Search for VBF production of heavy resonance decaying to Z(nunu)W/Z(qqbar) final state

Kamal Lamiachane, Shuichi Kunori, Andrew Whitbeck

Introduction
- July 4, 2012: Discovery of Higgs boson.
- Standard model (SM) got its complete form but fails to answer the following:
  - Gravity and why gravity is so weak, dark matter (confirmed from the astrophysical observations: gravitational lensing, rotational curve of galaxy) etc.
  - These persuaded the new physics beyond the SM (BSM) is very likely.

BSM Physics
- Extra-Dimension (ED): proposes a heavy resonance decaying to a pair of SM bosons.
- Randall-Sundrum (RS) model: the most attractive setup of warped ED at the TeV scale, as it provides an alternative solution to the aforementioned problems [1-3].
- Proposes one additional dimension i.e. 5th dimension which extends between the planck scale and the TeV (weak) scale
- Particles carry momentum to ED. So, from $E^2 = m^2$, what they look like to us are heavy particles of 0(ED).
- Radions (scalar): hold (stabilizes) the two branes together.
- Wprime: Do the higher generation exists for heavy vector boson.
- This motivated the search for a heavy resonance.

Abstract
A search for heavy resonances decaying to a pair of vectors bosons is presented which utilizes events in which a hadronically decaying Z or W boson is identified using jet substructure techniques and large missing transverse momentum is found. Data analyzed were recorded by the Compact Muon Solenoid experiment at the CERN Large Hadron Collider in 2016, 2017, and 2018, and correspond to 137 fb⁻¹. The events are categorized as having arisen from Vector Boson Fusion process or not, and are characterized by their transverse mass distribution. The standard model backgrounds are estimated based on observed yields in control regions. No excess of events above the expected SM background are observed and limits are placed on the production cross section of Radion (spin-0), Wprime (spin-1) andBulk graviton (spin-2) particles.

Experimental Techniques
Jet: collimated spray of particles (quarks, gluons, & their combinations (hadrons)). Reconstructed in a cone of radius R in descending order of pT with an algorithm (anti-kt (AK)) i.e. AKR. Commonly used jets are AK4 or AK5 (fat jet for boosted case).

Background Estimation & Limit Setting

Vector Boson Fusion (VBF) Feature
- Kinematics is significantly different for the ggF vs VBF production due to polarization effect [3]
- This quirky feature in VBF process is one of the significant aspects of this analysis, i.e., to explore the new physics scenarios which manifest themselves not just a traditional bump-like feature from a Jacobian peak, but with more complicated shapes that encode the polarization of the resonance itself.

Result
We didn’t see any excess of signal events over the standard model background. However, 95% CL limit plot on production of graviton does not exclude the possibility of resonance for any graviton mass. Hence, we need more data to either see or set up the more strict limit on the production of graviton mass. This analysis is published with 2016 data for the interpretation for spin 1 and 2 resonance produced via ggF production mode only.

Current efforts has been analyzing full Run-2 (2016-2018) data for the interpretation for spin 0.1.2 resonance produced via both ggF and VBF modes. Currently this analysis is in approval process for publication within the CMS collaboration at CERN, after which the results will be made public.

Conclusion
- We presented the analysis on search for a heavy resonance on Znunu/V(had) channel.
- We observed significantly different distribution for the key kinematic variable in VBF production mode than what we expected in ggF mode.
- This analysis facilitates the framework in search for the new physics using polarization as a key feature.
- We utilized the jet substructure technique as it is a powerful tool to get better S/B and will be even more inelivable as we march towards high mT LHC.
- Experimental data agrees well with the SM background prediction. We didn’t observe any excess in signal (based on 2016 data).
- If we see the signal, then we don’t only see the ED, we will see the first quantum gravity particle also.

References: