Searches for new heavy resonances in final states with leptons, photons, and jets at CMS

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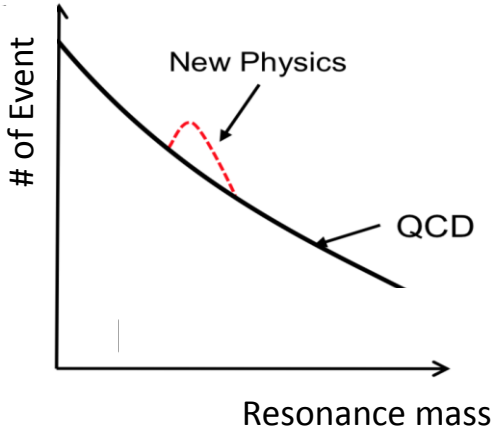
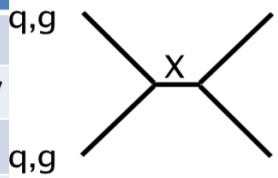
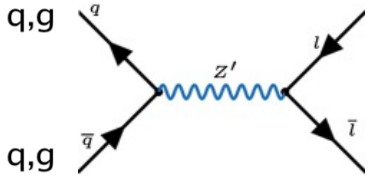
Introduction

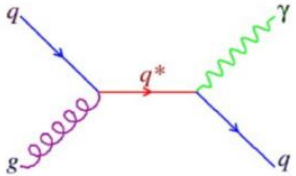
- Many models of beyond the standard model require new particles that couple to quarks and/or gluons and decay to photons, leptons and jets
  - Such as leptophobic Z', Extra dimensions, Compositeness and Quantum Black Hole (QBH).
- Photons, leptons and jets in the final states are "classic signatures" to search for New physics



Channel	Search	CMS	
Dijet final states	High/Low-mass resonances in dijet final state	EXO-16-056	
	Boosted di-jet resonance	EXO-17-001	JHEP 01 (2018) 097
	Dijet angular distributions	EXO-16-046	arXiv:1803.08030
	Di-bjet mass spectrum at 8 TeV	EXO-16-057	arXiv:1802.06149
Leptonic final States	High-mass resonances in dilepton final state	EXO-16-047 + EXO-18-006	arXiv:1803.06292
Photonic final state	Excited quarks in photon+jet final state	EXO-17-002	PLB 781 (2018) 390





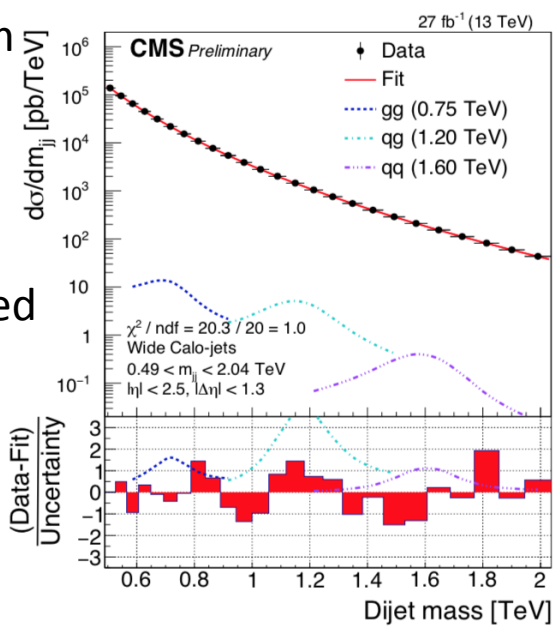


Search for high/low mass dijet resonances

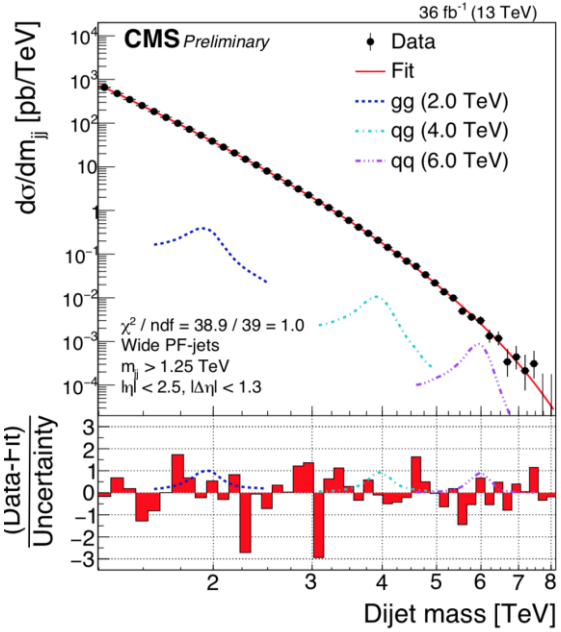
CMS-EXO-16-056

2016 data (36 fb^{-1})

- Look for bump in dijet mass spectrum
  - Separate searches by qq, qg, gg final state
- Select event with $|\Delta\eta| < 1.3$ && $|\eta| < 2.5$
- Close jets with $\Delta R < 1.1$ are combined into "wide jets" for the dijet mass
- **High mass :**
  - Become fully efficient after 1246 GeV
  - Use Particle Flow AK4 Jets
- **Low mass :**
  - Become fully efficient after 489 GeV
  - Use Calorimeter AK4 Jets
- No excess observed

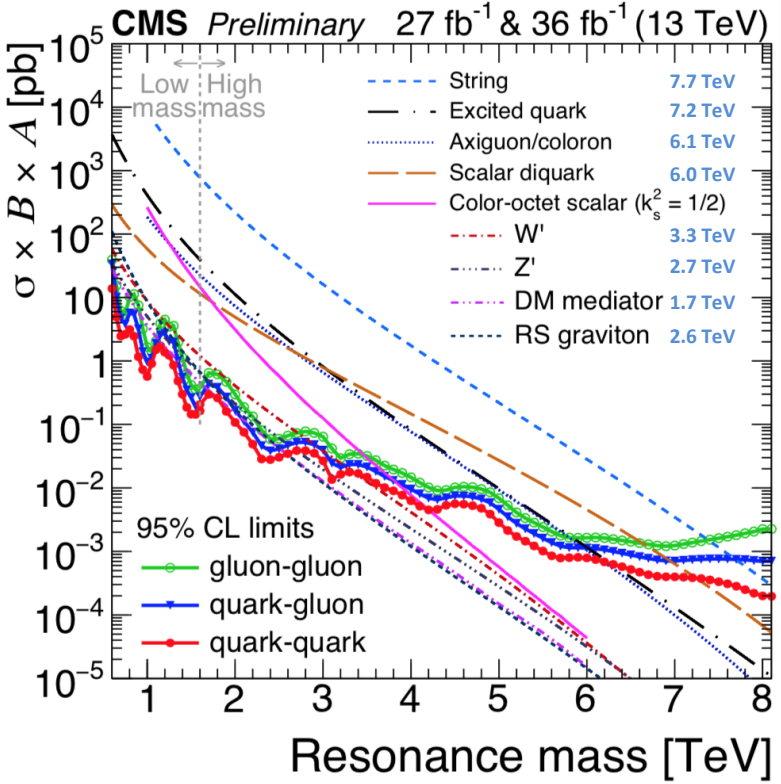


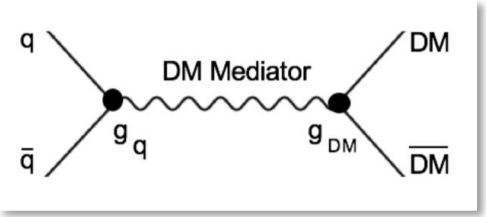
Low mass



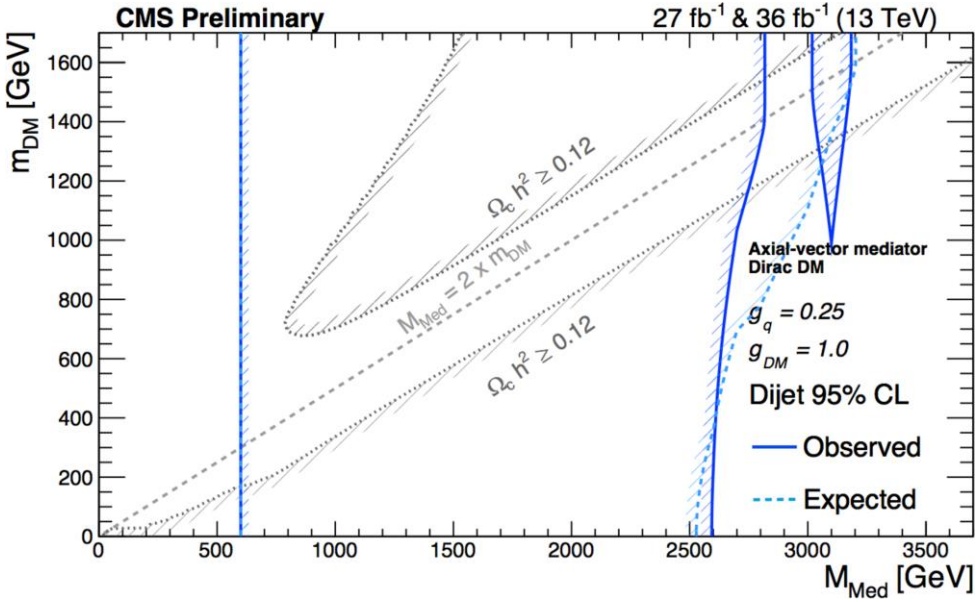
High mass

Search for high/low mass dijet resonances





We chose the simplified model recommended by the LHC DM working group to search for a DM mediator (arXiv:1603.04156)

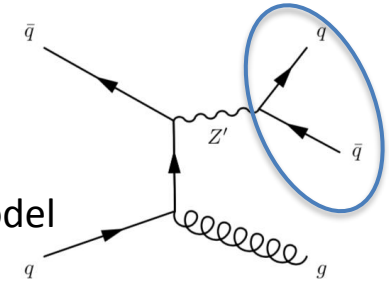


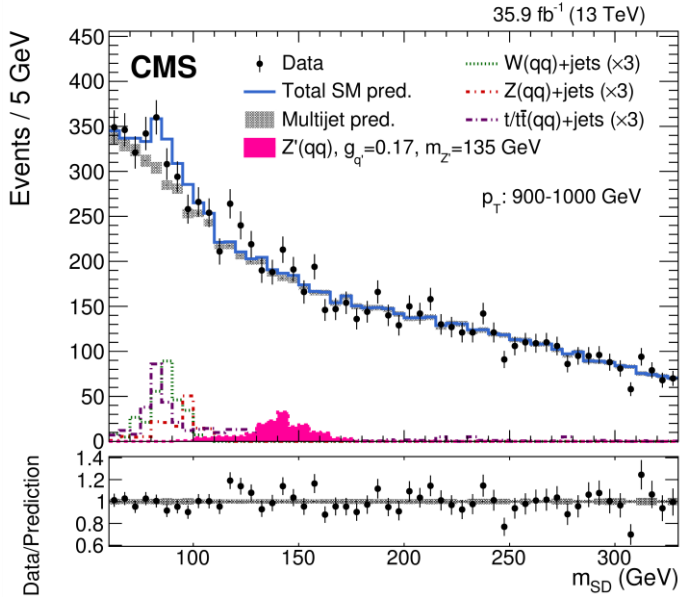
Boosted dijet resonances

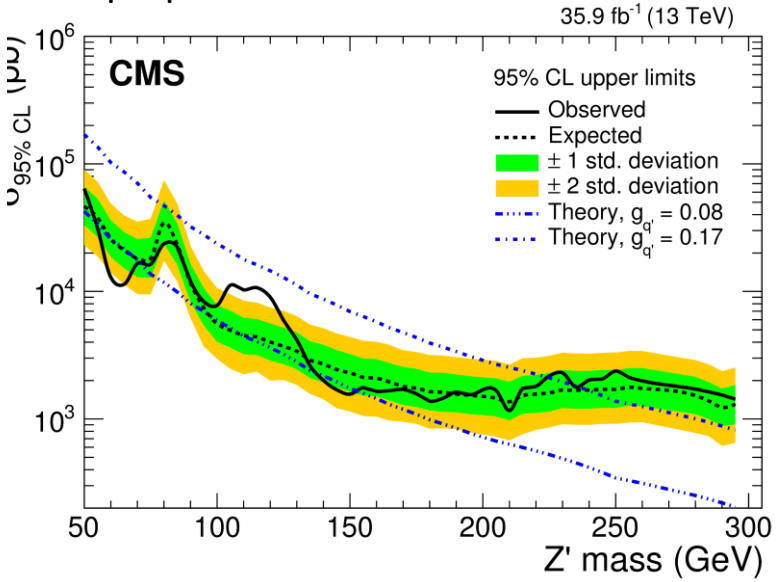
CMS-EXO-17-001 (JHEP 01 (2018) 097)

2016 data (35.9 fb^{-1})

- Boosted dijet + associated ISR jet/photon
- Soft Drop (SD) is a technique to remove soft and wide angle radiation from parton shower etc. arXiv,1503.01088
- No excess observed
- Limits are set on the parameter space of a leptophobic axial-vector Z' benchmark model







Set limits on the Z boson production cross section, compare to Z' with coupling either 0.08 and 0.17.

We extend the previous limits below 100 GeV.

Dijet angular distributions

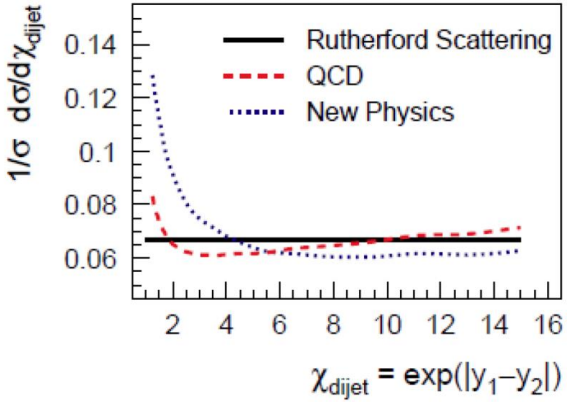
CMS-EXO-16-046 (arXiv:1803.08030)

2016 data (35.9 fb^{-1})

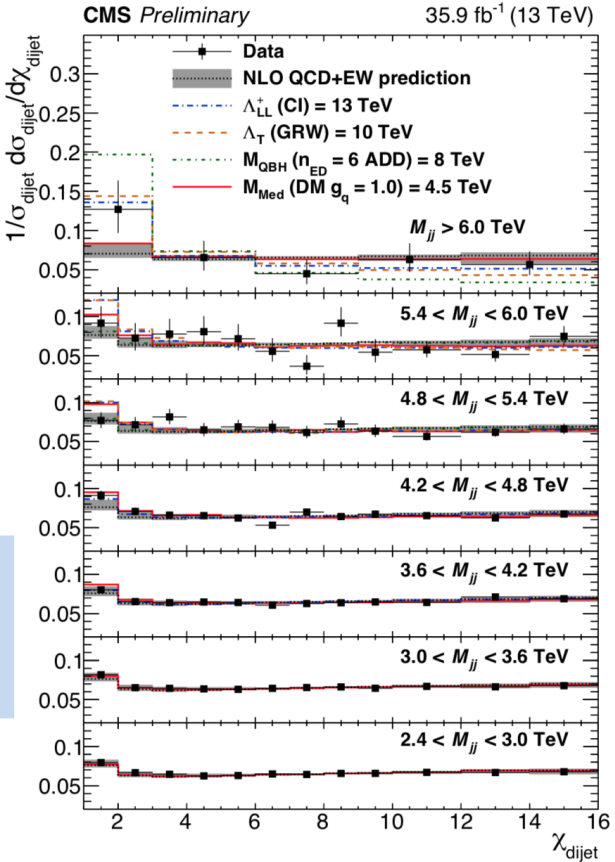
- Looking for rise at low χ, high m_{jj}

$$\chi = e^{2|y^*_{12}|} \sim \frac{1+\cos\theta^*}{1-\cos\theta^*}$$

- New Physics will change the χ_{dijet} distribution at low χ_{dijet} at high m_{jj}
- χ_{diiet} is relatively flat for Leading QCD process



DM mediator	**2 - 4.6 TeV**
QBH	**5.9 - 8.2 TeV**
Extra Dimension	**8.9 - 10.6 TeV**
Contact Interaction	**12.8 - 17.5 TeV**



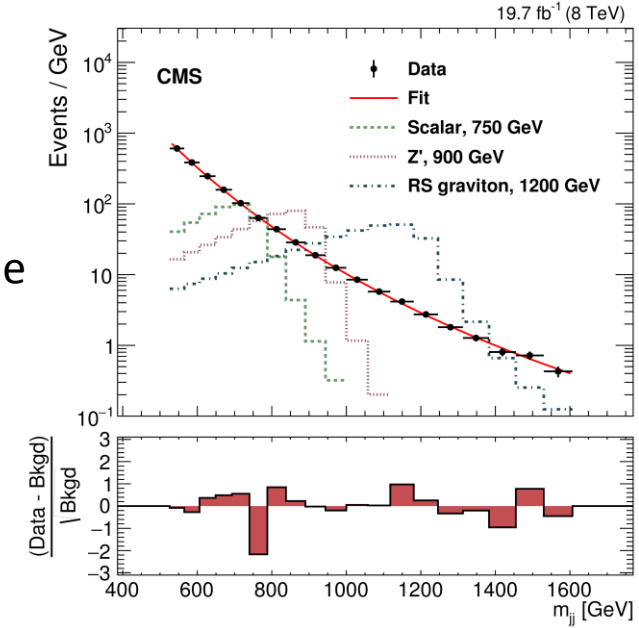
Di-bjet resonances search at 8 TeV

CMS-EXO-16-057 (arXiv: 1802.06149)

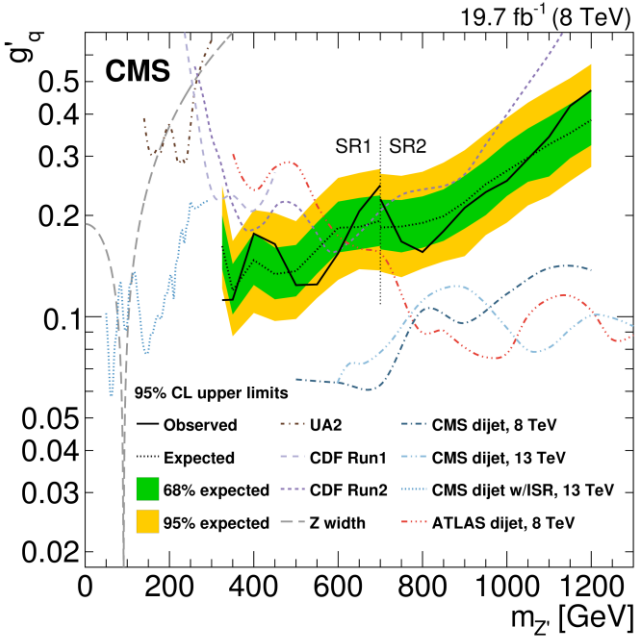
2012 data (**8 TeV**, 19.7 fb^{-1})

- Following the usual dijet searches, high mass resonance search with two b-tagged jets.
- Two signal regions due to the trigger requirement:

  Signal Reign 1: m_{jj} = [296 - 1058 GeV]
  Signal Reign 2: m_{jj} = [526 - 1607 GeV]
- No excess observed
- Limits are set on bottom quarks for spin 0, 1, and 2 resonances in the mass range of 325–1200 GeV.



b-tagged dijet mass spectrum in SR1



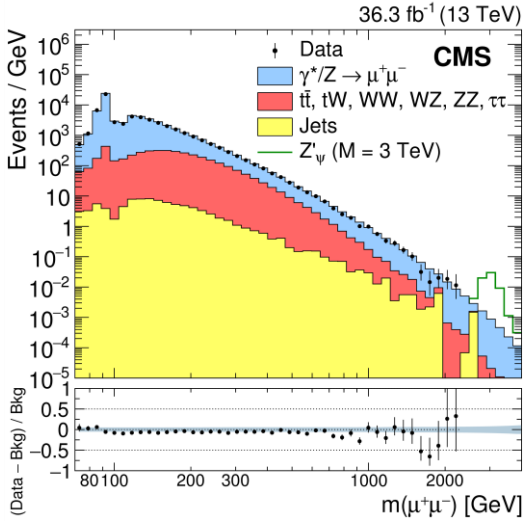
- The 95% CL upper limits on the universal coupling g'_q between the leptophobic Z′ and quarks.
- Limits from other experiments and earlier CMS analyses are also shown.

Search for high-mass resonance in dilepton final state

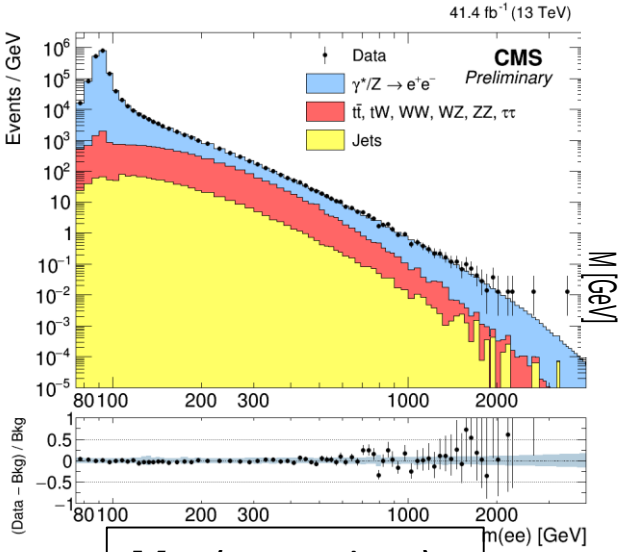
CMS-EXO-16-047 (arXiv: 1803.06292) & CMS-EXO-18-006

2016 data (36.3 fb^{-1}) + 2017 data (41.4 fb^{-1})

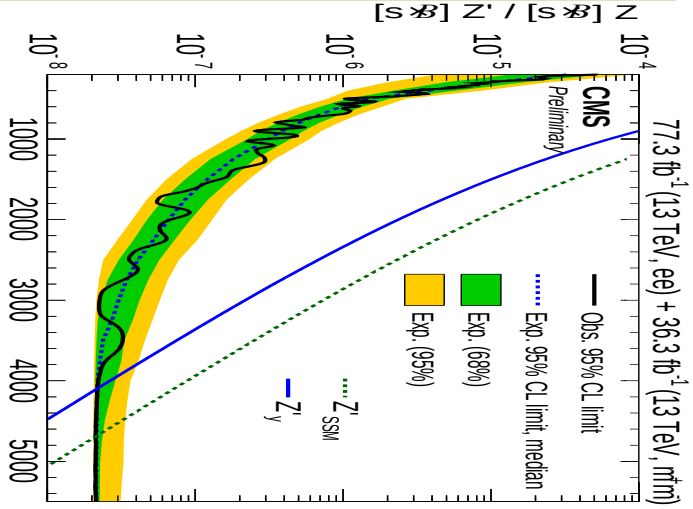
- Look for bump in dilepton mass spectrum
- One of the most clean signatures
- Events with two same-flavor leptons (e/μ) are selected
- No significant excess observed



$M_{\mu\mu}$ (2016 data)



M_{ee} (2017 data)



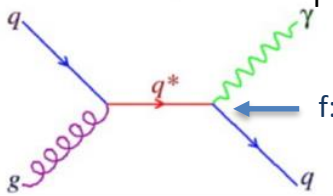
Obs. (Exp.) exclusion mass	
Z'_{SSM}	Z'_{ψ}
< 4.7 (4.7) TeV	< 4.1 (4.1) TeV

Search for the resonances in γ + jet final state

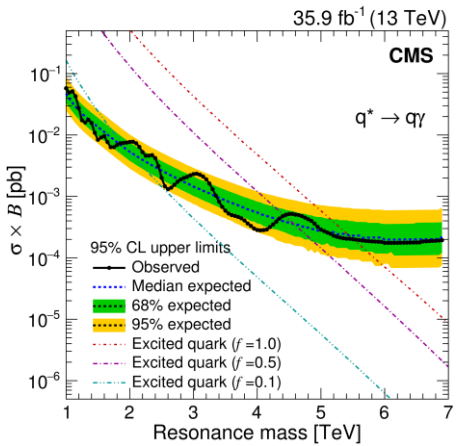
EXO-17-002 (PLB 781 (2018) 390)

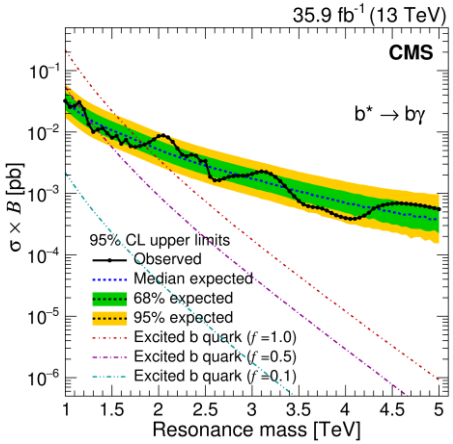
2016 data (35.9 fb^{-1})

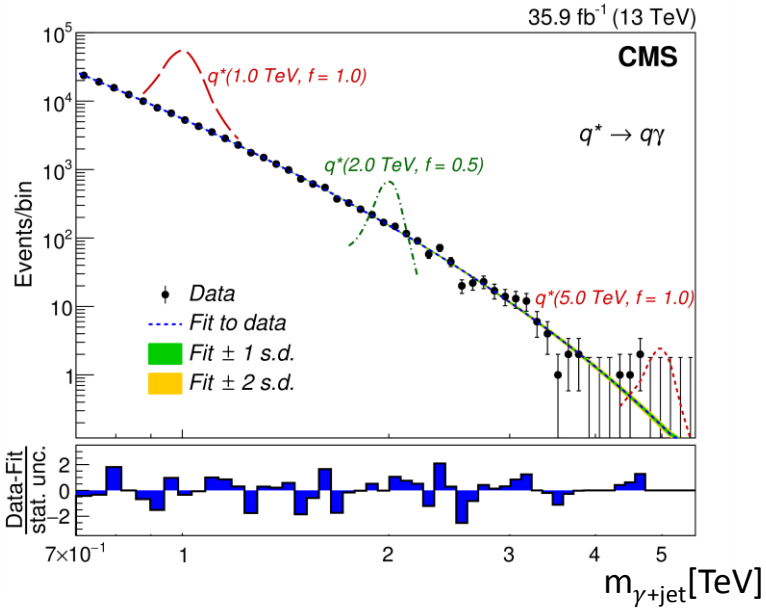
- If quark substructure exists, quarks may appear in excited states (b* or q*).
- P_T^{γ} > 200 GeV and P_T^{jet} > 170 GeV



f: coupling to quark







b* (f = 1.0)	q* (f = 1.0)
1.0 ~ 1.8 TeV	1.0 ~ 5.5 TeV

Conclusions

- Searching for heavy resonances is one of the most direct ways to find new physics at TeV scale.
- Many high mass di-jet, di-lepton and photonic resonance searches are performed.
- Limits are interpreted to constrain parameters of models predicting a narrow di-jet, di-lepton and photonic resonance.
- No signals of the new physics BSM has been found in data.
- CMS has begun exploring the full 13 TeV dataset. New exciting results are in the pipeline.