NON-LINEAR BEAM TRANSPORT FOR THE LENS 7 MEV PROTON BEAM*

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Abstract

A beam transport system has been designed to carry a high-intensity low-emittance proton beam from the exit of the RFQ-DTL acceleration system to the neutron production target of the Indiana University Low Energy Neutron Source (LENS). [1] The goal of the design was to provide a beam of uniform density over a 6cm by 6cm area at the target. Two octupole magnets [2] are employed in the beam line to provide the necessary beam phase space manipulations to achieve this goal. First order calculations have been performed using TRANSPORT [3] and second order calculations have been performed using TURTLE. [4] Second Order calculations have been done using both a Gaussian beam distribution and a particle set generated by calculations of beam transport through the RFQ-DTL using PARMILA. [5] Preliminary performance results for the beam transport system will be discussed.

INTRODUCTION

Indiana University is in the process of developing a Low Energy Neutron Source (LENS) to produce cold neutrons for a variety of experiments in neutron science. In its current phase the proton beam from the Radio Frequency Quadrupole – Drift Tube Linac (RFQ-DTL) system will be directed to a Beryllium target to produce cold neutrons. The RFQ-DTL was originally designed to produce a proton beam for injection to IU's Cooler Injector Synchrotron and has been modified to produce a 10mA 7MeV proton beam with 20 μs pulse width operating at 20 hZ. Future upgrades will lead to a 50 mA 13 MeV with a 5% duty factor. The design for the beam transport system has been driven by the power level in the future system.

BEAM TRANSPORT SYSTEM

In order to minimize thermal effects of the full power beam, it is desirable to spread the beam out over as large an area as possible at the beryllium target. We are using the concept of introducing third order focusing (octupole magnets) at appropriate locations in the beam line to convert a Gaussian beam distribution into one that is nearly uniform with sharp cutoffs. The idea of using octupoles to modify the beam phase space was first proposed by P.F. Meades [6] and has been discussed at length by a number of other authors [2], [7], [8], [9], [10], [11].

The PC based version of TRANSPORT [3] has been used for the first order calculations to define the basic parameters of the beam line and to determine optimal locations for the octupole magnets. The vertical beam profile (Figure 1) is a minimum at the location of the octupole which will be used to shape the horizontal phase space and thus there will be minimal mixing of horizontal and vertical phase space by the octupole. Commensurately the horizontal beam profile is a minimum at the location of the second octupole which will shape the vertical phase space. The beam line consists of a quadrupole triplet immediately after the exit of the RFQ-DTL, the X octupole, a quadrupole, the Y octupole, a quadrupole double, and a pair of dipoles configured to move the beam to a new axis displaced from and parallel to the original one.

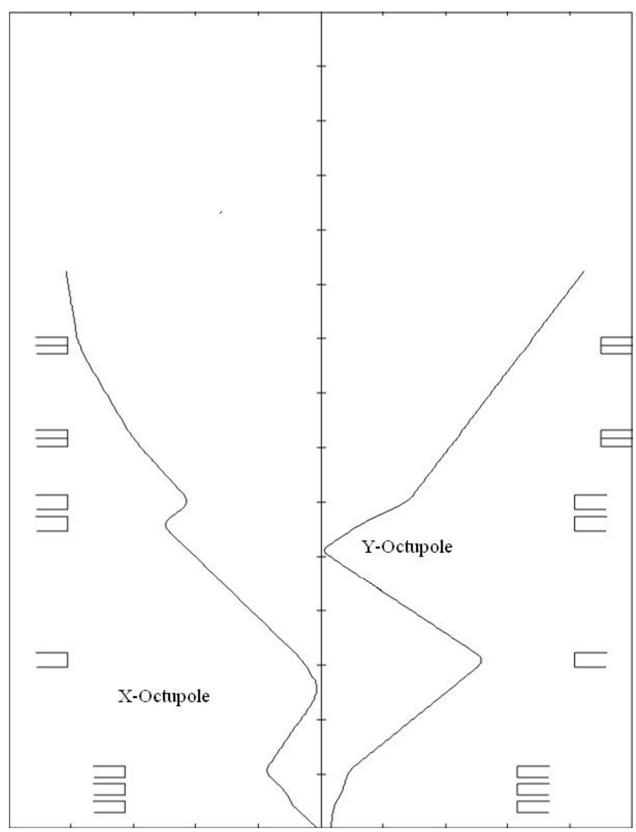

Figure 1: Beam Transport Envelope.

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The PC based version of TURTLE [4] has been used to perform Monte Carlo calculations including the effects of the third order focusing of the octupoles. Figure 2 shows the beam profiles at the target location with the octupoles turned on (upper portion of figure) and then turned off (lower portion of figure). The calculations were repeated using a set of ~100,000 particle trajectories that were the result of ray tracing calculations through the RFQ-DTL using a modified version of the code PARMILA [5].

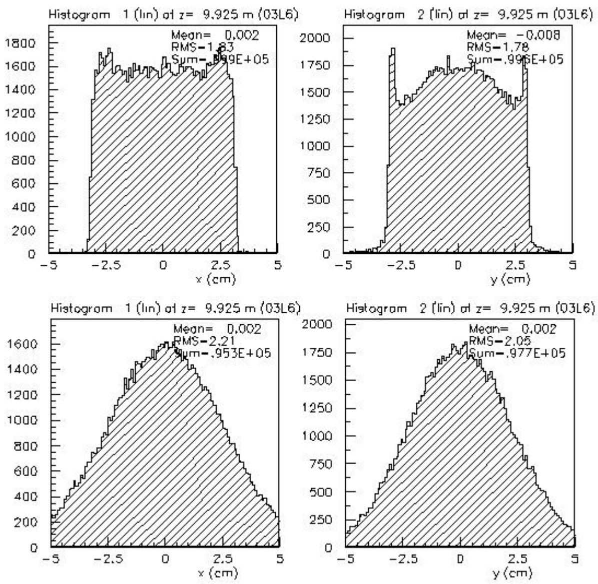

Figure 2: Effect of Octupoles on a Gaussian Beam Distribution. The Octupoles are turned off in the lower half of the figure.

Figure 3 shows the results of that calculation with the octupoles again turned on in the upper half of the figure and turned off in the lower half. The ears at the edges of the vertical profile are caused by overcorrecting with the octupole field and are enhanced relative to the Gaussian case because of the deviations from a Gaussian profile beam.

Two octupole magnets have been fabricated for this beam line with effective field lengths of 19 cm and maximum pole tip field of 6 Kg. The current calculations require less than 1/3 of that field strength.

Because of our concern about the importance of misalignments in the beam line we carried out a number of calculations studying the effects of magnet misalignments on the beam line performance. Figure 4 show the effect on the horizontal beam profile at the target location of a 1 mm horizontal displacement of Q2. The observed slope of the profile is quite typical of the sensitivity to misalignments of the beam line elements. As a consequence of this sensitivity, the magnet support systems have been designed to allow for adjustment of the magnets' positions after installation based on measurements of beam profiles during the commissioning process.

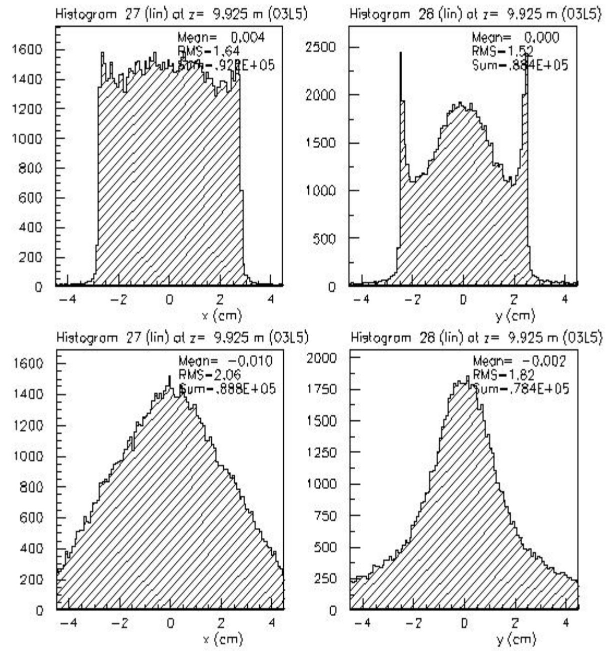

Figure 3: Effect of Octupoles on a Non-Gaussian Beam Distribution.

CURRENT STATUS

The beam line magnets have all been installed and the proton beam has been transported to the Beryllium target and a neutron beam has been produced. [1] The harps being developed for beam profile measurements have not yet been installed and consequently we have not yet attempted to operate the octupoles to manipulate the beam phase space. In our initial tests the proton beam has been transported to the target with no measurable loss of beam.

FUTURE PLANS

When the harps have been installed in the beam line we will begin work on commissioning the octupole system. We want to use the presently available beam with its lower thermal power (10mA 7MeV protons with 20 μs pulse width operating at 20 hZ) to learn how to reliably spread the beam over the full target area as uniformly as possibly and to ensure that beam losses resulting from the increased beam size occur only on the collimators that have been installed for that purpose and have the appropriate thermal capacity.

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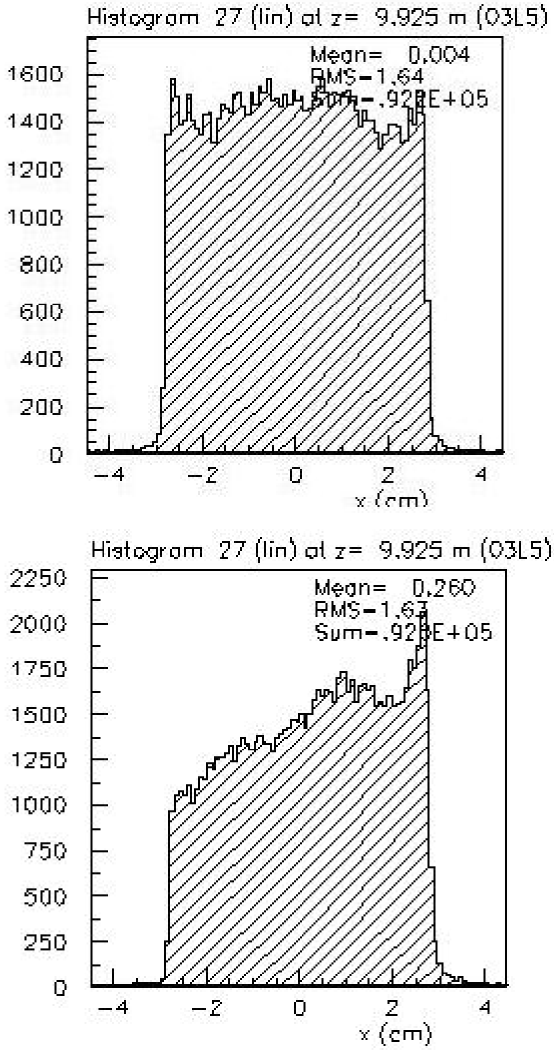

Figure 4: Effect on the horizontal beam profile by a 1mm horizontal displacement of Q2.

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