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OPTION FOR IMPROVING THE SLOW EXTRACTED BEAM

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AGS DIVISION TECHNICAL NOTE

No. 131

OPTION FOR IMPROVING THE SLOW EXTRACTED BEAM

H. Weisberg
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SUMMARY

Possible difficulties with the proposed change to E20 extraction are discussed. In addition, an alternative to E20 is outlined, in which the existing extraction at F10 is improved and the switchyard is rebuilt.

The main improvements which are planned for the AGS slow extracted beam are:

- (1) decrease the number of protons lost in the extraction and transport equipment by an order of magnitude and thereby decrease the exposure to radioactivity of the people who work on or near the equipment;
- (2) increase the number of protons delivered to the targets by a factor of about 1.5 and;
- (3) provide four simultaneous target stations with complete control over the splitting ratios.

These improvements involve both the extraction and the switchyard, and in one scheme¹ involve moving the extraction point to E20.

1. Extraction Options

A. Conceptual Uncertainties

There are several uncertainties in discussions of the possible performance proposed new extraction schemes. First, recent studies of the present slow extraction with and without the H20 electrostatic septum² show performance that is considerably worse than expected from the simple models one uses to discuss extraction efficiency. Whether these discrepancies come from deficiencies in

the model or deficiencies in the extraction equipment, one must understand them before one has real confidence that proposed improvements will be successful. Second, there is the question of close-coupled septa. It is somewhat uncertain whether extraction with an electrostatic septum in a separate upstream orbit bump can be highly efficient. Proposed schemes (like E20) with all the extraction equipment in a single orbit bump do not suffer from this uncertainty. A third problem is that the AGS emittance is not known accurately enough to make realistic estimates of beam divergence effects.

Despite these uncertainties, we proceed to a discussion of various extraction options.

B. Problems with E20 Extraction

The present plan¹ for E20 extraction is to have an electrostatic septum at E13, a 0.020 inch magnetic septum at E17 and a 0.375 inch magnetic septum at E20, with 22 mrad deflection.

If the horizontal emittance of the circulating beam is $\epsilon = E/\pi = 0.10$ inch-mrad ($\beta\gamma\epsilon = 77 \mu$ rad - m), then the divergence of the resonantly extracted beam at E13 is 0.30 mrad, and a total of 0.33 mrad deflection is needed to overcome the beam divergence and make a clean shadow at E17. But, the 36 inch long electrostatic septum which is planned, operating at 80 kV/cm, will have a deflection of only 0.26 mrad. The extraction loss would then be $\sim 1.5\%$ at E13 and a comparable amount at E17, for a total extraction efficiency of 97%.

Two other weaknesses of the present design for E20 extraction are worth mentioning. First, there is the requirements of new extraction magnets for E17 and E20 with the same deflection, but significantly less thickness, than the corresponding ones presently at F5 and F10. Second is the highly distorted optics of the extracted beam, which has been defocussed horizontally much more than with F10 extraction.

Several ways to overcome these difficulties suggest themselves. One is to re-engineer the ring magnets and vacuum chambers around E13 to allow for a 46" electrostatic deflector there, giving 98.5% extraction efficiency. There are a number of other possibilities. These will not be discussed explicitly because each of them is analogous to a scheme that can apply to the present F10 extraction, as discussed below.

C. Improving F10 Extraction

There are several ways to extract from F10 with improved efficiency.

(1) A curved, 90 inch long electrostatic septum using 0.002 inch wires at H20 followed by the existing 0.030 inch septum F5 and 0.53 inch septum F10 magnets. If such an electrostatic septum is built with curvature equal to 1/2 the trajectory curvature, the contribution of beam divergence effects to its apparent thickness is only 0.0015 inch. For a typical set of assumptions, the extraction efficiency is 97%.

(2) Same as (1) but with the electrostatic septum at A10. This has the advantage over (1) that the electrostatic septum is only 12 wavelengths upstream of the magnetic one instead of 24, and also it does not depend on non-linear effects for separation. The extraction efficiency is $\sim 98\%$.

(3) Thirty-six inch electrostatic septa at both F3 and F5 followed by a 36 inch long, 0.040 inch magnetic septum at F7 and the existing ejection magnet at F10. Despite its unfavorable lattice parameters, this brute force method with close-coupled septa gives complete clearance of the copper septa and a calculated extraction efficiency of 96%.

2. A New Switchyard for F10 Extraction

The most attractive feature of E20 extraction is the extra room it provides for a new switchyard design. This room makes it easy to include high efficiency electrostatic splitters, and to feed the three existing target stations A, B and C, along with a 29 degree left bend to a new D station.

However, it is also possible to design an equivalent switchyard for F10 extraction. Figure 1 shows a possible layout and Table 1 gives the parameters of the special components that are required.

The design is based on conservative assumptions about the emittance of the extracted beam:

$$\epsilon_x (99\%) = 0.06 \text{ in-mrad}$$

$$\epsilon_y (99\%) = 0.10 \text{ in-mrad}$$

(The horizontal emittance is based on a circulating beam emittance of $\epsilon_x = 0.10$ in-mrad, and the vertical emittance is based on E. Raka's recent flip-target measurements of vertical beam size.) The switchyard has been designed so that a beam of the assumed emittance clears the septa and vertical apertures with a safety factor of 1.5.

The four quadrupoles Q_{1-4} are adjusted to satisfy the following four conditions:

- (1) a horizontal waist at profile monitor W_2 ;
- (2) a vertical waist at W_2 ;
- (3) a horizontal beam size of 0.76 inches (full width) at W_1 ;
- (4) minimum vertical beam size at W_1 .

For the assumed emittance, the beam size is then 0.68 X 0.60 inches (H X V) at W_2 and 0.76 X 0.84 inches at W_1 , and the beam divergence is 0.36 X 0.66 mrad.

The D and A beams continue to drift after leaving the switchyard components shown in Fig. 1 until they reach quadrupole doublets which focus them on the D and A targets. The C beam is refocussed by symmetric triplet Q_{5-7} to a waist at W_4 with the same properties as the waist at W_2 ; after splitting the B and C beams drift and are carried by the existing beam transport to the B and C targets.

The beam splitting consists of a three-way D/A/C split, shown in more detail in Fig. 2, followed by a two-way B/C split. The D/A/C split is made in three stages, with electrostatic splitters E_{1-2} (field on each side of a wire anode) followed by thin copper septum magnets S_{1-2} and thick copper septum magnets D_{1-4} . The B/C split is made in only two stages (E_3 followed by S_{3-4}), since the angle between the B and C beams is only 10 mrad. Beam losses should be less than 1% on each of the three electrostatic septa.

The splitting ratios are controlled by remote mechanical motion of E_{1-3} and S_{1-2} , and by steering with steering dipoles V_{2-5} and septum magnets D_{1-2} .

FOOTNOTES

1. Memos by J.W. Glenn, 7/20/76 and by L.W. Blumberg, J.W. Glenn and H.H. Hsieh, 10/7/76.
2. These will be discussed in a separate report.

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TABLE 1

Components for Revised Switchyard

SEC	Secondary emission chamber
Q ₁₋₇	3Q52
Q ₁₋₇	3Q52
W ₁₋₄	
W ₁₋₄	Segmented wire ion chamber
E ₁₋₃	10 ft, ± 35 kV/cm electrostatic splitter, 0.002 in wire septum, ± 0.38 mrad deflection
S ₁₋₄	10 ft, 1.6 kG, 0.08 in Cu septum magnet, 1.25 in vertical aperture, 5 mrad deflection
D ₁₋₄	8 ft, 10 kG, 1.0 in Cu septum magnet, 1.0 in vertical aperture, 26 mrad deflection
V ₁₋₅	2 ft, 10 kG Vernier magnet with vertical trim winding
C ₁₋₅	5C90, 13 kG, 1.25 in vertical aperture, 30 mrad deflection
H ₁₋₃	6H300, 16 kG, 1.25 in vertical aperture, 130 mrad deflection

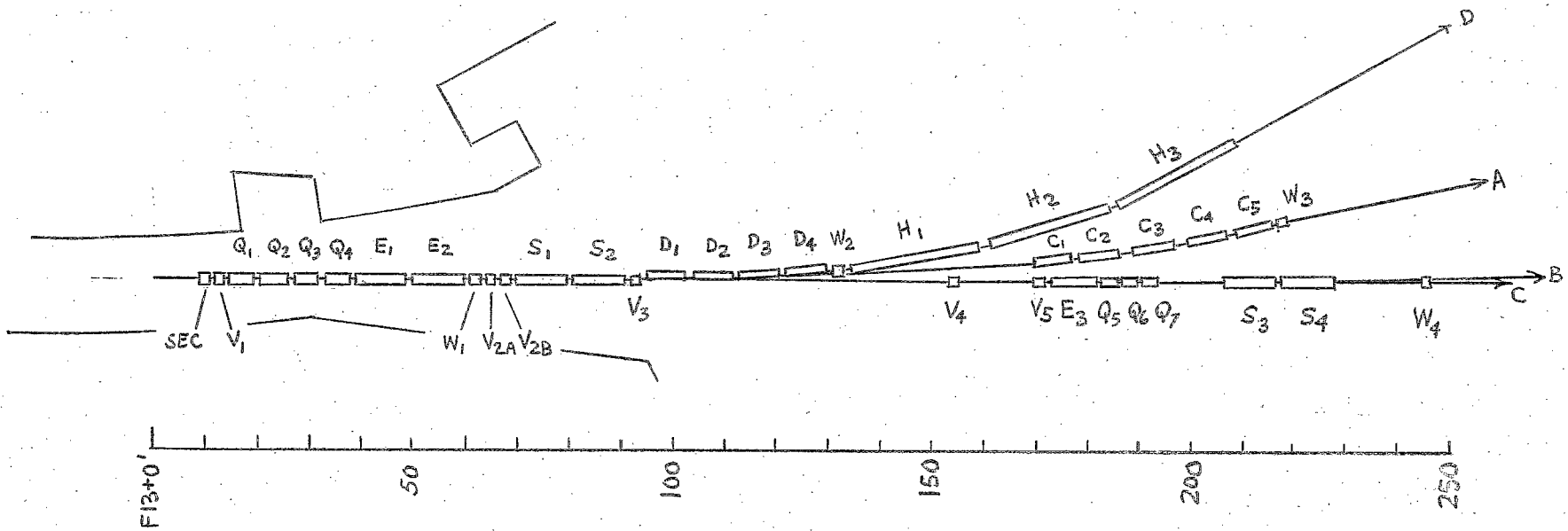


FIG. 1 Revised F10 switchyard layout

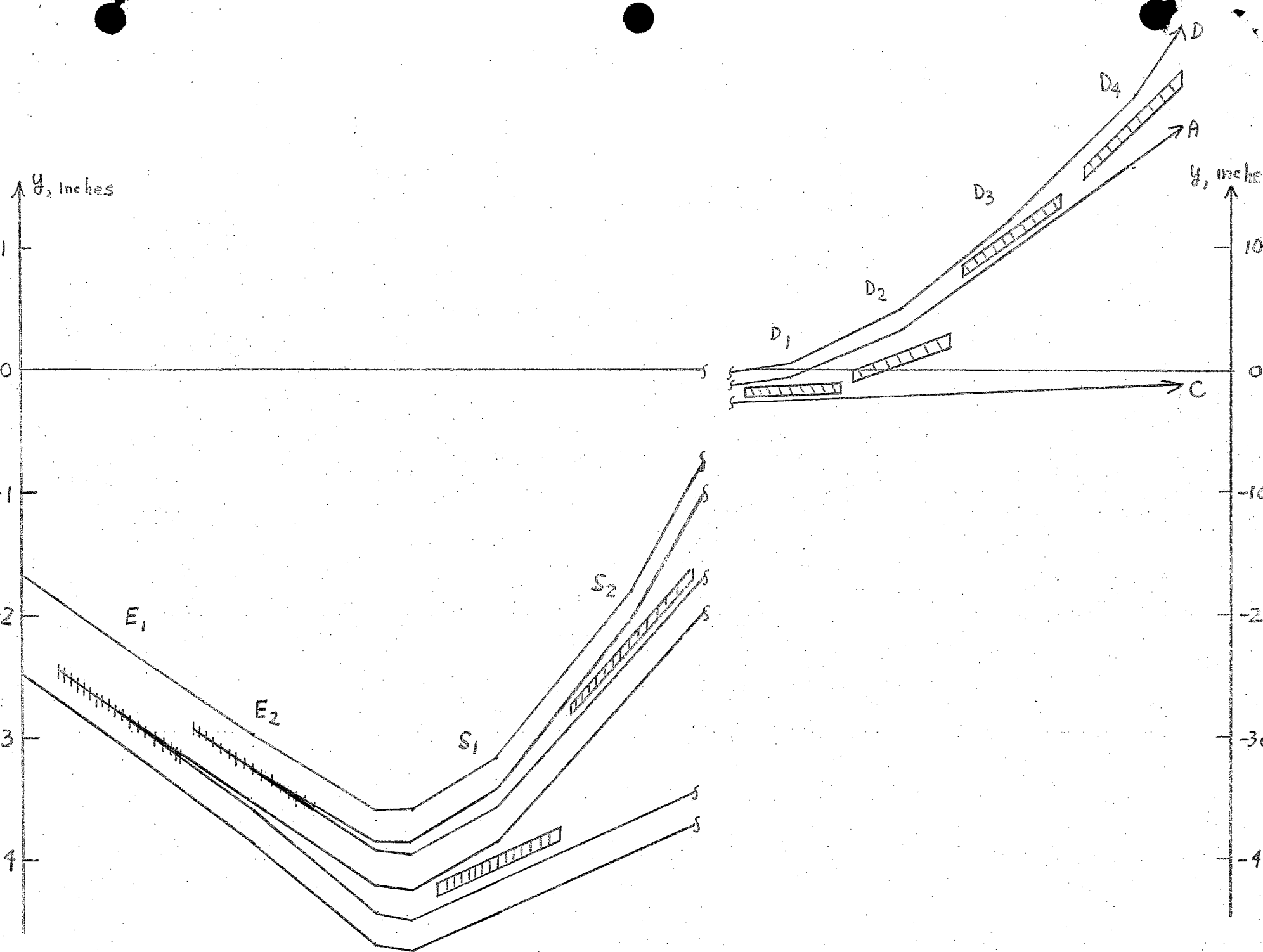


FIG. 3 Details of the D/A/C splitting. Note the change in transverse scale.