REPORT OF FIXED TARGET ACCELERATOR SUBGROUP

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Preface

It is now nearly an article of faith in particle physics that center of mass energy is the supreme figure of merit and that failure to preserve a linear Livingston plot is a sign of weakness, perhaps a fall from grace. Even though there are portents and oracles or a vast desert before us, our conviction that we should strive for even higher energy is firm, and doubtless we will do our best to collide something with something at the highest possible energy. However, nature is sublte; orthodoxy is suspect per se. Even as we strain toward a possible illusory asymputopia not only beauty but porbably truth as well lie near at hand.

Therefore, a few of us have chosen to consider (I) what additional is needed to render a facility optimized for very high energy pp or p$\bar{p}$ collisions suitable for a robust fixed target program and (II) what are the features and cost of a very high intensity proton accelerator at medium energy (16-32 GeV). For the first topic the focus has been on the longer range future exemplified by a 20 TeV ring or rings. The second topic is the option of creating within the next ten years a facility serving the needs of both particle physics (e.g. rare K decays, hyperon beams, intense neutrino beams) and nuclear physics (e.g. hypernuclei, K scattering) and providing as well intense muon beams of interest to both particle and solid state physicists. The two topics reflect a division of interest in the fixed target subgroup, and there was limited joint effort between those concerned with the two topics except relevent to their mutual concerns with targetry and managing beam loss. Thus, this report is also disjoint. Those considering very high energy treat mostly in a qualitative fashion the differences between a hadron storage ring and an accelerator for making external beams; those considering very high intensity medium energy accelerators have been more concrete and considered a complete facility modeled on the LAMPF II proposal. The fixed target accelerator subgroup consisted of: E. Fisk and J. MacLachlan (coordinators, both FNAL), C. Taylor (LBL), and R. Macek and H. Thiessen (both LASL).

In view of the present strong enthusiam for colliding beam machines it may be useful to restate some of the special advantages of a fixed target facility which greatly extend the range of phenomena open to investigation as well as the range of experimental techniques available to explore them. It does not seem probable that an adequate understanding of the natural world will be obtained without the most comprehensive possible investigation. Therefore, against the compelling advantage of colliders in delivering center of mass energy one must weigh a sizeable list of features of fixed target operation. We believe these features justify including fixed target capability from the start in any very high energy accelerator and that sufficient beam and facilities should be provided for handling several targets simultaneously. Even if limited funding requires that the maximum energy be scaled back a bit to provide for a little extra aperture and for external beam lines and experimental areas, that sacrifice should be made. Otherwise we have the unpleasant possibility of having what is almost a one-experiment machine engaged primarily in a null experiment. This is not the kind of desert machine that we would like to have.

Although superior luminosity is indeed an outstanding advantage of fixed target operation over the colliding beam mode, that advantage is not properly represented simply by comparing the primary interaction rates, because usually the beam of interest are the secondary beams. Thus, the mean multiplicity of 100 at 20 TeV, which is a handicap in analyzing colliding beam experiments, is an important bonus. Furthermore, contrary to the usual statement, the energy of the center of mass of the primary interaction is not wasted in the fixed target mode. Although it is not available for particle production it serves the very important function of collapsing the production into a narrow forward cone thereby permitting momentum selection, collimation, particle separation, etc. of very intense beams. The existence of beam lines makes it possible to share the use of the accelerator among many experimenters working in several areas tailored to special needs. Some of these areas can provide for fast changeover of quick, exploratory experiments which are much less costly than the monstrous detectors which are likely to sit in the colliding beam areas for years at a time. Another very important advantage of secondary beams is the possibility of measuring properties of reaction products within the beam phase space; one may never know what interesting physics goes down the beam pipe at a collider.

The foregoing remarks have been made to emphsize a complementarity between fixed target and colliding beam operational modes and to caution against foreclosing a potentially rich area of experimentation by an obsessive pursuit of the highest center of mass energy.

Accelerator Requirements for the Fixed Target Program

The principal differences between an accelerator designed to serve a fixed target program and one intended solely as a bunched-beam hadron collider arise from a faster acceleration cycle and higher beam current requirements. Resonant extraction may or may not require additional horizontal aperture beyond that needed for injection, depending on details of the design, but for this discussion it has been assumed that with an appropriate high-β insertion it will be possible to extract from the same ring that one would build for a storage accelerator. However, to inject the currents desired for the fixed target program it may be necessary to take a somewhat larger aperture.

One of the principal concerns of the accelerator technologists at this workshop has been the relative economy of different magnet designs. To provide some guidance in this respect the effects of fixed target operation have been considered for 20 TeV accelerators built from 10T magnets, improved ED/S magnets at 5T, or the 2.5T "superferric" magnets described at this workshop by R. Wilson. The parameters of the 10T machine are precisely those described at the ICFA Les Diablerets workshop. The 5T and 2.5T machines are closely comparable to each other but not so directly comparable to the 10T ICFA model because a more modest beam current and cycle time have been proposed as adequate. The properties of these accelerators most relevent to the special requirements of fixed target use are summarized in Table I. The conceptual framework for the consideration of the sample accelerators is given in Fig. 1. The question of extraction channel and splitting station design was only briefly considered. The Les Diablerets study was reviewed and the general conclusions regarding the scaling of elements and beam lines with respect to energy appear to be justified. The approximate cost of the extraction channel has been estimated by scaling from Fermilab TeV II without allowance for the possible problems arising from the stringent requirements on the electrostatic septa.

The principal conclusion of the fixed target accelerator group concerning a possible 20 TeV machine are reflected in the Table. From the Table and various informal discussions which occurred during the workshop we distill some qualitative conclusions:

1) The low field (2.5T) magnets seem especially well suited for fixed target operation because of lower power demand and because of simplifying the extraction somewhat. Also, the fact that the field is determined mostly by iron may permit a significantly lower injection energy. A slight disadvantage arises from the higher rf voltage needed for accelerating in the larger ring.
2) Extraction places few or no additional requirements on magnets or lattice except for a high-β insertion.
3) If beam-beam tune shift or other considerations should lead to the choice of a two ring collider, the fixed target program would be greatly enhanced by having the field in the two rings independent so that one could be used as a spill stretcher.
4) A beam intensity of 3×10^{14} ppp over an 8 min. cycle provides for a rich program; the acclerator might be expected eventually to handle more beam than this for any aperture that magnet builders are likely to want to build.
5) For both a ν beam (e.g. 80 spills, 1 ms long, of 2.5×10^{12} during a 2 min. flat top) and slow spill (1-2×10^{14} over 2 min.) the target and collimator heating is apparently within current experience.

LAMPF II COSTS

A high intensity 16 GeV synchrotron can be built on the LAMPF site. By using the LAMPF H^- Linac as an injector and taking advantage of the existing facilities. It will be possible to construct such a machine at minimum cost. The specifications for the LAMPF II synchrotron are as follows:

LAMPF II SYNCHROTRON

$0.8 \rightarrow 16$ GeV at 60 H_z

10^{13} protons/pulse (100μA)

40 meter radius

$67 \rightarrow 80$ MH_z radio frequency

14×10^6 Volts/turn

Fast Extraction 0.8-16 GeV

Slow Extraction 16 GeV

There are several possibilities for future expansion including 32 GeV final energy by doubling the rf and 400μA at 4 GeV, which would be useful for neutrino experiments.

The most expensive single component of the accelerator is the rf system. A copy of the Fermilab booster rf system would cost $\$70 \times 10^6$. We assume that a method will be found to reduce this cost to $\sim \$15 \times 10^6$. A cost estimate for the facility is given below:

LAMPF II

Accelerator	$\$45 \times 10^6$
Stretcher	$\$20 \times 10^6$
Tunnels	$\$10 \times 10^6$
Accelerator	$\$75 \times 10^6$
Experimental Areas & Detectors	$\$75 \times 10^6$
TOTAL	$\$150 \times 10^6$

These costs are given in FY 1981 dollars and do not include the inflation up to the time of construction. A more detailed cost estimate and optimization will be undertaken during the next year. The above estimate should be considered as only a rough approximation.

TABLE I
ACCELERATOR PARAMETERS RELEVENT TO 20 TeV FIXED TARGET OPERATION

B_{max}	10T (ICFA)	5T (imporved ED/S)	2.5T (Superferric)
$2\pi R$	70km	120km	194km
E_{inj}	1TeV	1TeV	400GeV
I_{beam}	10^{15}ppp 670 mA	3 x 10^{14}ppp 120 mA	3 x 10^{14}ppp 60 mA
t_{fill}	20s (?)	120s	120s
Injector	?	Conv. Synch $2\pi r$ = 12km	Conv. Synch $2\pi r$ = 9.7km
Cycle time	100s	480s	480s
injection	20	120	120
rise	40	120	120
flattor	20	120	120
fall	20	120	120
E_{beam}	3.2GJ	1GJ	1GJ
Aperture (VxH)	1.5" x 2"	1.5" x 2"	1.5" x 2"
Stored Energy	8GJ	4GJ	2GJ
RF Power (including. cavity loss)	160 MW	16MW	16MW
Incremental cold power (KW)			
Hysteresis	400	8.3	3
Eddy current	4.8	2.4	1.2
Synch radiation	26	2.2	.9
Resistive Wall	~0	~0	~.1
Total (kW)	431	12.9	5
Cost (1982 M$)	250	8	3
Extraction Channel			
Length (m)	1500	1500	1500
Cost (1982 M$)	7	7	7
E.S. septum (m)	55	33	33
Cost (1982 M$)	.3	.2	.2
Magnetec septum (m)	140	126	126
Cost (1982 M$)	1.5	1.3	1.3

Fig. 1: Principal Considerations in Adding Fixed Target Capability to a 20 TeV Hadron Collider