Exotic W^+W^-Z Signals at the LHC

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WCLHC

Premise

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- Show how to find **TWO** Higgs bosons in the early LHC

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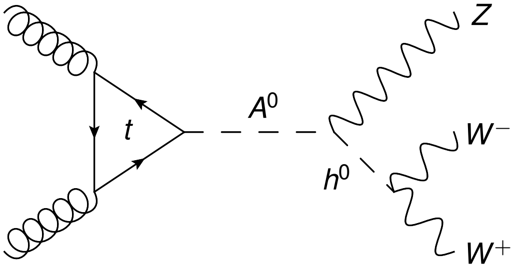
Topology of interest?



Fermion Masses in Strong EWSB

Fermion masses in Strong EWSB by $(\Psi\Psi^c) \sim H_{SM}$

$$\mathcal{L} \ni \frac{c}{\Lambda^{d-1}} Q\,(\Psi\Psi^c)\,t^c \sim c\left(\frac{v}{\Lambda_t}\right)^{d-1} Qt^c = m_{top} Qt^c$$

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$\Rightarrow$ new BSM spin-0 resonances
produced through GGF

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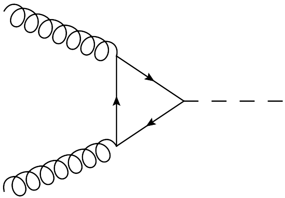

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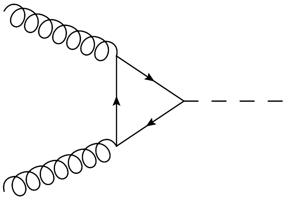

2HDM can mimic low-lying strong scalars

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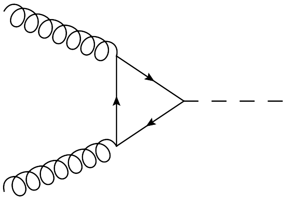

2HDM can mimic low-lying strong scalars

Electroweak Precision Data?

Two Higgs Doublet Model: Introduction

$$
\begin{aligned}
V &= m_1^2\Phi_1^\dagger\Phi_1 + m_2^2\Phi_2^\dagger\Phi_2 + \frac{\lambda_1}{4}\left(\Phi_1^\dagger\Phi_1\right)^2 + \frac{\lambda_2}{4}\left(\Phi_2^\dagger\Phi_2\right)^2 \\
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- (b-quark neglected; 2HDM Type I or Type II)

Two Higgs Doublet Model: Final States

Resonances: h^0, H^0 and $\mathbf{A} = \begin{pmatrix} A^+ & A^0 & A^- \end{pmatrix}$

(Note: $A \not\rightarrow WW, ZZ$ by CP and $h^0 \neq h_{SM}$)

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Final States: LOTS of these!

$$H^0 \to \begin{cases} W^+W^- \\ ZZ \\ t\bar{t} \\ b\bar{b}/\tau^+\tau^- \\ A^0Z/W^\mp A^\pm \\ W^+W^-h^0 \\ h^0h^0 \end{cases} \qquad A^0 \to \begin{cases} t\bar{t} \\ b\bar{b}/\tau^+\tau^- \\ W^+W^-Z \\ h^0Z/H^0Z \end{cases} \qquad h^0 \to \begin{cases} W^+W^- \\ ZZ \\ t\bar{t} \\ b\bar{b}/\tau^+\tau^- \\ A^0Z/A^\pm W^\mp \end{cases}$$

New states $\to$ massive gauge bosons, heavy quarks and each other!

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Signals not being looked for!

Higgs at Early LHC

Signals for Early LHC?

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m_A &= 330 \text{ GeV} \\
m_h &= 200 \text{ GeV} \\
m_H &= 1 \text{ TeV} \\
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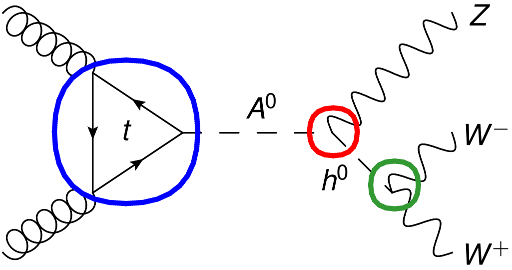

- $\sigma(pp \to A^0) \sim 2.6$ pb
- $\mathrm{BR}(A^0 \to h^0 Z) \sim 0.92$
- $\mathrm{BR}(h^0 \to W^+W^-) \sim 0.74$
- $\sigma(pp \to WWZ) \sim 1.75$ pb

Early LHC Signal: 4 leptons + $\not{E}_T$

Backgrounds: WWZ+jets, $t\bar{t}Z$+jets and WZ+jets

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Cut	Signal	Background
4 Leptons	2.20 fb	0.067 fb

Cuts: Need $> 4e/\mu$ with $\eta_e < 2.4$, $\eta_\mu < 2.1$, $p_{t,e\mu} > 8$ GeV

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Simple Search!!! 3 fb^{-1} of data, 6-7 signal events to no background

Early LHC Signal: 3 leptons + 2 jets: Cuts

Process	C1	C2	C3	C4	C5	C6
$Z+$ jets	???	???	???	???	???	???
$WZ+$ jets	5.53	4.96	4.69	3.56	1.03	0.241
$t\bar{t}Z+$ jets	0.718	0.669	0.519	0.366	0.223	0.037
$WWZ+$ jets	0.129	0.114	0.107	0.084	0.062	0.008
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Total	6.72	6.08	5.25	4.04	1.35	0.288
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All cross-sections in units of fb

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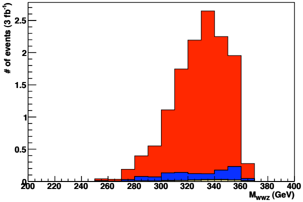
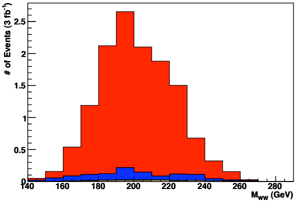
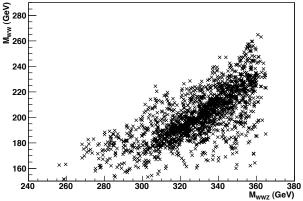
$Z+$ jets: C1 $\sim 10^{-3}$, C2 $\sim 10^{-2}$, C3, C4 ~ 1, C5 $\sim 10^{-1}$, C6 $\sim 10^{-1} \Rightarrow 10^{-7}$

Early LHC Signal: 3 leptons + 2 jets: Results







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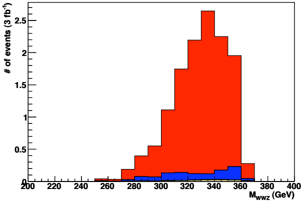

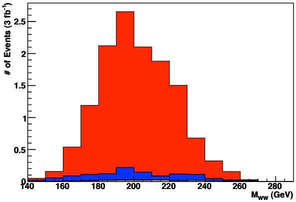

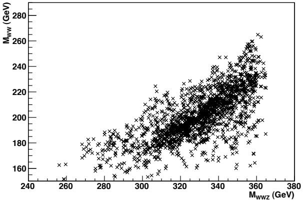

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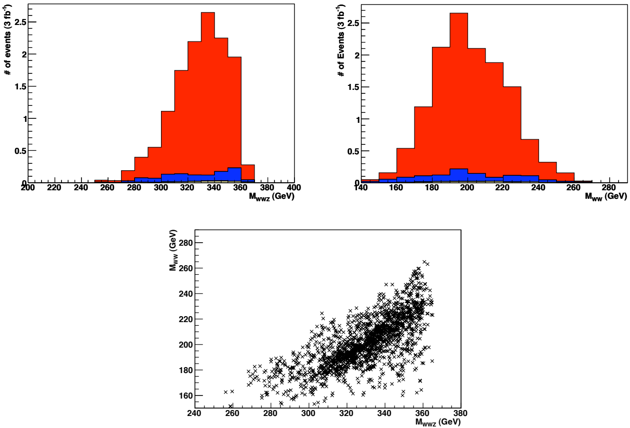

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Needs a full experimental analysis!

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- Evidence or discovery of two Higgs bosons in early LHC data

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