Pre-Approval of EXO-10-001/QCD-10-017: Search for New Physics in the Dijet Mass Spectrum

Sertac Ozturk
(Cukurova University / LPC)

on behalf of Authors

Exotica Meeting
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Authors of EXO-10-001/QCD-10-017

Search for Dijet Resonances in the Dijet Mass Distribution in pp Collisions at $\sqrt{s} = 7$ TeV

Robert M Harris[1], Ken Hatakeyama[6], Bora Isildak[4], Shabnam Jabeen[8], Chiyoung Jeong[3], Konstantinos Kousouris[1], Sung-Won Lee[3], Kalanand Mishra[1], Sertac Ozturk[2], Kai Yi[5], and Marek Zielinski[7]

[1] Fermilab, Batavia, IL, USA
[2] University of Cukurova, Adana, Turkey
[3] Texas Tech University, Lubbock, TX, USA
[4] Bogazici University, Istanbul, Turkey
[5] University of Iowa, Iowa City, IA, USA
[6] Baylor Univeristy, Baylor, TX, USA
[7] University of Rochester, Rochester, NY, USA
[8] Brown University, Providence, RI, USA

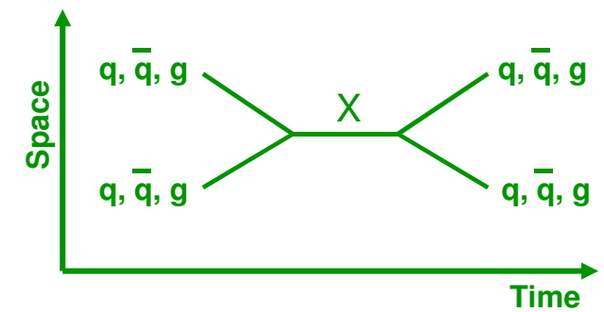
DRAFT

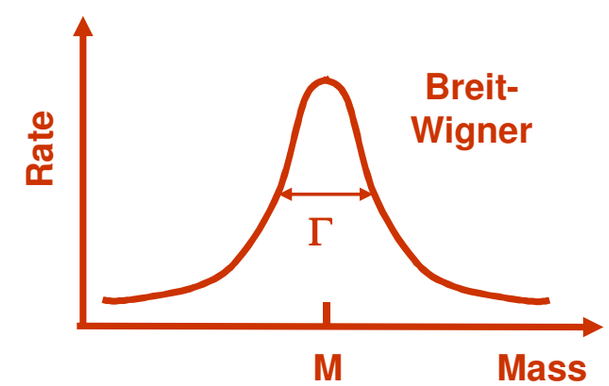
Outline

- Motivation
- Trigger Efficiency and Basic Distributions
- Dijet Mass Distribution and QCD
- Fits for Background and Signal
- High Mass Event
- Early Limit on Dijet Resonances
  - ✓ Statistical Error Only
  - ✓ Including Systematic Uncertainties
- Expected Future Limits
- Conclusion

Motivation

Model Name	X	Color	J^P	$\Gamma/(2M)$	Chan
Excited Quark	q*	Triplet	$1/2^+$	0.02	qg
E_6 Diquark	D	Triplet	0^+	0.004	qq
Axigluon	A	Octet	1^+	0.05	$q\bar{q}$
Coloron	C	Octet	1^-	0.05	$q\bar{q}$
RS Graviton	G	Singlet	2^+	0.01	$q\bar{q}$, gg
Heavy W	W′	Singlet	1^-	0.01	$q\bar{q}$
Heavy Z	Z′	Singlet	1^-	0.01	$q\bar{q}$
String	S	mixed	mixed	$0.003 - 0.037$	$q\bar{q}$, qq, gg and qg





- **String Resonances**
  - ✓ String Resonances are excitations of quarks, gluons and a new U(1) gauge boson in open string theory
  - ✓ Decay mainly to gg, but also qq, qg, q-qbar
  - ✓ Multiple spins at same resonance mass with large cross section

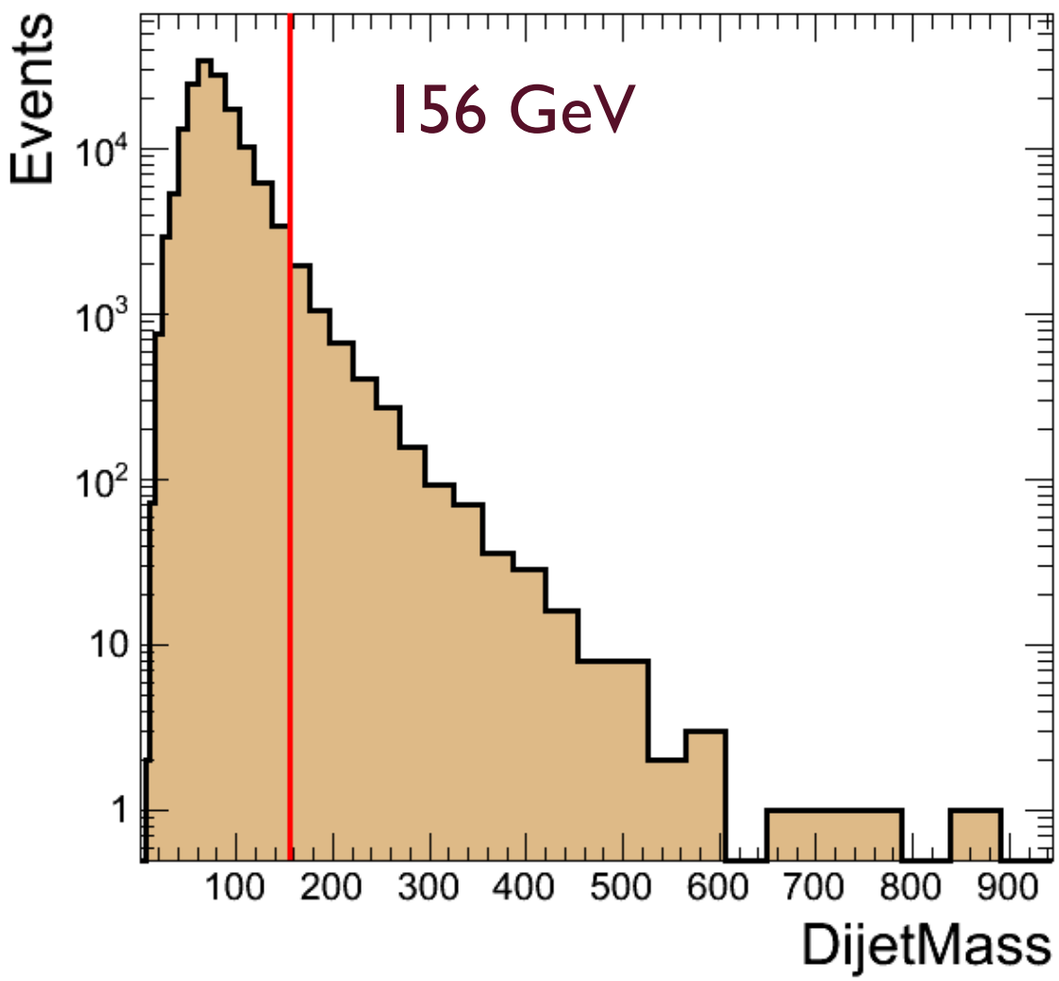
- We search for new physics beyond SM with Dijets
- New particles that decay to dijets
  - ✓ Produced in "s-channel"
  - ✓ Parton-Parton Resonaces
    - Observed as dijet resonances.
- Search for model with narrow width Γ.

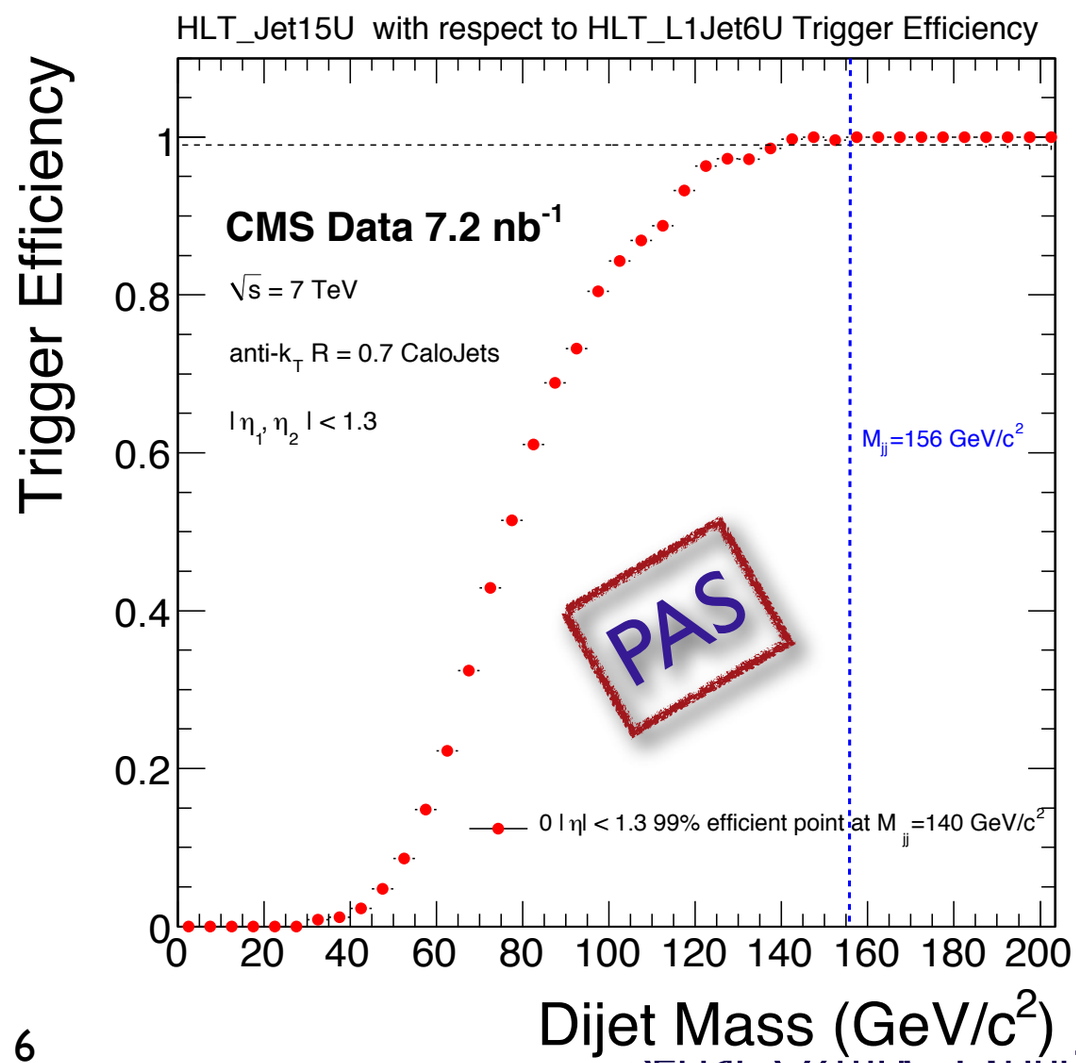
Event Selection

- Dataset
  - ✓ /MinimumBias/Commissioning10-SD_JetMETTau-v9/RECO
  - ✓ Run:
    - 133877, 133881, 133885, 133927,133928, 135149, 135175, 135445, 135521, 135523, 135525, 135528, 135534, 135535, 135537
  - ✓ Trigger
    - Require un-prescaled jet trigger and LHC bunch crossing and veto beam halo events:
    - HLT_Jet15U AND Trigger bits: '0 AND NOT (36 OR 37 OR 38 OR 39)'
  - ✓ Scraping event removal
  - ✓ Estimated Luminosity: 7.2 nb^{-1}
- Event Selection
  - ✓ AK7caloJets
  - ✓ JEC: L2+L3, "Spring10"
  - ✓ Require event vertex with |PVz| < 15 cm & PVndof >= 4
  - ✓ Require both leading jets have $|\eta|< 1.3$
  - ✓ Require both leading jets passing the "loose" jet id & Mjj > 156 GeV (corrected)
    - Loose JetID removed 2 events. Both were scanned and are HPD/RBX noise.
- Total: 4788 Dijet Events

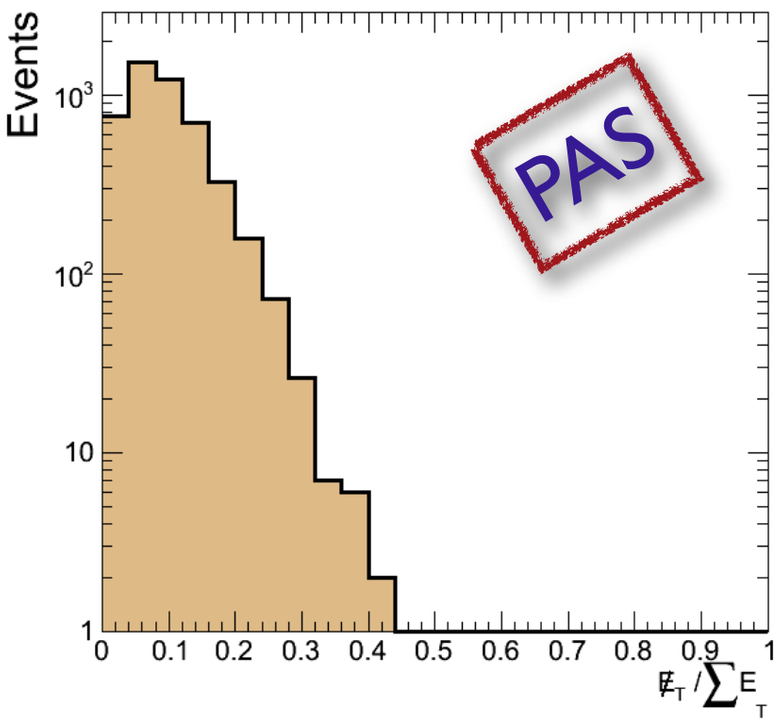
Trigger Efficiency

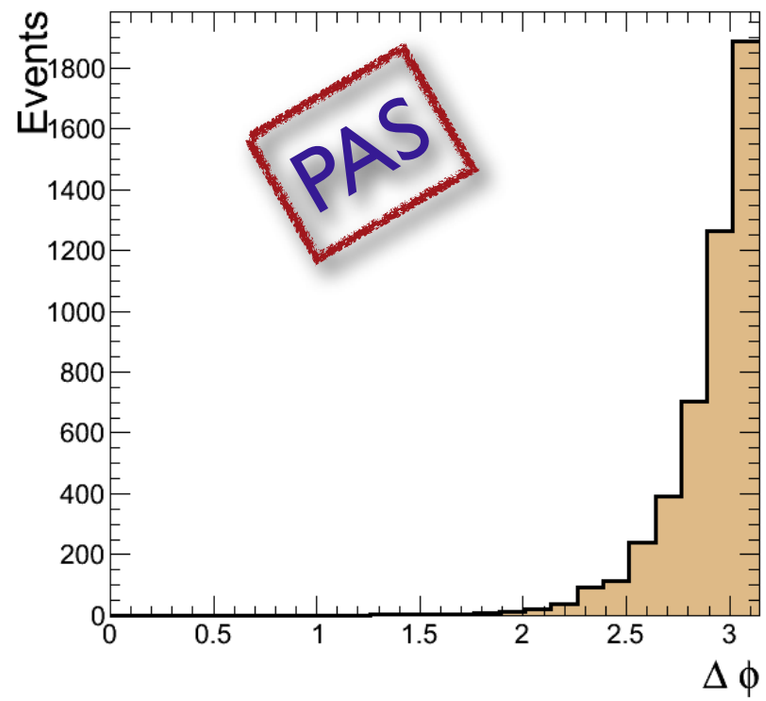
- Start analysis of Dijet Mass distribution at 156 GeV.
  - ✓ 156 GeV chosen for full trigger efficiency for both this analysis and dijet ratio (next talk)
  - ✓ It's a predefined bin-edge of variable width bins roughly equal to dijet mass resolution
- HLT_Jet15 trigger is clearly fully efficient at Mjj=156 GeV for |η|<1.3

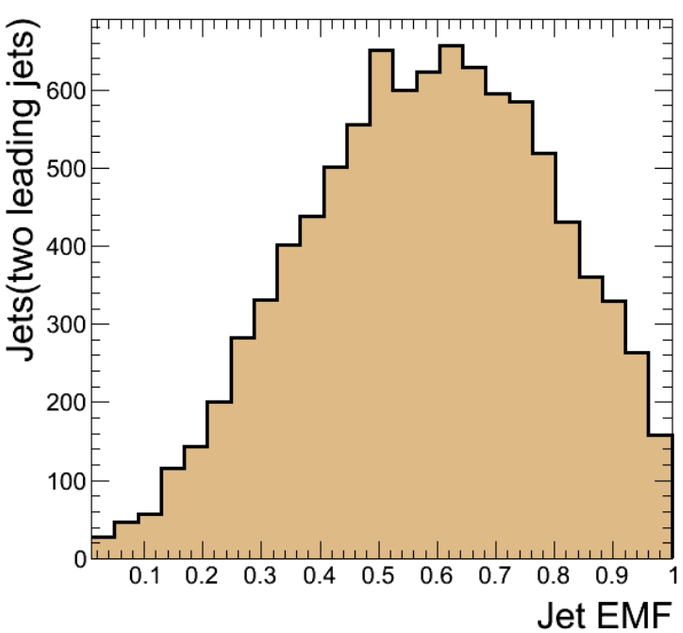


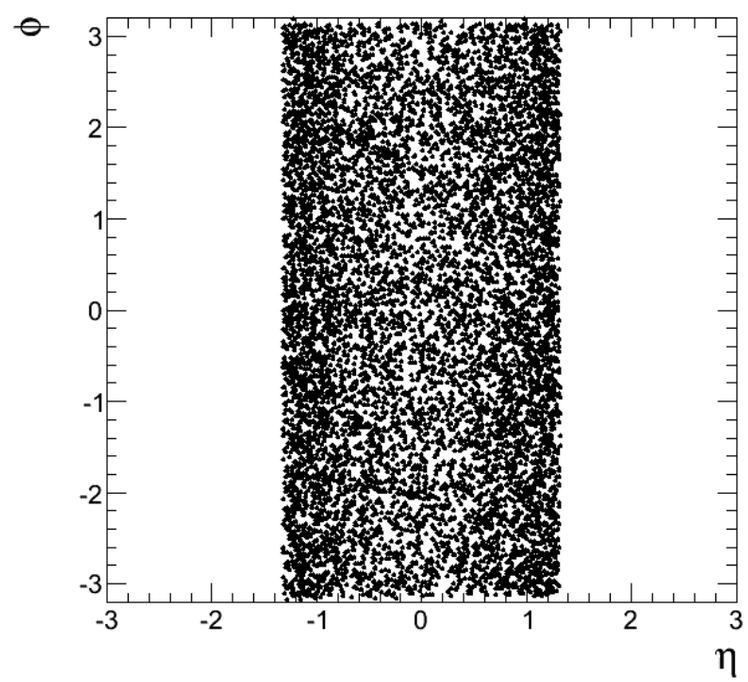


Dijet Data Quality





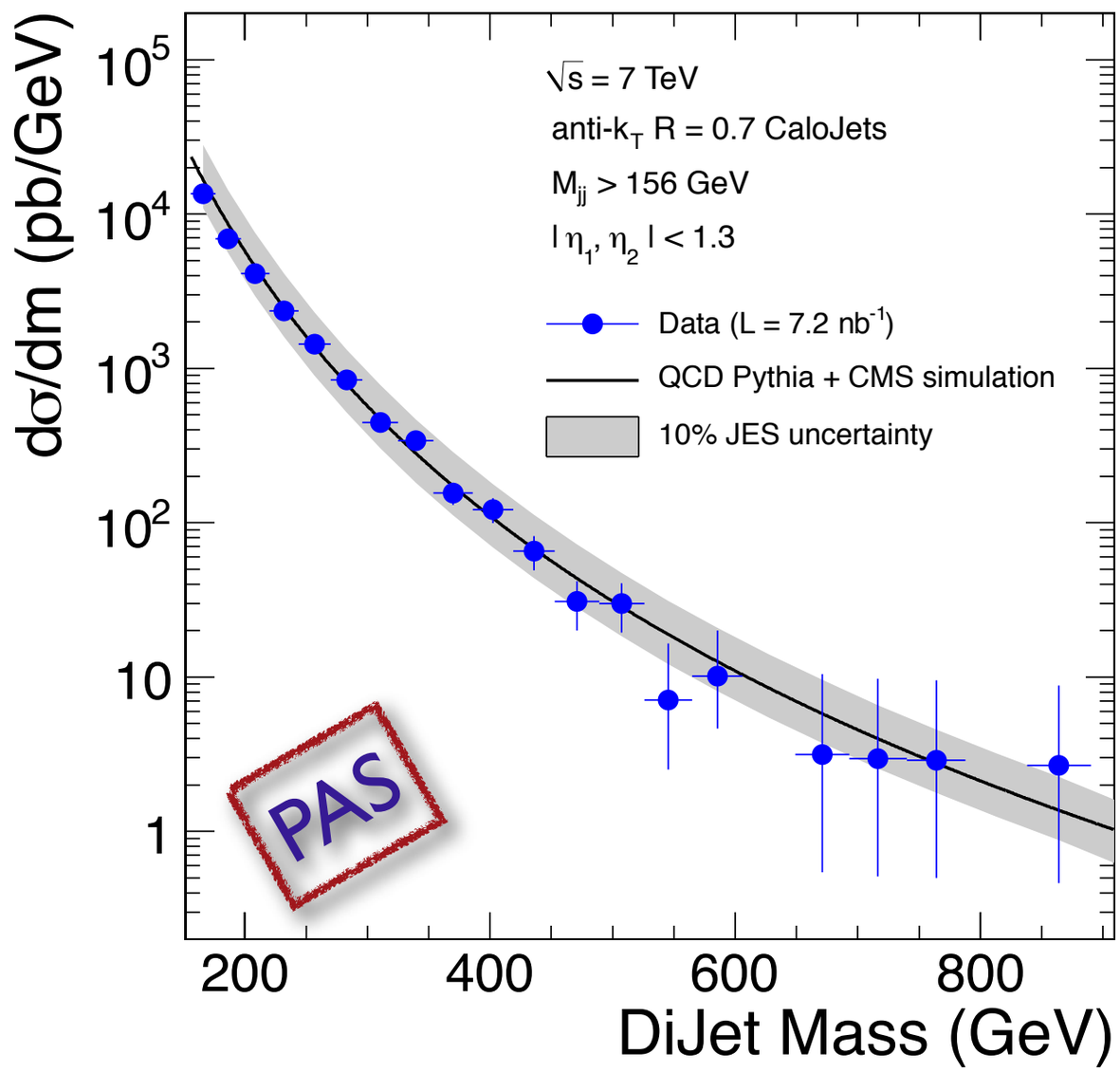




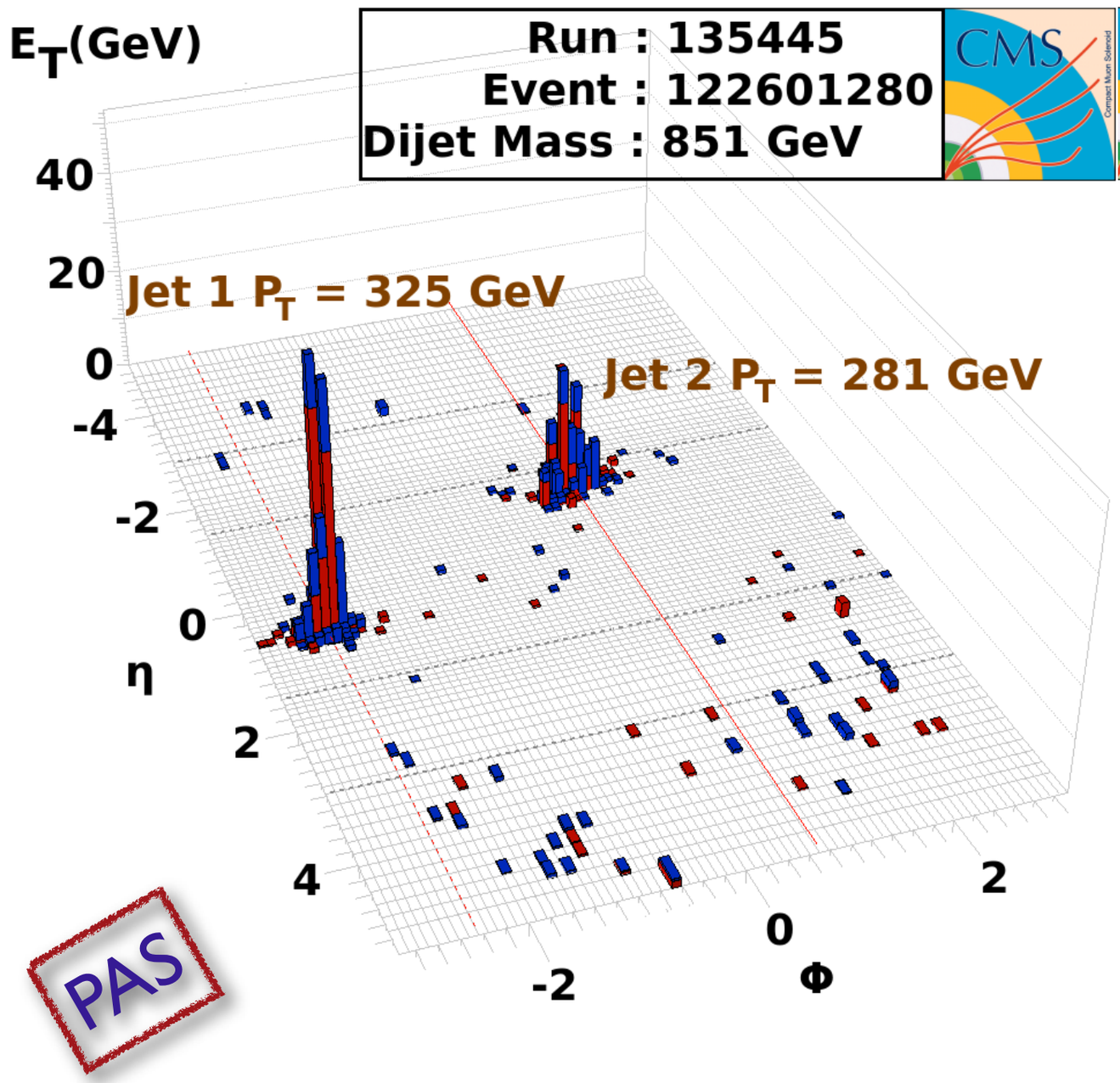
- Basic jet distributions look good.
  - ✓ Low MET
  - ✓ Back-to-Back in phi
  - ✓ No spike in EMF distribution near 0 and 1.
  - ✓ η-ϕ is uniform

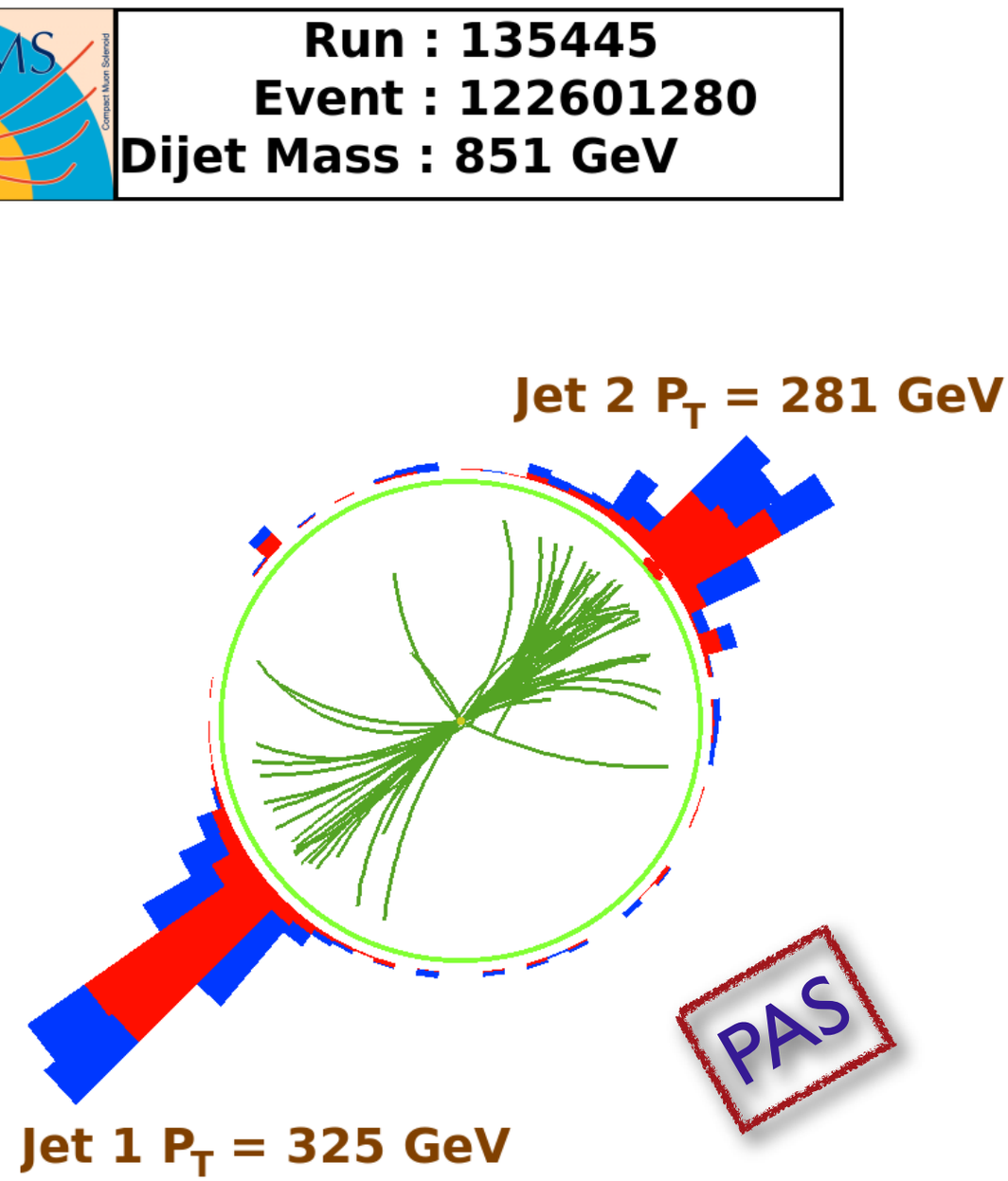
Dijet Mass and QCD

- The data is in good agreement with the full CMS simulation of QCD from PYTHIA.



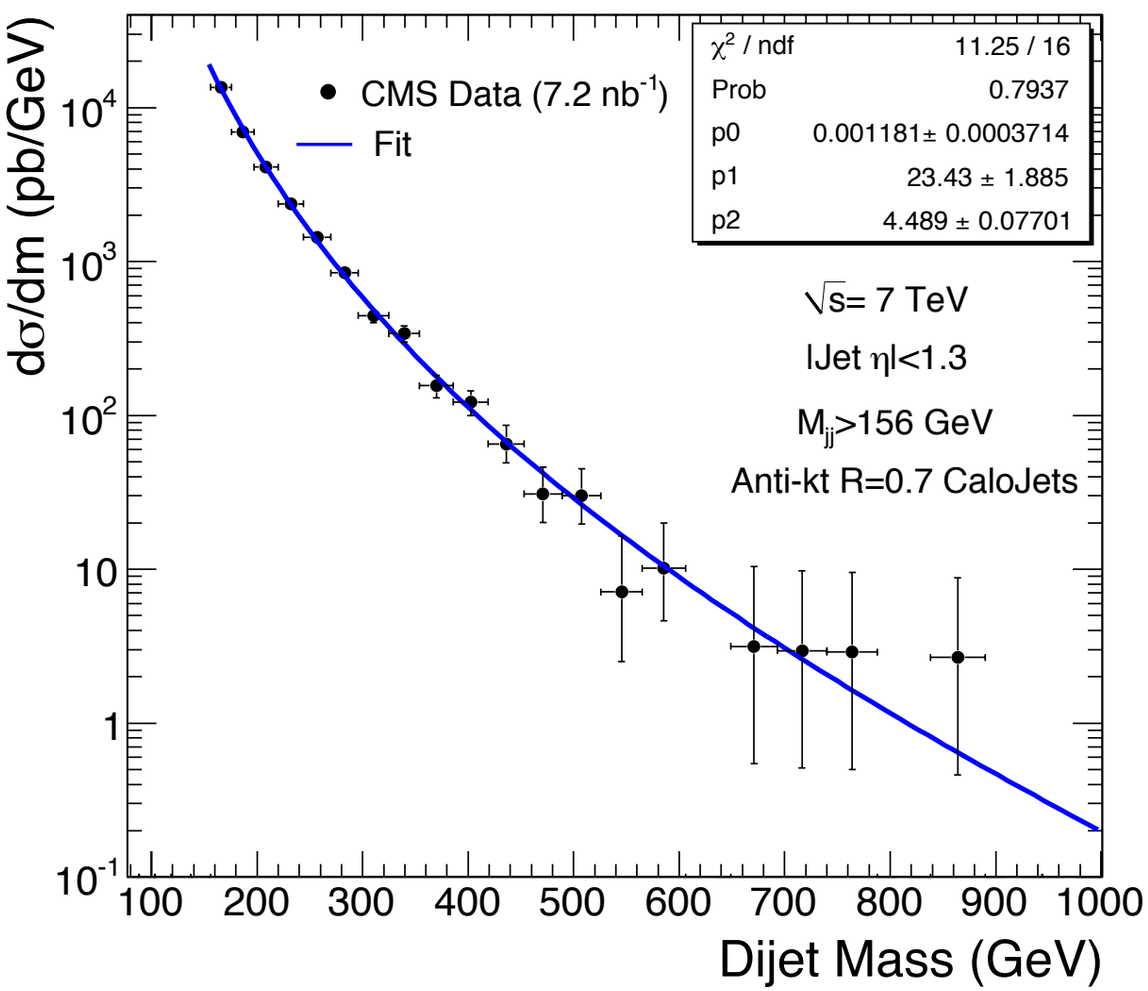
High Mass Dijet Event

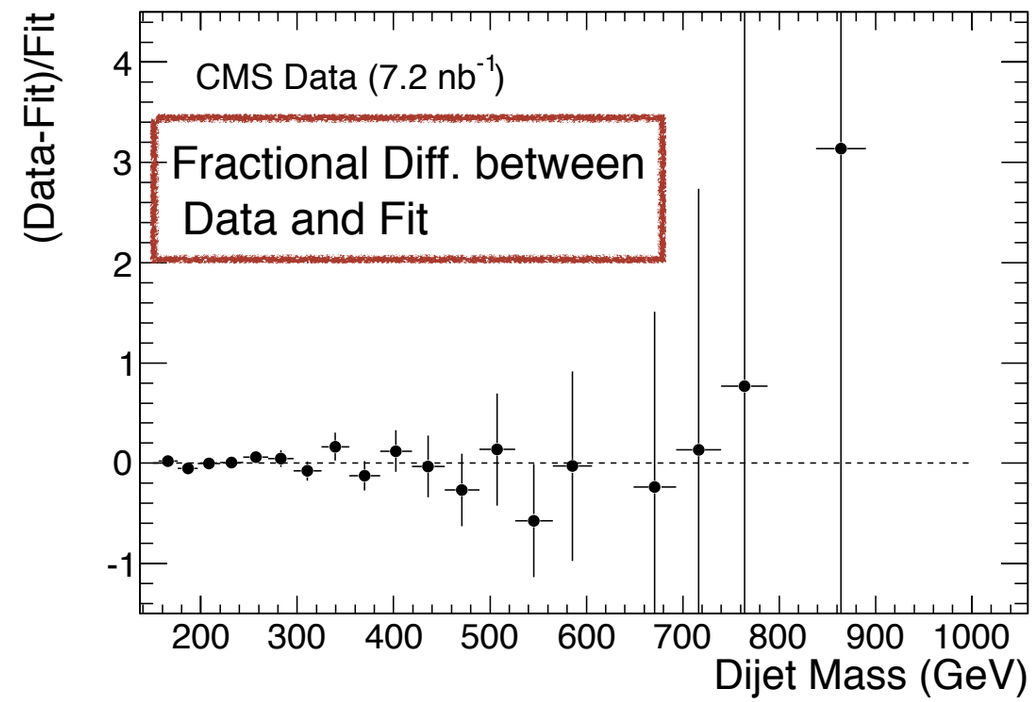


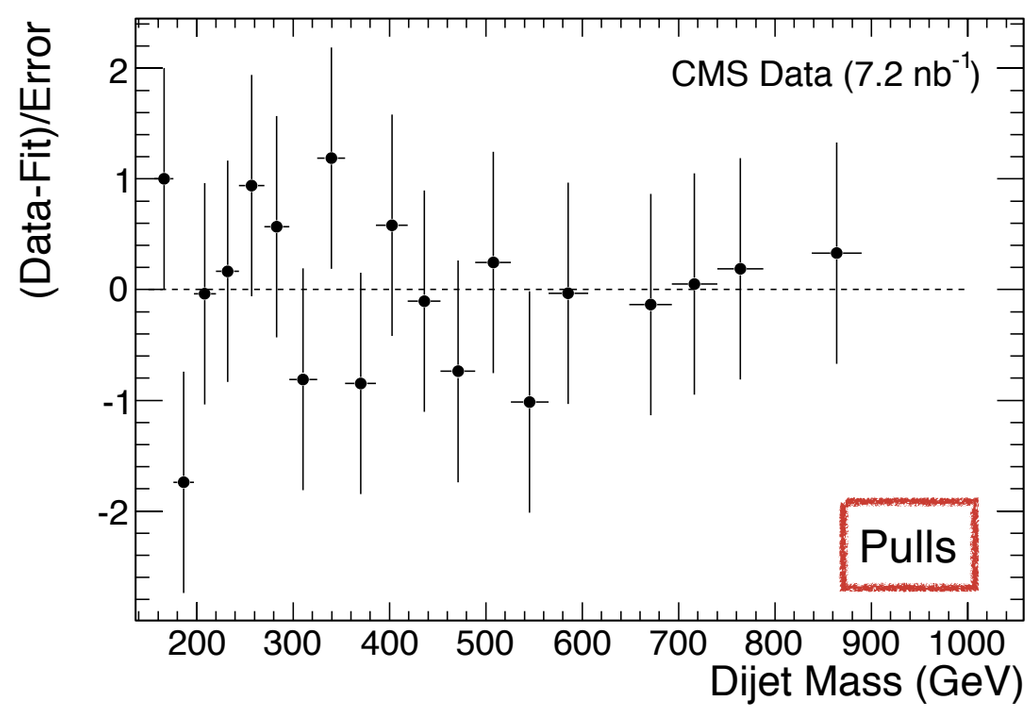


Dijet Mass and Fit

- We fit the data a the function containing 3 parameters.
- We get a good fit.







$$\frac{d\sigma}{dm} = p_0 \frac{(1-\frac{m}{\sqrt{s}})^{p_1}}{(m/\sqrt{s})^{p_2}}$$

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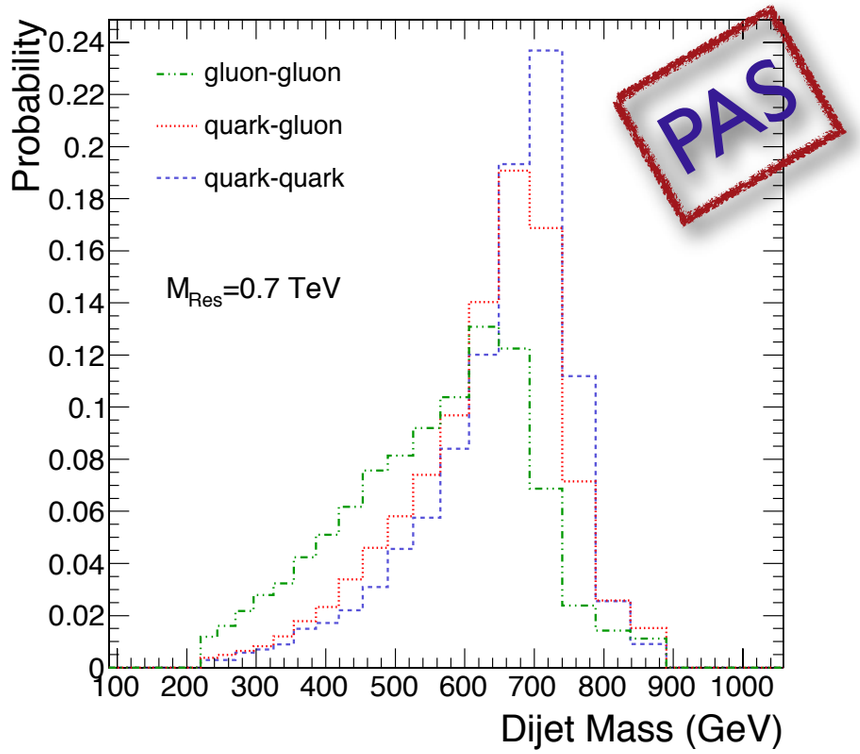
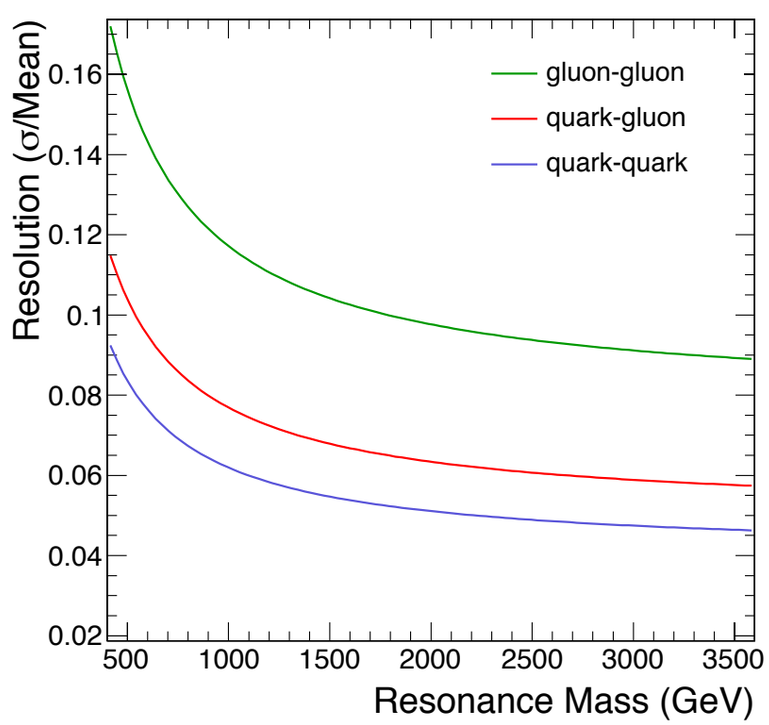
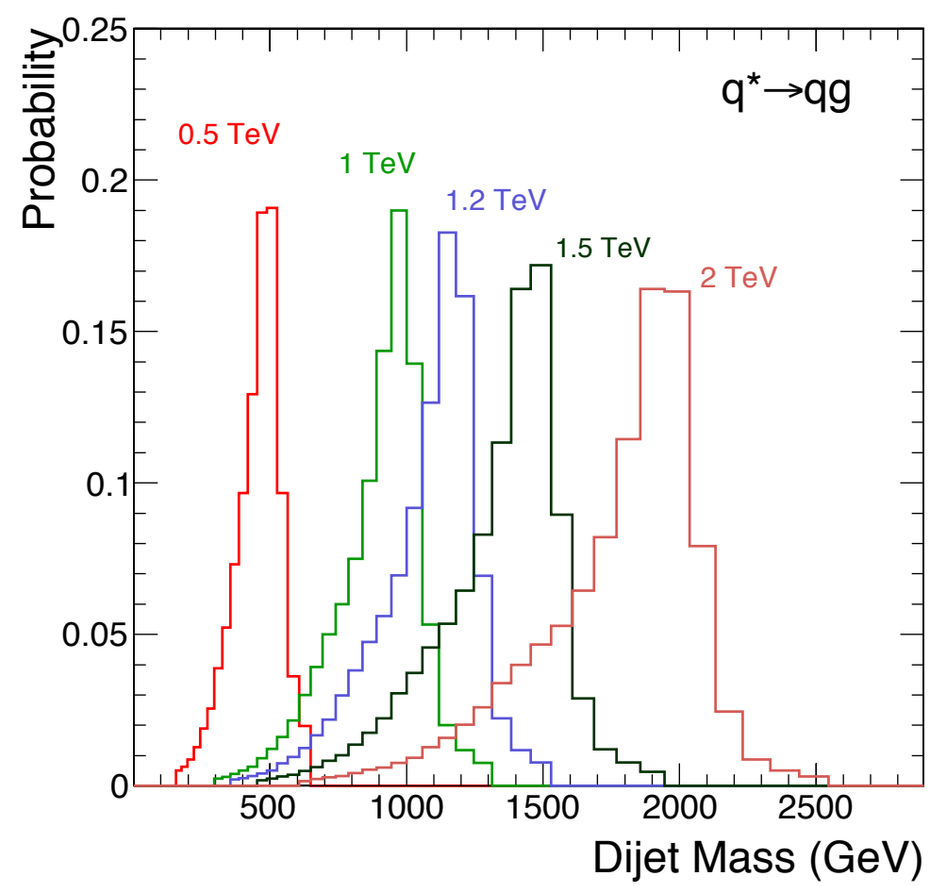
Resonance Shapes



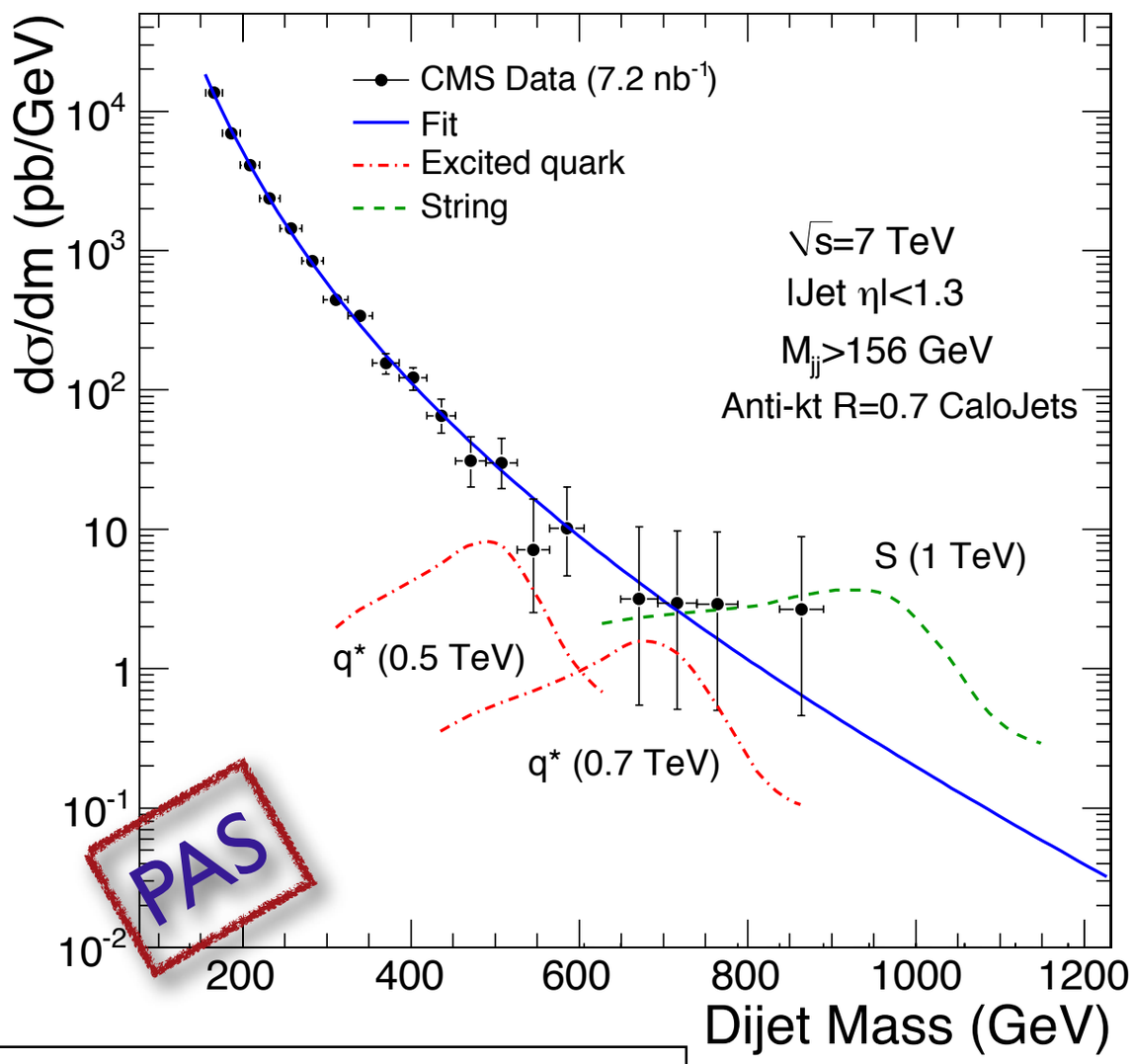
- We have simulated dijet resonances using CMS simulation + PYTHIA.
- qq, qg and gg resonances have different shape mainly due to FSR.
  - ✓ The width of dijet resonance increases with number of gluons because gluons emit more radiation than quarks.
- We search for these three basic types of narrow dijet resonance in our data.

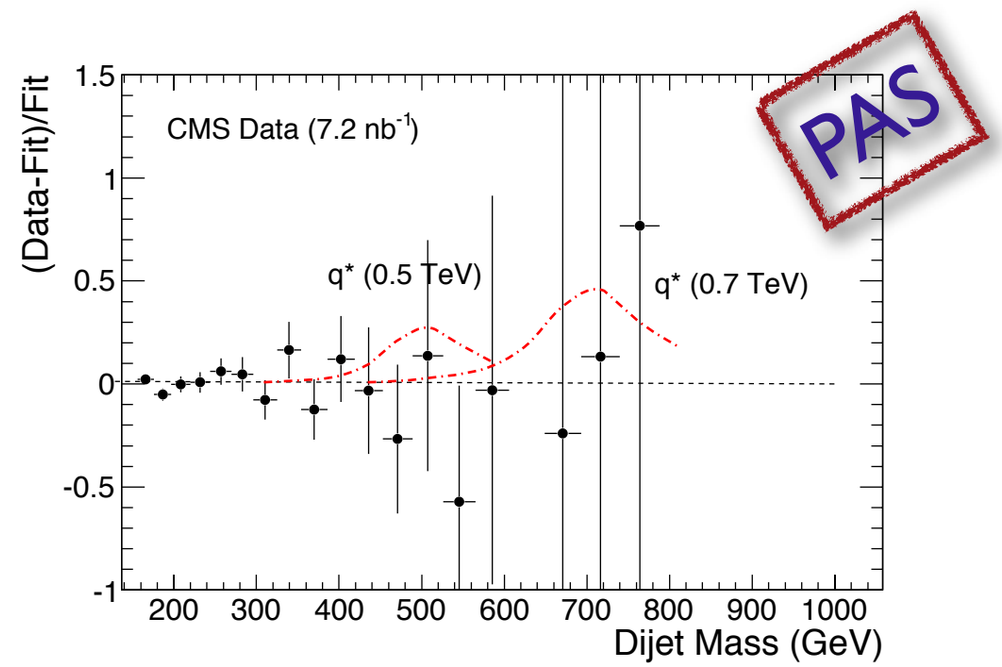


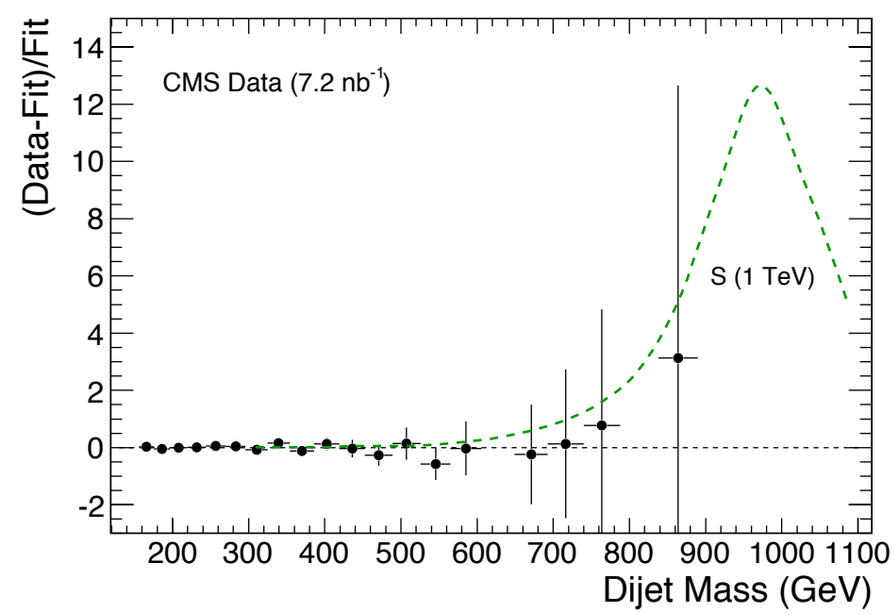


Fit and Signal

- We search for dijet resonance signal in our data.
- Excited quark signals are shown at 0.5 TeV and 0.7 TeV.
- String resonance is shown at 1 TeV.



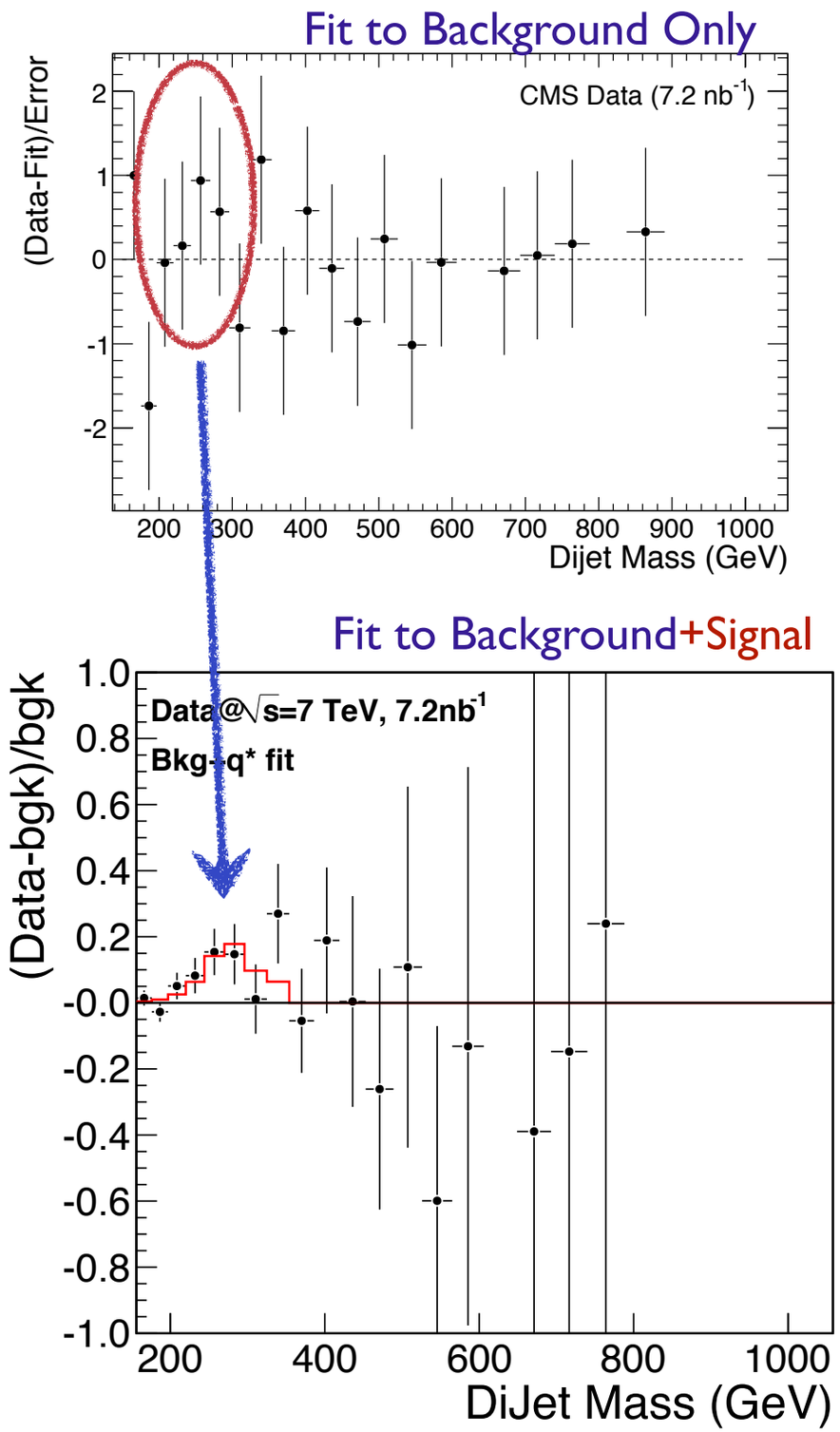




String resonance was added to this plot after June 1 PAS.

The Largest Fluctuation in Data

- Small fluctuation with shape of a resonance near 250 GeV
- Best fit resonance (M_{jj}=270 GeV) has significance only 1.7 sigma from log likelihood ratio.
- Significance reduced to just 0.1 sigma when including "look elsewhere" effect via a toy MC.



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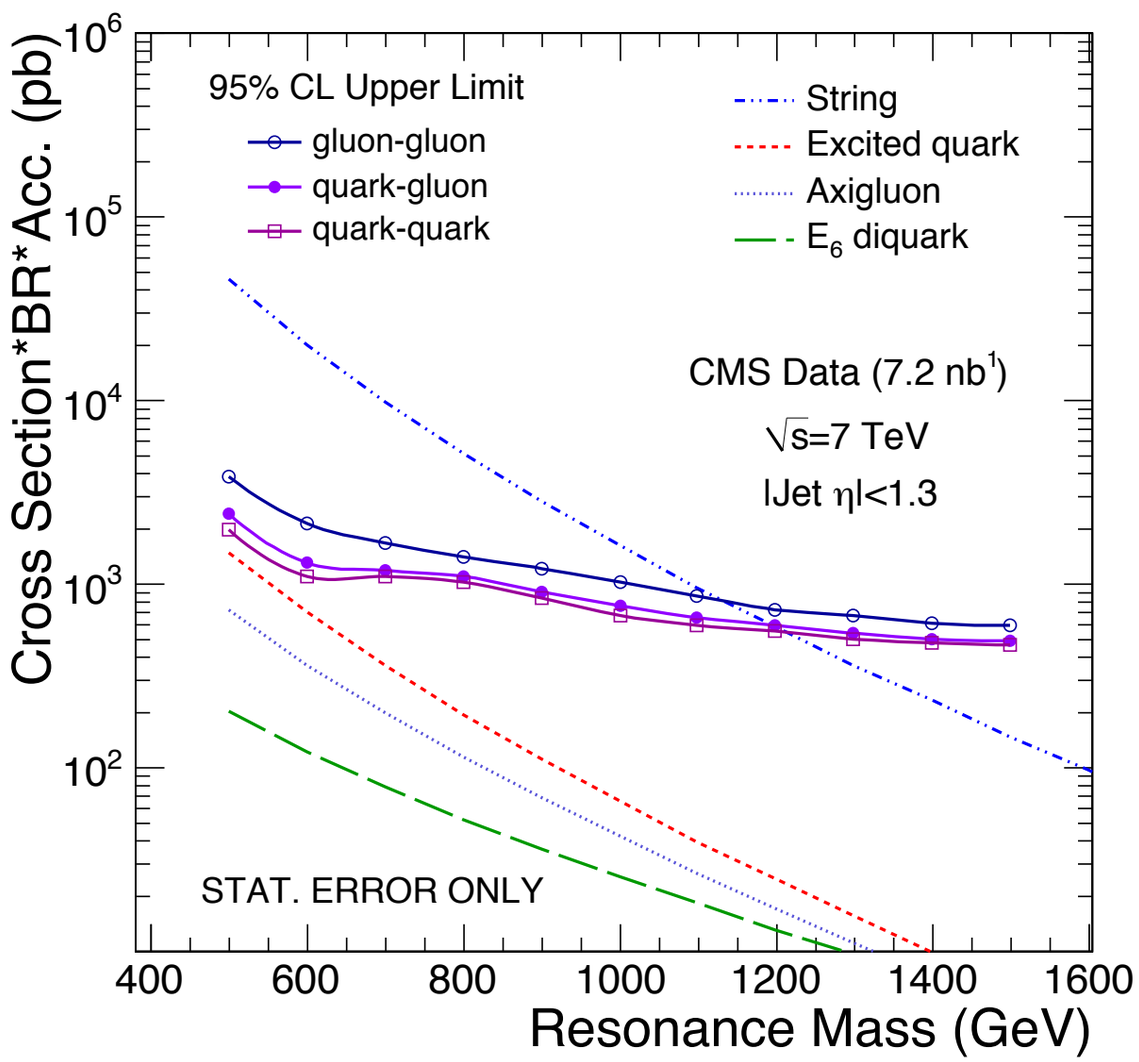
Early Limits with Stat. Error Only

- We use a flat prior to get the posterior probability density and find limit.
- We use a binned likelihood by the Bayesian approach to find limit on new particle cross section.
- 95% CL Upper limit with Stat. Error. Only compared to cross section for various model.
  - ✓ Show quark-quark and quark-gluon and gluon-gluon resonances separately.
  - ✓ gluon-gluon resonance has the lowest response and is the widest and gives worst limit.



	95% CL Upper Limit (pb)		
Mass (TeV)	quark-quark	quark-gluon	gluon-gluon
0.5	1984	2375	3815
0.6	1085	1291	2113
0.7	1094	1177	1635
0.8	1023	1095	1384
0.9	828	893	1208
1.0	672	749	1015
1.1	591	647	856
1.2	542	588	723
1.3	503	535	671
1.4	473	503	612
1.5	458	480	593

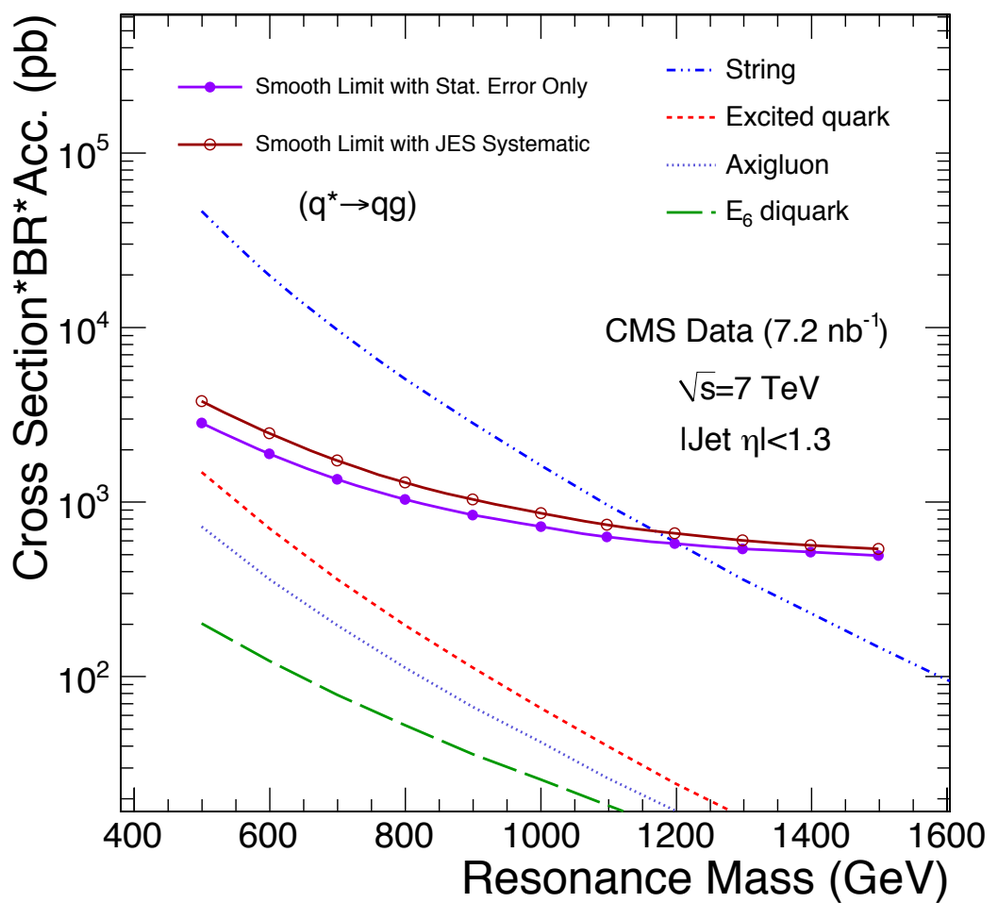
Systematics

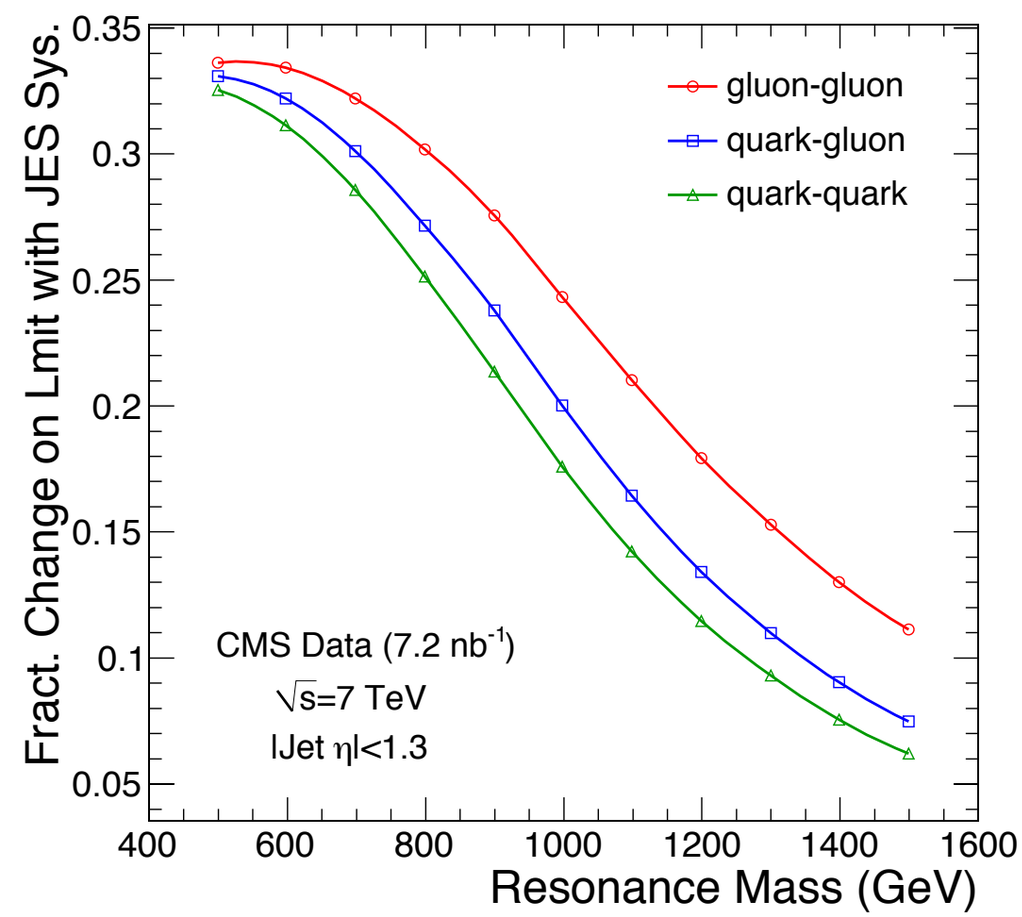
- We found the uncertainty in dijet resonance cross section from following sources.

  - ✓ Jet Energy Scale (JES)
  - ✓ Jet Energy Resolution (JER)
  - ✓ Choice of Background Parametrization
  - ✓ Luminosity

Jet Energy Scale (JES)

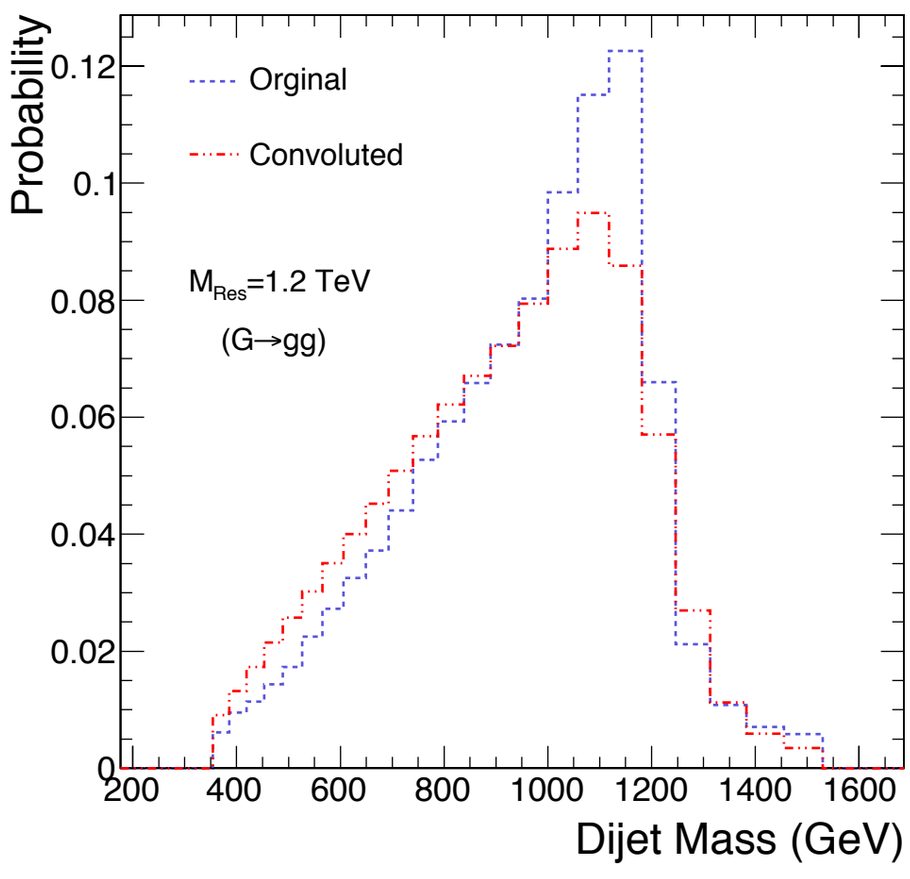
- JetMET guidance is 10% uncertainty in jet energy scale.
  - ✓ Shifting the resonance 10% lower in dijet mass gives more QCD background
  - ✓ Increases the limit between 6% and 34% depending on resonance mass and type.

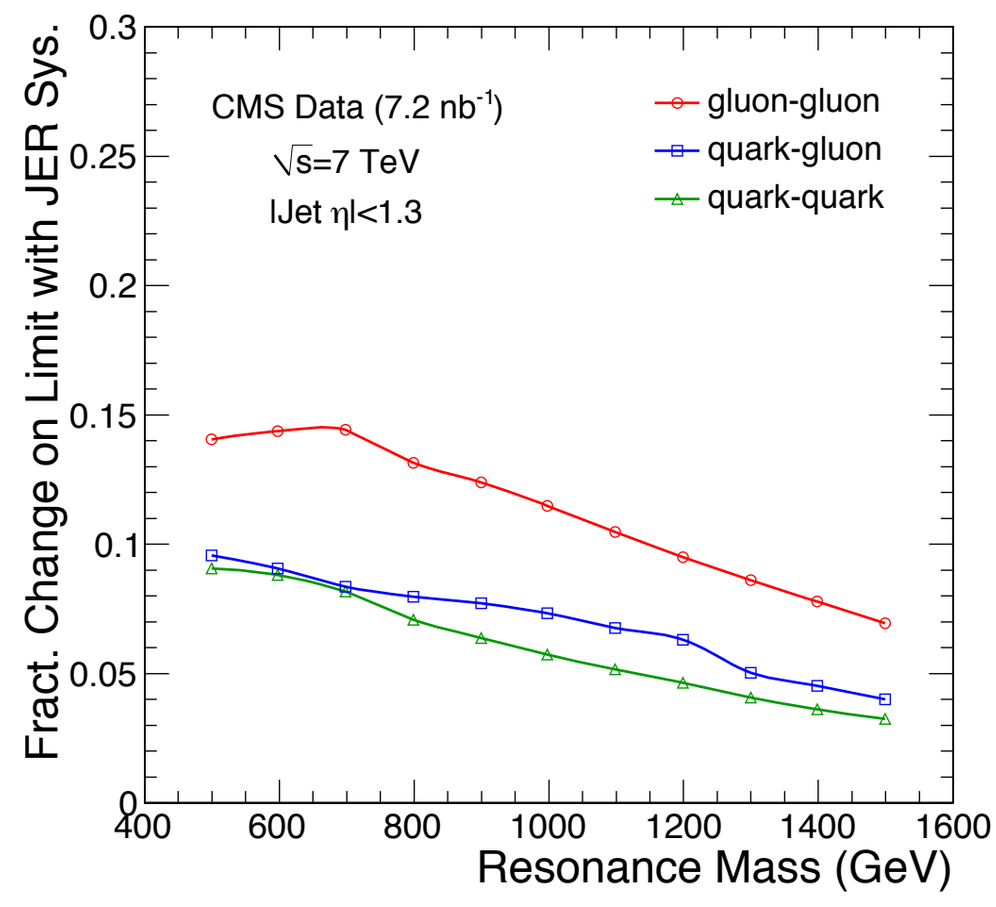




Jet Energy Resolution (JER)

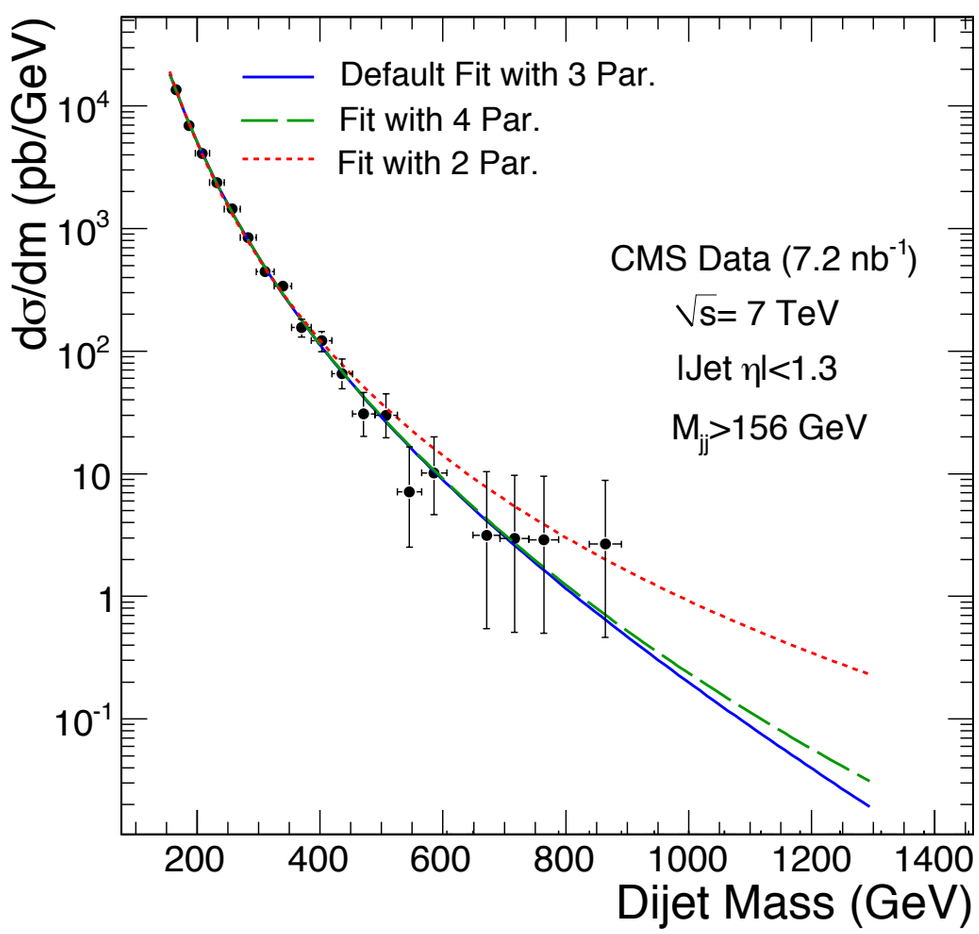
- JetMET guidance is 10% uncertainty in jet energy resolution.
- We smear our resonance shapes with a gaussian designed to increase the core width by 10%.
  - ✓ $\sigma_{Gaus} = \sqrt{\{(1.1)^2-1\}}\,\sigma_{Res}$
- This increases our limit between 3% and 15% depending on resonance mass and type.

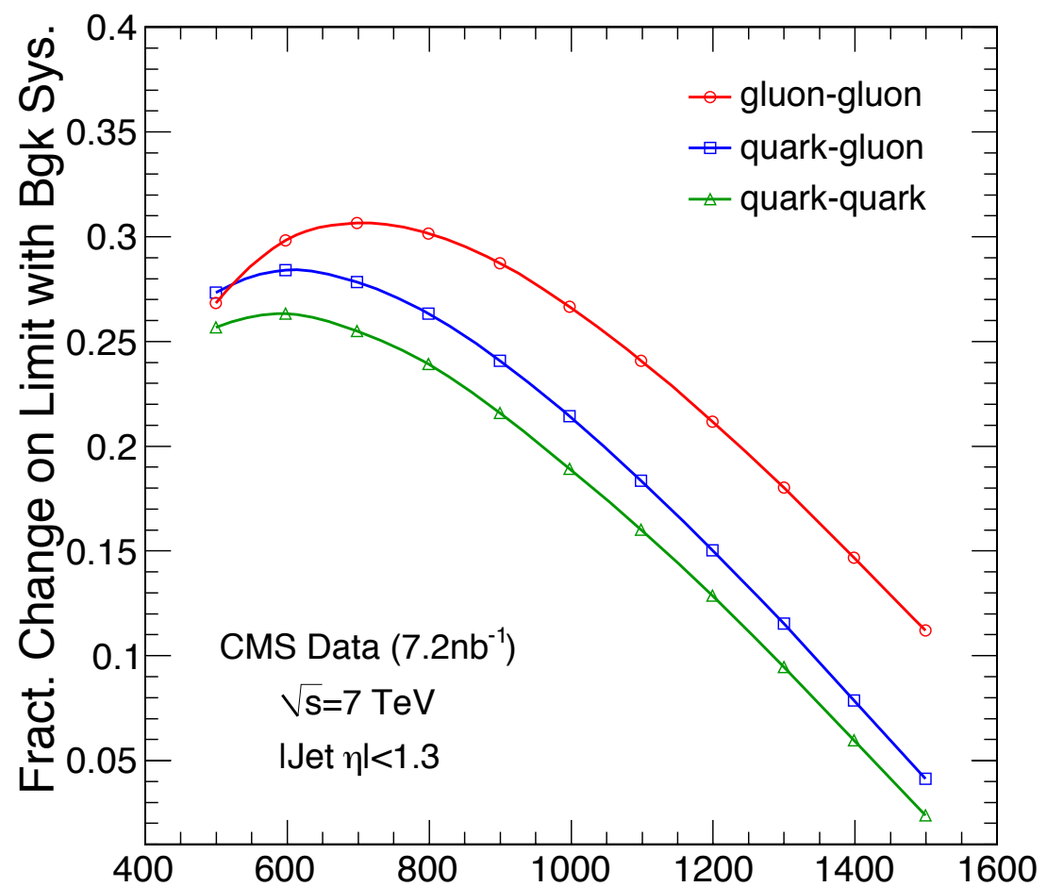




Background Parametrization Systematics

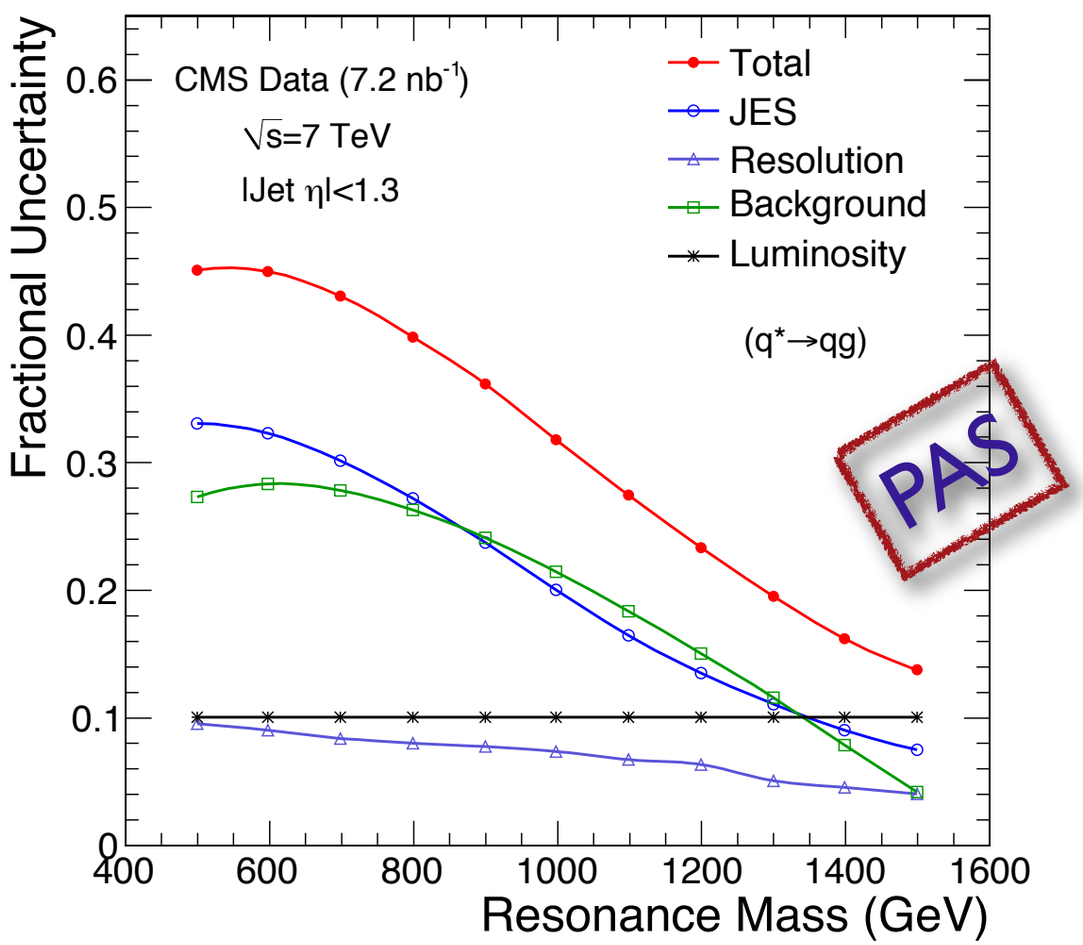
- We have varied the choice of background parametrization
- We use the 2-parameter fit as a conservative systematic on our background shape.
- This increases our limit between 2% and 31% depending on resonance mass and type.

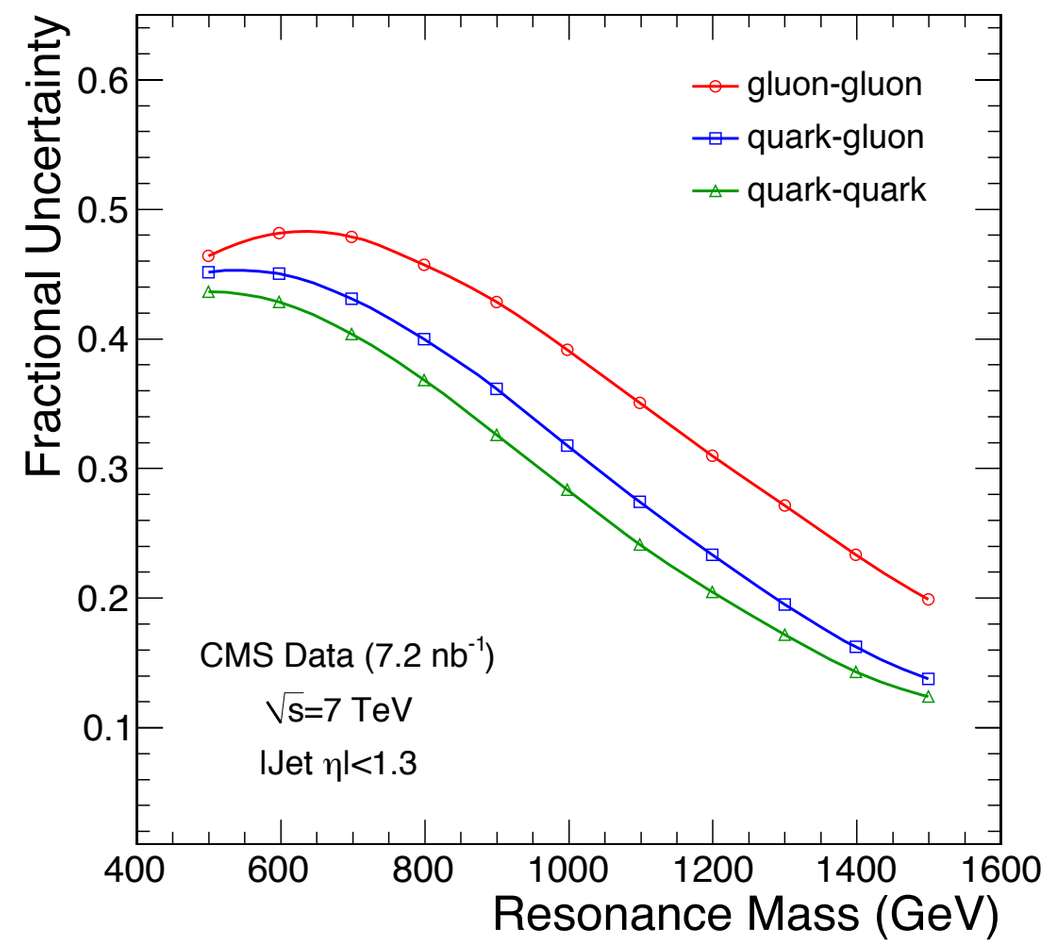




Total Systematic Uncertainties

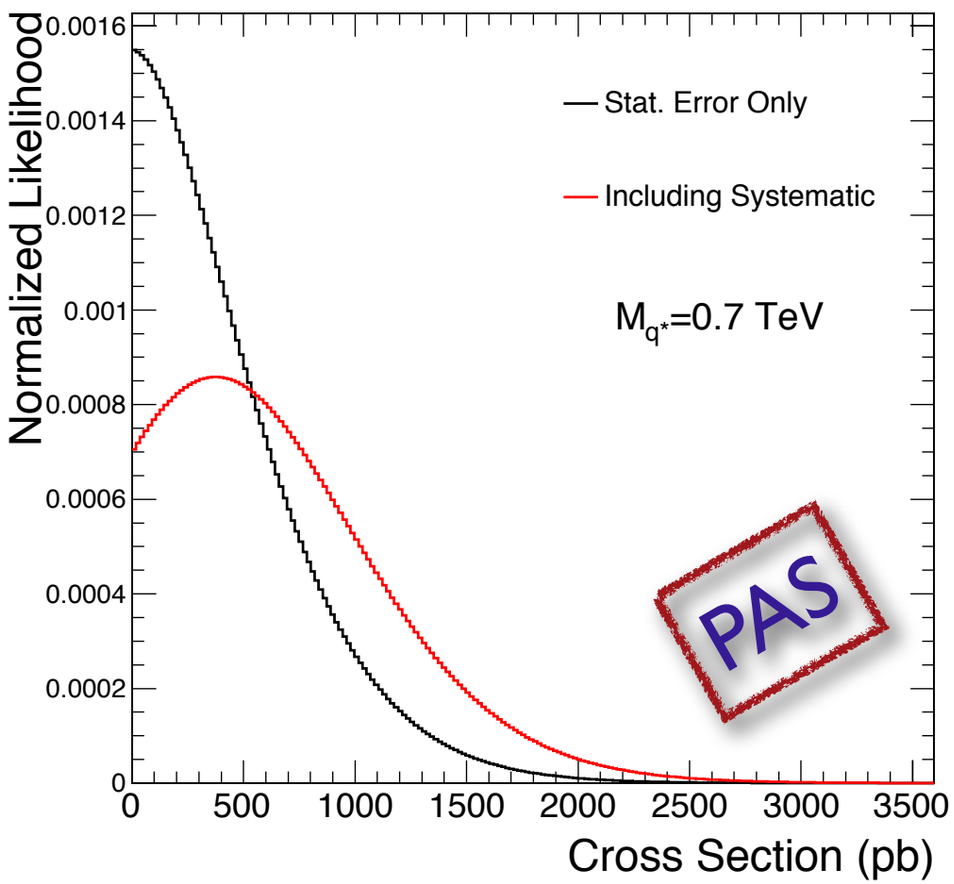
- We add all mentioned systematic uncertainties in quadrature, also 10% for luminosity.
- Total systematic uncertainty varies from 12% to 48% depending on resonance mass and type.





Likelihoods with Systematics

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



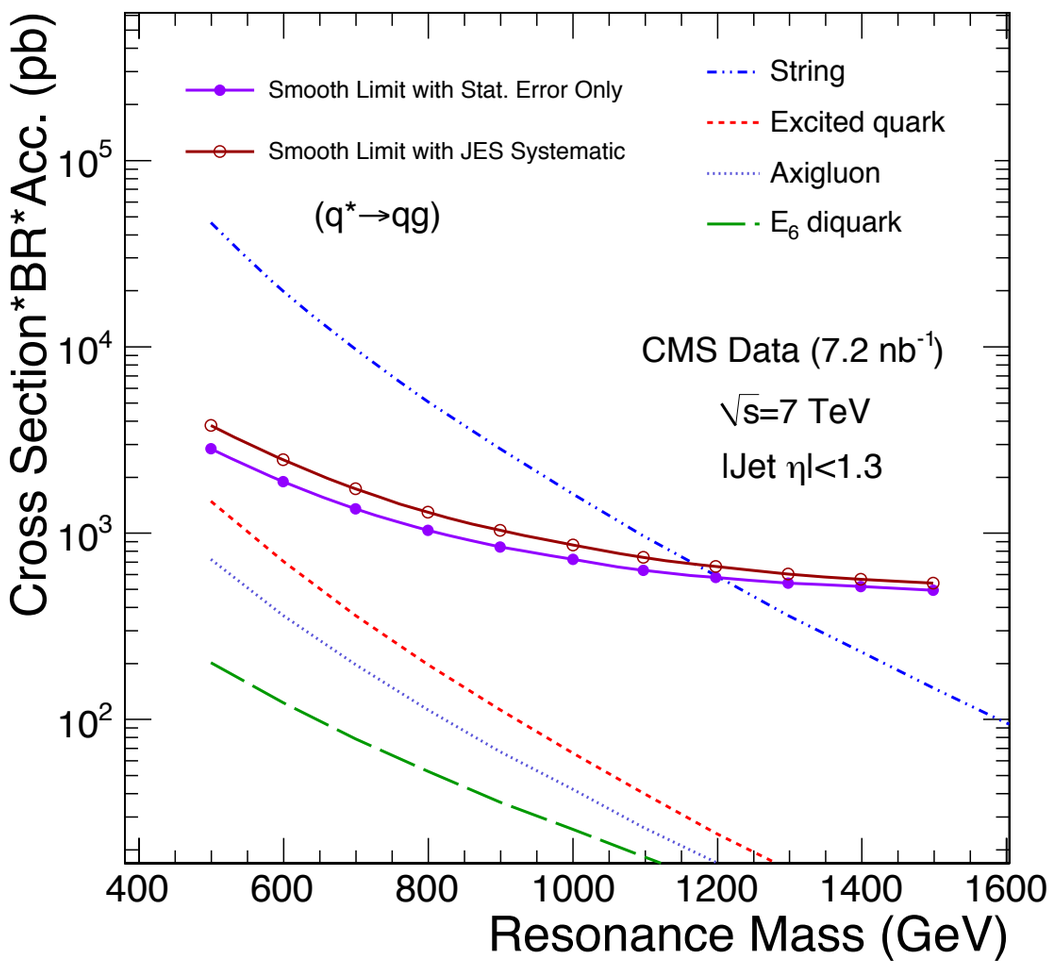
$$L(\sigma) = \int_0^\infty L(\sigma')G(\sigma,\sigma')d\sigma'$$

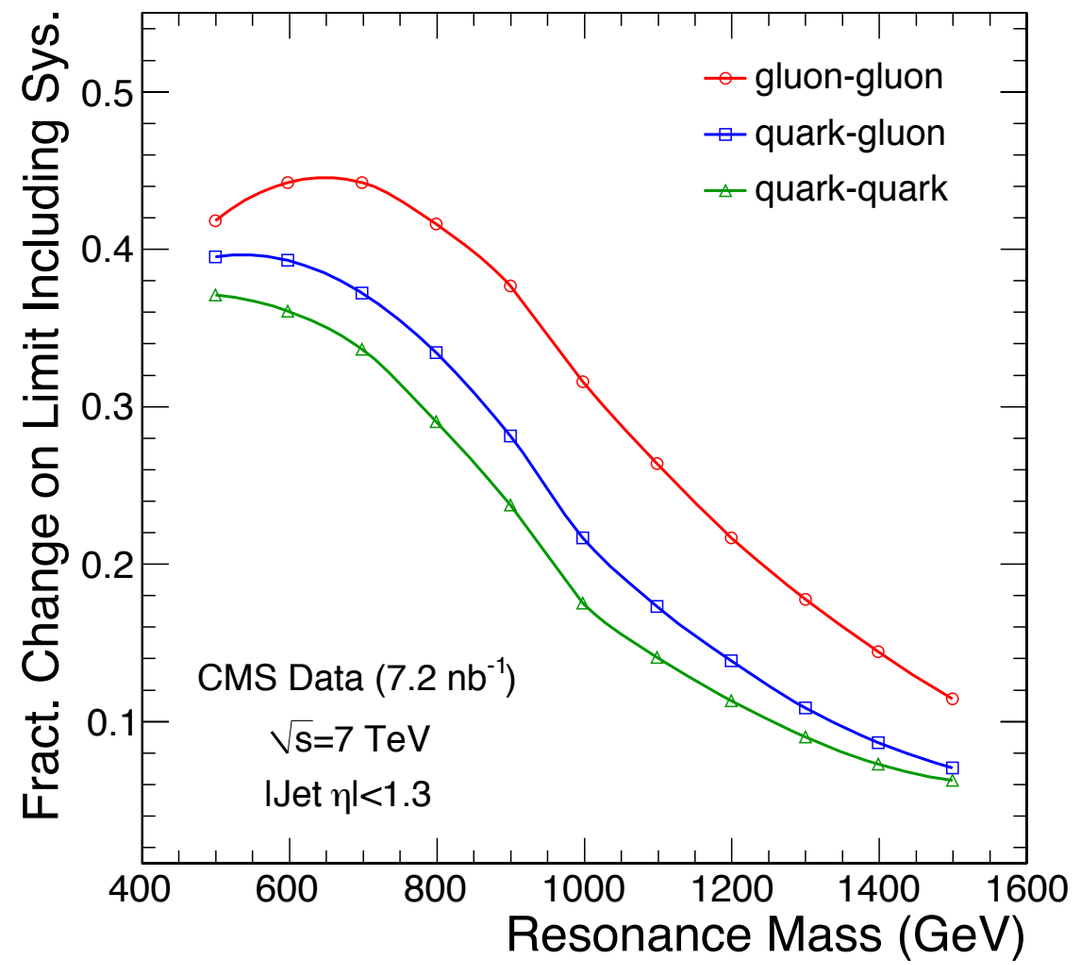
G: Gaussian distribution with RMS width equal to systematic uncertainty in cross section

* Posterior probability density assuming a flat prior in cross section

Effect of Systematics on Limit

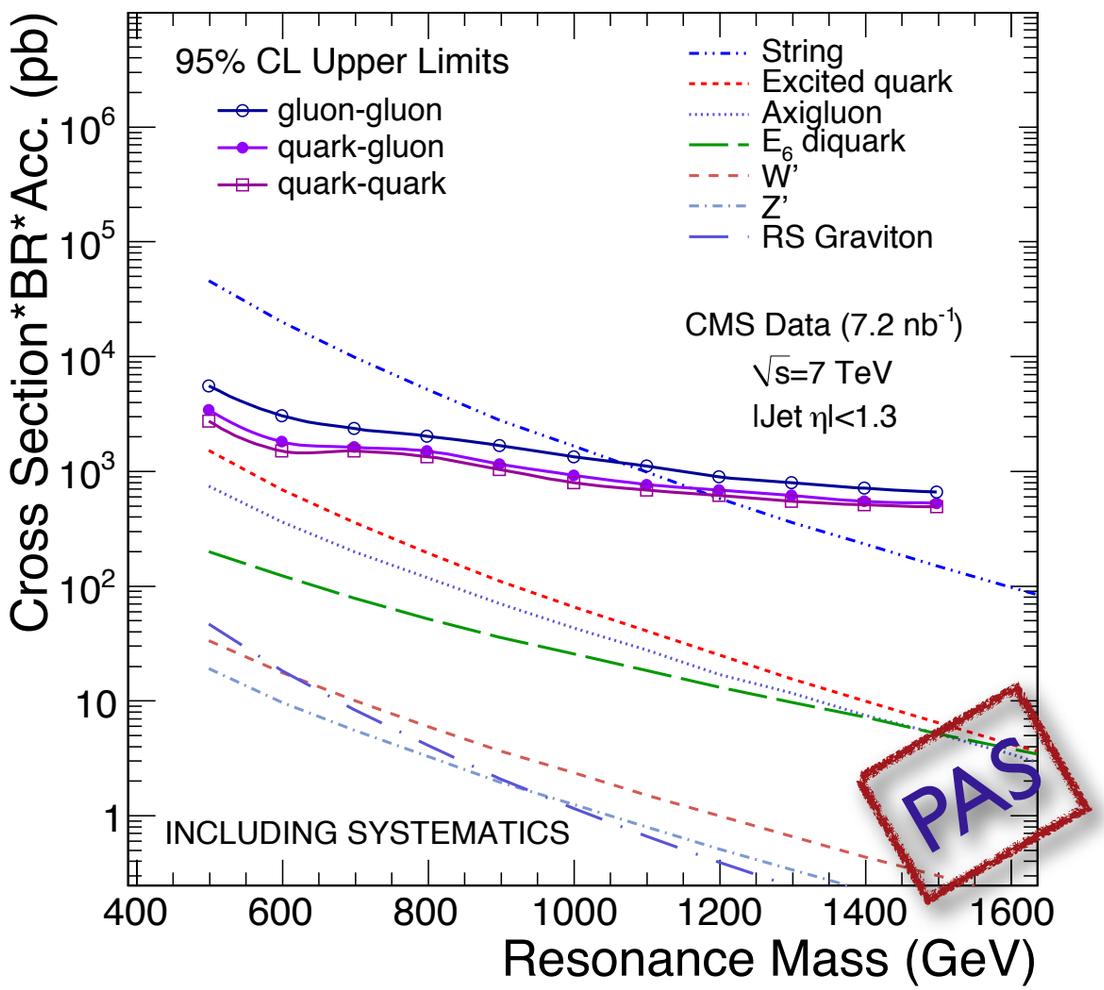
- 95% CL Upper limit with Stat. Error. Only and Including Sys. Uncertainties are shown separately
- Systematics are more significant at low mass where there is data.





Results

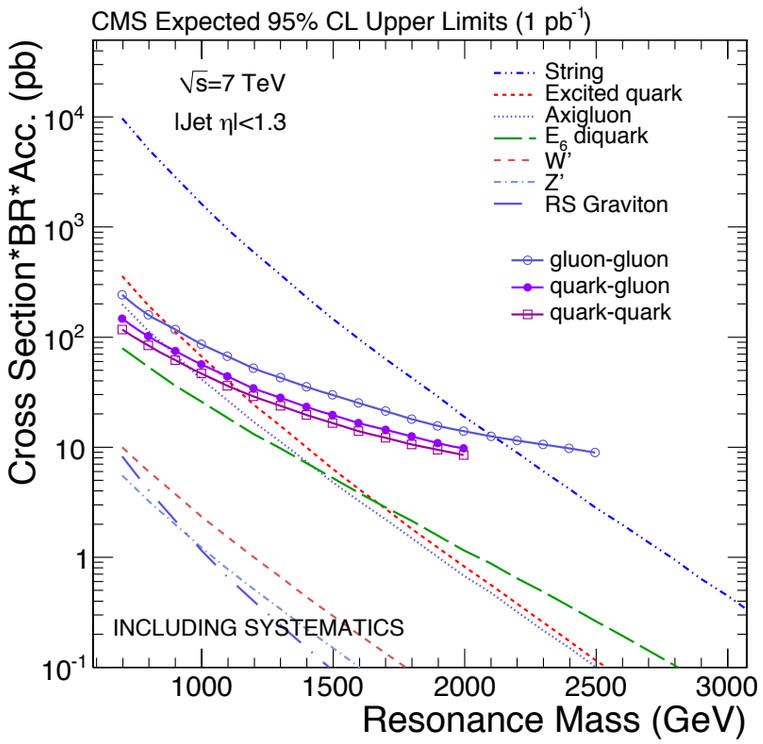
- The generic upper limits are compared to cross section upper limits for 7 resonance models.
- The limit for quark-quark, quark-gluon and gluon-gluon resonances are shown separately in the data with 7.2 nb-1.
- We excluded string resonances of mass M<1.0 TeV at 95% CL.

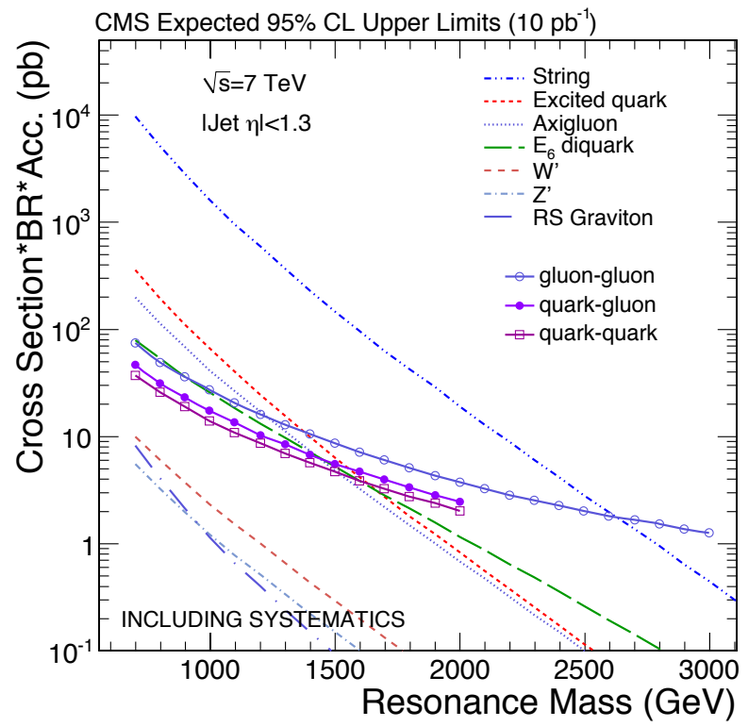


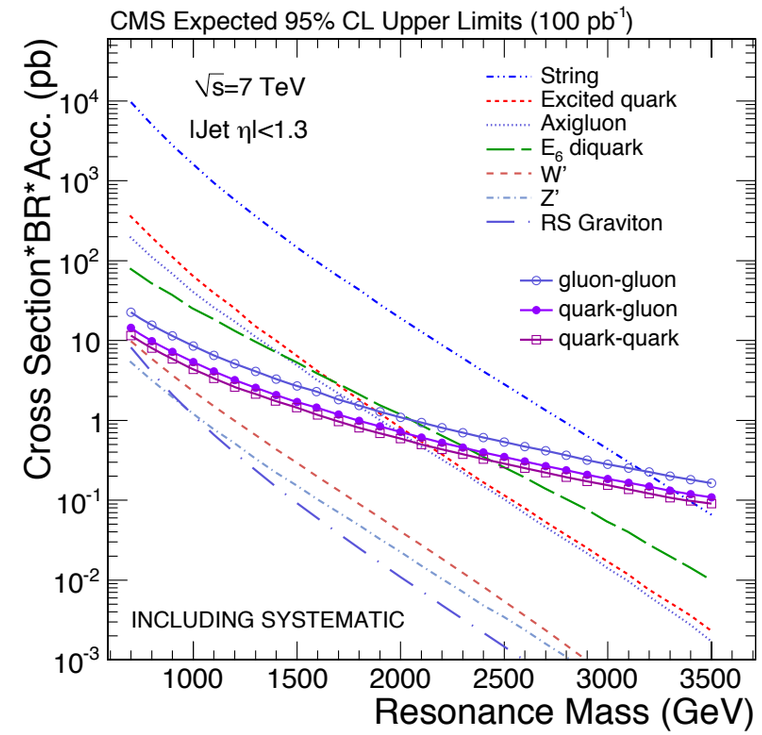
	95% CL Upper Limit (pb)		
Mass (TeV)	quark-quark	quark-gluon	gluon-gluon
0.5	2719	3312	5410
0.6	1476	1797	3047
0.7	1462	1615	2357
0.8	1320	1460	1959
0.9	1024	1144	1662
1.0	790	911	1335
1.1	674	759	1081
1.2	603	669	880
1.3	548	593	790
1.4	508	546	700
1.5	487	514	660

W', Z' and RSG were added to this plot after June1 PAS

Expected Future Limits

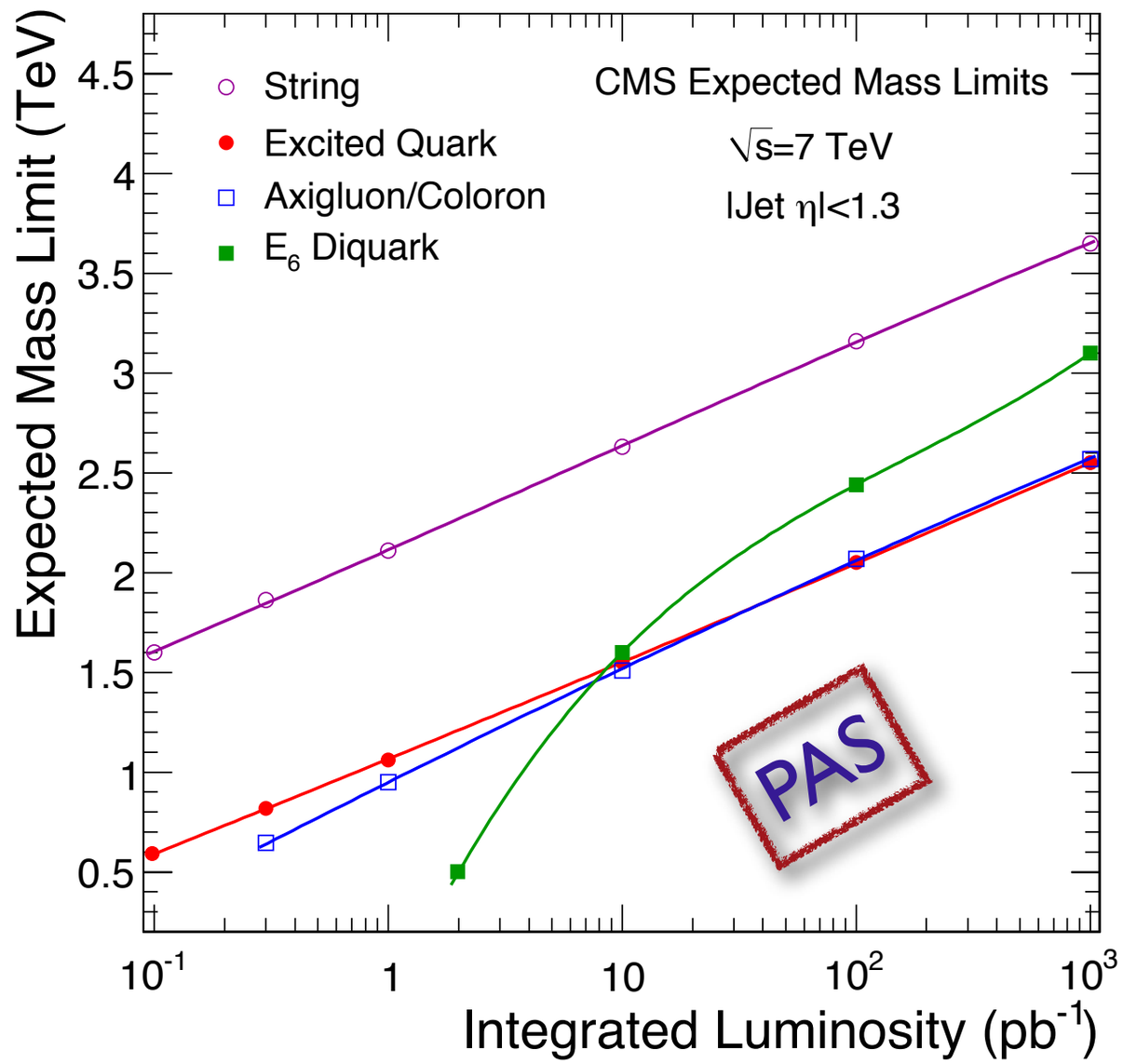






95% C.L. Excluded Mass (TeV)							
Model	CMS (Expected at 7TeV)						CDF (Excluded at1.96 TeV)
	0.1 pb^{-1}	0.3 pb^{-1}	1 pb^{-1}	10 pb^{-1}	100 pb^{-1}	1 fb^{-1}	1 fb^{-1}
String	1.60	1.85	2.10	2.60	3.15	3.65	N/A
Excited quark	0.59	0.82	1.06	1.55	2.05	2.55	M<0.87
Axigluon/ Coloron	N/A	0.64	0.95	1.51	2.07	2.57	M<1.25
E6 Diquark	N/A	N/A	N/A	1.60	2.44	3.1	M<0.63

Expected Mass Limit



String resonance was added to this plot after June 1 PAS.

- We expect to reach the Tevatron q* mass limit of 0.87 TeV with 400 nb^{-1}.

Conclusion

- We have a dijet mass spectrum that extends to 850 GeV with ~7.2 nb^{-1} data.
- The dijet mass data is in good agreement with a full CMS simulation of QCD from PYTHIA.
- The data is well fit by a simple parametrization with three parameters
- We have limits on dijet resonance cross section including systematics.
- We exclude String Resonances with mass M<1.0 TeV at 95% CL.
- Expected limits indicate we should reach the Tevatron q* limit of 870 GeV with 400 nb^{-1}.
- We seek pre-approval of this analysis documented in AN 2010/108 and PAS EXO-10-001.

Back-Up Slides

Setting Limits

- To calculate limit on new particle cross section we use a binned likelihood by the Bayesian approach.

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

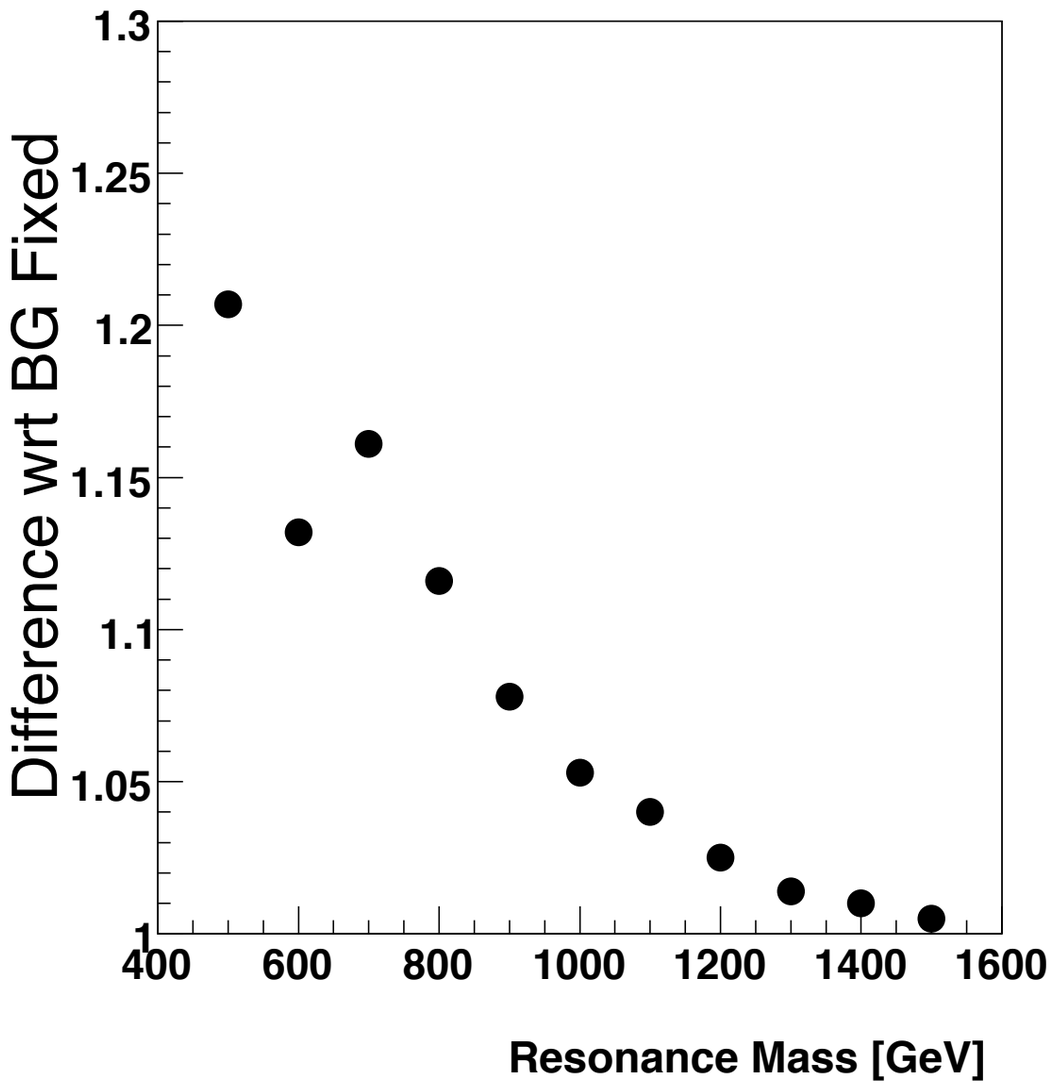
Measured # of events in data

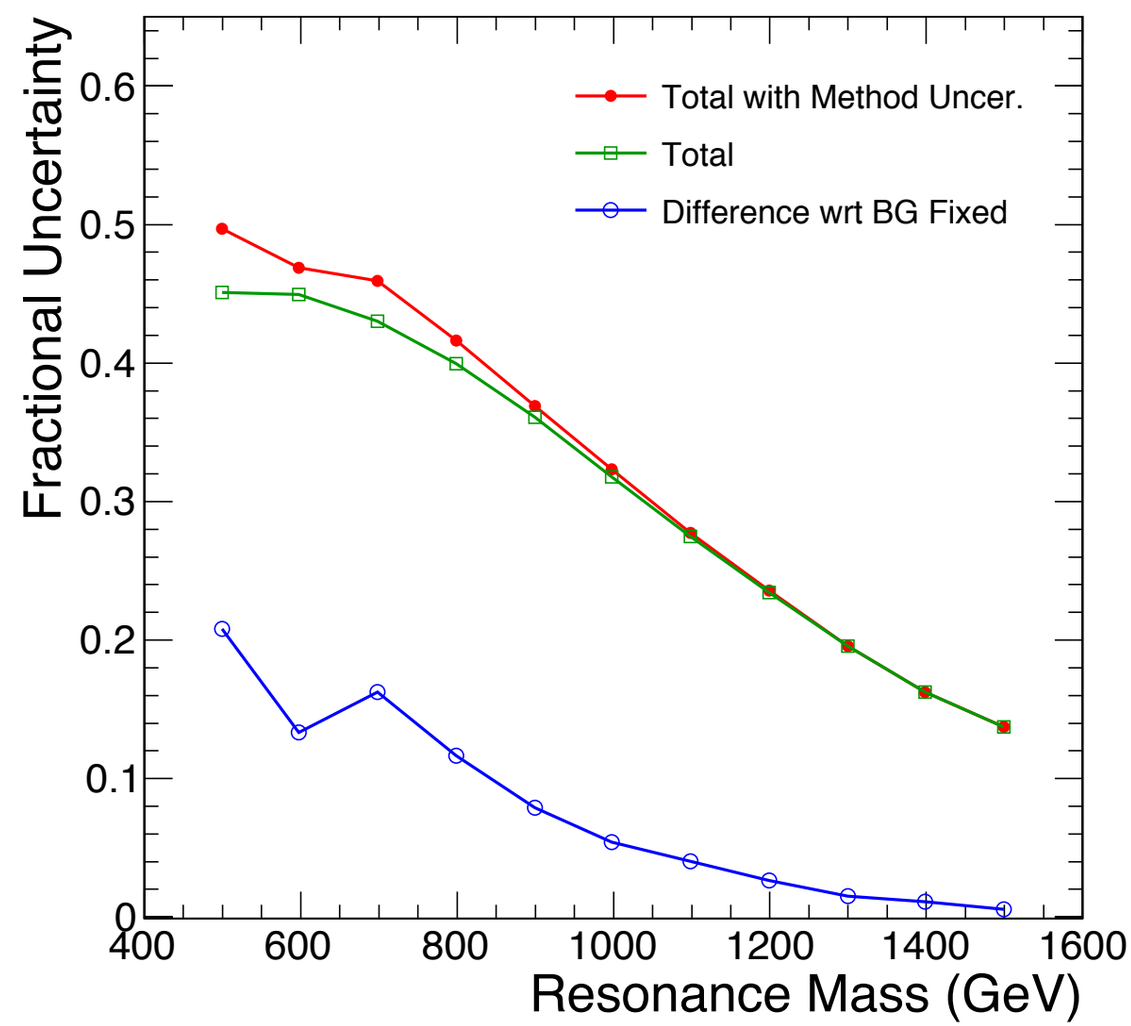
# of event from signal

Expected # of event from background

- The signal comes from our dijet resonance shapes.
- The background comes from Background+Signal fit.

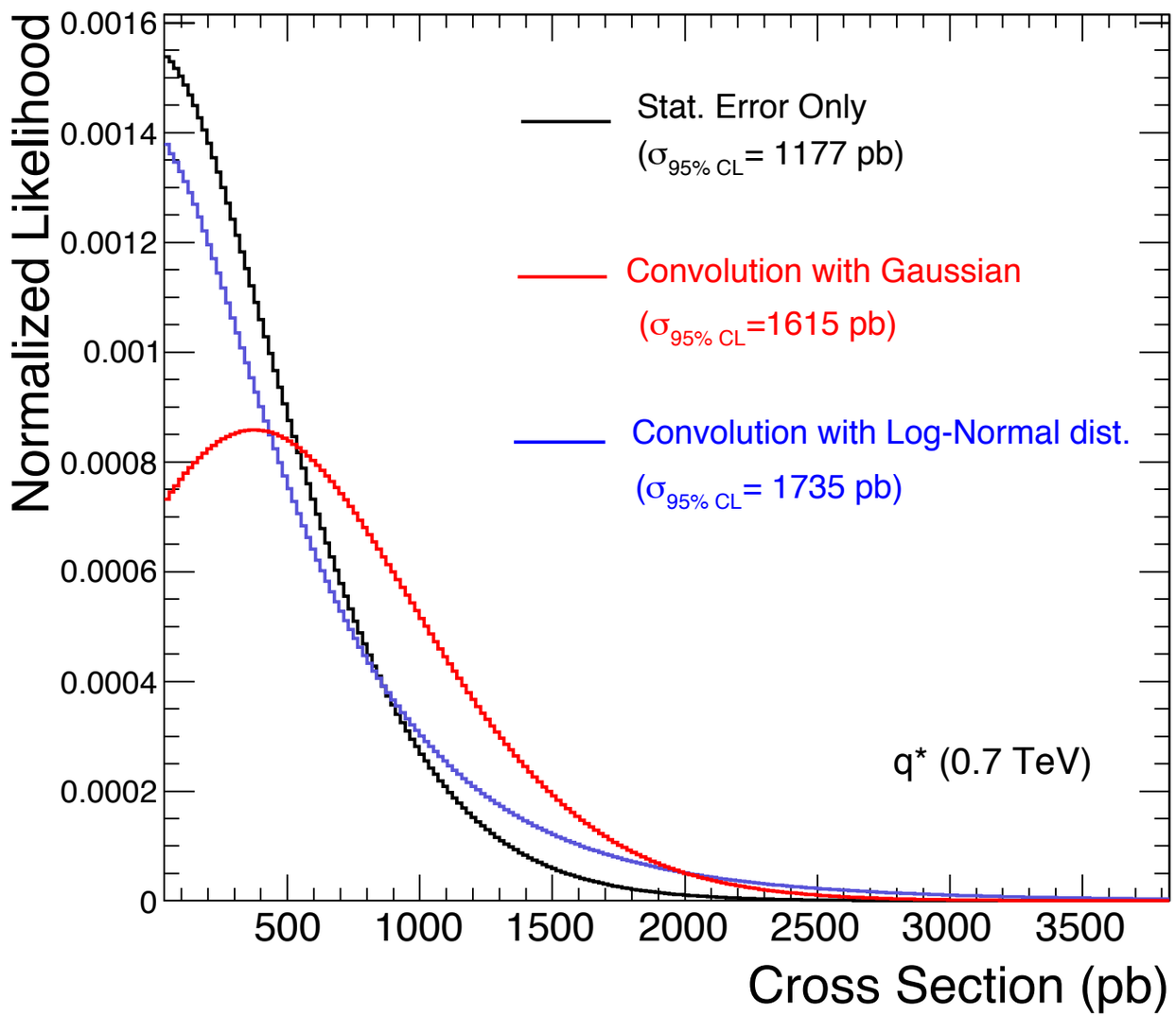
Profile Likelihood

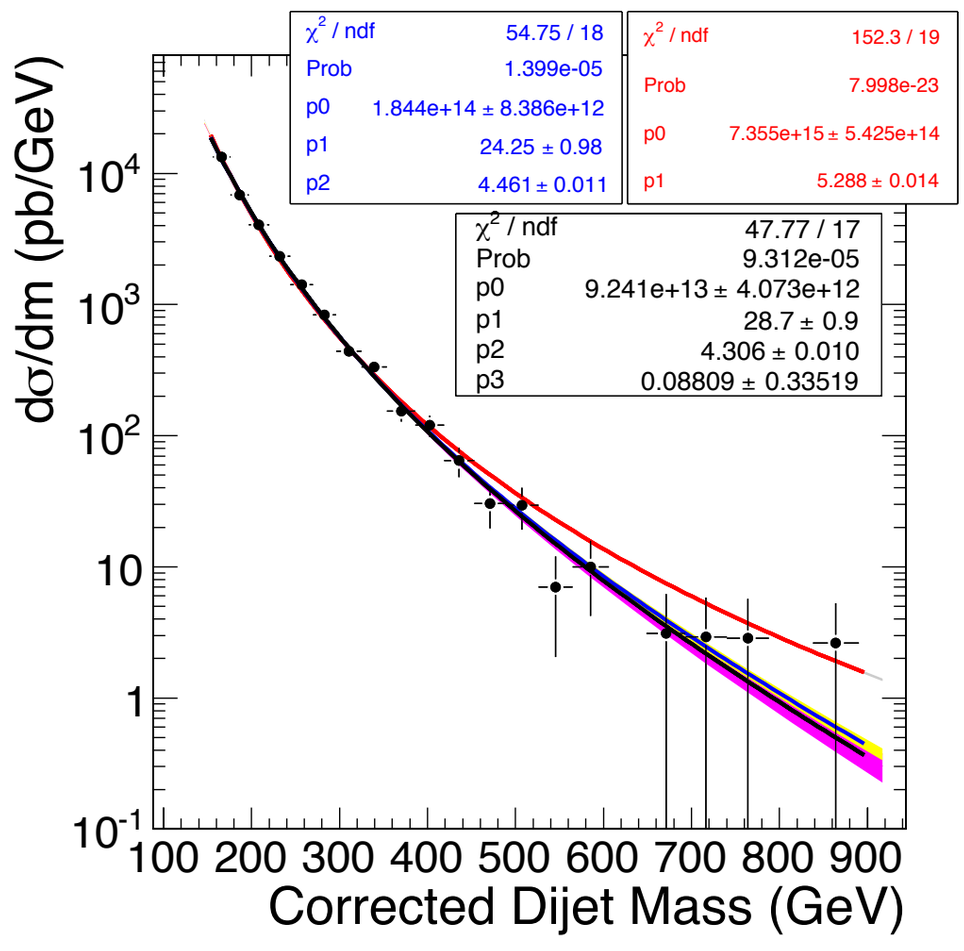
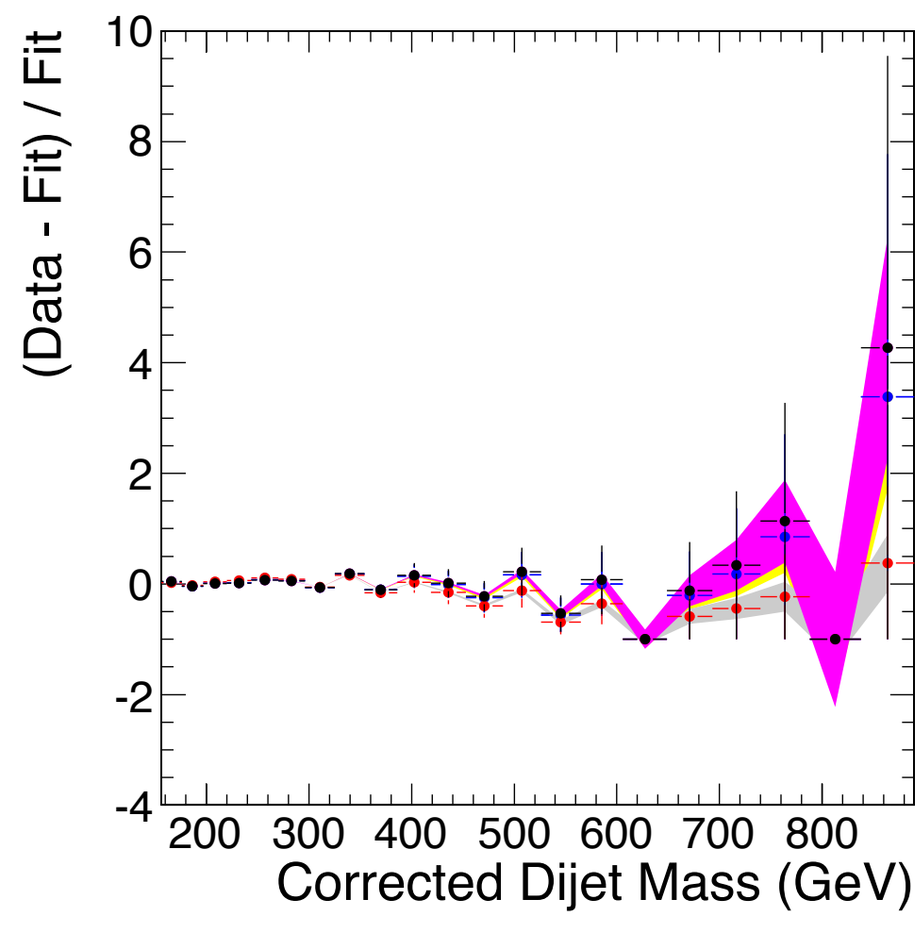




Changes in the 95% CL upper limits on the qg resonance cross section as a function of resonance masses when the profile likelihood is used, compared to the case in which the background parameters are fixed at the best Signal + background fit.

Nuisance Parameter



Background Fit Uncertainties

- We have studied fitting the data using 2,3 and 4 parameters.
- The fit functions with 1 sigma statistical error band are shown.
  - ✓ 2 parameters gives a marginal fit with noticeable sinusoidal variations.
  - ✓ 3 parameter is a good fit to data, we used it as our default.
- 2 and 4 parameter fit are considered as background systematic .
  - ✓ 2 parameter fit gives higher systematic and covers 4 parameter fit.