Search for Dark Matter in a Monotop Setup at the LHC

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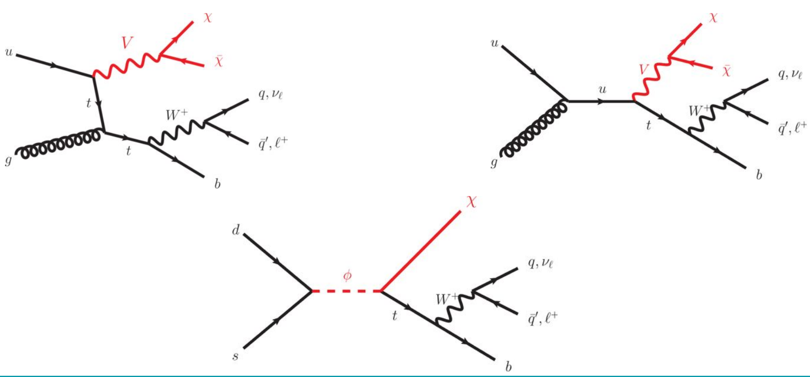
The Standard Model can be considered an approximation at a lower energy of a more fundamental theory which encourages the search for new physics. One evidence supporting that new particles beyond the SM might exist comes from astrophysical measurements that point to the existence of a kind of matter that does not interact with the electromagnetic force, usually referred to as Dark Matter (DM). Although the particles associated with this DM are not expected to interact significantly with detectors, the proton-proton collisions at the Large Hadron Collider (LHC) can produce new particles that couple both to DM candidate particles and to SM particles allowing the detection of these processes. The monotop setup searches for events with one top quark and large missing transverse energy from the DM candidates. The purpose is to present a detailed study on the search for DM in a monotop setup and also contribute to the analysis being done by the ATLAS experiment at the LHC.

Signal Phenomenology

Search for top quark in association with DM candidates. Focusing on the fully hadronic channel. On the top, Feynman diagrams for the Non Resonant case, and on the bottom, a Feynman diagram for the Resonant case are shown.



Mass Working Points

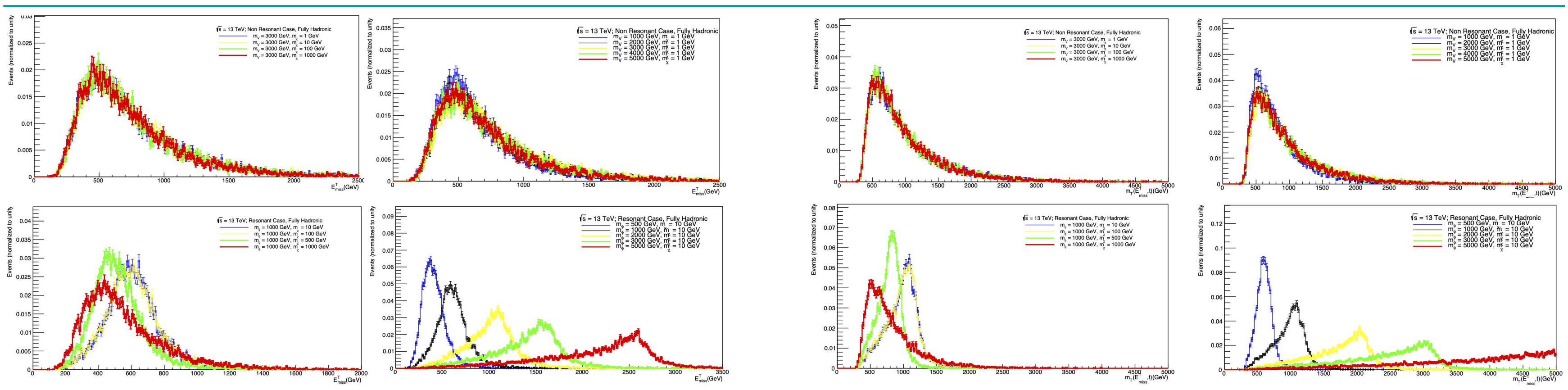
JobOption update from previous analysis [1], for a recent version of Athena.

Particle	χ	ϕ
Mass [GeV]	10	500
		1000
		2000
		3000
		5000
	10	1000
	100	
	500	
	1000	

Particle	χ	V
Mass [GeV]	1	1000
		2000
		3000
		4000
		5000
	1	3000
	10	
	100	
	1000	

On the left, the mass working points for the Resonant case, and on the right, the mass working points for the Non Resonant case are shown.

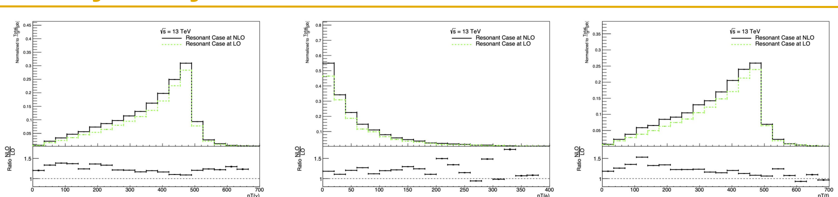
Validation Plots



On the left, the missing energy plots, and on the right the mass transverse between MET and top quark plots are shown. On the top for the Non Resonant case, and on the bottom for the Resonant case.

NLO vs LO Preliminary Study

A preliminary study for the Resonant case was done in order to compare NLO with LO. The samples were generated using MADGRAPH5_AMC@NLO and a new UFO model. [2]



Machine Learning Approach

The generation of signal (Monotop Resonant case) and backgrounds on MADGRAPH5_AMC@NLO with UFO model from the previous analysis [1] and with HL-LHC Delphes card was done. A functional Neural Network was created and there were several ML and HEP metrics implemented.

$$ROC = TPR \quad vs \quad FPR = \frac{TP}{TP+FN} \quad vs \quad \frac{FP}{FP+TN}$$

$$AP = \sum_n (R_n - R_{n-1})P_n$$

$$SIC = \frac{S}{\sqrt{B}}$$

$$Significance = 2(\sqrt{B+S} - \sqrt{B})$$

$$AMS = \sqrt{\sum_i 2\left[(S_i+B_i)ln\left(\frac{S_i+B_i}{B_{0i}}\right) - S_i - B_i + B_{0i}\right] + \frac{(B_i-B_{0i})^2}{\sigma_{bi}^2}}$$

$$B_{0i} = \frac{1}{2}\left(B_i - \sigma_{bi}^2 + \sqrt{(B_i-\sigma_{bi}^2)^2 + 4(S_i+B_i)\sigma_{bi}^2}\right)$$

A training with a set of random HyperParameters and the different metrics was done in order to compare the results with the limit calculation using the CL_s method.

B: Background; S: Signal; SIC: Significance Improvement Characteristic; AMS: Approximate Median Significance;
ROC: Receiver Operating Characteristic; TPR: True Positive Rate; FPR: False Positive Rate;
AP: Average Precision; P: Precision; R: Recall.

To Do

- ➔ Generate more statistics and calculate the k-factor for the NLO vs LO study;
- ➔ Limit calculations using the CL_s method;
- ➔ Conclude which is the best combination of HyperParameters and the best metric to use on HEP studies;
- ➔ GBDT study in order to define ATLAS strategy for the Monotop analysis.

References:

[1] **Aaboud, M., Aad, G., Abbott, B. *et al.*** *Search for large missing transverse momentum in association with one top-quark in proton-proton collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector. J. High Energ. Phys.* 2019, 41 (2019). https://doi.org/10.1007/JHEP05(2019)041

[2] **Cacciapaglia, Giacomo and Conte, Eric and Deandrea, Aldo and Fuks, Benjamin and Shao, Hua-Sheng.** *LHC constraints and potential on resonant monotop production.* Eur. Phys. J. C 79, 174 (2019). https://doi.org/10.1140/epjc/s10052-019-6675-x

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