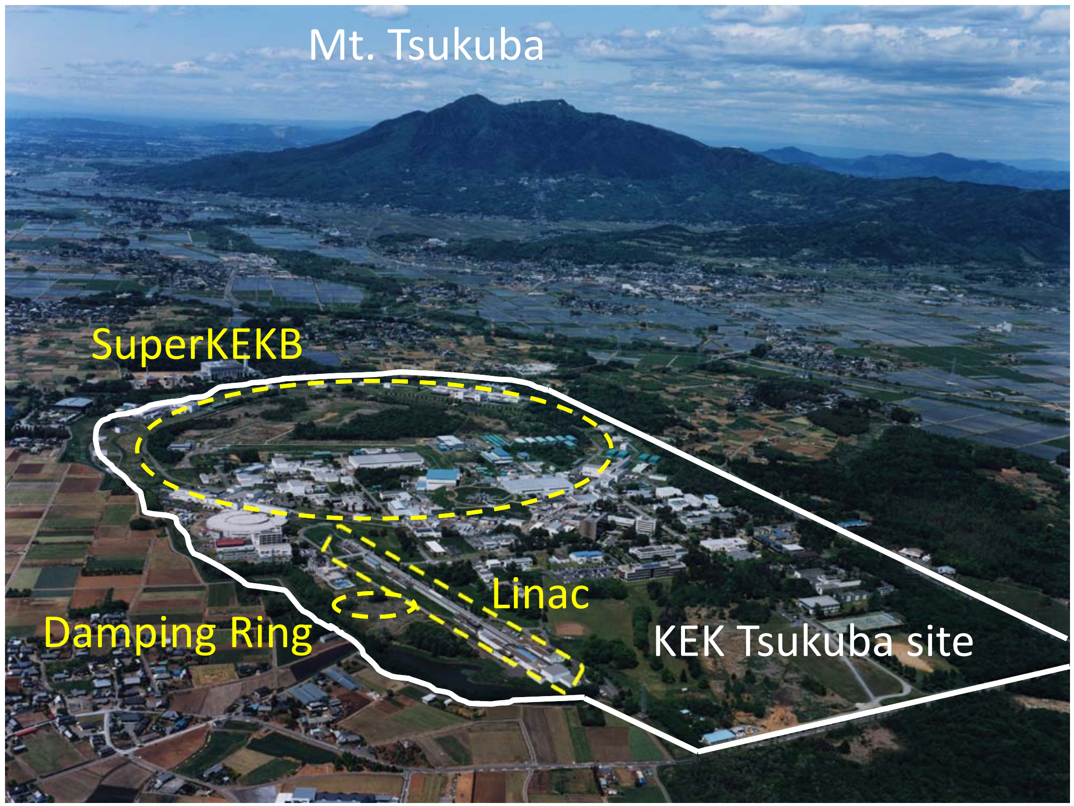
SuperKEKB Vacuum System



ECLOUD’12 (the 5th electron-cloud workshop)

2012.6.6

Kyo Shibata (on behalf of KEKB Vacuum Group)

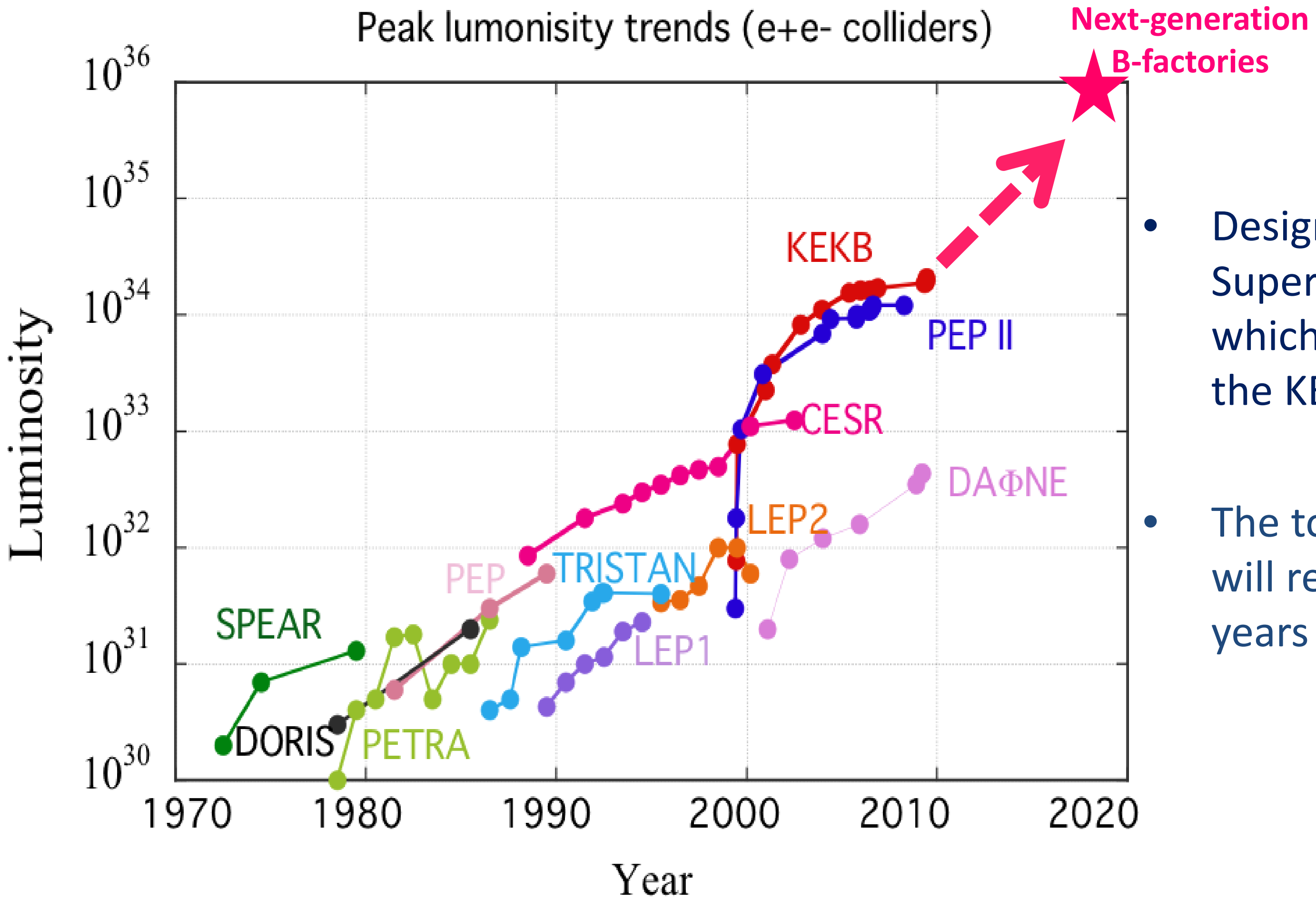
KEKB was shut down on Jun 30th 2010, and upgrade of KEKB has started.

- KEKB B-factory :
  - Electorn-positron collider with asymmetric energies of 8 GeV (e-) and 3.5 GeV (e+).
  - Made a great contribution to confirmation of CP violation in the neutral B meson system.
  - Operation period : 1998 to 2010
  - Peak luminosity : 2.1×10^{34} $cm^{-2}s^{-1}$
  - Total integrated luminosity : 1040 /fb
- To pursue research on flavor physics, much more luminosity is required and the SuperKEKB project was begun in 2010.
  - Commissioning of SuperKEKB will start in the second half of FY2014.

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

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

Mission of SuperKEKB



- Design Luminosity of SuperKEKB is 8×10^{35} /cm^2/s, which is about 40 times than the KEKB's record.
- The total integrated luminosity will reach 50 /ab just over ten years after inauguration.

Design Concept of SuperKEKB 1
How 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

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

Lorentz factor

Beam current

Beam-Beam parameter

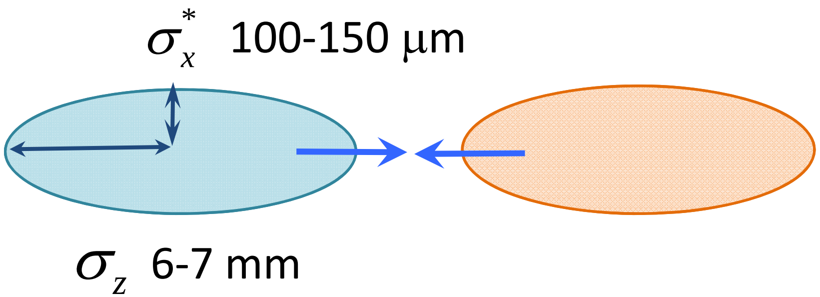
Geometrical reduction factors (crossing angle, hourglass effect)

Beam aspect ratio at IP

Vertical beta function at IP

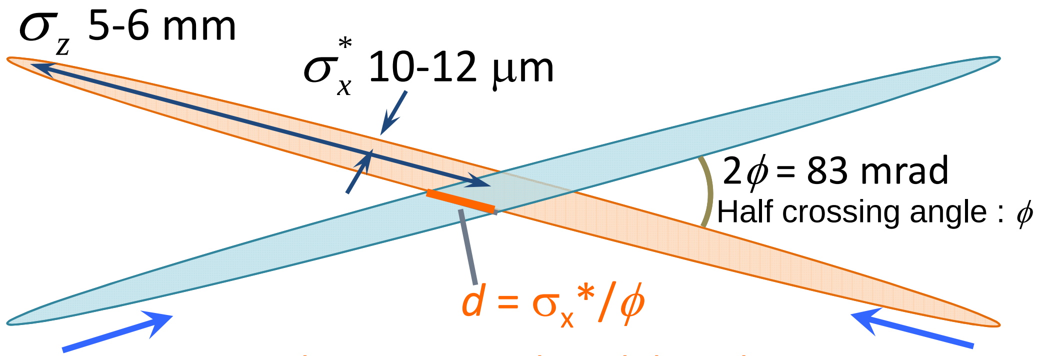
Collision Scheme
Nano Beam Scheme

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.

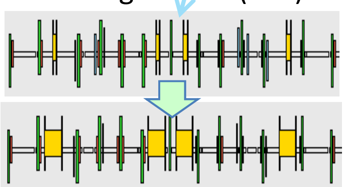
- Other features
  - No option for polarization at present.
  - Changing beam energy: 3.5/8.0 -> 4.0/7.0 GeV (e+/e-)
    - ✓ LER : Longer Touschek lifetime and mitigation of emittance growth due to the intra-beam scattering
    - ✓ HER : Lower emittance and lower SR power

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**

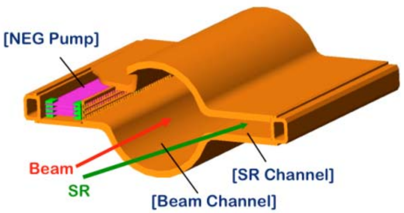
Outline of Upgrade to SuperKEKB

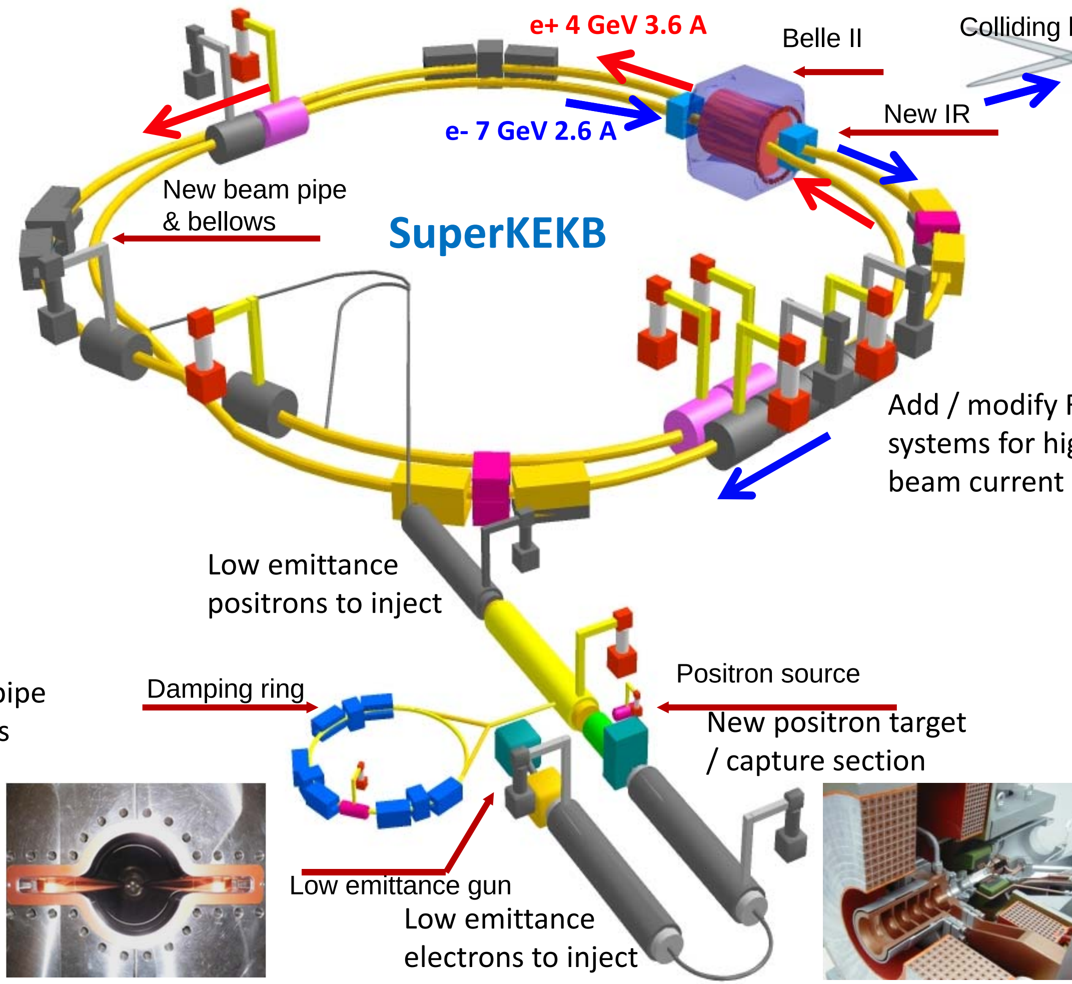
Replace short dipoles with longer ones (LER)



Redesign the lattices of both rings to reduce the emittance

TiN-coated beam pipe with antechambers



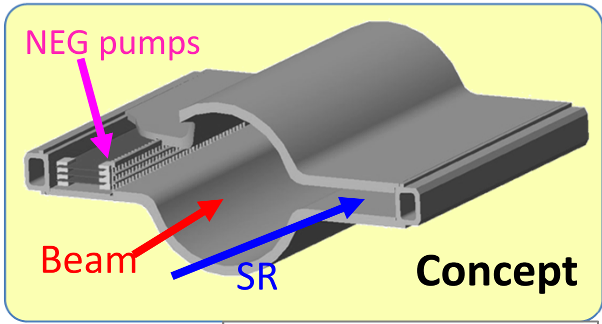


New superconducting /permanent final focusing quads near the IP

Add / modify RF systems for higher beam current

New Beam Pipes for SuperKEKB

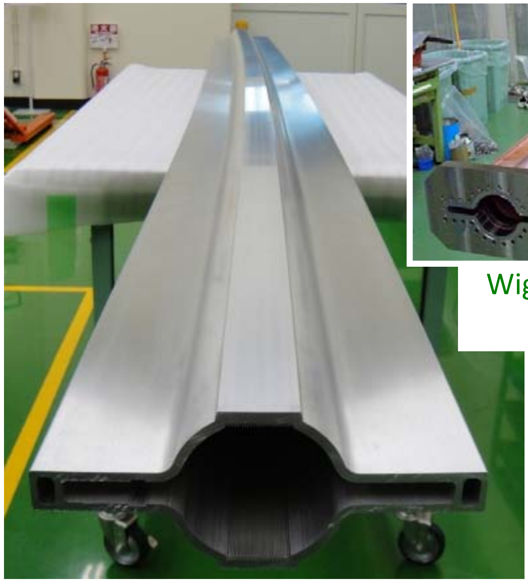
- To cope with the electron cloud issues and heating problems, antechamber type beam pipes are adopted with a combination of TiN coatings, grooved shape surfaces and clearing electrodes.



by courtesy of Y. Suetsugu

- 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.

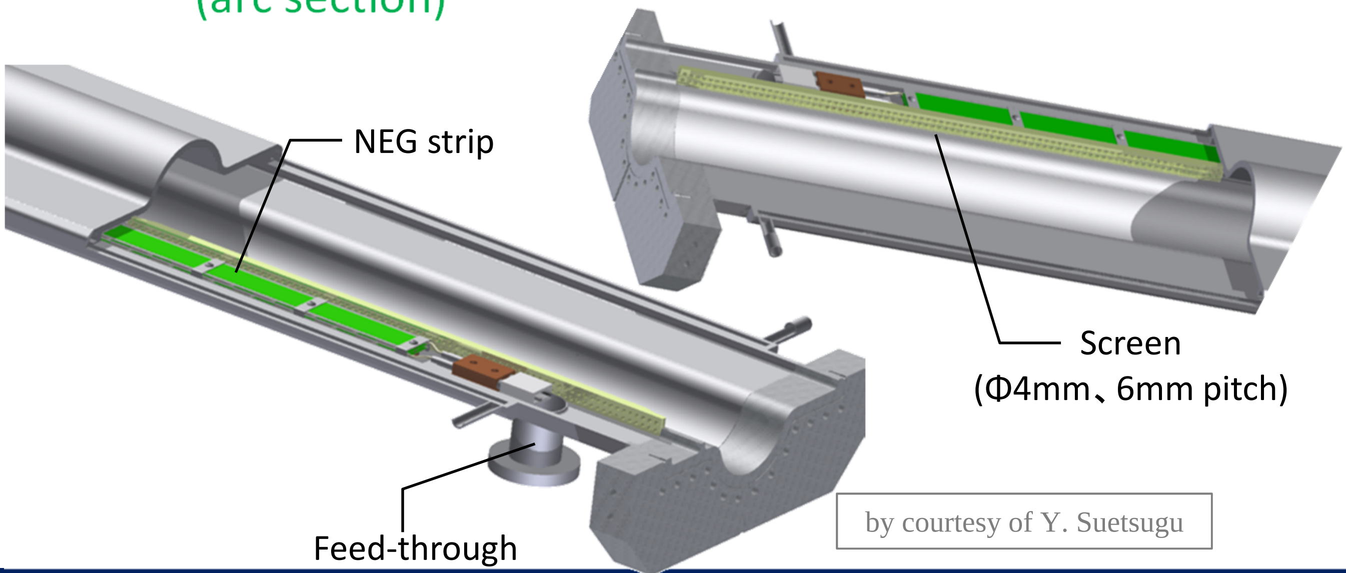
Wiggler section (copper)



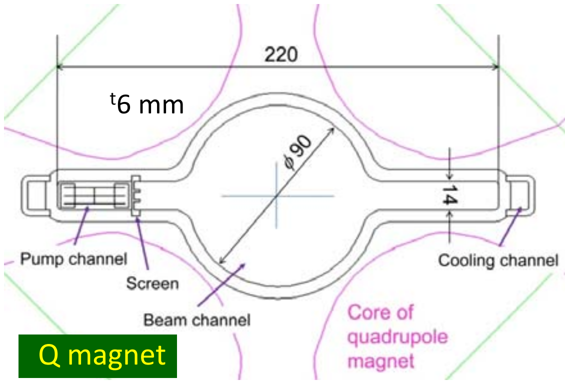
Arc section (aluminum)

Beam pipe with antechamber

- Features of new beam pipes with antechamber
  - Small effect of photoelectrons, low beam impedance, low SR power density
  - The cross section should fit to the existing magnets.
  - Aluminum alloy is available for LER arc section due to low SR power. Copper is required for wiggler section and HER.
  - NEG strips are installed in one antechamber isolated by the screen for RF shield. (arc section)



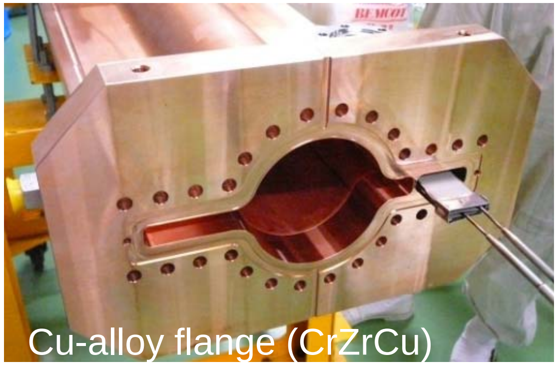
by courtesy of Y. Suetsugu

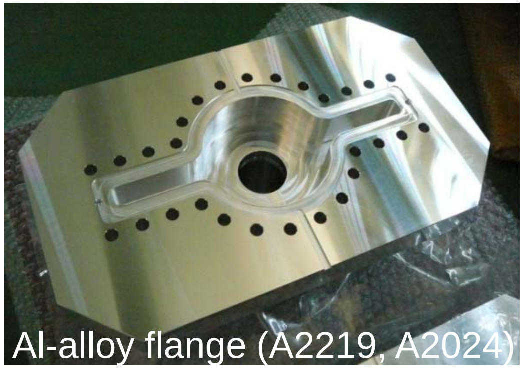


Flange, Bellows and Gate Valve

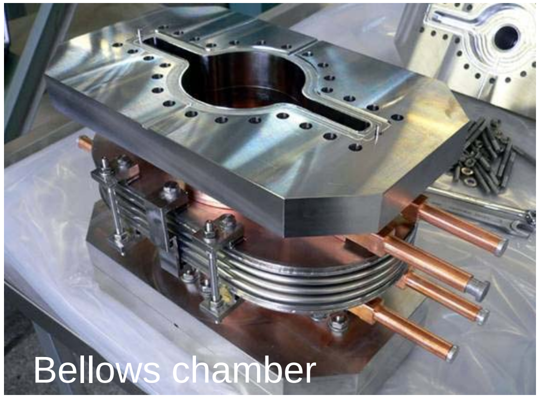
- Flange, bellows and gate valve applicable to antechamber scheme were also developed.

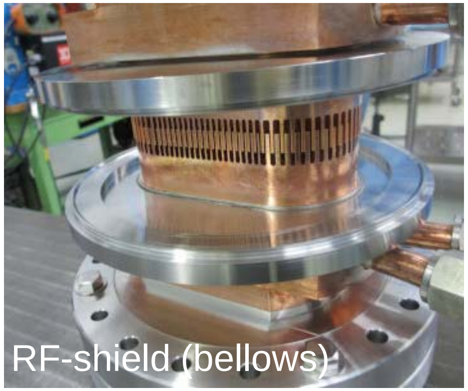
by courtesy of Y. Suetsugu

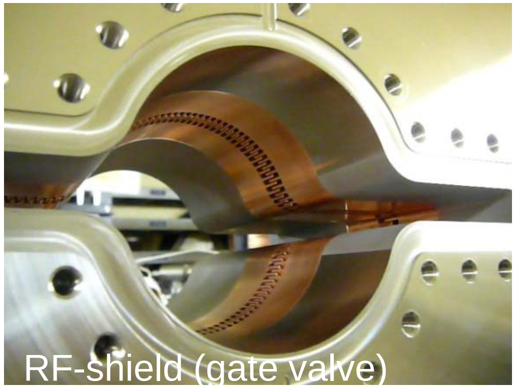

Cu-alloy flange (CrZrCu)


Al-alloy flange (A2219, A2024)


Gate valve


Bellows chamber


RF-shield (bellows)


RF-shield (gate valve)

Countermeasures against Electron Cloud Effect

- Electron cloud instability can be a serious problem for LER (e+)
  - The threshold of electron density to excite the head-tail instability is $\sim 1.6 \times 10^{11}$ e^-/m^3.
  - By using these countermeasures, the average electron density on the order of 10^{10} e^-/m^3 will be obtained.
  - Various mitigation techniques were evaluated at KEKB LER.

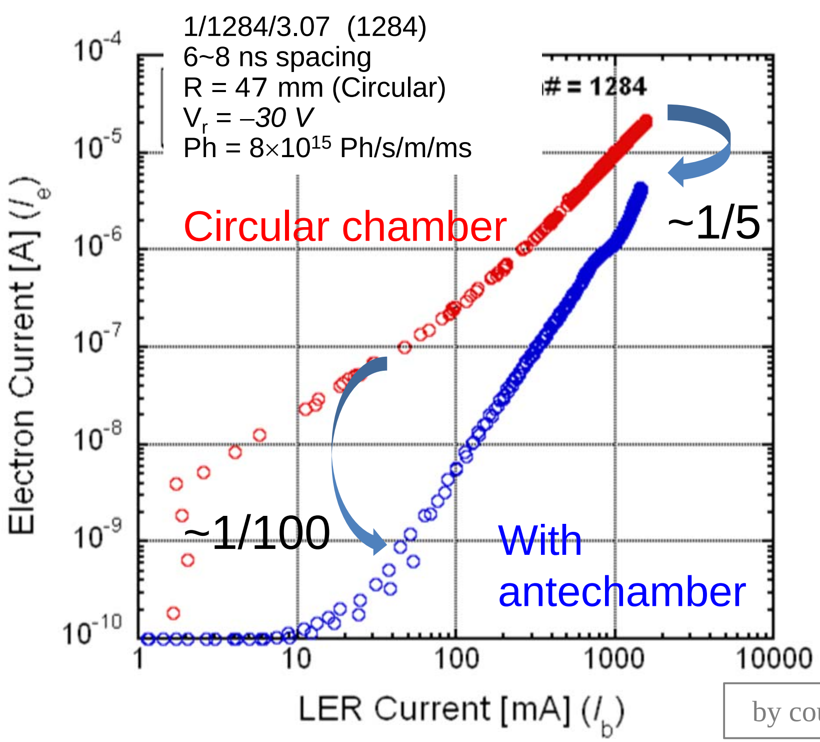
by courtesy of Y. Suetsugu

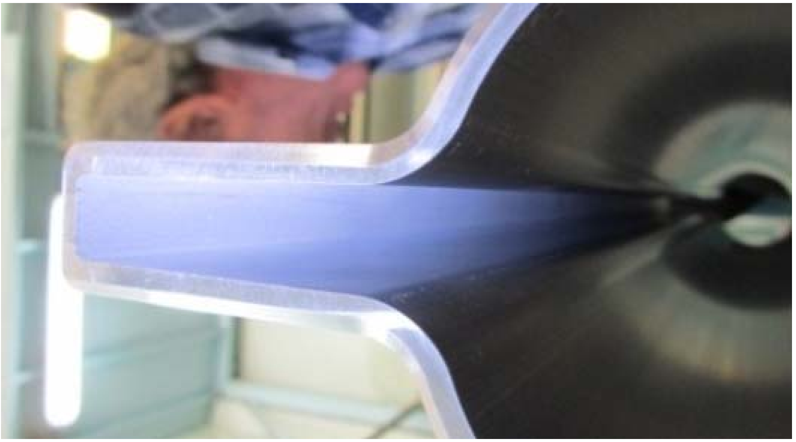
Sections	L [m]	L [%]	Countermeasure	Material
Total	3016	100		
Drift space (arc)	1629 m	54	TiN coating + Solenoid	Al (arc)
Steering mag.	316 m	10	TiN coating + Solenoid	Al
Bending mag.	519 m	17	TiN coating + Grooved surface	Al
Wiggler mag.	154 m	5	Clearing Electrode	Cu
Q & SX mag.	254 m	9	TiN coating	Al (arc)
RF section	124 m	4	(TiN coating +) Solenoid	Cu
IR section	20 m	0.7	(TiN coating +) Solenoid	Cu or ?

Electron cloud mitigation 1
Antechamber

- Antechamber is effective to mitigation of photoelectrons which can be source of the electron cloud.

Effect of antechamber



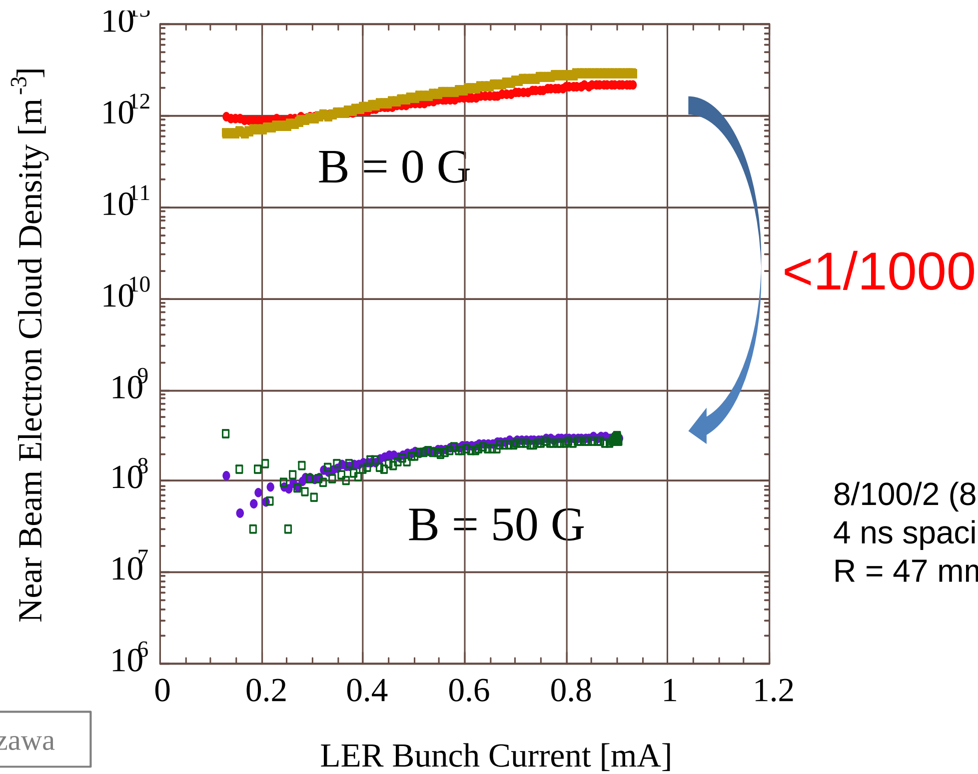


Rough surface at the side wall (Ra ~20) reduces the photon reflection.

by courtesy of Y. Suetsugu

Electron Cloud Mitigation 2
Solenoid Field

- It was confirmed that the solenoid field at drift section (50 G) is effective to both photoelectrons and secondary electrons.

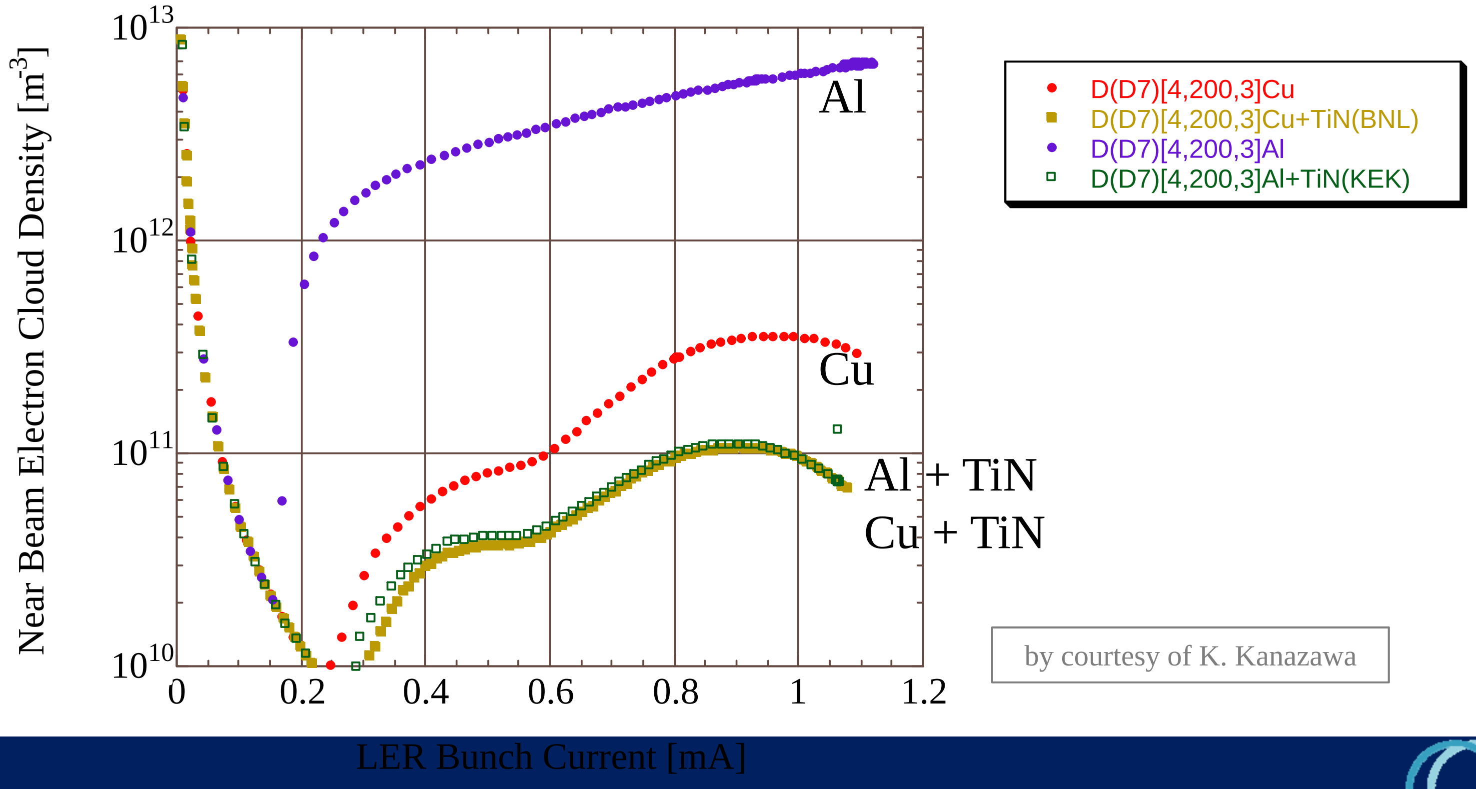


8/100/2 (800)
4 ns spacing
R = 47 mm (Circular)

by courtesy of K. Kanazawa

Electron Cloud Mitigation 3
TiN Coating

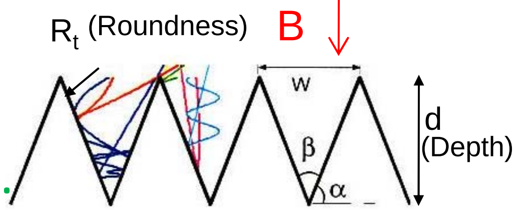
- TiN coating is effective to reduction of the secondary electrons.
- It was confirmed that TiN coated surface has a same property irrespective of base material.



by courtesy of K. Kanazawa

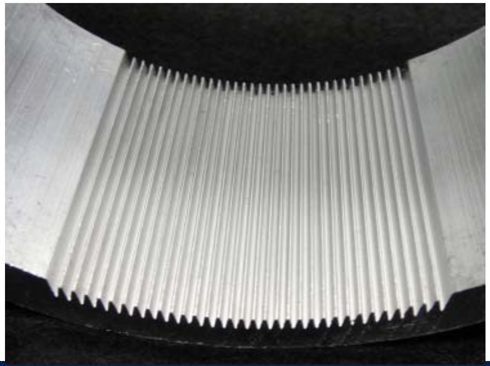
Electron Cloud Mitigation 4
Grooved Surface (in Bending Magnet)

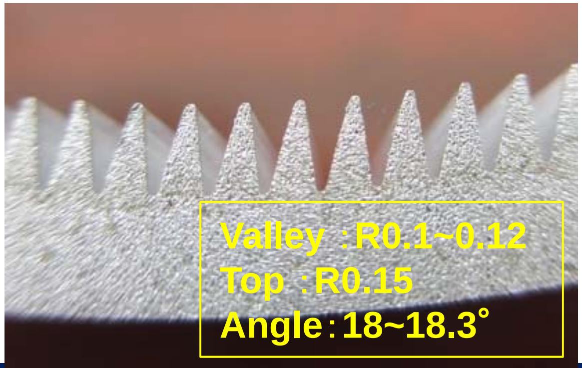
- Grooved surface in the bending magnet can reduce effective SEY structurally.
  - It was tested in KEKB and CesrTA.
  - It is expected to reduce the electron density by factors.
  - It can be formed by extrusion method.
  - In SuperKEKB LER, it will be used with TiN coating.
  - Grooved surface with TiN coating will be also adopted for positron damping ring.

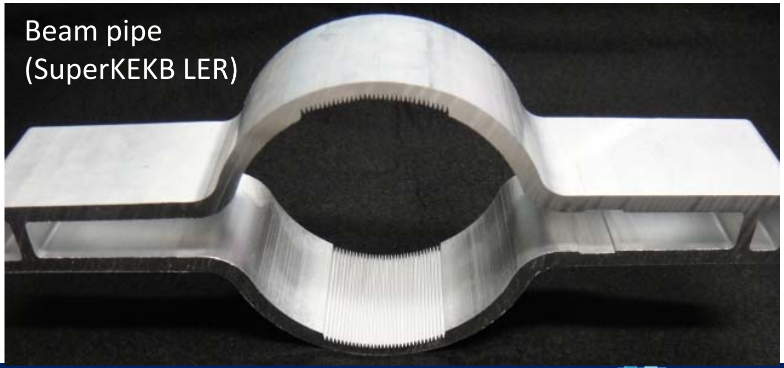


by L. Wang et al.

by courtesy of Y. Suetsugu



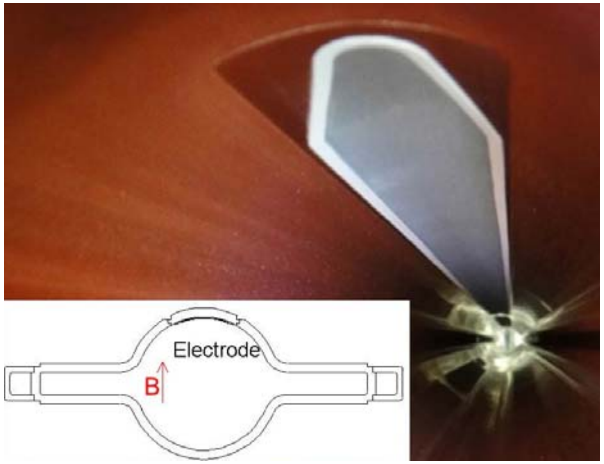


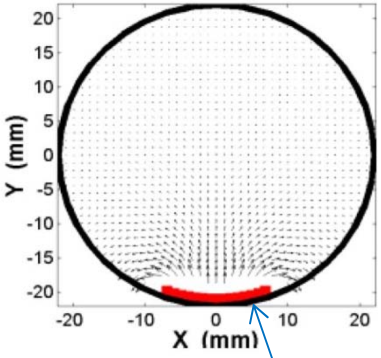


Electron Cloud Mitigation 5
Clearing Electrode (in Wiggler Magnet)

- Clearing electrode attracts the electrons by electrostatic field.
  - Very thin electrode was developed. (0.1 mm tungsten on 0.2 mm Al_2O_3)
  - It was tested in KEKB and CserTA.
  - It is expected to reduce the electron density around beam up to ~1/100.

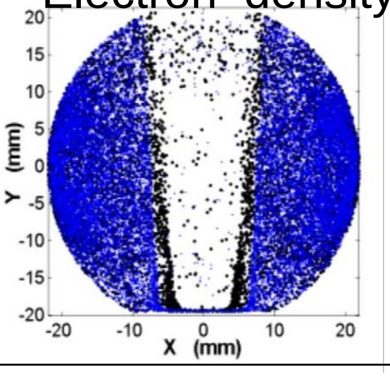
by courtesy of Y. Suetsugu



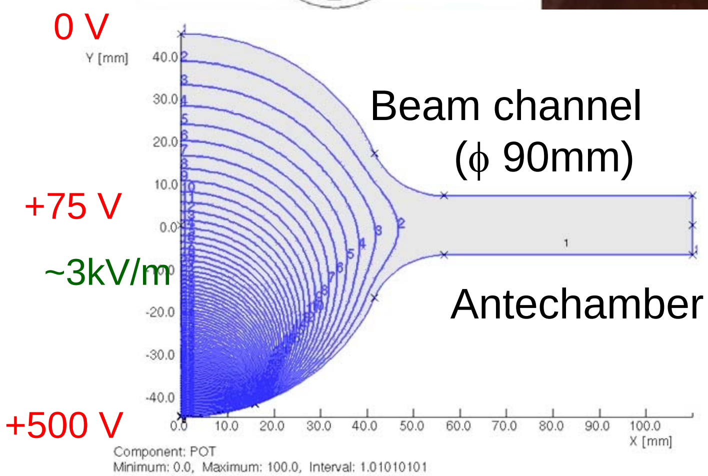


Electrode (+)

Electron density

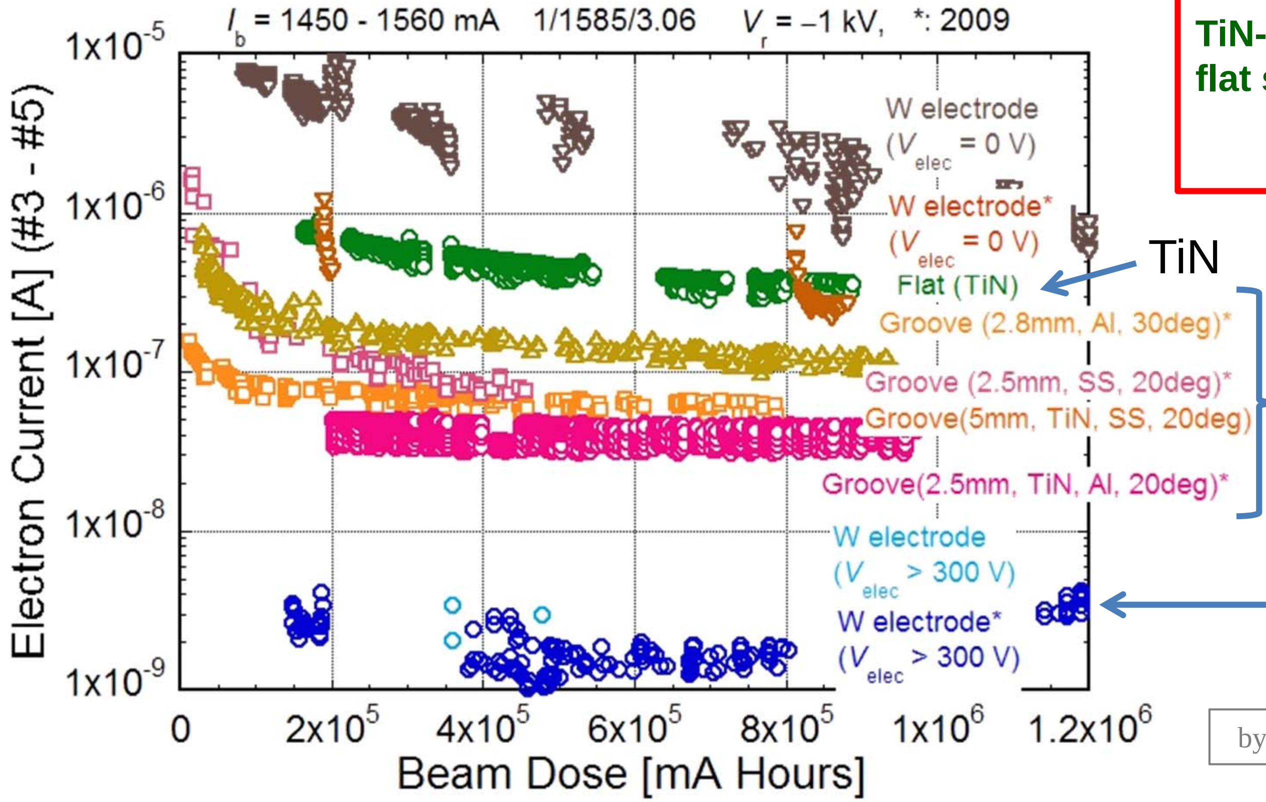


L. Wang et al, EPAC2006, p.1489



Electron Cloud Mitigation 5
Evaluation on Groove and Electrode

- Effectiveness of the grooved surface and the clearing electrode was evaluated at KEKB LER.



TiN-coated flat surface 〉〉 Grooved surface (β~20°) 〉〉 Clearing electrode

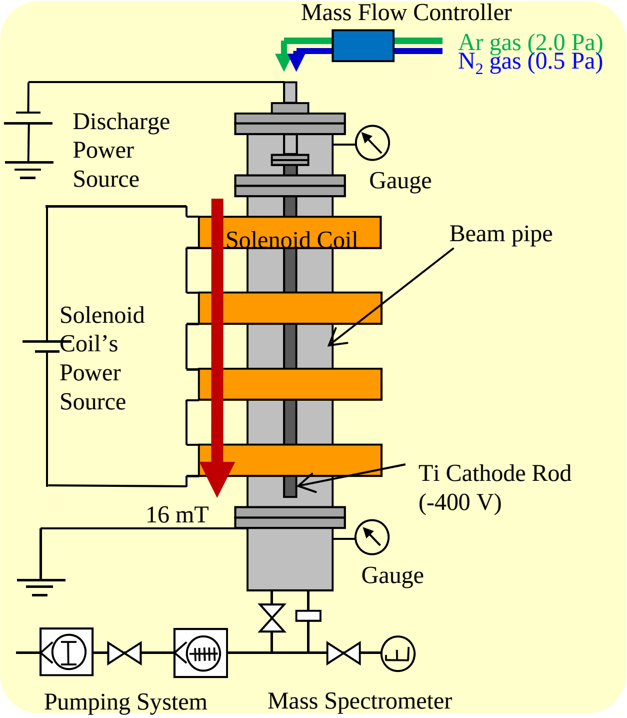
1/6~1/10 ~1/10

by courtesy of Y. Suetsugu

TiN Coating Facility 1

- We have to coat ~1100 beam pipes within 2 years.
  - TiN coating tests had been performed and the coating method was established.

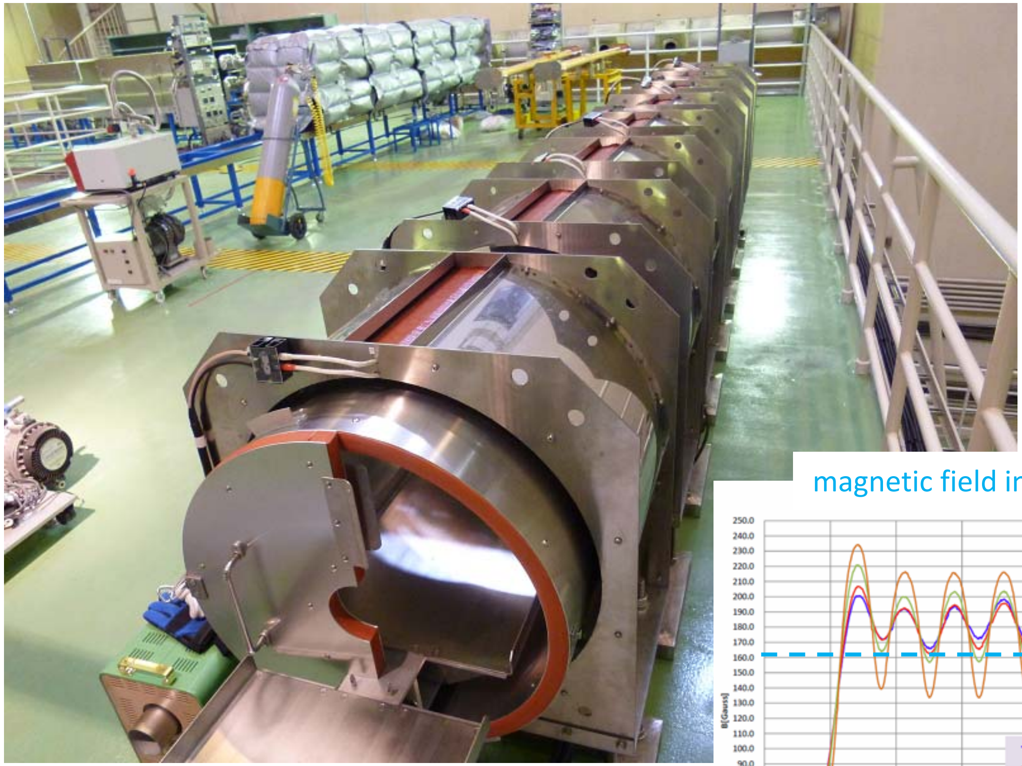
- TiN coating is done by a DC magnetron sputtering of Ti in Ar and N2 atmospheres.
  - A Ti cathode rod (-400 V) is hung from the top on the center axis.
  - Gases are supplied into the beam pipes uniformly though the Ti rod.
  - Magnetic field (16 mT) is supplied by a solenoid coil.

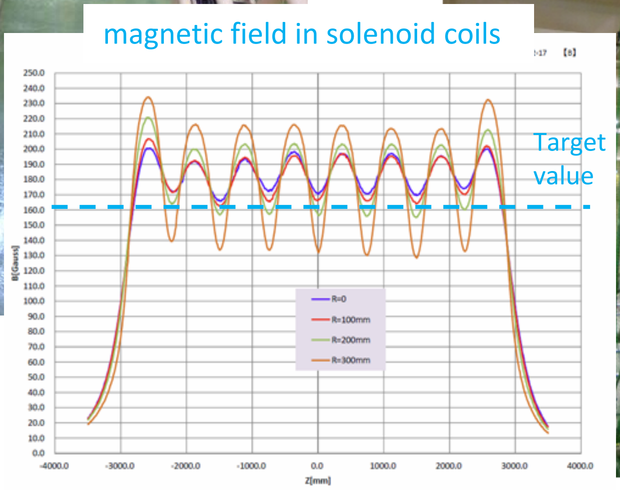


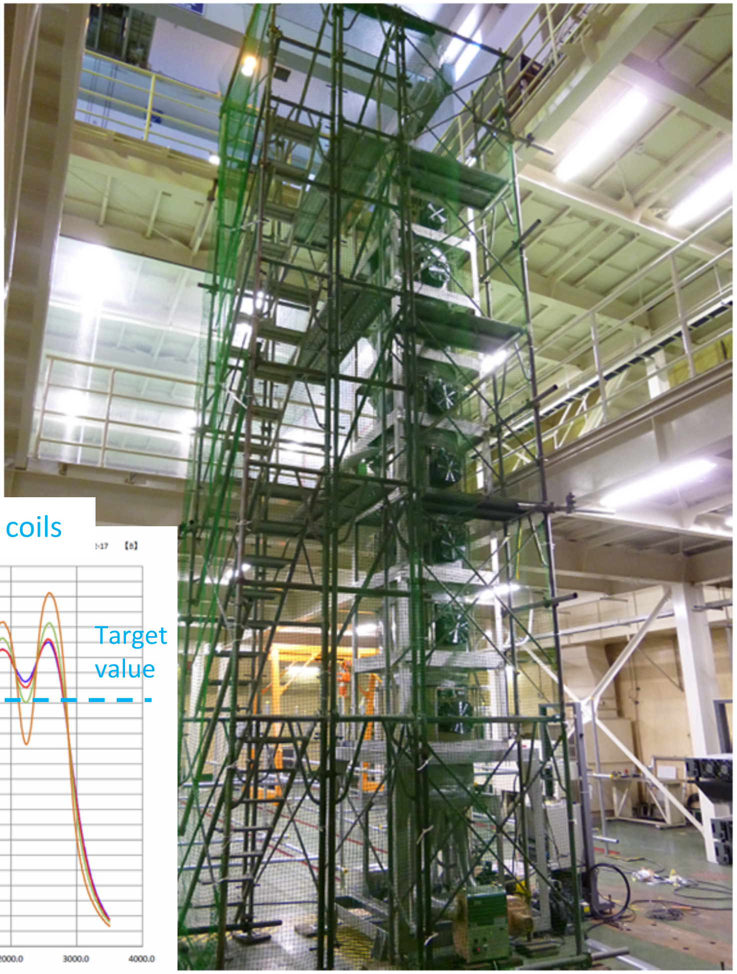
TiN Coating facility 2

- TiN coating facility for large-scale production are under construction now.
  - 5 vertical equipments for straight beam pipes.
  - 3 transverse equipments for bent pipes (of which one is test station).
  - Two line of the beam pipes can be mounted side-by-side in one equipment.
  - Beam pipe with a length up to 5 m can be coated.
  - Combination of hot-air oven and circulators are adopted to avoid the trouble of having to cover and uncover the aluminum foils and insulators.

TiN Coating facility 3



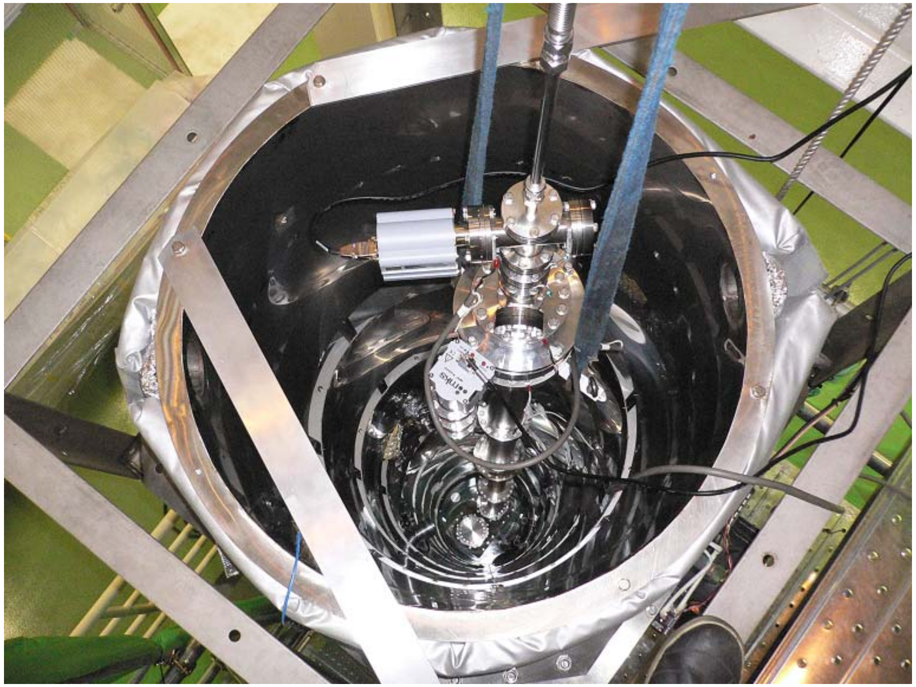


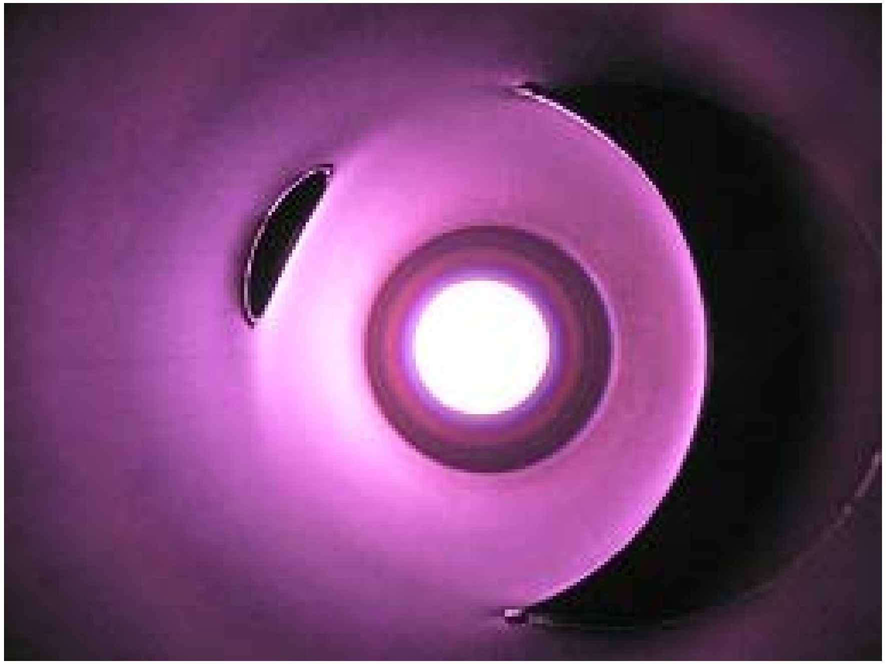


TiN Coating facility 3

TiN Coating facility 4

- Coating test is about done.
  - Coating on the beam pipes will be started in this month.
  - 1100 beam pipes will be coated within 2 years by this facility.





Now coating (view from the bottom)

Construction works are undergoing now.

- Fabrication of beam pipes:
  - LER beam pipes are being made on mass production lines.
- Baking of beam pipes (after coating):
  - All beam pipes will be baked with a temperature up to 150 °C at the laboratory before installation.
  - To cope with the large number of beam pipes (~1200), hot-air oven is used.
  - Baking works started in April. (Output : 6-8 pipes/week at present)
- Installation of beam pipes:
  - Installation works will start in the second half of this year.

by courtesy of Y. Suetsugu

Summary

- Construction works of SuperKEKB are going on now.
  - Commissioning of SuperKEKB will start in the second half of FY2014.
- Almost all LER and part of HER beam pipes become new.
  - To cope with the electron cloud issues and heating problems, antechamber type beam pipes are adopted.
- As the countermeasures against the electron cloud, various mitigation techniques are adopted.
  - Solenoid field
  - TiN coating
  - Grooved surface
  - Clearing electrode
- TiN coating are done in KEK Tsukuba site.
  - Coating facility are under construction now.
  - Coating test is about done and coating on the beam pipe will start this month.

END

Thank you very much for your attention.

Backup

Backup