Search for Dijet Resonance in pp Collisions at CMS and ATLAS

Sertac Ozturk
Cukurova University / Fermilab
The results of Dijet Resonance search based on 315 nb\(^{-1}\) data from ATLAS was accepted by PRL.

http://arxiv.org/abs/1008.2461v2

- v1, 14 August 2010
- v2, 29 September 2010

The results of Dijet Resonance search based on 2.88 pb\(^{-1}\) data from CMS was submitted to PRL. It is first research and jet paper from CMS.

http://arxiv.org/abs/1010.0203

- v1, 1 October 2010
What is a Dijet?

✓ Dijet results from simple $2 \rightarrow 2$ scattering of “partons”, dominant process
✓ Dijet is the two leading jets in an event
The highest-\(m^{jj}\) central event observed

\[ m^{jj} = 1.77 \text{ TeV}. \quad p_T^{j1} = 1.1 \text{ TeV}. \quad p_T^{j2} = 480 \text{ GeV}, \] partly in calorimeter gap.

\[ m = \sqrt{(E_1 + E_2)^2 - (\vec{p}_1 + \vec{p}_2)^2} \]
The models are listed.

✓ Produced in “s-channel”

✓ Parton-Parton Resonances
  ‣ Observed as dijet resonances.

• Search for model with narrow width $\Gamma$.

• ATLAS has only searched for excited quark model.

• CMS has searched for the all models.
Experimental Technique

• Measurement of dijet mass spectrum
• Comparison to PYTHIA QCD Monte Carlo prediction
• Fit of the measured dijet mass spectrum with a smooth function and search for resonance signal (bump)
• If no evidence, calculate model independent cross section upper limit and compare with any model cross section.
Event Selection

- CMS standard event quality cuts
  - At least two jets
  - Anti-kt R=0.7
  - CMS jet quality cuts
    - $M_{jj} > 220$ GeV
    - $|\eta| < 2.5$ & $|\Delta\eta| < 1.3$

- ATLAS standard event quality cuts
  - At least two jets
  - Anti-kt R=0.6
  - ATLAS jet quality cuts
    - $P_T^{(jet1)} > 80$ GeV and $P_T^{(jet2)} > 30$ GeV
    - $M_{jj} > 200$ GeV
    - $|\eta| < 2.5$ & $|\Delta\eta| < 1.3$
Eta Cut Optimization

QCD events in 1 pb⁻¹:

ATLAS Preliminary

Signal events in 1 pb⁻¹:

ATLAS Preliminary

\[ \eta \approx 60\% \]

\[ q^* \approx 50\% \]
- $|\Delta \eta|$ cut directly removes QCD $t$-channel pole in center of mass.
- $|\Delta \eta| < 1.3$ optimal for isotropic decays ($q^*$).
Both CMS and ATLAS fit the data to a function containing 4 parameters used by CDF Run II.

Variable Dijet mass bin which are equal to dijet mass resolution of signal. (from 10% at 0.5 TeV to 6% at 2.5 TeV)

There is a good fit.

No evidence of new physics

\[ \chi^2/\text{NDF}=32/31 \]
The JES uncertainty was quantified as a function of integrated luminosity, and the jet energy resolution (JER).

\[
\chi^2/NDF=27/22
\]

- The same fit function used by CDF Run II.
- The choice of dijet mass binning was motivated by the dijet mass resolution of the signal. (from 11% at 0.3 TeV to 7% at 1.7 TeV)
- There is good fit.
- No evidence of new physics.

\[
\frac{d\sigma}{dm} = p_0 \frac{(1-X)^{p_1}}{X^{p_2+p_3\ln(X)}} \quad x = m_{jj}/\sqrt{s}
\]
• CMS have simulated dijet resonances using CMS simulation + PYTHIA.

• $qq, qg$ and $gg$ resonances have different shape mainly due to FSR.

✓ The width of dijet resonance increases with number of gluons because gluons emit more radiation than quarks.

• CMS search for these three basic types of narrow dijet resonance in our data.
Setting Limits

- For setting upper limit on the resonance production cross section, a Bayesian formalism with a uniform prior is used by CMS and ATLAS.

\[ L = \prod_i \frac{\mu_i^{n_i} e^{-\mu_i}}{n_i!} \]

\[ \mu_i = \alpha N_i(S) + N_i(B) \]

- The signal comes from our dijet resonance shapes.
- The background comes from fixed to the best Background+Signal fit.
- The 95% CL upper limits are calculated for resonances with various masses.
We found the uncertainty in dijet resonance cross section from following sources.

✓ Jet Energy Scale (JES)
  ▶ 10% for CMS
  ▶ from 10% to 6% as a function of Pt for ATLAS

✓ Jet Energy Resolution (JER)
  ▶ 10% for CMS
  ▶ 14% for ATLAS

✓ Choice of Background Parametrization

✓ Luminosity
  ▶ 11% for both CMS and ATLAS

The all effects of systematics were incorporated as nuisance parameters.

The posterior probability density for the cross section is broadened by convoluting it.
Incorporating Systematic

- We convolute posterior PDF with Gaussian systematics uncertainties.

✓ Posterior PDF including systematics is broader and gives higher upper limit.

\[ L(\sigma) = \int_{0}^{\infty} L(\sigma') G(\sigma, \sigma') d\sigma' \]

G: Gaussian distribution with RMS width equal to systematic uncertainty in cross section
The mass limits for excited quark based on 315 nb-1 in ATLAS

- 0.4<M(q*)<1.26 TeV with MRST2007
- 0.4<M(q*)<1.20 TeV with CTEQ6L1
- 0.4<M(q*)<1.20 TeV with CTEQ5L
- 0.26<M(q*)<0.87 TeV from CDF

**TABLE I.** The 95% CL lower limits on the allowed q* mass obtained using different PDF sets.

<table>
<thead>
<tr>
<th>MC Tune</th>
<th>PDF Set</th>
<th>Observed Mass Limit [TeV]</th>
<th>Expected Mass Limit [TeV]</th>
</tr>
</thead>
<tbody>
<tr>
<td>MC09' a</td>
<td>CTEQ6L1 [37]</td>
<td>1.20 (Stat. + Syst.)</td>
<td>1.23 (Stat. only)</td>
</tr>
<tr>
<td>Perugia0 [39]</td>
<td>CTEQ5L [38]</td>
<td>1.22 (Stat. + Syst.)</td>
<td>1.25 (Stat. only)</td>
</tr>
</tbody>
</table>

a The MC09’ tune is identical to MC09 except for the PYTHIA [24] parameter PARP(82)= 2.1 and use of the CTEQ6L1 PDF set.
The mass limits with CTEQ6L1 based on 2.88 pb\(^{-1}\) data in CMS:

- **String**
  - 0.50 < M(S) < 2.50 TeV
  - M(S) < 1.40 from CDF\(^{+}\) (1 fb\(^{-1}\))

- **Excited Quark**
  - 0.50 < M(q\(^{*}\)) < 1.58 TeV
  - 0.40 < M(q\(^{*}\)) < 1.26 from ATLAS (0.32 pb\(^{-1}\))

- **Axigluon/Coloron**
  - 0.50 < M(A) < 1.17 TeV & 1.47 < M(A) < 1.52 TeV
  - 0.12 < M(A) < 1.25 TeV from CDF\(^{+}\) (1 fb\(^{-1}\))

- **E\(_6\) Diquark**
  - 0.50 < M(D) < 0.58 TeV & 0.97 < M(D) < 1.08 TeV & 1.45 < M(D) < 1.60 TeV
  - 0.29 < M(D) < 0.63 TeV from CDF\(^{+}\) (1 fb\(^{-1}\))
Conclusion

- CMS and ATLAS have been searching for dijet resonance.
- The dijet mass data is in good agreement with QCD from PYTHIA.
- There is no evidence for dijet resonances yet.
- CMS and ATLAS have published their results.
- CMS has the best mass limit on dijet resonance models, beyond those published by Tevatron and ATLAS.