Polarization of both beams at the ILC

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Collider Physics: From Tevatron to the LHC to the LC
Aspen, 2.9.2005

1. **Introduction**
   → General remarks
   → Polarization report

2. **The physics case for polarized e^- and e^+**
   → Top
   → Higgs
   → SUSY
   → Constraints from high-precisions tests at GigaZ
   → Other kinds of new physics

3. **Last-but-not-least: some technical details**

4. **Concluding remarks**

What is so special at a LC?

clean precisely known initial state, kinematics fully known
large S(ignal)/B(background) $\rightarrow$ clear signatures
excellent flavour tagging, c-, b-quark

precise high luminosity (300-500 fb^{-1}/year)
test of theory at loop (quantum) level
precise analysis of the chiral structure: polarized beams
excellent detector resolution

flexible tunable beam energy 90 - $\sim$500 GeV (1.phase)
upgrade 1000 GeV (2. phase)
high e^- and e^+ beam polarization
running options ($\gamma\gamma$, $e\gamma$, e^-e^-)

flexible+ at 1st phase: $\sqrt{s} = 500$ GeV$\rightarrow$ 650 GeV but $\mathcal{L}^{650} = \mathcal{L}^{500}/3$
without power changes!

$\Rightarrow$ The ILC is a precision as well as a discovery machine ...

$\rightarrow$ Beam polarization = decisive tool for exploring new physics!

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!
* Unravelling 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 - 'The role of polarized positrons and electrons in revealing fundamental interactions at the Linear Collider'

(working group POWER ≡ POlarization at Work in Energetic Reactions)

- **The 'physics case' for having both beams polarized:**
  150 pages, ∼ 80 authors, ∼ 35 institutes

→ **incl. 90 pages physics, 20 pages machine, 20 pages polarimetry**

→ *GMP et al., hep-ph/0507011, submitted to Phyics Reports*

→ **http://www.ippp.dur.ac.uk/~gudrid/power/**

→ **executive summary, 12 pages, same webpage**

- **News from physics with polarized beams in Susy, SM, other NP!**

→ **focus on use of P_{e^+} compared to P_{e^-} only**

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

Physics case for having both beams polarized – 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 table for longitudinally and transversely polarized beams

e) Technical aspects:

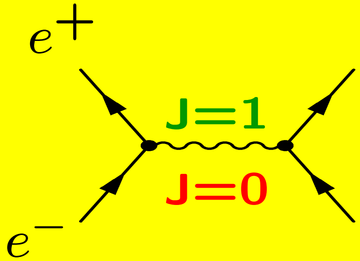
- ⋆ history of polarized e^- at SLC; polarized e^- source design for ILC
- ⋆ polarized e^+: undulator-based schemes , comments on laser-based scheme
- ⋆ polarization measurement via up-/downstream polarimetry, annihilation data

General remarks about the coupling structure

Def.: **left-handed** $\equiv P(e^{\pm}) < 0$ **right-handed** $\equiv P(e^{\pm}) > 0$

Which configurations are possible in principle?

s–channel:



← **contributions only from RL,LR: SM and NP (γ, Z)**

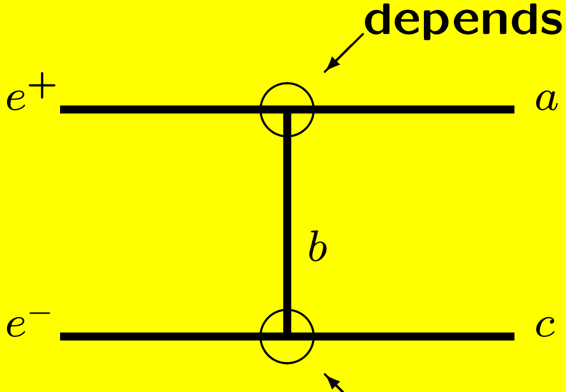
← **contributions only from LL,RR: NP!**

$\Rightarrow$ **In principle:** $P(e^-)$ **fixes also helicity of** e^+**!**

Which configurations are possible in the crossed channels?

t–channel:

depends on $P(e^+)$**!**



depends on $P(e^-)$**!**

$\Rightarrow$ **helicity of** e^- **not coupled with helicity of** e^+**!**

Some well-known statistical examples

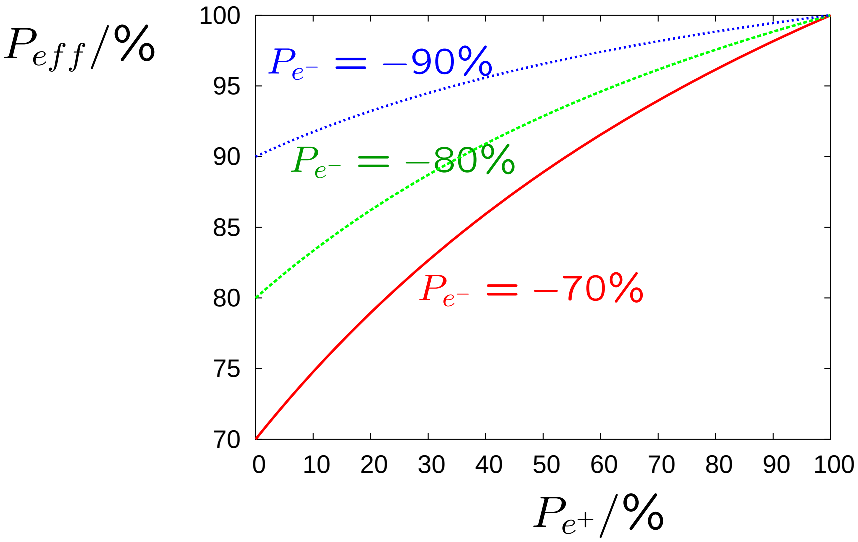
As warm-up: gain in effective polarization $P_{\rm eff}$ and A_{LR}

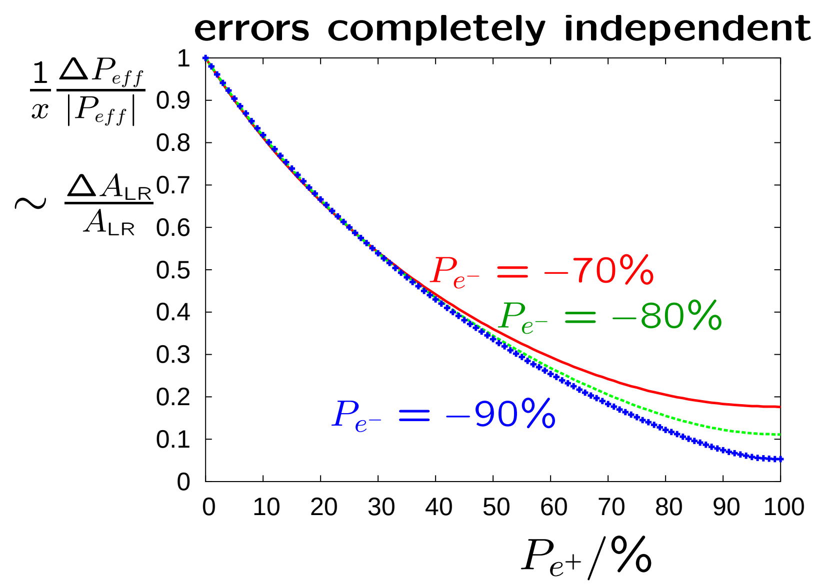
- **Enhancement of effective polarization and measurement of A_{LR}**

For many processes (V, A interactions) the cross section is given by:

$$\sigma_{P_{e^-}P_{e^+}} = \frac{1+P_{e^-}}{2}\frac{1-P_{e^+}}{2}\sigma_{\rm RL} + \frac{1-P_{e^-}}{2}\frac{1+P_{e^+}}{2}\sigma_{\rm LR} = (1-P_{e^+}P_{e^-})\,\sigma_0\,[1 - P_{\rm eff}\,A_{\rm LR}]$$

with $P_{\rm eff} = \frac{P_{e^-}-P_{e^+}}{1-P_{e^+}P_{e^-}}$





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

Let's start with 'safe' physics:
Top – determination of the electroweak properties

Process: $e^+e^- \to t\bar{t}$ (test of coupling $t \to \gamma$, Z)

$$\Gamma^{\mu}_{t\bar{t}\gamma,Z} = ie\{\gamma^{\mu}[F^{\gamma,Z}_{1V} + F^{\gamma,Z}_{1A}\gamma^5] + \frac{(p_t - p_{\bar{t}})^{\mu}}{2m_t}[F^{\gamma,Z}_{2V} + F^{\gamma,Z}_{2A}\gamma^5]\}$$

- **Studies at threshold:**

$v_t = (1 - \frac{8}{3}\sin^2\theta_W)$ **via** A_{LR}

$\Rightarrow \Delta A_{LR}/A_{LR} \sim \Delta P_{eff}/P_{eff}$

$\Rightarrow$ **(80%,0)→(80%,60%): factor 3!**

- **Studies at $\sqrt{s} = 500$ GeV:**

only for P_{e^-} so far!!!

estimated:

$\Rightarrow$ **(80%,0)→(80%,60%): ~factor 3!**

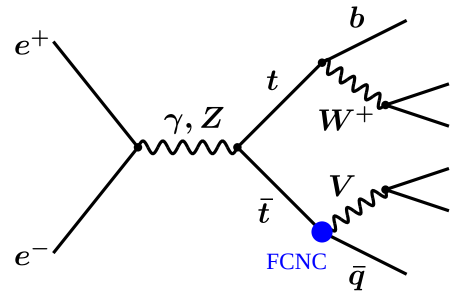
true simulation still missing!

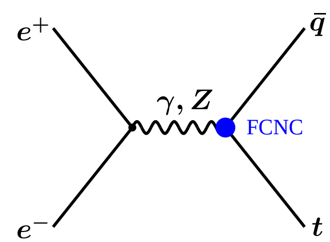
Form factor	SM value	$\sqrt{s} = 500$ GeV		$\sqrt{s} = 800$ GeV	
		$p = 0$	$p = -0.8$	$p = 0$	$p = -0.8$
F^Z_{1V}	1		0.019		
F^Z_{1A}	1		0.016		
$F^{\gamma,Z}_{2V} = (g-2)^{\gamma,Z}{}_t$	0	0.015	0.011	0.011	0.008
$Re\, F^{\gamma}_{2A}$	0	0.035	0.007	0.015	0.004
$Re\, d^{\gamma}_t$ $[10^{-19}$ e cm$]$	0	20	4	8	2
$Re\, F^Z_{2A}$	0	0.012	0.008	0.008	0.007
$Re\, d^Z_t$ $[10^{-19}$ e cm$]$	0	7	5	5	4
$Im\, F^{\gamma}_{2A}$	0	0.010	0.008	0.006	0.005
$Im\, F^Z_{2A}$	0	0.055	0.010	0.037	0.007
F^W_{1R}	0	0.030	0.012		
$Im F^W_{2R}$	0	0.025	0.010		

$\Rightarrow$ **Gain of about a factor 3 with P_{e^-} and P_{e^+}!**

Limits for flavour-changing neutral top-couplings

Processes: top pair production or singe top production





- **Single top:**
  → **more sensitive**
- **top pairs+decays:**
  → **better for disentangling**
- **Results:**

vector couplings:

(80%,0)→(80%,45%): $\sim$ 1.7

tensor couplings:

(80%,0)→(80%,45%): $\sim$ 1.8

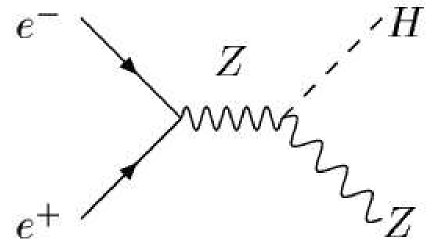
	unpolarized beams	$\lvert P_{e^-}\rvert = 80\%$	$(\lvert P_{e^-}\rvert, \lvert P_{e^+}\rvert) = (80\%, 45\%)$
	$\sqrt{s} = 500$ GeV		
$BR(t \to Zq)(\gamma_\mu)$	6.1×10^{-4}	3.9×10^{-4}	2.2×10^{-4}
$BR(t \to Zq)(\sigma_{\mu\nu})$	4.8×10^{-5}	3.1×10^{-5}	1.7×10^{-5}
$BR(t \to \gamma q)$	3.0×10^{-5}	1.7×10^{-5}	9.3×10^{-6}
	$\sqrt{s} = 800$ GeV		
$BR(t \to Zq)(\gamma_\mu)$	5.9×10^{-4}	4.3×10^{-4}	2.3×10^{-4}
$BR(t \to Zq)(\sigma_{\mu\nu})$	1.7×10^{-5}	1.3×10^{-5}	7.0×10^{-6}
$BR(t \to \gamma q)$	1.0×10^{-5}	6.7×10^{-6}	3.6×10^{-6}

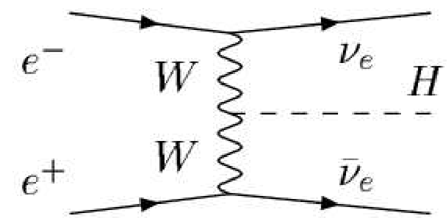
⇒ **With** $(80\%, 45\%)$ **ILC$_{500}$ extends LHC (w.r.t. γ_μ)**
(the ILC is anyway superior for tensor coupling)

Beam polarization for SM Higgs searches

Light Higgs, $m_H = 130$ **GeV:**

$\rightarrow HZ$ **and** $H\nu\bar{\nu}$ **similar rates**





P_{e^-}, P_{e^+} **needed for:**

a) separation

b) background supp.

Configuration (P_{e^-}, P_{e^+})	Scaling factors $e^+e^- \rightarrow H\nu\bar{\nu}$	Scaling factors $e^+e^- \rightarrow HZ$
$(+80\%, 0)$	0.20	0.87
$(-80\%, 0)$	1.80	1.13
$(+80\%, -60\%)$	0.08	1.26
$(-80\%, +60\%)$	2.88	1.70

$\Rightarrow \sigma(HZ)/\sigma(H\nu\nu)$:

improves by factor 4

(+80%,0)$\rightarrow (+80\%, -60\%)$

- side remark: WW background scales as $H\nu\bar{\nu}$:

$\Rightarrow P_{e+}$ **always helps!**

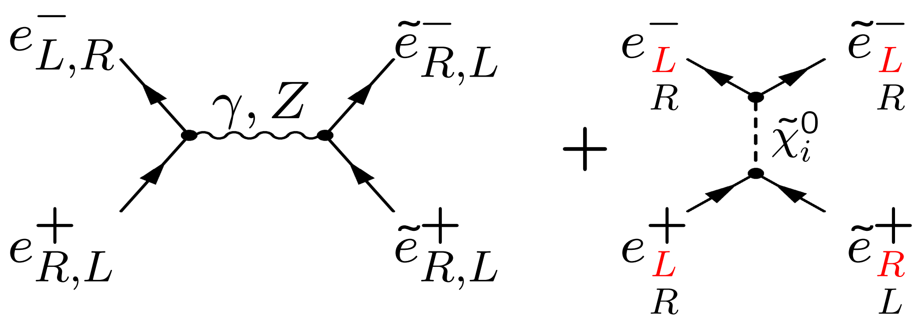
Gain with P_{e^+}	P_{e^+}	in addition to P_{e^-}
Signal 'S'	$\times 2$	$\times 2$
Background 'B'	$\times 0.5$	$\times 2$
S/B	$\times 4$	Unchanged
$S/\sqrt{B}$	$\times 2\sqrt{2}$	$\times\sqrt{2}$

$\Rightarrow P_{e-}$ **and** P_{e+} **very helpful for a light SM Higgs!**

Now new physics: discovery+unravelling – SUSY (e.g.)

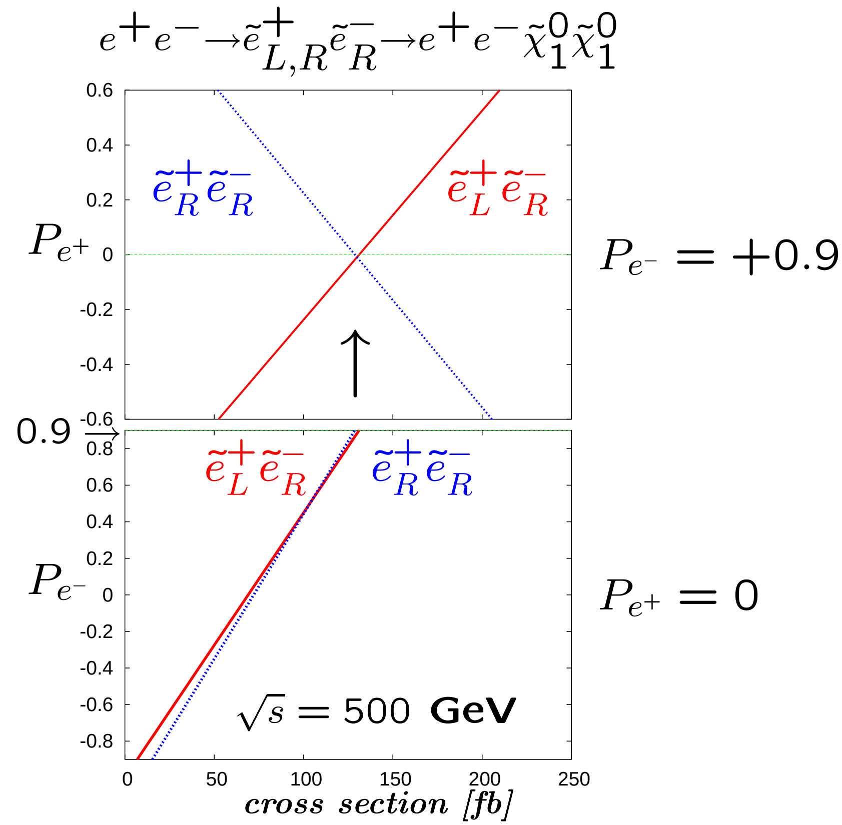
Selectron sector: Test of Susy quantum numbers

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 versus annihilation channel**

2. **test of 'chirality': only $\tilde{e}^-_R \tilde{e}^+_L$ may survive at $P_{e^-} > 0$ and $P_{e^+} > 0$!**



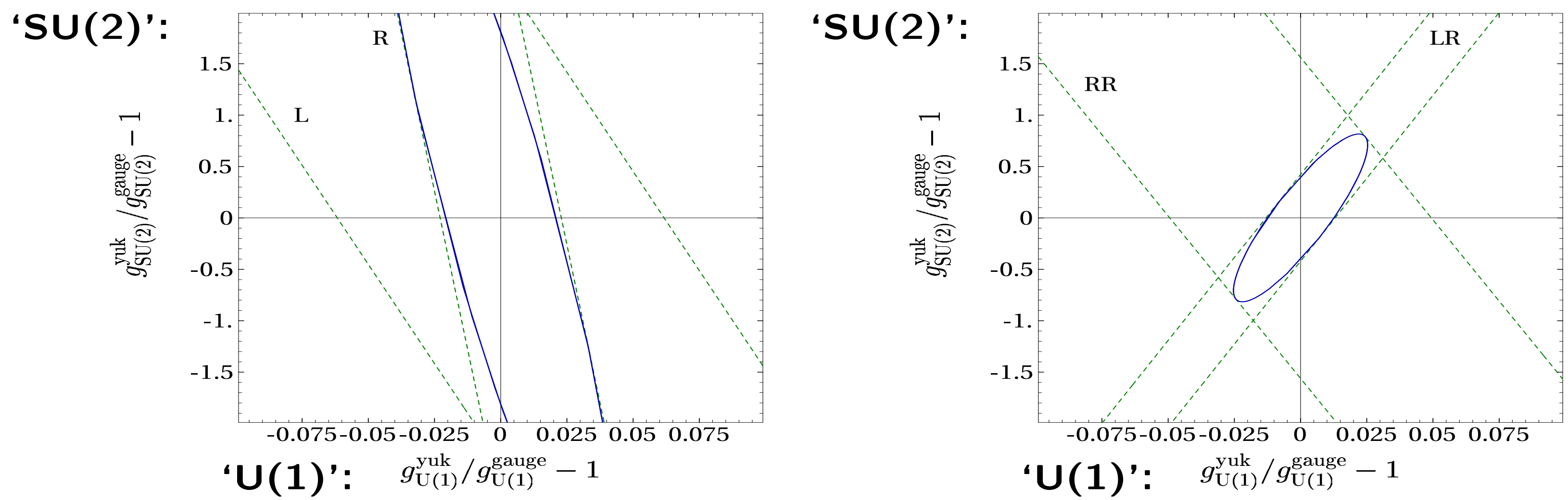
⇒ Even high P_{e^-} not sufficient, but P_{e^+} needed!

Selectron sector, cont.

Supersymmetry: Test of Yukawa couplings

Test of SU(2), U(1) gauge couplings $\equiv$ 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**



e^+ **Yukawa couplings: only** P_{e^-} — P_{e^-} **and** P_{e^+}

$\Rightarrow$ **SU(2), U(1) Yukawa coupling 'not' measurable** — $\Rightarrow$ $\triangle$ **SU(2)**$\sim 80\%$, $\triangle$ **U(1)** $\sim 2.5\%$

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

Selectron sector, cont.

Supersymmetry: Test of Yukawa couplings – next example

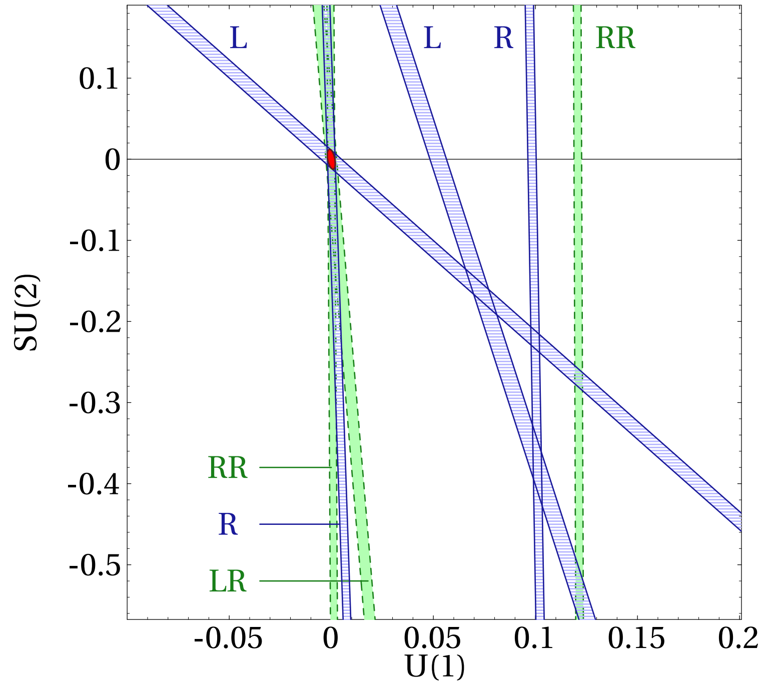
Determination of U(1), SU(2) Yukawa couplings of e^+:

further scenario with $m_{\tilde{e}_R} \ll m_{\tilde{e}_L}$, however no GUT relation between M_1 and M_2:

with $P_{e^-} = +90\%$ (R) and $P_{e^-} = -90\%$ (L)
$\Rightarrow$ four-fold ambiguity!

Adding: $(P_{e^-}, P_{e^+}) = (-60\%, +90\%)$ (LR)
and $(P_{e^-}, P_{e^+}) = (+60\%, +90\%)$ (RR)

$\Rightarrow$ unique determination with
$\Delta(U(1)) \sim 0.2\%$ and $\Delta(SU(2)) \sim 1.2\%$



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

Smuon mass measurement

SUSY mass measurement in the continuum

- To optimize threshold scans $\rightarrow$ continuum measurements important!

Example: $e^+e^- \rightarrow \tilde{\mu}^+_{L,R}\tilde{\mu}^-_{L,R}$

$\rightarrow$ **only s-channel**

Strong WW-background

$\rightarrow$ **all edges observable**

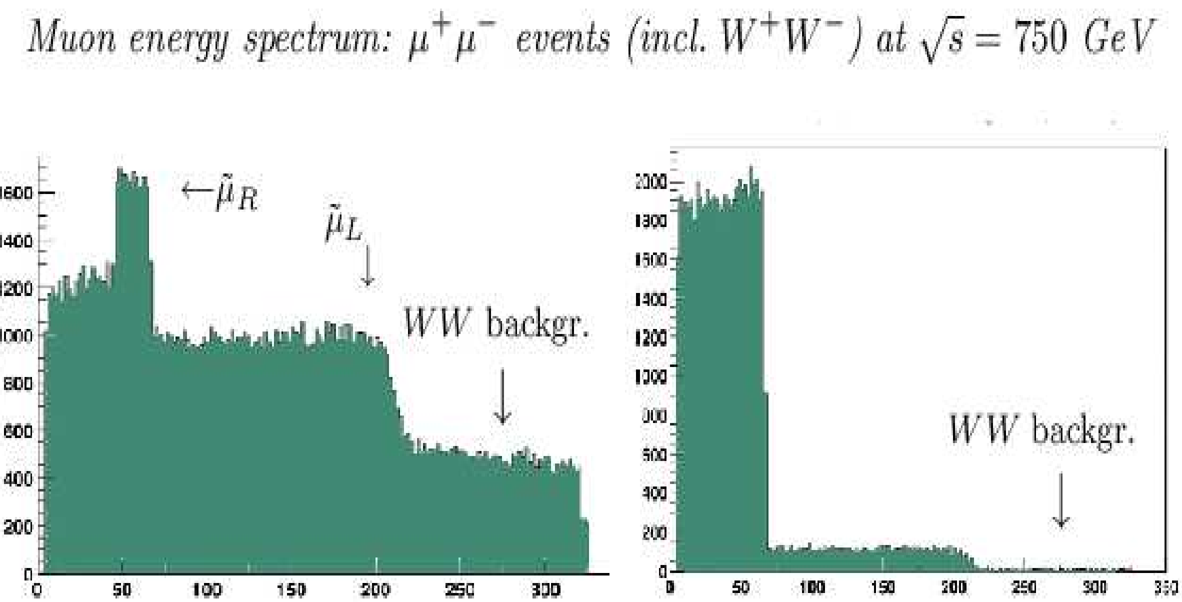
only with P_{e^-} and P_{e^+}

$\sim$65 GeV and 220 GeV

$\rightarrow$ **S/B=0.07** $(+80\%, 0)$

$\rightarrow$ **S/B=0.46** $(+80\%, -80\%)$

$\Rightarrow$ $\Delta(m_{\tilde{\mu}_{L,R}}) \sim$ **few GeV**



$(P_{e^-}, P_{e^+}) = (-80\%, +80\%)$ $\quad$ $(P_{e^-}, P_{e^+}) = (+80\%, +80\%)$

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

Third family: stop sector

Determination of stop mixing angle

Process $e^+e^- \to \tilde{t}_1\tilde{t}_1$ **(only** γ, Z **exchange): determination of** $\theta_{\tilde{t}}$

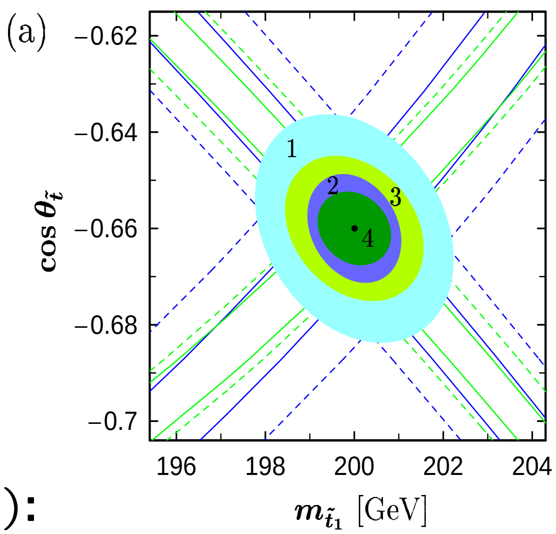
with $\sigma(\tilde{t}_1\tilde{t}_1)$ **or with** A_{LR}^{obs}

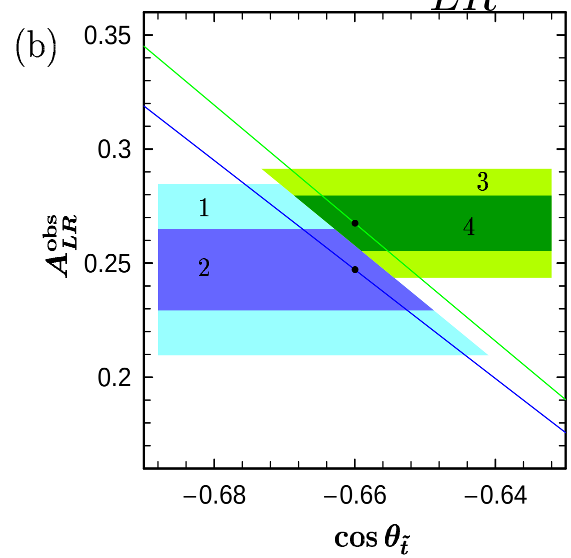
light colours '1', '3':

$\to \mathcal{L}_{\rm int} = 100$ **fb**$^{-1}$

dark colours '2', '4':

$\to \mathcal{L}_{\rm int} = 500$ **fb**$^{-1}$





$(\pm 90\%, 0) \to (\pm 90\%, \mp 60\%)$:

	with $\sigma(\tilde{t}_1\tilde{t}_1)$	with A_{LR}^{obs}
with $\mathcal{L}_{\rm int} = 100$ **fb**$^{-1}$	$\Delta \cos\theta_{\tilde{t}} \sim 3.6 \to 2.4\%$	$\Delta \cos\theta_{\tilde{t}} \sim 2.3 \to 1.4\%$
with $\mathcal{L}_{\rm int} = 500$ **fb**$^{-1}$	$\Delta \cos\theta_{\tilde{t}} \sim 1.8 \to 1.1\%$	$\Delta \cos\theta_{\tilde{t}} \sim 1.1 \to 0.7\%$

$\Rightarrow$ **'gain' factor about 1.6 for accuracy in** $\cos\theta_{\tilde{t}}$
and about 1.4 for $\Delta m_{\tilde{t}}$

Gaugino/higgsino sector

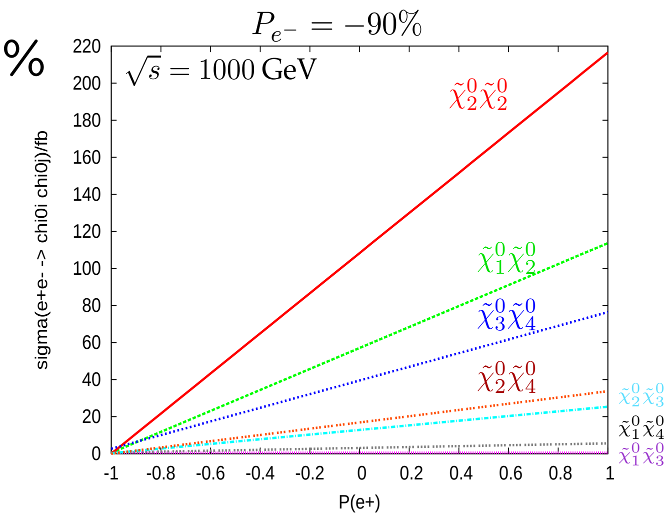
SUSY: determination of the new parameters
(already 105 new parameters in the 'minimal' model (MSSM)!)

- complicated interplay of SUSY parameters

  $\Rightarrow$ as many as possible observables needed!

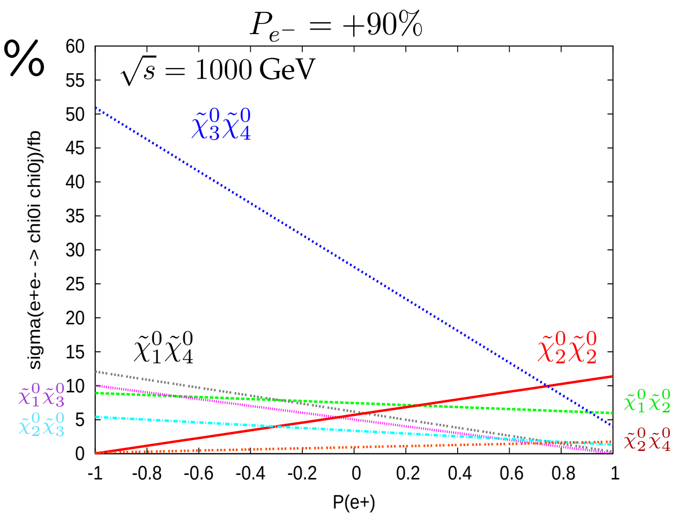
  exploit e.g. all possible cross sections of $\tilde{\chi}^0_i\tilde{\chi}^0_j$: $\sigma(e^+e^- \to \tilde{\chi}^0_i\tilde{\chi}^0_j)$/fb

$P_{e^-} = -90\%$



P_{e^+}

$P_{e^-} = +90\%$



P_{e^+}

- with P_{e^+} gain in cross sections up to factor $\sim$2 wrt P_{e^-} only

$\Rightarrow$ **Both e^- and e^+ beams should be polarized!**

Azimuthal asymmetries with trans. polarization CP-odd observables in neutralino production

- Cross sections: $\sigma^T \sim P^T_{e^-} P^T_{e^+} \int d\phi Re f_1 \cos(\eta - 2\phi) + Im f_2 \sin(\eta - 2\phi)$

(η gives azimuthal orientation of transverse beams w.r.t. to fixed reference frame)

$\Rightarrow$ both beams have to polarized, otherwise no contribution ($m_e \to 0$!)

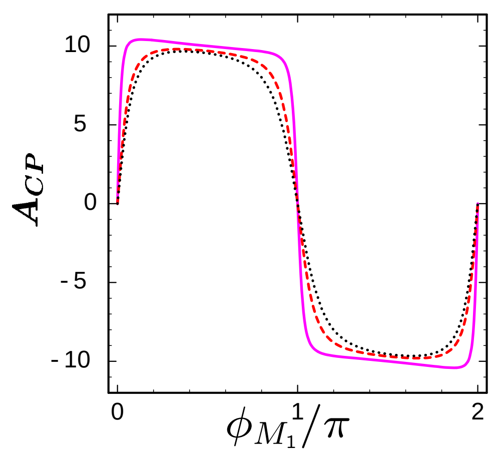
- CP-odd terms are $\sim \sin(\eta - 2\phi)$
  - $\to$ Dirac case: in $\tilde{\chi}^+_i \tilde{\chi}^-_j$ production CP-odd terms$\sim \sin(\eta - 2\phi)$ vanish!
  - $\to$ Majorana case: in $\tilde{\chi}^0_i \tilde{\chi}^0_j$ production CP-odd terms$\sim \sin(\eta - 2\phi)$ contribute!

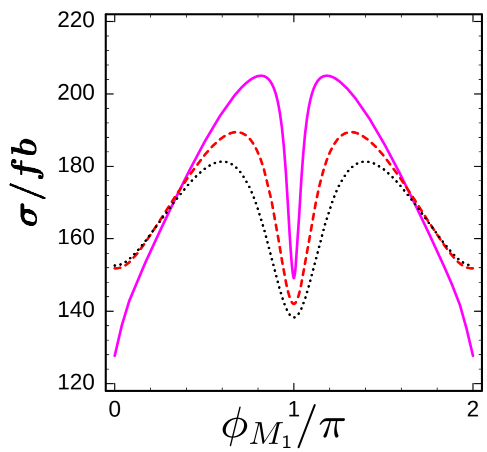
(because of t, u channel)

$e^+e^- \to \tilde{\chi}^0_1 \tilde{\chi}^0_2$:

at $\sqrt{s} = 500$ GeV

for $\tan\beta = 3, 10, 30$





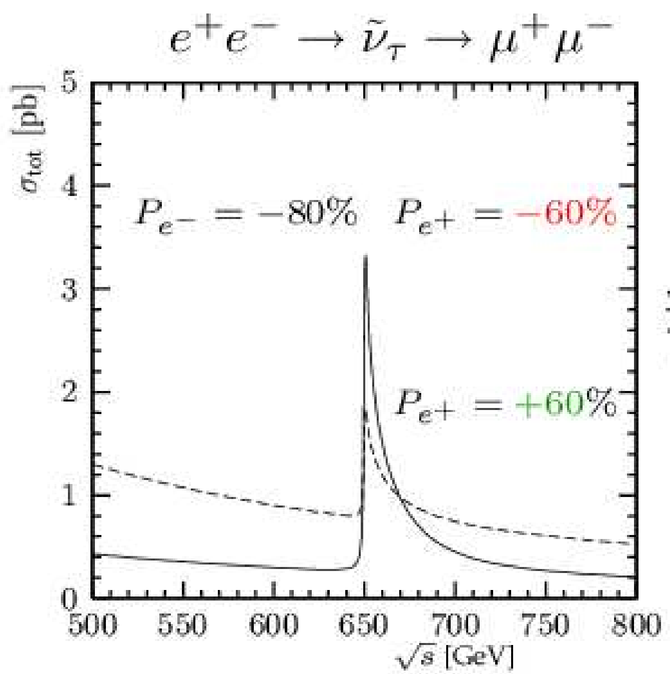
$\Rightarrow$ **Rather large A_{CP} expected, even for small CP-phases!**

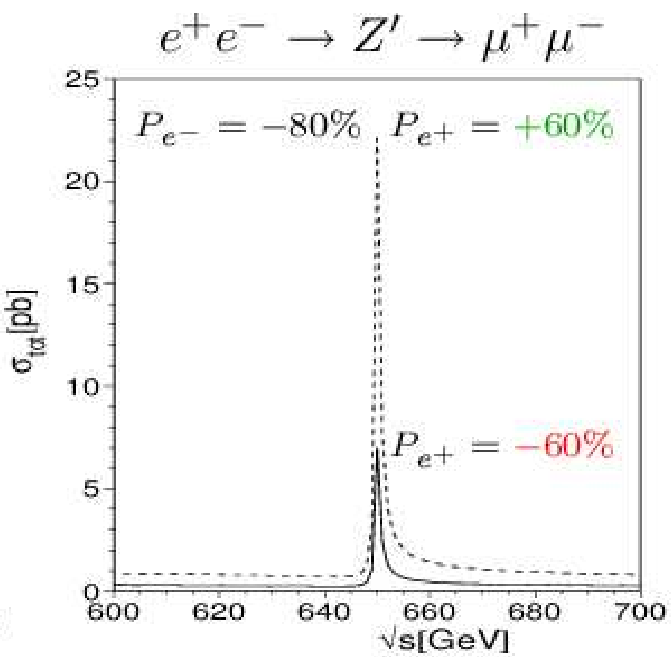
Extended SUSY model: R-parity violation

R-parity violation: single $\tilde{\nu}$ production in s-channel

- **Process** $e^+e^- \to \tilde{\nu}_\tau \to \mu^+\mu^-$ (only s-channel γ, Z, $\tilde{\nu}_\tau$ exchange)

  $\Rightarrow$ 'spin 0-$\tilde{\nu}$' $\to$ favours LL configuration, but e.g. Z' in SSM favours LR!





- direct test of spin in resonance production

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

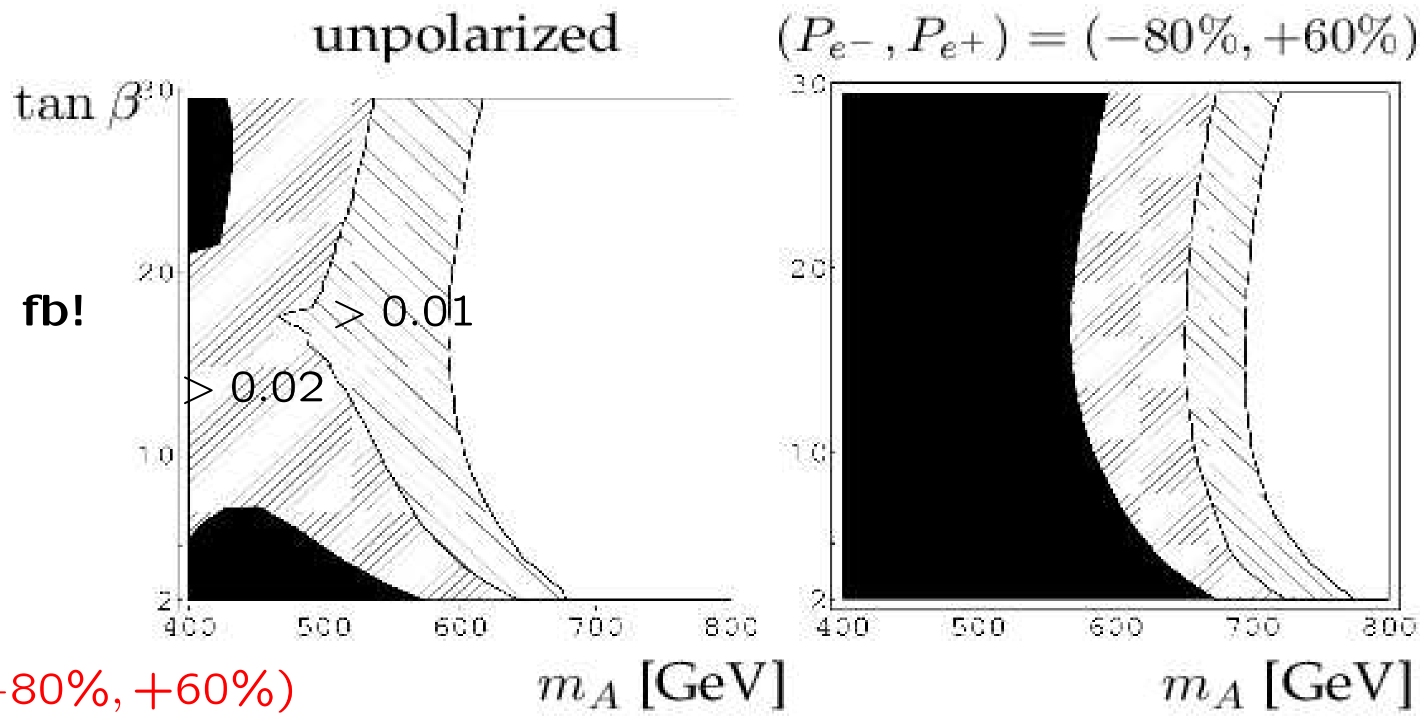
SUSY Higgs production

Heavy Higgs production in decoupling regime:

- **Process: single Higgs in $e^+e^- \to \nu\bar{\nu}H$ for $m_A \gg m_Z$**

  (rare process, since coupling (H,gauge bosons) suppressed!)

black: $\sigma > 0.05$ **fb!**



'gain':

$(-80\%, 0) \to (-80\%, +60\%)$

$\Rightarrow$ **factor 1.6**

$\Rightarrow$ **Both e^- and e^+ beams should be polarized for such rare processes!**

High-presicsion SM tests at GigaZ/WW threshold with high $\mathcal{L}$ –upgrade option at the ILC–

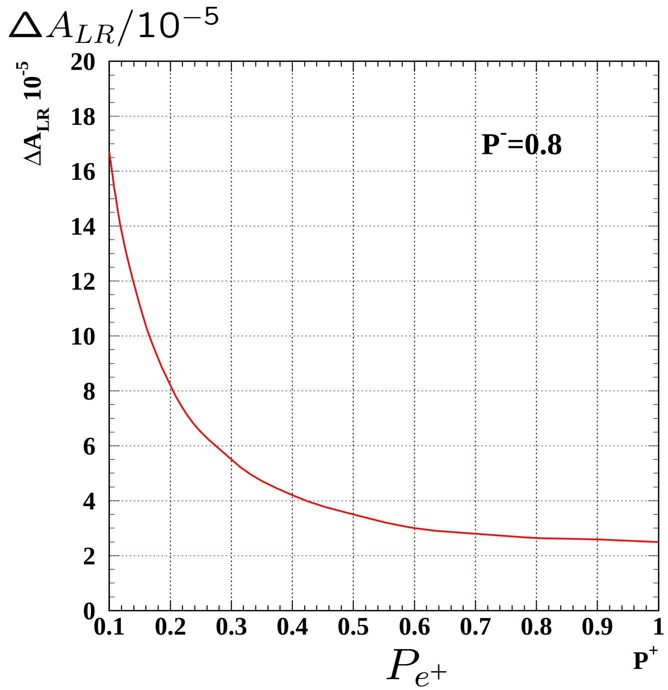
Measurement of $\sin^2\theta^\ell_{\rm eff}$ in $e^+e^- \to Z \to f\bar{f}$:

- ‘usually’ $\Delta P/P \sim 0.5\%$ sufficient

  (maybe $\Delta P/P \sim 0.25\%$ reachable!)

$$A_{LR} = \frac{2(1-4\sin^2\Theta^\ell_{eff})}{1+(1-4\sin^2\Theta^\ell_{eff})^2}$$

$$\stackrel{Blondel}{=} \sqrt{\frac{(\sigma^{RR}+\sigma^{RL}-\sigma^{LR}-\sigma^{LL})(-\sigma^{RR}+\sigma^{RL}-\sigma^{LR}+\sigma^{LL})}{(\sigma^{RR}+\sigma^{RL}+\sigma^{LR}+\sigma^{LL})(-\sigma^{RR}+\sigma^{RL}+\sigma^{LR}-\sigma^{LL})}}$$



- with $\Delta P/P = 0.5\%$ and $P_{e^-} = 80\%$ only:

  $\Rightarrow \Delta\sin^2\theta^\ell_{\rm eff} = 9.5\times 10^{-5}$

  (• with $\Delta P/P = 0.25\%$ and $P_{e^-} = 90\%$:

  $\Rightarrow \Delta\sin^2\theta^\ell_{\rm eff} = 5\times 10^{-5}$)

- with Blondel scheme: $(P_{e^-}, P_{e^+}) = (80\%, 60\%)$:

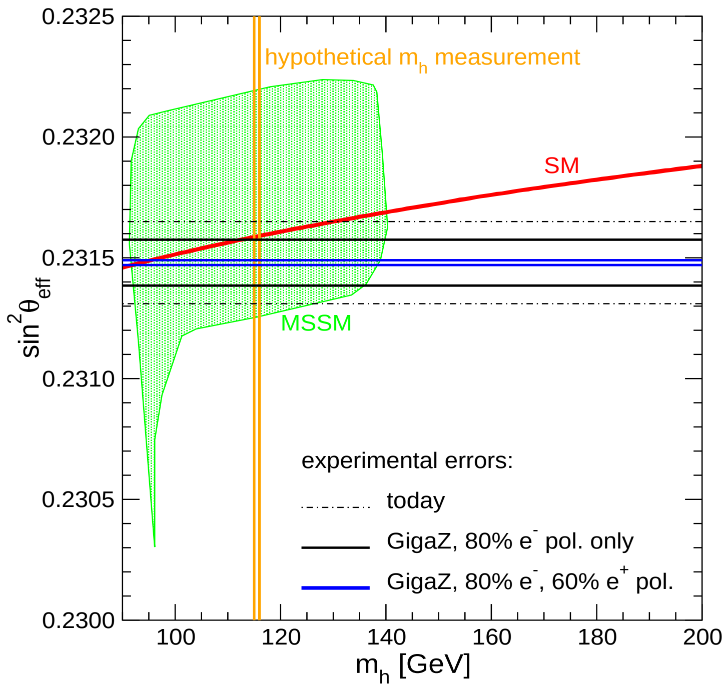
  $\Rightarrow \Delta\sin^2\theta^\ell_{\rm eff} = 1.3\times 10^{-5}$

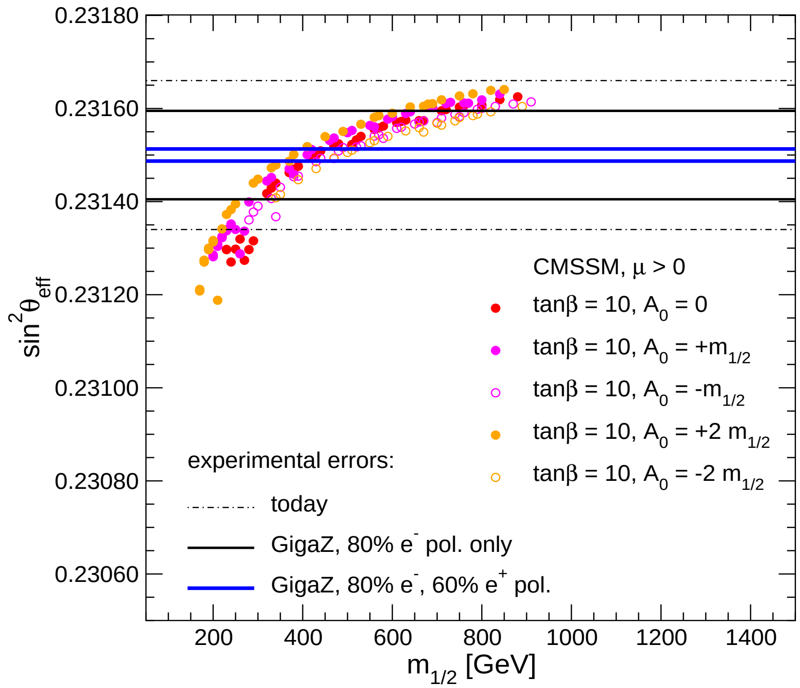
$\Rightarrow$ **Both e^- and e^+ beams polarized needed to reach desired precision!**

Impact of GigaZ for SUSY searches

Gain of about one order of magnitude in $\Delta \sin^2\theta_{\rm eff}$:

⇒ **Prediction/constaints for m_h and $m_{1/2}$**





- **'gain': bounds on SM $m_H \sim$ order of magnitude, on $m_{1/2} \sim$ factor 5!**

⇒ **Both e^- and e^+ beams polarized to exploit GigaZ constraints!**

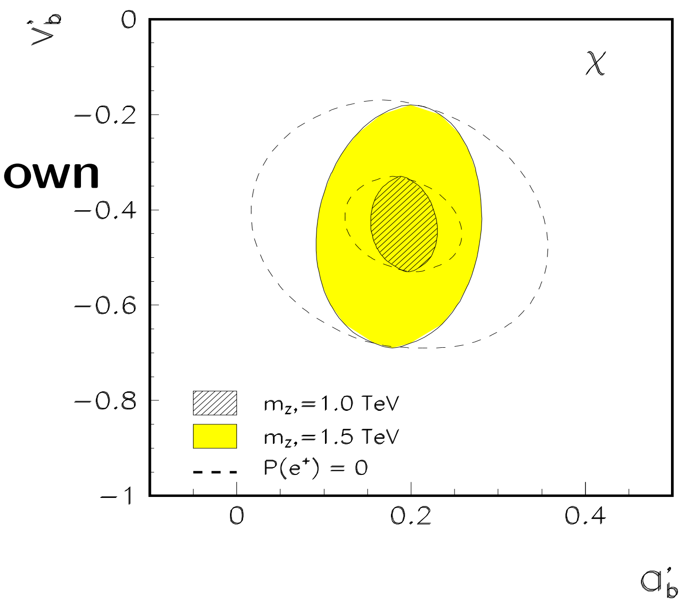
Some more 'non-SUSY' examples: indirect searches

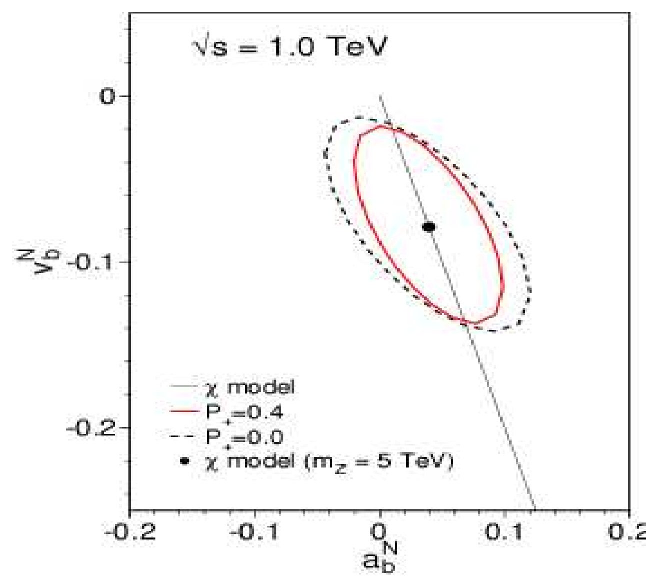
Who guarantees that we will ever reach the new heavy scale? ...

⇒ **indirect searches important!**

- **e.g. in $e^+e^- \to f\bar{f}$ searches for Z', extra dimensions, etc.**

m'_Z **known**





m'_Z **unknown**

→ **determination of couplings and mass reconstruction**

→ **gain factor with P_{e^+} ~1.6 cf. P_{e^-} only (reduction of systematic error!)**

- **e.g. P_{e+} decisive for model-independent bounds in CI**

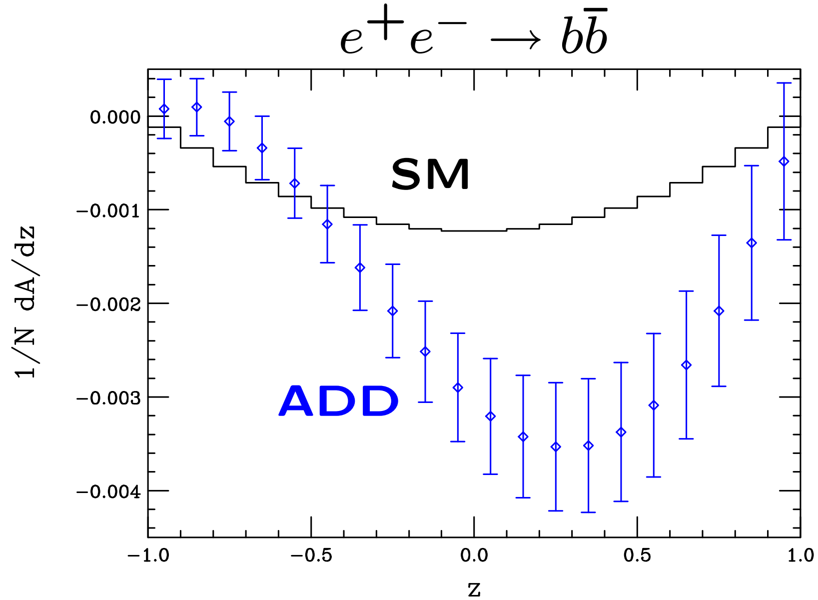
⇒ **Both e^- and e^+ beams should be polarized!**

Further gain for indirect searches

With transversely polarized beams:

$\rightarrow$ exploit azimuthal asymmetries also for indirect searches!

- distinction between SM and different models of large extra dimensions!



- access to new CP-violating kind of interactions in $t\bar{t}$, γZ, W^+W^-

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

$\Rightarrow$ Transversely polarized beams are very effective also for indirect seaches w/wo CP-violation

$\rightarrow$ both e^- and e^+ beams polarized required!

Possible interactions: pol-dependences in general

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!

Summary table from the report (hep-ph/0507011)

Case	Effects	Gain& Essentiality
SM:		
top threshold	Improvement of coupling measurement	factor 3
$t\bar{q}$	Limits for FCN top couplings reduced	factor 1.8
CPV in $t\bar{t}$	Azimuthal CP-odd asymmetries give access to S- and T-currents up to 10 TeV	$P_{e^-}^{\mathrm{T}} P_{e^+}^{\mathrm{T}}$ required
W^+W^-	Enhancement of $\frac{S}{B}$, $\frac{S}{\sqrt{B}}$	up to a factor 2
	TGC: error reduction of $\Delta\kappa_\gamma$, $\Delta\lambda_\gamma$, $\Delta\kappa_Z$, $\Delta\lambda_Z$	factor 1.8
	Specific TGC $\tilde{h}_+ = \mathrm{Im}(g_1^{\mathrm{R}} + \kappa^{\mathrm{R}})/\sqrt{2}$	$P_{e^-}^{\mathrm{T}} P_{e^+}^{\mathrm{T}}$ required
CPV in γZ	Anomalous TGC $\gamma\gamma Z$, γZZ	$P_{e^-}^{\mathrm{T}} P_{e^+}^{\mathrm{T}}$ required
HZ	Separation: $HZ \leftrightarrow H\bar{\nu}\nu$	factor 4 with RL
	Suppression of $B = W^+\ell^-\nu$	factor 1.7
SUSY:		
$\tilde{e}^+\tilde{e}^-$	Test of quantum numbers L, R and measurement of $e^\pm$ Yukawa couplings	P_{e^+} required
$\tilde{\mu}\tilde{\mu}$	Enhancement of S/B, $B = WW$ $\Rightarrow m_{\tilde{\mu}_{L,R}}$ in the continuum	factor 5-7
$\tilde{t}_1\tilde{t}_1$ ($\tilde{b}_1\tilde{b}_1$, $\tilde{\tau}_1\tilde{\tau}_1$)	Improvement in determination of $m_{\tilde{t}_1}$ and $\theta_{\tilde{t}}$	factor 1.4
HA, $m_A > 500$ GeV	Access to difficult parameter space	factor 1.6
$\tilde{\chi}^+\tilde{\chi}^-$, $\tilde{\chi}^0\tilde{\chi}^0$	Enhancement of $\frac{S}{B}$, $\frac{S}{\sqrt{B}}$	factor 2–3
	Separation between SUSY models, 'model-independent' parameter determination	
CPV in $\tilde{\chi}_i^0\tilde{\chi}_j^0$	Direct CP-odd observables	$P_{e^-}^{\mathrm{T}} P_{e^+}^{\mathrm{T}}$ required
RPV in $\tilde{\nu}_\tau \to \ell^+\ell^-$	Enhancement of S/B, $S/\sqrt{B}$	factor 10 with LL
	Test of spin quantum number	
ED:		
$G\gamma$	Enhancement of S/B, $B = \gamma\nu\bar{\nu}$,	factor 3
$e^+e^- \to f\bar{f}$	Distinction between ADD and RS modes	$P_{e^-}^{\mathrm{T}} P_{e^+}^{\mathrm{T}}$ required
Z':		
$e^+e^- \to f\bar{f}$	Measurement of Z' couplings	factor 1.5
CI:		
$e^+e- \to q\bar{q}$	Model independent bounds	P_{e^+} required
Precision measurements of the Standard Model at GigaZ:		
Z-pole	Improvement of $\Delta\sin^2\theta_W$	factor 5–10
	Constraints on CMSSM space	factor 5
CPV in $Z \to b\bar{b}$	Enhancement of sensitivity	factor 3

Last-but-not-least: a few technical remarks (Snowmass'05)

- **How to get polarized e^-?**

→ polarized laser beam on thin strained GaAs lattice (as at SLC)

recent results indicate: $|P_{e^-}| = 90\%$ achievable

- **Which kind of e^+ sources are under discussion?**

a) (unpolarized) conventional source: 6 GeV e^- beam on a thick target,

e^+ from electromagnetic cascade in target

b) (polarized) undulator-based source: > 150 GeV e^- through 200m undulator,

γ on thin target, e^+ from pair production

c) (polarized) laser-compton-based source: backscattering of laser off e^- beam,

γ on thin target, e^+ from pair production

- **Challenges for e^+ source at a linear collider?**

→ huge number required which have to fit within damping ring acceptance

→ $\sim 10^{10}$/per bunch particles needed

... not an easy game ...

What might be possible problems?

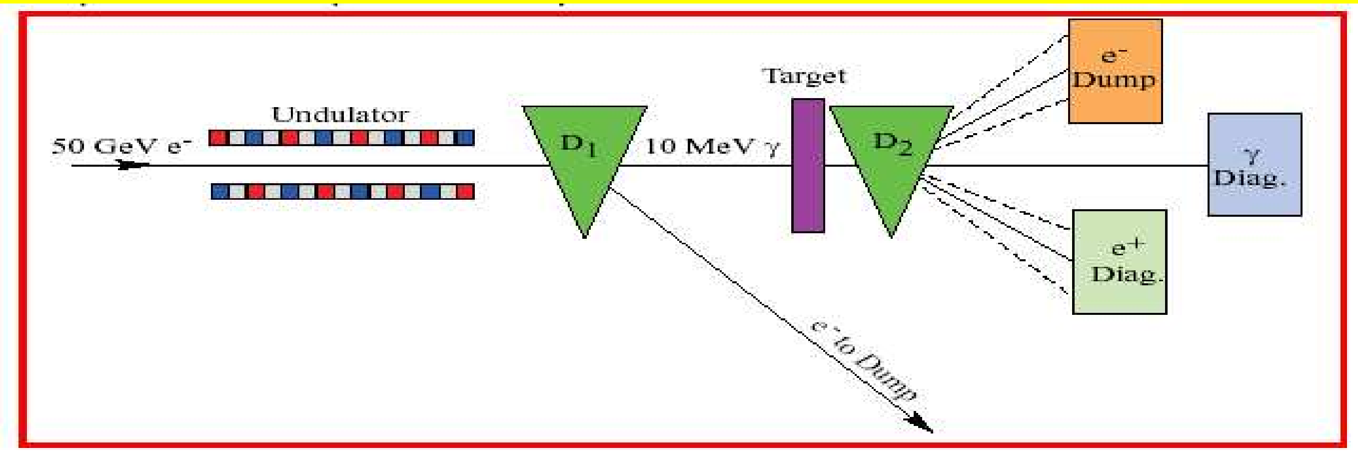
- conventional source: high 'thermal' stress at the target
  and capture efficiency lower ...
- undulator-based source: needs 150 GeV e^- beam
  → operation seems to be linked to whole ILC:
  commissioning, operation problems?
  → no, can be compensated with keep-alive beam
  → (reliability study of T. Himel, in SLAC+DESY collaboration)
- laser-based source: still R&D problems to get the high intensity
- upgrade to 1 TeV?
  ⇒ no problem for any of the sources!!!

Status of the possible e^+ choices

- **Conventional positron source at the SLC:**

  $\Rightarrow$ e^+ source with highest intensity operated so far

- **Prototype undulator-based source:** currently running project 'E166'@SLAC



first run: excellent data!

2nd (final) run: now!

- **Helical undulator designs in UK:**

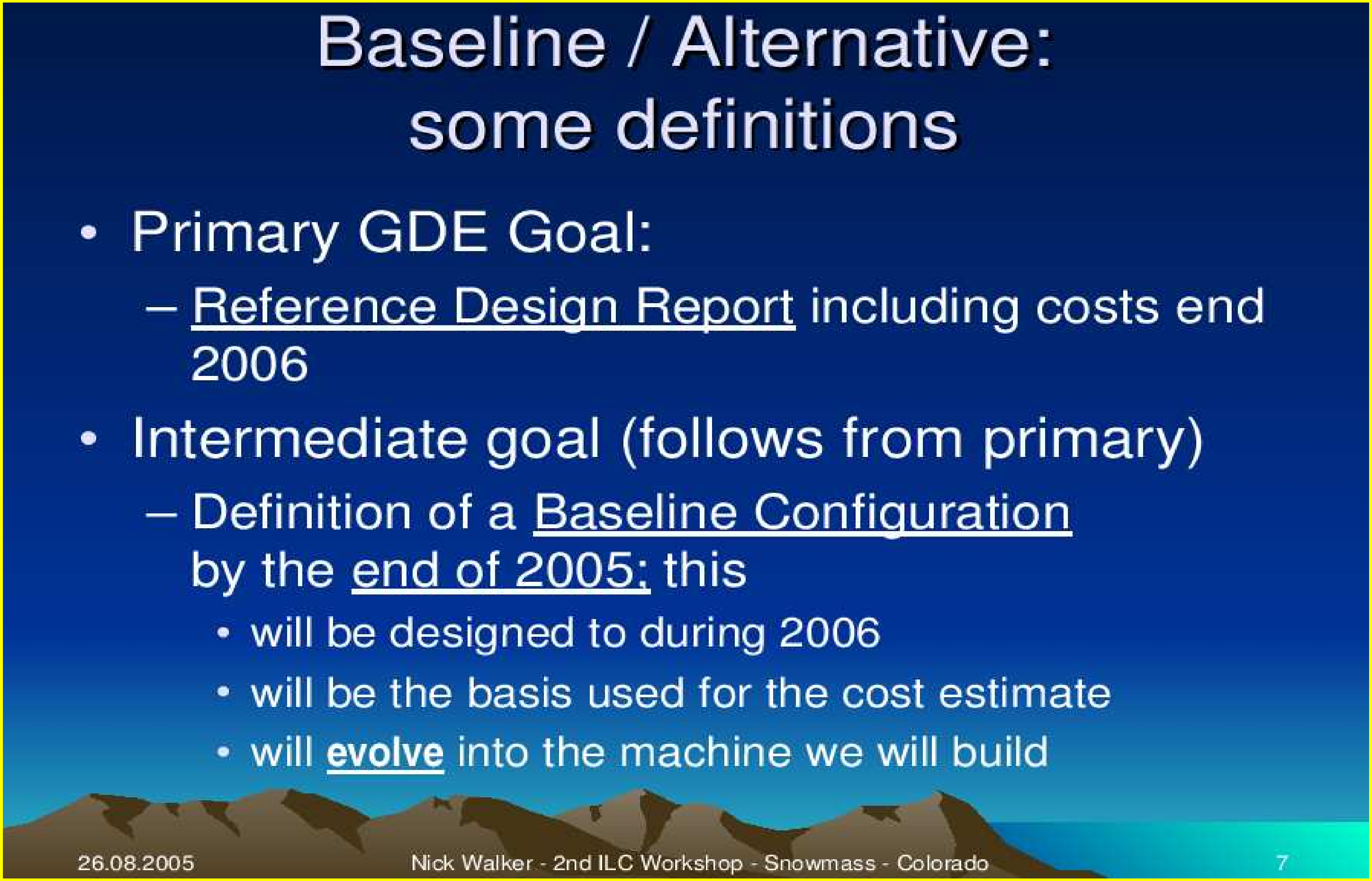
  $\Rightarrow$ ILC prototypes under construction

- **Prototype of laser-based source at KEK currently running:**

  $\Rightarrow$ γ- and e^+ polarization as predicted!

News from the way to the ILC with polarized e^- and e^+

– Summary talk of Nick Walker at Snowmass'05–



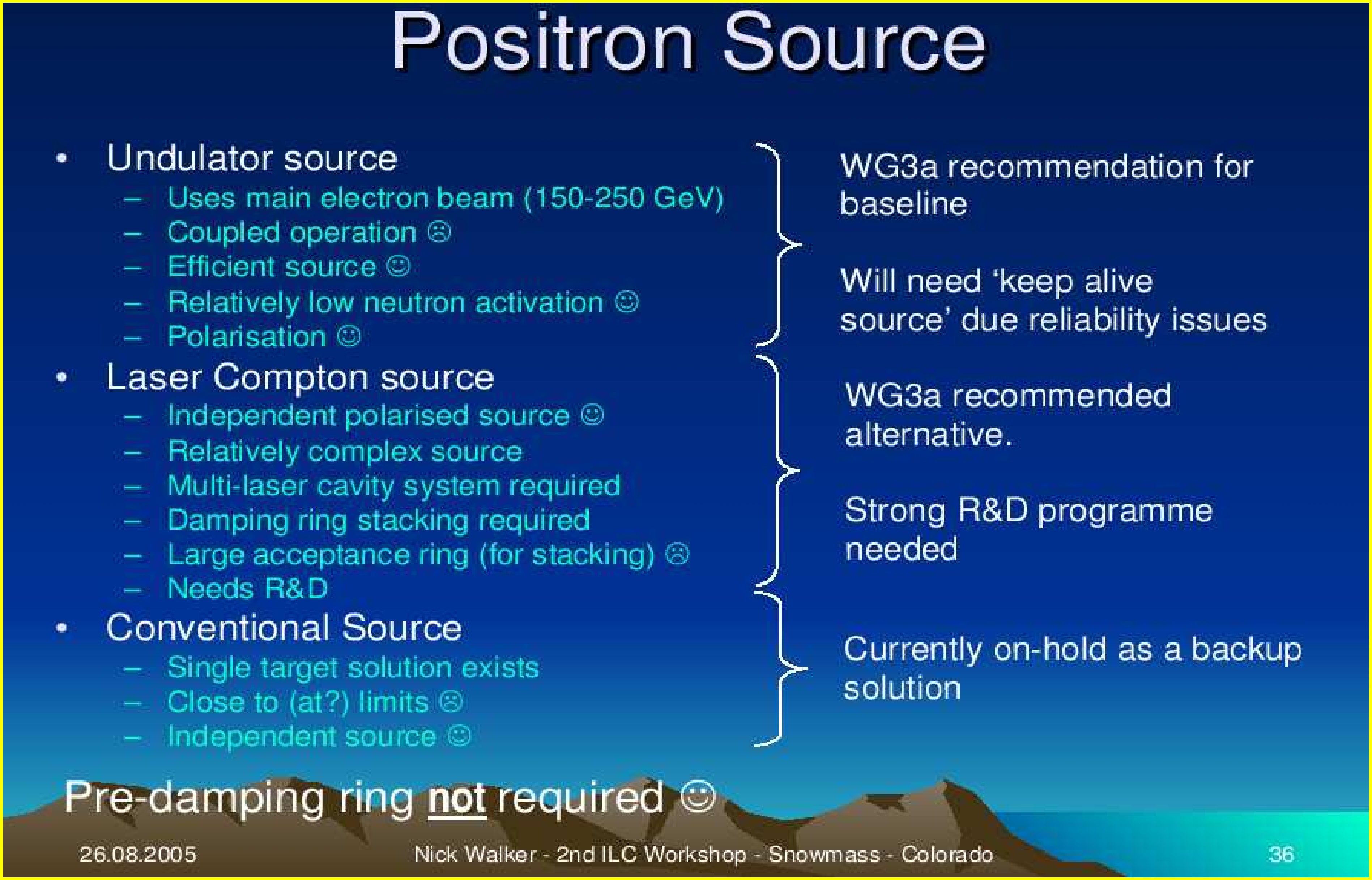
Positron Source

WG3a

Risks & Concerns

ITEM	Conventional	Undulator	Compton	Comment
L-band warm structure 1ms operation	1	1	1	It is likely to be safe according to the calculation.
Target thermal damage	1	0	0	It can be relieved by multi-targets.
Target radiation damage	0	1	0	It can be controlled by periodic maintenance.
Thermal load to the capture section	1	0	0	75kW/m acceptable?
Damage or failure by fast ion instability in the undulator.	0	1	0	Estimates look ok but more investigation needed
Field quality of helical undulator	0	1	0	Helical prototype. Can be solved with the planar undulator.
Positron Stacking in DR	0	0	2	Need investigation
e beam stability in Compton Ring	0	0	2	Need investigation
Vacuum pumping	0	1	0	Needs vacuum specification to check if problem
Stability of integration of optical cavities	0	0	2	It is going to be demonstrated experimentally with 2 cavities.
Mechanical failure on the rotation target	2	1	0	Need investigation/demonstration
Kicker difficulty	1	1	0	Undulator scheme need special care for the injection kicker.

What was the recommendation at Snowmass 2005?



Concluding remarks

- **Results of the report: 'the physics case for polarized e^- and e^+**
  - ⋆ **many**$\equiv (n+1)$ examples from **different** physics scenarios!

⇒ **Report should be seen as contemporary status report!**
still studies ongoing, new ideas+examples coming up

- P_{e^+} ⇒ **only gains, independent in which direction NP points**
  - ⋆ **key additional observables for unravelling the underlying physics: kind of interaction, chirality, particle properties, parameter det.,etc.**
  - ⋆ **significant improvement for model-independent approaches in direct as well as indirect searches for NP**
  - ⋆ **Analyzing NP might be challenging → best of all tools needed!**

- P_{e^+} **crucial preparation for 'being prepared for the Unexpected' !**

⇒ **full potential of the ILC could only be realized with P_{e^-} and P_{e^+}!**
expected: $P_{e^-} = \pm 90\%$, $P_{e^+} = \pm 60\%$ **and** $\Delta P_{\pm}/P_{\pm} = 0.25\%$

- **undulator-based (polarized) e^+ source now in the baseline design!**
  → **laser-based (polarized) e^+ source as alternative R&D design**