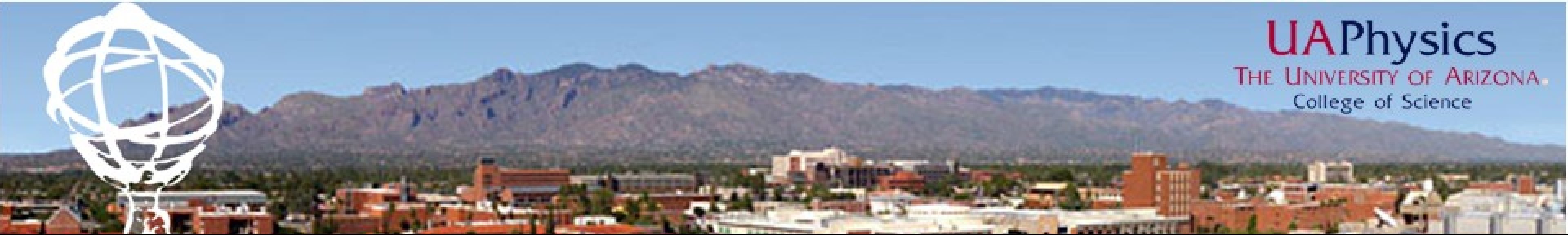


Resonances in Hadronic Channels and Quark Substructure

Frederik Rühr
on behalf of the
ATLAS Collaboration

LPCC Workshop on Higgs and BSM, April 2011, CERN

Introduction

Introduction

Search for new physics in inclusive dijet final states

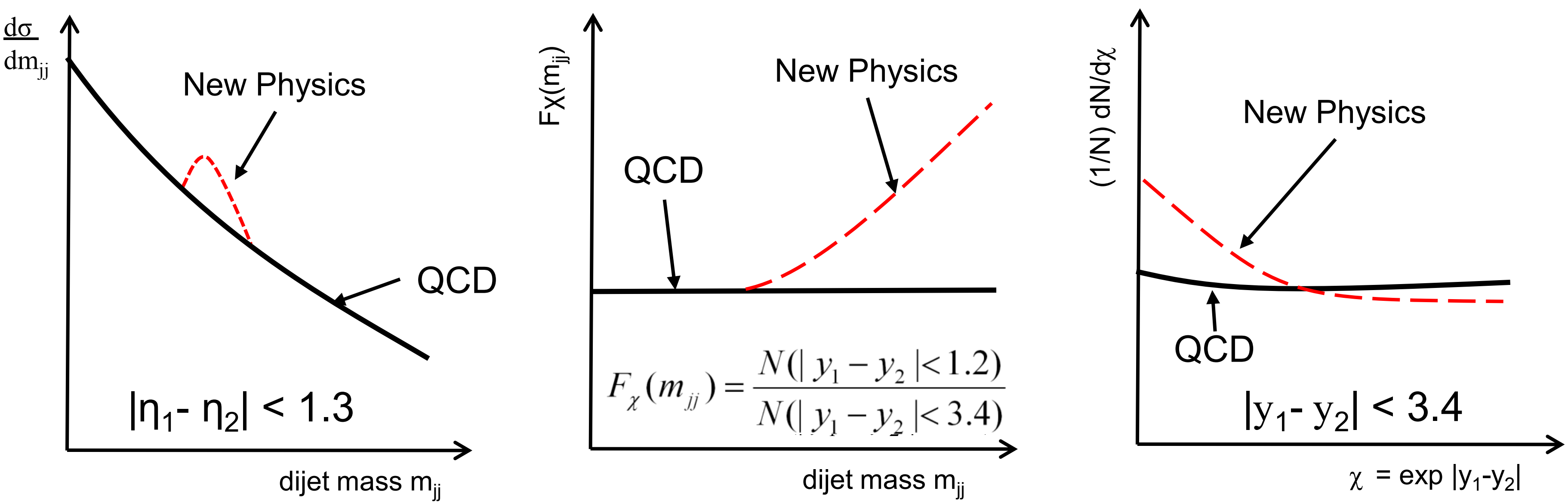
Benchmark hypotheses

- Quark contact interactions (CI)
- Excited quarks (q*)

plus

- Axigluons
- Quantum Black Holes (QBH)*
- Generic Gaussian Model

Three related observables:



Two-dimensional dijet mass/angular distribution space

- Different „slices“ specialized for signal types

* any potential quantum gravitational effect resulting in low multiplicity final states

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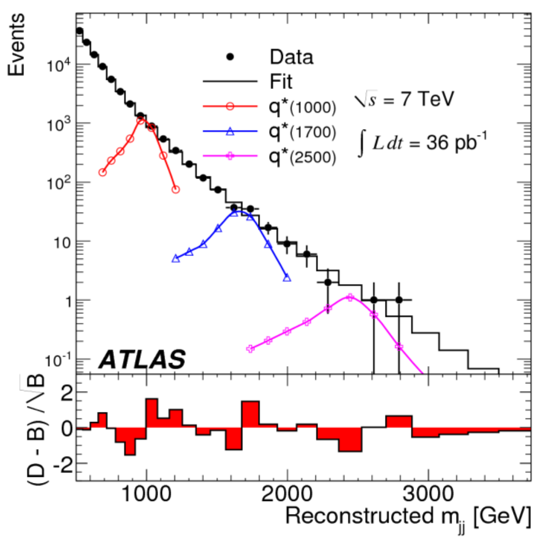
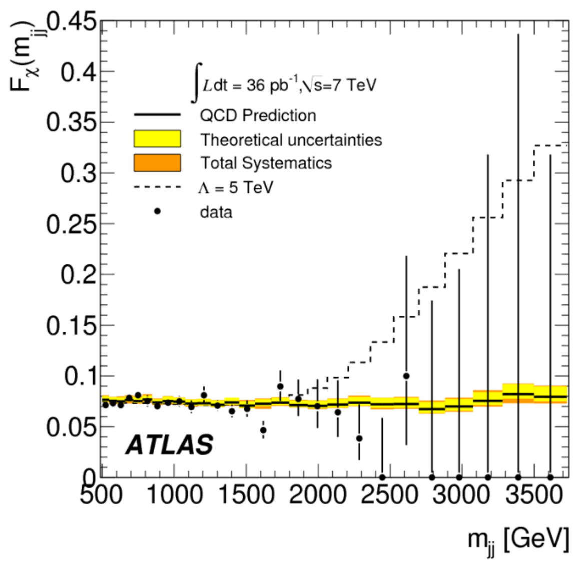
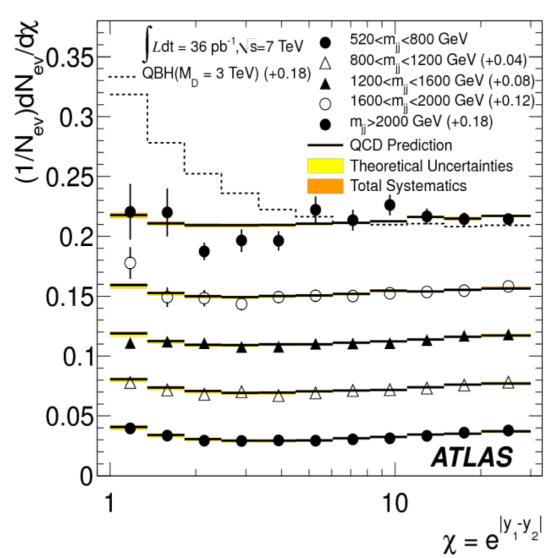






Two-dimensional dijet mass/angular distribution space

- Different „slices“ specialized for signal types

* any potential quantum gravitational effect resulting in low multiplicity final states

Reach of analyses

2010 data:

- High reach in m_{jj}
- Highest dijet mass event passing event selection for searches
  - 3.5 TeV

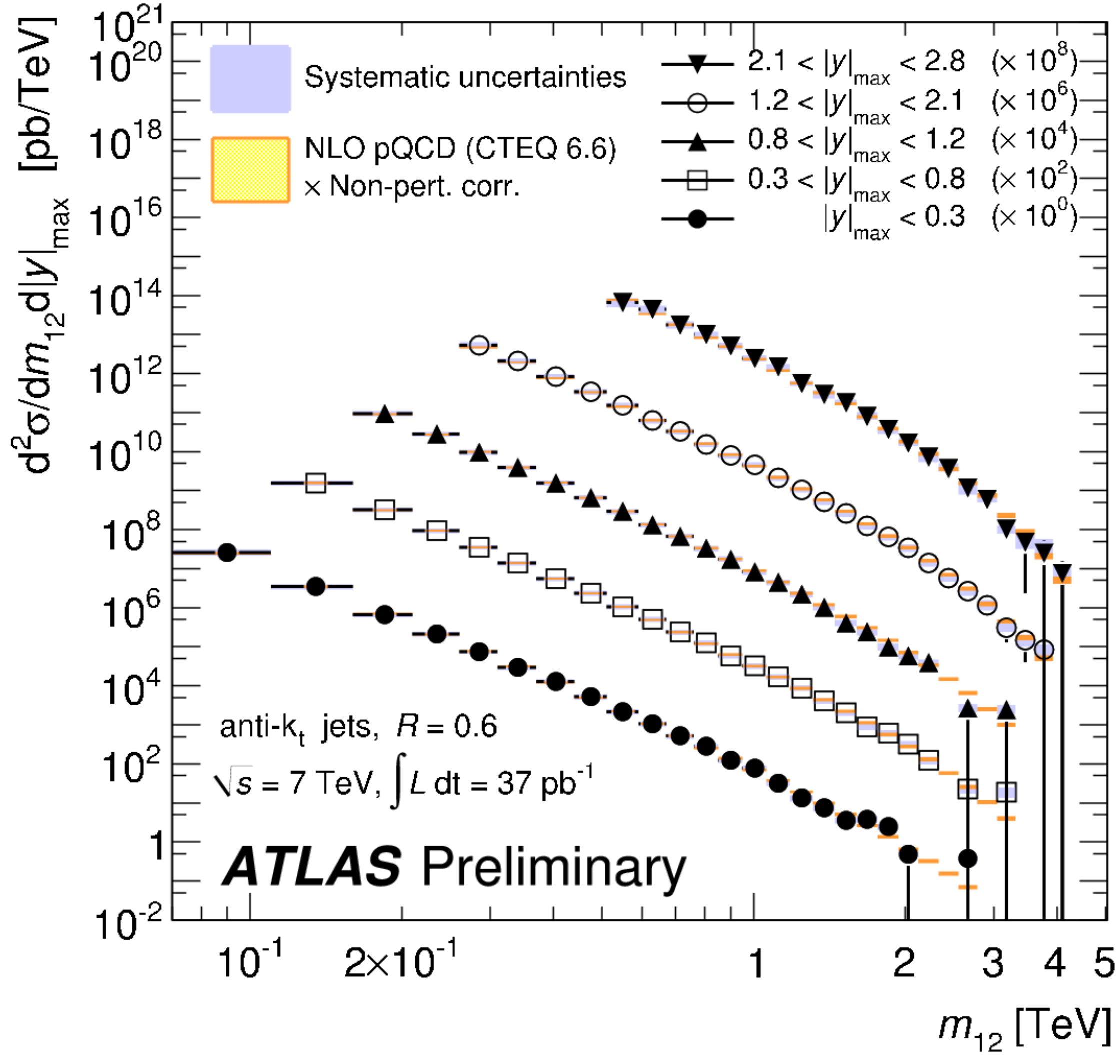
There could have been surprises

- Dijet cross-section in agreement with QCD prediction over many orders of magnitude

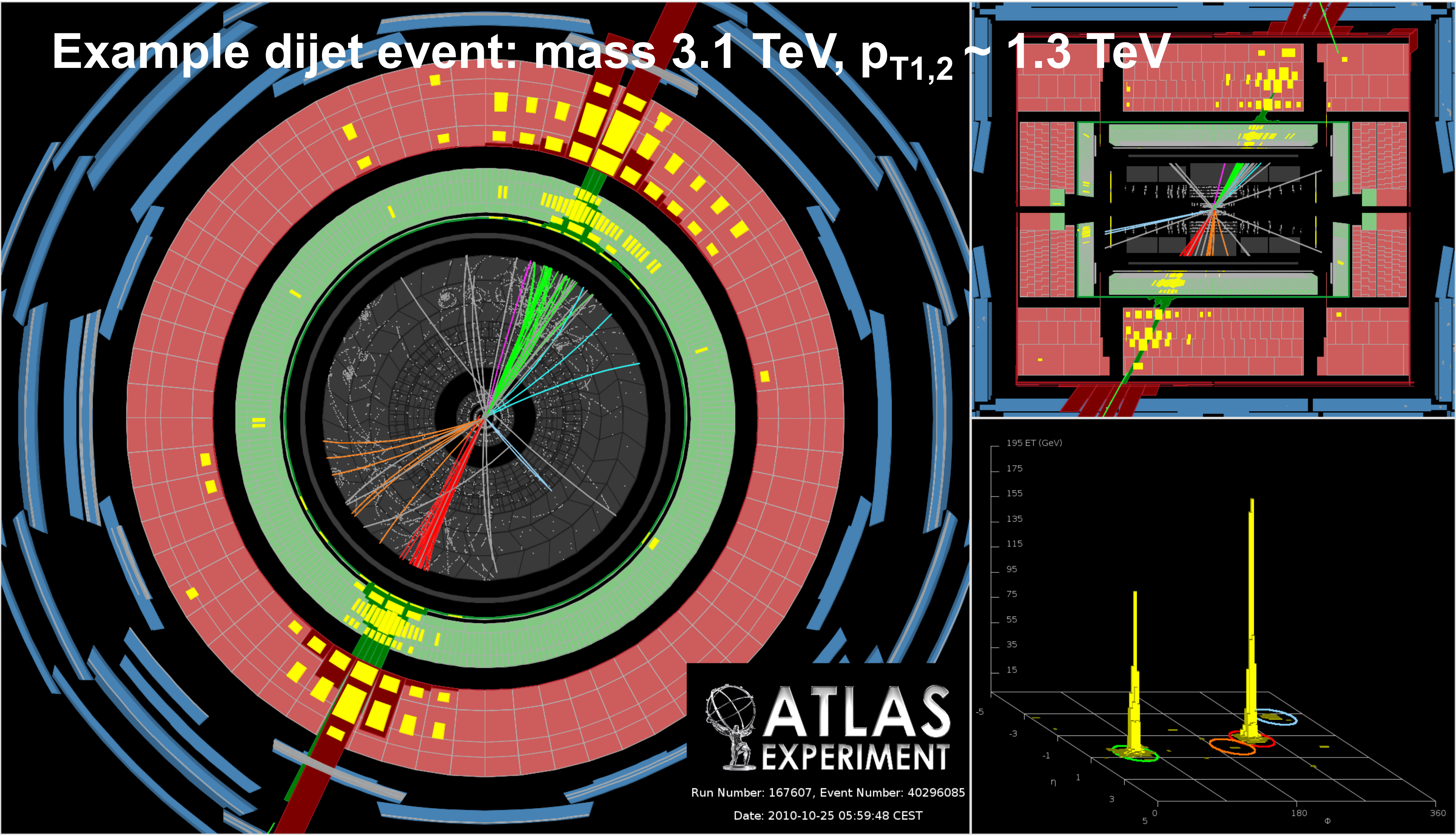
- **All searches (more sensitive)**
  - negative result

Limit setting

(ATLAS-CONF-2011-047)



Dijet Event Display



Dijet Resonance Search

Dijet Resonance Search

(arXiv:1103.3864v1 [hep-ex])

Is there a bump in m_{jj}?

- Potential signal enhanced by event selection on
  - $|\eta_1-\eta_2|<1.3$
- Background estimated by fitting uncorrected data with

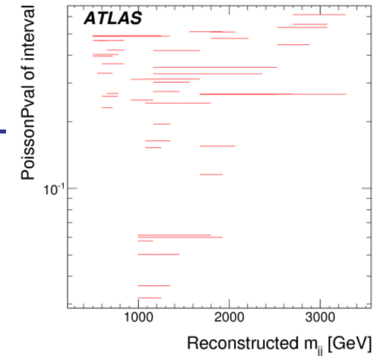
$$f(x) = p_0 \frac{(1-x)^{p_1}}{x^{p_2+p_3 \ln x}}, \quad x \equiv \frac{m^{jj}}{\sqrt{s}}.$$

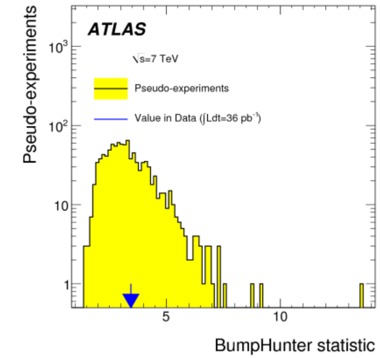
  - Fully data driven

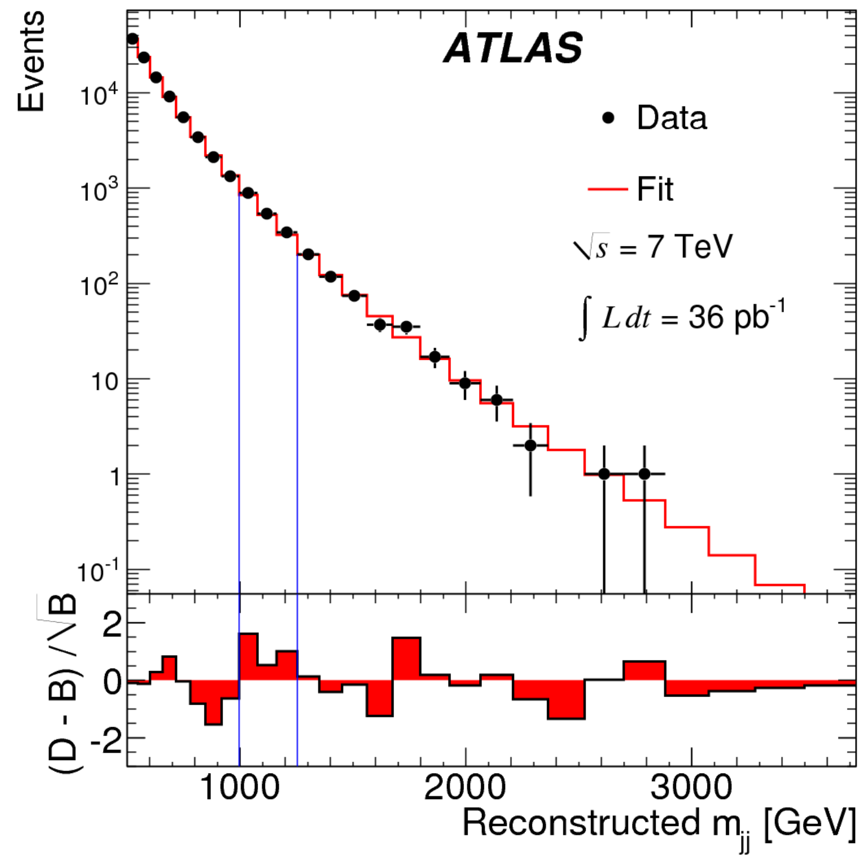
Model independent search phase

- p-value based on BumpHunter statistic
- How significant is the statistically most significant feature?
  - Bump at 995-1253 GeV
  - p-value = 39%

➡ **No new physics**







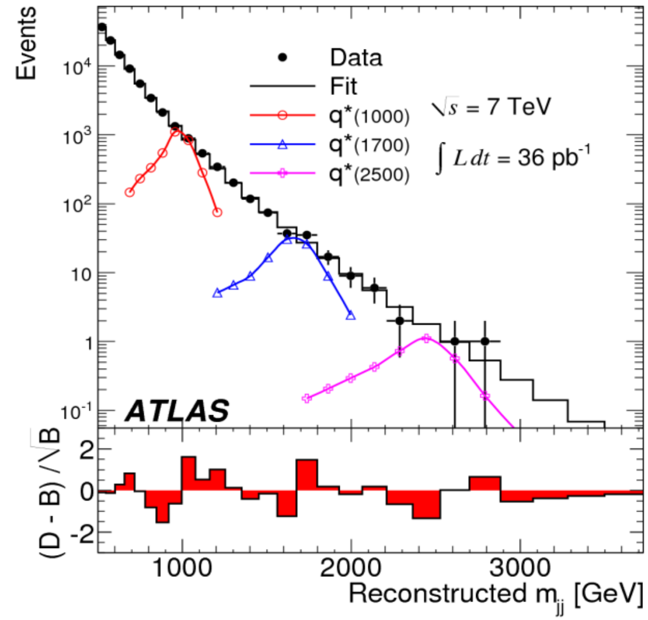
Dijet Resonance Limits

Benchmark hypothesis: excited quarks

- Spin ½, quark like couplings
- Compositeness scale set to mass of q*

Observed Bayesian* limit at 95% C.L. (expected)

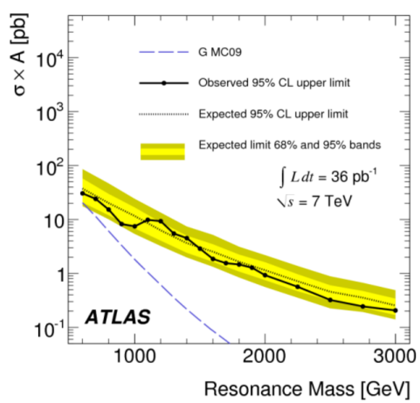
- **0.60 TeV < m_{q^*} < 2.15 TeV (2.07 TeV)**



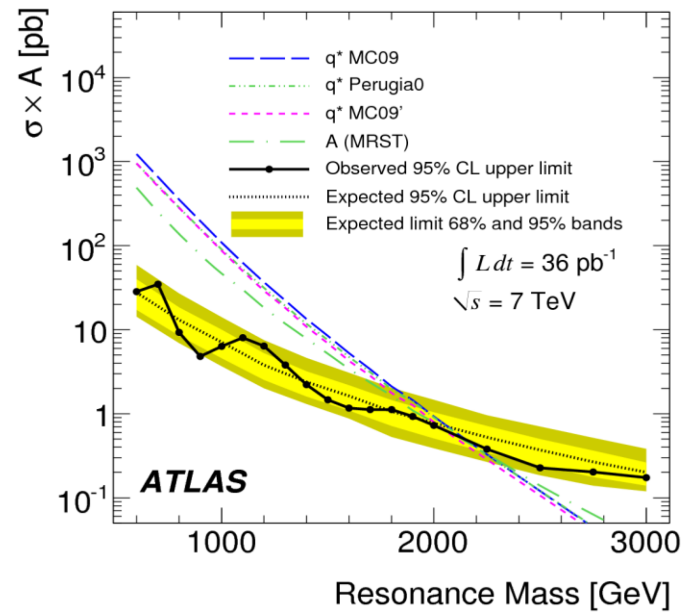
Additional new physics hypotheses

- Axigluons 0.60 < m < 2.10 TeV (2.01 TeV)
- QBH 0.75 < M_D < 3.67 TeV (3.64 TeV)

(e.g. n = 6)**



- RS Graviton:
  - σ x A limits
  - No exclusion



*Prior constant in signal strength

** n = number of spatial extra dimensions in the ADD scenario

Simplified Gaussian Model

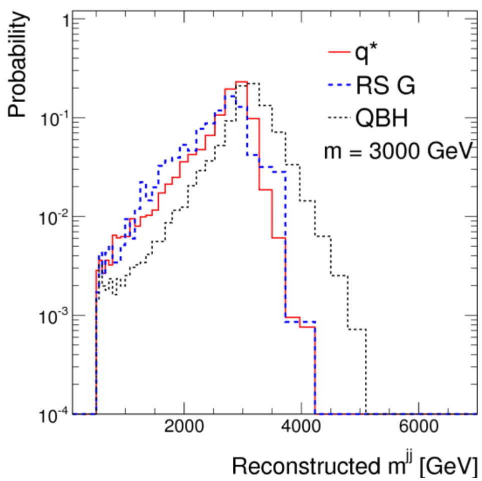
(arXiv:1103.3864v1 [hep-ex])

Goal:

- More model independent results
- Allow setting of limits on additional models not explicitly considered

Simplified Gaussian Model

- Resonance signal shape approximated by Gaussian
  - Within a 20% mass window around the peak
- Limits on event yield in $36pb^{-1}$, at 95% C.L.
  - Include all experimental uncertainties



	σ/m				
Mean m (GeV)	0.03	0.05	0.07	0.10	0.15
600	434	638	849	1300	1990
700	409	530	789	1092	945
800	173	194	198	218	231
900	88	103	123	162	311
1000	147	179	210	278	391
1100	143	169	204	263	342
1200	91	120	168	223	262
1300	65	80	101	120	122
1400	35	42	50	57	66
1500	24	27	32	40	60
1600	21	25	29	36	49
1700	26	27	28	38	43
1800	25	26	30	32	34
1900	22	22	25	25	26
2000	13	16	19	19	17
2100	10	12	14	16	17
2200	8.4	9.4	11	10	11
2300	6.8	7.3	7.4	8.3	9.0
2400	4.9	5.2	6.1	6.6	8.0
2500	4.6	4.9	5.4	6.4	6.9
2600	4.9	5.0	5.3	6.0	6.6
2700	5.1	5.0	5.0	5.2	5.7
2800	5.0	5.0	4.9	5.0	5.2
2900	4.6	4.5	4.7	4.6	4.8
3000	4.1	4.2	4.3	4.5	4.7
3200	3.2	3.5	3.6	3.8	4.1
3400	3.1	3.1	3.2	3.5	3.7
3600	3.1	3.1	3.1	3.3	3.6
3800	3.1	3.1	3.1	3.2	3.3
4000	3.1	3.1	3.1	3.1	3.3

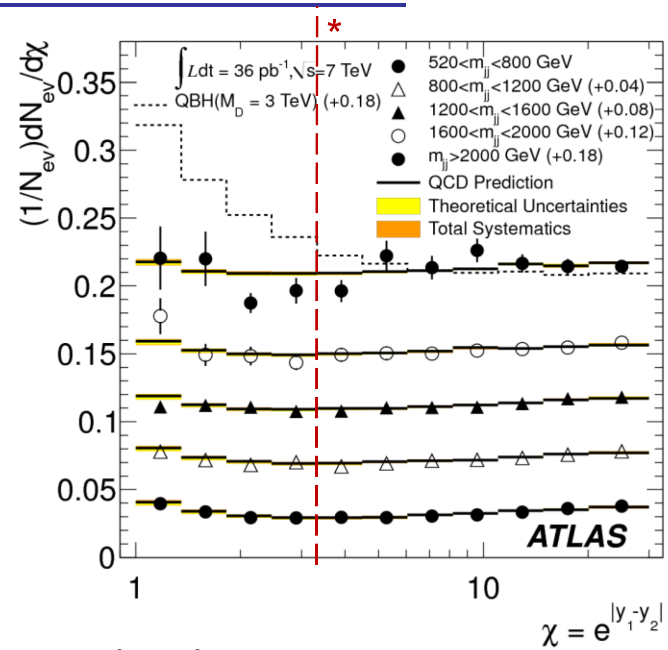
Angular Distributions

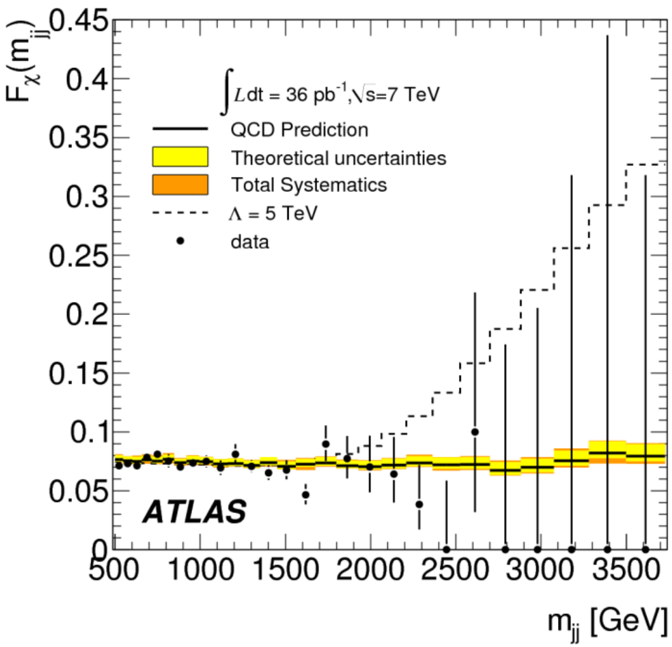
Dijet Angular Distributions

(arXiv:1103.3864v1 [hep-ex])

Two observables

- χ-spectra
  - finely grained in angular space
  - Single mass bin $m_{jj} > 2$ TeV
- $F_{\chi}(m_{jj})$
  - finely grained in dijet mass
  - Simple ratio (left of line* to total) in angular variable χ





Background estimate

- QCD Monte Carlo prediction including detector simulation and NLO k-factors

Search phase:

p-values with Likelihoods as statistic

- χ-spectra (low to high mass):
  - 0.44, 0.33, 0.64, 0.89 and 0.44
- $F_{\chi}(m_{jj})$ (bins with $m_{jj}>1.3$ TeV): 0.28

No new physics

Angular Distributions - Limits

Observable: F_χ

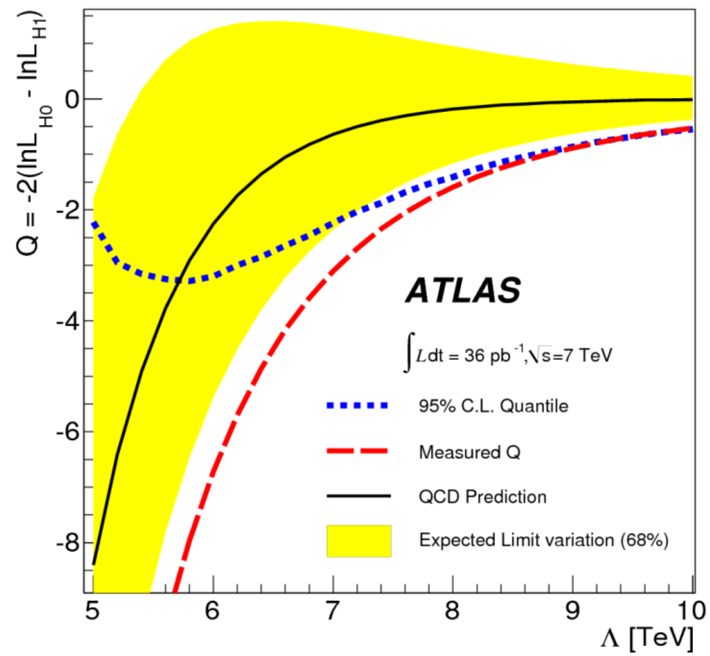
- Match approach to signal hypothesis

Benchmark hypothesis: **quark contact interactions**

- Effective Lagrangian

$$\mathcal{L}_{qqqq}(\Lambda) = \frac{\eta g^2}{2(\Lambda^{+}_{LL})^2_q}\bar{\Psi}^L_q\gamma^\mu\Psi^L_q\bar{\Psi}^L_q\gamma^\mu\Psi^L_q$$

- m_{jj} dependency of F_χ well described
- Signal extends to low masses
- **Finely binned $F_\chi(m_{jj})$**



(arXiv:1103.3864v1 [hep-ex])

Limit setting approach

- Frequentist CL_{s+b}, using "LEP" Likelihood ratio Q= -2 (lnL(H0) – lnL(H1))
- Lowest value of Λ compatible with data (expected):
  - **9.5 TeV** **(5.7 TeV)** – power of the test at observed limit = 8%

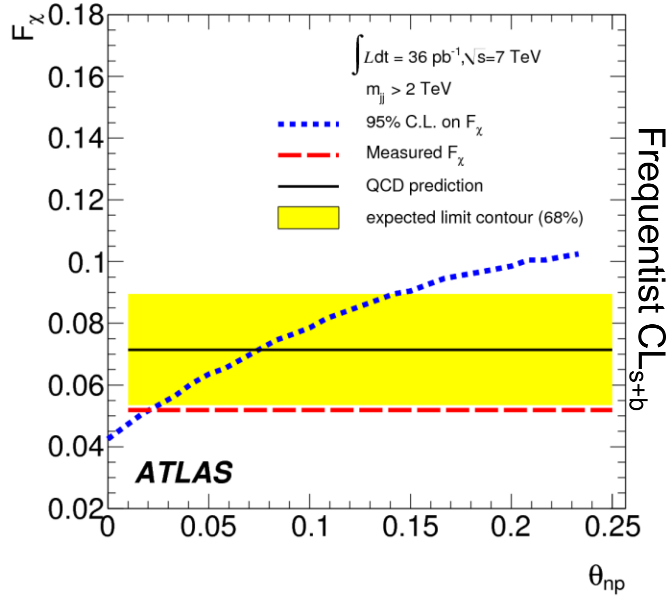
- Comparison of observed CL_{s+b} to e.g. CL_s not straightforward
- Bayesian result: 6.7 TeV (5.7 TeV)

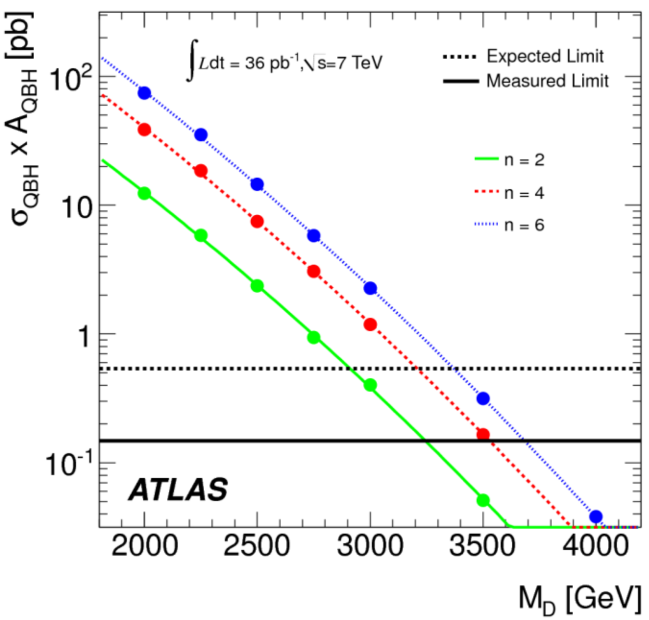
Angular Distributions - Limits

(arXiv:1103.3864v1 [hep-ex])

Quantum Black Holes decaying to two-particle final states

- Simple phenomenological signature using BlackMax generator
  - m_{jj} dependency above production threshold potentially not reliable
  - No signal below threshold
- F_χ with single mass bin of m_{jj} > 2 TeV
  - Less model dependent





Lower limits on production threshold (expected)

- N = x spatial extra dimensions
  - **2:** **3.26 TeV** (2.91 TeV)
  - **4:** **3.53 TeV** (3.20 TeV)
  - **6:** **3.69 TeV** (3.37 TeV)
- Production cross-section depends on model assumptions
  - Results also include generic limits on σ_{QBH} x A_{QBH} and predicted F_χ

Summary and Conclusions

Bayesian B
Frequentist CL_{s+b} F

Model and Analysis Strategy	95% C.L. Limits (TeV) Expected	Observed	
Excited Quark q^*			
Resonance in m_{jj}	2.07	2.15	B
$F_\chi(m_{jj})$	**2.12**	**2.64**	F
Randall-Meade Quantum Black Hole for $n = 6$			
Resonance in m_{jj}	**3.64**	**3.67**	B
$F_\chi(m_{jj})$	3.49	3.78	F
θ_{np} Parameter for $m_{jj} > 2$ TeV	3.37	3.69	F
11-bin χ Distribution for $m_{jj} > 2$ TeV	3.36	3.49	F
Axigluon			
Resonance in m_{jj}	**2.01**	**2.10**	B
Contact Interaction Λ			
$F_\chi(m_{jj})$	**5.7**	**9.5**	F
F_χ for $m_{jj} > 2$ TeV	5.2	6.8	F
11-bin χ Distribution for $m_{jj} > 2$ TeV	5.4	6.6	F
$F_\chi(m_{jj})$ Bayesian	5.7	6.7	B

- **The LHC has performed amazingly well in 2010**
  - many Tevatron results superseded
  - **We are well into uncharted territory**
- **Several ATLAS analyses have been performed to search for new physics in dijet final states**
  - No evidence for new physics yet
  - Most stringent limits to date were set on a number of models
  - Benchmarks, at 95% C.L. (expected:
    - **m(q*) > 2.64 TeV** (2.12 TeV) **Λ > 9.5 TeV** (5.7 TeV) **(CL_{s+b})**
  - Generic Gaussian Model: Limits on signal yield in $36pb^{-1}$ of down to 3.1 events (depending on resonance mass and width)
- 2011 data expected to quickly supersede 2010 results, leaving ample space for discoveries

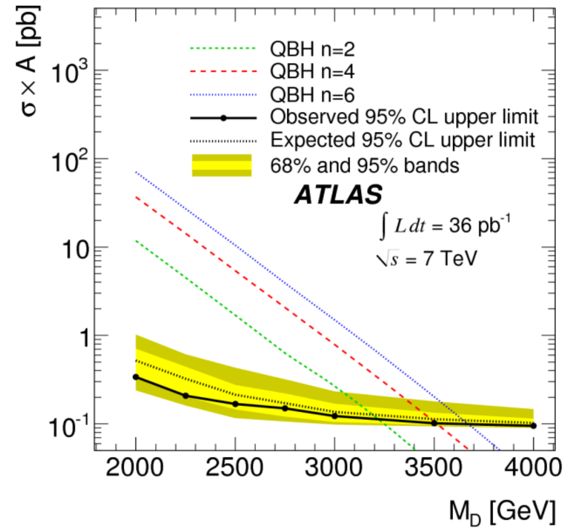
Thanks for your attention!

Backup

QBH in the resonance search

Limits on MD

- Signal: Threshold effect
  - Sharp enough rise in MC prediction for resonance analysis to be viable
- Bayesian
- Slightly more sensitive than slide 14, but depends on exact modelling of $d\sigma/dm_{jj}$ by MC generator



(arXiv:1103.3864v1 [hep-ex])

TABLE II. The 95% C.L. lower limits on the allowed quantum gravity scale for various numbers of extra dimensions.

Number of Extra Dimensions	Observed M_D Limit [TeV] Stat. ⊕ Syst.	Observed M_D Limit [TeV] Stat. only	Expected M_D Limit [TeV] Stat. ⊕ Syst.	Expected M_D Limit [TeV] Stat. only
2	3.20	3.22	3.18	3.20
3	3.38	3.39	3.35	3.37
4	3.51	3.52	3.48	3.50
5	3.60	3.61	3.58	3.59
6	3.67	3.68	3.64	3.66
7	3.73	3.74	3.71	3.72

q* in Dijet Angular Distributions

(arXiv:1103.3864v1 [hep-ex])

Limits on q* star mass from $F_\chi(m_{jj})$

- Signal: Bump
- Frequentist CL_{s+b}
- 95% C.L. observed (expected) limit:
  - **m(q*) > 2.64 TeV** (2.12 TeV)
- High observed limit due to downward fluctuation of F_χ in data around 2.5 TeV