CMS Search Plans and Sensitivity to New Physics Using Dijets

Example Presentation for Public Use

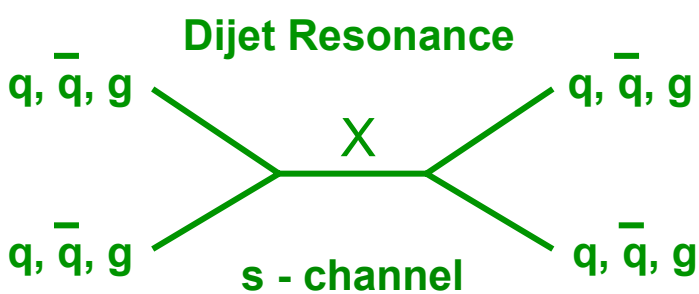
December 17, 2007

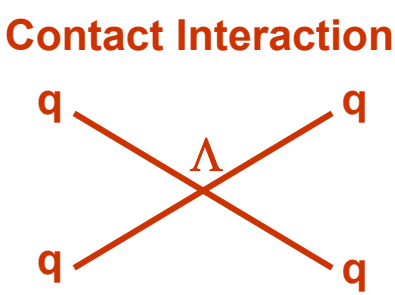
Outline

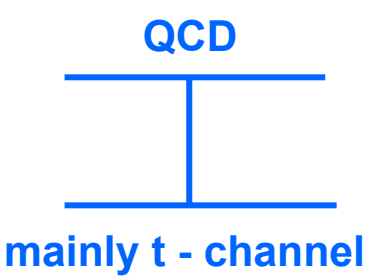
- Introduction
- Jet Measurement
- Inclusive Jet P_T
- Dijet Mass
- Dijet Ratio
- Conclusions

Introduction

- This presentation summarizes dijet analysis completed since the CMS Physics Technical Design Report (PTDR)
  - PTDR published in J. Phys. G: Nucl. Part. Phys. 34: 995-1579 (2007)
- Complementary to the PTDR sensitivity estimates
  - Explores how we do analysis, finds optimal and data-driven η cuts.
- Discusses two new analysis topics since PTDR
  - Contact Interaction search using jet P_T (joint with QCD group).
  - Dijet resonance search using dijet ratio.
- More discussion on angular distribution of dijet resonances than in PTDR

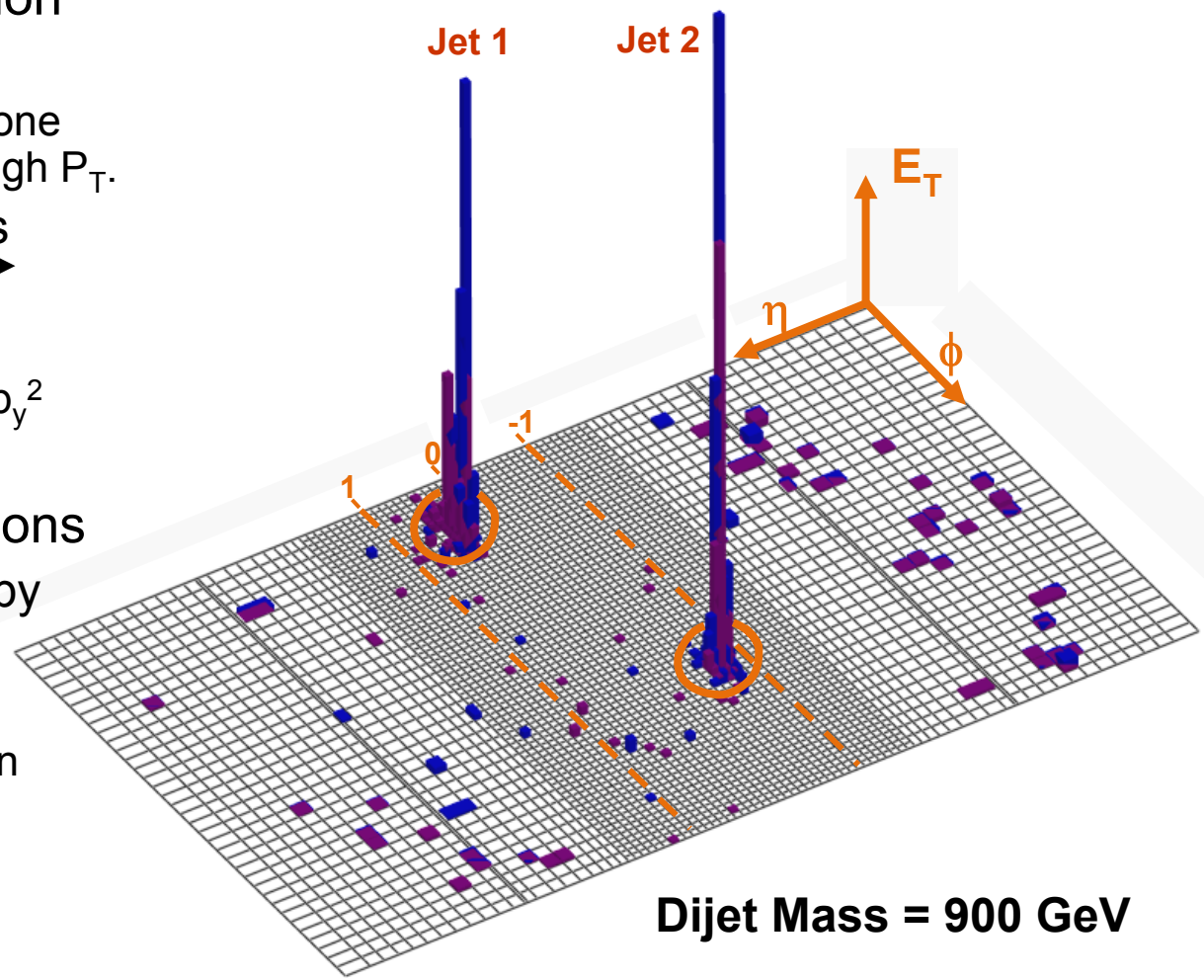






Jet Reconstruction & Correction

- Standard jet reconstruction
  - Cone algorithm R=0.5
    - Midpoint & iterative cone indistinguishable at high P_T.
  - Standard jet kinematics
    - Jet E = ΣE_i, Jet $\vec{p}=\Sigma\vec{p_i}$
    - $\theta = \tan^{-1}(p_y/p_x)$
    - $E_T = E\sin\theta$, $p_T=\sqrt{p_x^2+p_y^2}$
- Standard MC jet corrections
  - Scales Jet (E,p_x,p_y,p_z) by
    - ~1.5 at E_T = 70 GeV
    - ~1.1 at E_T = 3 TeV
    - for jets in barrel region
- Dijet is two leading jets.
  - $m=\sqrt{(E_1+E_2)^2 - (\vec{p_1}+\vec{p_2})^2}$



Dijet Mass = 900 GeV

Trigger

- Sensitivity studies done with PTDR Trigger Table

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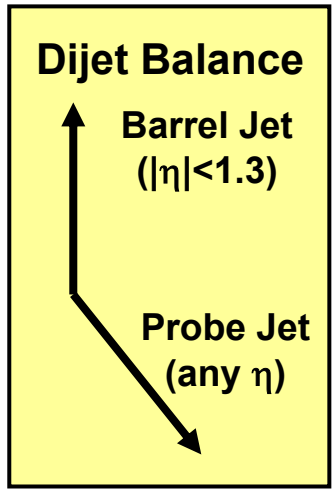
PTDR Jet Trigger Table for L = 10^{32}

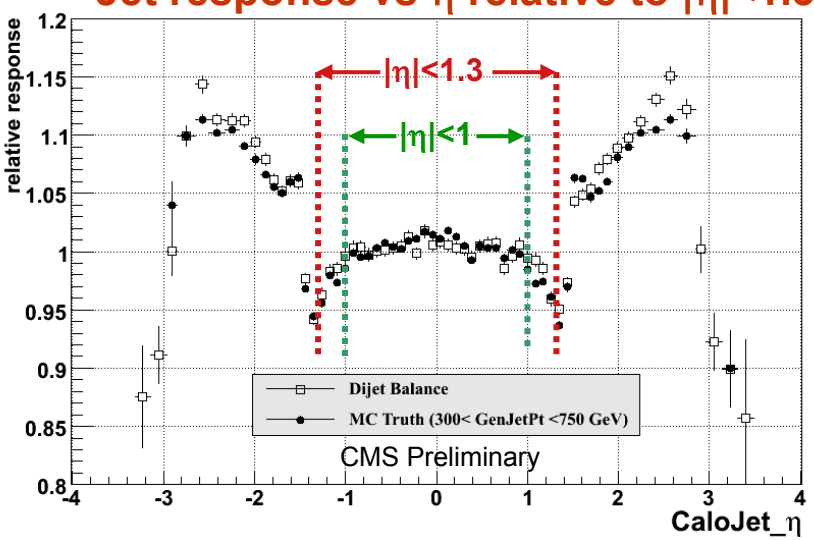
Path	L1			HLT	
	E_T (GeV)	Pre-scale	Rate (KHz)	**E_T (GeV)**	Rate (Hz)
Low	**25**	2000	0.020	**60**	**2.8**
Med	**60**	40	0.023	**120**	**2.4**
High	**140**	1	0.034	**250**	**2.8**

Jet η Region

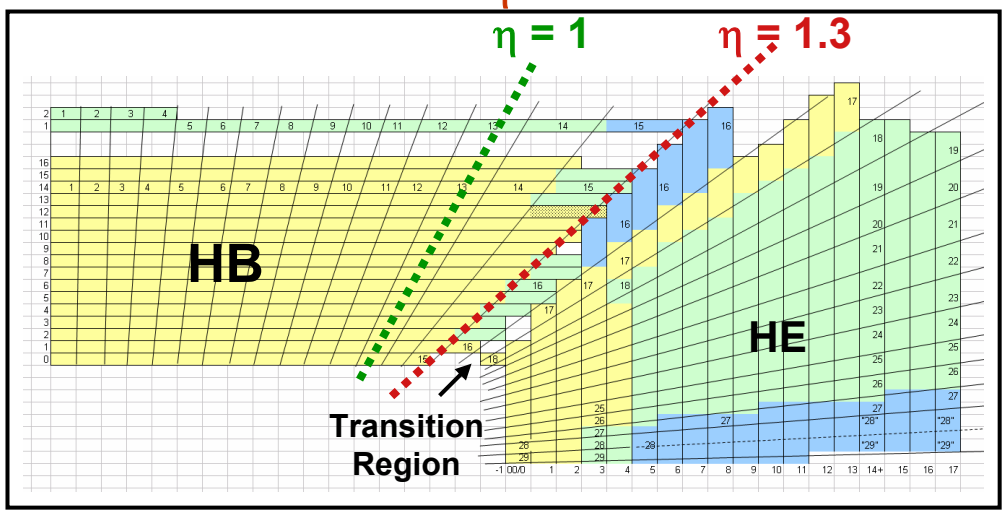
- Barrel jets have uniform response & sensitive to new physics
  - Jet response changes smoothly and slowly up to | jet η | = 1.3
    - CaloTowers with |η|<1.3 are in barrel with uniform construction.
    - CaloTowers with 1.3<|η|<1.5 are in barrel / endcap transition region
  - Some of our analyses use | jet η |<1.3, others still use | jet η |<1
    - All are migrating to | jet η |<1.3 which is optimal for dijet resonances
- Measure relative response vs. jet η in data with dijet balance
  - Data will tell us what is the region of response we can trust.



Jet response vs η relative to |η|<1.3



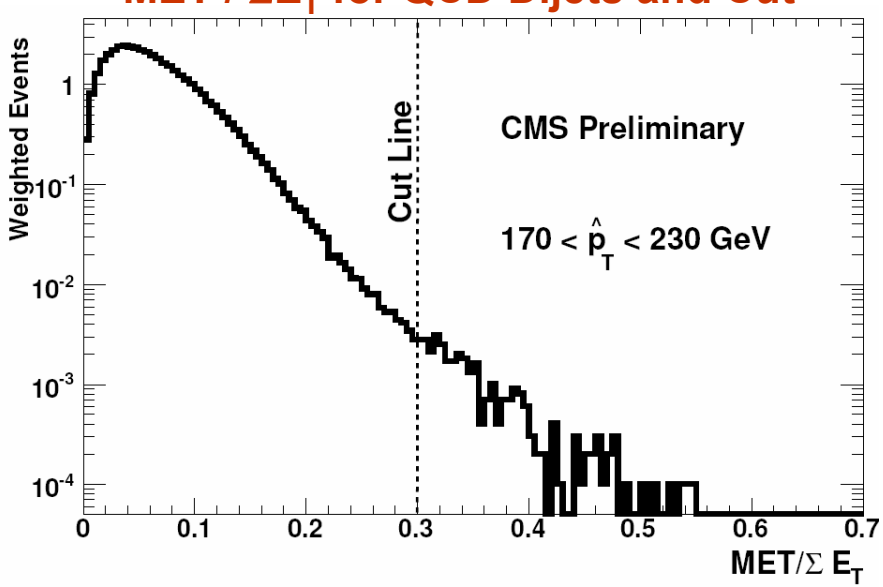
Hcal towers and η cuts



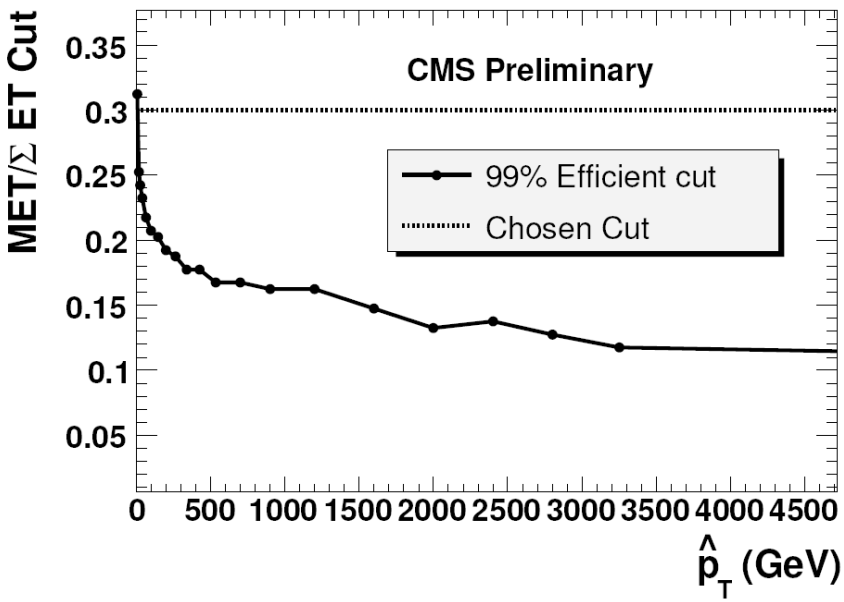
Dijet Event Cleanup

- Dijet events do not usually contain large missing E_T
  - A cut at MET / ΣE_T < 0.3 is >99% efficient for P_T > 100 GeV
  - Won't change the QCD background to new physics.
- Most unphysical background contain large missing E_T
  - Catastrophic detector noise, cosmic ray air showers, beam-halo backgrounds
  - A simple cut at MET / ΣE_T < 0.3 should remove most of these at high jet P_T.
  - This cut is our first defense, simpler and safer than cutting on jet characteristics.

MET / ΣE_T for QCD Dijets and Cut



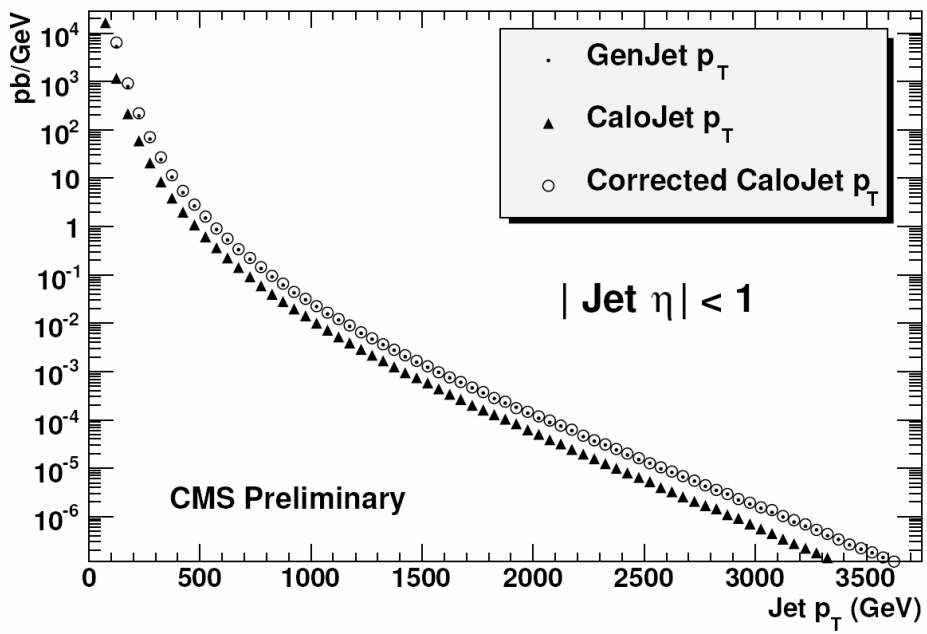
99% Efficiency Cut & Chosen Cut



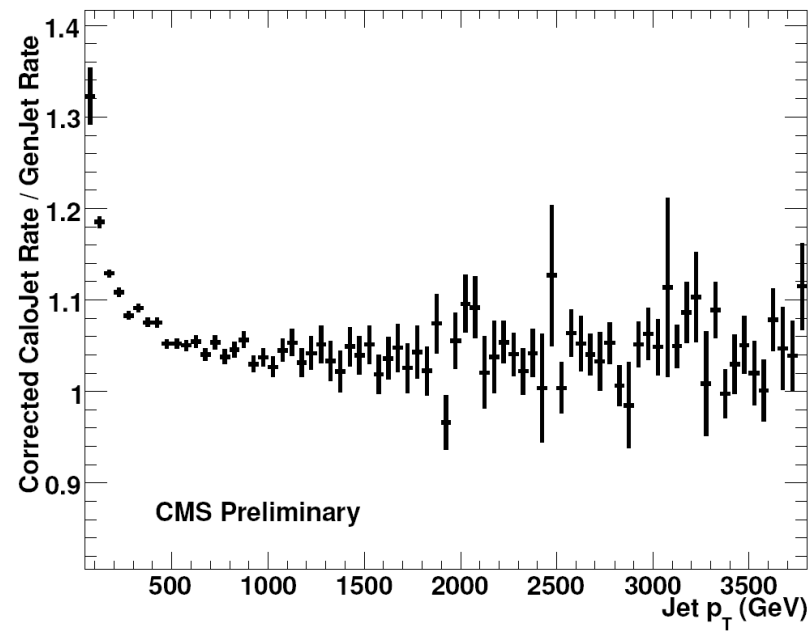
Inclusive Jet p_T

- Inclusive jet p_T is a QCD measurement that is sensitive to new physics.
  - Counts all jets inside a p_T bin and η interval, and divides by bin width and luminosity.
- Corrected CaloJets agree reasonably well with GenJets.
  - CaloJets before corrections shifted to lower E_T than GenJets
  - Ratio between corrected CaloJets and GenJets is "resolution smearing": small at high p_T.
- Simple correction for resolution smearing in real data is to divide rate by this ratio.

Inclusive Jet Cross Section



Resolution Smearing

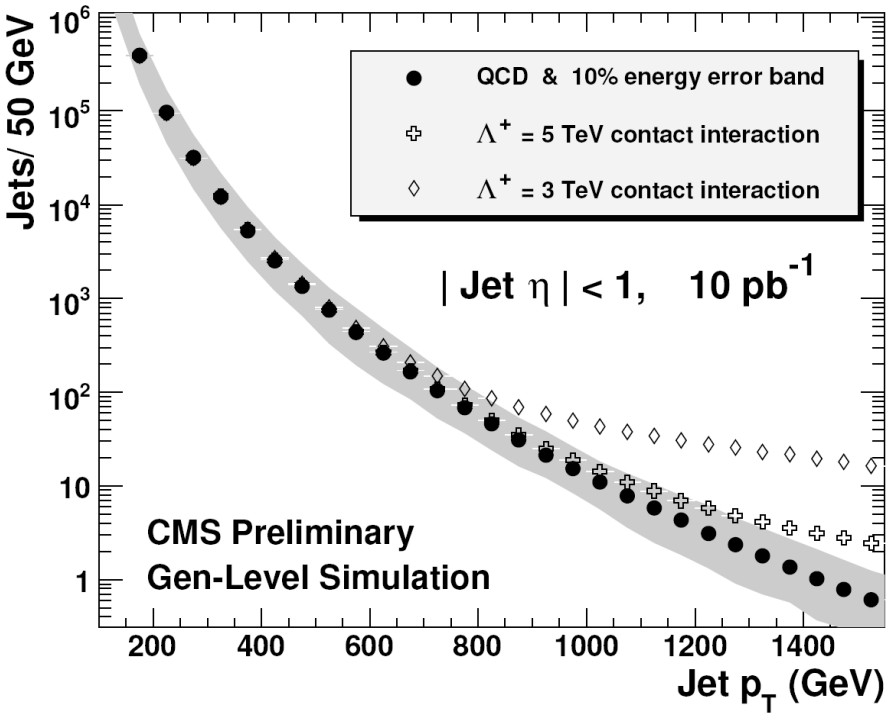


Inclusive Jet P_T and Contact Interactions

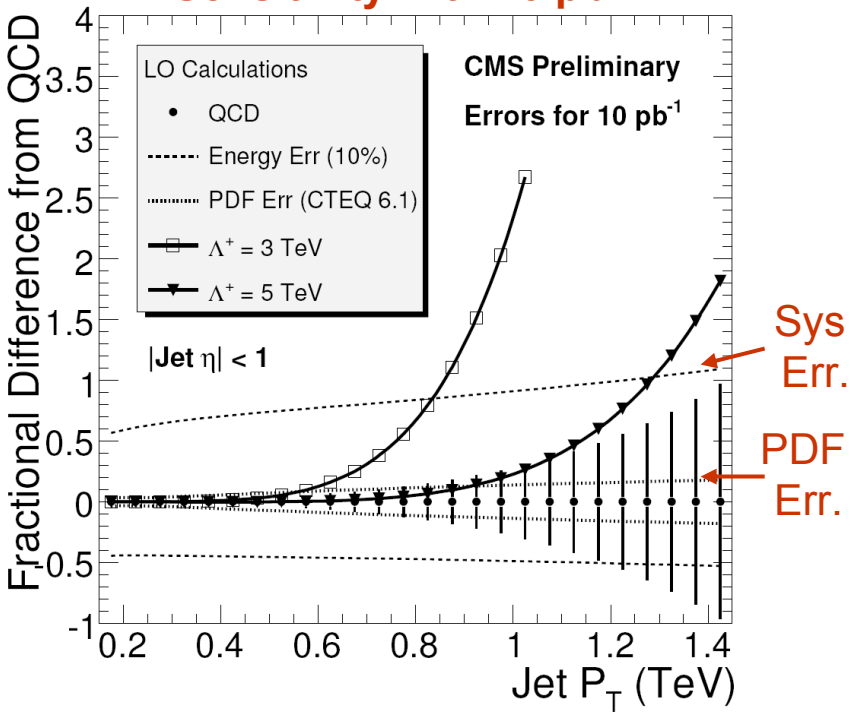
- Contact interactions create large rate at high P_T and immediate discovery possible
  - Error dominated by jet energy scale (~10%) in early running (10 pb^{-1})
    - ΔE~ 10% not as big an effect as Λ^+= 3 TeV for P_T>1 TeV.
  - PDF "errors" and statistical errors (10 pb^{-1}) smaller than E scale error

- With 10 pb^{-1} we can see new physics beyond Tevatron exclusion of Λ^+ < 2.7 TeV.

Rate of QCD and Contact Interactions



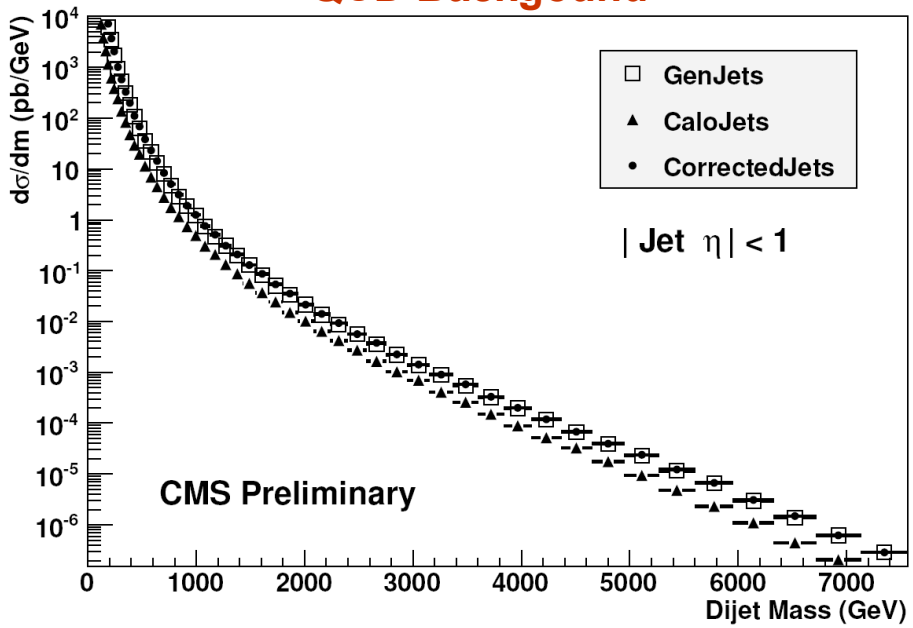
Sensitivity with 10 pb^{-1}



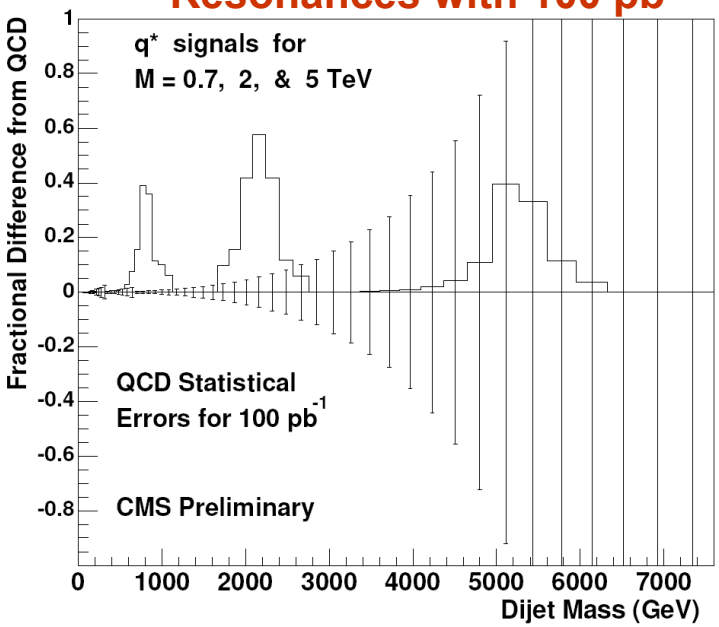
Dijet Resonances in Rate vs. Dijet Mass

- Measure rate vs. corrected dijet mass and look for resonances.
  - Use a smooth parameterized fit or QCD prediction to model background
- Strongly produced resonances can be seen
  - Convincing signal for a 2 TeV excited quark in 100 pb^{-1}
    - Tevatron excluded up to 0.78 TeV.

QCD Backgound



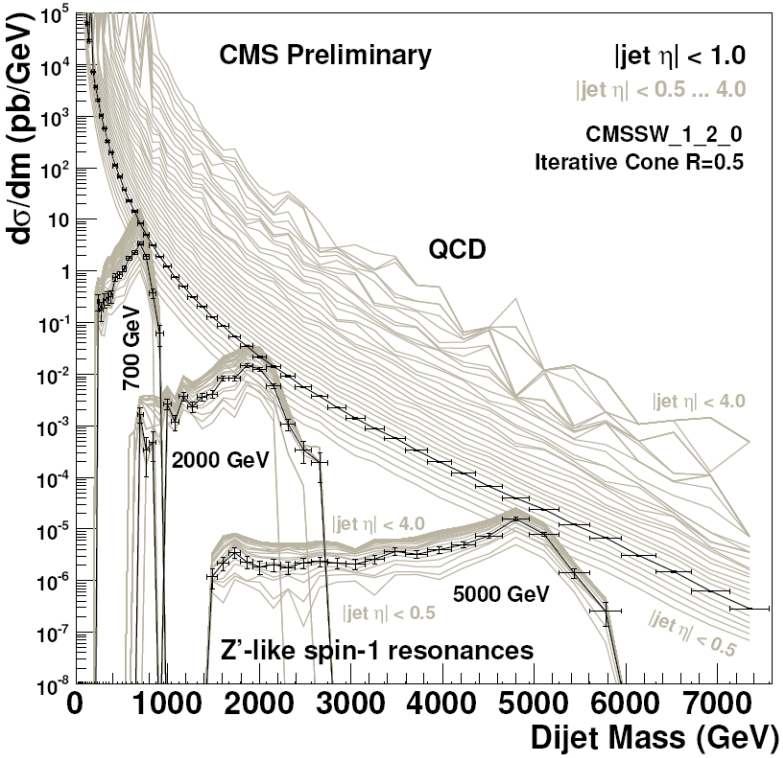
Resonances with 100 pb^{-1}



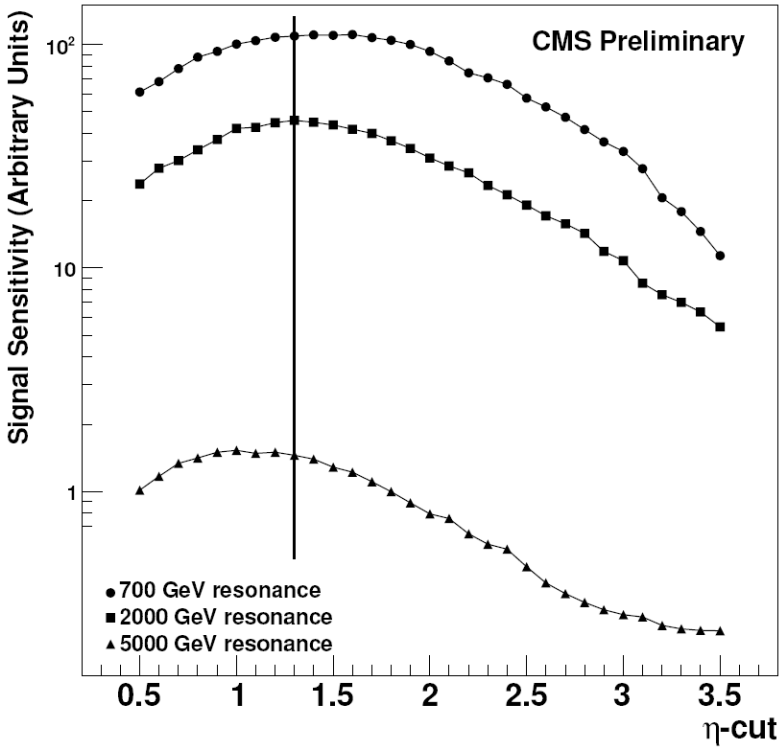
Dijet Resonances: Optimization of η cut

- QCD cross section rises dramatically with |η| cut due to t-channel pole.
  - Z' signal only gradually increases with |η| cut → optimal value at low |η|.
- Optimal cut is at |η| < 1.3 for a 2 TeV dijet resonance.
  - Optimization uses Pythia Z' angular distribution for the resonance.

η cut and cross section

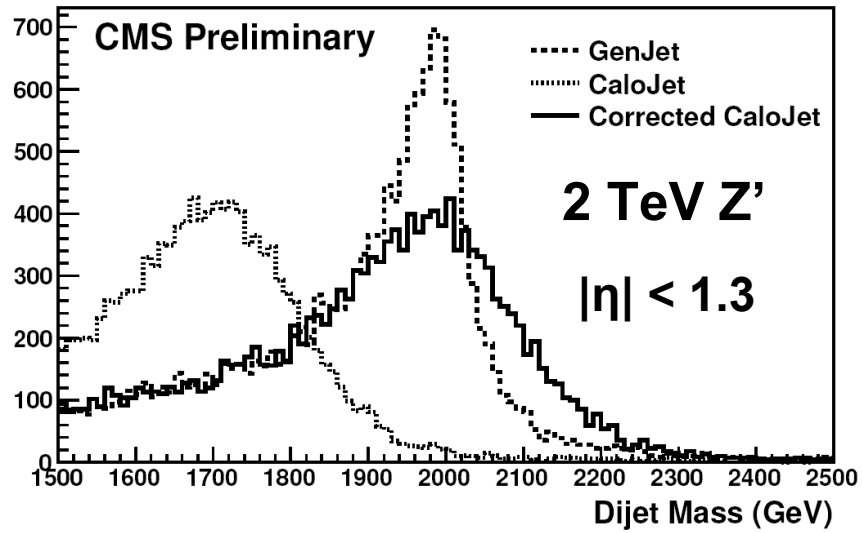


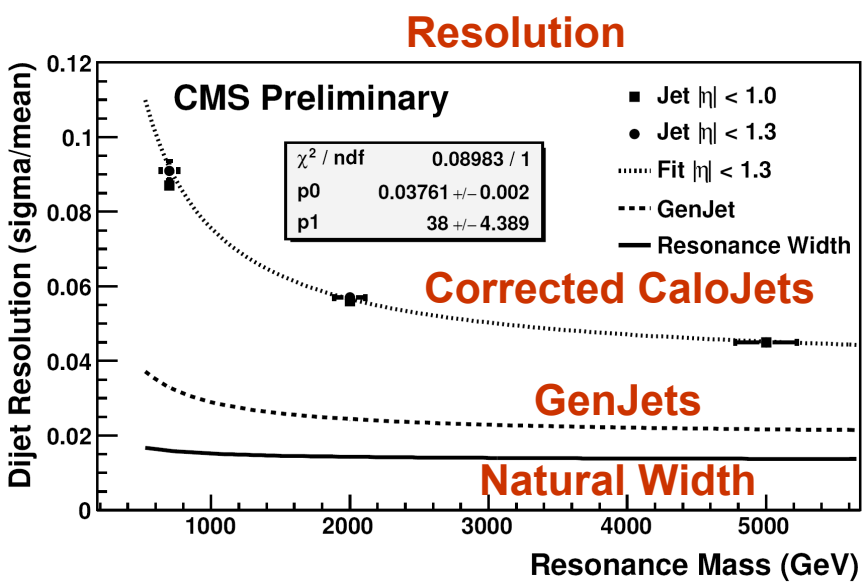
η cut and sensitivity

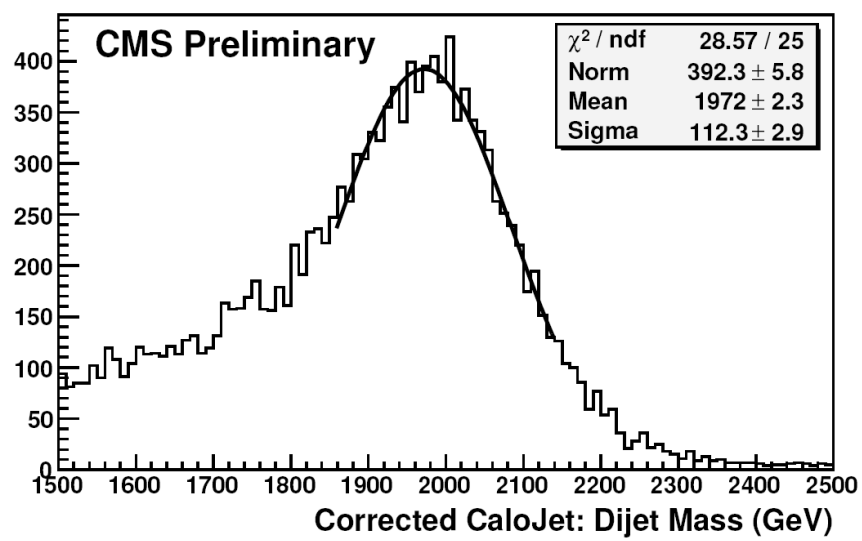


Dijet Mass Resolution

- First high statistics study of dijet resonance mass resolution.
- Gaussian core of resolution for $|\eta|<1$ and $|\eta|<1.3$ is similar.
- Resolution for corrected CaloJets
  - 9% at 0.7 TeV
  - 4.5% at 5 TeV
  - Better than in PTDR 2 study.





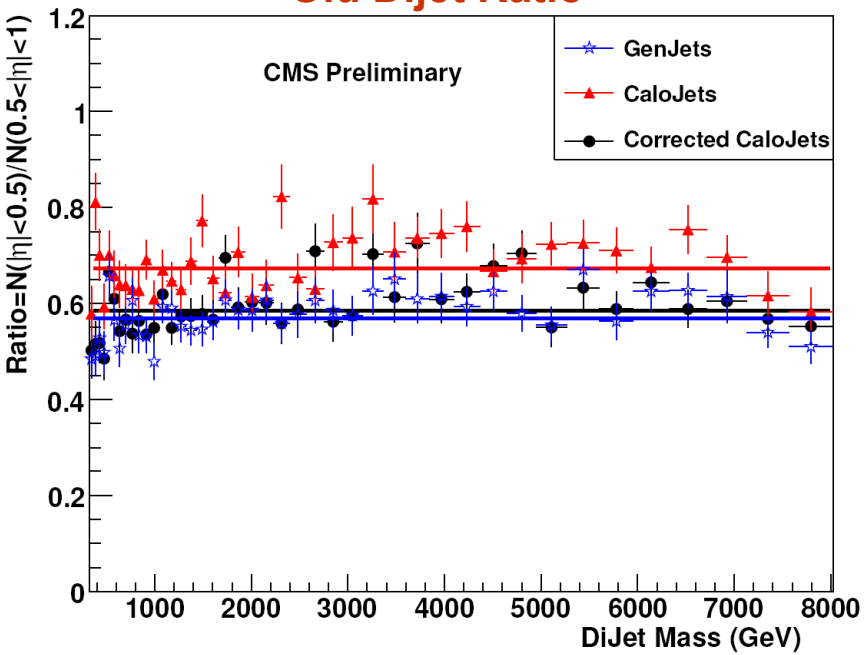


Dijet Ratio from QCD

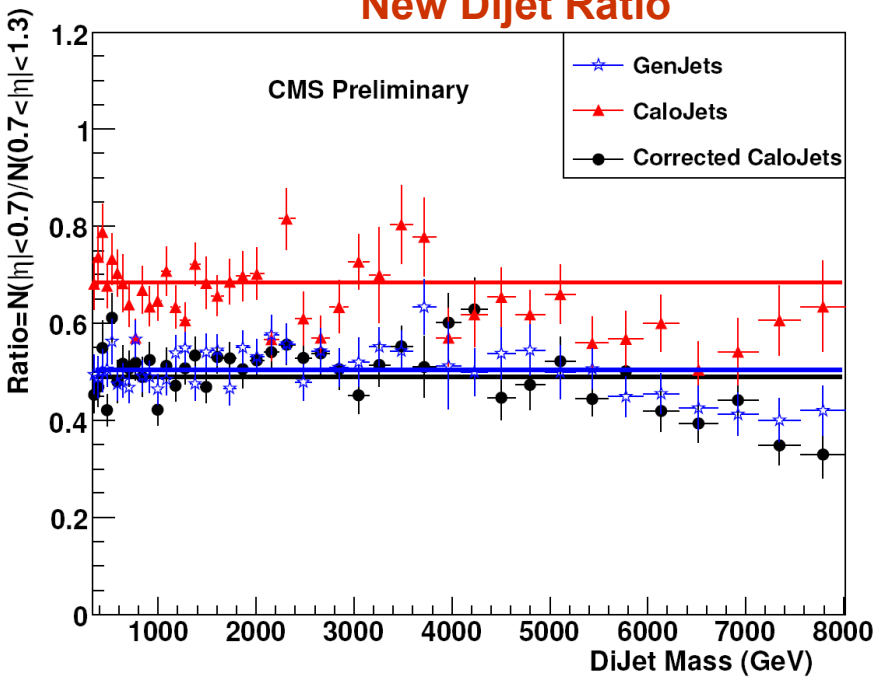
- We have optimized the dijet ratio for a contact interaction search in barrel
  - Old dijet ratio used by D0 and PTDR was N(|η|<0.5) / N(0.5<|η|<1.0)
  - New dijet ratio is N(|η|<0.7) / N(0.7<|η|<1.3)

- Dijet ratio from QCD agrees for GenJets and Corrected CaloJets
  - Flat at 0.6 for old ratio, and flat at 0.5 for new ratio up to around 6 TeV.

Old Dijet Ratio



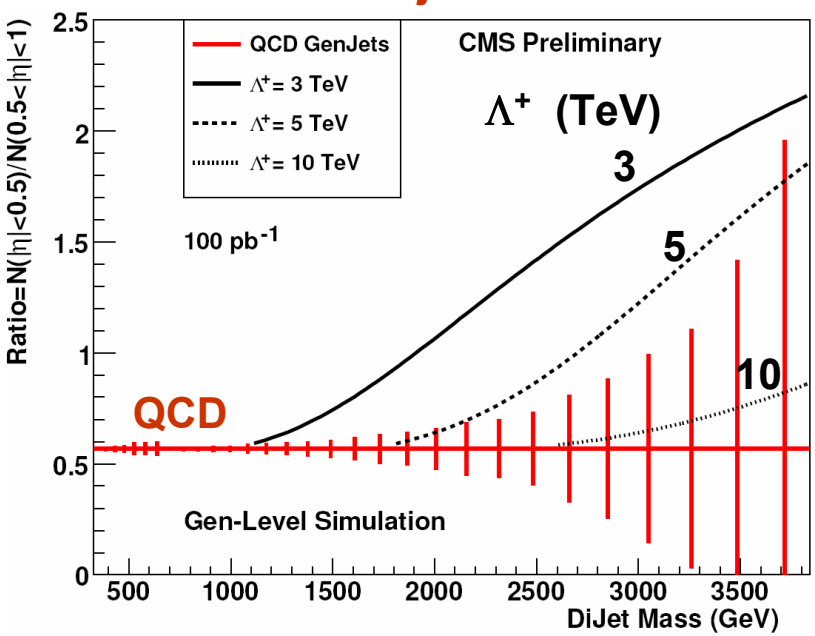
New Dijet Ratio



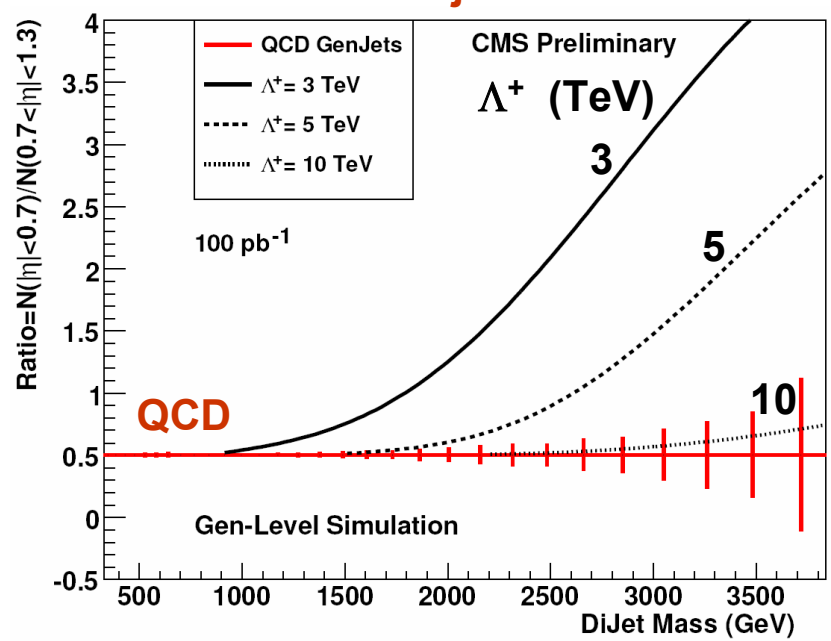
Dijet Ratio from QCD & Contact Interactions

- Optimization dramatically increases sensitivity to contact interactions.
  - Raising the signal and decreasing the QCD error bars.
  - Value of Λ^+ we can discover is increased by 2 TeV for 100 pb^{-1}
    - From $\Lambda^+ \approx 5$ TeV with old dijet ratio (PTDR) to $\Lambda^+ \approx 7$ TeV with new dijet ratio.

Old Dijet Ratio



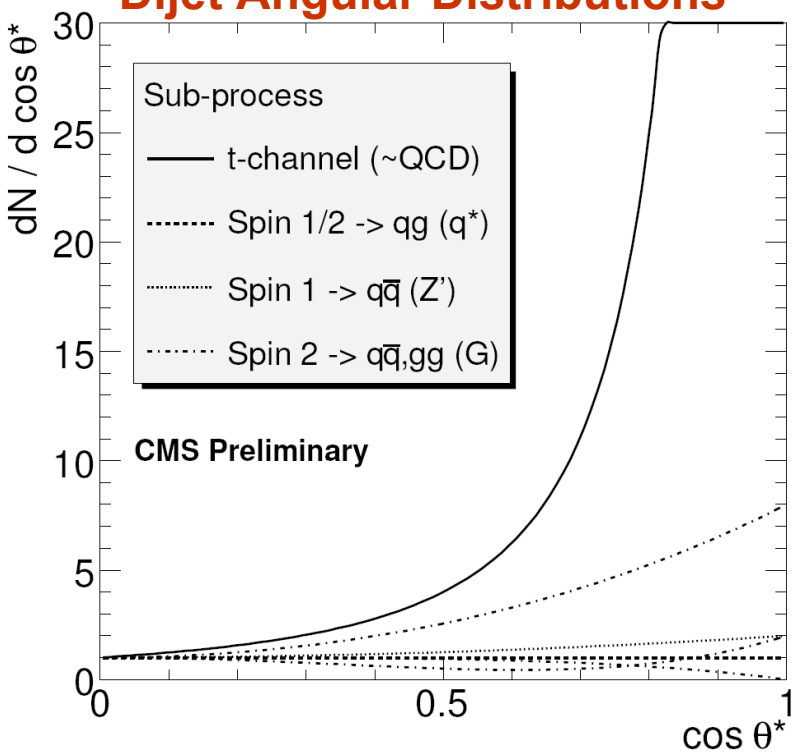
New Dijet Ratio



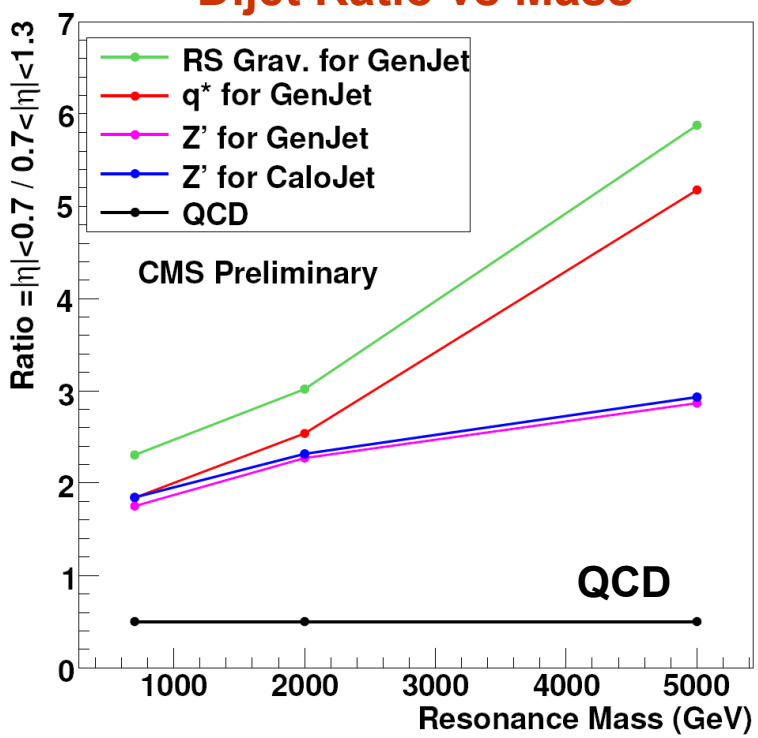
Dijet Resonances with Dijet Ratio

- All resonances have a more isotropic decay angular distribution than QCD
  - Spin ½ (q*), spin 1 (Z'), and spin 2 (RS Graviton) all flatter than QCD in dN / dcosθ*.
- Dijet ratio is larger for resonances than for QCD.
  - Because numerator mainly low cos θ*, denominator mainly high cos θ*

Dijet Angular Distributions



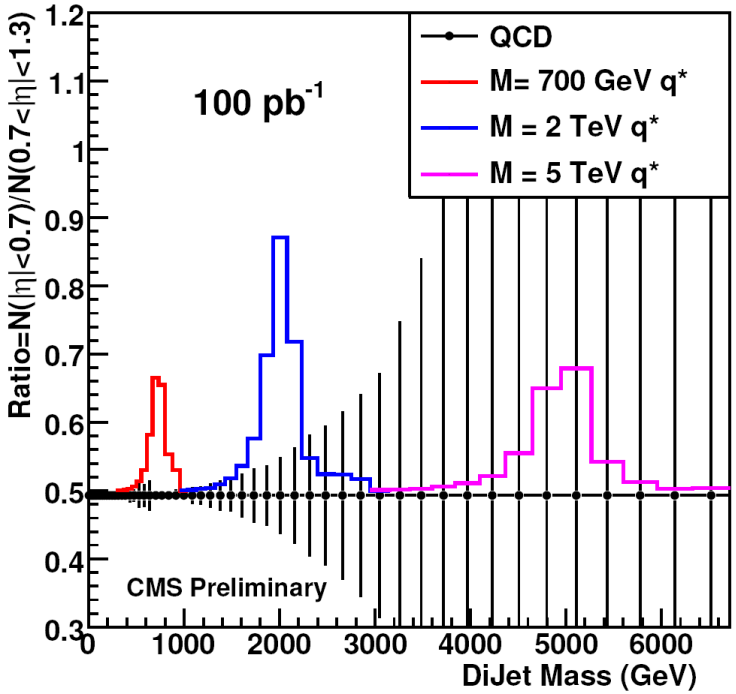
Dijet Ratio vs Mass



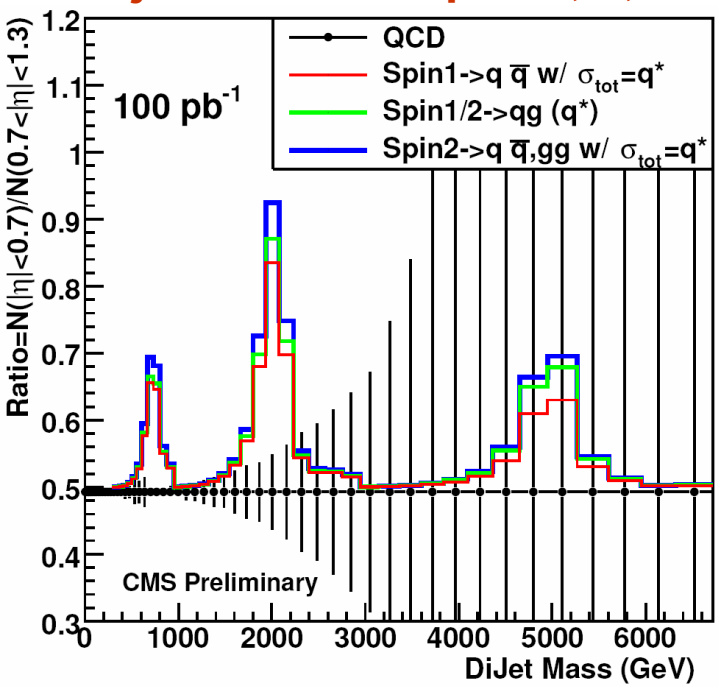
Dijet Resonances with Dijet Ratio

- Dijet ratio from signal + QCD compared to statistical errors for QCD alone
  - Resonances normalized with q* cross section for $|\eta|<1.3$ to see effect of spin.
- Convincing signal for 2 TeV strong resonance in 100 pb^{-1} regardless of spin.
- Promising technique for discovery, confirmation, and eventually spin measurement.

Dijet Ratio for q*



Dijet Ratio for Spin ½, 1, 2



Conclusions

1. We plan to reduce unphysical backgrounds by requiring MET / $\Sigma E_T < 0.3$
2. Inclusive jet p_T analysis gives a convincing signal for a contact interaction scale $\Lambda^+ = 3$ TeV in 10 pb^{-1} with jet energy errors of 10%.
3. Jet $|\eta| < 1.3$ is optimal for resonance searches in rate vs. dijet mass and has stable response vs. η which we will measure using dijet balance.
4. The Gaussian core of the resolution for a dijet resonance varies from 9% at 0.7 TeV to 4.5% at 5 TeV.
5. Rate vs. dijet mass analysis gives a convincing signal for a 2 TeV q* with 100 pb^{-1}
6. Optimized dijet ratio for contact interactions is $N(|\eta|< 0.7) / N(0.7 < |\eta| < 1.3)$
7. Dijet ratio can discover $\Lambda^+ \approx$ 4, 7 and 10 TeV for 10 pb^{-1}, 100 pb^{-1}, and 1 fb^{-1}
8. Dijet ratio can discover or confirm a dijet resonance, and eventually measure its spin. Gives a convincing signal for a 2 TeV q* with 100 pb^{-1}