The SFitter Project

7th Workshop of the TeV Physics working Group
In honor of Professor Yu-Ping Kuang
Beijing, China
Nov 14, 2012
Dirk Zerwas
LAL Orsay

- Introduction
- Determination of Higgs Couplings
- Determination of Supersymmetric Parameters
- Conclusions

Science publique

par Michel Alberganti

Le site de l'émission

le vendredi de 14h à 15h

Une formule mathématique universelle existe-t-elle ? 7

09.11.2012 - 14:00

57 minutes

Science publique

par Michel Alberganti

Le site de l'émission

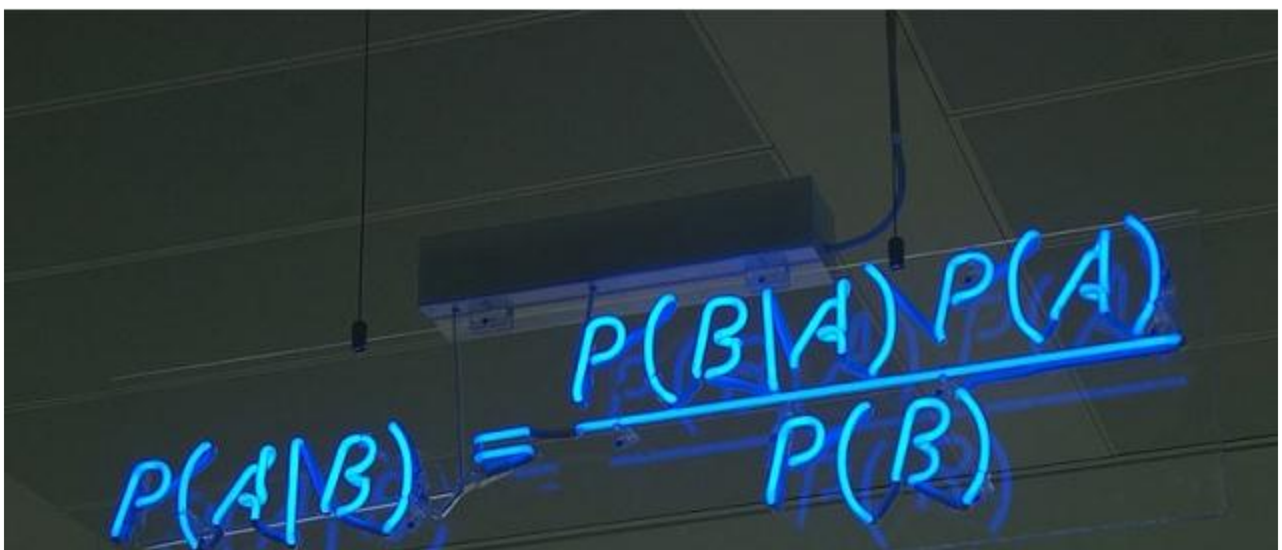
le vendredi de 14h à 15h

Une formule mathématique universelle existe-t-elle ?

7

09.11.2012 - 14:00

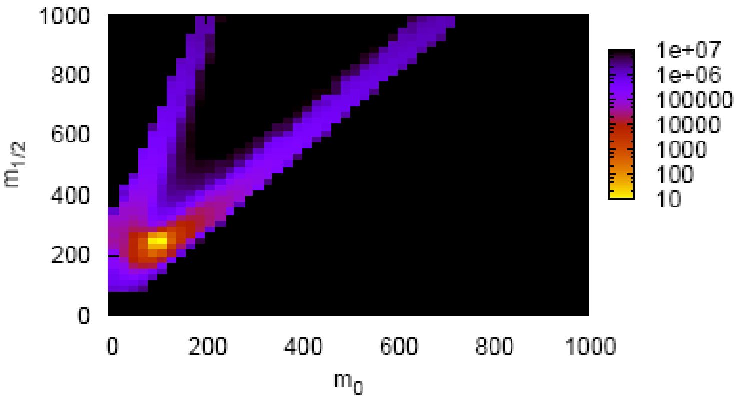
57 minutes



Introduction

SFitter origin: determine supersymmetric parameters
No one-to-one correlation of parameters to observables
correlations exp and theoretical errors
treatment of theory errors!
→ global ansatz necessary

Lafaye, Plehn, Rauch, Zerwas
started in the GDR Terascale (open network of exp and theo,
Charling Tao is a founding member)



SFitter, arXiv:hep-ph/0404282.
SFitter, Eur. Phys. J. C54, 617 (2008)
E. Turlay and SFitter, J.Phys. G38 (2011) 035003
C. Adam, J.-L Kneur and SFitter, Eur.Phys.J. C71 (2011) 1520

Search for parameter point, determine errors including treatment of error correlations:
Apply techniques developed for SUSY to the Higgs sector

Duhrssen and SFitter JHEP0908 (2009) 009, arXiv:0904.3866 [hep-ph]
Klute and SFitter, Phys.Rev.Lett. 109 (2012) 101801
Englert, P. Zerwas and SFitter Phys.Lett. B707 (2012) 512-516
Bock, P. Zerwas and SFitter Phys.Lett. B694 (2010) 44-53

many other groups: Contino, Falkowski, Espinosa, Ellis

The Higgs couplings

Several measurements possible
Future integrated luminosity 30fb-1 @14TeV

essential: HDecay, cross section calculations (Spira…)

JHEP0908 (2009) 009, arXiv:0904.3866 [hep-ph]

production	decay	$S+B$	B	S	$\Delta S^{(\mathrm{exp})}$	$\Delta S^{(\mathrm{theo})}$
$gg \to H$	ZZ	13.4	6.6 (× 5)	6.8	3.9	0.8
qqH	ZZ	1.0	0.2 (× 5)	0.8	1.0	0.1
$gg \to H$	WW	1019.5	882.8 (× 1)	136.7	63.4	18.2
qqH	WW	59.4	37.5 (× 1)	21.9	10.2	1.7
$t\bar{t}H$	$WW(3\ell)$	23.9	21.2 (× 1)	2.7	6.8	0.4
$t\bar{t}H$	$WW(2\ell)$	24.0	19.6 (× 1)	4.4	6.7	0.6
inclusive	$\gamma\gamma$	12205.0	11820.0 (× 10)	385.0	164.9	44.5
qqH	$\gamma\gamma$	38.7	26.7 (× 10)	12.0	6.5	0.9
$t\bar{t}H$	$\gamma\gamma$	2.1	0.4 (× 10)	1.7	1.5	0.2
WH	$\gamma\gamma$	2.4	0.4 (× 10)	2.0	1.6	0.1
ZH	$\gamma\gamma$	1.1	0.7 (× 10)	0.4	1.1	0.1
qqH	$\tau\tau(2\ell)$	26.3	10.2 (× 2)	16.1	5.8	1.2
qqH	$\tau\tau(1\ell)$	29.6	11.6 (× 2)	18.0	6.6	1.3
$t\bar{t}H$	$b\bar{b}$	244.5	219.0 (× 1)	25.5	31.2	3.6
WH/ZH	$b\bar{b}$	228.6	180.0 (× 1)	48.6	20.7	4.0

BgExtrapolFactor

Duehrssen et al.: Phys.Rev.D70:113009,2004.
hep-ph/0406323

ttH→bb: 50% signal reduction wrt PRD

Hbb: J. M. Butterworth, A. R. Davison , M. Rubin, G. P. Salam Phys.Rev.Lett.100:242001,2008. (4.2σ)

Measurement of luminosity	5 %
Detector efficiency	2 %
Lepton reconstruction efficiency	2 %
Photon reconstruction efficiency	2 %
WBF tag-jets / jet-veto efficiency	5 %
b-tagging efficiency	3 %
τ-tagging efficiency (hadronic decay)	3 %
Lepton isolation efficiency (decay $H \to ZZ \to 4l$)	3 %

Gluon fusion 37pb, WBF 4.5pb, ttH 450fb, Z/WH 2.2pb
Low (absolute) signal in many final states.

σ (gluon fusion)	13 %
σ (weak boson fusion)	7 %
σ (VH-associated)	7 %
σ ($t\bar{t}$-associated)	13 %

BR($H \to ZZ$)	1 %
BR($H \to WW$)	1 %
BR($H \to \tau\bar{\tau}$)	1 %
BR($H \to c\bar{c}$)	4 %
BR($H \to b\bar{b}$)	4 %
BR($H \to \gamma\gamma$)	1 %
BR($H \to Z\gamma$)	1 %
BR($H \to gg$)	2 %

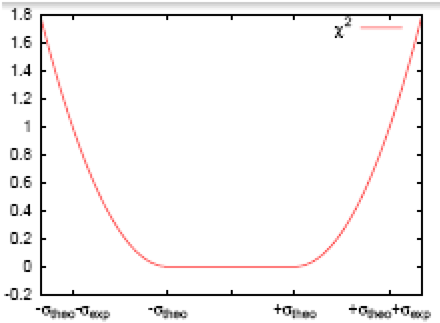
- **statistical errors**
- **systematic errors**
- **correlations**
- **theory errors (or accuracy)**

7+8TeV: ATLAS, CMS Ren-Yuan Zhu and Xin Chen

The Higgs sector: errors and parameter definition

RFit Scheme: Höcker, Lacker, Laplace, Lediberder

$$\chi^2 = \sum_{\text{measurements}} \begin{cases} 0 & \text{for } |x_{\text{data}} - x_{\text{pred}}| < \sigma_{\text{theo}} \\ \left(\frac{|x_{\text{data}} - x_{\text{pred}}| - \sigma_{\text{theo}}}{\sigma_{\text{exp}}}\right)^2 & \text{for } |x_{\text{data}} - x_{\text{pred}}| \geq \sigma_{\text{theo}} \end{cases}$$



- No information within theory errors: flat distribution
- intuitively reasonable
- central value!
- not necessarily "conservative"

Definition: ΔX deviation of XXH coupling from SM value:

$g_{XXH} = g_X \rightarrow g_X^{SM} (1+\Delta X)$

Loop induced coupling:

$g_{XXH} = g_X \rightarrow g_X^{SM} (1+\Delta X^{SM}+\Delta X)$

As observables are in g_j^2 : expected ambiguity for -2 and 0!

Overall phase choice: HWW positive
two sets of models:

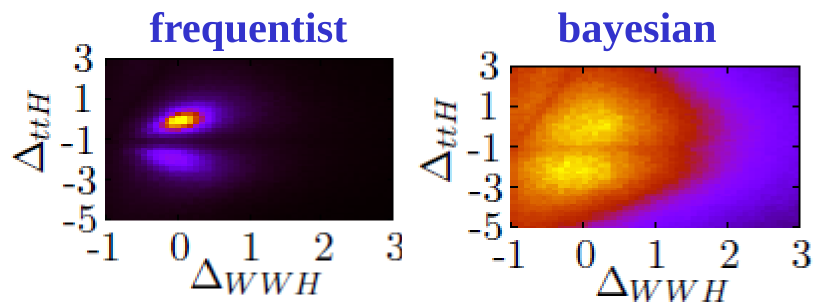
- without anomalous effective couplings
- with anomalous effective couplings
- both cases: Higgs boson mass measurement

Essential: decay and cross section calculation

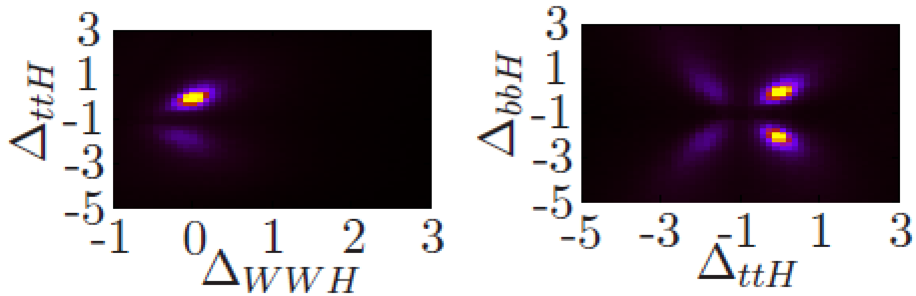
First step: likelihood map and projections to study correlations.

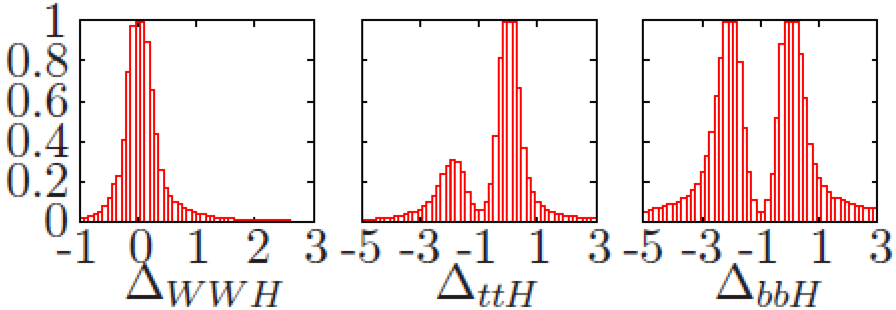
The Higgs sector: likelihood maps

- model: mH, ΔW, ΔZ, Δt, Δb, Δτ
- ΔW>-1 (unobservable global sign)
- general positive correlation among couplings due to total width ≈ bbH
- frequentist approach better adapted (no real secondary minima)
- thanks to γγ correct sign chosen for ttH



- increasing stat to 300fb-1 confirms picture
- same correlation in bbH with ttH

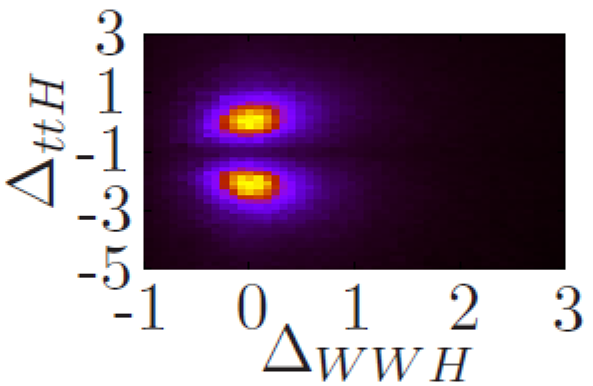


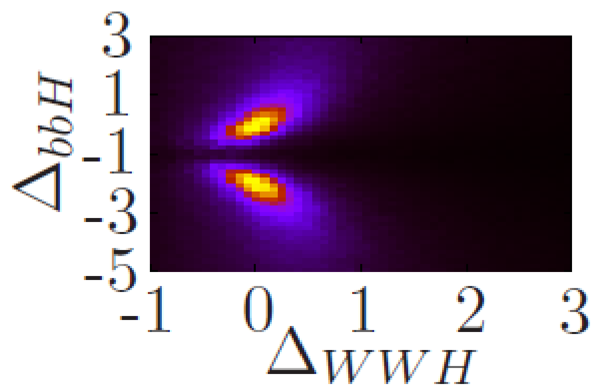


- complete projection for 30fb-1
- width give a first idea of error
- important: no-flat top in parameters, i.e., dominated by experimental errors

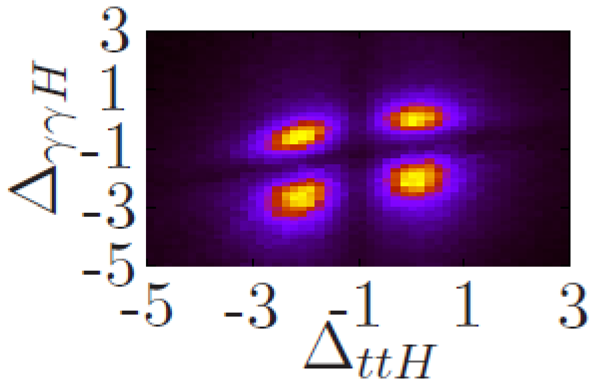
Impact of effective couplings

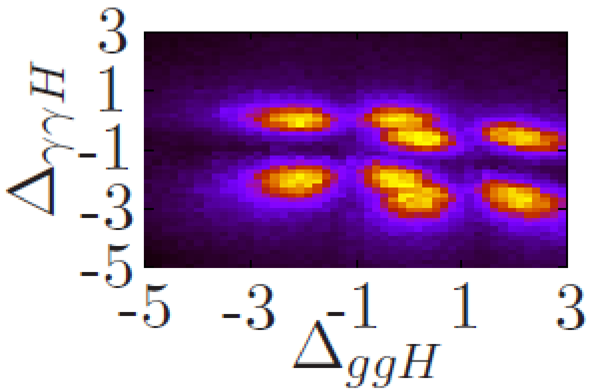
- model: mH, ΔW, ΔZ, Δt, Δb, Δτ, Δg, Δγ
- general positive correlation among non-bbH couplings due to total width ≈ bbH
- additional freedom prevents γγ correct sign choice
- some loss in sensitivity to Δt (contribution measured via Δg)





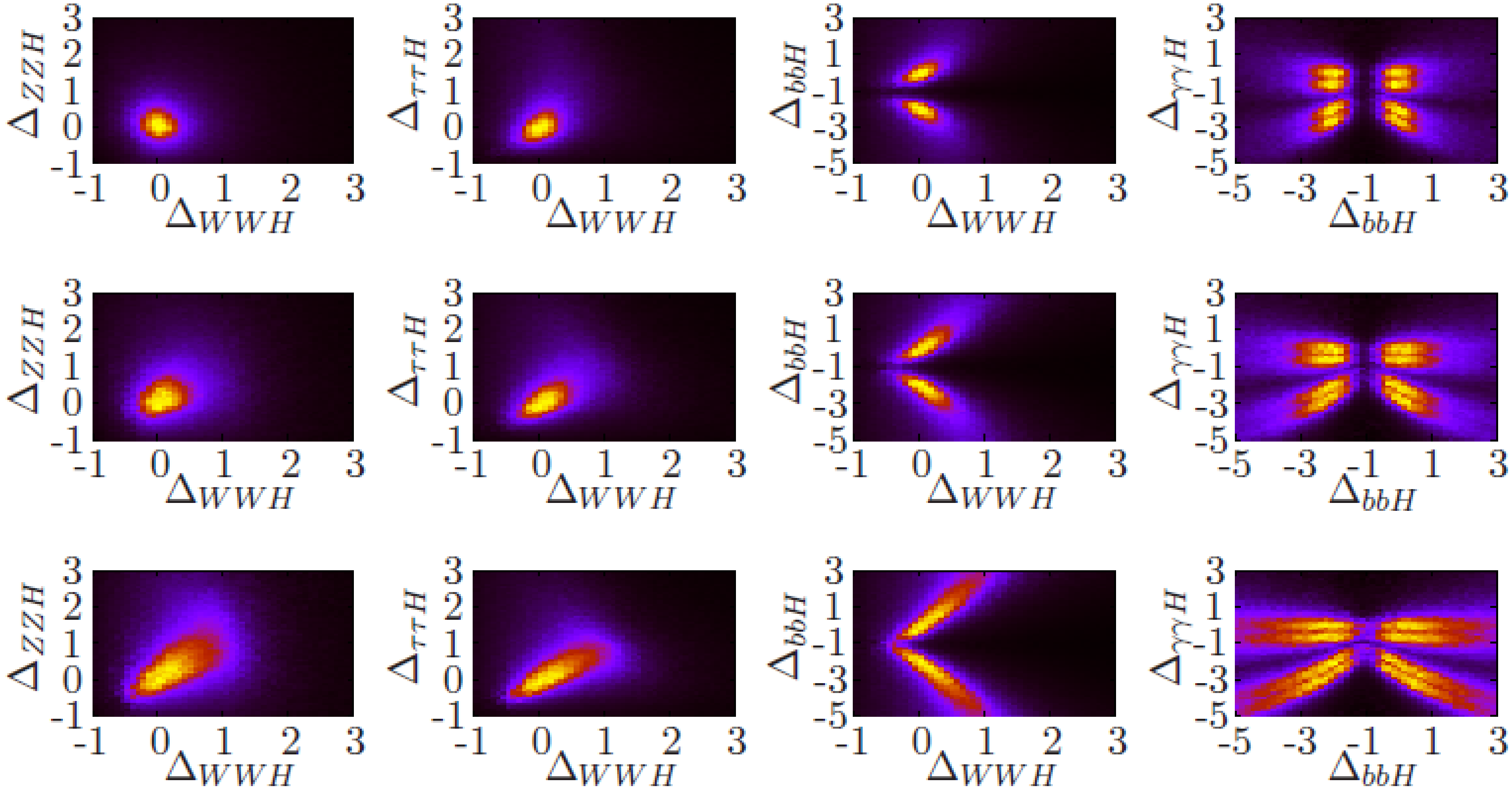
- complicated structure for ggH versus γγH





Δt=+ Δg=-2, Δt=+ Δg=0, Δt=- comp with Δg=2

Impact of subjet analysis

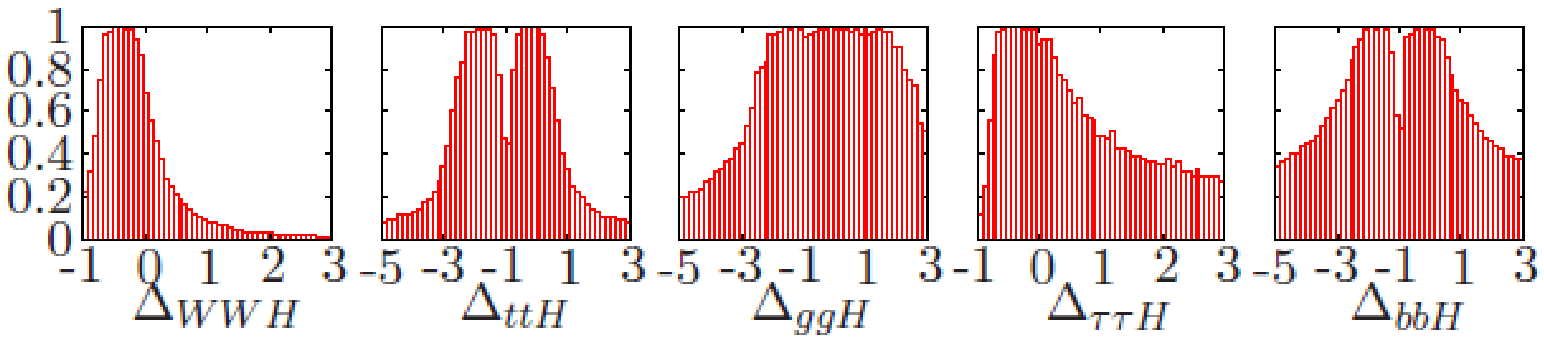


- top: nominal sensitivity
- middle: 50% sensitivity
- bottom: subjet analysis removed

- jury is still out on subjet with DATA, but boosted tops, gluinos RPV give hope….

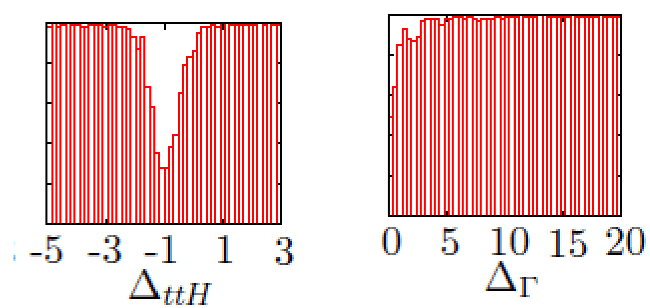
Impact of an unobserved Higgs Coupling

- **new scenario: ccH significantly increased**
- **impact on production side: small**
- **impact decay side: $*\Gamma_{SM}/\Gamma_{NP}$ reduces all observables**



- **all couplings shifted from 0 (=SM expectation)**
- **add additional parameter: contribution to total width:**

Measurements at LHC:
$\sigma \cdot BR \cdot L \cdot \sim g^2 \cdot g^2/\Gamma$
blind to simultaneous coupling/√width changes:



Assume:

$$\Gamma_{\rm tot} = \sum_{\rm obs} \Gamma_x(g_x) + \text{2nd generation} < 2\,\text{GeV}$$

Coupling Precision Higgs

Higgs portal:

- **add a hidden sector**

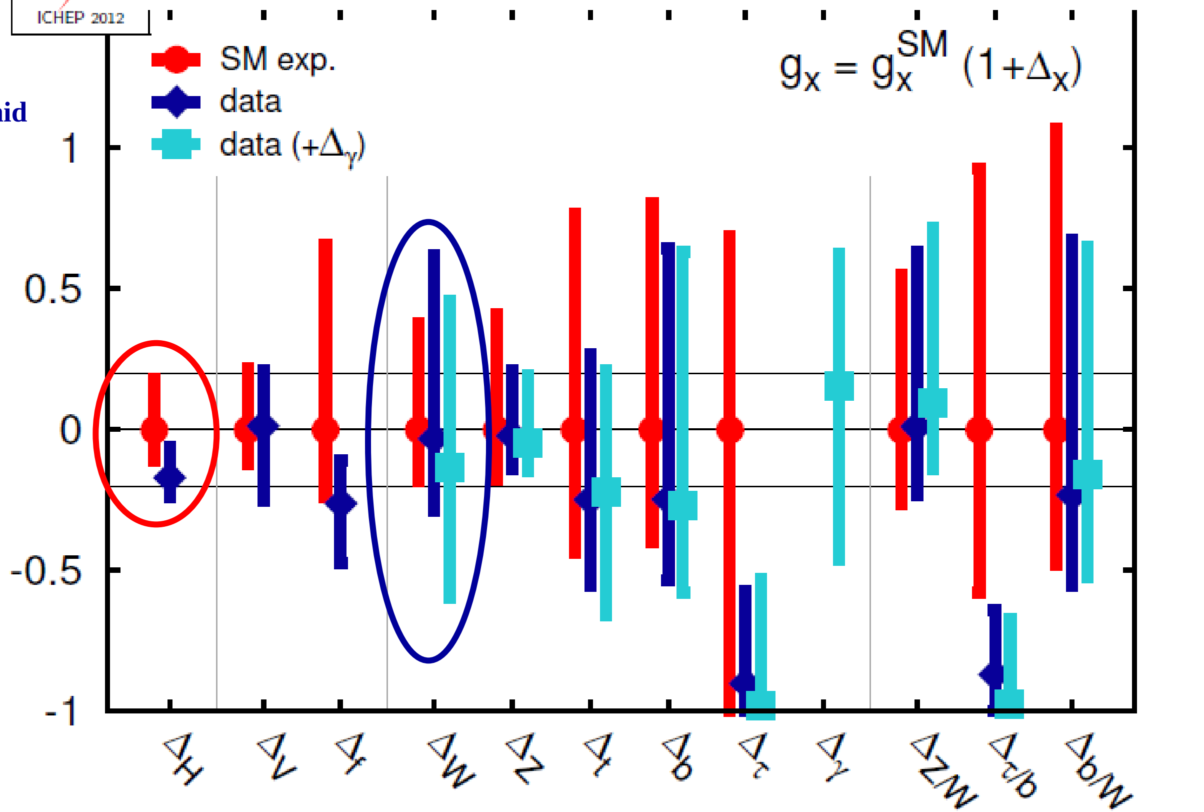
2-parameter model: $\Delta H = \cos\chi$, Γ_{hid}

$$\sigma = \cos^2\chi\,\sigma^{SM}$$
$$\Gamma_{vis} = \cos^2\chi\,\Gamma_{vis}^{SM}$$
$$\Gamma_{inv} = \cos^2\chi\,\Gamma_{inv}^{SM} + \Gamma_{hid}\ .$$

ΔH:

DATA	14TeV 3000fb-1
10%	5%

Tilman Plehn, Michael Rauch. arXiv:1207.6108 [hep-ph], EPL



Several publications by Prof. Kuang on this (anomalous) coupling, albeit with WW scattering

The Higgs sector precision

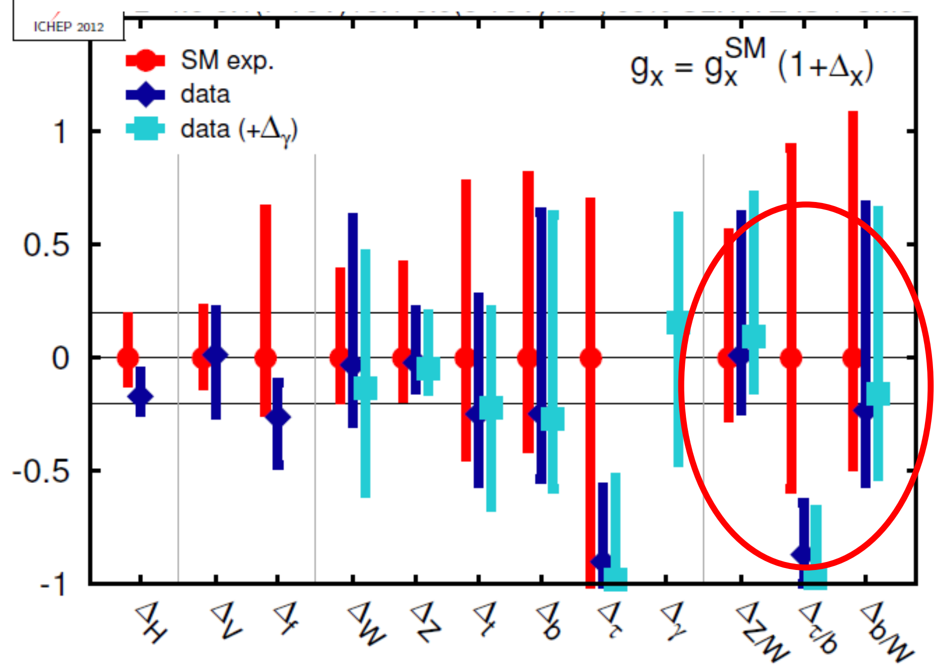
• limitation by theory errors appears
• no effective couplings lead to a slight increase of precision

ΔZ/W Δτ/b Δb/W:
• coupling ratio
• error reduced also for 7TeV:
+correl with Δb

ΔZ Δt Δb Δτ :
• direct coupling
• +correl with Δb

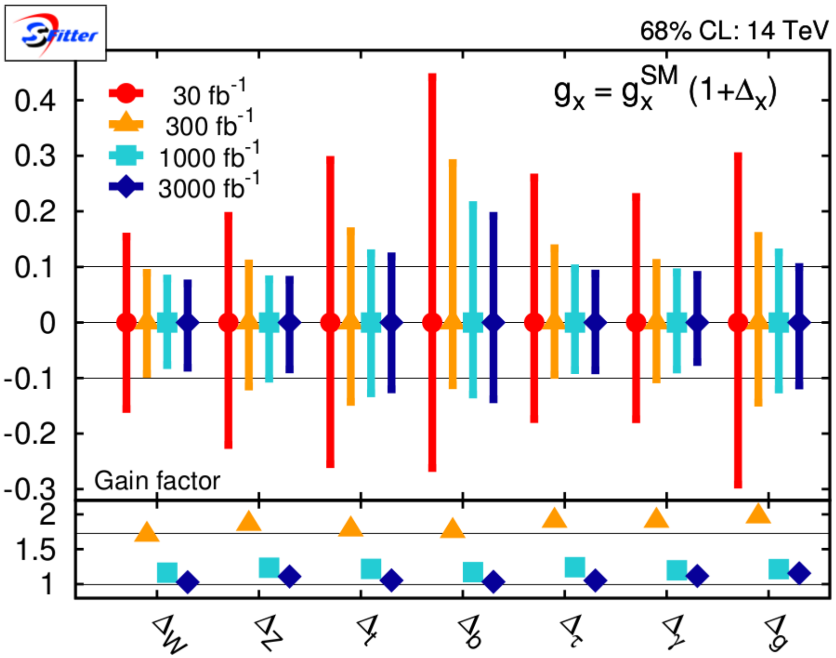
ΔZ Δt Δb Δτ Δγ:
• effective coupling
• additional contribution BSM
• 14TeV only

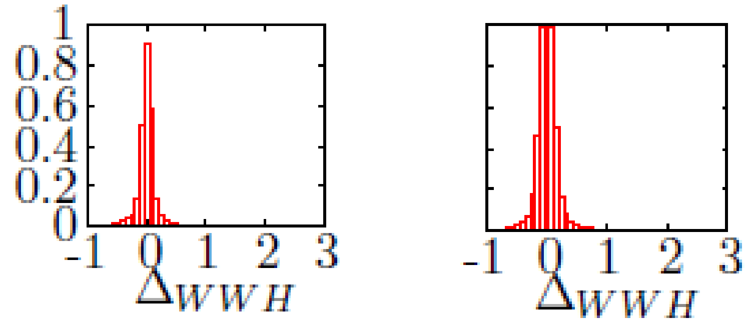
Tilman Plehn, Michael Rauch. arXiv:1207.6108 EPL



7+8TeV no subjet: Δb!
add TeVatron 100% Δb=0.4±0.25
• reduces error on Δb and Δτ
• but not below 14TeV+subjet
Wei-Ming Yao

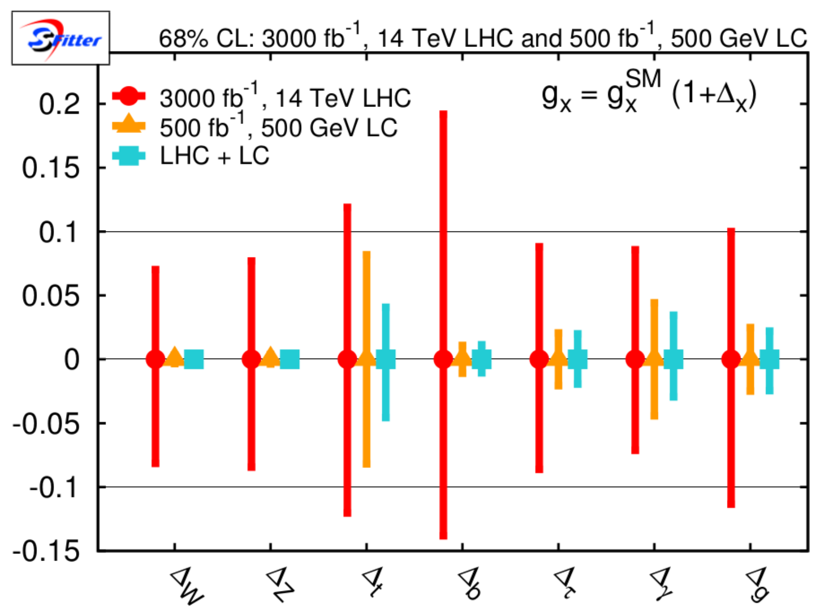
The Higgs sector precision





3000fb^{-1}:

- **extrapolate blindly**
- **full set including effective couplings**
- **flat top starting at order 100fb-1**
- **all errors on couplings <20%**
- **best order 10%**
- **gain factor less than sqrt(3), na ïve sqrt(L) scaling**



LHC+ILC combined analysis:

- **ILC (Jie Gao) only Gauss errors (Asian Study Group)**
- **clear improvement on Δt**
- **some improvement on D5 couplings $\Delta\gamma$, Δg**
- **LHC⊕ILC better than each machine alone**

Prof. Kuang is co-author of the ILC TDRs

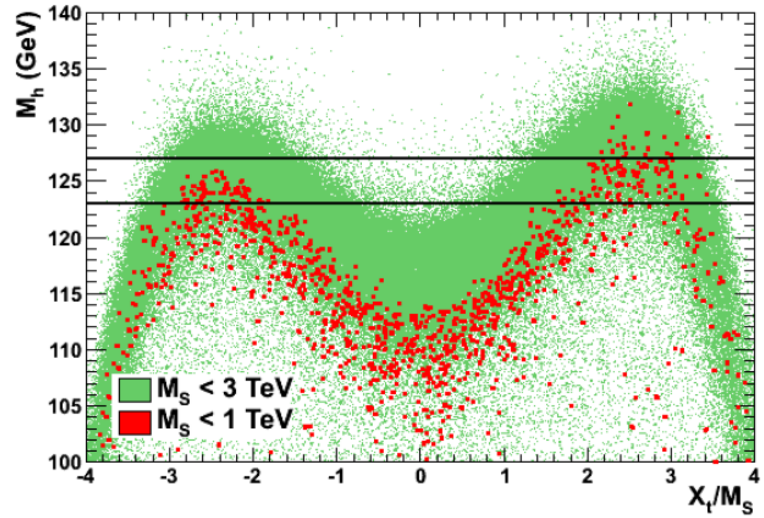
Higgs 125GeV and Supersymmetry

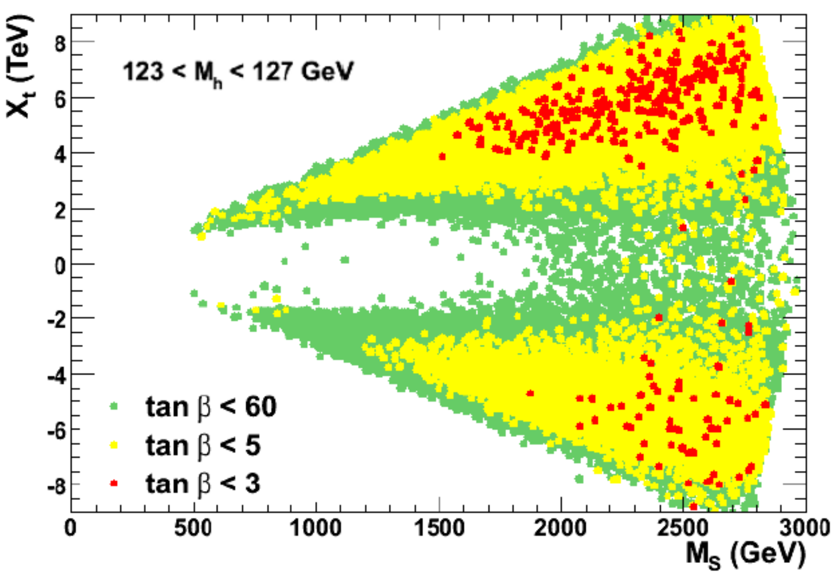
A. Djouadi et al.

$$M_h \xrightarrow{M_A \gg M_Z} M_Z|\cos 2\beta| + \frac{3\bar{m}_t^4}{2\pi^2 v^2 \sin^2\beta}\left[\log\frac{M_S^2}{\bar{m}_t^2} + \frac{X_t^2}{2M_S^2}\left(1-\frac{X_t^2}{6M_S^2}\right)\right]$$

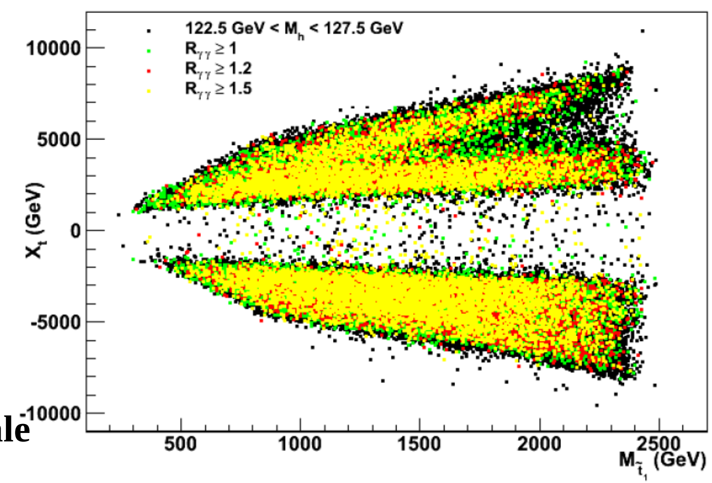
- **need to maximize the radiative corrections to increase Higgs boson mass**
- **electroweak scale (3TeV: maximal mixing)**
- **mixing parameter**

$$M_S = \sqrt{m_{\tilde{t}_1} m_{\tilde{t}_2}} \qquad X_t = \sqrt{6} M_S$$





Large mixing, but no constraint on the stop mass:



Lindner (et al): 125GeV good for Standard Model up to GUT scale

Measure Supersymmetry

SFitter: Lafaye, Plehn, Rauch, D.Z. and friends
arXiv:1007.2190
arXiv:0709.3985

	LHC	SLHC
χ_1^0	97.1±4.1	97.1±1.3
χ_2^0	180.3±4.0	180.3±1.3
χ_4^0	375.0±4.6	374.9±1.5
$\tilde{e}_R/\tilde{\mu}_R$	142.6±4.1	142.5±1.3
$\tilde{e}_L/\tilde{\mu}_L$	199.5±4.7	199.4±1.5
$\tilde{\tau}_1$	137.7±8.9	133.8±5.5
$\tilde{g}$	607.2±7.6	606.4±5.7
$\tilde{q}_L$	562.3±8.2	561.6±4.9
$\tilde{q}_R$	543.1±11.8	542.7±5.2
$\tilde{b}_1$	518.2±7.1	517.6±4.8
$\tilde{b}_2$	544.3±7.6	543.6±5.1

LHC:
- 5% level mass measurement

HL-LHC:
- improve to 1%

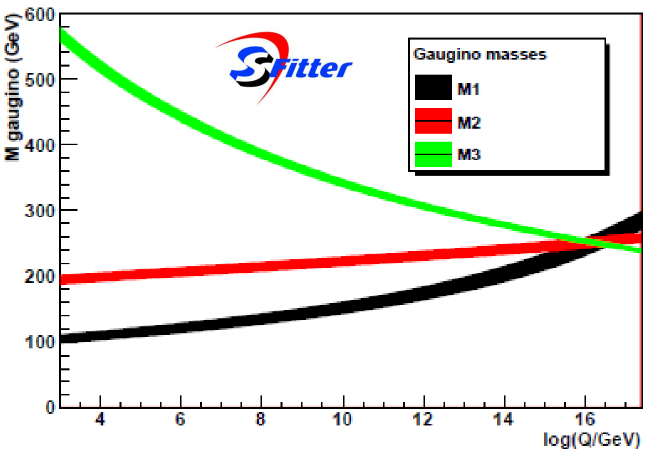
ILC:
- electroweak sector measurements
- precision 0.1%

solution	M_1	M_2	μ	$m_{\chi^0_{\text{pred}}}$
DS1	97.66	187.35	-358.43	367.7
DS2	182.44	98.54	-361.64	371.8
DS3	102.35	354.88	-184.61	195.5
DS4	368.7	120.16	-165.49	197.0
DS5	168.0	357.44	-115.27	127.3
DS6	369.45	144.05	-77.94	55.2
DS7	100.41	196.68	349.34	355.6
DS8	184.73	106.47	354.69	361.5
DS9	109.26	350.25	185.84	193.2
DS10	367.13	140.59	170.86	215.9
DS11	163.59	354.52	126.55	134.6
DS12	368.88	136.13	83.44	46.7

LHC:
- 12fold ambiguity

ILC:
- solves ambiguities

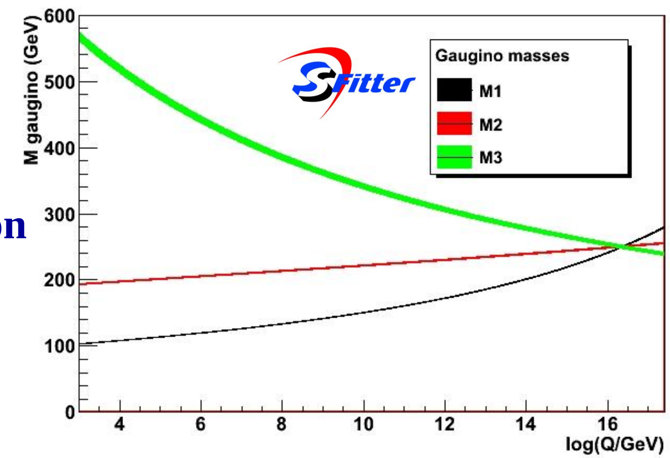
LHC



LHC:
- hint on Parameter unification

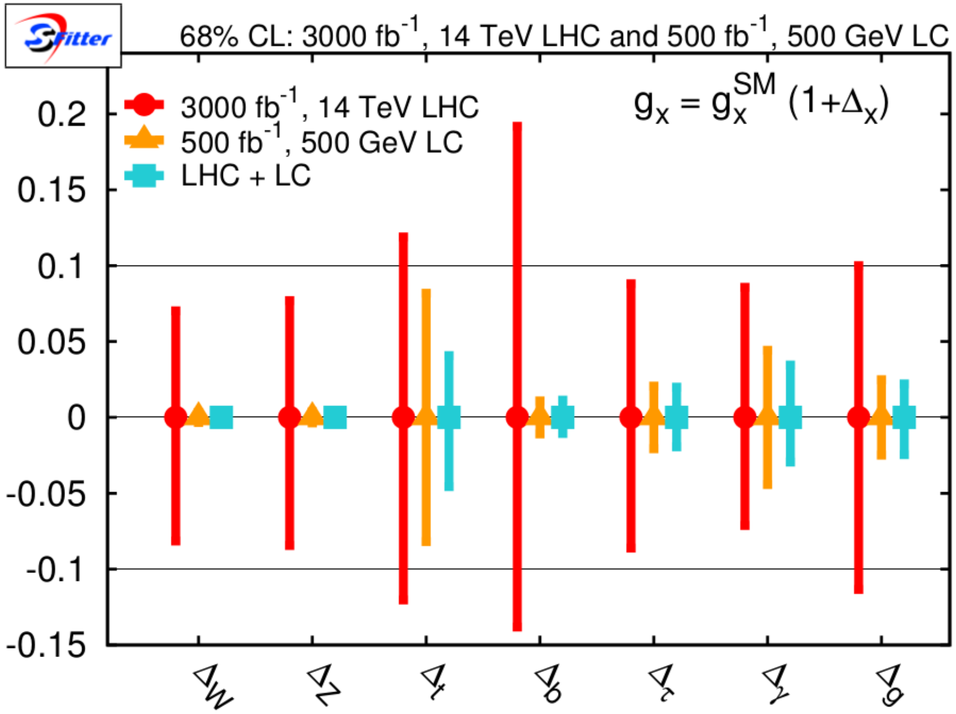
HL-LHC:
- increases precision

HL-LHC + ILC



Conclusions

- LHC already has provided a wealth of measurements for the Higgs boson
- ILC can take the precision to the next level
- LHC+ILC looking promising



Thanks to: Tilman Plehn, Michael Duehrssen, Markus Klute, Remi Lafaye and Michael Rauch

A very big thank you to the organizer for the wonderful workshop