SFitter

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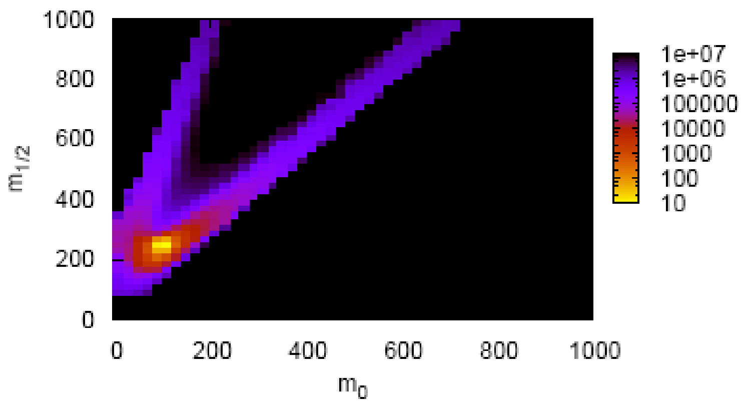
LAL Orsay

- Introduction
- Determination of Higgs Couplings 14TeV
- Conclusions

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



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

The Higgs couplings

Several measurements possible **(many authors, papers on signatures etc)**
Future integrated luminosity 30fb-1 @14TeV

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

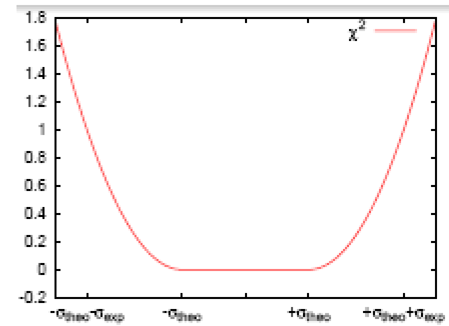
- **statistical errors**
- **systematic errors**
- **correlations**
- **theory errors (or accuracy)**

7+8TeV: Jae Yu on Tuesday

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:

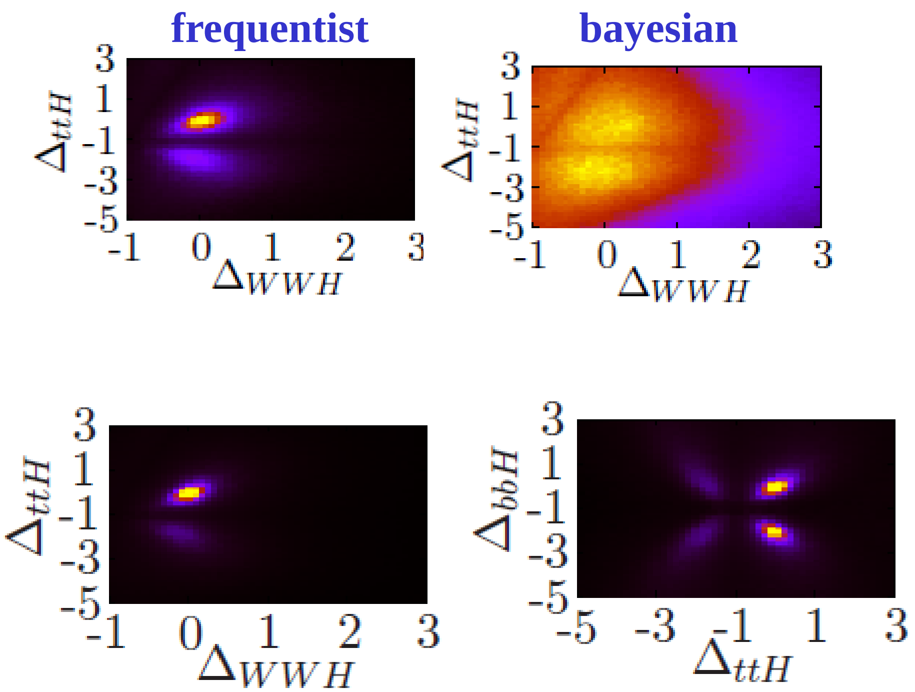
- without anomalous effective couplings
- with anomalous effective couplings
- both cases: Higgs boson mass measurement

Essential: decay and cross section calculation

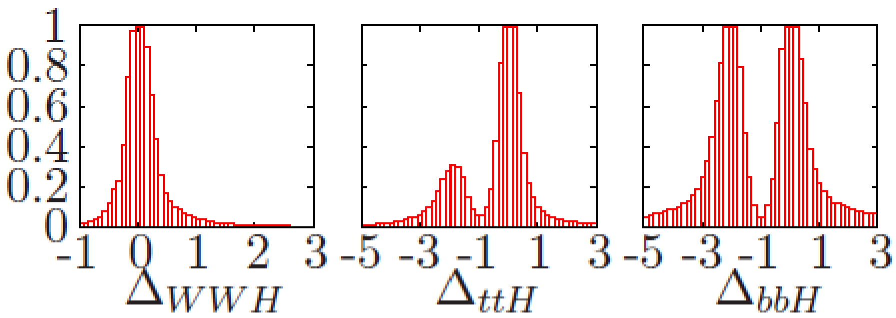
First step: likelihood map and projections to study correlations.

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



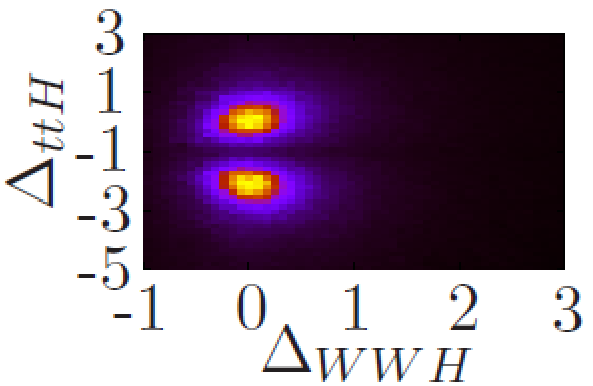
- increasing stat to 300fb-1 confirms picture
- same correlation in bbH with ttH

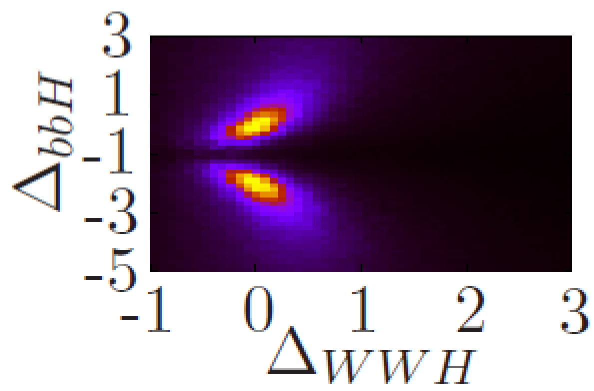


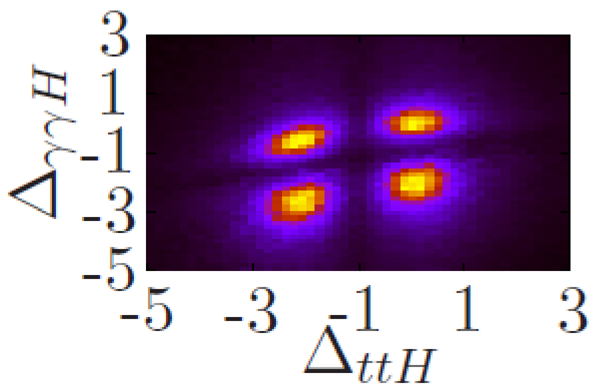
- complete projection for 30fb-1
- width give a first idea of error
- important: no-flat top in parameters, i.e., dominated by experimental errors

Impact of effective couplings

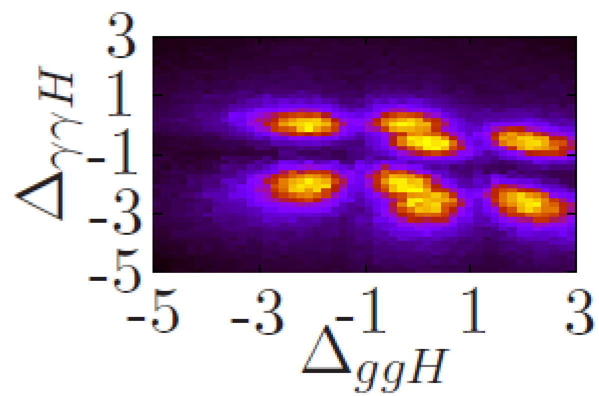
- model: mH, ΔW, ΔZ, Δt, Δb, Δτ, Δg, Δγ
- general positive correlation among non-bbH couplings due to total width ≈ bbH
- additional freedom prevents γγ correct sign choice
- some loss in sensitivity to Δt (contribution measured via Δg)





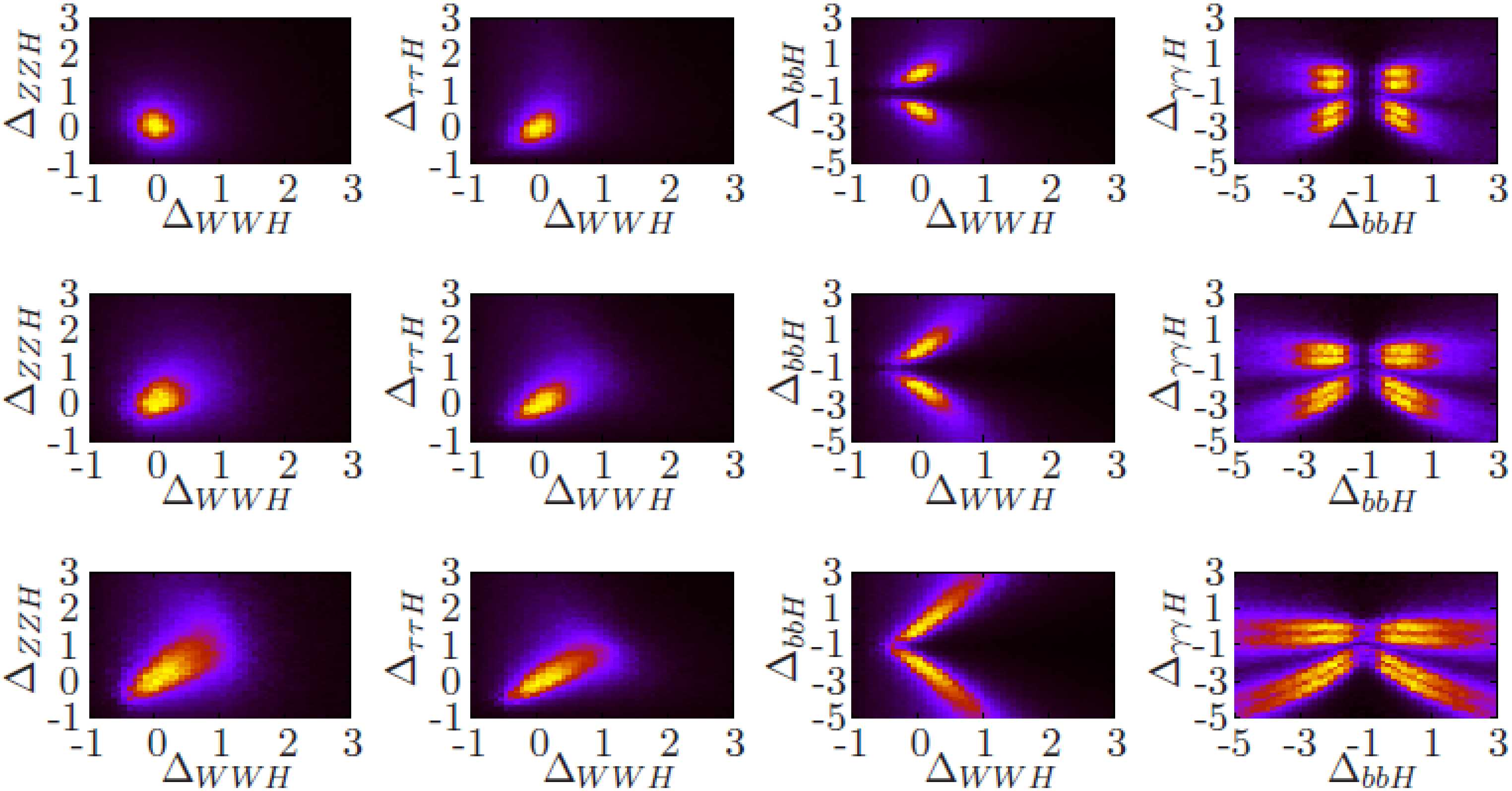


- complicated structure for ggH versus γγH



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

Impact of subjet analysis

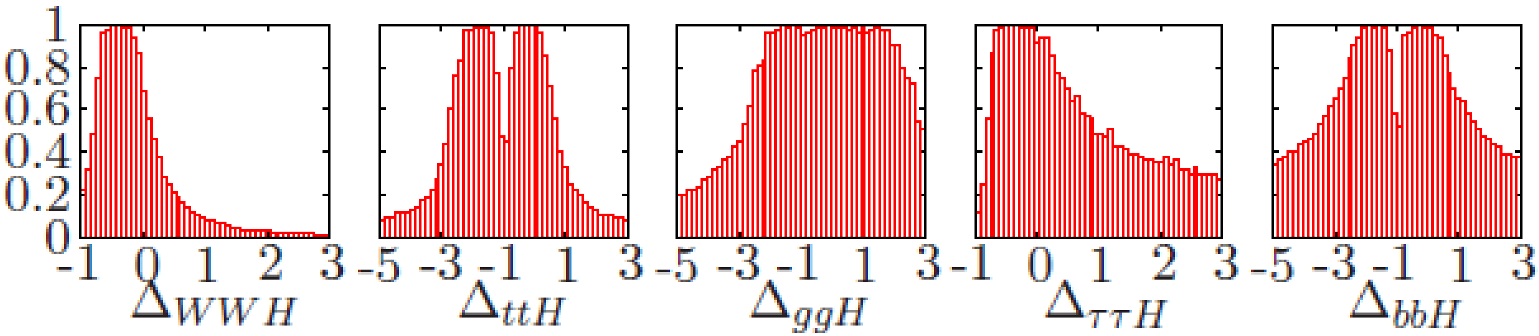


- top: nominal sensitivity
- middle: 50% sensitivity
- bottom: subjet analysis removed

- jury is still out on subjet with DATA!

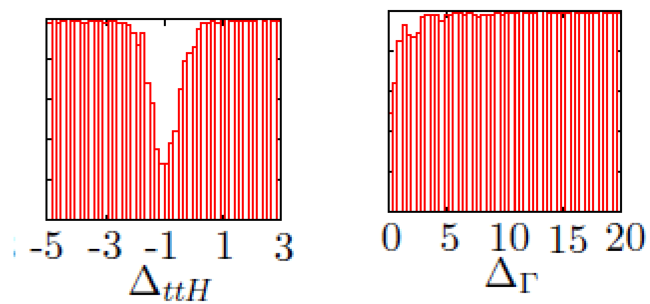
Impact of an unobserved Higgs Coupling

- **new scenario: ccH significantly increased**
- **impact on production side: small**
- **impact decay side: *Γ_{SM}/Γ_{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:

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

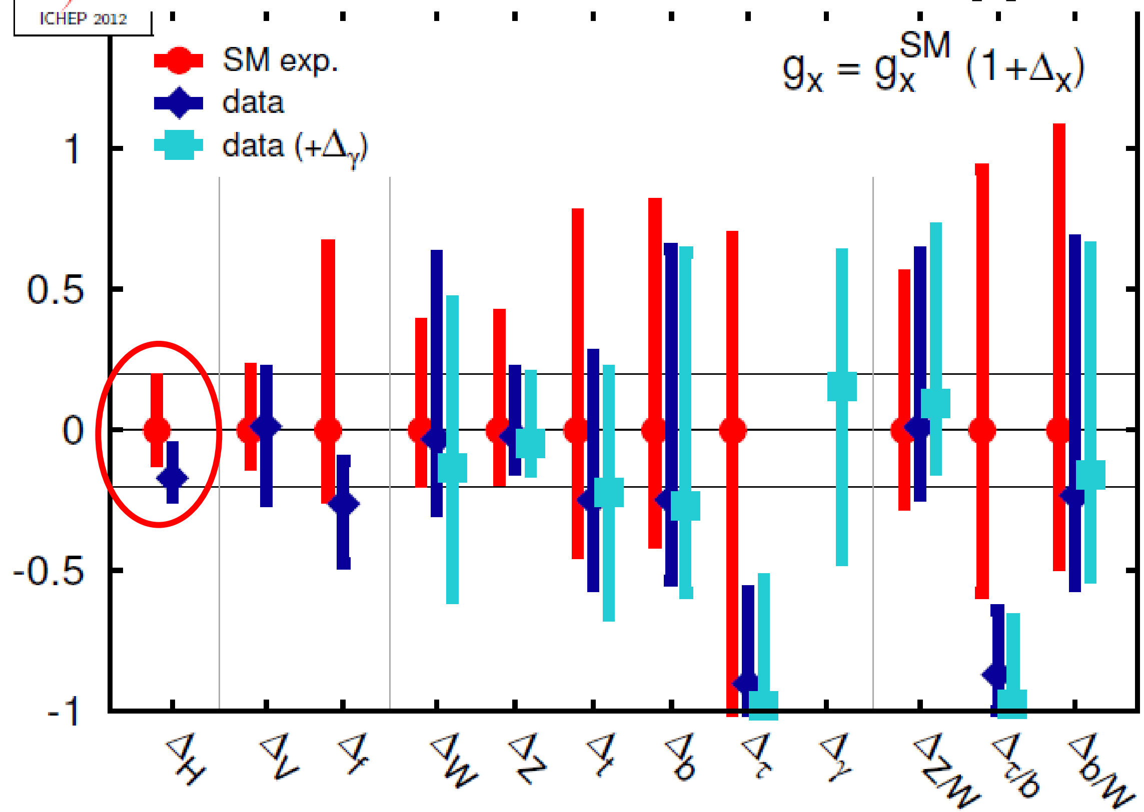
Coupling Precision Higgs

Higgs portal:
- **add a hidden sector**

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

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

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



ΔH:

DATA	14TeV 3000fb-1
10%	5%

The Higgs sector precision

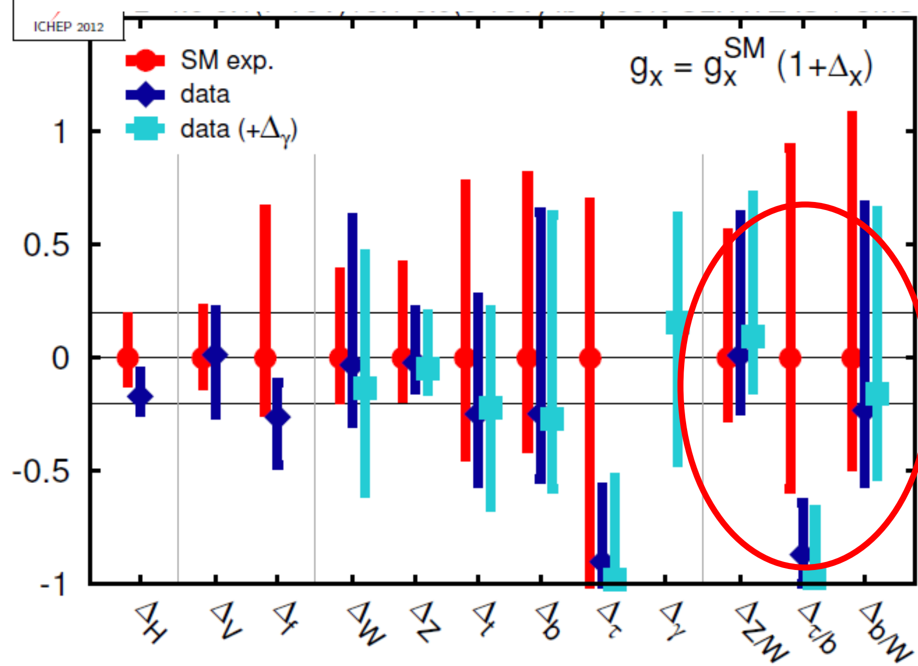
- limitation by theory errors appears
- no effective couplings lead to a slight increase of precision

$\Delta Z/W$ $\Delta\tau/b$ $\Delta b/W$:
- coupling ratio
- error reduced also for 7TeV: +correl with Δb

ΔZ Δt Δb $\Delta\tau$:
- direct coupling
- +correl with Δb

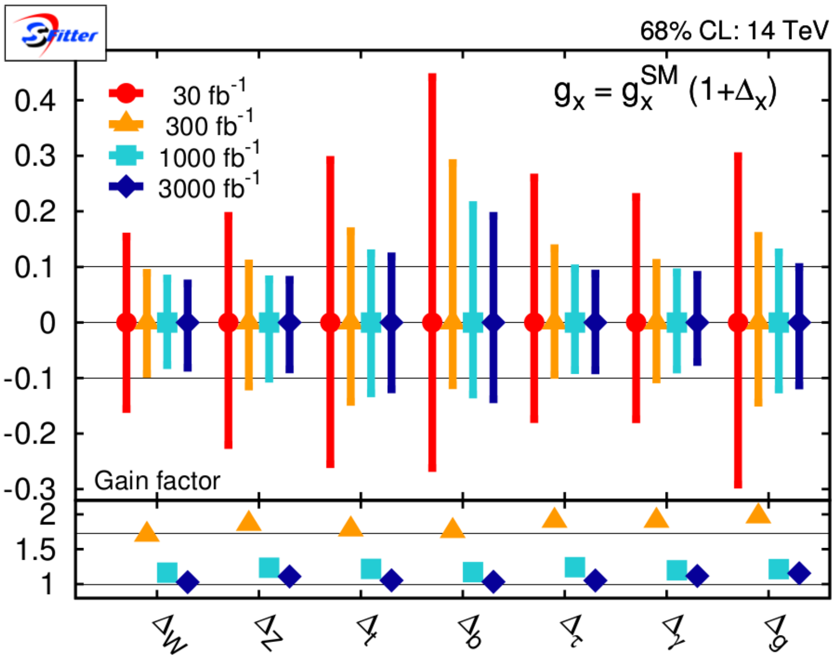
ΔZ Δt Δb $\Delta\tau$ $\Delta\gamma$:
- effective coupling
- additional contribution BSM
- 14TeV only

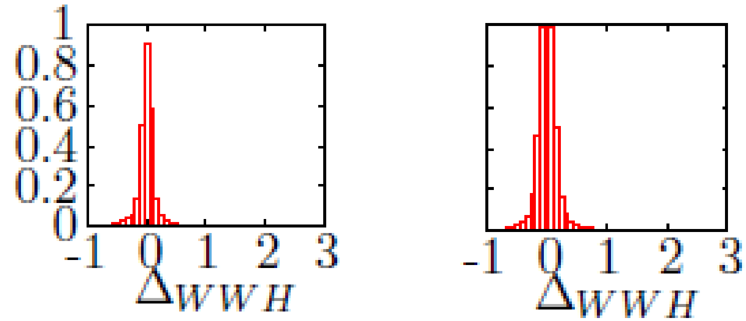
Tilman Plehn, Michael Rauch. arXiv:1207.6108 EPL



7+8TeV no subjet: Δb!
add TeVatron 100% $\Delta b = 0.4 \pm 0.25$
- reduces error on Δb and $\Delta\tau$
- but not below 14TeV+subjet

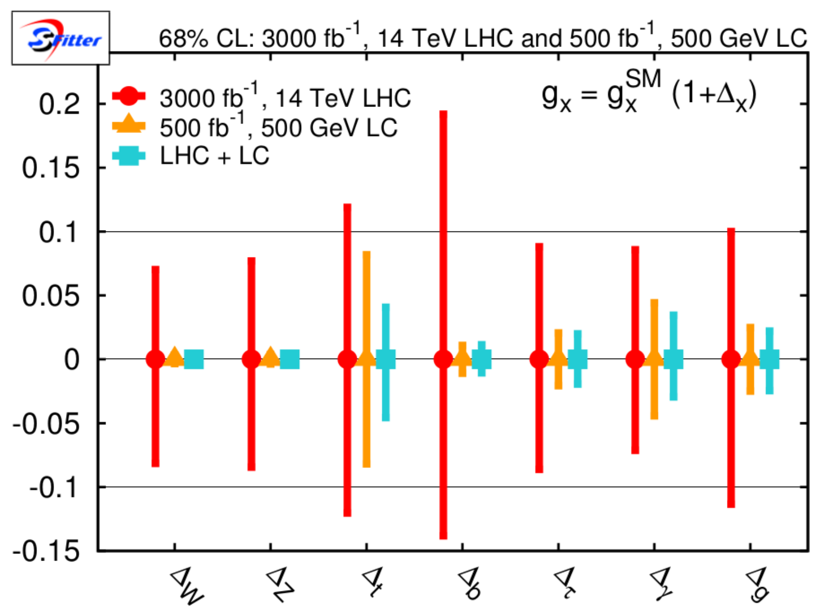
The Higgs sector precision





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), naïve sqrt(L) scaling



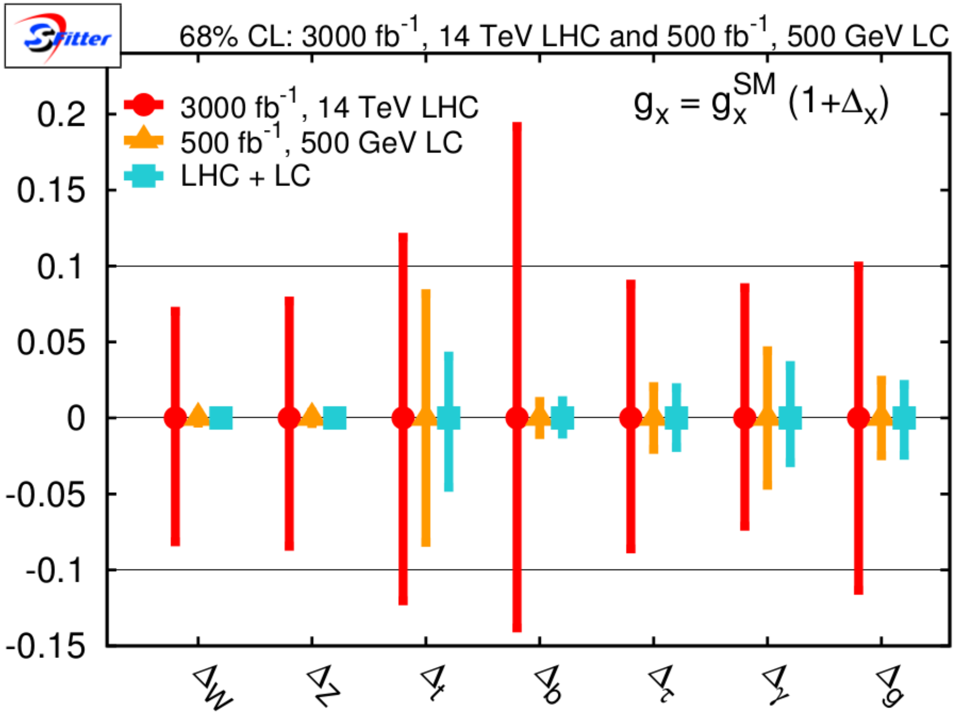
LHC+ILC combined analysis:

- ILC only Gauss errors (Keisuke Fujii/M. Peskin)
- clear improvement on Δt
- some improvement on D5 couplings Δγ, Δg
- LHC⊕ILC better than each machine alone

similar effect to SUSY param determination (closes the circle)

Conclusions

- LHC already has provided a wealth of measurements for the Higgs boson
- portal precision 5%
- typical precision 10-20%
- ILC? See Michael Peskin's talk



Thank you: Tilman Plehn, Michael Duehrssen, Markus Klute, Remi Lafaye and Michael Rauch