The Dijet Ratio at 10 TeV with 10 Inverse Picobarns of Integrated Luminosity at CMS

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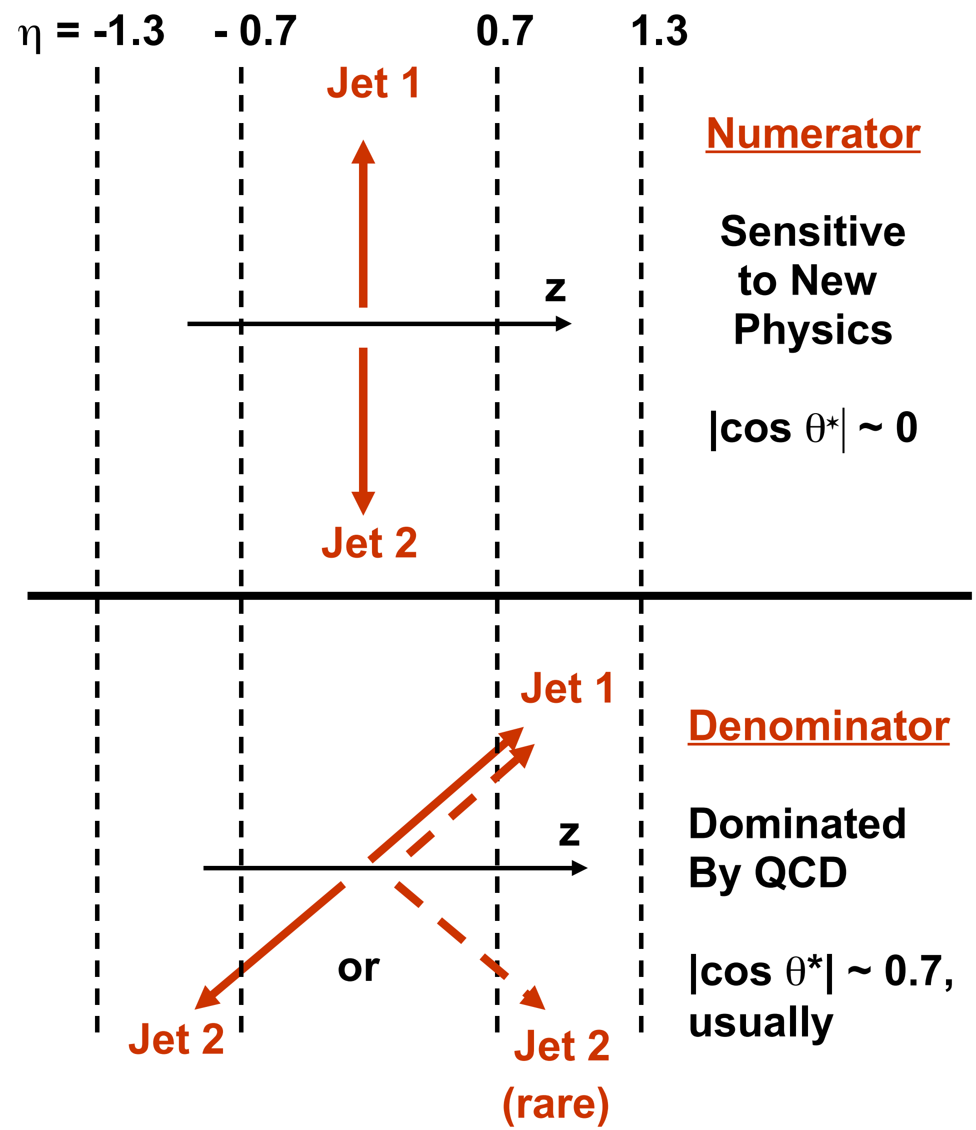
General Motivation

- A dijet is a collision event with at least two energetic jets
- The dijet signal is vastly dominated by quantum chromodynamic (QCD) processes predicted by the Standard Model
- New physics beyond the standard model often produces more isotropic (central) angular distributions than Standard Model QCD predictions
  - SM QCD test at lower masses, new physics signals at higher masses
- We desire a simple measurement sensitive to the dijet angular distribution
- Here we give an overview of an early paper draft on such a measurement, the dijet ratio (CMS AN-2009/114)

Definition

- We define an inner ($|\eta| < 0.7$) and outer ($0.7 < |\eta| < 1.3$) region in the barrel (where η is pseudorapidity)
  - restrict to barrel because this is a well-understood region of the detector with smooth and slowly varying jet energy corrections
- Both leading jets must pass regional selection
- Dijet Ratio = $N(|\eta| < 0.7) / N(0.7 < |\eta| < 1.3)$



Specific Motivation (1)

- Benefits of dijet ratio measurement technique:
  - simple and appropriate for early data analysis
  - uses natural detector variable η
    - CMS has good understanding of jet energy scale in η via dijet balance
  - many systematic uncertainties cancel in the ratio

Specific Motivation (2)

- The dijet ratio (as a function of dijet invariant mass) is sensitive to:
  - deviations from SM QCD predictions
    - even at low experimental statistics
  - resonances
    - show up as peaks
    - peak value is correlated with spin of intermediate state
  - contact interactions
    - show up as steady rise as function of mass
  - other unexpected new physics?

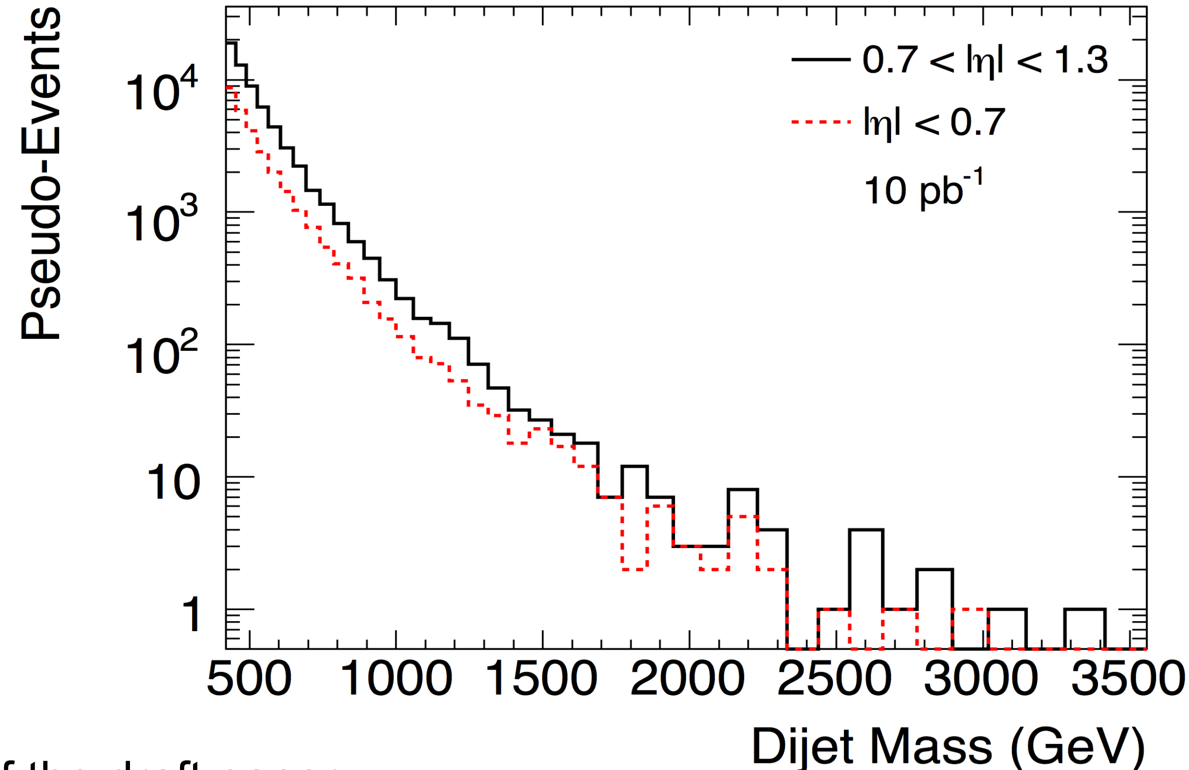
Analysis

- Jet clustering with SIScone R = 0.7
- Jet corrections applied as functions of η (L2) and pT (L3)
- Select 2 leading jets (dijet)
- Plan to remove “unphysical” (i.e. instrumental, cosmic, beam halo) backgrounds by requiring MET/SumEt < 0.3
  - 99% efficient for SM QCD, resonances and contact interactions at high mass (PAS-SBM-07-001)
- Ratio measured in same mass bins as dijet mass analysis
  - bin width roughly equal to dijet mass resolution
- Initially measure only m > ~0.4 TeV, where unprescaled jet trigger (HLT_Jet110) is fully efficient

Status of Analysis

- Starting with “Summer08 QCD” samples (PYTHIA-produced), generate smooth fits to inner and outer mass spectra
- Generated pseudo-dataset of arbitrary size
  - normalize smooth fits to appropriate statistics (in this case to 10 inverse picobarns)
  - Poisson-smear count per mass bin
- Evaluate mass spectra and dijet ratio for pseudo-data, and compare to smooth PYTHIA QCD and NLO QCD theory
- Currently working on setting confidence limits for BSM signals
  - Z', RS graviton, q*, contact interactions

Mass Spectra

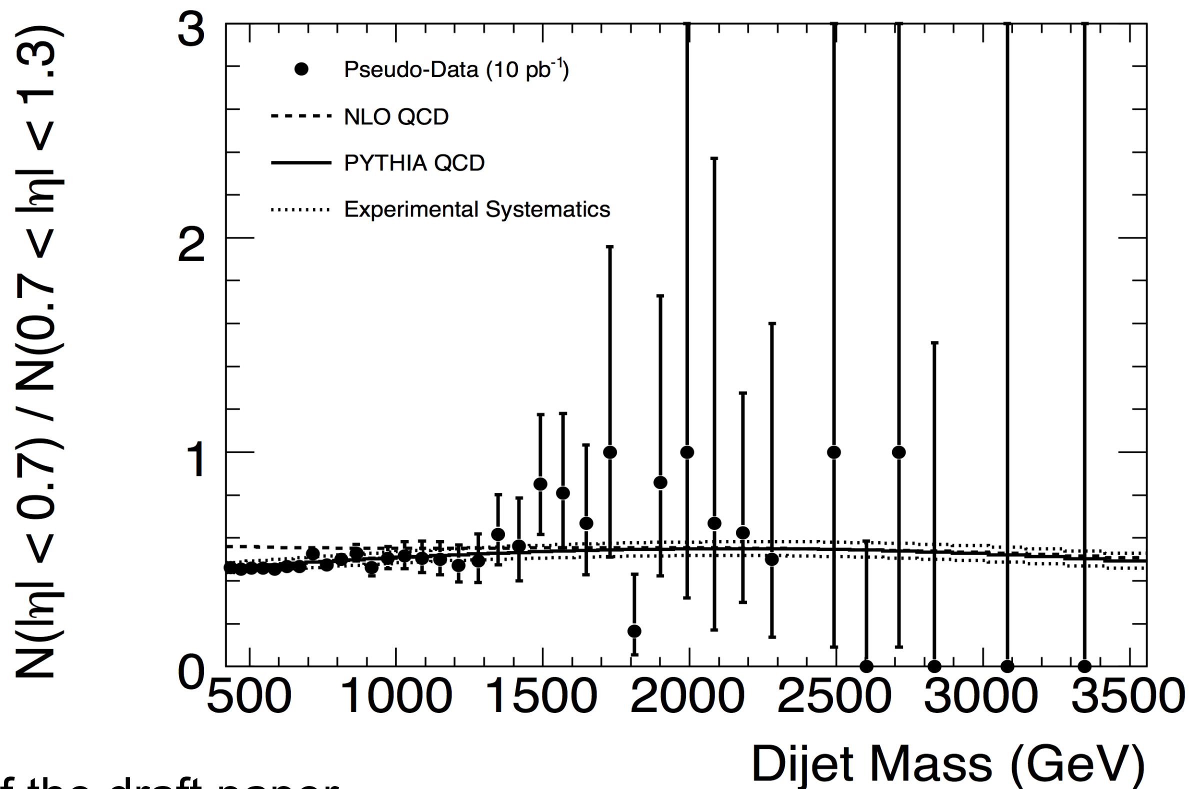


- Figure 1 of the draft paper
- Shows numerator and denominator of measured dijet ratio

Statistical Errors on the Dijet Ratio

- Not just a counting exercise – requires unusual tools
- Distributed (per mass bin) as ratio of two Poisson distributions
- Clopper-Pearson intervals provide a practical conservative tool for evaluating statistical errors in this case
  - references:
    - R. D. Cousins, K. E. Hymes, J. Tucker, arXiv:0905.3831v1 (2009)
    - C. J. Clopper and E. S. Pearson, Biometrika, Vol. 26, No. 4., pp. 404-413 (1934)

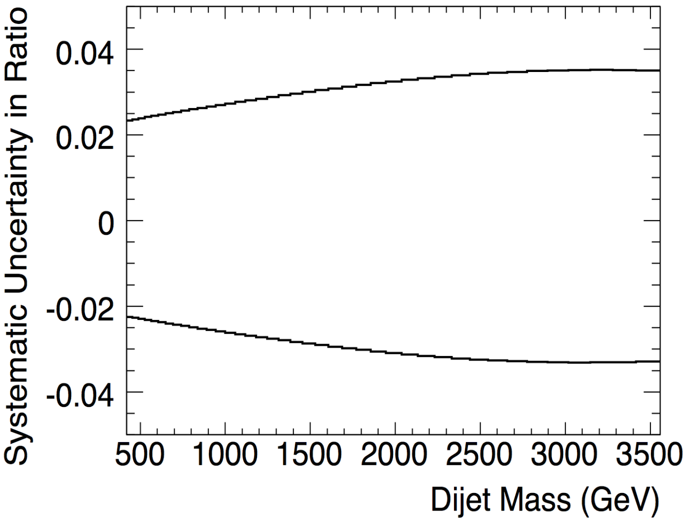
Dijet Ratio



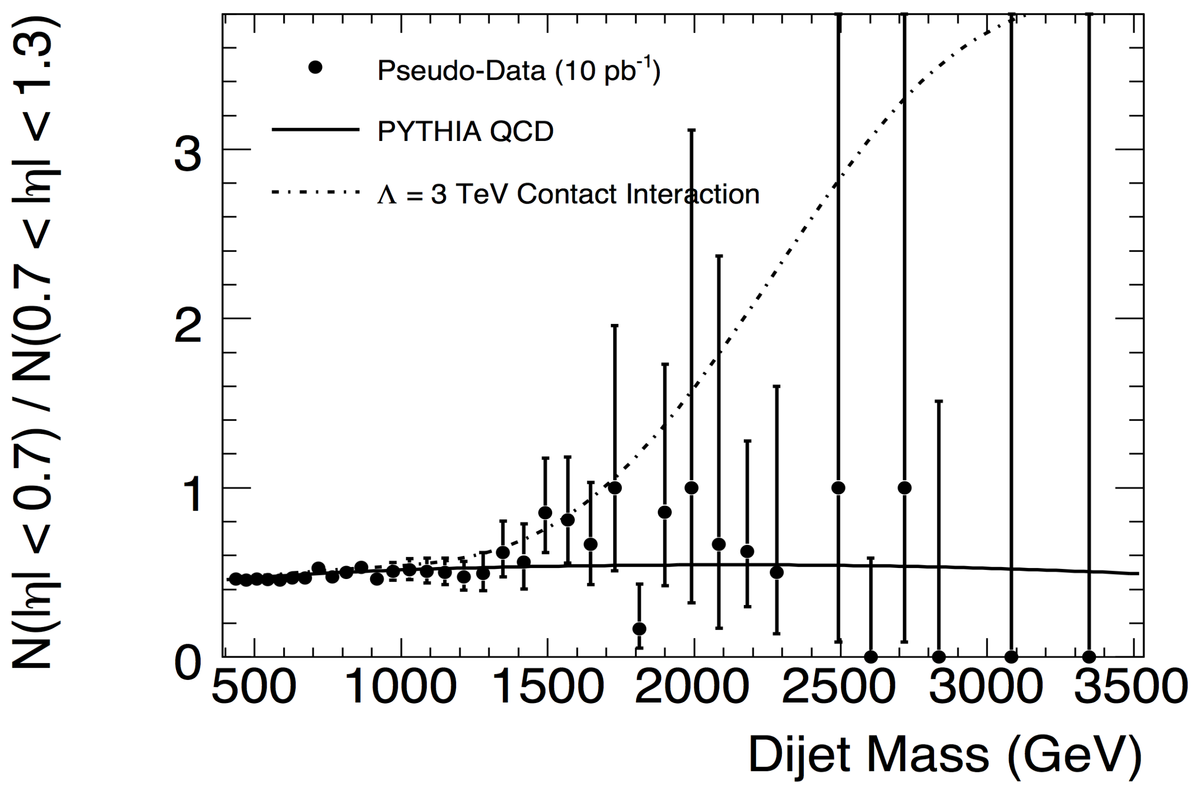
- Figure 2 of the draft paper
- Pseudo-data agrees with QCD within experimental uncertainties and theory variations (by construction)
- Systematics smaller than statistical errors for m > ~700 GeV

Systematic Uncertainties on the Dijet Ratio

- ~1% uncertainty in relative jet energy scale between barrel regions
  - from dijet balance studies (PAS JME-08-003)
  - shifting spectrum of ratio denominator by 1% in mass causes shift in the dijet ratio between .02 at 400 GeV and .04 at 3500 GeV



New Physics Example



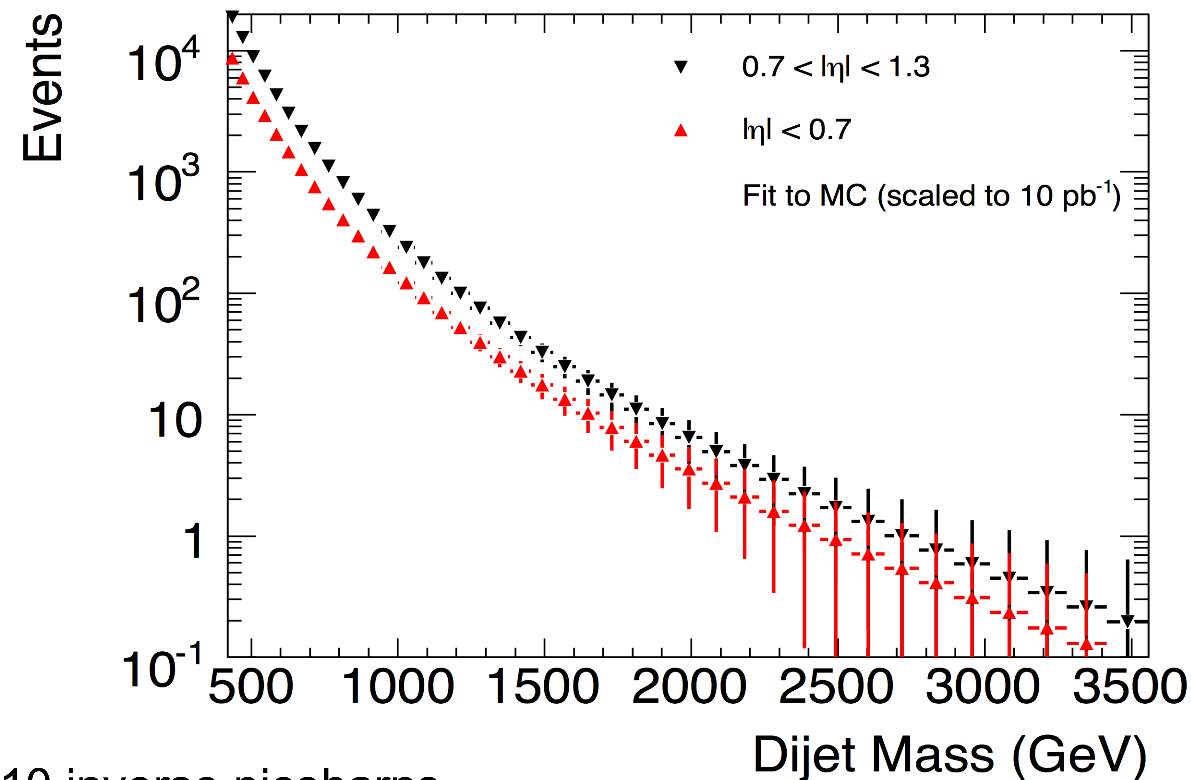
- QCD pseudo-data with 3 TeV contact interaction + QCD curves overlaid
- Qualitative demonstration of sensitivity to such new physics

Summary

- The dijet ratio provides a rugged observable with low systematics that is ideal for searching for new physics in early data
- We have simulated 10 inverse picobarns worth of standard model data and compared it with QCD predictions, producing example figures appropriate for an early paper
- Preliminary draft of early paper released (CMS AN-2009/114)
- We are in the process of evaluating sensitivities to new physics including (but not limited to) resonances and contact interactions

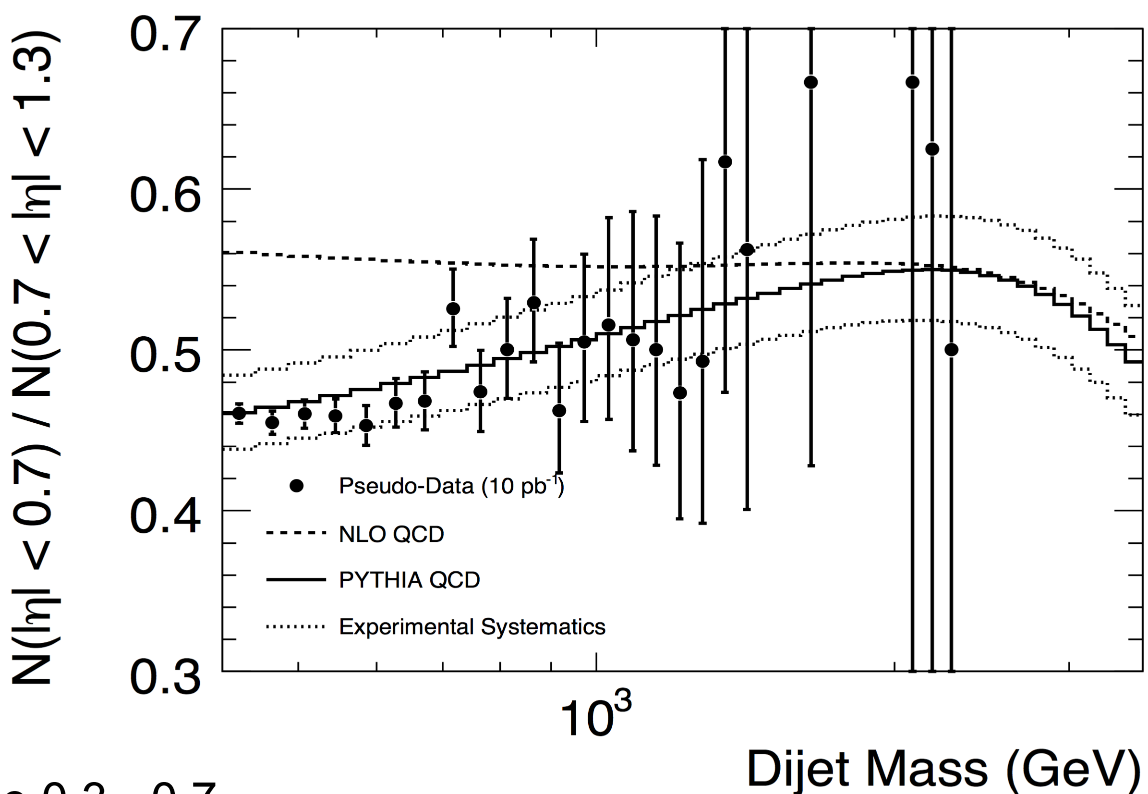
Backup Slides

Mass Spectra Fit to MC



- Scaled to 10 inverse picobarns
- With default ROOT errors

Dijet Ratio Closeup



- Ratio range 0.3 - 0.7
- Log scale on X-axis (dijet mass)

Event Table

mass range (GeV)	ratio	+ error	- error
419 - 453	8713 / 18918 = 0.461	0.00604	0.00596
453 - 489	5876 / 12923 = 0.455	0.00727	0.00715
489 - 526	4126 / 8967 = 0.460	0.00882	0.00866
526 - 565	2863 / 6238 = 0.459	0.0106	0.0104
565 - 606	2003 / 4422 = 0.453	0.0125	0.0122
606 - 649	1429 / 3061 = 0.467	0.0154	0.0150
649 - 693	1039 / 2220 = 0.468	0.0183	0.0176
693 - 740	767 / 1459 = 0.526	0.0245	0.0234
740 - 788	546 / 1152 = 0.474	0.0259	0.0246
788 - 838	409 / 818 = 0.500	0.0322	0.0302
838 - 890	316 / 597 = 0.529	0.0395	0.0368
890 - 944	208 / 450 = 0.462	0.0422	0.0388
944 - 1000	156 / 309 = 0.505	0.0547	0.0494
1000 - 1058	115 / 223 = 0.516	0.0664	0.0590
1058 - 1118	80 / 158 = 0.506	0.0798	0.0691
1118 - 1181	72 / 144 = 0.500	0.0835	0.0717
1181 - 1246	53 / 112 = 0.473	0.0933	0.0783
1246 - 1313	35 / 71 = 0.493	0.125	0.101
1313 - 1383	29 / 47 = 0.617	0.185	0.143
1383 - 1455	18 / 32 = 0.563	0.224	0.162
1455 - 1530	23 / 27 = 0.852	0.324	0.235
1530 - 1607	17 / 21 = 0.810	0.371	0.255
1607 - 1687	12 / 18 = 0.667	0.366	0.239
1687 - 1770	7 / 7 = 1.00	0.958	0.489
1770 - 1856	2 / 12 = 0.167	0.264	0.113
1856 - 1945	6 / 7 = 0.857	0.872	0.435
1945 - 2037	3 / 3 = 1.00	2.11	0.679
2037 - 2132	2 / 3 = 0.667	1.704	0.494
2132 - 2231	5 / 8 = 0.625	0.652	0.326
2231 - 2332	2 / 4 = 0.500	1.10	0.362
2332 - 2438	0 / 0 = nan	0.00	0.00
2438 - 2546	1 / 1 = 1.00	10.1	0.910
2546 - 2659	0 / 4 = 0.00	0.584	0.00
2659 - 2775	1 / 1 = 1.00	10.1	0.910
2775 - 2895	0 / 2 = 0.00	1.51	0.00
2895 - 3019	1 / 0 = inf	0.00	0.00
3019 - 3147	0 / 1 = 0.00	5.30	0.00
3147 - 3279	0 / 0 = nan	0.00	0.00
3279 - 3416	0 / 1 = 0.00	5.30	0.00
3416 - 3558	0 / 0 = nan	0.00	0.00

Table 1: dijet ratio values for 10 pb^{-1} of data

1

Clopper-Pearson Errors on the Dijet Ratio

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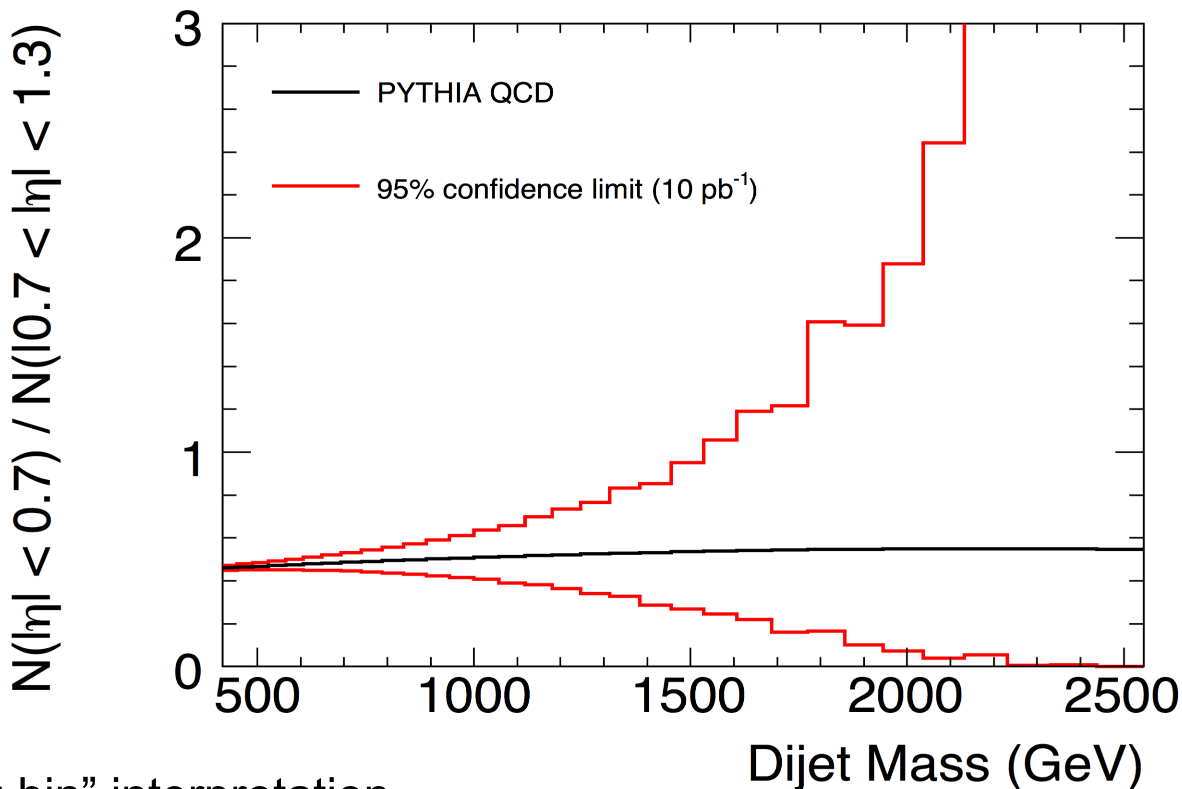
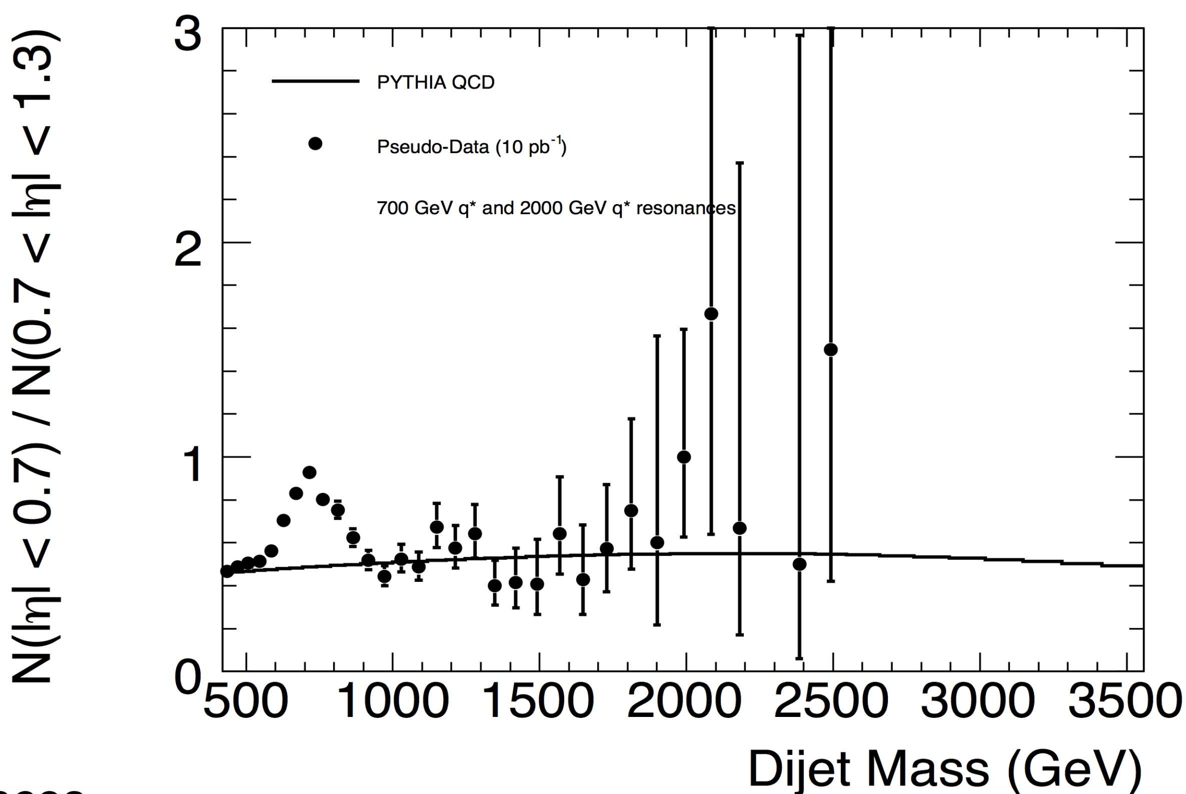
- Distributed (per mass bin) as ratio of two Poisson distributions
- Fixing total event count reduces distribution to a binomial
- Float the model parameter (which, in this case, is N($|\eta|$ < 0.7)):
  - as high as possible for the upper limit
  - as low as possible for the lower limit
  - so that the observed ratio is still within the central 68% of the distribution given that assumed (model) probability
- This is a conservative, frequentist approach

95% Confidence Limits



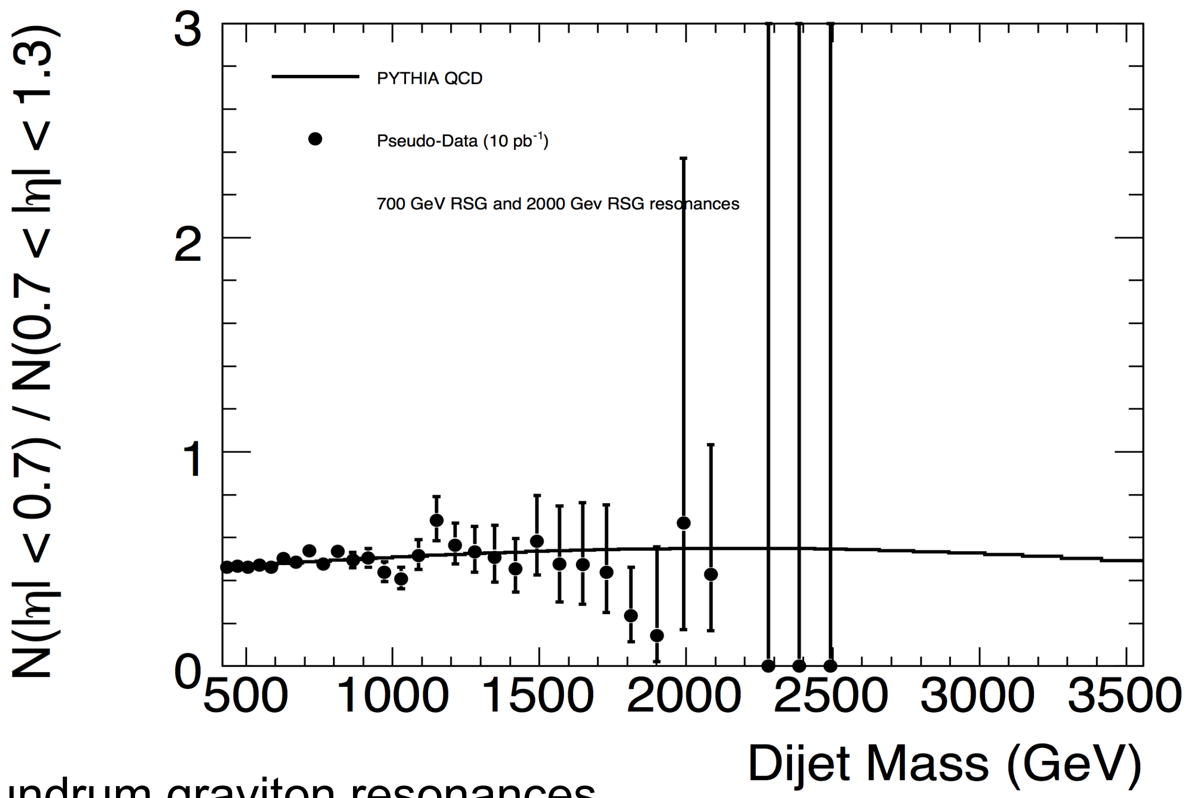
- Naive “per-bin” interpretation
- Calculated using Clopper-Pearson method
  - so may have over-coverage

New Physics (1)



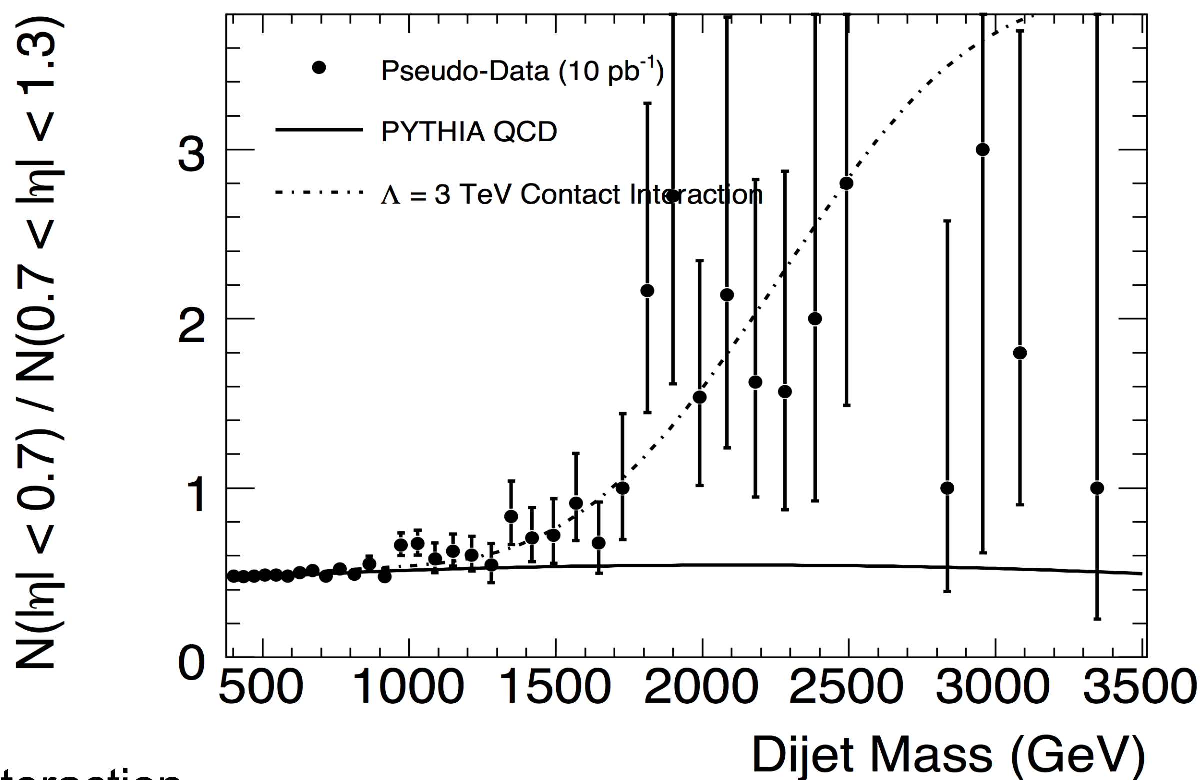
- q* resonances
- 700 and 2000 GeV

New Physics (2)



- Randall-Sundrum graviton resonances
- 700 and 2000 GeV

New Physics (3)



- Contact interaction
- 3 TeV scale