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Long-Lived Particles at HL-LHC with the ATLAS detector

Abstract

Several new physics models that extend the Standard Model require the existence of Long-Lived Particle (LLP) as a solution for the problems like Dark Matter and Naturalness. The new ATLAS Phase-II setup with its huge statistics and updated detectors offers an opportunity to probe the yet unexplored region of the phase space. For muon spectrometer based searches neutral LLP decaying to collimated jets of leptons and light hadrons (lepton-jets) are of great interest. These particles offer an unique signature that can lead to an early discovery. New triggering techniques and algorithms have been developed and studied to improve the selection of both highly and poorly boosted lepton-jets.

Run2 Level-1 di-muon Trigger Limitations

Dark sector models are a probe and a challenge for the ATLAS muon trigger system. A dark photon is considered as light vector mediator for this model [1]. The typical signature is a highly boosted object that can decay to collimated structures containing pairs of muons.
There are two critical features in triggering these events:

- Low p_T threshold
- Muon angular separation

The selection of close-by muon candidates, requires a separation of $0.2\,\eta \times 0.2\,\varphi$ between the two muon candidates. This results in large inefficiencies.
The distribution of the vector portal mediator p_T vs. the opening angle between the two outgoing muons is shown in **Fig.1**. These inefficiencies are also seen in many different searches like the B physics channel $B_s \rightarrow J/\psi\varphi$, **Fig2**.

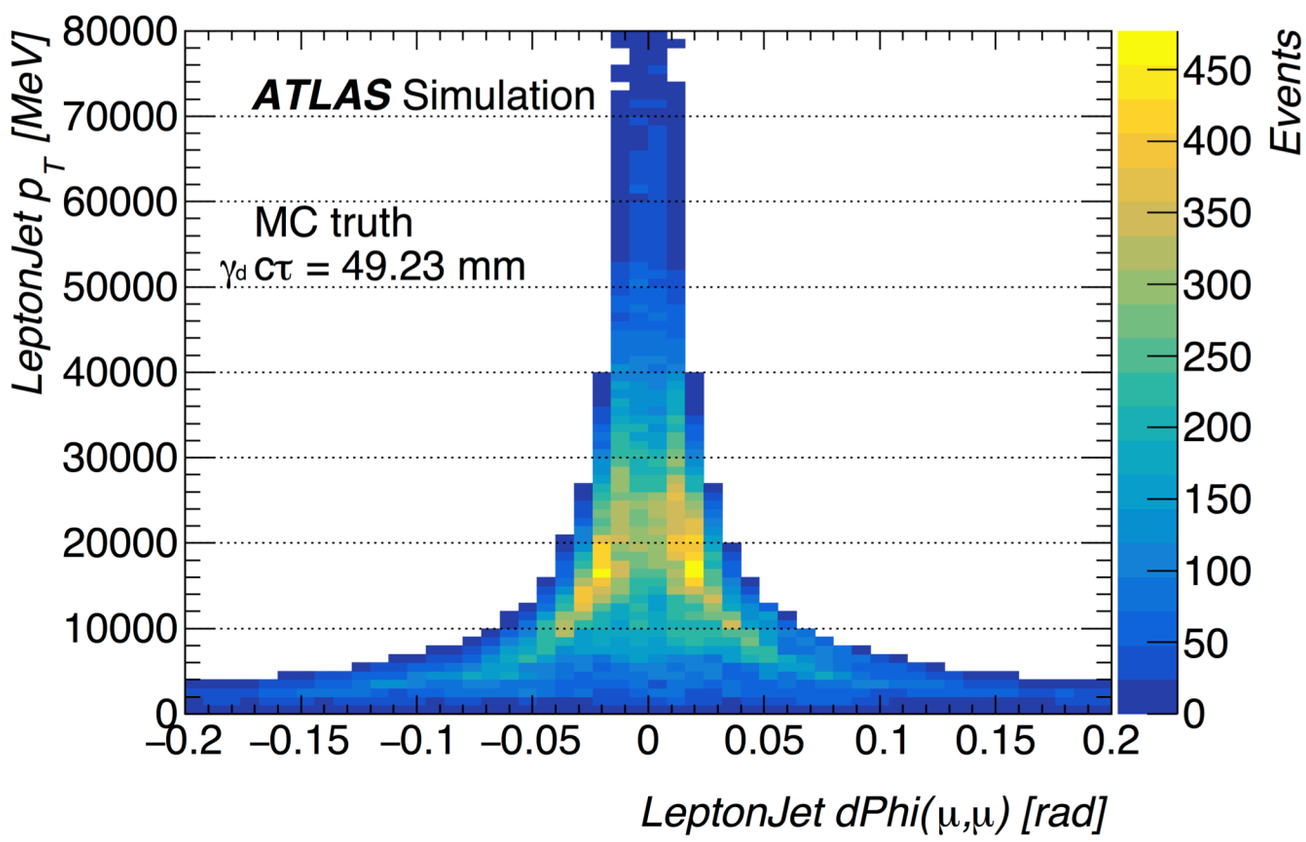

Fig.1 - Truth transverse momentum distribution of the γ_d, vector mediator, as a function of the opening angle in the Φ plane of the two outcoming muons, decay products of the γ_d. Sample with average lifetime $c\tau$ = 49.23 is considered, resulting from Dark Sector models [1].

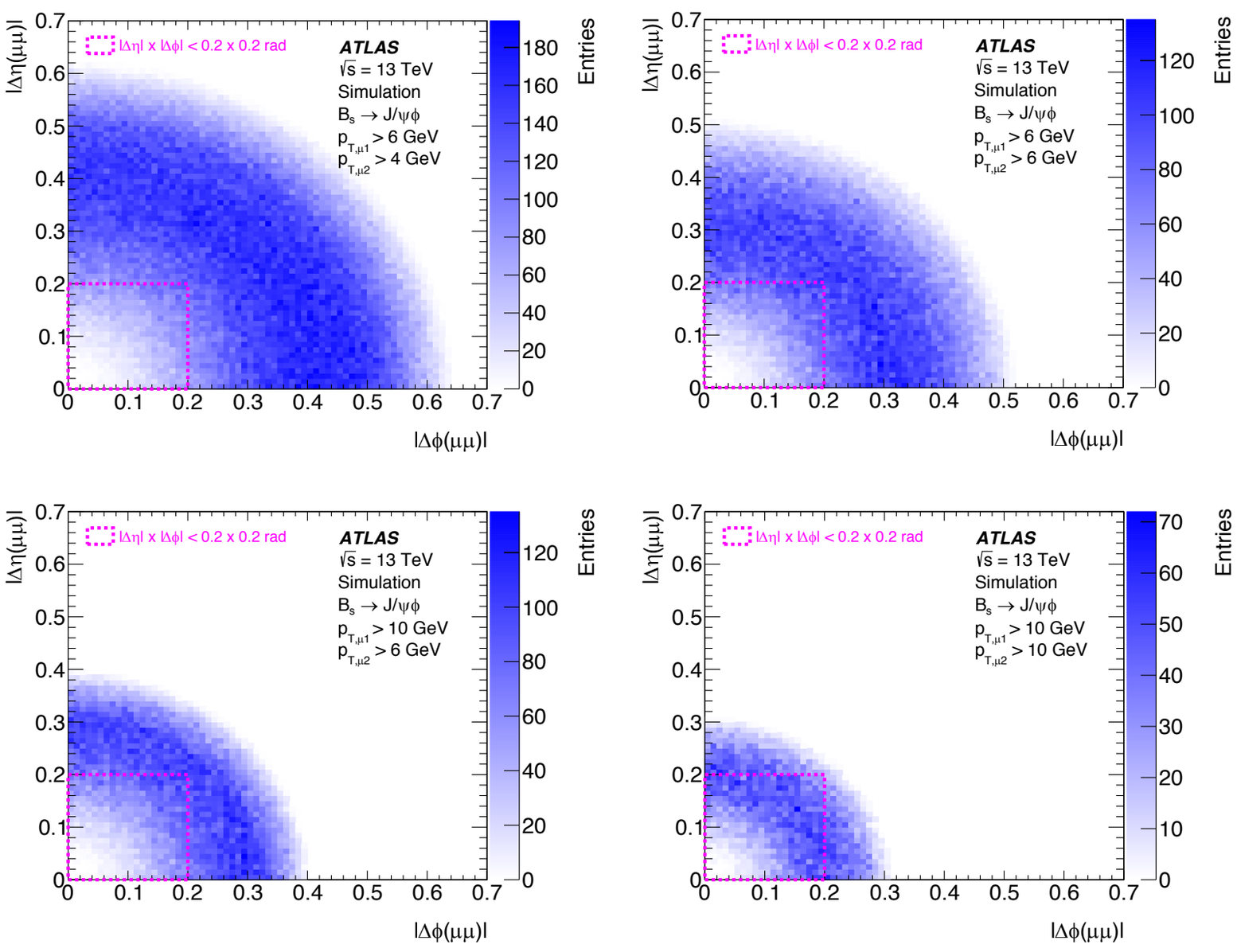

Fig.2 – Truth opening angle in the η plane vs. the Φ plane of the two outcoming muons, for the process $B_s \rightarrow J/\psi\varphi$, for different trigger p_T thresholds

Phase-II Level-0 New di-muon trigger

In these highly boosted events, the outcoming muons from the dark photon are close-by and likely to fall in the same RoI. The current system is able to select only one muon candidate per RoI (~ 0.2η × 0.2φ), any additional information is loss. As can be seen in **Fig.1,** most of the signal is between 10 and 20 GeV and fall in the same RoI. In the current setup, due to the high single muon trigger rate, the lowest possible threshold is a 20 GeV selection, losing most of the events.
A new trigger has been studied, in the context of the phase-II upgrade of the TDAQ system [2], to select multiple muon candidates in the same RoI. Adopting this new trigger it is possible to choose a lower p_T threshold, increasing the sensitivity without increasing sensibly the trigger rate. The efficiency of this algorithm depends on the resolution parameter, the smaller the resolution the higher the efficiency.
Adopting this new trigger a recover of phase space is achieved yielding an overall 10% gain in signal efficiency for the tested vector portal model [1].

[1] A. Falkowski, J. T. Ruderman, T. Volansky, J.Zupan - 'Hidden Higgs Decaying to Lepton Jets' - JHEP 1005:077,2010
[2] ATLAS Collaboration - 'Technical Design Report for the Phase-II Upgrade of the ATLAS TDAQ System' - CERN-LHCC-2017-020. ATLAS-TDR-029

Cristiano Sebastiani on behalf of the ATLAS Collaboration
'La Sapienza' University of Rome and INFN (Italy)