

Bottom Fermion Fusion initial states

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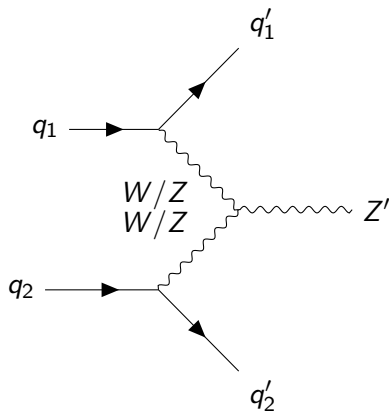
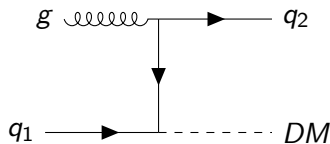


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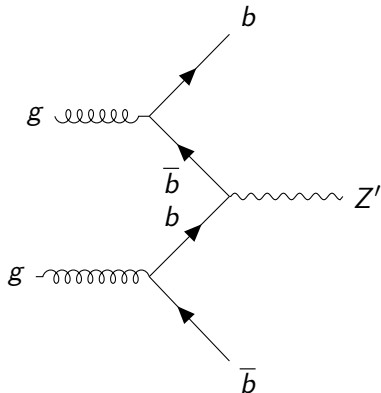
- 1 Motivation of BFF initial states
- 2 BFF kinematic properties
 - BFF vs QCD

The usefulness of special initial states

- Specific initial states are utilized in various ways to search for new physics:
 - 1 Direct dark matter production +1 jet \rightarrow Monojet searches
 - 2 New physics + Vector Boson Fusion quark jets \rightarrow VBF searches
- These kinds of analyses utilize known physics for the initial state to suppress Standard Model backgrounds
- As a bonus, different initial states make these analyses complementary by design
- So let's add a state to the list

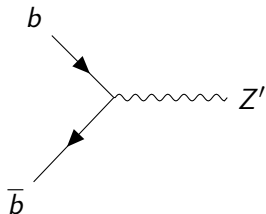


Bottom Fermion Fusion

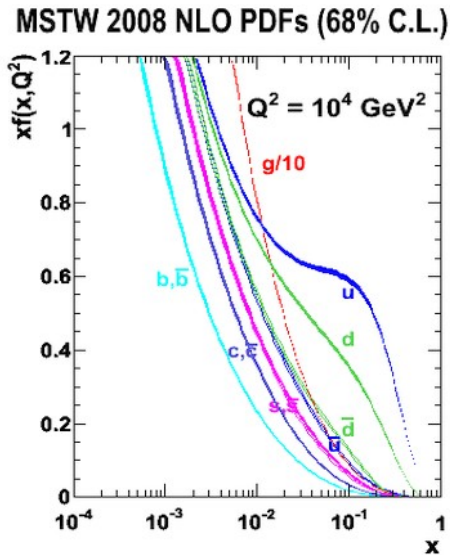


- Utilizes the only reliably identifiable jet state (bottom quarks)
- Is a handle on physics coupling to 3rd generation quarks
 - +0 jet states suppressed in direct production by bottom PDFs
 - +1 jet radiative diagrams suppressed by e. g. $\frac{1}{M_{Z'}^2}$

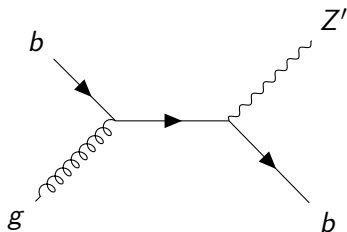
Suppression of $+0$ jet initial states



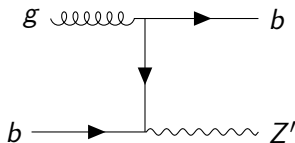
- Bottom states directly from the parton distribution functions are very rare
- Having a bottom + anti-bottom initial state carrying appreciable momenta is exceedingly unlikely



Suppression of +1 jet initial states



- Taking a gluon from one proton solves most of the necessary momentum supply for heavy resonance production
- But radiating e. g. a Z' is suppressed by a factor of $\frac{1}{M_{Z'}^2}$ in addition to the bottom pdf

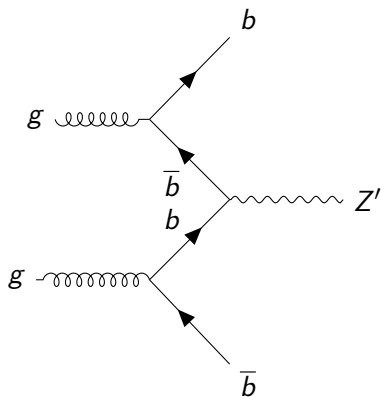


- Having a gluon split to $b\bar{b}$ solves the radiative suppression, but adds a $g \rightarrow b\bar{b}$ branching ratio factor in addition to the bottom pdf

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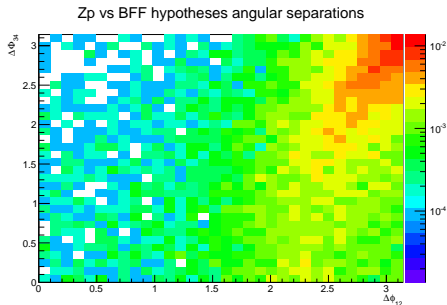
Kinematics of BFF compared to likely backgrounds



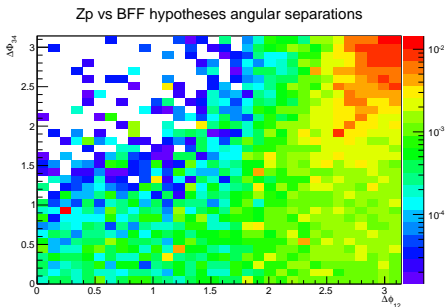
- If the BFF-produced heavy resonance decays hadronically, a final state with 4 bottom jets is likely
 - The dominant background in this scenario is QCD ($gg \rightarrow b\bar{b}b\bar{b}$, as well as misidentified jets)
 - Subdominant backgrounds include DY in $Z+2$ bottom jets and di-boson production
- If the BFF-produced heavy resonance decays leptonically, we'd expect two bottoms and two leptons in the final states
 - The dominant background in this scenario is $t\bar{t}$
 - Subdominant backgrounds include DY +2 jets and di-boson production

$$\Delta\phi_{34} = \text{BFF} \text{ vs } \Delta\phi_{12} = Z'$$

Z' 500 GeV



QCD

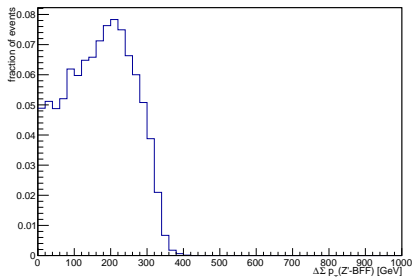


- If a heavy resonance is produced, the BFF jets are most likely to be the least energetic jets in the event
- So taking the 3rd and 4th leading jet (generator jet level, $p_T(4) > 30$ GeV) denotes the BFF system
- The first two leading jets are hypothesized to originate from a Z' here

Scalar transverse momenta gap between Z' and BFF

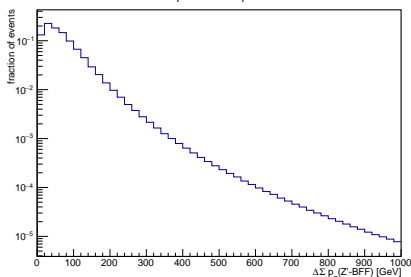
Z' 500 GeV

$\Sigma p_T(Z') - \Sigma p_T(\text{BFF})$



QCD

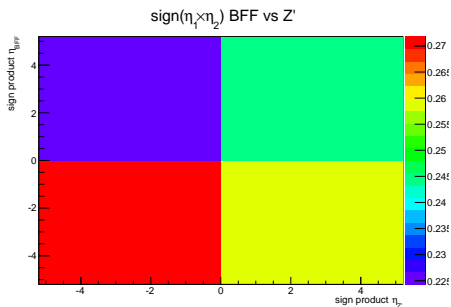
$\Sigma p_T(Z') - \Sigma p_T(\text{BFF})$



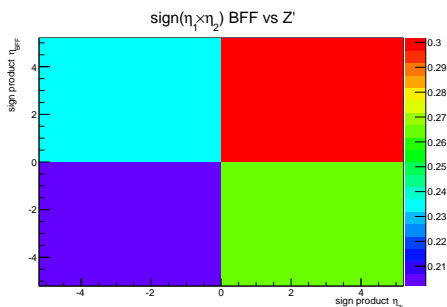
- Depending on the resonance mass, a large gap between the BFF jet transverse momenta and the Z' jet transverse momenta will occur
- For QCD, a large gap is the least likely case
- Thereby, in heavy resonance cases the background is more easily suppressed

Sign products of BFF vs Z' hypotheses

Z' 500 GeV



QCD



- The BFF production is, unlike for VBF, very central
- There are slight differences in the forward-backward configurations of the jet systems with respect to QCD

- Additional jets in initial states have their place in complementary ways to access new physics (Monojet or VBF)
- Bottom Fermion Fusion initial states might be yet another way to access new physics coupling to third generation quarks
- Preliminary look into discriminating variables are somewhat promising with respect to QCD and $t\bar{t}$