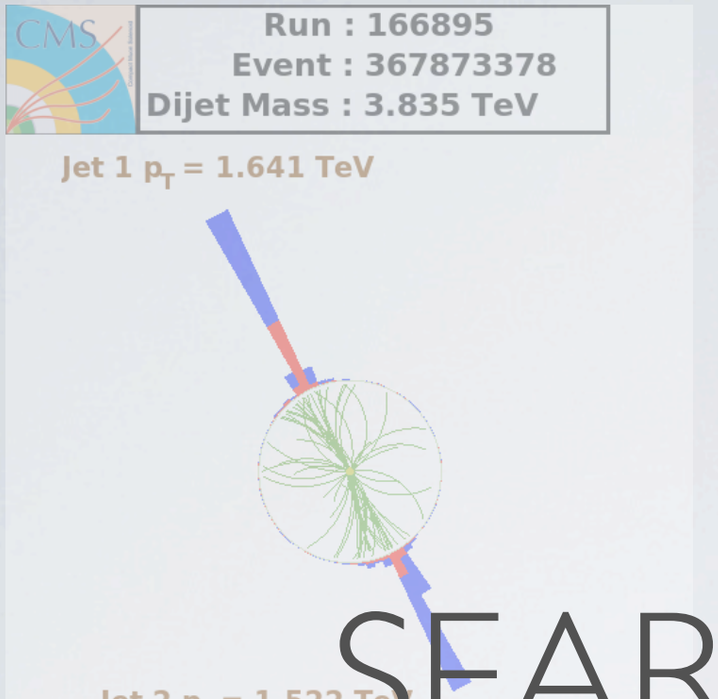
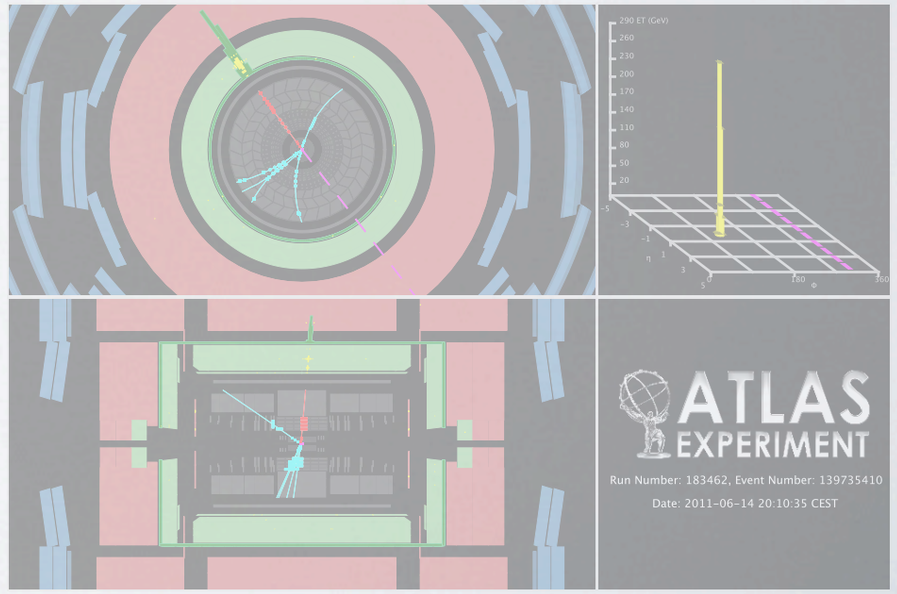


SEARCHES FOR NEW PARTICLES AT THE LHC

James Degenhardt
University of Pennsylvania

Blois 2012



DI-JET RESONANCES

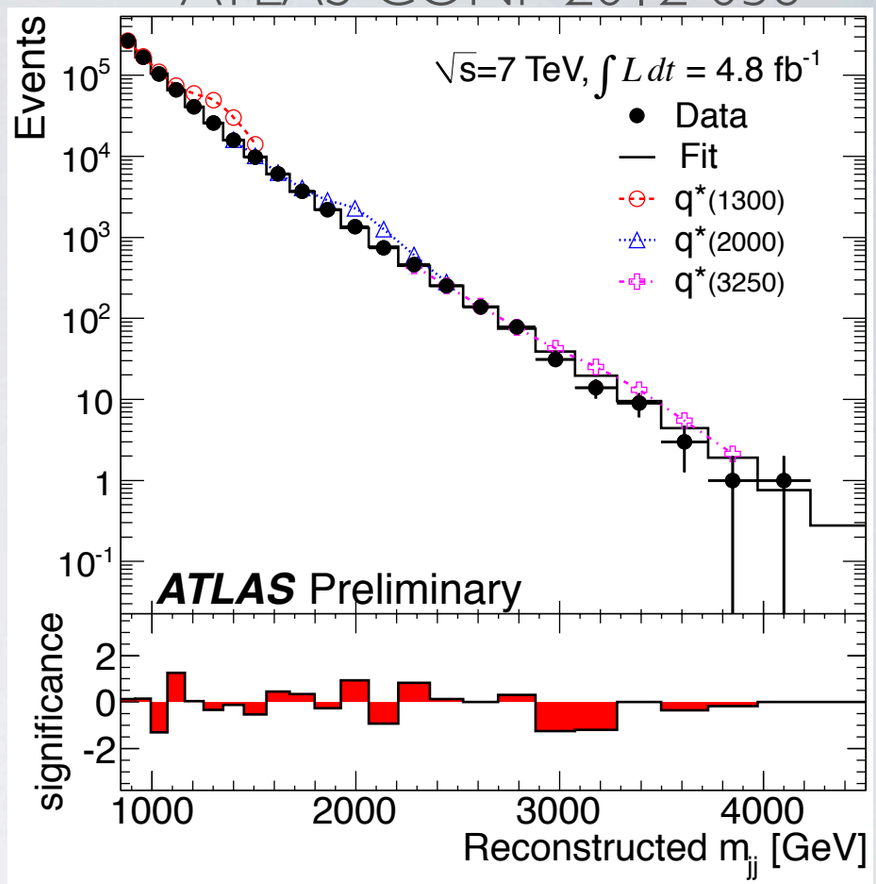
- A direct search for new particle resonances: **Scalar Color Octet (s8)**, **excited quarks (q*)**.

- Di-jet background is fit using the given function to minimize statistical fluctuations.

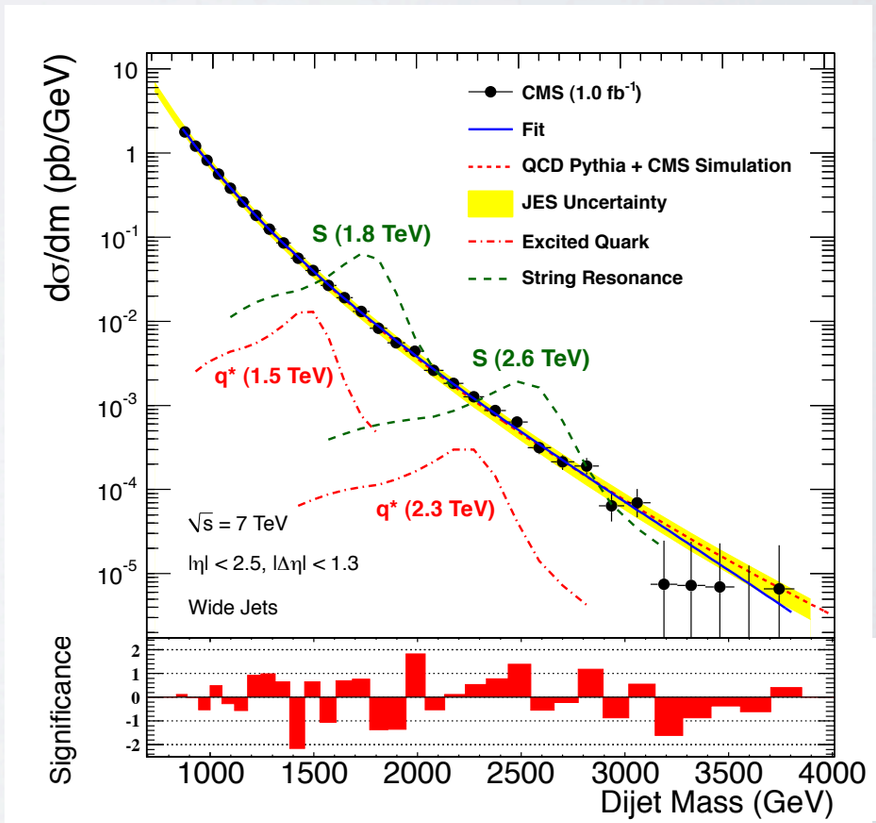
- New Phenomena (NP) are manifested as Bumps or gradual excesses in the mass and angular distributions.

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

ATLAS-CONF-2012-038



CMS-PAS-EXO-11-015



DI-JET ANGULAR DISTRIBUTIONS

- Use angular distributions to search for other indications of new physics: **Contact Interactions (CI)**, **Quantum Black Holes (QBH)**.

$$\chi = \exp(|y_1 - y_2|)$$

- QCD di-jets are flat in χ.

- y_1 is the rapidity of the leading jet.

- NP will usually manifest an excess at low χ (not necessarily).

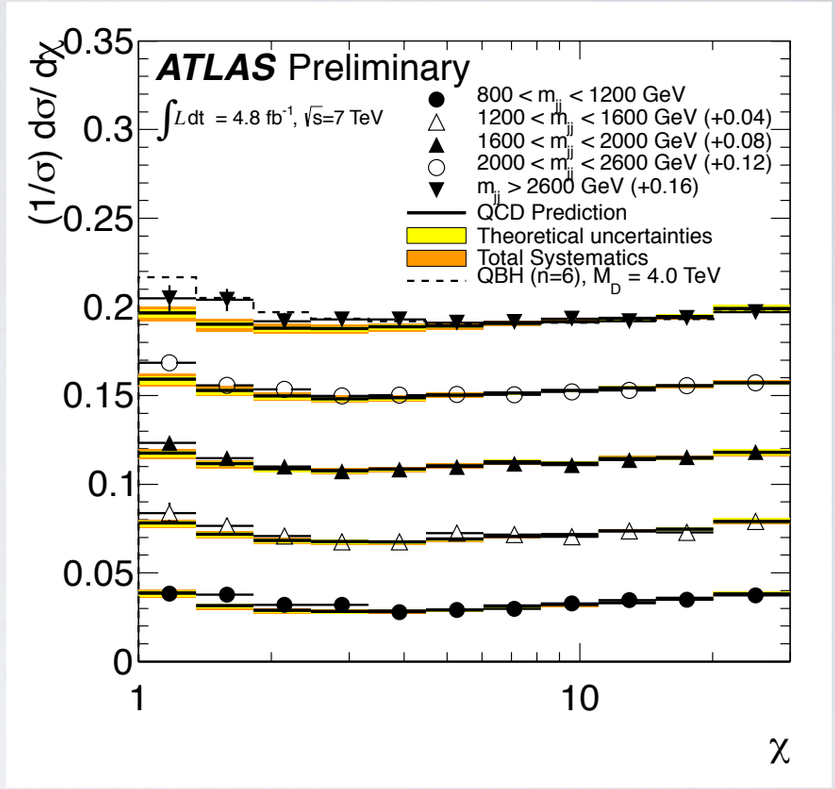
- F_χ is the fraction of central events to all events in the χ distribution.

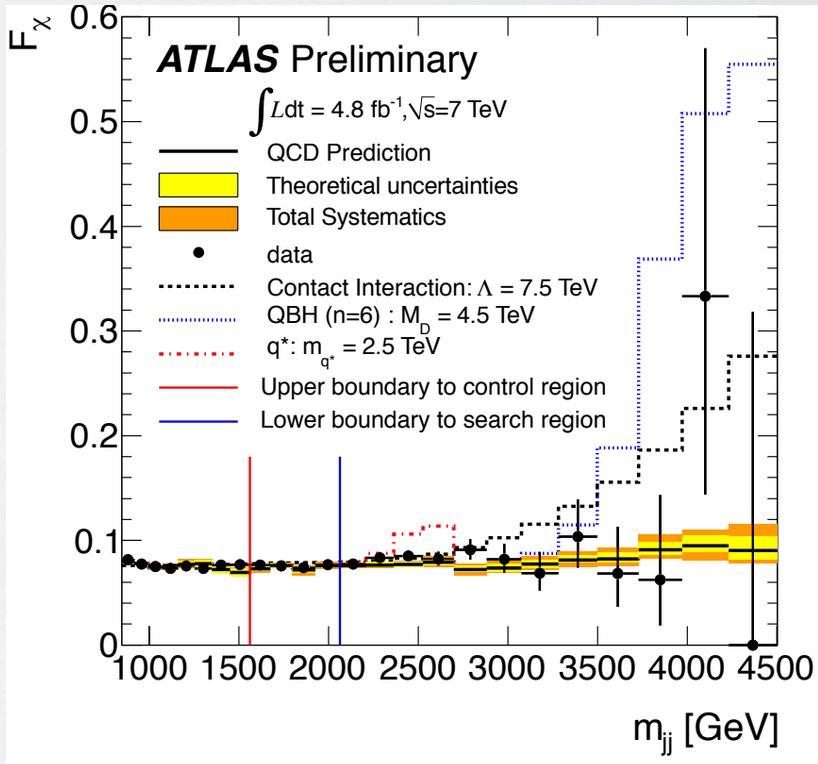
$$F_\chi = \frac{N_{\text{central}}}{N_{\text{total}}}$$

- Central is defined as $\chi < 3.32$.

- Total is defined as $\chi < 30$.

- A measure of isotropy of di-jet events.



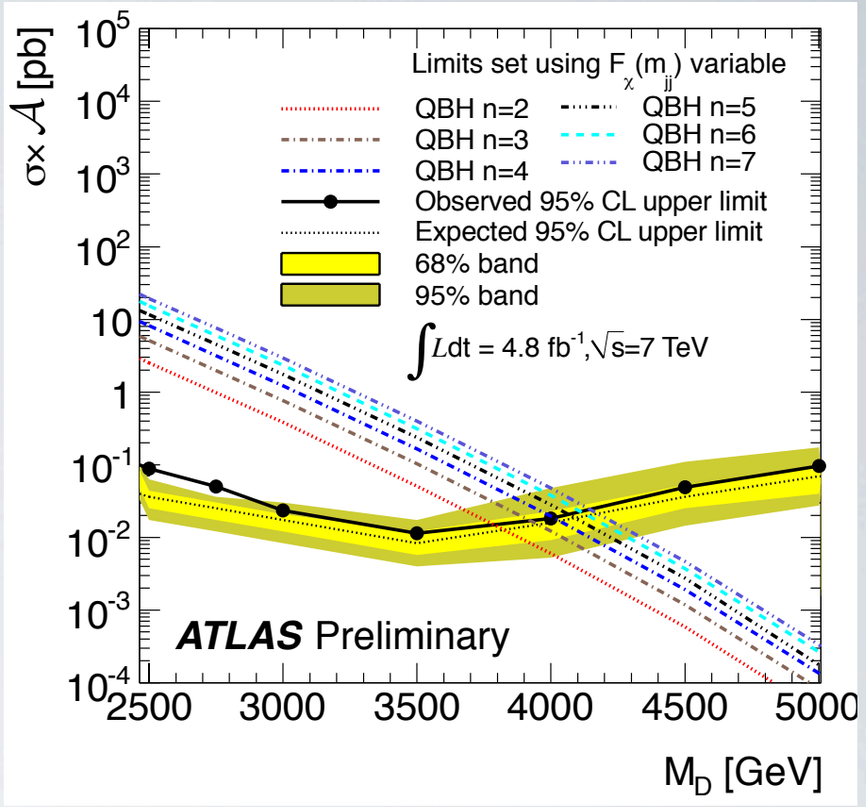


ATLAS-CONF-2012-038

DI-JET LIMITS

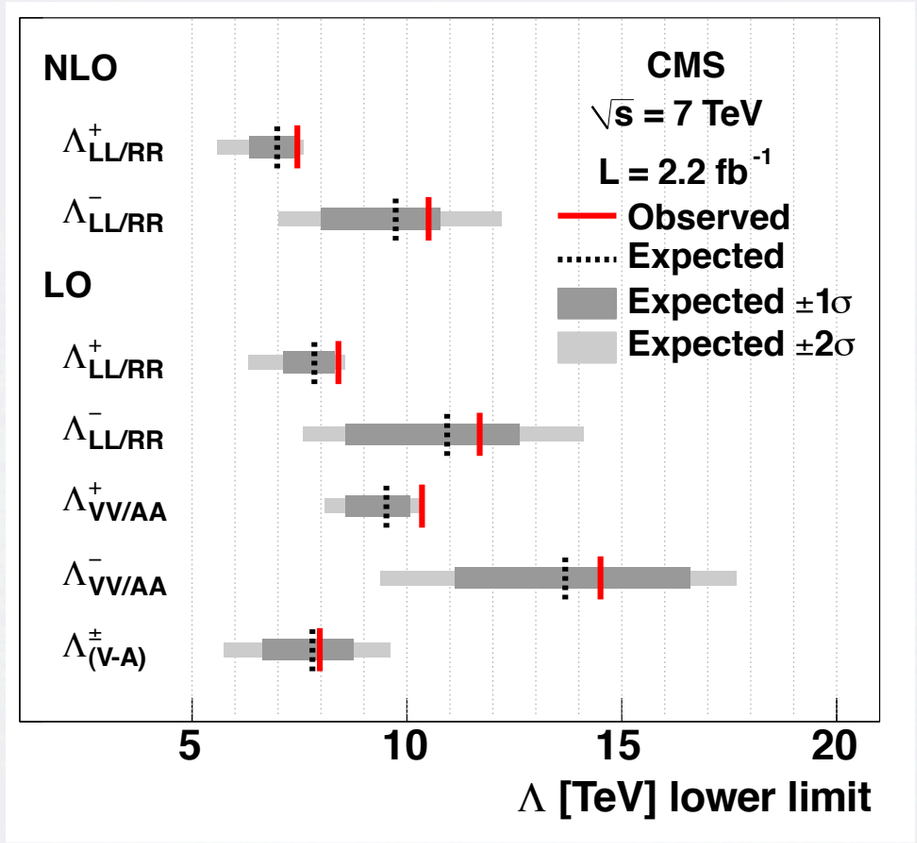
- Limits set on cross section times acceptance, using multiple techniques.
- Limits set using mass resonance on q* and s8 models.
- Limits on CI and QBH set using F_χ and χ distributions independently.

Model	Limit [TeV]
q* (m_{jj})	3.35(3.09)
q* (F_χ)	2.58(2.97)
s8 (m_{jj})	1.94(1.94)
QBH (F_χ)	4.11(4.14)
QBH (χ)	3.96(4.23)
CI(F_χ)	7.6(8.2)
CI(χ)	7.8(8.7)
String Res.	4.00(3.90)
E_6 diquarks	3.52(3.28)
Axigluons	2.47(2.66)
W′	1.51(1.40)



CMS-PAS-EXO-11-015

CMS-PAS-EXO-11-026



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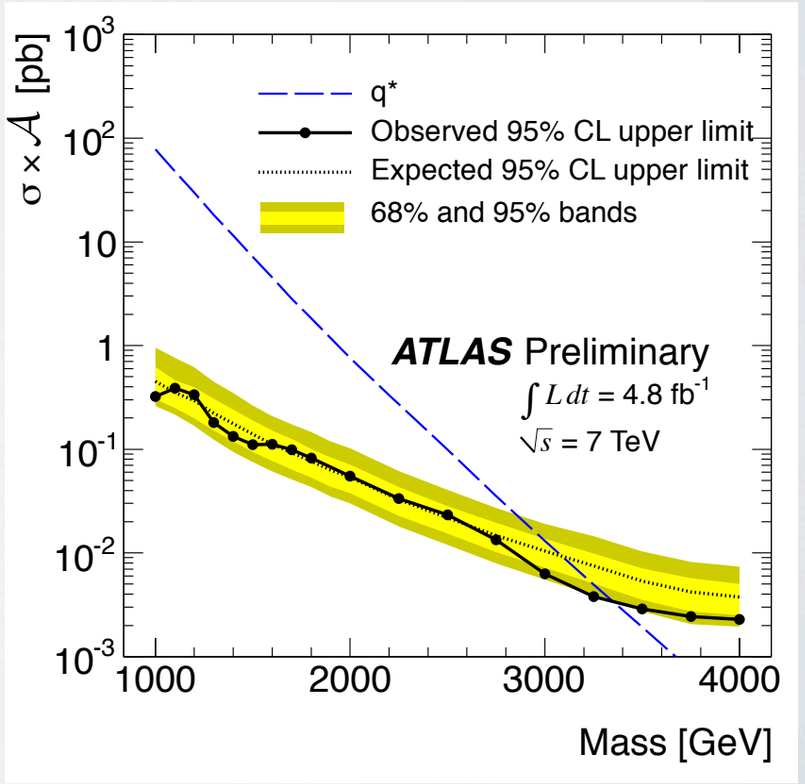


PHOTON + JET

- Use **excited quarks**(q*) as a benchmark. (other exotic models, **quirks**, **Regge excitations** of string theory, **topological pions**,postulate a γ + jet resonance.)

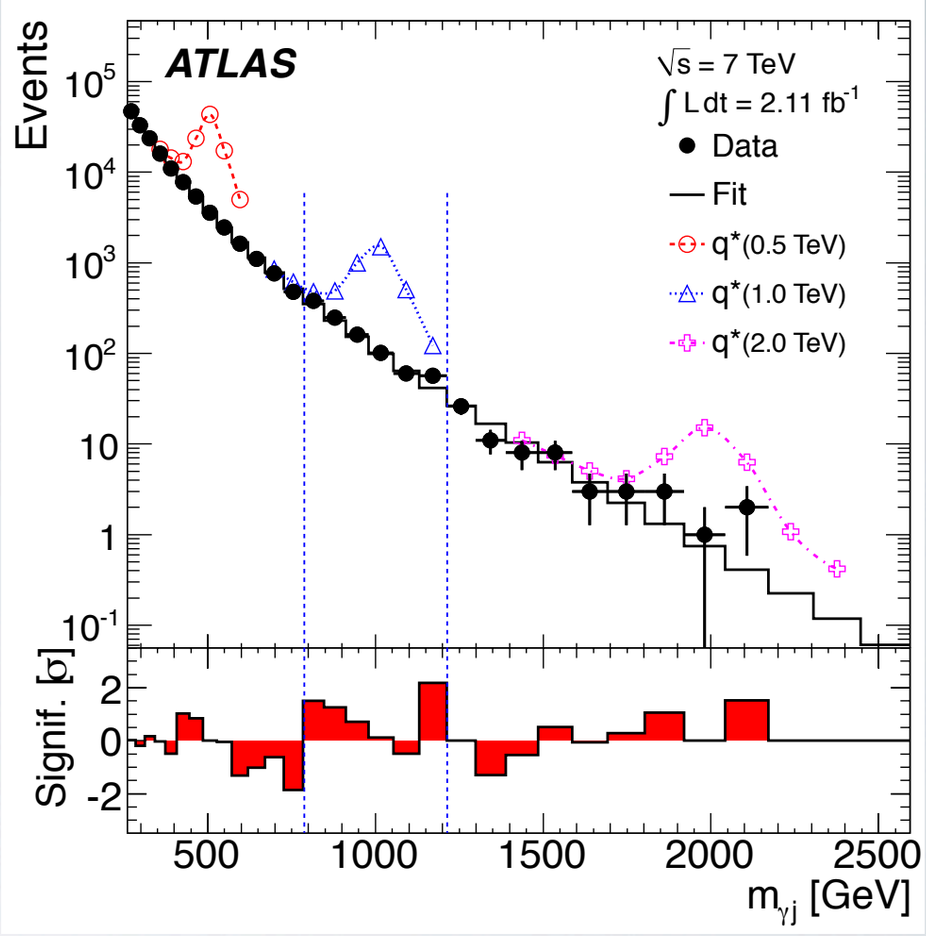
- SM γ + Jet production arrises from Compton scattering, qqbar annihilation, and final state radiation.

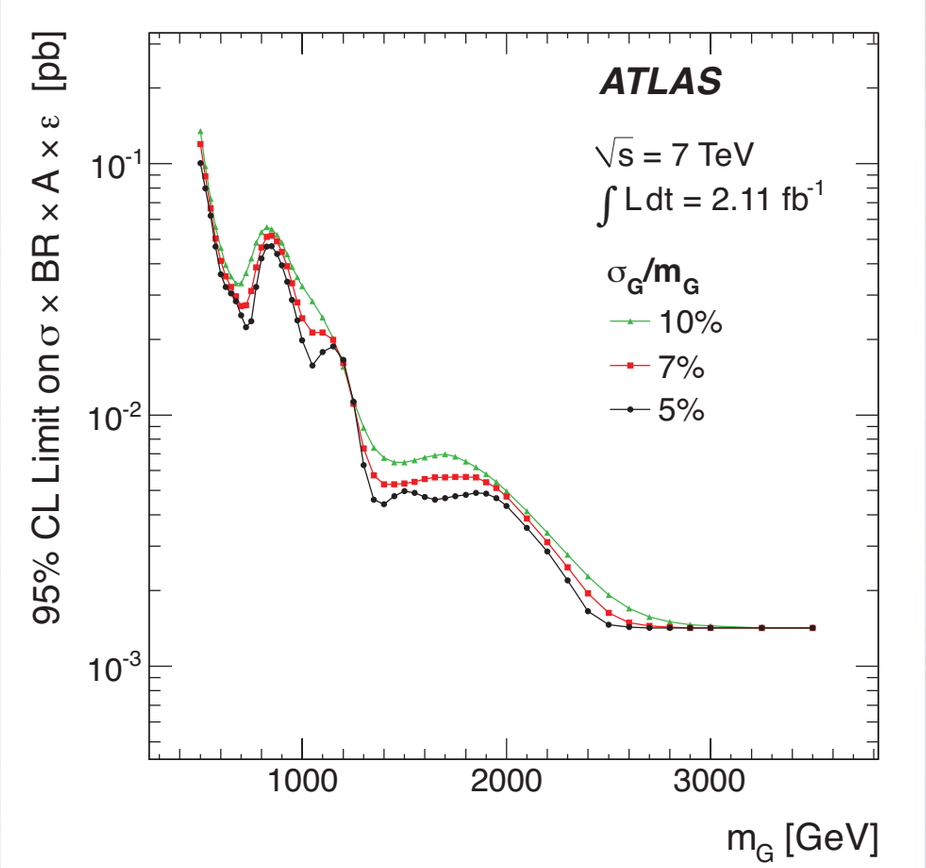
- For q* model; m_{q^*} set as compositeness scale, SU(3), SU(2), and U(1) coupling multipliers set to 1.

- These assumptions give, at $m_{q^*} = 2.5$ TeV, BR $(u^* \rightarrow ug(u\gamma)) = 0.85\ (0.02)$.

- q* excluded for masses below 2.46 TeV

- Limits also set on general gaussian resonance with varied widths.



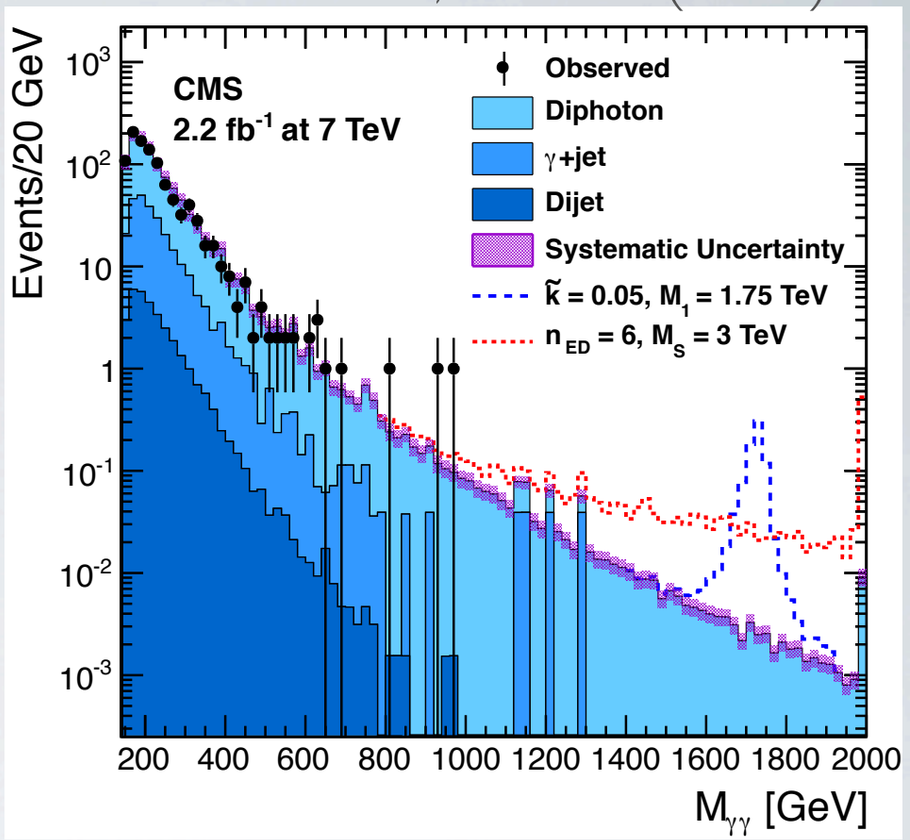


PRL vol. 108, 211802 (2012)

DI-PHOTONS

- Use di-photons mass distribution to search for **gravitons** in extra-dimensions: **Arkani-Hamed, Dimopoulos, Dvali** (ADD), and **Randall** and **Sundrum** (RS).
- RS (1 extra dimension) is characterized by the coupling parameter $k = \tilde{k}/\bar{M}_{Pl}$ [0.01 - 0.1], and M_1.
  - k is curvature of ED, $\bar{M}_{Pl}$ is reduced plank scale, M_1 is the resonance central value.
  - Search for resonances peaks in wide mass windows.
- ADD is characterized by M_s or η_G.
  - M_s is an ultra violet cut off, η_G is a parameter related to M_s and the graviton production.
  - Search for excess > 0.9 TeV.

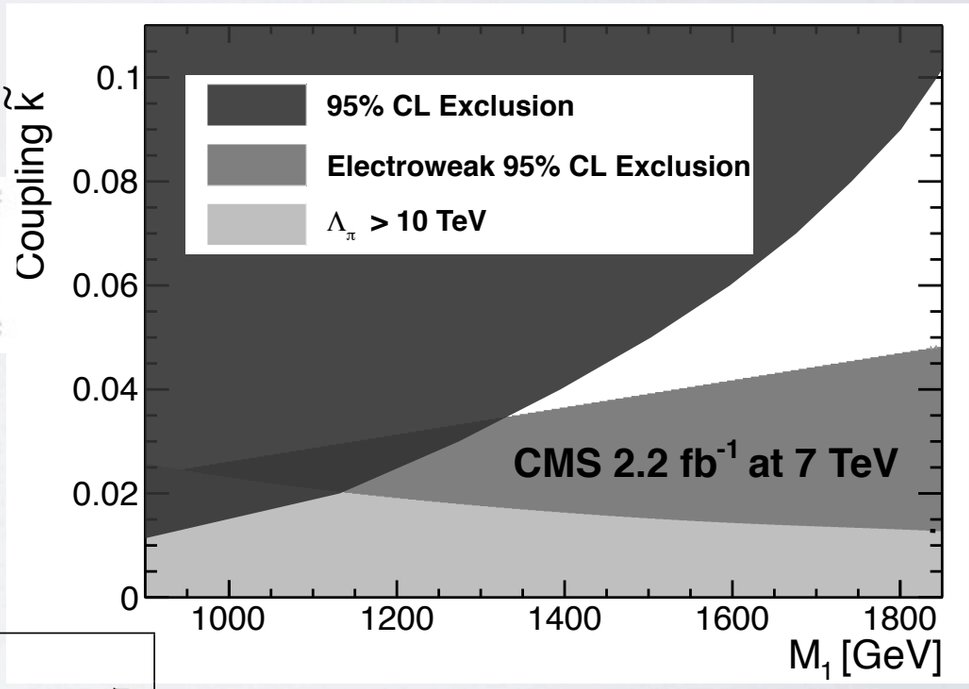
PRL vol. 108, 111801 (2012)



$S \equiv (\sigma_{tot} - \sigma_{SM}) \times B \times A$

$\tilde{k}$	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11
M_1 [TeV]	0.86	1.13	1.27	1.39	1.50	1.59	1.67	1.74	1.80	1.84	1.88

K factor	GRW	Hewett		HLZ (n_{ED})					
		pos.	neg.	2	3	4	5	6	7
1.0	2.94	2.63	2.28	3.29	3.50	2.94	2.66	2.47	2.34
1.6	3.18	2.84	2.41	3.68	3.79	3.18	2.88	2.68	2.53



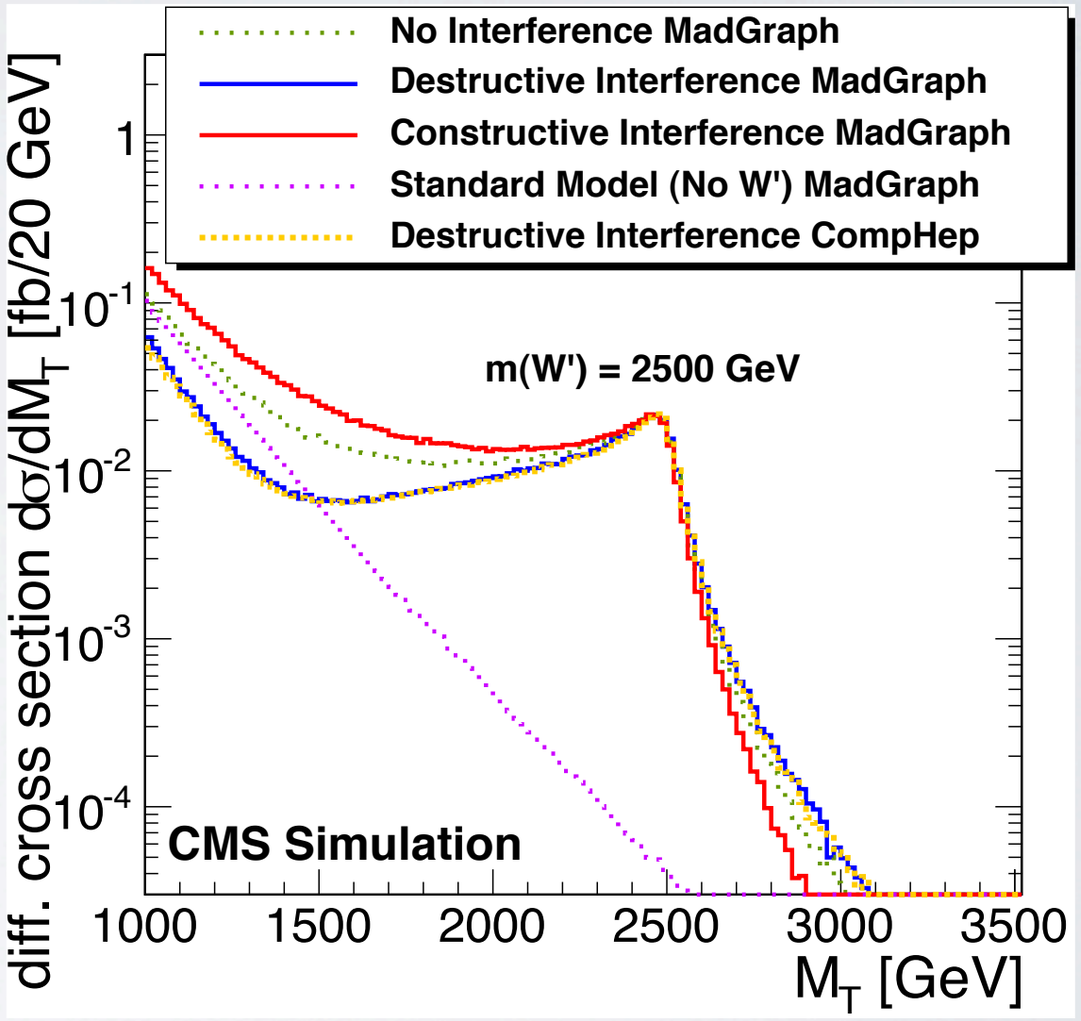
ADD K-factor	Λ_T [TeV] (GRW)	M_s [TeV] (HLZ)					
		$n=2$	$n=3$	$n=4$	$n=5$	$n=6$	$n=7$
$\mu\mu$, ee, and $\gamma\gamma$							
1.3 ($\mu\mu$ and ee), 1.6 ($\gamma\gamma$)	3.3	4.1	3.9	3.3	3.0	2.8	2.6

PLB. 710 (2012) 538-556

W PRIME

- Search for massive resonance in m_T of a lepton and missing energy, postulated by many Beyond the Standard Model (BSM) theories.
- Considered **L-R symmetric** models as well as interference in the **Sequential Standard Model** (SSM) framework.
- Depending on Interference the m_T spectra can be enhanced or reduced.
- Also considered are **Universal Extra Dimensions** (UED) or **Split-UED** models.
  - Model is characterized by R (size of ED) and μ (bulk mass parameter).
  - W^2_{kk} is only mode considered given the kinematic and theoretical constraints.
  - Decay to leptons is kinematically identical to SSM W′ .

arXiv:1204.4764

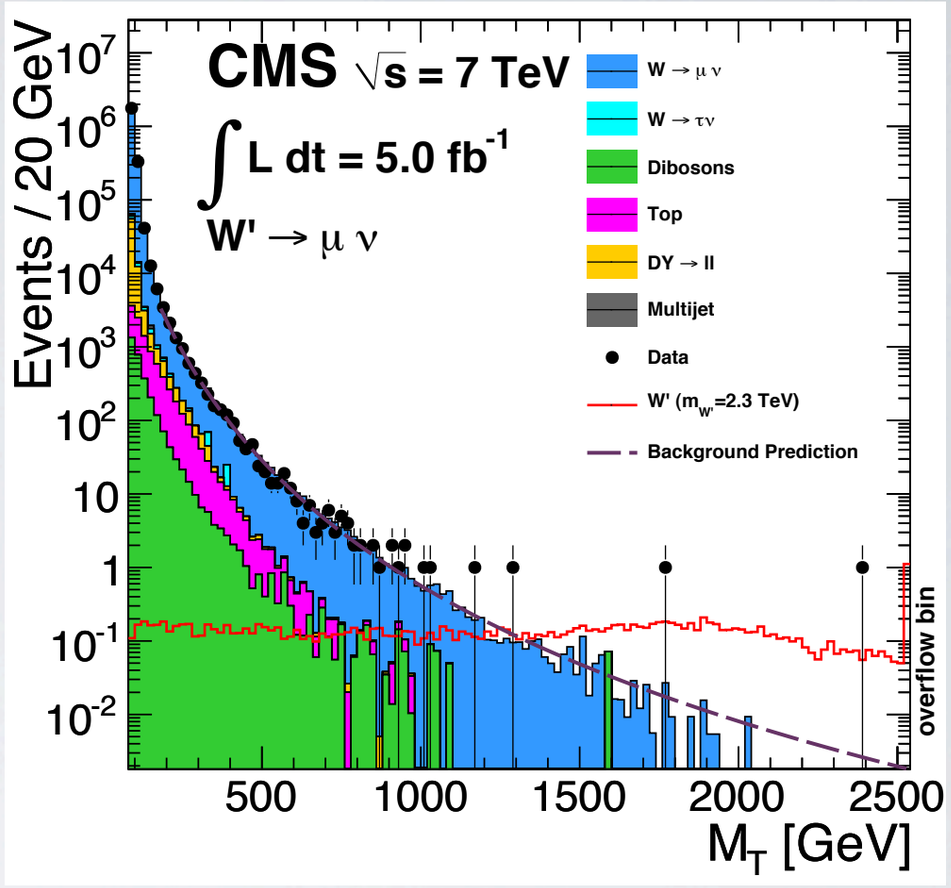


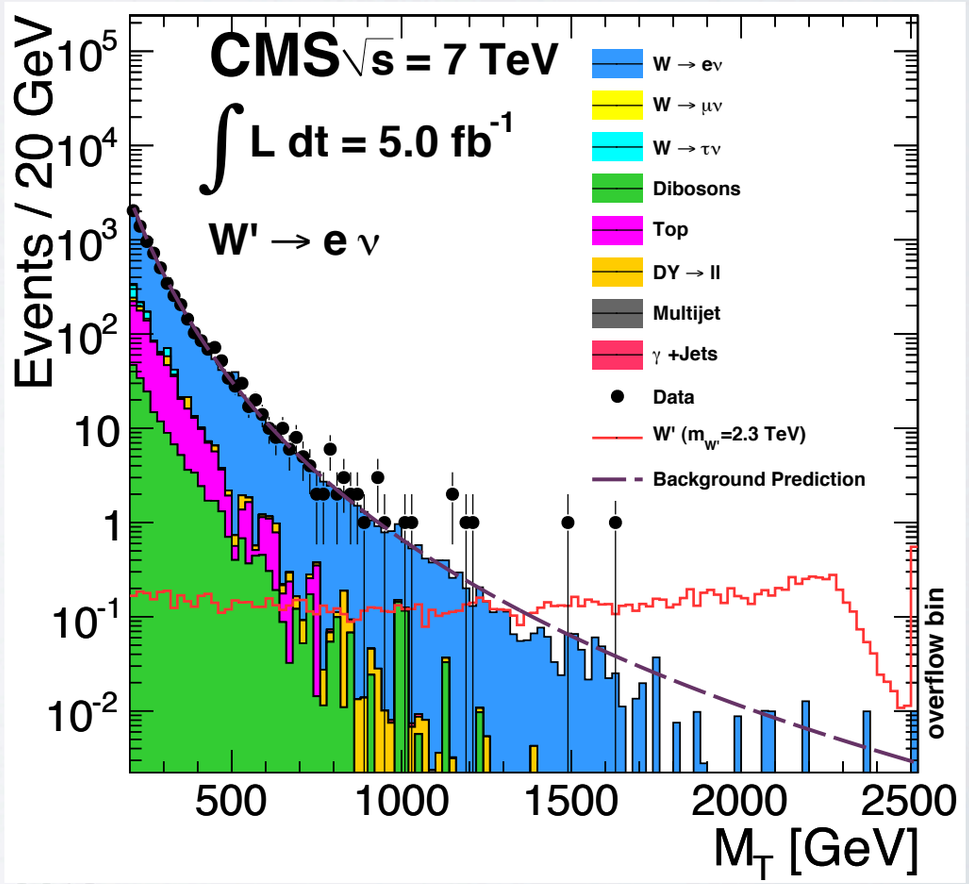
PLB. 705 (2011) 28-46

W PRIME

$$f(M_T) = \frac{a}{(M_T + b)^c}$$

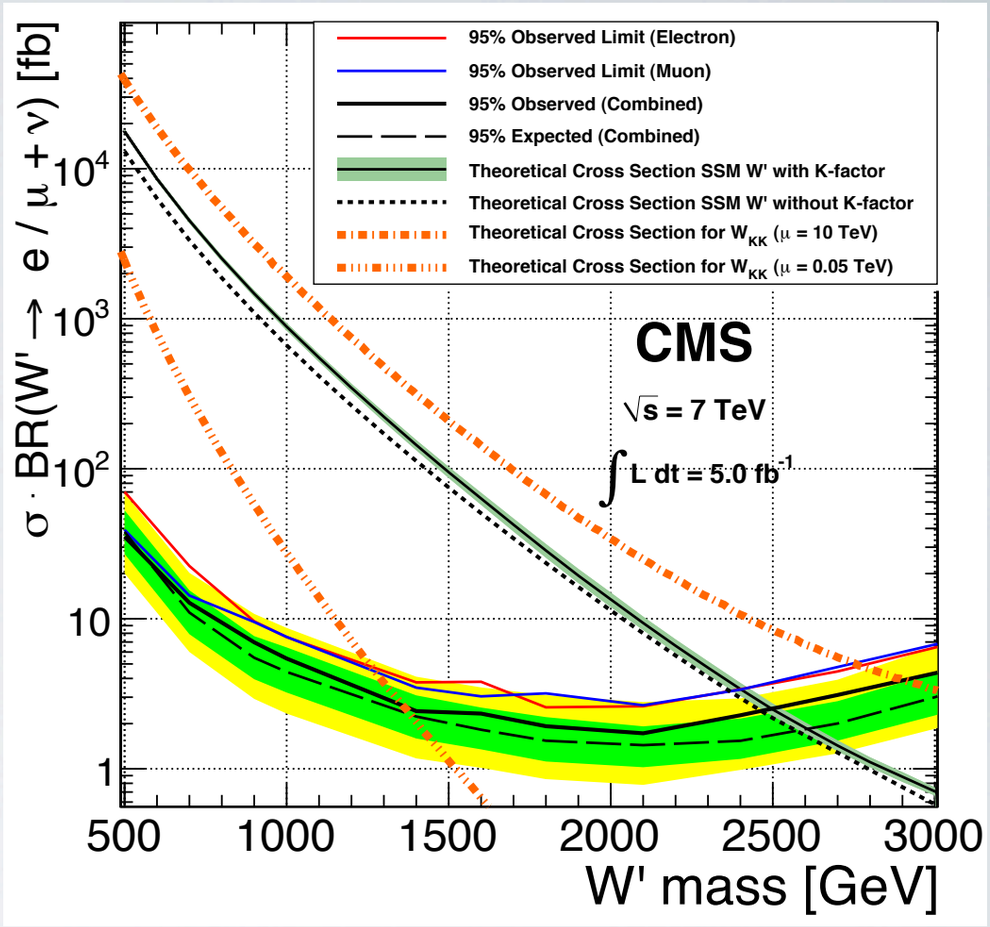
- MC Backgrounds are fit using the function given, and normalized to data (200 GeV < m_T < 500 GeV).
- Search for excess above m_{Tmin}. threshold.
- No excess is observed.





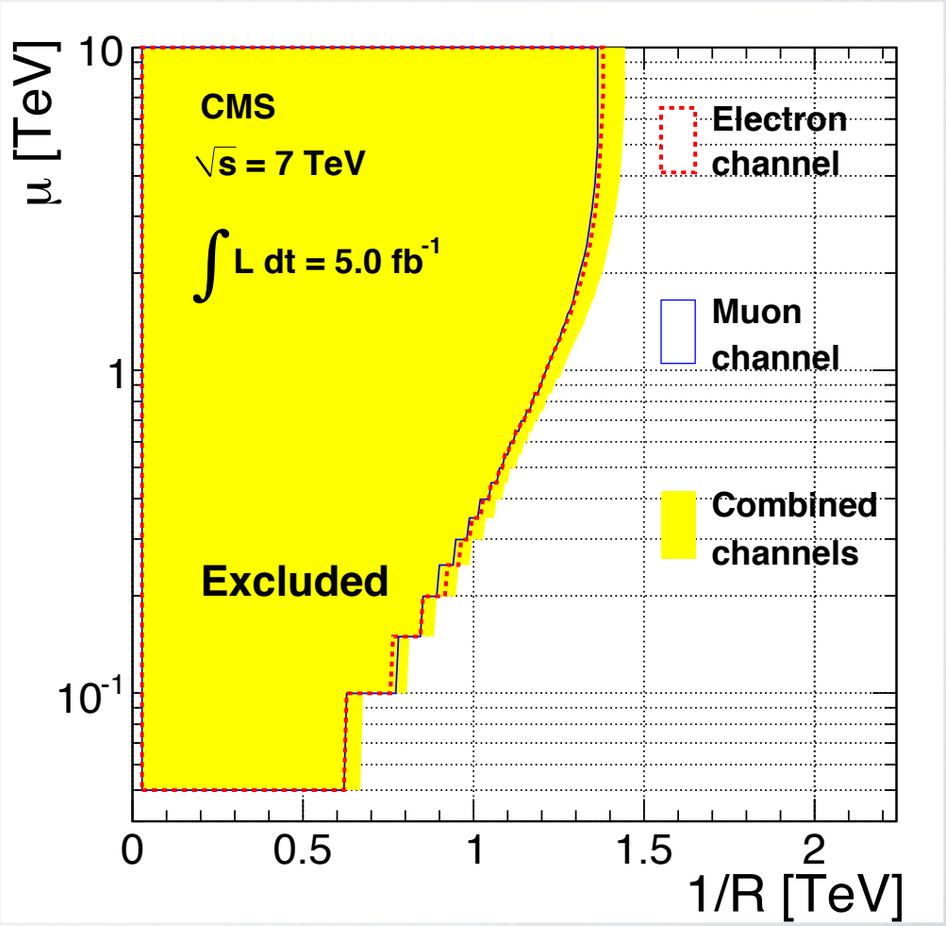
W PRIME LIMITS

- Limits set using a bayesian method assuming a flat prior.
- Limits on cross section times branching fraction set for SSM W Prime.
- Also shown are cross sections for W_{kk} from split-UED models.
- The paper also sets exclusion limits in 1/R, μ space.



- Acceptance loss is seen at higher masses due to kinematic limit for production of high mass W Prime.

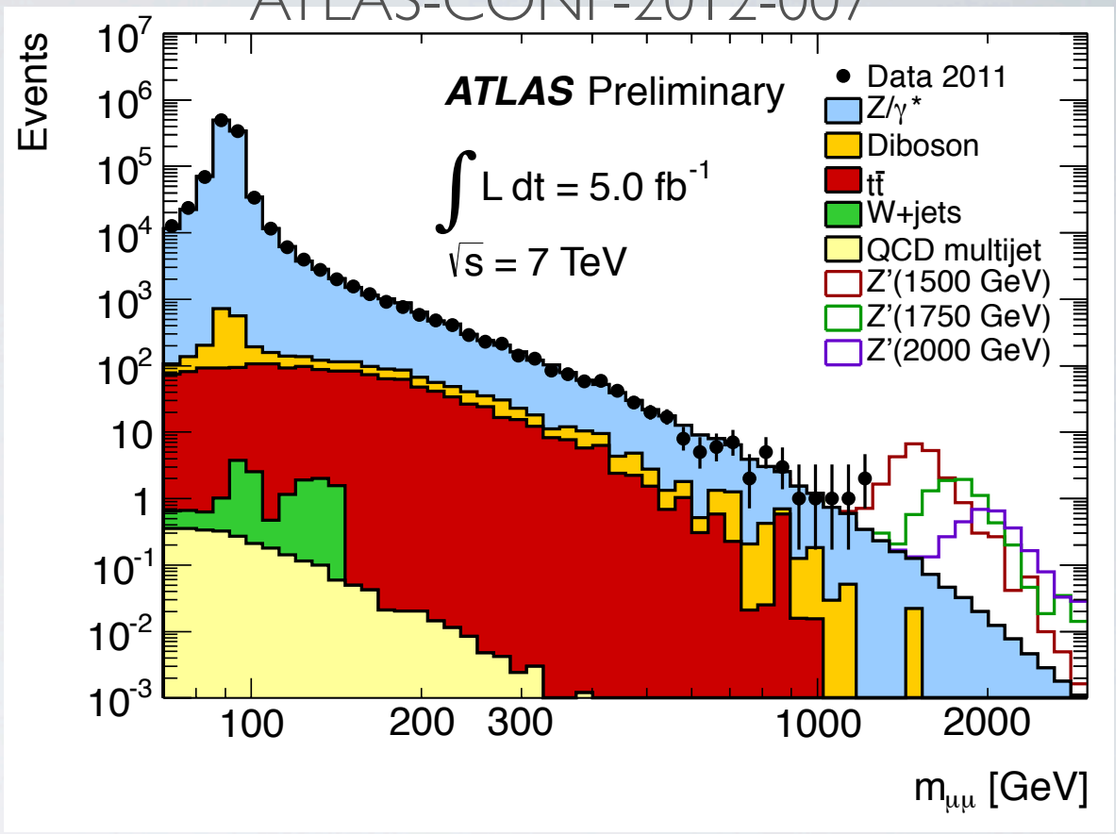
Model	Limit [TeV]
W_R'	2.50(2.60)
W_L' (const.)	2.63
W_L' (dest.)	2.43
W_{kk} (μ = 0.05TeV)	1.4
W_{kk} (μ =10 TeV)	2.9



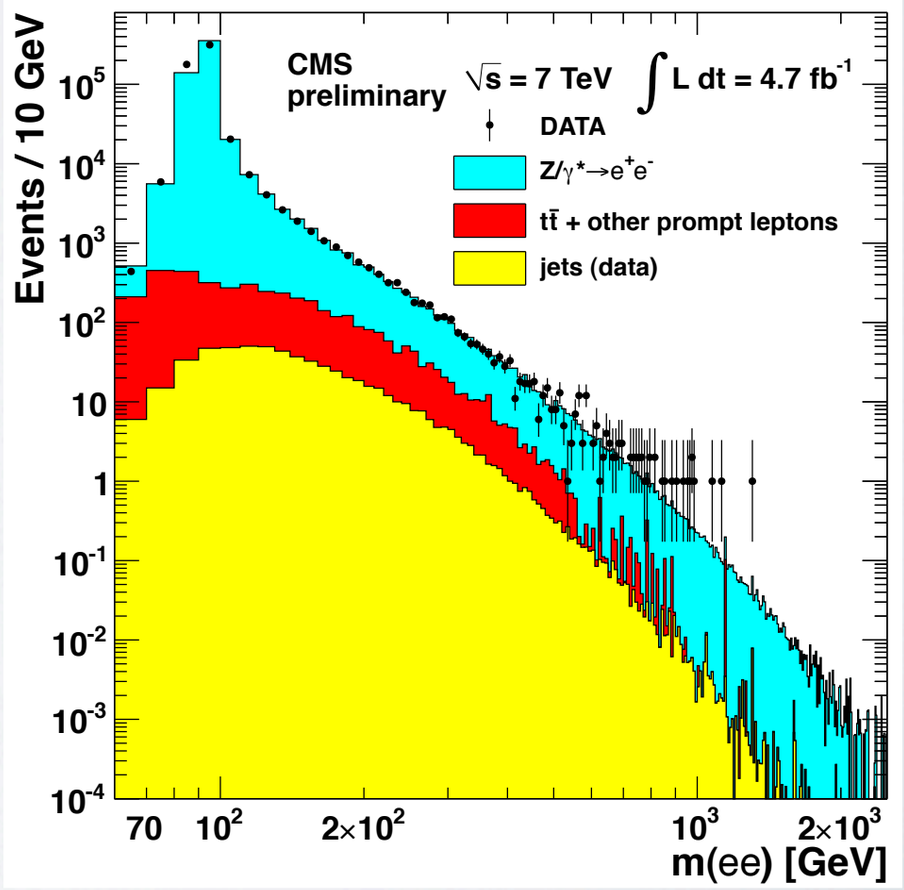
Z PRIME

- A general search for narrow high mass resonances in ee and μμ mass distributions.
- Use **SSM Z′**, and **E_6 Grand Unified theory**(GUT) Z′ as benchmarks.
  - The pattern of the symmetry breaking and the mixing angle (θ_{E6}) determine the Z′ fermion couplings.
    - E_6 GUT Z′ states: Z'_ψ, Z'_N, Z'_η, Z'_I, Z'_S Z'_χ
- Other models investigated are:
  - **Z***, **techni-mesons**, **spin-2 RS gravitons** (G^*, G_{kk})

ATLAS-CONF-2012-007



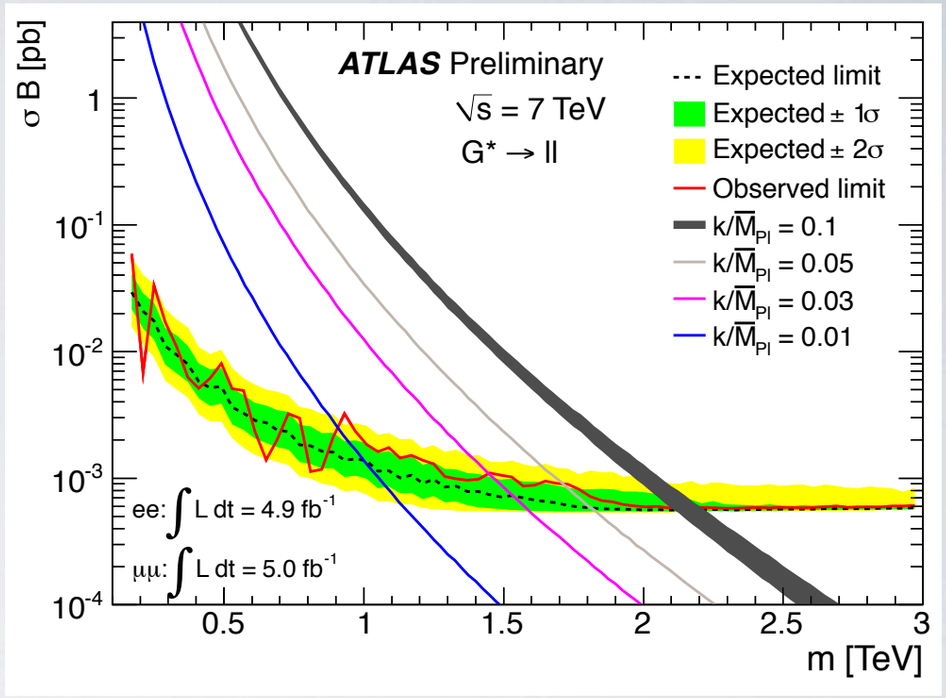
CMS-PAS-11-002



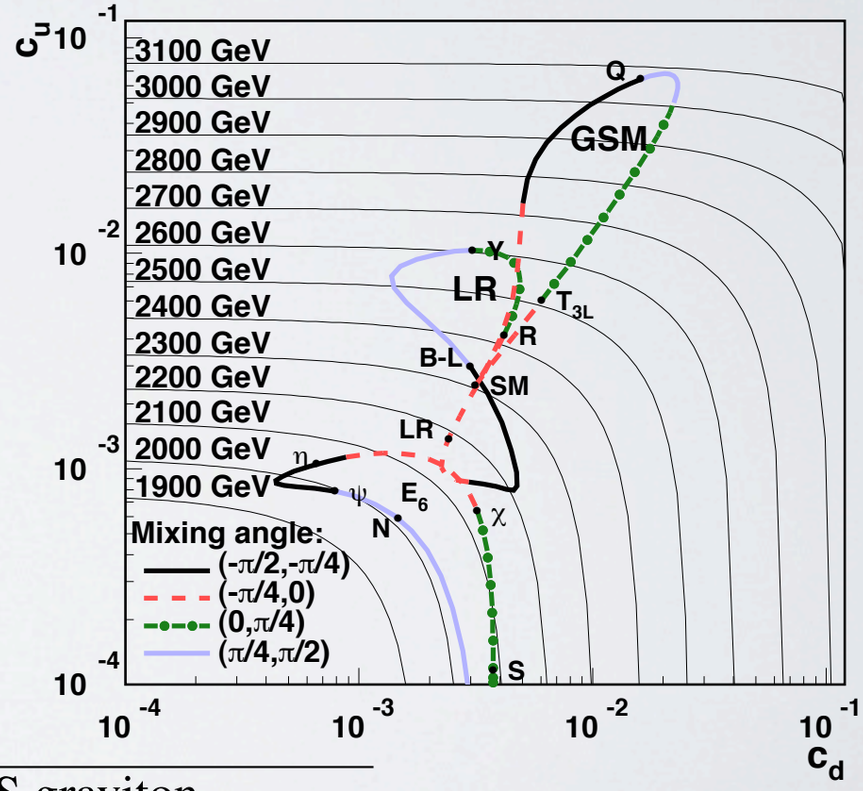
Z PRIME LIMITS

- Use a bayesian analysis with a flat prior to set limits on cross section times branching fraction.
- Limits set on E_6 GUT Z'.
- Limits also set on RS gravitons.

ATLAS-CONF-2012-007



CMS preliminary, $\int Ldt$ = 4.7/4.9fb^{-1}, ee/$\mu\mu$ $\sqrt{s}$ = 7 TeV

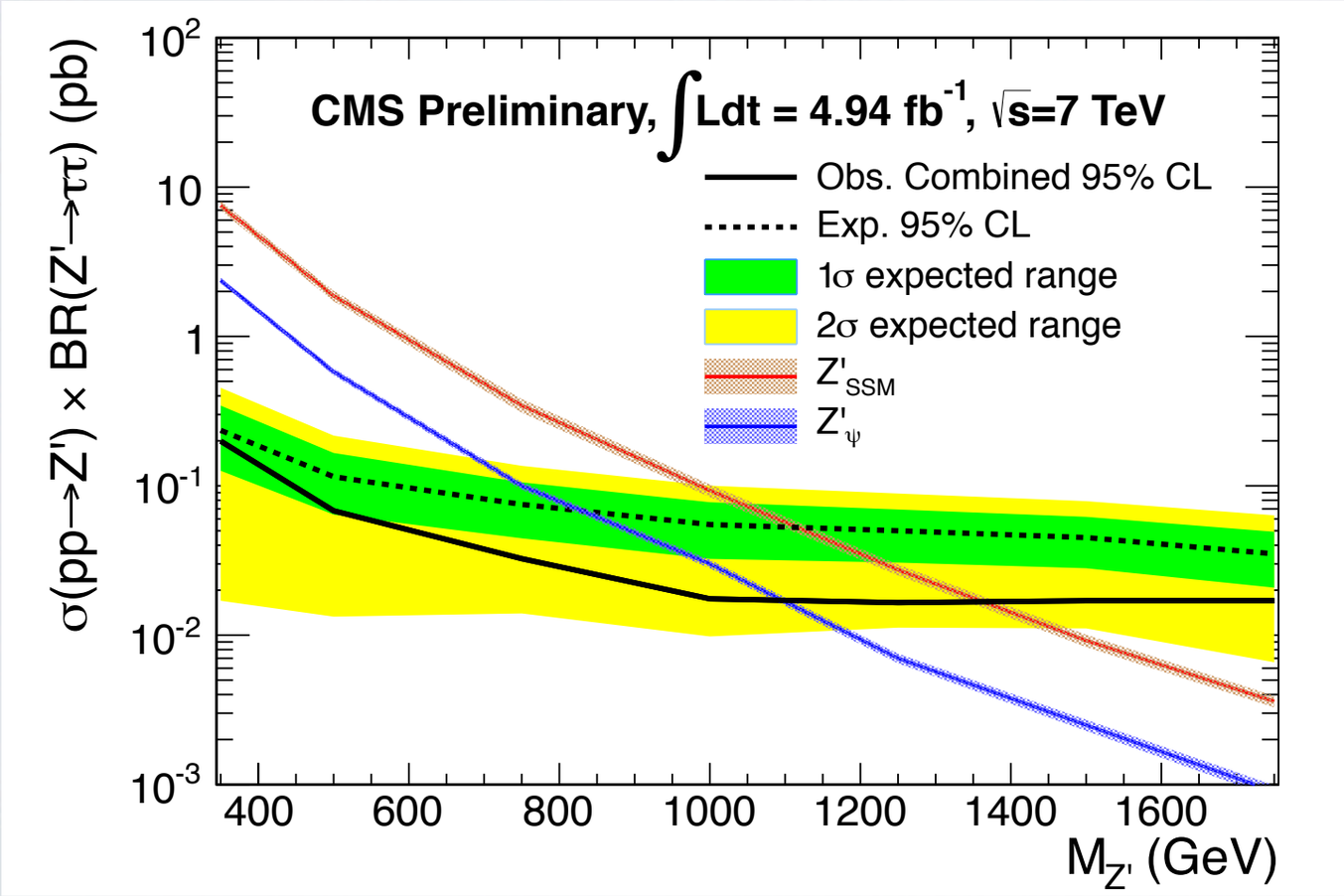


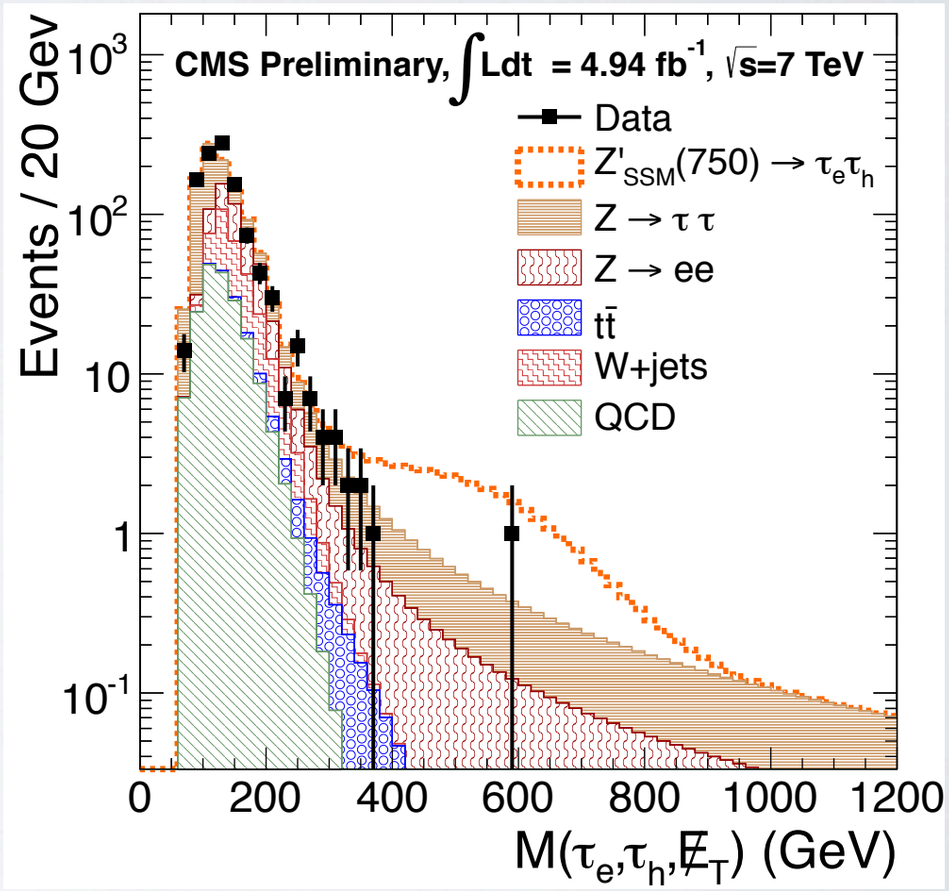
Model	Limit[TeV]
SSM Z'	2.32
Z'_ψ	2.00
G_{kk} ($\tilde{k}$=0.05)	1.81
G_{kk} ($\tilde{k}$ = 0.1)	2.14

	E_6 Z' models						RS graviton			
Model/Coupling	Z'_ψ	Z'_N	Z'_η	Z'_I	Z'_S	Z'_χ	0.01	0.03	0.05	0.1
Mass limit [TeV]	1.76	1.78	1.84	1.84	1.90	1.96	0.91	1.45	1.71	2.16

Z PRIME TO TAUS

- Search for resonance in visible mass spectrum.
- Look at all hadronic, e+had, μ+had and eμ channels.
- SSM Z' excluded up-to 1.36 TeV, and E_6 Z' excluded up-to 1.1 TeV

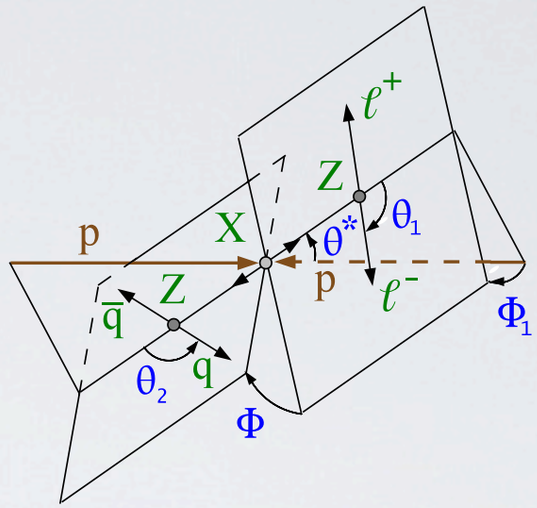




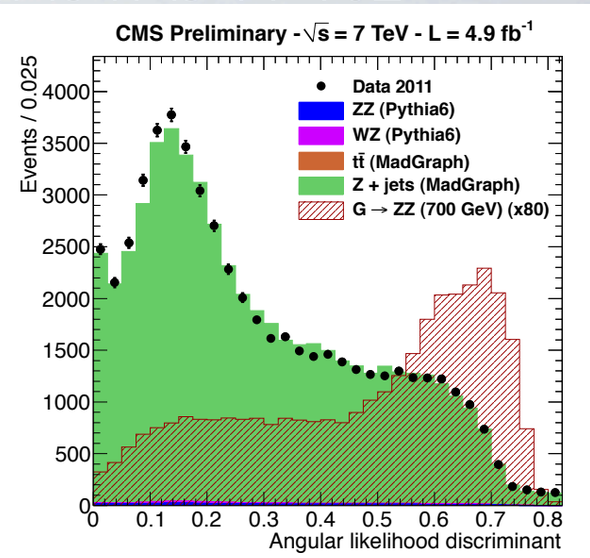
DIBOSON RESONANCES

- Heavy particles decaying to bosons is predicted by several models: **Extended Gauge Model** (EGM), **Extra Dimensions** (ED), and **Technicolor**.

- Look for resonances in ZZ, WZ, VZ.



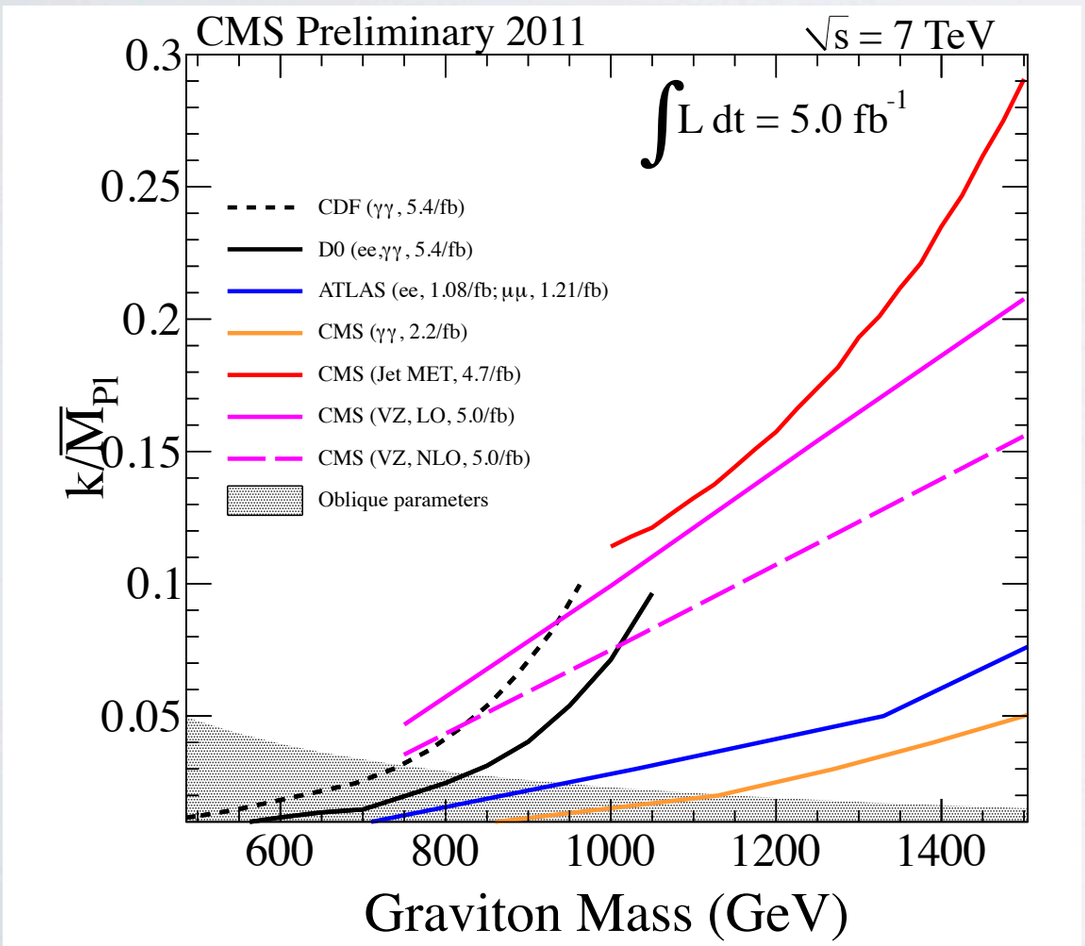
CMS-PAS-11-102



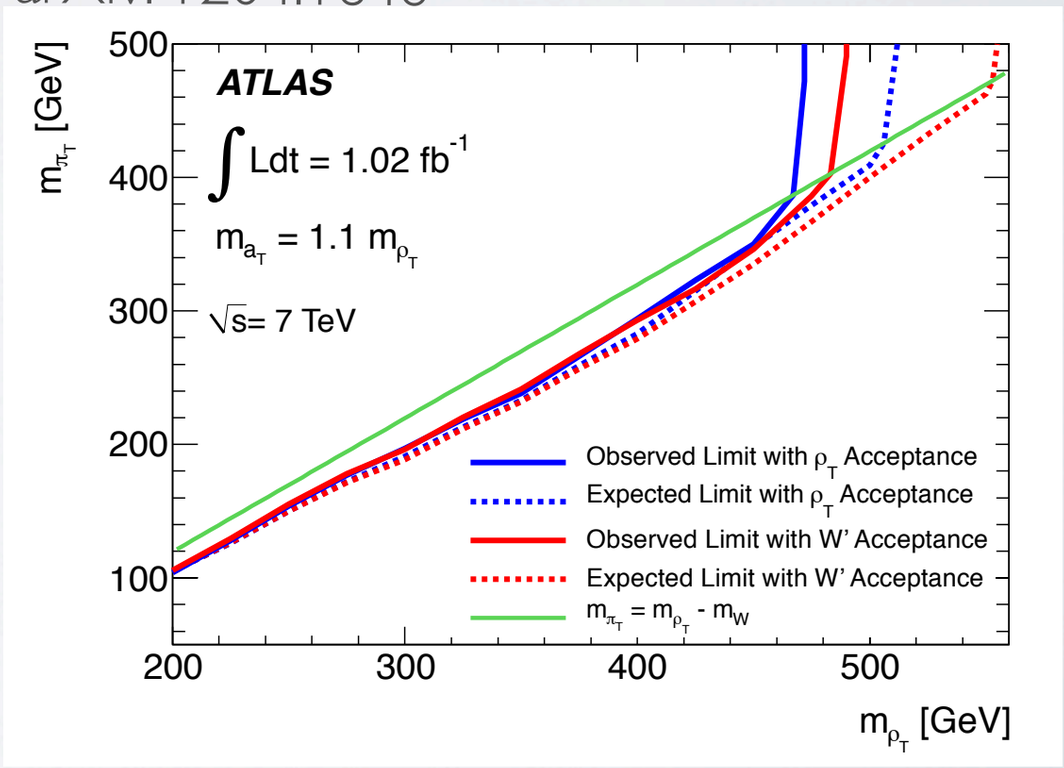
$m_{G^*} > 945$ GeV for $k = 0.1$

$760 < m_{G^*} < 850$ GeV for $k = 0.05$

CMS-PAS-11-81



arXiv: 1204.1648



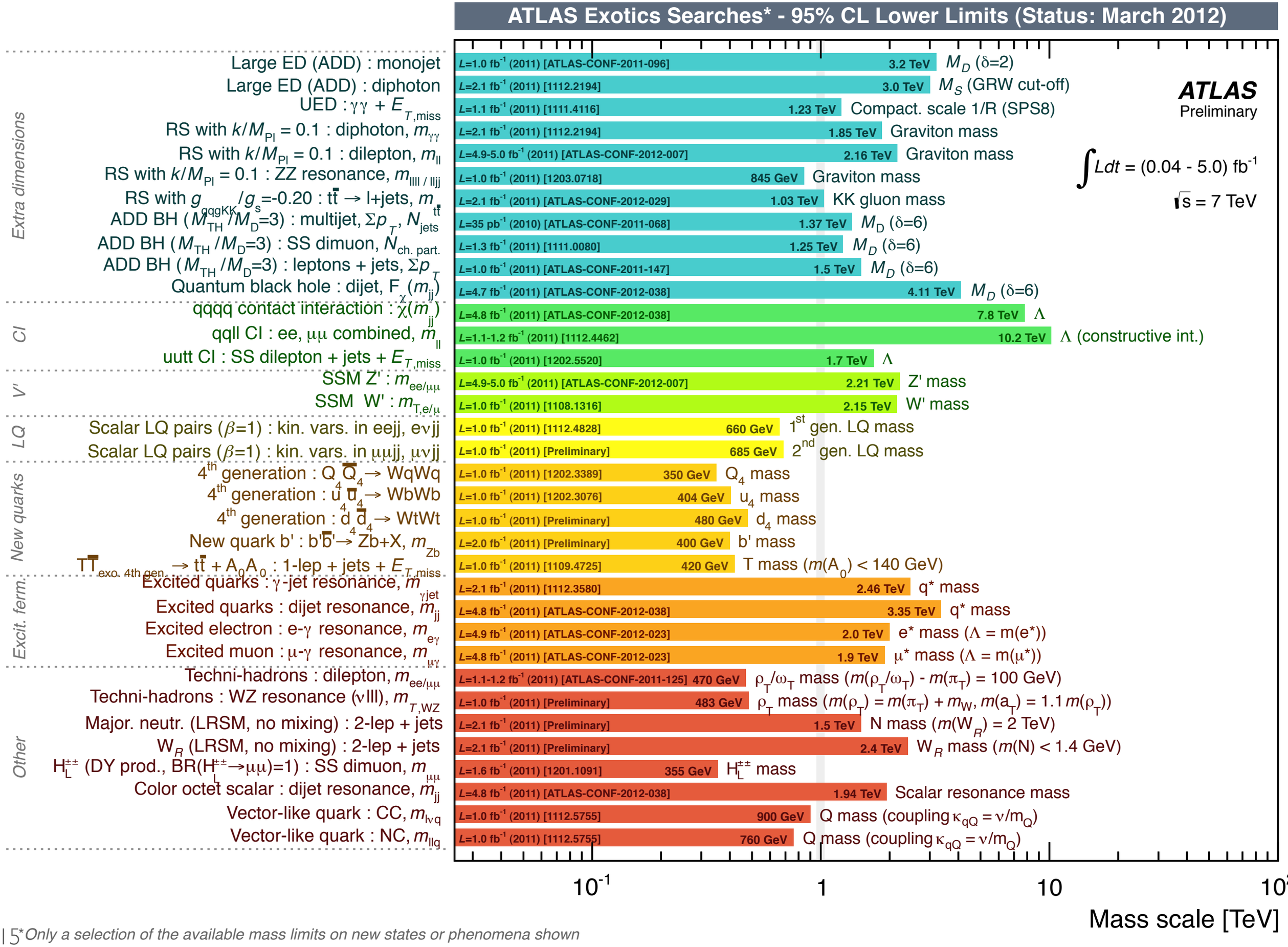
SUMMARY

- Presented was a selection of various searches for new physics particles from ATLAS and CMS.
- No evidence for new physics is found yet, but the search has only just begun.
- There are many searches being performed and expect more to be out very soon.

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ExoticsPublicResults

http://cms.web.cern.ch/org/cms-papers-and-results

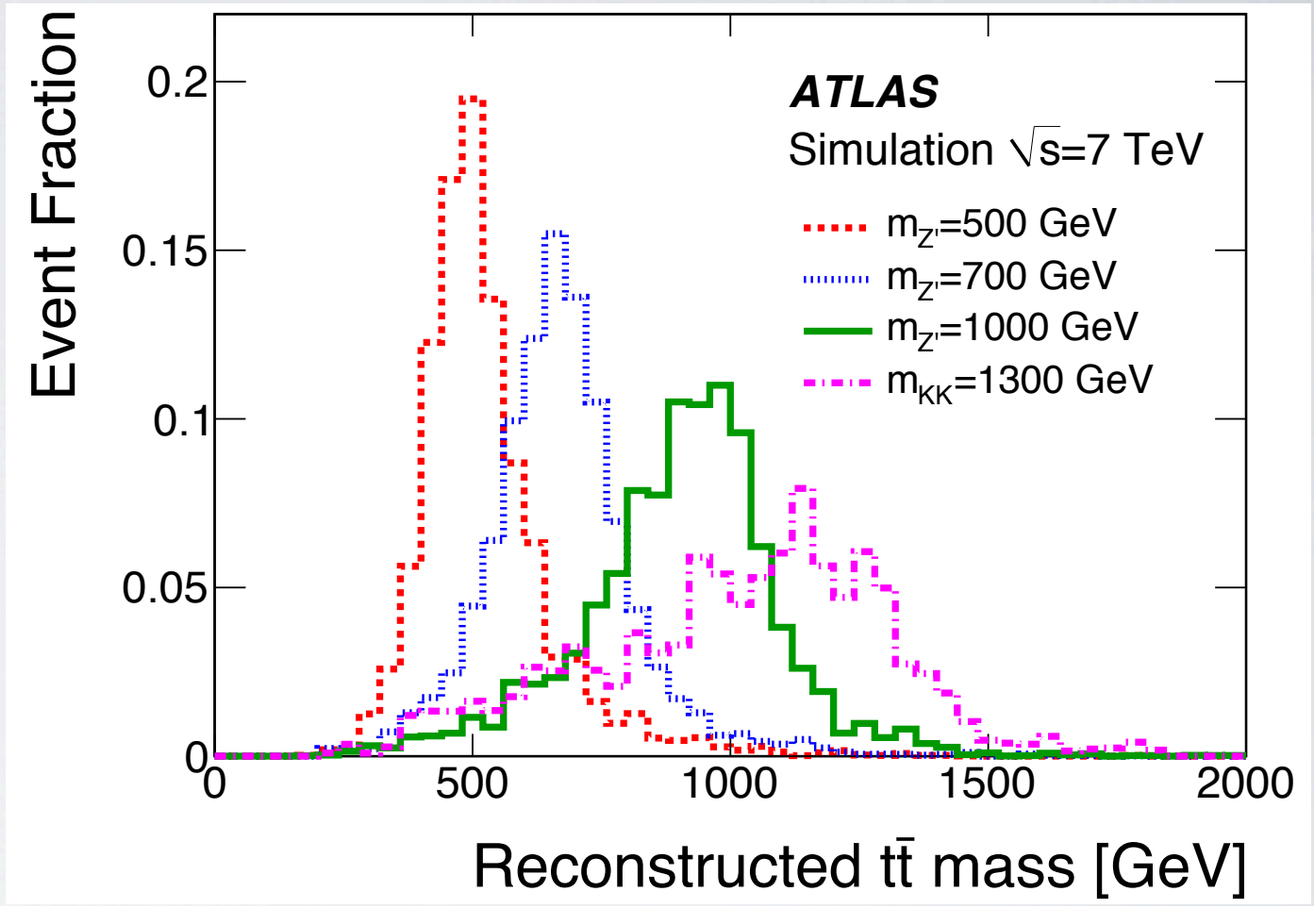
ATLAS Exotics Searches* - 95% CL Lower Limits (Status: March 2012)

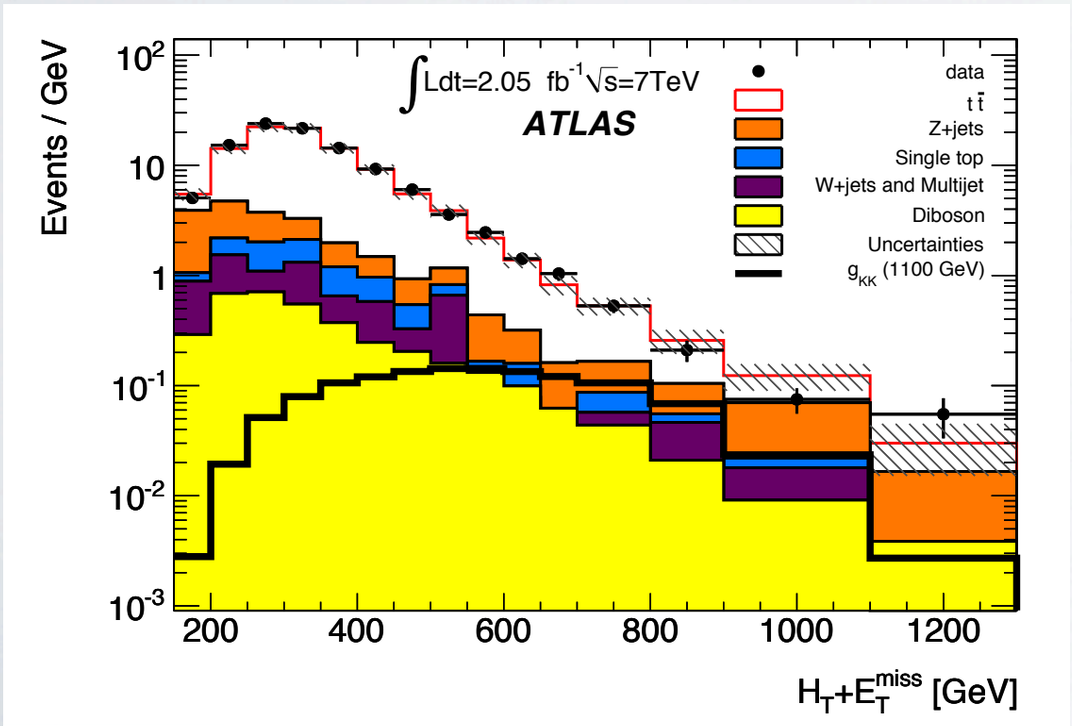


*Only a selection of the available mass limits on new states or phenomena shown

TOP RESONANCES

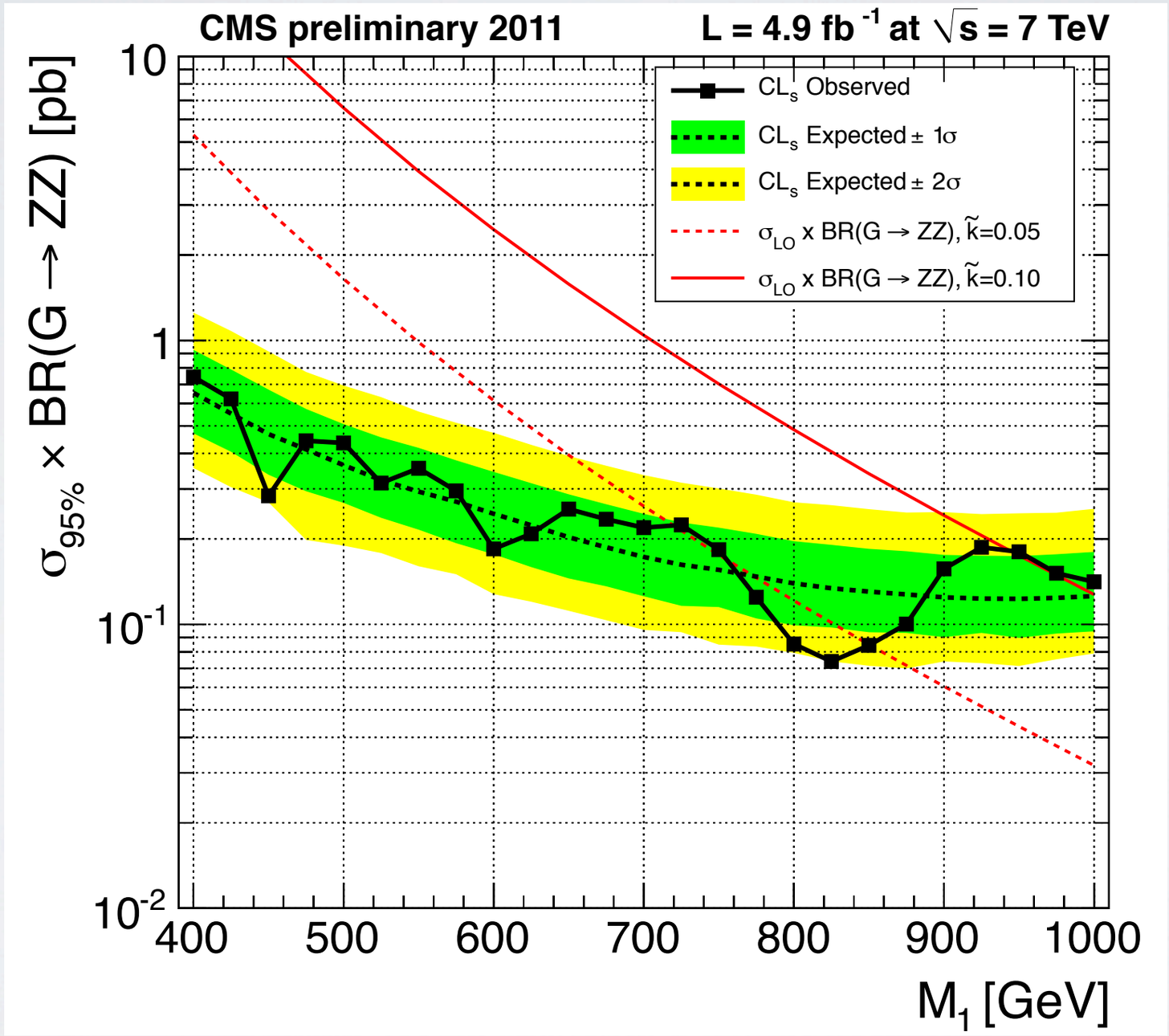
- searches for leptophobic Z' and Kaluza-Klein gluon excitation (g_{kk}).
- Looking at lepton+jets, and dilepton channels.
- Lepton+jets reconstruct the top pair mass using the W mass as a constraint.
- Dilepton channel looks at effective mass.



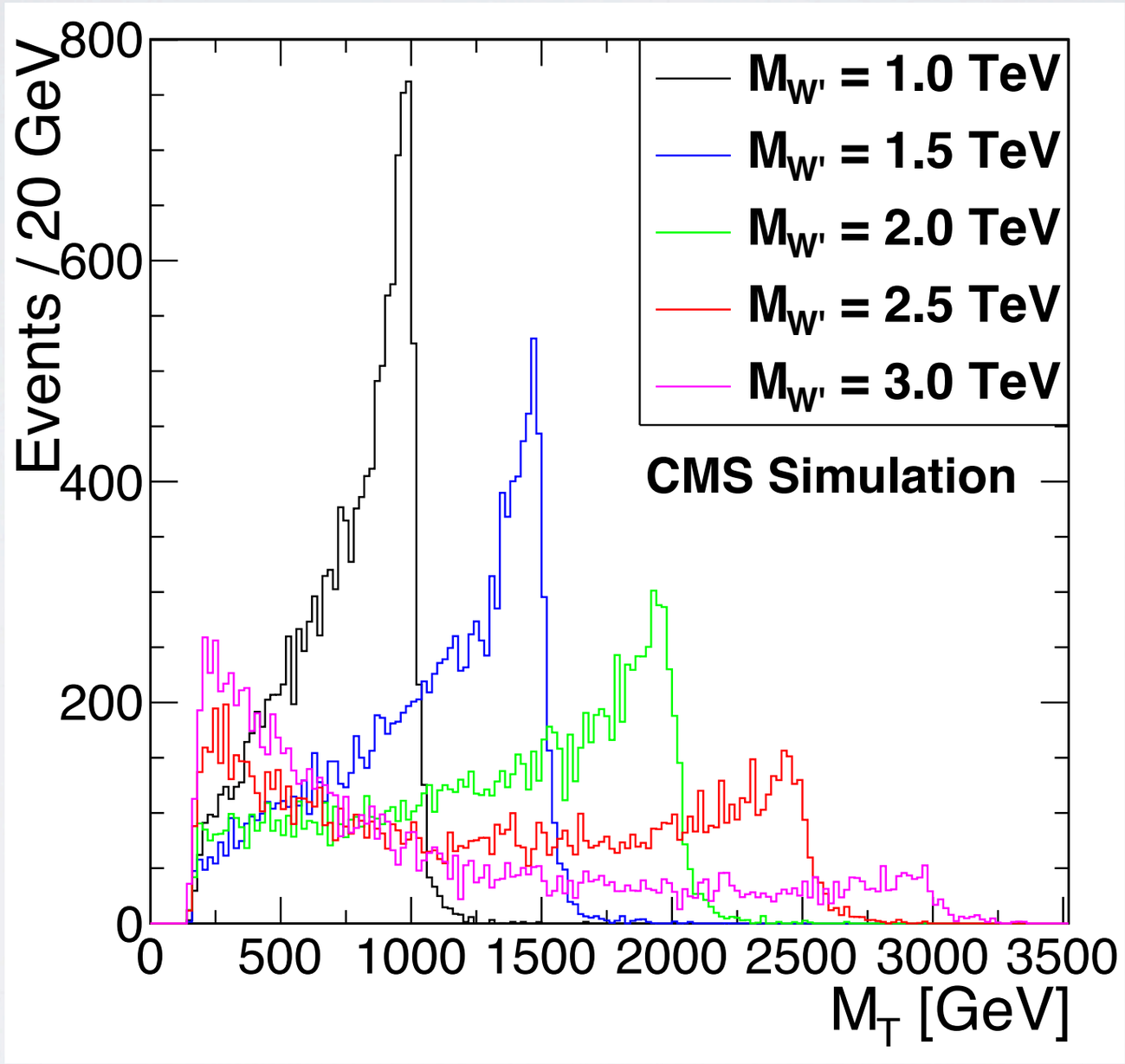


Model	Limit[TeV]
z'	0.88
gzz	1.13

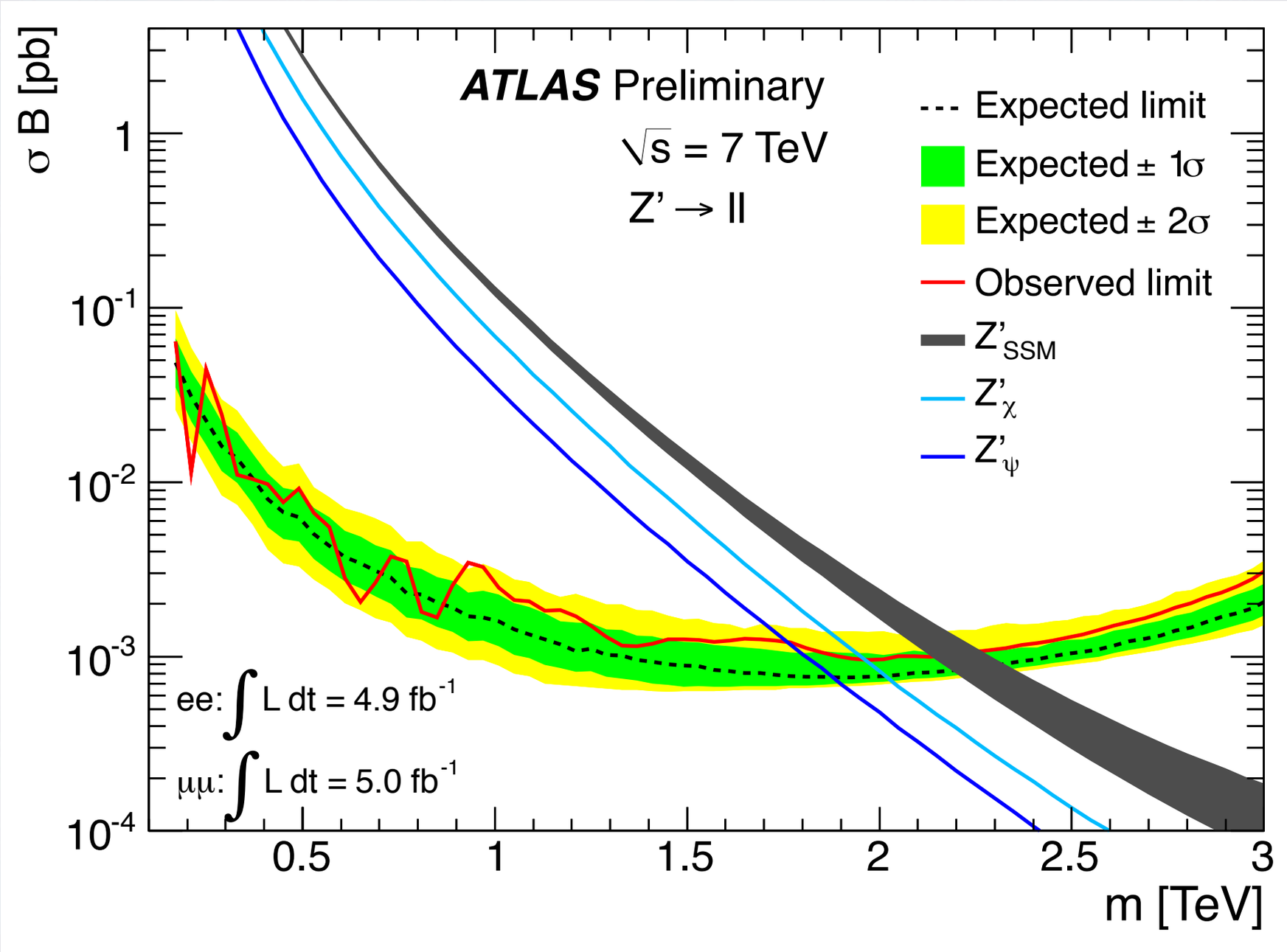
ZZ LIMITS


CMS preliminary 2011
L = 4.9 fb -1 at √s = 7 TeV
CLs Observed
CLs Expected ± 1σ
CLs Expected ± 2σ
σLO x BR(G → ZZ), k̃=0.05
σLO x BR(G → ZZ), k̃=0.10
σ95% x BR(G → ZZ) [pb]
M1 [GeV]
10
1
10-1
10-2
400
500
600
700
800
900
1000

W PRIME ACCEPTANCE



Z PRIME LIMITS



THREE JET RESONANCES

- Look for three jet resonance in 6 jet final states.
- Use gluino as a benchmark.