Forward Physics with the "Pipetron"

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A new, very large collider will certainly include one or two large, central 4π detectors, *a la* CDF, ATLAS, etc. The purpose of this note is to argue that provision should also be made for a detector engineered to completely cover the final-particle lego ($\eta - \phi$) space, i.e. to be sensitive to small angle, forward physics in addition to the central region. There are precedents for discussions of such a detector and dedicated straight section. These include the FAD proposal for the SSC by J.D. Bjorken and others[1], and plans for a similar detector, FELIX, at the CERN LHC[2]. In fact, up to the present, none of the hadron colliders (ISR, S$\bar{p}$pS, and the Tevatron) have provided for such facilities, with the consequence that all experiments which have addressed "forward physics" at these machines have been significantly compromised.

A full acceptance detector will maximize the ability to search for new physics in unexplored regions of phase space while pursuing a substantial agenda of more conventional physics. The physics agenda will include the full range of perturbative and semi-perturbative QCD processes which are of considerable intrinsic interest. Inclusive forward and very forward reaction products and leading particle effects can be explored, including disoriented chiral condensates and other related phenomena. Soft and hard single and double diffraction (Pomeron exchange) can be studied, as can higher order Pomeron physics effects. Related studies would include probing the fractal nature of QCD phase space, and the onset of color-coherence effects.

This forward kinematic region is in fact just that which is responsible for almost all high-energy cosmic ray phenomena. Here unusual and unexplained observations continue to be reported, and might contain totally new and unconventional physics. With the advent of the Auger project, there is also increasing motivation to better understand the forward physics at these energies in order to unambiguously interpret air shower and air scintillation data.

The kinematic range of rapidity for the colliding protons extends to a y of 12, while the central detectors generally cover only out to a pseudorapidity, η, of about 4. New and unusual physics may well lie in this small angle, large rapidity region at the higher energies which will become available.

The very large colliders discussed during this workshop have been 30$\times$30 TeV, 50$\times$50 TeV, and/or 100$\times$100 TeV. For the discussion below, we shall focus on the 200 TeV c.m. option, using the parameters presented by G. Dugan at this Workshop. The arguments all apply equally well for the other, lower energies.

The desirable characteristics of such a straight section and detector, based on discussions concerning FAD, FELIX, and a possible upgrade of the Fermilab C0 intersection region, are enumerated below.

(1) There should be an average of much less than one interaction per crossing, i.e. the luminosity should be of the order of 10^{30} or 10^{31}. It is necessary to isolate single events in much of the relevant physics, and (from the examples considered up to this time) event rates are not a problem. The β would therefore be about 1000$\times$ the low beta value, or hundreds of meters; quite comparable to the β in the accelerator arcs. Note that it is primarily the requirements of the low β quads (their location, small aperture, and physical size) that limits the capability of the large detectors in the high-luminosity intersection regions to achieve complete coverage of the large-η kinematic regions of lego space.

(2) The straight section should be long; 4 km overall is assumed here, although shorter, fall-back options are not ruled out. The quadrupoles would not be close to the intersection region, and there would be ample room for analyzing magnets along the beam lines and for detectors close to the circulating beams. We assume the intersection point would be at the center of this long s.s., so that there would be 2 km on either side for detectors and analyzing magnets, as well as quadrupoles. Possibly some of the analyzing magnets could include field gradients to provide the required beam optics (combined function).

(3) The detectors and analyzing magnets should make possible continuous coverage and detection of charged secondaries over $|\ \eta\ |$ up to 12 for p_t between 0.1 and 10 GeV/c. Such a coverage has been designed in the strawman design for FELIX at the LHC, and the same design principles can be readily extended to the present higher-energy, longer-straight section case discussed here.

(4) The circulating beams should be so bent through the intersection region that is would be possible to detect with calorimeters neutral hadrons and γs produced at and near 0° to the beams. Neutrons, kaons, and γs would be detected, with their energies and positions well measured.

(5) The entire detector system should be symmetric about the i.p. There would also be a significant central detector, but it may be much less elegant and costly than the CDF - ATLAS genre. It would be desirable to observe the lego space completely, including the central (η=0) region of lego space, but not necessarily with the capability of reconstructing Higgs, tops, Ws, etc. in the central region. One possibility would be to re-cycle the Fermilab CDF or D0 detector as the central detector for this system.

One significant impact of such a detector is on the civil construction. The pit for the central detector could be smaller in transverse dimensions than anticipated for the major 4π detectors, but perhaps longer, e.g. 200 m $\times$ 25 or 30 m. However, an extension of the central collision hall $\pm$a kilometer on either side at a width and depth of about 10 meters would be needed, and the remaining 900 m on either side should be opened to perhaps 5 m diameter, before joining the much smaller tunnel of the accelerator arcs.

We believe that such a detector is a logical and desirable component of a pipetron-class (30 - 100 TeV) machine and that provision for it should be included in the planning at an early stage.

1. J.D. Bjorken, Int.J. Mod.Phys. **A7,** 4189 (1992)

2. K. Eggert and C. Taylor “FELIX, a full acceptance detector for the CERN LHC” (to be published in the Proceedings of the VIII International Symposium of Very High Energy Cosmic Ray Interactions, Karlsruhe, 1996); see also: http://www.cern.ch/FELIX.