Search for long-lived particles decaying into displaced hadronic jets in the ATLAS Calorimeter

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2. a) Signal

•We look for two jets which are consistent with long-lived particles decaying in the Hadronic Calorimeter (HCAL) or the end of the Electromagnetic Calorimeter (ECAL)

•The **width** of the jet will be small due to the late decay

•The jet will leave most of its energy in the **HCAL**

•There will be **no tracks** pointing from the Interaction Point to the jet

2. b) Background

An event that does not come from signal, but manages to **mimic** it. There are three types (in order of increasing importance): Cosmic Muons, BIB, QCD

•**Cosmic Muons:** Muons created in the atmosphere may reach the detector and deposit energy in the Hadronic calorimeter

•**Beam-induced Background (BIB):** Muons created by LHC protons colliding with the ATLAS collimator or beam gas.

•If it loses most of its energy by bremsstrahlung in the Hadronic Calorimeter, will have all typical properties of our signal

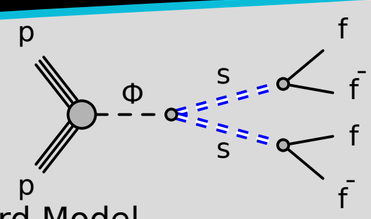
•**Jets** are quarks hadronizing into showers of particles

•A typical jet will start as **tracks** ( ) of charged particles, deposit energy in the **Electromagnetic Calorimeter** ( ) and beyond that the **Hadronic Calorimeter** ( )

•**QCD jet:** Standard model proton-proton interaction

•May mimic signal if many constituents are **neutral** or the jet is **mis-measured**

1. Hidden Sector model



•Hidden Sectors (HS) are an extension to the Standard Model

•They can give rise to **long-lived particles** and may also contain **dark matter candidates**

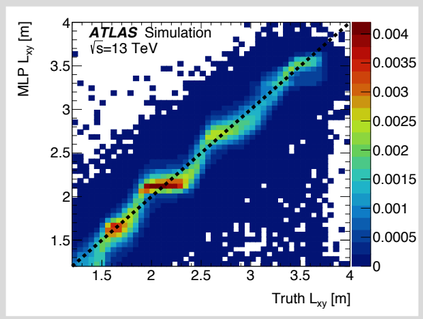
•This analysis uses the HS model as a benchmark to search for long-lived particles decaying in the ATLAS Calorimeter

•In this a model heavy neutral boson Φ [mass 125-1000 GeV] decays to two neutral long-lived particles s [mass 5-400 GeV]

4. Analysis Flow

•The ATLAS calorimeters are **segmented** in the radial and longitudinal directions

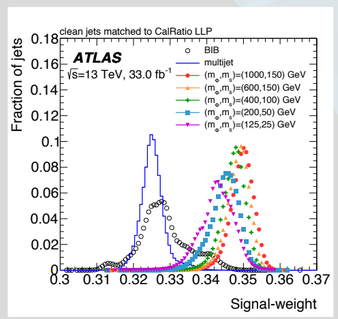
•These are used as inputs to a **Neural Network** which predicts the decay position of the particle which created the jet



NN

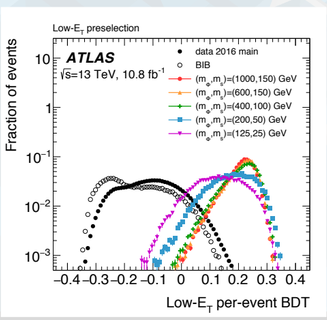
•Predicted decay position, jet and track variables, are input to the per-jet **Boosted Decision Tree** (BDT)

•This per-jet BDT gives each jet a Signal, BIB and QCD (multijet) weight - the higher the weight, the more confident the BDT is of the **jet type**



BDT

•The two jets with highest signal weight, and the two jets with highest BIB weight, in addition to other event variables, are input to an **event-level BDT**



BDT

5. Background Estimation

•The **data-driven** ABCD method is used for background estimation.

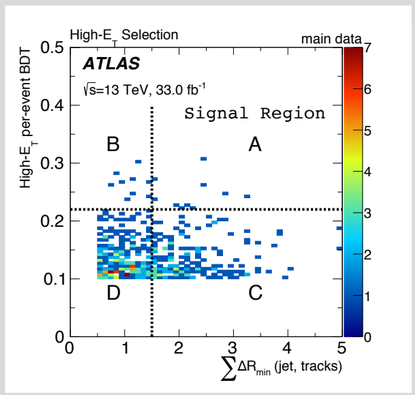
•Two uncorellated variables are used to factor the background distribution

•Region A is used as the **signal region**

•In absence of signal, $N_A = (N_B \cdot N_C)/N_D$, where N_X is the number of events in X

•A modified ABCD method is used that allows for signal contamination outside region A by fitting to background and signal models simultaneously

•BIB and Cosmic contamination checked to be small using a Validation Region



6. Results

•No excess of events is seen in Hidden Sector models tested

•The CL_S method is used to set **limits** on the benchmark Hidden Sector model used in the analysis

•**Systematic uncertainties**, such as those on the ABCD method, Monte Carlo modelling and Jet Energy Scale, are included as nuisance parameters in fit

•The results are **combined** with complimentary searches for long-lived particles decaying in the Muon Spectrometer of the ATLAS detector