Title: Exotic Resonance searches in Atlas data

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Abstract: TBA

Brief Summary of Dijet Searches

Summary of Paper Publications

... and more!

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Outline

- Tools for Dijet Searches: Jets!
  - The real question: *What is the Jet Energy Scale at ATLAS*?
- Overview of 2 dijet analyses
  - First 2 exotics analyses to be published with LHC data!
- *Dijet Angular Distributions @ 3.1 pb^{-1}*
  - Published in **PLB**, October 21st 2010 [*doi:10.1016*]
- *Dijet Resonances @ 3.1 pb^{-1}*
  - Published in **PRL**, October 10th 2010 [*ATLAS-CONF-2010-093*]

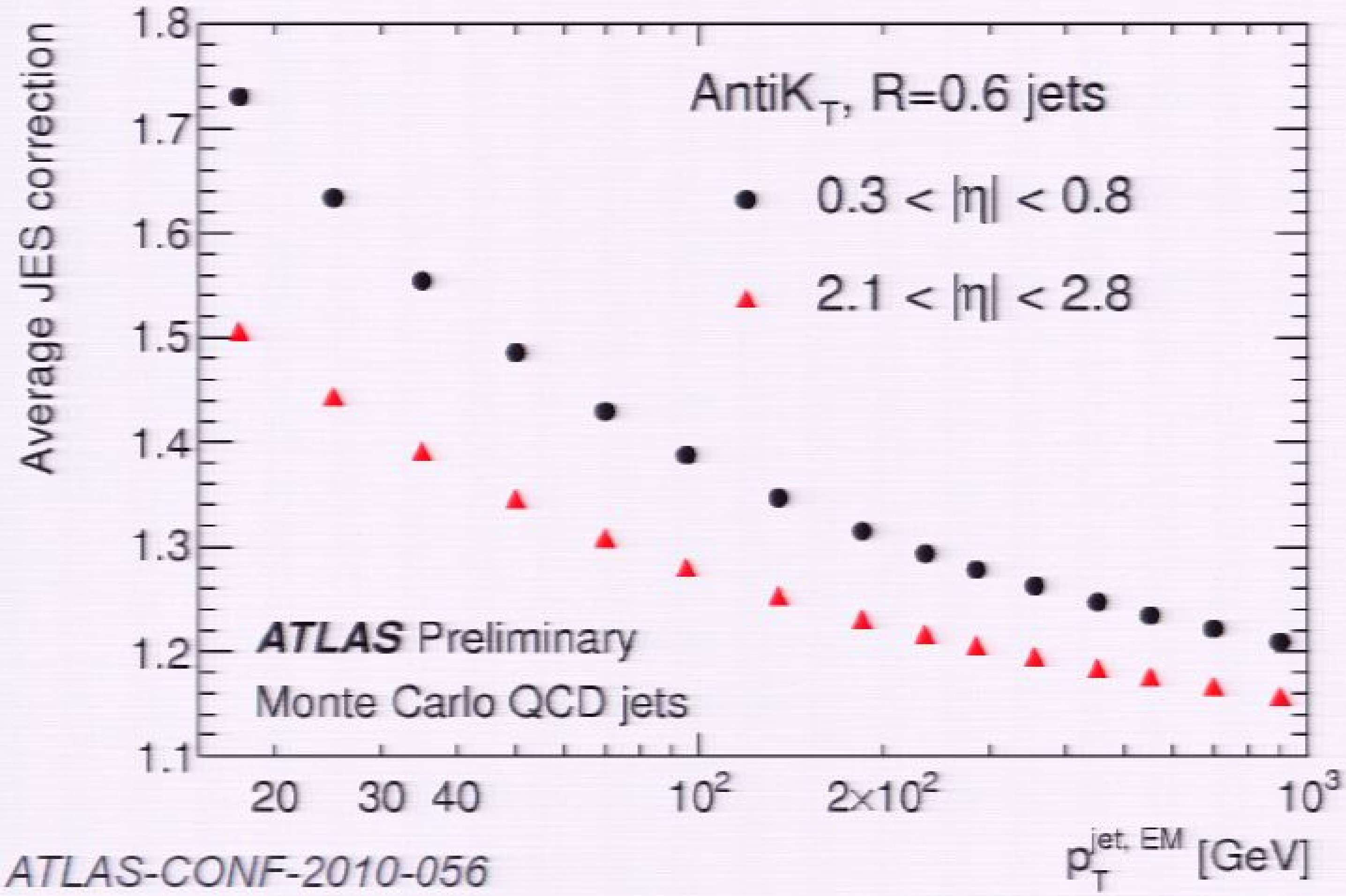
Jets at ATLAS

- **The Basics:**
  - The anti-k_T algorithm is used
    - Infrared-safe, colinear-safe, robust vs. pile-up, well-defined jet areas, the list goes on...
  - Size parameters 0.4 and 0.6 are 'supported' at ATLAS
    - For dijet topologies, 0.6 is used
  - Inputs to jet finding: *'Topoclusters'*
    - Noise suppressing 3-dimensional 'nearest neighbor' clustering
    - Uses characterization of the detector noise to group the energy deposits of cells 'single particles'

Jet Energy Scale

- *The uncertainty on the measurement of the energy of a jet*
  - *Reminder: ATLAS calorimeters are non-compensating*
- Jet calibration at ATLAS: ***Particle*** level
  - The jets are calibrated to the energy of the particles (hadrons, etc.) which fall into the jet area
- Simple calibration scheme:
  - p_T and η dependent correction factors scale the jet 4-momentum
  - Derived from Monte Carlo samples (*PYTHIA* + ...) by matching **'Truth Particle Jets'** (jets made from the generator bank of outgoing particles) to **'Reco Jets'** (jets made from the simulated energy depositions of said particles)
  - Why this works: ATLAS has a very sophisticated detector simulation program based on **GEANT4**: describes the energy loss mechanisms of particles in the detector

Jet Energy Calibration



ATLAS-CONF-2010-056

Jet Energy Scale - How??

- For first data, a conservative procedure:
  - Simulate **X** Monte Carlo 'variation' samples, with different simulation conditions
  - Each sample represents a **'best guess'** (*conservative*) at a possible aspect of the model(s) we may have gotten wrong
  - Use insight from testbeam, and single particle studies, to justify the educated guesses
  - Compare the response of jets between the variation samples and the default to extract an uncertainty

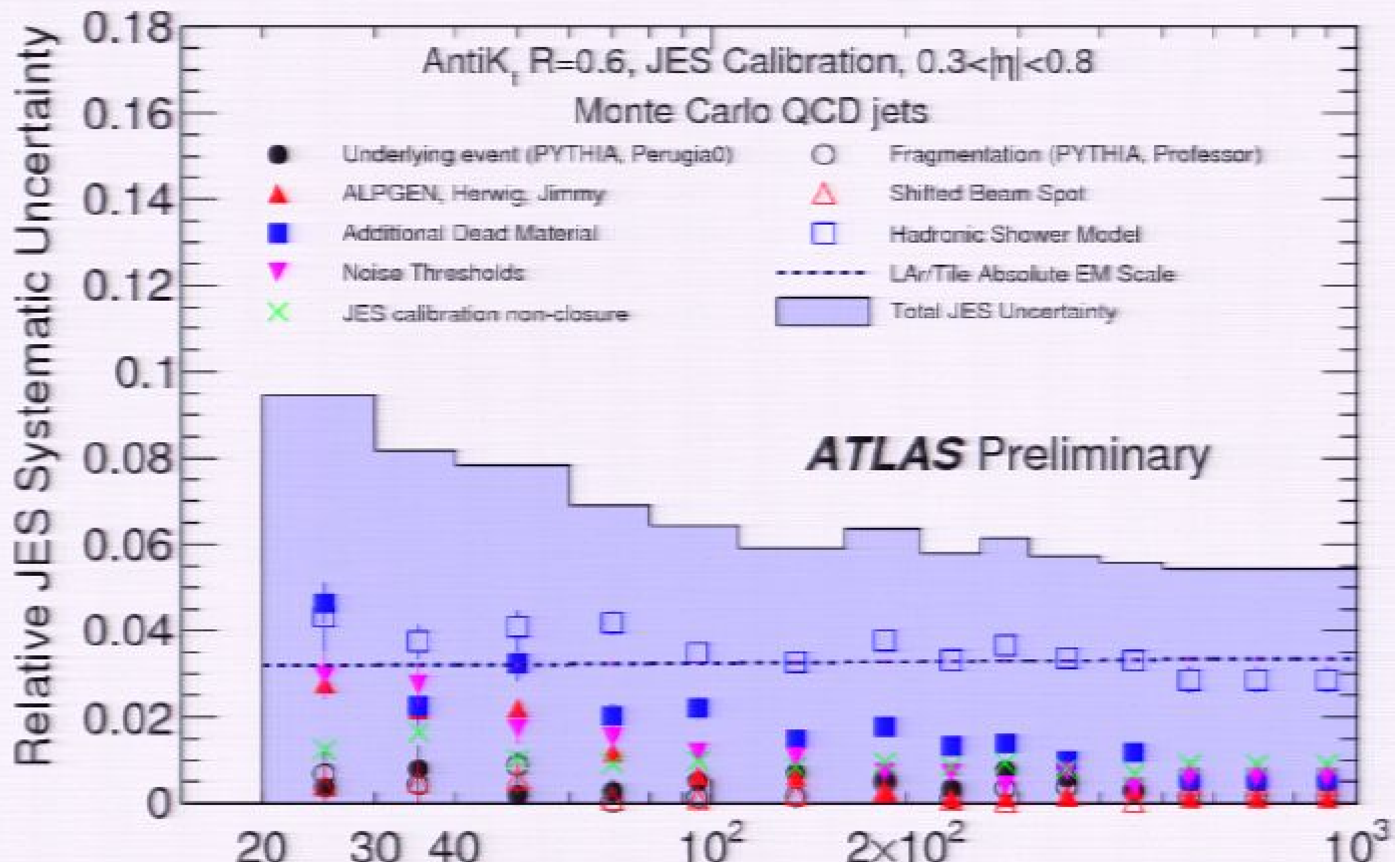
Uncertainties: A shopping list!

Shower Models	Fragmentation	Underlying Event
EM Scale (!!)	Dead Material	Pile-up
Noise modeling	Beamspot	MC generator
...	Non-closure	...

Jet Energy Scale – How is it??

- The size of this uncertainty will directly affect the sensitivity of searches based on jet signatures!

Just about 6% for central 100 GeV jets...



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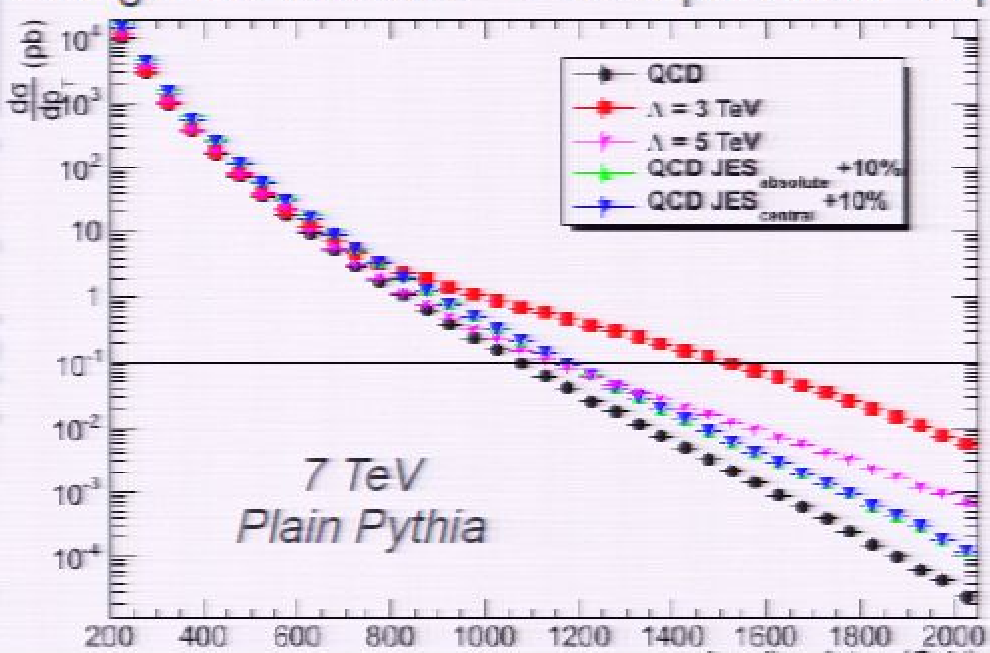
Dijet Angular Distributions

- We are searching for Quark Compositeness
  - Signature is an excess of dijet events at an invariant mass approaching the compositeness scale Λ compared to **QCD** predictions
  - Most natural thing to do: Look for deviations in the dijet invariant mass / p_T distribution!

Straight line indicates ~1 event per bin for 10 pb^{-1}



Compositeness
QCD
JES variations

Varying the JES leads to signal-like features!

Dijet Angular Distributions

- Alternative approach: Look at the *angular* distributions of dijet events, which are much less sensitive to the JES uncertainty! Two observables:
- $\chi = \exp|y_1 - y_2| = u/t$ [*in bins of* m_{jj}]
  - Originally introduced to write the differential cross-sections for QCD processes easily
  - $d\sigma/d\chi$ turns out to be approximately flat for dominant QCD t-channel, but clear deviations from flatness for isotropic processes (quark compositeness)
- $R_C = N(|\eta_{1,2}| < 0.7) / N(0.7 < |\eta_{1,2}| < 1.3)$ [*Centrality Ratio*]
  - Flat as a function of the invariant mass for QCD, shows 'turn-on' behavior in mass regimes approaching Λ in the case of compositeness
  - Allows to probe the angular distributions as a fine function of the invariant mass
  - Very 'detector-driven' – Good for early physics!

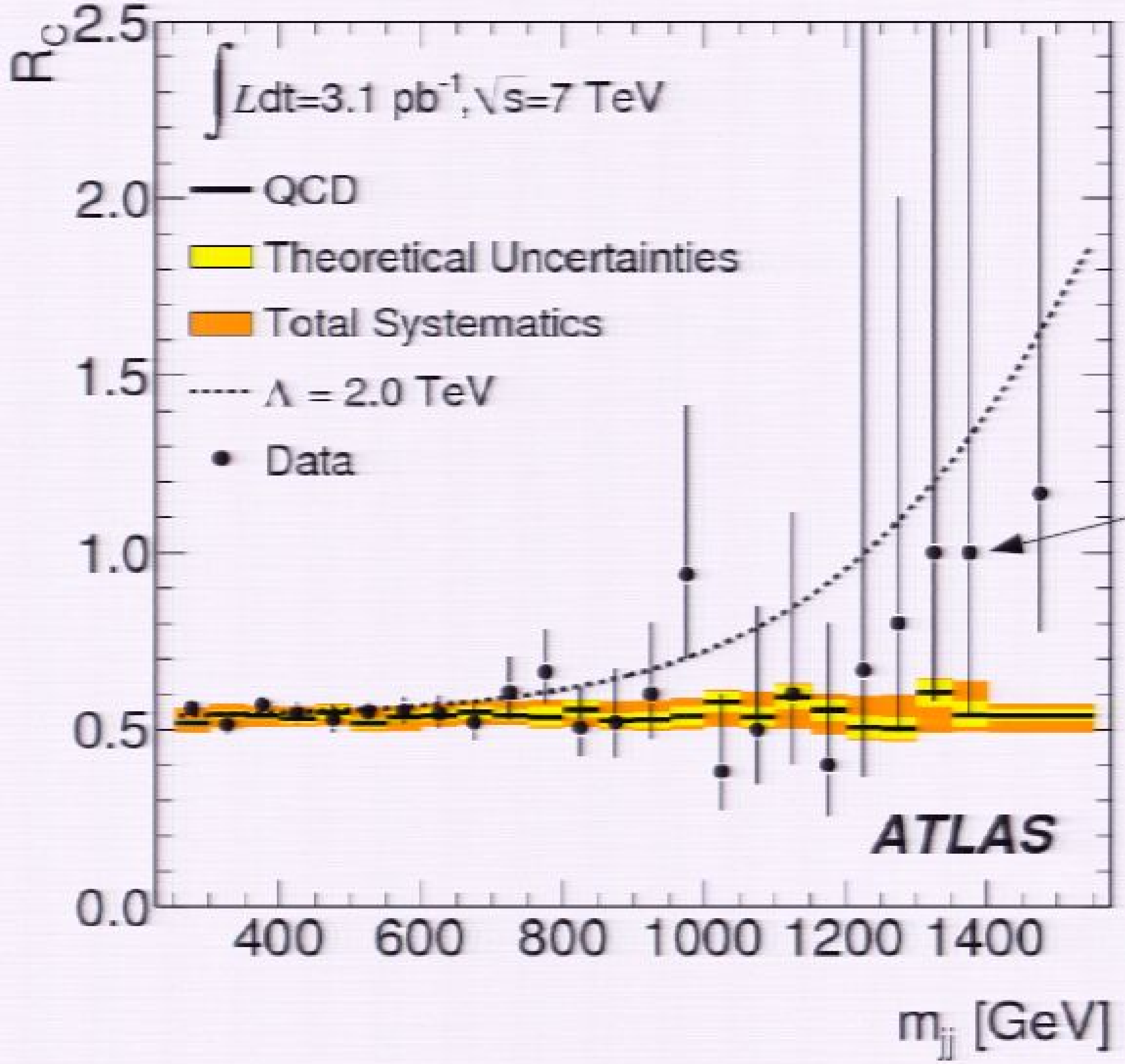
Philosophy

- Simple kinematic cuts to ensure that the triggers are fully efficient
- No attempt is made to unfold for jet resolution effects: the comparisons between Monte Carlo and data are purely at 'detector level'
- Normalize the distributions to remove any dependencies on theoretical cross-sections and luminosity: 'shape-only'
- Establish agreement between QCD and data with a simple figure of merit
- Set limits using Bayesian & Frequentist methods

Distributions: R_C

p-value:

0.85



'Prefers'
Λ = 2.9 TeV

Distributions: χ

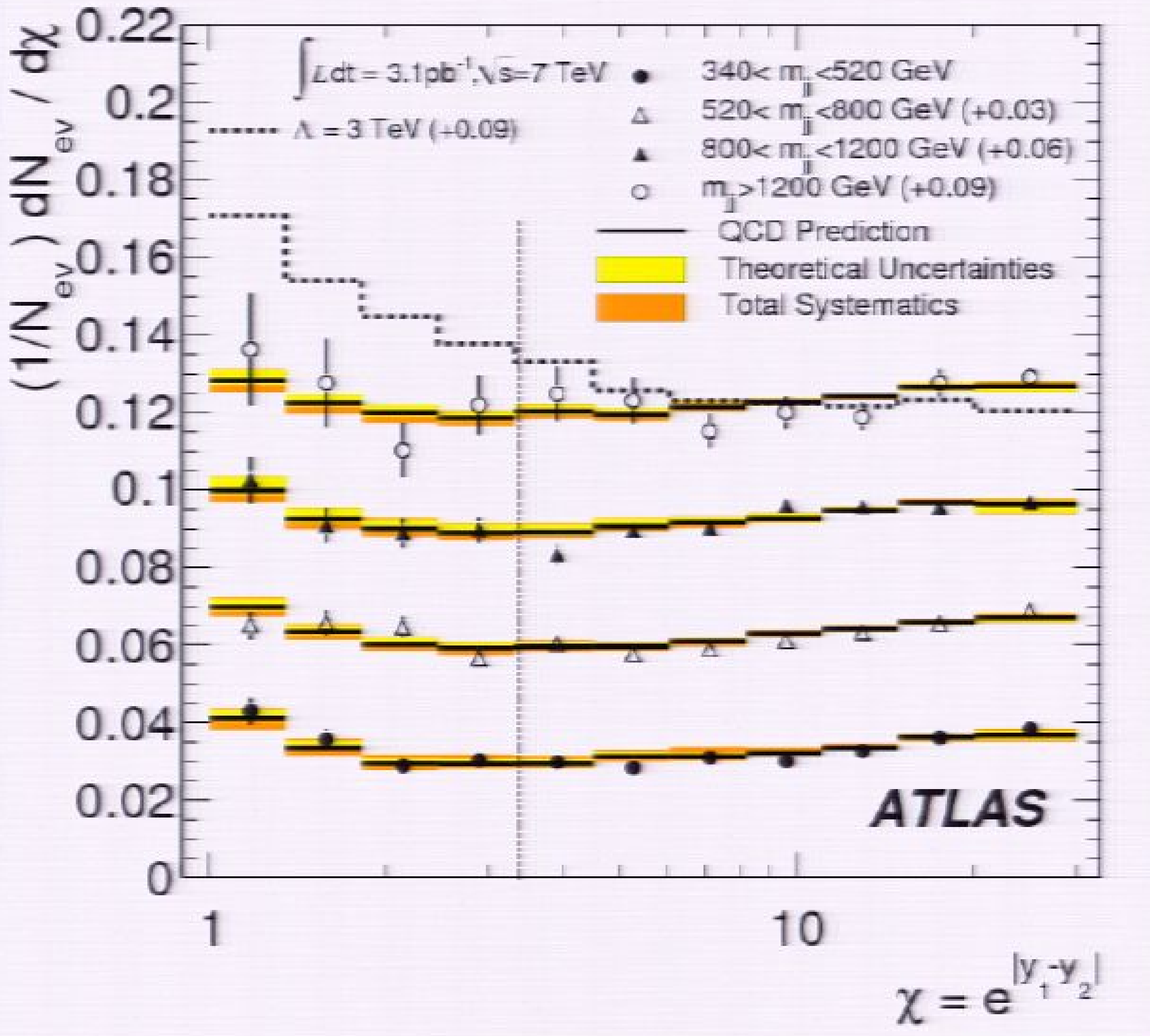
p-values:

0.54

0.27

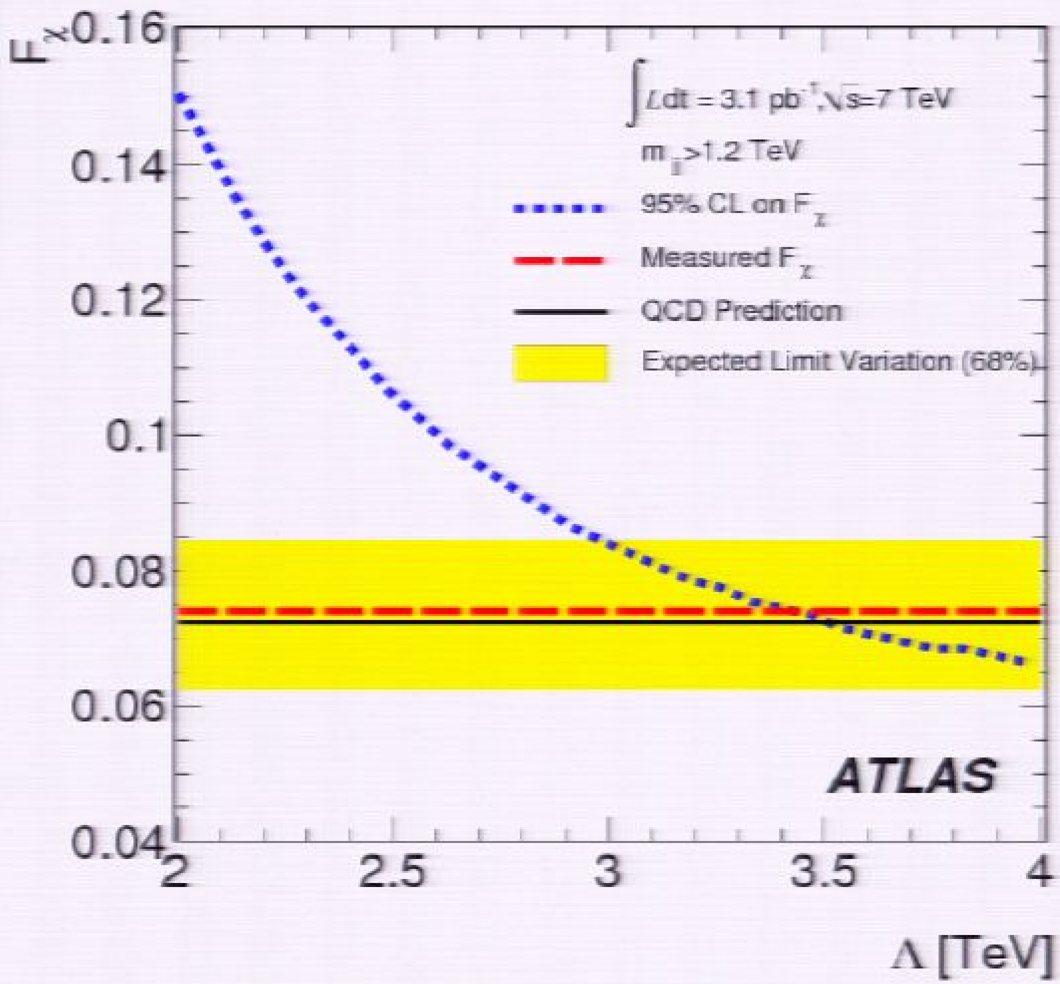
0.19

0.11



Setting Limits

- Use the highest invariant mass bin in χ
- Collapse all information about the χ spectrum into a single number, F_χ
  - F_χ = Ratio of contents of first 4 bins to total number of events
- Use a frequentist Neyman construction →



Limits:
3.4 TeV [Frequentist]
3.3 TeV [Bayesian - Cross-check]
2.0 TeV [R_C Bayesian]

3.1 TeV [Tevatron]

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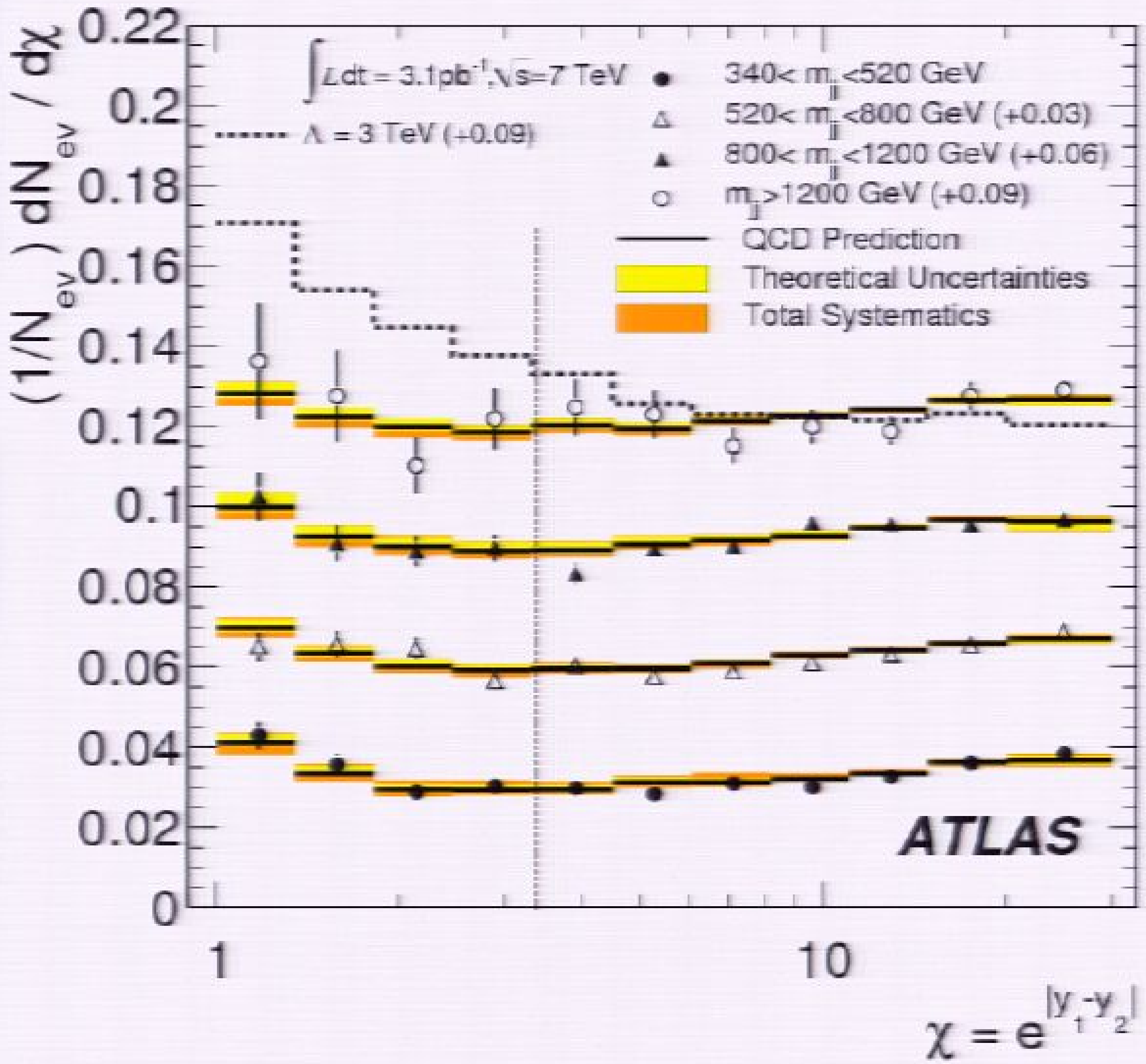

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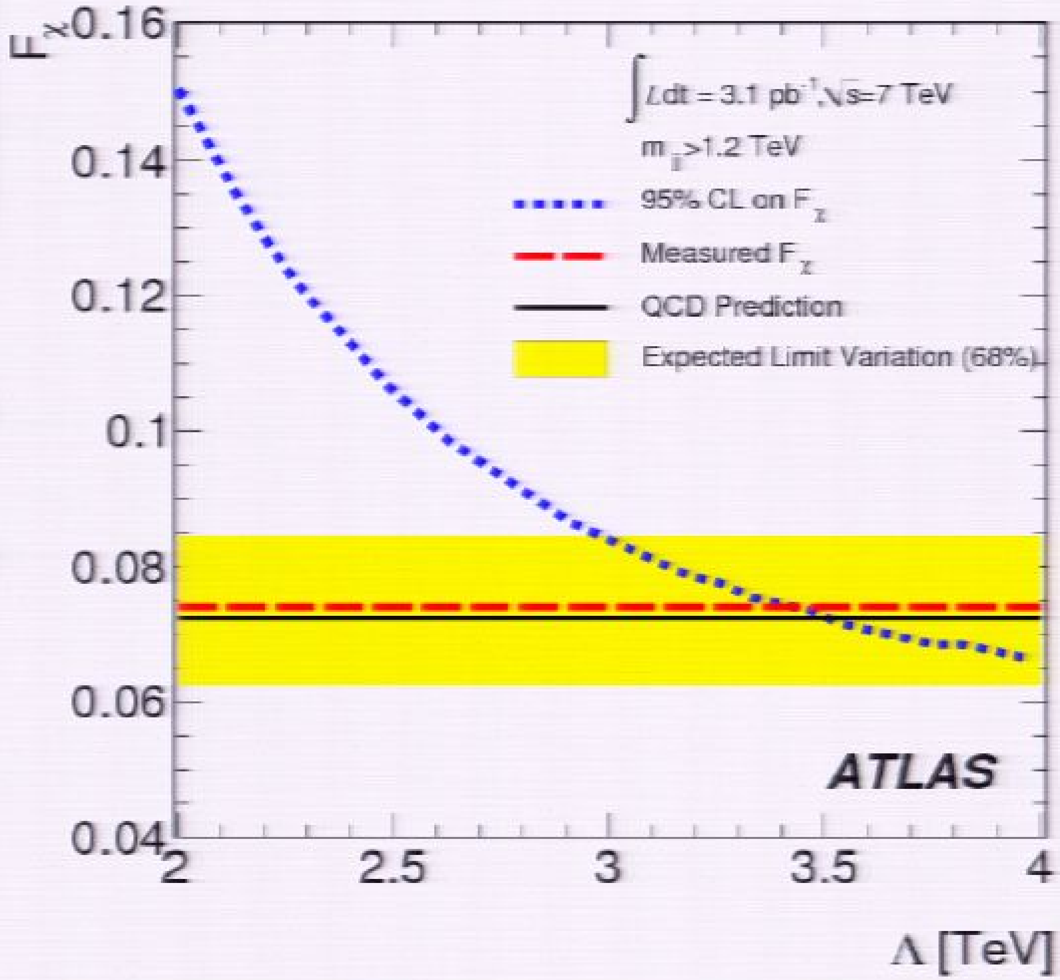

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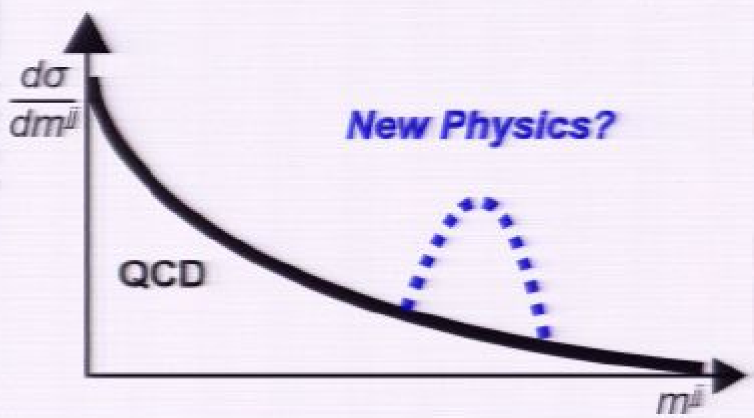
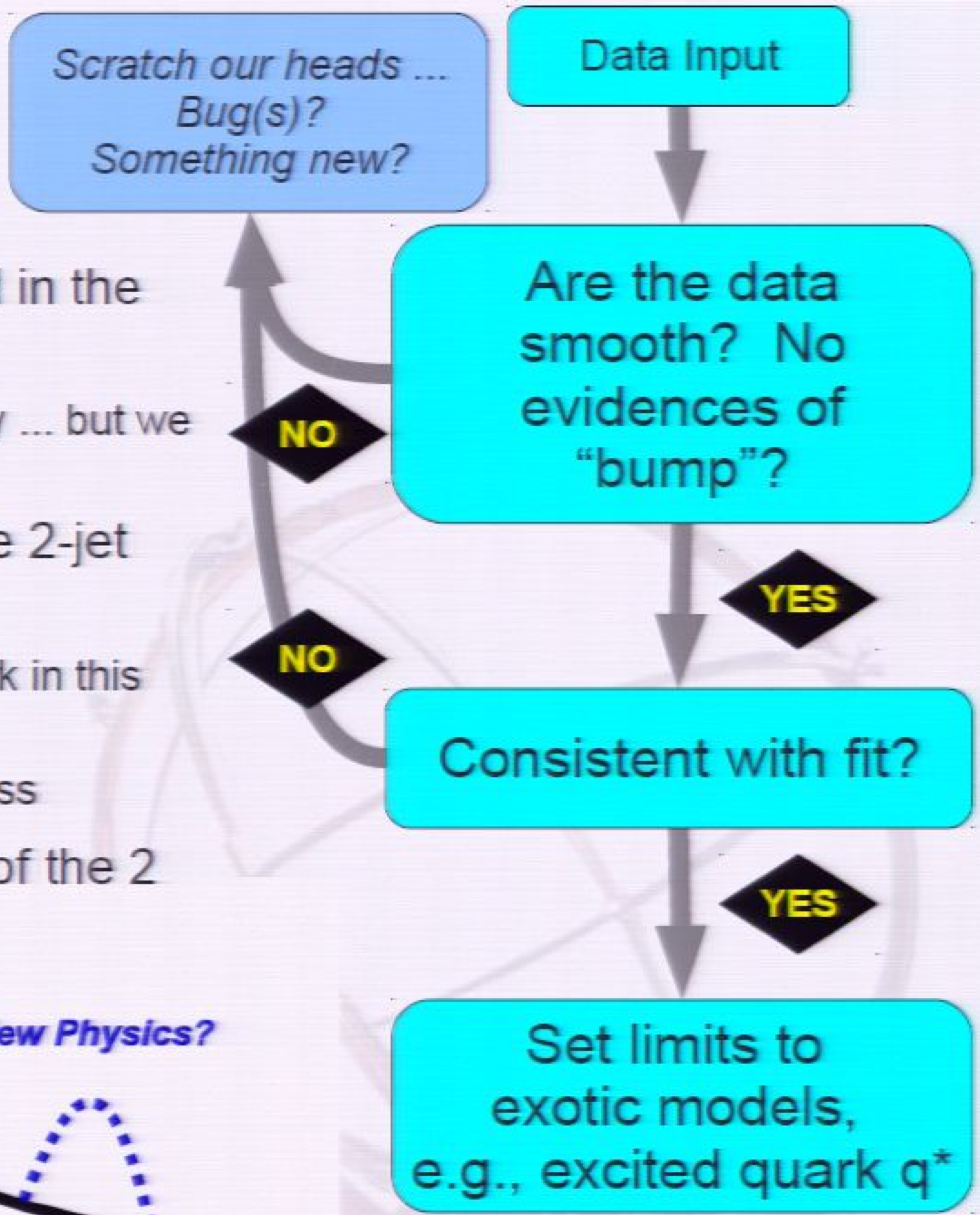
3.4 TeV [Frequentist]
3.3 TeV [Bayesian - Cross-check]
2.0 TeV [R_C Bayesian]

3.1 TeV [Tevatron]

Dijet Resonance:
Analysis Overview

- The analysis goal is summarized in the flow chart
  - Any "no" answer will make us worry ... but we havent been in this situation *yet!*
- Many exotic models exhibit in the 2-jet resonance signature
  - q* has been used as the benchmark in this analysis
  - More models are working in progress
- Observable: invariant mass m^{jj} of the 2 leading jets





Dijet Resonance:

Data smooth? No “bump”?

- After the event selection, we test the data distribution by fitting a smooth function

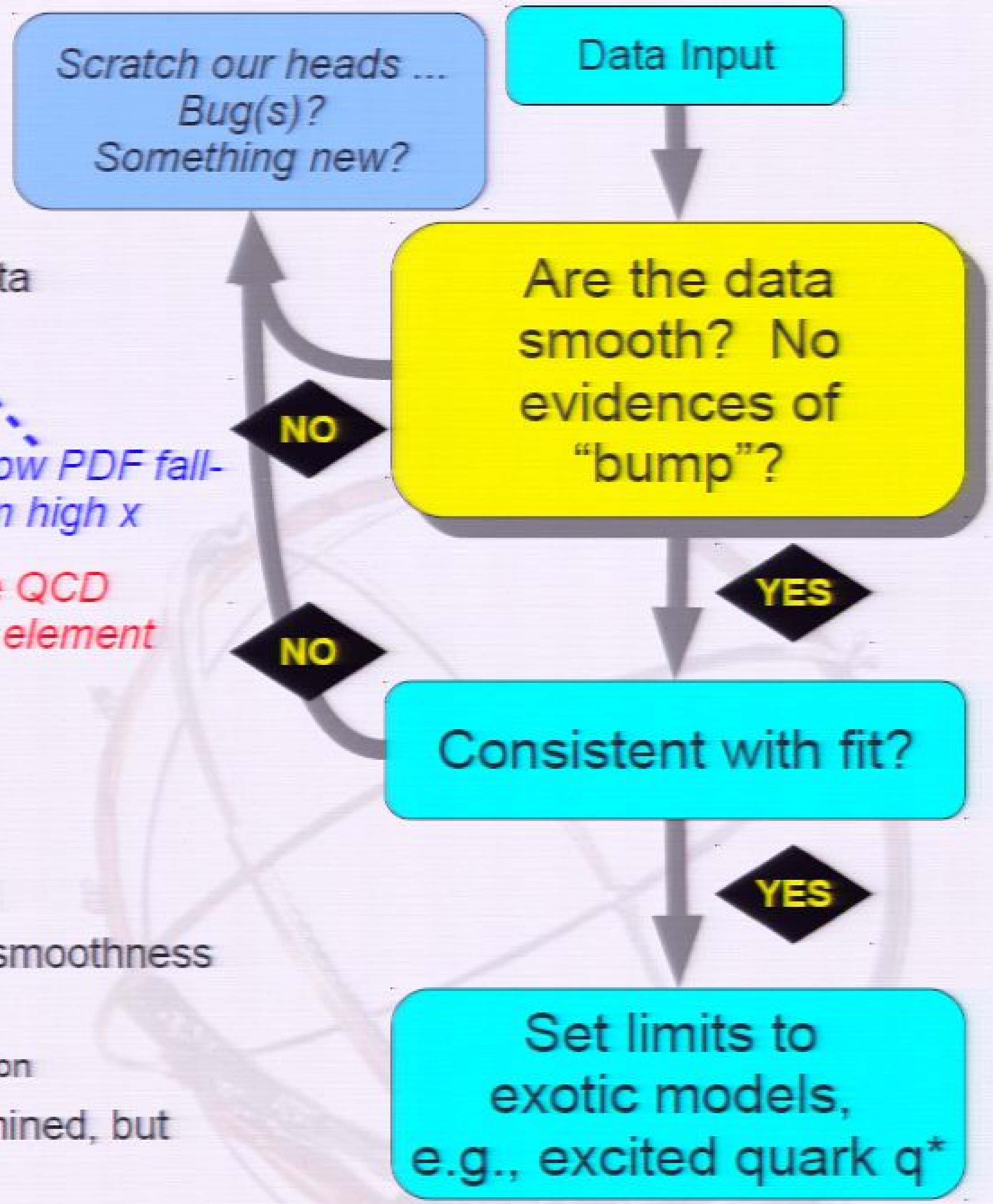
$$f(x) = p_0 \frac{(1-x)^{p_1}}{x^{p_2 + p_3 \ln x}}$$

where $x = m^{jj} / \sqrt{s}$

Follow PDF fall-off in high x

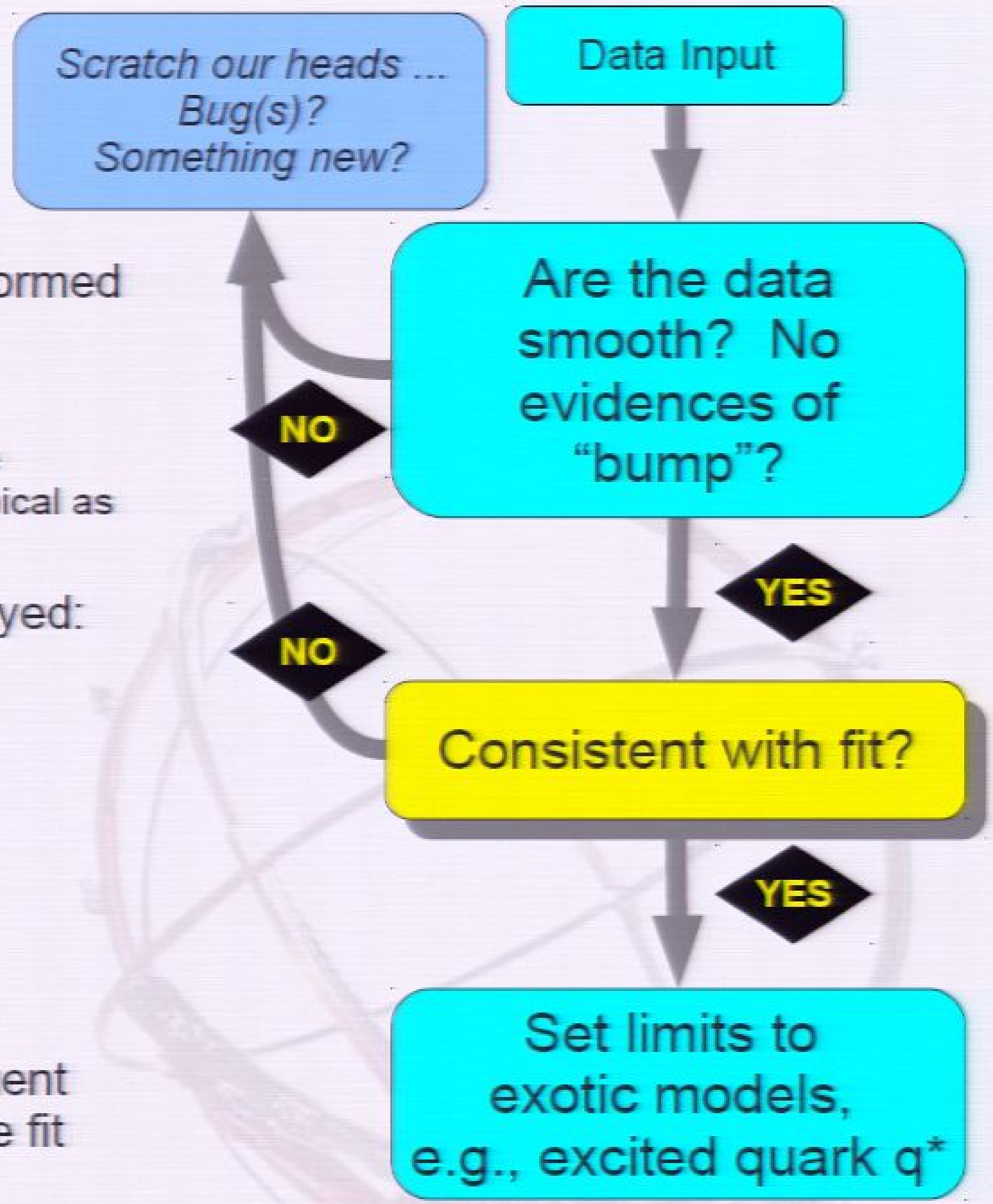
Imitate QCD matrix element

- This function
  - is continuous and differentiable
  - has a monotonic decreasing property
  - fits QCD very well
  - f(1) = 0 by the CM energy constraint
  - Also used in CDF [PRD, 79 (2009) 112002]
- The small value of chi2/ndf reflects the smoothness of the data distribution
  - No bumpy feature shows up in the distribution
- Other alternative forms have been examined, but so far none of them is satisfactory



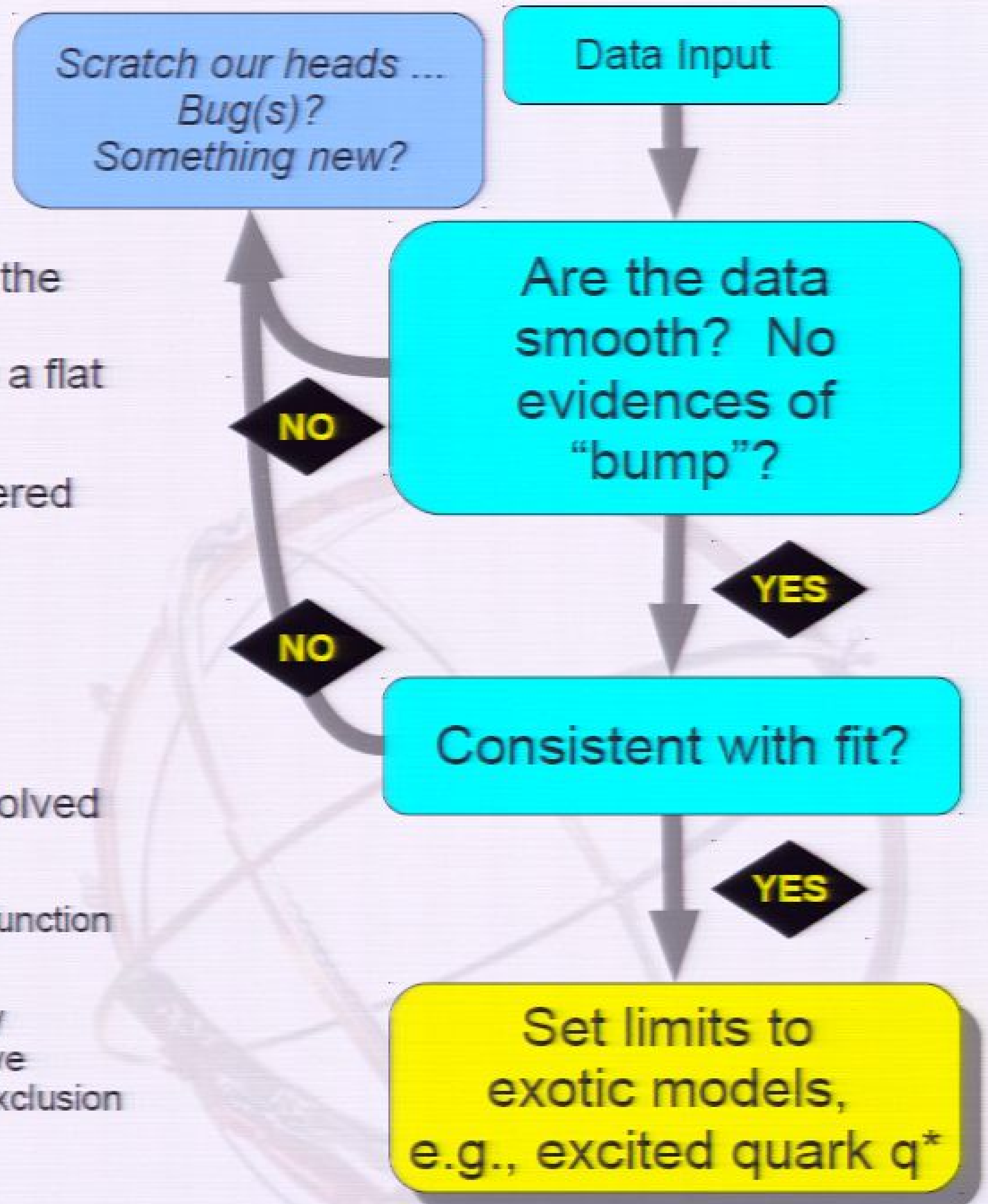
Dijet Resonance:
Consistent with fit?

- Pseudo-experiments are then performed with various statistical tests for goodness-of-fit
  - By measuring statistic of each PE, we examine if the observed data is as typical as any distributions from the PEs
- 6 statistical tests have been employed:
  - Bump Hunter
  - Jeffreys Divergence
  - Kolmogorov-Smirnov
  - - *ln* L
  - Pearson chi^2
  - TailHunter
- Large p-value shows good agreement between the observed data and the fit



Dijet Resonance:
Set Limit

- We take Bayesian approach and find the number of signal event that can be excluded, at 95% credibility level with a flat prior in signal cross section
- The following systematics are considered
  - JES uncertainty (dominant, 6-9%)
  - Fit uncertainty (dominant)
  - Luminosity (11%)
  - JER (negligible)
- These nuisance parameters are convolved in the likelihood calculation
  - We find the excluded signal events as a function of resonance mass
  - The mass limit for each model is found by looking for the crossing between the above curve and the theory curve in the mass exclusion plots

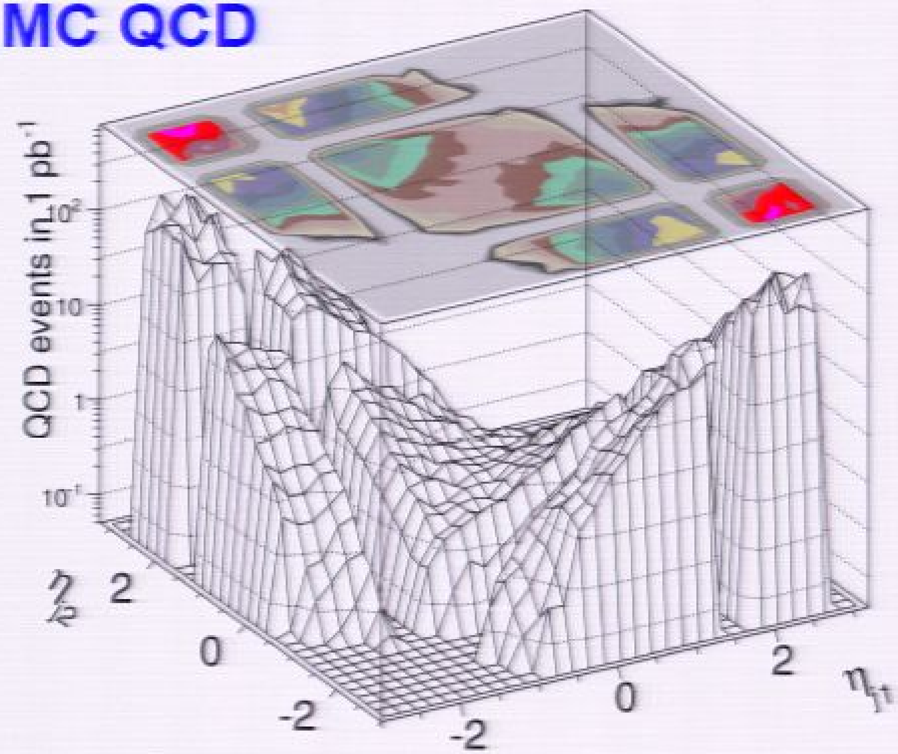


Dijet Resonance:

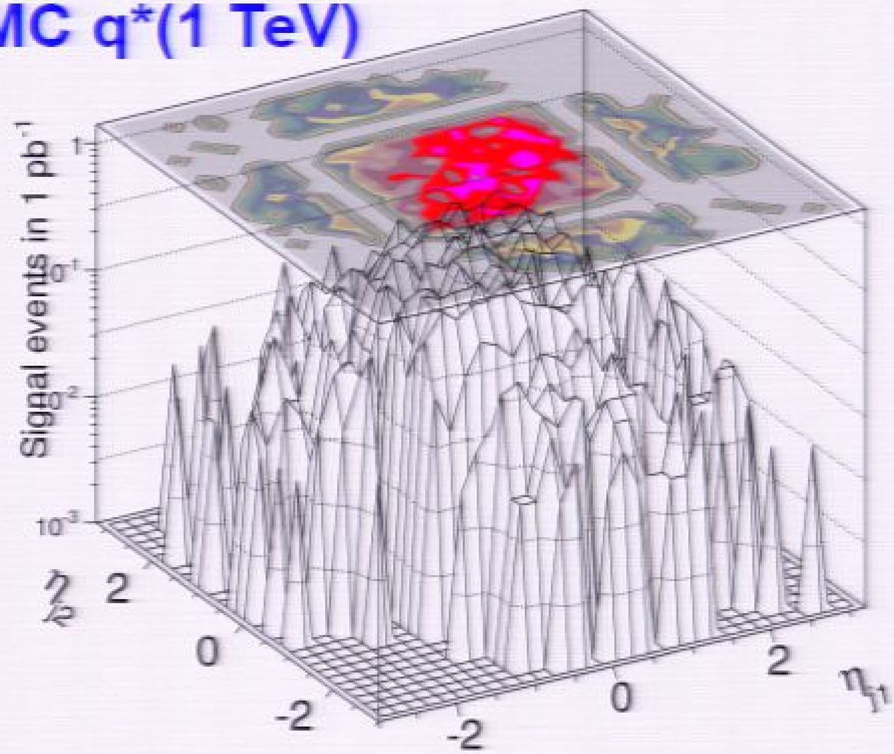
η Optimization with MC

$٨٧٥ < m^{jj} < ١٠٢٠ \, GeV$

MC QCD

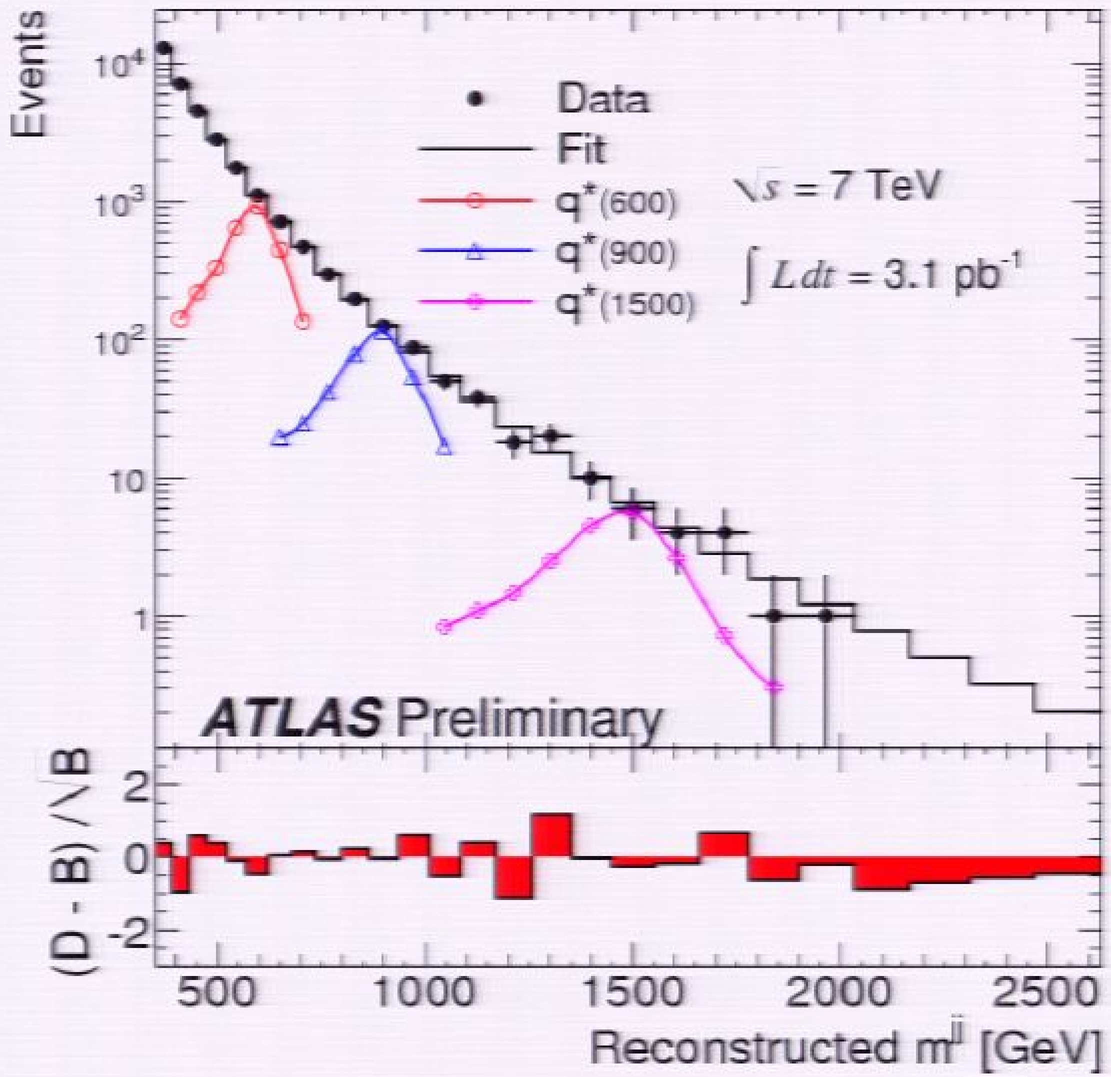


MC q*(1 TeV)



- Select MC events in a specific dijet mass range
- QCD jets are more forward (large $|\Delta\eta|$) while signal jets are more central (small $|\Delta\eta|$)

Dijet Resonance:
Searches with 3.1 pb^{-1}



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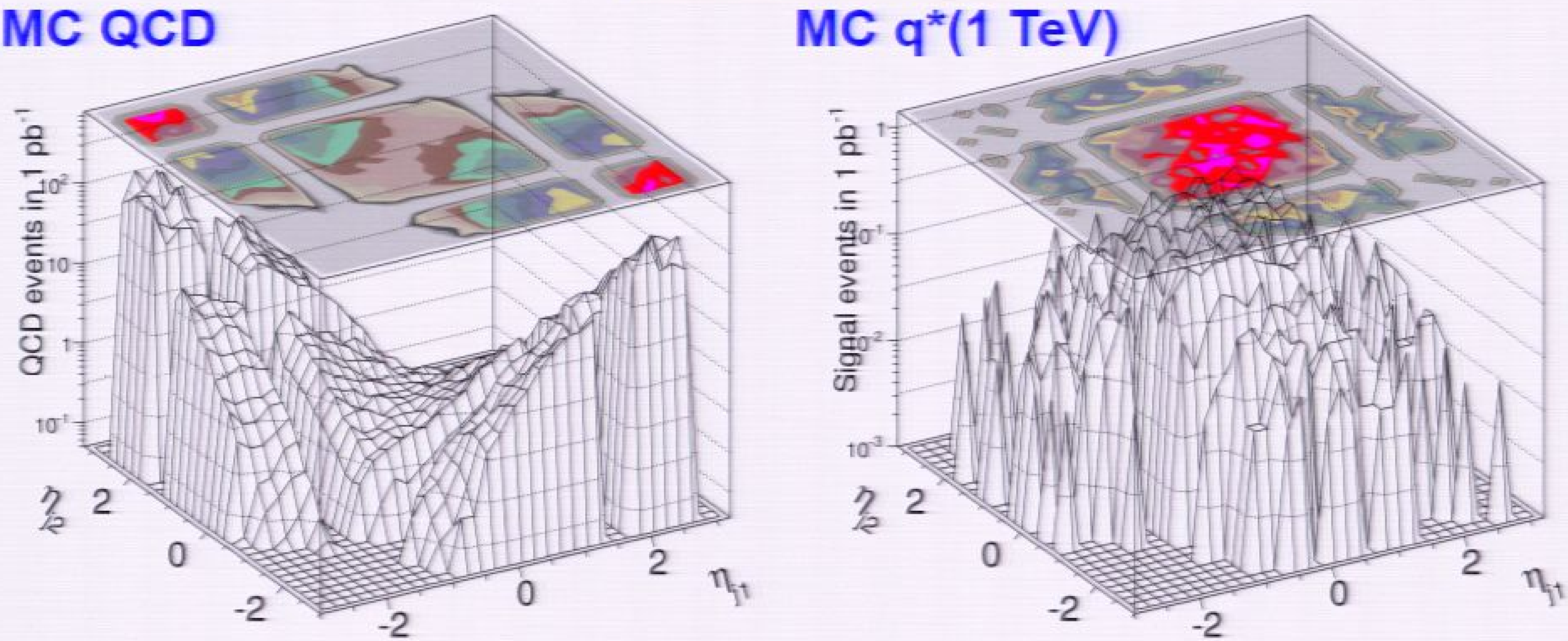

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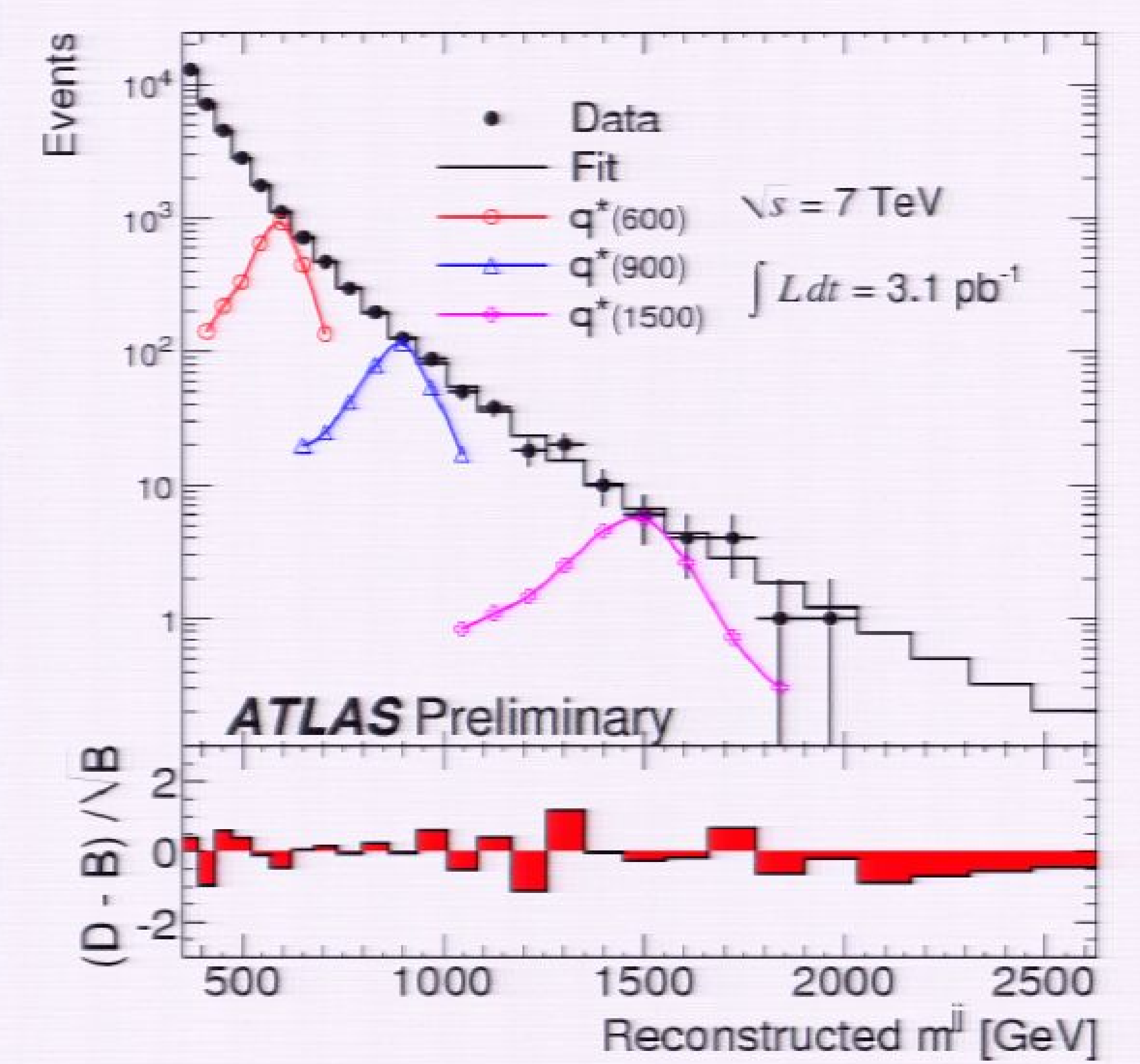
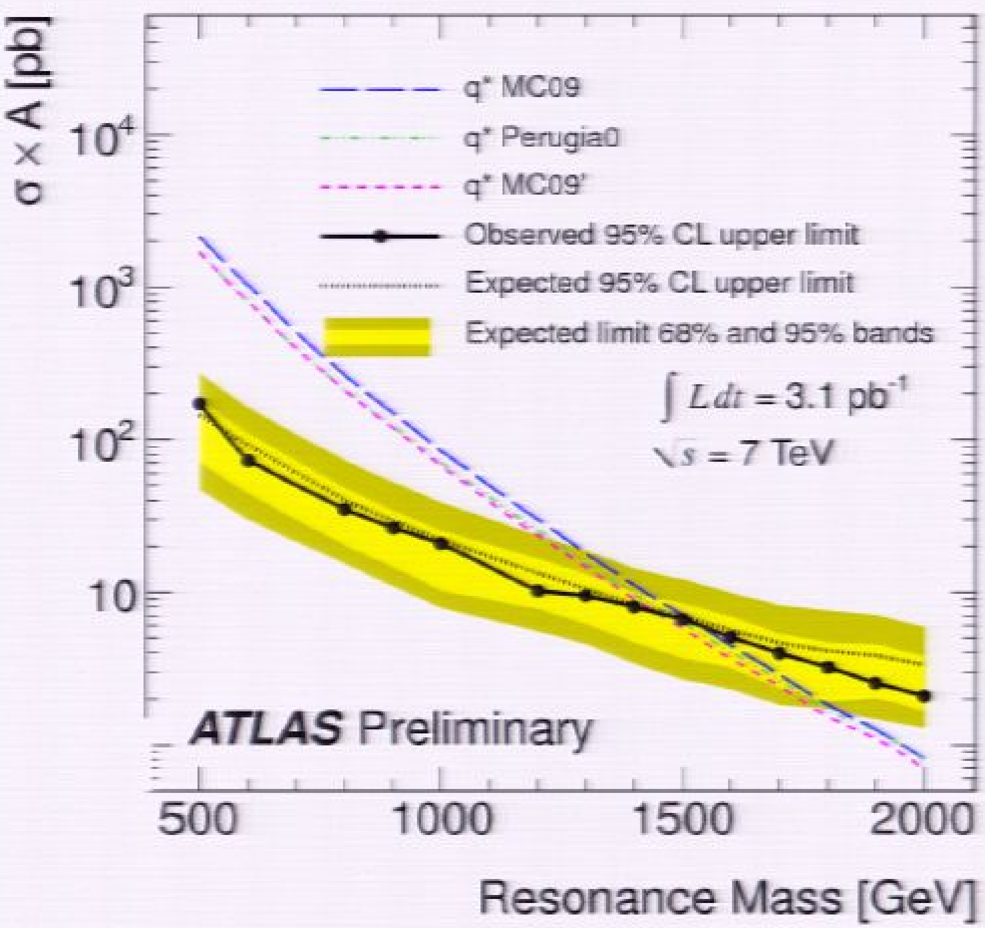


Dijet Resonance:

Limits with 3.1 pb^{-1}

0.30 < m(q*) < 1.26 TeV (MC09)

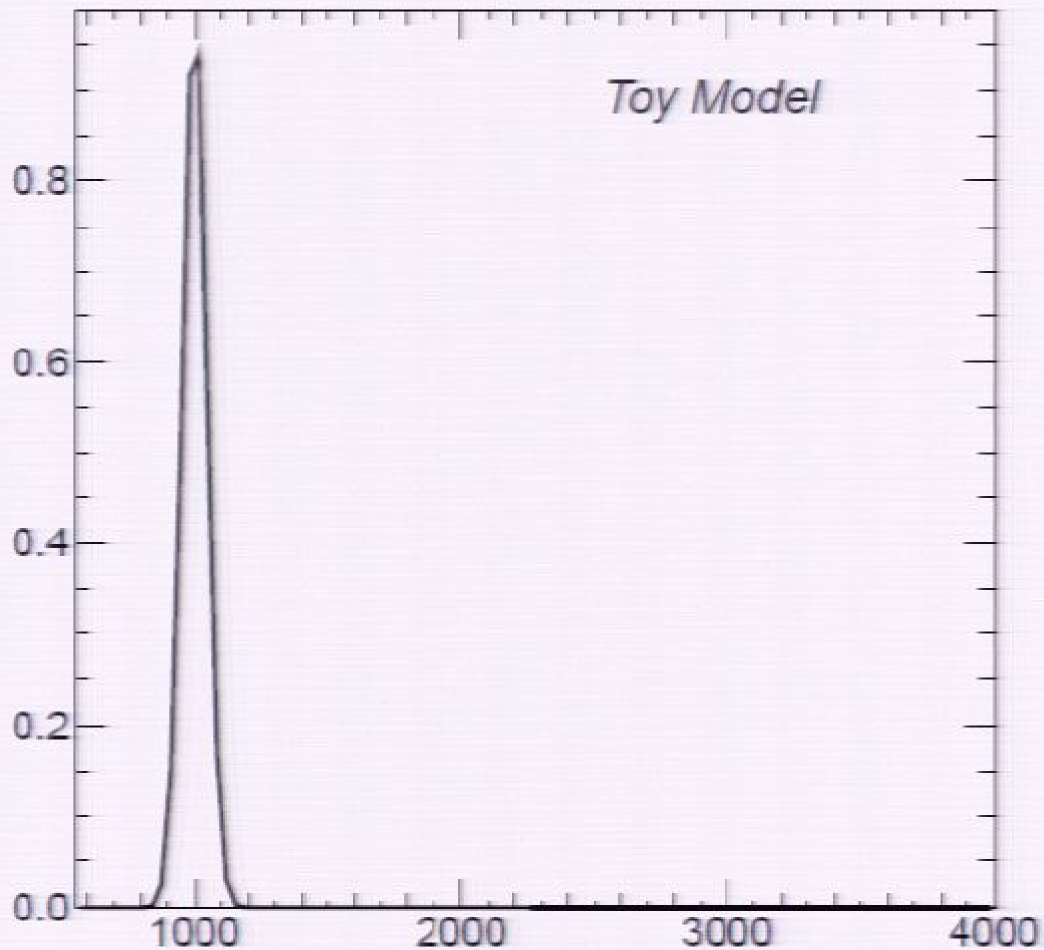


Dijet Resonance:
Model-independent Search

- Establish a way to provide information for theorists given a resonance model with a signal size
  - Build, e.g., a table of

    resonance mass | detector-level width | σ•A upper limit
  - For simplicity, assume Gaussian-shape signal

Dijet Resonance:
Example for m = 1000 GeV and width = 45 GeV



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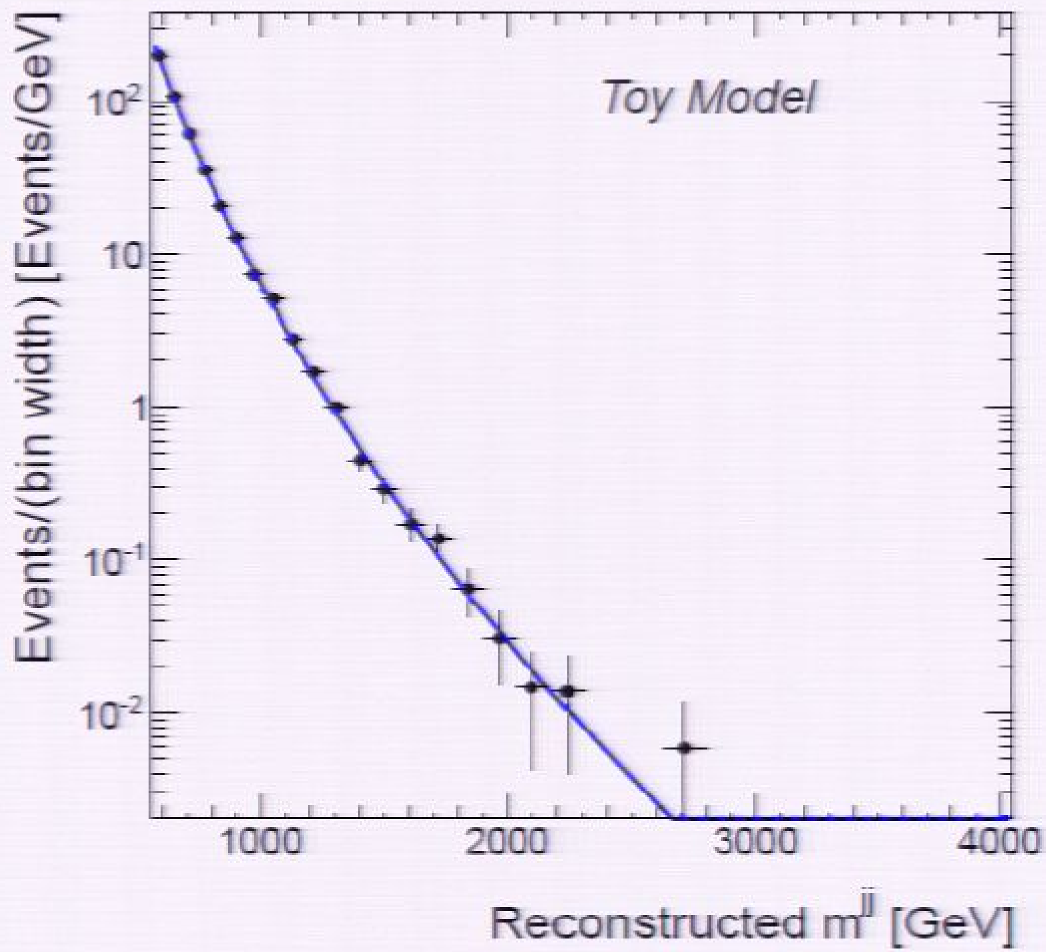

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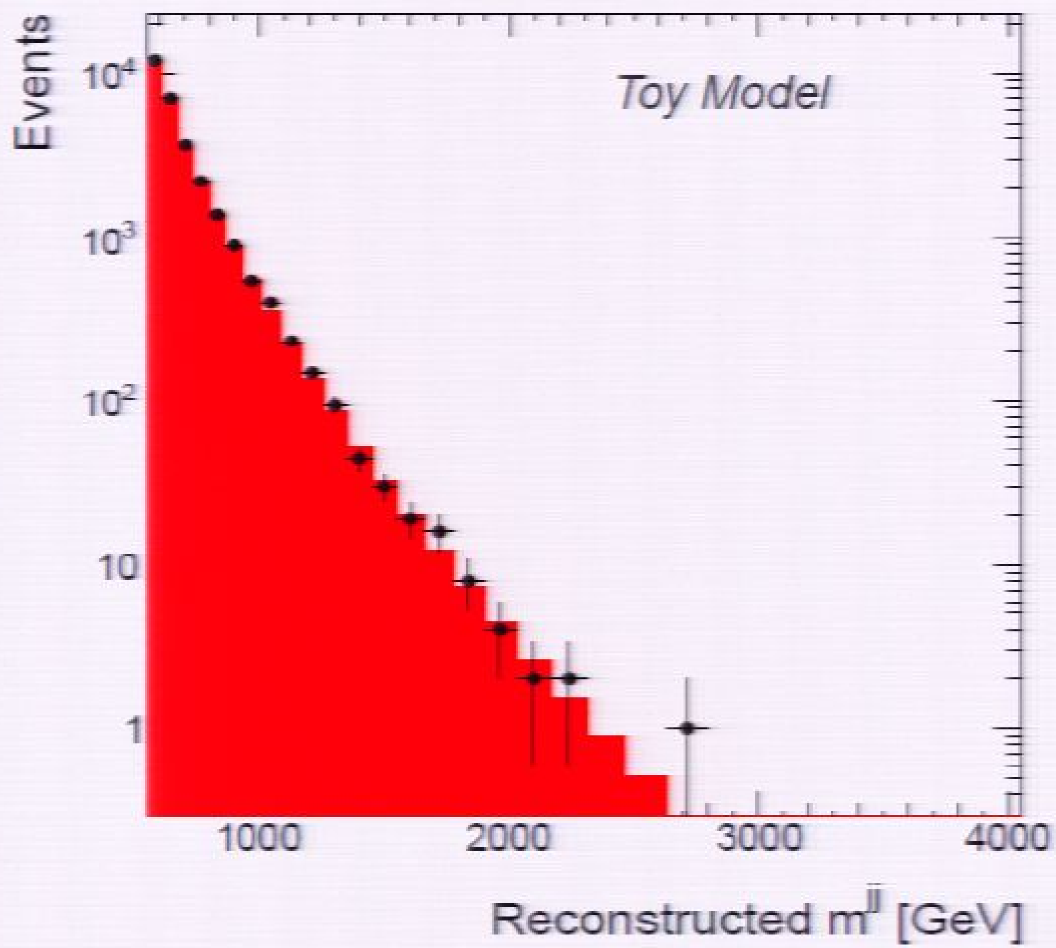

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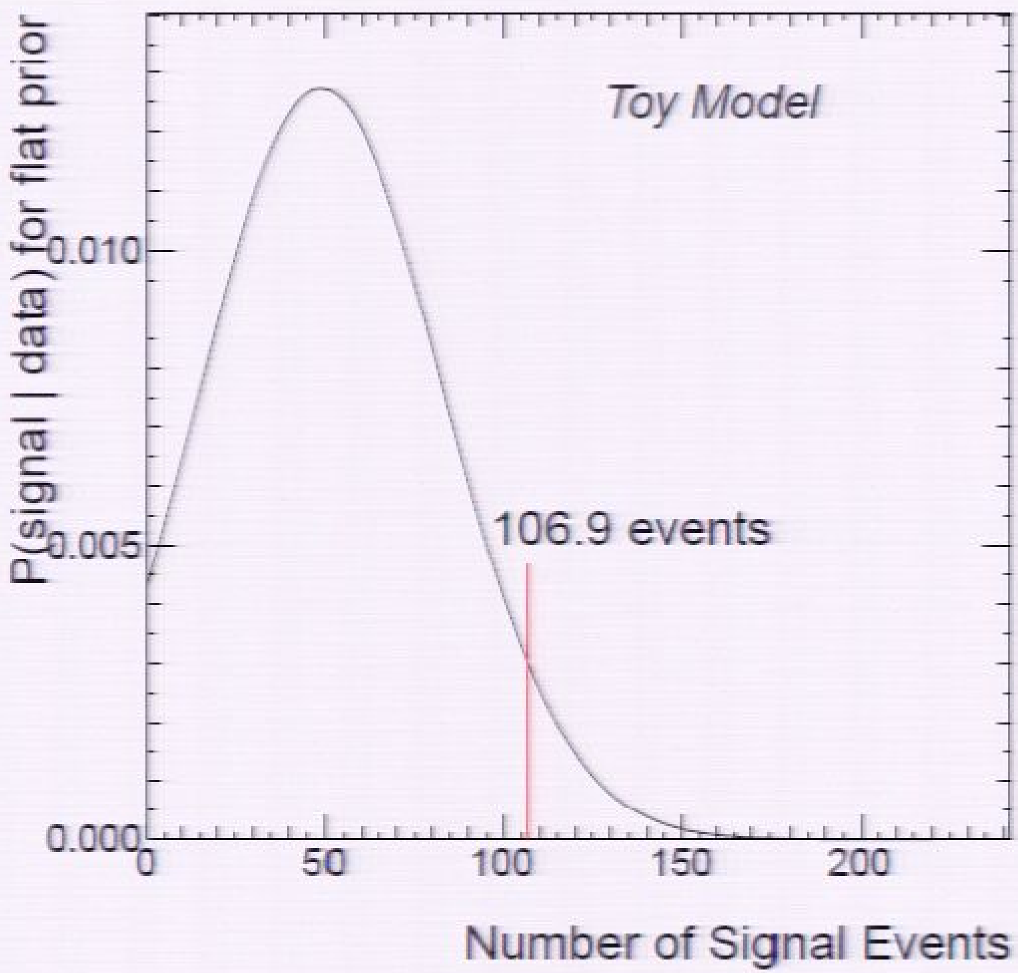
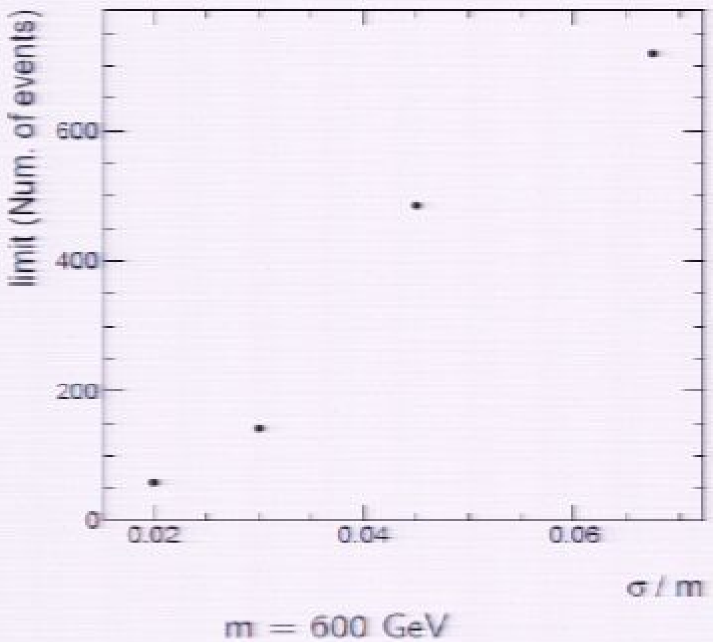
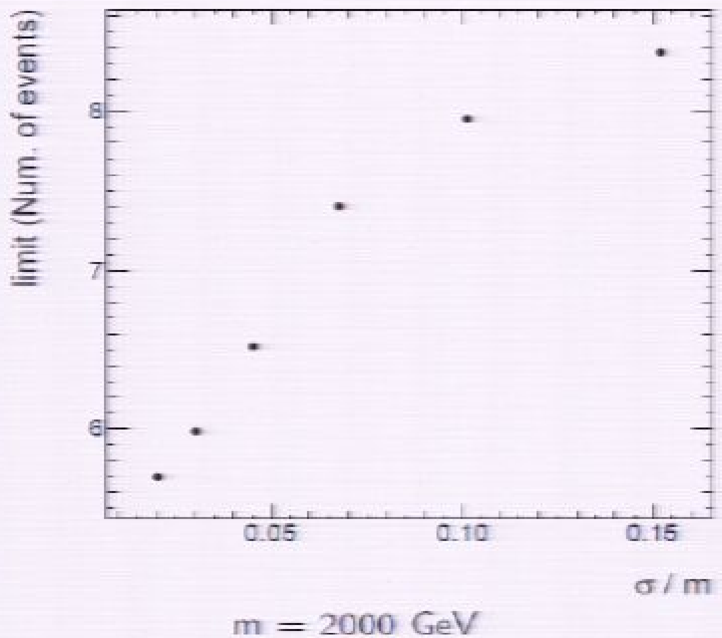


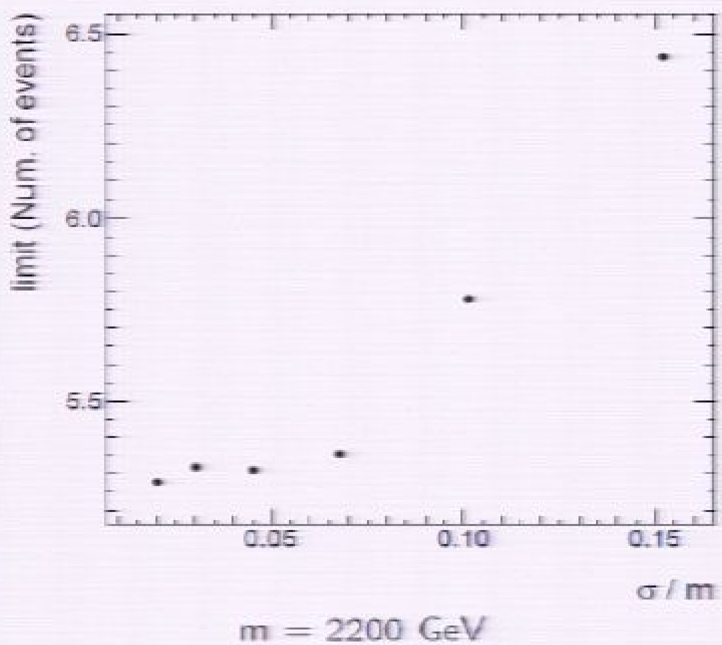
Dijet Resonance:
Table (example)

mass	detector-level width	sigma A upper limit
800	16	52.1191
800	24	52.3828
800	36	53.4375
800	54	53.7158
800	81	50.2368
800	121.5	54.4995
900	18	54.0161
900	27	57.2656
900	40.5	59.2383
900	60.75	61.5552
900	91.125	76.8164
900	136.688	134.058
1000	20	79.7607
1000	30	89.4531
1000	45	106.938
1000	67.5	143.555
1000	101.25	195.85
1000	151.875	278.179
1100	22	67.0947
1100	33	81.25

Dijet Resonance:
Table Plotting







Summary

- We've shown the results with 3.1 pb^{-1} of data
  - The data shows a good agreement with the predictions
  - The current limits are

    0.3 < m(q*) < 1.26 TeV [*0.87 TeV at Tevatron*]
- More results with other exotic models are underway with full 2010 data
- Model-independent search provides useful communication between us (theorists + experimentalists)
  - Statistical fluctuation only
  - What would make this more useful / practical?

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