Polarized e^- and e^+ at the ILC

Summary of the Polarization Report

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for the POWER group

LCWS05
Stanford, 22/03/2005

1. **'Polarization talks' at LCWS05**

2. **Polarization report ∼finished!**
   - → **The physics case for polarized e^- and e^+ beams**
   - → **Machine overview**
   - → **Polarimetry overview**

3. **Further news and events**

Very active 'POWER' group: Polarization related talks at LCWS05

- 'Physics':
  - 'The importance of e^+ polarization': U. Nauenberg@Susy
  - 'Review of physics with polarized beams': N. Paver@New Physics
- 'Machine':
  - 'Polarized e^+ sources at the ILC': V. Bharadwaj@Accelerator
  - 'Enhanced Fabry Perot resonators': A. Variola@Accelerator
  - 'Status of experiment E166 at SLAC': R. Pöschl@Accelerator
  - 'Beam dynamic simulation': W. Gai@Accelerator
  - 'Polarized e^+ Generation at KEK-ATF': T. Omori @Accelerator
  - + many questions and discussion
- 'Polarimetry':
  - 'Polarimetry for 2 IR's and downstream designs': K. Moffeit@MDI
  - 'Upstream Compton Polarimetry': N. Meyners@MDI

$\Rightarrow$ Only few examples here, for details, please, look at the talks directly and also at the 'POWER report' ! (www.ippp.dur.ac.uk/~gudrid/power/report.pdf)

Physics at the e^+e^- Linear Collider

* Discovery of New Physics (NP)
  - $\longrightarrow$ Large potential for direct searches
  - $\longrightarrow$ Impressive potential also for indirect searches!
* Unraveling the structure of NP
  - $\longrightarrow$ precise determination of underlying dynamics and parameters
  - $\longrightarrow$ model distinction through model-independent searches
* High precision measurements
  - $\longrightarrow$ tests of the SM with unprecedented precision
  - $\longrightarrow$ even smallest hints of NP could be observed

$\Rightarrow$ Beam polarization = decisive tool for direct and indirect searches!

'State of the art':

Polarized e^- beam at SLAC: SLC $\sim 75\%$

E158 $\sim 90\%$

at Nagoya, KEK: $\sim 90\%$

new results show that $P(e^-) \sim 90\%$ can be expected at ILC!

$\Rightarrow$ won't such high $P(e^-)$ suffice?

Polarization report - 'POWER Write-Up'

- **The physics case for having both beams polarized:**
  140 pages, $\sim$ 70 authors, $\sim$ 30 institutes
  $\rightarrow$ incl. 80 pages physics, 20 pages machine, 20 pages polarimetry
  $\rightarrow$ will be submitted to Phyics Reports and to hep-ph (very soon!)
  $\rightarrow$ http://www.ippp.dur.ac.uk/~gudrid/power/report.pdf

- **News from physics** with polarized beams in Susy, SM, other NP!
  $\rightarrow$ focus on use of P_{e^+} compared to P_{e^-} only

- **Machine overview** about polarized e^+ source
  and polarization measurements

- **Thanks a lot** to all authors!

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SLAC-PUB-xxxx

Final Draft

Revealing fundamental interactions: the rôle of polarized positrons and electrons at the Linear Collider*

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Outline of the report

a) Introduction:
- ⋆ possible general dependences on beam polarization w.r.t. kind of interaction
- ⋆ definitions and gain in accuracy for A_{LR} measurement with P_{e^+}

b) Open questions of the SM: top, Higgs, GigaZ
- ⋆ t and H couplings and properties
- ⋆ application of Blondel scheme for high precision tests

c) Searches for New Physics: Susy, CI, ED, LQ, new CP-violation,...
- ⋆ parameter determination (many!), CP-violating effects, background supp.
- ⋆ model-independent approaches in direct and indirect searches

d) Summary of the physics cases
- ⋆ qualitative and quantitative improvement factors listed in short summaries
- ⋆ summary tables for longitudinally and transversely polarized beams

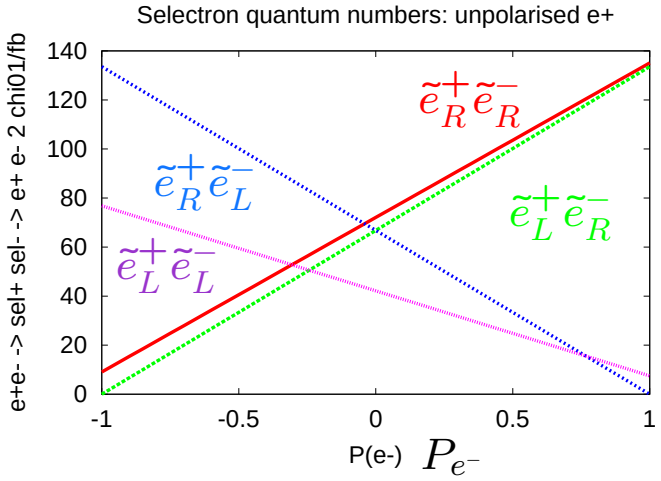
e) Technical aspects:
- ⋆ history of polarized e^- at SLC; polarized e^- source design for ILC
- ⋆ polarized e^+: undulator-based schemes , comments on laser-based scheme
- ⋆ polarization measurement via up-/downstream polarimetry, annihilation data

Some physics examples – quick rush through

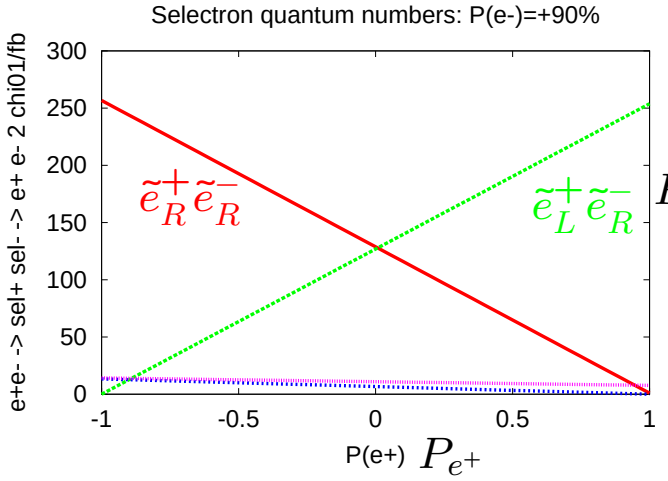
Supersymmetry: Test of quantum numbers

Association of chiral electrons to scalar partners $e^-_{L,R} \leftrightarrow \tilde{e}^-_{L,R}$ and $e^+_{L,R} \leftrightarrow \tilde{e}^+_{R,L}$

1. **separation of scattering (direct SM→SUSY vertex) ↔ annihilation channel**
2. **test of 'chirality': only $\tilde{e}^-_R\tilde{e}^+_L$ may survive at $P_{e^-} > 0$ and $P_{e^+} > 0$!**



high $P_{e^-} > 0$!



high $P_{e^-} > 0$ and $P_{e^+} > 0$!

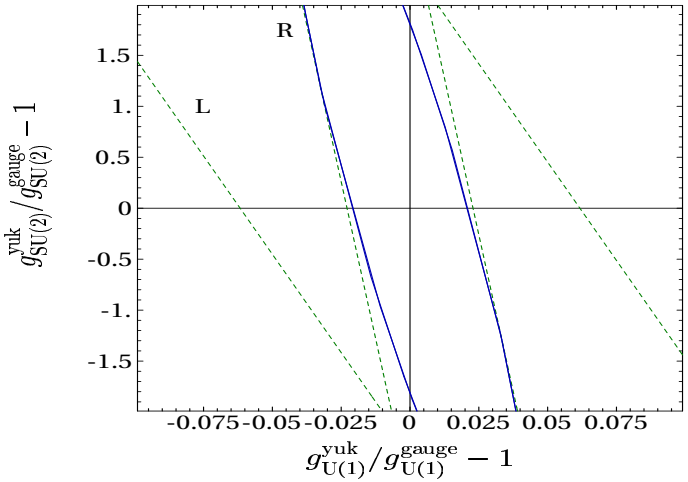
$\Rightarrow$ Even high P_{e^-} not sufficient but P_{e^+} needed!

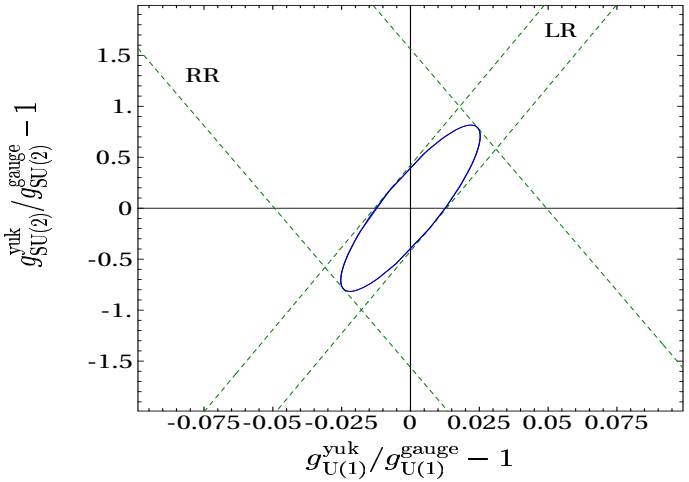
Some physics examples – quick rush through

Supersymmetry: Test of Yukawa couplings

Test of SU(2), U(1) gauge couplings ≡ SUSY Yukawa couplings

1. separation of the pairs $\tilde{e}^-_R\tilde{e}^+_R$ and $\tilde{e}^-_R\tilde{e}^+_L$
2. 'variation' of Yukawa couplings accepted within experimental uncertainty





Freitas

e^+ **Yukawa couplings: only** P_{e^-} $\Rightarrow$ **SU(2), U(1) Yukawa coupling 'not' measurable**

P_{e^-} **and** P_{e^+} $\Rightarrow$ **Δ SU(2)**$\sim 80\%$, **Δ U(1)** $\sim 2.5\%$

$\Rightarrow$ **Even high** P_{e^-} **not sufficient but** P_{e^+} **needed!**

Some physics examples – quick rush through

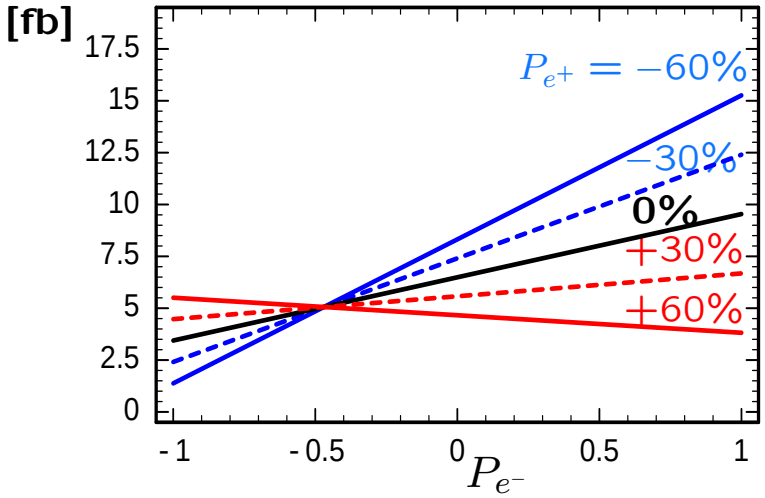
Searches for CP-violation, e.g. in SUSY (many new phases)

'Construction' of T-odd asymmetries with angular correlations

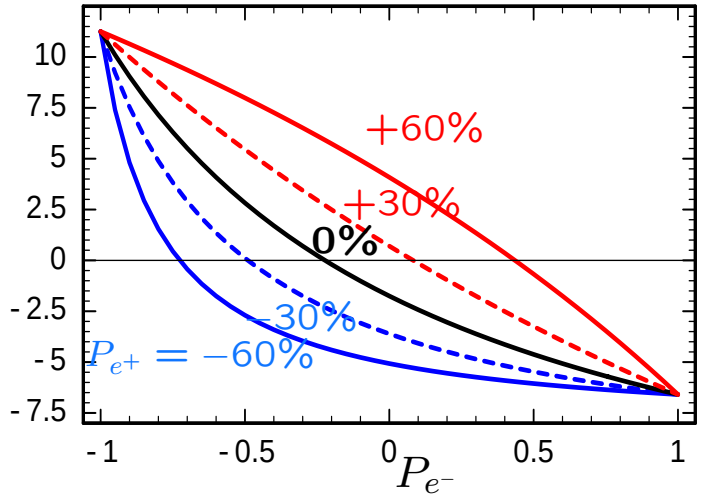
1. small phases → small asymmetries expected

$\phi_\mu = 0$, small ϕ_{M_1}

$\sigma(e^+e^- \to \tilde{\chi}_1^0\tilde{\chi}_2^0 \to 2\tilde{\chi}_1^0\ell^-\ell^+)$



$A_T(e^+e^- \to \tilde{\chi}_1^0\tilde{\chi}_2^0 \to 2\tilde{\chi}_1^0\ell^-\ell^+)$



Hesselbach

- with longitudinally pol. beams:

  P_{e^+} needed for better measurability of asymmetry $\sim |A_T|\sqrt{\mathcal{L} \times \sigma}$

- with transversely polarized beams: direct access to CP-odd asymmetries

$\Rightarrow$ Both e^- and e^+ beams have to be polarized!

Some physics examples – quick rush through

Transversely polarized beams also for indirect searches:

- Who guaranties that we will ever reach the new heavy scale?
  $\rightarrow$ indirect searches important!
  $\rightarrow$ however, strong model-dependence!
- With transversely polarized beams:
  exploit azimuthal asymmetries also for indirect searches!
  a) distinction between SM and different models of large extra dimensions *Rizzo*
  b) access to new CP-violating kind of interactions in $t\bar{t}$, γZ, W^+W^- *Nagel Rindani*

  $\rightarrow$ unique access to $\Re$ parts of CP-sensitive couplings!

$\Rightarrow$ Transversely polarized beams are very effective also for indirect seaches w/wo CP-violation
$\rightarrow$ in principle both e^- and e^+ beams polarized required!

Some physics examples – quick rush through

Which effects are possible? $|M|^2 \sim \bar{v}(\lambda_{e^+})\Gamma u(\lambda_{e^-})\bar{u}(\lambda'_{e^-})\Gamma^\dagger v(\lambda'_{e^+})$

Interaction structure		Longitudinal		Transverse	
Γ	$\Gamma^\dagger$	Bilinear	Linear	Bilinear	Linear
S	S	$\sim P_{e^-}P_{e^+}$	–	$\sim P^T_{e^-}P^T_{e^+}$	–
P	S	–	$\sim P_{e^\pm}$	$\sim P^T_{e^-}P^T_{e^+}$	–
V,A	S	–	–	–	$\sim P^T_{e^\pm}$
T	S	$\sim P_{e^-}P_{e^+}$	$\sim P_{e^\pm}$	$\sim P^T_{e^-}P^T_{e^+}$	
P	P	$\sim P_{e^-}P_{e^+}$	–	$\sim P^T_{e^-}P^T_{e^+}$	–
V,A	P	$\sim P_{e^-}P_{e^+}$	$\sim P_{e^\pm}$	$\sim P^T_{e^-}P^T_{e^+}$	$\sim P^T_{e^\pm}$
T	P	$\sim P_{e^-}P_{e^+}$	$\sim P_{e^\pm}$	$\sim P^T_{e^-}P^T_{e^+}$	
V,A	V,A	$\sim P_{e^-}P_{e^+}$	$\sim P_{e^\pm}$	$\sim P^T_{e^-}P^T_{e^+}$	–
T	V,A	–	–	–	$\sim P^T_{e^\pm}$
T	T	$\sim P_{e^-}P_{e^+}$	$\sim P_{e^\pm}$	$\sim P^T_{e^-}P^T_{e^+}$	–

P, S =(pseudo)scalar

A, V =(axial)vector

T =tensor

$\Rightarrow$ impact of beam polarization depends on kind of interaction(s)

- with P_{e^-} and P_{e^+} much higher flexibility with regard to NP candidates for direct as well as indirect searches!

Technical aspects of polarizing e^- and e^+ at the ILC

- Polarized electron source: strained photocathode technology

  $\Rightarrow P(e^-) \approx 90\%$ expected

- Positron sources under discussion for the ILC:

* Conventional source

  $\Rightarrow$ no polarization

* Undulator-based source

  $\Rightarrow$ polarized, > 150 GeV electrons needed

- Other schemes? Laser-based source $\Rightarrow$ polarized

- Status of polarimetry

  $\Rightarrow$ Compton polarimetry well advanced

  $\star$ up-, as well as downstream ILC designs under work

  $\star$ high accuracy expected $\Delta P/P \sim 0.25\%$!

  better precision requires P_{e^+}!

Results of the report

- clear physics case for polarized e^- and e^+
  - ⋆ many$\equiv (n+1)$ examples from different physics scenarios!
  - ⋆ P_{e^+} always advantageous, independent of direction of NP
  - ⋆ more observables, higher flexibility, better statistics+systematics

$\Rightarrow$ P_{e^+} crucial preparation for 'being prepared for the Unexpected'!

- ILC scheme designs well on track for $P_{e^-} = \pm 90\%$ and $P_{e^+} = \pm 60\%$
  + kicker system for pulse-train-to-pulse-train $\longrightarrow$ two IR's with $P_{e^\pm}$
  $\Rightarrow$ important also for switching $\pm P$

- possible to provide polarized beams without loss of peak luminosity and without any critical impact on commissioning!
  - ⋆ long undulator, additional polarized e^- source for commissioning,...

$\Rightarrow$ details have to be decided before the final ILC design!

- designs for up-/and downstream polarimetry for the ILc
  - ⋆ accuracy of $\Delta P_{e^\pm}/P_{e^\pm} \sim 0.25\%$

$\Rightarrow$**Report should be seen as contemporary status report!**

still studies ongoing, new ideas+examples coming up

however, the final source design should be decided soon!

Future events related to 'Beam Polarization at the ILC'

- 'Workshop on Positron Sources for the ILC', Daresbury, April, 11-13!
  - ⋆ Program: Polarized and unpolarized e^+ source
  - ⋆ Drive beams, target issues, polarimetry, capture issues, operational aspects
  - ⋆ webpage: www.astec.ac.uk/id_mag/workshop.htm
- ongoing experiment at KEK (since 2001)
  - ⋆ polarized e^+ from laser-compton scheme with $P_{e^+} \sim 80\%$ measured via transmission polarimetry
- First run of the project 'E166' at SLAC in May, 2005
  - $\Rightarrow$ first results hopefully soon!
- Helical undulator prototypes for ILC parameters in 2005
  - ⋆ Test of a SC helical undulator at Rutherford Lab already started
  - ⋆ Construction of a PPM helical undulator at Daresbury Lab started
- Snowmass in August 2005
  - Polarization session needed: detailed design comparison between conventional and undulator-based scheme, also news for laser-based scheme planned

Summary: polarized e^- and e^+ at the ILC

- P_{e^+} $\Rightarrow$ only gains, independent in which direction NP points
  - $\star$ key additional observables for unraveling the underlying physics: kind of interaction, particle properties, parameter determination,...
  - $\star$ significant improvement for model-independent approaches in direct as well as indirect searches for NP
  - $\star$ Analyzing NP might be challenging $\longrightarrow$ best of all tools needed!

$\Rightarrow$ full potential of the ILC could only be realized with P_{e^-} and P_{e^+}!

- undulator-based scheme is feasible and its design well advanced
  - $\star$ some prototypes for ILC design already under construction
- To-do list: detailed designs for both conventional and undulator-based source? revisit reliability issues? cost comparison? start with conventional? polarized source as upgrade? (expect $\sim$3% increment in ILC project cost to have both conventional and undulator-based sources)

$\Rightarrow$ Please, think about these questions now, i.e. in 2005, ... !

P_{e^-} only together with P_{e^+} provide a unique tool for the ILC:

- $\star$ high potential of applications
- $\star$ and preparation for the 'Unexpected!'