Search for New Particles Decaying to Dijets

Sertac Ozturk
Cukurova Univ./ LPC

Robert M. Harris **Kostas Kousouris**
Fermilab

Chiyoung Jeong **Sung-Won Lee**
Texas Tech University

Exotica Meeting
May 19, 2009

Overview

- Developing machinery to search for dijet resonances
  - Resonance shape as a function of mass
  - Parameterization for QCD background shape
  - Fitting of dijet mass “data” with background + resonances
  - Cross section of possible resonances observed in the fit
  - Calculating of likelihood vs. resonance cross section
  - Finding 95% C.L. cross section upper limit and comparing with model cross section for mass limits

- Here we present an example search with 100 pb^{-1}
  - And an “early paper” draft based on this search: CMS AN-2009/070.

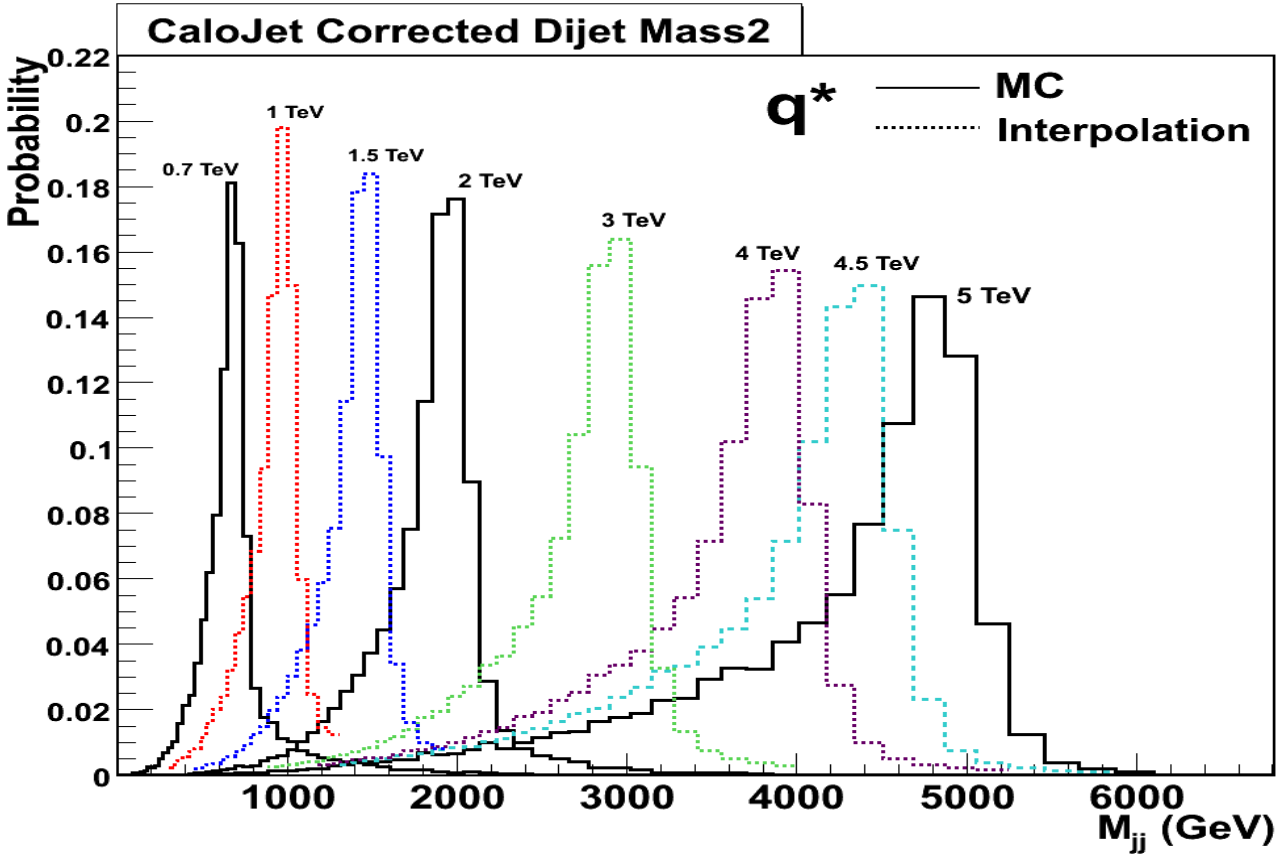
Dijet and Resonance Analysis

- Dijet Analysis
  - Jets from SISCone algorithm with cone size R=0.7
  - P_T and η dependent corrections were applied (L2 and L3).
  - Two leading jets were required to have $|\eta|<1.3$
  - Dijet mass plots use variable width bins
    - The bin width is equal to the dijet mass resolution.

- Our standard resonance shape comes from excited quark decays to dijets ($q^* \rightarrow qg$)
  - Three different q* samples were used
  - Exotica Summer08 Gen-Sim-Reco with M=0.7, 2, 5 TeV
  - We analyzed these with CMSSW_2_2_3

Resonance Shapes

- We wrote code to obtain the resonance shape at any resonance mass using interpolation technique.
  - Shape.h and Shape.C can be found in CVS (UserCode/Sertac)



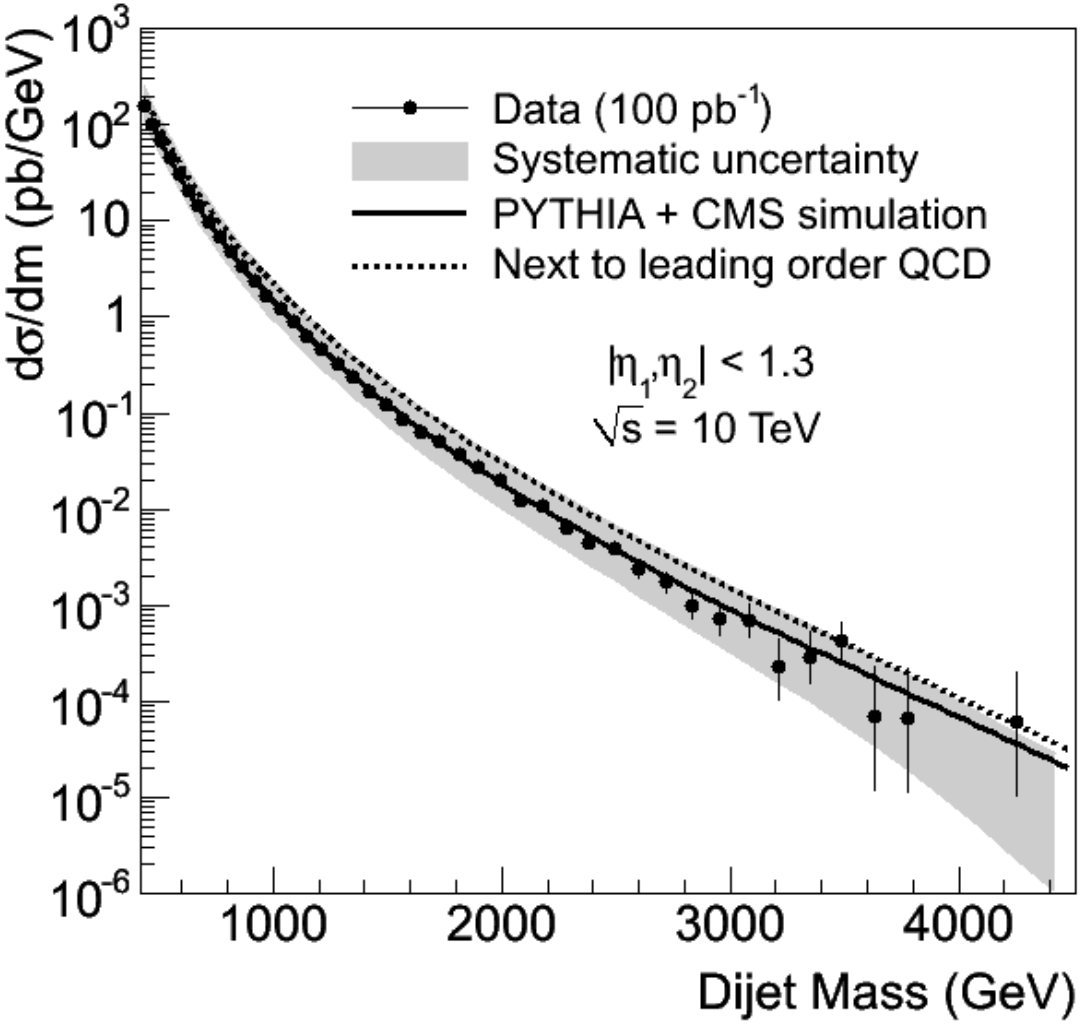
Pseudo-Data Sample

- We have produced a pseudo-data sample for search
  - QCD cross section from Summer 08 data sample was smoothed by fitting it to a parameterization.
  - Toy generator was written to produce random statistical fluctuation in smooth QCD background curve
    - Poisson fluctuation on tail,
    - Gaussian fluctuation where n>25.

- Gives pseudo-data sample with QCD background shape, 100 pb^{-1} of luminosity, and realistic fluctuations.

Data and QCD Theory

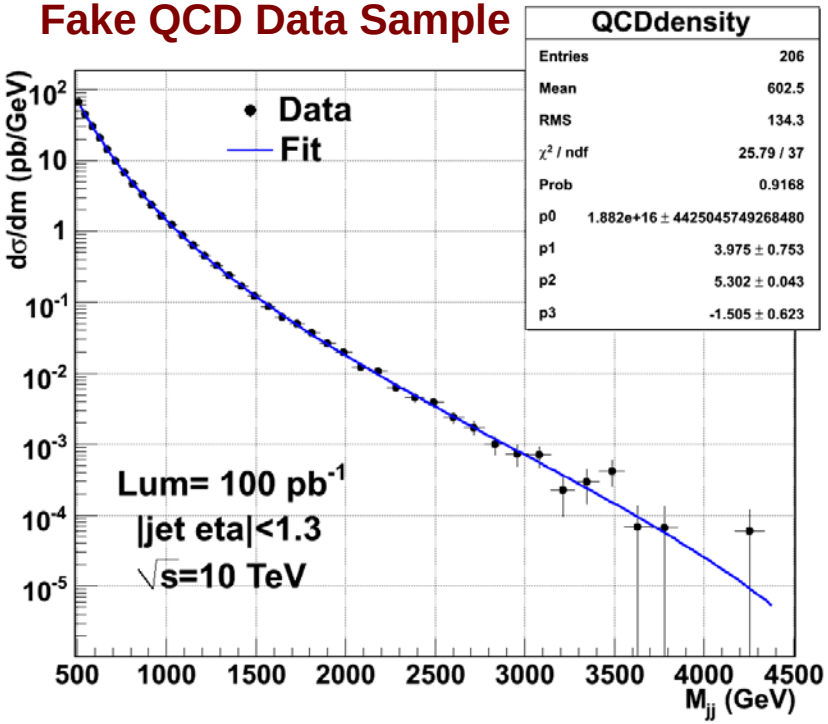
- The pseudo-data is compared to Pythia and NLO QCD
- This is a figure in our early paper draft
- It is intended to show the data is compatible with QCD
  - Within the experimental errors.
  - Assuming that likely scenario turns out to be the case.



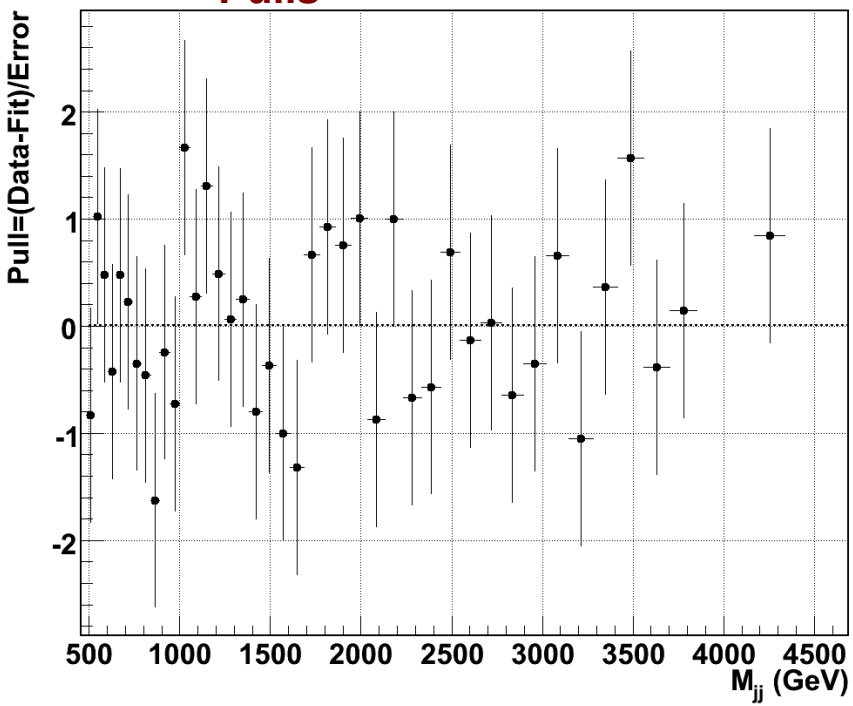
Data and QCD Background Fit

- The pseudo- data is well fit by the background parameterization

Fake QCD Data Sample



Pulls

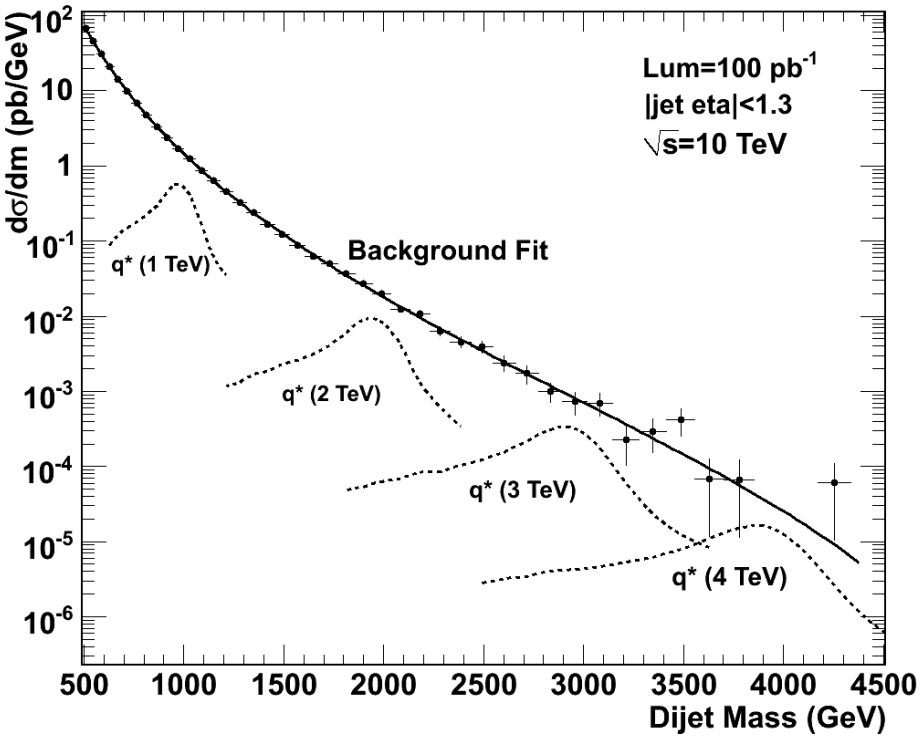


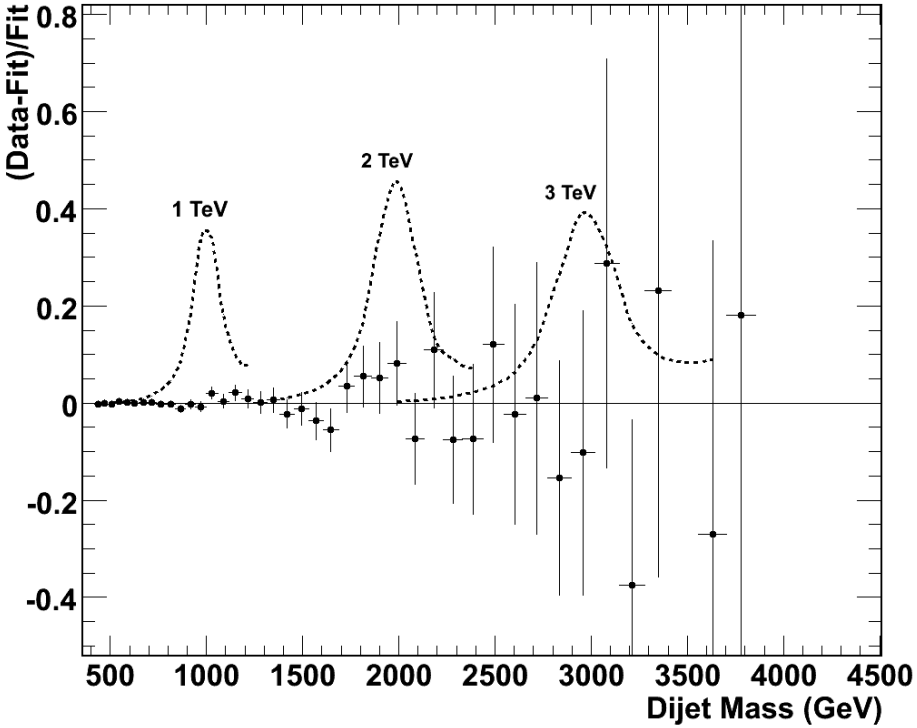
Fit Function

$$\frac{p_0\left(1-\frac{m}{\sqrt{s}}+\left(\frac{m}{\sqrt{s}}\right)^2 p_3\right)^{p_1}}{m^{p_2}}$$

The pulls are consistent with statistical fluctuations.

Background and Signal



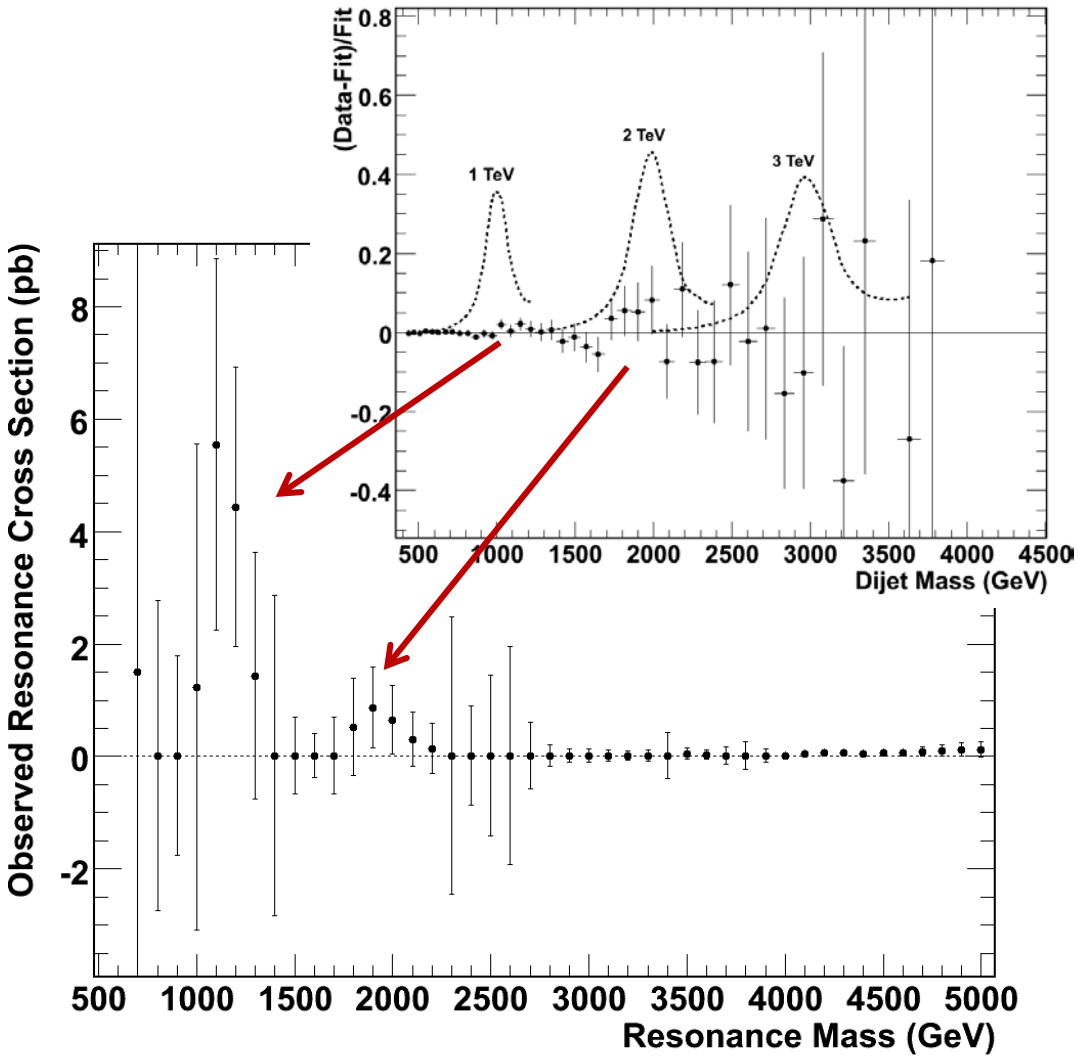


- Pseudo-data is compared to the background fit and to resonance signals
  - (data-fit)/fit shows that q* signals with M< 3 TeV could be seen or excluded
  - If the data looks like our pseudo-data then we will be setting limits.

- These are figures in our early paper draft.

Fitting for Resonance Signal

- We fit pseudo-data to the background + q* signal
  - M(q*)=0.7 - 5 TeV in 0.1 TeV steps
  - Signal cross section found is consistent with zero within errors
  - Background fluctuations at 1 and 2 TeV give positive cross sections with low significance.
- Background from this fit is chosen for setting limits.
  - It gives conservative limit.
  - CDF method from run I: PRD 55: 5263 (1997).



Likelihood

- To calculate limits on new particles cross sections we use a binned likelihood.

$$L = \prod_i \frac{e^{-\mu_i} \mu_i^{n_i}}{n_i!} \qquad \mu_i = \alpha N_i(S) + N_i(B)$$

measured # of events in data

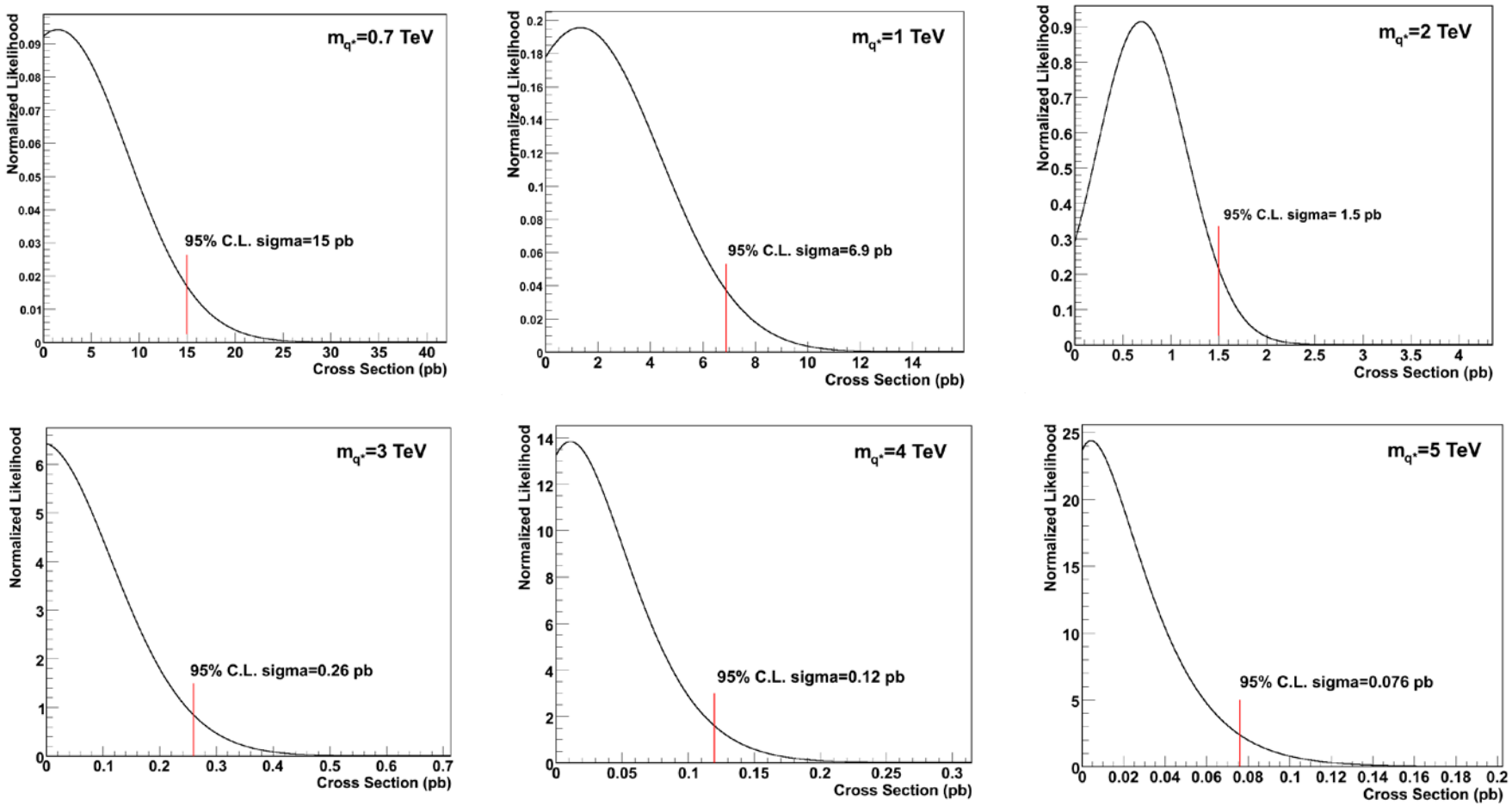
# of events from signal

expected # of events from background

- The signal comes from our interpolated q* shape
  - In UserCode/Sertac is QstarBinned.h with function QstarBinned Prob(m,M)
  - Returns <u>probability</u> in our bins of dijet mass, m, for any resonance mass M.
- The background comes from the fit.
- We calculate likelihood as a function of signal cross section for resonances with mass M = 0.7 to 5.0 TeV in 0.1 TeV steps.

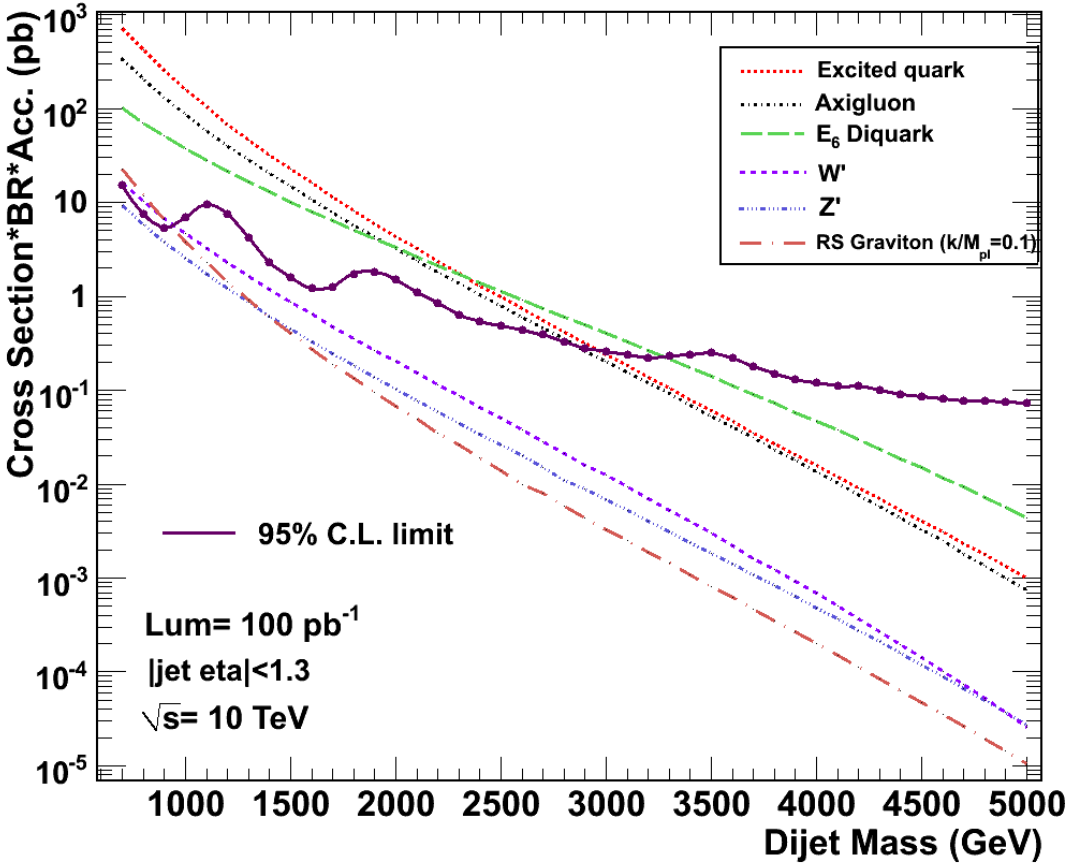
Likelihood Distributions

- From the likelihood we find the 95% CL upper limit on the cross section.



Dijet Resonance Limits

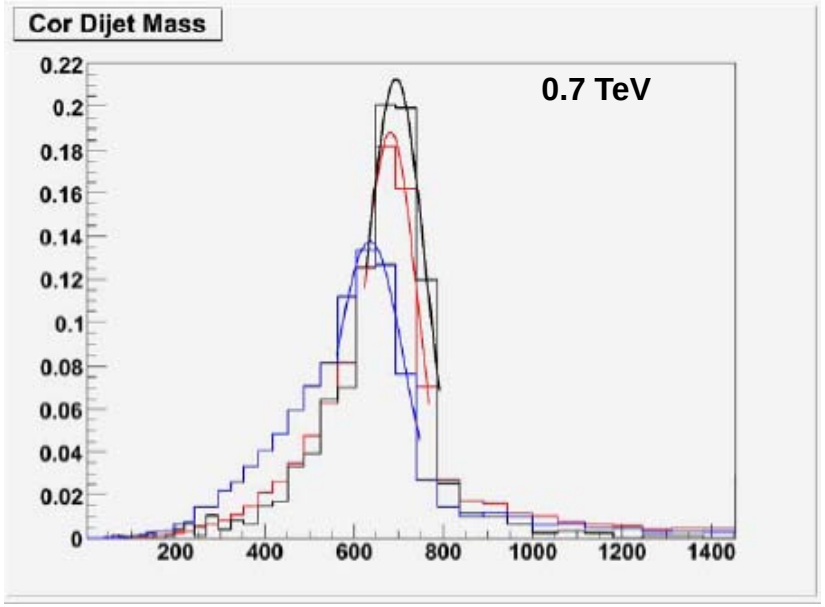
- 95% CL upper limit compared to cross section for various resonance models.
- These pseudo-limits include only statistical uncertainties.
  - Systematics are in progress.
    - Jet energy scale
    - Resonance shape
- Figure in early paper draft.

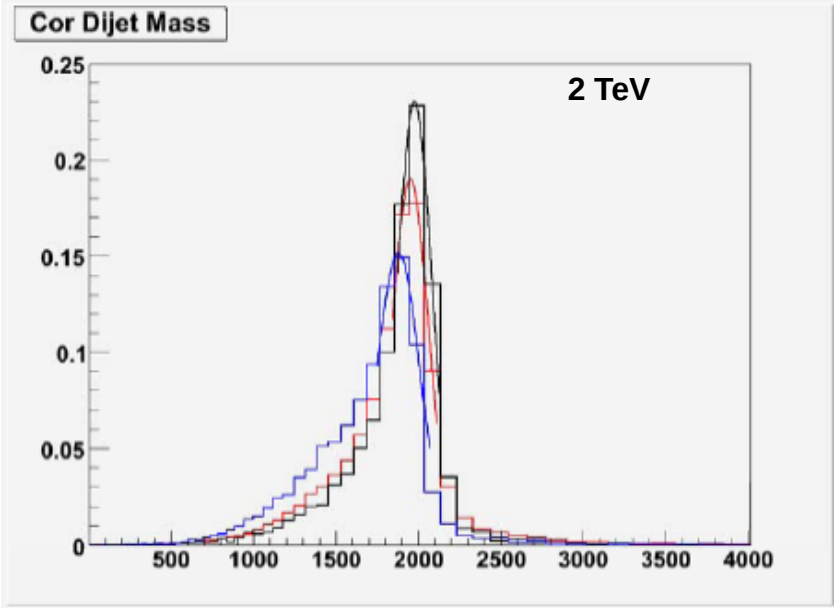


- CMS limits will be well beyond the published limits of the Tevatron
  - CMS (100 pb^{-1}): q*, Axigluon, and E6 diquark limit should be about 3 TeV.
  - CDF (1 fb^{-1}): q* <0.87 TeV, Axigluon < 1.25 TeV, E6 diquark < 0.63 TeV.

Resonance Shape Systematic

- Quark jets and gluon jets have different response at CMS.
  - Gives different resonance shapes for q qbar, qg & gg resonances
- qg resonance is an “average shape” somewhere q qbar and gg.





G -> q qbar , q* -> qg , G -> gg

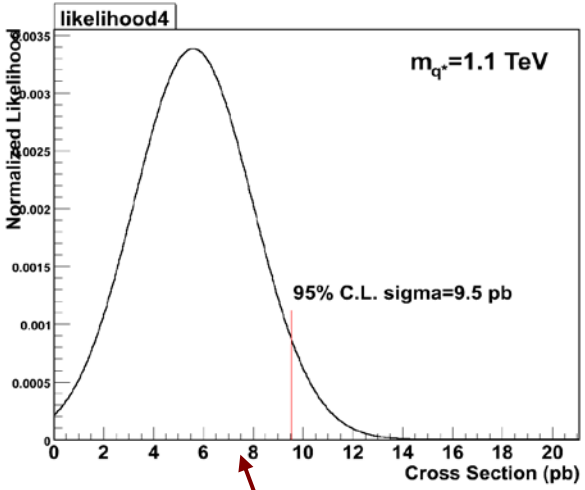
We plan to use the qg shape for our limits and use q qbar and gg shapes for systematic uncertainties on the limit.

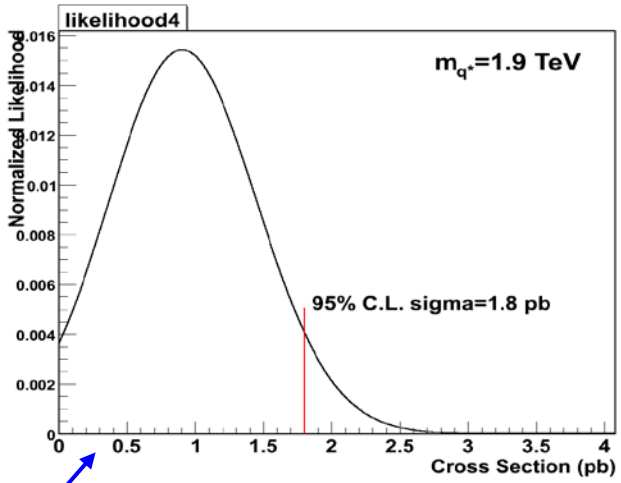
Summary

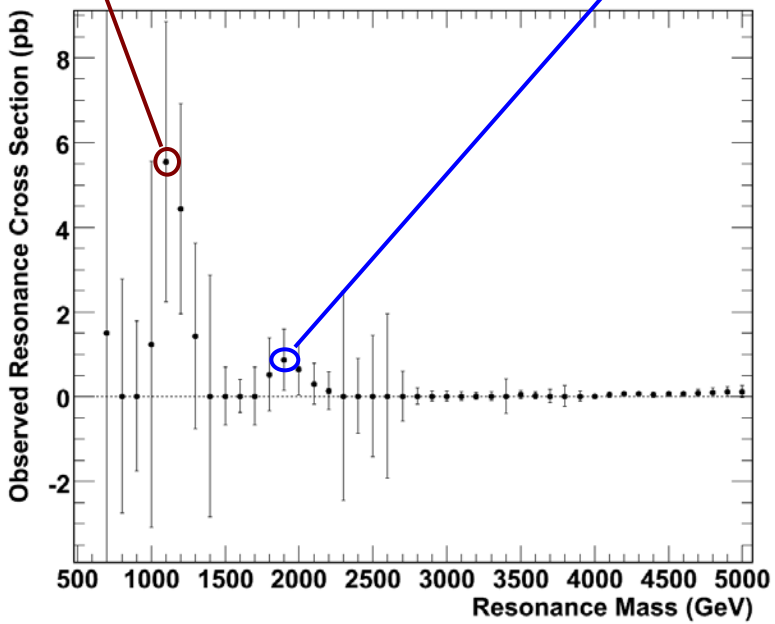
- We are preparing to search for resonances in early CMS data
- We have presented the basic machinery for this search and setting limits on dijet resonances
- CMS should be sensitive to excited quarks, axigluons and E6 diquarks up to ~3 TeV at 95% CL with 100 pb^{-1}
- Future plans are:
  - Systematic Uncertainties
  - Signal significance estimates from likelihood ratio
  - We have written an “early paper” on this search: CMS AN-2009/070.

BACKUP

Background Fluctuations and Likelihood







The likelihood distribution for upward fluctuations of background have a peak.