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Search for Excited and Exotic Electrons at the Collider Detector at Fermilab

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The first search at a hadron collider for the production of excited and exotic electrons in association with a positron is presented. The excited electron decays to an electron and a photon with high transverse momentum yielding an electron+positron+photon final state signature. The search uses 202 pb^{-1} of data collected in $p\bar{p}$ collisions at $\sqrt{s} =$ 1.96 TeV with the CDF II detector during 2001-2003. No excess of dielectron+photon events is observed. We present the e* sensitivity in the parameter space of the excited electron mass and the compositeness energy scale for both a gauge mediated and contact interaction model.

Keywords: excited electron; exotic electron; excited leptons, excited quarks.

1. Introduction

This is a search for e^* production in association with an oppositely charged electron where the e^* decays to an electron and photon as in the reaction: $q + \bar{q} \to e + e^* \to e + e + \gamma$. The $ee\gamma$ final state signature is a very clean experimental signal with low background expectations and good energy resolution

The discovery of e^* would be a first indication of quark and lepton compositeness. Two models are explored. In the gauge mediated model (GM) e^* is produced via gauge interactions, $q + \bar{q} \to Z/\gamma^* \to e + e^*$ [1]. In the contact interaction model (CI), the constituent particles of the quark and antiquark interact to produce $e + e^*$ [1].

CDF is described in detail in [2]. Both the central and forward regions of CDF out to $|\eta| < 2.8$ are used. Events with dielectron invariant mass in the range $81 < m_{ee} < 101$ GeV/c^2 are rejected to suppress $Z(\to ee)\gamma$ background.

2. Total Signal Acceptance

The CDF simulation is used to measure the total signal acceptance for each model at a series of mass values. For the GM model, e^* Monte Carlo events are generated

*Representing the CDF Collaboration; Fermilab, MS 318 CDF/Duke, P O Box 500, Batavia, IL 60510 and cross-sections calculated by implementing the Lagrangian into COMPHEP [3] using LANHEP [4]. For the CI model, PYTHIA [5] is used. At low mass ($M_{e^*} \sim 100$ GeV/c^2), the total signal acceptance is approximately 15%; it increases with mass to a maximum value of ~34% for the GM model and ~30% in the CI model. Primary sources of uncertainty are statistics, e and γ identification, and uncertainty in the amount of passive material in the simulation.

3. Backgrounds

Pure standard model $Z(\rightarrow ee) + \gamma$ production is predicted using the leading order ZGAMMA [6] program. Electron misidentification backgrounds include $W(\rightarrow e\nu)Z(\rightarrow ee)$ and $Z(\rightarrow ee)Z(\rightarrow ee)$ where an e is misidentified as a γ [a]. $t\bar{t} \rightarrow e^+\nu b + e\bar{\nu}\bar{b}$ produces an $ee\gamma$ signature when one of the b quarks radiates a high energy photon. PYTHIA is used to predict the WZ, ZZ, and $t\bar{t}$ backgrounds. Systematic uncertainties are predominately due to integrated luminosity, PDFs uncertainties on the cross-section, and higher order QCD corrections to leading order cross-sections.

The following are backgrounds due to jet misidentification: $Z(\rightarrow ee)+jet$, where a jet fakes a γ; multijet background where jets fake two e and a γ; $\gamma\gamma+jet$ where a jet fakes an e; and $W(\rightarrow e\nu)+\geq 2jets$ where a jet fakes an e and another fakes a γ. These backgrounds are predicted by measuring fake rates from data and applying the appropriate fake rate to jets in the signal dataset. The systematic uncertainties on the “fake” backgrounds are mostly from uncertainty in the fake rates.

$Z(\rightarrow ee) + \gamma$ and $Z(\rightarrow ee) + jet$ contribute the most to the total background expectation. The total expected number of $ee\gamma$ events is 3.0 ± 0.1 (stat)$^{+0.4}_{-0.3}$ (syst). The expected number of $e\gamma$ combinations is 6.5 ± 0.1 (stat)$^{+0.9}_{-0.7}$ (syst).

4. Data and Results

Three candidate events, with 7 $e\gamma$ combinations, are observed in the data. This is consistent with the total background prediction. However, the observed events have interesting high-mass characteristics and one is a $Z(\rightarrow ee)Z(\rightarrow ee)$ candidate.

We set 95% confidence level upper limits on the e^* production cross-section (and lower limits on e^* mass) using a Bayesian [7,8] approach. Mass-dependent uncertainties in the theoretical cross-sections due to PDFs and higher-order QCD corrections are included. Fig. 1(a) shows the mass limits for $M_{e^*} = \Lambda$. In the parameter space of f/Λ *vs* M_{e*} (Fig. 1(b)), $M_{e*} < 430$ GeV/c^2 is excluded for $f/\Lambda \sim 0.01$ GeV^{-1} at the 95% C.L, in the GM model, well beyond previous limits [9,10,11,12]. The first ever e^* limits set for the CI model are shown in Fig. 1(c) using the M_{e*}/Λ *vs* M_{e*} parameter space.

[a]For the search, electrons and photons in the forward detector have no tracking requirements and are treated as the same type of object. Thus, this background is predominate in the forward detector and minimal in the central detector where tracking efficiency is very high.

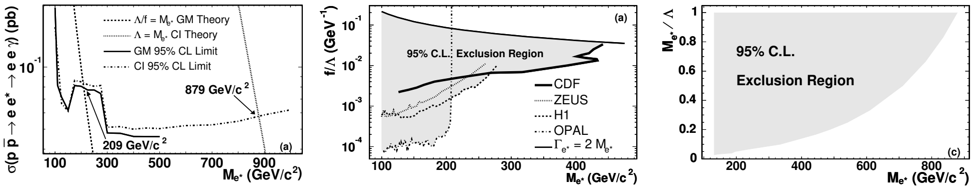

Fig. 1. The experimental cross-section limits for the GM and CI models, compared to the respective theoretical cross-sections for $M_{e*} = \Lambda$ (a). 2-D parameter space regions excluded by the GM model (b) and the CI model (c).

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