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Beam instrumentation for the Booster transport lines

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Why Worry About Instrumentation Now?

There are several reasons why we must firmly define the beam line instrumentation now even though Booster construction is not scheduled to start until FY 89. The transport of heavy ions requires vacuum of 10^{-9} to 10^{-11} Torr. The successful of the getter-strip technique used in the HITL line will probably also be used for the Booster. This approach makes it difficult to break into existing lines to add instrumentation at a later time. Therefore, you must anticipate future beam diagnostic needs by providing instrument boxes in key locations. All detectors which will be within the vacuum envelope must be designed at the same time as the vacuum system.

In some cases it is important to coordinate the location of beam monitors with transport elements as part of the initial design. For example, steering dipoles and position monitors must be located with the beta function in mind. Emittance measurements may be made with profile monitors. In one technique multiple detectors must be positioned with suitable phase advance between them. A second method requires a single detector to be placed downstream of a quadrupole which has enough range to sweep the beam profile through a waist without beam loss. The transport must be designed to include these provisions from the beginning. Detailled simulation of the measurement must be performed to assure that the detector location and quadrupole range will provide a meaningful emittance measurement. This was not done in the past.

Finally, it must be pointed out that beam instrumentation is most needed during the commissioning of the Booster and should all be available at that time.

Description of the Beam Instrumentation

Most of the detectors planned for the beam lines will follow the designs already in use. One exception is the position monitor in the Linac Injection and the Ejection lines. Capacitive pick-ups will be used in the Ejection line. The Linac line may also use these or strip-line detectors working on the 200 MHz bunched beam. The detectors for the high sensitivity beam loss measurements have not been determined at this time, but will be the same as selected for the system being put into the AGS.

Profile measurements in all beam lines will be made using multi-wire HARPs similar to those in the HITL line[1]. Variations in wire pitch and the electronics will be required to match to the new beam parameters.

Faraday cups will be used to measure beam intensity in the Heavy Ion Injection line. HITL-type beam transformers will monitor the low intensity beam in all 3 lines. High intensity in the Linac and the Ejection line will be observed with fast transformers of the type being installed in the LEBT upgrade.

Beam loss will be measured in the Linac Injection and in the Ejection lines. A dual system will be employed. The high intensity beam losses will be observed with a long cable ion chamber of the type used throughout the AGS[2]. A second system of high sensitivity detectors will be used to monitor the losses for the low intensity beam and to monitor the background activation. Detectors and electronics to perform this function are presently being developed for the AGS and are scheduled for installation in FY 89.

Deployment Philosophy

The beam instrumentation will be distributed throughout the beam lines to cover the maximum territory with the minimum number of detectors according to the following rules:

1. Profile monitors will be placed at the entrance to every bend section. Beam width and position information are necessary insure on axis entrance to the bend and to check the matching.

2. Position monitors will be located in pairs to allow both angle and position to be corrected. Steering dipoles will be located near the detectors.

3. Beam current transformers will be placed at the entrance and exits of the main line sections. While a larger number of these non-destructive detectors might be preferred, beam loss monitors will provide a more sensitive measure of beam scraping along the transport lines. The transformers will provide a quantitative measure of the transport efficiency.

The specific distribution of detectors will be discussed for each beam line.

The Linac Injection Line

The Linac Injection line is shown in schematic in Figure 1 (Figure 2 of Reference 3). The beam is bent from the present HEBT line into the Booster injection line by a 7-1/2 degree magnet. A high intensity transformer measures the H^- beam current, and an adjacent low intensity transformer measures the Polarized H^- beam current. A profile monitor precedes the bend through the 10-foot shield wall into the Booster tunnel. Another profile monitor is placed before the final bend towards the injection point. The long straight section to the Booster must be studied and specific locations recommended for the placement of the pairs of horizontal and vertical position monitors and steering dipoles. The final profile monitor will probably be located at the end of the longest drift section of this part of the line, to allow emittance measurements to be made. A study of the projected profile range for sweeping of the upstream quadrupoles in this region must be done before the final location can be chosen.

The final complement of detectors is:

	May 87	New
Profile Monitors........	3	
Position Monitors.......	4	
Beam transformers		
H^-................	2	
Polarized H^-.......	2	
Loss Monitors (high)....	8	
(low).....	8	

Heavy Ion Injection Line

(Note: The following discussion is based on the accepted Heavy Ion Injection line as of the end of October. An alternative design, proposed by T. Robinson, is not included. An addendum to this Technical Note will be issued if the beam line layout is changed in the future.)

The Beam from the Tandem Van De Graaff travels about 1500 feet to the AGS, presently entering through two 69-degree bends to the C-20 straight section. For Booster injection the beam will travel down an existing extension to the HITL tunnel rather than the 69-degree bend, entering the AGS tunnel at B10 near the old southwest extraction area. In the HITL matching section a 9-degree magnet points the beam towards the B10 pipe[4]. (Fig. 2). An existing profile monitor, Faraday cup and beam transformer precede the 69-degree magnet. In the preliminary design no transformer follows the new bend, but one should be provided at this point. The transformer provides the only non-destructive indication that the beam has entered this line, since radiation monitors will not work for heavy ions at this energy. This is a very desirable on-line monitor for operations. A profile monitor will be located at the entrance of the B10 penetration to help set-up the bend.

The section in the AGS tunnel is not fully designed yet but is envisioned as an N-pi phase shift through a total arc of about 42-degrees. It was felt that with a FODO structure, profile monitors at the entrance and exit of this section and a transformer to measure intensity, should provide sufficient instrumentation[5]. But without radiation monitors there is no way to observe and correct interior steering, since the 1:1 transformation between the ends washes this out. I would recommend the installation of segmented Faraday cups at the steering dipoles for the commissioning. These would at least give some steering information at much lower cost (about $6K vs $17K each) than profile monitors. No provision for these were included in the earlier estimates.

Following the bend into the HEBT tunnel the beam will go through a highly dispersive section before it is recombined by the second magnet (Fig. 3). A profile monitor has been suggested for the point of maximum dispersion. While it is not expected that the momentum spread will be easily observed at this point, it could provide a useful diagnostic for time variations due to ripple or other power supply perturbations. Another profile monitor would be located upstream of the second HEBT dipole. Although not in the initial proposal or later cost estimates, the addition of a beam transformer at the end of this section would provide the only on-line measure of beam transmission for this long run.

The final section of the Heavy Ion Injection Line transports the beam from the top of the HEBT tunnel through the shield wall to the Booster tunnel[6] (See Fig. 1). After a short matching section the beam is bent towards the inflector in the Booster. Profile monitors will be located upstream of the first bend and before the doublet in front of the shield wall. Other profile monitors will be located before the final bend and just before entrance into the Booster. A beam transformer will also be located at this point.

The total instrumentation for this line will be:

	May 87	New
Profile Monitors.........	8	
Beam Transformers (Low intensity).....	2	 2
Segmented Faraday cups...		 2

The Ejection Line

The layout of the Ejection Line (Fig. 4) was taken from Booster print No. BB-016-6. In this design the beam is kicked from the F6 straight section and bent through about 25.6-degrees to intersect the AGS at the L20 straight section. A profile monitors and high and low intensity transformers will be located upstream of the first dipole forming that bend. These will be upstream of the heavy ion stripping foil. A set of these same detectors will be located downstream of the bend, at the end of the first long drift. The low intensity transformer will measure the actual post-stripper heavy ion current in the line to the AGS. A third set will be located just before the beam enters the AGS. Two horizontal and two vertical position monitors will be located at an appropriate point in the downstream section of this line. Three additional profile monitors, with which to do an on-line emittance measurement, are to be located in this long straight section. The exact locations of the position monitors and the profile monitors must be determined by the transport design of the line.

Total instrumentation in the Ejection line:

May 87 New

Profile Monitors..........	6	
Position monitors.........	4	
Beam Transformers		
High intensity.......	3	
Low intensity........	2	 1
Loss Monitors		
High intensity.......	8	
Low intensity........	8	

Summary

The layout of the beam instrumentation for the injection and ejection lines has been described and functionally justified. Additional detectors beyond those in the original proposal are recommended as follows:

1 beam transformer in the HITL extension
1 beam transformer at the entrance of the Booster injection section
1 beam transformer in the Booster Ejection Line

3 Segmented Faraday cups in the Heavy Ion Injection Line.

Provision for the vacuum chambers for these devices must be made in the beam line design. Specific locations for the position monitors and 3 of the profile monitors must be made in the Ejection line, based on the beta function. In the Linac Injection line, the location of the position monitors and the emittance measuring profile monitor must be determined. In the Heavy Ion Injection line, the location of the profile monitor in the upstream matching section and in the final matching section must also be studied for emittance measurement capability. Estimates of the beam radius at all profile locations are needed before the detector array sizes can be chosen.

References

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2. J. Balsamo, N. M. Fewell, J. D. Klein, R. L. Witkover, "Long Radiation Detector System for Beam Loss Monitors", IEEE Trans Nucl. Sci., NS-24, No. 3, p1807, (1977)

3. R. C. Gupta, R. Damm, Y. Y. Lee, W. T. Weng, "H^- and Heavy Ion Injection Lines for the Booster", Booster TN - 90, Sept 17 1987, BNL

4. R. C. Gupta, Y. Y. Lee, "The Heavy Ion Injection Line for the AGS Booster", AD TN - 238, Feb 12, 1986, BNL

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6. Loc. Cit. Ref 3.

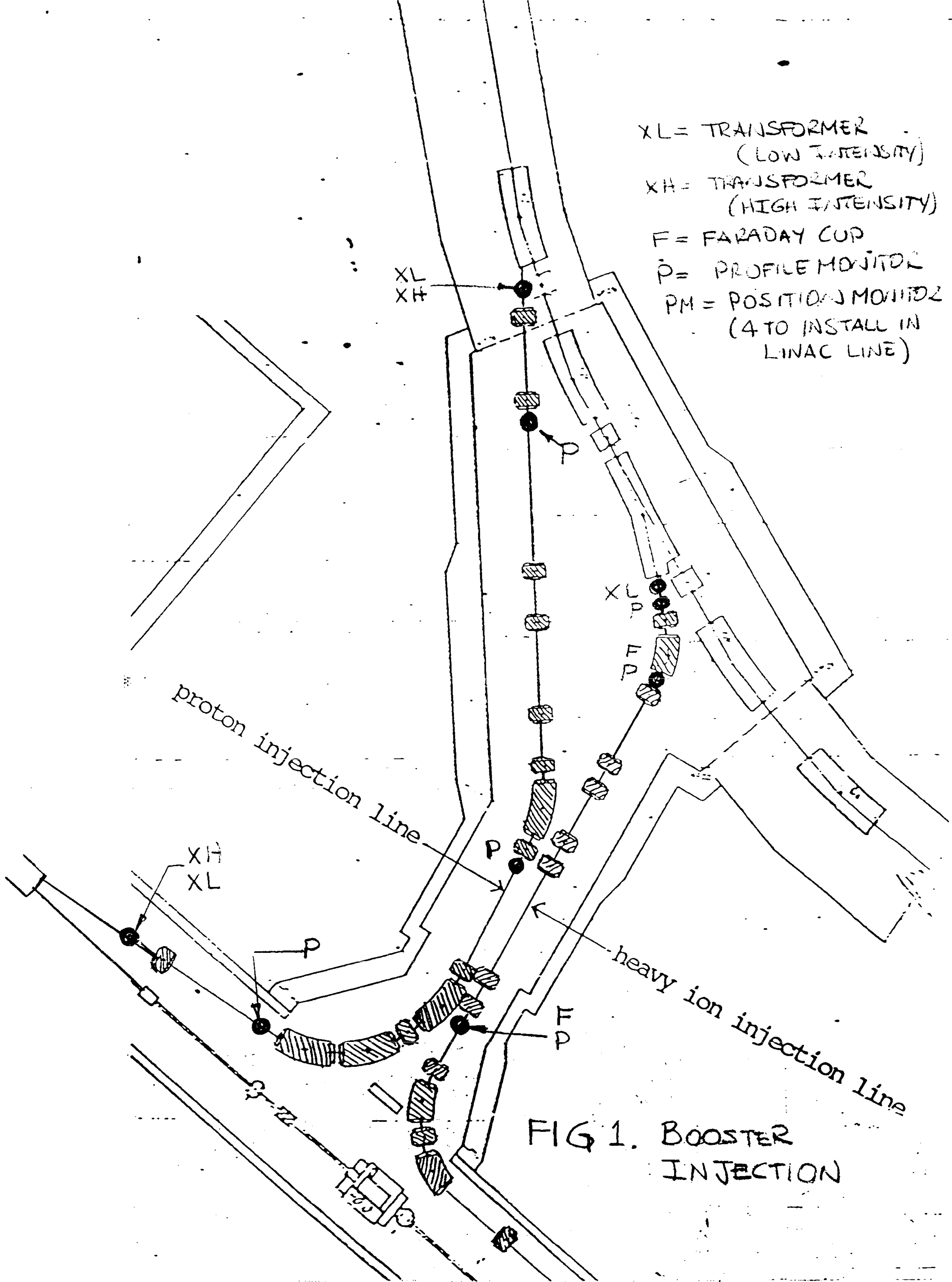

FIG 1. BOOSTER INJECTION

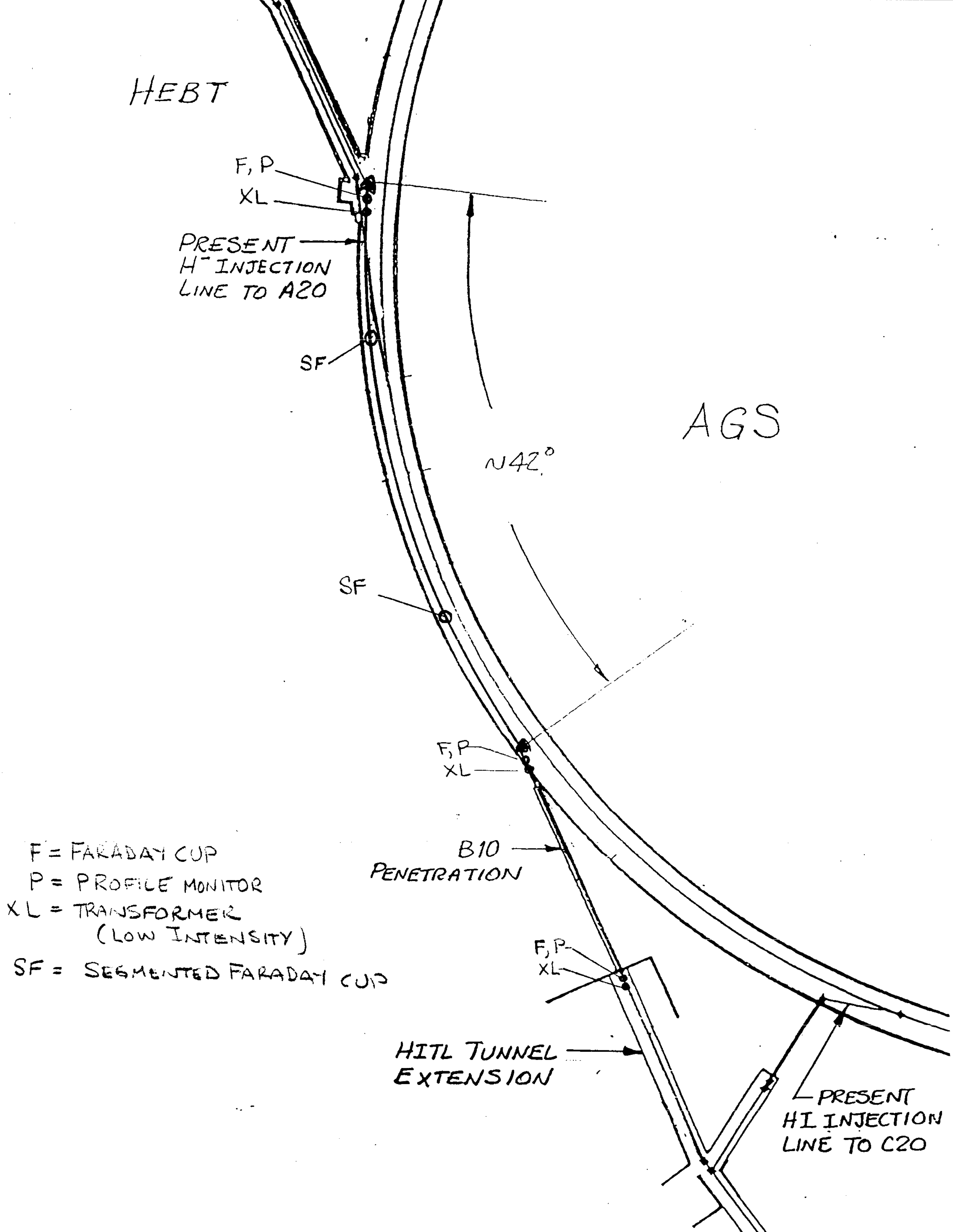

FIG 2. HITL EXTENSION (AGS)

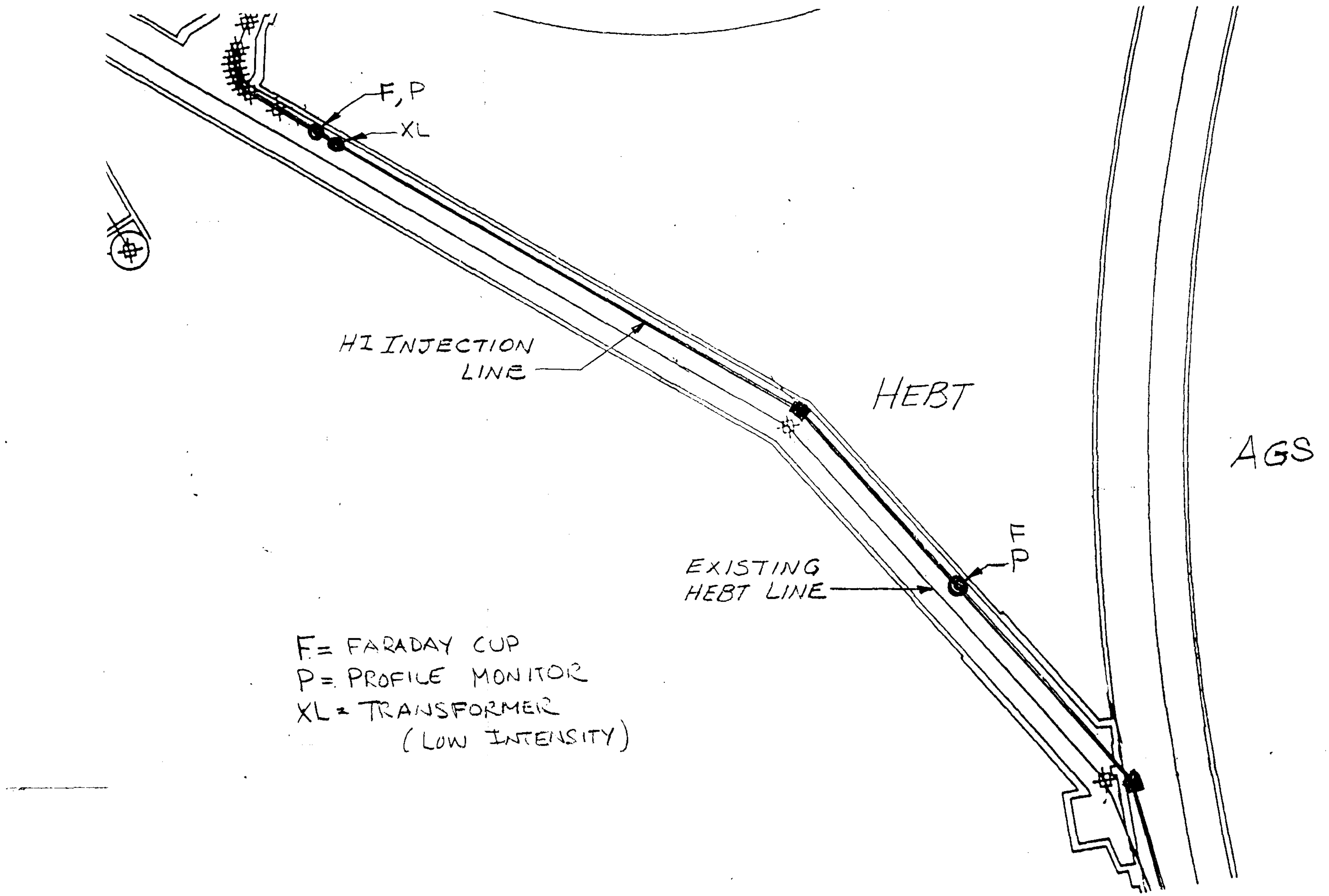

FIG 3. HITL EXTENSION (HEBT)

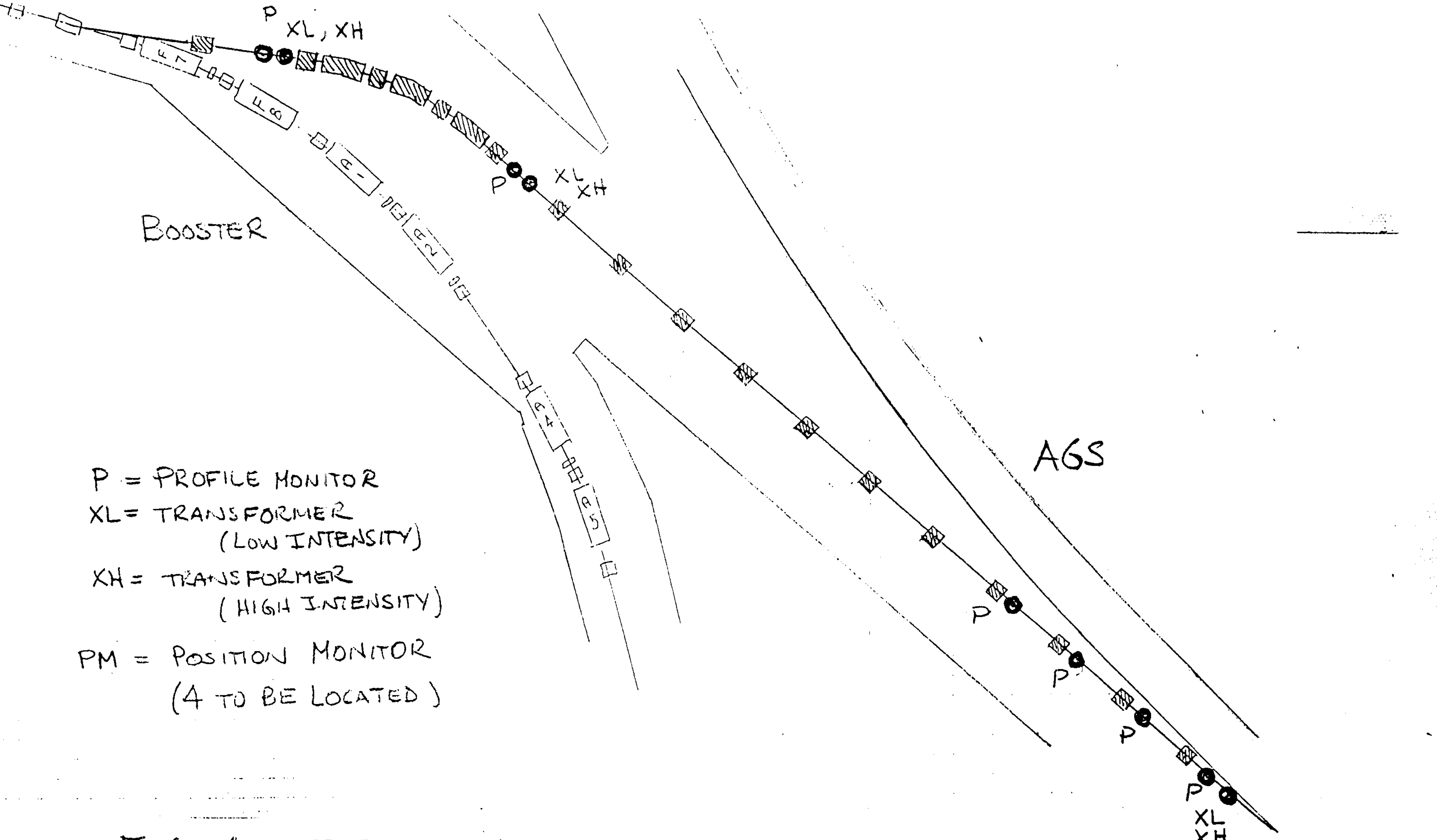

FIG 4. EJECTION LINE