

Search for dark matter in monojet events in proton-proton collisions at $\sqrt{s} = 33$ TeV

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Abstract

Dark matter becomes an important goal to be searched for many particle physics experiments. The future colliders are also an important step to search for the dark matter, i.e. for 100 TeV machine. In this project, it is studying about the possibility to probe the dark matter at 33 TeV proton-proton collider which is from Standard Model backgrounds to evaluate the discovery potential using the single jet and missing transverse energy. This project can be a part in the motivation for future colliders.

1. Introduction

The compositions of universe can be analyzed from the cosmic microwave background or CMB. From the data of the Planck satellite, the Universe is composed of 3 components. There are only 5% of ordinary matter, 68% of dark energy and 27% of dark matter. There are several evidences that support the existence of dark matter such as rotation curves of galaxies, gravitational lensing and structure formation of Universe.

There are 3 different ways to search for the existence of dark matter including direct detection, indirect detection and collider. The future collider is the way used in this work.

The most popular candidate of dark matter particle is Weakly Interacting Massive Particles (WIMPs) which is a popular type of extension to the standard model of particle physics. They need to be weakly interaction, massive, neutral, no color, stable on cosmological timescales and non-relativistic or cold to form the structure formation of the universe. They remain

undetected and their presence in an event must be inferred from an imbalance of the total momentum of all reconstructed particles in the plane transverse to the beam axis. The magnitude of such an imbalance is referred to as missing transverse energy (MET). The monojet signature can be used to search for the pair production of WIMPs in association with a jet from initial-state radiation (ISR), which is used to tag or trigger the event.

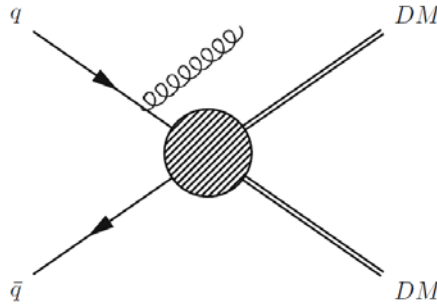


Fig. 1: Feynman diagrams for the pair production of DM particles with a jet emitted from an initial state radiation (ISR).

2. Objectives

To obtain background distributions after passing all selection cuts which are provided for applying data from generator level analysis. The background distributions' data is collected correspond to a normalized integrated luminosity of 10 fb^{-1} with proton-proton collision at a center-of-mass energy of 33 TeV by using DELPHES.

3. Methodology

3.1 Detector Simulation

Background Samples for 33 TeV LHC used in this work are from SNOWMASS2013 [3]. All background estimations are simulated with detector simulation named DELPHES - 3.2.0. Pile up effect of 50 pp interactions per bunch crossing had been included in these simulations.

3.2 Event Selection

The selection cuts below are based on the monojet events in proton-proton collisions at 8 TeV, correspond to the normalized integrated luminosity of 19.7 fb^{-1}

Data sets: Boson + jets, Single Top, Top pair, Diboson

Selection cuts:

$$\text{MET} > 200 \text{ GeV}$$

$$j_1: p_T > 110 \text{ GeV/c}, |\eta| < 2$$

Number of jets ≤ 2

$\Delta\phi(j_1, j_2) < 2$

Muon veto (Muon's $p_T > 10$ and Muon's $\text{Eta} < 2.4$)

Electron Veto (Electron's $p_T > 10$ and Electron's $\text{Eta} < 2.1$)

Tau Veto (Tau's $p_T > 20$ and Tau's $\text{Eta} < 2.3$)

MET > 300 GeV, 400 GeV, 500 GeV, 600 GeV, 700 GeV, 800 GeV, 900 GeV
and 1000 GeV

3.3 Background estimation

Boson + jets, which is the electroweak background mainly from “invisible Z” decays and W+jets, is a dominant background remaining after the monojet event selection. The other background processes are top pair production, single top quark and diboson processes, include ZZ, WZ, and WW.

4. Results

The results are not weighted for each event.

4.1 DELPHES analysis

Numbers of events in the table below come from different integrated luminosity. In fact, they should be normalized with some different factor to the same integrated luminosity which is 10 fb^{-1} before adding them together.

Selection Cuts	Boson + jets	Single Top	Top pair	Diboson	Total BG
MET > 200	3764484	3510145	10594331	1489799	19358759
J1	3652856	3188605	10390640	1301965	18534066
Number of jets ≤ 2	245196	226689	135138	162951	769974
Delta Phi	112714	70006	35814	106750	325284
Muon veto	80181	40140	18205	68768	207294
Electron Veto	46821	9342	4168	34858	95189
Tau Veto	41675	5364	2053	26095	75187
MET > 300	25594	2807	870	16100	45371
MET > 400	20318	1378	493	11638	33827
MET > 500	17276	788	343	7779	26186
MET > 600	13960	578	274	3744	18556
MET > 700	12086	384	223	1642	14335
MET > 800	11013	270	174	668	12125
MET > 900	10030	189	136	220	10575
MET > 1000	8696	131	111	32	8970

Table 1: Number of Events selected at each step of the analysis, for simulation.

4.2 Background distributions

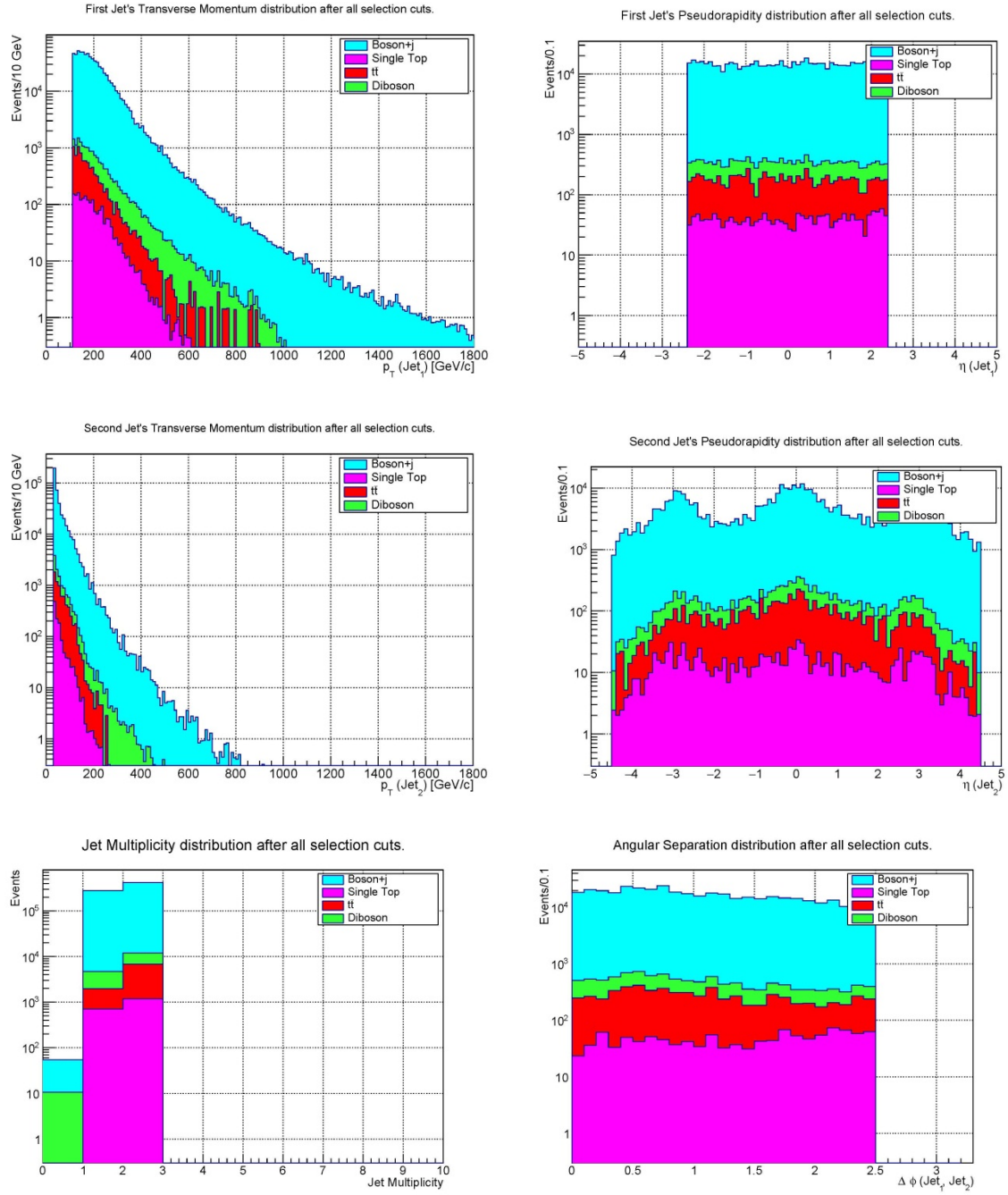


Fig. 2: Plots of basic selection variables for jets

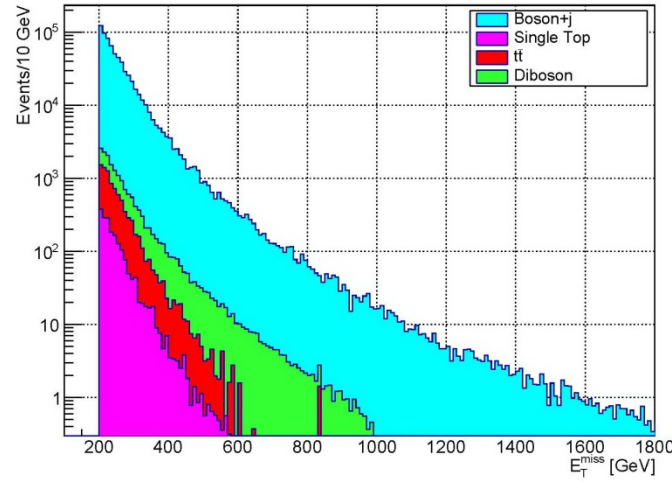


Fig. 3: The missing transverse energy after passing all selection cuts.

5. Summary

Background distributions after passing all selection cuts in the results are leading jet's transverse momentum, second jet's transverse momentum, leading jet's pseudorapidity, second jet's pseudorapidity, angular separation between leading jet and second jet, jet multiplicity and missing transverse energy where boson+jets is the dominant background. Their data will be used to find exclusion limit at some confident level in the next steps in order to know how far we can probe dark matter.

References

- [1] CMS Collaboration, Search for dark matter, extra dimensions, and unparticles in monojet events in proton-proton collisions at $\sqrt{s} = 8$ TeV. Eur. Phys. J. C 75, 235 (2015). doi: 10.1140/epjc/s10052-015-3451-4
- [2] Anwar Bhatti et al., Search for New Physics in the Monojet final state at CMS. CMS Draft Analysis Note CMS AN-12-421 (2014)
- [3] SNOWMASS2013, https://twiki.cern.ch/twiki/bin/view/CMSPublic/NPSnowmass2013Samples#Background_Samples_for_33_TeV_LH (2015)