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Extra Dimensions in Photon or Jet plus Missing Transverse Energy

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Recent studies of the CMS collaboration are presented on the sensitivity to searches for large (ADD) extra dimensions in channels with missing transverse energy (MET), i.e. the channels jets plus MET and photon plus MET. These studies are based on detailed detector simulation, including all Standard Model backgrounds. Particular emphasis is given to possible early discoveries, i.e. with 100 pb^{-1} or less. Projected 95% CL exclusion limits as function of luminosity are presented.

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1. Introduction

The Standard Model (SM) of Elementary Particles has been tested at a high level of precision by many accelerator- and non accelerator-based experiments, which have made it one of the major cornerstone of physics. Nevertheless, the SM is an effective theory valid up to a cut-off energy, affected by a pathology known as hierarchy problem, a puzzling difference between the Electroweak ($\sim 10^2$ GeV) and the Planck ($\sim 10^{19}$ GeV) scales. The Arkani-Hamed, Dimopoulos, Dvali (ADD) model [1] of extra dimensions solves the hierarchy problem introducing δ extra spatial dimensions, which in the simplest scenario are compactified over a torus and all have the same radius R. In this model the Planck scale becomes an effective scale related to the more fundamental scale M_D via the relation: $M_D^{\delta+2} R^\delta \sim M_{Pl}^2$. Consequences of the ADD model are that the extra dimensions can be 'macroscopic' for TeV-ish M_D scales and be tested at colliders such as Tevatron and LHC. Gravitons interact 'weakly' with the ordinary SM particles and escape detection: therefore, two clear ADD signatures of the direct graviton production, which will be probed with CMS detector [2], are a large missing transverse energy (MET) together with high transverse momentum jet or photon.

2. Search for γ + MET at 14 TeV

The topology of this signature is an energetic photon recoiling back to back with a large MET vector. SM processes which can mimic this signature are: Z+γ with Z decaying into neutrinos (irreducible background), the leptonic W+jets decay, W($e\nu$) and W($\tau(e\nu\nu)\nu$), QCD multijets, γ+jets, Z+jets with Z into neutrinos and $\gamma\gamma$ production. Both the signal and the SM backgrounds were processed with the CMS fast simulation. To reject the background a set of cuts is foreseen: MET > 400 GeV and p_T of most energetic jet (jet1) larger than 400 GeV, with the jet contained in the range $|\eta| < 2.4$, a veto against tracks with $p_T > 40$ GeV, $\Delta\phi(\gamma,$ MET$) > 2.5$ and identification of the photon thanks to an isolated photon likelihood > 0.2. The irreducible background can be estimated from Z($\mu\mu$/ee)+jets defining a control region with: photon within $|\eta| < 2.4$ and $p_T > 400$ GeV, muons with $|\eta| < 2.3$ and $p_T > 20$ GeV, electrons with $|\eta| < 2.4$, $p_T > 20$ GeV and electron likelihood > 0.65 and Z in the mass window 80 GeV to 100 GeV, $\Delta\phi(Z,\gamma) > 2.5$ and $(p_T^\gamma - p_T^Z)/(p_T^\gamma + p_T^Z) < 0.25$. The control samples can be then rescaled by branching ratios, acceptance and reconstruction efficiencies. Taking into account photon energy resolution, MET reconstruction uncertainty and PDF systematics, the preliminary result is that 5σ discovery is possible for $M_D \sim$ 1.0 TeV after O(100 pb^{-1}) and $M_D \sim$ 2.0 TeV after O(1 fb^{-1}) for δ = 2.

3. Search for Jet + MET final state at 14 TeV and 10 TeV

The topology of this signature is of one energetic jet back to back with a large MET vector . SM processes which can mimic this signature are: Z+jets with Z decaying into neutrinos (irreducible background), W+jets followed by a leptonic W decay, QCD multijets and $t\bar{t}$+jets and single top production. For this analysis the signal was generated with SHERPA generator [3] version 1.0.11, at 14 TeV, in 18 different samples, with M_D ranging from 2 to 7 TeV and δ = 2, 3, 4 and simulated with the CMS fast simulation, while the W/Z/$t\bar{t}$+jets were generated with ALPGEN 2.12 [3], QCD multijets with PYTHIA 6.409 [3] and simulated with the CMS full simulation. The optimal set

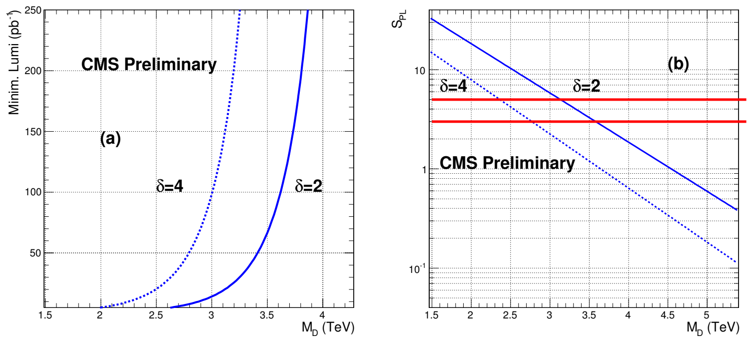

Figure 1: (a): 95% CL exclusion limits in terms of integrated luminosity as a function of M_D and δ. (b): Discovery potential as a function of M_D for 200 pb^{-1}. All estimates are for Monojet at 10 TeV LHC energy.

of selection cuts for this analysis was found to be: MET > 400 GeV, most energetic jet $p_T > 350$ GeV for jet with $|\eta| < 1.7$, Jet ElectroMagnetic Fraction (JEMF) < 0.9, no isolated tracks with $p_T > 15$ GeV in a cone of radius equal to 0.3, finally the azimuthal cuts $\Delta\phi$(MET,jet1) > 2.8 and $\Delta\phi$(MET,jet2) > 0.5 which are very effective to reduce the QCD multijets events. A data-driven technique has been prepared and tested which will allow to estimate the irreducible background from data, Z($\nu\nu$)+jets. This technique will rely on an almost pure W($\mu\nu$)+jets sample selected by requiring a well isolated lepton. The sample will be scaled by theoretical (W/Z ratio) and instrumental (trigger and isolation efficiency) factors after signal selections are applied. Taking into account all systematic uncertainties such as the PDF dependence using CTEQ6M, the potential of discovery was evaluated using the significance estimator S_{pL} [4]. A 5σ discovery reach can be achieved with M_D = 3.1 (2.2) TeV for δ = 2 (4) after O(100 pb^{-1}) (see also [5]). This analysis was repeated at 10 TeV center-of-mass energy. The new analysis exploits corrected jets and MHT, the vectorial sum of the jets above a certain threshold, which replaces the MET in all the analysis. This variable is expected to be less affected by instrumental effects than MET. The set of cuts chosen for this analysis is: MHT > 250 GeV, for jets with p_T > 50 GeV and $|\eta(jet)| < 3$, 0.1 < JEMF < 0.9, p_T (jet1) > 200 GeV, $|\eta(jet1)| < 1.7$, and all the other cuts as considered in the analysis at 14 TeV. Considering all the systematic uncertainties as in the previous analysis the conclusion (see also Fig. 1) is that after 200 pb^{-1}, M_D can be excluded better than 3.8(3.2)TeV for δ = 2(4). Also early discoveries for δ = 2(4) are possible, if M_D is below 3.1(2.3)TeV, respectively (see also [6]).

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