Higgs Couplings from the LHC

Tilman Plehn

Universität Heidelberg

Aspen, 2/2012

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Where we stand

Where we are going

First steps

In our way

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- ATLAS and CMS results published [ATLAS-CONF-2011-163, CMS-HIG-11-033]
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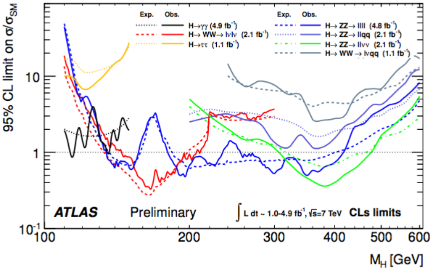

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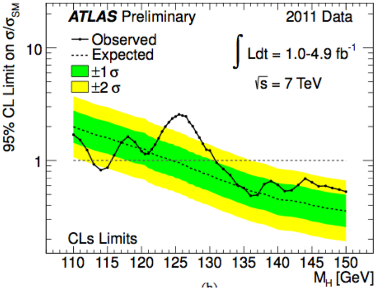

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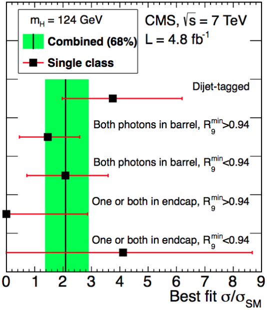

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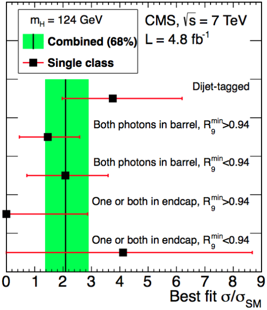

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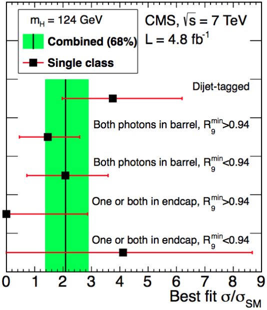

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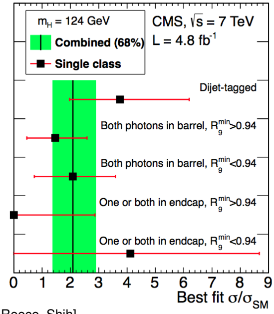

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hypersphere in $m_{\tilde{t}_{L/R}}$, $\tan\beta$, A_t, μ, m_A predicting little [$X_t^2/(m_{\tilde{t}_1} m_{\tilde{t}_2}) \gtrsim 1$]

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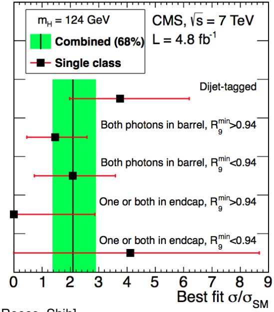

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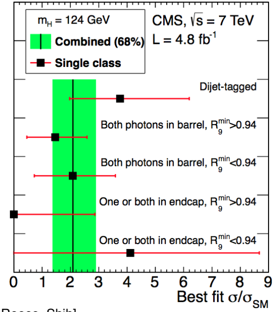

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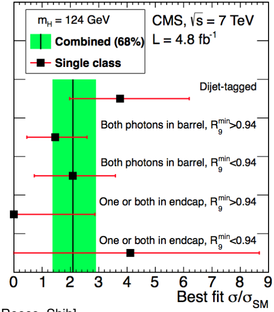

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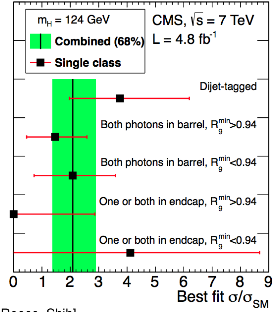

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$\Rightarrow$ completely justified over-excitement...

Our paper for that Wednesday

Impact of current results on a Higgs portal [Englert, Rauch, TP, Zerwas, Zerwas]

– general standard-hidden ansatz [Schabinger & Wells, Patt & Wilzcek,...]

$$H_1 = \cos\chi \, H_s + \sin\chi \, H_h$$

– visible and hidden decays [plus $H_2 \to H_1 H_1$ cascade decays]

$$\Gamma_1^{\text{tot}} = \cos^2\chi \, \Gamma_{\text{tot};1}^{\text{SM}} + \sin^2\chi \, \Gamma_1^{\text{hid}}$$

– constraints on event rate

$$\frac{\sigma[H_1 \to F]}{\sigma[H_1 \to F]^{\text{SM}}} = \frac{\cos^2\chi}{1 + \tan^2\chi \, \dfrac{\Gamma_1^{\text{hid}}}{\Gamma_{\text{tot},1}^{\text{SM}}}} \stackrel{!}{<} \mathcal{R}$$

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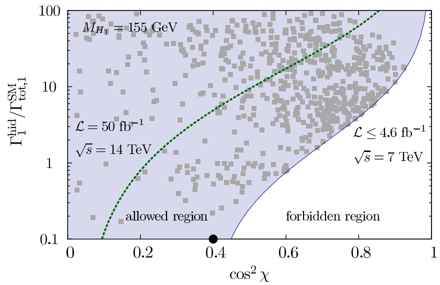
– two scenarios: $(m_H = 125, \mathcal{R} \sim 1)$ and $(m_H = 155, \mathcal{R} \sim 0.4)$



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$\Rightarrow$ invisible Higgs needed for final answer [Eboli & Zeppenfeldl, Englert, Jäckel, Re, Spannowsly]

Where we are going

Why 125 GeV is just perfect [Zeppenfeld, Kinnunen, Nikitenko, Richter-Was; Dührssen et al.; SFitter 2009]

– Higgs couplings to $W, Z, t, b, \tau, g, \gamma$ [SM-like operators]

– measurements: $GF: H \to ZZ, WW, \gamma\gamma$
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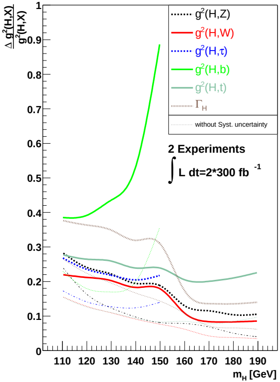

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SFitter analysis [Dührssen, Lafaye, TP, Rauch, Zerwas]

– all couplings $g_{HXX} = g_{HXX}^{\text{SM}} (1 + \Delta_{HXX})$ [$g_{HWW} > 0$ fixed]

– experimental/theoretical errors on signal and backgrounds

– Standard Model hypothesis [30fb^{-1} at 14 TeV]

coupling	without eff. couplings			including eff. couplings		
	σ_{symm}	σ_{neg}	σ_{pos}	σ_{symm}	σ_{neg}	σ_{pos}
Δ_{WWH}	± 0.23	-0.21	$+0.26$	± 0.24	-0.21	$+0.27$
Δ_{ZZH}	± 0.50	-0.74	$+0.30$	± 0.44	-0.65	$+0.24$
$\Delta_{t\bar{t}H}$	± 0.41	-0.37	$+0.45$	± 0.53	-0.65	$+0.43$
$\Delta_{b\bar{b}H}$	± 0.45	-0.33	$+0.56$	± 0.44	-0.30	$+0.59$
$\Delta_{\tau\bar{\tau}H}$	± 0.33	-0.21	$+0.46$	± 0.31	-0.19	$+0.46$
$\Delta_{\gamma\gamma H}$	—	—	—	± 0.31	-0.30	$+0.33$
Δ_{ggH}	—	—	—	± 0.61	-0.59	$+0.62$

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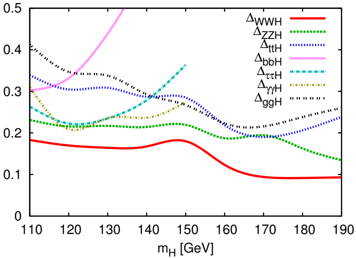

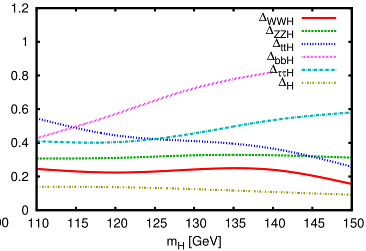

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Total width

– myths about scaling

$$N = \sigma\, BR \propto \frac{g_p^2}{\sqrt{\Gamma_{\text{tot}}}} \frac{g_d^2}{\sqrt{\Gamma_{\text{tot}}}} \sim \frac{g^4}{g^2 \dfrac{\Gamma_{\text{vis}}(g^2)}{g^2} + \Gamma_{\text{unobs}}} \xrightarrow{g^2 \to 0} = 0$$

gives constraint from $\sum \Gamma_i(g^2) < \Gamma_{\text{tot}} \to \Gamma_H|_{\text{min}}$

– $WW \to WW$ unitarity: $g_{WWH} \lesssim g_{WWH}^{\text{SM}} \to \Gamma_H|_{\text{max}}$ [Falkowski, Rychkov, Urbano]

– assume in SFitter $\Gamma_{\text{tot}} = \sum_{\text{obs}} \Gamma_j$ [plus generation universality]

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boosted channel vital, operators known, assumption about width necessary, linear collider will do better

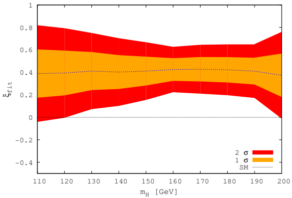
First steps: testing dreams

Strongly interacting Higgs at LHC [Espinosa, Grojean, Mühlleitner; SFitter + Bock, P Zerwas]

- looking like fundamental Higgs

1– all couplings scaled $g \to g\sqrt{1-\xi}$

- one-parameter fit in SFitter
  essentially Higgs portal without invisible decay
- 30 fb^{-1} and 120 GeV Higgs: $\Delta g/g \sim 10\%$
  best would have been $m_H \sim 160$ GeV: $\Delta g/g \sim 5\%$



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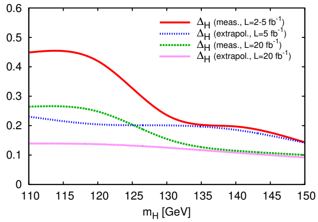

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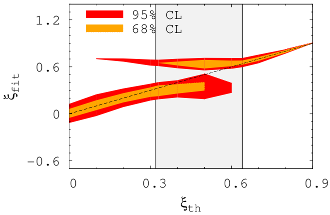
2– gauge couplings $g \to g\sqrt{1-\xi}$
Yukawas $g \to g(1-2\xi)/\sqrt{1-\xi}$

– sign change of Yukawas, $g_{\gamma\gamma H}$ correlated



In the way of Higgs analyses

Problems in Higgs sector analyses

1– pile-up in Higgs analyses
nothing I can do

2– channels for *bbH* and *ttH* couplings
Higgs and top tagging: tools in good hands [HEPTopTagger]

3– N^∞LO cross section predictions
too hard for me, ask Matthias

4– cuts on recoil jets, jet vetos
triggered during Aspen 2011, now ready

In the way of Higgs analyses

Higgs searches vs number of recoil jets?? [Englert, Gerwick, TP, Schichtel, Schumann]

– ‘soft’ gluon radiation infinitely likely [like soft photons]

– parton densities including ‘collinear’ jets [intro: arXiv:0910.4182, Springer Lecture Notes]

– ‘A jet or not a jet’ ill defined in perturbative QCD [fiducial volume vs soft/collinear]

⇒ study two types of n_{jets} distributions

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Poisson scaling [Peskin & Schroeder]

– example: photons off hard electron

$$\sigma_n = \frac{\bar{n}^n e^{-\bar{n}}}{n!} \qquad \Longleftrightarrow \qquad R^{\text{excl}}_{(n+1)/n} \equiv \frac{\sigma_{n+1}}{\sigma_n} = \frac{\bar{n}}{n+1}$$

1– radiation matrix element $\bar{n}^n$ [abelian fine, non-abelian for leading log and color]
2– phase space factor $1/n!$ [only combinatorics effect, matrix element ordered]
3– normalization factor $e^{-\bar{n}}$

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Staircase scaling [Steve Ellis, Kleiss, Stirling]

– observed since UA2

– same for inclusive and exclusive rates

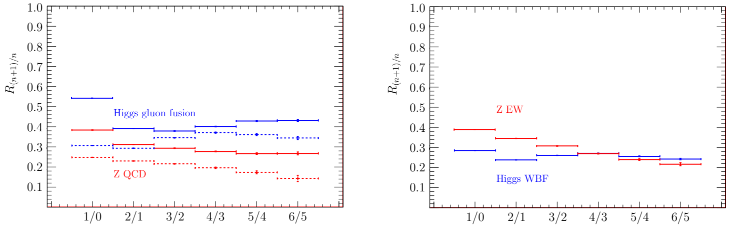
$$R^{\text{incl}}_{(n+1)/n} = \frac{\sum_{j=n+1}^{\infty} \sigma_j^{(\text{excl})}}{\sigma_n^{(\text{excl})} + \sum_{j=n+1}^{\infty} \sigma_j^{(\text{excl})}} = R^{\text{excl}}_{(n+1)/n} = \text{const}$$

Jet veto

Example: WBF $H \rightarrow \tau\tau$ [Gerwick, TP, Schumann]

– staircase scaling before WBF cuts [QCD and e-w processes]

– e-w *Zjj* production with too many structures



Jet veto

Example: WBF $H \to \tau\tau$ [Gerwick, TP, Schumann]

- staircase scaling before WBF cuts [QCD and e-w processes]
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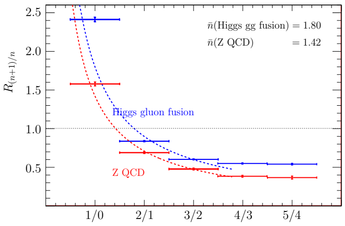
WBF cuts: two forward tagging jets

- count add'l jets to reduce backgrounds

$$p_T^{\text{veto}} > 20 \text{ GeV} \qquad \min y_{1,2} < y^{\text{veto}} < \max y_{1,2}$$

- Poisson for QCD processes ['radiation' pattern]



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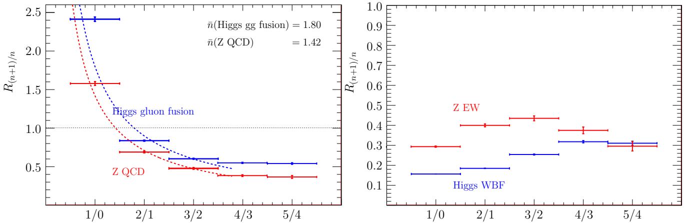
– Poisson for QCD processes ['radiation' pattern]

– (fairly) staircase for e-w processes [cuts keeping signal]

– n_{jets} distributions understood



Outlook

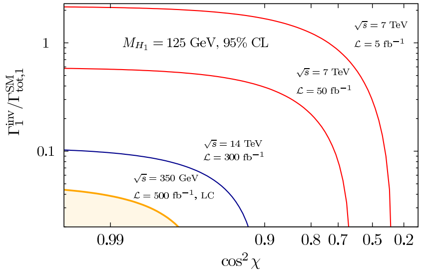
Confirming Higgs@LHC

– not a talk about first searches [ask experimenters]

– coupling analysis the main goal

– list of issues
statistial setup reliable
boosted channels needed and on track
jet counting/vetos understood

⇒ case for a 250 GeV linear collider



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