UNIVERSIDAD DE GUANAJUATO

Jefferson Lab

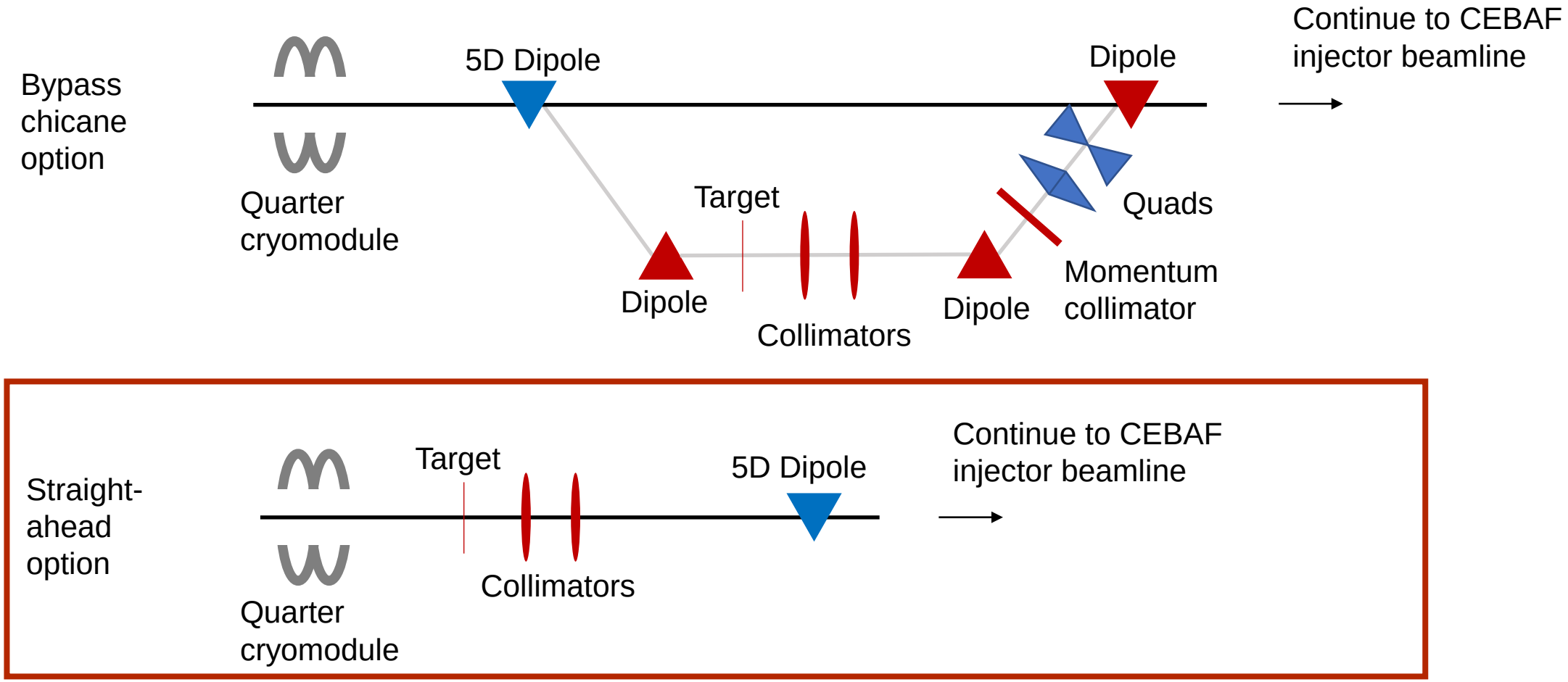
Progress in degrading electron beam simulations with Geant4

Victor Manuel Lizárraga-Rubio
Universidad de Guanajuato
Ph. D. Student

Outline

- Project scope
- Simulation details
- Results
- Summary and future perspectives

- Measuring the transverse and longitudinal acceptance of CEBAF.
- Why? Use the electron acceptance as a proxy for the acceptance of a future positron beam.
  - Positron beam larger in phase space than current electron beam



- Software used: Geant4
- Modified with four screens throughout for data acquisition
- Added apertures with varying size at $s = 0.5m, 1m$ after the target
- Materials used for target:
  - Carbon (z=6)
  - Tungsten (z=74)
- 1000000 electrons per beam

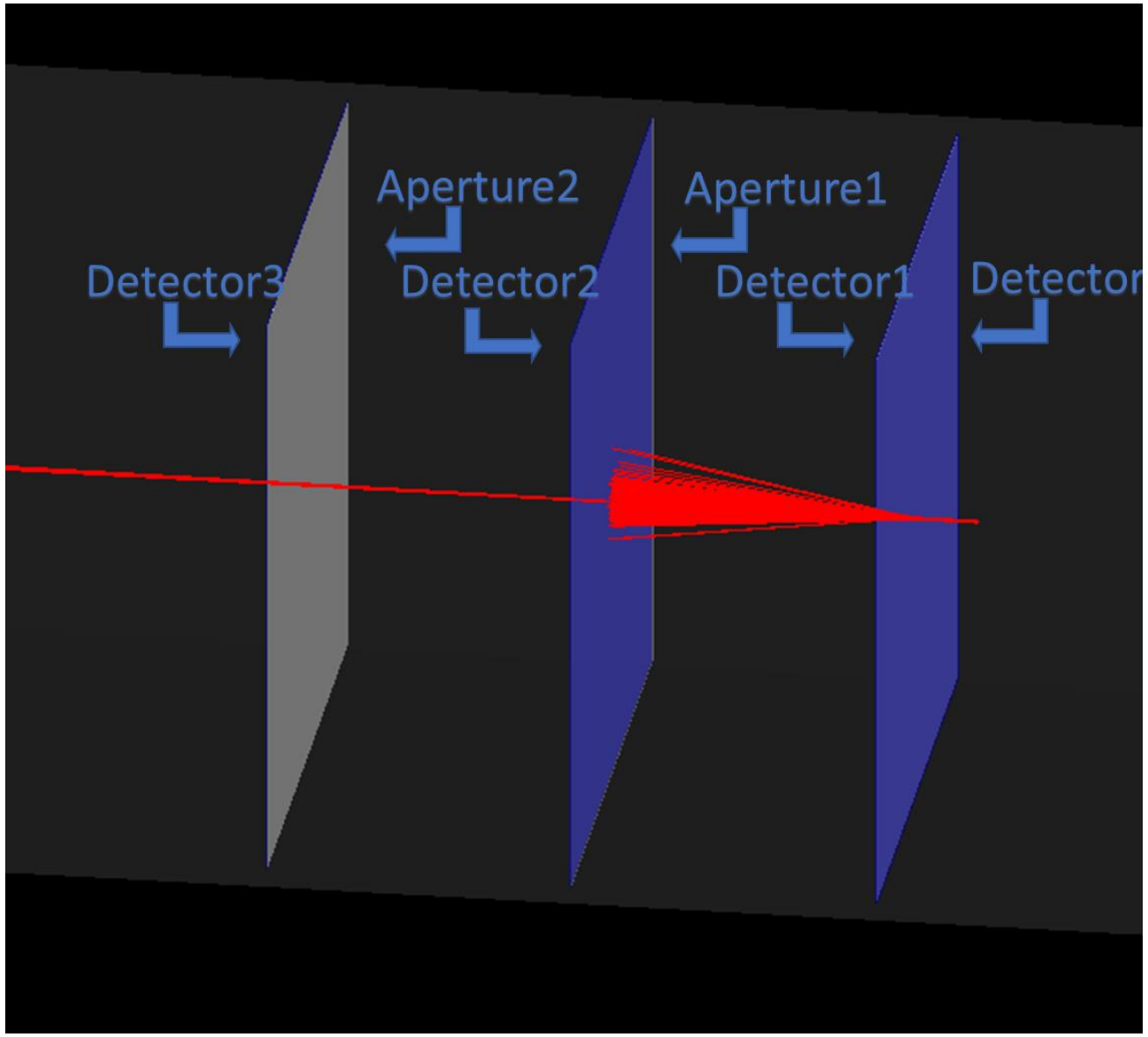
Simulation parameters

- Electron beam
  - Longitudinal momentum: $p_z = 6.74\ MeV/c$
  - XY center position: $\boldsymbol{r}_{x/y} = (0,0)$
  - Gaussian distribution: $\sigma_{x/y} = 1.27/0.8\ (mm)$
  - Initial transverse emittance: $\varepsilon_{x/y} = 251/81\ (nm)$
  - Initial longitudinal momentum spread: $\frac{\Delta p}{p} = 1 \times 10^{-3}$

- Target
  - Thickness: $100nm - 5\mu m$
  - Material: Carbon, Tungsten

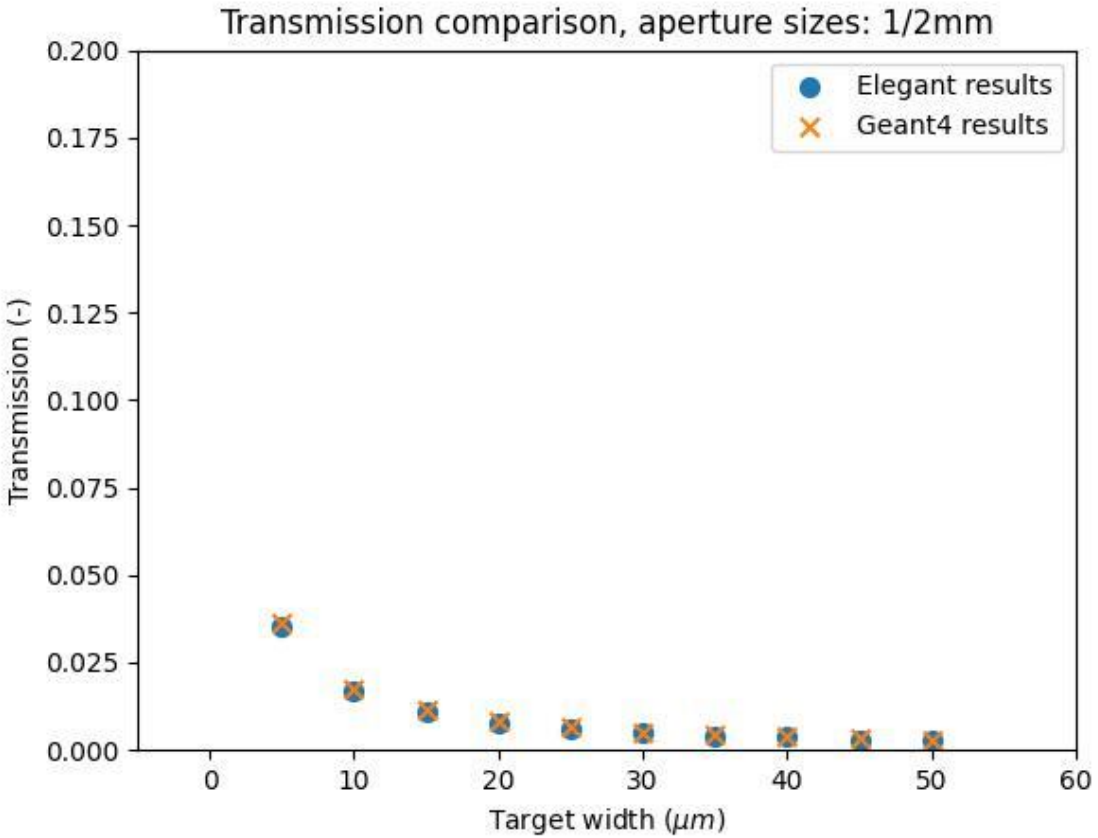
Aperture
- Position: $s = 0.5, 1m$
- Sizes: $r_{aper} = 1 - 2/2 - 4mm$
- “Perfect” apertures

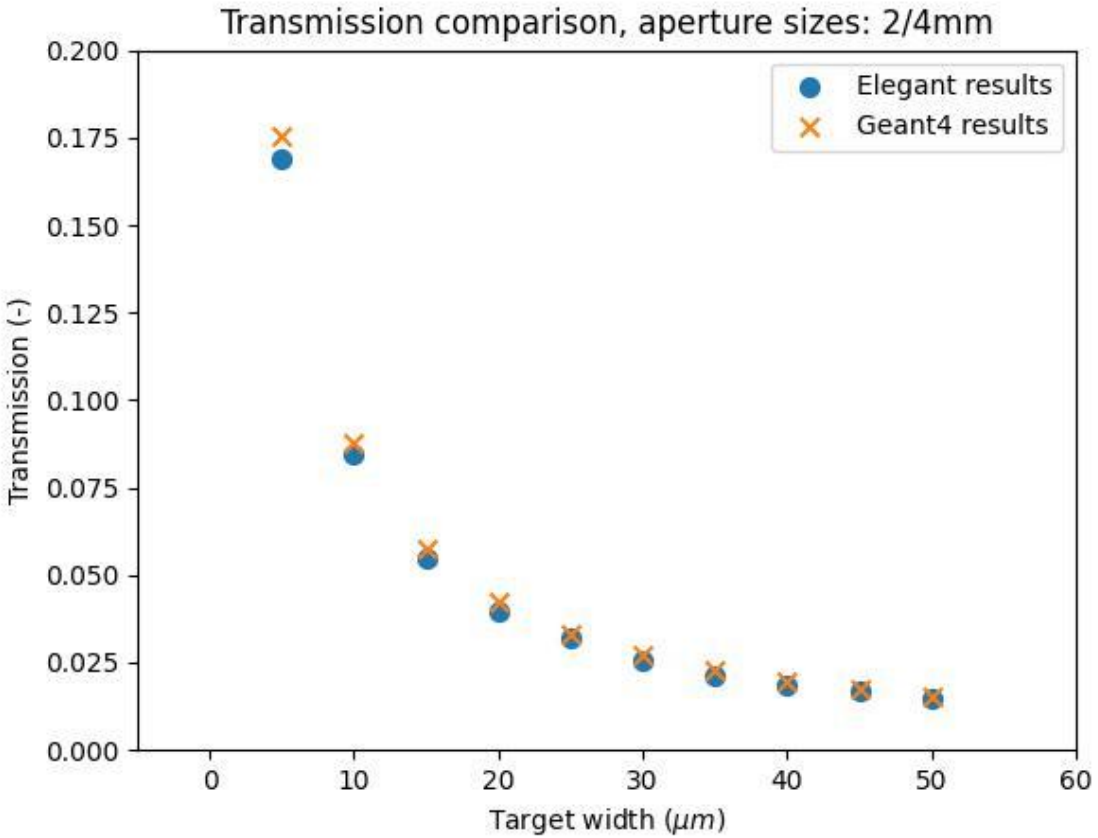
Simulation diagram

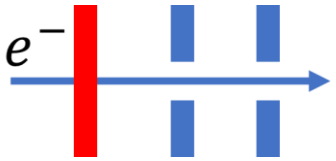


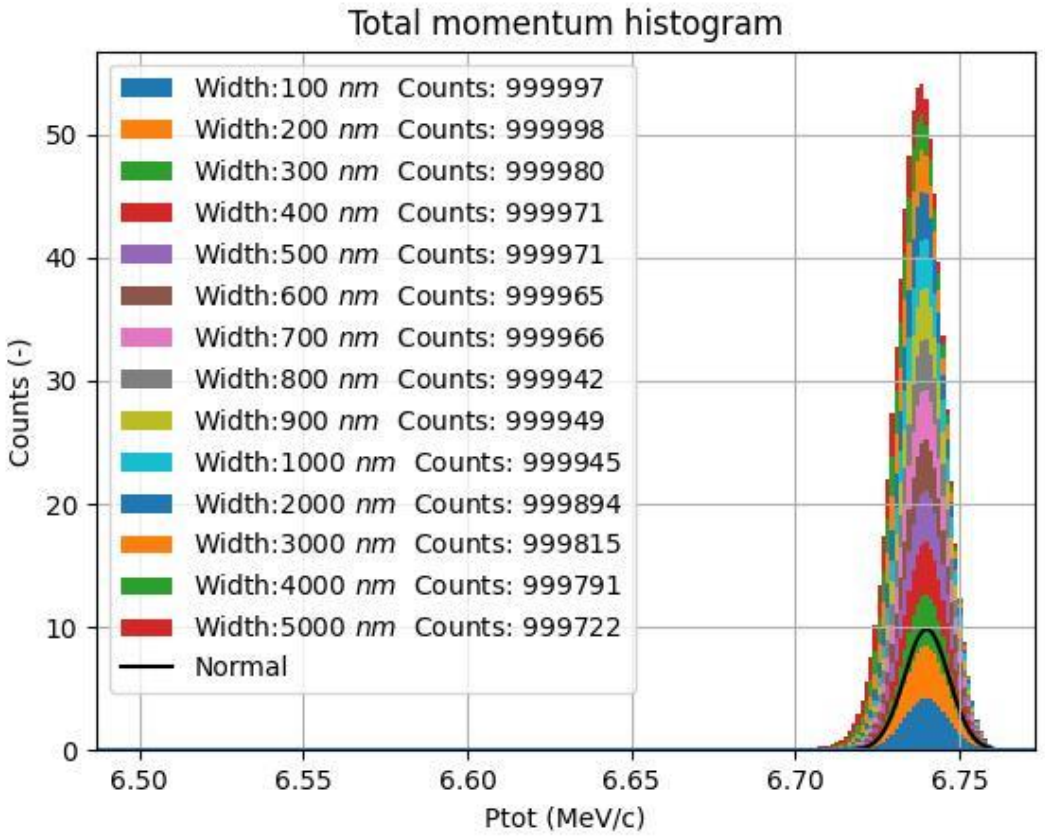
Test of implementation “perfect” apertures

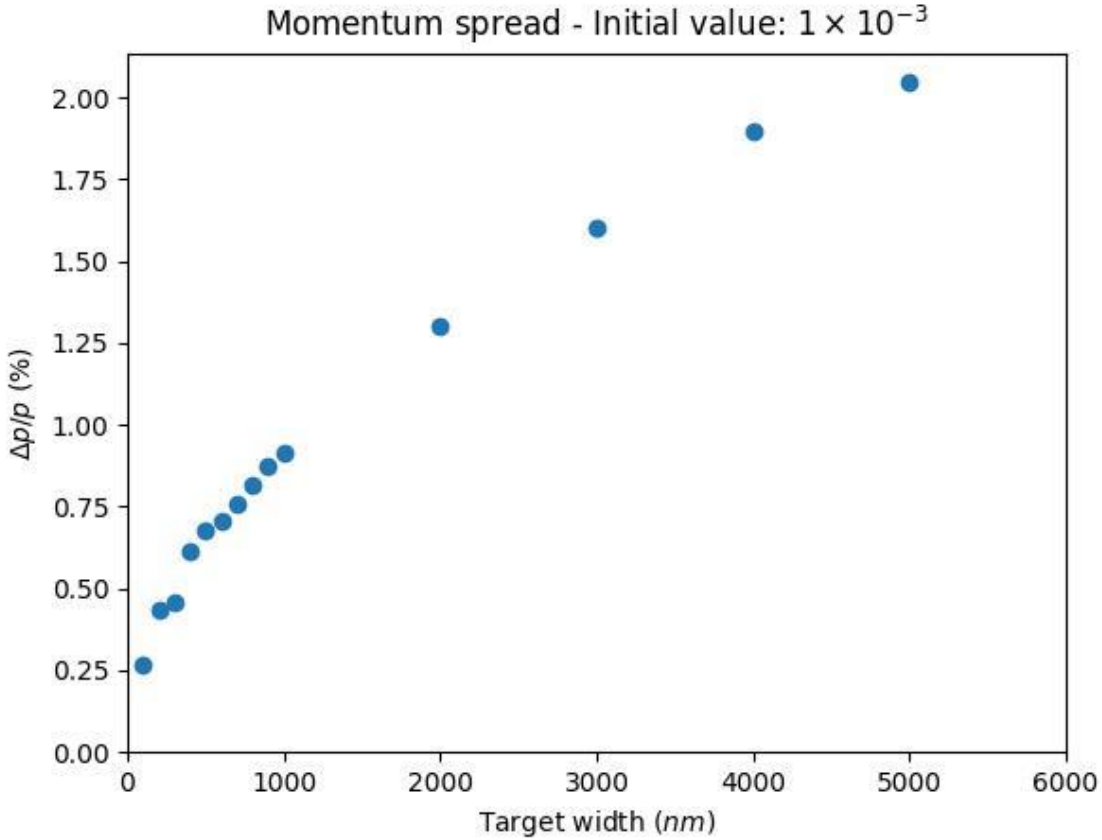
- Good agreement between the transmission after the two apertures from both Geant4 and Elegant using the same parameters
- This plots are from a test run

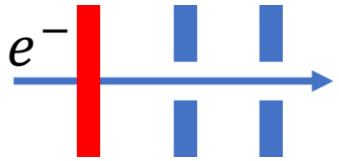


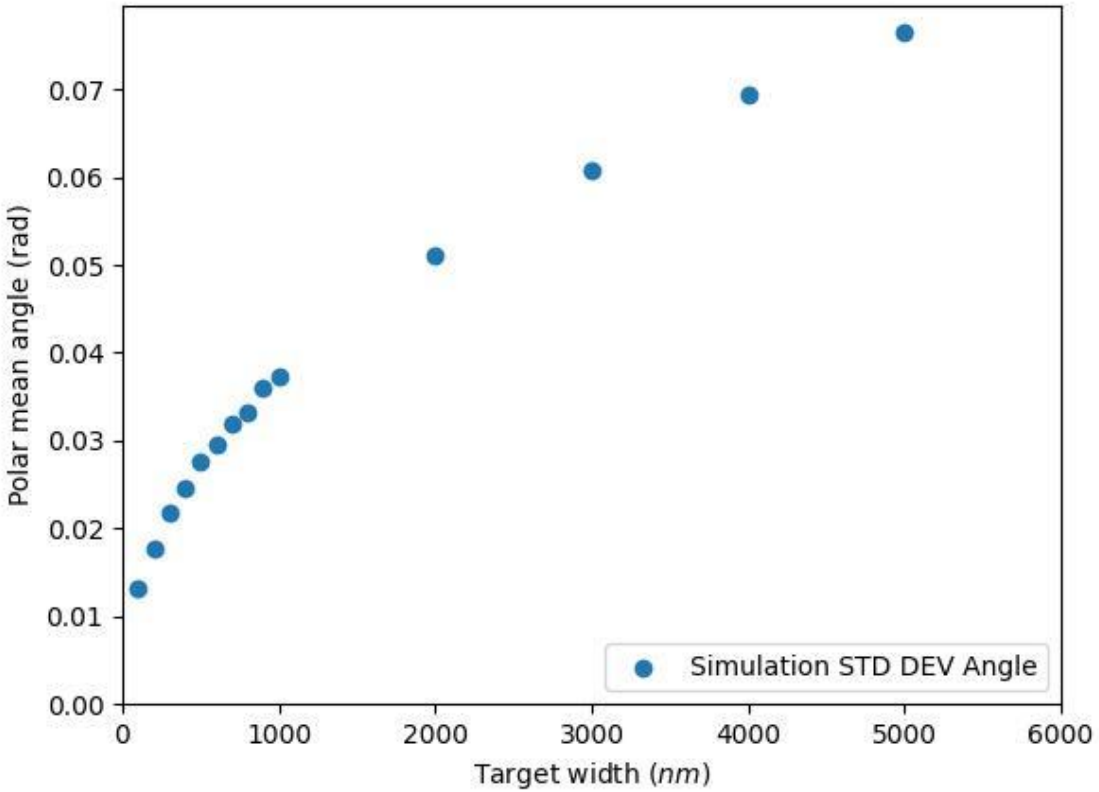


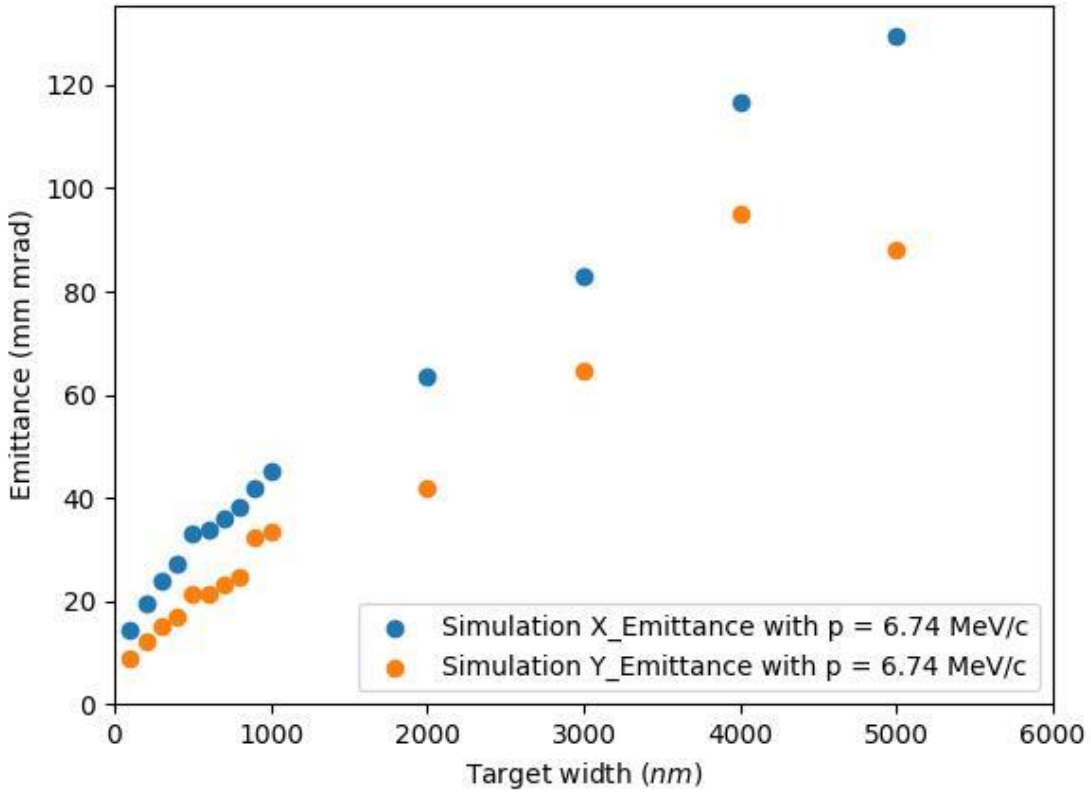

e^-

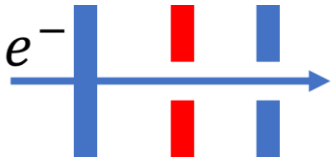

Total momentum histogram
Width:100 nm Counts: 999997
Width:200 nm Counts: 999998
Width:300 nm Counts: 999980
Width:400 nm Counts: 999971
Width:500 nm Counts: 999971
Width:600 nm Counts: 999965
Width:700 nm Counts: 999966
Width:800 nm Counts: 999942
Width:900 nm Counts: 999949
Width:1000 nm Counts: 999945
Width:2000 nm Counts: 999894
Width:3000 nm Counts: 999815
Width:4000 nm Counts: 999791
Width:5000 nm Counts: 999722
Normal
Counts (-)
Ptot (MeV/c)

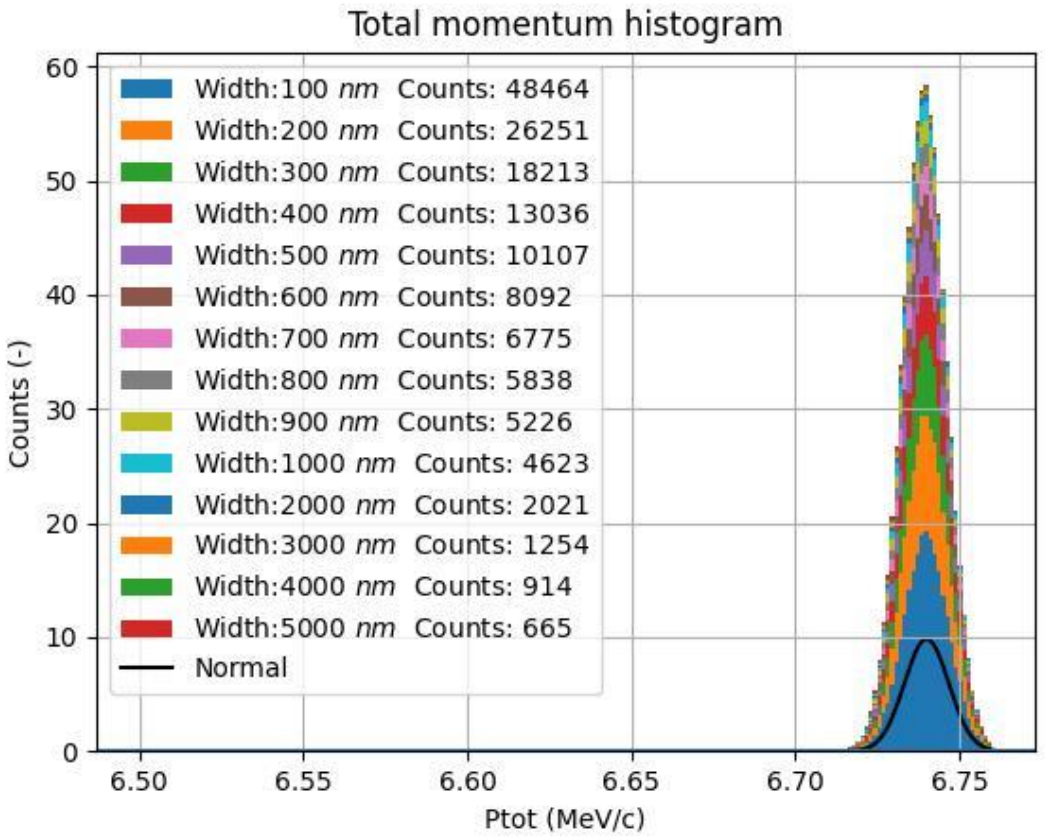

Momentum spread - Initial value: 1×10^{-3}
$\Delta p/p$ (%)
Target width (nm)

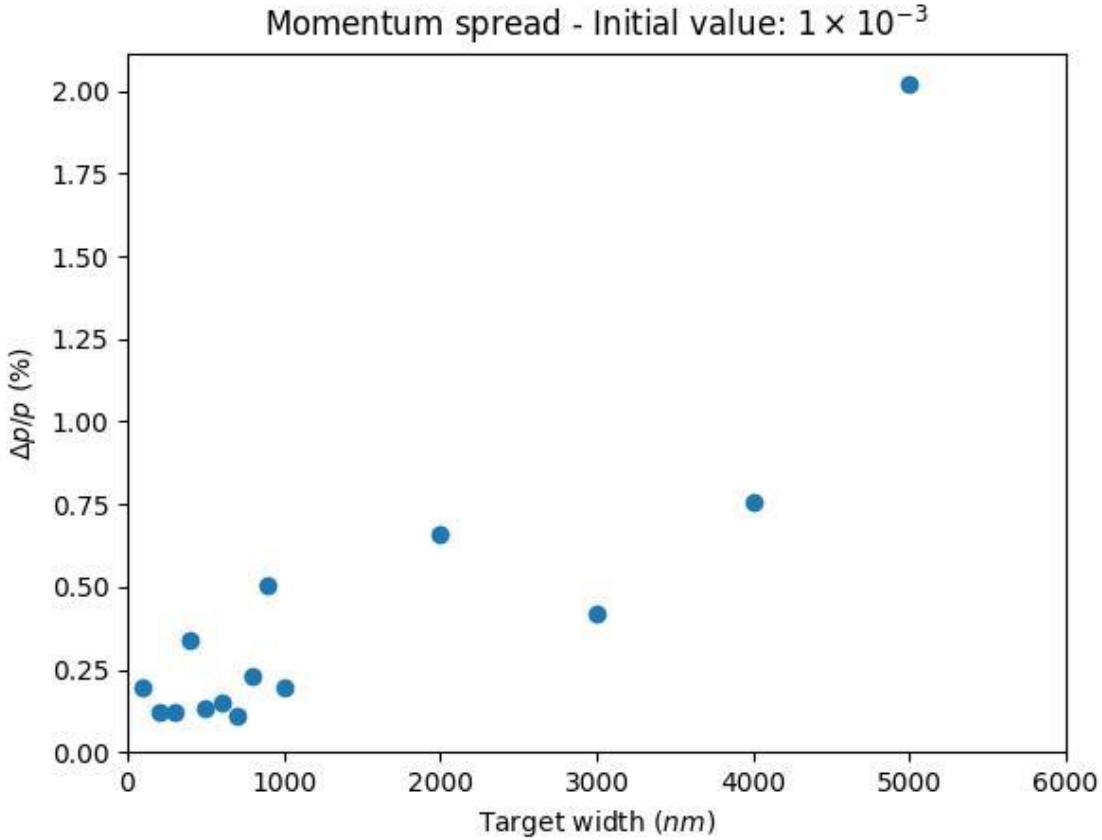

e^-


Polar mean angle (rad)
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0
1000
2000
3000
4000
5000
6000
Target width (nm)
Simulation STD DEV Angle

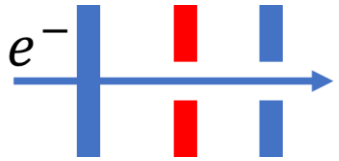

Emittance (mm mrad)
0
20
40
60
80
100
120
0
1000
2000
3000
4000
5000
6000
Target width (nm)
Simulation X_Emittance with p = 6.74 MeV/c
Simulation Y_Emittance with p = 6.74 MeV/c

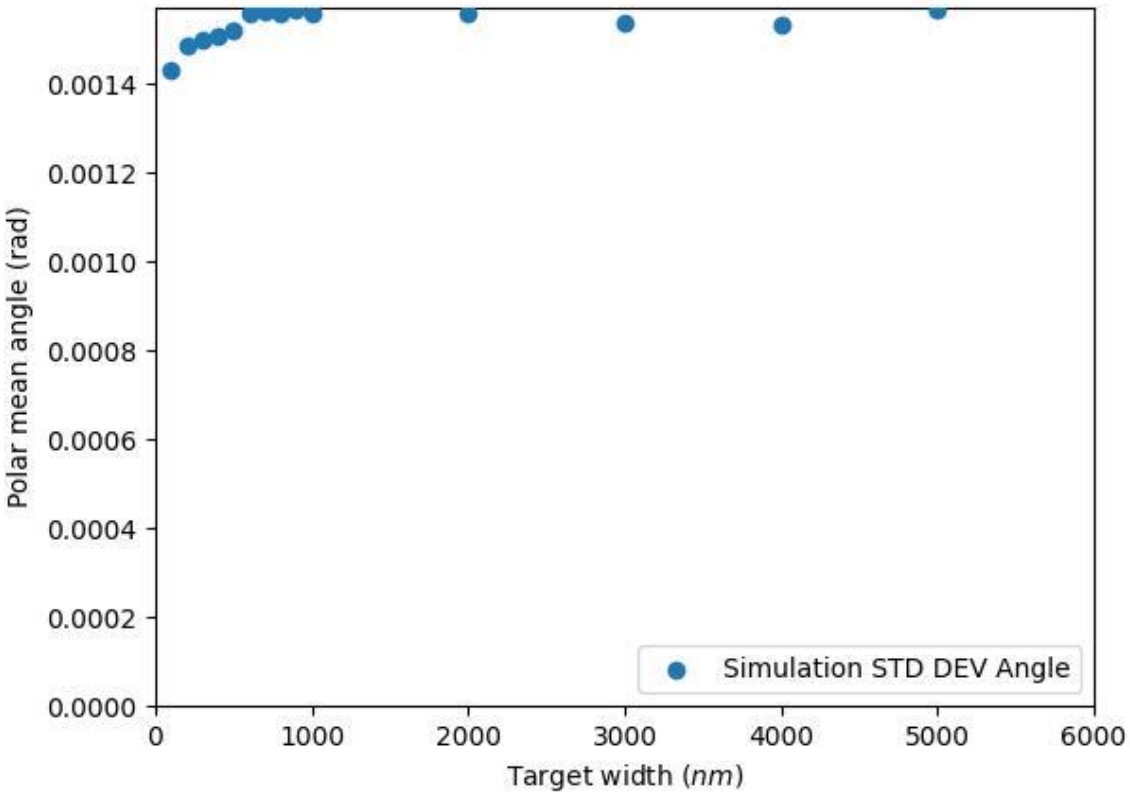

e^-

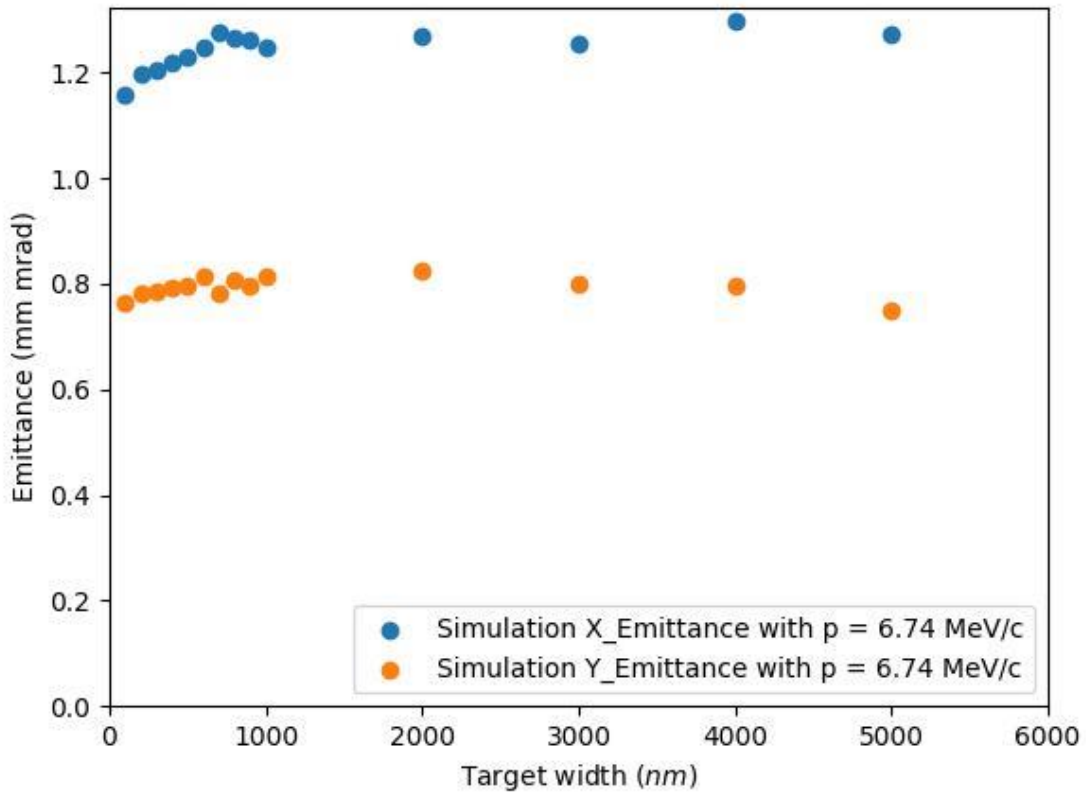

Total momentum histogram
Width:100 nm Counts: 48464
Width:200 nm Counts: 26251
Width:300 nm Counts: 18213
Width:400 nm Counts: 13036
Width:500 nm Counts: 10107
Width:600 nm Counts: 8092
Width:700 nm Counts: 6775
Width:800 nm Counts: 5838
Width:900 nm Counts: 5226
Width:1000 nm Counts: 4623
Width:2000 nm Counts: 2021
Width:3000 nm Counts: 1254
Width:4000 nm Counts: 914
Width:5000 nm Counts: 665
Normal
Counts (-)
Ptot (MeV/c)


Momentum spread - Initial value: 1×10^{-3}
$\Delta p/p$ (%)
Target width (nm)

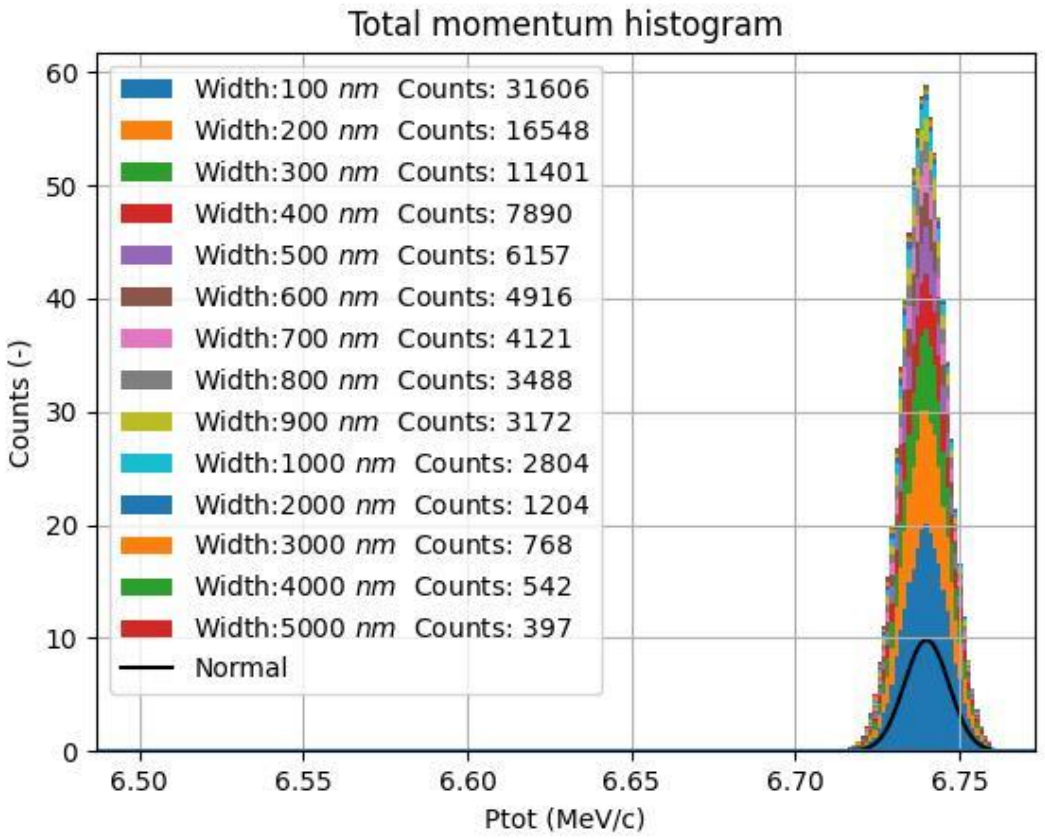
-Tungsten target- After first aperture/RMS polar angle and emittance

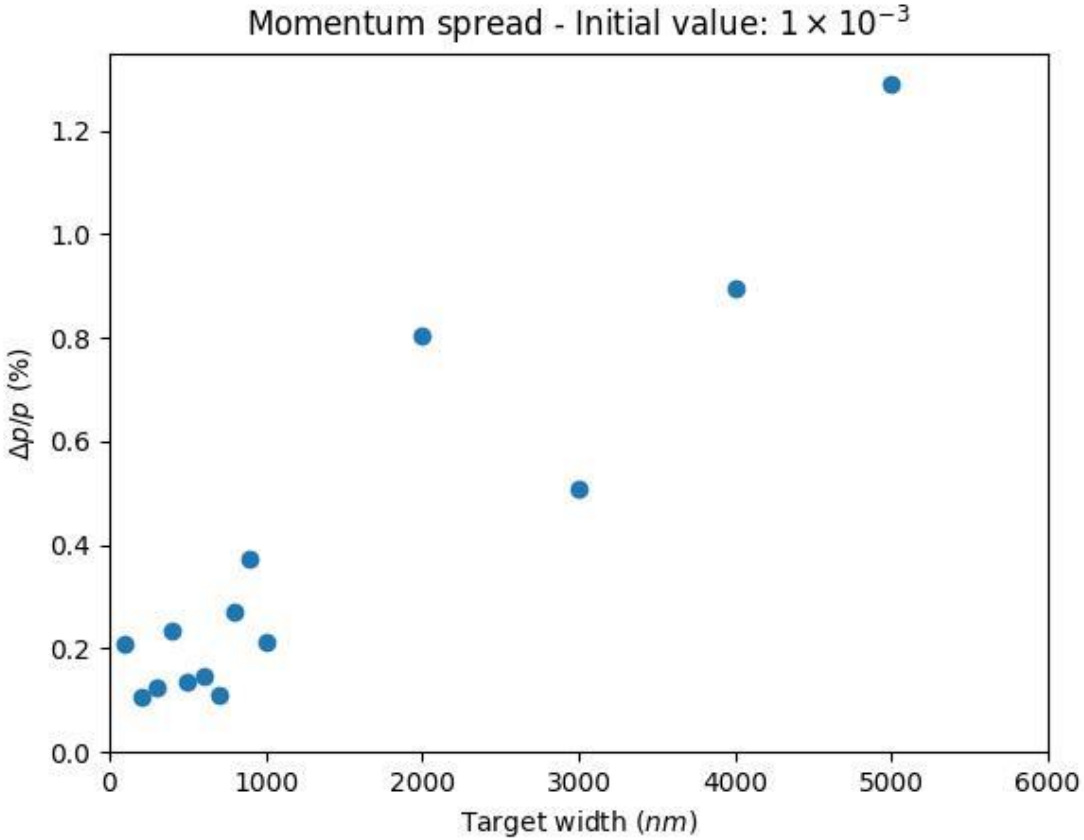




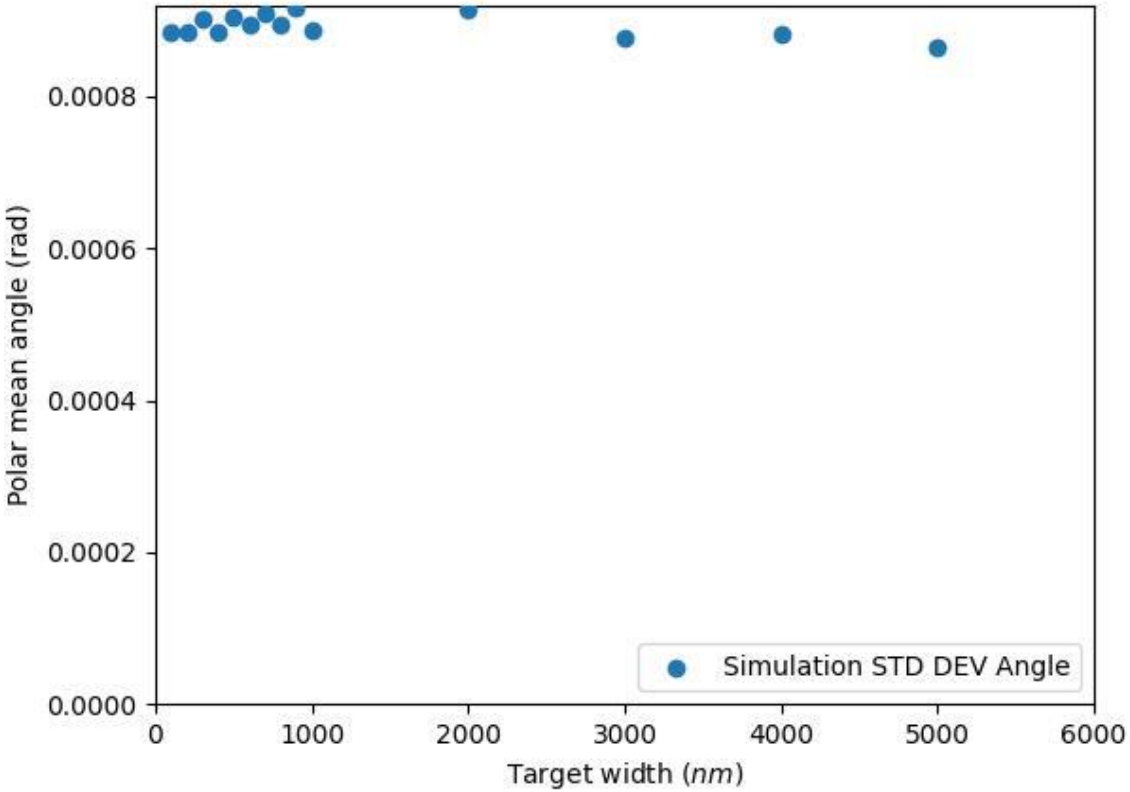


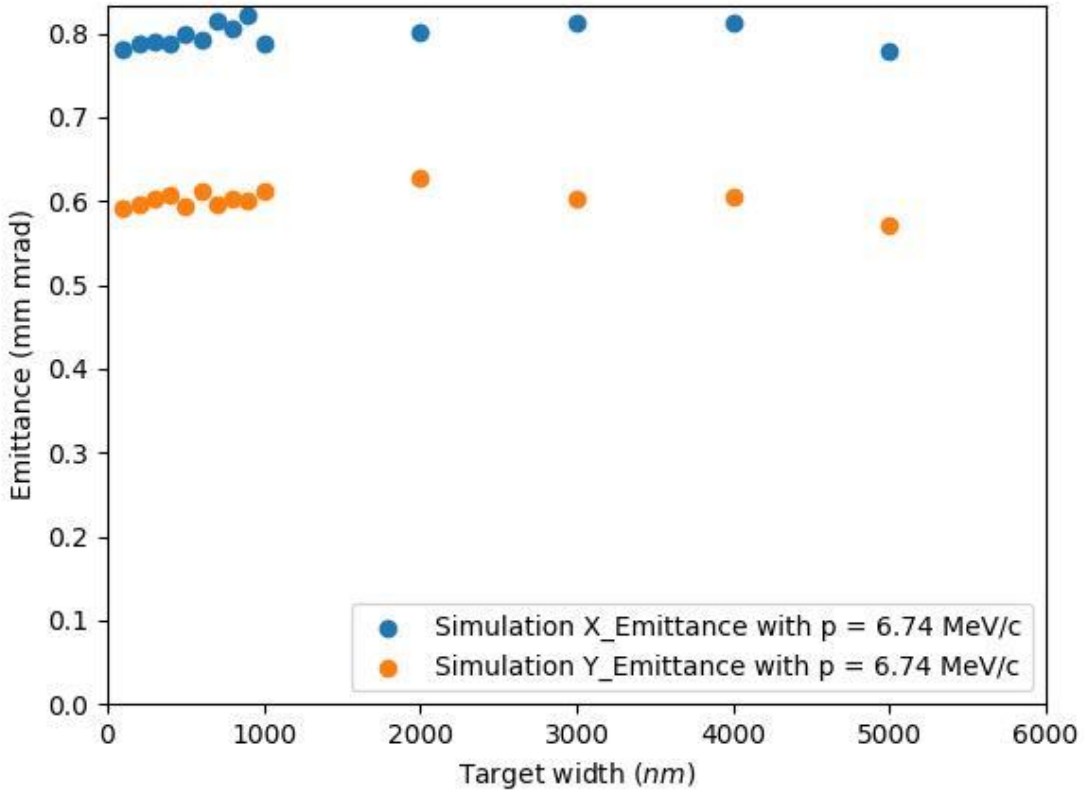

e^-


Total momentum histogram
Width:100 nm Counts: 31606
Width:200 nm Counts: 16548
Width:300 nm Counts: 11401
Width:400 nm Counts: 7890
Width:500 nm Counts: 6157
Width:600 nm Counts: 4916
Width:700 nm Counts: 4121
Width:800 nm Counts: 3488
Width:900 nm Counts: 3172
Width:1000 nm Counts: 2804
Width:2000 nm Counts: 1204
Width:3000 nm Counts: 768
Width:4000 nm Counts: 542
Width:5000 nm Counts: 397
Normal
Counts (-)
Ptot (MeV/c)

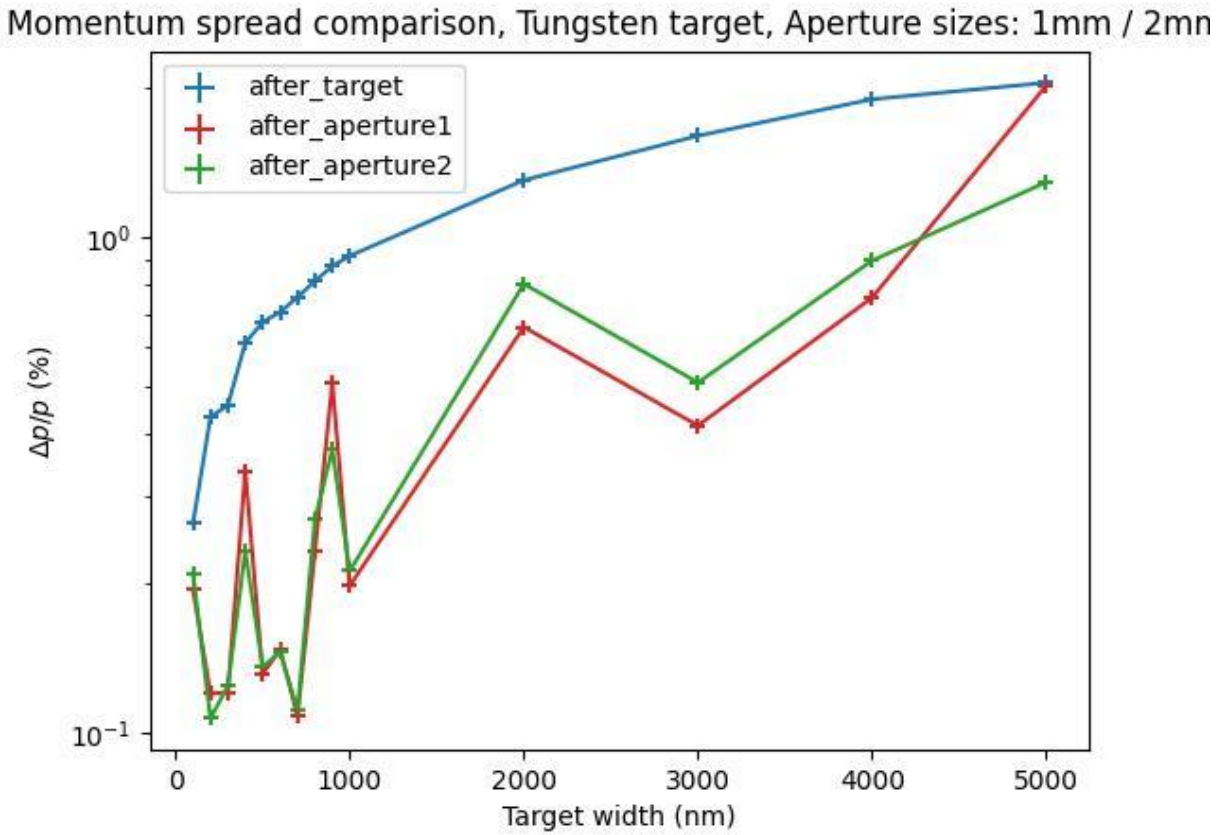

Momentum spread - Initial value: 1×10^{-3}
$\Delta p/p$ (%)
Target width (nm)

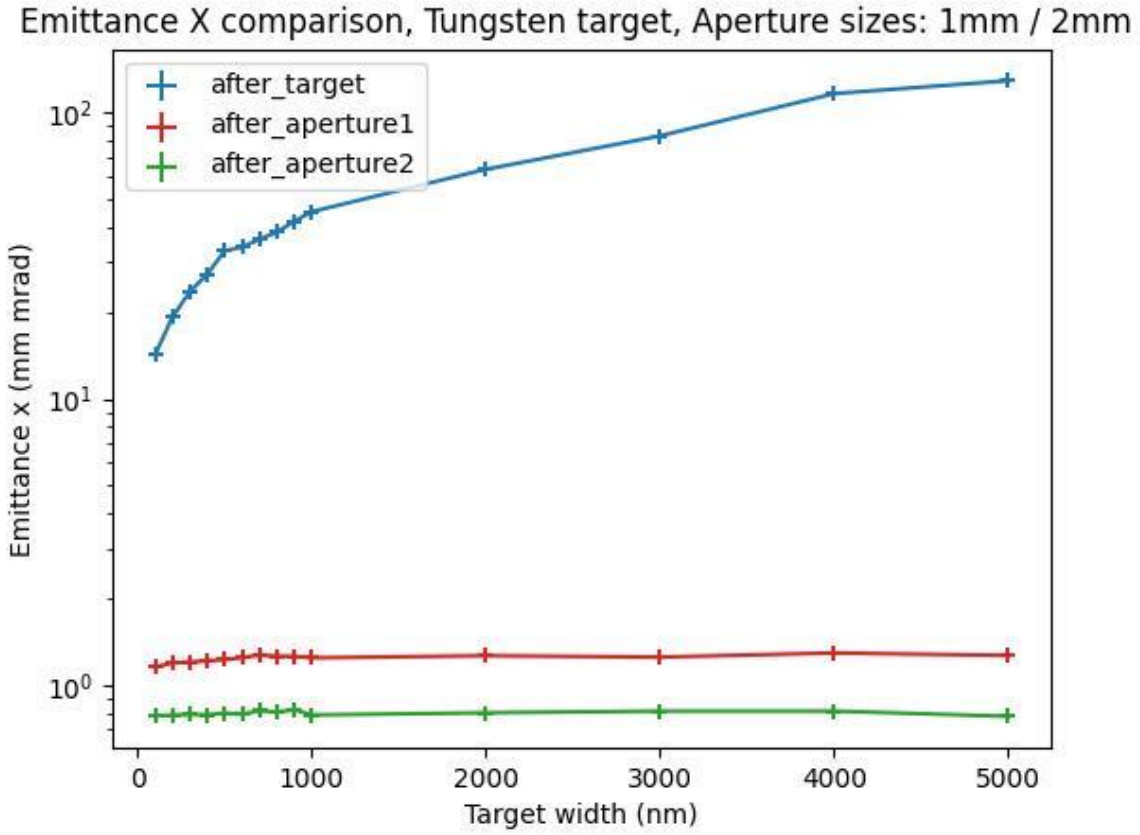
-Tungsten target- After second aperture/RMS polar angle and emittance



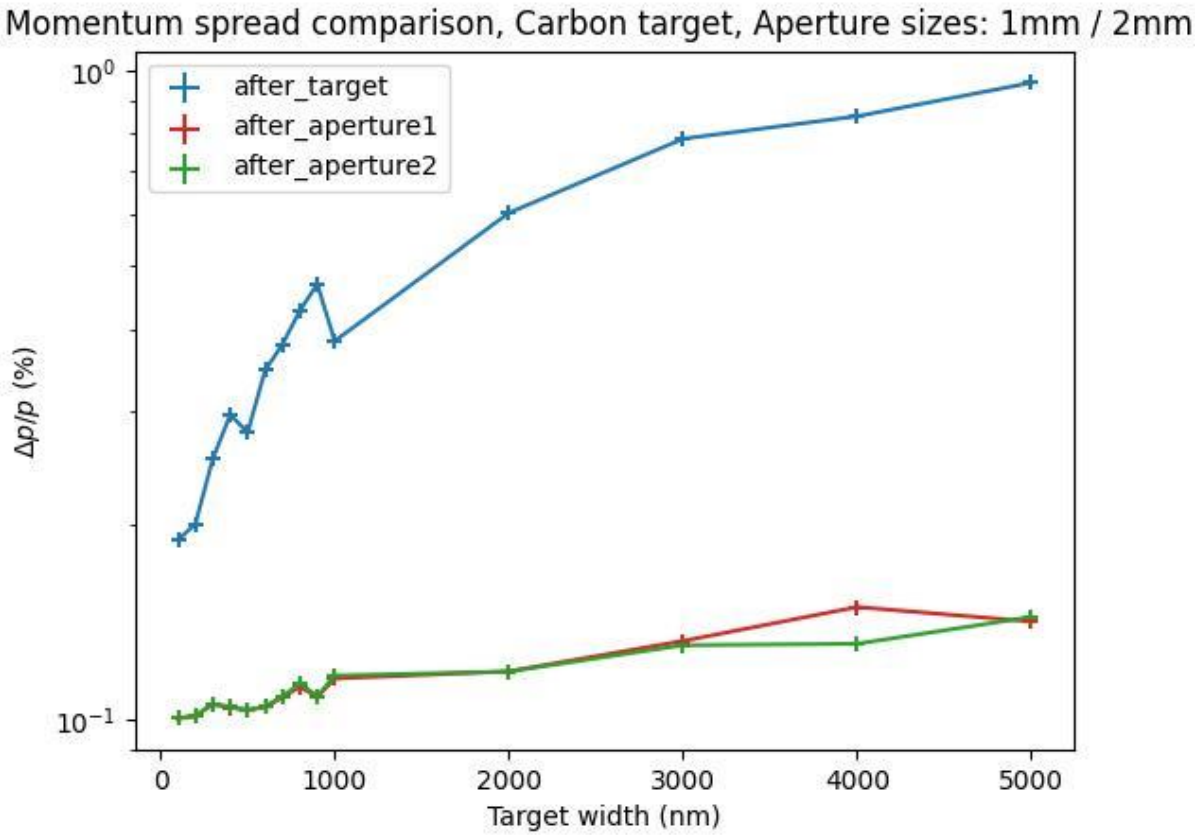


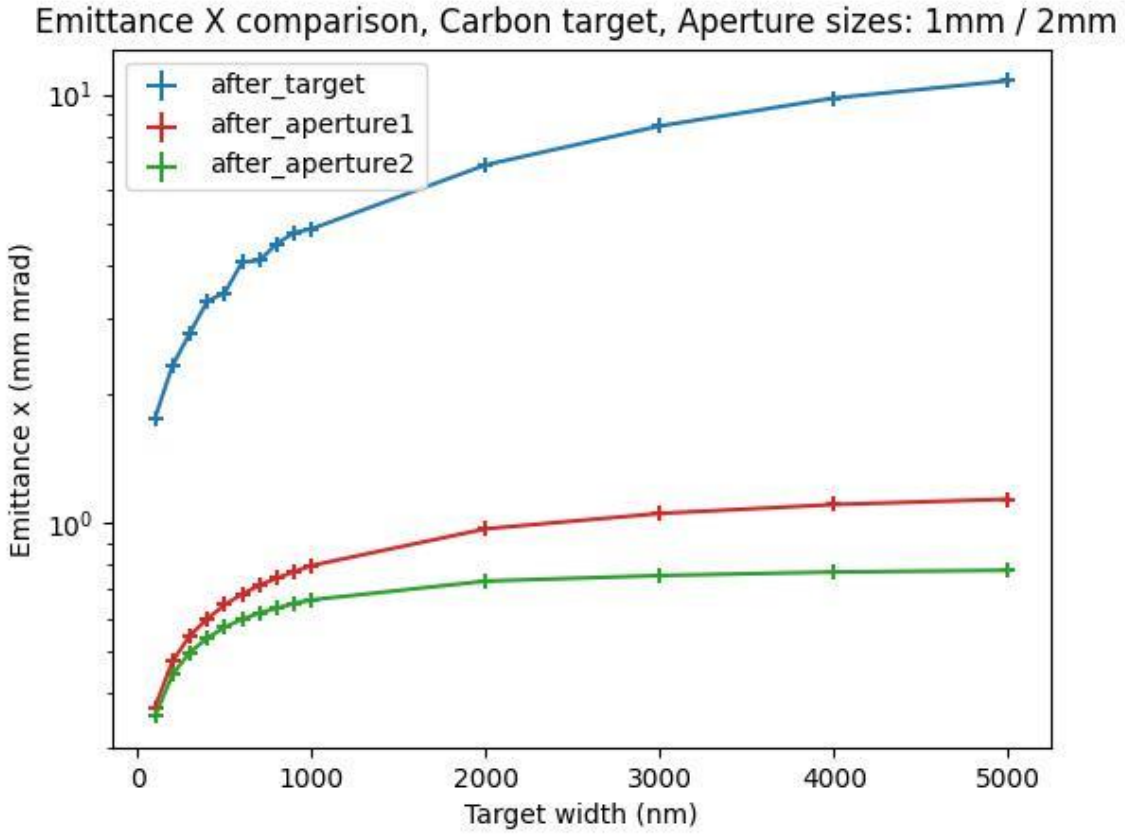
-Tungsten target- Momentum spread and emittance comparison



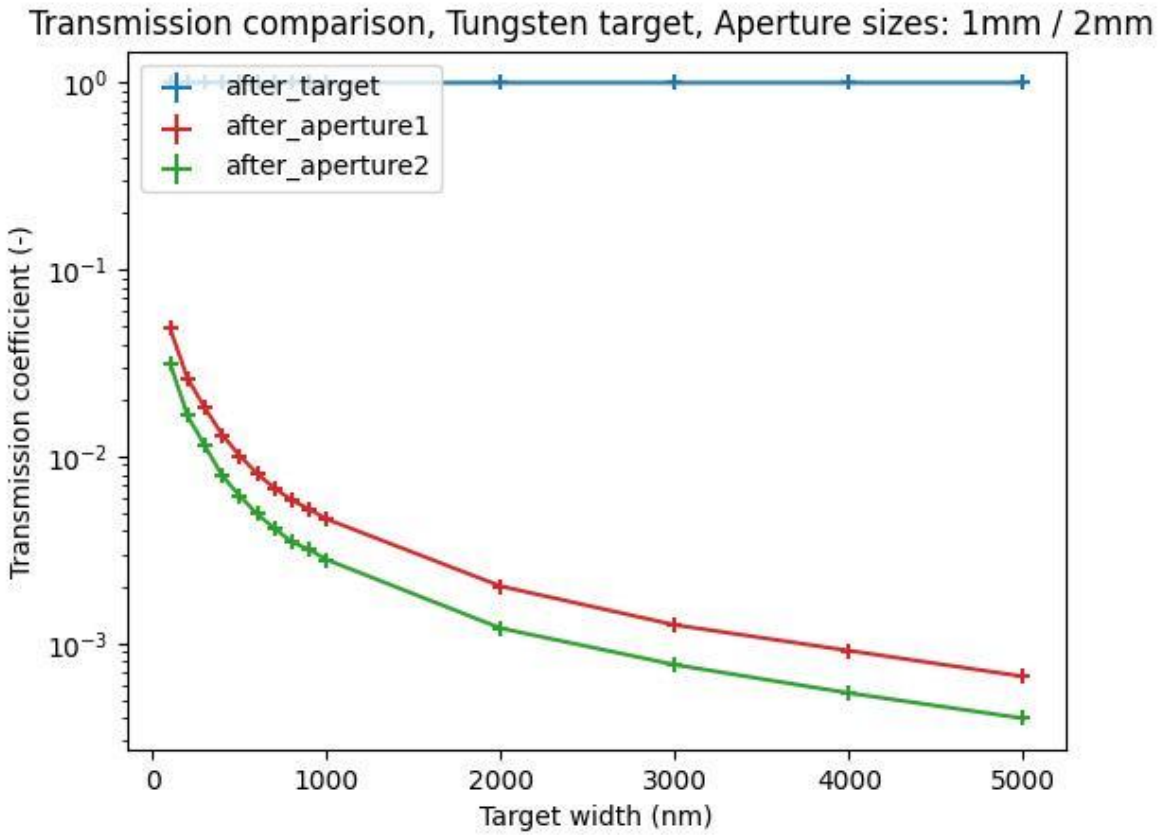


-Carbon target- Momentum spread and emittance comparison

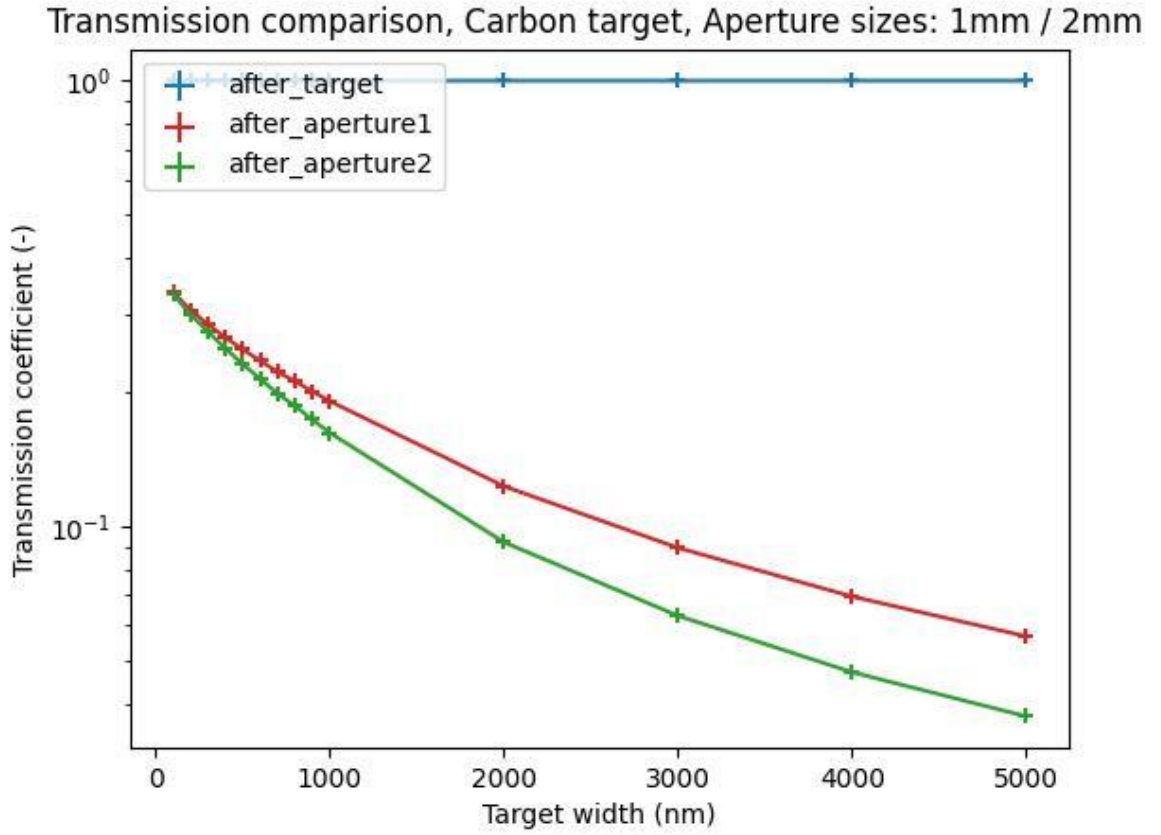




-Tungsten target-



-Carbon target-



Results summary

Target material	First Aperture (mm)	Second aperture (mm)	Emittance X (mm mrad)			Momentum spread (%)		
			Target	Aper1	Aper2	Target	Aper1	Aper2
Tungsten	1	2	$15-120$	~ 1.2	~ 0.8	$0.25-2$	$0.1-2$	$0.1-1.2$
	1	4	$15-120$	~ 1.2	~ 1.2	$0.25-2$	$0.1-2.5$	$0.1-1.2$
	2	2	$15-120$	~ 2.5	~ 1.2	$0.25-2$	$0.1-1.5$	$0.1-1.2$
	2	4	$15-120$	~ 2.5	~ 2	$0.25-2$	$0.1-1$	$0.1-1.2$
Carbon	1	2	$2-11$	$0.4-1.2$	$0.3-0.8$	$0.2-1$	$0.1-0.15$	$0.1-0.14$
	1	4	$2-11$	$0.4-1.2$	$0.3-1.2$	$0.2-1$	$0.1-0.15$	$0.1-0.16$
	2	2	$2-11$	$0.6-2.2$	$0.6-1.2$	$0.2-1$	$0.1-0.14$	$0.1-0.15$
	2	4	$2-11$	$0.7-2.2$	$0.7-2$	$0.2-1$	$0.1-0.16$	$0.1-0.16$

*Range given from values @ target width $(100nm - 5\mu m)$

Summary and future perspectives

- First results of degraded electron beam simulations with Geant4 using Tungsten and Carbon targets.
- Significant decrease in emittance and momentum spread by using two apertures at the cost of decrease in final current.
- Tungsten has a bigger impact on the momentum spread than carbon.
- Good agreement in transmission between Elegant and Geant4 as a sanity check.

Going forward:

- Implementation of better model for apertures (with correct material and inclusion of any secondary particle created).
- Geant4 distributions to elegant for particle tracking in the next components of the beamline.

Thank you for your attention!