WP3 update

Positron Source: Target and Capture System

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on behalf of the WP3 team

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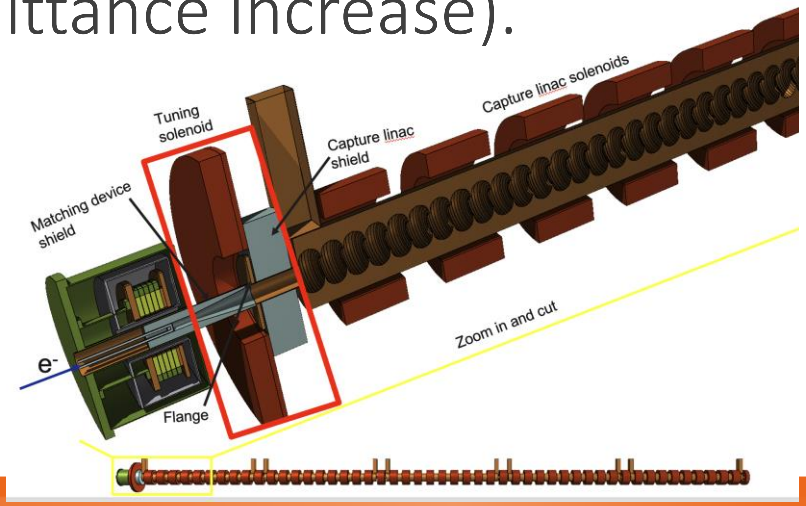
Towards FS report

- Baseline design relies on the HTS solenoid. The accepted e^+ yield is ~3 N_{e+}/N_{e-}. So far, no showstoppers found that prevent a SC solenoid matching device (proof-of-principle with P^3 experiment @PSI in 2026).

- For 2.86 GeV injector option, to fulfil the requirements for positron bunch charge, higher e^- drive beam charge is needed (~4.5 nC).

- The results are based on start-to-end simulations from production target to the DR using the realistic fieldmaps including collective effects and machine imperfections. The preliminary studies show negligible impact of typical imperfections (~1 % reduction in e^+ yield and < 1% emittance increase).

- Radiation load studies with FLUKA and target design.



FLUKA model of the e^+ source

FCC-ee positron source: current requirements

The complete filling for Z running => Requirement ~2.75 × 10^{10} e^+/bunch (4.4 nC) at the linac end

or 5.4 nC accepted in the DR

$$\eta^{e^+}_{\text{Accepted}} = \frac{N^{e^+}_{\text{DR accepted}}}{N^{e^-}_{\text{Primary}}}$$

$$N_{e-}/\text{bunch} \times \eta^{e+}_{Accepted} \geq \underbrace{5.4\ \text{nC/bunch} \times 2.5}_{13.5\ \text{nC}}$$

**A safety margin of 2.5 is currently applied for the whole studies (50% losses for injection in the DR + 20 % losses from target up to the end of the e+ linac)*

Accepted e^+ yield is a function of primary beam characteristics + target + capture system + DR acceptance

e^- drive beam

Beam energy	2.86 GeV
Bunch charge	~5.6 nC (max)
Bunch length	1 mm
Bunch transverse size	≳ 0.5 mm

Nb of bunches per pulse	4
Bunch separation	25 ns
Repetition rate	100 Hz
Beam power	~ 6.4 kW (max)

→ positron flux of ~1.3×10^{13} e^+/s (×2.5). *Demonstrated at SLC (a world record for existing accelerators): ~6 ×10^{12} e+/s*

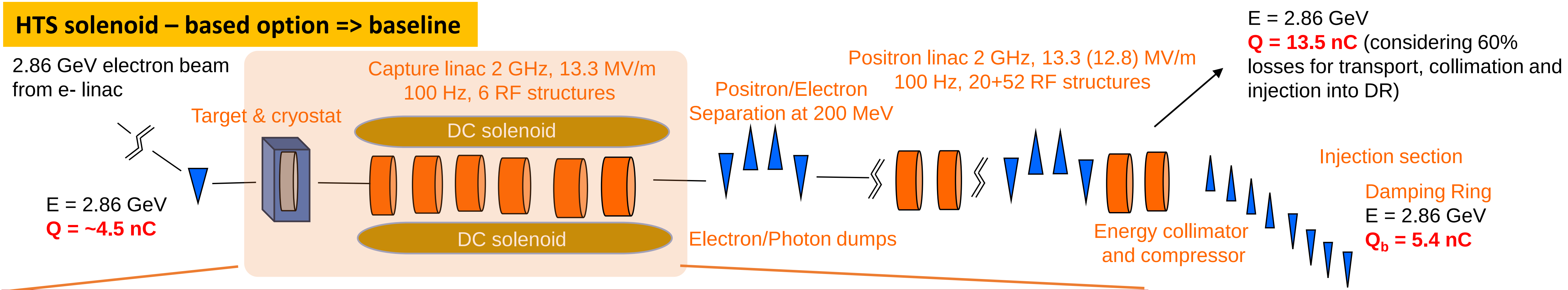
e- drive beam parameters (to be used for e+ generation)

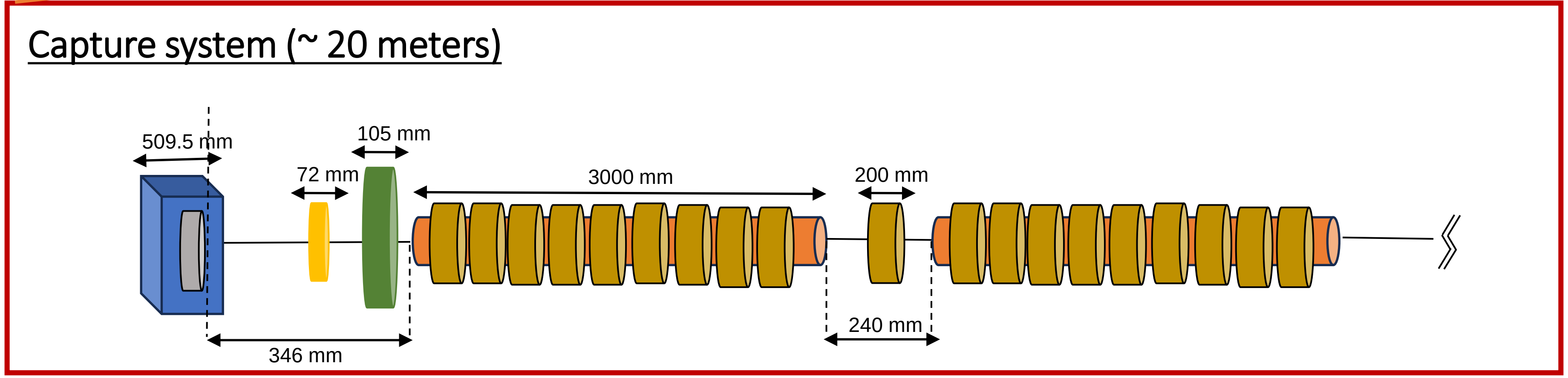
- Energy = 2.86 GeV
- Beam size (x, y) rms = 1 mm
- Beam position (x, y) = 0 mm
- Bunch length rms = 1 mm
- Energy spread rms = 5e-3
- Divergence (xp, yp) = 0.715 μrad, (px, py) = 2.04 KeV/c.
- Normalized emittance (x, y) = 4 μm rad.
- Statistics (Geant4) = 50k
- Simulation performed w/o mesh.

Beam matching section upstream the target (flexibility in beam size @Target)

Positron source physics design

HTS solenoid – based option => baseline





Positron production : conventional scheme (e- beam size on target = 1 mm rms). Target exit located at 40 mm w.r.t. HTS solenoid peak field.

Matching device is based on the SC solenoid (5 HTS coils, ∅ 60 mm 72 mm bore, ∅ 60 mm including shielding)

Capture linac is based on the 6 L-band TW RF structures (2 GHz, ∅ 60 mm, 3-m long)

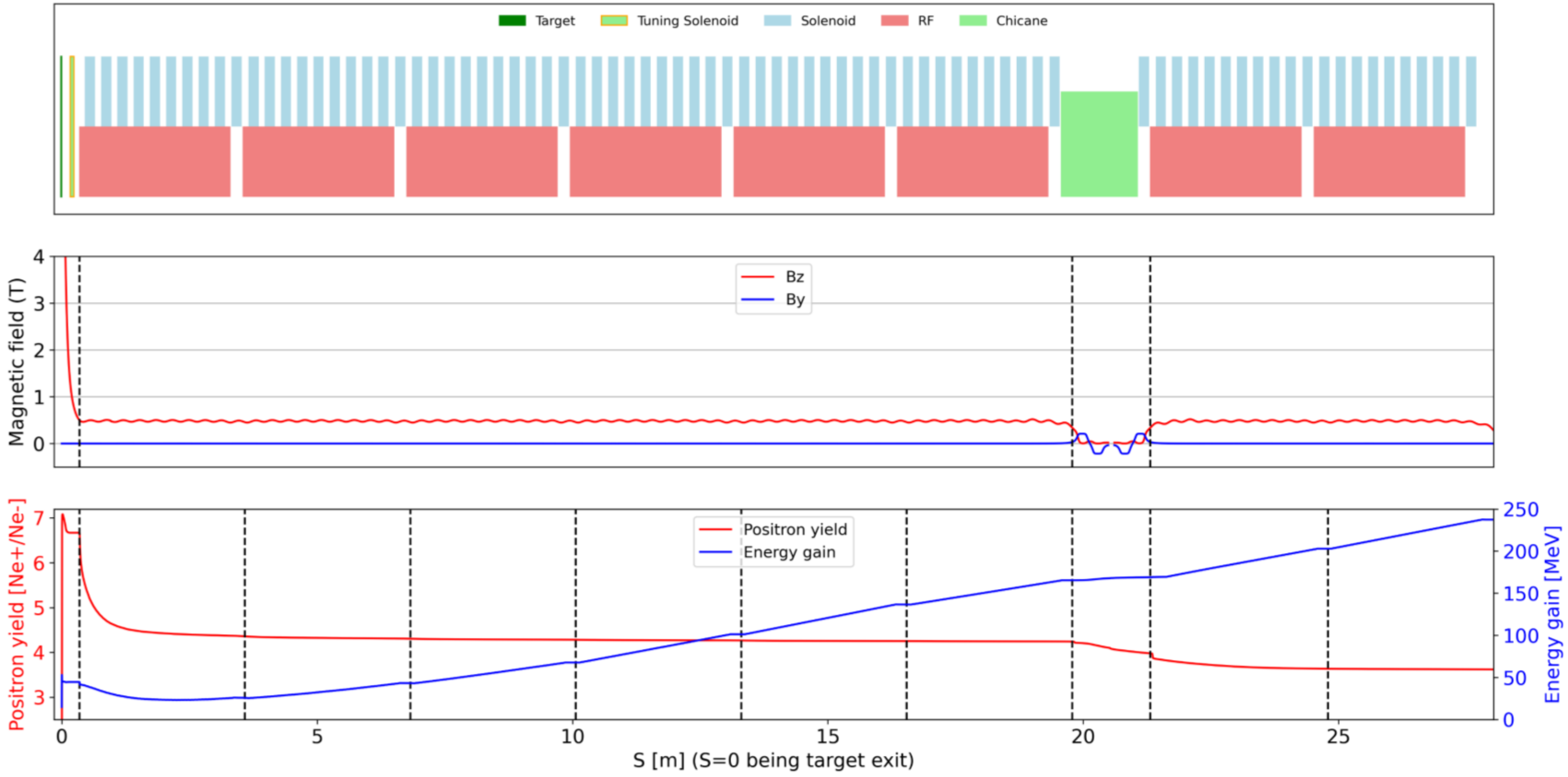
NC solenoid B = 0.5 T (realistic conventional design based on the short coils B = 0.31 T) + short "tuning" solenoid B = 0.25 T before the 1st RF structure

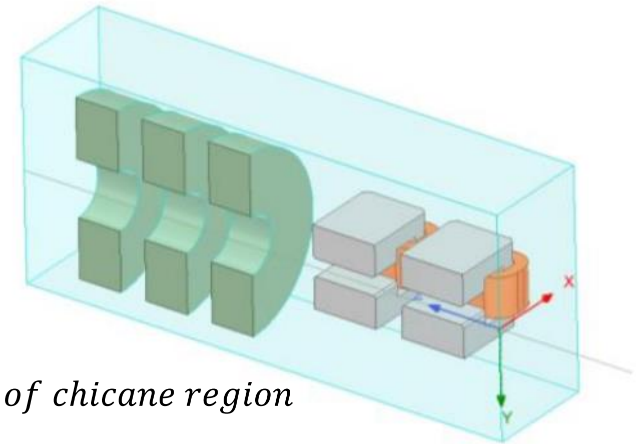
Capture Section design and performance

- <u>RF structures</u>: 2GHz L-band with aperture (2a) = 60 mm , 3 m-long and 13.3 MV/m.

- <u>Solenoids</u>: 10 NC short solenoids surrounding each RF structure to create 0.5 T magnetic channel.

- <u>Chicane</u>: 4 dipoles (0.2 T) to separate e- and e+, with electron stopper at the middle.





$^1/_4$ *view of chicane region*

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Positron source physics design

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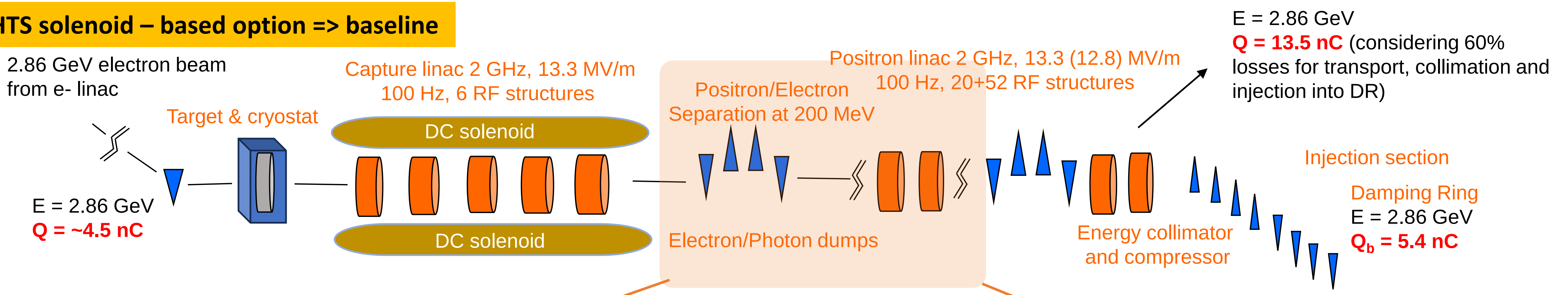


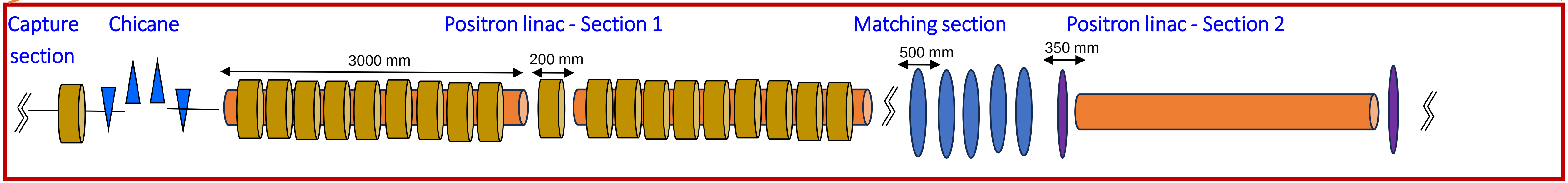
Positron linac (~ 280 meters)

Separator chicane : Rectangular beampipe and hor./vert. collimators, Dipole peak field: ~0.2 T

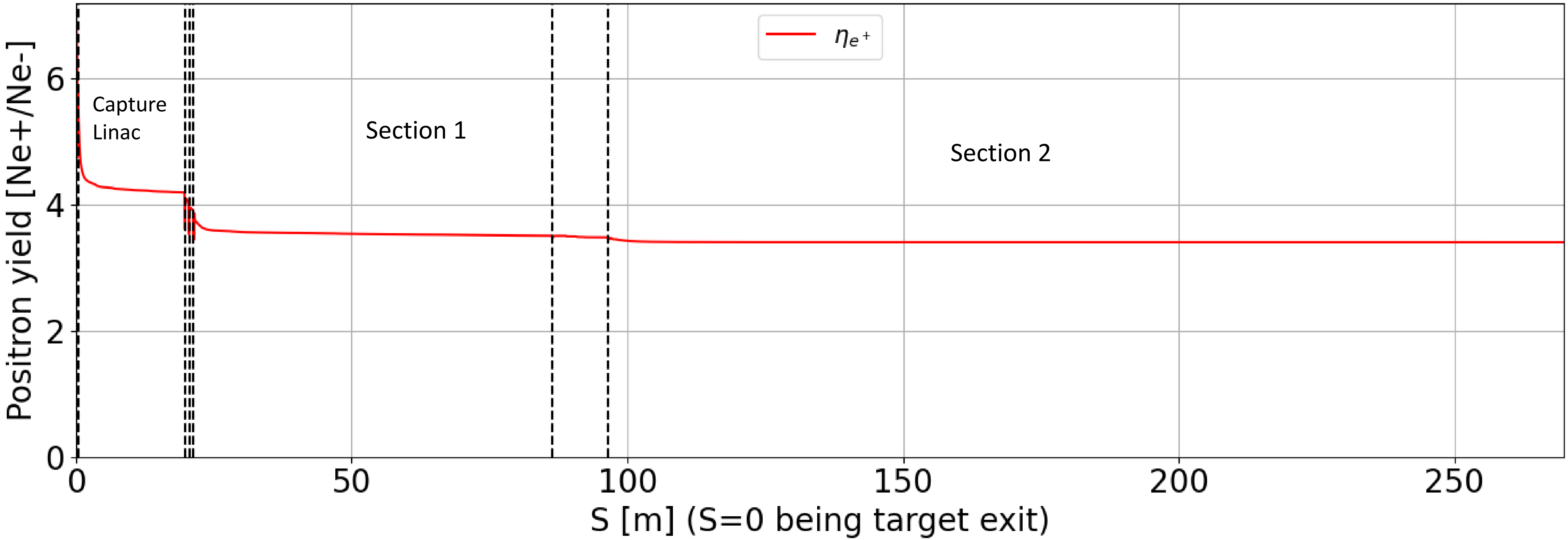
Section 1 : up to ~ 930 MeV. Same RF structure with Capture Linac (CL). 20 structures. G = 13.3 MV/m

Matching section : 5 quadrupoles. Quadrupole (0.4 m long)

Section 2 : up to 2.86 GeV. Same RF structure with CL. 52 structures. Quadrupole (0.4 m long), 2 structures per FODO cell. G = 13.3 MV/m



Positron linac design and performance



Y. Zhao

Summary of the simulation results

Parameter	Unit	
e^- beam energy	GeV	2.86
Number of bunches		4
Repetition rate	Hz	100
e^- bunch charge	nC	4.01
e^- beam power	kW	5.1
Target thickness	mm	15
Beam size, x/y	mm	1
Positron yield @ Target	Ne^+/Ne^-	7.1
Positron yield @ CS *	Ne^+/Ne^-	4.2/3.9/3.6
Positron yield @ PL**	Ne^+/Ne^-	3.37
Positron yield @ DR***	Ne^+/Ne^-	2.97
Target deposited power	kW	1.2
Target PEDD	J/g	6.8
e^+ beam emittance, ε_n x/y	mm.rad	13.5/13.6

** Yield before chicane/ after chicane/ @ s1 point (2 RF structures after chicane)*

*** full beam*

**** Estimated with the cut window*

DR acceptance window: (Energy : 2.86 GeV **± 2 % ;** Time : **± 10 mm/c**)

Emittance is estimated for the full e^+ beam

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Beam emittances at the end of the positron linac

For the latest 2.86 GeV: date (09/10/24)
Beam Emittances:
em_x = 2.38e-06 m*rad
em_y = 2.38e-06 m*rad

Beam normalized Emittances:
em_x_n = 13.3 mm*rad
em_y_n = 13.3 mm*rad

For the latest 2.86 GeV: date (06/12/24)
Beam Emittances:
em_x = 2.41e-06 m*rad
em_y = 2.43e-06 m*rad

Beam normalized Emittances:
Normalised Emitt_X : 13.5 mm*rad
Normalised Emitt_Y : 13.6 mm*rad

For the latest 1.54 GeV (6 GeV e- drive beam): (03/06/24)
Beam Emittances:
em_x = 3.52e-06 m*rad
em_y = 3.72e-06 m*rad

Beam normalized Emittances:
em_x_n = 10.6 mm*rad
em_y_n = 11.2 mm*rad