A REVIEW OF BEAM LAYOUTS AND EXPERIMENTAL FACILITIES FOR SECTOR-FOCUSED CYCLOTRONS

E.L. Kelly Lawrence Radiation Laboratory

In this paper, I shall confine myself primarily to medium energy sector-focused cyclotron facilities, although much of the material has more general application. I shall not attempt to catalogue all the experimental layouts in the field, but rather to emphasize some general ideas.

From Dr. Livingston's paper¹⁾, it is clear that this type of cyclotron has indeed arrived. The spiral ridge cyclotron is a very versatile precision accelerator with an external beam quality comparable to that of a van de Graaff machine. It is therefore appropriate in considering a cyclotron facility that one should increasingly focus ones attention on the experimental requirements.

In fact I would make the point that for the users the experimental layout, not the cyclotron presents the most important problem in designing a cyclotron project. And the detailed experimental layout must be specified early enough for the building design to properly incorporate its requirements.

Let me be more specific. It takes a detailed analysis by senior experimenters to design properly the various beam lines, the beam analysing magnets, the various focal points, the collimators, the spectrometer for the reaction products, etc. Is there adequate provision for all this?

For gamma coincidence work the stray gamma and neutron background must be low. This means at least one and preferably two bends after the last collimation plus adequate shielding. Does the plan include this?

How many simultaneous experimental setups are needed? When one experiment is in progress should the other setups be accessible? How many counting setups should there be? Should these be located near the control room or elsewhere? Are the utility trenches convenient to all the necessary areas? Will the floor support all these loads?

Changes in layouts will certainly occur. Are there adequate provisions for possible future expansion? The list is seemingly endless and yet the success of the project depends heavily on how well these questions are answered. Obviously there is no simple; pat solution; requirements vary widely and even for the same requirements there may be several good solutions. With these ideas in mind let us look at a few typical experimental layouts.

Figure 1 shows the University of Colorado plan. This facility has been built by a small staff with limited facilities, but the results are excellent. Two sides - 131



Fig. 1 University of Colorado sector-focused cyclotron facility.

of their cyclotron vault are movable for any future changes or for access to the machine. There are two shielded auxiliary caves, and one large experiment hall. The furthermost portion of this hall has a light floor and wall facilitating neutron experiments. There is room for multiple setups, and some room for shielding individual setups one from another.

Next consider the ORNL plan shown in Fig. 2. In Oak Ridge they do not feel as strongly as we do about the need for movable caves and have installed permanent shielding, which makes future expansion somewhat difficult. You will notice they have Proceedings of the International Conference on Sector-Focused Cyclotrons and Meson Factories





Fig. 2 ORIC external ion-optics system.



Fig. 3 University of Maryland sector-focused cyclotron facility.

Session IV

- 133 -

essentially two experimental vaults: a large one for high-resolution work, and a smaller one for various other experiments.

The University of Maryland setup, shown in Fig. 3, represents a different approach; the beam facilities are on two different floor levels. One of the main boundary conditions was the decision to put the facility in a wing of the physics building. You will note the cyclotron is underground. The high-current highresolution beams are piped to the floor above, using the scheme of Michigan State University. This arrangement makes excellent use of the shielding, provides a great deal of experimental space, and fits neatly into the building. It requires some difficult beam optics calculations and future expansion of the experimental areas would be difficult, unless provided for in the original construction plan.

Figure 4 shows the Rutherford Laboratory plan. This is a very neat compact layout. Unlike the other plans shown, this one is intended primarily for radiation damage studies. The bay window for the switching magnet surrounded by the three caves looks very good.



Fig. 4 Harwell sector-focused cyclotron facility.

Proceedings of the International Conference on Sector-Focused Cyclotrons and Meson Factories

- 134 -



Fig. 5 The first 88-Inch Cyclotron experimental layout.

Now let me turn to the 88-Inch Cyclotron plan. You might suppose, that with the Berkeley experience to call on, we proceeded at once to a lovely layout. Such was unhappily not the case. Progress was slow and we made some mistakes. The first experiment layout was made by the crew of the Berkeley 60-Inch Cyclotron. It really represented what they needed to carry on the existing programs at that time. It had some nice features as you can see by examining Fig. 5. There was a main experiment area with a corner for neutron work, and two small shielded areas for high current target work. There was no provision for targets in the circulating beam.

As we continued to refine our requirements, we came to several conclusions:

(1) We would make little or no provision for neutron work since no one seemed very interested in neutrons. Besides, an excellent neutron facility exists 40 miles away at the Livermore 90-Inch Cyclotron. - 135 -

- (2) Each experiment should be shielded separately so that any setup could be in use without restricting access to the other areas. Of course this required that no experimental equipment be inside the cyclotron vault.
- (3) We would do our best to physically separate high radioactivity experiments from the low activity ones.

From these considerations and others we arrived at the layout shown in Fig. 6. The deflector repair would be done in the same area as the target bombardment for isotope production. It would be possible to walk from the high radioactivity area directly to the chemistry laboratories but not directly to the low radioactivity areas. This would reduce accidental radioactive contamination. We also would enclose and separately ventilate the high level area.

Each beam line would be separately shielded but tandem setups would not. The plans for the so-called physics caves were not worked out in detail, but would be constructed of movable blocks, so that they could be rearranged later if desired.

This seemed like a good plan and we proceeded with the building construction.



Feet

Fig. 6 A more elaborate design for the 88-Inch Cyclotron experimental layout.

- 136 -



Fig. 7 Present 88-Inch Cyclotron experimental layout.

Figure 7 shows our present layout. You will note immediately that there is too little room along the beam line inside the cyclotron vault, in spite of the fact that we increased the vault size twice before the building design was frozen. If we had done a detailed beam optics study early we would have seen the need for more room. But now, in spite of our moveable shielding, this expansion is almost impossible. A large utility trench runs just outside this vault wall. Worse still, the roof blocks are supported by this wall; we would need new roof blocks and new foundation piers even if the trench were moved.

If one examines Fig. 7 in more detail one will notice a large number of what I call small hardware items. These are mostly diagnostic devices for beam lineup, beam optics measurements and for beam monitoring during an experiment. They include quartz plates, closed circuit television, remote measurement of beam profile, remotely controlled collimators, valves, beam pipes, etc. These items have made possible accurate and efficient beam measurements but they were not cheap. And unfortunately we did not allow for them in our budget. Again an early study of the beam optics would have shown the need for this small hardware.

Let me summarize by saying that I feel the biggest problem to be faced by the director of a new medium energy sector-focused cyclotron facility is this: how can

- 137 -

one get a satisfactory experiment layout specified early enough, and yet with adequate flexibility and adequate allowance for possible future expansion of all areas?

References

1. R.S. Livingston, Survey of Operating Sector-Focused Cyclotrons, see paper I-1.

DISCUSSION

SCHMIDT : Even in a rather simple scattering experiment or the study of a nuclear reaction it is often quite crucial not to have any slits in front of the target. If they are used, double or even triple bending is desirable to eliminate the back-ground scattering they produce.

I have two questions. First, have you made an estimate of the additional price of a floor which can support everywhere large amounts of movable shielding? Second, the cost of concrete blocks is more than the cost of poured concrete. Can you give any numbers for the relative cost of fixed and movable shielding?

KELLY: The shielding load on the floor of the experiment area is not much more than is required for heavy magnets (*). I believe that the cost of shielding blocks is not much higher than that of fixed shielding. We had rather expensive blocks, because ours were interlocking, and this means that they were difficult to build, and almost each one is special. I think that the next set of shielding blocks will be rectangular so that they are much easier to handle. In practice the shielding blocks are not moved very often.

FARWELL : I would like to comment a little further on the almost incompatible demands made upon the beam handling and defining systems in different kinds of experiments which use sector-focused cyclotrons. As Kelly pointed out perhaps the most difficult set of experimental conditions which one may attempt to achieve is that required by particle-y angular correlation experiments. There one demands a very high beam intensity on the target, and yet at the same time imposes the requirement that the beam should not strike any object like a collimator system in the vicinity, as this would create an intolerable y-ray background. This requires a high collection efficiency of the beam transport system and a good precision in focusing. The slit problem is made easier, first by the fact that in such an experiment one is usually willing to accept a moderate energy resolution in order to achieve a good intensity, and secondly by the use of a double bending system which eliminates most of the background from the slits. On the other hand, in an experiment which requires a very high resolution such as some scattering and reaction studies involving single levels, the γ -ray background can usually be ignored. Hence one should try to design a flexible beam transport system in which the focusing conditions and dispersion can readily be changed to suit any specific experiment within the range between the two extremes mentioned above.

^(*) See also the remark of Blosser in discussion following the next paper.