Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory

Title
A high transmission analyzing magnet for intense high charge state beams

Permalink
https://escholarship.org/uc/item/25g1x3b4

Authors
Leitner, M.
Abbott, S.R.
Leitner, D.
et al.

Publication Date
2002-06-11

eScholarship.org Powered by the California Digital Library
University of California

A HIGH TRANSMISSION ANALYZING MAGNET FOR INTENSE HIGH CHARGE STATE BEAMS *

M. Leitner, S.R. Abbott, D. Leitner, C. Lyneis LBNL, Berkeley CA, 94720, USA

Abstract

The low energy beam transport (LEBT) for VENUS will provide for extraction, mass analysis and transport to the axial injection line for the 88-Inch Cyclotron. The new LEBT was designed from the beginning to handle high intensity beams where space charge forces strongly affect the transmission. The magnet has a unique design with specially shaped poles to apply sextupole correction in both the horizontal and vertical plane.

1 INTRODUCTION

The advances in ECR ion sources that are being achieved by increasing the operating frequency and magnetic confinement have made the design of the LEBT (Low Energy Beam Transport) more challenging. For the VENUS (Versatile ECR for Nuclear Science) project [1,2] the LEBT was designed to take full account of the space charge forces present in the multi-charged beam extracted from the strong solenoidal fields which are produced by superconducting magnets. The two main design goals were to first provide good resolving power and matching into the 88-Inch Cyclotron injection line and second to produce a high intensity beam with small emittance that matches the baseline requirements for the RIA (Rare Isotope Accelerator) driver linac. [3] While VENUS will be used to boost the energy and intensity of beams from the cyclotron, it will also demonstrate the feasibility of producing intense high charge state heavy-ion beams needed for the RIA driver linac.

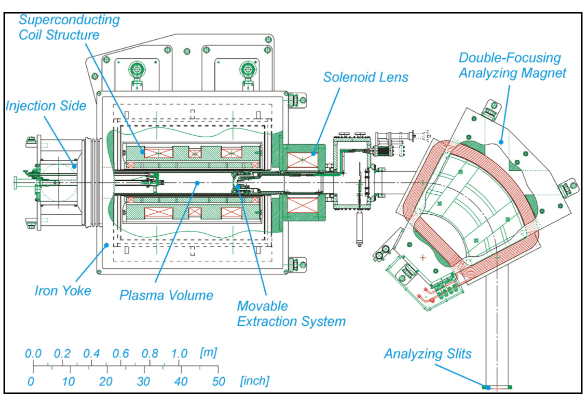

Figure 1: Plan view of VENUS and the LEBT.

2 SIMULATION AND DESIGN

The low energy beam transport (LEBT) for VENUS will provide for extraction, mass analysis and transport to the axial injection line for the 88-Inch Cyclotron. Unlike the LEBT for the AECR-U, the new LEBT [4,5] was designed from the beginning to handle high intensity beams where space charge forces strongly affect the transmission. Several computer codes were used in the simulation and design process including IGUN, GIOS and KOBRA.

Figure 1 shows the basic components of the LEBT. After extraction at voltages up to 30 kV, a Glaser lens matches the beam into the 90-degree analyzing magnet. It was decided to match directly into the analyzing magnet rather than to provide a waist in front to reduce the space charge effects. In the current design, the sole purpose of the solenoid lens is to adjust the angle of the beam going into the magnet. Since a single solenoid lens cannot control the actual beam diameter and the beam divergence simultaneously, a large magnet gap was chosen to accommodate the highest anticipated beam intensities. The required field strength of the solenoid lens is quite high for extraction at 30 kV. Future high field superconducting ECR ion sources could incorporate the first magnetic focusing element of the LEBT into the superconducting magnet structure, which would allow greater design flexibility and might lead to cost savings.

Figure 2: Computer model of the pole shape for the analyzing magnet illustrating the wings used to correct the sextupole terms.

The 90-degree analyzing magnet [7] is double focusing with specially shaped poles to provide simultaneous corrections in the horizontal and vertical planes. The main parameters of the magnet are summarized in Table I. The shaping of the poles is an improved design based on an ANL-magnet [6]. As shown in Fig. 2 upward wings are used at the entrance and exit of the magnet to generate a field gradient that increases quadratically from the location of the central ray and correct the sextupole term in the vertical plane. The downward wings in the central section generate a quadratically decreasing field to correct the sextupole term in the horizontal plane.

Table I: 90-degree analyzing magnet parameters

Bending radius	51 cm
Vertical gap in vacuum chamber	16 cm
Horizontal acceptance	30 cm
Maximum Rigidity	0.18 Tm
Maximum Power	21 kW

Figures 3 and 4 show that for beams filling 50% of the vertical gap the sextupole aberrations are corrected and this provides a normalized rms emittance as low as .04 pi mm mrad, which is well within the baseline design for the RIA driver linac. In addition, this higher order correction improves the mass resolution of the system, which is important for its operation with the cyclotron.

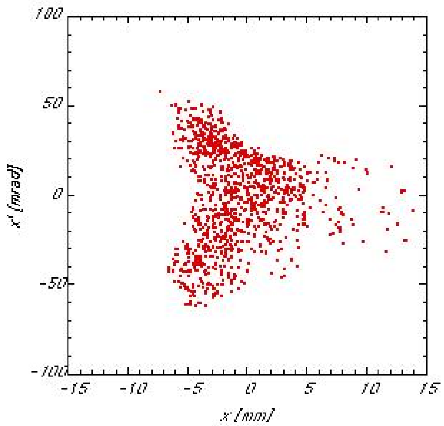

Figure 3: Results of particle tracking showing the transverse size without sextupole correction.

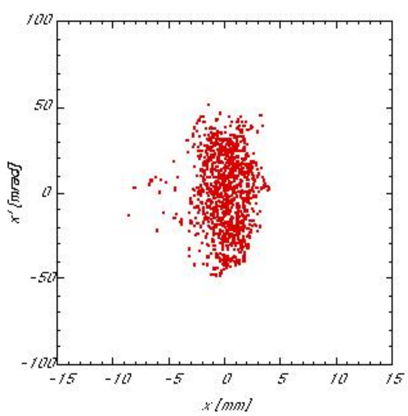

Figure 4: Particle tracking after sextupole correction.

The initial design of the poles used a smoothly varying shape to produce the desired quadratic terms. In order to reduce the complexity of machining the pole face, the number of cuts necessary and the associated costs, the curvature of the wings was reduced and their shapes simplified. Figure 5 shows the quadratic field component calculated for the final design compared to the ideal case. The poles were then cut on a numerically controlled horizontal milling machine. In Fig. 6 the upper pole is shown during the rough cut machining.

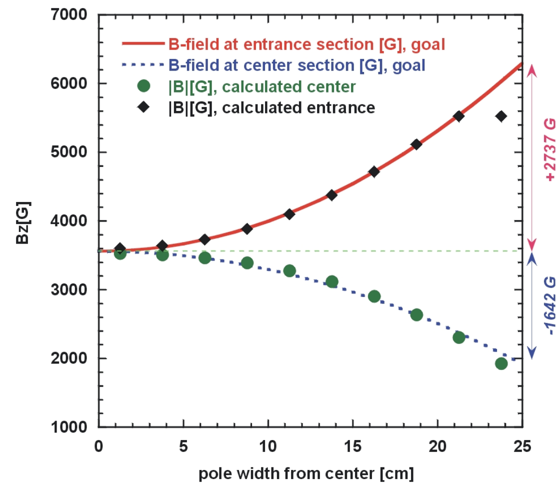

Figure 5: The calculated midplane magnetic field profiles for the final pole shape compared to the desired magnetic field profiles.

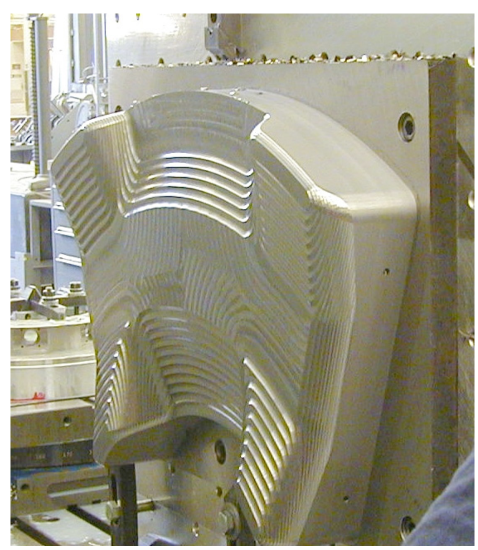

Figure 6: One of the magnet poles after the rough cut on the numerically controlled horizontal milling machine.

STATUS AND TEST PLANS

Installation of the LEBT on the vault roof of the 88-Inch Cyclotron was completed in June 2002 and the final components of the extraction system were installed in July. Beam tests with VENUS at 18 GHz are planned to begin in August. The emittance scanner [5] which now has both the horizontal and vertical axes instrumented will be installed on the LEBT just after the analyzing slits so that the emittance of the beam can be characterized.

REFERENCES

[1] Lyneis, C.M., Z.Q. Xie, and C.E. Taylor, Review of Scientific Instruments **69**(2), 682 (1998).

[2] C.M. Lyneis, M.A. Leitner, D. Wutte, C.E. Taylor and S.R. Abbott, Proc. *2001 International Conference on Cyclotrons and their Applications*, May 12-17 2001, East Lansing, Michigan

[3] K.W. Shepard, J.R. Delayen, C.M. Lyneis, J.Nolen, P. Ostroumov, J.W. Staples, J. Brawley, C. Hovater, M. Kedzie, M.P. Kelly, j. Mammosser, C. Piller, M. Portillo, Proceedings of the 9th Workshop on RF Superconductivity, Nov. 1-5, 1999 Santa Fe, New Mexico.

[4] Wutte, D., M.A. Leitner, C.M. Lyneis, C.E. Taylor, Z.Q. Xie, Proceedings of the *Eighth International Conference on Heavy-Ion Accelerator Technology (HIAT 1998)*, Argonne, Illinois, October 5-9, 1998, p. 384.

[5] D. Wutte, M.A. Leitner and C.M. Lyneis: Physica Scripta T92, 247, 2001

[6] E. Minehara, W. Kutschera, P. Den Hartog, P. Billquist, and Z. Liu, RSI 57, (5), 742 (1986)