Search prospects for b-associated Z’ in the dimuon final state

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• Hints at new BSM physics are scarce
• LHCb reports an excess in the muon to electron ratio of $R_{K^*} (B^0 \rightarrow l^+ l^- K^* \text{ JHEP 08 (2017) 055})$ and $R_K (B^+ \rightarrow l^+ l^- K^+ \text{ Phys. Rev. Lett. 113, 151601 (2014)})$
• Combining both measurements, the excess may amount to $\approx 4\sigma$ to date JHEP 1801 (2018) 093
A new heavy gauge boson $Z'$ with flavour violation?

- Model: A new heavy gauge boson $Z'$ with non-universal couplings
  
  $\text{Phys. Rev. D 97, 075035}$

- To explain observed anomalies, couplings to 3rd gen. quarks, 2nd gen. leptons + a flavour-violating bs-coupling necessary $g_\mu$

\[
g_b \cdot \delta_{bs}
\]

For this talk, I’ll only consider the above three couplings

Couplings in model inspired and restrained by flavour sector anomalies

Model proveds a direct connection between general purpose LHC experiments and heavy flavour sector experiments
1. Why look for b-associated Z’

2. How to find b-associated Z’

3. Current inclusive vs projected exclusive reach
As light quarks don’t couple directly to this kind of Z’, the bottom pdfs and the bottom luminosity from gluon splitting play a major role.

**0 assoc. jets**

**1 assoc. jets**

**2 assoc. jets**

For a medium b-tag requirement and $p_T(\text{jet}) \geq 30$ GeV, the rate of [0/1/2] associated b-tagged jets is [80.1%/18.5%/1.5%] for a 200 GeV Z’ and [71.8%/25.1%/3.0%] for a 500 GeV Z’.

Associated b-tagged jets are central and soft.

For $p_T(b) \geq 20$ GeV: [74.0%/23.8%/2.1%] for a 200 GeV Z’.

The flavour-violating coupling $\delta_{bs}$ switches on contributions by s quarks and lowers the relative amount of associated b-tagged jets.
An inclusive $Z'$ search from CMS (shown in the left) suffers mostly from $Z^0/\gamma^*$, followed by $t\bar{t}$ backgrounds.

*For preselection, we require two opposite sign muons as well*

*In addition, we require at least two jets ($p_T \geq 30$, $|\eta| \leq 5$) and at least 1 medium bottom tag among them*

*The preselection efficiency for (leptonic) $t\bar{t}$ is 8%*

*For (leptonic) DY, it’s 0.2%*

*For $Z'$ of [200/350/500] GeV, it is [7% / 10% / 13%]*

arXiv:1803.06292 [hep-ex]
Plots shown are after preselection

- After preselection, at least two jets and two muons are present
- We take both exclusive permutations of the leading two jet+muon pairs
- For the lowest difference in mass between pairs, we require the largest mass of that pair to be $> 170 \text{ GeV}$
- The efficiencies after preselection are: 17\% for $t\bar{t}$, 41\% for DY, [60\%/82\%/90\%] for a [200/350/500] GeV Z'}
Difference in hadronic vs leptonic activity

- Plots shown are after preselection

- The associated jet spectrum for the signal is soft compared to the backgrounds

- We require the scalar sum of the leading two muon transverse momenta $L_T$ to be greater than the scalar sum of the leading two jet transverse momenta $H_T$

- The efficiencies after preselection and top-mass bound are: 26% for $t\bar{t}$, 32% for DY, [74%/90%/94%] for a [200/350/500] GeV $Z'$
Plots shown are after preselection

- The $Z'$ signal has no natural source of transverse missing energy, bar reconstructed object mismeasurements
- Therefore, we normalize the $E_{T}^{\text{miss}}$ to the dimuon mass to account for the most energetic sources of mismeasurement, and require this quantity to be below 0.2
- The efficiencies after preselection, top-mass bound, and $H_{T} - L_{T}$ are: 27% for $t\bar{t}$, 54% for DY, [89%/97%/98%] for a [200/350/500] GeV $Z'$
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Current reach of CMS inclusive search - and where it may beat dedicated searches

- With this kind of selection, so far only Delphes limits by the presented phenomenology study are available.
- Still, it motivates where a dedicated studies might do better, and where it won’t.

For low flavour-violating couplings, a dedicated analysis might be complementary or better for \( m(Z') \leq 350 \text{ GeV} \)

For large \( \delta_{bs} \) couplings, inclusive analyses will cover more ground, unless going even closer to the \( Z \) peak with the \( Z' \) mass.

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The presented phenomenology study suggests that a dedicated search for b-associated Z′ is beneficial in searching for an explanation of the $R_K$ and $R_K^*$ anomalies.

Further pheno studies on different final states (like ditau) are work in progress.

As this model does not allow coupling to electrons, a data-driven background estimation from dielectron events should keep systematics to a minimum for experimentalists.

Defining further search regions, especially exactly 1 associated b-tagged jet (e.g. 12% rate for a 200 GeV Z′), may improve sensitivity of actual analyses beyond the shown projection.