Jan Kovermann

The E166 experiment





undulator based polarized positron source for the ILC

What is E166?

It is a proof-of-principle experiment for a new type of positron source! New sources are necessary for the planned positron current in the ILC...

...and it's polarized!

- does this principle work?
- what is the degree of polarization?



who and where? :

 ~50 persons from 13 universities as well as SLAC, DESY, KEK, CERN

• experimental setup was located in the FFTB at SLAC



Timeline of E166 :

- main principle first mentioned in 1970s
- first proposal to SLAC in 2001
- two runs in 2005 (june and september)
- about 12GB of raw data in ~3000 runfiles
- complete simulation of the setup with GEANT4
- experiment (and FFTB...) dismantled in spring 2006
- analysis of data is still in progress



ILC International Linear Collider

Ideal: ILC with polarized e⁺ <u>and</u> e⁻ beams

- Higher effective polarization
- Increased signal to background in SM-tests
- Enhancement of effective luminosity
- Precise analysis of many kinds of non-standard couplings
- The option to use transversely polarized beams



Why polarized? :

background and luminosity:

Pe-	P_{e^+}	$e^+e^- \to W^+W^-$	$e^+e^- \to ZZ$
0	0	1.0	1.0
0.8	0	0.2	0.76
-0.8	0	1.8	1.25
0.8	-0.6	0.1	1.05
-0.8	0.6	2.85	1.91

e-

C+									
P_{e^-}	P_{e^+}	RL	LR	RR	LL	$P_{\rm eff}$	$\mathcal{L}_{\mathrm{eff}}/\mathcal{L}$		
0	0	0.25	0.25	0.25	0.25	0.	0.5		
-1	0	0	0.5	0	0.5	-1	0.5		
-0.8	0	0.05	0.45	0.05	0.45	-0.8	0.5		
-0.8	+0.6	0.02	0.72	0.08	0.18	-0.95	0.74		



search for new physics:



Figure 4: Separation of the selectron pair $\tilde{e}_L^- \tilde{e}_R^+$ in $e^+e^- \rightarrow \tilde{e}_{L,R}^- \tilde{e}_{L,R}^+$ with longitudinally polarized beams in order to test the association of chiral quantum numbers to scalar fermions in SUSY transformations [13].

The helical undulator



First proposed by Mikhailichenko und Balakin in 1979:

The Conversion System for Obtaining High Polarized Electrons and Positrons, Budker Institute of Nuclear Physics, Preprint BINP 79–85 (1979)



The basic principle: _e^{_} undulator e[−] separator ρ. separation, adiabatic matching, filtering, acceleration, dump, damping ring, ...

thin target, about 0.5 X0



Why using an undulator?

Conventional positron source:

- unpolarized
- target >5 X0
- very high energy deposition in target (heatload)
- complex target, e.g. rotating WRe-Disc



Source with helical undulator:

- polarized
- target ~ 0.4X0
- smaller energy deposition in target (ILC won't kill it...)
- simple target (thin target, no switchyard necessary)



And in ILC?





The helical undulator...





(Color) Bifilar helixes having opposite helicities.



Helical undulator is a bifilar helix with opposed currents.

sensitive mechanics, line of sight about 0.7mm!





Low emittance beam necessary!



The helical undulator:



Cross-section of undulator, Fig.5. Two G10 rods are based in corners of long groove. Third rod with help of springing bars 4 compresses the windings to the other two ones. 1 – is a cover, 2 – is bi-helix. 3 – is a corps, 5 – are G10 rods, 6 – is filled with coolant. Parts 1, 3 made from Aluminum.





Needs cooling!



The helical undulator:

Produced radiation:

- first approximation in beam direction:
- @SLAC: E~50GeV results in ~10MeV photons



Figure 6: (a) The photon number spectrum, intensity spectrum, of undulator radiation, integrated over angle, for electron energy $E_e = 50$ GeV, undulator period $\lambda_u = 2.4$ mm and undulator strength parameter K = 0.17. The peak energy E_{c10} of the first harmonic (dipole) radiation is 9.62 MeV. (b) The polarization P_{γ} of the undulator radiation as a function of energy.



 $E_0 \approx \frac{2\gamma^2 hc}{\lambda}$

Produced radiation:





The helical undulator for the ILC:

- E166 competes with LASER-backscattering sources for use in the ILC
- E166 has to proof its principle and give a hint on its efficiency and the degree of polirization
- No advice on technical details of an ILC-scale positron source can be given

Parameter	Units	TESLA*	NLC	FFTB
Beam energy E_{ϵ}	${\rm GeV}$	150-250	150	50
N_e /bunch	0	$3 imes 10^{10}$	$8 imes 10^9$	$1 imes 10^{10}$
$N_{\rm bunch}/{ m pulse}$	Z	2820	190	1
Pulses/s	Hz	5	120	30
Undulator type	-	planar	helical	helical
Undulator strength K	~	1	1	0.17
Undulator period λ_u	\mathbf{cm}	1.4	1.0	0.24
1^{st} Harmonic cutoff, $E_{\rm c10}$	Mev	9-25	11	9.6
dN_{γ}/dL	photons/m/ e^-	1	2.6	0.37
Undulator length L	m	135	132^{\dagger}	1
Target material	×.	Ti-alloy	Ti-alloy	Ti-alloy
Target thickness	rad. len.	0.4	0.5	0.5
Yield	$e^+/\mathrm{photon}~(\%)$	1-5	1.5^{\ddagger}	0.5
Capture efficiency	%	25	20	-
N_+ /pulse	-	8.5×10^{12}	1.5×10^{12}	$2 imes 10^7$
N_+ /bunch	2	3×10^{10}	$8 imes 10^9$	$2 imes 10^7$
Polarization P^+	%		40-70	40-70

 \ast TESLA baseline design; TESLA polarized e^+ parameters (undulator and polarization) are the same as for the NLC.

 \dagger A length of 132 m is required for a unity gain $e^- \to e^+$ system. An undulator length of 200 m is under consideration in order to provide 50% overhead in positron production.

 \ddagger Includes the effect of photon collimation at $\gamma \theta_{\rm cut} = 1.414.$















FFTB at SLAC, 50GeV e⁻ @ 1 or 10 Hz :







The analysis part in detail:





E166 spectrometer and calibration:





E166 spectrometer and calibration:





The positron-polarimetry:

- Polarimetry uses spindependent Comptoncrossection, measures asymmetry
- Compare with Goldhaber-experiment e-





$$\delta(L) = \frac{T^+(L) - T^-(L)}{T^+(L) + T^-(L)} = \tanh(nLP_eP_\gamma\sigma_P) \approx nLP_eP_\gamma\sigma_P$$



Some preliminary results of E166:

- Helical undulator works and produces circularly polarized photons!
- Asymmetries measured for 6 different positron energies
- Asymmetries are in the expected range
- Analysis and simulation with GEANT4 is still in progress







Some preliminary results of E166:



International Polarized Positron Collaboration

Some preliminary results of E166:



The CsI-calorimeter:

- 3x3 matrix of CsI(TI)-crystals
- CsI(TI): high energy resolution (~5%) at E~1GeV
- 2 photodiodes per crystall
- photodiodes and amplifiers out of BaBar-inventories









International Polarized Positron Collaboration

My diploma thesis: Calibration of the E166 Csl-calorimeter

Analysis of run files with focus on:

- improved pedestals
- precise measurement of amplifier slopes
- calculation of high-resolution values

Simulation of cosmic muon events with GEANT4:

- implementation of cosmic muon generator
- implementation of cosmic trigger in geometry

Testbeam run in Hamburg to check linearity

















International Polarized Positron Collaboration

My diploma thesis:

Simulation with GEANT4 and calibration with cosmic muons:







International Polarized Positron Collaboration

My work for E166:

- Determination of amplifier slopes has been finished, with a precision better or equal to 2.5%
- Simulation with GEANT4 has been finished, first calibration with cosmic muon runs done at SLAC has been published

Analysis in progress:

- Testbeam run in testbeam-area 22 at DESY Hamburg
- First results show extrapolation within 5%-band possible

