Contact Interaction Searches at e^+e^- International Linear Collider: Role of Polarization

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Outline

- Variety of New Physics Scenarios
- Parametrization of NP (compositeness, *Z', W', LQ,* $\tilde{\nu}$, KK G_n ,...) in terms of four-fermion CI
- NP indirect effects at e^+e^- **ILC**
  - Processes: $e^+e^- \to \bar{f}f \; (f = \mu, \tau; \, c, b) \quad e^\pm e^- \to e^\pm e^-$
  - Observable: polarized differential distribution
  - Model-independent analysis of CI $\Rightarrow$ discovery reach
  - Distinction of models: identification of KK graviton exchange effects
- Role of polarization to enhance sensitivity to CI parameters

Introduction

It is generally expected that NP beyond the SM will manifest itself at future colliders such as the LHC and ILC either:

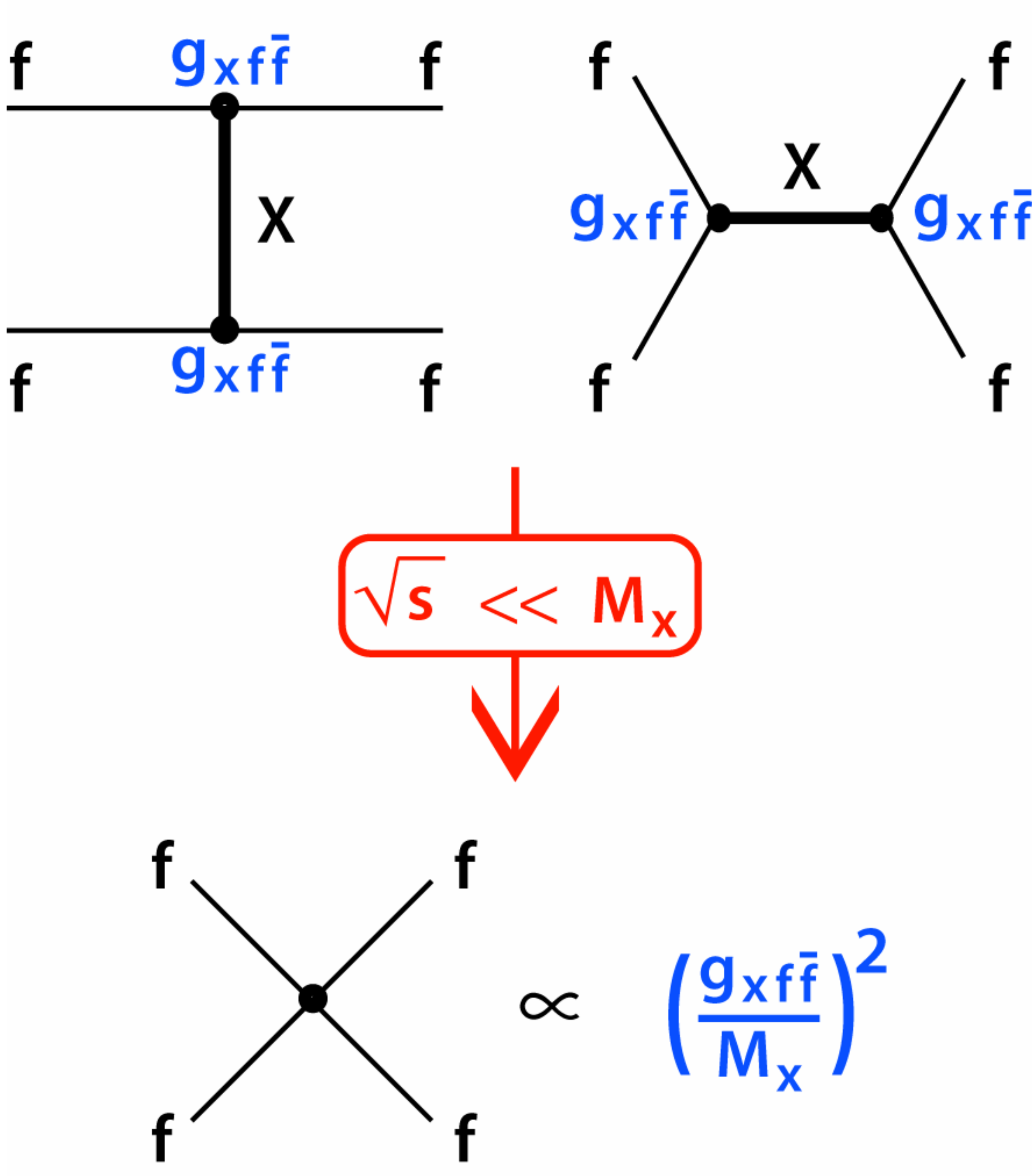
- **directly,** as in the case of new particle production, e.g., *Z'* and *W* vector bosons, SUSY or Kaluza-Klein (KK) resonances, or
- **indirectly** through *deviations* of observables from the SM predictions.

In the case of **indirect** discovery the effects may be subtle and many different NP scenarios may lead to the **same** or **very similar** experimental signatures. These NP scenarios predict *new particle exchanges* which can lead to **CI** below direct production threshold.

Various New Physics possibilities

- Composite models
- Heavy *Z'* exchanges
- Scalar and vector leptoquarks
- Sneutrino exchange
- Anomalous Gauge Couplings (AGC)
- Exchange of gauge boson KK towers
- Virtual KK graviton exchange (ADD)
- etc.

Of course, there may be many other sources of CI from NP models as yet undiscovered, as was the low-scale gravity scenario only several years ago.


f
$g_{Xf\bar{f}}$
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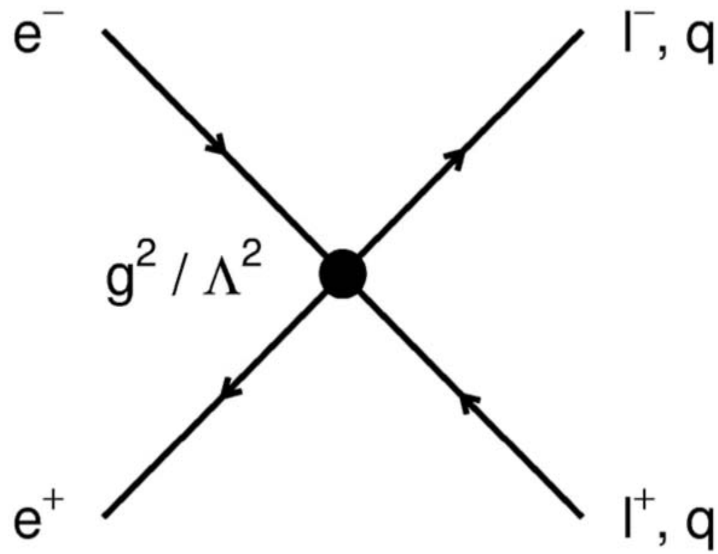
f
f
$\sqrt{s} << M_X$
f
f
f
f
$\propto \left(\frac{g_{Xf\bar{f}}}{M_X}\right)^2$

Nonstandard Scenarios

- Framework of effective Lagrangians (expansion in s/Λ^2)
- "Conventional" (dim-6) four-fermion contact interactions (**CI**) [compositeness]:
- effective Lagrangian:

$$\mathcal{L}^{\mathrm{CI}} = 4\pi \sum_{\alpha,\beta} \frac{\eta_{\alpha\beta}}{\Lambda^2_{\alpha\beta}} \left(\bar{e}_\alpha \gamma_\mu e_\alpha\right) \left(\bar{f}_\beta \gamma^\mu f_\beta\right) ,$$

$$\eta_{\alpha\beta} = \pm 1, 0; \; \alpha, \beta = \mathrm{L}, \mathrm{R}.$$



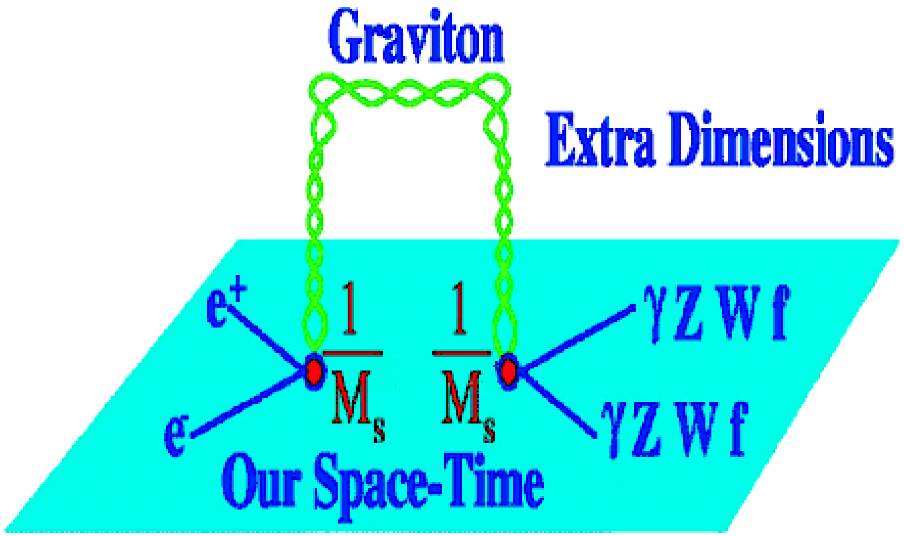
- Can describe also exchanges of heavy *Z', W',* Leptoquarks, *etc.*
- Current limits on "compositeness" scales [Tevatron, LEP]: $\Lambda > 10 - 20\,\mathrm{TeV}$

Definition of four-fermion CI models

CI model	η_{LL}	η_{RR}	η_{LR}	η_{RL}
LL	± 1	0	0	0
RR	0	± 1	0	0
LR	0	0	± 1	0
RL	0	0	0	± 1
VV	± 1	± 1	± 1	± 1
AA	± 1	± 1	∓ 1	∓ 1

- ADD scenario: Gravity in "large" compactified extra dimensions (gauge hierarchy)

- Gravity only can propagate in the full 4+N space



- Virtual exchange of the graviton KK excitation states is governed by the effective Lagrangian (similar to dim-8 CI):

$$\mathcal{L}^{\mathrm{ADD}} = i\frac{4\lambda}{{\Lambda_H}^4} T^{\mu\nu}T_{\mu\nu},$$

where Λ_H is the cut-off scale (convention of *Hewett*), $\lambda = \pm 1$.

- Introduce UV cut-off when summing over KK states:

$$\mathcal{M} \sim \sum_{\vec{n}=1}^{\infty} \frac{G_{\mathrm{N}}}{M^2 - m_{\vec{n}}^2} \rightarrow -\frac{\lambda}{\pi\Lambda_H^4}.$$

- current lower limit [Tevatron, LEP]: Λ_H > 1.3 TeV

- TeV $^{-1}$ - scale extra dimensions

Also SM gauge bosons may propagate in the additional dimensions: exchange of γ and Z KK excitations. Effective (contactlike) interaction:

$$\mathcal{L}^{\mathrm{TeV}} = -\frac{\pi^2}{3M_C^2}\left[Q_e Q_f(\bar{e}\gamma_\mu e)(\bar{f}\gamma^\mu f) + \right.$$
$$\left. +(g_{\mathrm{L}}^e \bar{e}_{\mathrm{L}}\gamma_\mu e_{\mathrm{L}} + g_{\mathrm{R}}^e \bar{e}_{\mathrm{R}}\gamma_\mu e_{\mathrm{R}}) \times (g_{\mathrm{L}}^f \bar{f}_{\mathrm{L}}\gamma^\mu f_{\mathrm{L}} + g_{\mathrm{R}}^f \bar{f}_{\mathrm{R}}\gamma^\mu f_{\mathrm{R}})\right].$$

$M_C \gg M_{W,Z}$: inverse of the compactification radius

Current limit [LEP2]: $M_C > 6.8\,\mathrm{TeV}$

Here:

- “Conventional” model-dependent CI analysis with polarized differential cross sections $\mathrm{d}\sigma(\mathrm{P}^+,\mathrm{P}^-)/\mathrm{d}\cos\theta$ in $e^+e^- \to \bar{f}\,f$

- vary only one individual CI parameter at a time $\Rightarrow$ model-dependent discovery reaches on Λ's

- Generic (model-independent) analysis: allow to vary all CI parameters simultaneously $\Rightarrow$ model-independent discovery reaches on Λ's

(extension of model-independent analysis of the CI at LEP2:

A.A. Babich, N. Paver, A.P. et al., Eur. Phys. J. C29 (2003) $\Rightarrow$ PDG2006)

- If New Physics effects are discovered, it is crucial to have good search strategies to determine its origin. Here, we will consider the problem of how to distinguish the potential New Physics scenarios from each other at the ILC. In particular, we will discuss such a technique based on the polarized angular distribution which offers a way to uniquely identify graviton exchange signature in ADD scenario.

- Role of beam polarization for discovery and identification reach enhancement

Relevant references:

- ► *A.A. Pankov, N. Paver*, Phys. Rev. D **72** (2005)
- ► *A.A. Pankov, N. Paver, A.V. Tsytrinov*, Phys. Rev. D **73** (2006); D **75** (2007)
- ► some recent results

Model-dependent analysis of CI. Discovery reach.

- Observables: polarized angular distributions $d\sigma / d\cos\theta$
- Processes: $e^+e^- \to \bar{f}f, \quad e^-e^- \to e^-e^-$ (*s,t,u*− channels)
- $d\sigma \propto |\mathrm{SM} + \mathrm{NewPhysics}|^2$

Polarized differential cross section of Bhabha process $e^+e^- \to e^+e^-$

$$\frac{d\sigma(P^-,P^+)}{d\cos\theta} = \frac{(1+P^-)(1-P^+)}{4}\frac{d\sigma_R}{d\cos\theta} + \frac{(1-P^-)(1+P^+)}{4}\frac{d\sigma_L}{d\cos\theta} + \frac{(1+P^-)(1+P^+)}{4}\frac{d\sigma_{RL,t}}{d\cos\theta} + \frac{(1-P^-)(1-P^+)}{4}\frac{d\sigma_{LR,t}}{d\cos\theta},$$

$$\frac{d\sigma_L}{d\cos\theta} = \frac{d\sigma_{LL}}{d\cos\theta} + \frac{d\sigma_{LR,s}}{d\cos\theta}, \qquad \frac{d\sigma_R}{d\cos\theta} = \frac{d\sigma_{RR}}{d\cos\theta} + \frac{d\sigma_{RL,s}}{d\cos\theta},$$

$$\frac{d\sigma_{LL}}{d\cos\theta} = \frac{2\pi\alpha^2_{\mathrm{e.m.}}}{s}\left|G_{LL,s} + G_{LL,t}\right|^2, \qquad \frac{d\sigma_{RR}}{d\cos\theta} = \frac{2\pi\alpha^2_{\mathrm{e.m.}}}{s}\left|G_{RR,s} + G_{RR,t}\right|^2,$$

$$\frac{d\sigma_{LR,t}}{d\cos\theta} = \frac{d\sigma_{RL,t}}{d\cos\theta} = \frac{2\pi\alpha^2_{\mathrm{e.m.}}}{s}\left|G_{LR,t}\right|^2, \qquad \frac{d\sigma_{LR,s}}{d\cos\theta} = \frac{d\sigma_{RL,s}}{d\cos\theta} = \frac{2\pi\alpha^2_{\mathrm{e.m.}}}{s}\left|G_{LR,s}\right|^2.$$

$$G_{\mathrm{LL},s} = u\left(\frac{1}{s}+\frac{g_{\mathrm{L}}^2}{s-M_Z^2}+\Delta_{\mathrm{LL},s}\right), \quad G_{\mathrm{LL},t} = u\left(\frac{1}{t}+\frac{g_{\mathrm{L}}^2}{t-M_Z^2}+\Delta_{\mathrm{LL},t}\right),$$

$$G_{\mathrm{RR},s} = u\left(\frac{1}{s}+\frac{g_{\mathrm{R}}^2}{s-M_Z^2}+\Delta_{\mathrm{RR},s}\right), \quad G_{\mathrm{RR},t} = u\left(\frac{1}{t}+\frac{g_{\mathrm{R}}^2}{t-M_Z^2}+\Delta_{\mathrm{RR},t}\right),$$

$$G_{\mathrm{LR},s} = t\left(\frac{1}{s}+\frac{g_{\mathrm{R}}\,g_{\mathrm{L}}}{s-M_Z^2}+\Delta_{\mathrm{LR},s}\right), \quad G_{\mathrm{LR},t} = s\left(\frac{1}{t}+\frac{g_{\mathrm{R}}\,g_{\mathrm{L}}}{t-M_Z^2}+\Delta_{\mathrm{LR},t}\right).$$

Here: $u,t = -s(1 \pm \cos\theta)/2$; M_Z is the mass of the Z; $g_{\mathrm{R}} = \tan\theta_W$, $g_{\mathrm{L}} = -\cot 2\,\theta_W$ are the SM right- and left-handed electron couplings to the Z, with θ_W the electroweak mixing angle.

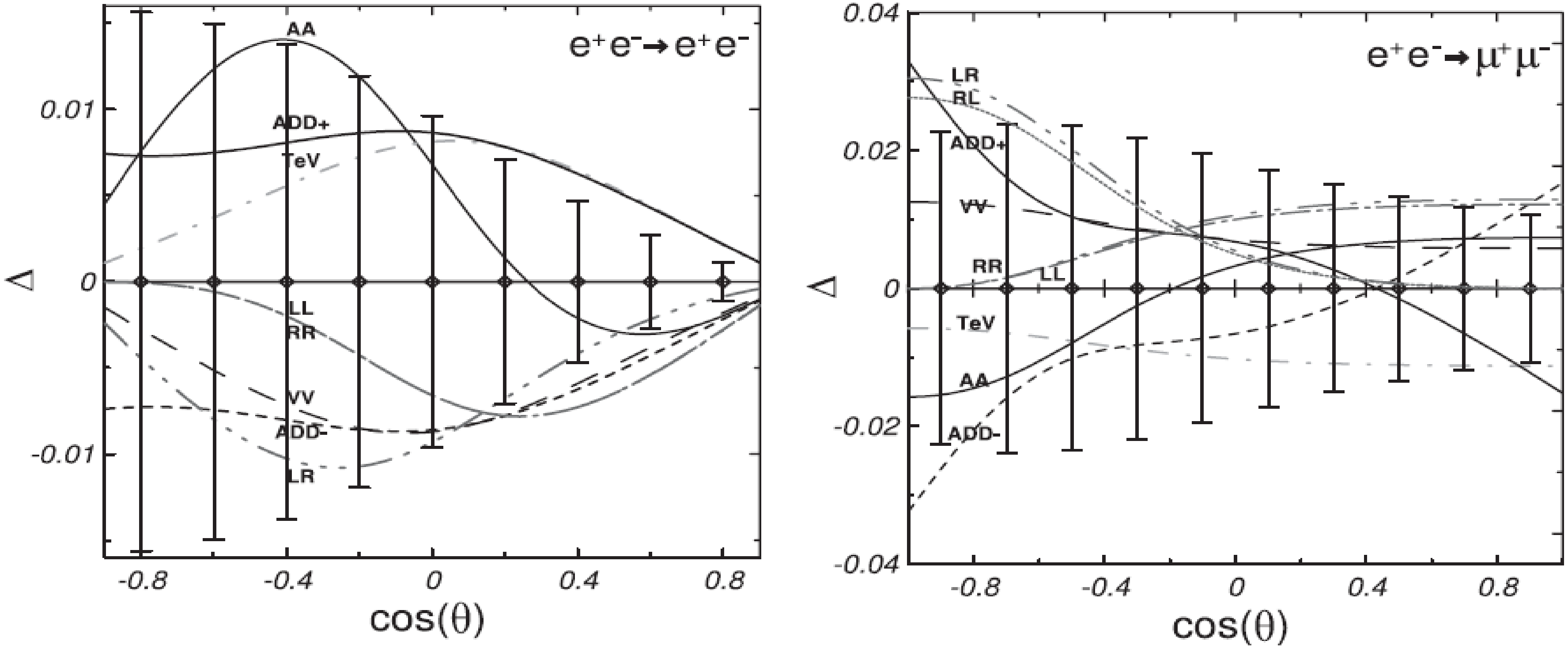
Parametrization of the $\Delta_{\alpha\beta}$ functions in different models

New physics model	$\boldsymbol{\Delta_{\alpha\beta}}$
Contact interactions	$\Delta_{\alpha\beta,s} = \Delta_{\alpha\beta,t} = \frac{1}{\alpha_{\mathrm{e.m.}}}\frac{\eta_{\alpha\beta}}{\Lambda_{\alpha\beta}^2}$
TeV^{-1}-scale extra dim.	$\Delta_{\alpha\beta,s} = \Delta_{\alpha\beta,t} = -(Q_e Q_f + g_\alpha^e\, g_\beta^f)\,\frac{\pi^2}{3\,M_C^2}$
ADD model	$\Delta_{\mathrm{LL},s} = \Delta_{\mathrm{RR},s} = \frac{\lambda}{\pi\alpha_{\mathrm{e.m.}}\Lambda_H^4}(u+\frac{3}{4}s)$ $\Delta_{\mathrm{LL},t} = \Delta_{\mathrm{RR},t} = \frac{\lambda}{\pi\alpha_{\mathrm{e.m.}}\Lambda_H^4}(u+\frac{3}{4}t)$ $\Delta_{\mathrm{LR},s} = -\frac{\lambda}{\pi\alpha_{\mathrm{e.m.}}\Lambda_H^4}(t+\frac{3}{4}s)$ $\Delta_{\mathrm{LR},t} = -\frac{\lambda}{\pi\alpha_{\mathrm{e.m.}}\Lambda_H^4}(s+\frac{3}{4}t)$

- Assumption: no deviation from the SM is observed within the experimental accuracy.

- **Deviations** of observables from the SM predictions:

$$\Delta(\mathcal{O}) = \frac{\mathcal{O}(SM+NP) - \mathcal{O}(SM)}{\mathcal{O}(SM)}, \qquad \mathcal{O} = \mathrm{d}\sigma/\mathrm{d}\cos\theta$$



Left panel: relative deviations of the unpolarized Bhabha differential cross section from the SM prediction as a function of $\cos\theta$ at $\sqrt{s} = 0.5$ TeV for the CI models: AA ($\Lambda^{+}_{\rm AA}$=48 TeV), VV ($\Lambda^{+}_{\rm VV}$=76 TeV), LL ($\Lambda^{+}_{\rm LL}$=37 TeV), RR ($\Lambda^{+}_{\rm RR}$=36 TeV), LR ($\Lambda^{+}_{\rm LR}$=60 TeV); for the TeV^{-1} model (M_C=12 TeV) and the ADD± models (Λ_H=4 TeV). The vertical bars represent the statistical uncertainty in each bin for $\mathcal{L}_{\rm int} = 100\,\mathrm{fb}^{-1}$.
Right panel: same as in the left panel but for $e^+e^- \to \mu^+\mu^-$, for the CI models: AA ($\Lambda^{+}_{\rm AA}$=80 TeV), VV ($\Lambda^{+}_{\rm VV}$=90 TeV), LL ($\Lambda^{+}_{\rm LL}$=45 TeV), RR ($\Lambda^{+}_{\rm RR}$=42 TeV), LR ($\Lambda^{+}_{\rm LR}$=41 TeV), RL ($\Lambda^{+}_{\rm RL}$=43 TeV); for the TeV^{-1} model (M_C=17 TeV) and the ADD± models (Λ_H=2.8 TeV).

- deviations must be compared to foreseen experimental uncertainties $\delta\mathcal{O}$ [statistical plus systematic]:

Discovery reach: $$\chi^2(\mathcal{O}) = \sum_{\{P^-,\ P^+\}} \sum_{\text{bins}} \left(\frac{\Delta(\mathcal{O})^{\text{bin}}}{\delta\mathcal{O}^{\text{bin}}} \right)^2 .$$

- Constraints on Λ_H, Λ's [expected discovery reaches] from:

$$\chi^2(\mathcal{O}) \leq 3.84 \quad (95\% \text{ C.L.})$$

Experimental inputs:

Bhabha and Møller scattering $(|\cos\theta| < 0.9,\ \epsilon \simeq 100\%,$ bin width: $\Delta\cos\theta = 0.2)$;

$\mu^+\mu^-,\ \tau^+\tau^-\ (|\cos\theta| < 0.98,\ \epsilon = 95\%)$;

$\bar{c}c\ (\epsilon = 35\%)$; $\bar{b}b\ (\epsilon = 60\%)$ $\quad \delta P^{\pm}/P^{\pm} = 0.2\%,\ \delta\mathcal{L}_{\text{int}}/\mathcal{L}_{\text{int}} = 0.5\%.$

radiative corrections included:

$$e^+e^- \to \bar{f}\,f \quad (ZFITTER \oplus ZEFIT)$$

$e^+e^- \to e^+e^-$ (structure functions approach)

95% C.L. model-dependent discovery reaches (in TeV). Left and right entries refer to the polarization configurations $(|P^-|, |P^+|)$=(0,0) and (0.8,0.6), respectively. $\sqrt{s} = 0.5$ TeV, $\mathcal{L}_{\rm int} = 100\, fb^{-1}$

Model	Process			
	$e^+e^- \to e^+e^-$	$e^+e^- \to l^+l^-$	$e^+e^- \to \bar{b}b$	$e^+e^- \to \bar{c}c$
Λ_H	4.1; 4.3	3.0; 3.2	3.0; 3.4	3.0; 3.2
Λ_{VV}^{ef}	76.2; 86.4	89.7; 99.4	76.1; 96.4	84.0; 94.1
Λ_{AA}^{ef}	47.4; 69.1	80.1; 88.9	76.7; 98.2	76.5; 85.9
Λ_{LL}^{ef}	37.3; 52.5	53.4; 68.3	63.6; 72.7	54.5; 66.1
Λ_{RR}^{ef}	36.0; 52.2	51.3; 68.3	42.5; 71.2	46.3; 66.8
Λ_{LR}^{ef}	59.3; 69.1	48.5; 62.8	51.3; 68.7	37.0; 57.7
Λ_{RL}^{ef}	$\Lambda_{RL}^{ee} = \Lambda_{LR}^{ee}$	48.7; 63.6	46.8; 60.1	52.2; 60.7
M_C	12.0; 13.8	20.0; 22.2	6.6; 10.7	10.4; 12.0

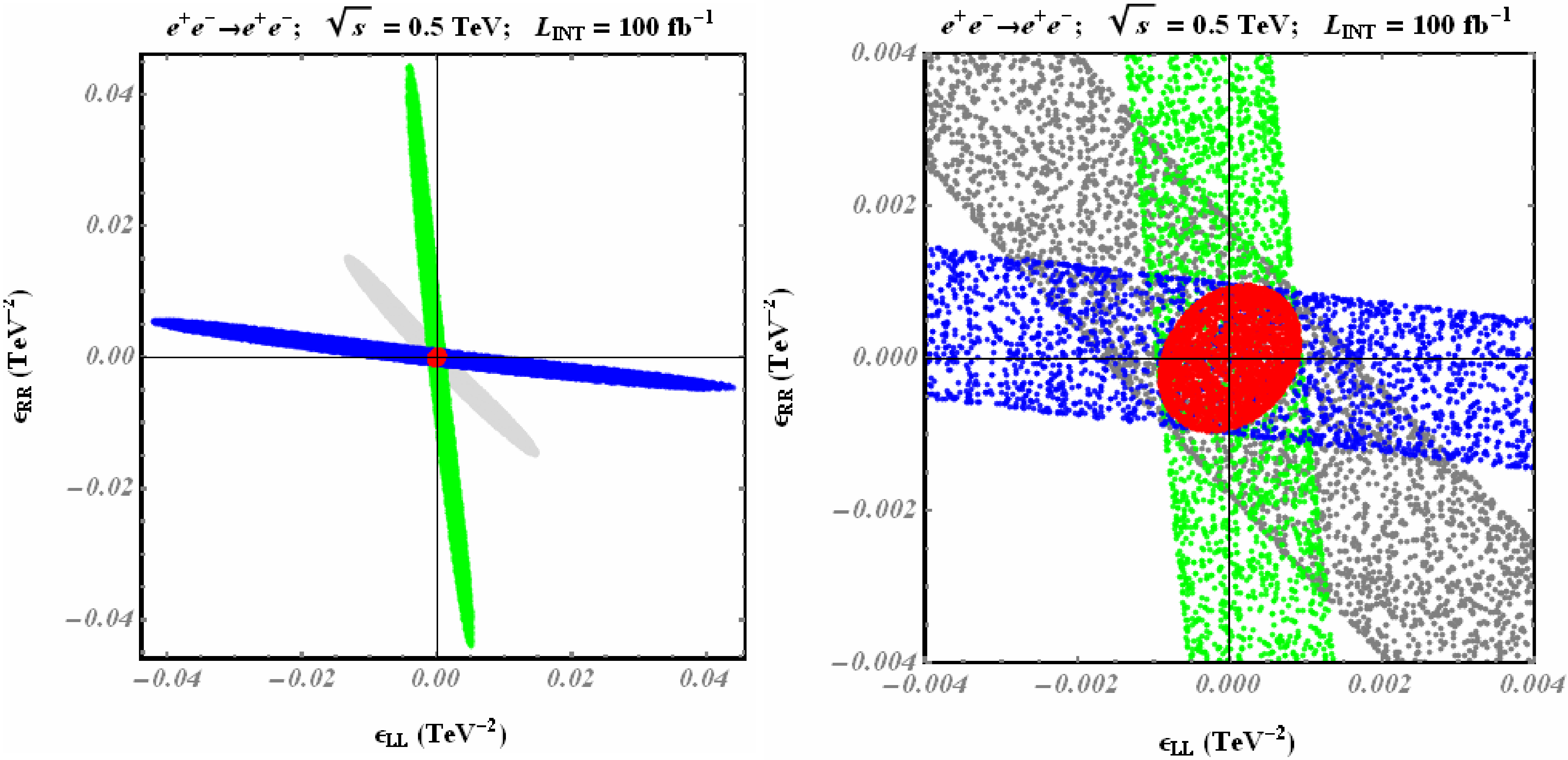
See also *S.Riemann, T.Rizzo, S.Godfrey.*

95% C.L. model-dependent discovery reaches (in TeV). Left and right entries refer to the polarization configurations ($|P^-|,|P^+|$)=(0,0) and (0.8,0.6), respectively. $\sqrt{s}=1.0$ TeV, $\mathcal{L}_{\rm int}=1000\,fb^{-1}$

Model	Process			
	$e^+e^-\to e^+e^-$	$e^+e^-\to l^+l^-$	$e^+e^-\to\bar{b}b$	$e^+e^-\to\bar{c}c$
Λ_H	8.7; 9.4	6.7; 7.0	6.7; 7.5	6.7; 7.1
Λ_{VV}^{ef}	173.6; 205.1	218.8; 244.3	185.6; 238.2	206.2; 232.3
Λ_{AA}^{ef}	109.9; 166.1	194.7; 217.9	186.; 242.7	186.4; 210.8
Λ_{LL}^{ef}	83.7; 122.8	128.3; 165.5	154.5; 175.8	131.3; 159.6
Λ_{RR}^{ef}	80.5; 122.1	123.4; 166.1	103.5; 176.9	111.8; 164.1
Λ_{LR}^{ef}	136.6; 166.8	120.5; 156.6	124.9; 170.2	92.7; 144.6
Λ_{RL}^{ef}	$\Lambda_{RL}^{ee}=\Lambda_{LR}^{ee}$	120.8; 158.3	120.1; 151.9	129.6; 151.1
M_C	27.2; 32.5	48.3; 54.2	15.6; 26.5	26.2; 30.2

Model-independent analysis of CI: role of polarization

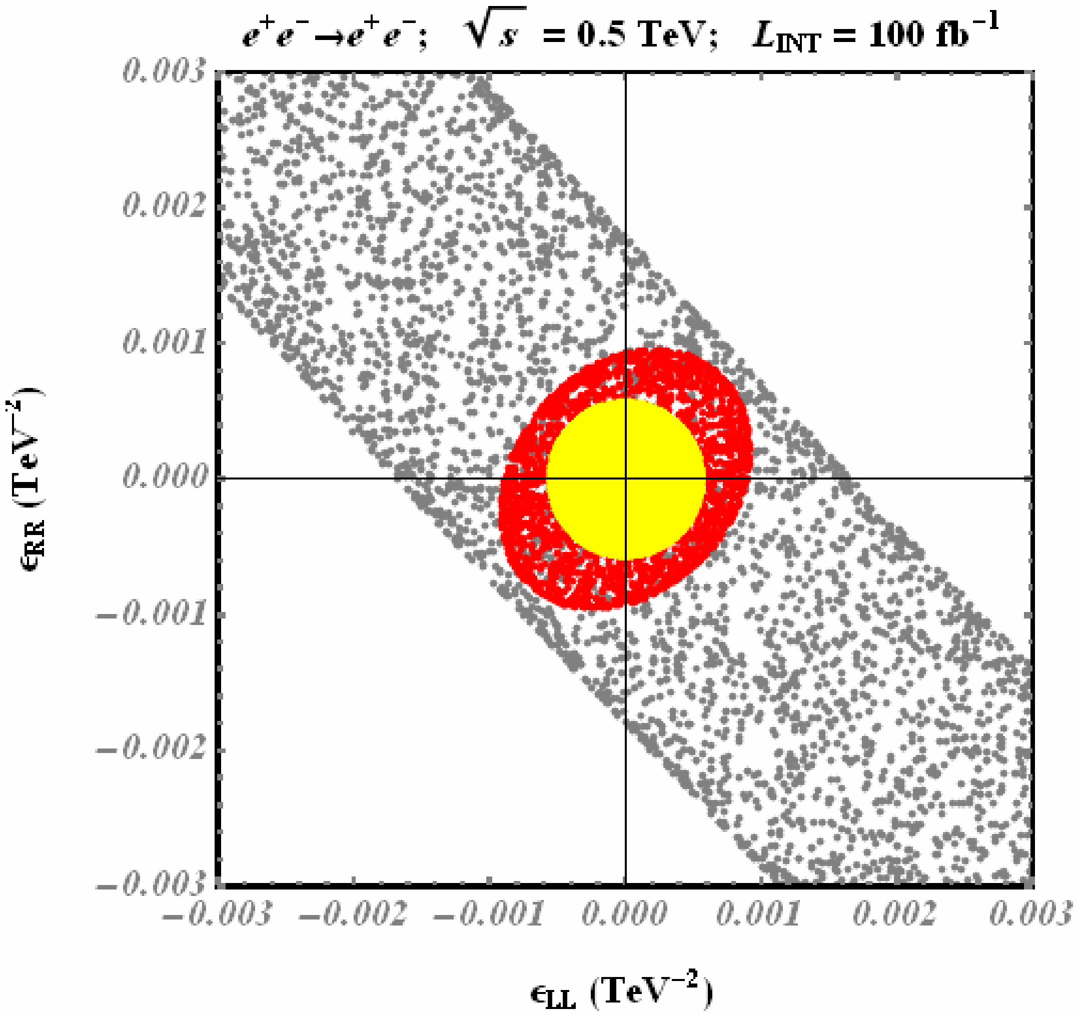
- Bhabha scattering: $\chi^2(\Lambda_{RR}, \Lambda_{LL}, \Lambda_{LR}) \leq 7.82 \quad (95\%\ \text{C.L.})$



$P^- = 0; \; P^+ = 0;$ $\quad$ $P^- = 0.8; \; P^+ = 0;$ $\quad$ $P^- = -0.8; \; P^+ = 0;$ $\quad$ $|P^-| = 0.8; \; P^+ = 0;$

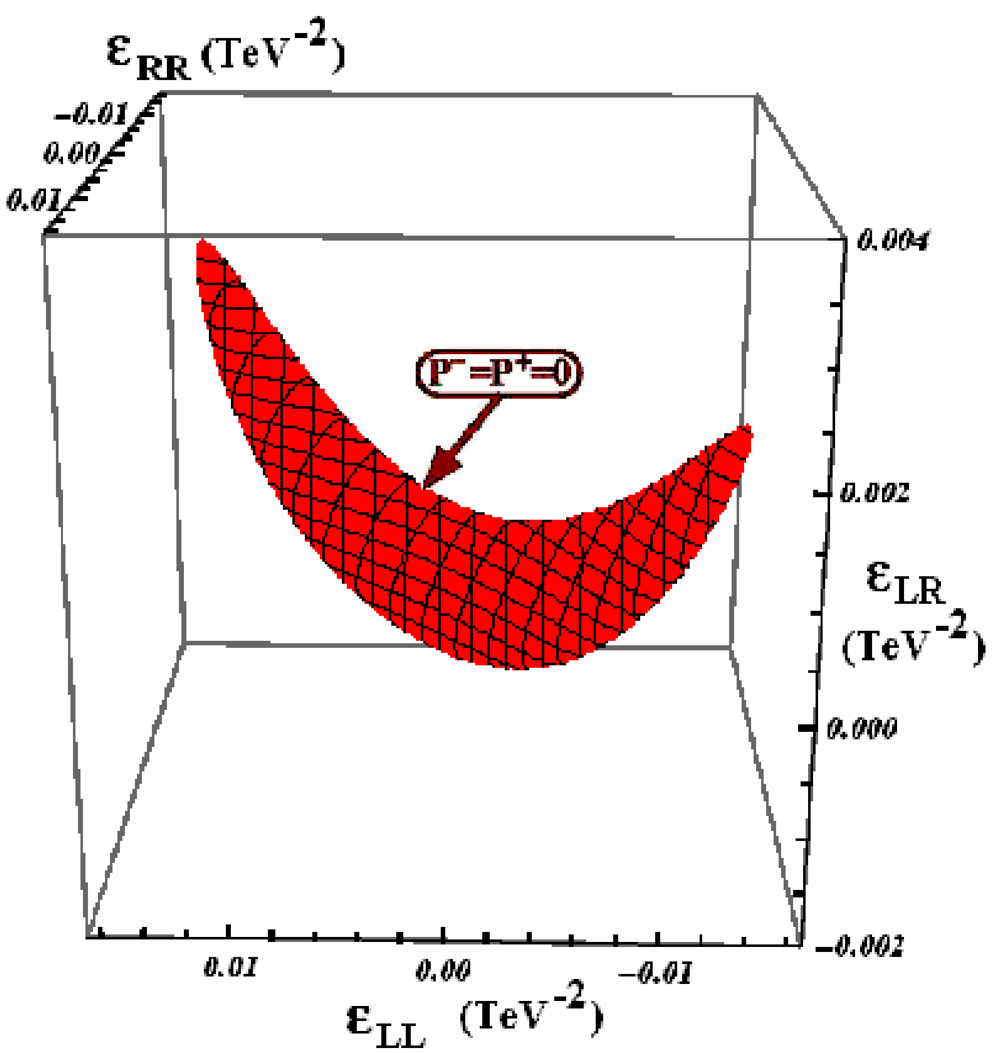
Model-independent analysis of CI: role of polarization

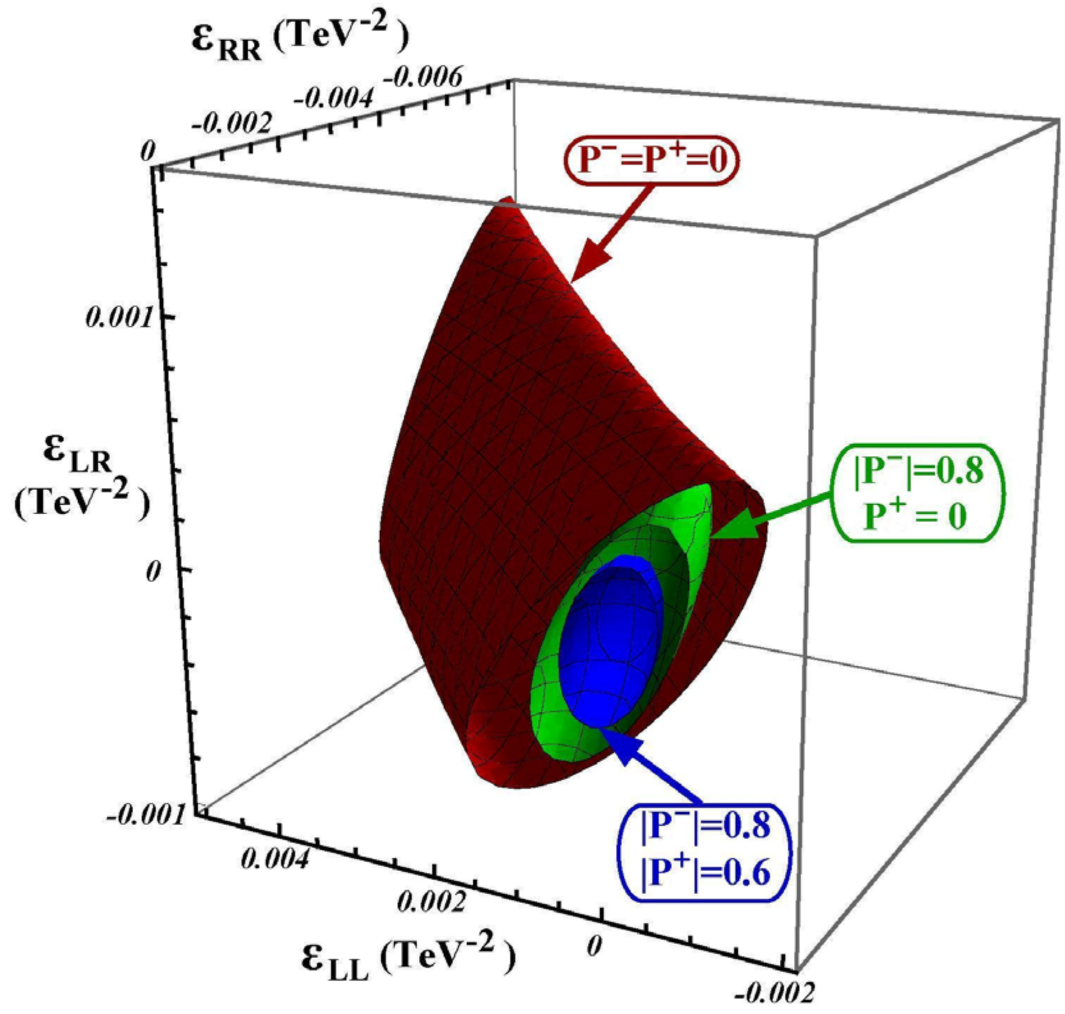
- Bhabha scattering: $\chi^2(\Lambda_{RR},\Lambda_{LL},\Lambda_{LR}) \leq 7.82 \quad (95\%\ \text{C.L.})$

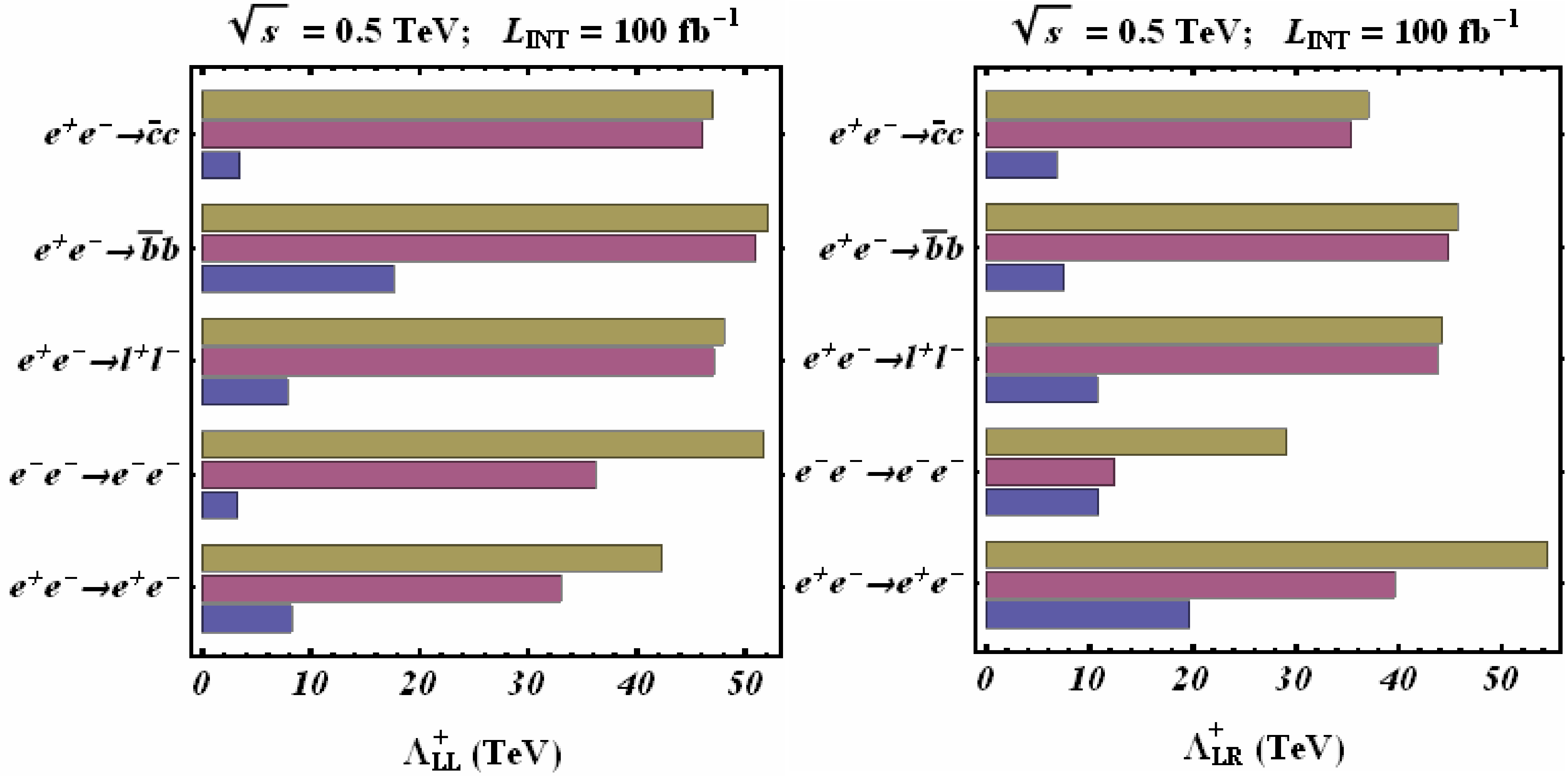


Grey: $P^- = 0;$ $P^+ = 0;$	Red: $\lvert P^-\rvert = 0.8;$ $P^+ = 0;$	Yellow: $\lvert P^-\rvert = 0.8;$ $\lvert P^+\rvert = 0.6;$

$$e^+e^- \to e^+e^-;\ \sqrt{s} = 0.5\,\mathrm{TeV};\ \ L_{INT} = 100\,\mathrm{fb}^{-1}$$



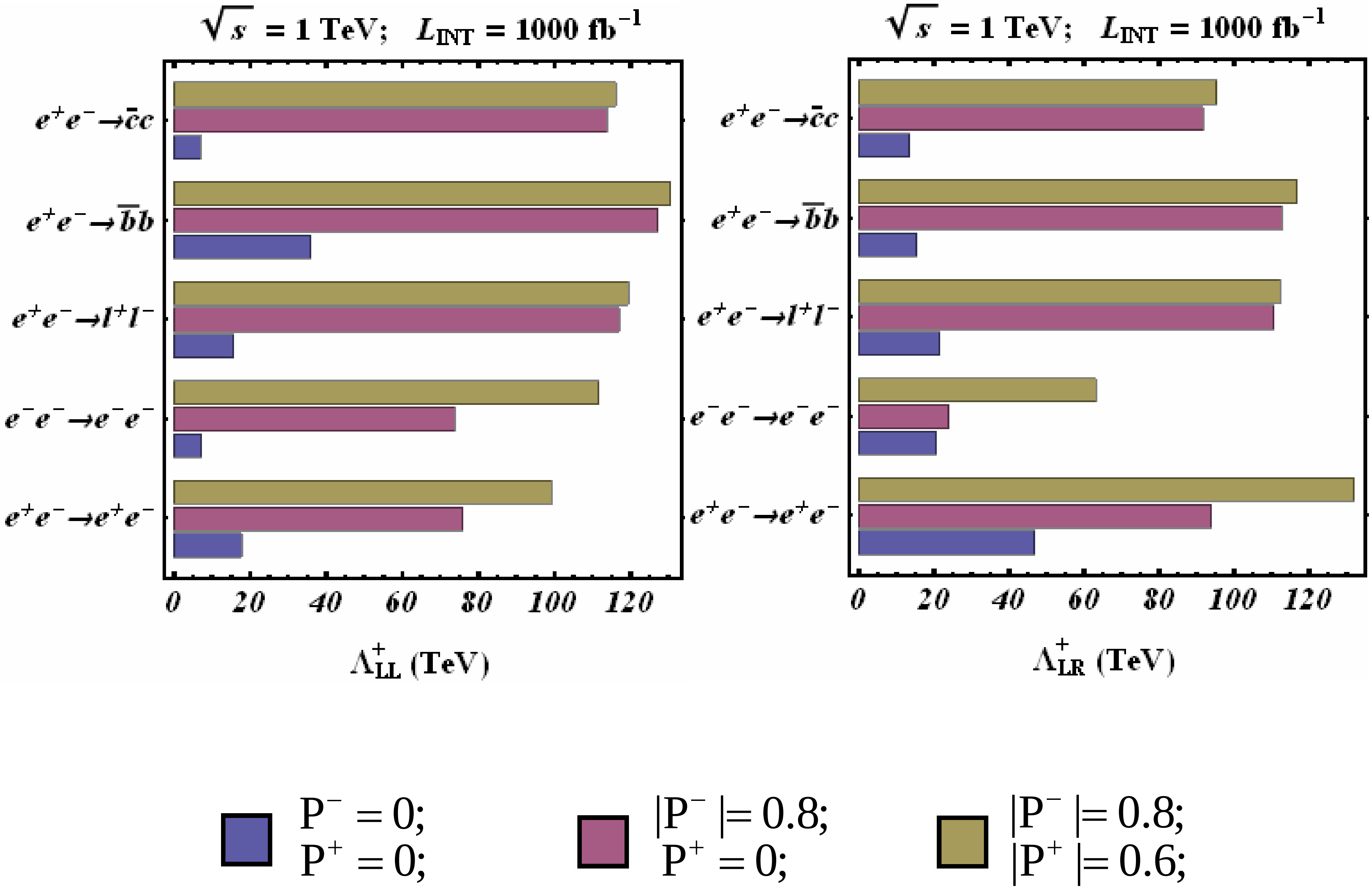




$P^- = 0;$ $P^+ = 0;$

$|P^-| = 0.8;$ $P^+ = 0;$

$|P^-| = 0.8;$ $|P^+| = 0.6;$



√s = 1 TeV; L_INT = 1000 fb^-1
e+e- → c̄c
e+e- → b̄b
e+e- → l+l-
e-e- → e-e-
e+e- → e+e-
0 20 40 60 80 100 120
Λ+LL (TeV)
√s = 1 TeV; L_INT = 1000 fb^-1
e+e- → c̄c
e+e- → b̄b
e+e- → l+l-
e-e- → e-e-
e+e- → e+e-
0 20 40 60 80 100 120
Λ+LR (TeV)
P- = 0; P+ = 0;
|P-| = 0.8; P+ = 0;
|P-| = 0.8; |P+| = 0.6;

Distinction among the New Physics models

- Generic consideration - processes with s-, t-, u-channels
  identification reaches

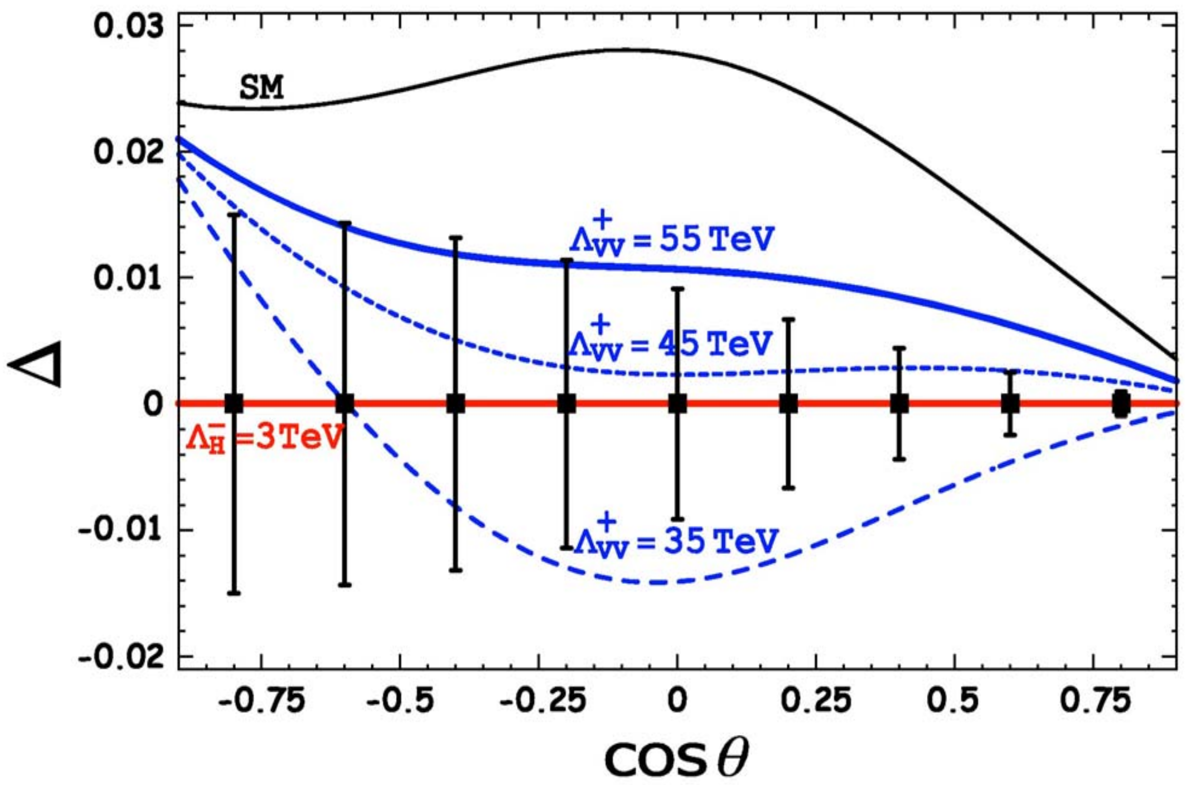
- Assumption: One of the models, say the ADD, is found consistent
  with experimental data with some value of Λ_H

- Deviations of observables from the ADD model prediction due to
  other models (say, the **CI** ones):

$$\tilde{\Delta}(\mathcal{O}) = \frac{\mathcal{O}(CI) - \mathcal{O}(ADD)}{\mathcal{O}(ADD)}$$

- assess the level at which ADD is distinguishable from the other models

Example: CI=VV (ADD vs. VV)



- **Region of confusion** of ADD with VV model determined by:

$$\tilde{\chi}^2(\mathcal{O}) = \sum_{\{P^-,\ P^+\}} \sum_{\text{bins}} \left(\frac{\tilde{\Delta}(\mathcal{O})^{\text{bin}}}{\tilde{\delta}\mathcal{O}^{\text{bin}}} \right)^2 \leq 3.84 \quad (95\%\ \text{C.L.})$$

Model-independent CI considerations

General case: for given f CI interaction could be any linear combination of individual models $[\Lambda_{\rm LL}, \Lambda_{\rm RR}, \Lambda_{\rm RL}, \Lambda_{\rm LR}]$

All $\Lambda_{\alpha\beta}$ and Λ_H simultaneously in deviation

$$\tilde{\Delta}(\mathcal{O}) = \frac{\mathcal{O}(\Lambda_{LL}, \Lambda_{RR}, \Lambda_{RL}, \Lambda_{LR}) - \mathcal{O}(\Lambda_H)}{\mathcal{O}(\Lambda_H)}; \quad \tilde{\chi}^2(\mathcal{O}) = \sum_{\{P^-,\ P^+\}} \sum_{\rm bins} \left(\frac{\tilde{\Delta}(\mathcal{O})^{\rm bin}}{\tilde{\delta}\mathcal{O}^{\rm bin}} \right)^2.$$

Confusion region in multi-parameter space:

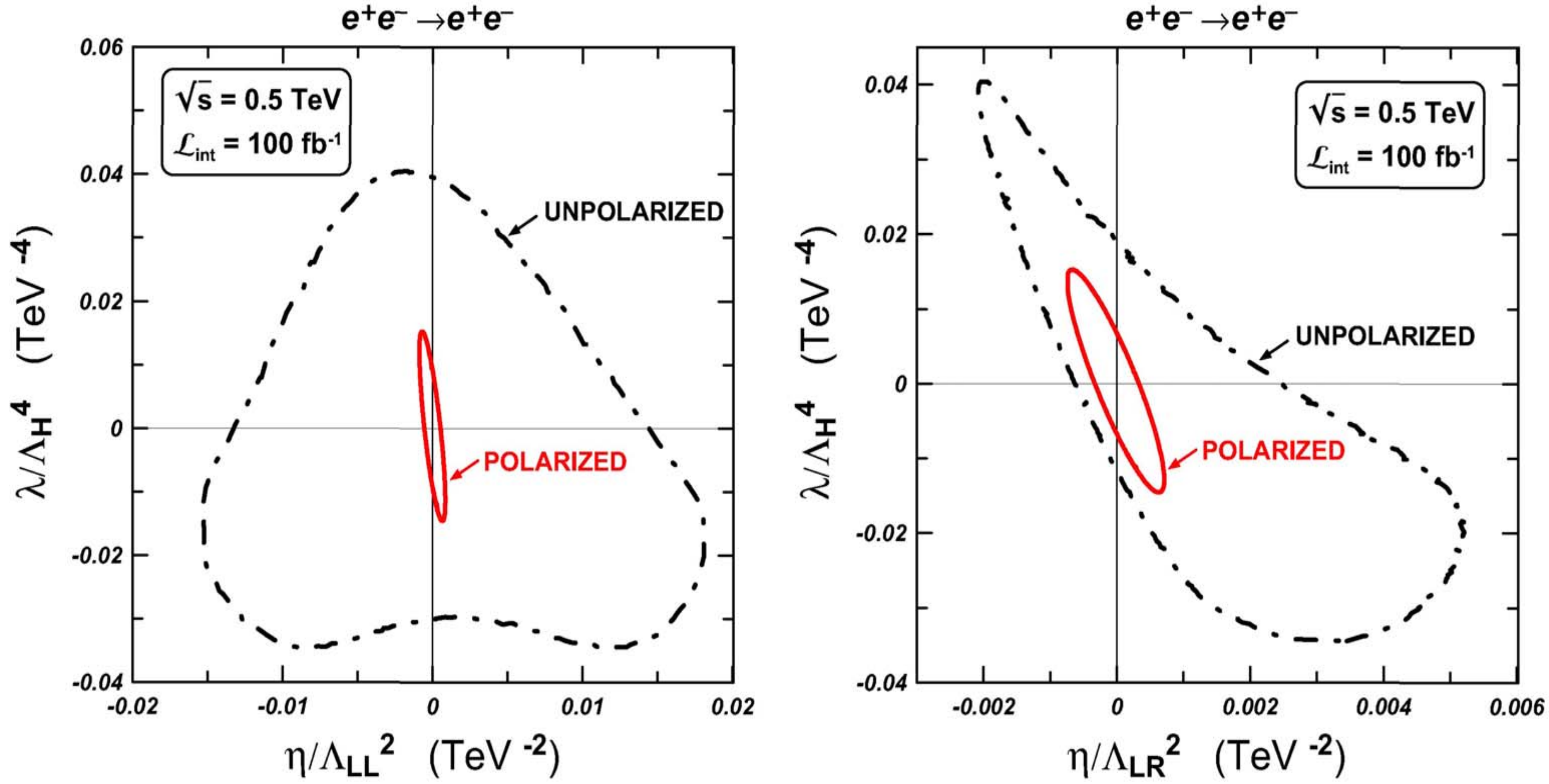
$$\tilde{\chi}^2 \leq \tilde{\chi}^2_{\rm CL}$$

Here, for 95% C.L.:

Bhabha scattering: $\tilde{\chi}^2_{\rm CL} = 7.82$

Annihilation $\bar{f}f$ channels ($f = \mu, \tau, c, b$): $\tilde{\chi}^2_{\rm CL} = 9.49$

Two-dimensional projection of the 95% C.L. confusion region onto the planes ($\eta_{\rm LL}/\Lambda^2_{\rm LL}$, λ/Λ^4_H) (left panel) and ($\eta_{\rm LR}/\Lambda^2_{\rm LR}$, λ/Λ^4_H) (right panel) obtained from Bhabha scattering with unpolarized beams (dot-dashed curve) and with both beams polarized (solid curve).



Model-independent ID reach for ADD model

95% CL identification reach on ADD model parameter Λ_H obtained from $e^+e^- \to \bar{f}f$ at two configurations of polarizations: $(|P^+|,|P^-|)$=(0,0) and (0.8, 0.6) respectively.

Λ_H^{ID} (TeV)	Process			
	$e^+e^- \to e^+e^-$	$e^+e^- \to l^+l^-$	$e^+e^- \to \bar{c}c$	$e^+e^- \to \bar{b}b$
$\sqrt{s} = 0.5$ TeV, $\mathcal{L}_{\mathrm{int}} = 10^2 fb^{-1}$	2.2; 2.9	2.3; 2.3	2.3; 2.4	2.6; 2.9
$\sqrt{s} = 1.0$ TeV, $\mathcal{L}_{\mathrm{int}} = 10^3 fb^{-1}$	5.0; 6.4	4.9; 5.1	5.1; 5.3	5.8; 6.2

Conclusions

- Fermion pair production is a powerful tool to search for new phenomena at the ILC
- e^-, e^+ polarization increases sensitivity to NP depending on NP model and channel
- Model-dependent sensitivity reach (95% C.L.) with $\mathrm{d}\sigma(\mathrm{P}^+,\mathrm{P}^-)/\mathrm{d}\cos\theta$
  - enhancement: $\Lambda^{pol}/\Lambda^{unp} \sim 1.1 - 1.4$
  - CI: eeqq, eell $\Lambda > (100 - 200) \cdot \sqrt{s}$
  - ADD: $\Lambda_H > 9 \cdot \sqrt{s}$
  - TeV^{-1}: $M_C > 55 \cdot \sqrt{s}$
- Model-independent sensitivity reach
  - ILC $(P^\pm = 0)$ vs. LEP2: minor improvement in sensitivity to NP $\Rightarrow \Lambda^{unp} \geq 3 - 10$ TeV
  - ILC $(P^\pm \neq 0)$: substantial improvement in sensitivity, $\Lambda^{pol}/\Lambda^{unp} \sim 2.5 - 30!$
  - CI: $\Lambda > (100 - 130) \cdot \sqrt{s}$

- If New Physics effects are discovered, it is crucial to have good search strategies to determine its origin.

- Example: distinction between ADD model and "conventional" CI (model independent consideration)

Identification reach (95% CL) depending on the ILC energy and luminosity:

$$\Lambda_H = 2.9 - 6.4 \text{ TeV}$$

- LHC vs. ILC
  - LHC eeqq, eejj ($\Lambda > 30 - 50$ TeV)
    ILC eeqq, eell ($\Lambda > 50 - 200$ TeV) $\Rightarrow$ complementary - not competing
  - LHC:
    model-dependent analysis (CI) is feasible (D-Y)
    model-indenpendent analysis (CI) is unfeasible
    (too many CI parameters)
  - LHC:
    identification of spin-2 particle exchange – center-edge asymmetry
    $A_{CE} \Rightarrow$ complementary