Search for excited quarks in the γ + jet final state in proton proton collisions at 8 TeV

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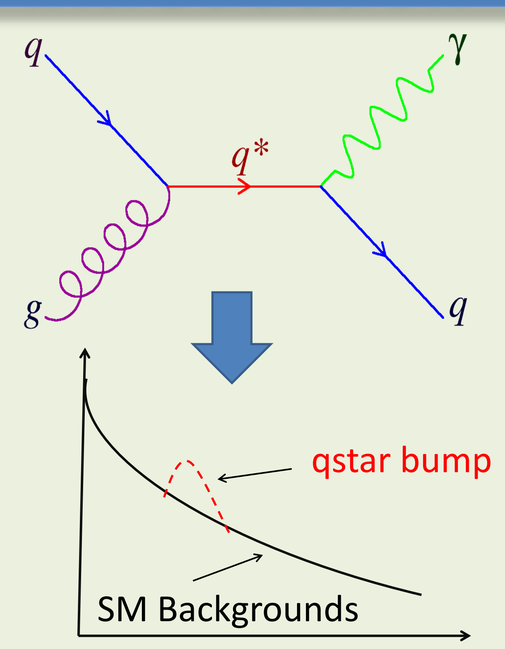
The poster presents a search for excited quarks (q*) decaying into a γ + jet final state at $\sqrt{s}$ = 8 TeV with the CMS[1] experiment, using the dataset corresponding to an integrated luminosity of 19.7 fb^{-1} collected during 2012 data taking at the LHC. Photons and jets with high transverse momentum are selected to search for a resonance peak in the γ + jet invariant mass distribution. The 95% confidence level upper limits on cross section times branching ratio are evaluated as a function of excited quark mass (M_{q*}). We exclude at 95% excited quarks with 0.7 < M_{q*} < 3.5 TeV for standard model coupling, and present exclusions of excited quark mass as a function of coupling strength.

Introduction

- Standard model (SM) of particle physics - most successful theory to describe observed phenomena in nature.
- Still many questions to answer → motivates to look in new directions.
- One such extension of SM → compositeness of quarks or excited states of quarks.
- The interaction of excited states with SM partners is given by lagrangian[2,3],

$$\mathcal{L}_{int} = \frac{1}{2\Lambda}\overline{q_R^*}\sigma^{\mu\nu}\left[\sum_i g_i b_i T_i^a G_{i\mu\nu}^a\right]q_L + h.c.$$

- Compositeness scale - denoted by Λ.
- The coupling parameters, f, f_s, f' - unknown dimensionless constants determined by compositeness dynamics.



Signal

- ✓ Excited quarks (q* → γ + jet)
- ✓ Assumptions : Compositeness scale, Λ = M_{q*}
- ✓ Coupling parameters $f = f_s = f'$
- ✓ Studied LO PYTHIA samples
- ✓ Considered f = 0.5 and 1.0 scenarios

Backgrounds

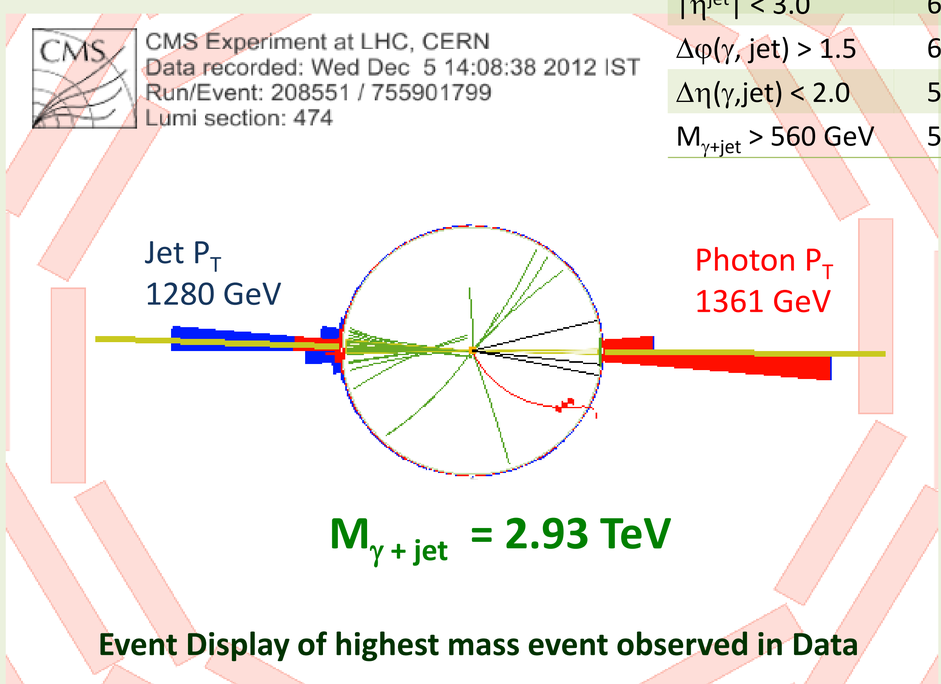
- ✗ Standard model γ + jet (PYTHIA × 1.3*).
- ✗ Di-jet final state : jet faking photon (PHYTIA × 1.3*).
- ✗ γ + W/Z : W/Z decays to a pair of jets.

*k-factor = 1.3

Event Selection

- Trigger - single photon trigger with p_T^γ > 150 GeV
- A good primary vertex is required with
  - |z| < 24 cm from the center of the detector
  - Tranverse distance from z-axis < 2cm
  - Number of degree of freedom > 4
- Photon Identification and Isolation*
  - Ratio of the energy deposited in the single closest HCAL tower to the energy deposited in the ECAL < 0.05
  - Shower shape $\sigma_{i\eta i\eta}$ < 0.011
  - Scalar Σp_T^γ within a cone of ΔR < 0.3, excluding strip of η = 0.015 < 0.5 GeV + 0.005p_T^γ
  - Σp_T of charged hadrons within 0.02 < ΔR < 0.3, < 0.7 GeV
  - Σp_T of neutral hadrons within ΔR = 0.3 < 0.4GeV + 0.04p_T^γ
- Leading photon , p_T > 170 GeV
- Leading photon, |η| < 1.4442
- Anti-kt5 Particle Flow jets with ΔR(γ, jet) > 0.5; ΔR = $\sqrt{(\Delta\eta^2 + \Delta\varphi^2)}$
- Leading jet, p_T > 170 GeV
- Leading jet, |η| < 3.0
- Δφ (γ, jet) > 1.5
- Δη (γ, jet) < 2.0
- $M_{\gamma + jet}$ > 560 GeV

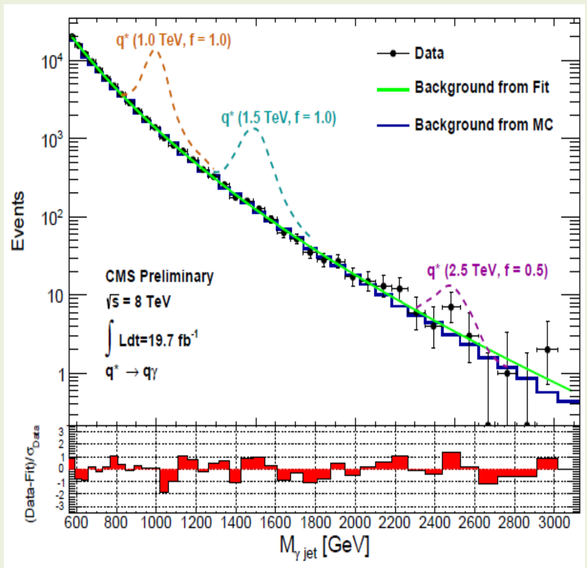
Selection	q* = 1 TeV
Photon ID	70.2 %
P_T^γ > 170 GeV	67.2 %
$\lvert\eta^\gamma\rvert$ < 1.4442	65.0 %
P_T^{jet} > 170 GeV	63.6 %
$\lvert\eta^{jet}\rvert$ < 3.0	63.4 %
Δφ(γ, jet) > 1.5	63.3 %
Δη(γ,jet) < 2.0	54.6 %
$M_{\gamma+jet}$ > 560 GeV	54.2 %



Event Display of highest mass event observed in Data

*Isolation is corrected for pileup effects

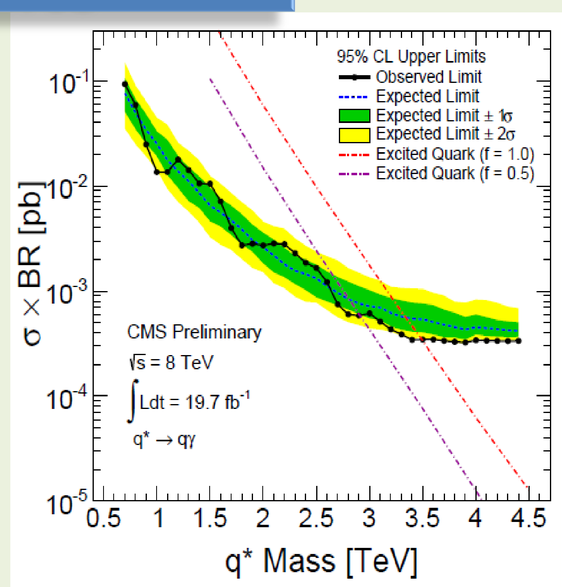
Results

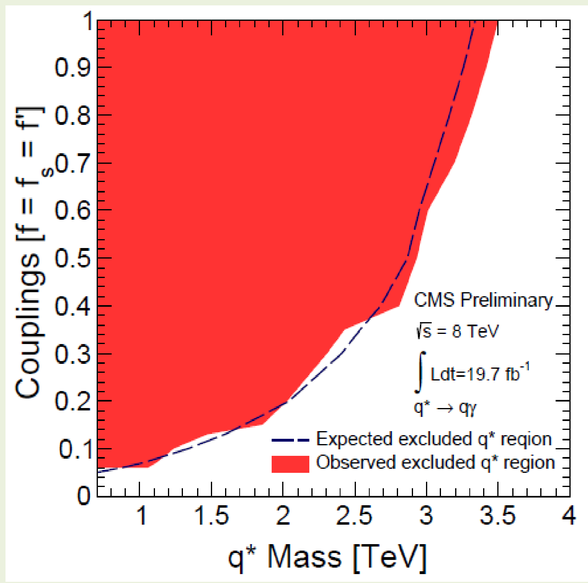


- ✗ Invariant mass distribution of the γ+jet events in data – compared to MC simulations after final selection.
- ✓ Background modelling from data.
- ✓ Fit it to a smooth parameterization

$$\frac{d\sigma}{dm} = \frac{P_0(1-m/\sqrt{s})^{P_1}}{(m/\sqrt{s})^{P_2+P_3 ln(m/\sqrt{s})}}$$

- ✓ No Excess observed → Set Limits





Systematic Uncertainty

- ✓ Background shape uncertainty – evaluated by varying the fit parameters.
- Upper limits on cross section – evaluated using Bayesian formalism with uniform prior

Major Sources	Uncertainty
Jet energy resolution	10%
Photon energy resolution	0.5%
Jet energy scale	0.5-0.7%
Photon energy scale	0.7%
Photon ID	3-4%
Luminosity	2.6%

Conclusions[4,5]

- A search for excited quarks in the γ + jet final state is presented .
- Set 95% CL upper limits on σ × BR for q* → γ + jet.
- We exclude **0.7 < M_{q*} < 3.5 (2.9)** TeV for f = 1.0 (0.5).
- Exclude region at 95% CL as function of coupling strength and q* mass.

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References
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[2] Int. J. Mod. Phys. **A2** (1987) 1285
[3] Phys.Rev. **D80** (2009) 015014
[4] CMS PAS EXO-13-003
[5] CMSPublic PhysicsResultsEXO13003

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