Physics news and open questions

ECFA@Valencia

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- **General remarks**
- **Physics case for polarized positrons**
  - can be compensated by higher electron polarization?
  - what happens if only 30%, but almost 'for free'?
  - status of the submitted POWER report
- **Some further news**
  - Questions of the parameter groups to the physics groups
  - new webpages for (polarized) ILC positron sources
- **Summary and open questions for the discussion**

General remarks

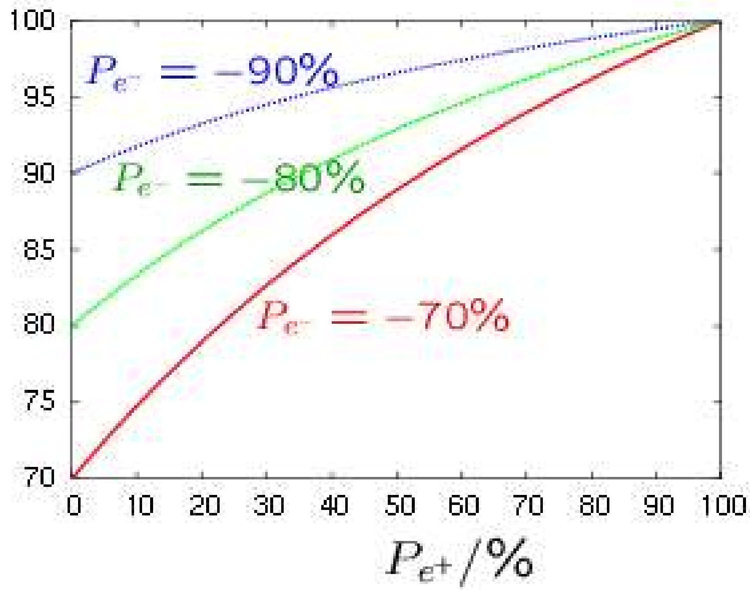
- Expected: e- polarization of about 90% .... won't such high P(e-) suffice?
- Polarimeter precision: $x = \Delta P_{e-} / P_{e-} = 0.5\%$ (→ 0.25%)
- Technical issues for the baseline design:
  - e+ source: helical undulator with 100 m length
  - provides automatically low but stable polarization (about 30%)
  - no spin rotators from LTR in baseline included
  - low dc polarization, has to be measured
- Suitable beam polarization of e- and e+
  - crucial to get a direct access to particle properties (couplings, quan. num., etc.)
  - 'compensates' missing lumi (higher rates, control of sys. and backgrd., etc.)
  - Successful ILC physics requires high lumi and polarized beams
- How much do we gain from 30% polarization?

Statistics -- gain in P_{eff} and A_{LR}

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

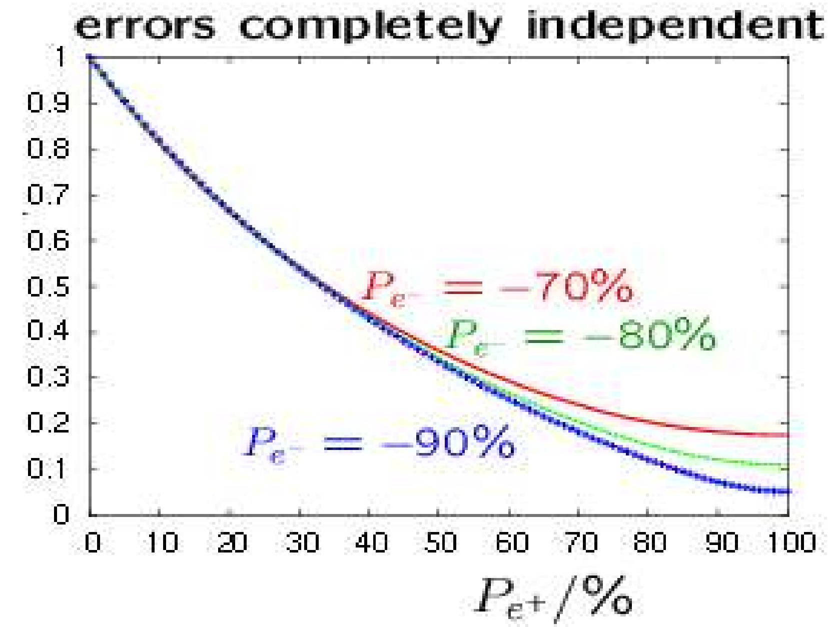
$$\sigma(P_{e-} P_{e+}) = (1- P_{e-} P_{e+})\, \sigma_0\, [1- P_{eff} A_{LR}] \quad \text{with} \quad P_{eff} = (P_{e-} - P_{e+}) / (1 - P_{e-} P_{e+})$$

P_{eff} /%



$\frac{1}{x}\frac{\Delta P_{eff}}{|P_{eff}|}$

~$\Delta A_{LR}/A_{LR}$



- (80%,60): P_{eff} = 95% (90%,60%): P_{eff} =97% (90%, 30%): P_{eff} =94 %
- $\Delta A_{LR}/A_{LR}$ = 0.3 $\Delta A_{LR}/A_{LR}$ = 0.27 $\Delta A_{LR}/A_{LR}$ =0.5

gain: factor~3 factor>3 factor~2

→ NO gain with only polarized e^- ! (error prop.: $\frac{\Delta P_{eff}}{P_{eff}} = \frac{1-|P_{e+}||P_{e-}|}{1+|P_{e+}||P_{e-}|}\, x$)

Example -- Determination of top couplings

- Process: $e^+ e^- \to t \bar{t}$ (test of couplings $t \to \gamma$, Z unique for the ILC)
  - Studies at threshold: since Δ ALR / ALR ~ Δ Peff / Peff

⇒ (80%,0)→(80%,60%): factor 3!

and with only

→ (80%,0) → (80%,30%): factor 2

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

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

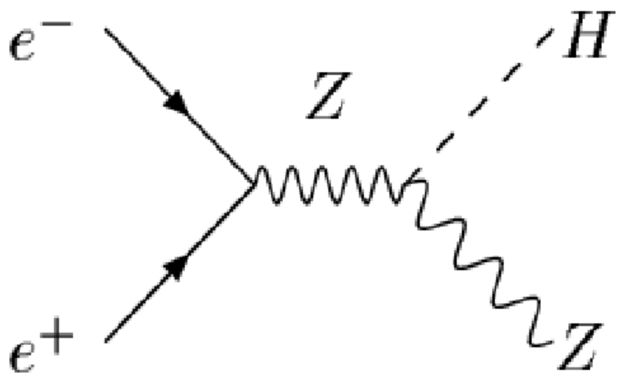
estimated:

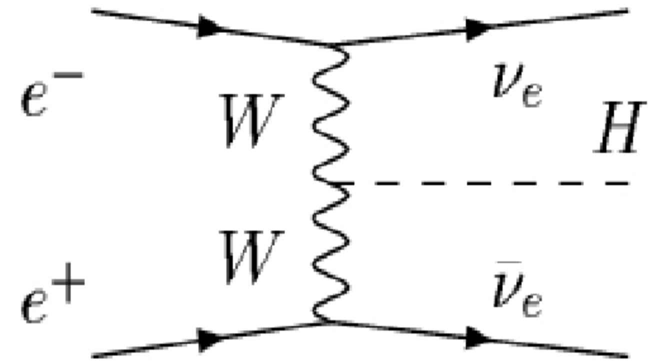
⇒ (80%,0)→(80%,60%): factor 3!

  - since again left-right asymmetry decisive: with (80%,30%) a factor 2 expected

Beam polarization for Higgs searches

- Light Higgs, e.g. mH=130 GeV: HZ and H νν similar rates at 500 GeV





- P(e-), P(e+) needed for:
  - separation
  - background suppression
- σ(H Z) / σ (H νν):

(+80%,0) → (+80%,-60%)

→ **improves by factor 4!**

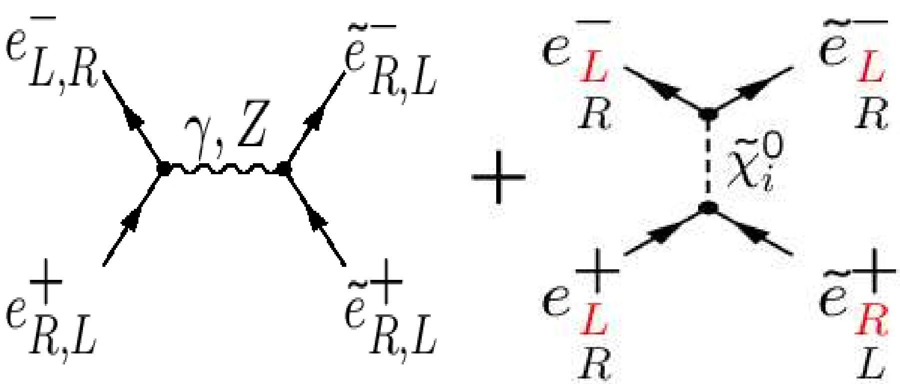
Configuration (P_{e^-}, P_{e^+})	Scaling factors $e^+e^- \to H\nu\bar{\nu}$	Scaling factors $e^+e^- \to HZ$
(+80%, 0)	0.20	0.87
(−80%, 0)	1.80	1.13
(+80%, −60%)	0.08	1.26
(−80%, +60%)	2.88	1.70
(+80%, -30%)	**0.14**	**1.06**
(-80%, +30%)	**2.34**	**1.42**

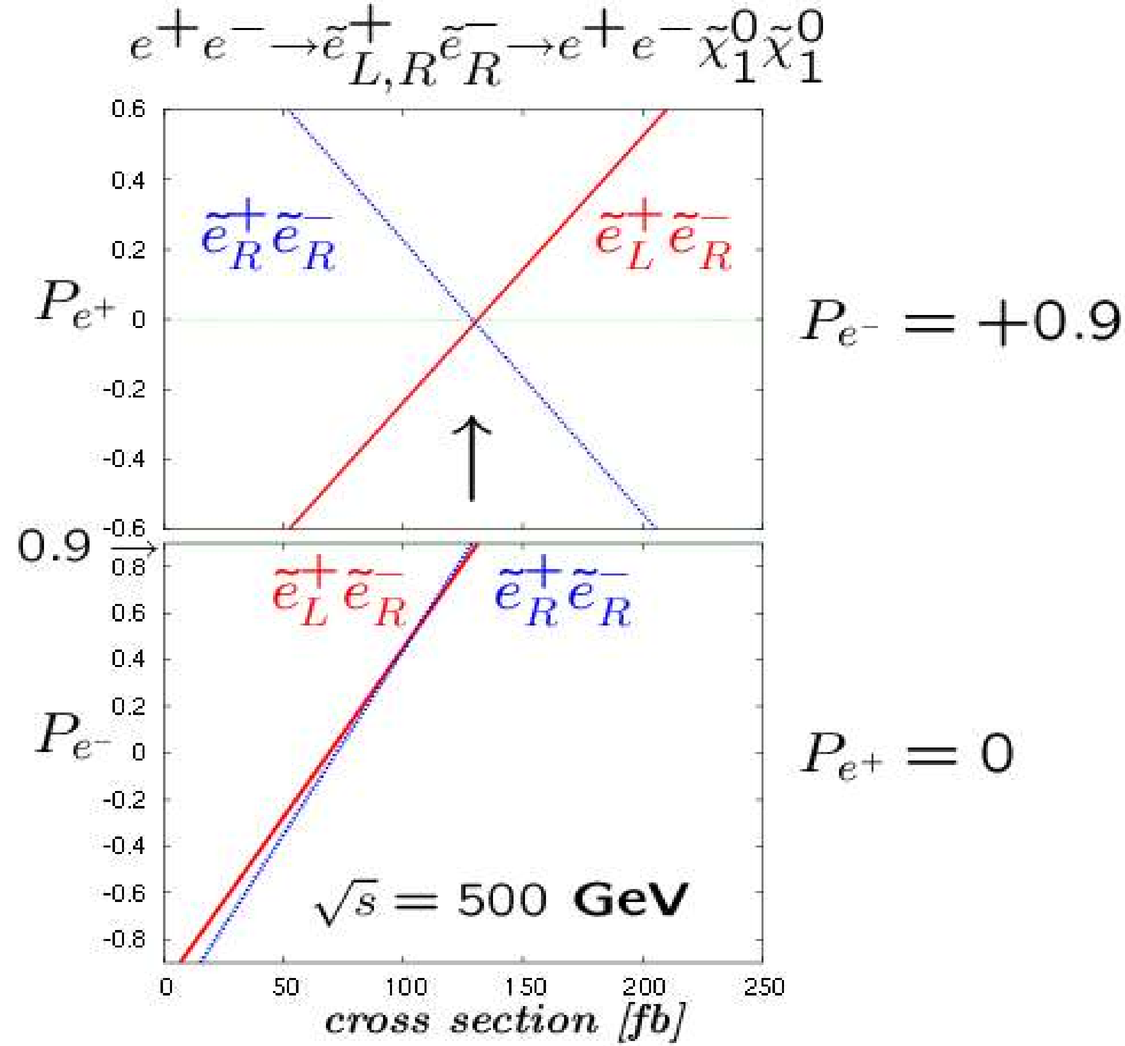
- (+80%,0) → (+80%, -30%): ratio HZ / H$\nu\bar{\nu}$ → gain ~ factor 2

Test of SUSY quantum numbers

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

s-channel **t-channel**





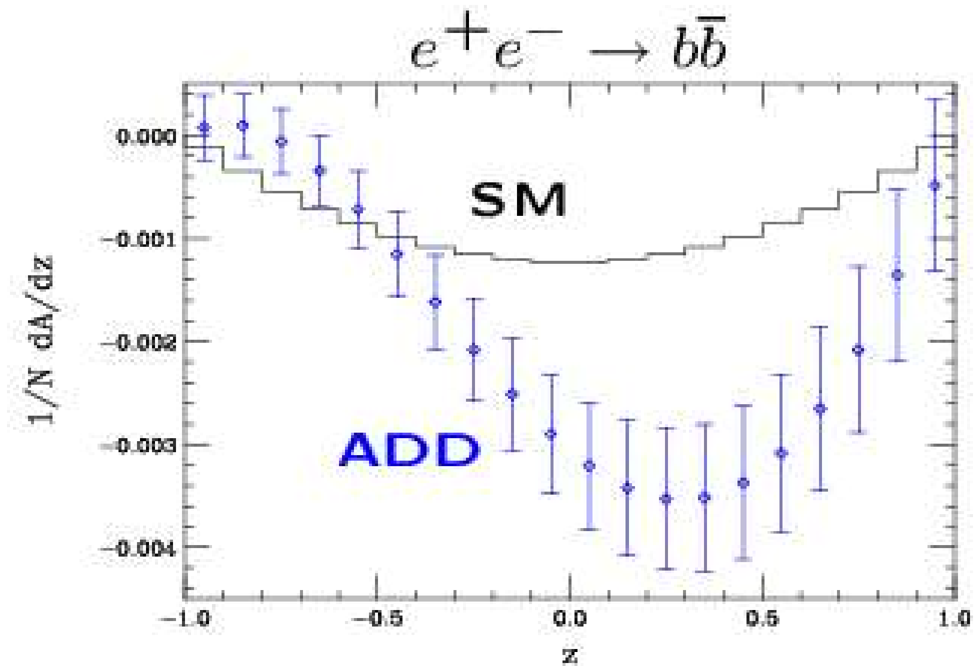
1. separation of scattering versus annihilation channel
2. test of 'chirality': only $\tilde{e}^+_L\tilde{e}^-_R$ survives at P(e-) > 0 and P(e+) > 0 !

→ (90%,60%)~200 fb / 50 fb ~ 4 , (90%, 30%)~ 175 fb / 75 fb ~ 2.3

- ***Even high P(e-) not sufficient, P(e+) is substantial!***

Indirect searches: extra dimensions

- **Transversely** polarized beams (only effects detectable of $P(e^-)$ and $P(e^+)$!)
  - enables to exploit azimuthal asymmetries !
- **Distinction** between SM and different models of extra dimension:
  - asymmetry signals contribution from spin-2 graviton



- Since $P_T(e^-)$ x $P_T(e^+)$-dependence:
  - effects decrease by about a **factor 2** when using (80%,30%) instead of (80%60%)

→ Transversely polarized beams very effective, need polarized e^- and e^+ !

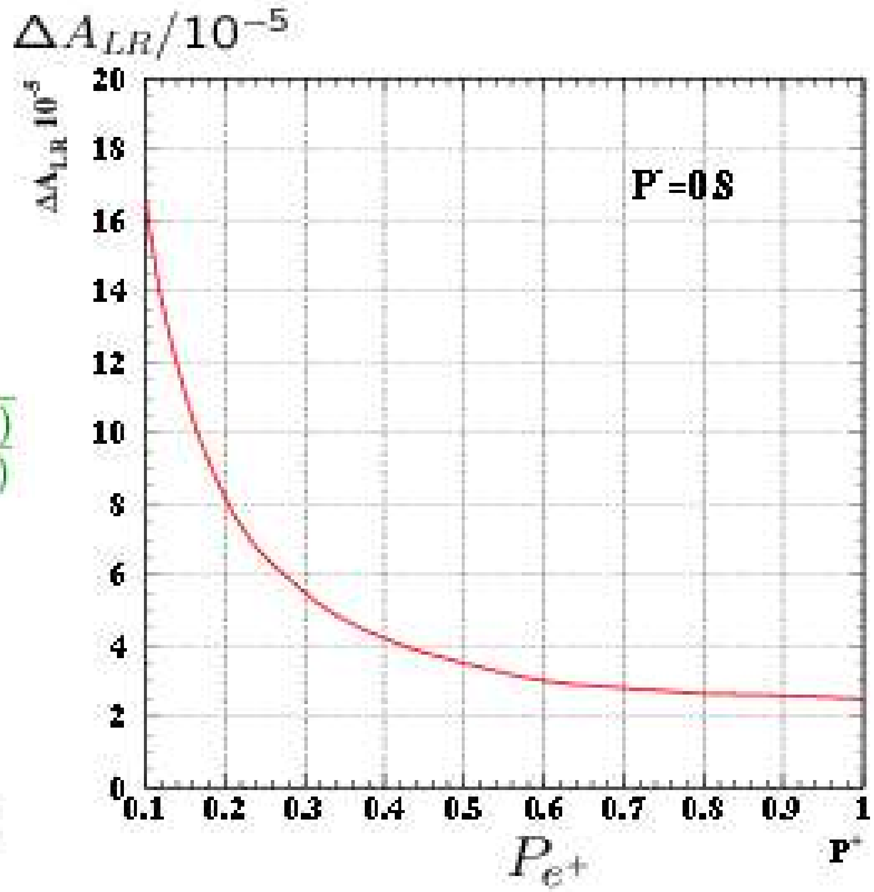
High precision tests at GigaZ

- Measurement of $\sin^2\theta_{eff}$ 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 $\Delta P/P \sim 0.5\%$ and $P(e^-)=80\%$ only:

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

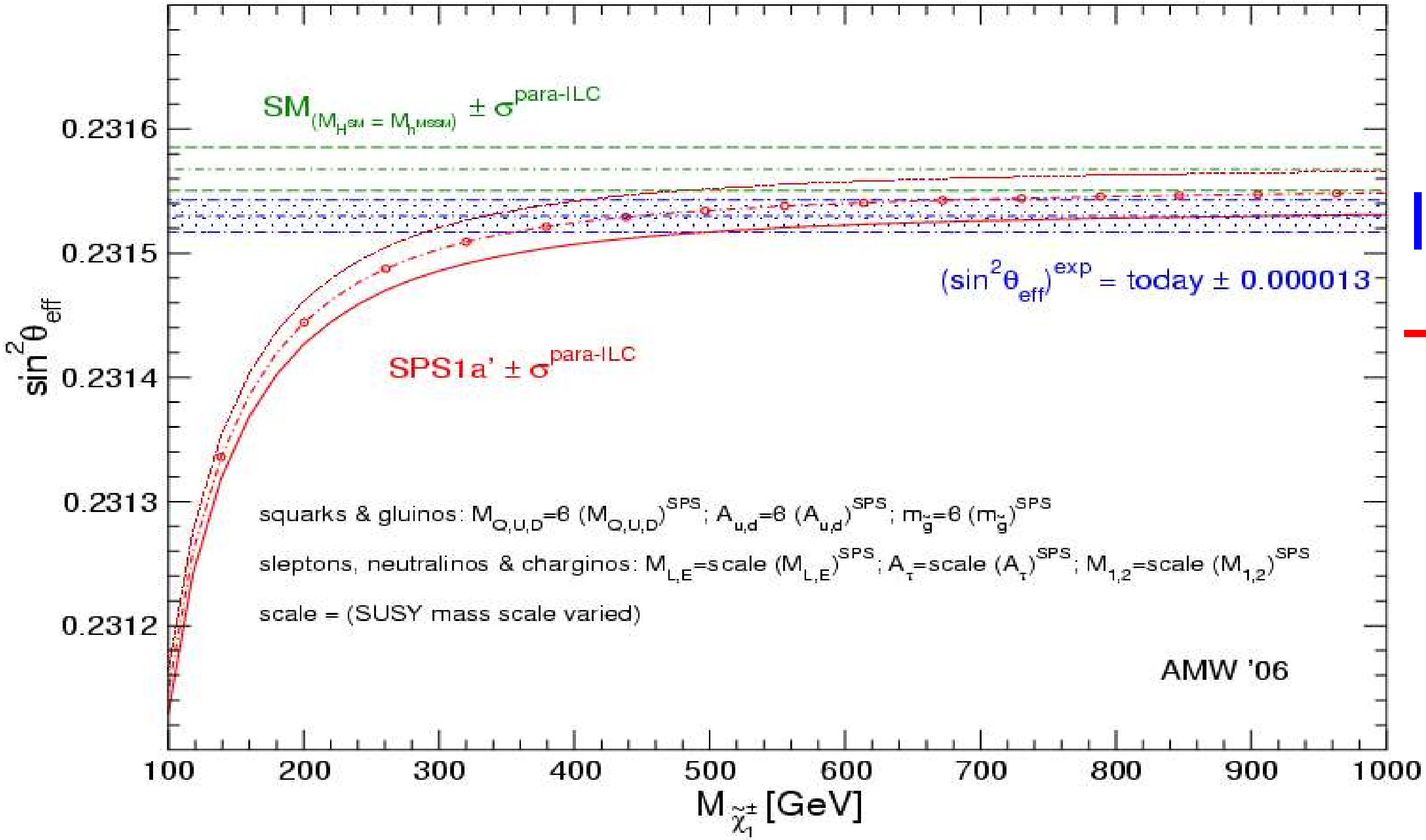
(• with $\Delta P/P = 0.25\%$ and $P_{e^-} = 90\%$:

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

- with Blondel scheme: [$P(e^-)$,$P(e^+)$]= [80%,60%] : $\Rightarrow \Delta\sin^2\theta^\ell_{\rm eff} = 1.3\times 10^{-5}$
- [80%,30%] : about a factor 2 worse

Sensitivity to high scales at GigaZ

- **Maybe quick upgrade path straight from 500 GeV to GigaZ needed?**
  - study worst (?) case scenario: no SUSY hints at LHC, none at ILC500 ....
  - help from GigaZ possible? concentrate on energy upgrade? or what else?



Arne Weber, Georg Weiglein

SM-value in '~decoupling' limit

current exp. value

SUSY prediction depending on mass scale of EW SUSY particles

- **Sensitivity to SUSY effects even if no SUSY signal seen at LHC and ILC500!**
  - **GigaZ may be crucial to outline needed higher energy scale for ILC, 2nd stage ....**

Summary table of POWER report: Tab 4.1

- **Comparison with (80%,0): estimated gain factor when**

Case	Effects for $P(e^-) \longrightarrow P(e^-)$ and $P(e^+)$	Gain& Requirement most (80%, 60%)	(80%, 30%)
Standard Model:			
top threshold	Electroweak coupling measurement	factor 3	gain factor 2
$t\bar{q}$	Limits for FCN top couplings improved	factor 1.8	gain factor 1.4
CPV in $t\bar{t}$	Azimuthal CP-odd asymmetries give	$P^T_{e^-} P^T_{e^+}$ required	$P^T_{e-}\ P^T_{e+}$ required
	access to S- and T-currents up to 10 TeV		factor 1.3 worse
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 $\tilde{h}_+ = \mathrm{Im}(g_1^R + \kappa^R)/\sqrt{2}$	$P^T_{e^-} P^T_{e^+}$ required	$P^T_{e-}\ P^T_{e+}$ required
CPV in γZ	Anomalous TGC $\gamma\gamma Z, \gamma Z Z$	$P^T_{e^-} P^T_{e^+}$ required	
HZ	Separation: $HZ \leftrightarrow H\bar{\nu}\nu$	factor 4	gain factor 2
	Suppression of $B = W^+\ell^-\nu$	factor 1.7	
$t\bar{t}H$	Top Yukawa coupling measurement at $\sqrt{s} = 500$ GeV	factor 2.5	gain factor 1.6

Summary table of POWER report: Tab 4.1

- **Estimated gain factor when only** P(e+)=30%

Case	Effects for $P(e^-) \longrightarrow P(e^-)$ and $P(e^+)$	Gain& Requirement
Supersymmetry:		
$\tilde{e}^+\tilde{e}^-$	Test of quantum numbers L, R	P_{e^+} required
	and measurement of $e^{\pm}$ Yukawa couplings	
$\tilde{\mu}\tilde{\mu}$	Enhancement of S/B, $B = WW$	factor 5-7
	$\Rightarrow m_{\tilde{\mu}_{L,R}}$ in the continuum	
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 $\tilde{\chi}^0_i\tilde{\chi}^0_j$	Direct CP-odd observables	$P^T_{e^-}P^T_{e^+}$ 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	

P_{e+} required
factor <2 worse

Summary table of POWER report: Tab 4.1

- **Estimated gain factor when only** P(e+)=30%

Case	Effects for $P(e^-) \longrightarrow P(e^-)$ and $P(e^+)$	Gain& Requirement
Extra Dimensions:		
$G\gamma$	Enhancement of S/B, $B = \gamma\nu\bar{\nu}$,	factor 3
$e^+e^- \to f\bar{f}$	Distinction between ADD and RS models	$P^{\mathrm{T}}_{e^-} P^{\mathrm{T}}_{e^+}$ required
New gauge boson Z′ :		
$e^+e^- \to f\bar{f}$	Measurement of Z' couplings	factor 1.5
Contact interactions:		
$e^+e- \to f\bar{f}$	Model independent bounds	P_{e^+} required
Precision measurements of the Standard Model at GigaZ:		
Z-pole	Improvement of $\Delta \sin^2\theta_W$	$\sim$ factor 10
	Improvement of Higgs bounds	$\sim$ factor 10
	Constraints on CMSSM parameter space	factor 5
CPV in $Z \to b\bar{b}$	Enhancement of sensitivity	factor 3

Physics case for pol e+ established:

`The role of polarized positrons and electrons in revealing fundamental interactions at the Linear Collider'

- GMP et al., hep-ph/0507011, submitted to Physics Reports
  - also available via *http://www.ippp.dur.ac.uk/~gudrid/power*
- Excellent and detailed referee report obtained: thanks to the referee!
  - more introductory remarks for physics studies; clarification of some studies
  - references missing
  - some plots have to be improved
  - already under work, but not yet finished: authors will then be contacted
- Further agreement with editor: since some updates on physics and machine are available during the meantime
  - recent results on top physics, experiments E166 and ATF etc. will be included for revised/published version

Question of the parameter group – *our answers ?*

- At which lumi become systematics dominant?
- Impact of reducing beamstrahlung by factor 2? (lumi vs background?)
- Any benefit from (80%,60%) versus (90%,0)?
- Influence from any other accelerator parameters?

- Top mass measurement: precision at a) threshold, b) 500 GeV? *P(e+) needed*
- Higgs (120 GeV): Precision for mass measurement at a) threshold, b) maximum of ZH cross section, c) 500 GeV ? *factor 4 vs 2 in sep.*

  Precision for top Higgs coupling at a) 500 GeV, b) 1 TeV ? *gain factor 2.4 vs. 1.1*

  Precision of BR(H -> tau-pairs) ?
- Precision of Z' couplings at a) 500 GeV, b) 1 TeV ? *systematics under control*
- Precision of SUSY particle properties (e.g. masses) a) in the light stau coannihilation region, b) light neutralino χ^0_1, χ^0_2 production ? *more observables*

properties more general: P(e+) needed

Further news: 'e+ sources' webpage series

- Idea: provide data base for 'sources' and 'non-sources' experts
  - cover all ILC sources
  - list all agreed facts and numbers
  - publications (e.g. POWER report, executive summary + 4 pages summary !)
  - provide useful links
  - all new results should be listed there as soon as possible ....please let me know!
- Pages should cover topics from source to IP
  - all possible technologies
  - target issues
  - related topics, e.g. damping rings, reliability etc.
  - list of open questions and topics
  - prototypes and current R&D status: many activities at Cornell, KEK, Orsay, UK !
- Please look at: *http://www.ippp.dur.ac.uk/~gudrid/source*

(Polarized) Positron Sources at the ILC

[Introduction](#)

[Physics case for polarized positrons](#)

[BCD source](#)

[ILC Positron Source Group](#)

[Undulator prototypes](#)

- [E166 at SLAC](#)
- [ILC undulator/UK](#)
- [Undulator at Cornell](#)

[Compton facilities](#)

- [Compton at KEK](#)
- [Lasers at Orsay (still under work)](#)

[Target and capture issues](#)

[Availability studies](#)

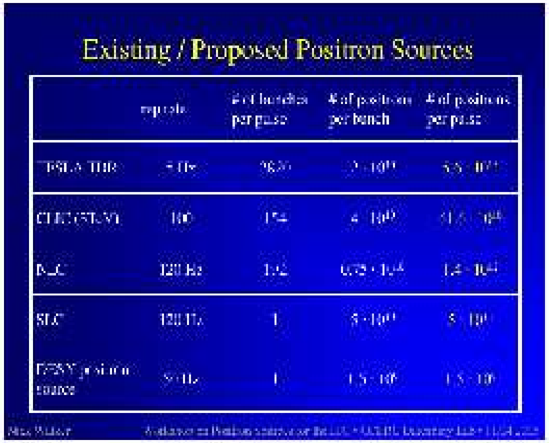
[Undulator features (still

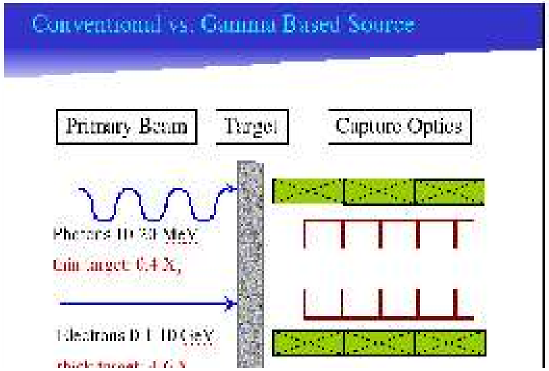
Introduction

Demands on a LC positron source and ILC designs:

An overview about the ILC parameters and the demands on the positron source is given in this talk: The ILC requires a large amount of positrons, about three orders of magnitude higher per pulse than at the positron source of SLC (see picture).

Positrons have to be produced from photons of some MeV energy via pair production in a target: either the photons are produced via bremsstrahlung from electrons in electromagnetic cascade processes in a rather thick target or via radiation processes of an electron beam and the direct conversion in a rather thin target.





Three kinds of positron sources for the ILC are under discussion:
a) conventional source (unpolarized positrons only)
b) gamma-based source via undulator radiation
c) gamma-based source via laser backscattering

More technical details, BCD design, current R&D status (in particular of prototypes) and still critical issues like target, availability, stacking are linked.

ILC Positron source group

- ILC Positron Source Group:

`Detailed positron system designs and documentation are required for ILC TDR at the end of 2009. It is important to organize the international activities so that essential work is accomplished and unnecessary duplication is reduced. The group meets three times a year, rotating Europe-Japan-America. '

- First meeting at Oxford, September 2006
  - John Sheppard elected at spokesman of the collaboration
- Planned: second meeting in China, Jan. 31st – Feb. 2nd (chaired by M. Kuriki)
- Registration for the 'ILC Positron Source Group' email list:

Please send to
Majordomo@durham.ac.uk
an email with
subscribe ph-ilc-positronsource
in the body (not in the subject). You will automatically be registered at the list and receive a confirmation email.

Summary and ......

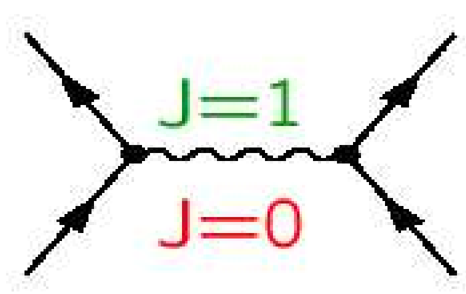
- Physics case for pol. e+ has been established !!! (-> POWER report + ...)
  - referee report now available, but revised version still under work
- Baseline design could already provide 30% polarization
  - already very constructive for physics
- Quick upgrade path to GigaZ might be very crucial to outline needed energy upgrade
  - high lumi and pol. beams needed to optimize physics at 500 GeV !!!
- However, to use such low polarization 'for free' still needed:
  - spin rotator for LTR, low enery polarimeter and kickers
- New 'ILC e+ sources' webpages: input needed, please provide news if available
- ILC Positron Source Group: registration for email list open
  - 2nd meeting: begin of February in China

Discussion *(thanks to Mike Woods, Eric Torrence, Peter Schmid, Tom Rizzo, ...)*

- Physics: shall we also write / answer to the questions of the parameter group?
  - even higher e- pol. can not compensate effects from pol. e+ .....
- Physics: shall we write-up the physics case for pol. e+ with P(e+)=30%?
- Machine: what is needed to exploit 30% polarization?
  - how much low dc polarization without spin rotators? (Mike: ~0.05% .... but has to be measured)
  - spin rotator for LTR
  - already flipping needed ? which scheme useful? kickers?
  - costs for add. polarimeter? but anyway needed to measure low dc polarization?
- Machine: change request useful to exploit 30%?
- What else? Did we overlook something?

General remarks about the coupling structure

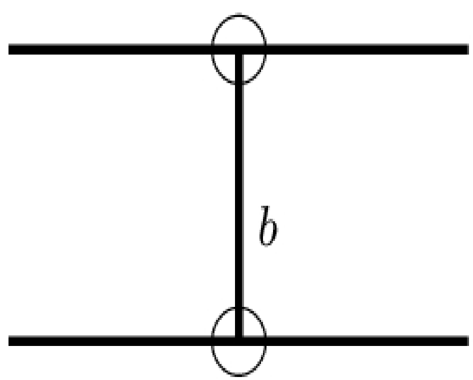
- Which configurations are possible in annihilation channels?



← contributions from LR, RL: SM and(?) NP (γ, Z)
(general (V-A) structure, e.g. top physics; P_{eff} decisive)

← contributions only from LL, RR: NP !

- Which configurations are possible in scattering channels?



← depends on P(e+)!

→ helicity of e- not coupled

with helicity of e+ !

← depends on P(e-) !

→ direct access to new physics particle properties: new effects