Higgs and Electroweak Physics
[theory status]

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Science & Technology Facilities Council

UK HEP Forum
"Physics at the LHC"
7–8 September 2011

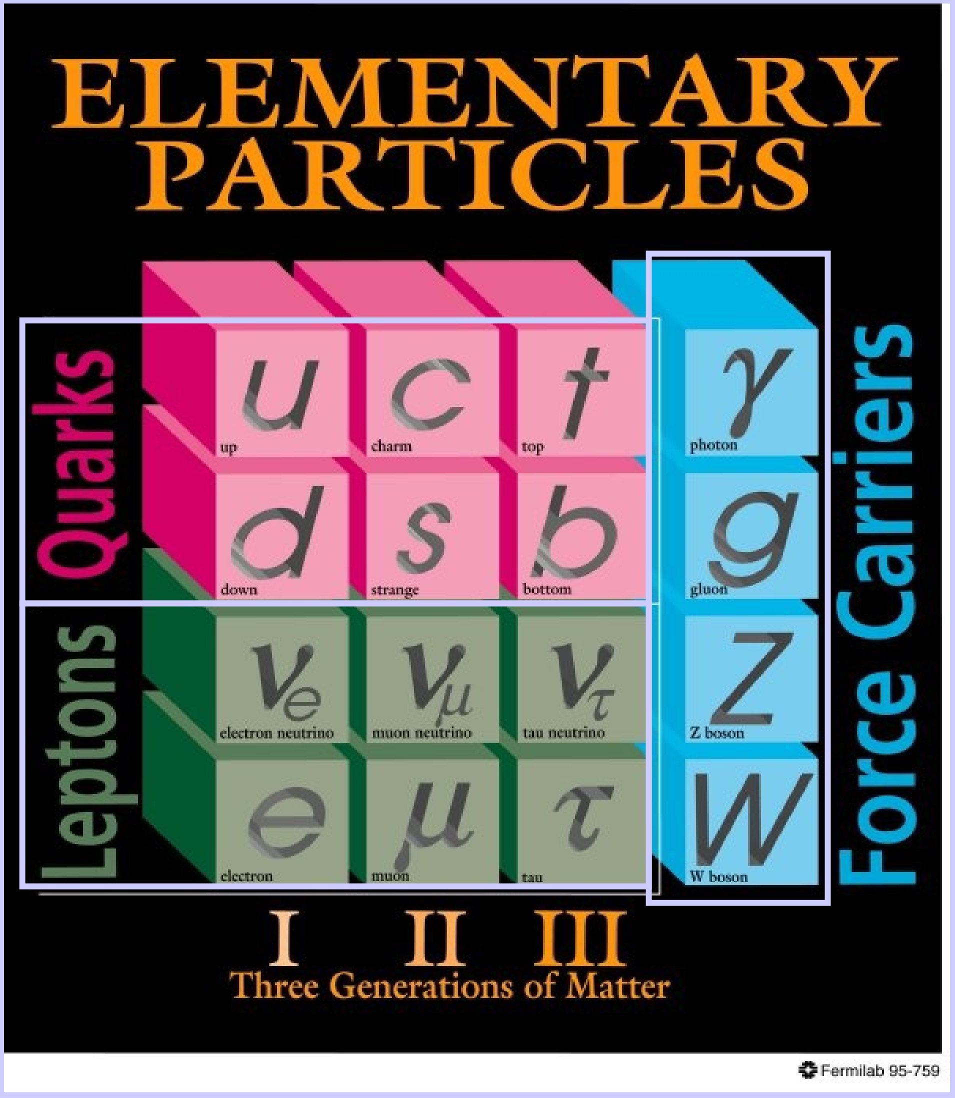
www.ippp.dur.ac.uk

Outline

- Introduction
  - *Higgs mechanism*
  - *Theory constraints*
  - *Electroweak Precision tests*
- SM Higgs boson search
  - *Production at the Tevatron and latest Limits*
  - *Production at the LHC and combined limits*
  - *Projections for Higgs search at the LHC*
  - *Prospects for Higgs coupling measurement*
  - *Diffractive Higgs production at the LHC*
- EWBSB beyond the SM and its signatures
- Conclusions

Status of the Standard Model

- Based on $SU(3)\times SU(2)_L \times U(1)_Y$ gauge symmetry spontaneously broken down to $SU(3)\times U(1)_e$:
- Matter: 3 generations of quarks and leptons



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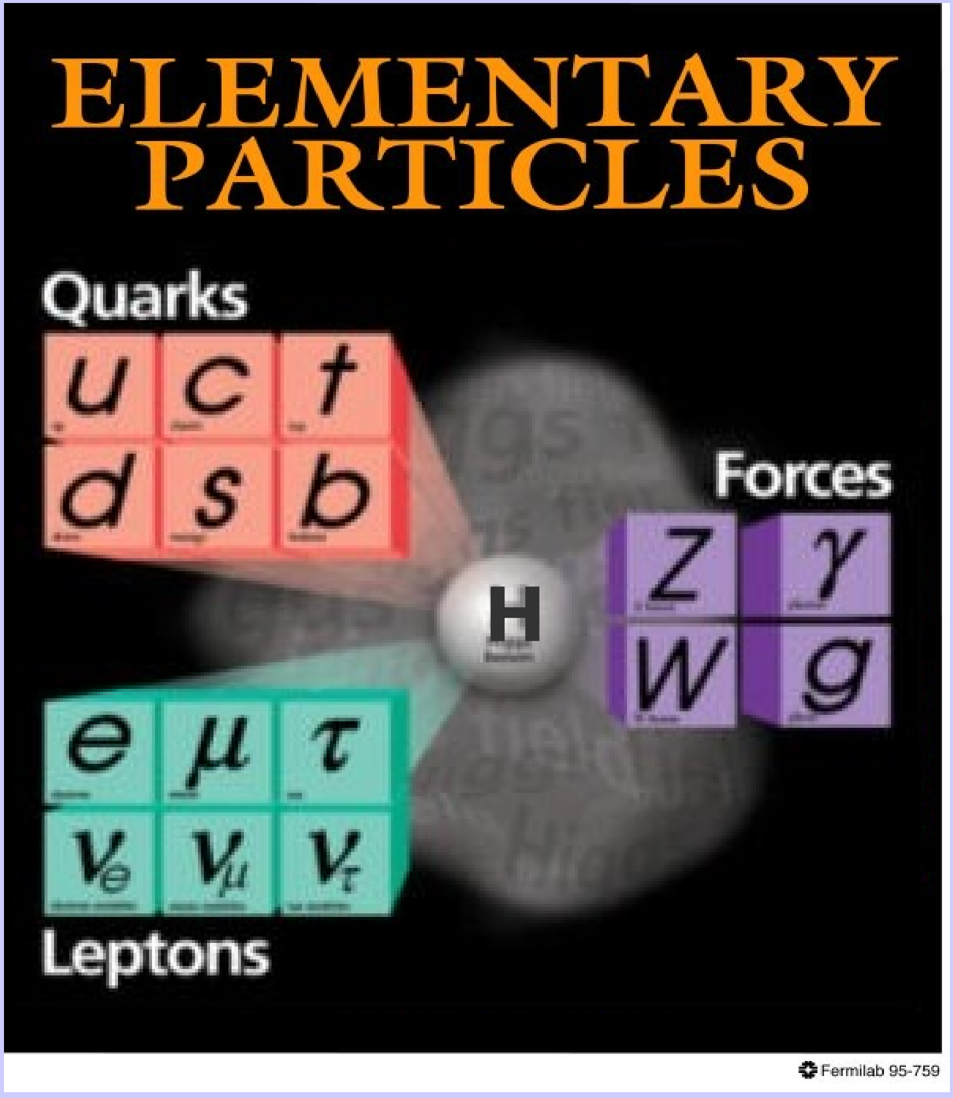
- Matter: 3 generations of quarks and leptons
- One of the central role is played by Higgs field
  - *one higgs doublet, interacts with all fields*
  - *develops condensate*
  - *W,Z bosons, lepton and quarks and Higgs field itself acquires mass*



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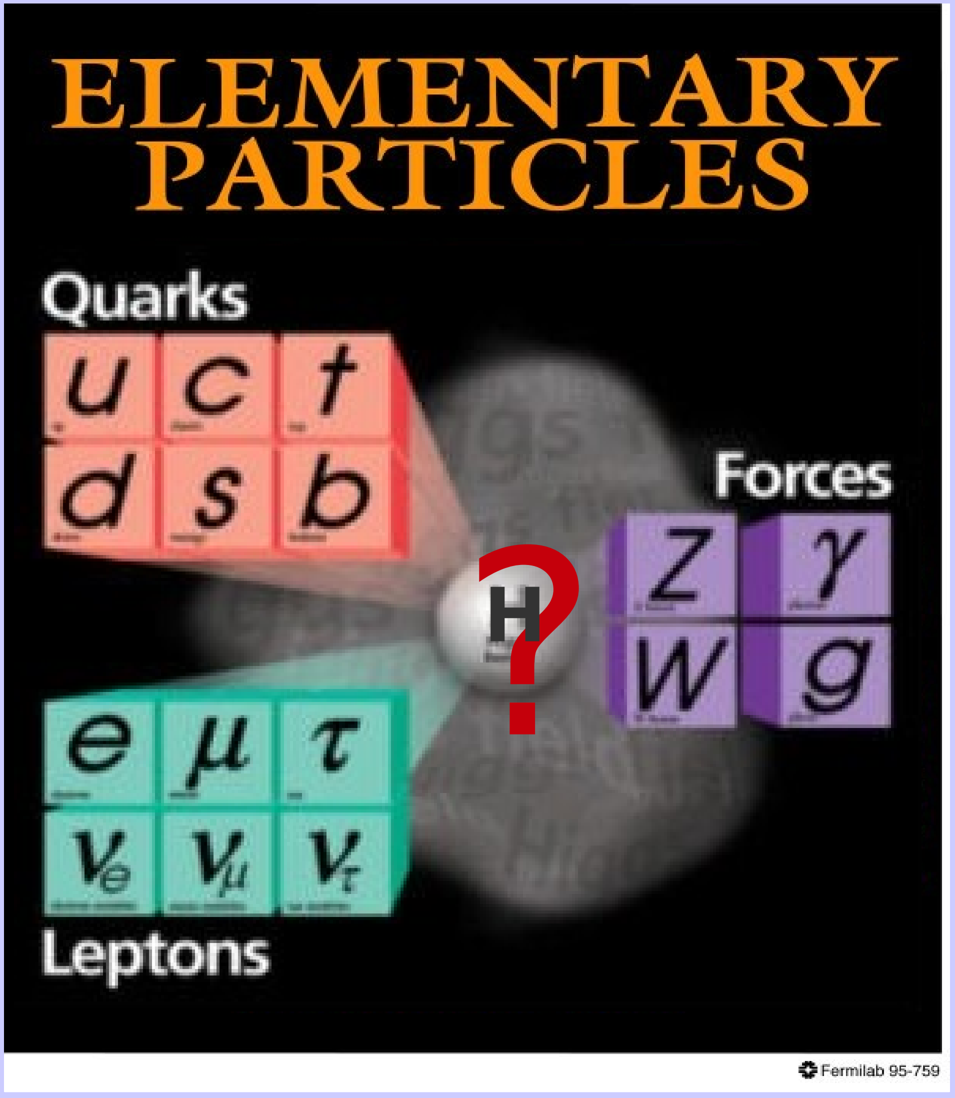


Higgs boson is not found yet and is the most wanted particle!
The mechanism responsible for EWSB symmetry remains unknown!

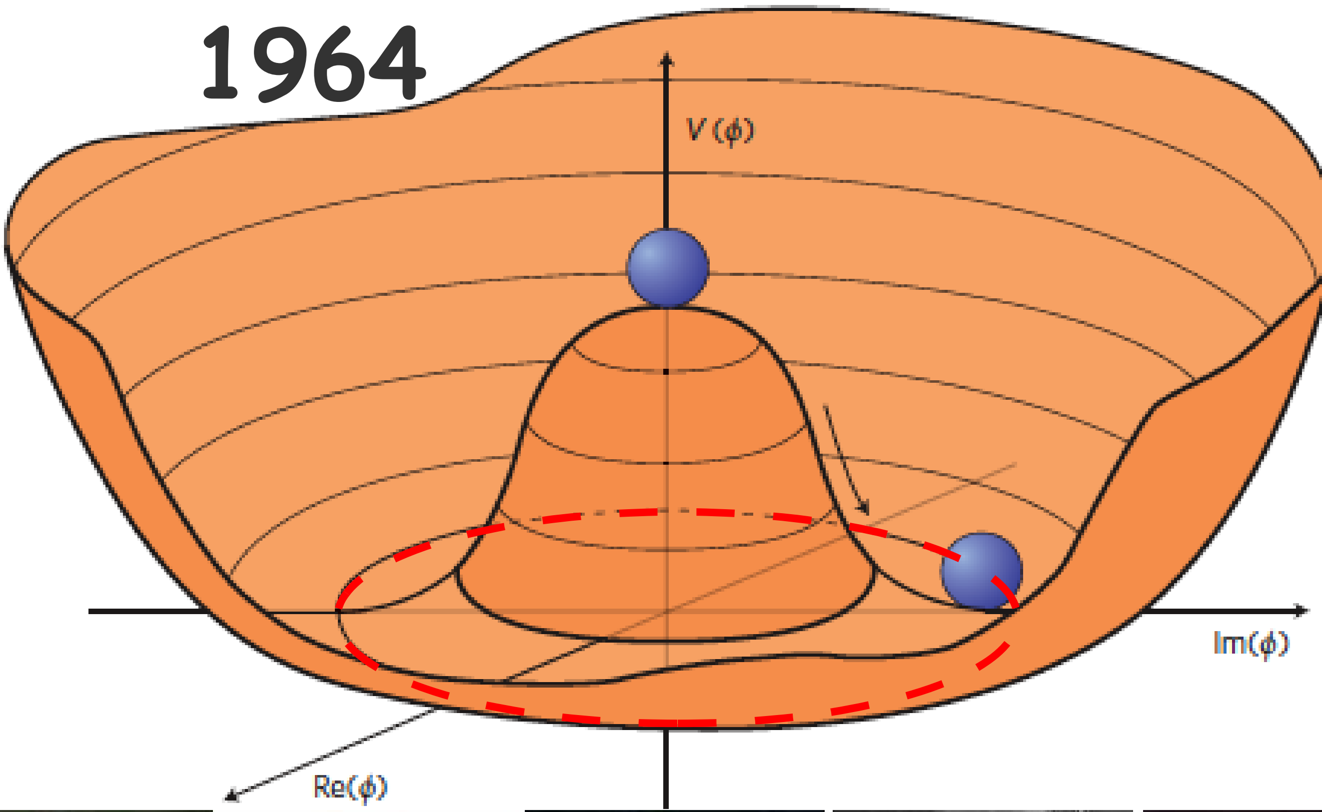
Theory of Electroweak Interactions

- Status: per-mil precision measurements confirm $SU(2)_L \times U(1)_Y$ gauge structure
- Unbroken Yang-Mills theory -> vector bosons are massless.
- Eventually it is not the case! Explicit introduction of the massive gauge bosons breaks gauge invariance.
- In general, there are serious problems in any Lorentz-invariant theory of massive vector bosons, unless those particles are Yang-Mills bosons and the gauge symmetry is spontaneously broken [Nambu; Higgs; Englert,Brout; Guralnik, Hagen,Kibble]. This is what we observe!
- What is the mechanism of $SU(2)_L \times U(1)_Y$ breaking?

  $SU(2)_L \times U(1)_Y$ does not break its own symmetry

  – couplings are weak

Spontaneous EWSB is SM



Brout Englert Guralnik Hagen Higgs Kibble Nambu

Higgs mechanism

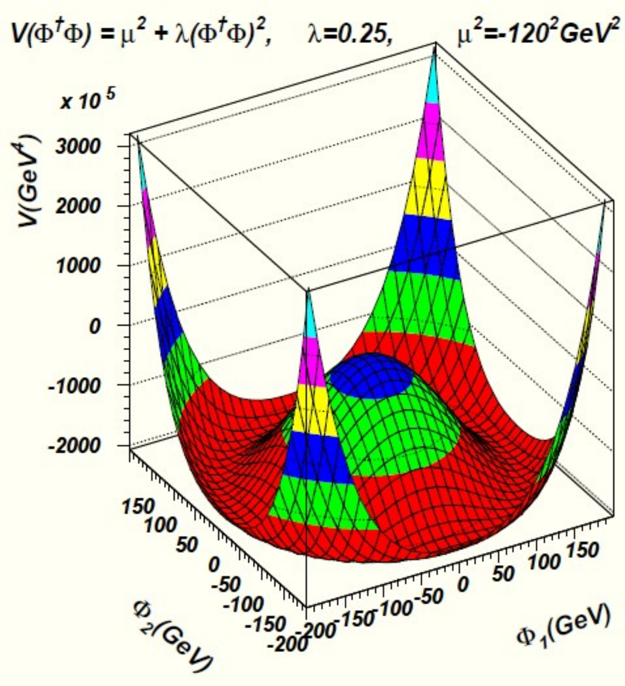
add one scalar doublet φ *with* $I=\frac{1}{2}, Y=+\frac{1}{2}$

$$\mathcal{L} = |D_\mu\varphi|^2 - V(|\varphi|) - \frac{1}{4}(F^a_{\mu\nu})^2 - \frac{1}{4}(G^a_{\mu\nu})^2$$

+ couplings to quarks and leptons

where $\langle\varphi\rangle \neq 0$

e.g. $V(|\varphi|) = \mu^2|\varphi|^2 + \lambda|\varphi^4|$ $\qquad \mu^2 < 0$



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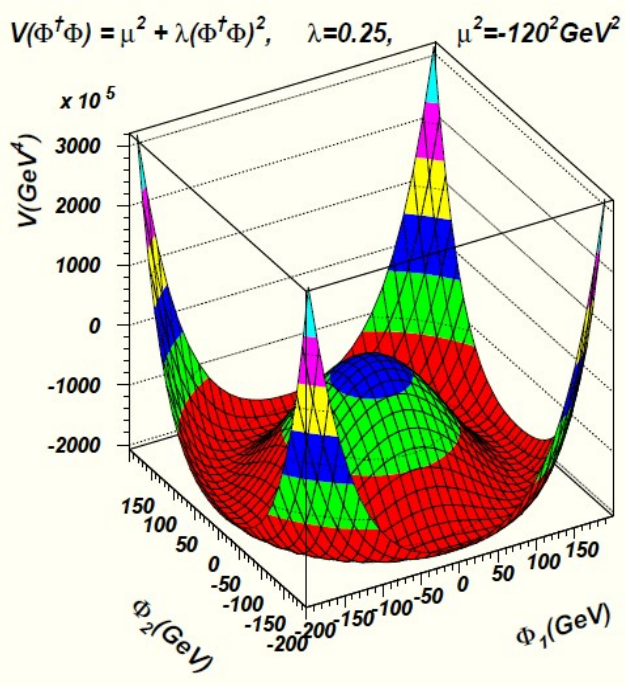

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the filed φ *has the general structure*

$$\varphi(x)=\begin{pmatrix}\pi^+(x)\\(v+h(x)+i\pi^0(x))/\sqrt{2}\end{pmatrix}$$

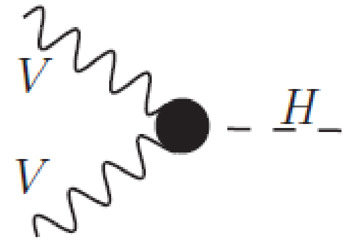
which be written as ("polar decomposition")

$$\varphi(x)=exp\left(i\frac{\pi^a(x)\tau^a}{v}\right)\begin{pmatrix}0\\(v+h(x))/\sqrt{2}\end{pmatrix}$$

$\pi^\pm$, π^0 are Goldstone bosons
In the theory with global symmetry, they are massless.
In the theory with gauge symmetry, they are gauge degrees of freedom, and become part of W, Z

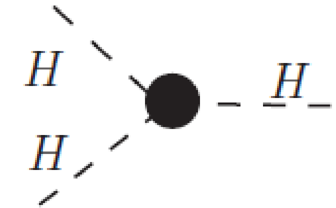
Higgs mechanism

The choice of $\langle\varphi\rangle = \frac{1}{\sqrt{2}}\begin{pmatrix} 0 \\ v \end{pmatrix}$

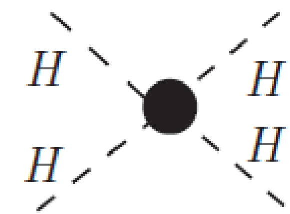


with $v = \sqrt{\frac{-\mu^2}{\lambda}}$ *breaks the symmetry*

$$\mathcal{L}_{\rm scalar} = \frac{g^2v^2}{4}W^+_\mu W^{-\mu} + \frac{1}{2}\frac{g^2v^2}{4\cos^2\theta_W}Z_\mu Z^\mu$$



$$-\frac{1}{2}(-2\mu^2)H^2 + \frac{\mu^2}{v}H^3 + \frac{\mu^2}{4v^2}H^4 + \ldots$$



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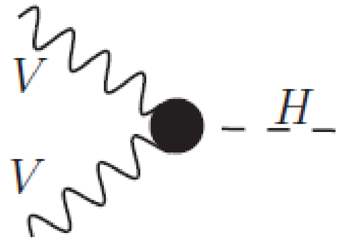

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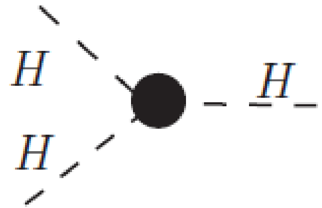

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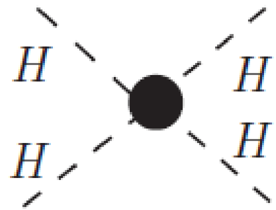

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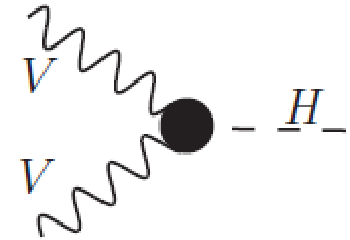

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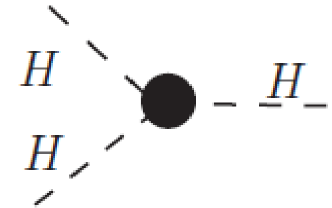

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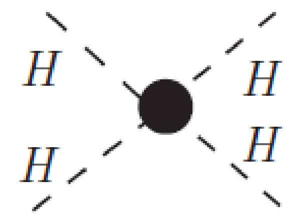
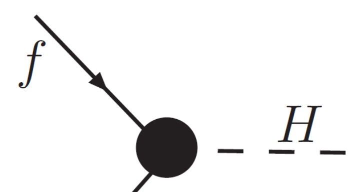


$$\mathcal{L}_{Yukawa} = -Y_u\bar{Q}_L\Phi^c u_R - Y_d\bar{Q}_L\Phi d_R - Y_\ell\bar{L}_L\Phi l_R + h.c.$$

generates fermion masses $m_f = Y_f\frac{v}{\sqrt{2}}$



$Y_f = \frac{\sqrt{2}m_f}{v}$

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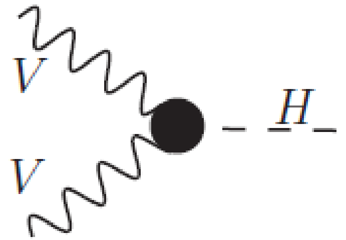

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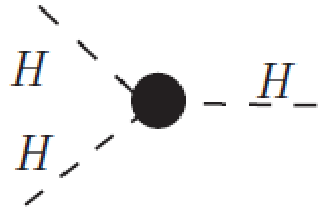

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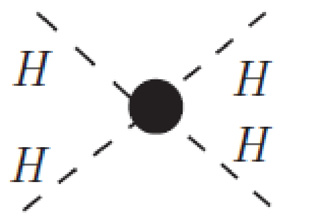

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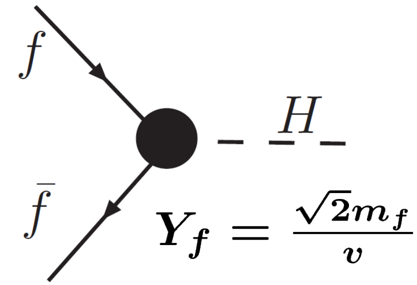
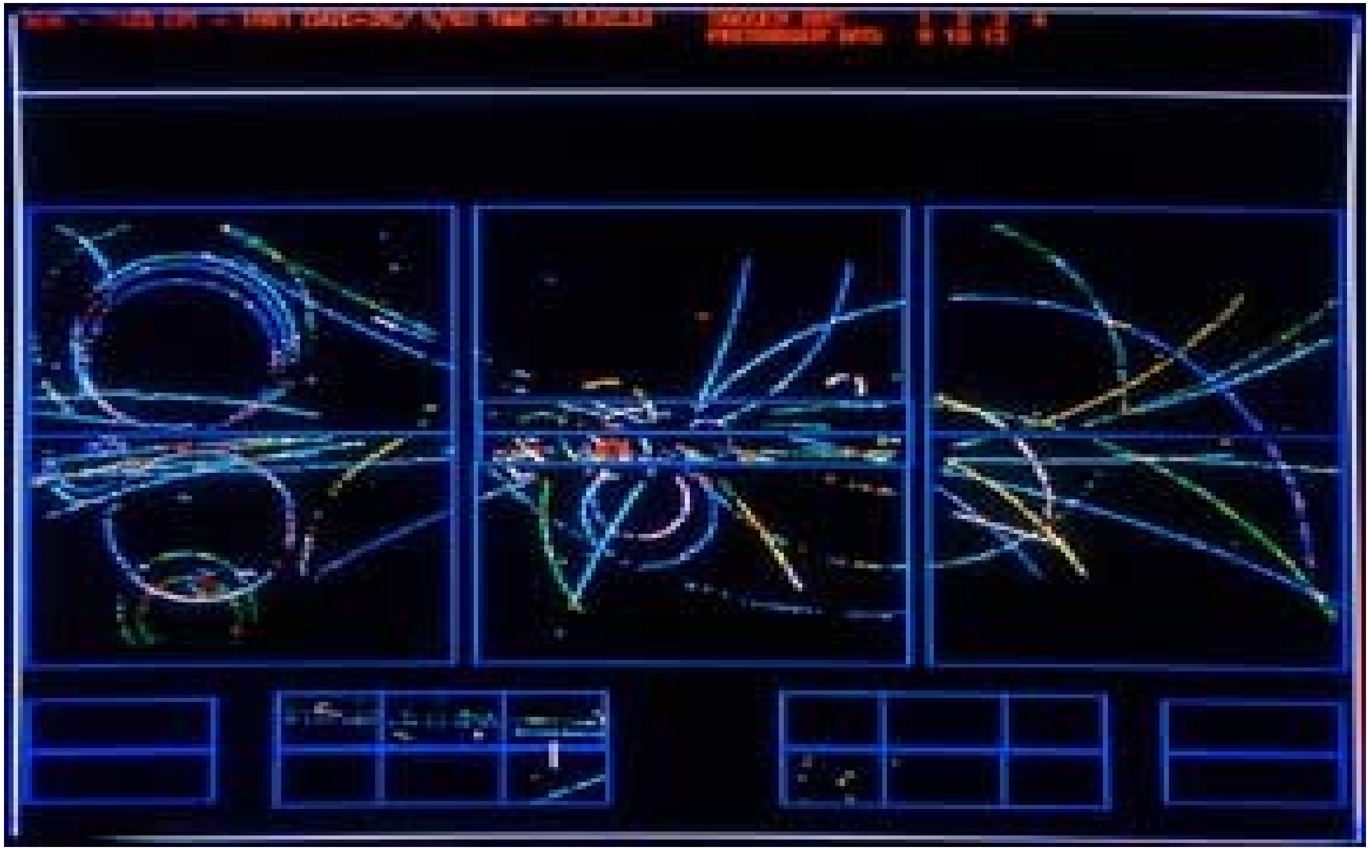
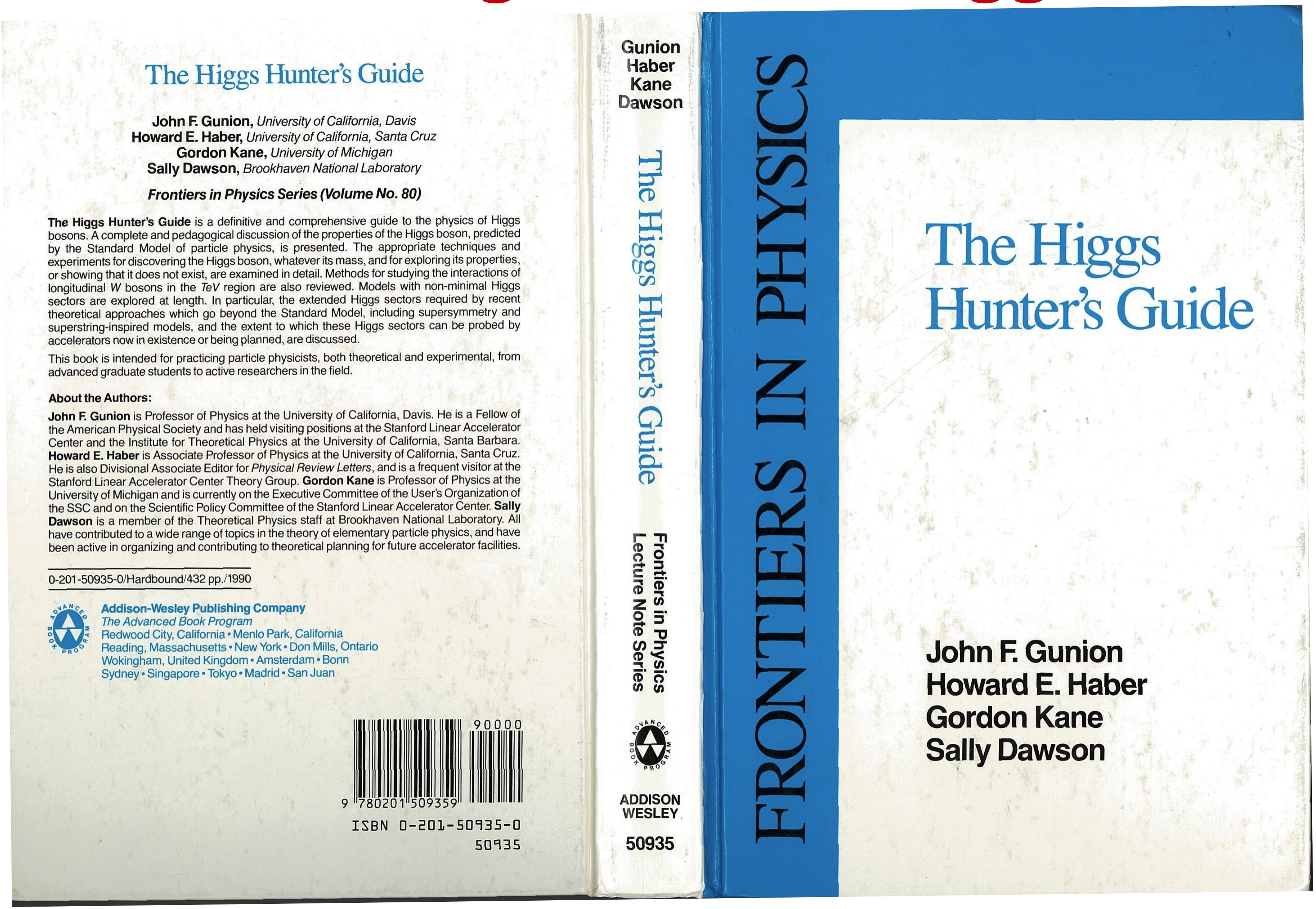


1983: Discovery of W- and Z- bosons at by UA1 and UA2 at SPS

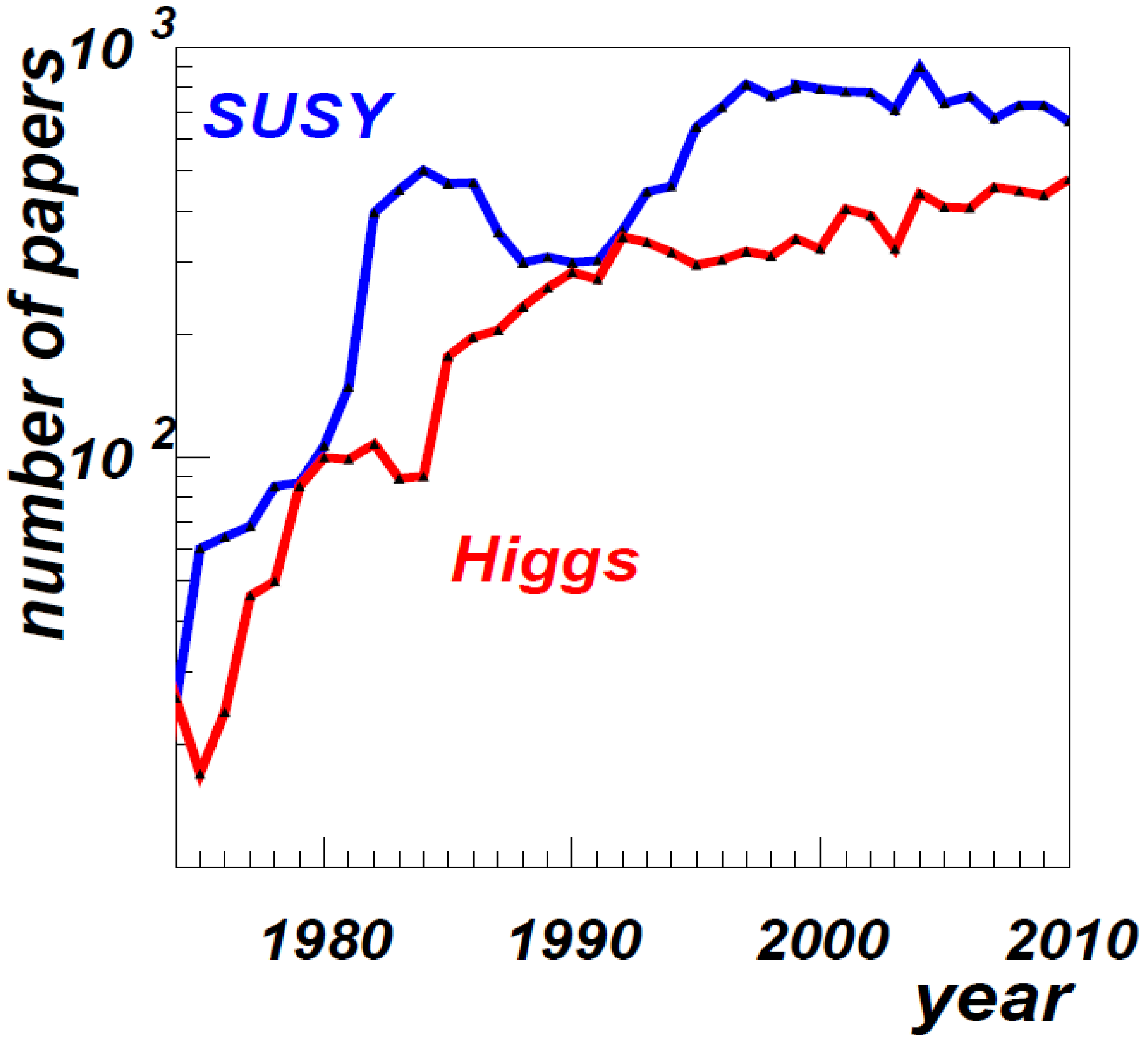


Hunting for the Higgs boson started!

Hunting for the Higgs

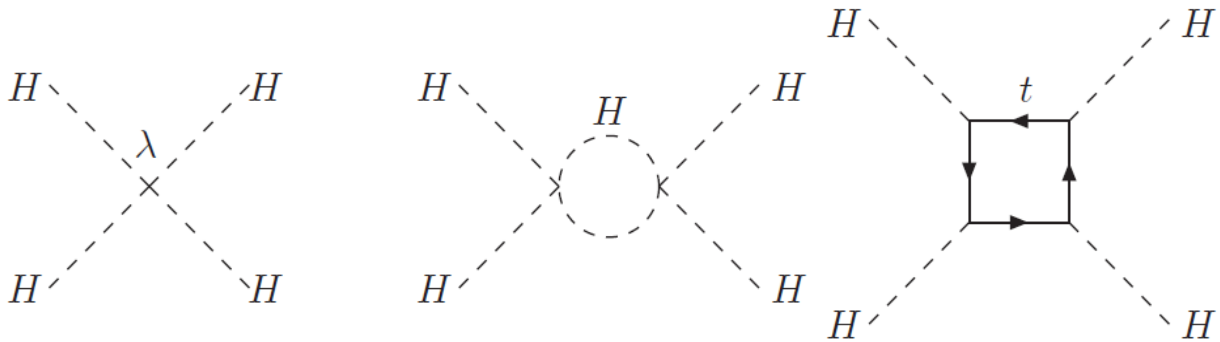


of Papers on Higgs boson



Theoretical constraints

$$\frac{d\lambda}{dt} = \frac{3}{8\pi^2}\left[\lambda^2 + \lambda y_t^2 - y_t^4 + \frac{1}{16}\left(2g^4 + (g^2 + g'^2)^2\right)\right]$$



$$M_H^2 \propto \lambda$$

Large λ: $\lambda(Q^2) = \dfrac{\lambda(v^2)}{1 - \frac{3\lambda(v^2)}{8\pi^2}\log\left(\frac{Q^2}{v^2}\right)}$ **from** $\lambda(\Lambda) < \infty \Rightarrow M_H^2 \leq \dfrac{8\pi^2 v^2}{3\log\left(\frac{\Lambda^2}{v^2}\right)}$

[triviality bound]

Small λ: $\lambda(Q^2) = \lambda(v^2)\dfrac{3}{8\pi^2}\left[-y_t^4 + \frac{1}{16}\left(2g^4 + (g^2 + g'^2)^2\right)\right]\log\left(\dfrac{Q^2}{v^2}\right)$

from $\lambda(\Lambda) > 0 \Rightarrow M_H^2 > \dfrac{v^2}{4\pi^2}\left[-y_t^4 + \frac{1}{16}\left(2g^4 + (g^2 + g'^2)^2\right)\right]\log\left(\dfrac{\Lambda^2}{v^2}\right)$

[vacuum stability bound]

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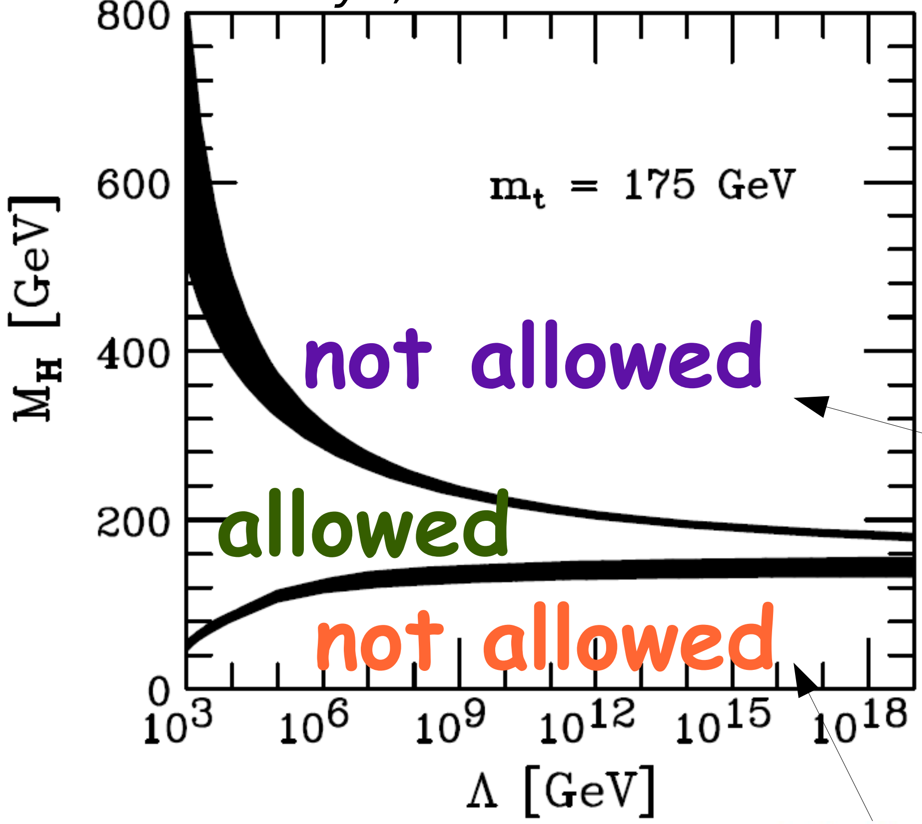
Hambye, Riesselmann '97



$$\lambda(\Lambda) < \infty \Rightarrow M_H^2 \leq \frac{8\pi^2 v^2}{3\log\left(\frac{\Lambda^2}{v^2}\right)}$$

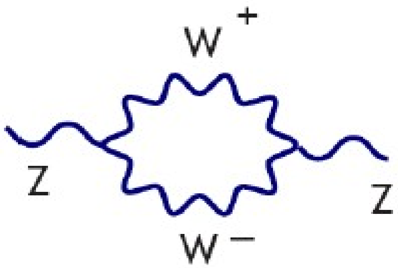
[triviality bound]

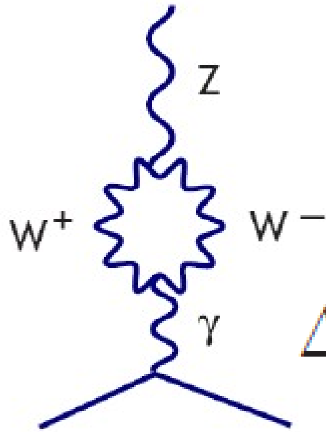
$$\lambda(\Lambda) > 0 \Rightarrow M_H^2 > \frac{v^2}{4\pi^2}\left[-y_t^4 + \frac{1}{16}\left(2g^4 + (g^2 + g'^2)^2\right)\right]\log\left(\frac{\Lambda^2}{v^2}\right)$$

[vacuum stability bound]

Electroweak Precision Fits

The level of agreement requires taking into account a-weak radiative corrections





$$M_W^2\left(1-\frac{M_W^2}{M_Z^2}\right)=\frac{\pi\alpha}{\sqrt{2}G_F}(1+\Delta r)$$

$$\Delta r_{1-\mathrm{loop}}=\Delta\alpha-\frac{c_{\mathrm{w}}^2}{s_{\mathrm{w}}^2}\Delta\rho+\Delta r_{\mathrm{rem}}(M_H^{\mathrm{SM}})$$

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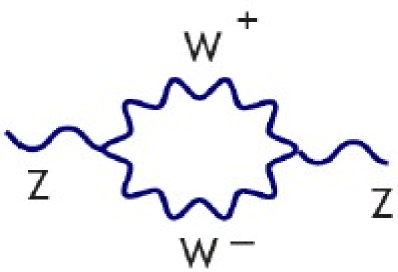

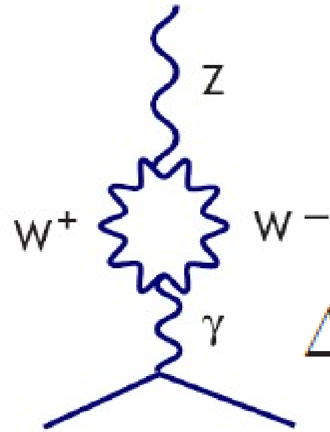

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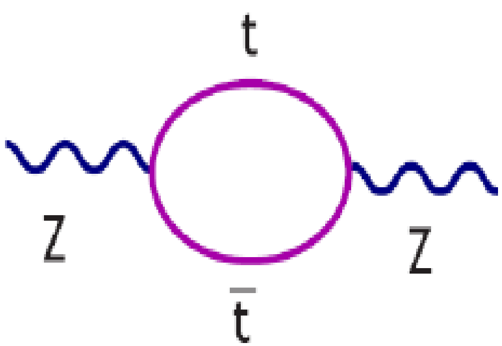
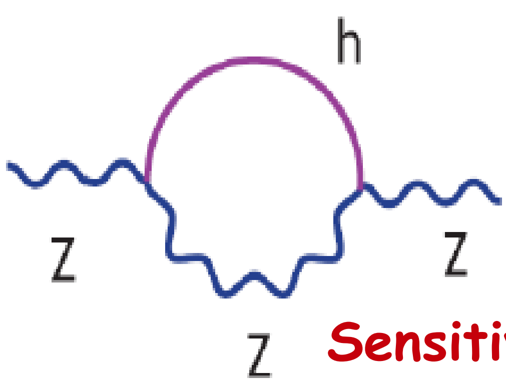


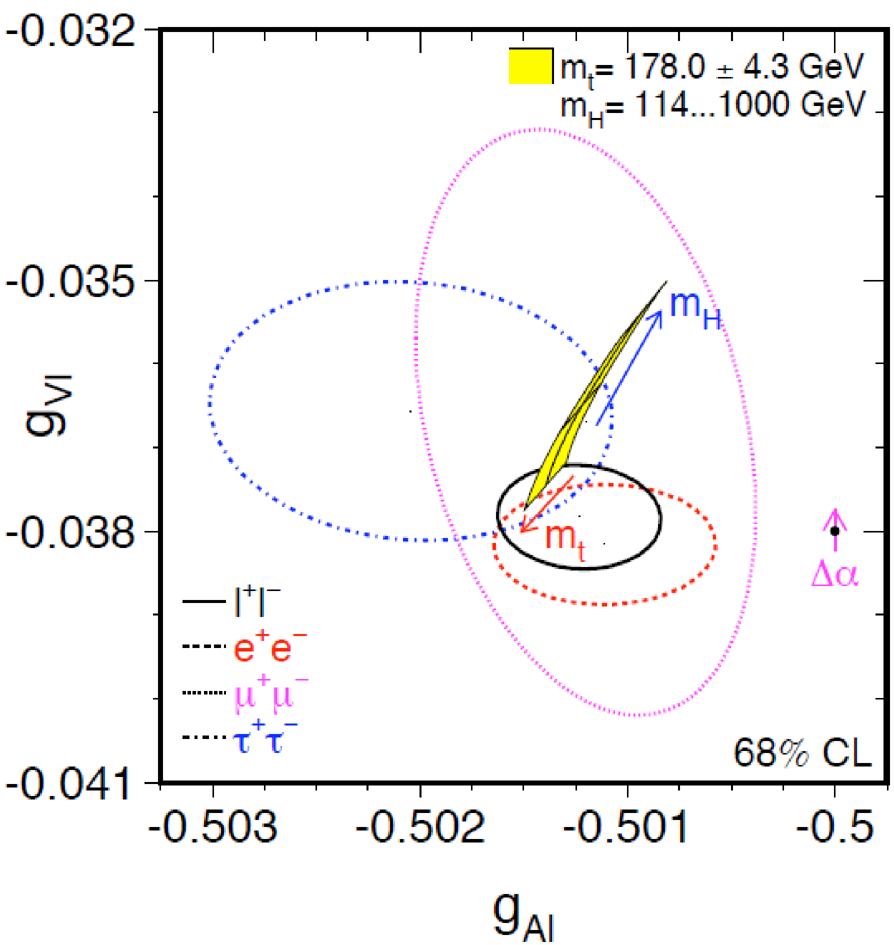
$$\Delta\rho=\frac{\Sigma^Z(0)}{M_Z^2}-\frac{\Sigma^W(0)}{M_W^2}\quad\sim m_t^2$$

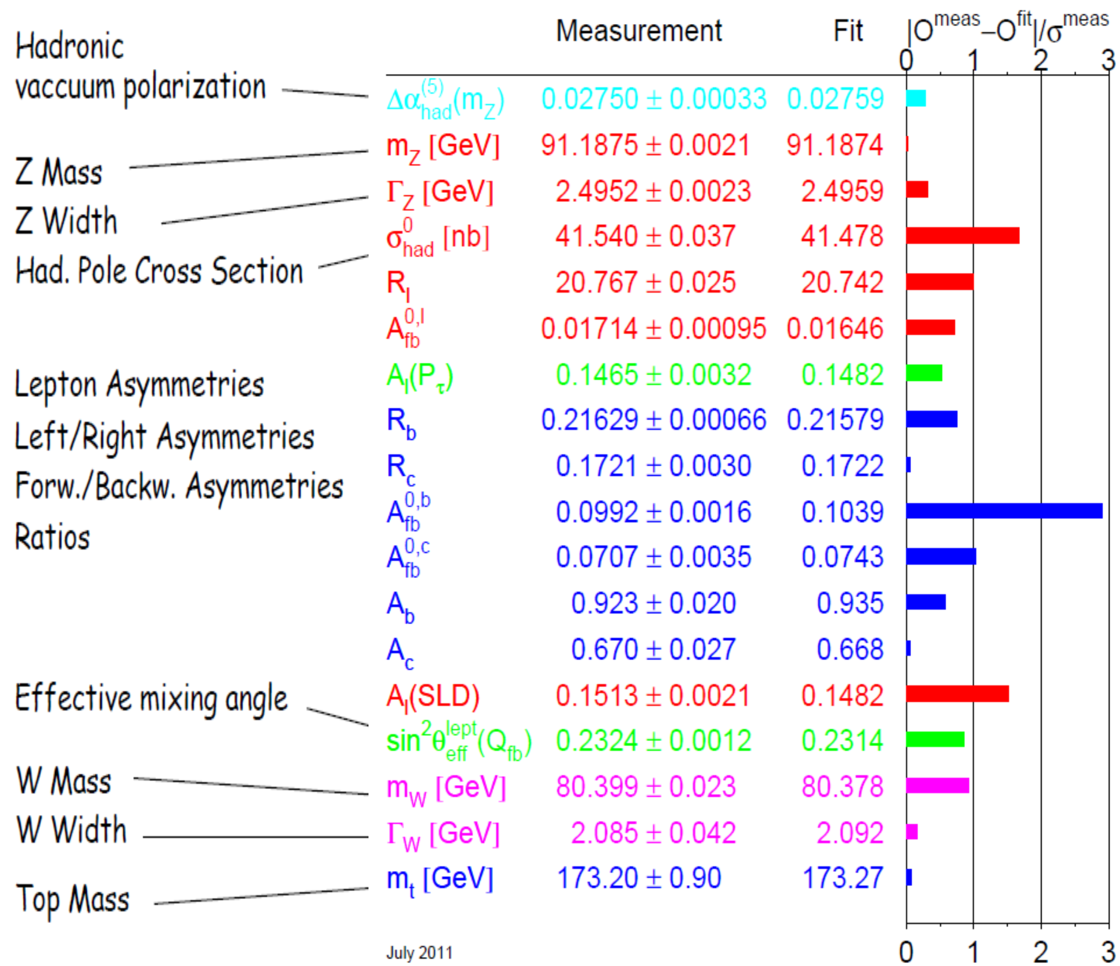


$$\Delta r_{\mathrm{rem}}\sim\log(M_H^{\mathrm{SM}}/M_W)$$

Sensitivity to the top quark mass >> sensitivity to Higgs mass!

Electroweak Precision Fits

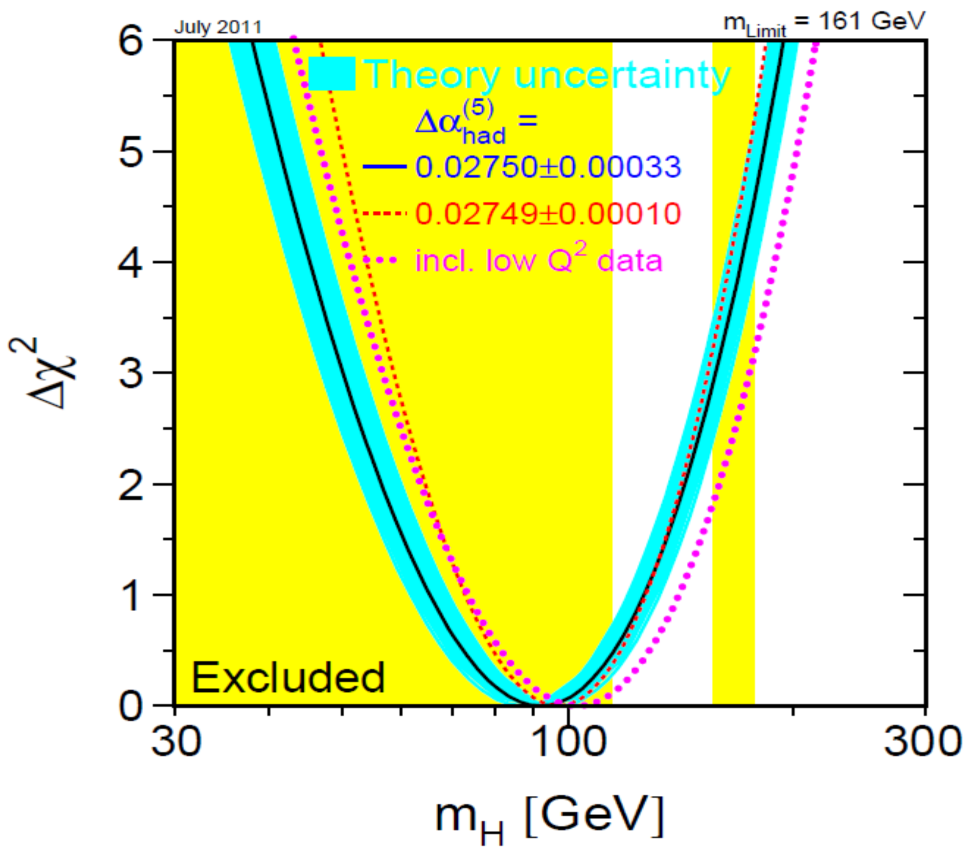


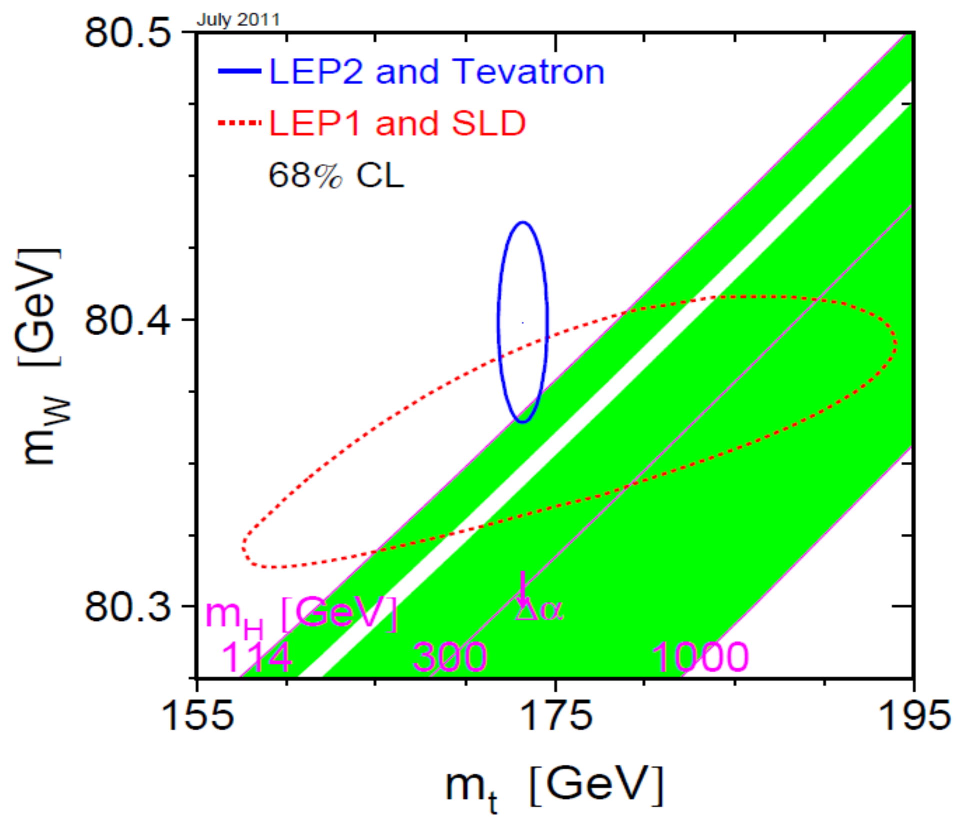


Lepton couplings confirm universality, incl. HO corrections

Pulls in global fit

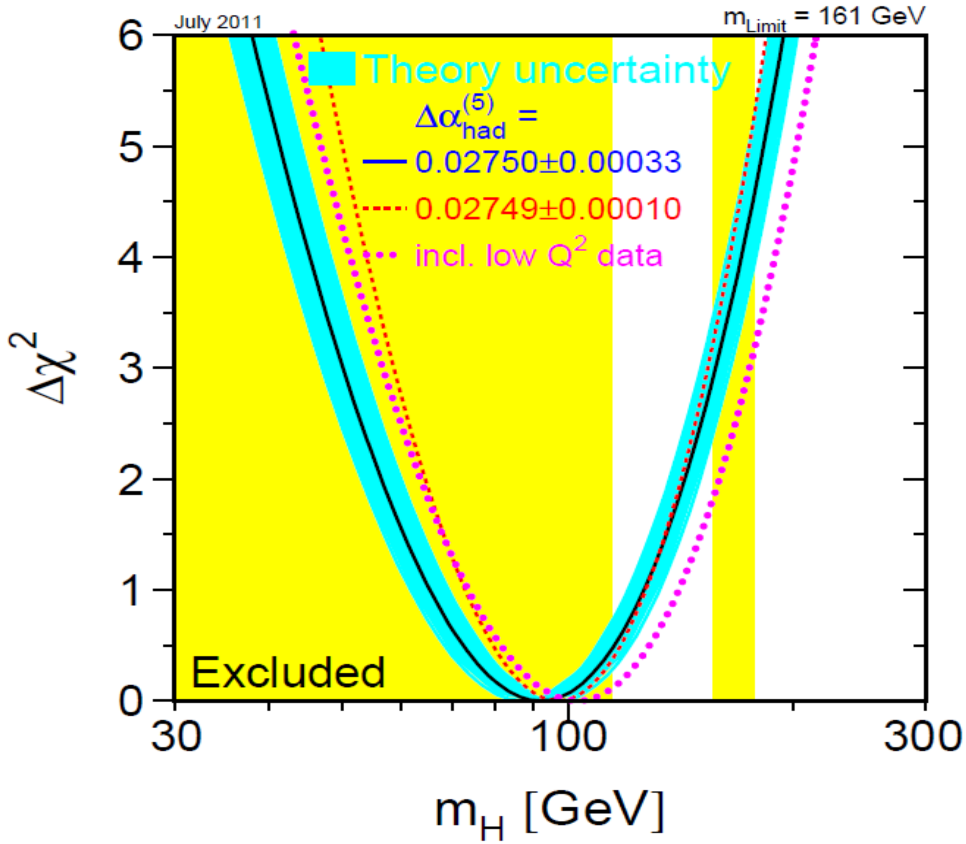
Sensitivity to the Higgs boson mass

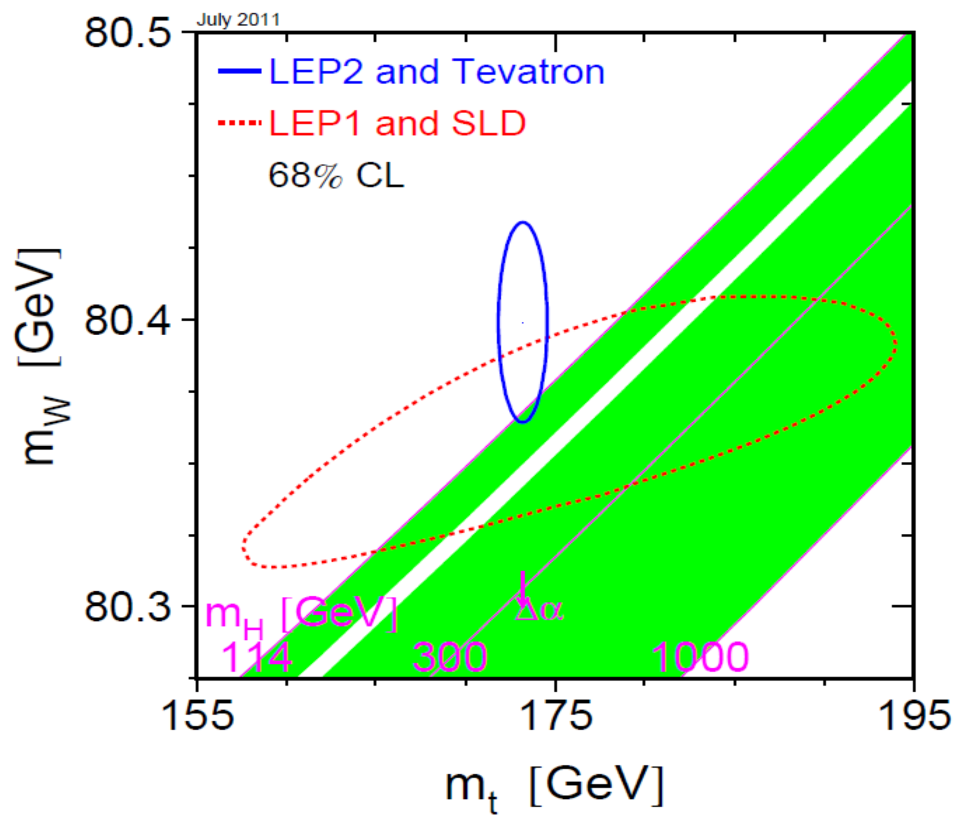




- "Blue band" fit : $M_H = 92^{+34}_{-26}$ GeV
- LEP2 direct bound: $M_H > 114.4$ GeV
- CDF/D0 combined @8.6fb^{-1} (observed): 156 GeV < M_H < 177 GeV
- ATLAS/CMS combined @ 1-2.3fb^{-1} (observed): (Claire's talk)
  M_H is excluded in 146-288, 296-466 GeV region

Sensitivity to the Higgs boson mass

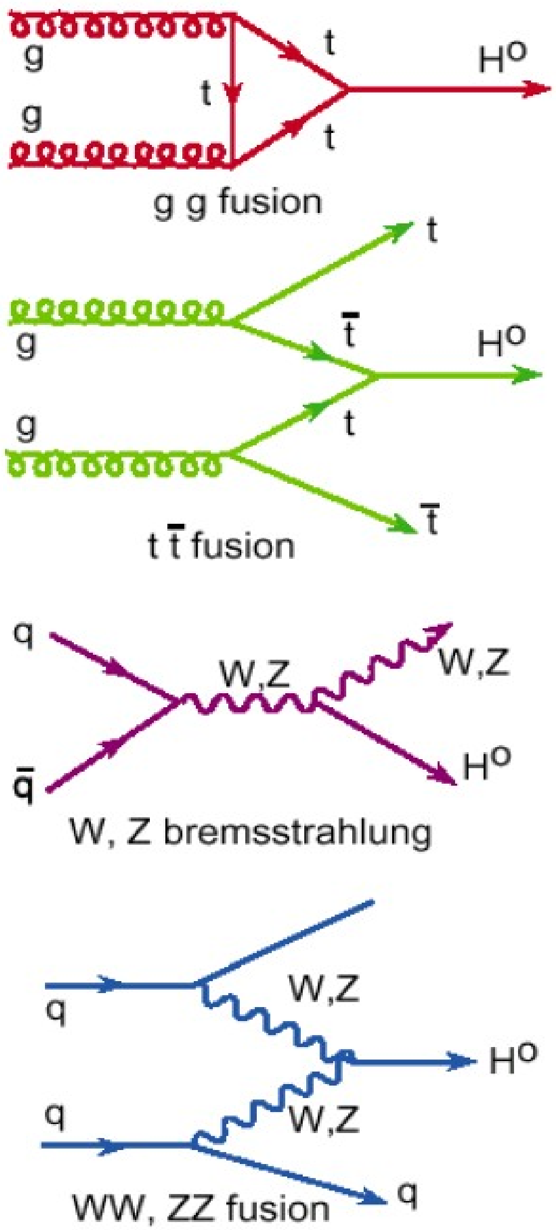


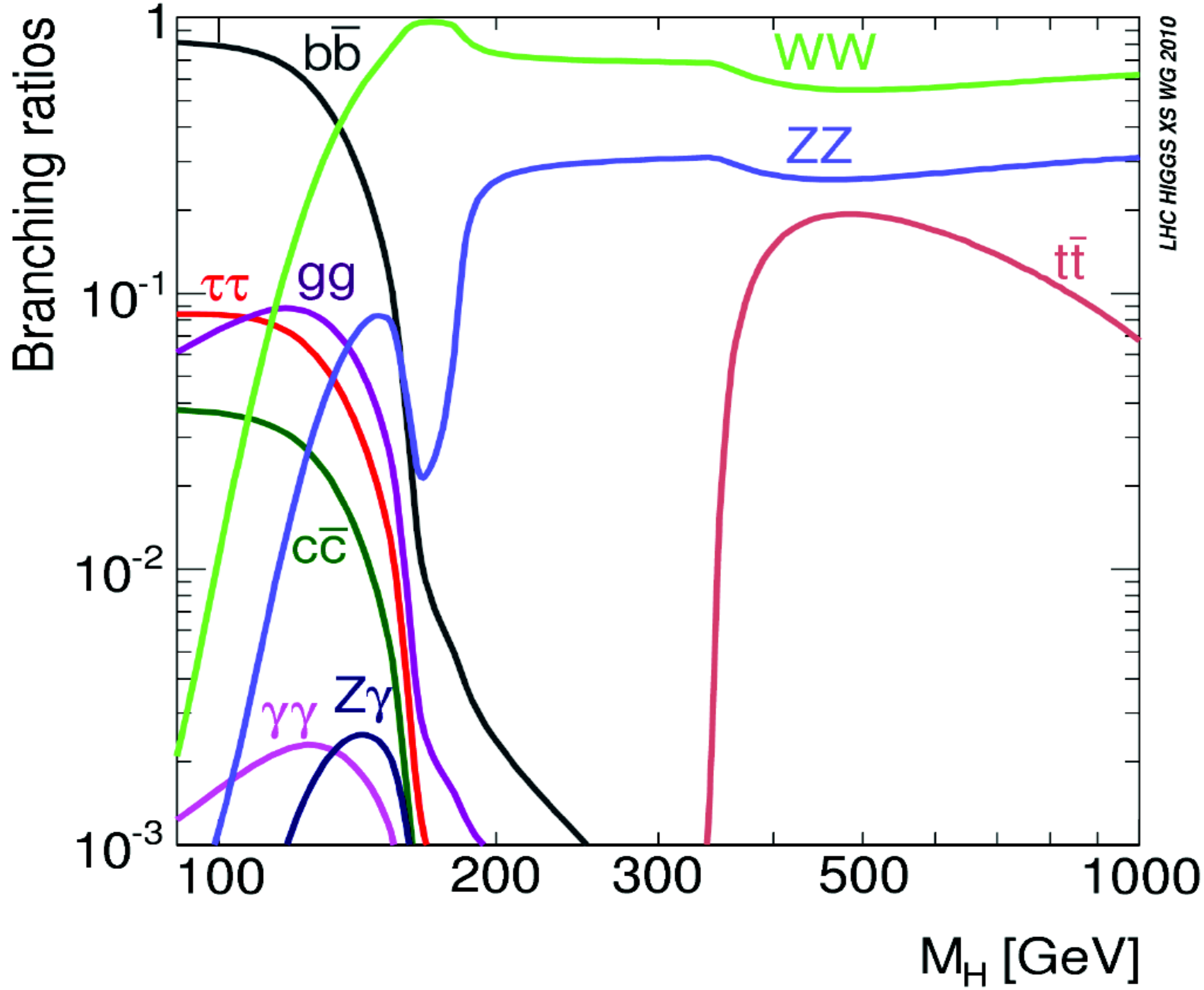


The light SM Higgs is favoured by fits but not found in direct searches ... There is still 114.4 – 146 GeV window left for SM.

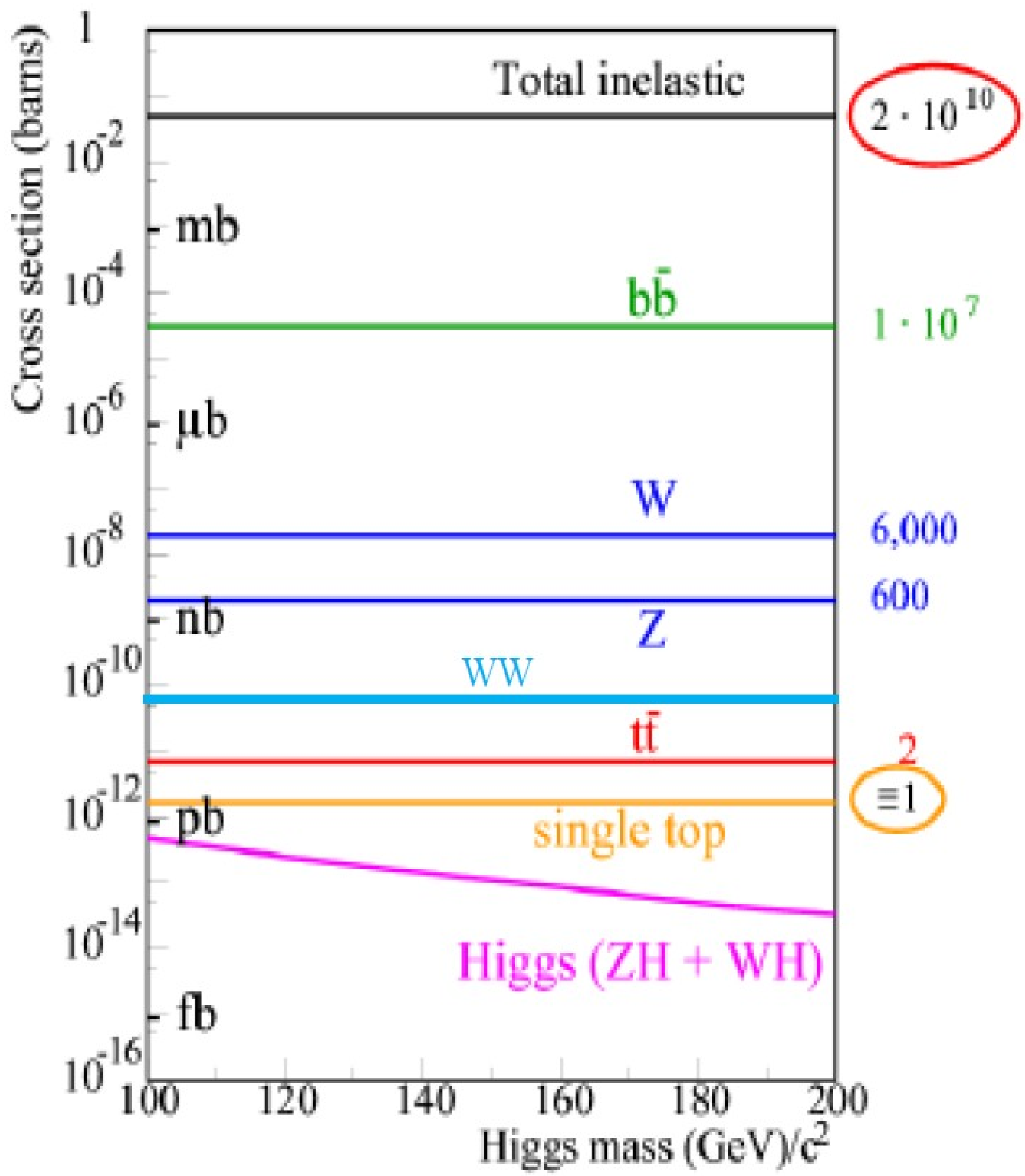
We can also conclude that New Physics with different Higgs couplings and/or Higgs sector is quite consistent with these fits too!

SM Higgs Boson Production and decay



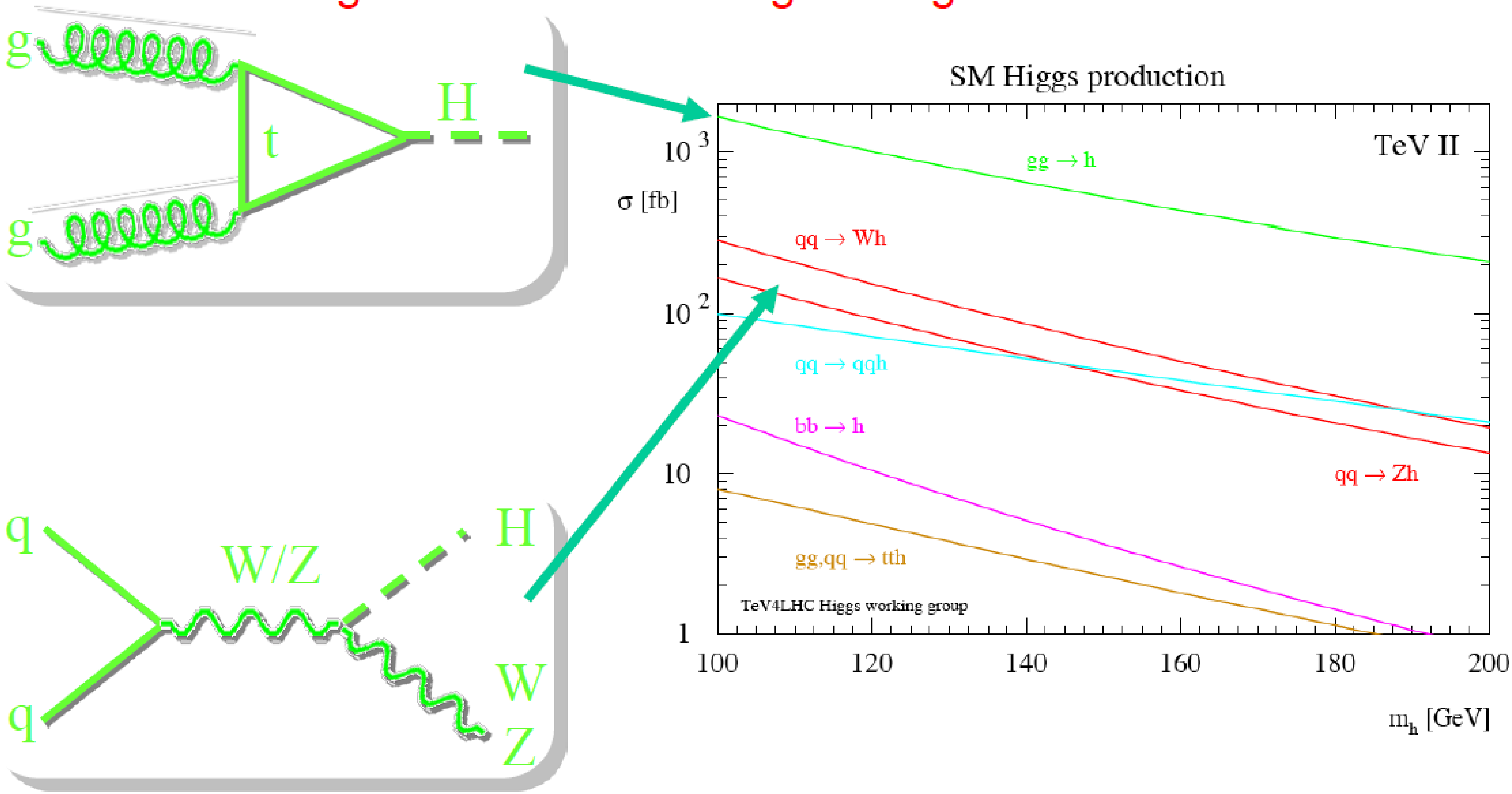


Higgs production vs BG at the Tevatron



Higgs production at the Tevatron

large cross section – huge background

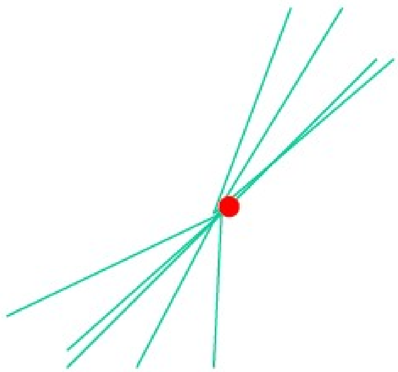


small cross section – moderate background

Ulrich Heintz - Moriond QCD

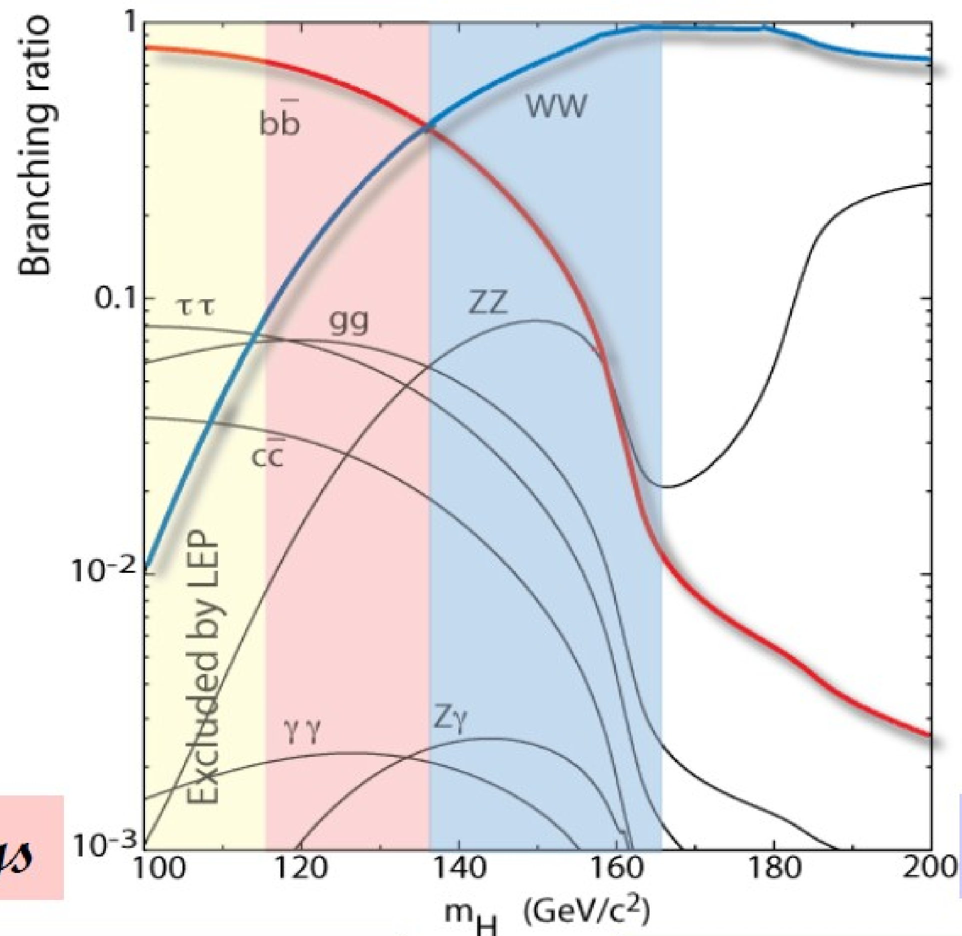
Higgs production at the Tevatron

$H \rightarrow b\bar{b}$

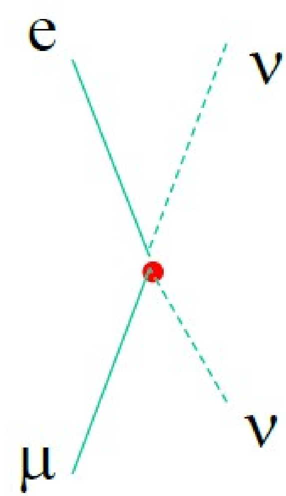


2 jets

"low mass" Higgs



$H \rightarrow WW$



2 acollinear leptons

"high mass" Higgs

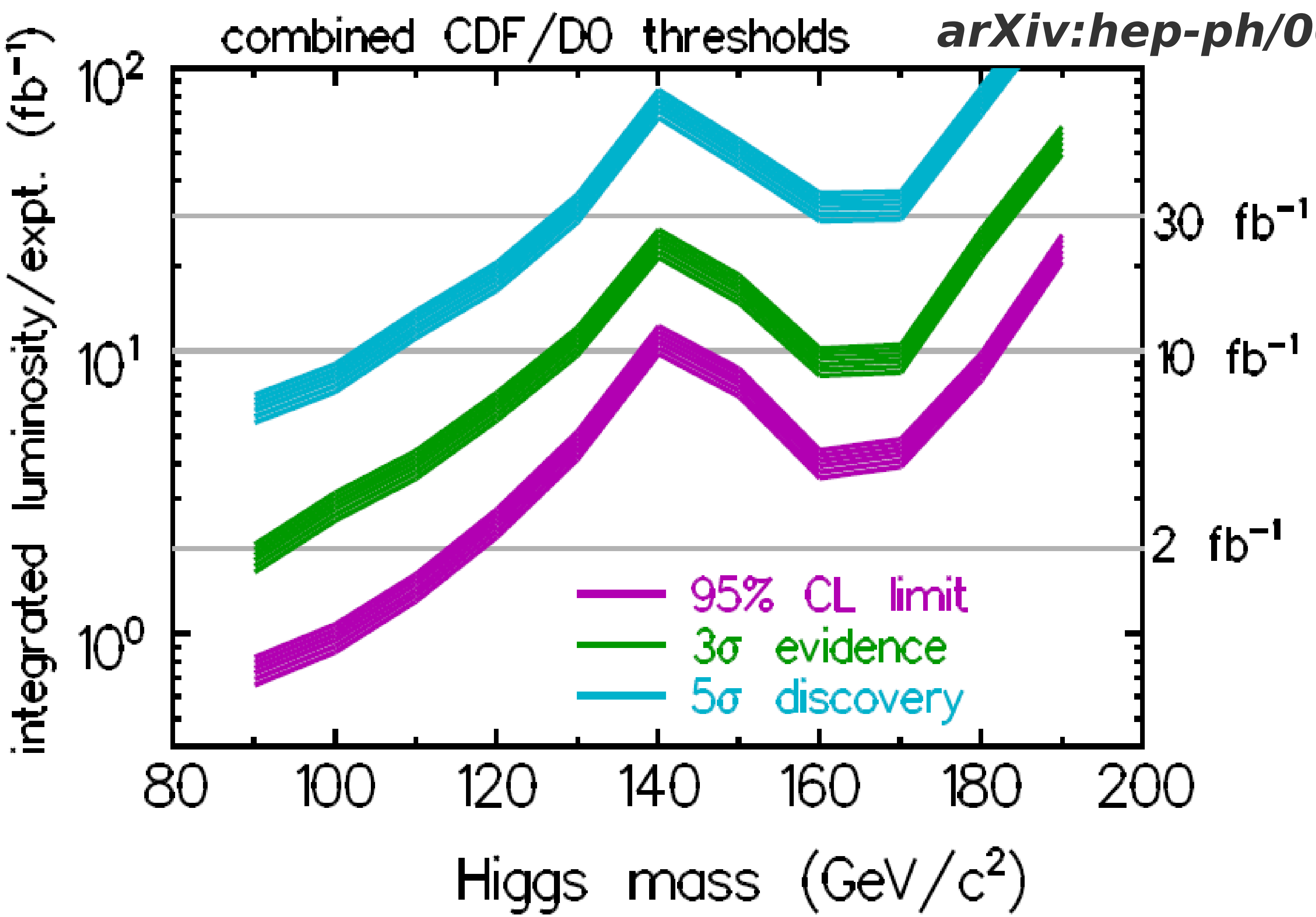
m_H < 135 GeV (H→bb)
background driven
WH→lνbb, ZH→ll/ννbb

m_H > 135 GeV (H→WW)
rate driven
all production modes

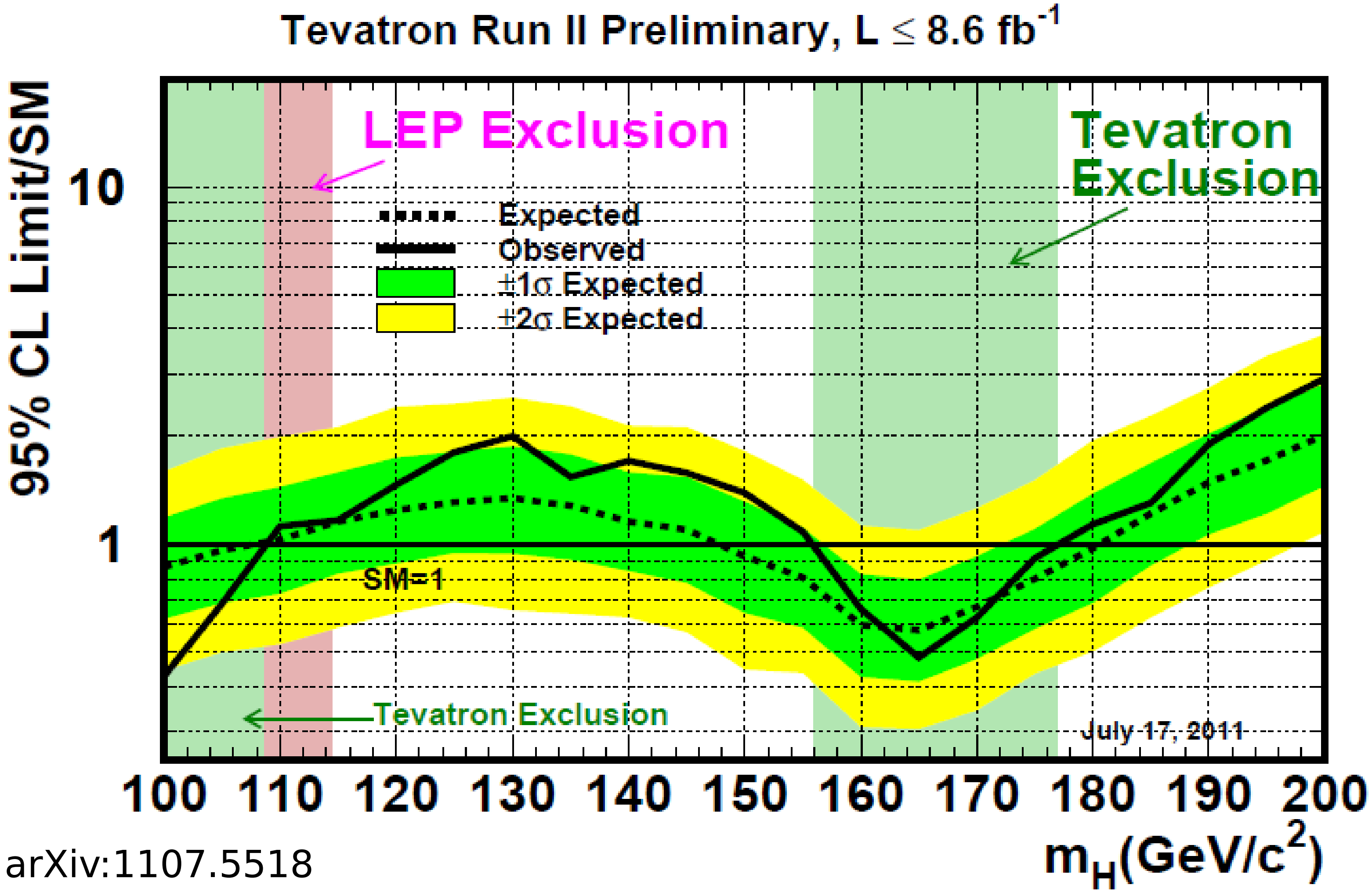
Ulrich Heintz - Moriond QCD

Projected results from RUNII Tevatron Higgs Workshop

arXiv:hep-ph/0010338



Latest combined limit on Higgs Boson mass from CDF & D0 @ 8.6 fb^{-1}



arXiv:1107.5518

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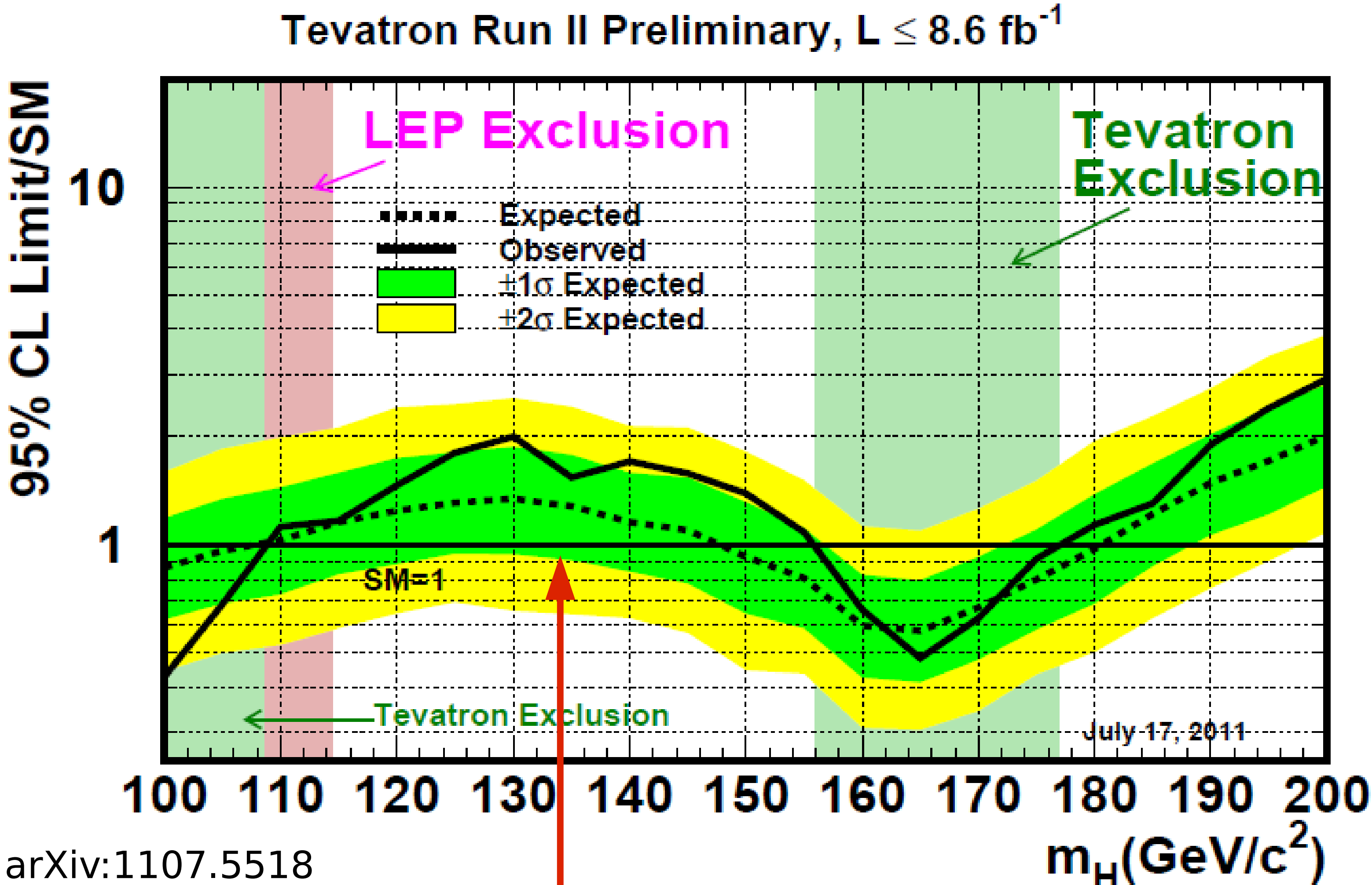

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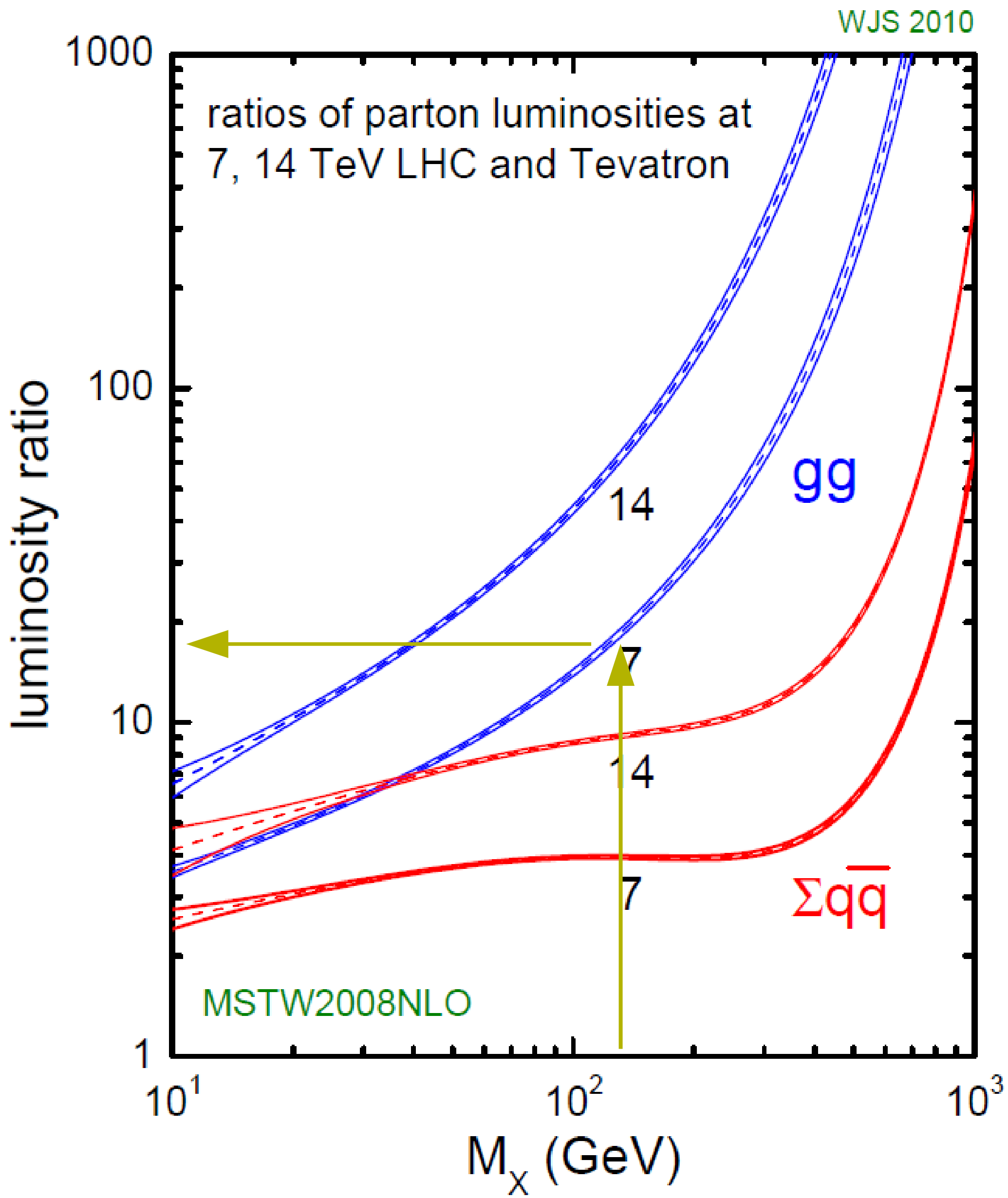
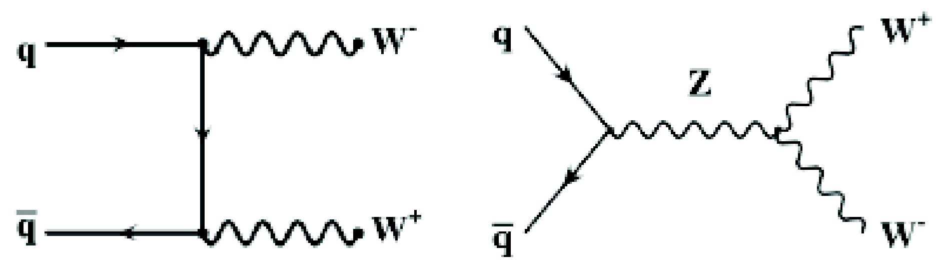
Predicted by RUN2 Tevatron Higgs Workshop.
Systematics plays a crucial role!

LHC vs Tevatron



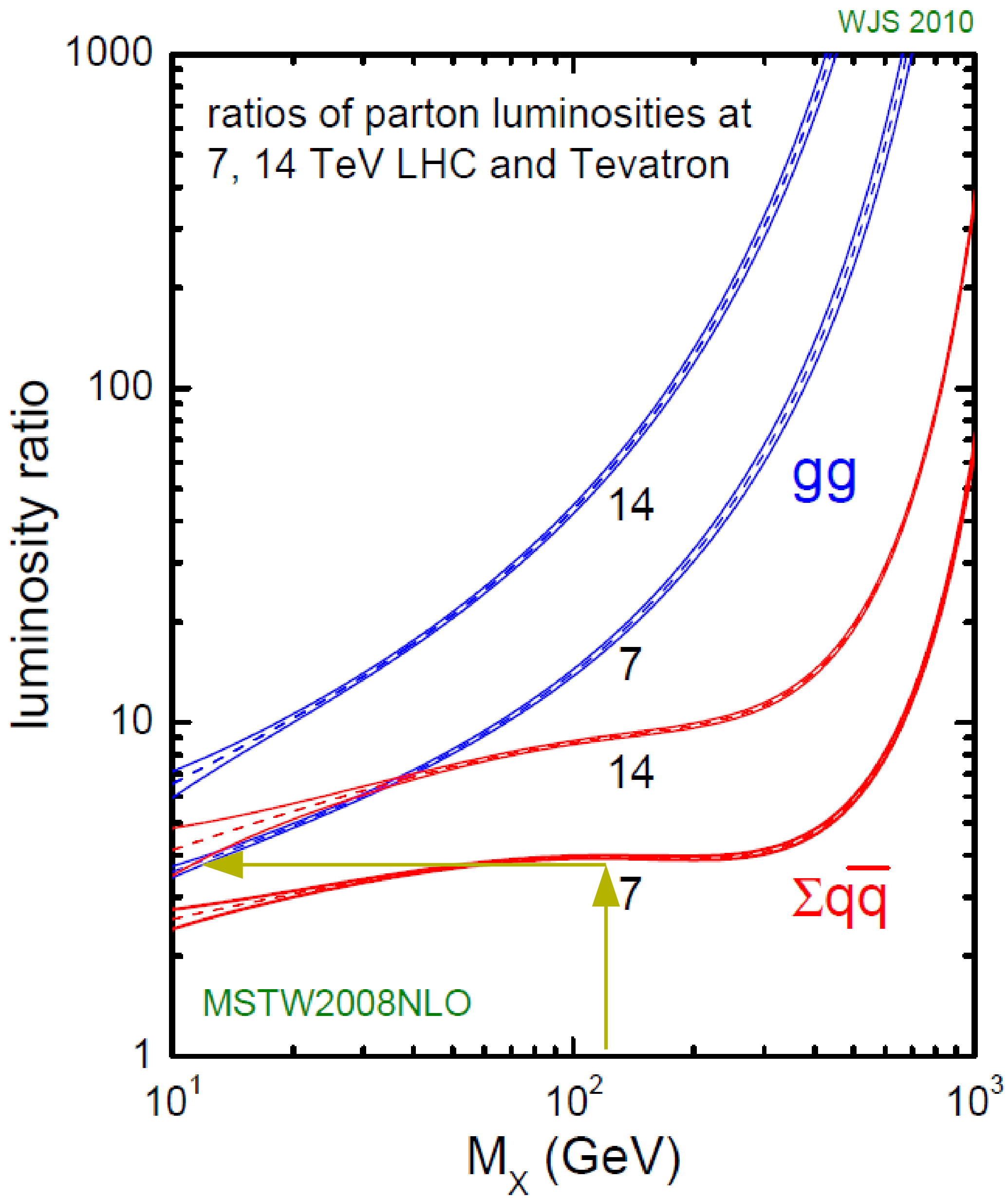
For M_H > 140 GeV
gg → H cross section at 7 TeV
is >15 times that at 2 TeV

Irreducible backgrounds (WW,ZZ) originate from $q\bar{q}$ process which rises relative slowly (pp vs $p\bar{p}$)



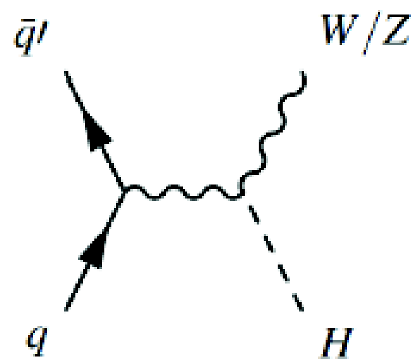
⇒ Larger signal, better S/N

LHC vs Tevatron



For M_H < 130 GeV

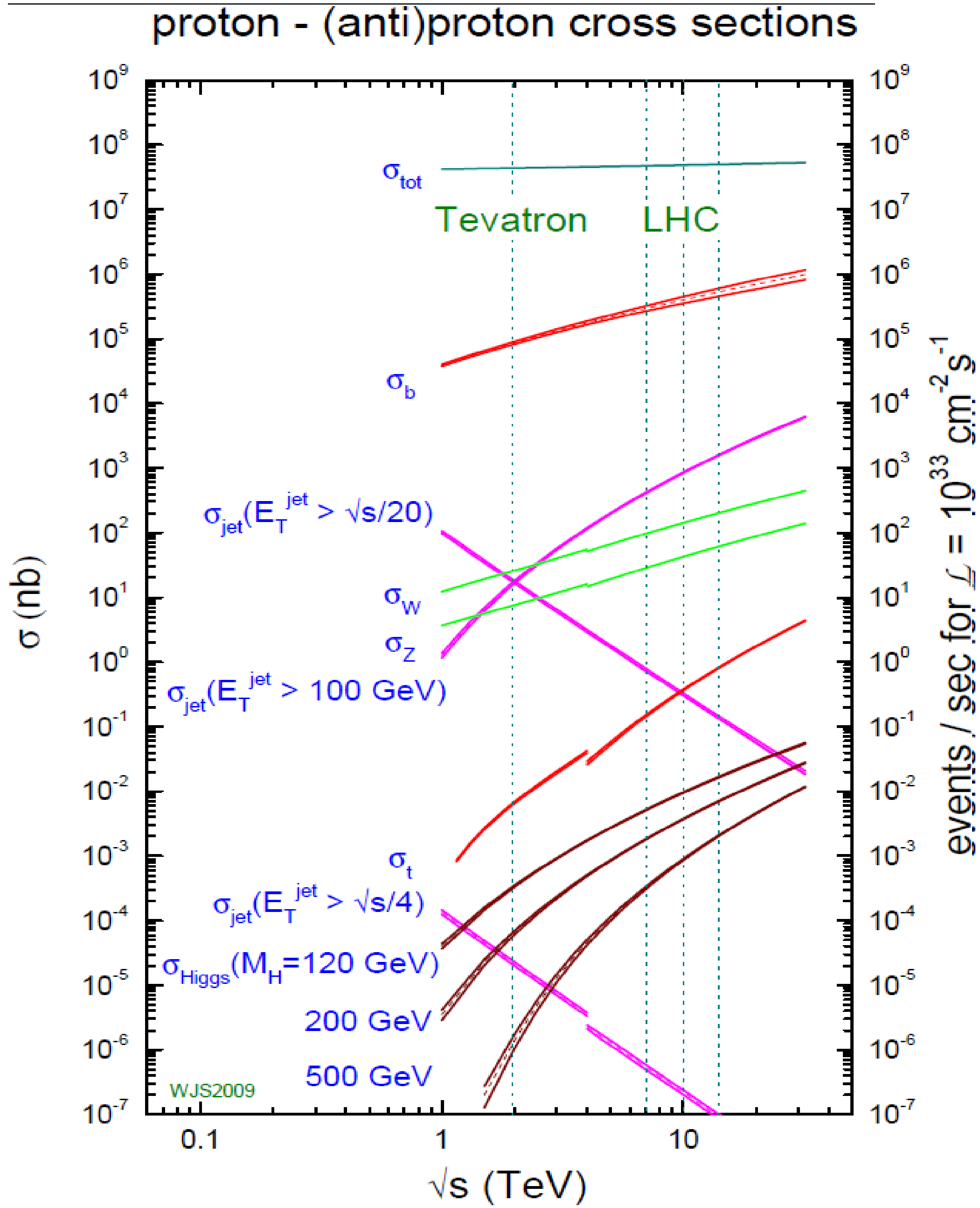
Modest rise in $q\bar{q}$ cross section at 7 TeV, pp → VH production only x 4 larger than at 2 TeV



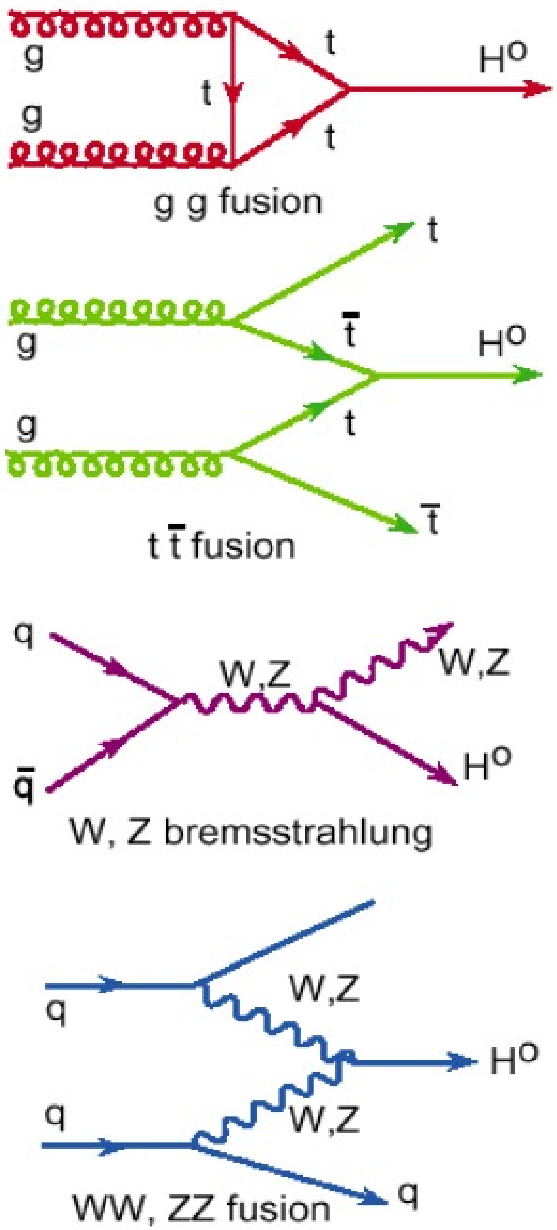
Major backgrounds are $W/Z+b\bar{b}$ & $t\bar{t}$ which rise sharply due to rise in qg and gg cross sections

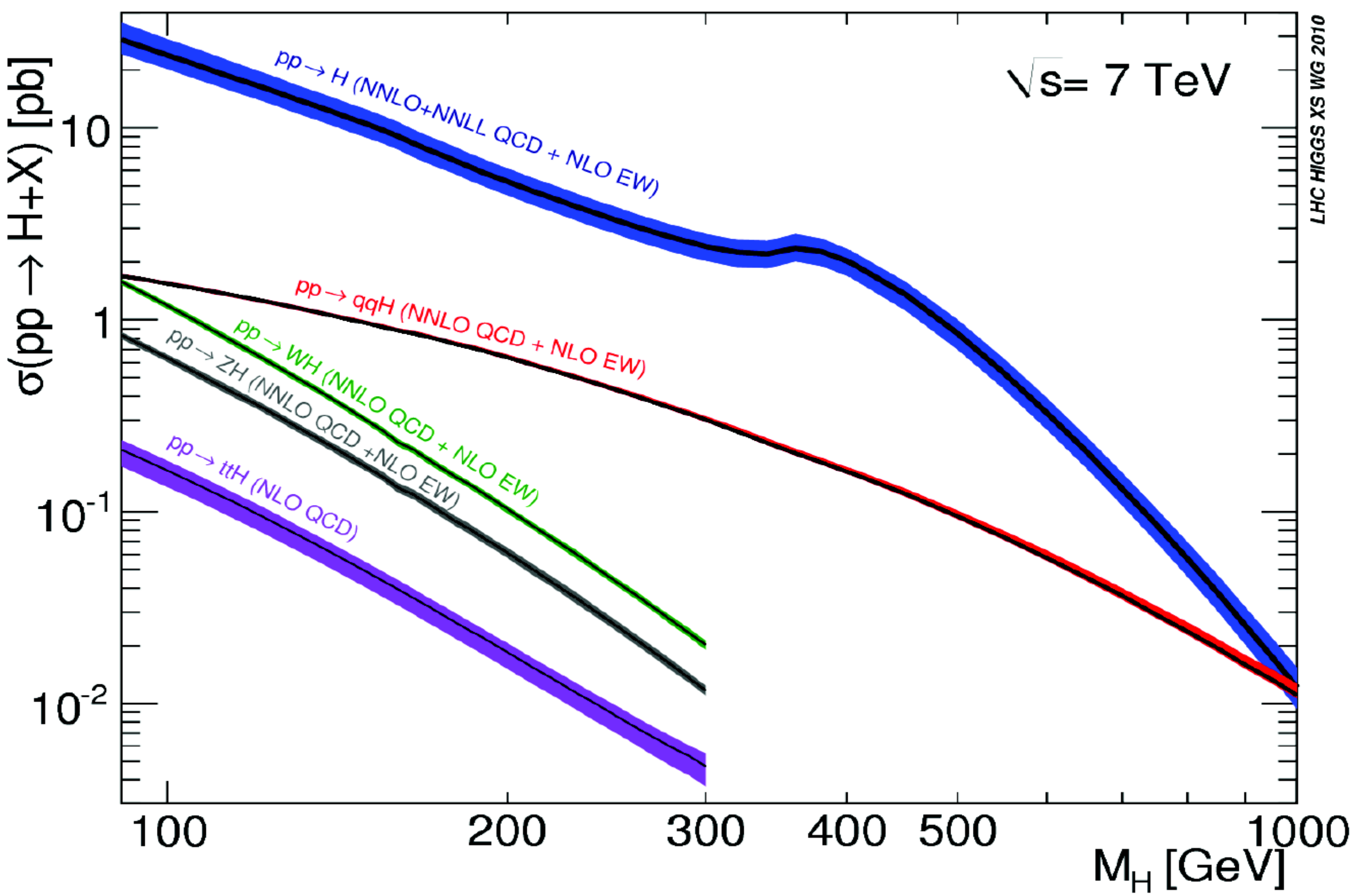
⇒ Small signal, worse S/N

Higgs and BG rates vs Energy

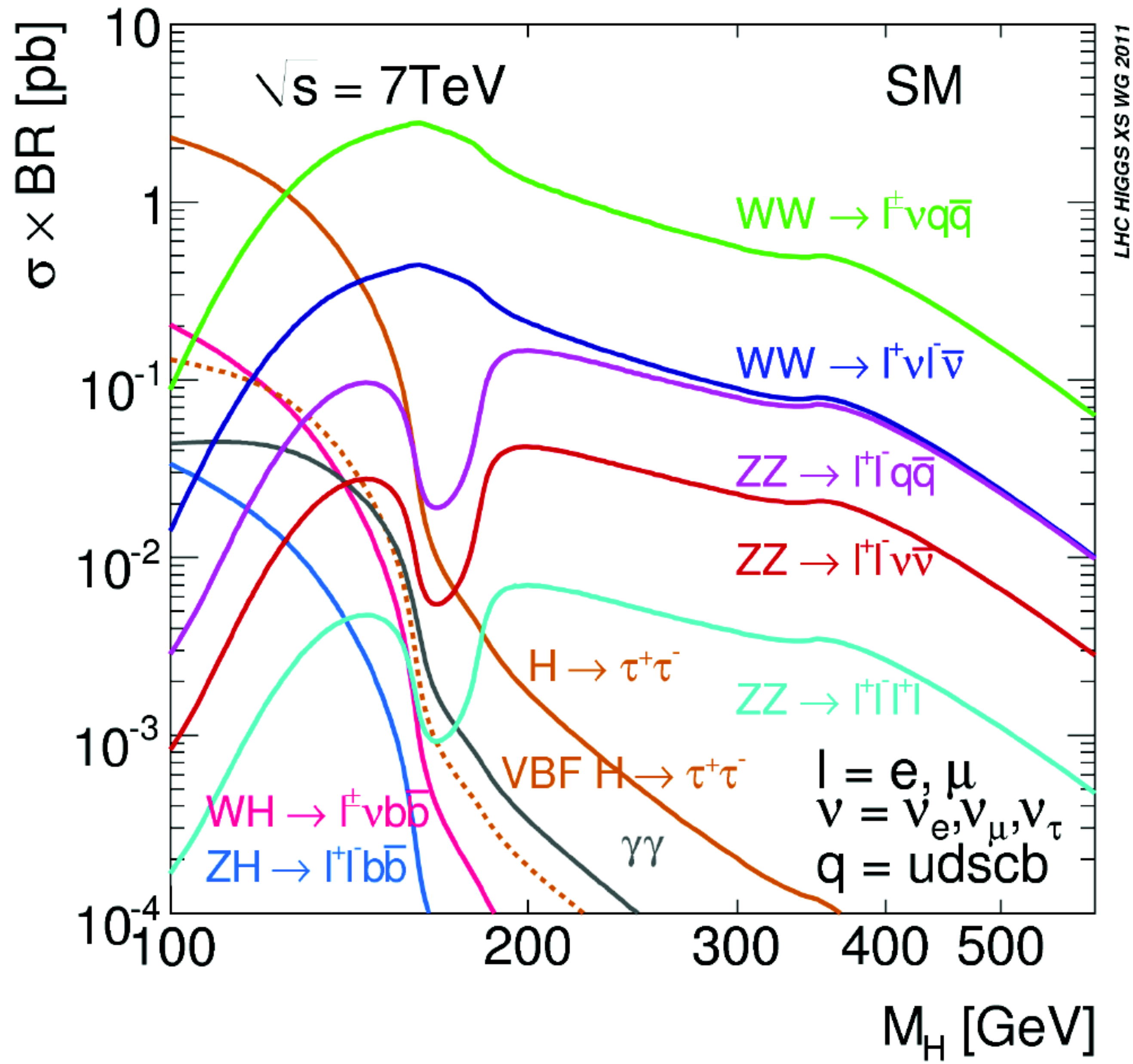


Higgs production at the LHC

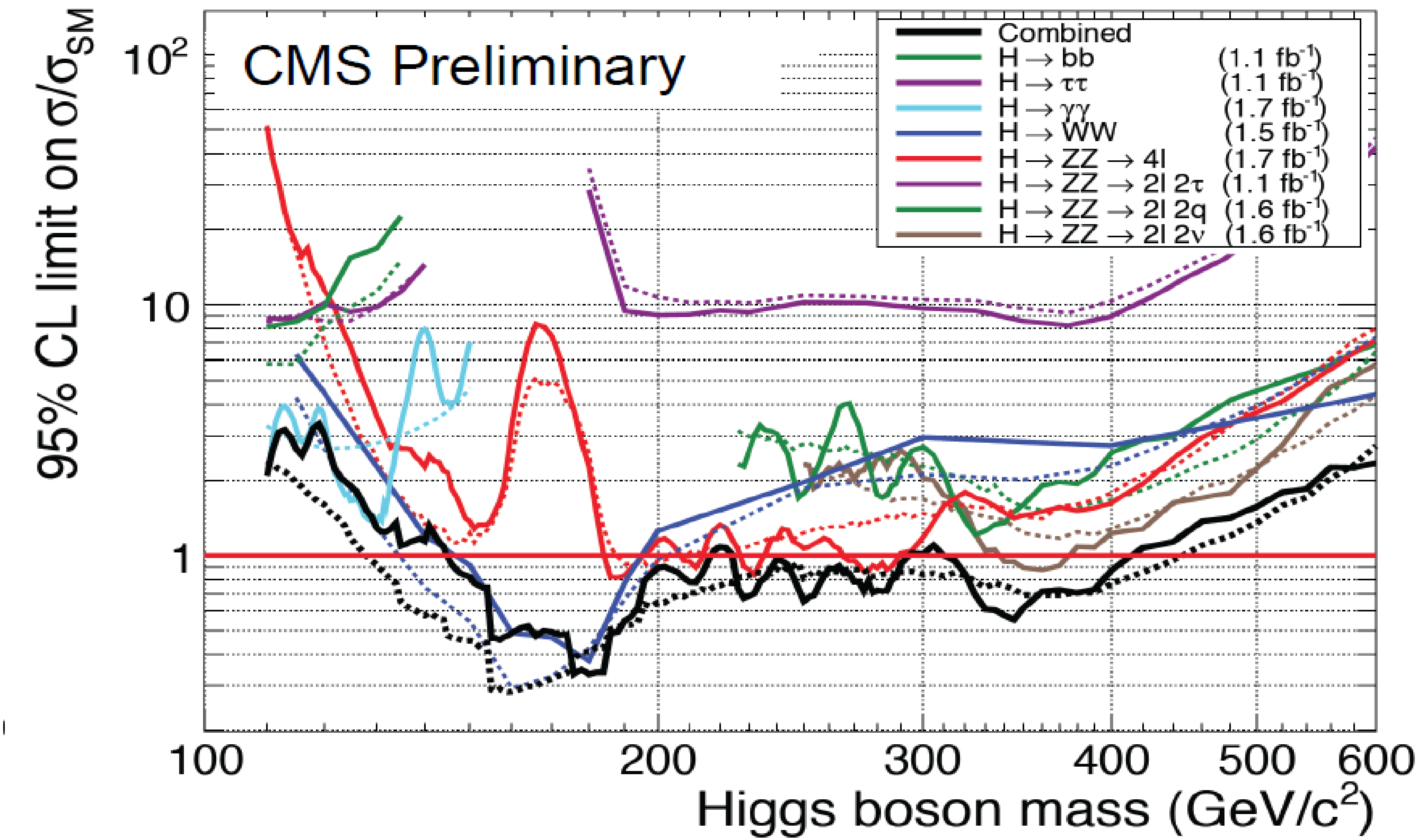




SM Higgs Boson Production at the LHC



Combined Limits



Conservative ATLAS+CMS combination:
146-288, 296-466 GeV
range is excluded @95% CL

[see details in Claire's talk]

LHC projections for Higgs search

mH < 130 GeV

– H → $\gamma\gamma$

130 < mH < 190 GeV

– H → W+W- → $\ell\ell\nu\nu$

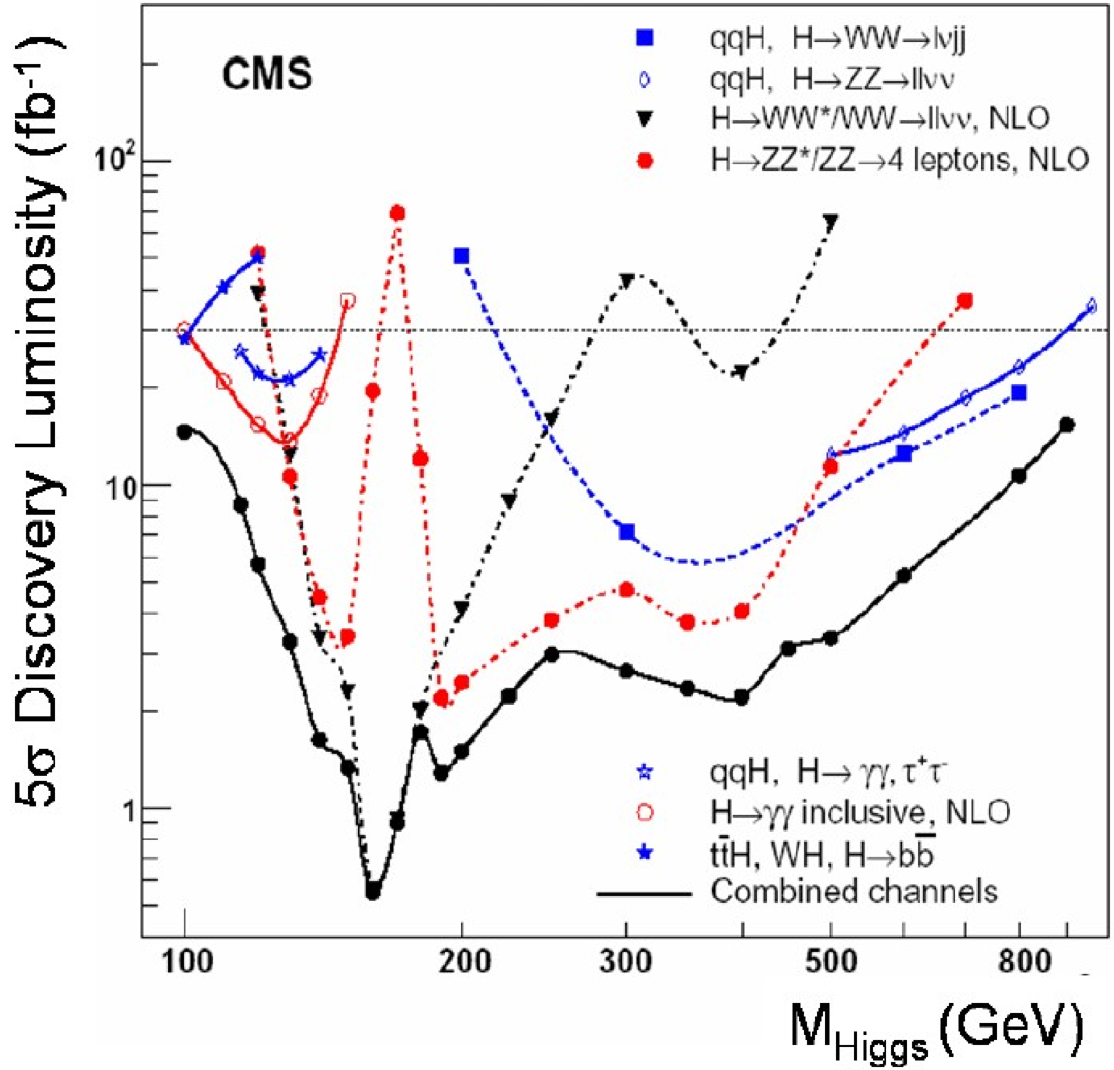
190 < mH < 460 GeV

– H → ZZ → $\ell\ell$ $\ell\ell$

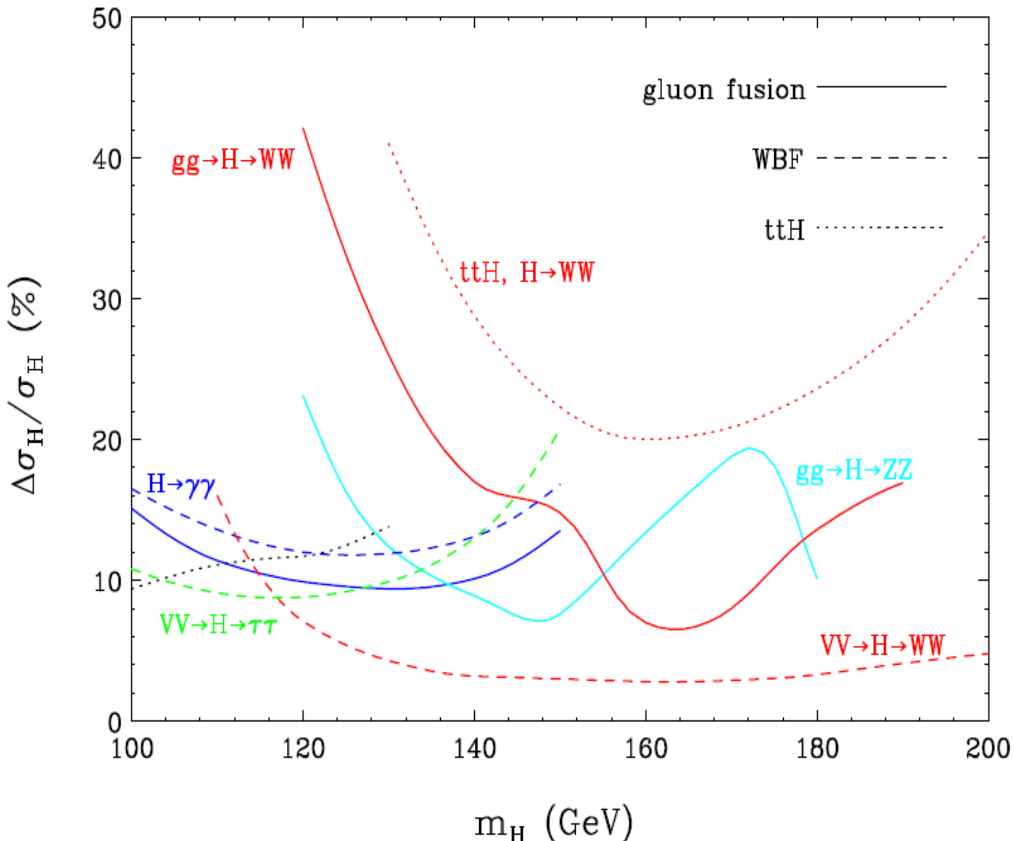
460 < mH < 800 GeV

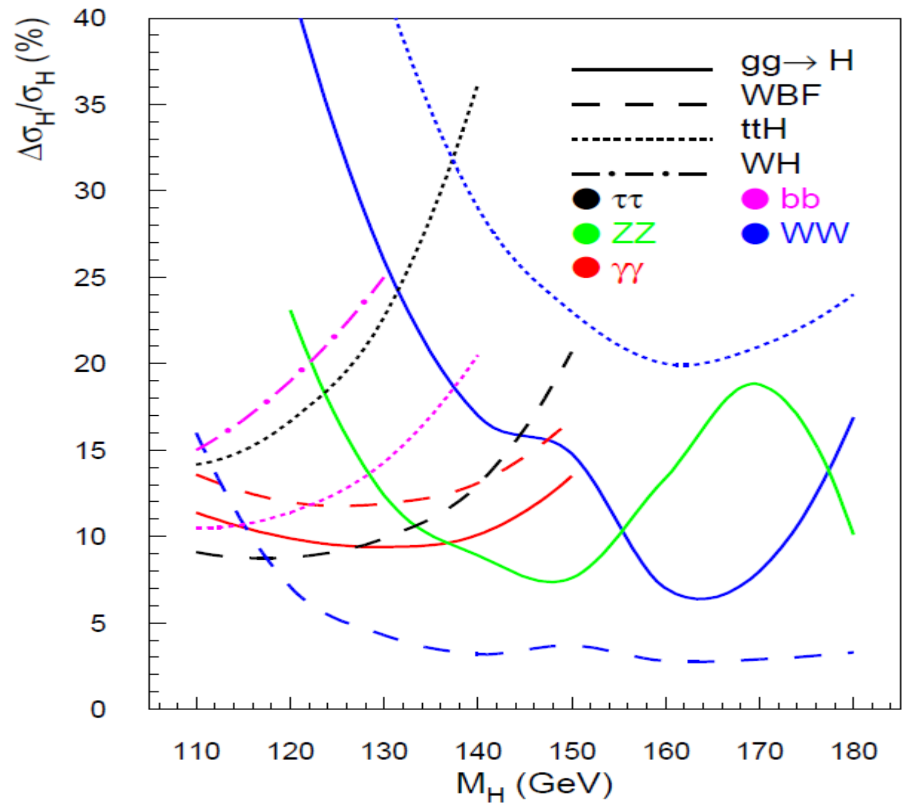
– H → W+W- → $\ell\nu qq$

E_{com} = 14 TeV



Measurement of Higgs couplings at the LHC





Zeppenfeld, Kinnunen, Nikitenko, Richter-Was 2000

AB, Reina '02

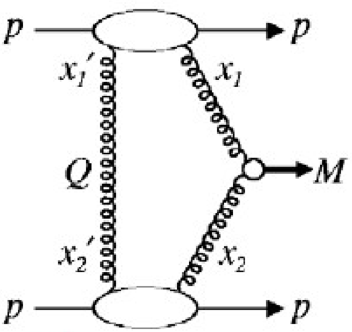
Also, Duhrssen, Heinemeyer, Logan,Rainwater, Weiglein, Zeppenfeld '04

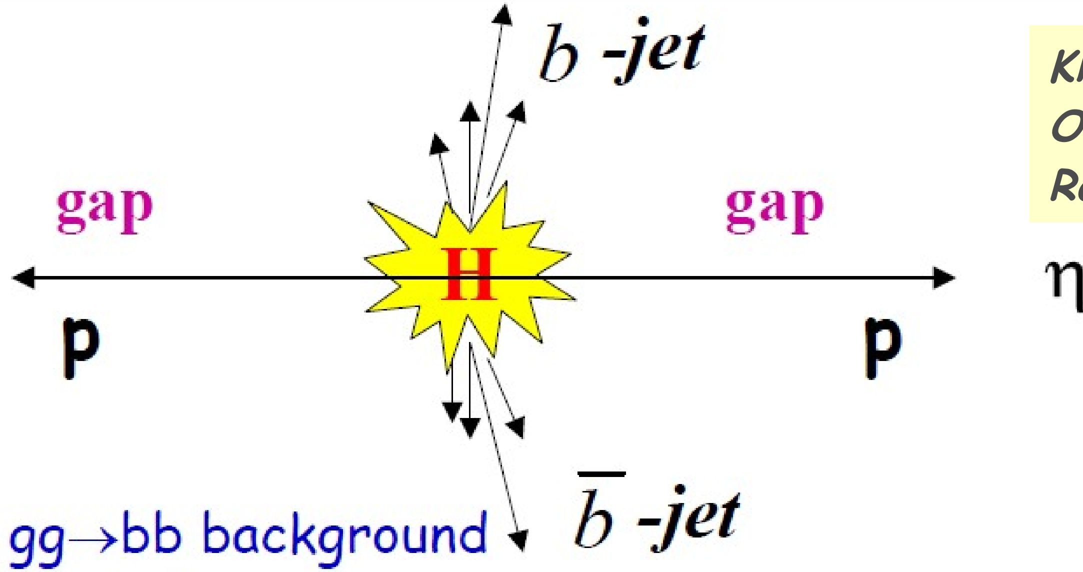
- $gg \to H,\ H \to \gamma\gamma$
- $qq \to qqH,\ H \to \gamma\gamma,\ \tau\tau,\ WW$
- $q\bar{q}, gg \to t\bar{t}H,\ H \to b\bar{b}$, $\tau\bar{\tau}$

- Assume branching ratio for Higgs decays into unexpected channels is small
- 200-300 fb^{-1}

Diffractive Higgs Production

Exclusive diffractive Higgs production pp→ p H p : 3-10 fb
Inclusive diffractive Higgs production pp → p+X+H+Y+p : 50-200 fb

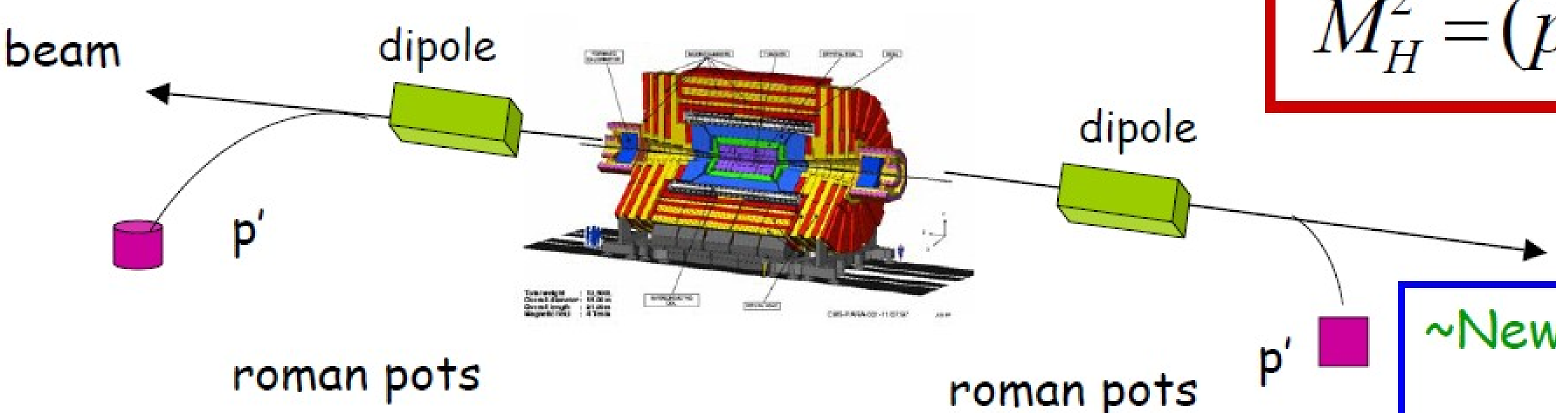




Khoze, Martin, Orava, Ryskin, De Roeck '02

Advantages:
- Jz=0 suppression of gg→bb background
- Mass measurement via missing mass

$$M_H^2 = (p + \bar{p} - p' - \bar{p}')^2$$

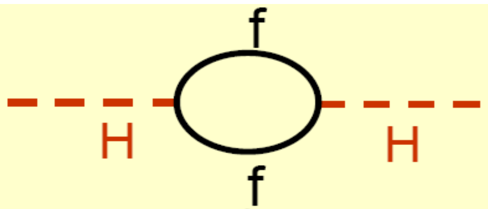


~New: Under study by many groups

Diffractive Higgs Albert De Roeck (CERN) 2

Beyond the SM Higgs

- SM Higgs boson accomplishes several things at once
  - *Provides masses to W and Z bosons*
  - *Provides masses to Fermions*
  - *Unitarizes WW scattering*
  - *Provides a good quality for of EW fits if M_H<200 GeV*
- Why we are not comfortable with SM Higgs?
  - *Fine-tuning*
  - *EW Symmetry is broken "by Hand" ->* $\mu^2 < 0$
  - *Fundamental Scalars never seen before*



$$\delta m_H^2 = \frac{|\lambda_f|^2}{16\pi^2}[-2\Lambda_{UV}^2 + ...]$$

SM : $\Delta M_H^2 \sim \Lambda_{UV}^2$

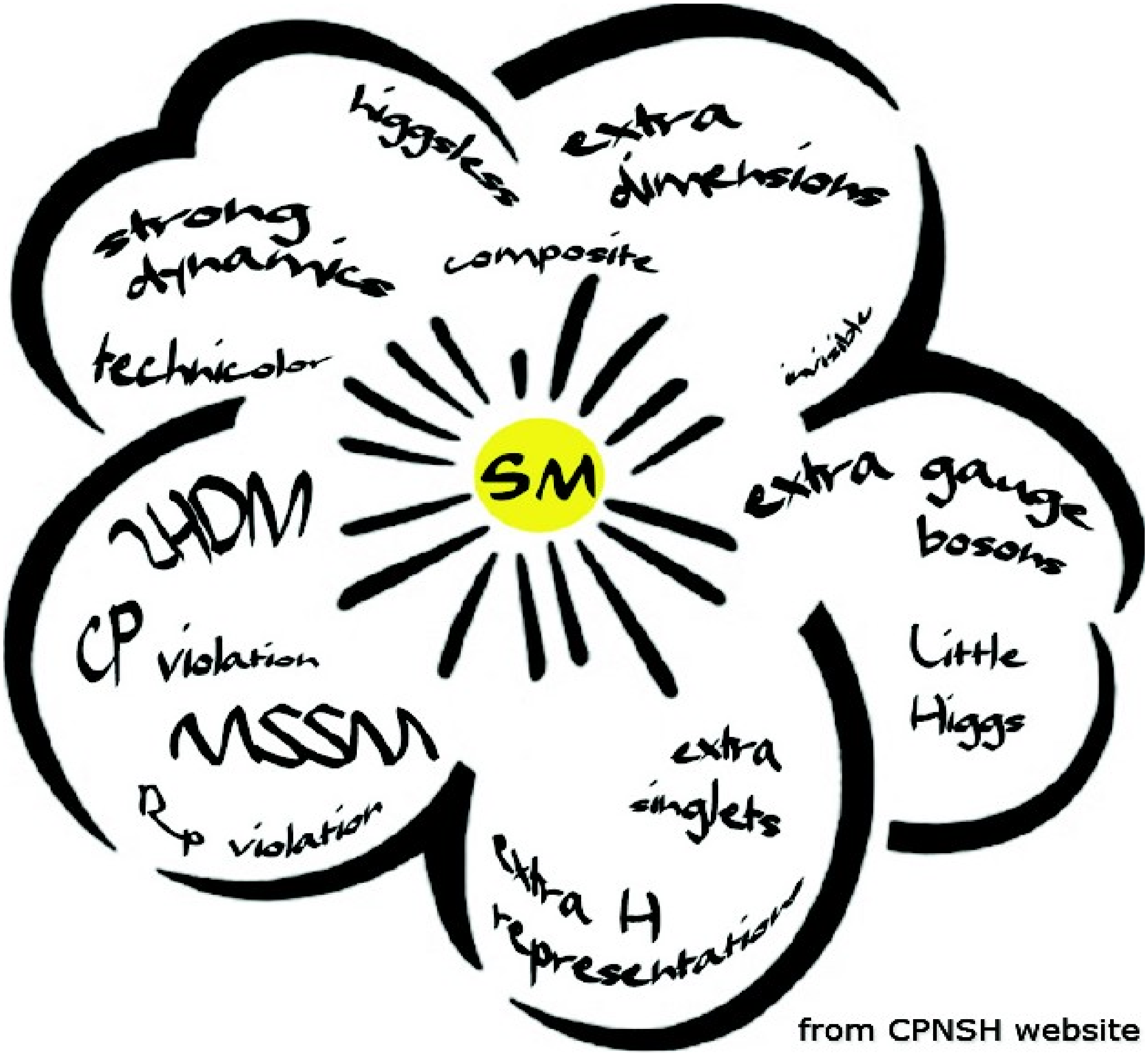
$$M_H^2 = M_{H^0}^2 \quad - \quad \Delta M_H^2,$$

(100 GeV)^2 = (10^{16} GeV)^2 – (10^{16} GeV)^2

the cancellation is at the 28th digit

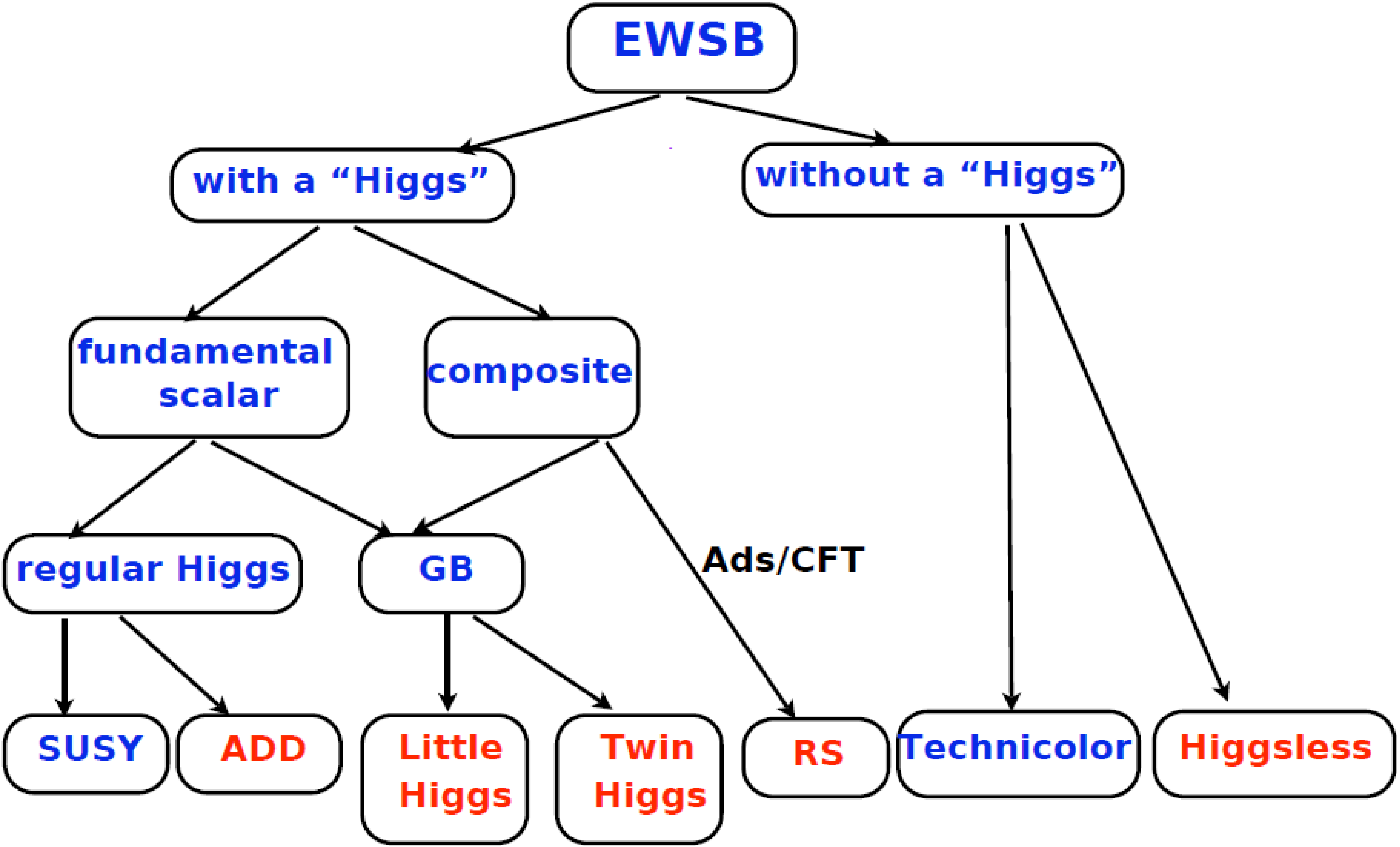
for Λ_{UV} ~ 10^{16} GeV

Variety of theories with SEWSB



from CPNSH website

Variety of theories with SEWSB



From Sufang Su

Higgsless Theories

$$\varphi(x) = exp\left(i\frac{\pi^a(x)\tau^a}{v}\right)\begin{pmatrix} 0 \\ (v+h(x))/\sqrt{2} \end{pmatrix}$$

$$\varphi(x) = exp\left(\Sigma(x)\right)\begin{pmatrix} 0 \\ (v+h(x))/\sqrt{2} \end{pmatrix}$$

One can eliminate h(x) and still have EWSB via Sigma term

in the Higgsless model – non-linear Sigma model

$$\mathcal{L}_H \to \mathcal{L}_\Sigma = \frac{v^2}{4}\mathrm{tr}\left([\mathcal{D}^\mu\Sigma]^\dagger \mathcal{D}_\mu\Sigma\right)$$

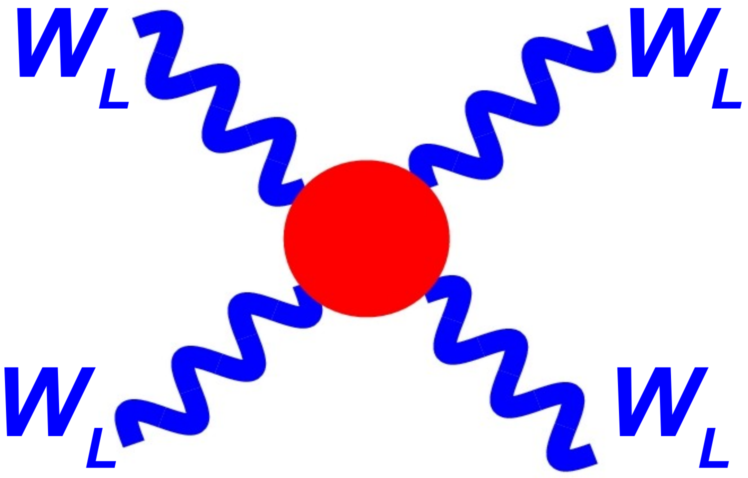
$$|D_\mu\varphi|^2$$

$$= \begin{pmatrix} 0 & v/\sqrt{2} \end{pmatrix}\left|\frac{g}{\sqrt{2}}W^+\sigma^+ + \frac{g}{\sqrt{2}}W^-\sigma^- + \frac{g}{2}W^0\sigma^3 + \frac{g'}{2}B\right|^2\begin{pmatrix} 0 \\ v/\sqrt{2} \end{pmatrix}$$

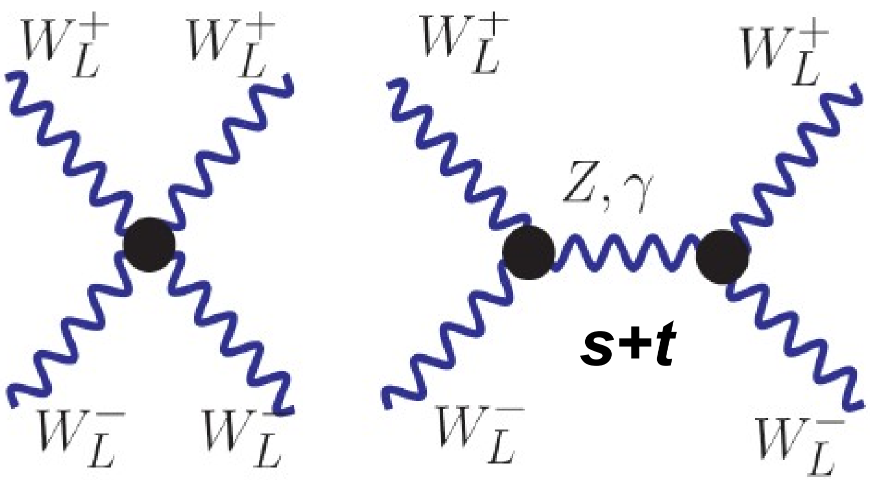
$$= \frac{v^2}{4}[g^2W^+W^- + \frac{1}{2}(-gW^0 + g'B)^2]$$

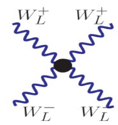
Electroweak Symmetry Breaking without Higgs boson but within the Electroweak theory

The Loss of Unitarity and EW precision data is the main worry!

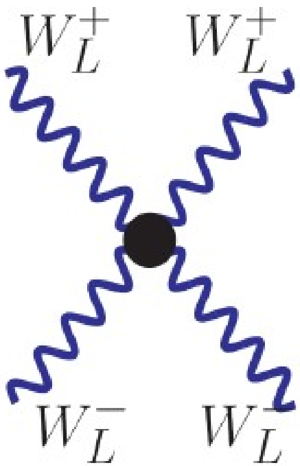


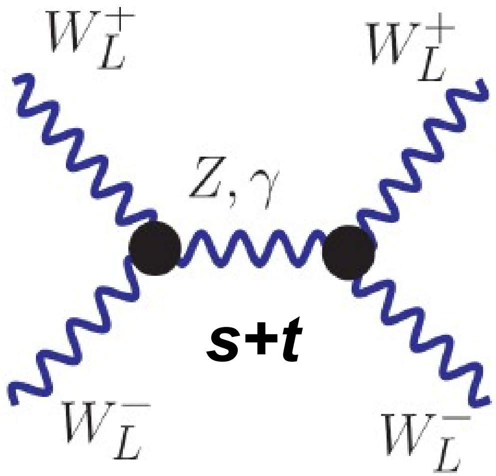
Unitarity with and without Higgs boson

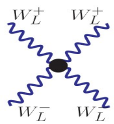


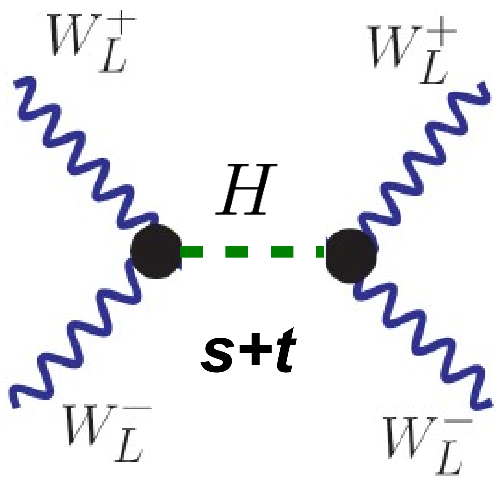
Graphs	$g^2\frac{E^4}{m_w^4}$	$g^2\frac{E^2}{m_w^2}$
	$-3 + 6\cos\theta + \cos^2\theta$	$+2 - 6\cos\theta$
s	$-4\cos\theta$	$-\cos\theta$
t	$+3 - 2\cos\theta - \cos^2\theta$	$-\frac{3}{2} + \frac{15}{2}\cos\theta$
Sum	0	$+\frac{1}{2} + \frac{1}{2}\cos\theta$

Unitarity with and without Higgs boson





Graphs	$g^2\frac{E^4}{m_w^4}$	$g^2\frac{E^2}{m_w^2}$
	$-3+6\cos\theta+\cos^2\theta$	$+2-6\cos\theta$
s	$-4\cos\theta$	$-\cos\theta$
t	$+3-2\cos\theta-\cos^2\theta$	$-\frac{3}{2}+\frac{15}{2}\cos\theta$
Sum	0	$+\frac{1}{2}+\frac{1}{2}\cos\theta$



$$-\frac{1}{2}-\frac{1}{2}\cos\theta$$

$$0$$

If no Higgs $\Rightarrow \mathcal{O}(E^2) \Rightarrow E < \sqrt{8\pi}v \simeq 1.2\,\mathrm{TeV}$

Non-linear sigma model

There are many 4D CP-conserving operators that can be written down

$\mathfrak{L}_1 = \frac{1}{2} g^2 \alpha_1 B_{\mu\nu} \mathrm{Tr}(T F^{\mu\nu})$

$\mathfrak{L}_2 = \frac{1}{2} i g \alpha_2 B_{\mu\nu} \mathrm{Tr}(T[V^\mu, V^\nu])$

$\mathfrak{L}_3 = i g \alpha_3 \mathrm{Tr}(F_{\mu\nu}[V^\mu, V^\nu])$

$\mathfrak{L}_4 = \alpha_4 [\mathrm{Tr}(V_\mu V_\nu)]^2$

$\mathfrak{L}_5 = \alpha_5 [\mathrm{Tr}(V_\mu V^\mu)]^2$

$\mathfrak{L}_6 = \alpha_6 \mathrm{Tr}(V_\mu V_\nu) \mathrm{Tr}(T V^\mu) \mathrm{Tr}(T V^\nu)$

$\mathfrak{L}_7 = \alpha_7 \mathrm{Tr}(V_\mu V^\mu) [\mathrm{Tr}(T V_\nu)]^2$

$\mathfrak{L}_8 = \frac{1}{4} g^2 \alpha_8 [\mathrm{Tr}(T F_{\mu\nu})]^2$

$\mathfrak{L}_9 = \frac{1}{2} i g \alpha_9 \mathrm{Tr}(T F_{\mu\nu}) \mathrm{Tr}(T[V^\mu, V^\nu])$

$\mathfrak{L}_{10} = \frac{1}{2} \alpha_{10} [\mathrm{Tr}(T V_\mu) \mathrm{Tr}(T V_\nu)]^2$

$\mathfrak{L}_{11} = \alpha_{11} \mathrm{Tr}[(\mathfrak{D}_\mu V^\mu)^2]$

$\mathfrak{L}_{12} = \frac{1}{2} \alpha_{12} \mathrm{Tr}(T \mathfrak{D}_\mu \mathfrak{D}_\nu V^\nu) \mathrm{Tr}(T V^\mu)$

$\mathfrak{L}_{13} = \frac{1}{2} \alpha_{13} [\mathrm{Tr}(T \mathfrak{D}_\mu V_\nu)]^2$

$\mathfrak{L}_{14} = \alpha_{14} [\mathrm{Tr}(F_{\mu\nu} V^\nu) \mathrm{Tr}(T V^\mu) - \mathrm{Tr}(F_{\mu\nu} V^\mu) \mathrm{Tr}(T V^\nu)]$

$\mathfrak{L}_{15} = 2 i \alpha_{15} \mathrm{Tr}(V_\mu \mathfrak{D}_\nu V^\nu) \mathrm{Tr}(T V^\mu)$

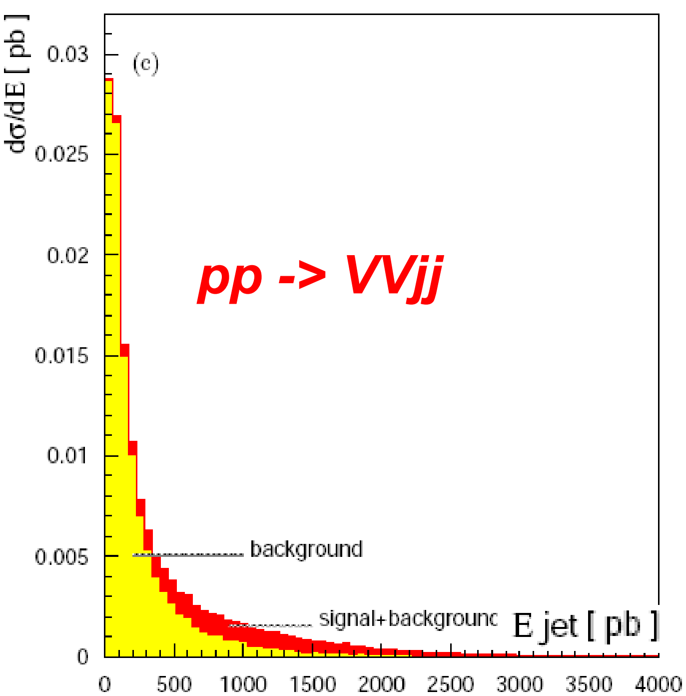
$\mathfrak{L}_{16} = i \alpha_{16} \mathrm{Tr}[T(\mathfrak{D}_\mu V_\nu + \mathfrak{D}_\nu V_\mu)] \times \mathrm{Tr}(V^\mu V^\nu)$

$\mathfrak{L}_{17} = \frac{1}{2} i \alpha_{17} \mathrm{Tr}[T(\mathfrak{D}_\mu V_\nu + \mathfrak{D}_\nu V_\mu)] \times \mathrm{Tr}(T V^\mu) \mathrm{Tr}(T V^\nu)$

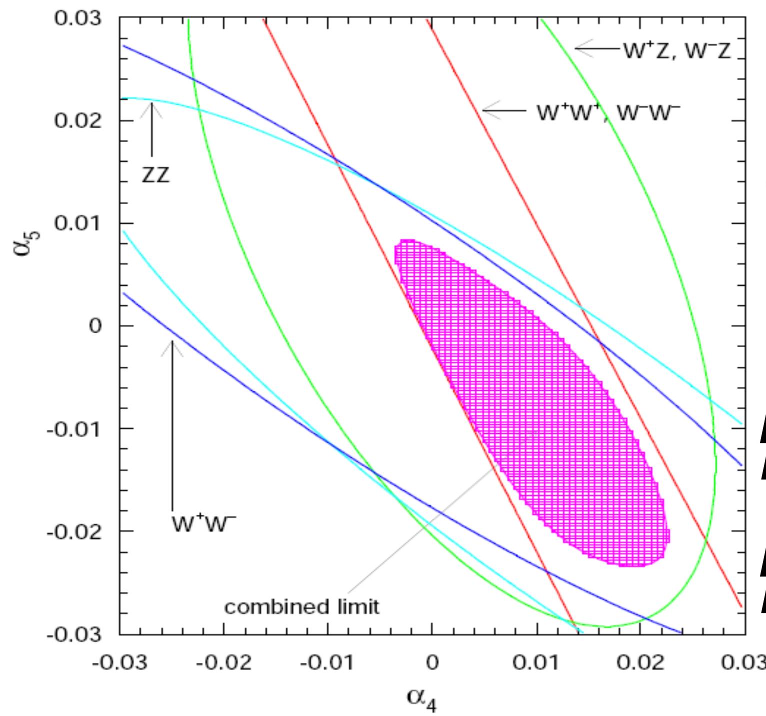
$\mathfrak{L}_{18} = \frac{1}{2} i \alpha_{18} \mathrm{Tr}([V_\mu, T] \mathfrak{D}^\mu \mathfrak{D}^\nu V_\nu)$

[Appelquist, Bernard '80 ; Longitano '80]

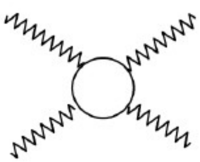
which can be tested at the LHC



pp -> VVjj



the only quartic interactions under custodial symmetry



$$\mathcal{L}_4 = \alpha_4 (\mathrm{tr}\,[V_\mu V_\nu])^2$$

$$\mathcal{L}_5 = \alpha_5 (\mathrm{tr}\,[V_\mu V^\mu])^2$$

[AB, Eboli, Gonzalez–Garcia, Mizukoshi, Novaes, Zacharov '98]

[Eboli, Gonzalez–Garcia, Mizukoshi '06]

Why do/should we think about
alternative way
of Electroweak Symmetry
Breaking?

Example of Comparison

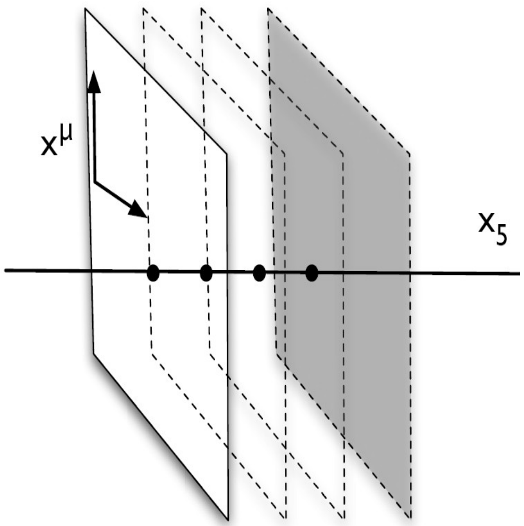
SM Higgs vs Technicolor

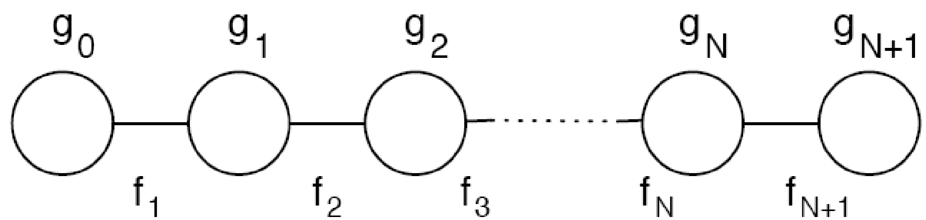
SM Higgs	Technicolor
simple and economical	*complicated at the effective theory level*
GIM mechanism, no FCNC problems, EW precision data are OK for preferably light Higgs boson	*FCNC constraints require* walking, *potential tension with EW precision data*
SM is established, perfectly describes data	*no viable ETC model suggested yet, work in progress*
fine-tuning and naturalness problem; triviality problem	*no fine-tuning, the scale is dynamically generated*
there is no example of fundamental scalar	*Superconductivity and QCD are examples of dynamical symmetry breaking*
Scalar potential parameters and yukawa couplings are inputs	*parameters of low-energy effective theory are derived once underlying ETC is constructed*

How one can preserve unitarity without Higgs ?

DECONSTRUCTION

moose diagram can be interpreted as the discretization of a continuum gauge theory in 5D along a fifth dimension

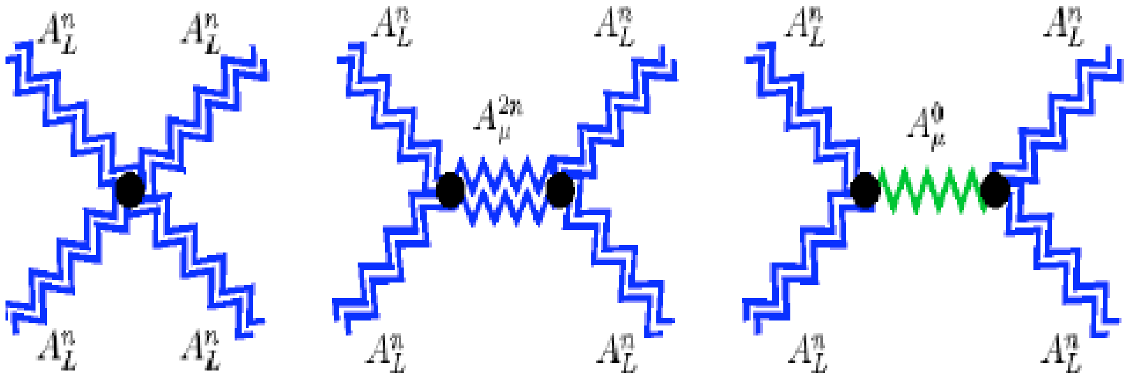




- Discretize fifth dimension
- 4D gauge group at each site
- Nonlinear sigma model link fields
- To include warping: vary f_j
- For spatially dependent coupling: vary g_k
- Continuum Limit: take N → infinity
- Finite N, a 4D theory w/o 5D constraints

Arkani-Hamed, Georgi, Cohen & Hill, Pokorski, Wang

Conflict S and Unitarity



- *Z' resonance unitarizes WW scattering, similar to what Higgs boson does in SM* *(Chivukula,He,Dicus)*

- ***Z' mass is bounded from above:*** $m_{Z_1} < \sqrt{8\pi}\, v$

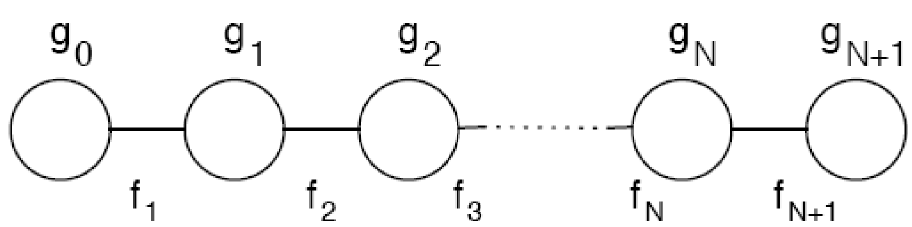
- ***... and yields too much a value of S-parameter:*** $\alpha\, S \geq \frac{4 s_Z^2 c_Z^2 M_Z^2}{8\pi v^2} = \frac{\alpha}{2}$
  [Chivukula, Simmons, He, Kurachi,Tanabashi]

- ***Solution – delocalization of the fermions:***
  mixing of "brane" and "bulk" modes!
  [Cacciapaglia, Csaki, Grojean, Reece,Terning; Foadi Gopalakrishna, Schmidt]

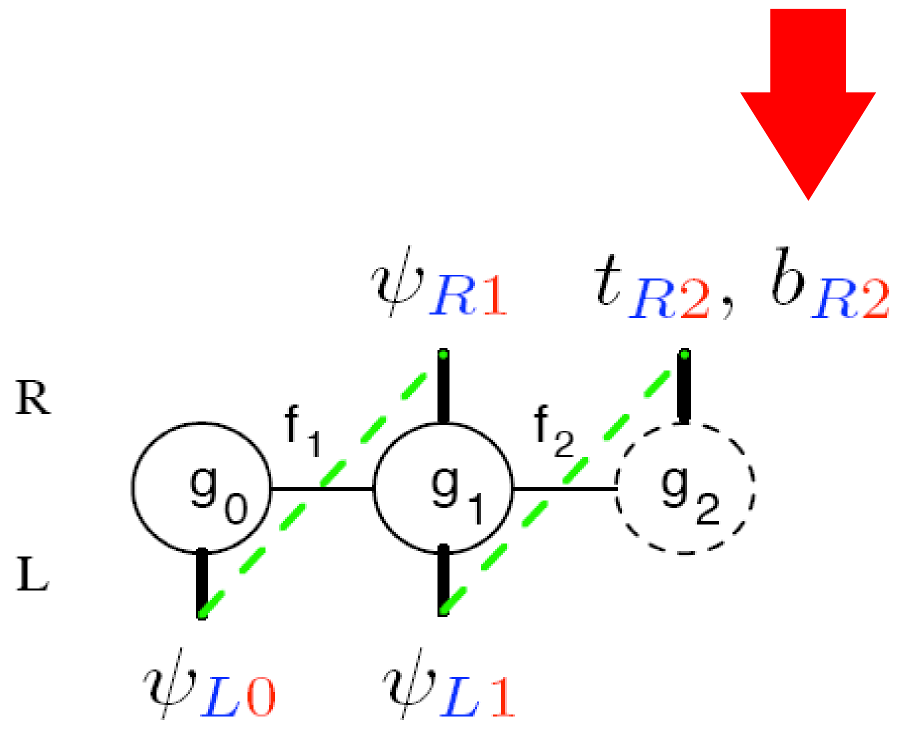
- ***Alternatively there could be a large contribution to T parameter***
  [see talk by Riccardo Barbieri]

Three site model (TSM)

simplest, realistic, highly deconstructed,higgsless



Discretized 5th dimension written in the language of 'theory space'
[Arkani-Hammed, Georgi, Cohen; Hill, Pokorski, Wang]



$$SU(2) \times SU(2) \times U(1)$$

[Chivukula, Coleppa, Di Chiara,Simmons '06]

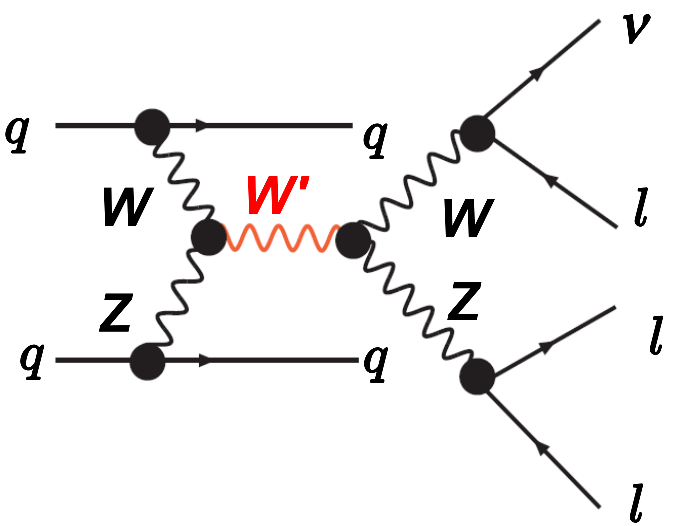
***gauge bosons:* photon,Z,W, Z',W'**

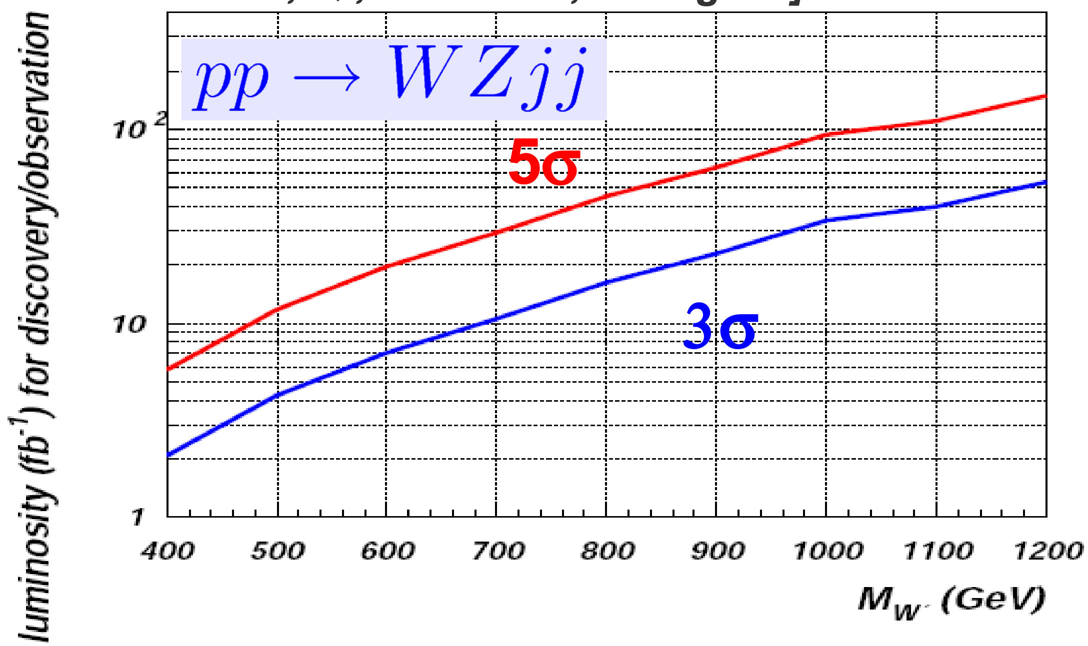
gauge sector is the BESS model
[Casalbuoni, De Curtis, Dominici,Gatto '85]

fermions: ***u, d, c, s, t, b***
U, D, C, S, T, B
plus leptons

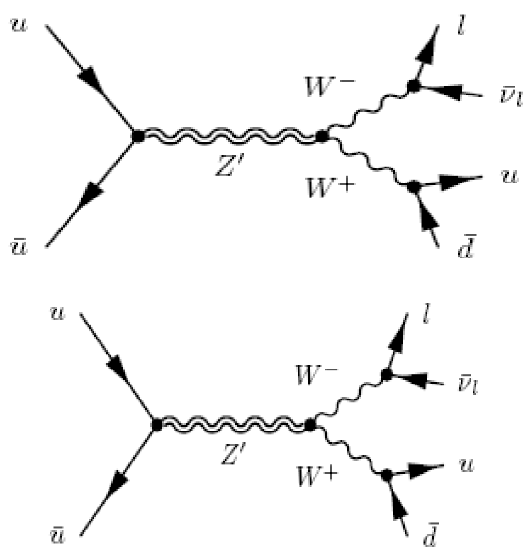
LHC reach for WZ->W' process

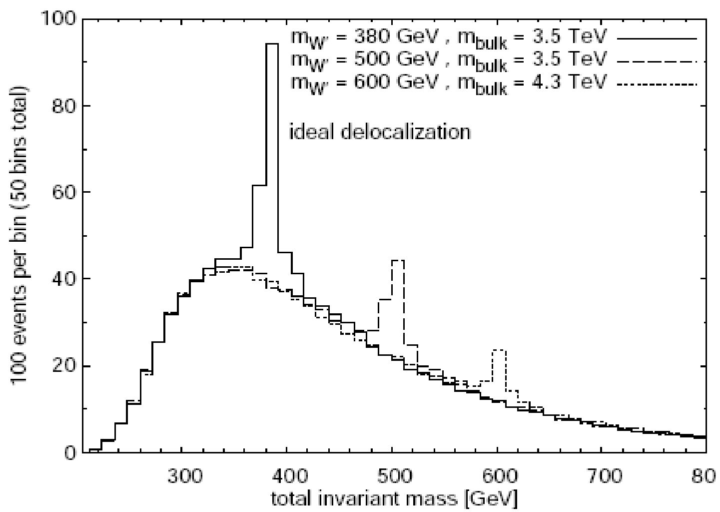
[AB, Chivukula, Christensen, He, Kuang, Pukhov, Qi, Simmons, Zhang '07]

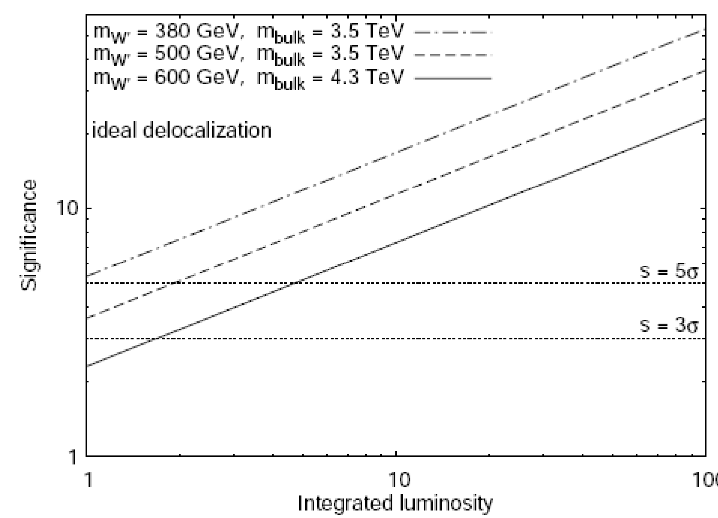




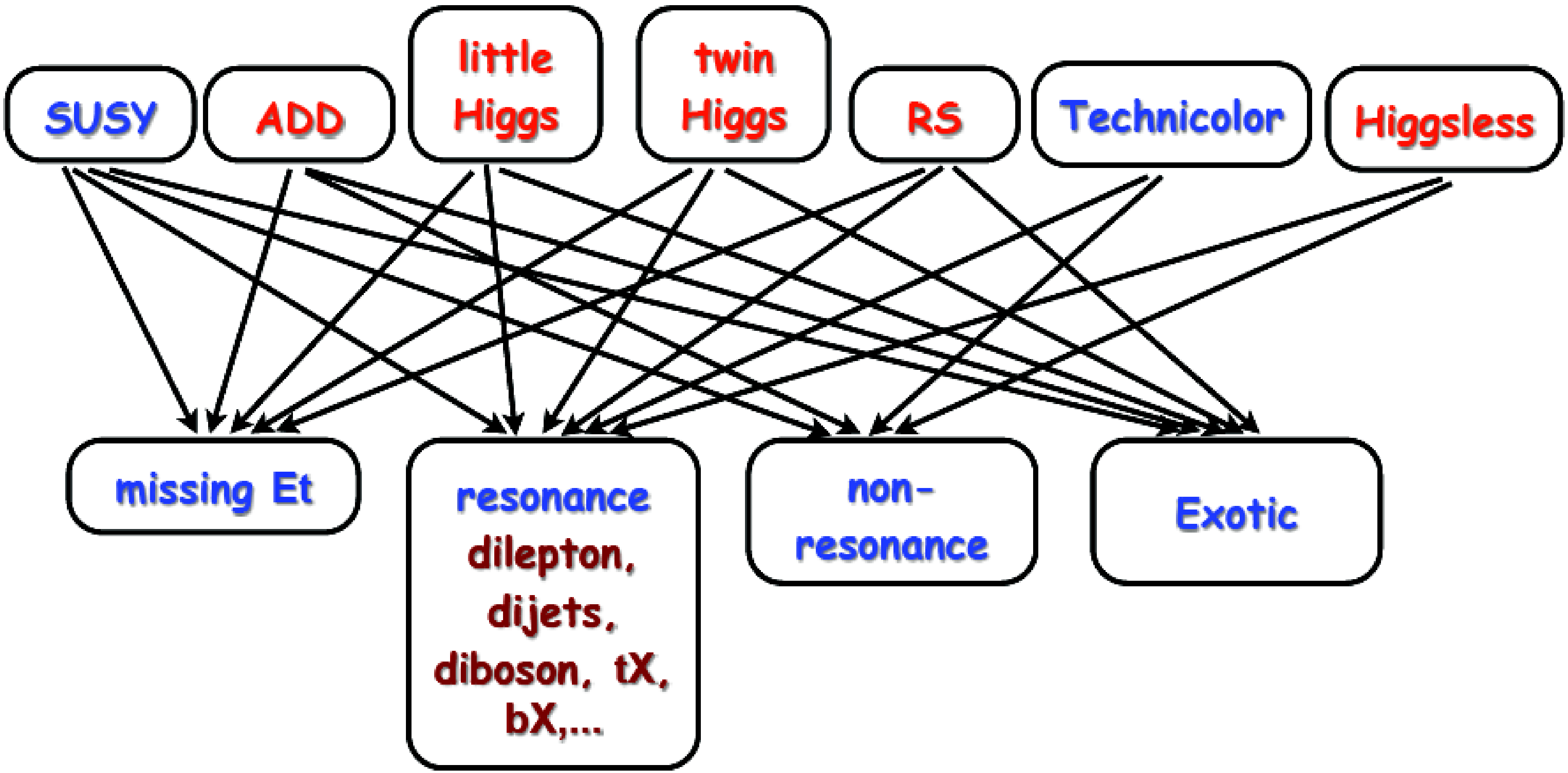
LHC reach for s-channel Z' and W' [Ohl,Speckner '08]





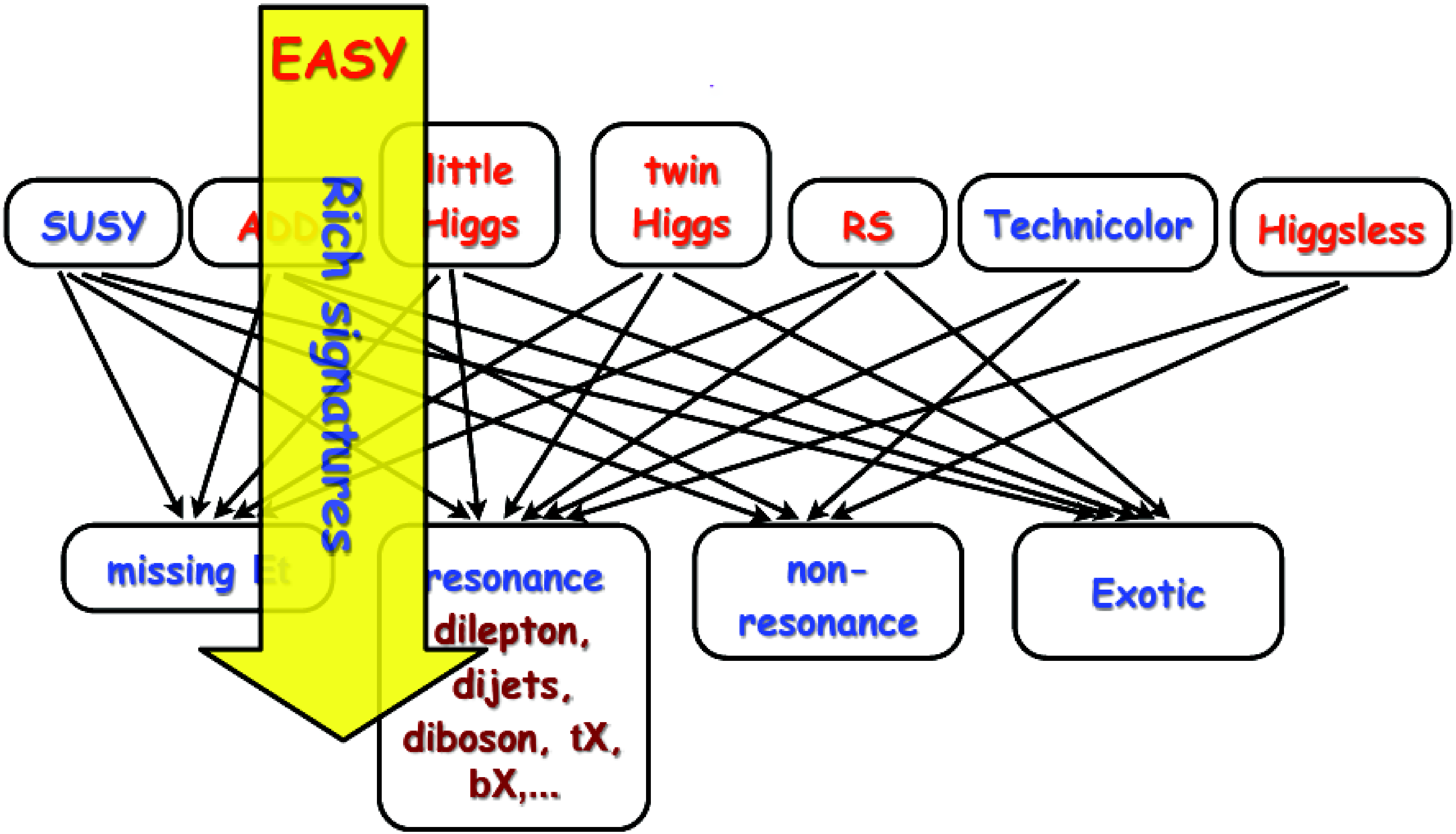


What we should really worry about?



From Sufang Su

What we should really worry about?



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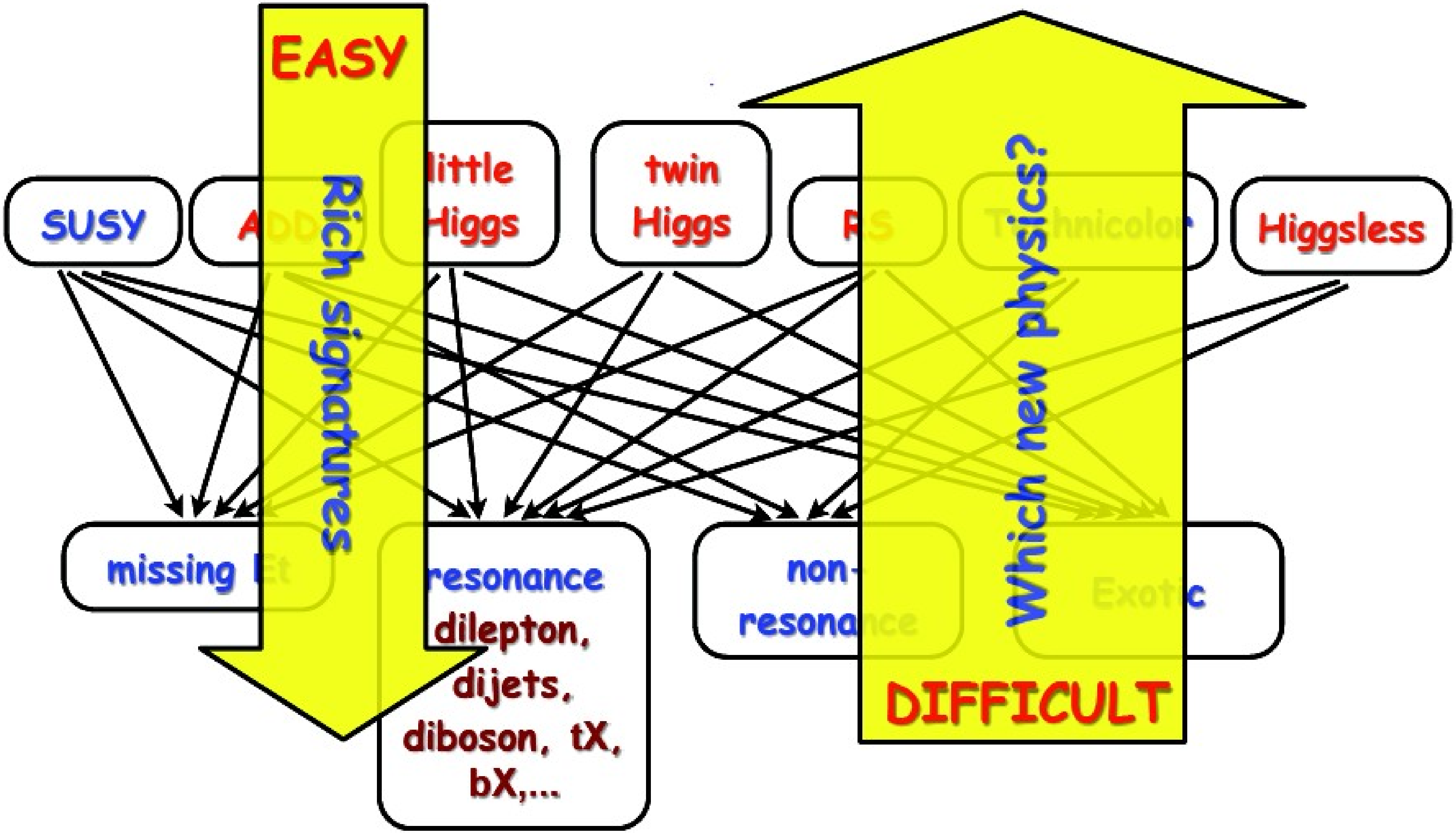

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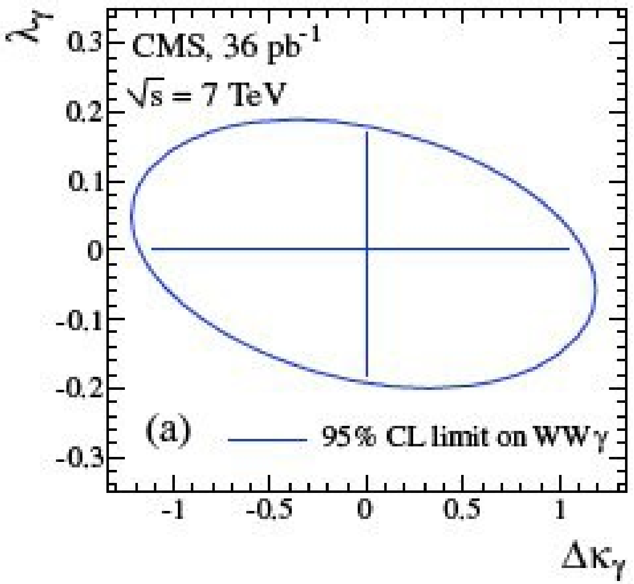
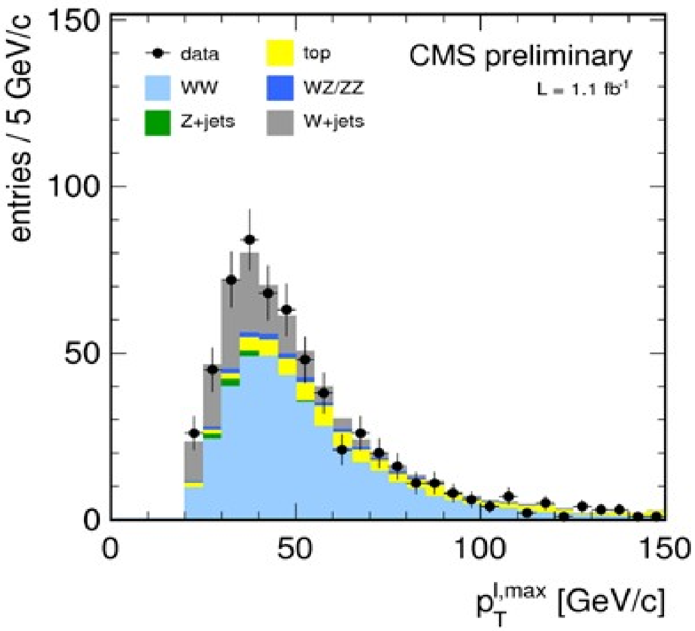
Reconstruction underlying theory of EWSB requires precision measurements

- Higgs couplings
- VV scattering in pp->VVjj process
- Couplings of vector bosons to fermions

ATLAS&CMS search for deviation from expectations for TGB couplings: no anomalous coupling observed





Reconstruction underlying theory of EWSB requires precision measurements

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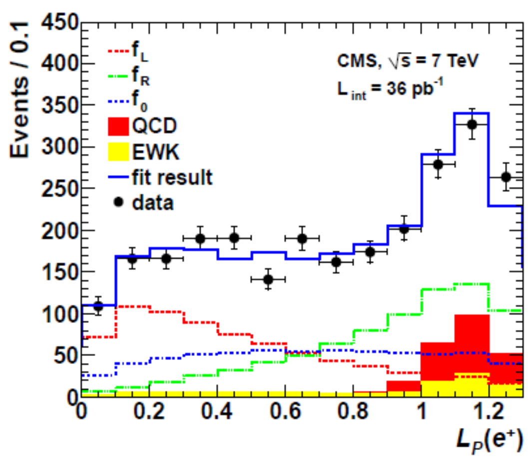
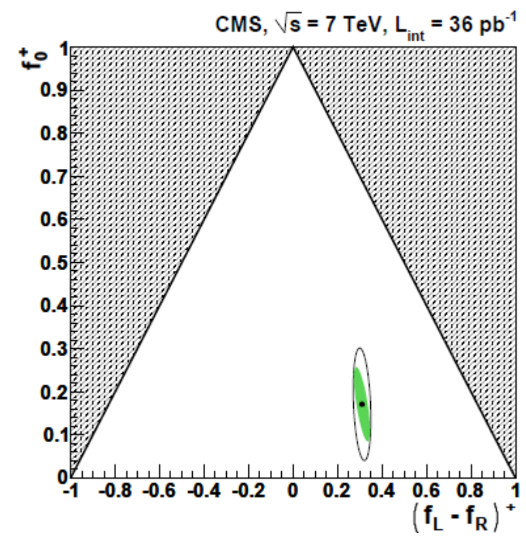
Measurements of fermion-fermion-W couplings at CMS arXiv:1104.3829

$$\frac{\mathrm{d}N}{\mathrm{d}\cos\theta^*} \propto (1+\cos^2\theta^*) + \tfrac{1}{2}A_0(1-3\cos^2\theta^*) + A_4\cos\theta^*.$$

$$L_P = \frac{\vec{p}_T(\ell)\cdot\vec{p}_T(\mathrm{W})}{|\vec{p}_T(\mathrm{W})|^2}$$

$$\cos\theta^* = 2(L_P - \tfrac{1}{2})$$





Message to exp:

There is no factorisation for production and decay of W if L_p is used!

Conclusions

- We are getting really close to understanding the nature of EWSB: LHC is closing the gap!
- Plenty different BSM scenarios are suggested and are possible. LHC has a potential to discover one or another.
- Understanding details of underlying theory of EWSB could be a tough job requiring precision measurements and generic strategy of reconstructing theory from various possible signatures