Search for new resonances decaying into boosted W, Z and H bosons at CMS
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Why look for Diboson resonances?

General searches for new physics connected to the gauge sector:
- coupled to $W$, $Z$ and $H$ bosons

Model independent analyses interpreted according to benchmark models:
- **Warped Extra Dimension:**
  Integration of gravity in SM and solution to hierarchy problem
  - Prediction of a spin-2 graviton or spin-0 radion
- **Heavy Vector Triplet model:**
  Hierarchy of the Higgs boson mass:
  - Introduction of spin-1 massive bosons ($X^0, X^+, X^-$)
Heavy resonances decaying to bosons

- Heavy new particles produce boosted SM bosons

\[ \sim \text{TeV} \]

\[ W/Z/H \quad \text{with } p_T \sim \text{few hundred GeV} \]

- Highest BR is from hadronic final states \((W/Z/H \rightarrow qq)\)
- Decay products from SM bosons are highly collimated

\[ dR(qq) \sim 2m/p_T \]
Boosted bosons

Bosons produced with high $p_T$ merge into a single large-$R$ jet (0.8 CMS).
Boson tagging

The boosted $W/Z/H(b\bar{b})$ signal is identified as large cone size jets:
- $R=0.8$
- PUPPI (PileUp Per Particle Id) is used to mitigate pile up effects

Our tools:
- jet mass
- the composite nature of the jet using substructure
- $b$-tagging to reconstruct the two B hadrons from the $b$ and $\bar{b}$ within the same fat jet
  - Measurable lifetime: $\tau \sim 500 \, \mu m \rightarrow \beta \gamma c\tau \sim 5 \, mm$ @ 50 GeV
  - displaced secondary vertex

$H/Z(b\bar{b})$ background $q/g$
**Boson Tagging observables**

- **JET MASS AFTER GROOMING**
  - remove soft and wide-angle radiation (soft drop)
  - Primarily aimed to separate W/Z/H-jets from q/g

- **JET SUBSTRUCTURE**
  - measures the degree to which a jet can be considered as composed of N prongs

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Tagging observables

Identifies the two B hadron decay chains from $b$ and $\bar{b}$ within the same fat jet.

• Identifies the two B hadron decay chains from $b$ and $\bar{b}$ within the same fat jet.
**X → VV/VH (V=W/Z)**

- **Hadronic** final state benefit from the highest BR
  - most sensitive at high mass
- **Leptonic** states give more sensitivity at lower masses to beat down backgrounds
$X \rightarrow VV \rightarrow JJ$

- Online selection full efficient for resonance mass $> 1$ TeV
- Two large cone size jets, each compatible with $V$ hypothesis
- Dijet mass is used to extract the signal
Sensitivity to BSM resonances decaying into WW, WZ and ZZ of cross section ~ 1-50 fb in the 1.2-4.1 TeV mass range
**$X \to VH \to J_{b\bar{b}}$**

- Similar approach as for $VV \to JJ$, and double-$b$ tagging to identify the $H(b\bar{b})$ candidates
$X \rightarrow VH \rightarrow J_{bb}$

Sensitivity to BSM resonances decaying into WH and ZHZ of cross section ~ $1-100$ fb in the 1-4.5 TeV mass range
$X \rightarrow HH(4b)$

- Similar approach as VH/VV $\rightarrow JJ$ and double-$b$ tagging to identify the H(b$b$) candidates
- Multijet background predicted from mass sidebands obtained by inverting the $b$-tagging requirement on the $p_T$ leading jet
$X \rightarrow HH$

$H(b\bar{b})H(b\bar{b})$ most sensitive channel for $m_X > 400/500$ GeV

$H(\gamma\gamma)H(b\bar{b})$ complement in the low mass
The 13 TeV dataset should increase by a factor 3 by the end of Run 2 in 2018

- LHC will probe *smaller couplings with more data*

- Improvements are also possible from:
  - optimized events selection and improved object reconstruction
  - include *theory improvements* on SM predictions

Stay Tuned
-Additional Material-
Performance

~40% improvement

light

g(bb̄)

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The mistag rate is approximately flat across the $p_T$ range by design.

Critical point for searches.
**Kind of ABCD**

* Get absolute normalization for the SR by interpolating between left and right jet mass sidebands
* using failed double-b tag events to predict those that would have passed
* If we require double-b tag on the other jet there is no overlap with VH

![Diagram showing the ABCD method]

AT * R = SR

Using A/B and C/D to predict N(AT)/N(SR) as function of jet mass
* but to take into account the correlations between double-b-tag and jet mass
  * more slices in jet mass
  * from a fit we determine the pass/fail ratio for the signal region
going further...

So we measure the $R_p/f$ as function of jet mass

$AT \times R(m_J-125) = SR$

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Uncertainty on the prediction

We associate two different errors to the prediction:

* **uncertainty on transfer factor as correlated among bins**
  * 2-15% impact on exp sensitivity
* **bin-by-bin statistical uncertainty from the anti-tag region statistics**
  * 1-4% impact on exp sensitivity