ISABELLE DESIGN STUDY*

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Introduction

Following the 1970 BNL Summer Study on AGS Utilization, John Blewett and I began to consider the design of colliding beam systems in the center of mass energy range from 200 GeV to 2000 GeV, since it seemed to us then that significant new phenomena could be expected in nuclear interactions in that energy range. We took as initial conditions, that we would employ the emergent technology of superconducting magnets, and that we would employ the AGS as the injector, hence requiring the acceleration of the full stored beam to final energies in the storage device. In the summer of 1971, the AUI Committee on High Energy Physics recommended that BNL undertake a study of such a device for 400 GeV maximum center of mass energy, and with sufficient luminosity ($L > 10^{33}/\text{cm}^2\text{sec}$) and experimental versatility to perform a variety of measurements of both weak and strong interactions, including collisions with other particles as well as p-p. The device was called the Intersecting Storage Accelerator, or ISA; the study was begun and called ISABELLE. Following one year of design, a summer study was held in 1972 to obtain the reaction of our colleagues to our efforts, and to seek new ideas to improve the design.

Detailed consideration of design features of the ISA are reported in this conference. Let me call attention to papers I-5 on superconducting magnets, J-8 on electron-proton collisions, J12 on the design of intersecting regions, J-20 on method of injection and acceleration and J-21 on problems with non-linearities. In addition to this, extensive information is available in the form of Accelerator Department Internal Reports, and in the literature.

In the time available to me today, I wish to present some highlights of the study, to trace the evolution of thinking on some topics, and to discuss some of the unresolved problems.

General

In Fig. 1, we see a plan view of the device. Experiments are performed in the 300 m long experimental insertions. Recently it has been decided to include two more 200 m insertions for experiments. Injection and protective fast extraction take place in short straight sections so as not to interfere with the experimental areas. In accumulating beam in the ISA, three AGS pulses of 12 bunches each are stacked longitudinally into the ISA, focussed by an RF system at the 36th harmonic of the ISA. These bunches are transported in momentum by the RF system and stacked. This is repeated until sufficient current is achieved. Following filling of both rings, the stacked beams are rebunched and accelerated to final energy, this process taking several minutes. In the curved sections of the device, the beams are transported in magnets separated in the vertical plane, as indicated in Fig. 2 and Fig. 3, photographs of the iron cores of several ISA model magnets. A half cell of the lattice includes three 3 m dipoles and one 1 m quadrupole in a dewar, the whole occupying some 12 meters. The magnets operate at about 4 T for 200 GeV protons. The ν values are chosen to be near 20 in order to avoid transition energy effects.

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Intersection Regions

The philosophy of design of the intersection regions is to remove the momentum dispersion, allow the beam to spread in size, to pass it through a strong lens and bring it to a small focus at the intersection region (low β). The process is then reversed to return it to the normal lattice. In some cases (elastic scattering), the beam is kept large, to obtain good angular resolution. What we have done is to design a "catalog" of intersecting regions, in cooperation with experimentalists, to fit the needs of particular experiments. Some of these appear in Fig. 4. It is not so much that we expect these to be the most important experiments, but rather that we hope to arrive at a method of design and a configuration which will allow great flexibility after construction, so as to enhance the versatility of the installation. Present designs include intersection regions with luminosities which satisfy our goal of $10^{33}/\text{cm}^2\text{sec}$ at beam currents comparable to those in the ISR. The principal design limitation, aside from beam-beam interactions, has been the chromatic aberrations introduced by the strong lenses, leading to a value of $\frac{\Delta\nu}{\nu}/\frac{\Delta p}{p} \approx -3$ to -4. In order to correct these aberrations in both transverse motions, it will be necessary to place sextupoles at both βmax and βmin locations in the regular lattice.[1] This is not yet a closed subject because of our concern with non-linear effects.

Vacuum

The design of the vacuum system is dominated by the regenerative ion desorption phenomena experienced by the ISR. (See Paper J-4.) It has been necessary to abandon the idea of a cryogenic (4.5°K.) vacuum chamber because of the low binding energies and high ion desorption coefficients of gases, particularly hydrogen, on cryogenic surfaces.[2] The present design calls for a warm bore of 7 cm diameter, 200-300 ℓ/sec pumps, each 3 m. This allows operation at 15 A with the desorption coefficient $\eta \sim 2.4$-2.9. (ISR results are $\eta \cong 2.2$ for stainless steel.) It will be advantageous to use high conductivity metal-copper or aluminum-for the chamber walls, to ameliorate both the resistive wall instability and the beam heating of the wall when the proton beam is bunched. Accordingly, H. Halama and J. Bittner are commencing measurements of ion desorption from these and other materials in a wide range of temperatures. As a result of this requirement, the magnet aperture has been enlarged to 12 cm diameter.

Non-linearities

Non-linearities arise from magnet imperfections, the experimental insertions and from the beam-beam interactions. Random magnet errors and the low symmetry of the intersection regions lead to high harmonics of the non-linear fields which provide driving terms for non-linear resonances of the type $k_1\nu_x+k_2\nu_z=\ell$. Unstable motion can ensue when k_1 and k_2 are of the same sign. The beam must have a spread in momentum as well as a spread in betatron frequencies to stabilize against longitudinal as well as transverse instabilities. If the beam is bunched by an RF system, then the phase oscillations of the particles cause them to traverse resonances. This can lead to a diffusion process which causes a gradual enlargement of the beam. It is important to assess the severity of this effect and to know which order resonances will effectively contribute to it, in order to determine whether or not it will be possible to find a suitable operating region in ν_x, ν_z "space".

Recent studies of superconducting magnets at BNL have emphasized the understanding of these non-linear terms. Although the magnet modelling program is not complete, it is clear that the measured results are consistent with what we understand to be the construction errors of 0.05 mm in current block position. From this position error, Parzen has estimated the strengths of the random multipoles to be expected. From these, we can estimate stop band widths and diffusion coefficients for an uncorrected device. These are presented in Table 1. This diffusion is uncomfortable in a

TABLE 1

Stop Band Widths and Diffusion Coefficients

$k_1\nu_x+k_2\nu_z = \ell$

$|k_1|+|k_2| = n =$ Order of res.

$\Delta\nu$ = Stop band width.

n	$\Delta\nu$	D (cm^4/sec)
3	10^{-3}	0.2
4	1.5×10^{-4}	0.003
5	2×10^{-5}	3×10^{-5}

magnetic system which is uncorrected. What must be determined is whether it will be better to use distributed corrections, or if it will be necessary to correct each individual magnet. Parzen has discussed such distributed corrections in his paper; Sampson has already achieved correction of individual magnets by a factor of ten at least, for specific multipoles.

We must also begin to consider the beam-beam effects and the role they will play in excitation of resonances and the onset of stochastic motion. What is needed most, however, is careful measurement, which can best be done on the ISR. We must have confident understanding of those processes which will disperse the proton beam.

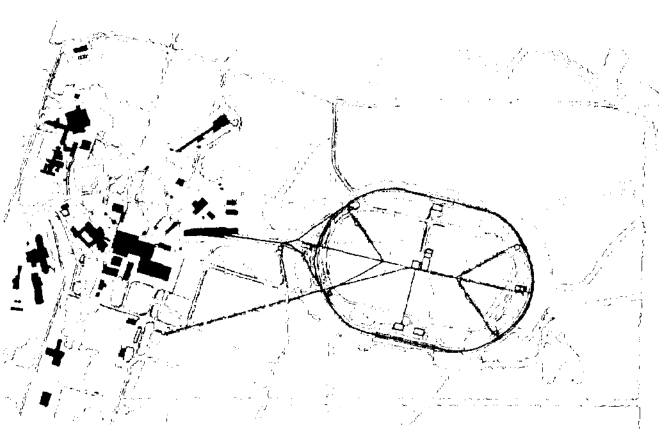

Fig. 1 Site Plan of AGS and ISA

References

1. M. Month, Particle Accelerators 1972, 3, p.183-188.

2. S.K. Events, G.M. McCracken, Sixth Symposium on Fusion Technology, Sept. 1970, p.181.

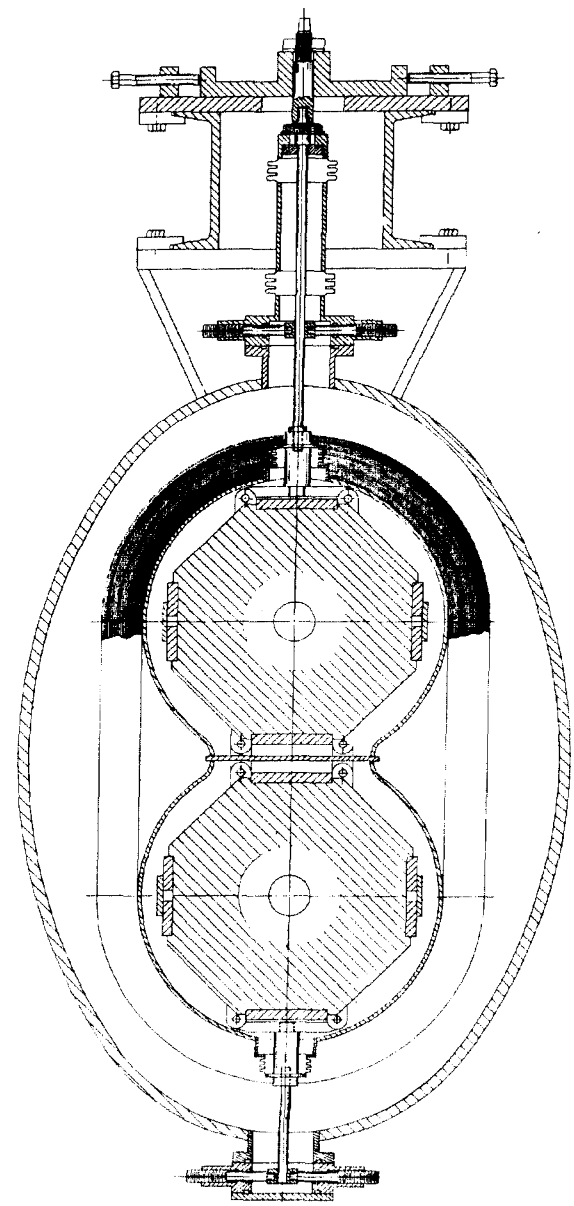

Fig. 2 Cross Section of Magnet Dewar

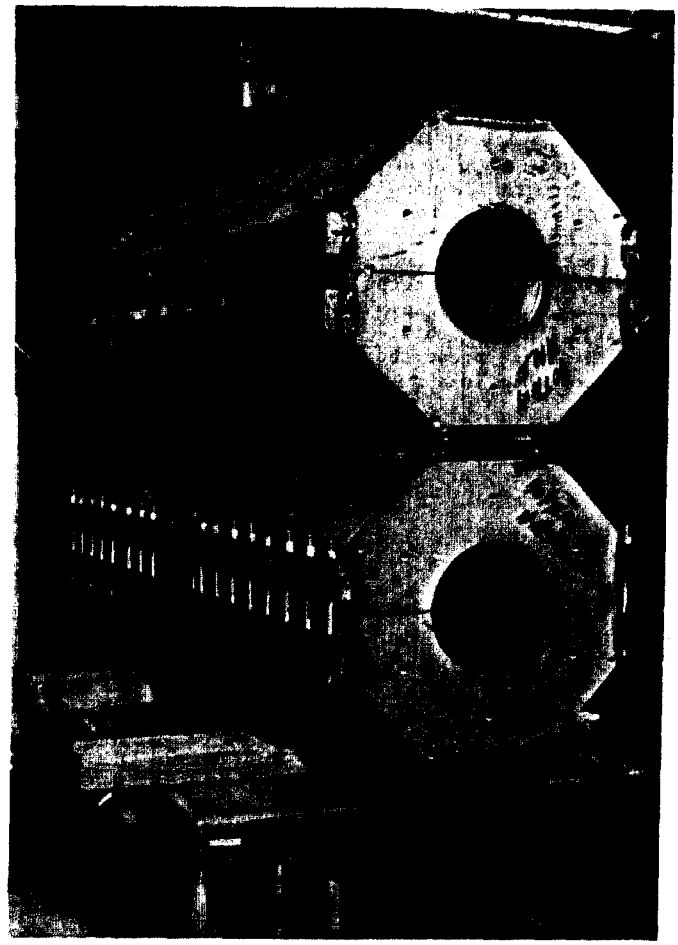

Fig. 3 Photograph of Fe Cores for 1 m Dipole Magnet Models

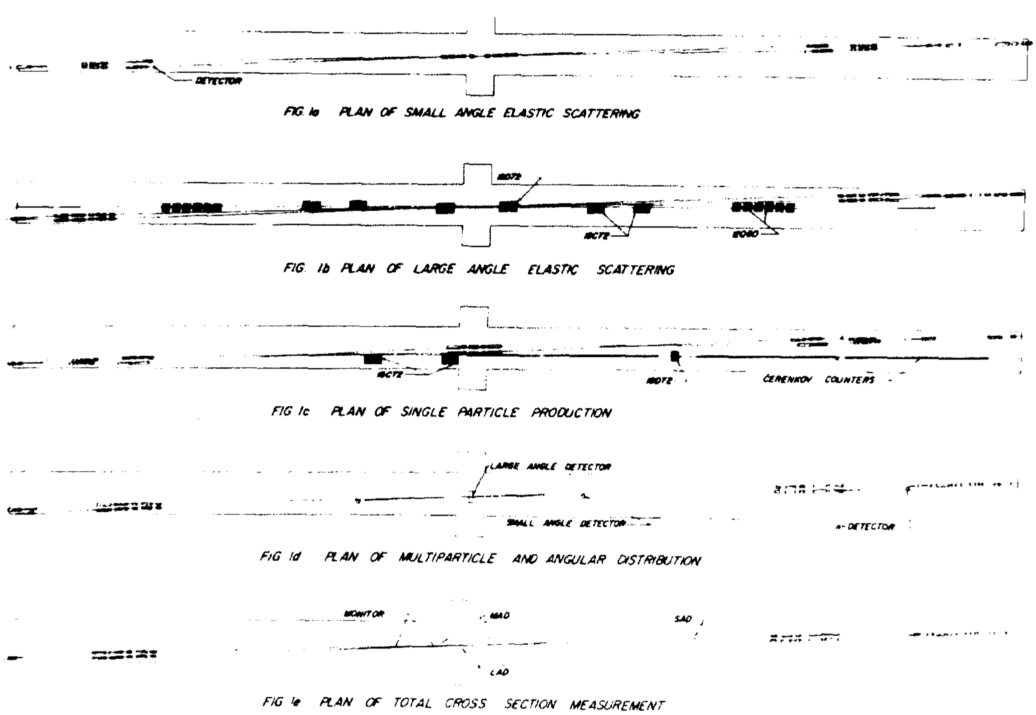

Fig. 4 Typical Intersection Region Designs