Search for BSM Physics using Challenging Signatures with the ATLAS Detector

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Abstract. Many theories beyond the Standard Model predict signatures difficult to reconstruct and for which estimating the background is also a challenge. This proceeding will focus on the most recent results using 13 TeV pp collisions produced at the LHC and recorded by the ATLAS detector.

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1 Introduction

Up to now, no striking deviations from the Standard Model (SM) have been observed at the LHC. Measurements are in agreement with SM predictions over a very broad range of cross sections. The ATLAS experiment [1] at the LHC has collected an unprecedented amount of data at the largest proton-proton collision energy of $\sqrt{s} = 13$ TeV. The current and future collision runs allow exploration of uncovered phase spaces. One of the most promising methods to search for new physics is unconventional signatures *e.g.* long-lived particles (LLPs). In these proceedings we review the latest searches performed by the ATLAS experiment targeting LLPs. First, methods to trigger on and reconstruct these peculiar final states are discussed, then a selection of LLP searches are presented.

2 Event Triggering and Reconstruction

Since Run1 ATLAS has designed specific triggers that have large efficiencies for LLP signatures [2]. It is possible to trigger efficiently down to relatively small energy/momentum thresholds without being swamped by background. As an example, to efficiently select LLPs decaying outside the electromagnetic calorimeter (ECAL) (*i.e.* with a decay length $L_{xy} \gtrsim 2$ m in the laboratory frame), the *CalRatio* trigger [3] looks for an unbalance in the energy deposited in the hadronic calorimeter (HCAL) with respect to that in the ECAL ($\log E_{\text{HCAL}}/E_{\text{ECAL}} > 1.2$). Trigger efficiencies are shown in Figure 1.

In ATLAS, tracking reconstruction has been optimized for tracks coming from the primary vertex or at most displaced vertices compatible with b -hadron and τ -lepton lifetimes. Tracks from LLPs decaying at distances larger than few mm might have not been reconstructed with traditional tracking algorithms. *Large Radius Tracking* has been developed to keep large efficiencies for LLPs

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Figure 1: Simulated *CalRatio* trigger efficiency as a function of the LLP decay length (left) and transverse momentum (right). Efficiencies for different mediator Φ and LLP masses are shown with different colors. Filled (Open) markers correspond to different Level-1 trigger selections optimized for higher (lower) transverse energy [3].

decaying up to $L_{xy} \sim 30$ cm. Since these are very CPU expensive algorithms, they run only on $\sim 1\%$ of the hits in the inner tracker.

3 Long-Lived Particle Searches

Searches for LLPs have been performed by ATLAS targeting several signatures.

3.1 Dark Photon

LLPs decaying in the HCAL and in the muon spectrometer (MS) have been interpreted as dark photons predicted, for example, by the FRZV model [4]. Pairs of dark photons could be produced by a boson, as the SM Higgs boson or another BSM boson, mediating the SM with the dark sector (*e.g.* $H \rightarrow \gamma_D \gamma_D + X$). Dark photons may be long lived and subsequently they decay in pairs of muons, electrons or pions. Events are triggered requiring a large multiplicity of muon candidates reconstructed only within the MS with relatively low transverse momentum threshold ($p_T > 6$ GeV) or considering decays in the outer portions of the calorimeter with the *CalRatio* trigger. Hadronic and muonic dark photon candidates are further discriminated from multijet and cosmic backgrounds, respectively, using Boosted Decision Trees [5]. The background has been evaluated with *data-driven* methods. Limits on the LLP proper decay length $c\tau$ have been translated in terms of the kinetic mixing parameter ϵ in the FRZV model as shown in Figure 2.

3.2 Displaced Jets

Neutral LLPs decaying in the HCAL or at the outer edge of the ECAL can be identified by looking at displaced jets signatures. These events are triggered with the *CalRatio* trigger. Jet candidates have been selected using a BDT

Figure 2: Exclusion regions for the decay $H \rightarrow \gamma_D \gamma_D + X$ of the Higgs boson as a function of the γ_D mass and of the kinetic mixing parameter ϵ [5].

Figure 3: Exclusion limit on $\sigma(pp \rightarrow \Phi) \times BR(\Phi \rightarrow ss)$ with $m_\Phi = 600$ GeV. Limits looking for events decaying before the calorimeter and MS have been combined [5].

discriminating signal from multijet and beam induced backgrounds that have been evaluated with data-driven methods. No significant excess was observed, and exclusion limits on the proper decay length of the LLP mediator boson Φ have been set for several mass hypotheses m_Φ [3]. In Figure 3 such limits are reported for $m_\Phi = 600$ GeV. This search improves the limit obtained by looking at decays in the MS in particular for $c\tau$ values $\simeq 10$ m.

4 Conclusions

No evidence of BSM physics has appeared so far at the LHC. Pursuing efforts towards signature-based searches for new physics, ATLAS has unleashed its physics potential by looking at unconventional signatures. However relevant efforts have to be made to adapt trigger and reconstruction algorithms targeting these specific signatures. This will become more and more important as larger integrated luminosities will be delivered.

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