RESONANT PRODUCTION OF COLOR OCTET ELECTRON AT THE LHeC

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ABSTRACT

In composite models with colored preons, leptogluons l_8 have the same status with leptoquarks, excited leptons and quarks etc. Excited fermions and leptoquarks are widely discussed in literature and their searches are inseparable parts of future collider's physics programs. Unfortunately, leptogluons did not attract necessary attention, while they are predicted in all models with colored preons We analyze resonant production of color octet electron l_8 at QCD Explorer stage of the Large Hadron electron Collider (LHeC). Lagrangian for e_8 interactions is presented and it's decay widths and production cross sections at different stages of LHeC are evaluated. The analysis of leptogluon signatures at QCD-E stages of the LHeC is given. It is shown that the e_8 discovery at the LHeC simultaneously will determine the compositeness scale. If Me_8=500 GeV, LHeC/QCDE-2 with L_{int}=10 fb^{-1} will be sensitive to Λ up to 570 TeV.

INTRODUCTION

A large number of "fundamental" particles, as well as observable free parameters (put by hand), in Standard Model (SM) indicate that it is not "the end of story". Physics met similar situation two times in the past: One is the Periodic Table of the Elements which was clarified by Rutherford's experiment, the other is hadron inflation which has resulted in quark model. This analogy implies the preonic structure of the SM fermions.

The preonic models predict a zoo of new particles such as excited leptons and quarks, leptoquarks, leptogluons etc. For example, in the framework of fermion-scalar models, leptons would be a $l=(F\bar{S})=1\oplus 8$ bound state of one fermionic preon and one scalar anti-preon (both F and S are color triplets), then each SM lepton has its own colour octet partner. Lower bound on leptogluon masses, 86 GeV, given in PDG reflects twenty years old Tevatron results. The fifteen years old H1 data on color octet electron, e_8 search has excluded the compositeness scale $\Lambda \leq 3$ TeV for $Me_8 \cong 100$ GeV and $\Lambda \leq 240$ GeV for $Me_8 \cong 250$ GeV. The advantage of lepton-hadron colliders is the resonant production of leptogluons, whereas at hadron and lepton colliders they are produced in pairs.

DECAY WIDTH AND PRODUCTION CROSS SECTIONS

For the interaction of leptogluons with the corresponding lepton and gluon we use the following Lagrangian:

$$L=\frac{1}{2\Lambda}\sum_{l}\{\bar{l}_8^{\alpha} g_s G^{\alpha}_{\mu\nu}\sigma^{\mu\nu}(\eta_L l_L+\eta_R l_R)+\text{h.c.}\}$$

where $G^{\alpha}_{\mu\nu}$ is the field strength tensor for gluon, index $\alpha=1,2,...,8$ denotes the color, g_s is gauge coupling, η_L and η_R are the chirality factors, l_L and l_R denote left and right spinor components of lepton, $\sigma^{\mu\nu}$ is the anti-symmetric tensor and Λ is the compositeness scale. The leptonic chiral invariance implies $\eta_L\eta_R = 0$. For numerical calculations we add leptogluons into the CalcHEP program. Decay width of color octet electron is given by formula given below. In fig. 1 decay widths of color octet electron are presented for $\Lambda = Me_8$ and Λ=10 TeV. In Table 1 contains tentative parameters of the LHeC linac-ring options.

$$\Gamma_{e8}=\frac{\alpha_s M_{e8}^3}{4\Lambda^2}$$

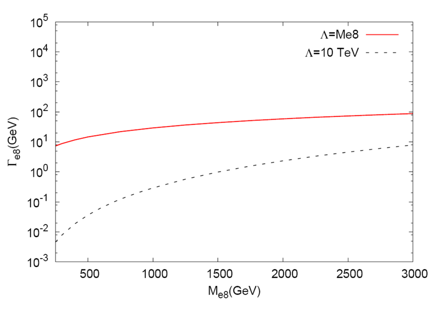

Fig.1 Decay widths of color octet electron.

Table 1

Tentative parameters of the LHeC linac-ring options. QCDE and EF denotes QCD Explorer and Energy Frontier, respectively.

Stage	E_e, GeV	$\sqrt{s}$, TeV	L, 10^{32} cm^{-2} s^{-1}
LHeC/QCDE-1	70	1.4	1–10
LHeC/QCDE-2	140	1.98	1–10
LHeC/EF	500	3.74	1

SIGNAL AND BACKGROUND ANALYSES LHeC/QCDE-1 STAGE

All calculations were performed at the partonic level using CalcHEP simulation program with CTEQ6l parton distributions functions. Hereafter the term jet means gluon for signal and quarks for background processes. The transverse momentum distribution of final state jets for signal at Λ=10 TeV and for background is shown in Fig. 2. It is seen that $p_T>150$ GeV cut essentially reduces background, whereas signal is almost unaffected. Figs. 3 and 4 represent pseudo-rapidity (η) distributions for electrons and jets, respectively. As seen from figure 4, η_e- distribution for signal and background are not drastically different. Concerning η_j, most of signal lies above $\eta=0$, whereas 99% of background is concentrated in $-2<\eta_j<0$ region. For this reasons below we use $p_T>150$, $|\eta_e|<4$ and $0<\eta_j<4$. With these cuts we present in Fig. 5 the invariant mass distributions for signal and background.

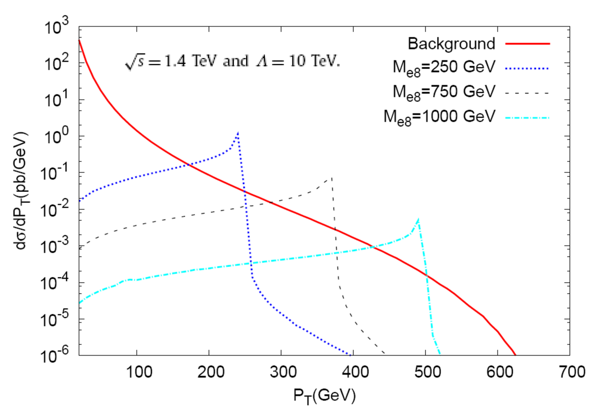

Fig. 2 Transverse Momentum distributions of final state jets for signal and background.

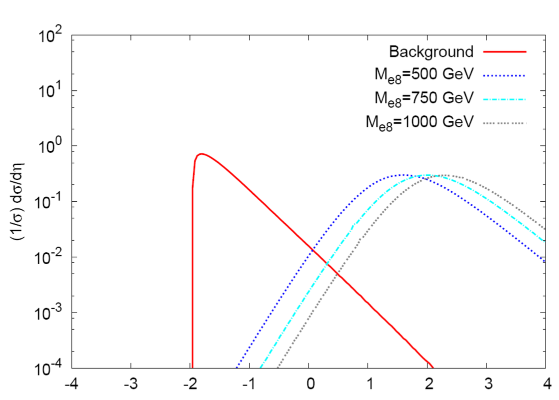

Fig. 3 Pseudo-rapidity distribution of Jets for signal and background.

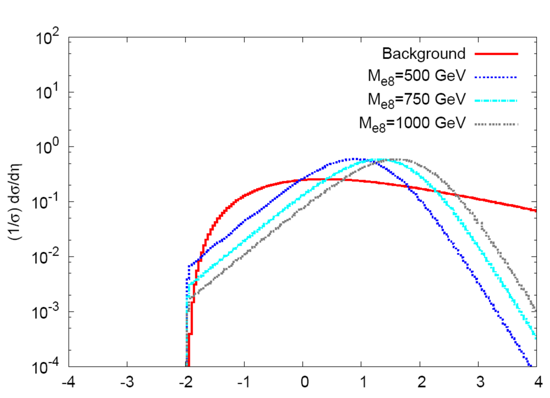

Fig. 4 Pseudo-rapidity distribution of Electron for signal and background.

The number of signal and background events for different Me_8 values are presented in Table 2 for L_{int}=1fb^{-1} . In calculating these values, in addition to cuts given above, we have used mass windows as $M_{e8}-2\Gamma_{e8}<M_{ej}<M_{e8}+2\Gamma_{e8}$ for $\Gamma_{e8}>10$ GeV and $M_{e8}-20$ GeV $<M_{ej}<M_{e8}+20$ GeV for $\Gamma_{e8}<10$ GeV.

It is seen that the resonant production of the color octet electron will provide very clean signature for masses up to Me_8 =1TeV. The reachable compositeness scale values for L_{int}=1 and L_{int}=10 fb^{-1} are given in Table 3. It is seen that multi-hundred TeV scale can be searched for Me_8 =500 GeV and the increase of the luminosity by one order gives two times higher values for Λ.

Lastly, for a given L_{int}=1 fb^{-1}, the upper mass limits for 5σ discovery at LHeC/QCDE-1 stage are Me_8 =1100 GeV and Me_8=1275 GeV for Λ=10 TeV and Λ=Me_8, respectively.

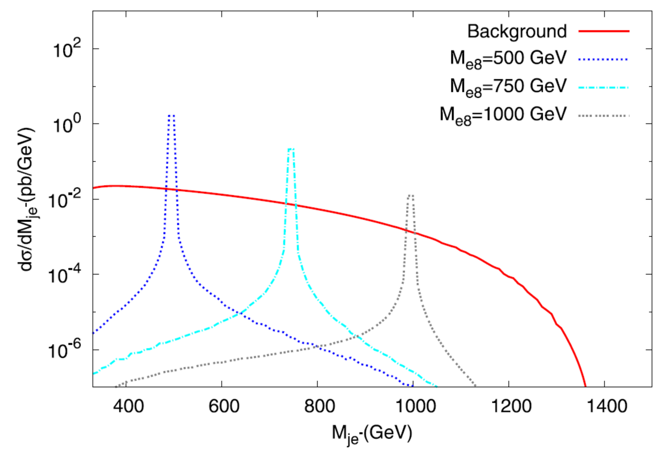

Fig. 5 ej invariant mass distributions for signal and background.

Table 2

Achievable compositeness scale Λ in TeV units at LHeC/QCDE-1 for 5σ (3σ) statistical significance.

M_{e8}, GeV	L_{int} = 1 fb^{-1}	L_{int} = 10 fb^{-1}
500	150 (200)	275 (350)
750	65 (90)	125 (160)
1000	22 (30)	45 (58)

SIGNAL AND BACKGROUND ANALYSES LHeC/QCDE-2 STAGE

In order to determine the corresponding cuts we present p_T , η_j and η_e distributions for signal and background processes in Figs. 6, 7 and 8, respectively. These figures indicate that significant change takes place only for η_j. In this sections we will use $p_T>150$ GeV, $|\eta_e|<4$ and $-0.5<\eta_j<4$. The invariant mass distributions obtained with this cuts are given in Fig. 9.

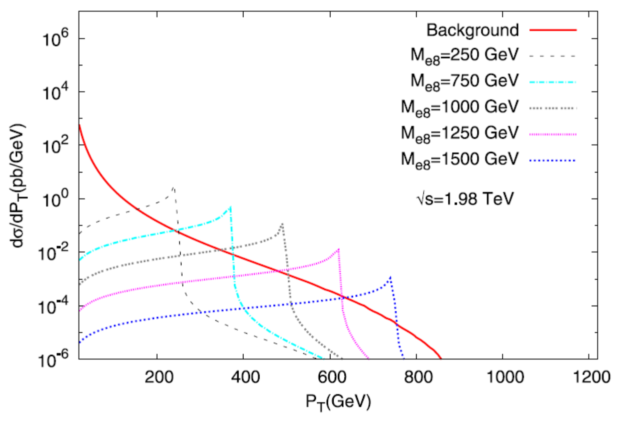

Fig. 6 Transverse Momentum distributions of final state jets for signal and background.

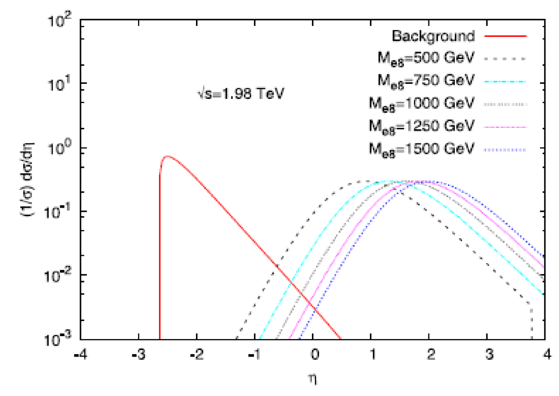

Fig. 7 Pseudo-rapidity distribution of Jets for signal and background.

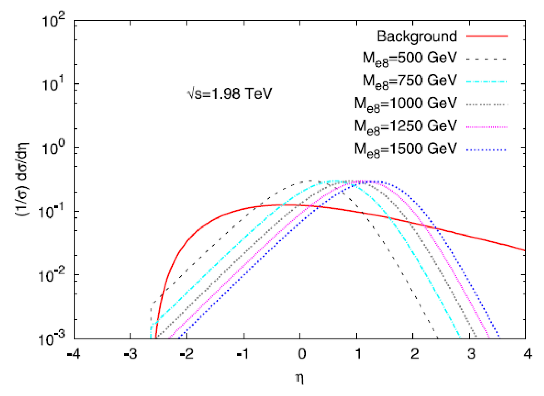

Fig. 8 Pseudo-rapidity distribution of Electron for signal and background.

The numbers of signal and background events for 6 different Me_8 values are presented in Table 3. As seen from the table very clean signal can be obtained up to $Me_8 \cong 1500$ GeV. The reachable Λ scales for 5 different mass values are given in Table 4.

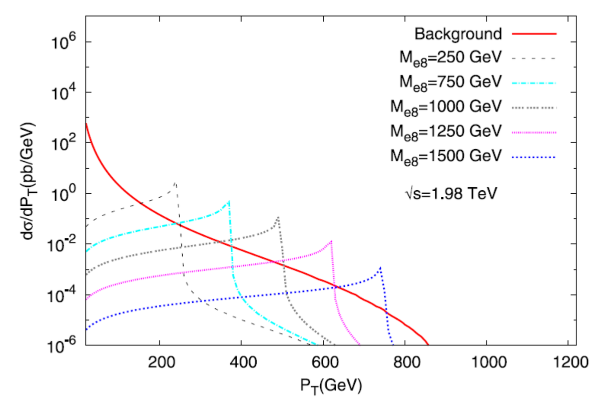

Fig. 9. Transverse momentum distributions of final state jets for signal and background at $\sqrt{s}=1.98$ TeV and $\Lambda=10$ TeV.

Table 3

Number of signal and background events for LHeC/QCDE-2 with $L_{int}=1$ fb^{-1}.

M_{e8}, GeV	$\Lambda=M_{e8}$		$\Lambda=10$ TeV	
	S	B	S	B
500	3.3×10^7	1.4×10^3	9.8×10^4	940
750	3.9×10^6	1000	2.6×10^4	445
1000	5.0×10^5	630	5.8×10^3	210
1250	5.3×10^4	270	980	76
1500	3.5×10^3	77	89	16
1750	55	6	2	1

Table 4

Achievable compositeness scale Λ in TeV units at LHeC/QCDE-2 for 5σ (3σ) statistical significance.

M_{e8}, GeV	$L_{int}=1$ fb^{-1}	$L_{int}=10$ fb^{-1}
500	245 (320)	440 (570)
750	150 (195)	275 (355)
1000	82 (110)	155 (205)
1250	41 (56)	81 (107)
1500	16 (23)	34 (46)

CONCLUSION

It seems that QCD Explorer stage(s) of the LHeC, together with providing necessary information on PDF's and QCD basics, could play essential role on the BSM physics, also. Concerning color octet electrons. LHeC/QCDE-1 will cover Me_8 mass up to O(1200 GeV), whereas LHeC/QCDE-2 will enlarge covered mass range up to O(1700 GeV).
The discovery of e_8 at this machine, simultaneously will determine compositeness scale. For example if Me_8=500 GeV, LHeC/QCDE-2 with L_{int}=10 fb^{-1} will be sensitive to Λ up to 570 TeV.

REFERENCES

1. I.A.D' Souza and C.S. Kalman, PREONS: Models of leptons, quarks and gauge bosons as composite objects, World scientific Publishing Co, 1992.
2. A. Celikel, M. Kantar and S. Sultansoy, Phys. Lett. B 443 (1998) 359.
3. G. Amsler et al. (Particle Data Group), Phys. Lett. B 667 (2008) 1.
4. S. Sultansoy, Eur. Phys. J. C 33 (2004) S1064.
5. S. Sultansoy, in: Proceedings of Particle Accelerator Conference, Knoxville, 2005, p. 4329.
6. A.N. Akay, H. Karadeniz and S. Sultansoy, arXiv:0911.3314 [physics.acc-ph].
7. The LHeC web page, http://www.lhec.org.uk.
8. F. Zimmerman et al., in: Proceedings of European Particle Accelerator Conference, Genoa, Italy, 2008, p. 2847.
9. A. Celikel and M. Kantar, Tr. J. of Phys. 22 (1998) 401.
10. A. Pukhov et al., hep-ph/9908288.
11. D. Stump et al., JHEP 0310 (2003) 046.
12. M. Sahin, S. Sultansoy and S. Turkoz, Phys. Lett. B 689 (2010) 172.