Searches for Heavy Resonances with ATLAS

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Mid-Run-2 Search Status

- Look to Run-II to uncover what is beyond the SM
- Other than the SM Higgs, no new particles discovered
- Many Run-1 search channels already explored at the new Run-2 energy
- Increasingly complex and new final states
  - 3rd generation quark searches
  - Resonances produced in association with other objects
  - Boson final states with hadronic decays
ATLAS has a total of 100 fb$^{-1}$ of 13 TeV pp data recorded
- Expect another $\sim$60 fb$^{-1}$

Two years of 13 TeV data ready for physics papers $\sim$36 fb$^{-1}$
- 2015 with $<\mu> = 13.4$
- 2016 with $<\mu> = 25.1$

First preliminary results including full 80 fb$^{-1}$ of 13 TeV data
- 2017 46.9 fb$^{-1}$ with $<\mu> = 37.8$
First Look at Complex Final States

Run: 267638
Event: 193690558
2015-06-13 23:52:26 CEST
Resonances in B-Jet Mass Spectrum

- Search for resonances in the invariant mass spectrum of jet pairs from b-quark(s)
  - New Physics with preferential coupling to 3rd generation quarks
- Dedicated low and high mass searches
  - Low mass makes use of b-jet trigger
    - Require two b-jets
    - Fills in gap with TeVatron result
  - High Mass uses single jet trigger
    - Search in single or double tag events
- Fit invariant mass spectrum of highest p_T jet pairs
  - Search for excess above smoothly falling background with BumpHunter
    - No significant excess seen → set limits on SSM Z’, leptophobic Z’, excited b*, & Gaussian signal
- At 95% Confidence Level limit on M_{Z’} < 2.0 TeV
  - Highest di-b-jet mass event observed at 6.77 TeV

J. Love -- ATLAS Heavy Resonances -- LHCP201
All Hadronic W’ to tb

- Search for resonances in the invariant mass spectrum of jets from top- & b-quarks
  - Large-R Jet Substructure techniques used to identify jets from the top-quark
    - Allow for b-tagged jet inside Large-R jet to increase sensitivity
    - First analysis to make use of the Shower Deconstruction Jet Sub-Structure technique
  - Shower Deconstruction calculates a likelihood of an observed shower configuration from the sum of all possible shower histories
    - Probability of observed jet to be initiated by top quark vs gluon/light-quark jet
    - Validated in semi-leptonic ttbar events

\[ \chi_{SD}(\{p_T^k\}) = \frac{\sum_{\text{perm}} P(\{p_T^k\}|\text{top-quark jet})}{\sum_{\text{perm}} P(\{p_T^k\}|\text{gluon/light-quark jet})} \]

See Poster by A. Dattagupta
All Hadronic W’ to tb

- Search performed in 3 signal regions
  - Based on number and quality of jet-tags
    - One or two b-tagged jets
    - Loose & top-tight tagged jet
  - Background templates modeled from 2D sideband method of tagged and untagged jets
    - Loose top tag & one b-tag jet used as validation region
- No excess observed use Log Likelihood Ratio of S+B/B use to set 95% CL limits
- Set limits on SSM W’ with either left or right handed coupling
  - Limit on $M_{W'R} < 3.0$ TeV
  - Limit on $M_{W'L} < 2.9$ TeV
  - Highest $m_{tb}$ observed at 5.8 TeV

See Poster by A. Dattagupta
Di-jet Resonances in Events with Leptons

- Search for resonances decaying to a pair of jets in events with leptons
  - Either produced as an Initial State Radiation or as part of a decay
- Fit di-jet invariant mass distribution with analytic function in sliding windows
  - No significant deviation found
    - Largest discrepancy at 3.5 TeV with 0.7σ global significance
- 95% CL limits are set on the upper limit of generic new physics signal as a function of mass and width
  - Mass limits are set on a low scale technicolor $\pi_T$ to be less than 0.5 TeV and a Sequential Standard Model $Z'$ less than 2 TeV
Hadronic Searches with Bosons
Search for resonances in the invariant mass of hadronically decaying W- or Z-bosons
- W/Z jets are identified via $p_T$ dependent JetMass and $D_2$ jet moment requirement
- W/Z jets are built out of Large-R jets of Track-CalorClusters (TCCs)
  - Particle flow like algorithm takes advantage of the energy response of the calorimeter and the angular resolution of the tracking detectors
- Clear improvement in resolution of $D_2$ jet moment over topocluster jets
  - Effect is increasing with jet $p_T$
Background is estimated via fit of an analytic function to the observed data
- Fit between $1.2 \, \text{TeV} < m_{VV} < 5.0 \, \text{TeV}$
  - Validated in data driven control region
  - No significant excess is observed
- 95% CL Limits are set on Heavy Vector Triplet and bulk RS $G_{KK}$
  - Bulk RS $G_{KK}$ excluded between $1.2 - 1.9 \, \text{TeV} \& 2.1 - 2.3 \, \text{TeV}$
  - HVT excluded between $1.2 - 3.4 \, \text{TeV}$ for $g_V=1$ and $1.2 - 4.15 \, \text{TeV}$ for $g_V=3$
Resonances decaying to HH $\rightarrow$ 4 b’s

- Search for high mass resonances decaying to Higgs pairs
  - Performed a resolved four jet and boosted two Large-R jet channel
    - Resolved channel selects events with two reconstructed Higgs pairs that minimizes the linear distance $D_{HH}$
    - Boosted channel selects events with b-tagged track jets (R=0.2) ghost associated with Large-R jets
- Data driven estimation of dominant backgrounds in both channels
  - No significant excess is observed
  - Limits are set on the cross section of a narrow width scalar
    - Additionally on $G_{KK}$ for two values of $k/M_{PL}=1, 2$
Search for $\gamma+{W/Z/H}$

- Search for resonances decaying to a $\gamma$ and a $W$-, $Z$-, or $H$-boson that decays hadronically
  - First search for $\gamma+H$
- Hadronic boson decays identified by $p_T$ dependent Jet Mass and $D_2$ jet moment requirement and ghost associated $N$ track requirement
- Fit $m_{\gamma j}$ distribution with analytic function
  - No evidence for resonances found
  - Most discrepant point at 2.5 TeV in $W\gamma$ with a <1$\sigma$ global significance

- 95% CL Limits are set on Spin-0, -1, -2 resonances
  - $\sigma x BR$ Limits on $\gamma+W/Z$ range from 10 fb to 0.1 fb between 1 - 6.8 TeV of mass
  - $\sigma x BR$ Limits on $\gamma+H$ range from 10 fb to 4 fb between 1 - 3 TeV of mass
Summary and Conclusions

• ATLAS has recorded 100 fb\(^{-1}\) of 13 TeV data
  • Two years and 36 fb\(^{-1}\) used in published papers so far
  • Preliminary results with 80 fb\(^{-1}\) now starting to come out
• Using the Run-II data ATLAS has performed searches in increasingly complex final states with more advanced techniques
  • Searches in di-jet final states
    • In final states with b-quarks use b-jet trigger to improve sensitivity to low mass
    • Shower Deconstruction used to improve sensitivity in \(W' \rightarrow tb\)
    • Di-jet mass search in association with a Lepton
  • Searches with Gauge Bosons
    • Resonances decaying to Di-W/Z boson improve sensitivity with TCC jets
    • Di-higgs resonances decaying to four b-quarks making use of b-jet triggers
    • Photon+W/Z/H new search in Higgs final state
• No significant deviation from the background only hypothesis has been observed
• More analyses are already underway to fully explore the 13 TeV LHC dataset
Additional Material