Search for Z' Present and Future

The LHC/LC Study group meeting
CERN

F. Richard LAL July 2002

Introduction

At Saint Malo 2 examples of LHC/LC complementarity were given:

- Assume that a mass peak is observed at LHC in l^+l^- : is it a Z' ? of which type ? is it a KK of Z/γ ?
- Assume that LHC finds a Higgs mass incompatible with LEP/Tevatron prediction

$\Rightarrow$Can FLC solve the puzzle ?

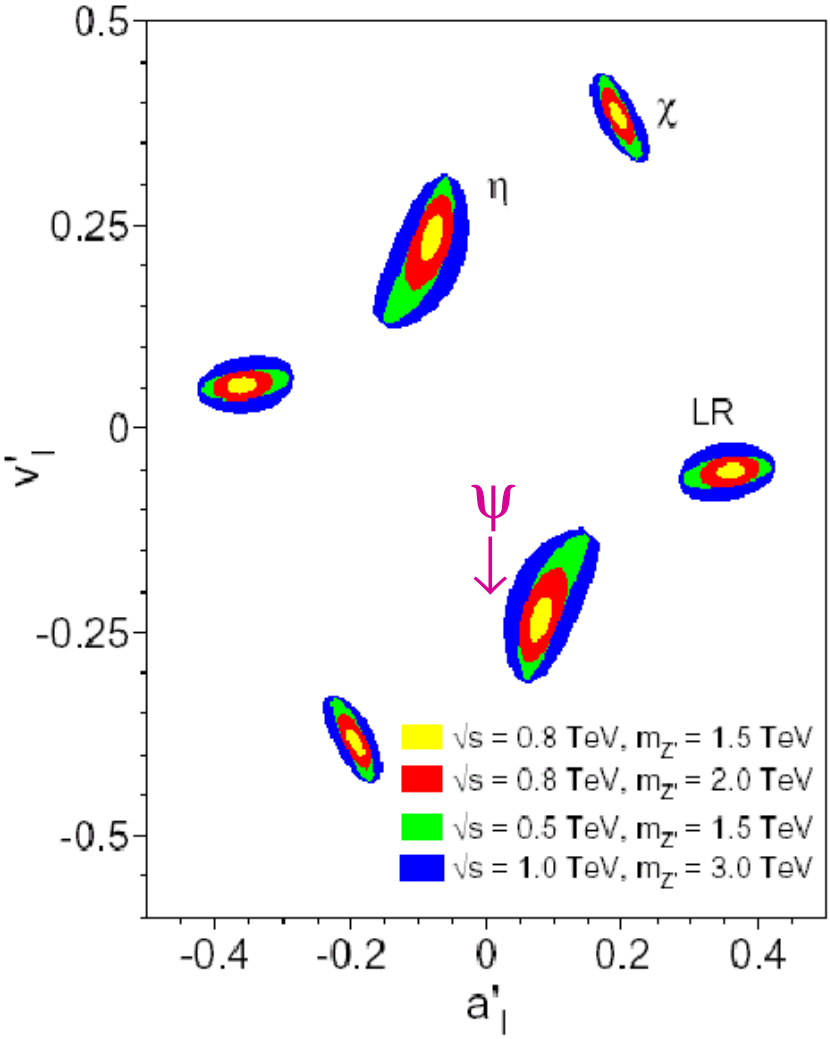
$\Rightarrow$Could this new input have an impact on LHC or Super-LHC ?

- In this talk, I will illustrate these ideas starting from LEP/SLD data

TeV ND>4 γ+Z

A'=-1.08 V'=-1.81

For leptons



J.L.Hewett et al hep/0203091

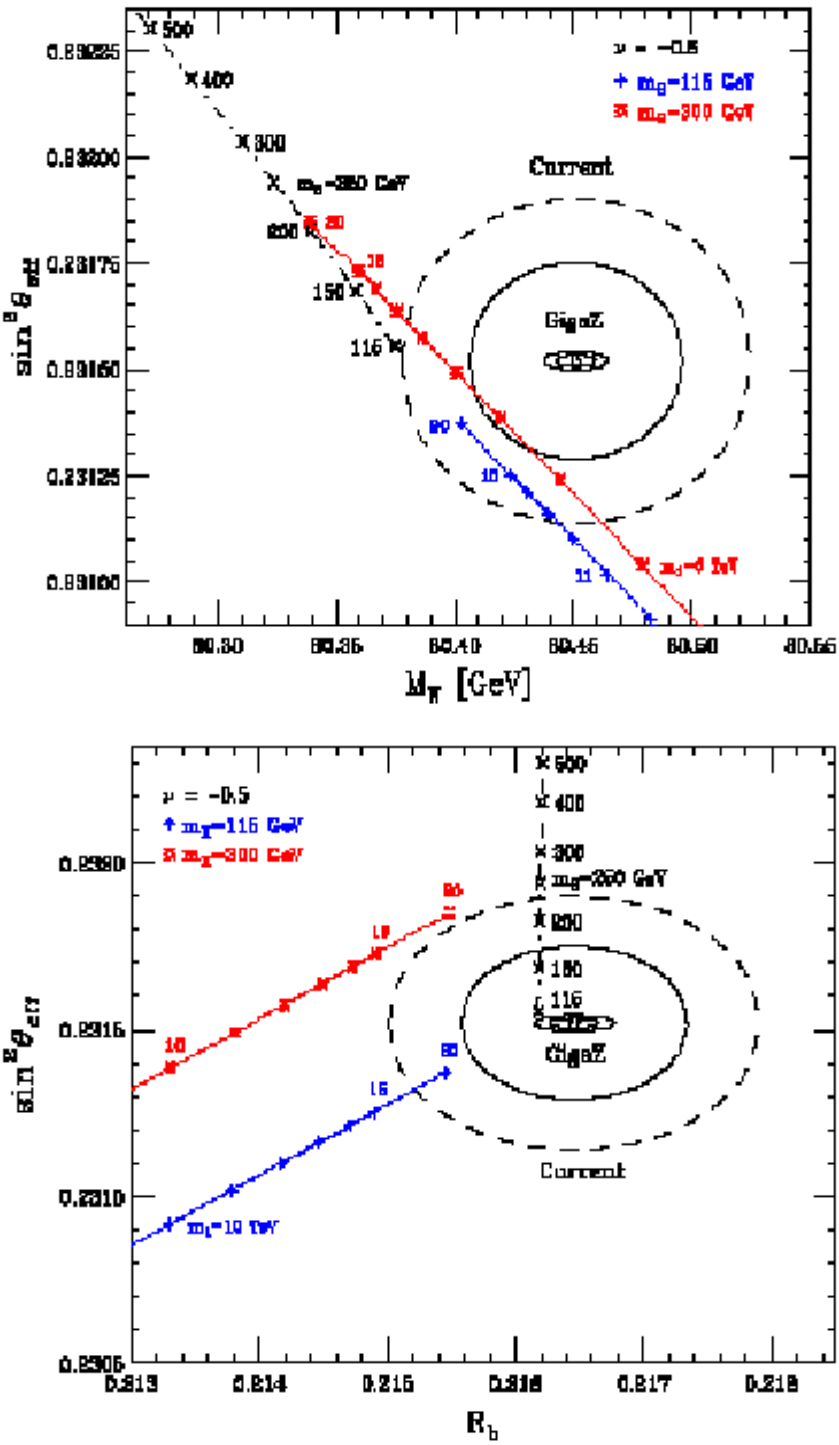
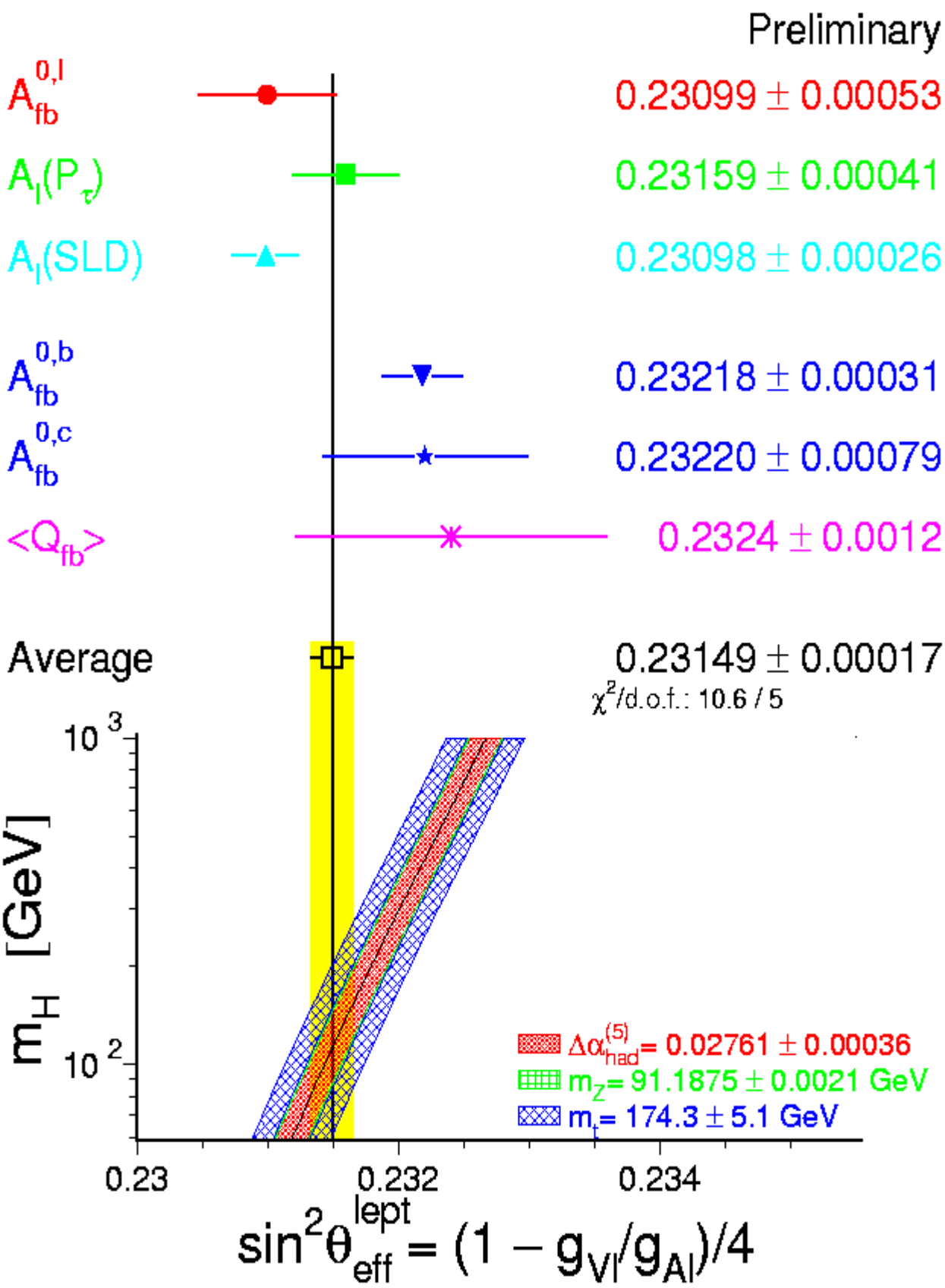


Figure 10: Plots of the $\sin^2\theta_{eff}$ versus M_W plane (top) and $\sin^2\theta_{eff}$ versus R_b plane (bottom) showing current and future sensitivities, SM predictions, and RS model predictions. The diamonds show the current measured values. The large solid and dashed ellipses represent respectively the 68% and 95% CL regions from current sensitivities, while the smaller solid ellipses anticipate the same after operation of GigaZ. The black dashdot lines show the SM

LEP1 SLD results

- With LEP1/SLD leptonic asymmetries
  m_H ~40 GeV
- Same is true from W mass
- Correlated effects through m_t
  $\rightarrow$ <2σ significance
- Speculative studies going on, e.g.
  G. Altarelli et al. SUSY
  V.A. Novikov New generation
- What about a Z' ?
- A^b_{FB} gives m_H ~600 GeV 3σ effect

$\Rightarrow$New physics or experimental bias ?
Discussion postponed but from now on this result is ignored.



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A Z' Scenario

- Extended GUT groups like E_6 'superstring inspired' or SO(10) predict $Z'_{\psi/\chi}$ or Z_R W_R
- Several other motivations like

ν_R, LR symmmetry, μ problem…

- No definite mass predictions: SB in steps, at GUT scale, with some subgroups possibly unbroken down to 1TeV
- Also true e.g. in D-brane string models (Ibanez et al hp0205083)
- A Z' at 1TeV allows for a heavy Higgs boson (Peskin and Wells)

$\Rightarrow$Seems ideally suited to explain an apparent light H at LEP1/SLD

Formulas

Peskin Wells
hep/0101342

$$m^2 = \begin{pmatrix} m^2 & \gamma m_Z^2 \\ \gamma m_Z^2 & M^2 \end{pmatrix} , \qquad \delta = \gamma^2 \frac{m_Z^2}{M^2} , \qquad \xi = \gamma \frac{m_Z^2}{M^2}$$

$$\begin{aligned} \Delta m_W &= 57.\,\delta \quad (\mathrm{GeV}) \\ \Delta \sin^2 \theta_w^{\mathrm{eff}} &= -0.33\,\delta + 0.22\,q_L \xi + 0.26\,q_R \xi \\ \Delta \Gamma_\ell &= 100\,\delta - 170\,q_L \xi + 150\,q_R \xi \quad (\mathrm{MeV}) \end{aligned}$$

Complementary observables

$$q_L = \cos\theta \frac{3}{2\sqrt{6}} + \sin\theta \frac{1}{6}\sqrt{\frac{5}{2}}$$

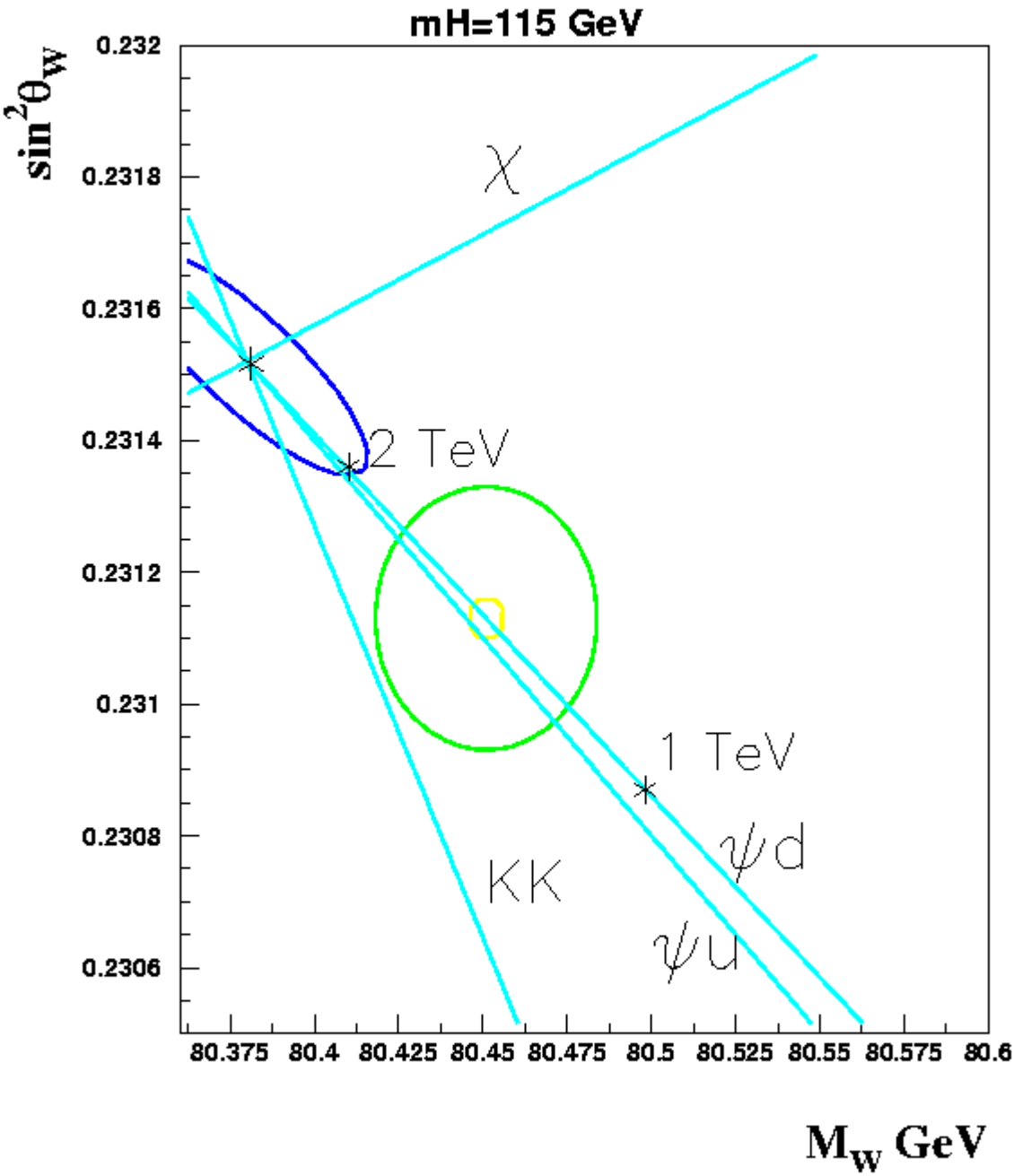
$$q_R = \cos\theta \frac{1}{2\sqrt{6}} - \sin\theta \frac{1}{6}\sqrt{\frac{5}{2}} ,$$

θ=0 Zχ

θ=π/2 Zψ axial

$$\gamma = 2s \sin^2\beta (\cos\theta \frac{1}{\sqrt{6}} - \sin\theta \sqrt{\frac{5}{18}}) + 2s \cos^2\beta (\cos\theta \frac{1}{\sqrt{6}} + \sin\theta \sqrt{\frac{5}{18}})$$

→Mixing in most cases



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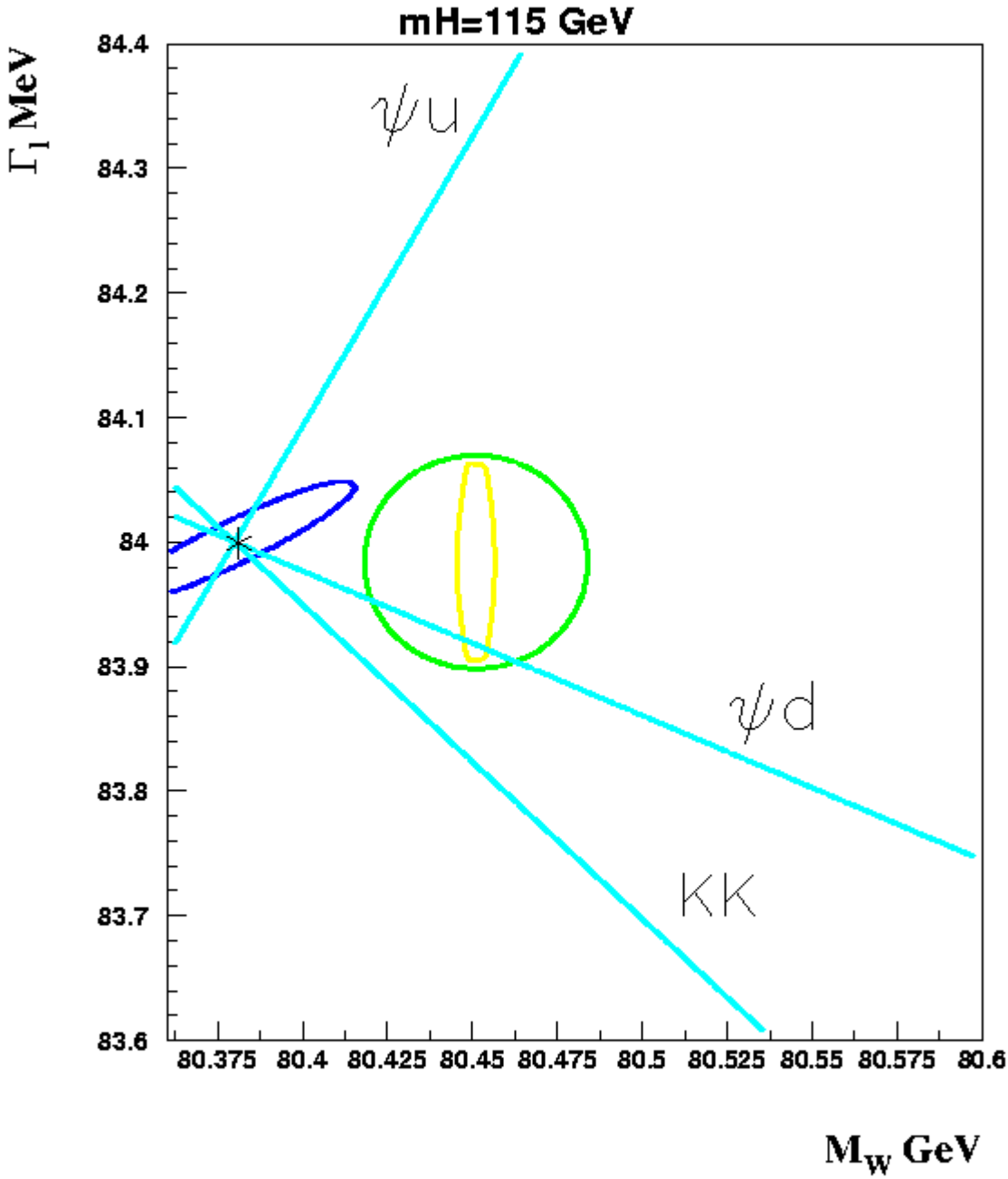

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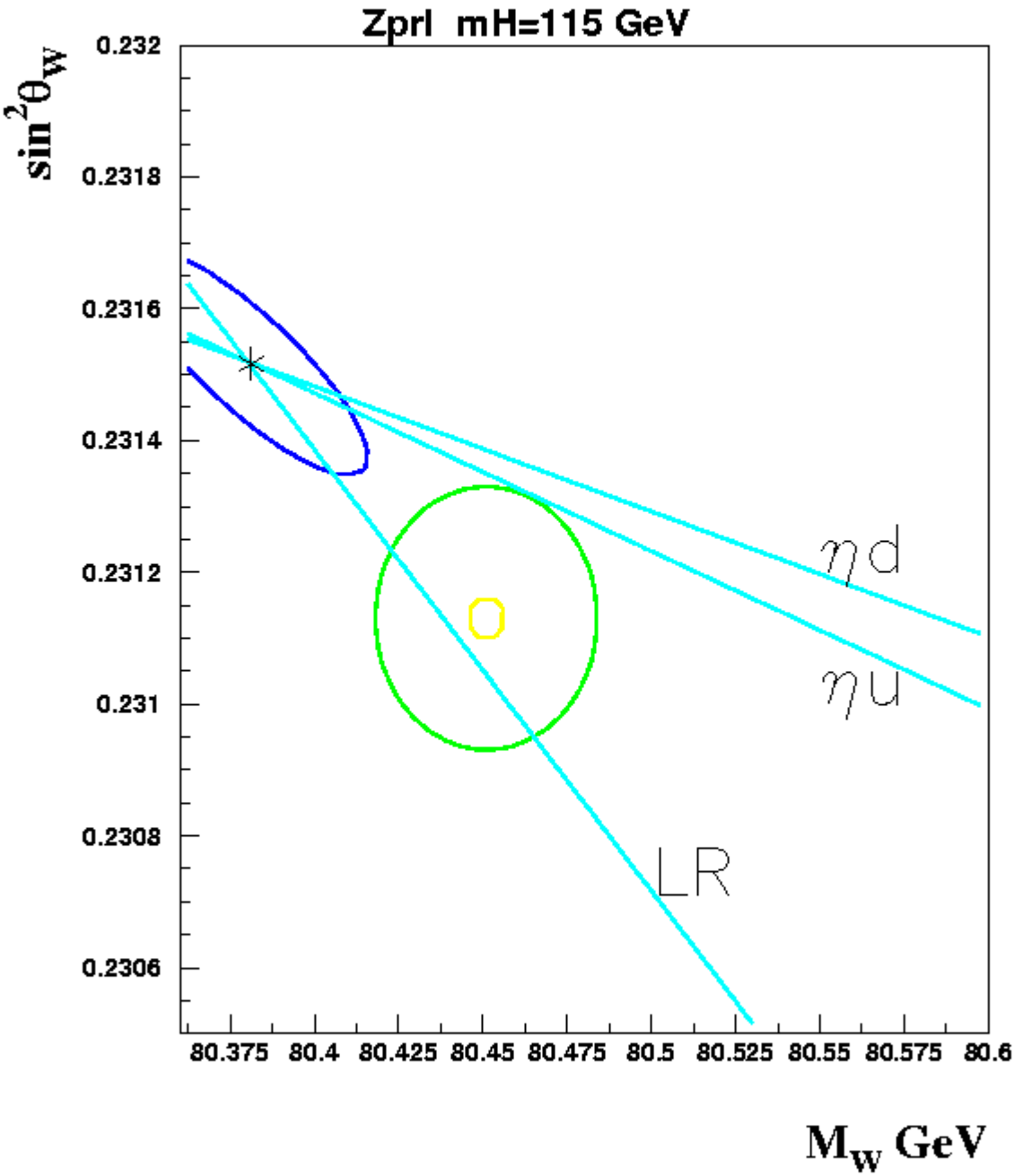

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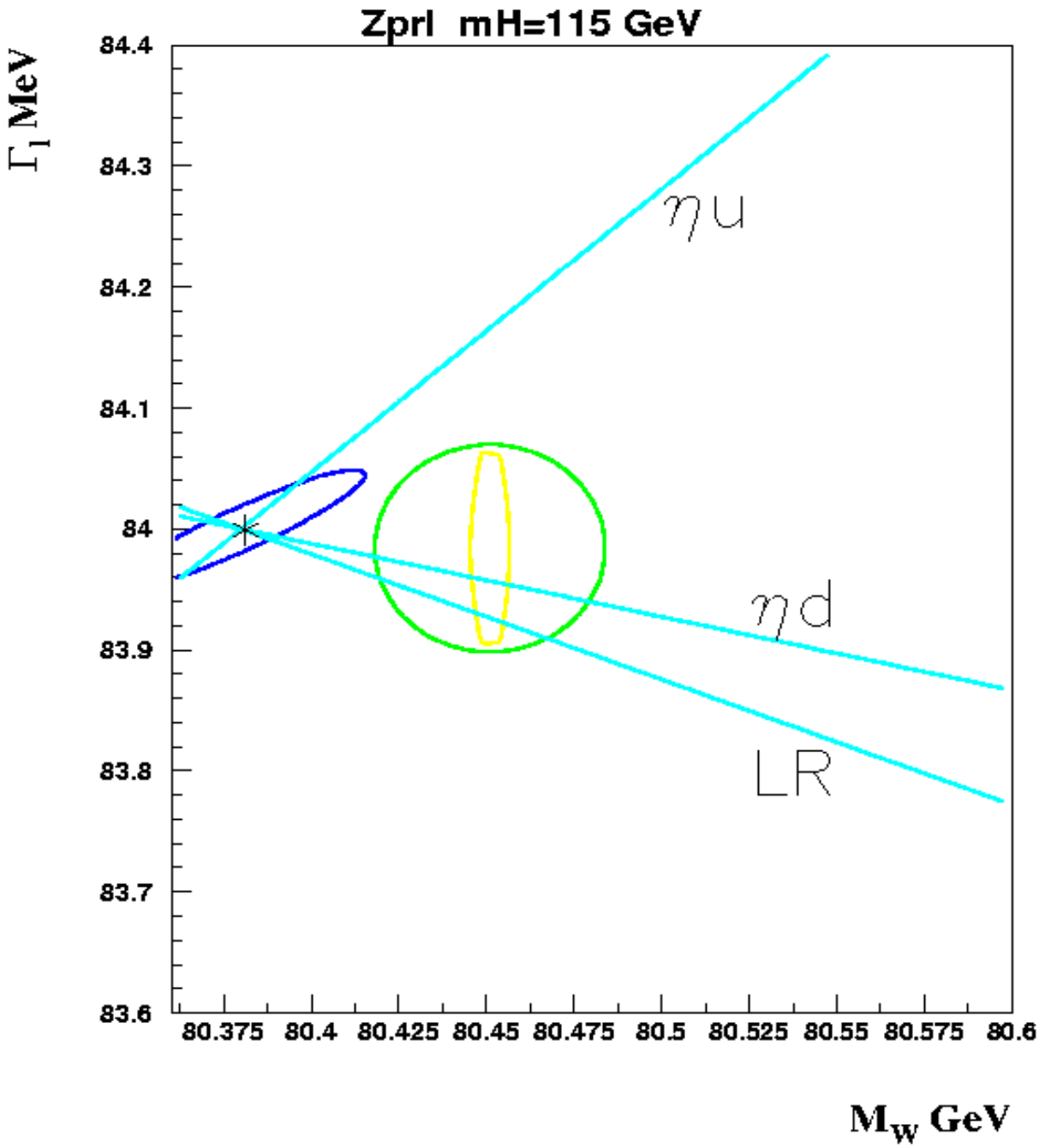

Zprl mH=115 GeV
Γ_l MeV
84.4
84.3
84.2
84.1
84
83.9
83.8
83.7
83.6
80.375
80.4
80.425
80.45
80.475
80.5
80.525
80.55
80.575
80.6
M_W GeV
ηu
ηd
LR

Z' at LEP1/SLD

Using combined LEP1/SLD data:

- $m_{Z'}$ =1.3TeV and ψ_d

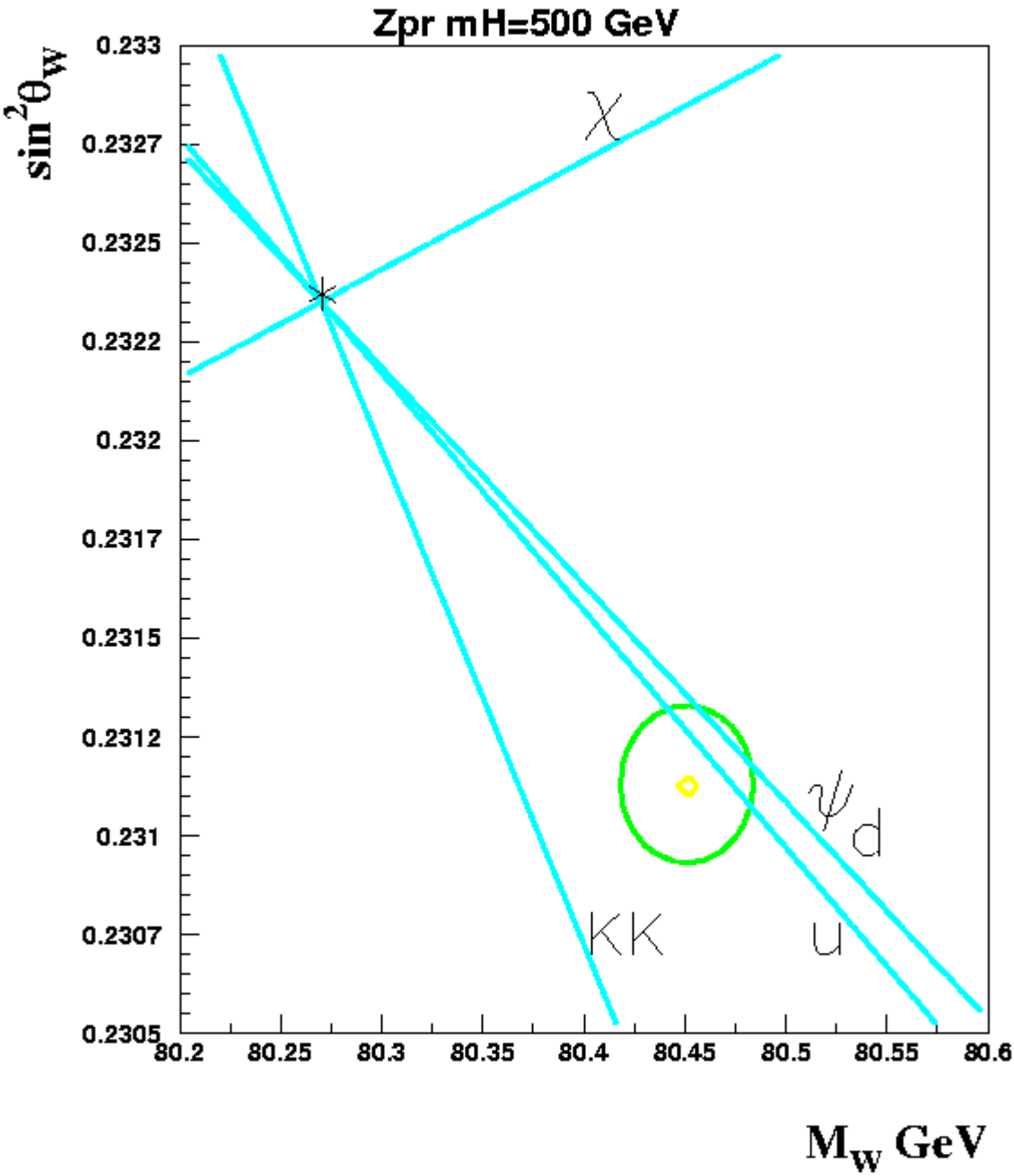
→ Perfect agreement LEP1/SLD

→ No contradiction with LEP2 et al.

- Not yet significant but shows the potential of a GIGAZ
- Significance could improve with m_t and M_W at FNAL (also with $\alpha(M_Z)$)
- The agreement is lost for a heavy Higgs at 500GeV
- Similar agreement with Z'_R at 1.9TeV

Model	χ	ψ	L-R
LEP2	630	510	950
FNAL	595	590	630
Atomic Parity	730	-	790

95% confidence level lower limit on the Z' mass



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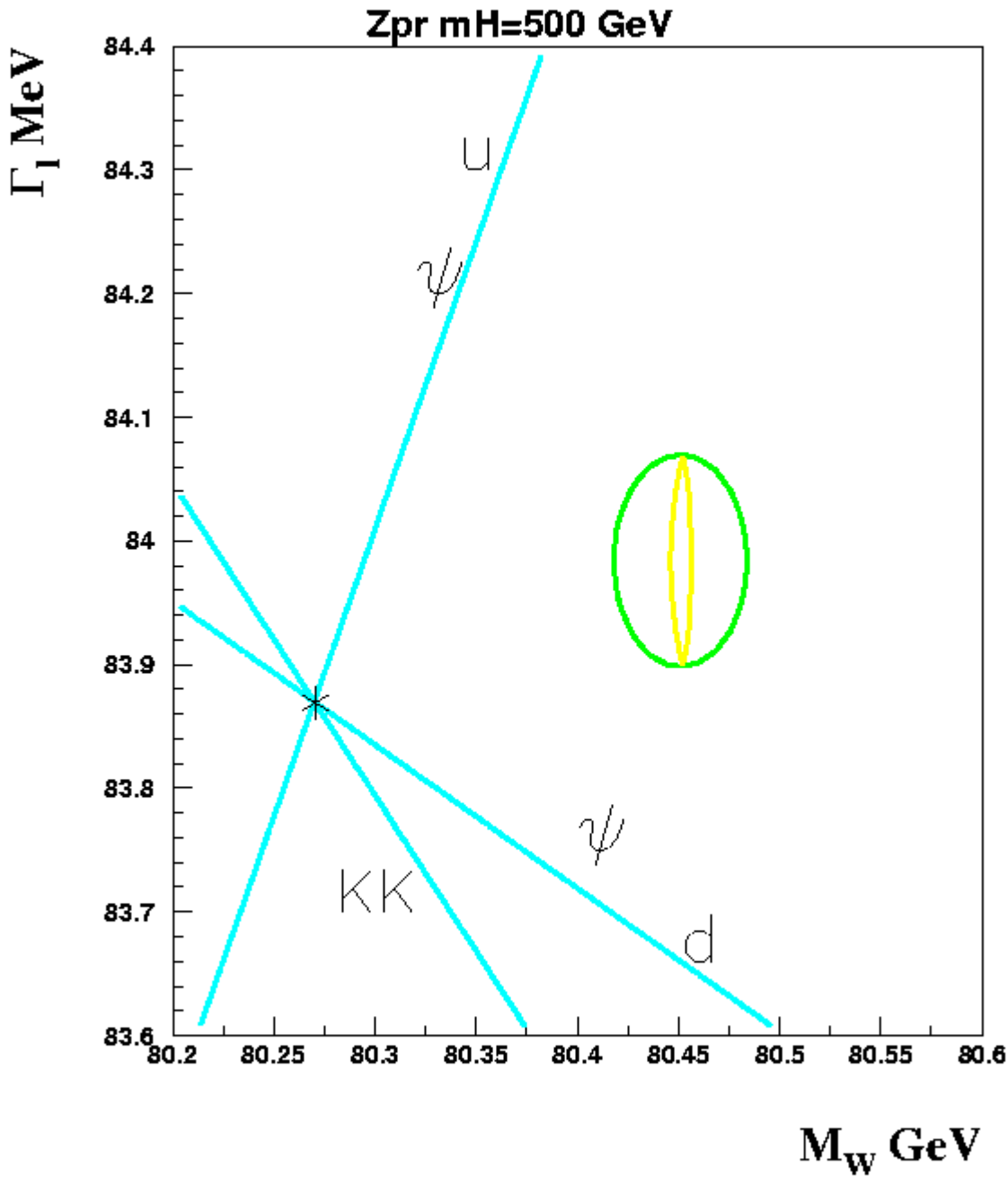

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From LEP/SLD to FLC

- FLC+LHC could give a very precise determination of Z′ parameters:

→ m_W gives γ and ξ using $m_{Z'}$ from LHC

→ $\sin^2\theta_W$ then gives θ

→ from γ+θ one can determine $\cos 2\beta$

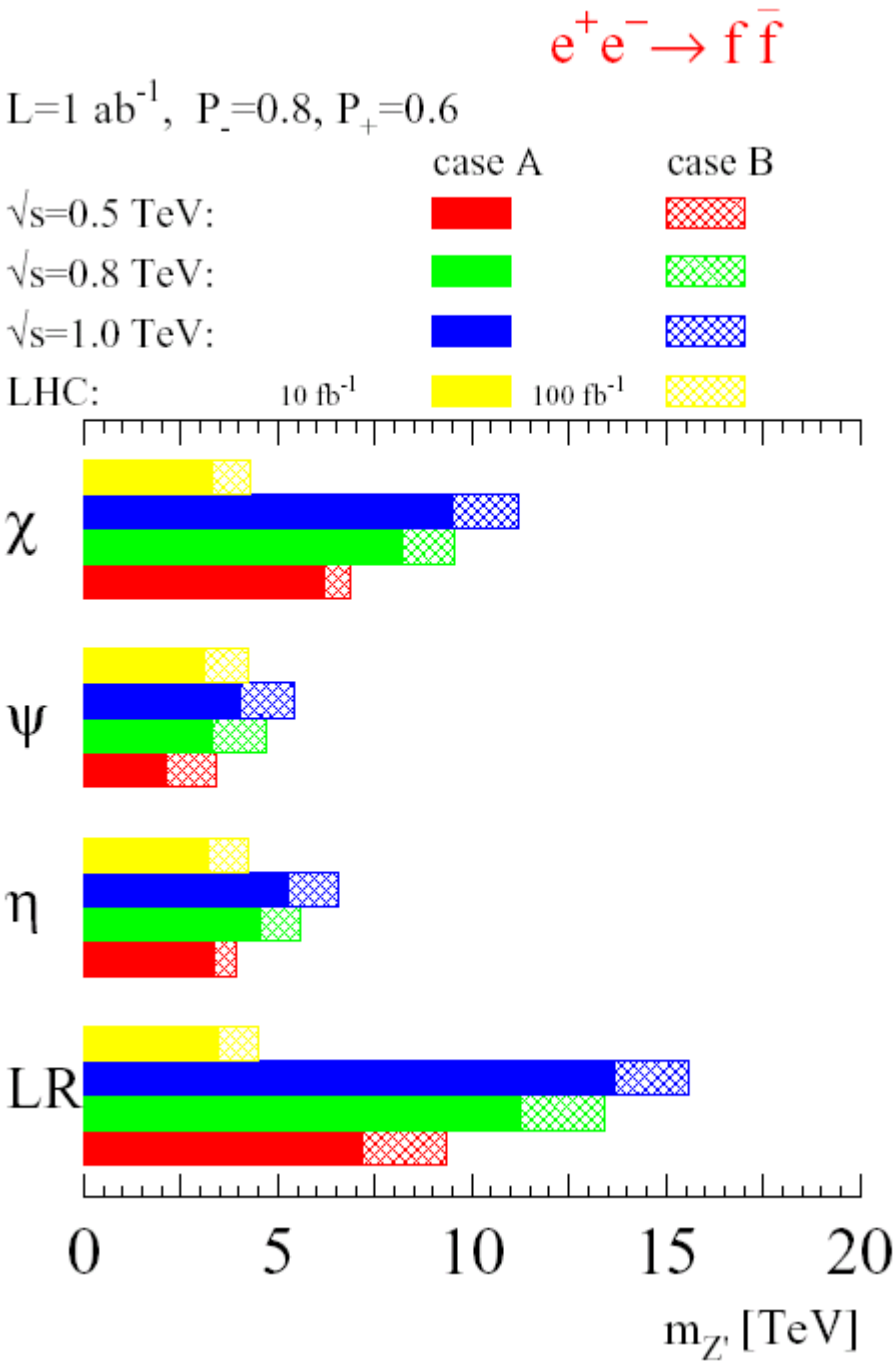
- From GIGAZ one expects

→ Mixing Z-Z′ ξ at %

→ Mixing χ-ψ θ to 0.1 rad

→ Symmetry breaking $\cos 2\beta$ to 0.1

- Unique opportunity to fully elucidate the origin of this Z′
- Works for $m_{Z'}$ up to 3-5TeV
- FLC at high energy +LHC allow to solve ambiguities (e.g. Z_ψ /Z_R)



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A^b_{FB} ?

- Discrepancy LEP/SLD ?

  $A^b_{FB}=0.0990(17)$ LEP1

  $A^b_{FB}=3/4A_bA_l=0.1038(25)$ SLD

  $A^b_{FB}=0.1036(08)$ SM

- E_6 model has D_L and D_R fermions which can mix with b quarks but there is no way to reconcile these effects with a standard R_b
- Other schemes are possible with unusual charges (D. Chang, E. Ma hep/9805273) or mirror fermions (D. Choudhury et al. hep/0109097)
- GIGAZ with polar to remeasure A_b A_l at per mil level

Conclusions

- A TeV Z' could explain the apparent light Higgs suggested by LEP1/SLD data (Z'_ψ 1.3TeV or Z_R 1.9TeV)

- This scenario illustrates how FLC can unambiguously determine the origin of a mass peak observed at LHC

- A similar game can be played with a KK recurrence of a Z for masses up to 10 TeV

- Presumably, knowing the origin of this effect, one can orient further searches at LHC/LC related to the underlying physics