SUMMARY REPORT FOR WORKING GROUP C: ACCELERATOR SYSTEM DESIGN, INJECTION, EXTRACTION, COLLIMATION

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The charge to this working group was the following:

1. Summarize the state of the art in H^- charge-exchange injection.
2. Summarize recent developments and future possibilities for novel injection techniques.
3. Summarize the problems encountered, the needs for further development and improvements in injection and extraction of high-intensity beams.
4. Summarize the state-of-the art in collimation system design.
5. Summarize the status of benchmarking of collimation system efficiency and performance.

To answers these questions, we attempted to gather up to date information from most major high intensity machines under operation or in design. This session included the following 8 talks and 4 posters:

- SNS Injection and Extraction Systems Issues and Solutions (M. Plum, ORNL)
- Injection and Extraction of J-PARC 3 GeV RCS (P. Saha, J-PARC)
- Future Prospects for Laser Stripping Injection In High-Intensity Machines (V. Danilov, ORNL)
- Challenges Associated with 8 GeV Injection in the Fermilab Project X Proton Driver (D. Johnson, FNAL)
- Lifetime Measurement of HBC Foil and Nanocrystalline Diamond Foil by Use of the KEK 650 KeV High Intensity DC H^- Ion Beam (I. Sugai, KEK)
- The Beam Collimation System of J-PARC Rapid Cycling Synchrotron (K. Yamamoto, J-PARC)
- Collimation System for Beam Loss Localization with Slip Stacking Injection in the Fermilab Main Injector (B. Brown, FNAL)
- Beam Preparation for Injection into the CSNS Ring (J. Tang, CSNS, presented by D. Raparia)
- Efficiency and Robustness of the PS2 Collimation System (Y. Papaphilippou, CERN)
- Comparison of Carbon Stripper Foils Under Operational Conditions at the Los Alamos Proton Storage Ring (T. Spickermann, LANL)
- 3D Simulation Studies of Beam Dynamics Issues in the SNS Ring Injection and Extraction (J. G. Wang, ORNL)
- A Triplet Insertion Concept for the PS2 (W. Bartmann, CERN)

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INJECTION AND EXTRACTION

Systems in operation

The SNS accelerator has recently been operating at the 500 kW level on it's way up to the design intensity of 1500 kW. The injection system did not work as anticipated for three distinct reasons: 1) The design injection chicane angles were not correct, 2) the second injection chicane magnet induced unanticipated vertical steering, and 3) beam loss in the injection dumpline was higher than expected. A number of modifications were implemented to reduce losses in the injection dump line and to close the orbit in the ring. To date the losses in the injection area are still high mainly due to foil scattering and long tails on the incoming linac beam. However, the overall system is operating well, including transport of the waste beams to the injection dump.

The SNS extraction system performs as designed with the exception of an unexpected skew quadrupole component in the extraction septum which induces significant transverse beam coupling in the transport line to the target. A plan to reduce this field component is underway.

An important lesson learned from the SNS experience is to perform 3D field simulations and magnetic measurements in complex regions such as injection and extraction. This work has now been extensively performed for the SNS ring injection and extraction regions and has aided in the redesign and reconfiguration of some lattice elements.

The J-PARC linac and 3 GeV ring are currently being commissioned and have recently been operating at the 1 kW level, with short stunts at higher powers. The injection and extraction system are working as designed. A recommendation for a future designer of such a system is to beware of magnetic interactions with nearby elements.

Additionally, both the SNS project and the J-PARC projects are suffering from insufficient diagnostics in critical areas of the machine such as extraction from the ring and RCS, respectively. A recommendation to the community is to reserve more real estate for diagnostics in important transitional regions.

Systems under Design

It is well known that the lifetime and losses associated with charge exchange foils is a serious limitation for achieving higher beam powers. Laser stripping injection is an attractive option to circumvent this issue, with the caveat of available laser power. The development at ORNL of a proof-of-principle laser stripping system is impressive and suggests that a practical laser stripping injection system can optimistically be achievable in four

to five years for SNS. For machines with higher energy injection energies (> 3.5 GeV), the problem of laser power is alleviated and such a system could work with present day technologies.

The Fermilab Project X faces new set of challenges due to its 8 GeV H^- injection into the recycler or Main Injector. It will be the first time when photo-detachment of H^- due to interactions with black-body photons is a major concern. Other single particle loss mechanisms include Lorentz stripping, and stripping by residual gas at this high energy. The experimental data for H^- stripping (Lorentz, gas and foil) cross-sections are available up to 800 MeV only; to extrapolate them to 8 GeV is a concern. Finally, injection into the recycler will be complicated by the need for a three stage painting system to accommodate the three consecutive bunch trains from the linac.

Lattice design work for an upgrade to the CERN PS machine is underway (PS2). Work is focusing on lattice options and insertion elements to optimize injection in the triplet cell with respect to Lorentz stripping and H0 excited states.

COLLIMATION

Systems in Operation

The J_PARC ring collimation system consists of a transverse scraper, an absorber and a longitudinal scraper. Initial operation of the system indicates that the transverse collimation system works as designed, but the longitudinal system does not.

The FNAL collimation system in the Main Injector consists of a scraper and fixed aperture movable secondary collimator. Early operation shows that the system works as designed. Considering that the system was designed to fit into an existing ring, this is a great success story.

Systems under Design

The CSNS is proposing a novel design for their transfer line collimation system; it consists of 60 degree triplet cells with carbon halo scrapers followed by dipole magnets to separate and direct the H^- to the ring and the protons (stripped H^-) to the beam dump. This scheme reduces the fabrication cost of the system at the expense of sensitivity to a triplet lattice scheme as compared to a FODO lattice.

A new collimation system will be included in the upgraded 50 GeV PS ring at CERN. Various lattice options are being evaluated in parallel with collimation system design work.

FOIL TEST

A major improvement in the lifetime of charge exchange injection foils through the development of hybrid boron carbon (HBC) foils was reported by I. Sugai of KEK. The new foils are composed of 25% boron and 75% carbon. Through experiments with the 650 keV KEK beam, these foils have been demonstrated to have lifetimes l0 times longer than the foils under use at other facilities.

Foil lifetime experience for various different foil types used in the Los Alamos Proton Storage Ring was summarized. It was shown that the SNS diamond foils have lifetimes comparable to the LANL foils, but they deteriorate faster under extreme conditions and cause higher first turn beam losses. The KEK HBC foils are currently being tested in the beam line.