WP3 Joint Meeting

Task 3.1 **Physics design of the positron target and capture system**

I. Chaikovska on behalf of the WP3 team

29 August 2024

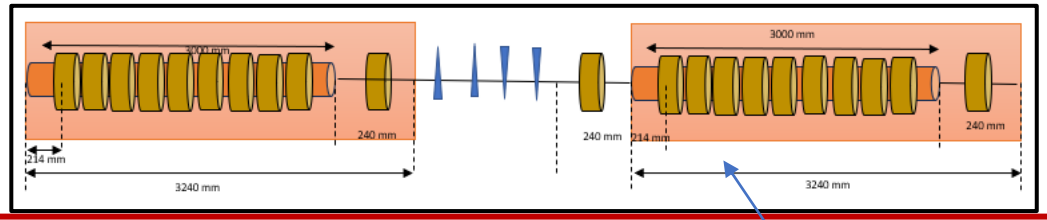
Ongoing (after FCC week)

- The studies focus on a 2.86 GeV electron drive-beam energy.
- Layout alignment between the FLUKA model of the positron capture system and beam dynamics simulation model.
- Chicane and 2 RF structures were introduced in the CL simulations for better understanding, optimization studies and more reliable results.
- With a new baseline: 4 RF structures per klystron instead of 2 → the gradient should be lower ~14 MV/m → more structures in CL? Effect of gradient on overall performance. *Any RF configuration in the capture linac is allowed to maximize the yield.*
- Flux Concentrator-based layout: studies for SuperKEKB (FC+BC) matching device.
- Solenoid vs. quadrupolar focusing after chicane (or at which energy ?). Input on power consumption is essential.
- Studies on a new layout with smaller aperture RF structures and higher field SC solenoid in CL.

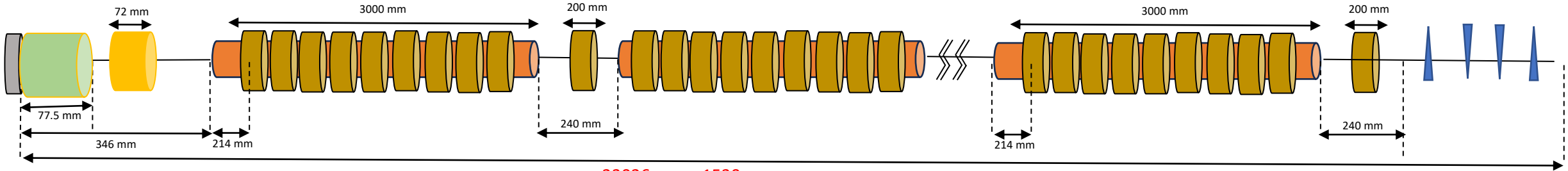
Layout: AMD + 7 structures + Chicane + 2 structures + analytical formulae

- Coordinate in RF Track simulation: z=0 @target exit
- Entrance of capture linac:
  z=346 mm/305 mm (HTS/FC)
- First Type 1 solenoid (center): 346 mm + 214 mm
- RF Track: s0=0 @target exit,
  s1=(0.346+22.68+1.53+6.48) m
- Length of tuning solenoid: 72 mm
- Length of shielding: 105 mm
- Center location of tuning solenoid: 204 mm
- Reference time: Bunch6d @ [0,0,0,0,17.5,10000]

- Incoming electron beam energy: 2.86 GeV
- 100 Hz ×4 bunches
- Cut windows: ΔE = ±2%, Δt = 20 mm/c
- Two gradients for CS: **14 MV/m** and 20 MV/m
- Tuning solenoid: 204 mm
- Phases after chicane: for max. yield/energy 253



Capture system -version 2 ?

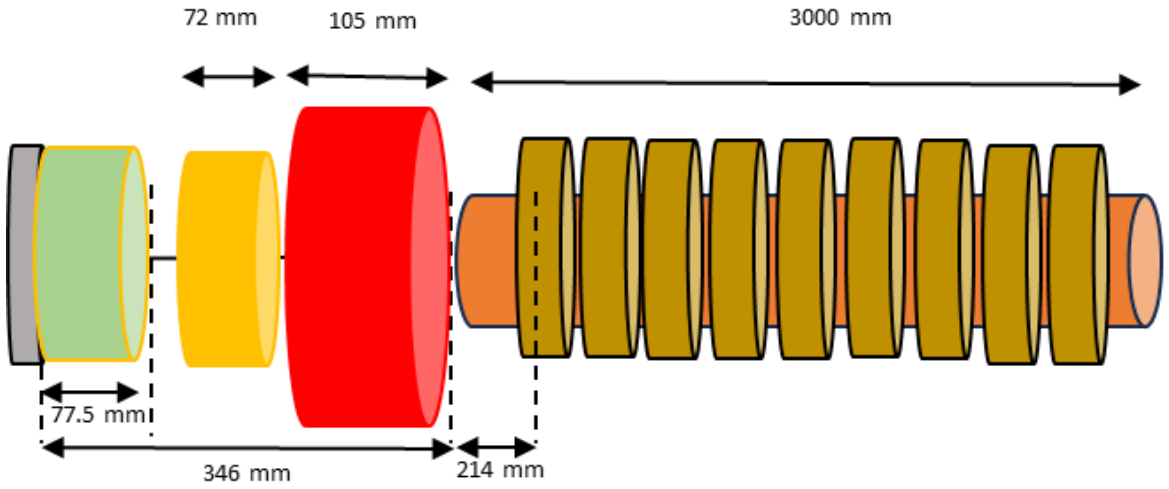


Some updates

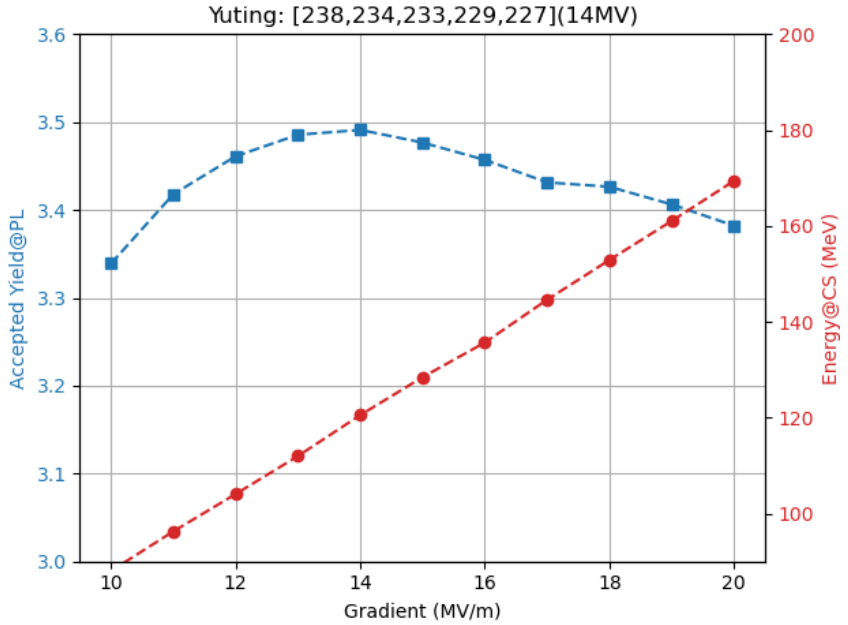
F. Alharthi, Y. Wang

- FLUKA model: shielding between the HTS and first cavity
  - From the beam dynamics point of view there is no dependence between the shielding location and the accepted yield.
  - We agreed with Barbara to place the *shielding after the tuning solenoid* as a starting point.
  - The tuning solenoid updated location is :

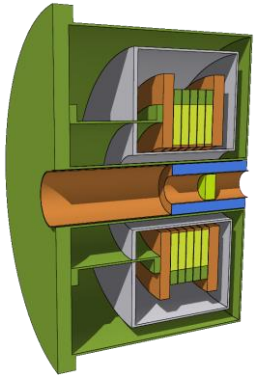
    z = 204 mm (z =0 is target exit.)



- Capture Linac gradient scan
  - For each gradient values the phases can be optimized easily.
  - No strong dependence between the gradient and the accepted yield (*w/o chicane in simulations*)
  - The only change would be increasing or decreasing the number of structures to continue using **V0 chicane**.

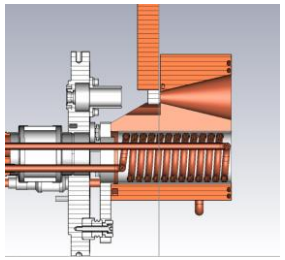


Update on FC-based layout

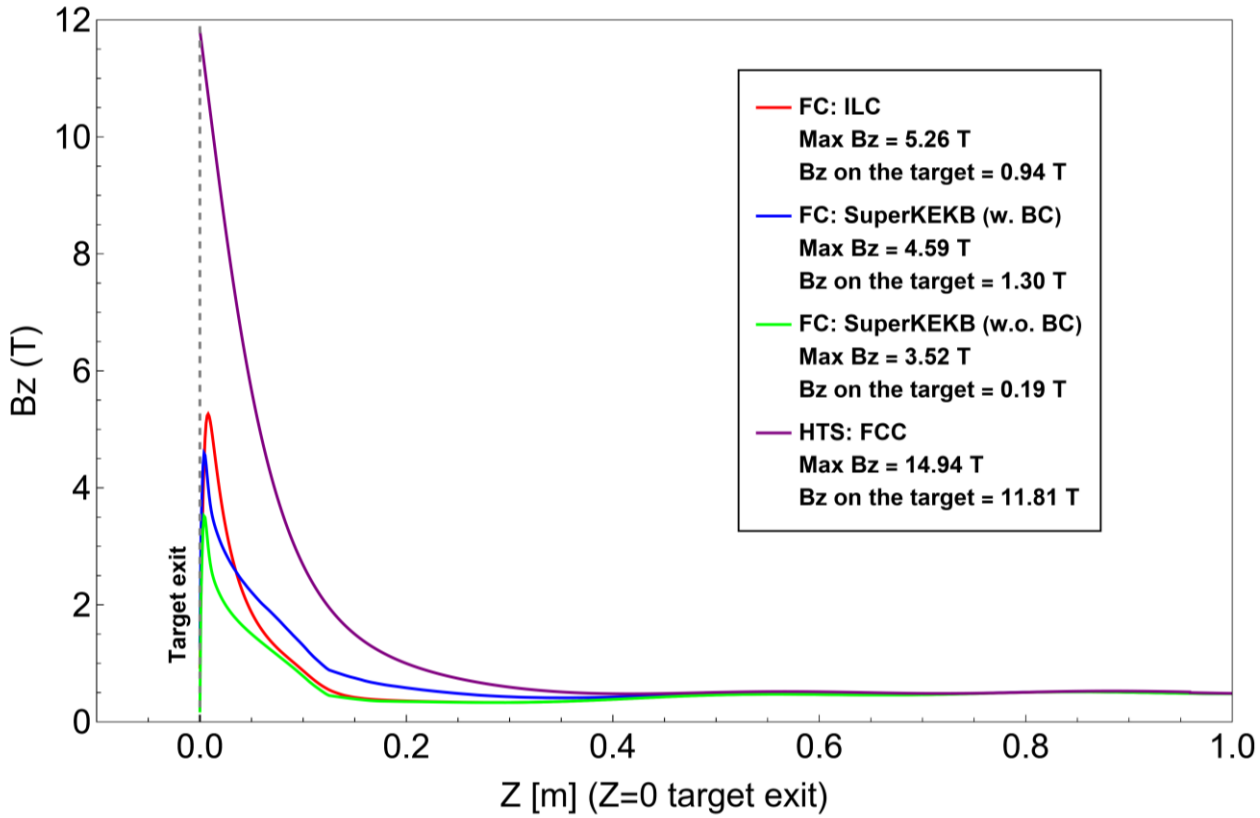


High-Temperature Superconducting (HTS) solenoid designed by PSI => HTS:FCC (submitted to mid-term review)

Originally designed by KEK for the SuperKEKB => FC:SKEKB-KEK
Under consideration for the FCC-ee : with and w/o BC



Designed by KEK for the ILC (Y. Enomoto) => FC:ILC-KEK
Under consideration for the FCC-ee

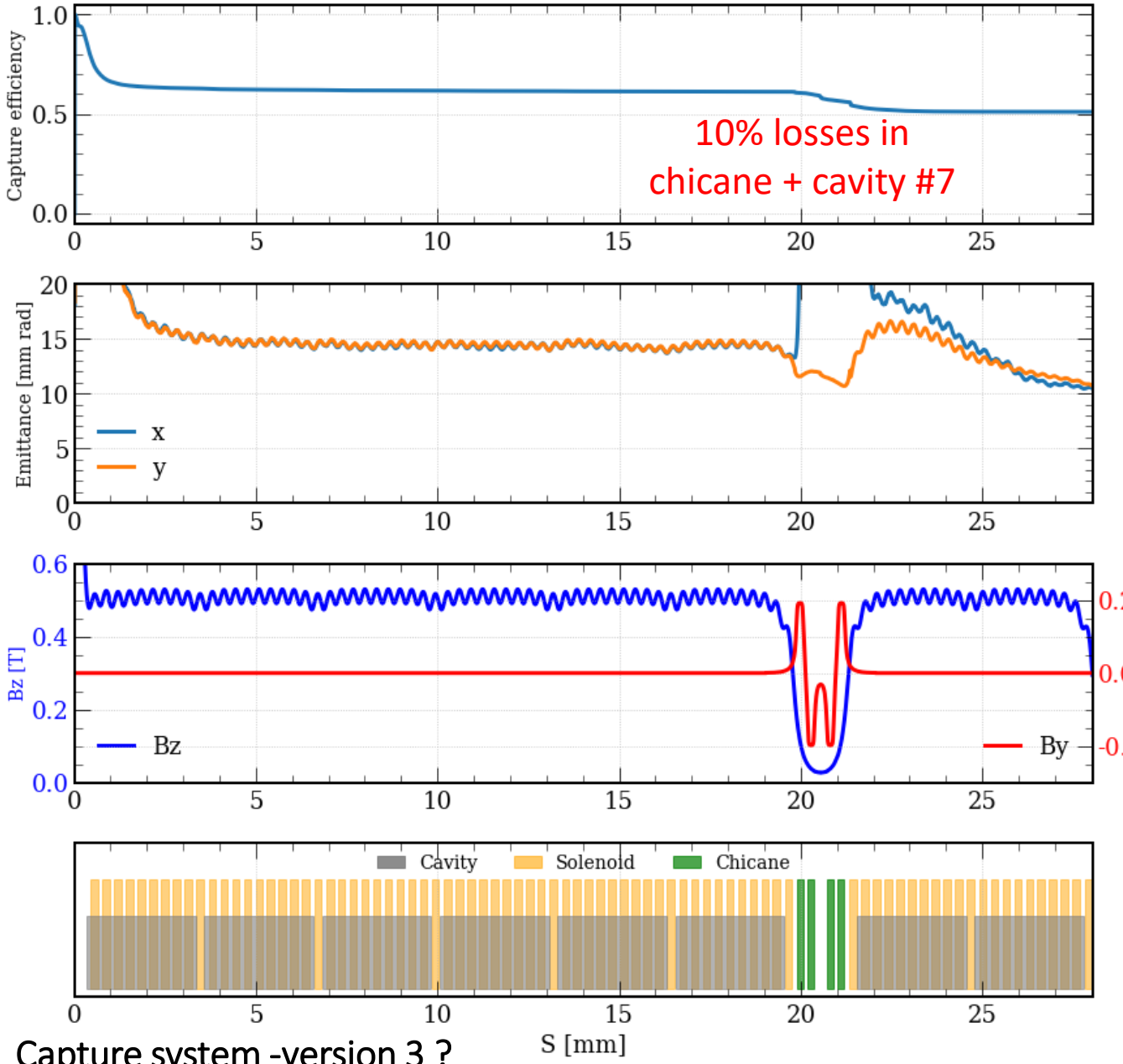


Update on FC-based layout

Y. Wang

	FCC - HTS	SuperKEKB (with BC) - FC	SuperKEKB (w/o BC) - FC	ILC - FC
Aperture of matching device	2r = 30~60 mm	2r = 7~52 mm	2r = 7~52 mm	2r = 12~64 mm
Positron yield @ target	7.09	7.09	7.09	7.09
Beam size x/y (mm) @ s1	7.52/7.47	6.24/6.11	6.48/6.34	7.92/7.7.46
Average total energy (MeV) @ s1	310.25	324.47	330.44	332.96
Energy spread (MeV) @ s1	34.35	23.46	25.28	36.11
Positron yield @ s1	3.75	1.40	1.02	1.23
Bunch length (mm) @ s1 (Accepted by cut window)	3.04	2.59	2.72	2.99
Positron yield @ PL (ΔE: 2%, Δt: 20 mm/c)	3.01 (2.9)	1.26	0.87	0.86
Primary bunch charge (nC)	4.49	10.71	15.52	15.70
Target deposited power (kW)	1.17	2.8	4.06	4.1
PEDD (J/g)	6.70	16.02	23.20	23.47
Emittance x/Emittance y (Normalized) (mm.rad) @ PL	9.63/10.52	7.08/6.68	6.62/6.06	9.57/8.57
Energy spread (%) @ PL	0.71	0.57	0.59	0.62

Latest Capture Linac layout



Capture system -version 3 ?

F. Alharthi

Capture Linac:

- 6 RF structures (2a = 60mm)
- Gradient = 14 MV/m
- **Results:**
  - Losses observed only at the beginning of CL.
  - Efficiency @end of CL ~ 0.61
  - Normalized emittance: ~ 15 mm rad

Chicane:

- V0 4 dipoles 3D field map used by Mattia and now by Yongke.
- e- stopper optimized by Yongke
- **Results:**
  - Efficiency @end of chicane ~ 0.56
  - Normalized x emittance: up to ~40 mm rad

S1 (8 RF structures):

- 2 RF structures added/simulated to optimize the CL

Results:

- Emittance oscillates between 18 and 12 mm rad
- Efficiency @end of S1 ~ 0.51.

Summary for the latest baseline layout

[233, 232, 229, 269, 273, 278] 6 cavities + chicane + 2 cavities + analytical formula	Values
Matching device peak magnetic field (@target)	HTS: 14.94 (11.77) T
Matching device aperture	2r = 30~60 mm
Positron yield @ target	7.09
Average total energy (MeV) @CL	190
Peak energy (MeV)@CL	240
Positron yield @s1 (@ 8 cavities)	3.61
Positron yield @ PL (ΔE: 2%, Δt: 20 mm/c)	2.93
Primary bunch charge (nC)	4.61
Target deposited power (kW)	1.2
PEDD (J/g)	6.89
Emittance x/Emittance y (normalized) (mm.rad) @PL	9.6/10.1
Energy spread (%) @PL	0.70
Bunch length (mm)	2.99

Positron Capture Linac studies

V. Mytrochenko

- **The baseline design :**

  HTS solenoid matching device, solenoidal focusing with **Bz=0.5 T**, 5 RF structures with 14 MeV/m and aperture of **∅60 mm**, the SKEKB type chicane.

  → **Ne^+/Ne^- @PL (ΔE: 2%, Δt: 20 mm/c) is 3.25**

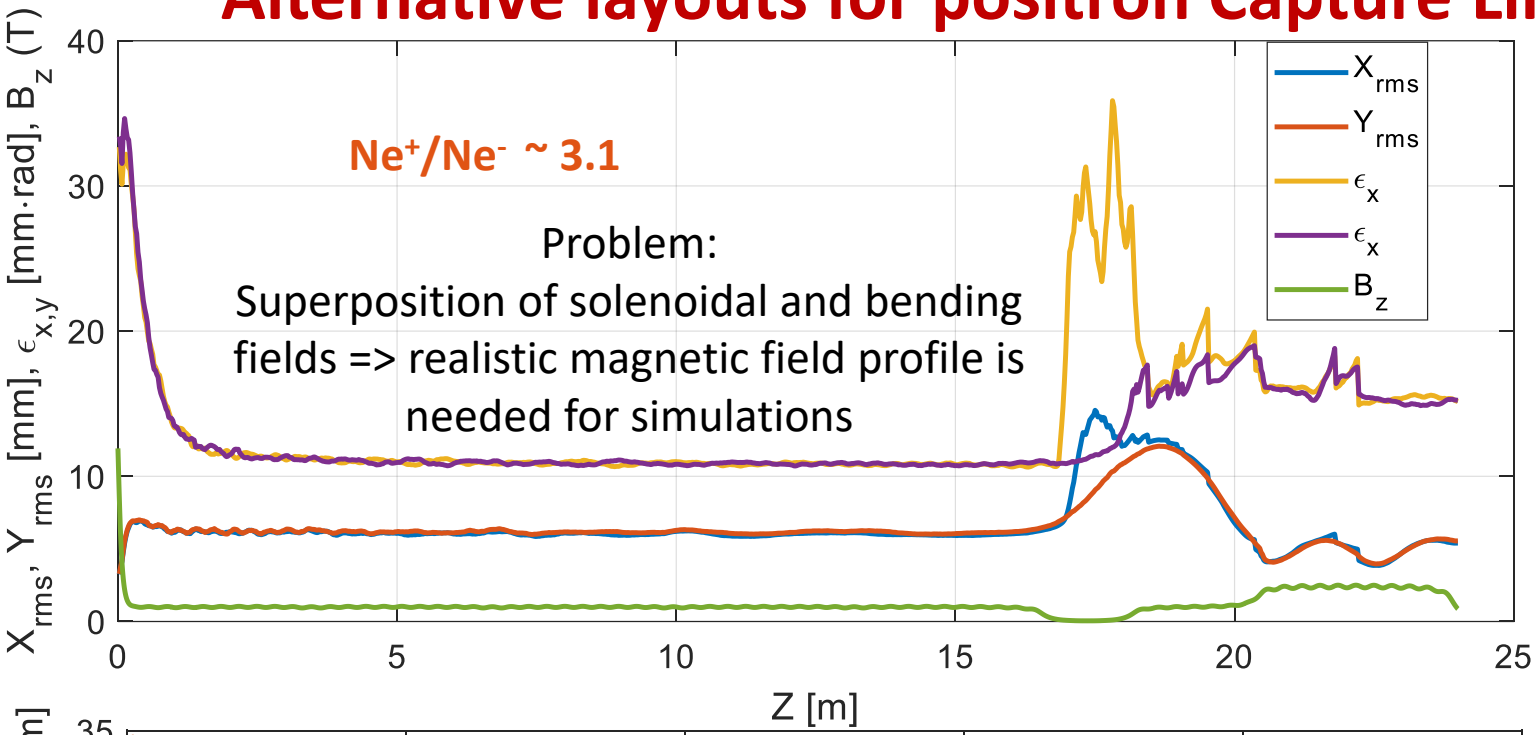
- **Alternative layouts of the positron capture linac:**

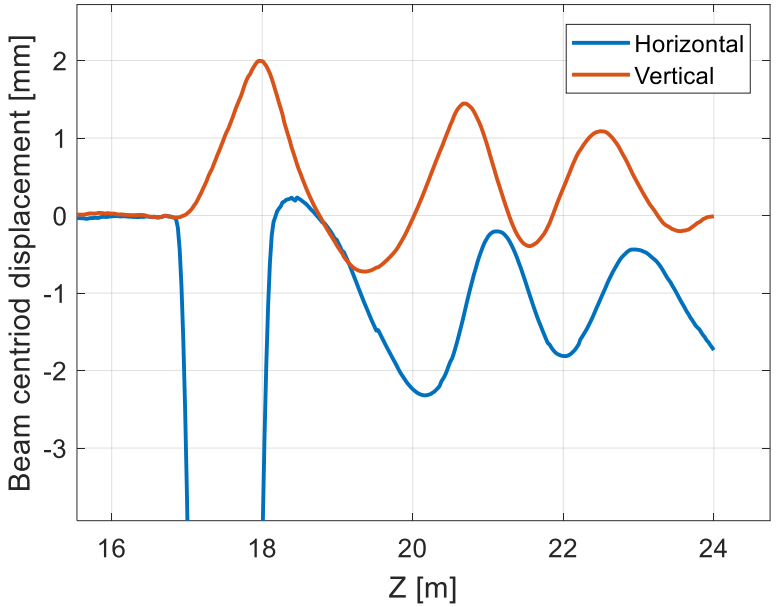
  1. HTS solenoid matching device, 5 RF structures with 14 MeV/m and aperture of **∅40 mm**, SC solenoidal focusing with **Bz=1 T** upstream of the SKEKB type chicane and **2.5 T** downstream.
     → **Ne^+/Ne^- @PL (ΔE: 2%, Δt: 20 mm/c) is 3.1** *(beam losses in chicane ~5%)*
  2. The same layout but with **quadruple focusing** downstream the 5th RF structure (4 quads upstream the chicane and 6 downstream the chicane).
     → **Ne^+/Ne^- @PL (ΔE: 2%, Δt: 20 mm/c) is 2.55**

  ☞ *FODO period is shorter than the section length, so it seems that the focusing channel should start with two FODO cells along the RF section.*

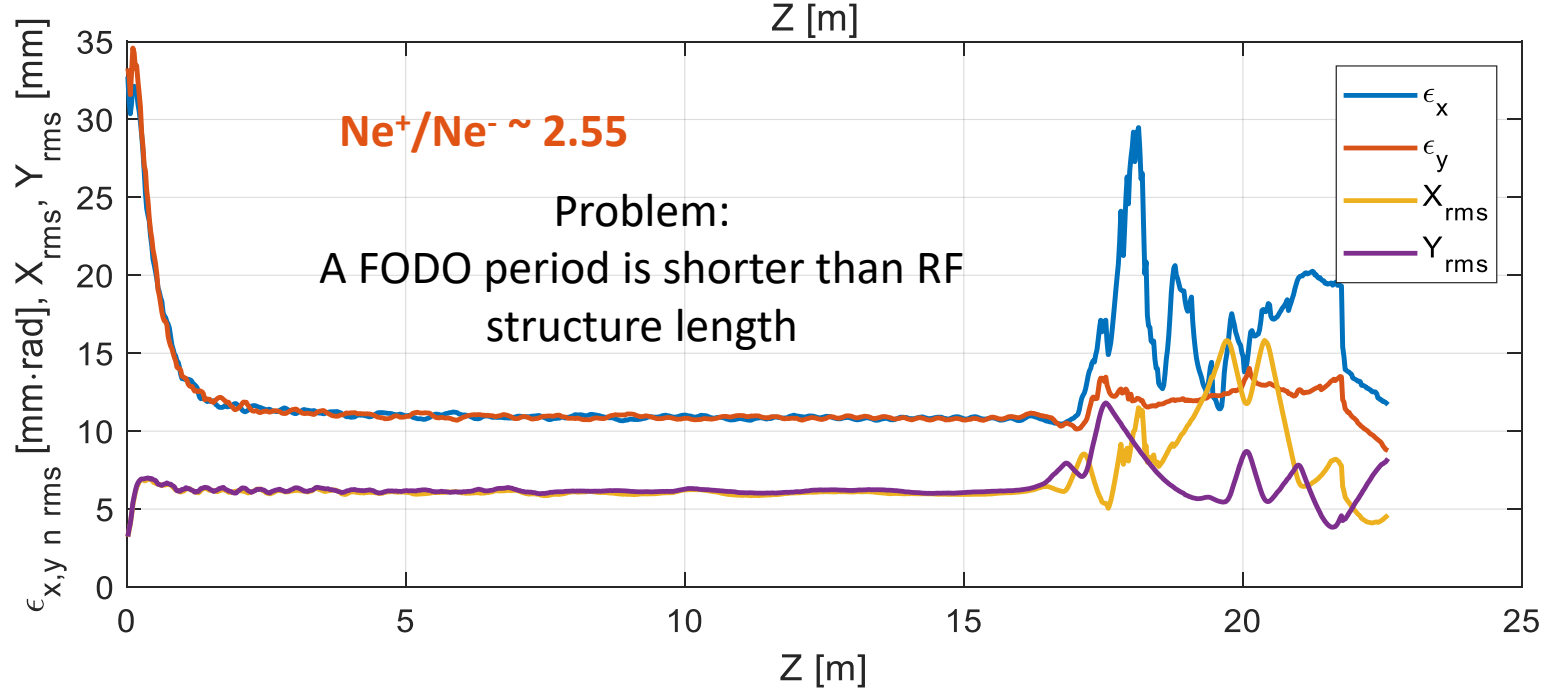
Alternative layouts for positron Capture Linac with ∅ 40 mm

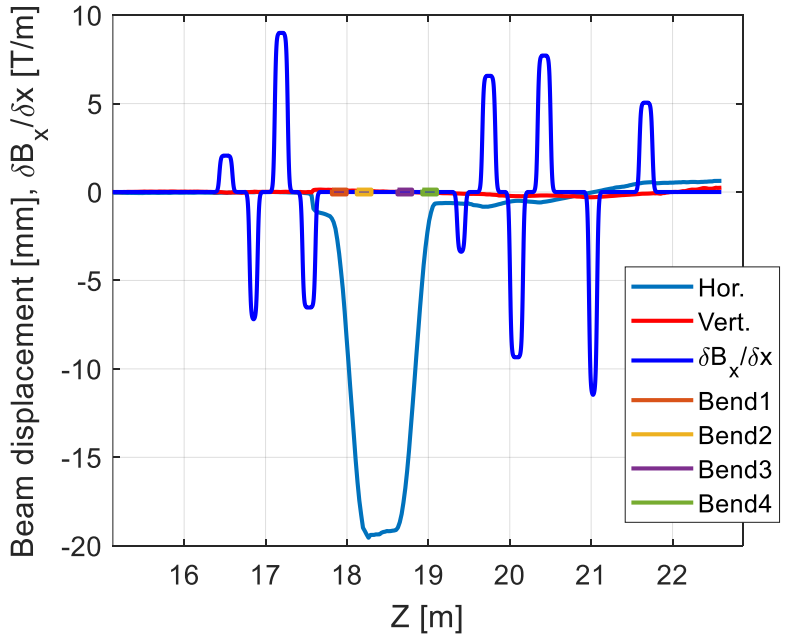
Solenoidal focusing





Solenoidal and quadrupole focusing

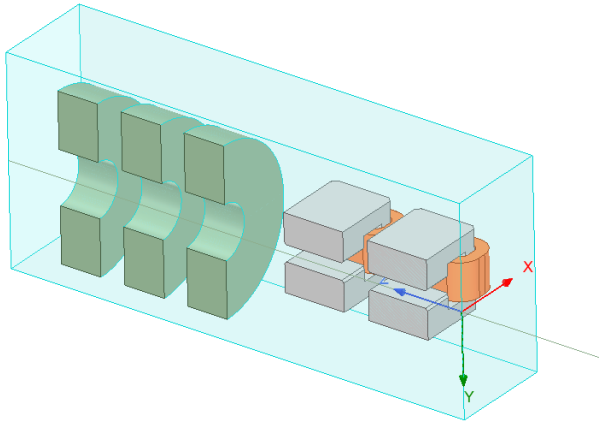




Next steps

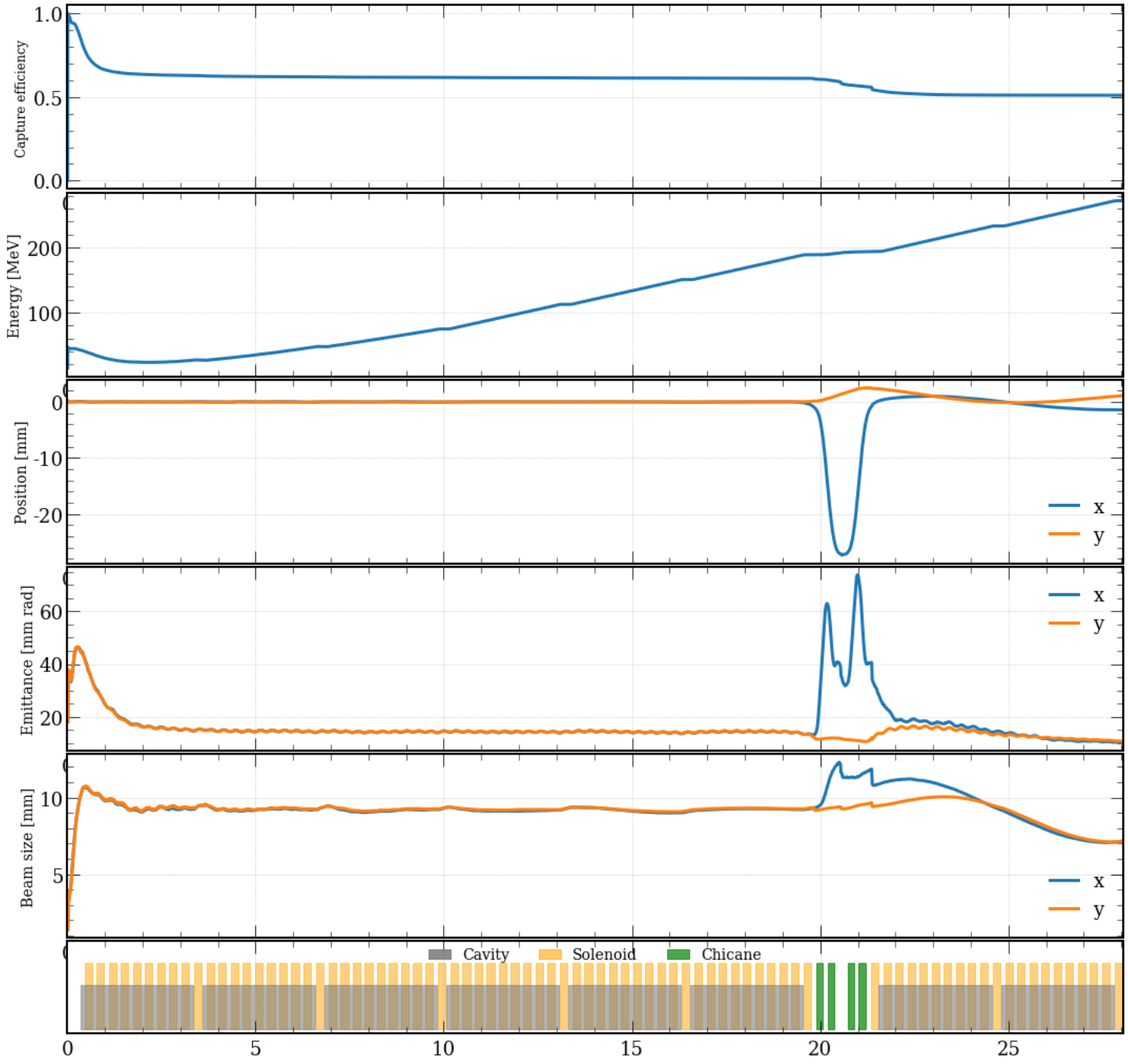
- Define the priorities (to finish technical work by December 2024).
- **Consolidation of the baseline design of the capture linac:** *number of RF structures and gradient.*
- Choice between *solenoidal vs. quadrupole focusing* after chicane (or at which energy ?
- In case of solenoid focusing, *more realistic magnetic fieldmap* (solenoid-chicane) is needed for more reliable results. Riccardo provided a model in Maxwell3D. Simulation/studies to be conducted.

- Further studies on a new layout with smaller aperture RF structures and higher field SC solenoid in CL: *feasibility of the SC solenoid to be investigated.*



Latest CL layout

Beam transport



Latest Capture Linac layout

Efficiency in the chicane