Search for Excited Leptons in CMS

Kerstin Hoepfner *a*, on behalf of the CMS collaboration

a *RWTH Aachen, III. Phys. Inst. A, Otto-Blumenthal-Str., 52074 Aachen*

E-mail: kerstin.hoepfner@cern.ch

Compositeness models are a popular explanation for the observed three generations of standard model (SM) particles. One consequence of compositeness would be the observation of excited leptons, such as excited electrons, e*, or excited muons, μ*. At the LHC such particles could be produced in pp collisions under the assumption that leptons are composite objects. Produced excited leptons are expected to transition to their corresponding SM lepton partner via gauge or via contact interaction. CMS has performed a recent search for e* and μ* in the contact interaction decay channel leading to a two-lepton plus two-jets final state using the 2016 and 2017 sqrt(s) = 13 TeV dataset. While no signal was observed, the exclusion results provide the best limits to date. The poster also compares to other complementary search channels and discusses the greater context of excited leptons searches.

40th International Conference on High Energy physics - ICHEP2020
July 28 - August 6, 2020
Prague, Czech Republic (virtual meeting)

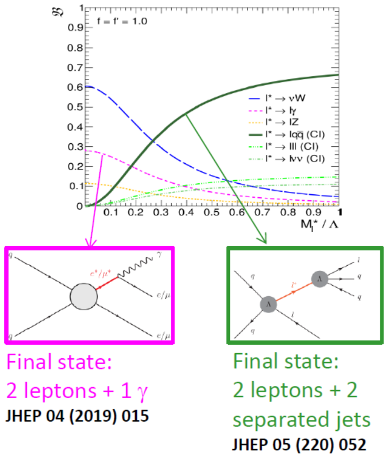
https://pos.sissa.it/

PoS(ICHEP2020)304

1. Compositeness and Excited Leptons

Experimental searches for compositeness are performed by looking for excited leptons (e*, μ*) in several channels. Excited leptons would decay either via gauge or via contact interaction

- Decay via gauge interaction (GI)
  - $\ell^* \to \ell W \to \ell jj$ ($\ell\ell\nu$ hard to separate)
  - $\ell^* \to \ell\gamma$ => best channel for high Lambda reach
  - $\ell^* \to \ell Z \to \ell jj$ (or $\ell\ell\ell$ very clean but low cross section)
- Decay via contact interaction (CI)
  - $\ell^* \to \ell jj$ => best channel for high m_{ℓ^*} reach (or $\ell\ell\ell$ but low cross section)



The excited lepton (ℓ^*) is produced in conjunction with its corresponding SM lepton. The model parameters are: the compositeness scale (Λ) where the substructure becomes visible, the excited lepton mass (M_{ℓ^*}), and the parameters f and f' which govern the fraction of GI and CI. The usual assumption of f and f' = 1 results in the branching fractions in Fig.1 showing that the CI channel – with the Feynman graph in the green box - is expected to have the best reach for high masses. The photon channel – in the pink box – should have the best reach in Λ.

Fig:1: Branching fractions of possible ℓ^* decay channels for the scenario f=f'=1. The CI channel (green box) is further discussed in this paper.

2. CI Search with 2l2j Final State. Standard analysis for f = f' = 1

Recently CMS [1] searched for excited leptons in the $2\ell 2j$ CI final state (with ℓ = e, μ) using 77.4/fb of 13 TeV pp collision data [2]. The events were triggered by single lepton triggers, either a single electromagnetic cluster with at least 230 GeV in transverse energy (E_T) or a single muon with a transverse momentum (p_T) above 53 GeV. These trigger thresholds determine the offline cut for the leading lepton while the second lepton can be softer.

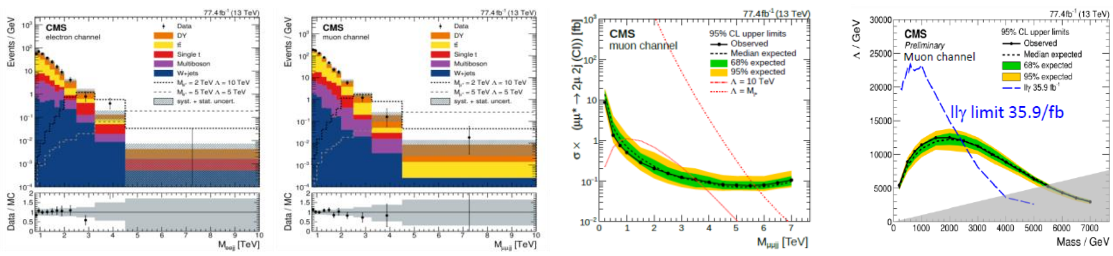


Fig:2: The left two plots show the 2e2j and 2μ2j distributions, respectively, in the signal region where the dilepton mass is above 500 GeV. The right two plots show cross section and Λ limits for the example of the muon channel.

Subsequently the analysis selects events containing two same-flavour leptons and two jets. The second lepton is required to have $p_T > 35$ GeV (e) and $p_T > 25$ GeV (μ), respectively. Jets should have at least 50 GeV.
The corresponding 4-body invariant mass ($M_{\ell\ell jj}$) is used as the discriminating variable for the analysis. The search is performed in a signal region defined by the dilepton mass above 500 GeV to suppress DY and tt background. A potential excited lepton signal would yield additional events at high $M_{\ell\ell jj}$ as indicated in Fig.2-left for two signal examples with ℓ^* masses of 2 and 5 TeV. Also shown in this Fig are the data in comparison to the SM expectation for the two studied channels, electron and muon. The data are consistent with the background. Hence exclusion limits are set. Excited electrons(muons) are excluded for masses up to 5.6(5.7) TeV which are the best mass limits to date. These limits can be reinterpreted in terms of compositeness scale, reaching 11 and 12 TeV, respectively, for a ℓ^* mass of 2 TeV (see Fig.2-right for the example of the muon channel).
Searches in the channel with two leptons and a photon are expected to be more sensitive in terms of compositeness scale in the low mass region as seen from the branching fractions in Fig.1. Another CMS search in this final state using 35.9/fb of pp data [3] yielded limits of 23 TeV (electron) and 24 TeV (muon), respectively (see Fig.2 for the muon channel).

3. CI Search - If f and f' < 1 allows to test larger values of Λ

The section discusses the case when f and f' are below 1 for the analysis in [2]. Such scenarios enhance the CI, as shown in the branching fraction plot for f=0.1 in Fig.3-left. The choice of f and f' has significant impact on the sensitivity on the compositeness scale Λ. For this choice of 0.1, the lambda limits increase to 17(19) TeV for the e(μ) channel, respectively. And increase even further, to 18 and 22 TeV for the extreme case where gauge couplings vanish. The limits on ℓ^* mass are not affected and stay at 5.6 and 5.7 TeV.

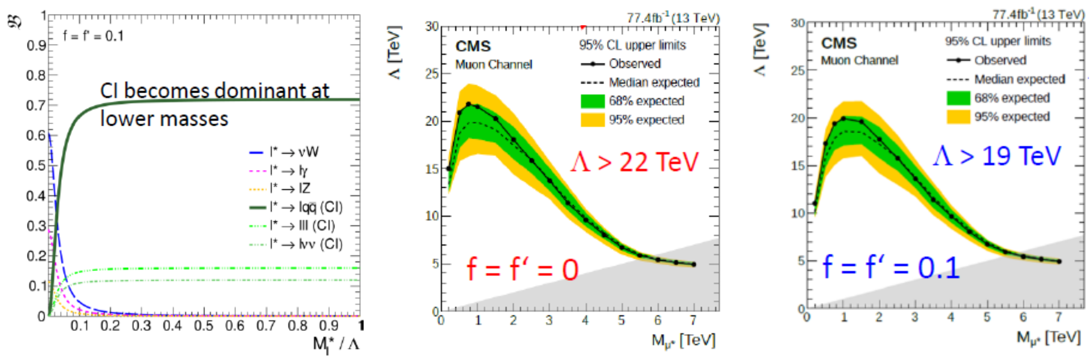


Fig.3: Branching ratios of the various decay channels assuming f=f'=0.1 (left). In this scenario CI becomes already dominant at low masses. While the limits on ℓ^* mass are not changing, the resulting limit on Λ increases to 19 and 22 TeV for the scenarios f=f'=0.1 and f=f'=0, respectively. +

References

[1] CMS coll., 'The CMS experiment at the CERN LHC', *JINST 3:S08004, 2008*

[2] CMS coll., CMS-PAS-EXO-18-013, *JHEP 05 (2020) 052*

[3] CMS coll., CMS-PAS-EXO-18-004, *JHEP 04 (2019) 015*