P-798

REQUEST FOR TEST BEAM TIME

(SSC Generic R&D proposal to build a prototype synchrotron-radiation detector)

Dr. Priscilla C. Petersen - Yale University
Dr. Roger W. Rusack - Rockefeller University

We request 3 weeks of beam time at Fermilab during the fall 1989 fixed target run in order to test a prototype preshower detector for the SSC. The development of this detector has been funded by a SSC Generic R&D grant, and the original proposal and request for follow-up funds are included for your perusal.

The prototype will consist of a lead/scintillating fiber sandwich, 3 radiation lengths thick, read out with image intensifiers and CCD's. It will be sensitive to the early development of the electromagnetic shower as well as the synchrotron radiation (SR) emitted by electrons as they pass through a high magnetic field. We hope to show that this method provides a means of tagging electron showers in a SSC detector.

The peak of the SR energy spectrum is given approximately by

$$E_\gamma = \frac{1}{3} E^2 B \quad keV$$

where E is the electron energy in GeV and B is the magnetic field in Tesla. We would like this mean energy to be no less than 20 MeV. Therefore, we would require either a 120 GeV electron beam with a 4.5 T superconducting magnet directly upstream of the detector or a 200 GeV beam with a 1.5 T warm magnet. Our preference would be for the higher field magnet to better match the design parameters of a compact, high field solenoid type of SSC detector. The total BL should be greater than 4 T-m to insure a reasonable number of SR photons. Dr. Garbincius has mentioned that a 1 meter, 4.5 T magnet may be available, although it will require some modification. Our measurement does not require an electron beam with a narrow energy spectrum or a high flux; a flux of 10**4 electrons per spill would be sufficient.

The detector will be 1m wide and 10cm high with additional space to either side for support stands and the image intensifiers. The thickness of the detector is only 5cm, but we need space directly upstream for the magnet where the SR is generated.

We estimate that we will need 3 weeks of beam time to set up the detector and to accumulate data at different magnetic fields and electron energies. We will, of course, debug our readout as far as possible using cosmic rays.

We have been discussing with Mike Crisler of E774, the possibility of using a similar device to detect the SR from electrons in the wide band electron beam. If this proves feasible, then this test run will not only benefit the SSC R&D process, but also the Fermilab scientific program. It should be noted, however, that the application for E774 and our beam test cannot be combined since we need to know the electron energy and its trajectory, and we have to place the detector in the beam.

SSC GENERIC R&D PROPOSAL

Contract DE-AC02-87ER40325, Task A

Proposal to build a prototype synchrotron-radiation detector for tagging electrons at the SSC.

<u>Progress Report</u>

R.W. Rusack and P.C. Petersen

Rockefeller University

New York City, July 20, 1988

Since the project was approved for funding in May 1988, we have familiarized ourselves with new advances in scintillating fiber material and located two promising sources of 250 micron plastic fiber. We have also identified U.S. suppliers of image intensifiers and CCD's. We expect to be placing orders for these items by November. Presently Monte Carlo studies are underway to investigate the optimal configuration and choice of materials for the identification of synchrotron photons in the 10 MeV region.

Dr. Petersen has taken a faculty position at Yale and will devote half her time to the project. She expects to interest several students in the project and has a possible new collaborator in Dr. David Winn who wishes to explore calibration schemes for scintillating fibers. Her "start-up" funds at Yale will be used to purchase a Vaxstation 3200, associated electronics and Fastbus debug software for both testing and data acquisition related to this project.

Our plans are now the following: Finalize the detector design by November 1988 and place purchase orders; start construction in January, 1989 with completion by March; test readout system with sources and cosmic rays during spring and summer in preparation for transporting to Fermilab for a test beam run in the fall.

We have had discussions with the Research Division at Fermilab and expect to obtain 3 weeks of test beam time during the next fixed target running period. The cost estimates below are based on these discussions and include modification and operation of an existing superconducting magnet.

Requested Funding for FY 1989
for
SSC Generic Research and Development

Cost Element	Proposed Estimate
1 Meter, 4.5 Tesla Magnet	
Installation of magnet and power supplies ------	$12,000.00
Mechanical modification	
Cold bore with Ti window -----------------	500.00
--OR--	
Warm bore without window -----------------	3,000.00
Liquid Helium @ $1.50/liter	
Cooldown needs 2,500 liters --------------	3,700.00
Running for 20 days at 250 L/day	7,500.00
Shipping detector to Fermilab ----------------------	1,600.00
Travel to Fermilab	
2 faculty + 2 students for 1 month -----------------	7,200.00
Domestic travel for consultation	
Thompson, ITT, FNAL ---------------------------------	2,500.00
Equipment:	
Fastbus Devices -------------------------------------	12,000.00
Total (assuming warm bore) -------------------------	$49,500.00
Indirect Cost (68%) ---------------------------------	25,500.00
Calculated on Modified Total Direct Cost Base (excluding equipment) DHHS Agreement 6/19/87 68% of $37,500	
TOTAL FUNDING REQUESTED ----------------------------	$75,000.00

SSC GENERIC R&D PROPOSAL

Proposal to build a prototype synchrotron-radiation detector for tagging electrons at the SSC.

R.W.Rusack[1] and P.C.Petersen[1]

Geneva, 8 September, 1987

Abstract: We request funding to design and build a prototype lead/fibre pre-converter as the front part of a compensating calorimeter. The pre-converter will be designed with the following requirements: It should be sensitive to the synchrotron radiation emitted by high energy electrons moving in a strong magnetic field. It should be able to identify tracks associated with the start of an electromagnetic shower and thus separate electron showers from those initiated by photons with a close charged track. It should be able to do this within the hostile environment of the SSC. Studying the behaviour of the prototype in test beams will provide the information necessary for the final design.

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Introduction

We would like to construct a prototype pre-shower detector. The prototype would consist of layers of lead and scintillating plastic fibers. The purpose would be to provide information about the early development of electromagnetic showers and to identify synchrotron radiation emitted by electrons traversing a strong magnetic field from the interaction region to the pre-shower detector.

At the Berkeley 1987 SSC Detector workshop it was suggested by the Compact Solenoid Group that at the SSC electrons could be identified by the synchrotron radiation that they emit in a high magnetic field which could be detected in a lead scintillating-fibre pre-shower detector [1] . A similar suggestion has been made elsewhere [2] . The purpose of this study is to develop the techniques which would be required to design build and use such a detector in an SSC detector. The principal questions that we want to address are how well synchrotron radiation photons with an energy between 1 MeV and 1 GeV can be localized, and how much background there is from albedo and other sources. We would also want to address questions on pattern recognition and the optimum arrangement of the lead/scintillator layers given the requirements of maintaining the compensation of the whole calorimeter, the ease of mechanical construction, and the mechanical stability. We propose only to build the pre-shower detector and assume that we would later work with a group building a lead/fibre calorimeter to test our calculations of compensation.

Previous work as part of the preparation for the UA2 upgrade [3] [4] has shown that a pre-shower detector can be constructed from lead and scintillating fibers and that details of the early shower formation can be obtained. We hope to establish that the technique can be simultaneously applied to high energy showers and synchrotron radiation. The total energy of the synchrotron radiation varies as the square of the energy of the electron and as the square of the magnetic field, and the spread of the deposited energy is linear with the field. We would like to investigate experimentally the energy at which pattern recognition fails for a given magnetic field.

We believe that this technique for accurate determination of the starting point of a shower in conjunction with high-precision tracking in front and compensating calorimetry behind will be a general feature of SSC detectors. Furthermore, if it can be shown that electrons can be recognized by their synchrotron radiation for reasonable magnetic fields then this will be of interest to all SSC magnetic detectors. We therefore maintain that this study is eligible for consideration as part of the generic R&D program for SSC detectors.

Motivation

It is well known that the high-event rate and the associated high multiplicities for each event will place very severe constraints on the detectors to be installed around the SSC interaction regions. Good photon and electron identification are required in order to study the production of W, Z and

Higgs particles as well as other physics, such as new flavor production. Moreover if the Higgs decays via two gammas, a good π^0 identification will be needed in order to reduce the QCD background. One can expect a pion rejection of 10^4 using the standard requirements of shower development and E/p matching. If the calorimeter is equipped with a pre-shower detector which has good spatial resolution as well as the ability to detect synchrotron radiation a further factor of the order of 10^2 can be expected.

Synchrotron Radiation

The physical characteristics are described in the standard textbooks on classical electromagnetism [5] . Their application in an experimental environment to identify electrons is described in references [6] [7] [8] . The synchrotron-radiation spectrum can be characterized by the total emitted intensity I and a critical photon energy $\hbar\omega_c$. The photons are emitted with an energy spectrum which peaks at around $\hbar\omega_c/4$ and cuts off at around the critical energy. For electrons [7]

$$I = 1.27\, E^2\, B^2\, L \qquad [\mathrm{KeV}]$$

$$\hbar\omega_c = 1.33\, E^2\, B \qquad [\mathrm{KeV}]$$

where E is the electron energy in GeV, B the magnetic field in Tesla and L the distance travelled by the electron in meters. The total number of photons (N_p) can be estimated by assuming that the mean photon energy is one quarter the critical energy, giving

$$N_p = 3.8 \, B \, L \, .$$

Synchrotron radiation is recognized by the characteristic pattern of hits in a narrow strip in the bending plane, since the photons are emitted tangentially to the electron track. Identification of synchrotron radiation would be by the deposition of photons in a narrow strip in the bending plane, outside the arc of the electron. The detector must be able to recognize and localize low-energy photons with energies between 1 MeV and 1 GeV, but without necessarily measuring the energy precisely. Using the compact solenoid detector discussed at the Berkeley conference and putting B = 5T and L = 60 cm, we find that a 200 GeV electron deposits 760 MeV of synchrotron energy in a 1.35 mm strip and a 20 GeV electron deposits a total of 7.6 MeV in a 13.5 mm strip. Thus there are two opposing factors at work: low energy electrons deposit less synchrotron energy in a longer strip while high energy electrons deposit more energy in a shorter strip.

In this study we will investigate the interplay between these two effects and develop software algorithms to identify the synchrotron radiation in the presence of the electron shower and background.

The Detector

The detector we are proposing to build is shown in Figure (1). It consists of a 15 layer sandwich of 10 × 50 cm² sheets. Each layer consists of 1 mm lead sheets, three layers of fibers with one view oriented normal to the bend plane and two stereo views, and tape to hold the fibers in place.

The exact stereo angle will be determined from considerations of reconstruction and mechanical design, but will be of the order of 10°. The total thickness would be 45 mm or 3 radiation lengths.

We would use aluminized plastic scintillator fibers with the smallest diameter commercially available (currently 500μ [2]). It should be noted that there is a proposal for significant funding for fiber detector development [9] and that we are in contact with this group. We will make use of the technical advances that they achieve where appropriate for this project. With 500μ fibers, each 10 cm wide layer would require 200 fibers giving a total of 9000 fibers.

Readout

To keep the cost of this project as low as possible, we would use a similar readout to that used by the UA2 group. Their readout, described in reference [3] , is via a three-stage image intensifier coupled to a CCD which in turn is read out through a FASTBUS module to CAMAC. We would not need the Aleph Event builder that the UA2 group used but instead would require the use of an online computer for data taking at the test-beam. We need 2 image intensifiers, similar to those used by the UA2 group, to read out the 9000 fibers. The image intensifier that they used has a fiber-optic window, an S20 photo-cathode sensitive in the 430 nm region, a large 80 mm diameter photocathode, and demagnification. The demagnification is necessary to match the fiber size to the pixel size of the CCD. These requirements make the image intensifier expensive since they are non-standard devices. We hope to find a less expensive solution in the US during the next six months, but our cost estimates are based on the assumption that this would not be possible.

Test-Beam Requirements

Ideally we would like a test beam of electrons with a 5T magnet immediately upstream of the detector. If such a facility were made available to us this would be our preference. However a 2.5m, 1.5T field in a beam with at least 200 GeV electrons would be adequate.

Timescale and Milestones.

This project is expected to last for about two years. A Monte Carlo program must be developed to understand the detector response to the different photon energies and to determine the optimum thicknesses for the lead and fiber layers. With this information a prototype detector will be designed and constructed. Installation in a test-beam and the analysis of the resulting data would complete the work. Below is a timetable of how we see the project evolving.

April 1988	Completion of Monte Carlo modeling of the detector and design of the detector itself. Selection of optical components and other elements of the readout.

August 1988	Completion of the detector construction and lab tests using sources and cosmic rays to test the detector read-out.
December 1988	Completion of the tests in the beam line. We would require a beam-line with at least 200 GeV electrons.
March 1989	Completion of the data analysis and the development of algorithms for pattern recognition within complicated events.
September 1989	Completion of tests with a full-size calorimeter.

Cost Estimate

A detailed breakdown of the cost estimate can be found in Table 1; the total cost estimate is $90000. This represents the total spending expected for the whole two year period. However since the cost is mostly materials it will have to be spent in the spring or summer of 1988.

Contribution Made by Rockefeller University.

The university will provide the machine shop time and the technical support to build the prototype. This includes the necessary equipment and laboratory space for the preparation of the prototype and the technical support to build the special electronics. The university will also provide the computational facilities for the modeling of the detector and for the data analysis.

Manpower Commitment.

Dr. R. Rusack, a faculty member of Rockefeller, will be able to commit 50% of his time to the project and he will take charge of the research. Dr. P. Petersen will be able to collaborate for a significant fraction of her time. Furthermore Dr. G. Valenti has expressed an interest in this work and in the near future will explore the possibility of collaboration and financial support from the INFN Bologna section. There are two technicians at Rockefeller who will be available to work on the construction stages of the project as required. For the test beam measurements other members of the faculty, either from the group working at FNAL on CDF or those working at CERN on UA6, will help with the data taking.

Table 1: Detector Costs

ITEM	QUANTITY	COST (k$)
Lead Foils	50	3
Scintillating Fibers	6km.	4
Construction Materials	5	5
Image Intensifiers.	2	52
CCD	2	3
Fastbus Digitizer	2	5
Camac Fastbus Interconnect	1	4
Fastbus Crate	1	3
Travel 3 trips to CERN		7
Internal US travel		4
	TOTAL	$90000

References

[1] Report of the Compact Solenoid Working Group, Berkeley SSC Detector Workshop (1987), in preparation.

[2] Today and Tomorrow for Scintillating Fibre Detectors, J. Kirkby, CERN-EP/87-60.

[3] Performance of a Scintillating Fibre Detector For the UA2 Upgrade R. E. Ansonge et al. CERN-EP/87-63

[4] The UA2 Experiment at ACOL, The UA2 collaboration, CERN-EP/87-78

[5] Classical Electrodynamics, J. D. Jackson, (Wiley, New York, 1975)

[6] Transition and Synchrotron Radiation Produced by Electrons and Particle Discrimination, B. Merkel et al., NIM 138 (1976) 625.

[7] Electron Identification Using a Synchrotron Radiation Detector, J. S. Dworkin et al., NIM A247 (1986) 412.

[8] Electron Identification Using Synchrotron Radiation, H. Harada et al. , Presented at the International Conference on Advances in Experimental Methods in Colliding Beam Physics, SLAC, March 1987, University of Rochester preprint 1000.

[9] Scintillating Fibre Detectors and High-Field Magnets. H.Leutz et al., Proposal to the LAA project (A. Zichichi), June 1987-11.

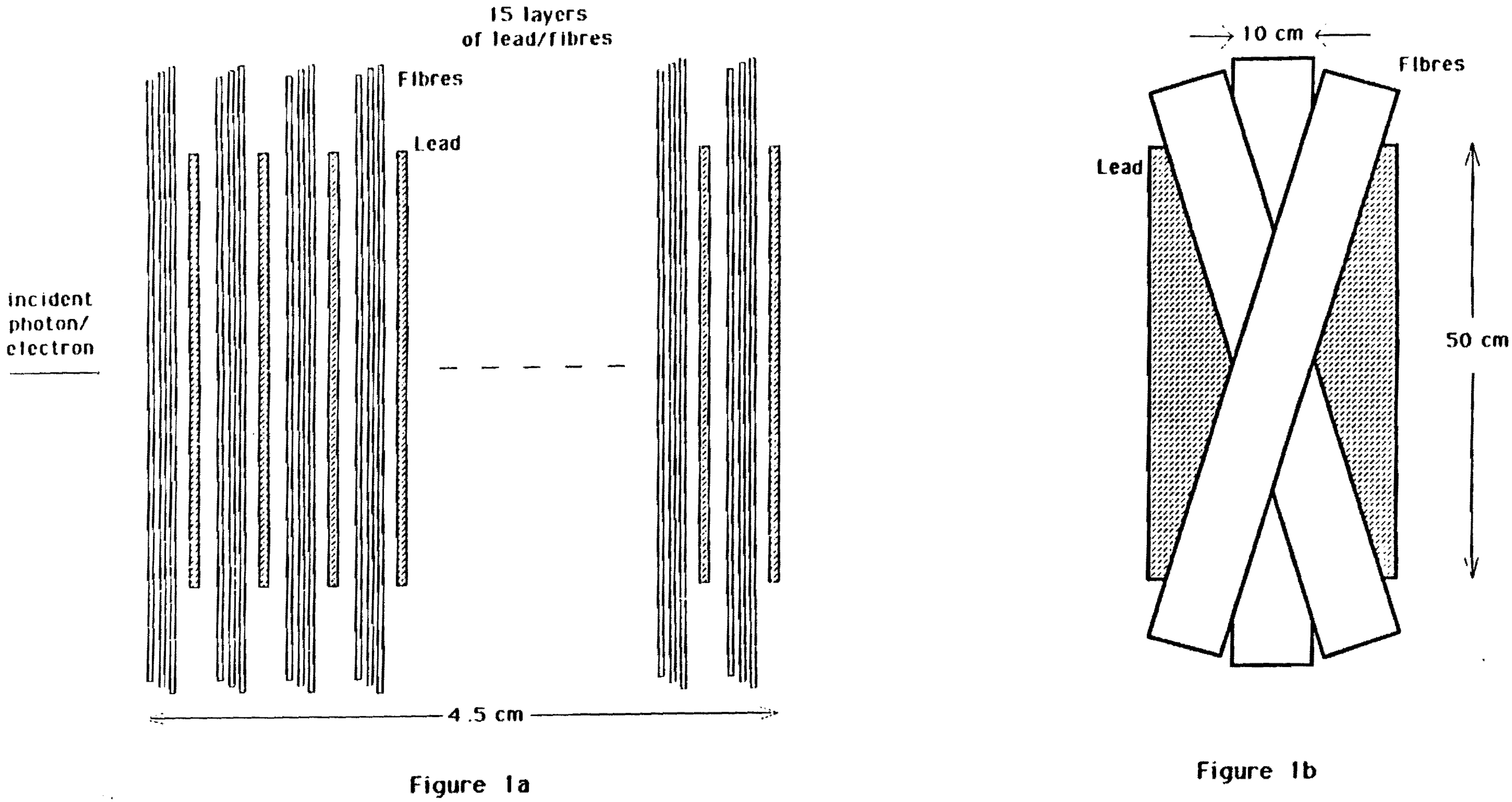

Figure (1) Sketch of the proposed detector.