FCC-ee Polarization Wigglers

J. Bauche, EPOL 2022 workshop, 27th September 2022.

Based on previous work from:
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Outline

- Specifications for FCC-ee wigglers
- LEP example
- Magnetic concept with floating poles
- Trim coils
- Next steps for design optimization
- Conclusions

Specifications

Comparison of FCC-ee vs. LEP wigglers

	FCC-ee	LEP
Number of units per beam	8×3	8
Full gap height (mm)	90	100
Central field B^+ (T)	0.7	1.0
Central pole length (mm)	430	760
Asymmetry ratio B^+/B^-	6	2.5
Critical energy of SR photons (keV)	900	1350

FCC-ee CDR wiggler specifications

In addition, the space allocated in the present layout is **16 m between quadrupoles** for **3 wiggler units**

→ *Assuming a unit length of the order of **3.5 – 4 m**, we could afford up to **1 m** between each unit*

LEP wigglers

(Mainly) 2 types of wigglers in LEP

Damping / emittance wigglers

- Single units with 3 «floating» poles
- 6 main coils powered in series
- 4 trim coils powered independently (saturation compensation)

→ *Elegant solution, requires **less transverse space**, **less material** than individual magnets*

→ ***Magnetic coupling** between central and end poles*

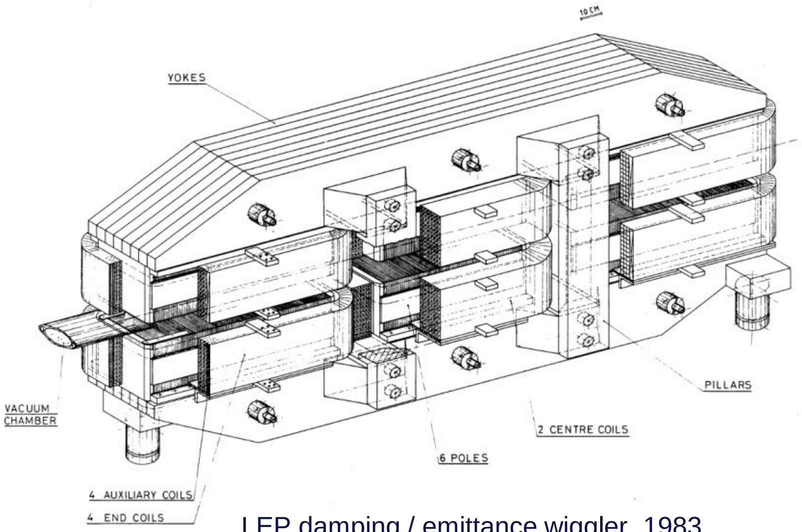
→ *Adjustment of **field integral** via **trim coils***

Polarization wigglers

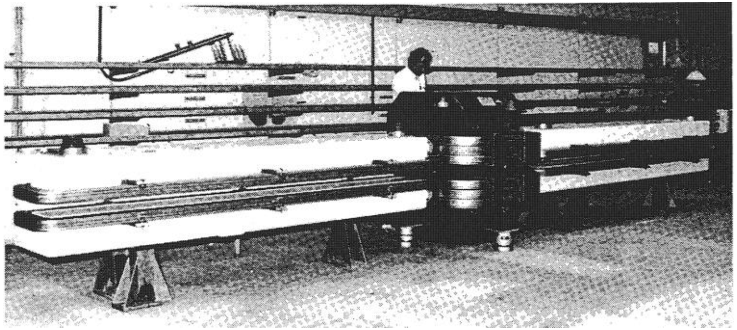
- 3 separate magnets
- End magnets powered in series; central one separately

→ *End magnets made of ½ main dipole cores*

→ *Adjustment of **field integral** via **main coils***



LEP damping / emittance wiggler, 1983

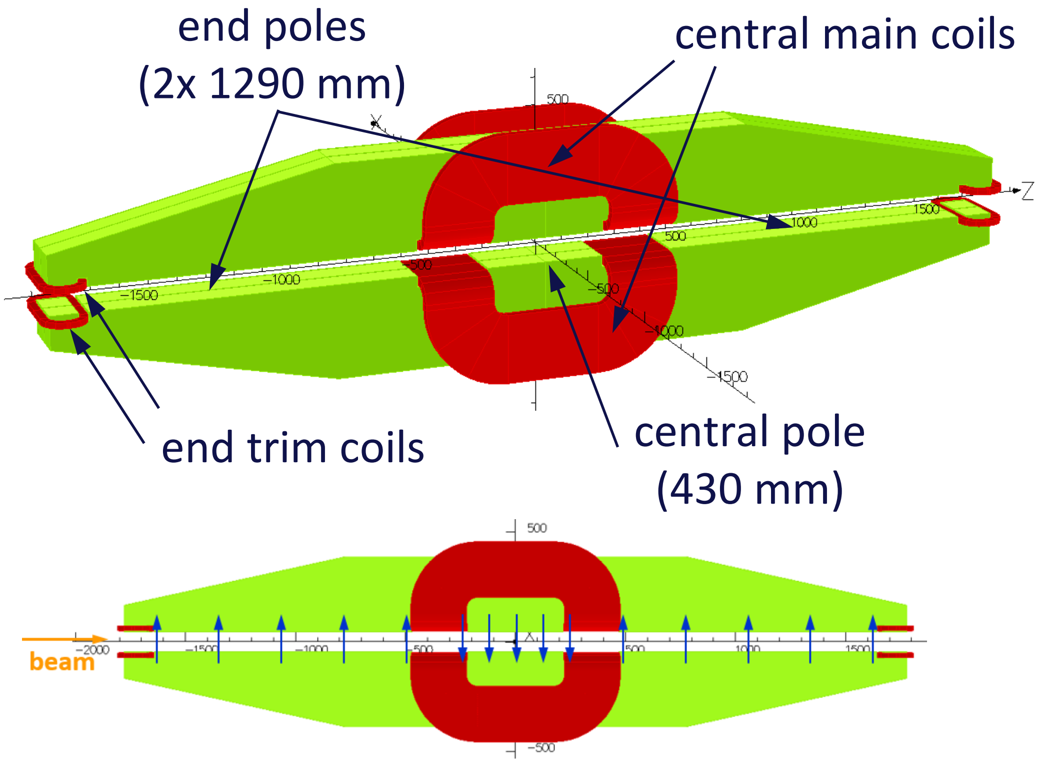


LEP polarization wiggler, 1988

Magnetic concept with floating poles

Design features

- Magnetic **flux** in **central pole** loops back through **end poles**
- **Single main** coil with enough ampere-turns is sufficient
- The **coil width** conditions a **clean transition** from B+ to B-
- A central **saddle coil** allows **smaller** magnet **transverse size**
- A design with **trim coils** at the pole ends has been explored



Concept of FCC-ee polarization wiggler with floating poles

Field self-cancellation

W = effective magnetic width

L = effective magnetic length

Flux conservation

$$\Phi_{cen} = \Phi_{end}$$

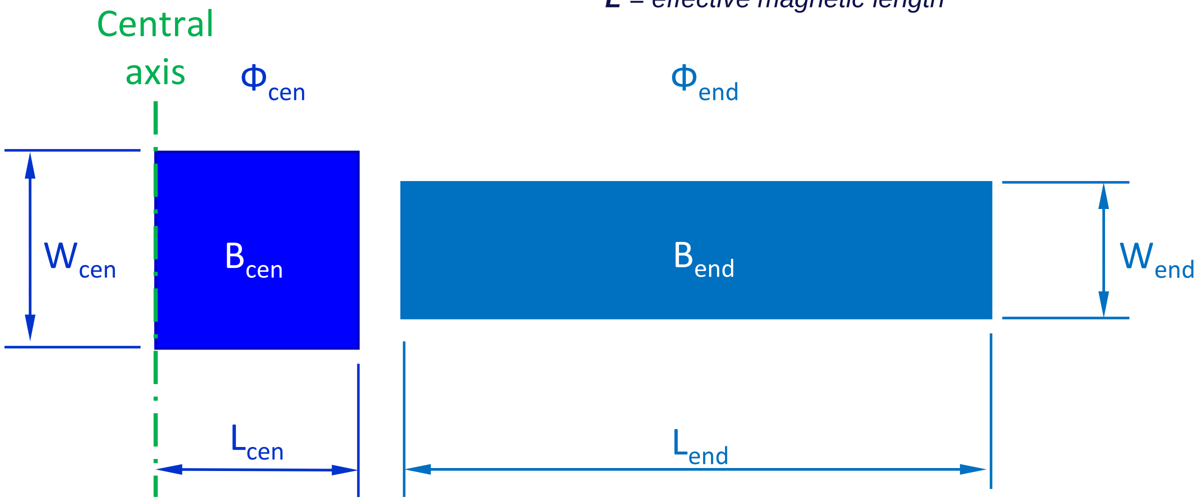
$$\Phi = B*S = B*W*L$$

Condition for self-cancellation of wiggler integral field strength:

$$B_{cen}*L_{cen} = B_{end}*L_{end}$$

Consequently:

$$W_{cen} = W_{end}$$



Schematic representation of pole effective surfaces (½ wiggler)

The translation of effective **magnetic** width/length to **physical** pole width/length is **valid outside saturation** and with **same aperture heights** on all poles

→ We could **shim** the end pole **width** to adjust the field integral to 0 during **magnetic measurements**

→ The (small) **dynamic range** of the wigglers needs to be **confirmed**

Longitudinal field distribution – trim coils

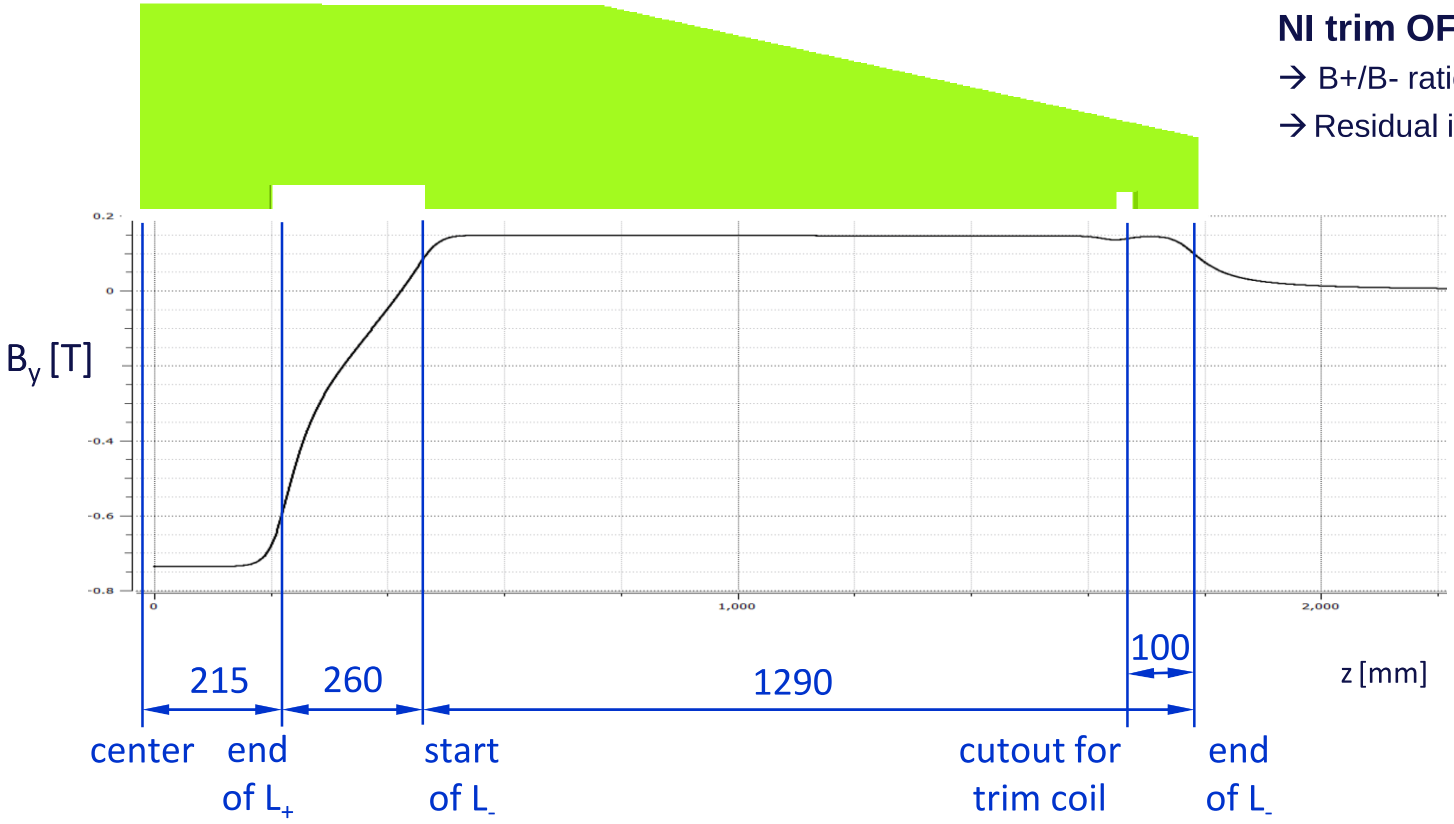
NI trim OFF

→ B+/B- ratio change: 0%

→ Residual int. field: 3.2 mTm

Beam excursion

~ 0.02 mrad at 45 GeV

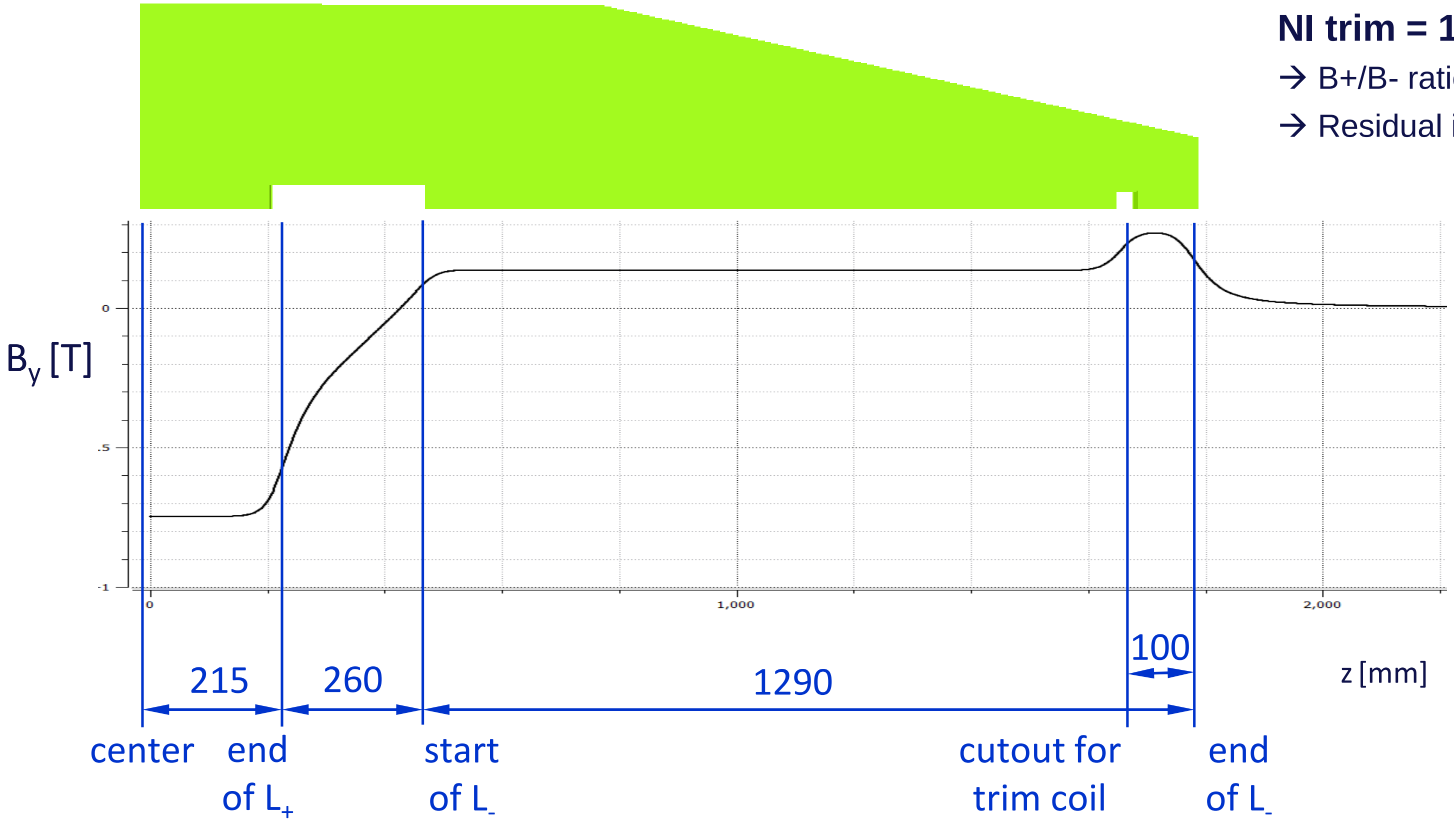


Longitudinal field distribution – trim coils

NI trim = 15% NI main

→ B+/B- ratio change: 10%

→ Residual int. field: 3.0 mTm

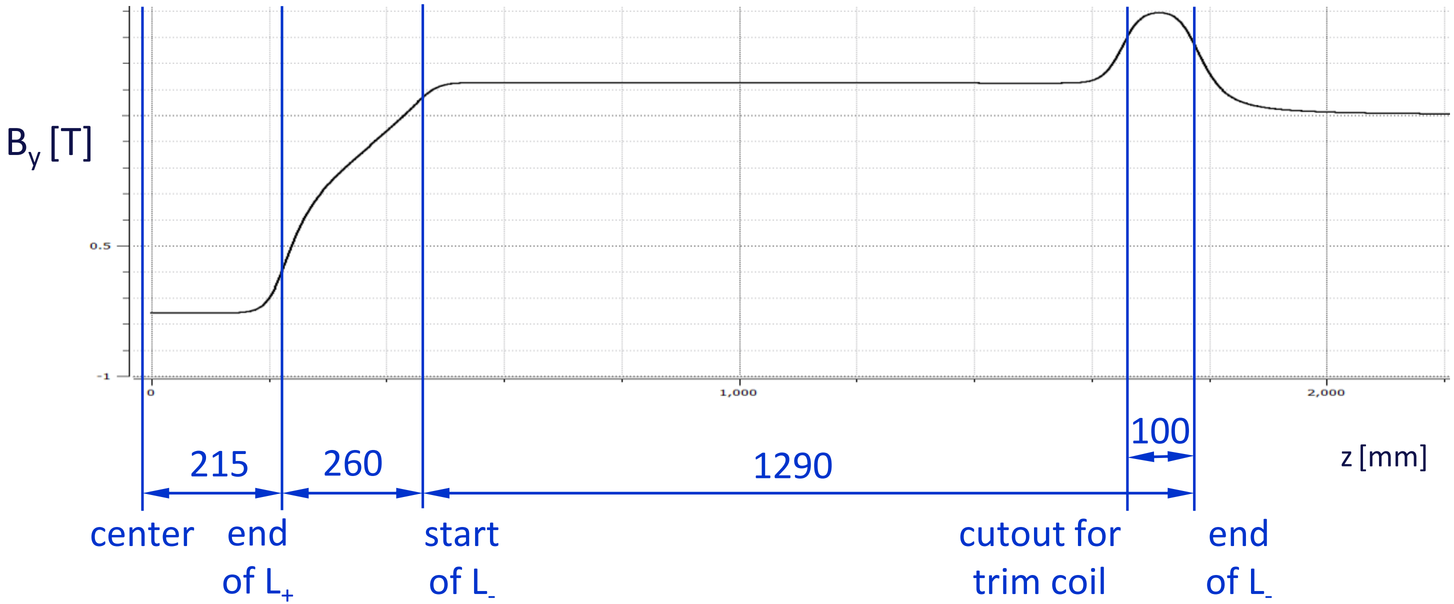


Longitudinal field distribution – trim coils

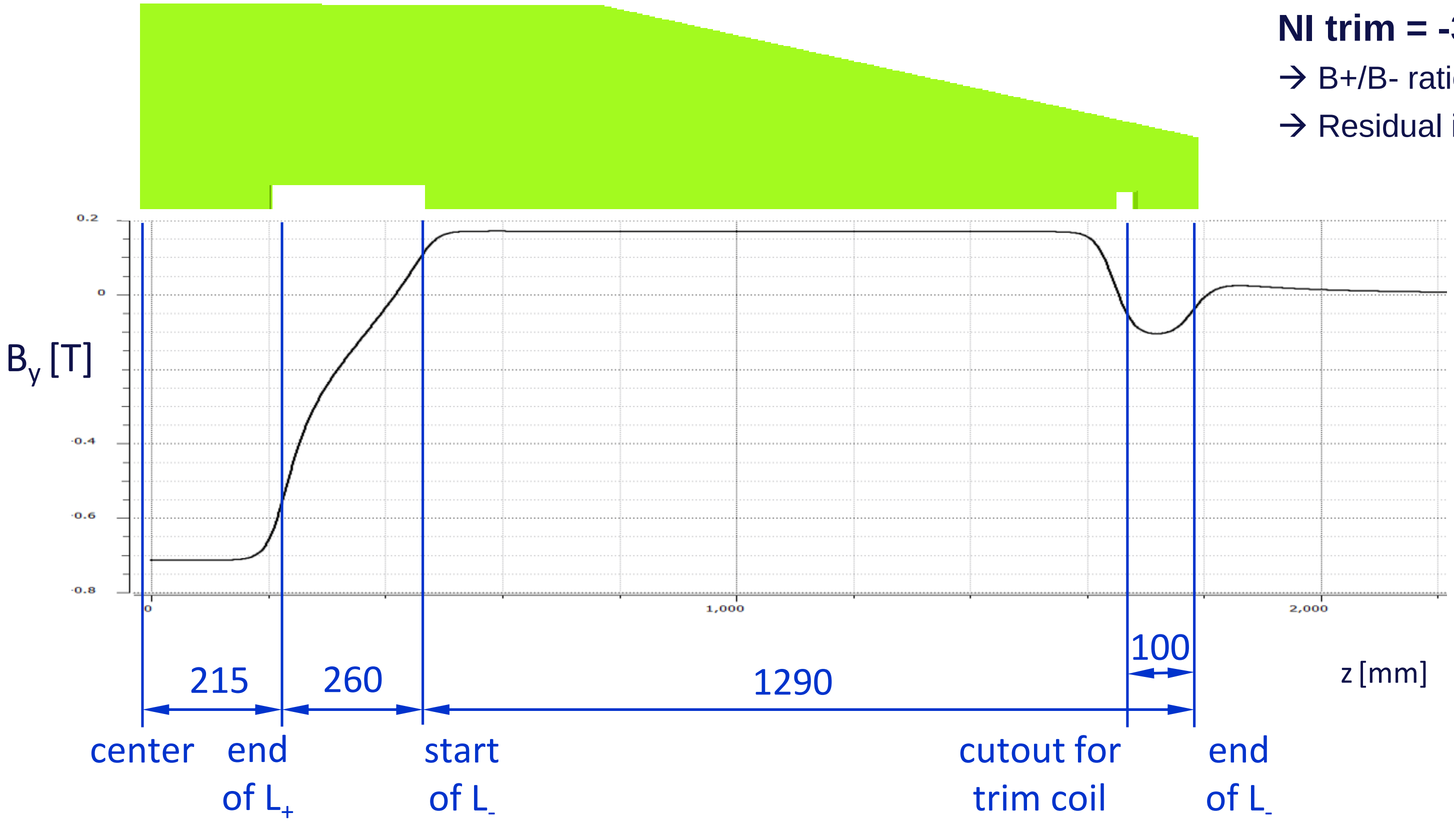
NI trim = 30% NI main

→ B+/B- ratio change: 22%

→ Residual int. field: 2.8 mTm



Longitudinal field distribution – trim coils



NI trim = -30% NI main

→ B+/B- ratio change: -16%

→ Residual int. field: 3.7 mTm

Usefulness of trim coils

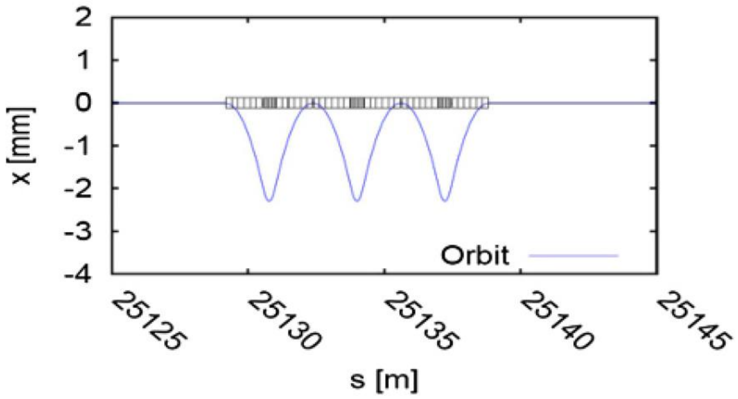
Effect of trim coils

- **B+/B- ratio** can be adjusted… but longitudinal **field profile affected**

→ Is there an interest? Impact on optics?

- The **residual field integral** is not much affected (already small due to field self-cancellation)

→ **No interest** in this respect



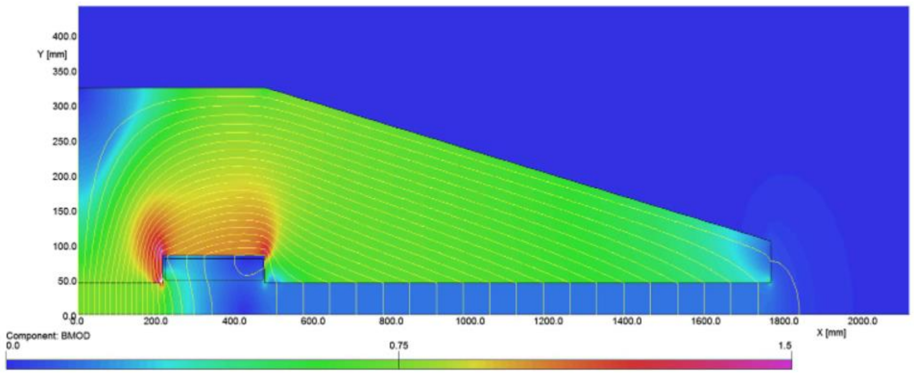
Orbit excursion in FCC-ee wigglers (CDR)

Next steps for wiggler development

What can we do next?

Precise the specifications

- Accuracy of **B+/B- ratio**
- **Dynamic range**
- Sensitivity to **residual integral field**
- Required **field homogeneity** and **harmonic** content
- Need for **adjustment** of longitudinal **field profile**



FCC-ee baseline design (CDR), without trims

Wiggler optimization

- 3D simulations to
  - → Optimize **field homogeneity** in beam transverse plane
  - → Evaluate and possibly **cancel field harmonics**

Shall we build a 1:4 scaled model of a wiggler unit to test the performance?

Conclusions

A magnet design with floating poles similar to the LEP damping/emittance wigglers has been proposed for the FCC-ee polarization wigglers

A version with a single central coil and a mechanical field adjustment would be very cost effective, but it requires confirmation of some specification parameters

A scaled 1:4 model magnet would be easy and relatively cheap to build. It would be the occasion to confirm the performance expected from a simulated model

FCC

Thank you for your attention.

Questions?