FCC-ee positron linac design

Y. Zhao, A. Latina, CERN

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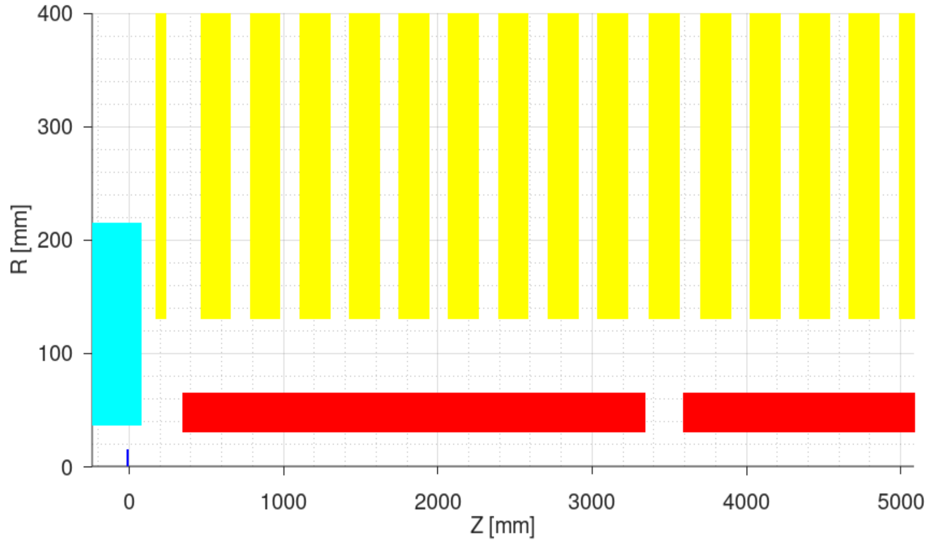
Positron production

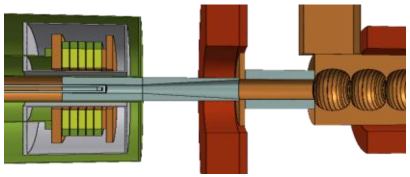
- Electrons
  - E = 2.86 GeV. σ_E / E= 0.1%. σ_z = 1 mm
  - $\sigma_{x,y}$ = 1 mm. $\varepsilon_{n,x,y}$ = 15 mm*mrad (i.e. $\sigma_{px,py}$ = 7.665 keV). Emittance can be larger or smaller, but the impact on positron yield is negligible
- Target
  - Conventional scheme (i.e. cylindrical shape, single amorphous tungsten)
  - Radius: R = 15 mm. Radius can be reduced to the minimum of 5 mm
  - Thickness: W = 15 mm

Capture section

- AMD
  - HTS solenoid. 2D field. B_0 ~ 14.94 T
  - Target exit position: 40 mm (w.r.t. HTS B_0)



- Matching solenoid
  - L = 72 mm. ~~1D~~ 3D field (Maxwell3D)
  - B_0 ~ 0.245 T
  - Center position: 244 mm (w.r.t HTS B_0)
- Shielding
  - Tapered aperture (optimized by WP3). Impact on yield is negligible

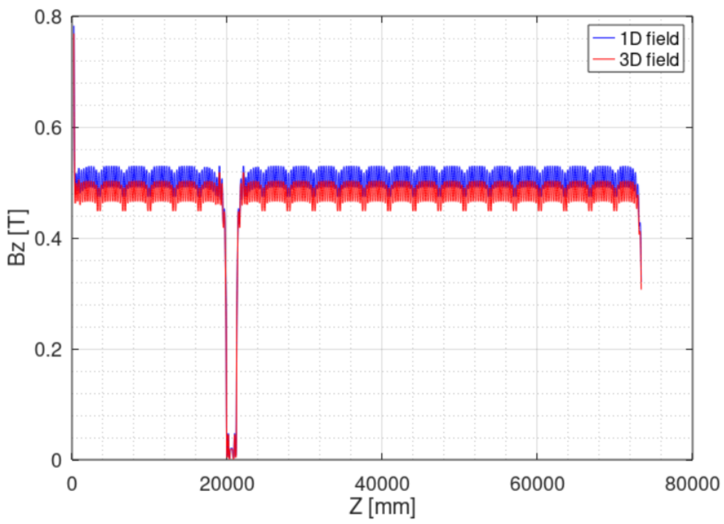


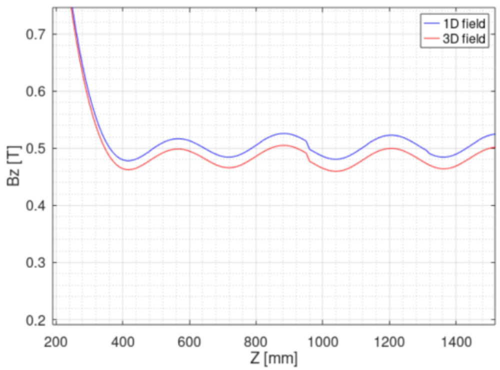
M. Daugaard

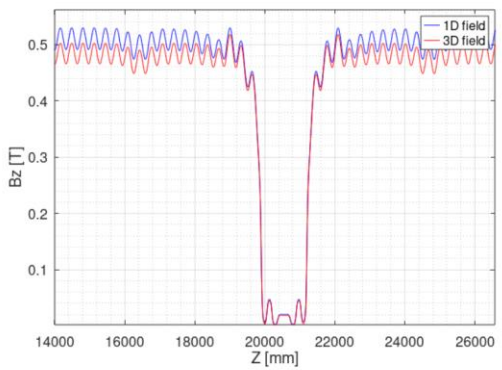
- Capture Linac (CL) – "V3"
  - RF structure length: 3 m. Iris radius: a_0 = 30 mm (constant)
  - N = 6, G = 14 MV/m, ϕ = [236 234 232 265 276 249]° (reoptimized by WP3)
  - Regular solenoids: L = 200 mm. ~~1D~~ 3D field (Maxwell3D). B_0 ~ 0.31 T. N = 9 (per structure)

Capture section

- Solenoid field comparison between 1D field from 2D simulation ("V0") and 3D field from 3D simulation ("V1"):
    - Impact on results is negligible, nevertheless, difference being investigated
    - 3D simulation has 1% lower current and peak field than 2D simulation due to different definition
    - Fringe field of 3D field is also slightly lower than 2D simulation leading to an overall 6% lower on-axis field
    - For consistency (with chicane simulation), leave it as it as now and use all 3D fields as baseline without any scaling for the moment

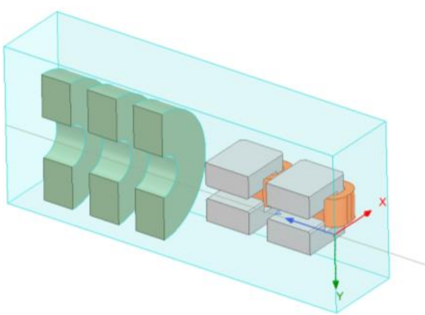




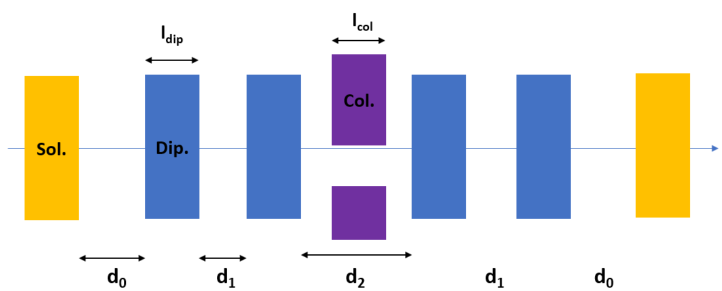


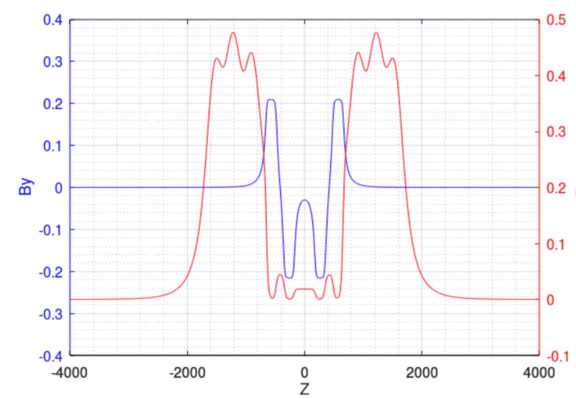
Chicane

- Chicane – "V2" (Collaboration with R. Zennaro)
  - ~~Individual simulation of chicane (four dipoles)~~
  - Combined simulation of chicane (four dipoles) and 6 neighboring solenoids. Therefore, parameters (lengths, apertures, distances) are fixed by design
  - Dispersion closed by increasing 2% the current of middle dipoles
  - 3D field (Maxwell3D)
  - Dipole yoke length: **l_{dip} = 180 mm**
  - Apertures of beam pipe: **Δx = 150 mm, Δy = 50 mm (yoke aperture is ~~60 mm~~ 70 mm)**
  - Distances between dipole yokes: **d1 = 125 mm, d2 = 350 mm**
  - Distance between solenoid and dipole yoke: **d0 = 125 m**



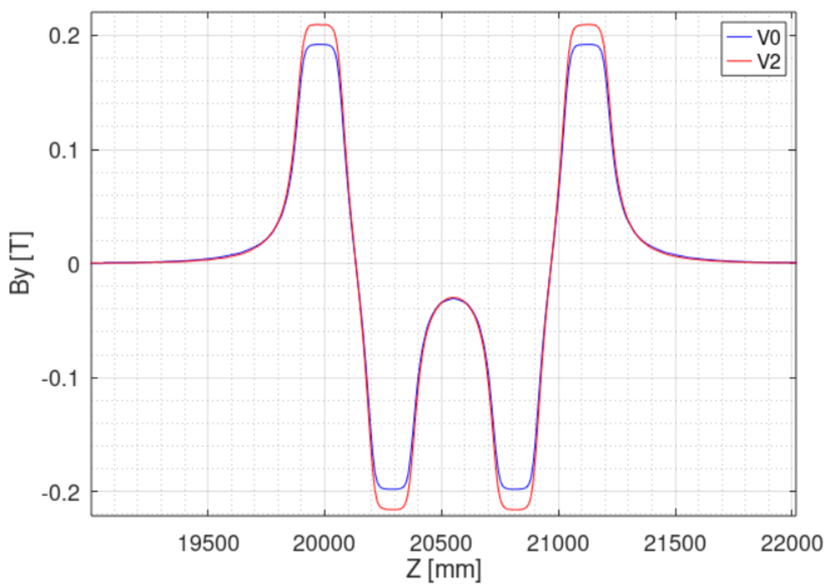
¼ view

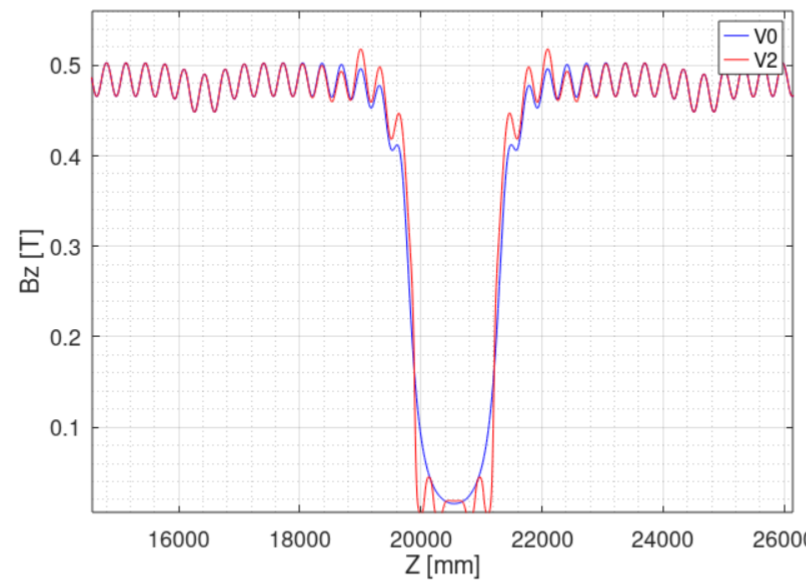




Chicane

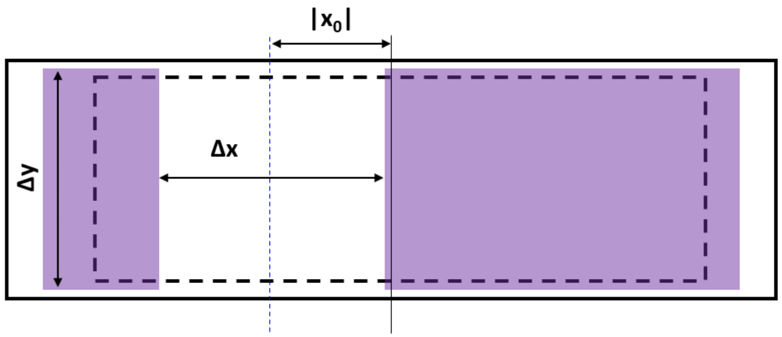
- Chicane field comparison between “V0” and “V2”:
  - “V0” has old design and simulation. “V1” design is obsoleted. “V2” is new baseline for the moment
  - “V2” has similar chicane design as “V0”, except for larger aperture and current
  - 3D simulation is used for both solenoid and chicane in both cases. Difference is:
    - “V0”: chicane and solenoid are simulated separately
    - “V2”: chicane and neighboring solenoids are simulated together

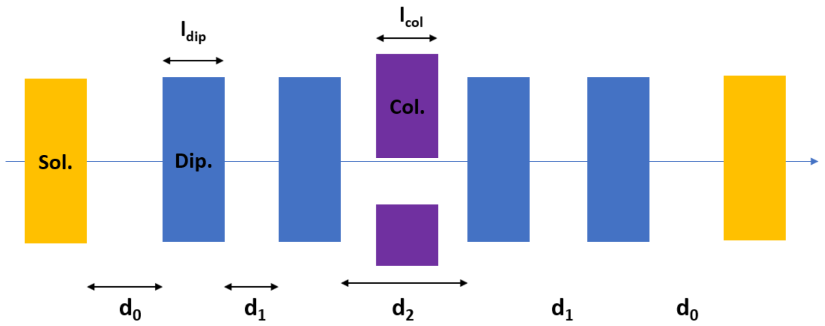


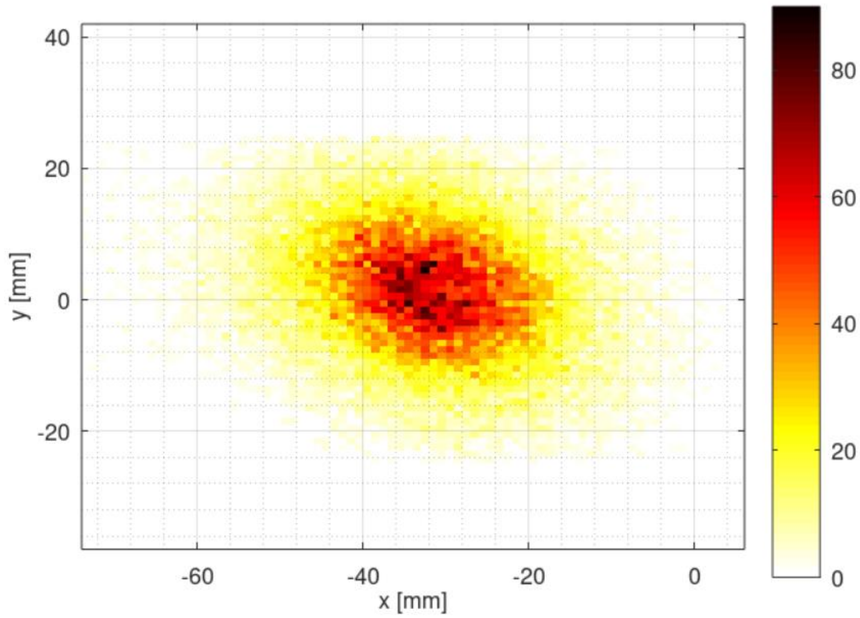


Collimator

- Collimator
  - Length: $\mathbf{l_{col} = 120}$ **mm**
  - Apertures: **Δx = 70 mm, Δy = 50 mm**
  - X offset: $\mathbf{x_0 = -35}$ **mm**

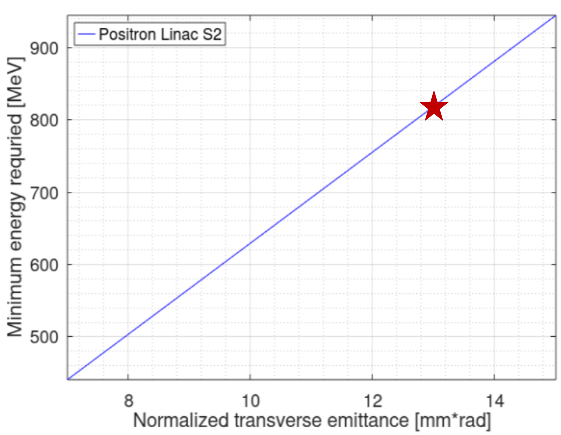




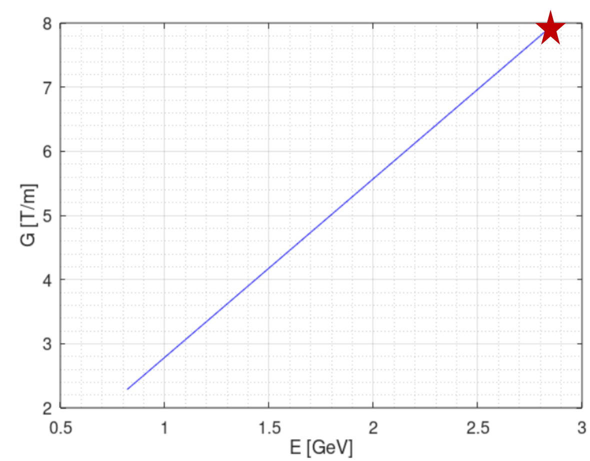


Positron linac design

- Section 1 (S1)
  - Same structure and solenoids as Capture Linac
  - N = 16, G = 14 MV/m, ϕ = -10° (optimized for max. yield)
  - Average energy (around bunch core) at exit: 820.6 MeV
- Section 2 (S2)
  - Same structure as Capture Linac
  - Periodic FODO cells. 2 structures per FODO cell. FODO phase advance: ~~90°~~ 76.345°
  - Quadrupole length: 0.4 m. Quadrupole-Structure distance: 0.15 m. Quadrupole spacing: 3.3 m
  - N = 52, G = 13.468 MV/m, ϕ = 5° (optimized for max. yield)
  - Average energy (around bunch core) at exit: 2.866 GeV



Min. energy vs emittance in S2



Quadrupole gradient vs energy in S2

8 T/m should be acceptable

- Section 3 (S3) removed

Positron linac power consumption

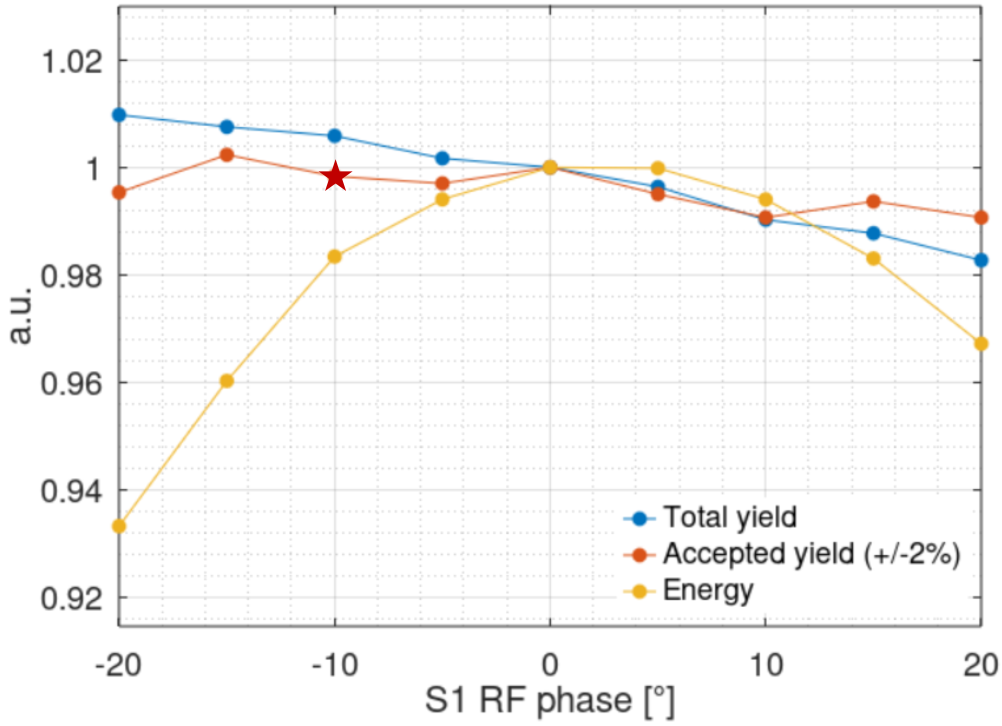
- **Power consumption in Positron Linac** (based on discussion with J. Raguin)

Parameter	Value
Average gradients in S1, S2 [MV/m]	~14
Number of structures per RF module	4
Number of **structures** in S1, S2	[16, 52]
Total number of RF modules	4+13+1 = 18
Total number of solenoids	16*10 = 160
Total number of quadrupoles	52+2 = 54
RF power consumption [MW]	18*0.19 = 3.42
Solenoid power consumption [MW]	160*0.016 = 2.56
Quadrupole power consumption [MW]	neglected
Total power consumption [MW]	**5.98**

✓ **Using 20 MV/m in S1 would likely reduce the power consumption, but it's a bit challenging, therefore not applied**

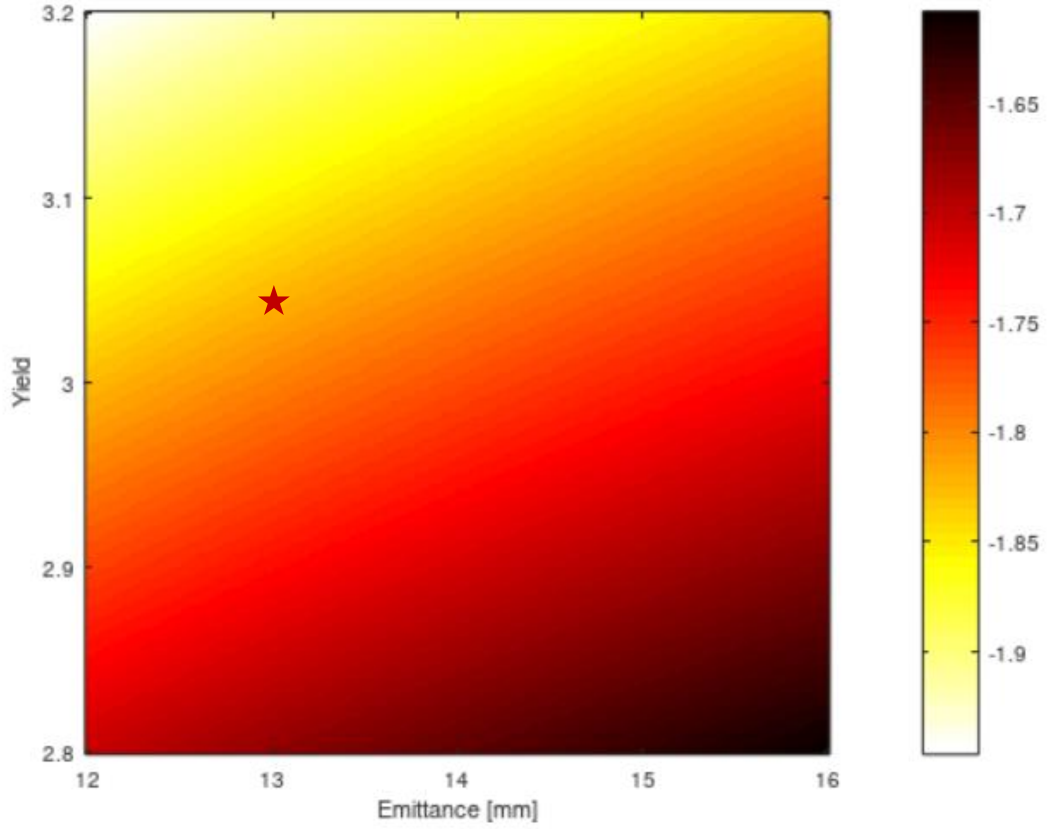
Positron linac optimization

- Section 1 (S1) RF phase optimized for maximum DR accepted yield:
  - 10% particles used in optimization
  - Collective effects not used in optimization
  - Tracking continues up to 2.86 GeV with analytic formula



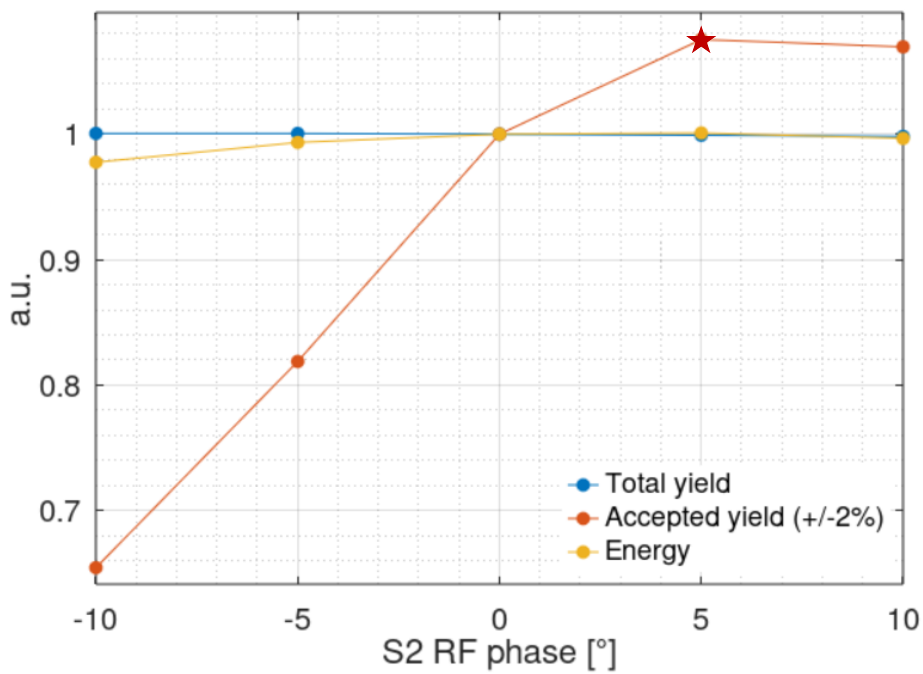
Positron linac optimization

- Matching section (5 quadrupoles and 6 distances) between S1 and S2 are optimized for maximum yield, as well as smaller emittance, with merit function defined as function of DR accepted yield and emittance:



Positron linac optimization

- Section 2 (S2) RF phase optimized for maximum DR accepted yield:
  - 10% particles used in optimization
  - Collective effects not used in optimization
  - Energy at 2.86 GeV scaled with analytic formula for maximum DR accepted yield



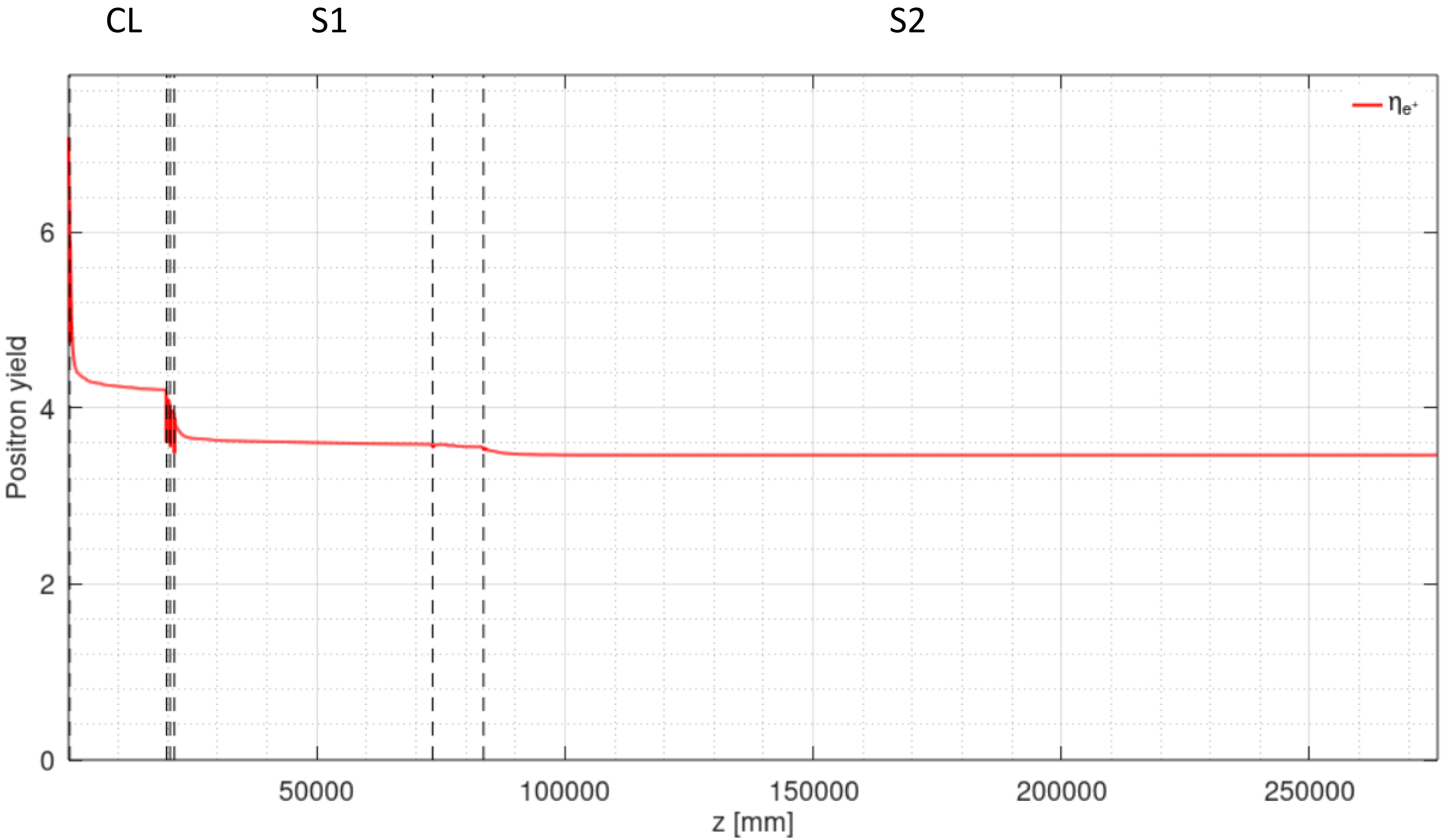
- Section 2 (S2) RF gradient and reference energy gain per structure are also optimized

Positron linac simulation results

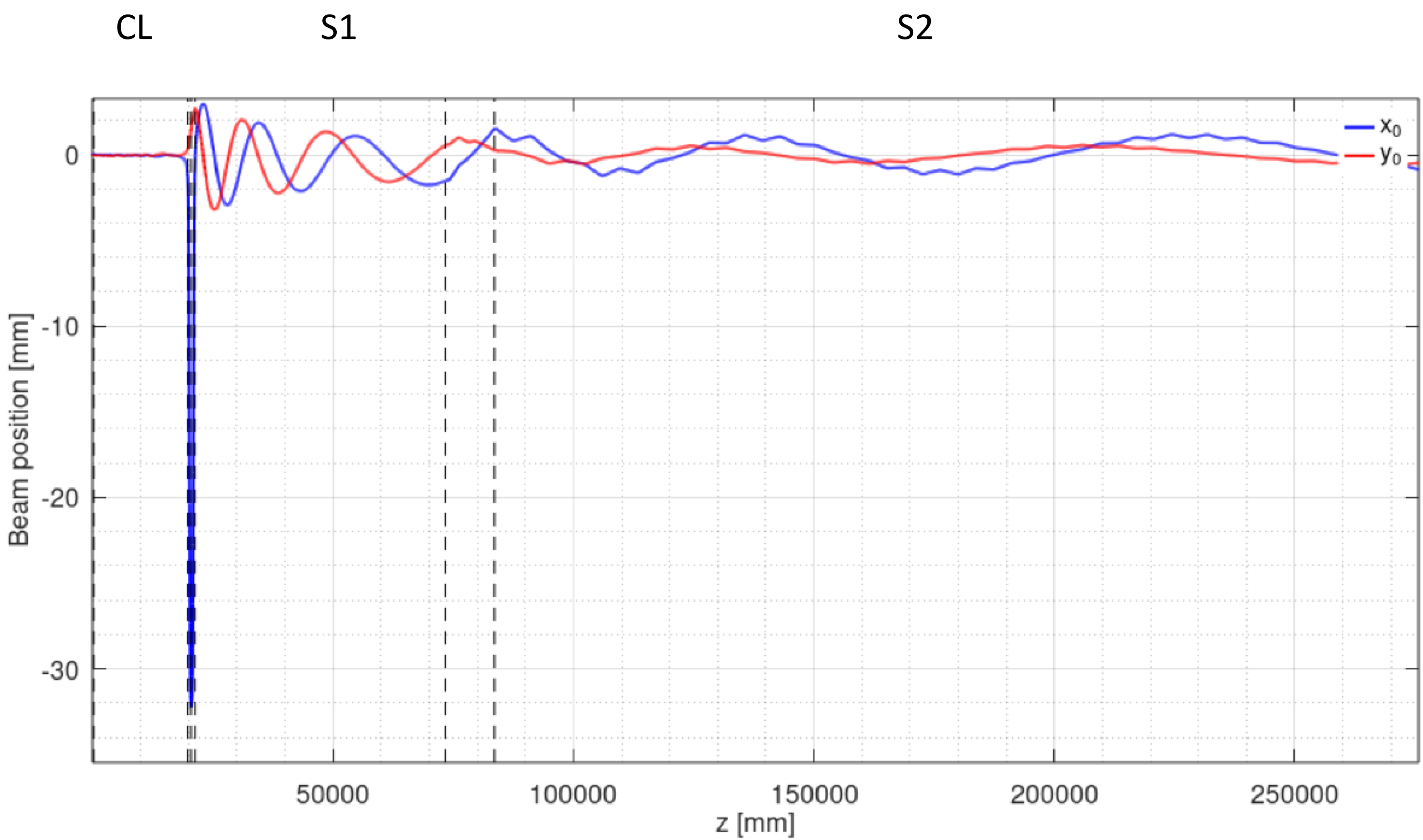
- **Positron Linac (PL) simulation results**

Parameter	Value
Collective effects considered	Space charge; Short-range wakefield
Primary electron bunch charge assumed for collective effects [nC]	5.0
Bunch length (around bunch core) at PL exit [mm]	2.85
Energy spread (around bunch core) at PL exit [%]	0.94
Total positron yield (all positrons) at PL exit	3.466
Normalized X, Y emittances (all positrons) at PL exit [mm*rad]	13.3, 13.3
Geometric X, Y emittances at (all positrons) PL exit [mm*mrad]	2.38, 2.38
Expected DR accepted yield with ±2% energy acceptance at PL exit	3.035
Normalized X, Y emittances (accepted positrons) at PL exit [mm*rad]	12.8, 12.9
Geometric X, Y emittances at (accepted positrons) PL exit [mm*mrad]	2.29, 2.30

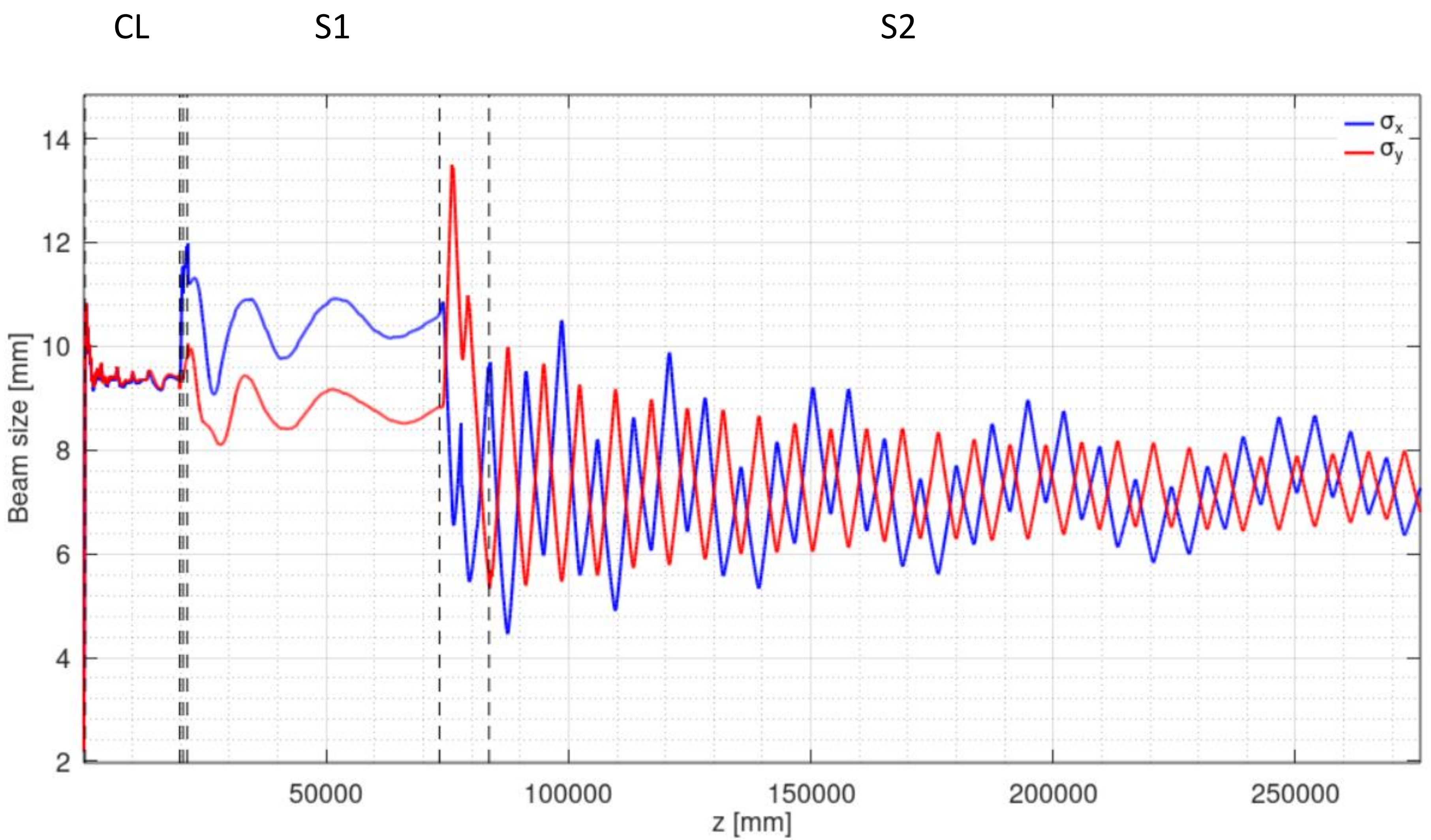
Yield evolution along z



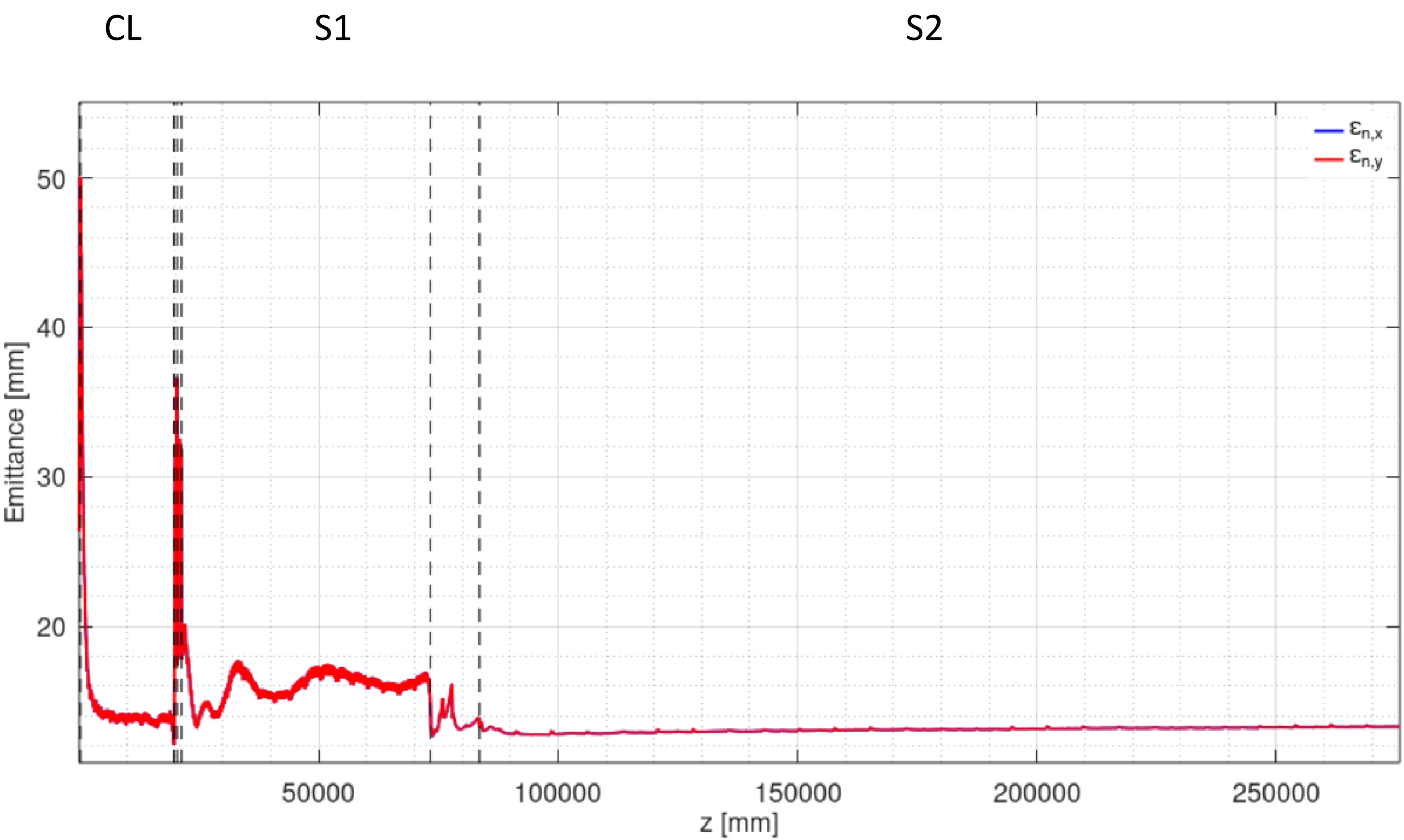
Beam position evolution along z



Beam spot size evolution along z

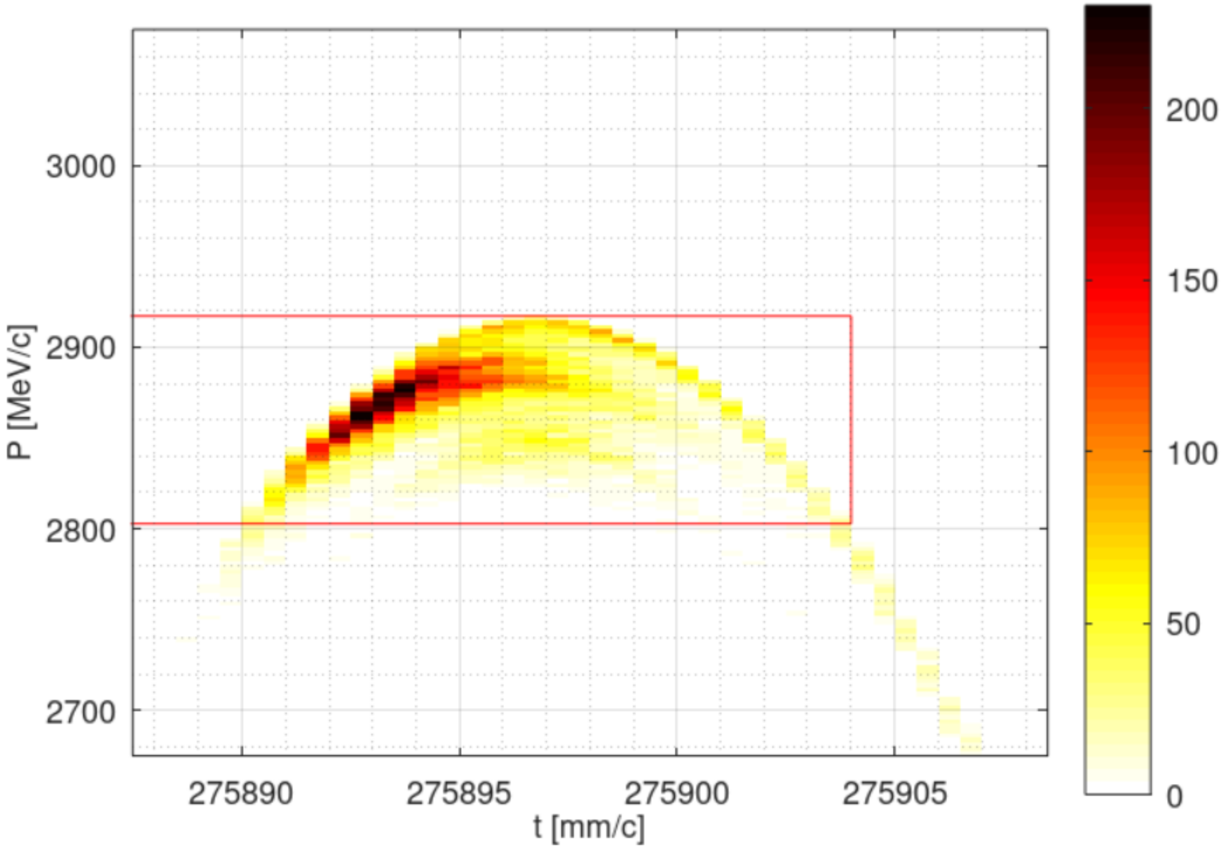


Normalized emittance evolution along z



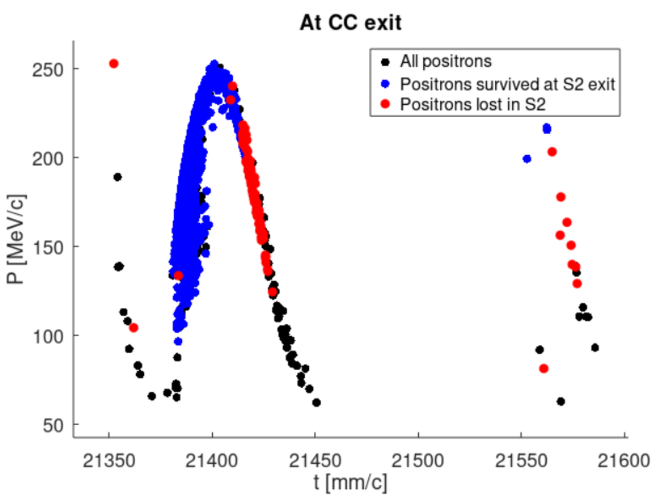
Longitudinal phase space

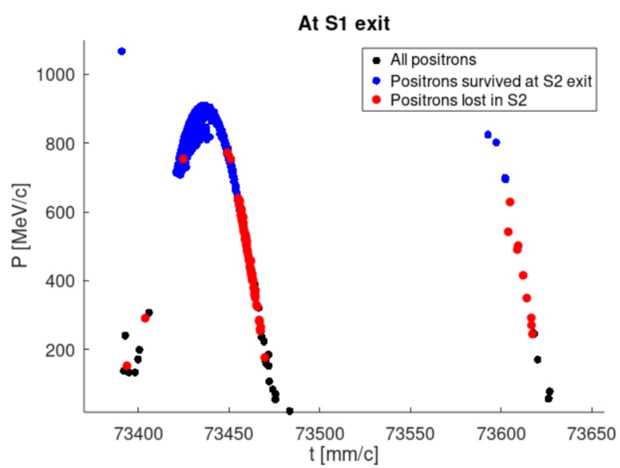
- At PL exit
  - Total yield: **3.47**
  - Yield with cuts (2.86 GeV ± 2% in energy, ±10 mm/c time): 3.04

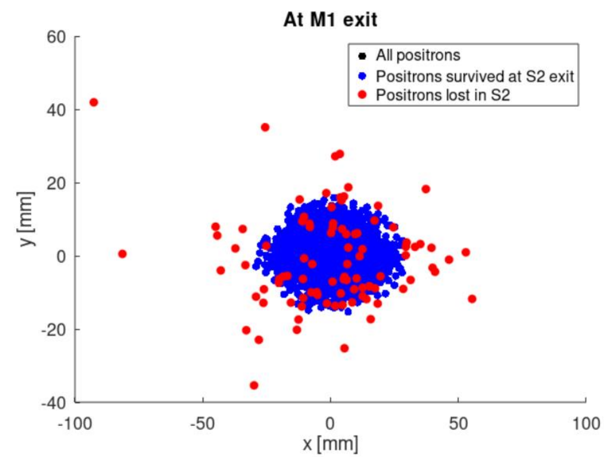


Loss investigation

- A 0.8% loss in matching section and 2.6% loss in S2. The loss is very small. We anyway investigate the possibility to avoid the loss or to have the loss earlier
- The loss is mainly in positrons with lower energies due to RF curvature in S1, which is difficult to be collimated in chicane. The loss is also in positrons with large radius after the matching, which is difficult to avoid







Data sharing

- Fieldmaps uploaded to FCC-ee CERNBox / task 3.1

  - NC_solenoid_fieldmap
  - Chicane_fieldmap

- Positron distribution at Positron Linac exit for WP4 uploaded to my personal CERNBox / FCCee / PositronLinacOutput

Name	Shares	Size
PL_2.86GeV_240904.dat.tgz		1.1 MB
PL_2.86GeV_240924_A25.dat.tgz		945 kB
PL_2.86GeV_240924_A28.dat.tgz		1.1 MB
PL_2.86GeV_240924_A30.dat.tgz		1.1 MB
PL_2.86GeV_241009.dat.tgz		1.2 MB

Backup