# UNIFORM CURRENT DENSITY FOR BLIP TARGET AT BROOKHAVEN 200 MeV LINAC *

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*Abstract*

Most of the beam from the Brookhaven 200 MeV linac is used for Brookhaven Linac Isotope Production (BLIP). The average current from the linac is up 130 μA and there is a plan to increase the average current in future. To produce uniform current distribution on the BLIP target, we have tried octupoles in the past but it did not produce uniform beam as calculated due to x-y coupling present in the linac.

A beam painting scheme in circular fashion involving two orthogonal dipoles with 90 degrees phase leg at 5 kHz will provide desire current density at the target. This paper discuss beam optics of the BLIP transport line and beam footprint on the target with given constrains.

## INTRODUCTION

The Brookhaven National Laboratory (BNL) 200 MeV drift tube linac (DTL) was built in 1970 [1] with following design parameters for proton: input energy 0.75 MeV, output energy 200.3 MeV, frequency 201.25 MHz, peak beam current 100 mA, beam pulse length (max) 200 μs, RF pulse length 400 μs, pulse repetition rate (max) 10 Hz. Over the 44 years of operations, it has gone through several improvements to increase the average current and reliability of the linac.

At present linac provides $H^-$ beam at 200 MeV for the polarized proton program for Relativistic Heavy Ion Collider (RHIC) and 66-200 MeV for Brookhaven Linac Isotope Production (BLIP). The RHIC program needs two pulses every AGS cycle (~4-5 sec), one for injection into the AGS booster and other for 200 MeV polarization measurements located in the High Energy Beam Transport line (HEBT). The rest of the pulses from high intensity source are delivered to BLIP. Requirements for these programs are quite different and they are following. (1) RHIC: 200 MeV, 500 μA beam current, up 400 μs pulse length, polarization as high as possible and emittance as low as possible, (2) BLIP: 66-200 MeV, 450 μs pulse length, current as high as possible (~45 mA), uniform beam distribution at the target, and beam losses as low as possible.

## TRANSPOT LINE TO BLIP

Layout of the BLIP line is shown in Figure 1 and 2. The total length of the line is 33.5 meters. BLIP line has 10 quadrupoles, two dipoles, two octupoles, eight steering magnet (three horizontal, five vertical), four current transformers, three multi-wires, eight collimators (temperature interlock), ten beam pipe temperature monitors (temperature interlock) and two 0.012 inch thick Be and AlBeMet windows. Following the DTL first two pulse quadrupoles are common for HEBT and BLIP line and rest of eight quadrupoles are dc. First 7.5 degrees dipole is pulse to select beam to BLIP or AGS booster pulse-by-pulse basis and second 22.5 degrees dipole is dc. Beam pipe diameter is increased long the length to prevent vacuum failures. There are several different size of collimator as shown in the Figure 1 and 2 equipped with thermocouples to monitor and inhibit the beam in case of overheating. There are 10 places temperature monitor (thermocouples) along the BLIP line capable of interrupting the beam. The octupoles are located after the 2nd dipole as shown in Figure 2 to flatten the beam profile at the BLIP Target.

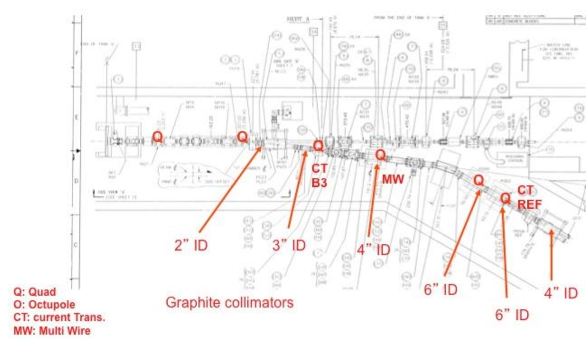


Figure 1: Layout-1 of the BLIP line showing quadrupoles (Q), octupoles (O), dipole magnet (D) and profile monitors.

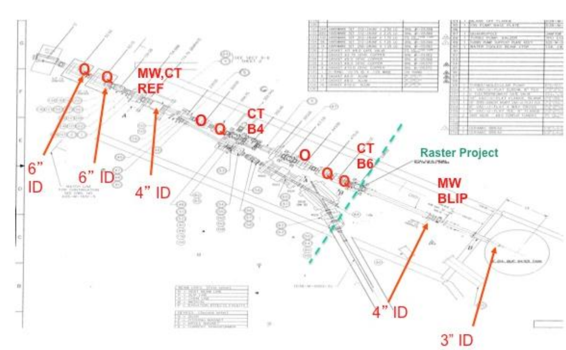


Figure 2: Layout-2 of the BLIP line showing quadrupoles (Q), octupoles (O), dipole magnet (D) and profile monitors

*Work performed under Contract Number DE-AC02-98CH10886 with the auspices of the US Department of Energy
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Figure 3 shows beam envelop along the BLIP line for 40 mA peak current at 118 MeV and phase spaces in transverse and longitudinal planes at beginning and end of the BLIP line. Code used was TRACE3D [2]. Beam is almost de-bunched as it drifts through tank 6 through 9 due to space charge effects. At the end of the BLIP transport line, beam is parallel as it reaches target.

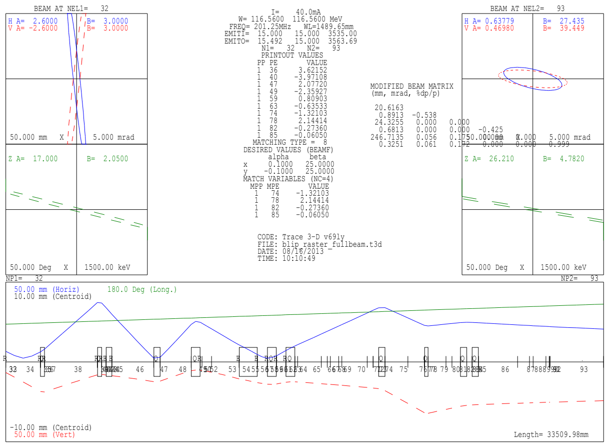

Figure 3: Trace3D output for the BLIP line for 118 MeV. Blue line -X, Red dash line-Y, and Green line -phase width.

Figure 4 shows the beam footprint at the BLIP target. Beam distribution was obtain by irradiating foil for few minutes and counting after one day. Coupling in horizontal and vertical direction can be seen in the distribution.

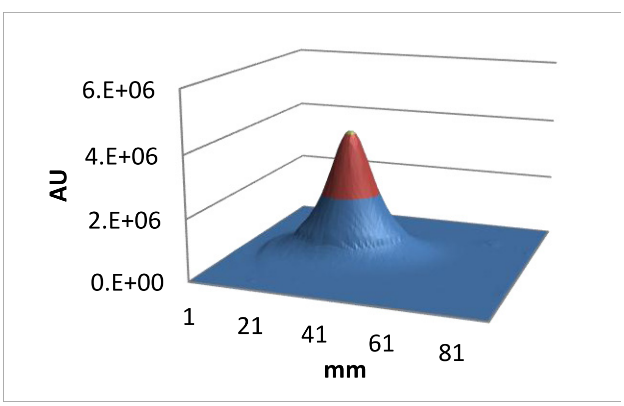


Figure 4: Beam footprint at the BLIP target for 130-µA-beam current.

Octupoles were install in 1996 to flatten the beam profiles at the target [3]. We were never able to flatten the both horizontal and vertical profiles simultaneously. Possible explanation is that x-y coupling is present in the line and due that beam never align to octupoles configuration. Figure 5 shows the beam footprint at the target with octupoles off/on measured with procedure describe about. We do not use octupoles for the isotope production runs.

## BEAM RASTERING FOR BLIP

The average current delivered to BLIP has been increasing steadily as shown in Figure 6. There is a plan to double the linac intensity by doubling the beam pulse length in future [4].

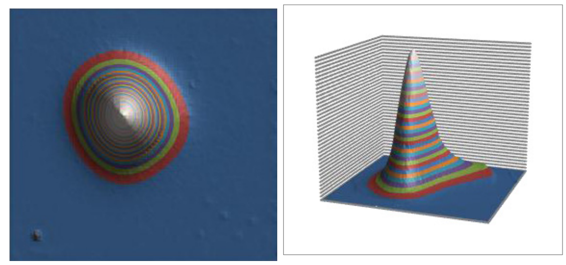

Figure 5: Beam footprint with octupoles off/on (left/right). Transverse coupling is visible in the footprint with couple off (left)

The desire to uniform beam distribution was for long time and Los Alamos isotope production facility (IPF) uses raster system to paint the beam in circular fashion. We decided to adopt raster scheme used by IPF at Los Alamos [5]. The difference between IPF and BLIP raster scheme is following; BLIP uses two raster radiuses while IPF uses only one, creating dip in the current density at the center.

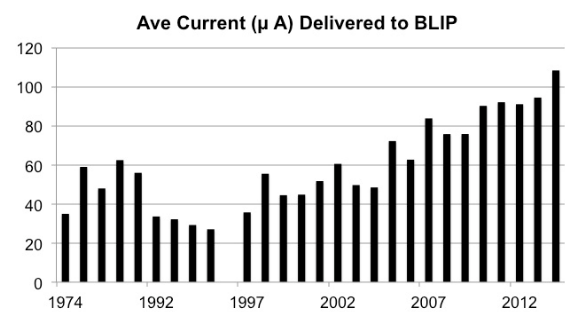


Figure 6: Average beam current delivered to BLIP over the years.

The purpose of the BLIP raster system is to paint the beam in a circular fashion to provide uniform distribution of beam on the BLIP target. Circular painting can be achieved by using two orthogonal dipoles driven by high frequency (~ 5 kHz) power supply at phase difference of 90 degrees. Goal of the raster system to make uniform surface current density within the target and minimize beam out side the target reference zone (diameter 2.205 inches). Figure 7 show the proposed raster scheme for BLIP. Four pulses with 6.5 mm of FWHM painted in circular fashion at Outer Radius (OR) of 13 mm and fifth pulse at Inner Radius (IR) of 6.5 mm. BLIP beam pulse length is 450 µs long at repetition rate of 6.67 Hz. Beam will be make two revolutions in per pulse. The final configuration of raster scheme will depend on the initial




ISBN 978-3-95450-142-7

test with beam. Figure 8 compares the current density between Gaussian and raster beam according recipe describe above.

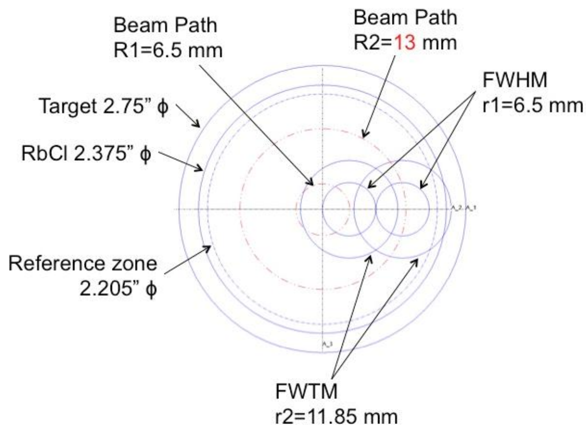


Figure 7: Raster scheme for BLIP. A 6.5 mm (FWHM) beam paint in circular fashion at radius of 13 mm for 4 pulses and 5th pulse at radius of 6.5 mm.

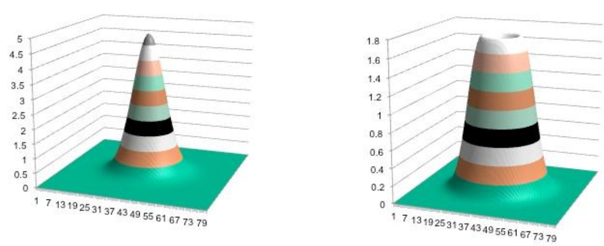

Figure 8: (left) Gaussian beam with FWHM of 18 mm, (right) raster beam as describe in Figure 6. Ordinate is in same arbitrary unit.

Table 1 compares beam distribution at target for Gaussian beam and raster ream according to recipe describe above. The peak density is reduced by 2.7 times while beam outside the target (RbCl, radius 30.2 mm) is about 0.12%. In case of 5 mm off-centred beam, only 0.46 % beam falls out side target.

Raster system will be install last leg of the BLIP line just after the last quadrupole magnet in the line. To monitor and beam inhibit purposes following diagnostic will be installed; two current transformers, two plunging harp, a laser profile monitor, a beam position monitor and two collimator with temperature monitor system. In the event of raster magnet failure beam will be stop within two pulses. We plan to measure magnetic field of the raster magnet and beam centroid by BPM to generate beam inhibit signal in case of magnet failure. Figure 9 shows the last leg of BLIP line with raster system. This upgrade should finish in 2016 [6].

Table 1: Beam Footprint for Gaussian and Raster Beam.

| **Parameter** | **Gaussian** | **Raster** |
|---|---|---|
| FWHM (mm) | 18 | 13 |
| Inner Radius (mm) | 0 | 6.5 |
| Outer Radius (mm) | 0 | 13 |
| # Pulses at IR | 0 | 1 |
| # Pulses at OR | 0 | 4 |
| Peak Density (nA/mm$^2$) | 272 | 100 |
| Beam Outside Target (%) | 0.04 | 0.12 |
| Raster Angle (mr) | 0 | ± 2.2 |
| Beam Outside Target for 5 mm Off Center (%) | 0.13 | 0.46 |

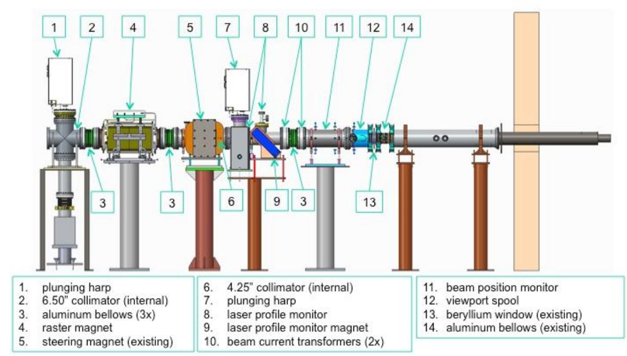


Figure 9: Proposed lay out of the last leg of the BLIP beam line.

## ACKNOWLEDGMENT

We would like to thanks B. Garnett and P. Walstrom of Los Alamos for providing useful information about IPF raster system.

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