Beamstrahlung Detector

Nathan Detgen
Department of Mechanical Engineering
Wayne State University, Detroit, MI, 48093

Abstract

A beamstrahlung detector could provide useful information about the beam-beam collision at CESR. This paper describes how the background radiation was calculated and shows that building this detector would be feasible. The paper also describes what would be needed to build the detector and provides a preliminary design.

Introduction

At CESR the most important parameter for describing the performance of the machine is the luminosity. A beamstrahlung detector at CESR could help to increase the luminosity of the machine, as well as provide new insight about what occurs in the beam-beam collision. The first step in determining whether a detector could be built was to calculate the power of our major source of background, namely the synchrotron radiation from the quadrupoles. We then calculated our signal power and looked for a frequency and location on the beam pipe where we had a favorable ratio of signal versus background. Once it was determined that the detector could be feasible we made a preliminary design.

Beamstrahlung

At the beam-beam collision region the particles of a beam are deflected towards the middle of the the other beam. When the particles are deflected they emit radiation called beamstrahlung. This radiation is polarized in the direction of deflection.

In the case of a perfect beam-beam collision the amount of polarization is equal in x and y (assuming round beams). However, when the beams don't collide optimally the information that can be extracted could be a very powerful tool[1]. In the case of an imperfect collision the polarization could tell you exactly how the beams are colliding, and how they need to be corrected to get them back to optimal conditions.

Background Calculations

The first step in determining the feasibility of a beamstrahlung detector was the calculation of the synchrotron radiation backgrounds. Stewart Henderson provided us with a simulation program that allowed the user to choose the location of the counters as well as a frequency range for the radiation. We were also provided with an initialization file that allowed us to change the beam offset in x between 0 and -2.2 mm, and the beam crab angle from 1.5 to 3.0 mrad. The beam line and beam optics used were the nominal CESR Phase III conditions.

With the help of Yu Lin we were able to identify two open locations on the beam pipe at 5.6 and 5.3 meters from the IR. At these locations the inner radius of the beam pipe was

6.36 cm. Detectors were placed at 30, 60, 90, 120 and 150 degree locations with respect to the x-axis (The innermost detector at 150 degrees with respect to the CESR ring). The backgrounds were then checked extensively at all of these locations.

We generally expected that there would be little or no background from either the center of beam where there is no field, or the extreme tails where there is no charge. A maximum was found to occur in between these two areas of the beam envelope at about two to three sigma away from the center. Figure 1 shows that the major source of background came from regions in the beam that were pointing in the general direction of the detectors. Because of this our sources of background are strongly polarized.

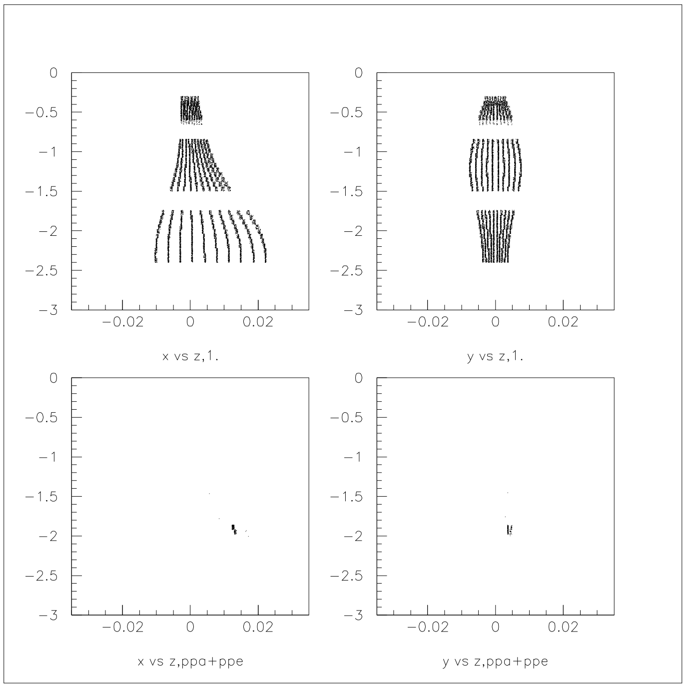

FIGURE 1. Incoming beam moving through the IR quadrupoles. The top two plots show the beam in $x - z$ and $y - z$ respectively. The lower two plots show where the radiation that is hitting the counters is coming from.

Initially we had wanted to design a detector that would work in the red ($\lambda = 660$nm) and blue ($\lambda = 330$nm) spectrum so that standard photomultipliers could be used. However, this proved to be impossible because our signal falls very steeply and does not get larger than our backgrounds until it is too small to measure.(Figure 2) We experimented with different wavelengths until we found that at near infrared ($1.2 < \lambda < 1.4\mu$m) we obtained a wonderful signal over background (Figure 3). This figure clearly demonstrates the feasibility of detector for the following reasons:

- There is clearly a strong signal over background at 10.5 mrad.

- The signal isn't affected much when the beam conditions that are responsible for changing the effective angle to the detectors are moved.
- At 5.6 meters and 90 degrees the beam pipe is seen at an effective angle of 11.4 mrad. This means that a detector at 10.5 mrad would have a minimal impact on the beam pipe.

Our results clearly show that a beamstrahlung detector would be feasible to implement at CESR.

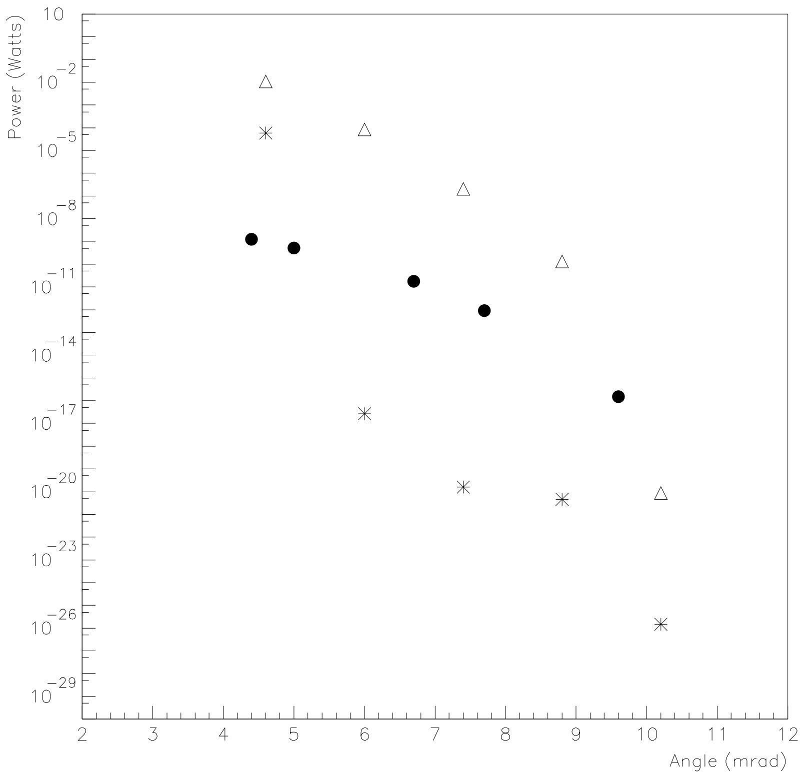

FIGURE 2. Power versus effective angle for the visible spectrum (600 to 660 nm).Black dots: beamstrahlung power. Stars: incoming beam. White triangles: outgoing beam.

Preliminary Design

The beamstrahlung detector Figure 4 starts with two mirrors located 5.6 meters from the IP and in the lower half of the beam pipe at -78.75 and -101.25 degrees with respect to the $x-$axis. The mirrors are 5.6 mm square and reflect light straight up through a vacuum window. The light then travels straight up for 60 cm before being collimated to obtain only the components of light that are between 9.5 and 10.5 mrad. The light is then reflected again in order to regain all of the polarization information. A calcite beam splitter is then be used to separate the beam into two perpendicular polarization components. Each of the polarized beams is then split into two using partially reflecting mirrors. Two of the four beams were used for measuring the infrared light and the other two were used for measuring the red. The

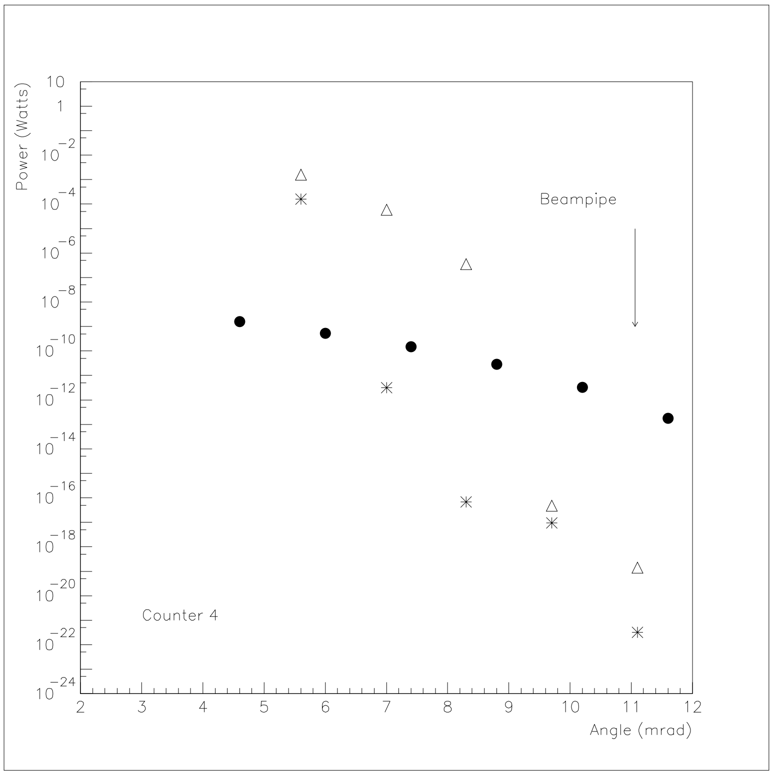

FIGURE 3. Power versus effective angle for the visible spectrum(600 to 660 nm). Black dots: beamstrahlung power. Stars: incoming beam. White triangles: outgoing beam.

infrared is separated by using a mirror that also acts as bandpass filter because it only reflects wavelengths between 1.2 and 1.4 microns. The red is separated by the photomultiplier which provides a cutoff at 0.3 and 0.7 microns. Focusing lenses are placed in front of the infrared photo multipliers because the effective area of these require it.

Conclusion

The largest source of background radiation has been well simulated and appears to be well below our signal power. One other possible background source is rescattered radiation. While it is thought that this will be a negligible value I will do some testing at Wayne State University to help determine a realistic value. A beamstrahlung detector at for CESR seems to be feasible. This detector would not only enhance our understanding of beam-beam physics, but it could also help to increase the luminosity by as much as 10 percent.

Acknowledgments

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References

1. G. Bonvicini, D. Cinabro, E. Luckwald, Phys. Rev. E **59** 4584, (1999).

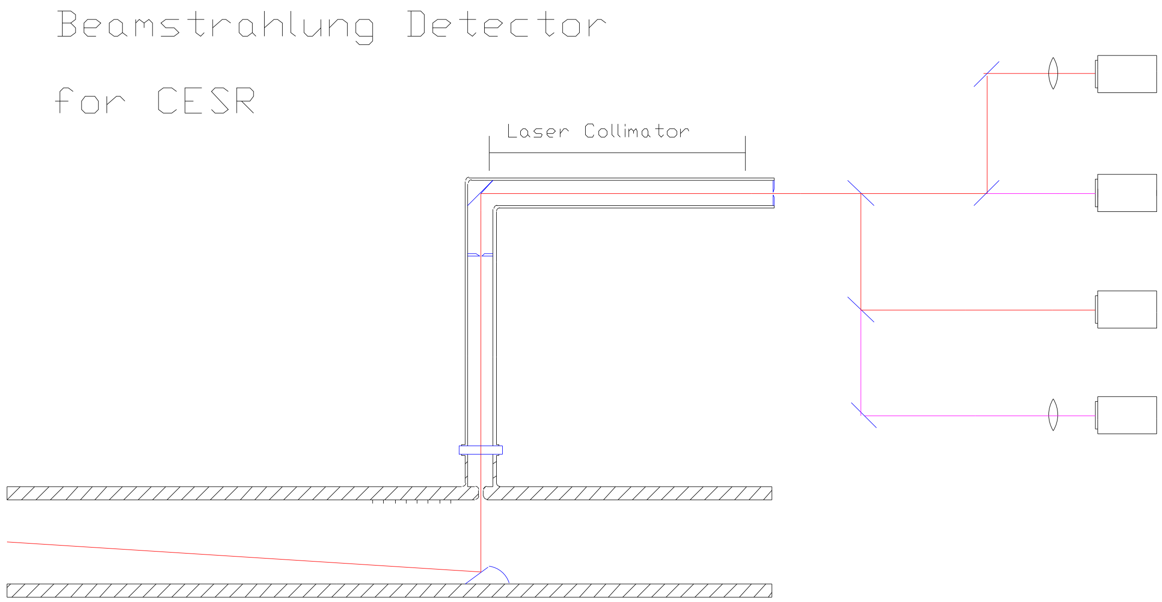

FIGURE 4. Preliminary design of beamstrahlung detector