Distinguishing s-channel resonances At the ILC

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Many Models of New Physics

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- Little Higgs $W_H^{\pm} \quad Z_H \quad B_H$

- Extra dimensions (ADD, RS, UED...): KK excitations
  - ADD: Graviton tower exchange effective operators: $i\frac{4\lambda}{M_H^4}T^{\mu\nu}T_{\mu\nu}$
  - Randall-Sundrum Gravitons: Discrete KK graviton spectrum

- Extended gauge sectors
  - Extra U(1) factors: $E_6 \to SU(5) \times U(1)_\chi \times U(1)_\psi$
  - Left-Right symmetric model: $SU(2)_L \times SU(2)_R \times U(1)$

- Topcolour

Many, many models

What do these models have in common?

- Almost all of these models have new s-channel structure at ~TeV scale
- Either from extended gauge bosons or new resonances

How do we distinguish the models?

How do we distinguish them?

Start by assuming the LHC discovers single rather heavy resonance

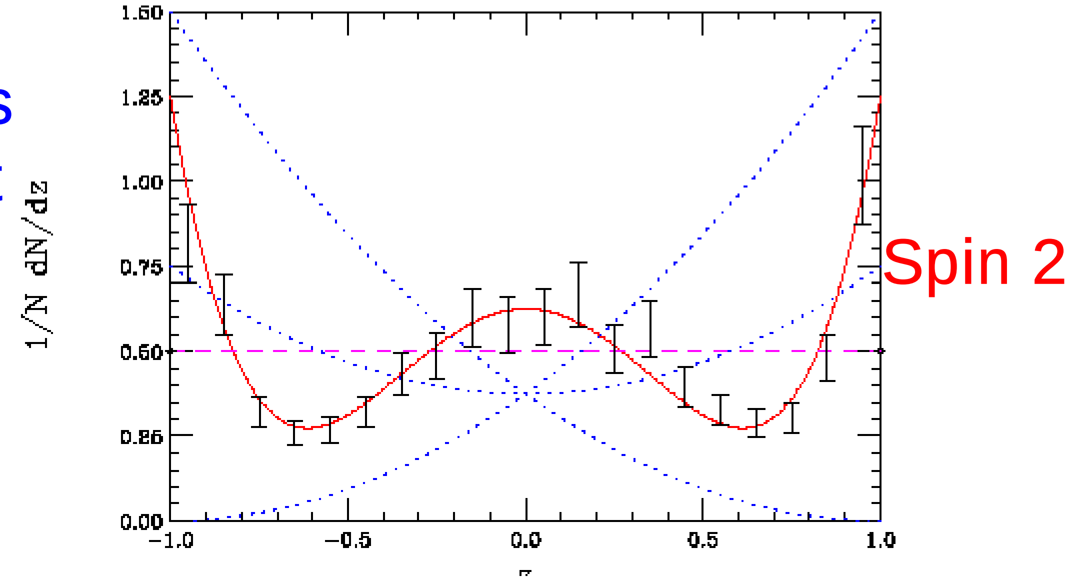
What is it?

Tools are:

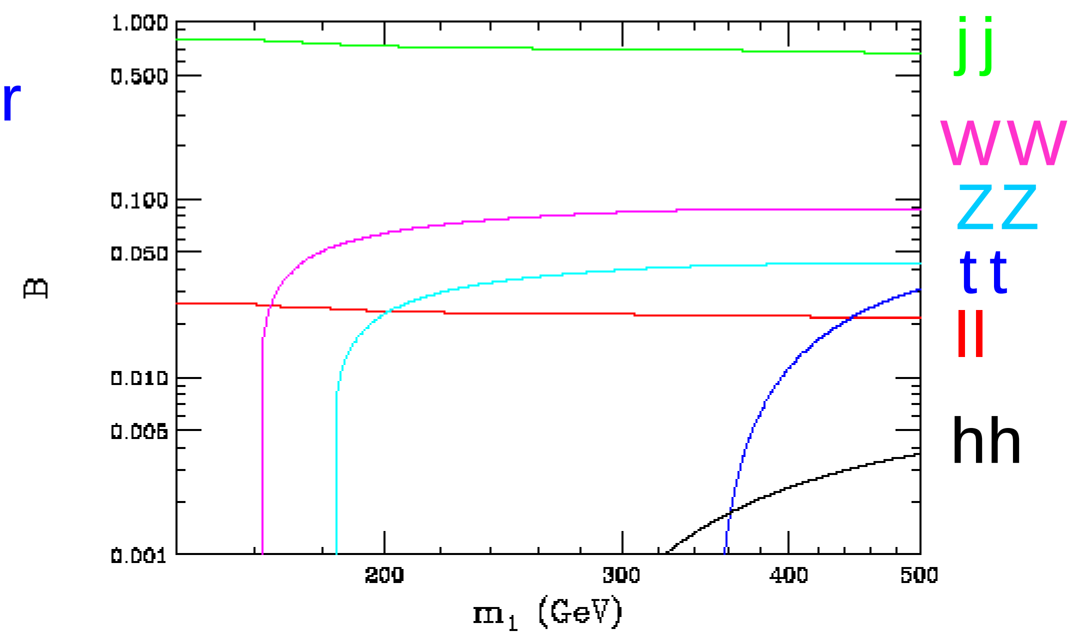
- Cross sections & Widths
- Angular Distributions
- Couplings (decays, polarization…)

On resonance production of (RS) Gravitons

Use angular distributions to test against different spin hypothesis



Measure BR's to test for Universal couplings



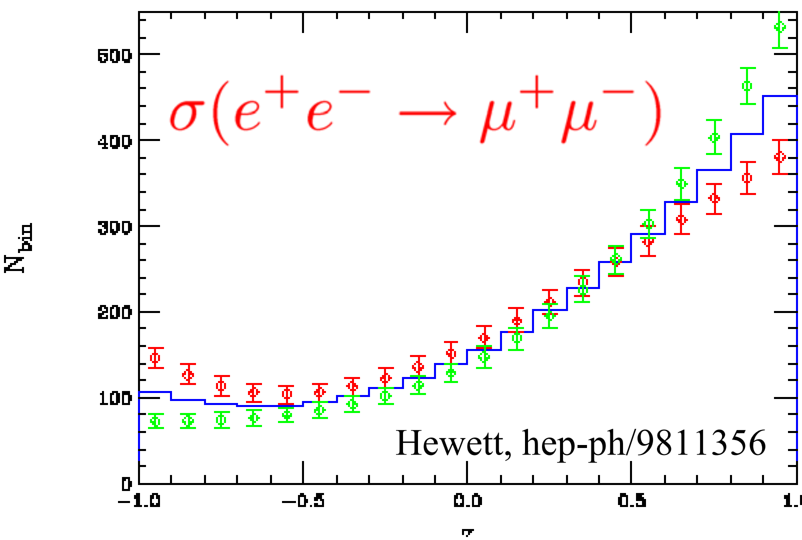
Davoudiasl, Hewett and Rizzo, Phys. Rev. D63, 075004 (2001) [hep-ph/0006041].

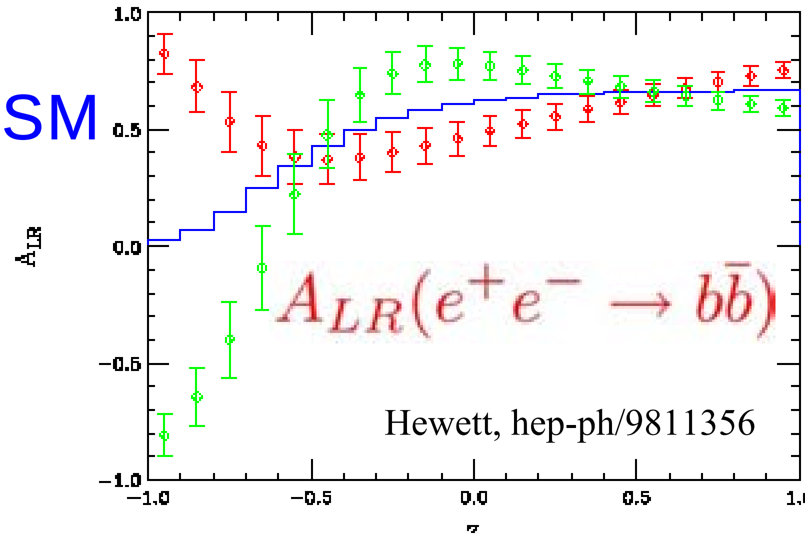
Indirect Signatures for Gravitons

Interference of exchange of virtual graviton KK states with SM amplitudes

ADD: $i\frac{4\lambda}{M_H^4}T^{\mu\nu}T_{\mu\nu}$

Leads to deviations in $e^+e^- \to f\bar{f}$ dependent on both λ and s/M_H





$\sqrt{s} = 5$ TeV $\quad L = 1\ \text{ab}^{-1} \quad M_s = 15$ TeV $\quad \lambda = \pm 1$

Can use multipole moments to distinguish spin 2 from spin 1

Rizzo: hep-ph/0208027

ID ADD Graviton Exchange

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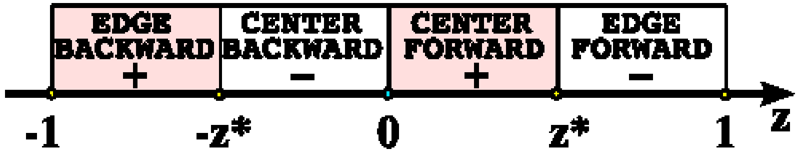
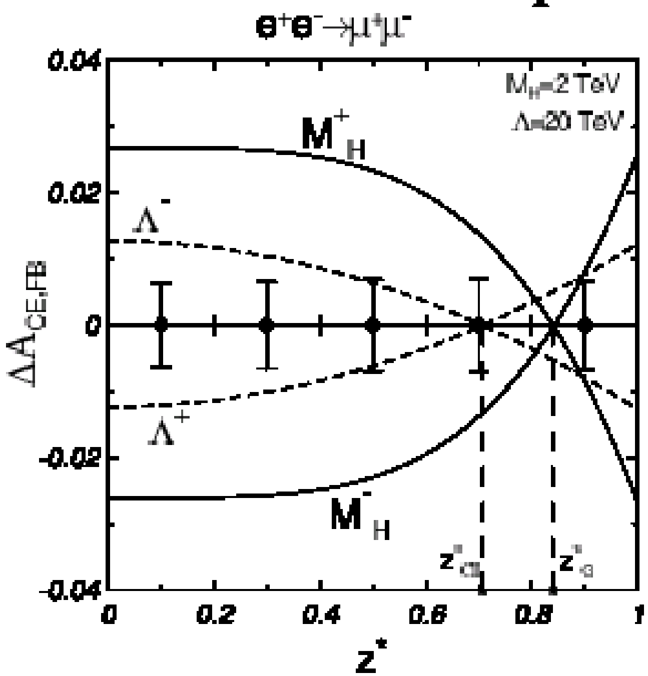
Pankov & Paver hep-ph/0501170

Suitable observables can divide possible models into subclasses

- To identify graviton exchange
- Forward-Backward Centre-Edge asymmetries: $\sigma_{CE,FB} = \sigma_{C,FB} - \sigma_{E,FB}$





LC: 5σ ident. reach on $M_H = 3.5 - 5.8$ TeV at $\sqrt{s} = 0.5 - 1$ TeV and $\mathcal{L}_{\rm int} = 500\ fb^{-1}$

Numerous difermion observables

18 di-fermion observables:

σ^μ

A^μ_{FB}

A^μ_{LR}

$A^\mu_{FB}(pol)$

σ^τ

A^τ_{FB}

A^τ_{LR}

P_τ

R^{had}

A^{had}_{LR}

σ^b

A^b_{FB}

A^b_{LR}

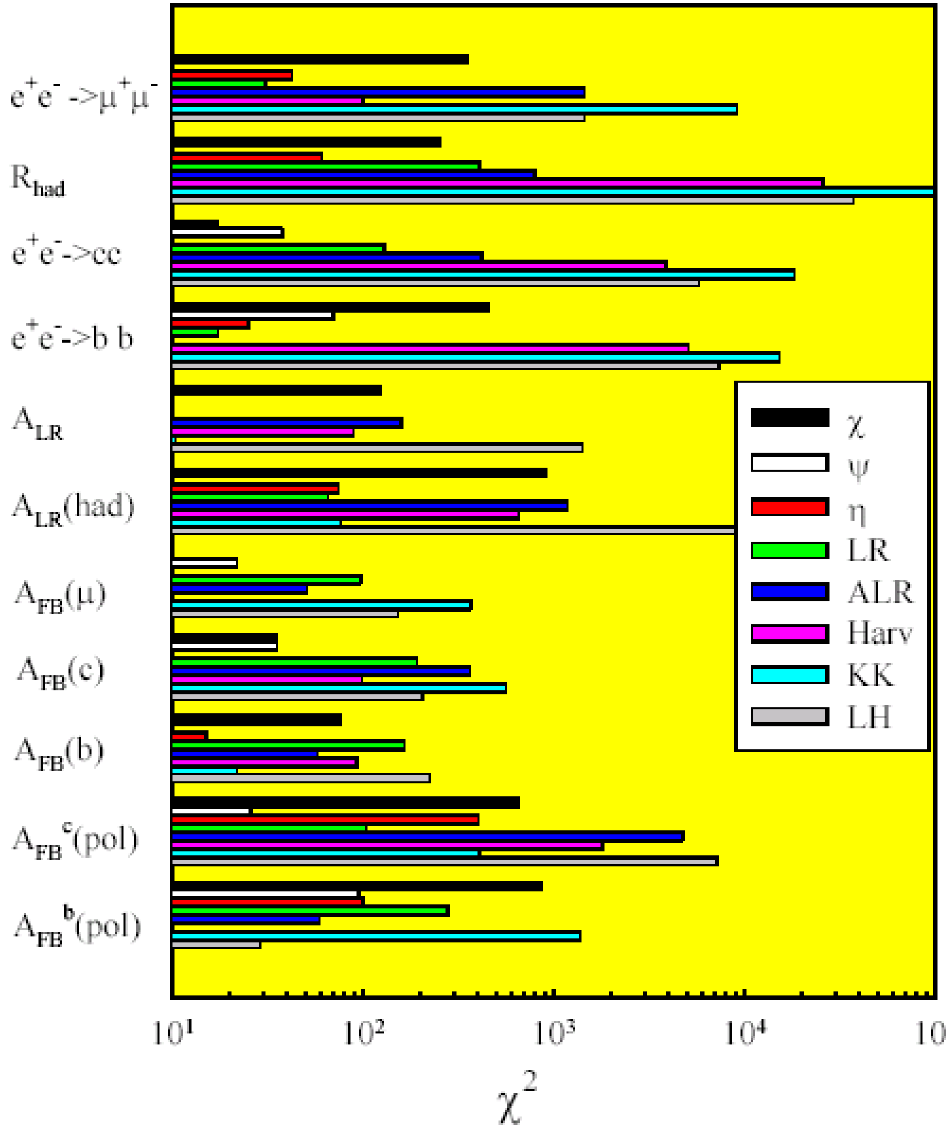
$A^b_{FB}(pol)$

σ^c

A^c_{FB}

A^c_{LR}

$A^c_{FB}(pol)$



Z' couplings

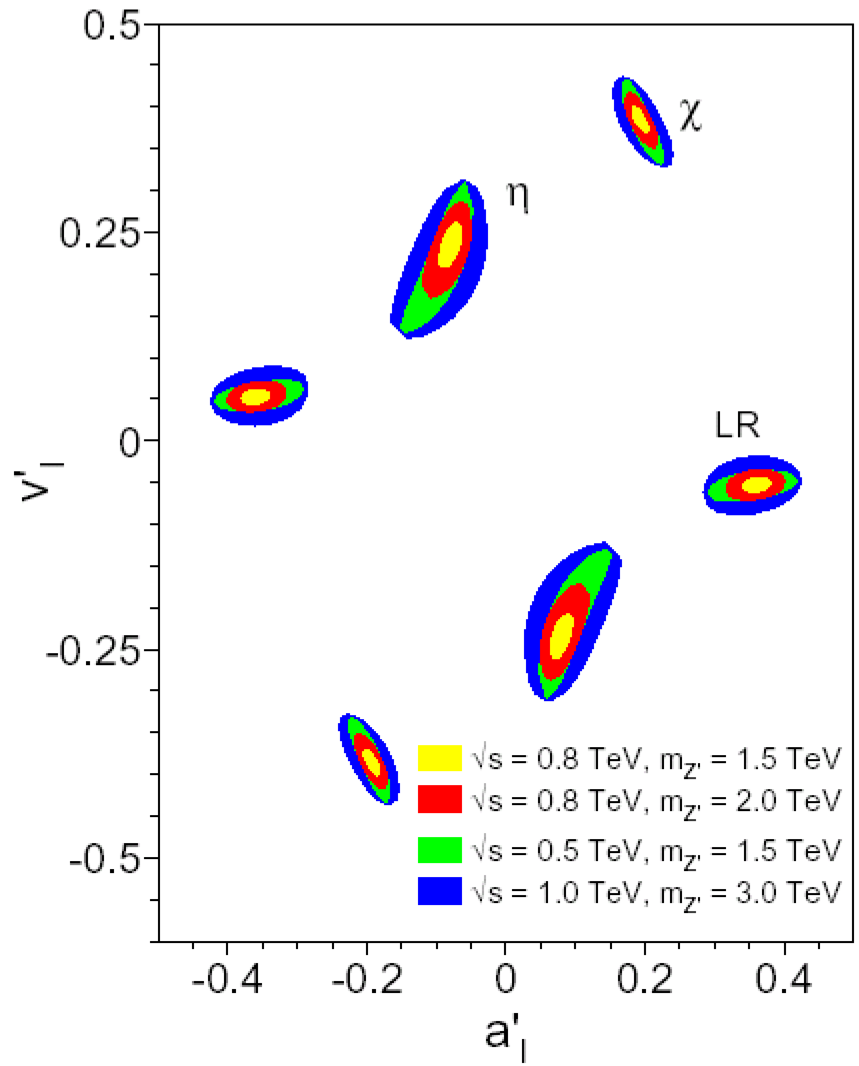
Extraction of Z' couplings
assuming $M_{Z'}$ is known from LHC

$\sigma^{\mu}_{P_e^- P_e^+}$ A^{μ}_{FB} A^{μ}_{LR}

95% C.L. bounds

L=1 ab^{-1} ΔL=0.2%, P_-=0.8, P_+=0.6, ΔP=0.5%

Note sign ambiguity



S. Riemann: TESLA TDR & LHC/LC Study

1. Can we resolve the sign ambiguity?

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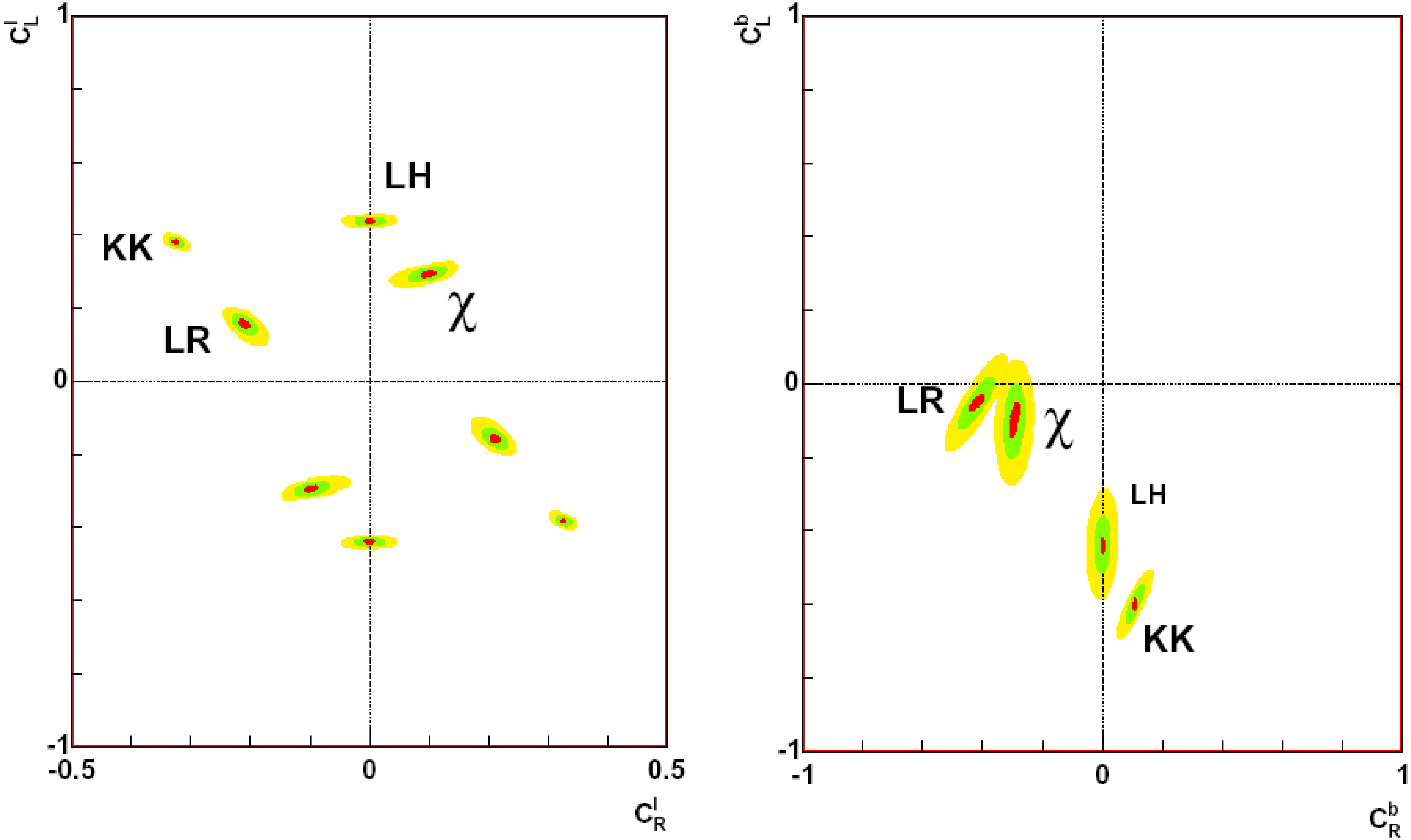
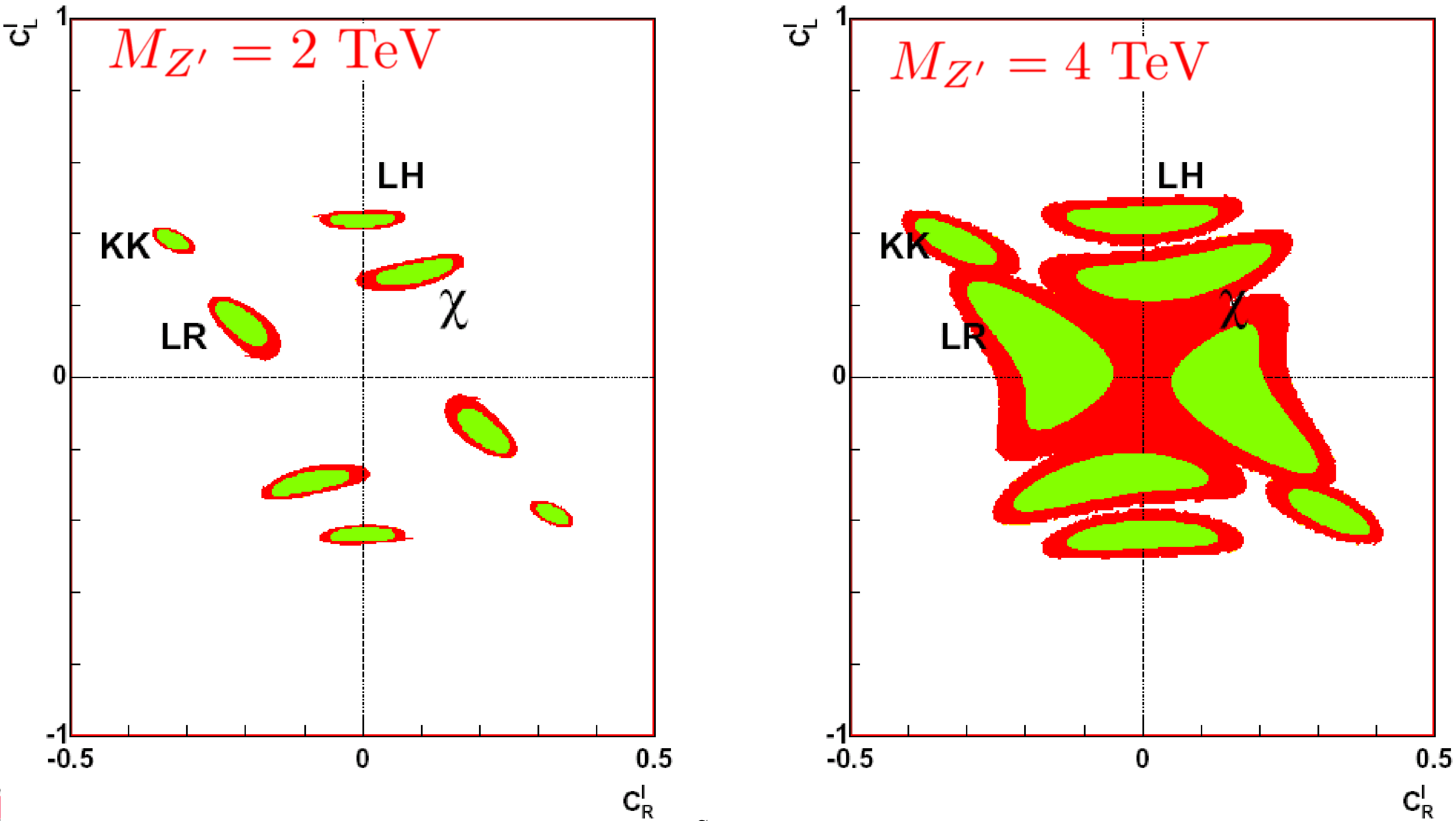
$\sqrt{s} = 500$ GeV $\quad \mathcal{L}_{int} = 1\ \mathrm{ab}^{-1} \quad M_{Z'} = 1,\ 1.5,\ 2$ TeV



2. How does it change with more observables?

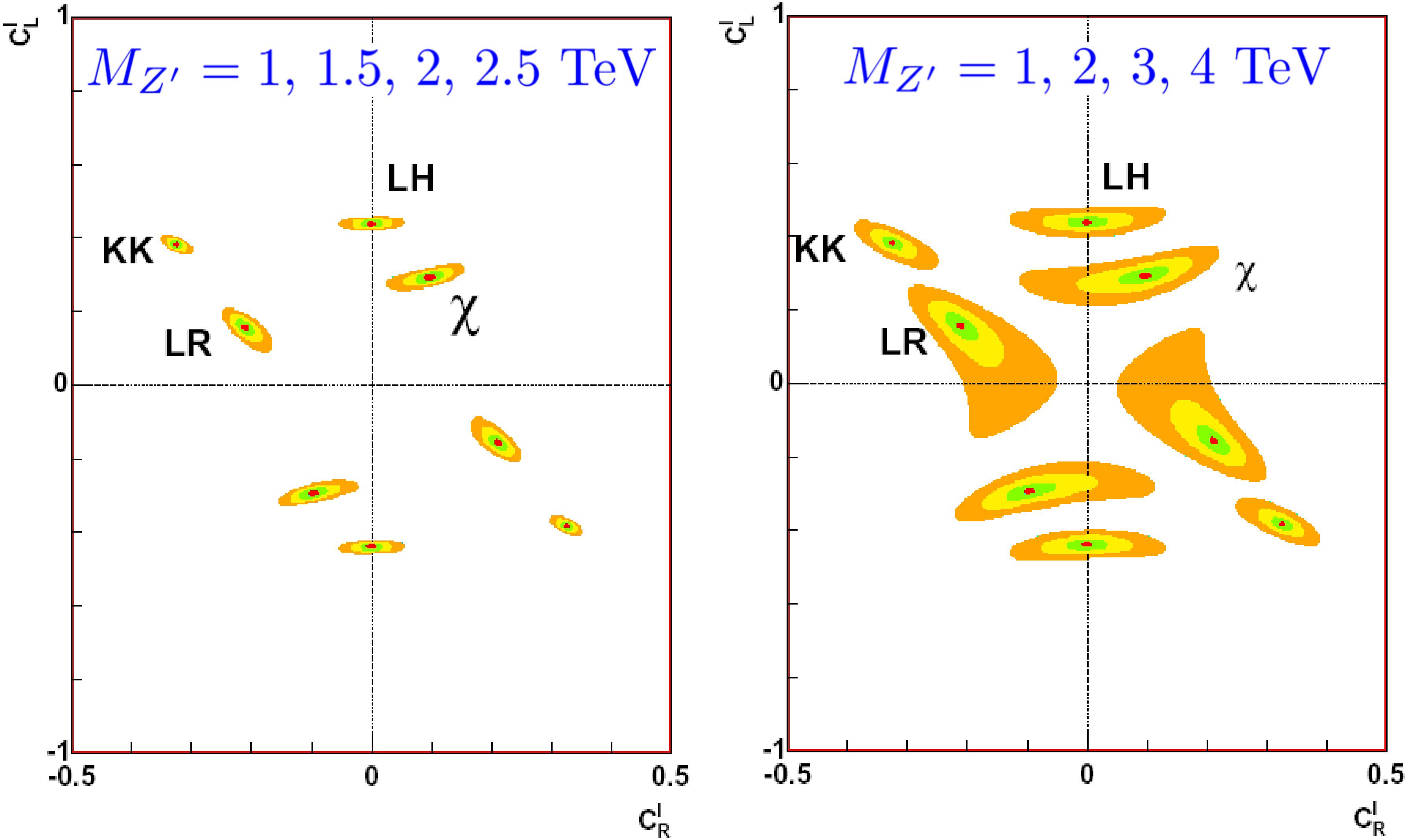
$$\sqrt{s} = 500 \text{ GeV} \quad \mathcal{L}_{int} = 1 \text{ ab}^{-1}$$

$\sigma^\mu \; A^\mu_{FB} \; A^\mu_{LR}$ $\qquad$ $\sigma^\mu \; A^\mu_{FB} \; A^\mu_{LR} \; A^\mu_{FB}(pol) \; \sigma^\tau \; A^\tau_{FB} \; A^\tau_{LR} \; P_\tau$



3. What happens for higher mass?

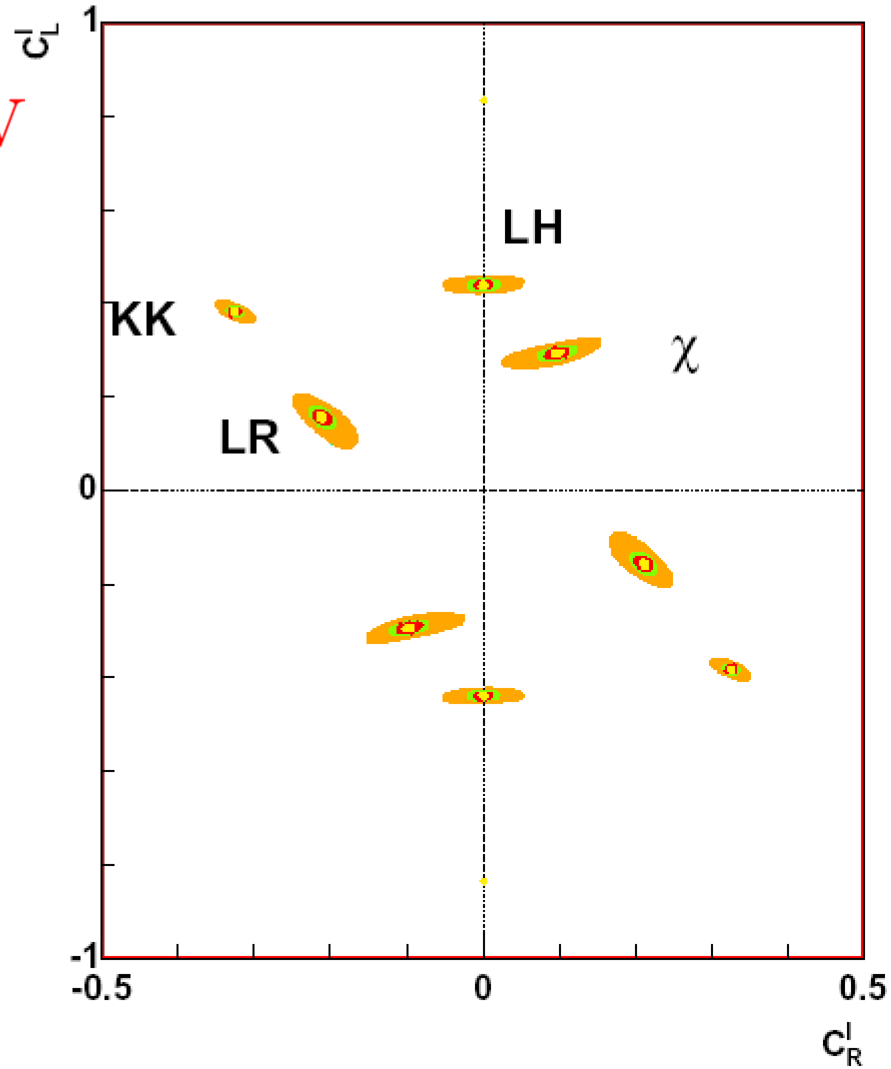
$\sqrt{s} = 500$ GeV $\mathcal{L}_{int} = 1$ ab^{-1}



4. What happens with higher energy?

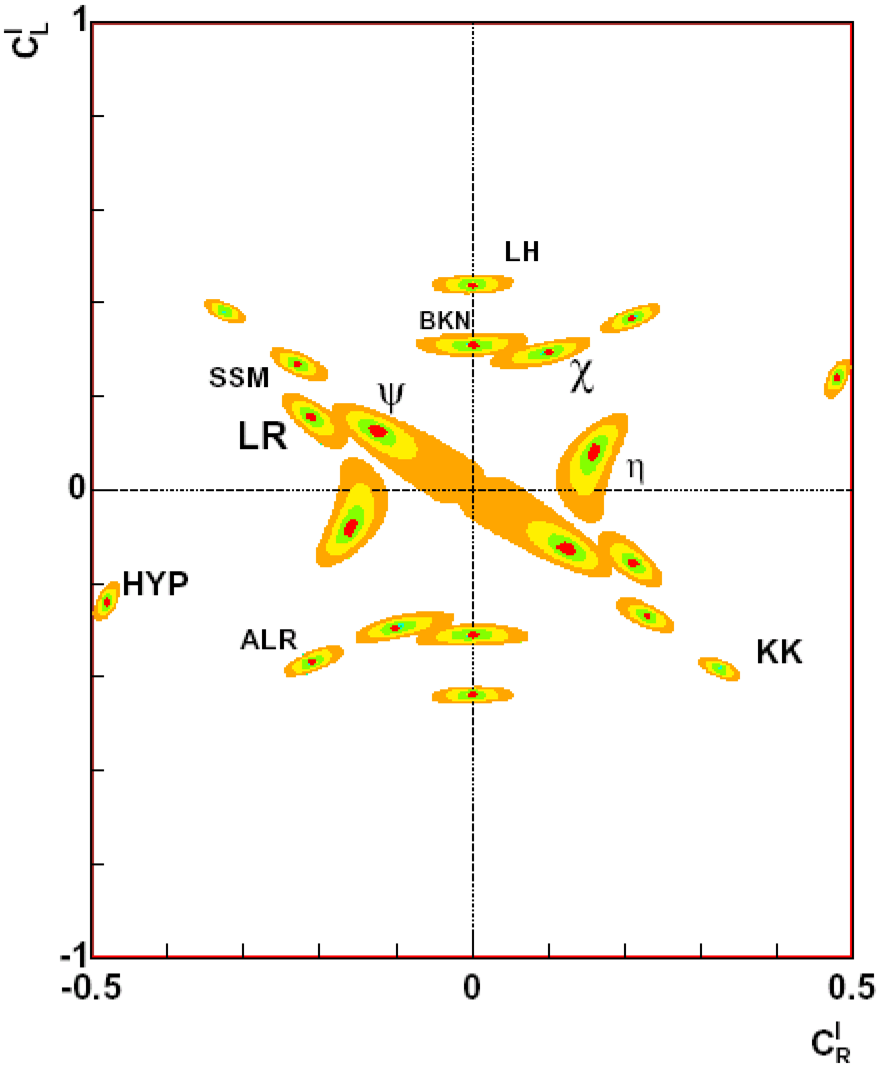
$M_{Z'} = 2.5$ TeV

$\sqrt{s} = 500,\ 800,\ 1000,\ 1500$ GeV

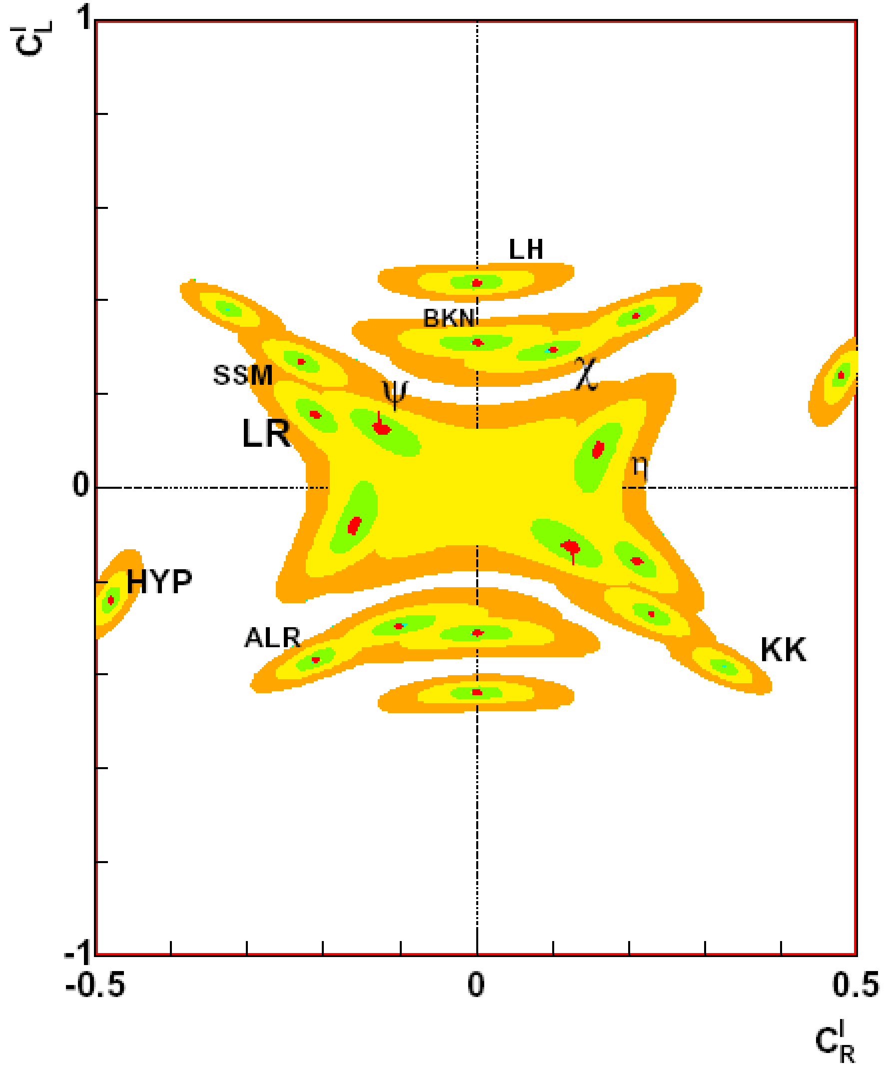


The “Peskin Plot”

$M_{Z'} = 1,\ 1.5,\ 2,\ 2.5$ TeV



$M_{Z'} = 1,\ 2,\ 3,\ 4$ TeV



$$\sqrt{s} = 500\ \text{GeV}\quad \mathcal{L}_{int} = 1\ \text{ab}^{-1}$$

Summary

The ILC will be an extremely powerful tool for understanding a resonance discovered at the LHC