`MuXboostedBTagger` user guide

Keith Pedersen (kpeders1@hawk.iit.edu)

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Abstract

This user guide explains how to use the `MuXboostedBTagger` module for Delphes, along with some of its internal kinematic expressions.

1 Code notes

1.1 Robust subjet mass

We define the subjet of B hadron decay

$$p_{\text{subjet}} = p_{\text{core}} + p_\mu + p_{\nu_\mu}, \tag{1}$$

where the "core" is ostensibly a charm hadron. Since the neutrino is not observable, we estimate it using the simplest choice ($p_{\nu_\mu} = p_\mu$, since most of the momentum comes from their shared boost). This gives us an approximate subjet

$$p_{\text{subjet}} \approx p_{\text{core}} + 2\,p_\mu. \tag{2}$$

The core is found by reclustering the jet using a much smaller radius parameter. This produces a list of *candidate* cores, of which only one is the "correct" core; this is found by using the hardest muon in the jet to find the core which produces $\sqrt{p^2_{\text{subjet}}}$ closest to $m_B = 5.3$ GeV (the mass of a B hadron admixture). However, since m_{core} is not accurately measured (from the granularity of the Calorimeter), we must first constrain it to its hypothesized mass under the B hadron decay hypothesis ($m_{\text{core}} = 2$ GeV).

In order to find the core quickly, we don't want to correct the mass of each core candidate before adding the muon. Instead, we can use our large cut on muon p_T to treat the muon as massless, then calculate the mass of the subjet analytically

$$p^2_{\text{subjet}} \approx m^2_{\text{core}} + 2\,p_{\text{core}} \cdot p_\mu \approx m^2_{\text{core}} + 4\,E_\mu E_{\text{core}}(1 - \cos(\xi)\sqrt{1-g}), \tag{3}$$

where ξ is the angle between the muon and the core and $g \equiv \gamma^{-2}_{\text{core}}$. Using $y = \tan(\xi)^2 = \left(\frac{\vec{p}_{\text{core}} \times \vec{p}_\mu}{\vec{p}_{\text{core}} \cdot \vec{p}_\mu}\right)^2$ and $\cos(\xi) = \frac{1}{\sqrt{1+y}}$ (since $\xi < \pi/2$), this becomes

$$p^2_{\text{subjet}} \approx m^2_{\text{core}} + 4\,E_\mu E_{\text{core}}(1 - \frac{\sqrt{1-g}}{\sqrt{1+y}}). \tag{4}$$

This expression can be optimized to minimize floating point cancellation, (which should be small, eliminating unnecessary cancellation is a good habit)

$$p^2_{\mathrm{subjet}} \approx m^2_{\mathrm{core}} + 4\,E_\mu E_{\mathrm{core}} \frac{g+y}{1+y+\sqrt{1-((g-y)+g\,y)}}. \tag{5}$$