CONSTRUCTION SCHEDULE

CIS construction priorities are governed via a series of PERT schedules for all major hardware systems, and a final assembly schedule which project the start of ring commissioning by the end of March, 1997. Manpower requirements of the individual PERTs are combined into a single projection used to forecast manpower needs of the whole project. Space precludes the inclusion of the PERT output in this report, although scheduling details for the fabrication of the various major systems are included in the discussions of those systems above. It has always been recognized that IUCF does not have the personnel available in-house to meet this demanding schedule. Accordingly, the PERT projections show manpower deficits in several areas throughout 1996. Some of this deficit was removed by the acquisition of surplus equipment from several national laboratories, by designing equipment to be fabricated at commercial facilities, and by the use of professional consultants and hourly employees at IUCF. At present, the construction schedule is still on track for meeting the March 1997 schedule for the start of ring commissioning, even though a few of the in-house activities and the delivery of the linac have slipped by three months. On the other hand, delivery of the four ring dipoles, the small injection dipoles and ring quads is on schedule. The first prototype dipole mapping is complete, and the delivery of the remaining three dipoles is promised by the end of November, 1996. Linac and BLPL beam commissioning can begin in September, and final ring assembly will begin in December, 1996. The challenge to IUCF will be to complete the many small fabrication and installation tasks needed to complete the ring following installation of the dipoles. The work completed during the next few months is critical to meeting this goal.

1. D.L. Friesel *et al.,* in *Proc. of 1995 Particle Accel. Conf.,* Dallas, TX, (May 1-5, 1995) p. 357.
2. D. Li *et al.,* in *Proc. of 1995 Particle Accel. Conf.*, Dallas, TX, (May 1-5, 1995) p. 357.
3. M. Ball and B. Hamilton, in *Proc. of the 1996 Beam Inst. Workshop*, AGNL, (May 6-9, 1996) to be published.
4. A. Pei *et al.,* in *Proc. of 1995 Particle Accel. Conf.,* Dallas, TX, (May 1-5, 1995) p. 1705.
5. A. Pei *et al.,* in *Proc. of 1995 Particle Accel. Conf.,* Dallas, TX, (May 1-5, 1995) p. 1708.

H^- POLARIZED ION SOURCE FOR CIS

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A Technical Advisory Committee (TAC) met at IUCF in February 1996 to consider which available polarized ion source options would meet the requirements of CIS, would minimize the cost for a given performance, and would result in a reasonable schedule for delivery of the first polarized beam to CIS. The TAC consisted of Tom Clegg (TUNL) and Willy Haeberli (Wisconsin).

The luminosity requirements for experiments to be mounted in the Cooler synchrotron were reviewed. For experimental programs using polarized beams and unpolarized targets, an average luminosity of 10^{32} $cm^{-2}s^{-1}$ is required, and for polarized beams and targets an average luminosity of 10^{30} $cm^{-2}s^{-1}$ is needed. The predicted performance of the CIS-to-Cooler injection efficiency then can be used to calculate the ion source current needed to fill CIS with 2.5×10^{10} particles. This leads to a minimum beam current of about $100 - 200$ μA within an emittance of 1.0 π mm $\cdot$ mrad to meet this performance level. The source would be pulsed at a maximum of 6 Hz and with pulse lengths of 300 μs.

In the report of the TAC meeting, it was recommended that "The laboratory should avoid compromising polarized beam operation of the present Cyclotron and Cooler experimental programs. . . . This will require a new polarized source separate from HIPIOS . . . " Because of the requirement for tensor polarized deuteron beams they " . . . recommend against an OPPIS-type source." "An atomic beam system, . . . [when] taking advantage of the known intensity gain demonstrated from pulsing the gas and discharge of the dissociator . . . [and] by use of permanent magnet sextupole systems," would provide more than the necessary flux for the ion beam intensity required. "Two ionizer designs . . . would meet the . . . requirements for CIS:" the resonant charge-exchange ionizer developed by A. Belov at INR-Moscow and the pulsed Cs^0 beam charge-exchange ionizer similar to that now being used at BNL.

Pulsed Ion Source Design Overview.

Only within the last four years have polarized H^- (and D^-) ion sources improved to the performance level required for the CIS project, obtaining 200 μA of peak current for the pulsed beam in a phase space area of 1.0 π mm $\cdot$ mrad (normalized). This major improvement in beam current is a result of development efforts with atomic beam sources and the negative ion production mechanism. In contrast to pulsed sources, atomic beam ion sources operating in the DC mode typically produce less than 10 μA of negatively polarized beam current.

Pulsing an atomic beam source (ABS) reduces the residual gas attenuation when compared with a DC atomic beam source. In a pulsed source, the gas density along the axis of the sextupoles and the beam path is reduced significantly. A higher instantaneous gas flow, and therefore atomic flux transmitted to the ionizer, becomes possible. One state-of-the-art ABS, built by the HERMES collaboration,[1] operates in DC mode and can produce an atomic flux of hydrogen in two spin states of $0.81 \pm 0.02 \times 10^{17}$ atoms/s. A comparable source built in Wisconsin[2] and used in the Cooler synchrotron at IUCF produces 0.67×0^{17} atoms/s. Both sources produce an atomic beam focused into a 1-cm diameter, 10-cm long tube at the entrance of a polarized gas target, and use permanent magnet sextupoles carefully designed to match gas attenuation properties, the velocity distribution of the atomic beam, and the beam size requirements at the target entrance. By comparison, the high intensity polarized ion source at IUCF (HIPIOS)[3] uses electrically excited sextupole magnets to focus an atomic beam of 0.50×10^{17} atoms/s to a beam diameter of 2.2 cm.

Pulsed atomic beam sources already produce more than a factor of two greater flux using older sextupole technology that results in an atomic beam diameter similar to the HIPIOS ABS. Brookhaven National Laboratory (BNL) uses a pulsed ABS in conjunction with a fast beam of neutral Cs. An atomic beam flux of 1.0×10^{17} atoms/s is estimated to exist at the ionizer. At INR Moscow, a pulsed atomic beam source with a resonant charge-exchange ionizer has a reported flux, measured 65 cm downstream of the last sextupole, of 2.0×10^{17} atoms/s within a diameter of 2 cm. The INR atomic beam source differs from the BNL source in that the first tapered sextupole has an aperture that varies from 11 mm to 27 mm compared to an 8 mm to 12 mm taper. The second sextupole has an aperture of 31 mm compared to the BNL aperture of about 17 mm. The larger sextupoles in the INR source were chosen to reduce the atomic beam divergence in the drift space between the second sextupole and the ionizer. A common feature of the ABS used by these four groups is a dissociator nozzle cooled to between 70 K and 80 K.

These pulsed source designs would benefit greatly from the experience gained from the state-of-the-art DC sources cited above. Large diameter permanent magnet sextupoles designed for the characteristics of the pulsed dissociator, and optimized to focus the atomic beam into a 1 cm diameter at the ionizer, would greatly improve the intensity of the BNL source and should reduce the emittance of the INR source by more than a factor of two. A smaller diameter atomic beam will result in an extracted ion beam with a relatively smaller emittance. The emittance of an ion beam extracted axially from a solenoid is proportional to $\epsilon \propto BR^2$ where B is the strength of the magnetic field and R is the radius at which the atom is ionized.

There are currently two techniques in use for the production of negative ions from a pulsed beam of polarized hydrogen atoms. These are the colliding neutral Cs beam technique and the resonant charge-exchange method. To obtain the high intensities reported, the ionizers are operated in the pulsed mode. The BNL polarized H^- source[4] has produced a maximum of 60 μA of beam, and $30 - 40$ μA average for long term operation. This is less than the total intensity required for CIS, but does come within an emittance of 0.2 π mm·mrad (normalized). The INR-Moscow source[5] produces a beam with a peak current of 1 mA in an emittance of 1.8 π mm·mrad. During recent operation with a 1-mA peak beam current extracted, the polarization of the H^- beam was measured to be $P_z = 0.87 \pm 0.02$. There are no apparent technical limitations to producing both vector or tensor polarized D^- beams by switching the atomic beam to D^0 and the ionizer to a hydrogen plasma ionizer. The source has been tested in this mode although the polarization of the D^- beam was not measured.

Stability, reliability and polarization studies for both polarized H^- and D^- ions are underway at INR and will continue through the summer of this year. Initial results indicate that there is no loss in vector polarization or peak beam current when the source is switched between hydrogen and deuterium operation, and that there are no technical limitations to achieving the long term operation that IUCF requires for CIS. A further study to evaluate the long term operation of this source is the subject of a 1996 grant proposal by P. Schwandt and A. Belov to the CRDF.

It is apparent that a combination of an optimally-designed pulsed ABS plus resonant charge exchange ionizer will allow us to exceed the CIS requirements (Figs. 1 and 2). The

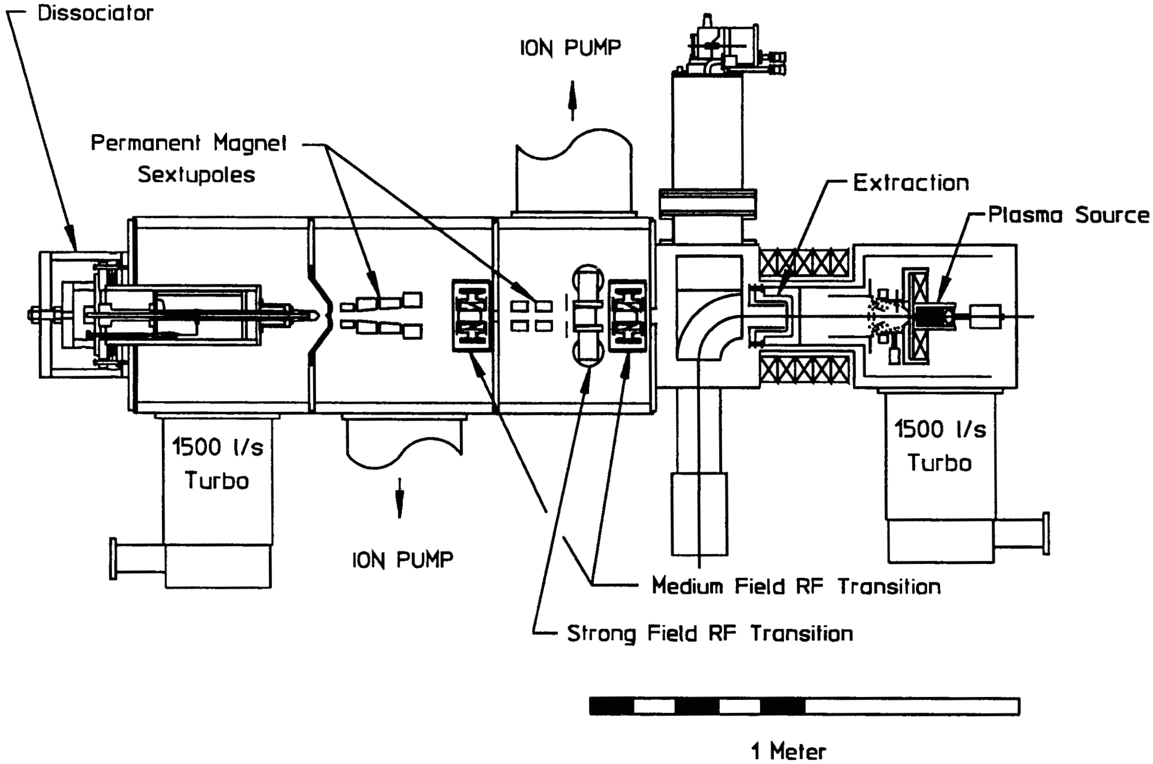

Figure 1. Proposed atomic beam section with ionizer.

excess capability will provide the option of further improvement of the luminosity available for experiments.

1. F. Stock for the HERMES target group (AIP Conf. Proc. 339, New York, 1995) p. 674.
2. T. Wise *et al.* (AIP Conf. Proc. 339, New York, 1995) p. 680.
3. V. Derenchuk *et al.* (AIP Conf. Proc. 339, New York, 1995) p. 662.
4. J.G. Alessi, A. Kponou, and Th. Sluyters, Hel. Phys. Acta **59**, 563 (1986); J.G. Alessi *et al.* in *Proc. of the Int'l. Workshop on Polarized Ion Sources and Polarized Gas Jets,* KEK Report 90-15, 93 (1990).
5. A.S. Belov *et al.,* Rev. Sci. Instrum. **67**, 1293 (1996).

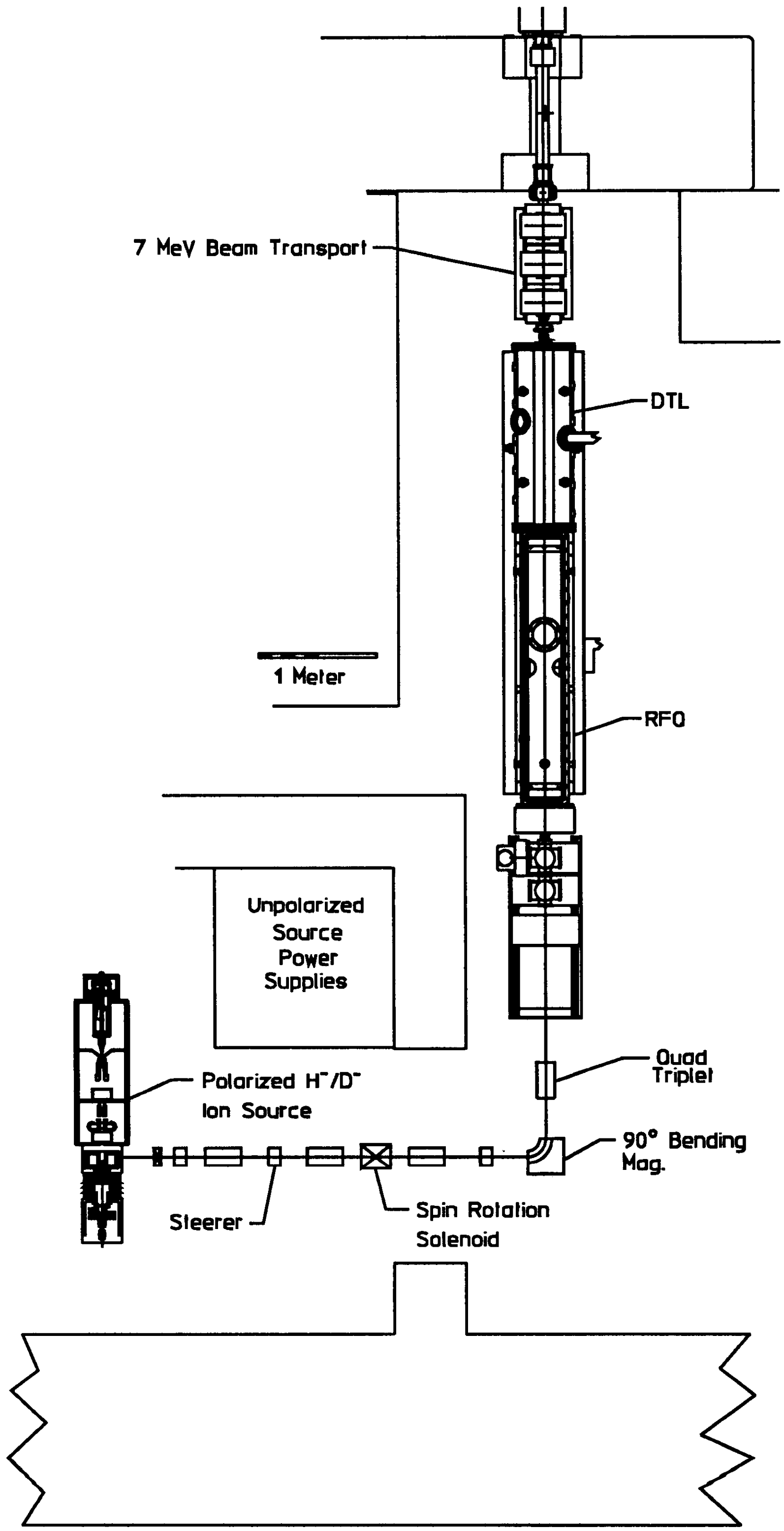

Figure 2. Proposed polarized ion source installation floor plan.