FUTURE CIRCULAR COLLIDER

CERN

Summary WP2

J. Keintzel, K. Oide, J. Wenninger
For the WP2

2d FCC Polarization Workshop (EPOL) 2022

Joint EIC-FCC Working Meeting on e+/e- Polarization

23th September 2022

FCCIS – The Future Circular Collider Innovation Study. This INFRADEV Research and Innovation Action project receives funding from the European Union's H2020 Framework Programme under grant agreement no. 951754.

Timetable

- One parallel session on Tuesday afternoon

15:30 → 18:35 **WP2: 3162/1-K01**

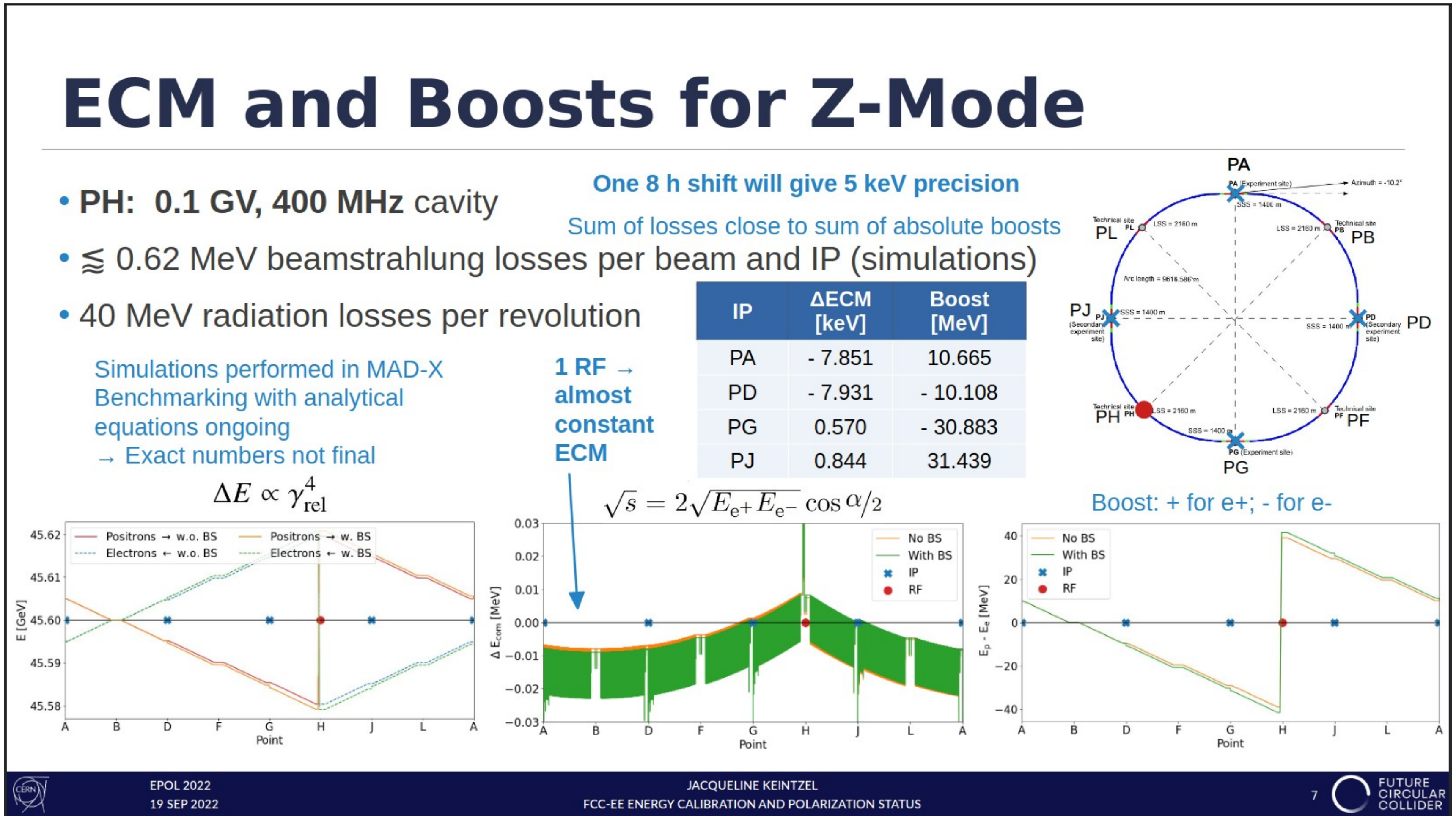
Join

15:30	**Energy sawtooth due to SR and CM energy** **Speaker**: Jacqueline Keintzel (CERN) 20220920_Keintzel_...	30m
16:00	**Energy loss due to impendance and impact on local energy and on energy differences of colliding and non-colliding bunches** **Speaker**: Emanuela Carideo (Sapienza Universita e INFN, Roma I (IT)) 2022_09_20_EPOL_... 2022_09_20_EPOL_...	30m
16:30	**Energy loss due to Beamstrahlung and impact on local energy and on energy differences of colliding and non-colliding bunches** **Speaker**: Dmitry Shatilov (Budker Institute of Nuclear Physics (RU)) EPOL_shatilov.pdf EPOL_shatilov.pptx	30m
17:00	**Beam-beam offset and OSVD** **Speaker**: Jorg Wenninger (CERN) OSVD.EpolWs-Sep2... OSVD.EpolWs-Sep2...	30m
17:30	**Dispersion at the IPs: what to expect, ways to correct** **Speaker**: Michael Hofer (CERN) MH_FCC_EPOL_dis...	20m

J. Keintzel

Center-of-Mass Energy at Z-pole

- Almost constant ECM with one RF at all 4 IPs, even with beamstrahlung



ECM and Boosts for Z-Mode

- **PH: 0.1 GV, 400 MHz** cavity
- ≲ 0.62 MeV beamstrahlung losses per beam and IP (simulations)
- 40 MeV radiation losses per revolution

One 8 h shift will give 5 keV precision

Sum of losses close to sum of absolute boosts

Simulations performed in MAD-X
Benchmarking with analytical equations ongoing
→ Exact numbers not final

1 RF → almost constant ECM

IP	ΔECM [keV]	Boost [MeV]
PA	- 7.851	10.665
PD	- 7.931	- 10.108
PG	0.570	- 30.883
PJ	0.844	31.439

$\Delta E \propto \gamma_{\mathrm{rel}}^4$

$\sqrt{s} = 2\sqrt{E_{e+}E_{e-}}\cos\alpha/2$

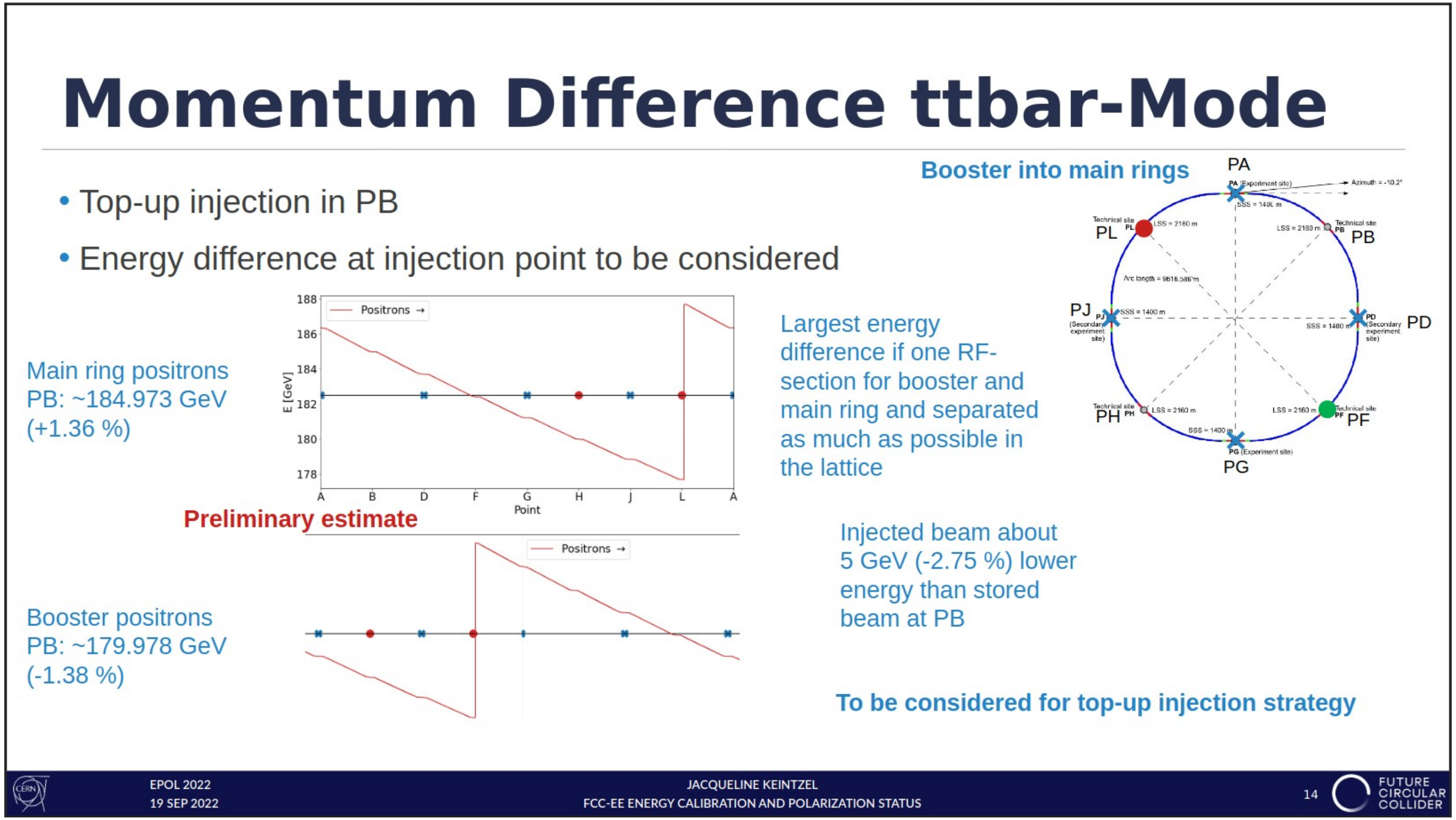
Boost: + for e+; - for e-

EPOL 2022
19 SEP 2022
JACQUELINE KEINTZEL
FCC-EE ENERGY CALIBRATION AND POLARIZATION STATUS
7

J. Keintzel

Energy Losses at ttbar

- Sufficient momentum aperture required for top-up injection



Impact on top-up injection to be studied

E. Carideo

Center-of-Mass Energy

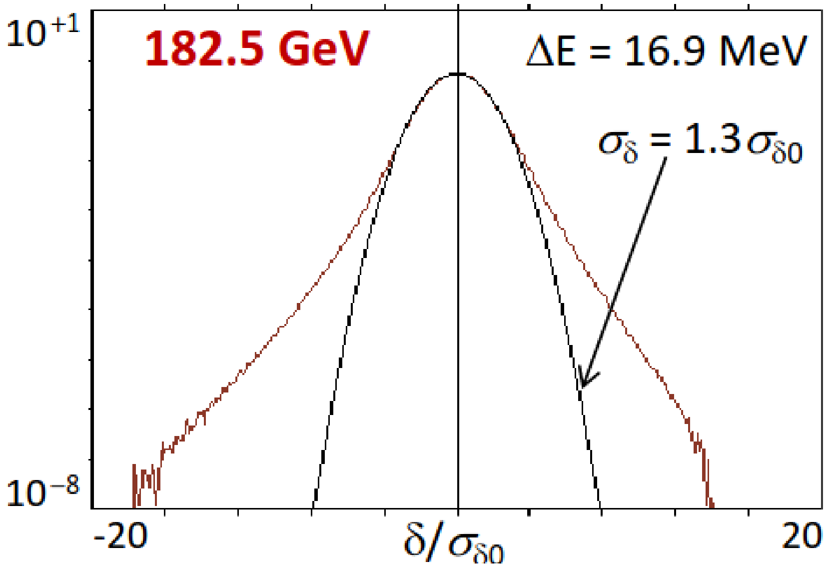
- Longitudinal impedance, mainly resistive wall and bellows, leads to constant energy loss at the Z-pole
- Longitudinal wakefields at ttbar almost negligible

	Pilot bunch (3×10^{10} ppb)	Nominal intensity (2.6×10^{11} ppb)	Nominal intensity and beamstrahlung (2.6×10^{11} ppb)	SR
Energy spread	0.039 %	0.045 %	0.143 %	0.039 %
Energy loss	0.8 MeV	4.2 MeV	~ 1.6 MeV	39 MeV
Bunch length	5 mm	8.3 mm	17.2 mm	4.4 mm

D. Shatilov

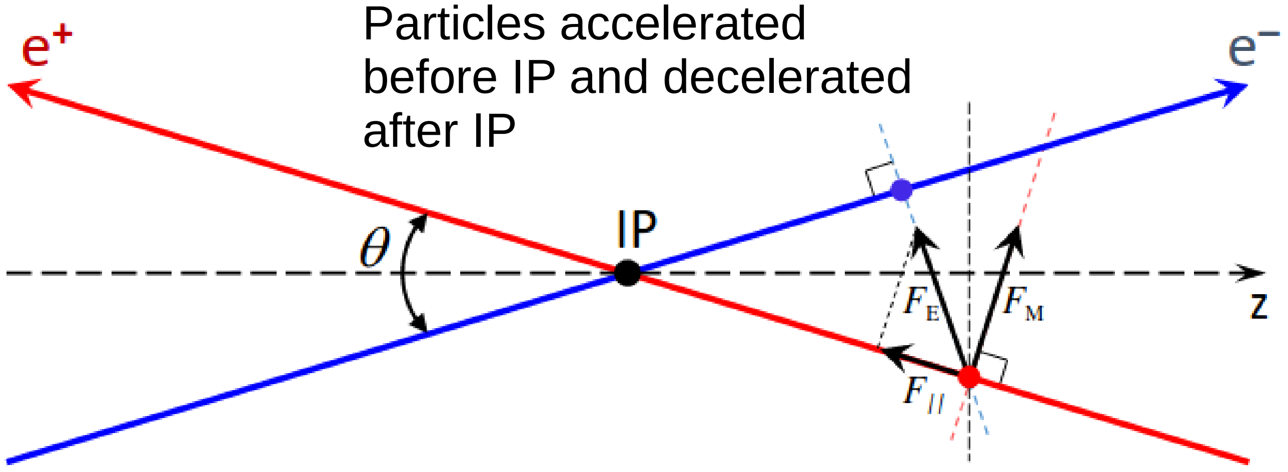
Beamstrahlung and Crossing Angle

- Beamstrahlung leads to an increased energy spread for colliding bunches
- Beam energy and crossing angle changes during collision, however **not ECM**



E (GeV)	45.6	80	120	182.5
δE (keV)	61	108	212	1480

Without beamstrahlung – the same values!



Bunch intensities must be within +/- 5% of nominal one

If the bunch populations deviate from the nominal value by ±5%, then σ_δ, σ_z and ΔE differ about twice, and the centers of bunches no longer meet at the IP. As a result, the weak (less populated) bunch decelerates and the strong one accelerates by ~1 keV, which contributes to ΔE.

J. Wenninger

Opposite Sign Vertical Dispersion

- To minimize ΔECM: **minimize dispersion at IP and beam offset**

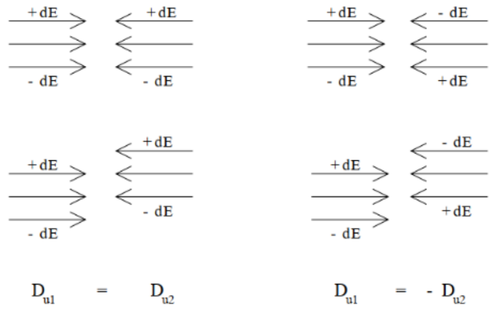
Opposite sign dispersion and CM energy

While the impact of dispersion on the **CM energy spread** depends on

- the **dispersion** at the IP (D_{ui}),
- the **beam energy spread** ($\sigma_\varepsilon = \sigma_E/E_0$),
- the **betatronic beam size** at the IP (σ_u),

… the CM energy shift depends also on

- the **separation of the two beams** (total separation = $2u_0$).



$$\Delta E_{CM} = -2u_0 \frac{\sigma_E^2 (D_{u1} - D_{u2})}{E_0(\sigma_{B1}^2 + \sigma_{B2}^2)}$$

I =1,2 labels the two beams
u = x,y labels the planes

$$\sigma_{E_{CM}}^2 = \sigma_E^2 \left[\frac{\sigma_\epsilon^2 (D_{u1} + D_{u2})^2 + 4\sigma_u^2}{\sigma_{B1}^2 + \sigma_{B2}^2} \right]$$

$$\sigma_{Bi}^2 = \sigma_u^2 + (D_{ui}\sigma_\epsilon)^2$$

Total beam size

for head-on collisions !

Opposite sign dispersion and collision offsets at the interaction points - J. Wenninger

J. Wenninger

Dispersion at FCC-ee

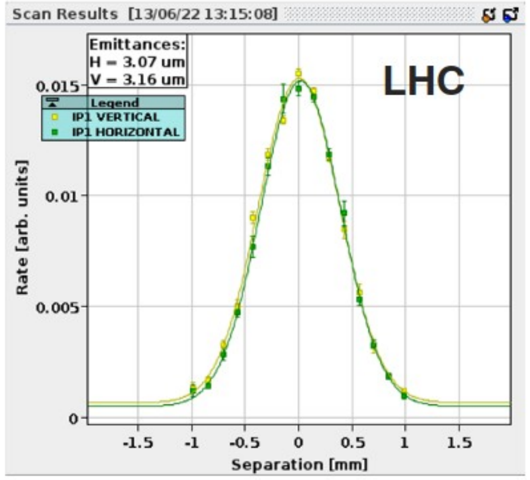
- **10 µm** vertical dispersion, the ECM error is **1 MeV/nm**
- Uncertainty limited below **0.1 nm** to limit systematic errors **< 100 keV**

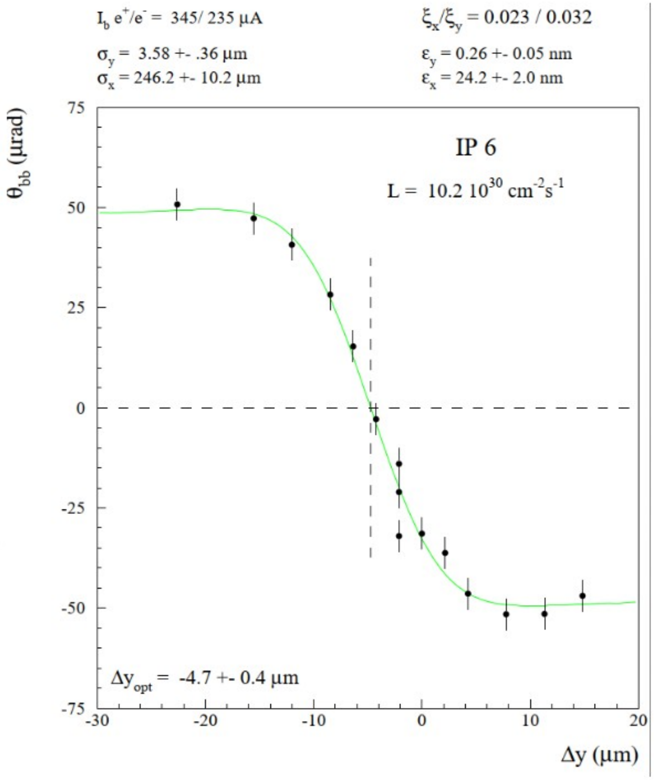
Orbit offset and vertical dispersion must be controlled and corrected

$$|\Delta\sqrt{s}| = 96\ |u_0|\ [\text{keV}/\text{nm}]$$

for $\Delta D^* = 1\ \mu m$, $\sigma_E/E = 0.13\%$

- Measure by
- Luminosity scans
- Beam-beam deflection





J. Wenninger

Beam-Beam Kick and Dispersion

- Induced a change of the externally imposed vertical separation and thus orbit change

Realistic BB tracking simulation must be performed

Vertical dispersion measurement spoiled by BB → cannot fully trust dispersion from BPM readings

Colliding and non-colliding bunches with same intensity required to disentangle BB and dispersion

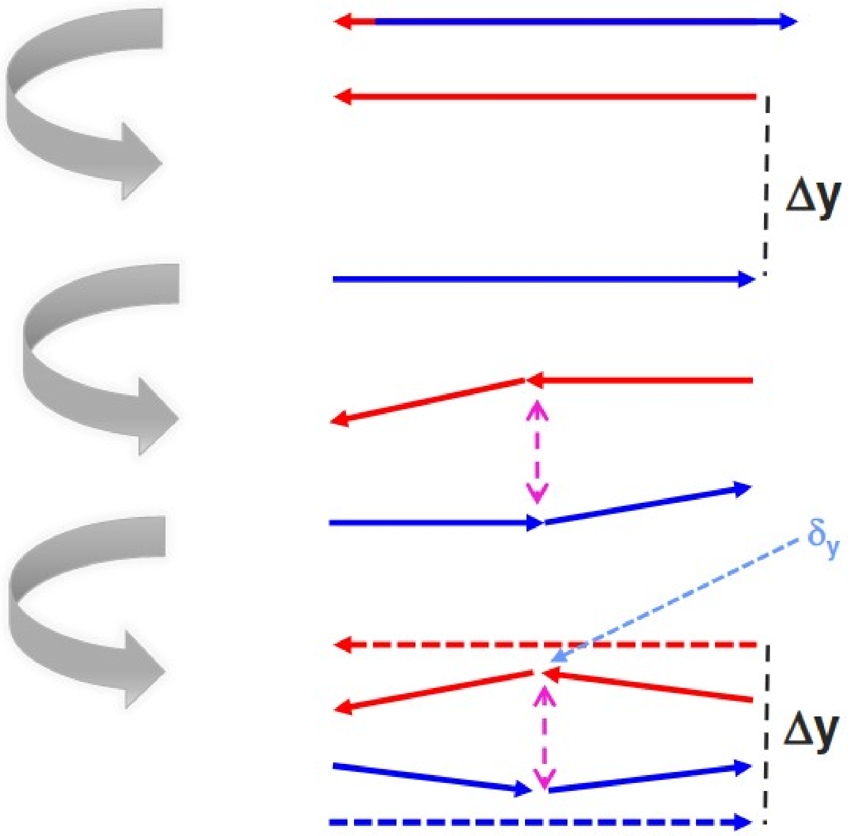
Apply a separation δ of the beams at IP

Beam-beam kick due to the separation δ

The beam-beam kick induces a **closed-orbit change** δ_y, leading to an **effective separation** that is **smaller than Δy** (for an attractive bb force and fractional Q in [0,0.5]).

$$\delta_y = \theta_{bb} \frac{\beta^*}{2 \tan \pi Q}$$

This first order estimate is only valid for δ << Δy, small BB kick.



M. Hofer

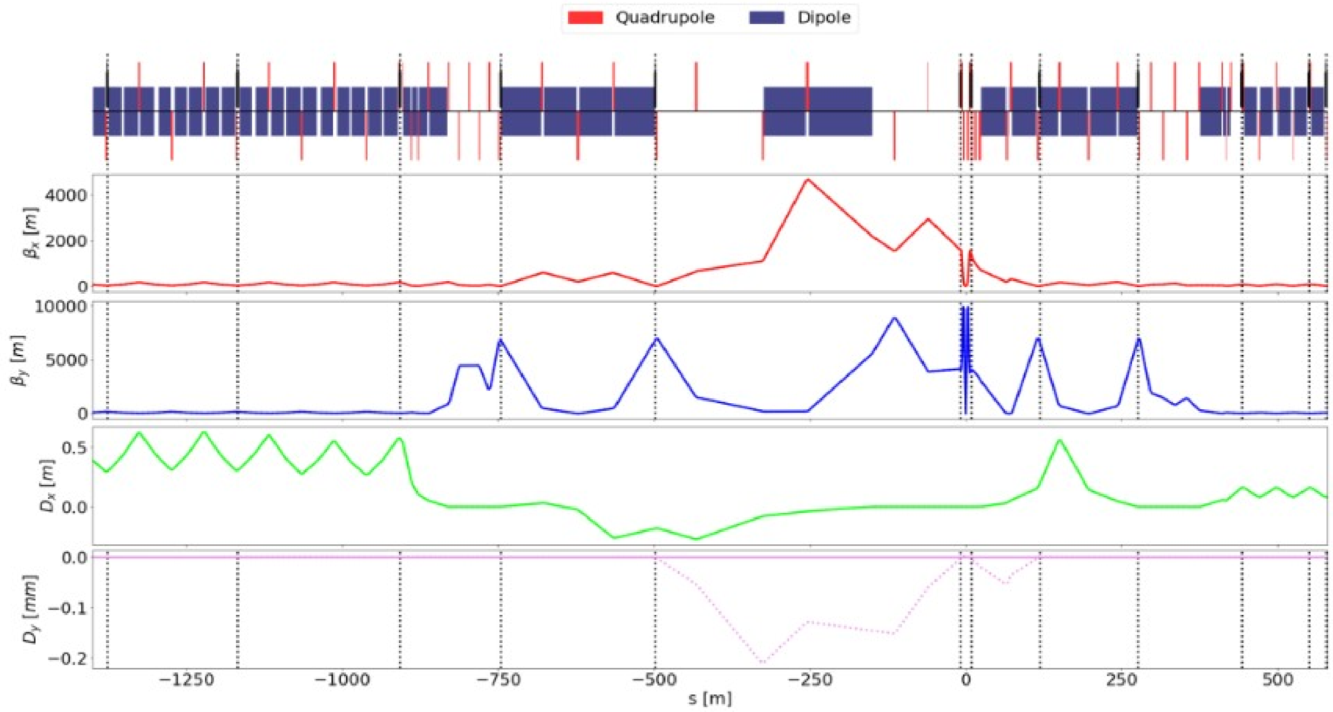
Dispersion Control

- Knobs for horizontal and vertical dispersion control at IP being designed
- Aim to not perturb linear optics
- Could break phase constraint for crab-sextupoles
- Tilted solenoid creates 3 µm at IP

Knobs to be defined

Impact on chromatic optics to be evaluated

Impact on DA to be studied



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Thank you!

Energy calibration and polarization
indico.cern.ch/category/8678

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