Search for New Physics in Leptonic Decays with the CMS Experiment at the LHC

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Motivation

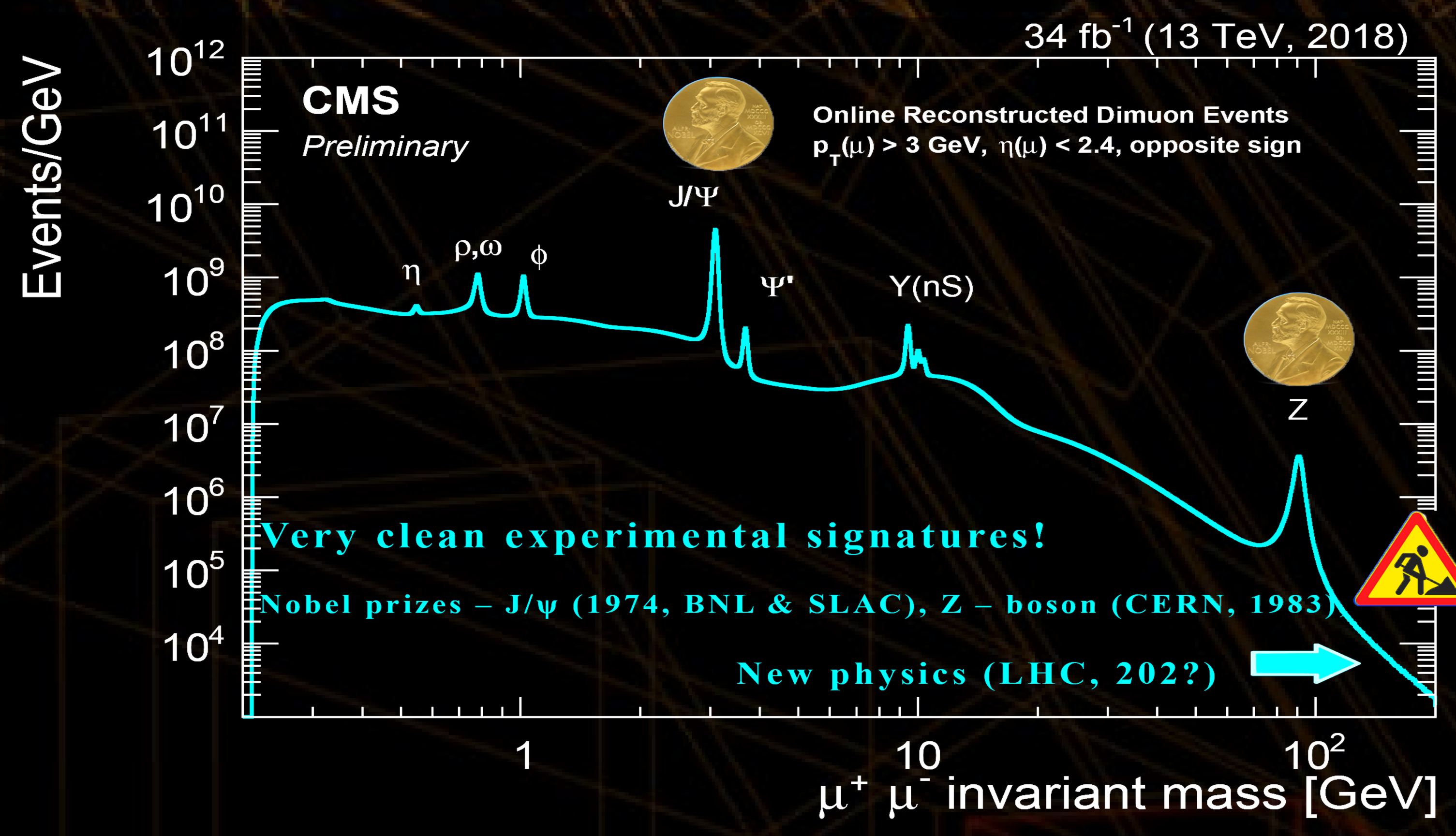
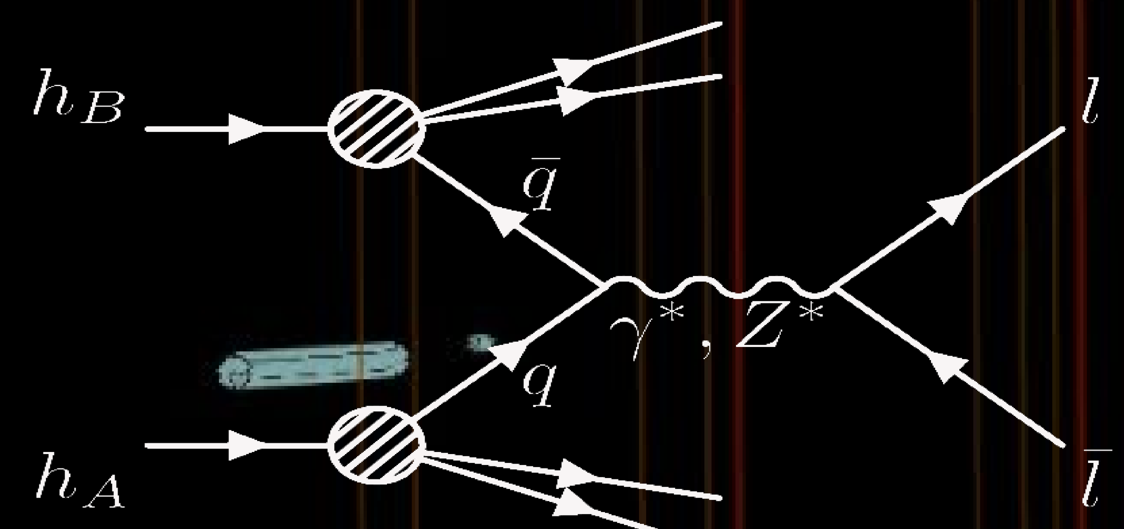


Figure 1: Picture showing the dimuon spectrum and highlighting some of the discoveries made over the years

Are there more fundamental particles than the ones we currently know? Do we live in a Universe with additional spatial dimensions? These hypotheses are among the many ideas that have been suggested to explain how to unify the electroweak and strong interaction or how to describe gravity at the subatomic scale. In addition, the results of astrophysical observations leave open the question of the nature of dark matter. There are many different ideas for new physics beyond the standard model, many of them predict new phenomena in the proton-proton collisions at the LHC that result in the production of pairs of very energetic electrons or muons.

The dominant source of new physic background comes from the dielectron or dimuon decay of a photon or standard model Z boson, whose production at hadron colliders such as the LHC is also known as the Drell-Yan process.



$$\frac{d^2\sigma}{d\theta^* d\phi^*} = \sum_{i=0}^{5} \sigma^i = (1+\cos^2\theta^*) + A_0\frac{1}{2}(1-3\cos^2\theta^*) + A_1\sin(2\theta^*)\cos\phi^* + A_2\frac{1}{2}\sin^2\theta^*\cos(2\phi^*) + A_3\sin\theta^*\cos\phi^* + A_4\cos\theta^*$$

Depending on the signal model, the spatial distribution of the leptons can differ significantly from that of the standard model backgrounds.

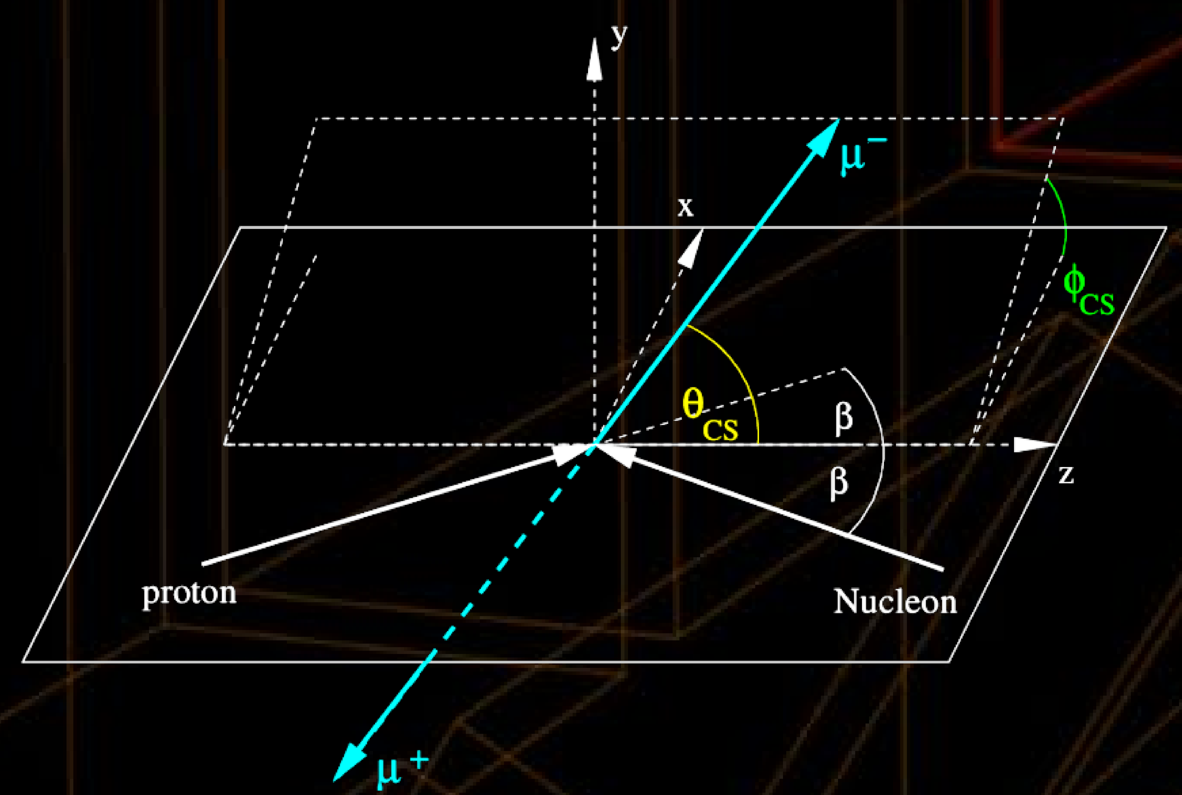


Figure 3: Dimuon center of mass (Colins-Soper) frame

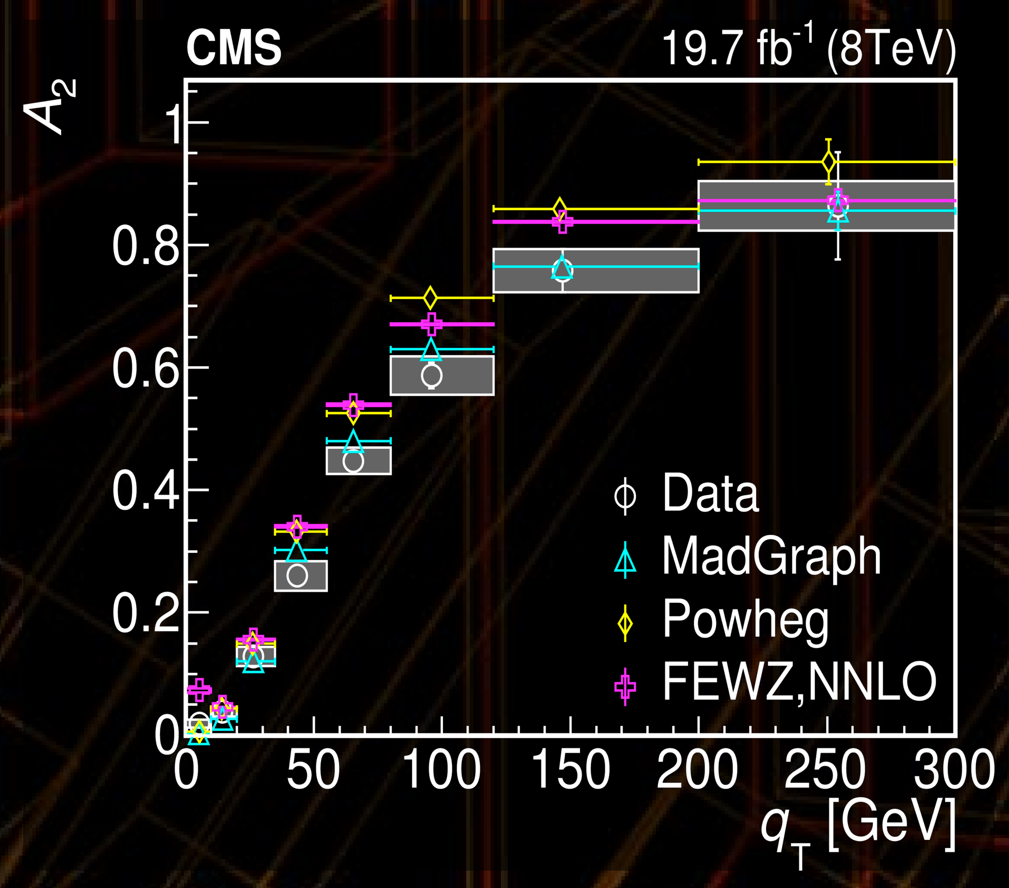


Figure 4: Angular polarization coefficient A_2 [2]

One quantity sensitive to such effects is the muon scattering angles θ^* and φ^* in dimuon center of mass frame. Measurements of lepton angular distributions also give a lot of information about inner structure of protons.

The Last Updates

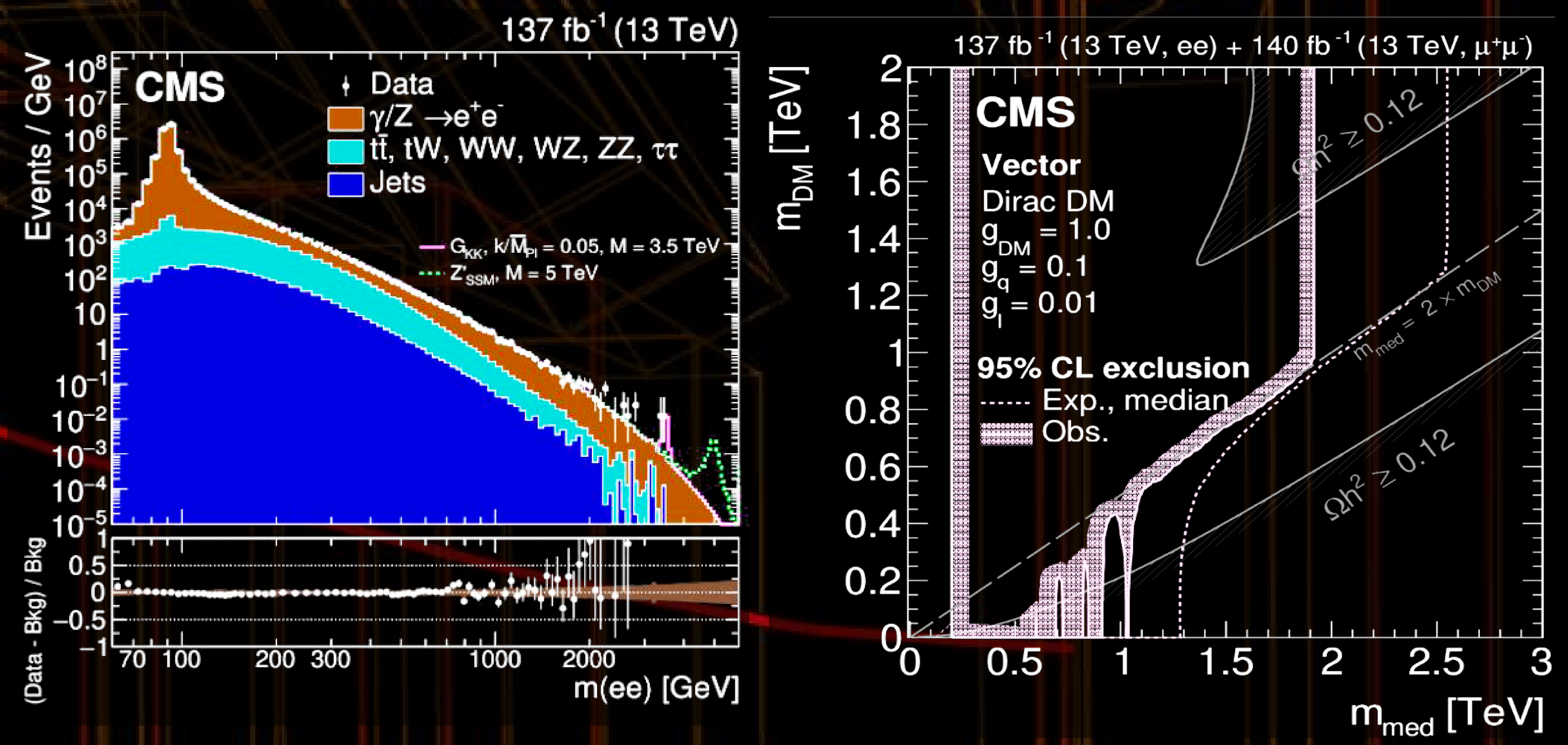


Figure 2: a) The dielectron invariant mass spectra observed with this analysis [1]; b) Summary of upper limits at 95% CL on the masses of the DM particle and its associated mediator, in a simplified model of DM production via a vector mediator

One of the rules of the standard model is that bosons such as the Z boson will decay equally into muons and electrons. But if the standard model is incomplete, the data could show a preference for one type of lepton over the other.

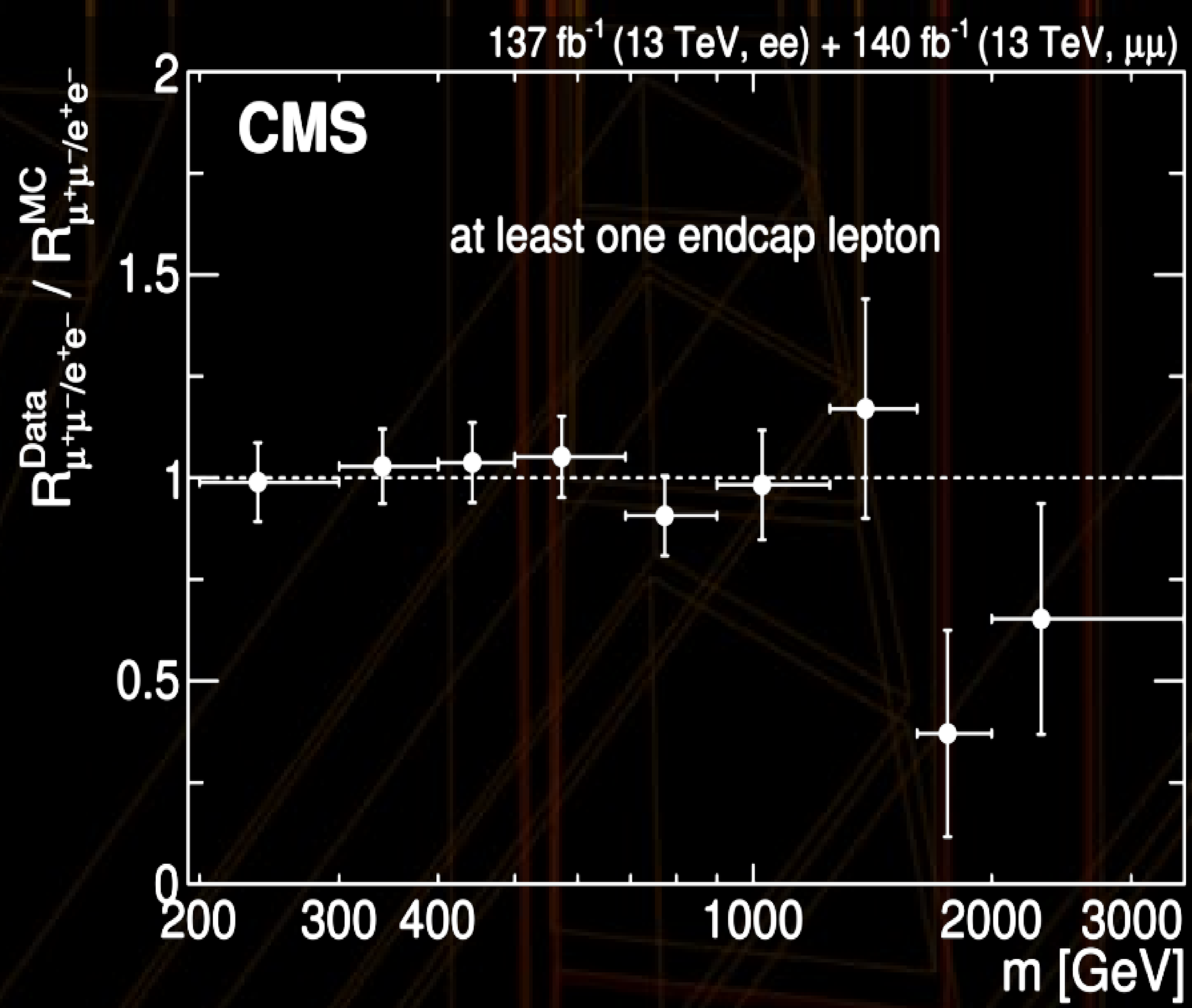


Figure 5: The ratio of decays into muons compared to electrons as observed in data, with respect to that predicted through simulations [1]

Conclusions

We did not observe any significant signs of new phenomena in dilepton decays. The absence of a signal nevertheless tells us a lot about potential physics beyond the standard model. We set the strongest constraints to date on the masses of possible new particles that decay into two leptons from a variety of models. Stringent constraints are also set on the parameters of models with a new contact interaction between particles or specific models with extra dimensions.

References

[1] CMS Collab. Journal of High Energy Physics v. 2021, Article number: 208 (2021)
[2] CMS Collab. Phys. Let. B, v. 750, 2015, p. 154-175