ELW. AND ALTERNATIVES WG SUMMARY REPORT

Michael Spira (PSI)

other convenors: A. Denner, K. Mönig, T. Ohl, G. Pasztor

• Signatures of new ρ-resonances from strong EWSB in $e^+e^- \to \nu\bar{\nu}t\bar{t}$	Ivan Melo
• Strong electroweak symmetry breaking from $ee \to VV\nu\nu$	Predrag Krstonosic (presented by K. Mönig)
• Triple gauge couplings in $\gamma\gamma$ collisions	Jadranka Sekaric
• Four-fermion production at future photon colliders	Axel Bredenstein
• Precision measurements of beam polarization at the LC (The case of single-W production)	Filip Franco-Sollova
• Two-loop Sudakov logarithms in electroweak processes	Bernd Feucht
• Electroweak precision observables in the MSSM with non minimal flavor violation	Sven Heinemeyer

ECFA - Durham

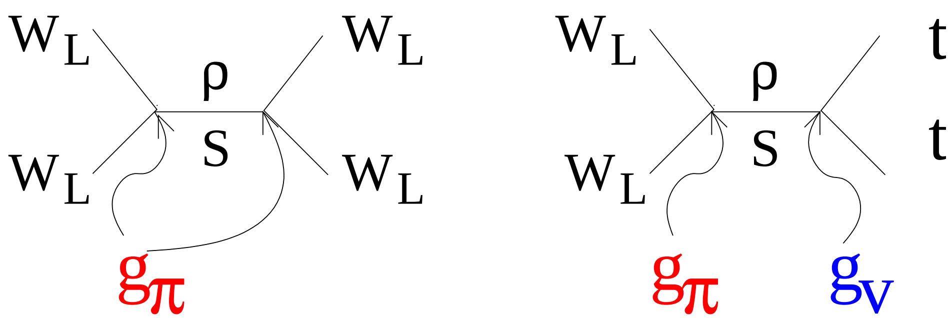
Sep 2004

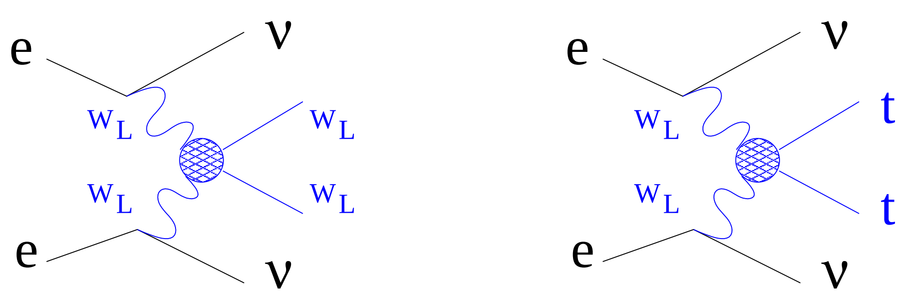
Signatures of new vector resonances from strong EWSB in $e^+e^- \to \nu\bar{\nu}t\bar{t}$

Ivan Melo

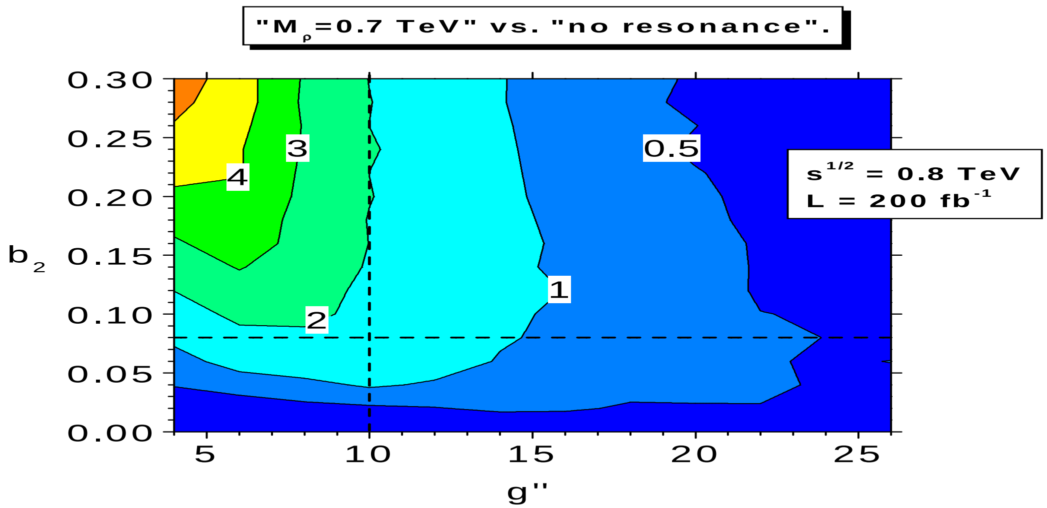
D. Bruncko (IEP SAS Kosice)
M. Gintner (University of Zilina)
I.Melo (University of Zilina)

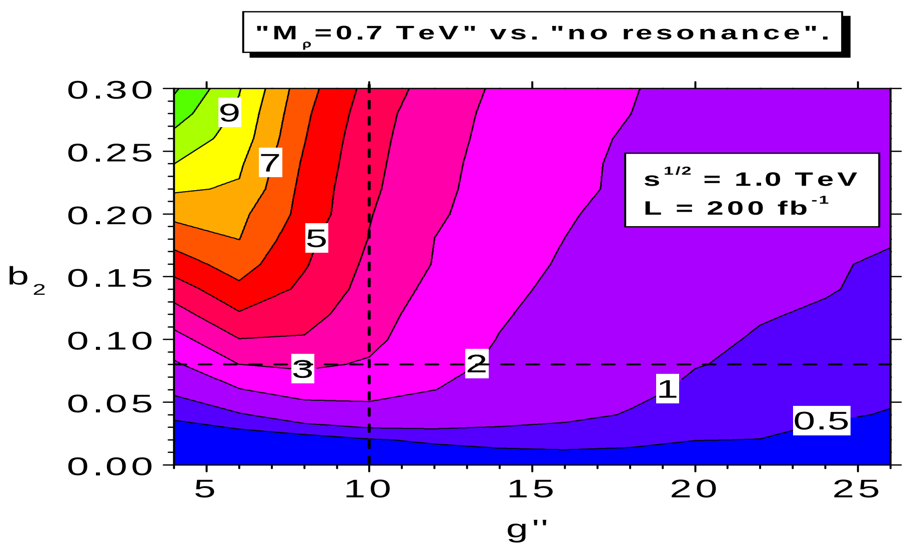
$W_L W_L \to t\bar{t}$ scattering





$$R = \frac{|N(\rho) - N(\text{no resonance})|}{\sqrt{N(\text{Background}) + N(\text{no resonance})}}$$





Conclusions

ρ in $e^+e^- \to \nu\bar{\nu}t\bar{t}$ (Pythia and CompHEP)

- agreement within 10 %
- no t decays

σ(0.8 TeV) = 0.20 (0.13) fb
σ(1.0 TeV) = 0.16 (0.035) fb

R (ρ vs no resonance) values up to 8

- optimize cuts
- finalize analysis for all models considered
- $e^+e^- \to \nu\bar{\nu}W^+W^-$

Strong Electroweak Symmetry Breaking from $e \; e \rightarrow \nu \; \nu \; \boldsymbol{V}$

K. Mönig , P. Krstonosic

DESY - Zeuthen

Introduction

- In absence of light Higgs interaction among gauge bosons becomes strong at high energy
- Effective Lagrangian contains five CP conserving operators that can be directly probed in weak boson scattering

$$L_4 = \frac{\alpha_4}{16\pi^2} tr\left(V_\mu V_\nu\right) tr\left(V^\mu V^\nu\right) \qquad L_5 = \frac{\alpha_5}{16\pi^2} tr\left(V_\mu V^\mu\right) tr\left(V_\nu V^\nu\right)$$

$SU(2)_C$

$$L_6 = \frac{\alpha_6}{16\pi^2} tr\left(V_\mu V_\nu\right) tr\left(TV^\mu\right) tr\left(TV^\nu\right)$$

$$L_7 = \frac{\alpha_7}{16\pi^2} tr\left(V_\mu V^\mu\right) tr\left(TV_\nu\right) tr\left(TV^\nu\right) \qquad L_{10} = \frac{\alpha_{10}}{16\pi^2}\left(tr\left(TV_\mu\right) tr\left(TV_\nu\right)\right)^2$$

$SU(2)_C$

- Couplings are related to the scale of “new” physics by $\frac{\alpha_i}{16\pi^2} = \left(\frac{v}{\Lambda_i^*}\right)^2$

,

and it’s necessary to do the multidimensional analysis in order to obtain the information on scale and dynamics of

Fit

- Binned Maximum Likelihood fit to the expected distributions for a SM sample (all quartic couplings equal zero)

$$L = -\sum_{ijkl} N^{DATA}_{ijkl} \ln(N^{MC}_{ijkl}) + \sum_{ijkl} N^{MC}_{ijkl}$$

$$N^{MC}_{ijkl} = \sum_{SM} 1 + A\cdot\alpha_4 + B\cdot\alpha_4^2 + C\cdot\alpha_5 + D\cdot\alpha_5^2 + E\cdot\alpha_4\cdot\alpha_5$$

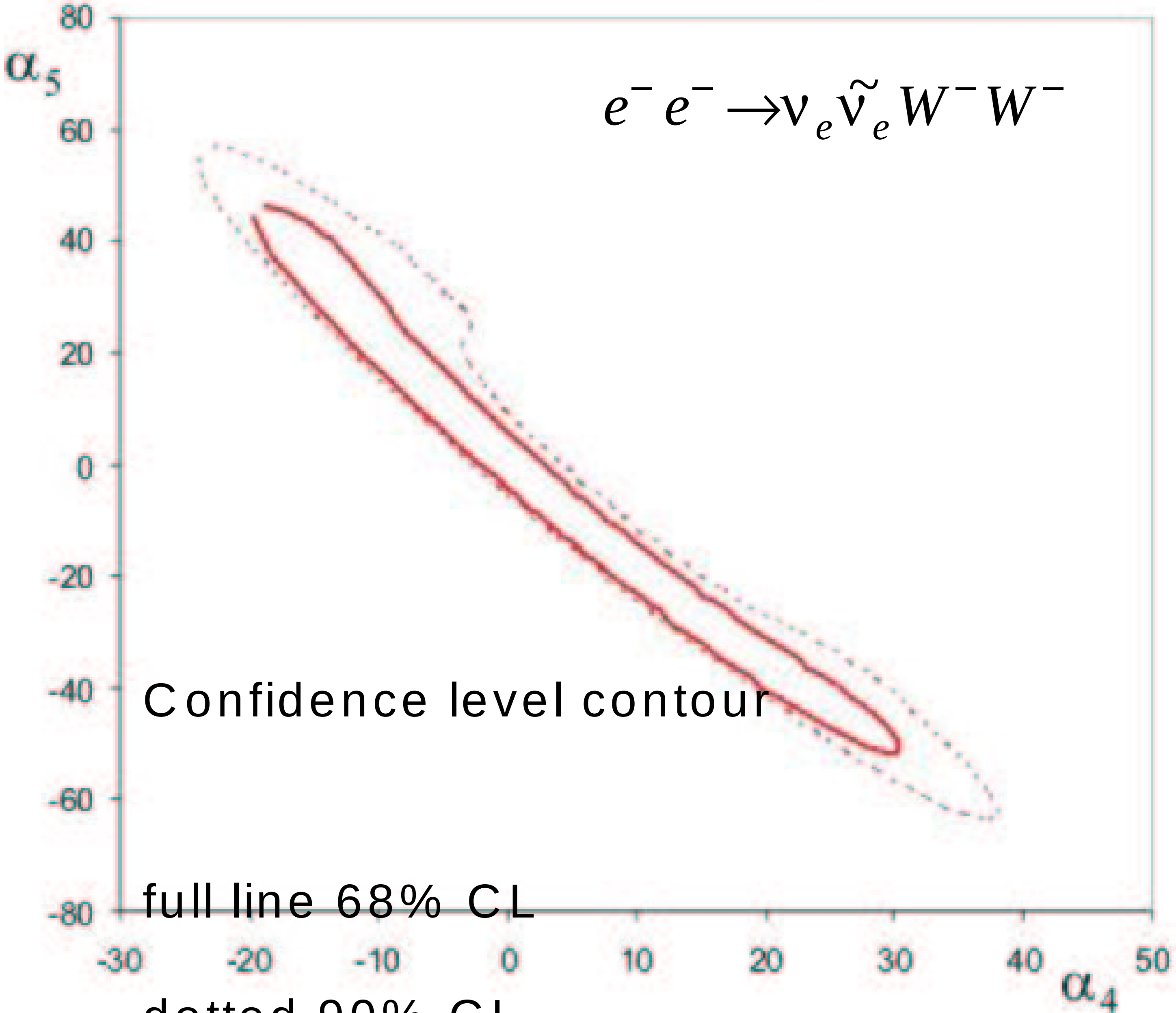
- Coefficients obtained by recalculating matrix elements in 5 points in ?$_4$?$_5$ space for each event and solving system of equations:

$$R_i = 1 + A\cdot\alpha_{4i} + B\cdot\alpha_{4i}^2 + C\cdot\alpha_{5i} + D\cdot\alpha_{5i}^2 + E\cdot\alpha_{4i}\cdot\alpha_{5i} \quad i = 1,5$$

R is the ratio of the matrix element to the SM one.

- After separate analysis for signal processes double counted events were assigned to one or another sample according to the distance form M(V)+M(V) mass (V=W or Z)

$W^- W^-$ result



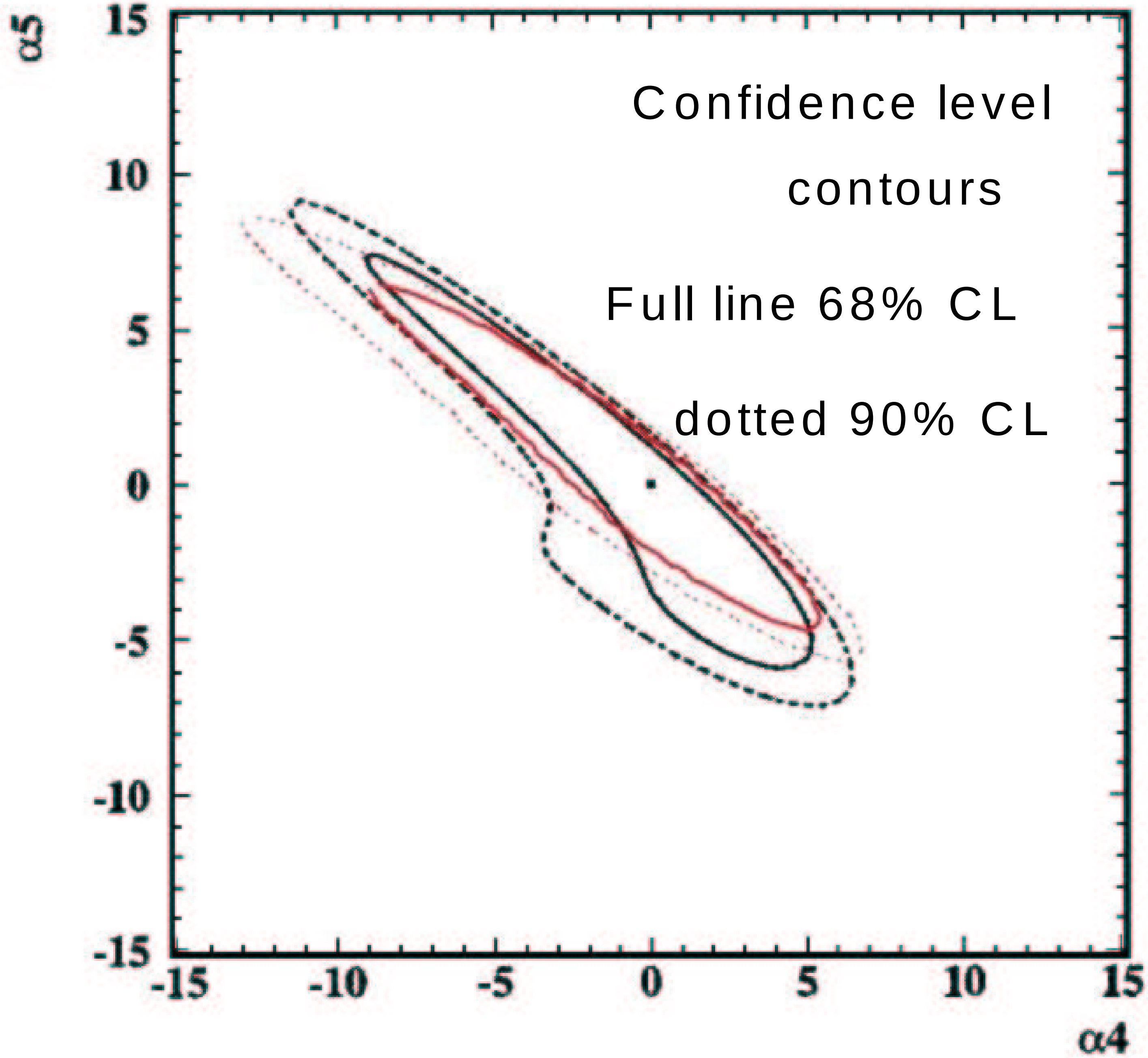
Confidence level contour

full line 68% CL

dotted 90% CL

- 350 fb^{-1} sample

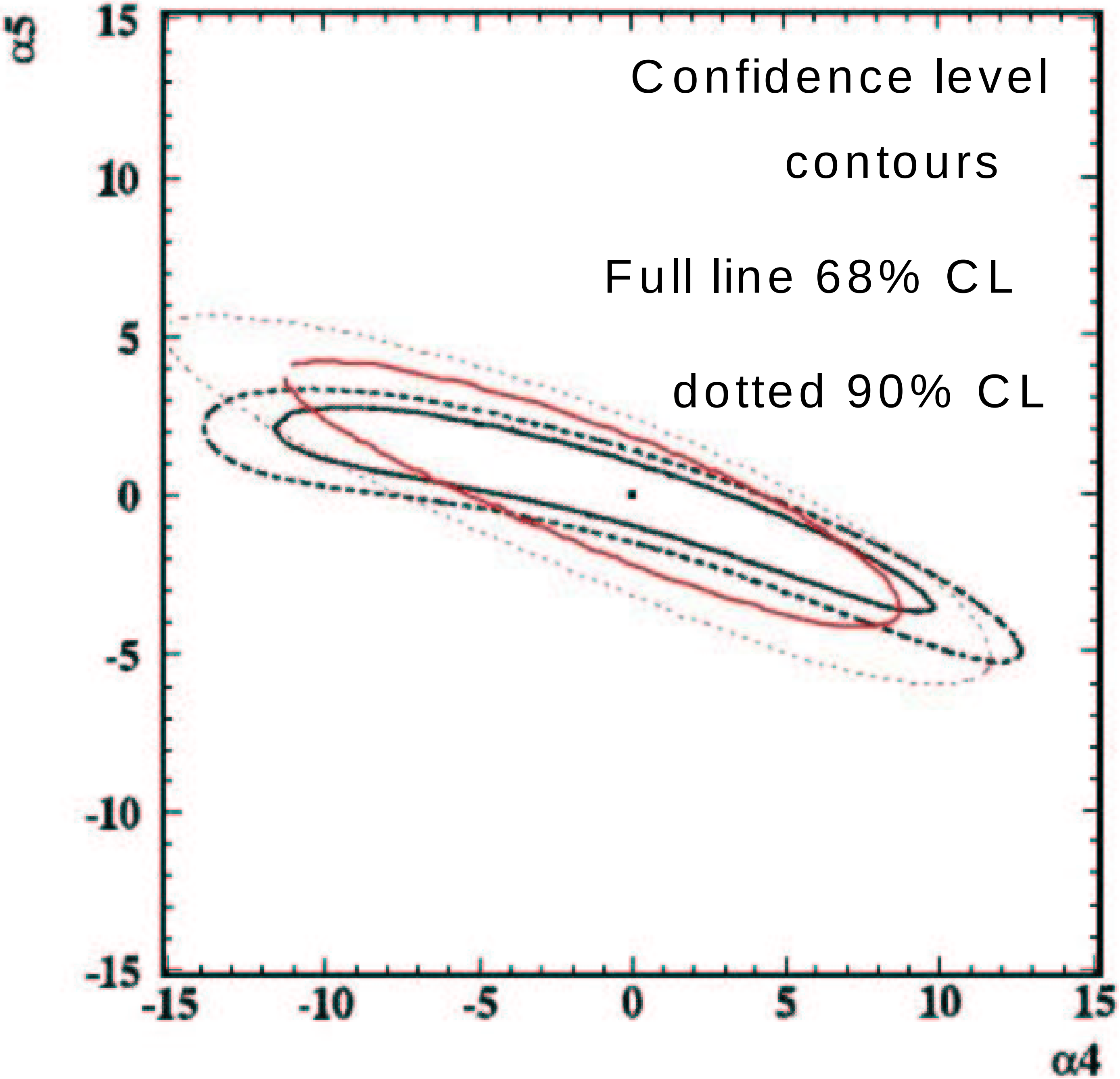
$W^+ W^-$ result



In **red present analysis in black**

*** Strong Electroweak Symmetry Breaking Signals in W W Scattering at TESLA Roberto Chierici, Stefano Rosati and**

ZZ result

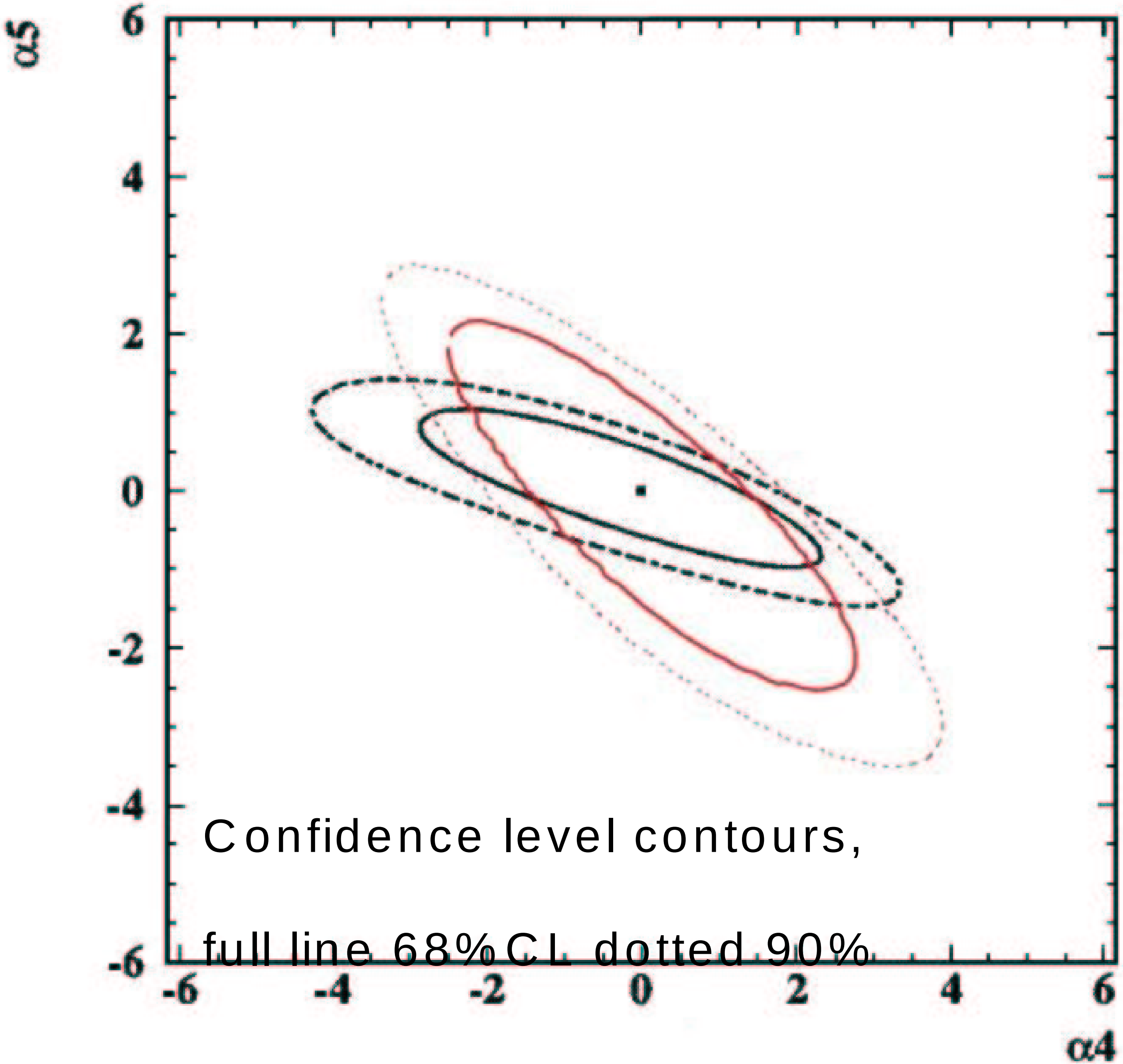


In red present analysis in black

* Strong Electroweak Symmetry Breaking Signals in WW Scattering at TESLA Roberto Chierici, Stefano Rosati and Michael Kobel

α_6 α_7 set to zero

e+e- & e-e- processes combined



Confidence level contours,

full line 68% CL dotted 90%

In red analysis results, in black combined fit for W+W- and ZZ only from *

α_6 α_7 set to zero

Future

- improvement in Z Z analysis still possible
- results in easy to use and combine form
- W Z analysis in progress
- combined limits on full parameter set at 800GeV to be obtained soon
- going for 1TeV

WTGCs at a
??–collider at TESLA

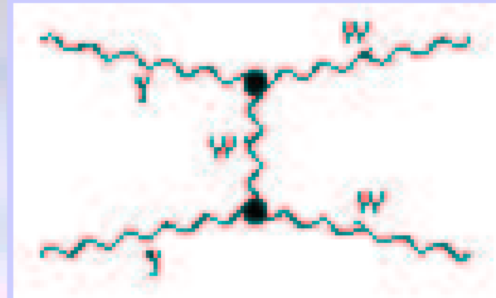
K.Mönig, J.Sekaric

DESY-Zeuthen

Introduction

$$?? \to W^+W^- \to q\bar{q}q\bar{q} \quad \sqrt{S} =$$

Dominating diagram for ?? → W⁺W⁻



TGC

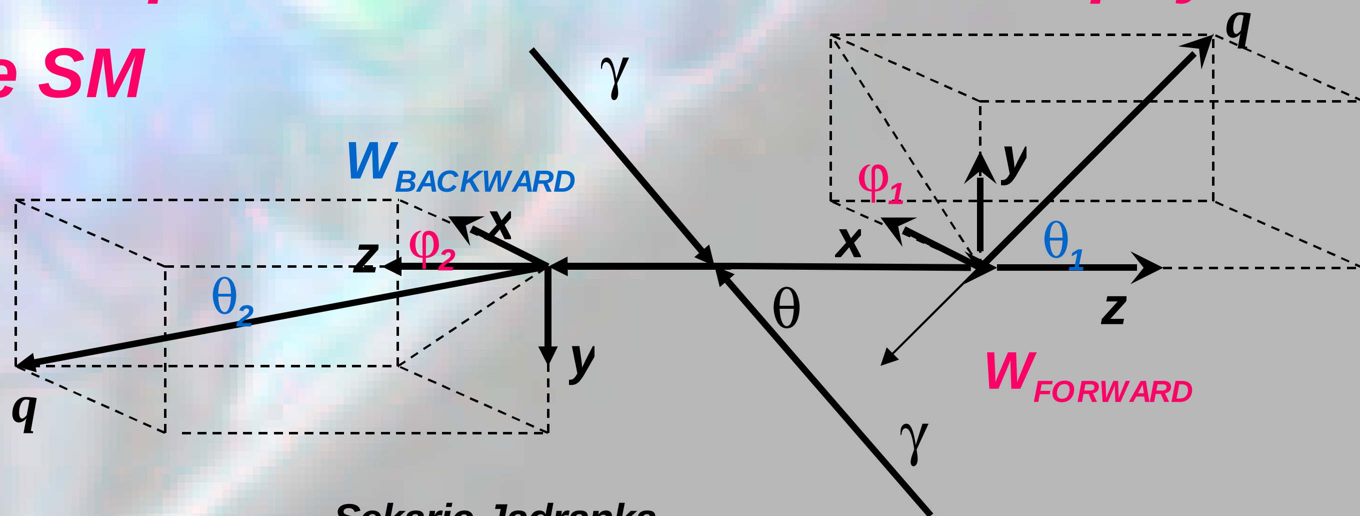
Two couplings, $?_?$ in dim-4 and $?_?$ in dim-6 operators

Deviations from SM TGC values → test of EW theory, probe of some possible extensions → new physics beyond the SM

Ambiguities :

$(cos?_{1,2},?_{1,2})$?

$(-cos?_{1,2},?_{1,2}+?)$



2 Parameter Fit Results – J_z=0

J_z=0 3D/5D	E_{CM} = 400 GeV, L = 110 fb^{-1} , FBE Likelihood (normalized)		
ΔL	1%	0.1%	accurate
$\Delta\kappa_\gamma \cdot 10^{-4}/10^{-4}$	26.0/14.4	6.2/5.4	3.8/2.6
$\Delta\lambda_\gamma \cdot 10^{-4}/10^{-4}$	14.4/3.0	13.7/3.0	13.7/3.0

$\Delta\kappa_\gamma \cdot 10^{-4}$ +pileup	15.4	5.4	2.6
$\Delta\lambda_\gamma \cdot 10^{-4}$ +pileup	3.8	3.8	3.8

3D → 5D decreases the error in κ_γ ; in λ_γ significantly !

Pile-up distorts the ?-distribution → increase of error in λ_γ for ~20%

κ_γ dependences on normalization

2 Parameter Fit Results – J_z=2

J_z=2 3D/5D	E_{CM} = 400 GeV, L = 110 fb^{-1} , FBE Likelihood (normalized)		
ΔL	1%	0.1%	accurate
$\Delta\kappa_\gamma \cdot 10^{-4}/10^{-4}$	29.0/19.9	6.2/6.2	3.9/3.8
$\Delta\lambda_\gamma \cdot 10^{-4}/10^{-4}$	1.8/1.5	1.6/1.5	1.6/1.5

$\Delta\kappa_\gamma \cdot 10^{-4}$ +pileup	23.2	6.3	3.9
$\Delta\lambda_\gamma \cdot 10^{-4}$ +pileup	2.0	2.0	2.0

3D $\rightarrow$ 5D no influences in the error estimations

Pile-up distorts the ?-distribution $\rightarrow$ increase of error in λ_γ for ~25%

κ_γ dependences on normalization

Conclusions

- J_Z =0,2 are sensitive to the anomalous couplings $\rightarrow$ to the possible scenarios of EWSB
- ? distribution important for J_Z=0
- Pile-up influences on $?_?$ measurement (~25%)
- Promising channel for $?_?$ - $?_?$ measurements

$??_?$, $??_?$ ~ 10^{-4}

FUTURE

to include the possible backgrounds, variable beam energy

rejection of bad tracks from pileup

Four-fermion production at the $\gamma\gamma$ Collider

Axel Bredenstein

in collaboration with Stefan Dittmaier und Markus Roth

Max-Planck-Institut für Physik, Munich

September 1,2004

based on Eur. Phys. J. C **36** (2004) 341 [arXiv:hep-ph/0405169]

Contents

Calculation of $\gamma\gamma \to 4f$ und $\gamma\gamma \to 4f\gamma$ in lowest order

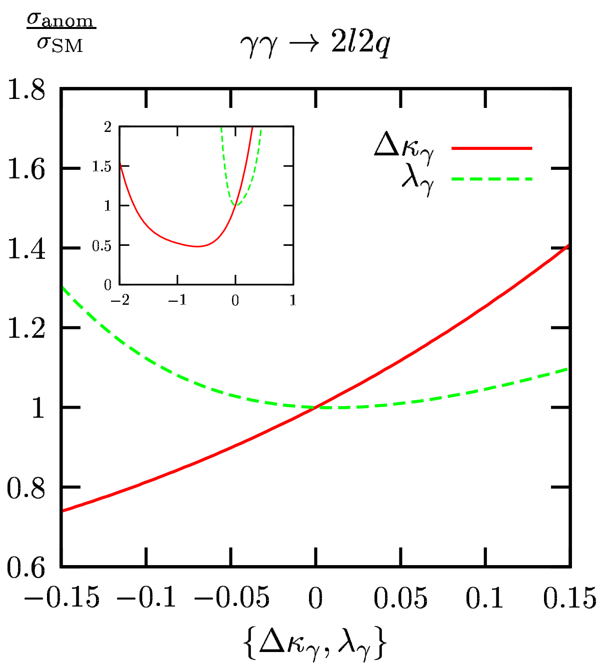
Construction of a Monte Carlo generator

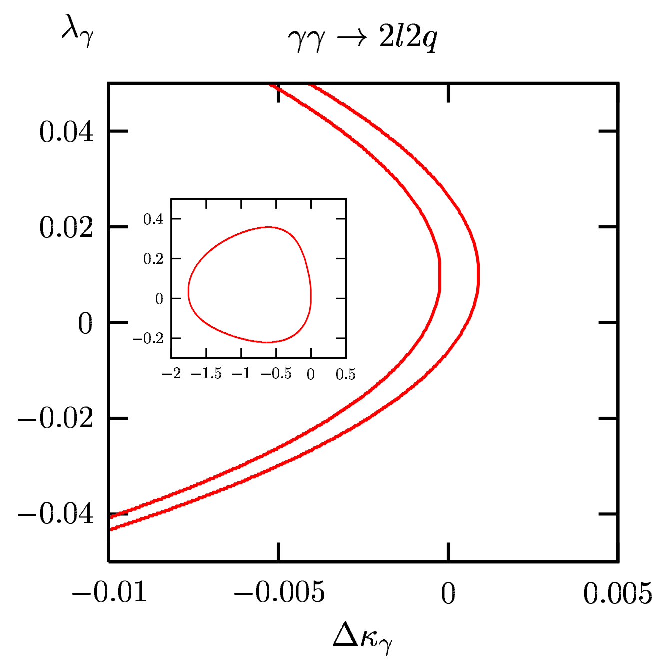
- Motivation
- Calculation of helicity amplitudes
- Phase space and photon spectrum integration
- Anomalous couplings
- Effective Higgs coupling
- Finite gauge-boson width
- Double-pole approximation

Anomalous triple couplings

$\gamma\gamma \to 4f$ all semi-leptonic final states photon spectrum included

$\sqrt{s_{ee}} = 500\,\mathrm{GeV}$ $\int L dt = 100\,\mathrm{fb}^{-1}$ $\chi^2 = 1$ $\chi^2 \equiv \frac{(N(a_i) - N_{\mathrm{SM}})^2}{N_{\mathrm{SM}}}$





$\longrightarrow$ large interference with SM amplitude

expected limits comparable to e^+e^--mode (see also Baillargeon et al. '97; Bozovic-Jelisavcic et al. '02)

full study requires consideration of distributions

Summary

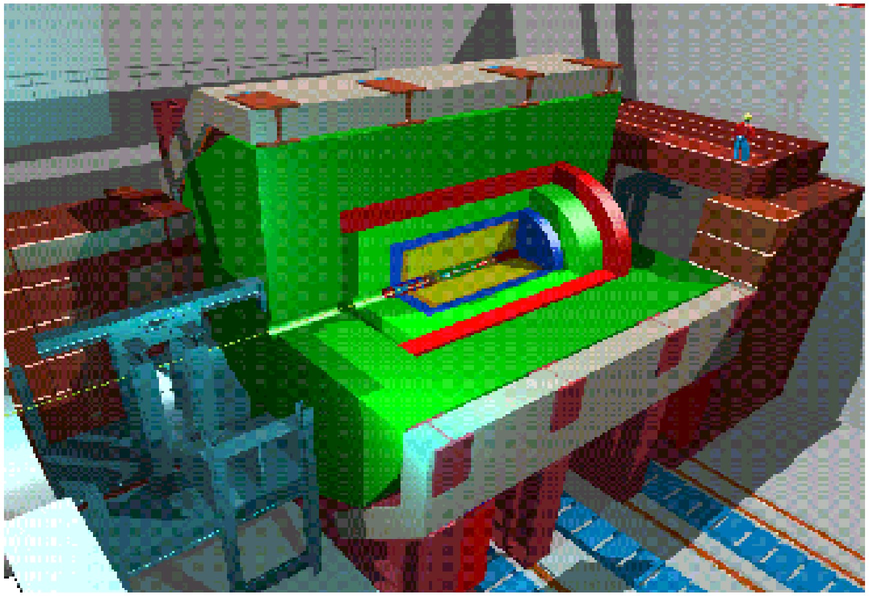
- Relevance of $\gamma\gamma \to \mathrm{WW}$ due to its high cross section
- Calculation of Born amplitudes for $\gamma\gamma \to 4f$ and $\gamma\gamma \to 4f\gamma$
- Monte Carlo generator with multi-channel Monte Carlo integration
- Inclusion of a realistic photon spectrum
- Anomalous couplings, Higgs resonance
- Double-pole approximation is a promising approach for radiative corrections (cf. RacoonWW), work in progress

Precision Measurements of Beam Polarization at the LC
(The Case of Single-W Production)

Filip Franco-Sollova

Contents

Beam Polarization at the LC



High Lum. Linear Collider

+

Longit. Beam Polarization

=

Precision Measurements to test the SM

For some studies this is possible
ONLY if Beam Polarization is accurately determined

MEASURING THE POLARIZATION

A Solution: Measure the polarization directly using physical proceses.

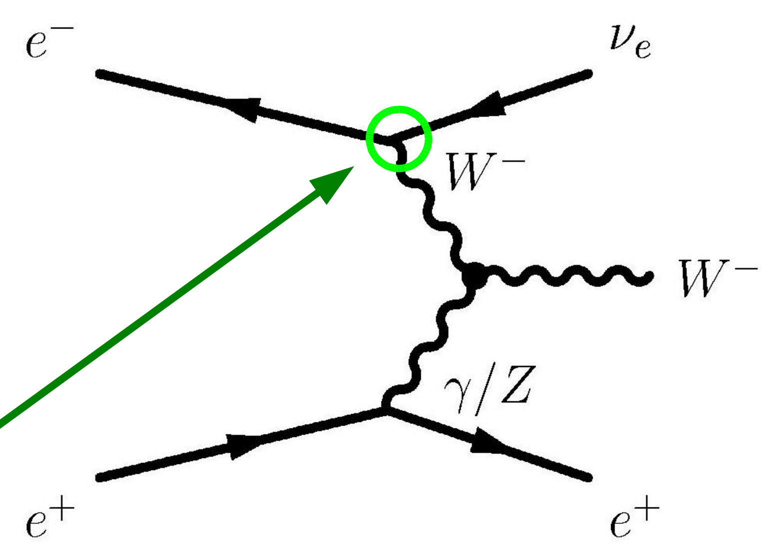
(It is not a replacement of the polarimeters !)

Advantage: No problem with depolarization effects !

(Measures the polarization directly at the interaction point)

SINGLE-W

- $\sigma_{\text{single-W}} \approx \sigma_{\text{W-pair}}$ (At 500 GeV)
- Single-W- only sensitive to e- polarization
- Single-W+ only sensitive to e+ polarization



How to measure the polarization ? .....

Measuring the Polarization

a) Disadvantages of measuring the asymetry:

$$|P| = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$

- The luminosity must be split for measuring σ_+ and σ_-

b) Disadvantages of measuring one cross section σ:

$$P_- = 1 - \frac{4\sigma}{(\sigma_{LL} + \sigma_{LR}) - P_+(\sigma_{LL} - \sigma_{LR})}$$

- The theoretical values of σ_{LL} and σ_{LR} can not be accurately determined
- Anomalous TGCs are problematic

Conclusions and Outlook

- From the conditions considered in this stage of the study, the best value for the polarization measurement error is ≈ 0.73% (for $\cos\theta_{e+} > 0.90$)

- The best value of luminosity sharing is:
  Left electrons ≈ 25% Right electrons ≈ 75%
  (considering only the $e^+\nu_e\,\mu^-\ \bar{\nu}_\mu$ final state)

- Optimization of the signal selection

- Untagged events (μμ background)

- Solve technical isues:
  - Detector forward region
  - Problem of ISR and beamstrahlung in Whizard (not mentioned in the talk)

- Simultaneous measurement of electron and positron polarization

2nd workshop of the ECFA “Physics and Detectors for a Linear Collider” study series

Durham, 1–4 September 2004

Electroweak Sudakov logarithms

The form factor in a massive U(1) model
and in a U(1)×U(1) model with mass gap

Bernd Feucht

Institut für Theoretische Teilchenphysik, Universität Karlsruhe

In collaboration with Johann H. Kühn, Alexander A. Penin and Vladimir A. Smirnov

I Why logarithmic 2-loop results in EW theory?

Electroweak (EW) precision physics

- experimentally measured by now at energy scales up to $\sim M_{W,Z}$
- future generation of accelerators (LHC, LC) $\rightarrow$ TeV region

Electroweak radiative corrections at high energies $\sqrt{s} \sim$ TeV $\gg M_{W,Z}$

Kühn et al. '00, '01; Fadin et al. '00; Denner et al. '01, '03; B.F. et al. '03; Pozzorini '04; ...

large negative corrections in *exclusive* cross sections

- EW corrections dominated by Sudakov logarithms $\alpha^n \ln^{2n}(s/M_{W,Z}^2)$
- 1-loop corrections $\gtrsim$ 10%
- 2-loop corrections $\sim$ 1%, need to be under control for LC

Massive U(1) form factor in 2-loop approximation

Known from resummation & full calculation of n_f contribution: (n_f = # fermions)

$$\alpha^2 F_2 = \left(\frac{\alpha}{4\pi}\right)^2 \left[+\frac{1}{2}\ln^4\left(\frac{Q^2}{M^2}\right) - \left(\frac{4}{9}n_f + 3\right)\ln^3\left(\frac{Q^2}{M^2}\right) + \left(\frac{38}{9}n_f + \frac{2}{3}\pi^2 + 8\right)\ln^2\left(\frac{Q^2}{M^2}\right) - \left(\frac{34}{3}n_f + \ldots\right)\ln\left(\frac{Q^2}{M^2}\right) + \left(\frac{16}{27}\pi^2 + \frac{115}{9}\right)n_f + \ldots \right]$$

Kühn, Moch, Penin, Smirnov '01
B.F., Kühn, Moch '03

- growing coefficients with alternating sign:

$$\begin{array}{ccccccccc} & -\,0.4\,n_f\ln^3 & + & 4.2\,n_f\ln^2 & - & 11.3\,n_f\ln & + & 18.6\,n_f \\ +\,0.5\ln^4 & -\;\;3\;\;\ln^3 & + & 14.6\;\;\ln^2 & - & \ldots\;\;\ln & + & \ldots \end{array}$$

- $Q \sim 1$ TeV $\to +\ln^4 \sim -\ln^3 \sim +\ln^2$
  $\to$ large cancellations between logarithmic terms

Complete 2-loop corrections in logarithmic approximation necessary.

Massive U(1) form factor in 2-loop approximation: result $(n_f = 0)$

B.F., Kühn, Penin, Smirnov, hep-ph/0404082

$$\alpha^2 F_2 = \left(\frac{\alpha}{4\pi}\right)^2 \Bigg[$$

$$+\frac{1}{2}\ln^4\left(\frac{Q^2}{M^2}\right)$$

agreement ✓

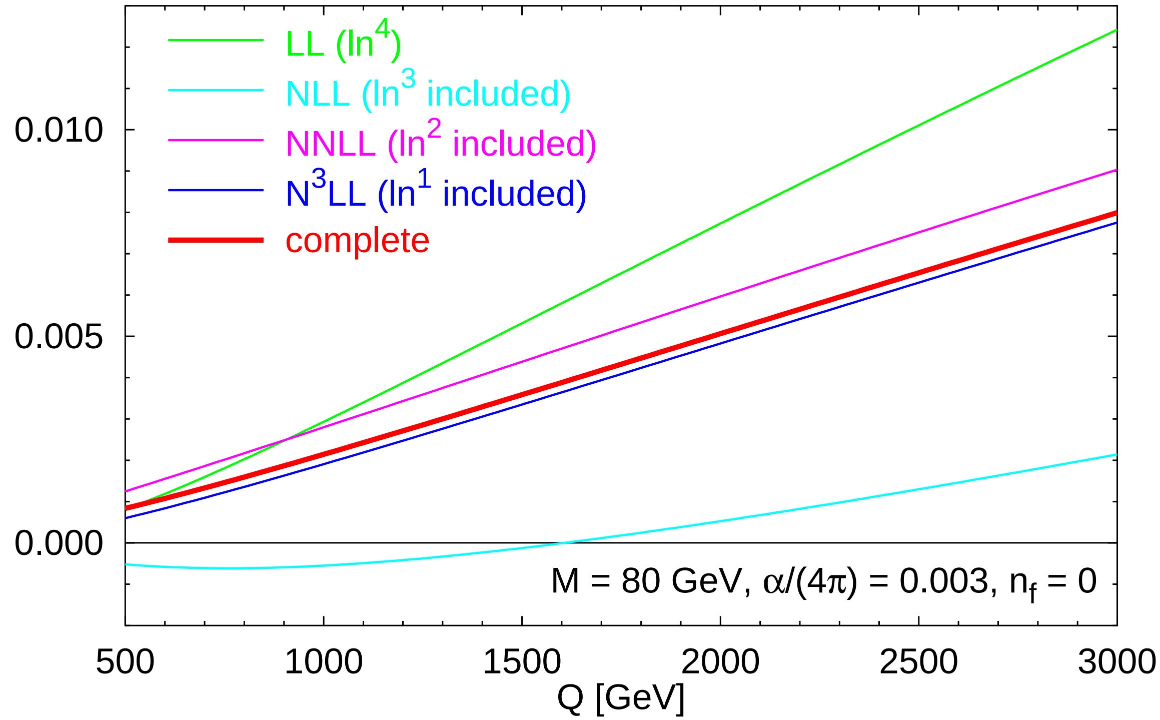
$$-3\ln^3\left(\frac{Q^2}{M^2}\right)$$

$$+\left(\frac{2}{3}\pi^2+8\right)\ln^2\left(\frac{Q^2}{M^2}\right)$$

$$-\left(-24\zeta_3+4\pi^2+9\right)\ln\left(\frac{Q^2}{M^2}\right)$$

$$+256\,\mathrm{Li}_4\left(\frac{1}{2}\right)+\frac{32}{3}\ln^4 2-\frac{32}{3}\pi^2\ln^2 2-\frac{52}{15}\pi^4+80\zeta_3+\frac{52}{3}\pi^2+\frac{25}{2}\Bigg]$$

new!



size of coefficients:	$+0.5\ln^4$	$-3\ln^3$	$+14.6\ln^2$	$-19.6\ln$	$+26.4$
at $Q = 1$ TeV:	$+326$	-387	$+372$	-99.2	$+26.4$

⇒ alternating signs! small constant (N^4LL) contribution

V Summary & outlook

Massive U(1) form factor

- complete 2-loop result in logarithmic approximation ✓

⇒ precise control of radiative corrections

U(1)×U(1) model with mass gap

- factorization of IR singularities shown explicitly ✓

Applications

- calculation with mass gap reduced to the 1-mass case $M_W = M_Z = M_{\text{photon}}$
- $M_Z \neq M_W$ taken into account by expanding around the equal mass approximation

Outlook

- extend to non-Abelian models: SU(2), SU(N), SU(2)×U(1)
- consider Higgs contributions
- 4-fermion scattering amplitude
- predictions for EW corrections to $f\bar{f} \to f'\bar{f}'$ cross sections

Electroweak precision observables in the MSSM with NMFV

Sven Heinemeyer, CERN

Durham, 09/2004

based on collaboration with
W. Hollik, F. Merz and *S. Peñaranda*

1. Introduction
2. Results for M_W and $\sin^2\theta_{\rm eff}$
3. Results for m_h
4. Conclusions

NMFV in the MSSM

NMFV: Non Minimal Flavor Violation

$\longrightarrow$ Mixing of scalar quark families (beyond CKM)

Mixing of stop/scharme and of sbottom/sstrange:

$$(\tilde{t}_L, \tilde{t}_R, \tilde{c}_L, \tilde{c}_R) \begin{pmatrix} \widetilde{T} & 0 \\ 0 & \widetilde{C} \end{pmatrix} \begin{pmatrix} \tilde{t}_L \\ \tilde{t}_R \\ \tilde{c}_L \\ \tilde{c}_R \end{pmatrix} \qquad (\tilde{b}_L, \tilde{b}_R, \tilde{s}_L, \tilde{s}_R) \begin{pmatrix} \widetilde{B} & 0 \\ 0 & \widetilde{S} \end{pmatrix} \begin{pmatrix} \tilde{b}_L \\ \tilde{b}_R \\ \tilde{s}_L \\ \tilde{s}_R \end{pmatrix}$$

$\downarrow$ add NMFV $\downarrow$

$$(\tilde{t}_L, \tilde{t}_R, \tilde{c}_L, \tilde{c}_R) \begin{pmatrix} \widetilde{T} & \neq 0 \\ \neq 0 & \widetilde{C} \end{pmatrix} \begin{pmatrix} \tilde{t}_L \\ \tilde{t}_R \\ \tilde{c}_L \\ \tilde{c}_R \end{pmatrix} \qquad (\tilde{b}_L, \tilde{b}_R, \tilde{s}_L, \tilde{s}_R) \begin{pmatrix} \widetilde{B} & \neq 0 \\ \neq 0 & \widetilde{S} \end{pmatrix} \begin{pmatrix} \tilde{b}_L \\ \tilde{b}_R \\ \tilde{s}_L \\ \tilde{s}_R \end{pmatrix}$$

$\neq 0$:

- experimentally only partially restricted
- can e.g. be induced by RGE running in mSUGRA
- changes Higgs-squark couplings
- changes Gauge boson-squark couplings

Analytical result:

evaluation with arbitrary NMFV couplings

Numerical result:

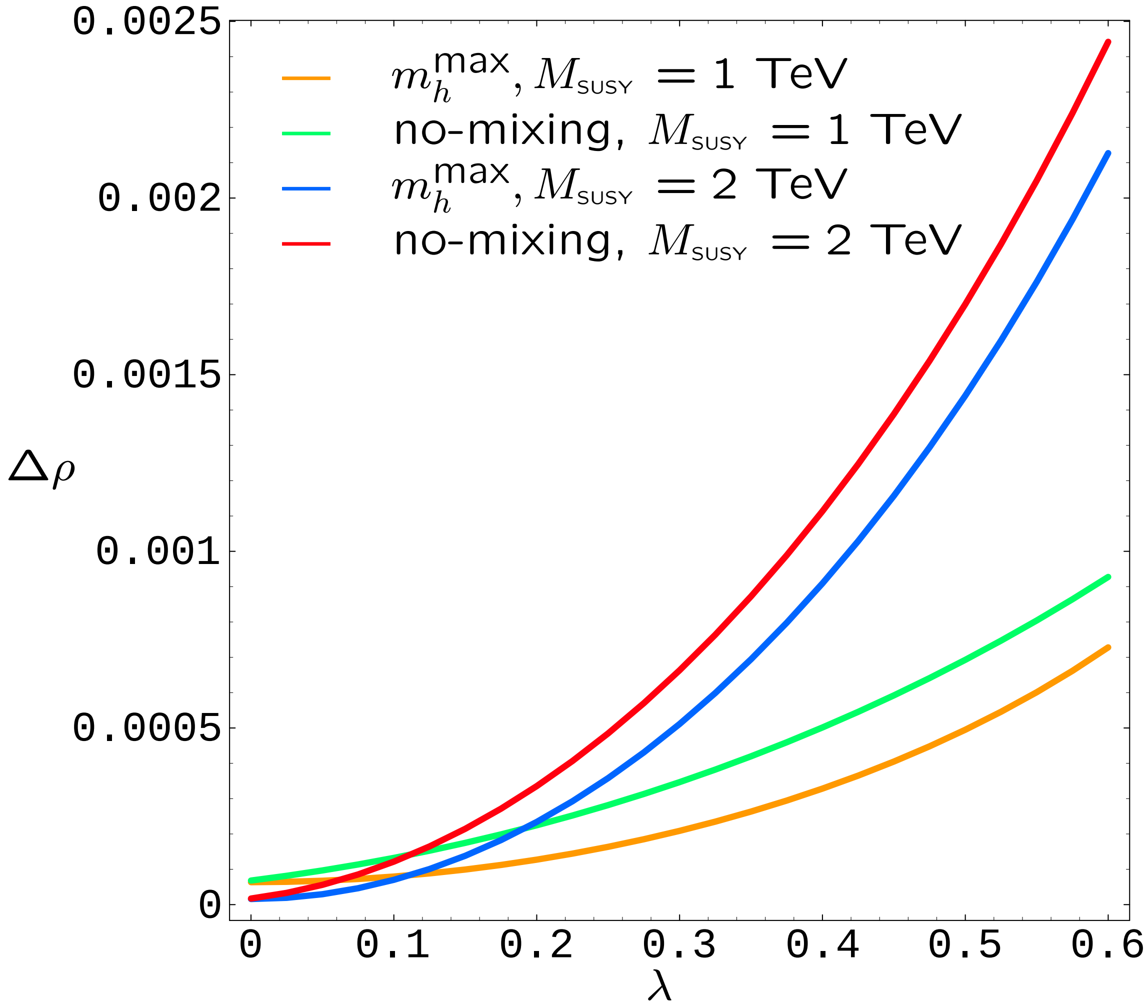
$$\tilde{t}/\tilde{c}: \quad \begin{pmatrix} \lambda\sqrt{\tilde{T}_{LL}\tilde{C}_{LL}} & 0 \\ 0 & 0 \end{pmatrix} \qquad \tilde{b}/\tilde{s}: \quad \begin{pmatrix} \lambda\sqrt{\tilde{B}_{LL}\tilde{S}_{LL}} & 0 \\ 0 & 0 \end{pmatrix}$$

$SU(2)$: $\tilde{T}_{LL} \approx \tilde{B}_{LL}$, $\tilde{C}_{LL} \approx \tilde{S}_{LL}$

$\rightarrow$ suggested by RGE analysis

$\rightarrow$ no relevant experimental bounds on λ

$\Delta\rho$ as a function of λ:

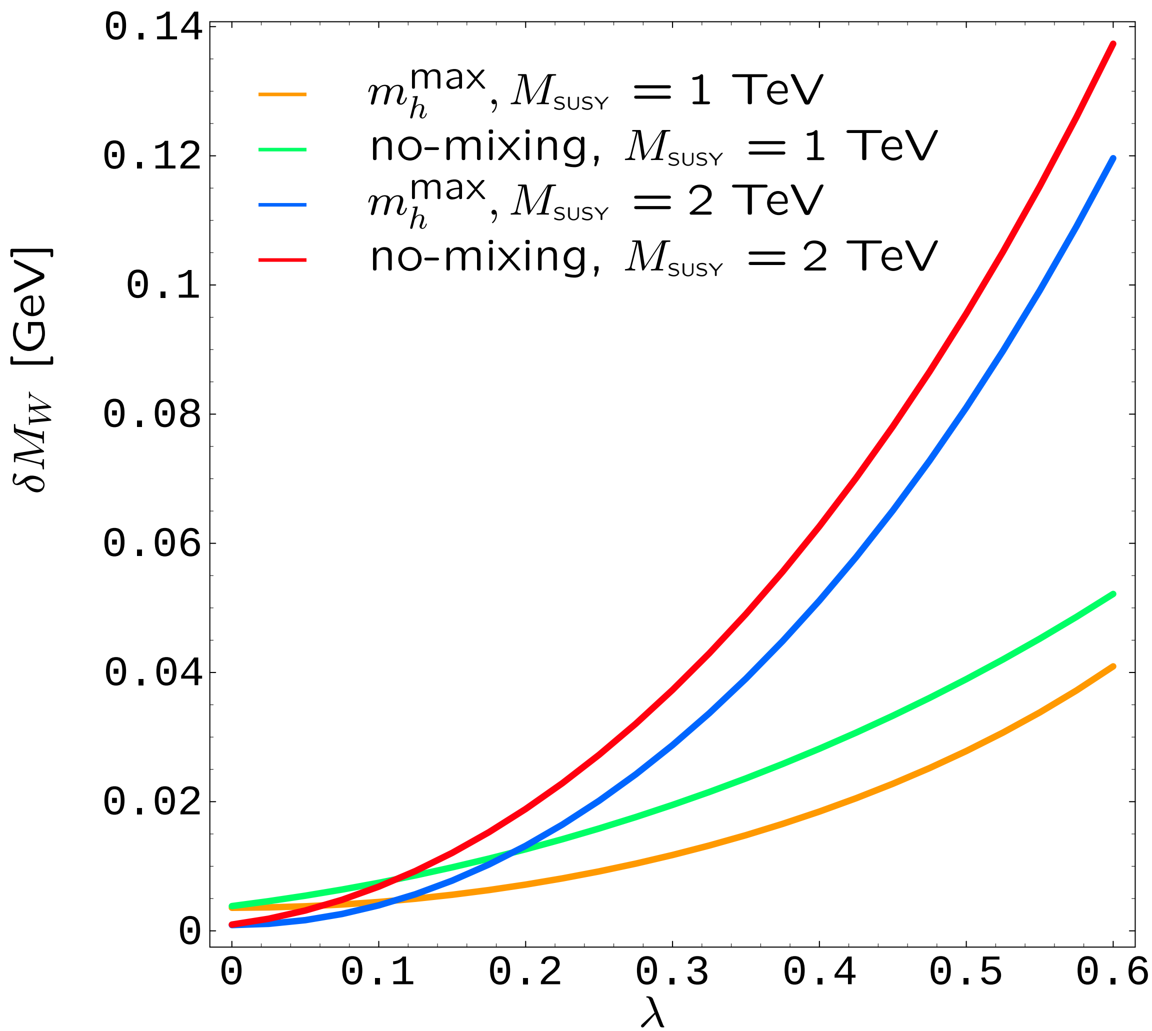


increasing λ
$\Rightarrow$ increasing mixing
$\Rightarrow$ increasing $\Delta\rho$

increasing $M_{\rm SUSY}$
$\Rightarrow$ increasing mixing
$\Rightarrow$ increasing $\Delta\rho$

$\Delta\rho \lesssim 2 \times 10^{-3}$ can be saturated

δM_W as a function of λ:



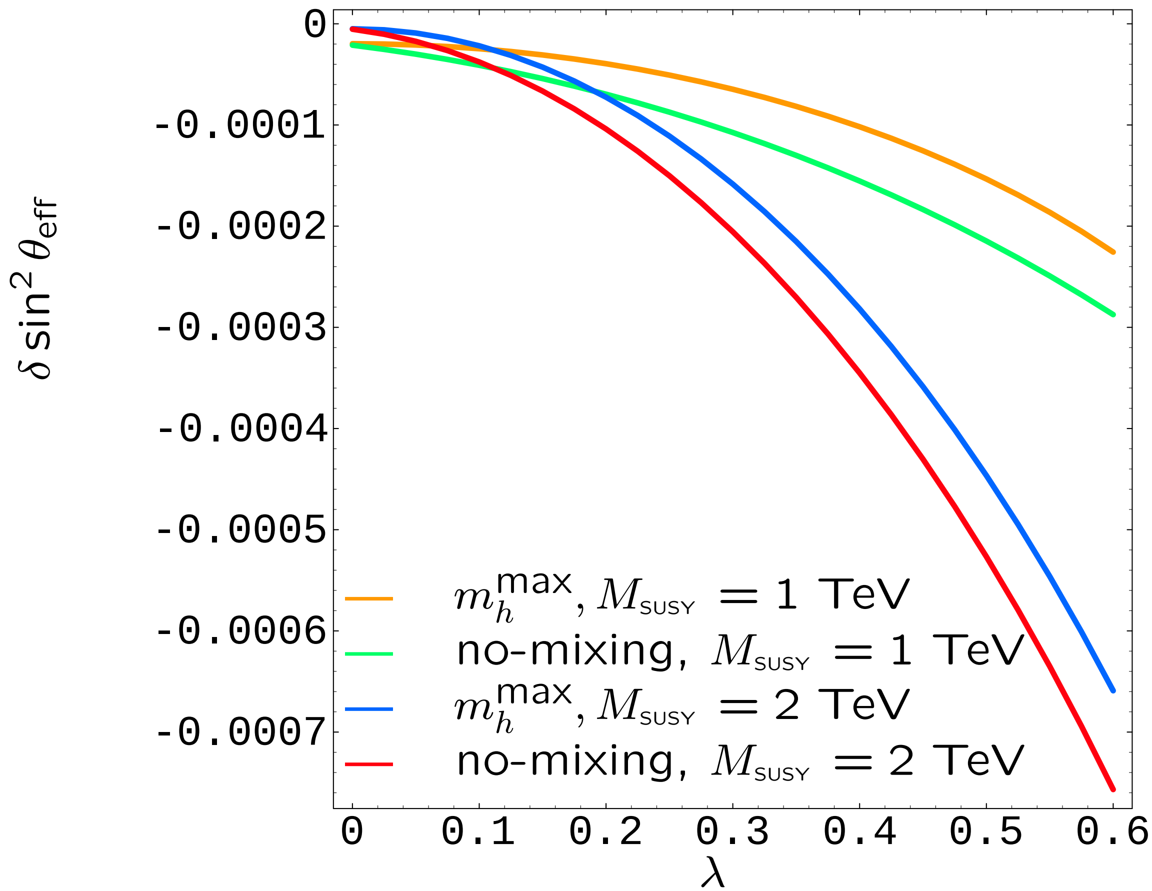
follows the behavior of $\Delta\rho$

$\delta M_W^{\text{exp,today}} = 34$ MeV

$\delta M_W^{\text{exp,future}} = 7$ MeV

$\Rightarrow$ extreme parameter regions already ruled out

$\delta \sin^2 \theta_{\rm eff}$ as a function of λ:



follows the behavior of $\Delta\rho$

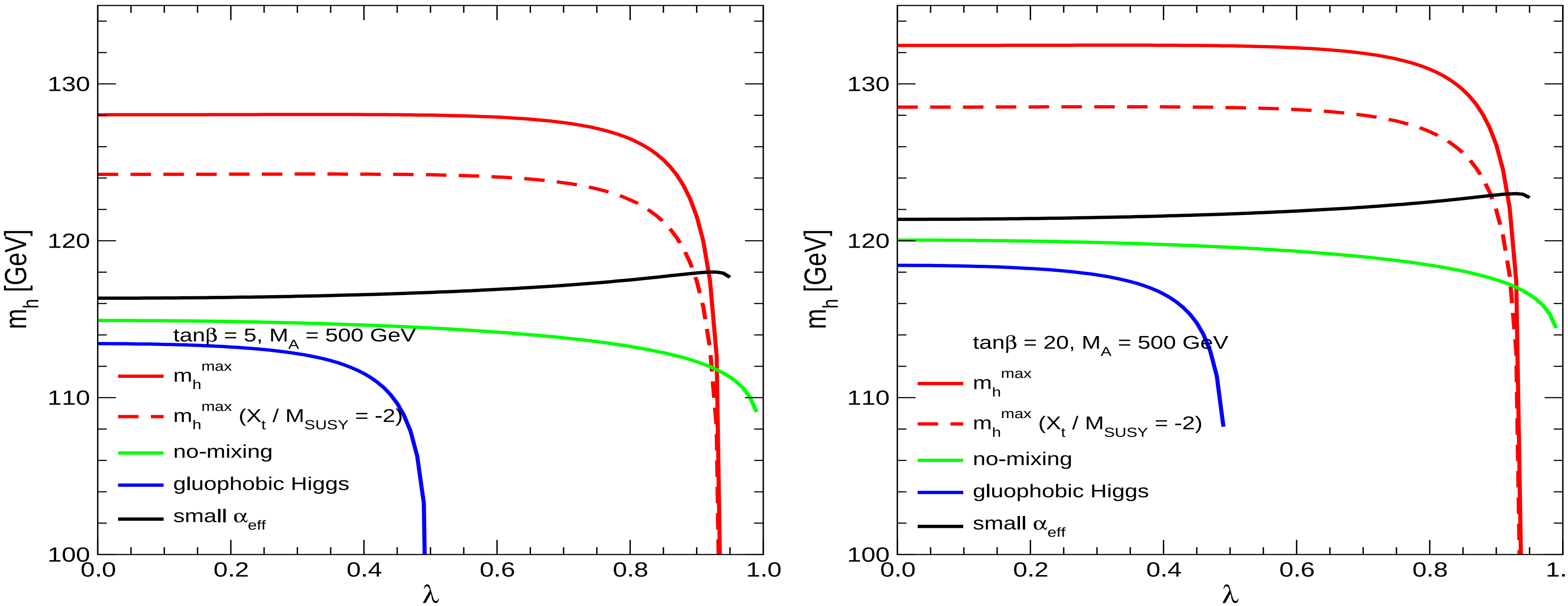
$\delta \sin^2 \theta_{\rm eff}^{\rm exp,today} = 17 \times 10^{-5}$

$\delta \sin^2 \theta_{\rm eff}^{\rm exp,future} = 1.3 \times 10^{-5}$

$\Rightarrow$ extreme parameter regions already ruled out

$\Rightarrow$ highly sensitive test in the future

Effects in benchmark scenarios:



$\Rightarrow$ small effects for small/moderate λ

$\Rightarrow$ $\delta m_h = \mathcal{O}$ (5 GeV) only for very large λ

$\rightarrow$ mostly decreasing m_h, but also increase possible
(e.g. in small $\alpha_{\rm eff}$ scenario)

4. Conclusinos

- Precision observables can
  - give valuable information about the "true" Lagrangian
  - constrain MSSM parameter space already today

- MSSM with NMFV:

  mixing in the $\tilde{t}/\tilde{c}$ and in the $\tilde{b}/\tilde{s}$ sector

- $\Rightarrow$ Evaluation of M_W, $\sin^2\theta_{\text{eff}}$, m_h in NMFV MSSM

- Analytical results: for arbitrary mixing

  Numerical results: only for LL mixing, parametrized with λ
  corresponds to $(\delta_{LL})_{23}$

- large effects possible for M_W, $\sin^2\theta_{\text{eff}}$: $\lambda \lesssim 0.2 \Rightarrow \delta M_W \lesssim 20$ MeV

  $\lambda \lesssim 0.2 \Rightarrow \delta \sin^2\theta_{\text{eff}} \lesssim 10^{-4}$

- moderate effects possible for m_h only for large λ