Higgs Physics for the LHC

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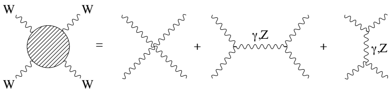
Standard Model Higgs Sector

Massive W, Z bosons [Yukawa, 1935]

– start with $SU(2)$ gauge theory [like QED with massless W, Z]

– include measured masses $\mathcal{L} \sim -m_{W,Z} A_\mu A^\mu$

$\Rightarrow$ data driven but not gauge invariant/unitary



Unitarity

– test theory in $WW \to WW$ scattering
$\to \mathcal{A} \propto G_F E^2$ like Fermi's theory, not unitary above 1.2 TeV [barely LHC energy]
$\to$ postulate additional scalar Higgs boson to conserve unitarity
$\to$ fixed coupling $g_{WWH} \propto m_W$

– add fermions and test $WW \to f\bar{f}$
$\to$ fixed coupling $g_{ffH} \propto m_f/m_W$

– test new theory in $WW \to WWH$
$\to$ fixed coupling $g_{HHH} \propto m_H^2/m_W$

– final test: $WW \to HHH$
$\to$ fixed coupling $g_{HHHH} \propto m_H^2/m_W^2$

$\Rightarrow$ Higgs couplings non-negotiable

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Spontaneous symmetry breaking [Higgs, 1964]

– break symmetry through vacuum: SU(2) doublet with vev [review: arXiv.0910.4182]

– first attempt: renormalizable Higgs potential [does all we want]

$$\mathcal{L}_{\text{Higgs}} = |D_\mu \Phi|^2 - V$$

$$V = \lambda \left(|\Phi|^2 - \frac{v^2}{2} \right)^2 = \mu^2 |\Phi|^2 + \lambda |\Phi|^4 + \text{const}$$

– not the whole story with new scale Λ

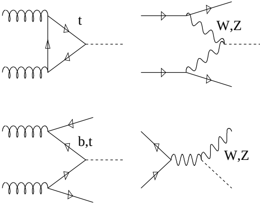
$$V = \sum_{n=0} \frac{\lambda_n}{\Lambda^{2n}} \left(|\Phi|^2 - \frac{v^2}{2} \right)^{2+n}$$

– D6 Higgs operators allowed by e-w precision data

$$\mathcal{O}_{\text{kin}} = \frac{1}{2} \partial_\mu (\Phi^\dagger \Phi) \partial^\mu (\Phi^\dagger \Phi) \qquad \mathcal{O}_{\text{pot}} = -\frac{1}{3} (\Phi^\dagger \Phi)^3$$

$\Rightarrow$ need to test renormalizable Higgs sector

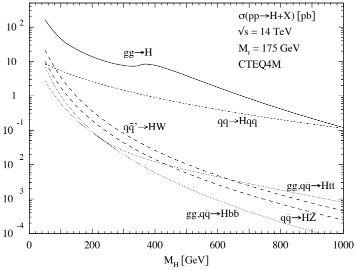
Higgs Production and Decay

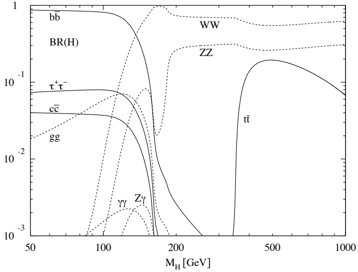


Higgs searches for the LHC

- unitarity limit $m_H < 1$ TeV
  triviality & stability bound
  electroweak precision tests $m_H \lesssim 200$ GeV
- production & decay of light (Standard Model) Higgs

$gg \to H$ $qq \to qqH$ $gg \to t\bar{t}H$ $q\bar{q}' \to WH$	$\leftrightarrow$	signal $\times$ trigger backgrounds systematics $S/\sqrt{B}$ vs. S/B mass resolution...	$\leftrightarrow$	$H \to b\bar{b}$ $H \to WW$ $H \to \tau^+_{\ell h}\tau^-_{\ell}$ $H \to \gamma\gamma$ $H \to \mu\mu$...





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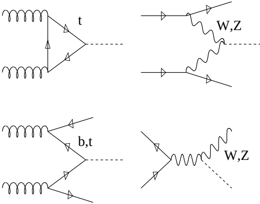

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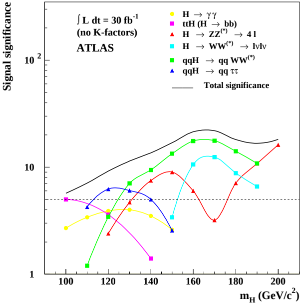
Some numbers

– $H \to ZZ \to 4\mu$ no-brainer ['golden channel' above 140 GeV, mass resolution excellent]
– $H \to WW$ only slightly harder, no mass peak [above 150 GeV, off-shell still unclear]
– $gg \to H \to \gamma\gamma$ [mass resolution $\Delta m_H/m_H \sim \Gamma/\sqrt{S} < 0.5\%$]
– $qq \to qqH \to qqWW$ [down to $m_H < 120$ GeV]
– $qq \to qqH \to qq\tau\tau$ [important for MSSM]
– more channels, comments from 2006

$gg \to t\bar{t}H \to t\bar{t}b\bar{b}$ [likely dead]
$gg \to t\bar{t}H \to t\bar{t}WW$ [likely to work]
$gg \to t\bar{t}H \to t\bar{t}\tau\tau$ [yet unclear]
$q\bar{q}' \to WH \to Wb\bar{b}$ [killer QCD backgrounds]
$qq \to qqH \to qqb\bar{b}$ [no ATLAS trigger]
$qq \to qqH \to qq\mu\mu$ [long shot]

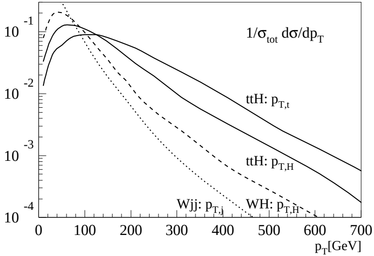
$\Rightarrow$ many channels to test Higgs



Higgs to bottoms

New strategy for $H \to bb$ [Butterworth, Davison, Rubin, Salam]

- desperately needed for light Higgs [2/3 of all Higgses; inclusive CMS $S/B \sim 1/80$]
- S: large m_{bb}, boost-dependent R_{bb}
  B: large m_{bb} only for large R_{bb}
  S/B: go for large m_{bb} and small R_{bb}, so boost Higgs
- fat Higgs jet $R_{bb} \sim 2m_H/p_T \sim 0.8$
- $q\bar{q} \to V_\ell H_b$ sizeable in boosted regime [$p_T \gtrsim 300$ GeV, few % of total rate]



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$\Rightarrow$ non-trivial challenge to jet algorithms

jet definition	σ_S/fb	σ_B/fb	$S/\sqrt{B}_{30}$
C/A, $R = 1.2$, MD-F	0.57	0.51	4.4
$k_\perp$, $R = 1.0$, y_{cut}	0.19	0.74	1.2
SISCone, $R = 0.8$	0.49	1.33	2.3

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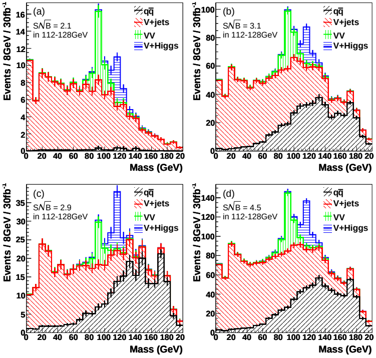
Results and checks

- combined channels $V \to \ell\ell, \nu\nu, \ell\nu$
- NLO rates [bbV notorious, not from data alone]
- Z peak as sanity check
- checked by Freiburg [Piquadio]
  subjet b tag excellent [70%/1%]
  charm rejection challenging
  $m_H \pm 8$ GeV tough

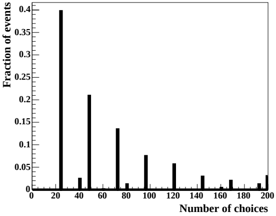
$\Rightarrow$ discovery channel for $\sim 40\text{fb}^{-1}$



Saving $t\bar{t}H$

Traditional $t\bar{t}H$, $H \to b\bar{b}$ [Atlas-Bonn study, CMS-TDR even worse]

- trigger: $t \to bW^+ \to b\ell^+\nu$
  reconstruction and rate: $\bar{t} \to \bar{b}W^- \to \bar{b}jj$
- continuum background $t\bar{t}b\bar{b}$, $t\bar{t}jj$ [weighted by b-tag]
- no chance:
  1– combinatorics: m_{bb} from $pp \to 4b_{tag}\ 2j\ \ell\nu$



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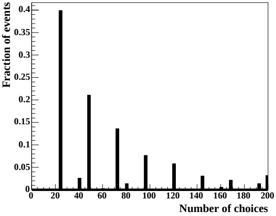
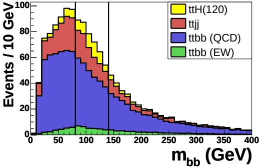
  2– kinematics: peak-on-peak





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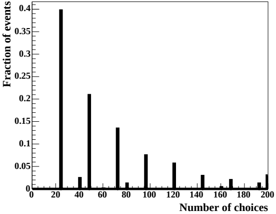

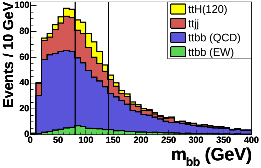

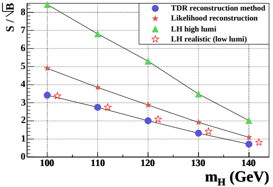

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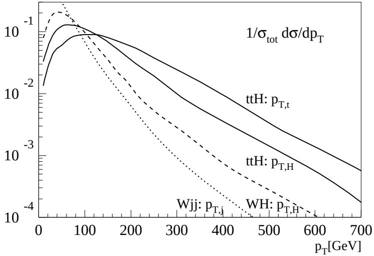
Fat jets analysis [TP, Salam, Spannowsky]

- S: large m_{bb}, boost-dependent R_{bb}
  B: large m_{bb} only for large R_{bb}
  S/B: large m_{bb} and small R_{bb}; correct bottom pair boosted [solves 1]
- $pp \to t_\ell t_h H_b$ even better than VH?
  also boost different for S and B [solves 2]
- cool: fat Higgs jet + fat top jet
  uncool: QCD [Dittmaier et al: $K = 2.3$ for $t\bar{t}b\bar{b}$]
- see how far we get... [watch S/B for 3]



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Analysis

- require tagged top and Higgs
  trigger on lepton
- remove 'Higgs' as $t_\ell \to b$ plus QCD
  3rd b tag in continuum
  only continuum $t\bar{t}b\bar{b}$ left

per 1 fb^{-1}	signal	$t\bar{t}Z$	$t\bar{t}b\bar{b}$	$t\bar{t}$+jets
events after acceptance	24.1	6.9	191	4160
events with one top tag	10.2	2.9	70.4	1457
events with $m_{bb} = 110 - 130$ GeV	2.9	0.44	12.6	116
corresponding to subjet pairings	3.2	0.47	13.8	121
subjet pairings two b tags	1.0	0.08	2.3	1.4
including a third b tag	0.48	0.03	1.09	0.06

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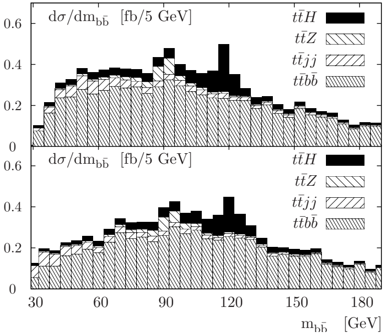
m_H	S	S/B	$S/\sqrt{B}_{100\text{fb}^{-1}}$
115	57	1/2.1	5.2 (5.7)
120	48	1/2.4	4.5 (5.1)
130	29	1/3.6	2.9 (3.0)

$\Rightarrow$ just a suggestion...



Top and Higgs tagging

Higgs tag for busy QCD environment [BDRS; TP, Salam, Spannowsky]

– uncluster one-by-one: $j \to j_1 + j_2$
  1– unbalanced $m_{j_1} > 0.8 m_j$ means QCD; discard j_2
  2– soft $m_{j_1} < 30$ GeV means QCD; keep j_1
– double b tag [possibly add balance criterion]
  three leading $J = p_{T,1} p_{T,2} (\Delta R_{12})^4$ vs m_{bb}^{filt}
  no mass constraint — side bin
– jets everywhere; underlying event and pileup deadly
  filter reconstruction jets
  decay plus one add'l jet at $R_{\text{filt}} \sim R_{jj}/2$
  reconstruct masses w/ QCD jet

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HEPTopTagger [TP, Salam, Spannowsky, Takeuchi; cf Johns Hopkins, Princeton, Washington]

– known for heavy resonances [Johns Hopkins, Stony Brook, Princeton, Washington, Michigan, Atlas,...]

– testable top tagger?

– start like Higgs tagger [R=1.5, filtering]
$m_t^{\text{rec}} = 150...200$ GeV
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additional m_{jb} constraint [new in public version]

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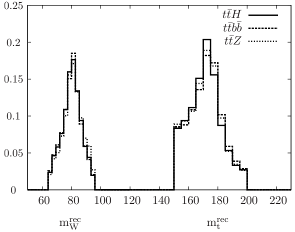
⇒ tagger implemented by ATLAS



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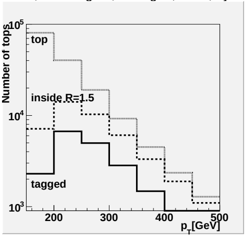

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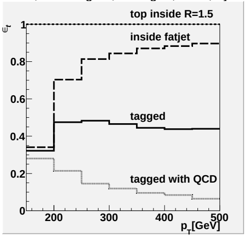

Markov chains

Probability maps

– honest LHC parameters: weak-scale Lagrangean [Higgs, MSSM, dark matter,...]

– problem in grid: huge phase space, find local best points?
problem in fit: domain walls, find global best points?

– likelihood map: data given a model $p(d|m) \sim |\mathcal{M}|^2(m)$

– Bayes' theorem: $p(m|d) = p(d|m)\ p(m)/p(d)$ [$p(d)$ normalization, $p(m)$ prejudice]

$\Rightarrow$ given measurements: 1– compute map $p(d|m)$
2– rank local maxima
3– derive probabilities for parameters

Markov chains

– classical: representative set of spin states
compute average energy on this reduced sample

– BSM physics: map $p(d|m)$ of parameter points
evaluate same probability or additional function

– Metropolis-Hastings
starting probability $p(d|m)$ vs suggested probability $p(d|m')$
1– accept new point if $p(d|m') > p(d|m)$
2– or accept with $p(d|m')/p(d|m) < 1$

Improving Markov chains

Weighted Markov chains [Lafaye, TP, Rauch, Zerwas; Ferrenberg, Swendsen]

- special situation
  measure of 'representative': probability itself
- example with 2 bins, probability 9:1
  10 entries needed for good Markov chain
  2 entries needed if weight kept
- binning with weight would double count
  bin with inverse averaging

$$P_{\text{bin}}(p \neq 0) = \frac{\text{bincount}}{\sum_{i=1}^{\text{bincount}} p^{-1}}$$

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Cooling Markov chains [Lafaye, TP, Rauch, Zerwas]

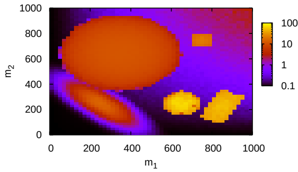
– need to zoom in on peak structures

– modified condition [inspired by simulated annealing]
  Markov chain in 100 partitions, numbered by j

$$\frac{p(m')}{p(m)} > r^{\frac{100}{j\,c}} \qquad \text{with} \quad c \sim 10, \qquad r\epsilon[0,1] \quad \text{random number}$$

– check for parameter coverage with many Markov chains

Frequentist vs Bayesian

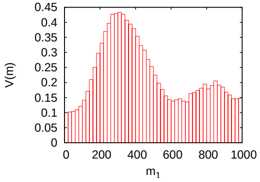


Getting rid of model parameters

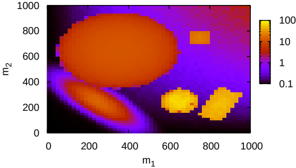
– poorly constrained parameters
  uninteresting parameters
  unphysical parameters [JES part of m_t extraction]

– two ways to marginalize likelihood map

1– integrate over probabilities
  normalization etc mathematically correct
  integration measure unclear
  noise accumulation from irrelevant regions
  classical example: convolution of two Gaussians



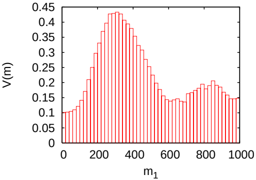
Frequentist vs Bayesian



Getting rid of model parameters

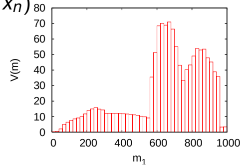
– poorly constrained parameters
  uninteresting parameters
  unphysical parameters [JES part of m_t extraction]

– two ways to marginalize likelihood map



1– integrate over probabilities
  normalization etc mathematically correct
  integration measure unclear
  noise accumulation from irrelevant regions
  classical example: convolution of two Gaussians

2– profile likelihood $\mathcal{L}(.., x_{j-1}, x_{j+1} ....) \equiv \max_{x_j} \mathcal{L}(x_1, ..., x_n)$
  no integration needed
  no noise accumulation
  not normalized, no comparison of structures
  classical example: best-fit point



– childish civil war if applied to same question
  frequentist: flavor, Higgs,...
  Bayesian: dark matter, new physics,...

– simply: two questions, two answers

Higgs couplings

Higgs-sector analysis at the LHC [Zeppenfeld, Kinnunen, Nikitenko, Richter-Was; Dührssen et al.]

– optimistic LHC scenario: everything working and good data

– Higgs vs. scalars? SM vs MSSM? doublet vs. general Higgs?

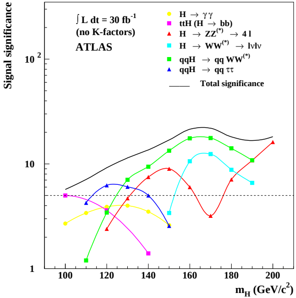
– light Higgs around 120 GeV: 10 main channels ($\sigma \times BR$) [*bb* channel new]

– measurements: $GF : H \to ZZ, WW, \gamma\gamma$
$WBF : H \to ZZ, WW, \gamma\gamma, \tau\tau$
$VH : H \to b\bar{b}$ [Butterworth, Davison, Rubin, Salam]
$t\bar{t}H : H \to \gamma\gamma, WW, (b\bar{b})$...

– parameters: couplings $W, Z, t, b, \tau, g, \gamma$ [plus Higgs mass]

– hope: cancel uncertainties

$(WBF : H \to WW)/(WBF : H \to \tau\tau)$
$(WBF : H \to WW)/(GF : H \to WW)$...



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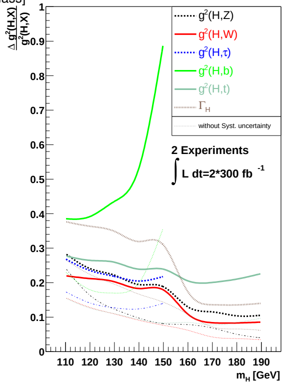

Total width

- degeneracy $\sigma\, BR \propto (g_p^2/\sqrt{\Gamma_H})\,(g_d^2/\sqrt{\Gamma_H}) \equiv C > 0$
- inconsistent scaling

$$C = \lim_{g^2 \to 0} \frac{g^4}{\Gamma_H} = \lim_{g^2 \to 0} \frac{g^4}{g^2(\Gamma_{\text{vis}}/g^2) + \Gamma_x} = 0$$

  means constraint: $\sum \Gamma_i(g^2) < \Gamma_H \to \Gamma_H|_{\text{min}}$
- $WW \to WW$ unitarity: $g_{WWH} \lesssim g_{WWH}^{\text{SM}} \to \Gamma_H|_{\text{max}}$

Higgs couplings

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

– all couplings varied $g_{HXX} = g_{HXX}^{\text{SM}} (1 + \delta_{HXX})$
$\delta_{HXX} \sim -2$ sign flip [$g_{HWW} > 0$ fixed]

– loop-induced couplings $g_{ggH}, g_{\gamma\gamma H}$ free?

– likelihood map and local errors from SFitter

– experimental/theory errors on signal and backgrounds [do not ask theorists!]

luminosity measurement	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 ($H \to 4\ell$)	3 %

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

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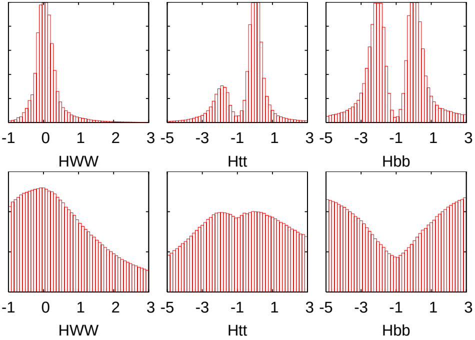
– error bars for Standard Model hypothesis [smeared data point, 30fb^{-1}]

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	$+0.62$
m_H	± 0.26	-0.26	$+0.26$	± 0.25	-0.26	$+0.25$
m_b	± 0.071	-0.071	$+0.071$	± 0.071	-0.071	$+0.072$
m_t	± 1.00	-1.03	$+0.98$	± 0.99	-1.00	$+0.98$

Higgs couplings

One-dimensional distributions to check....

1– noisy environment preferring profile likelihoods [no effective couplings, 30 fb^{-1}]



Higgs couplings

One-dimensional distributions to check....

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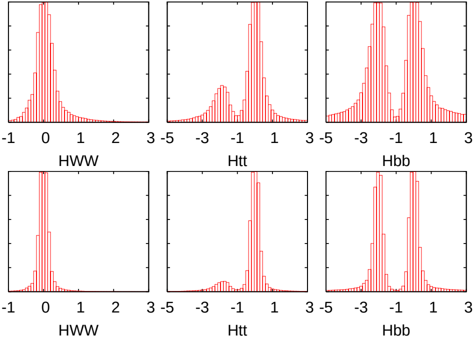
2– higher luminosity quantitatively different [no effective couplings, 30 vs 300 fb^{-1}]



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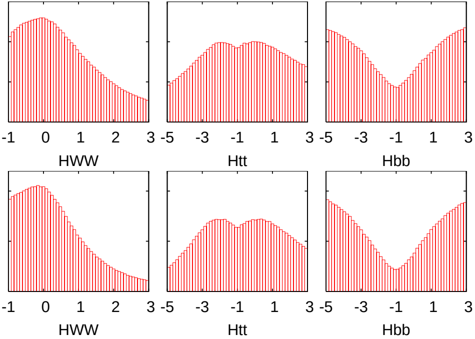
3– but not saving Bayesian statistics [no effective couplings, 300 fb^{-1}]



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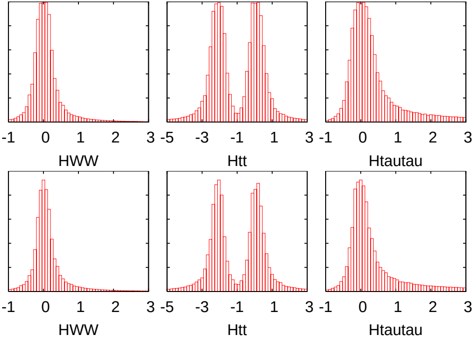
2– higher luminosity quantitatively different [no effective couplings, 30 vs 300 fb^{-1}]

3– but not saving Bayesian statistics [no effective couplings, 300 fb^{-1}]

4– theory errors not dominant for 30 fb^{-1} [with effective couplings, 30 fb^{-1}]



$\Rightarrow$ profile likelihood for 30 fb^{-1}, local structures, pretty pictures in backup

Refining Higgs hypotheses

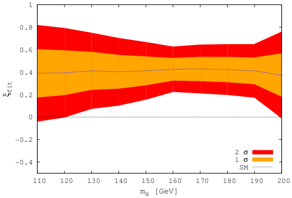
Strongly interacting Higgs at LHC [Espinosa, Grojean, Mühlleitner; SFitter + Bock, P Zerwas]

– looking like fundamental Higgs

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

– one-parameter fit in SFitter

– 30 fb^{-1} and 120 GeV Higgs: $\Delta g/g \sim 10\%$
best around $m_H \sim 160$ GeV: $\Delta g/g \sim 5\%$



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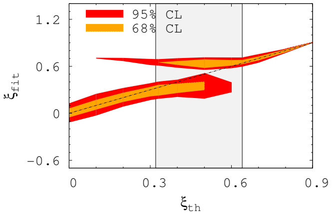

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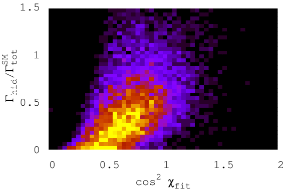
Higgs portal

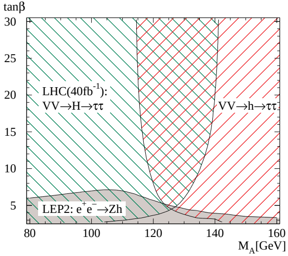
- – universal scaling $\sqrt{1-\xi} \equiv \cos\chi$
- – invisible Higgs decay measurable [Eboli & Zeppenfeld]
  two-parameter fit Γ_{hid} vs $\cos\chi$
- $\Rightarrow$ hypotheses testable with 30 fb^{-1}



Weak boson fusion and supersymmetry

Higgs analysis beyond the Standard Model

- extension of Higgs analysis to BSM scenarios
  comparison SM-MSSM [no-lose: TP, Rainwater, Zeppenfeld]
- define hypothesis
  known particles: known corrections
  new particles: theory error
- general: heavy additional states at one loop
  example: MSSM sectors Higgs–weak–strong



Technical questions [Hollik, TP, Rauch, Rzehak]

- vertex corrections dominant? [Djouadi & Spira]
- which one larger: QCD vs EW? [similar for Standard Model: Ciccolini, Denner, Dittmaier]
- corrections from Higgs sector? [renormalization scheme/higher orders]
- general phase space generator?
- Germans: we can do 52504 diagrams [Hadcalc: automized IR-finite one-loop $2 \longrightarrow 3$]

$\Rightarrow$ input for MSSM-Higgs analysis

Weak boson fusion and supersymmetry

Higgs sector corrections

– finite momentum, different masses → Feynman diagrams [FeynHiggs]
  consistent self couplings → effective potential [SubH]

– check identical limit: effective angle α_{eff}

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- check identical limit: effective angle $\alpha_{\rm eff}$

SUSY corrections

- QCD corr針 suppressed:

  color flow and forward jets [no interference, like SM]

  mass suppression of one-loop $q_L q_L W$ vertex [$1/m_{\tilde{g}}$]

  up-down concellation in one-loop $duWh$ vertex [$T_3 - Q s_w^2 = -1/3, +5/16$]
- electroweak corrections as expected

diagram	$\Delta\sigma/\sigma$ [%]	diagram	$\Delta\sigma/\sigma$ [%]
$\Delta\sigma \sim \mathcal{O}(\alpha)$		$\Delta\sigma \sim \mathcal{O}(\alpha_s)$	
self energies	0.199		
$qqW + qqZ$	-0.392	$qqW + qqZ$	-0.0148
qqh	-0.0260	qqh	0.00545
$WWh + ZZh$	-0.329		
box	0.0785	box	-0.00518
pentagon	0.000522	pentagon	-0.000308

⇒ electroweak corrections dominant

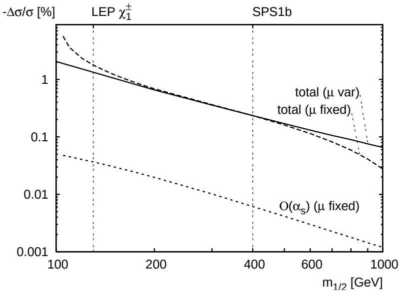
Weak boson fusion and supersymmetry

Higgs sector corrections

- finite momentum, different masses → Feynman diagrams [FeynHiggs]
  consistent self couplings → effective potential [SubH]
- check identical limit: effective angle α_{eff}

SUSY corrections

- SPS1b with variable mass scale $m_{1/2}$
- perfect decoupling at one loop
- typical corrections around 1%
  maximum corrections below 4%



Outlook

Trying to understand Higgs@LHC

– not a talk about first searches [ask experimenters]

– many LHC search channels, let's see for when

– decay to bottoms part of them

– parameter analysis the final goal

– open questions: jet veto, recoil uncertainties,...
not the time for BSM parameter studies
let's go and solve real problems!

$\Rightarrow$ Higgs phenomenology at LHC still progressing

Analysis errors

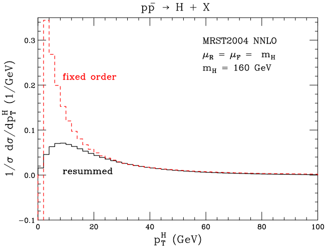
Worries about $H \rightarrow \gamma\gamma$ etc [Anastasiou, Dissertori, Grazzini, Stockli, Webber; Anastasiou, Melnikov Petriello]

– used to be easy: double side-bin analysis

– learning from Tevatron $H \rightarrow WW$: $p_{T,H}$, $\phi_{\ell\ell}$ and N_{jets} in NN
combine 'slices' of side-bins

– typical tool to improve 3σ to 5σ

– NN training tool for signal/background and theory uncertainties?
sensitive to p_T resummation tricky
sensitive to first jet challenging
sensitive to n jets a nightmare



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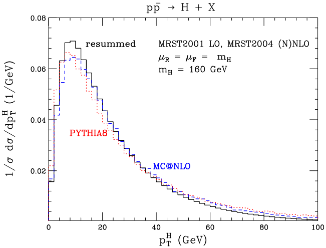

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– combination of scale uncertainties [Tevatron]

$$\frac{\Delta N}{N} = 60\% \cdot \begin{pmatrix} +5\% \\ -9\% \end{pmatrix} + 29\% \cdot \begin{pmatrix} +24\% \\ -23\% \end{pmatrix} + 11\% \cdot \begin{pmatrix} +91\% \\ -44\% \end{pmatrix} = \begin{pmatrix} +20.0\% \\ -16.9\% \end{pmatrix}$$

– adding stat'l significance at high p_T
pull degrading from theory error
dangerously small individual S/B

– advanced analyses finally getting me scared...

Error analysis

Sources of uncertainty

- statistical error: Poisson
  systematic error: Gaussian, if measured
  theory error: not Gaussian
- simple argument
  LHC rate 10% off: no problem
  LHC rate 30% off: no problem
  LHC rate 300% off: Standard Model wrong
- theory likelihood flat centrally and zero far away
- profile likelihood construction: RFit [CKMFitter]

$$-2\log\mathcal{L} = \chi^2 = \vec{\chi}_d^T \, C^{-1} \, \vec{\chi}_d$$

$$\chi_{d,i} = \begin{cases} 0 & |d_i - \bar{d}_i| < \sigma_i^{(\text{theo})} \\ \dfrac{|d_i - \bar{d}_i| - \sigma_i^{(\text{theo})}}{\sigma_i^{(\text{exp})}} & |d_i - \bar{d}_i| > \sigma_i^{(\text{theo})} \end{cases} ,$$

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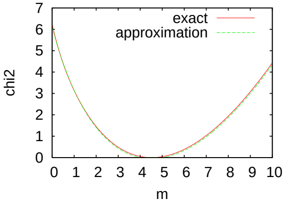
(Inconsistent) combination of errors

– Gaussian $\otimes$ Gaussian: half width added in quadrature
  Gaussian $\otimes$ flat: RFit scheme
  Gaussian $\otimes$ Poisson: ??

– approximate formula

$$\frac{1}{\log\mathcal{L}_{\text{comb}}} = \frac{1}{\log\mathcal{L}_{\text{Gauss}}} + \frac{1}{\log\mathcal{L}_{\text{Poisson}}}$$

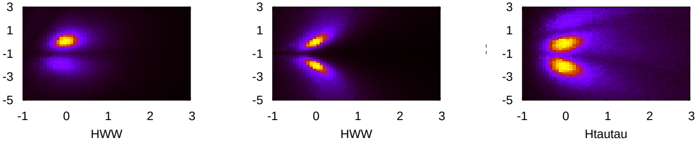
– good to 5% for 5 events with 10% Gaussian



Pretty colorful pictures

Two-dimensional correlations and effective coupings

1– including effective g_{Hgg}
sign of g_{Htt} fixed by $g_{HWW} > 0$
correlation of g_{Hbb} and g_{HWW} [loops and width]
g_{Hgg} accessible



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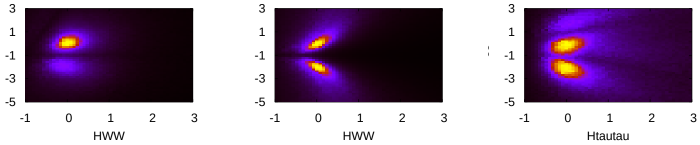
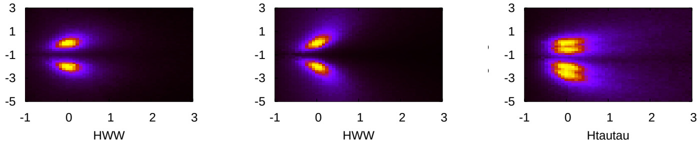


2– only effective $g_{H\gamma\gamma}$
correlated g_{Htt} and g_{HWW} on both branches
$g_{H\gamma\gamma}$ structure more complex



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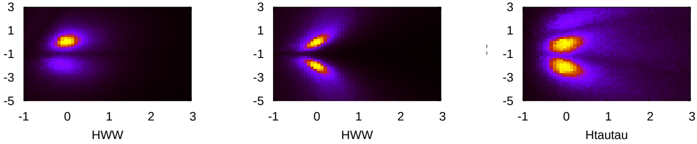

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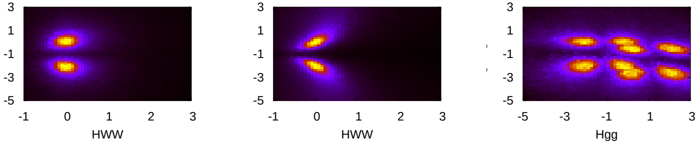
3– both effective couplings
discrete structures getting out of hand



Unobserved vs invisible

Invisible Higgs

– two channels at LHC
  $pp \to qqH$: tagging jets plus nothing [Eboli & Zeppenfeld]
  $pp \to ZH$: recoil against nothing [Atlas CSC notes]

– g_{inv} another parameter

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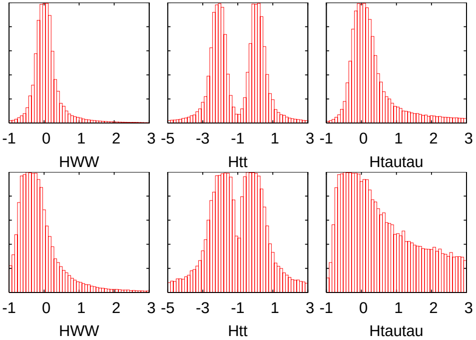
– see scaled-down couplings



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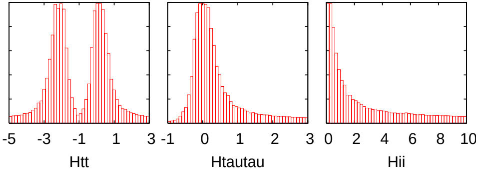
1– fit only $\Gamma \to \Gamma(1 + \Delta_\Gamma)$

2– include $\Delta\Gamma$ and fix g_{HWW}



⇒ not as unobservable as people think...