Dijet Resonance Search with Dijet Mass

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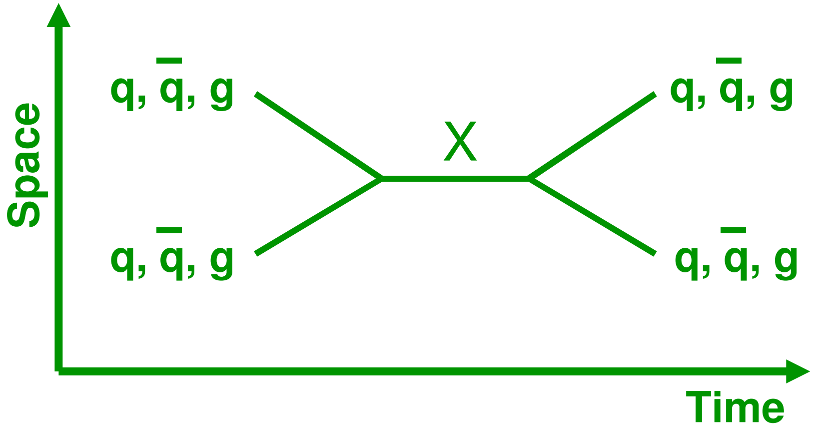
Outline

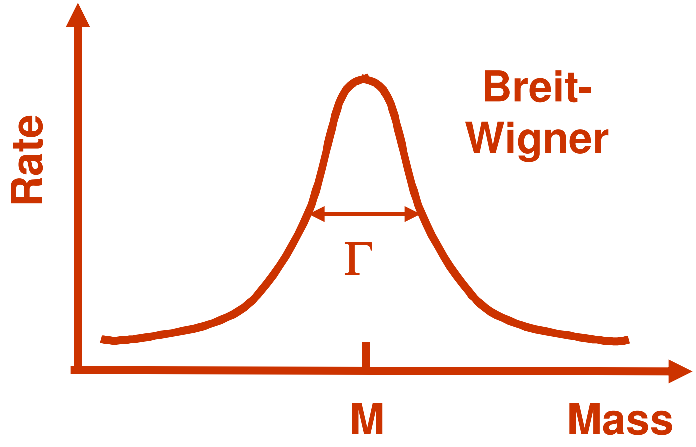
- Introduction
- Review of dijet resonance search analysis
- Limits for qq, qg and gg dijet resonances
- Limits including systematic uncertainties
- Conclusions

Dijet Resonances

- New particles that decay to dijets
  - Produced in “s-channel”
  - Parton - Parton Resonances
    - Observed as dijet resonances.
  - Many models have small width Γ



Model Name	X	Color	J^P	Γ / (2M)	Chan
E_6 Diquark	D	Triplet	0^+	0.004	ud
Excited Quark	q*	Triplet	$\frac{1}{2}^+$	0.02	qg
Axigluon	A	Octet	1^+	0.05	$q\bar{q}$
Coloron	C	Octet	1^-	0.05	$q\bar{q}$
Octet Technirho	ρ_{T8}	Octet	1^-	0.01	$q\bar{q}$,gg
R S Graviton	G	Singlet	2^-	0.01	$q\bar{q}$,gg
Heavy W	W ‘	Singlet	1^-	0.01	$q_1\bar{q}_2$
Heavy Z	Z ‘	Singlet	1^-	0.01	$q\bar{q}$



Review of Dijet Resonance Search

- The machinery of dijet resonance search
  - 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
  - Limits for quark-quark, quark-gluon and gluon-gluon resonances
  - Systematic uncertainties

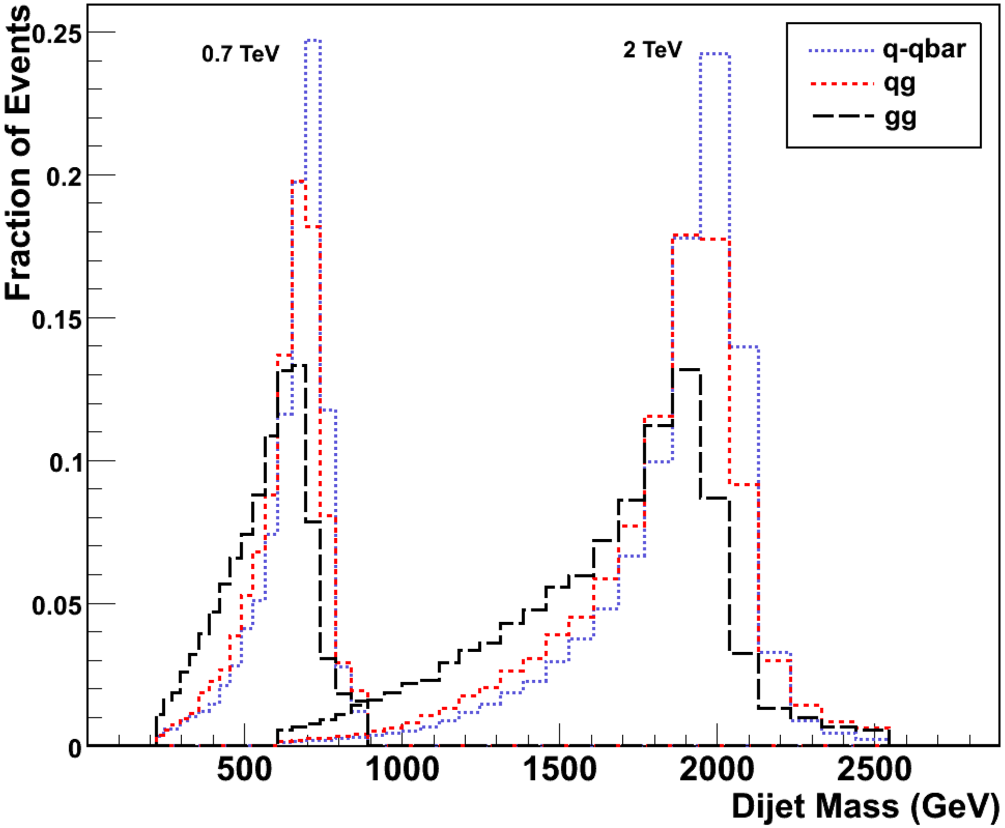
- We present an example search with 10 pb^{-1}
  - With pseudo-data that have statistical fluctuation appropriate for 10 pb^{-1}
  - And we have written the “early paper” draft based on this search: CMS AN-2009/070.

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 $G \to qq$, $q^* \to qg$, $G \to gg$.
    - 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.



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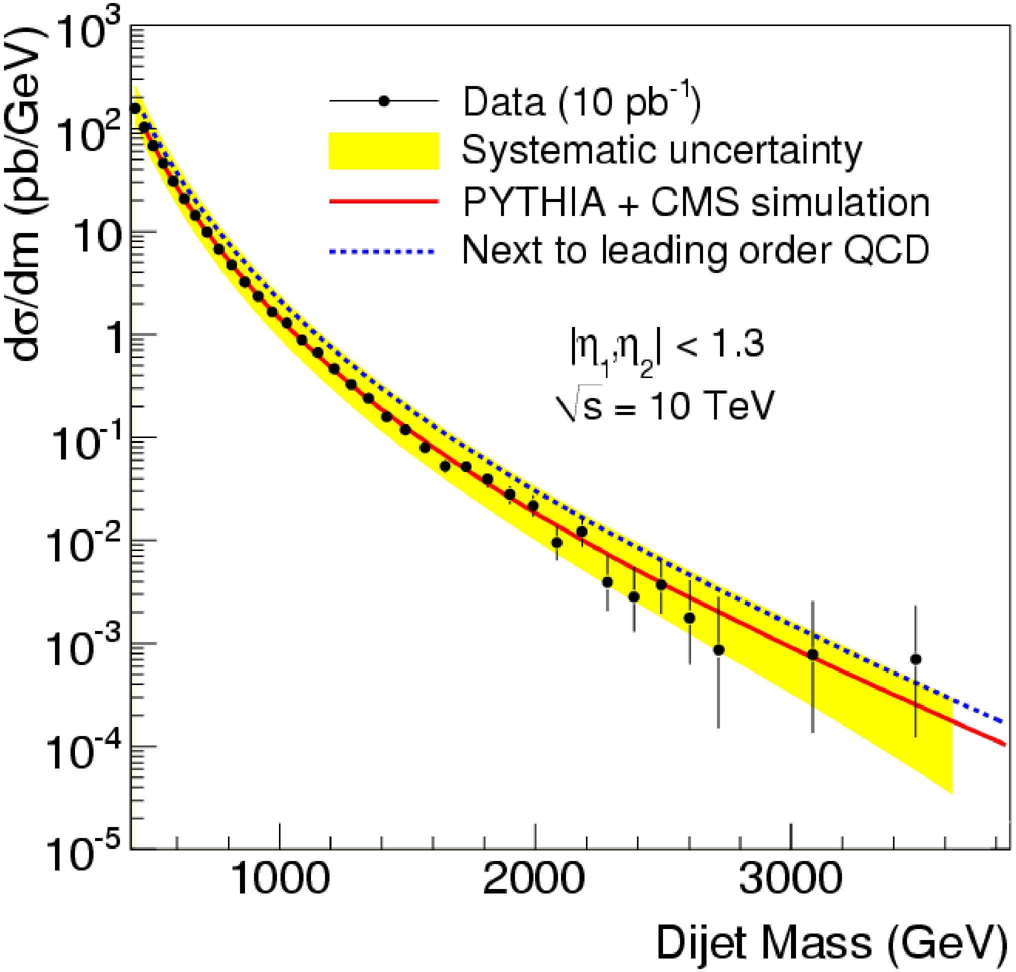
Pseudo-data and QCD Theory

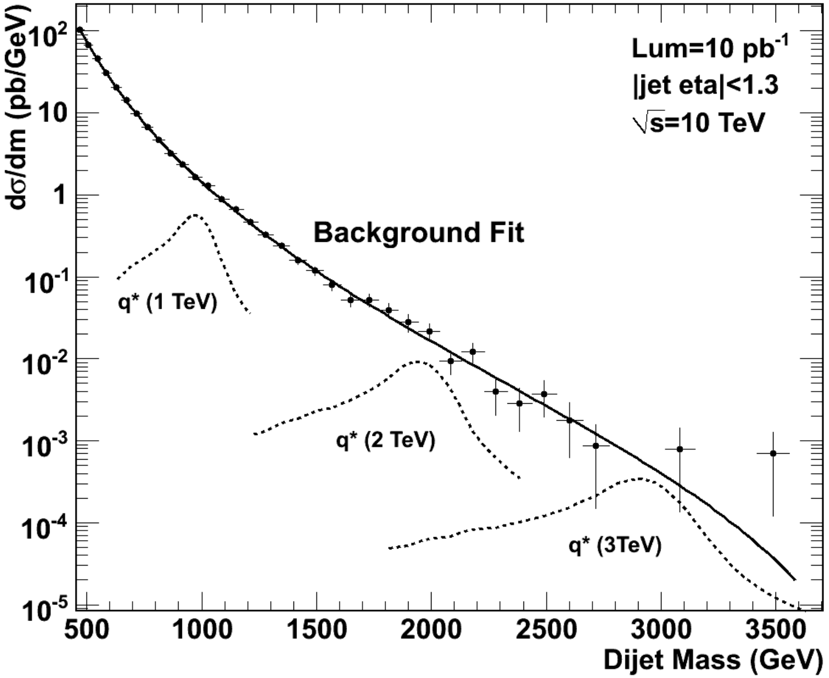
- We produce pseudo-data from PYTHIA QCD dijets.
    - ➔ Stat. fluctuations for 10 pb^{-1}

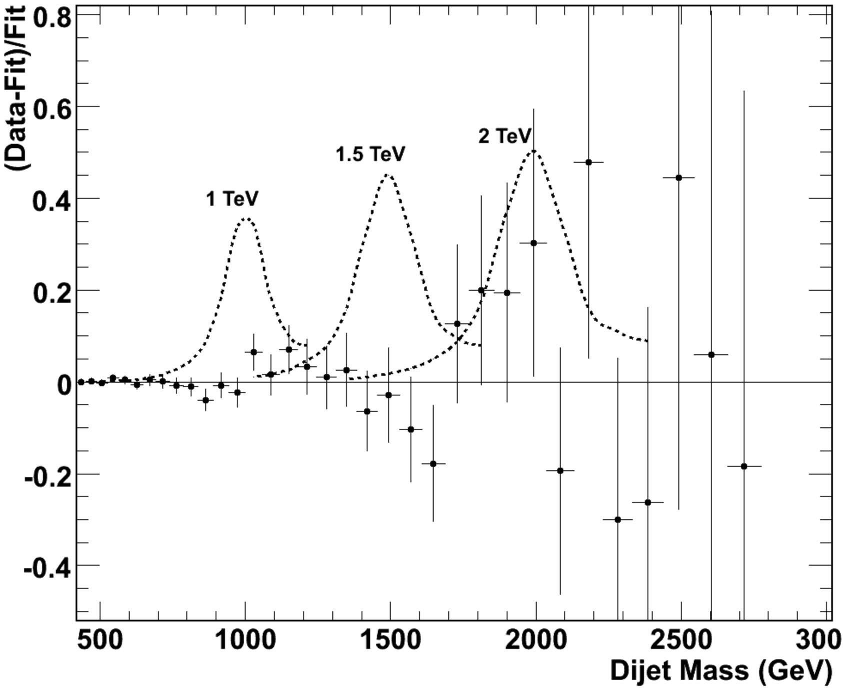
- The pseudo-data is compared to PYTHIA and NLO QCD
    - ➔ Like we will do with real data.
    - ➔ Agreement would indicate no evidence of dijet resonances

- 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

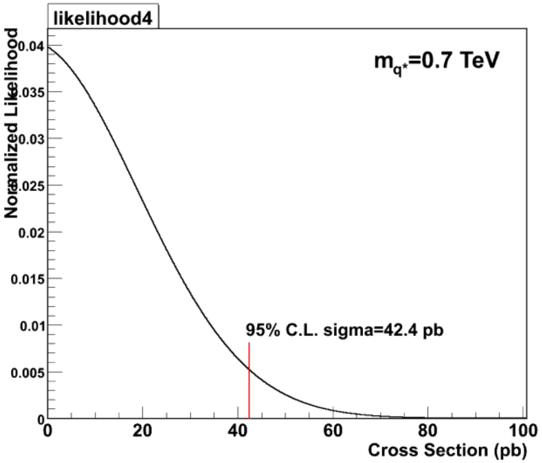
# of events from signal

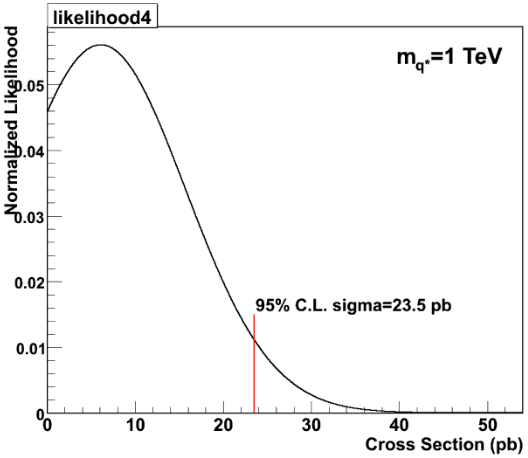
expected # of events from background

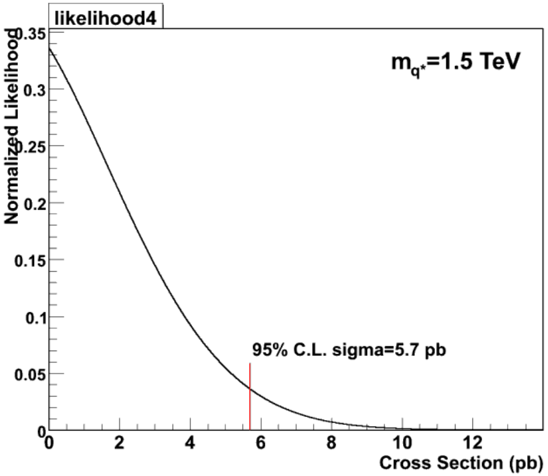
- The signal comes from our dijet resonance shapes for qq, qg and gg
- The background comes from the fit.
- We calculate likelihood as a function of signal cross section for resonances with mass M = 0.7 to 3.5 TeV in 0.1 TeV steps.

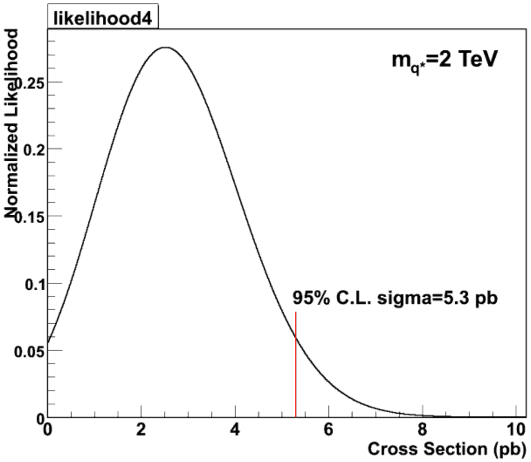
Likelihoods with Stat. Error Only (for qg)

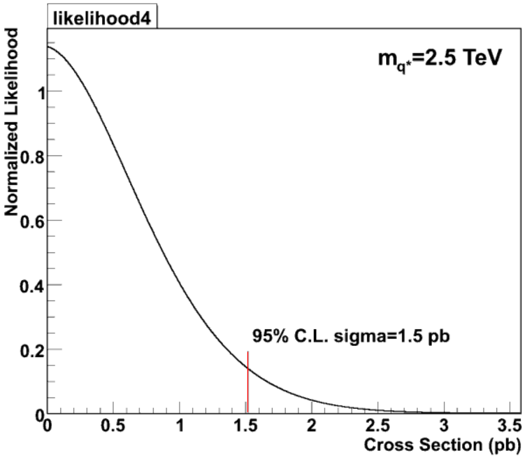
- From the likelihood we find the 95% CL upper limit on the cross section.

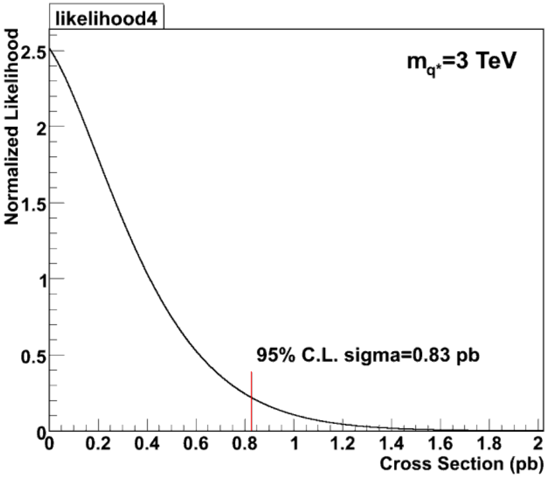






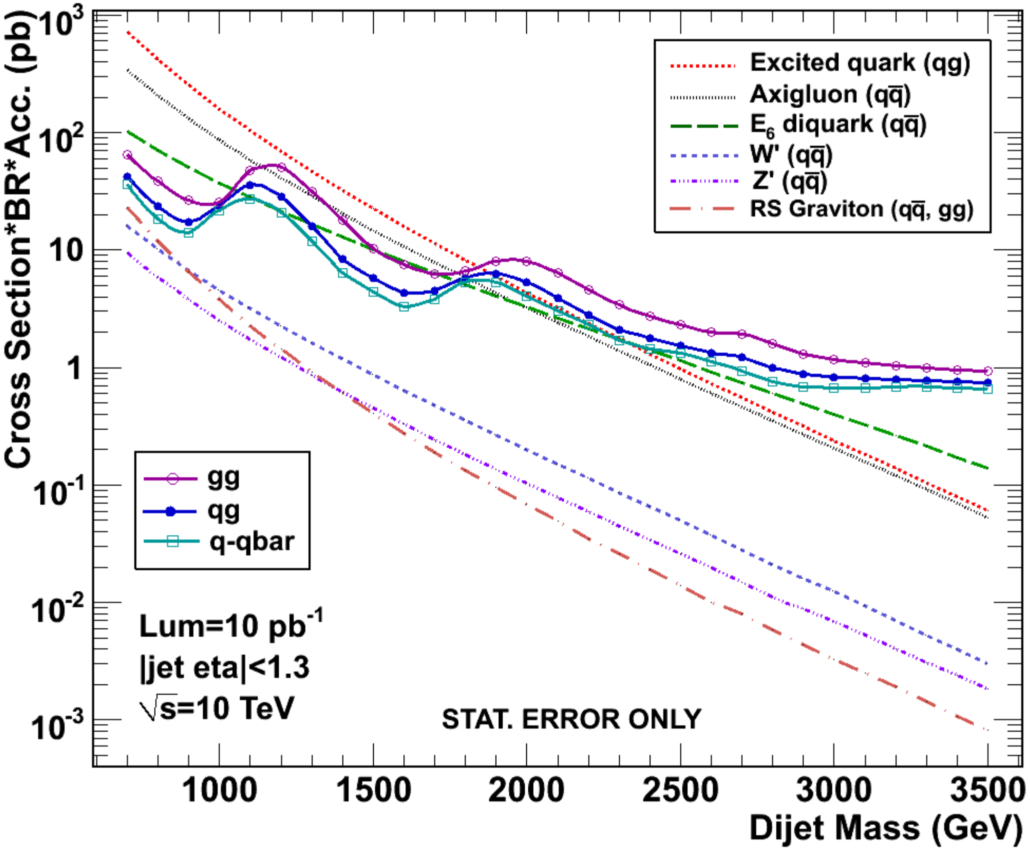






Dijet Resonance Limits with Statistical Uncertainties Only

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



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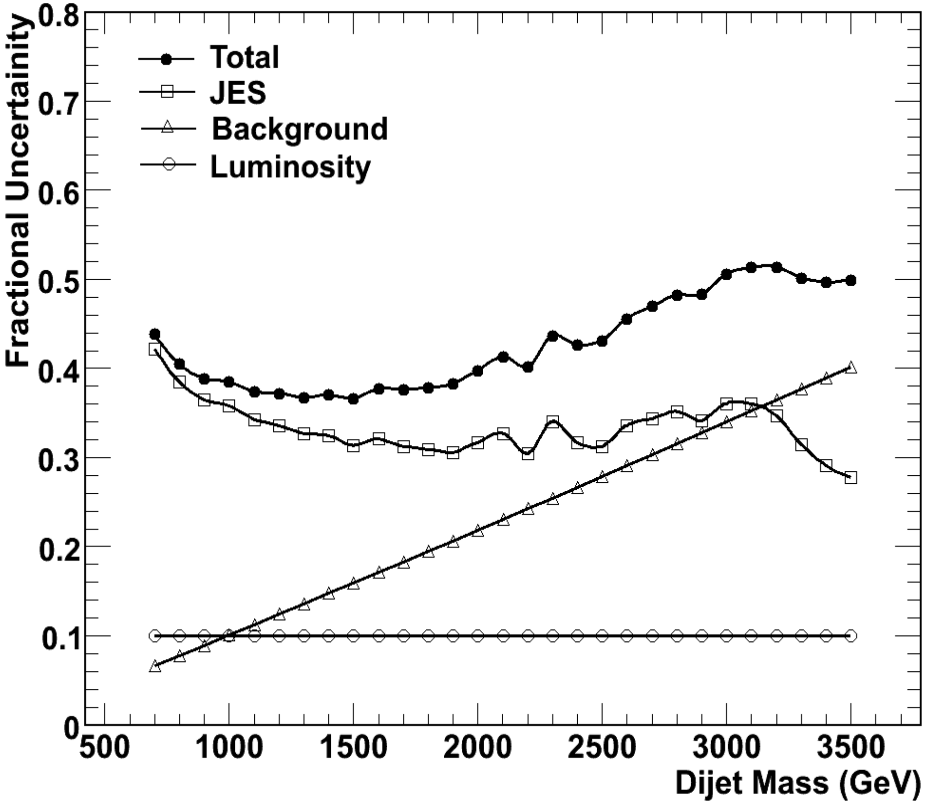
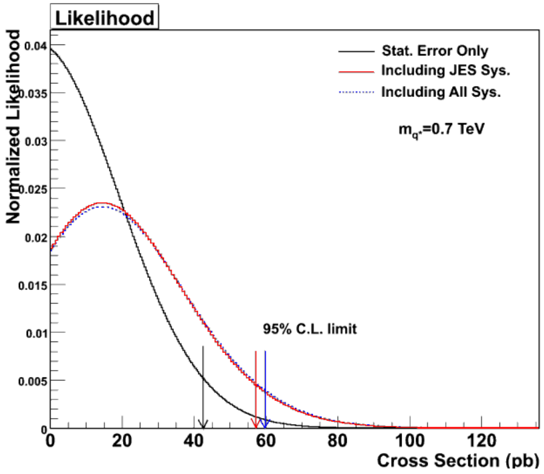
Total Systematic Uncertainties

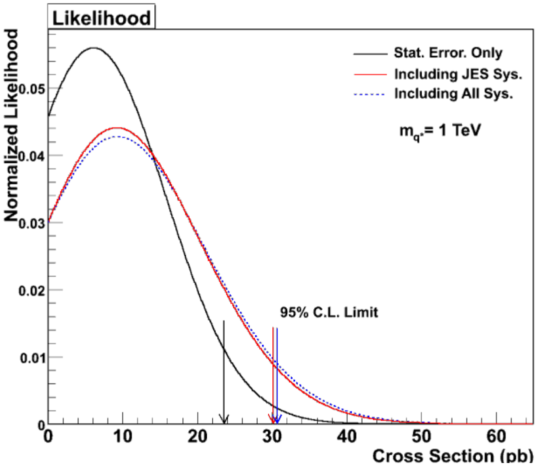
- We found the uncertainty in the dijet resonance cross section from following sources
    - Jet Energy Scale (JES)
        - Uncertainty assumed to be 10% at start-up
    - Choice of background parameterization
        - We consider 3 functional form used by CDF
    - Luminosity
        - Uncertainty assumed to be 10% at start-up
- We add in quadrature the individual systematic uncertainties
    - Total systematic uncertainty varies from 45% at m=0.7 TeV to 50% at m=5 TeV

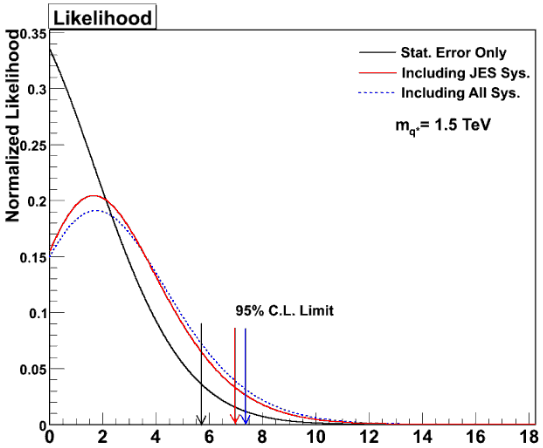


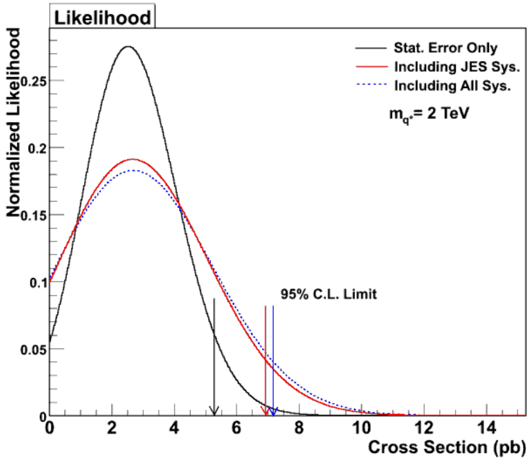
Likelihoods with Systematics (for qg)

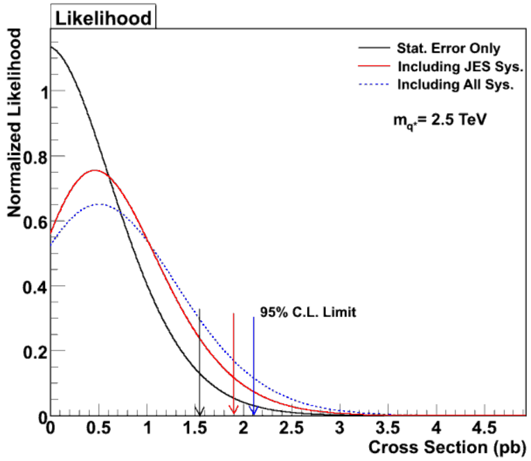
- We convolute Poisson likelihoods with Gaussian systematic uncertainties
  - ➔ Total likelihood including systematics is broader and gives higher upper limit.

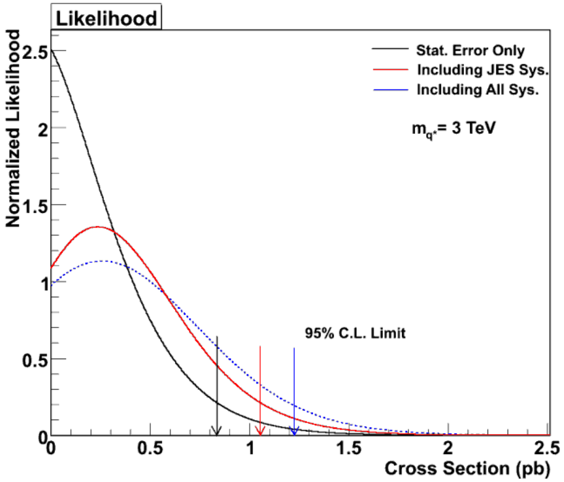






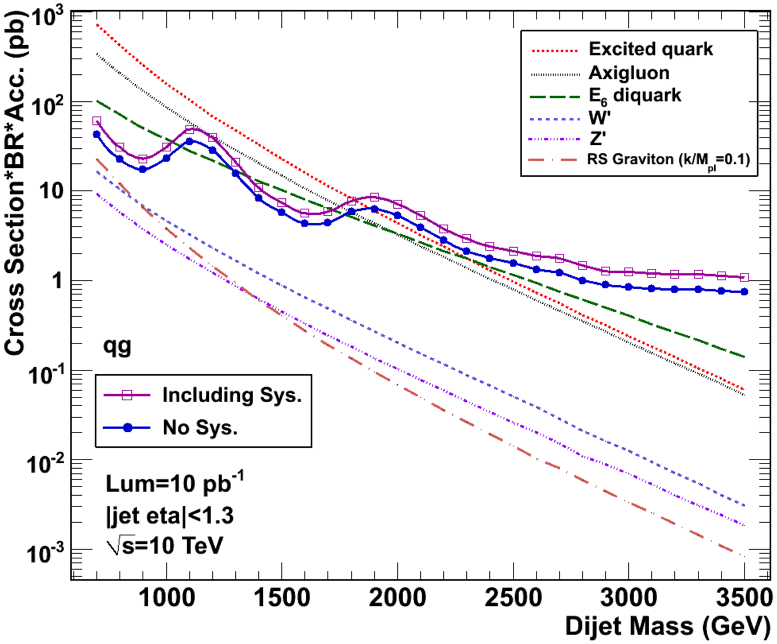


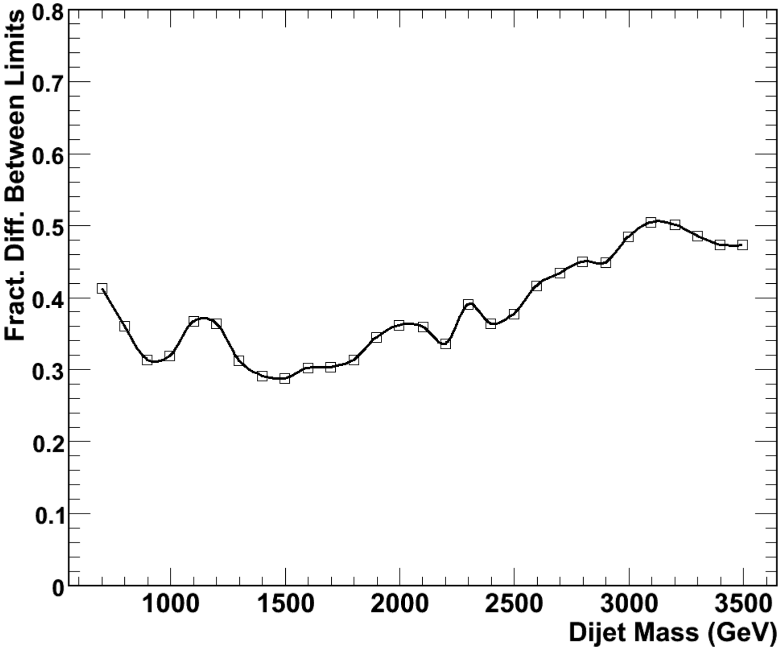




Effect of Systematics on Limit

- 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.

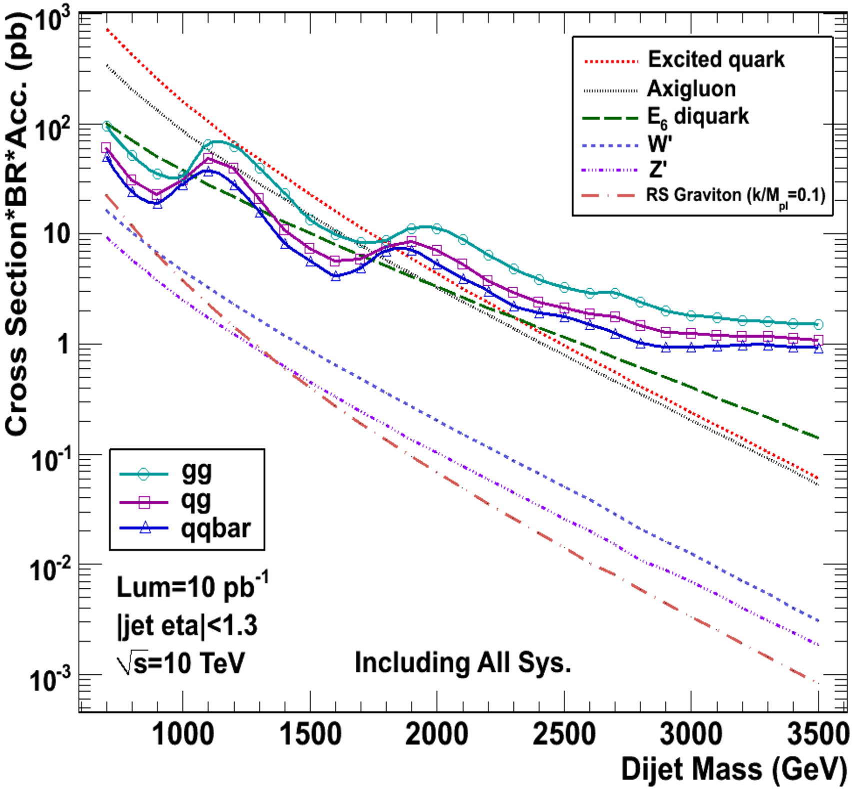




Results

- 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**



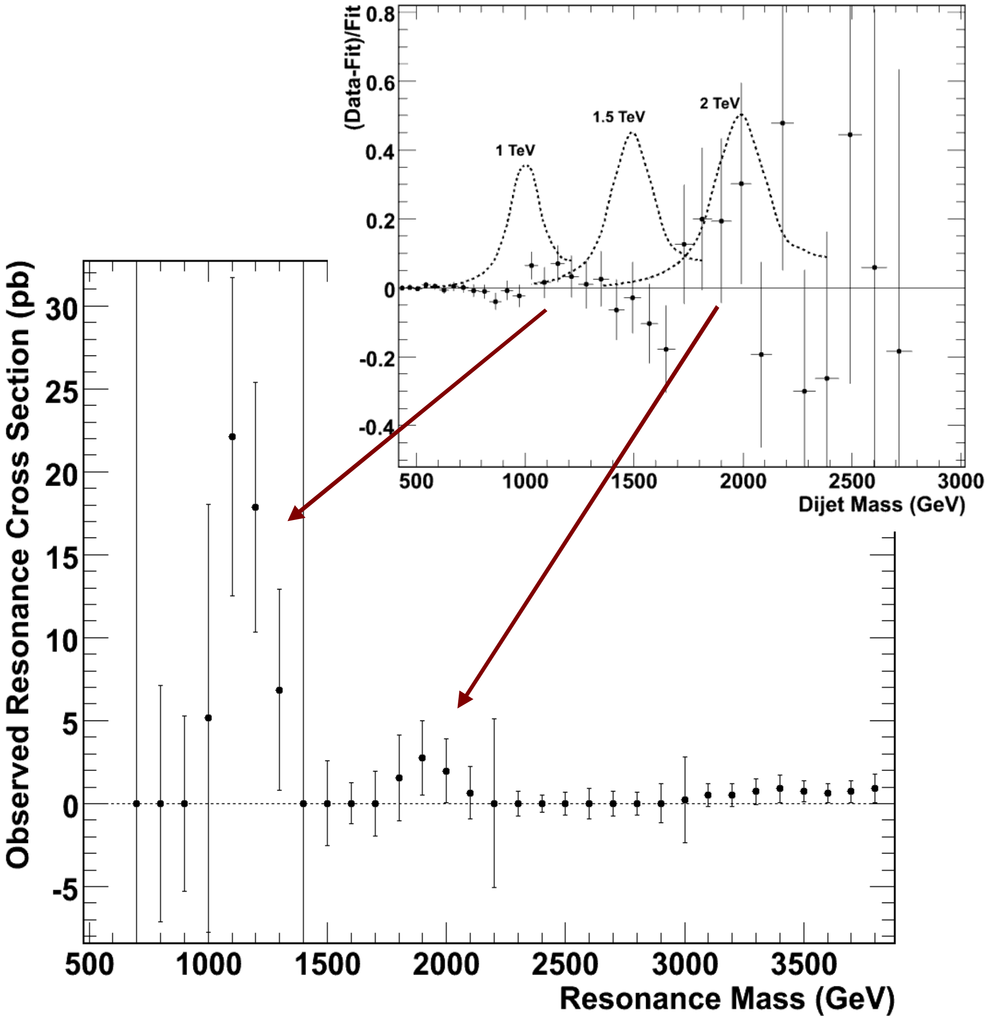
Conclusions

- We are ready to search for new physics at the TeV scale using dijets.
- We plan to search separately for qq, qg and gg resonances.
- CMS should be sensitive to excited quarks, axigluon/coloron, and E_6 diquarks up to ~2 TeV at 95% CL with 10 pb^{-1}
- New discoveries are highly possible even in early CMS data.

BACK-UP

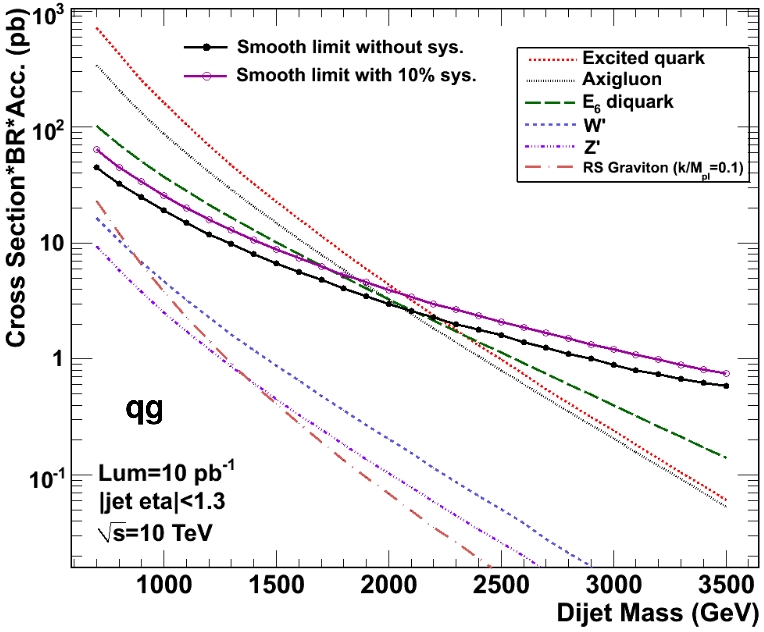
Fitting for Resonance Signal

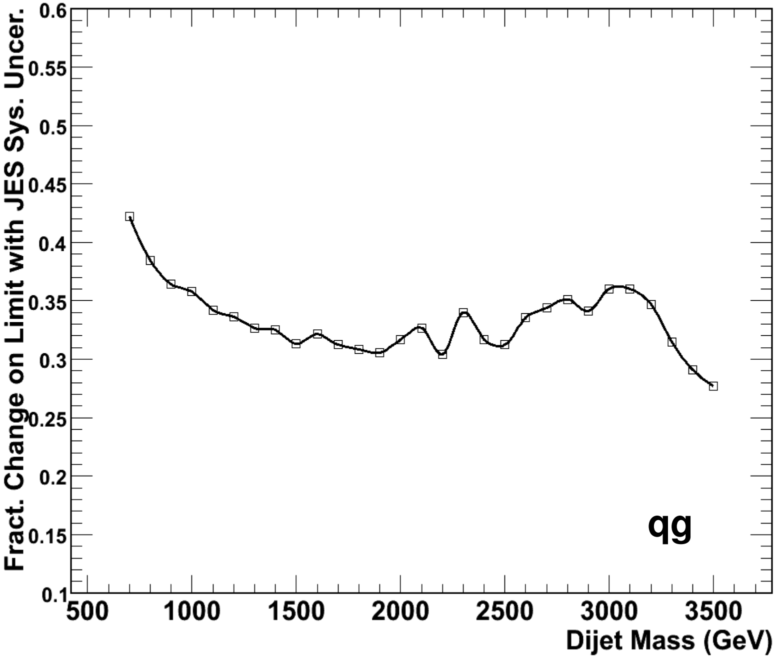
- We fit pseudo-data to the background + q* signal
  - M(q*)=0.7 – 3.5 TeV in 0.1 TeV steps
  - Signal cross section found is consistent with zero within errors
  - Background fluctuations at 1 and 2 TeV give positive cross sections with low significance (~2σ).
- No significant evidence of resonances in the pseudo – data sample
  - We proceed to set limits



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