THE ENERGY DOUBLER AND THE SUMMER STUDY

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I. Introduction

The energy doubler played a peculiar role at the Summer Study. Neither could its existence within a few years be assumed nor could the possibility of its construction in the near term be ignored. Further, though conceived as a "short term" project, the doubler may evolve into a long range project for reasons discussed in the next section and become a competitor for funding with the other major proposals of the study. Thus, though not one of the four major topics on which recommendations were solicited, the doubler received considerable attention. It is the purpose of this section of the summer study report to summarize the doubler-related discussions.

II. The Energy-Doubler Concept

In his statement before the Joint Committee on Atomic Energy on March 9, 1971, R. R. Wilson described the possibility of raising the maximum energy capability at NAL to the 1000-GeV range by installing a ring of superconducting magnets in the present main accelerator enclosure. Following the initiation of the high energy physics program at NAL, it became feasible to mount a modest effort to examine this proposition in some detail. Throughout the latter part of 1972, a series of discussions were held on a biweekly basis. It was concluded that a figure of $20 million was within the realm of possibility for construction of superconducting magnets and their associated refrigeration system--the major hardware components of the doubler ring. It was further concluded that a significant prototype study was necessary in order to test the magnet construction and refrigeration system ideas, for not only was a new technology involved whatever the cost, but also design principals were proposed such that, if proved valid, would effect the considerable economies necessary to reach the $20 million level.

Now, if the major hardware components of the superconducting ring could indeed be obtained for $20 million, that would be an interesting conclusion, for one may conceive of the construction of an energy doubler using funds provided by the initial $250 million authorization for the laboratory. On the other hand, should the components cost, say $50 million, the energy doubler would surely require new and larger funds for its construction and, though still a very interesting idea, would of necessity be viewed within the context of long range planning.

Accordingly, a magnet and cryogenic system prototype effort was initiated at NAL in January of this year having as its principal goals the fabrication of a number of full-scale superconducting magnets suitable for an energy doubler and their installation in the "Protomain" enclosure at the NAL Village with appropriate refrigeration equipment. This activity is scheduled for completion in early 1974, and is described in more detail in the next section. Since the Summer Study took place at roughly the midpoint of the prototype work, it was too early for decisive cost information to be available--a circumstance which could not help but contribute to the difficulty of assessing the role of the doubler during the Summer Study.
III. The Doubler Design Study

As noted above, the focus of the doubler design effort is on cryogenic magnet and refrigeration system development. There are many other accelerator-related topics which deserve investigation, but the principal unknowns (cost and otherwise) lie in the application of the new superconducting technology and that is where the emphasis must be placed for the present.

An important milestone in the design of the present main accelerator was the construction in a model enclosure at the NAL Village—in the so-called Protomain tunnel—of a "basic period" of the machine, consisting of a 200-ft segment of the ring made up of eight 20-ft dipoles and two 7-ft quadrupoles, including vacuum, power, and control equipment. It is the intent of the doubler design study to install in the same location a basic period of a superconducting ring.

At this writing, two parallel efforts are in progress which point toward the above goal. First, a series of small magnets have been constructed. These magnets—up to one meter in length—are in a sense studies in fabrication technique. The six and seventh of these, which are now being readied for test, are of particular interest in that they are two presumably identical dipoles. Assembled in a common cryostat, they will provide valuable information on magnet-to-magnet tracking under pulsed conditions. The next step will be the construction of what is to be the first of the full scale 20 ft long dipole magnets, tooling for which is currently being set up.

Second, a 200 liter per hour helium liquefier has been procured and installed at the Protomain. It is now undergoing acceptance tests. A closed loop liquid helium flow system has been assembled in the enclosure, and studies of overall refrigeration system design, including simulation of magnet heat loads, will be carried out in the near future. Since this liquefier has about one-half of the capacity of that which would be needed in each of the twenty-four main accelerator service buildings (one of two possibilities for the refrigeration system, the other being a twelve-refrigerator system) for the complete doubler, this aspect of the study is being conducted at a meaningful scale. As full scale prototype magnets become available, they will replace sections of the test loop.

Although the work is characterized as an Energy Doubler Design Study, the results of this effort will be equally applicable to other superconducting magnets systems that have been discussed this summer. Thus, even if the energy doubler is not constructed, the design effort will in no sense be wasted. In fact, at this stage the doubler design study may be more appropriately described as a large scale experimental investigation of the use of superconducting magnets in periodic focusing systems.

IV. Commentary at the Summer Study

Quite naturally, interest in the doubler was concerned with it as a complete device rather than in the restricted set of design problems that the doubler effort is now studying. Three principal applications were discussed: (i) use as a conventional accelerator, (ii) use as a "beam-stretcher" for the main ring, and (iii) use as an injector into large storage rings.

*For a more extensive discussion of these plans see "Some Preliminary Concepts About the Proposed Energy Doubler Device for the 200/500 GeV Proton Accelerator at the United States National Accelerator Laboratory, Batavia, Illinois" TM-421.
(i) Use as a conventional accelerator. The main questions here concerned the intensity that might be expected, whether or not an extracted beam could be directed into the existing switchyard, and what the physics interest in 1000-GeV protons might be.

As currently envisaged, the doubler would be a slow-cycling machine with a cycle time in the 100-sec region. Assuming that the main accelerator achieves its design goal of $5 \times 10^{13}$ protons per pulse, a single turn injection process into the doubler would result in an average intensity from the doubler the same as that now delivered at 300 GeV from the main ring, i.e., some $5 \times 10^{14}$ protons per sec. Subsequently, stacking in the doubler may conceivably be employed to increase the average intensity, though this would be a later development. The problem of extracting from the doubler into the existing beam lines was studied by H. Edwards. In the following paper, she outlines the extracted beam transport and a few minor modifications to the doubler lattice that would make it feasible to introduce the 1000-GeV beam into the present switchyard system some 150 ft downstream of the Transfer Hall. Of course, the external beam line would have to be upgraded to 1000-GeV capability, probably by the introduction of superconducting magnets.

During the second week of the study, a meeting was held at which D. Drickey, A. Mann, and W. Walker commented on the potential of the Energy Doublor for high energy physics experiments. Notes on the talks by Drickey and Walker follow in this section of the report; Mann's discussion is incorporated in the papers of the Experimental Areas Group.

(ii) Use as a beam stretcher. Here, the doubler is used as a means of improving the duty-factor of the main accelerator. In this mode, the doubler would not accelerate; rather, protons would be injected into it at the peak of the main-ring cycle and a very slow spill set up lasting hopefully, until the next main-ring pulse was ready for injection. A long, ripple-free extraction should in fact be easier from the doubler than from the main ring. This mode presumes that injection be possible into the doubler at the peak energy of which the main ring is capable: such an injection system is sketched in the next paper.

(iii) Use as an injector for storage rings. Though the problems associated with accelerating a high-current beam in a storage ring are probably soluble, there is clearly an advantage in injecting into a storage ring at the energy at which the storage ring is to be used. Thus the doubler is the natural injector for the 1000 GeV proton rings recommended by the Summer Study. Here again, interest was expressed in a somewhat higher average intensity than that associated with the basic doubler concept in order to shorten an otherwise lengthy filling time.

Finally, though all participants who expressed their views on the doubler were by no means in agreement concerning the advisability of constructing the doubler at the expense of other short term and long-term goals at NAL, this writer felt there was a clear-cut consensus in favor of continued and increased effort on superconducting magnet development at NAL.