Summary from WG5

Angeles Faus-Golfe, IJCLab; Frank Zimmermann, CERN

EPOL Workshop 2022, 19 - 30 September 2022

20 September, Tuesday

D. d'Enterria, CERN, Physics and operational requirements for monochromatization

- FCC-ee can provide the by far most precise measurement of the e- Yukawa coupling.

- Large background is a concern and can or must be suppressed by suitable cuts and algorithms (e.g. selection of gluon jets) and also by optimizing the monochromatization parameters

→ further work on experimental side and detector simulations

A. Blondel, U. Geneva, Measurement of monochromatization parameters

- Plenty of dimuon events contain superb information of collision energy spread with and without monochromatization, and mean energy difference between electron and positron beams

- Suggestion to test the monochromatization scheme early-on during highest-luminosity Z running (impact on optics design and question whether beamline footprint can be held constant)

→ scenario(s) for test during FCC-ee Z operation ; compatibility studies

→ develop proposals for near-future beam tests at DAFNE and / or SuperKEKB !

21 September, Wednesday

A. Faus-Golfe, IJCLab, Towards monochromatization optics

- approach: modify the final-focus bending for all energies and add final-focus quadrupoles to achieve the monochromatization
- for operation with crab cavities need to reduce bunch length (different arc optics?) or need to increase betay* ?
- one could also resonantly create dispersion from the arcs (P. Raimondi ; see A. Zholents & F. Ruggiero at LEP)

→ study need for crab cavities
→ study potential of resonant generation

H.-P. Jiang, IJCLab, First draft optics

- draft optics with IP dispersion created by addt'l bends and quad's in the final focus, launch of GP simulations

→ check if synchrotron radiation photon energies would be OK for ttbar running
→ emittances need to be updated for each working point, and both bunch population and IP dispersion should be optimized
→ decreasing betax* should also be considered

P. Raimondi, SLAC, Monochromatization with chromatic waist shift

- monochromatization with chromatic waist shift could be simulated with GuineaPig to explore useful parameter range and possible gain
- other alternative approaches include change of partition number and/or Robinson wigglers

→ simulations and studies on these alternative approaches and combinations thereof

29 September, Wednesday

D. Shatilov, CERN, Old Thoughts about Monochromatization at FCC-ee

- Optimization Strategy:

1) Try to achieve small β_x^* and large η_x^*. This is the key point, and it can be done independently of the following two.
2) Choose the arc cell lattice and RF parameters. This will determine the emittances and the bunch length. The latter determines β_y^*. What to watch out for: the synchrotron tune. The RF team and the depolarization team should be involved in the discussion. This process may need to be iterated in conjunction with bunch length optimization.
3) Decide whether we will do crab crossing or not. Crab cavities greatly affect the efficiency of monochromatization.
4) Perform beam-beam simulations in a simplified model: linear lattice without errors. What to watch out for: emittance growth due to beamstrahlung (both horizontal and vertical!). Make a scan of the bunch population to find the optimum. Examine bunch length dependence.
5) Perform beam-beam simulations in a realistic model: nonlinear lattice with errors, misalignments and corrections, residual vertical dispersion at the IP, non-zero orbit at the IP, etc. Again, carry out a scan of the bunch population to find the optimum.

→ crab cavities are an attractive option, giving a factor 2 higher Higgs production rate, and providing more optics flexibility

H.-P. Jiang, IJCLab, Analytical calculation of beamstrahlung impact on energy spread and emittance

-This work is continuing

- new parameters for the standard case with 4 IPs
- numerical calculations of monochromatization case with new parameters
- optimisation of bunch population and bunch length
- Guinea-Pig simulation with new emittance and dispersion values with BS
- re- Plot the relation line between energy spread and luminosity in significance contours, then find the best choice of dispersion

→ parameter scan to carry out the optimization

Monochromatization Factor

<u>Similarity between dispersion at the IP and crossing angle</u>

X-coordinate consists of betatron and synchrotron parts. The latter is proportional to either Z or δ, which are shifted in phase of the synchrotron oscillations by π/2.

$$\lambda_m = \frac{\sigma_{xs}}{\sigma_{x\beta}} = \frac{\sigma_\delta \eta_x^*}{\sqrt{\varepsilon_x \beta_x^*}}$$ – analog of Piwinski angle ϕ

Modification of formulas for $\xi_{x,y}$ and luminosity:

<u>crossing angle</u>

$$\sigma_x \Rightarrow \sigma_x \sqrt{1+\phi^2}$$

<u>dispersion</u>

$$\sigma_x \Rightarrow \sigma_{x\beta} \sqrt{1+\lambda_m^2}$$

Suggested name for λ_m – monochromatization parameter (used in articles in the 80s)

Monochromatization factor: $\Lambda = \sqrt{1+\lambda_m^2}$

But this formula is valid only without crossing angle...

In general case:

$$\Lambda = \sqrt{1 + \frac{\lambda_m^2}{1+\phi^2(1+\lambda_m^2)}} < \sqrt{1+\frac{1}{\phi^2}}$$

$$\phi = \frac{\sigma_z}{\sqrt{\sigma_{x\beta}^2 + \sigma_{xs}^2}} \tan\left(\frac{\theta}{2}\right)$$

How to decrease ϕ if the crossing angle is fixed? 1) decrease in σ_z and increase in σ_x or 2) switch to crab crossing, which makes $\phi = 0$.

<u>Strategy for optimization</u>:

1) Define the desired value for Λ
2) Try to minimize β_x^*, then with the given ε_x we obtain $\sigma_{x\beta}$
3) Find the required σ_{xs} (i.e. find η_x^* since σ_δ is fixed)

Without crab crossing, larger dispersion is required for the same Λ.

Dmitry Shatilov

Possible target function to maximize:
(proportional to the Higgs event rate) $f_H = \frac{L}{\sqrt{\Gamma_H^2 + \sigma_{ecm}^2}}$

$\sigma_{ecm} = \frac{\sqrt{2} E_0 \sigma_\delta}{\Lambda}$ – center-of-mass energy spread

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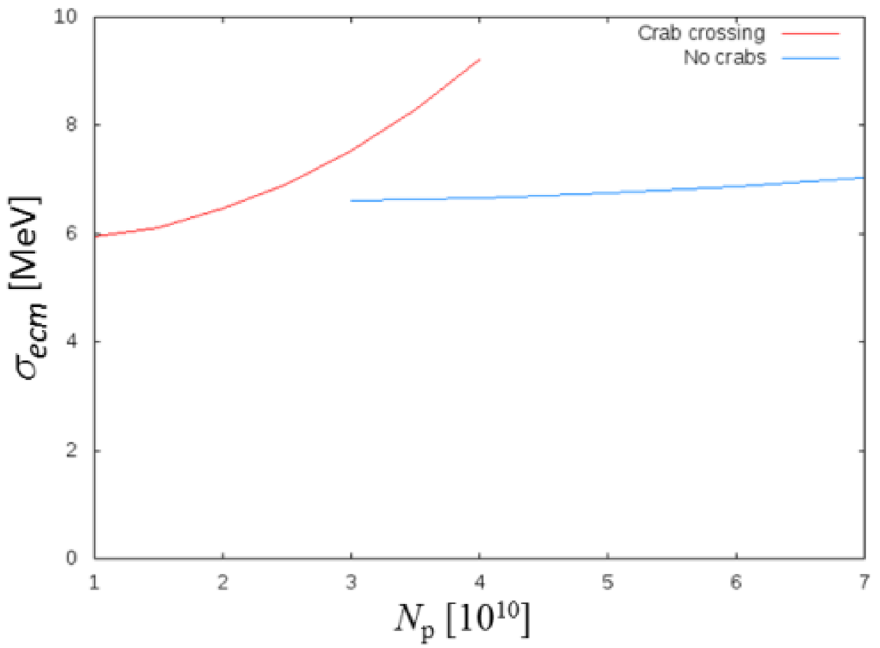
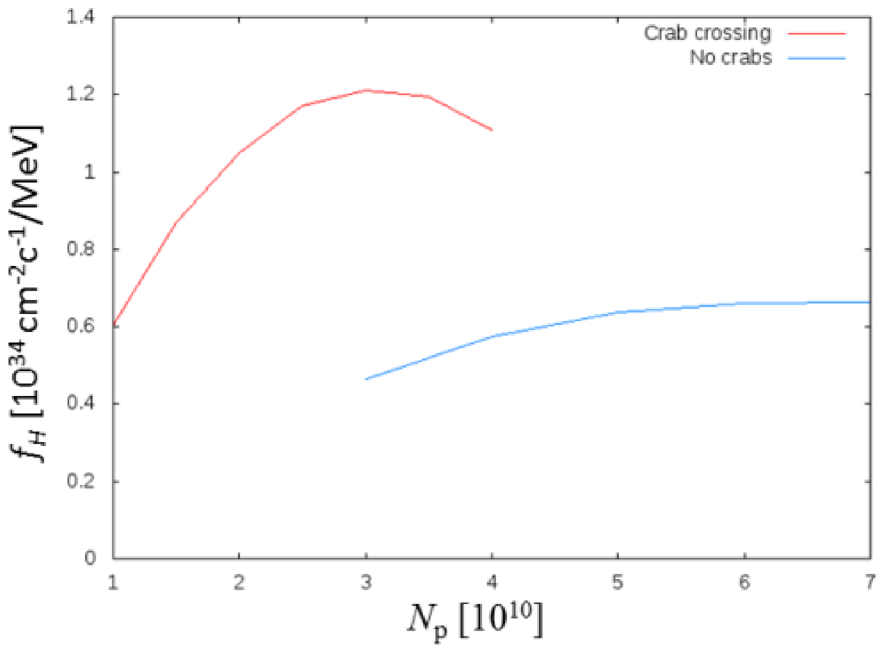
Example from CDR





The colors correspond to head-on collision with η_x^* = 15 cm (red), and collision without crabbing and η_x^* = 50 cm (blue).

These plots correspond to CDR with 60°/60° arc cell, β_x^* = 20 cm, β_y^* = 2 mm, and σ_z = 2.4 mm.

In the crab waist collision without monochromatization one can obtain f_H = 0.72 with $N_p = 3 \cdot 10^{10}$ and σ_{ecm} = 54 MeV.