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REPORT OF TEST BEAM SUBGROUP

L. Nodulman
Argonne National Laboratory, Argonne, IL 60439

D. Groom, M. Harrison, T Toohig
SSC Central Design Group, Lawrence Berkeley Laboratory, Berkeley, CA 94720

R. Gustafson
University of Michigan, Ann Arbor, MI 48109-1120

T. Kirk
Fermi National Accelerator Laboratory, Batavia, IL 60510

Summary

The test beam subgroup took its charge to be a review of the SSC test beam facilities as presented in the CDR.[1] The immediate reactions to the CDR plan were an impression that the HEB facilities looked rather thin, and disappointment that no beam above 1 TeV was provided. Presumably the perceived demand did not justify the expense. The tasks taken on by group members were to explore issues of demand for test beams and particularly for high energy, flesh out the possibilities of the CDR HEB beams, and to seek inexpensive ways of providing high energy facilities. Some of the resulting work is reported here and some has been written up separately and will be quickly summarized here.

Test beam time demands were summarized for Snowmass 84 by Cooper.[2] Discussions with members of various detector groups at Snowmass revealed universal enthusiasm for a >1 TeV beam but a fear that the expense would be comparable to a "small" detector (~ 60 M$), in which case, wouldn't you rather have the detector? Although there were many SSC extracted beam schemes in Snowmass 84, perhaps none were sufficiently frugal. We settled on a plan of one shared use SSC derived beam facility.

Comments on demand were made by Nodulman in a personal extrapolation of the CDF experience.[3] The perversity of calorimetry response drives a desire to test performance at interesting and accessible energies above 1 TeV. This desire would not involve full time running for each group and a single facility could be shared. If less effort than CDF is needed for calibration, the demand will be picked up by the need for various systematic studies. If there is a squeeze for running time, R&D for future generation SSC detectors will likely be hardest hit.

The HEB test beams have been fleshed out in a separate report by Kirk[4]. The separate targeting for either pair of beams is not much of a constraint on data taking due to the large duty factor of the HEB running in slow extracted mode. The interdependence of the two beams of a pair is made more flexible by using target angle dipoles to allow secondary energies to be chosen in each of the two beams. Good yields and favorable conditions can be achieved within the scope of the CDR HEB facility.

Mike Harrison has taken a brief look at the possibility of producing an external neutral beam from a low-beta IR as described in the CDR. The approach taken is a minimal one in an attempt to provide coexistence with the machine layout and any possible high luminosity detector.

The forward going stream of neutral particles produced from the high luminosity IR regions provides a relatively intense beam of secondaries. In the CDR these particles were intercepted by a neutral beam dump, as shown in Figure 1, to provide a luminosity monitor signal. At a given IR only one of these devices is needed, so that a potential source of neutrals is available at each collision point.

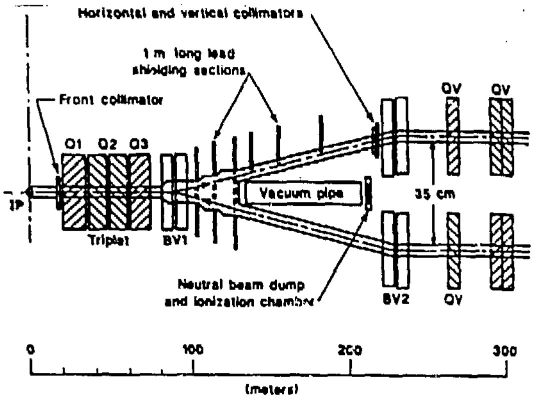

Figure 1. IR neutral beam dump.

In order to use these particles a straight beam line must be constructed which relies on the natural bending of the accelerator to provide the necessary separation between the circulating and the extracted beam. The circulating beams in the IR regions are separated by a vertically bending dipole string outboard of the quadrupole triplet, as shown in Figure 1. Beyond this point the circulating beams are in separate magnets. The beam separation is 35 cm for a distance of ~ 250 m before a second vertical step increases the separation to the final 70 cm value. After the vertical split, the first horizontal bending takes place in the dispersion suppressor which comprises of series of standard length half cells with slightly modified focussing properties. This layout is shown schematically in Figure 2.

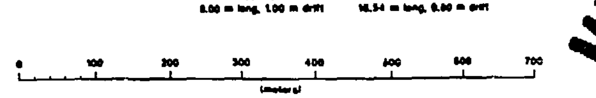

Figure 2. First horizontal bonding.

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The first problem for the neutral beam line occurs in the 35 cm vertically separated section. The proposed vertical bending magnet layout in this region is shown in Figure 3. The reduced beam separation requires the magnets from both rings to lie in a common cryostat with essentially no free space between the iron yokes in the median plane. It should be possible to design these magnets so that a ~ 2.5 cm radius beam pipe could run the full length of this common cryostat region between the iron yokes without compromising the magnets. It should be noted that most of the magnets in this region are quadrupoles which already have a ~ 10 cm gap between the yokes and hence are not affected by this hypothetical beam pipe.

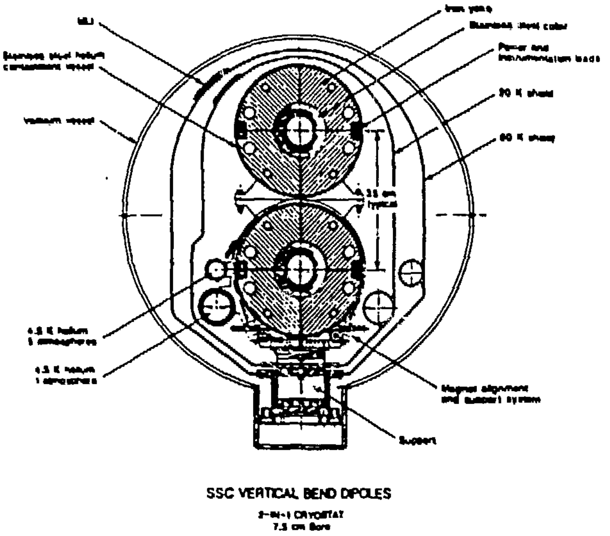

Figure 3. Magnets at 35 cm separation.

Downstream of this section the beam separation is increased to 70 cm and we encounter the horizontally bending dipoles (and quads) in individual cryostats one on top of the other. The proposed cryostat diameter is ~ 60 cm thus if the magnets were located in the center of the cryostats there would be potentially 10 cm of space for a beam pipe. The cryostat layout is shown in Figure 4 and one can see that the magnet is not located centrally and the neutral beam would pass directly through the magnet support structure internal to the cryostat. It would be difficult to redesign the support structure to accommodate a beam pipe within the cryostat especially since the horizontal bending means that the relative position of the neutral beam pipe with respect to the cryostat varies along the magnet length, and from magnet to magnet. Once the accelerator magnets split into individual cryostats then the beam pipe must lie outside the cryostats. The easiest way to accomplish this would be to simply to rotate the upper cryostat by 180 degrees so that the magnet hangs from the supports rather than rests on them. This idea is not quite as absurd as it may seem at first sight since the existing magnet supports work under tension as well as compression, though one suspects that, at the cost of additional heat leak, modifications to the magnet supports within the cryostat would be required. The total horizontal bend angle in the first half cell is ~ 8 mrad which results in a separation of 40 cm between the neutral and circulating beams at the quadrupole (95 m) so that the modifications to the standard cryostats are restricted to the first half cell (5 dipoles) only. A special spool piece would be needed to connect to the standard cryostats in the next half cell. The cryostat support structure would also need modifications in this region. Downstream of this point the separation between the two beams increases rapidly.

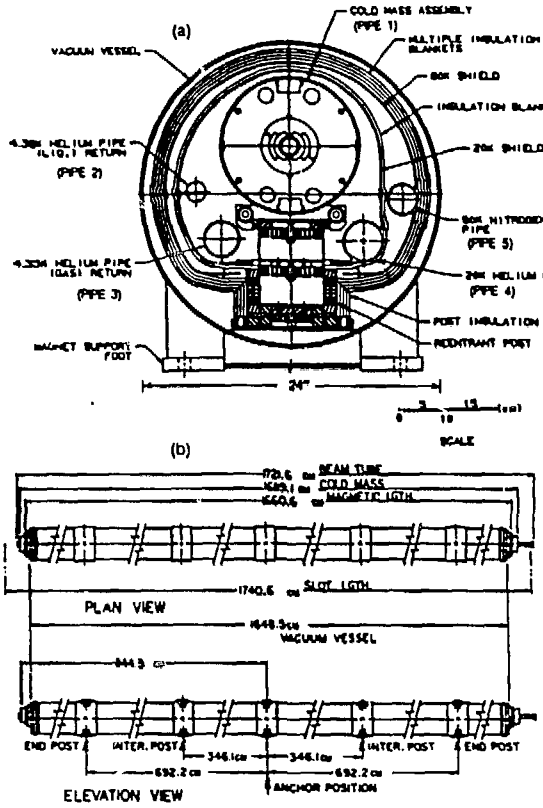

Figure 4. Cryostat at 70 cm separation.

Having demonstrated that a straight beam pipe leading from an IR is not unthinkable, the question remains whether any useful flux would emerge from the end. The beam line admittance is defined by the 2.5 cm radius pipe which in this scheme would run ~ 450 m before any possible increase in cross-section. This corresponds to ~ 100 μrad acceptance in both planes in the forward direction. Monte Carlo studies of the luminosity monitor using ISAJET with the minimum bias option,[5] in Figure 5, would indicate that due to the steeply falling cross-section, ~ 50% of the total hadron energy for forward going neutral hadrons is contained within this solid angle and hence should result in a useful beam.

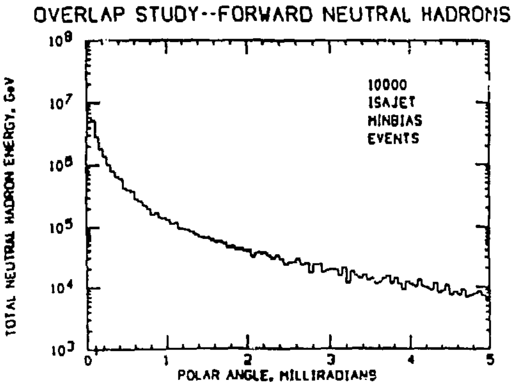

Figure 5. Estimate of forward neutral energy.

A neutral beam line from the high luminosity IR regions appears feasible. Conflicts with a central detector are unlikely (if they wish to observe forward neutrals they can use the other side). Significant modifications are required to he vertical bending dipoles in the common cryostat, minor modifications are required to whole of this common cryostat region. Dipoles in the first half cell of the dispersion suppressor in the upper ring need to be reoriented within their cryostats as well. A special spool piece is necessary. The beam line would produce a significant flux.

Don Groom has investigated the possibility of multi-TeV muon test beams.

Reasonably intense muon beams collimated with the outgoing proton beams are produced at each SSC interaction point. The muons arise from prompt production (mostly from c decay), the decay of primary kaons and charged pions, and through several other processes. Since the prompt muon spectrum is harder than that from stable meson decay, it dominates at large x ($= p_\ell / p_{beam}$). As is evident from the meson spectrum shown in Fig. 4.8-3 of the SSC Conceptual Design Report (CDR), most of the particles with x greater than x = 0.3 (6 TeV) exit from the first separation dipole (VB1), without crossing its return yoke, at about 90 m from the IP. These 6 TeV muons are 62 cm above the beam line at the exit of the next vertical bend (BV2), 220 m from the IP. Using the dimensions of this dipole as given in Fig. 5.2-18 of the CDR, we see that a 10 TeV muon just misses the return yoke of BV2.

This 6 TeV + 10 TeV "beam" continues to diverge with an opening angle of 1.7 mr. When the proton beams reach the nominal 70 cm separation 504 m from the IP (at the entrance to Q^6), 10 TeV muons are 104 cm above the top beam line, and 6 TeV muons 69 cm higher. They are positive if the outgoing beam is on top, and the situation is correspondingly reversed if the top beam is ingoing or we are considering muons below the bottom beam. This geometry is illustrated in Fig. 6, which is from a slightly updated version of Fig. 5.11-1 of the CDR.

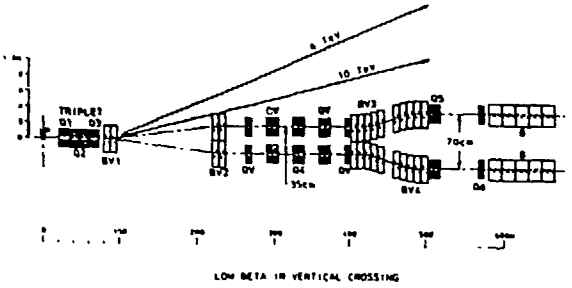

Figure 6. Muon production geometry.

Intensities at 0° are difficult to calculate in the context of existing production models. However, the following estimate is probably correct to within one or two orders of magnitude:[6] The total cross section for the production of charm is 1 mb and that for bottom an order of magnitude lower. The distribution may be taken as flat in rapidity, and we span perhaps 10% of the available range. Our acceptance may be 10% in this region, and the branching ratio for charm decay to muons is also about 10%. The product is 10^{-30} cm^2, so for the nominal low-β* luminosity at the SSC the expected rate is about 1000 s^{-1}.

A muon penetrating one pole piece or the other is of course not excluded; its trajectory is simply complicated by the process. Muons softer than 6 TeV enter the BV1 yoke before its end, and are deflected into our "beam" with a flatter trajectory. In addition, meson decay contributes to the sample. If background rates are reasonable, tracking planes could be used to ensure proper trajectories, and incidentally, to determine the muon's momentum. The requirements are modest: The vertical dispersion is 16 GeV/mm at BV2 and 6 GeV/mm at Q6.

The whole complex of scrapers, collimators, shielding sections, and neutral beam dump as shown in Fig. 5.11-5 of the CDR is at best highly schematic. We suggest that the final design include provision for the μ^+/μ^- "test beam" as described here in one or more of the low-β* IR's. The test sites might be near the beginning of BV3 (410 m) or end of BV4 (500 m), and at opposite ends of the IR (or above and below), providing positive and negative multi-TeV muon test beams.

A reconfiguration of the whole test beam facility has been studied in a separate report by Toohig and Harrison.[7] This configuration saves "civilizing" expense and allows combined conventional facilities for HEB test beams and SSC derived beams. SSC derived beam possibilities include bent crystal halo extraction in the injection/abort section, a 0° neutral beam from the nearest IR, and perhaps a muon beam. Since conventional "civilizing" costs dominate the cost of adding >1 TeV test beam facilities, the substantial saving is quite significant.

Much of the late test beam needs of the first round users can be satisfied by a good implementation of HEB beams with the scope described in the CDR. Early test beam use is by definition elsewhere. This may be tight, particularly for second generation R&D, so hooks for expansion should be built in. One (or more) test beams from the SSC may be able to share the convectional facilities and should be included in the design if this does not do violence to the budget at the level of a "small" detector. A limited fixed target program such as emulsion exposure could be included essentially with no impact. Even if a sufficiently frugal high energy test beam proves impossible, unlikely as it seems, provisions for adding these facilities later, such as shaping the tunnel for installing a 0° neutral beam from an IR, would save much pain later. Eventual addition of some such facility is inevitable.

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