Development of a Polarized Positron Source for CEBAF

Sami Habet

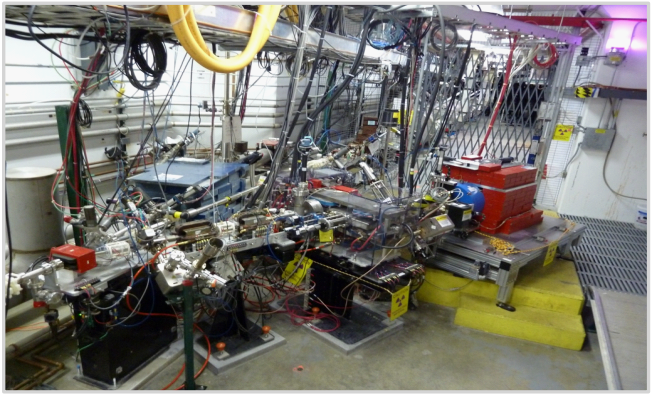
IJCLab & JLab

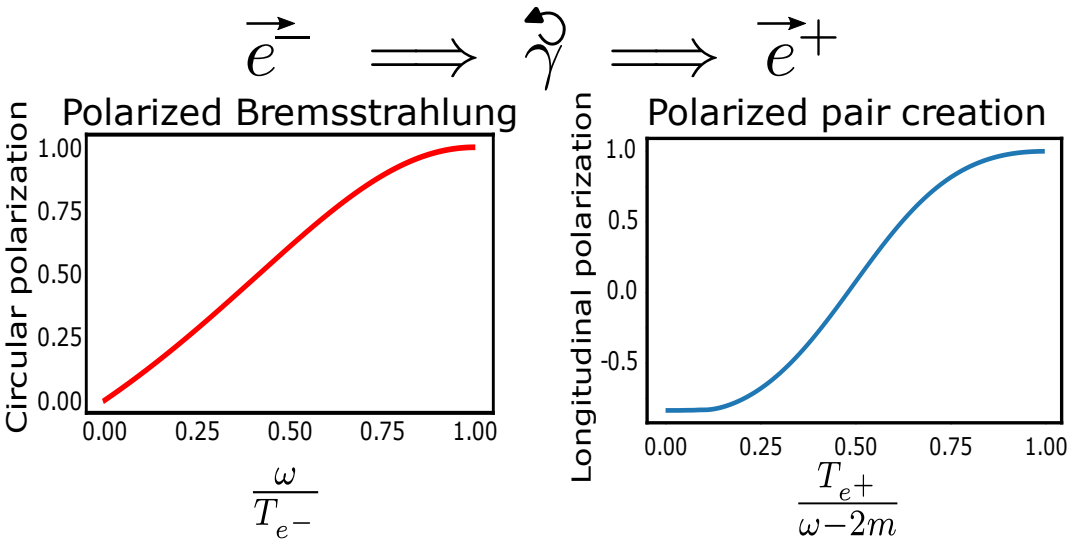
March 4, 2023

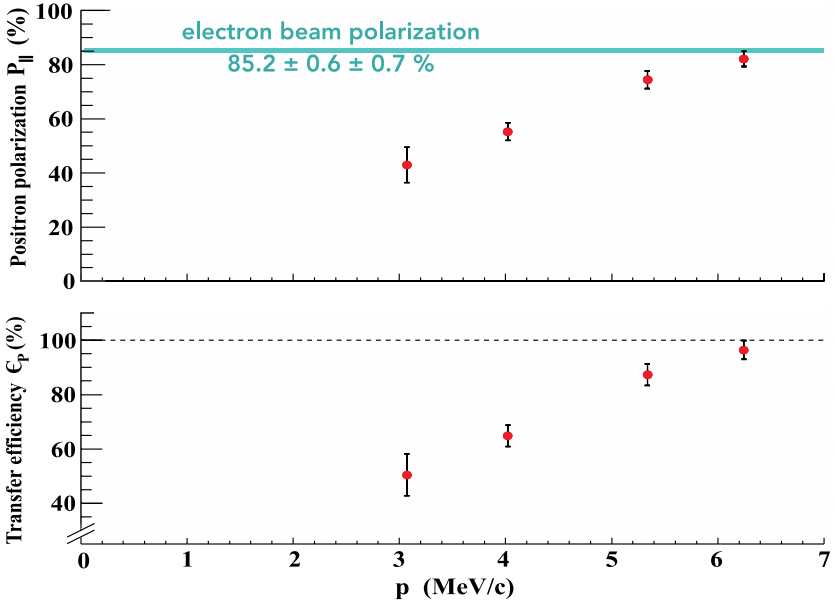
This research work is part of a project that has received funding from the European Union's Horizon 2020 research and innovation program under agreement **STRONG - 2020 - No 824093**

Introduction

J. Grames, E. Voutier et al.,JLab Experiment E12-11-105 (2011)

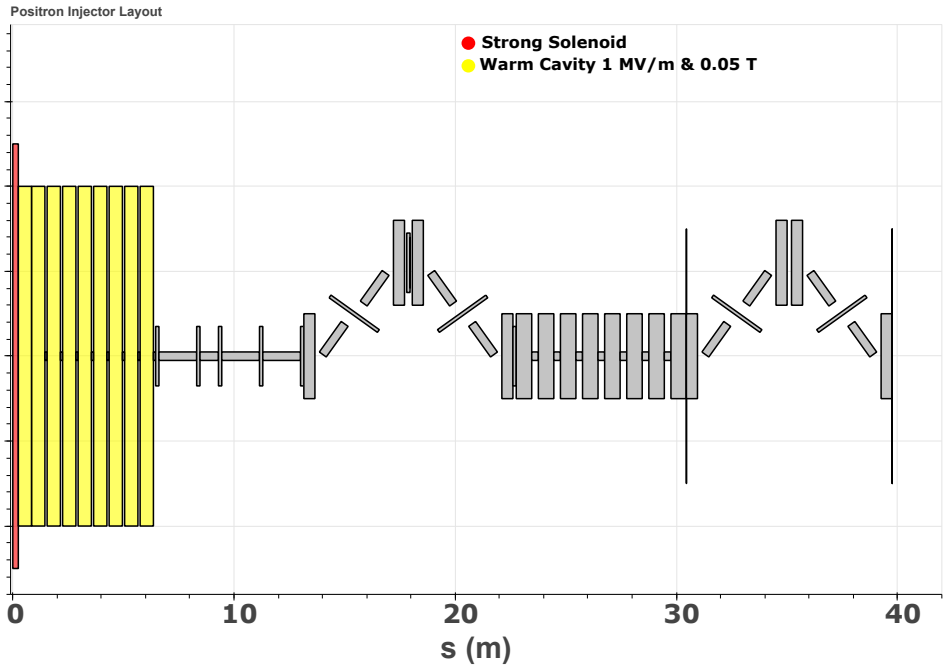






Plan

1. Target optimization
2. Collection system
3. Momentum collimation
4. Longitudinal optimization
5. Un-Polarized mode
6. Conclusion



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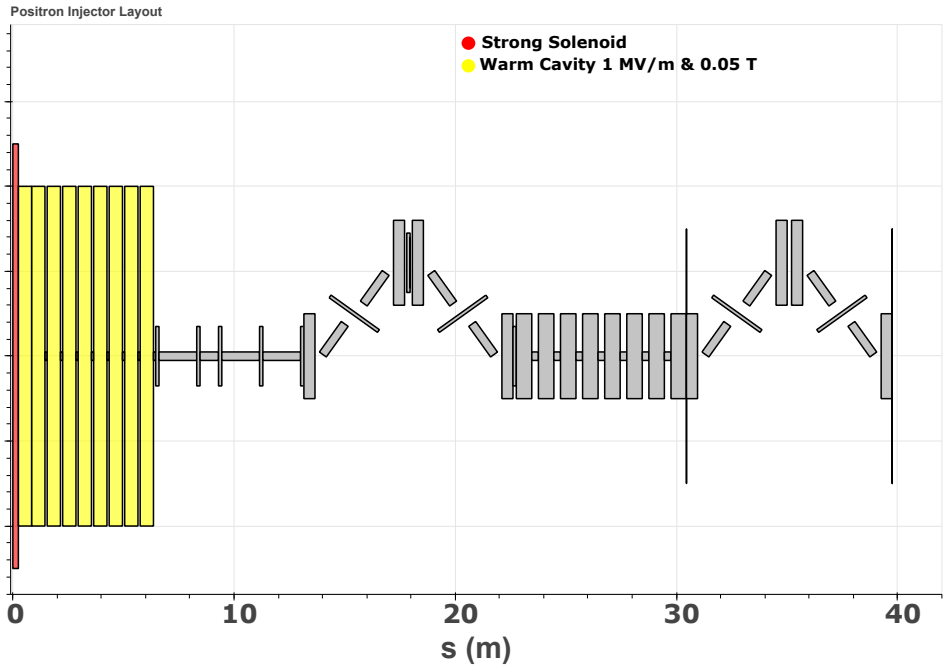

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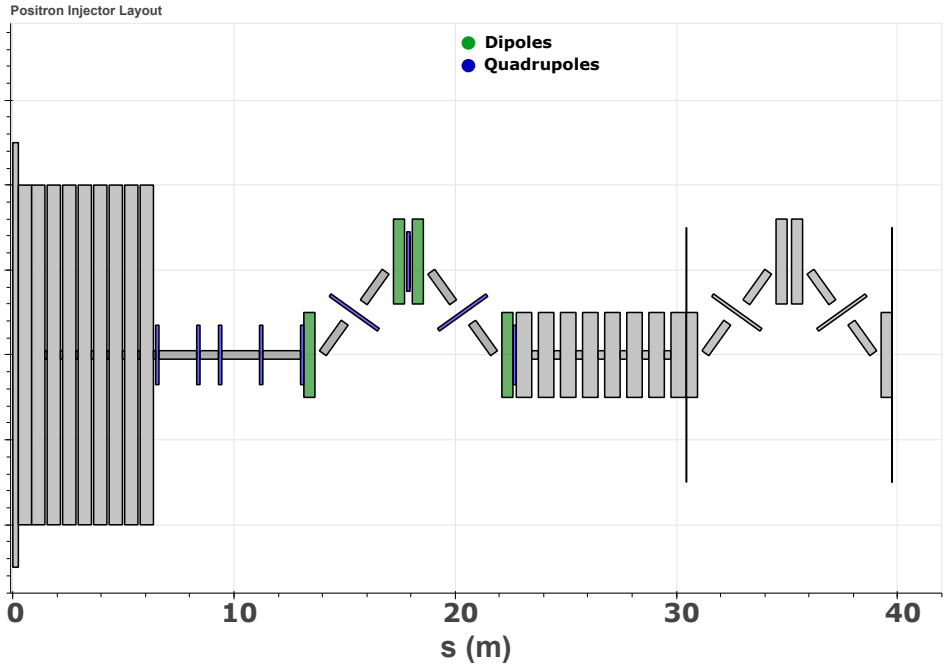

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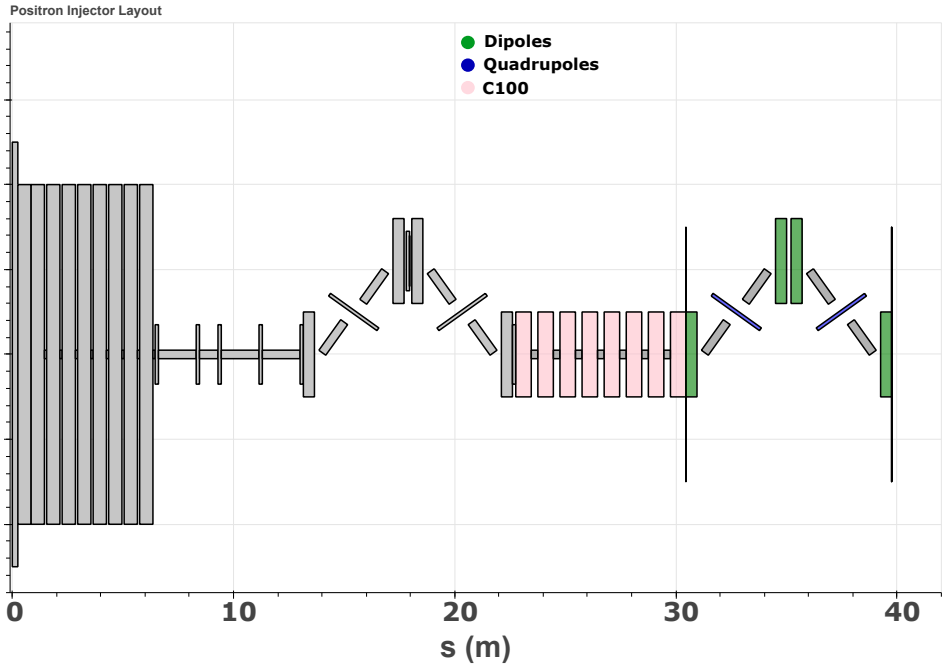

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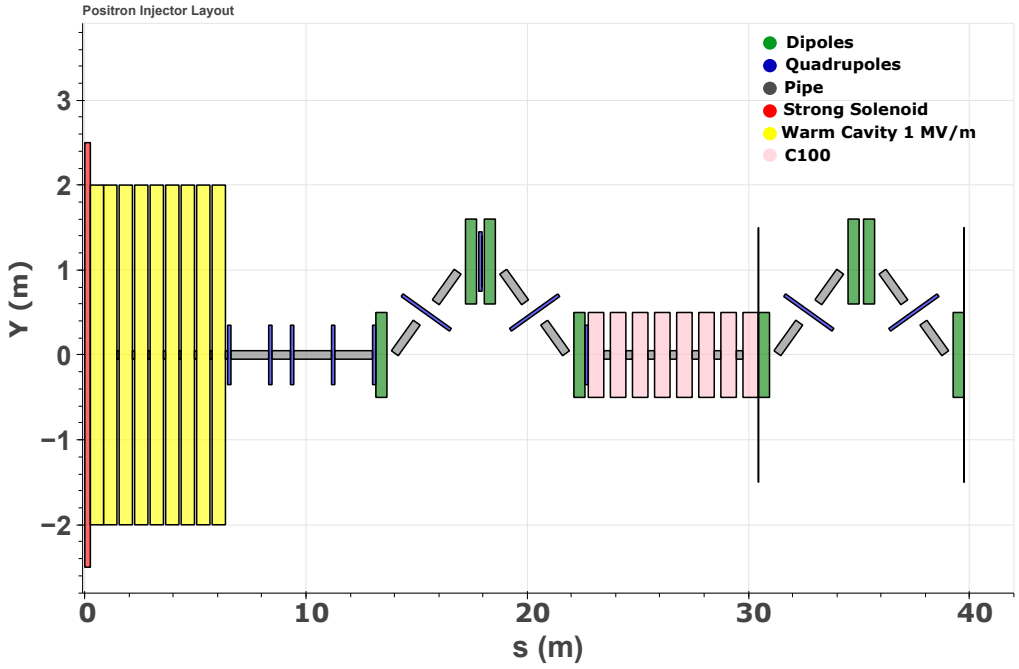

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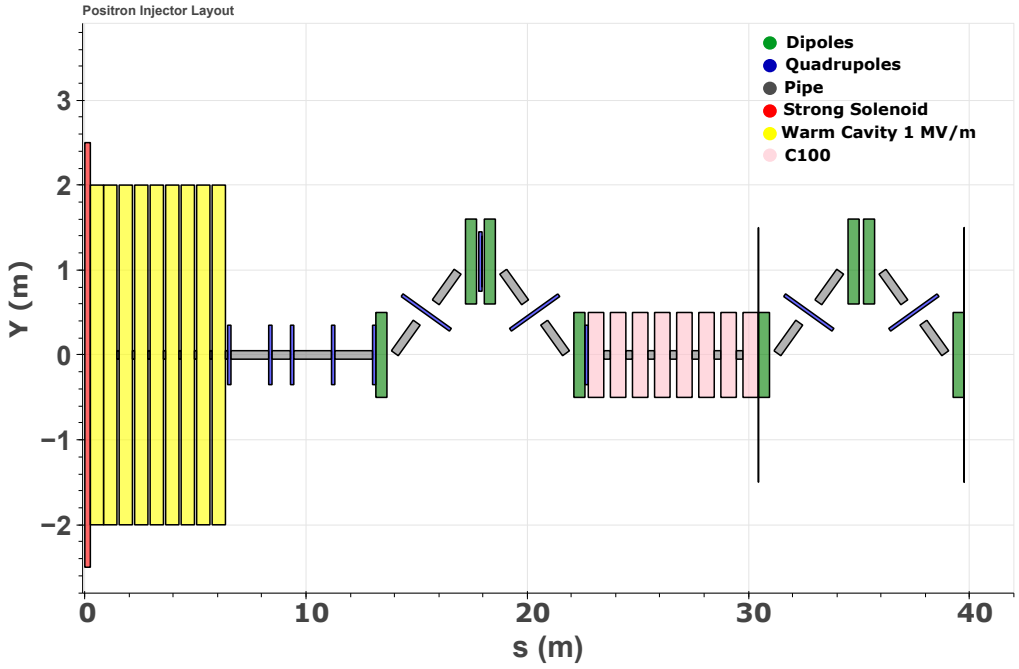


Outline

European Union s Horizon 2020 research and innovation program agreement No 824093.

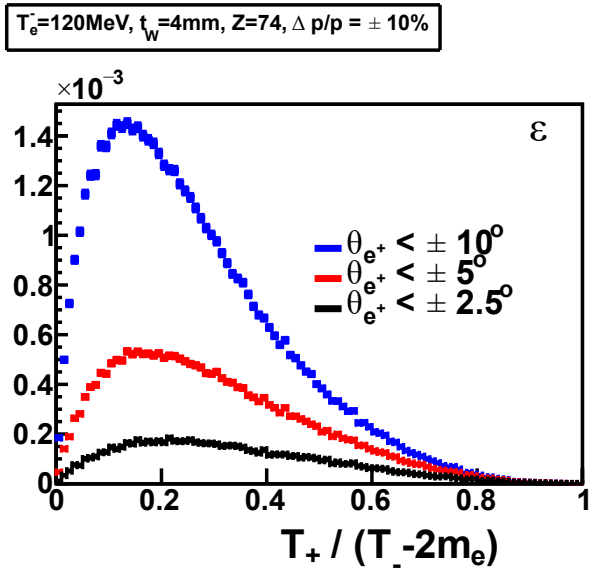
Target optimization

Unpolarized mode

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

Polarized mode

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



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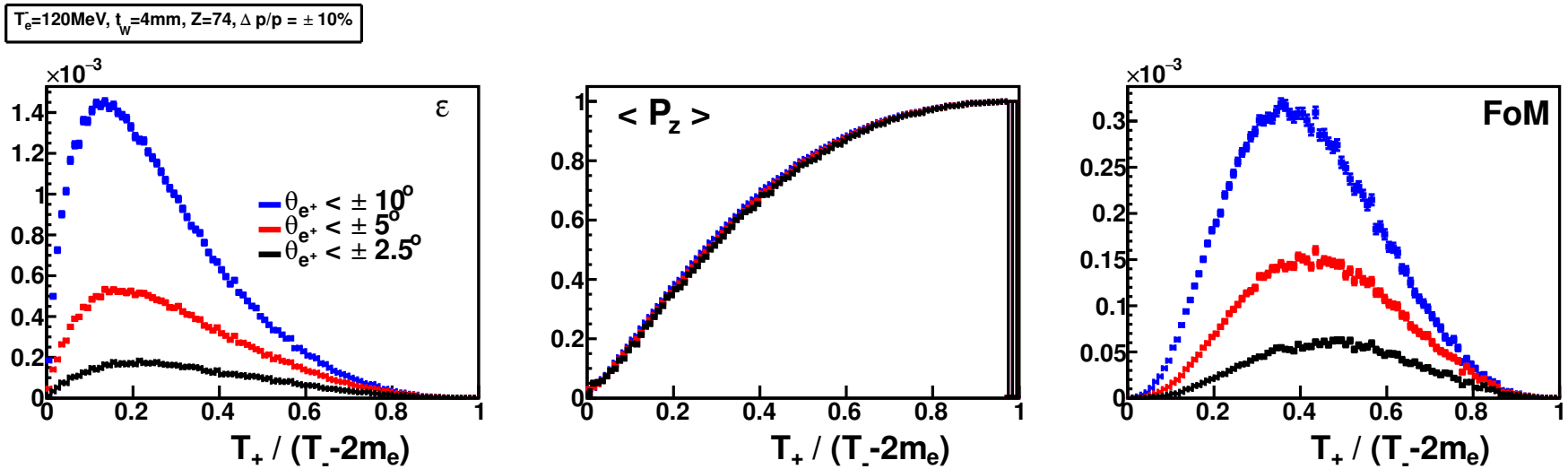

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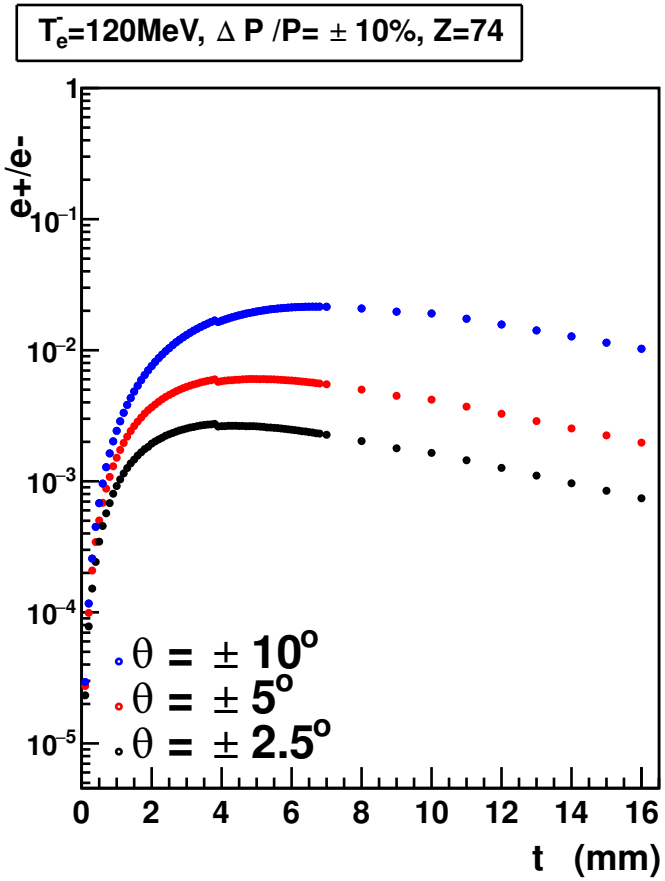

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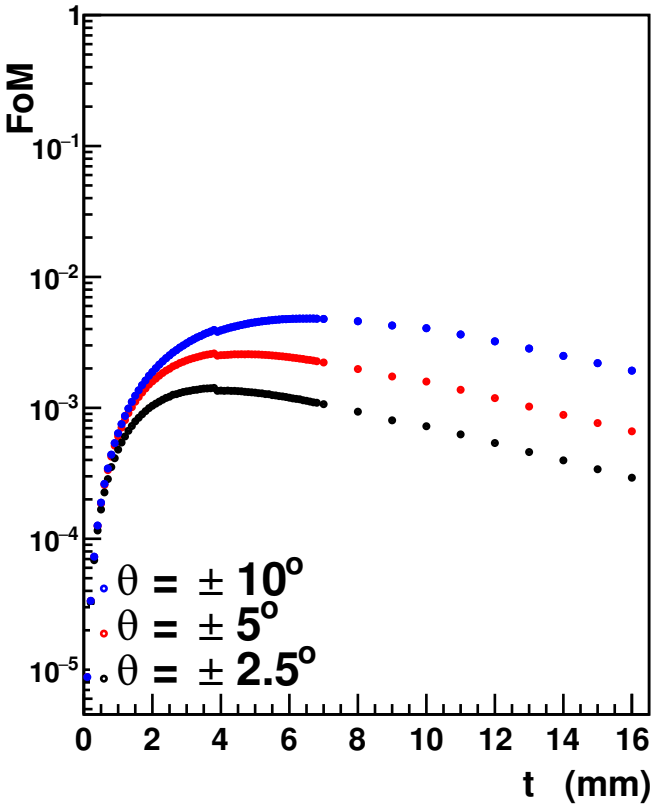

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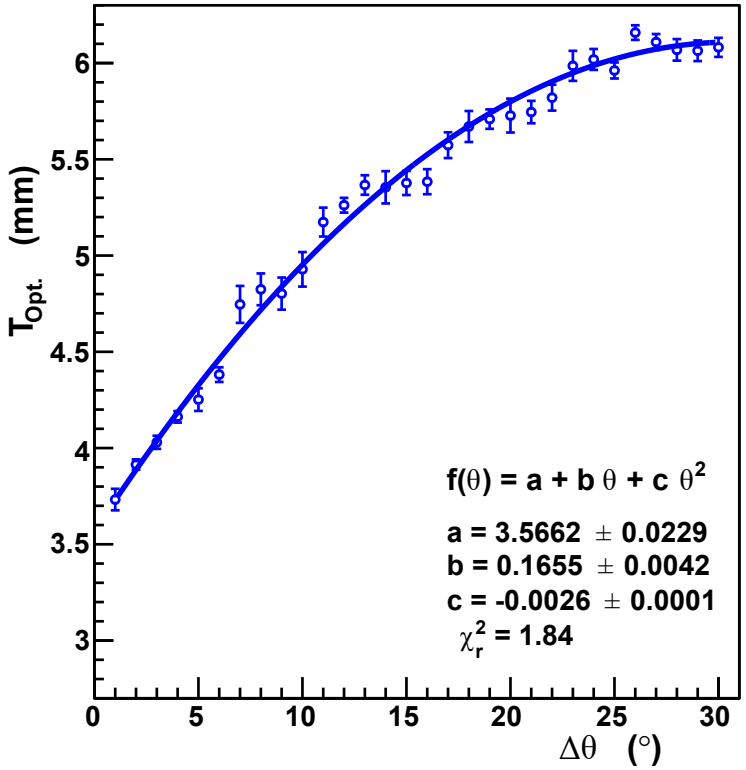

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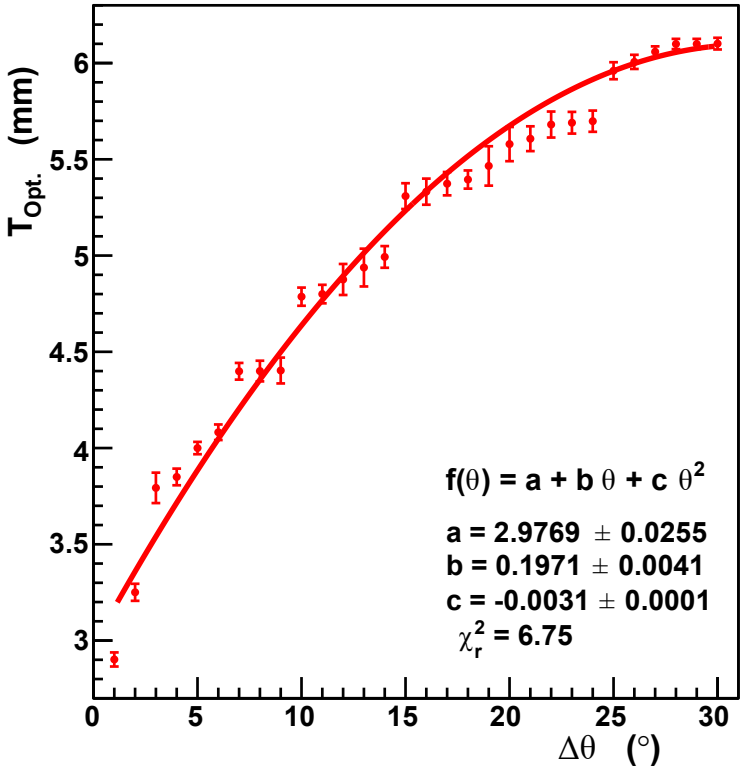

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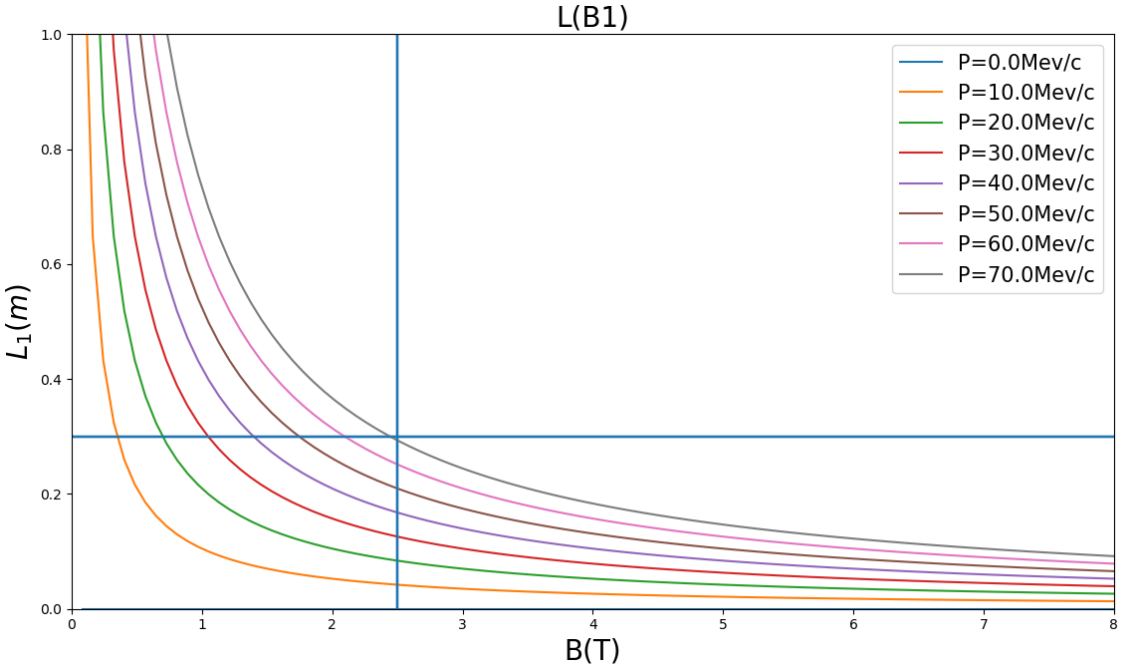
Quarter Wave Transformer

- Reduce the angular transverse spread $x_p = \frac{p_x}{p}$ and $y_p = \frac{p_y}{p}$.
- 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.
- QWT acceptance :
  - Radial acceptance $r_0^{QWT} = \frac{B_2}{B_1} R$
  - Transverse acceptance $p_t^{QWT} = \frac{eB_1 R}{2}$

- L_1:Short solenoid length
- B_1: Magnetig field in L_1
- R: Accelerator aperture



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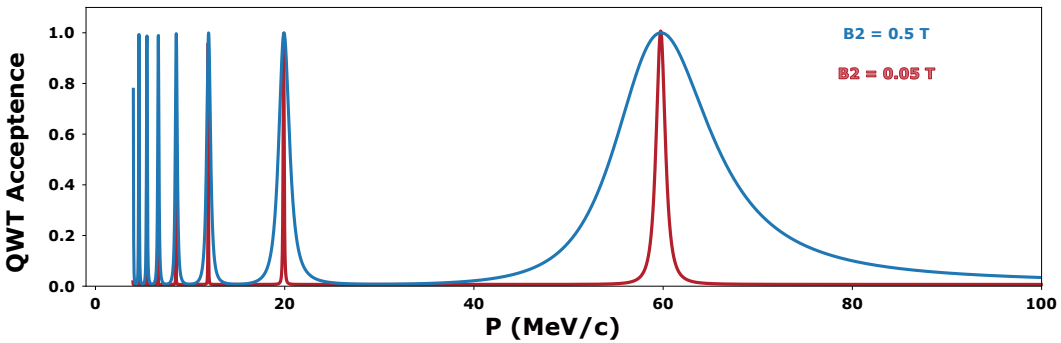

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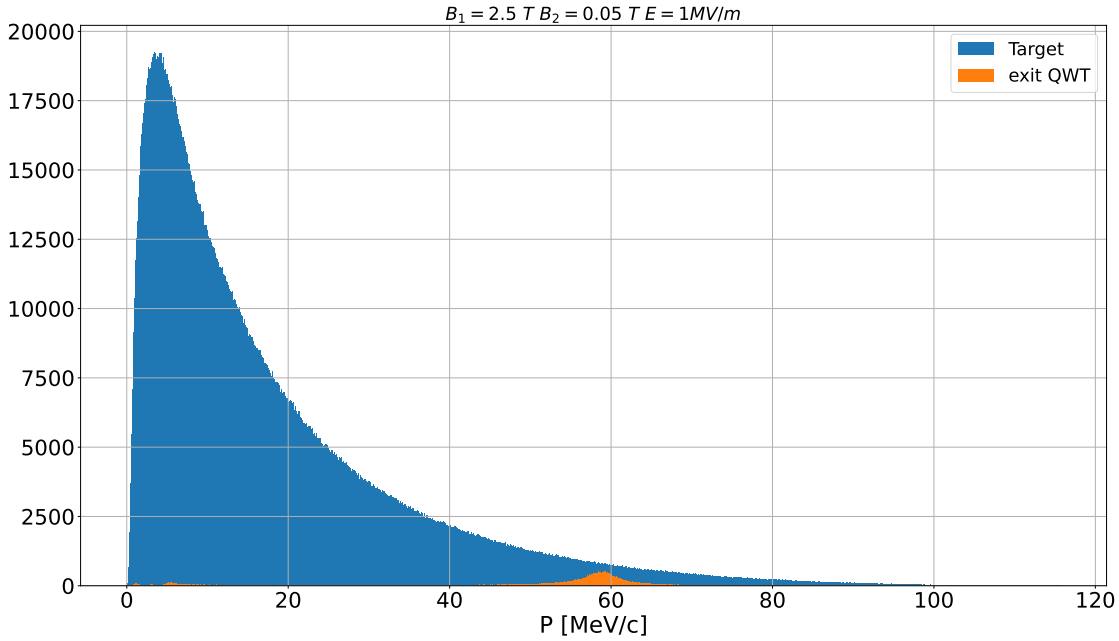

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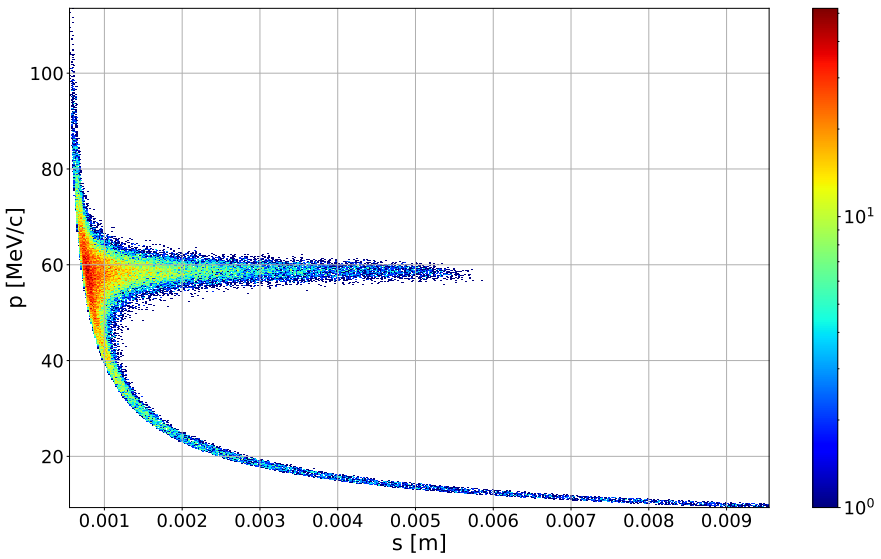

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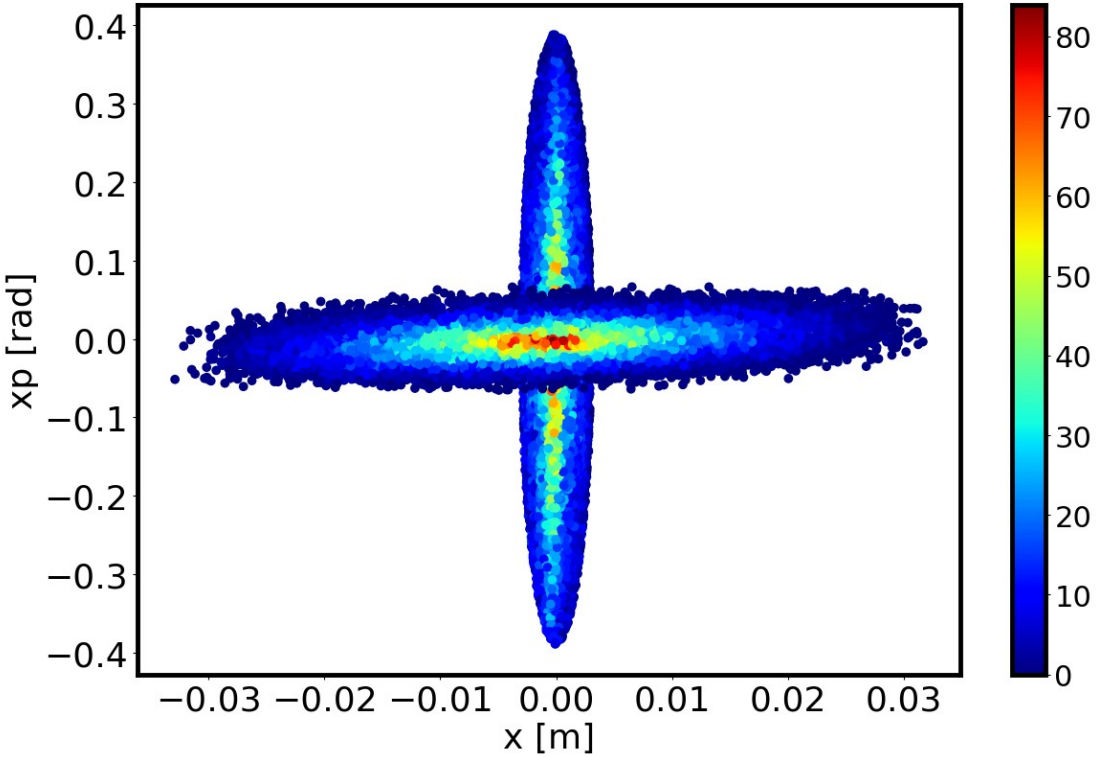

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Accelerating warm section

Goal

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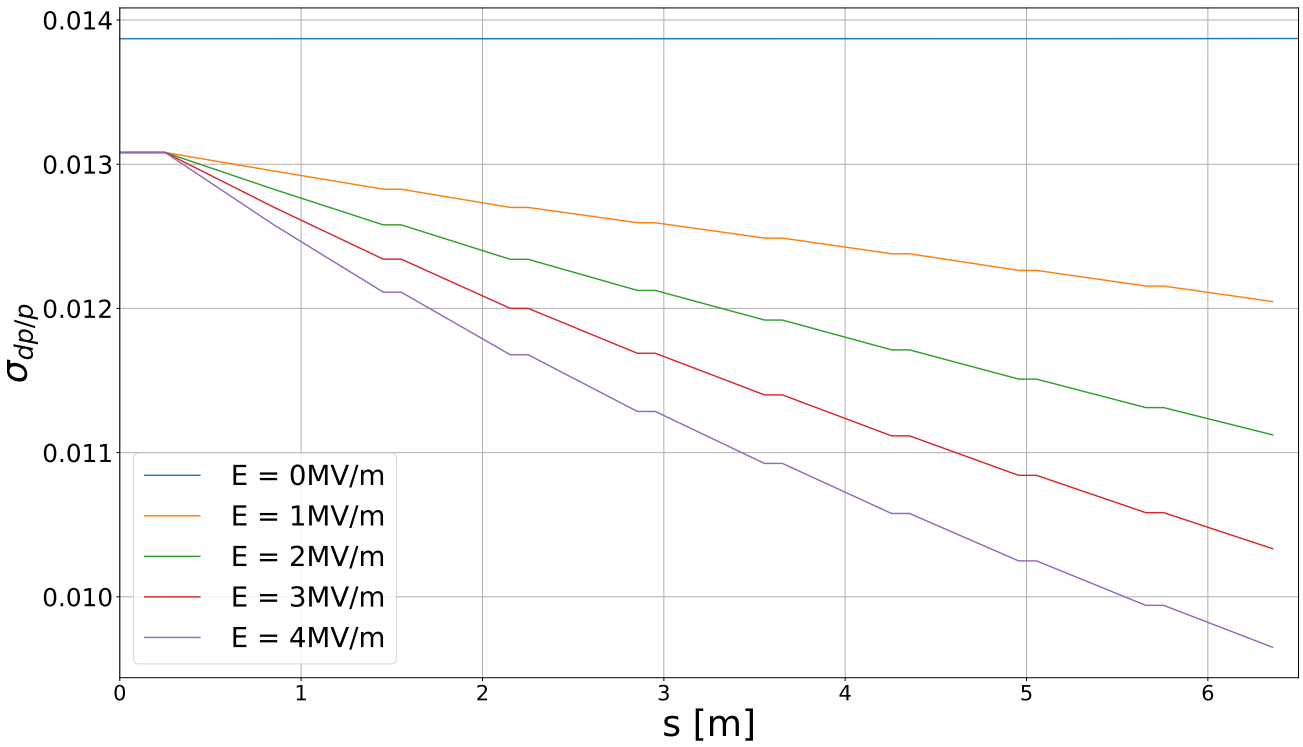

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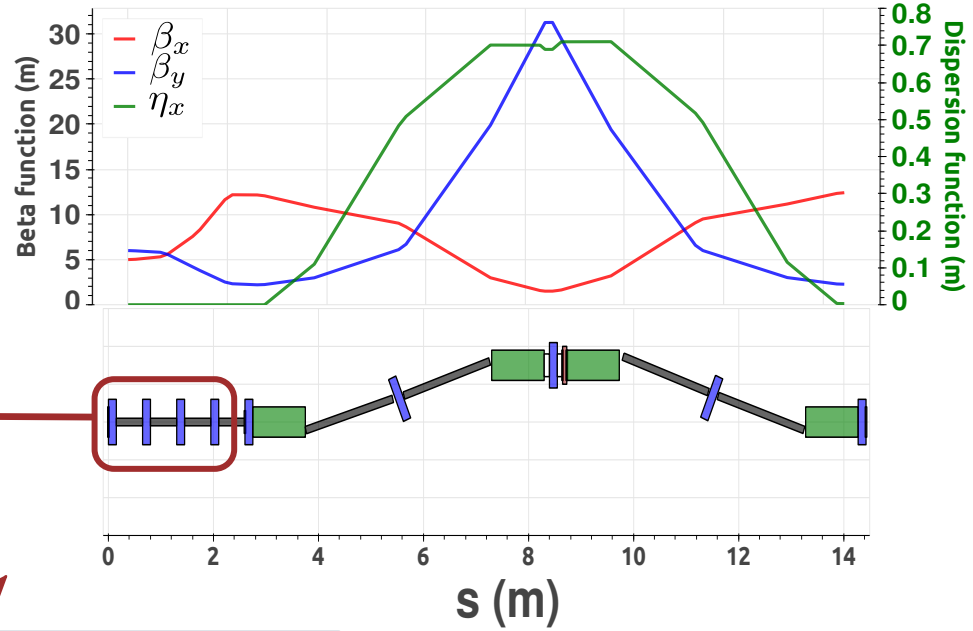
Beam size optimization



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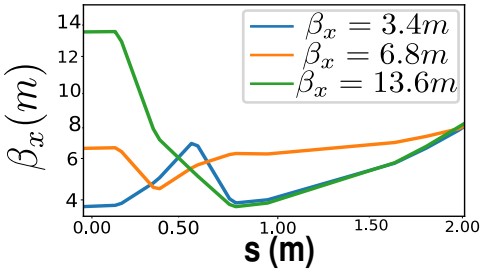
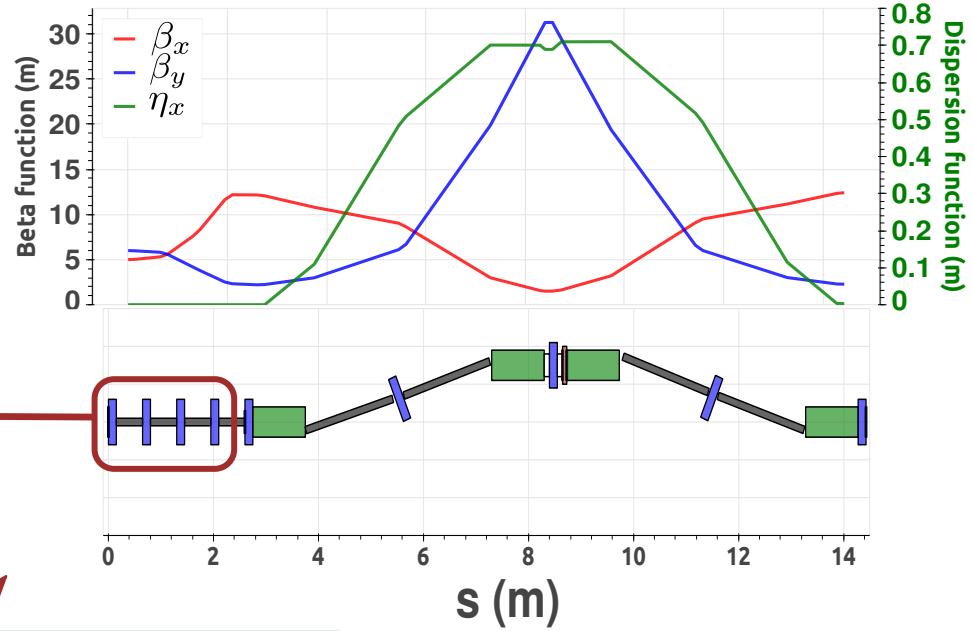
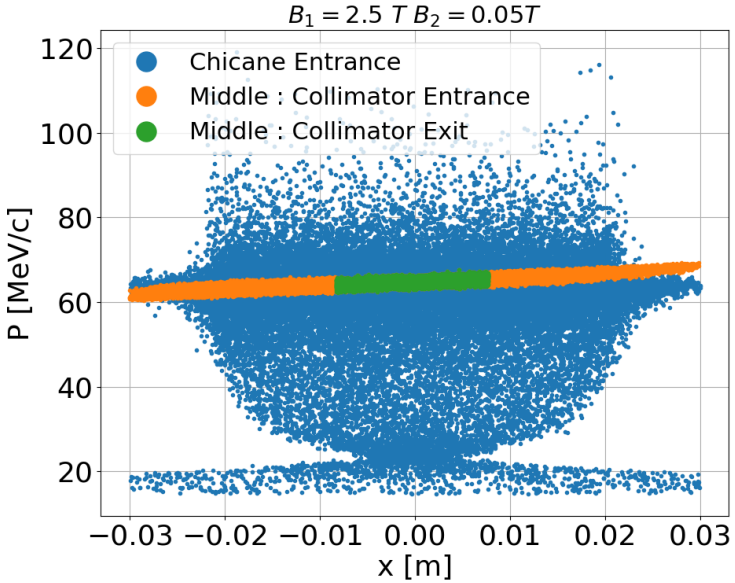


- **Periodic Twiss in FODO:**
  $$\beta_{x,y_{in}} = \beta_{x,y_{out}}$$
- **Minimum beam size condition:**
  $$\beta_x = \beta_{x_{MIN}} \longrightarrow \alpha_x = 0$$

Beam size optimization





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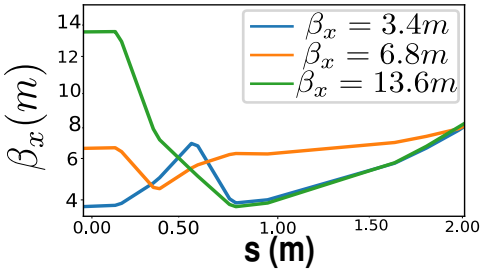

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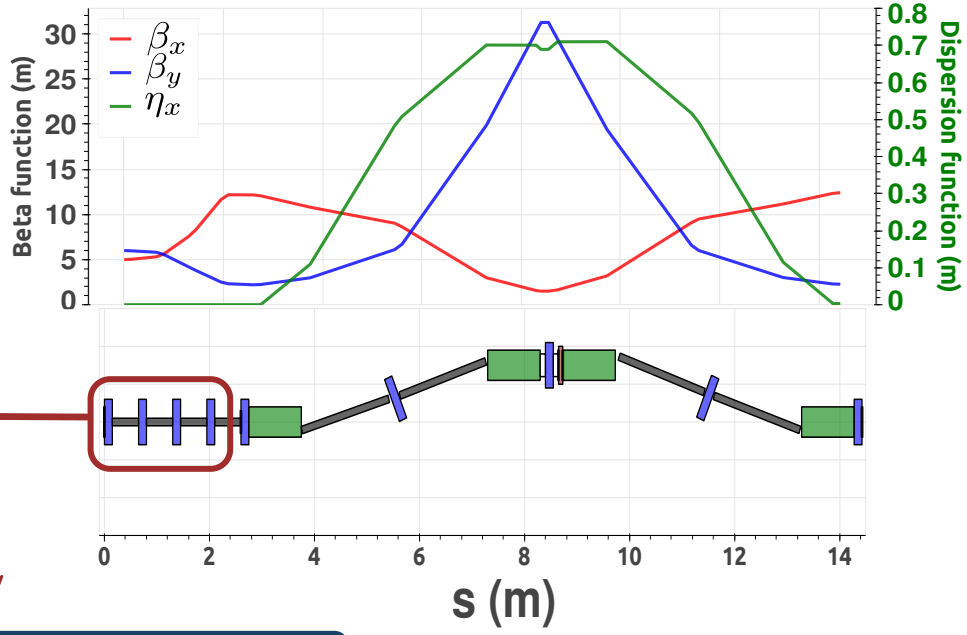

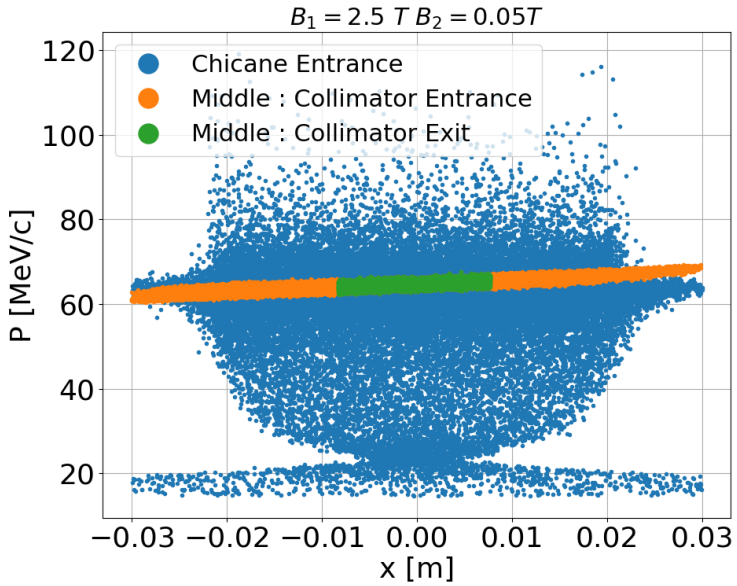

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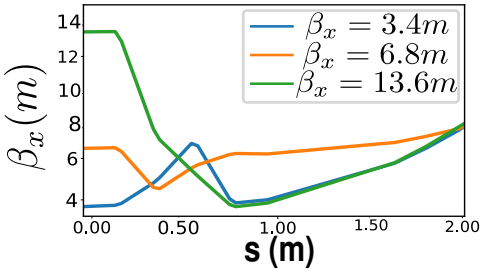

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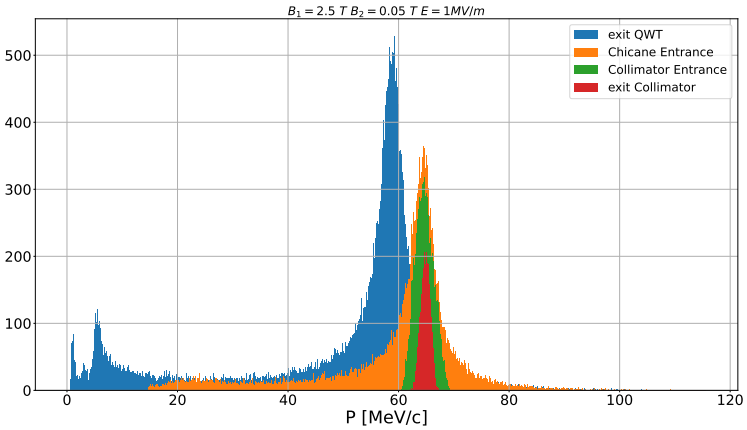
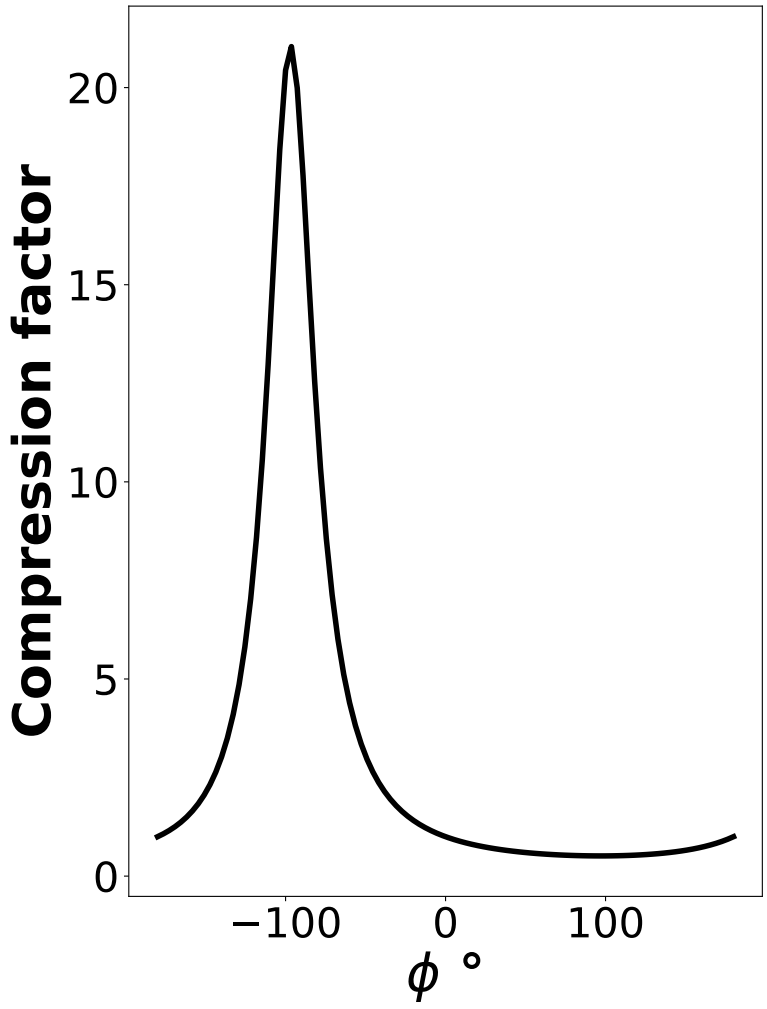


Outline

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]
  - E_0 Central energy [MeV]
  - ϕ Cavity phase advance.



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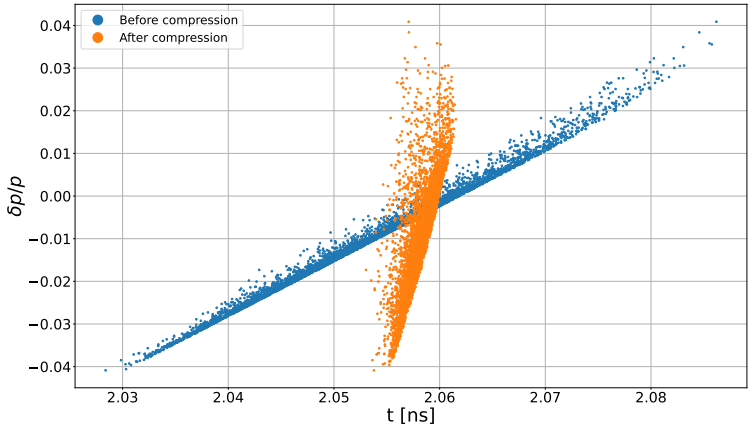

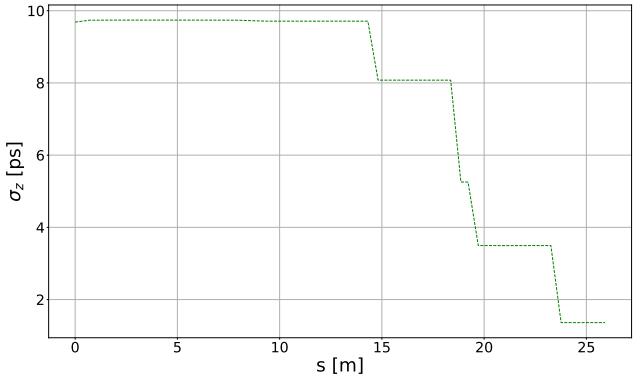

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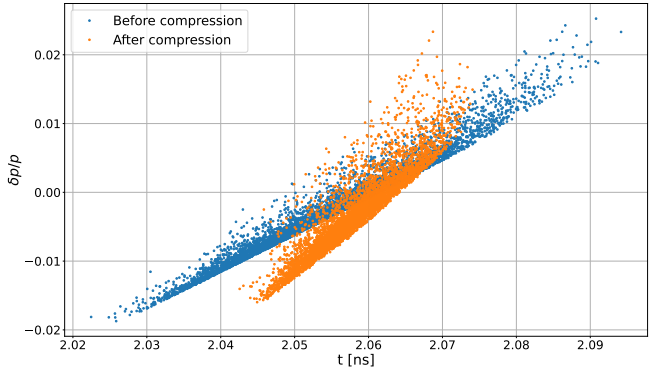
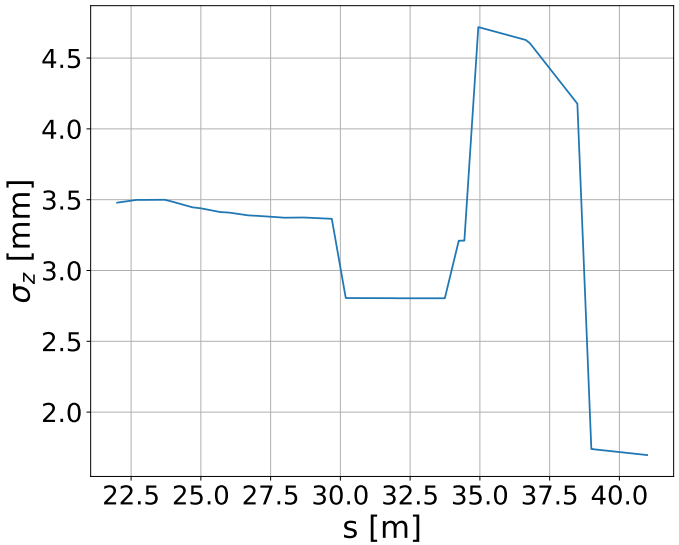
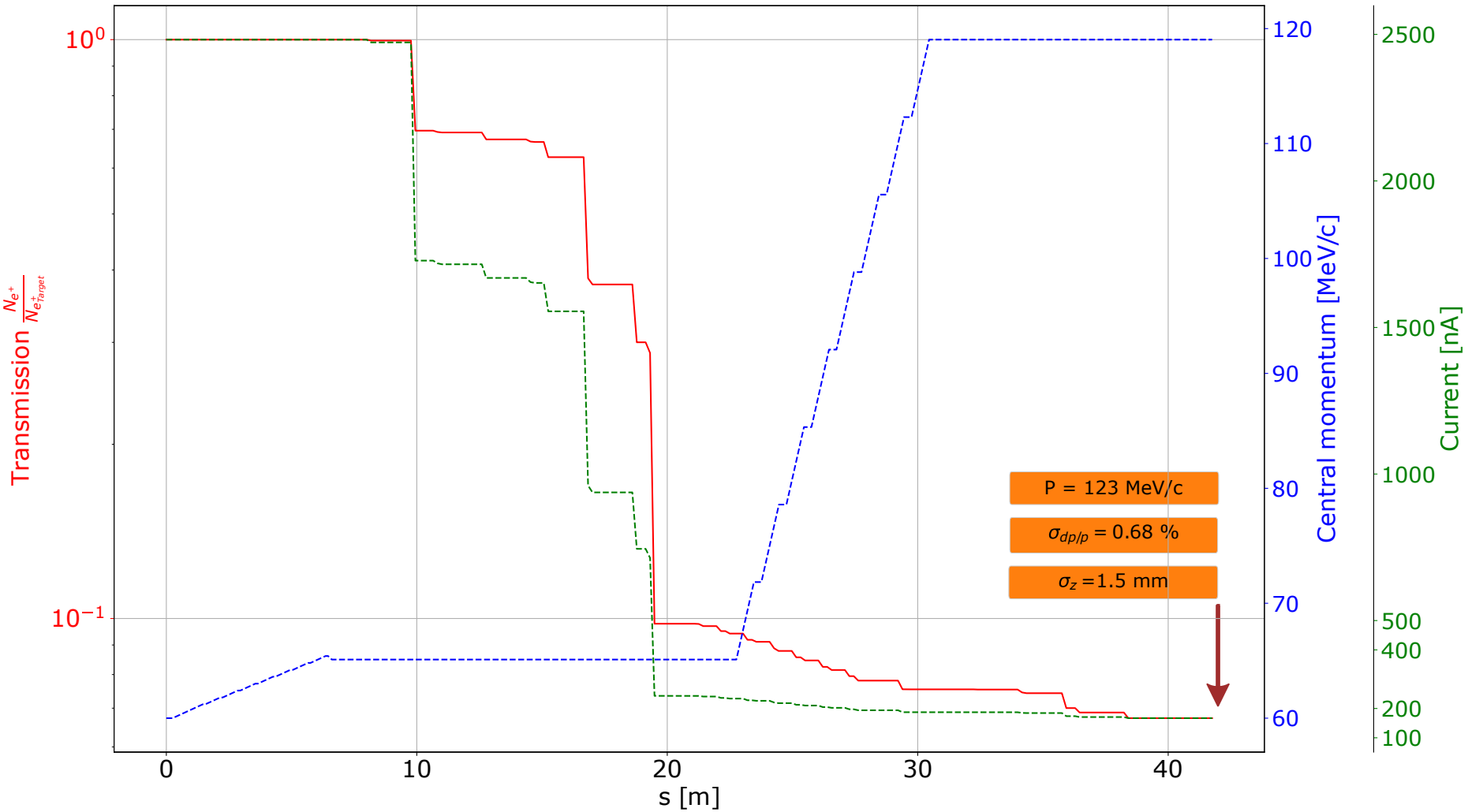




Transmission and Curent



summary

Ce+BAF Parameter	e^+ model	Target value
$\sigma_{dp/p}$ [%]	0.68	$\pm$ 1%
$\sigma_z[ps]$	4	$\leq$ 4
$\sigma_x[mm]$	6	$\leq$ 3
N $\epsilon_n[mm\ mrad]$	140	$\leq$ 40
Mean Momentum [MeV/c]	123	123
e^+ ($P > 60\%$)	170 nA	50 nA

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Outline

Un-Polarized mode: Positron Capture

- Reduce the magnetic field in the first solenoid.
- Rotate the transverse phase space (x, x_p) and (y, y_p) at the exit of the QWT.
- Use the same QWT as an energy filter.
- QWT acceptance :
  - Radial acceptance $r_0^{QWT} = \frac{B_2}{B_1} R$
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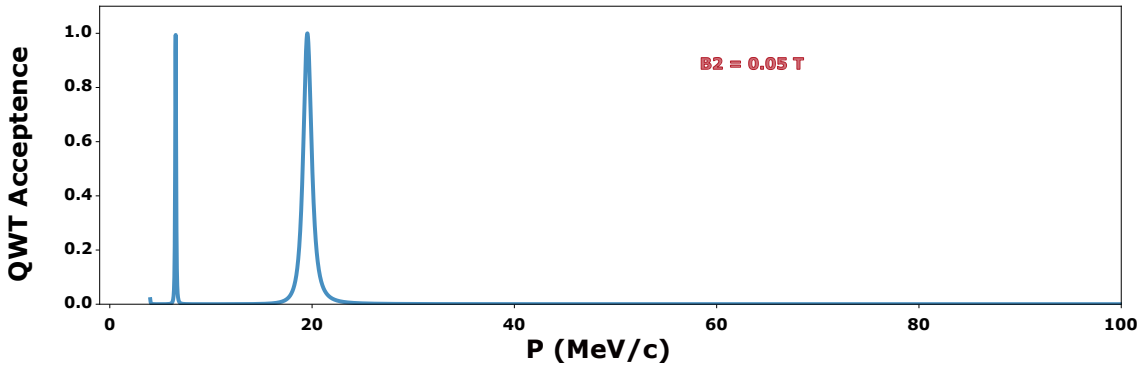
- $L_1 = 0.24\ cm$:Short solenoid length
- $B_1 = 0.96\ T$: Magnetig field over L_1
- $R = 3\ cm$: Accelerator aperture



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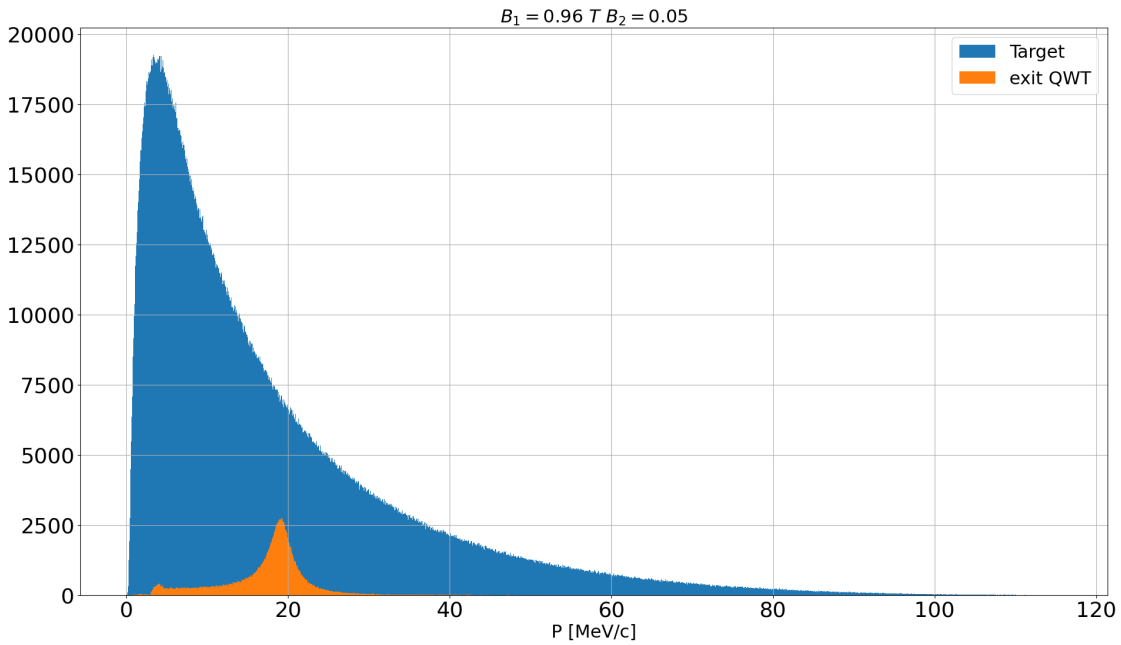
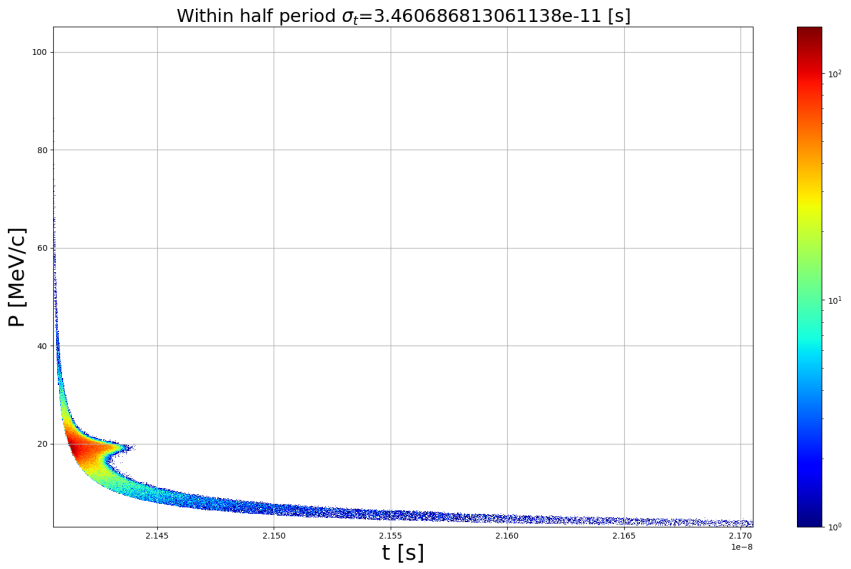


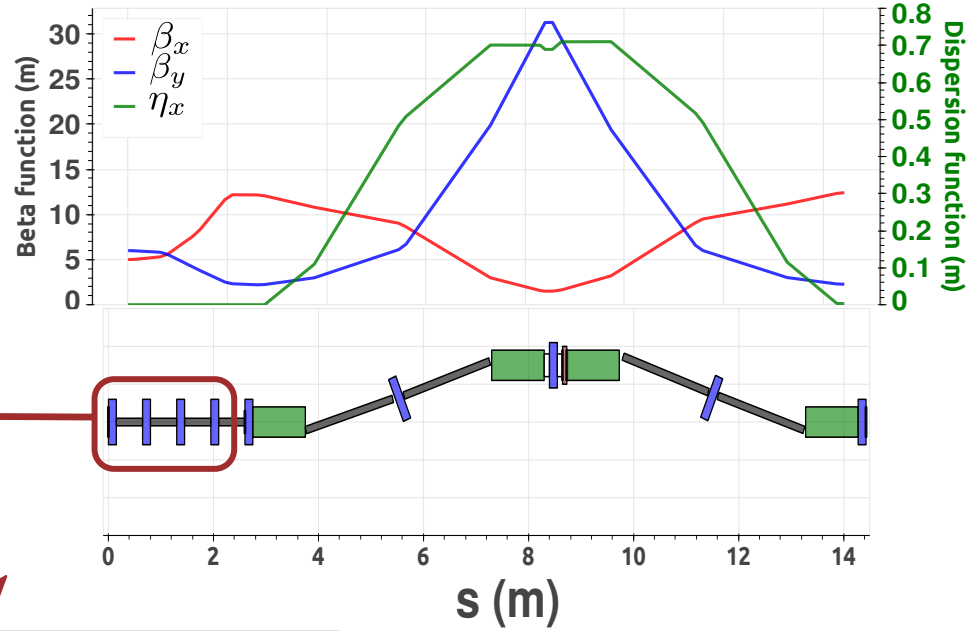
Un-Polarized mode: Positron Capture

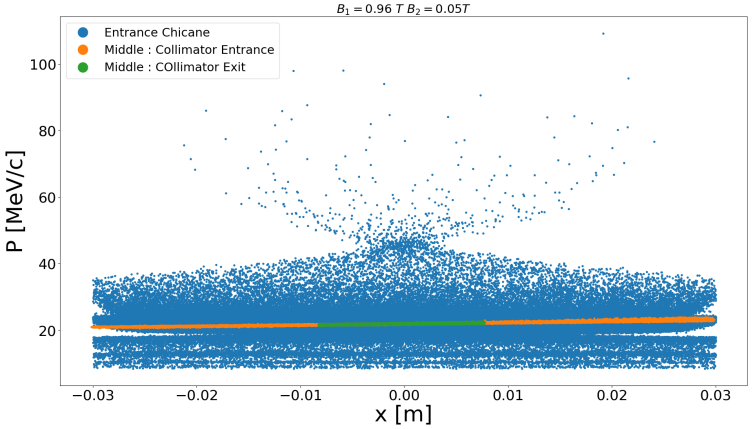
- Reduce the magnetic field in the first solenoid.
- Rotate the transverse phase space (x, x_p) and (y, y_p) at the exit of the QWT.
- Use the same QWT as an energy filter.
- QWT acceptance :
  - Radial acceptance $r_0^{QWT} = \frac{B_2}{B_1} R$
  - Transverse acceptance $p_t^{QWT} = \frac{eB_1 R}{2}$

- $L_1 = 0.24\ cm$:Short solenoid length
- $B_1 = 0.96\ T$: Magnetig field over L_1
- $R = 3\ cm$: Accelerator aperture

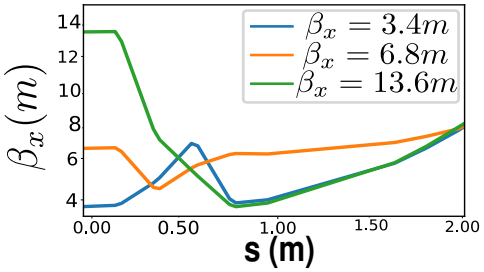


Momentum collimation





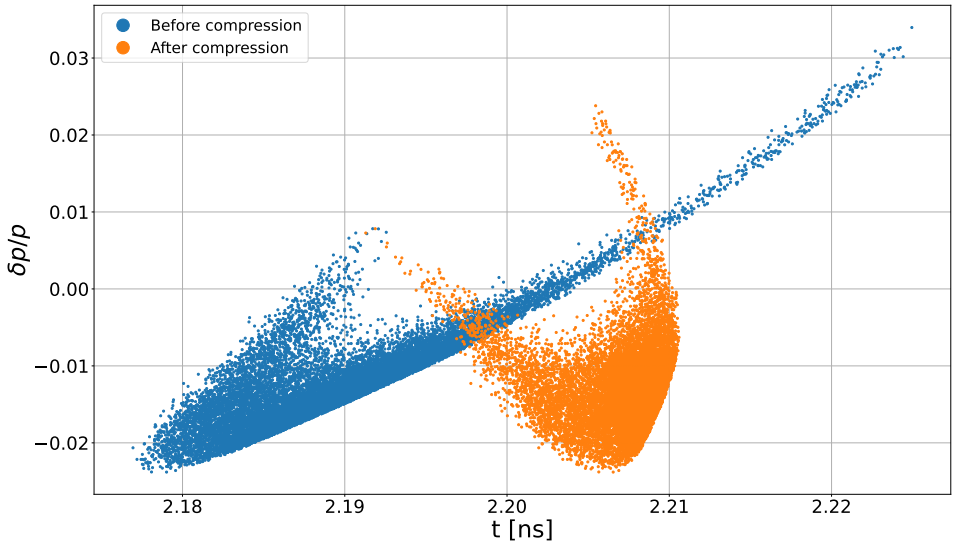
Matching section

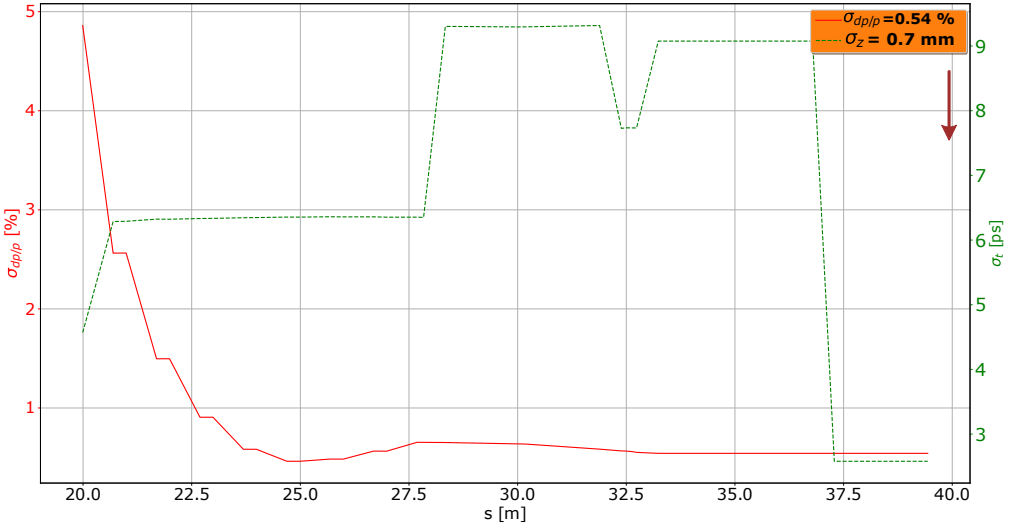


- **Periodic Twiss in FODO:**
  $$\beta_{x,y_{in}} = \beta_{x,y_{out}}$$
- **Minimum beam size condition:**
  $$\beta_x = \beta_{x_{MIN}} \longrightarrow \alpha_x = 0$$

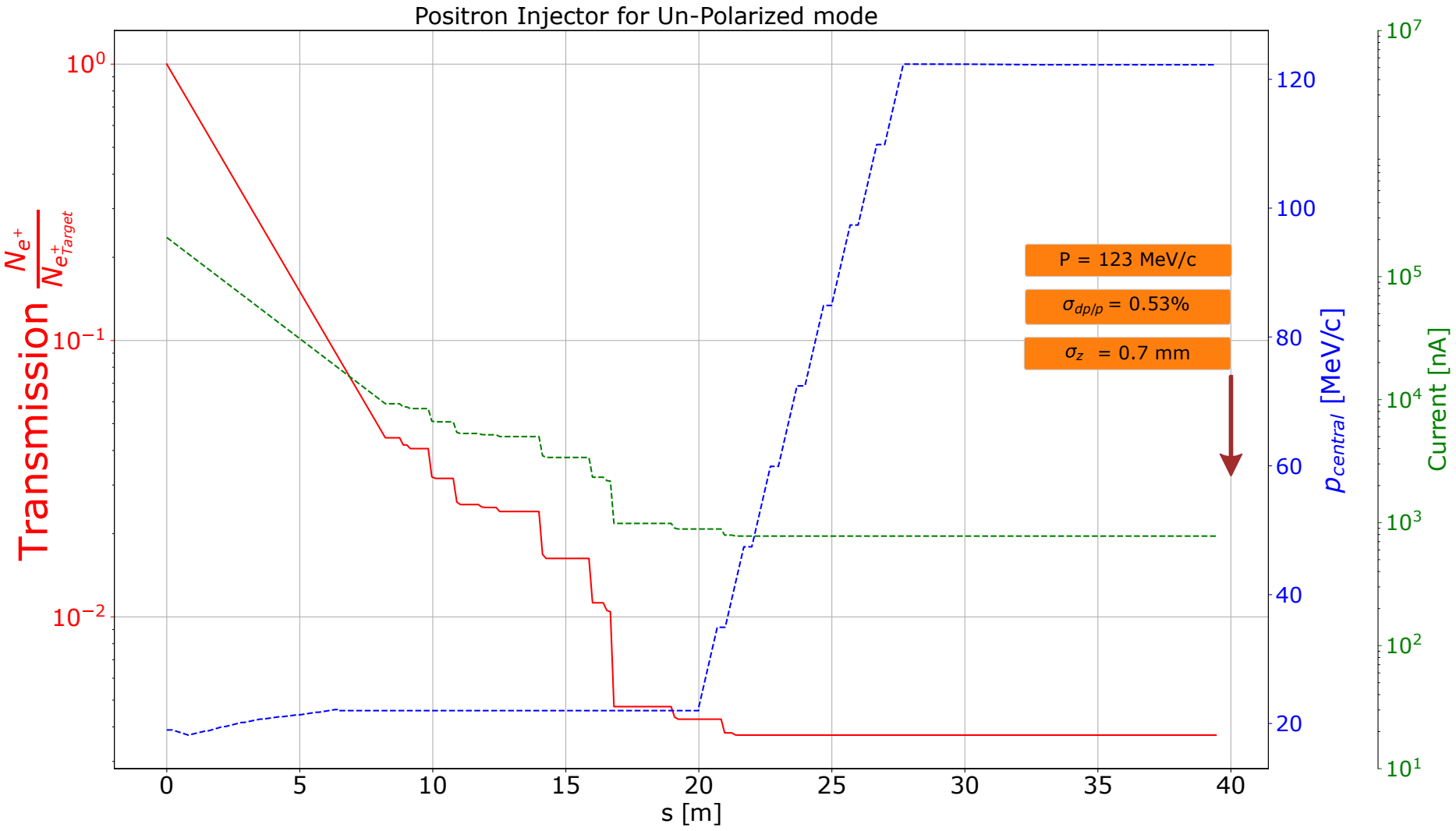
Longitudinal optimization

- The longitudinal energy spread dp/p is reduced by accelerating from 22 MeV/c to 123 MeV/c.
- The accelerating section is utilized to produce the required energy chirp.
- The same compression chicane is employed to effectively reduce bunch length.





Unpolarized mode: Transmission current



summary

Ce+BAF Parameter	e^+ model	Target value
$\sigma_{dp/p}$ [%]	0.5	$\pm$ 1%
$\sigma_z[ps]$	2	$\leq$ 4
$\sigma_x[mm]$	2	$\leq$ 3
N $\epsilon_n[mm\ mrad]$	140	$\leq$ 40
Mean Momentum [MeV/c]	123	123
e^+ ($P > 20\%$)	700 nA	1 μA

European Union s Horizon 2020 research and innovation program agreement No 824093.

Outline

European Union s Horizon 2020 research and innovation program agreement No 824093.

Conclusion

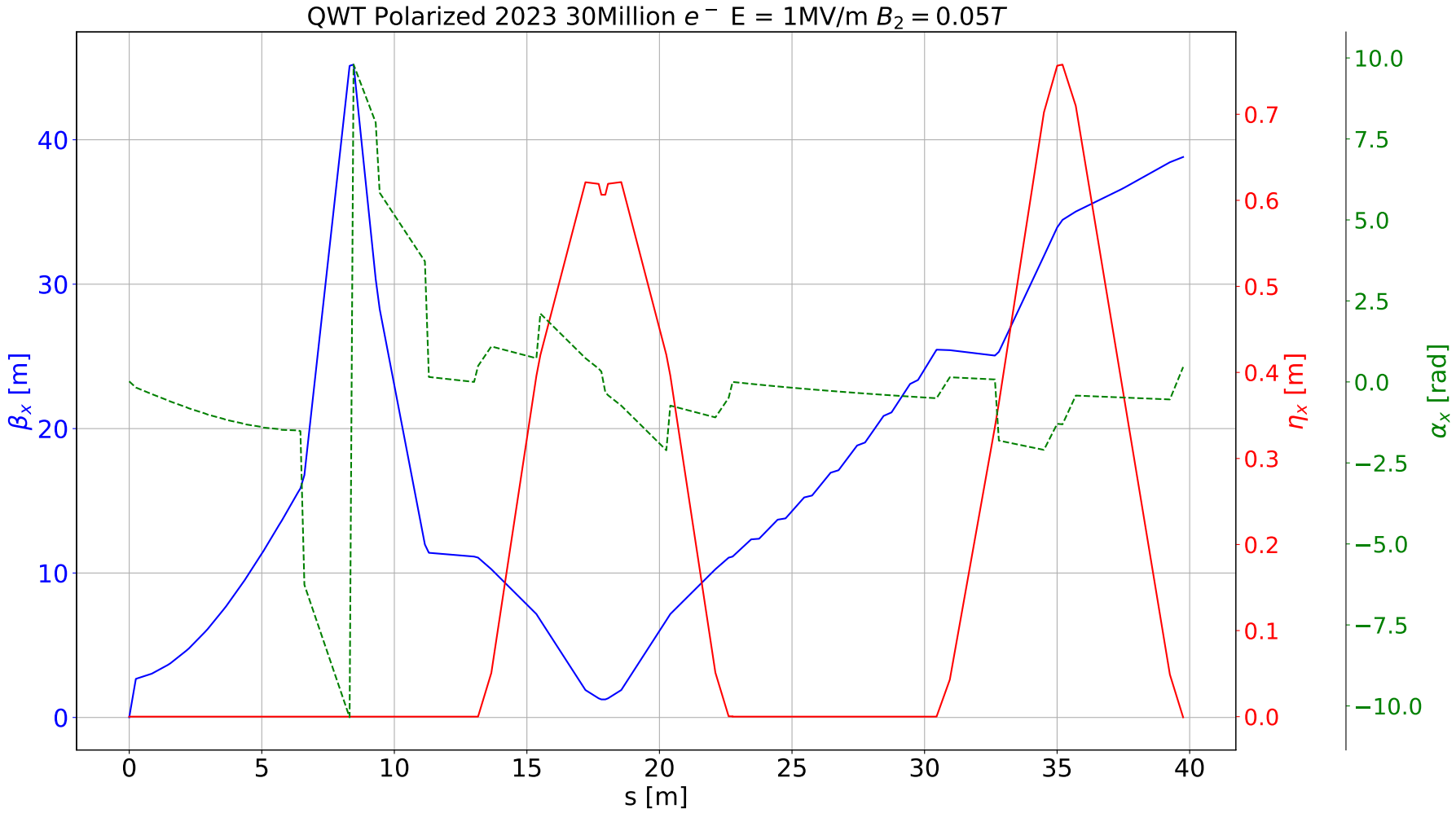
- The performance of the positron system is heavily dependent on the central momentum. To obtain a high yield of positrons, the central momentum should be set to 15 MeV/c, while a high polarization requires a central momentum of 60 MeV/c.
- The QWT plays a crucial role in selecting the desired momentum and reducing the spread of transverse angles. accelerating section significantly impacts the longitudinal plane, reducing the energy spread to meet the CEBAF requirement of $\sigma_{dp/p} = \pm 1\%$.
- It is possible to achieve a compromise between the energy spread and the bunch length to meet the appropriate longitudinal CEBAF requirement during the injection.
- To achieve a higher current of around 1 μA for the unpolarized mode with a momentum of 15 - 20 MeV/c, it is necessary to adjust the variable parameters of the layout.

European Union s Horizon 2020 research and innovation program agreement No 824093.

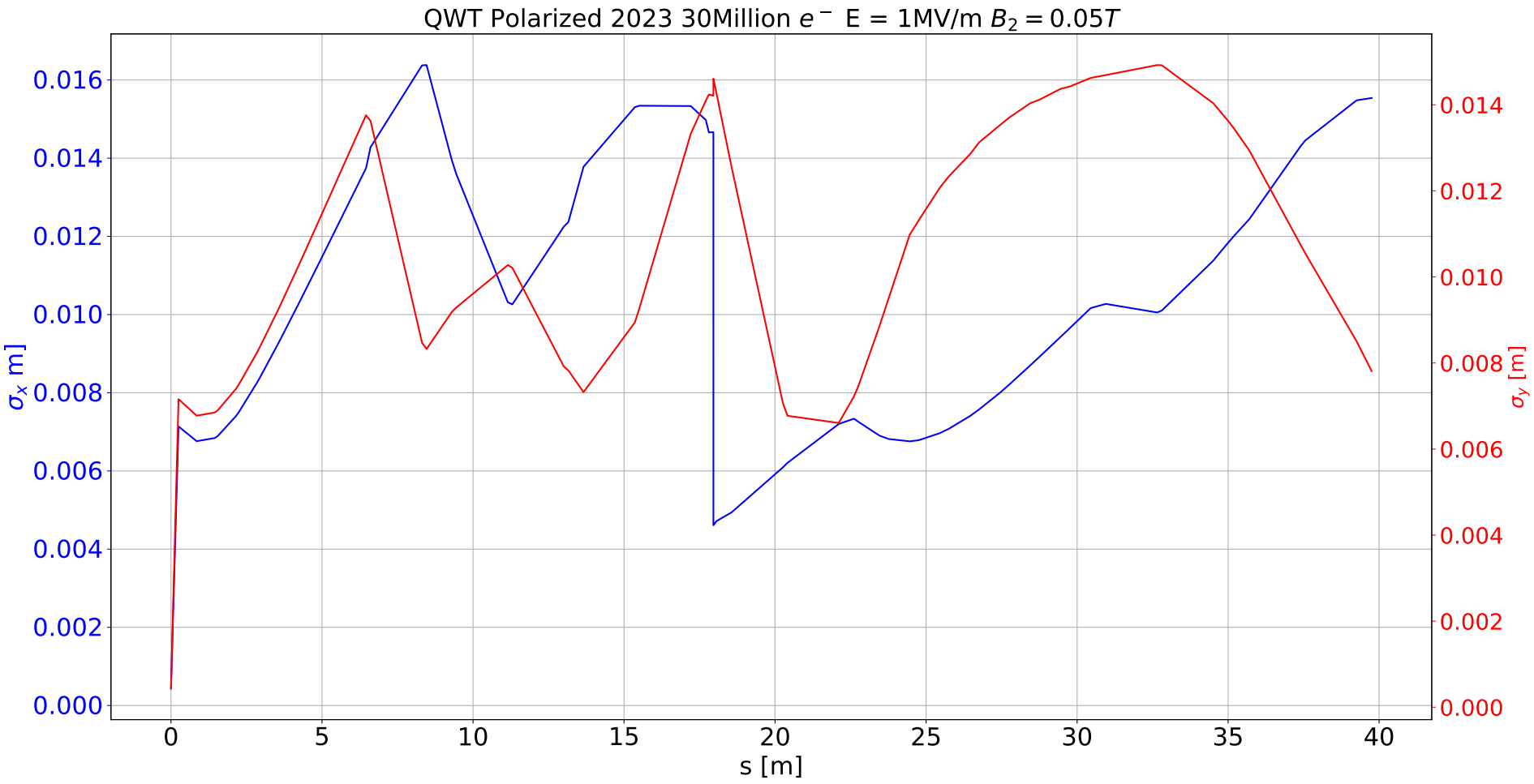
Acknowledgements

This research work is part of a project that has received funding from the European Union's Horizon 2020 research and innovation program under agreement **STRONG - 2020 - No 824093**.

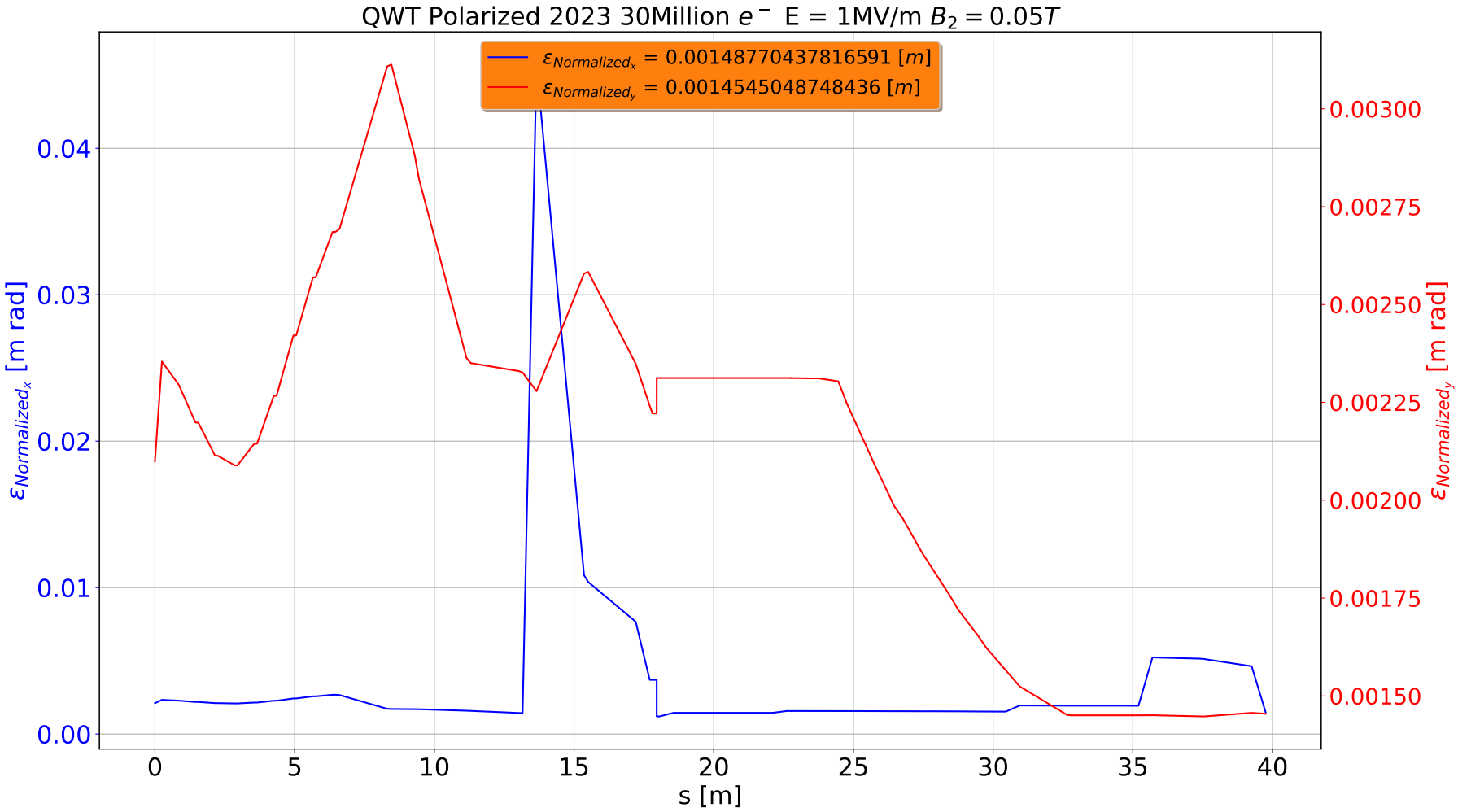
Twiss functions



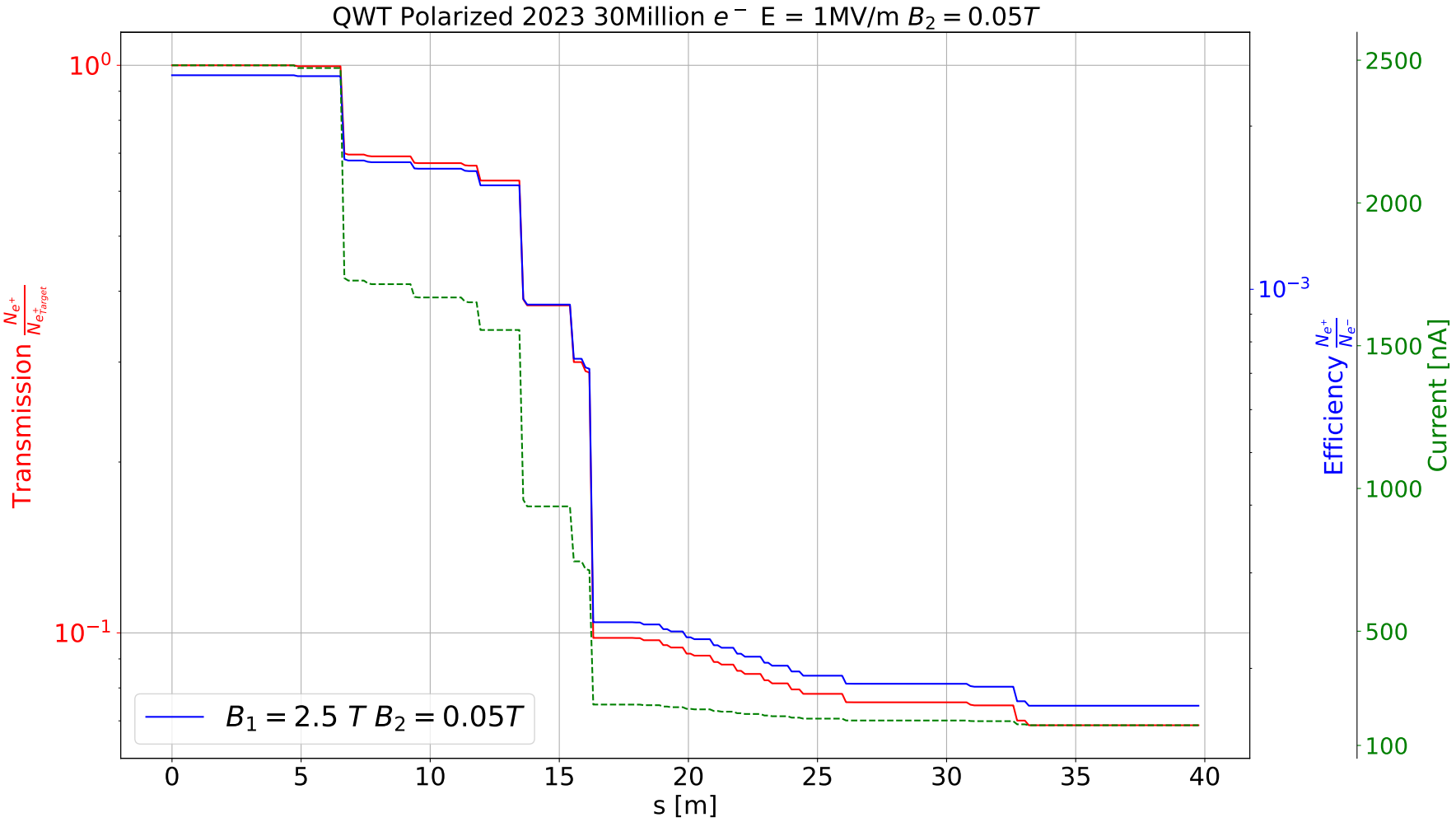
Beam size


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

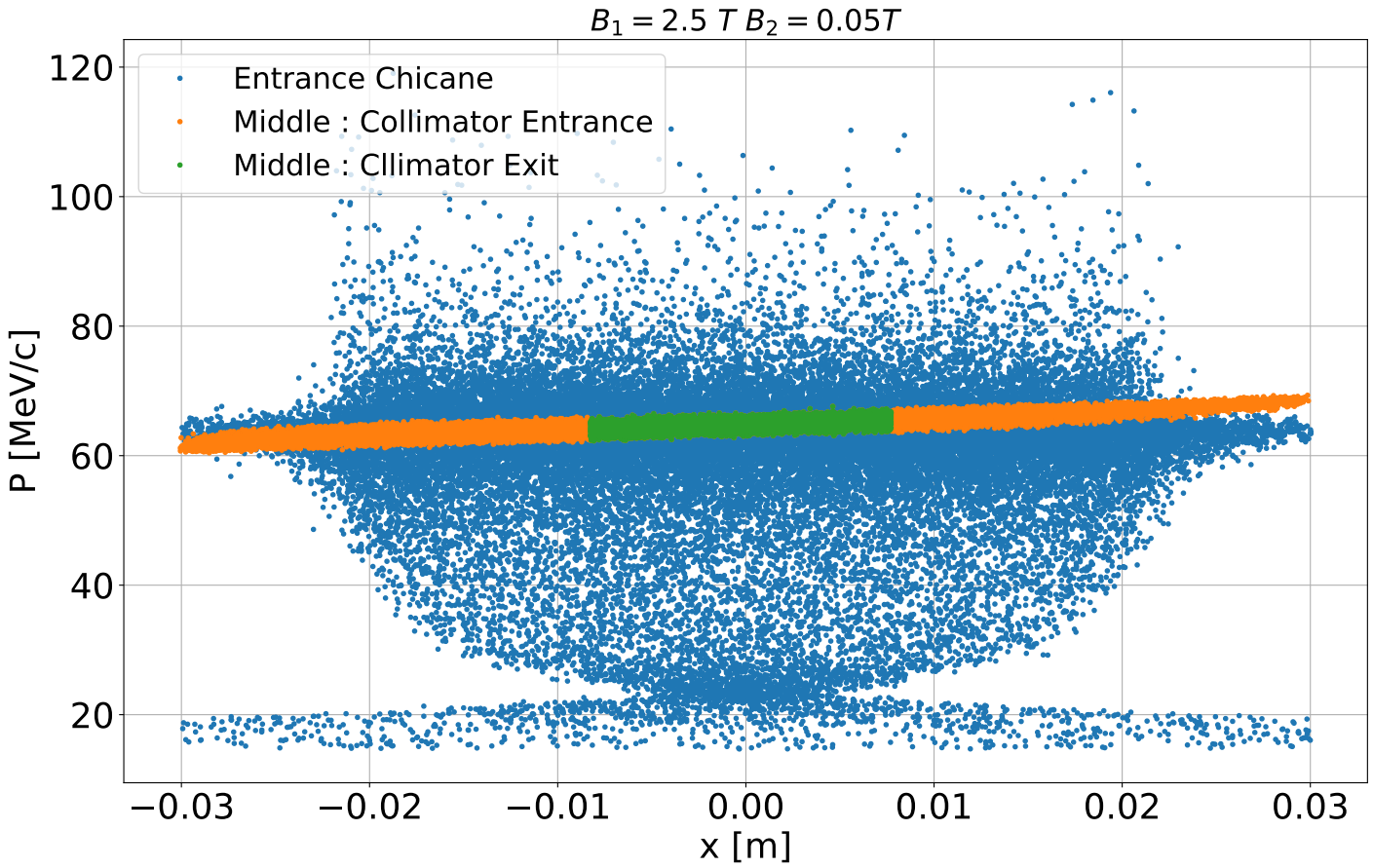
Normalized emittance



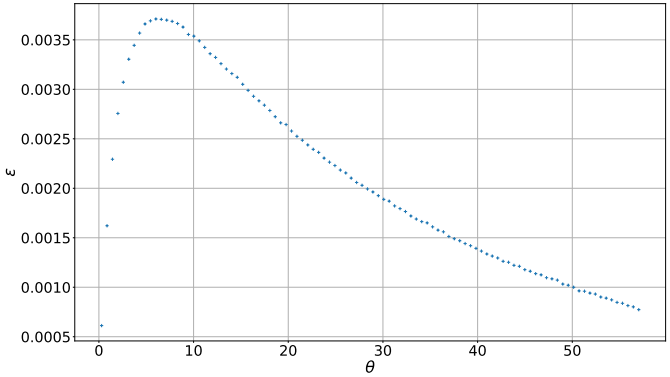
Transmission and current

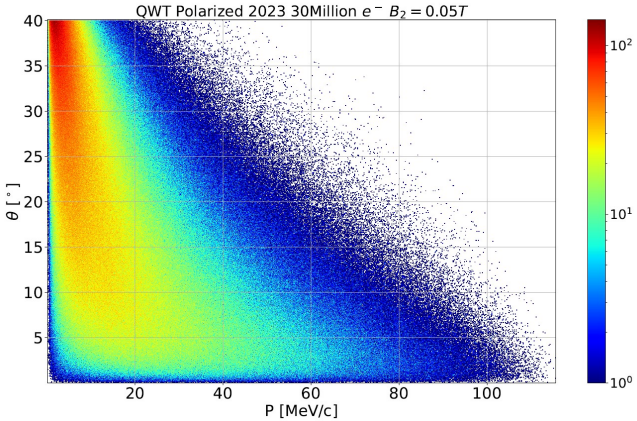


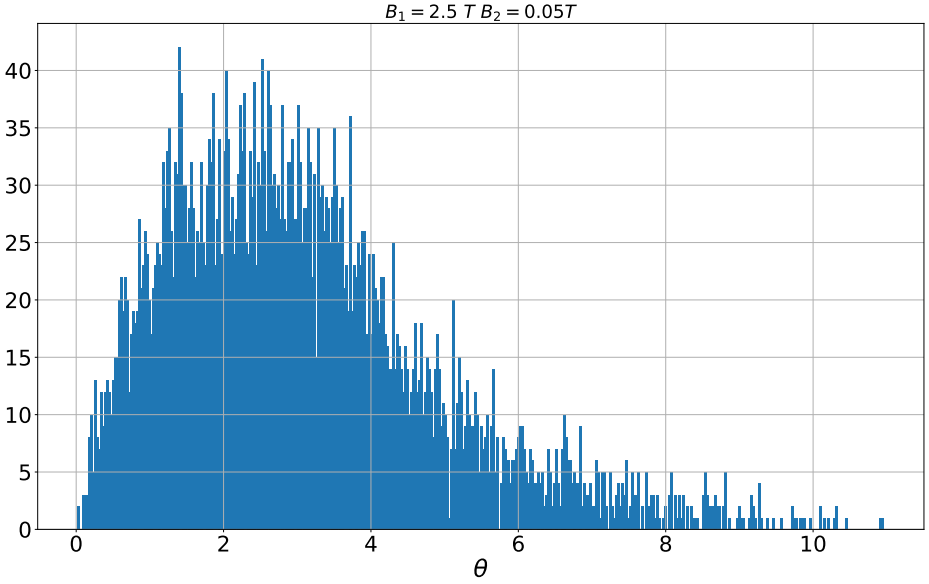
Momentum collimation



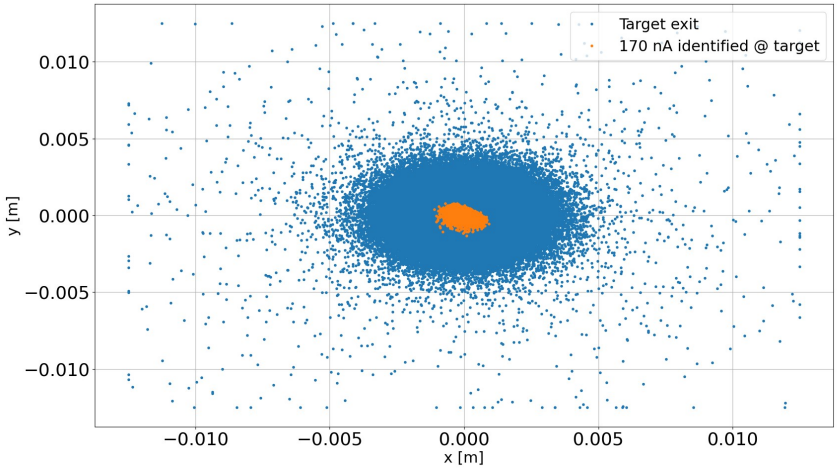
Angular distribution

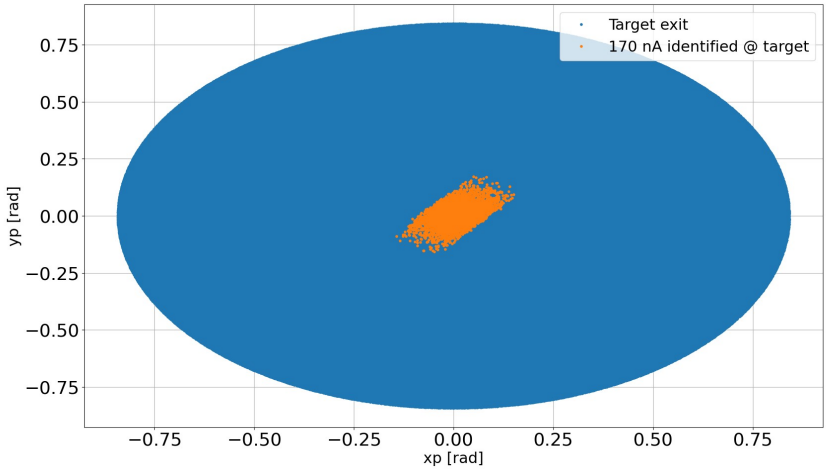






Transverse space





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