Development of a Polarized Positron Source for CEBAF

Beam dynamics: Design and optimization

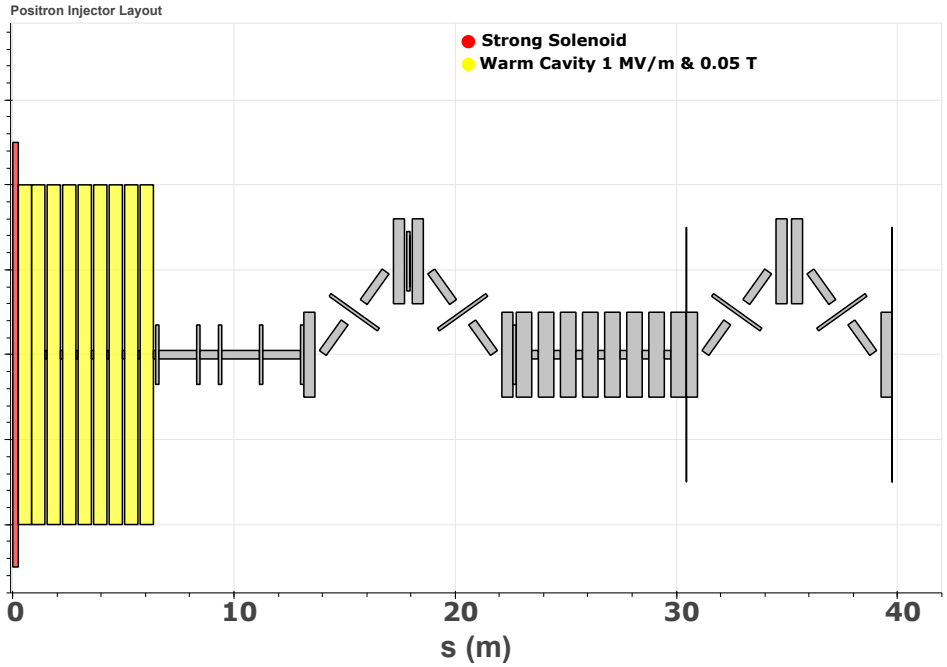
Sami Habet

IJCLab & JLab

February 13, 2023

Plan

1. Target optimization
2. Collection system
3. Momentum collimation
4. Longitudinal optimization
5. Conclusion



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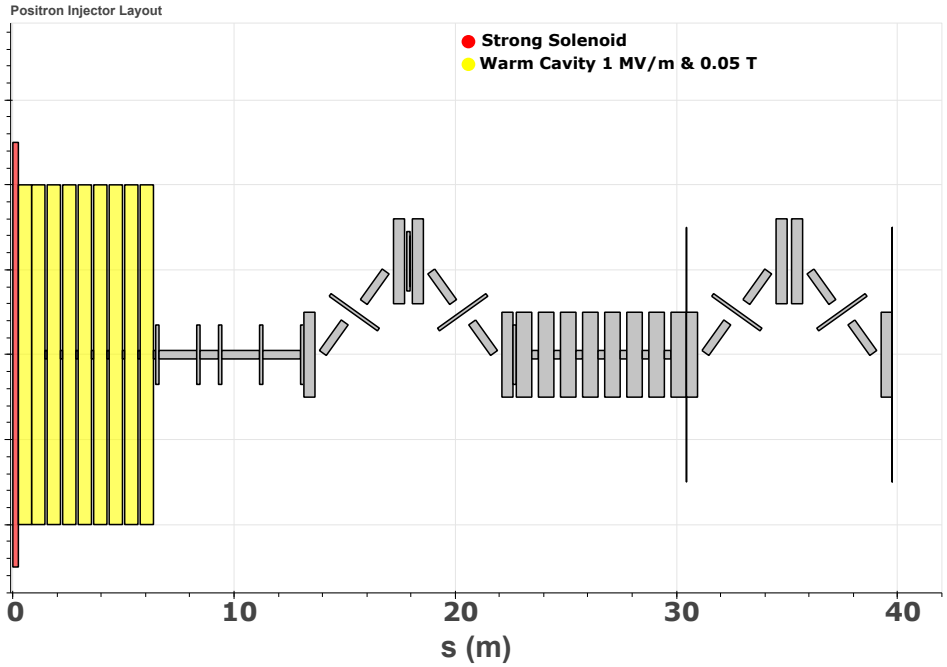

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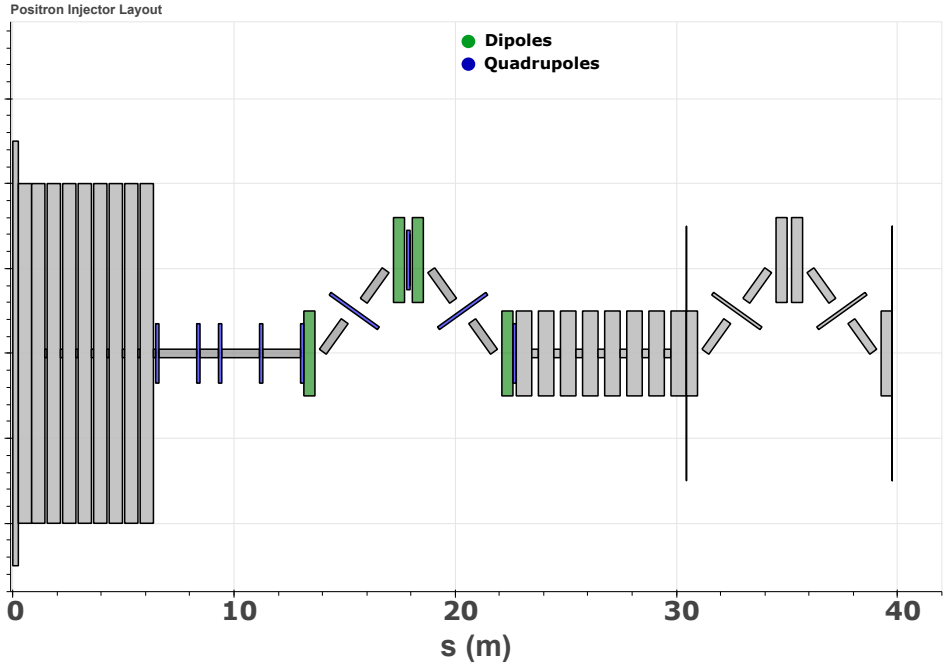

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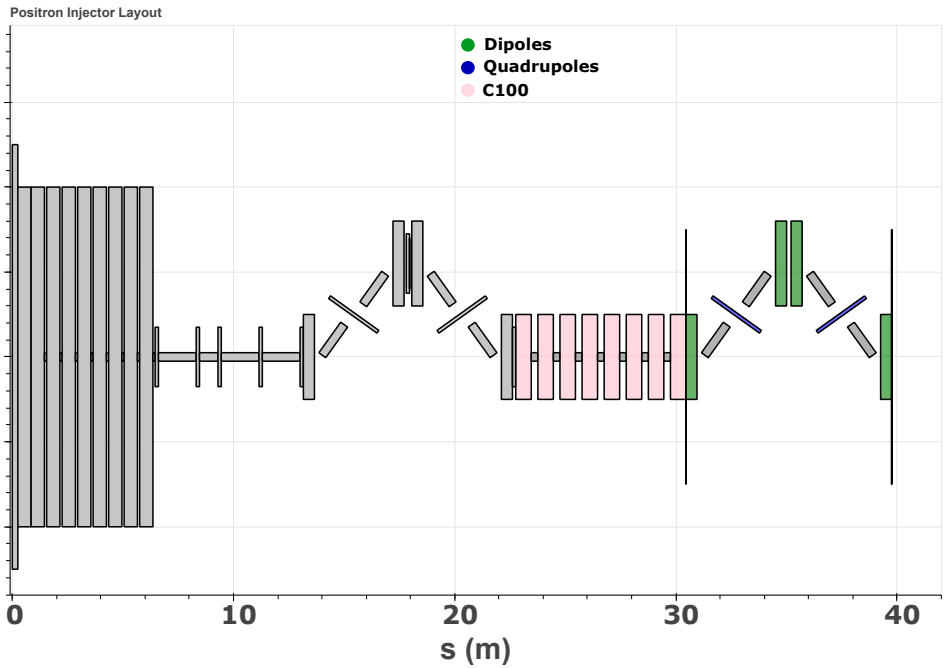

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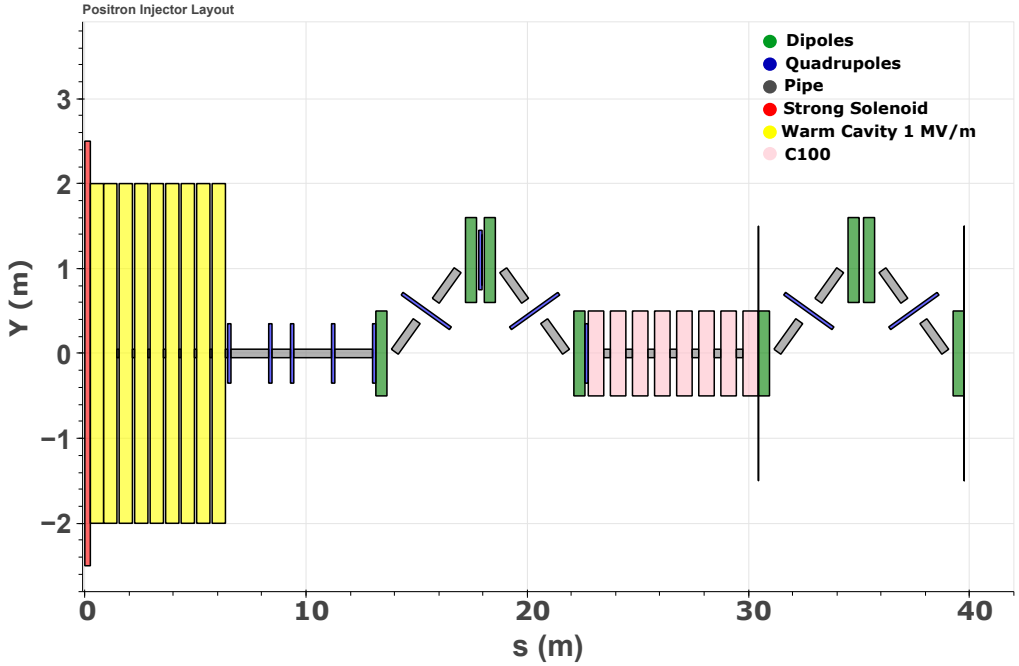


Outline

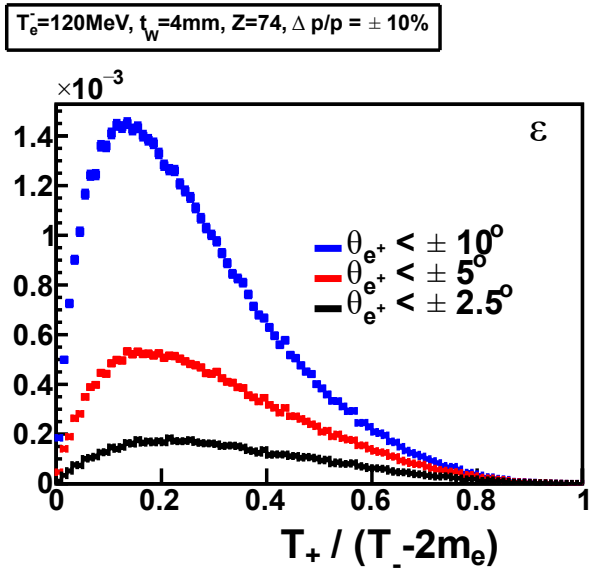
Positron characterization

Unpolarized mode

- Efficiency : $\epsilon = \frac{N_{e+}}{N_{e-}}$

Polarized mode

- Figure-of-Merit FoM$=\epsilon P_{e+}^2$



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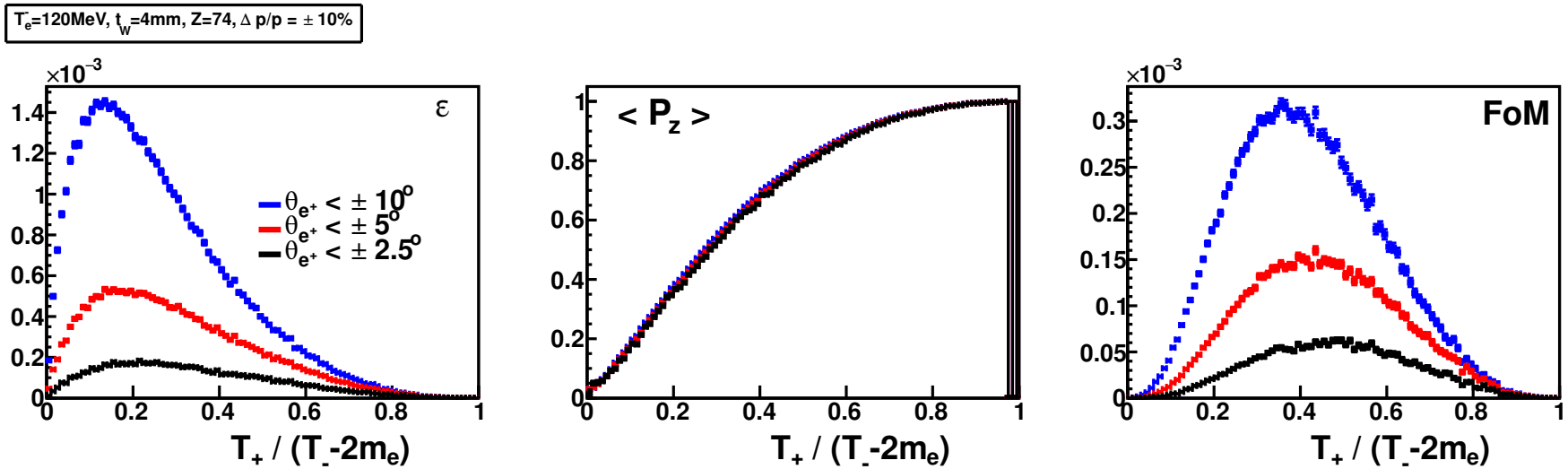
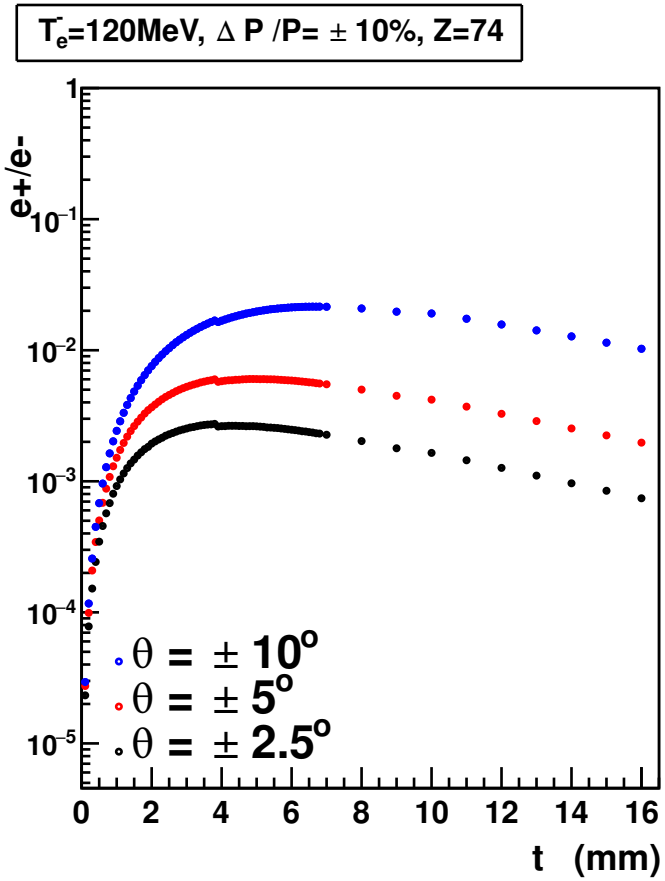
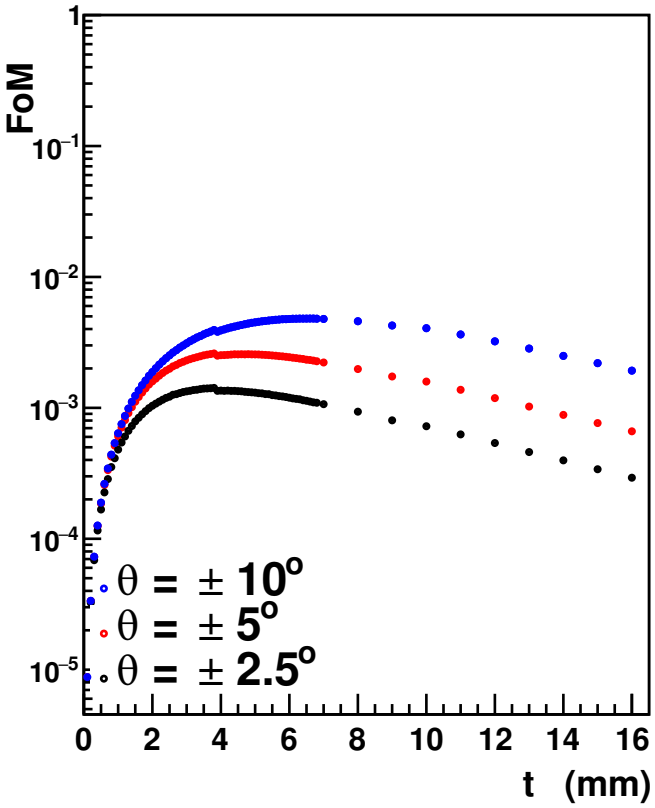


Target thickness optimization

Unpolarized mode



Polarized mode



Outline

Quarter Waves Transformer

- Reduce the angular transverse spread $x_p = \frac{p_x}{p_z}$ and $y_p = \frac{p_y}{p_z}$.
- Rotate the transverse phase space (x, x_p) and (y, y_p) at the exit of the QWT.
- Use a QWT as an energy filter.

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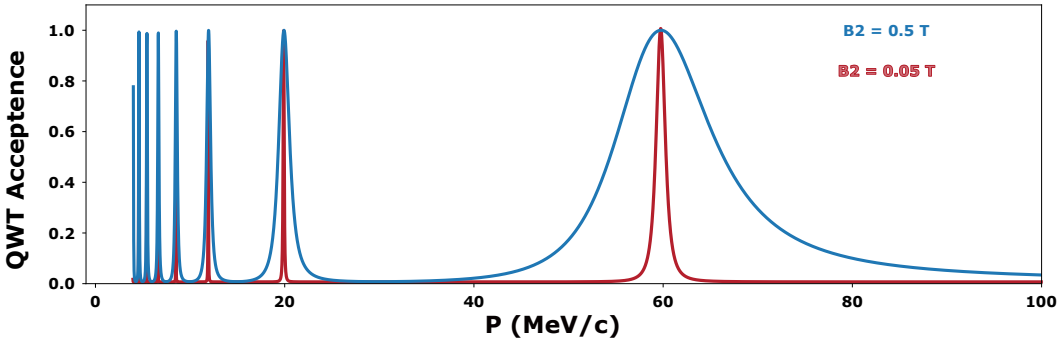

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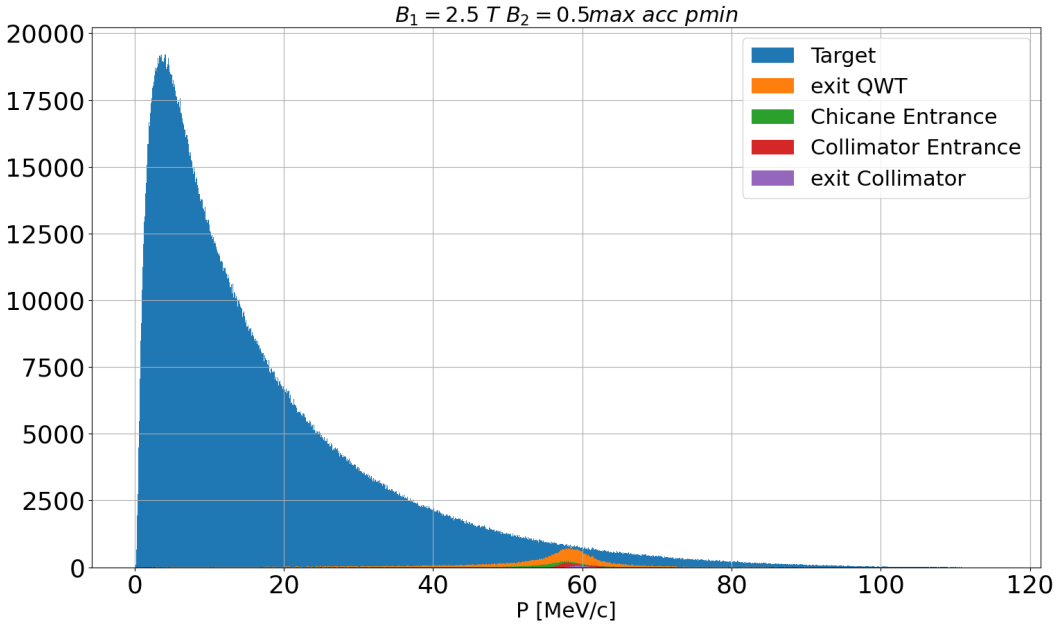

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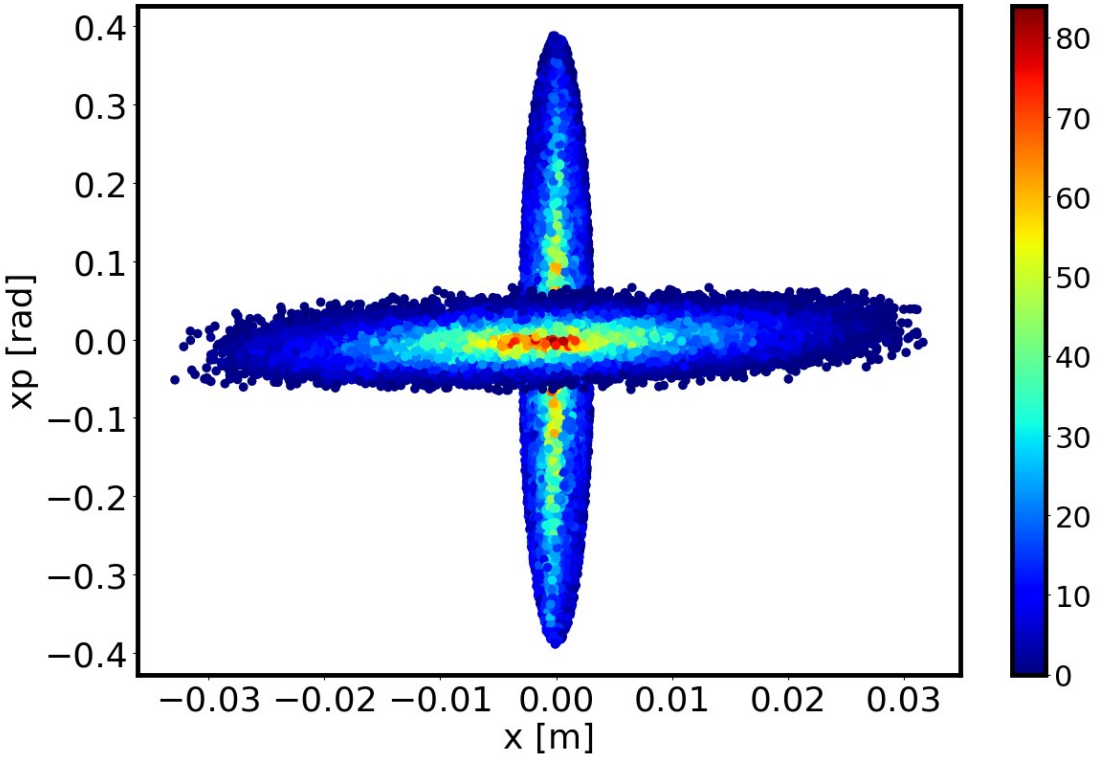

Accelerating warm section

Goal

- Reduce the energy spread of the accepted e^+ @ p = 60 MeV/c
- $f = 1497\ Mhz$
- $E = 1\ MV/m$
- $L_{cell} = 0.2\ cm$
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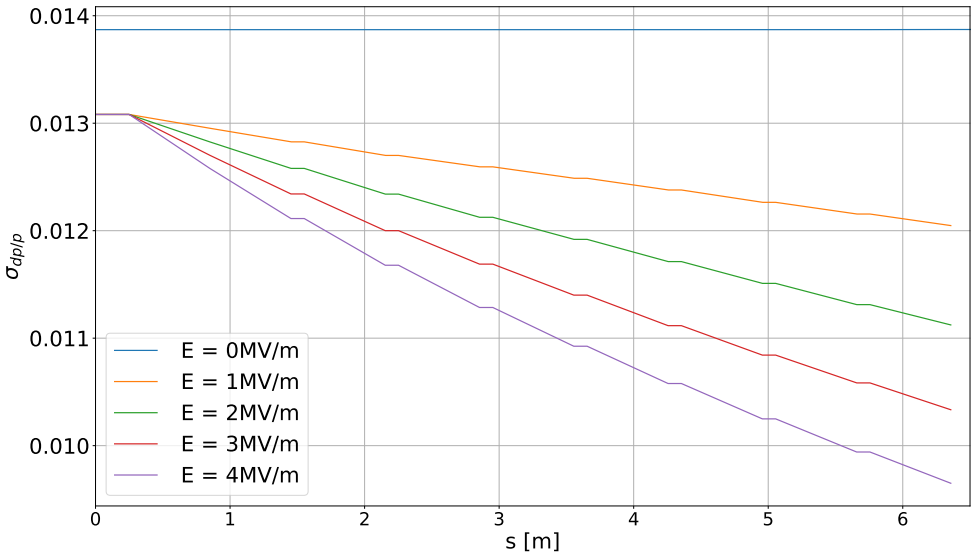
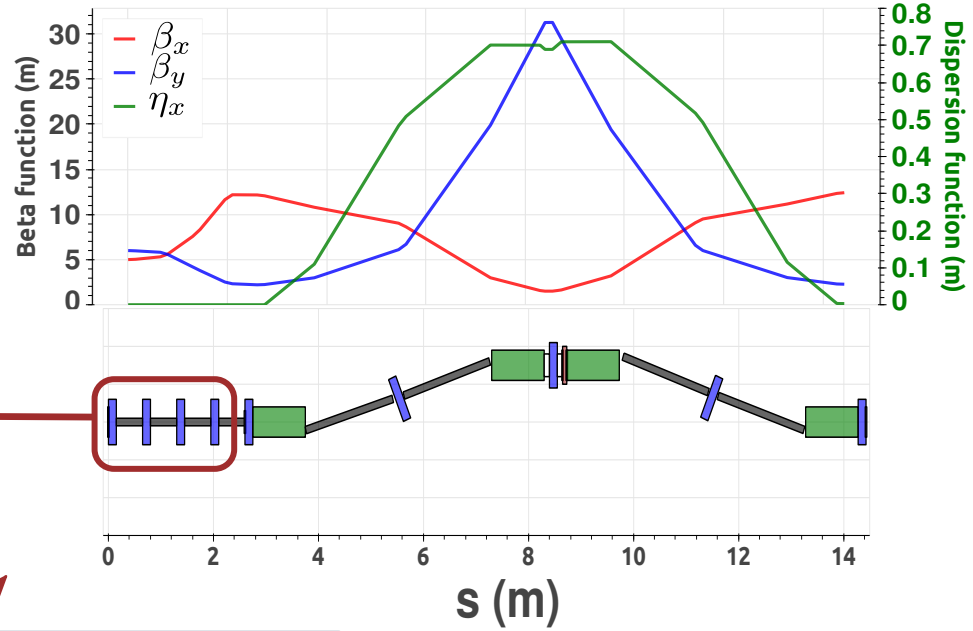
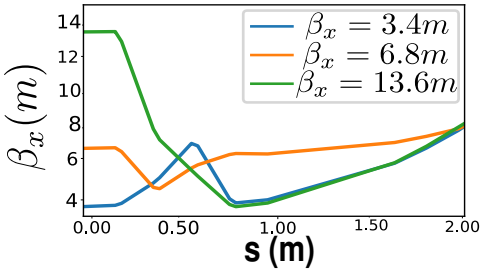


Outline

Beam size optimization



Matching section



- **Periodic Twiss in FODO:**
  $$\beta_{x,y_{in}} = \beta_{x,y_{out}}$$
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  $$\beta_x = \beta_{x_{MIN}} \longrightarrow \alpha_x = 0$$

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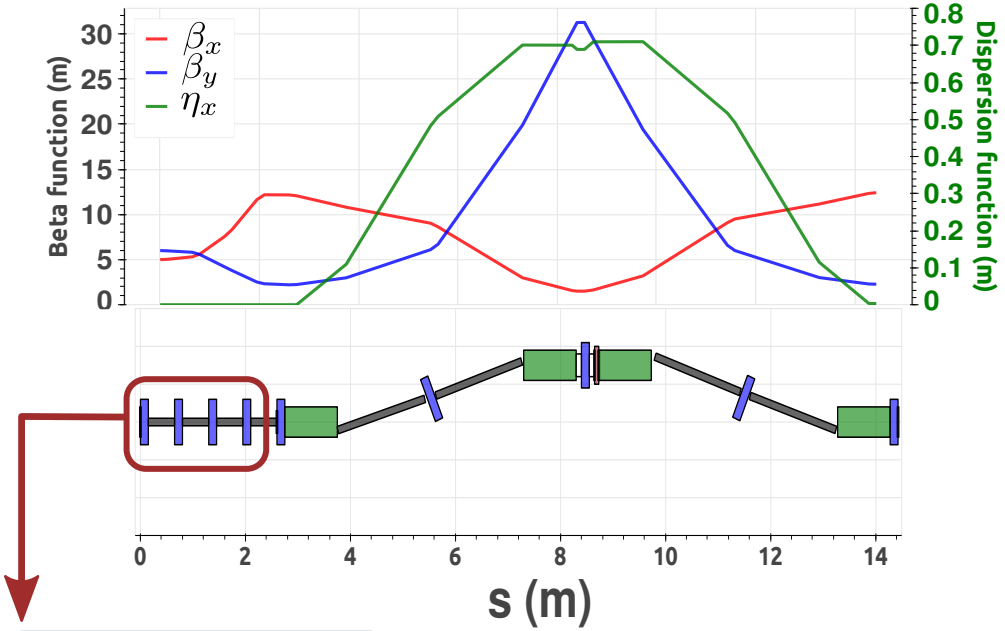

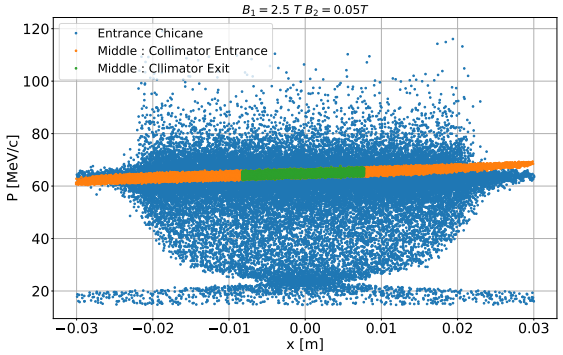

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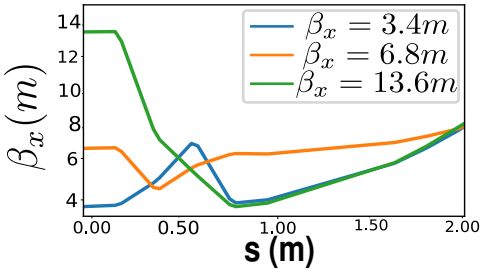

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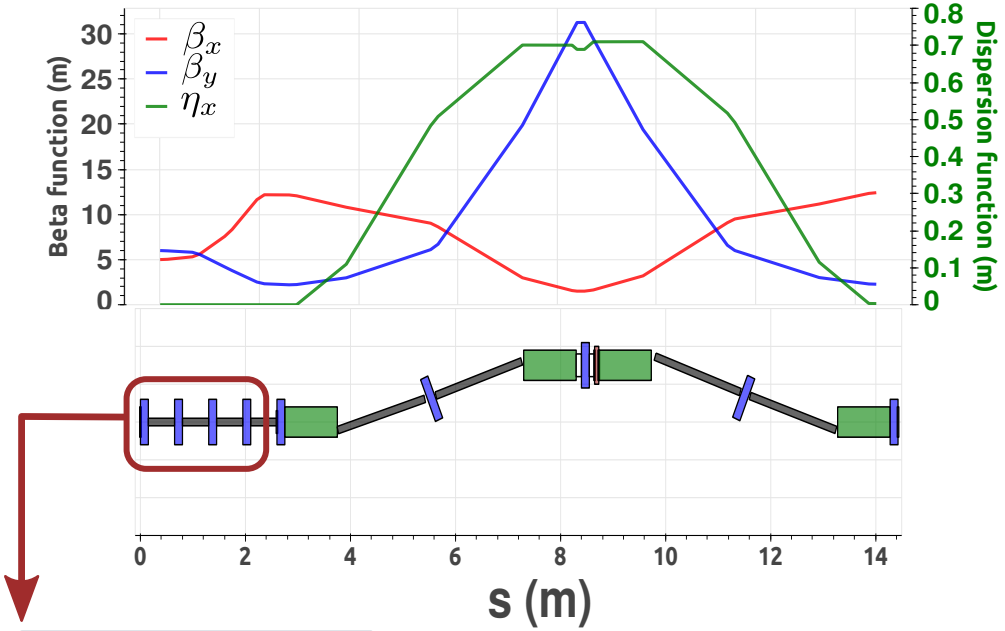

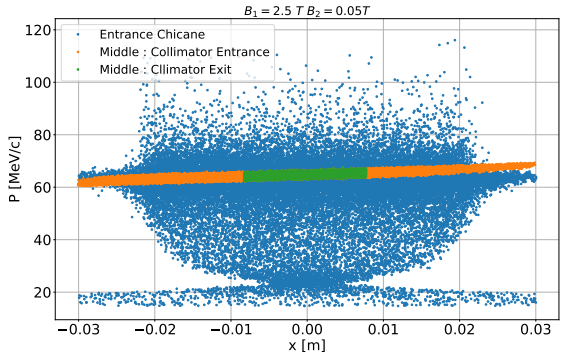

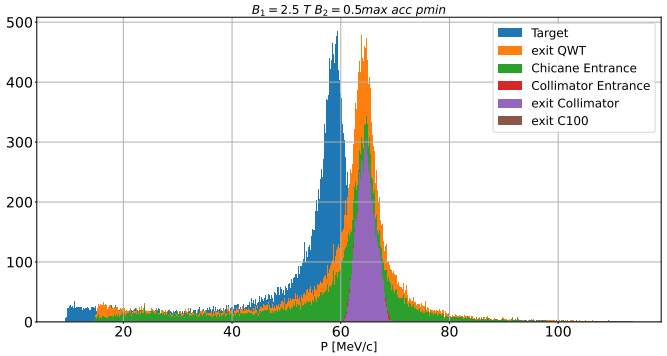

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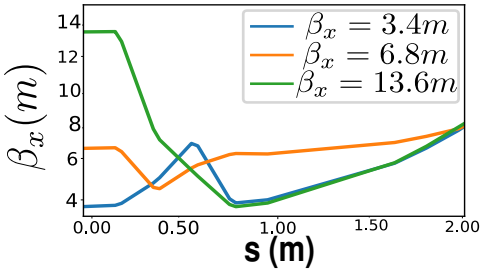

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Longitudinal optimization: Energy spread and bunch length

- **Compression factor** $= \frac{Bunch\ length_{\textbf{Entrance}}}{Bunch\ length_{\textbf{Exit}}}$
- $C = \frac{1}{1+[R_{56} \times \kappa]}$
- $\kappa = \frac{d\delta_p}{dz} = \frac{-keV_0}{E0+eV0\cos\phi} \sin\phi$
- Where:
  - R_{56} : Longitudinal chicane element.
  - $k = 2\pi\frac{f}{c}\ [m^{-1}]$
  - f is the cavity frequency
  - eV_0 Cavity acceleration [MeV]
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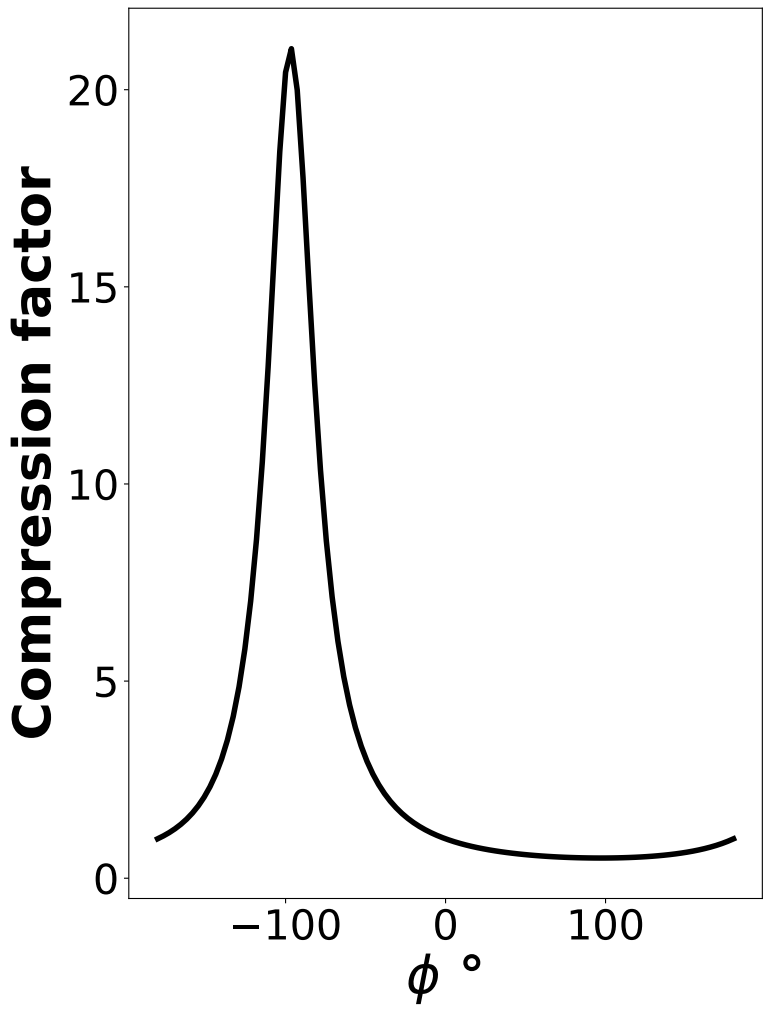

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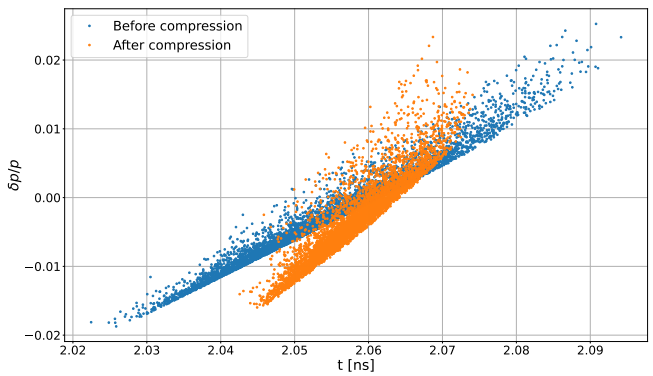

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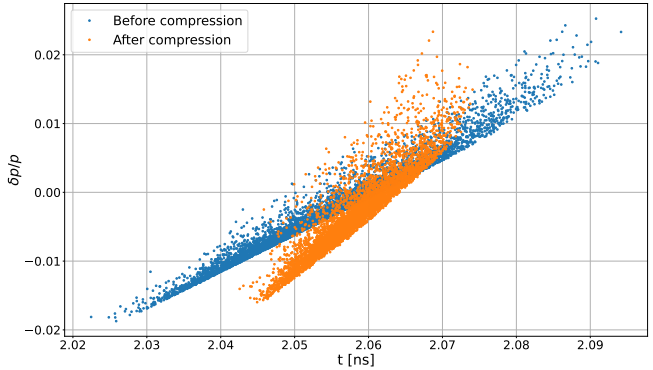
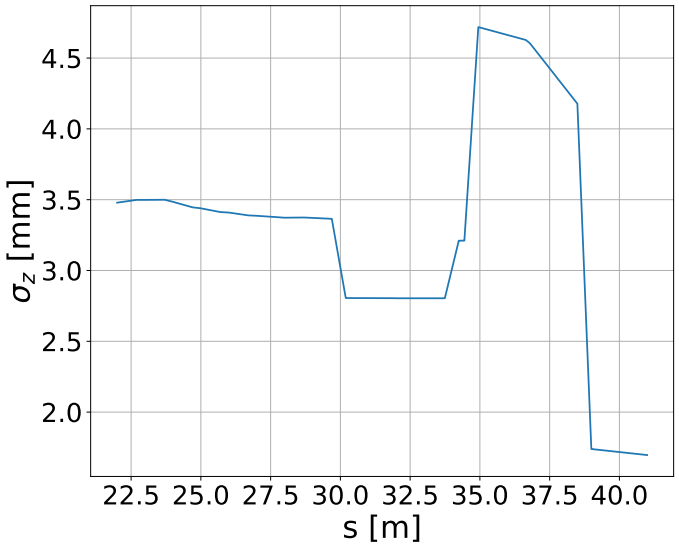
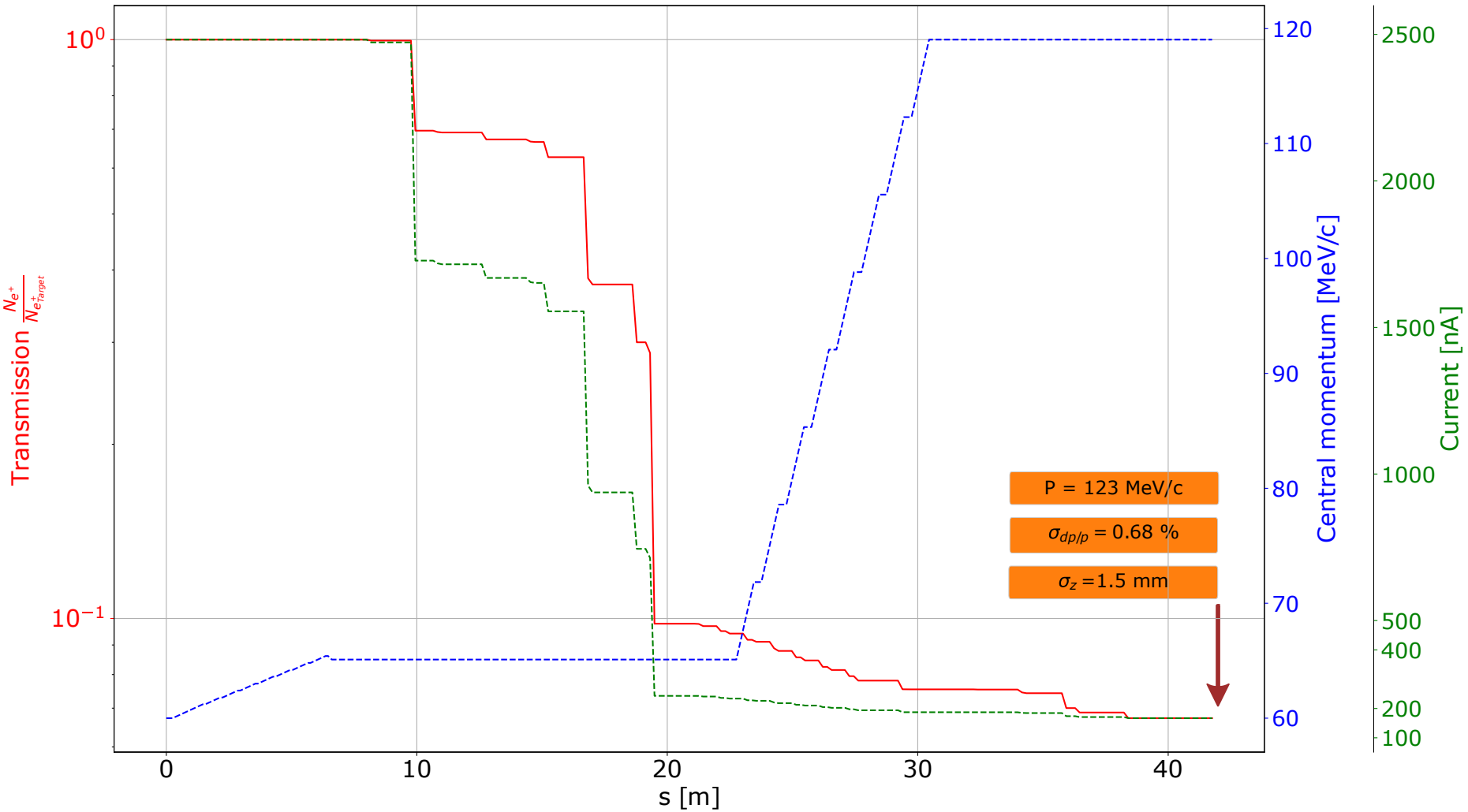




Transmission and Curent



Summury

Params	e^- beam	Target Exit one period	Exit
$\sigma_{dp/p}$ [%]		1.3870	0.68
$\sigma_z[m]$		0.0002	0.0016
$\sigma_x[m]$	0.0005	0.0028	0.0081
σ_{xp} [rad]	pencil beam	0.0021	0.0007
N $\epsilon_x[mrad]$		0.019	0.0014
N ϵ_y [m rad]		0.02	0.0014
p Central [MeV/c]	120	60	123
e^+	1 mA	2482 nA	170 nA

Outline

Conclusion

- The performance of the positron system is heavily influenced by the central momentum. For a high yield of positrons, the central momentum should be set to 15 MeV/c, while a high polarization requires a central momentum of 60 MeV/c.
- The QWT helps the selection of the desired momentum and reduces the spread of transverse angles.
- The accelerating section exerts significant influence on the longitudinal plane, thereby reducing the energy spread to meet the CEBAF requirement of $\sigma_{dp/p} = \pm 1\%$.
- For improved compression, the energy spread at the exit of the C100 must be at least five times smaller.
- Expecting higher current for the unpolarized mode P=15 MeV/c.

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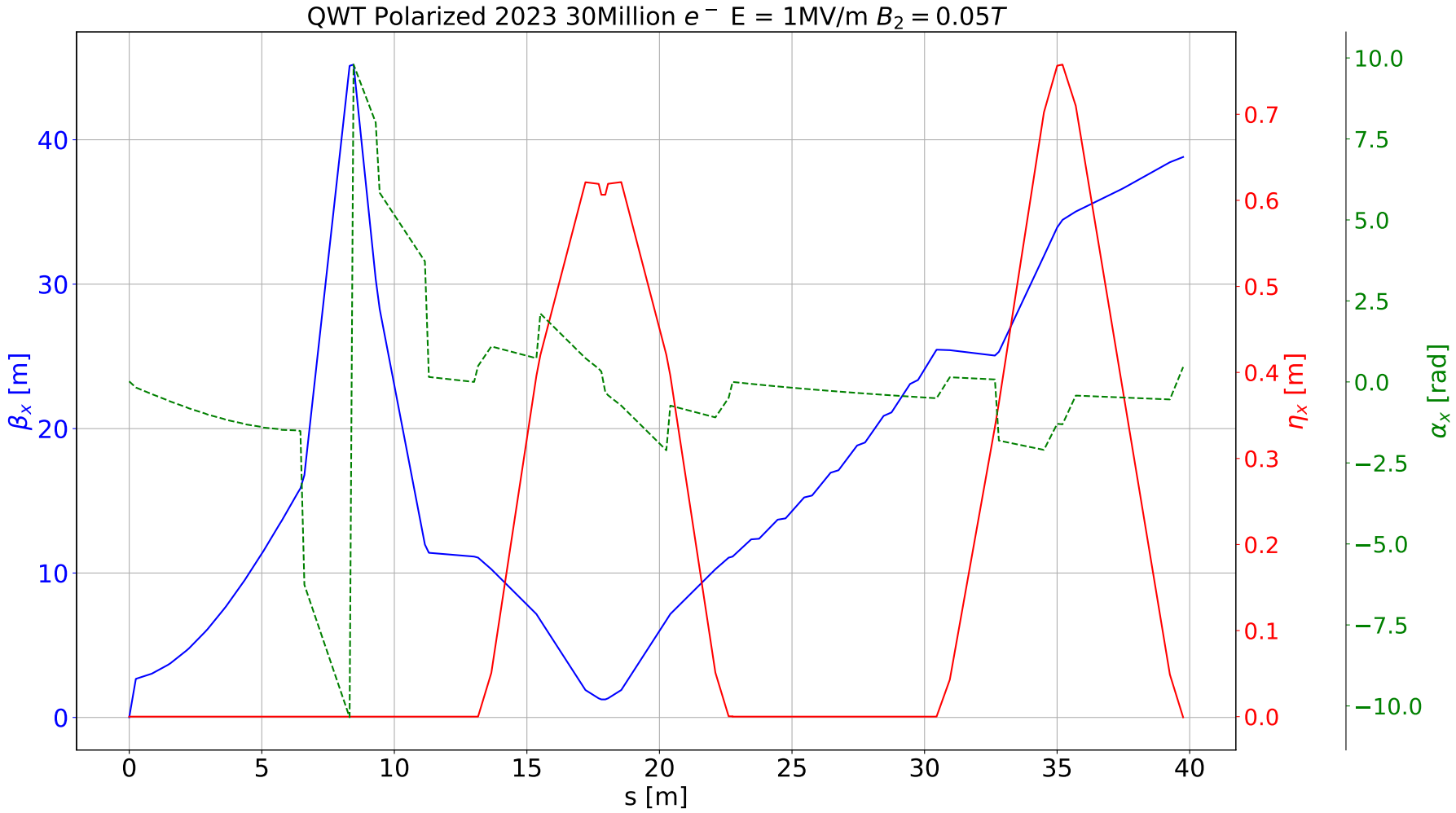
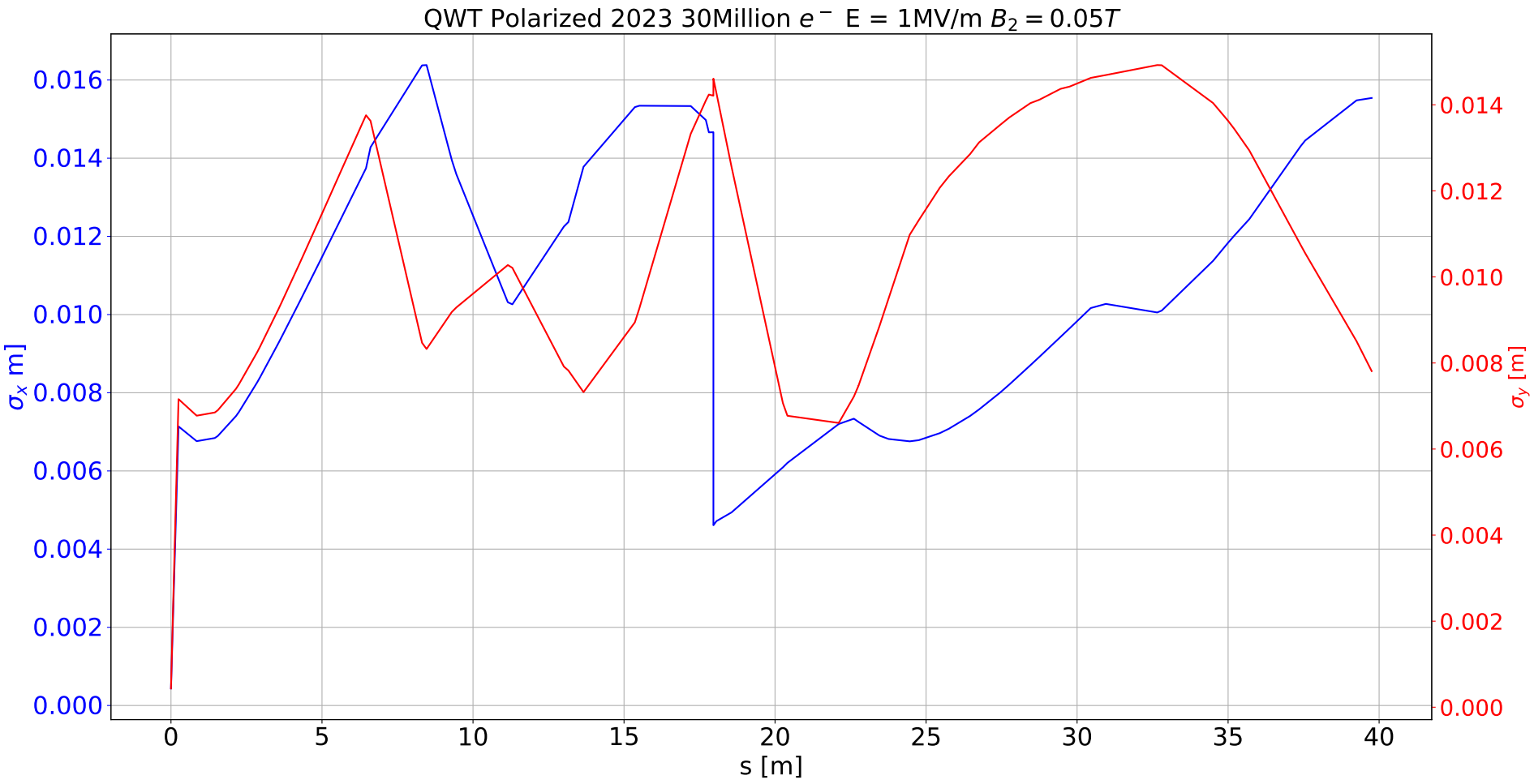
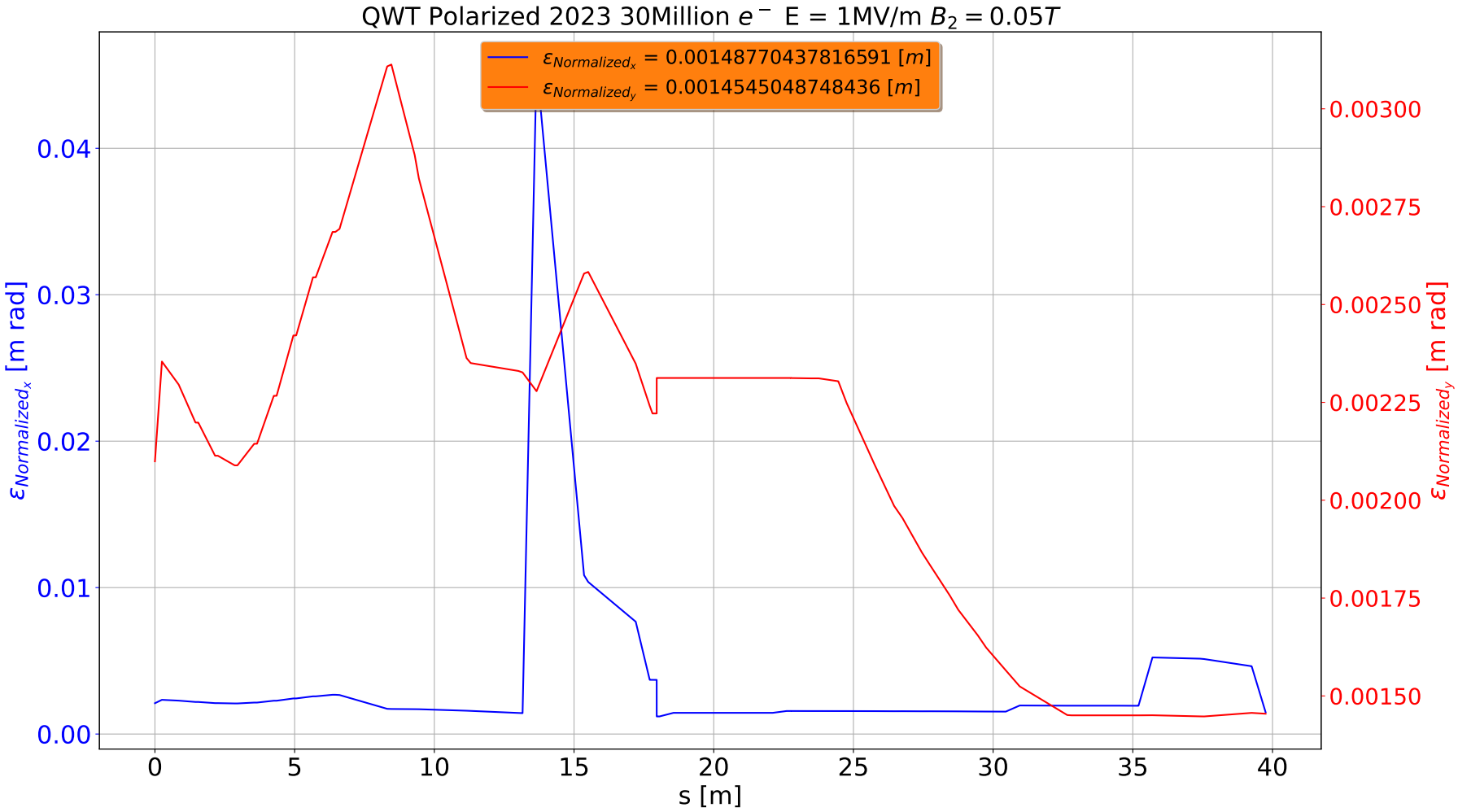
Twiss functions



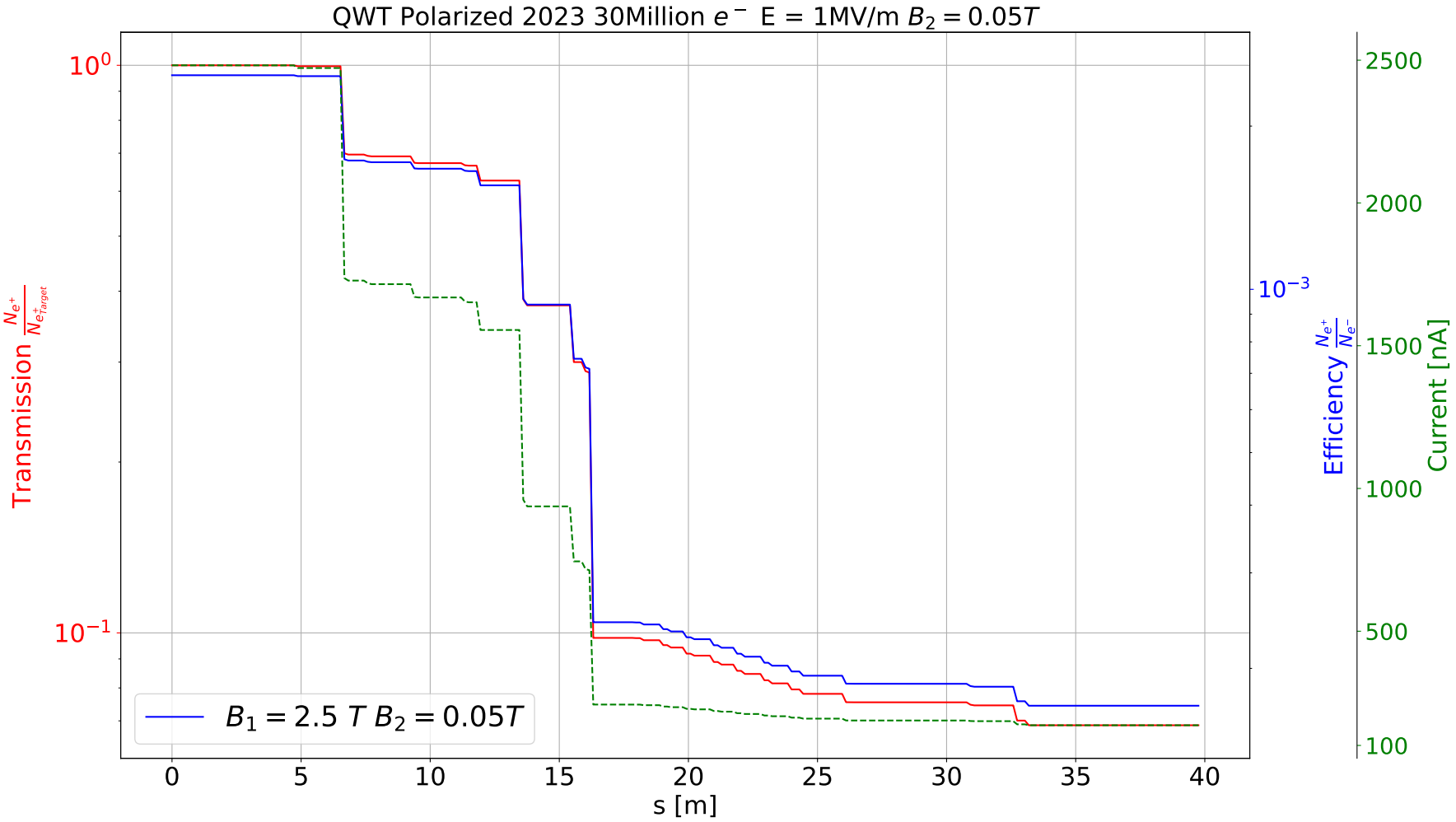
Beam size


QWT Polarized 2023 30Million e^- E = 1MV/m $B_2 = 0.05T$
σ_x [m]
σ_y [m]
s [m]
0.000
0.002
0.004
0.006
0.008
0.010
0.012
0.014
0.016
0
5
10
15
20
25
30
35
40

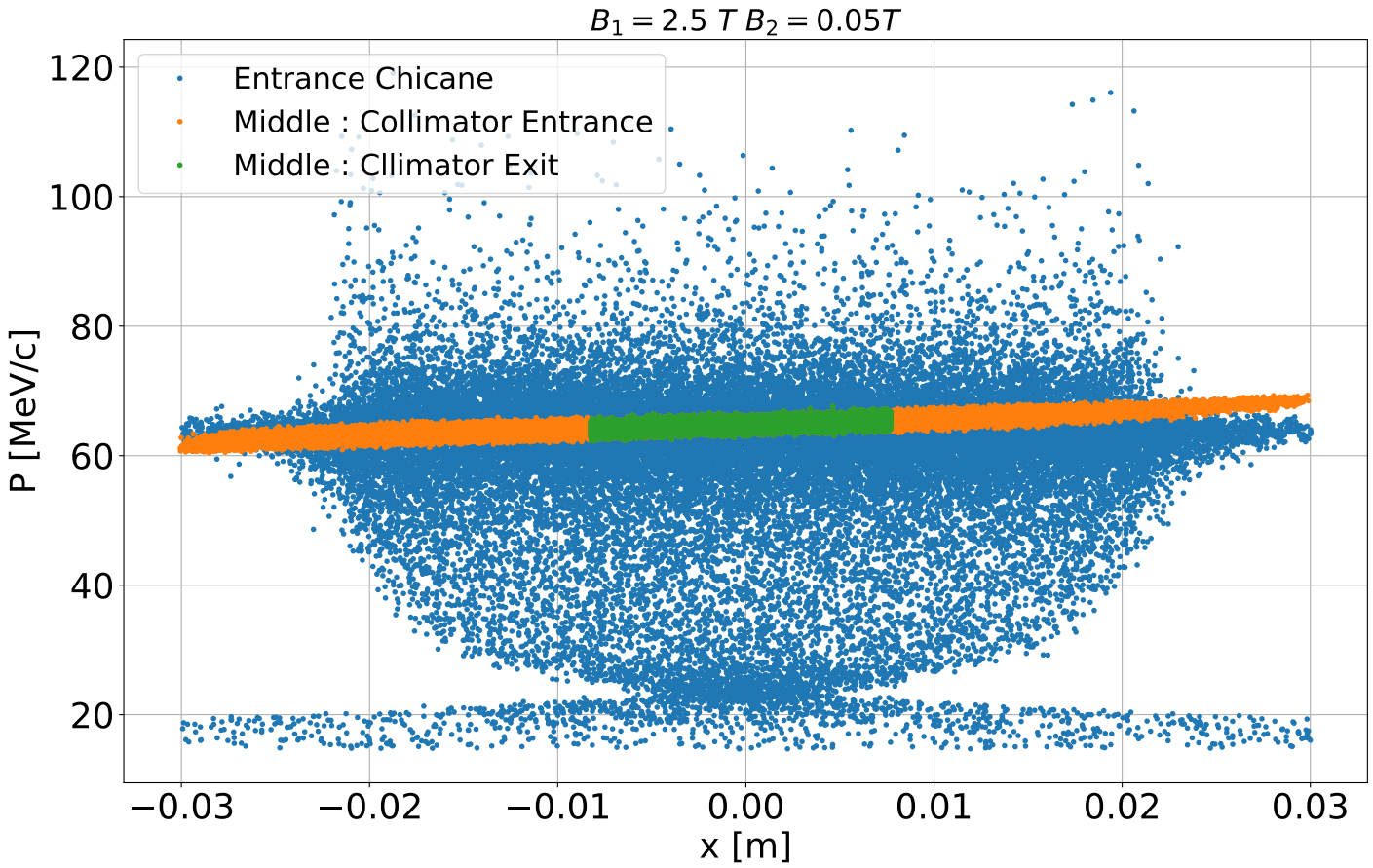
Normalized emittance



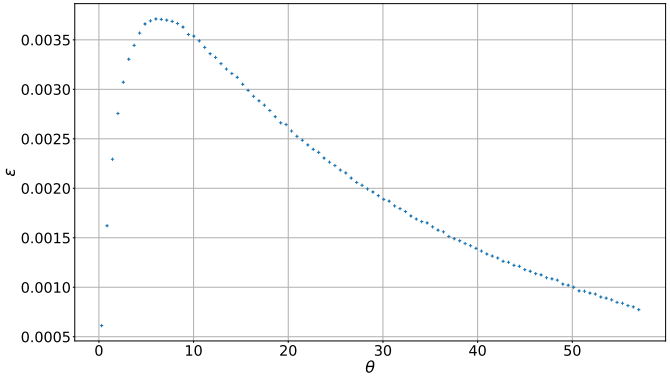
Transmission and current

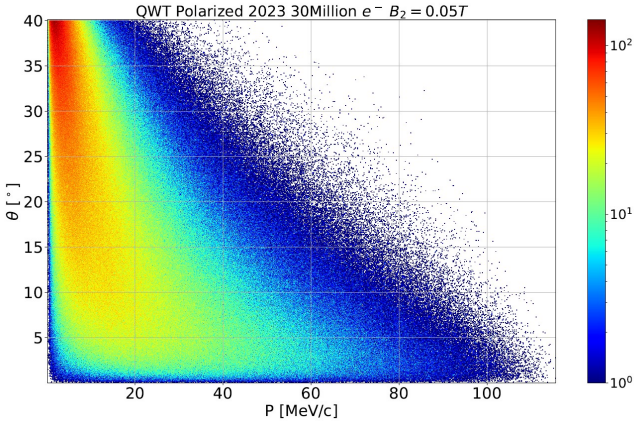


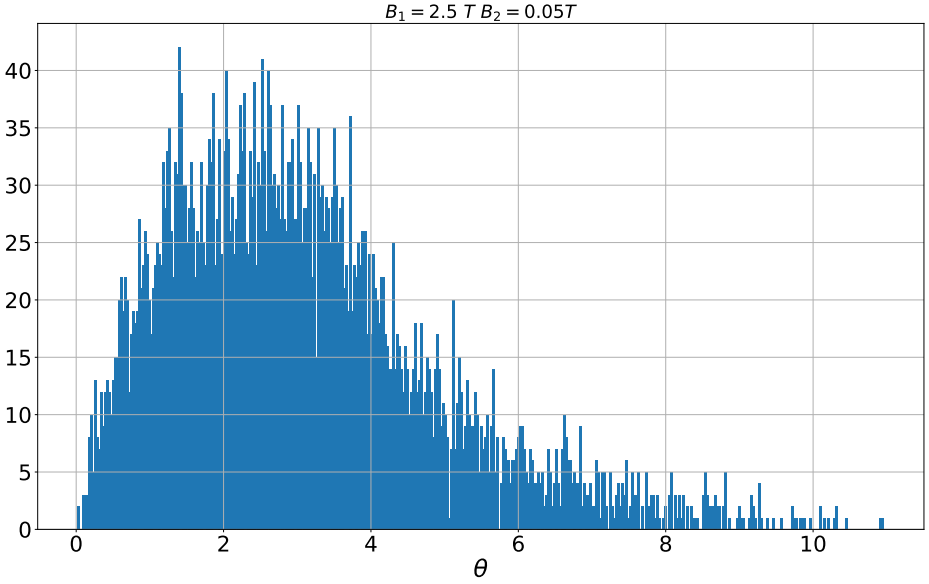
Momentum collimation



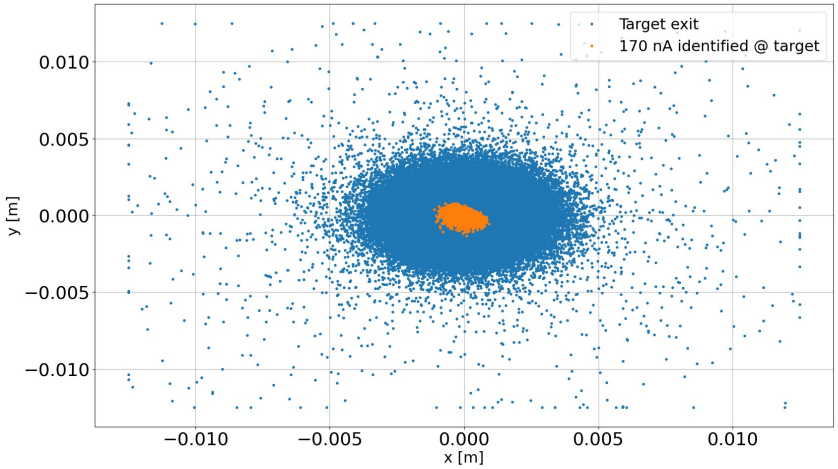
Angular distribution

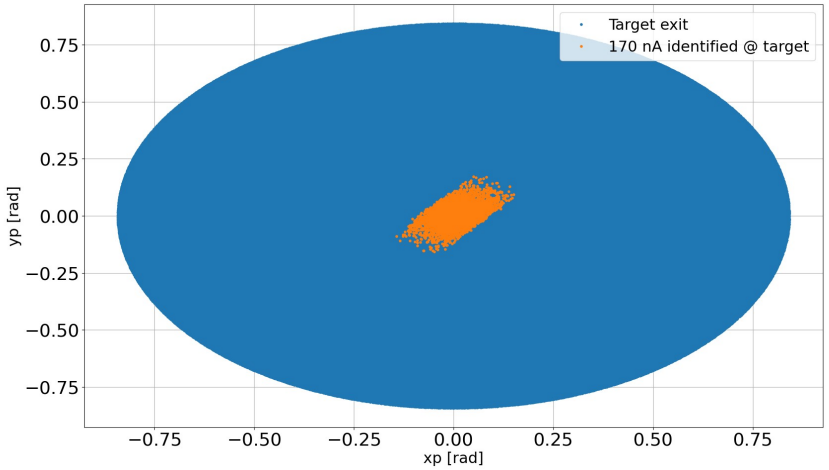






Transverse space





- The transmitted positrons are within the acceptance of the QWT
- $p_t^{QWT} = \frac{eB_1R}{2}. = 10.31°$
- $r_0^{QWT} = \frac{B_2}{B_1} R = 0.6\ mm$