THE FERMILAB HINS TEST FACILITY AND BEAM MEASUREMENTS OF THE ION SOURCE AND 325 MHz RFQ*

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Abstract

The Fermilab High Intensity Neutrino Source (HINS) project is intended to test new concepts for low-energy, high-intensity superconducting linacs. HINS initial design consists of a 50 KeV ion source, a 2.5 MeV Radiofrequency Quadrupole (RFQ) followed by room temperature and superconducting spoke resonator acceleration sections. At present, a proton ion source and the 325 MHz RFQ, followed by a beam diagnostics section, have been operated with beam. This paper will discuss the beam measurement results for the proton ion source and for the 325 MHz RFQ module and improvements to the beam diagnostic instrumentation. In addition, this paper will discuss the role of HINS as a test facility for the development of beam diagnostic instrumentation required for future high-intensity linacs.

INTRODUCTION

The world community is proposing a number of new high-intensity, multi-GeV, superconducting RF (SRF), proton and H- accelerators for many different applications from particle physics to Accelerator Driven Systems (ADS) to spallation neutron sources [1]. The high energy community has identified the intensity frontier as one key areas of research for the future of particle physics. Under this guidance, Fermilab is proposing Project X, which has as its core element a 3 GeV SRF CW linac, accelerating H- to 3 MW beam power [2]. In order to address the low-energy needs of such a linac, Fermilab has started the High Intensity Neutrino Source (HINS) project [3].

The HINS accelerator project is intended to pursue advanced low-energy linac technologies. HINS has undergone various changes, but is presently being adapted for the testing and design of key low-energy elements for Project-X. Details of the HINS program can be found in [3]. Table 1 gives a list of nominal beam parameters for HINS.

Table 1: HINS Nominal Beam Parameters

Particle	H+ then H-	
Nominal Bunch Frequency/Spacing	325 3.1	MHz Nsec
Particles per Pulse	37.5	E13
Avg Pulse Current	up to 20	mA
Pulse Rep. rate	2.5/10	Hz
Pulse Length	3/1	Msec
Bunch Current	32	mA
Bunch Intensity	6.1 98	E8 pCoul

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The HINS project initially identified four basic goals [3]:

1. Demonstrate beam acceleration using superconducting spoke type cavity structures.
2. Demonstrate the use of high power RF vector modulators to control multiple RF cavities by a single high power klystron for acceleration of a non-relativistic beam.
3. Demonstrate beam halo and emittance growth control by the use of solenoidal focusing.
4. Demonstrate a fast bunch-by-bunch beam chopper.

In addition, HINS is being developed as a test facility for beam diagnostic research and development for Project X.

ION SOURCE AND LEBT MEASUREMENTS

As part of the initial HINS configuration, a 20 mA, 50 keV, pulsed proton source has been developed. This proton source is followed by a solenoid focusing low energy beam transport (LEBT). The dual solenoid LEBT design allows for beam matching between the proton source and the HINS 2.5 MeV RFQ. Initial measurements of the RFQ performance however indicated poor beam transport through the RFQ [4]. Further studies seem to indicate that the proton source is being dominated by non-proton species. Figure 1 show the test setup used to characterize the proton source. This test setup uses a spectrometer magnet to measure the source beam energy and to characterize the proton source species.

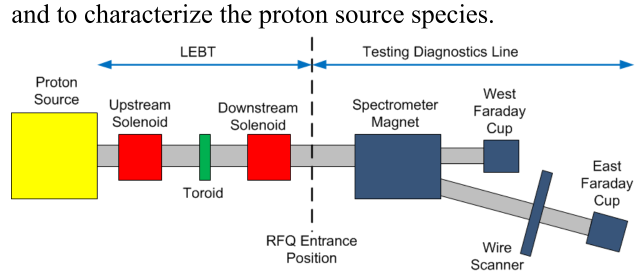

Figure 1: Ion source and LEBT measurement setup.

Figure 2 is a series of measurements of the proton source showing H+, H_2+ and H_3+ production. The figure shows three plots of the east Faraday cup, at the end of the spectrometer line, versus the current in the spectrometer magnet. For each plot the downstream solenoid is optimized to transport each species to the Faraday cup. Measurements indicated that the proton source produces ~ 40% protons and ~30% H_2+ and ~30% H^3+. Even though the LEBT is optimized to transport protons from the source to the RFQ, the LEBT toroid current measurement includes contributions from the non-proton component.

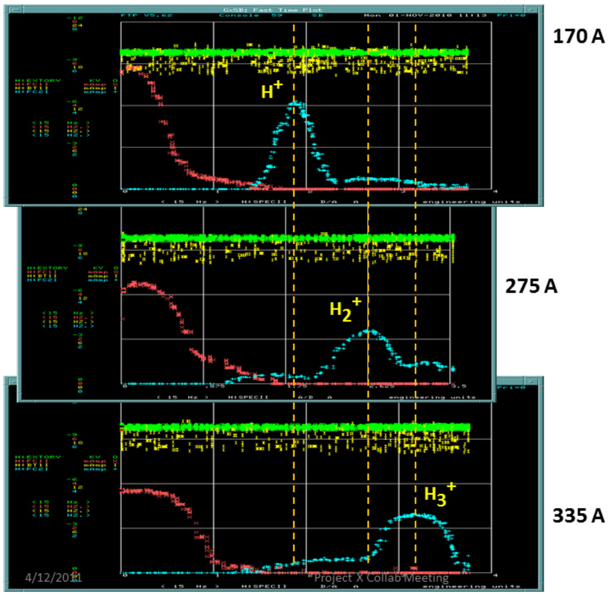

Figure 2: Measurement of ion source species content. Plots show Faraday cup intensities versus spectrometer magnet current. The LEBT downstream solenoid has been optimized to focus individual species to the east Faraday cup. Red curves show west Faraday cup current (straight line) while blue curves show east Faraday cup current (spectrometer line).

INITIAL RFQ MEASUREMENTS

Initial beam measurements with the HINS 325 MHz, 2.5 MeV RFQ have been made and presented [4]. The proton ion source was operated as 500 μs pulses at a rate of 1 Hz. The RFQ was operated without cooling. Because of this RF power was limited to 50 μs pulses. Detailed information on the operational experience with the RFQ can be found in [5].

Figure 3 show the HINS beamline and beam diagnostics used for the initial RFQ measurements. Although this diagnostics layout allows for a number of important measurements of the RFQ, it also has a number of short comings. Specifically, the diagnostics line has no focusing elements and suffers from transverse beam blow-up. This effect, coupled with the beam current toroid being too far from the RFQ output, prevents accurate beam current measurements. The transverse beam blow-up also prevents the measurement of transverse emittance. In addition, absolute beam energy measurements by time-of-flight were not possible due to lack of unique bunch structure in the beam pulse. Finally, the diagnostics line has no longitudinal bunch shape measurement capability.

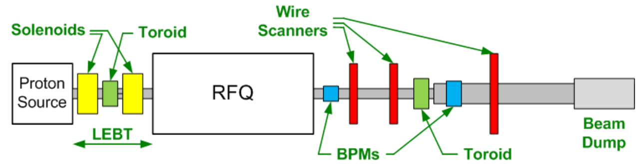

Figure 3: HINS beamline and diagnostics for initial RFQ measurements.

Improvements to the Beam Diagnostics Line

A number of improvements have been made to the HINS beam diagnostics line. First, a beam current toroid has been mounted to the output flange of the RFQ. This toroid is inside of the RFQ vacuum vessel. Second, quadrupole focusing has been added right after the RFQ to prevent transverse beam blow-up. Third, a spectrometer magnet has been added to allow for absolute beam energy and energy spread measurements. In addition, a number of new beam diagnostic tools have been added to the line. Figure 4 is a block diagram of the upgrade HINS beam diagnostics line.

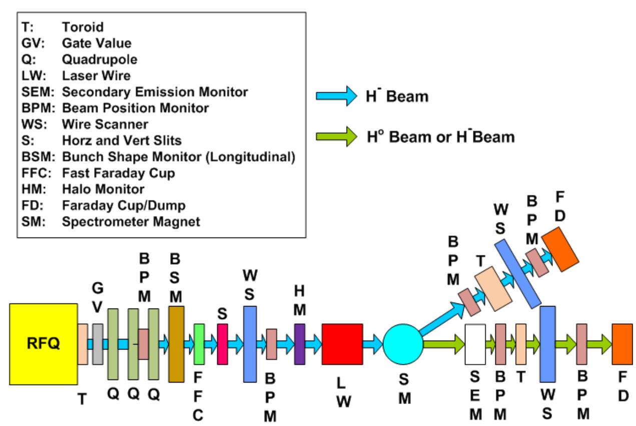

Figure 4: Block diagram of HINS improved diagnostics line for RFQ measurements and future HINS accelerator configurations.

This new diagnostics line allows for a number of beam measurement devices as well as space for R&D of new diagnostics for Project X. Transverse emittance measurements will now be made by (1) slit-wire scanner technique and by (2) quadrupole scan technique. Also, two longitudinal bunch shape detectors have been added. The first is a high-bandwidth faraday cup and the second is a “Feschenko” style scanning wire bunch shape monitor [6]. Figure 5 shows the front-end of the new diagnostics line installed at HINS.

BEAM DIAGNOSTIC R&D AT HINS FOR PROJECT X

Configuration of this new diagnostic line allows for a number of new diagnostic R&D projects for Project X. Because of the SCF structures of Project X, beam intercepting wire monitors pose a danger for the superconducting cavities. Transverse profile measurements of H- beams have been made with lasers, utilizing photo-detachment, with minimal interaction with the beam [7]. Fermilab will use HINS as a test facility for development of a “standard” transverse laser profile monitor for Project X.

Similar to laser-based transverse profile measurements, longitudinal profile monitors based on lasers offer the possibility of non-intercepting monitors. The Spallation Neutron Source (SNS) has made longitudinal profile measurements in their MEBT using a femtosecond Ti:Sapphire laser [8]. Fermilab is collaborating with LBNL to develop and test a longitudinal profile monitor with short-pulse (~ ps) laser systems at HINS [9].

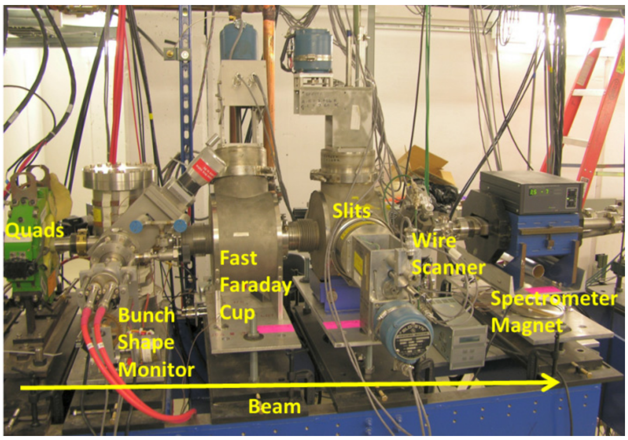

Figure 5: Front-end of the new diagnostics line installed at HINS.

HINS AS A USER TEST FACILITY

HINS is a unique linac injector R&D facility with access to high-intensity, low-energy beam for user projects. HINS allows for the development of Fermilab projects for Project X as well as provide a facility for external collaborators. Potential project areas for HINS include beam diagnostics R&D, low-energy beam dynamics studies and beam chopper development.

SUMMARY

Beam measurements have been made on the HINS 325 MHz, 2.5 MeV RFQ. These initial measurements revealed a number of short comings with the beam diagnostics. Improvements and additions to the diagnostics line have been made and are undergoing beam tests. In addition, HINS has also been presented as a possible low-energy, high-intensity accelerator test facility for R&D activities.

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