Search for Supersymmetry in a Vector Boson Fusion-Like Topology at CMS

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Outline

• Classical SUSY Searches
• Supersymmetry in VBF
• What is VBF and Why?
• 8 TeV Analysis
  ❖ VBF + MET+Dilepton SUS-14-005, JHEP 11 (2015) 189
  ❖ VBF + MET SUS-14-019, PRL 118 (2017) 021802
• Prospect for 13 TeV search:
  ❖ New Approach with Mu+VBF Trigger
• Summary
Classic SUSY Searches

- Many SUSY searches focused on the colored sector
- Limits of these models probe masses up to ~1.7 TeV for squark gluinos.
- These type of signatures have final states with MET+multijets (+leptons)(+photons)
- Colored objects expected to be heavy and the production cross-sections are large
- In compressed mass spectra scenarios MET is small and jets (+leptons) (+photons) are soft
- No good sensitivity for compressed spectra scenarios

- DM particles produced in pairs after cascade decay of chargino neutralino
- Signature: Met+leptons and ISR Jet
Why VBF?

• VBF tagging useful in tackling some of the interesting physics channels
• VBF topology provides a complementary probe to look for compressed spectra
• Smaller predicted cross sections but lower level of hadronic activity
• Complements the color searches
• EWK’s expected to be light compared to the colored particles
VBF Kinematics?

• One jet pair with $m_{jj} > 250$

• Jet $P_T > 50$

• $|Δη| > 4.2$

• While V+Jets more central with small dijet invariant mass, Signal characterized by non-central Jets with large dijet invariant mass

• MET>75
Main BG’s

- $Z \rightarrow \ell\ell + \text{jets}$:
  1. $Z \rightarrow ee/\mu\mu$: fake $E_T^{\text{miss}}$ from mis-measured jets + ISR jets conforming to the VBF topology
  2. $Z \rightarrow \tau\tau$: real $E_T^{\text{miss}}$ from the tau decays + ISR jets.

- $W + \text{jets}$: prompt lepton from the $W$ ($W \rightarrow \mu/e/\tau + \nu$) and recoil jets and ISR jets passing the VBF cuts.

- multijets:
  1. b-jets and leptons from $t\bar{t}$
  2. QCD light quark/gluon
Data-Driven Background Estimation

- Our general strategy to predict backgrounds across all channels:

- Scale background estimation before VBF cuts with a control region ‘CF(CR w/o VBF)’ where CF is correction factor data to MC.

- Determine efficiency of VBF cuts with another (independent) control region ‘$\epsilon_{VBF}$’.

- A closure test is performed in MC. The difference between the nominal and predicted yields in the closure test, is taken as a systematic error.
8 TeV EWK SUSY Search

- Data: 19.7 fb\(^{-1}\) at 8 TeV with inclusive muon trigger \((p_t^\mu> 24\,\text{GeV})\) and di-tau trigger \((p_t^\tau> 35\,\text{GeV})\)
- Final states with \(\text{e}\mu, \mu\mu, \mu\tau, \tau\tau\) plus MET and 2 VBF Jets
- Both Opposite and Same sign charge pair
- \(|\eta_{\text{lepton}}|<2.1, |\Delta\eta_{\text{jets}}|>4.2\) and \(\eta_1\eta_2<0, p_t^{\text{jets}}>30/45\,\text{GeV}\)
- \(p_t^{\text{miss}}>75/30\,\text{GeV}\)
- Main Backgrounds: ttbar, V+Jets, VV
- Analysis performed by looking at shape of Mjj as discrimination variable

No excess above SM observed
All 8 channels combined

Observed upper bound limit of 170 GeV and an expected limits of 180 GeV set for Compressed scenario
For the average-mass assumption with an uncompressed-mass spectrum the corresponding limit is \(~300\) GeV.
8 TeV Compressed Mass Spectra squark

Signature

- 2 high-pT forward jets and large MET
- Same VBF-like topology strategy as in the EWKino case

Trigger: MET65+VBFDiJet35

Selection: Two jets ($p_T > 50$ GeV with $\eta \eta_2 < 0$; large rapidity gap $|\eta_1 - \eta_2| > 4.2$ and invariant mass $m_{12} > 750$ GeV; no b-tag); MET>250 GeV; veto further jets ($p_T > 30$ GeV)

Dominant bgs: $(Z \to \nu \nu) +$ jets & $(W^\pm \to l^\pm \nu) +$ jets estimated from data

Consistent with SM!

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<tr>
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<th>Expectation</th>
<th>Observed</th>
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<tbody>
<tr>
<td>Signal region</td>
<td>132 +/- 14</td>
<td>118</td>
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- Use yield and shape of dijet mass distribution to search for supersymmetry
• Data is consistent with SM expectation
• Up to 315 GeV (obs.) and ~315 (exp.) for $\Delta M < 10$ GeV for compressed sbottom (& stop)

8 TeV Compressed Mass Spectra squark
Prospects of Run II at 13 TeV

- Mu+VBF trigger is commissioned in Run II
- $p_{t\mu}>8$ GeV, $M_{jj}>750$, $p_{tj}>40$ GeV, HTT>600 GeV and MET>60 GeV.

- L1 VBF trigger (L1_Mu6_Mj30j30_360) with L1 seeds including HF → One jet with $|\eta|<3.0$, one jet with $|\eta|>3.0$
- There is a significant difference, Sharp trigger turn-on!
- improved eff. with L1 VBF

- At least one HF jet at L1
Summary

- First VBF topology based search performed successfully with 8 TeV data of CMS
  - SUS-14-005 in dilepton + VBF channels (published in JHEP)
    - A combined observed upper bound limit of 280 GeV and an expected limit on 295 GeV is set, for the large mass gap scenario
    - For the compressed mass spectra scenario we set a combined observed upper bound limit of 170 GeV and an expected limits of 180 GeV
    - The stringent limit of 315 GeV obs. and (~315 GeV expected) for squark in compressed mass spectrum scenario ($\Delta M \sim 5$ GeV)
- New Dedicated lepton+VBF trigger for Run II to improve search sensitivity
  - Trigger active for all of 2016, 2017 data taking
- Stay tuned for interesting results!
Mjj Distributions