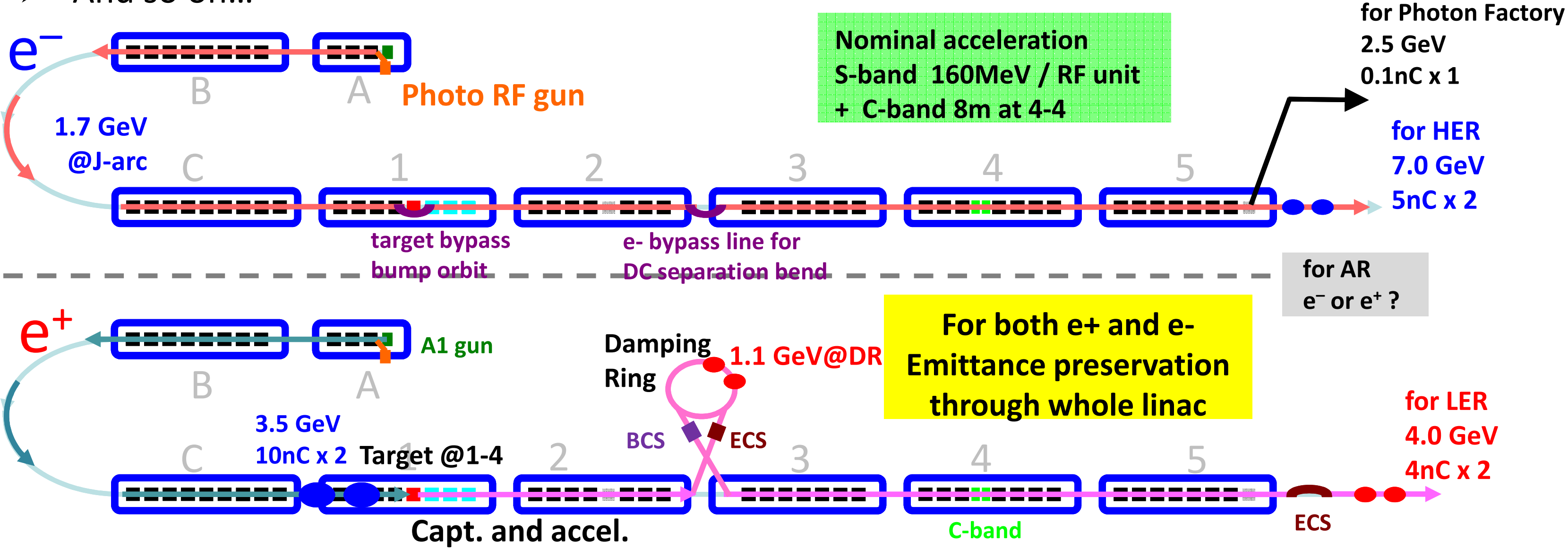
➢ SCC (superconducting cavity):
  - ✓ Improve HOM dampers.

Start with low beam current. At T=0 the maximum current is less than the design value (maybe 60~70%). Increase to the design current will take about two years or more.



Major Items for Construction 6
Linac and beam transport system

- Upgrades to the injector linac and beam transport system are designed to improve the rate and quality of injected beams to deliver the required beams with increased injection efficiencies.
  - New low-emittance RF electron gun
  - Improvement of the positron source
  - installation of a 1.1 GeV positron damping ring
  - And so on…

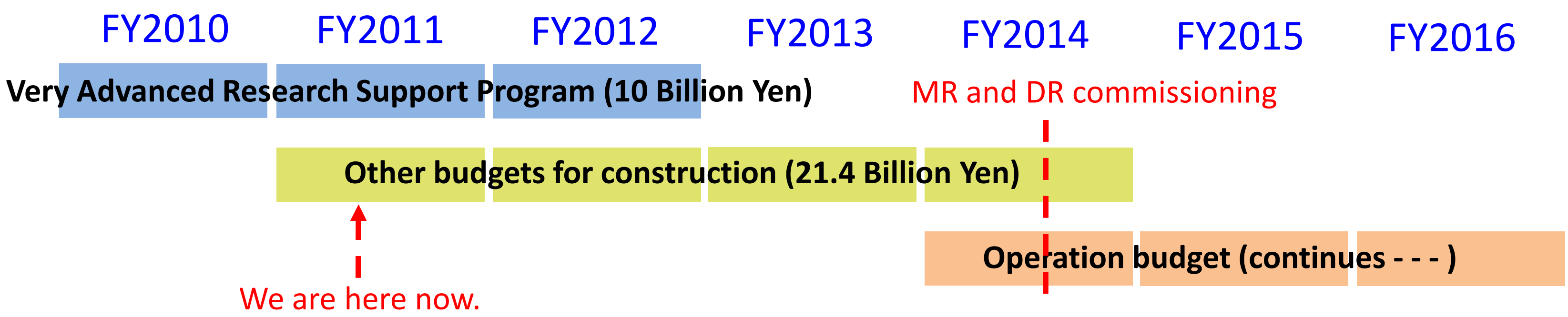


Major Items for Construction 7 Others

- The beam monitor and control system will also be improved.
- Cooling system will be reinforced for the magnets and vacuum system.
- Tunnel and buildings and additional transformers for damping ring will be built.
- Dismantlement of KEKB, R&D, design, fabrication and installation of components, checking and adjustment for commissioning.

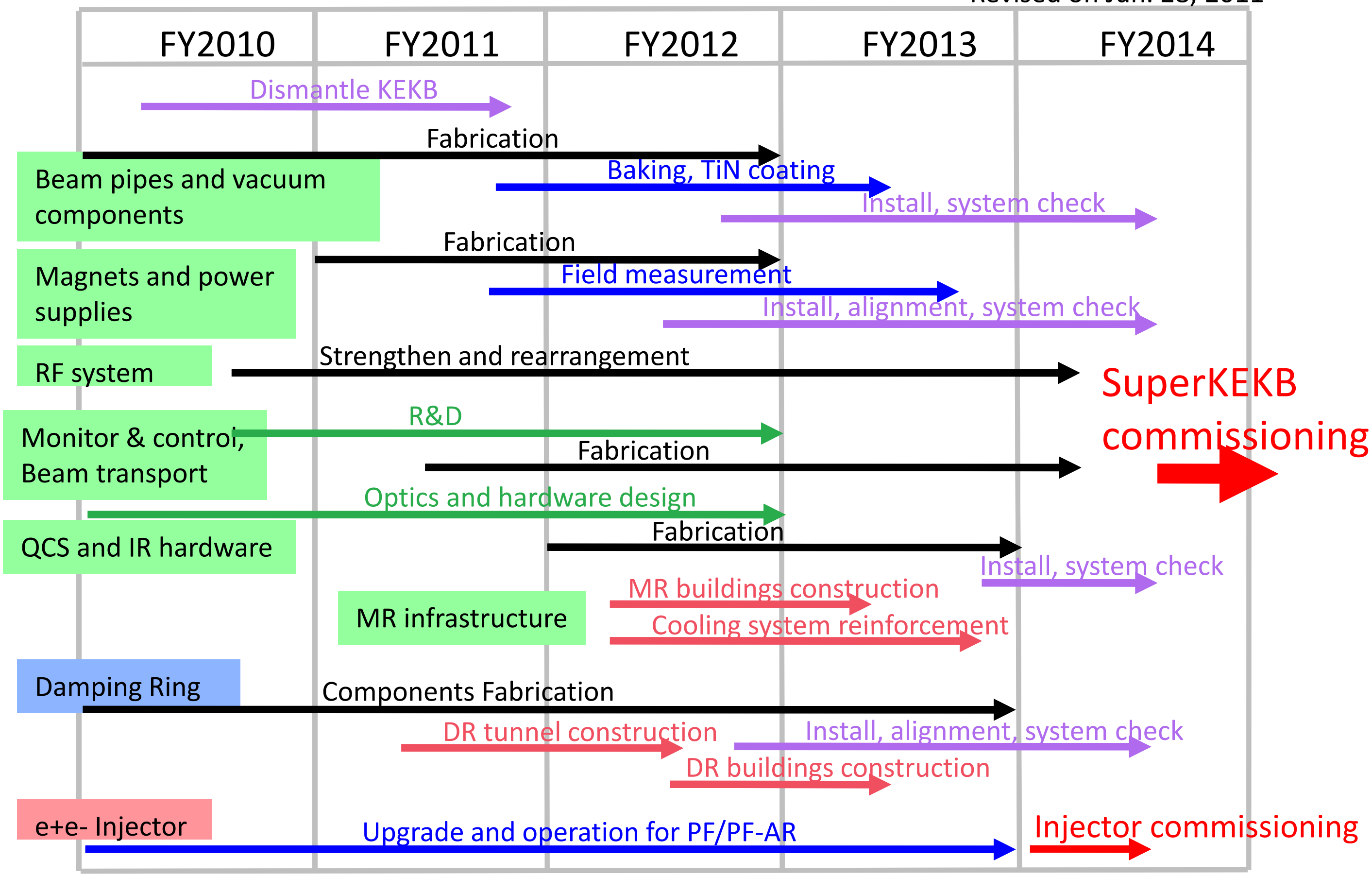
  And so on…
- Total budget for upgrade is 31.4 billion yen ($392 Million). (JFY2010-2014)
  - Operation budget is expected in FY2014 and later.

$1 = 80 yen



SuperKEKB Construction Schedule

Revised on Jun. 28, 2011



Dismantlement of KEKB is now in progress

Dismantlement of KEKB is now in progress

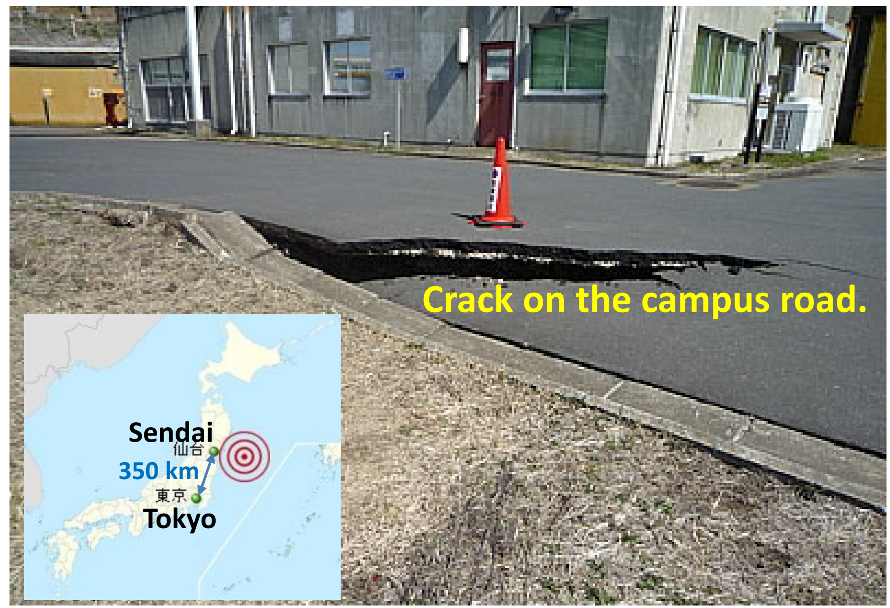
Dismantlement of KEKB is now in progress

Dismantlement of KEKB is now in progress

Damages from Earthquake

- A huge earthquake hit eastern Japan on March 11.
  - All KEK personnel and users were safe.
  - At KEK-Tsukuba site some infrastructures and components of accelerators were damaged, even though we are some 300 km away from the epicenter.
  - The damage to the KEKB main rings appears to be less serious, though non-negligible.
  - No serious damage has been reported so far at Belle.

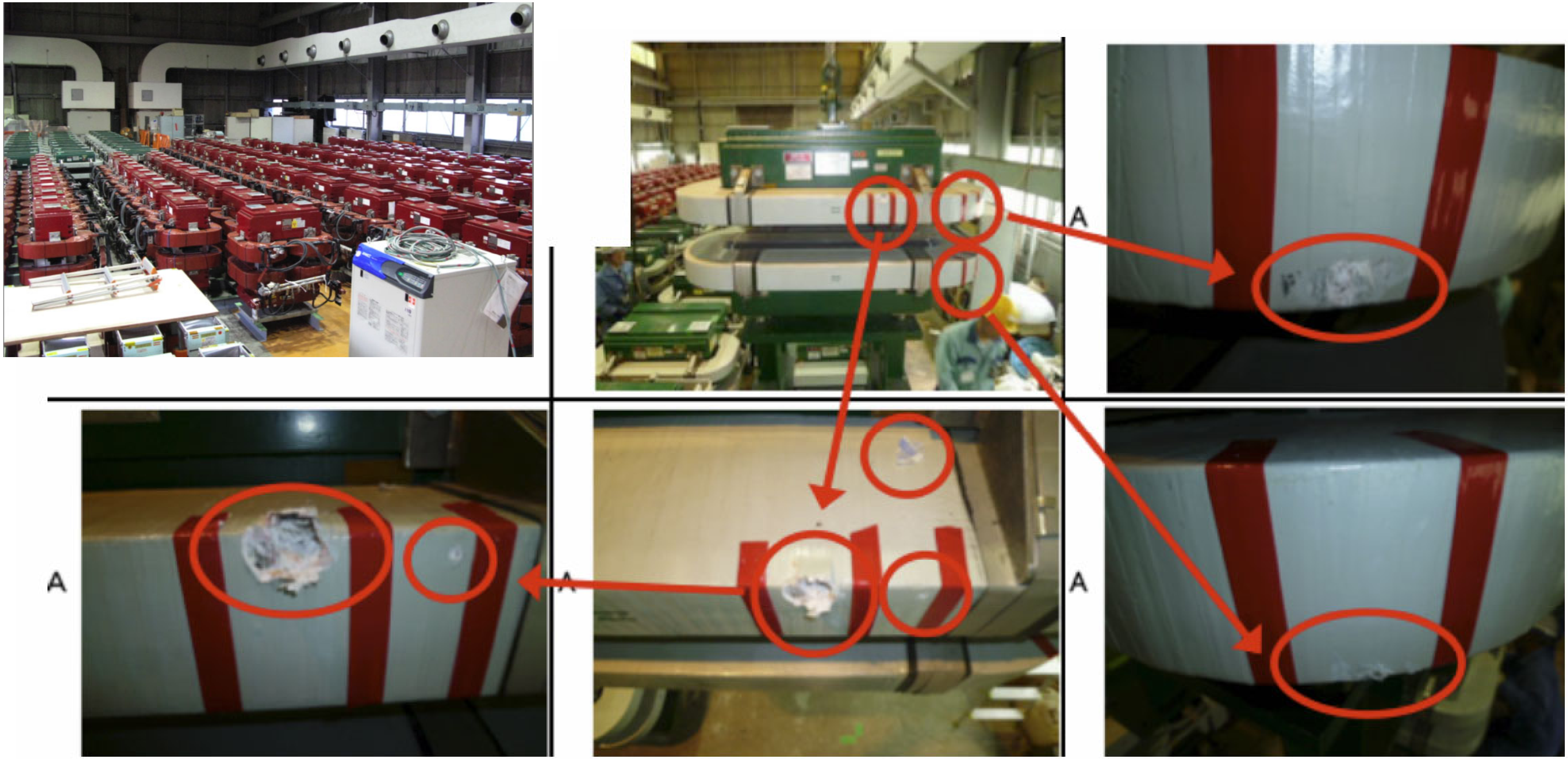
Damaged air-fin cooler for klystron



Crack on the campus road.

Damages from Earthquake

Damage of Magnet



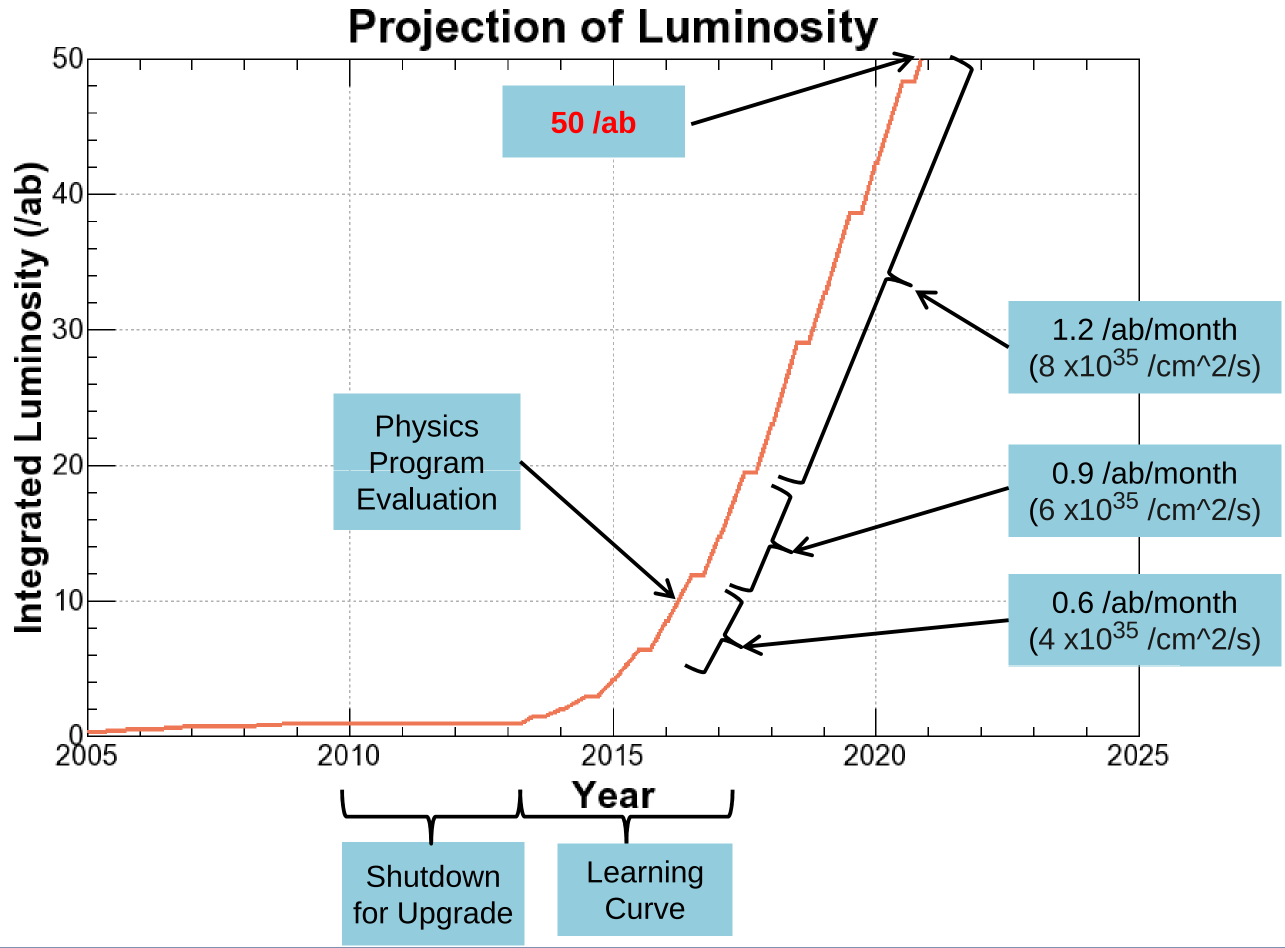
Aftermath of Earthquake

- Damage of components of accelerator
  - Some components, such as an air-fin cooler for klystron, RF control system, equipments for beam monitor, etc. were damaged.
  - Some magnets, which were removed from tunnel and kept above ground for reuse, collided with each other and were damaged.
  - These damaged components should be repaired or replaced.
  - We are determining the extent of the damage of other components by an operational check with electric power supplied to the devices.
  - Detailed checks including high-power test are necessary for the final judgment on the damage situation.
- Damage of buildings and tunnel
  - Distortion of the tunnel made large gaps of up to 4 mm at the expansion joints.
  - Survey and realignment of magnets and reference points are necessary.
- Dismantlement works
  - We are trying to eliminate 1.5 month delays in the dismantlement works within a time frame of the construction.

Commissioning Plan

- Machine commissioning
  - Main Ring and Damping Ring commissioning will start in the second half of FY2014.
  - Linac is in operation for PF and PF-AR during the construction period. Test operation for the upgrade will be performed in parallel. Commissioning of Linac for SuperKEKB will start in the beginning of FY2014.
- Detector
  - The detector people want that the machine operation starts without Belle II. So the machine commissioning will start with some dummy chambers with a luminosity monitor at the IR (so called BEAST).
  - IR configuration before Belle II roll-in is under discussion (for example, “Do we need solenoids or special skew-Q, special radiation shield in the place of Belle, etc. with an extra cost?”). We have no concrete plan for this so far.

Projection of Luminosity



END

Thank you very much for your attention.

Backup