MODELING AND TUNING THE BEAM LINES OF THE THE SVEDBERG LABORATORY

V. Ziemann, The Svedberg Laboratory, Uppsala, Sweden

Abstract

We briefly describe efforts to model the TSL beam lines that allow fast representation of the current beta functions, steering and beam sizes on the control computers. The beam matrix of the input beam delivered from the Gustav Werner Cyclotron is measured by quadrupole scans and subsequently matched semi-automatically into the beam lines. Moreover, experience with delivering beams to different experiments in a interleaved mode is reported.

1 INTRODUCTION

The Gustav Werner Cyclotron [1] delivers a wide variety of ions to experiments in nuclear physics and material sciences and also to biomedical groups for cancer treatment. Moreover, about 40 % of beam time is devoted to filling CELSIUS [2]. In order to reach the various experimental and treatment areas, the beam passes through about 200 m beam lines. The basic layout is shown in Fig. 1. The A-line is used for radio-isotope production, the B- and D-line predominantly for nuclear physics experiments, the C-line for biological experiments, the G-line for proton therapy, the I- and K-line for material sciences, and the F-line brings the beam to CELSIUS. The various experiments are served with beams ranging in mass from hydrogen to xenon with various charge states.

In order to quickly and reliably set up the beam lines for their respective experiments we initiated a program to develop new standard beam optics and methods to match the varying input beam from the cyclotron into the beam lines. These tools and methods will be discussed in this report.

Some of the experiments only use the beam a fraction of their alloted time and we started using simple switching programs to serve parasitic users in other beam lines in the remaining time. We discuss the means of how this is achieved.

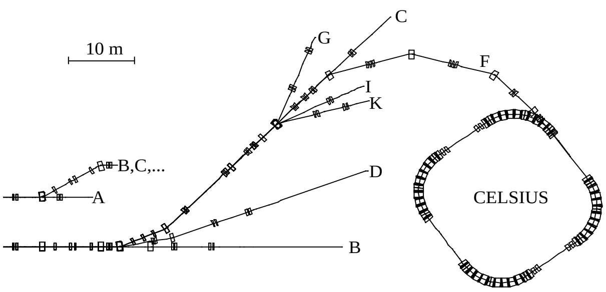

Figure 1: Layout of the TSL Beam Line Complex

2 MODELING

The geometry of the beam lines is stored in a MAD [3] input file that resides on a cluster of centrally administered VAX/ULTRIX computers. We did not install MAD on the control computers to avoid excessive demands on memory which would slow down the response time. However, choosing the MAD input language as the starting point allows using the capabilities of MAD to calculate the positions of elements. Furthermore the SURVEY output format is easily convertible to other formats. We use it to generate a flat input file for every unique section of the beam lines. These input files are then transferred to the SUN/Solaris control computers where we use a library of home-grown FORTRAN subroutines that allow calculation of beta functions, steering, and many other beam dynamics features.

The flat input file is updated from the current magnet's currents by a program that reads the currents, converts them to magnetic fields or gradients using a database of calibration constants and writes a new input file representing the current state of the beam line.

In order to obtain information about the beam size in the beam line complex we need to know the properties of the beam delivered by the cyclotron. We will describe that next.

3 EMITTANCE MEASUREMENTS

Both horizontal and vertical emittances of the beam exiting the cyclotron can be measured within a few minutes by scanning the first two quadrupoles and observing the spot size on a downstream wire scanner, named “walking pin”. The incoming beam matrix can be determined in a simple linear fit from these measurements. In practice the operators only have to tune the quadrupoles to produce small spots on a screen near by the “walking pin” and then start a program that varies the quadrupoles and calculates the incoming beam matrix, without further human intervention.

In practice the calculated emittances have to be interpreted with a grain of salt, because the measurements often look like those shown in Fig. 2 which shows a scan of $^{40}Ar^{11+}$. Clearly the beam has a large tail which makes any interpretation in terms of rms quantities, such as emittance, problematic. Preliminary attempts to quantify the tails [4] by fitting gaussians with different widths to the left and right hand side of the distribution are under way and we plan to use this information to tune the cyclotron and reduce the tails. This will make the further use of the derived quantities more reliable.

Having determined the input beam and having a faithful representation of the current state of the beam lines we use standard matrix techniques to propagate the input beam through the beam lines and display the beta functions, beam sizes, and orbits (with a grain of salt, or two) on the control computers.

4 AUTOMATIC MATCHING

Using the input beam and the computer representation of the beam line, we can use a matching routine that is part of the above mentioned FORTRAN library and tune the first few quadrupoles to produce standard beta functions at certain reference points. These standard beta values can be achieved irrespective of the beam that comes out of the cyclotron. The parts of the various beam lines that lie downstream of a reference point can then be set to standard lattices that just need to be rescaled to the proper energy, but do not depend on the beam from the cyclotron. This strategy was tested successfully using 180 MeV protons to set up the beams for the biomedical areas.

There remain, however, a few problematic points: 1) the bending magnets saturate at high excitations and the calibration constants are unreliable, 2) the beam's energy is not known very accurately without dedicated energy measurement, 3) the fringe field of big bending magnets affects the focusing of the beam which is difficult to model accurately, and 4) the already mentioned fact that the beams often have sizable tails that take the measurement of the incoming beam matrix dubious. More work is needed to refine modeling until it can be trusted to set up the beam lines automatically.

5 BEAMLINE SWITCHING

In order to allow easy switching between beam lines we wrote several simple programs. One implements the Multiknob concept and reads a file which specifies selected elements and the values to which these elements should be set. Another program reads the time in the CELSIUS cycle and executes specified commands at certain points in that cycle. Combining the two programs it is very easy to switch a bending magnet and a few additional elements such as quadrupoles and steering magnets at specified times.

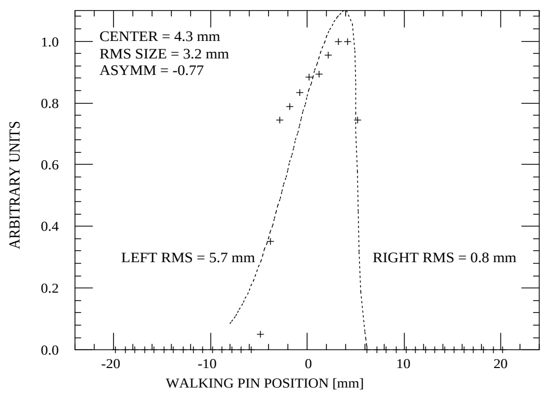

Figure 2: Vertical scan of $^{40}Ar^{11+}$.

When running CELSIUS the beam is only needed at CELSIUS during injection and by switching we can deliver beam to other users when not filling CELSIUS. This was tested and found to work reliably over a 20 hour period.

The switching programs are also successfully used to deliver beams to nuclear physics experiments parasitically while treating patients in the biomedical beam line. The biomedical group only uses the beam for a small fraction of their total alloted time for setting up and the actual treatment.

Note that the newly implemented methods are software-only methods and provide added functionality at no extra cost.

6 ACKNOWLEDGEMENTS

The author wishes to thank K. Gajewski, L. Thuresson, and the controls group for providing a very powerful base of soft- and hard-ware to work with. Discussions with D. Reistad and the CELSIUS crew are gratefully acknowledged. I wish to thank the Cyclotron oprators for sharing their experience about setting up the beam lines with me.

7 REFERENCES

1. S. Holm et al., *New Accelerators in Uppsala,* Physica Scripta, **34**, 513, 1986.

2. T. Bergmark et al., *Recent Activities at CELSIUS,* these proceedings.

3. H. Grote, F. C. Iselin, *The MAD Program,* CERN/SL/90-13(AP).

4. W. Spence, F. Decker, M. Woodley, *Transverse Tails and Higher Order Moments,* Proceedings of the 1993 Particle Accelerator Conference, Washington, D.C., 1993, p. 3576.