Search for neutral long-lived particles decaying into displaced jets in the ATLAS calorimeter

Motivation for Long-Lived Particle Searches
- Long-lived particles (LLPs) have finite lifetimes $\tau$ such that $c\tau \gtrsim 10 \mu$m
- Many theories aimed at resolving fundamental mysteries such as dark matter, baryogenesis, neutrino masses, and naturalness predict the existence of neutral LLPs beyond the Standard Model (SM) [1]
- Most LHC searches focus on promptly decaying particles and could overlook the unique detector signatures of LLPs

Results
- Event Selection
  - At least one signal jet candidate must match a triggering HLT jet
  - Limits compared to a separate search at short lifetimes in Figure 12
  - Event is cut if time of signal or BIB jet candidates not consistent with IP collision

Backgrounds
- QCD multijet events with neutral hadrons are the dominant background due to large cross section
- Beam-induced background (BIB) results from particles traveling nearly parallel to the beamline upstream from ATLAS, as illustrated in Figure 3
- Cosmic rays can also fake displaced jets

Event Selection
- Two jets classified most signal-like by BDT are considered signal jet candidates
- At least one signal jet candidate must match a triggering HLT jet
- Event is cut if time of signal or BIB jet candidates not consistent with IP collision
- Low-$E_T$: selection
  - Complete visible with $E_T(j_1) > 160$ GeV, $p_T(j_2) > 60$ GeV, $\Sigma E_T(j) > 2.5$, $E_T^{\text{miss}} < 0.6$
  - $1$ and $2$ refer to the jet candidates
- $H_T^{\text{miss}}$ is the transverse component of the vector sum of the momenta of all jets with $p_T > 30$ GeV, and $H_T$ is the scalar sum of their $p_T$
- Event BDT output shown in Figures 7 and 8

Full Run 2 Analysis Plans
- Full analysis workflow preserved in RECAST framework
  - Using to reinterpret with new signals
    - Low-$E_T$, trigger was active for only part of 2016 but all of 2017-2018
    - Replacing per-jet BDT with a deep neural network to identify displaced jets
    - Long short-term memory (LSTM) architecture
    - Uses information from topoclusters, tracks, and muon segments
    - Studying channels that combine in-calorimeter decays with other LLP detector signatures in order to improve limits and extend to lower or higher lifetimes
    - For example, one LLP decaying in the calorimeter and the other decaying within the inner detector into two nearly trackless jets (Figure 14)

References
[2] A. Manousos et. al., ATL-SOFT-SLIDE-2016-832
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