A SUMMARY OF BEAMLINE OPERATIONS WITH THE A1200

J.W. Stetson

1998 marked the last full year of operation with the A1200 fragment separator as part of the high-energy beam line system. Logs of this year show 80 beamline tunes of primary beam and 40 secondary beams, but not all such tunes were considered interesting enough to record. A one-word description of these activities is "routine". What follows is a brief history of what was done to achieve routine operation.

In 1991, beamline tunes were done essentially by hand with minimal software assistance. (An exception to this was the program "BOSS", which controlled only the A1200 beamline segments). Predictions of optics codes were not in routine use and the principal tuning parameter was a "small spot" on the viewers. Long setup times (as long as 24 hours) and difficulty achieving the desired conditions on the experimental target indicated another approach was needed. A process was begun to correct this situation, including the following measures:

1) Generate predicted magnet field values with the TRANSPORT optics code.
2) Code software to set, scale, store and compare to calculated values the settings of all beamline magnets (BL_SETUP).
3) Modify TRANSPORT input files to achieve good results with respect to real world values. Particular attention was paid to setting the A1200 magnets correctly since every beam passes through it and the optical conditions for correct particle separation are strict.
4) Consistently start each tune with predicted rather than saved settings.
5) Expand the set of available optics solutions to include the wide range of experimental requirements.
6) Code software to include the above features with a graphical interface that made it more accessible to users. (BARNEY)

The guiding principle remained a practical one, namely to achieve "good enough" quality beam on target as rapidly as possible. For example, initial setups with the A1200 showed disagreement between the TRANSPORT-predicted settings for quadrupoles and what was in practice required to achieve the desired beam properties. Steps taken to remedy this problem included: a) revising CAD drawings to reflect the as-installed situation rather than the design ideal, b) re-measuring magnetic fields in a quad doublet and triplet to improve the current-to-field conversions in the control programs, c) more precise calibration of magnet power supplies, d) changing the effective lengths used in the calculation, e) using the computer code COSY INFINITY [2] to include higher-order terms and edge effects not possible to do with TRANSPORT. These steps resulted in improvements, but not enough to achieve the degree of predictability desired. The final "solution" was to develop a list of so-called "fudge-factors" that simply took the predicted fields of a few quadrupoles and shifted them by a fixed percentage before loading into the beamline elements. Doing this allowed the A1200 to be set correctly from values otherwise predicted by TRANSPORT the first time every time with no further adjustment. The reason fudge-factors were required was never determined.

Similar "good enough" principles were used in the philosophy of tuning. A fully proper way of tuning would be to take the extracted beam, measure its properties over some distance, back-calculate to determine the initial starting conditions in 6-dimenasional phase space, forward calculate to get settings achieving the desired conditions on target, measure the actual beam envelope and re-calculate a correction to final settings. Given the constraints on time, manpower, and money, this was deemed impractical and a single, key simplifying assumption was made. This assumption was that the beam, tuned to a small spot at the object of the optical system (usually the "mid-acceptance" location located in the A1200 target box, or the "low acceptance" location located upstream of that), was uncorrelated and dispersionless (x|theta = y|phi = x|dp = theta|dp = 0). This assumption has proven "good enough" to eliminate the possible need for new optics for each beam.

A routine tune of 1998/99 is mostly a product of thinking and typing with very little dialing. First the optical condition is selected based on requirements of the experiment. With over 100 tunes in the library of predictions, new calculations are seldom needed. Two files are generally required, a small file for the elements from the cyclotron to the object, and another for the object to the experimental target. A third file is required for the S800. The fact of having 3 possible objects and 11 targets requires a large library of optics files to cover a significant set of options. Then the desired rigidities are determined. Beam rigidity is altered by any change of charge or energy loss while passing through a foil or detector. Each group of magnets that could see a certain rigidity is called a beamline segment and depending on the location of the experiment, the beam can traverse up to 8 segments. For reasons of background, beam purity and identification, the beam is almost always "stripped" at the object with a 1 mg/cm^2 foil. Often there will be 2 or more other changes in rigidity as well. Knowing the approximate rigidities and optics, the magnet currents can then be set. Also based on magnetic rigidity the exit dipole is set by BL_SETUP or BARNEY.

The first step with beam is to center the it with small changes in the K1200 magnetic channels, leaving the exit dipole at the predicted value. Then, using two reference points, the beam is centered along the line before the object using the exit dipole and 3 degree bending magnet. Small changes in quadrupole values bring the beam to a small spot at the object. (An exception to this is where one wants a round beam with a non-gaussian distribution for uniform irradiations. In this case, the beam is larger in order to illuminate an aperture.)

The next step depends on whether the beam is a secondary (fragment) beam or not. If it is, the particle ID is conducted and the beam purified in the A1200 with a wedge and slits as described elsewhere.[3] If not, the beam is centered through momentum-defining slits after the first 22.5 degree bend and the bending field is read by NMR probes. In both cases, one now has a final rigidity with which to set the post-A1200 magnets.

The largest remaining uncertainty is setting of the bending magnets in beamlines following the A1200 because they are generally without reliable field-measuring devices. If the beam is visible on the scintillating viewers, then tiny adjustments are made to bring the beam to the reference centers. If not, then either a relatively intense "pilot" beam at a rigidity near to that desired is guided to target and the lines are scaled to the final rigidity, or the riskier task is undertaken, to see the beam electronically only at the final target.

Finally, either visually (sometimes aided by a image-intensifier) or electronically, the final spot size is adjusted by tweaking by a couple percent a pair of quadrupoles near the end of the beam transport system. It is entirely typical to have the entire set of quadrupole values from object to target to remain at the predicted values with the exception of this last pair. There is essentially no quad tuning.

Tuning times vary a lot depending on the complexity of the requirements and of particle ID. For reference, a plain generic primary beam tune from scratch usually takes less than 1 hour. However, a marked tendency was noted over 1991-1998 period to push the limits of our beam-controlling abilities by designing more aggressive experiments, challenges that were for the most part met. One group, for example, brought their forward-angle detectors from 5.0 degrees to 0.5 degrees during this period, yet recorded a drop in the background rate from 1:10 to 1:5000.

An important final point about routine beamline operation at the close of the A1200-era that can hardly be overstated is the fact that having a trustworthy and reproducible tuning process not only reduces the normal setup times and increases beam quality on target, it helps immensely in troubleshooting problems when things go wrong. In other words, if the beam doesn't show up at the expected place in the expected way, there is a hardware problem that tuning won't solve.

It’s expected that a similar program with the A1900 and new beamlines will achieve similar results.

References

[1] K.L. Brown, et. al. TRANSPORT: A Computer Program for Designing Charged Particle Beam Transport Systems. CERN 80-04, 1980.

[2] M. Berz. Computational aspects of design and simulation: COSY INFINITY. Nucl. Instr. and Meth. A298:473, 1990.

[3] B. M. Sherrill et al., Nucl. Instr. And Meth. B56/57 (1991) 1106.