REPORT ON IP FEEDBACK STUDIES AT SUPERKEKB

188th FCC-ee Accelerator Design Meeting 10/07/2024

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Outline

Introduction

SuperKEKB IP Feedback

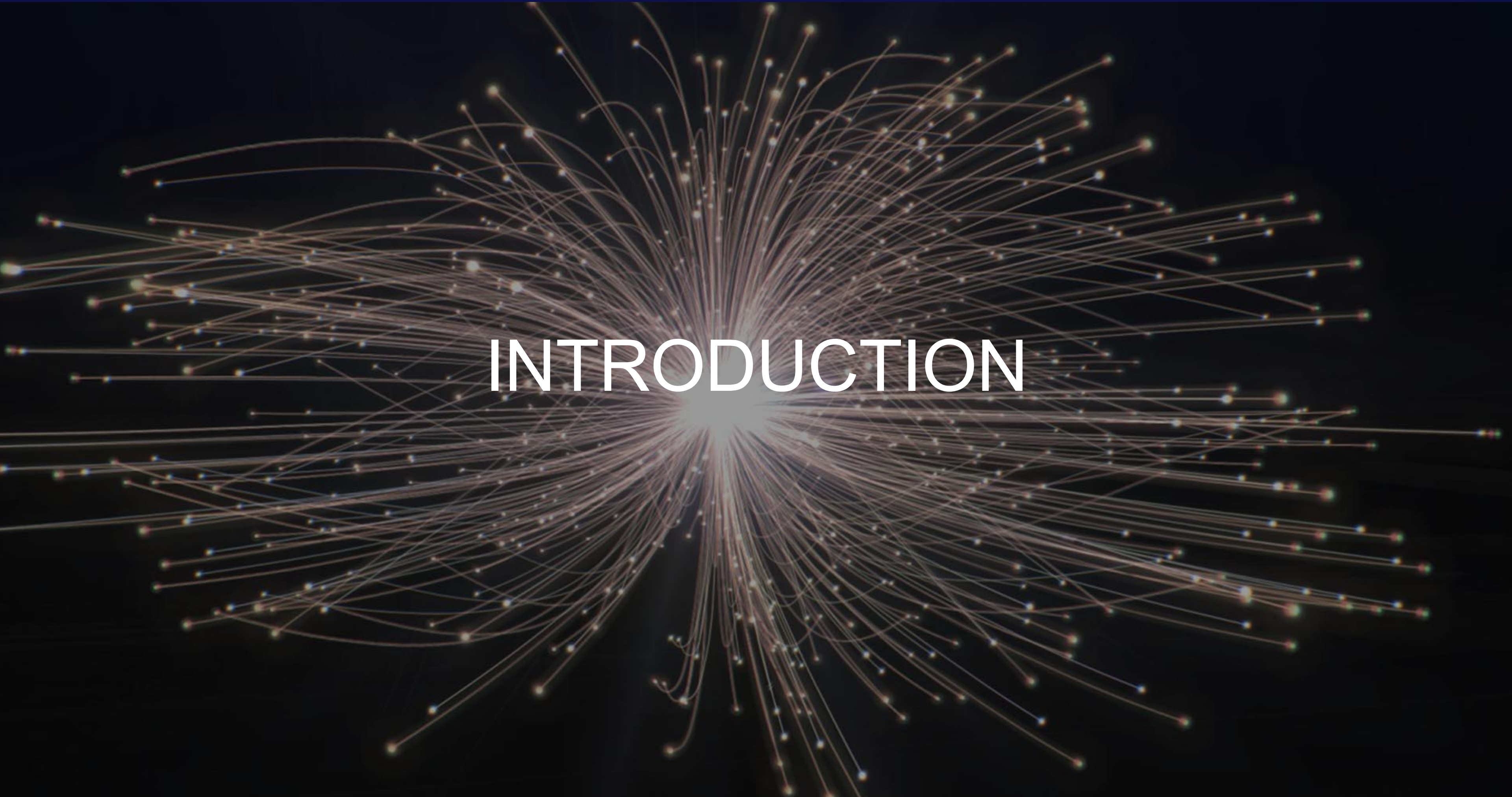
SuperKEKB iBump Feedback Study

SuperKEKB Optics Modelling

Open questions for FCC-ee

With thanks to Frank Zimmerman, Phil Burrows and all FCC-ee colleagues

INTRODUCTION



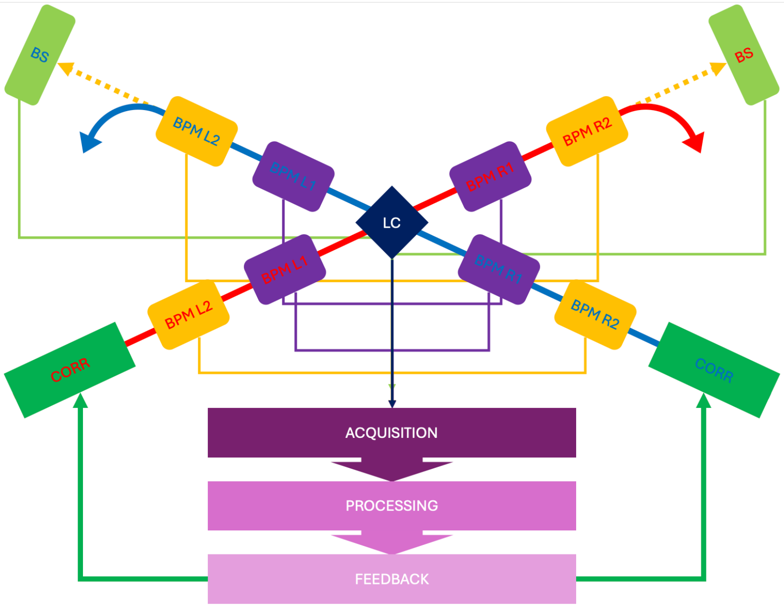
Interaction Point Feedback

- **Required to maintain luminosity and beam lifetime**

  Cannot be an afterthought

- Local correction

- Strict requirements at FCC-ee:
  - EPOL requirement for collision offset of **within ~$\mathbf{0.1\sigma_y}$** (J. Keintzel)
  - Physics performance requirement for collision offset **within ~$\mathbf{0.02\sigma_y}$** (J. Wenninger)
  - Beam-beam stability requirement for collision offset **within ~$\mathbf{0.05\sigma_y}$** (D. Shatilov)
  - Centering within detector **within $\sim\mathbf{100\mu m}$** (M. Dam)



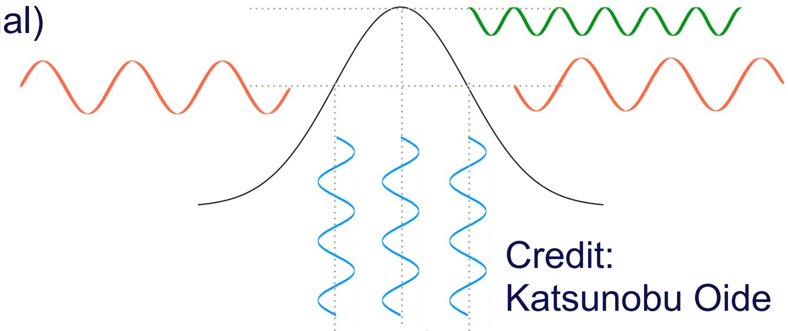
Feedback Types

Beam-Beam Deflection

- Detect an offset using a combination of upstream and downstream BPMs (or by using beamstrahlung light)
- Requires resolution of the monitor better than the downstream offset
- For small offsets (the case required for beam stability) well approximated by the linear model
- Implemented at SLC and SKEKB (vertical)
- *For large beam-beam parameters*

Dithering

- Applies in cases where beam beam parameter is small (all horizontal except tt)
- Drive one beam with a known frequency
- Detect the modulation of luminosity
- Nullify this component to optimise luminosity
- Developed at PEP II, implemented at SKEKB (horizonal)

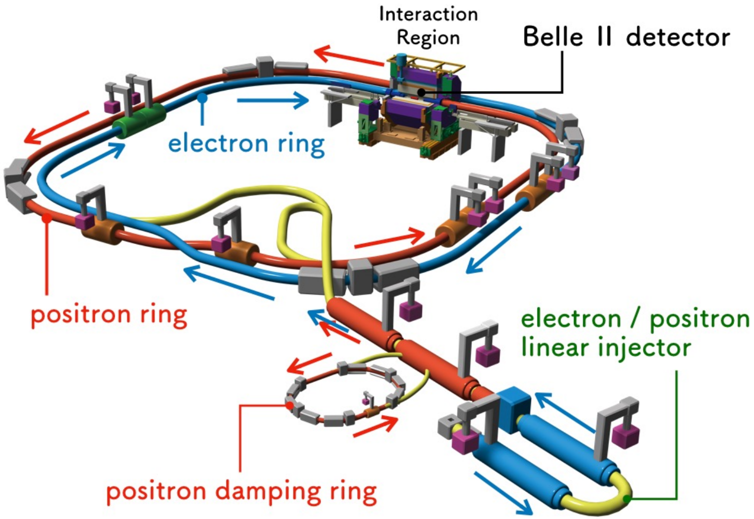


Credit: Katsunobu Oide

SuperKEKB Studies

- Secondment May-June 2024 under EAJADE

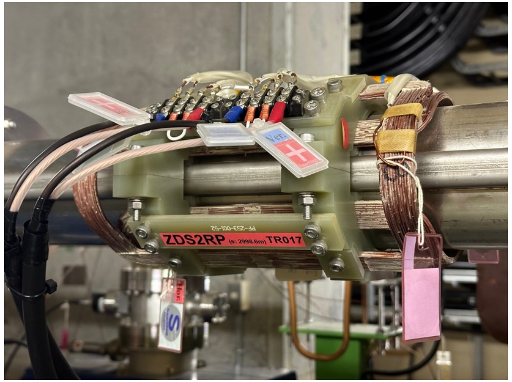
- SuperKEKB Secondment Activities
  - Participation in IP feedback tuning
  - Tour of interaction regions and IP Feedback system hardware
  - Dedicated MD time: testing drift of ‘IP feedback target’ with beam current
  - SuperKEKB Optics Modelling with Xsuite
  - Simulation meetings
  - Tour of Oxford FONT feedback system at ATF2

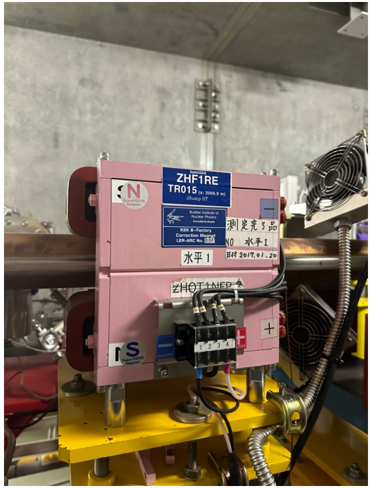


SUPERKEKB IP FEEDBACK

SuperKEKB IP Feedback

- Two types of Feedback:
  - iBump Deflection feedback
    - Hardware based fast feedback
    - Slow CPU based feedback
    - Dedicated horizontal and vertical correctors in IR straight
  - Dither Feedback
    - Currently unused
    - SLAC collaboration
    - Air cooled, yoke free correctors (left) in IR straight

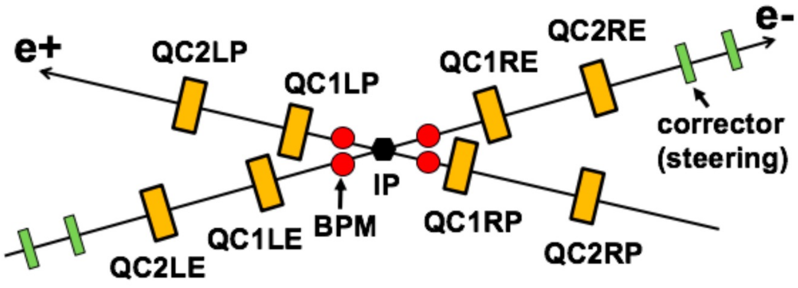


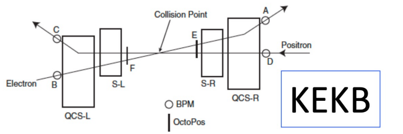


- **LER (e+) beam corrected with global feedback only**
- **HER (e-) beam corrected with IR correctors**

SuperKEKB iBump Feedback

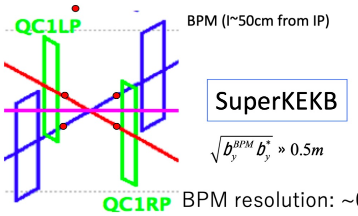
- Based on signals from BPMs ~0.5m from IP
  - Mechanically coupled to IP (BELLE-II)
- Dedicated correctors outside final focus quadrupoles
- Based on a matrix approach
  - Offset at IP calculated from BPM deflections
  - Linear Theory





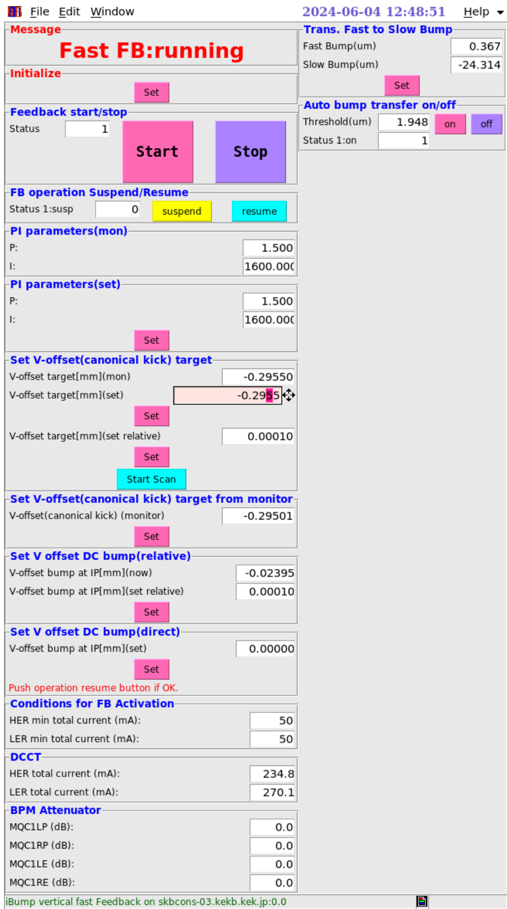
$\sqrt{\beta_y^{BPM}\beta_y^*} \approx 2.0m$ A,B,C,D: BPM ~2.4m from IP

BPM resolution: ~2μm@1.6A



$\sqrt{\beta_y^{BPM}\beta_y^*} \approx 0.5m$

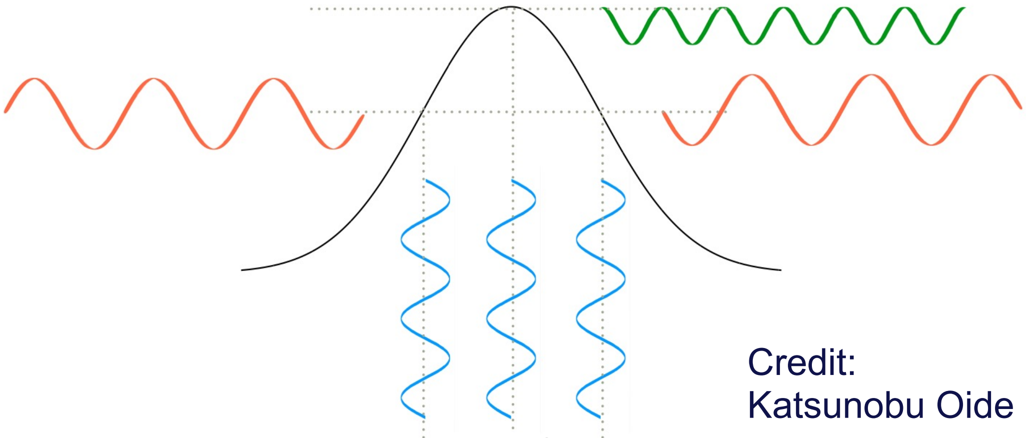
BPM resolution: ~0.2μm@3.6A



SuperKEKB Dither Feedback

- Currently unused
  - Running far from nominal parameters

- Upgrade planned
  - From analogue to digital control board
  - Perhaps autumn this year, run schedule permitting

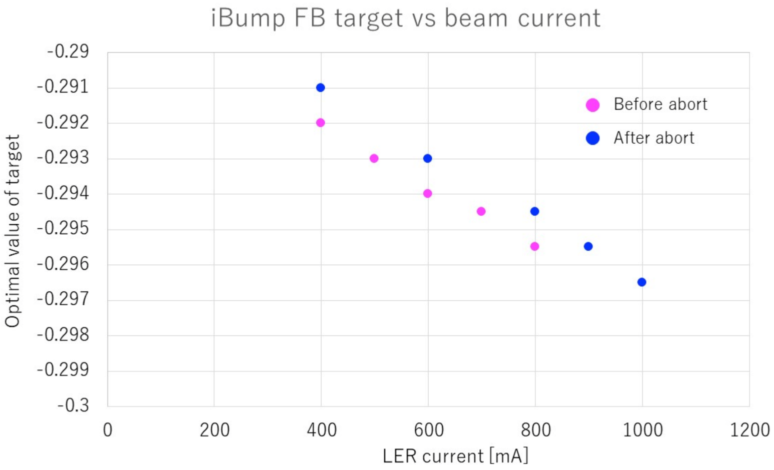


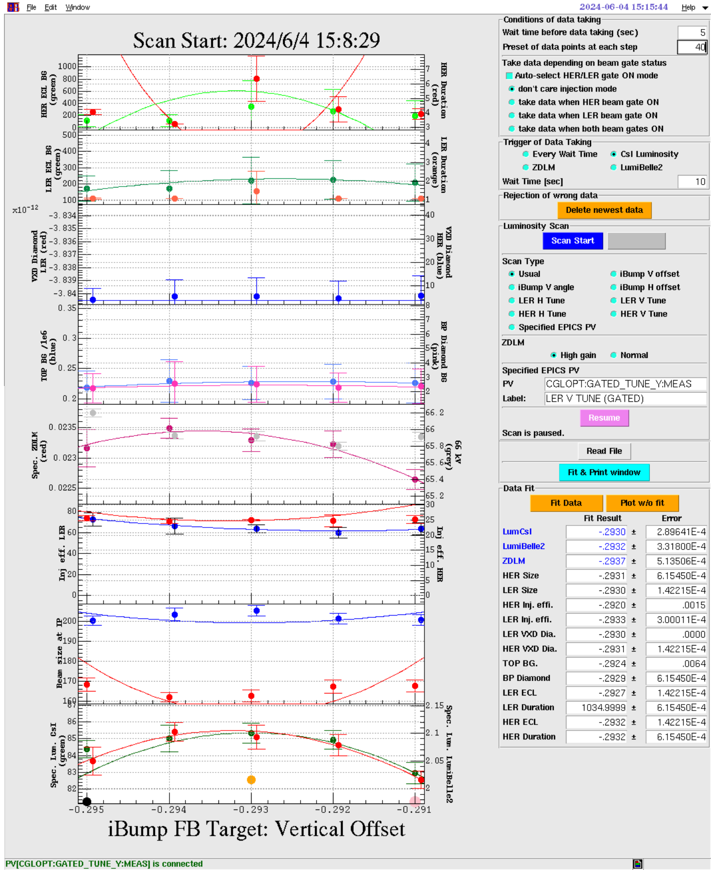
Credit:
Katsunobu Oide

SUPERKEKB IBUMP FEEDBACK TARGET STUDY

MD: SuperKEKB Feedback Target Scan

- From the BPM signals a relative offset is calculated
- Also requires a **feedback target**
- This target is scanned for typically at the start of each shift
- This target is observed to drift with current
- It also seems to drift with other events e.g. beam loss

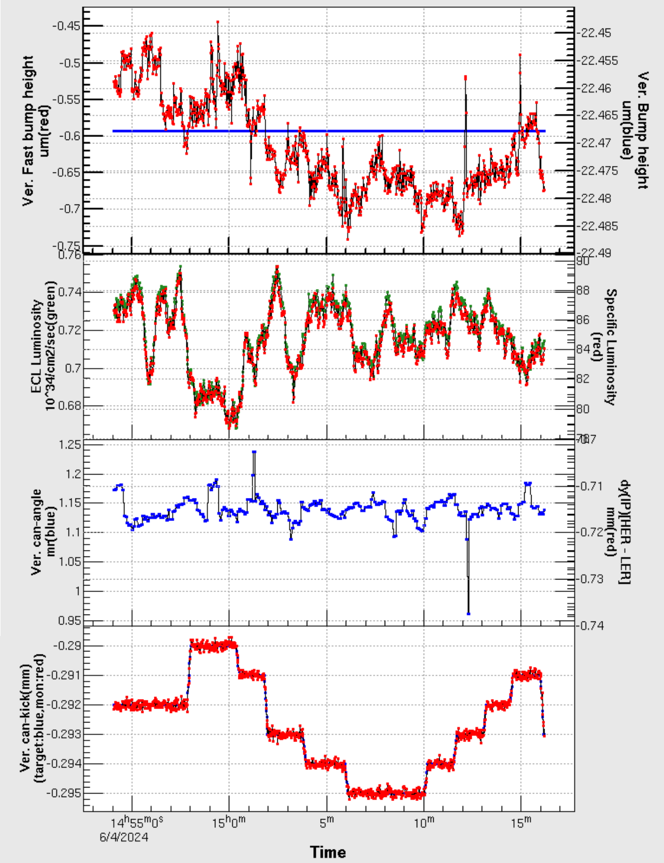


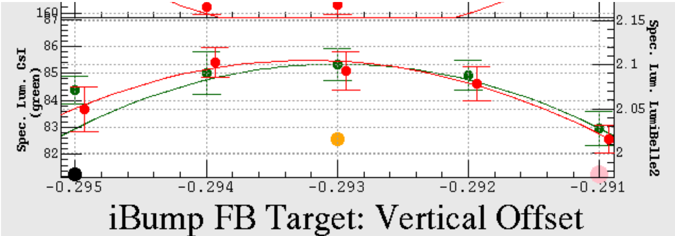


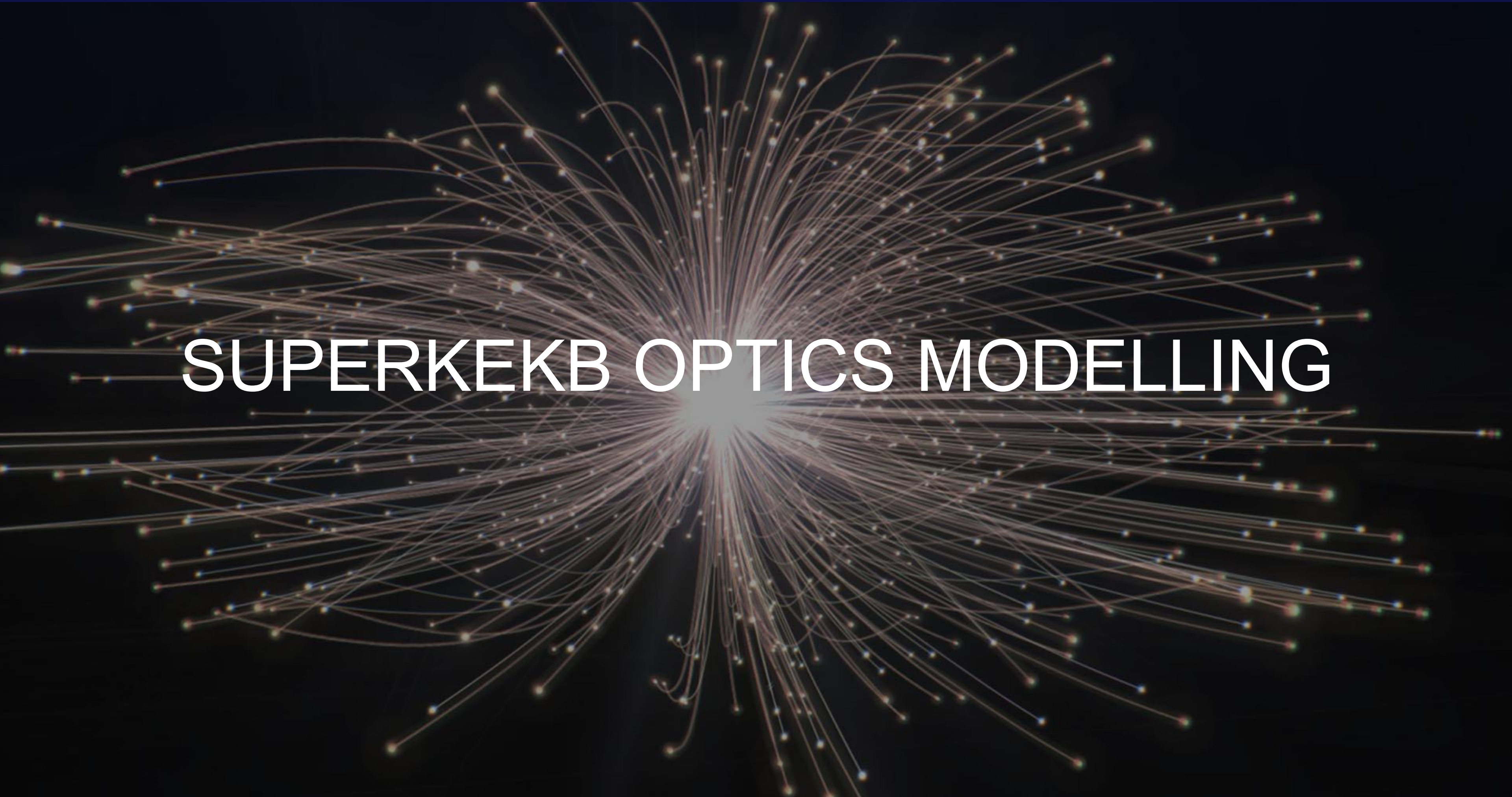
SuperKEKB Luminosity Variance

- Measuring the feedback target also poses difficulties as luminosity is unstable over these timescales
- Shown: target scan and the measurements over the same timeframe
- Clear jitter of the luminosity within each measurement period (step on the vertical canonical kick) is observed

- This makes feedback tuning difficult, and demonstrates luminosity loss vs nominal





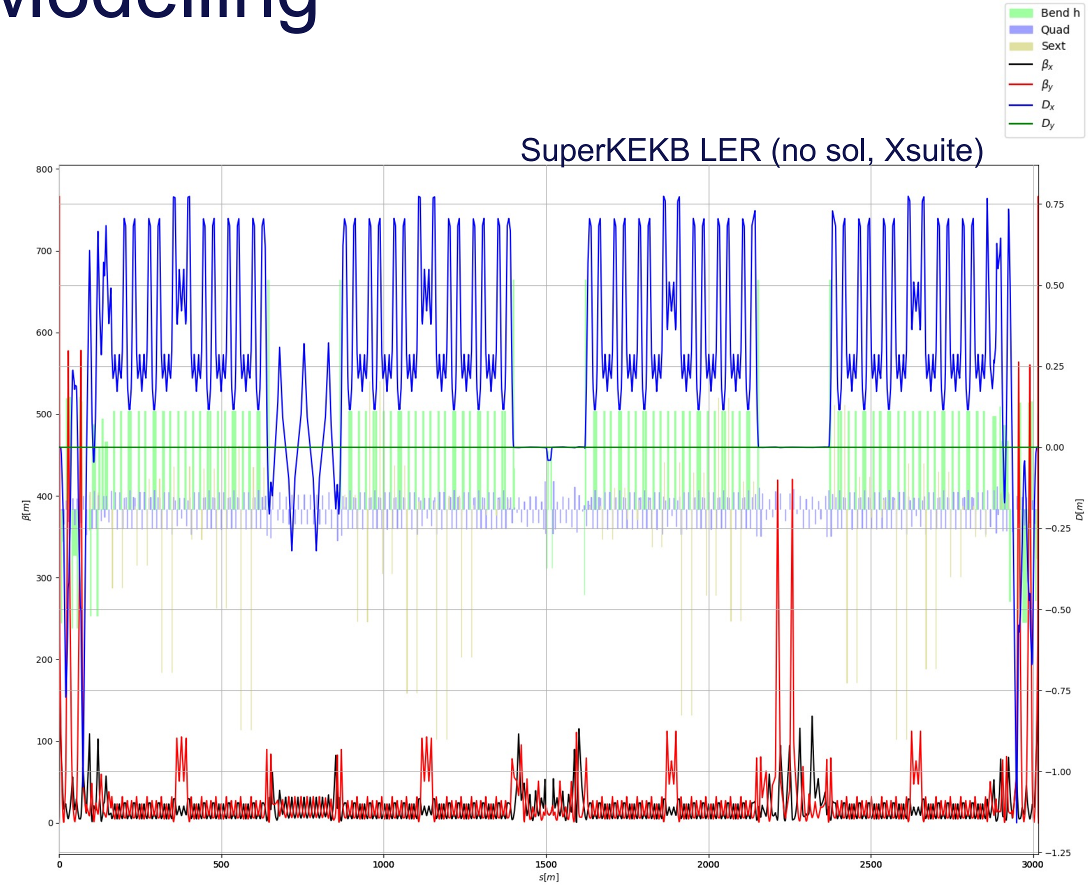


SUPERKEKB OPTICS MODELLING

SuperKEKB Optics Modelling

- Xsuite SuperKEKB lattice model is in active development in Xsuite
  - Collaboration between J. Salvesen, G. Broggi and G. Iadarola
  - *Supported by Optics team at KEK (H. Sugimoto)*
- Hoping to have the model ready in the coming weeks

SuperKEKB LER (no sol, Xsuite)



OPEN QUESTIONS FOR FCC-EE

Requirements

- IP Position Requirements
  - Current value of $\sim 100\mu m$ (M. Dam)
    - Approximate value
    - Luminosity monitor requires within $\sim 500\mu m$
  - Stricter requirement than this for physics performance?

- Offset tolerance
  - Currently multiple different values
  - Strictest is J. Wenninger ("*Opposite sign dispersion and collision offsets at the IPs*")
    - collision offset **within ~$\boldsymbol{0.02\sigma_y}$** (nm or below)

This seems ambitious….

Input Signals

- Beam Position Monitors
  - Number of BPMs within the IR?
  - BPM Placement?

  All dependant on the cryostat and FFQs

- Beamstrahlung Monitor
  - Discussions ongoing with BI

- Luminosity Calorimeter
  - Availability of data directly from the detector luminosity calorimeter?

Correctors

- Number of correctors and placement
  - Space?
  - Is there the luxury of dedicated correctors just for the IP feedback?
  - Do these correctors need to be used for multiple systems?
  - Impact on SR/backgrounds at the detector?

- For simulations on the response of the feedback, need further details:
  - Corrector response
  - Beam-pipe response (placement dependant)
  - Power supply response and stepping

Global Feedback (!!!)

- Will global feedback be good enough that IP feedback only needs to be applied to one beam?
- What is the global feedback strategy?
  - Correction timescales?
  - Correction locations?

Error Sources

- Ground motion vibration

  Ongoing discussions with LAPP to address this

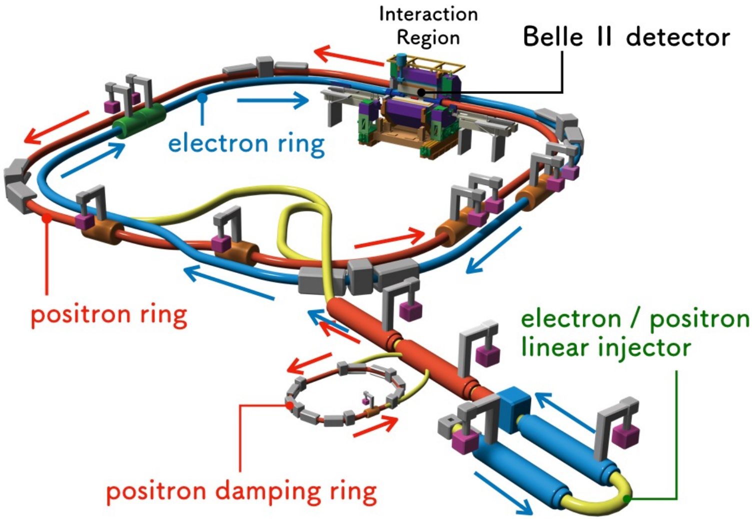
- Other mechanical sources?

Thank you
for your attention.

APPENDICES

SuperKEKB Studies

- Why SuperKEKB?
  - Similarities to FCC-ee design
    - Nano-beam scheme
    - Crab collision optics with cryogenic final focus
  - Single IP
    - Simplified feedback system vs FCC-ee requirements



Interaction Region Considerations

- Several key beam-beam effects at play:
  - The hourglass effect (focusing)
  - Dynamic Beta (beta dependance on beam-beam)
  - Loss of dynamic aperture (chaotic motion)
  - Emittance blowup
  - Beamstrahlung radiation
- Strength of beam-beam effects quantified by the *Beam-Beam Tune Shift*
  - For comparison to linear colliders, disruption parameter in appendix

Parameter	Z	WW	ZH	tt
ξ_x [10^{-3}]	2.2	13	10	73
ξ_y [10^{-3}]	97.3	128	88	134

Linear Beam-beam deflection

$$\Delta a' = \pm \frac{2\pi}{\beta_a^*} \xi_a \Delta a \qquad a \in x, y$$

The beam beam deflection is directly proportional to the beam-beam tune shift within the linear regime

Recirculating beam: **Beam quality must be maintained to maintain luminosity and lifetime**