TOWARD A BIG MACHINE*

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## Introduction

The U. S. High Energy Physics Advisory Panel, on advice from its Wood's Hole Subpanel, has recently (July 1983) recommended to the Federal Government agencies which support high-energy physics that they proceed toward the creation of an accelerator facility that can give access to the mass region up to 1-2 TeV as soon as possible. This recommendation is the outgrowth of some years of discussion within the high-energy physics community about the possibilities for a very high energy accelerator. These discussions were formalized in two ICFA workshops, one at Fermilab in 1978, another at CERN in 1979, a summer study at Snowmass sponsored by the Division of Particles and Fields of the American Physical Society in 1982, and the Cornell workshop on the 20 TeV Hadron Collider in 1983.[1-4]

From the various discussions there has emerged a concensus that the accelerator most likely to meet the economic and technical feasibility criteria on the desired time scale is a proton-proton collider with beam energies of 10-20 TeV built with superconducting magnets: the Superconducting Super Collider (SSC). It is widely felt that the technology of both superconducting magnets and proton colliders is sufficiently mature to allow the undertaking of such a project.

To plan for such a device, many technical decisions must be made. Some of the many questions to be considered are suggested by the parameter list given in Table I. What is the optimum choice of magnetic field? What new technical developments are needed to support the magnet choice? What new problems are posed for controlling an accelerator with a circumference of at least 75 km?

## Accelerator Physics

Within the range of parameters suggested in Table I, conventional design for the optics seem to be satisfactory. Existence-proof-level solutions for the needed optics have been obtained (4). Figure 1, for example, shows a possible solution for an interaction region with $\beta^*$ of about 2 m and $\beta_{max}$ of about 1750 m.

The beam intensity required to attain the nominal luminosity of $10^{33}$ does not put extreme demands on known methods. Stability against collective effects and radiation shielding should be relatively straightforward to achieve.

## Magnets

Several possible magnet technologies for the 20-TeV machine have been discussed: weak field, 2.5-3T, superferric magnets; 4-6T magnets based on extrapolation of present NbTi technology, 8T NbTi magnets operating at 2K, and, 10T magnets using $Nb_3Sn$. Some consequences of these choices are illustrated by the partial parameter list shown in Table I. In particular, lower field magnets can be expected to be less expensive per unit length, but imply a longer tunnel and proportionally higher civil construction costs. Higher magnetic fields allow a shorter tunnel and lower civil construction costs but with greater costs per unit length for the magnets. Figure 2 suggests the relative sizes of the rings required for three choices of the guide fields; the Fermilab ring is shown for comparison.

We will be relying heavily on established industrial capacity for production of large quantities of high quality, sophisticated superconductor. A new relatively high current NbTi alloy that is now being made in commercial quantities may prove to be the material of choice. Or $Nb_3Sn$ may prove to be more cost-effective. Commercial production of $Nb_3Sn$ is now in the pilot development stage. These and many other questions must be answered at the earliest possible time by a vigorous R&D program.

## Controls and Instrumentation

Effective control of 100 km, more-or-less, of accelerator will present many challenges. The large distances and the resulting delay times mean that many control functions will normally be under local control at the remote (from the central control complex) site. In all cases, continual monitoring and supervisory control by the central control complex will be necessary. Flexibility will be needed to allow operator-control of many systems, for example, vacuum and refrigeration, from either the remote or central locations. Beam position monitoring and orbit correcton will be highly automated. Only by exploiting the latest electronics and computer technologies will we be able to provide reliable and affordable solutions to these and other demanding controls problems.

## Design Technology

The great size and cost of a 20-TeV collider makes it essential to be "right" about design choices. To cope with size-related complexities, computer modeling and simulation methods will play a crucial role in the design and optimization process. Topics that must be investigated in the search for an optimal design include:

- dynamic aperture computation (tracking) and optimization.
- beam-beam effect and its effect on operation.
- simulation in aid of beam stability assurance
- system simulations:
  - control systems
  - magnet and power supply systems
  - cryogenic systems
- optimization of operating mode for stability and economy.

Further development of computer modeling methods will be required.

## Civil Construction Technology

The size of a 20-TeV collider takes us into the realm where important economies of scale must be realized by using modern large-scale construction and materials-handling techniques. This possibility must be considered carefully in the site selection process. An acceptable site, while requiring only minimal improvement to provide a stable foundation for the accelerator, will exhibit a high degree of geologic uniformity in order to obtain the greatest benefit from efficient construction techniques. It will be necessary to work closely with geologist and geotechnical engineers to identify a number of such sites.

## Epilogue

Discussion to this point has focussed on the large hadron collider per se. The economic and technical feasibility of possible ancillary features have yet to be evaluated. Should, for example, provision be made for:

- fixed-target experiments; secondary beams?
- an e-p capability?
- a back-scattered gamma beam?
- se of the injectors for physics research?

These questions must now be promptly answered.

R&D germane to a large hadron collider has been going on for some time at various places, as shown by the papers on the "Big Machine" contributed to this conference. As a result of the HEPAP recommendation, a coordinating plan is now being developed to help focus the research and development program as we proceed toward the Big Machine.

## References


[*] Prepared by Al Russell, Fermilab, Scientific Secretary for this session.

[1] Proceedings of the Workshop on Possibilities and Limitations of Accelerators and Detectors, D. A. Edwards, ed., Batavia, IL., 1979.

[2] Proceedings of the Second ICFA Workshop on Possibilities and Limitations of Accelerators and Detectors, U. Amaldi, ed., Les Diablerets, Switz., 1979.

[3] Proceedings of the 1982 DPF Summer Study on Elementary Particle Physics and Future Facilities, R. Donaldson, R. Gustafson, F. Paige, eds., Batavia, IL., 1983.

[4] Report of the 20 TeV Hadron Collider Technical Workshop, M. Tigner, coordinator, Ithaca, NY, 1983.


Table I. Illustrative Parameter List for a 20 TeV on 20 TeV Proton-Proton Collider

| | | | |
|---|---|---|---|
| B (T) | 2.5 | 5 | 8 |
| average radius (km) | 37 | 18 | 12 |
| half-cell length (m) | 200 | 130 | 100 |
| interaction points | | 6-8 | |
| number of particles | | $10^{14}$ | |
| beta at I. P. (m) | | 2 | |
| luminosity ($cm^{-2}$ $s^{-1}$) | | $10^{33}$ | |
| aperture (cm) | | 2-3 | |
| tune | | approx. 100 | |
| free space at I. P.'s (m) | | approx. 20 | |
| total power consumption (MW) | | 75 | |

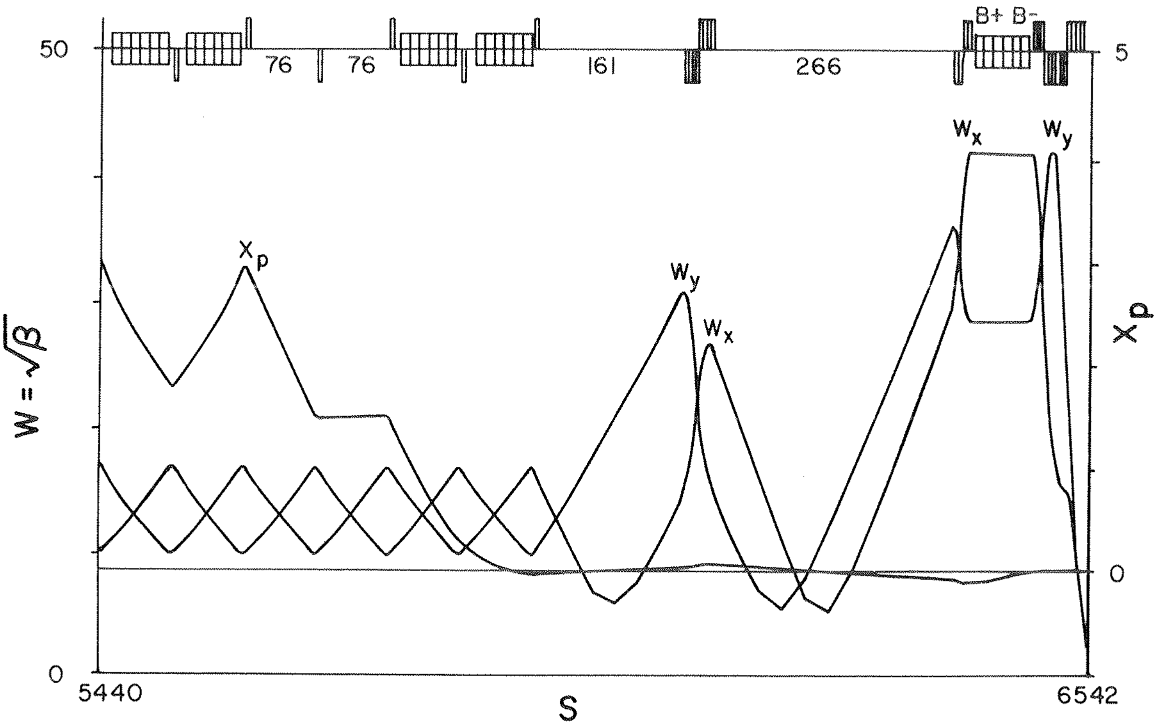


Fig. 1. Antisymmetric p-p insertion, left side.

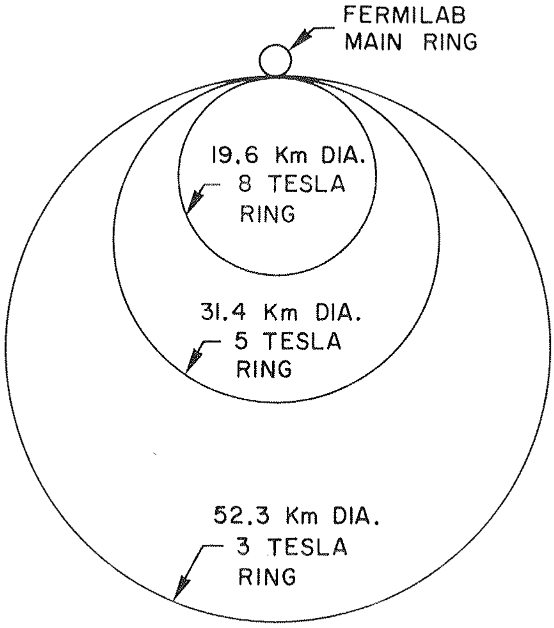


Fig. 2 Comparative sizes for 20 TeV ring at three field strengths.