Quark Anomalous Chromomagnetic Moment Bounds - Projection to Higher Luminosities and Energy*

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ABSTRACT

The statistical limits on detectability of an anomalous chromomagnetic moment of a quark coupling to a gluon are projected to higher luminosities at the Tevatron at Fermilab, and to the LHC. They roughly scale as the energy, and are not strongly improved with increasing lumonisity.

I. ANOMALOUS CHROMOMAGNETIC MOMENTS OF QUARKS

New interactions or composite structure can lead to anomalous magnetic moments for electromagnetic interactions and anomalous chromomagnetic moments for colored intermediate states of colored quarks. The form of the interaction is

$$\mathcal{L}_{eff} = g\bar{\psi}\frac{\lambda_a}{2}(-\gamma_\mu G^a_\mu + \frac{\kappa'}{2}\sigma_{\mu\nu}G^a_{\mu\nu})\psi \qquad (1)$$

It has been shown[1] that these could account for a possible discrepancy between CDF and D0 data and QCD[2, 3], although this can also be accounted for by larger gluon structure functions.

Since these same interactions can contribute to the mass of the quarks, they are usually considered to be small for light mass quarks[4, 5], but can be larger for heavier quarks, such as the b and certainly for the t quark. New heavy mass intermediate fermions could be allowed, however, if balanced by much heavier bosons since the ratio $\kappa' \propto m_F/m_B^2$ occurs[4, 5]. (Supersymmetry avoids this problem by only having squarks couple to gauginos with either pure L or R coupling, never mixing the two to form a mass term.) Here we examine without prejudice the phenomenology assuming the same anomalous chromomagnetic moment for each quark. Separate analyses have been made for only the t quark[6, 7, 8] or also the b quark[1] having the moment. Formulas for the cross sections in high tranverse energy jets[1] and high transverse energy prompt photon production[9] have been given.

In this short contribution, we define a statisitical criteria for comparing the sensitivity of new accelerators in energy and luminosity to set limits on $\kappa' \equiv 1/\Lambda$. Λ is not to be taken literally as the scale of the new phenomena, due to the complex relation cited above.

II. SIMPLE CRITERIA FOR STATISTICAL SENSITIVITY IN HIGH TRANSVERSE ENERGY JETS AND IN PROMPT PHOTON PRODUCTION

Without a full Monte Carlo of the detector including energy determination errors, we will treat here only the statistical sensitivity of the various experiments. Our criteria[10] is to take bins of appropriate size for the energy range being examined, and find the E_T called E_T^* at which the QCD cross section statistical error bars are 10%. These will be bins in which there are 100 QCD events. We then explore the cross section due to QCD plus the anomalous chromomagnetic moment contribution, and find the value of $\kappa' \equiv 1/\Lambda$ or Λ where the excess over QCD is 10% at this E_T^*. These E_T^* and Λ are shown in Table I. Since the cross section is steeply falling, varying the bin size by a factor of two makes only a small change in the value of E_T^* or Λ. The limits in $|\eta|$ used are 0.9 for CDF and the Tevatron, and 1.0 for LHC.

We see from the table that Λ sensitivity is roughly the same scale as the beam energy. We also see that large increases in luminosity do not increase Λ proportionately even to the square root of the luminosity.

III. EQUIVALENT CHALLENGES IN THEORY AND SYSTEMATICAL ERRORS

To match a 10% statistical uncertainty, the theory and systematic errors must be reduced to the same amount. Since structure functions enter as a product of two of them, the dominant regions have to have errors less than 5% each. The value of α_s at these transverse energies must also be known better than 5%. The main systematic error is non-linearities in the energy measurement at these high E_T. $d\sigma/dE_T$ falls at least as fast as E_T^{-3} on dimensional grounds, and also picks up some of the $(1 - x_T)^n$ powers from the structure functions, from $x_1 \approx x_2 \approx x_T \equiv E_T/(\sqrt{s}/2)$. Using the minimum falloff of E_T^{-3}, a 3% error on the linearity of E_T at E_T^* becomes a 10% error on the cross section.

These give goals for theory and energy measurement to be strived for to make use of the high energy and luminosity achievable at the Tevatron and at the LHC. Finally, the statistical significance of several bins in a row with deviation in the same direction can easily be increased above the 1-σ deviation of a single bin used here by grouping all such bins into a large bin. The details of doing this in a specific case will depend on the other errors as well.

Table I: Table of High E_T Bins at 10% Statistical Error and 1-σ Sensitivity for Λ in That Bin

Accelerator	E_{cm}	Integrated Luminosity	Bin Width	E_T Jets E_T^*	Λ	Photons E_T^*	Λ
	TeV	fb^{-1}	GeV	GeV	TeV	GeV	TeV
Tevatron:							
Run I	1.8	0.1	10	360	1.8	140	0.7
Run II	2.0	2	20	490	2.8	260	1.5
Stretch	2.0	10	20	540	3.3	325	1.9
TeV33	2.0	30	20	575	3.5	370	2.1
LHC	14	10	100	2500	13	1000	4.5
LHC	14	100	100	3100	17	1400	6.3

IV. REFERENCES

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