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MASTER

ISABELLE - A 200 + 200 GeV COLLIDING BEAM FACILITY*

E.D. Courant†
Brookhaven National Laboratory, Upton, New York 11973
and
State University of New York, Stony Brook, New York

ABSTRACT

Plans are under way for the construction of a pair of intersecting storage rings providing for colliding beams of protons of energy at least 200 GeV. The rings (circumference 2.62 km) will contain superconducting magnets constructed with braided Nb-Ti filamentary wire, with a peak field of 4.0 Tesla corresponding to an energy of 200 GeV. A current of 10 amperes of protons will be injected at 29 GeV from the existing AGS accelerator at Brookhaven, using the energy stacking technique similar to that employed at the CERN ISR; subsequently the stored beam will be accelerated gradually in the storage rings. Six intersection areas will be provided for experiments. They are designed to provide flexibility in beam characteristics for different experiments. The maximum luminosity at full energy is expected to be 1.0×10^{33} $\mathrm{cm}^{-2}\mathrm{sec}^{-1}$, at 29 GeV it will be approximately 10^{32} $\mathrm{cm}^{-2}\mathrm{sec}^{-1}$. Recent work with prototype magnets indicates that fields of 5.0 Tesla can be produced. This has led to an alternative design of somewhat larger rings (circumference 3.77 km) that should be capable of providing colliding beams at 400 + 400 GeV.

A proposal for a colliding beam facility for protons in the range of 200 GeV (ISABELLE or ISA) has been studied at Brookhaven for the past several years, and has been described at several previous conferences./1-3/ In this report the current status of the proposal will be summarized.

ISABELLE is to be a pair of intersecting storage accelerators using superconducting magnets, with injection from the existing 30 GeV AGS at Brookhaven, and acceleration to 200 GeV taking place in the storage rings. With a circulating current of 10 amperes in each ring, the luminosity will be in the range of 10^{32} to 10^{33} $\mathrm{cm}^{-2}\mathrm{sec}^{-1}$ depending on the details of the intersection configuration. (see Fig. 1)

I. Operating Cycle

A. Injection and Stacking

Pulses are injected from the AGS into the ISA ring at 29 GeV and accumulated

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†The work reported here is the result of the joint efforts of a large number of individuals at Brookhaven National Laboratory.

DISCLAIMER

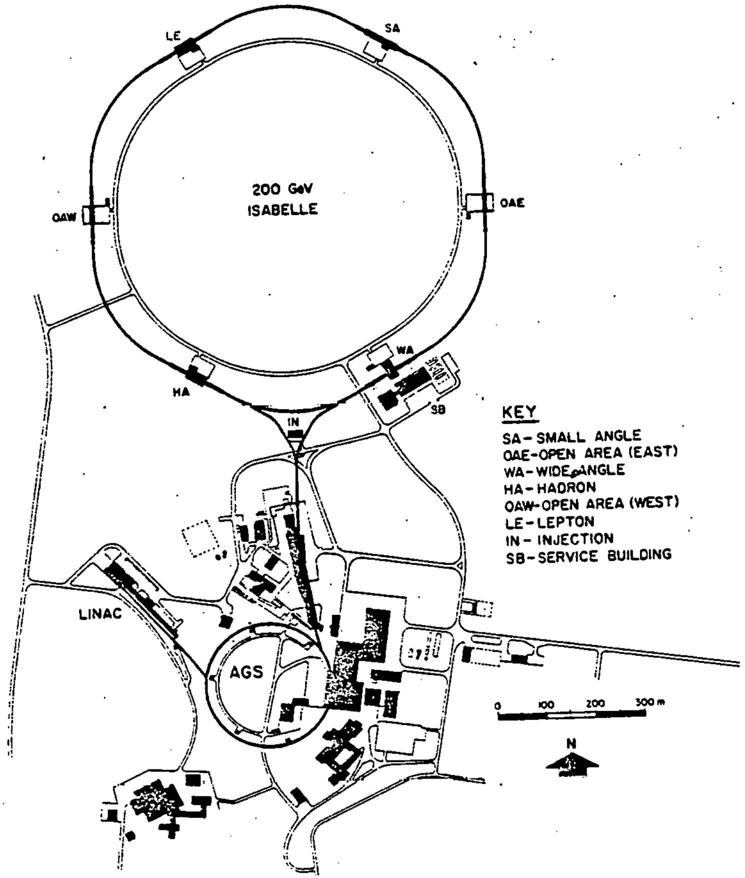

Fig. 1

by an energy stacking technique similar to the one used at the CERN ISR. In order to optimize phase space density, the intensity of the AGS will be reduced to approximately 3.5 × 10^{12} protons per pulse; 11 of the 12 AGS bunches are then injected into the ISA ring, accelerated by an rf system at the AGS frequency (39th harmonic in ISA) to a stacking orbit, and then debunched. This is repeated approximately 180 times for each ring, building up a stack of 10 amperes with a momentum spread of 0.67%. The stacking process requires approximately 6 seconds per cycle, for a total of 18 minutes.

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B. Acceleration

The stack is rebunched by a second rf system operating at the second harmonic of the revolution frequency, i.e. 228 kHz with a peak voltage of 30 kV. The magnetic field is then ramped up slowly, at the rate of about 240 Gauss per second, and the beam accelerated at 11 keV per turn to the peak energy of 200 GeV corresponding to a field of 4.0 Tesla, or (if desired) to a lower peak energy. The acceleration cycle takes 150 seconds.

C. Collisions

The beam in each ring is then debunched, and the two beams collide at six intersection points. Colliding beam experiments can now proceed for times of many hours to several days, with the two beams at equal or unequal energies anywhere between 30 and 200 GeV.

II. Magnets and Lattice

The two interlaced rings each have a circumference of 2623 meters, 3.25 times that of the AGS. Each ring is arranged in a lattice of superconducting bending and focussing magnets, with six insertions where the two beams intersect. Each sextant contains nine "FODO" Cells of 4 bending magnets and two quadrupoles; each insertion has 1½ modified cells with some bending magnets omitted or shortened so as to bring the dispersion function to zero in the central region, followed by two quadrupole doublets which focus the beam down to a small cross section at the intersection point, and then a reflection of the above structure (Fig. 2)

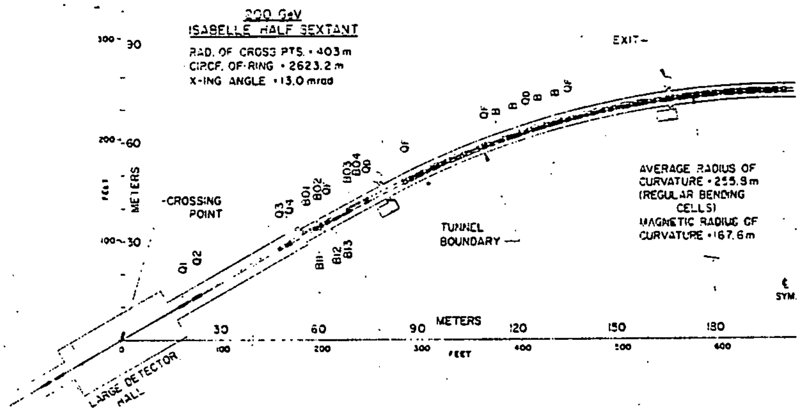

Fig. 2

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The bending magnets will be 4.35 m long (magnetically), constructed with cosine windings of multifilamentary Nb-Ti braid and surrounded by an iron shield. The quadrupole magnets are 1.5 m long, wound with the same braid. Full-scale prototypes of both dipole and quadrupole magnets have been built and tested, and assembled into a half cell of the lattice; these are described more fully in a paper by P. F. Dahl at this conference./4/

The prototypes have worked extremely well and appear capable of fields well in excess of the nominal 4 Tesla design value.

The vacuum chamber will be a warm stainless steel tube with inner diameter 8 cm, while the magnet's inner coil diameter is 12 cm, with insulation inbetween (see Fig. 3).

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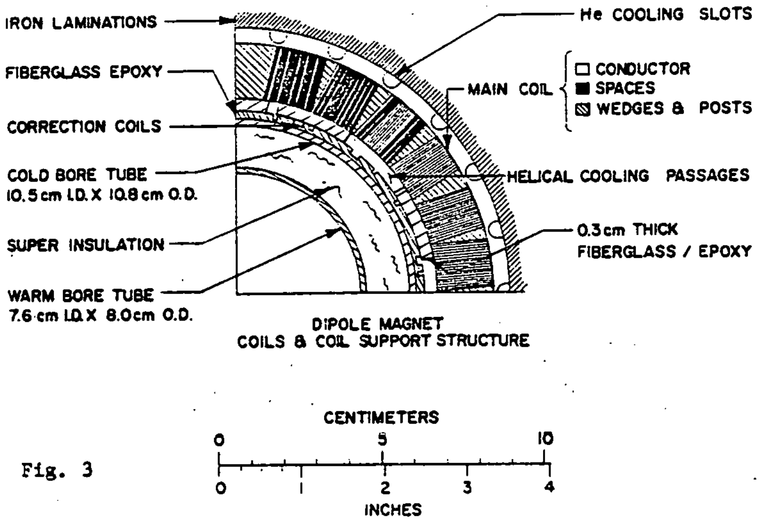

Fig. 3

III. Experimental Insertions

The six insertions are designed with flexible optical characteristics: by changing the strength of quadrupoles but not their locations, the amplitude function β and thus the beam cross section can be modified to produce the optimum conditions for experiments of various types. The free space around the collision point is 40 meters long. In the "standard" configuration the beams intersect at an angle of 13 milliradians. With the help of auxiliary bending magnets in the central free space, this angle can be varied between 5 and 50 milliradians so as to provide either for higher luminosity or a shortened intersection region.

Several particular configurations are envisaged. In the standard insertion the amplitude functions at the center are $\beta_x = 20$ m, $\beta_y = 4$ m, rms beam height $\sigma_y = 0.25$ mm, intersection angle $\alpha = 13$ milliradians, luminosity at 200 GeV = 2.3×10^{32} cm^{-2}sec^{-1}. For high luminosity the angle α is reduced to 5.6 mr, $\beta_y = 1.0$ m, $\sigma_y = 0.13$ mm, $L = 1.0 \times 10^{33}$; this configuration is particularly suited to weak-interaction experiments with secondaries at large angles. If precise location of the source point of interactions is desired, one may use the "small-diamond" variant, where the intersection angle is increased to 50 mr; here the crossing region is just 4 cm long, but the luminosity will be lower. Finally, by making $\beta_x = \beta_y = 64$ m at the center, one can reduce the rms angular spread of the beam to about 10 microradians (at the expense of the luminosity), making this high-beta configuration suitable for experiments on small-angle elastic p-p scattering. The amplitude and dispersion functions in these variants are plotted in Fig. 4; Fig. 5 shows the trajectories for high luminosity and "small-diamond" cases.

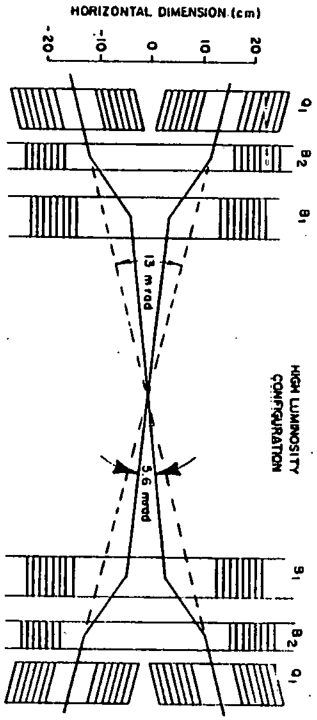

Fig. 5

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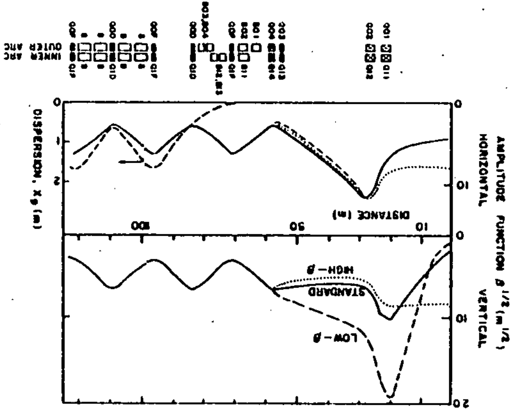

Fig. 4

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Different experimental halls have been designed for these interaction regions; sketches of several of them are shown in Figs. 6-9. Initially there will be four halls with different widths and length most suitable for different types of experiments; two insertions will be left free to provide flexibility for future developments.

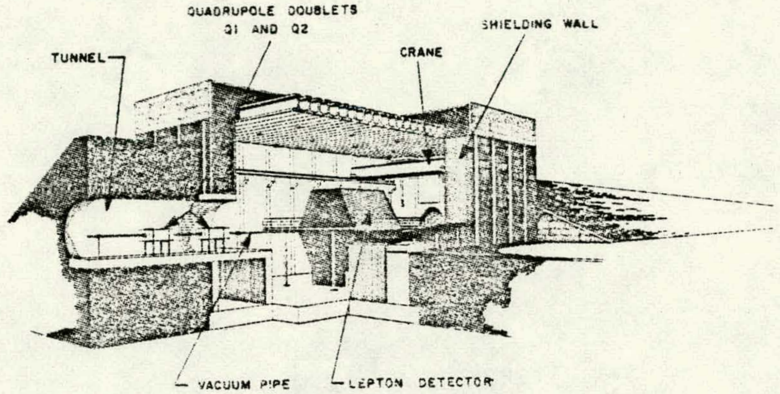

Fig. 6

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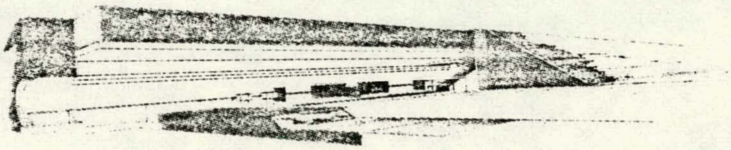

Fig. 7

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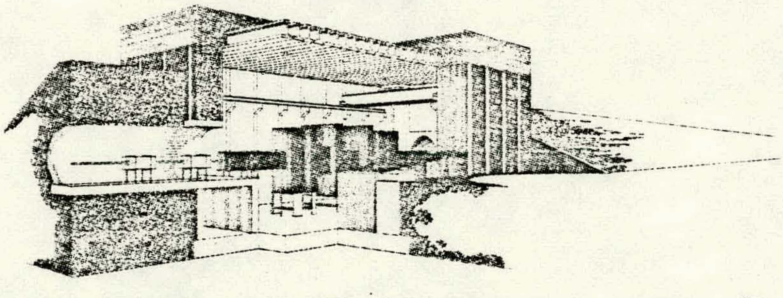

Fig. 8

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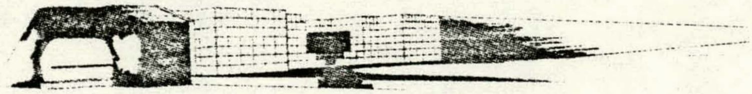

Fig. 9

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IV. Performance Limitations

The performance capability of ISABELLE is limited by the usual phenomena: longitudinal and transverse instabilities, beam-beam interactions, and resonances induced by imperfections in the magnet structure.

To avoid resonances, we propose to operate in the "window" between $\nu = 22.60$ and 22.667. With a momentum spread of 1.6% (during stacking and acceleration) this means that the chromaticity must be not more than about 3 units, as against 35 for a linear lattice. Therefore, sextupole windings are incorporated in the magnets.

Longitudinal instabilities are expected to be most severe for the individual injected pulses during the stacking process, because these pulses have a very small energy spread. To alleviate this, we choose the transition energy well below the injection energy ($\gamma_t = 19.3$). For high mode numbers corresponding to the microwave range, it is then found that the vacuum chamber coupling impedance must be kept below $Z/n \approx 5$ ohms; this is provided for by avoiding sharp discontinuity in the vacuum chamber. During acceleration and final storage the longitudinal instabilities are less severe. The choice of the second harmonic for acceleration avoids the dipole mode of bunched-beam longitudinal instabilities.

Transverse instabilities can be avoided if the spread in betatron tunes is large enough. It is estimated that a tune spread of 0.02 units at injection (corresponding to chromaticity of 3 units) is sufficient.

Beam-beam interactions in the colliding beams can produce a slow diffusive growth of oscillations. The conventional rule of thumb is that the tune shift due to beam-beam interactions must be less than 0.005 units. In our design, this shift is smaller than this by a factor of 2 to 5 in all the interaction regions described above.

V. Extensions of Performance

Antiproton production acceleration, and storage for $\bar{p}$-p collisions should be possible. By ejecting a 200 GeV proton beam from one ring it appears to be possible to produce a beam of about 1 milliampere of antiprotons in the second ring: $\bar{p}$-p collisions with luminosity around 10^{29} cm^{-2}sec^{-1} seem feasible./5/ With the help of cooling techniques (stochastic cooling as developed at CERN, electron cooling as developed at Novosibirsk) it should be possible to attain a luminosity an order of magnitude larger, around 10^{30}.

Another possibility is the addition of an electron storage ring in the ISABELLE tunnel./6/ with luminosities in the range of 10^{31} to 10^{32} with 15 GeV electrons or positrons colliding with 200 GeV protons.

An alternate version of ISABELLE for 400 + 400 GeV collisions is described by A. van Steenbergen in another paper at this Conference.[7] In addition, M. Month[8] will present an alternative design with an intermediate accumulator ring for injection and collisions of bunched beams in which some of the performance limitations are less stringent that in the version described here, and which should, therefore, be capable of attaining a higher luminosity.

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