# Updates on beam-beam simulations and recent results of machine studies

Demin Zhou

Accelerator theory group, Accelerator laboratory, KEK

Acknowledgments

Y. Zhang, and SuperKEKB commissioning group

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# Outline

- Updates on beam-beam simulations
- Machine studies



# Achievements in 2022a run

- investigated
  - Impact on luminosity performance to be identified
- group for their great work)
  - The interplay of BxB FB system and vertical impedance caused vertical blowup
  - Fine-tuning of FB system could avoid the vertical blowup

#### Significant improvement of specific luminosity (~15%) was achieved

- The factors contributing to luminosity gain are to be identified (personal viewpoint)
- Better optics correction ( $\epsilon_{v\pm} \leq 20$  pm achieved); ...

Chromatic coupling correction in LER (rotatable sextupoles) and HER (skew-sextupoles) was

#### The Source of "-1 mode instability" in LER was well understood (congratulations to ITF-TMCI

Weak sawtooth instability (~10 ms growth time with FB off) was observed in LER; The instability can be suppressed by FB system

Possible factors: Tune optimization at the end of 2021c run; Chromatic coupling correction in LER; Fine-tuning of FB system in LER;



## Luminosity performance in 2022a

• Significant improvement of specific luminosity was achieved in 2022a run







- BBSS simulations: Scan LER  $\nu_x$  (with LER  $\nu_y$  table of 2021.12.21)
  - Machine parameters were relatively stable since 2021c run.

|                         | 2021.12.21 |         |
|-------------------------|------------|---------|
|                         | HER        | LER     |
| I <sub>bunch</sub> (mA) | le         | I.25*le |
| # bunch                 | 393        |         |
| ε <sub>x</sub> (nm)     | 4.6        | 4.0     |
| ε <sub>y</sub> (pm)     | 35         | 20      |
| β <sub>x</sub> (mm)     | 60         | 80      |
| β <sub>y</sub> (mm)     |            | I       |
| σ <sub>z0</sub> (mm)    | 5.05       | 4.60    |
| Vx                      | 45.53      | 44.524  |
| Vy                      | 43.572     | 46.589  |
| Vs                      | 0.0272     | 0.0233  |
| Crab waist              | 40%        | 80%     |

#### • BBSS simulations: Scan LER $\nu_{\chi}$ (with LER $\nu_{y}$ and HER $\nu_{\chi,y}$ fixed as the values of the parameter





• BBSS simulations: Scan LER  $\nu_{\chi}$  (with LER  $\nu_{\chi}$  and HER  $\nu_{\chi,\chi}$  fixed as the values of the parameter table of 2021.12.21)







- BBSS simulations: Scan LER  $\nu_x$  (with LER  $\nu_y$  and HER  $\nu_{x,y}$  fixed as the values of the parameter table of 2021.12.21)
  - Similar features of vertical blowup by IBB (Left) and BBSS (Right)





#### IBB (Y. Zhang)









- BBSS simulations: Scan LER  $\nu_{\chi}$  (with LER  $\nu_{\chi}$  and HER  $\nu_{x,v}$  fixed as the values of the parameter table of 2021.12.21)
  - blowup by IBB (Left) and  $I_{b+}$ <0.7 mA.
  - when  $I_{h+}$ >0.7 mA.



#### IBB (Y. Zhang)

#### BBSS (K. Ohmi)







- BBSS simulations: Scan  $\nu_{x-} = \nu_{x+}$  (with  $\nu_{y\pm}$ ulletfixed, same as the parameter table of 2021.12.21)
- Longitudinal wakes of LER and HER included ullet
- Transverse wakes not included
- Simulations are done with  $\nu_{s-} = \nu_{s+}$
- Increasing  $\nu_s$  widens the space between ullet $\nu_x - k\nu_s = N/2$  resonances, qualitatively agreeing with C. Lin's simulations [1]



[1] C. Lin, 7th meeting of beam-beam sub-group, https://kds.kek.jp/event/41224/



- BBSS simulations: Scan  $\nu_{x-} = \nu_{x+}$  (with  $\nu_{y\pm}$  fixed, same as the parameter table of 2021.12.21)
- Longitudinal wakes of LER and HER included
- Transverse wakes of LER included
- Simulations are done with  $\nu_{s-} = \nu_{s+}$
- Do transverse wakes enhance beam-beam instability? To be confirmed.





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## Machine studies: Chromatic coupling correction in LER

- Mar. 14, 2022: Rotatable sextupoles study
  - Knobs of  $dR_2/d\delta$  were done by tuning rotatable sextupoles.
  - Clear response in  $\nu_x \nu_y k\nu_s = N$  (with  $\nu_s$  defined as negative) vs.  $dR_2/d\delta$  was investigated by tune survey with low bunch currents.
  - $dR_2/d\delta$ =-0.05 m gave minimum strength of  $\nu_x - \nu_y - 2\nu_s = N.$
  - It was seen that  $\nu_x \nu_y \nu_s = N$  and  $\nu_x - \nu_y - 2\nu_s = N$  could not be suppressed simultaneously.



# Machine studies: Chromatic coupling correction in HER

- Mar. 29, 2022: Skew-extupoles study
  - Knobs of  $dR_1/d\delta$  and  $dR_2/d\delta$  were done by tuning skew-sextupoles.
  - Tune survey to identify strengths of  $\nu_x \nu_y k\nu_s = N$ (with  $\nu_s$  defined as negative) with low bunch currents.

- 
$$dR_2/d\delta$$
=-50 mm was set to suppress   
 $\nu_x - \nu_v - 2\nu_s = N.$ 







#### Backup



# **Recommendations from ARC Intermediate ITF Review**

- General Remarks
  - include the other divisions in the ITF activities.
    - Response: ITF-BB group meetings will be announced to all divisions of Acc. Lab., KEK
  - to unravel the limitations in optics, impedance and beam-beam.
    - Beam dynamics virtual workgroup reactivated
    - Beam-beam related machine studies under the plan
- Beam-beam
  - The high momentum compaction optics (when/once available) should be tried in operation before the shutdown.
    - consideration

#### Clarify the performance reach of the crab waist scheme, its operational range in usable strength and its impact on reachable specific luminosity and on dynamic aperture

- Under discussion with the commissioning group
- beam simulations.
  - So far no clear strategy; strong-strong simulations are ongoing (KEK: workstations with ~150 CPUs; IHEP: Cluster)

#### Future ITF subgroup meetings could be announced to all KEK accelerator divisions to strengthen the cooperation and to better

It is important to assign sufficient time to machine studies together with extra manpower (from inside and outside KEK) in order

Beam-beam simulations with  $\nu_{s-} = \nu_{s+}$  undergoing; a proposal to commissioning group under preparation; optics design team under

#### Consider using supercomputer facilities or an upgrade of CPU power for the important and very insightful strong-strong beam-

Complete the inclusion of both longitudinal and transverse beam coupling impedance model in the beam-beam simulation tools TMCI group (T. Ishibashi) is leading this task of impedance modeling; Available data are implemented in beam-beam simulations





# **Recommendations from ARC Intermediate ITF Review**

#### Beam-beam

- - Under consideration
- crab waist strengths, other than the actual settings (80%/40%).
  - Strong-strong simulations with SC is not trivial; Strategy to be defined
  - Increasing HER CW strength was simulated/proposed; Other options under investigation -
- vertical blowup control.

Study the effect of measured magnitude of longitudinal bunch oscillations (if any) on the simulated beam-beam performance.

# Simulate the specific luminosity versus bunch-current product including the space charge. Carry out simulations for different

#### From an operations point of view, refine chromatic coupling optimization which could give a rather easy gain in terms of

Chromatic R2 correction in LER was done; Chromatic coupling correction using skew-sextupoles in HER was done

