FERMILAB-Conf-98/279-E
D0

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October 1998

Published Proceedings of the *XXIX International Conference on High Energy Physics - ICHEP98*, Vancouver, B.C., Canada, July 23-29, 1998

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The DØ Collaboration *
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(September 11, 1998)

Abstract

The DØ dijet angular distribution is used to place limits on flavor–universal colorons. Models with $M_c/\cot\theta < 759$ GeV/c^2 are excluded at the 95% confidence level.

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*Submitted to the *XXIX International Conference on High Energy Physics - ICHEP98,* July 23 – 29, 1998, Vancouver, B.C., Canada.

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A flavor universal coloron model [1] has been proposed to explain the excess in the inclusive jet cross section as measured by CDF [2] without contradicting other experimental data. The model is minimal in its structure, in that it involves the addition of one new interaction, one new scalar multiplet and no new fermions. The QCD gauge group is extended to $SU(3)_1 \times SU(3)_2$, with gauge couplings ξ_1 and ξ_2 respectively, with $\xi_2 \gg \xi_1$. All quarks are assigned to triplet representations of the stronger group $SU(3)_2$. The symmetry is broken to its diagonal subgroup, $SU(3)_{\rm QCD}$, when a scalar boson Φ which transforms as a $(3,\bar{3})$ under the original two SU(3) groups acquires a vacuum expectation value $< \Phi >= f$. Thus at low energies there exist both ordinary massless gluons and an octet of heavy coloron bosons, $C^{\mu a}$. As described in [1], the colorons couple to all quarks as:

$$\mathcal{L} = -g_3 \cot\theta J^a_\mu C^{\mu a}, \tag{1}$$

where J^a_μ is the color current ($J^a_\mu = \bar{q}\gamma^\mu(\lambda^a/2)q$) and $\cot\theta = \xi_2/\xi_1$. The coupling g_3 is identified with the QCD coupling constant and has a value of approximately 1.2 (corresponding to $\alpha_3(M_Z) \approx 0.12$). In terms of these parameters the mass of the coloron is

$$M_c = \left(\frac{g_3}{\sin\theta\cos\theta}\right) f. \tag{2}$$

Below the scale M_c, coloron–exchange can be approximated by the effective four–fermion interaction

$$\mathcal{L}_{\rm eff} = -\frac{g_3^2 \cot^2\theta}{2! M_c^2} J^a_\mu J^{\mu a}. \tag{3}$$

Note, this interaction can be rewritten in the form usually used in studies of quark compositeness:

$$\mathcal{L}_{\rm eff} = \frac{-g_3^2}{2!\Lambda^2} J^a_\mu J^{a\mu} \tag{4}$$

where $g_3^2 \equiv 4\pi$ and $\Lambda\sqrt{\alpha_{\rm s}} = M_c/\cot\theta$.

The phenomenology of the coloron has been studied [3] and limits have been placed on M_c and $\cot\theta$. Constraints on the size of the weak–interaction ρ parameter require $M_c/\cot\theta > 450$ GeV [1] and a direct search for colorons in the dijet mass spectrum at CDF [4] excludes colorons with mass below 1 TeV for $\cot\theta \lesssim 1.5$.

In analogy with the effects of quark compositeness [5], the low-energy effects of coloron exchange (equation 3) will lead to to an excess of events at small values of χ in the dijet angular distributions ($\chi = \exp(\Delta\eta)$ where $\Delta\eta$ is the separation in pseudorapidity between the two jets ($\eta = -\ln[\tan(\theta/2)]$)). Predictions of the dijet angular distribution with colorons are available at leading order (LO). To simulate a next–to–leading order (NLO) prediction, the effects of the coloron LO predictions for several values of $M_c/\cot\theta$ are generated. The fractional difference between the angular distribution with $M_c/\cot\theta = \infty$ and the distribution with a finite value of $M_c/\cot\theta$ are then measured. The coloron NLO prediction is then obtained by multiplying a NLO QCD prediction obtained using the JETRAD program [6] by the LO fractional differences obtained above. The results are shown in Fig. 1.

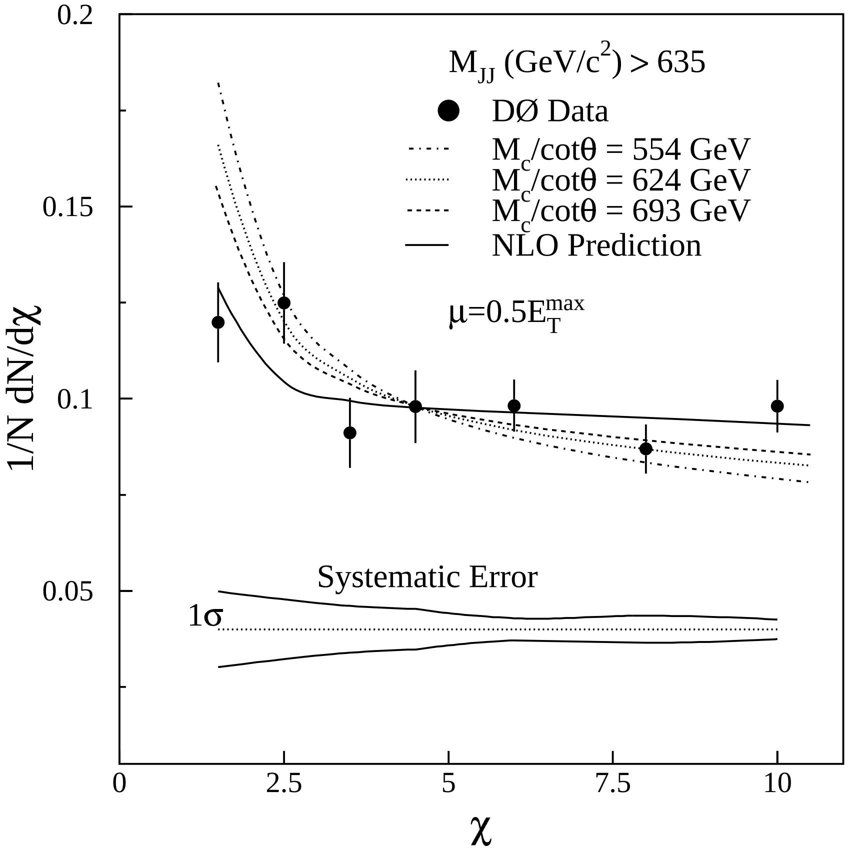

FIG. 1. DØ data compared to theory for different values of $M_c/\cot\theta$ (see text for details on how the coloron distributions are calculated). The errors on the points are statistical and the band represents the correlated $\pm 1\sigma$ systematic uncertainty.

Also shown in Fig. 1 is the dijet angular distribution as measured by DØ [7] for $M_{\rm JJ} > 635$ GeV/c^2. Limits on the coloron mass are calculated using the ratio

$$R_\chi = \frac{N(\chi < 4.)}{N(4. < \chi < \chi_{\rm max})}, \tag{5}$$

where $N(\chi)$ gives the number of events in the given χ range. The calculation of R_χ removes the correlated errors that are a function of χ. Table I gives R_χ for the different mass ranges and their statistical and systematic uncertainties, which are fully correlated in mass.

Mass Range (GeV/c^2)	R_χ	Stat Error	Sys Error
260-425	0.191	0.0077	0.015
425-475	0.202	0.0136	0.010
475-635	0.342	0.0085	0.018
635-	0.506	0.0324	0.028

TABLE I. The dijet angular ratio R_χ and its statistical and systematic uncertainty.

The coloron limit is calculated using Bayesian techniques with a Gaussian likelihood function ($P(x)$) for R_χ as a function of mass:

$$P(x) = \frac{1}{|S|\, 2\pi^2} \exp\left(-\frac{1}{2}\left[d - f(x)\right]^T S^{-1} \left[d - f(x)\right]\right) \tag{6}$$

where d is the vector of data points for the different mass bins, $f(x)$ is vector of theory points for the different masses at different values of x where $x = 1/\Lambda^n$, and S^{-1} is the inverse of the covariance matrix.

The limit depends on the choice of prior probability distribution for $P(x)$. Motivated by the form of the Lagrangian the prior probability is assumed to be flat when $x = 1/\Lambda^2$. Since the dijet angular distribution is sensitive to the choice of renormalization scale, each possible choice is treated as a different theory. The 95% confidence limit (CL) on Λ is calculated by requiring that

$$Q(x) = \int_0^x P(x)dx = 0.95Q(\infty). \tag{7}$$

The limit in x is then transformed back into a limit on Λ. If a renormalization scale, $\mu = E_T^{\max}$ (where $E_T^{\max}$ is the transverse energy of the highest E_T jet) then the 95% CL on the coloron mass is $M_c/\cot\theta > 759$ GeV/c^2. If $\mu = 0.5E_T^{\max}$ then the 95% CL is $M_c/\cot\theta > 786$ GeV/c^2. The resulting limits are plotted in Fig 2.

In conclusion, the dijet mass spectrum as measured by DØ can be used to exclude flavor–universal colorons with $M_c/\cot\theta$ below 759 GeV/c^2 at the 95% confidence level.

ACKNOWLEDGEMENTS

We thank R. Harris for the use of his program based on Refs. [5,1]. We thank the staffs at Fermilab and collaborating institutions for their contributions to this work, and acknowledge support from the Department of Energy and National Science Foundation (U.S.A.), Commissariat à L'Energie Atomique (France), State Committee for Science and Technology and Ministry for Atomic Energy (Russia), CAPES and CNPq (Brazil), Departments of Atomic Energy and Science and Education (India), Colciencias (Colombia), CONACyT (Mexico), Ministry of Education and KOSEF (Korea), and CONICET and UBACyT (Argentina).

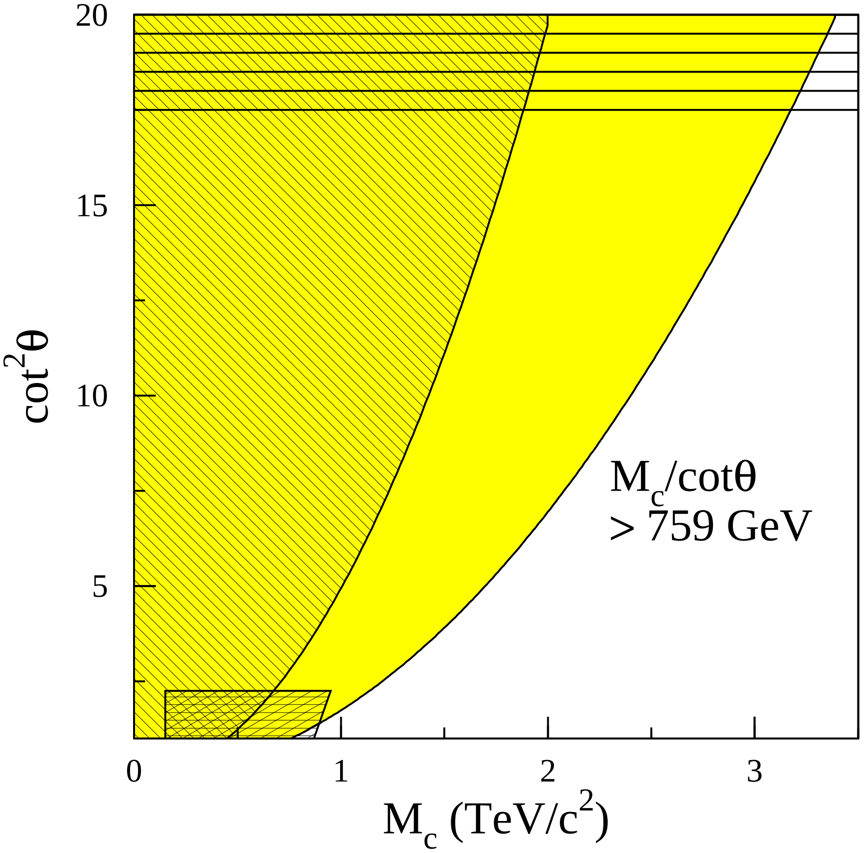

FIG. 2. Limits on the coloron parameter space: coloron mass M_c vs. mixing parameter $\cot\theta$. The shaded region shows the 95% CL exclusion region for the DØ dijet angular distribution measurement ($M_c/\cot\theta > 759$ GeV/c^2). The horizontally hatched region at large $\cot\theta$ is not allowed in this phase of the model [1,3]. The diagonally hatched region is excluded by the value of ρ ($M_c/\cot\theta > 450$ GeV/c^2) [1]. The cross–hatched region is excluded by the CDF search for new particles decaying to dijets [4].

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