Search For Low-Mass Quark-Antiquark Resonances Produced With an Initial State Photon at 13 TeV Using the CMS Detector

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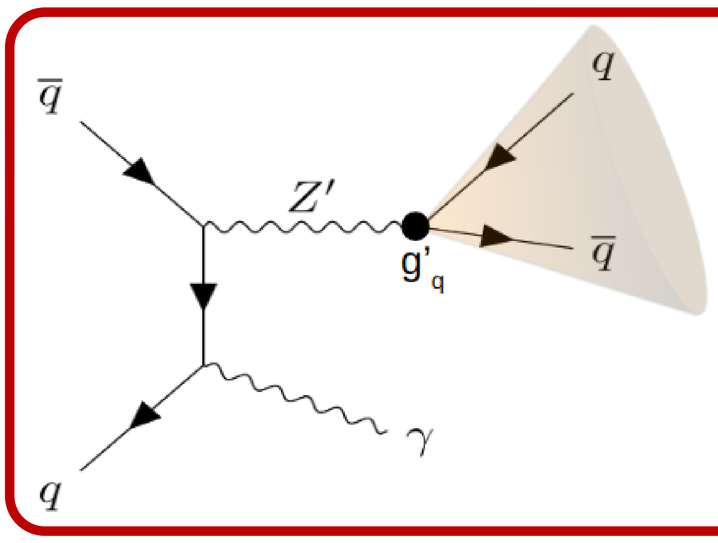
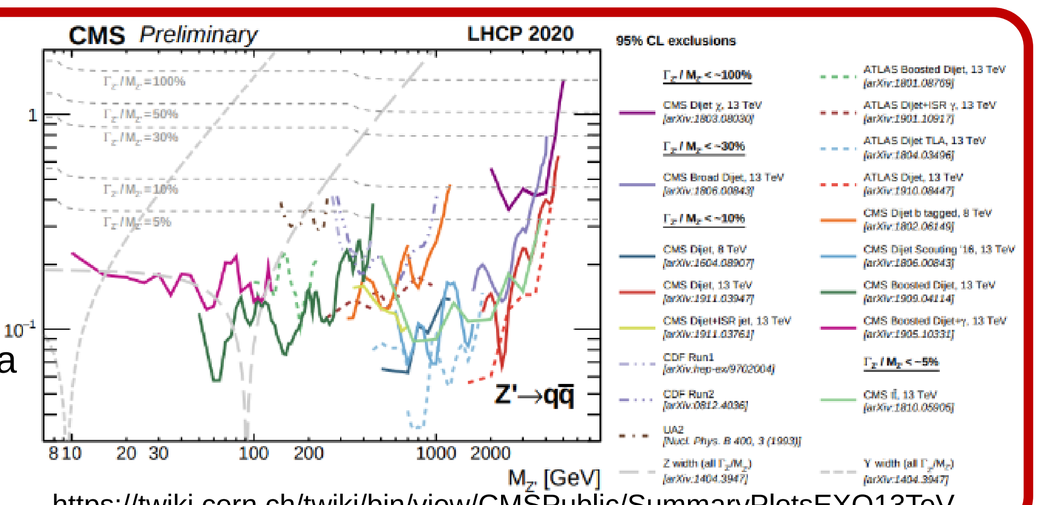
Abstract

We present a search for low-mass narrow $q\bar{q}$ resonances. This search uses data from LHC pp collisions at a center of mass of 13 TeV in Run 2, and corresponds to an integrated luminosity of 137 fb^{-1}, currently using 10% of data. Utilizing full Run 2 data allows the use of a lower photon p_T threshold trigger than a previous analysis performed with only 2016 data, allowing this analysis to be more sensitive to resonances in the low mass region. We require an initial state photon recoiling against the narrow resonance, leading to the resonance having a high transverse momentum. The high p_T decay products of the resonance collimate and are reconstructed as a single large jet with an internal two-pronged substructure. A two-pronged dijet score based on the ParticleNet tagger is used to select jets with two-pronged substructure. The background is estimated via a data-driven method using a transfer factor between the distributions which fail and pass the two-pronged substructure requirement. The new physics signal is searched for as a narrow peak excess above the Standard Model backgrounds in the jet mass spectrum.

Introduction



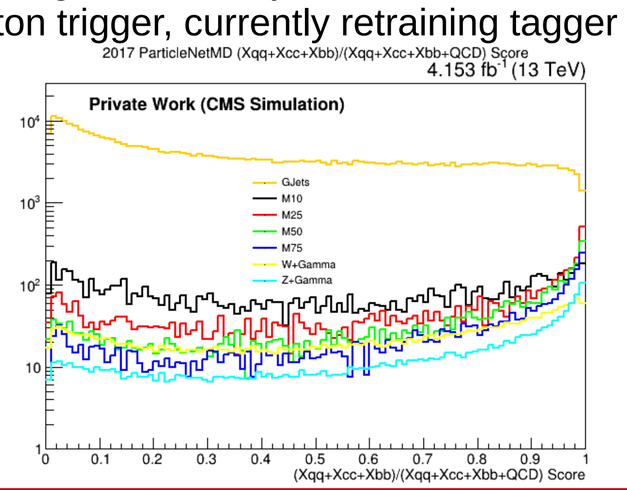
- Resonances coupling to $q\bar{q}$ are common in many **BSM** theories
  - e.g. leptophobic particle Z', or dark matter mediator
- We search for low-mass $q\bar{q}$ resonances recoiling against initial state photon
- Previously published analysis (PRL 123, 231803 (2019)) used only 36 fb^{-1} of Run 2 data
- Current analysis uses 10% of 137 fb^{-1} Run 2 Data, new low photon p_T trigger, and ParticleNet tagger



https://twiki.cern.ch/twiki/bin/view/CMSPublic/SummaryPlotsEXO13TeV

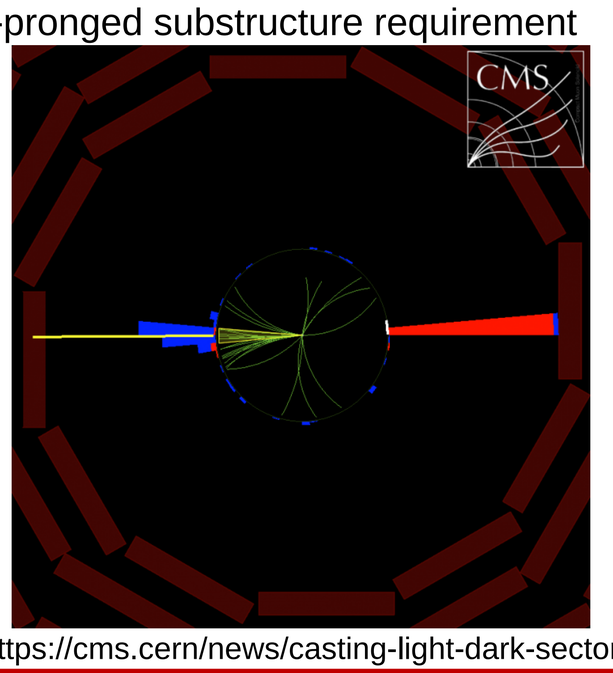
ParticleNet Tagger

- ParticleNet tagger gives mass de-correlated classification scores for $X \rightarrow q\bar{q}$ as well as QCD
- Build two-pronged metric: (Xqq+Xcc+Xbb)/(Xqq+Xcc+Xbb+QCD)
- ParticleNet is not yet trained in the 120-200 GeV region added by 2018 lower threshold photon trigger, currently retraining tagger



Event Selection

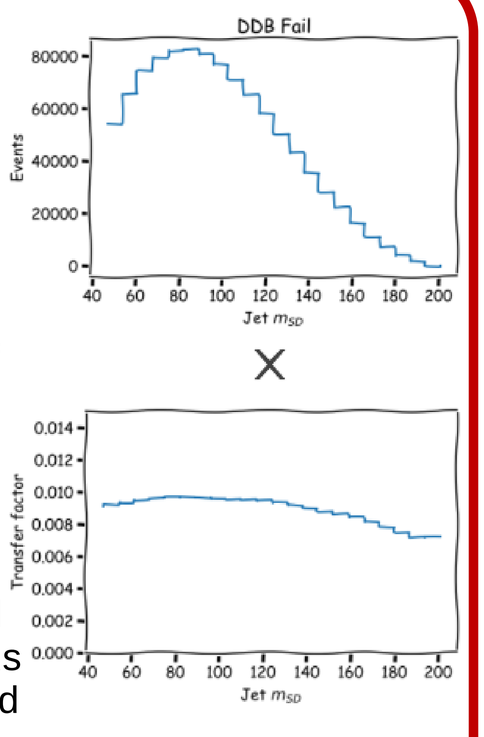
- Photon and jet must have p_T above a minimum threshold determined by trigger
- Additional ID requirements
- Jet is sufficiently boosted, defined $\rho \equiv \ln(m^2/p_T^2)$
- Separation of photon and jet by $\Delta R \geq 2.2$
- Two-pronged substructure requirement



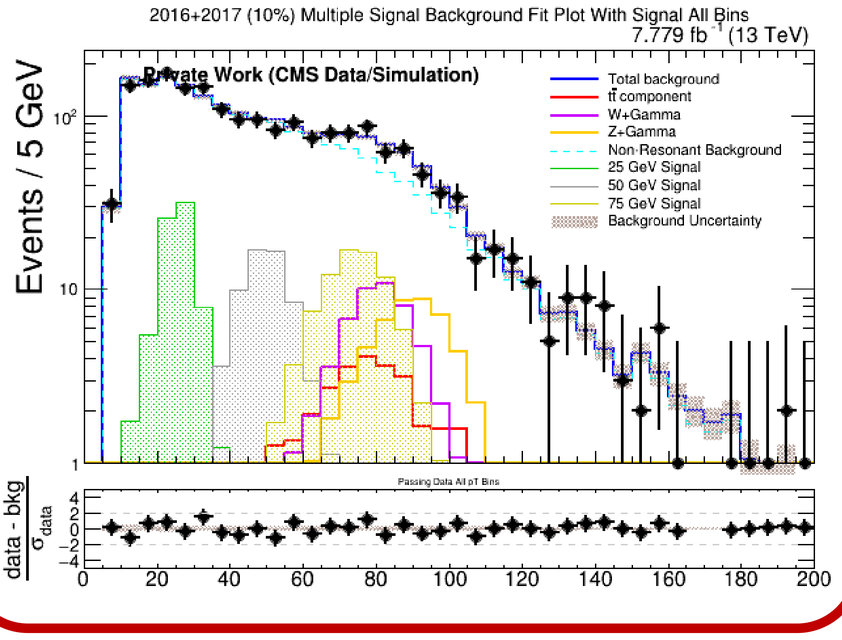
https://cms.cern/news/casting-light-dark-sector

Background Fit

- Data-driven background estimate, using Transfer Factor (TF) between distribution failing and passing two-pronged metric cut
- TF is a Bernstein polynomial function of ρ and p_T
- $N_{pass} = TF(\rho, p_T) \times N_{fail}$
- TF fits non-resonant background well, avoids fitting peaks associated with signal
- Resonant backgrounds are taken from MC and allowed to float within 10% of theory cross-section
- Background fit currently using 10% of data, with the rest remaining blinded
  - Not including 2018 due to ongoing ParticleNet retraining

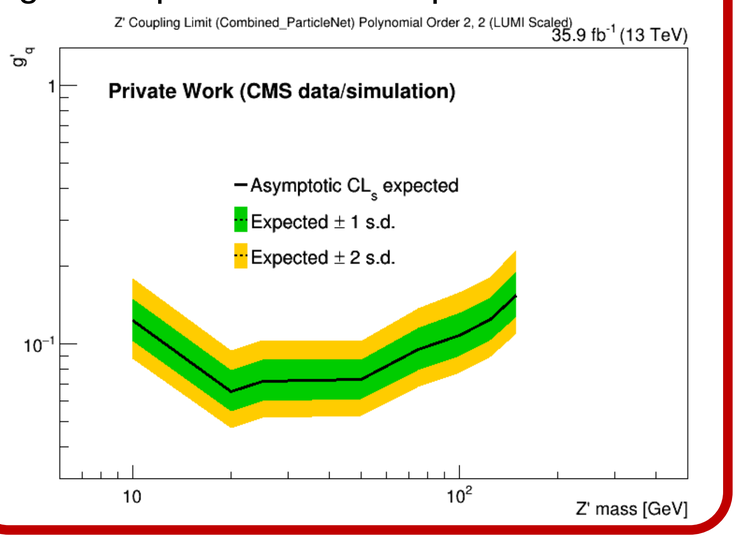


2016+2017 background fit with signal MC



Preliminary Limits

- 95% Confidence Level (CL) expected limits on $Z' \rightarrow q\bar{q}$ coupling strength (g'_q) using combined 2016 and 2017 background fits
- ParticleNet currently being retrained for 2018 in 120-200 GeV region
- All experimental uncertainties are accounted for in limits
- Scaling limit to 2016 luminosity shows great improvement over previous limits



Conclusion

- Analysis searches for low-mass $q\bar{q}$ resonances recoiling against an initial state photon using the Run 2 CMS data
- The following improvements over the previous analysis are being implemented:
  - Full 137 fb^{-1} Data of Run 2 will be used
  - Currently only using 10% of data
  - A lower transverse momentum (p_T) photon trigger added in 2018 allowing for more sensitive probe of the low mass region
  - New two-prong jet tagger with ML (ParticleNet) is being used as two-pronged jet metric
- Significant improvement in sensitivity is expected
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