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Excited quark production at a 100 TeV VLHC

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I look for a dijet resonance produced by an excited quark q^* in a simulated sample corresponding to $3\,\mathrm{ab}^{-1}$ of pp collisions at $\sqrt{s} = 100\,\mathrm{TeV}$. Using a cut and count analysis approach, I demonstrate the potential to explore q^* masses up to 50 TeV, corresponding to a length scale of around 4 am.

1.1 Introduction

At the new energy regime afforded by a $\sqrt{s} = 100\,\mathrm{TeV}$ pp collider (VLHC) [1], it should be possible to search for structure of the quarks of the standard model [2, 3, 4]. The primary background for a signal of this type is the QCD dijet production.

1.2 Data and detector simulation

Using PYTHIA [5] and the CTEQ6L1 PDF's, I genererate both background and signal events and perform the parton showering. The center of mass energy of the pp collisions is 100 TeV. The "Snowmass" detector [6], based on the Delphes [7] detector simulation package, provides the detector response. The foreseen rate for "pile-up" pp interactions is an average of 140 minimum bias interactions per bunch crossing. The integrated liminosity is expected to reach $3\,\mathrm{ab}^{-1}$. During the production of the signal samples, I use the convention $\Lambda = m_{q^*}$. The cross-sections reported by PYTHIA for the considered processes are contained in Table 1-1. As in [2] the branching fraction to dijets is 85%.

Table 1-1. *Cross-sections for signal processes.*

q^* mass	cross-sections (fb)
30 TeV	22.8
40 TeV	0.986
50 TeV	4.38×10^{-2}
60 TeV	2.22×10^{-3}

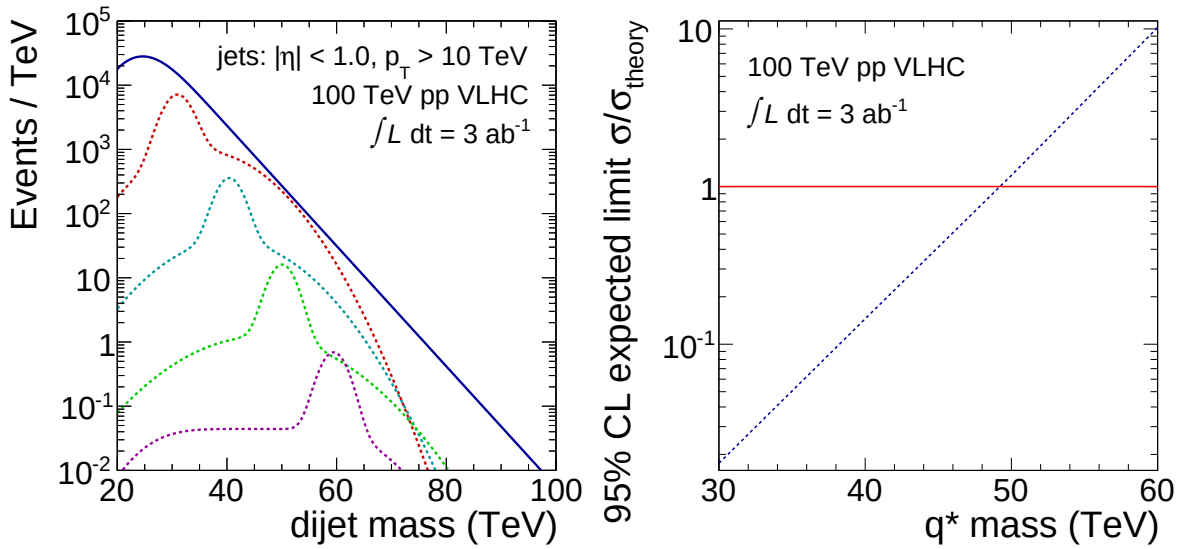

Figure 1-1. *(left) Dijet mass spectrum for background dijet production (solid blue line) and q^* models with masses from 30 TeV to 60 TeV (dashed colored lines). (right) 95% CL upperlimit on the cross-section of q^* resonance as a function of its mass normalized by the theoretical prediction for the cross-section.*

1.3 Analysis

From the signal and background samples, I select the two jets with the largest p_{T}. To reduce the relative contribution of the QCD dijet production, I require that the jet $p_{\mathrm{T}} > 10\,\mathrm{TeV}$ and $|\eta| < 1.0$. I use the dijet invariant mass spectrum to separate the signal and background components. The mass spectra for the background and signals with masses from 30 TeV to 60 TeV are shown in Fig. 1-1(left).

Because of the large cross-section for the QCD process, I parameterize the spectral shape from a large sample of simulated events and scale this shape to provide the background estimate. The functional form selected for the background is an exponential decay with an error function turn-on at the low-mass end of the specturm. The line-shapes for the various signal hypotheses are parameterized by a Gaussian distribution for the peak plus a wide structure to capture poorly reconstructed events.

Limits are derived using a simple counting method. I select a signal window corresponding to $\pm 2\sigma$ of the peaking component of the line-shape. Using the signal and background counts within the signal window, I place an asymptotic 95% CL upper limit on the cross-section for a given q^* mass. Systematic uncertainties are not included in the limits. Given the simplicity of the analysis, degradations due to systematic uncertainties can likely be compensated through more advanced analysis techniques.

1.4 Results

Figure 1-1(right) shows the expected limit as a function of q^* mass. The full $3\,\mathrm{ab}^{-1}$ of integrated luminosity should allow the exploration of q^* masses up to 50 TeV at the VLHC. A reach of 50 TeV would study substructure within quarks at the scale of 4 am.

References

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