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Search for Extra dimensions in a single-jet and missing energy channel at CMS experiment

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A possible solution to the hierarchy problem is the presence of extra spatial dimensions beyond the three ones which are known from our everyday experience. The phenomenological ADD model of large extra-dimensions predicts a missing transverse energy plus a single-jet signature. This contribution addresses the sensitivity of the CMS detector at the LHC pp collider to parameters of this model, focusing on the conditions expected for second half of 2010 running ($\sqrt{s} = 10$ TeV, O(100) pb^{-1}). It is shown that a significant improvement of the existing limits can be obtained in such an early stage.

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This contributions outlines the analysis procedures for the search of large extra dimensions in the missing transverse energy plus a single-jet channel, using the Compact Muon Solenoid (CMS) detector [1]. The description of the detector performance and the simulated samples of events correspond to what expected for 10 TeV center-of-mass energy and integrated luminosity up to 200 pb^{-1}. Full details of the analysis can be found in Ref. [2].

The phenomenological ADD model [3] aims to solve the hierarchy problem between the electroweak and Planck scales by introducing a number δ of extra spatial dimensions, which in the simplest scenario are compactified over a torus and all have the same radius R. The fundamental scale M_D is related to the effective 4-dimensional Planck scale M_{Pl} according to the formula $M_{Pl}^2 \sim M_D^{\delta+2} R^{\delta}$. Current experimental constraints allow a scenario with $\delta \geq 2$, corresponding to extra-dimensions sizes below $5 \cdot 10^{-2}$ mm if the fundamental scale M_D is of the order of TeV. Searches in both the jet+E_T^{miss} and the $\gamma + E_T^{miss}$ have been performed by CDF [4], D0 [5], and LEP experiments [6]. The best 95% confidence limits on M_D are 1.40(1.04) TeV for the extra dimensions scenario with $\delta = 2(4)$.

This study is focused on the production of a graviton balanced by a energetic hadronic jet via the $q/g\bar{q} \rightarrow g/qG$ processes. The new physics signature is a high-transverse-momentum ($p_T > 100 \div 200$ GeV) jet in the central region of the detector, recoiling back-to-back in the transverse plane with a E_T^{miss} of similar magnitude.

The Standard Model process $Z(\nu\nu)$+jets leads to invisible energy recoiling against jets and is described by the same signature as the signal, thus the contribution from this "irreducible" background needs to be estimated in the best possible way. Other important background sources are $W(l\nu)$+jets, QCD di-jets, top-pair and single-top production.

The ADD model signal has been produced with the SHERPA Monte Carlo generator [7], in different samples with M_D ranging from 1 to 3 TeV and δ from 2 to 6. The transverse momentum of the outcoming parton was required harder than 150 GeV. A set of background processes were generated and processed by a full simulation of the detector. The hadronization and fragmentation of quarks and gluons (along with the underlying event) were performed using PYTHIA 6.409 [8] and the CTEQ61L Parton Density Functions (PDF) [9] were used.

The analysis procedure is based on a set of cuts aimed to maximize the ratio of number of signal events over the square root of number of background events. At trigger level, a single jet stream is exploited, requiring at least 1 jet with $p_T > 70(110)$ GeV at Level 1 (High Level Trigger). The signal leads to a long tail in the distribution of the vectorial sum of jets transverse momenta (MHT), hence a cut MHT >250 GeV was imposed at the pre-selection level. In order to reduce the impact of jets not coming from hard interaction, only jets with transverse momenta larger than 50 GeV within $|\eta| < 3$ are considered. To clean the events from isolated lepton contamination and electrons and photons misidentified as jets, the fraction of jet energy collected by the electromagnetic calorimeter over the total energy is required to be lower than 0.9 and isolated tracks (having less than 10% of p_T in a $0.02 < \Delta R < 0.35$ cone) are removed. The leading jet (jet 1) is required to have $p_T > 200$ GeV and $|\eta| <$1.7. A veto against events with more than two jets and two angular cuts $\Delta\phi(\text{jet}\,1, MHT) > 2.8$, $\Delta\phi(\text{jet}\,2, MHT) > 0.5$ complete the selection. The signal shows up in the MHT distribution an excess of events on top of the dominant background $Z(\nu\nu)$+jets.

The most important systematic uncertainties from theory come from the cross section sensitivity to the renormalization and factorization scale ($^{+7.5\%}_{-6.7\%}$), and from uncertainties on the PDF ($^{+11.5\%}_{-9.5\%}$). Uncertainties associated to energy and angular jet resolution (assumed to be 10% and 0.1 rad, respectively) and jet calibration (shifted by $\pm$10%) turn to be the most relevant instrumental effects. Their relative shift from the value with no systematic effect depends on the ADD points, ranging from 10% to 16%. The value of instantaneous luminosity, that is assumed to have a $\pm$10% uncertainty, was incorporated.

The irreducible background of $Z(\nu\nu)$+jets ("invisible Z") can be deduced from samples of events containing a high-p_T W boson decaying leptonically. The selection defining the control region has been kept the same of signal region, except that a single isolated muon with $p_T >$ 20 GeV and $|\eta| <$2.4 was required. This procedure allowed to reproduce the same kinematic region that was designed for the signal, but having a muon for which the hypothesis of coming from W is highly probable. This sample was cleaned from the processes with at least one well-isolated muon passing the selection, then corrected by the ratio between W+jets and Z+jets production cross sections and muon reconstruction and isolation efficiency. The number of invisible Z events in the signal region is found to be $N(Z(\nu\nu)+\text{jets})^{Sign} = 163 \pm 22\,(\text{stat}) \pm 13(\text{syst}) \pm 17(\text{MC})$[1], to be compared with $N(Z(\nu\nu)+\text{jets})^{MC} = 182 \pm 13\,(\text{stat})$.

The same region was used to measure the $W(l\nu)$+jets contribution in the signal region. All the background estimates are consistent with the result from simulations.

The total background was evaluated as $N_B = 243 \pm 23\,(\text{stat}) \pm 13\,(\text{syst})$ events after 200 pb^{-1}of integrated luminosity. The 95% C.L. limit was extracted by scanning the parameter space to minimize the negative Log Likelihood [11]. The amount of data needed for a 5σ discovery was also calculated, using an estimator based on Profile Likelihood.

These results indicate that the current exclusion limits from Tevatron experiments can be matched at LHC with the first physics run. Exclusion limits at 95% for $M_D = 3$ TeV , $\delta = 2$, $M_D = 2$ TeV , $\delta = 4$ can be reached after only 11 pb^{-1}and 5.0 pb^{-1}, respectively; also early discoveries for $\delta = 2(4)$ scenarios are possible, if M_D is below 3.1(2.3) TeV , respectively.

References

[1] CMS Collaboration, *CERN-LHCC 2006/001*

[2] CMS Collaboration, *CMS-PAS-EXO-09-013*

[3] N. Arkani-Hamed, S. Dimopoulos, G. Dvali, *Phys. Lett.* **B 429**, 263

[4] CDF Collaboration, *FERMILAB-PUB-08-247-E,* submitted to *Phys. Rev. Lett.*

[5] D0 Collaboration, *Phys. Rev. Lett.* **101**, 011601 (2008)

[6] DELPHI Collaboration, *Eur. Phys. J.* **C 38**, 395 (2005)

[7] T. Gleisberg, S. Hoeche, F. Krauss et al. **JHEP 0402**, 056 (2004)

[8] T. Sjöstrand et al. *Comput. Phys. Commun.* 135 **238** (2001)

[9] J. Pumplin et al., **JHEP 07**, 012 (2002)

[10] W.-M. Yao et al. [Particle Data Group], *Journ. of Phys. G* **33**, 1 (2006)

[11] R. D. Cousins, J. T. Linnemann, J. Tucker, *NIM* **A595** 480, (2008)

[1]Notation *MC* refers to the counting error due to the limited number of generated Monte Carlo events.