Discussion: Electroweak (global) Fits

Snowmass 2013 Community Planning Meeting

Fermilab, October 12 , 2012

Physics with W and Z bosons at high-energy colliders

W and Z production processes are one of the theoretically best understood, most precise probes of the Standard Model (SM):

- Test of the SM as a fully-fledged Quantum Field Theory: sensitivity to multi-loop and non-universal radiative corrections.
- Check of the consistency of the SM by comparing direct with indirect measurements of model parameters, e.g., $m_{top}, M_W, \sin^2\theta_{eff}, M_H$.
- Search for indirect signals of Beyond-the-SM (BSM) physics in form of small deviations from SM predictions, yielding exclusions of, and constraints on, BSM scenarios.
- Search for BSM particles appearing as resonances in W, Z distributions at high invariant lepton-pair masses.
- Sensitive probe of proton structure.

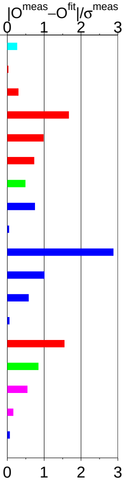
Multi-boson production:

- EW gauge boson pair and triple production directly probes the non-abelian gauge structure of the SM.
- Search for non-standard gauge boson self couplings allowed by Lorentz and gauge invariance provide a unique indirect way to look for signals of new physics in a model-independent way.
- Improved constraints on anomalous triple-gauge boson couplings (TGCs) and quartic couplings (QGCs) probe scales of new physics in the multi-TeV range.
- Important backgrounds to Higgs and BSM searches.

Status

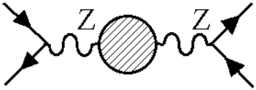
During the last 30+ years the Standard Model (SM) of strong and electroweak interactions has been thoroughly scrutinized at LEP/SLC,HERA,Tevatron,. . ., probing its validity down to distances of about 10^{-18} meters with high precision.

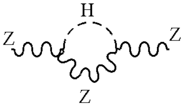
	Measurement	Fit
$\Delta\alpha_{had}^{(5)}(m_Z)$	0.02750 ± 0.00033	0.02759
m_Z [GeV]	91.1875 ± 0.0021	91.1874
Γ_Z [GeV]	2.4952 ± 0.0023	2.4959
σ_{had}^0 [nb]	41.540 ± 0.037	41.478
R_l	20.767 ± 0.025	20.742
$A_{fb}^{0,l}$	0.01714 ± 0.00095	0.01645
$A_l(P_\tau)$	0.1465 ± 0.0032	0.1481
R_b	0.21629 ± 0.00066	0.21579
R_c	0.1721 ± 0.0030	0.1723
$A_{fb}^{0,b}$	0.0992 ± 0.0016	0.1038
$A_{fb}^{0,c}$	0.0707 ± 0.0035	0.0742
A_b	0.923 ± 0.020	0.935
A_c	0.670 ± 0.027	0.668
A_l(SLD)	0.1513 ± 0.0021	0.1481
$\sin^2\theta_{eff}^{lept}(Q_{fb})$	0.2324 ± 0.0012	0.2314
m_W [GeV]	80.385 ± 0.015	80.377
Γ_W [GeV]	2.085 ± 0.042	2.092
m_t [GeV]	173.20 ± 0.90	173.26



March 2012

So far, the SM withstood all experimental tests (apart from $m_\nu \neq 0$).





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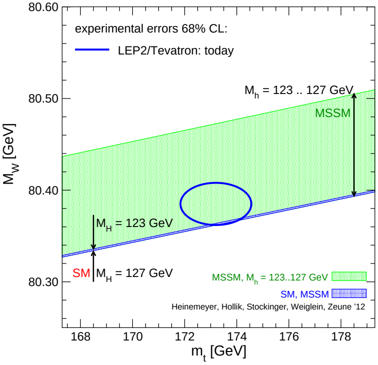
Indirect Bound on the SM Higgs boson mass from EW precision data

M_W - M_Z correlation:

$$M_W^2\left(1-\frac{M_W^2}{M_Z^2}\right)=\frac{\pi\alpha(0)}{\sqrt{2}G_\mu(1-\Delta r(M_W,m_t,M_H,\ldots))}$$



Heinemeyer, W. Hollik, D. Stockinger, G. Weiglein, L. Zeune '12

Δr: radiative corrections to μ decay

Direct and indirect measurements

of M_W are in good agreement:

$M_W(\mathrm{LEP}, p\bar{p}) = 80.385 \pm 0.015$ GeV

$M_W(\mathrm{LEP/SLD}) = 80.363 \pm 0.032$ GeV

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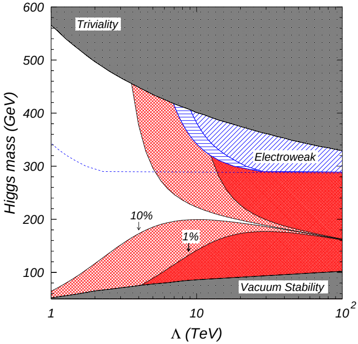
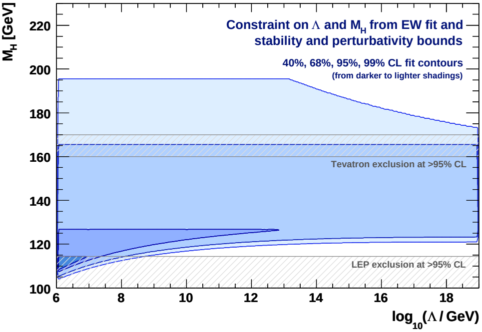
all data: $M_H < 171$ GeV at 95 % C.L.

$M_H = 94^{+29}_{-24}$ GeV at 68% C.L.

Impact of possible $M_H = 125$ GeV on scale of new physics

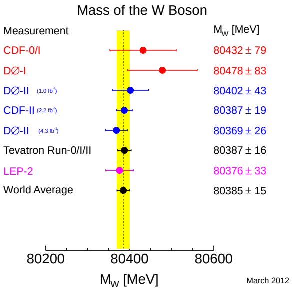
Unitarity: $W_L W_L$ scattering violates unitarity unless $M_H < 780$ GeV.
Loop-effects impact Higgs mass (μ) and self coupling (λ) :
Triviality: If $\lambda(Q^2)$ becomes too strong, theory becomes non-perturbative.
Vacuum stability: If $\lambda(Q^2) < 0$, $V(\phi)$ may become unstable (new vacuum).
Finetuning: Large loop corrections to μ have to be canceled so that M_H of $\mathcal{O}(100)$GeV.

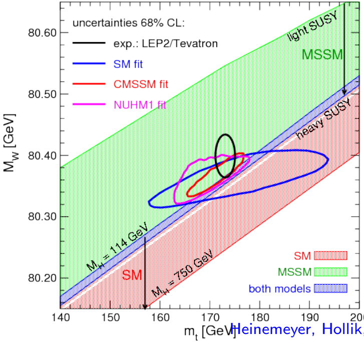




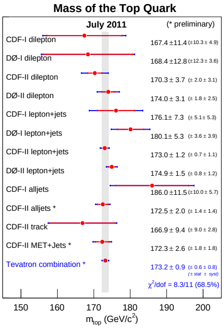
Kolda, Murayma, hep-ph/000316; Ellis, Espinosa, Giudice, Hoecker, arXiv:0906.0954

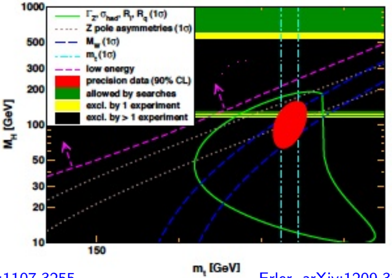
Improved consistency checks and sensitivity to BSM physics





Heinemeyer, Hollik, Stockinger, Weiglein, Zeune





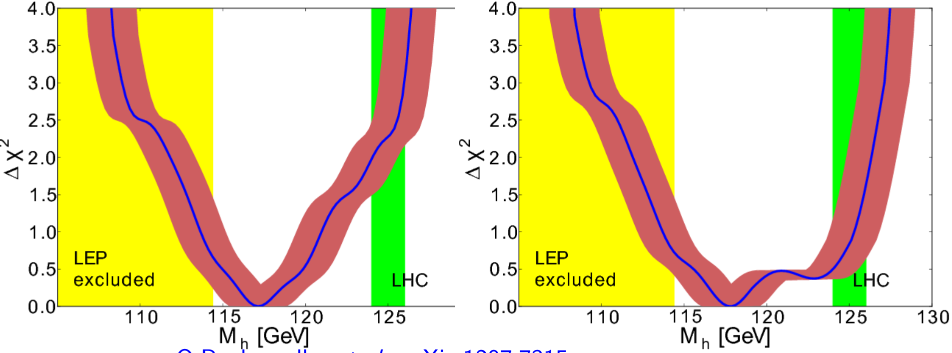
TEVEWWG, arXiv:1107.3255

Erler, arXiv:1209.3324

Example: Gobal fits in CMSSM and NUHM1

CMSSM: universal A_0, $m_{1/2}$, m_0 at GUT scale; NUHM1: soft SUSY break. contrib. to Higgs masses non-univer. but equal

Fit including LEP, $pp/p\bar{p}$, XENON obs. and B_s:



O.Buchmueller *et al.*, arXiv:1207.7315

Beyond Supersymmetry: impact of Z' in global fits; S, T, U parameters

Discussion

Lesson from the first phase of the LHC: again the SM has proven to be very robust!

How can EW physics help to make a 'dent' ?

- What is the potential of global fits to constrain BSM models depending on improvements in experimental and theorectial accuracy of SM observables that go into these fits ?
- Can these fits provide information complementary to direct searches, if no signal (or if a signal) of BSM physics is found at the LHC ?
- What is needed to predict the SM Higgs mass from global fits at *xy*% precision, e.g., 8% provided $\delta M_W = 3$ MeV, $\delta \sin^2\theta_{eff} = 1.7 \cdot 10^{-5}$?
- ... your question