Status Report on E-166
Undulator-Based Production of Polarized Positrons

J. C. Sheppard
SLAC
ISG 11 Meeting
KEK, December 17, 2003
E-166 is a demonstration of undulator-based polarized positron production for linear colliders

- E-166 uses the 50 GeV FFTB beam in conjunction with a 1 m-long, helical undulator (λ = 2.4 mm, ID = 0.9 mm) to make 10-MeV polarized photons.

- These photons are converted in a ~0.5 rad. len. thick target into e+ (and e−) with ~50% polarization.

- The polarization of the positrons and photons will be measured.

- E-166 was approved, following presentation to the EPAC in June 2003, for a main data run in 2005, pending demonstration in a test run in 2004 that beam-relate backgrounds are sufficiently low.
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DIRECTOR'S MEMORANDUM

TO: John Sheppard, Kirk McDonald
FROM: Jonathan Dorfan
SUBJECT: E-166 Schedule

December 9, 2003

Dear John and Kirk,

We have studied and discussed with you both, the possible schedules for E-166. You proposed a background test run in FY04 with a data run in FY05, but due to the fully booked schedule for the FFTB in FY04 and the considerable installation requirements for E-166, we propose both runs in FY05. Here is a suggested schedule that I think you will find attractive as it could complete the experiment by February 05.

2004

August and September  Install E-166 (The whole apparatus for both background tests and data acquisition.)

Oct. 4 – 8          Linac turn on and tune up, without PEP

Oct. 8 - Nov. 1 at 0800  Background tests and first data taking

Nov. 1 – Nov. 4       Remove minimal E-166 apparatus to reinstall SPPS

Nov. 4 – Dec. 22      SPPS data run


Jan. 3 – Jan. 31      E-166 Final Data Run

This is a schedule which assumes success within these two runs, and with the other requests for the FFTB beamline, means that further E-166 runs could not be scheduled until many months later.
E-166 Beam Measurements

- Photon flux and polarization as a function of undulator K \( (P_\gamma \sim 75\% \text{ for } E_\gamma > 5 \text{ MeV}). \)

- Positron flux and polarization vs. energy for \( K = 0.17, 0.5 \text{ r.l. of Ti} \) \( (P_{e^+} \sim 50\%). \)

- Positron flux and polarization for 0.1 r.l. and 0.25 r.l. Ti and 0.1, 0.25, and 0.5 r.l. W targets.

- Each measurement is expected to take about 20 minutes.

- A relative polarization measurement of 5% is sufficient to validate the polarized positron production processes.

- The undulator will be pulsed in a random pattern of beam pulses to permit continuous monitoring of undulator-off background levels.
E-166 Beam Request

6 weeks of activity in the SLAC FFTB:
• 2 weeks of installation and check-out
• 1 week of check-out with beam
• 3 weeks of data taking:
  Roughly 1/3 of time on photon measurements,
  2/3 of time on positron measurements.

Schedule (December, 2003):

E-166 Beam Parameters

<table>
<thead>
<tr>
<th>$E_e$</th>
<th>$f_{\text{rep}}$</th>
<th>$N_e$</th>
<th>$\gamma \varepsilon_x = \gamma \varepsilon_y$</th>
<th>$\beta_x, \beta_y$</th>
<th>$\sigma_x, \sigma_y$</th>
<th>$\sigma_{E/E}$</th>
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<tbody>
<tr>
<td>GeV</td>
<td>Hz</td>
<td>$e^-$</td>
<td>$m$-rad</td>
<td>$m$</td>
<td>$\mu m$</td>
<td>$%$</td>
</tr>
<tr>
<td>50</td>
<td>30</td>
<td>$1 \times 10^{10}$</td>
<td>$3 \times 10^{-5}$</td>
<td>$5.2, 5.2$</td>
<td>40</td>
<td>0.3</td>
</tr>
</tbody>
</table>
Beam Background Studies in 2004

E-166 may have backgrounds due to:
1. Showers from beam electrons upstream of the undulator.
2. RF pickup from electrons near the dump.
3. Backsplash from the dump.
4. Showers from electrons that interact with the Protection Collimator in front of, or with gas in, the undulator tube.
5. Soft $e^\pm$ and $\gamma$'s that scatter within the polarimeters.

The test run @ 28 GeV in 2004 is to verify that sources 1-4 cause backgrounds less than 5% of the expected signals.

High-quality beam tuning (as for E-144) is essential.

The success of the test run is to be reviewed by a committee: Robert Noble (chair), C. Field, H. Lynch, and M. Ross.
Expected Signals (per $10^{10}$ $e^-$):

- **CsI calorimeter**: $10^3 \gamma$'s @ 5 MeV $\Rightarrow$ 5 GeV
- **SiW calorimeter**: $4 \times 10^7 \gamma$'s @ 5 MeV $\Rightarrow$ 200 TeV
- **Aerogel**: $2 \times 10^7 \gamma$'s x $10^{-3}$ p.e./$\gamma$ $\Rightarrow$ $2 \times 10^4$ photoelectrons

Allowable Backgrounds (5% of signals):

- **CsI**: 250 MeV
- **SiW**: 10 TeV
- **Aerogel**: $10^3$ p.e.

EGS, Fluka $\Rightarrow$ Backgrounds @ 50 GeV will be ~ 2 times @ 28 GeV.
E-166 Background Study
(28-46 GeV)

Use 28 GeV beam of same invariant emittance as at 50 GeV.

⇒ Spot size at 28 GeV is \( \sqrt{50/28} = 4/3 \) times that at 50 GeV,

⇒ Use 1.2 mm undulator tube at 28 GeV.
EGS simulation of 28 and 50 GeV electrons hitting undulator Protection Collimator (PC).

⇒ 3 times as much background energy into E-166 detectors at 50 GeV as at 28 GeV.

⇒ 0.14 GeV per electron that hits the PC goes thru the 3-mm-diameter aperture of the collimator in front of the $\gamma$ converter.
⇒ 70,000 e's give 10 TeV in the SiW calor.

⇒ 0.05 GeV per electron that hits the PC into the 400 cm$^2$ area of the CsI calor.
⇒ 50 e's give 250 MeV in the CsI calor. IF NO SHIELDING.

The simulation does not yet include the ~ 3 m of iron/alinco between undulator and CsI calor., nor does it include any lead.
28 GeV Test Run Preparations: Implications of Simulations

- γ polarimetry viable for up to ~ 100,000 e’s hitting the undulator Protection Collimator (10⁻⁵ of the beam).
  ⇒ Beam tuning must be at least this good.
  ⇒ Average vacuum in undulator tube must be < 10⁻² Torr.

- Shielding of the CsI calor. must reduce background energy flux by ~ 20,000 in the worst case that is viable for the SiW calorimeter.

50 $X_0$ of lead attenuates energy by ~ 20,000 (EGS4).

⇒ Prepare to add ~50 $X_0$ of lead (30 cm) upstream of CsI calor. (in addition to the 150 $X_0$ of iron/AlNICO already there).
Two positions:
1. Undulator tube and Protection Collimator on the electron beam.
2. Beam profile monitor + 1” beam pipe on the electron beam.

Position 2 is default for other use of the FFTB than E-166.
28 GeV Test Run Preparations:
Gear Near the Undulator Tube

Trim Magnets

Beam Position Monitor

Hard-Soft Bend Magnet

Optical Transition Radiation Monitor

Wire Scanner

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- Prototype SiW calorimeter for $\gamma$ polarimetry is now in the FFTB tunnel.
  [T-467 parasitic data: no shielding, E165 beam $\Rightarrow$ CsI backgrounds $10^5$ times too high.]

- The PCAL calorimeter of E-144 has been reinstalled above the FFTB dump magnets to monitor undulator scraping.
Two Cerenkov counters with aerogel of index $n = 1.0095$ are now in the FFTB tunnel.

Index measured with a Michaelson interferometer.
One CsI calorimeter with PMT already in FFTB tunnel.

One more with PMT, and another with photodiodes, ready by Dec. 1. (Thanks to BaBar.)

Calibration via sources and cosmics.
PC-based data acquisition system with LabView software and CAMAC interface.

Software will build on E-165 experience.

System now installed in Bldg 407.
E-166 gear can remain in place during E-164/165/SPPS running provided:

- The undulator tube/1” tube sliding table is set to 1” tube on beam.

- The radiation safety dump for the E-164 $\gamma$ line is moved upstream and placed on a sliding table.

For E-166 to run:

- The retractable components of E-164/165/SPPS should be removed from the e and $\gamma$ lines.

- The E-164 pair spectrometer in the $\gamma$ line must be removed.

- The air gaps in the e line downstream of the FFTB dump magnets, used by E-164/165, should be closed up (with vacuum pipes).
# 28 GeV Test Run

**Beam Requirements**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>(E_0)</td>
<td>28</td>
<td>GeV</td>
</tr>
<tr>
<td>Beam Current</td>
<td>(n_b)</td>
<td>(0.1 - 1.0 \times 10^{10})</td>
<td>(\text{e-/bunch})</td>
</tr>
<tr>
<td>Repetition Rate</td>
<td>(f_{\text{rep}})</td>
<td>~10</td>
<td>Hz</td>
</tr>
<tr>
<td>Emittance</td>
<td>(\gamma \varepsilon)</td>
<td>(\leq 5 \times 10^{-5})</td>
<td>m-rad</td>
</tr>
<tr>
<td>Bunch Length</td>
<td>(\sigma_z)</td>
<td>~0.5</td>
<td>mm</td>
</tr>
<tr>
<td>Spot Size @ IP1</td>
<td>(\sigma^*)</td>
<td>50</td>
<td>(\mu\text{m})</td>
</tr>
</tbody>
</table>

Time early for installation: February 1, 2004
Time required for installation and non-beam check-out: 2 weeks
Time required to conduct measurements: 9-18 shifts (?)
Stages of the 28 GeV Test Run

1. Tune 28 GeV beam with long pulse for low losses.  
   (No installation needed.)

2. Tune beam through the undulator tube.  
   (Install undulator tube and nearby beam diagnostics.)

3. Study backgrounds in prototype E-166 detectors.  
   (Install shielding and reconfigure the FFTB $\gamma$ line.  
   Prototype detectors already installed.)

Beam tuning is critical,  
$\Rightarrow$ Schedule initial tuning well before end of FFTB running.
28 GeV Test Run Preparations: Timeline/Milestones

1 Dec 2003:
- All detectors for the test run complete.
- Complete design of sliding tables for undulator and E-164 $\gamma$ line dump.

1 Jan 2004:
- Complete installation and checkout of detectors in FFTB tunnel (during occasional accesses).
- Complete checkout of BPM’s, OTR, 2$^{nd}$ soft bend magnet.
- Complete design of shielding for detectors.

1 Feb 2004:
- Complete fabrication of the two sliding tables.
- Complete fabrication of detector shielding components.

15 Feb 2004:
- Complete installation of sliding tables, E-166 beam diagnostics, and detector shielding (during a 2 week shutdown of the FFTB).
From a Successful Test Run in 2004 to the Data Run in 2005

1. Fabricate the undulator and power supply.
2. Fabricate the magnetized iron absorbers.
3. Fabricate the positron polarimeter transport magnets.
4. Fabricate the 4 x 4 CsI calorimeter.
5. Implement the final shielding configuration.
## E-166 Institutional Responsibilities

<table>
<thead>
<tr>
<th>Beamline</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electron Beamline</td>
<td>SLAC</td>
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<tr>
<td>Undulator</td>
<td>Cornell</td>
</tr>
<tr>
<td>Positron Beamline</td>
<td>Cornell/Princeton/SLAC</td>
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<tr>
<td>Photon Beamline</td>
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<tr>
<td>Polarimetry:</td>
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<tr>
<td>Overall</td>
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<tr>
<td>Magnetized Fe Absorbers</td>
<td>DESY</td>
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<tr>
<td>Cerenkov Detectors</td>
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<tr>
<td>Si-W Calorimeter</td>
<td>Tenn./ S. Carolina</td>
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<tr>
<td>CsI Calorimeter</td>
<td>DESY/Humboldt</td>
</tr>
<tr>
<td>DAQ</td>
<td>S. Car./SLAC</td>
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</tbody>
</table>
Appendix: Preliminary Concept of Detector Shielding at 28/50 GeV

Bright items to be used @ 28 GeV; faint items added @ 50 GeV.
Appendix: Preliminary Concept of Higher Acceptance Positron Transport

Add focusing element(s) near positron production target to increase acceptance.