BEAM TRANSFER, INJECTION, AND EJECTION

Summary Report of Working Group*

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Before starting the discussion of the summary of the Beam Transfer Group effort, I have been asked to apologize for the absence of Lee Teng, the Chairman of the group, who would have given this presentation, but had to leave early this morning to report back to FNAL before going on vacation. His absence today is certainly not due to a lack of enthusiasm, since we worked late last night in order to complete the essence of this summary report.

The best way of discussing the group's effort is to outline the objectives for the group as they were formulated prior to the study and sequentially then to deal with each of these topics. A summary of the objectives is as follows:

Beam Manipulation in the AGS and ISA
Transfer Synchronization and Component Tolerances
Phase Space Clean-Up, Transfer Dilution, Distributions
Injection Kicker Stray Field Tolerance on the Stack
Injection Components, Impedances.

Ejection, Slower Versus Existing Fast Ejection
Analysis of Ejection System Losses and Tolerances
Particle Spectrum Downstream of Ejection Septum
Protective Beam Dump Trigger Logic
Redundant Internal Dump
Ejection Components, Impedances.

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Beam Scraping at Injection, During Acceleration, Ejection
Residual Phase Space Distributions
Effectiveness of Scraping at High Energy
Impedances of Beam Scraping Hardware
Beam Dump Absorber, Caloric Denisty Distribution
Cascade Data vs Primary Energy, Beam Size, etc.
Absorber Design Criteria, Stress vs Melting Point Criteria.

ISA Beam Losses, Definition of Sources and Characteristics
Shielding, etc.

Even though the design of the injection and ejection-beam dump systems were essentially complete, it was the group's desire to spend some time on reviewing the details of this in order to arrive at independent judgments and to see if one could come up with clever solutions, improvements, etc. It was decided to spend the first half of the first week on this subject and, if the right ideas evolved to follow through on these or, alternatively, if the concepts were found to be basically sound, to accept these and then to proceed with the outlined objectives. Since I may be slightly prejudiced on the subject, I will quote here the statement of the external chairman verbatim, as follows: "We spent some time in examining these designs and found them sound and workable and that there are no obvious ways to improve upon them". Consequently, after the first half week the group turned to examine in detail the above mentioned objectives. The overriding considerations which crucially dominate the design of the injection, ejection and beam scraper systems are (1) longitudinal impedance, (Z/n) and (2) beam loss in the ISA Rings.

1. Longitudinal Impedance

Since the injected beam has a relatively small momentum spread it is readily susceptible to longitudinal instability. This puts a limit on the maximum allowable impedance (Z/n) of the beam enclosure. Various estimates put this limit at approximately 5 Ω. This is a very low value when considering standard injection and ejection components as one encounters these, typically, in the FNAL accelerator or the BNL accelerator. Abrupt changes in cross section, etc., within the vacuum chamber can easily contribute more than 5 Ω at high mode numbers, n (GHz range), if special features are not incorporated in the design. An example of such an irregular structure is the ISA injection kicker (Fig. 1). This is a vertical fast kick injection device to direct the injected beam onto the injection orbit. Typically, this unit was examined in detail with regards to structure in order to arrive at a small component impedance, Z/n, It can be stated, in general, that the group made a special effort to insure that none of the injection, ejection and beam scraper components would add significantly to the (undesirable) Z/n magnitude.

As a preliminary conclusion it can be stated that the impedance sum of all the components involved in the above systems is expected to be less than 1 Ω.

2. Beam Loss in the ISA Rings

The superconducting magnets in the ring will quench when struck by an excessive amount of stray beam. Theoretical and experimental results indicate an ultimate upper limit on the tolerable energy deposition in the superconductor-copper matrix of $\sim 30\ mJ/cm^3$. One order of magnitude less than this is considered safe. During normal beam injection and stacking there is a significant amount (up to 50%) of beam loss of the 30 GeV beam associated with the desire to "overstack" in order to obtain high phase-space density. Also, during normal protective ejection there is an approximately 0.1% loss of 200 GeV beam on the ejection septum. In the event of component failure, more disastrous beam loss may occur. In order to absorb safely these losses, high efficiency beam scraping and absorption systems must be incorporated which can effectively reduce the energy deposited by stray beams anywhere in the superconducting magnets to below $3\ mJ/cm^3$ at all times.

at $\beta_x = 40$ m; $\beta_y = 8$ m; $X_p = 1.7$ m

with $A_H = A_V = 0.4\ \pi\ 10^{-6}$ rad-m

Note: Prior to stack rebunching, the beam would be centered by field adjustment. Simultaneous with rebunching the beam would be scraped to the 0.7% high density stack only.

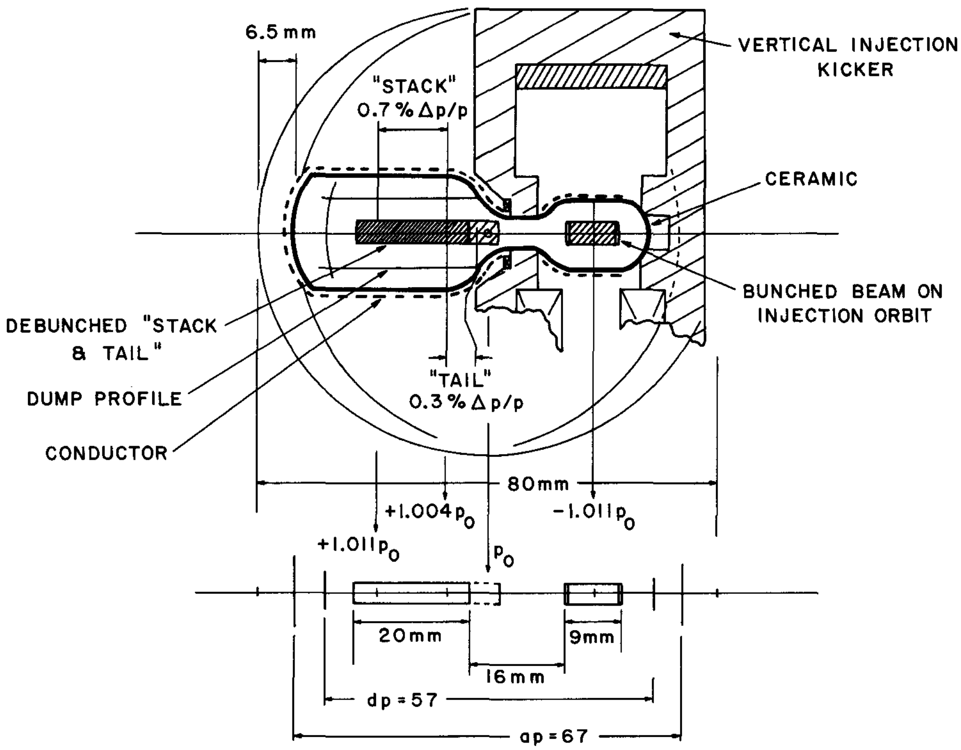

Fig. 1. ISA aperture subdivision during beam stacking at the injection kicker location.

A significant part of the group's effort was directed to the identification and characterization of the normal operational and potential accidental beam losses. Also, conceptual designs of scraper-absorber combinations have been worked out. Available computer programs were used to evaluate the development of the nuclear cascades in the absorbers and hence the energy deposition. Realistic ISA model geometries could not be used yet in the study of the effectiveness of the absorber units because of certain limiting features of the existing programs. Specific cascade programs are now underway from CERN, with which it will be possible to simulate the ISA geometries realistically. These should then be used to refine the proposed scraper-absorber designs and evaluate its final overall efficiency.

As a preliminary conclusion of the group's effort in the design of the scraper-absorber systems it can be stated that all normal operation particle losses can be absorbed safely in the scraper-absorber systems as conceptually designed, that a fast accidental beam dump on the internal absorber at 30 GeV will not damage the absorber or drive the superconducting structure normal, that the same holds true for a fast internal beam dump at 200 GeV, except that in the latter case the beam absorber would suffer local damage.

The present arrangement for the scraper-absorber system and cascade shield distribution in Insertion VIII is shown in Figs. 2 and 3.

Having discussed so far the main emphasis of the group's effort let me now turn back and mention some of the results and efforts related to the list of original objectives. Beam manipulation in the AGS and ISA was left to the rf group, although some aspects of this were considered in connection with the study of Transfer Synchronization and Component Tolerances. This latter topic was examined closely and it was concluded that the AGS-ISA transfer beam manipulation and synchronization did not demand excessive parameter tolerances. A quick check was made of the acceptable stray field

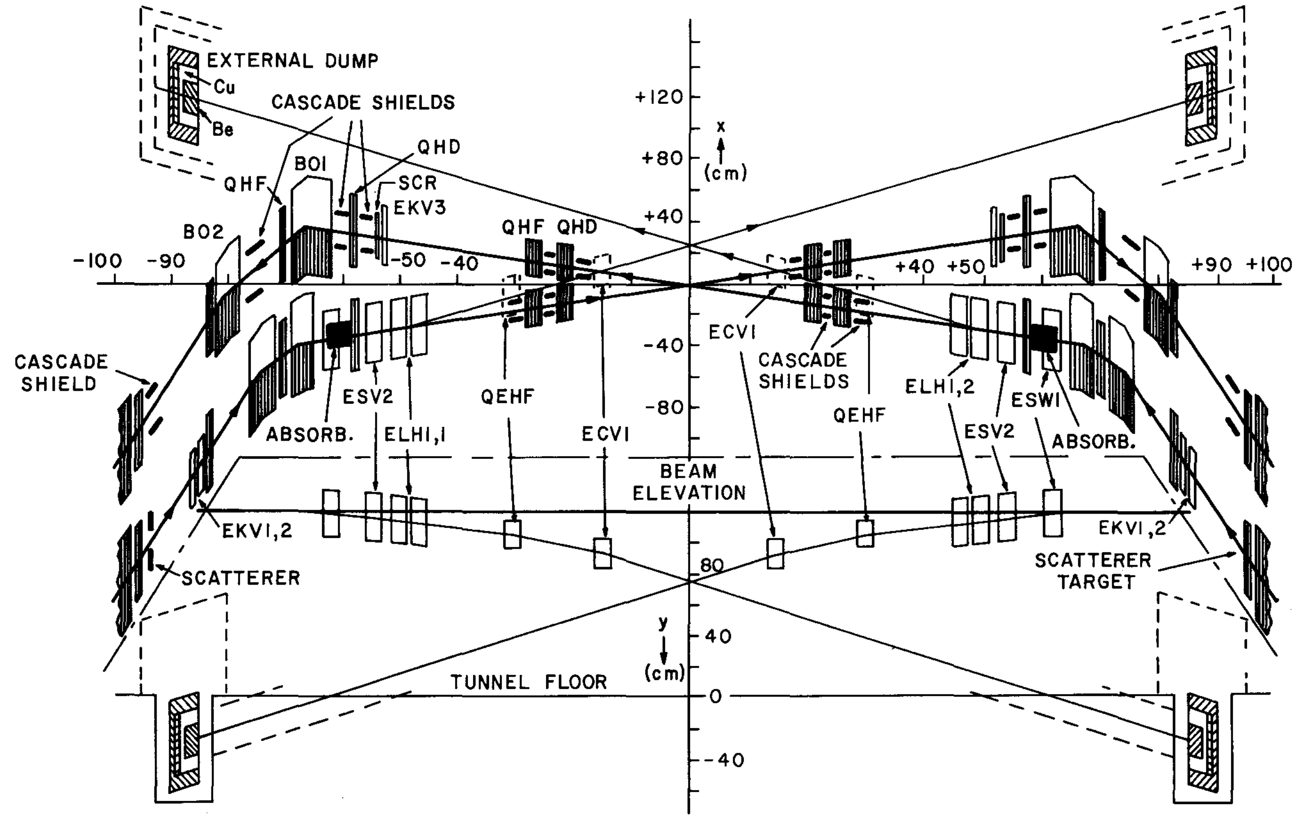

Fig. 2. Beam scraper-absorber combinations for beam clean-up in insertion VIII.

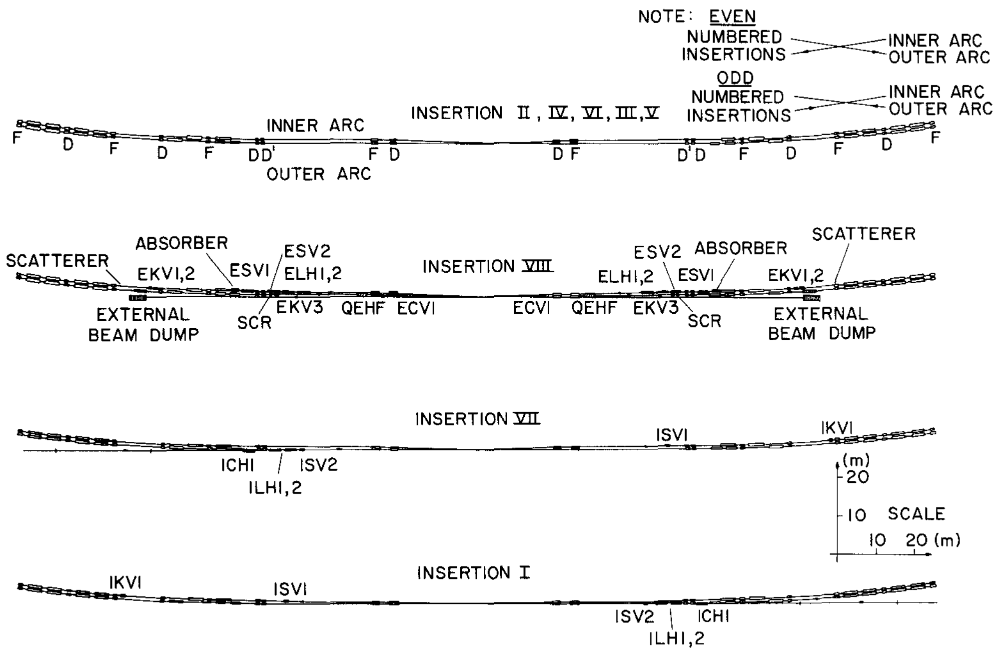

Fig. 3. ISA insertion, distribution auxiliary components.

of the injection kicker and its effect on the stack leading to a confirmation of the calculations carried out at BNL before. The injection components were studied, as indicated before, mainly with the objective of reducing impedance.

No further study was made of the possibility of a slower mode of ejection, mainly because of the difficulty associated with the protection against the cascade particles resulting from the ejection component losses and also because the cost savings would only be very modest. The protective beam dump logic was examined and it was concluded that the addition of the dump profile sensors to the usual trigger elements such as dI/dt, etc., would be advantageous. Also, the essentialness and basic design of the redundant internal dump absorber, a last "ditch stand" element in the ISA superconducting magnet protective system was confirmed. Use would be made of fast dumping on the internal absorber only, if the external beam dump sequence fails. Again, impedance aspects were studied associated with the ejection components.

Most aspects of the beam scraping-absorber systems have already been mentioned. There was no time to go into details and analytics of the beam residual phase-space distributions. The maximum caloric deposition criteria for the beam dump absorber were examined. In this respect it may be useful to define the magnitude of the caloric deposition problem as follows:

Deposition into Supercon Magents $\ll$ 30 mJ/cm^3
Reality; total beam stored energy 20 MJ
Example; dump 7×10^{14} p , 1 mm^2 beam,
into Aluminum $\rightarrow \hat{D}_{A\ell} \sim 40$ kJ/cm^3
into Copper $\rightarrow \hat{D}_{Cu} \sim 1$ MJ/cm^3
External Dump Absorber; 7×10^{14} p, 200 mm^2 beam,
into Beryllium $\rightarrow \hat{D}_{Be} \sim 0.8$ kJ/cm^3

Some cascade calculations were carried out for the dump absorber, confirming the earlier empirical expressions for caloric deposition densities which were based on published isodensity contours for various materials and 400 GeV protons. As a result the precise structure of the sequence of absorber elements in the dump absorber could be finalized.

Although anticipated beam losses were detailed, this was mainly done with the objective of designing the shields for the superconducting magnets. No effort was devoted in this group to the ISA biological shield design. This concludes this summary report.