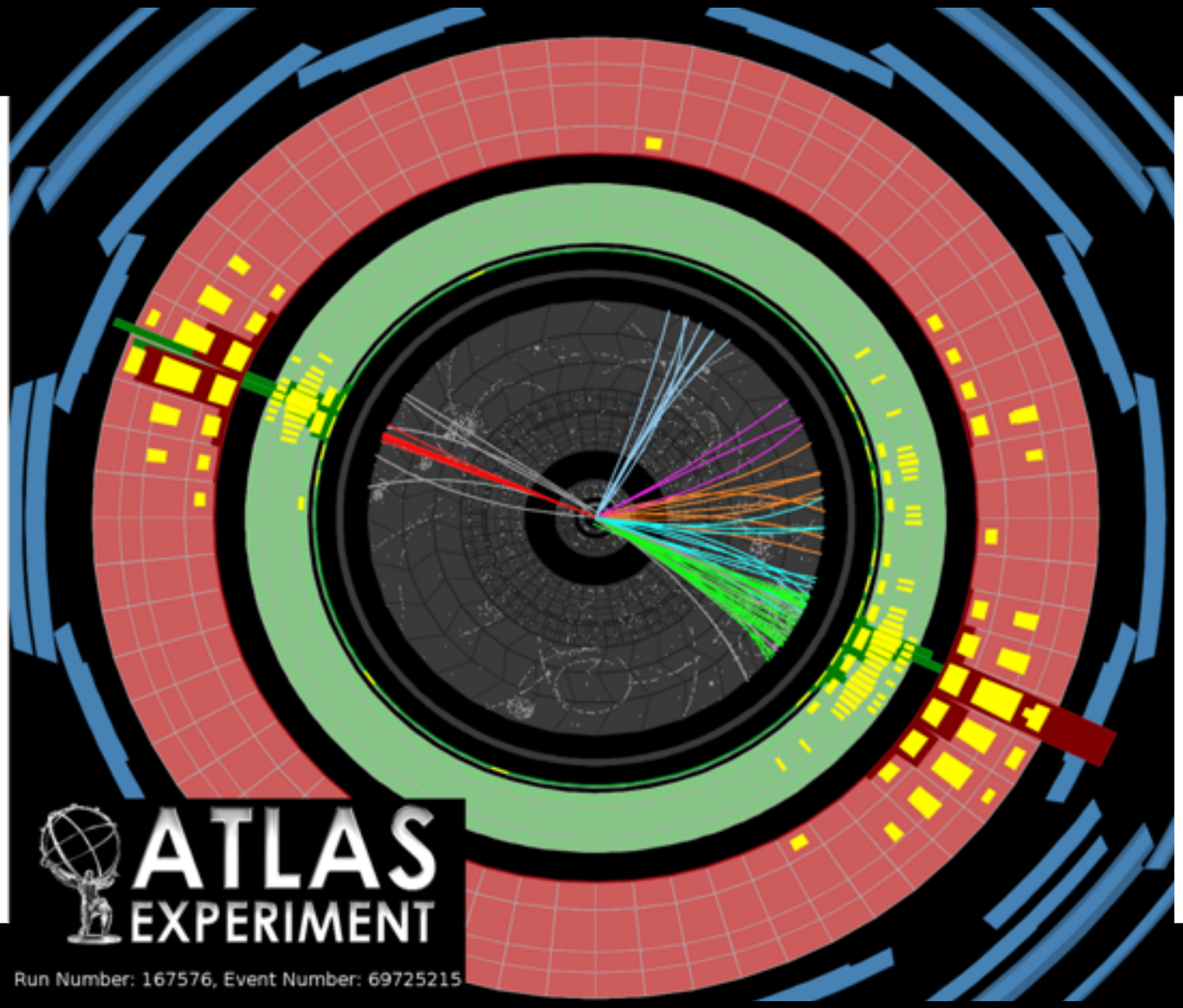
Results from the ATLAS Exotics Group



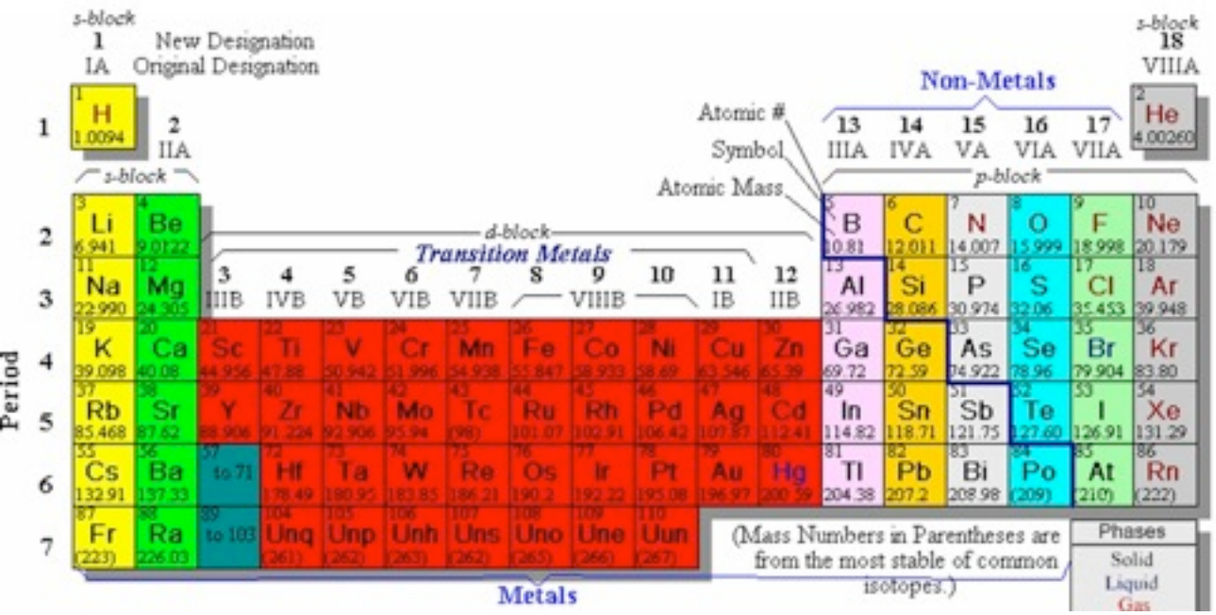
Katherine Copic
Columbia University

on behalf of the ATLAS Collaboration

New Data from the Energy Frontier

Aspen, Colorado
February 17, 2011

Periodic table of Particle Physics



Rows and columns, masses of the periodic table provide clues to underlying physics

We have yet to understand the structure and values in our own periodic table

L E P T O N S

Electron Neutrino	Muon Neutrino	Tau Neutrino
Mass << 1	<< 1	<< 1
Electron	Muon	Tau
0.5	106	1777

Q U A R K S

Up	Charm	Top
Mass 3	1270	173000
Down	Strange	Bottom
5	101	4190

Questions for the Exotics group

Even if we find the Higgs, even if we find SUSY - and especially if we don't - questions remain

Why are there multiple copies of the same particles?

Are there more quarks, leptons or gauge bosons?

Where do the values of the masses come from?

What is the nature of space?

What about gravity??!


LHC data is like a long banquet - so far we have just a taste...

LHC data is like a long banquet - so far we have just a taste...

ATLAS Exotics
Tasting Menu

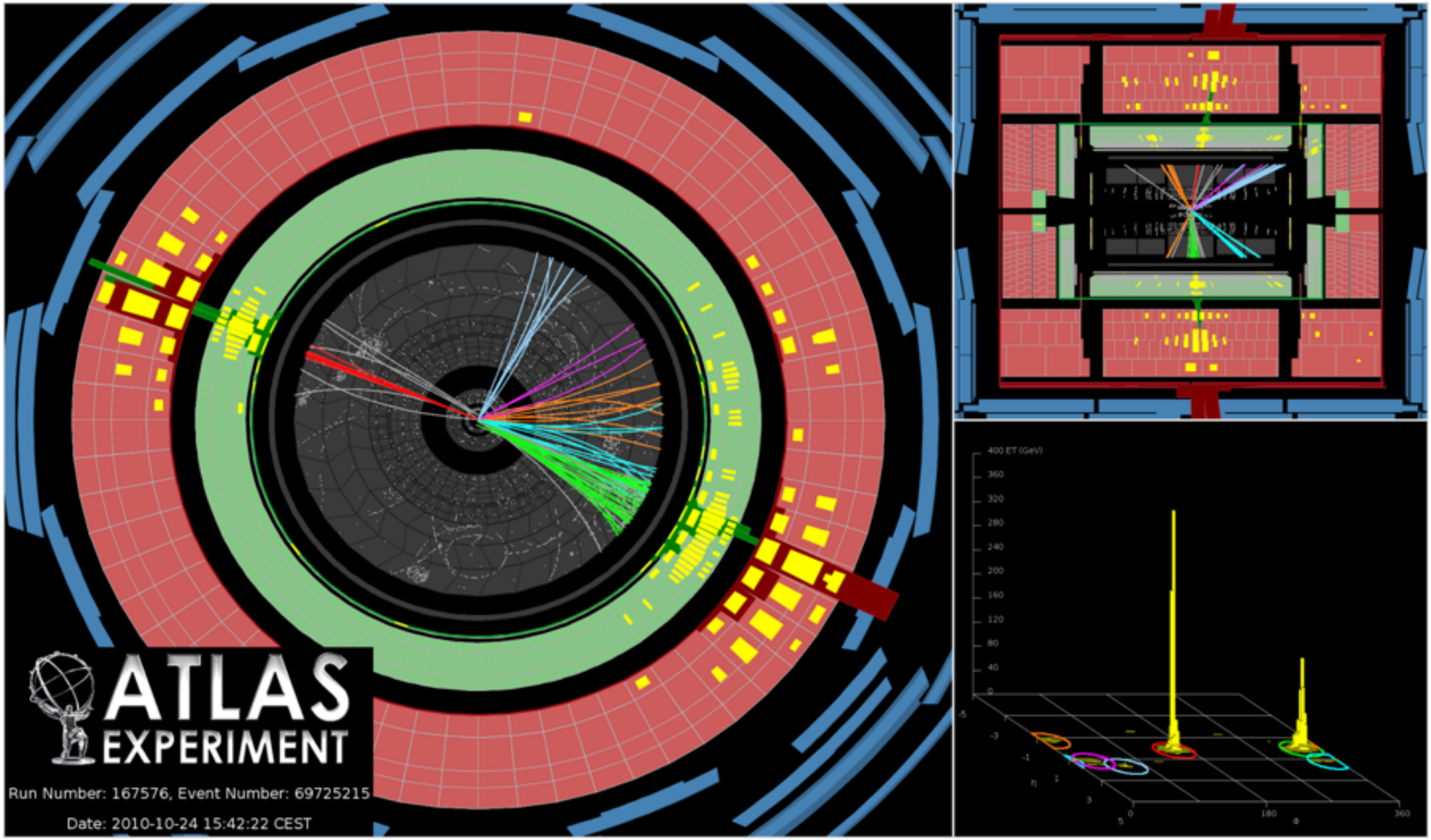
Jets three ways

Duo of photons with
Missing Transverse Energy

Highly Ionizing Particles

W Prime search with very
high pT Leptons

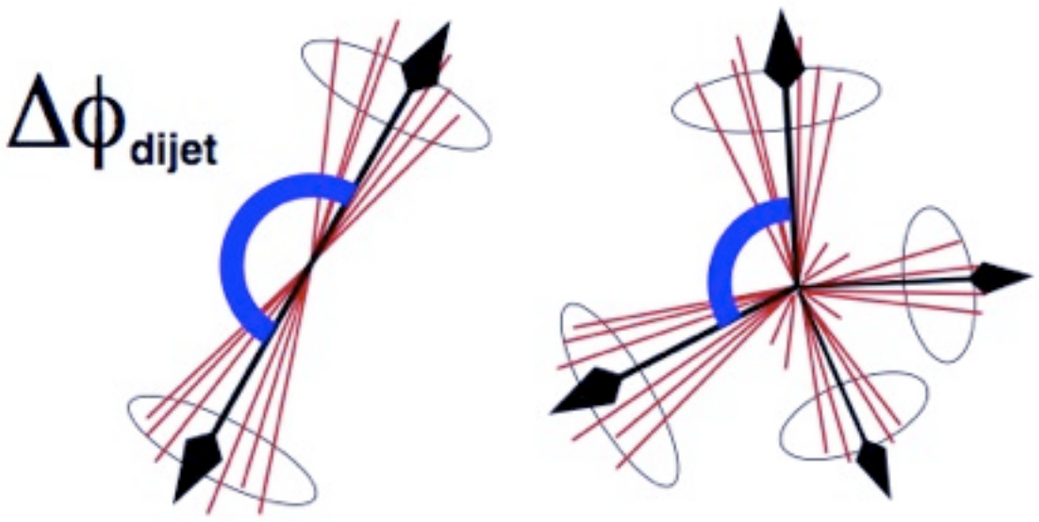
Jets!

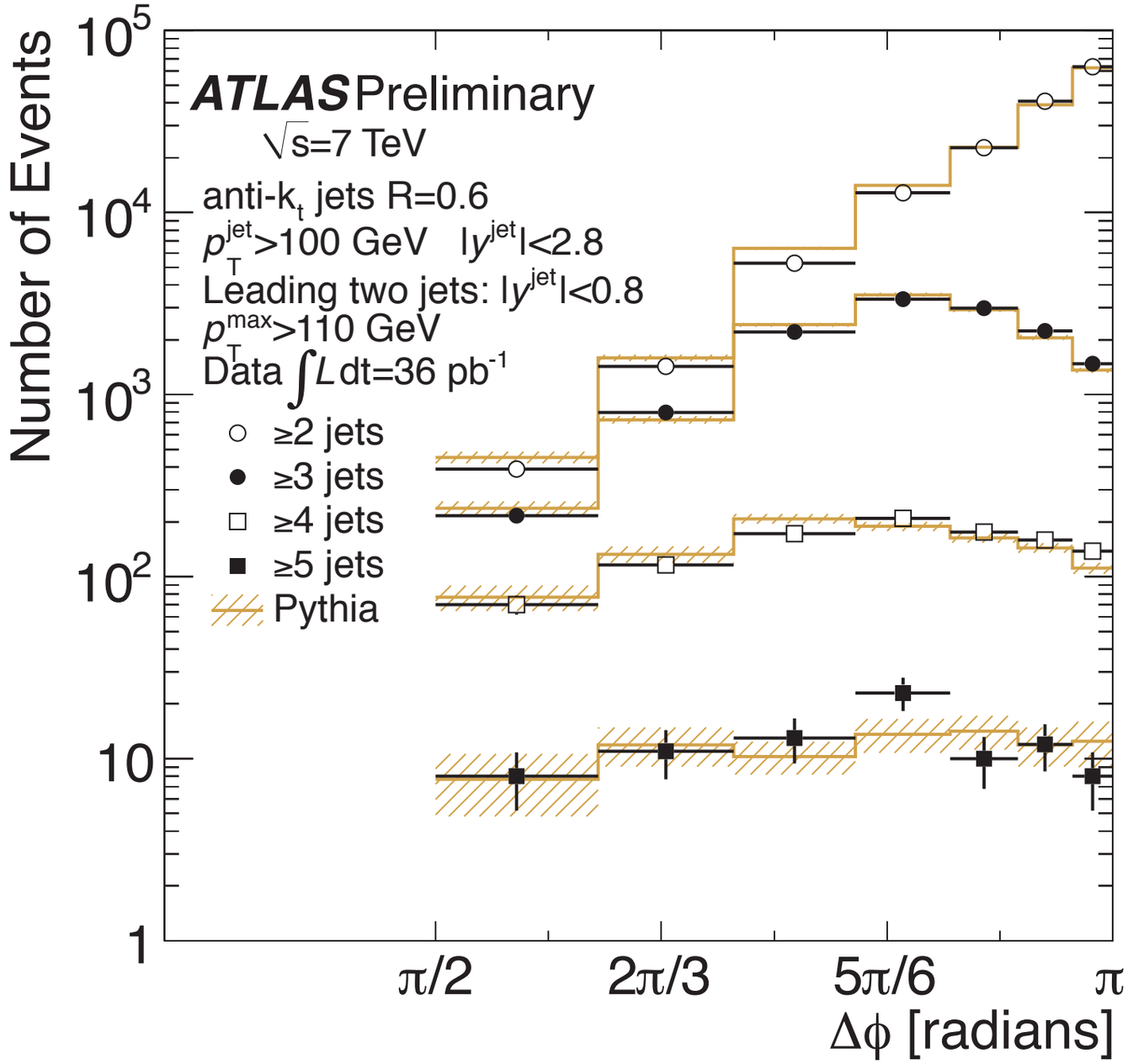


Dijet event: jets with pT of 1.2 and 1.3 TeV

Understanding jets

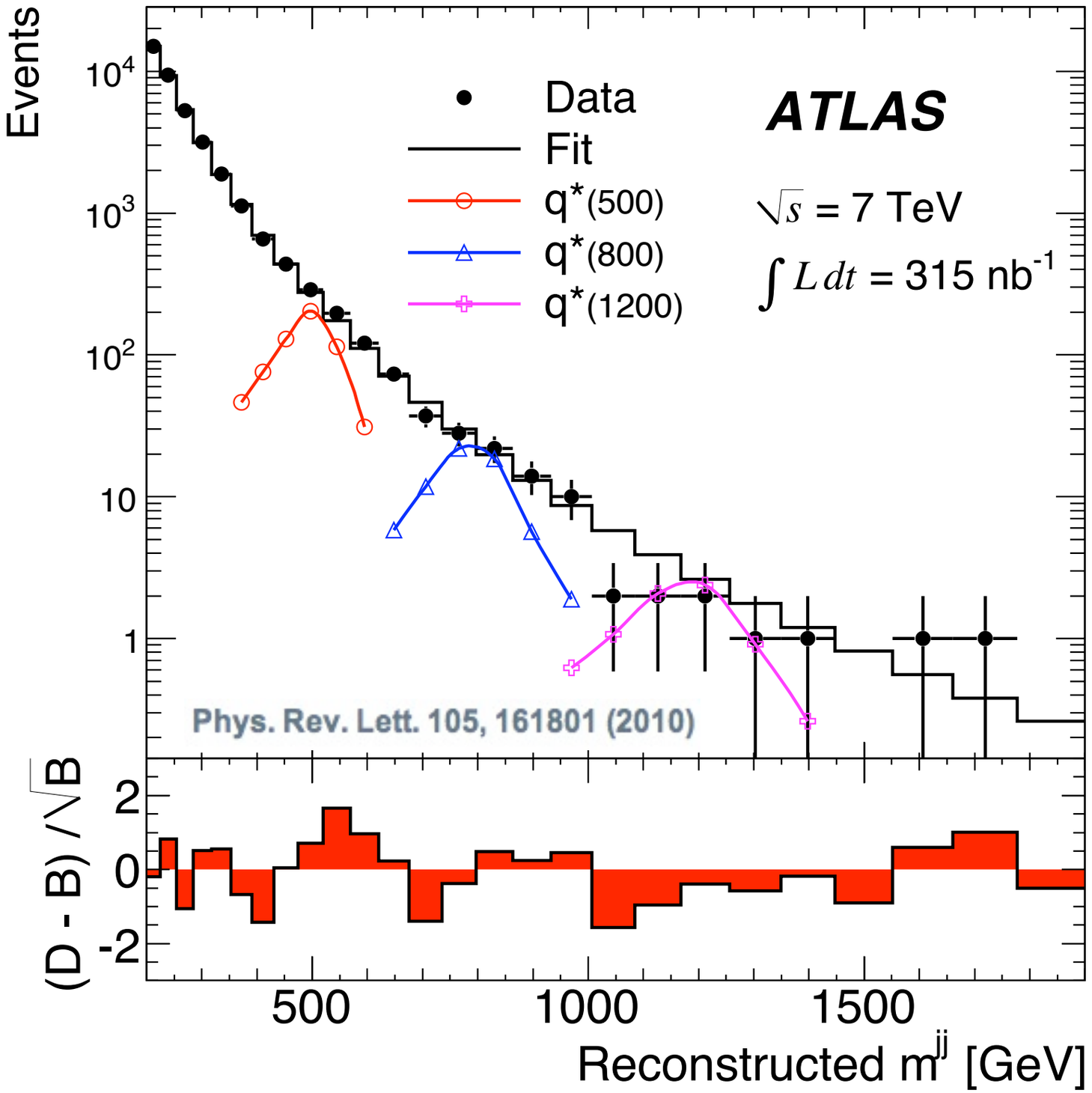
Beyond inclusive jet cross sections, we can investigate event topology to check agreement with the Standard Model





Dijet Azimuthal Decorrelations
Submitted to PRL: arXiv:1102.2696

Searching for Resonances

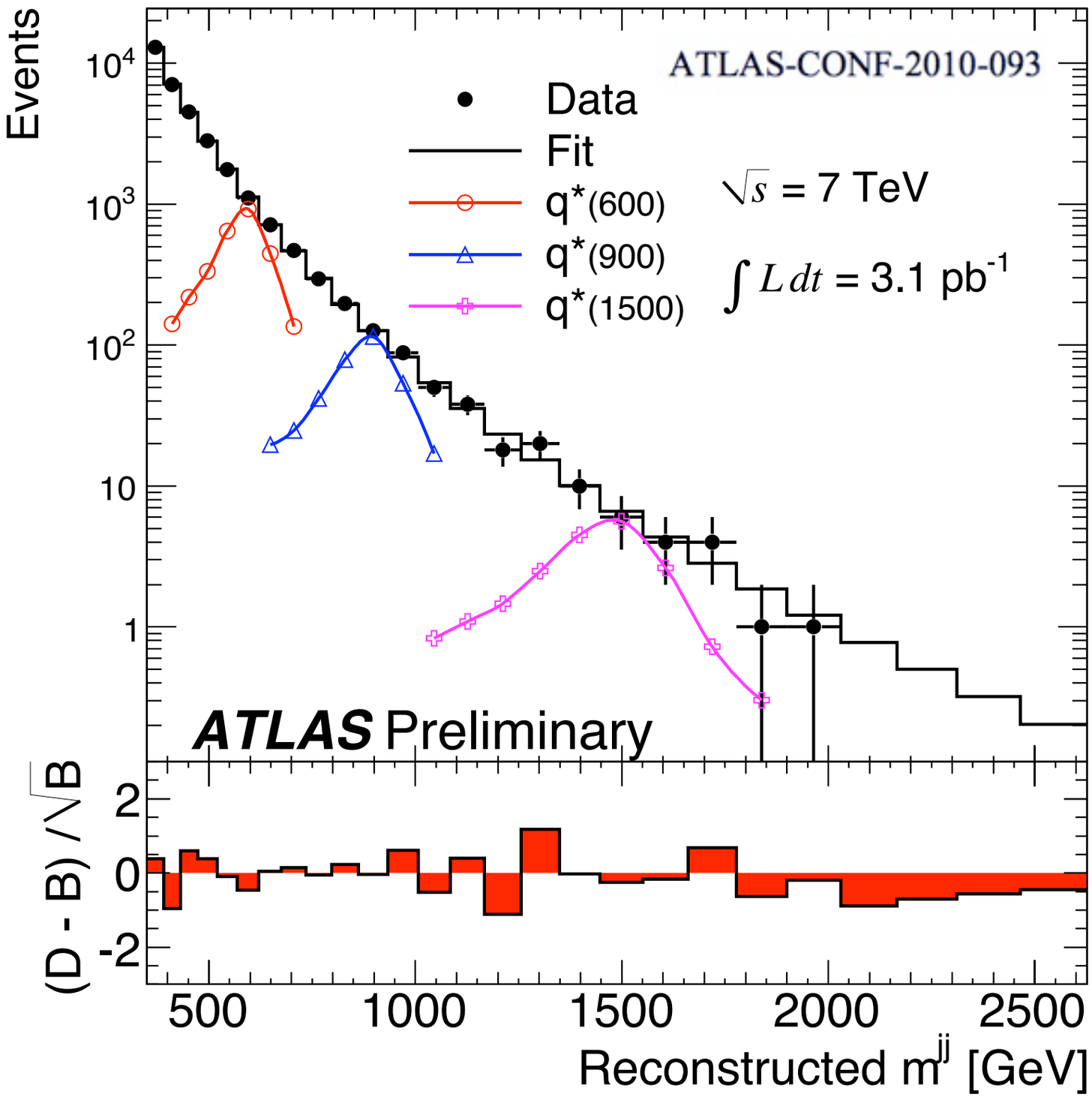


$$m^{jj} = \sqrt{\left(E_1 + E_2\right)^2 + \left(\vec{p}_1 + \vec{p}_2\right)^2}$$

Compare to a smooth function:

$$f(x) = p_1(1-x)^{p_2} x^{p_3 + p_4 \ln x}$$

Searching for Resonances



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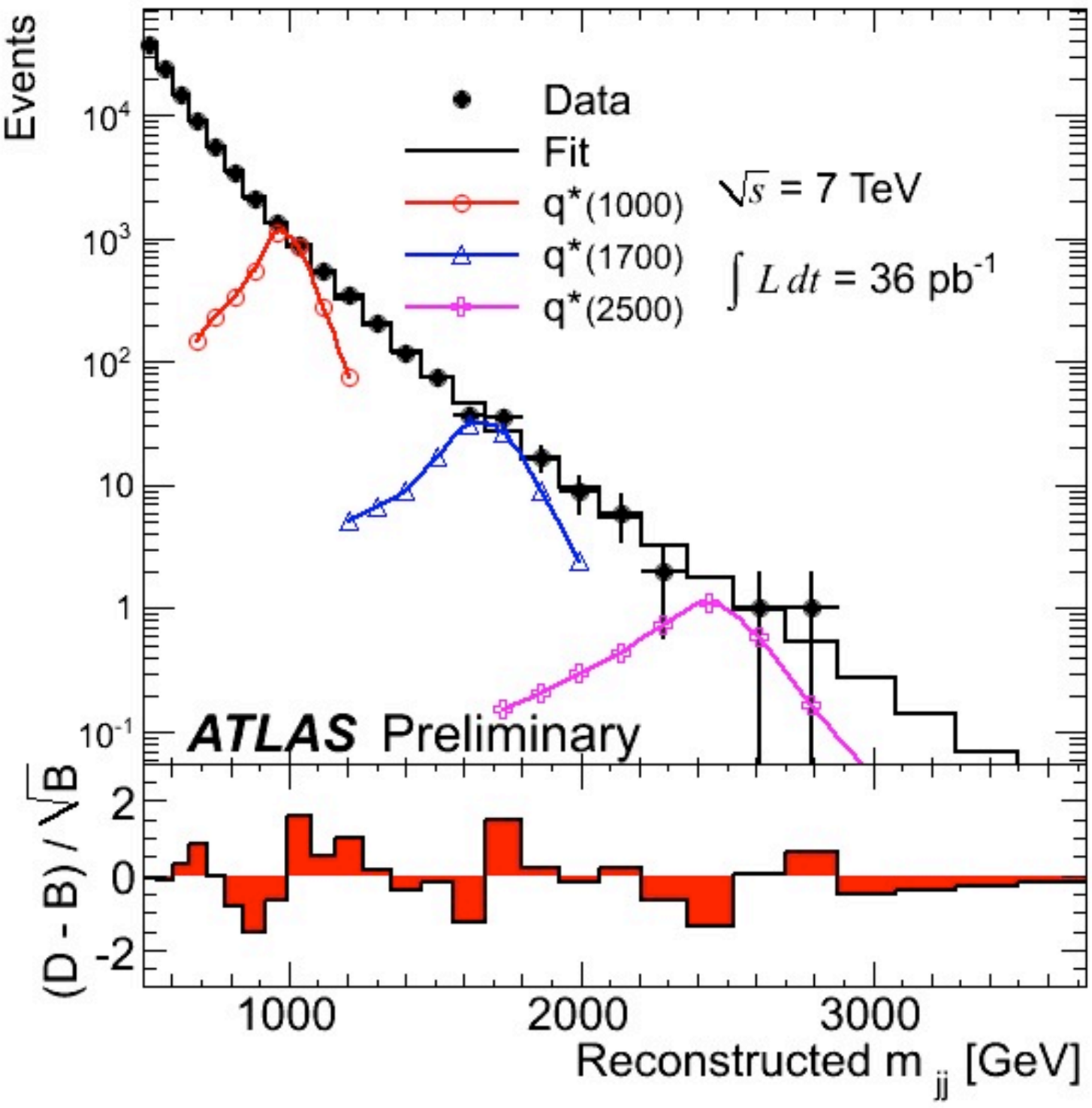
Searching for Resonances



Dijet resonance search performed with 10 times more data

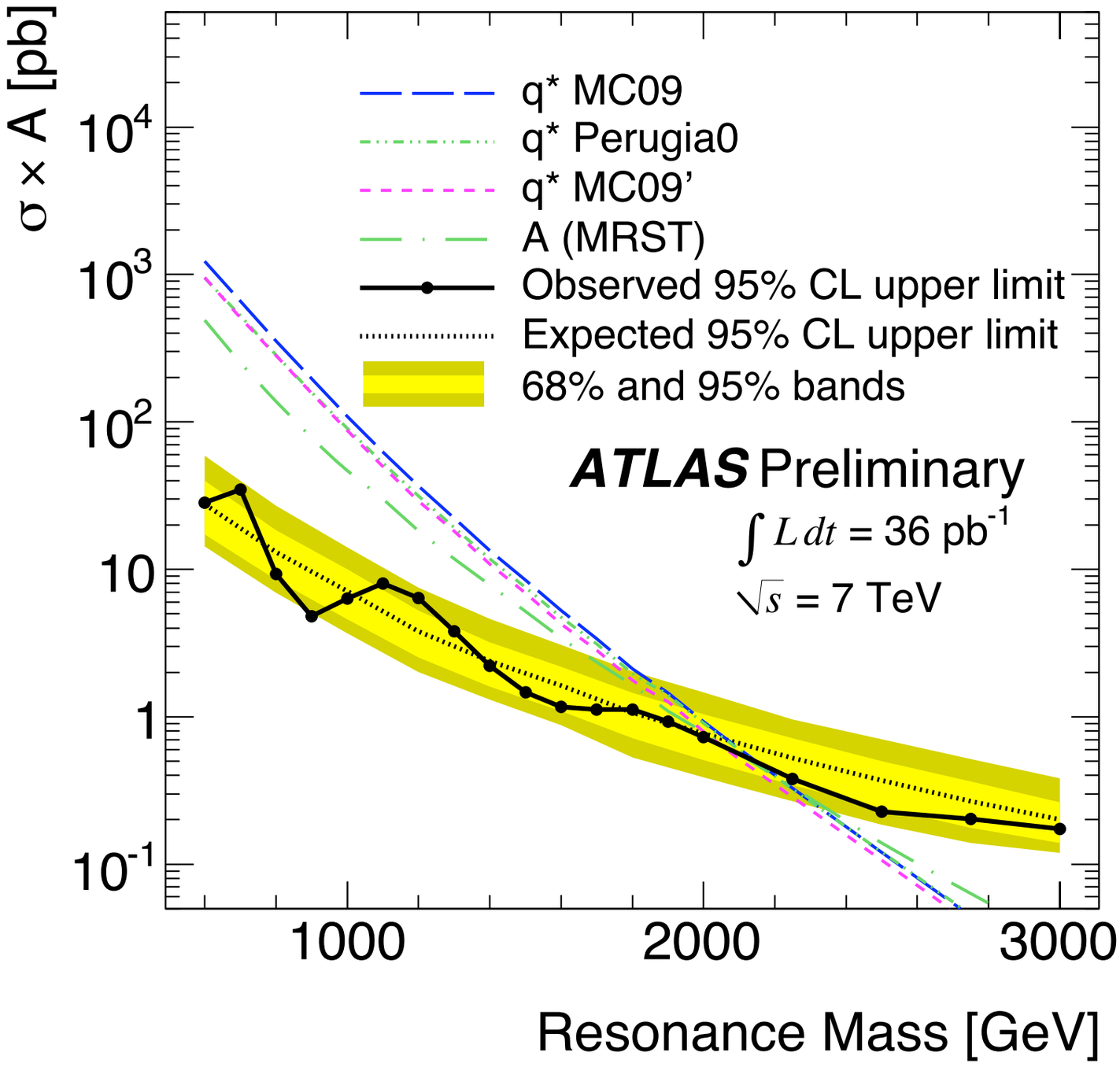
$$m^{jj} = \sqrt{\left(E_1 + E_2\right)^2 + \left(\vec{p}_1 + \vec{p}_2\right)^2}$$

Compare to a smooth function:

$$f(x) = p_1(1-x)^{p_2} x^{p_3 + p_4 \ln x}$$

No hints of a peak

Dijet resonance limits



Can place limits on several models:

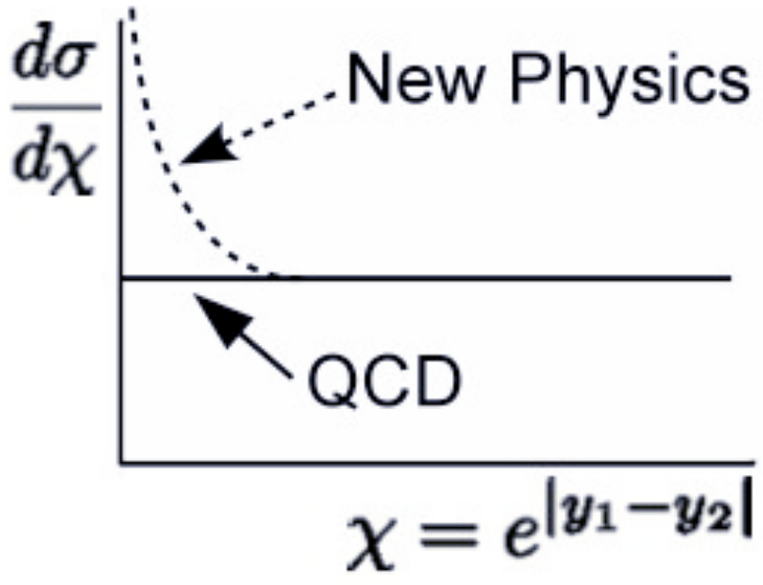
Excited quark, q*:
2.15 TeV

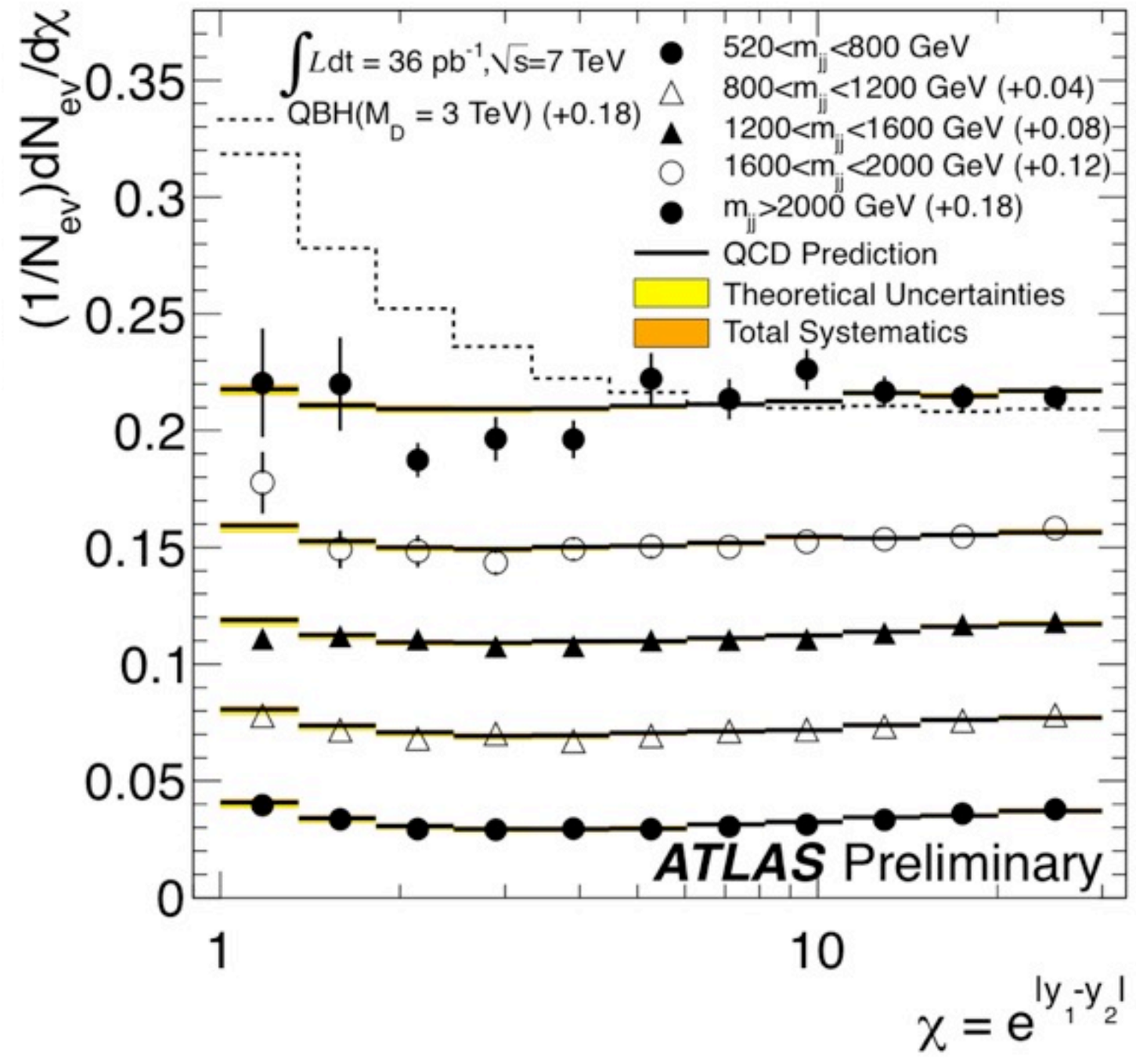
Axigluon (chiral color):
2.10 TeV

Randall-Meade
Quantum Black Holes:
3.67 TeV

Going beyond resonances

Use angular information: Define X and separate into m_{jj} bins



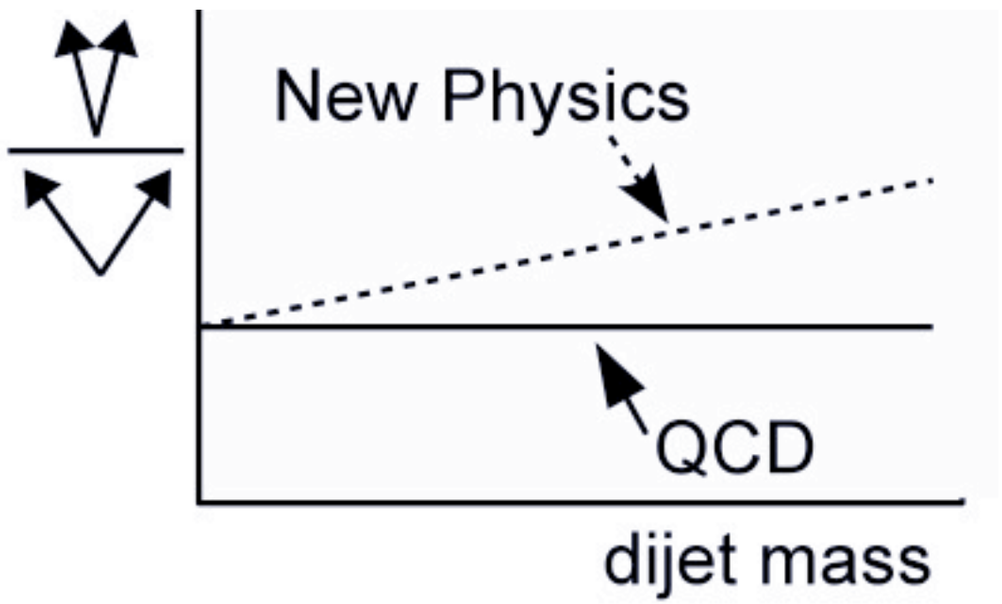


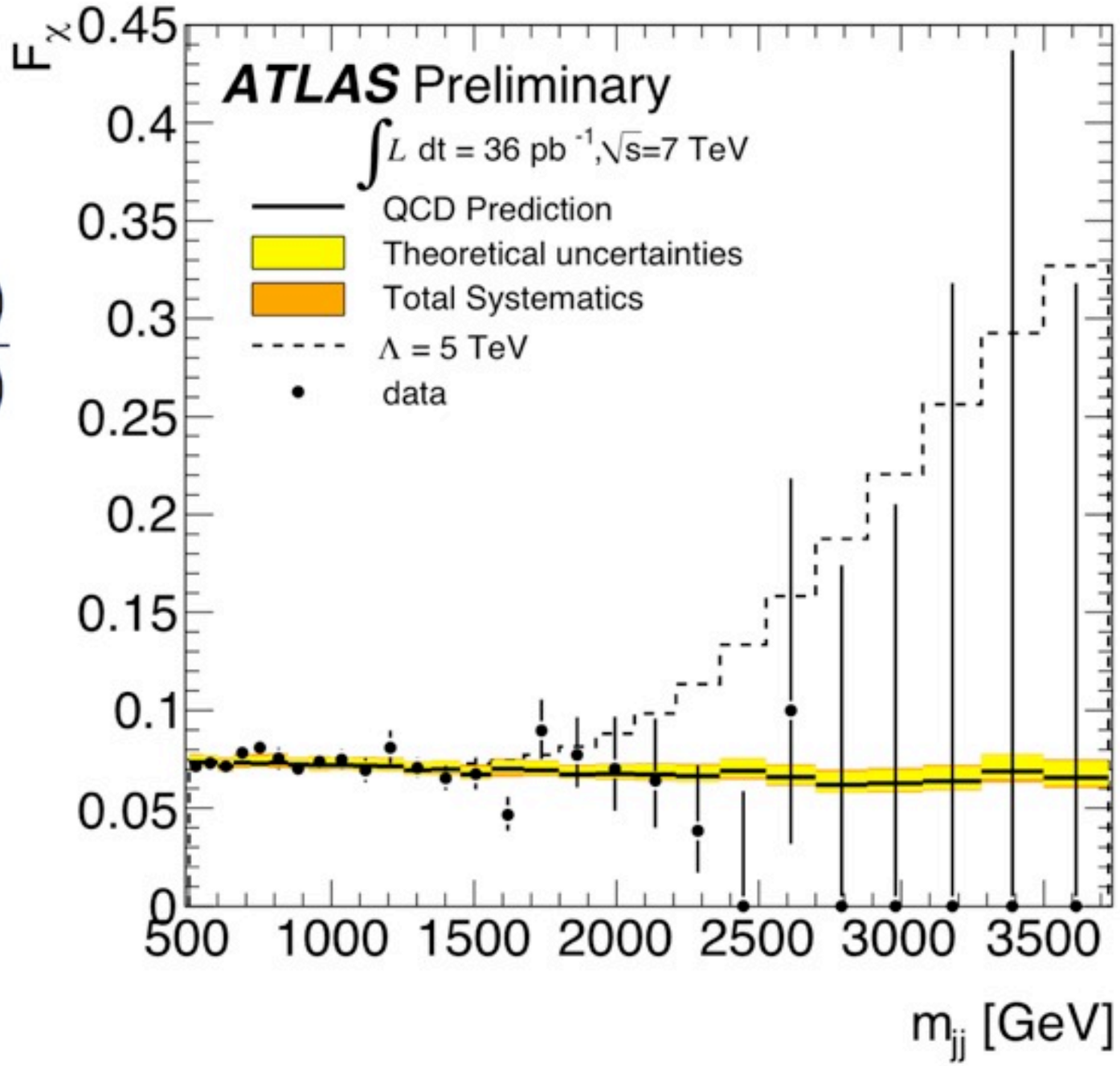
Using Chi Fraction

Gain even more information from the ratio:

$$F_\chi(m_{jj}) = \frac{N_{events}(|y^*| < 0.6)}{N_{events}(|y^*| < 1.7)}$$

$$y^* = \tfrac{1}{2}(y_1 - y_2)$$





Limits from Jet Analyses

Model and Analysis Strategy	95% C.L. Limits (TeV)	
	Expected	Observed
Excited Quark q^*		
Resonance in m_{jj}	2.07	2.15
$F_\chi(m_{jj})$	2.08	2.60
Randall-Meade Quantum Black Hole for $n = 6$		
Resonance in m_{jj}	3.64	3.67
$F_\chi(m_{jj})$	3.50	3.84
$dN/d\chi$ for $m_{jj} > 2$ TeV	3.37	3.69
Axigluon		
Resonance in m_{jj}	2.01	2.10

Chi fraction does as well as traditional resonance search for bumps, more sensitive to tails

Contact Interactions: For a smaller dataset, $\Lambda < 3.4$ excluded: Update coming soon

Phys. Lett. B694 (2011) 327-345

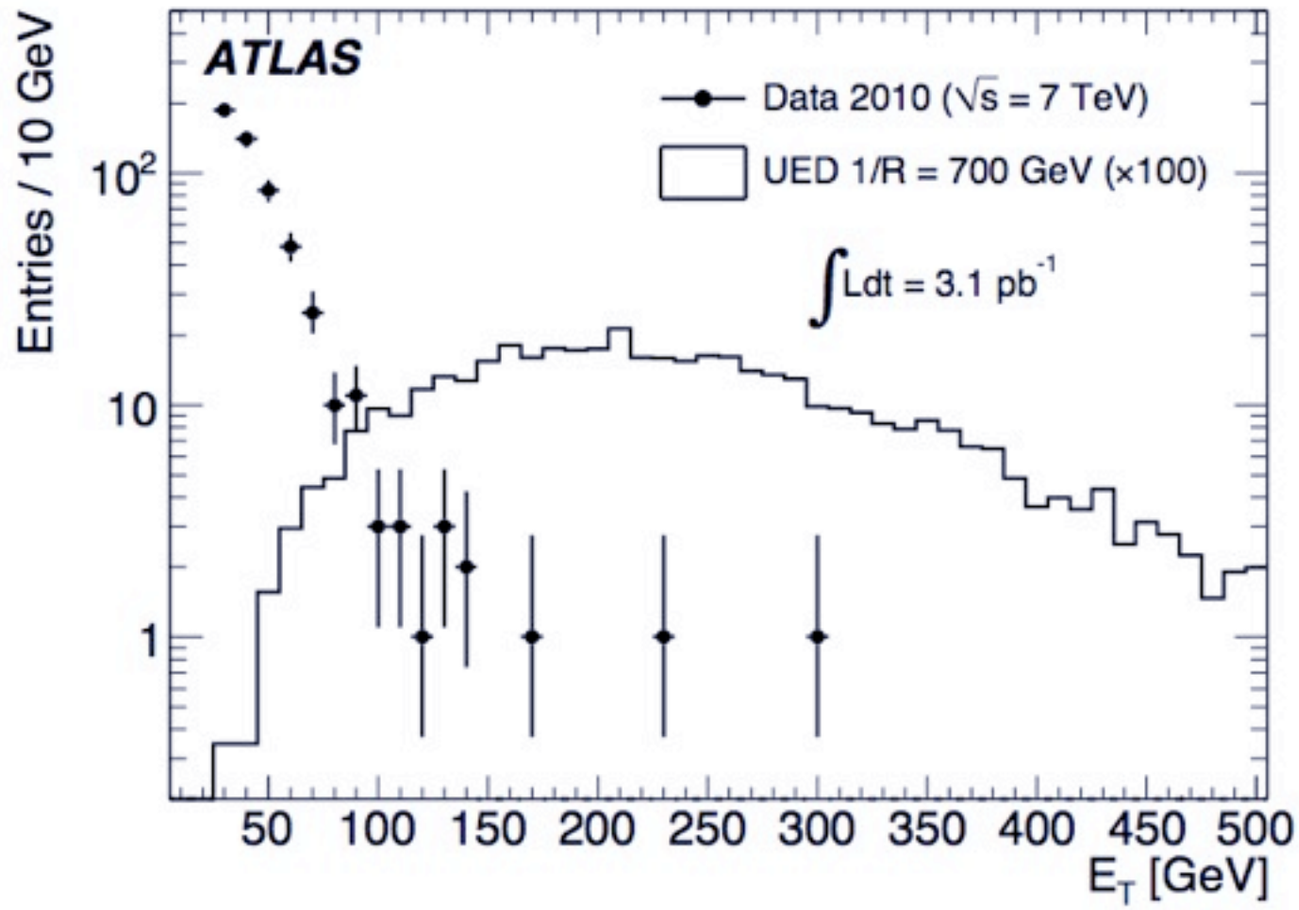
Exotics with Photons

Select events with two isolated photons with ET > 25 GeV

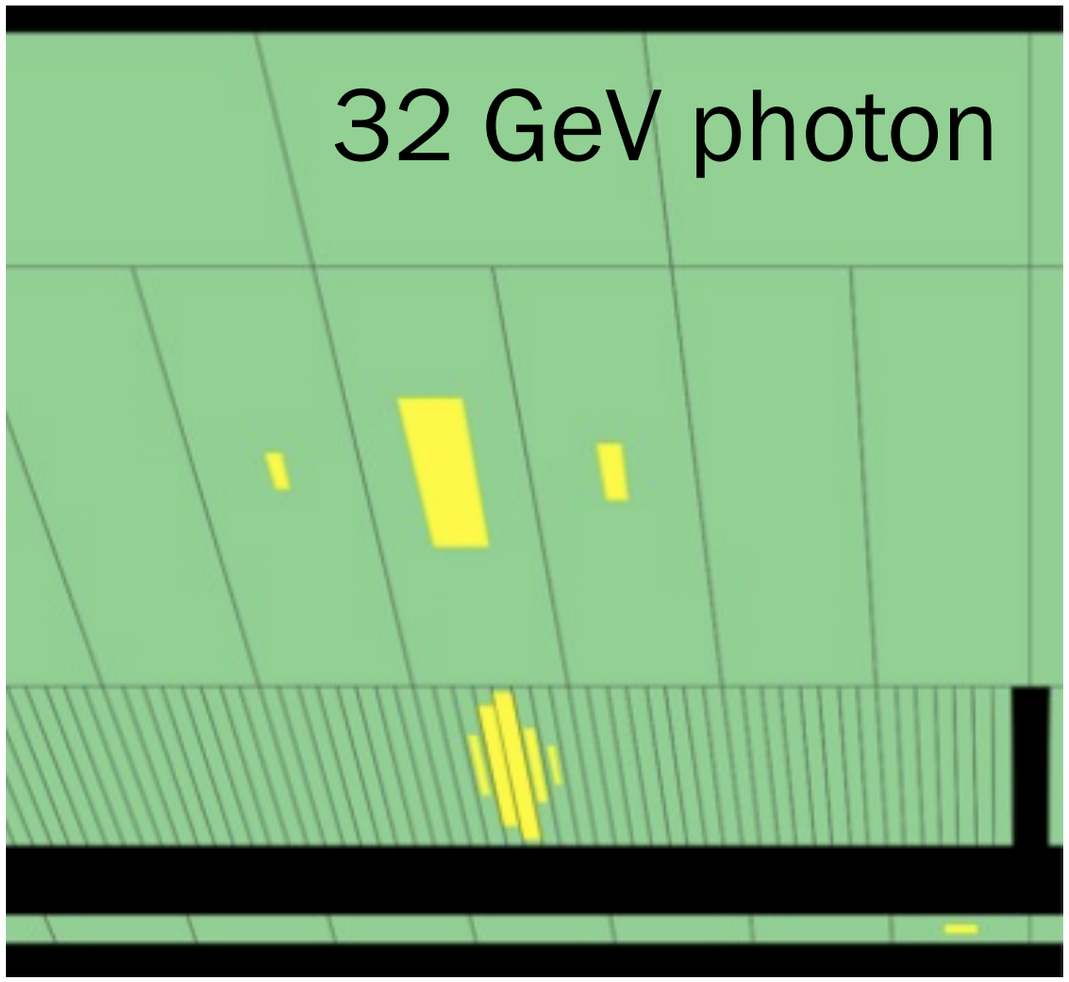
One model that could produce diphotons + MET: Universal Extra Dimensions

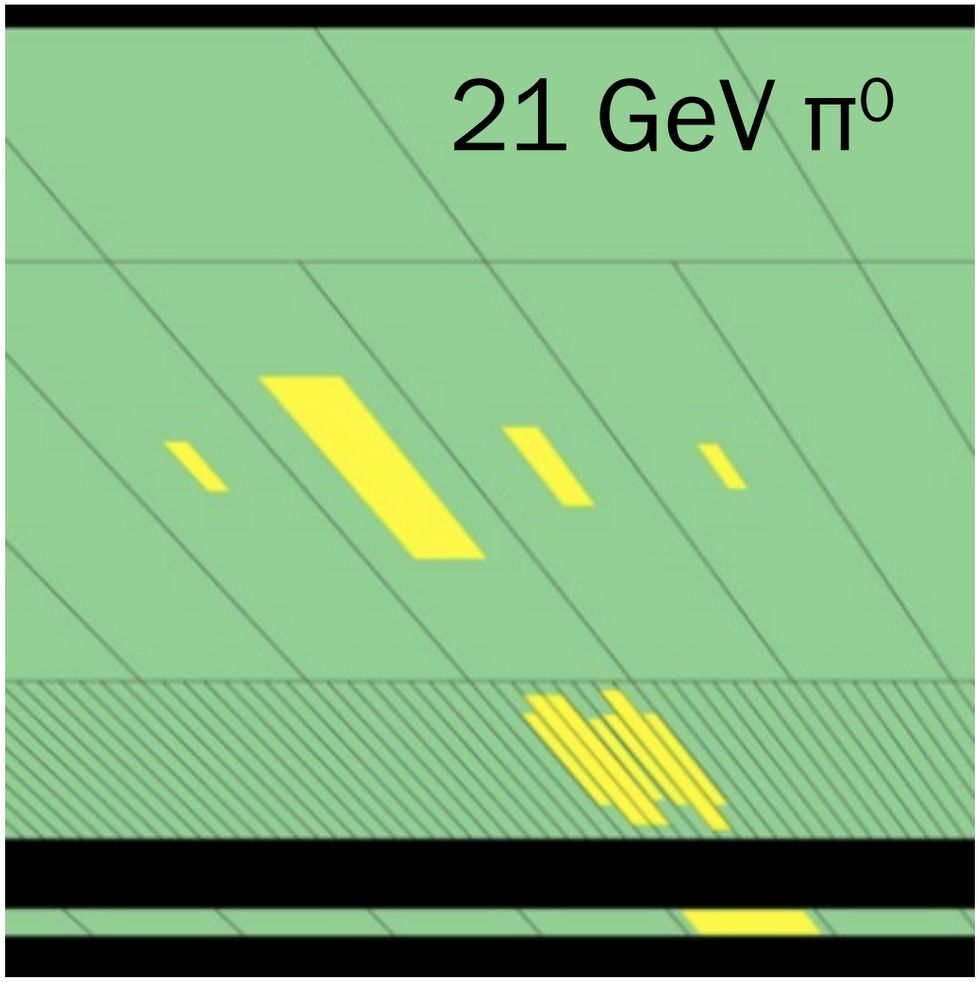
$$\gamma^* \rightarrow \gamma + G \quad \text{x 2}$$

+ other SM particles from cascade decays



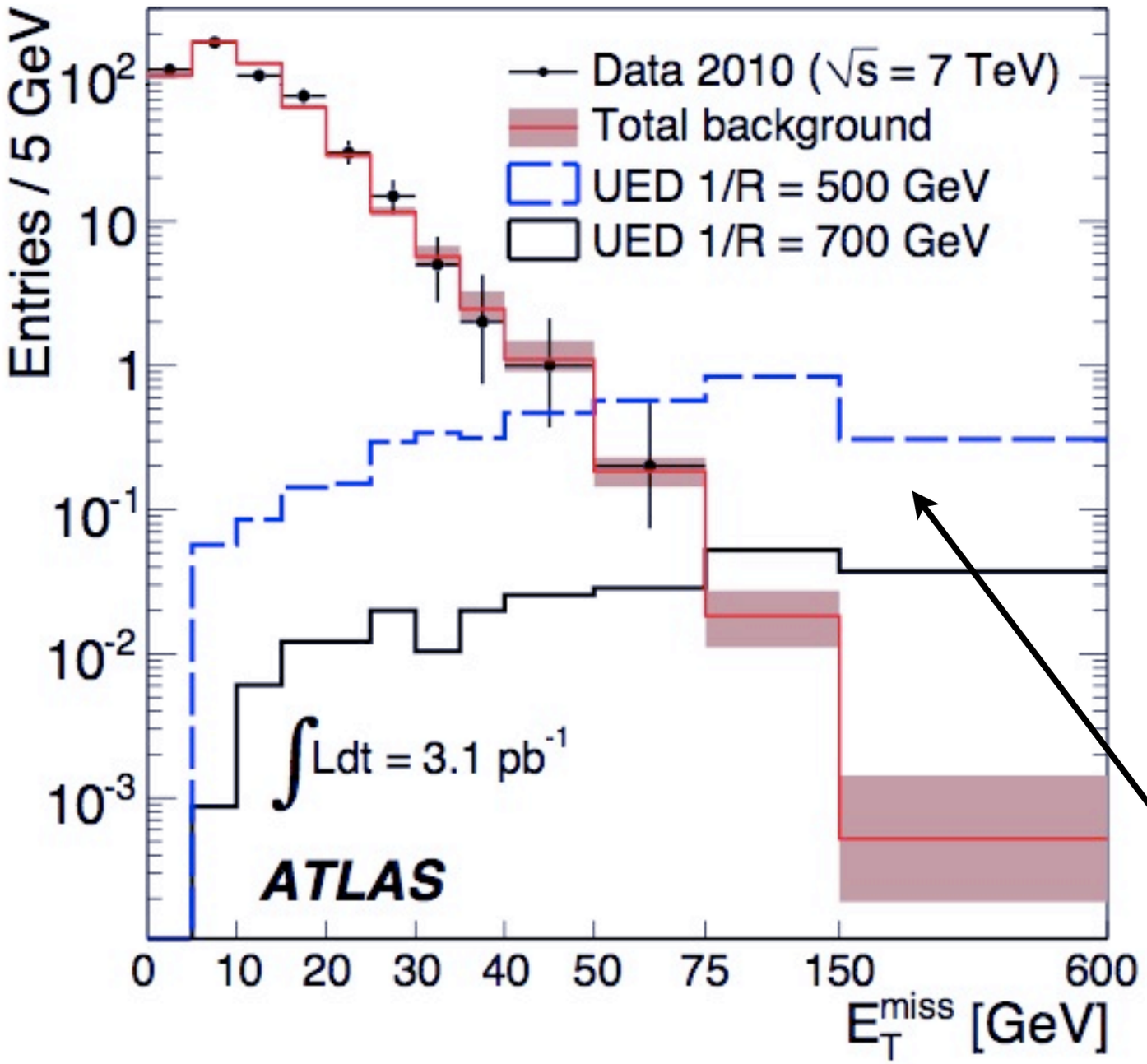
Identifying photons

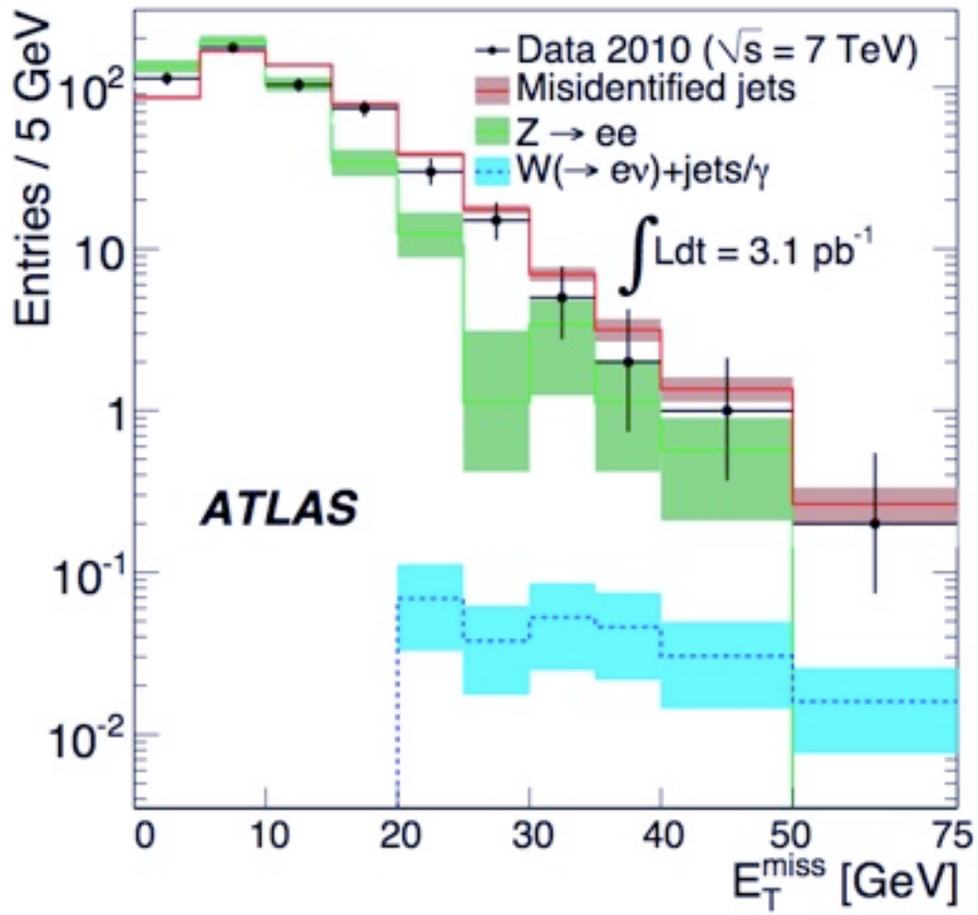




Longitudinal segmentation of the ATLAS EM calorimeter can provide good discrimination between photons and π^0

Data-driven backgrounds





Zero events observed in the MET > 75 GeV signal region

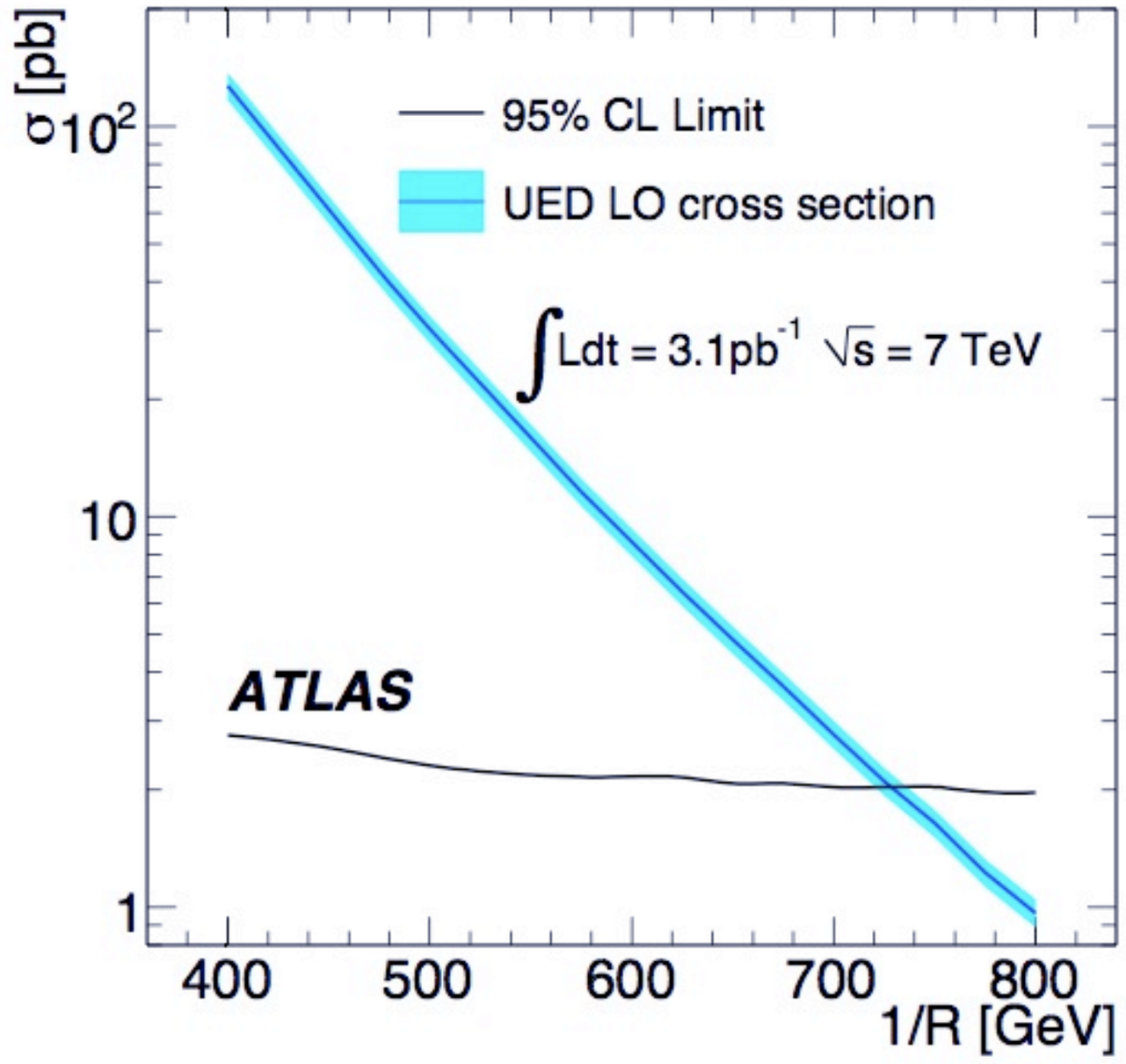
Best limit on UED

Exclude

1/R < 729 GeV at 95 % CL

Far surpassing Tevatron limits of 1/R < 477 GeV

R= compactification radius of the Universal Extra Dimension

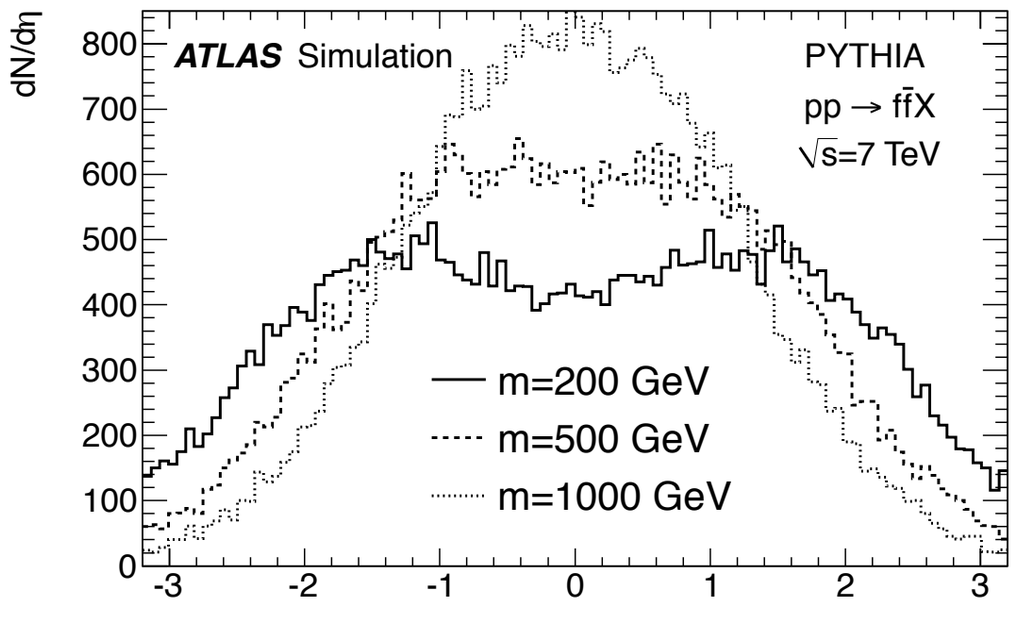


Submitted to PRL: arXiv:1012.4272

Highly ionizing particles

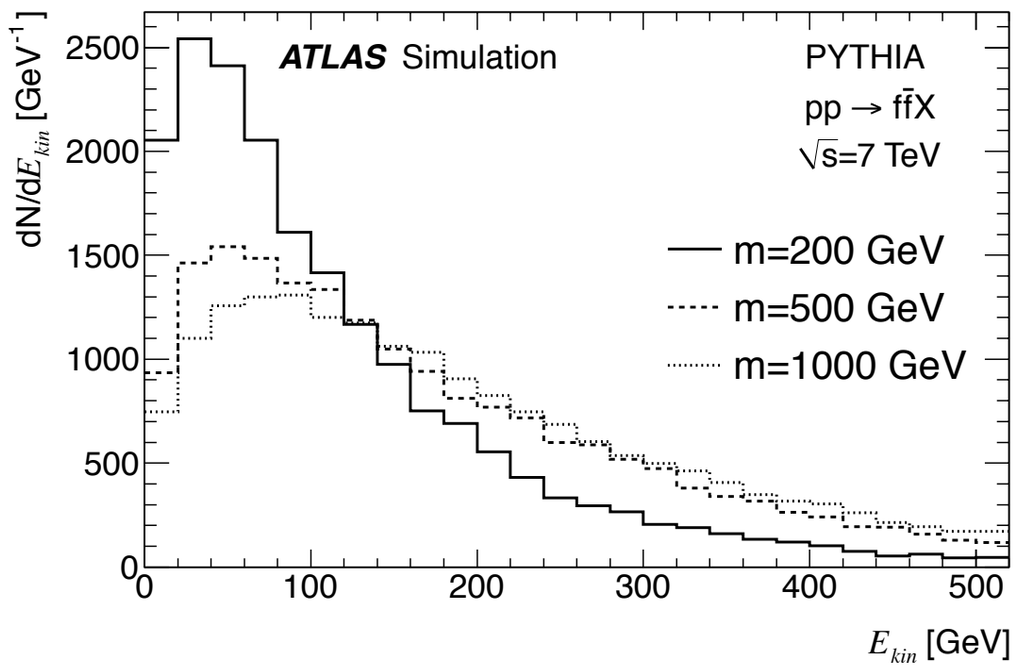
Search for a massive long-lived highly ionizing particle with $|q| \gg e$

Large mass (100's of GeV), non-relativistic speed



HIPs with charges from 6e - 17e generated with Pythia

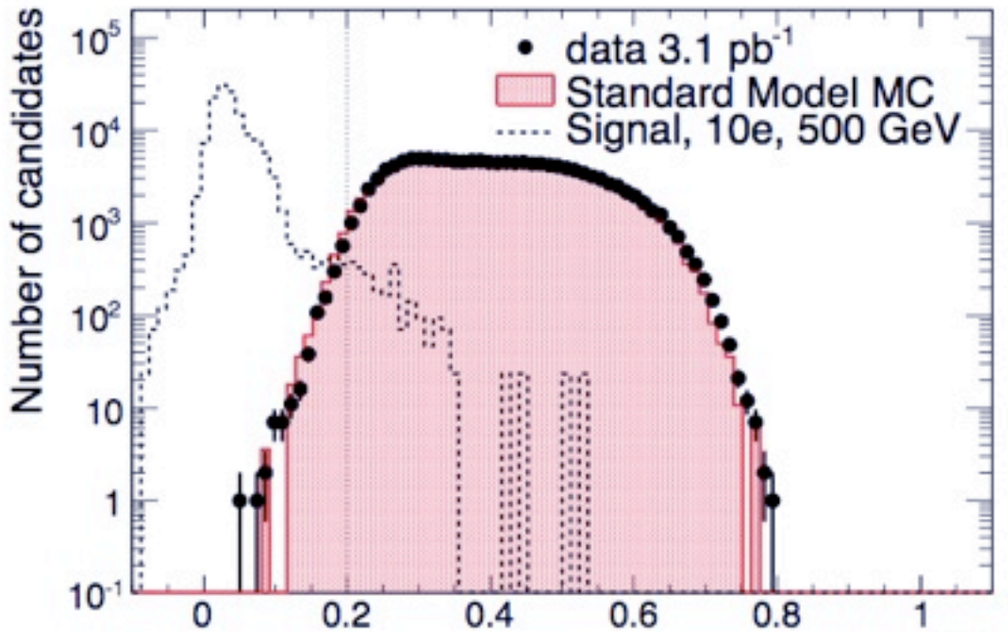
$$p + p \rightarrow f + \bar{f} + X$$

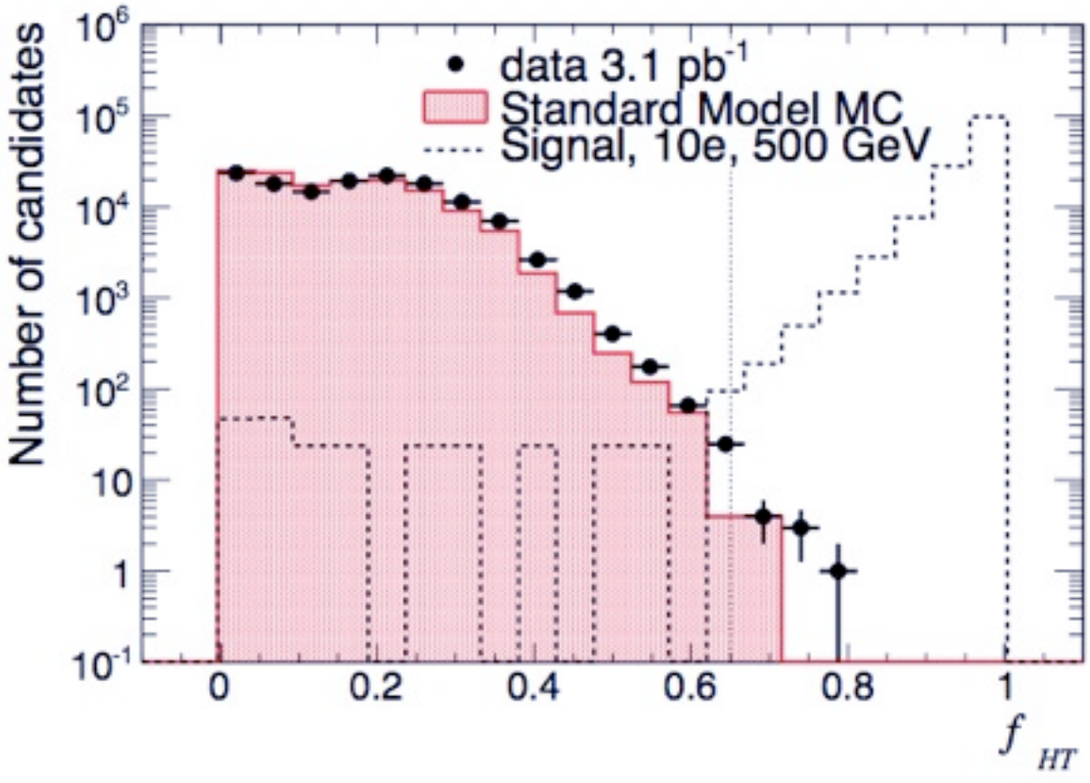


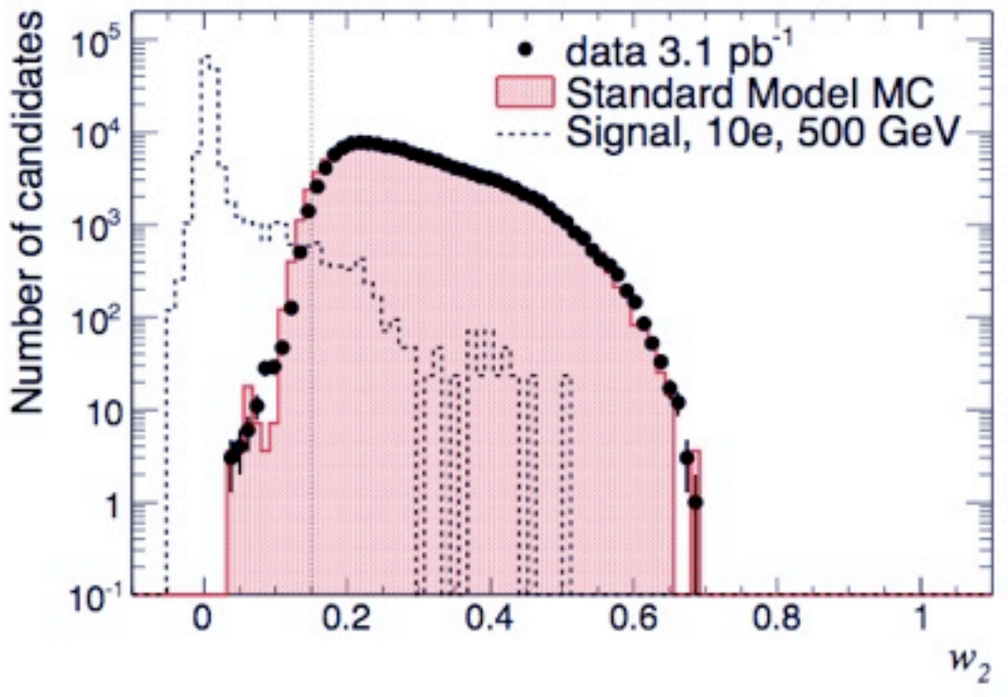
Discriminating variables

Examine detector variables that should be sensitive to HIP's, 96% efficient for signal

No events pass these cuts







Limits on HIPs

m [GeV]	$\|q\| = 6e$	$\|q\| = 10e$	$\|q\| = 17e$
200	1.4	1.2	2.1
500	1.2	1.2	1.6
1000	2.2	1.2	1.5

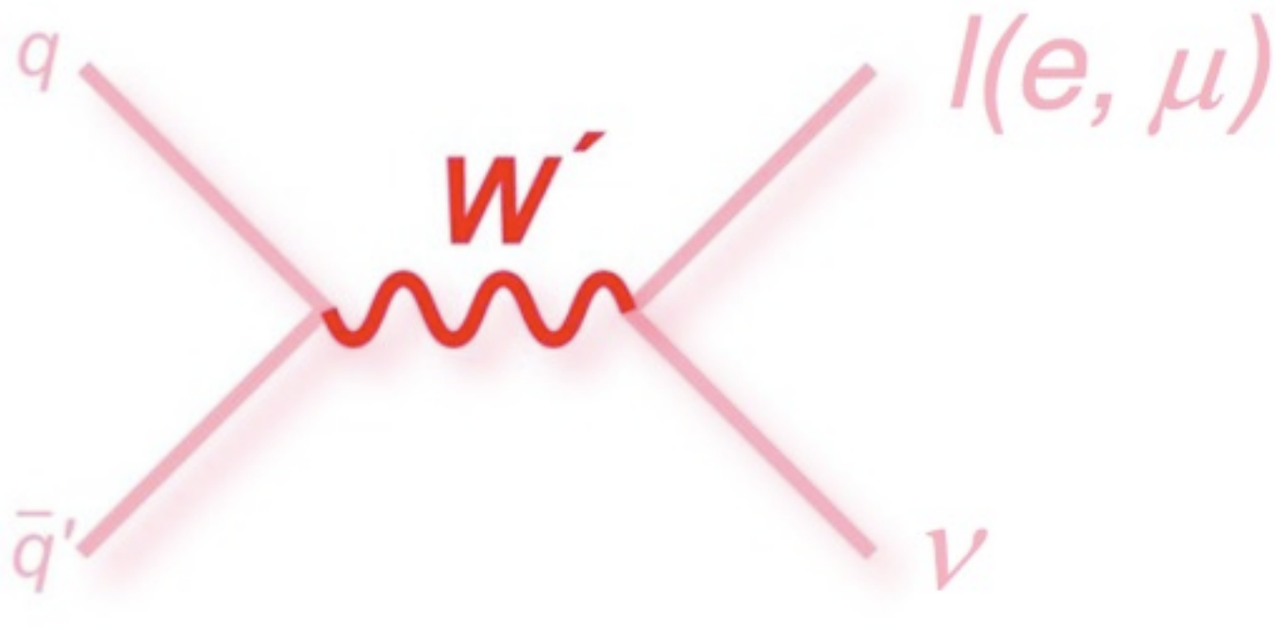
Cross section limits in pb are calculated such that they can be used for any model

m [GeV]	$\|q\| = 6e$	$\|q\| = 10e$	$\|q\| = 17e$
200	11.5	5.9	9.1
500	7.2	4.3	5.3
1000	9.3	3.4	4.3

Cross section limits in pb are also given assuming Drell-Yan like production mechanism to model kinematics

Submitted to PLB: arxiv:1102.0459

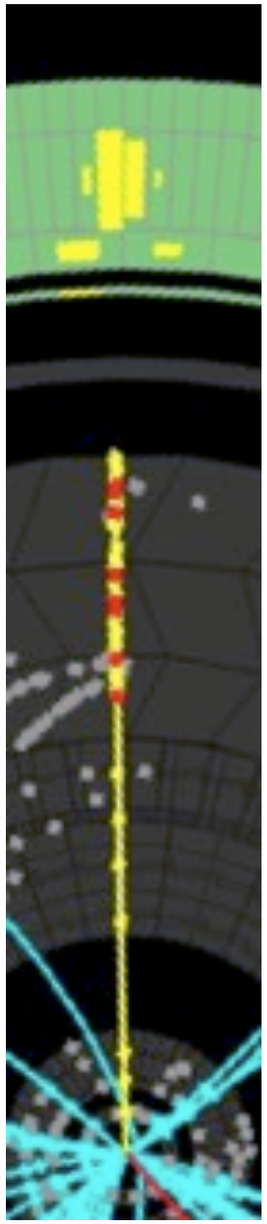
Looking for Heavy Bosons



W' and Z' are the first searches at the LHC to use very high pT leptons (>> 100 GeV)

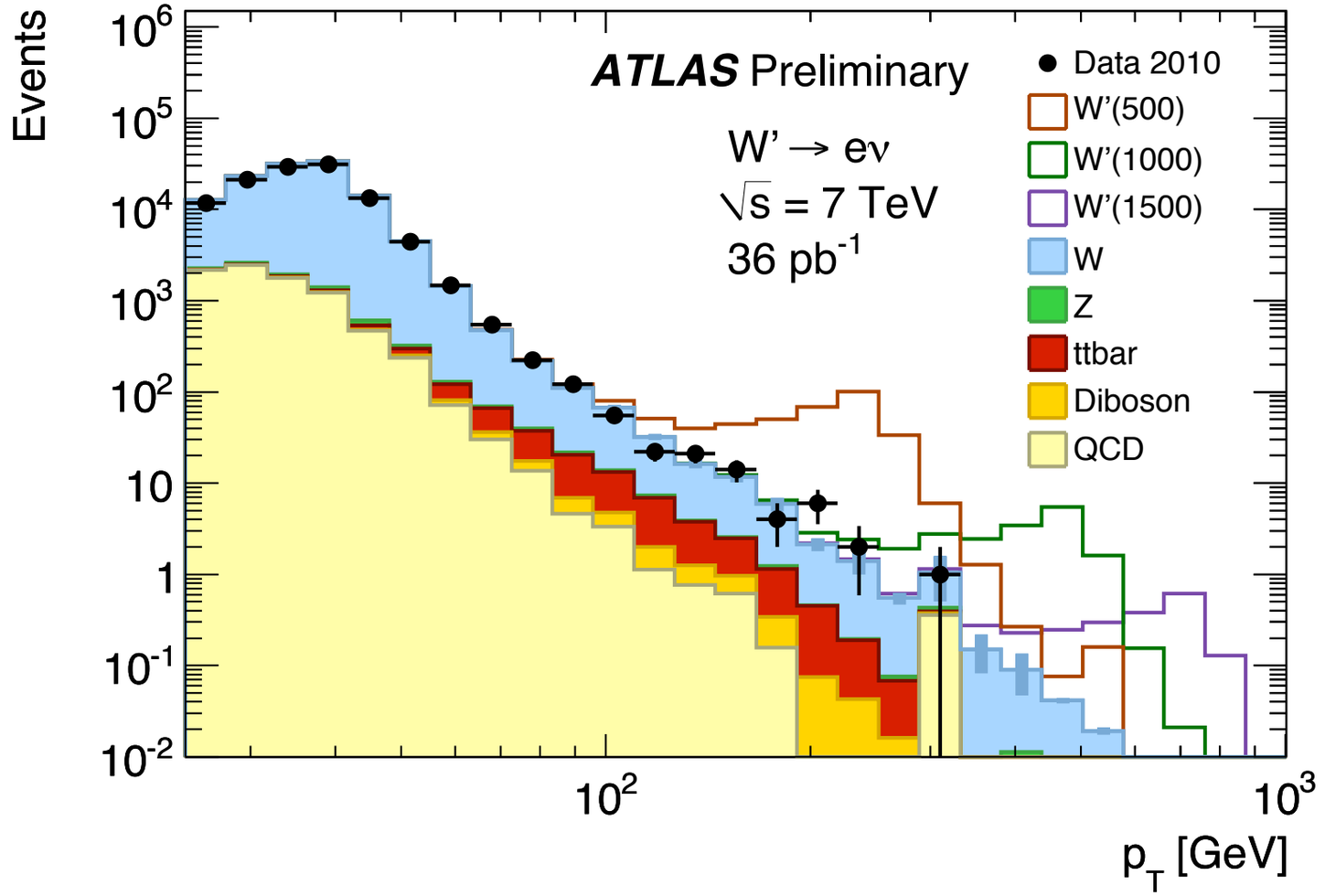
With limited statistics, choose selection carefully, designed for discovery

W' Electron Channel



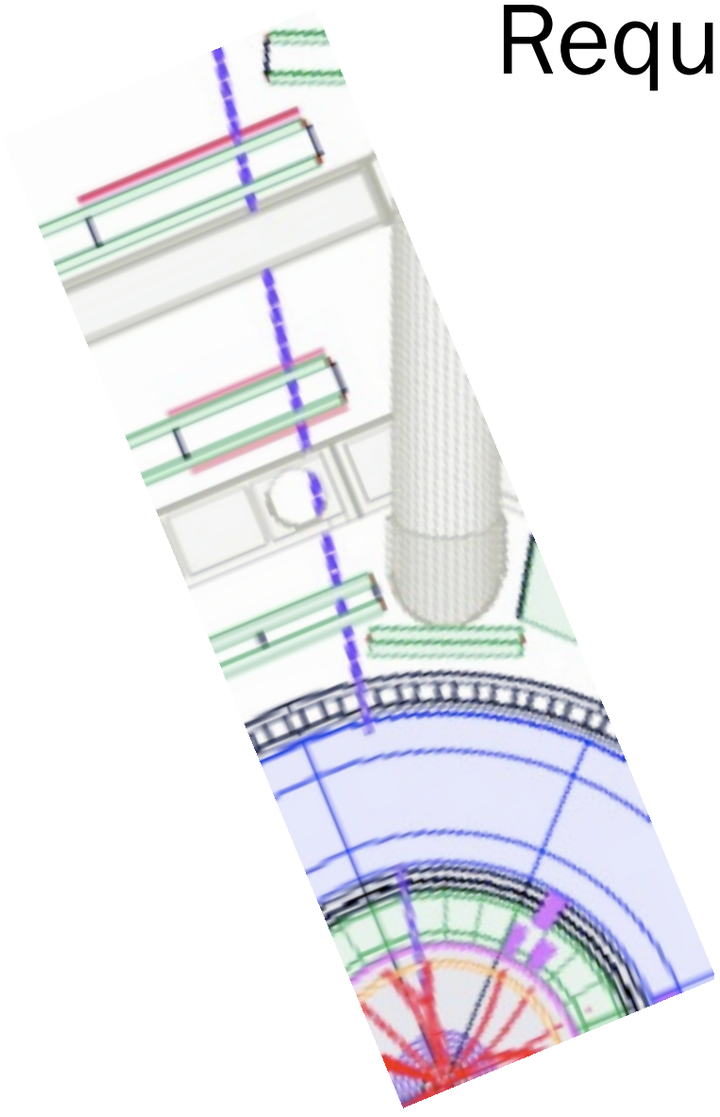
Choose events with one isolated electron with pT > 25 GeV, MET > 25 GeV

Largest backgrounds: W, ttbar, diboson events, and QCD

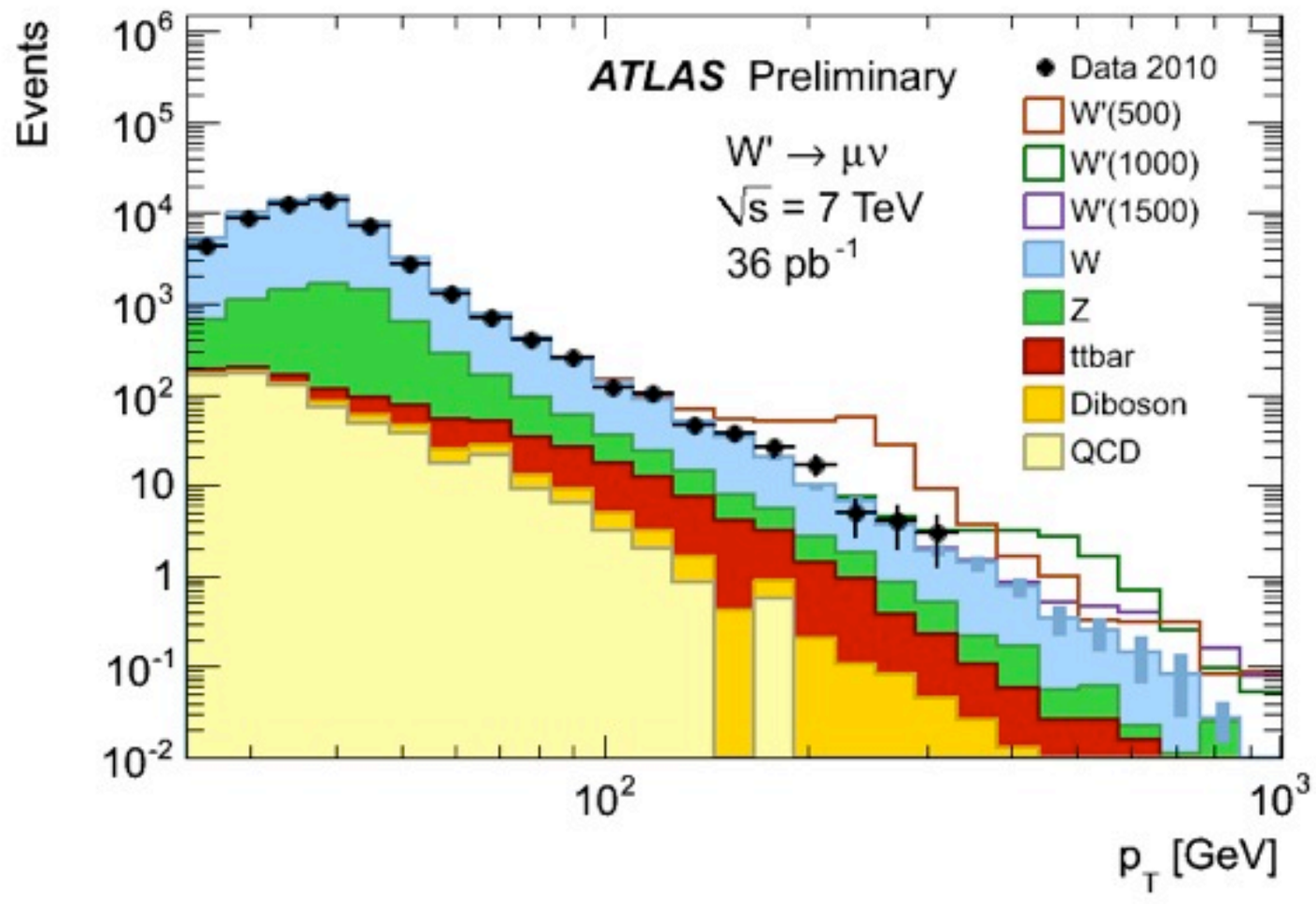


W’ Muon Channel

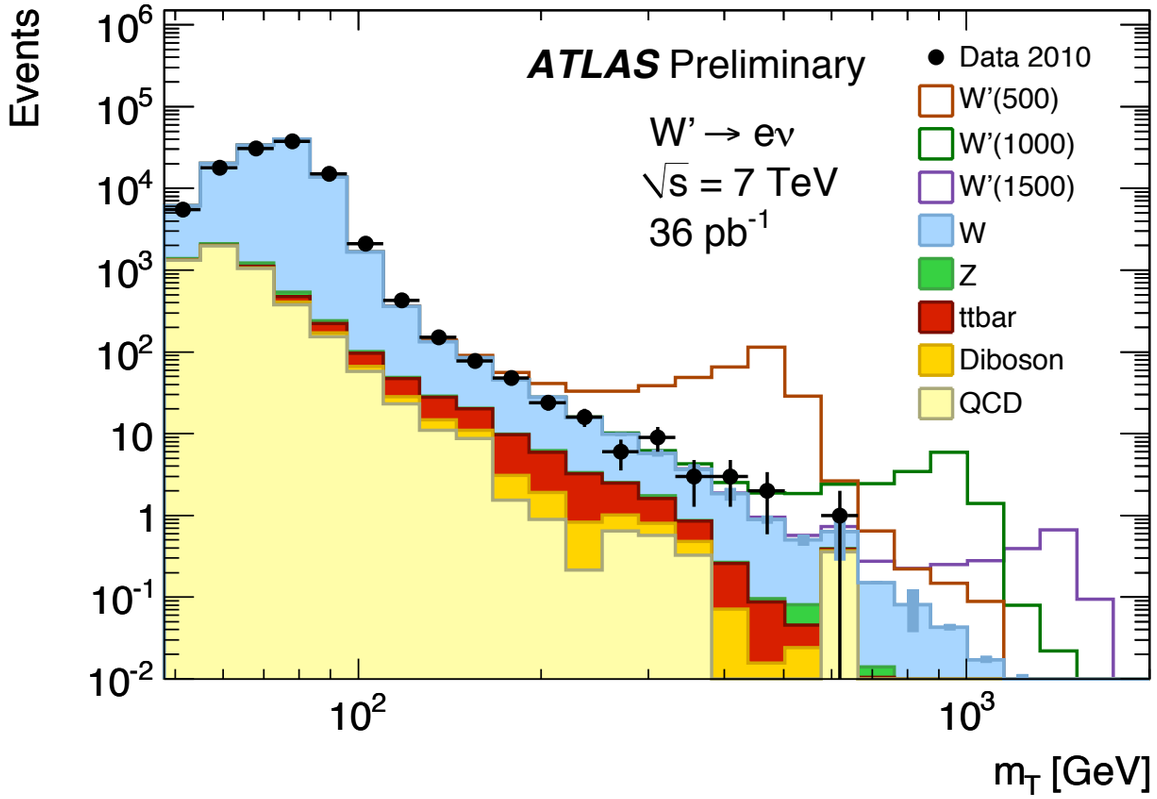
For this first data, make very strong quality cuts on the muons to ensure a well-measured pT

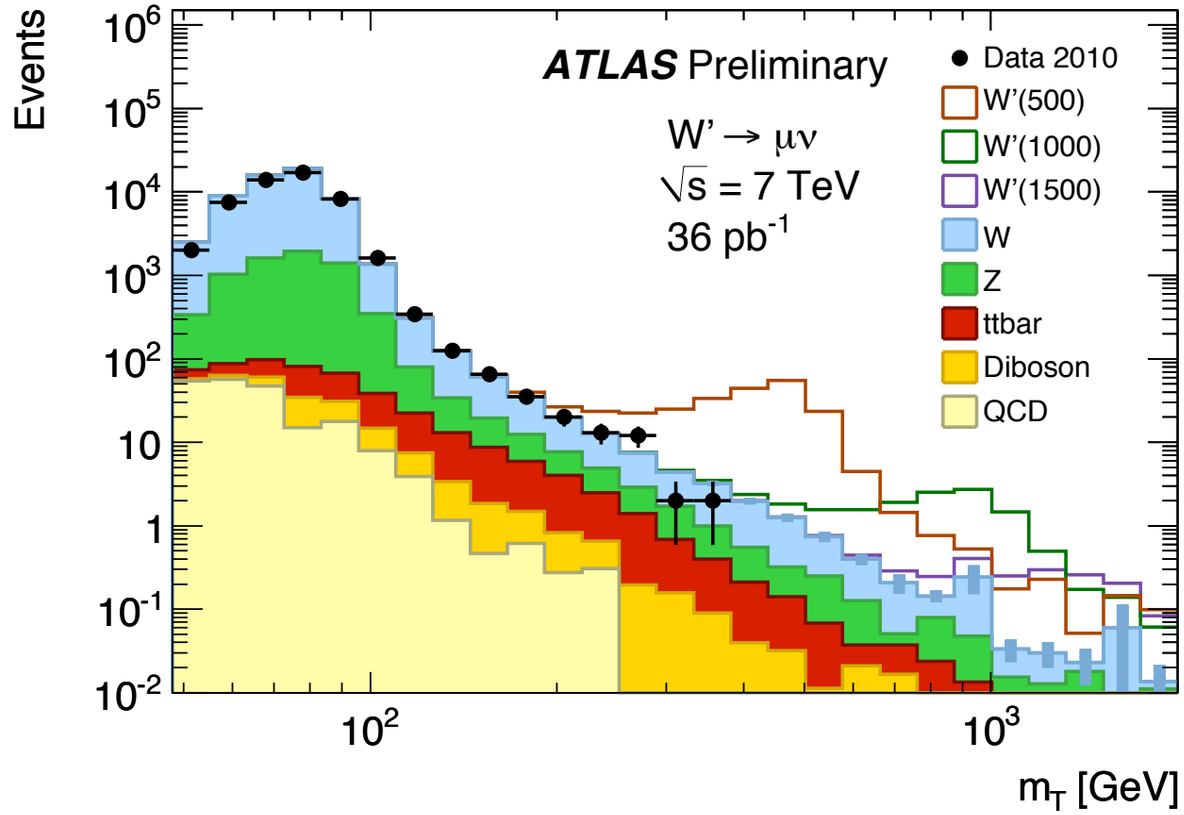


Require 3 muon stations, $|\eta| < 1.05$



Looking for Signal





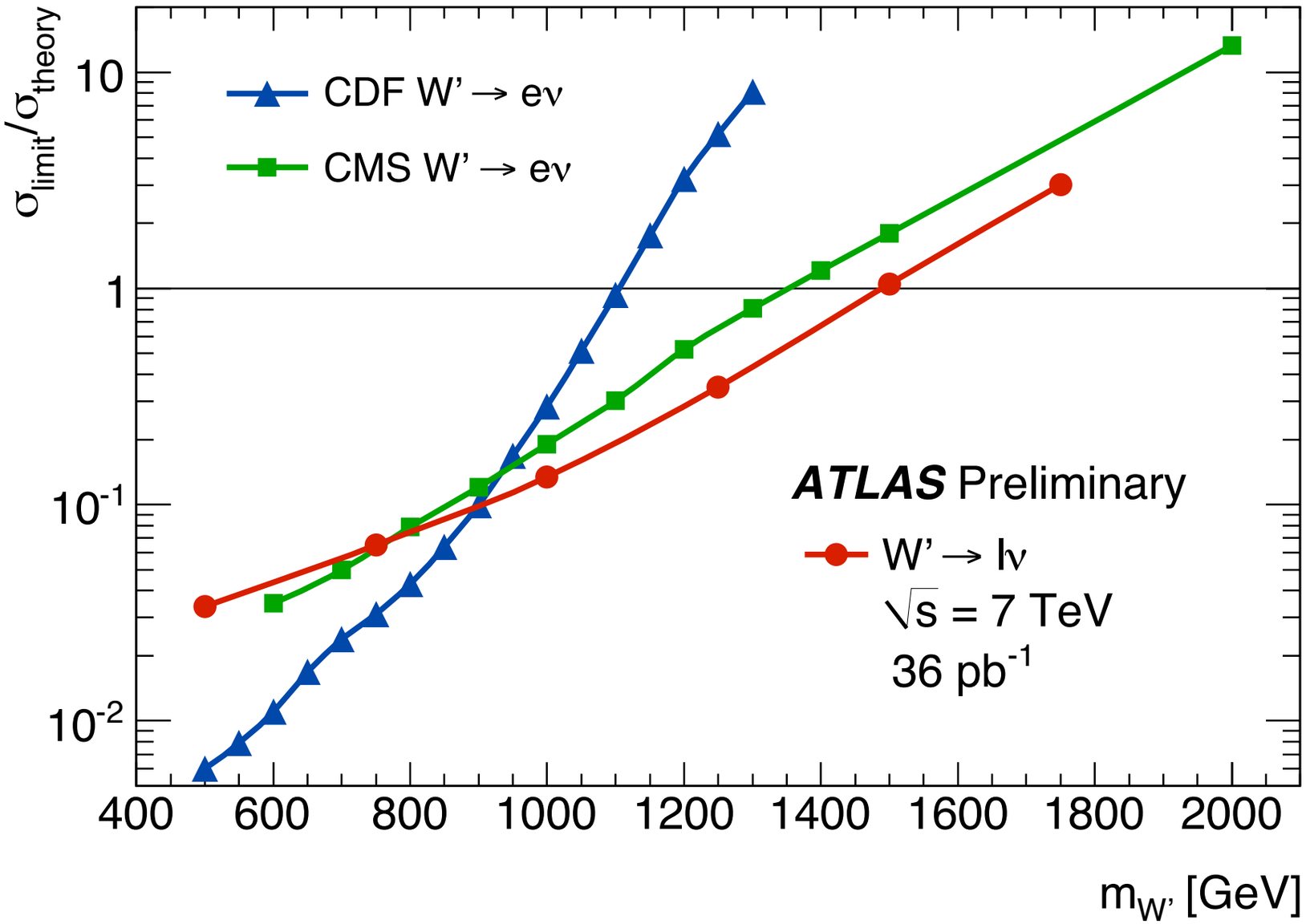
Look in the tails of the Transverse Mass distribution

Observing no signal, set limits combining the two channels: W' > 1.49 TeV at 95% confidence level

Electron channel: 1.36 TeV Muon channel: 1.29 TeV

Limits on W’

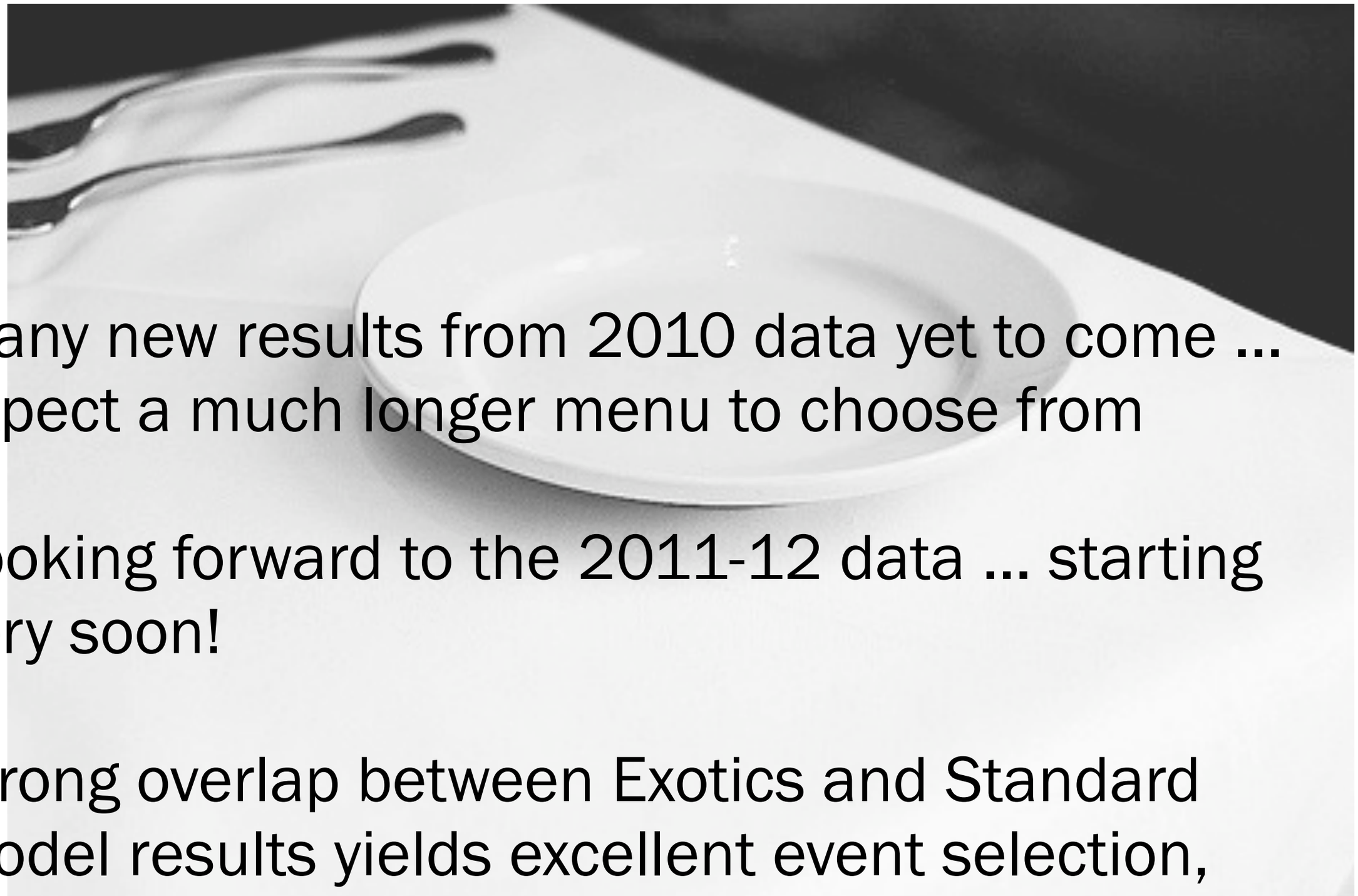
Combination of electron and muon channels yields best limits



Also place limits on W* (charged partner of chiral boson doublet)

m_{W^*} > 1470 GeV (1380 e, 1210 mu)

Still hungry?



- Many new results from 2010 data yet to come … expect a much longer menu to choose from
- Looking forward to the 2011-12 data … starting very soon!
- Strong overlap between Exotics and Standard Model results yields excellent event selection, background estimation, 2011-ready analyses

2010-2012 dataset is and will be exciting for exotics!

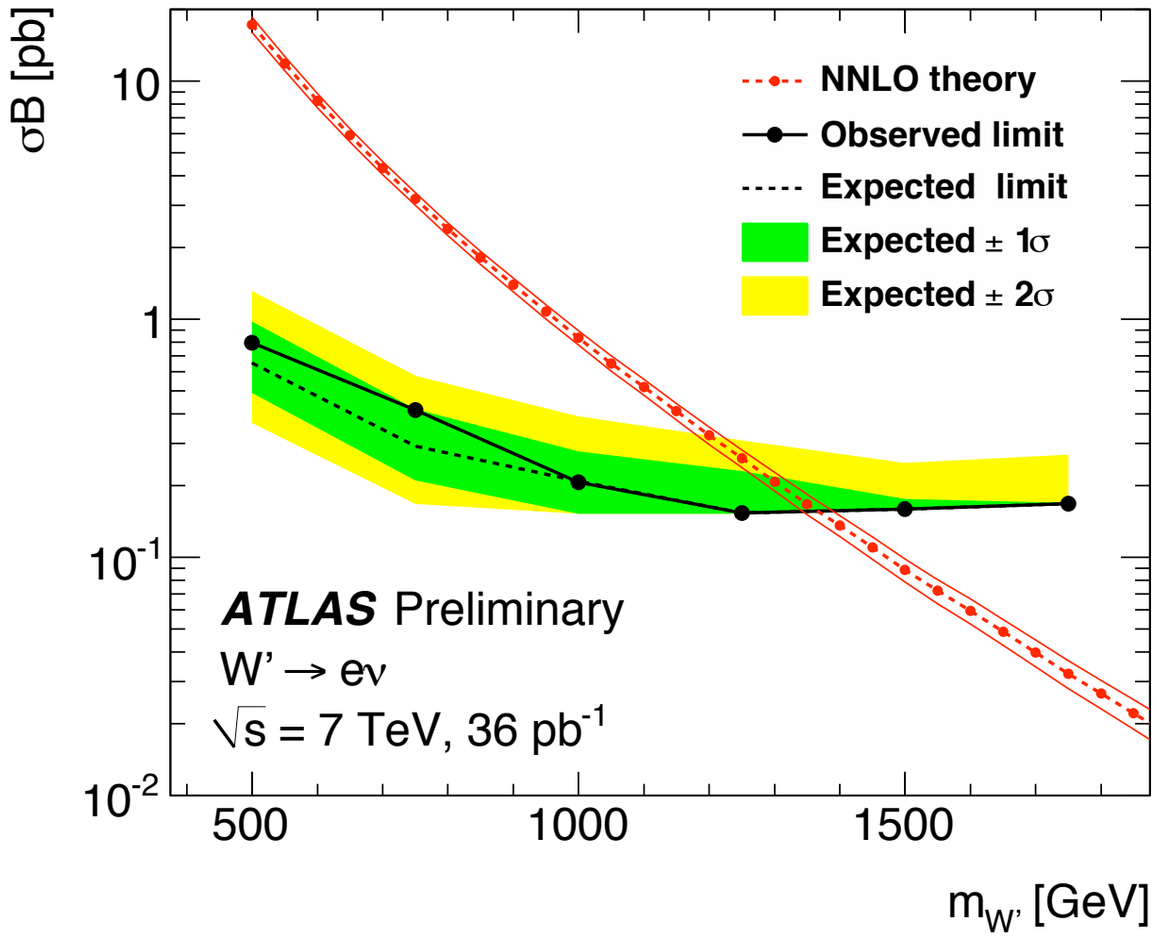
Excited quarks
Gravitons
Black Holes
Contact Interactions
Highly Ionizing Particles
Extra Dimensions
New gauge bosons
Leptoquarks
Majorana neutrinos
...
A wide, wide range of signatures to explore

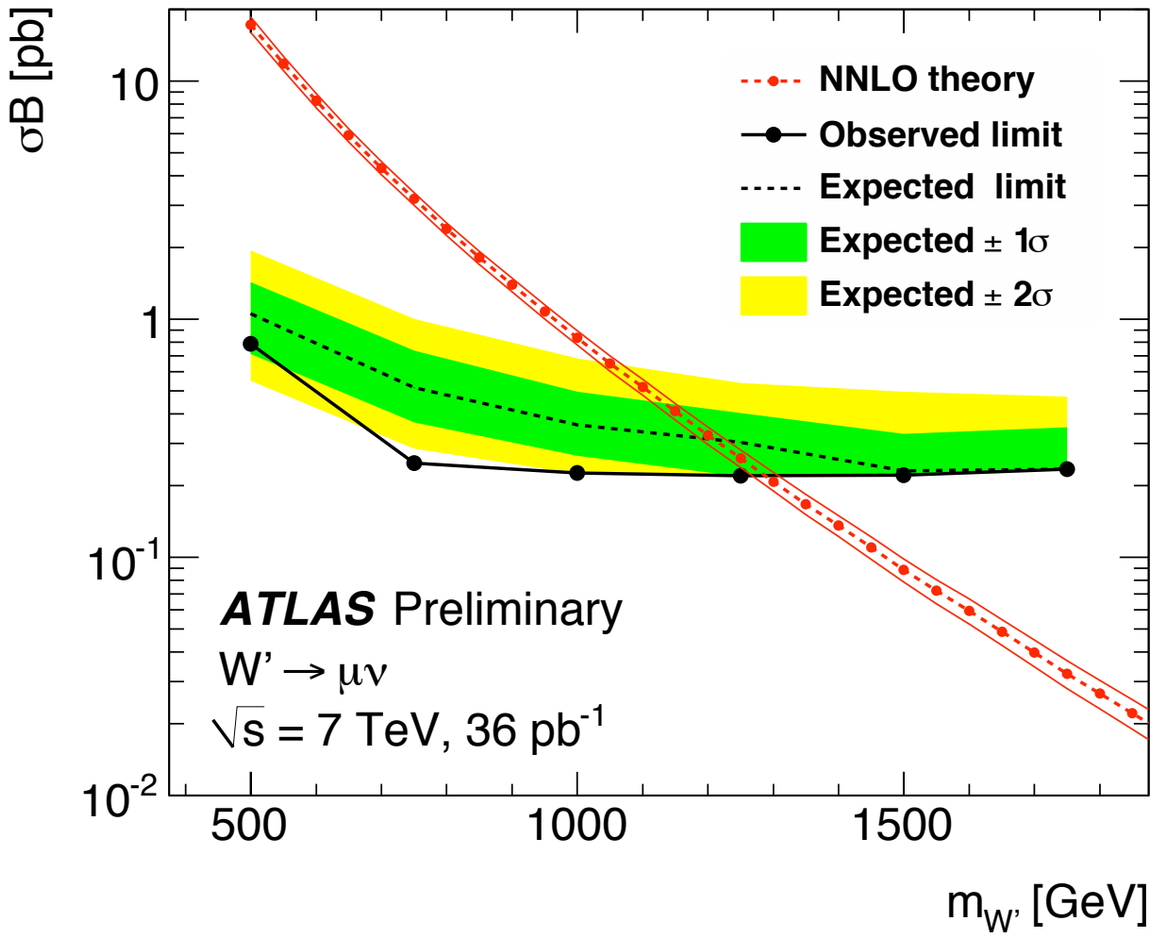
???

All these and more!

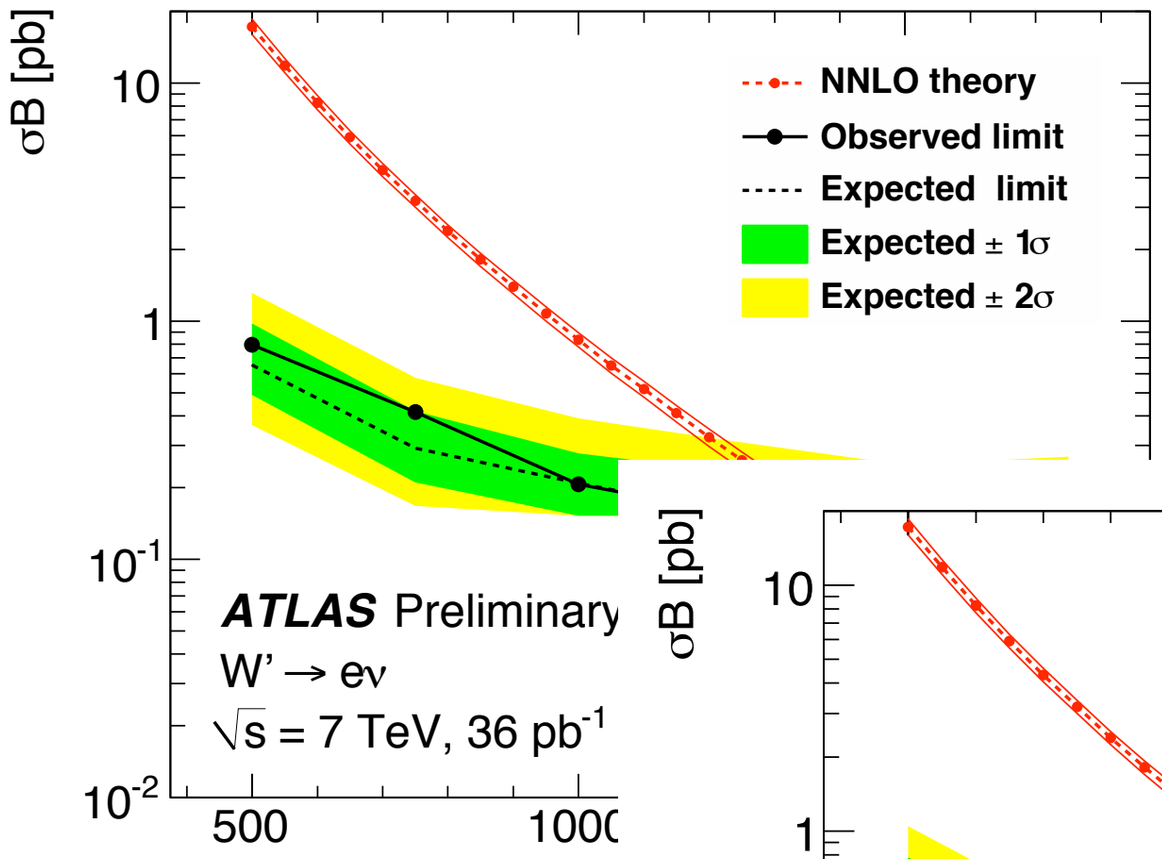
Backup Slides

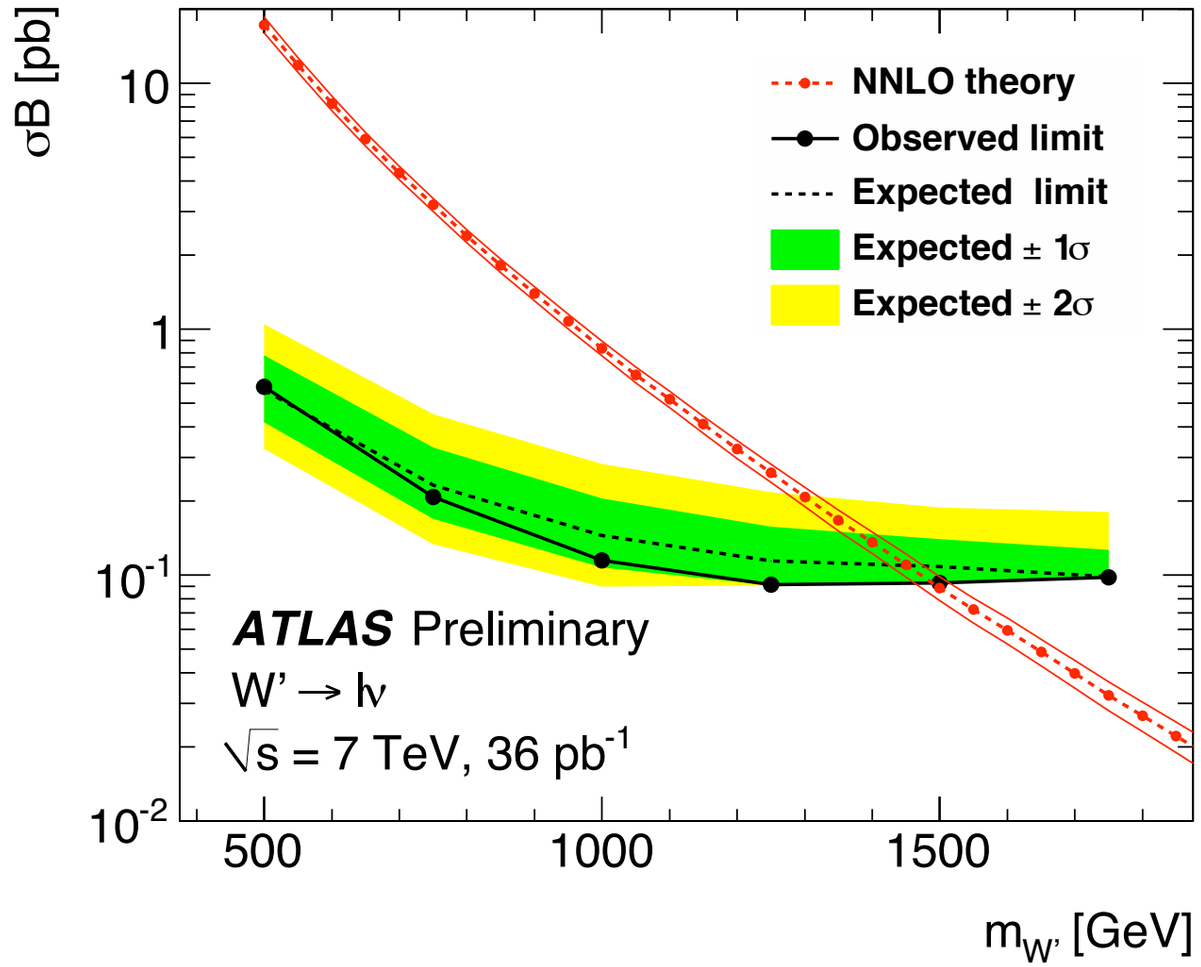
Limits for W’

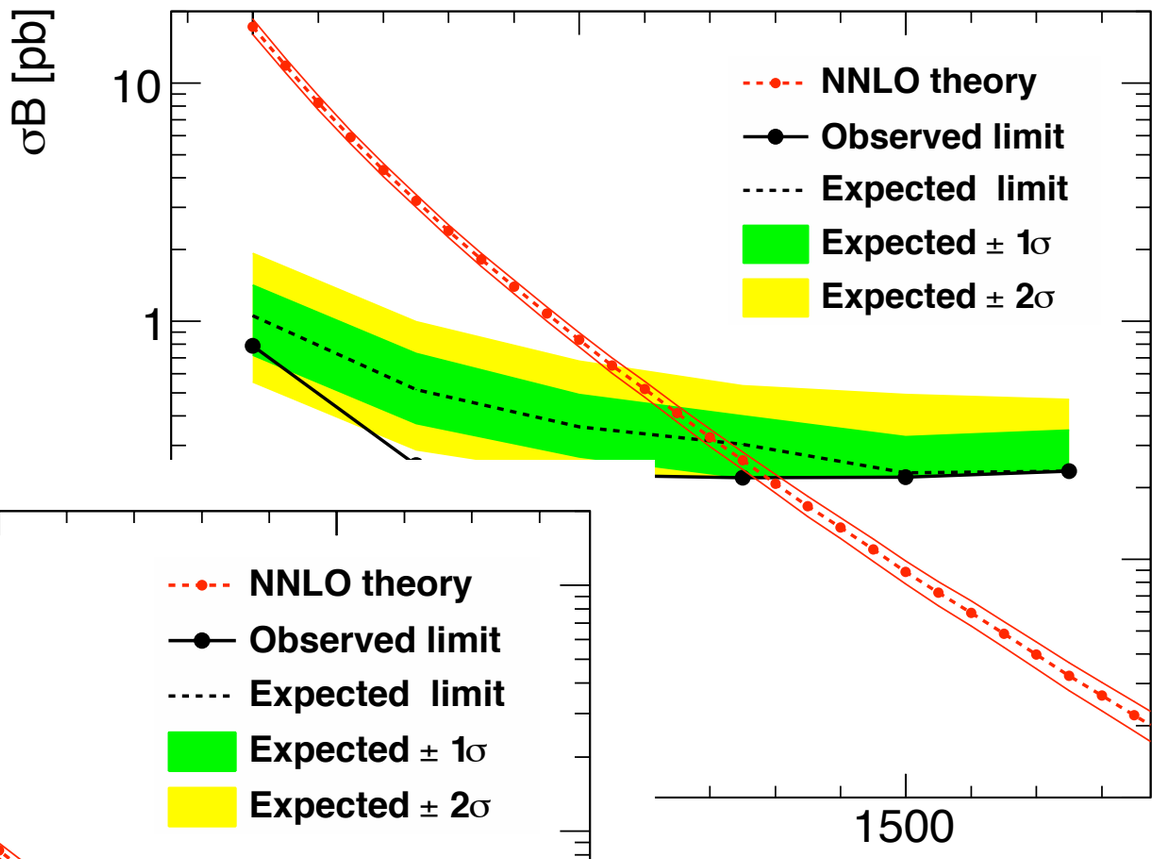

σB [pb]
10
1
10^-1
10^-2
NNLO theory
Observed limit
Expected limit
Expected ± 1σ
Expected ± 2σ
ATLAS Preliminary
W’ → eν
√s = 7 TeV, 36 pb^-1
500
1000
1500
m_W’ [GeV]


σB [pb]
10
1
10^-1
10^-2
NNLO theory
Observed limit
Expected limit
Expected ± 1σ
Expected ± 2σ
ATLAS Preliminary
W’ → μν
√s = 7 TeV, 36 pb^-1
500
1000
1500
m_W’ [GeV]

Limits for W’


σB [pb]
10
1
10^-1
10^-2
NNLO theory
Observed limit
Expected limit
Expected ± 1σ
Expected ± 2σ
ATLAS Preliminary
W’ → eν
√s = 7 TeV, 36 pb^-1
500
1000


σB [pb]
10
1
10^-1
10^-2
NNLO theory
Observed limit
Expected limit
Expected ± 1σ
Expected ± 2σ
ATLAS Preliminary
W’ → lν
√s = 7 TeV, 36 pb^-1
500
1000
1500
m_W’ [GeV]


σB [pb]
10
1
NNLO theory
Observed limit
Expected limit
Expected ± 1σ
Expected ± 2σ
1500
m_W’ [GeV]

W* Model

We will consider new spin-1 bosons with the internal quantum numbers identical to the Standard Model Higgs doublet, transforming under fundamental representation of $SU(2)_L$ and solving the Hierarchy Problem.

$$\begin{pmatrix} H^+ \\ H^0 \end{pmatrix} \leftrightarrow \begin{pmatrix} W^{*+}_\mu \\ Z^*_\mu \end{pmatrix}$$

M. V. Chizhov, V. A. Bednyakov, and J. A. Budagov, Physics of Atomic Nuclei **71**, 2096 (2008), ISSN 1063-7788.

M. V. Chizhov and G. Dvali (2009), 0908.0924v1.

M. V. Chizhov, V. A. Bednyakov, and J. A. Budagov, Nuovo Cimento **C33**, 343 (2010).

Dijet Models & MC

Resonance search cuts:

$$p_{\mathrm{T}}^{j_1} > 150 \text{ GeV}$$

$$|\eta_j| < 2.5 \text{ and } |\Delta\eta_{jj}| < 1.3$$

Angular analysis cuts:

$$p_{\mathrm{T}}^{j_1} > 60 \text{ GeV}$$

$$p_{\mathrm{T}}^{j_2} > 30 \text{ GeV}$$

$$|y^*| < 1.70 \quad |y_{1,2}| < 2.8$$

$$|y_B| < 1.10$$

$$y \to y - y_B = y - \tanh^{-1}(\beta_B)$$

Fully simulated Pythia q*, RS Graviton, contact interaction + QCD samples

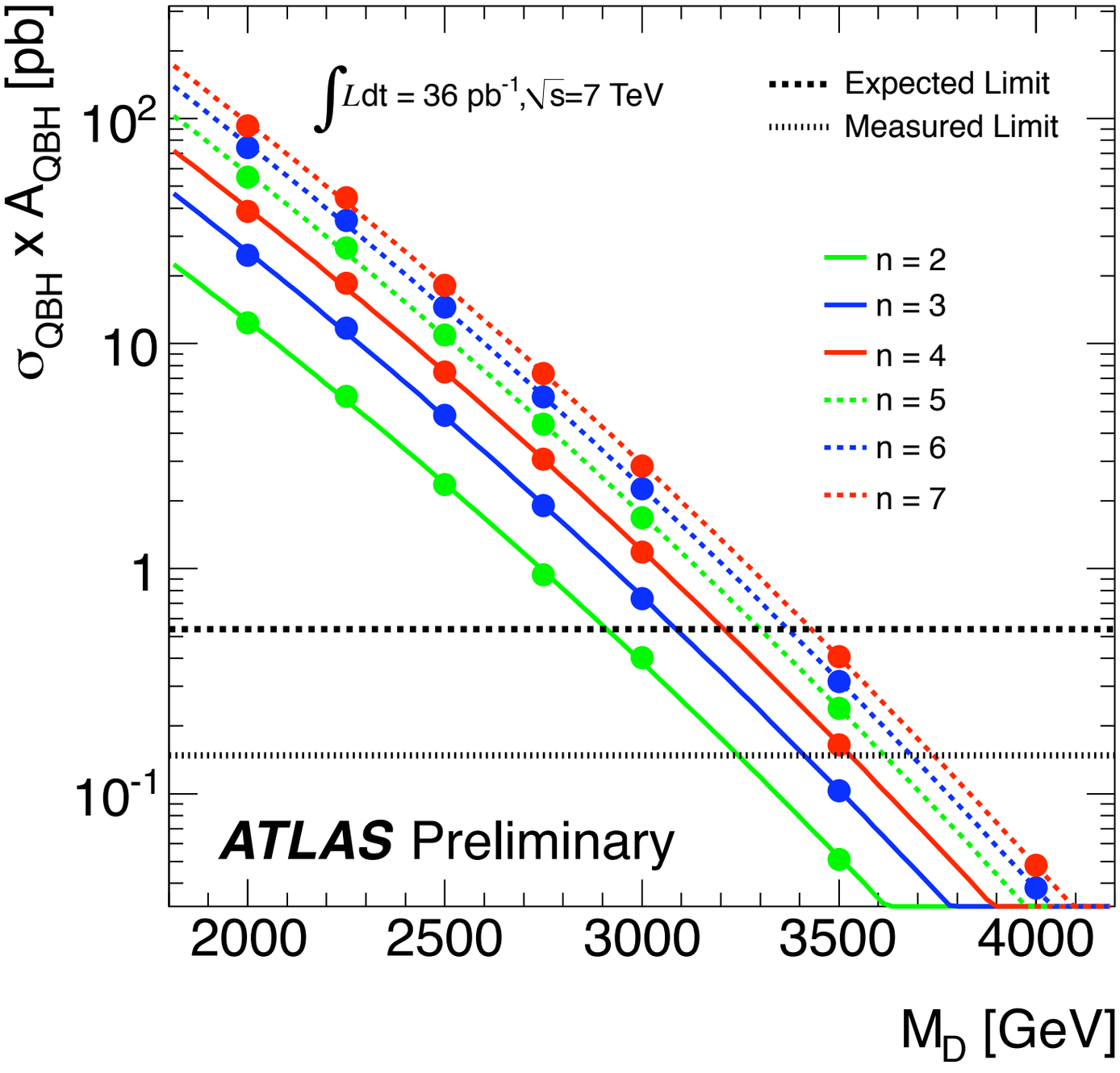
Pythia QCD for angular analyses (plus k factor from NLOJet++)

Randall-Meade low multiplicity quantum black holes from Blackmax+Pythia

- Fully simulated for six extra dimensions

Axigluons from CalcHEP+Pythia

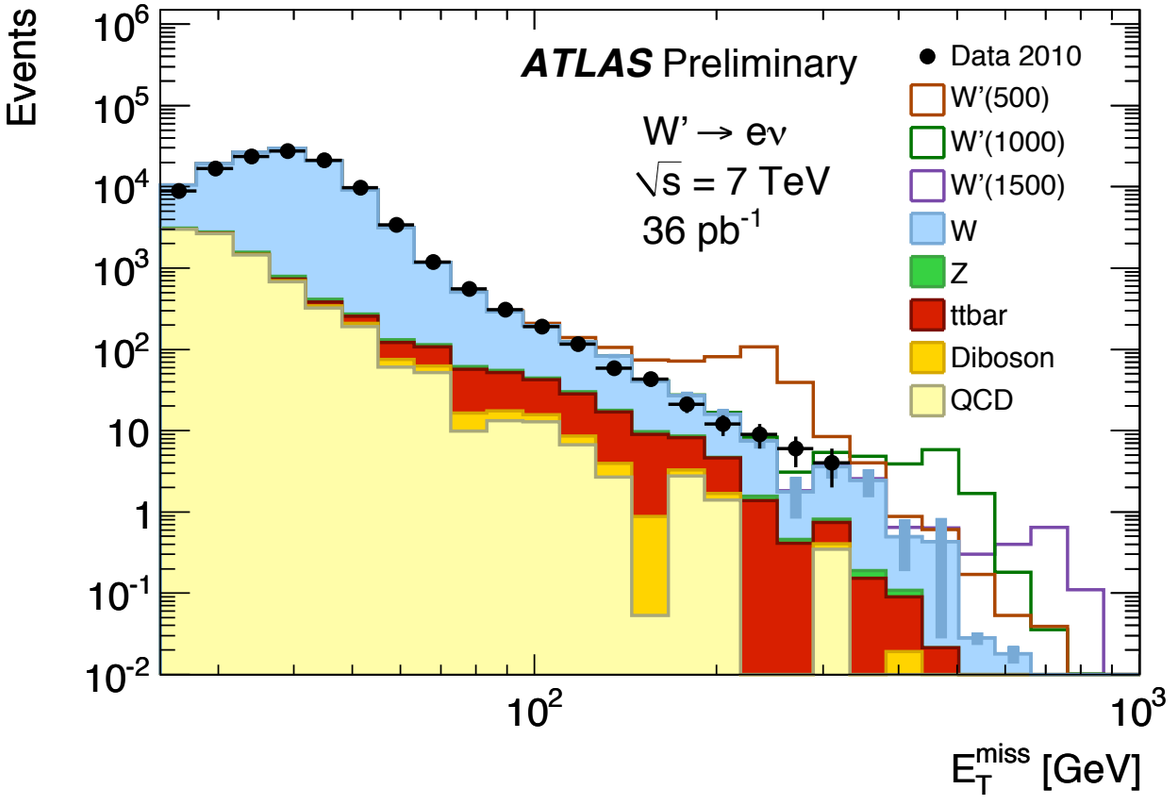
Quantum Black Holes

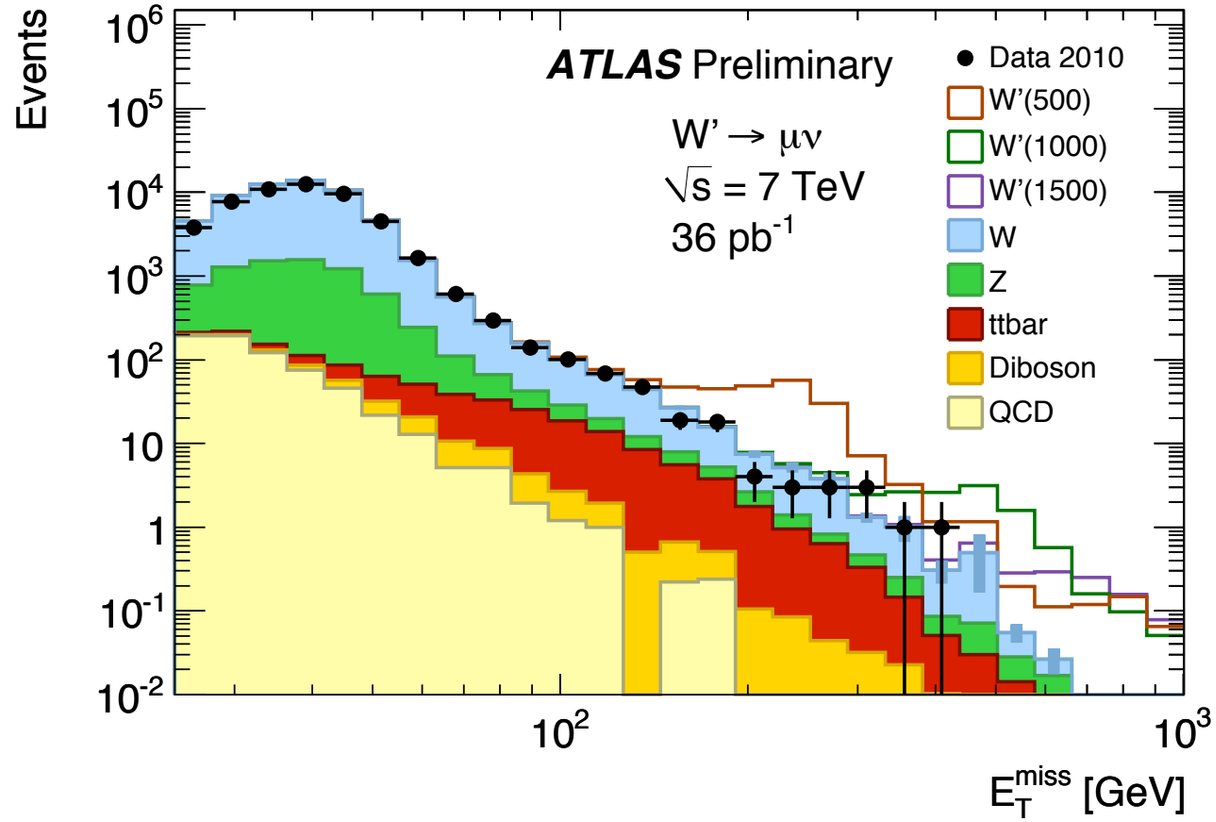


Used BlackMax to simulate a simple two-body decay for a given fundamental quantum gravity scale, M_D.

n = number of extra space time dimensions

Missing Transverse Energy

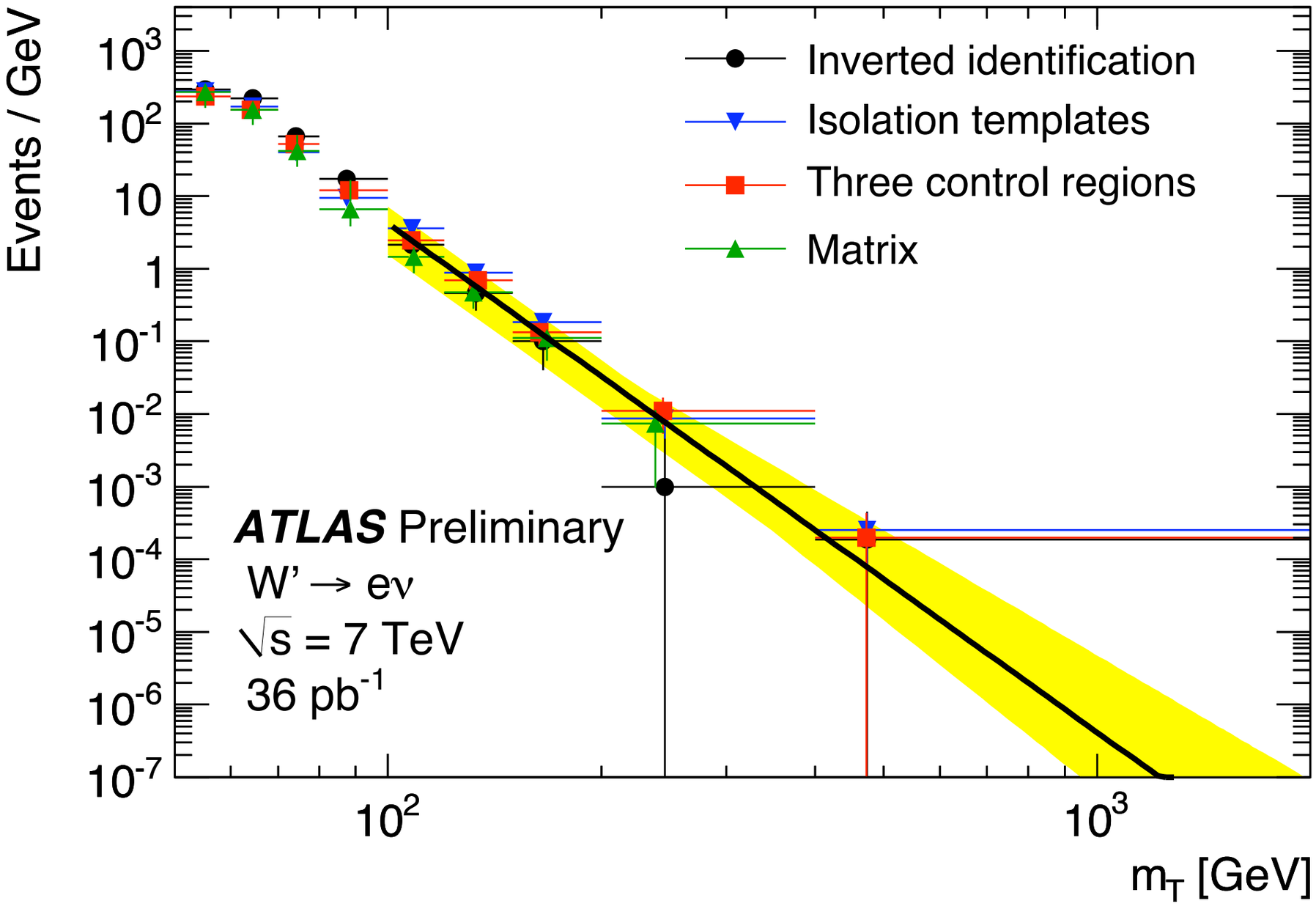




MET must be well-modeled for this and other searches

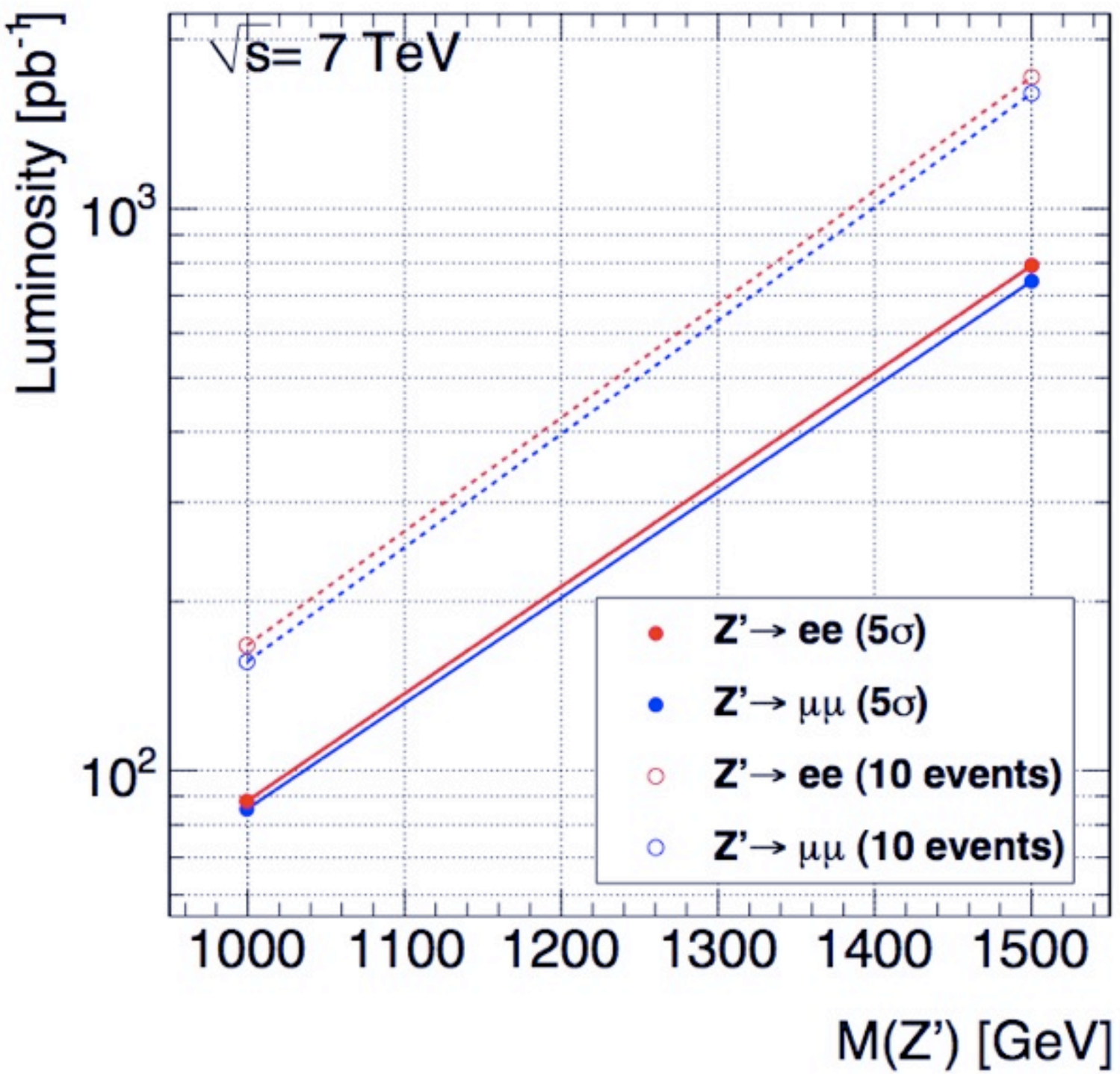
Use data-driven QCD background estimates

W' backgrounds



Multiple data-driven methods used for QCD

Z' Sensitivity Study for 7 TeV



ATLAS CONF note available with W' and Z' prospects