Search for charginos and neutralinos produced in Vector Boson Fusion processes through $\tau_+\tau_- + 2$ jets final state with CMS detector at $\sqrt{s} = 8$ TeV

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Introduction

- Supersymmetry (SUSY) is one of the best studied theories for physics beyond the Standard Model (SM).
- Provides natural solution to hierarchy problem, origin of dark matter and many other unsolved problems.
- In SUSY, to each fermion (boson) of SM, there corresponds a supersymmetric boson (fermion).
- Minimal Supersymmetric Standard Model (MSSM) is the simplest extension of the SM that includes SUSY.
- MSSM involves five Higgs bosons ($h^0, H^0, A^0, H^+, H^-$) along with four neutralinos ($\chi_1^0, \chi_2^0, \chi_3^0, \chi_4^0$) and four charginos ($\chi_1^\pm, \chi_2^\pm$) produced from mixing of gaugino and higgsino states.
- No experimental evidence of SUSY particles found till date, which implies it is a broken symmetry with sparticles masses large enough to evade current experimental bounds.
- SUSY models involving conservation of R-parity, resulting in pair-production of SUSY particles with a stable Lightest SUSY particle (LSP) which is considered as a Dark Matter candidate.
- Each generation SUSY particles are less constrained in those searches.
- Based on searches performed so far, gluinos and 1st/2nd generation SUSY particles found till date.
- Provides natural solution to hierarchy problem, origin of dark matter and many other unsolved problems.
- Provides a way to probe scenarios with compressed spectra by selecting two forward jets with mass $M(jj) \sim 1$ TeV.
- Provides a strong handle on backgrounds by selecting two forward jets with mass $M(jj) \sim 1$ TeV.
- Cross-section of slepton production via Drell-Yan and VBF processes becomes almost comparable at $\sqrt{s}$ = 8 TeV.
- VBF production provides a very strong handle on backgrounds by selecting two forward jets with mass $M(jj) \sim 1$ TeV.
- Experimental evidence of SUSY particles found till date, which implies it is a broken symmetry with sparticles masses large enough to evade current experimental bounds.

VBF as SUSY probe

Based on searches performed so far, gluinos and 1st/2nd generation SUSY particles are less constrained in those searches.

SUSY in VBF processes - complementary to searches for gluinos and 1st/2nd generation SUSY particles.

Provides a way to probe SUSY scenarios with compressed spectra by selecting two forward jets with mass $M(jj) \sim 1$ TeV.

VBF Kinematics

Benchmark Point: $M(\chi_2^+) = M(\chi_2^-) = 180$ GeV, $M(\chi_1^0) = 90$ GeV, $M(\chi_1^+) = 300$ GeV.

QCD Background Estimation

- QCD multijet is the dominant background for fully hadronic final state.
- The MC statistics is not sufficient to model it properly so fully data-driven approach is used.
- Keep the same central selections, but invert opposite-sign requirement i.e. select like-sign $\tau\tau$ pairs (No VBF selections).
- Subtract the like-sign non-QCD MC backgrounds from the like-sign data (contamination from like-sign non-QCD MC backgrounds is very very small ~ 1%).
- $R_{QCD}$ is measured using a sample of non-isolated taus.
- Extract the shapes and QCD contribution by applying $R_{QCD}$ to the like-sign region.

Z-$\tau\tau$ Background Estimation

- For additional validation, obtained a semi-clean enriched sample of Z-$\tau\tau$ background by requiring opposite-sign tau-pair to have invariant mass < 90 GeV.
- Enhances confidence in the understanding of Tau ID selections and double-Tau trigger.
- Data-to-MC scale factor = 1.07 $\pm$ 0.17.
- Negligible Bkg contribution in the Signal Region.

Signal and Background Processes

- QCD: Multijets fake hadronic taus.
- Z-$\tau\tau$: Two real taus decay hadronically.
- Z-$\rightarrow$\mu\mu/ee: $\ell$+$\nu$+$\ell$+$\nu$ fake hadronic taus.
- W+$\tau$+$\nu$: Isolated leptons combined with non-isolated jets.
- $\tau$+$\nu$+$b$: Two $\tau$s from top decay provide jets (fake $\tau$s) along with b-jets.

Analysis Strategy

- **Central Selections:**
  - Standard TauID selections.
  - Central selections expected to be well simulated by MC.
  - Whenever possible, obtain background enriched control regions.
  - Obtain Data-to-MC correction factor in these control regions.

- **VBF Selections:**
  - Select at least one pair of high $p_T$ jets with large separation ($\Delta R$) and large invariant mass.
  - VBF selections provide background suppression of the order of $\sim 10^{-3}$-$10^{-4}$.
  - Mis-modelling of background rate in the Signal Region is expected to come from VBF selections.

- **Standard Model Backgrounds:**
  - Z+$\rightarrow$\mu\mu/ee: $\ell$+$\nu$+$\ell$+$\nu$ fake hadronic taus.
  - Z+$\rightarrow$\mu\mu/ee: $\ell$+$\nu$+$\ell$+$\nu$ fake hadronic taus.
  - W+$\tau$+$\nu$: Isolated leptons combined with non-isolated jets.

- **Analysis Strategy:**
  - **QCD Multijet Background:**
    - For additional validation, obtained a semi-clean enriched sample of Z+$\rightarrow$\mu\mu/ee by requiring opposite-sign tau-pair to have invariant mass < 90 GeV.
  - **Z+$\rightarrow$\mu\mu/ee Background:**
    - Enhances confidence in the understanding of Tau ID selections and double-Tau trigger.
  - **W+$\tau$+$\nu$ Background:**
    - Data-to-MC scale factor = 1.07 $\pm$ 0.17.
  - **Negligible Bkg contribution in the Signal Region.**

**SUMMARY**

- The SM backgrounds can be controlled by VBF cuts (2 energetic forward jets) to probe light EWKinos and slepton sectors.
- Searches for EWKinos and sleptons via VBF processes are complementary to existing SUSY searches.

References