A Search for New Resonances with the Dijet Angular Ratio Using the Compact Muon Solenoid Experiment

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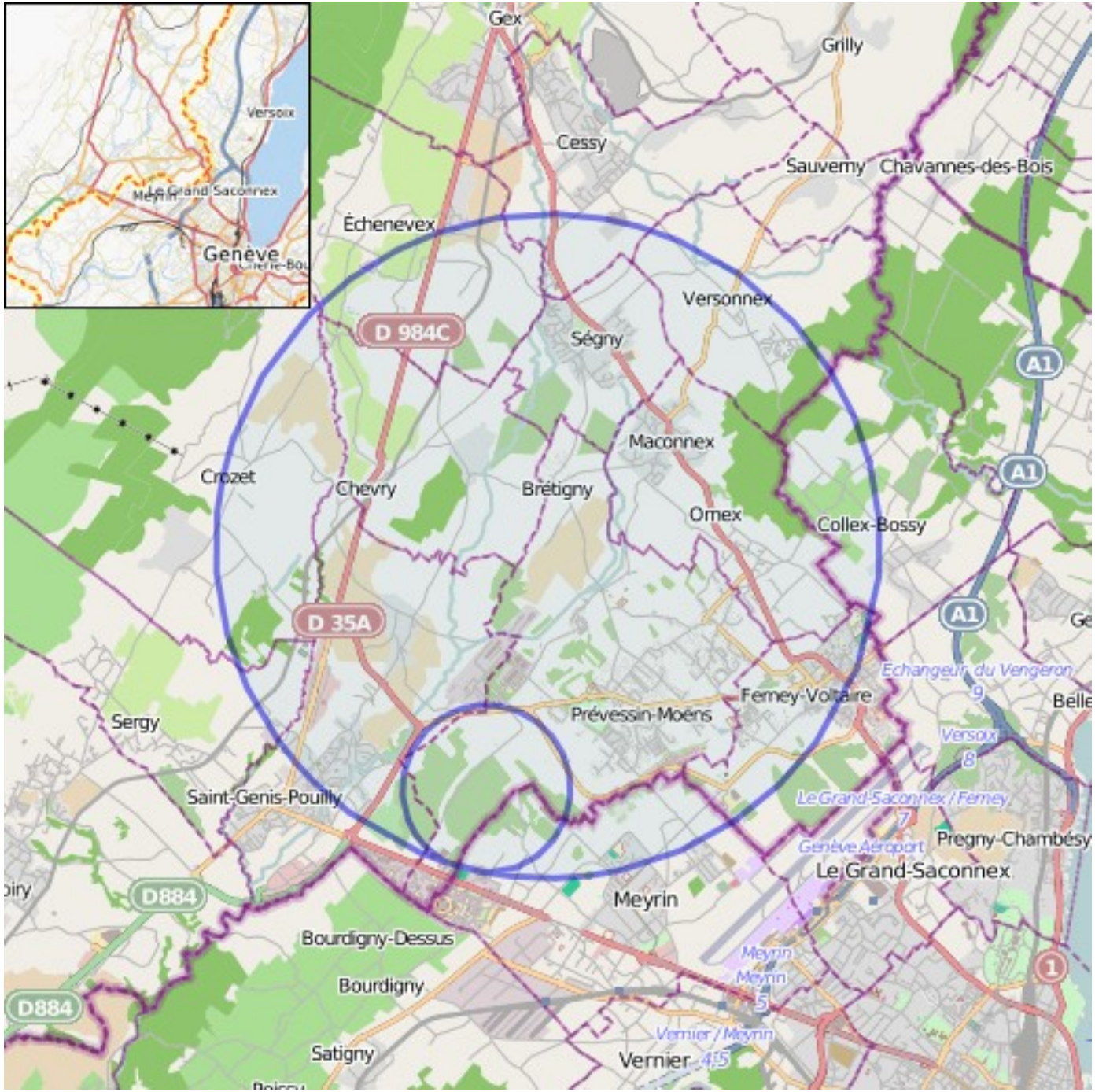
Outline

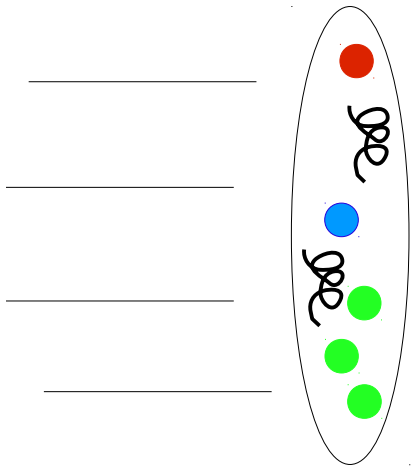
- Groundwork
  - Proton collisions
  - Jets
  - Compact Muon Solenoid
- Motivation for this Study
- Trigger
- Data, Background, and Signal
- Limits
- Systematic Uncertainty
- Conclusion

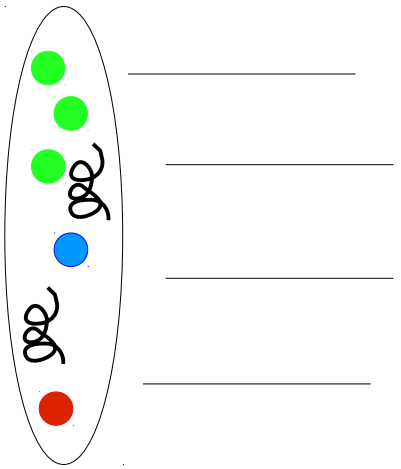
Motivation: The Large Hadron Collider

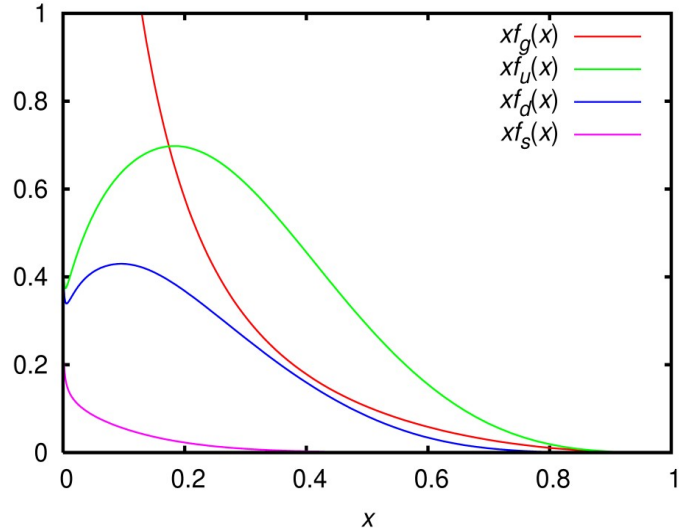


Groundwork

Any outgoing parton from a high-energy particle collision must be part of a color-neutral hadron. The process of making these nearly always produces many such hadrons, borrowing from the available energy and momentum.

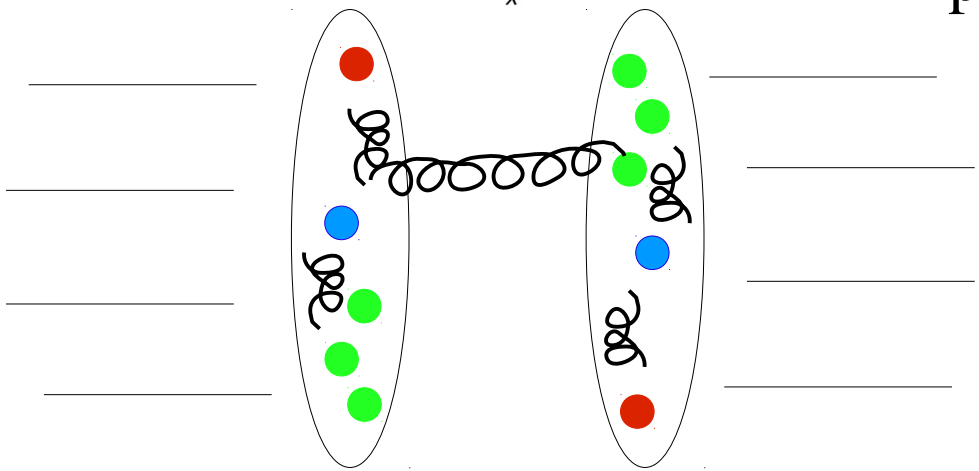






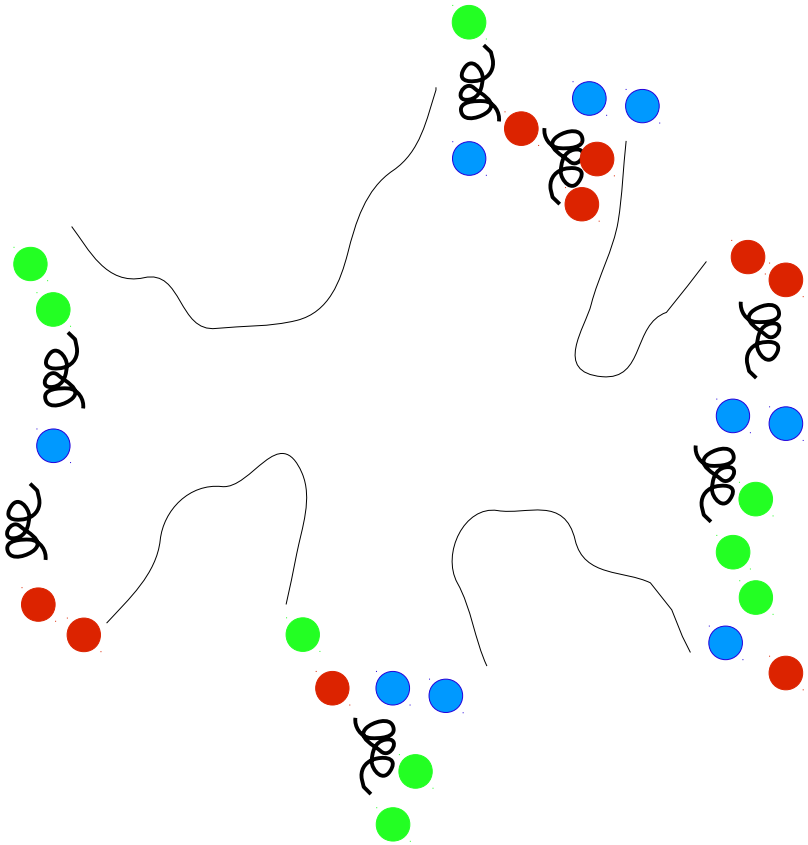
← Example PDF (CTEQ6 $\overline{\text{MS}}$ at Q^2=2GeV)

x: fraction of proton momentum



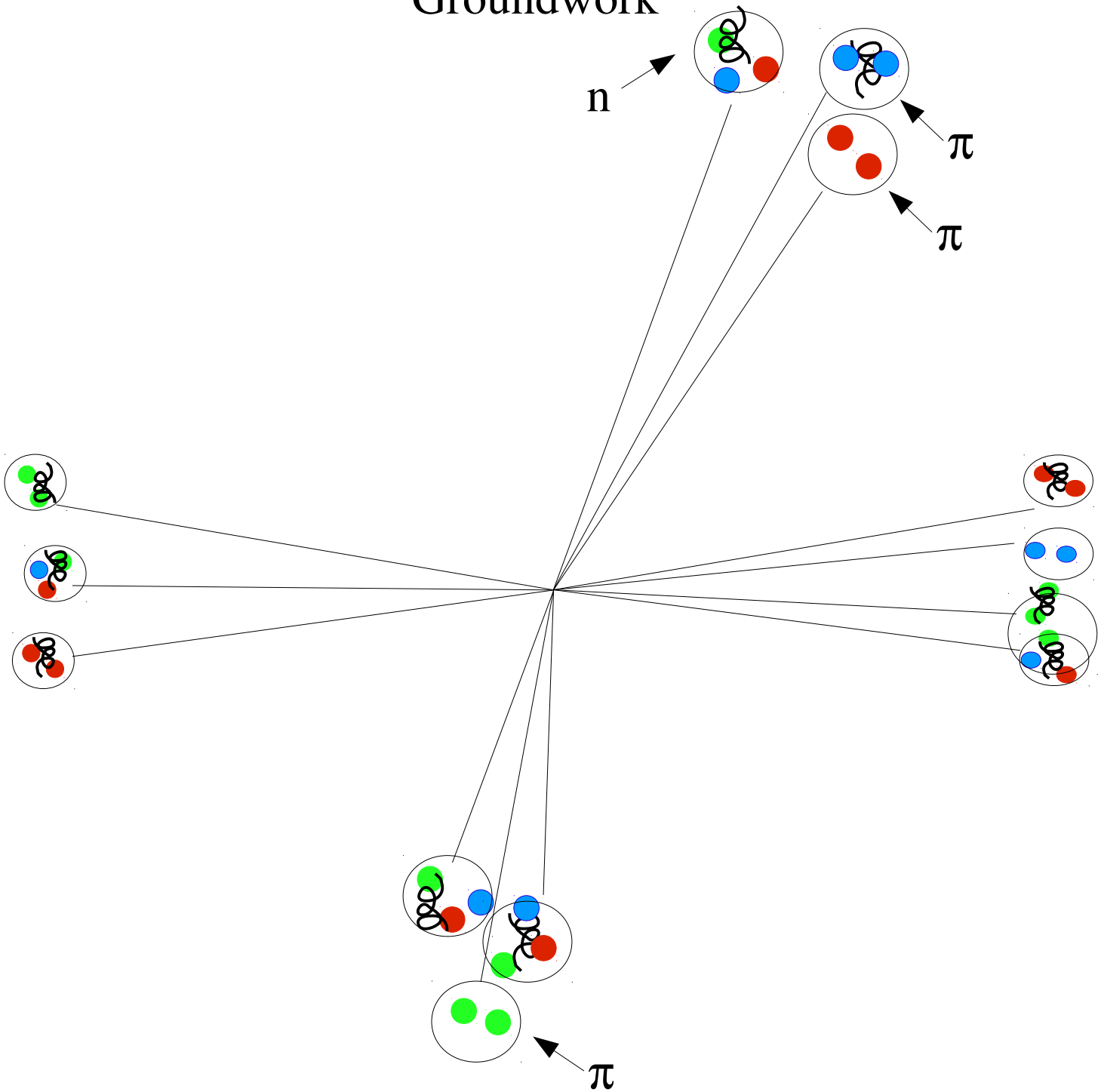
Collision momenta of the incoming partons are probabilistically determined, as summarized in the Parton Distribution Functions.

Groundwork



Color connections between partons (Lund model) store energy, which is realized in the final-state hadrons

Groundwork



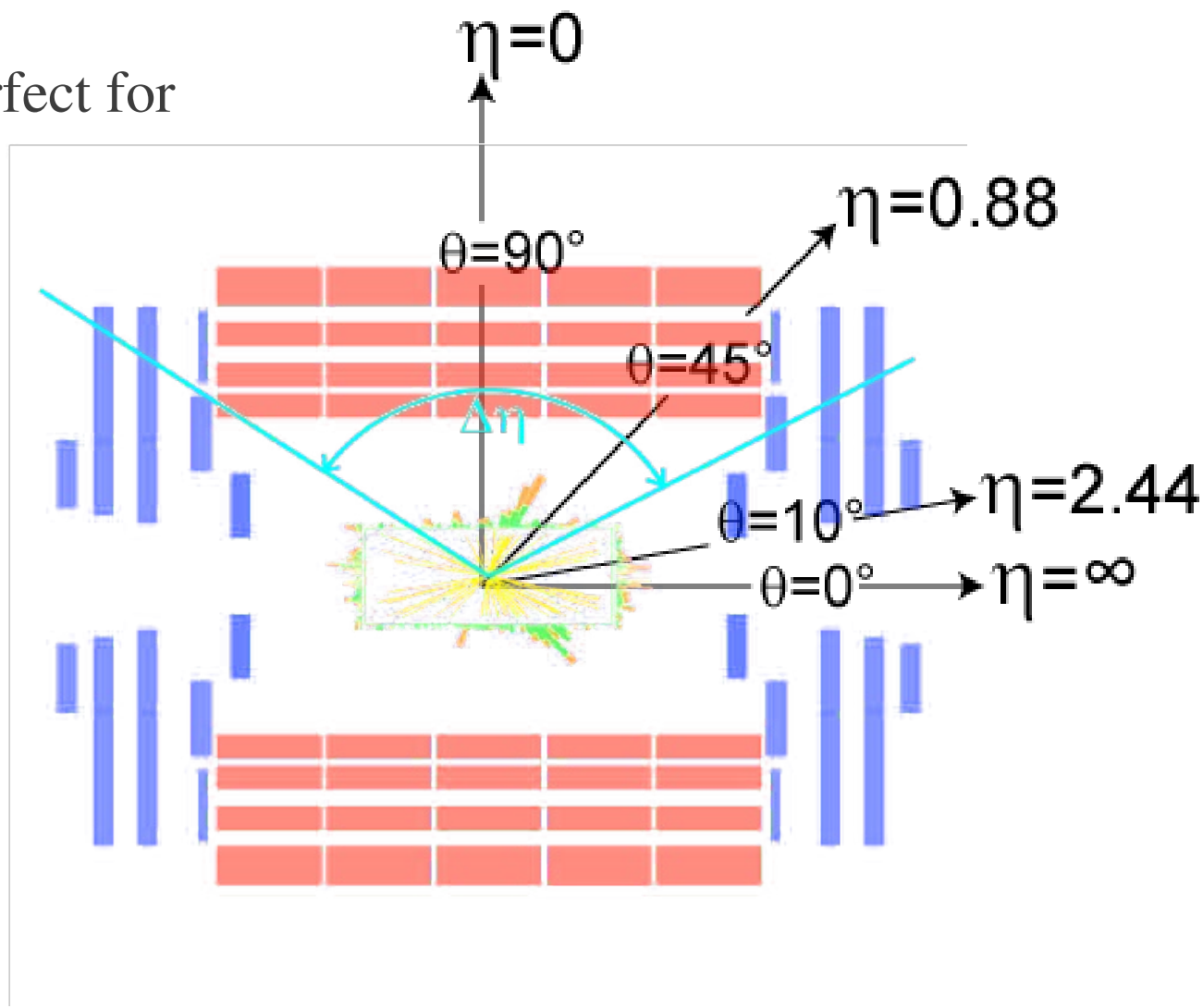
Orientation: Coordinates

$$y = \frac{1}{2} \ln\left(\frac{E + p_L}{E - p_L}\right)$$

Approximation $y \approx \eta$ is perfect for massless 4-vectors

$$\eta = \frac{1}{2} \ln\left(\frac{|\vec{p}| + p_L}{|\vec{p}| - p_L}\right)$$

$$\eta = -\ln\left(\tan\frac{\theta}{2}\right)$$



Orientation: Jet Algorithms

When is a jet a jet?

How about a jet-finding algorithm?

Input: Jet constituents (4-vectors)

Output: Jets

Pairwise combinations:

$$d = R^2$$

$$d_{ij} = (\Delta_{ij}\eta^2 + \Delta_{ij}\varphi^2)$$

Merge smallest d_{ij}, recalculate others.

When $d = R^2$ is the smallest distance in the list, you're done!

↑ "Cambridge-Aachen" ↑

This analysis uses anti-kT R=0.7 jets. (ak7)

Alternately, use p_T:

$$d_i = p_{T,i}^{-1} R^2$$

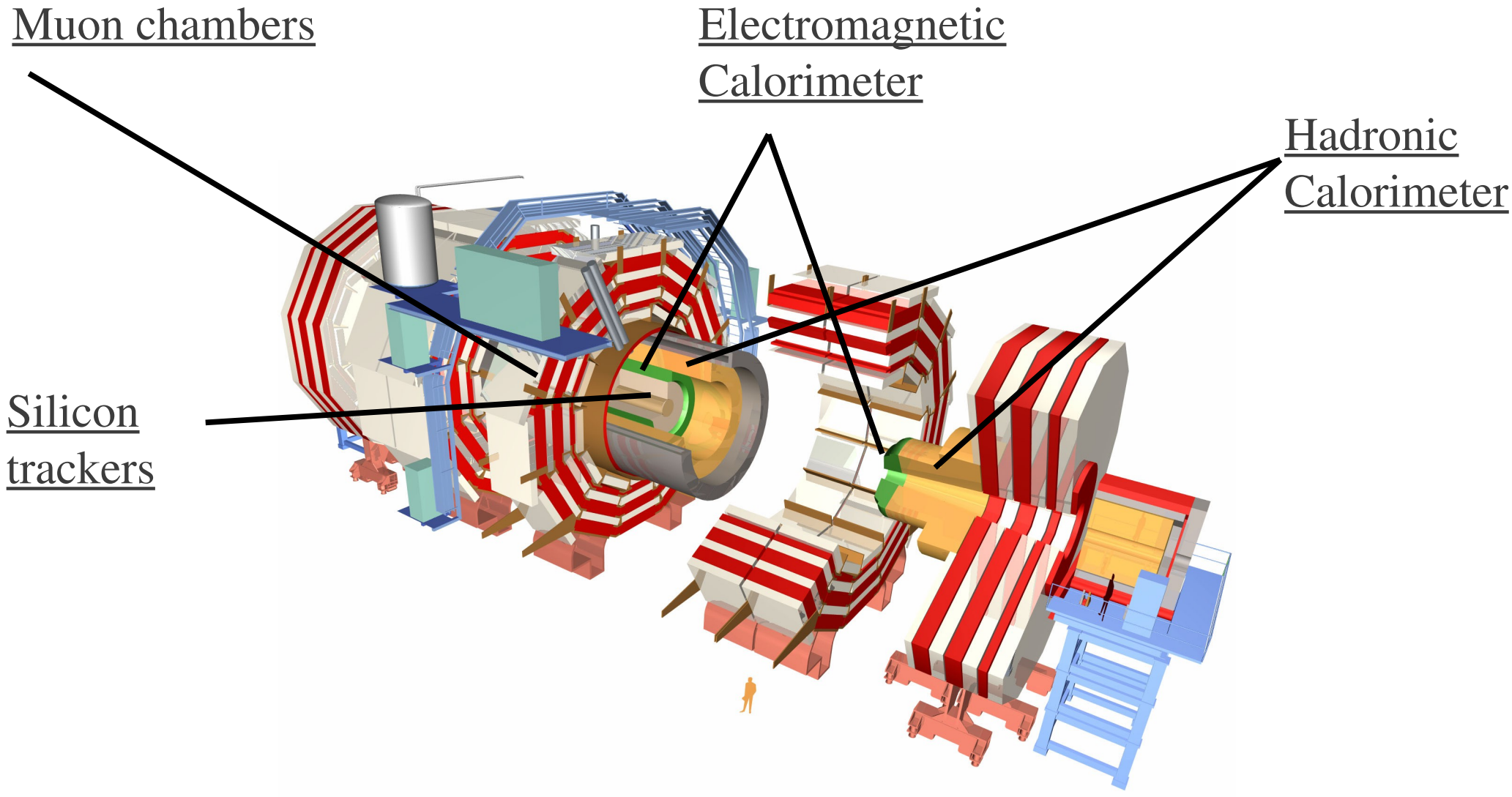
$$d_{ij} = \min(p_{T,i}^{-1}, p_{T,j}^{-1})(\Delta_{ij}\eta^2 + \Delta_{ij}\varphi^2)$$

Merge smallest d_{ij}, and recalculate others.

When d_i is the smallest distance in the list, that's a jet!

↑ "anti-kT" ↑

Orientation



Another place we can apply the jet algorithm

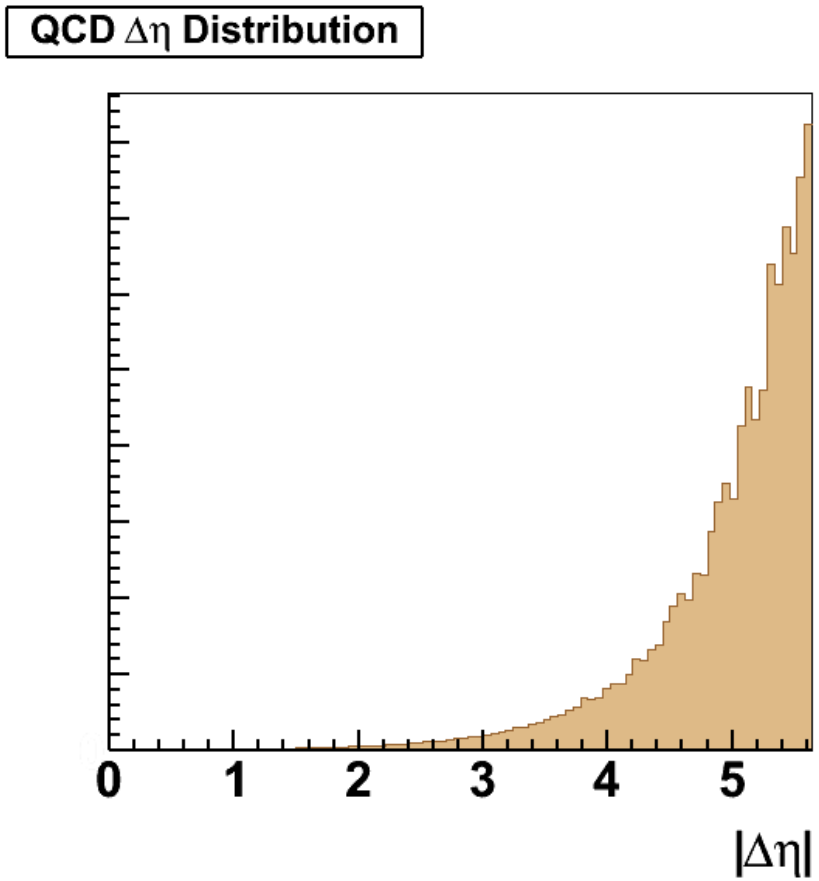
Motivation

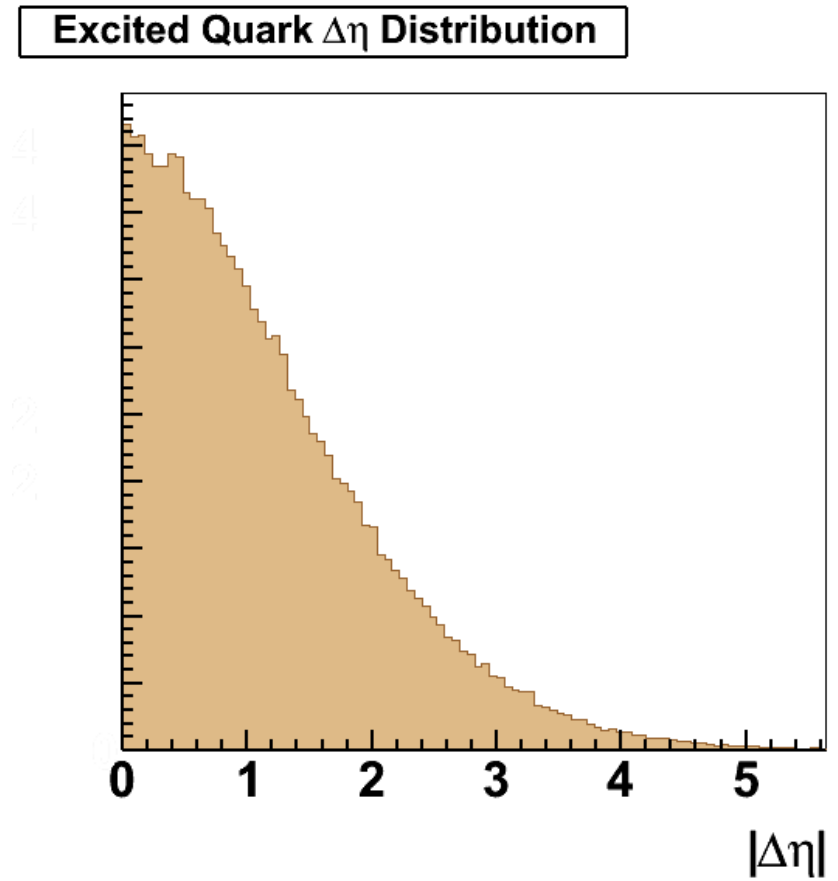
- We present the first search for dijet resonances at CMS using dijet angular information.
- CMS has published searches for dijet resonances using the dijet mass distribution.
  → Excluded an excited quark with mass < 2.49 TeV using 1 fb^{-1}
- Here we present a search for dijet resonances using 2.2 fb^{-1} and the dijet angular ratio.
  - A single number characterizing dijet angular distribution in a bin of dijet mass

$$R_{|\Delta\eta|} \equiv \left.\frac{N(|\Delta\eta| < 1.3)}{N(1.3<|\Delta\eta|<3.0)}\right|_{|\eta| < 2.5} = \frac{\#\ \text{inner}}{\#\ \text{outer}}$$

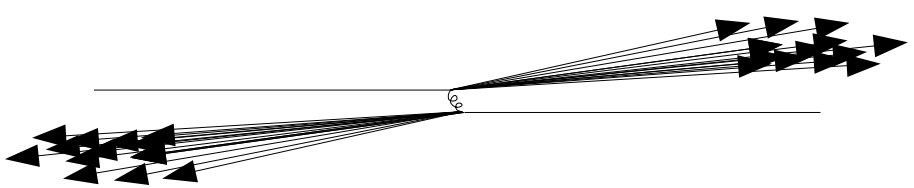
- Dijet resonances (s-channel) have a more isotropic angular distribution than QCD (predominantly forward). This gives large values for the dijet angular ratio above the QCD background.

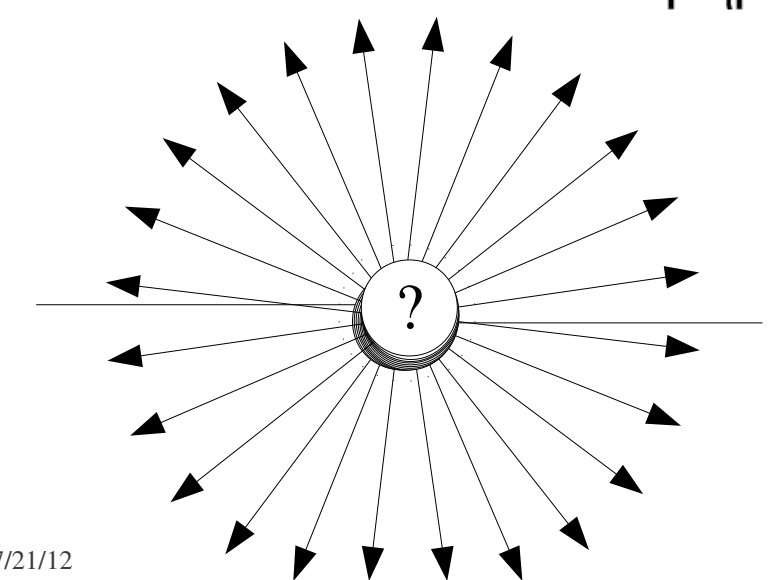
Motivation: Isotropy and |Δη|





Many events overlaid,
as in histogram

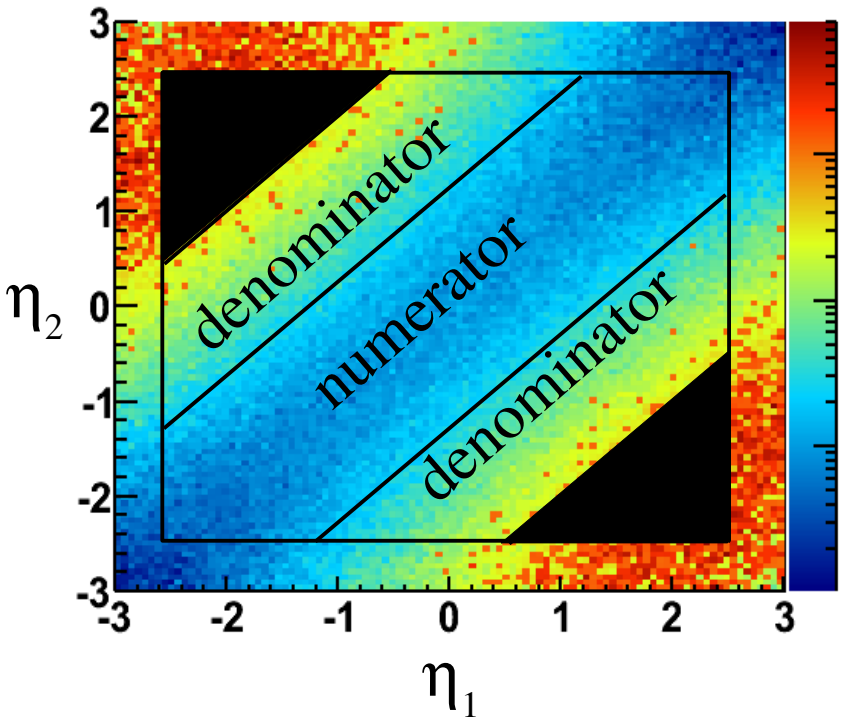




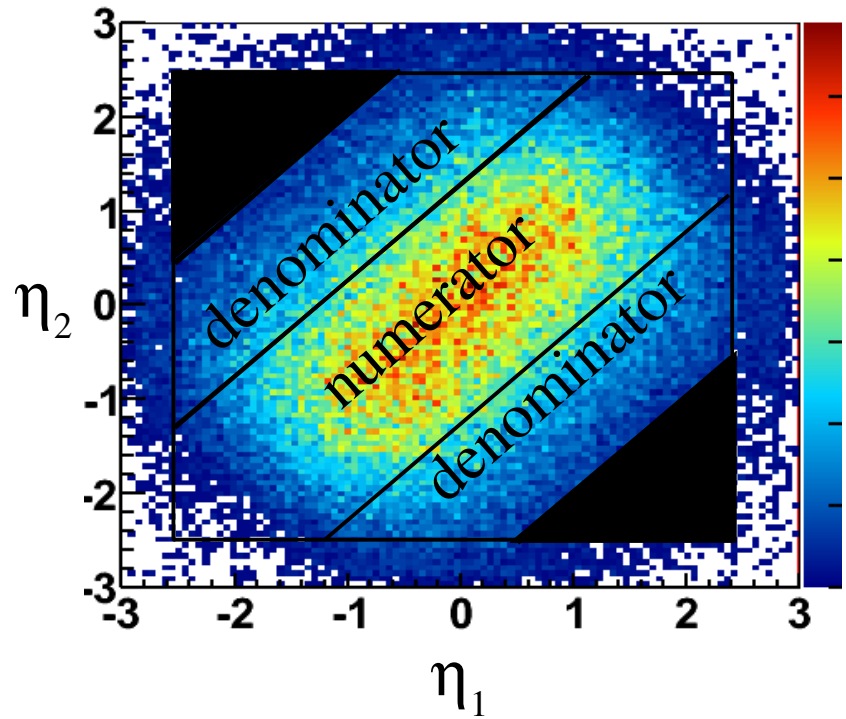
Motivation

A ratio of small-|Δη| events to larger-|Δη| events would rise at the mass of new resonance.
Some systematics cancel.

QCD



Excited Quark



Event Distributions in
η_1-η_2 plane

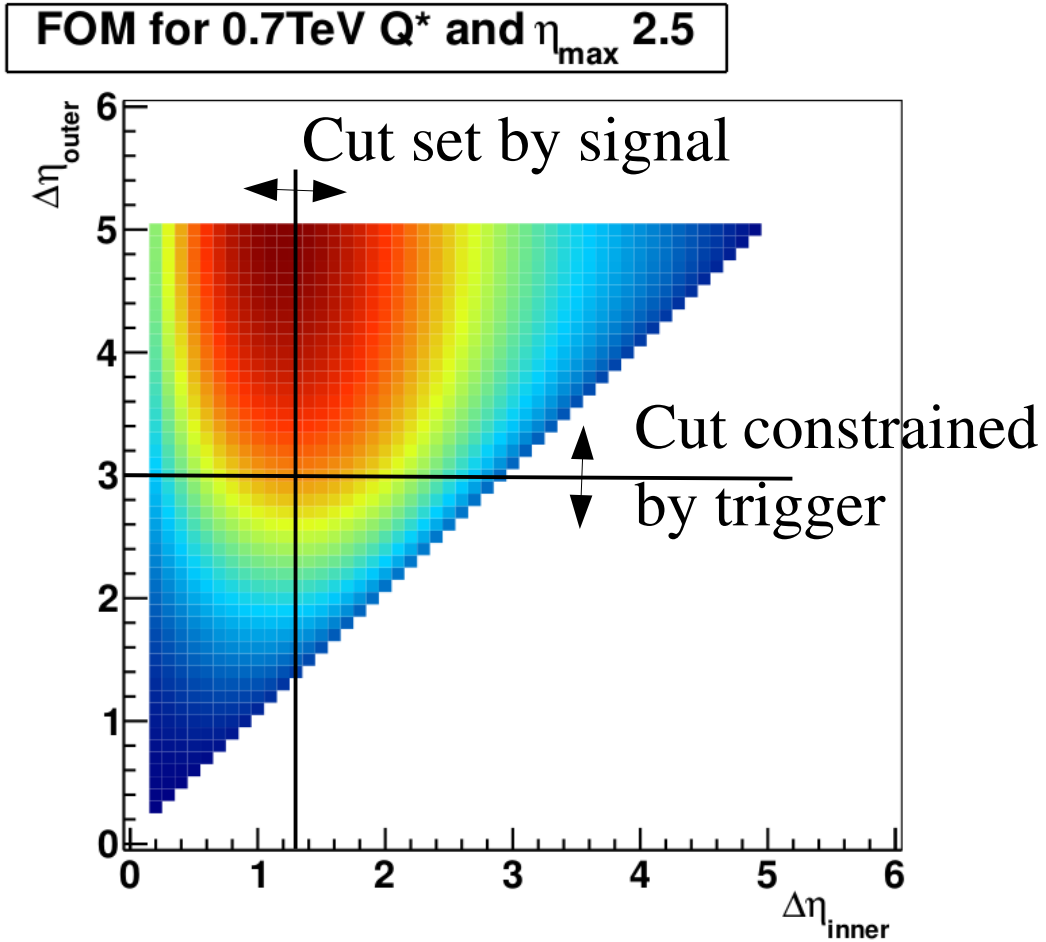
Cut Definitions

Estimate for sensitivity

$$\sum_{\text{bins}} \frac{R_{|\Delta\eta|}^{\text{QCD+Resonance}} - R_{|\Delta\eta|}^{\text{QCD}}}{\sigma^{\text{QCD}}}$$

by varying $|\Delta\eta|_{\text{inner}}$, $|\Delta\eta|_{\text{outer}}$

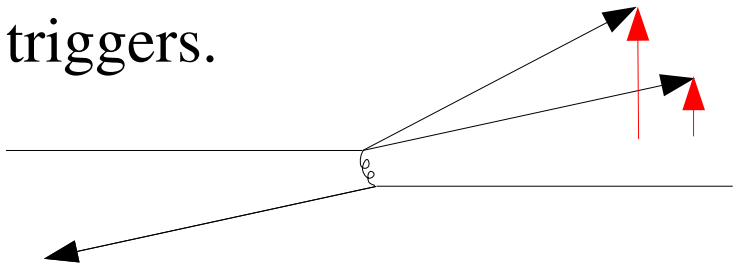
Max $|\Delta\eta|_{\text{outer}}$ required to keep some trigger efficiency



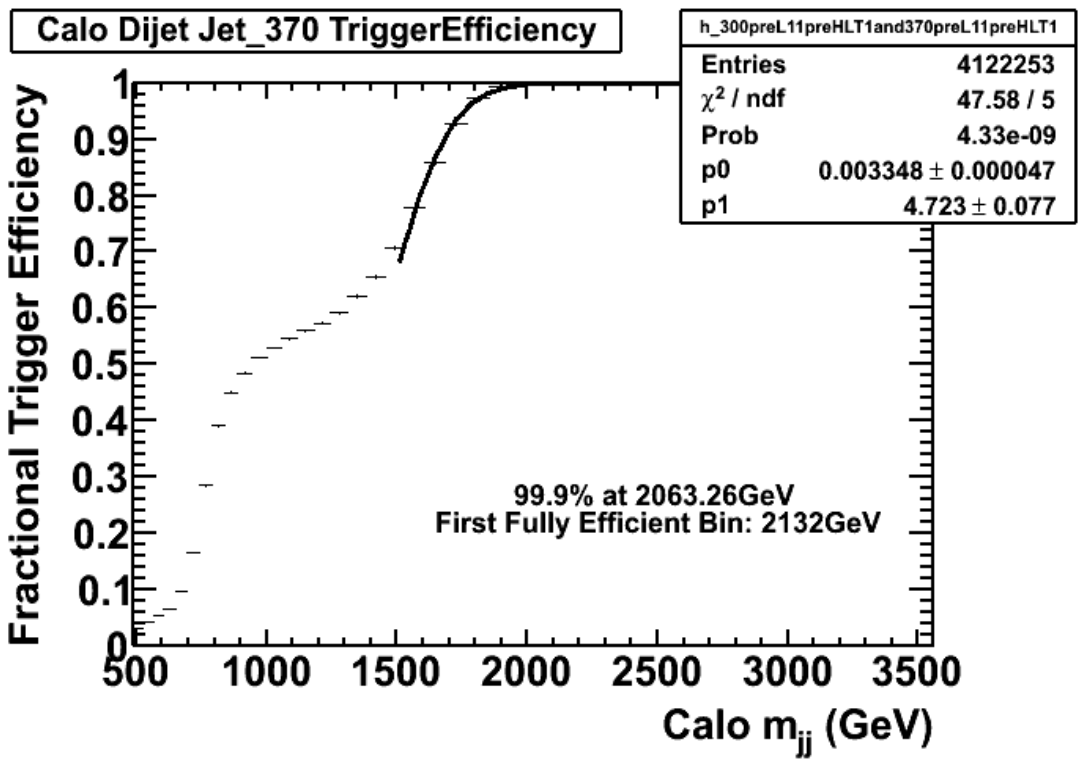
$$R_{|\Delta\eta|} \equiv \left.\frac{N(|\Delta\eta| < 1.3)}{N(1.3<|\Delta\eta|<3.0)}\right|_{|\eta| < 2.5} = \frac{\#\text{ inner}}{\#\text{ outer}}$$

Jet Trigger Usage

Large-|Δη| events have low efficiency for jet p_T triggers.



Accept events only when trigger is >99.9% efficient at the dijet mass.



Jet p_T Trigger	Fully efficient Bin bound m_{jj} (GeV)
HLT_Jet370	2037
HLT_Jet300	1687
HLT_Jet240	1313
HLT_Jet180U	1313
HLT_Jet190	1118
HLT_Jet140U	1058
HLT_Jet100U	838
HLT_Jet150	788
HLT_Jet70U	649
HLT_Jet110	565
HLT_Jet80	526
HLT_Jet50U	453
HLT_Jet60	386

Data Usage

We cluster calorimeter energy with the anti-kT algorithm ("ak7 calojets (loose ID)")

- Check result with ak7 ParticleFlow jets and tight ID
- We use calojets for their better trigger turn-ons

Apply Jet Energy Corrections:

Subtract noise, correct for η-dependence, correct for p_T dependence, correct for instantaneous luminosity

Event selection:

CMS-certified good data from 2010 -2011 (First 2.2 ± 0.1 fb^{-1})

Dijets are inclusive; Two leading jets in p_T

Require both $|\eta| < 2.5$

Require both jets to pass jet quality (jet ID)

Require vertex to be of good quality, and $|z| < 24$cm

Measure the dijet angular ratio $R_{|\Delta\eta|}$

Data: 2.2 fb^{-1}

CMS Runs & Datasets

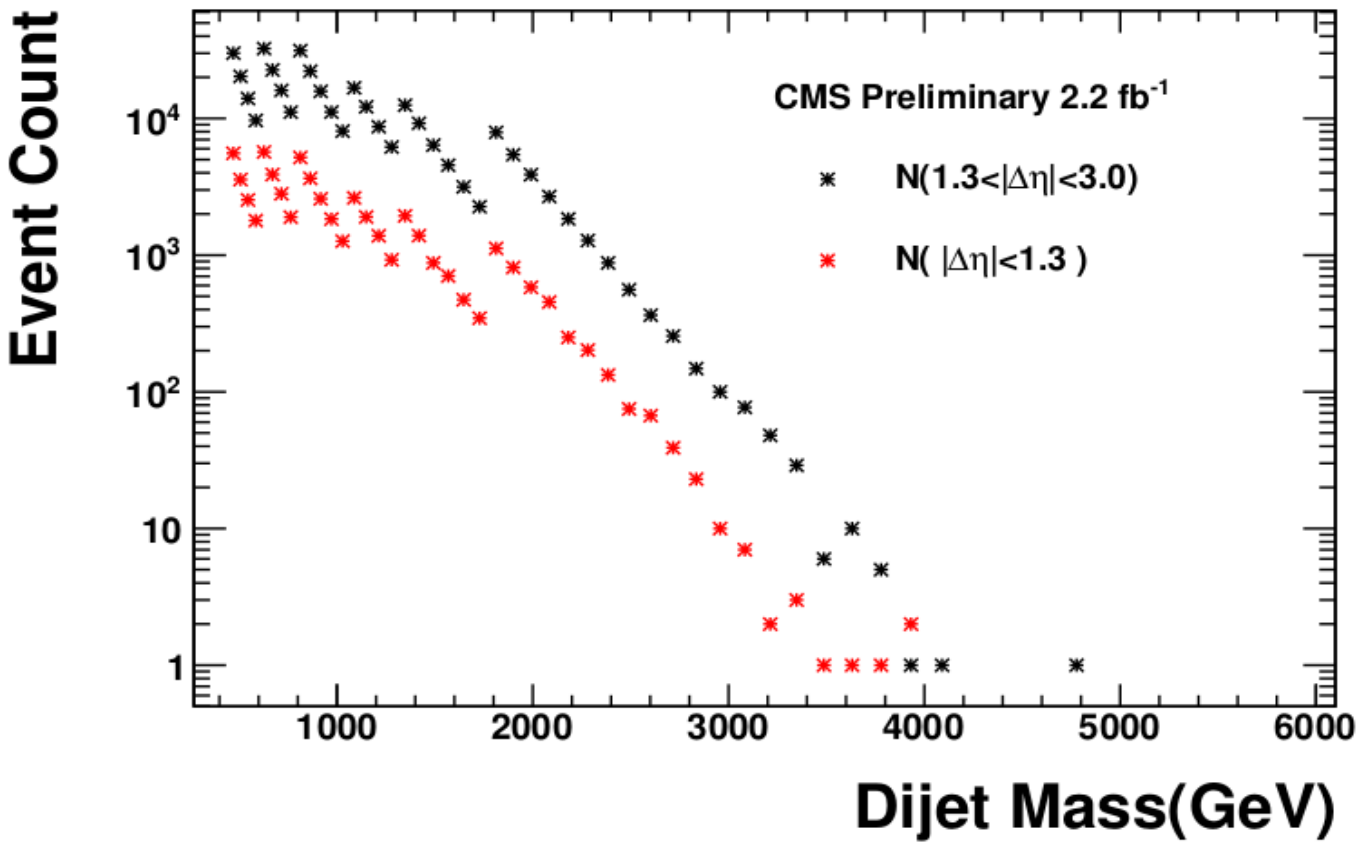
(136033-141949) /JetMETTau/Run2010A-Apr21ReReco-v1/AOD
(141950-145761) /JetMET/Run2010A-Apr21ReReco-v1/AOD
(145762-149442) /Jet/Run2010B-Apr21ReReco-v1/AOD
(160404-163869) /Jet/Run2011A-May10ReReco-v1/AOD
(165088-168437) /Jet/Run2011A-PromptReco-v4/AOD
(170053-172619) /Jet/Run2011A-PromptReco-v5/AOD
(172620-173692) /Jet/Run2011A-PromptReco-v6/AOD

JSON @ https://cms-service-dqm.web.cern.ch/cms-service-dqm/CAF/certification/Collisions11/7TeV/Prompt/
(136033-149442)
Cert_136033149442_7TeV_Apr21ReReco_Collisions10_JSON.txt
(160404-163869)
Cert_160404-163869_7TeV_May10ReReco_Collisions11_JSON_v3.txt
(165088-173692)
Cert_160404-173692_7TeV_PromptReco_Collisions11_JSON.txt

Data

The numerator and denominator event counts:

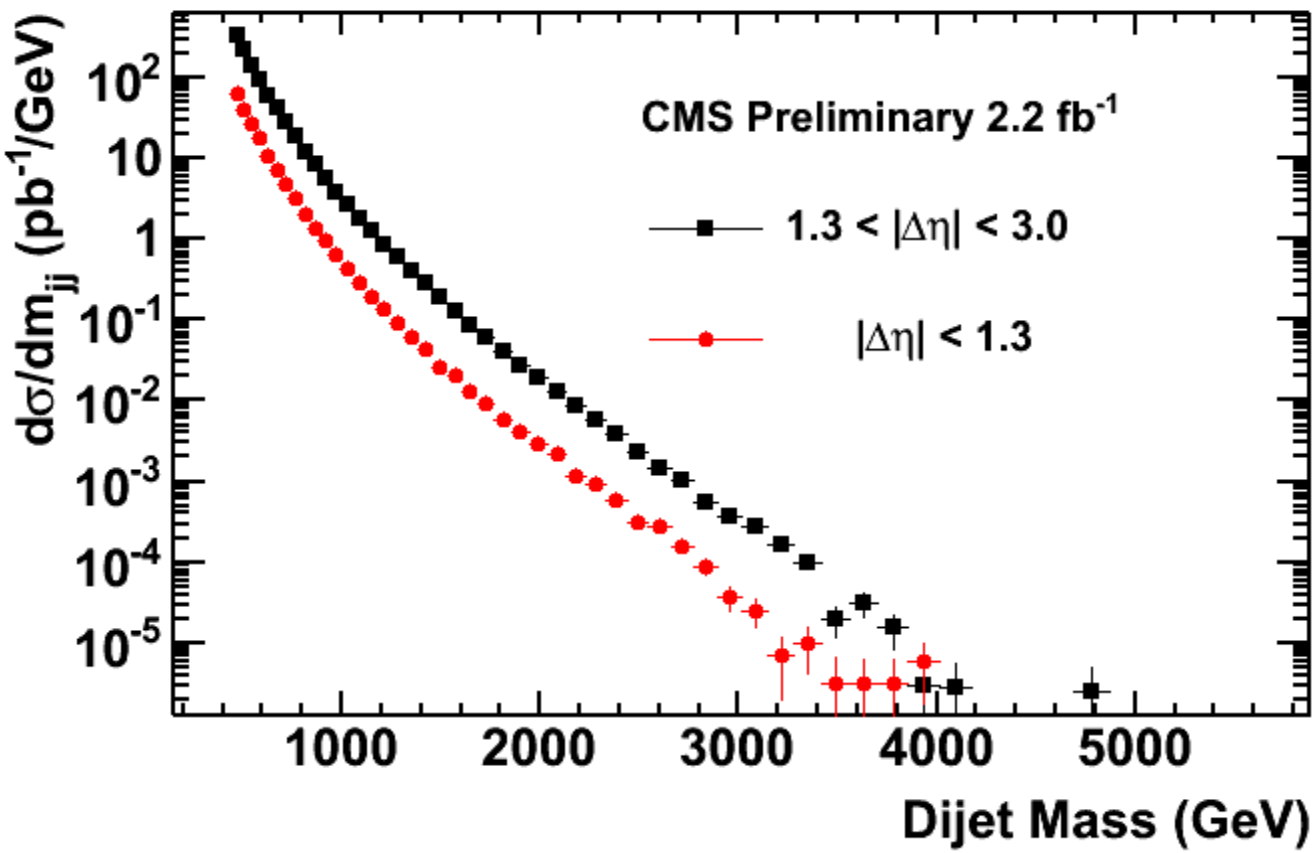
(inner) (outer)



There are more **outer** dijets than **inner** dijets, as expected.

Data

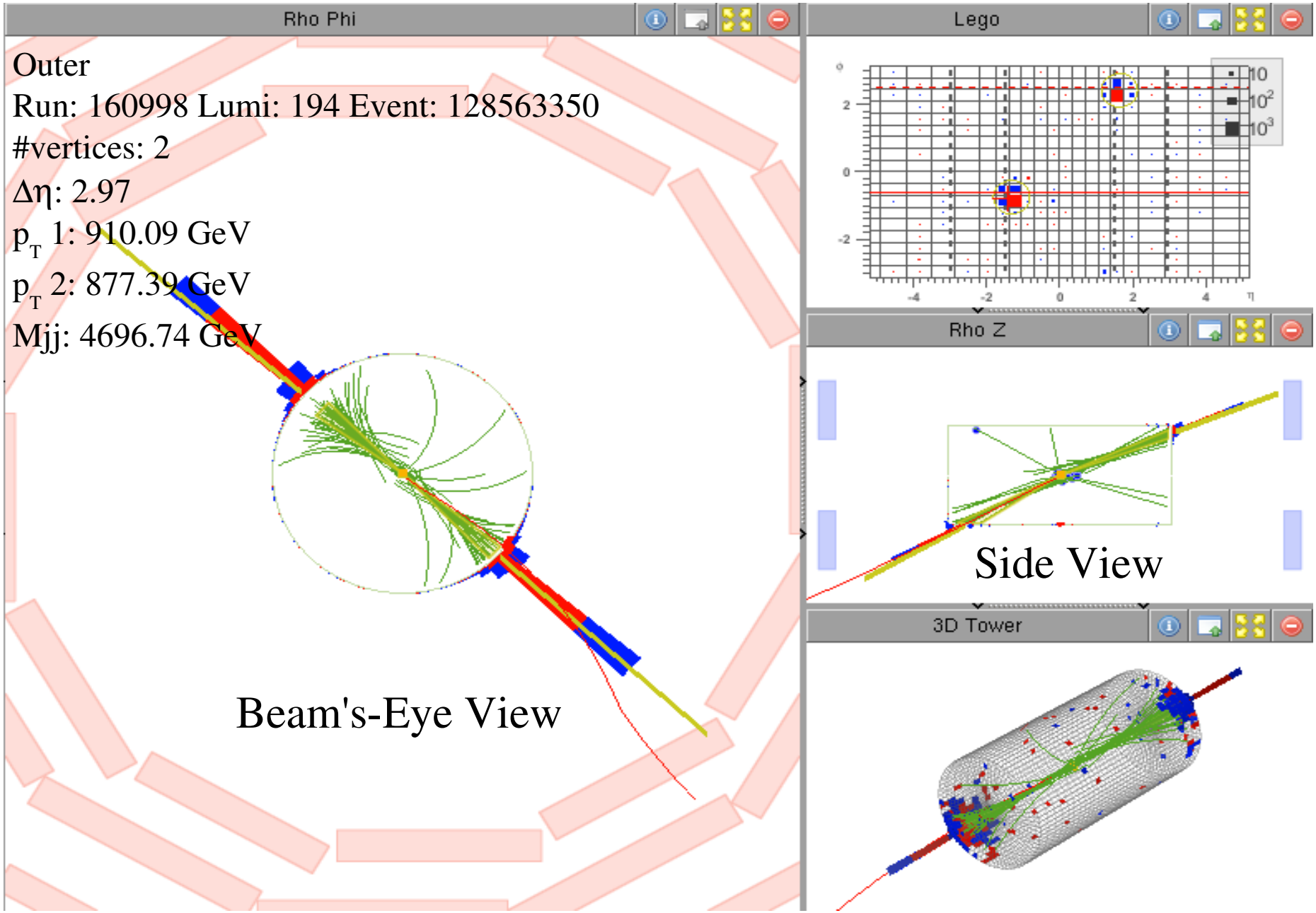
The numerator and denominator differential cross sections:
(inner) (outer)



There are more **outer** dijets than **inner** dijets, as expected.

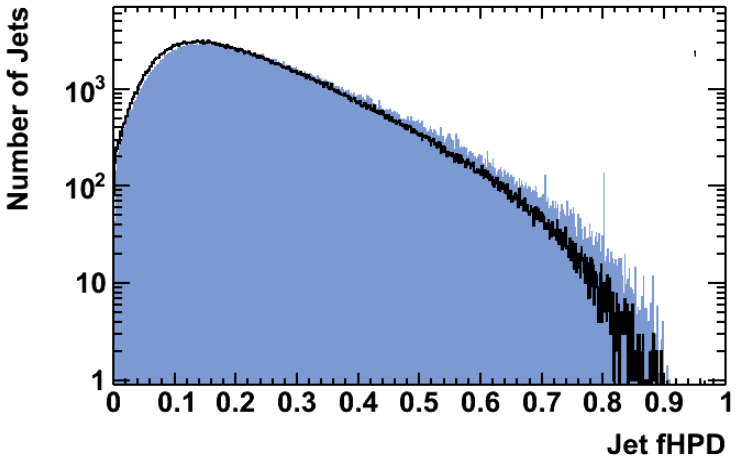
Highest Mass Event

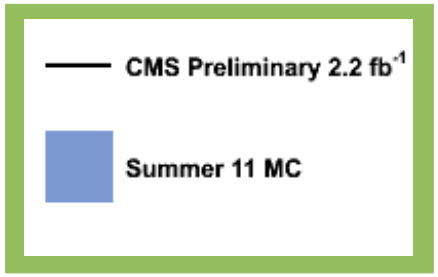
Scanned and investigated high-mass events. Look like good dijets.

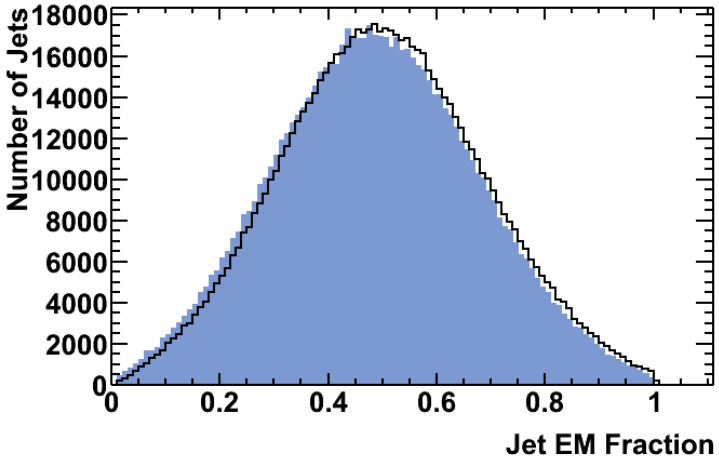


Data: Jet ID Variables

Our jets' fractional energy in a single HCAL HPD is smoothly distributed.
Jet-ID requires fHPD < 0.98

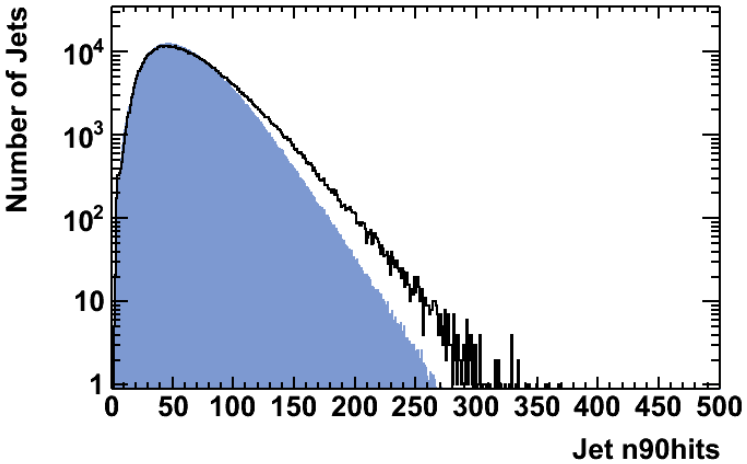




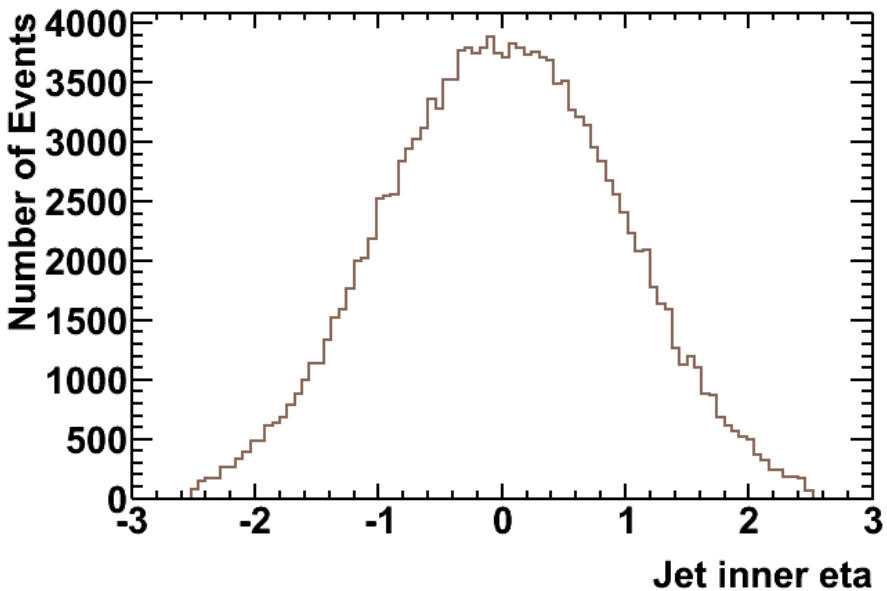


Our jets' electromagnetic fraction is smoothly distributed.
Jet-ID requires EMF > 0.01

Our jets' minimum hit count composing 90% of energy is also smoothly distributed.
Jet-ID requires n90hits > 1

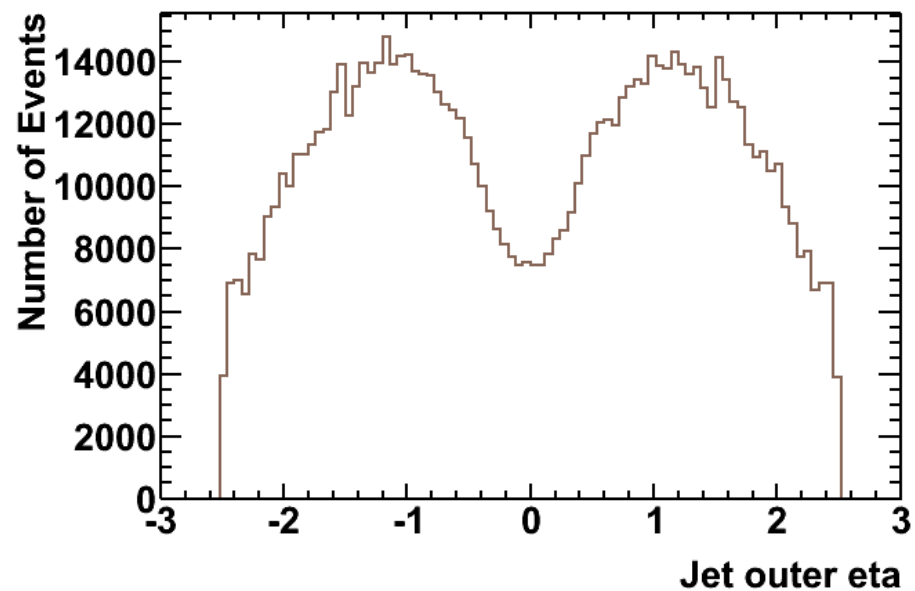


Data: Jet Properties



Jets from Inner Dijets

$|\Delta\eta| < 1.3$



Jets from Outer Dijets

$1.3 < |\Delta\eta| < 3.0$

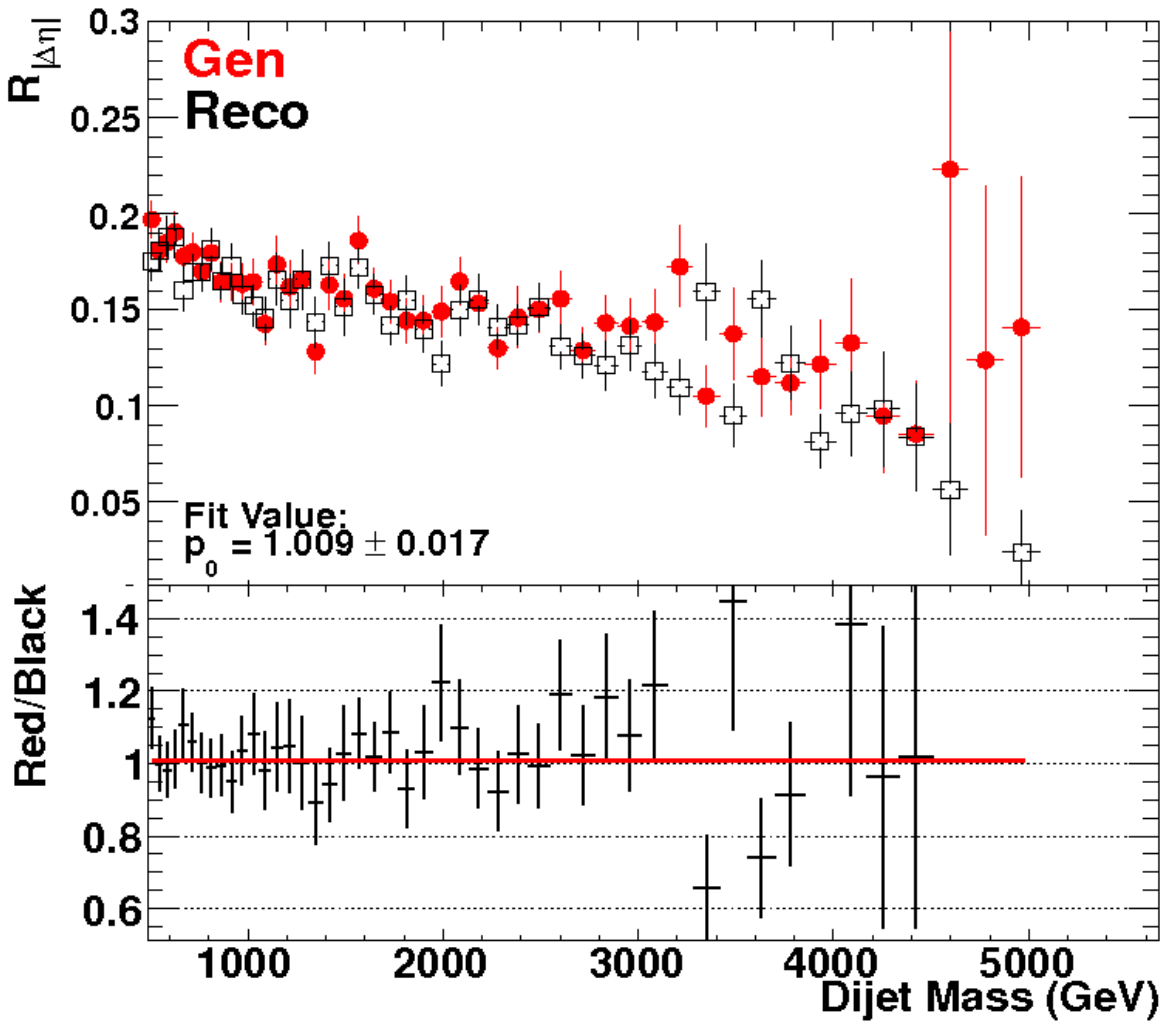
Our jets' η distributions look like healthy CMS jet η distributions.

Background Expectations

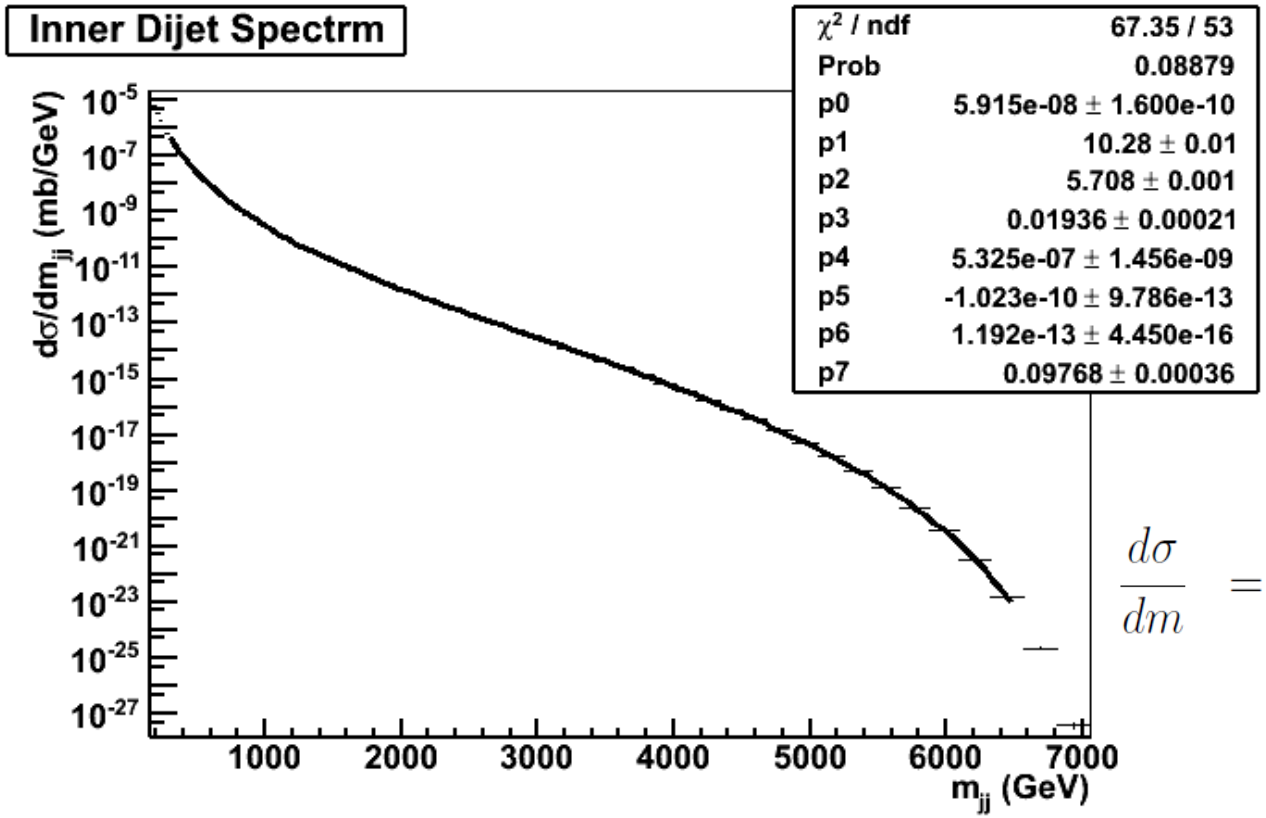
Simulated effect of detector in MC consistent with zero.

Encourages us to take gen-level predictions of the angular ratio more seriously.

We can make high-stats predictions of gen-level PYTHIA.

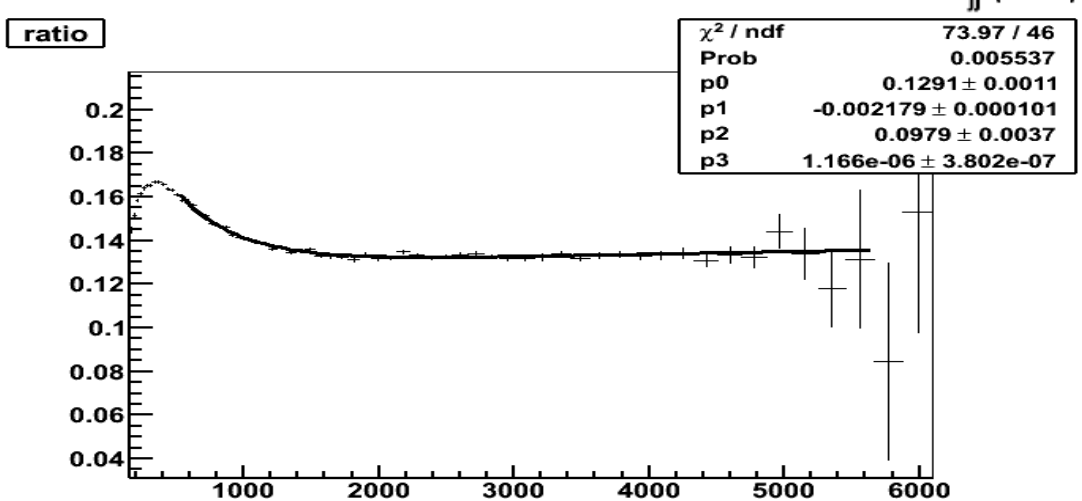


Background Expectations (cont'd)



Sample:
>1e9 events
gen-level
PYTHIA6 D6T

$$\frac{d\sigma}{dm} = \frac{p_0(1-y+p_3y^2)^{p_1}}{y^{-p_2-p_4\ln y}}(p_5+p_6m_{jj}+p_7m_{jj}^2)$$



Fit $R_{|\Delta\eta|}$ with
Exponential + linear.

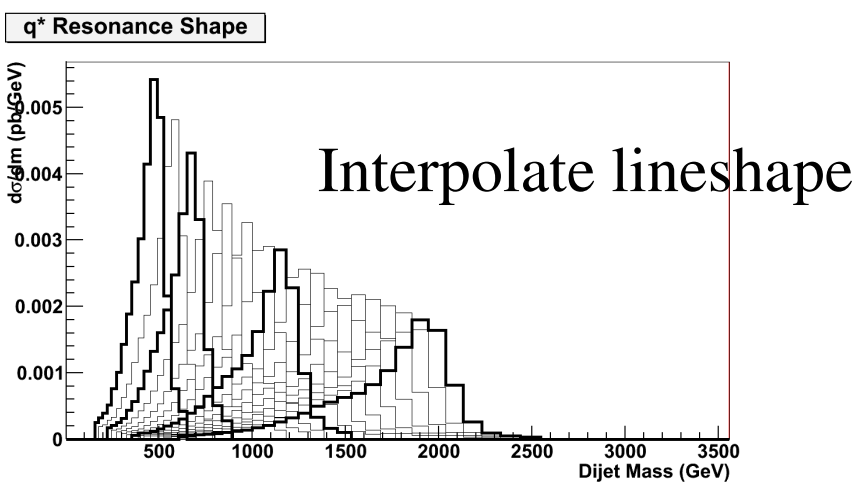
Signal Expectations

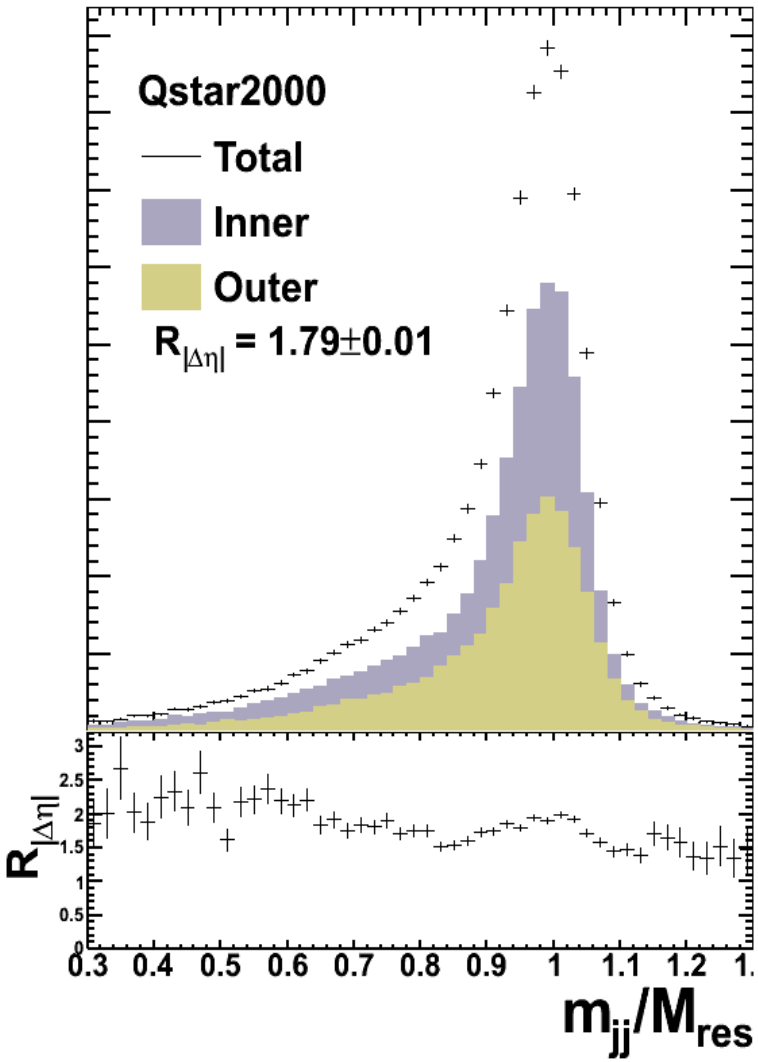
Modeling the Dijet Angular Ratio in the presence of a resonant signal

We can approximate lineshape to be the same in inner & outer events. The two lineshapes are taken from MC predictions.

- Add resonance and QCD cross sections before taking ratio.
- Only allow signal modeling

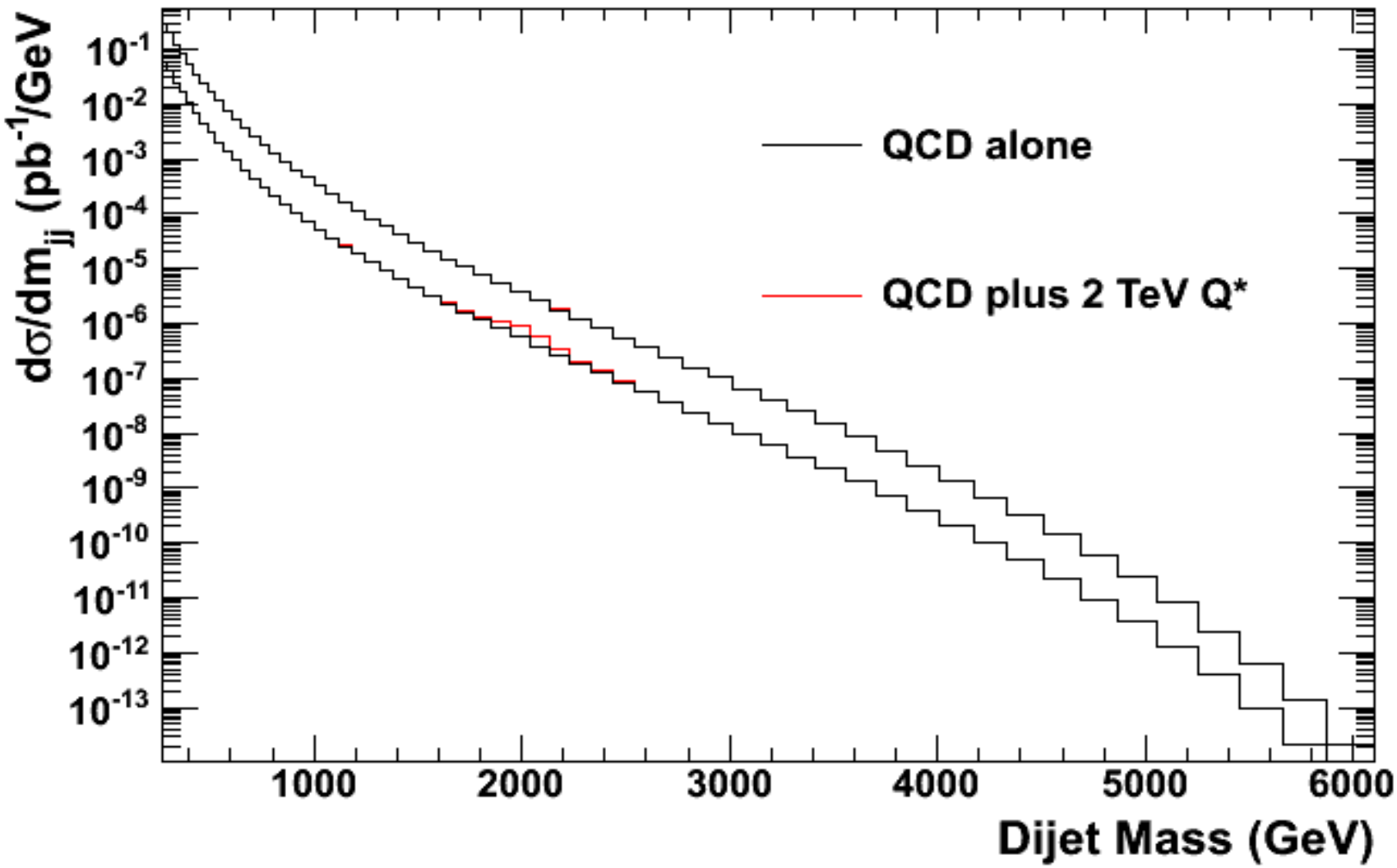
$$0.3M_{res} < m_{jj} < 1.3M_{res}$$





Signal Expectations

Modeling the Dijet Angular Ratio in the presence of a resonant signal.
Signal is present, but not obvious.

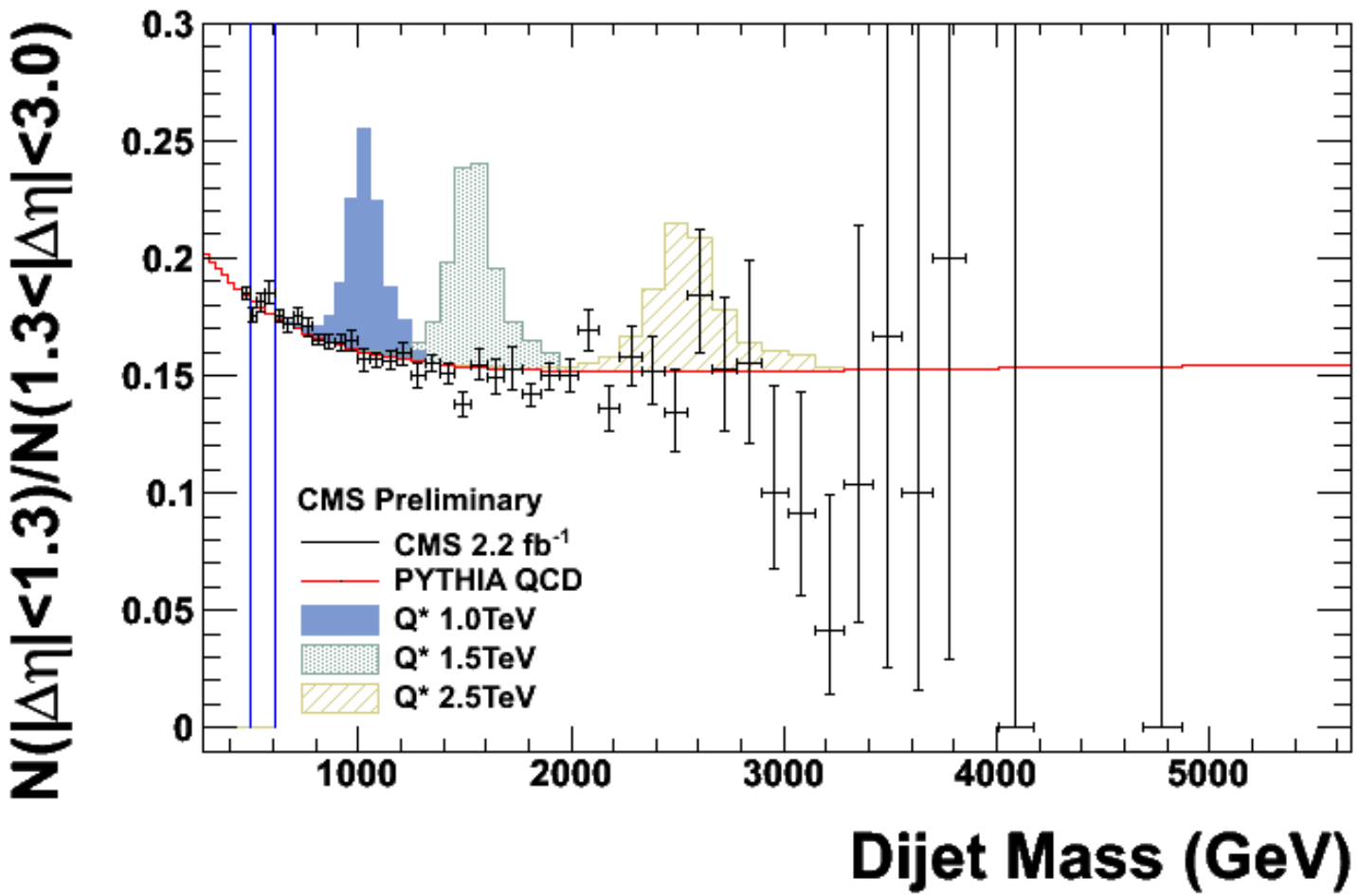


Measured $R_{|\Delta\eta|}$ and Expectations

Measured dijet angular ratio is fairly flat vs dijet mass, in good agreement with PYTHIA prediction + additive normalization 0.019 ± 0.0019 from sideband (489-606 GeV)

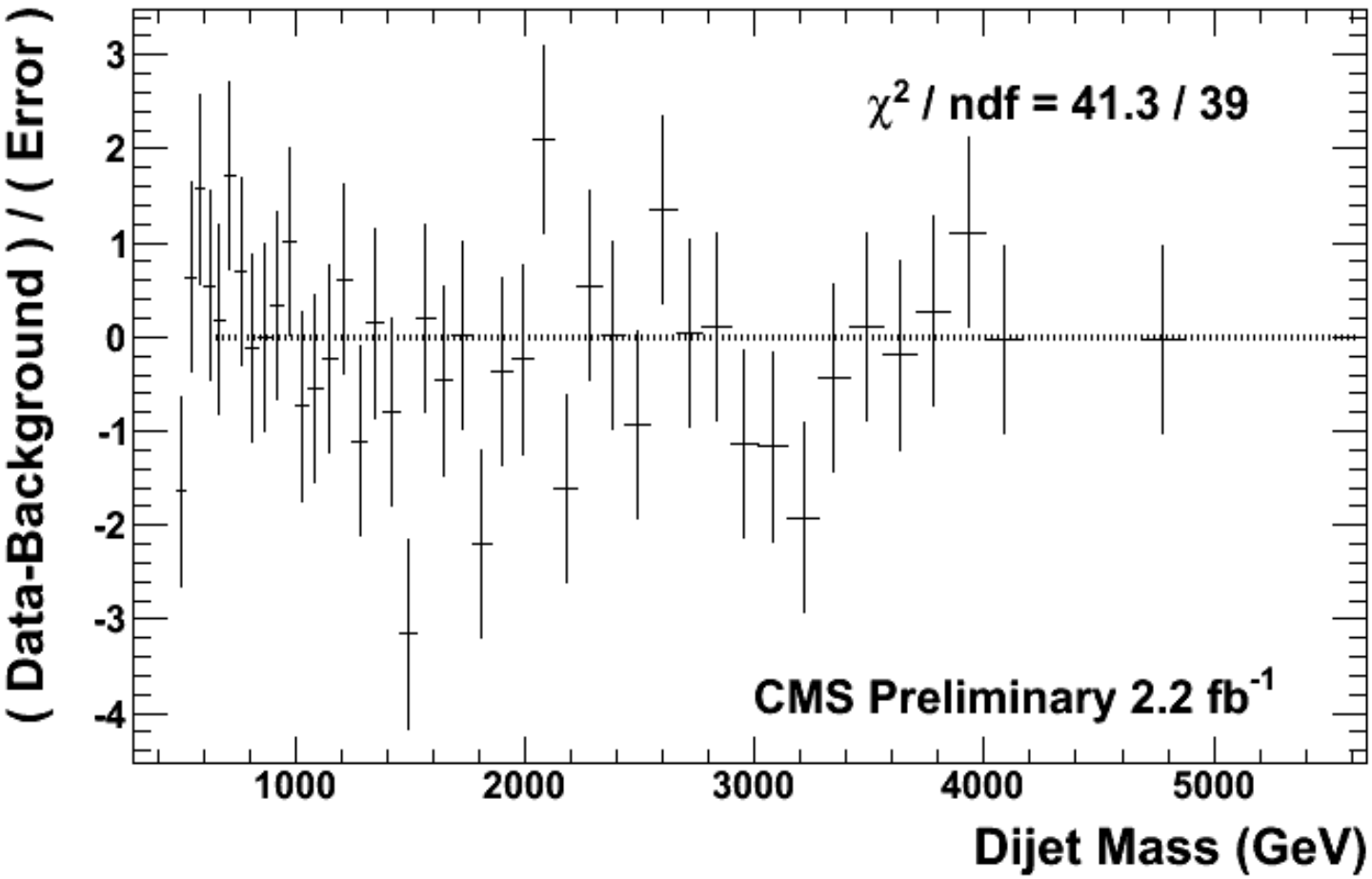
There is no evidence for new physics.

Excited quarks from PYTHIA would give excludable peaks up to ~3TeV



PYTHIA QCD Prediction Fits Data

Largest upward fluctuation, at 2TeV, is ~2σ (local significance).
No evidence for new physics.



Downward fluctuation near 3TeV

- Also in Dijet Angular Distribution EXO-11-017

- Will improve our limit slightly with respect to expectation.

Limit-Setting Procedure

- For any data or MC measurement of R:

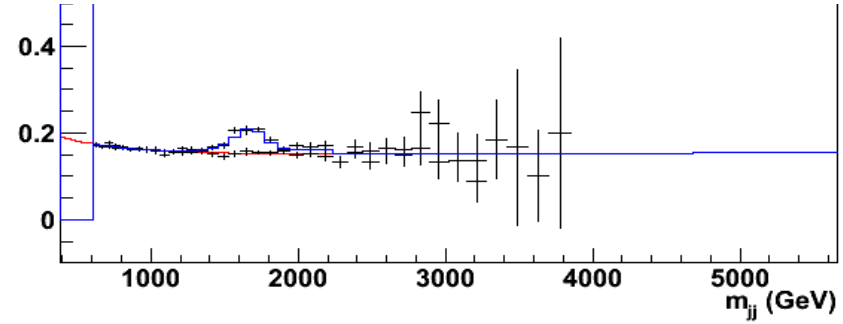
One number (another ratio!)

Likelihood it's QCD + Resonance

over

Likelihood it's QCD

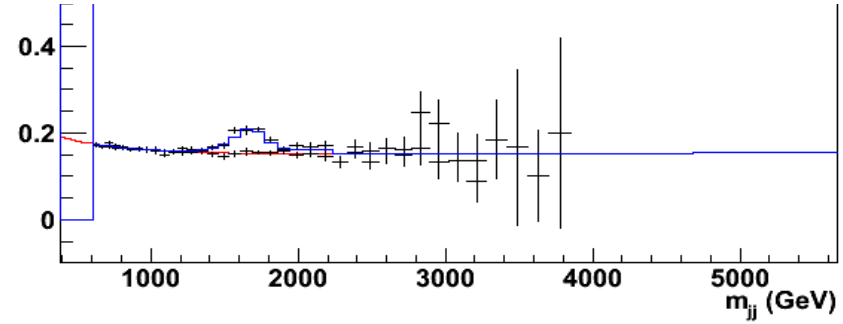
$$R_{LL} = \ln(\mathscr{L}_{QCD+Res} / \mathscr{L}_{QCD})$$



$$\mathscr{L} = \prod \text{Binom}(R_i \mid \mu_i, \text{tot})$$

where R_i is measured, μ_i is expected.

Limit-Setting Procedure



- For any data or MC measurement of R:

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Likelihood it's QCD + Resonance

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Likelihood it's QCD

$$R_{LL} = \ln(\mathscr{L}_{QCD+Res} / \mathscr{L}_{QCD})$$

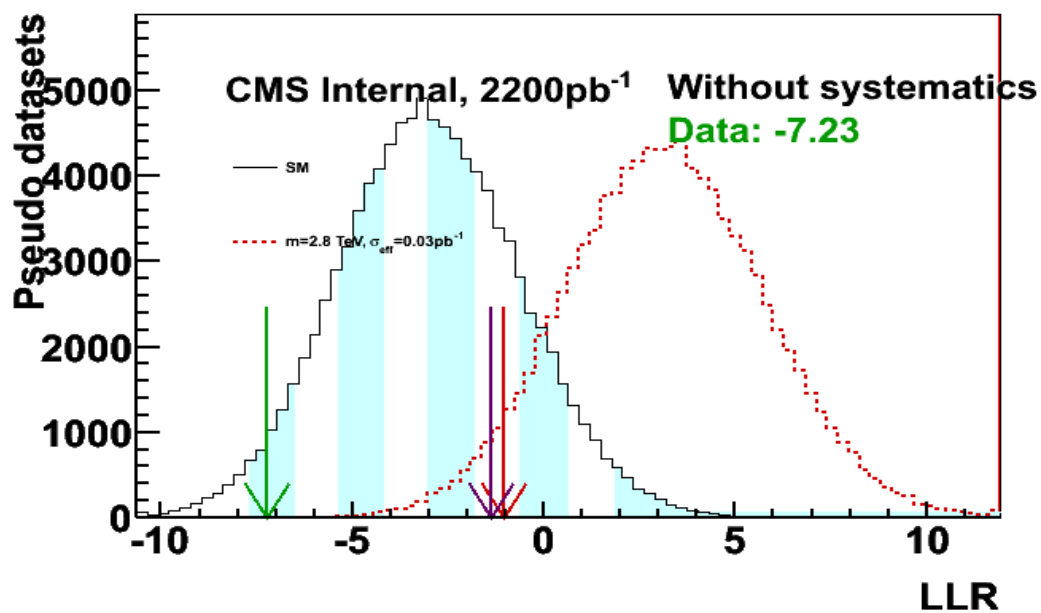
$$\mathscr{L} = \prod \text{Binom}(n_{inner,\,i} \mid n_{total,\,i}, \rho_i)$$

where R_i is measured, ρ_i is expected.

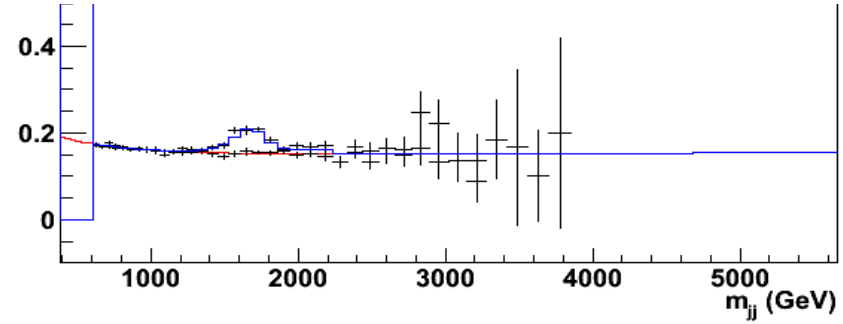
- Make 100k pseudo datasets (QCD, and QCD+Res) at each mass, cross section combination

These distributions compare

- R_{LL}^{data} (green)
- $R_{LL}^{95\%\ CLs\ exclusion}$ (purple)
- $R_{LL}^{95\%\ S+B}$ Quantile (red)



Limit-Setting Procedure



- For any data or MC measurement of R:

One number:

Likelihood it's QCD + Resonance

over

Likelihood it's QCD

$$R_{LL} = \ln(\mathscr{L}_{QCD+Res} / \mathscr{L}_{QCD})$$

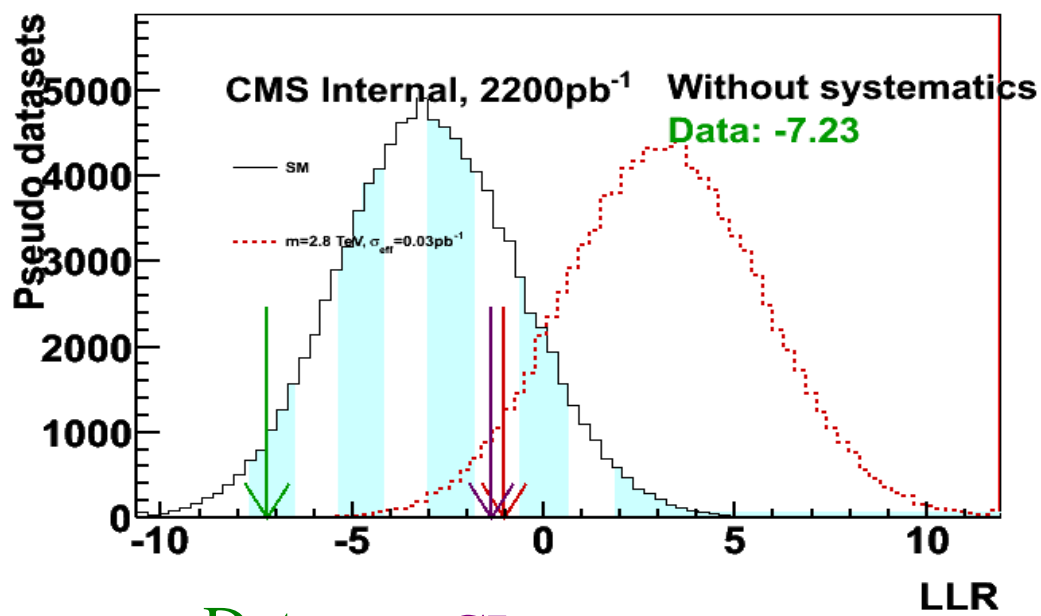
$$\mathscr{L} = \prod \text{Binom}(n_{inner,\,i} \mid n_{total,\,i}, \rho_i)$$

where R_i is measured, ρ_i is expected.

These distributions compare

- R_{LL}^{data} (green)
- $R_{LL}^{95\%\ CLs\ exclusion}$ (purple)
- $R_{LL}^{95\%\ S+B}$ Quantile (red)

$$\frac{\int_{-\infty}^{LLR_{CLs}} PDS_{S+B}}{\int_{-\infty}^{LLR_{CLs}} PDS_B} = 0.05.$$

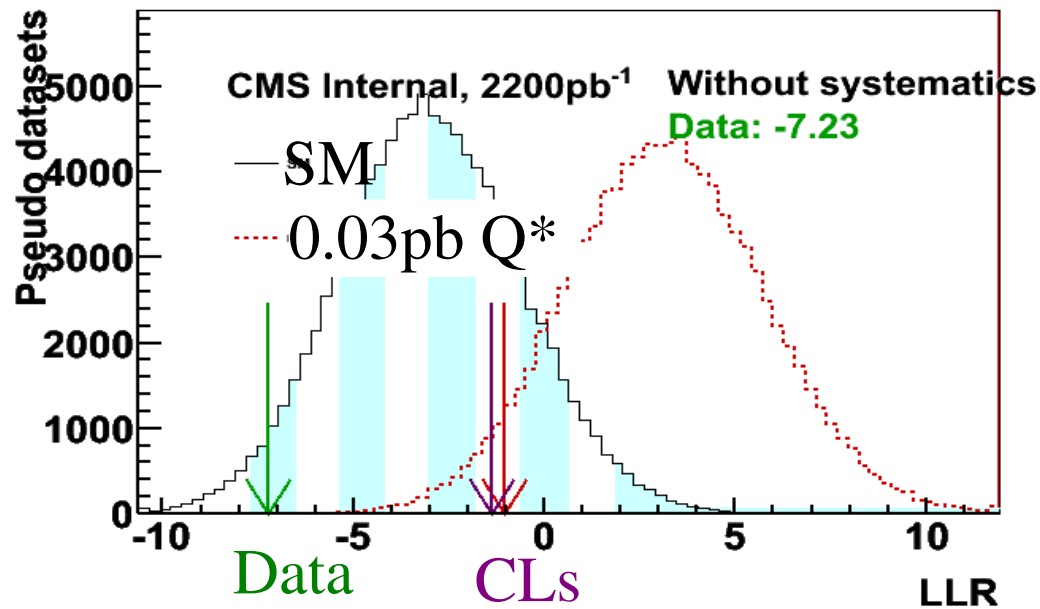


Data CLs

Limit-Setting Procedure

Find lowest 95% CL excluded xsec at each resonance mass.

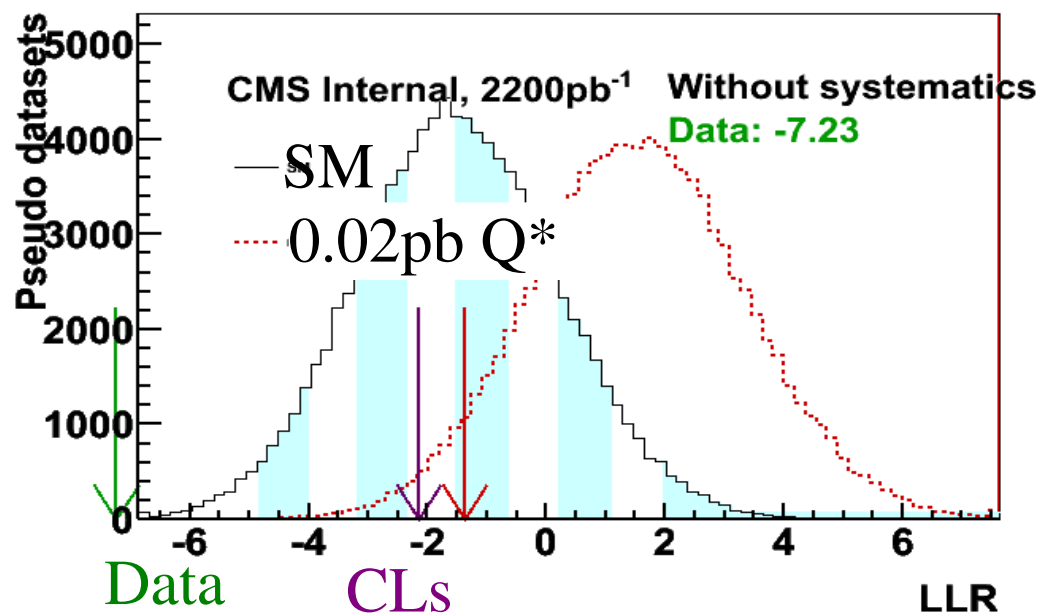
0.029 pb



Test many cross sections at the same mass.

Example: 2.8TeV

0.020 pb



$$\frac{\int_{-\infty}^{\mathrm{LLR_{CLs}}} PDS_{S+B}}{\int_{-\infty}^{\mathrm{LLR_{CLs}}} PDS_{B}} = 0.05.$$

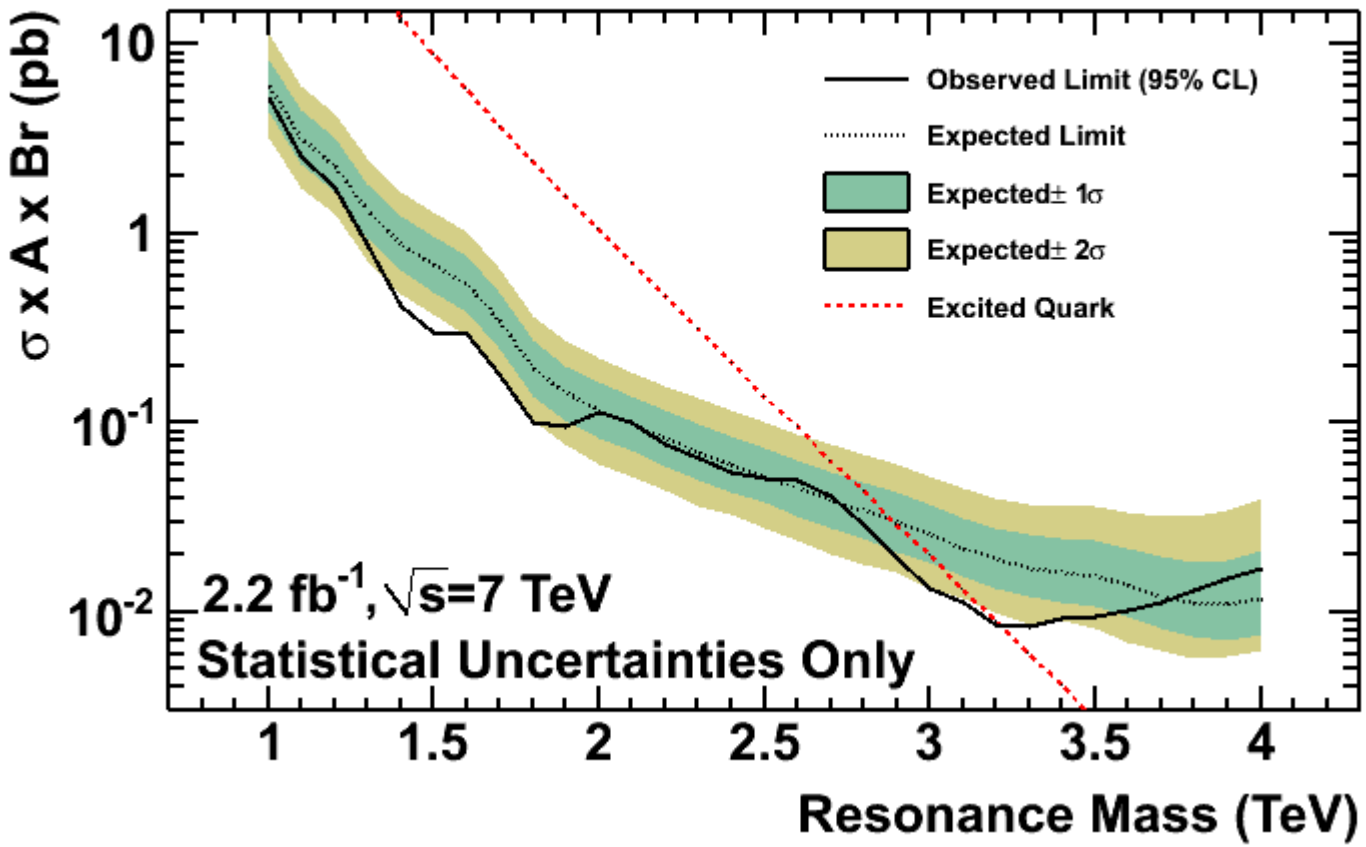
Statistics-only Limits

Expected and observed CL_s limits first obtained with statistical errors only.

Limits apply to excited quarks or any isotropically decaying qg resonance.

Compare to the model cross section within acceptance
$|\eta| < 2.5$
$|\Delta\eta| < 3.0$

With only statistical errors the limit is 2.85 TeV expected and 3.2 TeV observed.

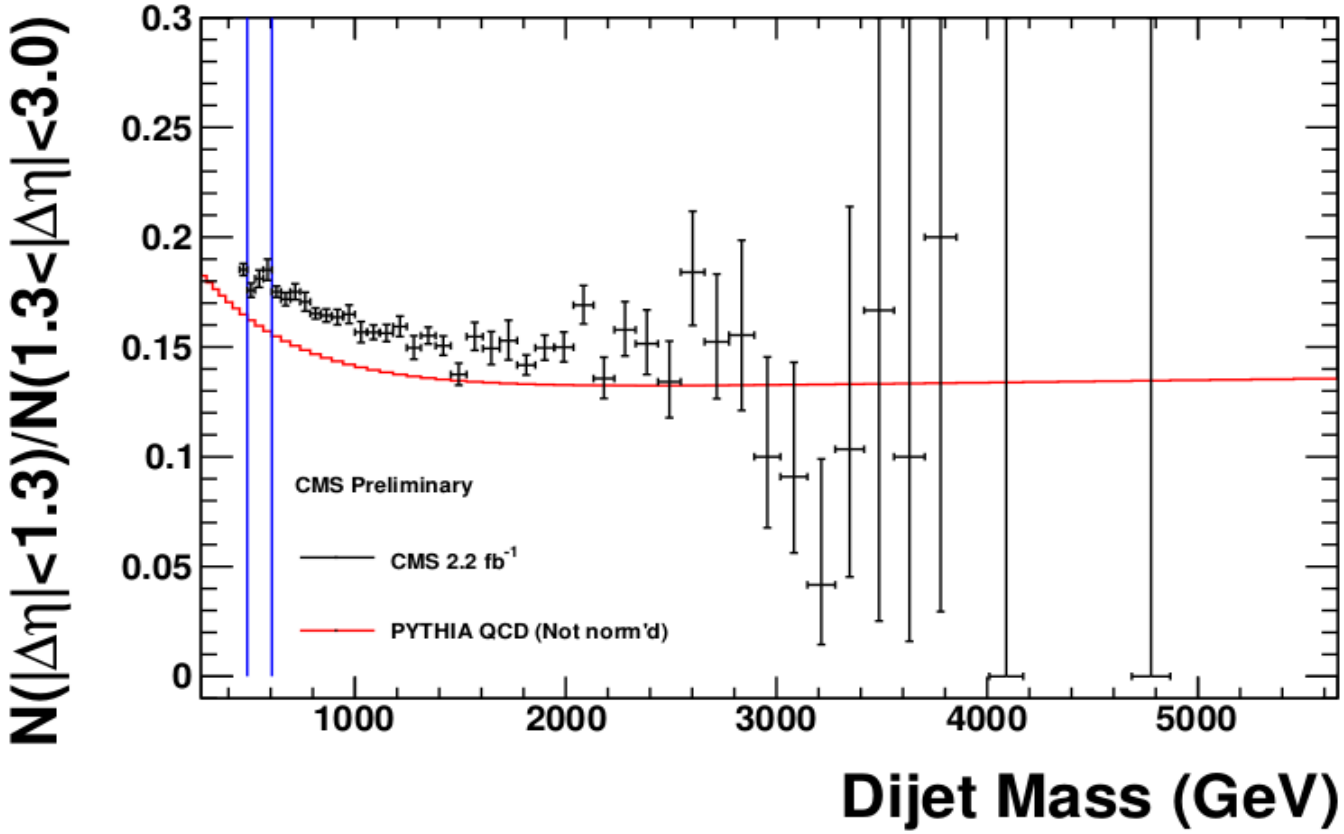


Systematics: Background

Additive normalization from sideband contributes an additive ±0.0019 constant in dijet mass, to the background model

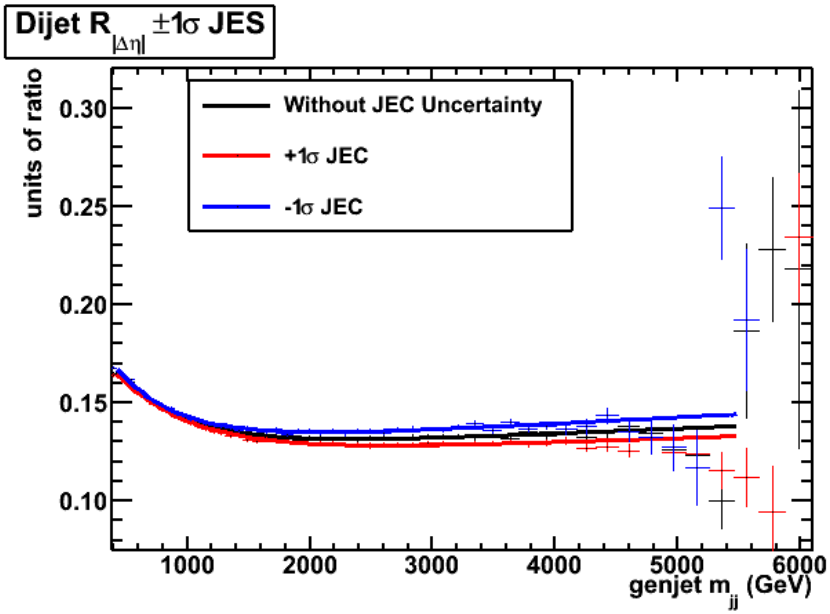
PYTHIA6 prediction is shifted upward 0.0188 ± 0.00186.

Uncertainty is from the fit in the sideband region (blue lines)

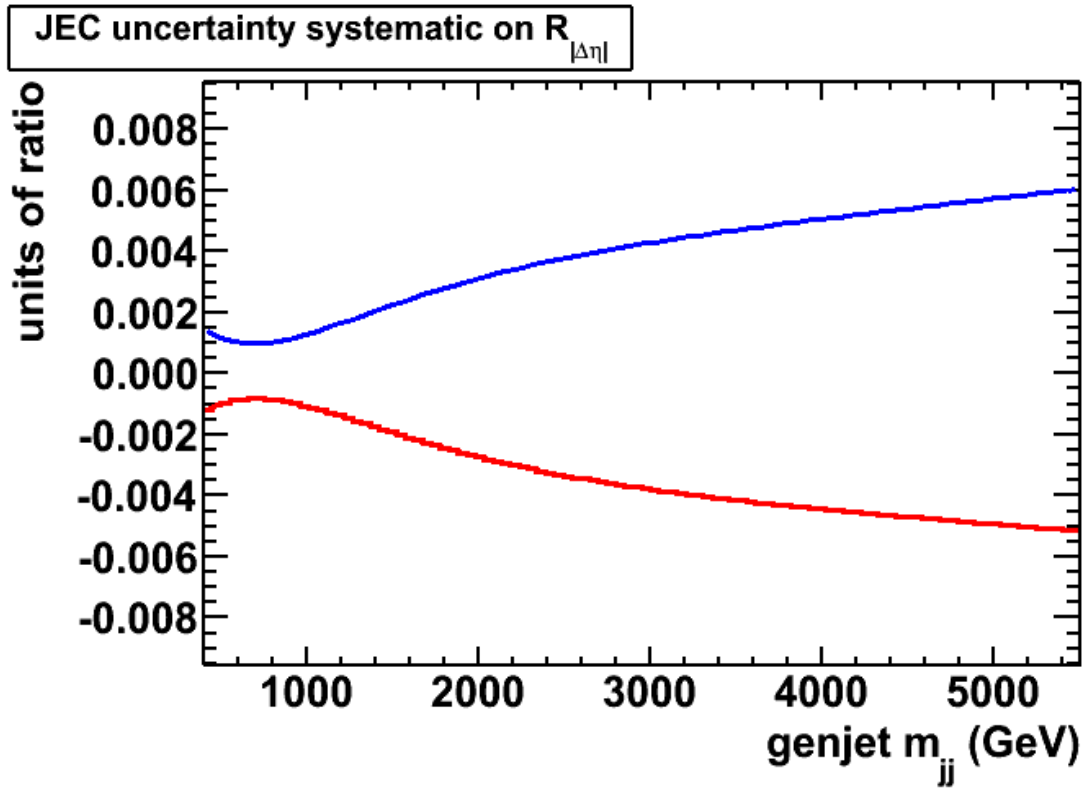


Shift is needed because LO QCD has no hard gluon emissions. Underestimates small-|Δη| dijets.

Systematics: Background



QCD MC with Jet Energy Correction ±1σ propagates to uncertainty on background



Resulting systematic uncertainty has mass-dependent envelope.

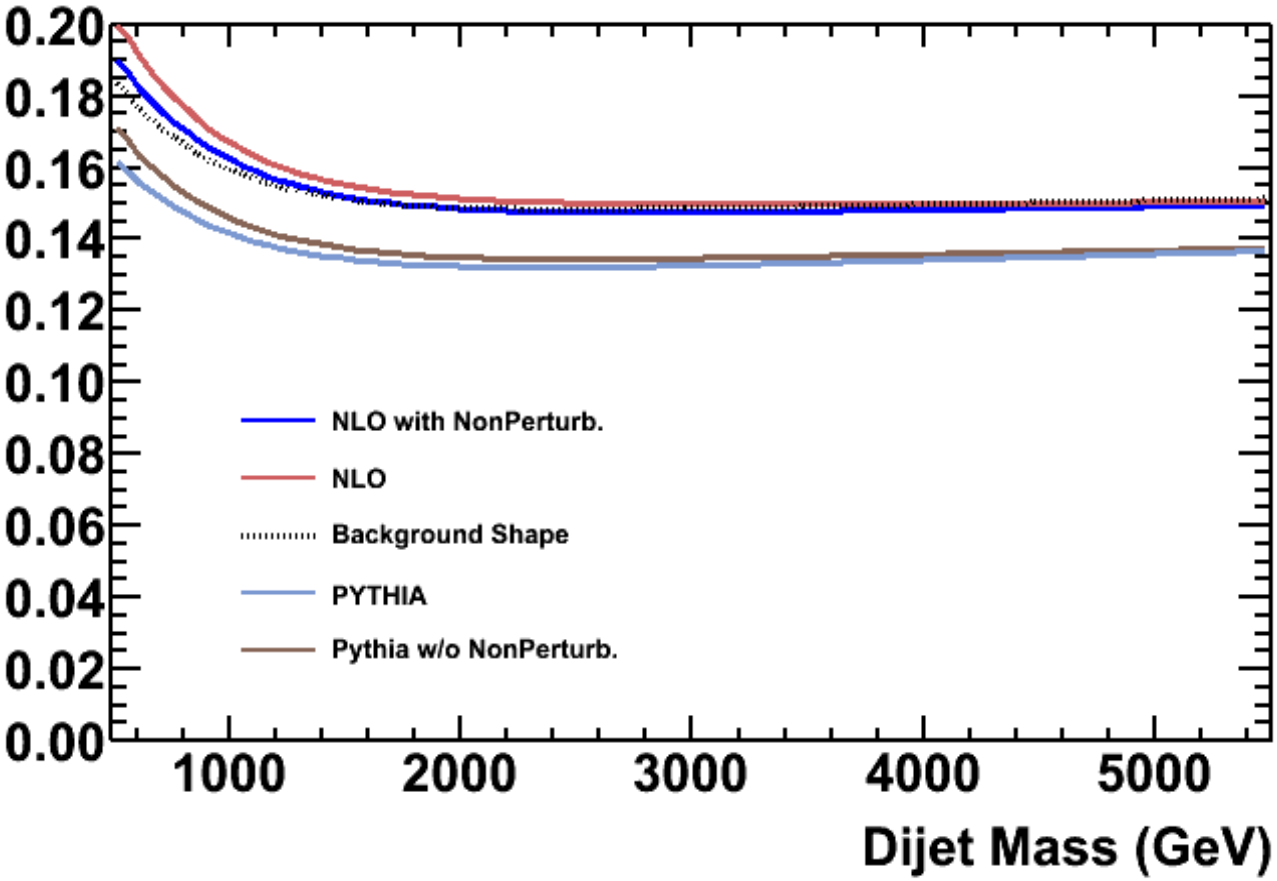
Systematics: Background

We take a background model systematic from NLO:

fastNLOv2 and NLOJet++ 4.1.3

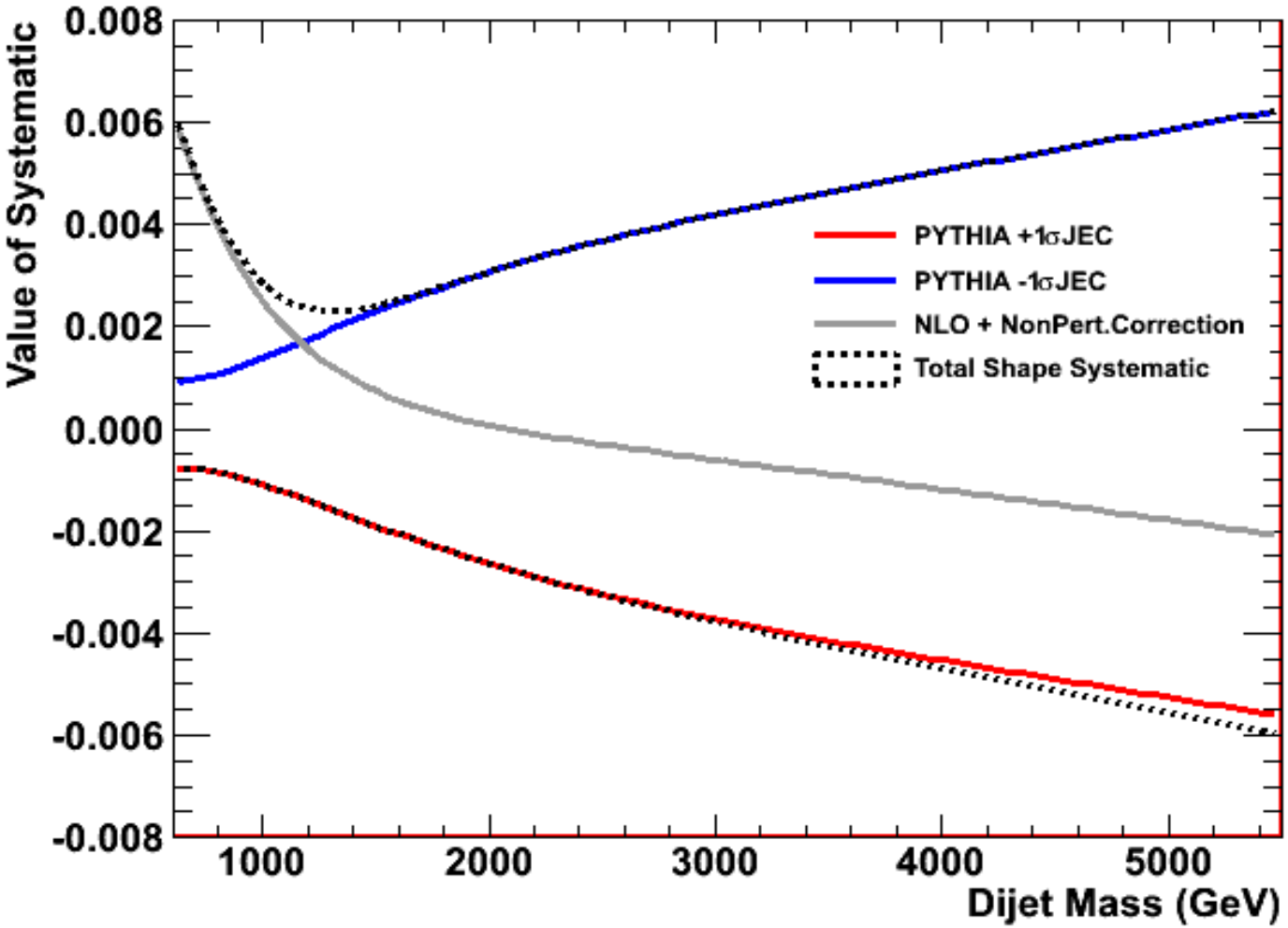
corrected for non-perturbative effects taken from PYTHIA when switching back on MPI, HAD, & UE.

Agreement from +4% to -1% with expectation from shifted PYTHIA model



Systematics: Background

Total systematic uncertainty on background prediction from JEC uncertainty and model uncertainty (NLO)



Systematics

Additionally we take all of the following into account:

Background rate:

- Total background rate in $|\Delta\eta|<1.3$ and $|\eta|<2.5$ is needed to calculate the affect of the signal on the ratio.
- gives 1.6% uncertainty from fit of PYTHIA prediction to data

Signal JEC uncertainty

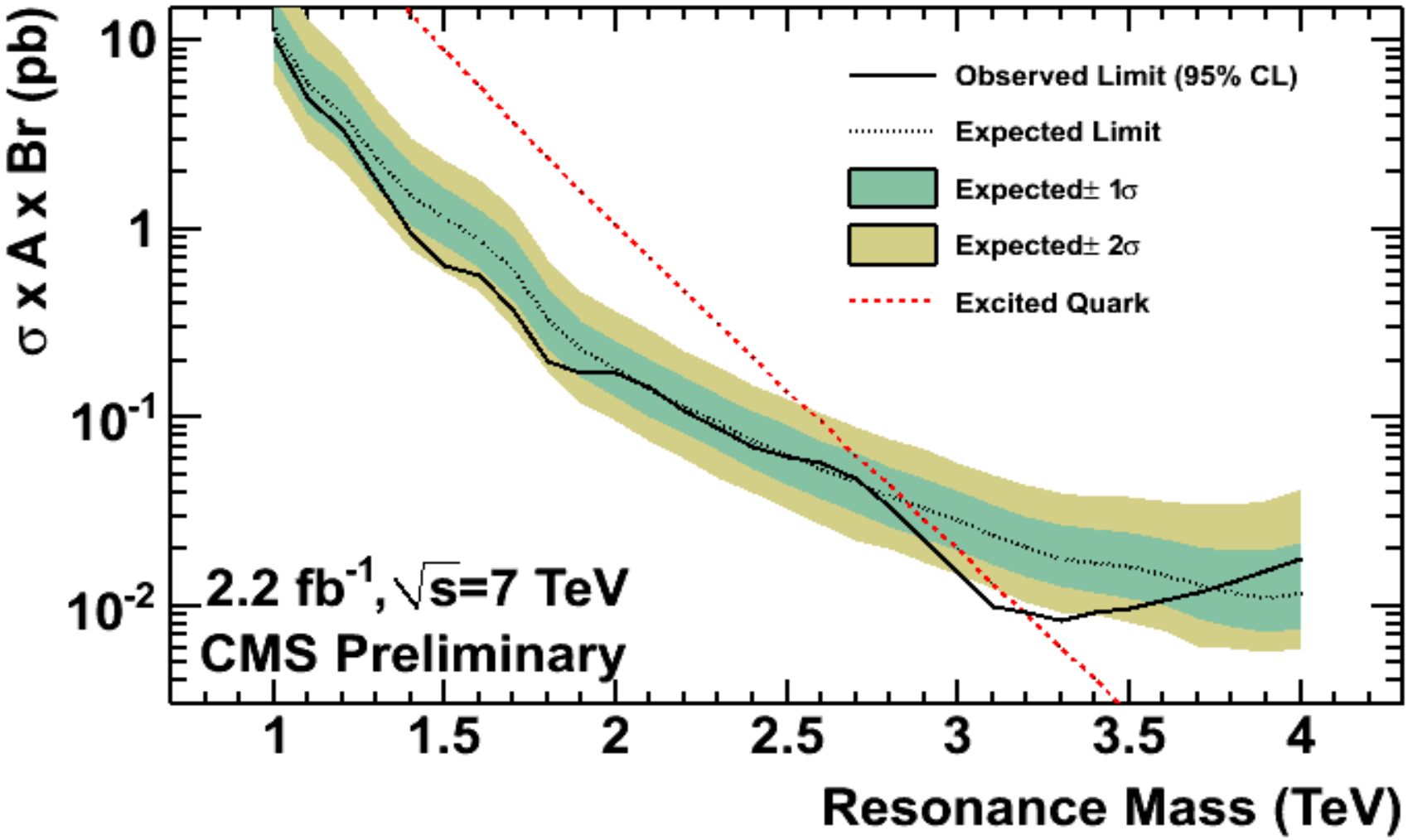
- 2.2% dijet mass uncertainty → simulated mass 2.2% uncertain

Luminosity uncertainty

- 4.5%

Limits

Including effects of systematic uncertainties, the limit on an excited quark mass is 2.8 TeV expected and 3.2 TeV observed, very close to limit without systematics.



Conclusion

We have presented the first search for dijet resonances using the dijet angular ratio and 2.2 fb^{-1} of CMS data.

The data are in good agreement with the standard model background. There is no evidence for a dijet resonance.

We exclude an excited quark of mass of 3.2 TeV at 95% C.L., where the expected limit is 2.8 TeV.

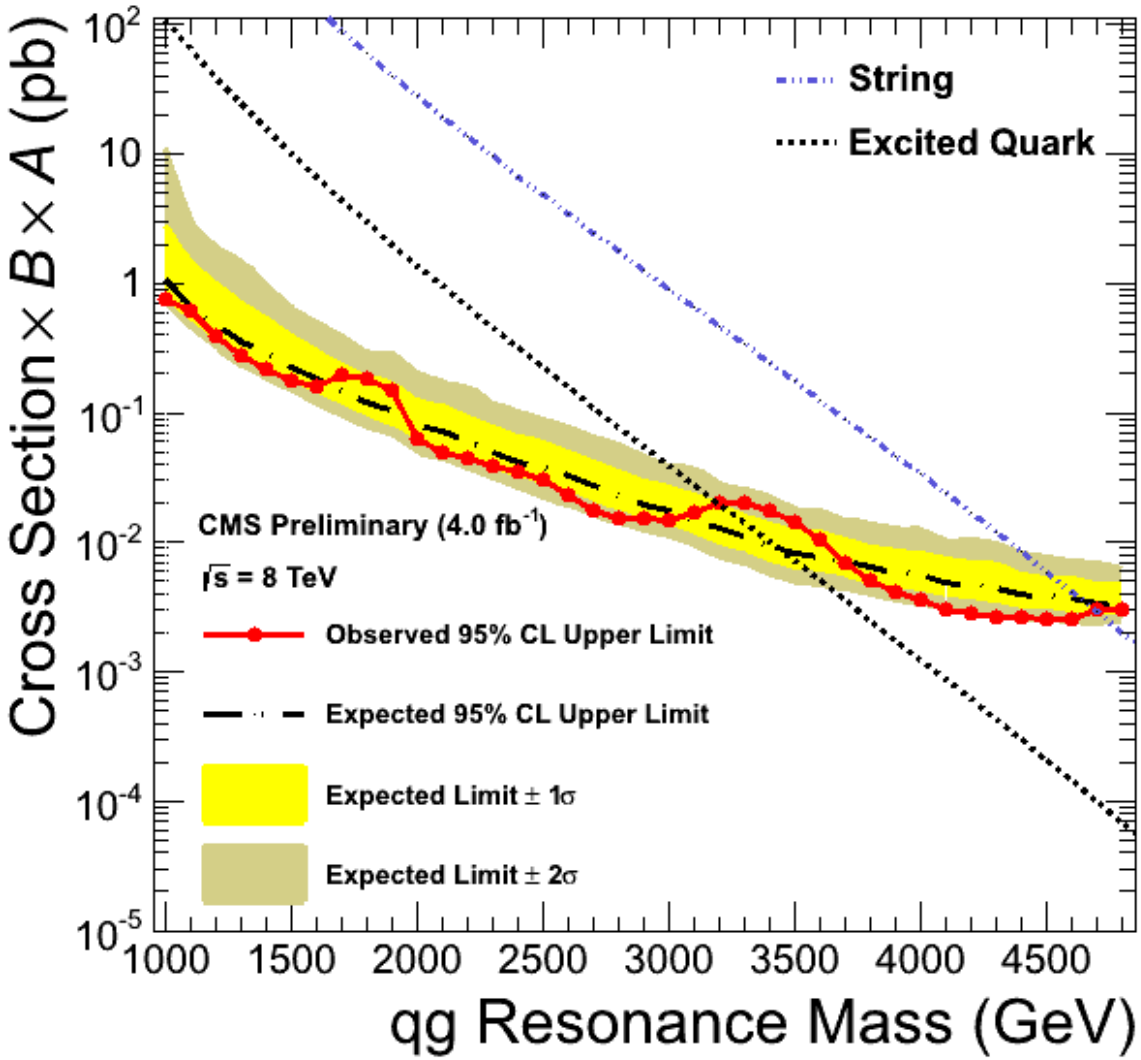
This limit compares to the published limits with 1.0 fb^{-1} from CMS* (2.68 expected, 2.49 observed) and ATLAS** (2.81 expected, 2.99 observed).

* CMS Collaboration, "Search for Resonances in the Dijet Mass Spectrum from 7 TeV pp Collisions at CMS", CERN-PH-EP/2011-119 (2011).

** ATLAS Collaboration, "Search for New Physics in the Dijet Mass Distribution using 1 fb^{-1} of pp Collision Data at sqrt(s) = 7TeV collected by the ATLAS Detector",122 CERN-PH-EP-2011-127 (2011).

Updated Result

Update from 2012 data (8TeV)



Observed exclusion
1.0 - 3.19 TeV

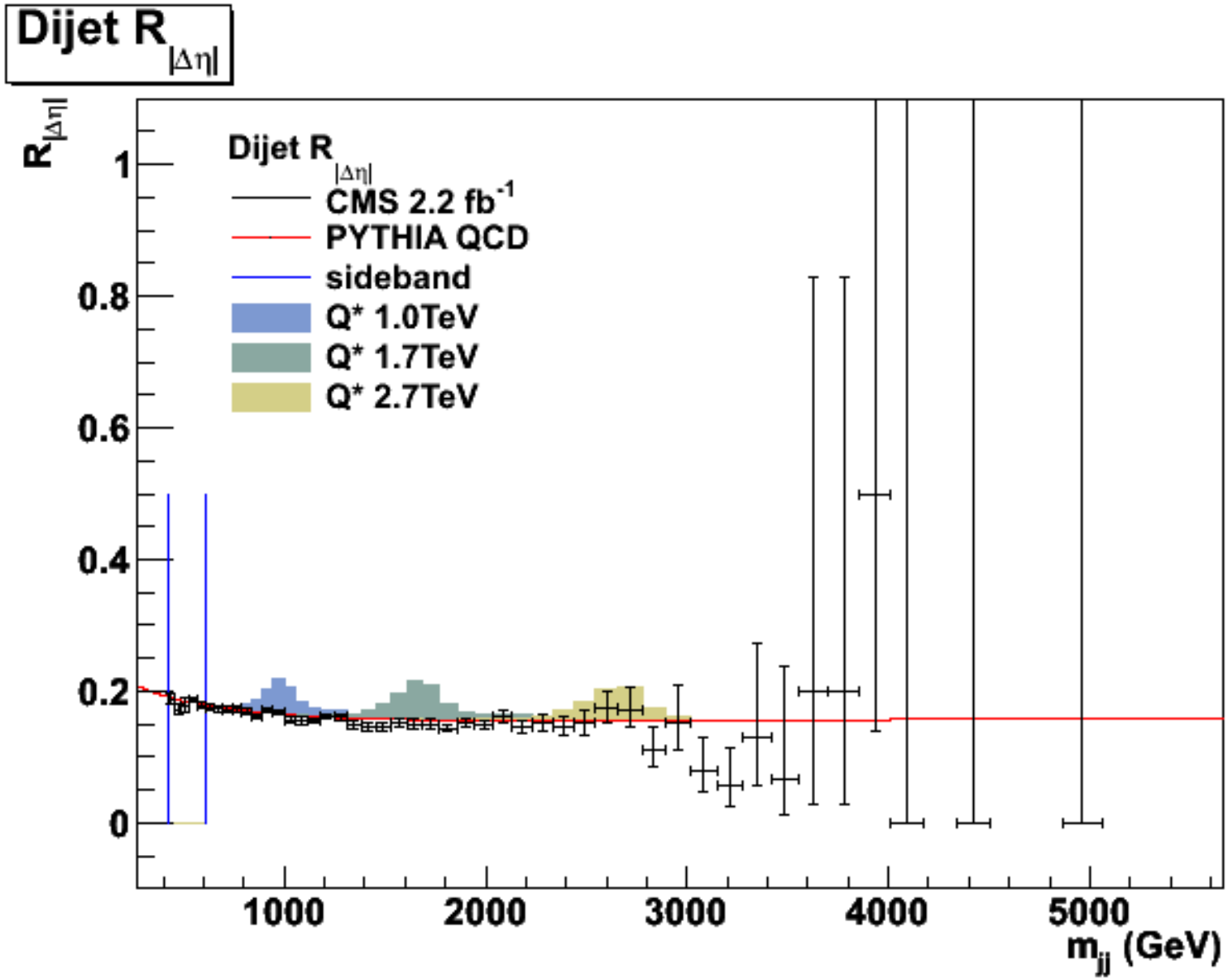
Expected exclusion
1.0 - 3.43 TeV

CMS Collaboration, "Search for Narrow Resonances in the Dijet Mass Spectrum in pp Collisions at √s = 8 TeV"
CMS-PAS-EXO-12-016 CERN PAS

Thank you.

Uh-oh

Dijet Angular Ratio zoomed out

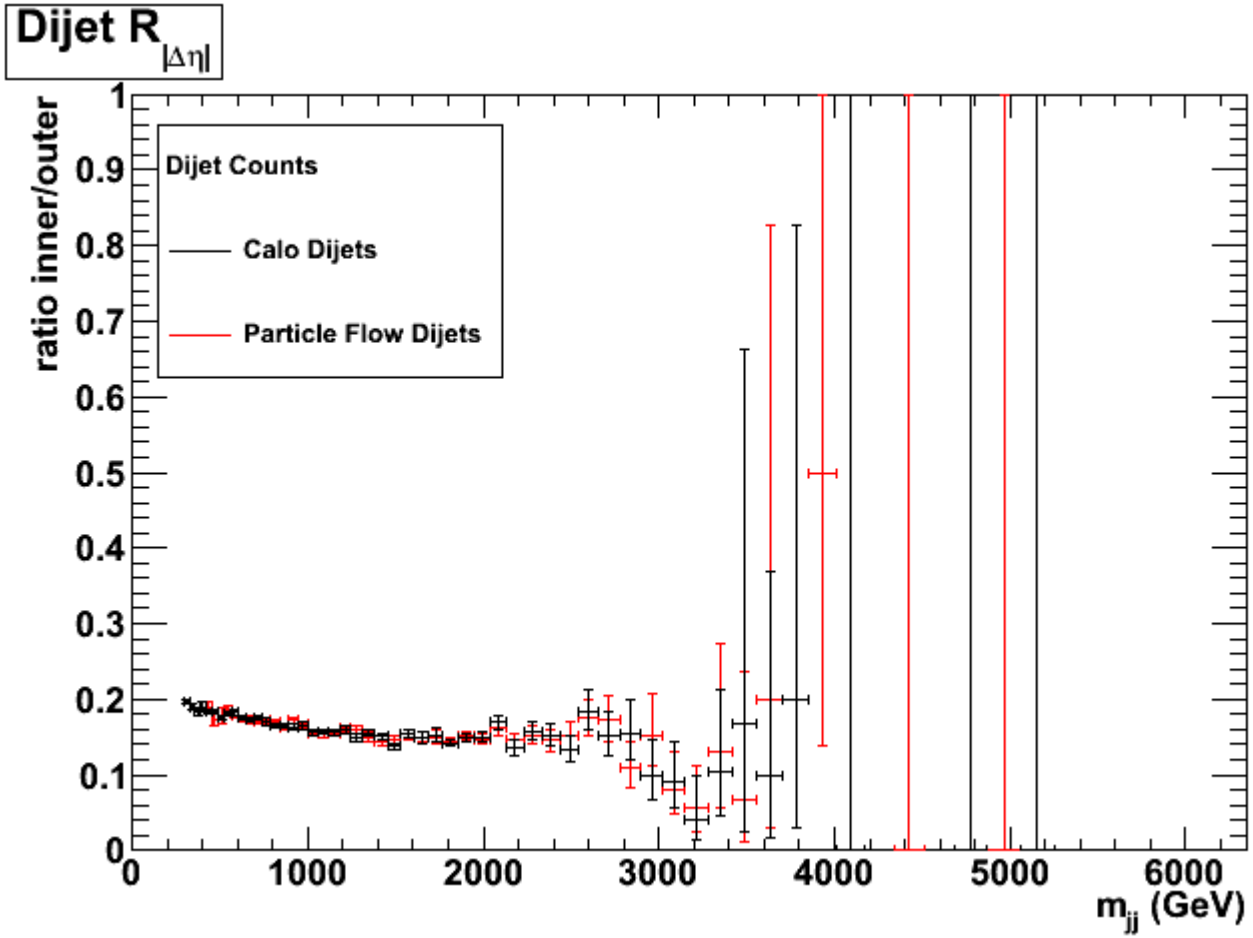


Calo jets and PF jets

CaloJets are fully efficient for the trigger at lower dijet mass than PF jets. The trigger uses calojets.

Trigger Name Scale (GeV)	Fully Efficient Bin (GeV) PF jets	Fully Efficient Bin (GeV) Calojets
HLTJet370	2231	2132
HLTJet300	1770	1770
HLTJet240	1455	1313
HLTJet190	1118	1058
HLTJet150	838	788
HLTJet110	740	606
HLTJet180U	1455	1313
HLTJet140U	1118	1058
HLTJet100U	890	788
HLTJet70U	693	606
HLTJet50U	526	453

Dijet Angular Ratio is consistent with Calojet

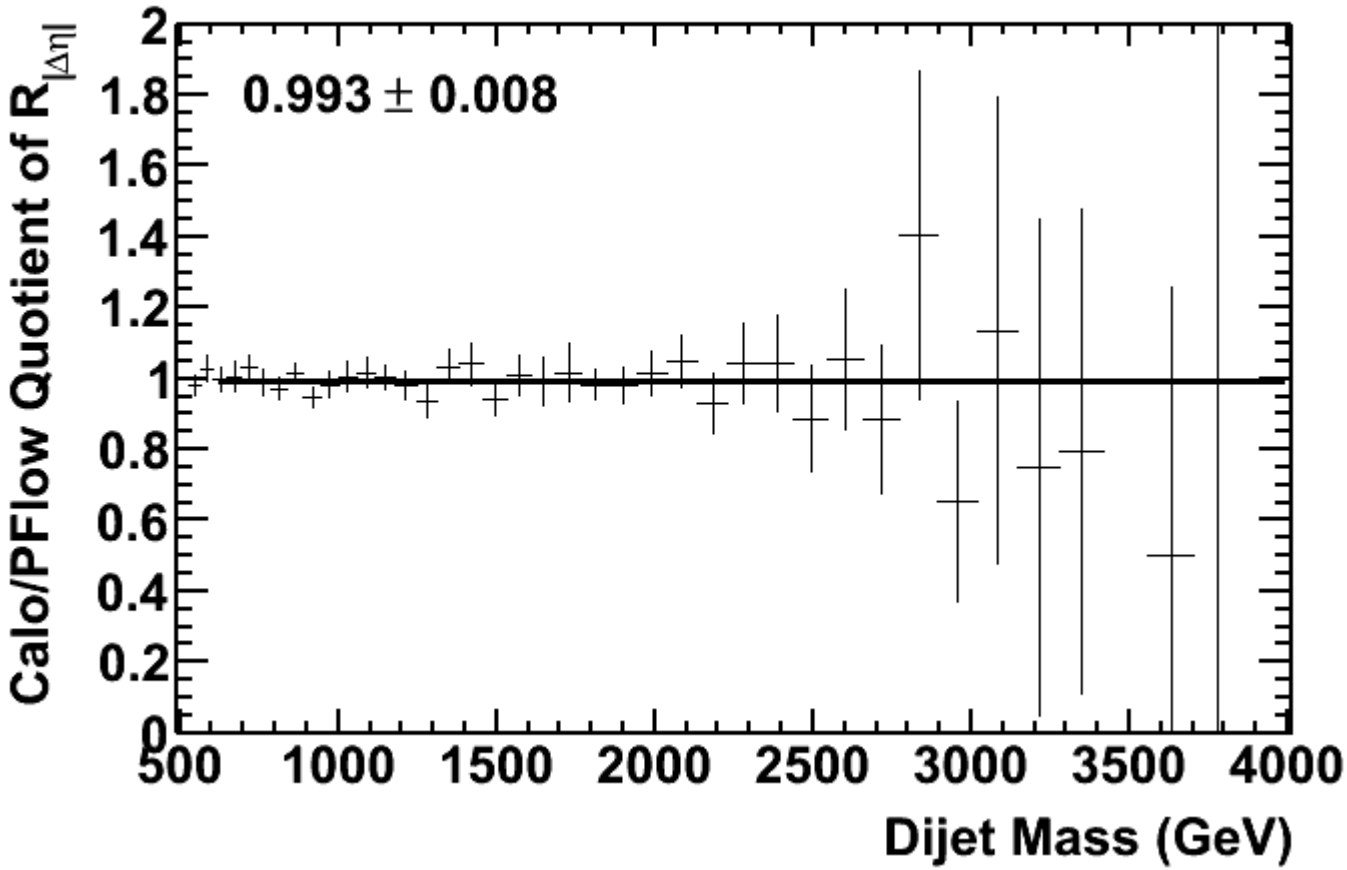


Calo jets and PF jets

We use ak7 calojets (loose ID)

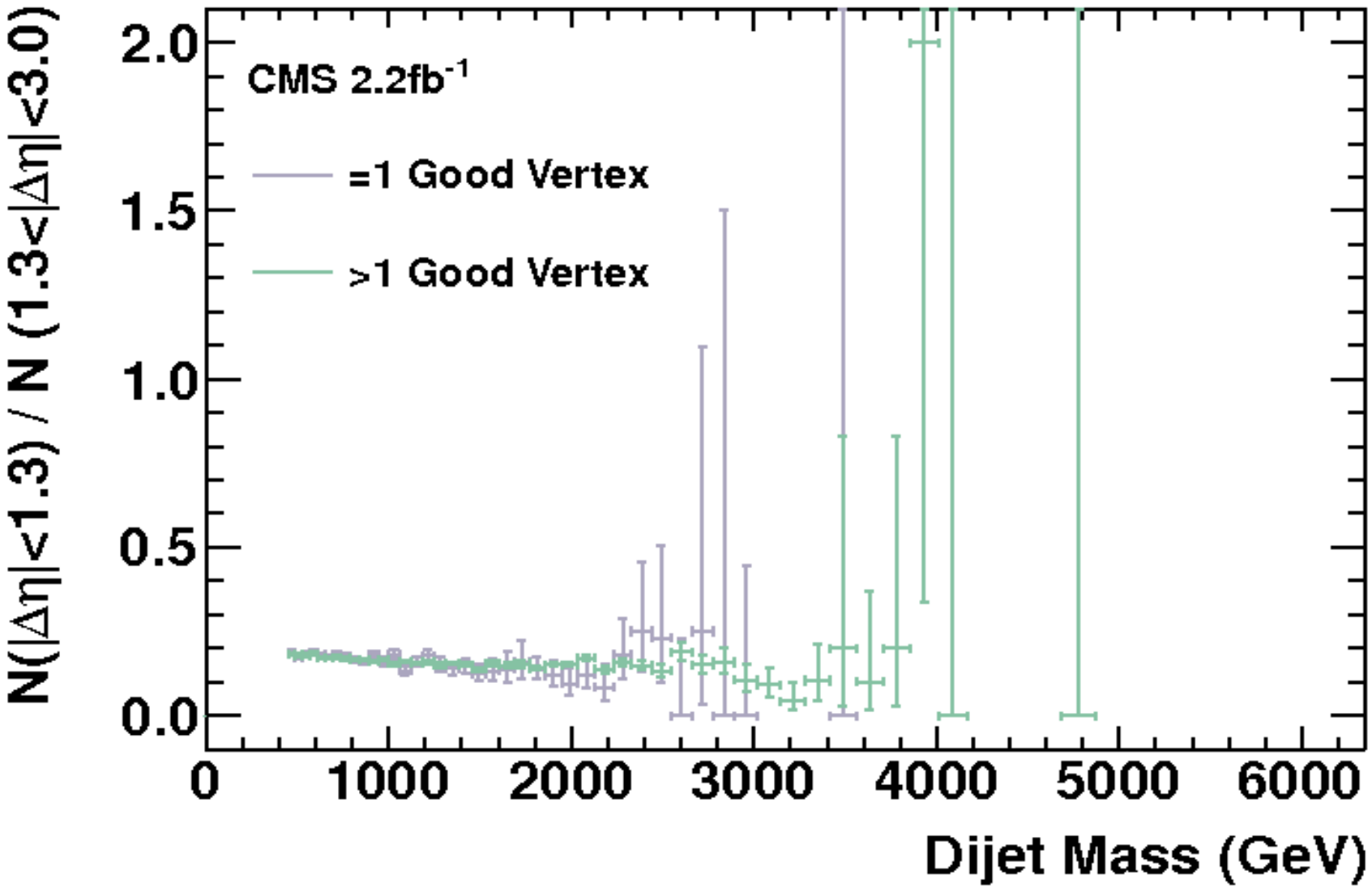
- Check result with PF jets and tight ID
- We use calojets for their better trigger turn-ons

Calo and PF jets give the same dijet angular ratio



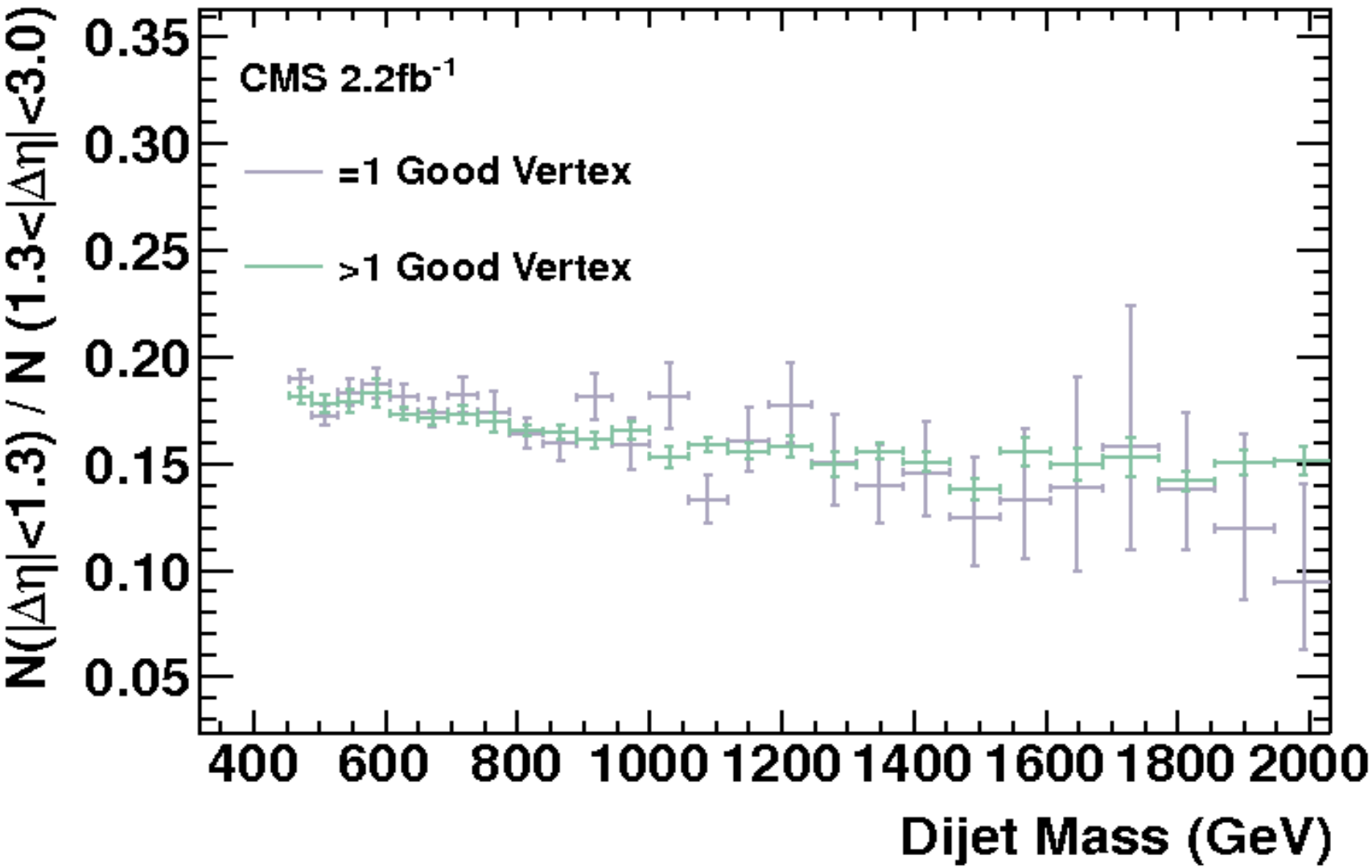
Measured $R_{|\Delta\eta|}$ and Expectations

Effect of pileup consistent with zero in data



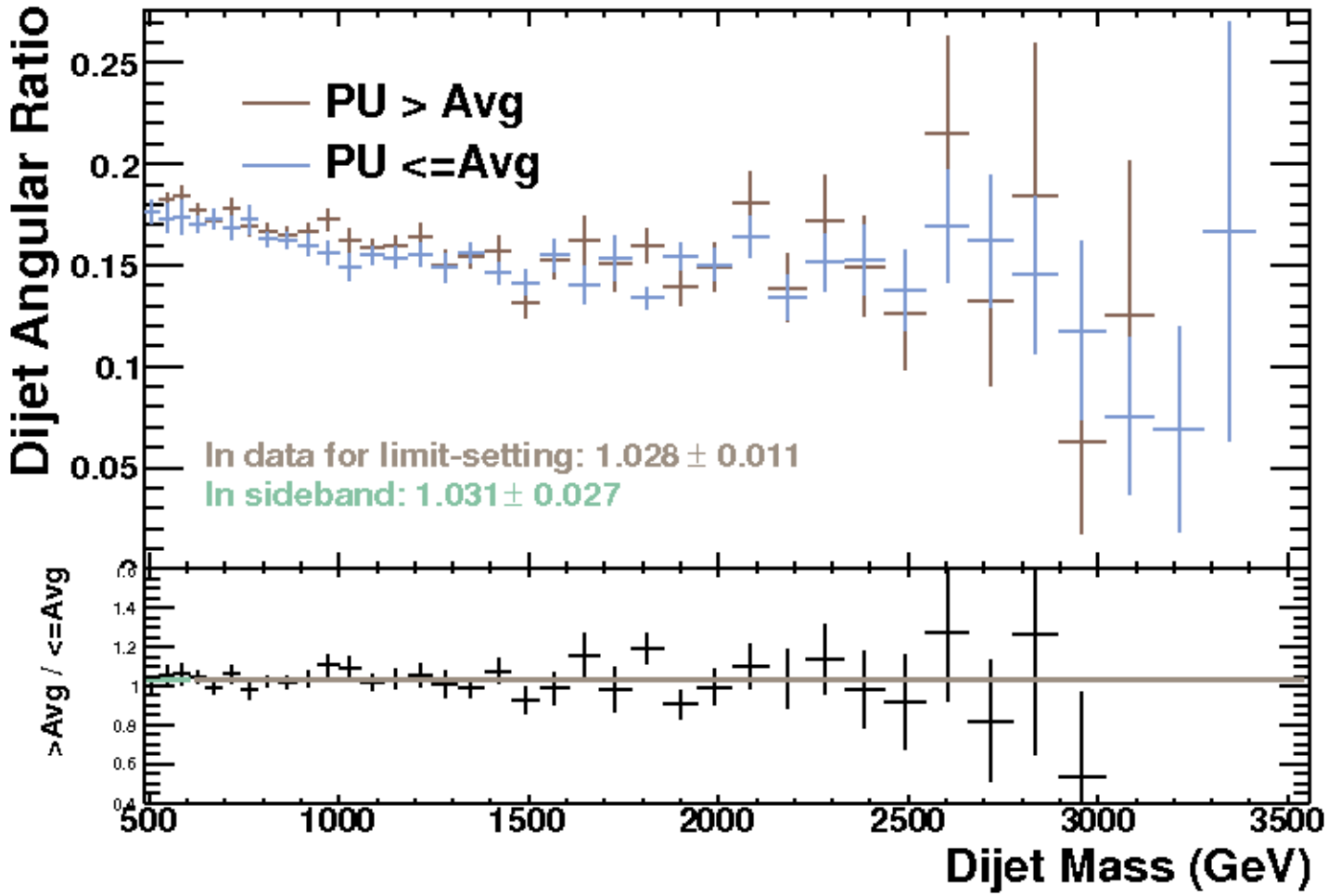
Measured $R_{|\Delta\eta|}$ and Expectations

Effect of pileup consistent with zero in data in our high-statistics bins

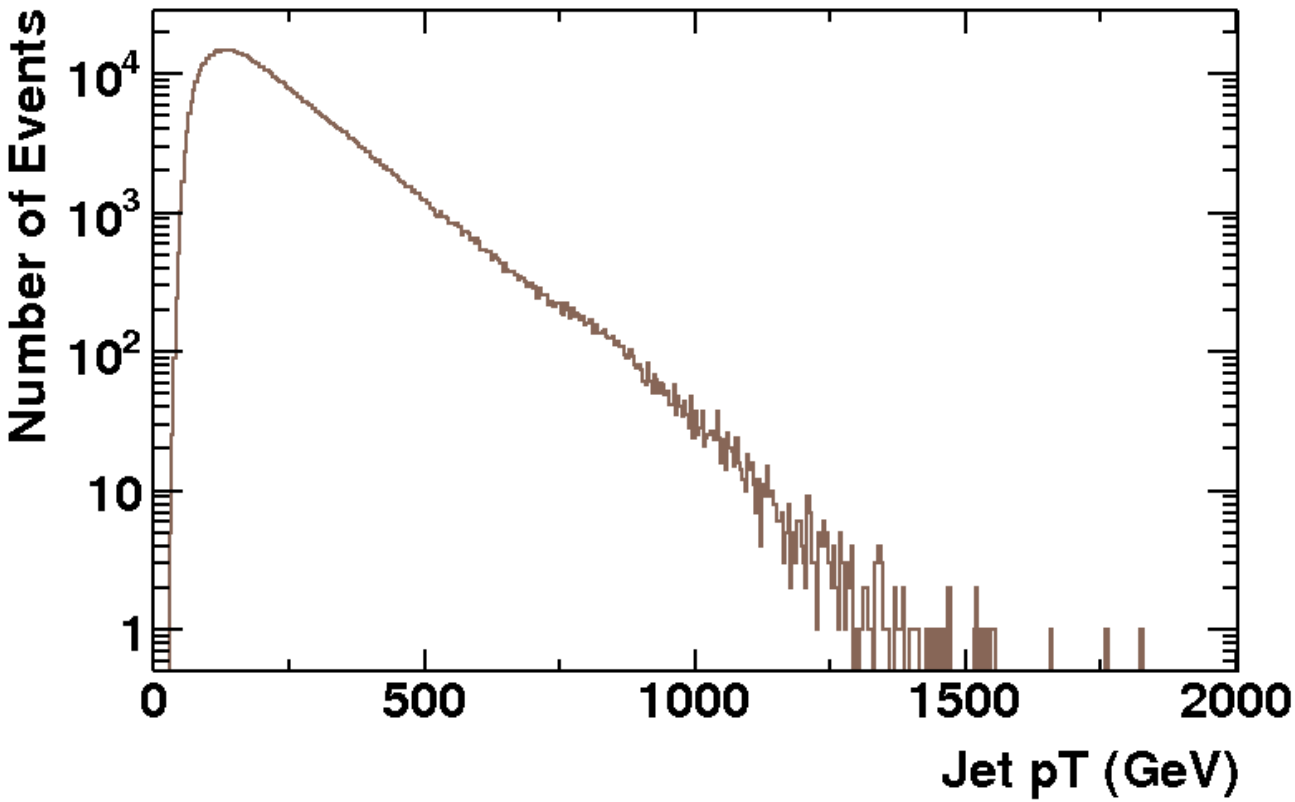


Measured $R_{|\Delta\eta|}$ and Expectations

Effect of pileup consistent with zero in data above and below average PU



Data: Jet Properties



MC Expectations: Signal

Resonances:

Summer11-PU_S4_START42_V11_v1

Qstar, Zprime, RSGraviton toJJ

0.5, 0.7, 1.2, 2.0, 3.5TeVMass

ak7 calo jets

Lineshape from I/FSR

Restrict range

$0.3 < m_{jj}/M_{RES} < 1.3$

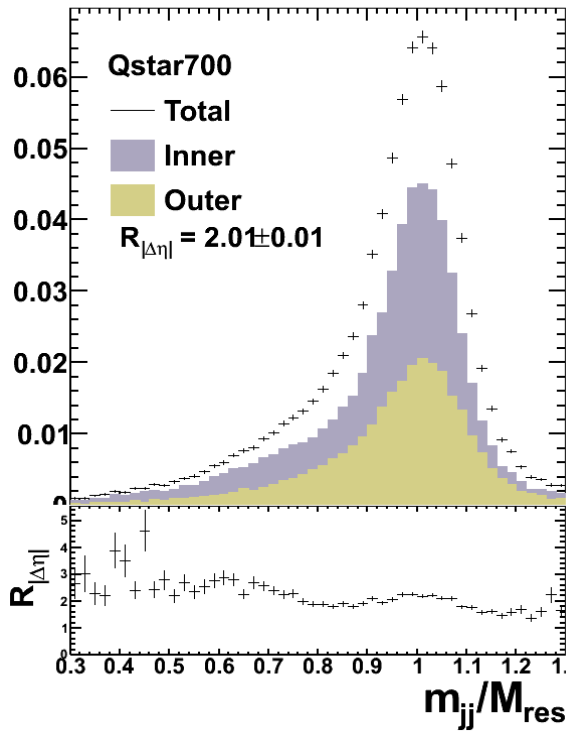
~~Same lineshape~~

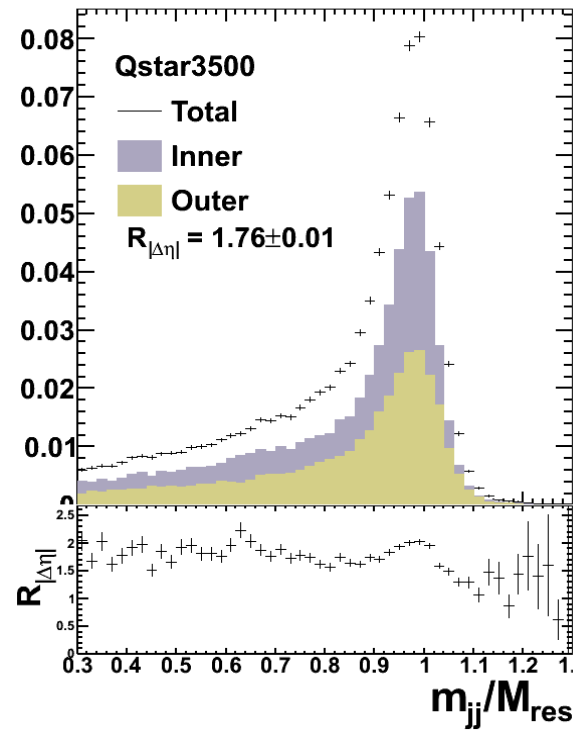
~~inner & outer,~~

~~in different proportions.~~

~~Proportion changes~~

~~(slowly) with M_{res}~~

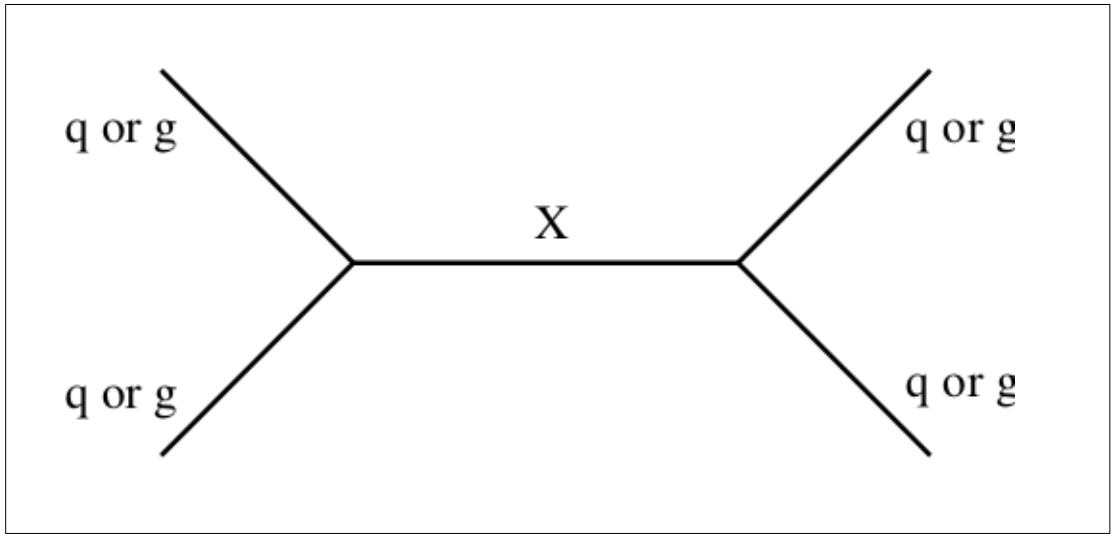


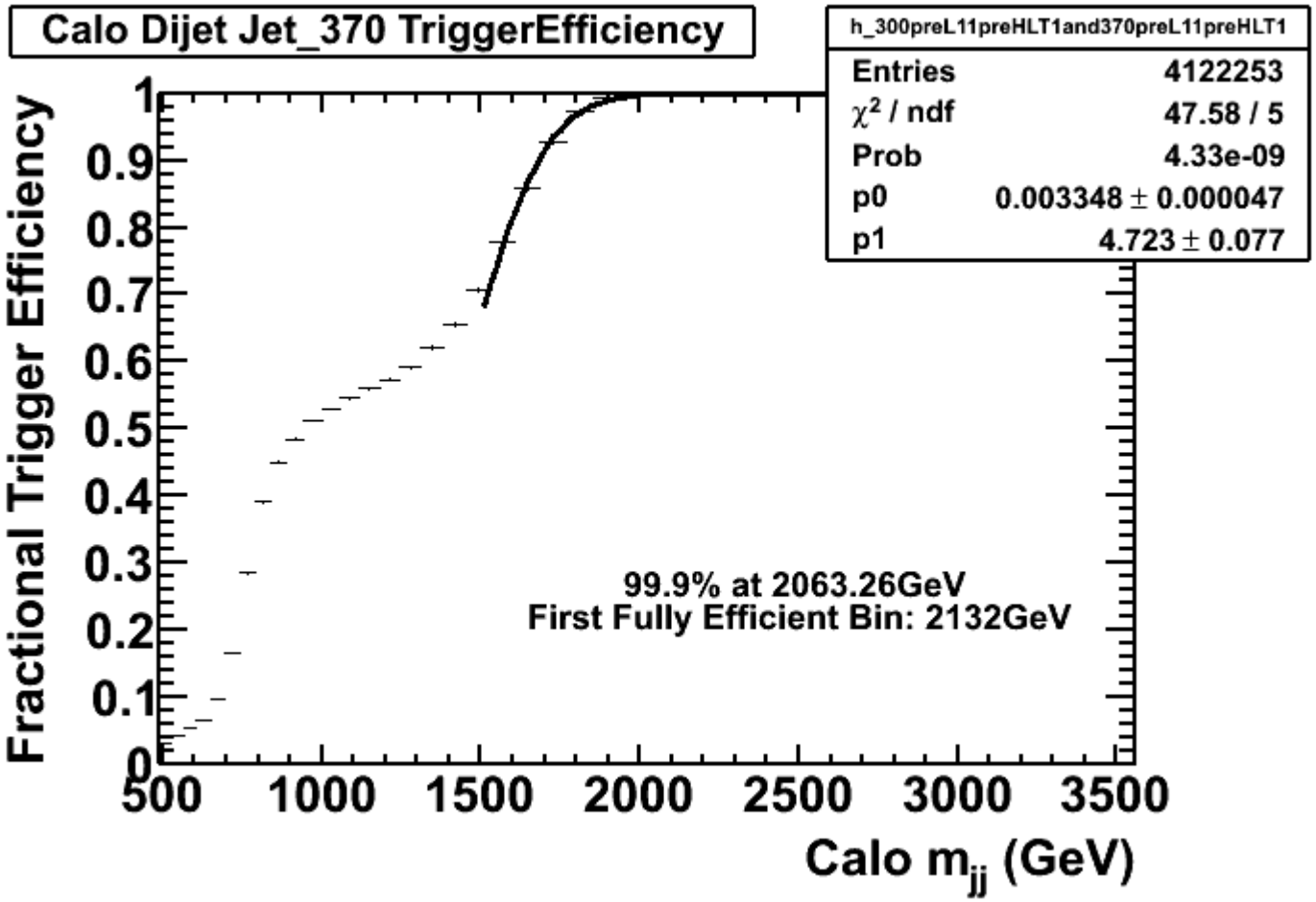


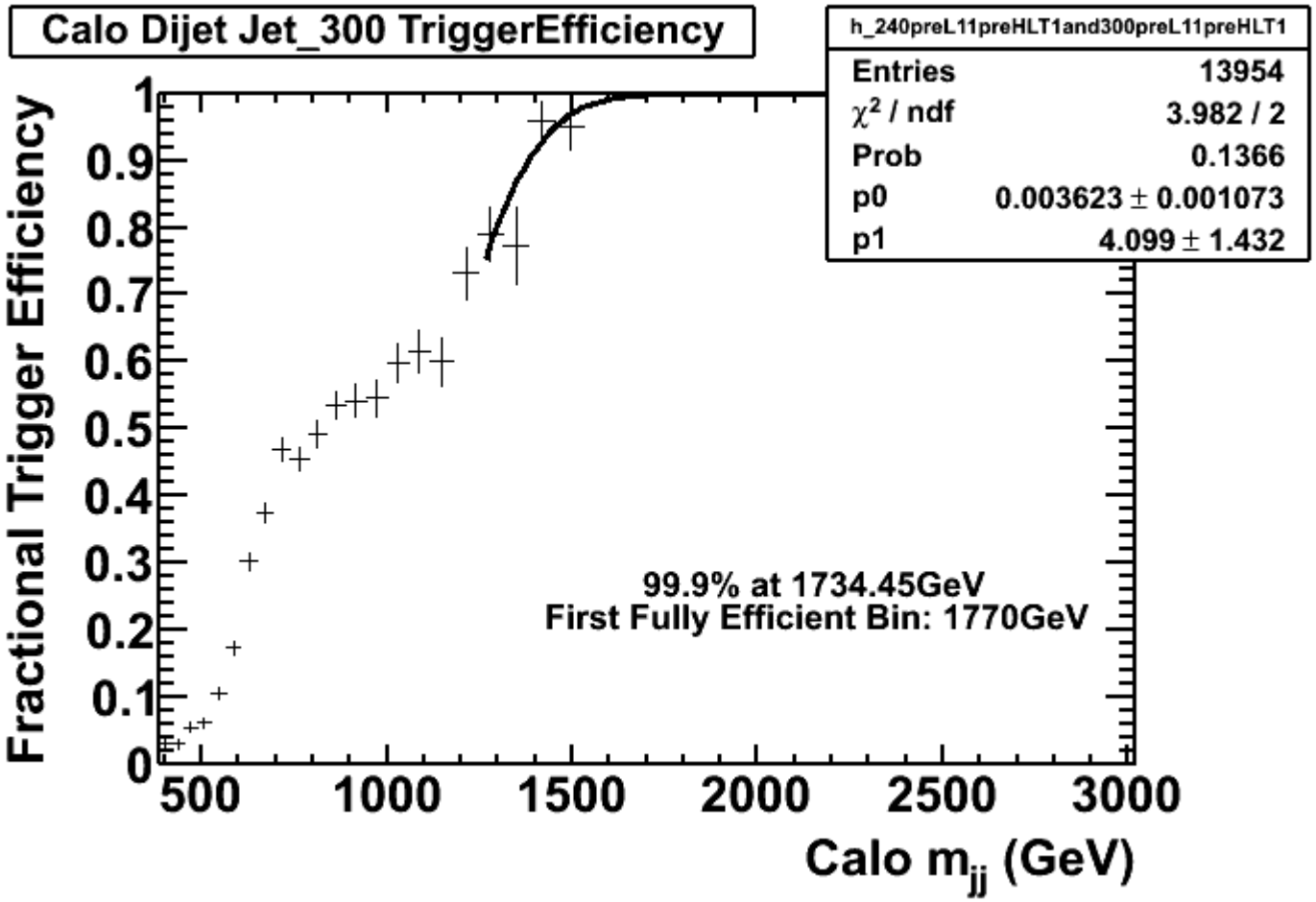
M_{res} :	0.5TeV	0.7TeV	1.2TeV	2.0TeV	3.5TeV
Avg R:	2.4	2.0	1.8	1.8	1.8

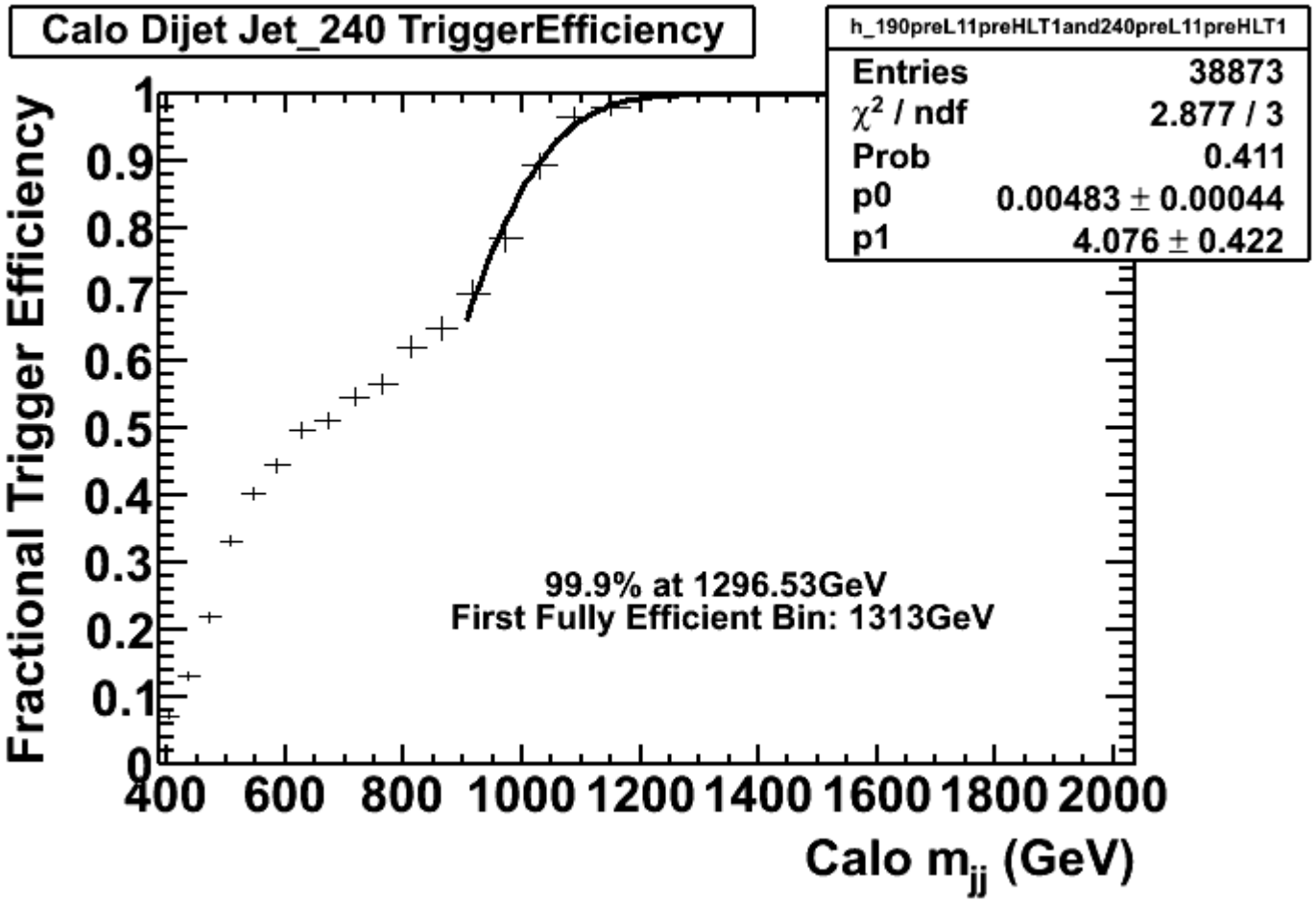
Motivation

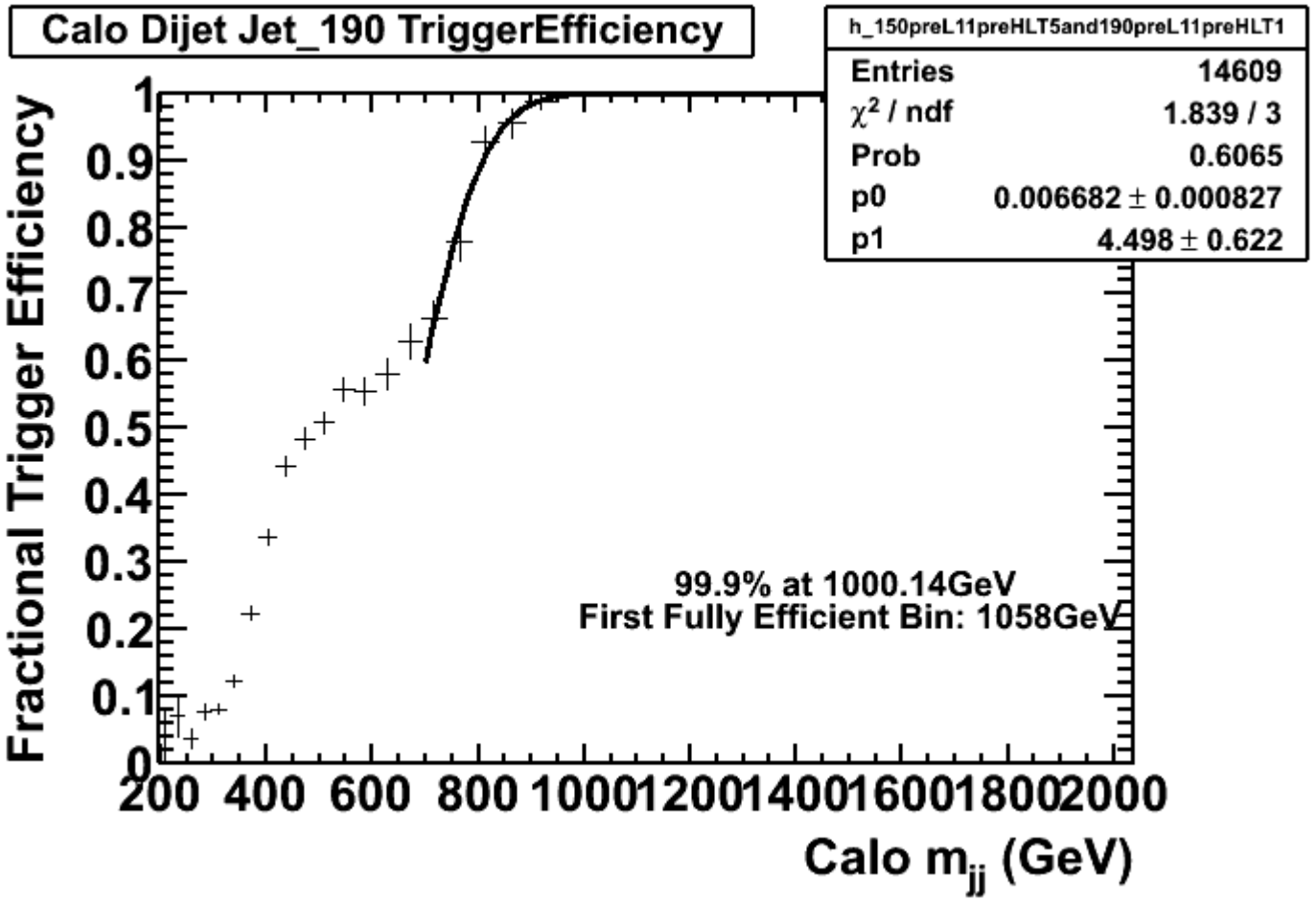
Two-to-two parton scattering dominates LHC *pp* events

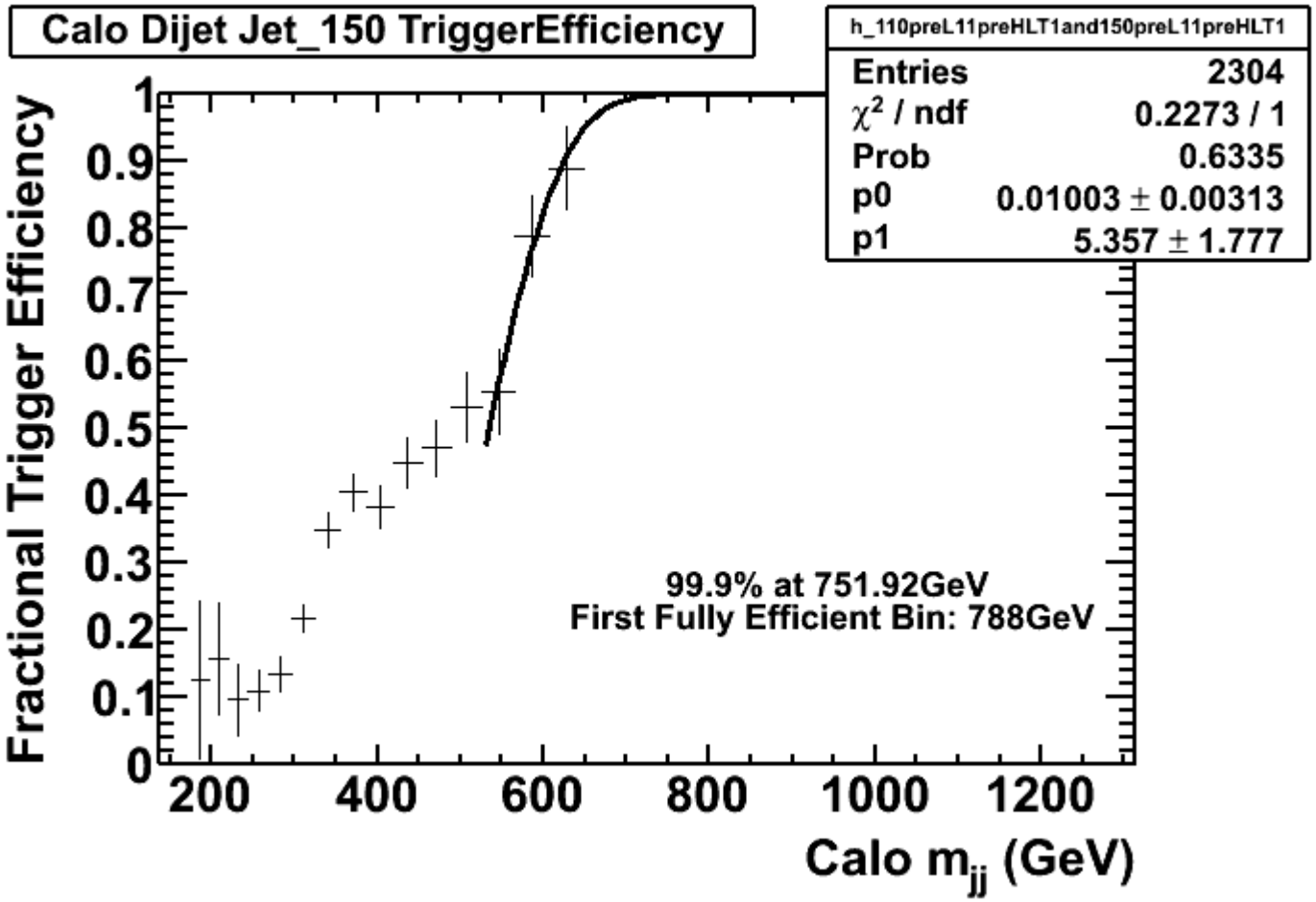


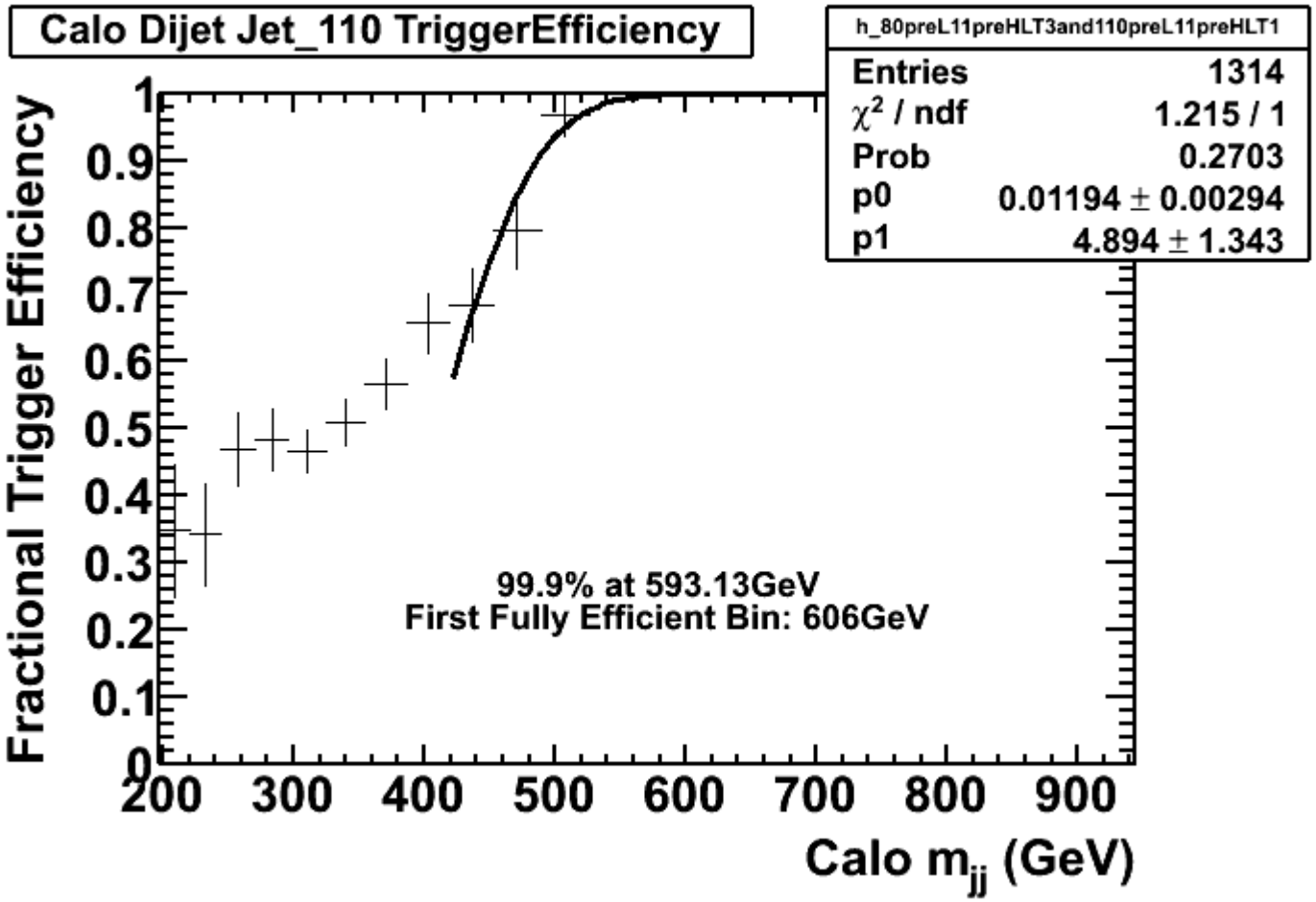

Calo Dijet Jet_370 TriggerEfficiency
h_300preL11preHLT1and370preL11preHLT1
Entries 4122253
χ² / ndf 47.58 / 5
Prob 4.33e-09
p0 0.003348 ± 0.000047
p1 4.723 ± 0.077
99.9% at 2063.26GeV
First Fully Efficient Bin: 2132GeV
Fractional Trigger Efficiency
Calo m_jj (GeV)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
500
1000
1500
2000
2500
3000
3500

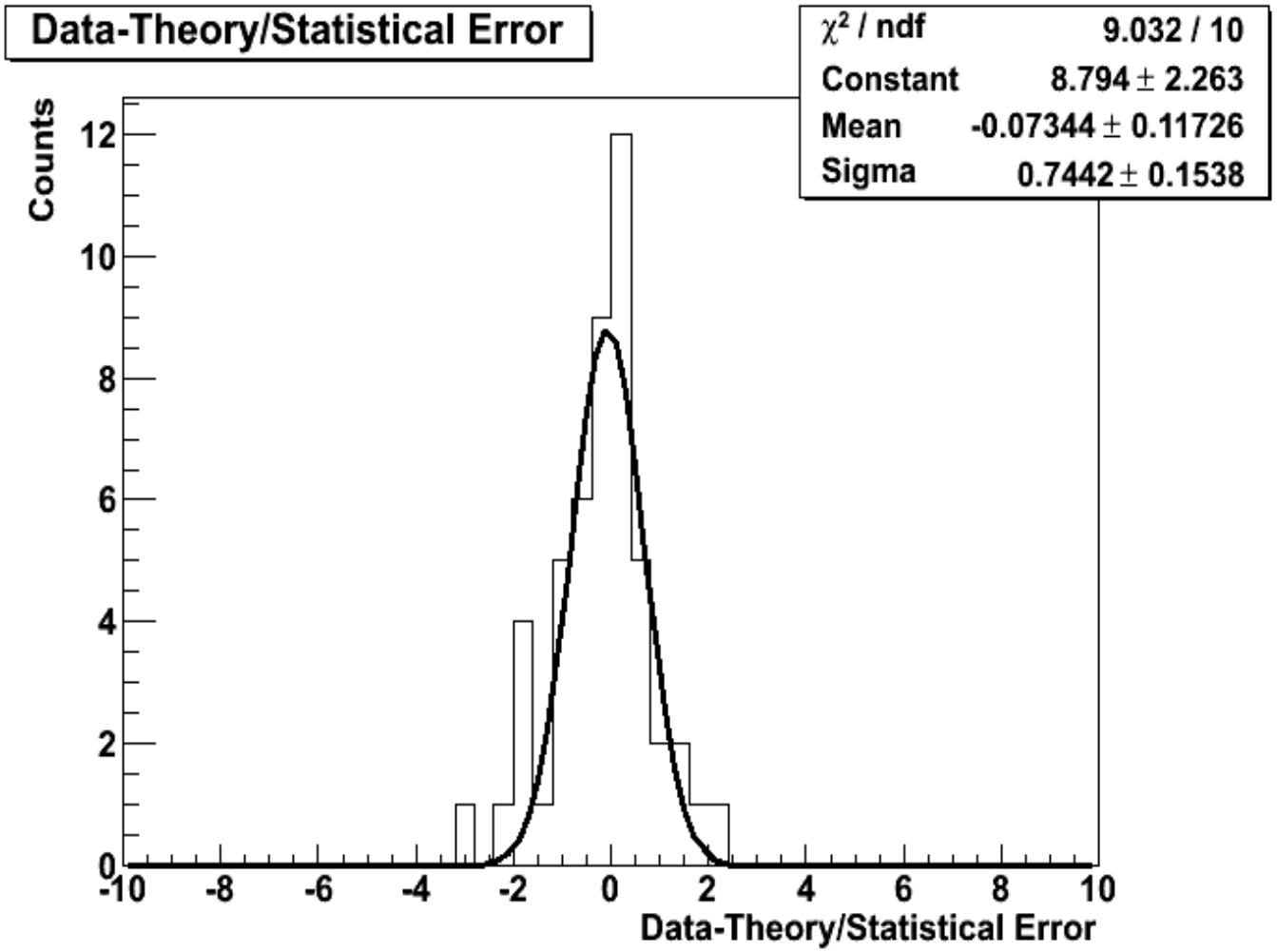

Calo Dijet Jet_300 TriggerEfficiency
h_240preL11preHLT1and300preL11preHLT1
Entries 13954
χ² / ndf 3.982 / 2
Prob 0.1366
p0 0.003623 ± 0.001073
p1 4.099 ± 1.432
99.9% at 1734.45GeV
First Fully Efficient Bin: 1770GeV
Fractional Trigger Efficiency
Calo m_jj (GeV)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
500
1000
1500
2000
2500
3000


Calo Dijet Jet_240 TriggerEfficiency
h_190preL11preHLT1and240preL11preHLT1
Entries 38873
χ² / ndf 2.877 / 3
Prob 0.411
p0 0.00483 ± 0.00044
p1 4.076 ± 0.422
99.9% at 1296.53GeV
First Fully Efficient Bin: 1313GeV
Fractional Trigger Efficiency
Calo m_jj (GeV)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
400
600
800
1000
1200
1400
1600
1800
2000


Calo Dijet Jet_190 TriggerEfficiency
h_150preL11preHLT5and190preL11preHLT1
Entries 14609
χ² / ndf 1.839 / 3
Prob 0.6065
p0 0.006682 ± 0.000827
p1 4.498 ± 0.622
99.9% at 1000.14GeV
First Fully Efficient Bin: 1058GeV
Fractional Trigger Efficiency
Calo m_jj (GeV)

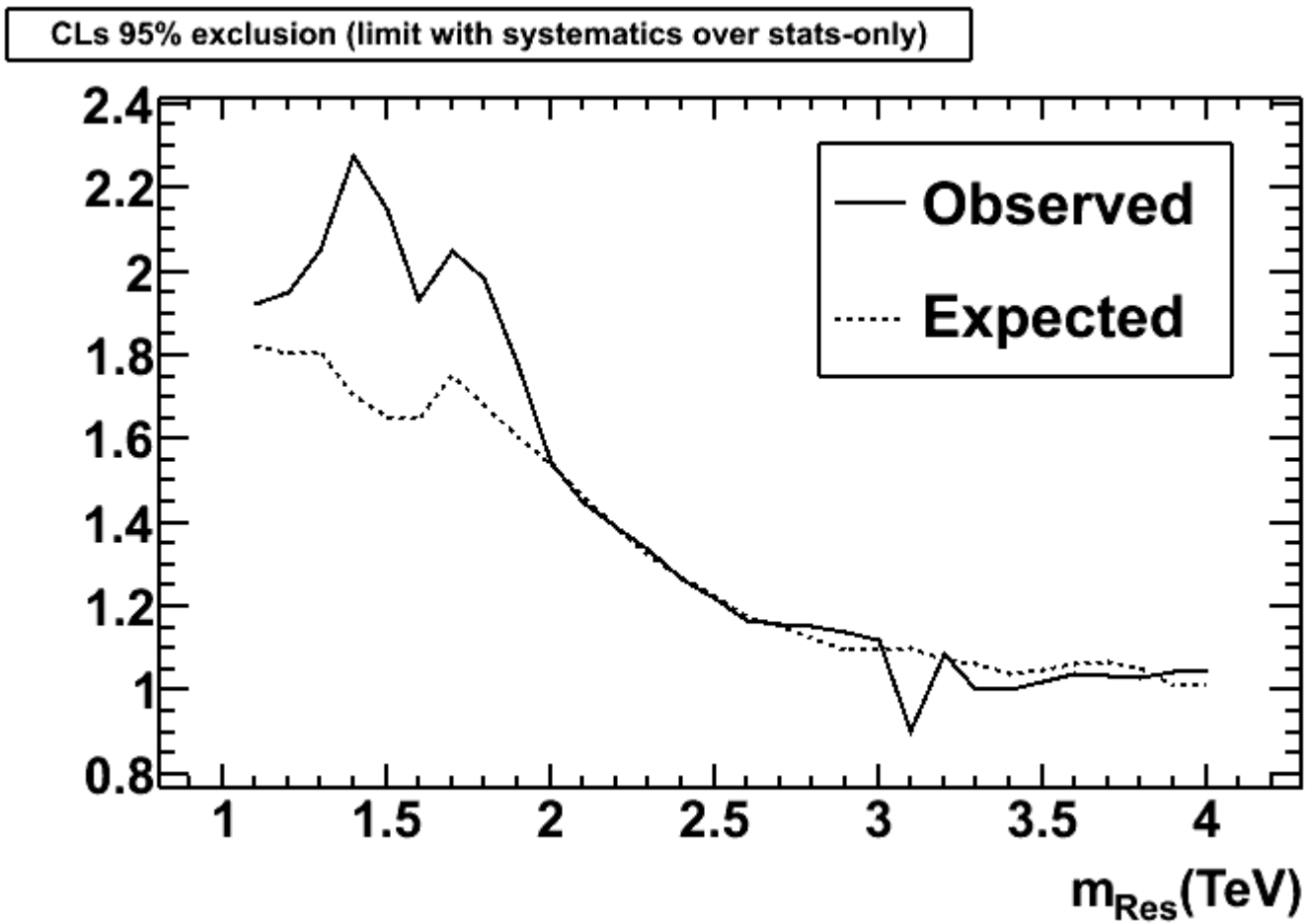

Calo Dijet Jet_150 TriggerEfficiency
h_110preL11preHLT1and150preL11preHLT1
Entries 2304
χ² / ndf 0.2273 / 1
Prob 0.6335
p0 0.01003 ± 0.00313
p1 5.357 ± 1.777
99.9% at 751.92GeV
First Fully Efficient Bin: 788GeV
Fractional Trigger Efficiency
Calo m_jj (GeV)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
200
400
600
800
1000
1200


Calo Dijet Jet_110 TriggerEfficiency
h_80preL11preHLT3and110preL11preHLT1
Entries 1314
χ² / ndf 1.215 / 1
Prob 0.2703
p0 0.01194 ± 0.00294
p1 4.894 ± 1.343
99.9% at 593.13GeV
First Fully Efficient Bin: 606GeV
Fractional Trigger Efficiency
Calo m_jj (GeV)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
200
300
400
500
600
700
800
900

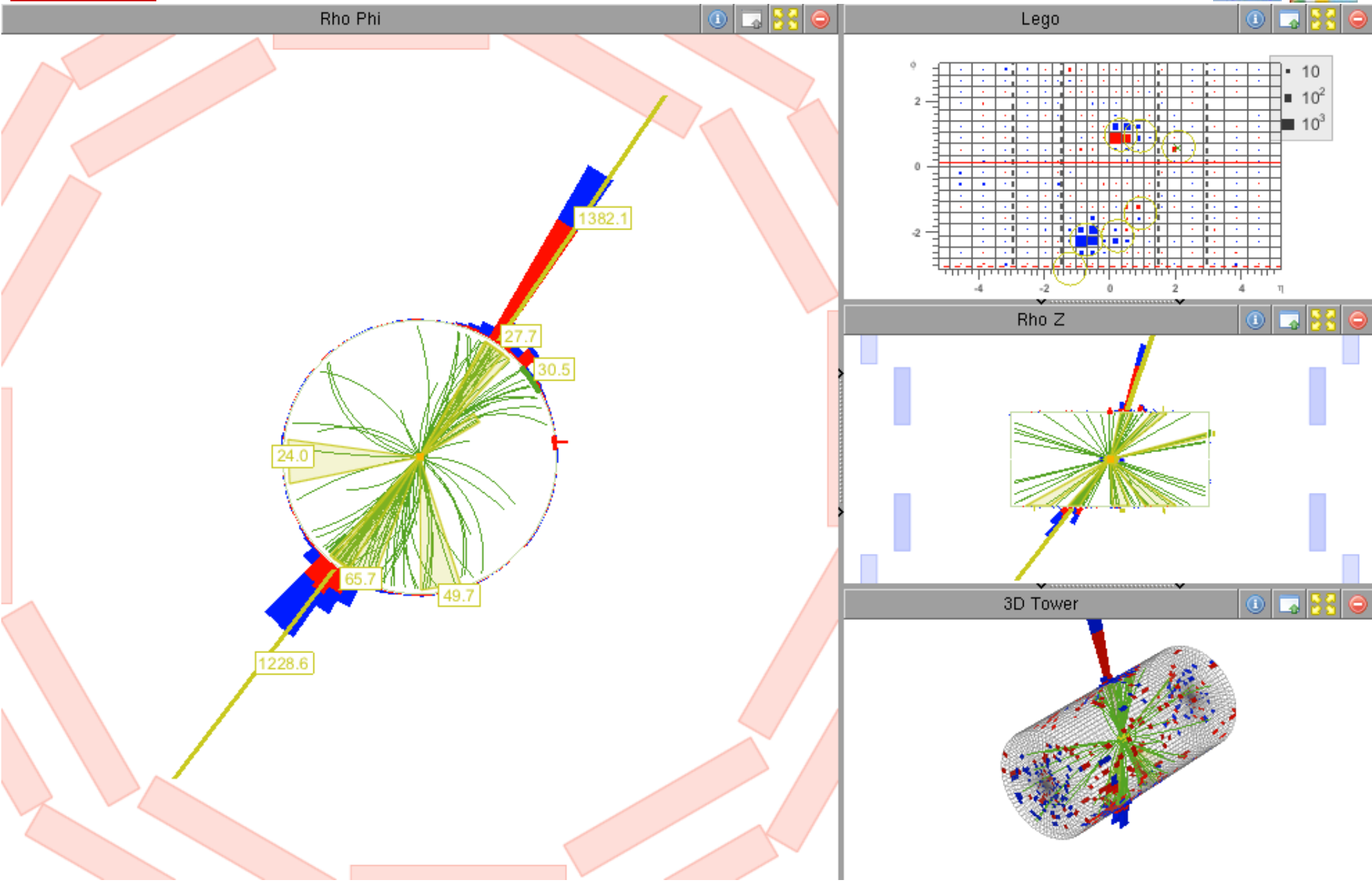

Data-Theory/Statistical Error
χ^2 / ndf 9.032 / 10
Constant 8.794 ± 2.263
Mean -0.07344 ± 0.11726
Sigma 0.7442 ± 0.1538
Counts
0
2
4
6
8
10
12
-10
-8
-6
-4
-2
0
2
4
6
8
10
Data-Theory/Statistical Error

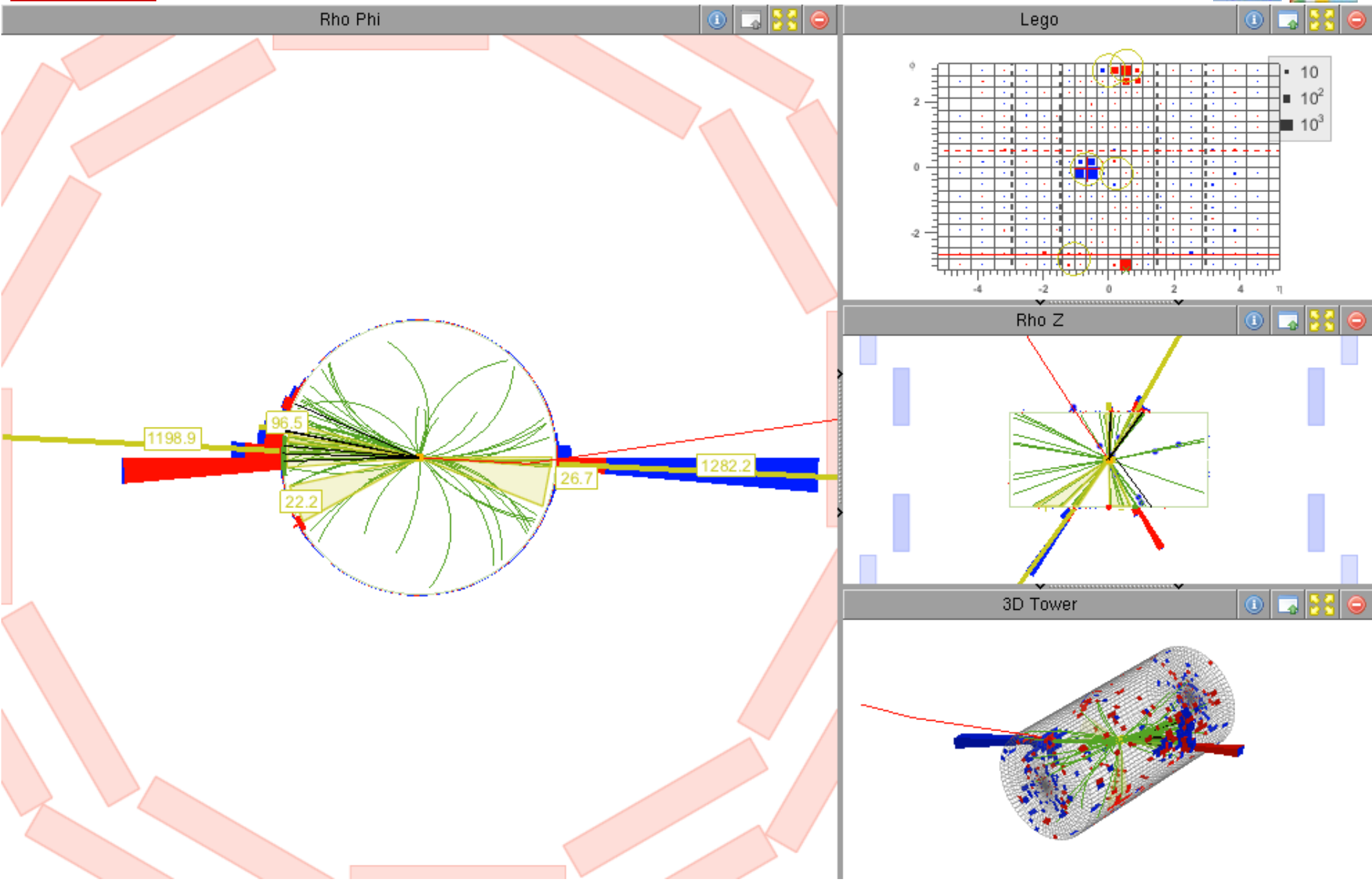
Effect of Systematics on Limits

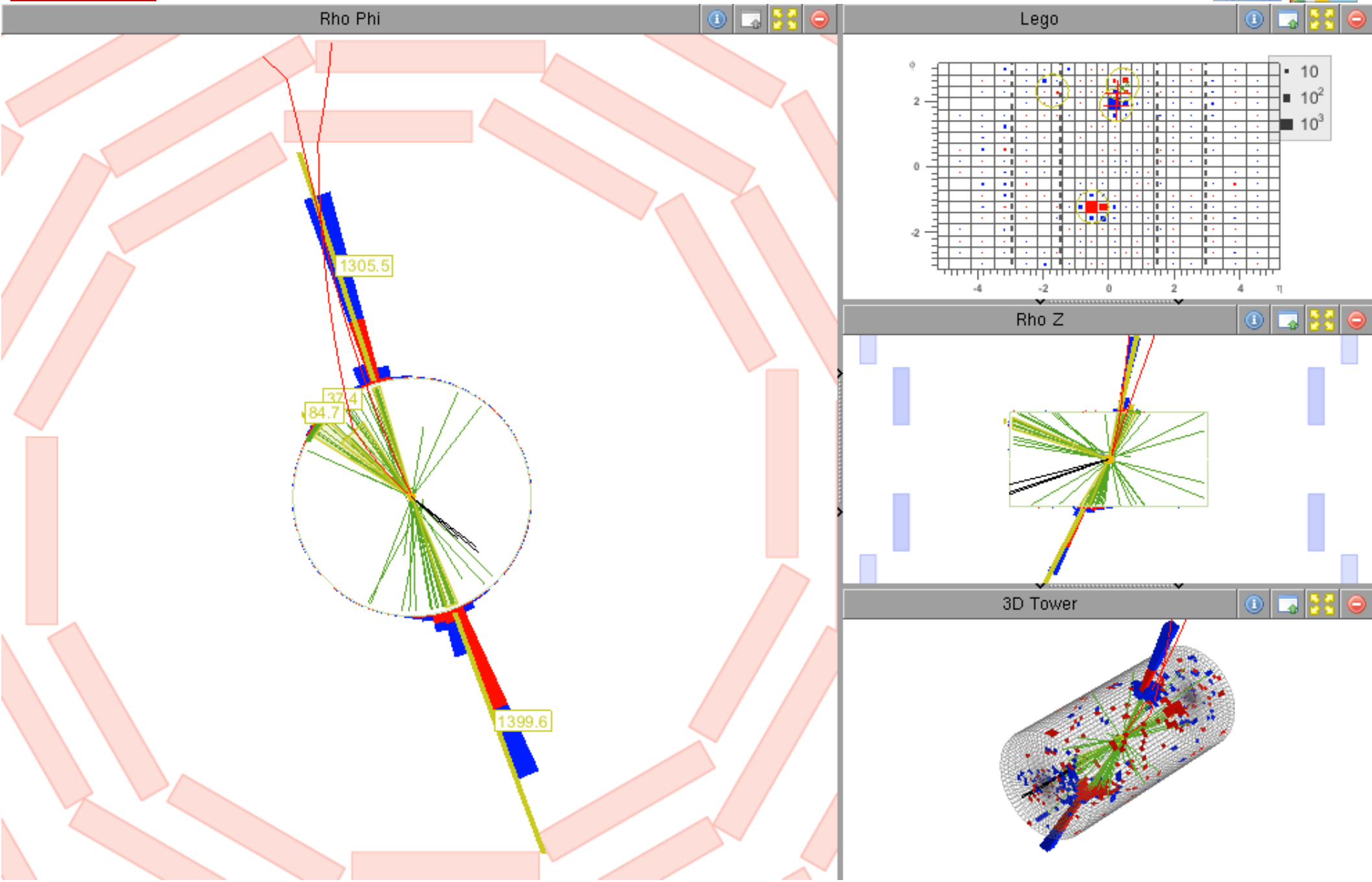
Systematics affect the limit mainly at low resonance mass, where statistical uncertainties at low dijet mass are small.

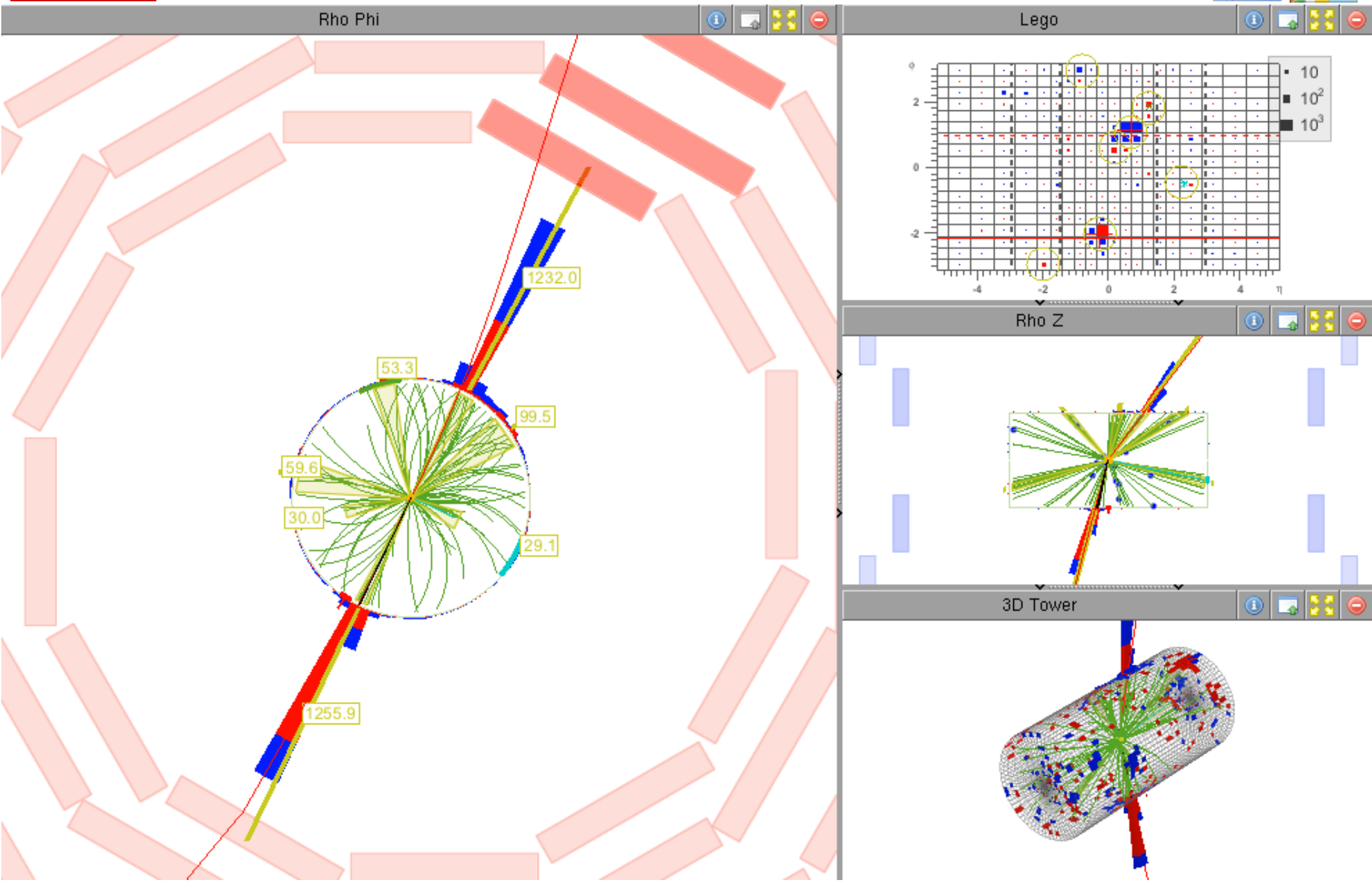


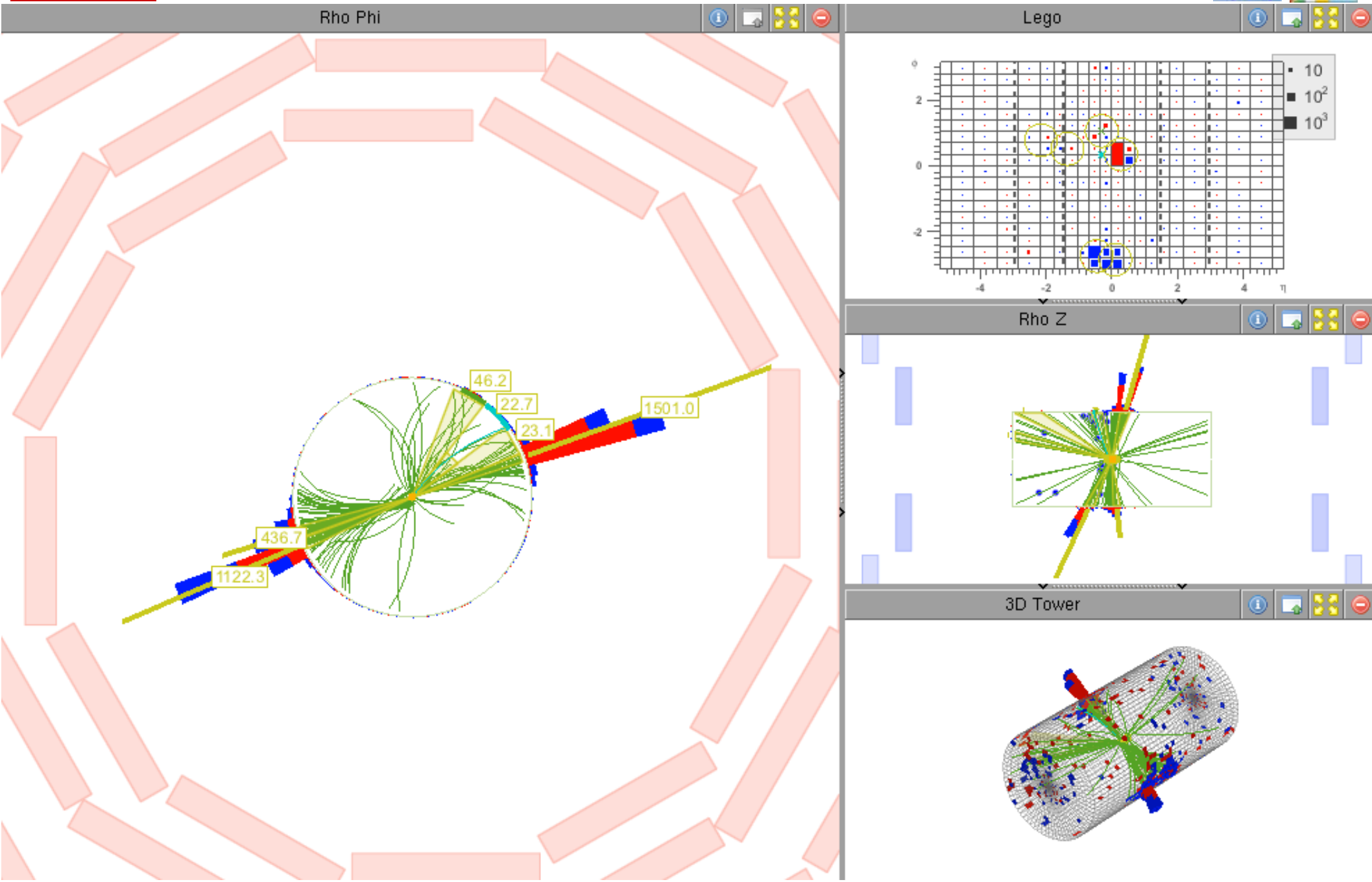
At high dijet mass the effect of systematic uncertainties is negligible.

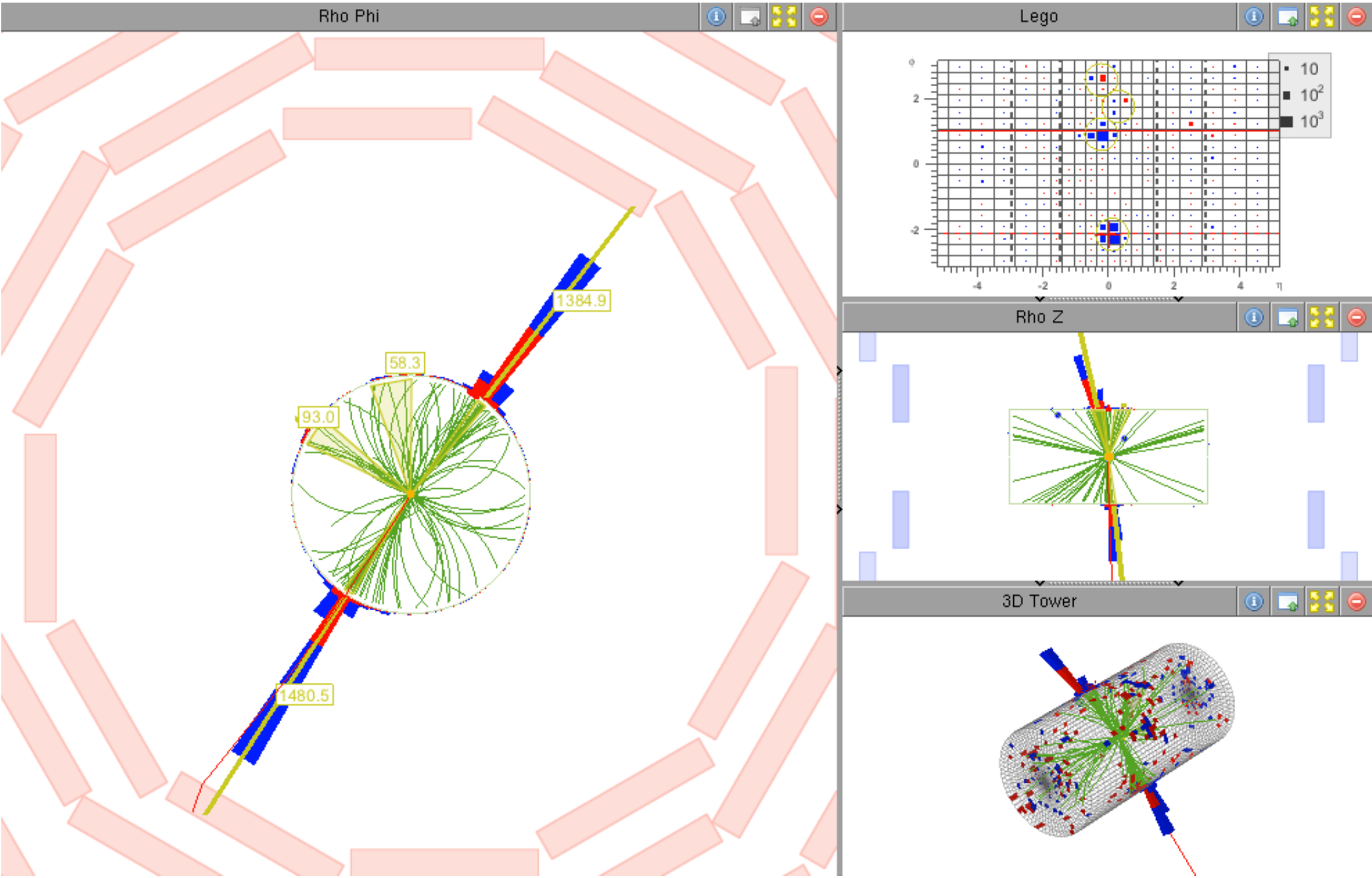

Rho Phi
1382.1
27.7
30.5
24.0
65.7
49.7
1228.6
Lego
10
10^2
10^3
Rho Z
3D Tower

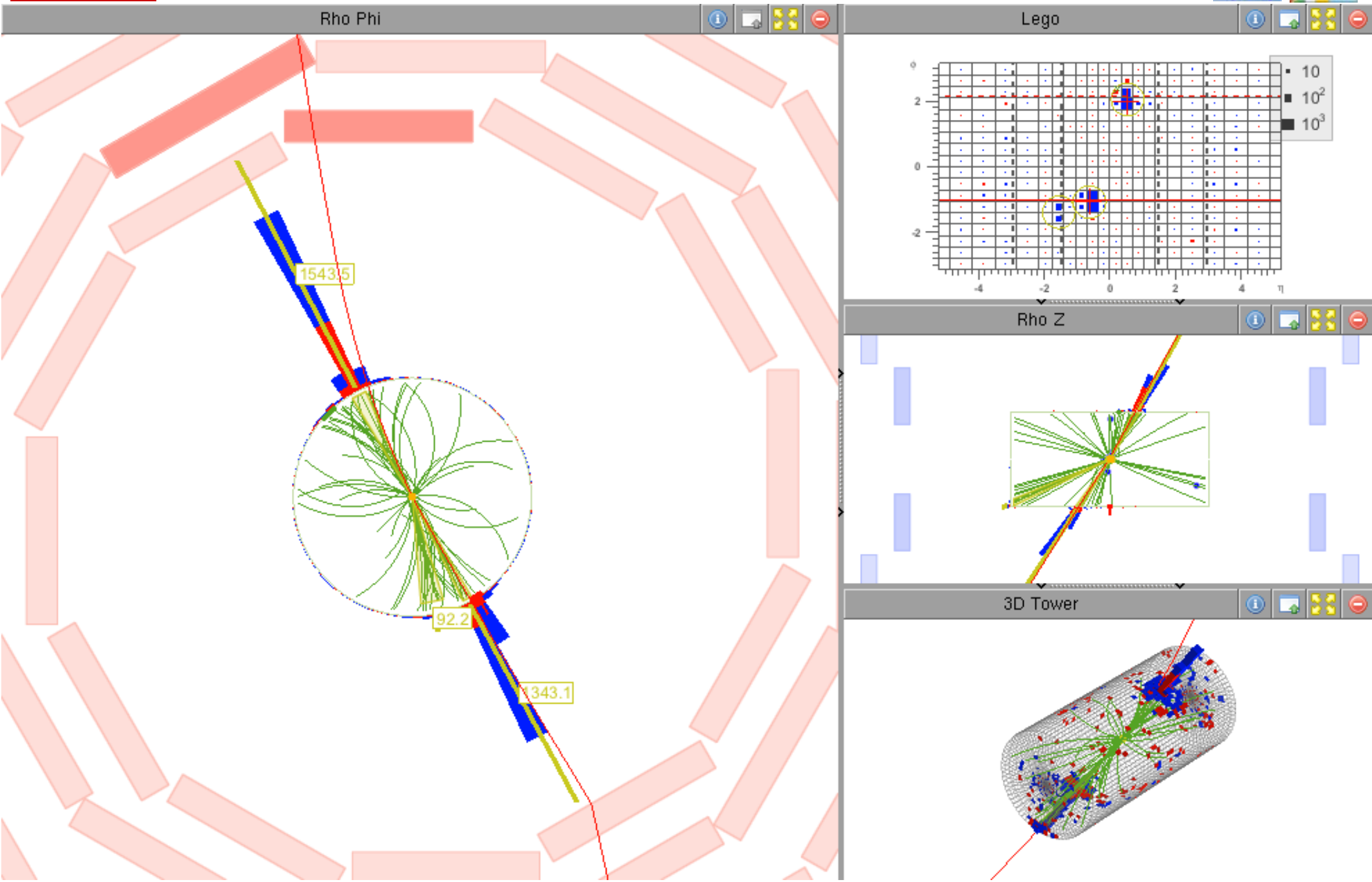

Rho Phi
1198.9
96.5
22.2
26.7
1282.2
Lego
10
10^2
10^3
Rho Z
3D Tower

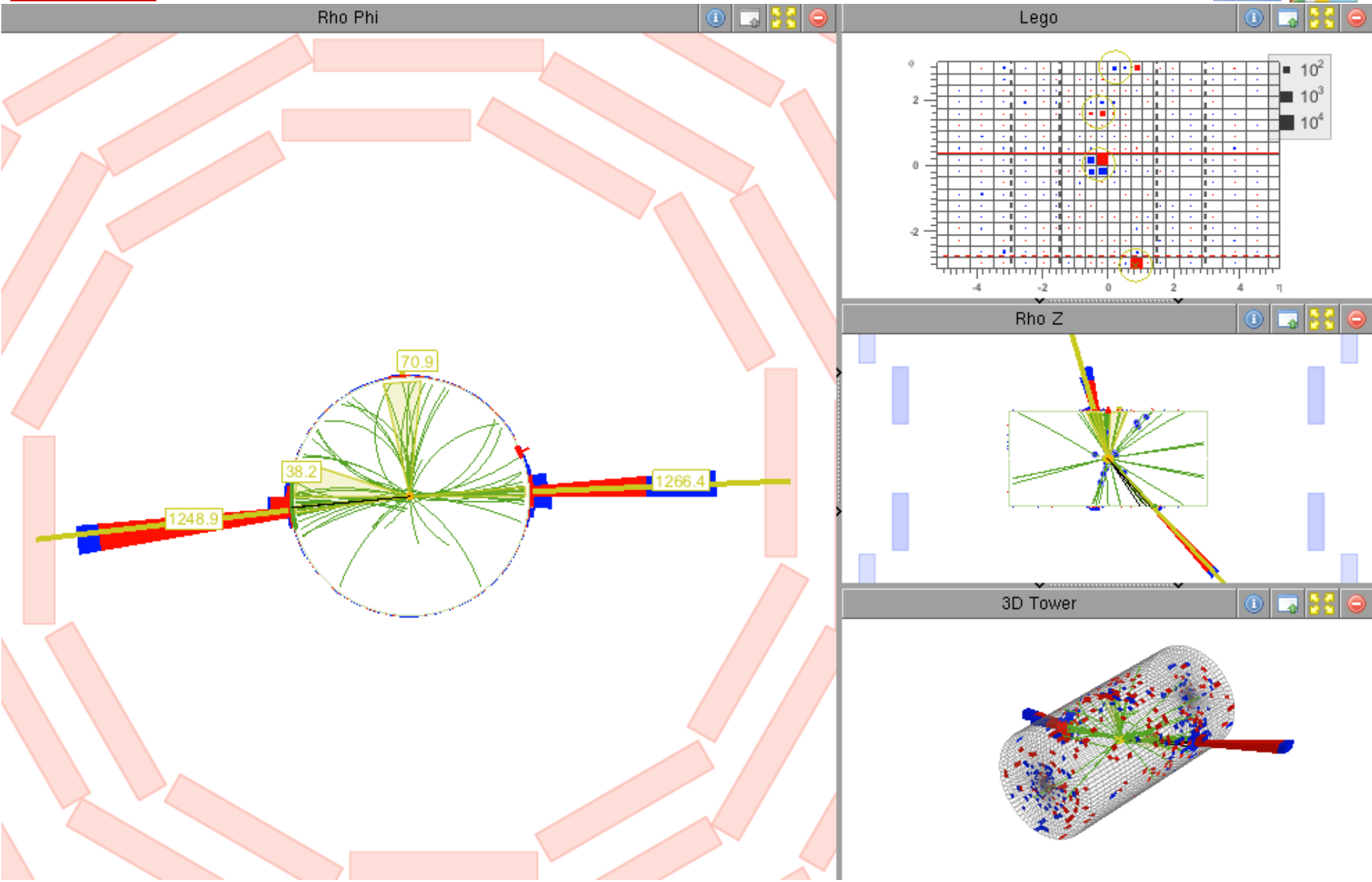

Rho Phi
1305.5
37.4
84.7
1399.6
Lego
10
10^2
10^3
Rho Z
3D Tower

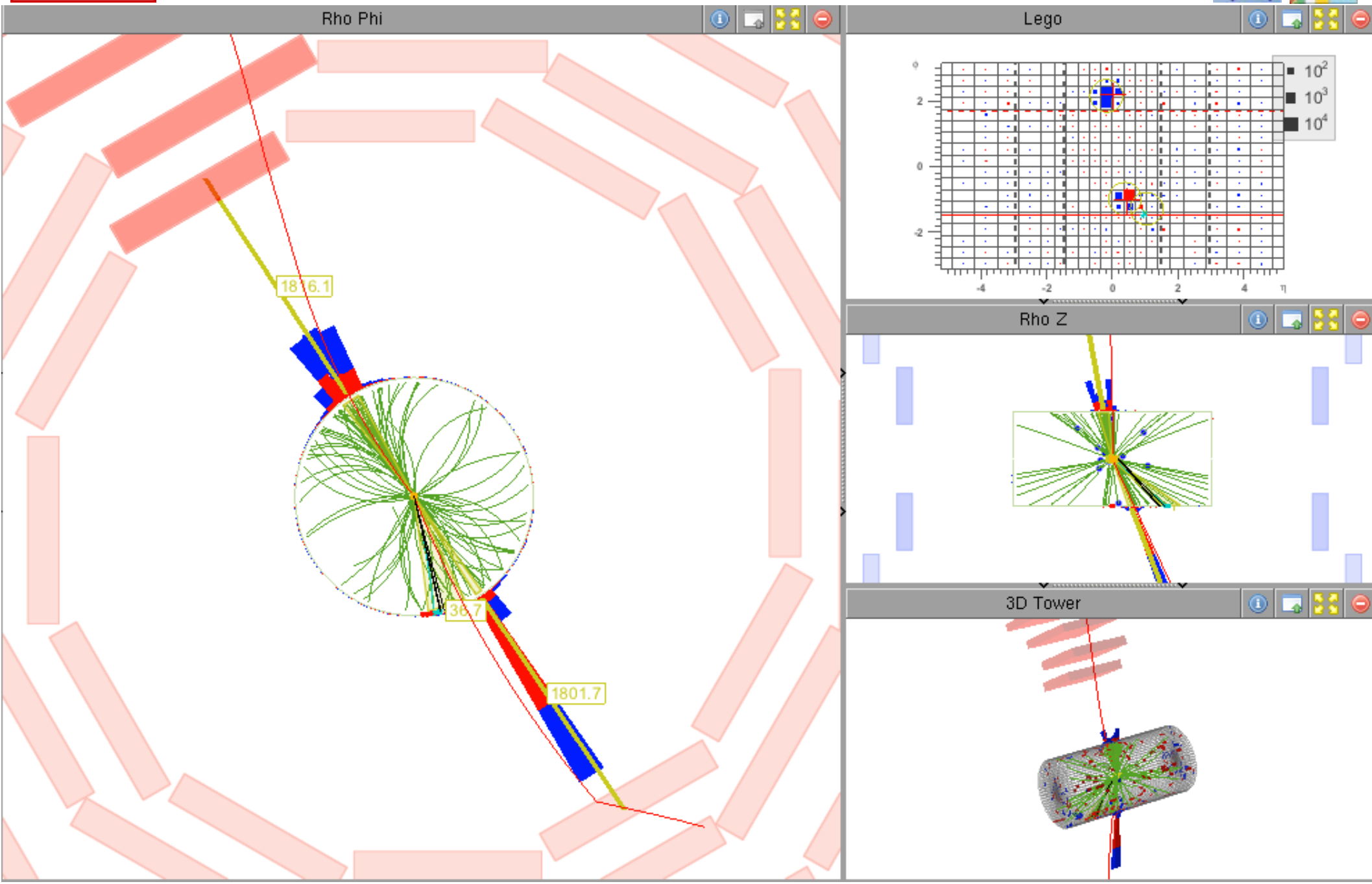

Rho Phi
1232.0
53.3
99.5
59.6
30.0
29.1
1255.9
Lego
10
10^2
10^3
Rho Z
3D Tower

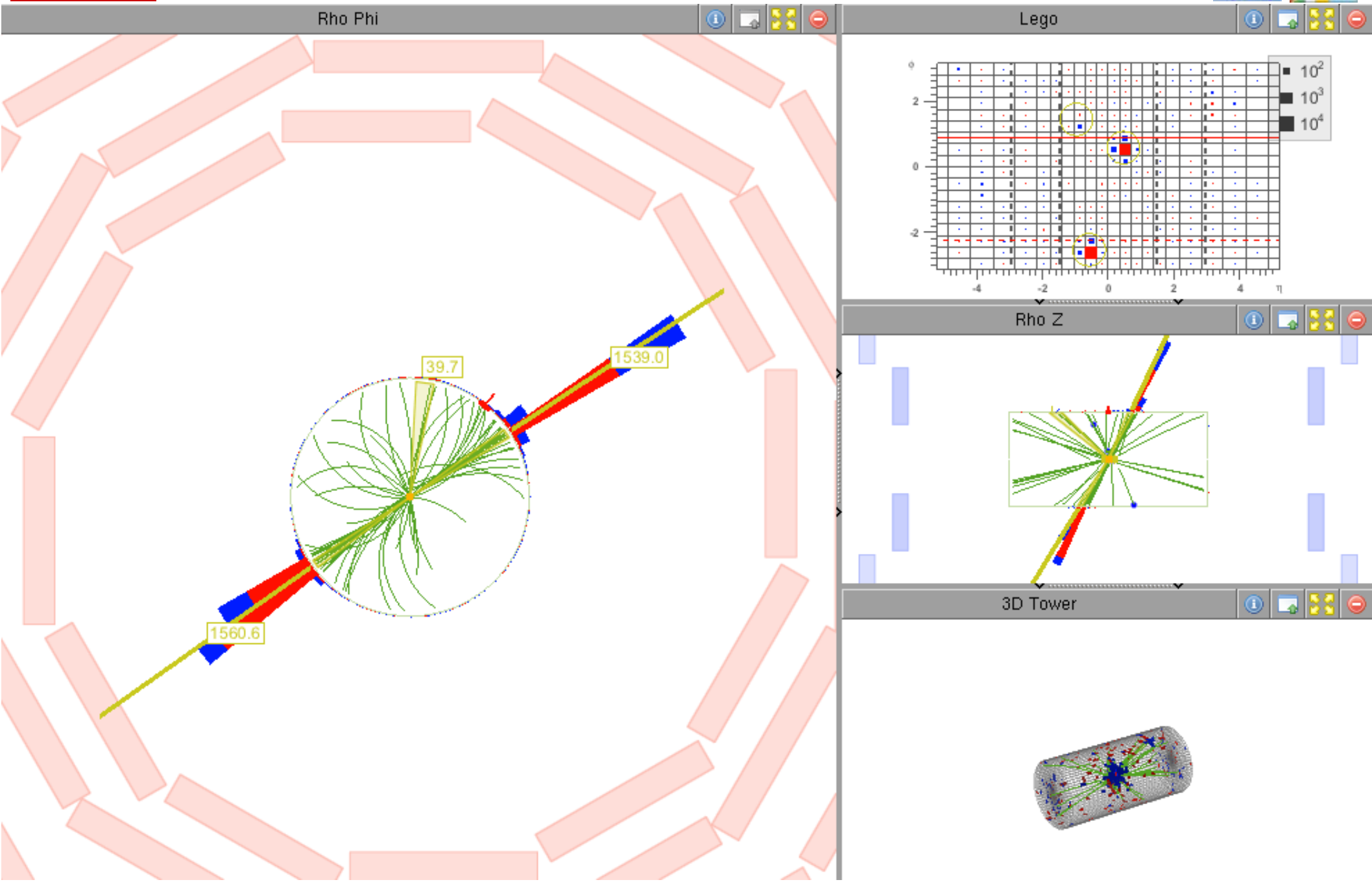

Rho Phi
46.2
22.7
23.1
1501.0
436.7
1122.3
Lego
10
10^2
10^3
Rho Z
3D Tower

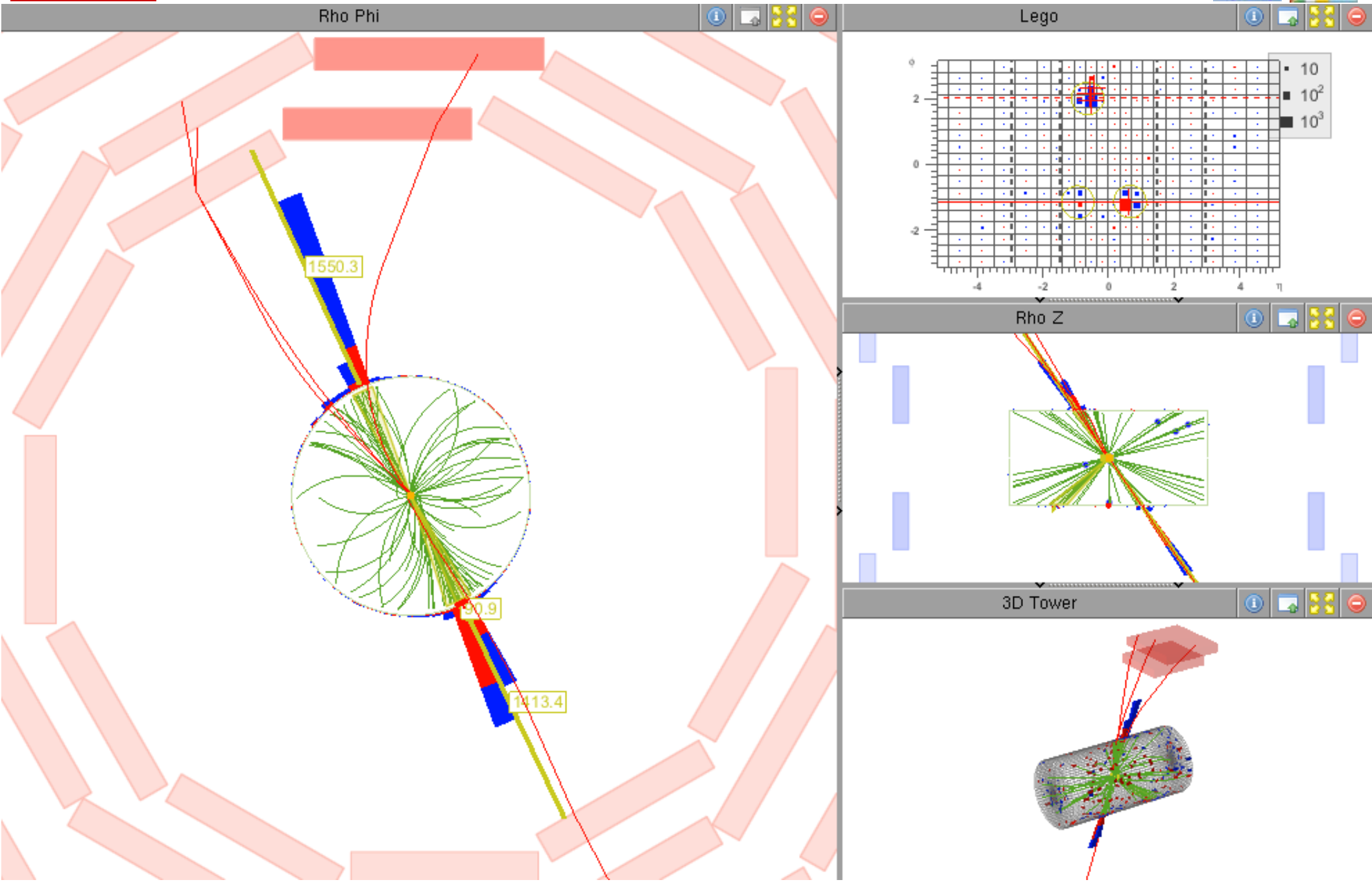

Rho Phi
1384.9
58.3
93.0
1480.5
Lego
10
10^2
10^3
Rho Z
3D Tower

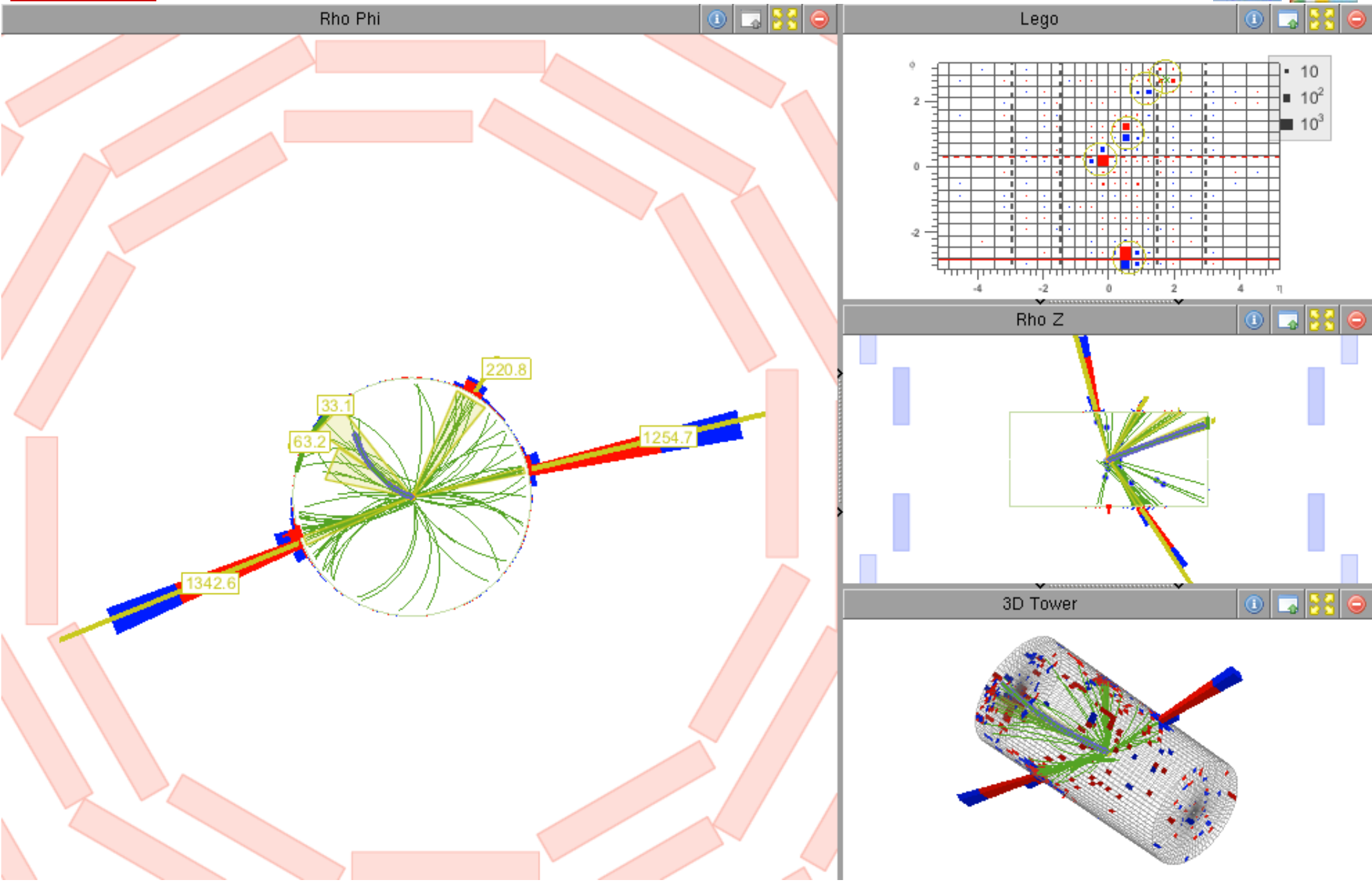

Rho Phi
1543.5
92.2
1343.1
Lego
10
10^2
10^3
Rho Z
3D Tower

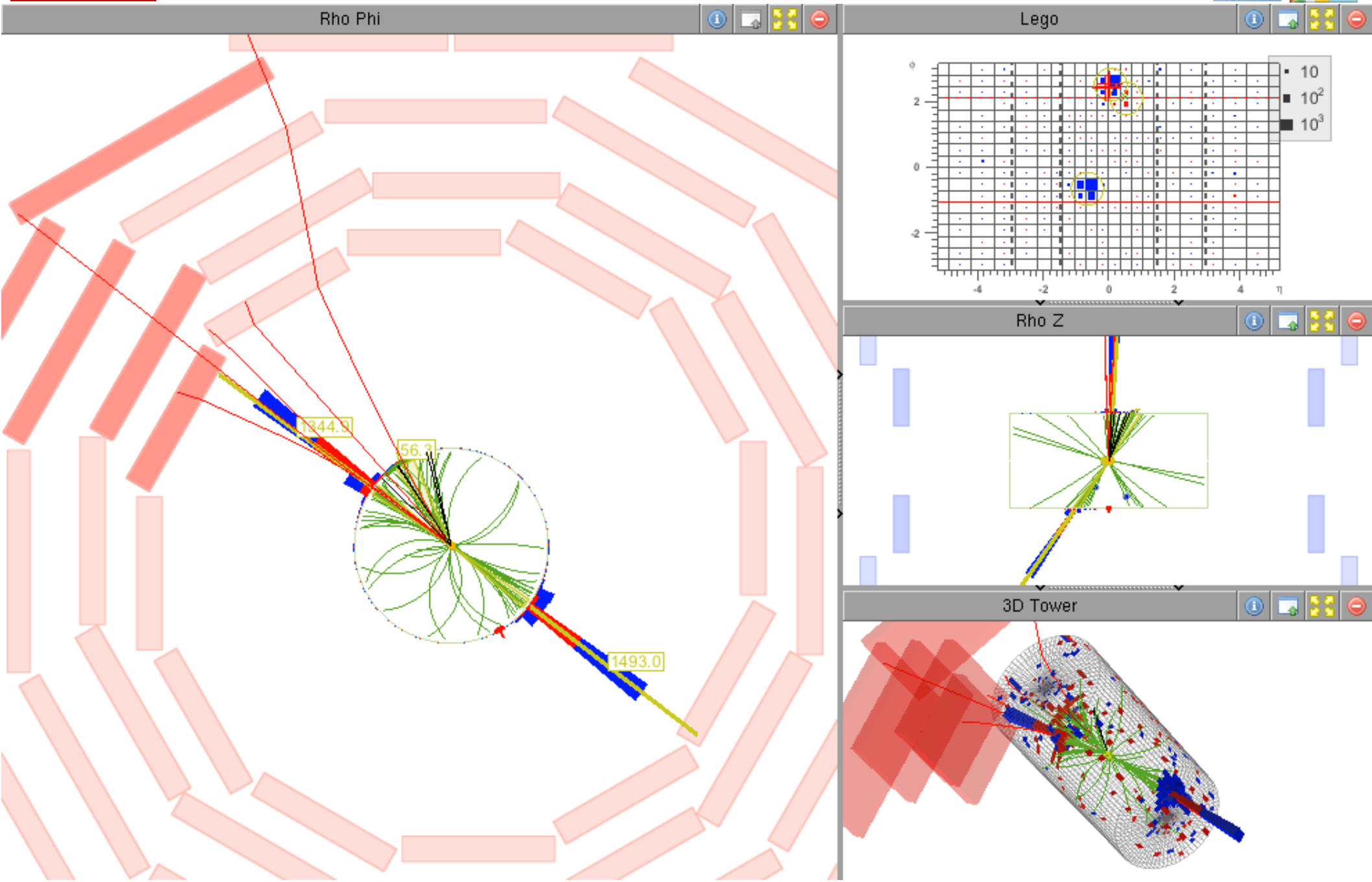

Rho Phi
70.9
38.2
1248.9
1266.4
Lego
10^2
10^3
10^4
Rho Z
3D Tower

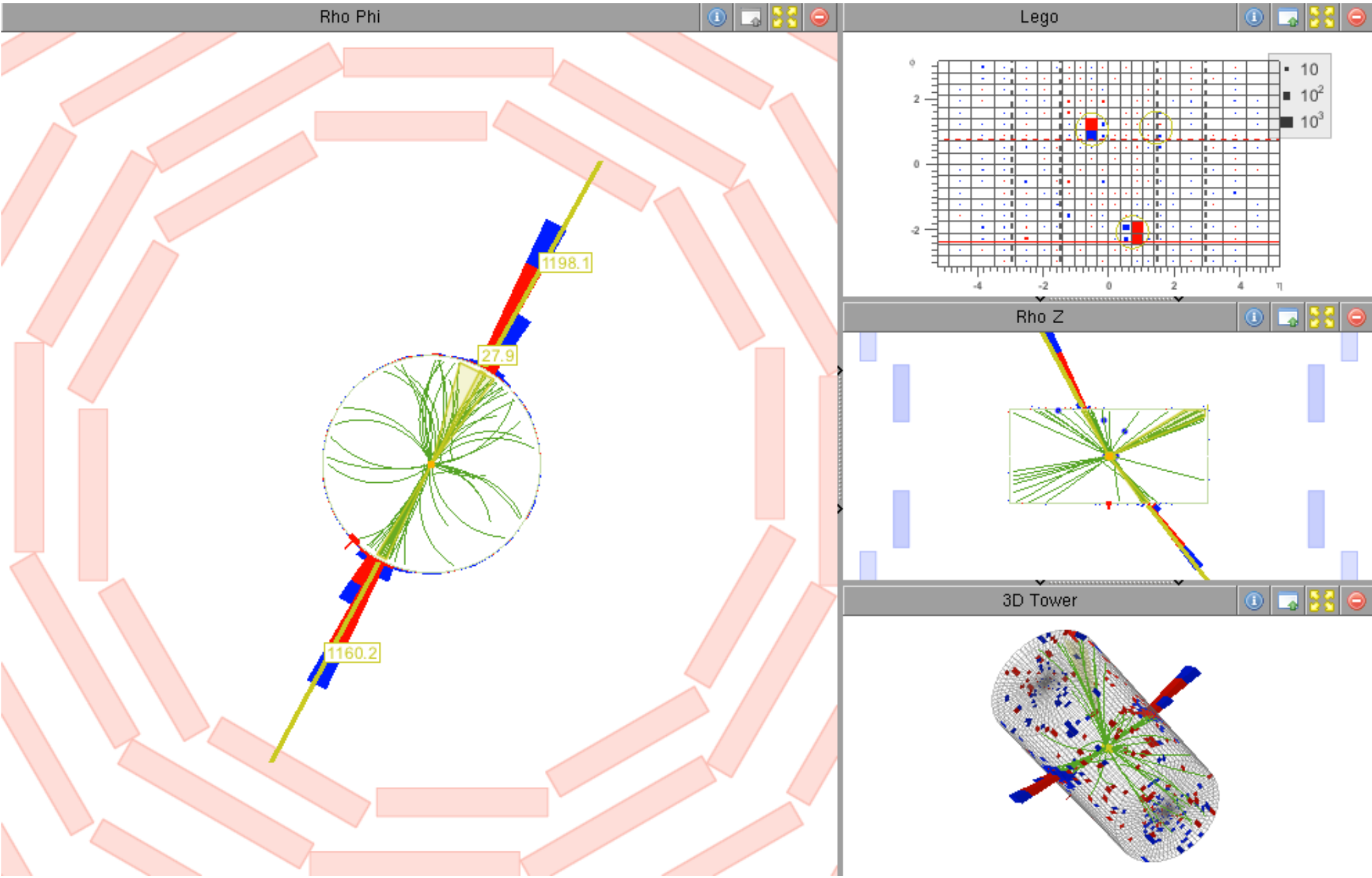

Rho Phi
1816.1
1801.7
Lego
10^2
10^3
10^4
Rho Z
3D Tower

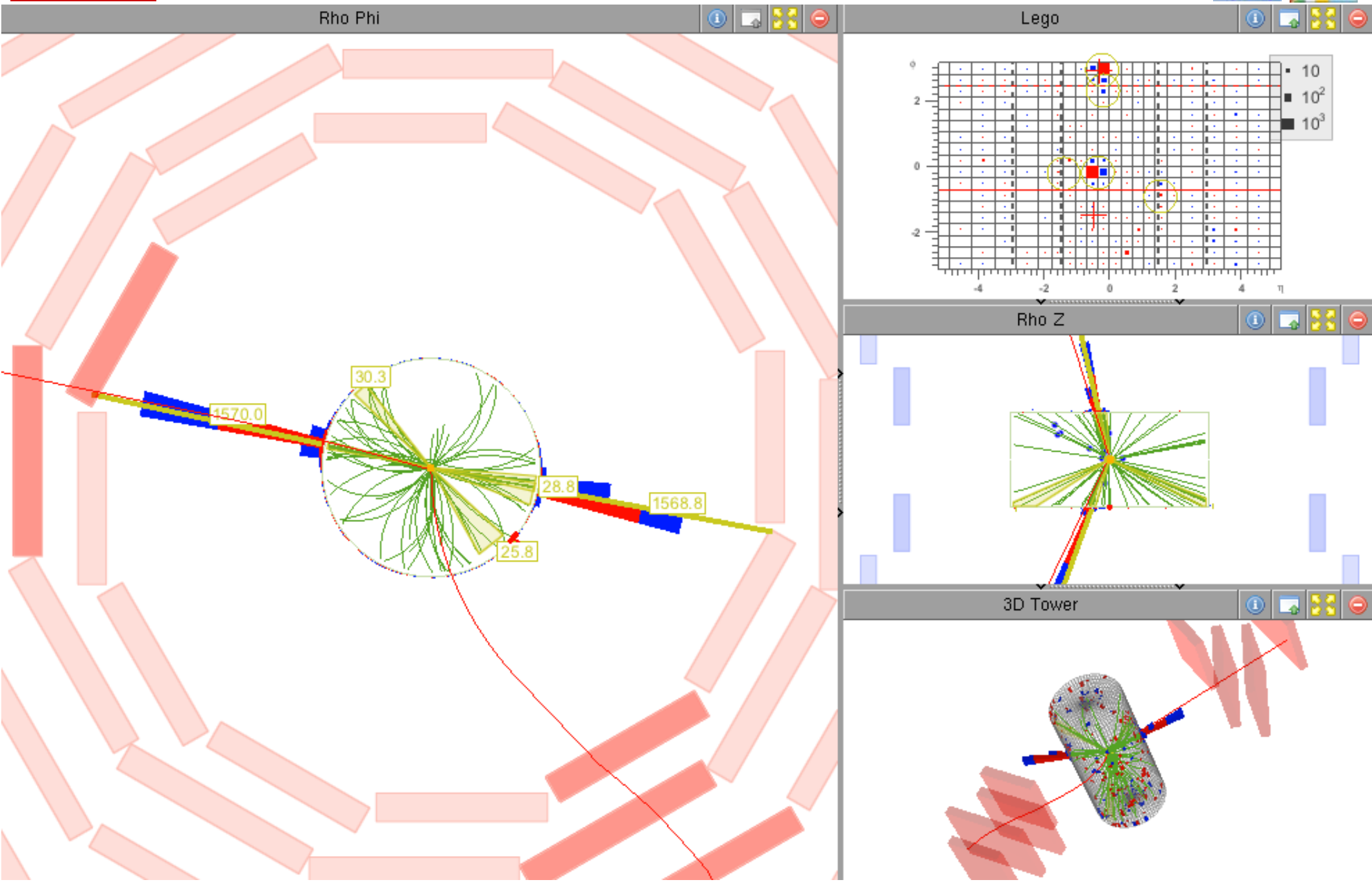

Rho Phi
39.7
1539.0
1560.6
Lego
10^2
10^3
10^4
Rho Z
3D Tower

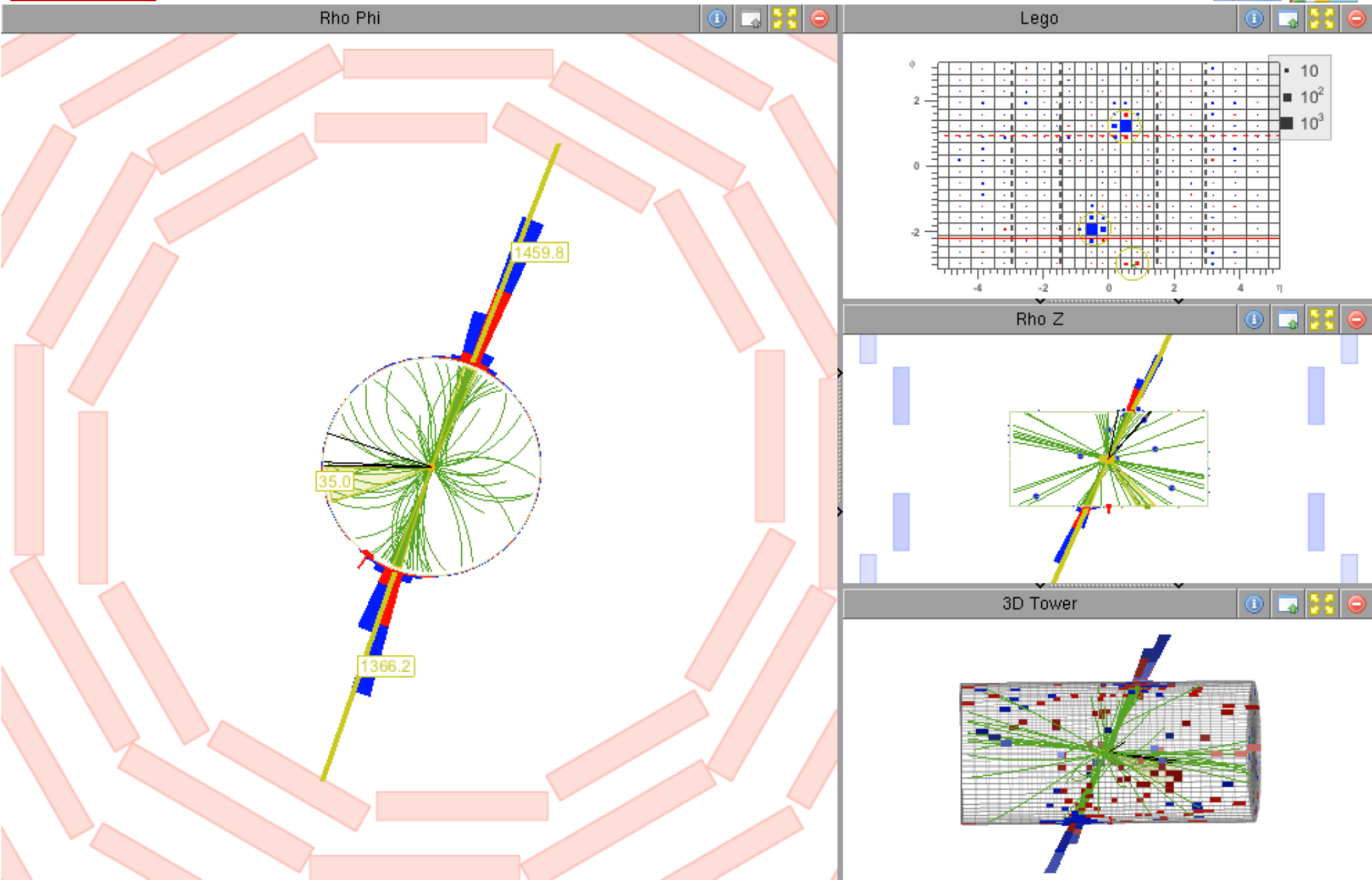

Rho Phi
1550.3
Lego
10
10^2
10^3
Rho Z
3D Tower


Rho Phi
220.8
33.1
63.2
1254.7
1342.6
Lego
10
10^2
10^3
Rho Z
3D Tower


Rho Phi
1844.9
56.3
1493.0
Lego
10
10^2
10^3
Rho Z
3D Tower

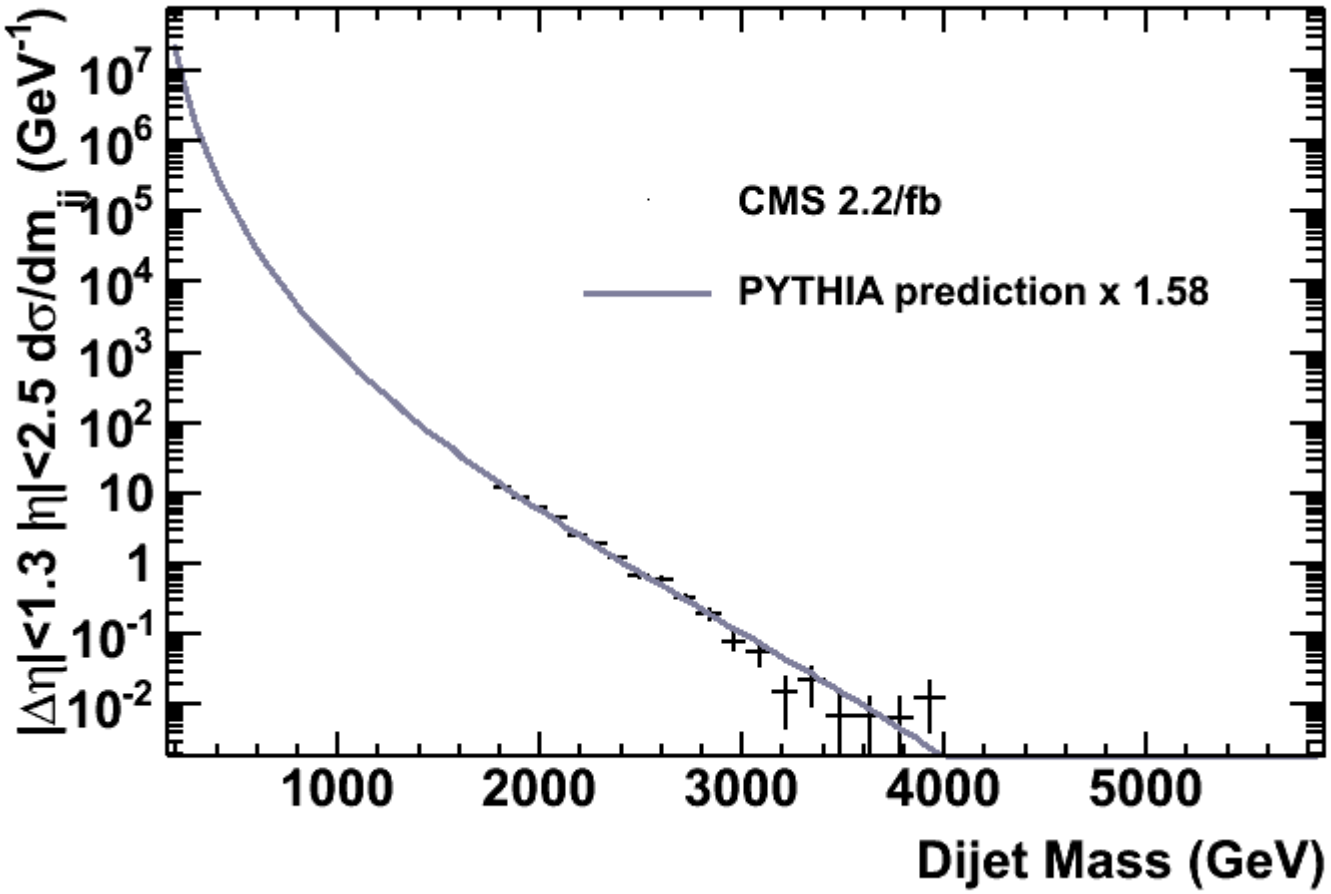

Rho Phi
1198.1
27.9
1160.2
Lego
10
10^2
10^3
Rho Z
3D Tower


Rho Phi
30.3
1570.0
28.8
1568.8
25.8
Lego
10
10^2
10^3
Rho Z
3D Tower


Rho Phi
1459.8
35.0
1366.2
Lego
10
10^2
10^3
Rho Z
3D Tower

Systematics: Background

PYTHIA QCD dijet rate prediction is low compared to unprescaled data.
Correction factor has 1.6% statistical uncertainty from fitting.

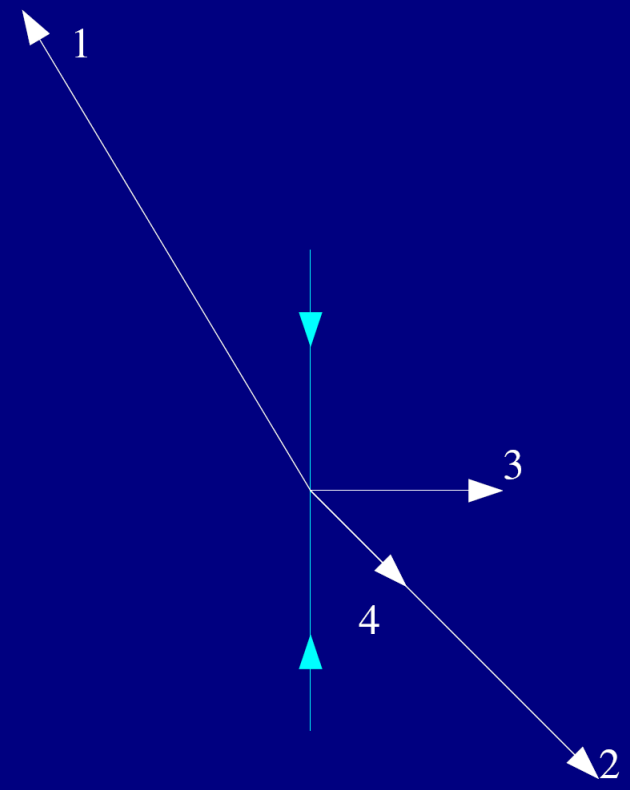


Kt by hand

Example with R=1

	d
1	34
2	18
3	4
4	2
1,2	216
1,3	40.8
1,4	4.2
2,3	3.08
2,4	0.00
3,4	1.54

	E_T	η	φ
1	5.83	0.57	3.14
2	4.24	-0.88	0.00
3	2.00	0.00	0.00
4	1.41	-0.88	0.00



Round One:

$$d_{2,4} = \min_{2,4}\{E_T^{\,2}\}(\Delta_{2,4}\eta^2+\Delta_{2,4}\phi^2)$$

$$= E_{T,2}^{\,2}(0^2+0^2)$$

Cluster to make new candidate '5.'

Eliminate where i,j=2,4.

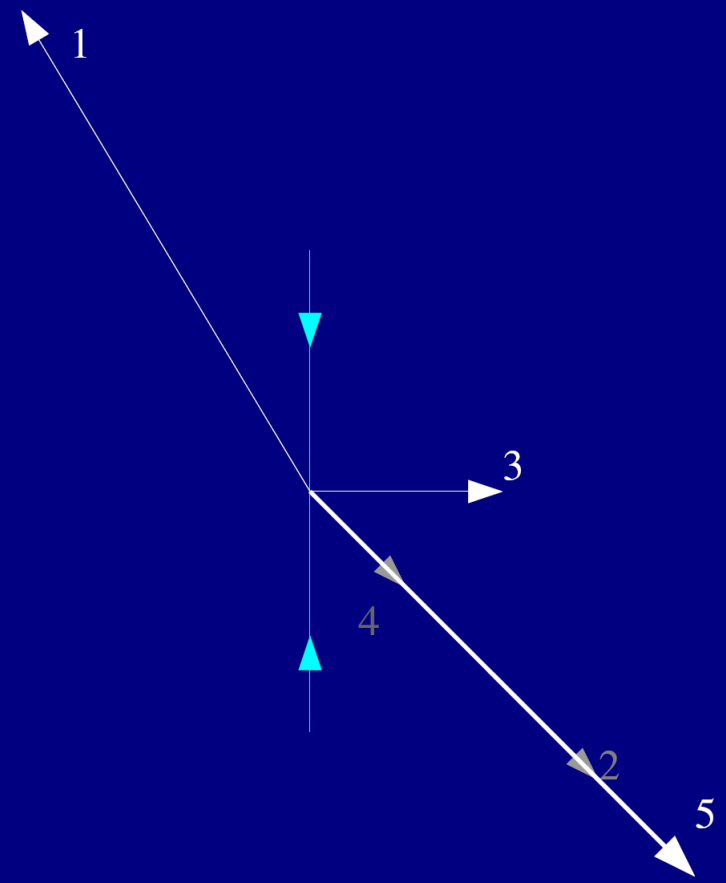
Calculate new d_{5i}, d_5, $E_{T,5}$, η_5, ϕ_5 (trivial this time)

Kt by hand

Example with R=1

	d
1	34
3	4
5	32
1,3	40.8
1,5	384
3,5	3.10

	E_T	η	φ
1	5.83	0.57	3.14
3	2.00	0.00	0.00
5	5.66	-0.88	0.00



Round Two:

$$d_{3,5} = \min_{3,5}\{E_T^{\,2}\}(\Delta_{3,5}\eta^2+\Delta_{3,5}\phi^2)$$

$$= E_{T,3}^{\,2}(0.88^2+0^2)$$

Cluster to make new candidate '6.'

Eliminate where i,j=3,5.

Calculate new d_{6i}, $E_{T,6}$, ϕ_6

$d_6 = E_{T,6}^{\,2} = 52$ (simple vector sum)

$$\eta_6 = (E_{T,3}\eta_3 + E_{T,5}\eta_5) / E_{T,6}$$

$$= (2.00*0.00 - 5.66*0.88) / 7.21$$

Kt by hand

Example with R=1

	d
1	34
6	52
1,6	66.8

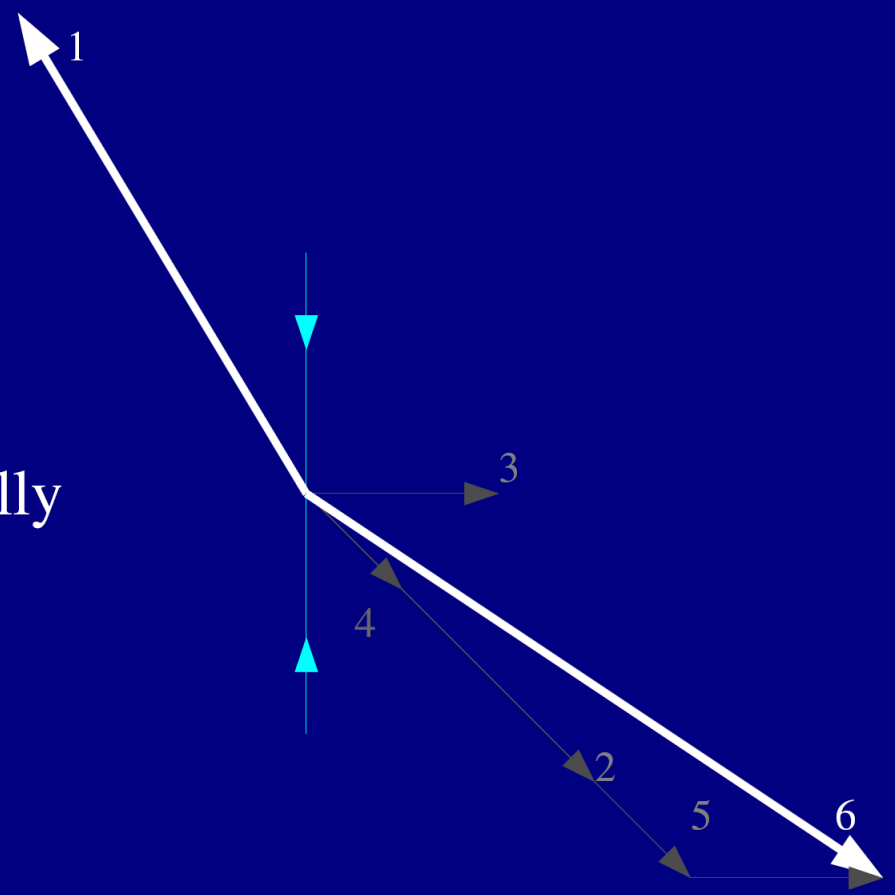
	E_T	η	φ
1	5.83	0.57	3.14
6	7.21	-0.69	0.00

Round Three:

1 is a jet!

Round Four:

6 is a jet!

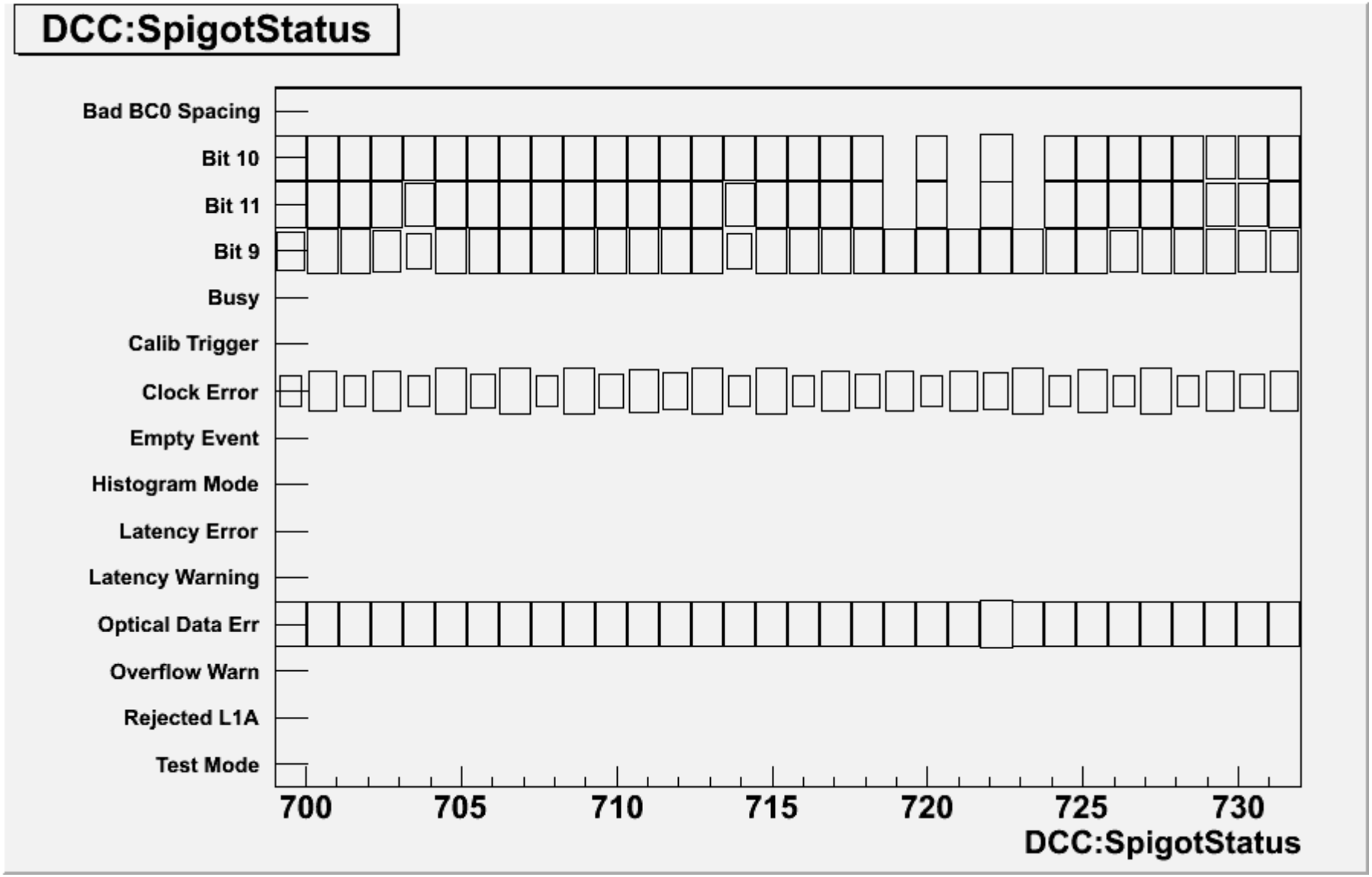


Notes:

- Low-energy jets emerge, then monotonically increasing E_T.
- Candidate collection rapidly deflates, as

$$ {}_{n}C_{2} + n \rightarrow {}_{n-1}C_{2} + n\text{-}1 $$

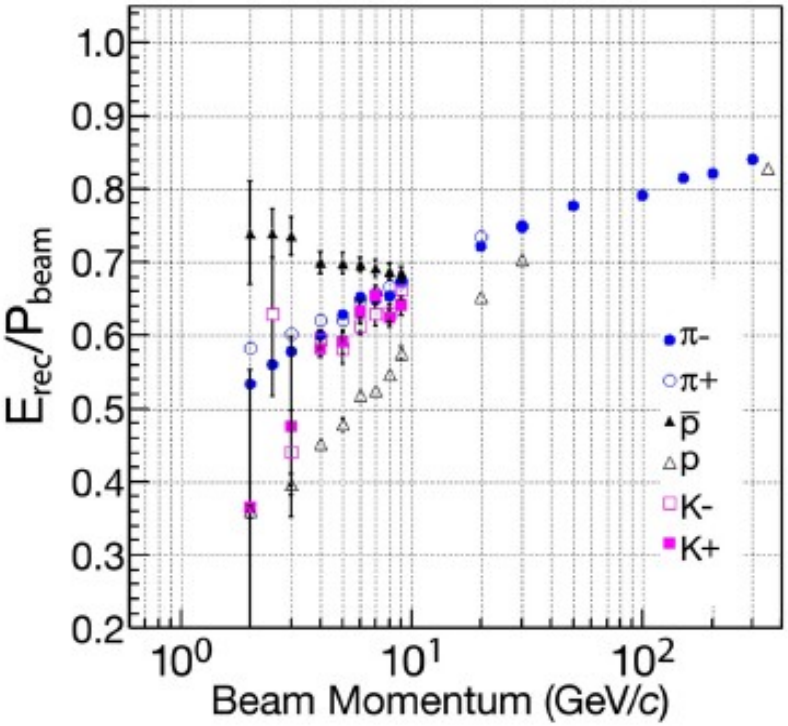
Example MonVis Plot, fed by hcalDCCMonitoring

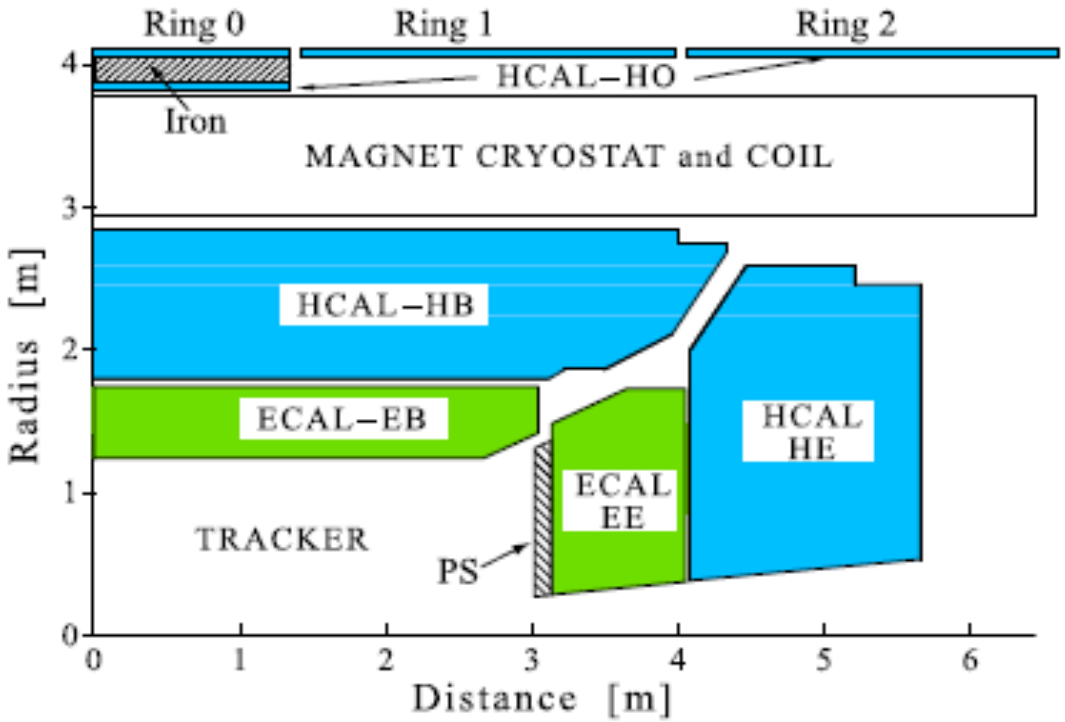


How to Calibrate CMS for Jets

- Calibrating Calorimeters
  - testbeam slice
  - in-situ source tests
  - in-situ single-pion measurements
  - phi symmetry
- Calibrating Jets
  - photon-jet balancing
  - Z-balancing
  - dijet asymmetry (distribution also gives jet resolution)

Eur. Phys. J. C (2009) 60: 359-373
DOI 10.1140/epjc/s10052-009-0959-5





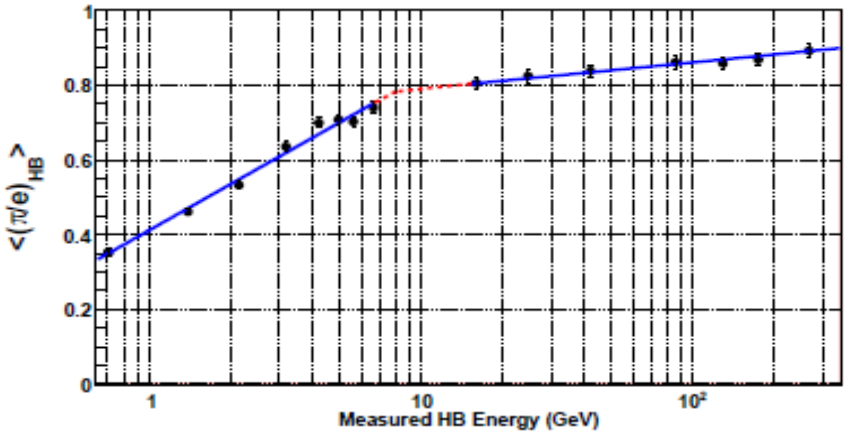
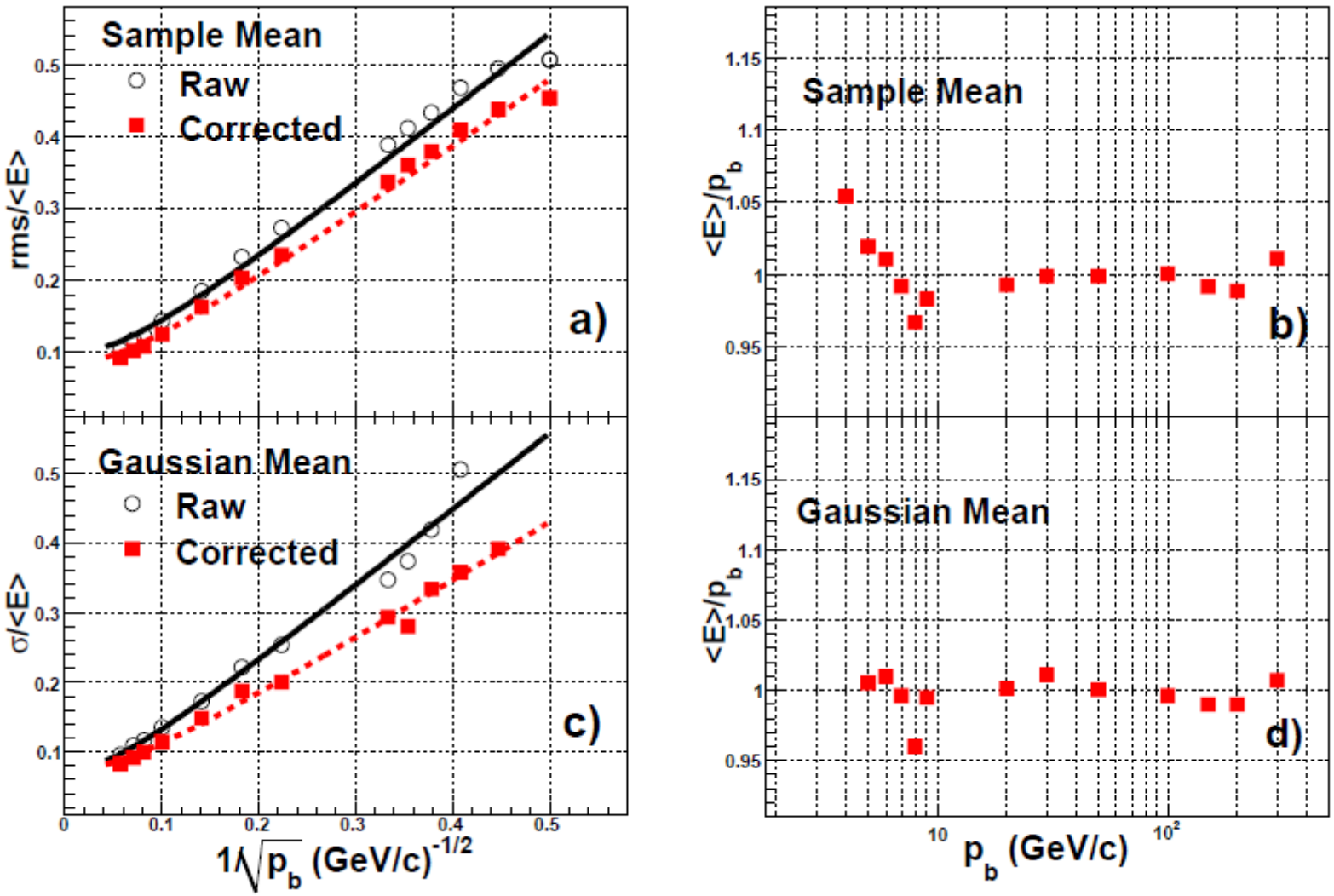


Fig. 17. π/e *vs* E_{HB} for events interacting in the HB. The data are fit to two separate log functions with a break at about 8 GeV.

Eur. Phys. J. C (2009) 60: 359-373
DOI 10.1140/epjc/s10052-009-0959-5



Eur. Phys. J. C (2009) 60: 359-373
DOI 10.1140/epjc/s10052-009-0959-5

Usual resolution parameterization:

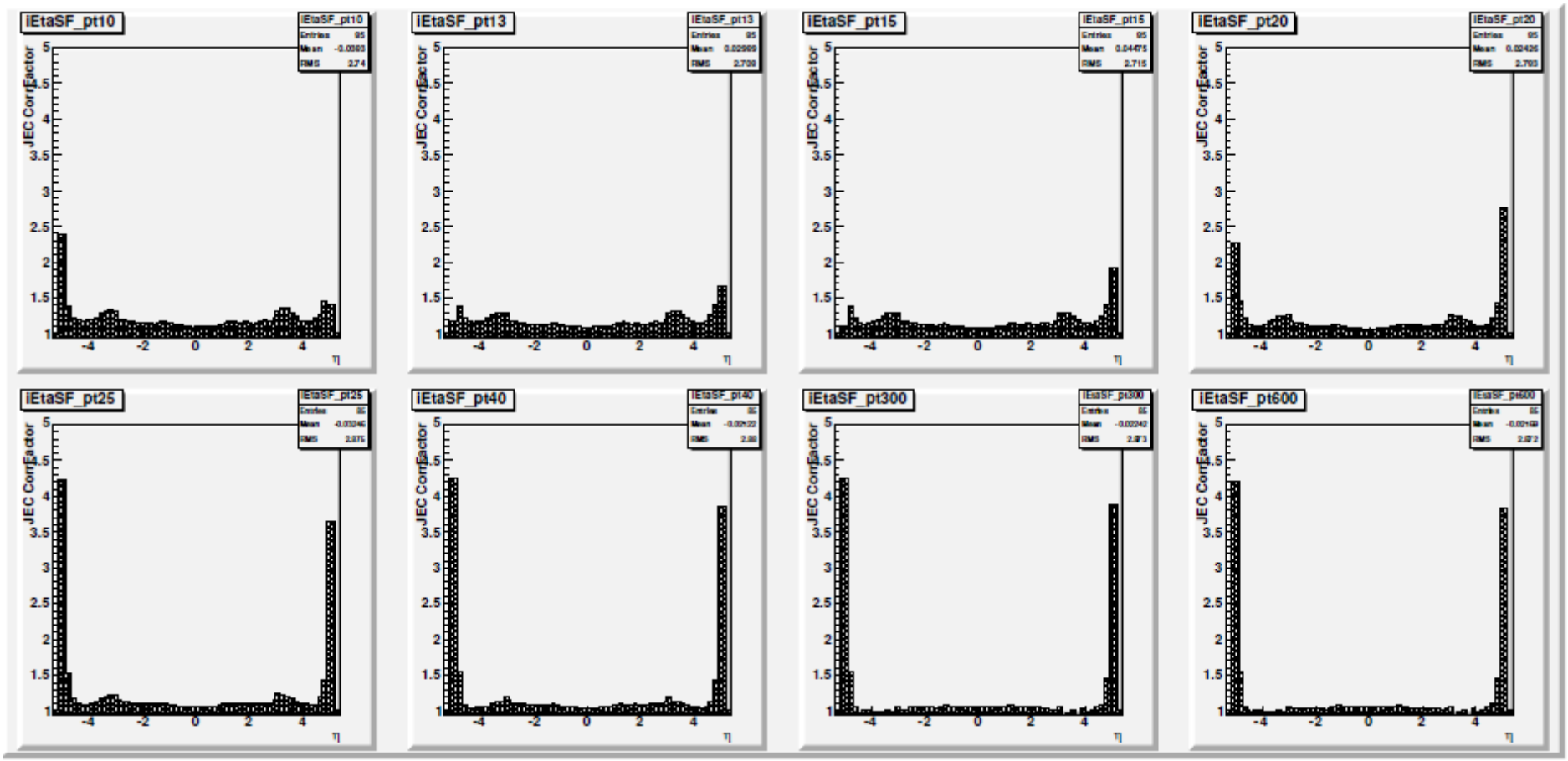
$$\sigma/E = a/\sqrt{(E)} \oplus b$$

Total EB+HB	a	b
RMS (raw)	111.5±2.1%	8.6±1.4%
RMS (corr'd)	94.3±1.2%	8.4±1.0%
Gauss'n (raw)	110.7±3.1%	7.3±1.7%
Gauss'n (corr'd)	84.7±1.6%	7.4±0.8%

Parameter fits depend upon details of methodology. Values nonetheless comparable.

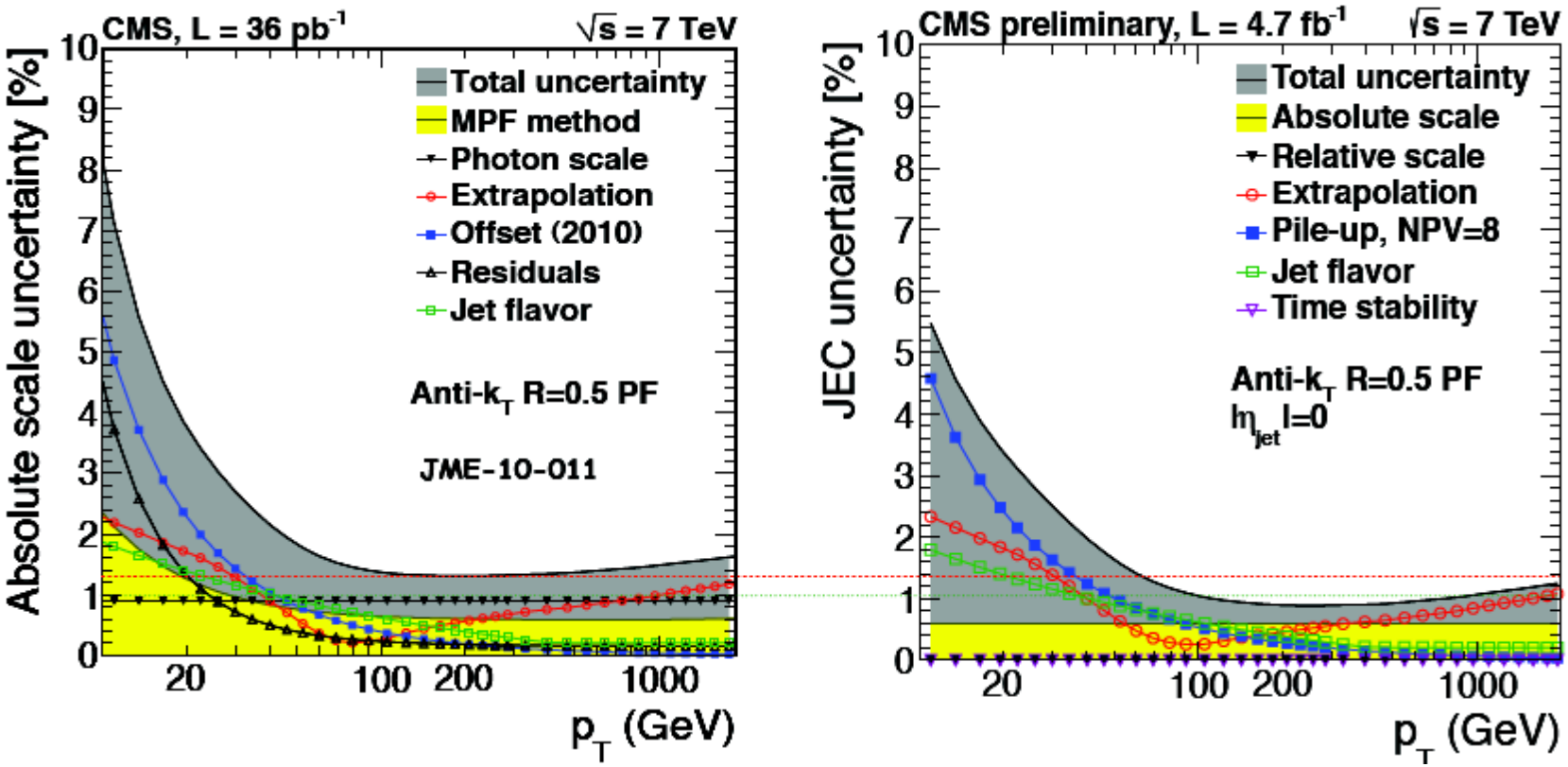
Jet Corrections

50% - few%, depending on η and p_T



Very large (~400%) in the very forward calo.
Being investigated.

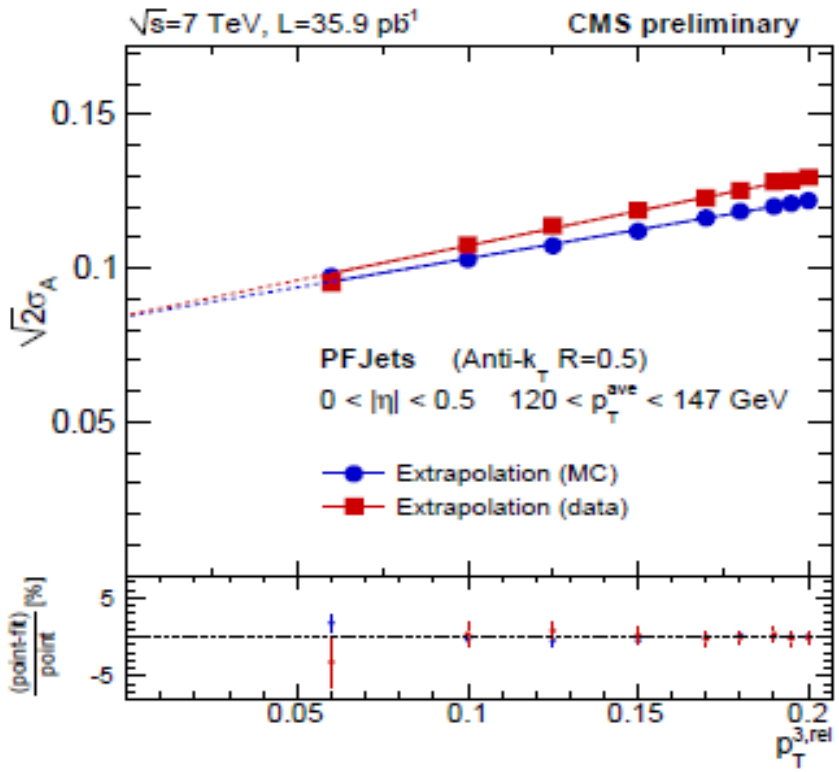
Jet Correction Uncertainties



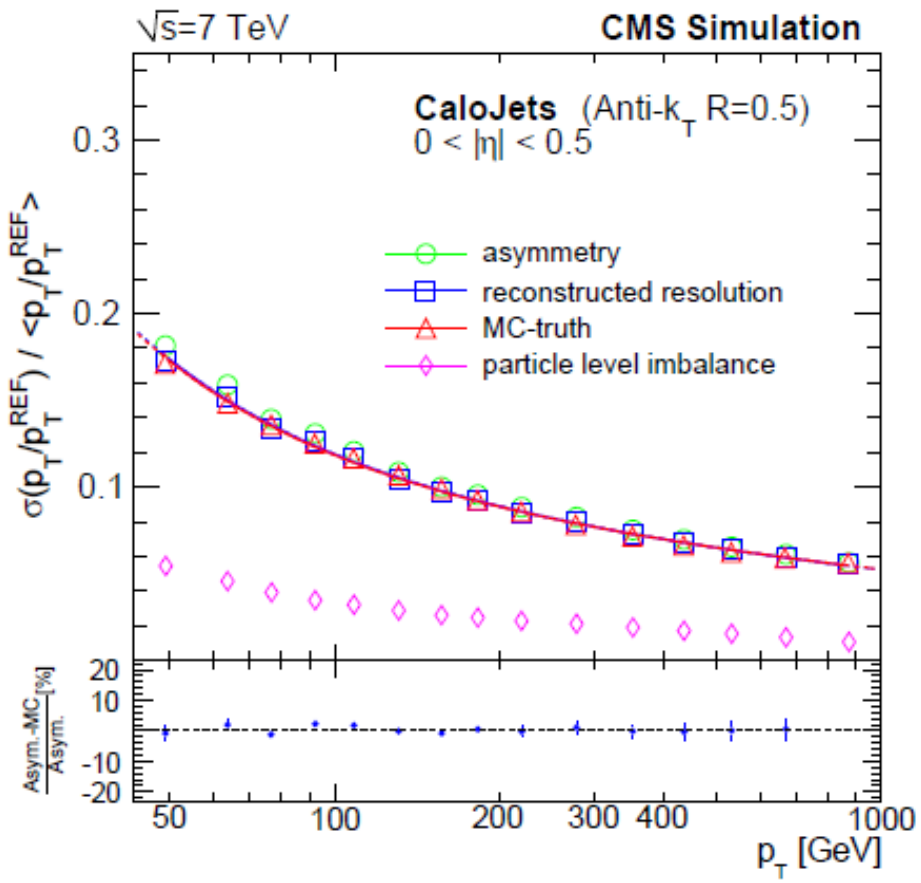
Shown here for ak5 PF, but not very different for other choices.

Dijet Resolution: Asymmetry Method

$$A = \frac{(p_T^{Jet1} - p_T^{Jet2})}{(p_T^{Jet1} + p_T^{Jet2})}$$

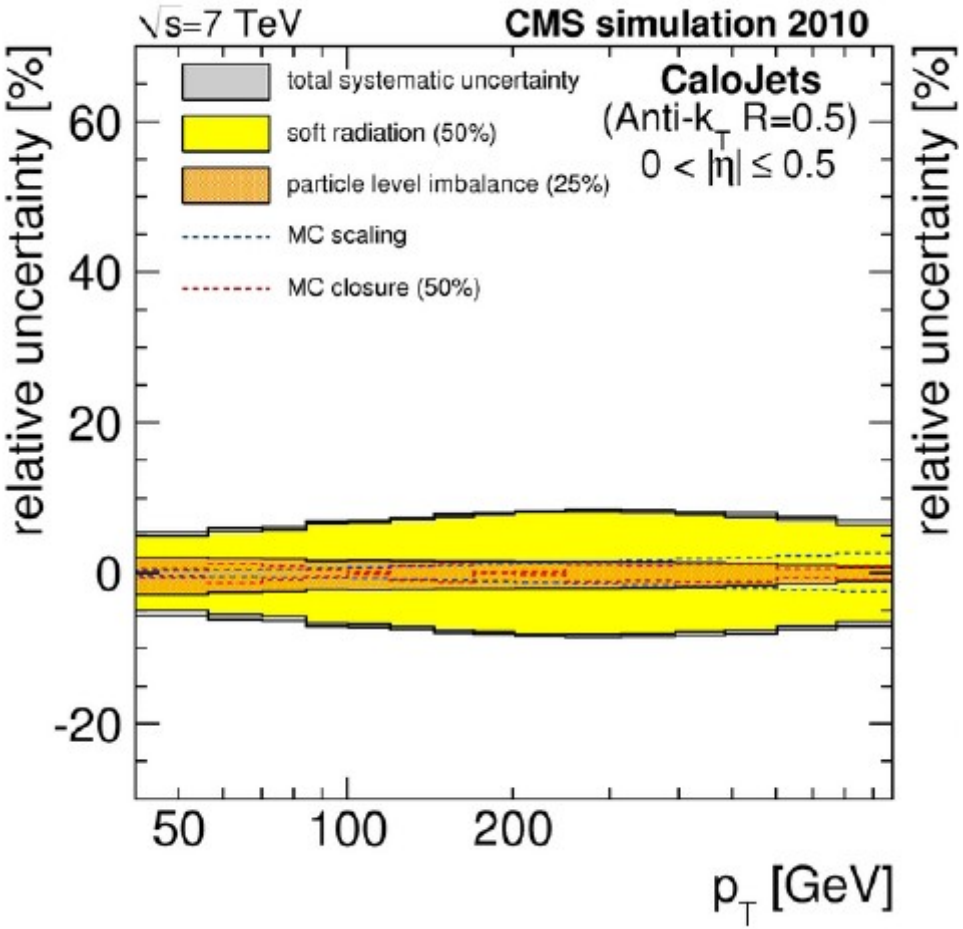


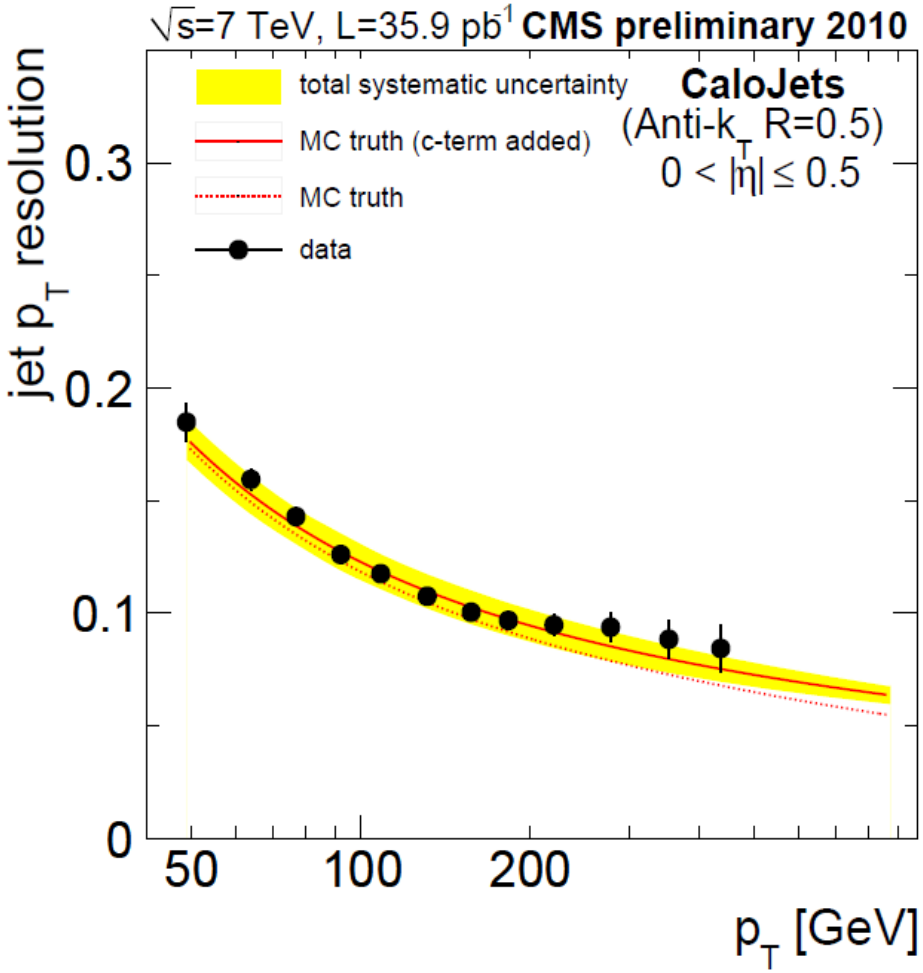
$$\left(\frac{\sigma(p_T)}{p_T}\right) = \sqrt{2}\sigma_A$$



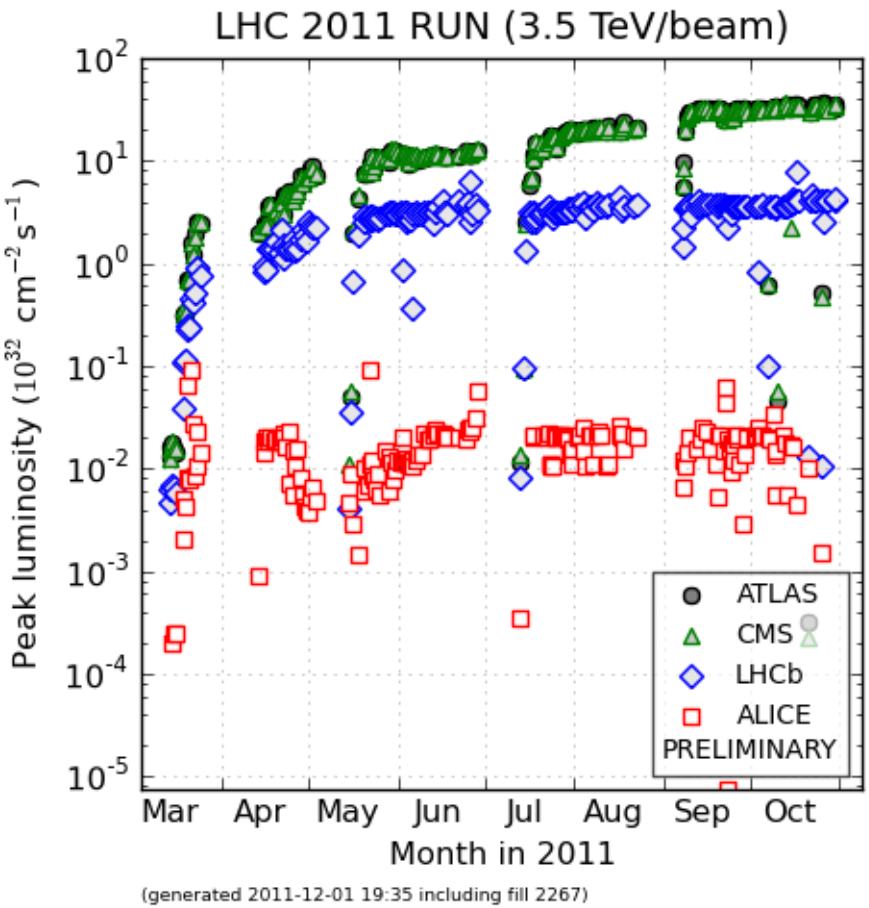
Dijet Resolution: Asymmetry Method

$$A = \frac{(p_T^{Jet1} - p_T^{Jet2})}{(p_T^{Jet1} + p_T^{Jet2})}$$

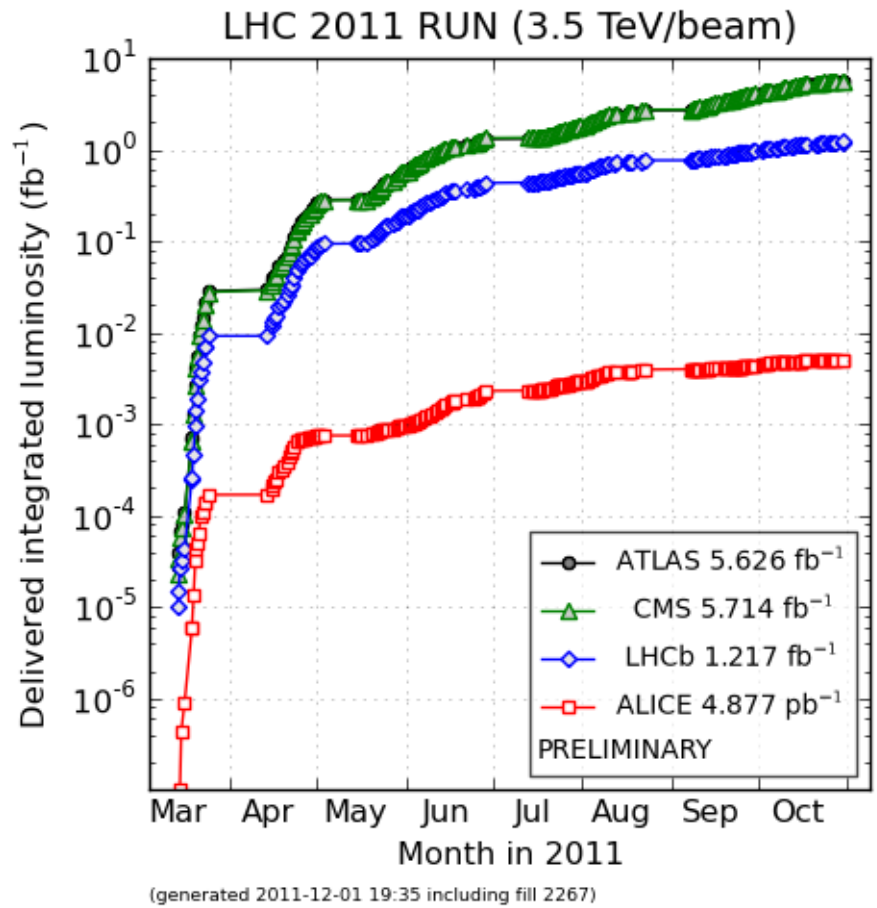


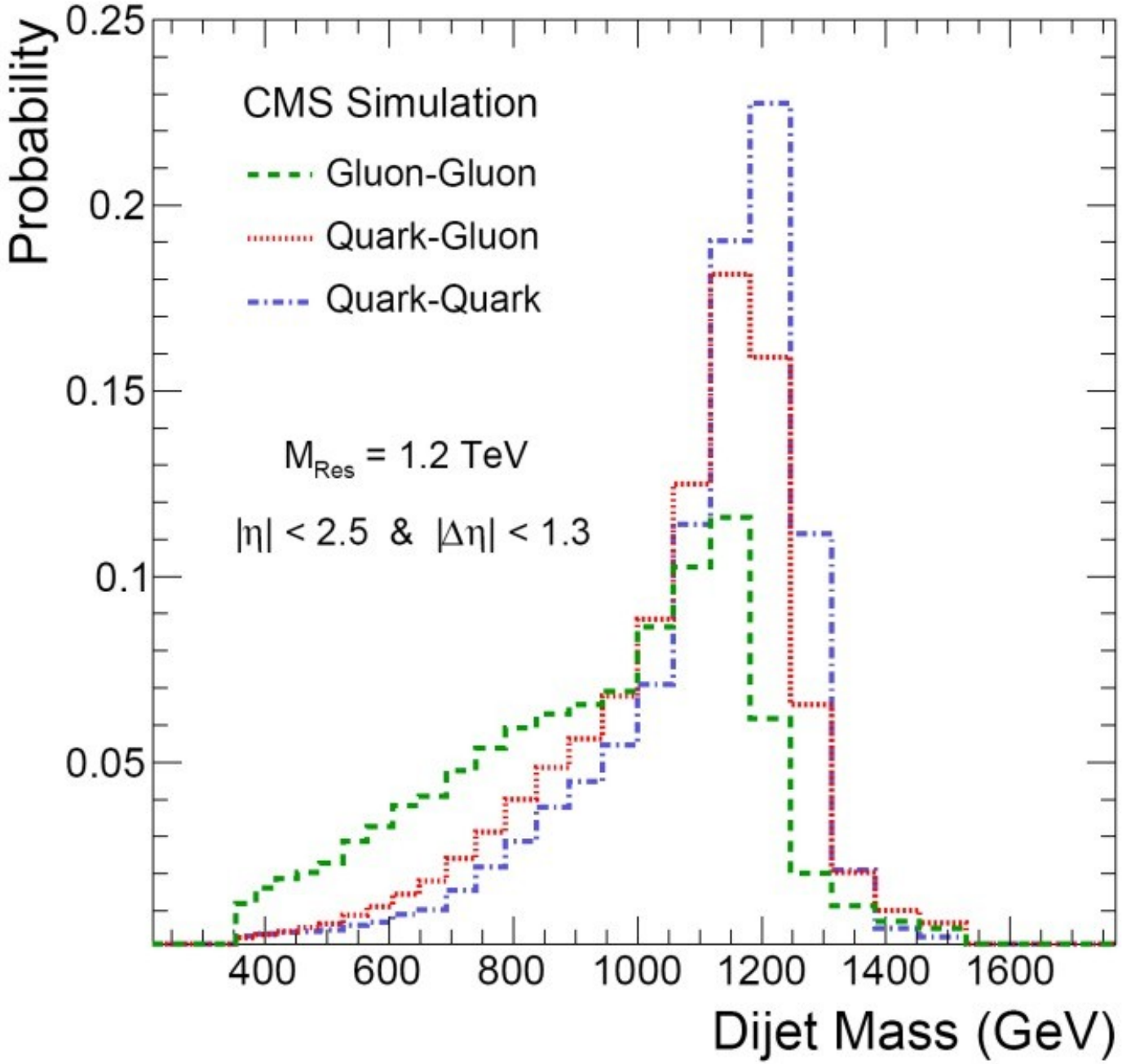


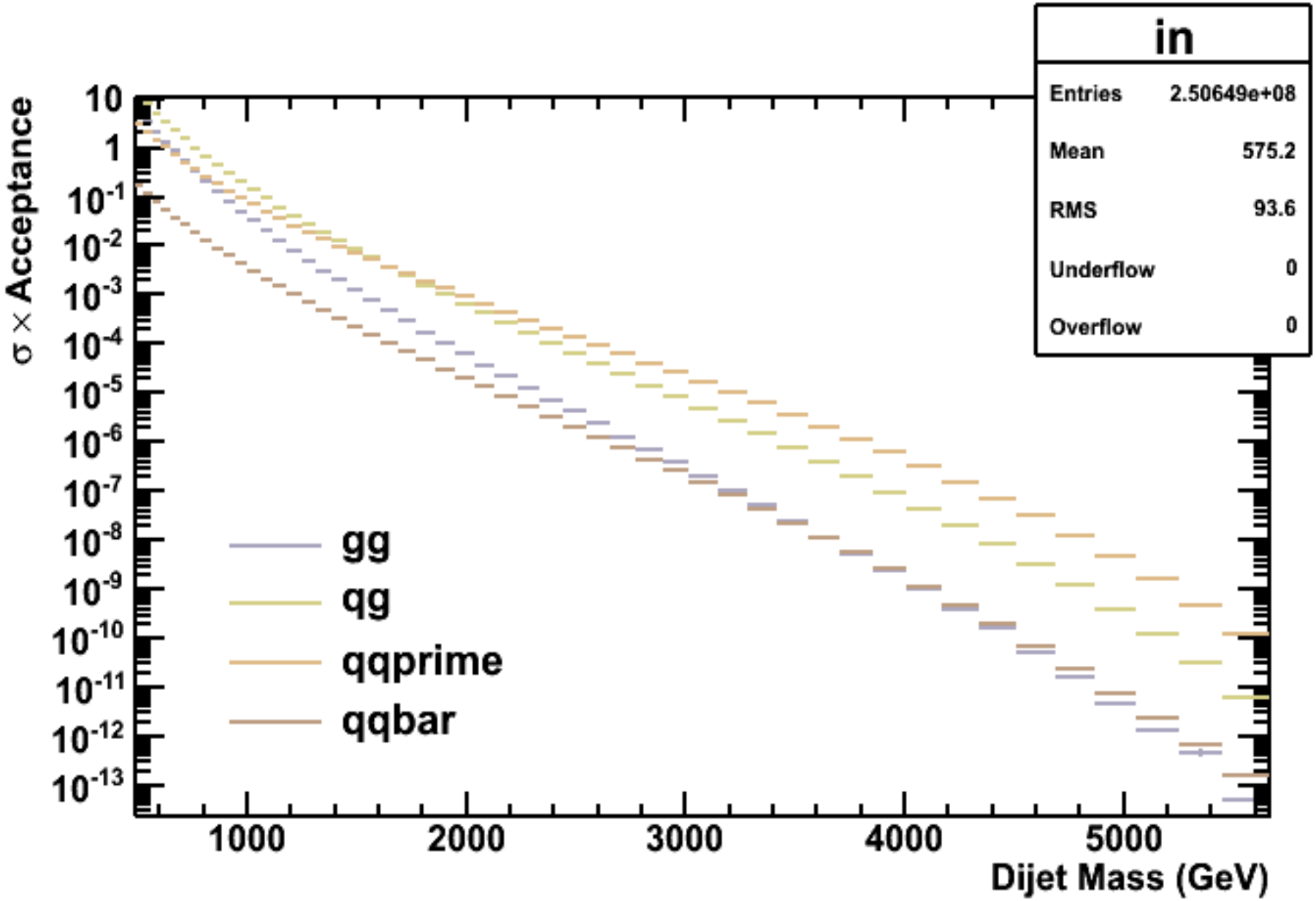
peak lumi

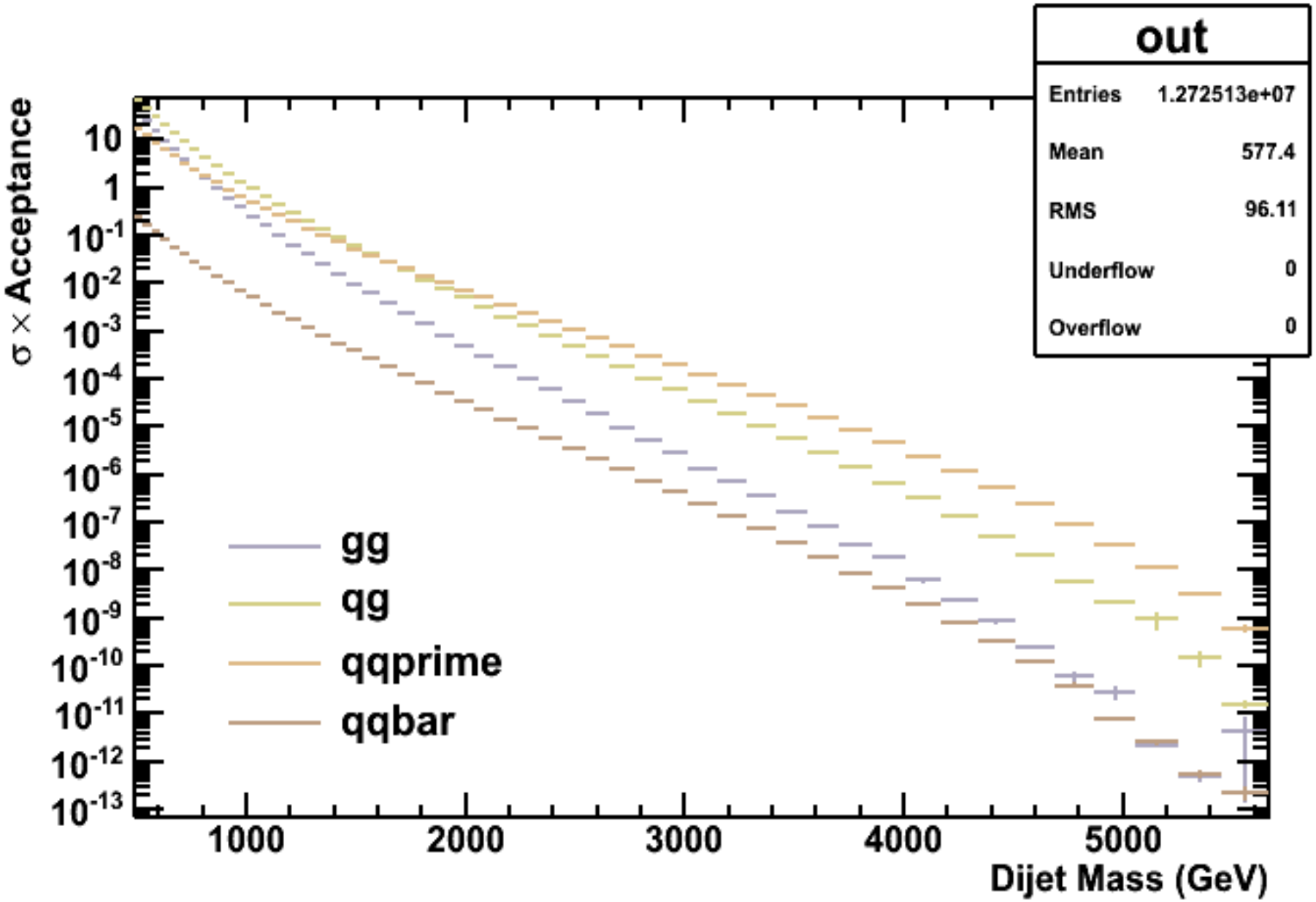


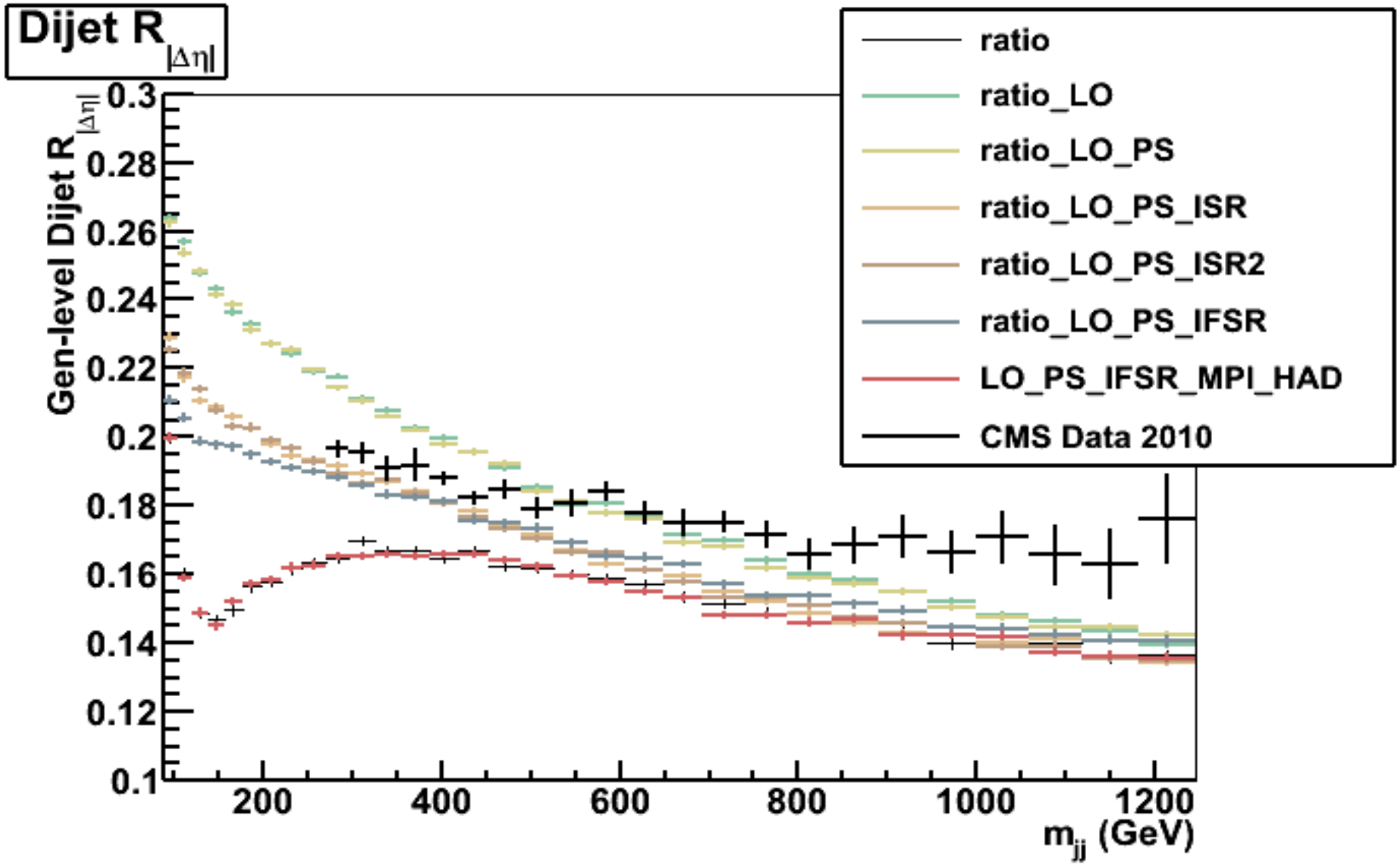
integrated lumi

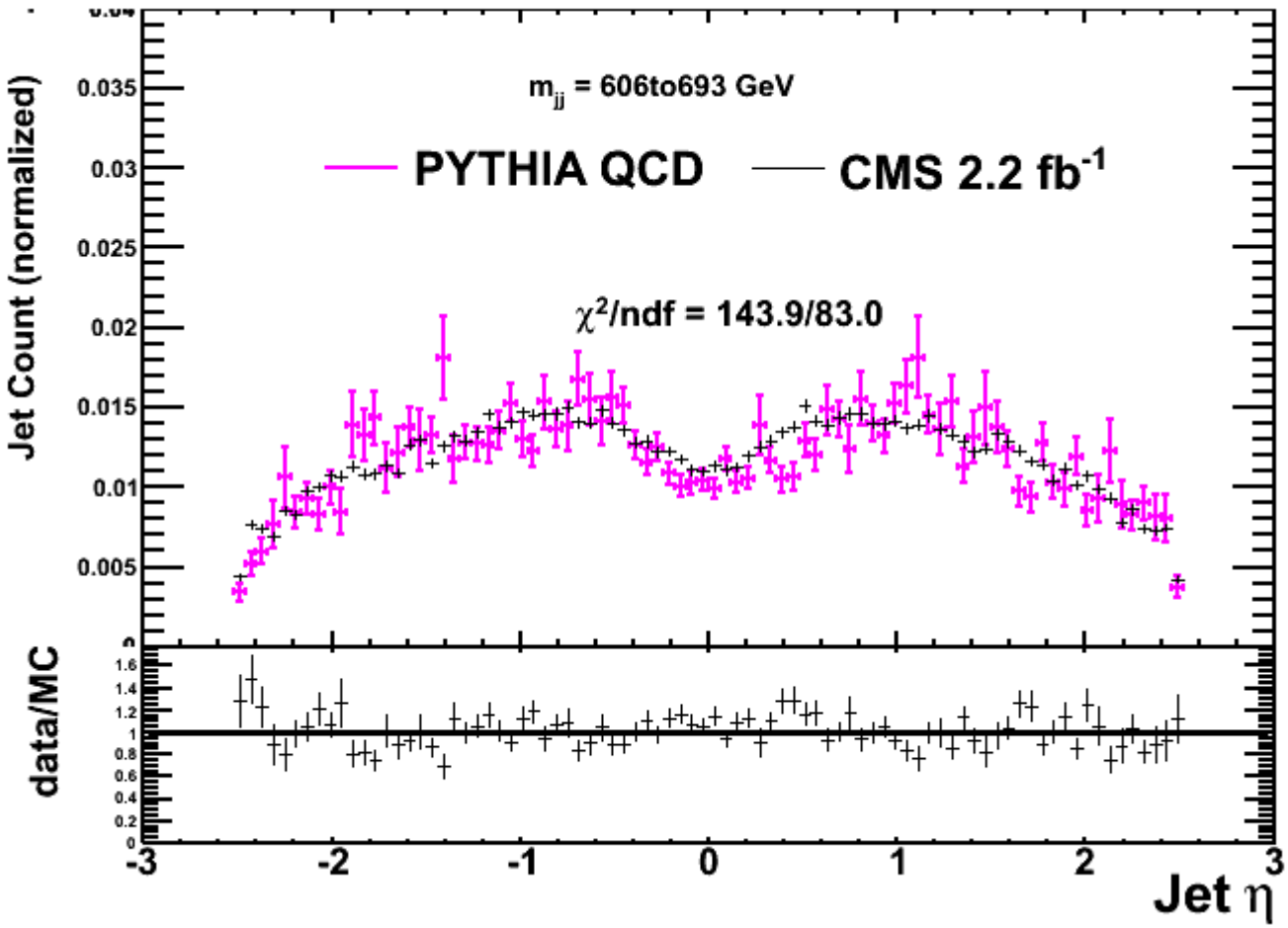


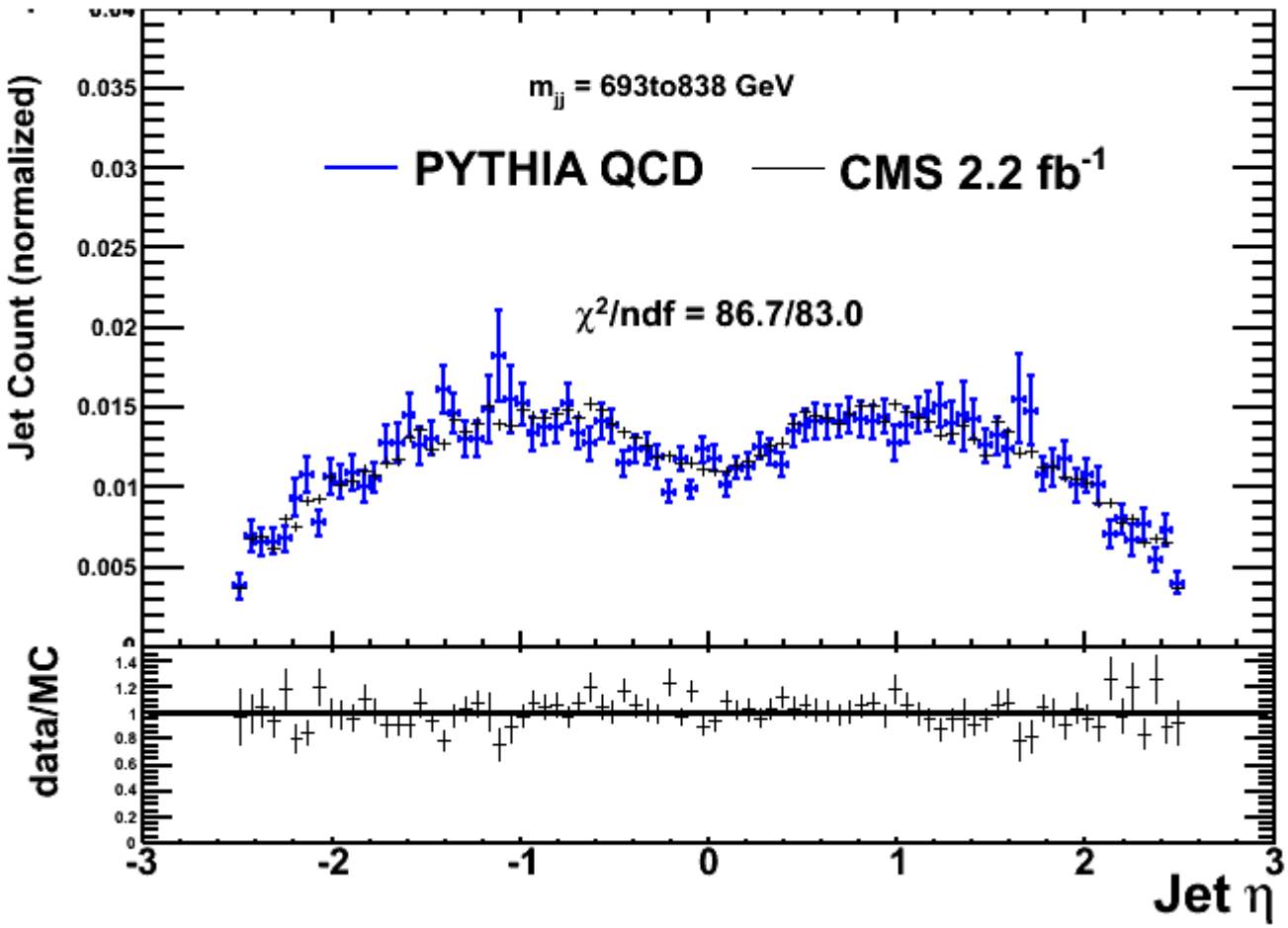

CMS Simulation
Gluon-Gluon
Quark-Gluon
Quark-Quark
M_{Res} = 1.2 TeV
$|\eta| < 2.5$ & $|\Delta\eta| < 1.3$
Probability
0.25
0.2
0.15
0.1
0.05
400
600
800
1000
1200
1400
1600
Dijet Mass (GeV)

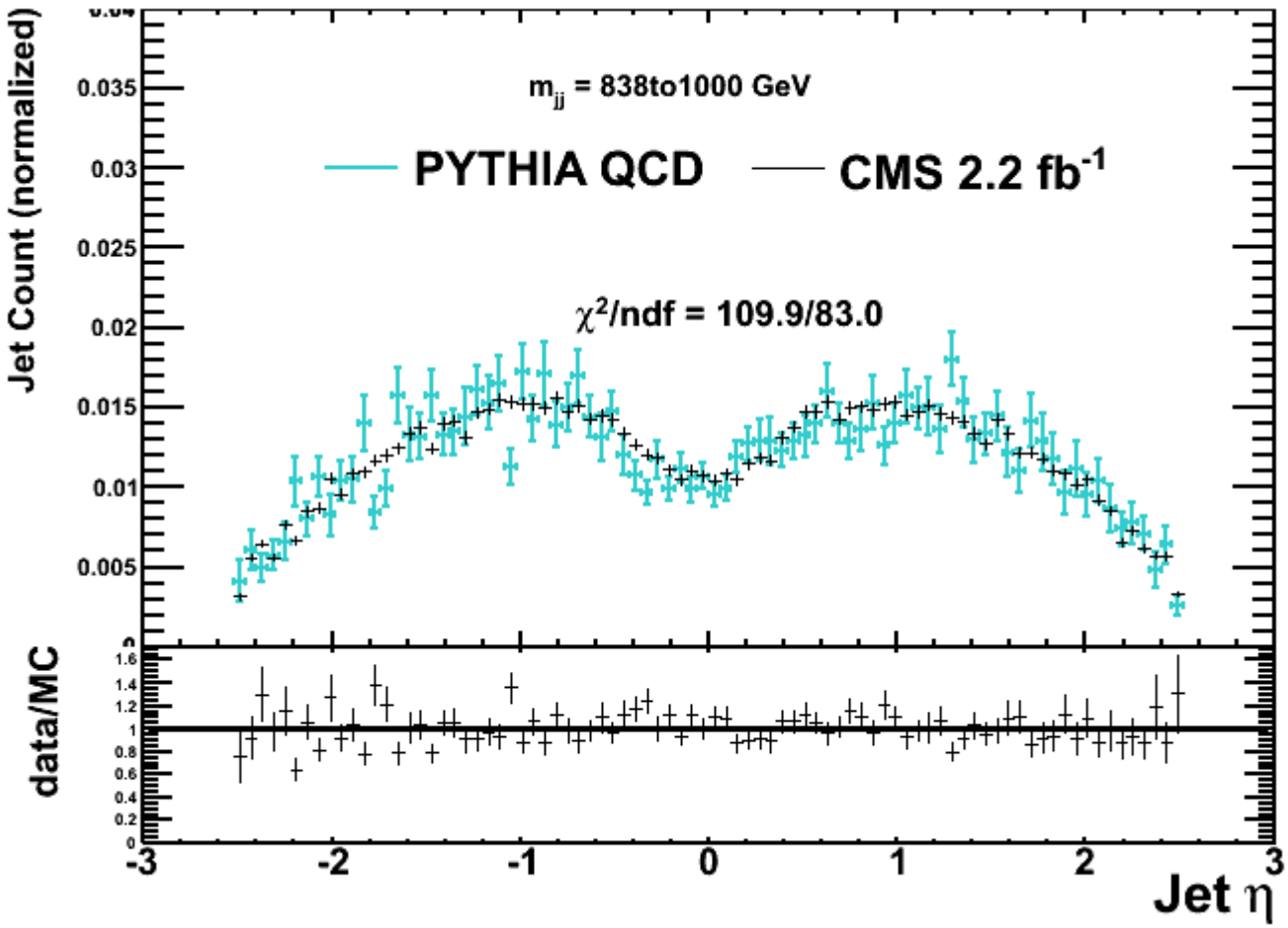

in
Entries 2.50649e+08
Mean 575.2
RMS 93.6
Underflow 0
Overflow 0
σ × Acceptance
10
1
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
10^-8
10^-9
10^-10
10^-11
10^-12
10^-13
gg
qg
qqprime
qqbar
1000
2000
3000
4000
5000
Dijet Mass (GeV)

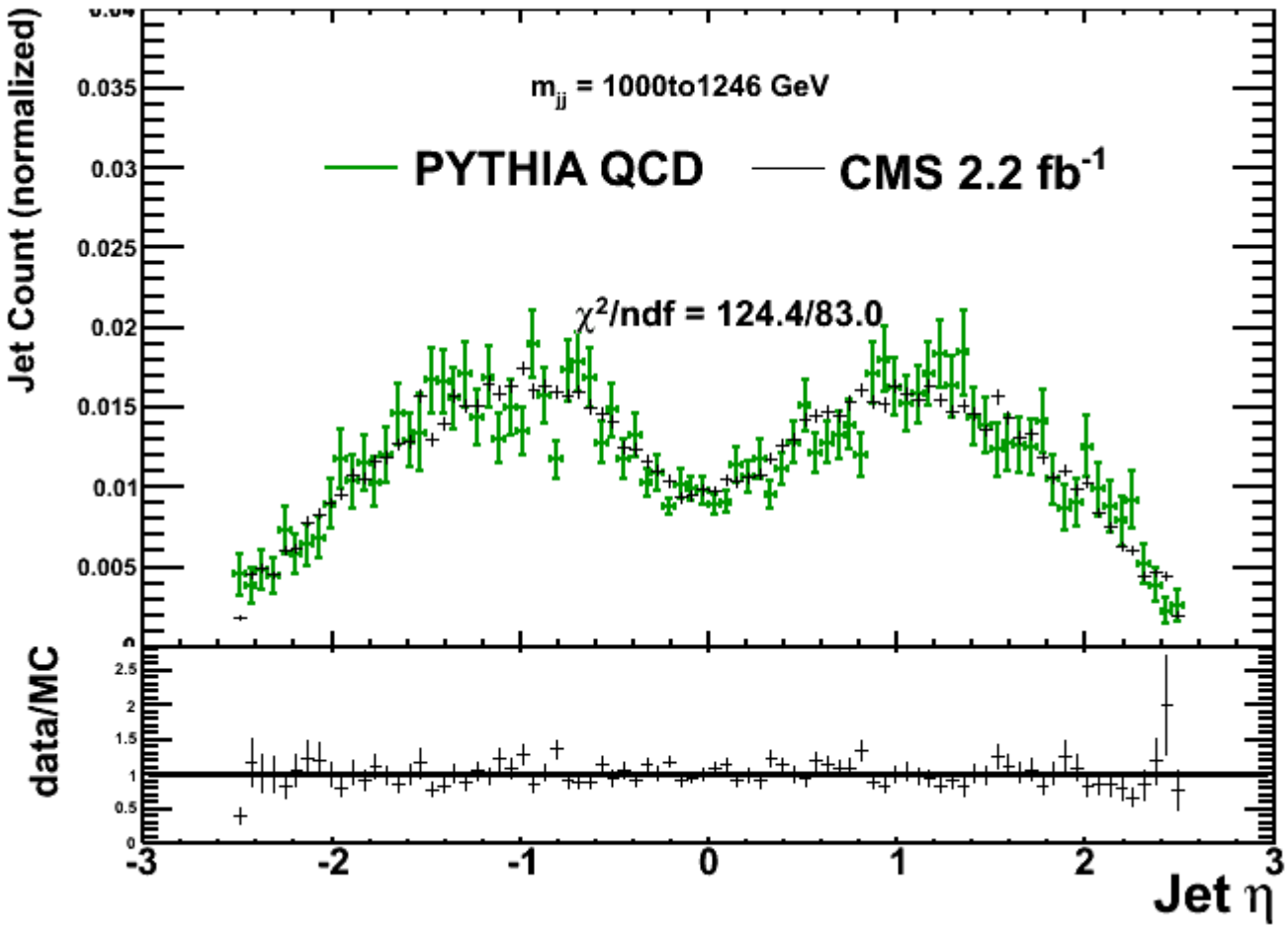

out
Entries 1.272513e+07
Mean 577.4
RMS 96.11
Underflow 0
Overflow 0
σ × Acceptance
10
1
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
10^-8
10^-9
10^-10
10^-11
10^-12
10^-13
gg
qg
qqprime
qqbar
1000
2000
3000
4000
5000
Dijet Mass (GeV)

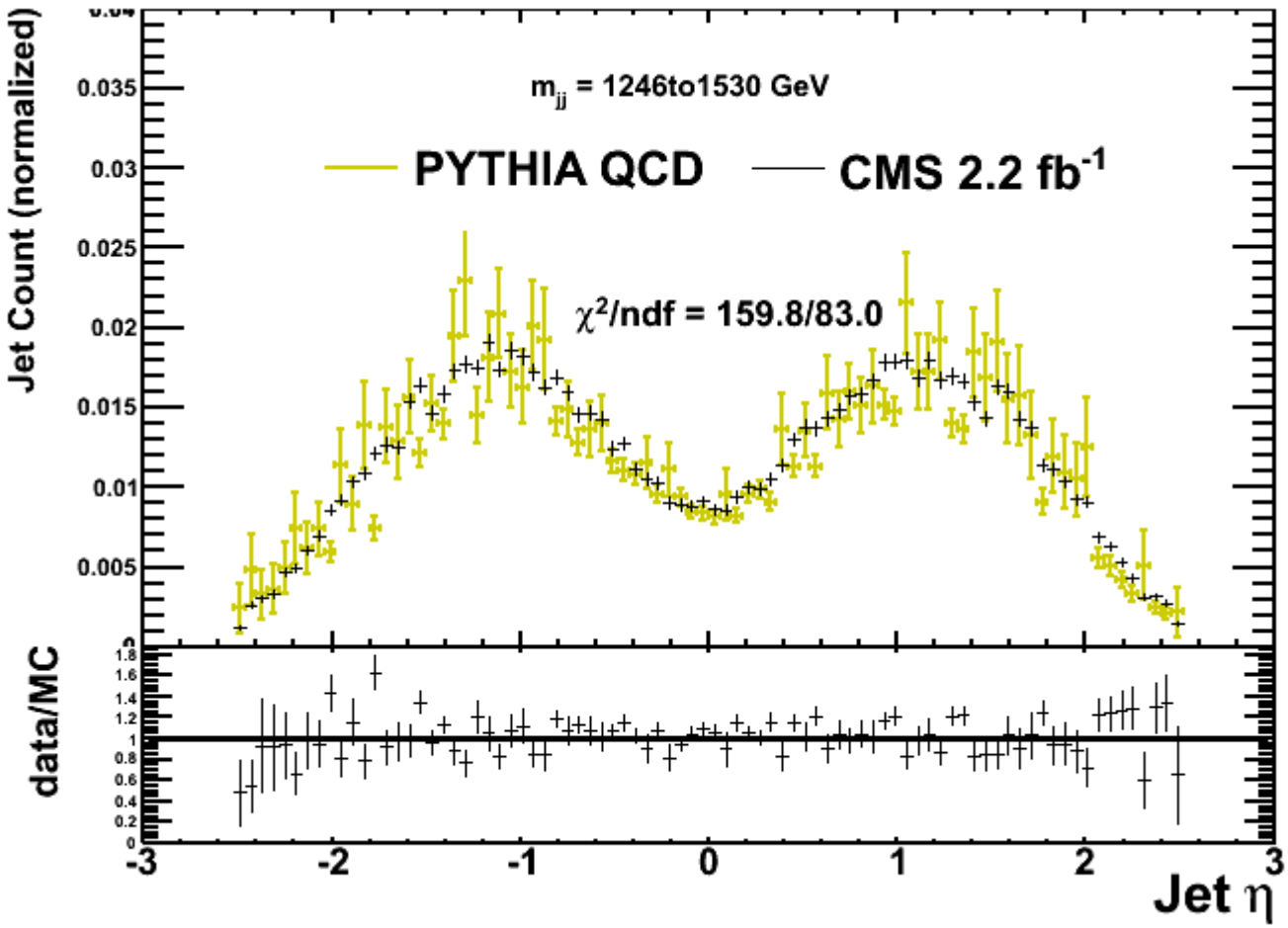

Dijet R|Δη|
Gen-level Dijet R|Δη|
0.3
0.28
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
200
400
600
800
1000
1200
m_jj (GeV)
ratio
ratio_LO
ratio_LO_PS
ratio_LO_PS_ISR
ratio_LO_PS_ISR2
ratio_LO_PS_IFSR
LO_PS_IFSR_MPI_HAD
CMS Data 2010

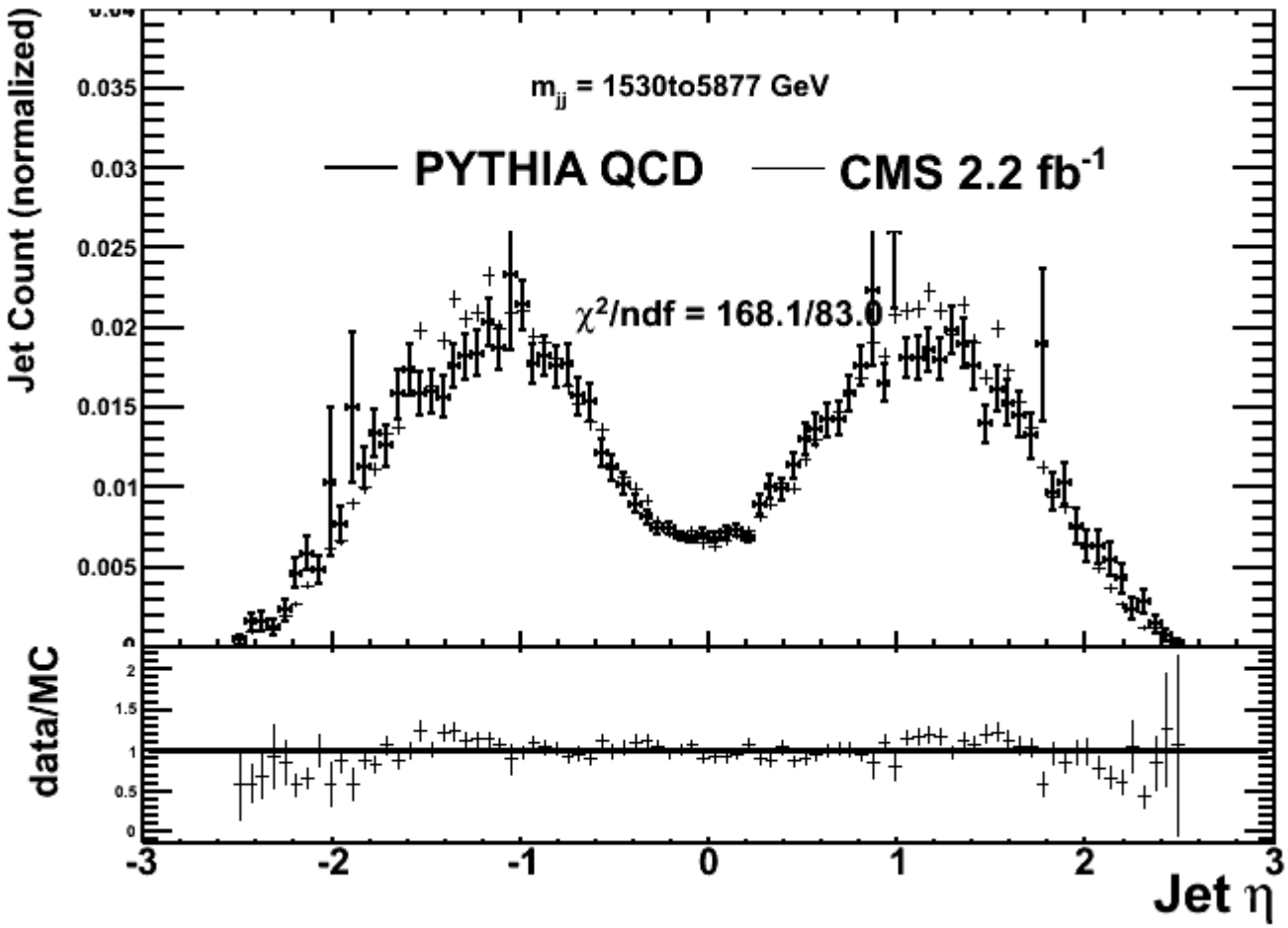

m_{jj} = 606to693 GeV
PYTHIA QCD
CMS 2.2 fb^{-1}
χ^2/ndf = 143.9/83.0
Jet Count (normalized)
data/MC
Jet η

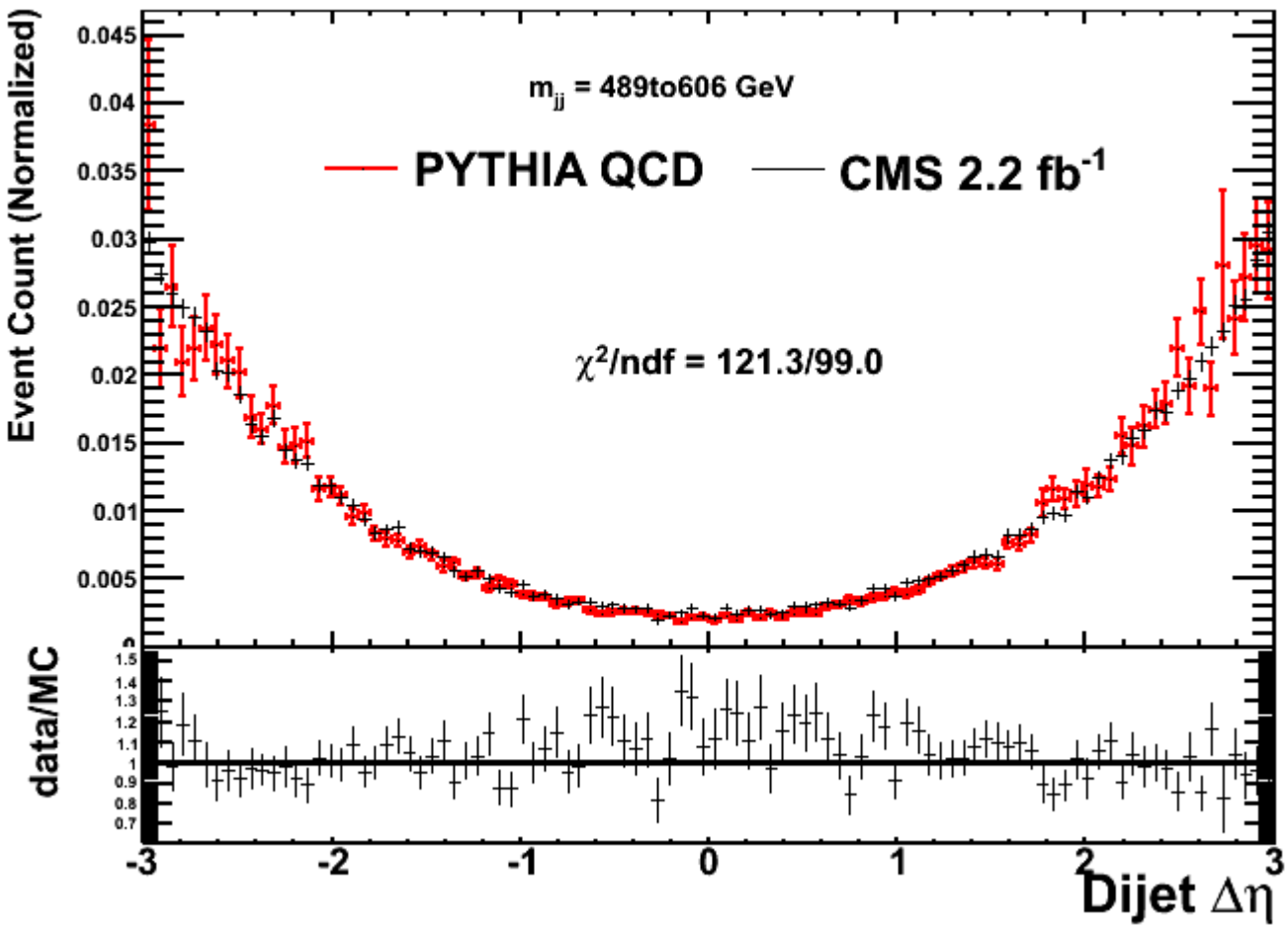

m_{jj} = 693to838 GeV
PYTHIA QCD
CMS 2.2 fb^{-1}
χ^2/ndf = 86.7/83.0
Jet Count (normalized)
data/MC
Jet η

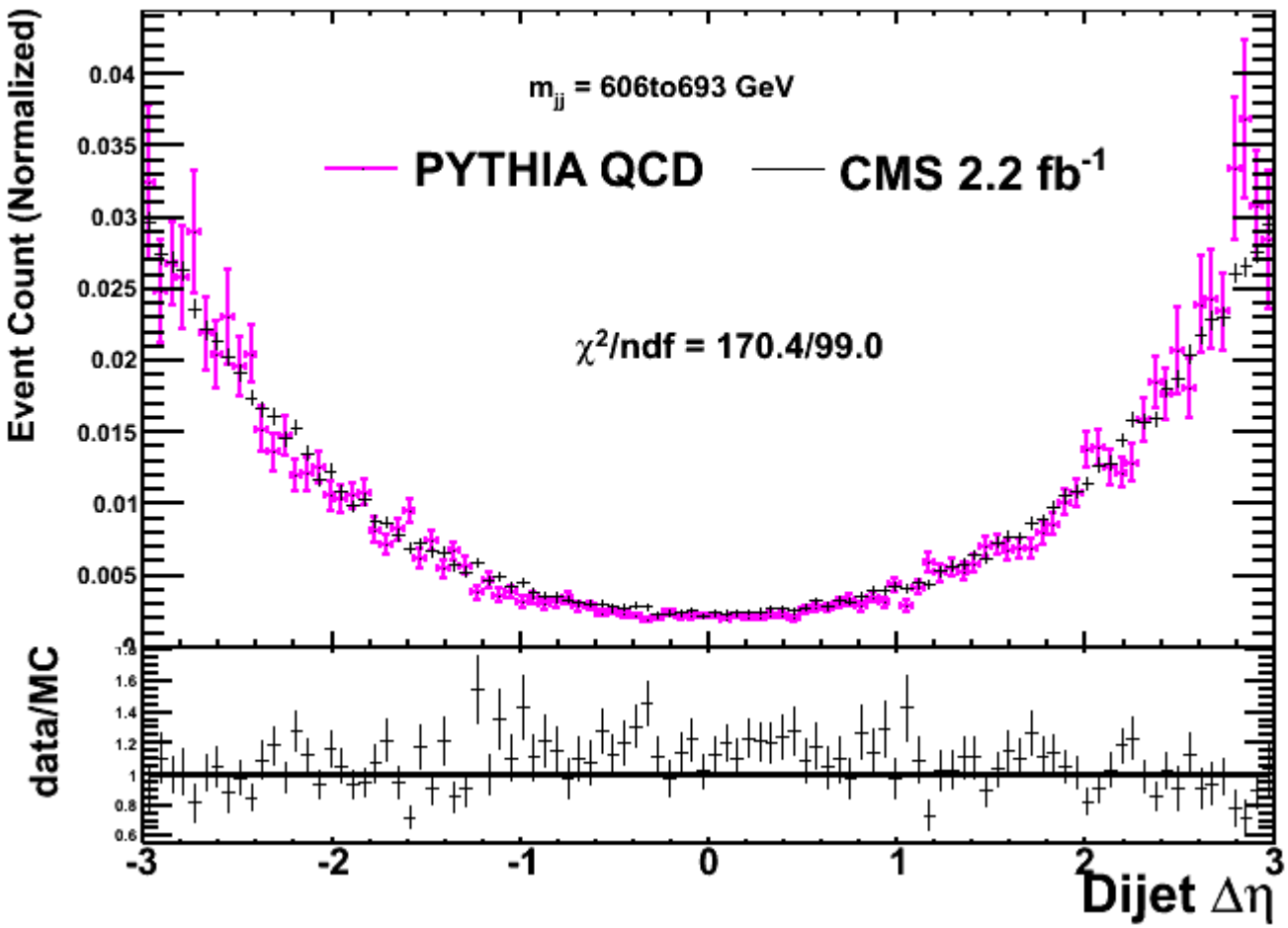

m_{jj} = 838to1000 GeV
PYTHIA QCD
CMS 2.2 fb^{-1}
χ^2/ndf = 109.9/83.0
Jet Count (normalized)
data/MC
Jet η

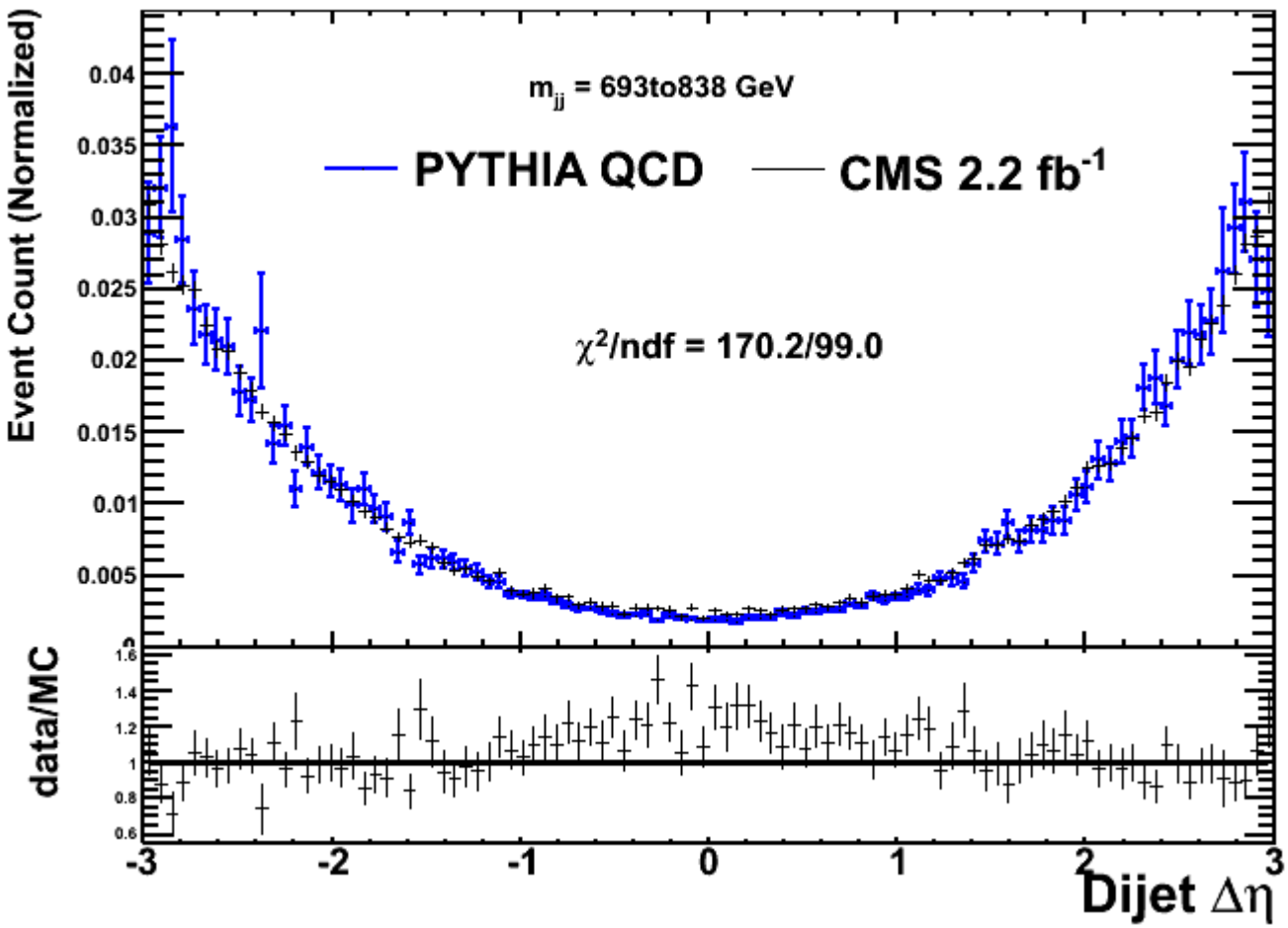

m_{jj} = 1000to1246 GeV
PYTHIA QCD
CMS 2.2 fb^{-1}
χ^2/ndf = 124.4/83.0
Jet Count (normalized)
data/MC
Jet η

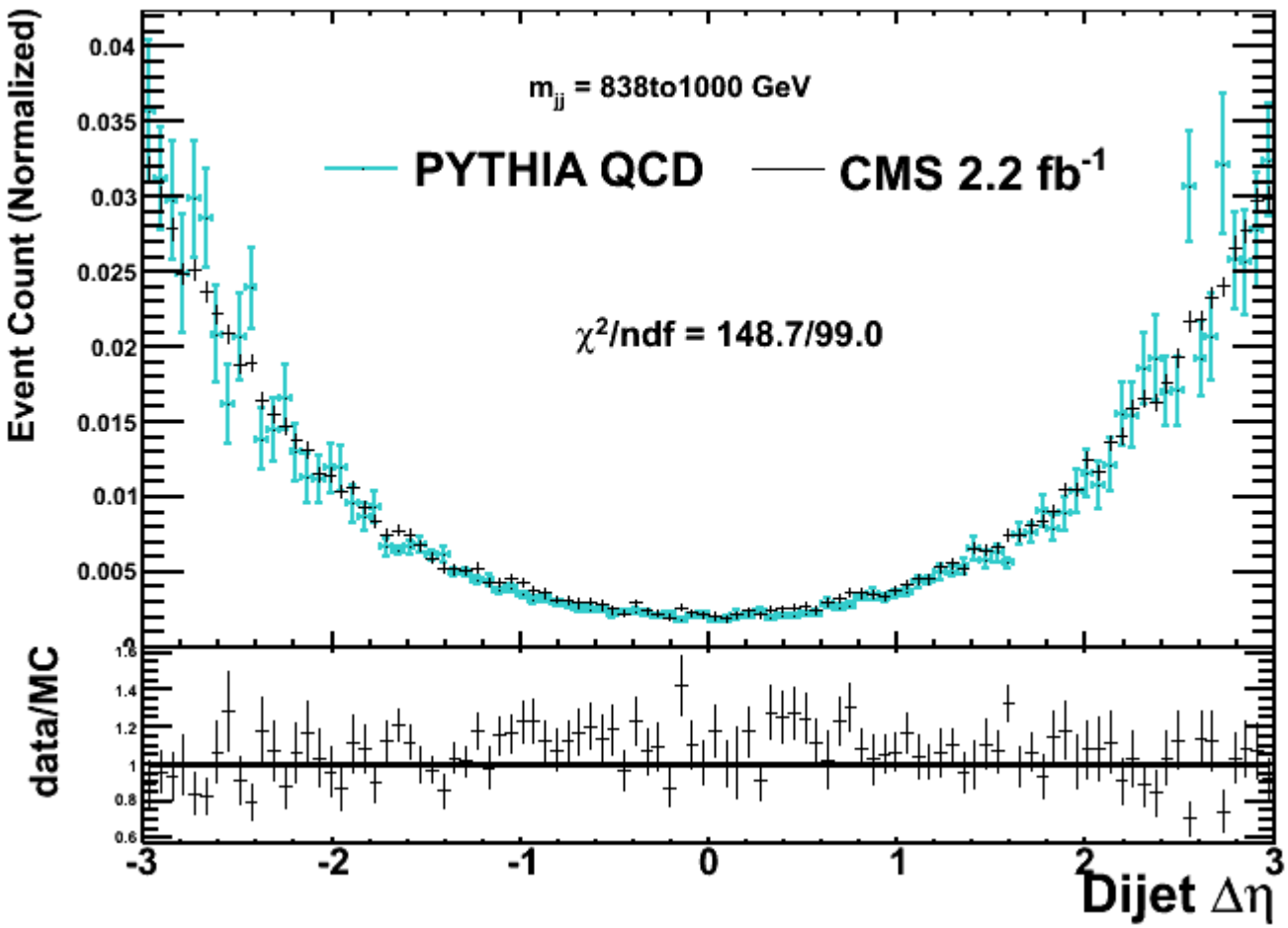

m_{jj} = 1246to1530 GeV
PYTHIA QCD
CMS 2.2 fb^{-1}
χ^2/ndf = 159.8/83.0
Jet Count (normalized)
data/MC
Jet η

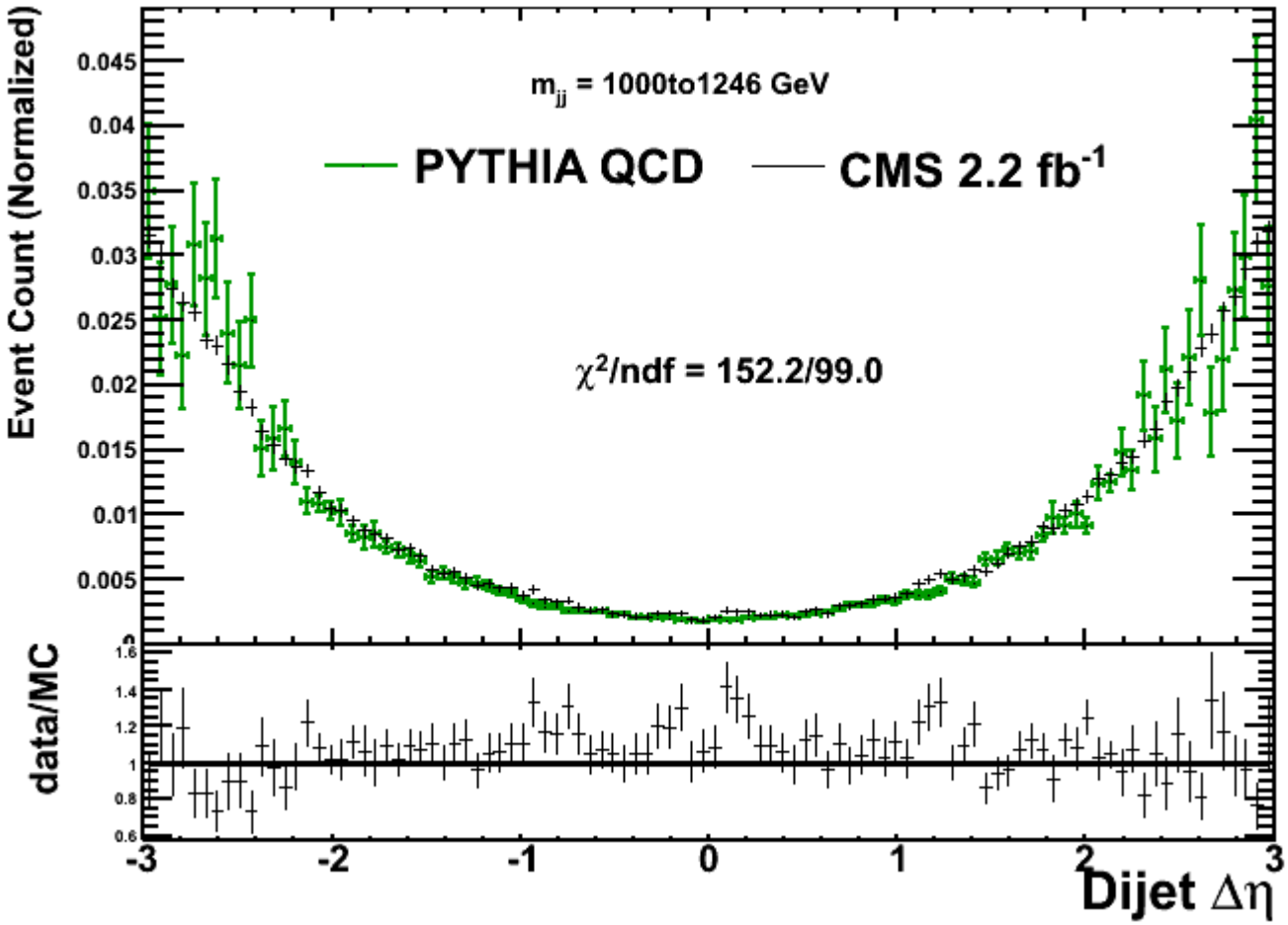

m_jj = 1530to5877 GeV
PYTHIA QCD
CMS 2.2 fb^-1
χ²/ndf = 168.1/83.0
Jet Count (normalized)
data/MC
Jet η

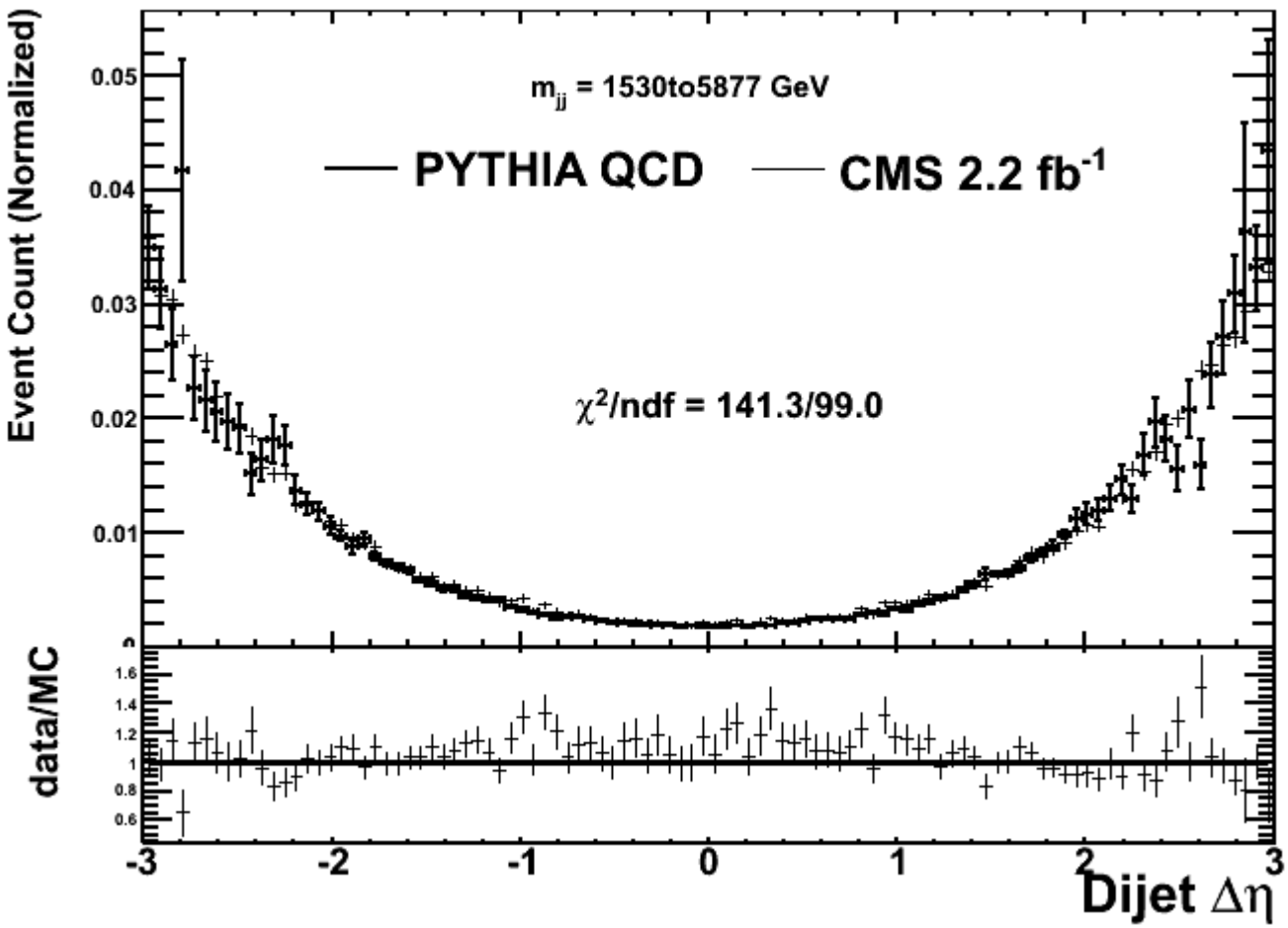

m_jj = 489to606 GeV
PYTHIA QCD
CMS 2.2 fb^-1
χ²/ndf = 121.3/99.0
Event Count (Normalized)
data/MC
Dijet Δη


m_jj = 606to693 GeV
PYTHIA QCD
CMS 2.2 fb^-1
χ²/ndf = 170.4/99.0
Event Count (Normalized)
data/MC
Dijet Δη


m_jj = 693to838 GeV
PYTHIA QCD
CMS 2.2 fb^-1
χ²/ndf = 170.2/99.0
Event Count (Normalized)
data/MC
Dijet Δη


Event Count (Normalized)
m_{jj} = 838to1000 GeV
PYTHIA QCD
CMS 2.2 fb^{-1}
χ^2/ndf = 148.7/99.0
data/MC
Dijet $\Delta\eta$


m_jj = 1000to1246 GeV
PYTHIA QCD
CMS 2.2 fb^-1
χ²/ndf = 152.2/99.0
Event Count (Normalized)
data/MC
Dijet Δη


m_{jj} = 1530to5877 GeV
PYTHIA QCD
CMS 2.2 fb^{-1}
χ^2/ndf = 141.3/99.0
Event Count (Normalized)
data/MC
Dijet $\Delta\eta$

End