Optimization of CW Polarized Positron Source for JLab

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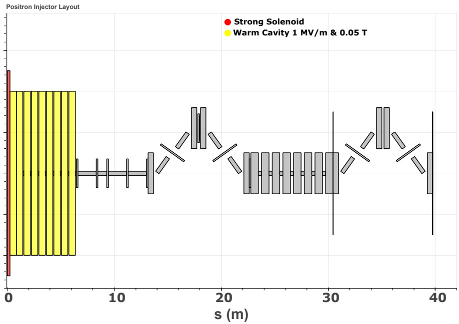
IJCLab & JLab

May 16, 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**

Plan

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



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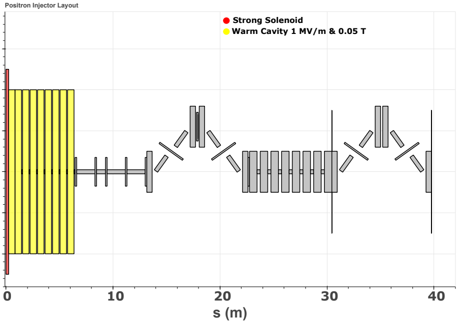

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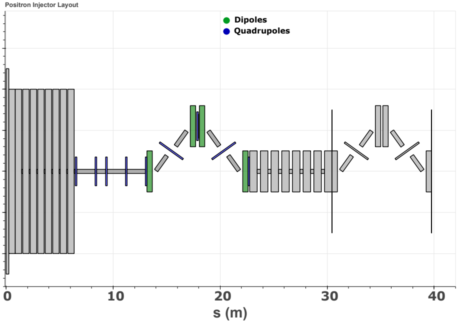

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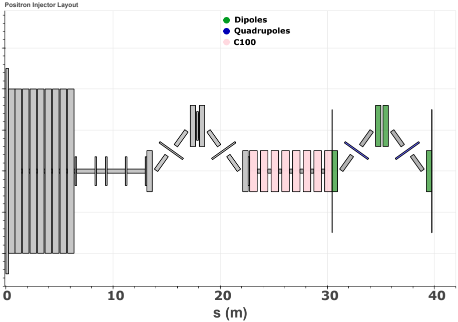

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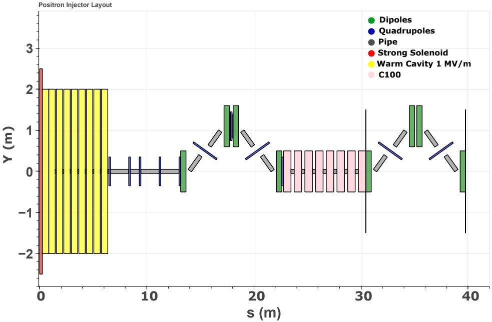

Outline

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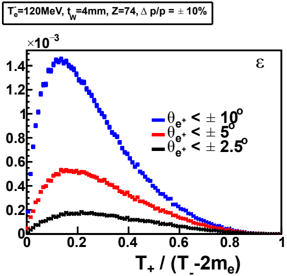
Target optimization

Unpolarized mode

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

Polarized mode

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



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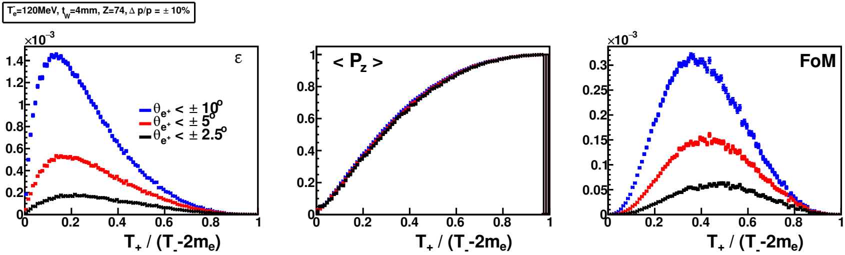

Target optimization

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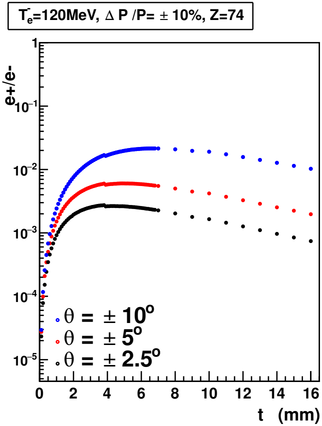
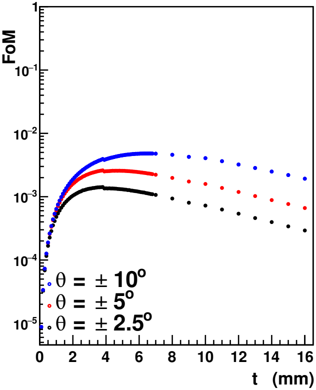


Polarized mode



Outline

Quarter Wave Transformer

- Reduce the transverse angular divergence $x_p = \frac{p_x}{p}$ 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 $r_0^{QWT} = \frac{B_2}{B_1} R$
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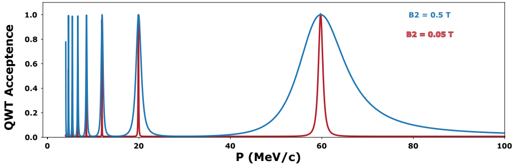
- L_1:Short solenoid length
- B_1: Magnetig field in L_1
- R: Accelerator aperture



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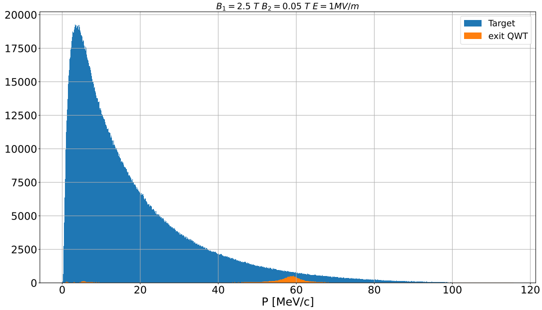

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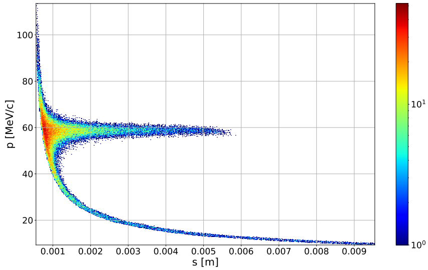

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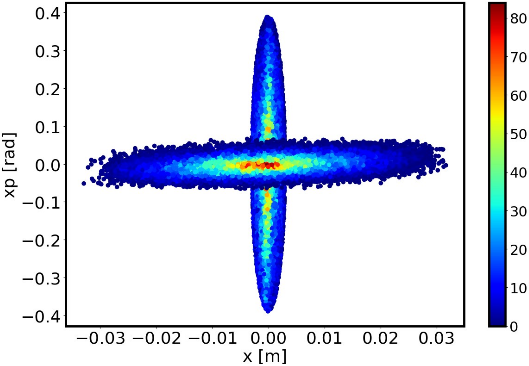
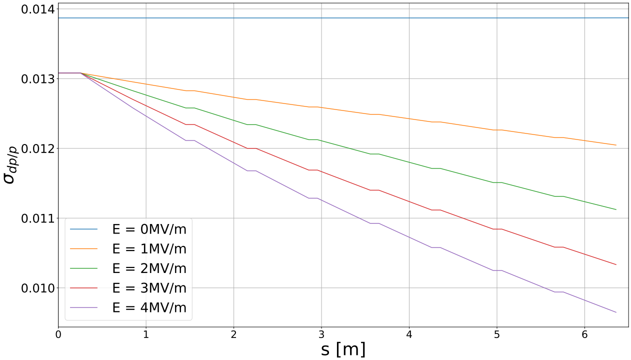


Accelerating warm section

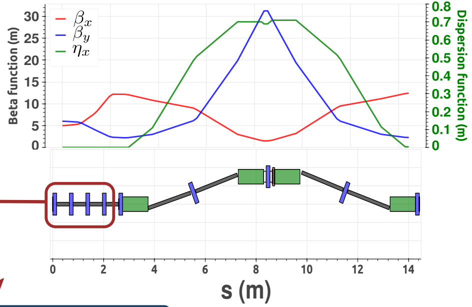
Goal

- Reduce the longitudinal energy spread of the accepted e^+ at p = 60 MeV/c
- $f = 1497\ Mhz$
- $E = 1\ MV/m$
- $L_{cell} = 0.2\ cm$
- $r_{cell} = 3\ cm$

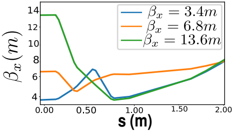


Outline

Beam size optimization



Matching section

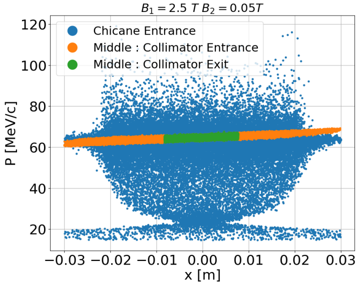


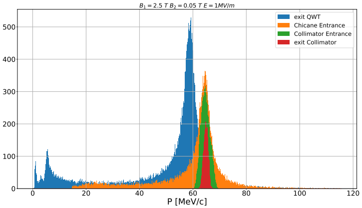
- **Periodic Twiss in FODO:**

$$\beta_{x,y_{in}} = \beta_{x,y_{out}}$$

- **Minimum beam size condition:**

$$\beta_x = \beta_{x_{MIN}} \longrightarrow \alpha_x = 0$$

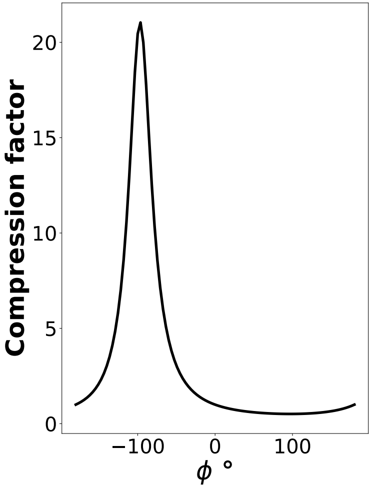




Outline

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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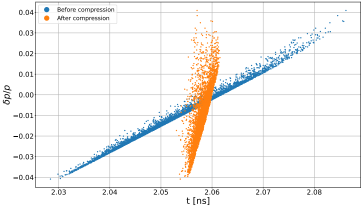
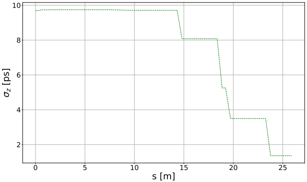
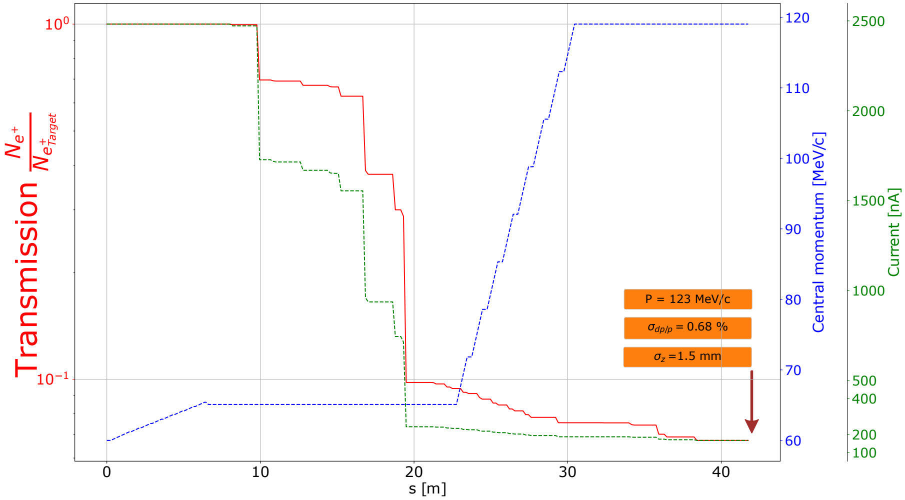




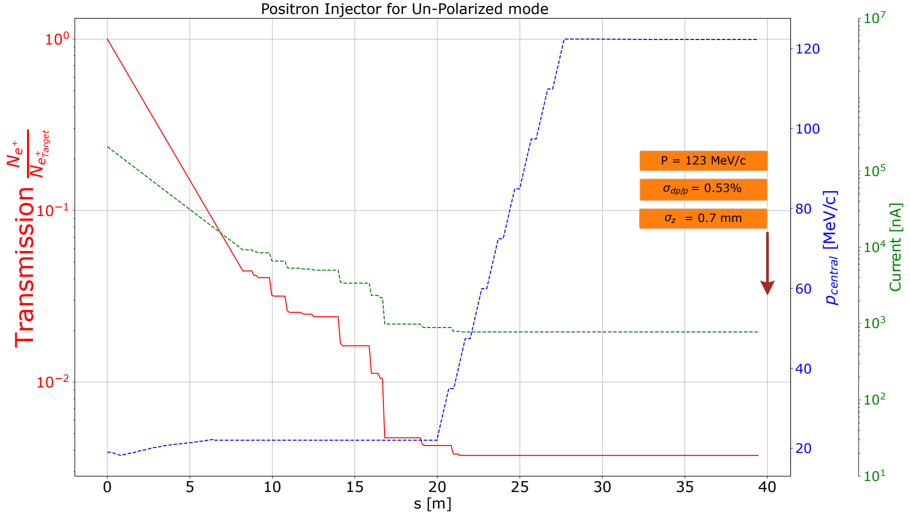
Transmission and Current



summary: Polarized mode

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

Unpolarized mode: Transmission current



summary: Unpolarized mode

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

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Conclusion

- The performance of the positron system is heavily dependent on the central momentum. The central momentum should be set to 15 MeV/c to obtain a high yield of positrons, 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.
- Including the electron beam after the target could be an interesting way to test our layout.
- Our positron injector is unique because it operates using a CW mode, which is challenging compared to other positron sources.

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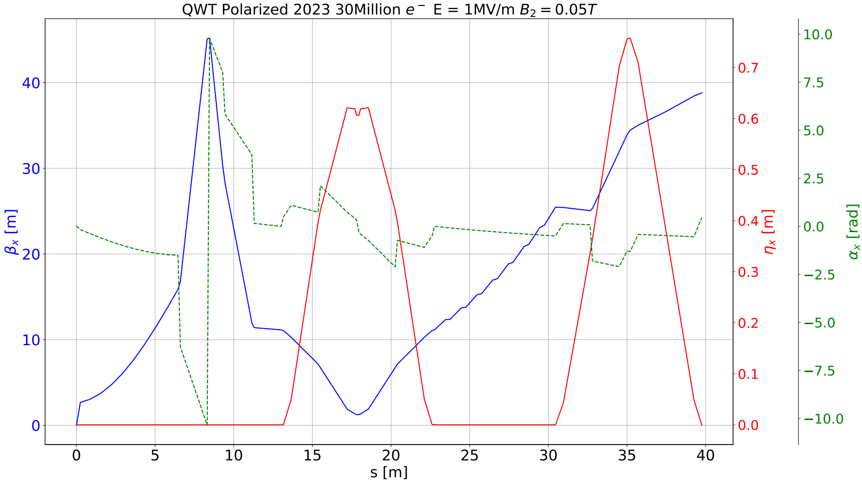
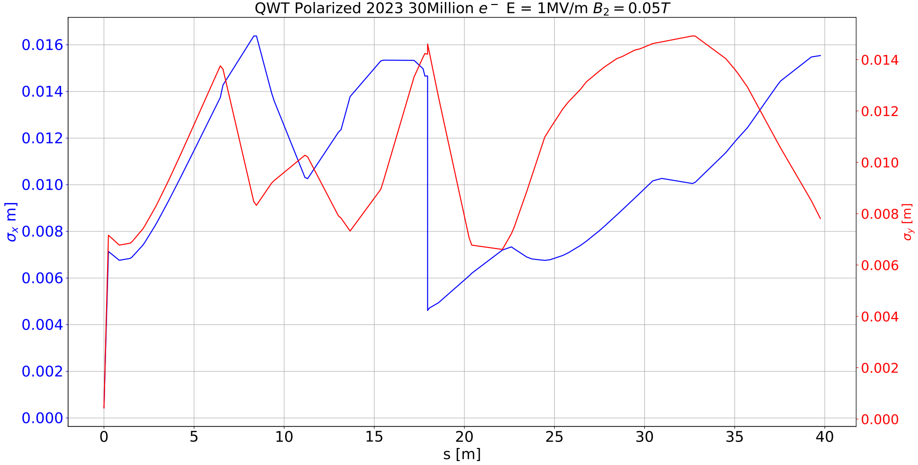
THANK YOU FOR YOUR ATTENTION!

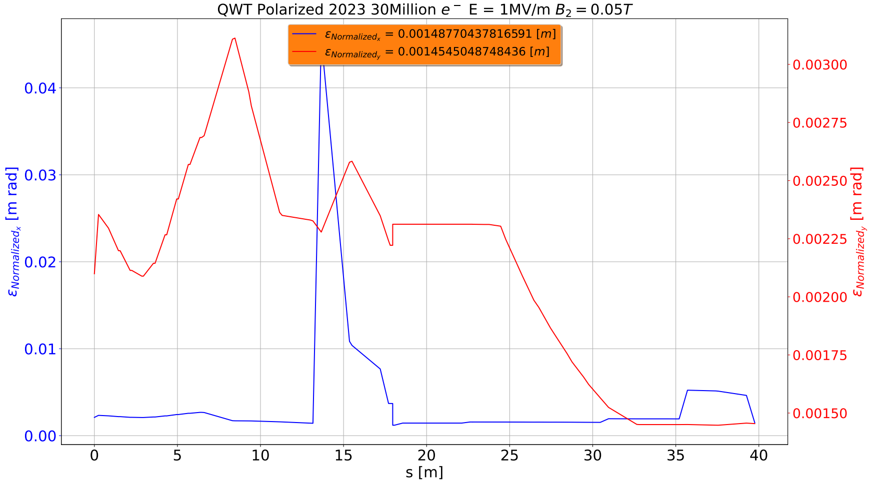
Twiss functions



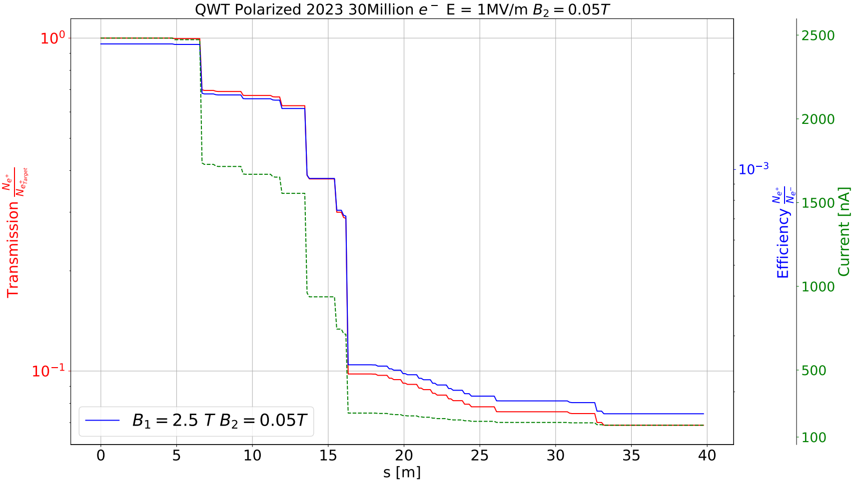
Beam size


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

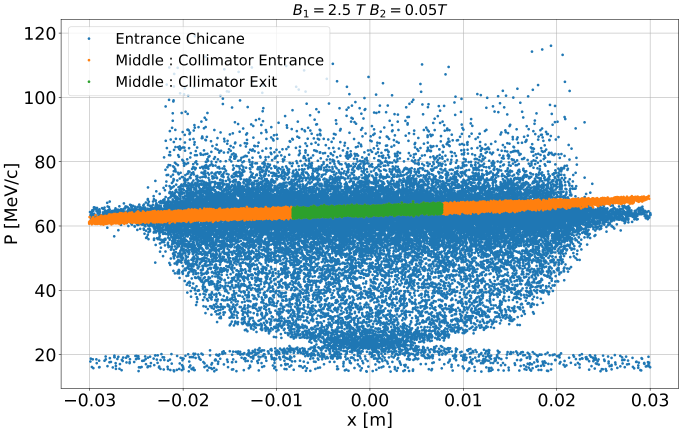
Normalized emittance



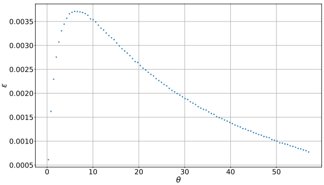
Transmission and current

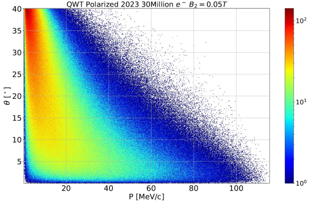


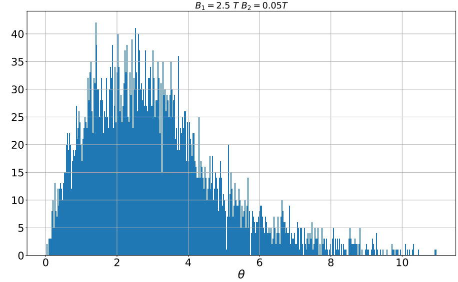
Momentum collimation



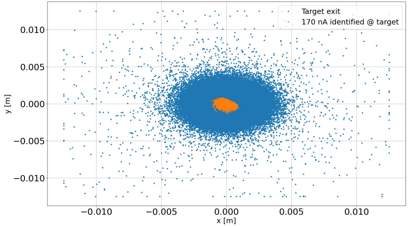
Angular distribution

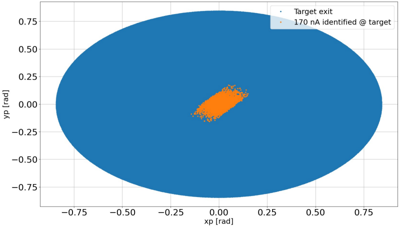






Transverse space





- The transmitted positrons are within the acceptance of the QWT
- $p_t^{QWT} = \frac{eB_1 R}{2} . = 10.31°$
- $r_0^{QWT} = \frac{B_2}{B_1} R = 0.6\ mm$

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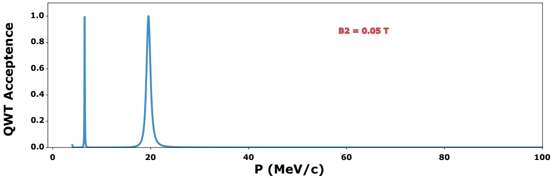
- $L_1 = 0.24\ cm$:Short solenoid length
- $B_1 = 0.96\ T$: Magnetig field over L_1
- $R = 3\ cm$: Accelerator aperture



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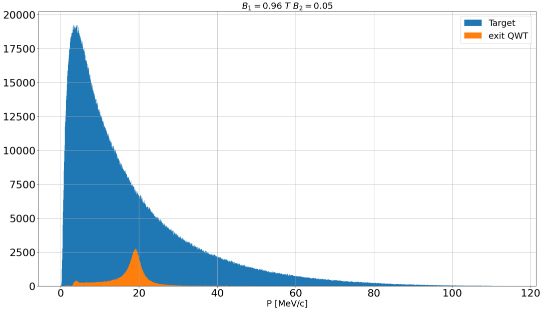

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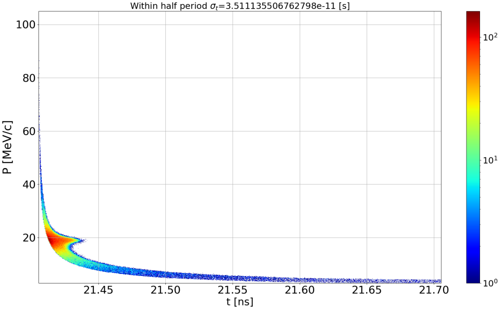
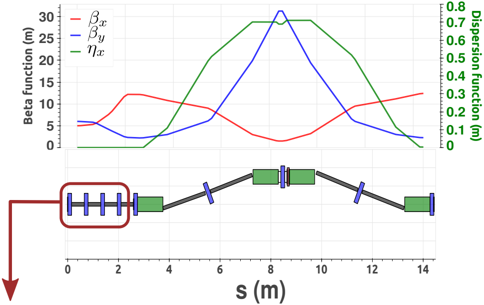
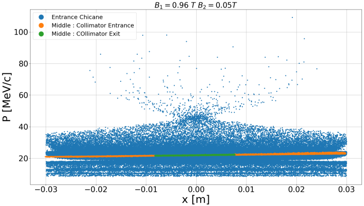
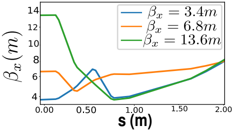


Momentum collimation





Matching section



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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.