OVERVIEW OF MACHINE STUDY GROUP *

M. Month

Brookhaven National Laboratory

NOTICE
This report was prepared as part of a contract with the United States Government. Neither the United States nor the United States Energy Research and Development Administration nor any of their employees, nor any of their contractors, subcontractors, or their employees makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information appearing in this report. It is also understood that its use would not infringe privately owned rights.

The machine group was charged with looking into the following questions:

- What is the range of flexibility of the ISABELLE collision region parameters? What constraints are imposed by the ISABELLE "operational philosophy"?
- What are the implications with respect to machine performance of six insertions rather than eight?

1. First, let us consider what conclusions were arrived at with regard to collision region parameters.

- The crossing angle could be reduced substantially from the 11.4 mrad standard value. This is accomplished at the expense of straight section length. Also, of course, the collision diamond increases proportionately with $(1/\alpha)$. Essentially angles very close to zero are possible with about ± 4 m still available.

- The horizontal β value could be decreased from its nominal value of 20 m to about 5 m in the low- β configuration. This would require increasing the gradient in the special focusing doublet near the collision point to about 3.8 kG/cm rather than the design 3.1 kG/cm.

- The small diamond configuration was studied. Increased bending allows a crossing angle of 50 mrad with a free space length for experimental apparatus of ± 2.5 m. The geometric configuration is given in Fig. 1. The potential collision characteristics are: ($\alpha = 50$ mrad).

$$\begin{aligned} \text{Standard focusing, } p = 200 \text{ GeV/c} \quad & \int \ell_{\text{int}} = \pm 5.5 \text{ cm} \\ (\beta_v^* = 4 \text{ m, } \beta_h^* = 20 \text{ m}) \quad & L = 4.8 \times 10^{31} \text{ cm}^{-2} \text{ sec}^{-1} \end{aligned}$$

*R. Chasman, D. Edwards, A. Garren, D. Johnson, J. Herrera, G. Parzen, E. Raka, H. Wiedemann.

MASTER

CONFIDENTIAL - THIS DOCUMENT IS UNCLASSIFIED

$B_1 = 40 \text{ kG}, \ell_1 = 4.17 \text{ m}$

$B_2 = 38.0 \text{ kG}, \ell_2 = 1.0 \text{ m}$

CHAMBER $A_p = 30 \text{ cm}$

$\alpha = 50 \text{ mrad}$

MASTER

$$\text{Low } \beta, \beta_v^* = 1 \text{ m}, \beta_h^* = 20 \text{ m}$$

$$\begin{cases} \Delta_{\text{int}} = \pm 5.5 \text{ cm} \\ L = 1.0 \times 10^{32} \text{ cm}^{-2} \text{ sec}^{-1} \end{cases}$$

$$\text{Low } \beta, \beta_v^* = 1 \text{ m}, \beta_h^* = 5 \text{ m}$$

$$\begin{cases} \Delta_{\text{int}} = \pm 2.8 \text{ cm} \\ L = 1.0 \times 10^{32} \text{ cm}^{-2} \text{ sec}^{-1} \end{cases}$$

- The ISABELLE design philosophy allows the preserving of high symmetry and mild focusing in the identical insertions, meaning a large momentum aperture, during injection, stacking and acceleration. The collision diamond character can be changed at collision time. The momentum aperture is reduced because of the change in focusing in the insertions, but this is consistent with the reduced momentum aperture required for a simple coasting stack.

- The high- β insertion was studied as well as an operating state having 2 symmetrically placed low- β insertions. The conclusions are that: 1) the momentum aperture is slightly worse in the 2 low- β case, but not significantly, 2) further study on the effect of the sextupoles on the betatron motion should be done, 3) the use of more than 2 sextupole families should be pursued to see if the momentum aperture could be opened up if one or more than one low- β is used, and 4) the high- β insertion is not a significant perturbation on lattice stability.

- The free space for experimental gear is not fixed forever. There is the possibility of increasing it, although this is not planned in the first stages of ISABELLE operation and it is not encouraged. The impact, of course, is that it essentially means that stacking and acceleration would have to be done with reduced symmetry. Remember that the total straight length of the insertion is fixed at about 116 m. Much of this must be used for the matching and focusing quadrupole system.

- The effect of the vacuum chamber design in the insertions were considered. The required high-vacuum conditions seemed achievable. For rapid changes in vacuum chamber cross section, it was concluded that clearing electrodes would be required because regions

of radius change represent potential wells where electrons tend to get trapped and neutralize the proton beam. In fact, it appears that changes of chamber radius larger than about 1 cm require special clearing precautions.

2. In considering the 6 vs 8 insertion ISABELLE, it was assumed that 2 insertions were simply removed with no other changes.

This is a reasonable comparison. Attempting to complicate the comparison by keeping the circumference the same and increasing the bending length in the 6 insertion case is not meaningful. Increasing the bending and thereby the energy would either substantially increase ISABELLE's susceptibility to longitudinal instability and/or increase the spatial aperture required for the beam (meaning, of course, a larger magnet aperture!). We therefore ignore this possibility.

It should be kept in mind that the possibility of increasing the energy in ISABELLE by increasing the bending length, i.e. the circumference, with either 6 or 8 insertions is feasible. However, to accomplish this would require the inclusion in the ISABELLE complex of a 3rd, conventional stacking ring. It would have the size roughly of the AGS (~ 800 m circumference). Although certainly an interesting and beneficial addition to the ISABELLE complex, the 3rd ring is not in the immediate ISABELLE plans.

The main effects of going to 6 insertions:

- Circumference reduced ($3-2/3 C_{\text{AGS}} \rightarrow 3-1/3 C_{\text{AGS}}$) by about 270 m.

- Insertion quadrupoles removed for 2 insertions (reduction is $8/\text{insertion} \times 2 \text{ insertions} \times 2 \text{ rings} = 32$ quadrupoles).

Conclusion: It is primarily a cost consideration. There is no 1st order effect on ring stability.

The Secondary Effects on Ring and Beam

- Insertions add to ring chromaticity so, 6 fold symmetry - increased momentum aperture.

However, the dominant impact on the momentum aperture is the low- β insertion (9) and this effect is independent of whether we have 6 or 8 insertions.

- The beam is quite dense in the insertions since there is zero momentum dispersion. The removal of 2 insertions, therefore, implies a slight decrease in the beam self-field tune shift as well as the resistive wall instability threshold and further implies a slight decrease in overall electron clearing requirements. The order of magnitude resulting corresponds to 15 - 20% effects.

- The optimization for ring tune (21.6 rather than 25.6) in the 6 insertion case yields longer cells and correspondingly longer bending magnets.

$$L_B = 4.25 \text{ m (8 insertion case)}$$

$$\rightarrow L_B = 4.50 \text{ m (6 insertion case)}$$

The implications of this are: Slightly reduced transition energy, meaning $(Z/n)_{\text{limit}}$ for longitudinal stability increased by about 60%, and slight increase in dispersion, which means increased spatial aperture required at injection.

Conclusions on 6 vs 8 insertions

There is some advantage to 6 insertions from the machine viewpoint.

But, both are feasible.

There is no compelling argument for one or the other.

Other considerations, such as capital cost, or the cost of support requirements to operate as many as 8 facilities, should be used to come to a final decision on this point.

FIGURE CAPTION:

Fig. 1. Small diamond beam geometry.