Letter of Intent to Submit a 2-Stage Proposal to Test Production of Polarized Positrons with the SLAC 50 GeV Beam in the FFTB

Stage I:
Production and Polarimetry of Polarized $\gamma$’s with a Helical Undulator in SLAC’s FFTB

Stage II:
Production of Polarized $e^+$ with the Polarized $\gamma$’s from Proposal I, and their Polarimetry


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Abstract
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1 Introduction

1.1 Why Positron Polarization at All?

The importance of beam polarization in general has been demonstrated at the Stanford Linear Collider (SLC), where 75% polarization provided an effective luminosity increase of \( \approx 25 \) for many \( Z^0 \) asymmetry observables. It enabled the SLD to make the world’s best measurement of the weak mixing angle at Z-pole Energies, an essential element for predictions of the Higgs mass. Added positron availability will be of great importance for future linear electron-positron (\( e^+e^- \)) colliders because it will allow increased precision in many important measurements. The most direct reasoning is that a sizeable positron polarization is equivalent to an increase in the (effective) electron polarization [1], as shown in Figure 1. Already at the SLC/SLD the systematic error in the polarization measurement was the dominating error; with the increased luminosity in Future Colliders it will be even more dominating. Asymmetries to be measured are proportional to the polarization, and thus their errors decrease with increased (effective) polarization, allowing measurements with smaller systematic errors.

![Effective Polarization vs. Positron Polarization](image)

Figure 1: The desirability of a polarization of the positron is visible in this Figure: the effective polarization goes up steeply even with modest positron polarization

However, there has not yet been an experimental demonstration of a viable scheme to produce, and measure, the polarization of \( \gamma s \) (and later positrons) for possible use at a high-energy Linear Collider. With viable we mean based on technology on hand now. In the following we will briefly discuss several proposed approaches for polarized \( \gamma s \). We will give
reasons why a test experiment with undulator-produced \( \gamma \)s seems to be the most practical at the present time, notwithstanding what will happen in 5-10 years with the technology of polarized \( \gamma \) production.

The reasons why an effort to understand the polarimetry of gammas (and positrons) at the 10's of MeV range, a terra incognita, should be started now is easy to understand. It took experimenters about 10 years to master the polarization measurement at SLC to the 0.3% level; a similar learning curve can be expected for an NLC to the 0.1% level for the electron polarization. There is no experience at all with the measurement of \( \gamma \) and positron polarization below 5%. There also seems to be no experience at all with polarization measurements of any kind in the 5-50 MeV region. This learning curve is even more difficult to predict.

1.2 Advantage of Using External \( \gamma \)s

But even without the polarization aspect, there is a very good reason to look into positron production with externally produced \( \gamma \)s. Traditionally positrons have been produced by impinging electrons on a heavy Z target, typically W-Re alloys of many radiation lengths thickness. The electrons first produce bremsstrahlung \( \gamma \)s in the field of the High-Z nuclei in the target material, which then produce electron-positron pairs. The demands for several \( 10^{10} \) positrons per picosecond pulse at the SLC has pushed the material strength of W-Re to the limit, and the SLC target eventually failed. Going this classical target route for the NLC, which requires \( 10^{12} \) positrons in 300 nanoseconds, will require several targets in parallel for the NLC, and is all but impossible for the requirements of TESLA.

If the \( \gamma \)s needed are produced externally outside the target, be it by undulators or Compton back scattered lasers, and not in the target, a light material like Ti, or Carbon Composites, can be used for the target material. These materials can have a higher damage threshold than the heavy Z materials used in the past. For example, for the case of the NLC pulse format, the fatigue stress in W-Re occurs at an energy deposition of about 40 J/gm while for Ti-alloy the fatigue stress is reached at an energy deposition of 340 J/gm \[2\]. Linear thermal expansion coefficients and heat capacity of the materials conspire to make Ti a much better suited material for as positron target material than W, even so the mechanical yield strength of W is much higher than that of Ti.

1.3 A Brief History of Understanding Polarized Pair Production

The foundation of the theory of polarized positron (and electrons) production and how conceptually to measure their polarization has been laid in the 50's Tolhoek \[3\] and by Olson and Maximon \[4\]. Plotting the formulas of Reference \[4\] and comparing it with modern Spin-EGS [EGS] simulation it shows that the zero thickness calculations agree very well (Figure 2), giving us confidence into the simulations. The

The concepts of polarimetry were then further developed in the early 60’ by Schopper \[5\] and Ullmann et al. \[6\]. The definite papers about helical undulators have been written by Kincaid \[7\] and Blewett and Chasman \[8\] in back to back papers in 1977.
Figure 2: The formalism of Ref. [4] is compared to Monte Carlo calculations based on the Spin-EGS [EGS] program. It is apparent that Olsen and Maximon’s calculation agree well with a zero thickness EGS calculation, giving us confidence into the latter. (—–to be replaced by 10 MeV simul)—–.

The basic concepts of (polarized) positron production through (polarized) $\gamma$‘s from helical undulators have been independently proposed by Balakin and Mikhailichenko [9] and Amaldi and Pelligrini [10]. Here reference [9] went straight to the possibility of producing polarized positrons. Reference [10], while mentioning the polarized $\gamma$‘s, focused on an energy recovery scheme. These proposals are the foundation of the base plan of TESLA for positron production [11].
2 Concepts

2.1 Methods of Producing Polarized Gammas

2.2 Methods of Producing Polarized Positrons

2.3 Methods of Measuring Polarization for $\gamma$'s and Positrons
3 Actual Choices

3.1 Polarized $\gamma$ Production

3.2 Polarized Positron Production

One important parameter for the FFTB experiment is the target thickness. It does not only determine the polarization (Figure 2), it also determines the yield (Figure 3).

While a thicker target here seems to be better, in fact there is another variable to be optimized for the FFTB experiment: the target thickness alone determines the angular spread of the positrons produced. Since for reasons of complexity and costs we have decided to work without a flux concentrator and additional acceleration after the target, which traditionally is being used to reduce the angular spread (divergence) we depend on the angular spread being modest so that we can transport the positrons without undue losses, and so that we can make good polarization measurements. For the energy (momentum) spread, collimators in the spectrometer can cut out an appropriate momentum bite; no such remedy is obvious for the angular spread except using a thin enough target.

![Yield versus Target Thickness, monoenergetic $\gamma$s](image)

Figure 3: (---to be replaced by 10 and 20 MeV simul)---
3.3 Polarimetry

10-20 MeV Polarimeter

Figure 4: Instead of separate S-bend magnets wide poletip magnets which can accomodate $e^+$, $\gamma$'s and $e^-$ together are choosen. Charged particles or $\gamma$'s not desired in the counters can be blocked with instrumented smart bricks.

3.3.1 Polarimetry for $\gamma$'s

In the end, the polarimetry for $\gamma$'s and for positrons go back the the concept of Schopper [5], nameley to use the polarization dependent cross section for Compton Scattering in magnetized iron [12]. That means the polarized positrons are reconverted into polarized $\gamma$'s, which are measured in an Iron Transmission Polarimeter.

By bending the charged particles back with a dogleg wide magnet spectrometer, we are able to use the same Iron Polarimeter for the straight ahead $\gamma$'s and the polarized positrons, Figure 4.

3.3.2 Polarimetry for Positrons

4 Request to SLAC

We request N weeks of checkout at 10HZ repetition rate at $10^{10}$ electrons, and M weeks of running at a linac repetition rate of 30 Hz. This assumes that the run takes place between PEP-II fills with an average data collection efficiency of 50%.
The collaboration will provide many of the target and beam line components, such as
... We request that SLAC acquire equipment needed to run in FFTB, such as ...

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References


