Degraded beam study of CEBAF

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Jefferson Lab

U.S. DEPARTMENT of ENERGY

Outline

Background

Degrader project details

Commissioning plan

Beam studies

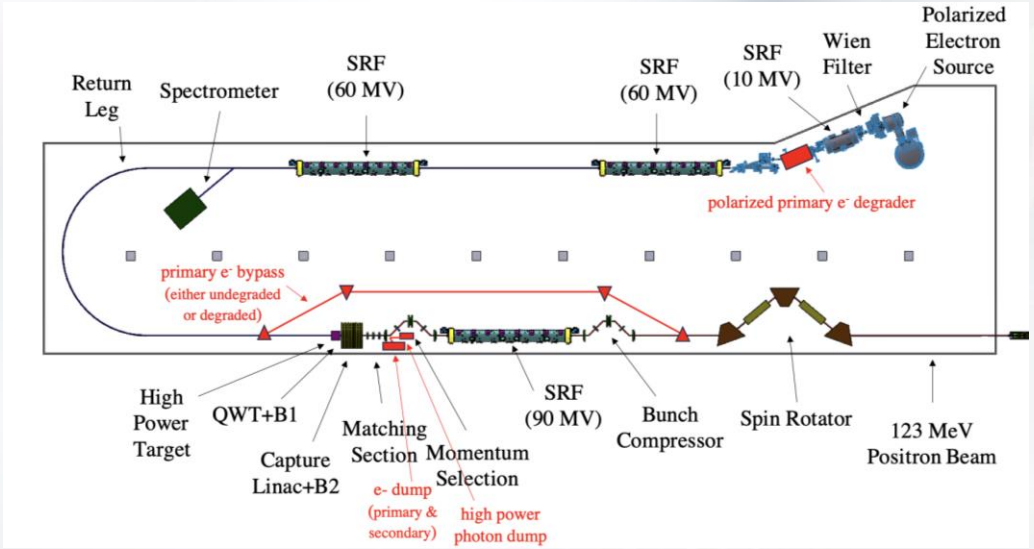
Preliminary results

Summary and outlook

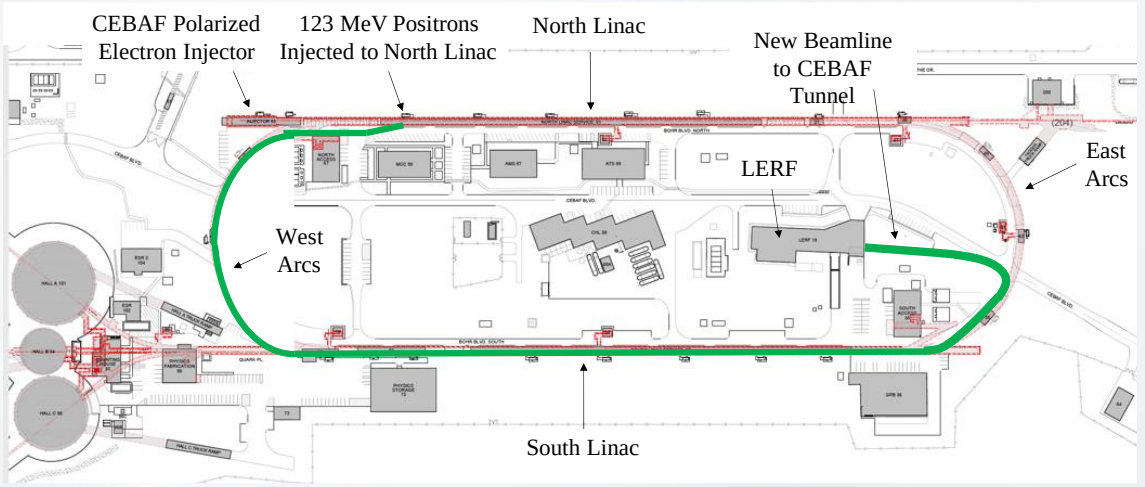
Motivation

- Proposed Ce+BAF upgrade
- Circulation of large emittance beams in CEBAF

Preliminary LERF positron source layout



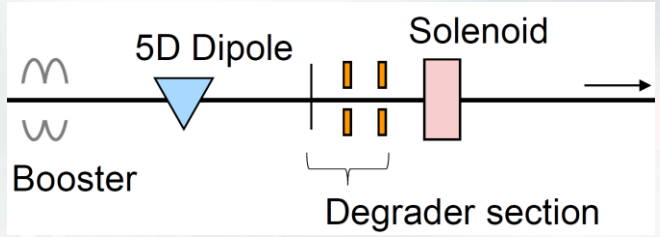
Transfer line from LERF to CEBAF



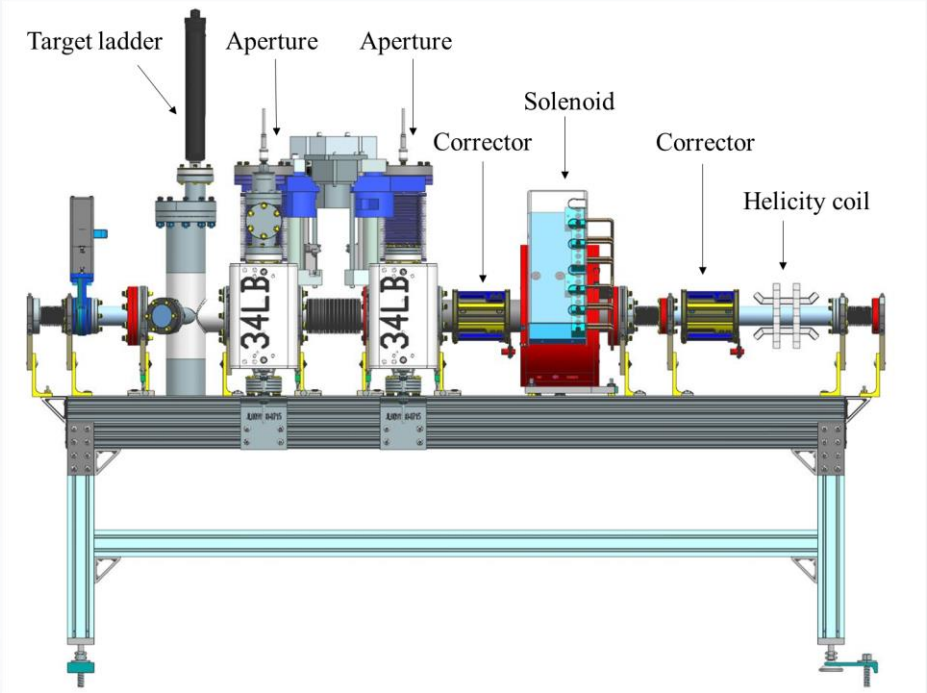
LDRD degrader project: Assessing CEBAF using degraded beams for the Ce+BAF positron upgrade

- Goals of the project:
  - Measurement of the acceptance of CEBAF
  - Characterization of emittance evolution in CEBAF as a function of initial beam emittance from the injector beamline
- FY2024 goals:
  - Design, procurement and installation of degrader components
  - Measurements of CEBAF transverse and longitudinal acceptance

Straight-ahead degrader schematic



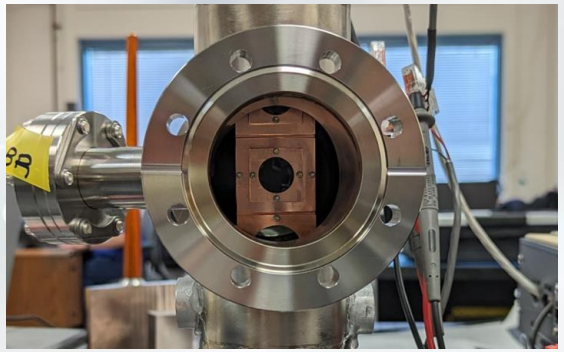
Degrader girder 3D CAD model



Degrader apparatus details

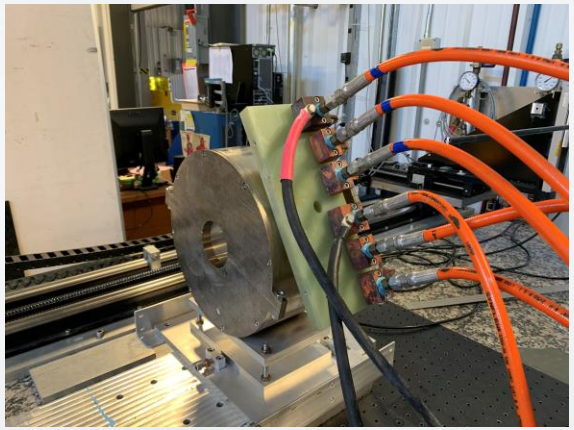
- The degrader has three main components:
- A target ladder with three carbon foils and a YAG viewer
  - Degrades the incoming beam through multiple scattering
  - Foils thicknesses are 1, 5 and 10 microns
- Two collimating apertures with two holes sizes each
  - Defines the maximum transmitted transverse emittance
  - First aperture (A5) hole radii are 1 mm and 3 mm
  - Second aperture (A6) hole radii are 4 mm and 8 mm
- Focusing solenoid
  - Helps with transport of degraded beam

Target Ladder

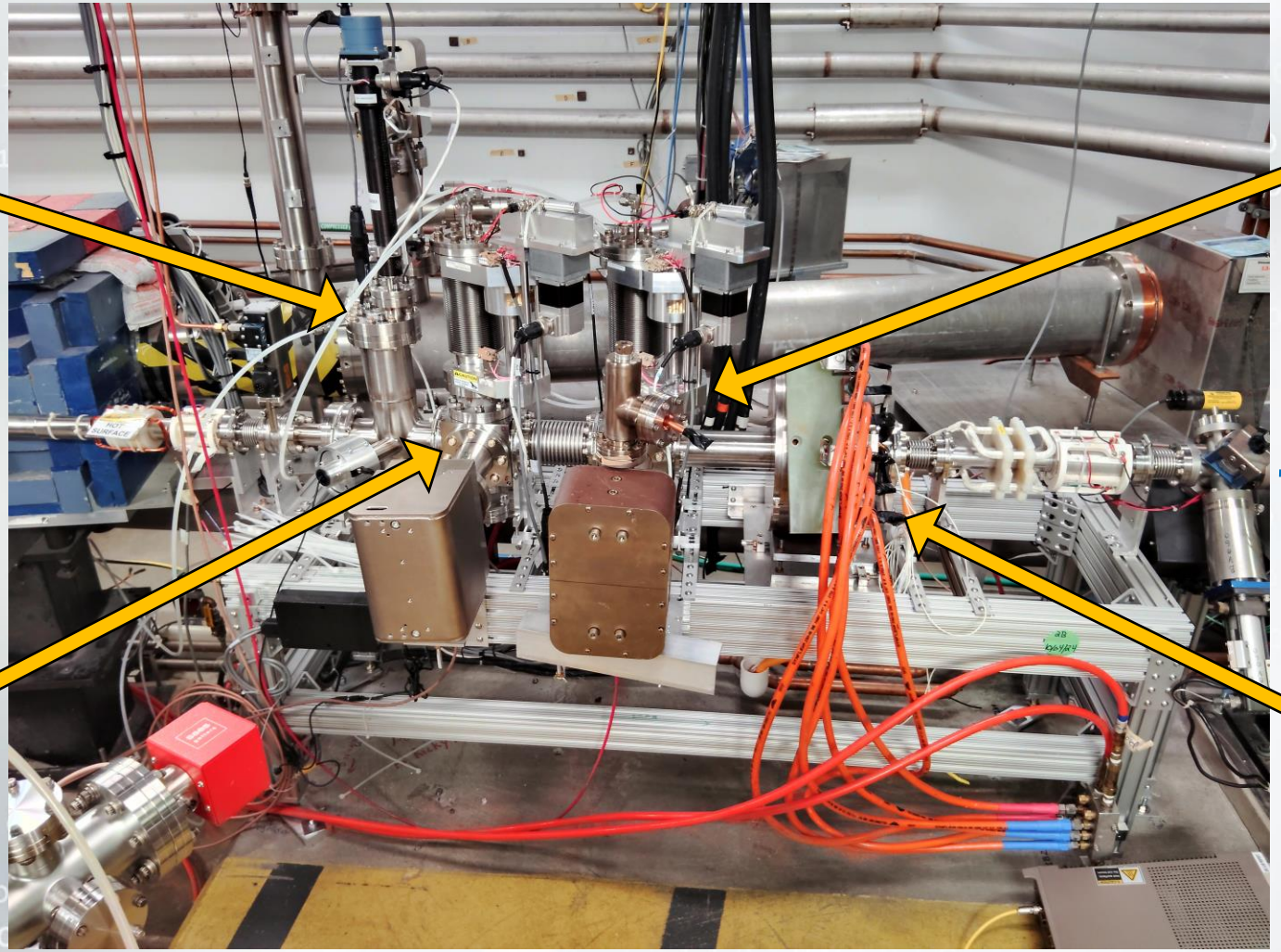


Aperture

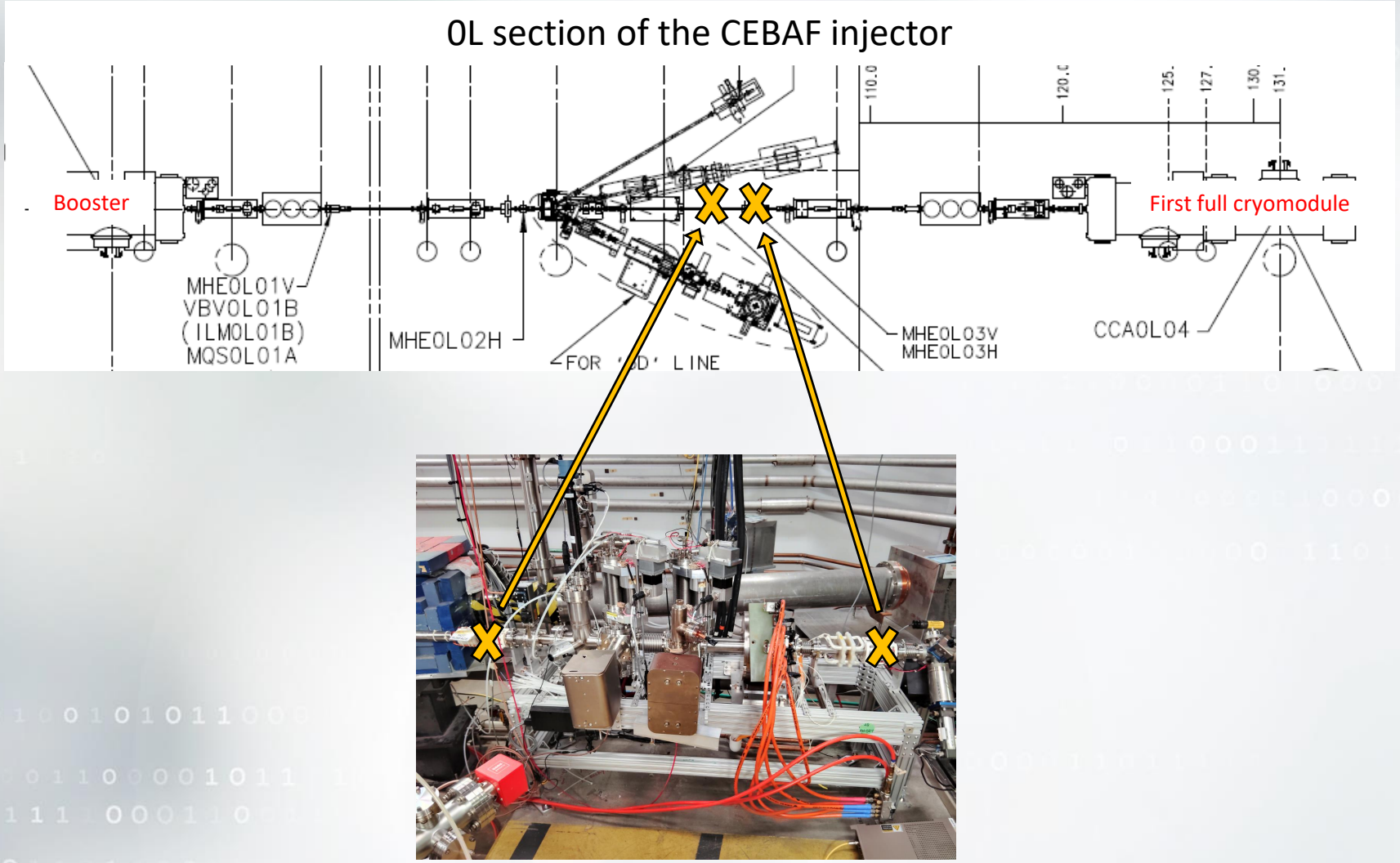
Solenoid



Degrader installation in the CEBAF injector beamline



Degrader apparatus location



Recent Experiment Readiness Review

- ERR was held on February 3rd, 2025
- Information presented:
  - Project description
  - Personnel safety; radiological, electrical, magnetic fields
  - Machine safety; target heating, current limits, interlocks
  - Readiness to operations; control screens, failure modes, operator training.
  - Commissioning and beam studies (more detail in the next two slides)

- Project was finally approved for operations last Thursday!
  - Division safety officer sign off is still missing
  - Commissioning and beam studies to happen at allotted beam study time during the upcoming physics run

Commissioning plan

- Plans to verify degrader works as intended and doesn't affect normal CEBAF operations

- Beam studies:
  - Verify optics response of the solenoid
  - Calibrate aperture current readbacks vs. FC2
  - Scan apertures with beam to map position and size
  - Measure baseline vacuum and radiation levels for each target foil
  - Measure effects of the solenoid residual field before and after initial power-on

Exciting update!

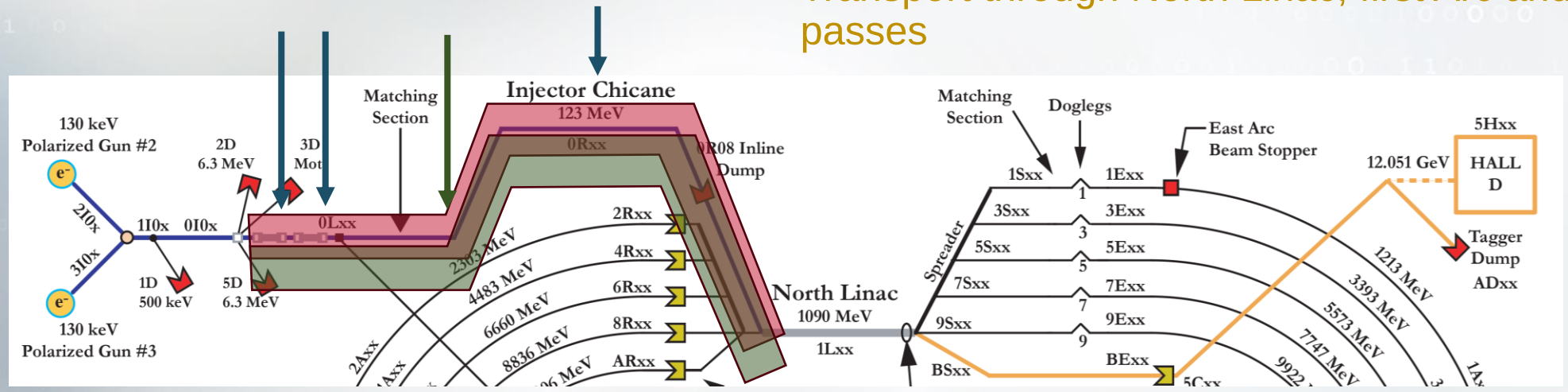
- Commissioning started yesterday!

- Aperture scans with beam also started

View of the first beam on the degrader viewer (ITV0L02A)

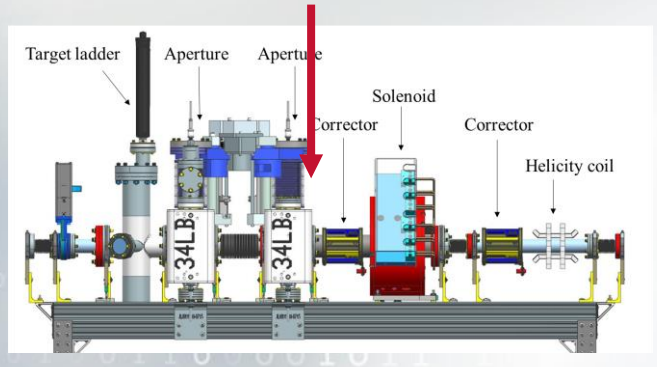
Planned beam studies related to the degrader

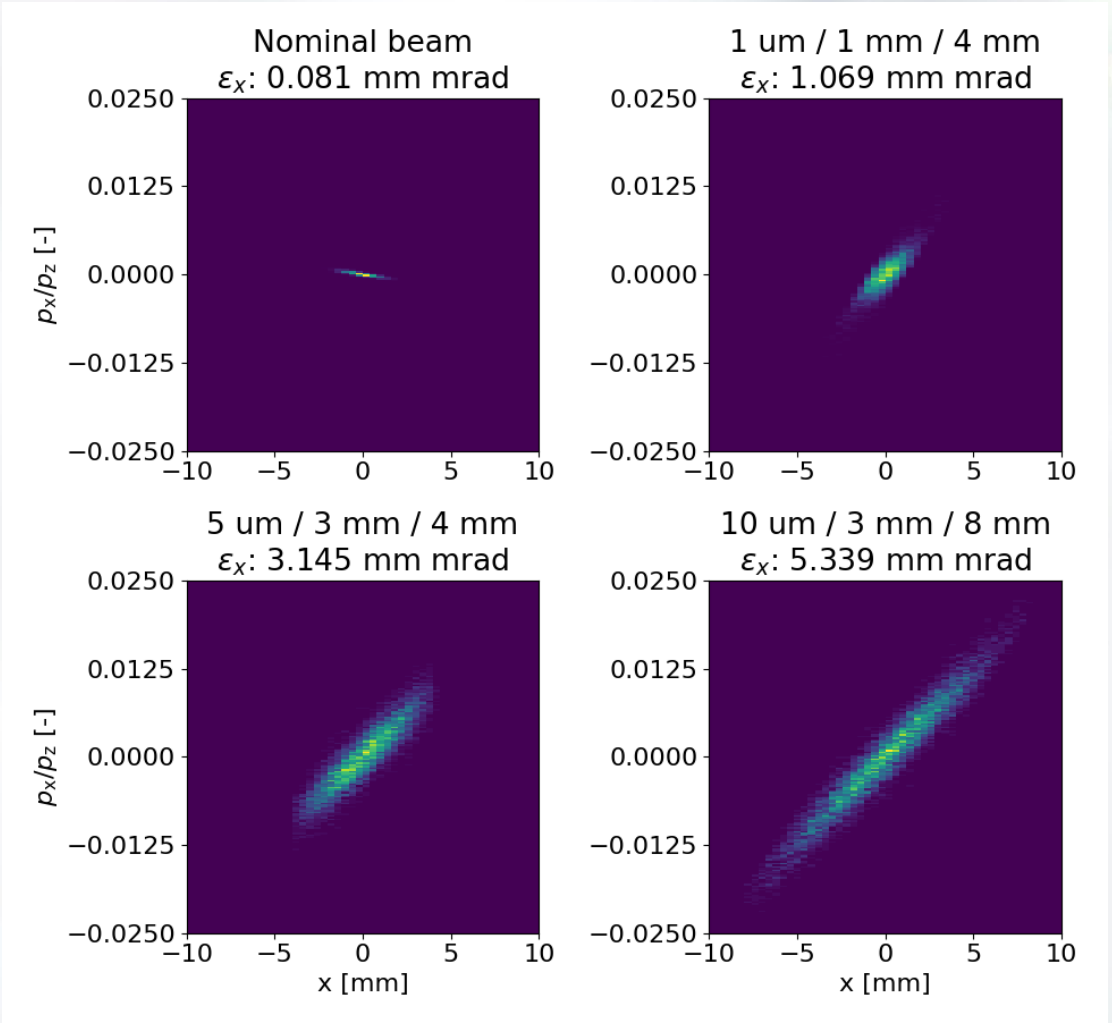
- With nominal beam:
  - Transverse aperture study
    - Mapping the beampipe aperture using correctors
  - Longitudinal acceptance
    - Bunch length and momentum spread limitations in the CEBAF injector
- With degraded beam:
  - In the injector region:
    - Measure optics and emittance from various target-aperture combinations after 0L04 cryomodule
    - Measure energy spread at the 4D spectrometer (before the injector chicane)
  - If there's no issues with the degraded beam transport in the injector beamline:
    - Transport through North Linac, first Arc and further passes



Simulation results – Resulting phase space

- Six different target aperture combinations (only nominal and three of them shown here)
- Transverse phase space right after the second aperture (A6)* →
- Simulated with Geant4



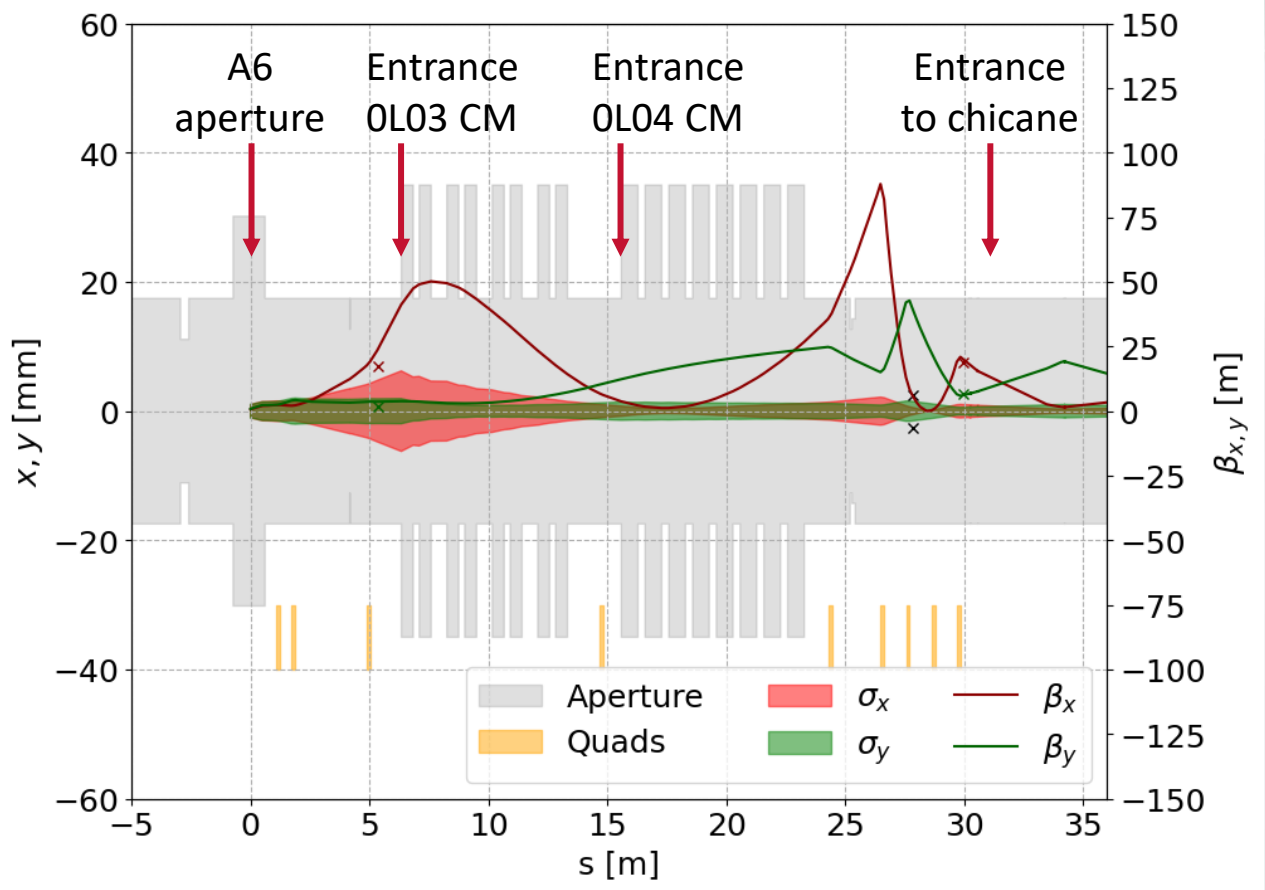


*Preliminary results using old CEBAF optics

Simulation results – Beam matching

- Goal is to find the quad settings that match the optics of the different degraded distributions to nominal optics
- Match in two steps
  - First match in the region before first full acceleration cavity, prioritizing minimizing beam loss in the area
  - Second match before the injector chicane
- Simulation with Elegant

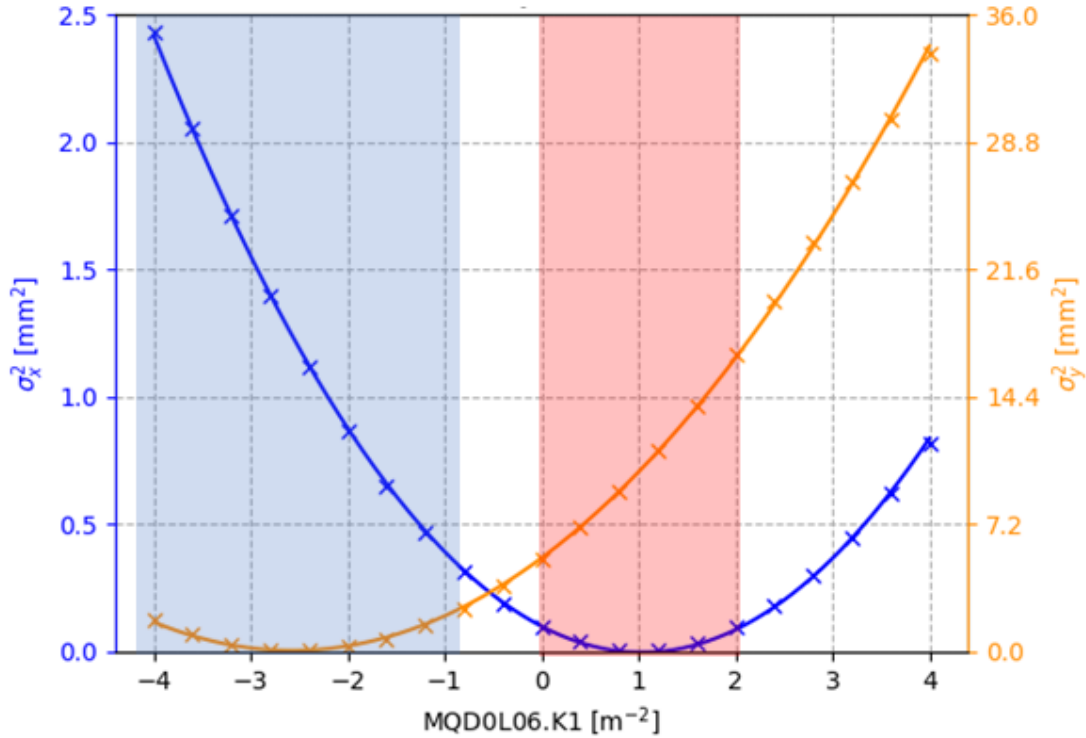
Matched degraded distribution with
(1 um / 1 mm / 4 mm) degrader configuration*



*Preliminary results using old CEBAF optics

Simulation results – Quad scan simulations

- Simulation of emittance measurement downstream of second full accelerating cavity (0L04)
- Vary MQD0L06 focusing strength (K) and register beam size at position of wire scanner
- Simulation with Elegant



	ε_x[mm mrad]	ε_y[mm mrad]
Simulated	0.05618	0.05310
Fitted	0.05599	0.05237

*Preliminary results using old CEBAF optics

Simulation results – Final beam parameters

- Beam tracking through the rest of the injector beamline after matching
- Beam parameters at the end of the injector chicane, at the merging point to main CEBAF, for different degrader combinations
- Simulation with Elegant

*Preliminary results using old CEBAF optics

Momentum spread and geometric emittance for different degrader configurations*

Target-A5-A6 [um-mm-mm]	$\delta p/p$ [$\times 10^{-3}$]	$\varepsilon_{geo,x}$ [nm]	$\varepsilon_{geo,y}$ [nm]
1-1-4	0.051	56.1	53.1
1-3-4	0.068	76.5	78.9
5-3-4	0.105	157.0	137.9
10-3-4	0.124	176.5	153.7
5-3-8	0.198	215.4	184.0
10-3-8	0.272	268.5	234.7

Simulated expected positron geometric emittance and momentum spread after injector Chicane from Y. Roblin JLAB-TN-21-043

	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

Measured and simulated momentum aperture

- Experimental measurements performed by Dennis Turner

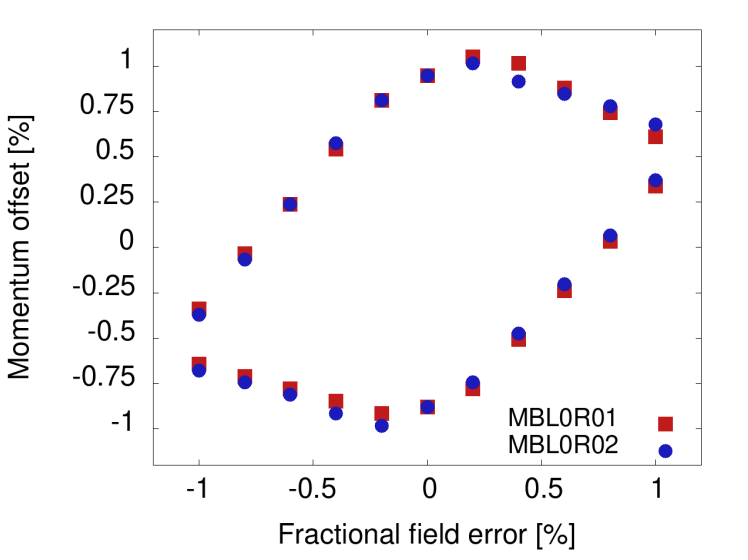
- Measured the momentum aperture in the Injector Chicane giving a momentum offset using the last two cavities of 0L04

- Simulations suggest that asymmetry could be explained by fractional error in the first two chicane dipoles
  - Stray fields from CEBAF dipoles also have an effect

Measurement

p [MeV/c]	Momentum aperture
118.14	$-7.00 \times 10^{-3}, 4.25 \times 10^{-3}$

Simulation



Summary & outlook

- The electron beam degrader has been installed in the CEBAF injector
- Degrader experiment has been approved
- Beam tracking in the CEBAF injector has been simulated with degraded distributions including the transverse aperture
- Preliminary simulations of expected measurements have been started

- Commissioning and degraded beam studies will begin as soon as beam study time is available
- Simulations with the most updated optics will be redone to find optimum beam line magnet settings

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QUESTIONS?

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