LLNL-PROC-533135

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Photon Linear Collider Gamma-Gamma Summary

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February 27, 2012

International Workshop of Linear Colliders
Granada, Spain
September 26, 2011 through September 30, 2011

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High energy photon - photon collisions can be achieved by adding high average power short-pulse lasers to the Linear Collider, enabling an expanded physics program for the facility. The technology required to realize a photon linear collider continues to mature. Compton back-scattering technology is being developed around the world for low energy light source applications and high average power lasers are being developed for Inertial Confinement Fusion.

1 Physics Case

The physics case for a high energy photon linear collider has been previously reviewed in [1]. While there is a variety of interesting processes, many of the most interesting processes involve the direct production of a Higgs boson. The Higgs boson can be produced in photon-photon collisions through a triangle diagram which is sensitive to the existence of charged particles of arbitrarily high mass. This single particle production allows for a greater energy reach for the production of supersymmetric Higgs bosons (MSSM H and A) in regions of low sensitivity at the LHC. Control of the polarization of the Compton photons allows intial states of definte CP to be created providing a probe of the CP nature of the observed Higgs boson.

The photon linear collider also provides an opportunity to search for new physics by searching for anomalous couplings in double and single W boson production. As well there is the potential for production of supersymmetric particles in electron-gamma collisions. This would provide a greater energy reach to search for these particles than in the linear collider.

2 Technology Requirements

The fundamental physics of Compton scattering and the design of a photon collider has been laid out [2, 3]. Compton scattering can transfer 80% of the incident electron energy to the backscattered photons when a 1 micron wavelength laser pulse is scattered from a 250 GeV electron beam. A laser pulse of 5 Joules, compressed to 1 ps width and focused to a diffraction limited spot can convert most of the incoming electrons in a bunch to high energy photons. An enormous amount of average laser power would be required to provide 15,000 laser pulses per second to match the electron beam structure. Since most of the laser energy goes unused in the Compton process the required energy can be greatly reduced if the laser pulses can be recirculated.

A design of a recirculating cavity [4] was created in 2001 which takes advantage of the long inter-bunch spacing in the superconducting machine to recirculate the laser pulses around the outside of the detector. Calculations showed that the required laser power could

*This work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344

be reduced by a factor of 300 in this design. Recent studies have shown that a laser with sufficient phase stability to drive such a cavity is probably ahievable with current technology and would cost in the vicinity of 20 million dollars.

Warm RF technology has a different electron bunch structure which precludes use of the large recirculating cavity. The small inter-bunch spacing does not allow sufficient time for laser pulses to travel around the outside of the detector. A concept for a linear collider based on warm RF systems could be either a single pass system or a much smaller recirculating cavity within the detector with multiple circulating bunches. A single pass system would still require a prodigous amount of average laser power. Capital costs for such a system would be driven by the cost of laser diodes to transfer wall plug power to the laser amplifier crystals. The available power saving for a recirculating system would depend on the achievable size of the cavity. That would determine how many times a pulse could be reused in a single electron bunch train.

Implementation of the photon collider option has several requirements for both the detector and the electron accelerator. Apertures must be opened in the forward part of the detector to allow the laser pulses to reach the Interaction Point and be focused a few millimeters before the electron beams collide. The electron beam will be left with an enormous energy spread after the Compton backscatter and a large crossing angle will be required in order to allow sufficient aperture for the spent beam to be extracted. Finally, the photon collider option will require its own beam dump design in order to handle the photon beam which will have about 50% of the final beam energy.

3 Ongoing Developement of Compton Technology

Compton backscattering for the creation of MeV gamma-ray light sources is a world-wide activity. The basic techniques of bringing an electron beam and a laser pulse into collision is independent of the electron beam energy and these facilities are providing vital experience in the development of these techniques for the linear collider. These facilities are also developing the technology for recirculating laser pulses which will be critical to achieve a cost effective solution for the photon linear collider.

Current MeV gamma-ray sources include the ThomX [5] machine at LAL, the LUCX [6] machine at KEK and the T-REX [7] machine at LLNL. The MightyLaser collaboration is developing a four mirror recirculating cavity for the demonstration of Compton backscattering at ATF [8].

4 Future Prospects

The technology of Compton backscattering and recirculating cavities is being developed for the applications of MeV light sources, polarized positron sources and beam diagnostics. High average power, short-pulse lasers are being developed for the application of Inertial Confinement Fusion. All of these efforts push forward the technical feasibility of a photon linear collider. While the photon linear collider has always been envisioned as a second stage to the basic linear collider program there may be advantages to considering it as a first stage. The photon collider requires an electron linear collider to drive it but it does not require positrons and it does not require flat electron beams at the Interaction Point in order to reduce the beamsstrahlung. This opens up the possibility of creating a first stage linear collider without a positron source. The creation of a low-emittance RF electron gun might also create the possibility of eliminating the damping rings in the first stage. Both would provide major cost savings. If the Higgs is discovered at LHC and its mass is low it might also be worthwhile to create a lower energy dedicated photon collider Higgs factory as a first stage to the linear collider program.

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