Early Exotic Searches with Jets in ATLAS

Georgios Choudalakis[1]

on behalf of
the ATLAS Collaboration

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[1]University of Chicago

Motivation

Dijet final state: sensitive to a variety of SM extensions.

- Compositeness?
  - Very old idea. Are quarks made of "preons"?
- TeV-scale gravity?
  - Large extra dimensions (e.g. ADD)
  - Warped extra dimensions (e.g. RS)
- New strong dynamics
  - Technicolor
  - Chiral Color (Axigluons)
- And more...

It offers statistics to probe new energies early on.

New territory – Nature may surprise us.

Early ATLAS searches in the inclusive dijet final state

1. Dijet Resonance search, in 296 nb^{-1}
   - $m^{jj} = \sqrt{(E_1 + E_2)^2 - (\vec{p}_1 + \vec{p}_2)^2}$
2. Contact interactions, in 61 nb^{-1}
   - $\chi = exp(|y_1 - y_2|)$
   - η-ratio $= \frac{N(|\eta_{1,2}|<0.5)}{N(0.5<|\eta_{1,2}|<1)}$

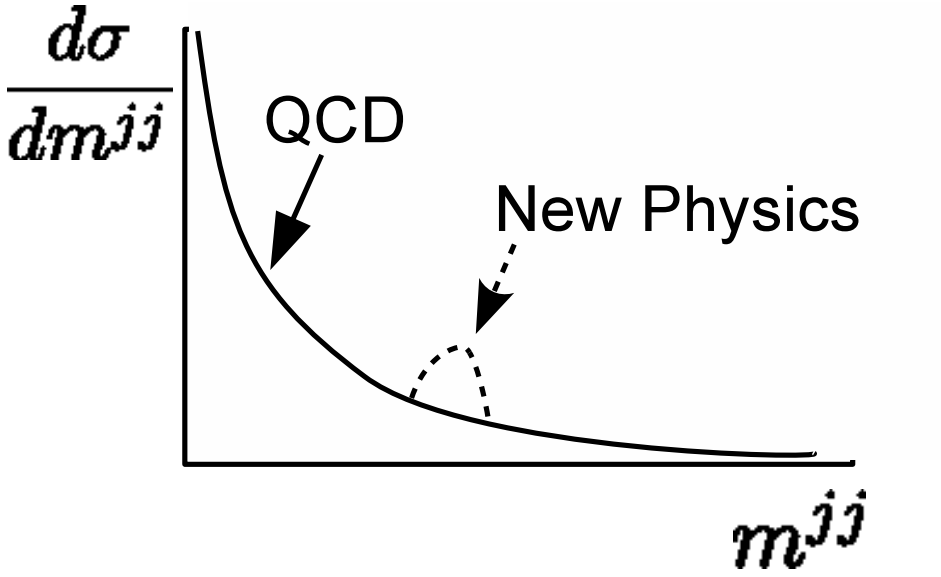
For both analyses:

Jet algorithm: anti-k_T $R = 0.6$

Topoclusters of energy $\Rightarrow$ noise suppression. [See A. Schwartzman's talk]

Calibration: Jet response correction based on simulation, validated *in situ*.

Dijet mass resonance search



- Is there a bump in m^{jj}?
- If not, set limits on excited quark production.

  [Representative example of a narrow resonance.]

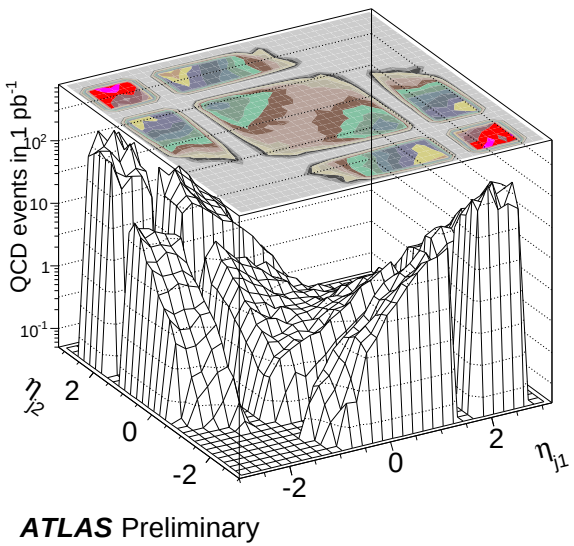
Event selection

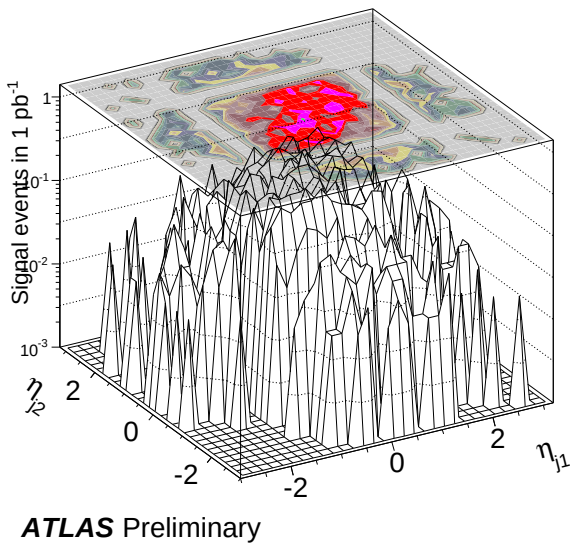
- Standard event quality cuts
- Veto events with poorly measured jets of $p_T > 15$ GeV.

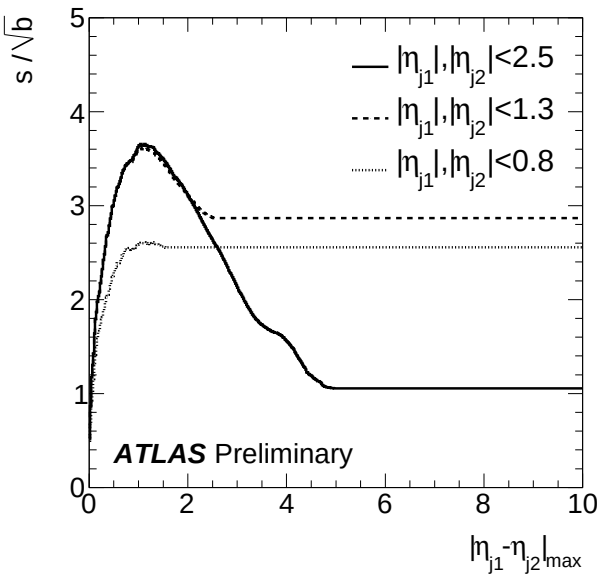
  [Rejecting 1/1000 events]
- Require the two leading jets:
  - to have $p_T^{j1} > 80$ GeV and $p_T^{j2} > 30$ GeV.
  - to have $|\eta| < 2.5$ and $|\Delta\eta| < 1.3$

Optimization

$875\,GeV < m^{jj} < 1020\,GeV$



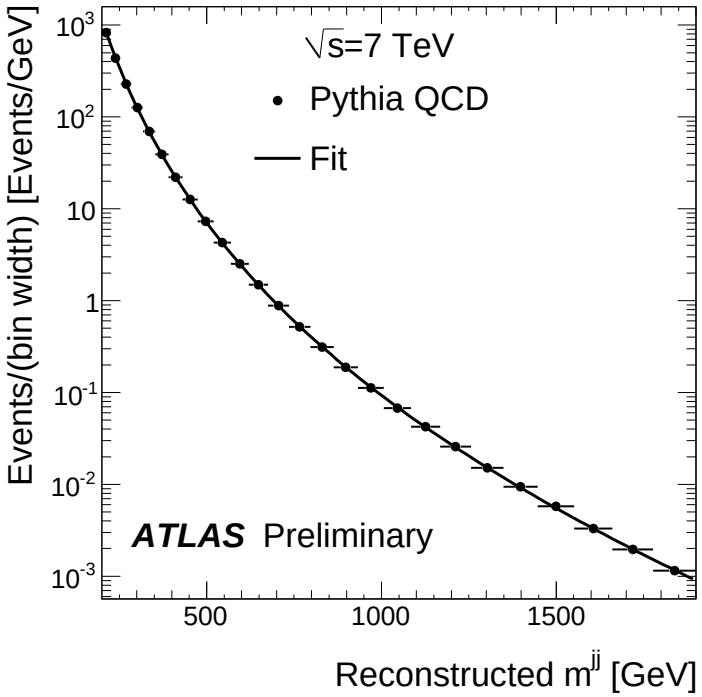


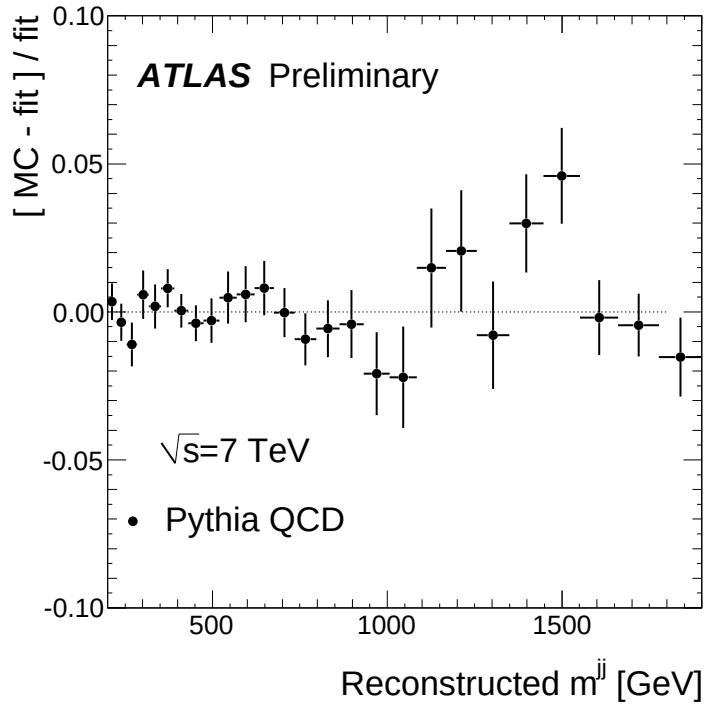


Data-driven background determination

The background is obtained by fitting the following function to the data:

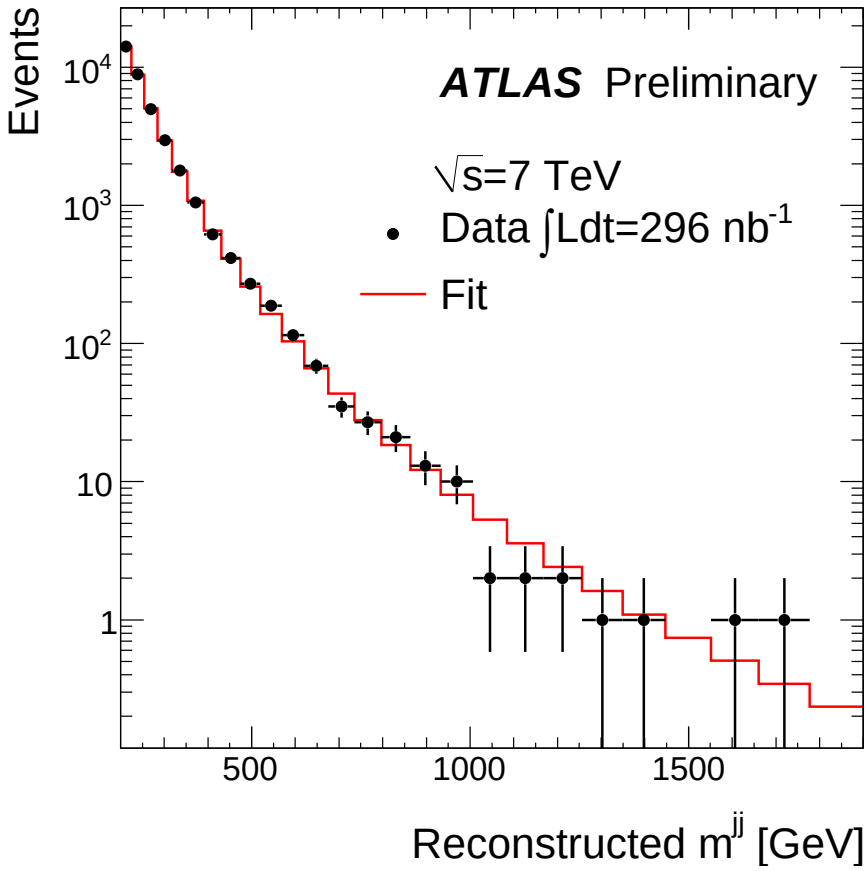
$$f(x) = p_0 \frac{(1-x)^{p_1}}{x^{p_2+p_3 \ln x}}, \quad x \equiv \frac{m^{jj}}{\sqrt{s}}.$$

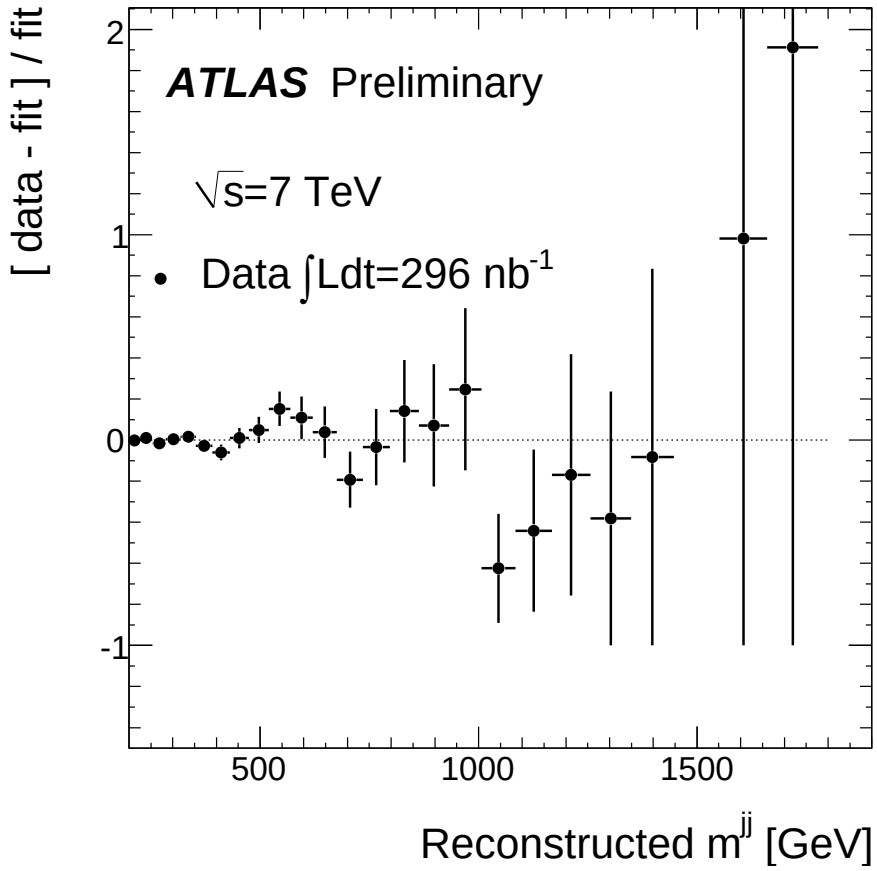




SM QCD described well by $f(x)$.

Are the data smooth? Is there any bump?



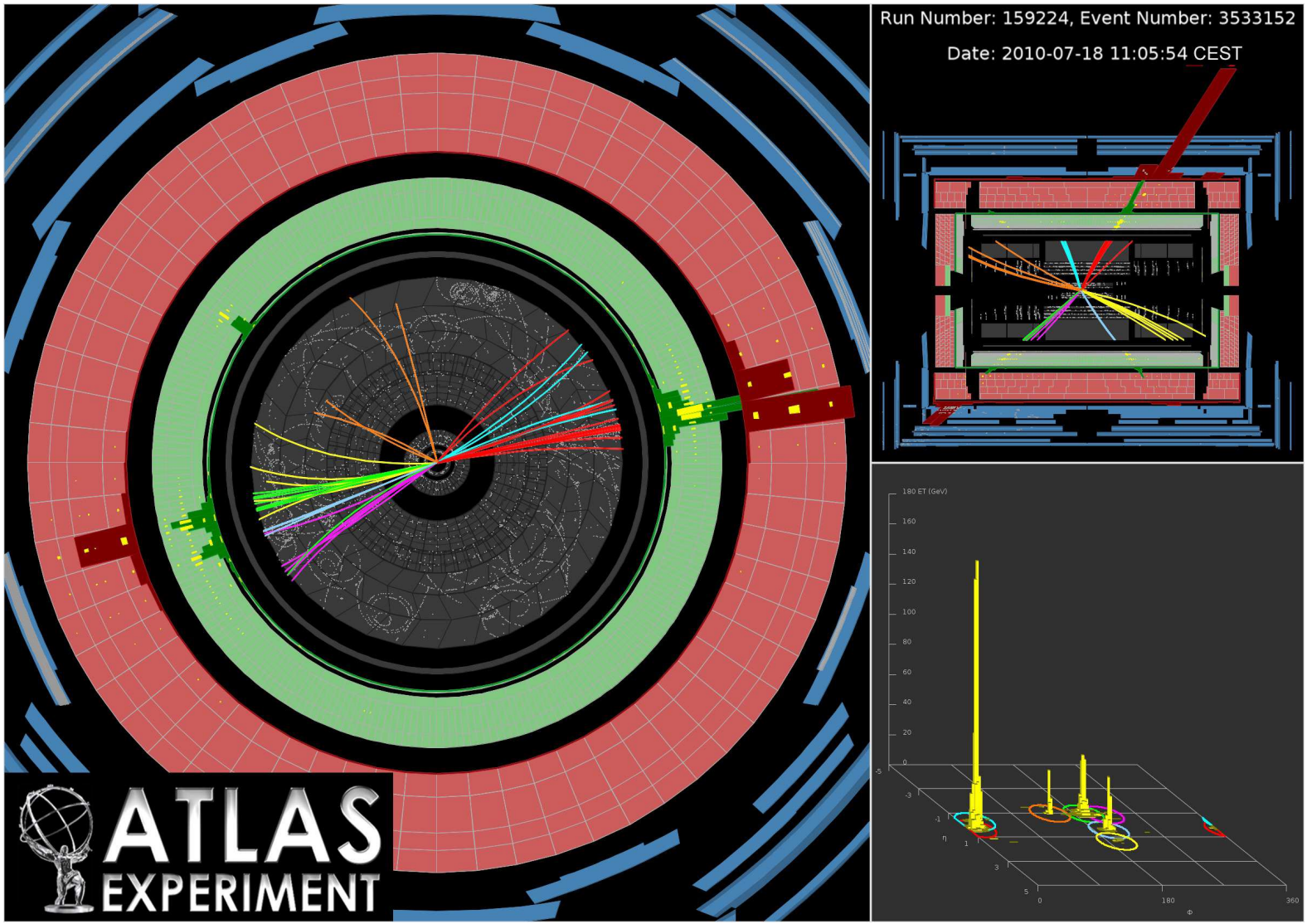


Checked for significant bumps, or tails, or overall shape difference.

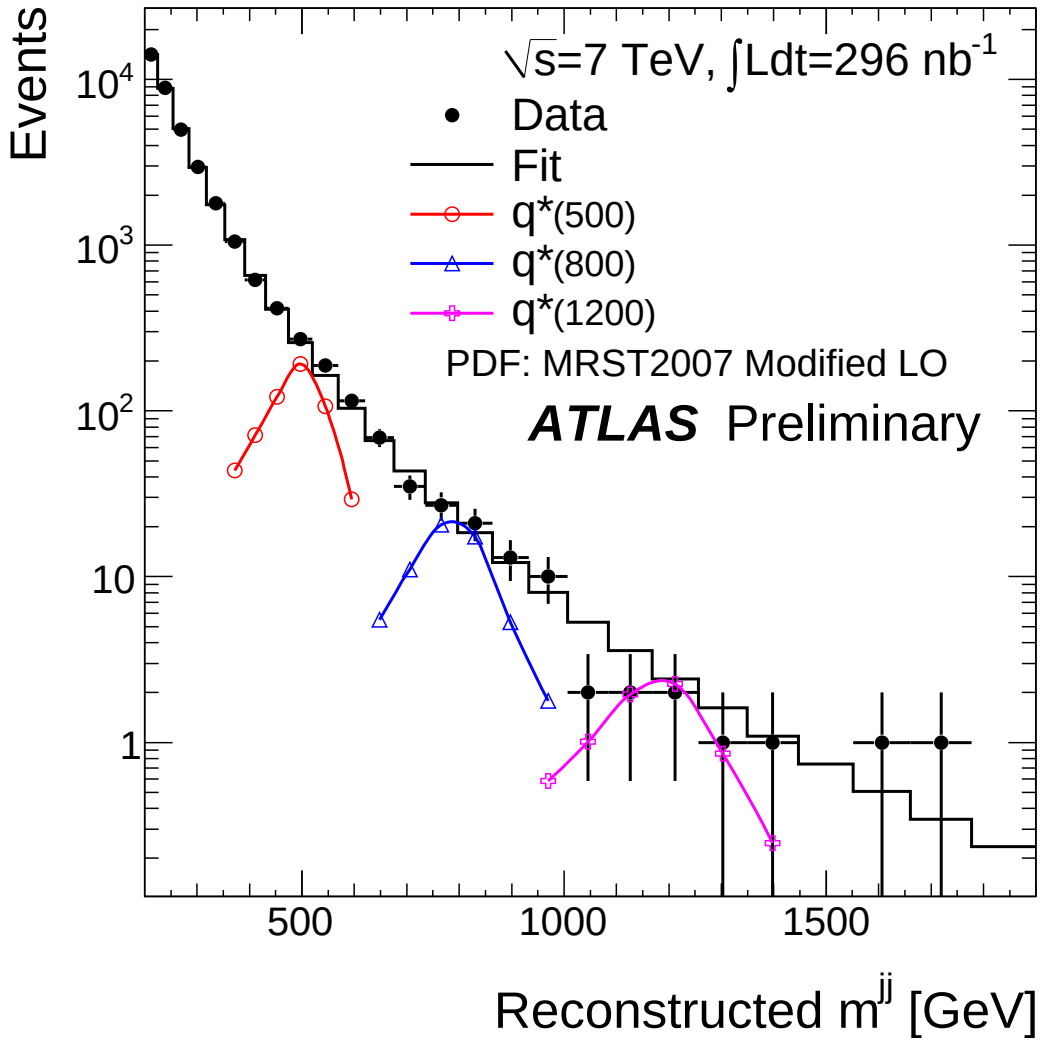
All tests indicated no significant discrepancy.

The highest-m^{jj} central event observed

$m^{jj} = 1.77$ TeV. $p_T^{j1} = 1.1$ TeV. $p_T^{j2} = 480$ GeV, partly in calorimeter gap.



Signature of excited quark



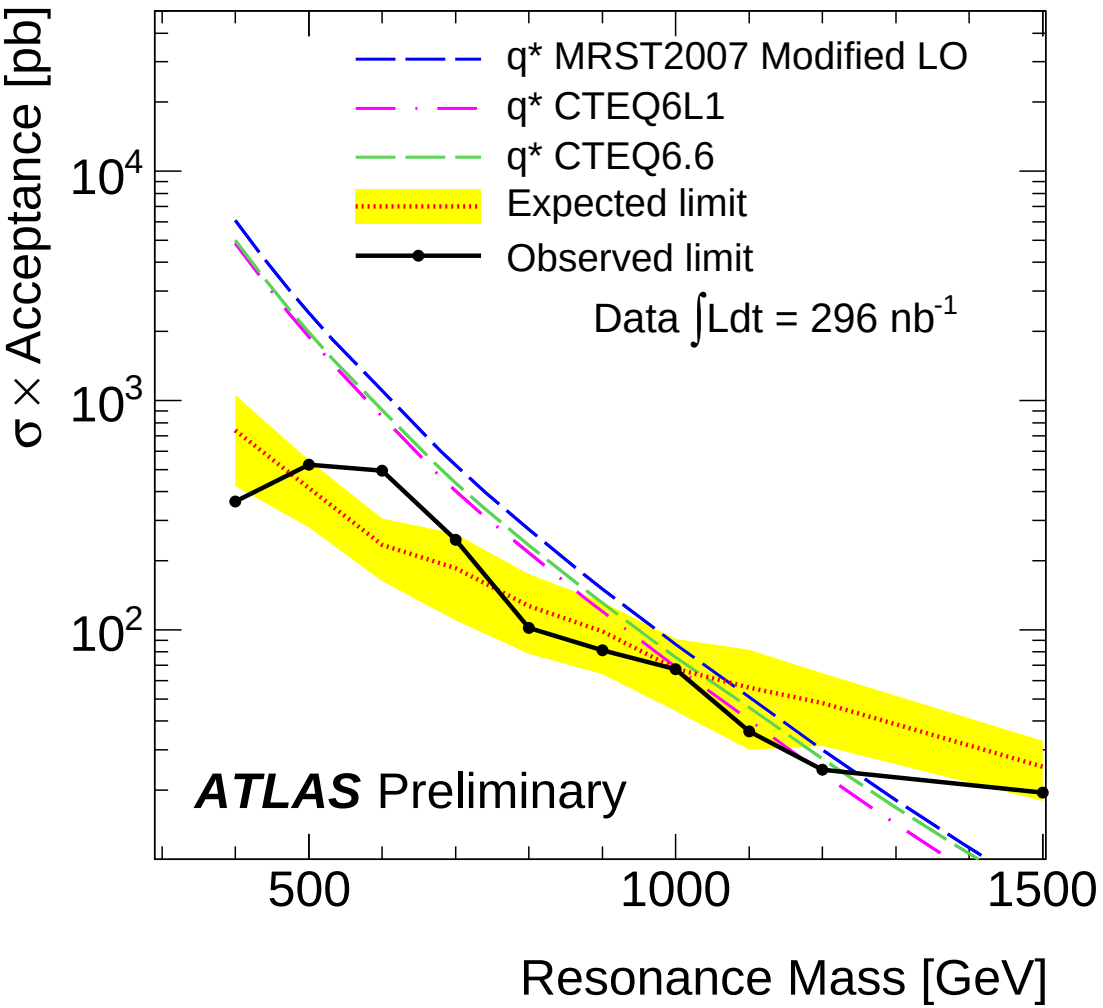
Events expected after selection.

Signal acceptance $\simeq$ 50%

Systematic uncertainties

- Jet energy scale uncertainty
  - Varies with p_T and η, between 5 and 10%. [See A. Schwartzman's talk]
- $\int Ldt$ uncertainty: 11%
- Background fit uncertainty
  - 3% to $\sim$30% from low to high m^{jj}

Bayesian limit on q^* production



Excluded at 95% C.L.:

With MRST:

$400 < m_{q^*} < 1290$ GeV

With CTEQ6L1:

$400 < m_{q^*} < 1180$ GeV

Latest published limit:

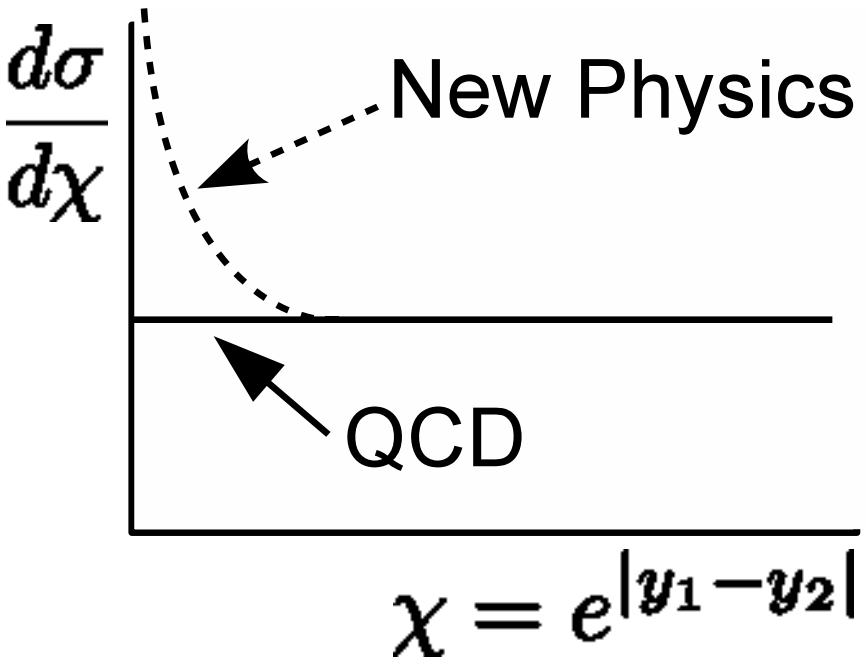
870 GeV, with 1.1 fb^{-1}

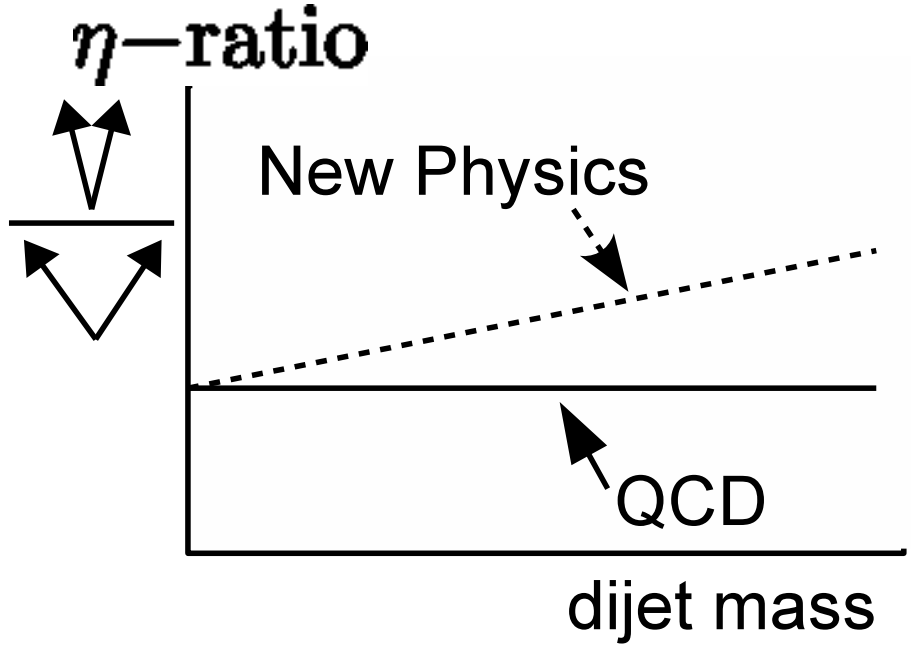
CDF Collaboration,

Phys.Rev.D 79 (2009) 112002

Dijet angular distribution

Observables:





Target:

- Non-resonant production of new physics at high m^{jj}:
  - Quark compositeness at high scale Λ

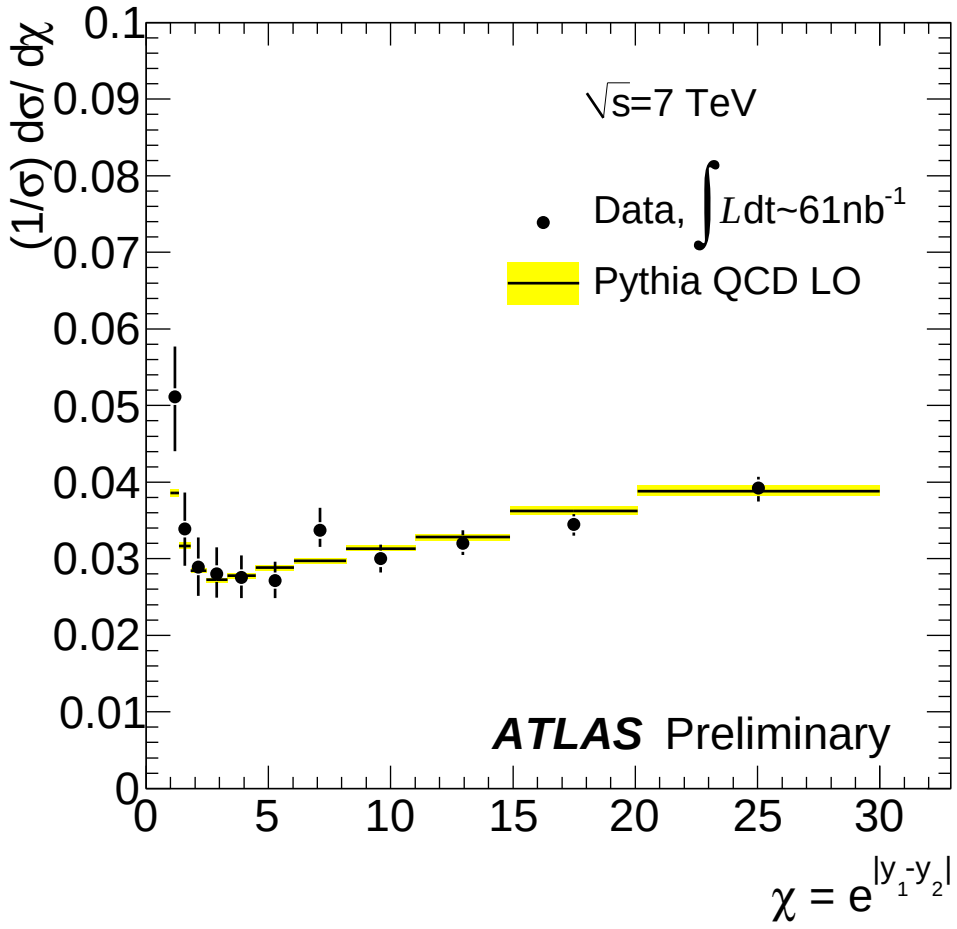
$\mathcal{L}_{qqqq}(\Lambda) = \frac{\eta g^2}{2\Lambda^2} \bar{\Psi}^L_q \gamma^\mu \Psi^L_q \bar{\Psi}^L_q \gamma^\mu \Psi^L_q$, where $g/4\pi = 1$ and $\eta = +1$.

Event Selection

As shown earlier, except for:

- leading jet $p_T > 60 GeV$ in control region
- $|y_1 + y_2| < 1.5 \Rightarrow$ Constrains boost to suppress PDF uncertainty
- $|\eta_{1,2}| < 1.0$ for the η-ratio.

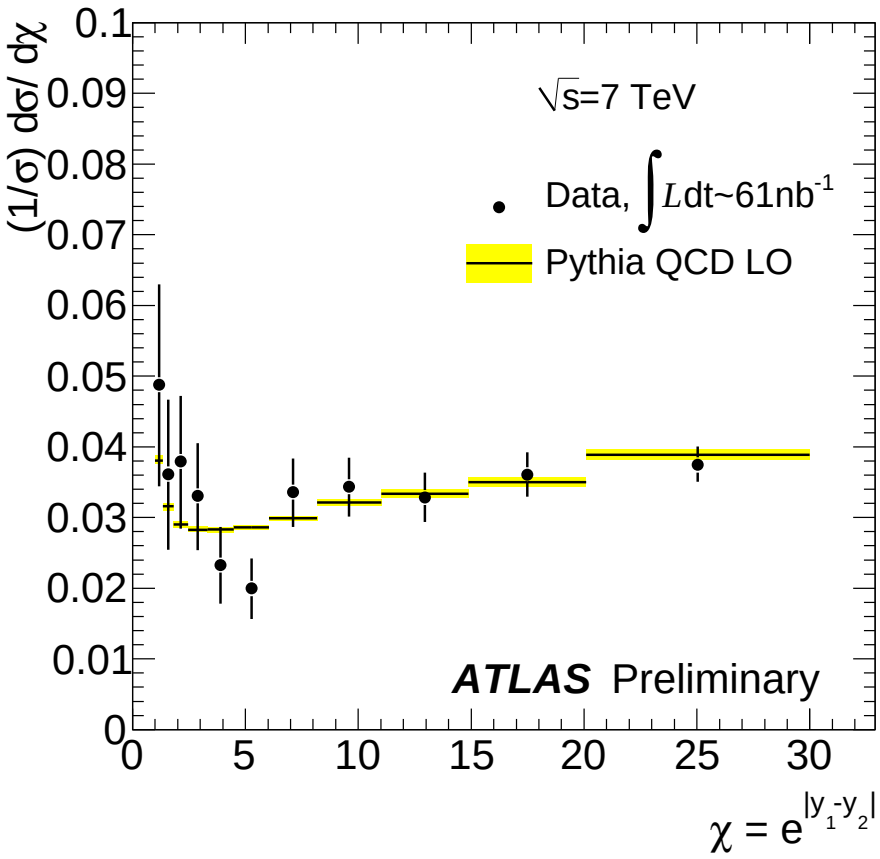
χ Control Region: $320 < m^{jj} < 520$ GeV



Detector-level comparison of normalized spectra

Good agreement in control region: $\chi^2/NDF = 1.47 \Rightarrow p\text{-value} = 15\%$

χ Signal Region: $520 < m^{jj} < 680$ GeV

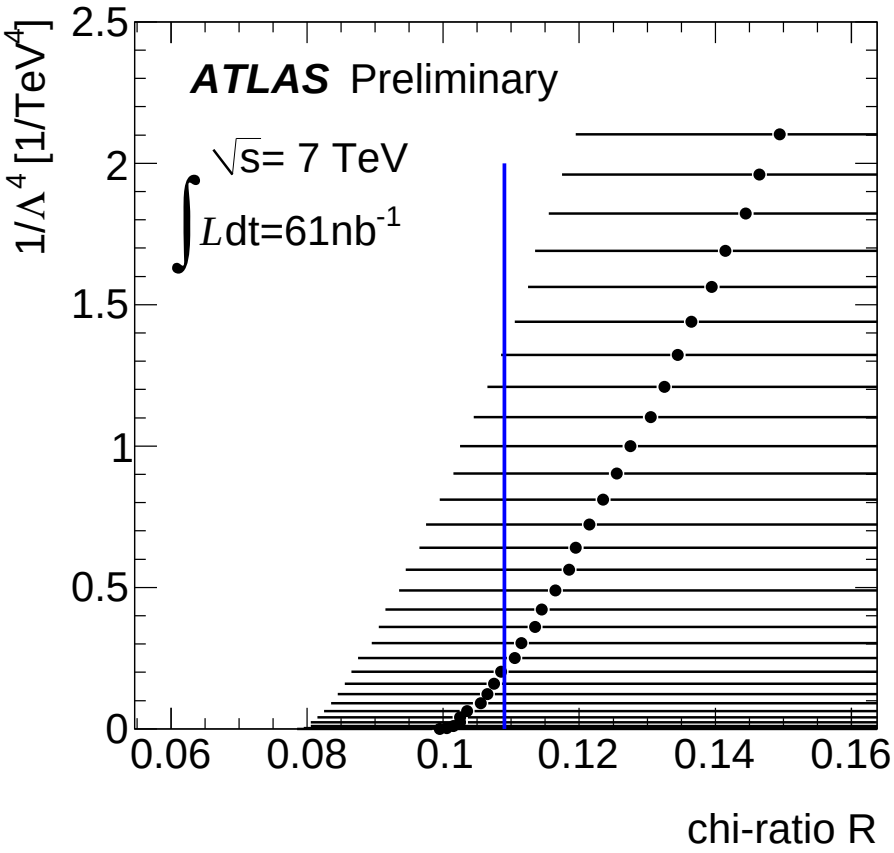


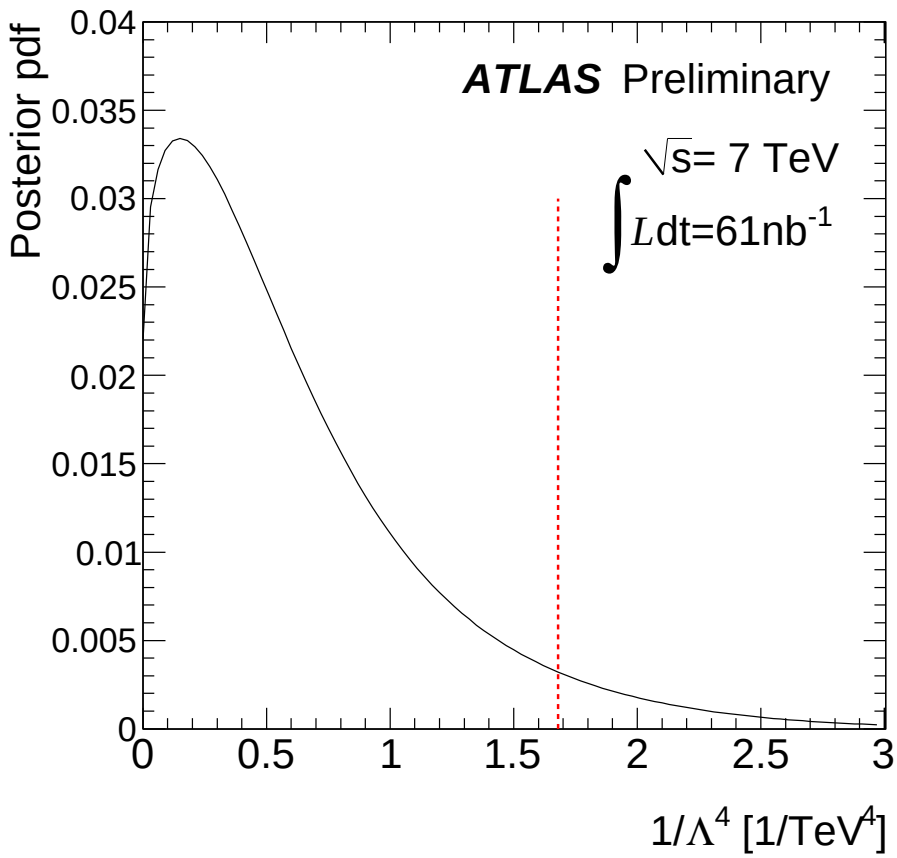
Good agreement in signal region:
$\chi^2/NDF = 1.07 \Rightarrow p\text{-value} = 38\%$

The fraction of events in first 5 bins is used for the frequentist limit.

The whole spectrum is used for the Bayesian limit.

Limits on q compositeness scale Λ, from χ, at 95% C.L.





Frequentist: $\Lambda >$ **930 GeV**

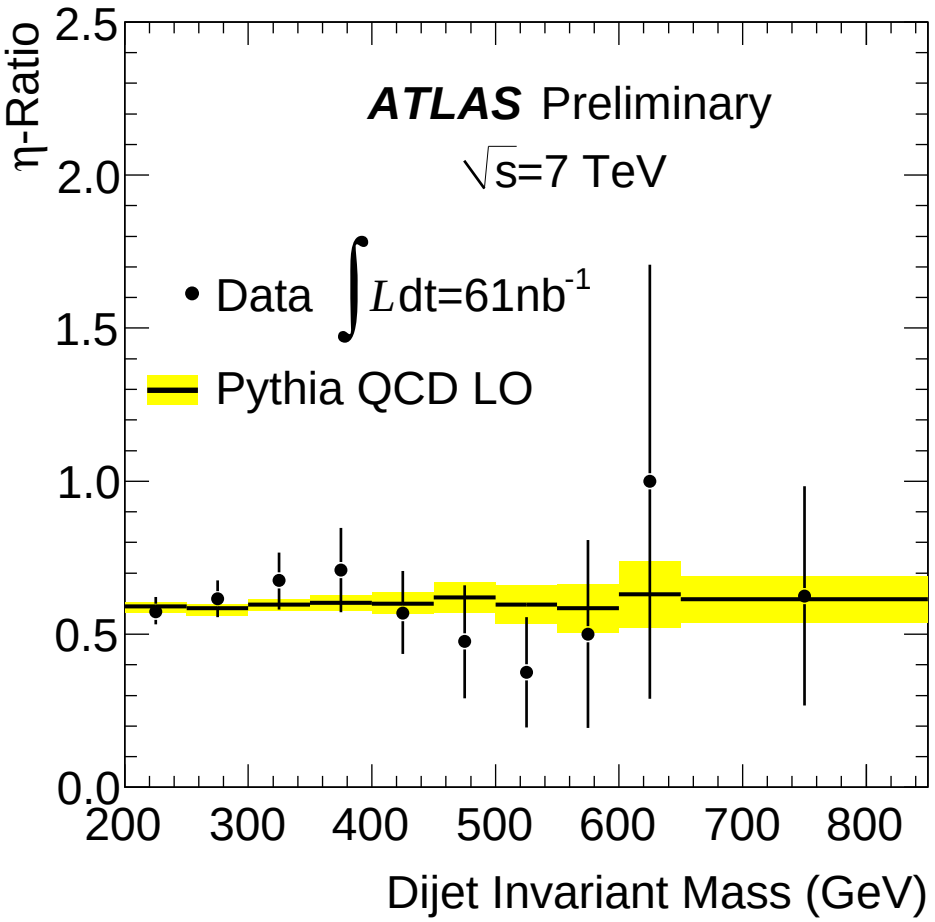
Bayesian: $\Lambda >$ **875 GeV**

This preliminary limit is *unphysical*.

More data will give access to physical Λ values.

DØ Collaboration, Phys.Rev.Lett.103:191803,2009 : $\Lambda > 2.8$ TeV

η-ratio as a function of m^{jj}



Good agreement observed. p-value ~ 0.5 using a χ^2 test.

Bayesian 95% C.L. limit: $\Lambda >$ **760 GeV**

Summary

Presented preliminary ATLAS searches for new physics (NP) in inclusive dijet channel.

- Non-resonant NP in angular distribution, with 61 nb^{-1}
  - Good agreement with QCD.
  - Excluded, at 95% C.L., $\Lambda < 930$ GeV
- Resonant NP in mass spectrum, with 296 nb^{-1}
  - No resonance found.
  - Excluded, at 95% C.L., a q^* of $400 < m_{q^*} < 1290$ GeV.[2]
  - **One of the first competitive limits. The LHC is already on a new territory.**

[2] Or 1180 GeV, assuming CTEQ6L1.

Backup

5. p-values of tests comparing data to fit
6. The 2nd highest mass event
7. Data vs MC
8. Convolution effects
9. Coverage
10. Tevatron searches
11. Black holes

Statistical tests of goodness-of-fit

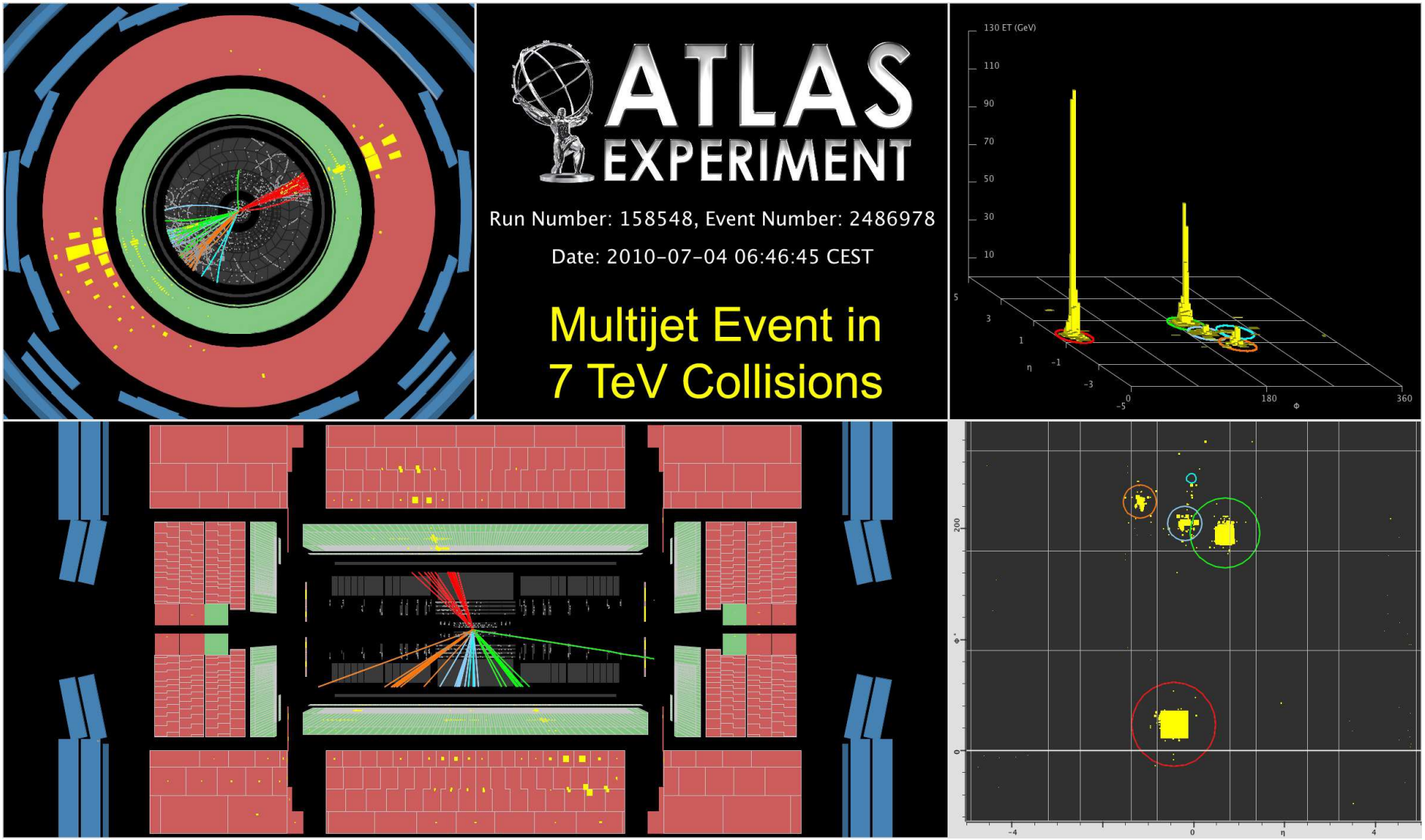
Statistic	data vs fit
Bump Hunter	0.54
Jeffreys Divergence	0.43
Kolmogorov-Smirnov	0.52
$-\ln L$	0.51
Pearson χ^2	0.62
TailHunter	> 0.999

Large p-values $\Rightarrow$ Data consistent with fit.

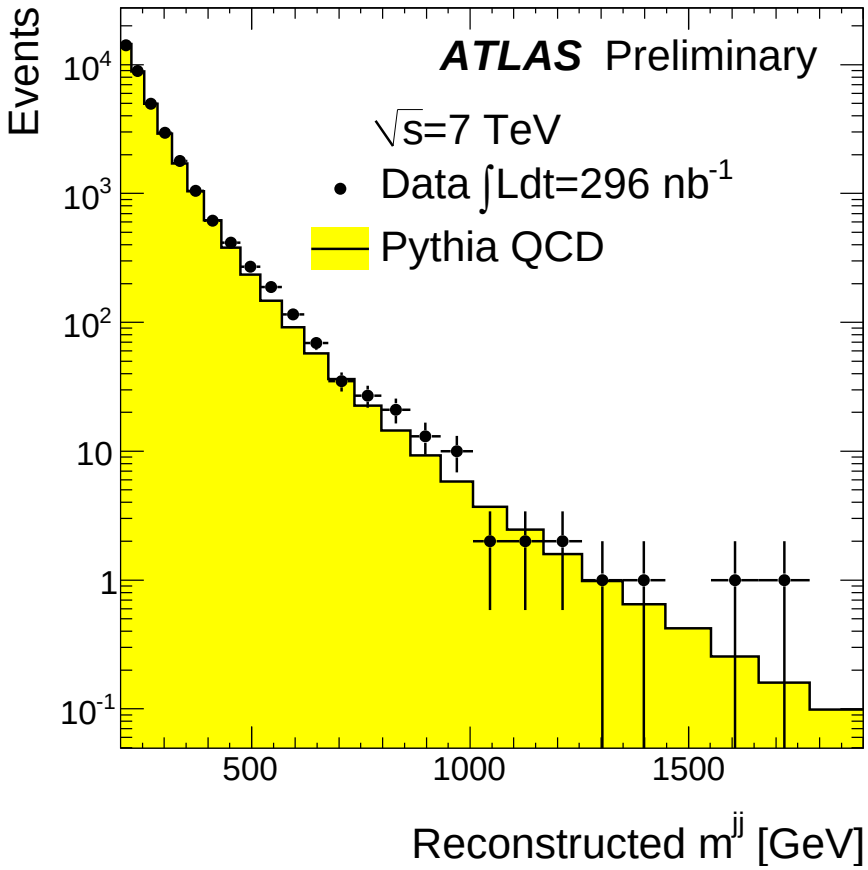
No evidence of mass resonances.

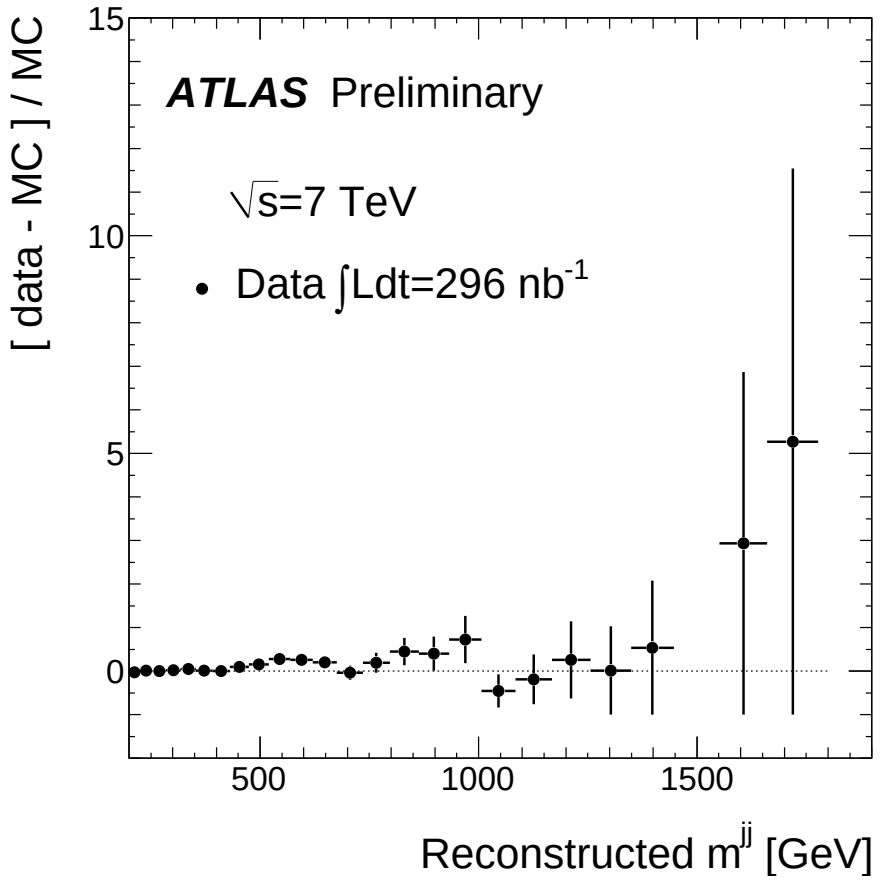
The 2nd highest-m^{jj} central event observed

$m^{jj} = 1.55$ TeV. $p_T^{j1} = 805$ GeV. $p_T^{j2} = 550$ GeV



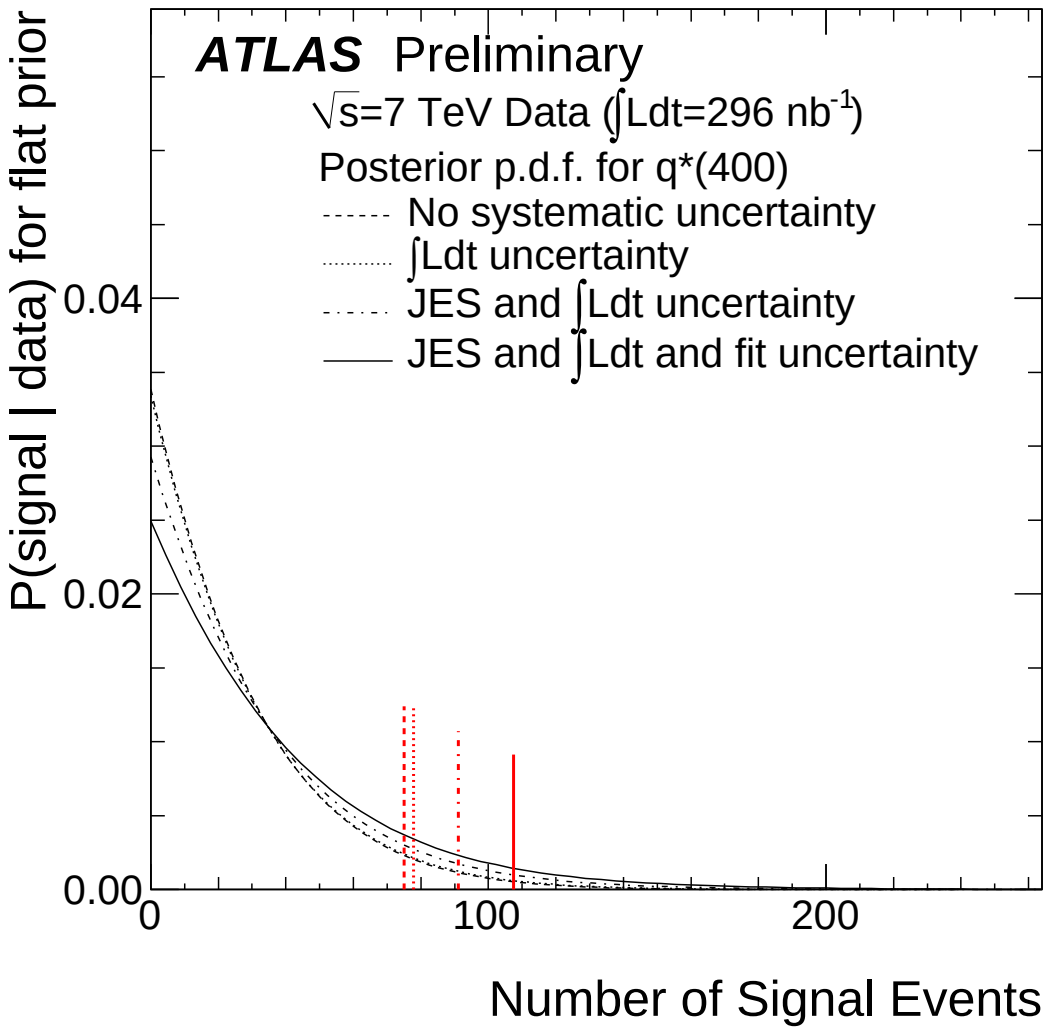
A test, comparing the data to LO PYTHIA QCD



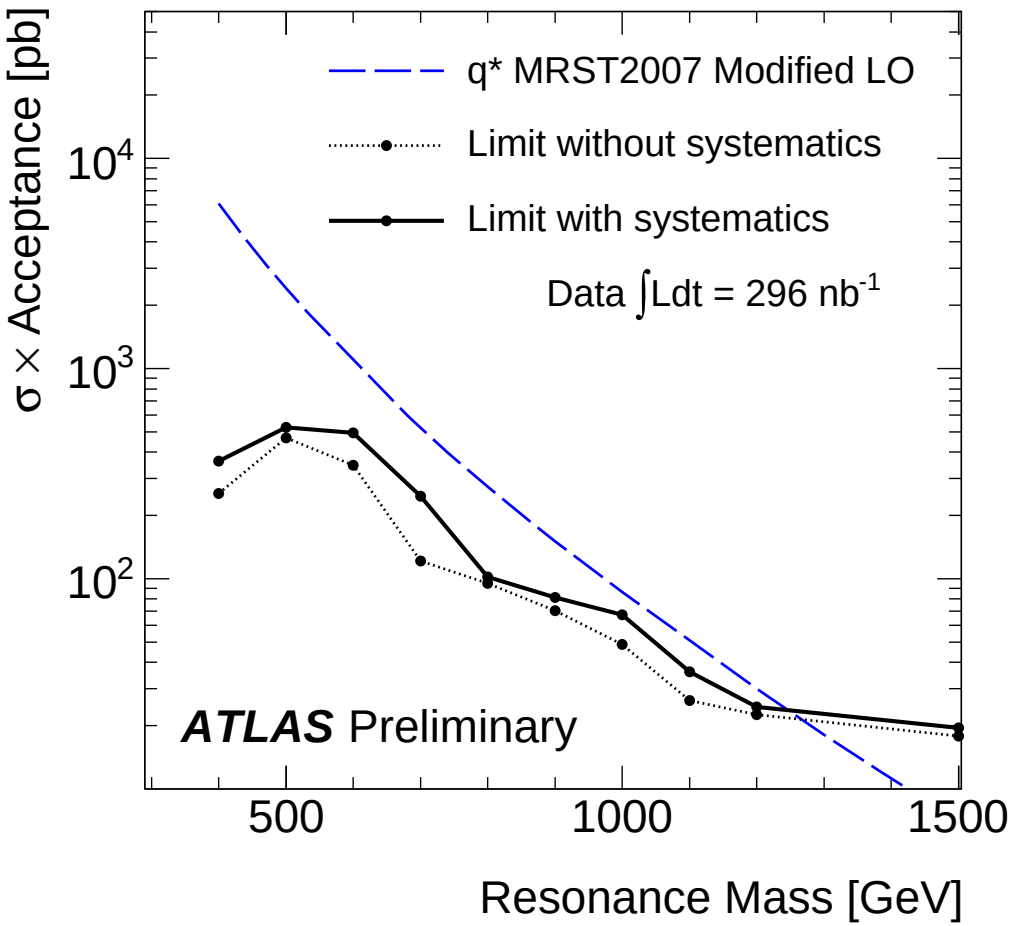


Some disagreement between data and LO PYTHIA QCD is not surprising.

Effect of convolution



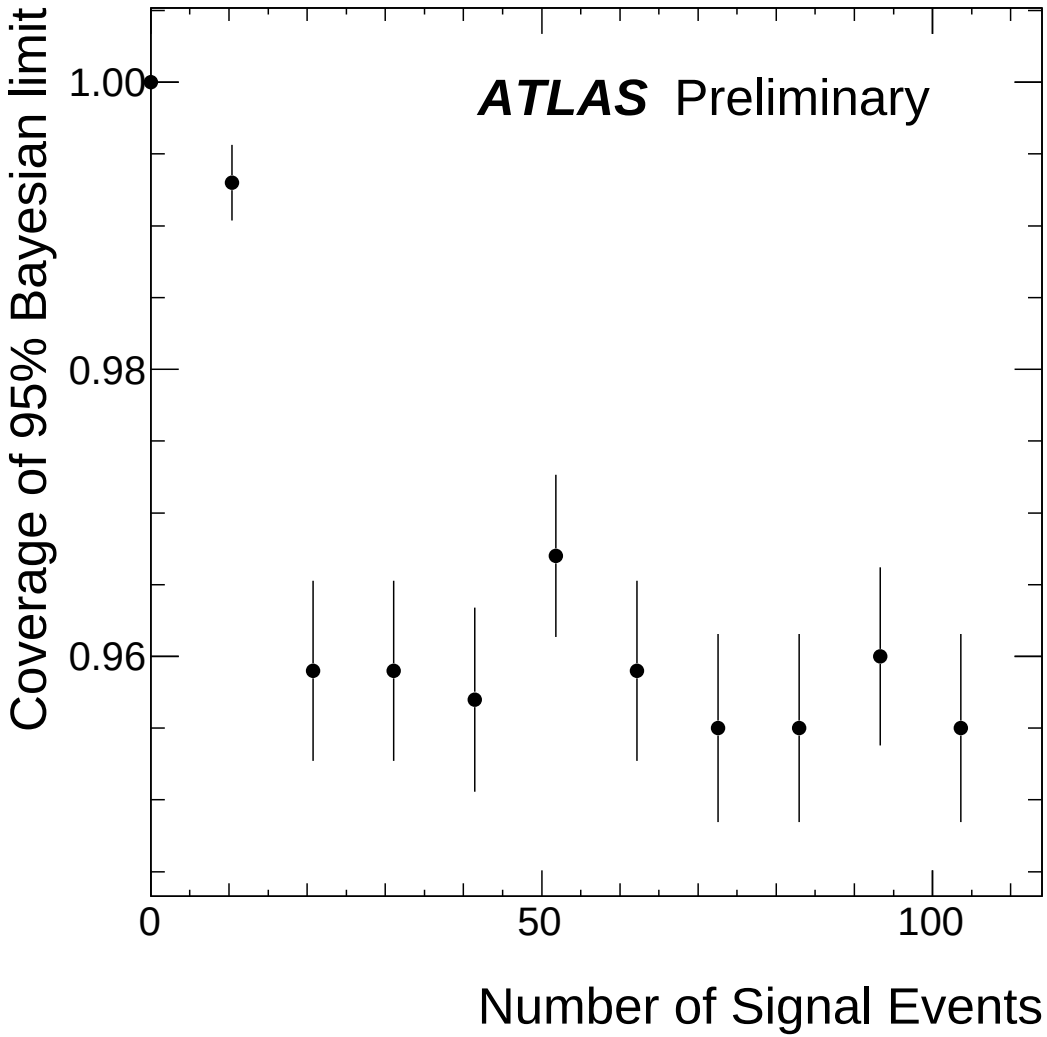
Mass Exclusion, with and without systematics



Excluded range at 95% CL: $400 < m_{q^*} < 1290$ GeV

[Without systematics: $400 < m_{q^*} < 1320$ GeV]

Frequentist coverage of the Bayesian limit

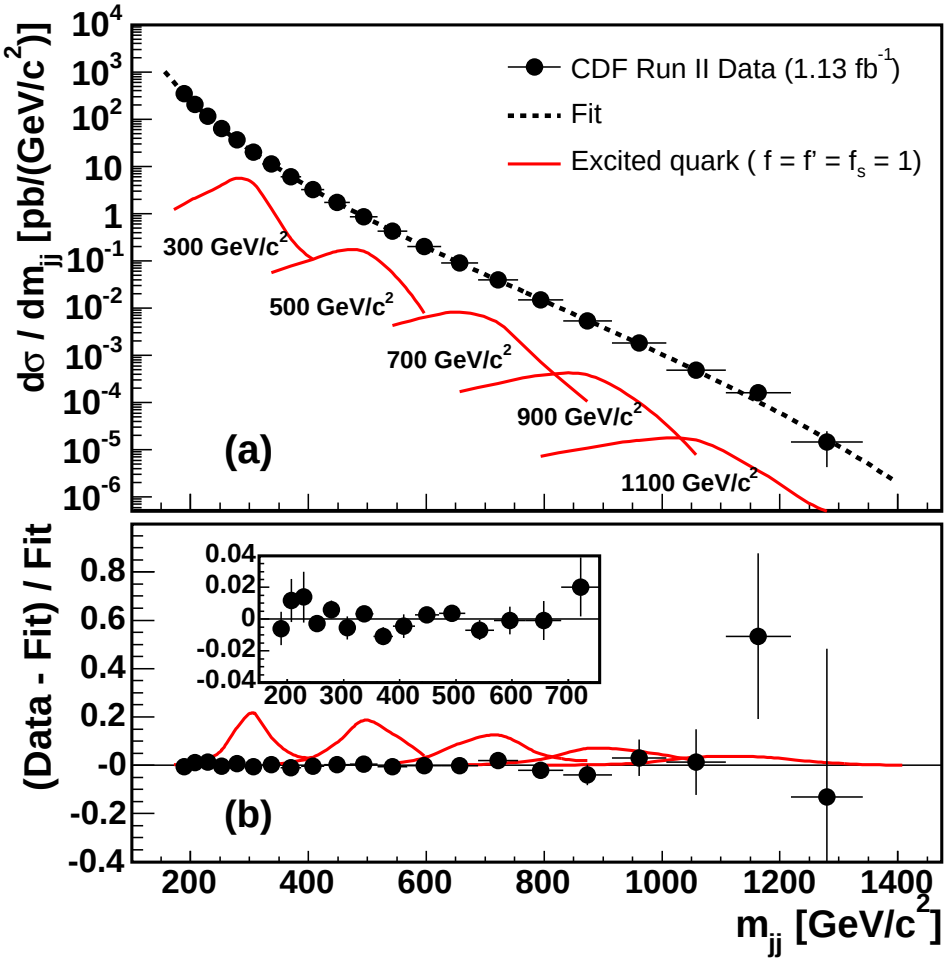


Using 900 GeV q^*, with similar results for different masses.

Latest experimental studies

- CDF Collaboration,
  Phys.Rev.D 79 (2009) 112002

  Excited quark mass limit:
  870 GeV [at 95% CL]



Latest experimental studies

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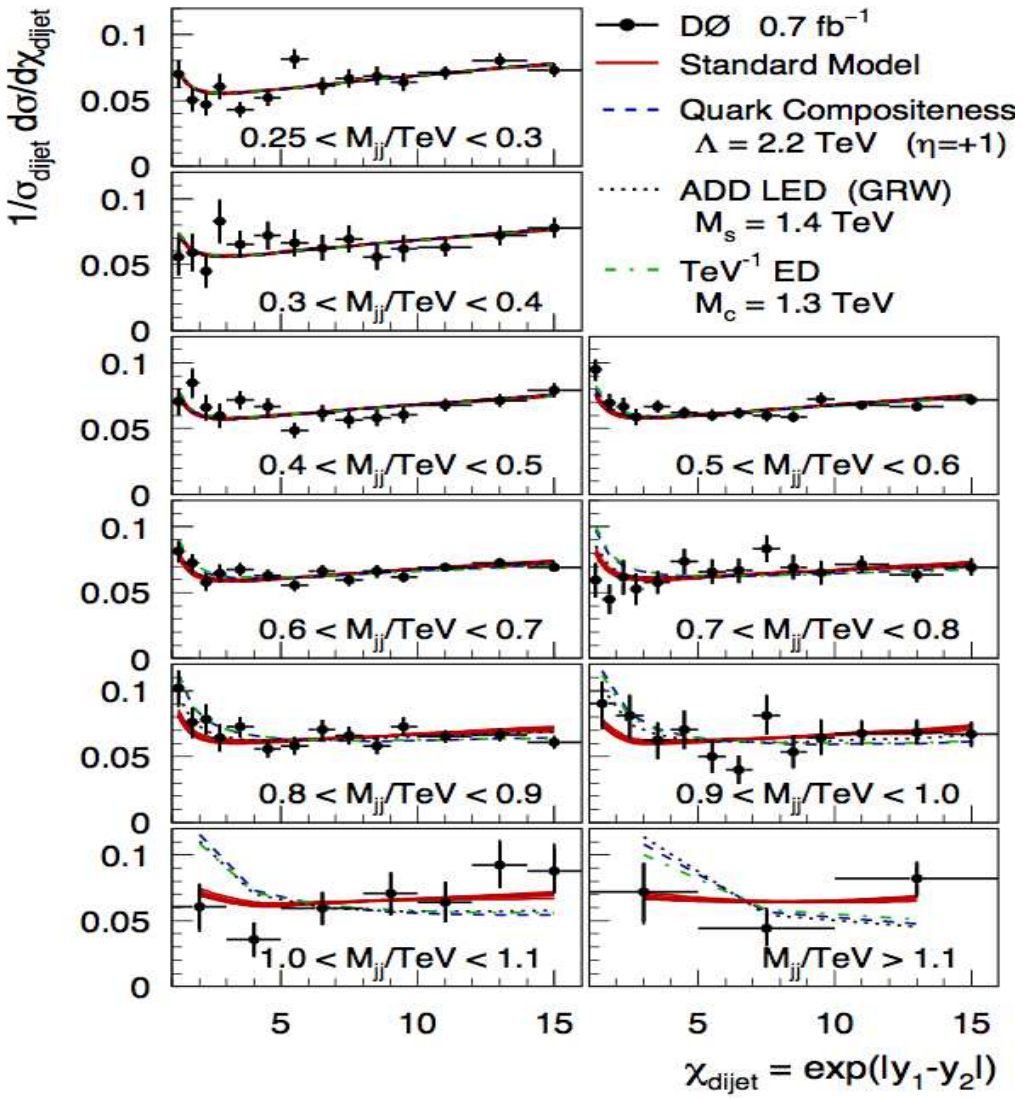
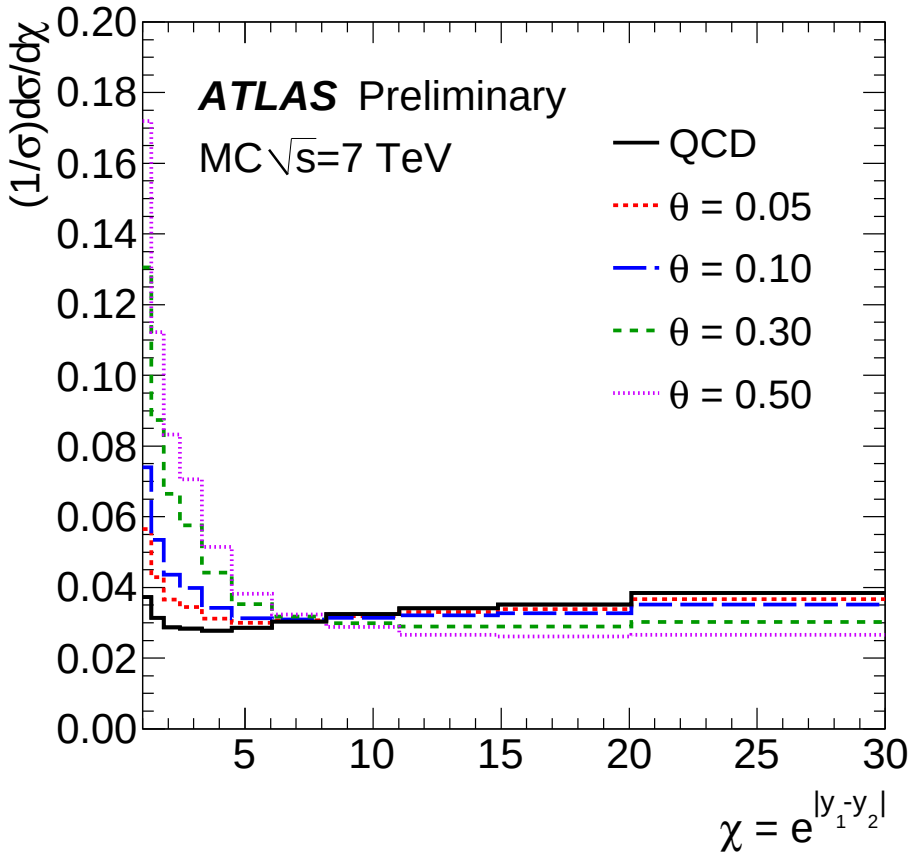
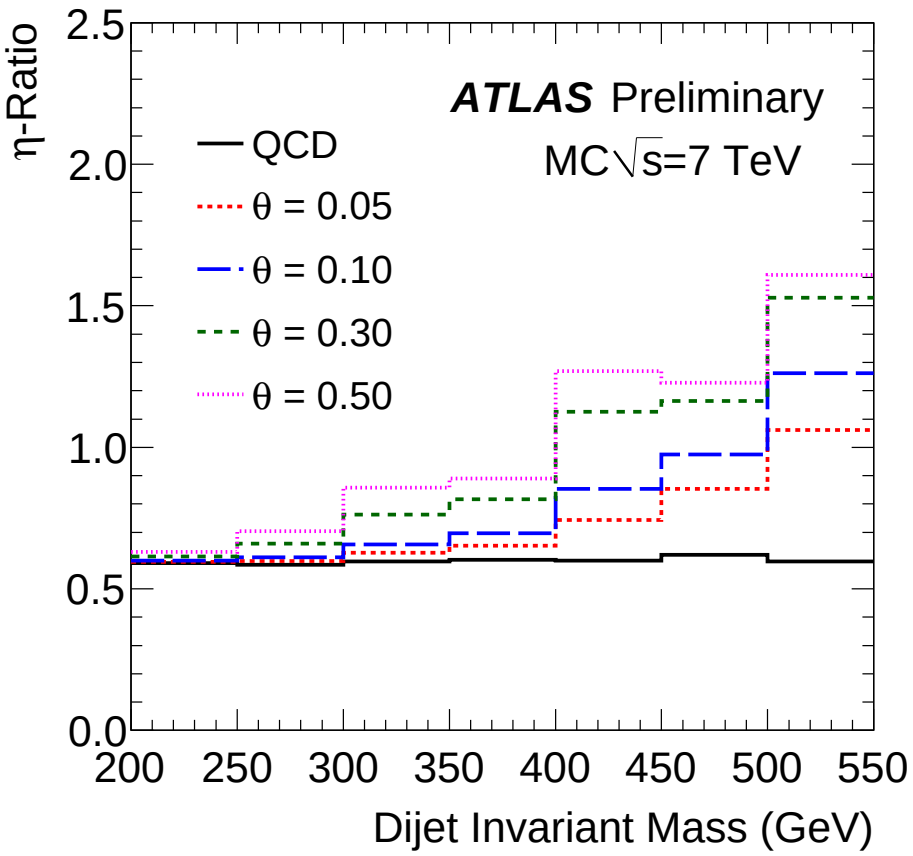
  Phys.Rev.Lett.103:191803,2009

  Quark compositeness scale limit:
  2.8 TeV [at 95% CL]



Signal examples in χ and in η-ratio





QCD + Black hole signal, with $n = 6$ and $M_D = 600$ GeV.

$\theta = \frac{\text{signal events}}{\text{QCD events}}$ in the m^{jj} signal region.

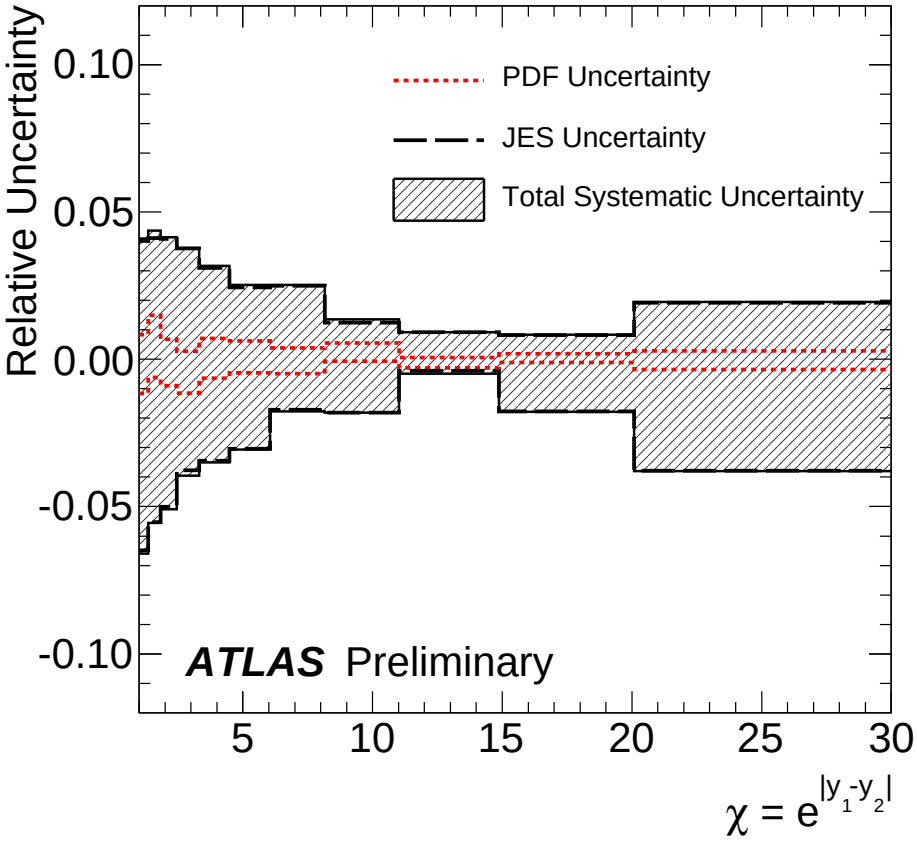
Quark compositeness would appear as a similar deviation.

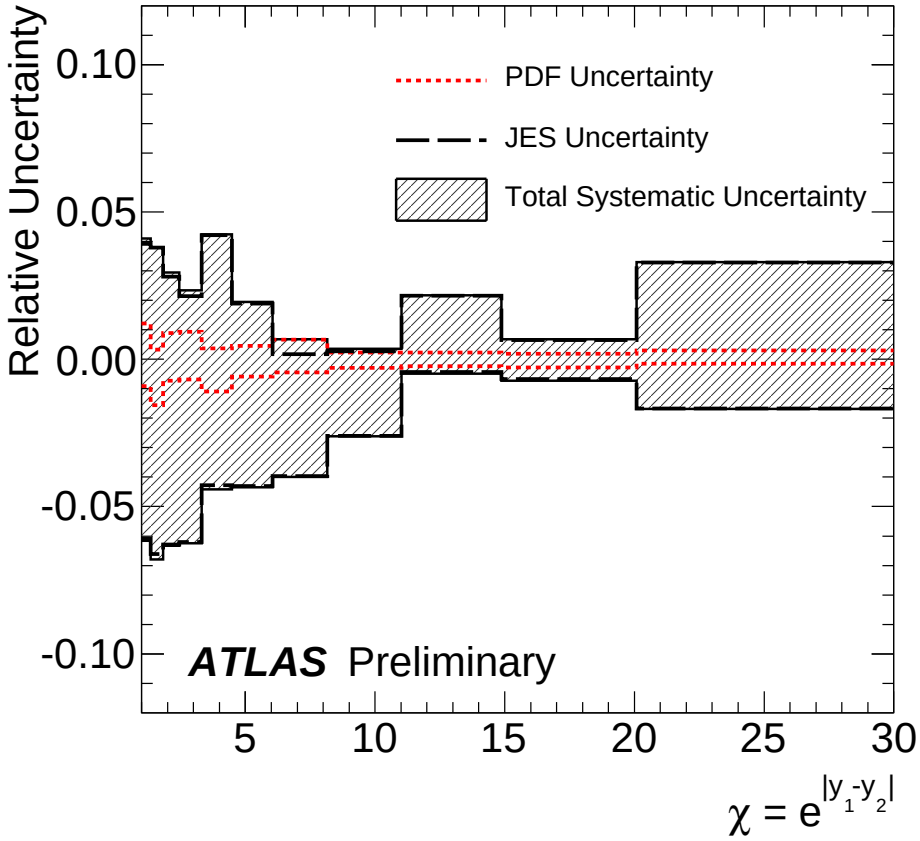
Limits on black hole production

	χ-spectrum			η-ratio	
M_D [GeV]	Frequ.	Bayes.	QBH, n=6	Bayes.	QBH, n=6
600	8.9%	8.0%	109%	1.6%	17%
800	9.6%	8.1%	13%	0.8%	7%

Systematic uncertainties

- Jet energy scale uncertainty
- PDF uncertainty





Control region: $320 < m^{jj} < 520$ GeV

Signal region: $520 < m^{jj} < 680$ GeV

Systematic uncertainties

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