# Higgs and SFitter

**LHC2TSP
CERN
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**On behalf of:
SFitter: R.Lafaye, T.Plehn, M.Rauch, D.Zerwas
and Higgs friends: C. Englert, M. Duehrssen, M.Klute,
P.Zerwas**

- **Introduction**
- **7 TeV results**
- **14 TeV results**
- **Conclusions**

LABORATOIRE
DE L'ACCÉLÉRATEUR
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# The Higgs sector: 14TeV

**Gluon fusion and VBF in well defined final states** (many authors and papers)

**Example for $M_H$=120GeV**

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

**ttH→bb: 50% signal reduction**

Hbb: J. M. Butterworth, A. R. Davison , M. Rubin, G. P. Salam Phys.Rev.Lett.100:242001,2008
ATLAS: ATL-PHYS-PUB-2009-088.

| production | decay | $S+B$ | $B$ | $S$ | $\Delta S^{(exp)}$ | $\Delta S^{(theo)}$ |
|---|---|---|---|---|---|---|
| $gg \to H$ | $ZZ$ | 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 |

## Experimental Errors

| | |
|---|---|
| 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 % |
| $\tau$-tagging efficiency (hadronic decay) | 3 % |
| Lepton isolation efficiency (decay $H \to ZZ \to 4l$) | 3 % |

## Theory Errors

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

# The Higgs sector: 7TeV

| ATLAS | WW | 0-jet |
|---|---|---|
| | WW | 1-jet |
| | $\gamma\gamma$ | |
| | $ZZ \to 4\ell$ | |
| CMS | $\gamma\gamma$ | |
| | $\gamma\gamma$ | di-jet |
| | $ZZ \to 4\ell$ | |
| | WW | 0-jet |
| | WW | 1-jet |
| | WW | 2-jet |
| | $\tau\tau$ | 0/1-jet |
| | $\tau\tau$ | Boosted |
| | $\tau\tau$ | VBF |
| | $b\bar{b}$ | WH |
| | $b\bar{b}$ | $Z(\to \ell\bar{\ell})H$ |
| | $b\bar{b}$ | $Z(\to \nu\bar{\nu})H$ |

**Cross checks performed (A.Read's comment):**
• **exclusion**
• **signal strength**

**Correlated measurements and parameters: apply SUSY search techniques for parameter extraction**

**Difficulty: convolution of Gaussian+Poisson+Flat errors**
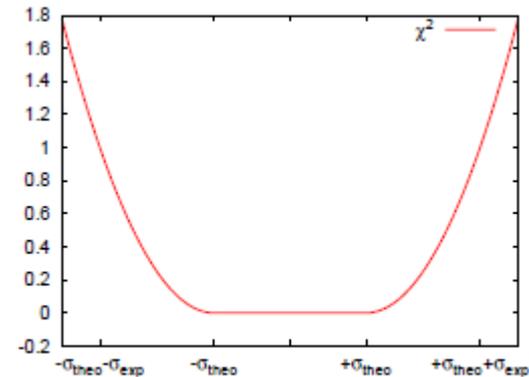
# The coupling definitions

**Definition: ΔX deviation of XXH coupling from SM value:**

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

**Loop induced coupling:**

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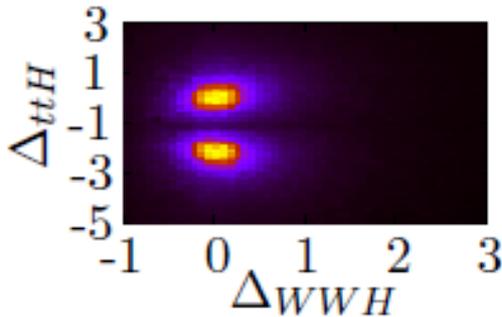


**Add Δg and Δγ: sign preference power of H→γγ disappears**

**Common assumptions:**
- **fermion universality (charm)**
- **no invisible decays**
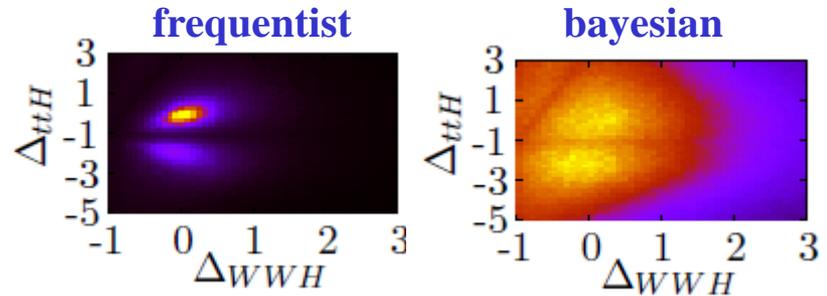


- **general positive correlation among non-Hbb couplings due to total width ≈ Hbb**
- **frequentist approach better adapted (no real secondary minima)**

**Measurements at LHC:**
**σ · BR · L · ~ g² · g²/Γ**
**blind to simultaneous coupling/√width changes:**
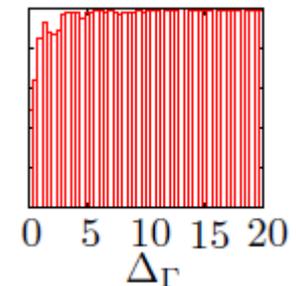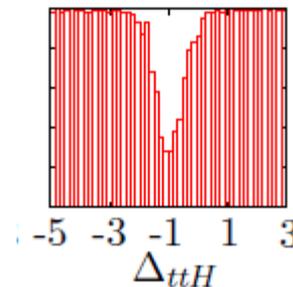
# Hidden sector: 14 TeV

**Patt, Wilczek**

**Higgs portal:**
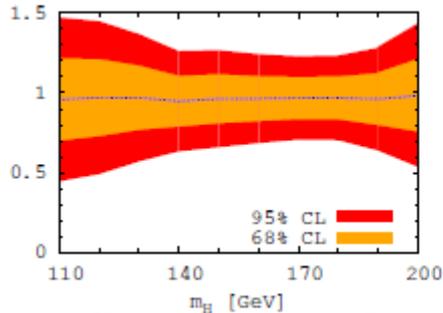- hidden sector
- all widths modified by the same parameter
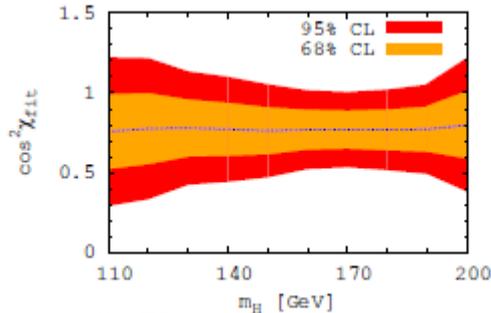- set $\Gamma_{hid}=0$

$$\sigma = \cos^2\chi\, \sigma^{SM}$$

$$\Gamma_{vis} = \cos^2\chi\, \Gamma_{vis}^{SM}$$

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

$\cos^2\chi = 1$ $\qquad$ $\cos^2\chi = 0.8$ $\qquad$ $\cos^2\chi = 0.6$



**Typical precision:
10-20%
better than cpls**
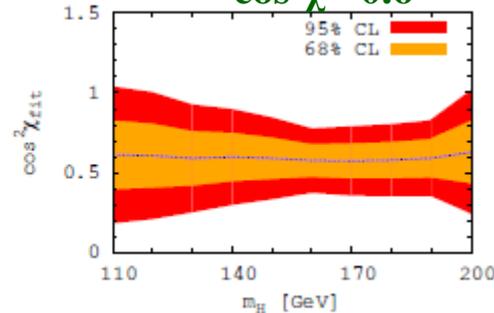
well reconstructed (step=10GeV)

**Non-discovery of Higgs (<140GeV) does not mean non-existence (Englert et al, Phys.Lett. B703 (2011) 298-305 ):**

| | # observable Higgs bosons | |
|---|---|---|
| $\sin^2\chi \lesssim 0.2$ | 1 | SM-type Higgs $H_1$ $(\sigma_{H_1} \geq 3,\ \sigma_{H_2} \leq 1)$ |
| $0.3 \lesssim \sin^2\chi \lesssim 0.4$ | 0 | neither SM-type nor hidden-type Higgs $H_1, H_2$ $(\sigma_{H_1,H_2} < 3)$ |
| $0.4 \lesssim \sin^2\chi \lesssim 0.6$ | 2 | SM + hidden-type Higgs $H_1, H_2$ $(\sigma_{H_1,H_2} \geq 3)$ |
| $\sin^2\chi \gtrsim 0.6$ | 1 | hidden-type Higgs $H_2$ $(\sigma_{H_1} \leq 1,\ \sigma_{H_2} \geq 3)$ |

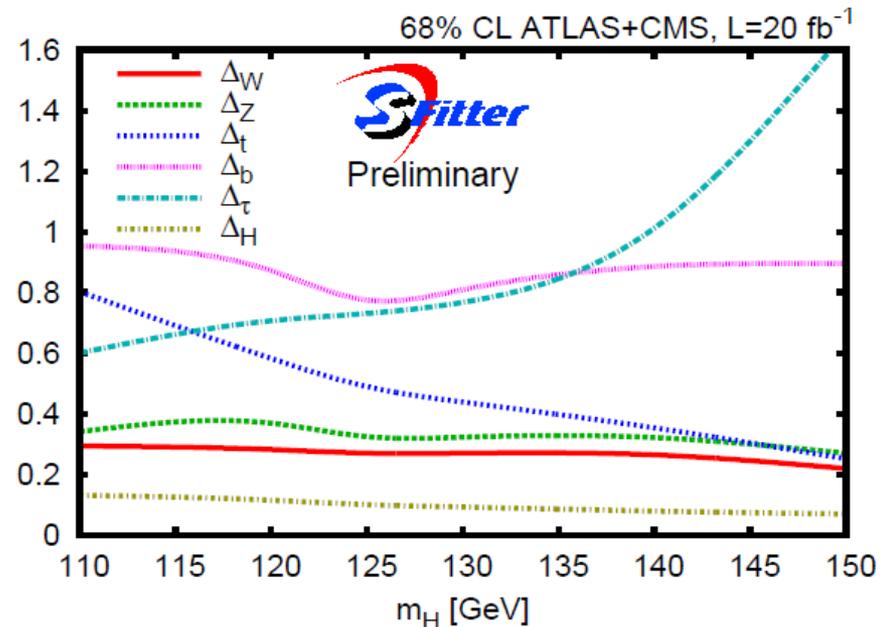# The Higgs sector precision: 7 TeV
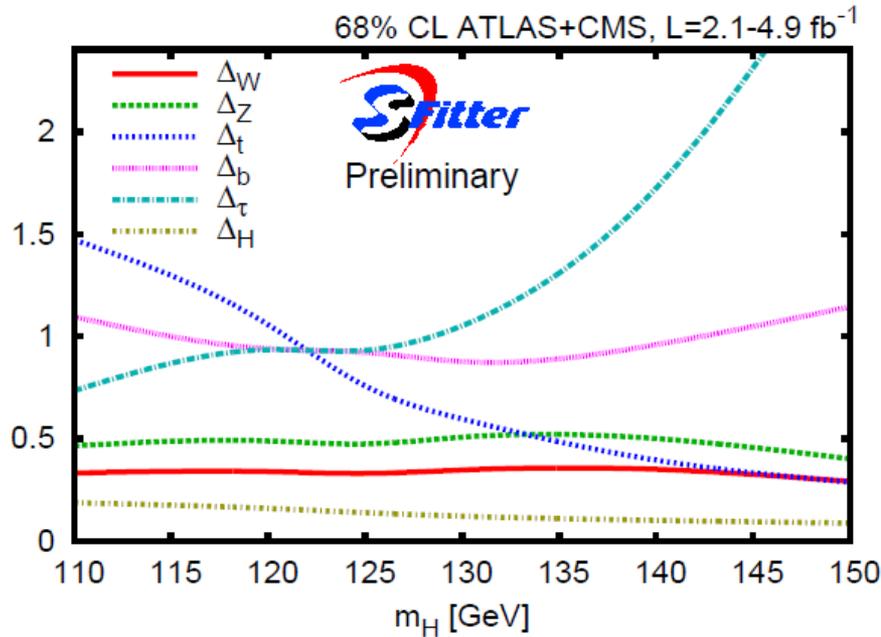


**Parameters:**
- **ΔW ΔZ Δt Δb Δτ**
- **effective couplings hopeless**

**2.1-4.9fb⁻¹: pre-Moriond**
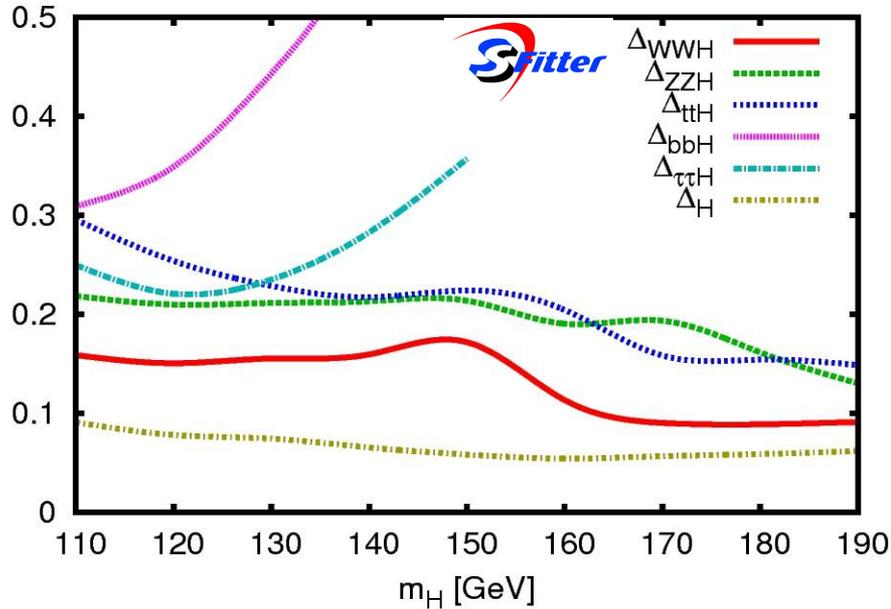- **all errors on couplings <1**
- **portal precision: 15%**

**Extrapolation to 20fb⁻¹**
- **most errors on couplings <0.5**
- **portal precision 10%**
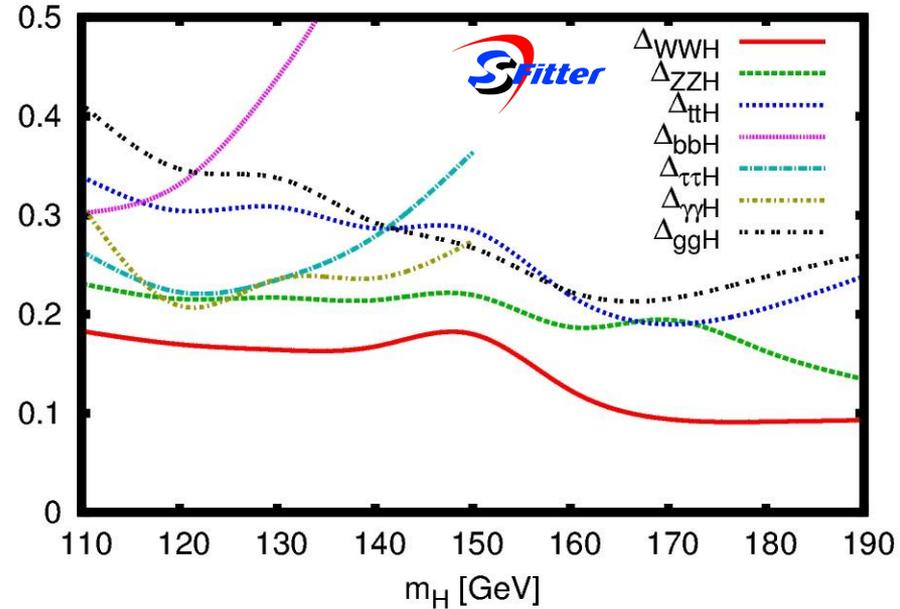- **scaling roughly statistical as expected**

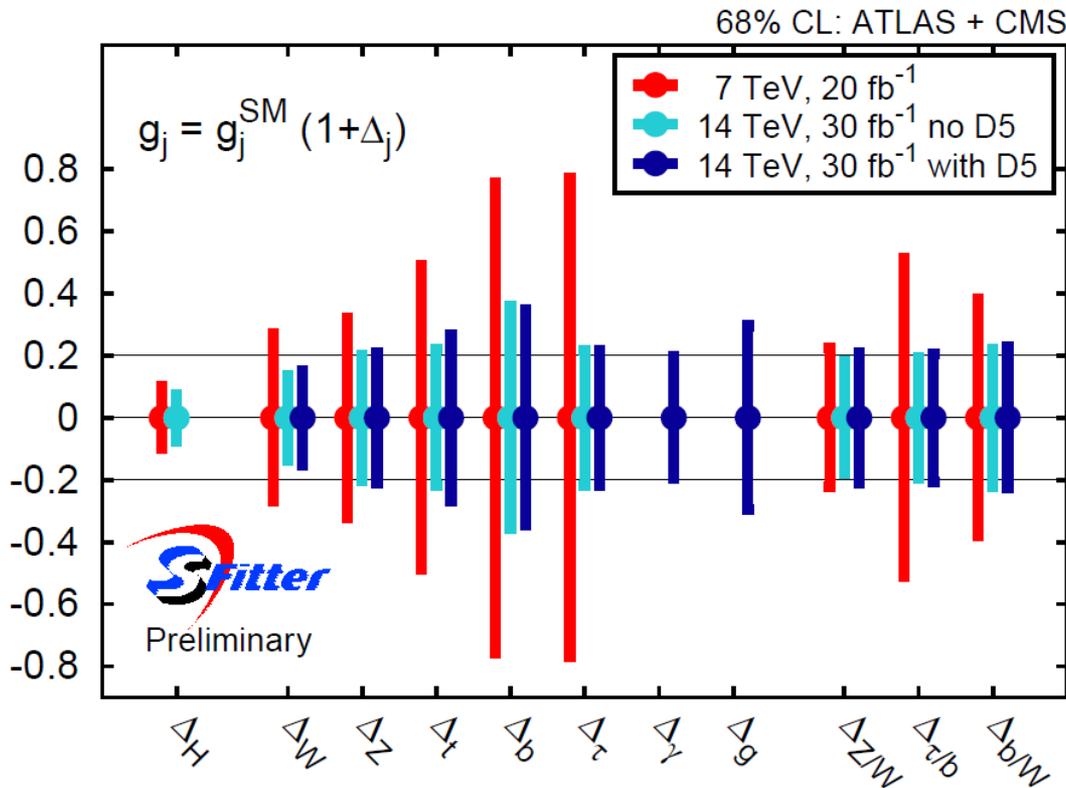# Higgs sector: 14 TeV

## 14TeV no effective couplings:



## 14TeV with effective couplings:



- **no effective couplings lead to a slight increase of precision**
- **coupling precision in general better than about 0.3**
- **portal precision better than 0.1**

# The Higgs sector precision: zoom on 125 GeV



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

**ΔH:**
- **one parameter fit**
- **best precision**

**ΔZ Δt Δb Δτ :**
- **direct coupling**
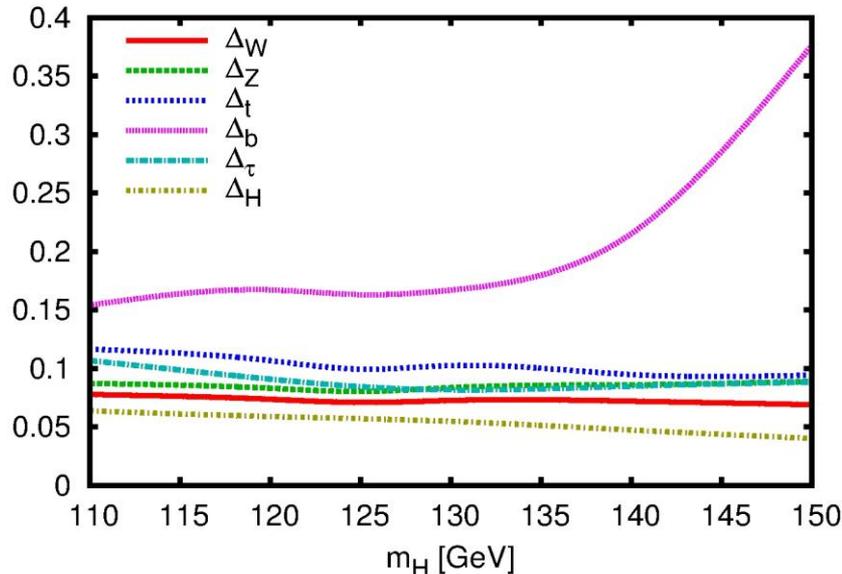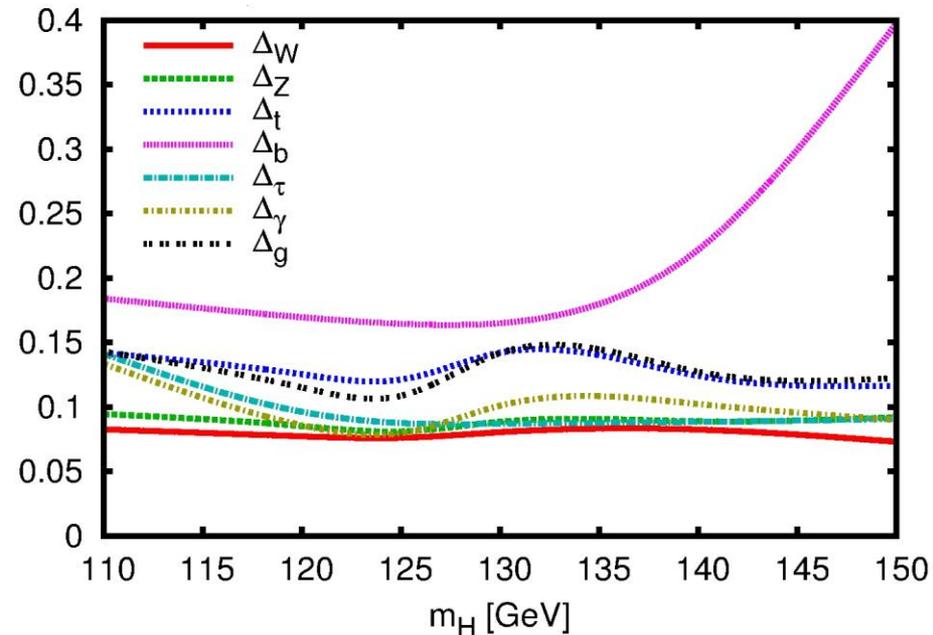- **+correl with Δb**

**Δγ Δg:**
- **effective coupling**
- **additional contribution BSM**
- **14TeV only**

# The Higgs sector precision: far far future

**For Francois Lediberder et al.**

**3000fb⁻¹:**
- extrapolate blindly
- full set including effective couplings
- all errors on couplings <20%
- most better than: 15%
- best at 10%



**3000fb⁻¹:**
- no effective couplings
- all errors on couplings <15%
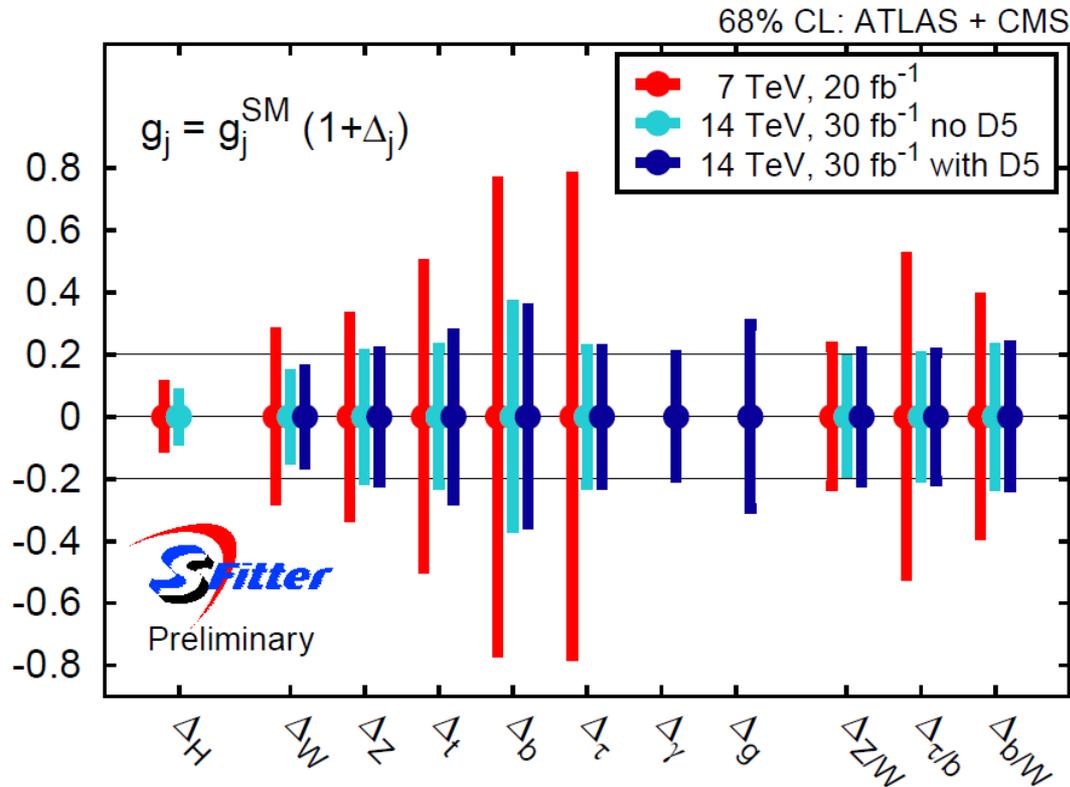- most better than: 10%
- best at 7%

- portal:
- 5%
- reached theory error
- theory error on Xsection (cpl 0.5)

# Conclusions



- **couplings known to better than 0.5 ☺**
- **portal precision: 10%**
- **post-Moriond being prepared**