Search for New Particles Decaying to Dijets

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Outline

- Introduction
- Review of dijet resonance search analysis
- Limits for qq, qg and gg dijet resonances
- Limits including systematic uncertainties
- Conclusions

Introduction

- We previously presented the dijet resonance search analysis
  - Fitting of dijet mass “data” with background param + resonances
  - 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 update the procedure to include
  - Limits for quark-quark, quark-gluon and gluon-gluon resonances
  - Systematic uncertainties in the analysis

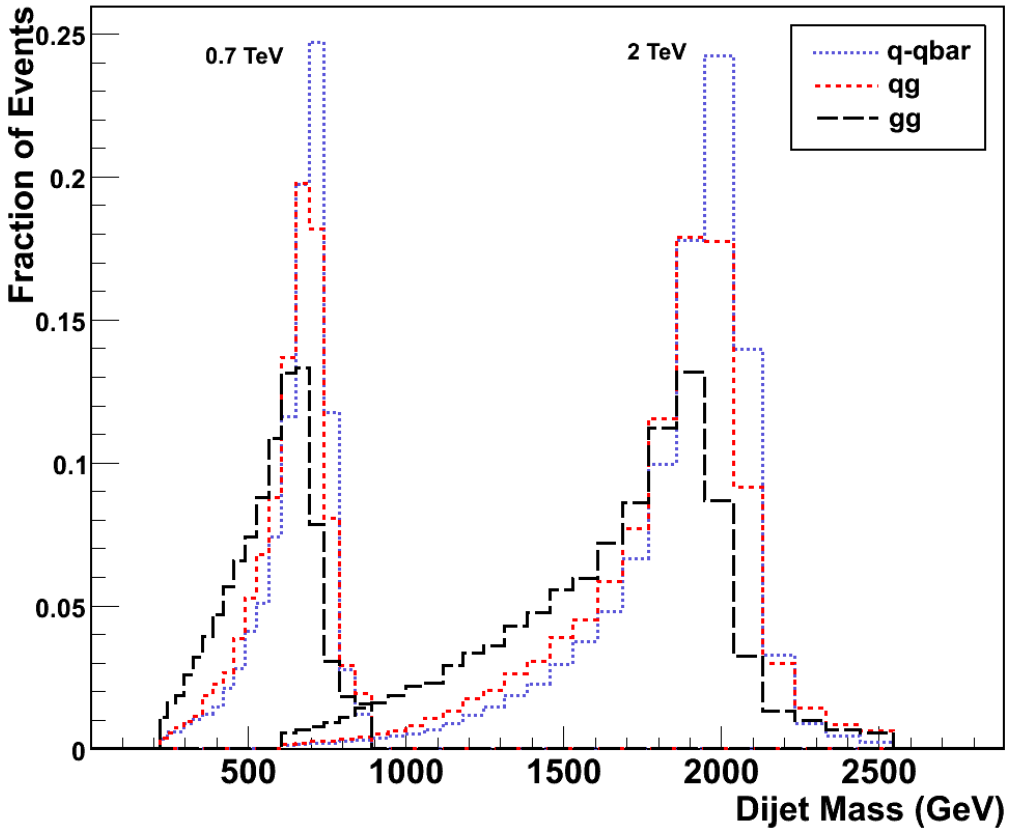
- We present an example search with 10 pb^{-1}
  - And we update the “early paper” draft based on this search: CMS AN-2009/070.

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.
  - Analyze jet data from unprescaled jet trigger (HLT Jet 110).
- Our resonance shapes comes from PYTHIA + CMS simulation
  - High statistics Fastsim samples of qq, qg and gg resonances
    - Extracted from the procesess $G\rightarrow qq$, $q^*\rightarrow qg$, $G\rightarrow gg$.
    - Agrees with both Winter09 Fastsim and Summer08 Fullsim samples.
  - Resonance masses of M=0.7, 2, 5 TeV were produced
  - Resonances of intermediate mass values found by interpolation.

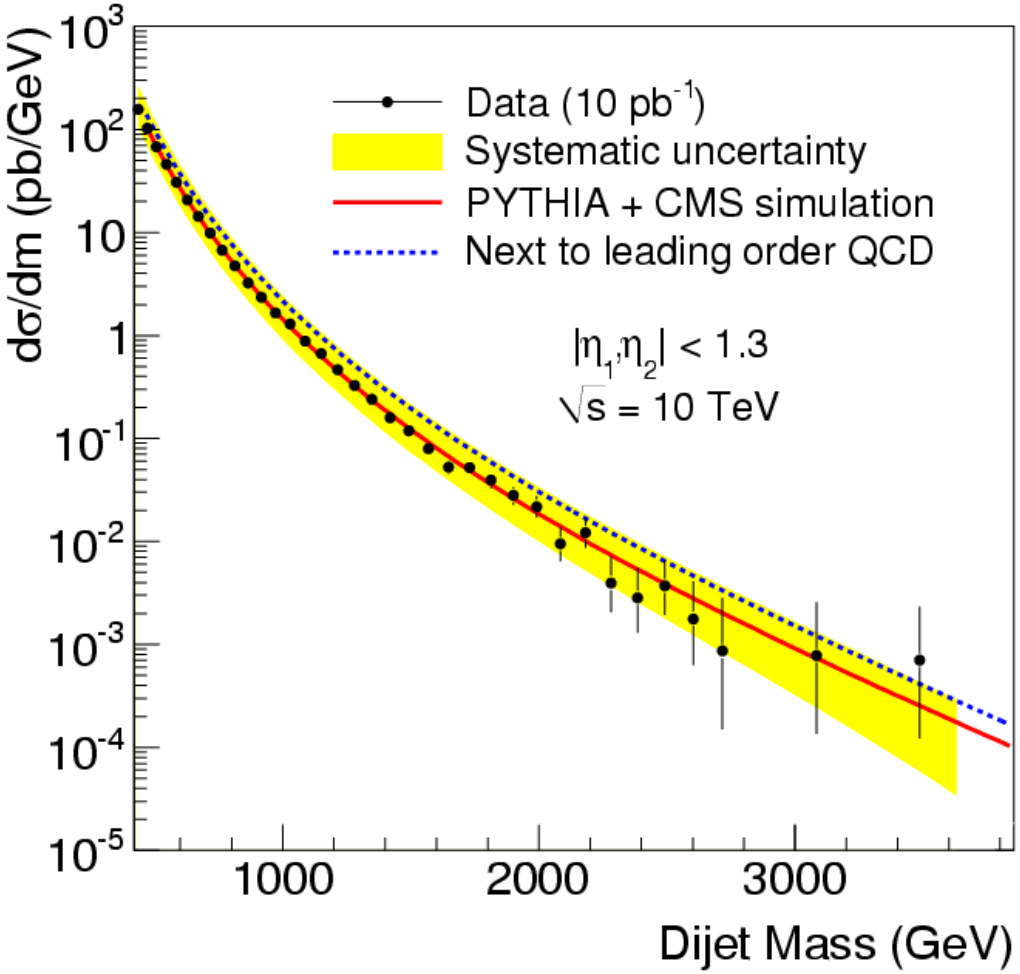
Resonance Shapes

- Dijet resonances shapes from qq, qg and gg have small differences.
  - Due to differences in ISR, FSR and CMS jet response as previously discussed.

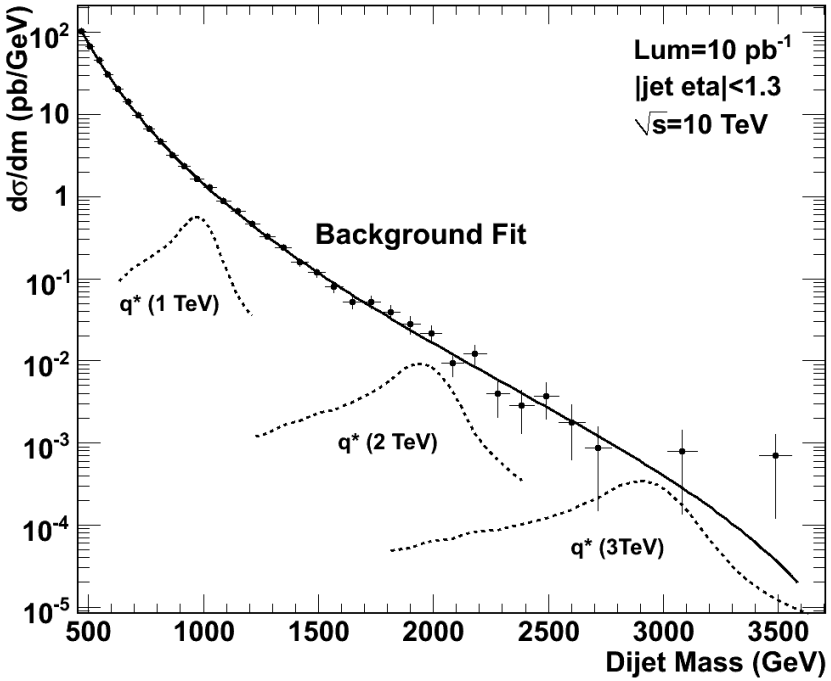


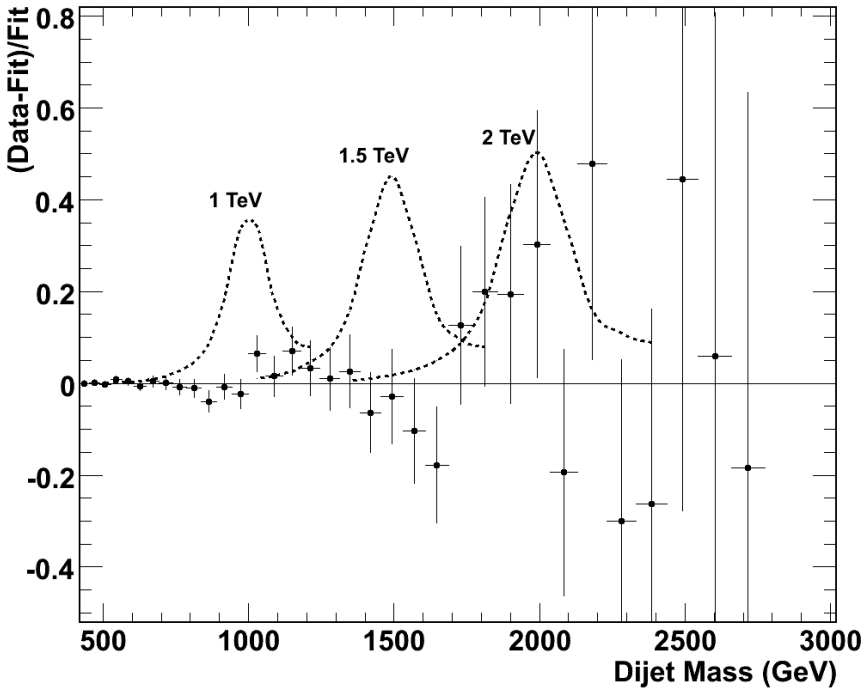
Pseudo-data and QCD Theory

- We produce pseudo-data from PYTHIA QCD dijets.
  - Stat. fluctuations for 10 pb^{-1}
- The pseudo-data is compared to PYTHIA and NLO QCD
  - Like we will do with real data.
  - Agreement would indicate no evidence of dijet resonances
- We would proceed to set limits



Background Fit and Signal





- Pseudo-data is compared to the background fit and to resonance signals
  - (data-fit)/fit shows that q* signals with M< 2 TeV could be seen or excluded

Fit Function

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

Limits with Statistical Uncertainties

- 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

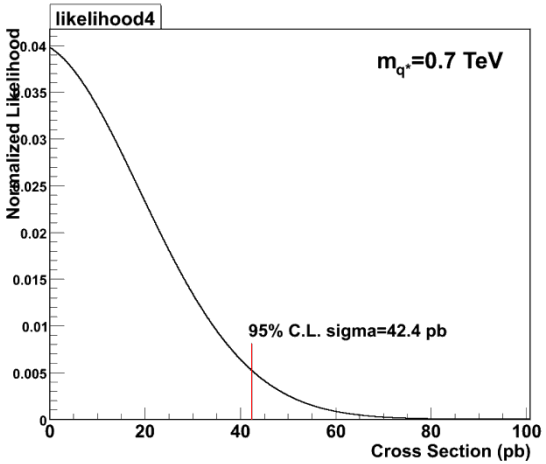
# of events from signal

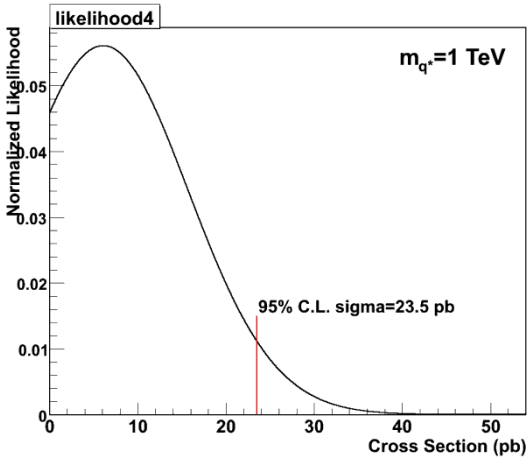
expected # of events from background

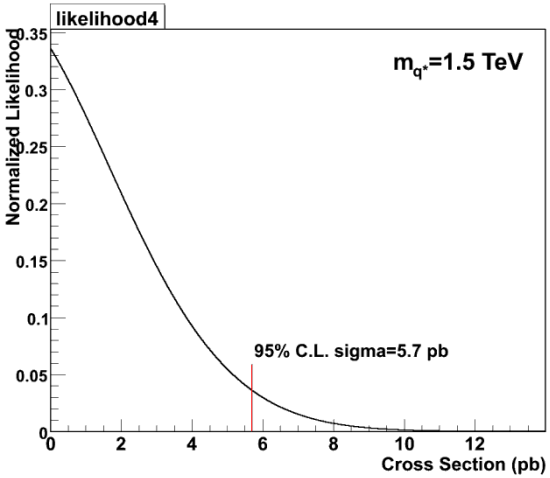
- The signal comes from our dijet resonance shapes for qq, qg and gg
- The background comes from the fit.
- We calculate likelihood as a function of signal cross section for resonances with mass M = 0.7 to 3.5 TeV in 0.1 TeV steps.

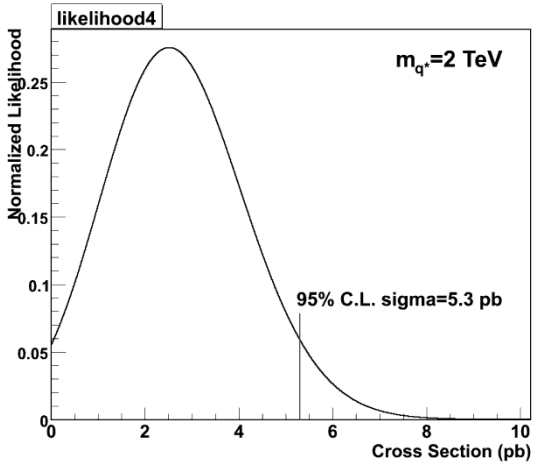
Likelihoods with Stat. Error Only (for qg)

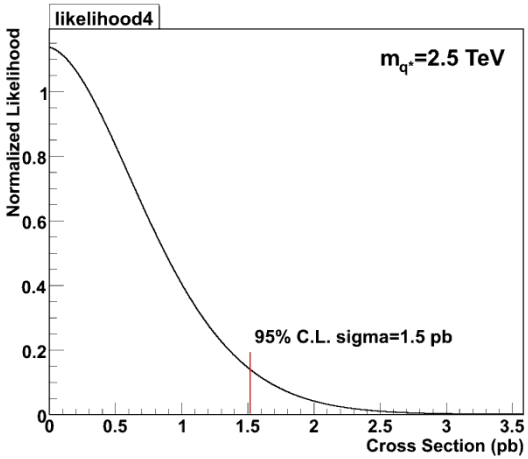
- From the likelihood we find the 95% CL upper limit on the cross section.

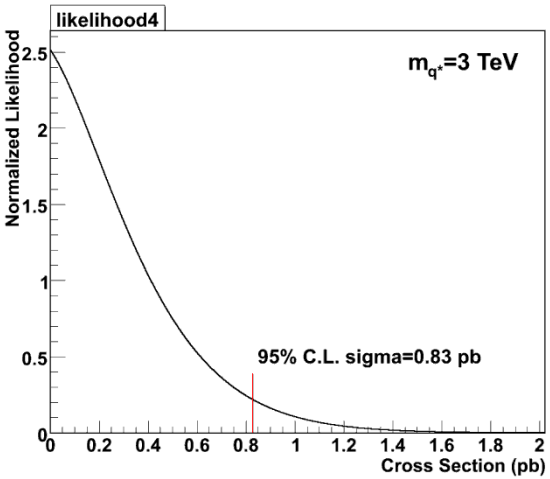






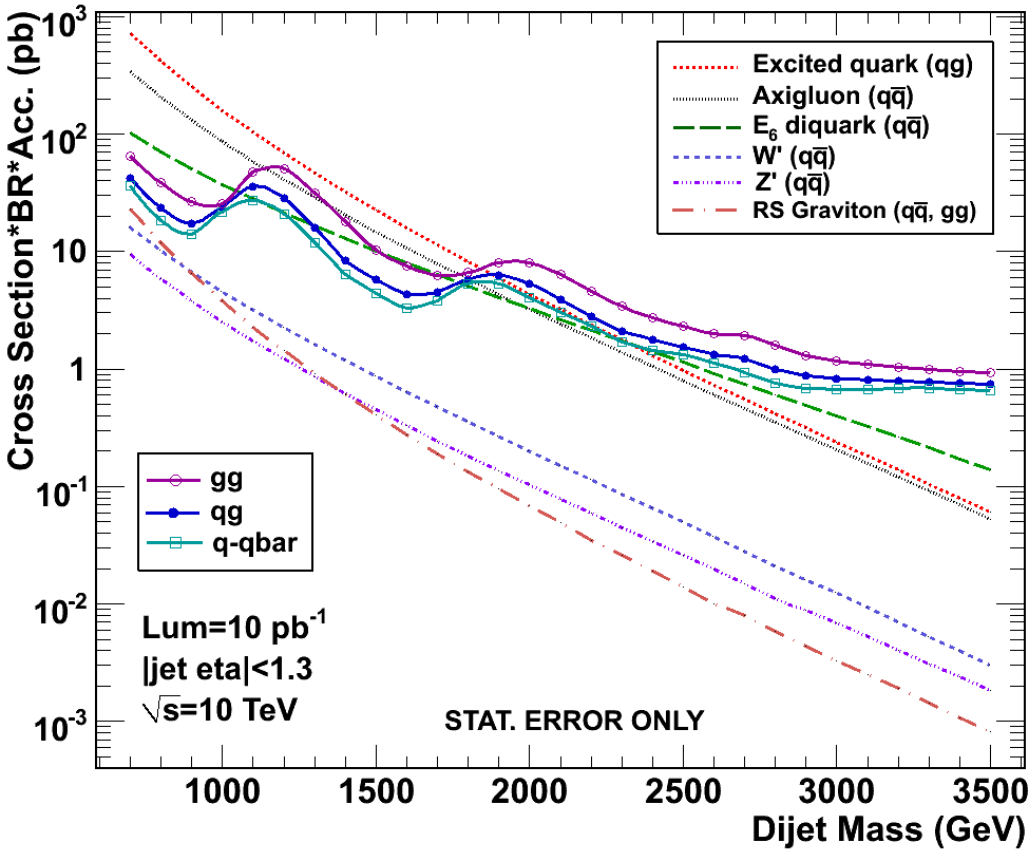






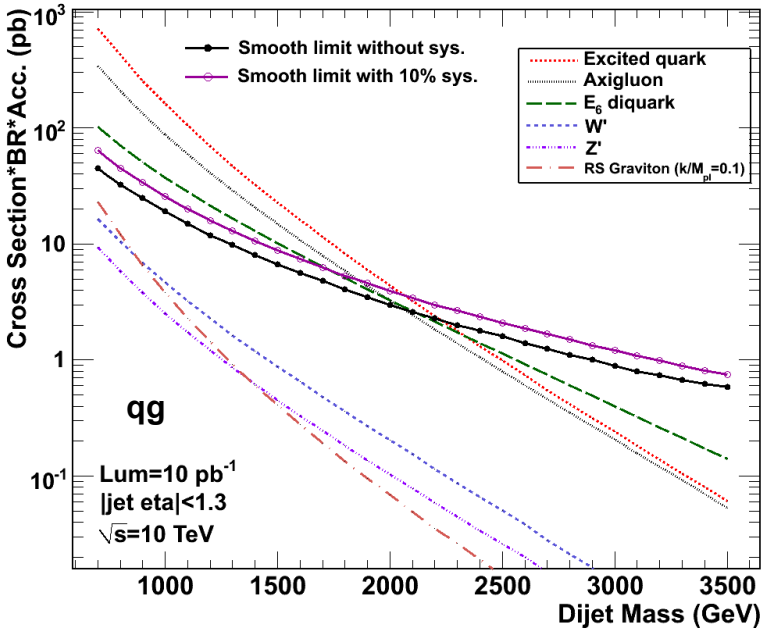
Dijet Resonance Limits with Statistical Uncertainties Only

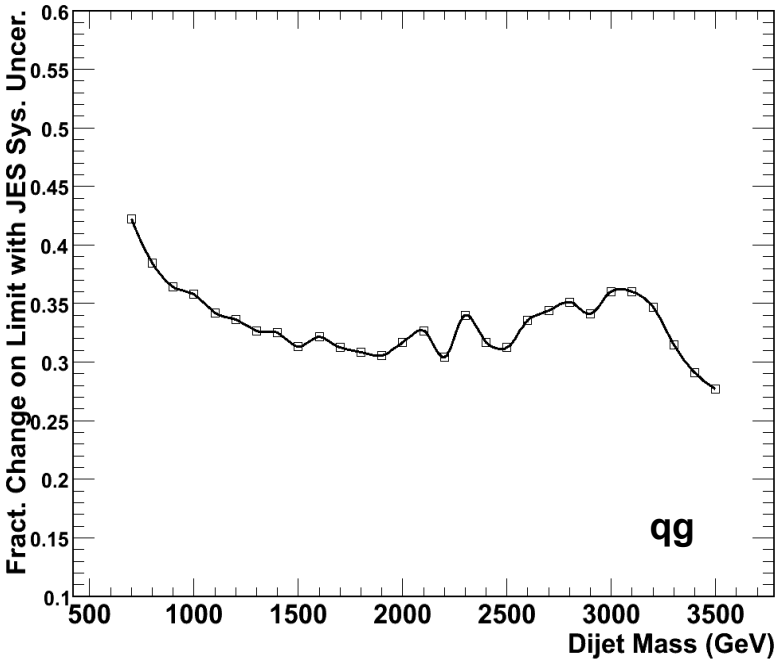
- 95% CL upper limit compared to cross section for various models.
  - Shown separately for qq, qg and gg resonances.



Jet Energy Systematic

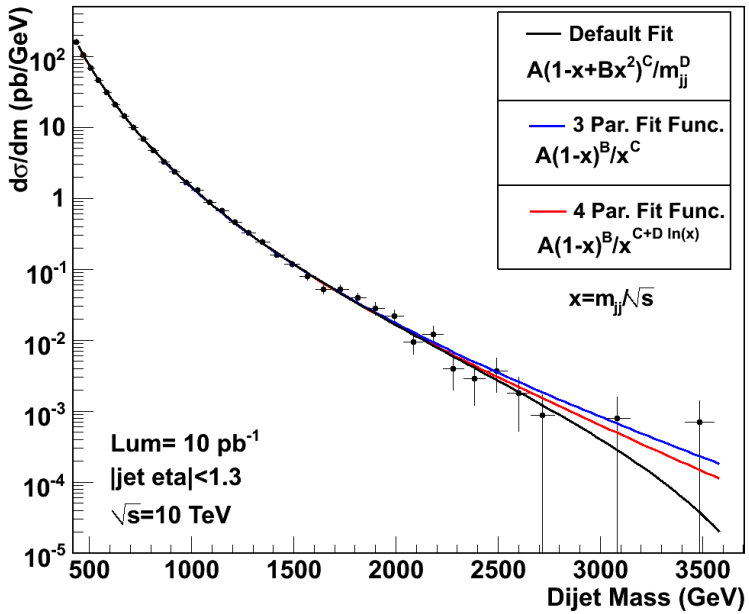
- Systematic uncertainty in jet energy is roughly 10% at startup
  - We have decreased the mass of the dijet resonance by 10%
    - Shown here for qg, Similar for qq and gg.
  - This increases the pseudo-data in the region of the resonance, giving a worse limit.
  - Use a smoothed sample of pseudo-data to reduce statistical fluctuations in systematic
  - Systematic uncertainty varies from 45% at m=0.7 TeV to 30% at m=5 TeV

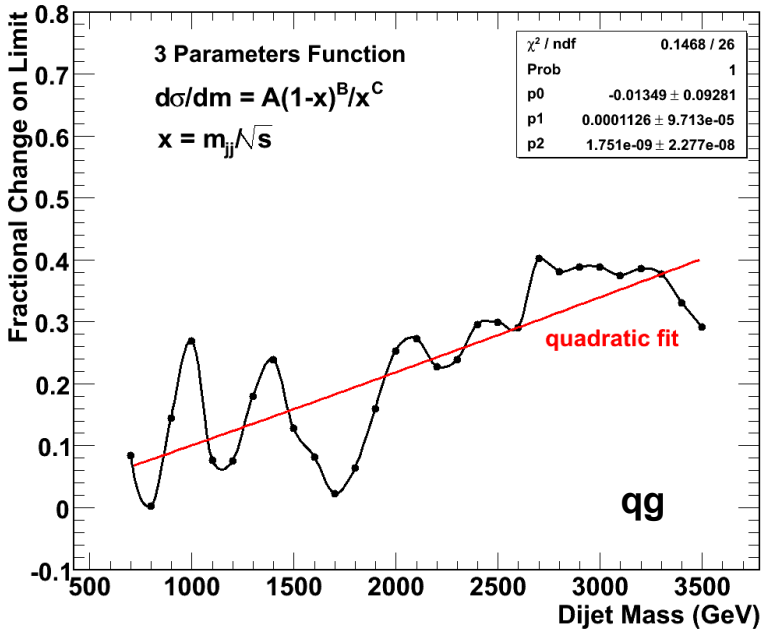




Background Parameterization Systematic

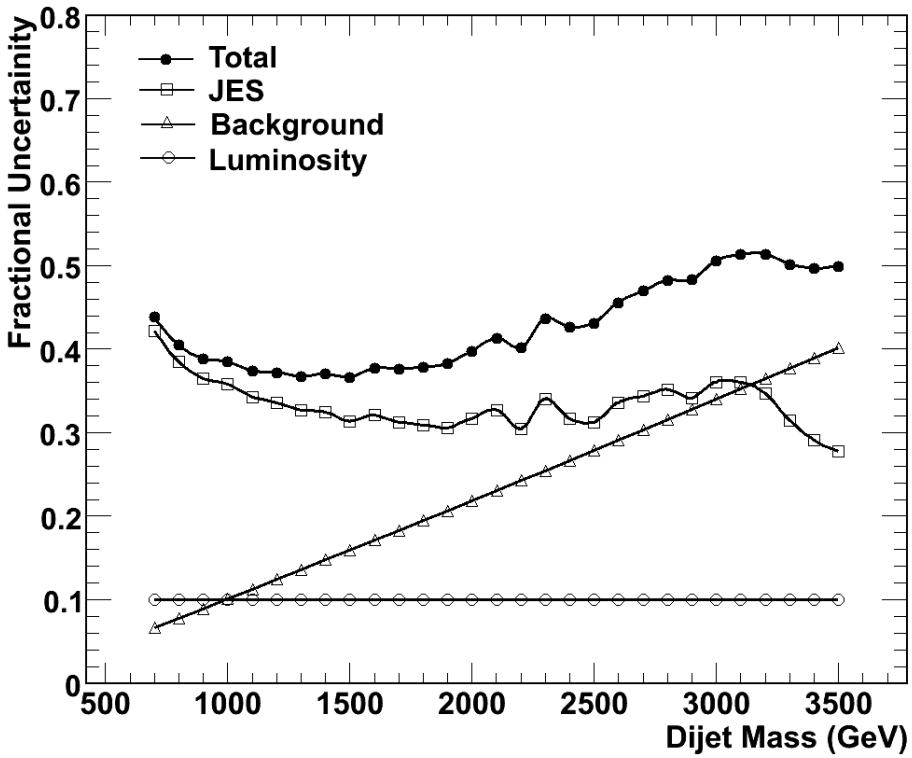
- We have varied the choice of background parameterization
  - A simpler functional form with 3 parameters and another with 4 parameters.
    - Both functional forms were used by CDF.
    - We found the 3 parameter form gave the largest change.
  - We smoothed the statistical variations in the absolute change in the limit.
  - Systematic uncertainty varies from 8% at m=0.7 TeV to 40% at m=5 TeV





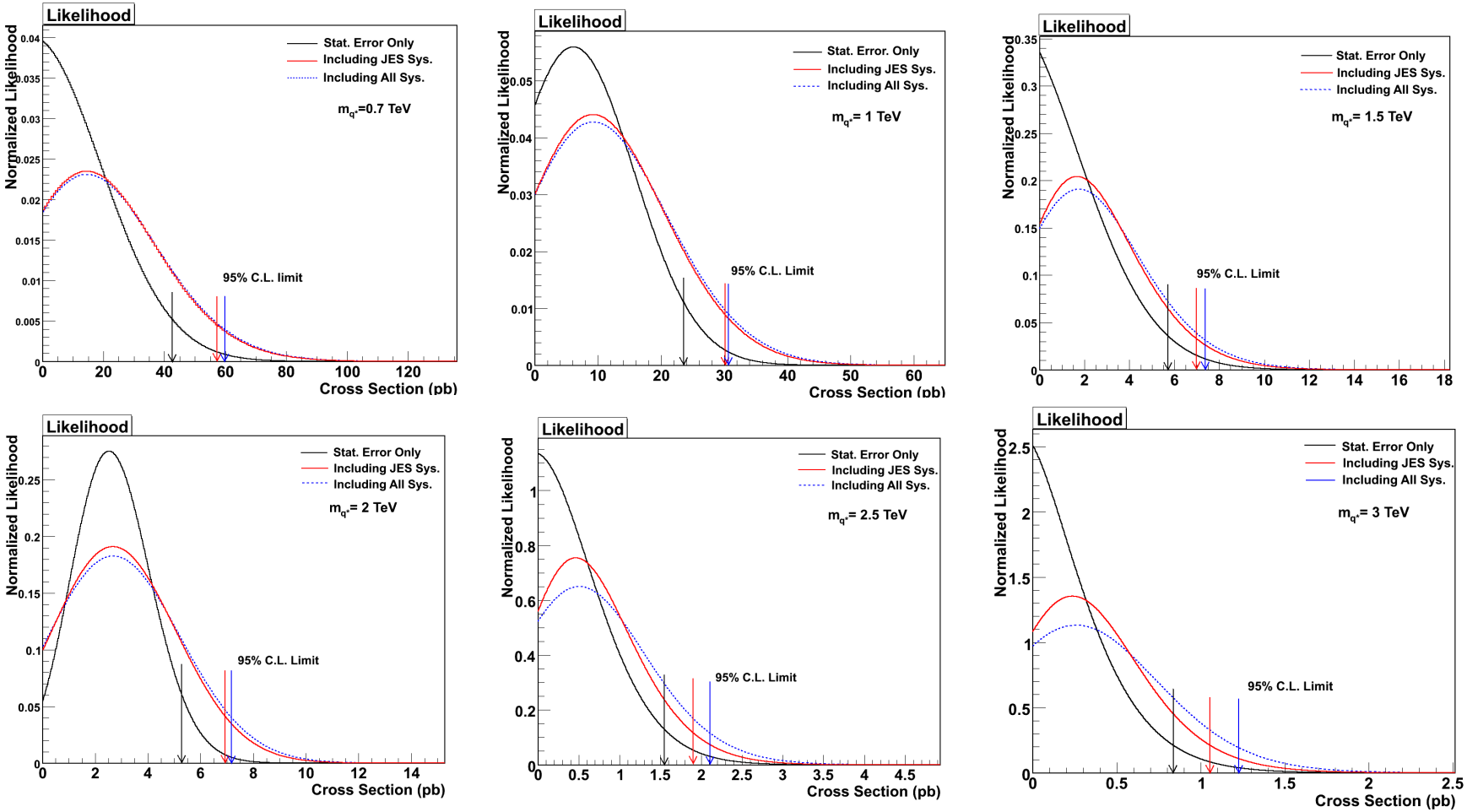
Total Systematic Uncertainty

- We add in quadrature the individual systematic uncertainties
  - JEC, background parameterization and luminosity
  - Total systematic uncertainty varies from 45% at m=0.7 TeV to 50% at m=5 TeV



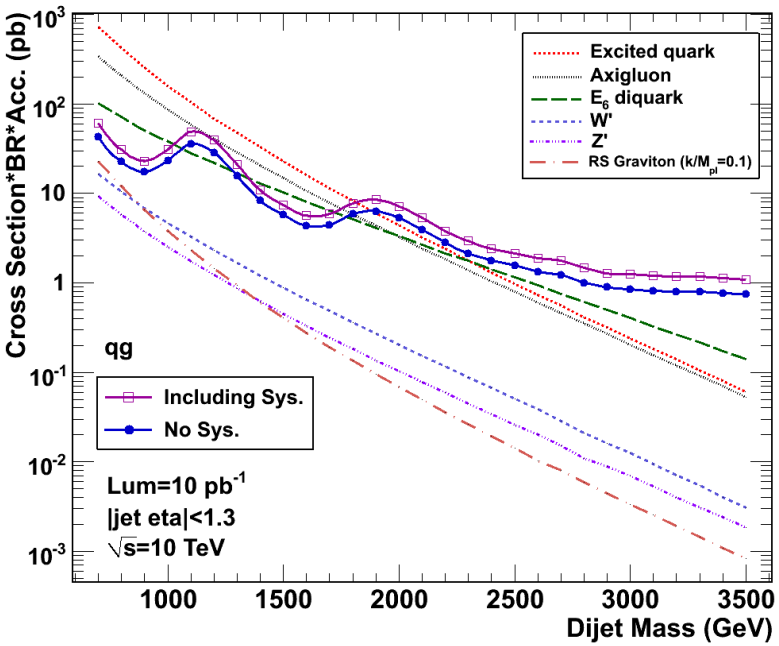
Likelihoods with Systematics (for qg)

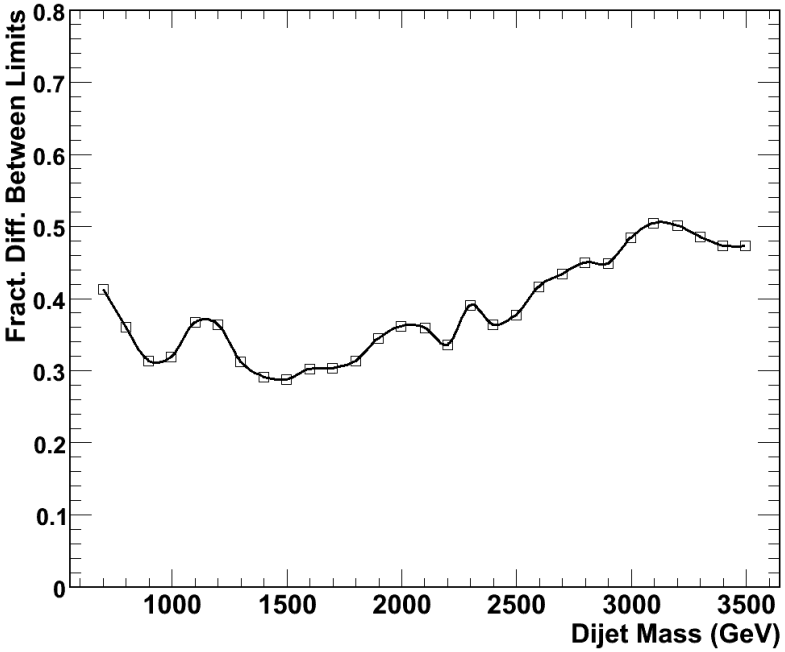
- We convolute Poisson likelihoods with Gaussian systematic uncertainties
  - Total likelihood including systematics is broader and gives higher upper limit.



Effect of Systematics on Limit

- Cross section limits increase by about 30%-50% with systematic uncertainties
  - q* mass limits decrease by about 0.1 TeV with systematic uncertainties
  - Similar changes for qq and gg.

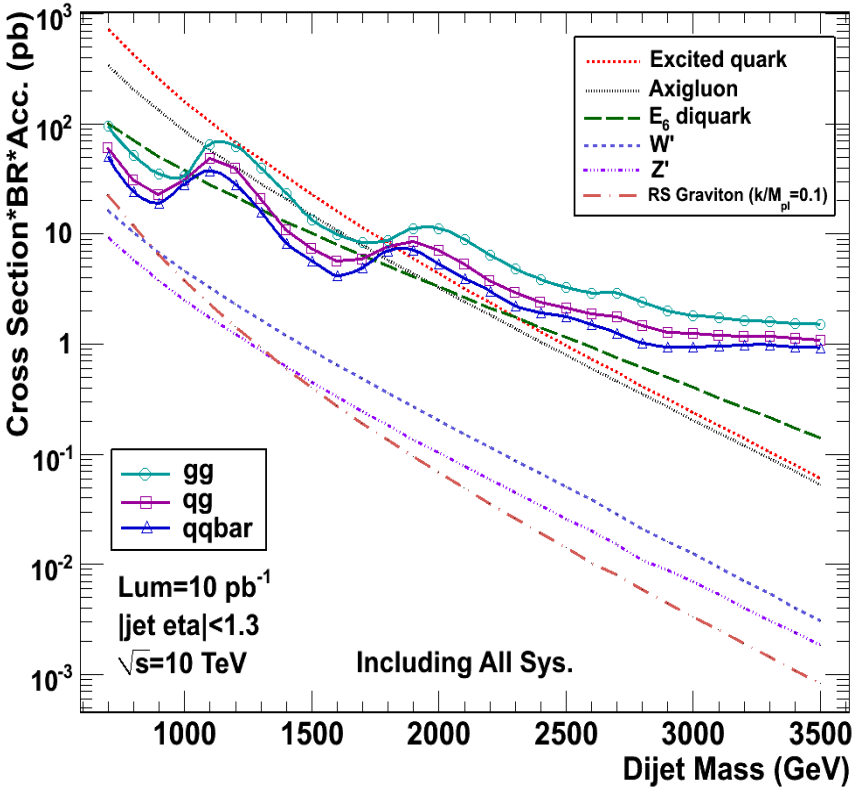




Results

- Final limits for qq, qg and gg resonances compared to models.
  - For excited quark, qg resonance was used,
  - For axigluon, coloron and E_6 diquark, qq resonance was used.

95% C.L. Excluded Mass (TeV)		
	CMS ($10\ pb^{-1}$)	CDF ($1\ fb^{-1}$)
Excited quark	M<1.8	M<0.87
Axigluon, Coloron	M<1.8	M<1.25
E_6 diquark	M<1.1 , 1.3<M<1.7	M<0.63

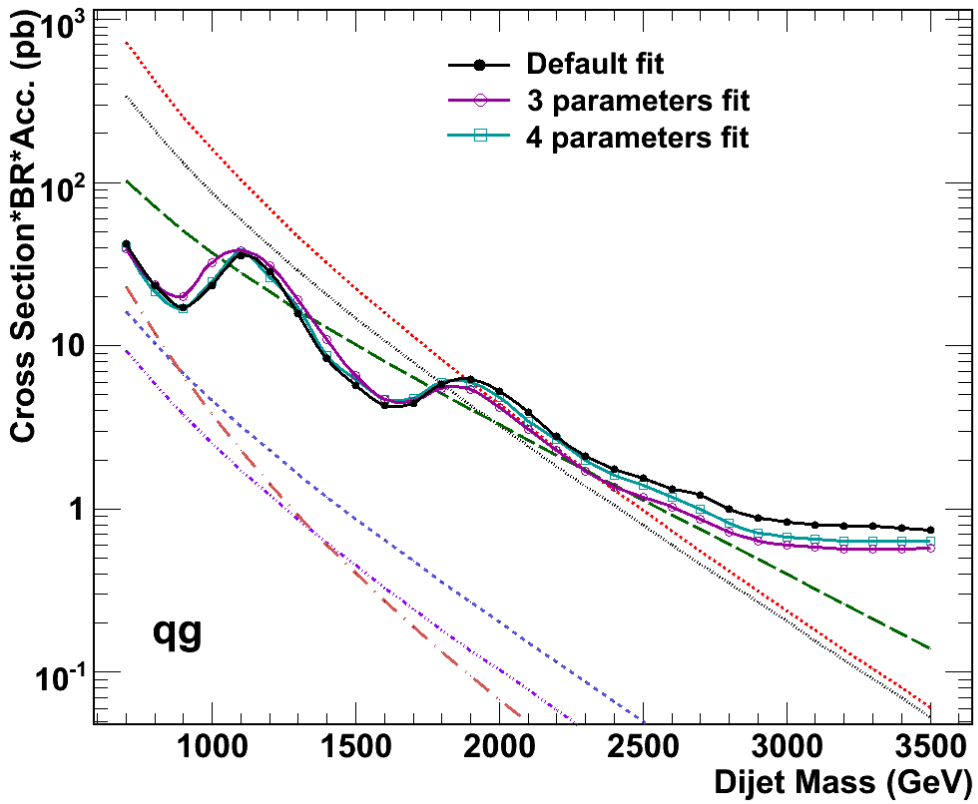


Conclusions

- We are preparing to search for resonances in early CMS data
- We can now search separately for qq, qg and gg resonances.
- We have included systematic uncertainties in the search.
- CMS should be sensitive to excited quarks, axigluon/coloron, and E_6 diquarks up to ~2 TeV at 95% CL with 10 pb^{-1}
- Future plans are:
  - Signal significance estimates from likelihood ratio
  - We have written an “early paper” on this search (CMS AN -2009/070)
  - We plan to update it to include resonance types and systematic

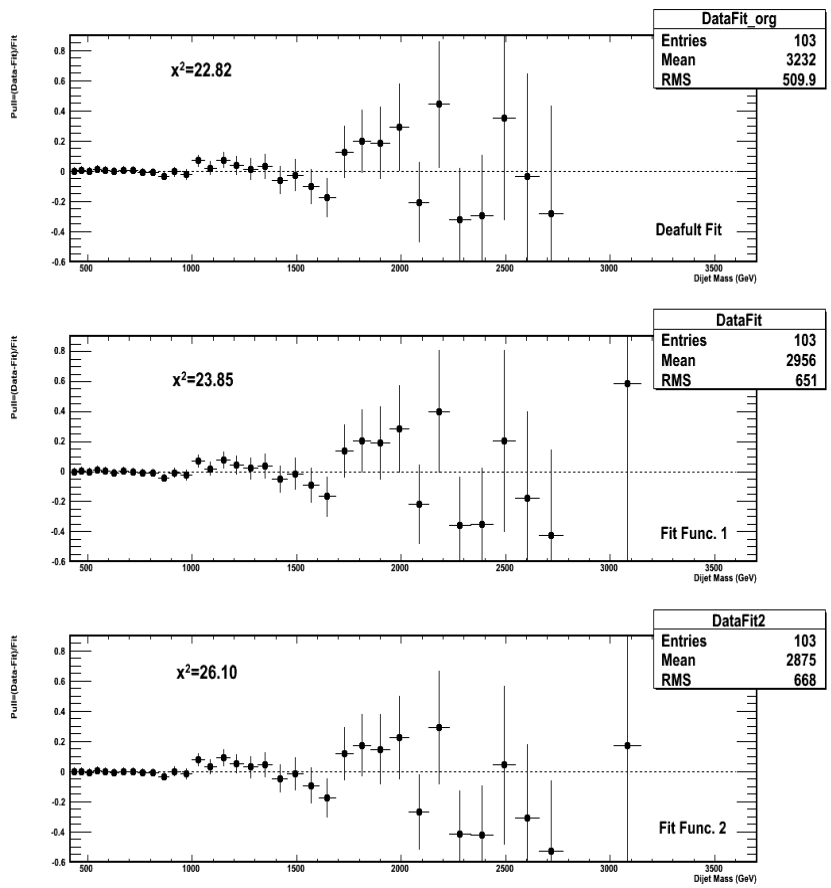
BACKUP SLIDES

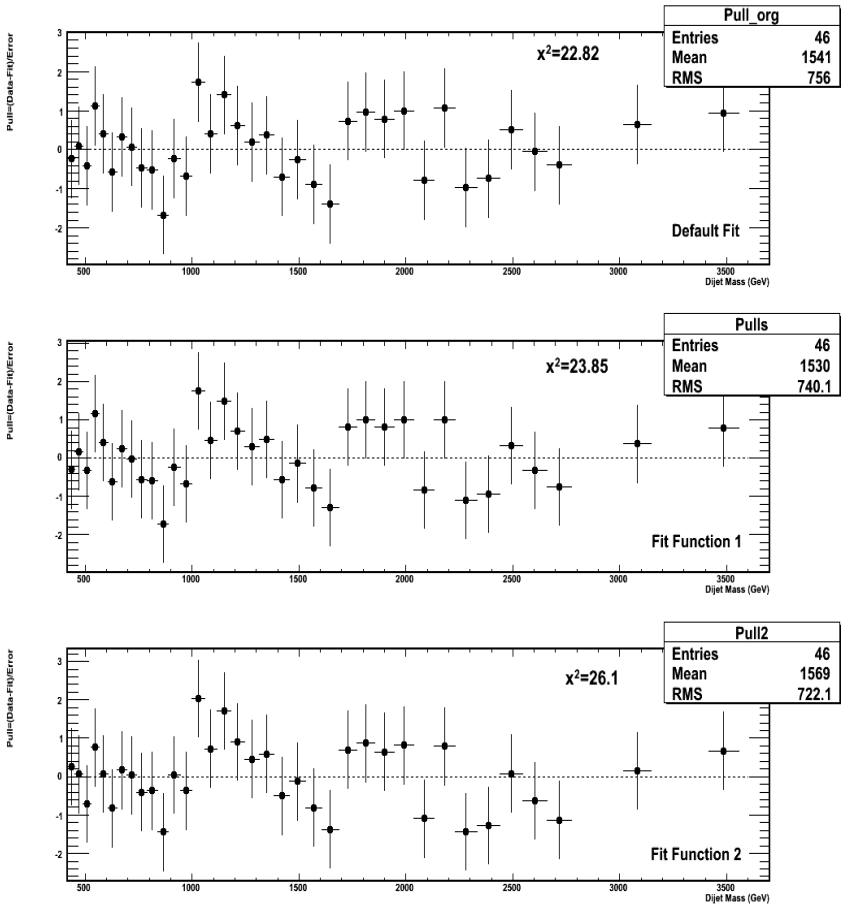
Background Systematic



It shows the comparison between limits with different background parameterization

Background Systematic (II)

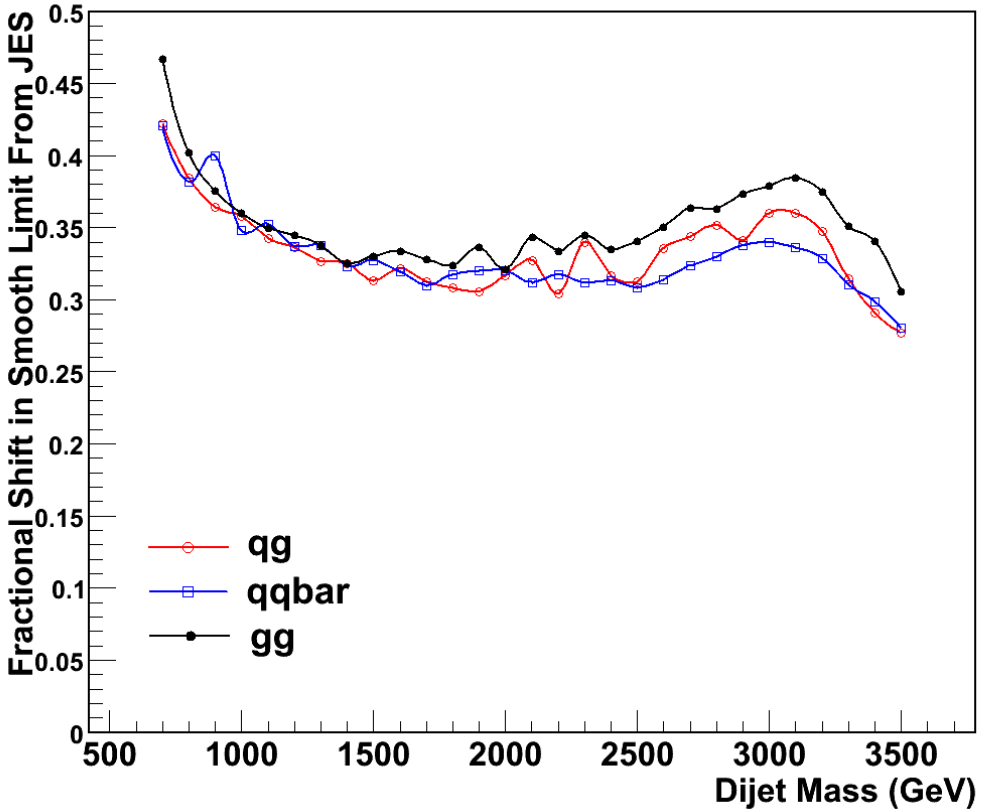




(Data-Fit)/Fit

(Data-Fit)/Error

JES Systematic



It shows the comparison of fractional shift in smooth limit from JES between qq, qg and gg