ATLAS Beamline Tuning and Characterization

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Introduction and Motivation

The Argonne Tandem Linear Accelerating System (ATLAS) is capable of delivering heavy-ion beams of elements from hydrogen to uranium. The beamline consists of sequential sections with focusing elements that must be tuned to maximize the beam transmission and assure the beam matches the acceptance of components along the accelerator. These sections are:

Low Energy Beam Transport (LEBT)
Radio Frequency Quadrupole (RFQ)
Positive Ion Injector (PII)
PII to Booster Line (P2B)

This study is a comparison of TRACK simulations to data recorded during a run on March 10th 2016. These simulations are the only way for operators to determine where emittance growth and transmission loss occur because there are no emittance diagnostic tools past the Pepper-pot detector. A program was written to extract the beam emittance from quadrupole scan data taken at the end of PII to Booster line.

TRACK Beamline Simulations

Pepper-pot Data Analysis

Data from a Pepper-Pot detector was analyzed to find the conditions of the beam entering the LEBT.

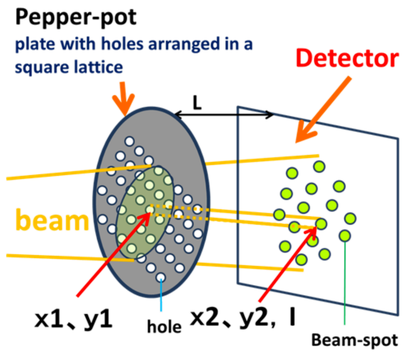
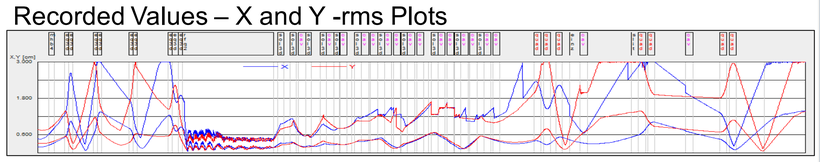


Table 1: Beam Initial Conditions

ϵ_{xn} [pi cm mrad]	0.041 ±0.004
ϵ_{yn} [pi cm mrad]	0.069 ±0.008
α_x	0.23 ±0.06
α_y	0.30 ±0.05
β_x [cm/rad]	44 ±6
β_y [cm/rad]	72 ±9

Focusing Component Optimization Overview

Recorded Values – X and Y -rms Plots



Optimized – X and Y -rms Plots

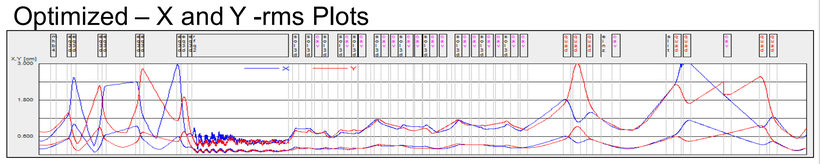


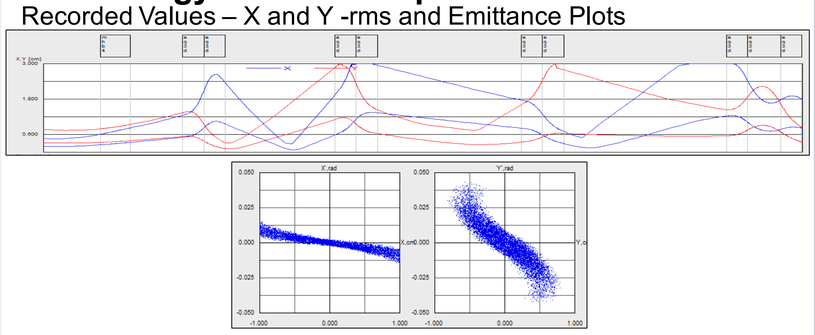
Table 2: Comparison of Transmission Values

	Recorded Values % Transmission	Optimized Values % Transmisson	Measured % Transmission
LEBT	91.5%	100.0%	100.0%
RFQ	31.5%	82.4%	(no measuring device)
PII	92.5%	100.0%	88.1%
P2B	87.97%	99.4%	90.3%

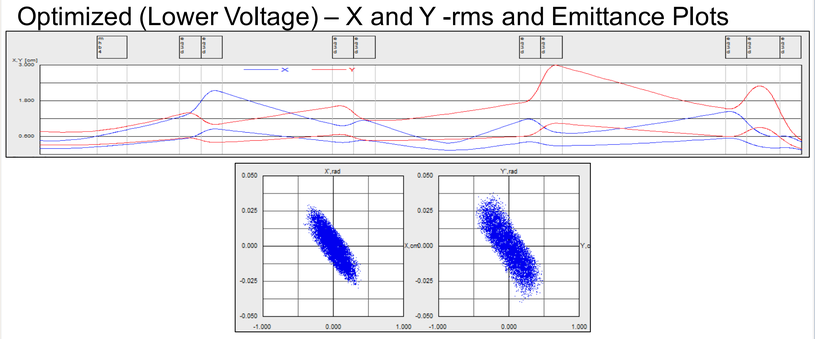
- Focusing elements were optimized in TRACK for better agreement with measured transmission results
- Measured 90.3% transmission to Booster when 100% should be achievable

Low Energy Beam Transport

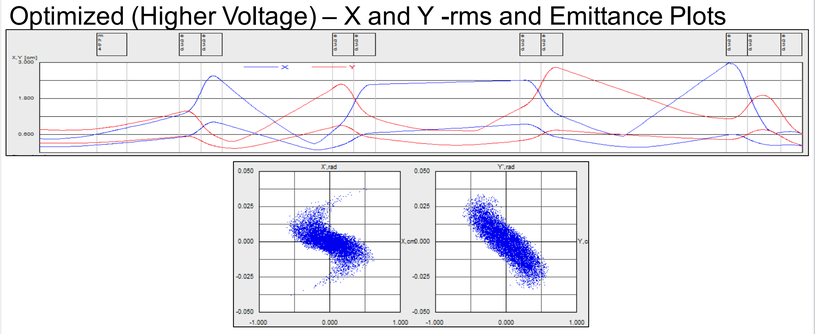
Recorded Values – X and Y -rms and Emittance Plots



Optimized (Lower Voltage) – X and Y -rms and Emittance Plots



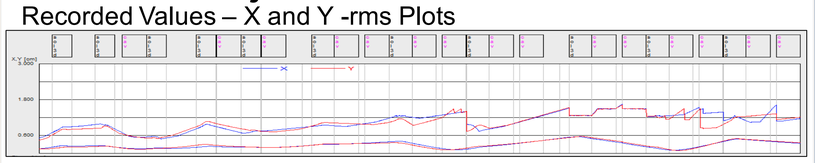
Optimized (Higher Voltage) – X and Y -rms and Emittance Plots



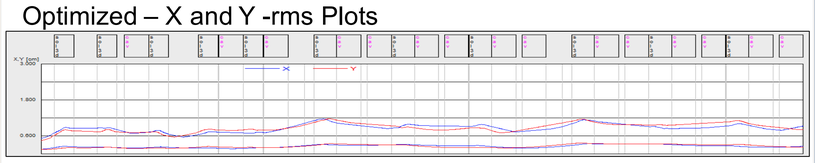
- 42.4% avg. difference between recorded and low voltage optimized quadrupole strengths
- 17.0% avg. difference between recorded and high voltage optimized quadrupole strengths
- High voltage emittance is 31.8% larger than low voltage emittance
- Both low and high voltage optimizations match the acceptance of the RFQ and result in transmission similar to that measured

Positive Ion Injector

Recorded Values – X and Y -rms Plots



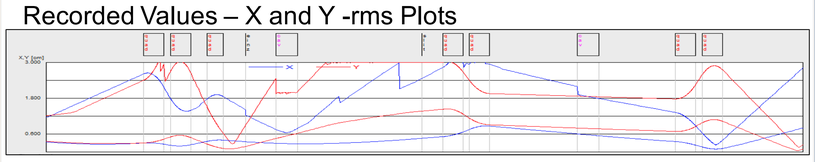
Optimized – X and Y -rms Plots



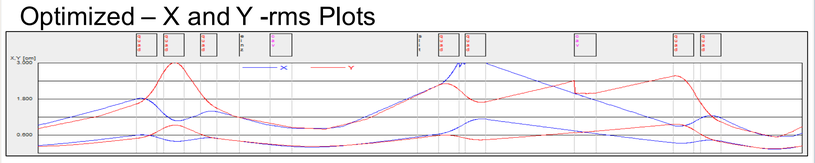
- 20.1% avg. difference between recorded and optimized solenoid strengths

PII to Booster Line

Recorded Values – X and Y -rms Plots

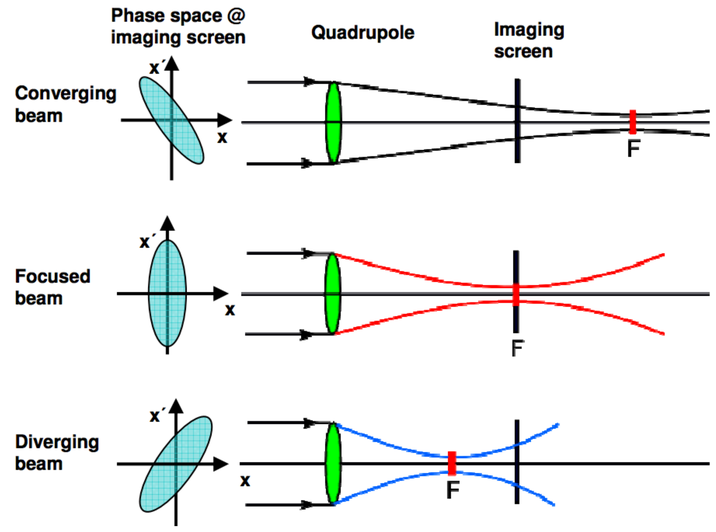


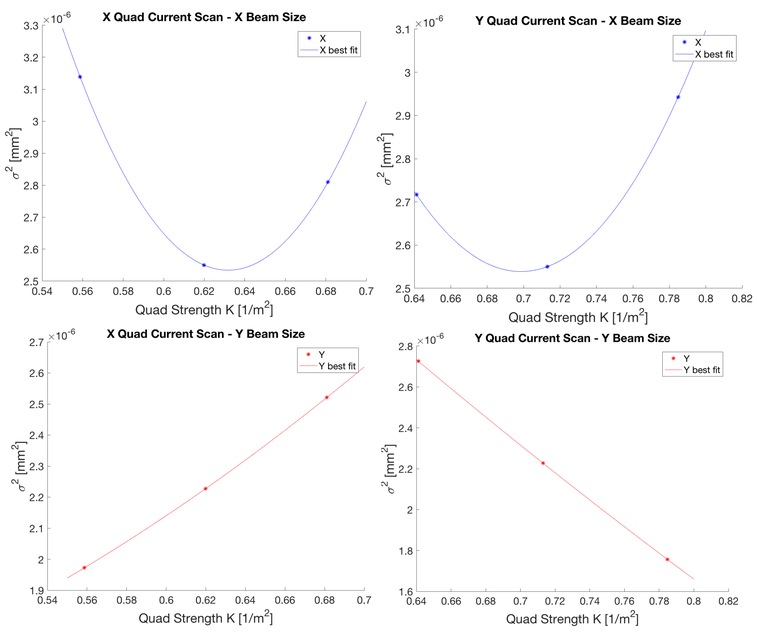
Optimized – X and Y -rms Plots



- 9.8% avg. difference between recorded and optimized quadrupole strengths

Quadrupole Scan Technique





A quadrupole scan is a method to find the emittance from three or more measurements of the rms beam size. There are currently Mathematica and MATLAB versions of code to automate the calculation. More testing must be done however to confirm agreement with experiment.

The X emittance matches with a 37.6% difference. However, the Y emittance was large (206.7% difference) because the three data points far from the parabola's vertex do not allow for accurate fitting. Going forward it would help to take more data points per scan to determine the error in these calculations.

Table 3: Comparison between Initial Emittance at the Pepper-pot and Final Emittance

	$4\,\epsilon_{Nrms}$ Pepper-pot	$4\,\epsilon_{Nrms}$ TRACK	$4\,\epsilon_{Nrms}$ Quad Scan Calculation
X	0.0467	0.0630	0.0403
Y	0.0280	0.0653	0.230

Conclusion

- LEBT quadrupoles should be operated at lower current to minimize emittance growth; this could be a significant cause of the particle loss experienced during runs at higher beam currents
- Agreement between quad scan calculated emittance and TRACK emittance is tentative, as we move further from recorded focusing element values correlation with the increasingly idealized simulation is lost

Acknowledgements

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References

- Nagatomo et al, "Development of a Pepper-pot Emittance Meter for Diagnostics of Low-energy Multiply Charged Heavy Ion Beams Extracted from an ECR Ion Source." *Rev. Sci. Inst.* 87.2 (2016)
- Rudolph, J. "Slice Emittance Measurement Techniques." Helmholtz Zentrum Berlin.