Proposal to the University Consortium for a Linear Collider

August 21, 2002

Proposal Name

Beam-beam collision monitoring using Large Angle Beamstrahlung

Classification (accelerator/detector: subsystem)

Accelerator: beamstrahlung monitor

Personnel and Institution(s) requesting funding

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Collaborators

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Project Overview

One of the greatest challenges for the successful operation of a Linear Collider (LC) will be to monitor the beam-beam collision. A device which directly observes the transverse sizes of the beams, their offsets, and relative orientation at the collision point and which can be used as soon as the machine turns with weak beams would be an invaluable monitoring and diagnostic system for the LC. We have described a technique using wide angle beamstrahlung photons [1]-[4] that passively and precisely observes the beam-beam collision region and measures the transverse sizes, offsets and orientations with an accuracy better than 10%. Beamstrahlung photons preserve in their polarization information about the forces and torque exerted by one beam on the other. This information is presented concisely in the beamstrahlung diagram which can be used to study and optimize the delivered luminosity [2].

We obtained a three year NSF Major Research Instrumentation grant in September 2001 to build a device to study large angle beamstrahlung at CESR. At this writing we have installed a single-arm, one PMT prototype in the CESR/CLEO interaction region at an angle of 11 mrad from the beam axis. We have obtained data by varying the observation angle, the beam energy, the PMT spectral response (visible, red, or infrared), and the beam-beam offset. We have developed techniques to point the device, which has an angular acceptance of approximately 2×2 mrad^2, to the IP and observe that backgrounds are consistent with our predictions. Specifically in the infrared at nominal CLEO-c conditions we expect the signal rate to be of order $10^2 - 10^3$ times the background. Work to do includes

1. observation of large angle beamstrahlung
2. full installation of a four armed system as described in [4]
3. construction of the beamstrahlung diagram and confirmation of its properties

4. integration of the beamstrahlung system into CESR/CLEO operations to maximize delivered luminosity

The system can also be used to study the beam-beam limit and, with the addition of fast-gating electronics, bunch-to-bunch differences. We have already noted the limitation that the system is not sensitive at low beam currents which are typically used in machine studies.

Our recent studies have focused on coherent beamstrahlung which has not been previously considered. Coherence occurs at wavelengths longer than the bunch length when the beams have a non-zero offset at the collision point. A system that is sensitive to coherent beamstrahlung will provide many benefits including sensitivity to small beam currents and the ability to measure the bunch length by studying the wavelengths of the coherent radiation. At an LC we have considered the spectrum of coherent beamstrahlung as shown in Figure 1. Note that a measurement of the discrete wavelength pattern of coherent beamstrahlung determines the bunch length and the coherent power is enhanced my many orders of magnitude over the incoherent. A system sensitive to coherent beamstrahlung will be sensitive at low beam currents due to the power enhancement and will be able to measure bunch lengths with high accuracy by observing the power spectrum. We are working on a paper describing the properties of coherent beamstrahlung.

We would like to develop the design of a coherent beamstrahlung system for an LC. The incoherent beamstrahlung detector design would start from the suggestion of our former graduate student G. Sun to use elliptical gratings to separate light from the IP and background light[5]. We would like to design and build a coherent beamstrahlung detection system and operate it at LINX[6], which would be an ideal prototype for an LC system, or, if that project does not go forward, at CESR. What we learn from this prototype would be used to design a coherent beamstrahlung device for the LC. Note that at LINX or the LC with bunch lengths of $\sim 100\ \mu$m the coherent beamstrahlung radiation is in the infrared while at CESR with bunch lengths of ~ 1 cm it is in microwaves.

FY2003 Project Activities and Deliverables

Work will be continuing on the funded MRI incoherent beamstrahlung system at CESR. We will make a preliminary design for an LC beamstrahlung monitor system including both incoherent and coherent beamstrahlung radiation detectors.

FY2004 Project Activities and Deliverables

Complete design and simulation studies for an LC beamstrahlung monitor system. Begin design and construction of an incoherent beamstrahlung monitor at LINX preferably or CESR.

FY2005 Project Activities and Deliverables

Install and operate a coherent beamstrahlung detector. Refine the design of an LC beamstrahlung monitor system.

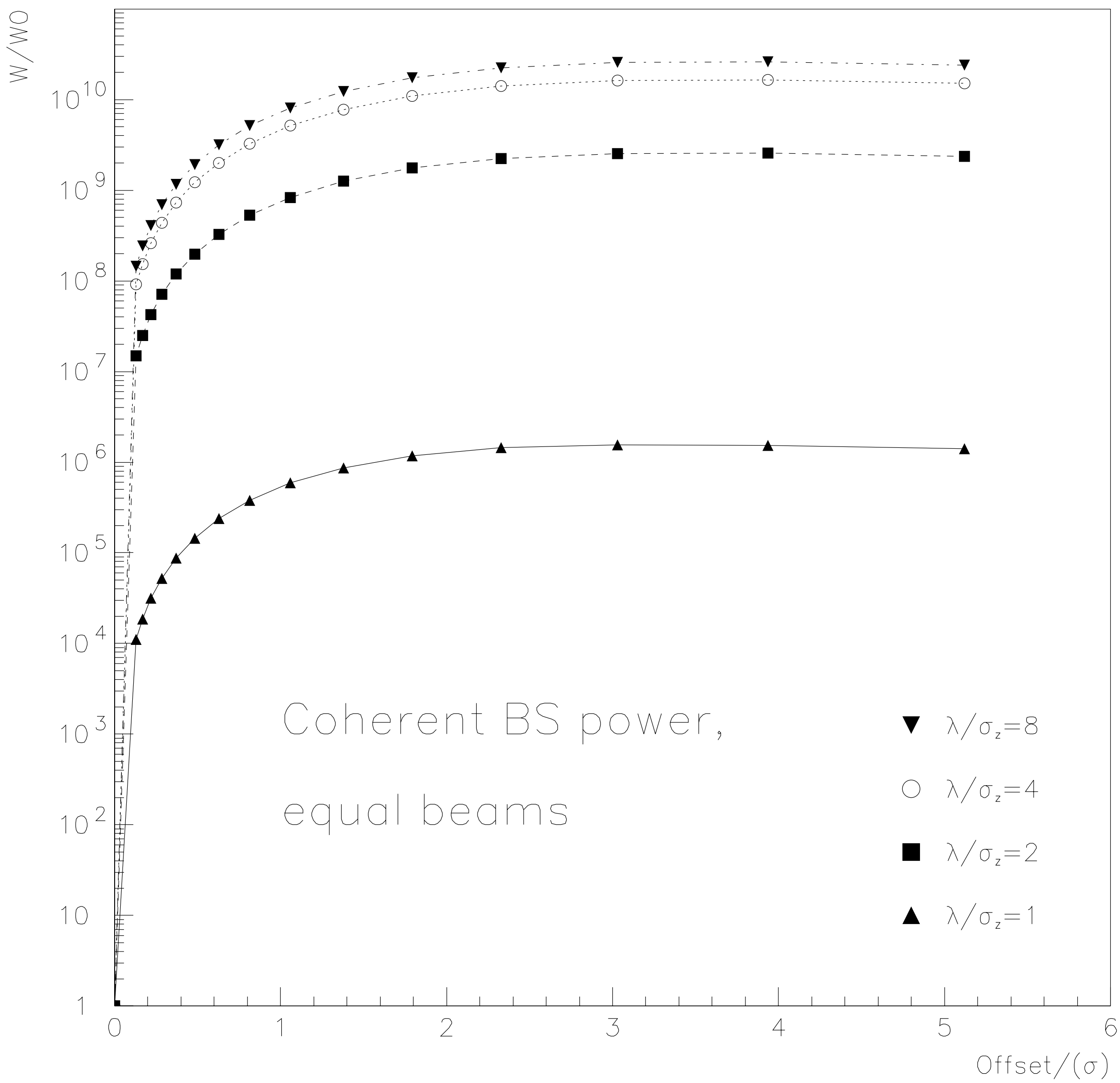

Figure 1: Long wavelength coherent beamstrahlung power, normalized to the zero-offset total incoherent beamstrahlung power at a 500 GeV LC, as a function of the beam-beam offset. and beam length, $r = \lambda/\sigma_z$. The curves for $r = 4$ and $r = 8$ are nearly identical, pointing to the onset of complete coherence. The curve was computed using beams with ten times less current than nominal conditions.

Budget justification

In year 1 some travel money to aid LC collaboration. In year 2 the equipment for the coherent beamstrahlung system and the continuation of funding for our MRI supported post-doc. In year 3 equipment for installation and operation of the coherent beamstrahlung system and continued funding for our post-doc. The post-doc will be doing the design and construction activities discussed above. Indirect costs are 49% of non-equipment costs.

Three-year budget, in then-year K$

Institution: Wayne State

Item	FY2003	FY2004	FY2005	Total
Other Professionals	0	30	40	70
Graduate Students	0	0	0	0
Undergraduate Students	0	0	0	0
Total Salaries and Wages	0	30	40	70
Fringe Benefits	0	7	10	17
Total Salaries, Wages and Fringe Benefits	0	37	50	87
Equipment	0	20	10	30
Travel	5	10	10	25
Materials and Supplies	0	0	0	0
Other direct costs	0	0	0	0
Total direct costs	5	67	70	142
Indirect costs	3	23	29	55
Total direct and indirect costs	8	90	99	197

References

[1] G. Bonvicini and J. Welch, Nucl. Inst. and Meth. 418, 223, 1998.

[2] G. Bonvicini, D. Cinabro and E. Luckwald, Phys. Rev. E 59: 4584, 1999.

[3] G. Bonvicini, CESR Colliding Beam Note, CBN-98-12.

[4] N. Detgen *et al.*, CESR Colliding Beam Note, CBN-99-26.

[5] G. Sun, CESR Colliding Beam Note, CBN-98-13.

[6] http://www-project.slac.stanford.edu/lc/linx/