THE BEAMLINE FOR THE SECOND AXIS OF THE DUAL AXIS RADIOGRAPHIC HYDRODYNAMIC TEST FACILITY[+]

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Abstract

During normal DARHT II[1] operation, the beam exiting the accelerator will be well characterized by its nominal design parameters of 20-MeV, 2000-Amperes, 2-μsec-pulse length, and 3 cm-mr unnormalized emittance. Normal operation will have the beam delivered to a beam dump via several DC magnets. A 2-way kicker magnet is used to deflect portions of the beam into the straight ahead beamline leading to either a diagnostic beamline or to the converter target beamline. During start up and or beam development periods, the beam exiting the accelerator may have parameters outside the acceptable range of values for normal operation. The Enge beamline must accommodate this range of unacceptable beam parameters, delivering the entire 80 KiloJoule of beam to the dump even though the energy, emittance, and/or match is outside the nominal design range.

1. THE BEAMLINE

The beamline system consists of four operationally distinct beamlines: 1) the Enge beamline, 2) the main dump beamline, 3) the diagnostic beamline, and 4) the target beamline. These lines share some components and floor space within the DARHT building. The beamline considered here extends from the exit of the accelerator, some 12 meters before the beginning of the shielding wall. Depending on the magnet settings, the beam from the accelerator is transported to the "Enge dump," a "tuning dump," kicked into a "diagnostic line," or kicked into the "transport line" with eventual delivery to the x-ray converter target outside the shielding wall. The two dump beamlines and diagnostic beamline are constrained to lie within the DARHT shielding wall. The beamline to the converter target penetrates the shielding wall and extends some 5.9 meters from the exit of that wall to the converter target. When ready to produce a radiograph we use the 2-way kicker to cancel the DC field of the kicker bias dipole allowing a section of the beam to pass undeflected into the target beamline. We repeat this up to four times during the 2-μsec-beam duration, producing up to four beam pulses separated by 600 ns. The x-rays are produced when the electrons are tightly focused by the final focusing lens to the correct position on a Bremsstrahlung target.

2. THE BEAM

The beam delivered by the DARHT accelerator consists of a 2-μsec-beam body of 20-MeV electrons. This is preceded by the "beam head," a 0.4-μsec dribble of electrons 8-20 MeV with current increasing from .1 to 2 kA. If a beam head cleanup section is used after the first 8 cells, this head is reduced to a 0.05-μsec dribble of particles in the energy range of 15-20 MeV, current 0 to 2 kA

3. THE ENGE BEAMLINE

The Enge beamline must be capable of handling the entire 80 KiloJoule of thermal energy over a wide range of beam energy, emittance, or other parameters. This beamline is capable of handling and characterizing the beam from the accelerator "no matter" what its energy, emittance, or other parameters are. This beamline consists of a series of solenoid lens leading to an Enge magnet [1] that bends the beam about 90 degree independent of beam energy. The bent beam is then strongly overfocused by a lens and deposited into a beam dump. After the beam energy and emittance is determined, the Enge magnet is turned off and the beamline magnets are set to pass the beam into the tuning dump.

4. THE TUNING DUMP BEAMLINE

The tuning dump beamline also handles the entire 80 KiloJoule of thermal beam energy. A pair of 8 cm diameters beam scrapers separated by 2.0 meters provides a degree of phase space limitation of the beam that can be passed through the kicker. The kicker DC bias dipole deflects the beam by 0.59 degrees (kicker off). This beam enters a quadrupole septum 2.78 meters downstream 3.33 cm off axis. The quadrupole gradient is -13.44 kG/m vertically focusing. The beam offset contributes a 447 Gauss dipole field component that increases the beam

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[1] Second axis of the Dual Axis Radiographic Hydrodynamic Test facility.

deflection angle to 9.5 degrees. 0.2 meters further downstream the beam enters a 1.06 kG dipole septum magnet. The fringe focusing of this magnet combined with the focusing of the quadrupole septum is sufficient to reduce the energy density of the 20-MeV 2-μsec beam to less than 600 Joule/cm^2 at the beam dump. The 20 MeV beam is bent by 45 degrees, the beam head is spread between 45 and 85 degrees.

5. THE DIAGNOSTIC BEAMLINE

The diagnostic beamline handles up to 4 KiloJoule of thermal energy. This beamline consists of a magnetic spectrometer with better than a 1/4 percent momentum resolution, and an emittance measuring diagnostic. After accurate determination of the beam parameters, the target beamline magnets are set and the diagnostic beamline turned off. The beam can then be kicked into the line for delivery to the x-ray target.

6. THE TARGET BEAMLINE

Beam sections are kicked into the straight-ahead beamline through the center of the quadrupole septum. Three additional quadrupoles re-establish a round beam matched to solenoid transport. This beam passes through a 4 dipole chicane with maximum offset of 7 cm to prevent target ejecta from coming back into the accelerator. The final focus lens is an 18 kG pulsed solenoid with a 10 μsec flat top to reduce power consumption. The beam final focus on the target is 0.1 meters beyond the exit of that lens. The beam must be focused to smaller than 1.3 mm FWHM time integrated.

7. TARGET IMAGE SIZE SENSITIVITY

We have investigated the sensitivity of the final spot to variations in initial beam parameters. Figure 1 shows the final target beam radius vs. beam momentum, accelerator exit radius, accelerator exit match, and beam emittance. The nominal design operating points is at 20.505 MeV/C, 0.5 cm, and 3.0 cm-mr.

8. OPERATING GOAL

The high power 80 KiloJoule beam from DARHT cannot be allowed to hit the wall. This is why we have developed several beamlines allowing the successively more accurate characterization of the beam all the while, delivering that beam to the high power beam dumps. If you are going to transport an 80 kJ beam through some transport space, you better know its parameters, for if you don't and that beam hits something, the vacuum becomes atmosphere and you have a problem. The beamline sections following the kicker-septum only handle beam pulses of 4 or less KiloJoule of thermal energy.

In this spirit, we attempt to accommodate beams with emittance an order of magnitude above the design value, with energy that is “unknown.” This is necessary so that during tune-up and debugging periods of operation, the machine can be adjusted without having the beam blasting holes through the vacuum wall. Figures 2, 3, and 4 show the beamline layout and beam profile for the tuning dump and target beamlines [2].

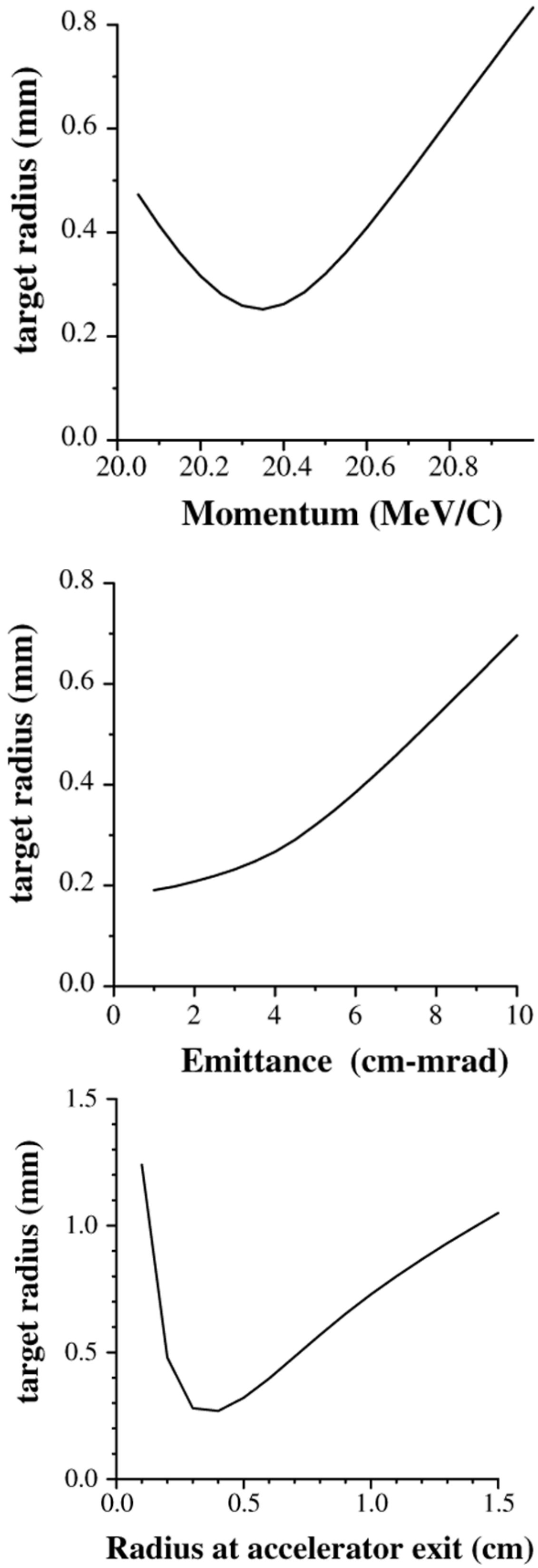

Figure 1.

References
[1] "Achromatic Magnetic Mirror for Ion Beams," Harold A. Enge, Review of Scientific Instruments, April 1963, page 385-389.
[2] "Transport – An Ion Optic Program LBL Version," Arthur C. Paul, Feb. 1975, LBL-2697. Modified at LLNL for X11 Graphics and DARHT application.
[3] "The Mechanical Design for the Second Axis Beam Transport Line for the DARHT Facility," L. R. Bertolini, et al, to be published in the proceedings of this conference

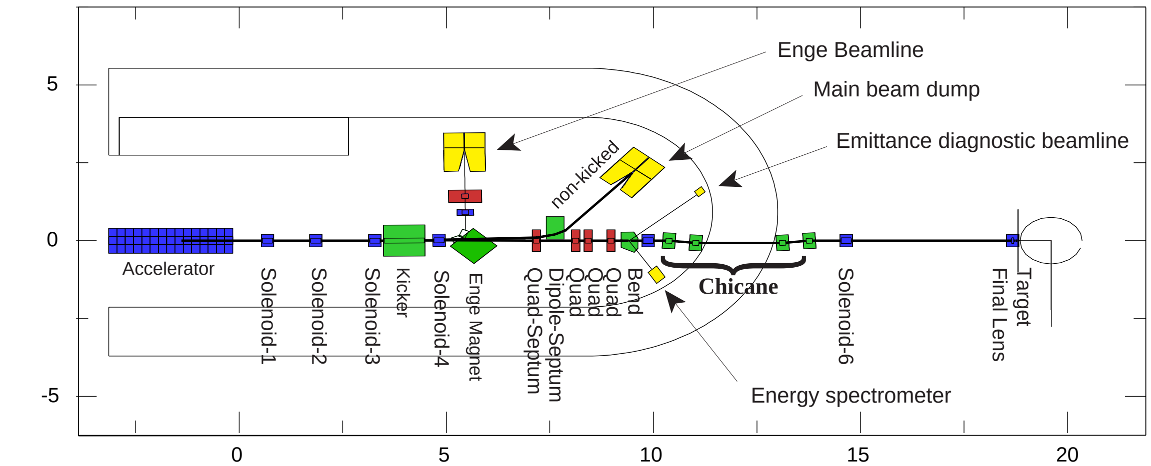

Figure 2. Layout of the proposed transport elements in the DARHT-II hall.

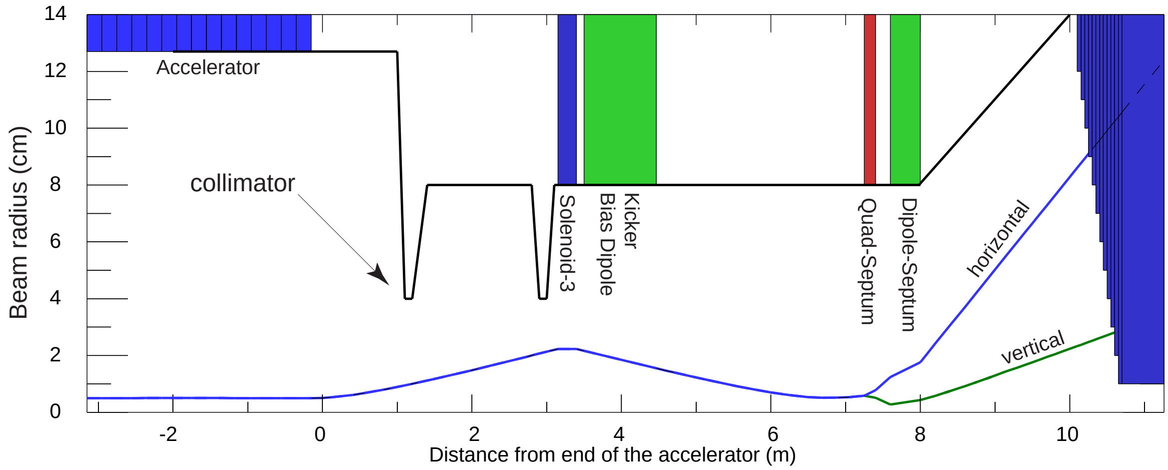

Figure 3. Transport for the non-kicked portion of the beam from the end of the accelerator to the beam dump.

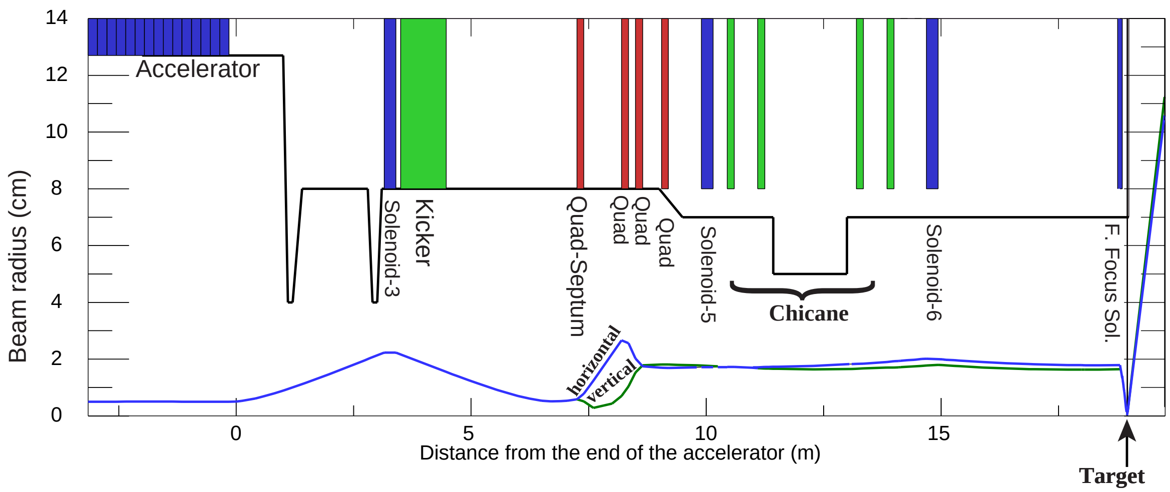

Figure 4. Transport for the kicked portion of the beam from the end of the accelerator to the target.