Proposal to the
University Consortium for a Linear Collider

August 23, 2002

Proposal Name

BACKGAMMON: A Scheme for Compton backscattered photoproduction at the Linear Collider

Classification (accelerator/detector: subsystem)

Accelerator: beyond the interaction point

Personnel and Institution(s) requesting funding

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Collaborators

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Project Overview

We propose to investigate the possibility of Compton backscattering low energy laser pulses off the spent electron and positron beams at the Linear Collider. The hot backscattered photons would then scatter off fixed targets for a rich variety of physics studies in a scheme dubbed BACKGAMMON, for BACKscattered GAMMas On Nucleons. The first objective would be to operate a heavy quark factory, since the cross sections for charm and bottom quark production would be favorable for producing large numbers of these flavors. Secondly, if the incident laser pulses are circularly polarized, the backscattered photons would be circularly polarized as well, allowing the possibility of producing polarized τ pairs on fixed targets. Also, BACKGAMMON's polarized hot photons could scatter off polarized targets and play an important role in elucidating the spin structure of nucleons. Finally, there is the possibility of studying the photon structure function in spent electron beam scattering on laser photons.

The original idea for using the Linear Collider for producing Compton backscattered photon beams for operation of a heavy quark factory is described in Reference [1]. There it is shown that, if one had an electron beam of hundreds of GeV energy, then one could produce greater than the 10^9 B meson pairs per year that the theorists said were needed to elucidate CP violation in the B meson system. That was before the advent of the current generation of B factories using electron-positron colliders. Soon after the description of BACKGAMMON for heavy quark production, it became clear that this scheme could be used to operate a polarized τ factory as well. This and subsequent ideas are contained References [2-6].

Milburn [7] and independently Arutyunian and collaborators proposed the original idea of using Compton backscattering in accelerators [8-10]. The detailed theory of Compton backscattering, incorporating the accelerator lattice functions of the initial electron beam, was derived in Reference [1]. The first practical application of Compton backscattering in a physics experiment was the measurement by Ballam *et al.* of γp hadronic cross sections in a bubble chamber at SLAC [11]. Since that initial experiment, there have been a number of studies using Compton backscattered photons, including the Brookhaven National Laboratory's Laser Electron Gamma Source (LEGS) Facility [12,13] and applications of Compton backscattered photon beams to measure the polarization of electron beams [14-19]. Thus, Compton backscattering has enjoyed a rich history.

This project describes research that is unobtrusive to the baseline Linear Collider design. It should be viewed as an add-on experiment to the Linear Collider that is worthy of further study. Accordingly, in this project, three physics objectives initially would be pursued:

BACKGAMMON I
Unpolarized laser pulses would be incident on the spent electron beam to produce unpolarized hot photons for the photoproduction of heavy quark flavors to study a variety of phenomena, including CP violation in the neutral B meson system, high precision studies of bottom and charm decays, searching for rare and forbidden bottom and charm decays, QCD studies using heavy quark pair events, heavy quark spectroscopy, heavy quark baryons, and other checks on the Standard Model.

BACKGAMMON II
While BACKGAMMON I is using the spent electron beam, circularly polarized laser pulses would be incident on the spent positron beam to produce circularly polarized hot photons for the photoproduction of polarized τ pairs, to study a variety of phenomena, including improving the τ neutrino mass limits from such decays as $\tau \rightarrow K^- K^+ \pi^- \nu_\tau$, searching for CP violation in the lepton sector of the Standard Model, searching for rare and forbidden τ decays, studying the Lorentz structure of τ decays, and other checks of the Standard Model.

BACKGAMMON III
At the conclusion of BACKGAMMON II, the polarized hot backscattered photons would be incident on polarized nucleon targets to measure the gluon contribution to the nucleon spin. An excellent discussion of this point is contained in Reference [20]. The spin content of the nucleon still is not understood.

Laser Requirements

In Reference [5], the laser requirements of BACKGAMMON are briefly discussed. There, it is emphasized that the laser requirements in this scheme are less stringent than those for a γ-γ collider. For the γ-γ collider, the aim is to convert each electron in the collider bunch into a hot photon, leading to the requirement of 1 Joule per laser flash with a 1 kHz repetition rate. In BACKGAMMON, for 10^9 electrons per bunch, only 1 mJ per laser pulse at 1kHz will produce the 10^9 B pairs per year; while for 10^{10} electrons per bunch, as called for in the LC designs, 10^{10} B pairs per year would be produced. Moreover, if one could push the laser rep rate up to the 10 kHz called for in the LC designs, then one could produce up to 10^{11} B pairs per year. These B meson pairs would be produced in a much cleaner background than that of the hadron machines, such as the 10^{11} B pairs per year proposed for the BTeV experiment at Fermilab.

A specific laser design and implementation at BACKGAMMON could lay the groundwork for the γ-γ collider laser system, with the main difference being the lower power requirements for BACKGAMMON. For the γ-γ collider, it has been suggested that a diode pumped semiconductor laser is plausible [21]. However, for the high repetition rates needed in both these schemes, it may be necessary to time-multiplex a set of lasers. More R&D is needed to settle this issue.

FY 2003 Project Activities and Deliverables

During the first year, we will study the feasibility of using the disrupted beams after the electron-positron interaction point for Compton backscattering laser pulses. Initial discussions with TESLA accelerator physicists make the idea sound promising. Also, we will study the backgrounds from the electron-positron interaction point to insure that they are manageable and design beamlines to bring the best quality electron and positron spent beams to the two interaction points with the lasers. On the theoretical side, we will understand the details of the angular dependences of the polarizations of the photoproduced τ pairs, and we will perform theoretical studies of the physics issues as outlined above. This would involve both analytic approaches and simulations of the phenomenology. The results of all the first year's activities will be written up in a detailed report.

FY 2004 Project Activities and Deliverables

Assuming that we have verified that the spent beams are indeed usable for Compton backscattering laser pulses, we will understand the requirements on the laser systems and decide how best to implement them for BACKGAMMON. For instance, should a system of lasers be time-multiplexed to match the 10 kHz repetition rate of the electron and positron bunches. We will undertake a detailed study that couples the entire system from the electron-positron interaction point to the electron and positron-laser interaction points to the backscattered photons on the fixed targets. Also, we will begin detailed simulations of the experiments that are being proposed. The results of all the second year's activities will be written up in a detailed report.

FY 2005 Project Activities and Deliverables

In the third year, we will concentrate on the detector design and data acquisition. We will study the FOCUS experiment (Fermilab E831) and determine how to improve its detector system for BACKGAMMON I. One advantage of BACKGAMMON I is that the statistics will be several orders of magnitude higher so that a much higher data acquisition rate will have to be implemented. Also, we will propose appropriate detector systems for BACKGAMMONS II and III. By the end of the third year, we will produce a detailed technical design report of the proposed experiments. Finally, we will begin to investigate the possibility of using the doubly spent electron beam (after both e^+e^- and e^--laser interaction points) to scatter off a second low energy laser pulse and study the photon structure function. For a review, see Reference [22].

Budget justification

The entire project will consist mainly of computational and theoretical calculations, with heavy use of simulation codes. The first year's budget mainly will support one graduate student and travel for the Principal Investigator (PI) and one collaborator to visit each other's university for the purpose of working on the project. Computational equipment will be purchased for the graduate student.

During the second year, we include the same funds as requested the first year, increased mostly for inflation. Also, computational equipment will be purchased for the PI.

During the third year, we include the same funds as requested the second year, increased mostly for inflation. Also, additional computational equipment will be purchased for the PI.

Indirect costs are calculated at North Carolina A&T's 41% rate on modified total direct costs, which excludes tuition.

Three-year budget, in then-year K$

Institution: North Carolina A&T State University

Item	FY 2003	FY2004	FY 2005	Total
Graduate student (RA)	12	13	14	39
Undergraduate Students	0	0	0	0
Total Salaries and Wages	12	13	14	39

Fringe Benefits	0	0	0	0
Total Salaries, Wages & Fringe Benefits	12	13	14	39
Equipment	3	3	3	9
Travel	3	3	3	9
Materials and Supplies	1	2	3	6
Other direct costs (Tuition)	12	13	14	39
Total direct costs	31	34	37	102
Indirect costs	8	9	10	27
Total direct and indirect costs	39	43	47	129

References

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