Introduction

We numerically study the positron generation and acceleration by injecting two incident electron bunches on a high-Z target using the Monte Carlo code EGS5 and the 3D particle-in-cell code QuickPIC. An experiment to demonstrate this concept is possible at a new 10 GeV electron beam facility, Facilities for Accelerator Science and Experimental Test (FACET) II, which is under construction at SLAC. Since the beam density at FACET II is expected to reach ~10^10 cm^-2 under certain conditions, we also discuss the possibility of strong magnetic field generation inside the high-Z target which enhances the gamma-ray flux and the number of positrons.

Motivation and Outline

Motivation
Knowledge of how to accelerate high-quality positron beams using a plasma wakefield accelerator is necessary for building future plasma-based colliders. In the upcoming FACET-II experiment, we propose to use a two-bunch configuration to produce and subsequently accelerate positron beams.

Outline
- Positron acceleration concept
- Experimental setup for two-bunch positron acceleration
- Simulation of positron generation using Monte Carlo code EGS5
- Simulation of the trailing positron acceleration using QuickPIC

Experimental setup capable at FACET-II

- We utilize two 10 GeV electron bunches (< 40 mm-mrad) provided for the PWFA talk by C. Joshi on FACET II.
- High-Z target will be placed inside the plasma oven where the lithium plasma is formed by the self electric field of the drive bunch.
- Detection threshold of positron charges (~ 1 eC).

Monte Carlo simulation configuration

- EGSS (Monte Carlo) is used for the Monte Carlo simulation.
- Two incident electron beams with the energy of 10 GeV passes through the 1.2 mm thin target.
- Initial beam parameters taken by FACET-II design parameters (with a certain design margin).

3D QuickPIC simulation configuration

- We performed particle-in-cell simulation using QuickPIC with 2.5D of electron-driven positron bunches from EGSS with the same energy and with densities.
- Plasma density is 5 x 10^14 cm^-3 throughout the propagation.

Wakefield structure

- Time evolution of plasma density (red color scale), beam density (rainbow color scale) and the longitudinal field (blue solid line) are shown below.

Positron generation and acceleration concept

- Drive-trailing electron bunch configuration used for the incident beams.
- Interaction of two beams with high-Z foil target generates positrons within these bunches because of pair-production.
- Drive electron bunch excites plasma wakefield, coincident positrons are detected.
- Trailing positron bunch at a proper phase is accelerated, coincident electrons are defocused by the wake.

Typical EGSS results

- Typical EGSS results for the simulation of 10 GeV electron beams passing through the tantalum target.
- The graph below shows energy spectrum for two different thickness cases.

Trailing positron bunch diagnosis

- Positron acceleration of several GeV for the available beam parameter of the incident beam.
- Larger energy gain observed for the larger drive charge.
- Beam energy spread for the nonlinear wake case.

Conclusions

- Numerically investigated the trailing positron generation and acceleration scheme.
- Performed Monte Carlo (EGSS) simulations to generate the 3D phase space distribution of electrons and positrons after the interaction of electron beam with the high-Z target material.
- Imported the 3D-phase space distribution onto the QuickPIC simulation.
- Simulation results demonstrated:
  - Positron acceleration of several GeV for the available beam parameter of the incident beam.
  - Larger energy gain observed for the larger drive charge.
  - Beam energy spread for the nonlinear wake case.
- The drive-trailing electron configuration may allow us to study the drive-electron trailing positron acceleration scheme.

Acknowledgments

Dr. N. Yamaoka
SLAC National Accelerator Laboratory
Dr. M. Oppen
SLAC National Accelerator Laboratory
Dr. J. Zhang
University of California, Los Angeles

Positron beam current monitoring: DE-BP001664