Physics Team Report “Extra dimensions”

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References:

-Tilman Plehn: Extra Dimensions at Colliders
-Giudice et al: Quantum Gravity and Extra Dimensions at High-Energy Colliders
-Eur. Phys. J. C (2015) 75:299: “Search for new phenomena in final states with an energetic jet and large transverse momentum in pp collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector”

Summary:

The theory of extra dimensions is motivated as it could solve the hierarchy problem of the Standard Model. The hierarchy problem describes, briefly speaking, the fact that the Standard Model scale of about 10^3 GeV is 16 orders of magnitude smaller than the Einstein gravity scale of 10^{19} GeV. Without any additional structure, there is no reason for two mass scales of the same theory to be so different. During the physics-team discussion, we reviewed two well-known scenarios of extra dimensions with different geometries. The theory with large extra dimensions is known as the ADD model and the Randall-Sundrum (RS) model has a warped geometry. The ADD model assumes a (4+d)-dimensional space time, where d is the number extra compactified spatial dimensions. Gravity could propagate through all (4+d) dimensions while the other three fundamental forces are confined to the 4-dimensional subspace, which is usually assumed to be a D3-brane. Hence, the (4+d)-dimensional Planck scale could be far reduced to electroweak scale if the extra dimensions have large size according to Kaluza-Klein reduction. An unsatisfying feature of the ADD model is the difficulty to stabilize the large extra dimensions, namely there is no satisfied dynamics to controlled the size of the extra dimensions. In warped extra-dimensional models (the RS model), the size of the extra dimension is not required to be large to solve the hierarchy problem. Instead, one assumes a 5-dimensional theory with the extra dimensions being a line with a finite distance (Denoted as y, $0 \leq y \leq u$) and at its both ends sitting two non-flat 4 dimensional objects (dubbed as D3-brane). The energy scale of the D3-brane at y=0 should be as high as the Planck scale and the other D3-brane at y=u should only be on the order of TeV. Higgs fields in the Standard Model are stuck to TeV D3-brane while gravity still probes the entire five-dimensional space time. In order to solve the hierarchy problem, the distance between the two Branes does not need to be large but of a relatively natural size. We also shortly review a satisfying stabilization in RS model which, shortly speaking, is that length of the line segment is dictated by the VeV of some scalars.

The existence of extra dimensions can manifest itself in Kaluza-Klein

excitations of massive graviton modes due to quantized momentum states in the compactified extra dimensions. When gravitons are produced in high-energy proton-proton collisions, they escape undetected into the extra dimension, but leave characteristic event signatures with large missing transverse momenta. ATLAS and CMS performed searches for new phenomena in various final states with missing transverse momenta. During the physics teams, the ATLAS analysis with an energetic jet and large missing transverse momentum at a center-of-mass energy of 8 TeV was discussed as an example. Events with a mono-energetic jet with a transverse momentum larger than 120 GeV/c with missing transverse energy between 150 GeV and 700 GeV are considered. Contributions from Standard-Model processes with W- and Z-boson decays and jets or multi-jets backgrounds are obtained from simulated events that are normalised using data in selected control regions. The impact of the ADD model with different sizes of the extra dimensions is obtained from simulation. The resulting observed number of events are compatible with Standard-Model expectations and the results can be used to obtain limits on the parameters of the ADD model.