BEYOND STANDARD MODEL SEARCHES FOR HIGGS BOSONS AT THE TEVATRON
OUTLINE

- Introduction
- 4th Generation and fermiophobic scenarios
- Scalar bosons in cascade decays
- Neutral bosons inspired by MSSM
- Overview and Conclusions
Ten year RunII ended 30\textsuperscript{th} September 2011

\(~12 \text{ fb}^{-1} \text{ delivered}\)
\(~10 \text{ fb}^{-1} \text{ recorded for analysis}\)
Broadly similar general purpose detectors
With differing strengths

CDF: excellent central tracking with large lever arm

DO: Hermetic calorimeter and large muon acceptance
Extension of SM – add an extra generation of fermions

Extra quarks:
- gluon-gluon fusion dominates production overwhelmingly
- modifies low mass BRs

Extra leptons:
- possibly modified high mass BRs depending on masses

Reanalysis of SM search in WW and ZZ with only ggF signal – selection re-optimised

95% CL in two scenarios:

Low mass:

\[ m_{l4} = 100 \text{ GeV} \quad m_{v4} = 80 \text{ GeV} \]
\[ m_{u4} = 450 \text{ GeV} \quad m_{d4} = 400 \text{ GeV} \]

121 – 225 GeV (observed)
118 – 270 GeV (expected)

High mass:

\[ m_{l4} = m_{v4} = 1000 \text{ GeV} \]
\[ m_{u4} = 450 \text{ GeV} \quad m_{d4} = 400 \text{ GeV} \]

121 – 232 GeV (observed)
118 – 290 GeV (expected)

Accepted PRD: arXiv:1303.6346
Assume scalar boson couplings to fermions vanish but otherwise SM-like

Only VH and VBF production contribute

WW decay dominates
But enhancement of $\gamma\gamma$ contributes most sensitivity at low mass
Reanalysis of SM searches – combination of WW, ZZ and $\gamma\gamma$ with only VH and VBF signals

95% CL exclusions:

$100 < M_{Hf} < 116$ GeV (observed)

$100 < M_{Hf} < 135$ GeV (expected)

Accepted PRD: arXiv:1303.6346

(See also, coupling fits in Gavin’s talk on Friday afternoon)
CASCADE DECAYS

Considers decay chain with heavy scalar $H^0$, assuming $h^0(126)$:

$$H^0 \rightarrow H^\pm + W \rightarrow W + h^0 + W \rightarrow W + bb + W$$

Simplified 2HDM model

Event selection similar to top-pair production, lepton+jets analyses:
1 electron or muon,
4 or more jets,
>0 b-tags
significant missing ET

Signal:
Madgraph+PYTHIA

Background:
top and W/Z+jet ALPGEN+PYTHIA
multijet – data driven control region

Select events with $M_{jj} \sim M_W$
Search in $M_{bb}$
Cross section limits derived in 2D space: $M_{H^\pm}$ vs $M_{H^0}$

Vary between 1300 to 15 fb, no theoretical exclusion

Tevatron combination of searches with b-quark final states

3 or 4 b-quarks in the final state

Single boson production inspired by MSSM with enhanced \(bb\phi\) couplings for \(\tan\beta>1\)

Avoid too much model dependence – could be sensitive to other new physics
MSSM-LIKE NEUTRAL BOSON

CDF:
2.6 fb\(^{-1}\)
- b-jet triggers, 3 jet selection with secondary vertex b-tagging

Require 3-bjets ~ 11.5k events

Data driven background templates

Signal: PYTHIA reweighted to MCFM cross section versus pt
MSSM-like Neutral Boson

**DO**:  
5.2 fb\(^{-1}\)  
b-jet triggers,  
3 jet selection with NN b-tagging  

Require 3/4-bjets ~ 15k / 12k events  

Backgrounds:  
Ratio of MC templates used to reweight data with 2 b-tags  

Signal PYTHIA reweighted to MCFM
Model independent limit assumes narrow state $pt > 12$ GeV on associated b-jet

Model dependent MSSM scenario - full width simulation

Excess about 2 s.d. after trials factor

Many different searches over the years:
MSSM inspired searches for neutral and charged bosons
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MSSM inspired searches for neutral and charged bosons

**Neutrals:**
- Phys. Rev. Lett. 102, 051804 (2009)

**Charged:**
- Phys. Rev. Lett. 102, 191802 (2009)
- Phys. Rev. D 80, 051107 (2009)
- Phys. Rev. D 80, 071102 (2009)
- Phys. Rev. D 80, 101804 (2009)
- Phys. Rev. D 84, 071102 (2011)
Many different searches over the years:
nMSSM, double charged bosons, long lived states, heavy states, Hidden valley scenarios
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Doubly charged Higgs:

nMSSM:

Hidden Valley and long lived Higgs:
Many different searches over the years:
Fermiophobic and 4th generation fermion scenarios
Many different searches over the years:
Fermiophobic and 4th generation fermions

4th Generation Searches:
+ accepted Phys. Rev. D:
arXiv:1303.0823
arXiv: 1303.6346

Fermiophobic:
Phys. Rev. Lett. 102, 231801 (2009)
Also in:
arXiv:1303.0823
arXiv:1303.6346
Huge programme of research covering many areas of BSM Higgs physics

Over 40 publications in Run II 😊

No sign of physics beyond the SM 😞
Tevatron Run II,
$L_{\text{int}} \leq 10 \text{ fb}^{-1}$
SM4 Higgs combination

95% C.L. Limit/SM4 (low mass) Pred.

Expected w/o Higgs
Observed
Expected ± 1 s.d.
Expected ± 2 s.d.
SM4 (high mass)

$m_H (\text{GeV/c}^2)$