Search for new Bosons at the LHC

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SAIP 2015, UCT, July 4th-8th 2016
Outline

- Habemus Novum Boson
- Search in the high mass di-photon spectrum
  - Anatomy of the excess
- ZZ, WW resonances
- hh resonances
- Heavy scalar and DM
- Prospects
On July 4th 2012 reported both experiments reported ~5σ effects

Habemus novum Boson

On July 4th 2012 reported both experiments reported ~5σ effects
The search for heavy bosons in the di-photon invariant mass spectrum

Back in December 2015 the ATLAS and CMS collaborations reported similar excesses in the region of 750 GeV in the di-photon invariant mass spectrum.

These excesses have triggered a burst of theoretical papers (over 400).

Major updates coming from experiments expected in August at ICHEP 2016, in Chicago.
Photons are selected with dedicated Identification and isolation criteria. Spectrum fitted with background-only unbinned likelihood fit.

Results for Spin-2 search yield similar excess in the 13 TeV data.

No events observed with M>2 TeV.
The CMS experiment classifies the photon pairs according to two categories, denoted as EBEB when both photons are reconstructed in the barrel electromagnetic calorimeter and as EBEE when one of the two photons is observed in the endcap. Each category is further subdivided into events recorded with the full magnetic field of 3.8 Tesla and when it was switched off.
p-values for search of a narrow scalar with 13 TeV data

ATLAS

$\sqrt{s} = 13$ TeV, 3.2 fb$^{-1}$
NWA
Spin-0 Selection

2.9$\sigma$ local significance @750 GeV
ATLAS makes a p-value scan with respect to the width of the scalar resonance. Maximum significance 3.9$\sigma$ local (2.1$\sigma$ global)
p-values for search of a narrow scalar with 8 and 13 TeV data
Local significance of 3.4σ (1.6σ global) @750 GeV
ZZ and WW resonance searches
$H \rightarrow 4\ell$

First Run II study with CMS
Analysis performed for different assumptions of widths
Good understanding of MET essential, achieved already with first Run II data.
Complex analysis that includes b-tagging and boosted (fat) jets
hh resonance searches
Sophisticated analysis based on a multivariate technique.
Analysis close to Run I paper strategy, including event counting and constrained mass.
Heavy Scalar and Dark Matter
Di-photon candidates are classified according to presence of Missing energy.
Prospects for 2016
ATLAS Online Luminosity

- LHC Stable Beams

Peak Lumi: $10.8 \times 10^{33}$ cm$^{-2}$ s$^{-1}$

LHC Design target

\sqrt{s} = 13$ TeV
Results shown here correspond to just ~3 fb⁻¹ taken in 2015
We are here

May get ~30 fb\(^{-1}\) this year alone
Stay tuned for massive updates

SA well represented with Z.Vilakazi in the IC, A.Muronga and BM as convenors

ICHEP
2016 CHICAGO
AUGUST 3-10, 2016
AT SHERATON GRAND CHICAGO
ICHEP2016.ORG
ABSTRACT SUBMISSION THROUGH FEB. 7, 2016

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MAYDA VELASCO, NORTHWESTERN UNIVERSITY
Additional Slides
Higgs production at Hadron Colliders and decays

- Gluon-gluon fusion
- Vector Boson Fusion
- Associated Production
Higgs Cross-Sections at LHC

\[ \sqrt{s} = 8 \text{ TeV} \]

\[
\sigma(pp \to H+X) \text{ [pb]}
\]

- \(pp \to H\) (NNLO+NNLL QCD + NLO EW)
- \(pp \to qgH\) (NNLO QCD + NLO EW)
- \(pp \to WH\) (NNLO QCD + NLO EW)
- \(pp \to ZH\) (NNLO QCD + NLO EW)
- \(pp \to t\bar{t}H\) (NLO QCD)

\[
M_H \text{ [GeV]}
\]
Main Decay Modes

Higgs BR + Total Uncert

$M_H [\text{GeV}]$

$10^{-3}$

$10^{-2}$

$10^{-1}$

$1$
In the standard model there is a physical state, a Higgs boson with well defined couplings to weak bosons, fermions and self interactions

<table>
<thead>
<tr>
<th>Gauge</th>
<th>Self-interaction</th>
<th>Fermion</th>
</tr>
</thead>
<tbody>
<tr>
<td>$HW_{\mu}^+ W_\nu^-$ : $(-ig_{\mu \nu})2 \frac{m_W^2}{\nu}$</td>
<td>$HHH : (i)3 \frac{m_H^2}{\nu^2}$</td>
<td>$Hff : (i) \frac{m_f}{\nu}$</td>
</tr>
<tr>
<td>$HZ_{\mu} Z_\nu : (-ig_{\mu \nu})2 \frac{m_Z^2}{\nu}$</td>
<td>$HHHH : (i)3 \frac{m_H^2}{\nu^2}$</td>
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The exploration of the coupling to weak bosons plays now a pivotal role in understanding the nature of the scalar boson observed experimentally. **New physics can be hidden in these couplings.**
When measuring the Higgs boson transverse momentum certain discrepancies were found with the Standard Model

\[ H \rightarrow \gamma\gamma \]

\[ H \rightarrow ZZ^* \rightarrow 4\ell \]
Combination with the SM (HRes) is 2% 

Look at other talks in this session for BSM interpretations of this plot.
<table>
<thead>
<tr>
<th>Variables</th>
<th>Cut Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lepton $p_T$ (leading, subleading)</td>
<td>&gt;$(30 \text{ GeV, } 20 \text{ GeV})$</td>
</tr>
<tr>
<td>$m_{\ell\ell}$</td>
<td></td>
</tr>
<tr>
<td>$E_T^{\text{miss}}$</td>
<td>$76–106 \text{ GeV}$</td>
</tr>
<tr>
<td>$\Delta R_{\ell\ell}$</td>
<td>$&gt;120 \text{ GeV}$</td>
</tr>
<tr>
<td>$\Delta \phi(\vec{p}_{T\ell\ell}, \vec{E}_T^{\text{miss}})$</td>
<td>$&lt;1.8$</td>
</tr>
<tr>
<td>Fractional $p_T$ difference</td>
<td>$&gt;2.7$</td>
</tr>
<tr>
<td>Number of $b$-jets</td>
<td>$&lt;0.2$</td>
</tr>
<tr>
<td>$\Delta \phi(\vec{E}_T^{\text{miss}}, \text{jets})$</td>
<td>$0$</td>
</tr>
<tr>
<td>$p_{T\ell\ell} / m_T^{ZZ}$</td>
<td>$&gt; 0.4$</td>
</tr>
<tr>
<td></td>
<td>$&lt; 0.7$</td>
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