Physics Benefits of Positron and Tranverse polarisation

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LCWS’02 – Jeju, Korea
28/08/02

- General remarks
- Positron polarisation: the physics case
- Transverse polarisation
- Conclusion

General Remarks

Linear Collider: precision instrument
⇨ spin dependent amplitudes carry additional information

SLC: in spite of lower luminosity than LEP
most precise single measurement of $\sin^2\theta_W$ from A_{LR}

LC case for electron polarisation rather well studied
Technically relatively firm P(e-) ~ 80% from polarized source

Positron polarisation technically more complicated (helical undulator)
P(e+) ~ 40–60%

Polarimetry: $\Delta P < 0.5\%$ from Compton polarimeter

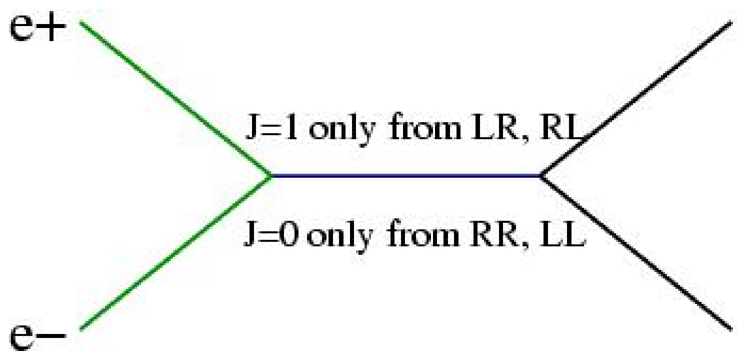
Since it doesn't come 'for free', better work out the physics case!

Sources for this talk:
G.Moortgat-Pick, H.Steiner, LC-TH-2000-055, EPJdirect C6(2001)1.
G.Moortgat-Pick, talk at ICHEP02, Amsterdam
POWER working group http://www.desy.de/~gudrid
Thank you, Gudi!

General Remarks

Different qualitative polarisation effects for different classes of diagrams

1. s-channel:



SM: J=1 (gamma, Z)

BSM: might be J=0

Electron polarisation selects ‘correct’ helicity for positrons

⇨ e- Polarisation sufficient to select the ‘signal’ state

But: Positron polarisation helps in increasing:

a) Effective Luminosity

b) Effective Polarisation

Example ⇨

For s-channel Spin 1 exchange:

General Remarks

Effective Polarsation: $(\# LR - \# RL)/(\# LR + \# RL) = (P^{e-} - P^{e+})/(1 - P^{e-} P^{e+})$

Effective Luminosity: $(\# LR + \# RL)/(\# all) = 0.5 \times (1 - P^{e-} P^{e+})$

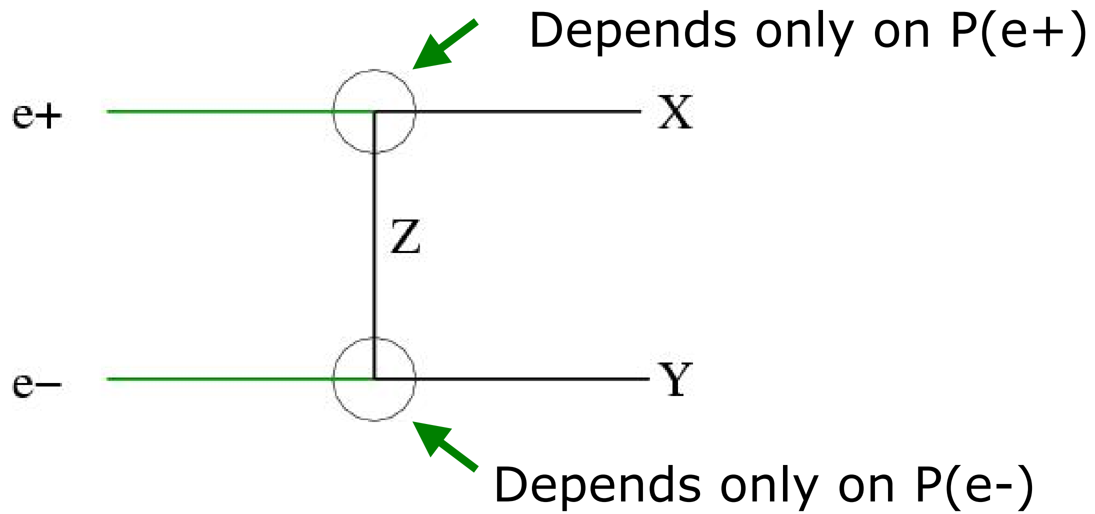
Fraction of collisions:

P	RL	LR	RR	LL	Effective Polarisation	Effective Lumi
P(e-) = 0 P(e+) = 0	0.25	0.25	0.25	0.25	0.	x 0.5
P(e-) = -1 P(e+) = 0	0.	0.50	0.	0.50	1.	x 0.5
P(e-) = -0.8 P(e+) = 0.	0.05	0.45	0.05	0.45	0.8	x 0.5
P(e-) = -0.8 P(e+) =+0.6	0.1x0.2= 0.02	0.9x0.8= 0.72	0.1x0.8= 0.08	0.9x0.2= 0.18	0.95	x 0.74

wanted! (RL, LR) unwanted! (RR, LL)

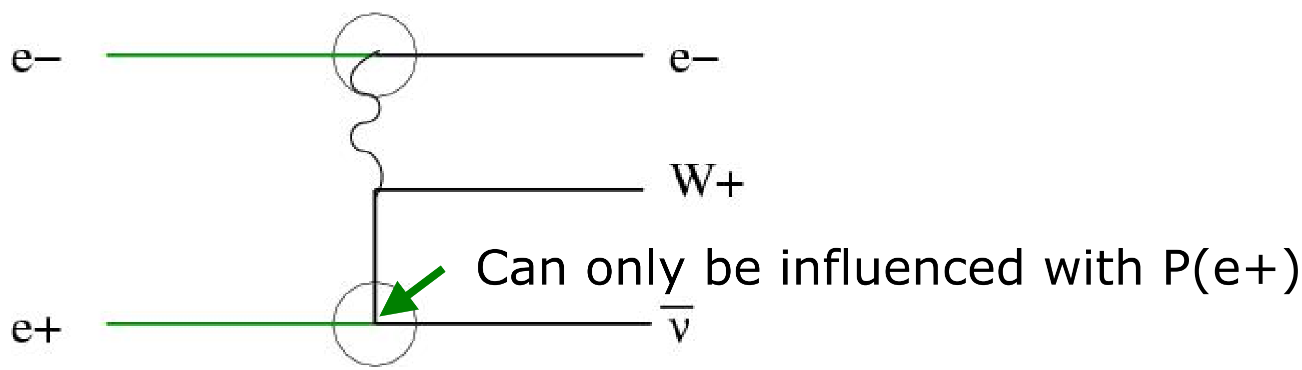
General Remarks

2. t-channel:



e+ and e- polarisation are ‘functionally’ different!

Famous SM example single W production:



Positron Polarisation Physics Case: Giga-Z A(LR)

Goal: $\Delta\sin^2\theta_W = 0.000013$ needs $\Delta P_{eff} < 0.1\%$

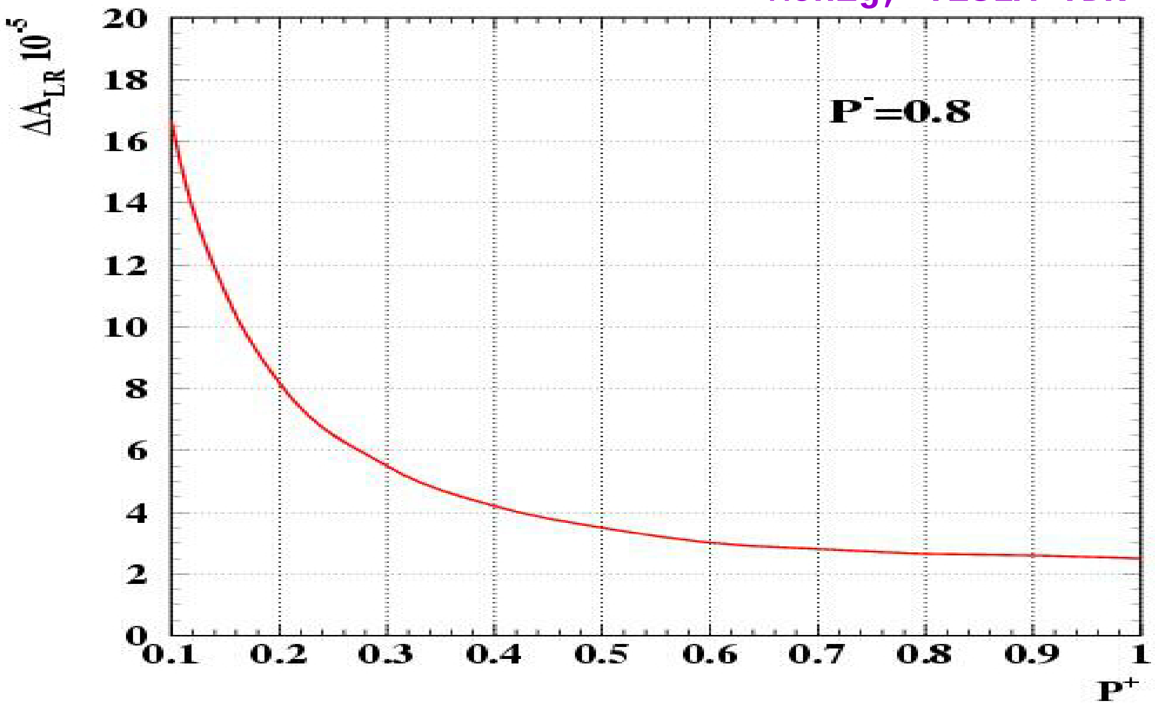
Difficult with Compton polarimetry ⇨ obtain Polarisation from data

Blondel scheme:

$$\sigma = \sigma_{unpol}[1 - P_{e^-}P_{e^+} + A_{LR}(P_{e^+} - P_{e^-})],$$

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

Mönig, TESLA TDR



Positron Pol. Physics Case: WW Production and TGC's

Advantages of Positron polarisation for WW-physics:
- increase of effective Polarisation ⇨ better t-channel suppression
- polarimetry through A(LR) in forward region
- alternatively: Blondel scheme

error [10^{-4}]:	Δg_Z^1	$\Delta\kappa_\gamma$	λ_γ	$\Delta\kappa_Z$	λ_Z
unpolarized beams					
$\sqrt{s} = 500$ GeV	38.1	4.8	12.1	8.7	11.5
$\sqrt{s} = 800$ GeV	39.0	2.6	5.2	4.9	5.1
only electron beam polarized, $\lvert P_{e^-}\rvert = 80\%$					
$\sqrt{s} = 500$ GeV	24.8	4.1	8.2	5.0	8.9
$\sqrt{s} = 800$ GeV	21.9	2.2	5.0	2.9	4.7
both beams polarized, $\lvert P_{e^-}\rvert = 80\%$, $\lvert P_{e^+}\rvert = 60\%$					
$\sqrt{s} = 500$ GeV	15.5	3.3	5.9	3.2	6.7
$\sqrt{s} = 800$ GeV	12.6	1.9	3.3	1.9	3.0

Menges

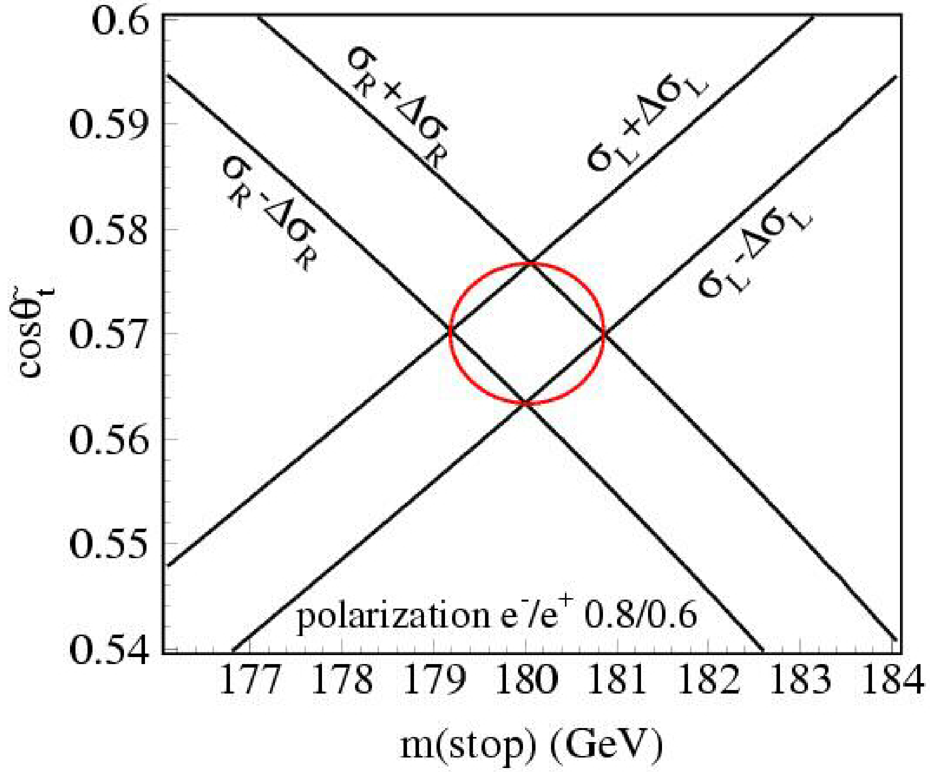
(TESLA TDR)

Positron Polarisation Physics Case: SUSY

The big challenge: 105 new parameters to measure ⇨
The more observables the better ⇨
Positron polarisation essential!

1. s-channel diagrams e.g. (smuon, stau, stop):

take advantage from higher effective Lumi and Polarisation
Example: stop

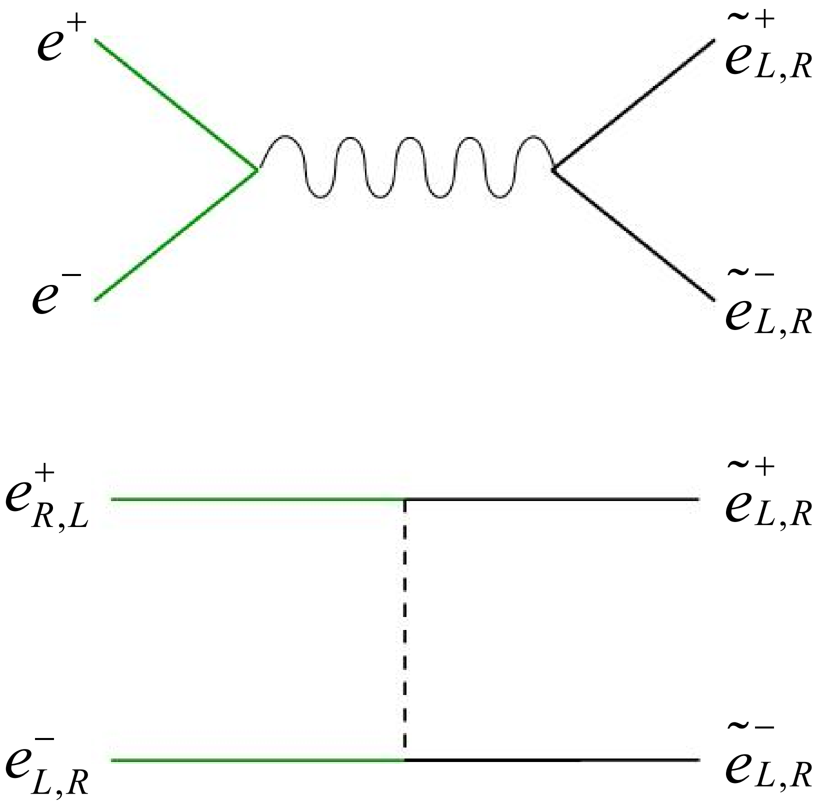


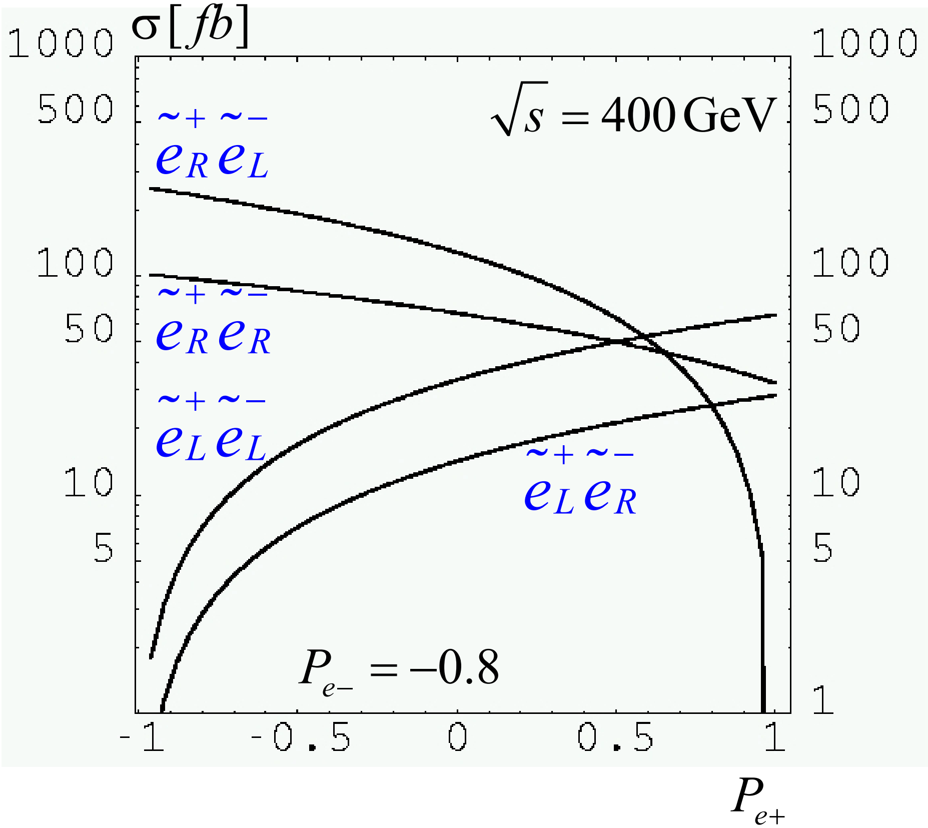
Keränen et al
Kraml et al

Positron Polarisation Physics Case: SUSY

2. selectrons: disentangle R and L

Blöchinger,Fraas,Moortgat-Pick,Porod hep-ph/0201282

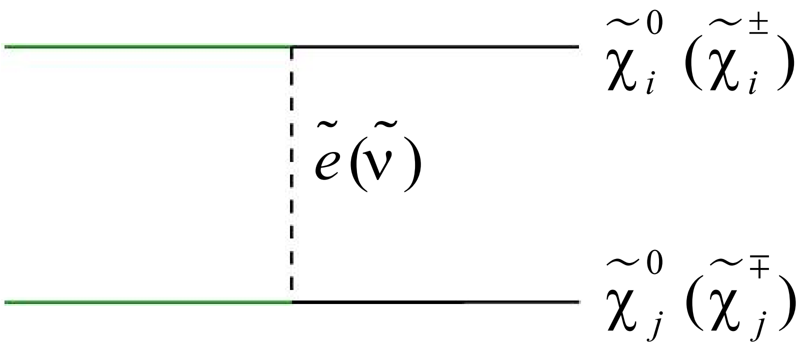




t-channel:
unique relation between incoming chirality and chiral QN of SUSY-partner

Positron Polarisation Physics Case: SUSY

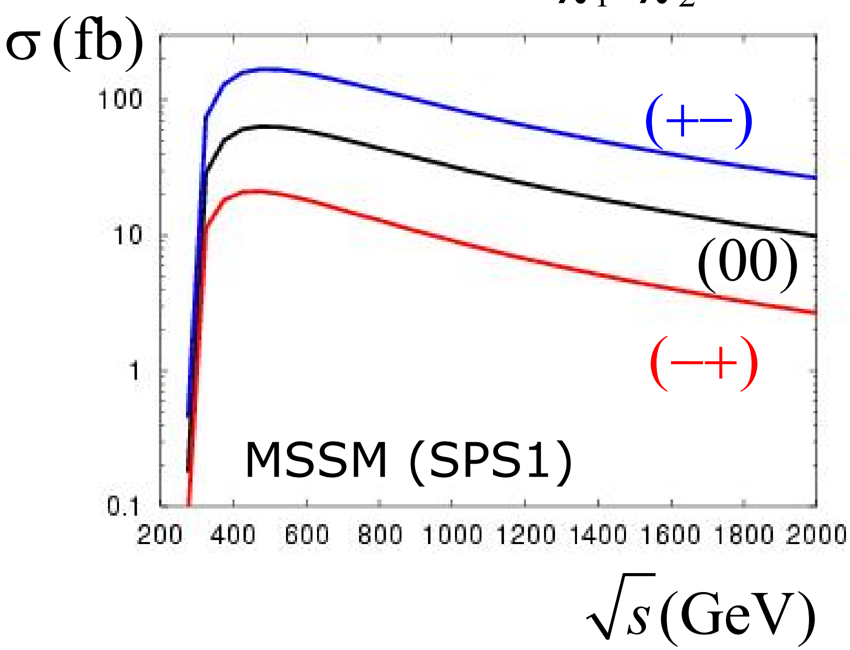
3. Charginos/Neutralinos:

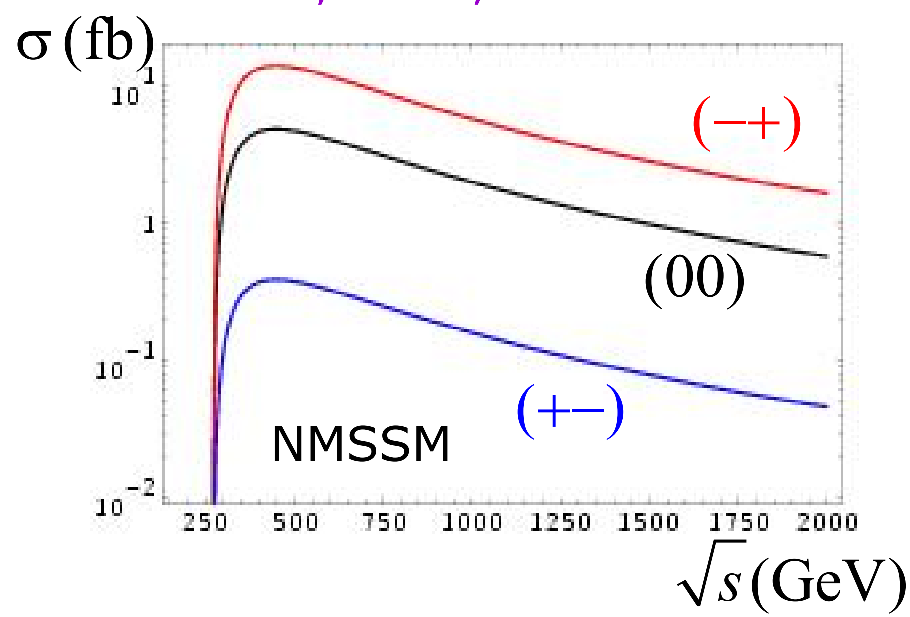


If t-channel contribution relevant,
Additional important handle on
Chiral structure of gaugino sector

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

Moortgat-Pick,Hesselbach,Franke,Fraas 99
Hesselbach,Franke,Fraas 01

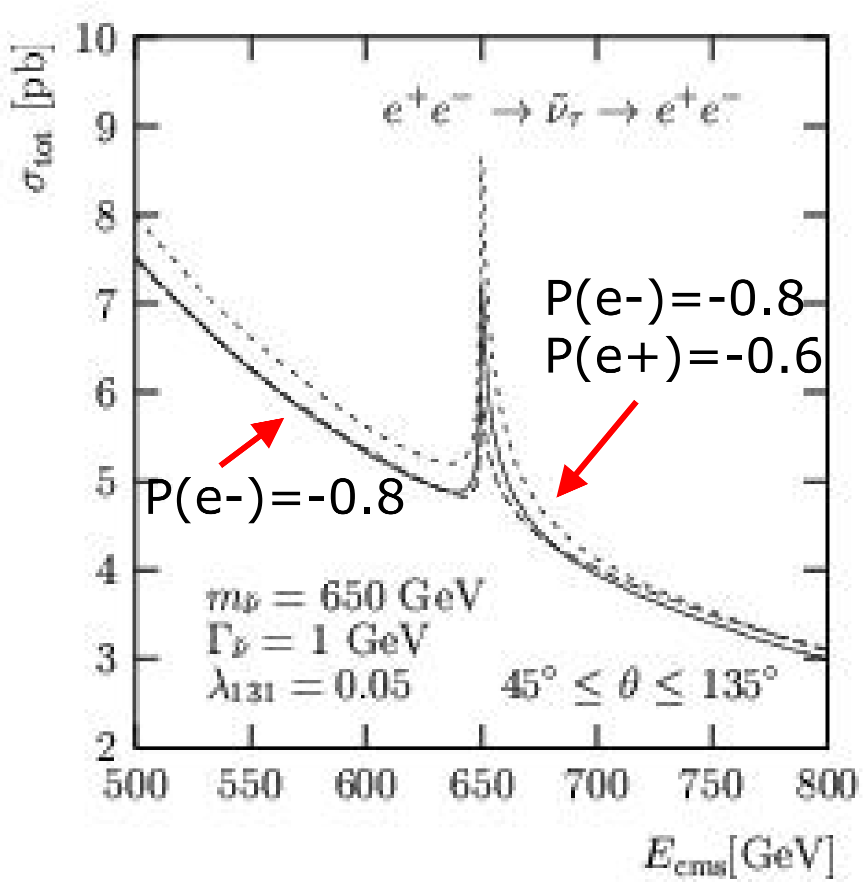




Positron Polarisation Physics Case: SUSY

4. R-parity violation: sneutrino in s-channel:

Need Positron polarisation to switch off SM s-channel background



Heyssler, Rückl, Spiesberger hep-ph/9908319+TESLA TDR

Positron Polarisation Physics Case: Extra Dimensions

Real Gravition emission

$$e^{+}e^{-} \rightarrow G\gamma$$

Needs e- and e+ polarisation to supress SM backgounds:

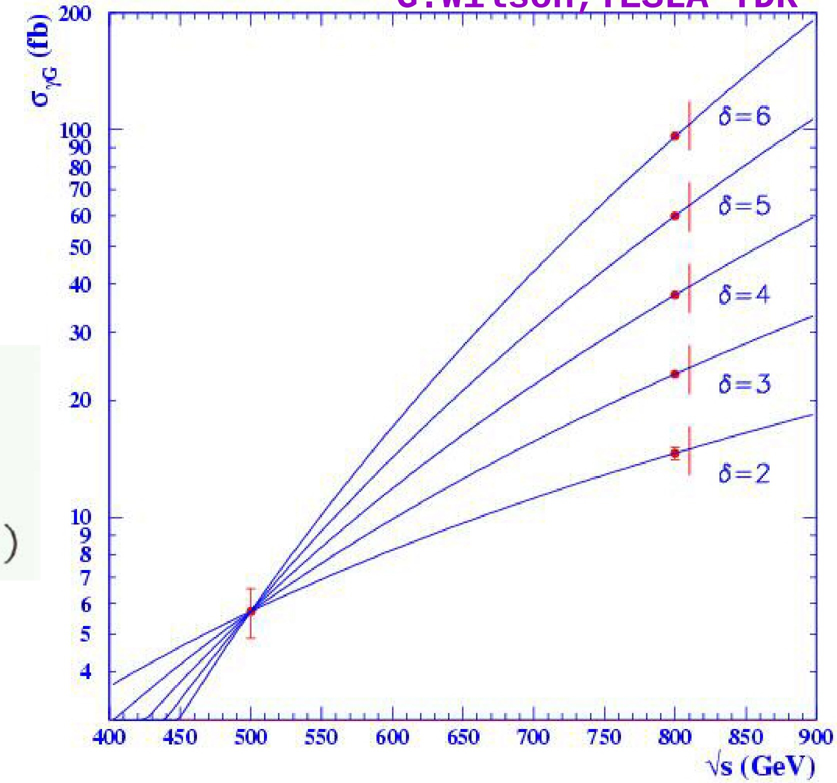
Background: $e^{+}e^{-} \rightarrow \nu\bar{\nu}\gamma$

$\Rightarrow$ $S/\sqrt{B}$ increases:

by a factor 2.1 for $+80\%(e^{-})$

by a factor 4.4 for $+80\%(e^{-})$, $-60\%(e^{+})$

G.Wilson,TESLA TDR

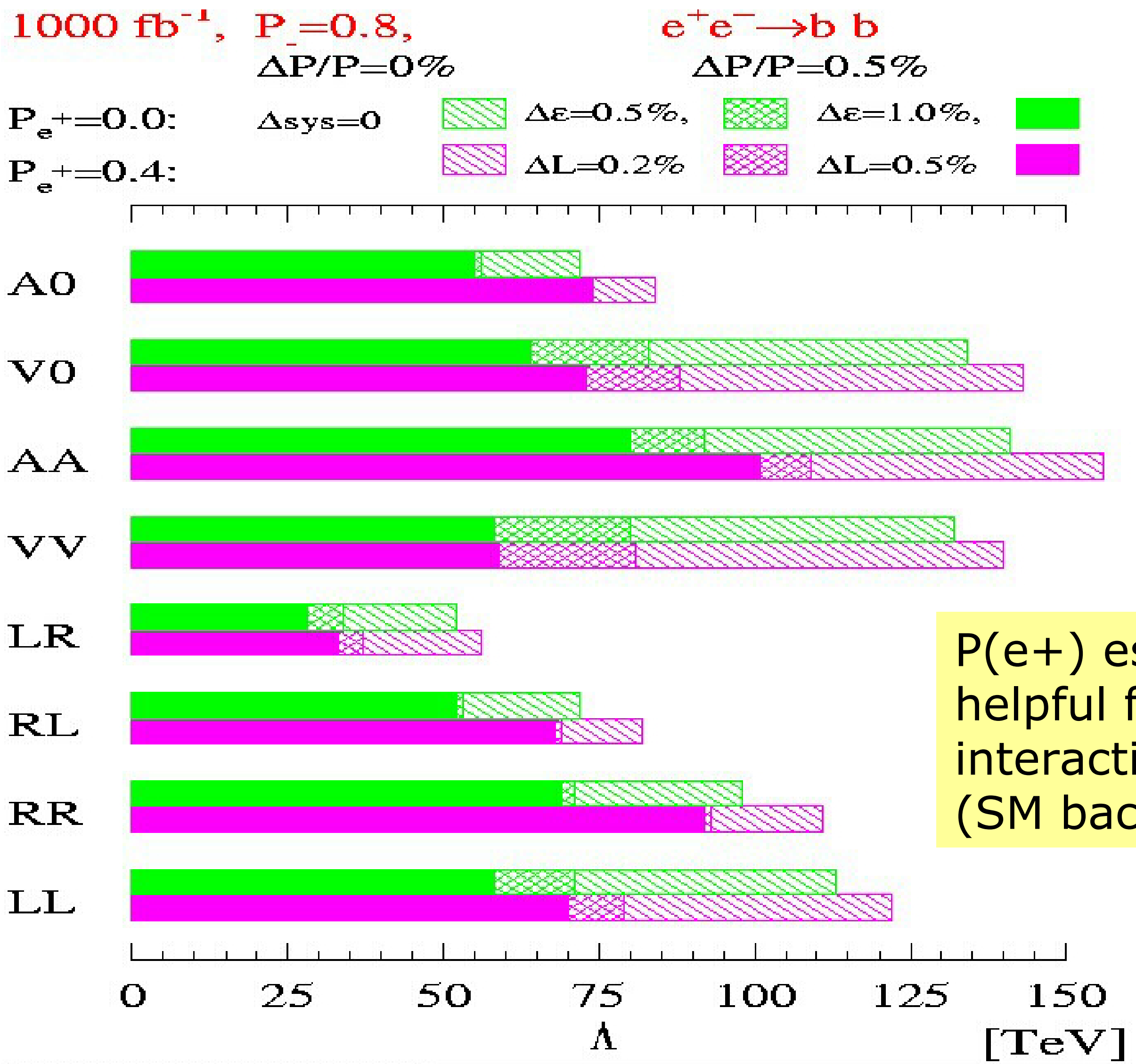


Sensitivity to M_* in TeV at $\sqrt{s} = 800$ GeV, 1 ab^{-1}:

Polarization	$\delta = 2$	$\delta = 4$	$\delta = 6$
0	5.9	3.5	2.5
$80\%(e^{-})$	8.3	4.4	2.9
$80\%(e^{-})$, $60\%(e^{+})$	10.4	5.1	3.3

Positron Polarisation Physics Case: Contact interactions

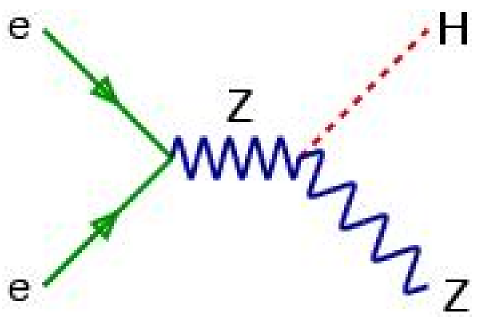
S.Riemann,TESLA TDR

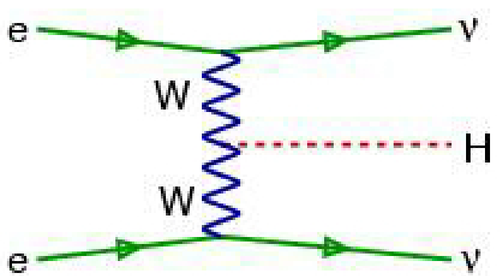


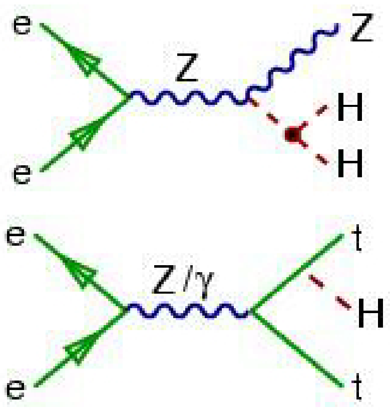
P(e+) especially
helpful for right-handed
interactions
(SM background suppression)

Positron Polarisation Physics Case: Higgs

Higgs is scalar: no particular sensitivity to long. polarisation, but increased effective luminosity is helpful:







Cross section scaling factors w.r.t. unpolarised case:

Configuration $(sgn(P_{e^-})sgn(P_{e^+}))$	Higgs Production $e^+e^- \to H\nu\bar{\nu}$	Higgs Production $e^+e^- \to HZ$	Background $e^+e^- \to WW$, $e^+e^- \to Z\nu\bar{\nu}$	Background $e^+e^- \to ZZ$
$(+0)$	0.20	0.87	0.20	0.76
(-0)	1.80	1.13	1.80	1.25
$(+-)$	0.08	1.26	0.10	1.05
$(-+)$	2.88	1.70	2.85	1.91

Transverse Polarisation

- Transverse polarisation is possible by indroducing spin rotators

- Transverse polarisation leads to azimuthal asymmetries:

$$\overline{|M|^2} = \frac{1}{4}\Big[(1 - P_L P_L')\left(|M_+|^2 + |M_-|^2\right) + (P_L - P_L')\left(|M_+|^2 - |M_-|^2\right) \\ + (2\, P_T P_T')\left(\cos(2\phi_W)\,\mathrm{Re}(M_+ M_-^*) - \sin(2\phi_W)\,\mathrm{Im}(M_+ M_-^*)\right)\Big]$$

- proportional to P(e-)P(e+) ⇨ only useful if both beams are polarised

- Projector for relative phases between Amplitudes
  ⇨ important tool for all CP-violating effects

- not very well studied yet, much more work to be done!

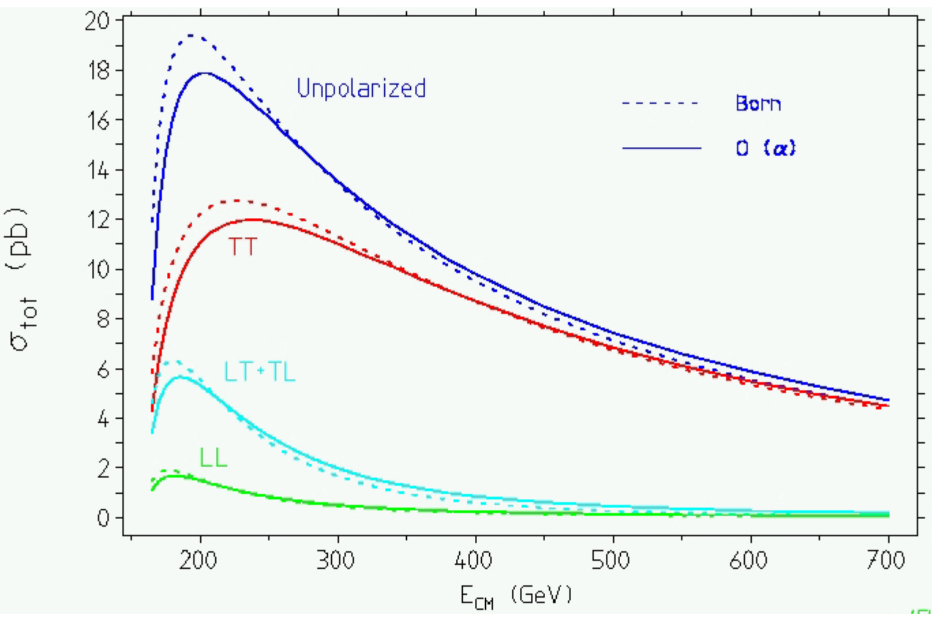
Transverse Polarisation

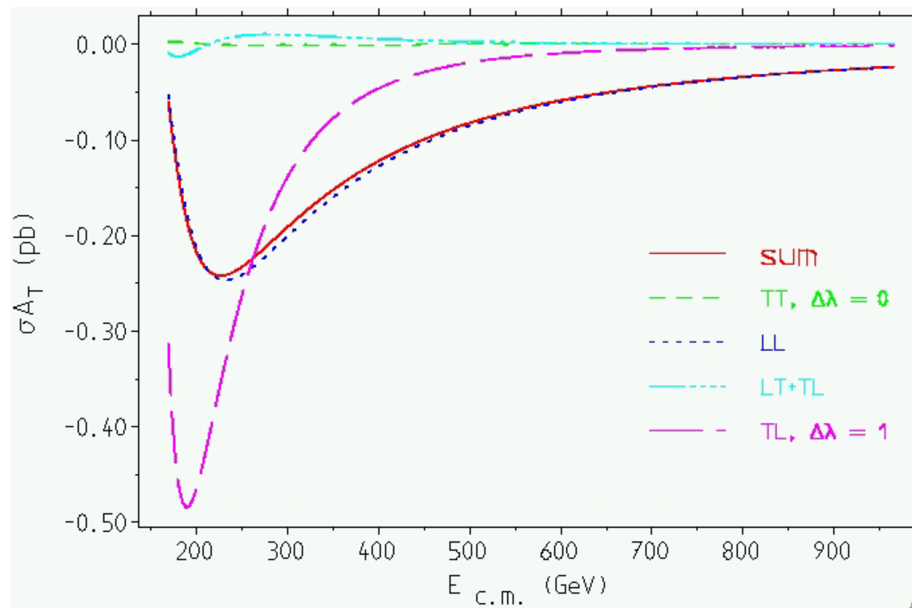
Worked out example: WW production

Fleischer,Jegerlehner,Kolodziej PRD49(1994!!)2174.

Probe longitudinal W bosons at $\sqrt{s} \gg 2\,m_W$

Measure azimuthal asymmetry





Transverse Polarisation

Another example: $e^+e^- \to q\bar{q}$

Olsen,Osland,Øverbø, PLB97(1980!!)286.

Azimuthal asymmetries differ for up- and down-type quarks
⇨ separate them might be useful (was tough at LEP)

More possibilities are being worked on:

- Sensitivity to Higgs CP
- SUSY: access to CP-violating phases

Still a lot to do!

International working group POWER (Polarization at Work in Energetic Reactions)
Machine – Experiment – Theory joint venture
Contact: G. Moortgat-Pick
More info at http://www.desy.de/~gudrid

Conclusion

Positron polarisation adds significantly to physics potential

- increase of effective Luminosity and effective Polarisation
- SM background supression for rare channels
- Sensitivity to non-standard couplings
- Provides new independent observables (whenever t-channel is relevant)

Transverse Polarisation

- adds new observables sensitive to phases ⇨
- clean projector for CP violating effects
- access to anomalous TGC's, access long. W's
- other applications are under study, work ongoing
- more contributors welcome! ⇨ POWER group