UNIVERSIDAD DE GUANAJUATO

Jefferson Lab

Simulations of large momentum spread beam at the injector

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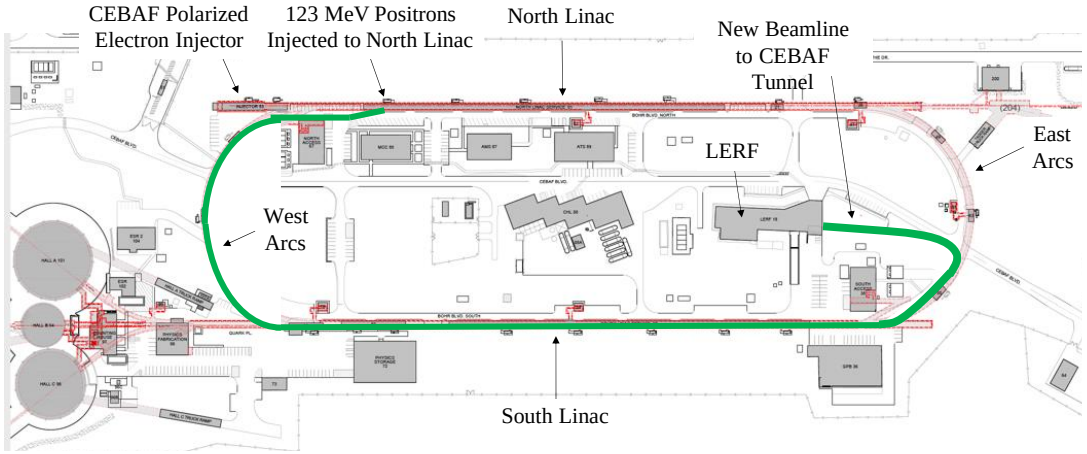
Outline

- Introduction
- Electron beam degrader
- Past degrader simulations
- GPT simulations

Positrons at CEBAF

- Proposed upgrade to 12 GeV CEBAF
- Positron beams will have larger phase space than nominal e- beam
- Need to study the limits of what can be transported in CEBAF



From J. Grames PWG workshop “Positron beams at Ce+BAF: Status and R&D plan”

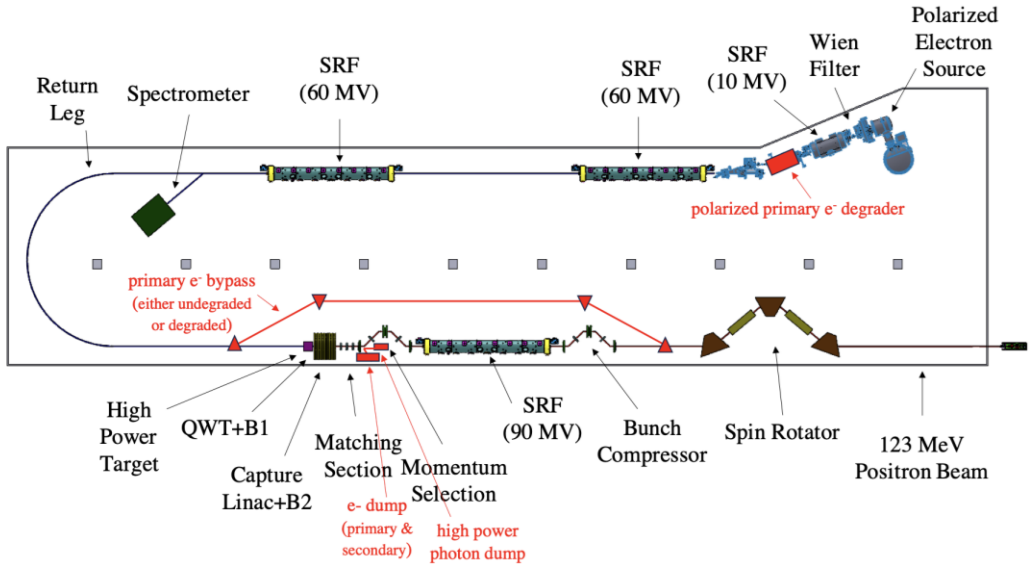


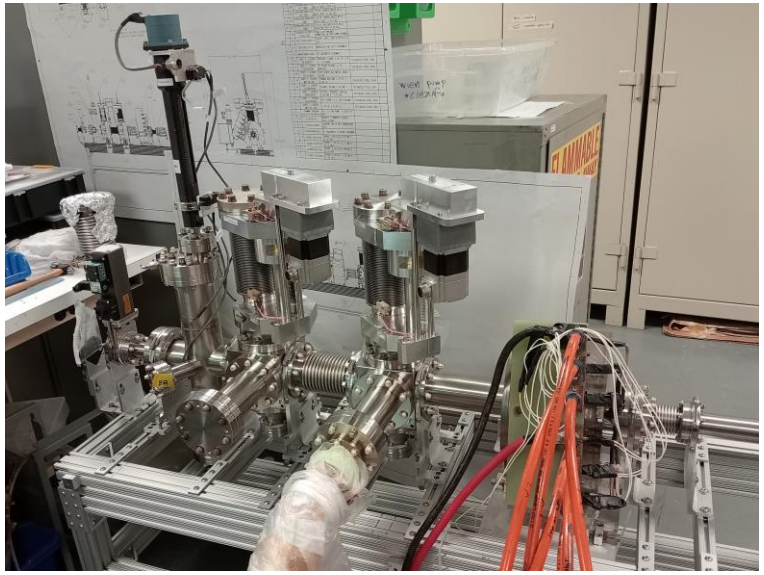
Table 1: Simulated Emittances in CEBAF [4], [5]

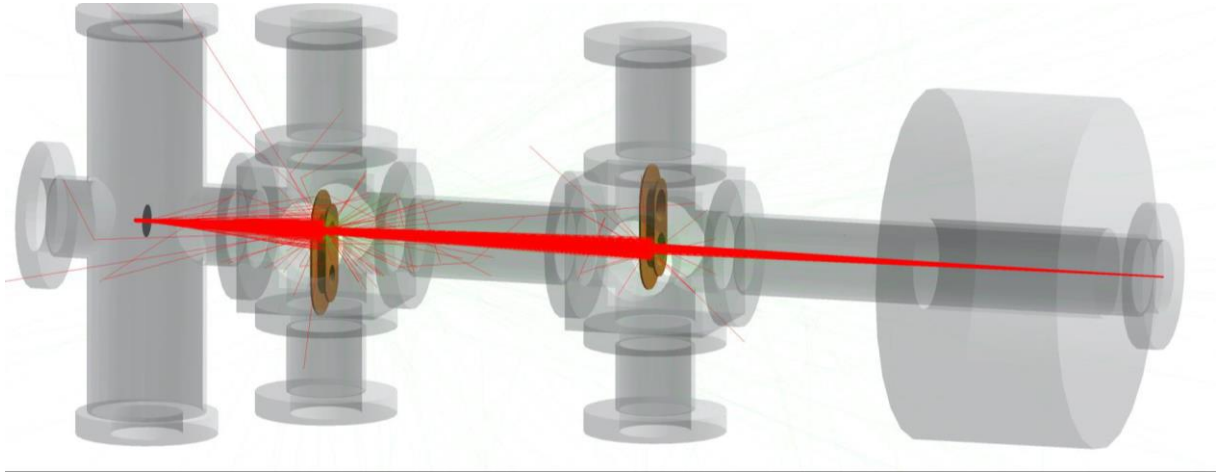
	Electrons			Positrons		
Area	$\delta p/p[\times 10^{-3}]$	$\varepsilon_x[nm]$	$\varepsilon_y[nm]$	$\delta p/p[\times 10^{-3}]$	$\varepsilon_x[nm]$	$\varepsilon_y[nm]$
Chicane	0.5	4.00	4.00	10	500	500
ARC1	0.05	0.41	0.41	1	50	50
ARC2	0.03	0.26	0.23	0.53	26.8	26.6
ARC3	0.035	0.22	0.21	0.36	19	18.6
ARC4	0.044	0.21	0.24	0.27	14.5	13.8
ARC5	0.060	0.33	0.25	0.22	12	11.2
ARC6	0.090	0.58	0.31	0.19	10	9.5
ARC7	0.104	0.79	0.44	0.17	8.9	8.35
ARC8	0.133	1.21	0.57	0.16	8.36	7.38
ARC9	0.167	2.09	0.64	0.16	8.4	6.8
MYAAT01	–	–	–	0.18	9.13	6.19
ARC10	0.194	2.97	0.95	–	–	–
Hall D	0.18	2.70	1.03	–	–	–

Simulated emittance evolution in CEBAF for electron and positron beams
Y. Roblin JLAB-TN-21-043

Electron beam degrader

- Objective of degrading the electron beam by multiple scattering through thin carbon target
- Copper apertures for emittance definition
- Solenoid for focusing

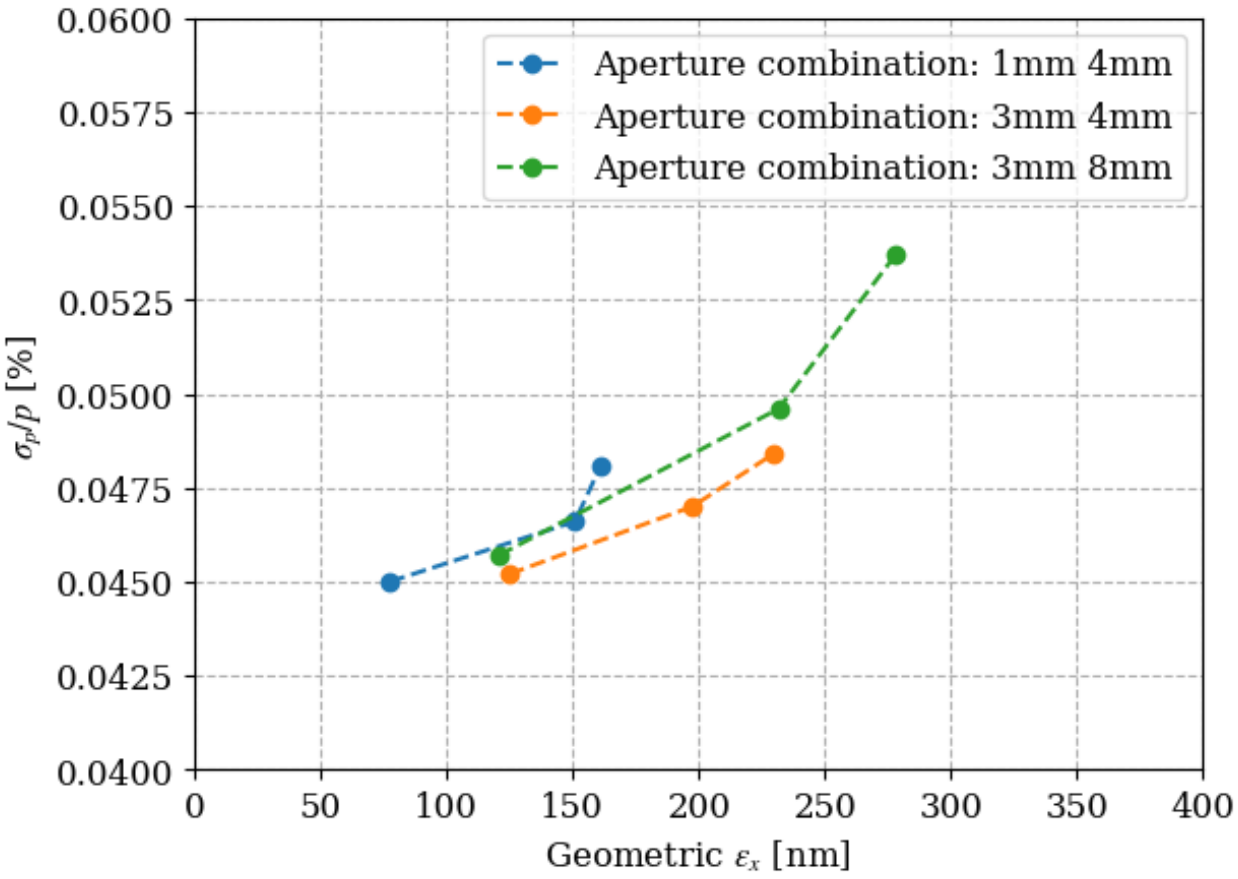




- Ready for installation

- Different target and aperture combinations done to explore the emittance parameter space
- Simulations showed most of the degradation is in the transverse plane
  - Low-Z and very thin
- Longitudinal emittance almost unaffected
- Modify upstream cavities to increase the momentum spread before the degrader

Geometric emittance and momentum spread at the end of the injector chicane



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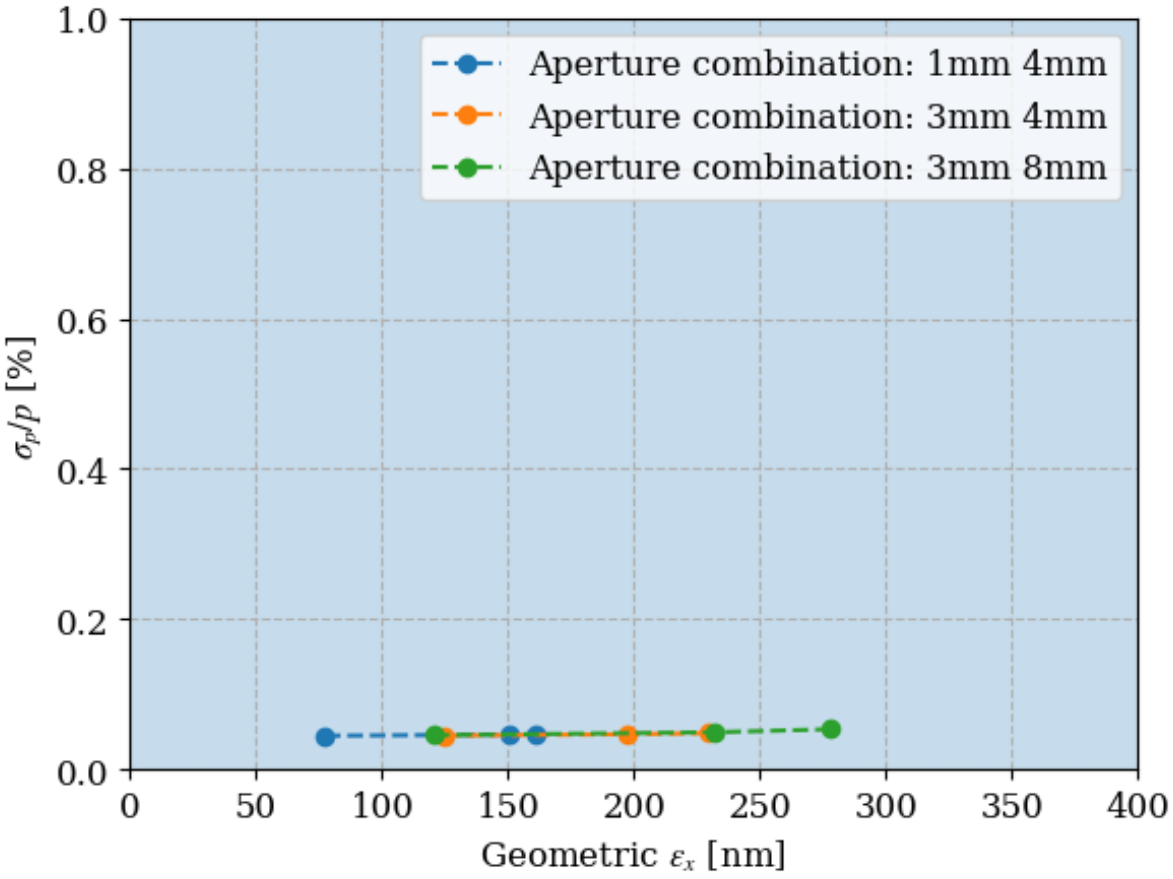
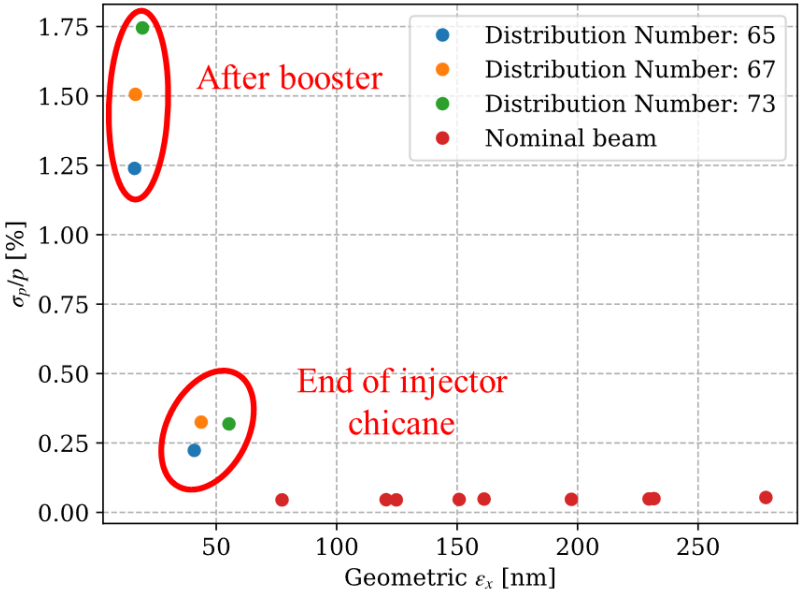
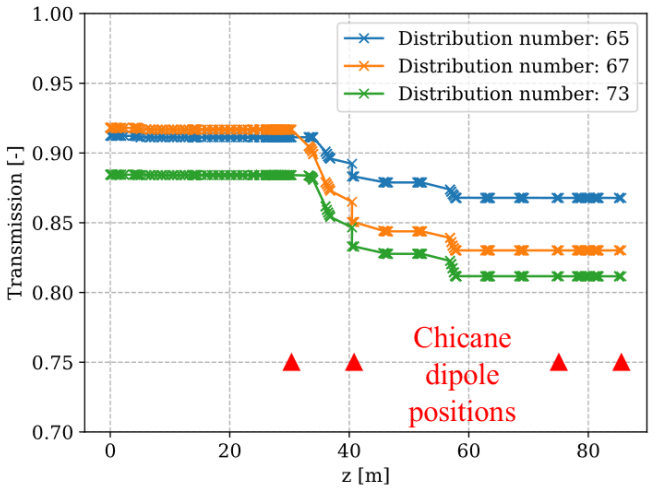
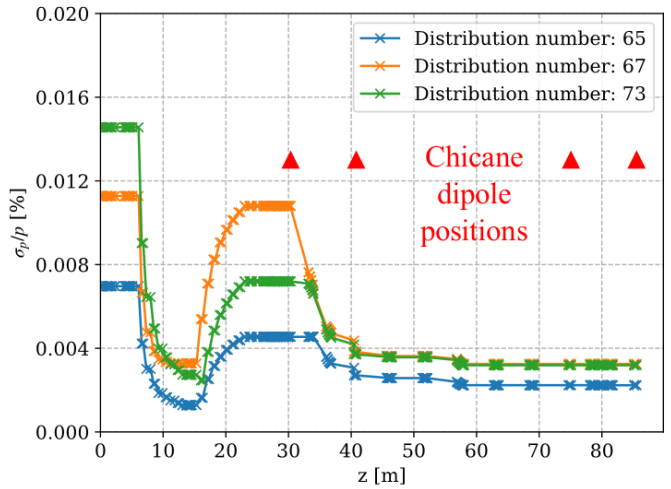


First large momentum spread simulations

- Alicia Hofler provided us with a lot of large momentum spread distributions
- Ran full injector simulations (including the degrader) with solenoid/quad optimization
- However, there was no guarantee on the way the distributions were generated
- ***Task for the summer:*** find realistic cavity settings to increase the momentum spread of the beam upstream of the degrader.

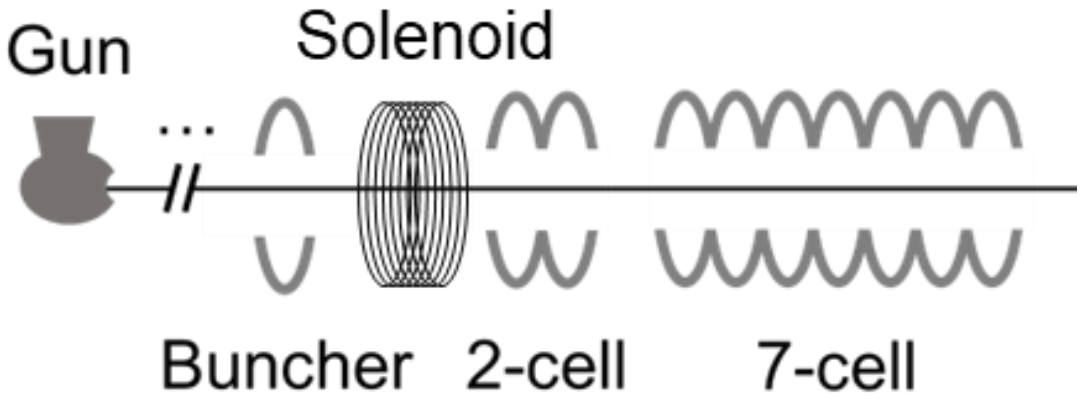






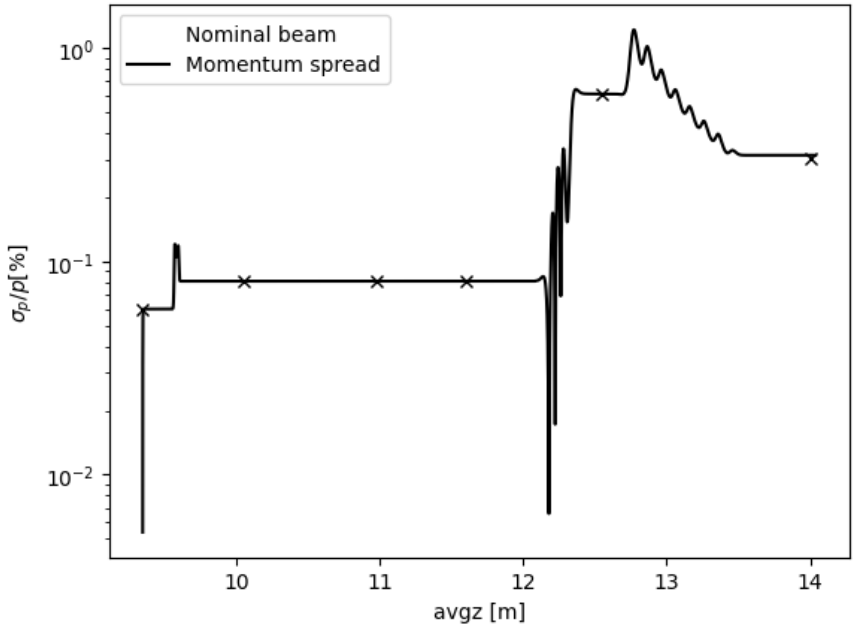
- First step: to find the cavity settings that give the nominal distribution

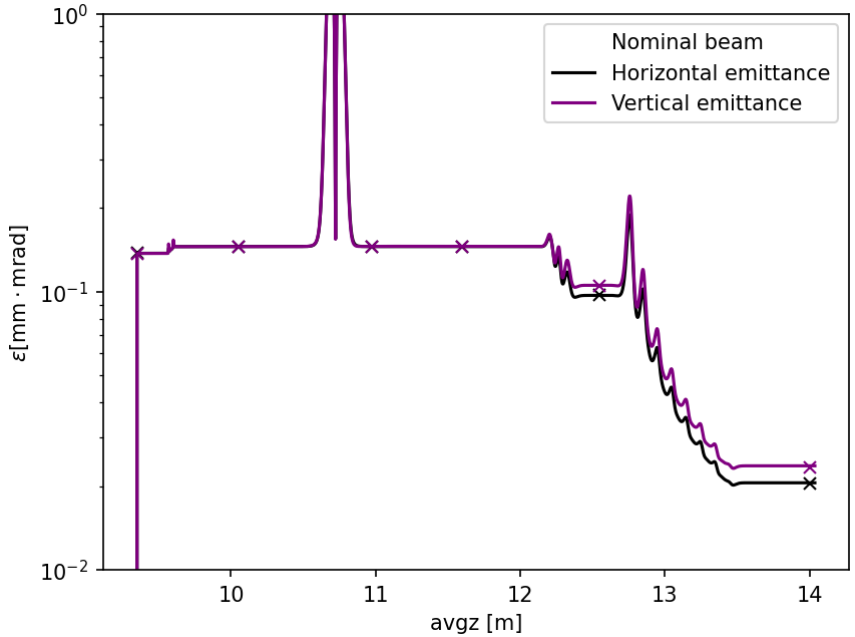
- Parameters to tweak:
  - Buncher gradient and phase
  - Solenoid magnetic field
  - Booster 2-cell gradient and phase
  - Booster 7-cell gradient and phase



Matched distribution to the nominal settings

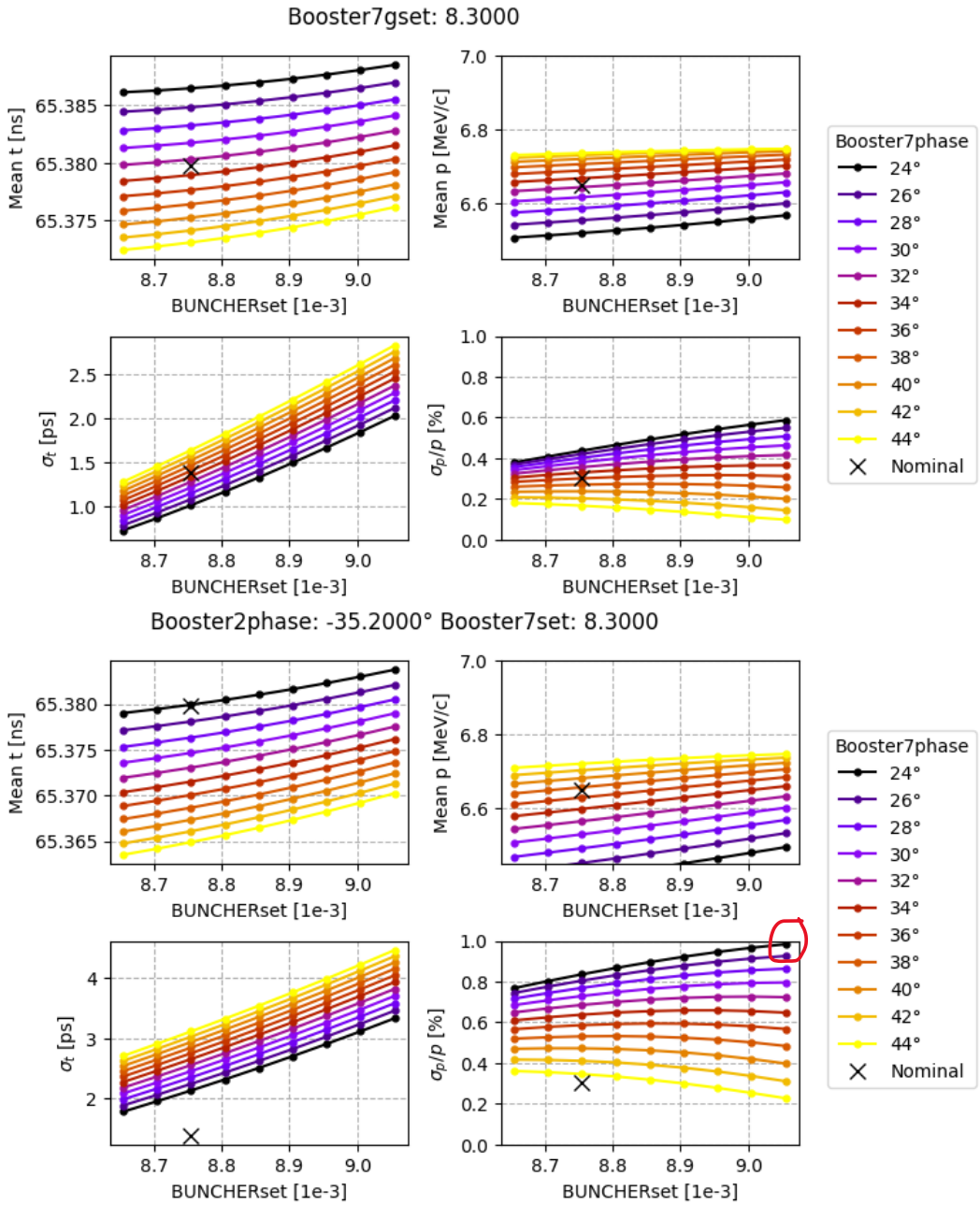
- Buncher
  - Amp: 8.75e-3 → 8.755e-3
  - Phase: -20.5° → -20.508°
- Booster 2-cell
  - Amp: 0.405 → 0.408
  - Phase: -45° → -45.2°
- Solenoid
  - Amp: 0.535
- Booster 7-cell
  - From 3-d field map to 2.5-d field map
  - Amp: 2.0325 → 8.3
  - Phase: 34° → 35°





- **Buncher** gradient scan
- **Booster 7-cell** phase scan ($\pm 10°$)

- **Buncher** gradient scan
- **Booster 2-cell** -10° phase offset
- **Booster 7-cell** phase scan ($\pm 10°$)



- Buncher
  - Gradient factor: 8.755e-3 → 9.055e-3 (3.4% increase)
- Booster 2-cell
  - Phase: -45.2° → -35.2° (-10° offset)
- Solenoid
  - Same settings
- Booster 7-cell
  - Amp: 8.3 → 8.535 (2.8% increase)
  - Phase: 35.2° → 25° (-10° offset)

Longitudinal parameters after 7-cell

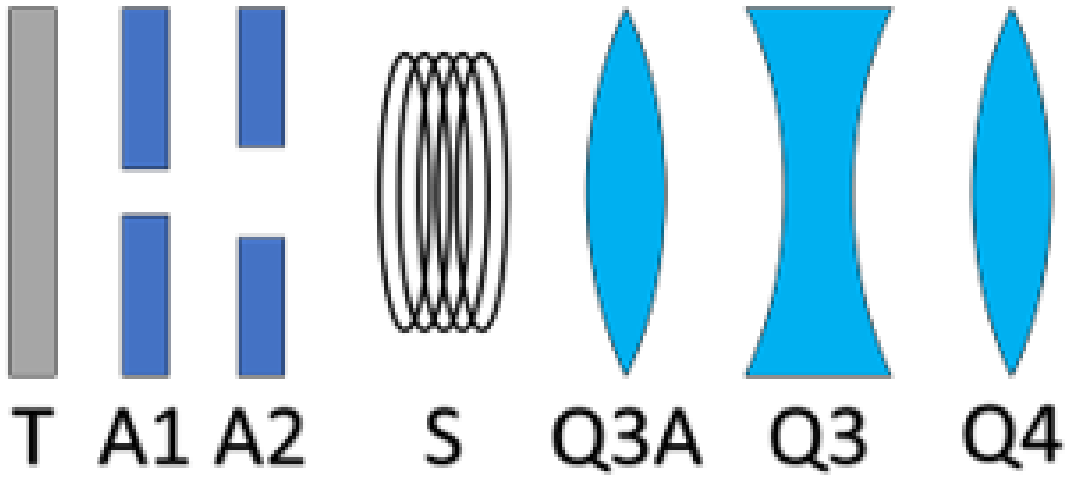
$$p = 6.83\ \mathrm{MeV}$$
$$\sigma_p/p = 1.08\%$$
$$\sigma_z \approx 0.917\ \mathrm{mm}$$

Geant4 and Elegant simulation of the rest of the degrader

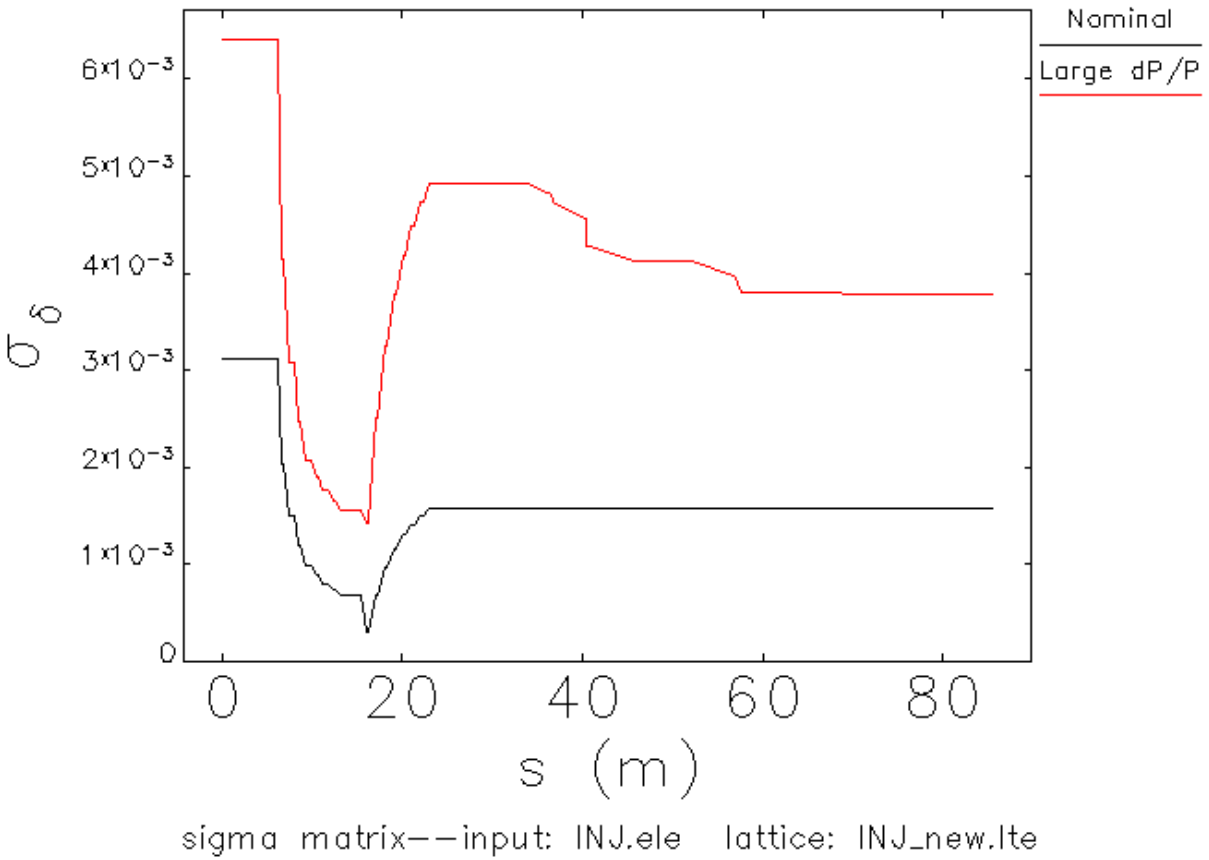
- Exported data to Elegant and ran through the rest of the injector beamline (two full cryomodules and injector chicane)

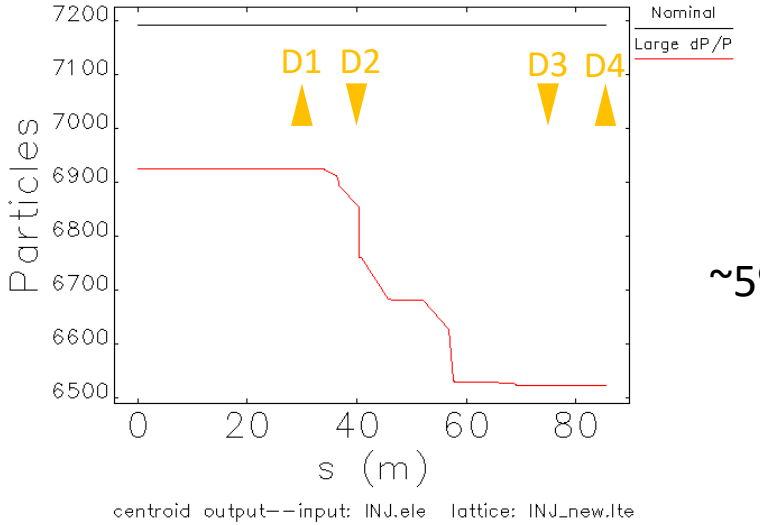
- Degrader settings:
  - 1 micron target and 1 mm/ 4mm apertures
  - 10 microns target and 3 mm/ 8mm apertures

- Performed solenoid field and quad gradient optimization for maximum transmission

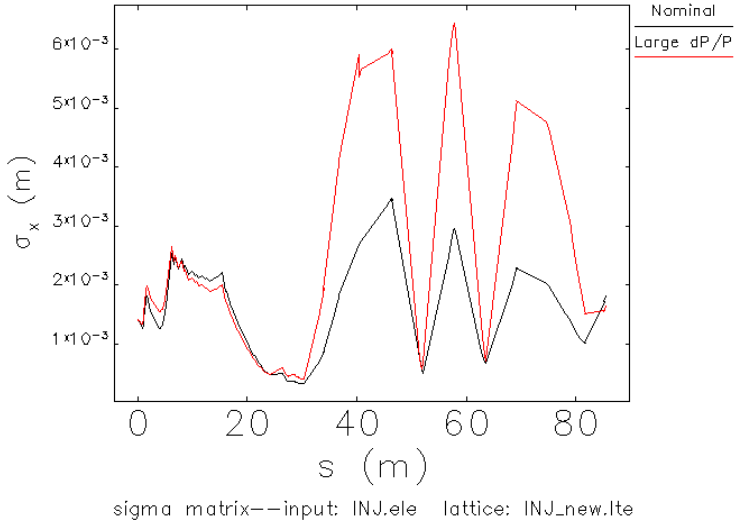


Result of optimization - 1 micron target and 1 mm/ 4mm apertures

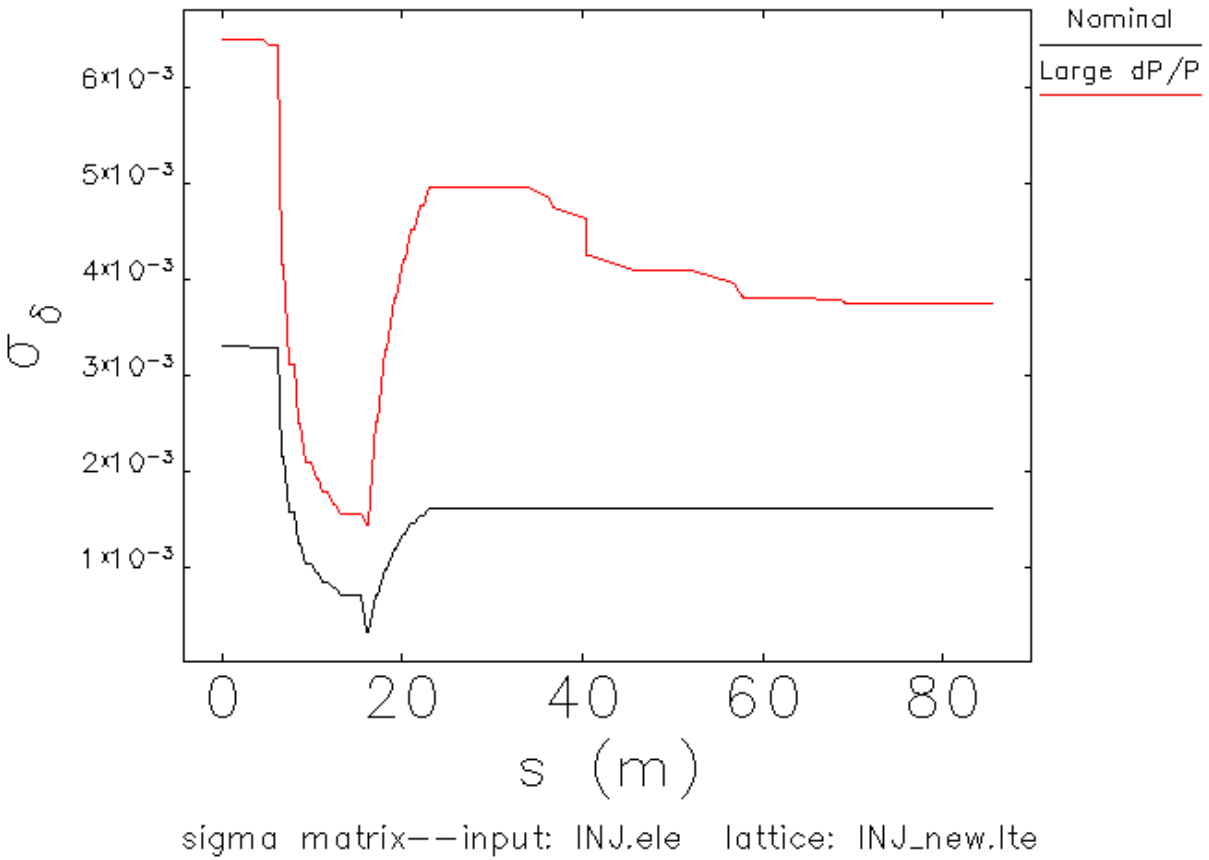


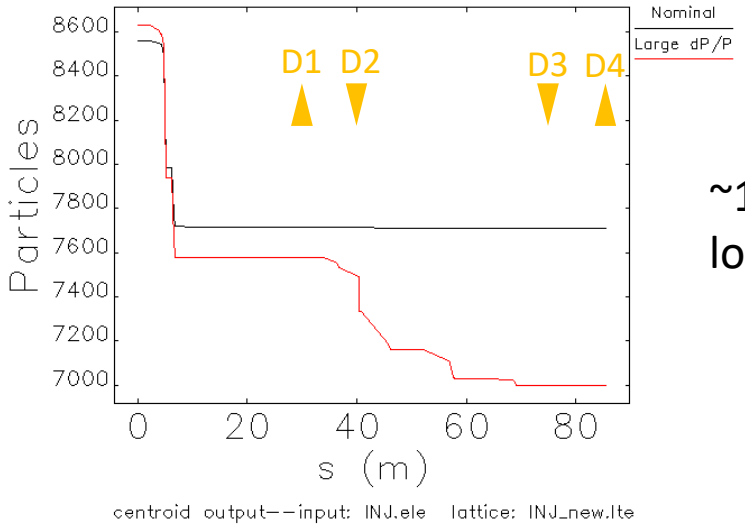


~5% loss

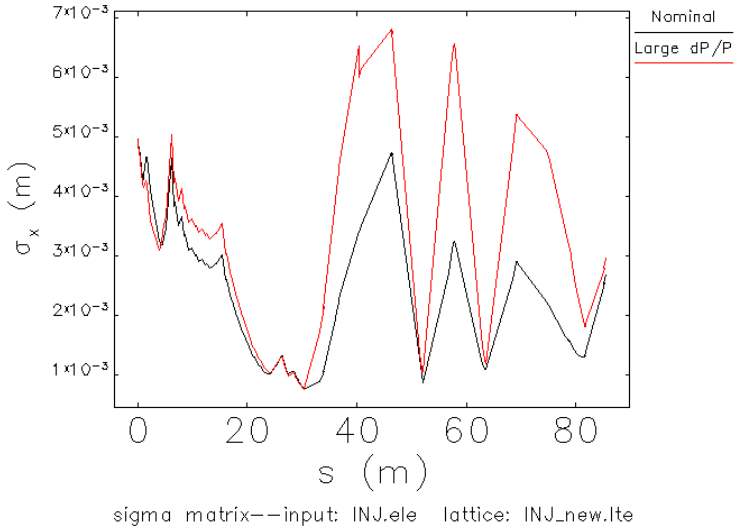


Result of optimization - 10 microns target and 3 mm/ 8mm apertures





~16% loss



Summary and further work

- In GPT, implemented a section of the injector upstream of the degrader position (buncher and booster).
- Found the settings that achieve the nominal beam distribution
- Tweaked cavity phases and gradients to increase the momentum spread
- Ran degrader and rest of the injector simulations with Geant4 and Elegant. Also performed optimization for maximum transmission in the rest of the chicane
  - Loss before the 0L03 is still present for thickest target
  - For large momentum spread distribution, most beam loss at the injector chicane as expected

Further work

- Find intermediate settings to get closer to the injector chicane momentum acceptance
- Check feasibility of using those settings in the machine in future beam studies
- Focus on polarized positron production simulations for PSTP’24 presentation.