[WEPML058]

DEVELOPMENT OF LOW-Z COLLIMATOR FOR SuperKEKB

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INTRODUCTION

We designed a new collimator to fit the antechamber scheme. The location of the collimators is shown in Fig. 1.

- Collimators were installed in the main ring of SuperKEKB to suppress background noise (BG) in a particle detector complex named Belle II. The collimators successfully reduced the BG when the gaps of the collimator were closed. However, in high-current operations (greater than 500 mA), collimator jaws were occasionally hit and damaged by abnormal beams. As a solution to this problem, a low-Z collimator with a jaw made of car-bon, which is relatively durable even if it collides with an abnormal beam, has been designed to protect important components.

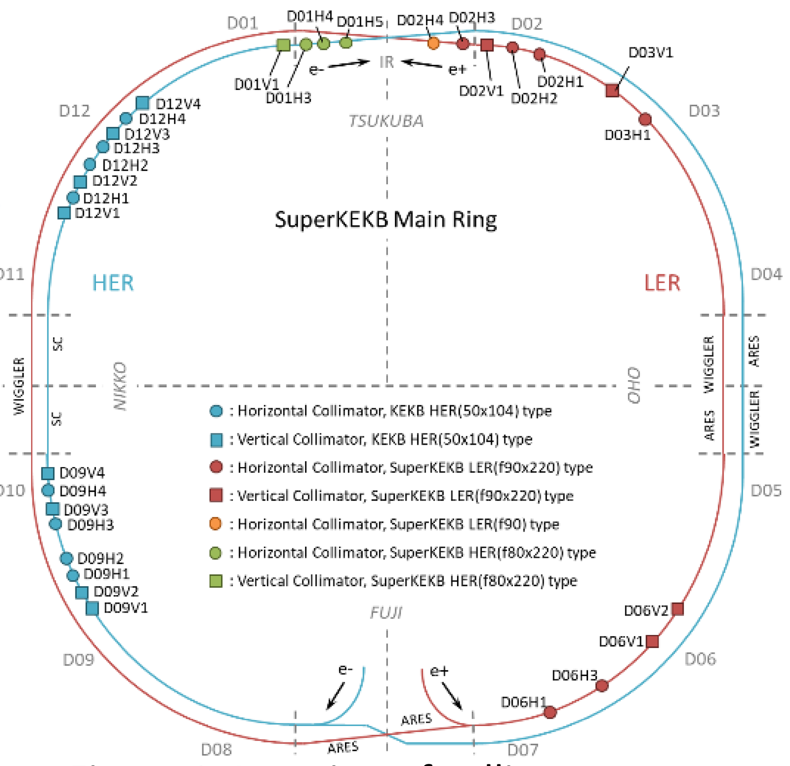

Figure 1: Location of collimators in the main ring of SuperKEKB.

MATERIAL AND STRUCTURE OF LOW-Z COLLIMATOR JAWS

Selection of the material for the collimator head

- To select a suitable material for the collimator head, the maximum temperature and melting point were investigated using FLUKA when the beam was shot into the sample. We observed from the result that carbon had the largest difference between the maximum temperature and melting point.
- In SuperKEKB, the beam that was scattered with the residual gas became BG in Belle II, so an ultra-high vacuum state is required. Therefore, we investigated whether outgassing from carbon would be a problem. In the electron/positron ring accelerator, outgassing through photon stimulated desorption (PSD) was the main source of out-gases source. We measured PSD as illustrated in Fig. 2 using BL21 at the photon factory. **The PSD of carbon (red circles) was found to be at good levels compared to that of copper (black circles).**

Beam tracking of scattered particles

- **When using carbon as the collimator head, we had to confirm that there is no risk of breakdown of Belle II due to scattered particles by the low-Z collimator.**
- L denotes the longitudinal length of the collimator head. Figure 3 illustrates the results of the absorbed particles in the jaw attached carbon (L = 60 mm). From Fig. 3, we found out that the number of absorbed particles in carbon is small even though carbon is at the tip. **This confirmed that carbon does not break easily when used as the collimator head.**

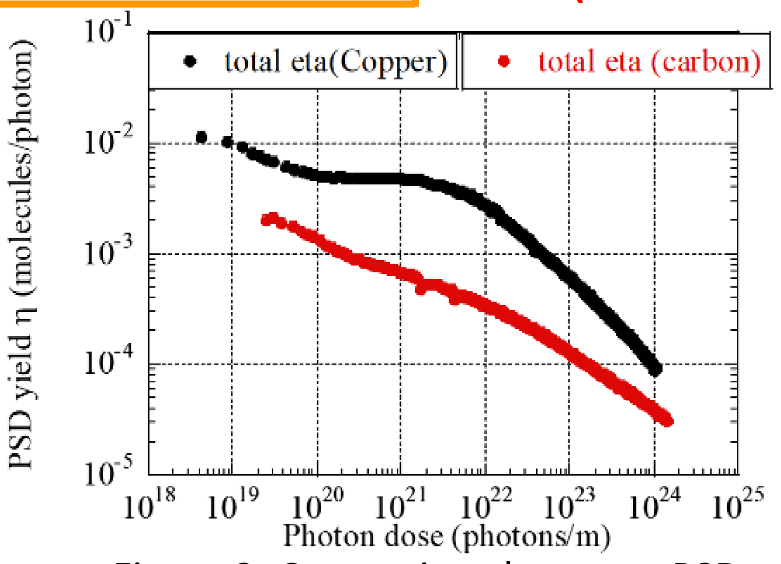

Figure 2: Comparison between PSD of copper and carbon.

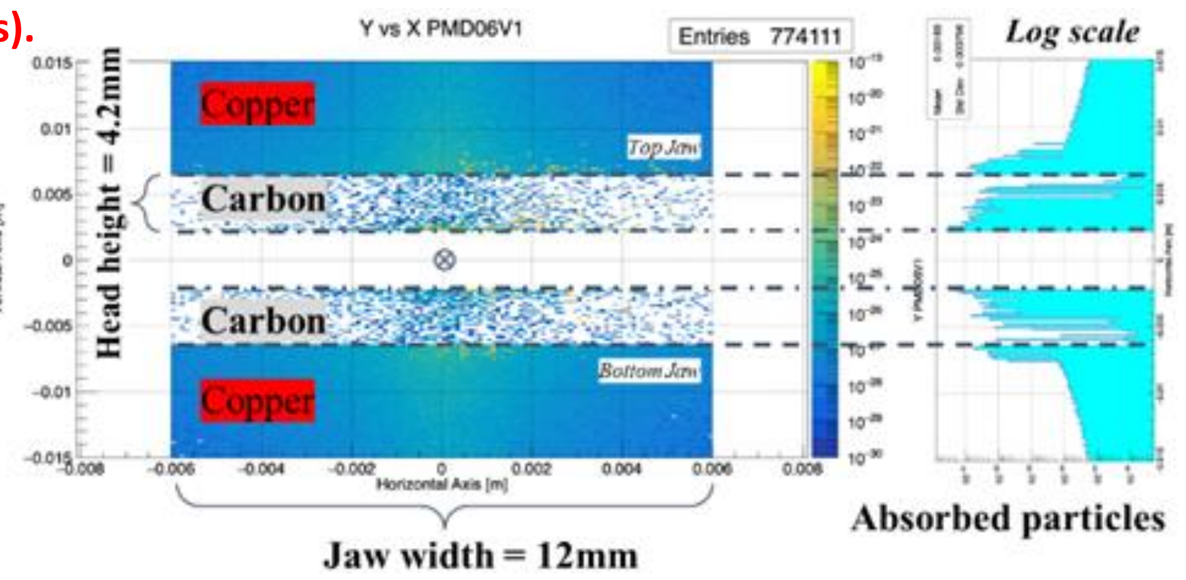

Figure 3: Absorbed particle distribution at the D06V1 jaw attached carbon (L = 60 mm).

Dust generation from the carbon

- While using carbon in the vertical collimator, it is necessary to select carbon that generates very little dust. If the beam interacts with the dust falling by gravity, this beam loses energy and travels through an abnormal orbit, therefore it can damage important components.
- Figure 5 shows the number of dust particles generated from the samples of carbon and glassy carbon with a carbon coat (GCWC). **In Fig. 5, we observed that GCWC generates less dust than carbon with/without gamma irradiation.**

Structure of low-Z collimator jaw

- Since collimator head gets heated owing to the resistive wall impedance, the structure of the jaw should have a cooling mechanism. If a gap exists between the body of the collimator jaw and the head, there is a possibility of discharging in the gap, therefore, there should be no gap between the jaw and head of the collimator. **We discovered a way to bond copper and carbon as shown in Fig. 4.**

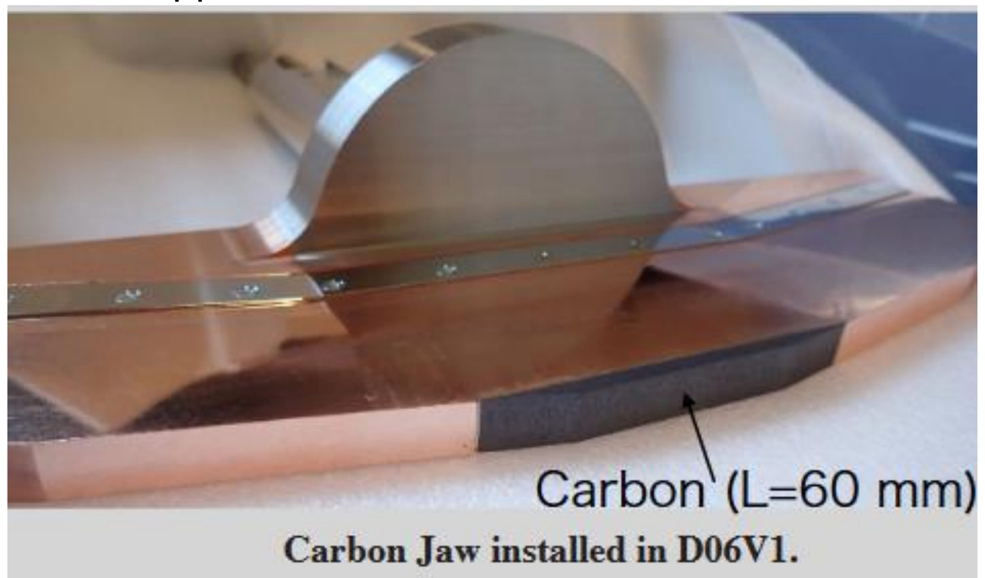

Figure 4: The jaw attached carbon

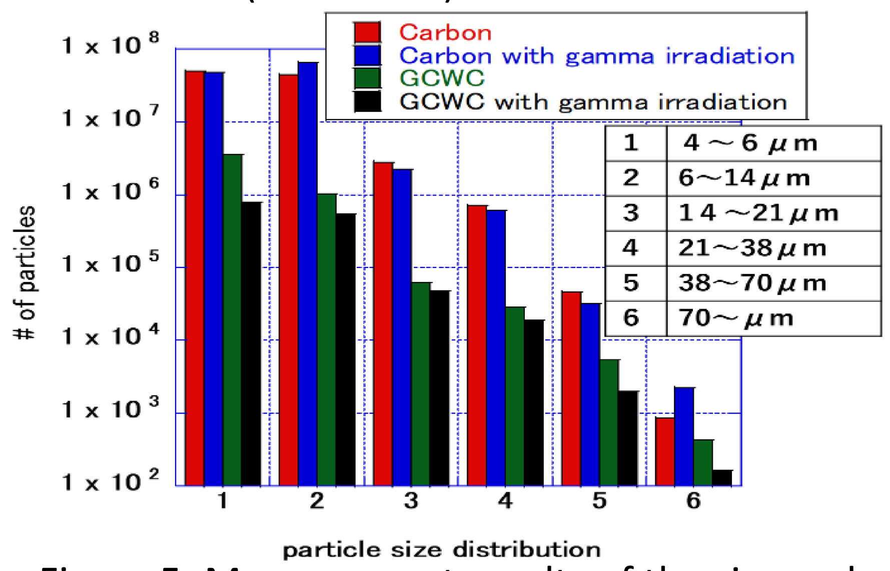

Figure 5: Measurement results of the size and number of the dust particles generated.

Electrical resistance in the high frequency range of carbon

- The bunch length of SuperKEKB LER is approximately 6 mm, thus it has a very high frequency component. Carbon has the property of passing direct current (DC). However, it has been reported that it has high frequency absorption characteristics depending on the manufacturing method. We attempted to estimate the skin effect of carbon from the measured Q value using a cavity, as illustrated in Fig. 6. First, using coppers as end plate, we checked whether the modes could be separated. The measured value of the frequency difference between the modes in which the degeneracy was resolved was 22 MHz, which matched the calculated value as shown in Fig. 7.
- From the Q value of TE011 mode measured at 5.04 GHz, the calculated resistance value was 3.33 × 105 Ω· m assuming the characteristics of the skin effect of the metal. **It can be inferred that high frequency absorption of carbon is not significantly large in high frequency range.**

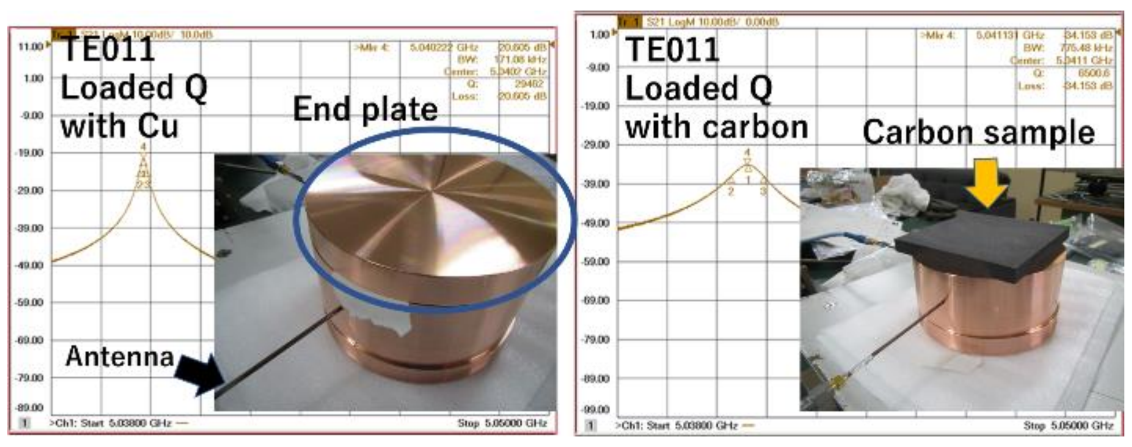

Figure 6: Cavity for measurement of electronic conductivity of the sample.

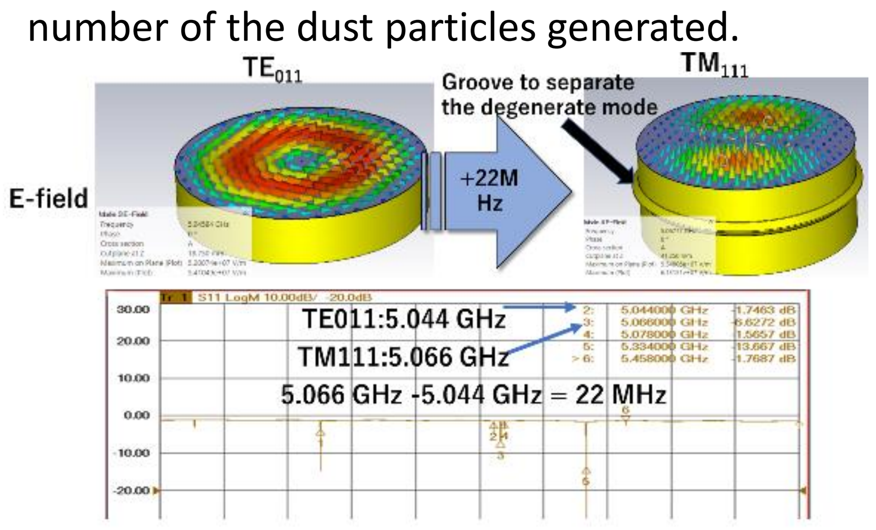

Figure 7: Excited mode in the cavity.

THE IMPACT OF LOW-Z COLLIMATOR ON BEAM COMMISSIONING

BG reduction and pressure change

- We conducted an investigation to establish whether the low-Z collimator had any negative effects on BG. From Fig. 8, we observed that BG decreases when the gap of the low-Z collimator was closed. Therefore, we concluded that the low-Z collimator had no negative effect on BG.
- The pressure normalized by the beam current (dP/dI) as a function of the beam dose, which is measured using a cold cathode gauge beside the D06V1 collimator, is shown in Fig. 9. We observed that the low-Z collimator jaws did not have any negative effect on pressure.

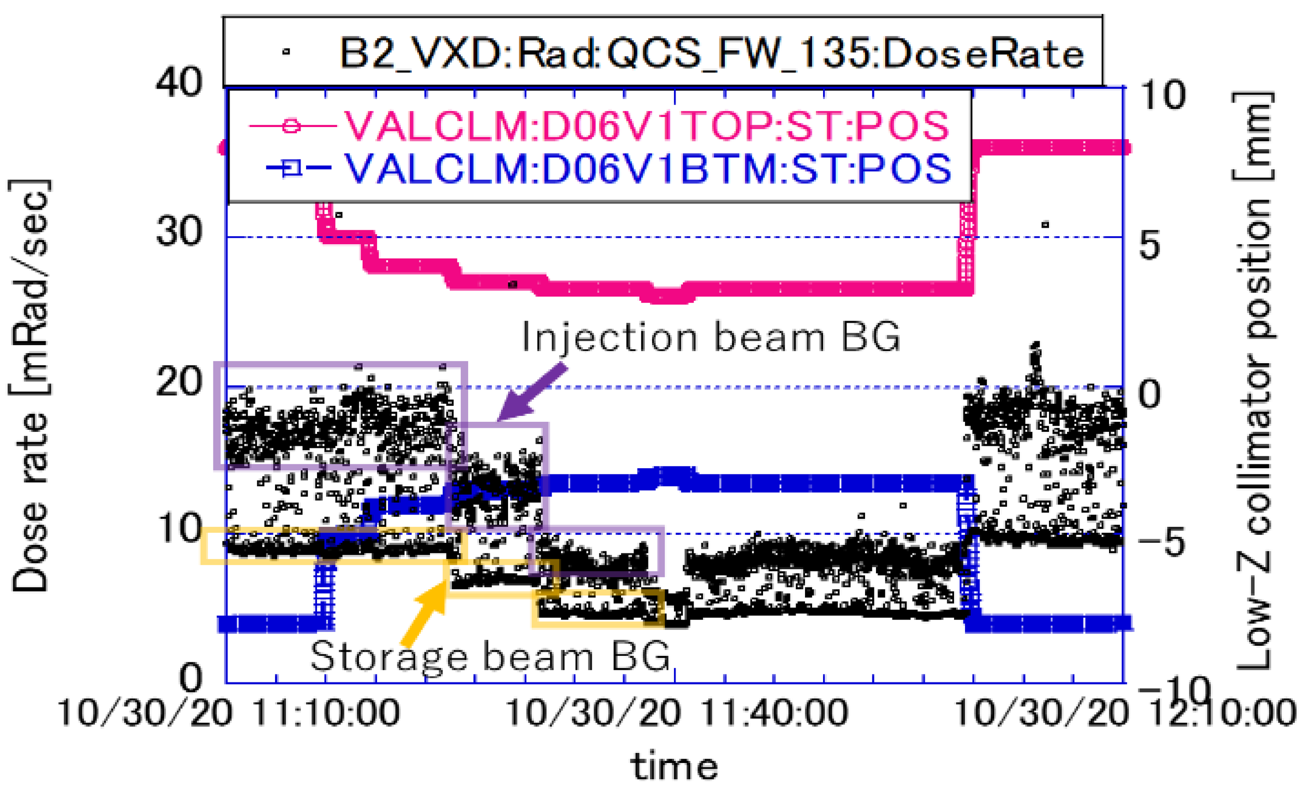

Figure 8: Measured value of BG when the gap of low-Z collimator changed.

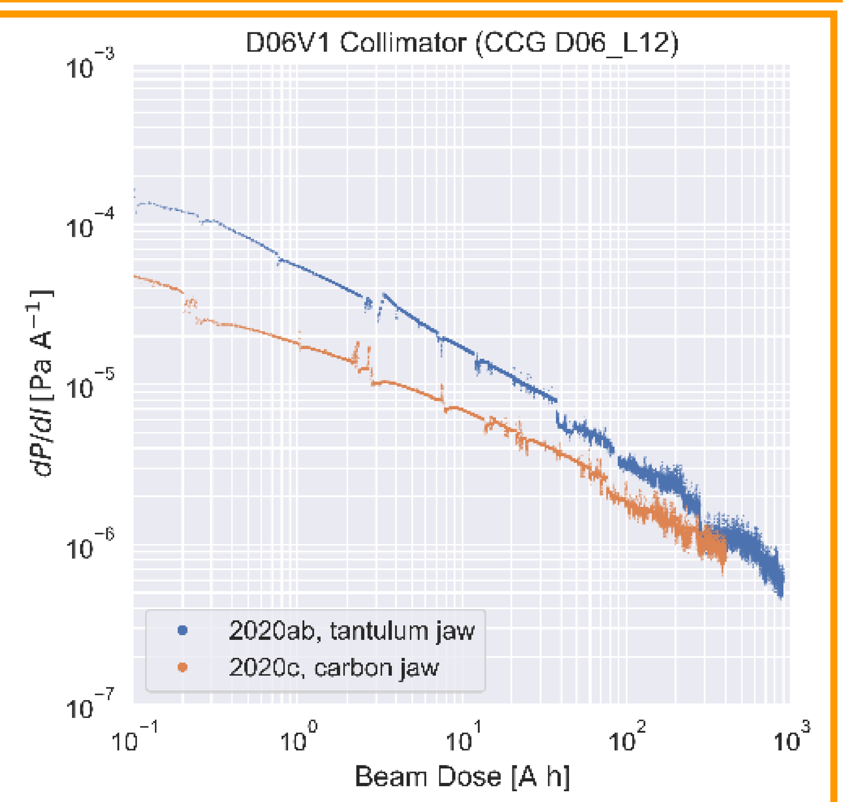

Figure 9: dP/dI beside the low-Z collimator as a function of the beam dose.

Effect of beam impedance

- It is well known that impedances can cause transverse mode coupling instability (TMCI) and limit the bunch current in storage rings [9]. In SuperKEKB, the main transverse impedance source is the collimators owing to their small gaps. The low-Z collimator (L = 60 mm) has a higher impedance than normal collimators attached to tantalum jaws (L = 5 or 10 mm). We measured the tune shift and observed mode coupling as illustrated in Fig. 10 and 11, respectively, and checked their relation to the gap of the low-Z collimator.
- **We observed that the measured value of the tune shift was consistent with the calculated value. However, the beam size blow-up, which is correlated with bunch current and impedance, was observed earlier than expected. We think localized wake of collimators is probably the cause.**

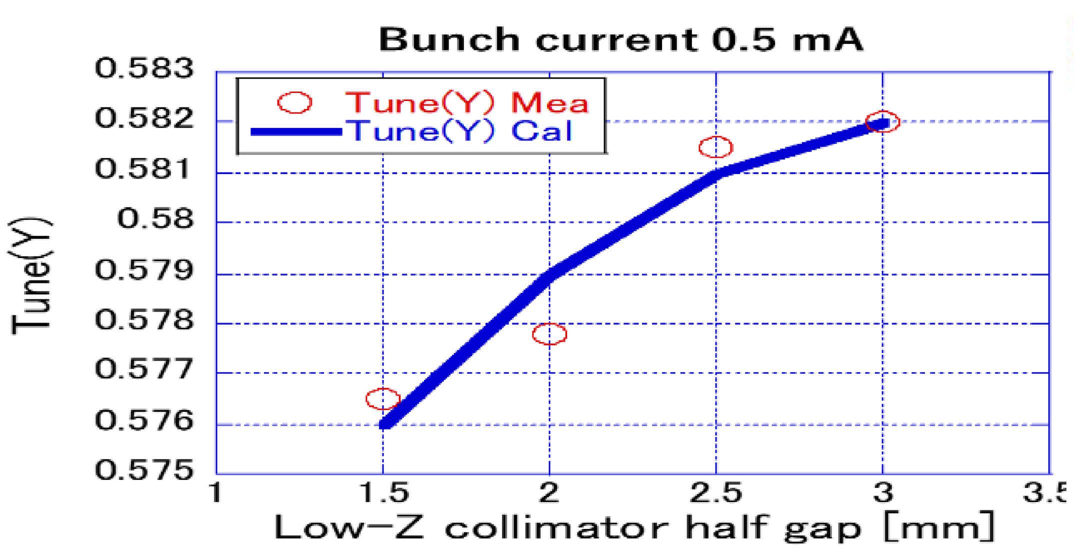

Figure 10: Measured tune shift compared with the estimated values from calculated impedance.

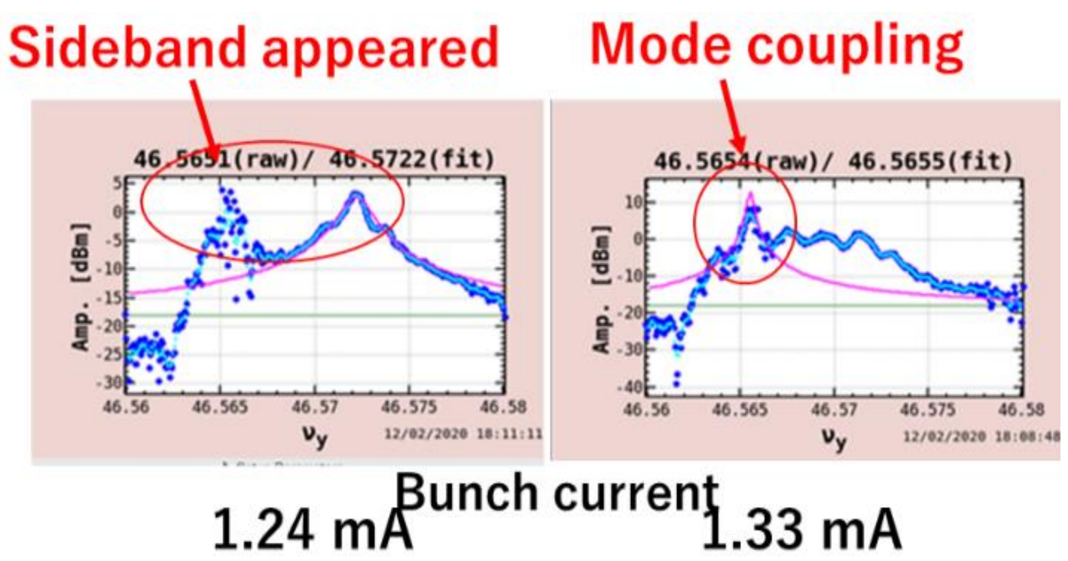

Figure 11: Observation of TMCI phenomenon (0 mode and -1 mode coupling)

CONCLUSION AND OUTLOOK

- To make the low-Z collimator, we performed numerous calculations and measurements. Based on the results, we developed a low-Z collimator using carbon for the SuperKEKB.
- We observed that the low-Z collimator did not adversely affect BG and pressure. However, beam size blow-up correlated with bunch current and impedance was observed earlier than expected.
- As part of future developments, it is under consideration to perform geometry optimization for the purpose of reducing transverse impedance from the low-Z collimator and thereby increasing the TMCI threshold in SuperKEKB.