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23rd May, 1990

Dear Roy,

I enclose a First Expression Of Interest in the SSC experimental program signed by myself and a number of colleagues. You will immediately see that this is not a "letter of intent–like" object as forseen in the PAC FEOI guidelines, but I am sure you will know that before looking at it, since we discussed in April the utility of a less formal document such as this. It does identify us as wishing to take part in SSC experiments, and gives some idea of the way we think we can best contribute.

I would like to add a word about our Soviet collaborators who have signed this document, they have contributed in a major way to the effort to achieve tracking and electron identification at high luminosity. They are under heavy pressure from their authorities to join one or the other Letters of Intent, but we feel they will be more effective for the time being by working in the context of our present FEOI. Any help you could give us in this respect would be most useful.

Yours sincerely,

William J. Willis

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High Luminosity at the SSC

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1. Introduction

We wish to submit a First Expression of Interest in the experimental program at the SSC. Our particular interest is in helping to ensure that one, or more, of the experiments available at the start of colliding beams are capable of operating efficiently at luminosities well above $10^{34} cm^{-2} sec^{-1}$, and with full capabilities to measure leptons and jets.

We see that excellent work is being done on development of experiments capitalizing on the SSC at luminosities of about $10^{33} cm^{-2} sec^{-1}$ and we do not propose to duplicate that work. We feel we can , however, contribute to the work on operating detectors at significantly higher luminosities.

High luminosity poses two key problems for SSC detectors: radiation damage to components, especially active electronics, and the need for faster and more selective triggers. In addition, physics requirements do not allow sufficient room for standard cables. We propose to attack these problems with an approach employing analog optical modulators and fiber optic cables, with no light-emitting elements on the detector. By removing most of the electronics from the radiation environment of the detector we can relax the constraints on the design and allow the necessary sophistication in the design of processing elements and triggers.

2. Physics

It is an obvious and often stated point that the SSC has the twin objectives of rigorously testing the current "standard model" and of observing "new" physics. The case for both objectives benefits greatly from running at high luminosity. We need to show that the choices necessary to operate a detector at these luminosities do not exclude high acceptance for desired events. We discuss briefly, and only as illustrative examples, three different physics topics. We choose to define high luminosity as $2 \times 10^{34} cm^{-2} sec^{-1}$ to be consistent with recently published luminosity curves at the SSC. We do not yet know if that is indeed the upper limit on detectors.

Observation of the "standard Higgs" leads the list of standard physics issues at the SSC. A definitive experiment will need to extend the observable mass range to 1 TeV. The decay modes with most favorable signatures are $H^0 \rightarrow Z^0 Z^0 \rightarrow \ell^+\ell^-\ell^+\ell^-$ and $H^0 \rightarrow Z^0 Z^0 \rightarrow \ell^+\ell^-\nu\bar{\nu}$. A year of running ($10^7$ sec) at 2×10^{34} luminosity will yield 300 and 1800 *produced* events for these two decay modes. It should be noted that since the width of the H^0 increases as the third power of its mass, higher mass Higgs will be very broad and will have poorer signal to background ratios and hence require as large a sample of well-measured events as possible.

An interesting prospect at the SSC would be the indication that quarks are not the most elementary constituents of matter. The scale of the "compositeness" of the quarks is completely unknown. The SSC will explore scales beyond existing colliders, i.e. multi-TeV. The simplest signatures might be an excess of higher ($\geq$ 5 TeV) P_t jets, or an excess of events with two jets of high invariant mass beyond that predicted by the QCD continuum. The later signature is less sensitive to the resolution and compensation problems often encountered in hadron calorimeters. Higher statistics significantly extend the coverage of

compositeness mass scale. For example a standard $10^7 sec$ run at $10^{33} cm^{-2} sec^{-1}$ offers sensitivity to a compositeness mass scale of less than 20 TeV, while at $2 \times 10^{34} cm^{-2} sec^{-1}$ one can cover the region up to 40 TeV.

The production of extra, and heavier, gauge bosons is a signature of physics beyond the standard model. The figure of merit is the mass region covered at some particular event limit. If the discovery region is defined as having at least 100 *produced* events, then an integrated luminosity of $10^{40} cm^{-2}$ covers a region up to about 5 TeV, while a factor of 20 increase in the luminosity increases the coverage to about 13 TeV.

3. Detector Issues

3.1 The Central Tracking Detector.

We propose to develop an electron identification capability by Transition Radiation Detection, integrated in a tracking system. A number of us are part of the SSC Subsystem R&D effort for TRD development. From the outset, we have tried to see how we could extend the operation into the very high luminosity domain. This is a major element in our endeavor since the tracking detector is most sensitive to the high luminosity environment. The next remarks outline our strategy to retain an electron capability into the highest possible luminosities foreseen.

This capability survives as the luminosity is raised above $10^{34} cm^{-2} sec^{-1}$, with some changes in the nature of the electron identification. At a luminosity below $10^{34} cm^{-2} sec^{-1}$ we reported in our SSC subsystem proposal that we can distinguish true electrons from conversions in the transition radiator, by analysis of the pattern of hits above three thresholds of energy deposit in the xenon gas detectors. Further simulations show that these patterns become less distinctive at higher luminosities, due to the increasing pile-up of hits from tracks from random events, and that the rejection of conversions suffers accordingly. The more vital distinction, between electrons and photons from the primary collision, is retained even at luminosities for which the tracking of charged pions fails due to excessive pile-up. This is due to the lower occupancy for the relatively high threshold in the x-ray detector.

The issues which we must address for such a detector are given below (with a brief indication of our state of knowledge about them).

1. **The Kapton "straw" tube.** Kapton is one of the most resilient organics, and we expect good performance at the high values of radiation which we will encounter at distances of order 0.7 m from the beam.
2. **The straw tube chamber.** Measurements are underway with the radiation-tolerant Xenon-CO_2 gas mixture. No deleterious effects have been noted at charge accumulation of 1 Coulomb per centimeter at the anode wire, or several years of high luminosity operation.
3. **The CH2 foam radiator.** This plastic is known to start losing strength at 10^7 Rads. However, shape distortion, not strength, is the primary concern. We will need to study shape distortion at $> 10^8$ Rads.
4. **The local electronics.** We wish to minimize, or eliminate, the local electronics. We will investigate the transfer of signals into an optical fiber by means of

an electro-optical modulator. An optical signal is brought in from an external source and used to power 16-32 modulators on a single substrate. Each of these is excited by the electrical signal from the straw tube, and the corresponding optical signal exits on an optical fiber. We are studying the noise levels to see if a preamp is required, or if the anode of the proportional counter can be connected directly to the modulator. The former case is still very advantageous, since the modulator is a very high impedance load, requiring little power to drive it, while preserving the rise time of the output signal over as long a fiber as may be convenient for generating delay for trigger purposes. Even with one fiber per channel, the mass of the whole fiber plant is quite acceptable. If no preamp is needed, we add the great advantage of entirely eliminating transistors, with their inherent sensitivity to radiation, from the inner detector.

The radiation sensitivity of the optical modulators themselves needs further studies, though it is thought to be good. The L_iNbO_3 substrate, the Ti diffused waveguides, and the Au deposited electrodes all seem to be intrinsically radiation hard materials. The infrared wavelengths used, probably about 1.3 μ, are those for which absorption is very low, and the absorption induced by radiation is low compared to the $\sim$ 40 mm scale of waveguide length in the modulator.

5. **The quartz fibers.** They have been thoroughly studied up to doses of 10^8 rad for our use, and we believe 10^9 rad to be also possible. There are self-repair mechanisms that reduce absorption after a few days and photo-bleaching can also be used if necessary. Quartz shows no significant mechanical damage at doses of 10^{10} rads.

3.2 The Calorimeter

Physics simulations show that high energy electromagnetic showers can be seen above pile-up at very high rates, even assuming the 100 nsec shaping time characteristic of liquid Argon calorimeters (which can be made radiation hard). The same is true of hadronic jets above a minimum threshold energy, which rises slowly with rate (a factor of 2 increase in noise for a factor of 20 increase in luminosity).

For reasons of inductance the readout elements must be placed very close to the individual detector elements, at liquid Argon temperatures. Cryogenic silicon FET amplifiers can endure $> 10^7$ Rad, and GaAs may be hardier still. The power required to drive low impedance output cables is substantial and the use of GaAs requires further study. In fact this power, and the mass of output cables, represent two serious drawbacks of the standard electronics chain.

The use of the optical modulators with high input impedance can relieve the power problem, give more freedom in preamp design, and dramatically reduce the mass and volume of the output "cables". In a cryogenic detector this simplifies the cold feedthrough and lowers the heat loss due to copper cables. The combination of the two power reducing aspects can lower the cryogenic power requirements of a liquid argon calorimeter by more than an order of magnitude. In addition, we will also pursue the possibility of direct readout with the optical modulator.

3.3 Trigger and Data Acquisition

The complexity of the trigger and data acquisition system are related more to the details of the detector subsystems than to the overall luminosity. We point out that the "no transistor" approach outlined earlier has a secondary benefit on the trigger system. The optical fiber cables can provide the delay for Level 1 trigger execution, eliminating the need for pipes (digital or analog) needed for every signal in the detector. One need not maintain these, and other elements, entirely in a hostile and inaccessible environment. This is an operational simplification that outweighs the cost and development efforts of the fiber optics readout, and hence could be useful even at the standard luminosity. Furthermore the placement of the processing elements outside the detector will allow for significantly more elaborate trigger elements and combinations that may be necessary to deal with the higher luminosity.

Since we anticipate handling the higher luminosity through more selective triggers, the data acquisition solutions at standard luminosity will be directly applicable at higher luminosities.

4. Proposed Program of Work

4.1 The Tracking and TRD

1. Simulations of tracking and electron identification at very high rates are continuing. They will be extended to include the effects of secondary interactions.
2. Irradiation tests in the foam radiators are underway.
3. Lifetime tests on straw tubes with Xenon−CO2 filling are continuing. Tests will be done also on Xenon−CF4. Sensitivity to impurities, gas flow rate, and gas amplification will be studied.
4. A prototype optical modulation readout of a typical straw tube will be set up using modulators from at least 3 commercial sources. A system performance from the point of view of noise, pile-up and rate effects will be studied.
5. The signal receiver at the end of the fiber will be optimized and the signal recording system will be studied.
6. Irradiation of the modulators will be studied to identify transient effects and long term lifetime. Some special modulators will be ordered from commercial sources with certain design changes specified to improve radiation hardness.
7. Modulators which trade off unneeded bandwidth for improved noise performance will be developed.
8. Multi-channel modulators incorporating one signal drive and a multi-channel commercial output connector, such as the 12-channel snap-on connector now in use in the field, will be obtained from at least two industrial sources.
9. A system test in a high- energy beam giving jets which simulate SSC conditions will be performed with approximately 200 straw tubes.

4.2 Calorimeter Readout

1. Modulator performance will be evaluated at liquid nitrogen temperature.
2. The radiation tolerance of the cryogenic and room-temperature readout will be determined.
3. A modulator with both a low-gain and high-gain outputs for each input channel will be designed and procured from industry. This is necessary because it is unlikely that a dynamic range of 10^5 will be possible in one output channel.
4. Studies of noise-performance, including a matching transformer option, will be continued especially to investigate the possibility of a direct input.
5. A feed-through design for large bundles of fibers will be developed.

4.3 Trigger and Data Acquisition

1. The trigger hardware simulation subsystem effort currently supported by the SSC will continue with emphasis on high luminosity.
2. The development of Level 2 trigger hardware will start later this year under the same subsystem proposal and possibly in collaboration with other efforts.

5. Support Required to Continue This Program

5.1 Present Status

1. Support at Boston University and BNL is provided by several SSC generic and subsystem grants as well as the on-going HEP program.
2. At Columbia, support is at present provided by the NSF HEP grant and University funds with participation in the SSC subsystem grant anticipated in the next fiscal year.
3. The Moscow group is supported by the USSR HEP program and UNK development funds.
4. A close collaboration with groups from CERN and Sweden is maintained.

5.2 Future Support

1. We believe that it will be possible to carry out a small effort with the present support outlined above.
2. We will surely require SSC support to carry out the work proposed. The most natural means of supporting the proposed work would be the generic R&D program. In the absence of such a program, the support could come from continued subsystems R&D grants or from some modality connected with this FEOI. Perhaps it may be possible to work in direct collaboration with some of the other FEOI teams.
3. Under the assumption that the support is in terms of subsystem grants, we plan on submitting detailed budgets in the next round of subsystem R&D proposals this september, and in subsequent years.