The Dijet Resonance Shape Study

--Texas Tech University--
Chiyoung Jeong*
Sungwon Lee
Igor Volobouev

-- FNAL--
Robert Harris

--Cukurova University--
Sertac Ozturk

Outline

1. Dijet resonance shapes for qq, qg, gg.
2. Affect of Initial State Radiation (ISR)
3. Affect of Final State Radiation (FSR)
4. Limits on qq, qg and gg resonances
5. Conclusions

Introduction

1. The dijet resonance search analysis sets separate limits on qq, qg and gg resonances.

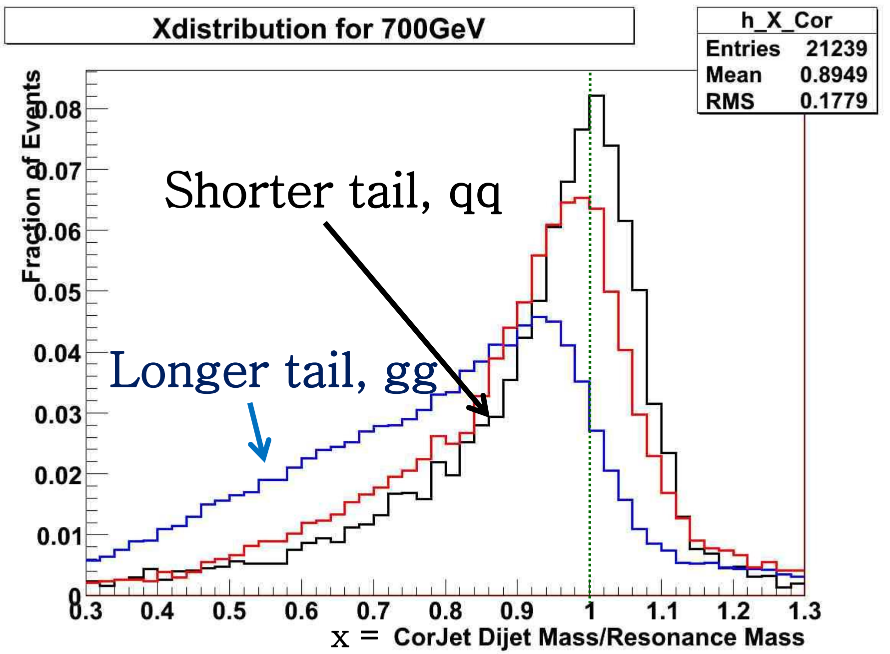
2. These resonances have different shapes.

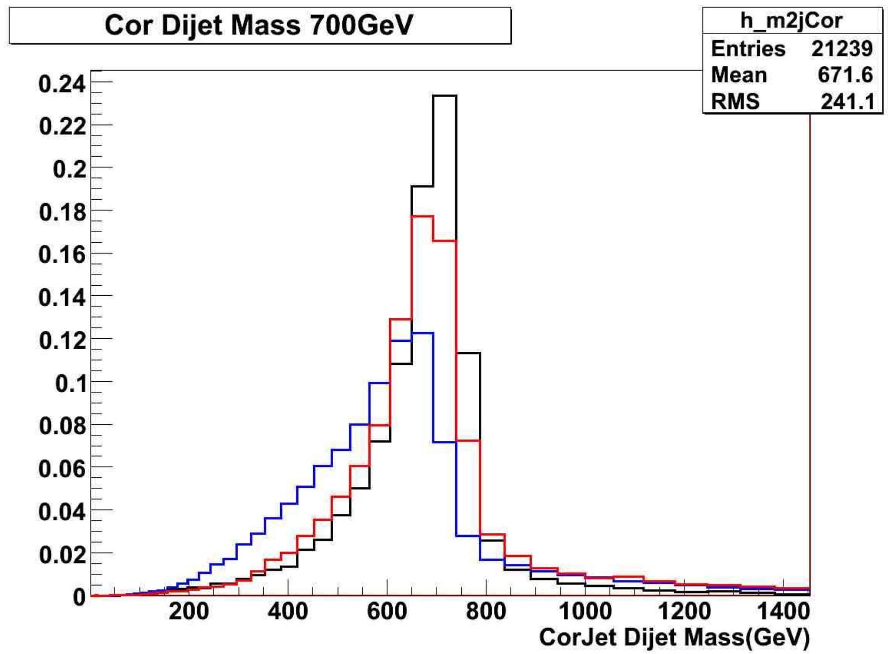
3. Here we study the sources of these different shapes
   - We investigate the effect of initial and final state radiation in PYTHIA on the dijet mass distributions for partons, genjet and corrected calojets.

Datasets and Analysis

1. PYTHIA 6.4.16, CMSSW_2_2_6 is used for generation, simulation and reconstruction. CMSSW_2_2_7 is used for analysis
2. Jet Analysis
    1. Winter09 jet correction is used – L2L3corrections_Winter09_cff.py
    2. Algorithms : Siscone R=0.7
    3. Require 2 leading jets have |eta|<1.3
3. Resonance dataset produced
    1. Randall-Sundrum graviton (0.7, 2, 5 TeV)
    2. Excited quark (0.7, 2, 5 TeV)
4. We also made dataset without ISR and FSR (backup slide)
5. We study dijet mass and X=(dijet mass / input resonance mass)

Corrected Calojet Resonance Shape (0.7 TeV)





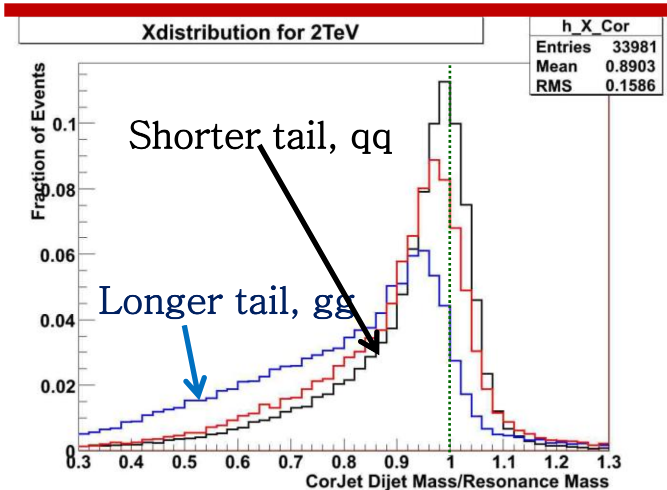
- Tails increase with the number of gluons.
- Peak shift to the left with the number of gluons.

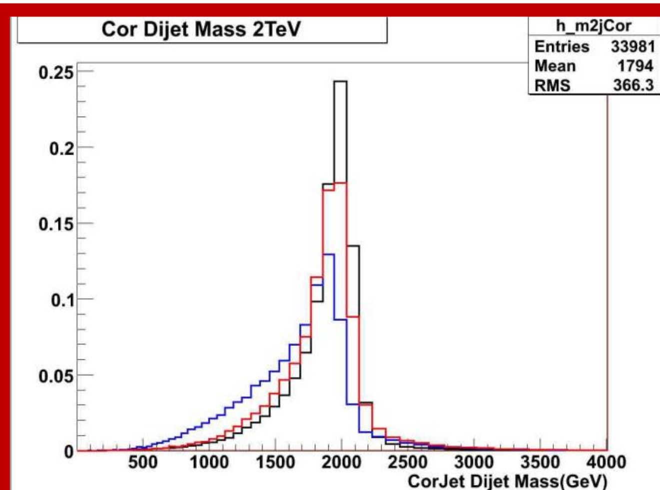
The black is for $q\bar{q} \to G \to q\bar{q}$

The red is for $qg \to q^* \to qg$

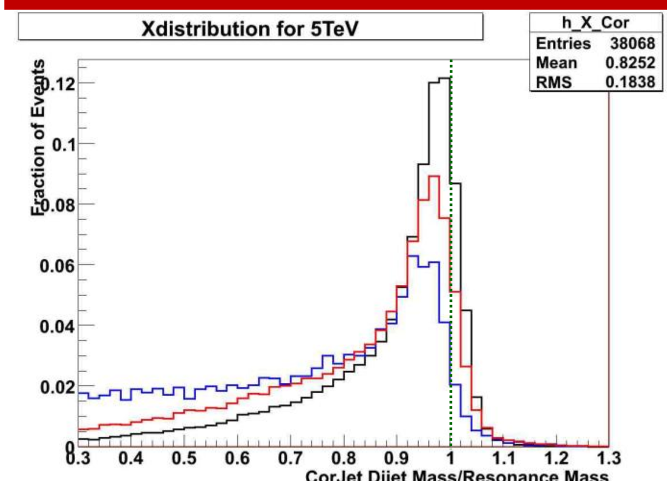
The blue is for $gg \to G \to gg$

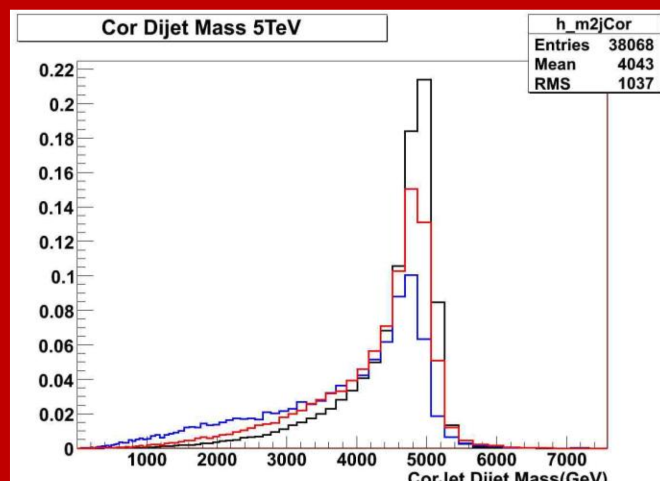
Corrected Calojet Resonance Shape (2, 5 TeV)





2 TeV





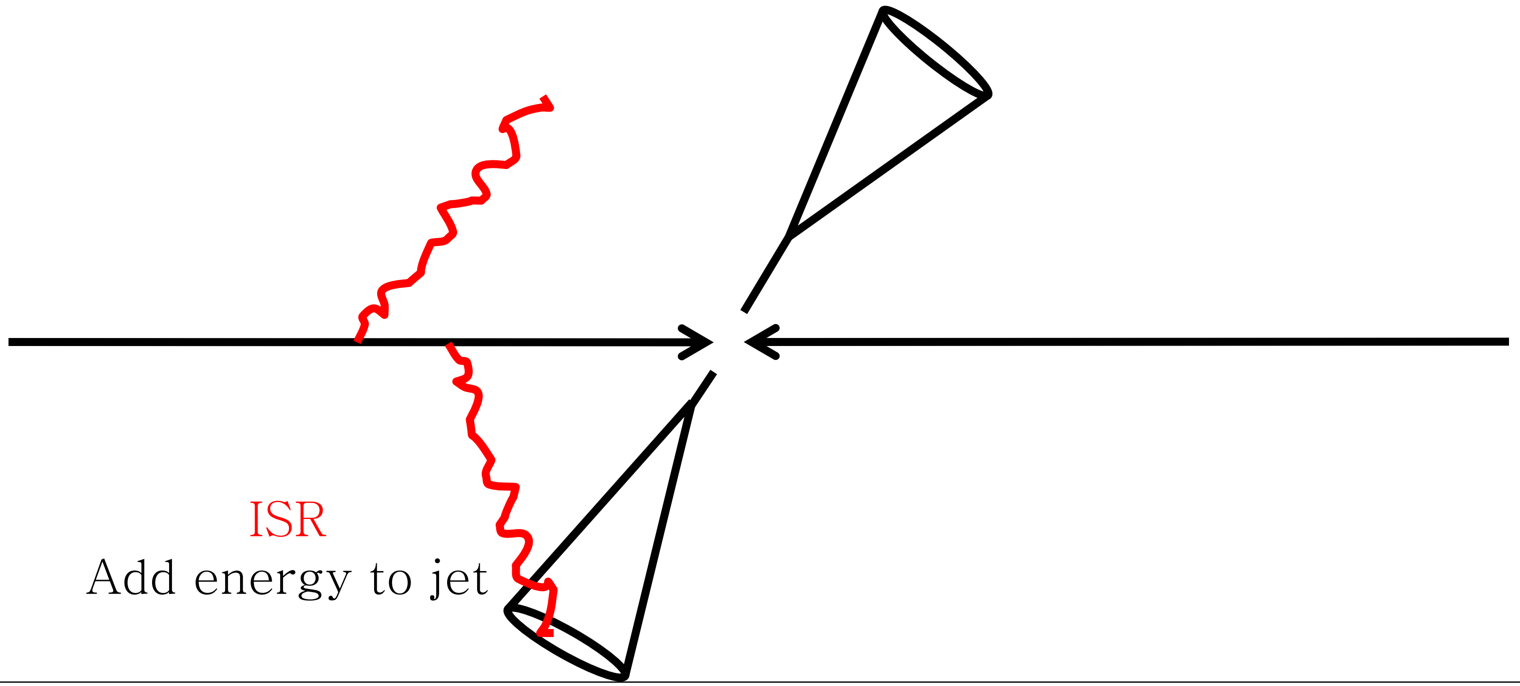
5 TeV

Less shift in peak for gluons at higher masses, but tail are still long

The black is for $q\bar{q} \to G \to q\bar{q}$
The red is for $qg \to q^* \to qg$
The blue is for $gg \to G \to gg$

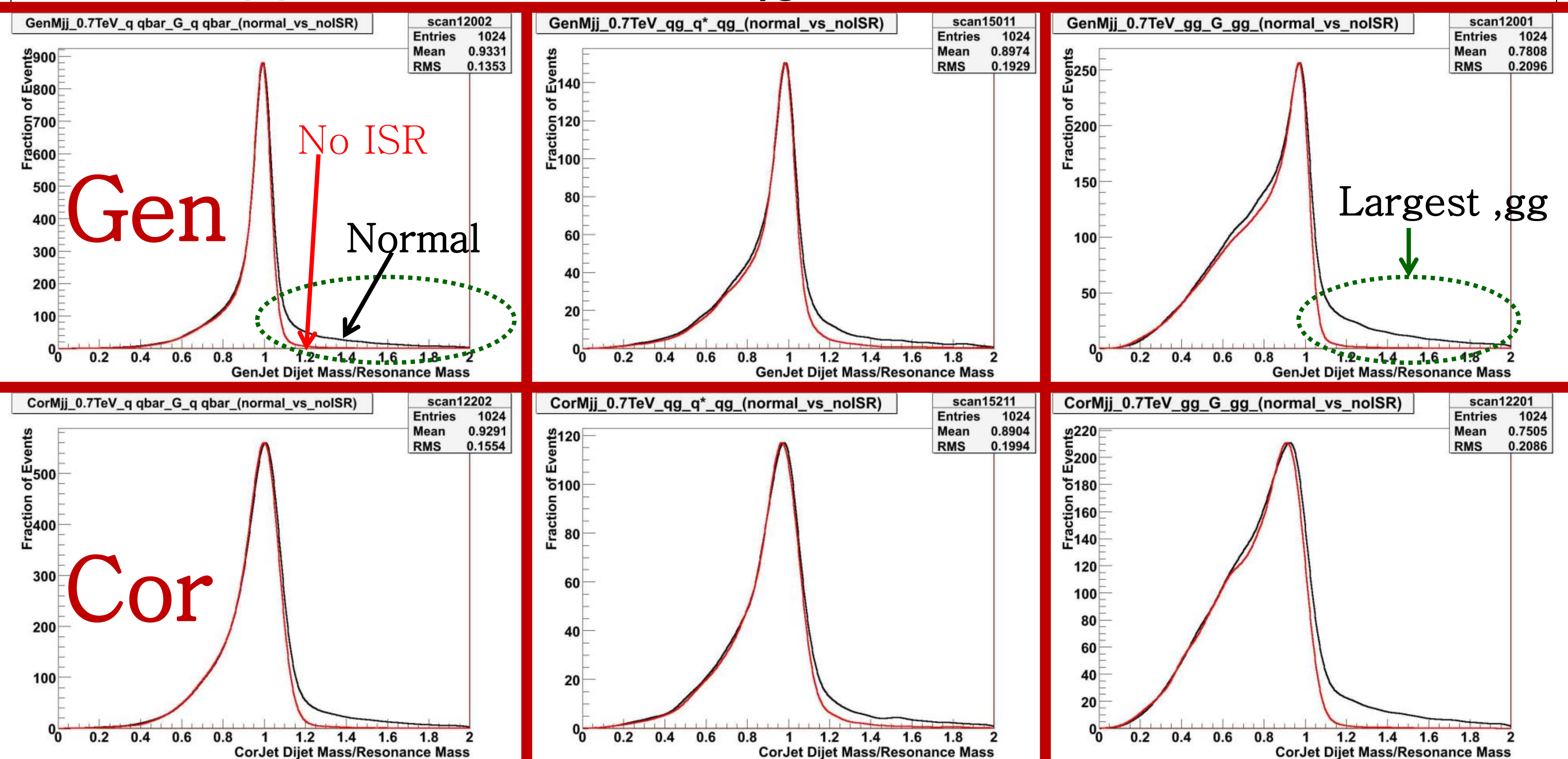
Introduction to ISR

1. We have done a study turning off ISR in PYTHIA
2. Turning off ISR is unphysical, but it has the following affect
    1. It reduces the high mass tail on the dijet resonance
    2. We believe this high mass tail mainly comes from ISR falling into the jet cone.



Affect of ISR for 0.7 TeV

$q\bar{q}$ | qg | gg

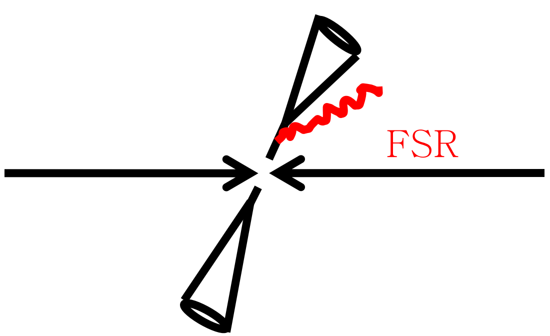


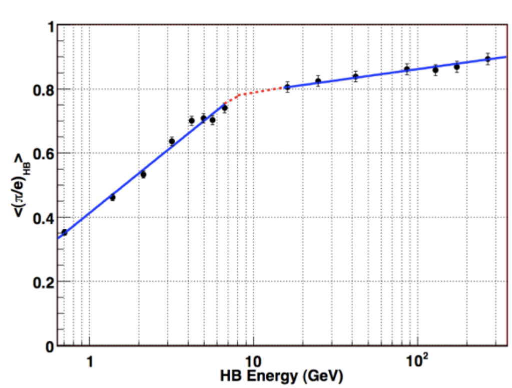
Tail to high mass is caused by ISR. Largest for gg resonance
Smaller effect for 2 and 5 TeV resonances in backup slides.

Normal in black
No ISR in red

Introduction to FSR

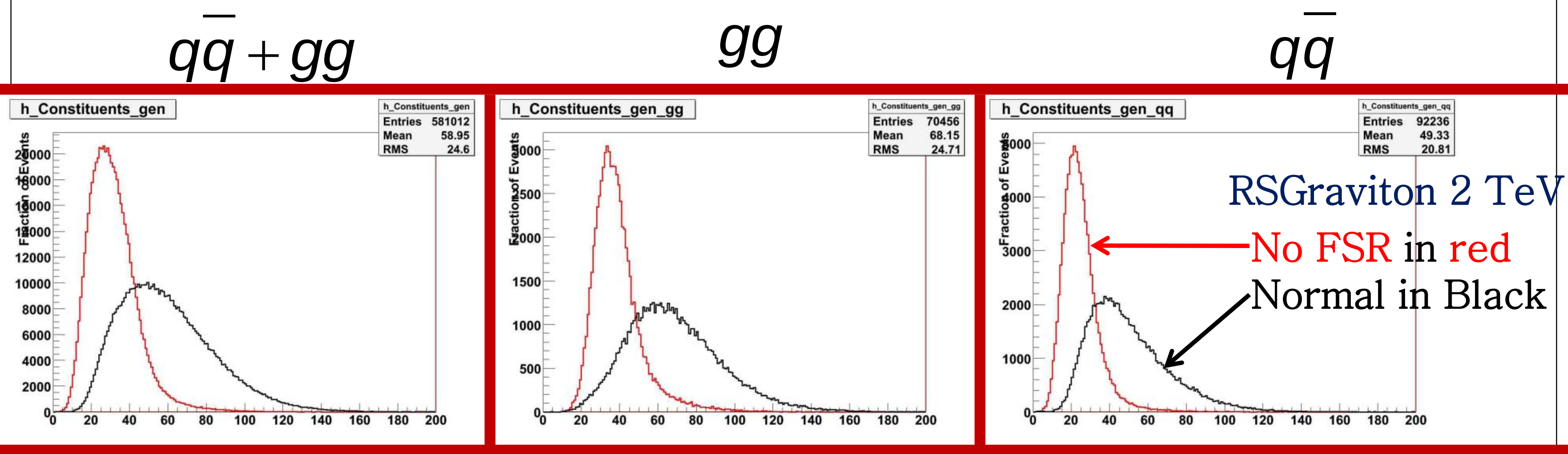
1. We have done a study turning off FSR in PYTHIA
2. Turning off FSR has two effects, both unphysical
   1. **It removes FSR which can be lost outside the cone and gives the low mass tail.**
   2. **It removes the parton shower in PYTHIA which causes differences in response between quarks and gluons.**
      1. Gluons normally radiated more gluons in the parton shower, giving lower momentum particles and towers.
      2. Turning off FSR makes the particle and tower content of quark and gluon jets more similar
      3. Turning off FSR increases the calorimeter jet response because it makes jet fragment into fewer particles.





Pion response versus energy in the HCAL barrel.
Lower energy particle has worse reponse than higher energy particle.
(CMS HCAL/ECAL Collaborations, Eur. Phys. J. C (2009) 60: 359–373)

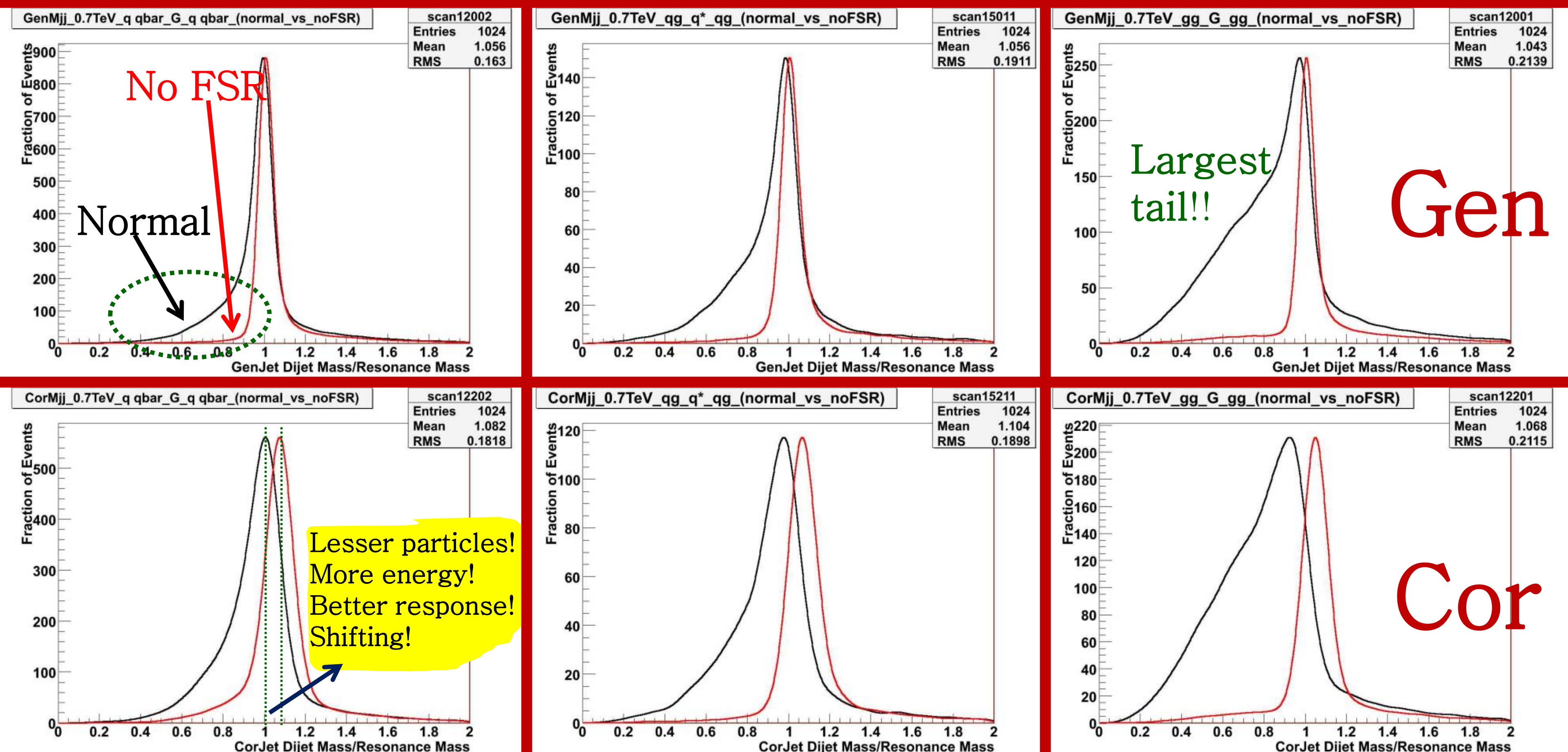
Number of Particles for GenJets with and without FSR



- Number of particles in the genjet decreases significantly when FSR is turned off.
  - We think this is because the parton shower is either reduced or eliminated.
- The average particle in the jet without FSR contains more energy
  - Higher energy particles have higher response in the calorimeter: non-linearity.
- Thus dijet resonances without FSR have higher dijet mass in corrected calojets

Affect of FSR for 0.7 TeV

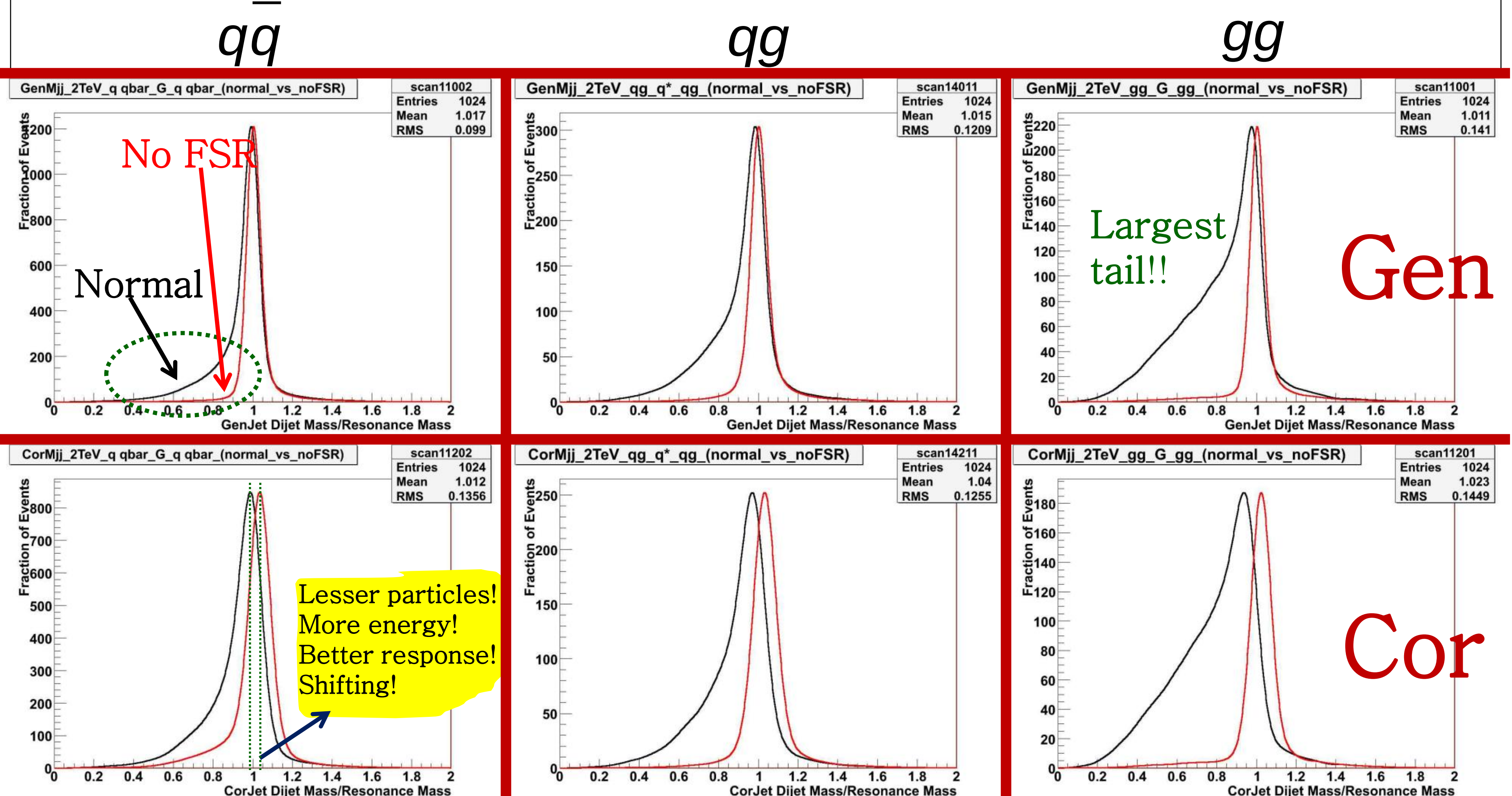
$q\bar{q}$ qg gg



Tail to low mass and shift of jet energy is caused by FSR.

Normal in black
No FSR in red

Affect of FSR for 2 TeV

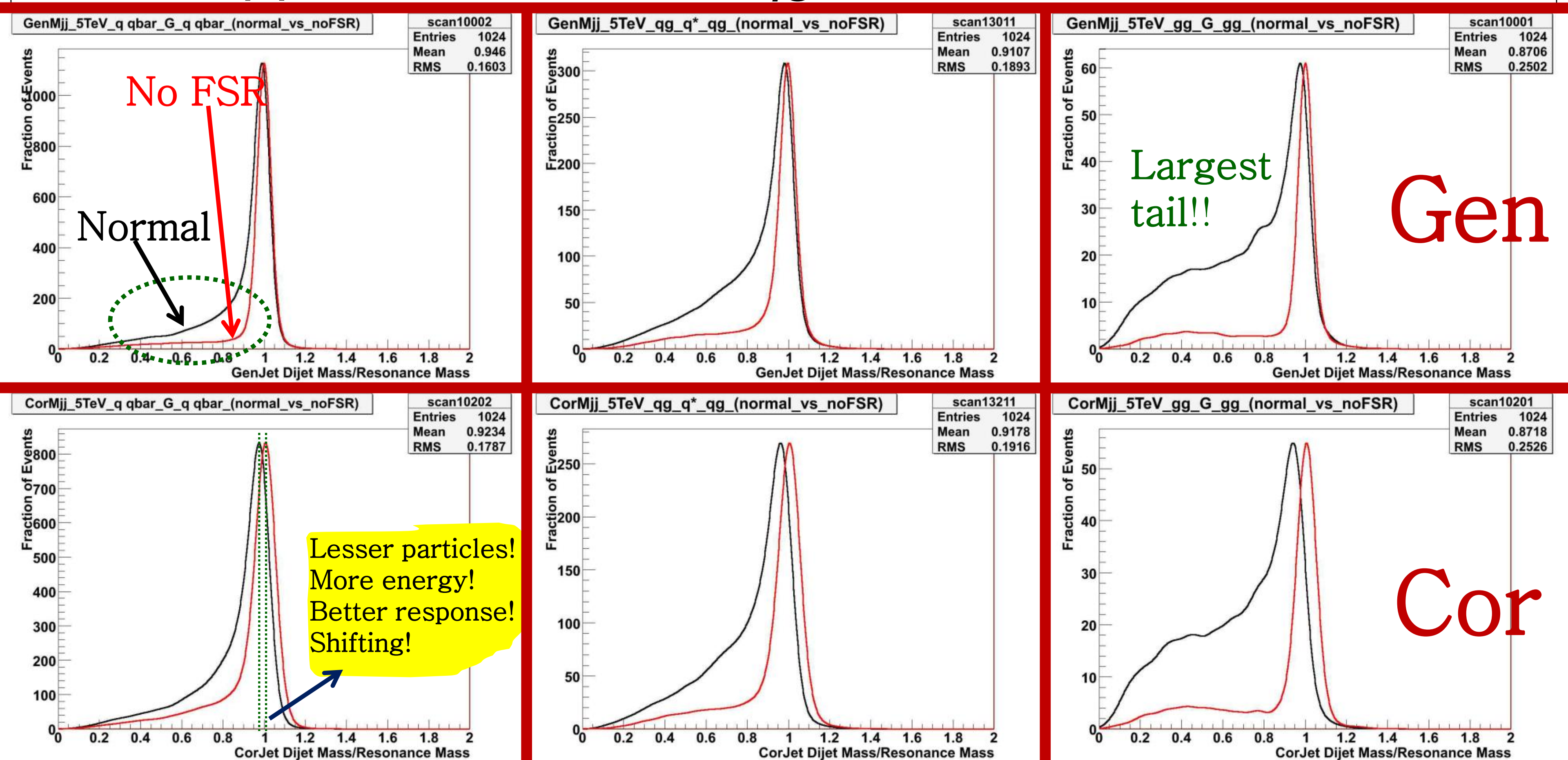


Tail to low mass and shift of jet energy is caused by FSR.

Normal in black
No FSR in red

Affect of FSR for 5 TeV

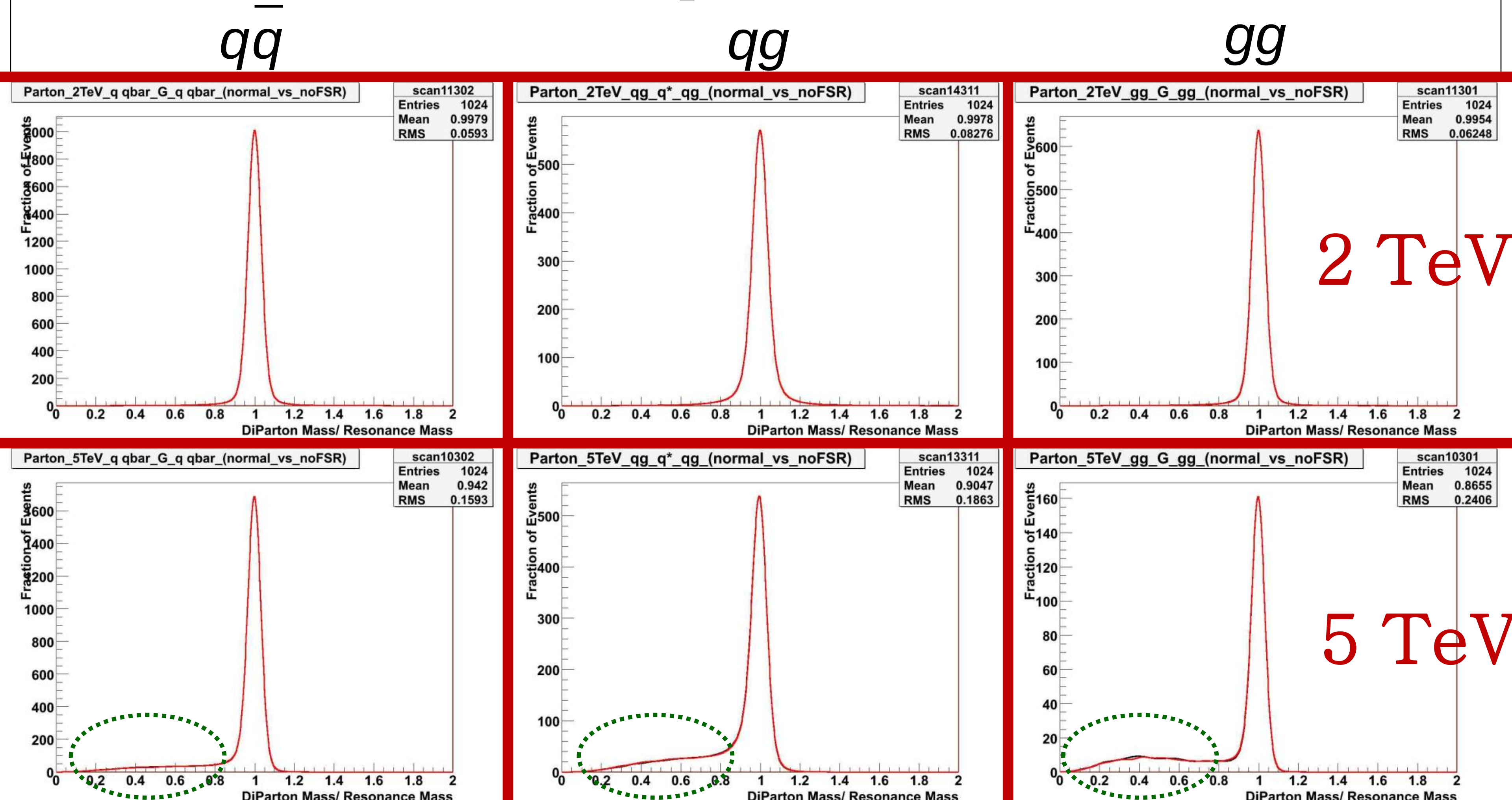
$q\bar{q}$ qg gg



Tail to low mass is mainly caused by FSR.

Normal in black
No FSR in red

Resonance at parton level

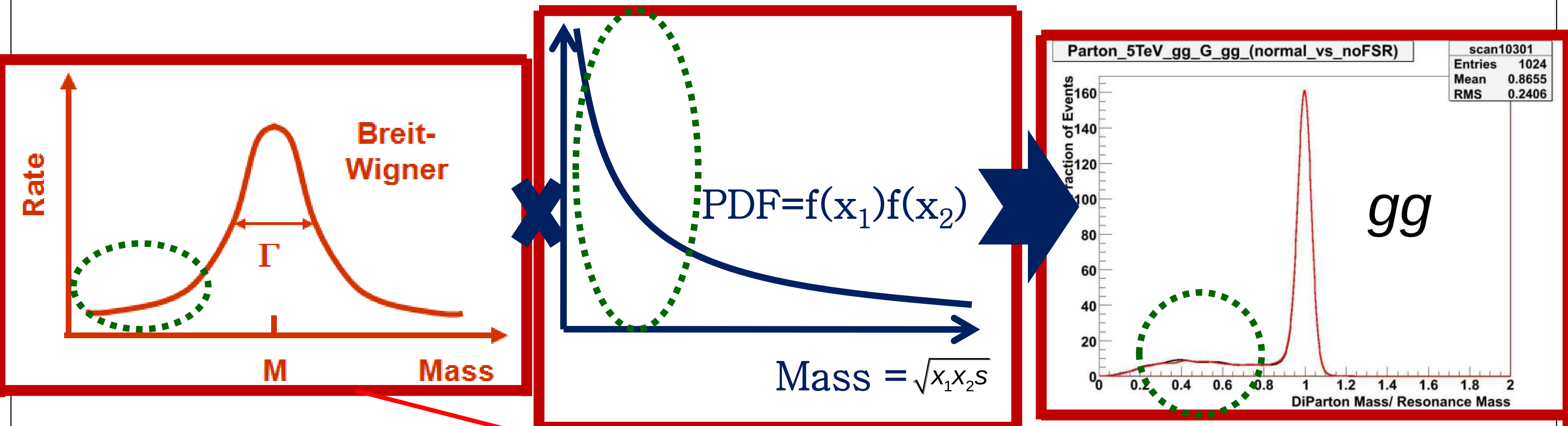


The low mass tail comes from PDFs modifying the resonance Breit-Wigner"

Normal in black
No FSR in red

PDF and Breit-Wigner Distribution

Cross Section calculation is convolution of PDF(Parton distribution function) and Breit-Wigner distribution.

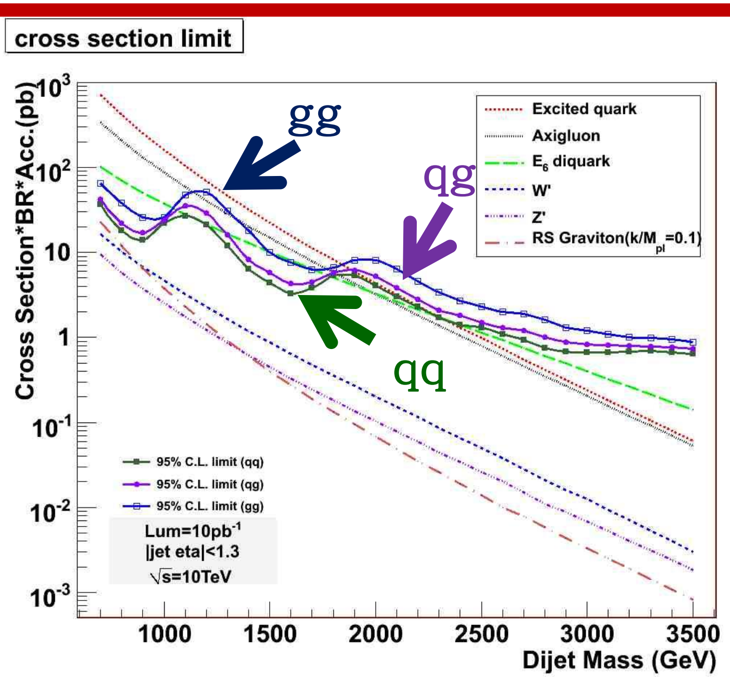


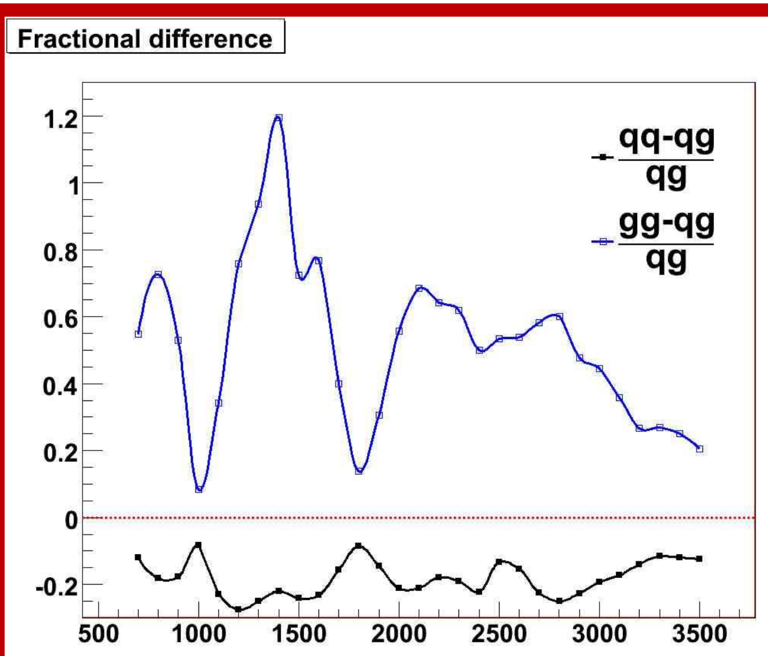
$$\sigma = \int_0^1 dx_a dx_b \, f(x_a, Q^2) f(x_b, Q^2) \sigma(x_a, x_b, Q^2)$$

x = Parton Momentum fraction (P_{parton}/E_{beam})
Q^2 = Momentum transfer

Cross section limits

1. We have used the different qq, qg and gg shapes to separately determine limits as described in the next talk.
2. The limit for qq are a little better than qg.
3. The limit for gg are significantly worse than qg





Conclusions

1. The qq, qg and gg resonanace shapes are different.
   1. The differences increase with the number of gluons.

2. The differences are caused by
   1. ISR which produces a small tail to high mass.
   2. FSR which produces a long tail to low mass.
   3. PDFs modify the Breit-Wigner line shape for high mass resonances producing a low mass tail even at the parton level..
   4. Different calorimeter jet response for quarks and gluons is related to differences in FSR and the parton shower for quarks and gluons.

3. We have determined the qq, qg and gg resonance shapes with PYTHIA and we are using them to set limits

Backup slide

Datasets

Number of events

	normal	No ISR	No FSR
Qstar 5 TeV	47500	50000	47500
Qstar 2 TeV	50000	42500	50000
Qstar 0.7 TeV	50000	50000	45000
RSGraviton 5 TeV	250000	250000	160000
RSGraviton 2 TeV	270000	260000	230000
RSGraviton 0.7 TeV	280000	260000	220000

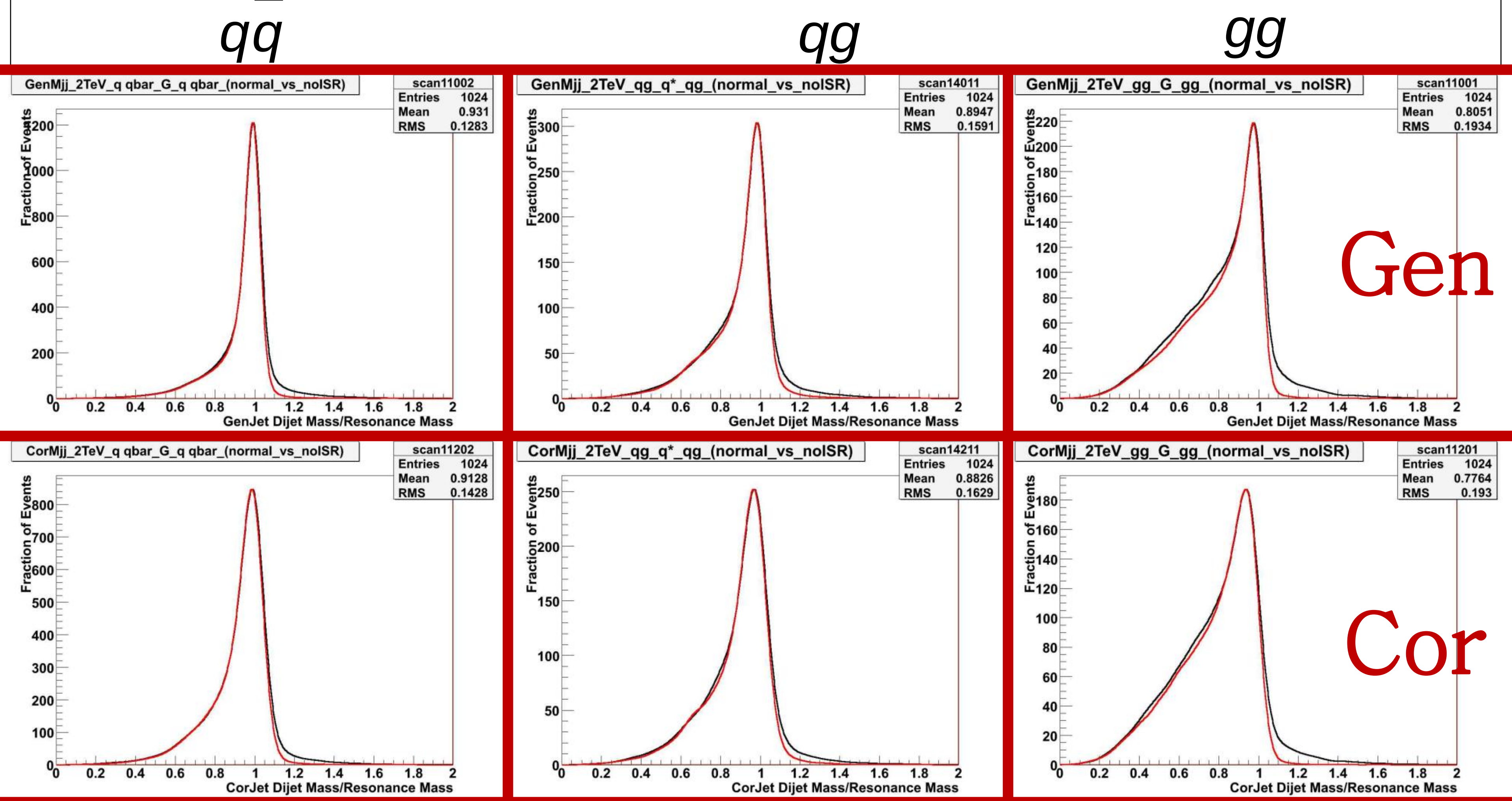
The more detail of this dataset can be found from below talk (May 26)
http://indico.cern.ch/getFile.py/access?contribId=2&resId=0&materialId=slides&confId=59593

PYTHIA setting for no ISR and no FSR

MSTP(61) = 0 (2 for QED and QCD, 1 for QCD, 0 for none)

MSTP(71) = 0 (default -> turn on, 0 -> turn off)

Affect of ISR for 2 TeV

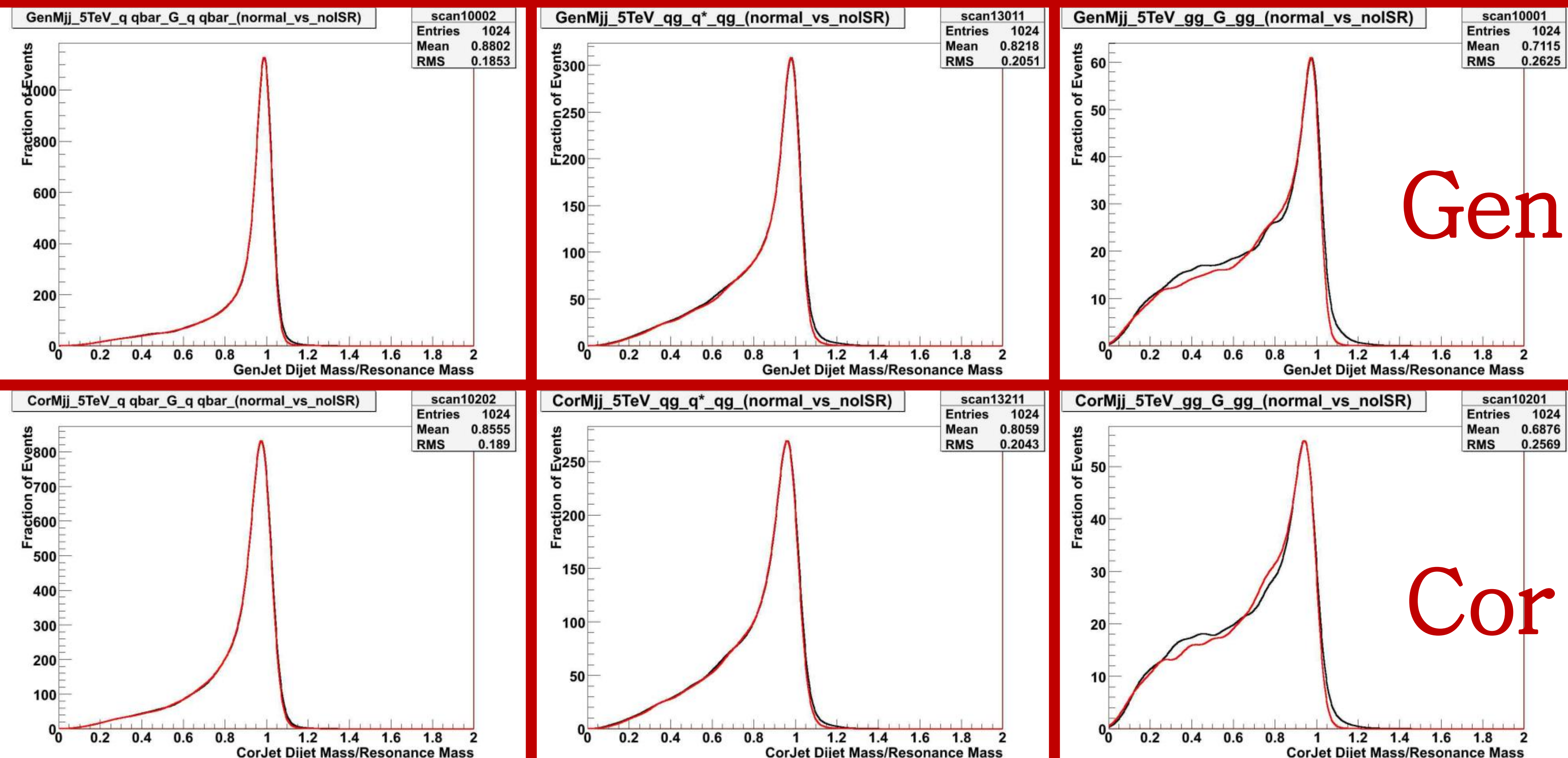


Tail to high mass is caused by ISR. Largest for gg resonance

Normal in black
No ISR in red

Affect of ISR for 5 TeV

$q\bar{q}$ qg gg

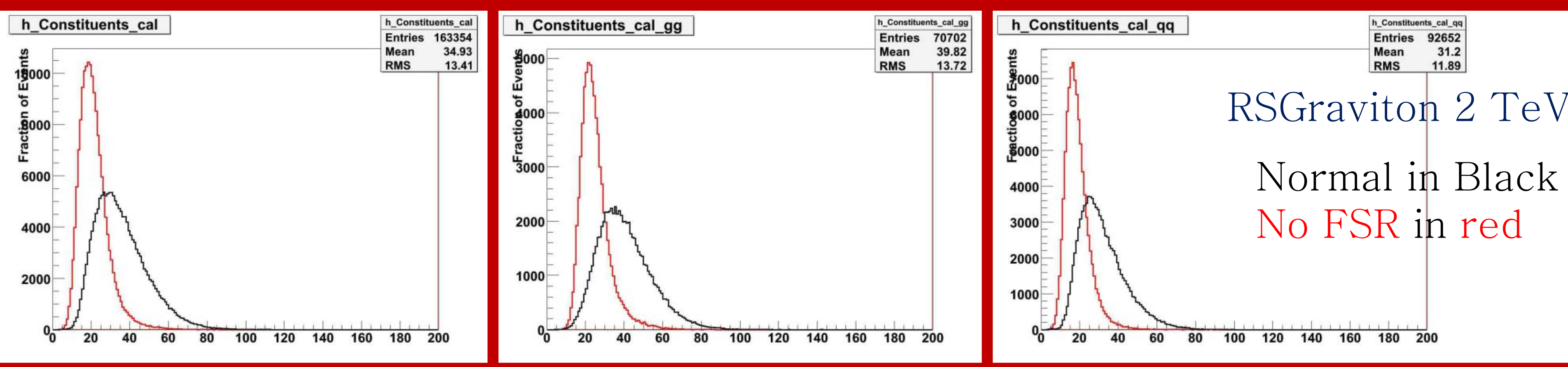


Tail to high mass is caused by ISR. Largest for gg resonance

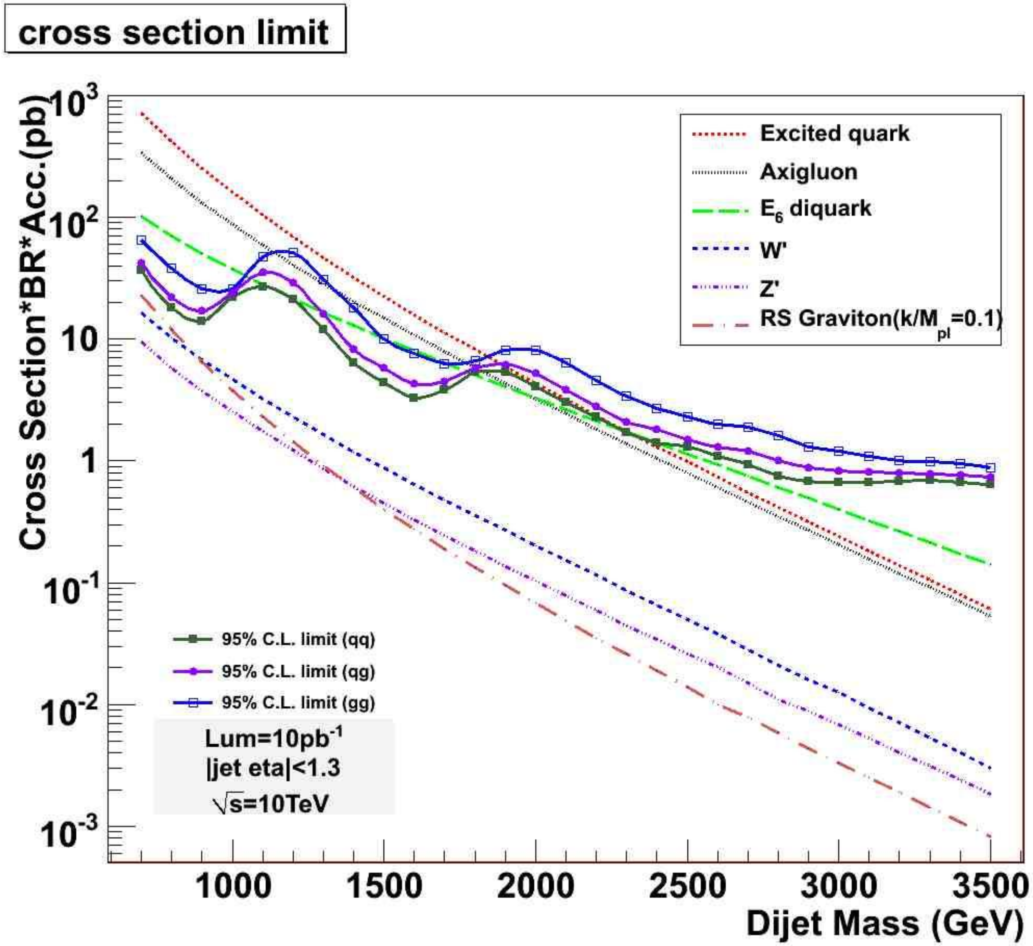
Normal in black
No ISR in red

Number of Calotowers for Corr CaloJets with and without FSR

$q\bar{q} + gg$ gg $q\bar{q}$



Cross section limit



Kernel Density Estimation

- Used a variant of ‘Kernel density estimation(KDE)’ for making the plots I used.
- I built finely binned histogram first(1024 bins) and then convolves it with the kernel (Gaussian).
- The sigma for Gaussian is 1.