Preliminary design consideration for CEPC fast luminosity feedback system

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Introduction

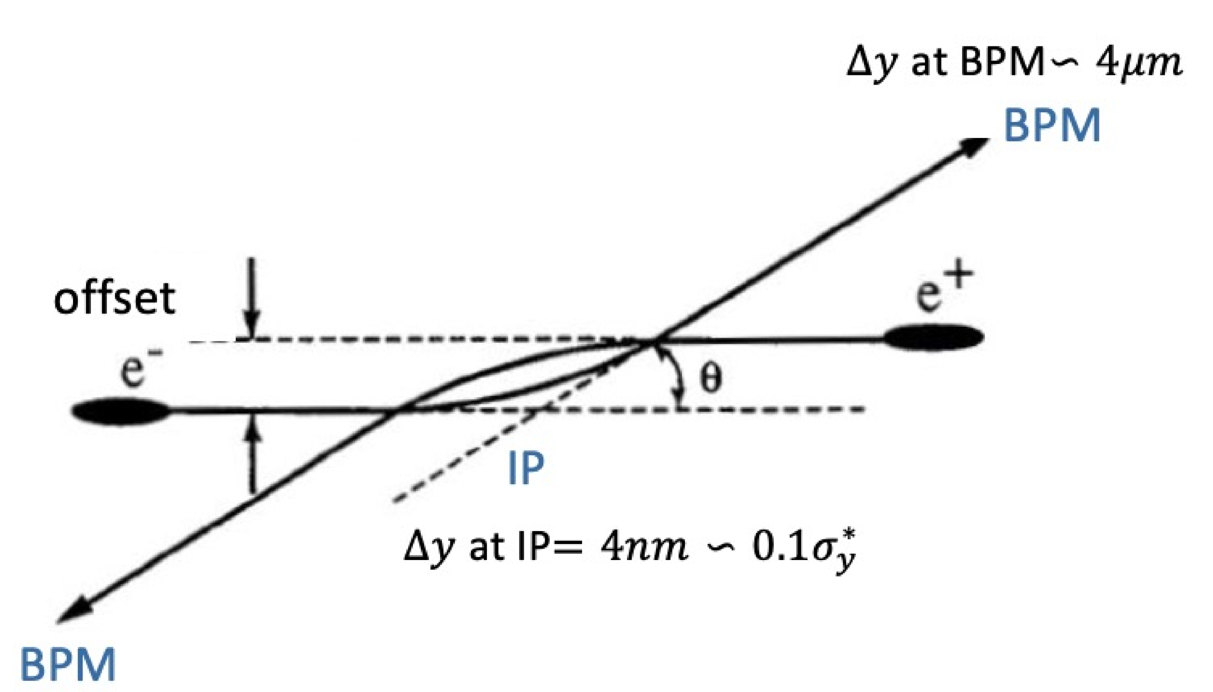
With very small beam sizes at IP (several tens of nanometers in the vertical direction) and the presence of strong FFS quadrupoles in the CEPC, the luminosity is very sensitive to the mechanical vibrations, requiring excellent control over the two colliding beams to ensure an optimum geometrical overlap between them and thereby maximize the luminosity. Fast luminosity measurements and an IP orbit feedback system are therefore essential. In this paper, we will show the preliminary design consideration for a fast luminosity feedback system at CEPC.

Orbit feedback methods

There are two methods for the IP orbit feedback system at CEPC[1,2,3]:

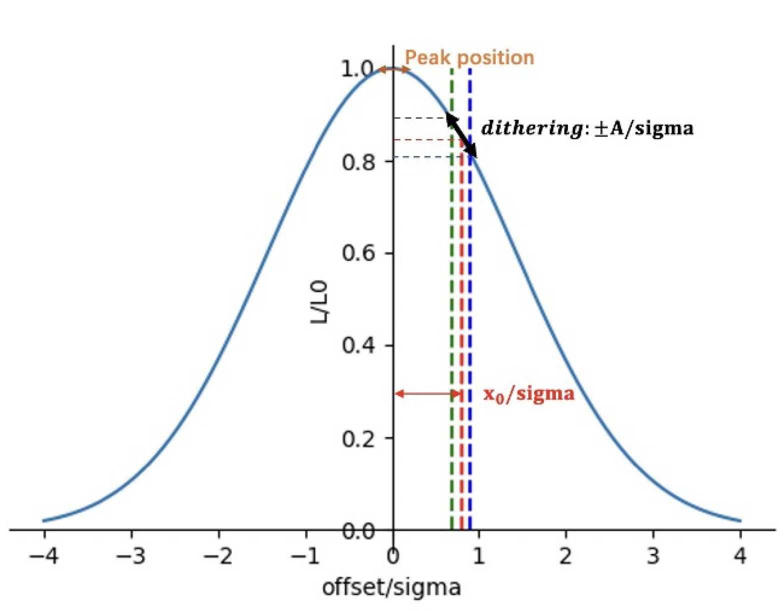
- **Beam-beam deflection driven method [vertical]**

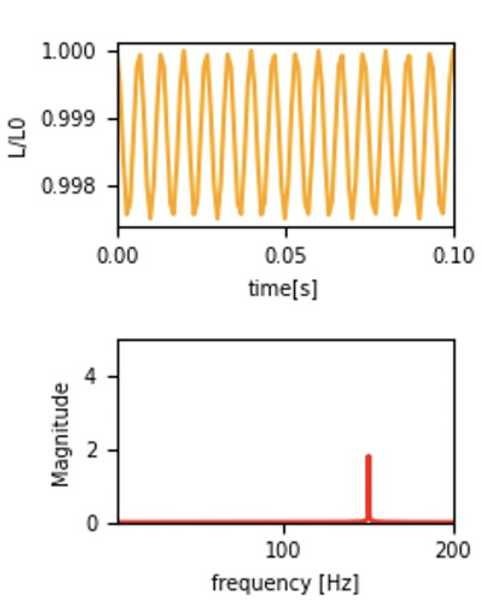
  The small offset between the two colliding beams at IP can introduce an deflect angle due to beam-beam effect, which will be converted into a large offset as the beams propagate forward and collide, by measuring this beam orbit with BPMs around IP, can estimate the offset and sign at the IP.



- **Luminosity driven system [horizontal]**

  Based on the measurement of the luminosity, we can know the offset between two beams, but cannot easily know its sign. And many other effects may also cause luminosity changes at relatively low frequency, should introduce a dithering with certain frequency.

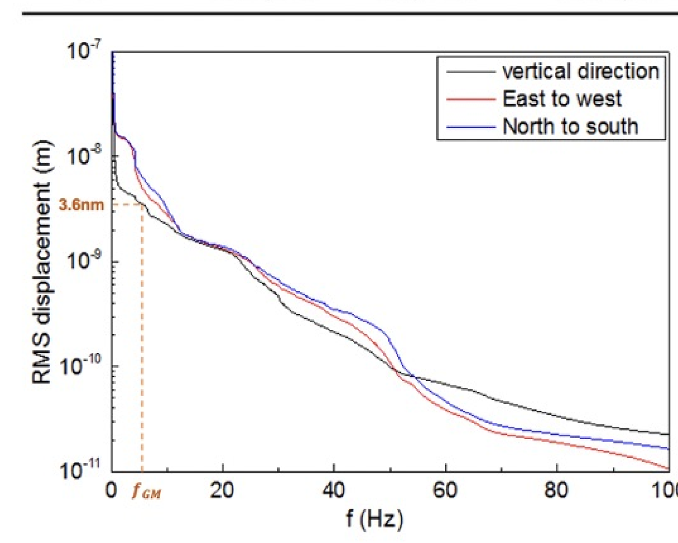


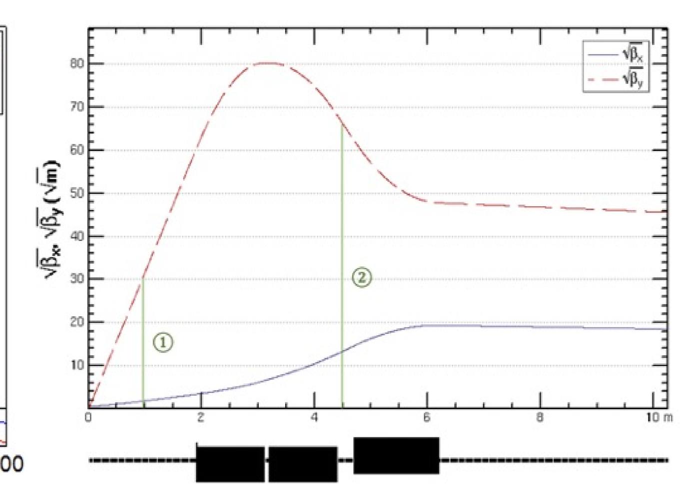


Vertical—Beam-beam deflection driven method

Using the beam-beam deflection method for vertical orbit feedback at the IP, our preliminary scheme is to place 2 paris of BPMs on both sides of the IP for each ring.

CEPC [Scheme]	β_x^*/β_y^* [m/mm]	σ_x^*/σ_y^* [μm/nm]	ξ_x^*/ξ_y^*	$\Delta x_{IP}/\Delta y_{IP}$ [μm/nm]	$\Delta x'/\Delta y'$ [μrad]	$\Delta x_{BPM}/\Delta y_{BPM}$ [μm]
Z	0.13/0.9	6/35	0.004/0.127	0.6/3.5	-0.1/-3.1	-0.1/-2.8
WW	0.21/1.0	13/42	0.012/0.113	1.3/4.2	-0.5/-3.0	-0.4/-2.7
Higgs	0.30/1.0	14/36	0.015/0.11	1.4/3.6	-0.4/-2.5	-0.4/-2.2
$t\bar{t}$	1.04/2.7	39/113	0.071/0.1	3.9/11.3	-1.7/-2.6	-1.4/-2.4





① The initial designed BPM ($0.2\mu m@500Hz$) → **good enough for vertical direction**

$$\Delta y_{BPM}=\sqrt{\beta^*\beta_{BPM}}\Delta y' \approx s*\Delta y' = 0.85\times(-2.5\mu rad) = 2.2um \approx 11\ \mathrm{BPM_{res}}@500\mathrm{Hz}$$

$$\Delta x_{BPM}=\sqrt{\beta^*\beta_{BPM}}\Delta x' \approx s*\Delta x' = 0.85\times(-0.4\mu rad) = 0.4um \approx 0.4\ \mathrm{BPM_{res}}@100\mathrm{Hz}$$

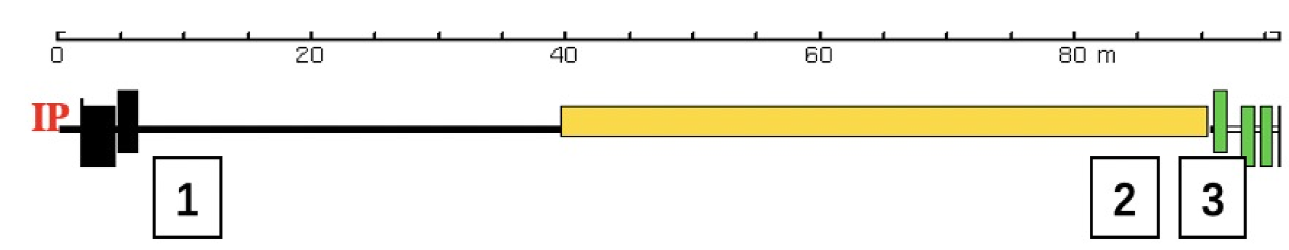
② Utilize 2 pairs of BPMs → **potential BPM failures or decreased accuracy and resolution**

→ add another pair of BPMs at locations with larger βy values ($\pm 4.5m\ far\ from\ IP$):

$$\Delta y_{BPM}=\sqrt{\beta^*\beta_{BPM}}\Delta y' \approx \sqrt{1\times10^{-3}}\times66\times(-2.5\mu rad) = 5.2um \approx 26\ \mathrm{BPM_{res}}@500\mathrm{Hz}$$

Horizontal—Fast Luminosity Monitor

The fast luminosity monitor based on radiative Bhabha at zero degree, which has a very large cross section ($\approx 150mbarn$). Find 3 possible detector positions where the loss rate is large enough and radiative Bhabha at zero degree process dominates over the sum of other particles loss processes.



	Position1	Position2	Position3
Distance from IP	10m	84m	90.5m
Average Number detected/collision	3.4(two sides)	3(one side)	3.2(one side)
Average Number detected/ms	2830	2500	2670
Expected Measured Precision	1.9% @1kHz	2.0% @1kHz	1.9% @1kHz
Average Energy of scattered electron	24GeV	70GeV	75.3GeV
Average Hitting Angle	1.7×10^{-4}rad	7×10^{-4}rad	7×10^{-4}rad
Maximum Secondary Particle Position	88mm	104mm	105mm
Detection Area	$5\times20cm^2$	$3\times15cm^2$	$3\times15cm^2$
Backgrounds	SR Photons in 1 Side	-	-
Beam-Beam Deflection Impact	sensitive	less sensitive	less sensitive
Detector Number	2	1	1
Detector Measurement Parameters	Number of signals within 1ms		
Detector Time Resolution	600ns		
Detector technology possibility	LGAD, SiC, Diamond		

Conclusion

- **Fast Luminosity Tuning System, including fast BPMs and fast luminosity monitor, would be necessary for CEPC.We already have some candidate positions and potential detector solutions.The detailed design of the detectors is get started.**
- **More detailed simulations needs to be done to study more, including determine the detailed location and quantity of BPMs and the design of detectors and feedback.**

[1] Y. Funakoshi et al., “Interaction point orbit feedback system at SuperKEKB”, in Proc. 6th Int. Particle Accelerator Conf. (IPAC’15), Richmond, VA, USA, May 2015.
[2] D. El Khechen, “Fast Luminosity Monitoring Using Diamond Sensors for SuperKEKB”, PhD thesis, Université Paris-Sud, Orsay, France, 2016.
[3] C. G. Pang et al., "A fast luminosity monitor based on diamond detectors for the SuperKEKB collider", Nucl.Instrum.Meth. A931 (2019) 225-235.