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Search of extra space dimensions with ATLAS

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Abstract. If extra spatial dimensions were to exist, they could provide a solution to the hierarchy problem. The studies done by the ATLAS Collaboration on the sensitivity of the detector to various extra dimension models are reported in this document.

Keywords. Extra dimension; ATLAS; large hadron collider.

1. Introduction

A few years ago, Nima Arkani-Hamed, Savas Dimopoulos and Georgi Dvali proposed a solution to the hierarchy problem by speculating that there is only one fundamental scale in nature; the electroweak scale [1]. In this setup gravity is much weaker than other forces because it can propagate in extra spatial dimensions and hence its flux lines are diluted, while the standard model fields are confined to the three space dimensions. Since then, the idea of extra dimensions has been a subject of intense phenomenological study.

2. ATLAS studies

The sensitivity of the ATLAS detector to a number of phenomenological models have been studied. The results of some of these studies are reported in the following sections. Most of these studies have used a parameter-based fast Monte Carlo, ATLFAST, to simulate the effects related with the detector. ATLAS is expected to accumulate 100 fb^{-1} data in a high luminosity run of LHC in a year. Most studies use the high luminosity run as a benchmark.

2.1 *Large extra dimension*

In the presence of large extra dimensions gravitons will appear as towers of massive Kaluza–Klein (KK) states from the 4-d point of view. Since the coupling of graviton to matter is very weak, a direct production of KK graviton will result in signals with large missing transverse energy in the detector. ATLAS studies have been done on

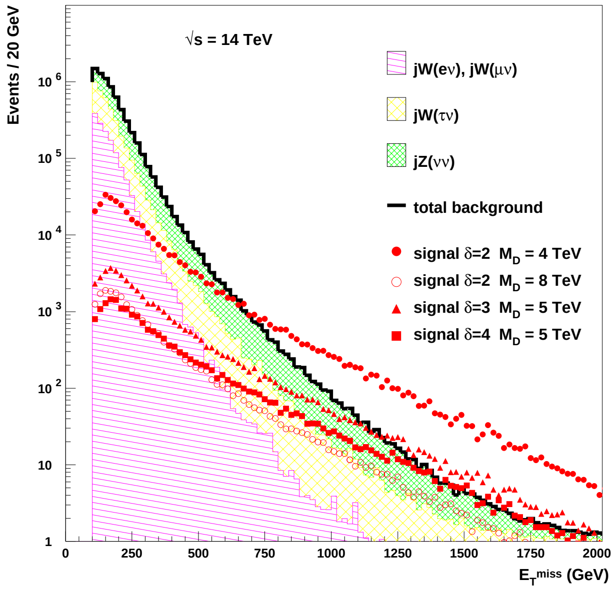

Figure 1. Distribution of missing transverse energy for signal and background.

sensitivity to the scale of extra dimension and to the number of extra dimensions in the jet + missing E_{T} and γ + missing E_{T} channels [2]. Figure 1 shows signal and background distribution. This study shows that after one year of high luminosity run, a five sigma discovery can be made for mass scale of 9(6) TeV with 2(4) extra dimensions.

A virtual production of KK graviton will result in the modification of Drell–Yan cross-section. Studies have been done with the photon and lepton pair in the final state, where there should be a large enhancement of the cross-section in the high invariant mass region. One year of high luminosity run should have sensitivity up to 8(7) TeV for number of extra dimension between 5(2) [3].

2.2 *TeV*$^{-1}$ *extra dimension*

An interesting variation to the above scenario is the one in which only the standard model fermions are confined to the three space dimensions, while there can be Kaluza–Klein excitations of the gauge boson in the presence of small extra dimensions ($R \sim 1$ TeV). Studies of leptonic decay of excited γ and Z boson with one small extra dimension [4] show that it will be possible to detect resonances up to 5.8 TeV in the high luminosity run. If the resonance cannot be observed, a sensitivity up to masses of 13 TeV is reached from the interference effect on the SM Drell–Yan process.

2.3 *Randall–Sundrum models*

The Randall–Sundrum model postulates a universe with two 4-d surfaces (TeV and Planck brane) bounded by 5-d space-time. Standard model fields live only on the TeV brane, while gravitons live everywhere: TeV brane, Planck brane and the bulk. The metric is exponentially warped, resulting in a natural resolution to the hierarchy problem. The theory permits two types of excitations: narrow graviton resonances and graviscalars named radion.

ATLAS has performed a model independent study of narrow graviton resonances signal [5]. In the context of RS model they obtain a five sigma sensitivity up to 2.1 TeV of graviton mass in the di-electron production channel. Studies of the angular distribution of the polar angle of electrons, show that a spin-two resonance can be distinguished from a spin-one resonance up to a mass of 1.7 TeV with 90% CL. The phenomenology of radion is similar to SM Higgs boson, it mixes with it and it also has large effective coupling to gluon. Based on the studies of the standard model Higgs, limits on radion decay to $\gamma\gamma$ and ZZ is obtained. Studies have also been done in the case when radion is more than twice as heavy as Higgs and can decay in the two Higgs [6].

2.4 *Effects of renormalization group equations*

Another scenario is that the standard model gauge boson can propagate through the extra dimensions. In such a scenario, the renormalization group equations will be modified such that the evolution of coupling constant is different from the normal logarithmic behavior. Studies have been done to look for possible suppression of di-jet production as α_s decreases rapidly with energy scale. A compactification radius of 5–10 TeV could be probed using one year of high luminosity data at LHC [7]. The sensitivity goes down to $\sim$ TeV when the effect of parton distribution function is taken into account.

2.5 *Extra dimensions and supersymmetry*

ATLAS has investigated the possibility to discover supersymmetry through the decay of charged Higgs to τ and neutrino. In the usual MSSM scenario, the decay into a neutrino with a right helicity is strongly suppressed but this can be changed if the right-handed neutrino could propagate in the extra dimensions. Therefore the channel holds prospect for discovering both extra dimensions and supersymmetry [8].

3. Summary

The ATLAS Collaboration has studied different phenomenological models with extra space dimensions. The experiment will be very sensitive in the presence of these extra dimension and will be able to probe mass scales of 5 to 10 TeV, depending on the model.

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