TUOCB01

First Commissioning of The SuperKEKB Vacuum System

Y. Suetsugu, K. Shibata, T. Ishibashi, K. Kanazawa, M. Shirai, S. Terui and H. Hisamatsu

KEKB Vacuum Group

- SuperKEKB vacuum system
- Present status
- Results and problems
- Summary

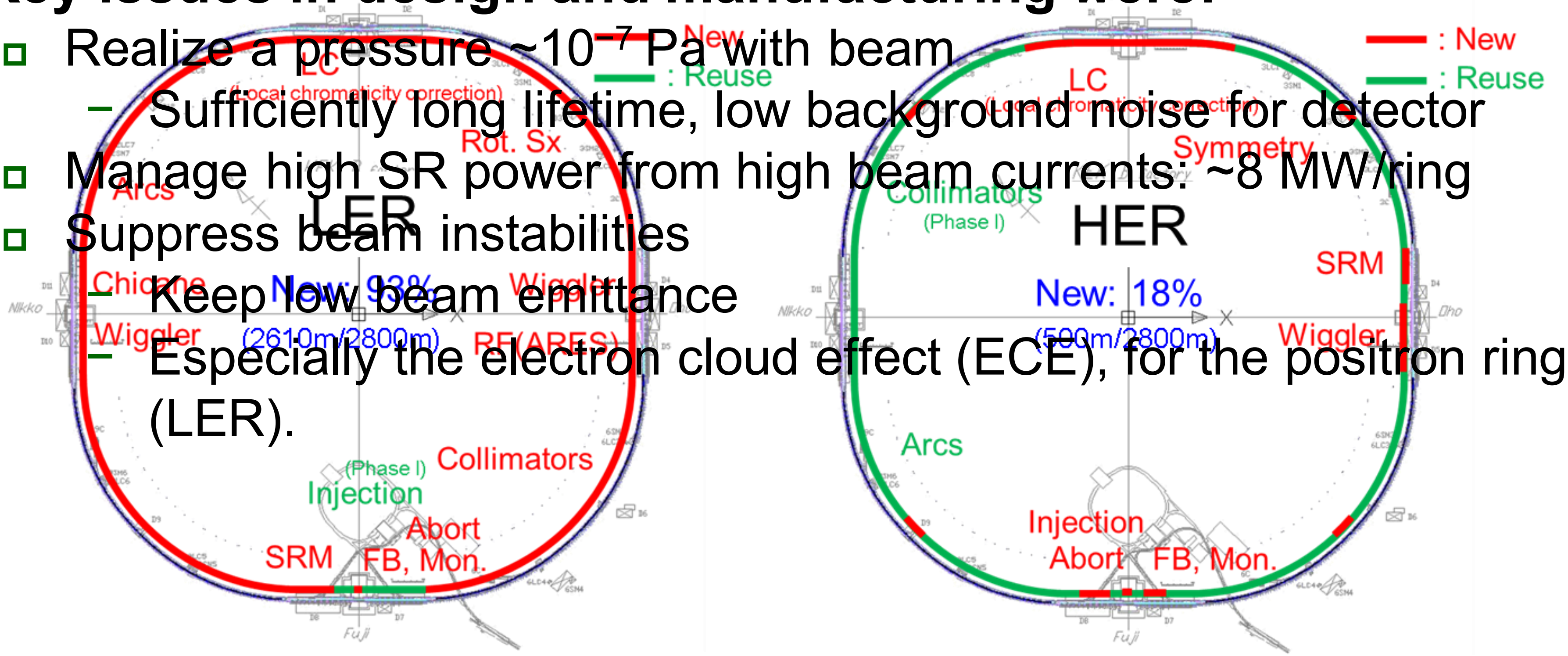
SuperKEKB

- **Upgrade project of KEKB B-factory**
  - Quest new theories beyond the standard model at B-meson regime.
- **e^- - e^+ two-ring collider consisting of**
  - Injector (Linac): *L* ~600 m
  - Damping ring (e^+): *C* ~100 m
  - Main ring (MR): *C* ~ 3016 m
    - HER: 7 GeV e^-, 2.6 A
    - LER: 4 GeV e^+, 3.6 A
  - BELLE-II detector

- **Goal luminosity**
  - 80×10^{34} cm^{-2}s^{-1}
    (~40 times of KEKB)
- **The present status of MR vacuum system is reported here.**

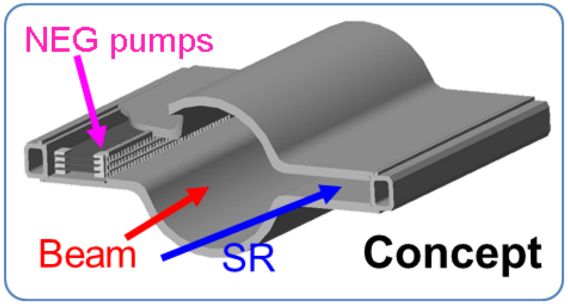
SuperKEKB vacuum system

- **Construction of the MR vacuum system was one of major items for the upgrade.**
  - 93 % and 18 % of the beam pipes and components of LER and HER, respectively, were replaced with new ones.
  - Other sub-systems were basically reused, upgraded as necessary.
- **Key issues in design and manufacturing were:**
  - Realize a pressure ~10^{-7} Pa with beam
    - Sufficiently long lifetime, low background noise for detector
  - Manage high SR power from high beam currents: ~8 MW/ring
  - Suppress beam instabilities
    - Keep low beam emittance
    - Especially the electron cloud effect (ECE), for the positron ring (LER).

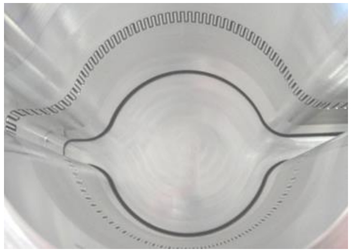


Design features

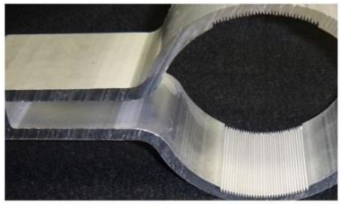
- **New beam pipes with antechambers**
  - Approximately 1230 beam pipes with various cross sections

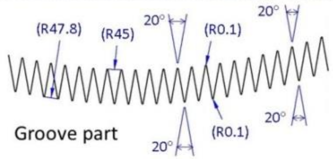


- **Main pump: NEG strips ST707 (arc)**
  - Averaged linear pumping speed = 0.14 $m^3s^{-1}m^{-1}$ for CO after activation.
- **Bellows chambers and gate valves with Comb-type RF shield**
  - Approximately 1240 bellows chambers and 40 gate valves
- **Connection flanges: MO-type flanges**
  - Approximately 4800 flanges



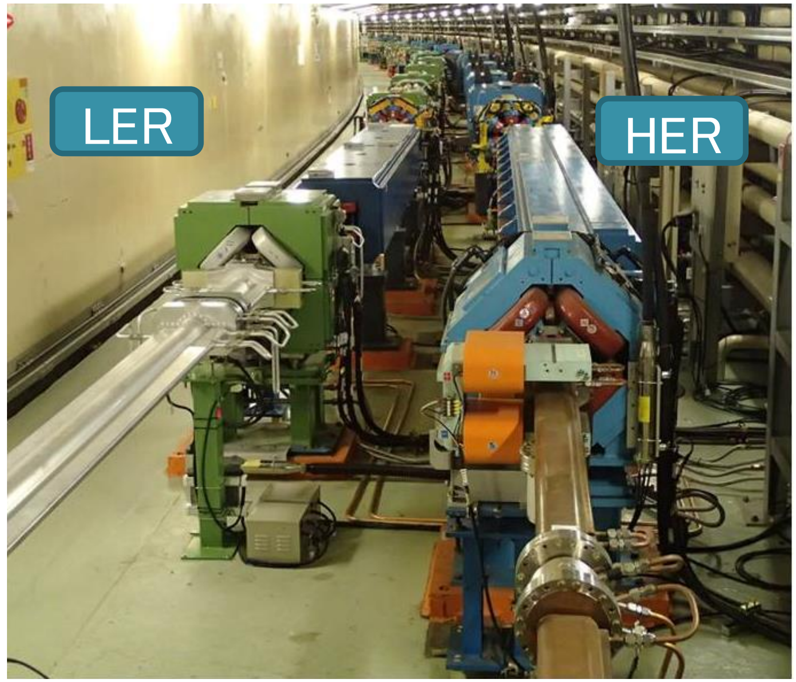
- **Countermeasures against electron cloud effect (ECE)**
  - ECE: a critical issue for the positron ring (LER)
  - Antechambers, TiN coating, grooves in dipole field, clearing electrodes in wiggler magnets.
  - Solenoid field will be prepared but not yet applied in this Phase-1 commissioning.





Construction

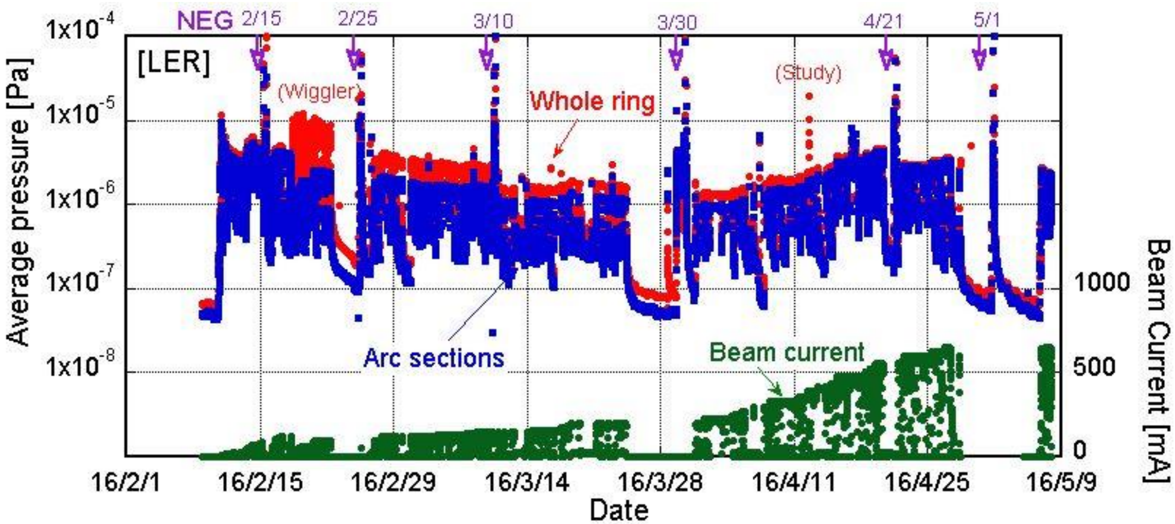
- **Construction started in 2010.**
- **Installation of components into the tunnel and update of sub-systems had finished by the end of 2015.**



- **Beam commissioning (Phase-1) has started in February 2016.**
  - We have no particle detector in Phase-1.
  - Dedicated for accelerator tuning.
  - From February to June, 2016

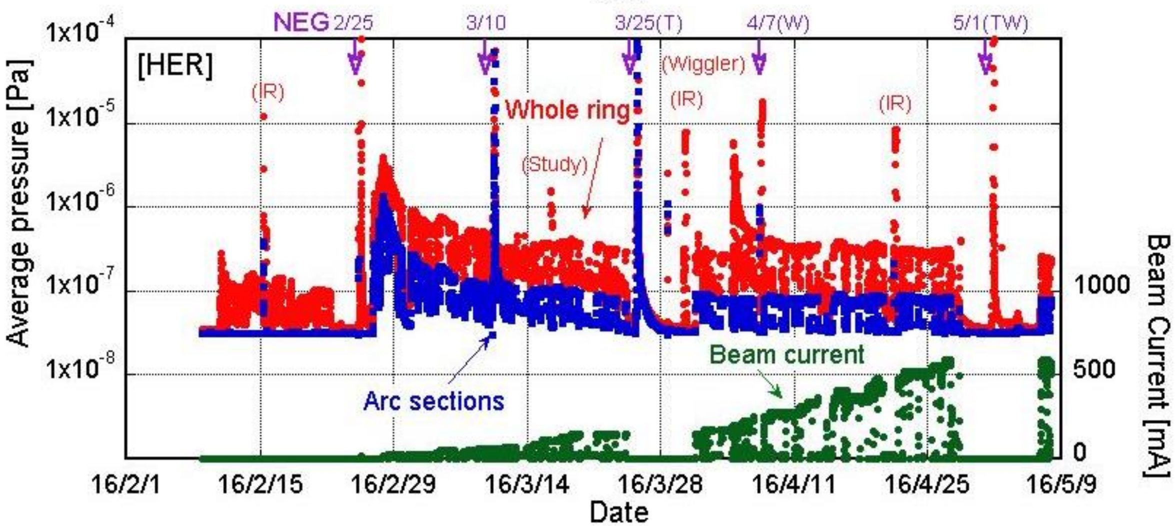
Present status

- The vacuum system made a good start.
- Beam currents and average pressures (~2016/5/7)



[LER]

- Max. Beam current: 650 mA
- Avg. Pressure ~ 3×10^{-6} Pa
- Lifetime ~ 80 min.



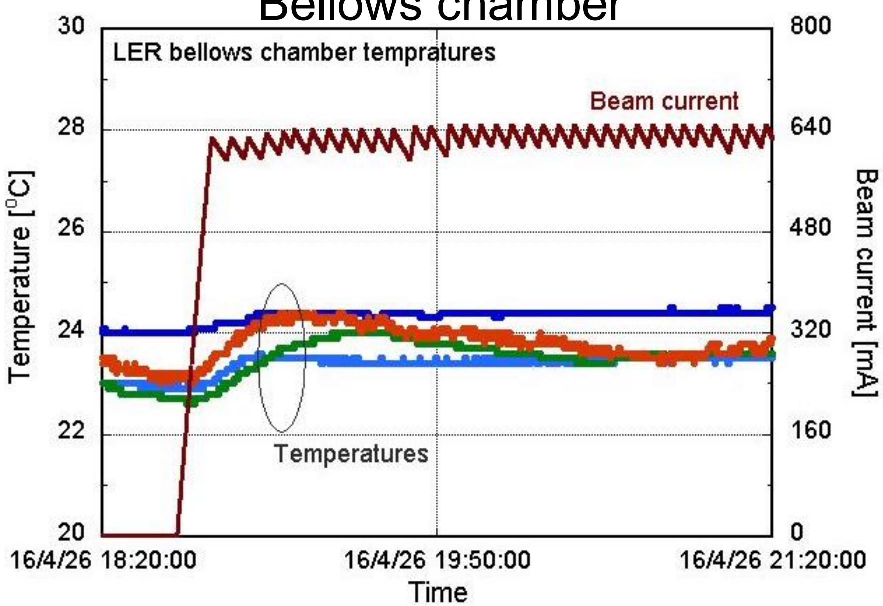
[HER]

- Max. Beam current: 590 mA
- Avg. Pressure ~ 3×10^{-7} Pa (whole ring) ~ 1×10^{-7} Pa (arc sections)
- Lifetime ~ 600 min.

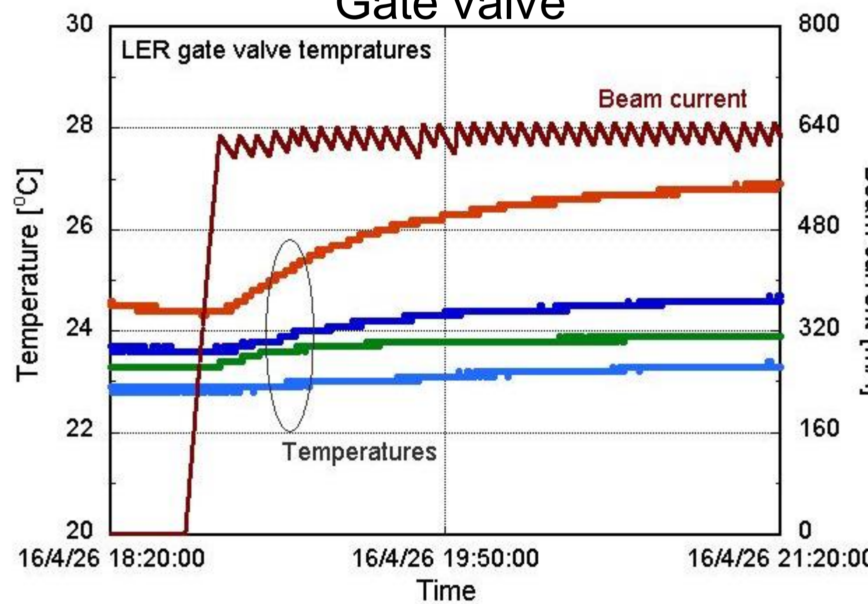
Present status

- **Status of new vacuum components**
  - Confirming the stability of the new vacuum components was a major subject for the Phase-1 beam commissioning.
  - No extra heating or abnormal pressure rise in these components has been observed so far.
  - The temperature rises in the bellows chambers, gate valves and flanges are less than 2 °C at 650 mA, for example.

Bellows chamber

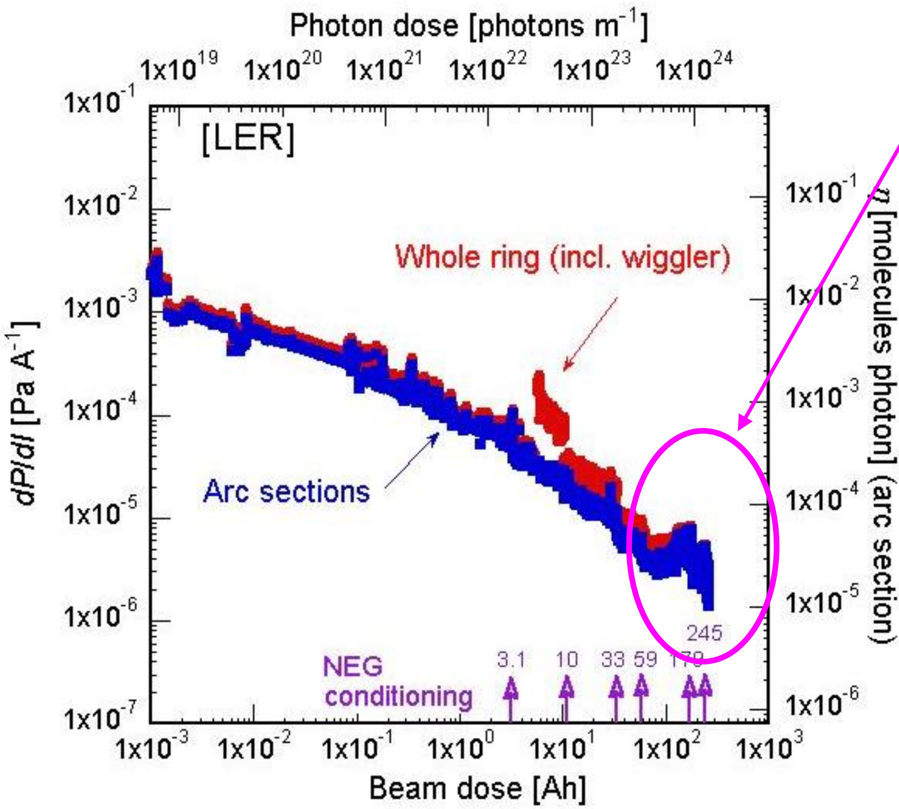


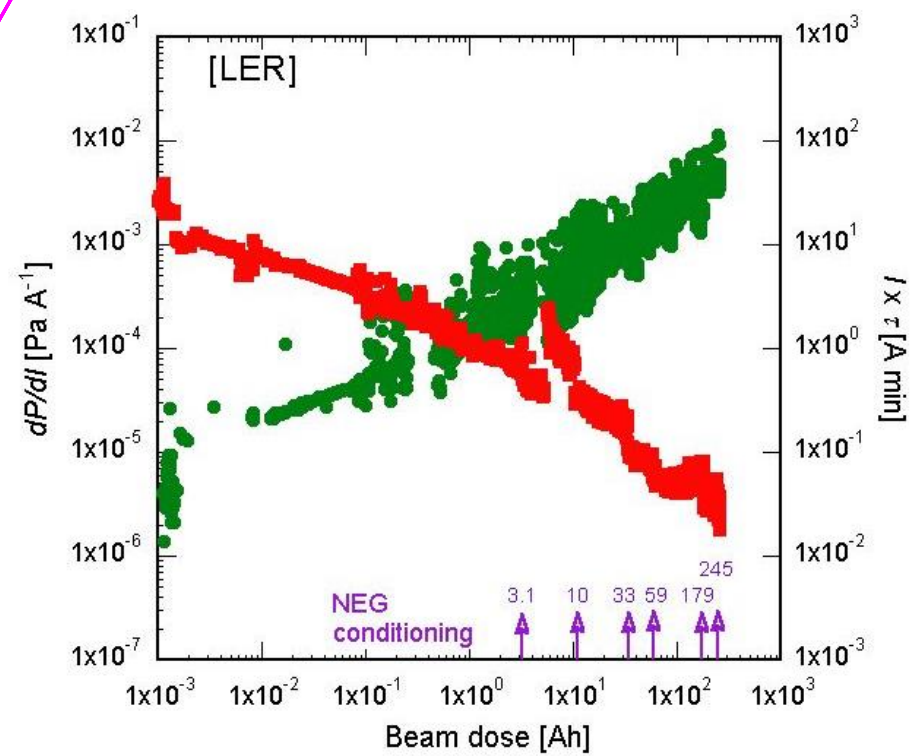
Gate valve



Present status

- **Vacuum scrubbing: LER(1)**
  - The *dP/dI* value for arc section, where all of the beam pipes were newly fabricated, was ~3×10^{-6} Pa A^{-1} at the beam dose of 200 Ah. The η was ~2×10^{-5} molecules $photon^{-1}$ [for pumping speed = 0.4 $m^3s^{-1}m^{-1}$].
  - The decrease rate of *dP/dI* slowed down recently. ← nonlinear behavior of pressures against the beam current (discussed later).

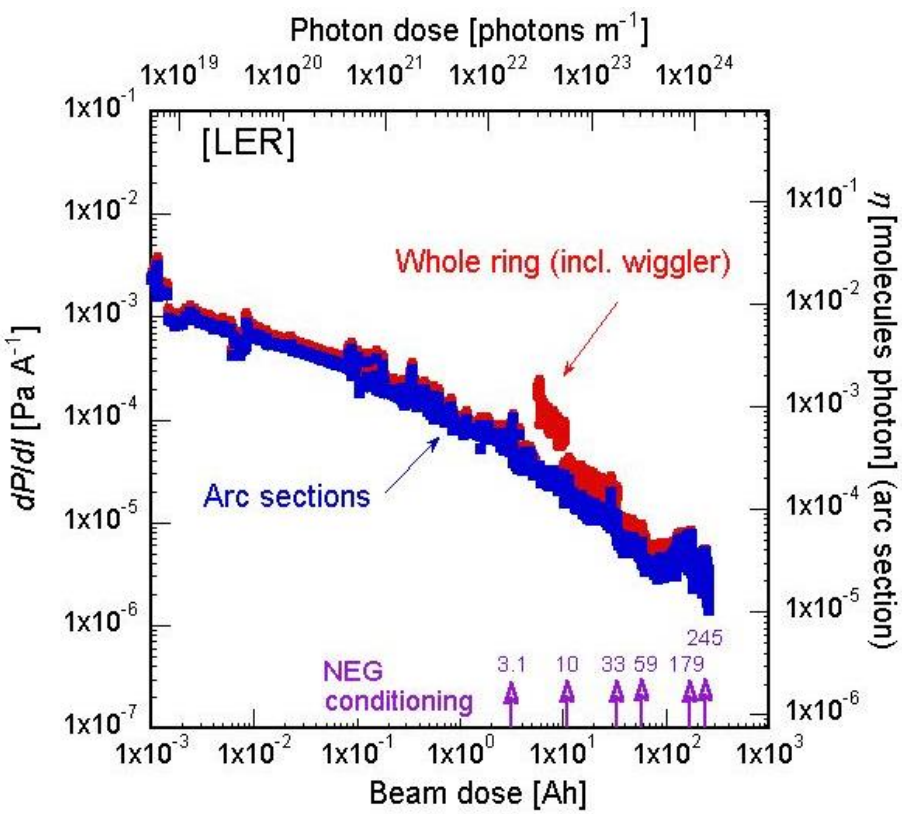


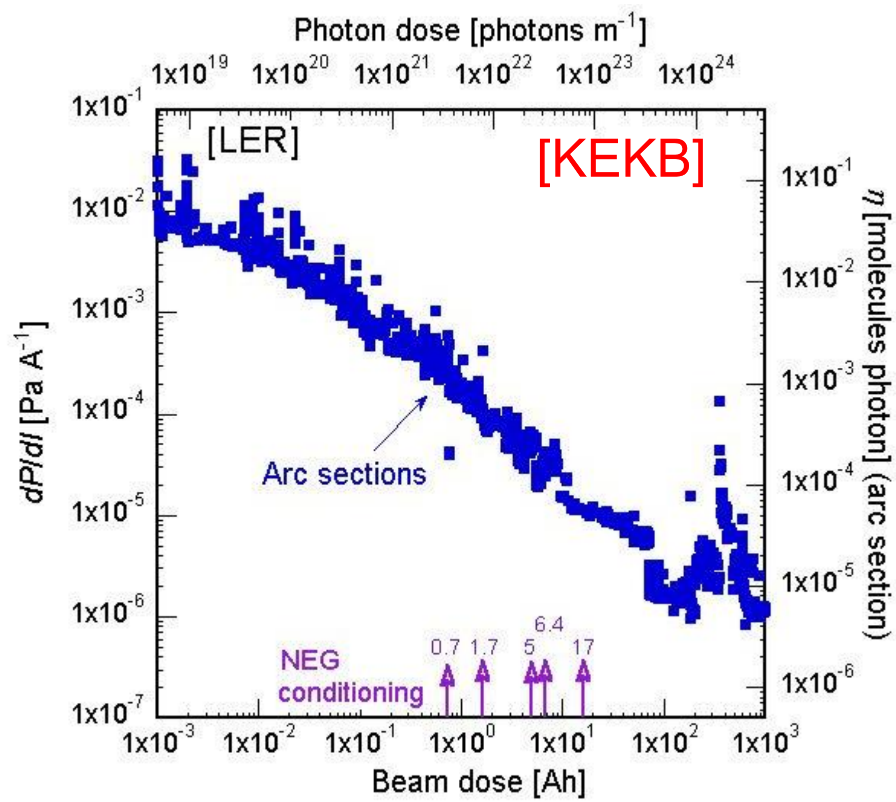


Present status

Vacuum scrubbing: LER(2)

- Compared to the case of the KEKB, which used circular copper beam pipes without any coating, *dP/dI* value at the initial stage was lower by several factors. Recently, however, *dP/dI* value is almost the same as the case of KEKB at the same beam dose.

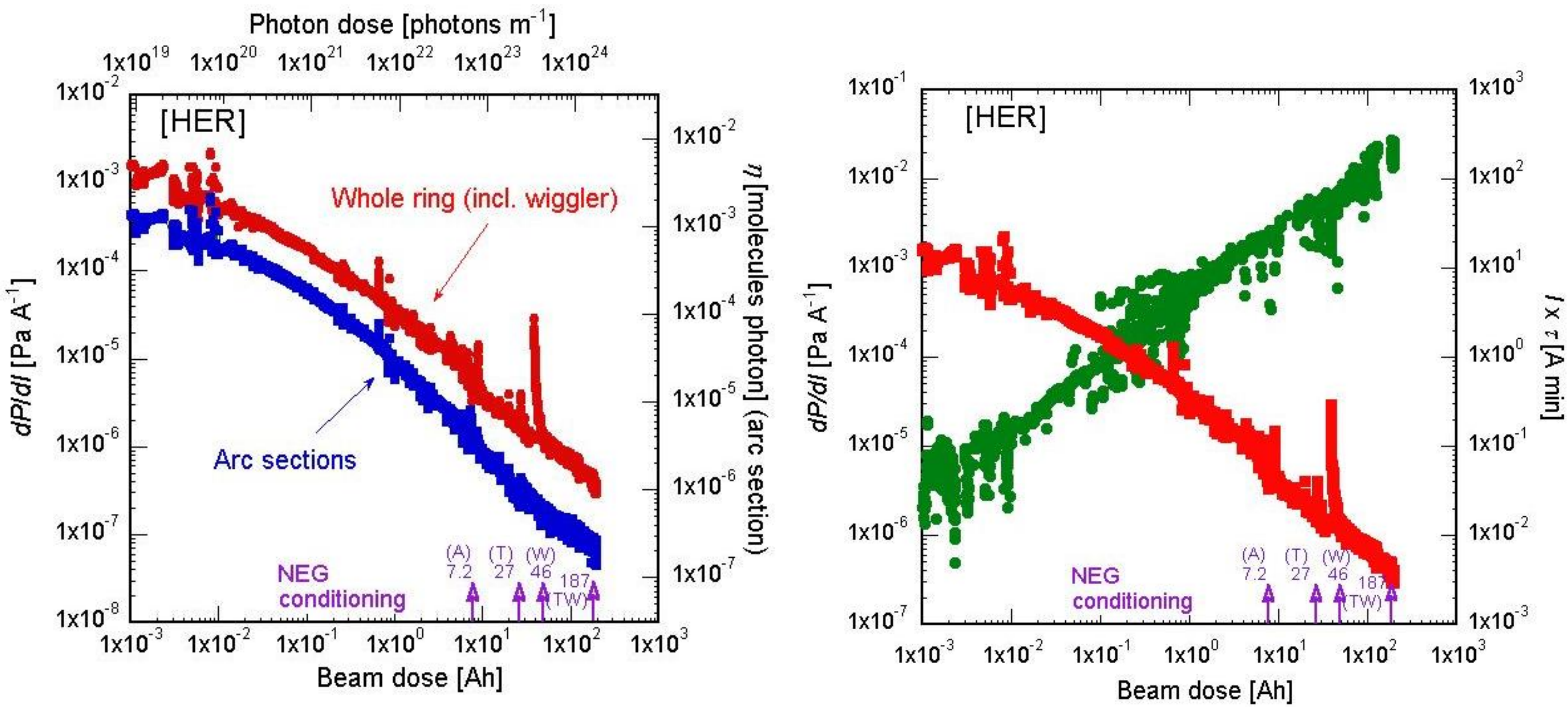




Present status

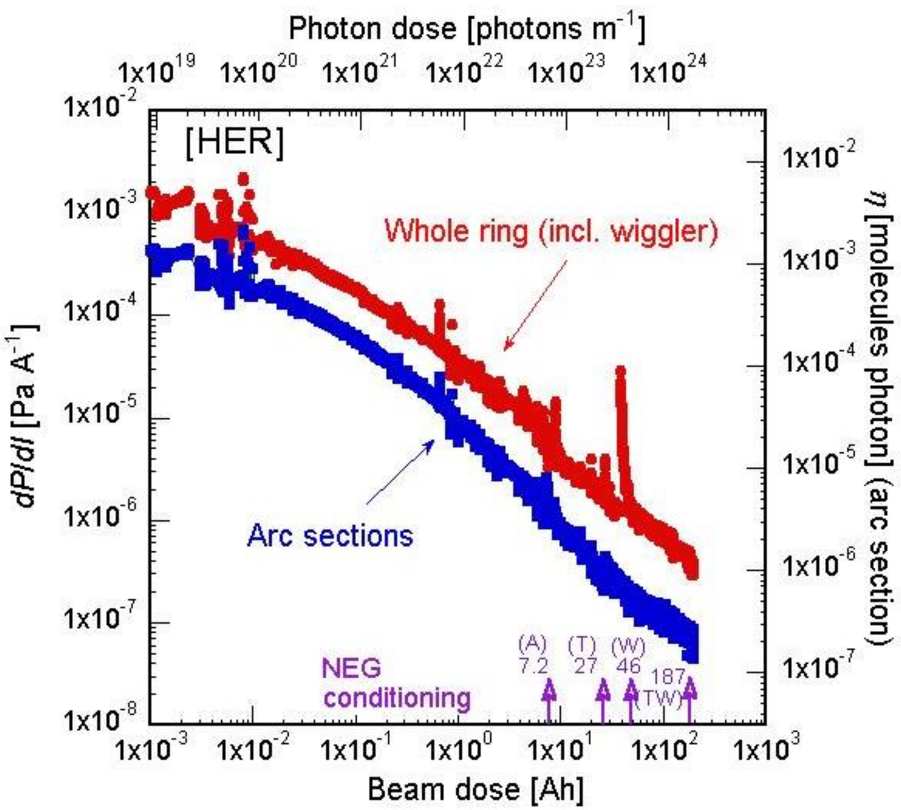
Vacuum scrubbing: HER(1)

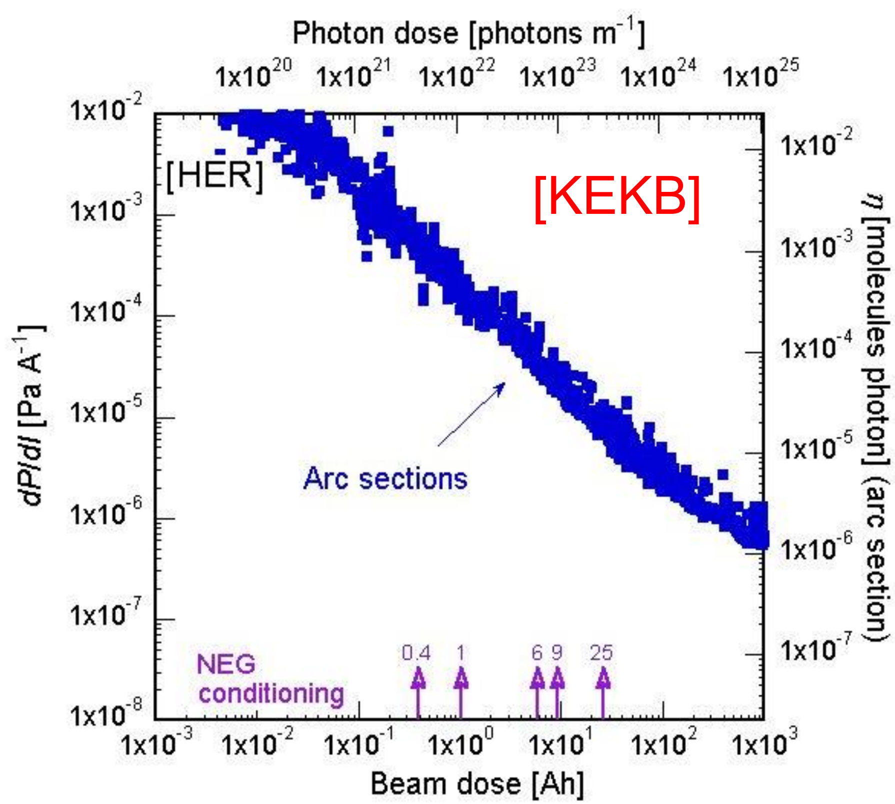
- The *dP/dI* value at the arc section, where most of the beam pipes was reused from KEKB, was ~1×10^{-7} Pa A^{-1} at the beam dose of 200 Ah. The η was ~3×10^{-7} molecules $photon^{-1}$ [for pumping speed = 0.3 $m^3s^{-1}m^{-1}$]. The η is much smaller than that of LER.



Present status

- **Vacuum scrubbing: HER(2)**
  - The *dP*/*dI* value is comparable to that in the case of KEKB at the final stage. This means that the surface of the reused beam pipes "remembers" the conditions in the KEKB, even though the beam pipes were exposed to the air for vacuum work.

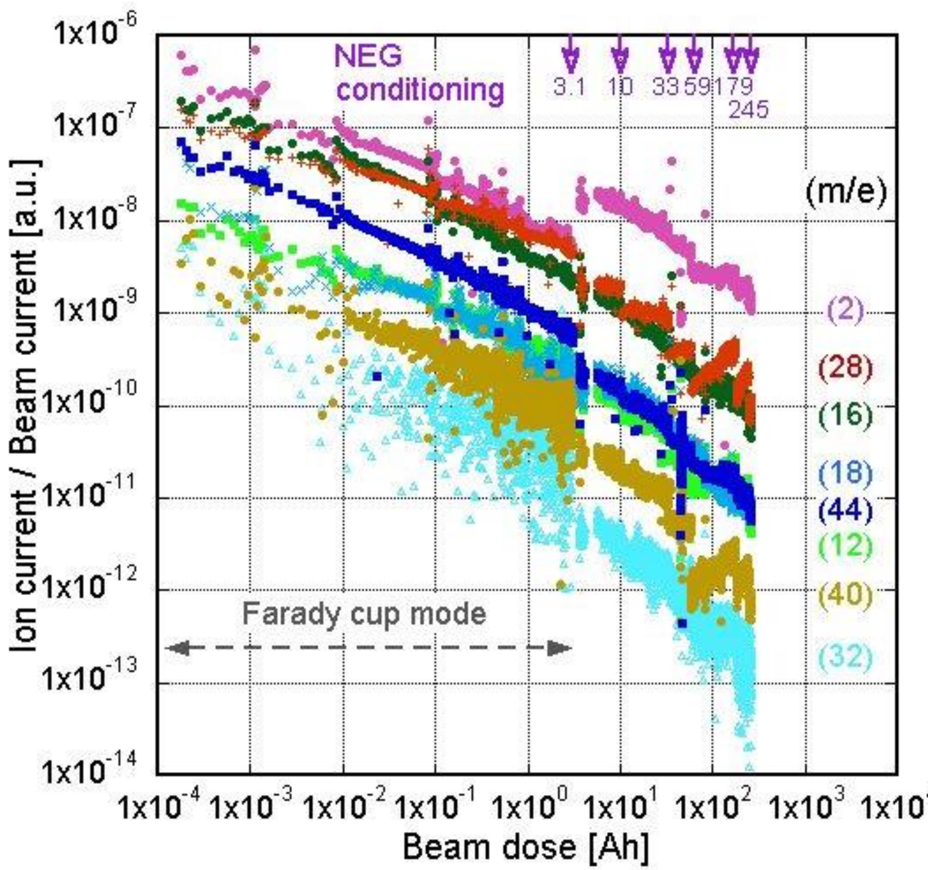




Present status

➢ Residual gases

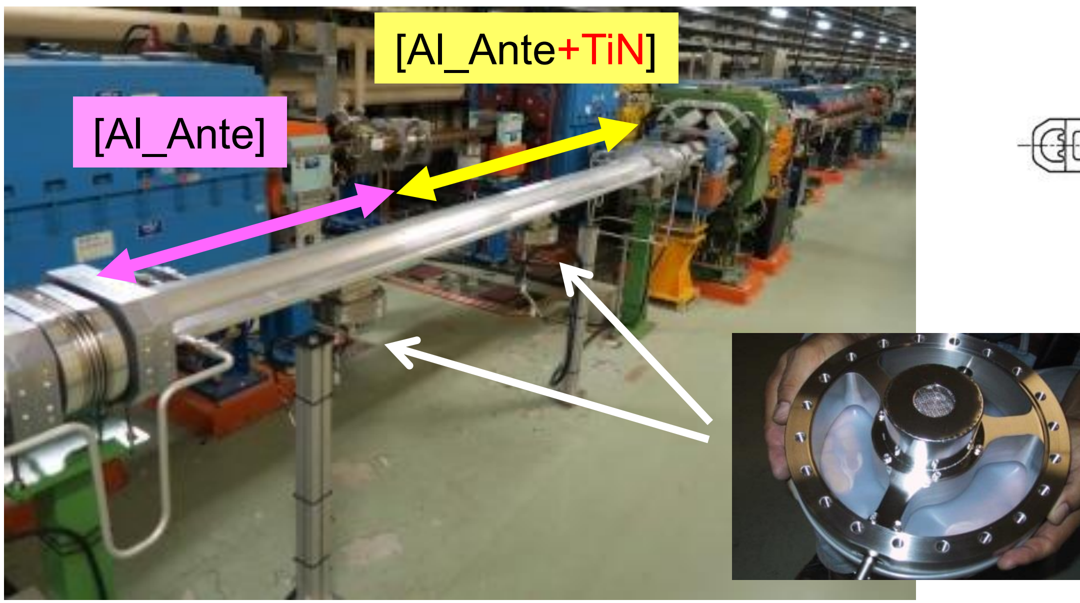
- Residual gases during the beam operation have been monitored with a quadrupole mass analyzer (QMA) at an arc section.
- The QMA is located just above a sputter ion pump.
- The main gases are hydrogen (m/e = 2), carbon monoxide (m/e = 28), methane (m/e = 16), water (m/e = 18), and carbon dioxide (m/e = 44).
  - The high partial pressure of methane should be due to the pumping system using NEG as a main pump.
  - Because the beam pipes were not baked in the tunnel, water vapor still remains in the beam pipe.

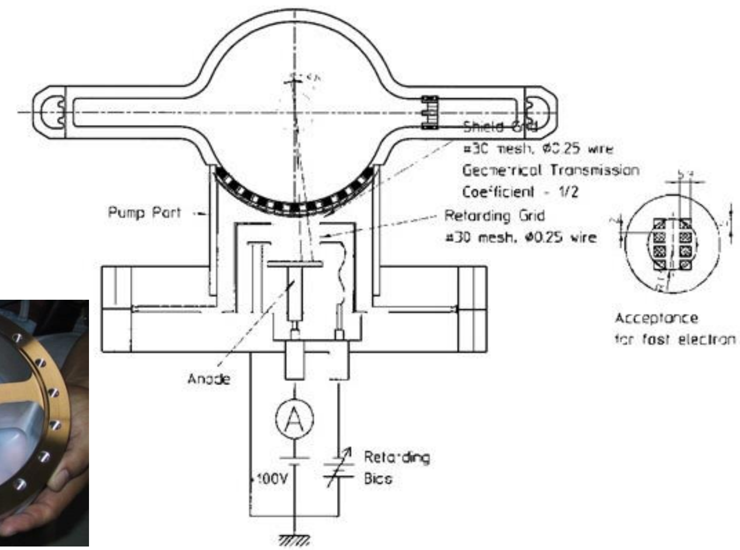


Present status

➢ Electrons in positron beam pipe(1)

- In relation to the ECE, we set up two electron current monitors used in the experiment in KEKB for measuring the electron numbers around the circulating beam in the new aluminum beam pipe
  - The measured electron currents almost reflect the electron density around the beam orbit.
- The electron currents at an aluminum beam pipes with and without TiN coating can be measured at the same time now.





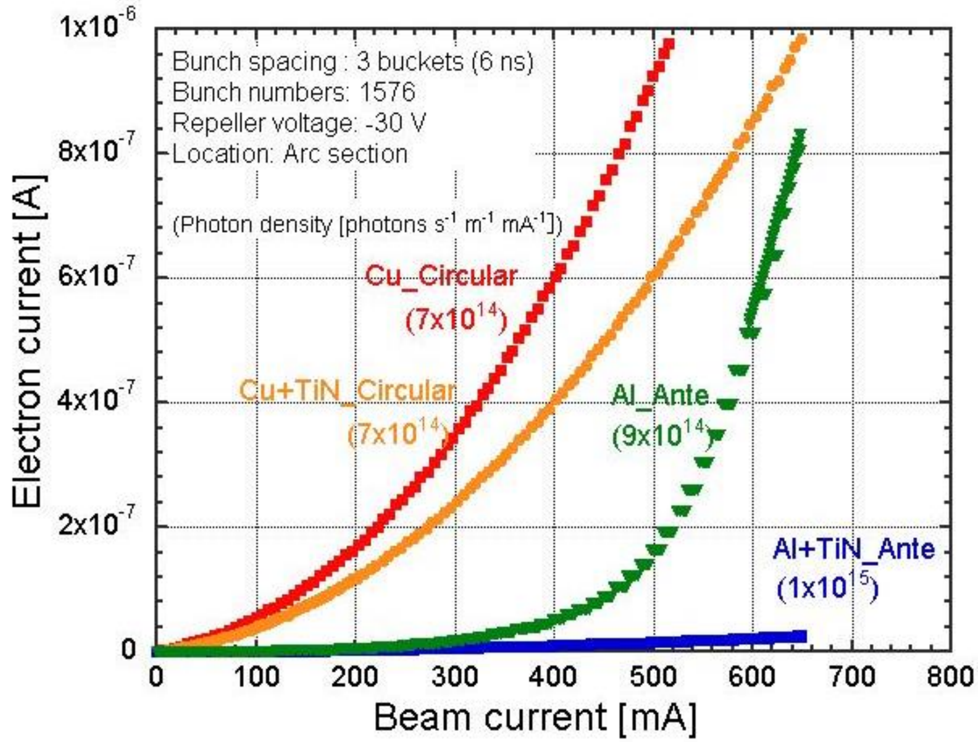
Curtesy of Kanazawa

Present status

➢ Electrons in positron beam pipe(2): Preliminary experiments

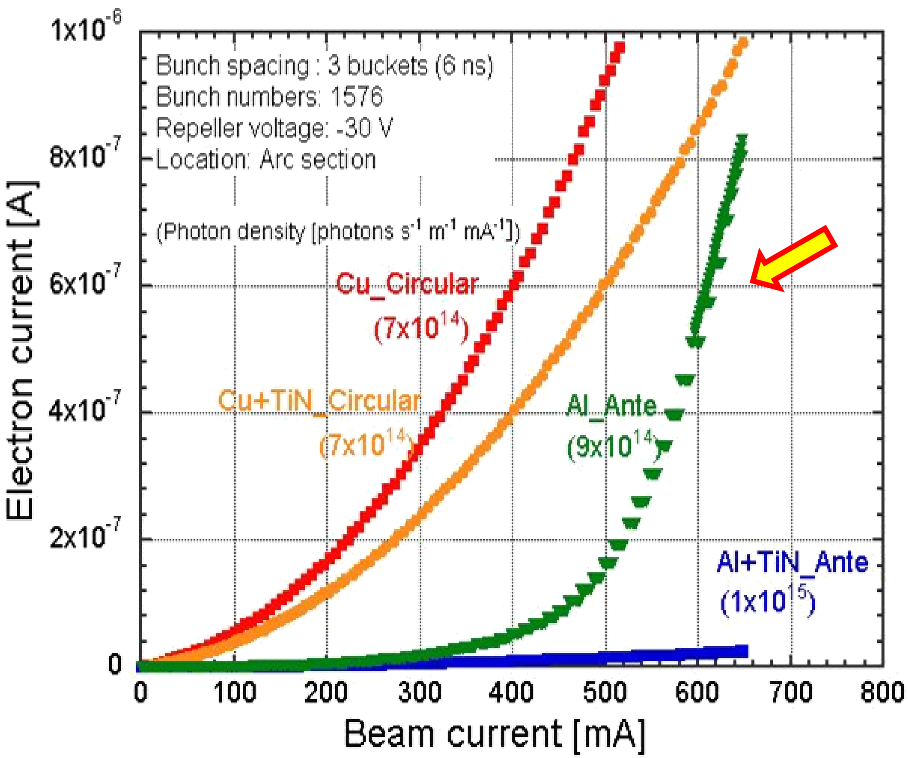
- The electron currents were measured during the beam operation, and compared with the data of KEKB, where circular beam pipes were used.
- The effect of the antechambers was clearly observed, that is, the photoelectrons in the beam channel are much reduced.

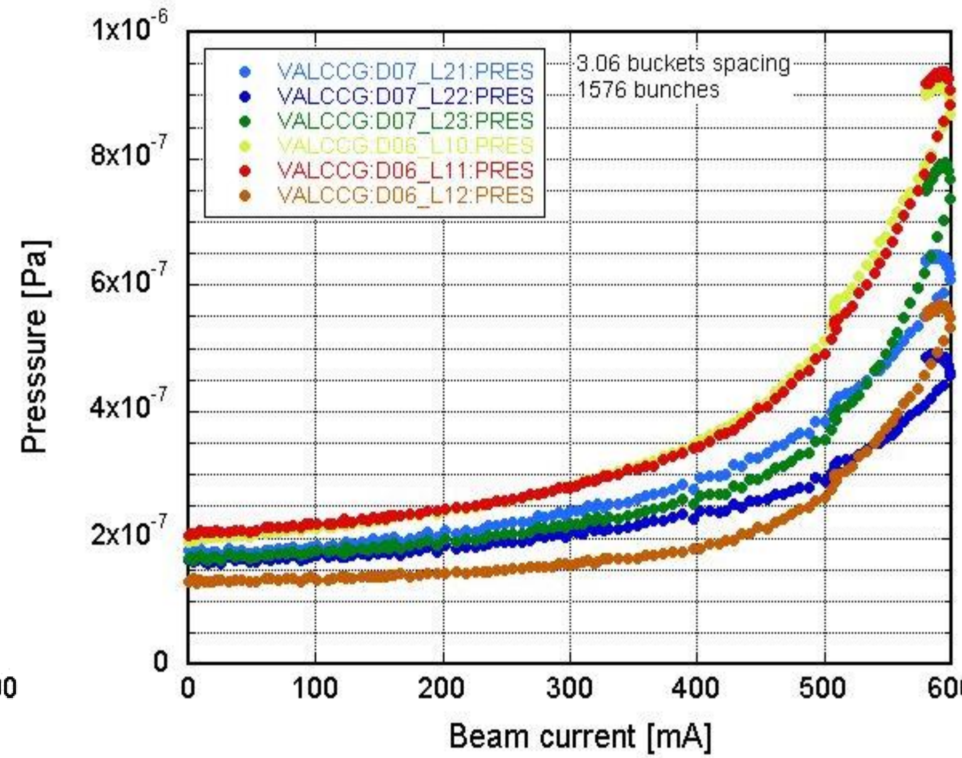
- For the case of aluminum beam pipes without TiN coating, the multiplication of secondary electrons was observed from > 400 mA.
  - SEY of bare aluminum surface is much higher than TiN-coated aluminum surface.
  - TiN coating is working!
- We will continue the experiments.



Problem-1

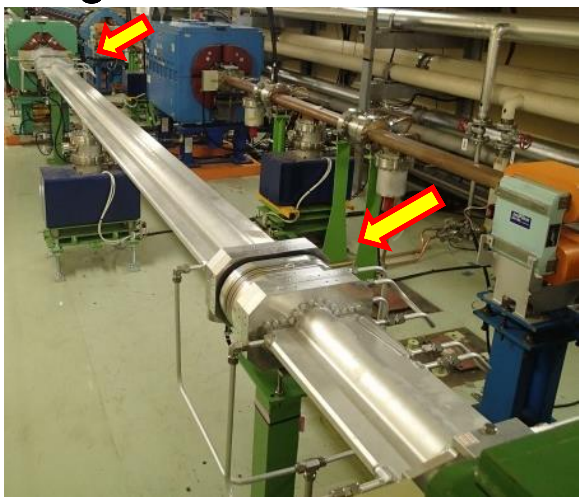
- **Non-linear pressure rise against beam current in LER**
  - The pressures at whole LER ring showed the nonlinear behavior against the beam current over 400 mA.
  - The behavior is quite similar to that of electron currents measured at aluminum parts without TiN coating.

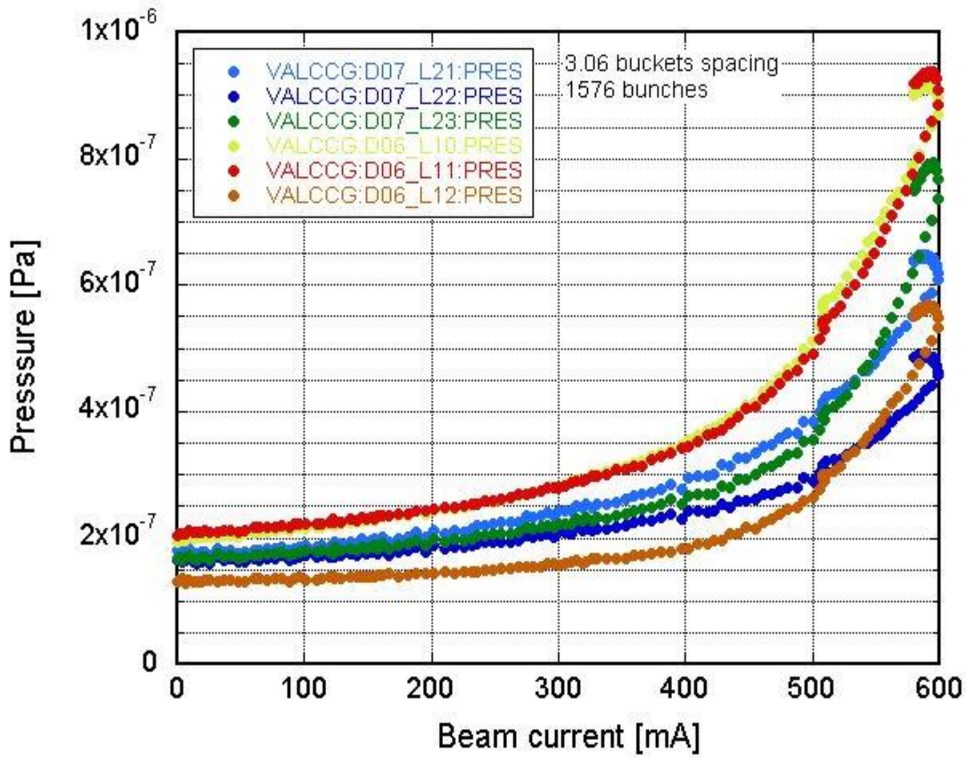




Problem-1

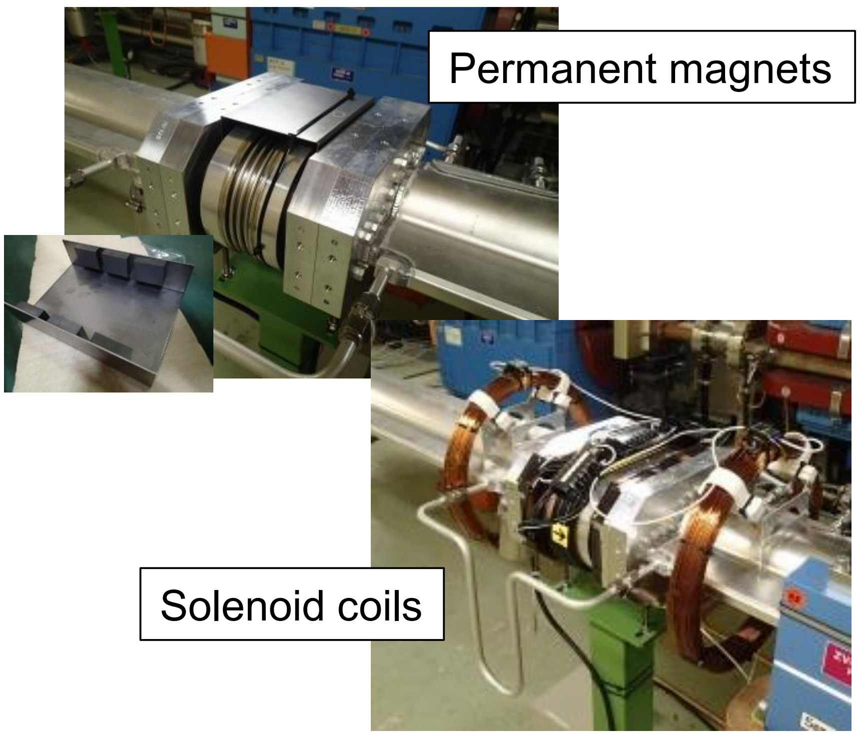
- **Non-linear pressure rise against beam current in LER**
  - The pressures at whole LER ring showed the nonlinear behavior against the beam current over 400 mA.
  - The behavior is quite similar to that of electron currents measured at aluminum parts without TiN coating.
  - Actually, we have aluminum bellows chambers without TiN coating along the ring. The bellows chamber has a length of 0.2 m and located every 3 m on average.

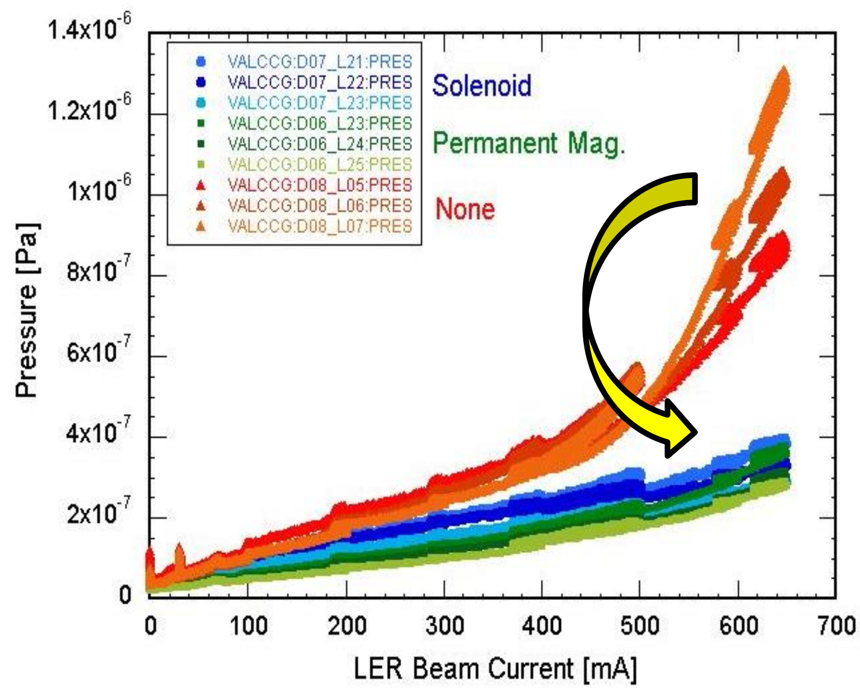




Problem-1

- **Non-linear pressure rise against beam current in LER**
  - As a test, we applied a solenoidal magnetic field by solenoids or permanent magnets at nine aluminum bellows chambers (~30 m section). The strength is 40 ~ 100 G at the center.
  - As a result, the rate of pressure rise at this section relaxed!
  - We will wind solenoids or put permanents magnets on all of the aluminum bellows chambers before the physics run (Phase-II commissioning).

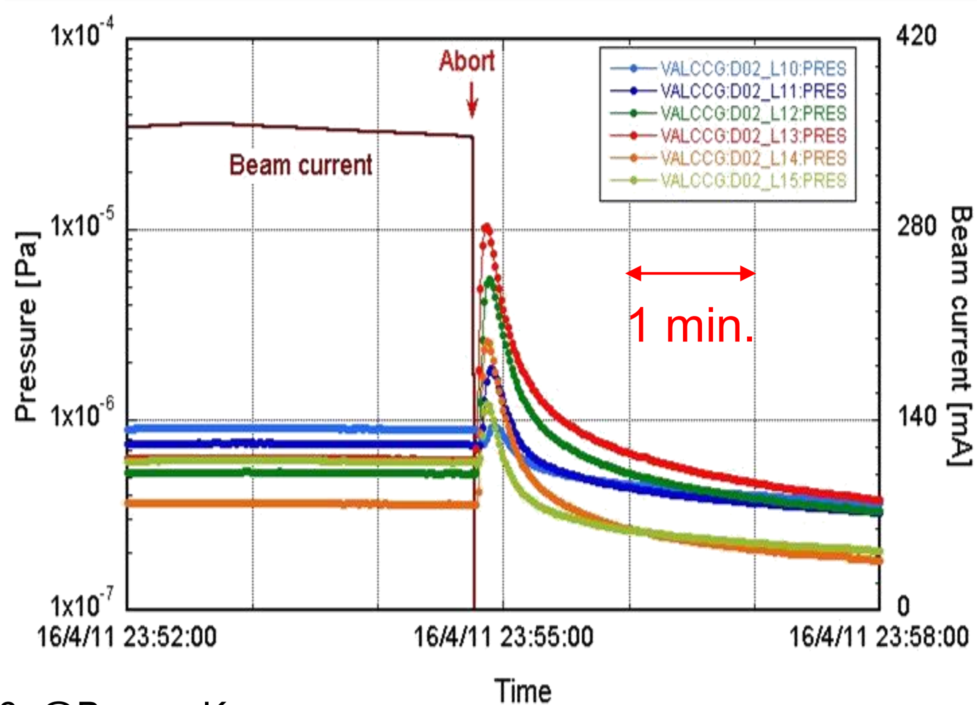




Problem-2

Pressure bursts accompanying beam loss in LER

- One recent concern is that beam aborts accompanied by localized pressure bursts have been frequently observed in the LER.
- The beam loss monitors trigger the beam aborts.
- The locations of the pressure bursts have spread to more than 10 points along the ring.
  - In most cases, the bursts were observed near aluminum beam pipes for dipole magnets, with groove structure.
- The reason for the pressure bursts is not well understood.
- Possible causes are the discharge at poor electrical contacts by the wall current and the collision of dusts (small particle) with circulating beams.
- In any way, careful and continuous observation is required.



Summary

- **The first commissioning of the SuperKEKB vacuum system started satisfactorily.**
  - No abnormal temperature rises or vacuum pressure has been observed for the new vacuum components so far.
  - Vacuum scrubbing is progressing steadily.
  - The reused beam pipes for HER remembered the condition in the KEKB.
  - The residual gases are typical one for the NEG pump system.
  - The effects of the antechambers and TiN coating can be observed in the electron densities in the LER.
  - The nonlinear behavior of pressures were observed in the LER, which should be due to the multipacting of electrons at aluminum bellows chambers.
  - The pressure burst accompanying beam aborts is a major concern recently.
- **The status will be continuously monitored.**
- **The stored beam currents will be gradually increased to close to 1 A during the Phase-1 commissioning.**

Thank you for your attention

	LER (positron)	HER (electron)	Unit
Material of new beam pipe	Al-alloy (arc) OFC (wiggler)	OFC (arc), OFC (wiggler)	
Cross section of new beam pipe	ϕ90 + Antechambers	Racetrack (50×104) ϕ50 + Antechambers	
Main pumps	NEG (strip)	NEG (strip + cartridge)	
Total Power of SR	1.1 (arc:2200 m) 6.3 (wiggler:300 m)	5.2 (arc: 2200 m) 1.1 (wiggler:100 m)	MW
Critical Energy of SR	1.9 (arc) 9.2 (wiggler)	7.2 (arc) 17 (wiggler)	keV
Max. SR power line density	2.6 (arc) 13 (wiggler)	7.7 (arc) 9 (wiggler)	kW m^{-1}
Avg. photon flux line density	~5.5×10^{18}(arc) ~4.7×10^{19}(wiggler)	~6.8×10^{18}(arc) ~1.3×10^{19}(wiggler)	photons s^{-1} m^{-1}
Linear pumping speed	~0.1 (arc)	~0.06 (arc)	m^3 s^{-1} m^{-1}
Ave. pressure with beam	~10^{-7}		Pa
Ave. base pressure	~10^{-8}		Pa