Search for New Particles
Decaying to Two Jets

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The DØDetector

- \( M_{jj}^2 = 2 \times E_{T_1} \times E_{T_2} \times (\cosh(\Delta \eta) - \cos(\Delta \Phi)) \) (massless)
- \( E_T \) is the energy transverse to the beam. \( E_T = E \sin \theta \)
- Pseudorapidity, \( \eta = -\ln(\tan(\theta/2)) \), the derivative of which is lorentz invariant, is used instead of \( \theta \).

- The DØ calorimeter measures the energy of “jets” produced from \( p\bar{p} \) collisions at \( (\sqrt{s}) = 1.8 \) TeV
- \( |\eta| < 4.2 \)
- Hadron resolution \( \frac{0.15}{\sqrt{E}} + 0.003 \)
**Data Selection and Corrections**

- Run Ia and Ib data, with a luminosity of 109 pb⁻¹.
- Cuts: $|\eta_{1,2}| < 1.0$ and $\Delta \eta = |\eta_1 - \eta_2| < 1.6$.
- Standard Run I DØjet quality cuts and vertex cut efficiencies were used.

Figure 1: Run Ia and b data, where corrected events

$$= \mathcal{L} \times \sigma \times \text{acceptance}$$

Corrected events $= \mathcal{L} \times \sigma \times \text{acceptance}$
Resolution Smearing of Simulated Signal and Background

The jet energy scale corrections make an average correction to the jets. Additional energy dependant corrections are needed.

**Single Jet resolution**

\[
\frac{\sigma_E}{E} = \sqrt{\frac{N^2}{E^2} + \frac{S^2}{E} + C^2} \tag{1}
\]

Applied to PYTHIA signal.

**Dijet Mass Resolutions**

Mass resolutions are determined by smearing every jet in a dijet Monte Carlo sample by the single jet resolution. Then the smeared(dijet mass)/unsmereared(dijet mass) is plotted and fitted with a gaussian distribution. The half width for each mass is plotted. The parameterized result follows:

\[
\frac{\sigma_M}{M} = \sqrt{\frac{A^2}{M^2} + \frac{B^2}{M} + C^2 + D^2M} \tag{2}
\]

Applied to JETRAD background.
Signal Models

- The $q^*$ model was generated using PYTHIA for coupling constants $f = f' = f_s = 1.0$ and $\Lambda^* = M_{q^*}$ (PYTHIA used for all signal)
- The $Z'$ ($Z' \rightarrow q\bar{q}$) was allowed to decay into $d\bar{d}, w\bar{u}, s\bar{s}, c\bar{c}, b\bar{b}$ and $t\bar{t}$
- The $W'$ ($W' \rightarrow q\bar{q}'$) was allowed to decay into $u\bar{d}, c\bar{s}$ and $t\bar{b}$.

Excited Quarks

$$q^* \rightarrow qg (q = u, d) \quad (3)$$

$$\sigma = \frac{\pi^2 \alpha_s}{3\Lambda^*} f_s^2 \frac{dL^{qq}}{d\tau}, (\tau = \frac{M_{q^*}^2}{s}) \quad (4)$$

Monte Carlo Simulation

- JETRAD Simulation.
- $q^*$ Line Shapes

$\sigma$ is the cross section and $\alpha_s$ is the strong coupling constant.
Confidence Limits

The probability that \( N_i \) events were observed in a given mass bin is then given by (assuming that \( N_i \) follows a Poisson distribution):

\[
P(N_1, \ldots, N_n | \sigma_{QCD}, \sigma_X, N_{X_i}, A, \mathcal{L}, \epsilon_{\text{vert}}, \omega_i, I) = \frac{e^{\mu_i} \mu_i^{N_i}}{N_i!} \quad (5)
\]

Applying Bayes’ theorem to the left hand side of equation 5 yields:

\[
P(\sigma_X | N_i, \sigma_{QCD}, \sigma_X, N_{X_i}, A, \mathcal{L}, \epsilon_{\text{vert}}, \omega_i, I; (i = 1 \ldots n)) \quad (6)
\]

- \( \sigma_{QCD} \) is the predicted JETRAD cross section
- \( A \) is a normalization factor for the QCD cross section
- \( N_{X_i} \) is the fraction of signal in the mass bin
- \( \sigma_X \) is the signal cross section
- \( \epsilon_{\text{vert}} \) is the efficiency of the vertex cut
- \( \omega_i \) is the event weighting based on the quality cuts
- \( I \) is all prior information

The confidence limit:

\[
0.95 = \int_0^{UL} P(\sigma_X) d\sigma \quad (7)
\]
Uncertainties

The uncertainties in the following values are taken care of by varying them randomly within a range of specified uncertainties over many iterations inside the confidence limit calculator.

- $\mathcal{L}$ for Run Ia and Run Ib
- Matching errors between Run Ia and Run Ib
- Matching errors between certain triggers
- Jet Energy Scale corrections, a correlation matrix is needed for these uncertainties.

Uncertainties on resolution smearing for generated signal and background are taken care of by generating a set of 61 curves that represent a sampling of smearings between $\pm 3\sigma$ and selecting the curves randomly during the confidence calculation.

Figure 2: (Dijet mass resolutions)/M
Figure 3: Comparison of q* 95% confidence limits to theory, where $f = f' = f_s = 1$
Figure 4: Comparison of limits for the excited quark model
Figure 5: Comparison of W’ 95% confidence limits to theory
DØ Preliminary (109 pb\(^{-1}\))

$|\eta| < 1.0$ and $|\Delta \eta| < 1.6$

Excluded

$400 \text{ GeV}/c^2 < M_{Z'} < 625 \text{ GeV}/c^2$

Figure 6: Comparison of $Z'$ 95% confidence limits to theory
Conclusion

Preliminary 95% confidence limits on the cross sections for various models have been measured. We see no evidence for new particles for the following regions and models:

- The q\* model is excluded for $M_{jj} < 800$ GeV
- The W’ model is excluded for $375$ GeV $< M_{jj} < 650$ GeV
- The Z’ model is excluded for $400$ GeV $< M_{jj} < 625$ GeV

Future models to be studied are technirho ($\rho_T \rightarrow q\bar{q}$) and axial gluons ($G \rightarrow gg$).