Development of a Polarized Positron Source for CEBAF

Sami Habet

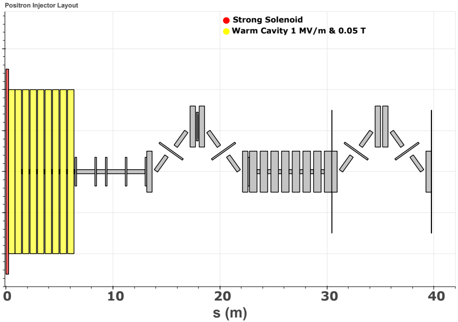
IJCLab & JLab

March 17, 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**

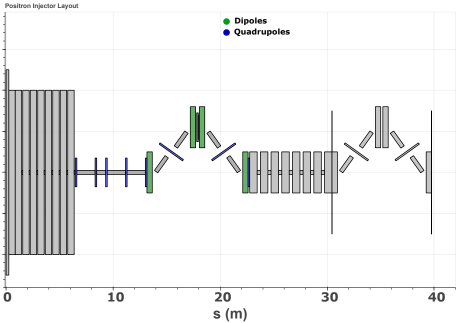
Plan

1. Collection system
2. Momentum collimation
3. Acceleration and Bunch compression
4. Discussion
5. Conclusion



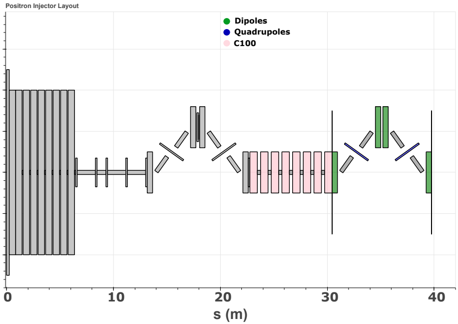
Plan

1. Collection system
2. Momentum collimation
3. Acceleration and Bunch compression
4. Discussion
5. Conclusion



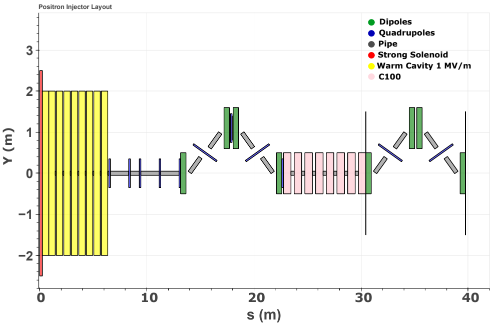
Plan

1. Collection system
2. Momentum collimation
3. Acceleration and Bunch compression
4. Discussion
5. Conclusion



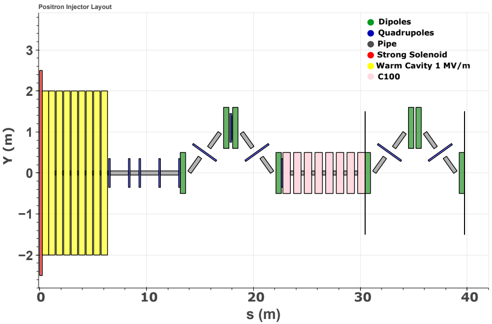
Plan

1. Collection system
2. Momentum collimation
3. Acceleration and Bunch compression
4. Discussion
5. Conclusion



Plan

1. Collection system
2. Momentum collimation
3. Acceleration and Bunch compression
4. Discussion
5. Conclusion



Outline

1. Collection system
2. Momentum collimation
3. Acceleration and Bunch compression
4. Discussion
5. Conclusion

Outline

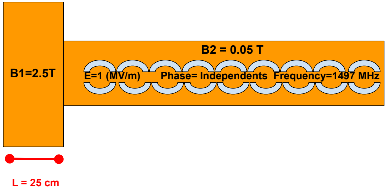
1. Collection system
2. Momentum collimation
3. Acceleration and Bunch compression
4. Discussion
5. Conclusion

Outline

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 $p_t^{QWT} = \frac{eB_1 R}{2}$

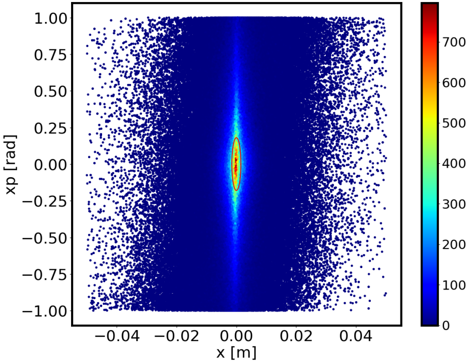
- L_1:Short solenoid length
- B_1: Magnetig field in L_1
- R: Accelerator aperture



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 $p_t^{QWT} = \frac{eB_1 R}{2}$

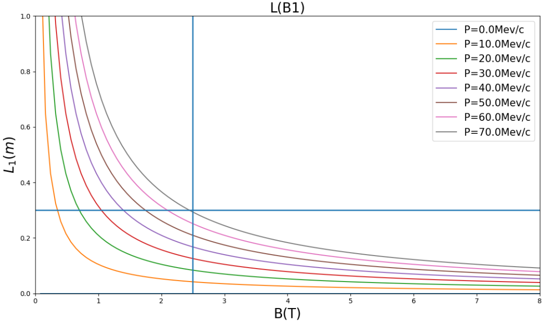
- L_1:Short solenoid length
- B_1: Magnetig field in L_1
- R: Accelerator aperture



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 $p_t^{QWT} = \frac{eB_1 R}{2}$

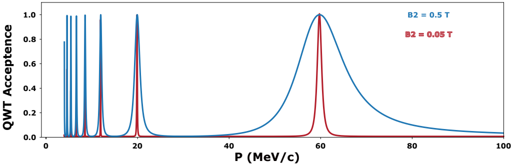
- L_1:Short solenoid length
- B_1: Magnetig field in L_1
- R: Accelerator aperture



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 $p_t^{QWT} = \frac{eB_1 R}{2}$

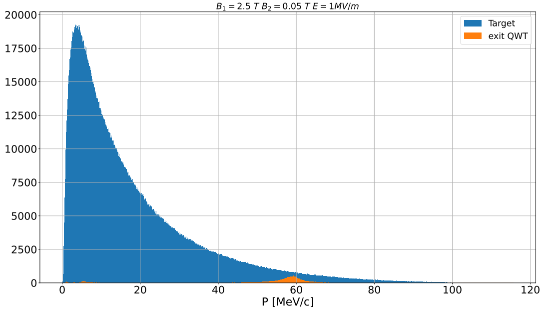
- L_1:Short solenoid length
- B_1: Magnetig field in L_1
- R: Accelerator aperture



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 $p_t^{QWT} = \frac{eB_1 R}{2}$

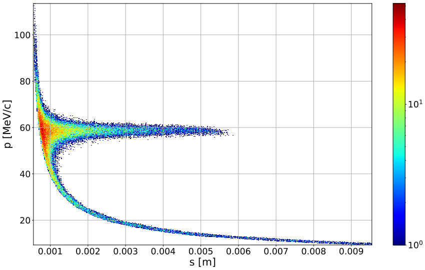
- L_1:Short solenoid length
- B_1: Magnetig field in L_1
- R: Accelerator aperture



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 $p_t^{QWT} = \frac{eB_1 R}{2}$

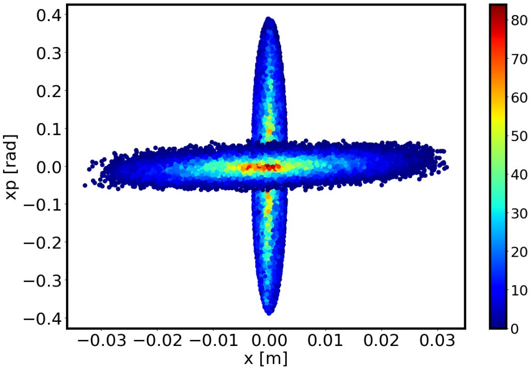
- L_1:Short solenoid length
- B_1: Magnetig field in L_1
- R: Accelerator aperture



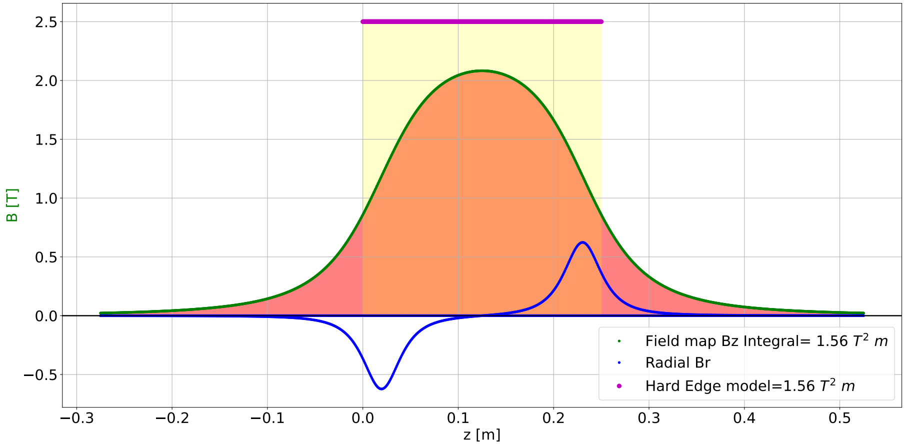
Quarter Wave Transformer

- 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

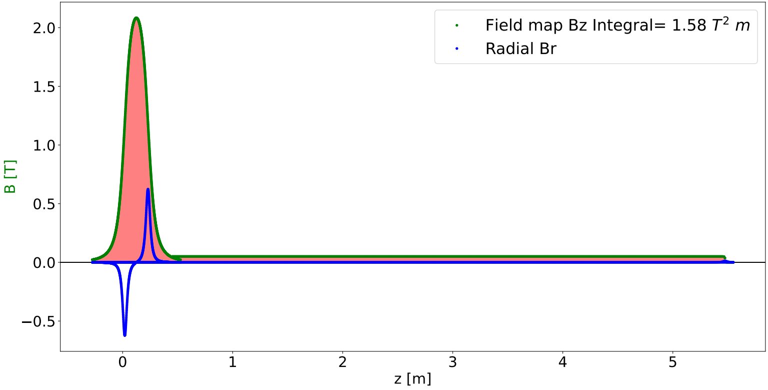


Quarter Wave Transformer: Hard Edge model Vs Field map



- The field map has to be adjusted to match with the $\int B_z^2 dl$.

Quarter Wave Transformer: Hard Edge model Vs Field map

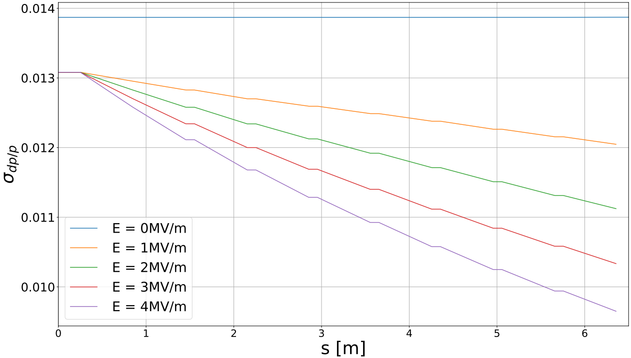


- The field map has to be adjusted to match with the $\int B_z^2 dl$.

Accelerating warm section

Goal

- Reduce the longitudinal energy spread of the accepted e^+ at p = 60 MeV/c
- $f = 1497\ Mhz$
- $E = 1\ MV/m$
- $L_{cell} = 0.7\ cm$
- $r_{cell} = 3\ cm$
- $N_{cell} = 8$



Outline

First Matching section

- K: Geometric focusing strength
- QM: Quadrupole

Element	Length (m)	K ($1/m^2$)	$B \times \rho\,(T\ m)$	k:(kG/cm)	$P_c(MeV/c)$
QM1	0.15	-2.531	0.217	-0.0548	65
QM2	0.15	2.958	0.217	0.0641	65
QM3	0.15	-0.437	0.217	-0.0095	65
QM4	0.15	-2.010	0.217	-0.0435	65

First chicane: Quads

- K: Geometric focusing strength
- QM: Quadrupole

Element	Length (m)	K $(1/m^2)$	$B \times \rho\,(T\ m)$	k:(kG/cm)	$P_c(MeV/c)$
QM1	0.15	0.304	0.217	0.0066	65
QM2	0.15	1.383	0.217	0.0300	65
QM3	0.15	-2.786	0.217	-0.0604	65
QM4	0.15	1.383	0.217	0.0300	65
QM5	0.15	0.304	0.217	0.0066	65

First chicane: Dipoles

- K: Geometric focusing strength
- DP: Dipole

Element	Length (m)	$B \times \rho\,(T\ m)$	$P_c(MeV/c)$	Bend angle (rad)
DP1	0.5	0.217	65	0.204
DP2	0.5	0.217	65	-0.204
DP3	0.5	0.217	65	-0.204
DP4	0.5	0.217	65	0.204

Second Matching section

- K: Geometric focusing strength
- QM: Quadrupole

Element	Length (m)	K $(1/m^2)$	$B \times \rho\ (T\ m)$	k:(KG/cm)	$P_c(MeV/c)$
QM1	0.15	-2.531	0.41	-0.103	123
QM2	0.15	2.495	0.41	0.102	123
QM3	0.15	1.501	0.41	0.061	123
QM4	0.15	-4.785	0.41	-0.196	123

Second chicane: Quads

- K: Geometric focusing strength
- QM: Quadrupole

Element	Length (m)	K $(1/m^2)$	$B \times \rho\,(T\ m)$	k:(kG/cm)	$P_c(MeV/c)$
QM1	0.15	0.304	0.41	0.0124	123
QM2	0.15	1.382	0.41	0.056	123
QM3	0.15	-2.785	0.41	-0.114	123
QM4	0.15	1.382	0.41	0.056	123
QM4	0.15	0.304	0.41	0.012	123

Second chicane: Dipoles

- K: Geometric focusing strength
- DP: Dipole

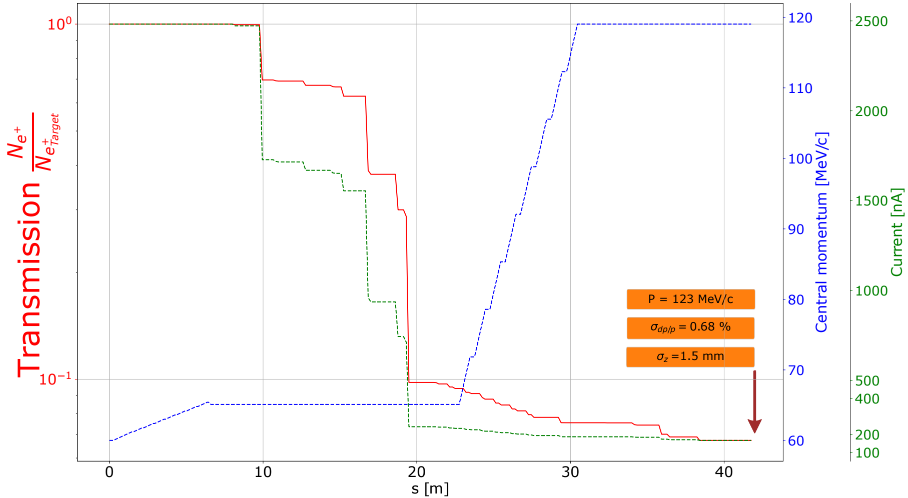
Element	Length (m)	$B \times \rho\,(T\ m)$	$P_c(MeV/c)$	Bend angle (rad)
DP1	0.15	0.41	123	0.154
DP2	0.15	0.41	123	-0.154
DP3	0.15	0.41	123	-0.154
DP4	0.15	0.41	123	0.154

RF: Accelerating section

- f: Frequency
- r: Radius
- E: Gradient
- Gap: Drift space

Element	Length (m)	f (MHz)	r (m)	E (MV/m)	Gap (m)
$Cell_{warm}$ (8 cells)	0.7	1497	0.03	1	0.299
C100 (8 $\times$ *cell*)	0.7	1497	0.03	10.7	0.299

Transmission and Current: High polarization



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

Outline

Conclusion

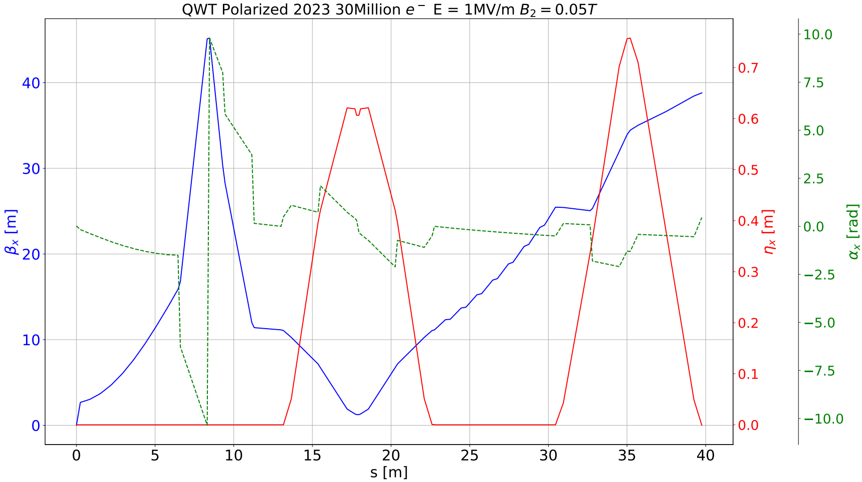
- The performance of the positron system is heavily dependent on the central momentum. a high polarization requires a high magnetic field 1-2 T to collect positrons momentum of 60 MeV/c.
- The QWT plays a crucial role in selecting the desired momentum and reducing the spread of transverse angles, thus we need a realistic magnetic field.
- The accelerating section significantly impacts the longitudinal plane, reducing the energy spread to meet the CEBAF requirement of $\sigma_{dp/p} = \pm 1\%$.
- Including the electron beam after the target could be an interesting way to test our layout.

Acknowledgements

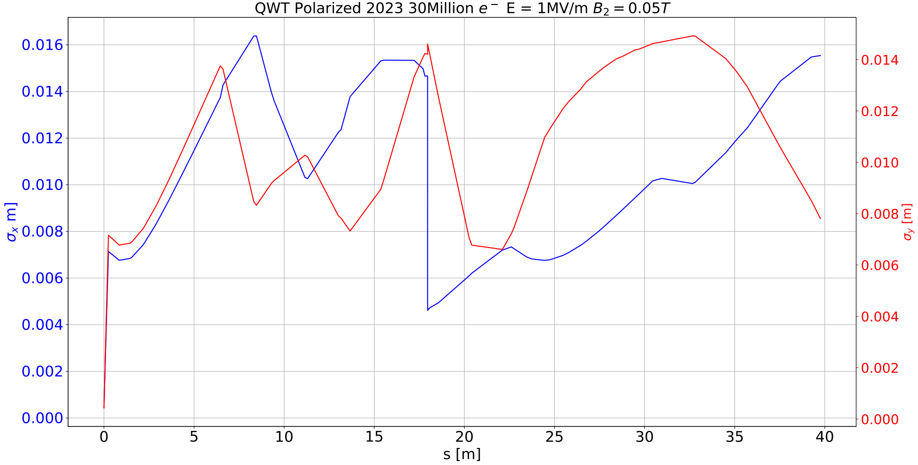
This research work is part of a project that has received funding from the European Union's Horizon 2020 research and innovation program under agreement **STRONG - 2020 - No 824093**.

THANK YOU FOR YOUR ATTENTION!

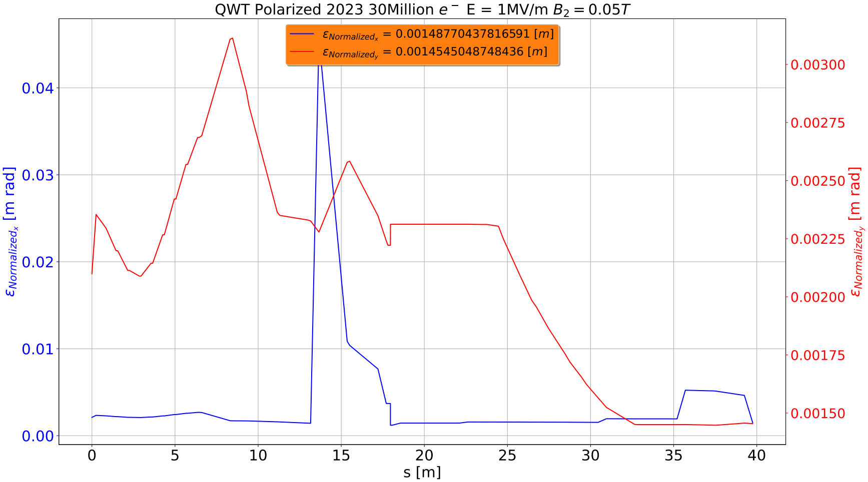
Twiss functions



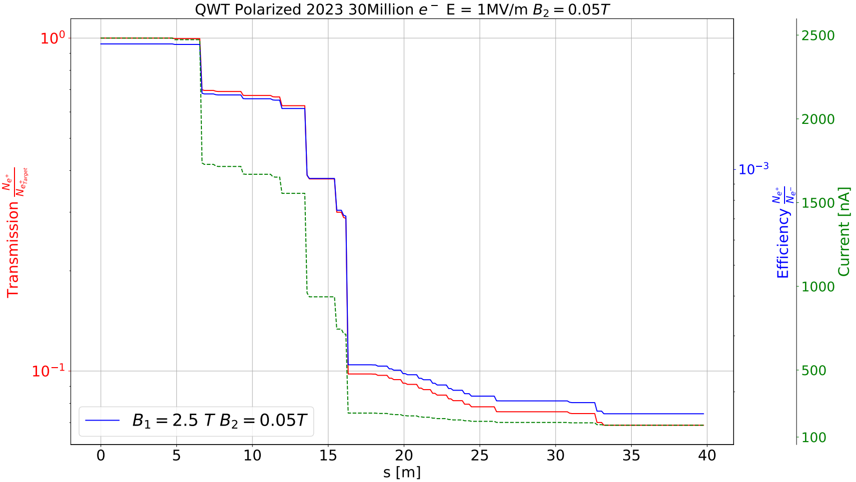
Beam size


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

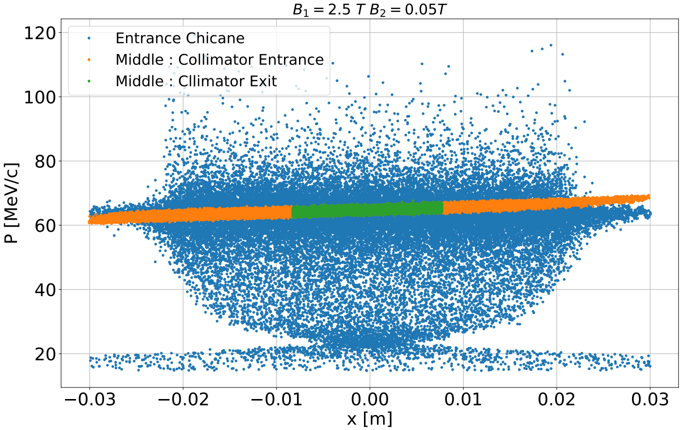
Normalized emittance



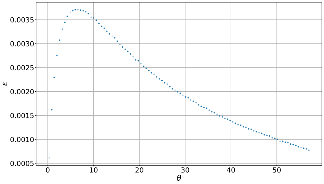
Transmission and current

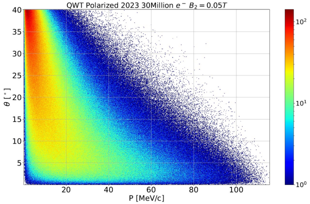


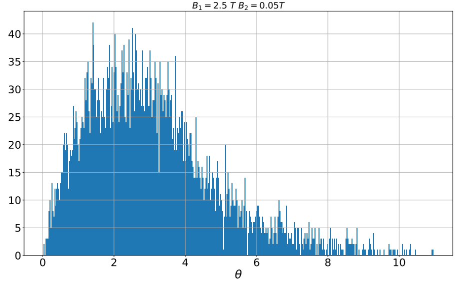
Momentum collimation



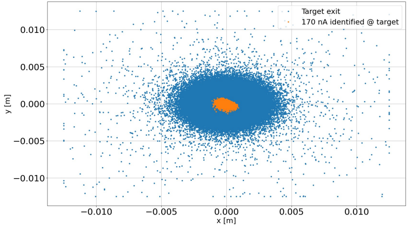
Angular distribution

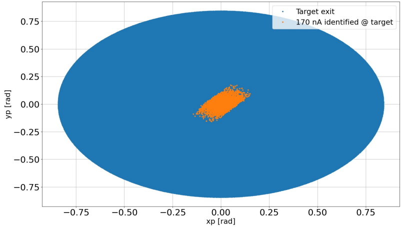






Transverse space





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