20-TeV HADRON COLLIDER WORKSHOP

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Introduction

The general subject of proton colliders in the 20 TeV range has been discussed by the world community of particle physicists for some time. Two ICFA workshops, one in 1978 at Fermilab and one in 1979 at CERN, considered this type of accelerator among other potential candidates for truly frontier instruments in high-energy physics. At these workshops general techniques and schemes for reaching very high energies were discussed while costs and engineering details were left for the future. In the intervening four years, magnet and colliding-beam technologies germane to hadron colliders have made substantial advances.

Inspired by these technical advances and the enormous scientific opportunities that would be opened up by a 20-TeV hadron collider, leaders in the field of elementary particle physics have suggested that we exploit the new technology and begin construction of such an accelerator at the earliest possible date. An examination of this suggestion by the U.S. HEP community was begun as part of the 1982 summer study of the Division of Particles and Fields of the American Physical Society held at Snowmass, Colorado.

Building on the Snowmass findings[1,2] and encouraged by the administrations of the U.S. laboratories engaged in particle physics as well as by the U.S. Federal Administration and many scientists in the field, this workshop was convened to consider further the technical issues pertaining to a 20-TeV collider facility.

Forty U.S. and European experts in accelerator science and accelerator and construction technology met March 28 through April 2, 1983, the issue of which is a report to the U.S. HEP community. In it we attempt to offer the best technical advice we can give today with regard to the feasibility and appropriate time scale for a 20-TeV class hadron collider.

In particular, we have tried to answer the questions:

- What, if any, are the interesting technical options for a 20-TeV hadron collider in the luminosity range 10^{31} to 10^{33} $cm^{-2}sec^{-1}$?
- If such options exist, what engineering and technological developments are needed before we start to build?
- How long might the preparations take?
- What might be the economics of such a facility?

In carrying out this examination we divided ourselves into four task groups, each coordinated by a secretary. The task groups and their secretaries were:

• Accelerator Physics	D. A. Edwards
• Magnets and Cryogenics	C. Taylor
• Systems Engineering	B. D. McDaniel
• Sources and Injectors	R. Martin

Under the rubric of Systems we have subsumed civil construction, accelerator assembly, auxiliary systems, facilities, shielding, etc.

Accelerator Physics

This task group was concerned with interaction region optics, good field aperture requirements, extra aperture required for $\bar{p}p$ operation, single-beam stability requirements, intra-beam scattering and synchrotron-radiation effects. Although all of these issues will need to be addressed again in detail if a serious design study is launched, none of them seem to present major difficulties. Existence proof level solutions for needed optics were found and are displayed in the report. Evidently an aperture of about 1 inch will be adequate from both beam-containment and stability points of view. Configurations permitting both head-on collisions of bunched beams and collisions of continuous beams crossing at a small angle were considered. Luminosities up to 10^{33} appear to be feasible.

Magnets and Cryogenics

Costs and technical feasibility for five possible magnet systems were discussed: i) direct use of Saver magnets, ii) use of "superferric" magnets at 2.5 to 3 Tesla, iii) use of a small-aperture version of Saver or CBA magnets at 4-6 Tesla, iv) use of improved Nb-Ti conductor at 2 Kelvin with or without iron and, v) use of Nb_3Sn with field up to 10T and operating temperature above 4K. Portions of the various systems contributed to a lively debate. Although many specifics remain to be thrashed out, it was generally agreed that more than one of the proposed systems could be viable candidates for a 20-TeV ring.

Systems Engineering

This task group considered the accelerator system and associated facilities as a whole, including construction and accelerator assembly methodologies, shielding and utility requirements, etc. Fortunately a wide range of possible construction technologies exist. In studying optimization of an integrated collider facility based on the various possible magnet systems and at various possible sites, many of these construction

methods will need to be considered in detail. No matter what system may ultimately be adopted, the application of mechanization to most aspects of accelerator construction, installation and maintenance will be crucial.

Shielding requirements, at least for luminosities up to 10^{33}, with head-on collisions of bunched beams, will be easy to meet. Six meters of earth cover or substantially less under some circumstances will be entirely sufficient.

Surprisingly, the utility requirements will be relatively modest. At full operation, it is expected that about 75 MW of electric power may be required.

Sources and Injectors

The fact that the injector system for a 20-TeV collider will, in many aspects of performance, be the equivalent of the largest accelerator complexes in operation today shows the magnitude of the project envisioned. The existence of these complexes shows the technical feasibility of the requisite injector system, but application of the technology to be used for the main collider will be needed to control the cost. Technology for producing antiprotons sufficient for luminosities of $10^{31}cm^{-2}$ sec^{-1} will be in hand shortly. Technology for producing proton beams of the intensity and the phase space density needed for luminosities up to 10^{33} is in hand today.

Cost Estimate

Even with assured technical feasibility, cost considerations for a 20-TeV ring will dominate. For this reason, the workshop participants spent considerable effort in attempting to make conservative estimates and to identify areas of important cost uncertainty. Cost estimate breakdowns and uncertainty assignments are given in the workshop report in tabular and graphical form. Briefly, we concluded that if we started today, using Saver magnets, we could build a 20 TeV on 20 TeV $p\bar{p}$ collider with luminosity $\sim 10^{31}$ for a cost somewhere between 2.4 and 3 (G$). After three or four years of engineering development, we might reasonably expect to be able to build a 20 TeV on 20 TeV pp collider with luminosity $\sim 10^{33}$ for a cost somewhere between 1.3 and 2 (G$) including the cost of a new lab. By lowering the beam energy to 10 TeV, at least 25% of the cost could be saved and probably more.