http://quark.phy.bnl.gov/~dawson/win03.pdf

# Progress in Electroweak Symmetry Breaking

- It's not just the Higgs….

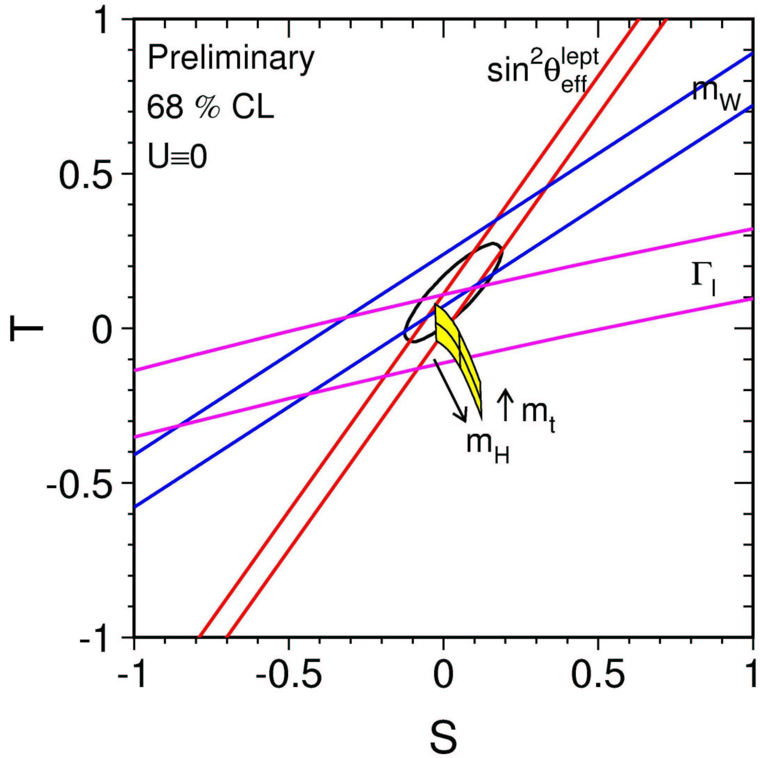
Weak Interactions and Neutrinos 03


Sally Dawson

BNL

October, 2003

# SM works well




•Any new physics severely constrained by precision measurements

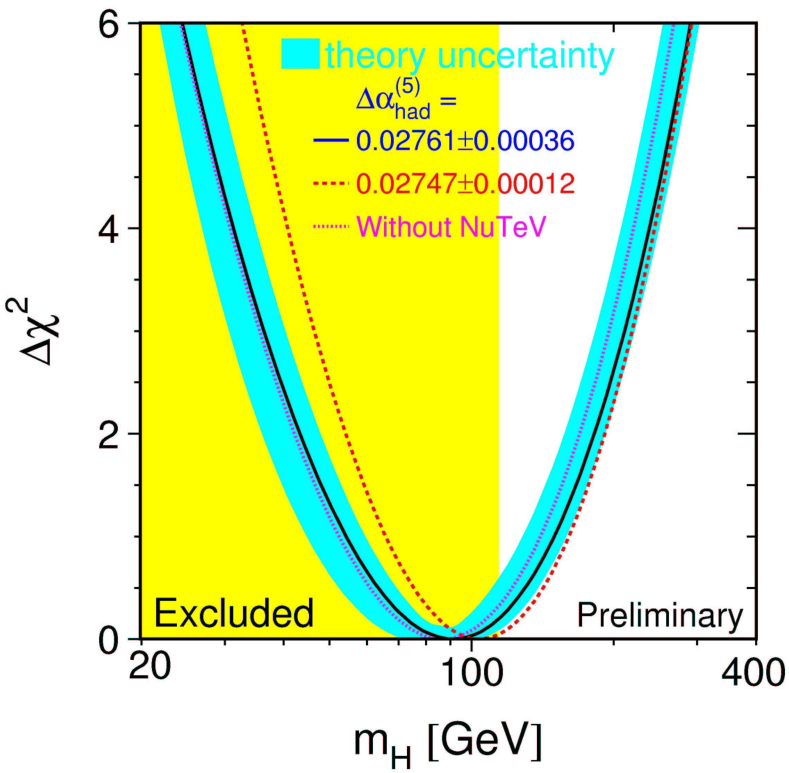
•Fit assumes $M_h$=150 GeV

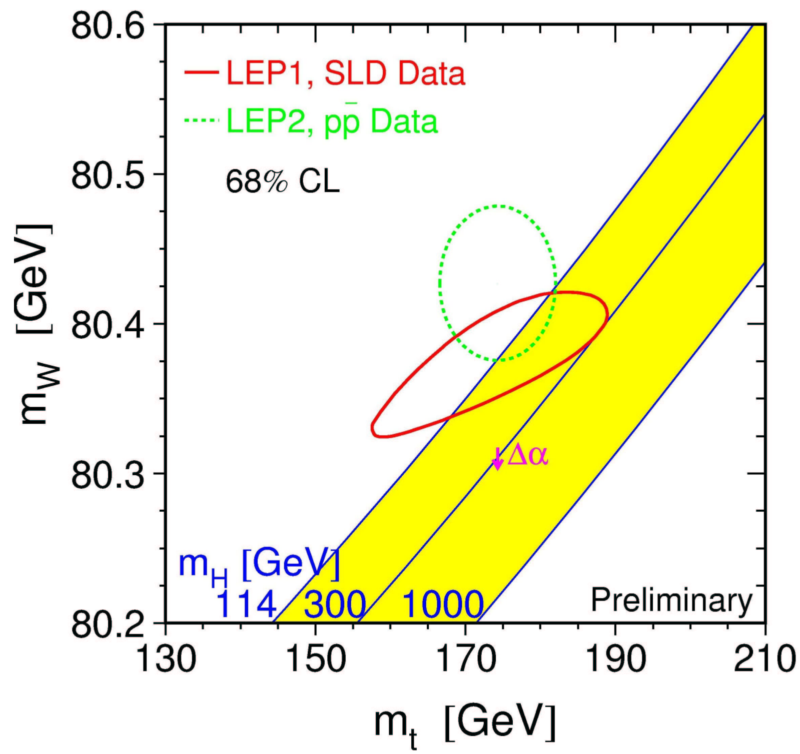
•LEP EWWG 2003

# Who needs a Higgs?

## Precision EW Measurements:

$M_h < 211$ GeV

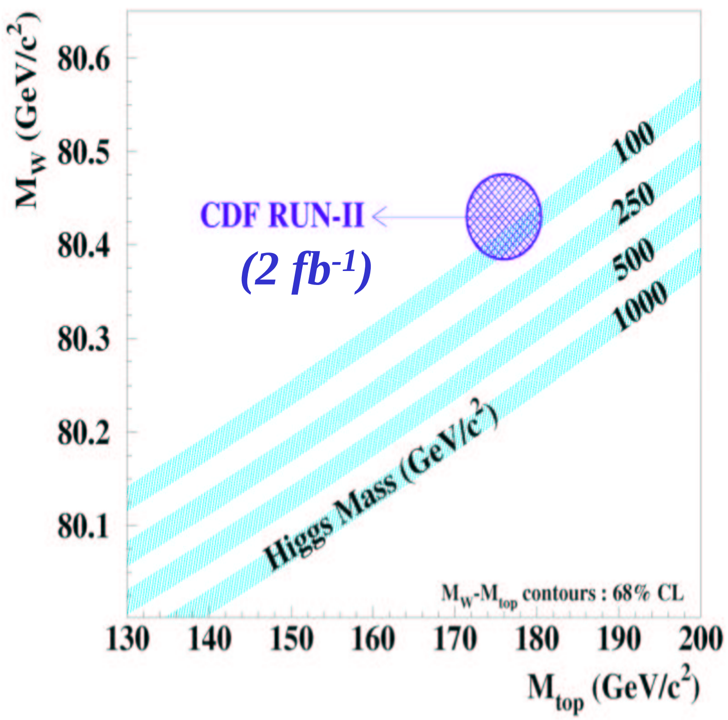



Note: Poor quality of fit

- NuTeV questions don't change Higgs conclusions
- See talk by B. Claire

# The Tevatron will point the way….




***•Increasing $M_t$ by 5 GeV increases upper bound on $M_h$ by 35 GeV!***

D0 preliminary:

$M_t$=180.1±3.6±4.0 GeV

# Why are we so sure this isn't the whole story?

***Why not just have a Standard Model Higgs with $M_h$<200 GeV?***

- Boring!
- Leaves many questions unanswered
  - Origin of fermion mass
  - Higgs mechanism accommodates fermion masses, but doesn't explain them
  - What about CP?
  - No gauge unification
  - …..

# Light Scalars are unnatural

- Higgs mass grows with cut-off, Λ

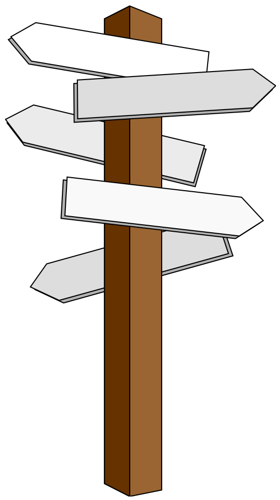

$$\delta M_h^2 = \frac{G_F}{4\sqrt{2}\pi^2}\Lambda^2\left(6M_W^2 + 3M_Z^2 + M_h^2 - 12M_t^2\right)$$

$$= -\left(\frac{\Lambda}{0.7\ \text{TeV}}\ 200\ \text{GeV}\right)^2$$

$M_H \leq 200$ GeV requires large cancellations

# Solutions:

- Remove Higgs completely
  - Dynamical symmetry breaking
  - Higgsless models in extra D
- Lower cut-off scale
  - Large extra dimensions
- Force cancellations
  - SUSY
  - Little Higgs
  - Make Higgs component of gauge field in extra D



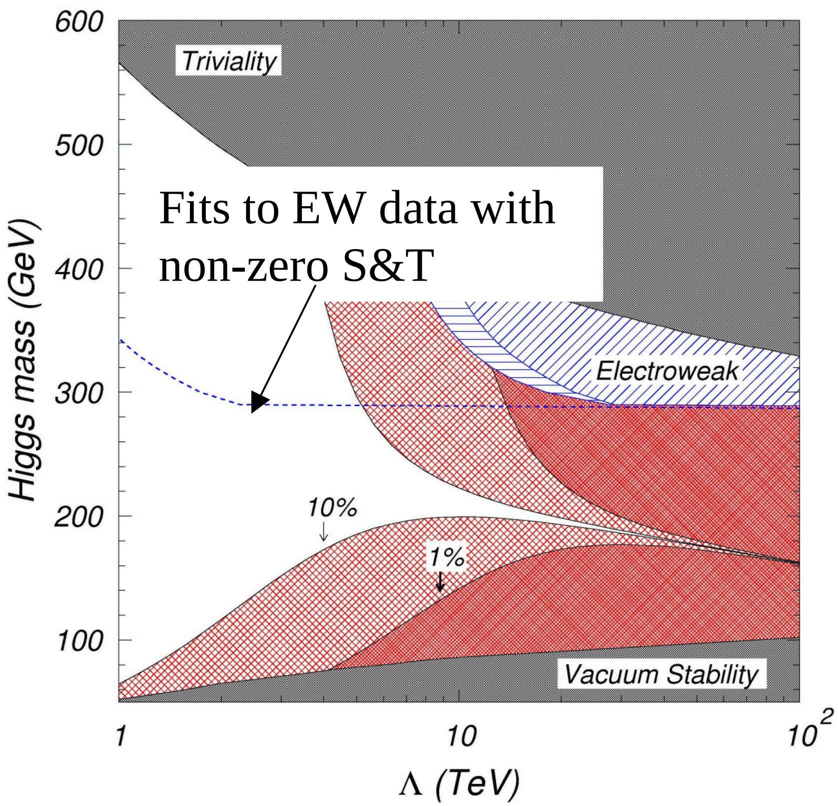
Which way to go?

***Symmetries maintain cancellations at higher order!***

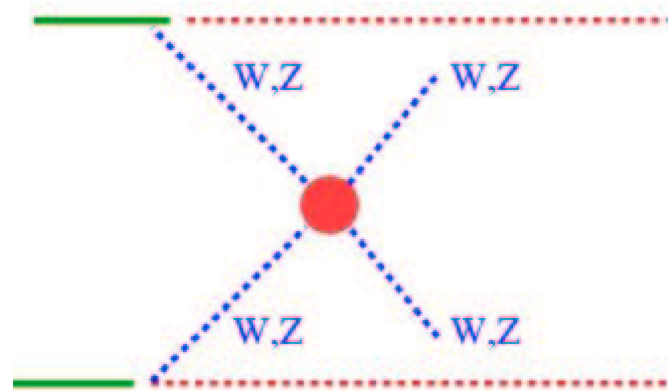
***Ultimate answer will come from data*!**

# Why the TeV Scale?
# We expect new physics on very general grounds

***Either a light Higgs, or strong WW Scattering***



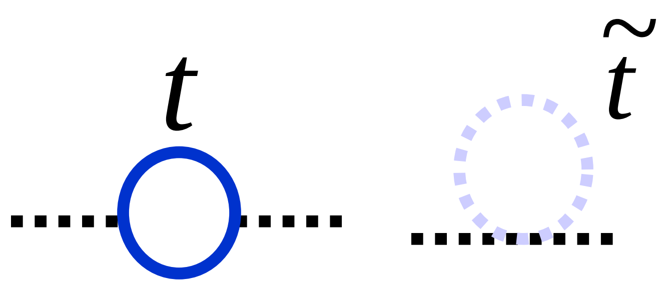

Kolda & Murayama, hep-ph/0003170




Standard Model inconsistent without Higgs unless new physics around 1.3 TeV

# SUSY….Our favorite model*

- Quadratic divergences cancelled automatically if SUSY particles at TeV scale
- Cancellation result of ***supersymmetry***, so happens at every order




$$\delta M_h^{\,2} \approx (....) G_F \Lambda^2 (M_t^{\,2} - M_{\tilde{t}}^{\,2})$$

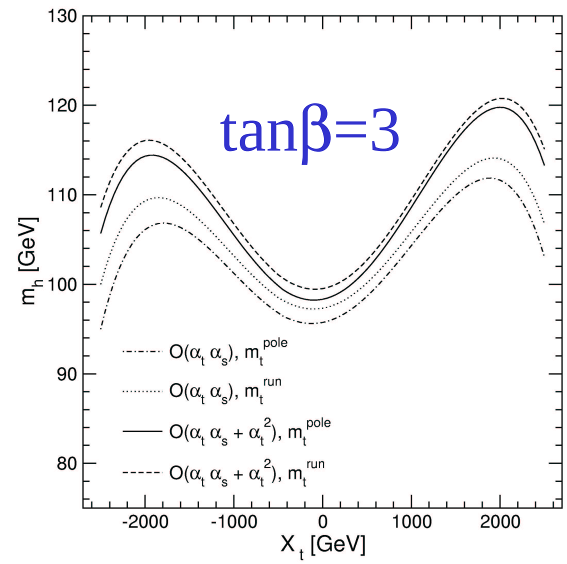
* Spires: 7421 papers after 1990 with title supersymmetry or supersymmetric!

# MSSM requires light Higgs

- Tension: stop should be **TeV scale** to cancel quadratic divergences in $M_H$ from top loops
- Stop needs to be **heavy** so that lightest Higgs mass satisfies LEP bound,

  $M_H > 114$ GeV
- Reasonable to consider expanding model by adding Higgs triplets and singlets

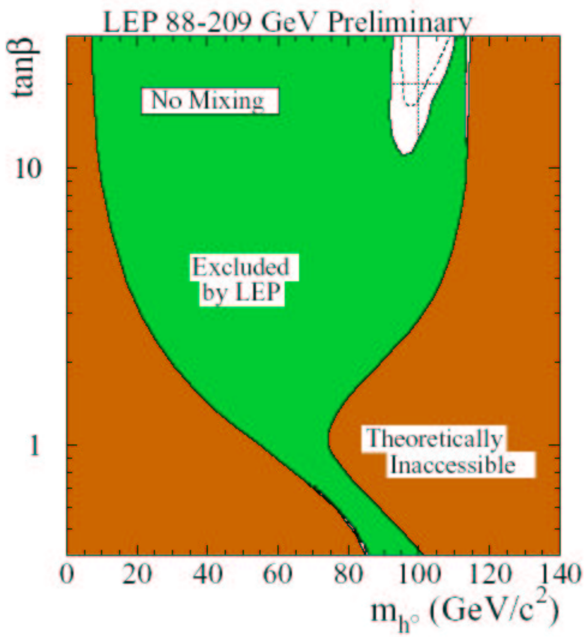
$$M_H^{\,2} \le M_Z^{\,2}\cos^2 2\beta + \frac{3G_F}{\sqrt{2}\pi^2}\ln\left[\frac{\tilde{m}_t^{\,2}}{m_t^{\,2}}\right] + \ldots$$

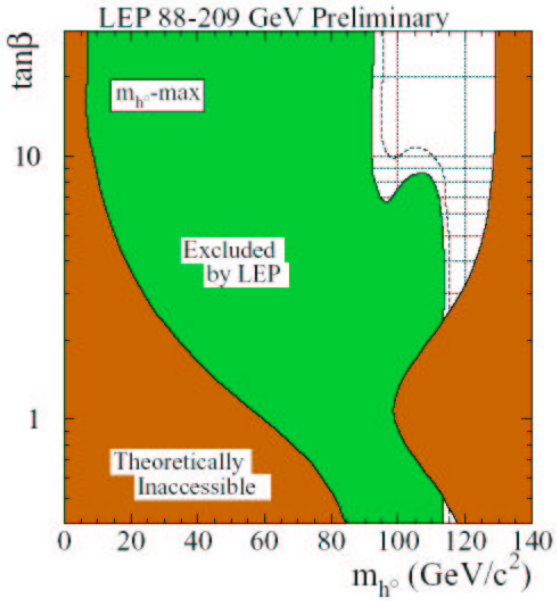



$X_t = A_t - \mu\cot\beta$

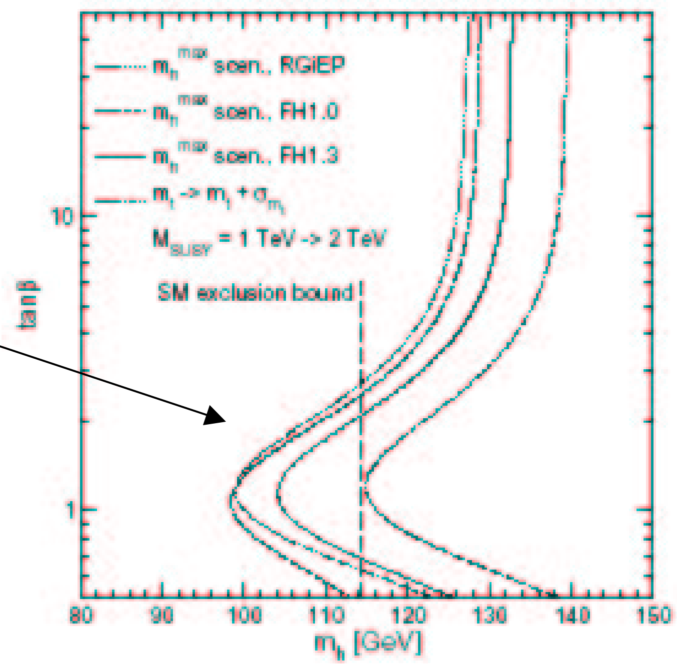
Degrassi,Heinemeyer, Holliuk, Slavich, Weiglein, hep-ph/0212020

# LEP MSSM Higgs Bound




•Boundaries of theoretically inaccessible region ("the nose") have shifted due to 2- and 3-loop calculations of MSSM Higgs mass




Degrassi-Heinemeyer-Hollik-Slavich-Weiglein

# Add Scalars to MSSM

- Add Higgs singlet S, triplets $T_0, T_{\pm 1}$
- Superpotential, $W = \lambda_1 H_u H_d S + \lambda_2 H_u T_0 H_d$
$+ \chi_1 H_u T_1 H_u + \chi_2 H_d T_{-1} H_d$

- At tree level, lightest Higgs mass bound becomes,

$$M_H^{\ 2} \leq M_Z^{\ 2} \cos^2 2\beta + v^2(\lambda_1^{\ 2} + \frac{\lambda_2^{\ 2}}{2}) \sin^2 2\beta$$
$$+ 4v^2(\chi_1^{\ 2} \cos^4 \beta + \chi_2^{\ 2} \sin^4 \beta)$$

- Higgs mass bound depends on particle content
  - Assume couplings perturbative to $M_{GUT}$ and SUSY scale ≈1 Tev

$M_h < 150 – 200$ GeV with singlet and triplet Higgs

- Singlets and triplets can be consistent with precision measurements

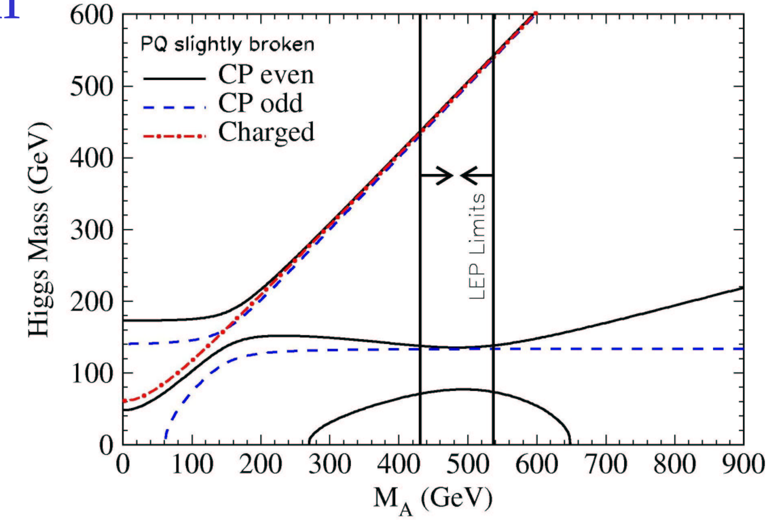
Espinosa & Quiros, hep-ph/9809269, Kobe & Wells, 2002

# Beyond the MSSM (NMSSM)

- Add singlet Higgs (doesn't spoil gauge unification)

$$W_S = \lambda S H_1 H_2 + \frac{\kappa}{3} S^3$$

- $S^3$ term necessary to avoid PQ axion
- $\lambda \langle S \rangle$ gives $\mu$ term of MSSM
  - $W = \mu H_u H_d$ in MSSM
  - Why is $\mu$ weak scale?
- Higgs phenomenology very different than MSSM:
  - 3 Neutral Higgs, 2 pseudoscalar Higgs
- Many scenarios have $h^0$, A at EW scale



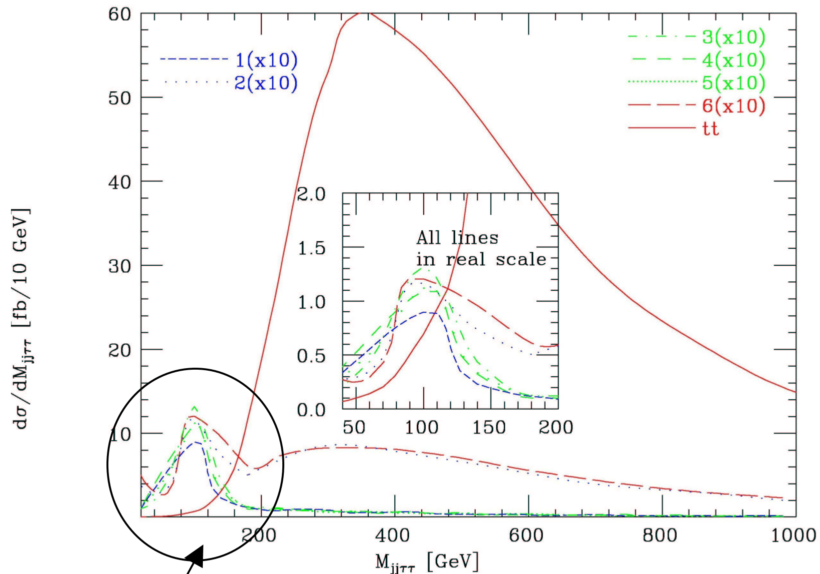

Miller, Nevzorov, Zerwas, hep-ph/0304049

•See talk by D. Miller

# MSSM, h→AA excluded Experimentally

- h→AA important discovery channel in NMSSM
- h can be SM-like and A light in NMSSM
- Look for
  - $W^+W^{-} \to h \to AA \to \tau^+\tau^- jj$
  - Statistically significant at LHC with 300 $fb^{-1}$/detector

Curves are different models




•Look for enhancement at low mass

•Not Gold-Plated!

Ellwanger, Gunion, Hugonie, Moretti, hep-ph/0305109

# CP Violation in MSSM

- mSUGRA type models [$m_0$, $m_{1/2}$, $A_0$, tan $\beta$, sign($\mu$)] can have ***phases in $m_{1/2}$, $A_0$***
- Phases change Higgs mass spectrum, couplings
  - Could suppress hZZ coupling
  - ***Light Higgs ($M_h \approx 60$ GeV) could have escaped LEP detection***
- New signatures

$$p\bar{p} \rightarrow H^{\pm}h^{0}$$
$$\sigma_{Tevatron} \approx 100\ fb$$

  - Can arrange large branching ratio $H^{\pm} \rightarrow h^0 W^{\pm}$

Computational Progress: CPSUPERH has MSSM masses with CP violation. (hep-ph/0307377)

•See talk by S. Mrenna

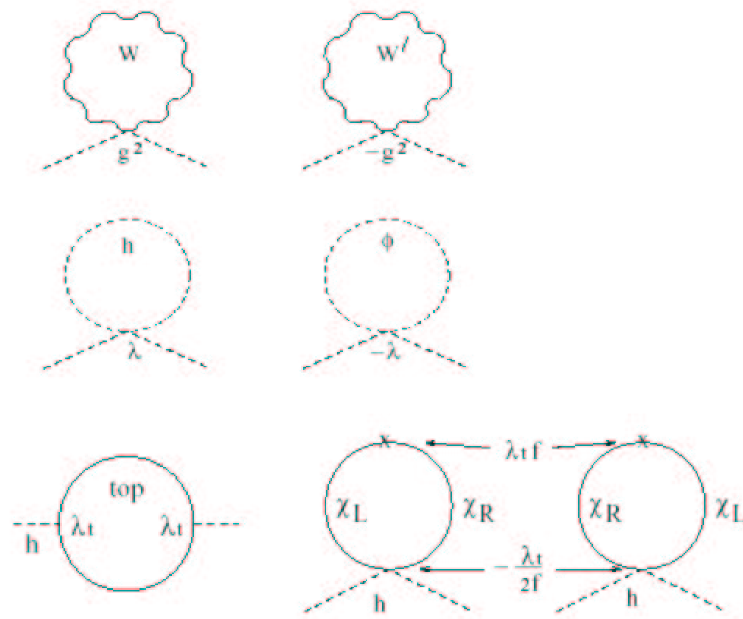
# Little Higgs Models

New particles at scale f ~ Λ cancel SM quadratic divergences

Cancellation from same spin particles

Need symmetry to enforce cancellation

- Heavy $W_H$,$Z_H$,$A_H$ cancel gauge loops
- Scalar triplet cancels Higgs loop
- Vector-like charge 2/3 quark cancels top loop



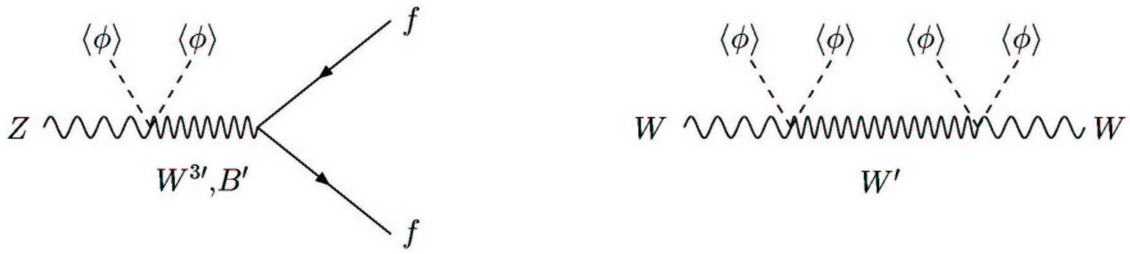

•Arkani-Hamed, Cohen, Katz, Nelson, hep-ph/0206021

# More on little Higgs

- Global Symmetry, G (SU(5))
  - Broken to subgroup H (SO(5))
- Higgs is Goldstone Boson of broken symmetry
  - Effective theory below symmetry breaking scale
- Gauged subgroups of G ($[SU(2)xU(1)]^2$) contain SM
- Higgs gets mass at 2 loops (naturally light)
- Freedom to arrange couplings of 1st 2 generations of fermions (their quadratic divergences small)

- Heavy W's, Z's, $\gamma$'s
- Heavy top
- Extended Higgs sector

# Little Higgs & Precision EW




- Mixing of heavy-light gauge bosons leads to problems with precision measurements

$$\frac{\delta\Gamma_Z}{\Gamma_Z} \approx 1 + (\ldots)\frac{v^2}{f^2}$$

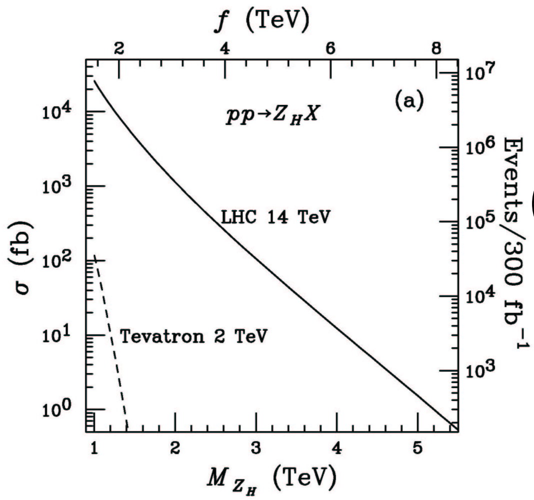
$$\frac{\delta M_W{}^2}{M_W{}^2} \approx 1 + (\ldots)\frac{v^2}{f^2}$$

- Many models
- Typically, $f \geq 3-4\,TeV$

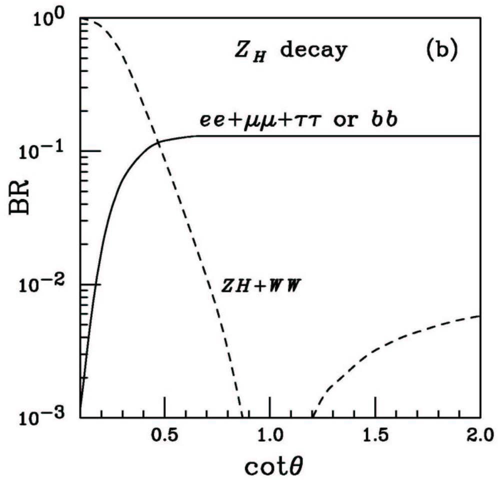
•See talk by G. Kribs

# New Phenomenology in Little Higgs Models

- Drell-Yan production of $Z_H$
  - EW precision limits prefer cot θ≈.2 (Heavy-light gauge mixing parameter)
  - BRs very different from SM
- Look for heavy tops
- Look for non-SM 3 gauge boson vertices




Scale down by $\cot^2\theta\approx.04$



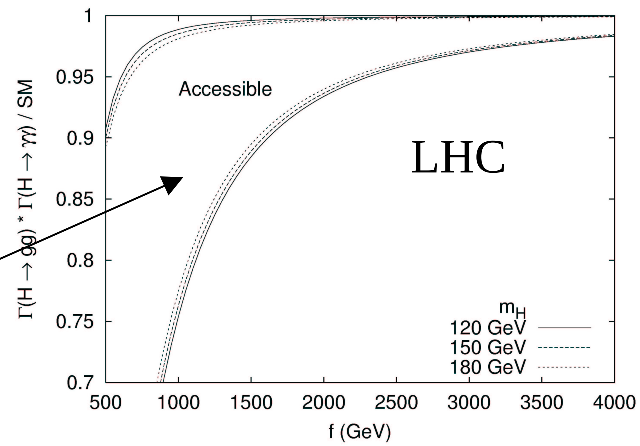

Han,Logan,McElrath, Wang, hep-ph/0301040

# Higgs production & decay in Little Higgs Models

***•Growing realization that EWSB isn't just Higgs discovery, but requires finding spectrum of new particles!***

- Rate could be reduced by ≈25%
- Later….could see same type of effect in radion models
  - How to tell the difference?
- Have to see new particles
  - $Z_H$, $W_H$, $\gamma_H$

$gg \rightarrow h \rightarrow \gamma\gamma$




This is theoretically allowed region

Han, Logan, McElrath, Wang, hep-ph/0302188

# Look for Higgs Triplets

- Present in little Higgs models
  - Easy to add to SUSY models
  - Left-Right models
- Triplet VEVs contribute to ρ parameter
  - Model with one real Higgs triplet: $\delta\rho \approx 4v'^2/v^2$
- Complex triplets give $H^{++}$ (unique signal for triplets)
  - Lots of new signals
    - $Z^* \to H^{++}H^{--}$
    - $W^-W^- \to H^{--}$

D0 limit: $M(H^{++}) > 116$ GeV

•See talk by M.-C. Chen

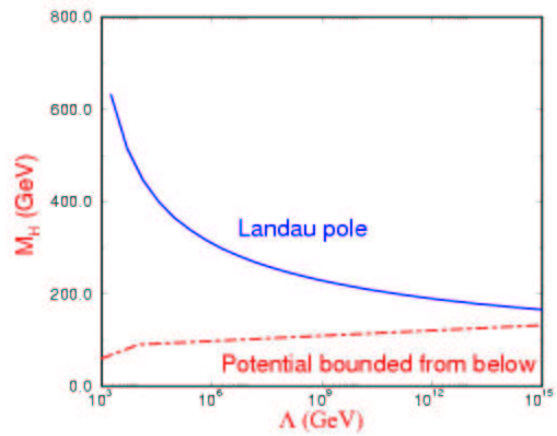
# Can We Evade Higgs mass Bounds?

- Higgs self-coupling scales with energy

$$L_{SM} \approx -\frac{M_h^{\ 2}}{2} h^2 - \lambda v h^3 - \frac{\lambda}{4} h^4$$

- $\lambda \to \infty$ at scale $\Lambda$

$$\frac{d\lambda}{d\log Q^2} = \frac{3\lambda^2}{4\pi^2}$$

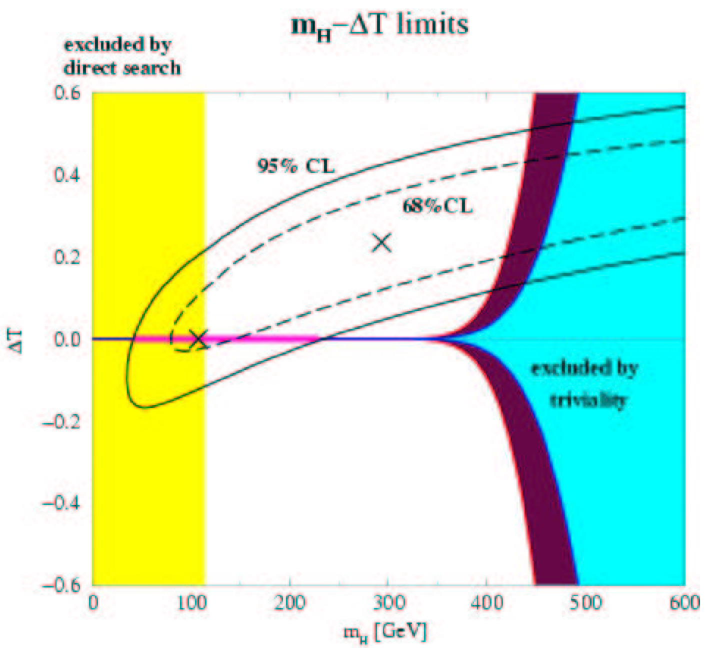



- Heavier the Higgs ($\lambda = M_H^2/2v^2$)
  - The smaller the scale $\Lambda$
- Relatively low scale of new physics

***Consider SM as effective theory***

# Higgs can be heavy with new physics

- Non-zero $\Delta S$ and/or $\Delta T$ required for heavy Higgs
- $M_h \approx$ 450-500 GeV allowed with large $\Delta T$
- Include all operators allowed by symmetries to construct effective theory




•See talk by W. Kilian

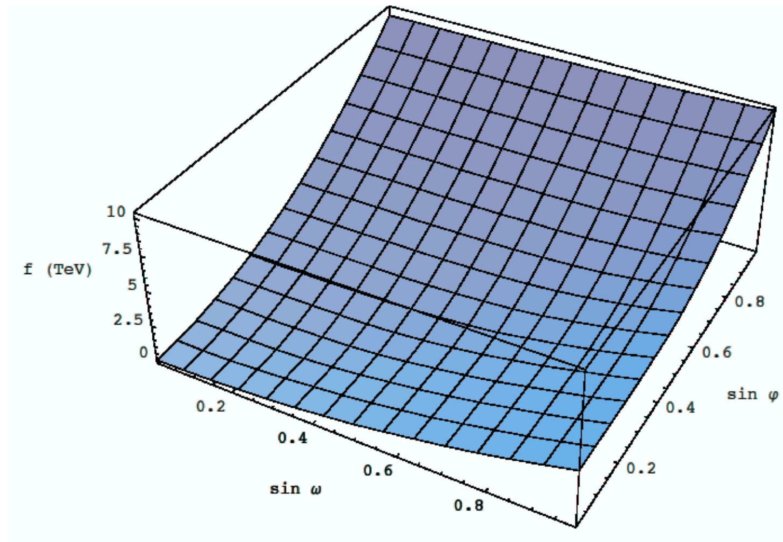
•Chivukula, Holbling, hep-ph/0110214

# Hard to construct explicit models

- Models are complicated
- Tend to have replicated weak gauge structure
  - SU(2) x SU(2)
    - non-commuting extended TC
    - topflavor
    - ununified SM
  - U(1) x U(1)
    - topcolor-assisted TC
    - topflavor-seesaw
- General analysis of limits from precision measurements
  - Fermion charge assignments have major effect

***None of these models give better fits to EW precision data than SM***

95% cl bound on new physics scale




–Topcolor, NCETC, UUM

new physics scale bounded≈ 10 TeV…..Extra gauge bosons too heavy to be observed at LHC

–Topflavor bounds ≈ few TeV

Chivukula, He, Howard, Simmons, hep-ph/0307209

# Solving naturalness problem with low scale extra dimensions

Flat:

$$M_{Pl} \approx R^{\delta/2} M_D^{1+\delta/2} \qquad D = 4 + \delta$$

Warped:

$$M_{Pl} \approx M_5 e^{-KR\pi}$$

Where does Higgs live? On the brane? In the bulk?

Maybe electroweak symmetry breaking through boundary conditions on the brane?

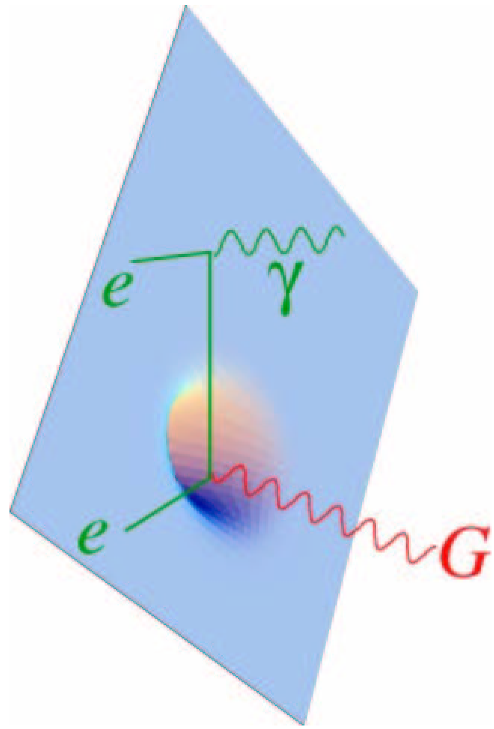
Can Higgs be $5^{th}$ component of gauge field in 5D?

See talk by B. Dobrescu

# Models with Extra Dimensions provide another good comparison point for SM

- Extra-D Models have towers of new Kaluza Klein Gravitons
- Graviton emission can measure the number of hidden dimensions
- Graviton exchange affects precision measurements,

  Drell-Yan production, missing $E_T$ measurements….



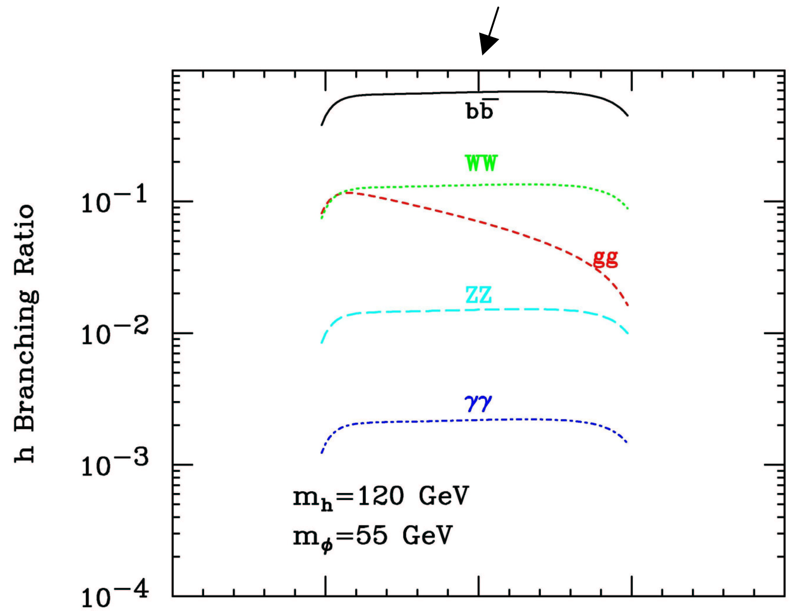
# Once we find something, we want to know what it is….

Is it a Higgs or is it a radion?

- Warped extra D has radion: $\phi$
- $\phi$ couples like Higgs, but with strength $\phi$/TeV instead of h/v
- Higgs-$\phi$ mixing suppresses standard channel, $gg \to h \to \gamma\gamma$
- How do you know it's a radion?

Have to find both Higgs & radion

SM Limit




Higgs-Radion Mixing Parameter

Battaglia, DeCurtis, DeRoeck, Dominici,& Gunion, hep-ph/030425

Dominici, Grzadkowski, Gunion, Toharia, hep-ph/0206192

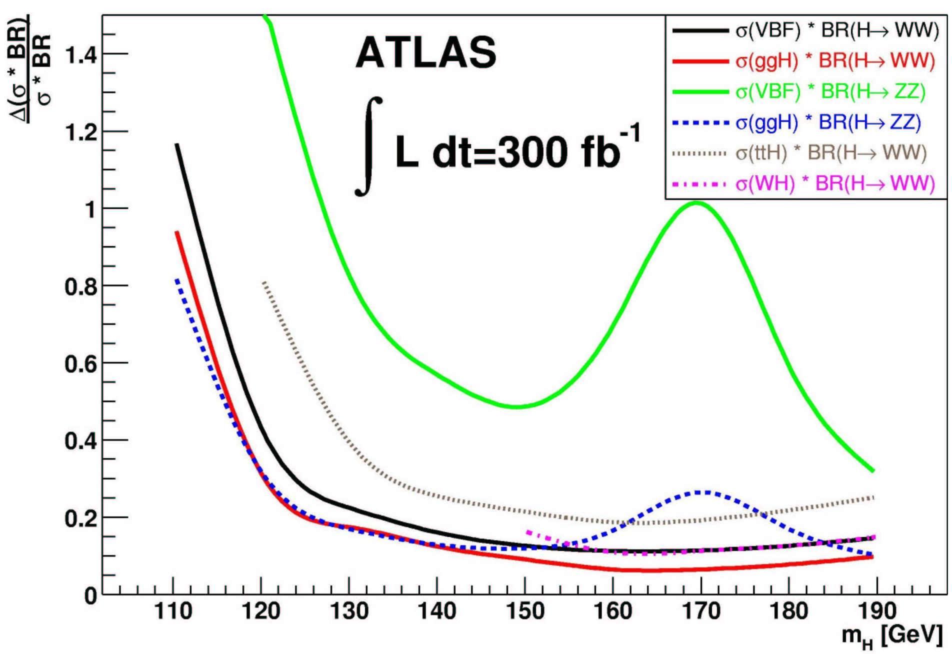
Hewett & Spiropulu, hep-ph/0205100

# If we find a “Higgs-like” object, what then?

- We need to:
  - Measure Higgs couplings to fermions & gauge bosons
  - Measure Higgs spin/parity
  - Reconstruct Higgs potential
- Reminder: Many models have other signatures:
  - New gauge bosons (little Higgs)
  - Other new resonances (Extra D)
  - Scalar triplets (little Higgs, NMSSM)
  - Colored scalars (MSSM)
  - etc

# *Coupling Constant Measurements*

LHC measures σ BR for Higgs production and decay



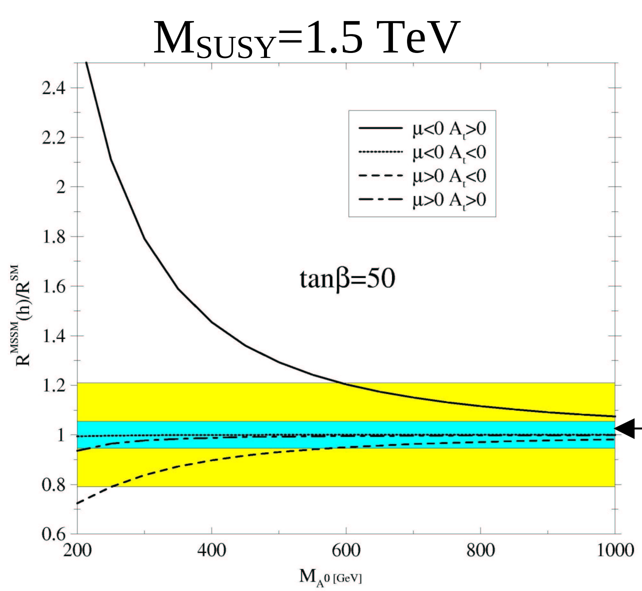

Duehrssen

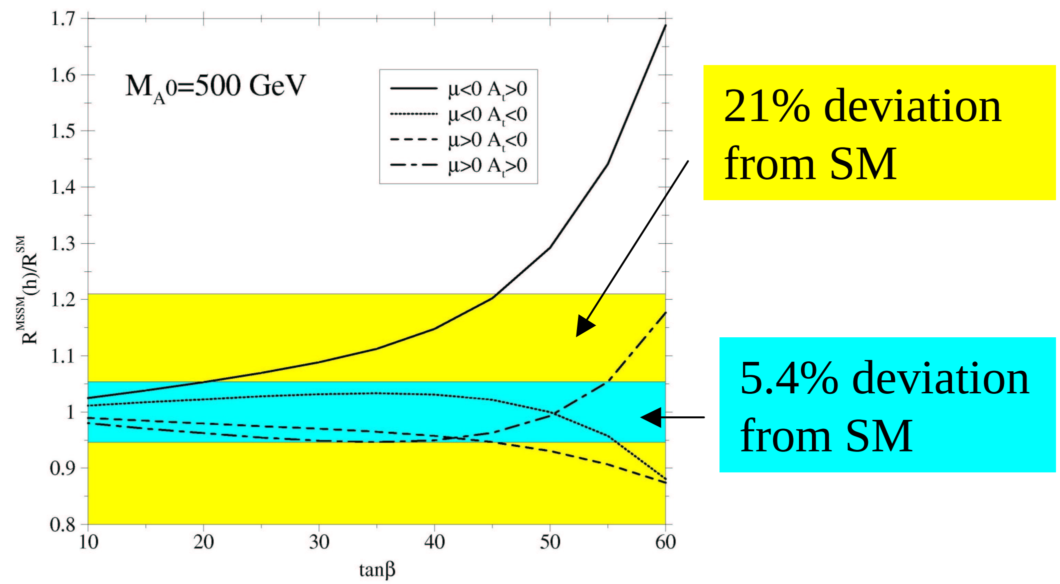
- Individual measurements depend on combinations of coupling constants
- Do global fit to relative couplings
- How well do we need to do?

# How well do we need Higgs couplings?

- MSSM example:

$$R = \frac{BR(h \to b\bar{b})}{BR(h \to \tau^+\tau^-)}$$

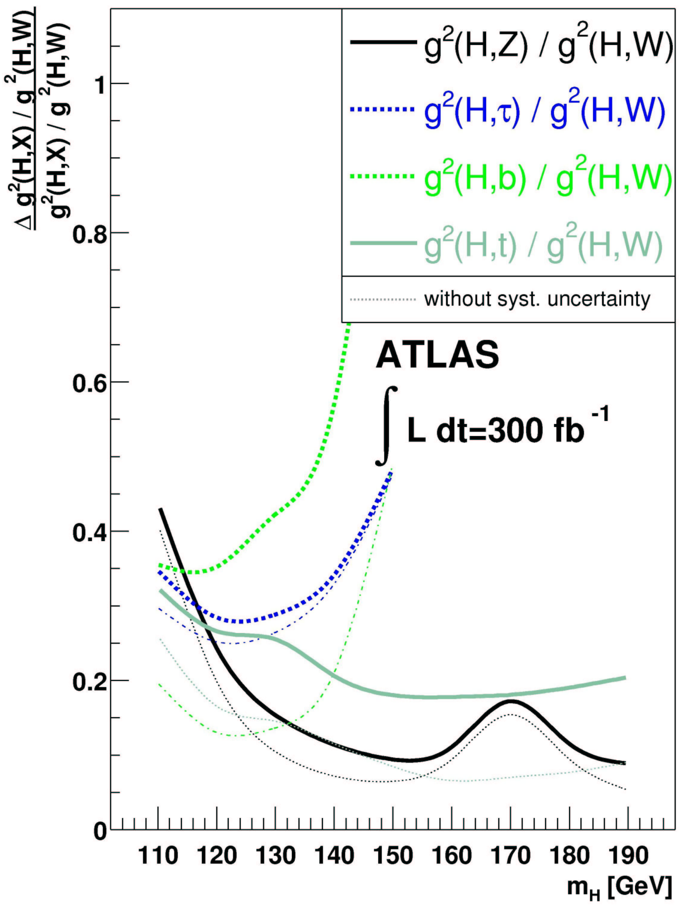



Note rapid approach to decoupling limit

Guasch, Hollik, Penaranda, hep-ph/0307012

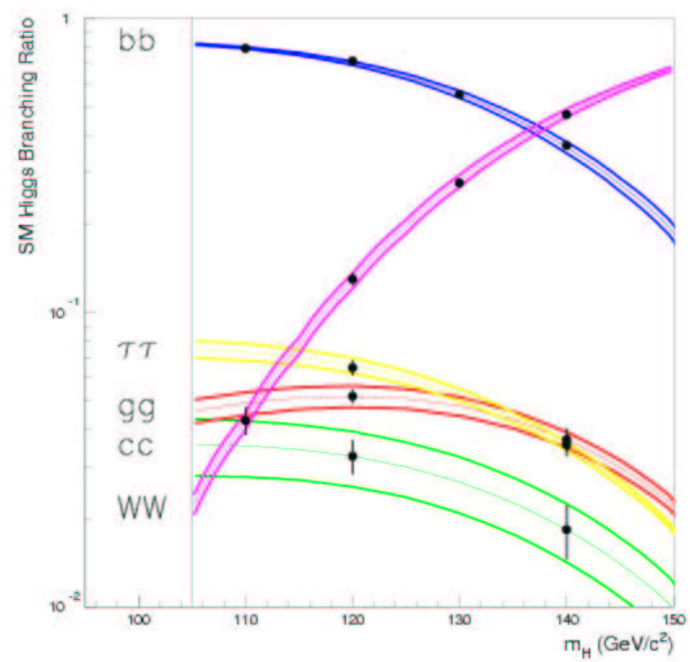
# Absolute measurements of Higgs couplings




Duhrssen, ATL-PHYS-2003-030

$e^+e^-$ LC at $\sqrt{s}$=350 GeV

L=500 $fb^{-1}$, $M_H$=120 GeV



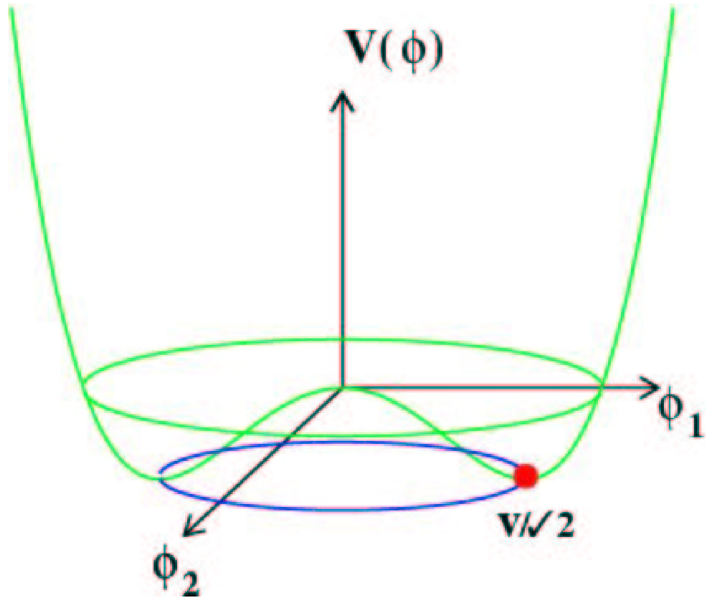

Battaglia, Desch, hep-ph/0101165

# Can we reconstruct the Higgs potential?

$$V = \frac{M_h^{\ 2}}{2} h^2 + \lambda_3 v h^3 + \frac{\lambda_4}{4} h^4$$

$$+ \sum_n C_n \frac{(h^2 - v^2)^n}{\Lambda^{(2n-4)}}$$

$$SM: \ \lambda_3 = \lambda_4 = \frac{M_h^{\ 2}}{2v^2}$$



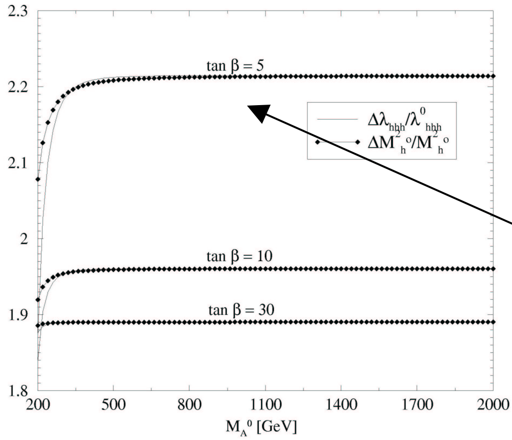

Fundamental test of model!

See talks by A. deRoeck and S. Martin

# Higgs self-couplings require careful interpretation

- MSSM, corrections to $\lambda_3, \lambda_4$ largely absorbed in definition of Higgs mass

$$\frac{\Delta\lambda_3}{\lambda_3} \approx \frac{\Delta M_h^2}{M_h^2}$$




Dobado, Herrero, Hollik, Penaranda, hep-ph/0210315

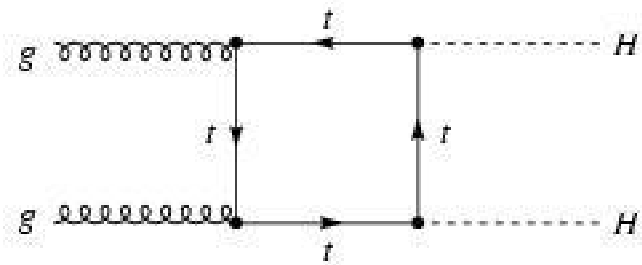
•Little Higgs models generate effective Higgs potential from integrating out heavy particles

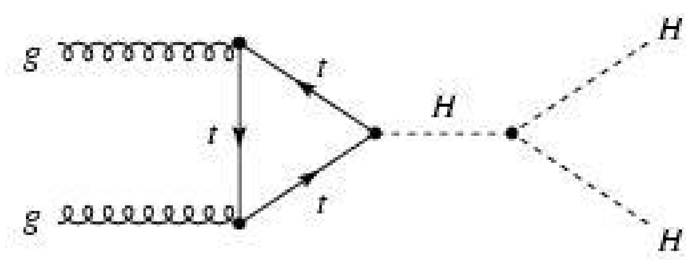
•At one-loop, quadratic sensitivity to cutoff

•No prediction for $\lambda_3, \lambda_4$

Genuine corrections to $\lambda_3$, $\lambda_4$ are differences between curves

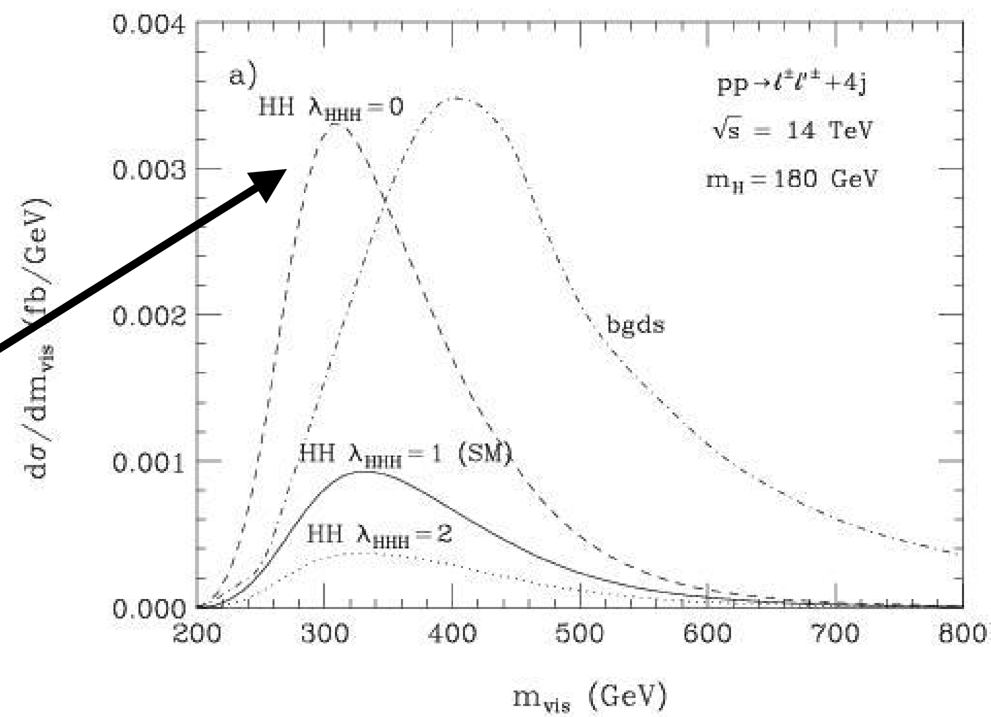
# Reconstructing the Higgs potential




- $\lambda_3$ requires 2 Higgs production
- $M_h$<140 GeV, $h \rightarrow bbbb$
- Overwhelming QCD background
- Easier at higher $M_h$

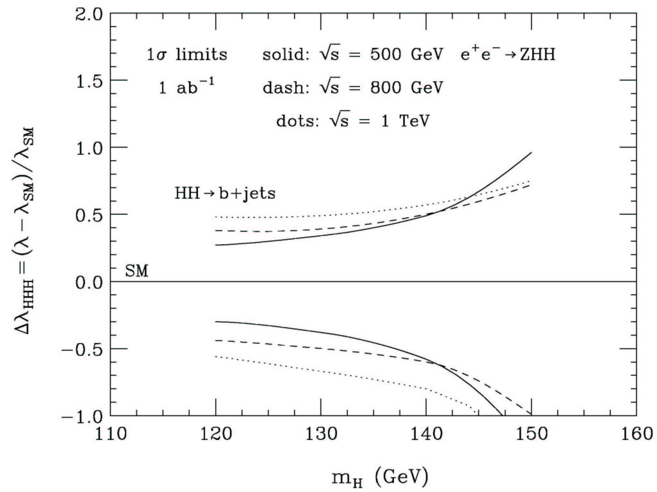
Can determine whether $\lambda_3$=0 at 95% cl with 300 $fb^{-1}$ for 150<$M_h$<200 GeV




Baur, Plehn & Rainwater, hep-ph/0304015

# Tri-Linear Higgs Coupling at e+e- Colliders

- $M_h$<140 Gev, $e^+e^- \rightarrow Zhh$
  - Dominant decay, $h\rightarrow bb$
  - High efficiency for identifying b's recoiling from Z
  - $M_h$=120 GeV, $\sqrt{s}$=500 GeV, L=1 $ab^{-1}$




- $M_h$>150 GeV, $h\rightarrow W^+W^-$
  - Phase space suppression
  - $\sigma$(Zhh) decreases at higher $\sqrt{s}$; sensitivity to $\lambda$ decreases
  - $\sigma(\nu\nu hh) << \sigma(Zhh)$
  - $\sqrt{s}$=500 GeV optimal energy

***LHC & LC are complementary:***

***LHC sensitive to $M_h$>150 GeV,***
***LC sensitive to lighter $M_h$***

Castanier, hep-ex/0101028

Baur,Plehn, Rainwater, hep-ph/0304015

# Look for dimension-6 Higgs Interactions

- Model independent approach

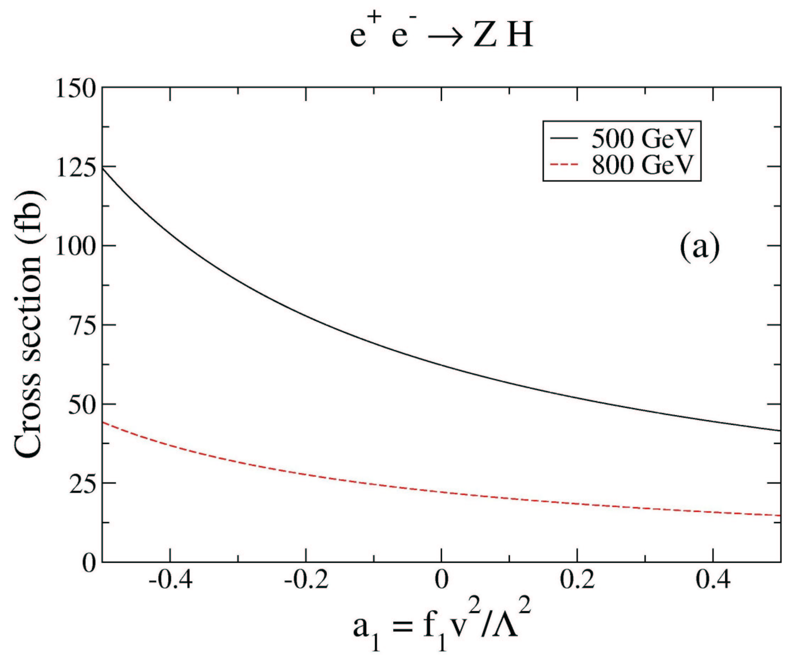
$$L = \sum \frac{f_i}{\Lambda^2} O_i$$

$$O_1 = \frac{1}{2}(\partial_\mu \Phi^+ \Phi)\partial^\mu (\Phi^+ \Phi)$$

$$O_2 = -\frac{1}{2}(\Phi^+ \Phi)^3$$

- Lose connection between $M_h$ and $\lambda_3$ with dimension-6 operators

$$M_h{}^2 = 2\lambda_3 v^2 \left(1 + O\left(\frac{fv^2}{\Lambda^2}\right)\right)$$

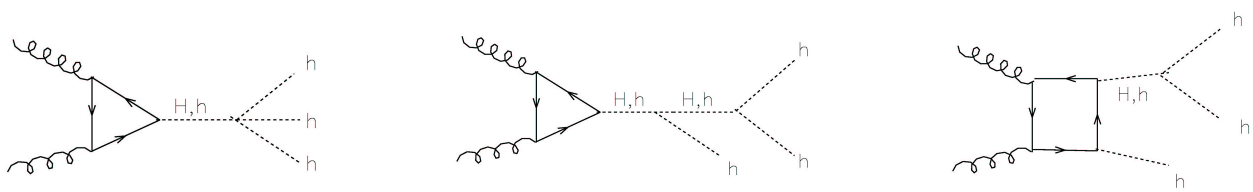



***Is there a model?***

Barger et al, hep-ph/0301097

# ? What about Quartic Higgs Coupling ?

- Requires 3 Higgs production
  - 10 TeV, e+e⁻ collider has 5 $e^+e^- \rightarrow hhh\nu\nu$ events with L= 1 $ab^{-1}$
  - Maybe resonant enhancement in gg →hhh in MSSM?
    - Unfortunately, no sensitivity to quartic coupling




•Cynolter, Lendvai, Pocsik, hep-ph/0003008

New Physics Searches require
***Precision Calculations***

- Is it new physics?
  - Extra dimensions
  - Little Higgs
  - SUSY
  - Something really new…..
- Or is it QCD?

Effects typically $O(v^2/\Lambda^2)$

↓

Unless you see a new particle or resonance!

↓

QCD effects $O(\alpha_s)$ same size

# $(g-2)_\mu$ example of need for higher order corrections

BNL g-2 experiment latest result from 2000 $\mu^+$ data released 2002

$$a_\mu = 11659203(8) \times 10^{-10}$$

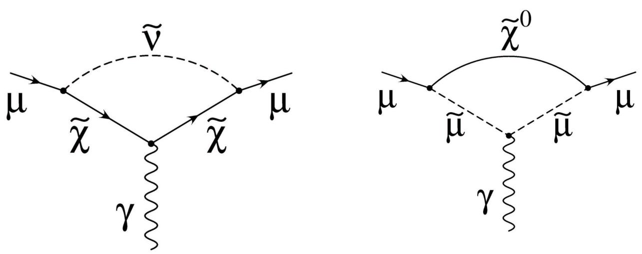
Soon result of 2001 $\mu^-$ data expected

$\Rightarrow$30% error reduction

Excellent place for new physics

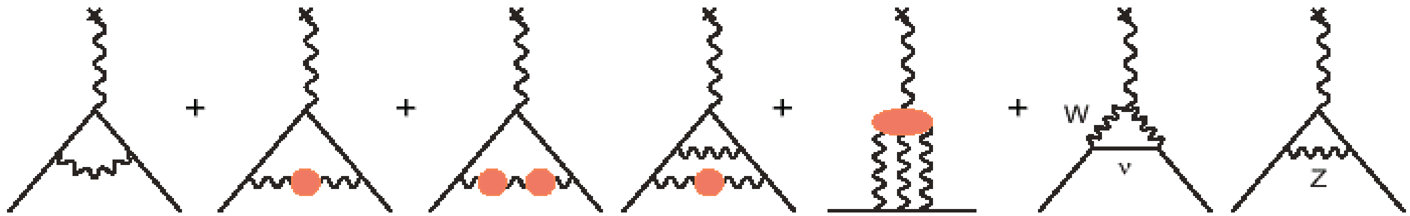
$\Rightarrow$unexplored loop effects ~ $m^2_\mu/\Lambda^2$

Supersymmetry is natural candidate at moderate/large tanβ



# Lots of contributions to $(g\text{-}2)_\mu$

$$a_\mu^{SM} = a_\mu^{QED} + a_\mu^{had,LO} + a_\mu^{had,HO} + a_\mu^{had,LBL} + a_\mu^{weak}$$

= 


= (QED) $(11\,658\,470.35 \pm 0.28)10^{-10}$ (5-loop!)

+ (had,LO) $(684.7 \text{ to } 709.0 \pm 6)10^{-10}$ 4loop big, never checked!

+ (had,HO) $(-10.0 \pm 0.6)10^{-10}$

+ (had,LBL) $(8.0 \pm 4.0)10^{-10}$ (sign change since 1998)

+ (weak) $(15.4 \pm 0.2)10^{-10}$ (2-loop)

$a_\mu^{had,LO}$ from data via dispersion integral

$$a_\mu^{had,LO} = \frac{1}{4\pi^3}\int_{4m_\pi^2}^{\infty} \sigma^0_{had}(s)K(s)ds$$

Recent data included CMD-2, SND, BES 2-5 GeV, ALEPH $\tau$.
NEW: CMD-2 prelim update

Dominated by low energy region, ρ resonance

•Slide from P. Gambini

# New data for hadronic contribution

Final CMD-2 π π data (2002) 0.6% syst error!

Hagiwara et al (HMNT) NEW result:
$a_\mu^{had,LO} = 691.7 \pm 5.8_{exp} \pm 2.0_{r.c.}$

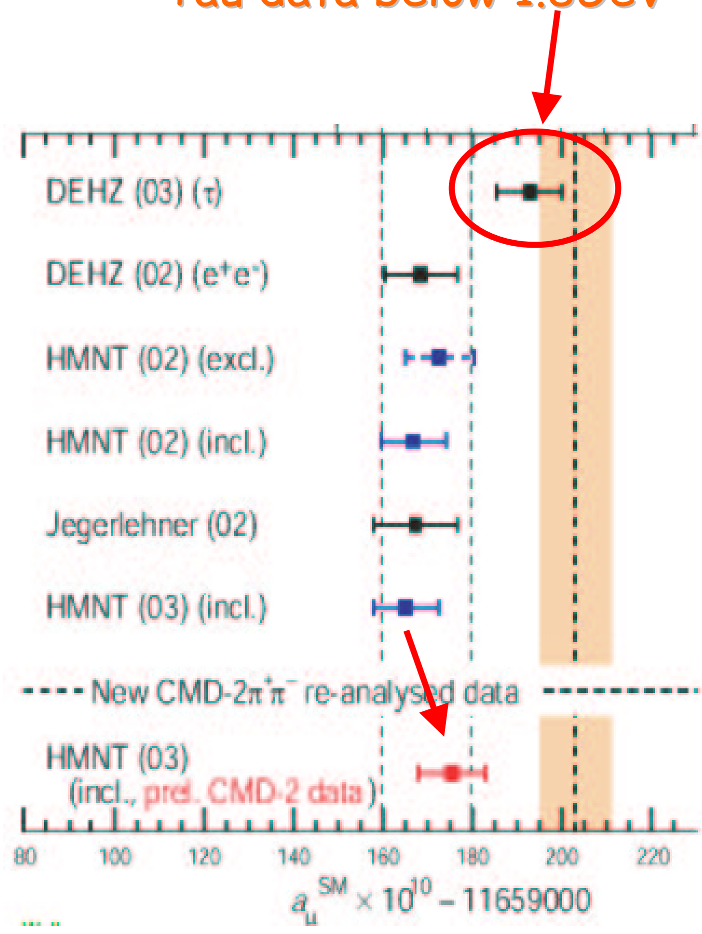
This translates to a ~2-2.5σ discrepancy

Using τ data below 1.8 GeV Davier at al (DEHZ)
$a_\mu^{had,LO} = 709.0 \pm 5.1_{exp} \pm 1.2_{r.c} \pm 2.8_{SU(2)}$

Good agreement between Aleph, CLEO, Opal τ data

My Editorial Comment: Still can't make case for new physics!

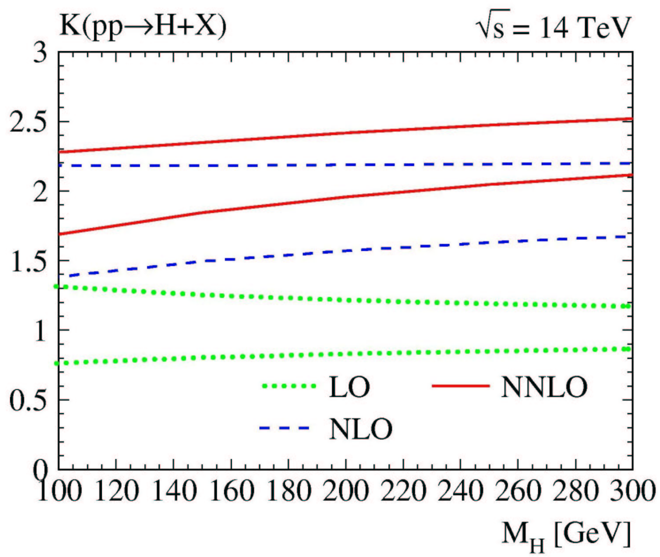
Tau data below 1.8GeV

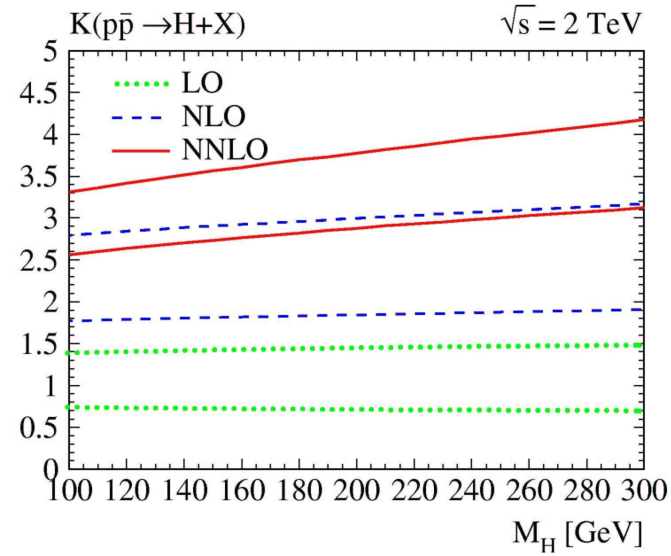



•Slide from P. Gambini

# Progress in Theoretical Predictions

- NNLO results for inclusive Higgs production, pp→h



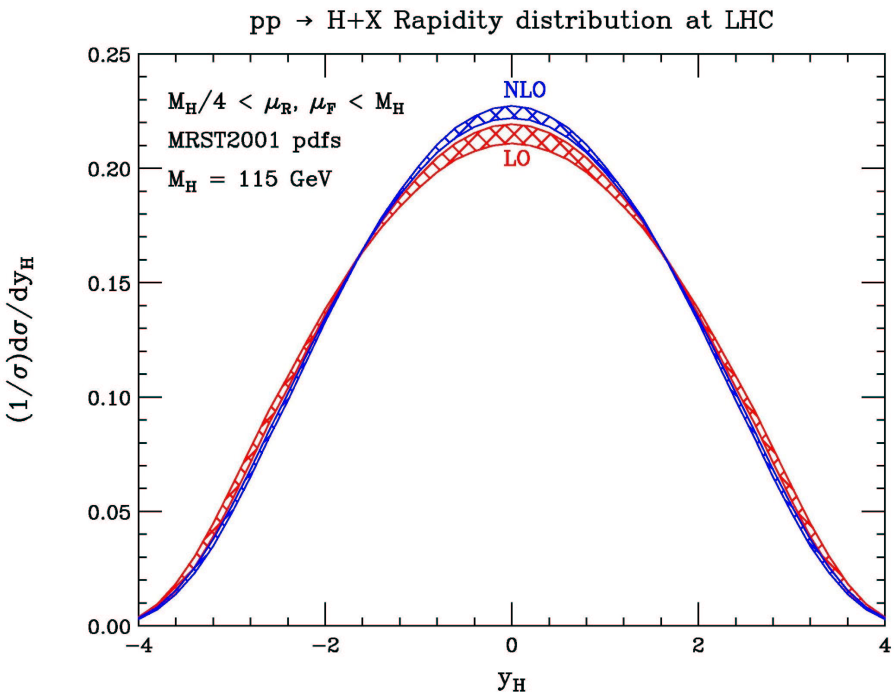

Note reduced scale dependence at NNLO

Harlander & Kilgore, hep-ph/0201206,
Anastasiou, Melnikov, hep-ph/0207004

→ ***Large corrections***

# Higgs Distributions at NLO

Higgs $p_T$ spectrum at NLO QCD:




NLO corrections to shape small, 5% at y=0

Suggests using LO Monte Carlo, weighted by NNLO cross section

Need case by case study


Anastasiou, Dixon, &Melnikov, hep-ph/0211141

Glosser & Schmidt, hep-ph/0209248

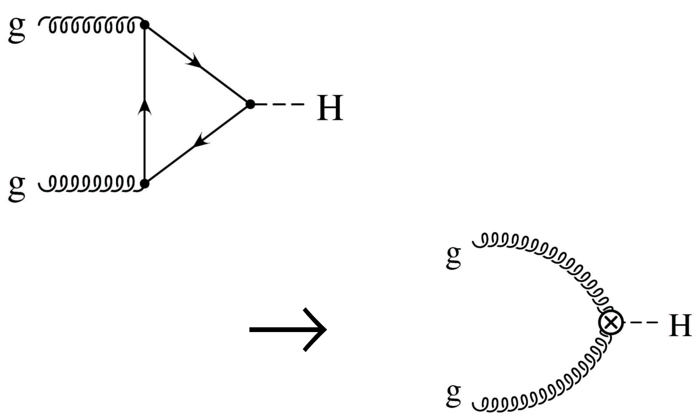
Ravindran, Smith, & van Neervan, hep-ph/021114

deFlorian, Grazzini, & Kunszt, hep-ph/9902483

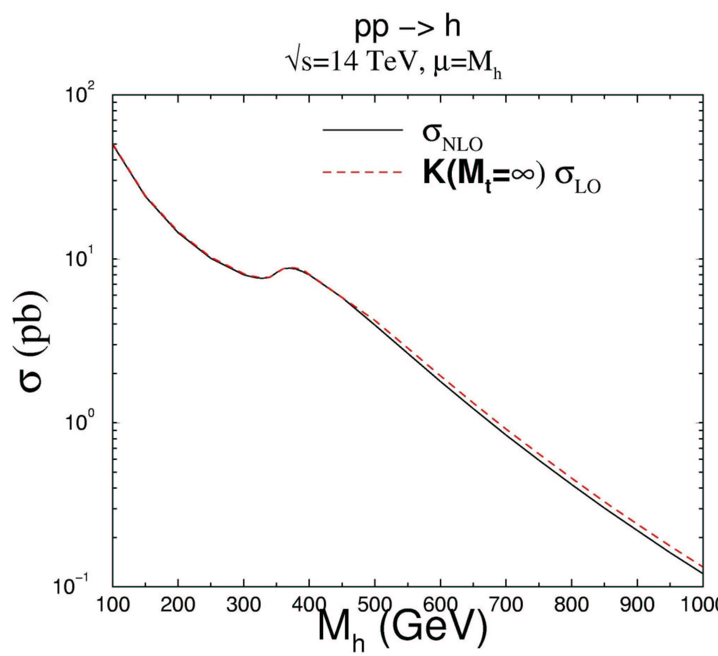
# Large $M_t$ limit and QCD corrections

- NLO, NNLO use effective theory:

$$L = -\frac{h}{v} C_1(\alpha_s) G_{\mu\nu}{}^{a} G^{a\mu\nu}$$



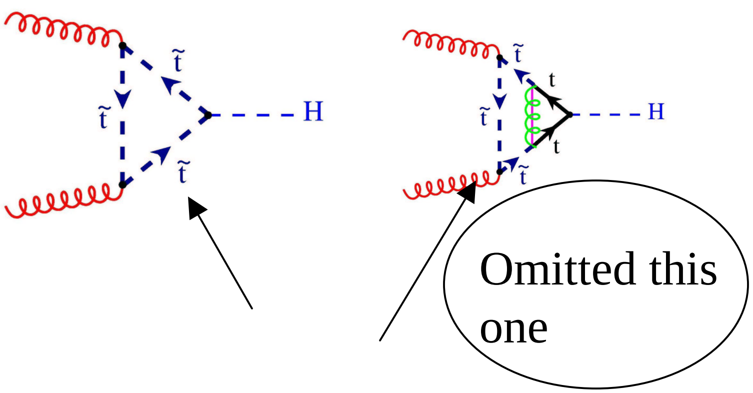

Effective theory is extremely accurate approximation



# Does effective theory work for SUSY?

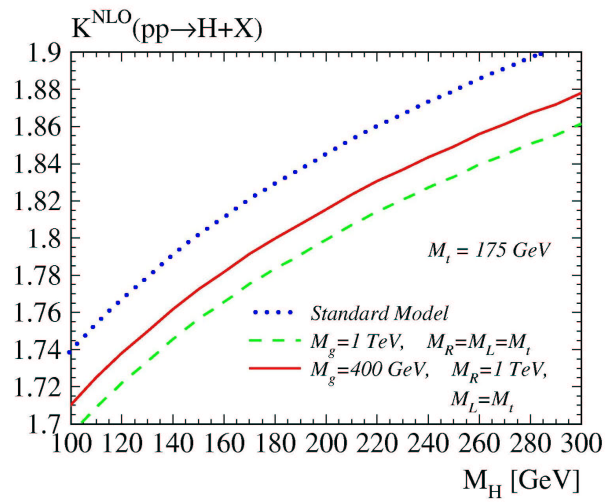
- Use effective theory only for small $\tan\beta$ where b loop is suppressed
- Include stop, gluino loops

***• No decoupling for heavy gluino with SUSY couplings maintained***




Dawson, Djouadi, Spira, hep-ph/9603423

gg→h at NNLO




• SUSY effects tend to suppress rate

Harlander and Steinhauser, hep-ph/0307346

# Tremendous progress in automated programs

GRACE collaboration: Automated system for 1-loop electroweak processes

- General non-linear gauge: check gauge independence
  - Also check ultraviolet and infrared finiteness
- $2 \to 2$ processes at one loop EW:
  - $e^+e^- \to \nu\nu$, $e^+e^-$, $W^+W^-$, ZZ, hZ
  - $tb \to W^+\gamma, W^+Z, W^+h, \ldots.$
  - etc
- Uses finite photon mass
  - Not easily generalized to QCD
- Start on automating $2 \to 3$ 1-loop EW
  - $e+e- \to tth$
  - $e+e- \to \nu\nu h$
  - $e+e- \to Zhh$
- Many new multi-loop calculations….
  - Review by Dittmaier , hep-ph/0308070

GRACE collaboration, Belanger et al, hep-ph/0308080

# NNLO QCD and NLO EW Corrections to Wh and Zh production

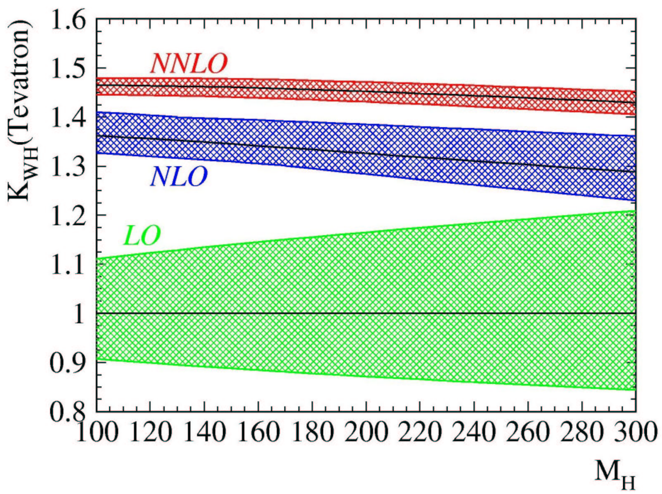
- Two loop $O(\alpha_s^2)$ corrections to Wh and Zh production at Tevatron and LHC
- Increase rate 5-10%
- Theoretically very clean
  - Almost no scale dependence at NNLO

•Complete EW corrections

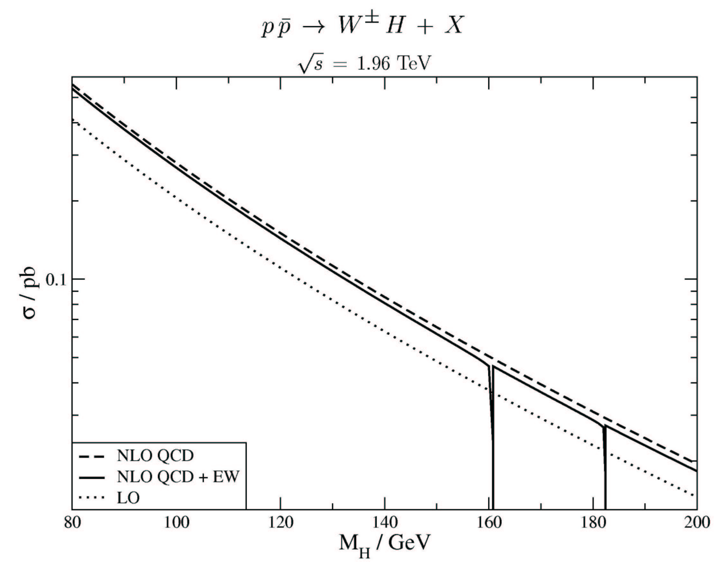
•Decrease rate

•Opposite sign from QCD !

$p\bar{p} \to Wh$ *at Tevatron*



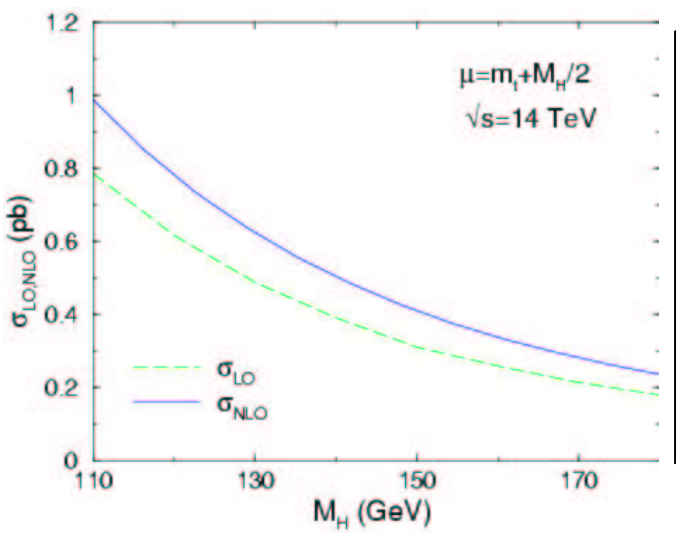

Brein, Djouadi, Harlander, hep-ph/0307206



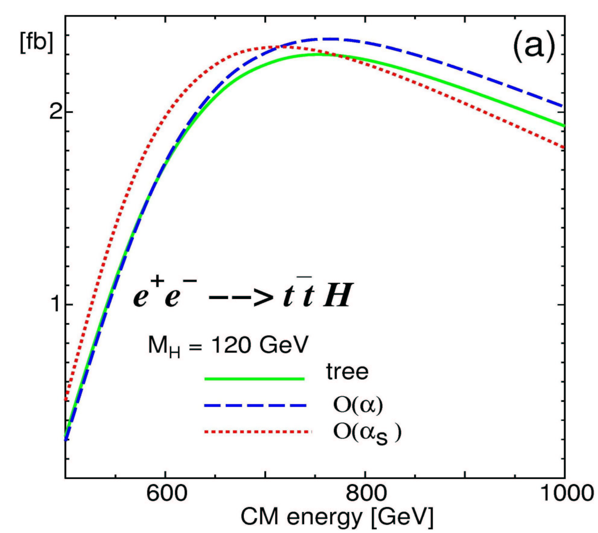

Ciccolini, Dittmaier, Kramer, hep-ph/0306234

# NLO QCD &EW Corrections to tth Production

QCD correction to tth production large at LHC




Cancellation of QCD & EW corrections at high √s



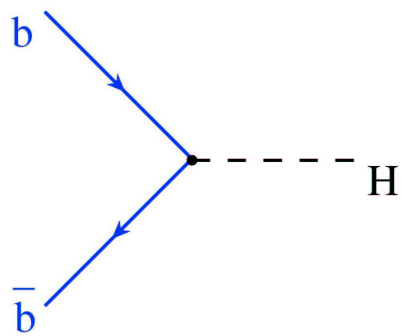

- Dawson, Jackson, Orr, Reina, Wackeroth,hep-ph/0305087
- Beenakker et al, hep-ph/0211352

Belanger et al, hep-ph/0301040

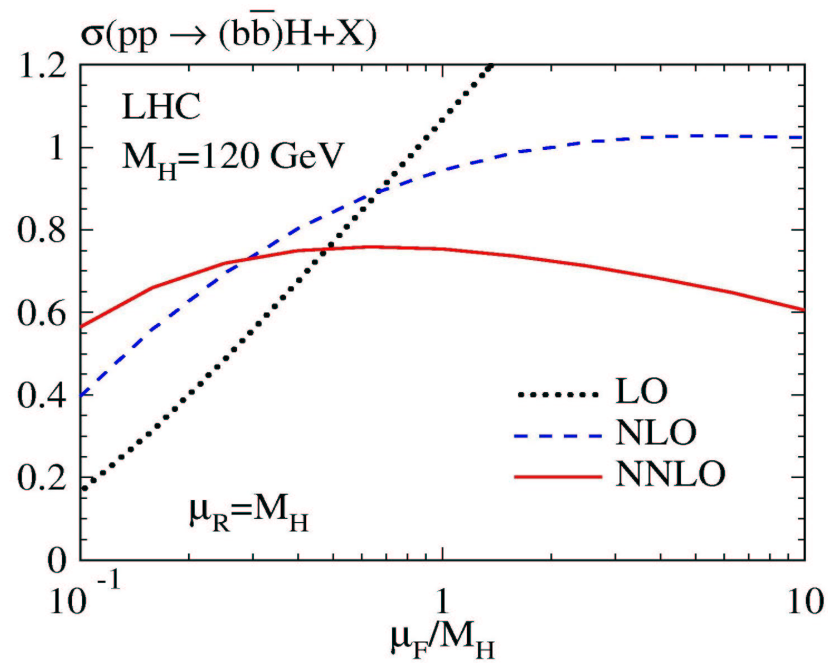
Denner, Dittmaier, Roth, Weber, hep-ph/0309274

# bb→h in MSSM

bb→h




Reduced theoretical error from reduced μ dependence




Only relevant in SUSY with large tan β

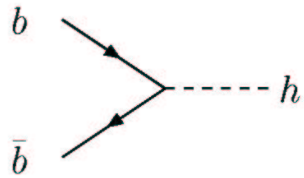
When is the b quark a parton????

Leads to new signatures with single b's: gb→bh

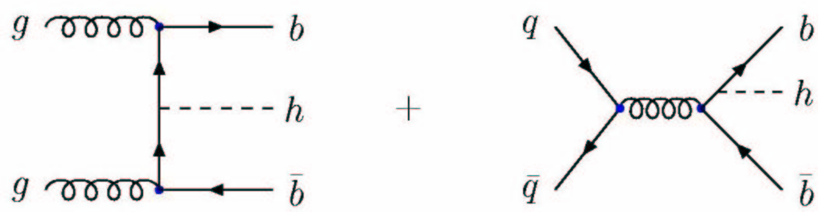
NLO: Maltoni, Sullivan, & Willenbrock, hep-ph/0301033

NNLO: Harlander & Kilgore, hep-ph/0304035

# What is the dominant process?







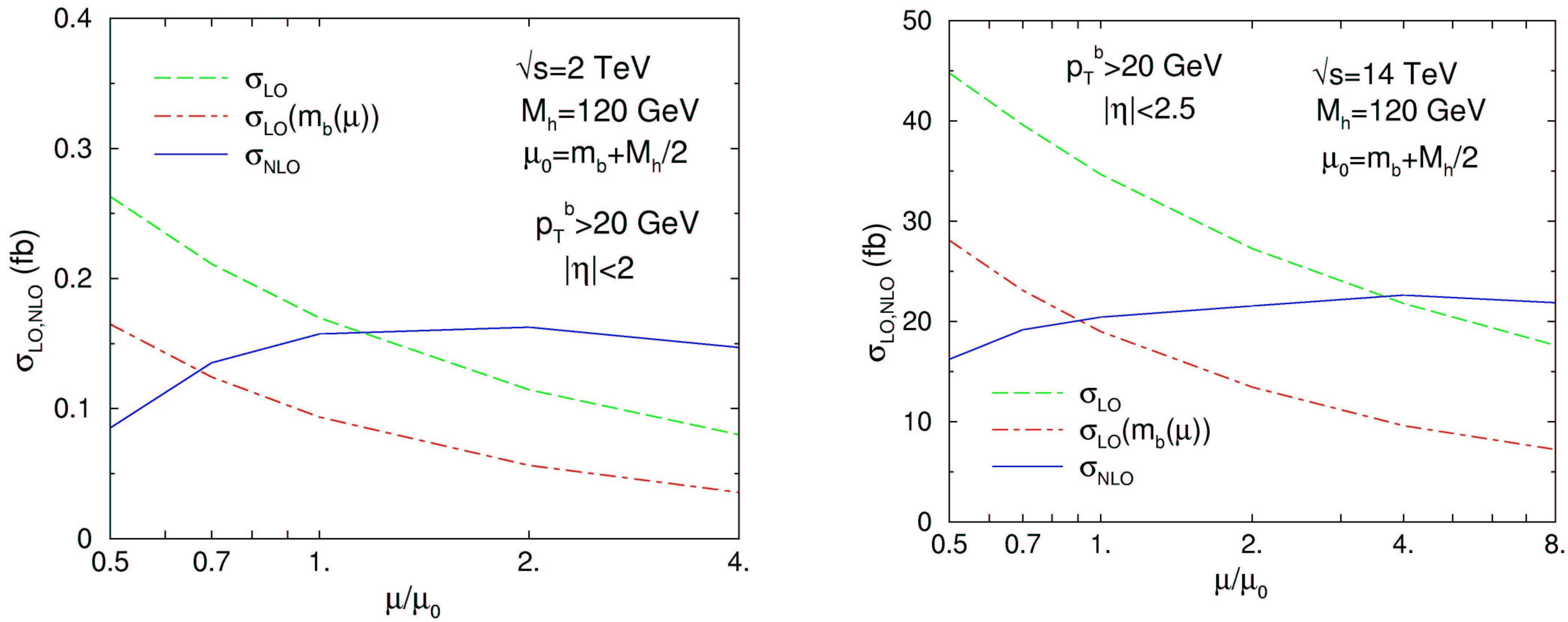

***Answer depends on whether you tag outgoing b's***

b densities enhanced: $b(x) \approx \alpha_s \ln(Q^2/m_b^2)\, g(x)$

# Exclusive cross section for $p\bar{p} \rightarrow b\bar{b}h$

- Use high $p_T$ b-quarks to suppress background: need NLO

$$q\bar{q},\ gg \rightarrow b\bar{b}h$$




Dittmaier, Kramer, Spira, hep-ph/0309204

S. Dawson, C. Jackson, L. Reina, D. Wackeroth

# Tevatron Check Sheet: Tevatron can probe EWSB!

- Measure $M_t$:
  - 5 GeV in $M_t$ is 35 GeV in Higgs limit
- Measure $M_W$:
  - Precision measurements are critical constraint on models of new physics
- Measure Drell-Yan:
  - Probes heavy Z of Little Higgs, Extra-D
- Search for Non-SM Higgs (You don't know they're not there until you look!)
  - CP violating MSSM, NMSSM, triplets, 2HDM…
- Search for new particles:
  - Models of new physics have lots of new particles
- ***Workshop Goal: FILL IN MORE ENTRIES!***

•It's not just the Higgs!

# Conclusions

- Explosion of new models
  - Models strongly impacted by precision measurements
- Think outside the box….
  - Look for Higgs triplets, singlets, new gauge bosons, heavy fermions….
- Calculational progress vital to distinguish new physics from radiative corrections