Searches for non-SUSY Exotics at the CMS Experiment

On behalf of the CMS collaboration
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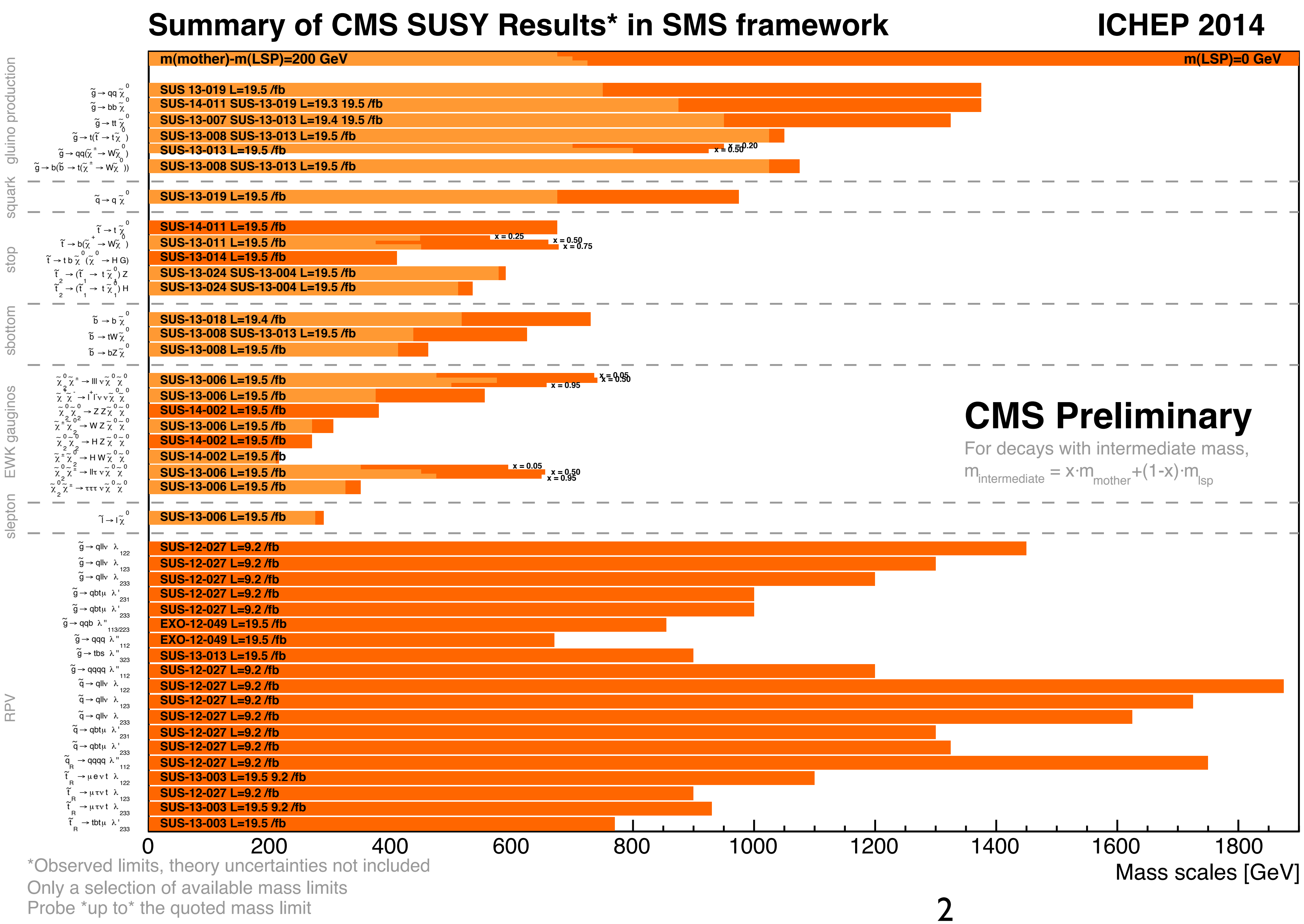
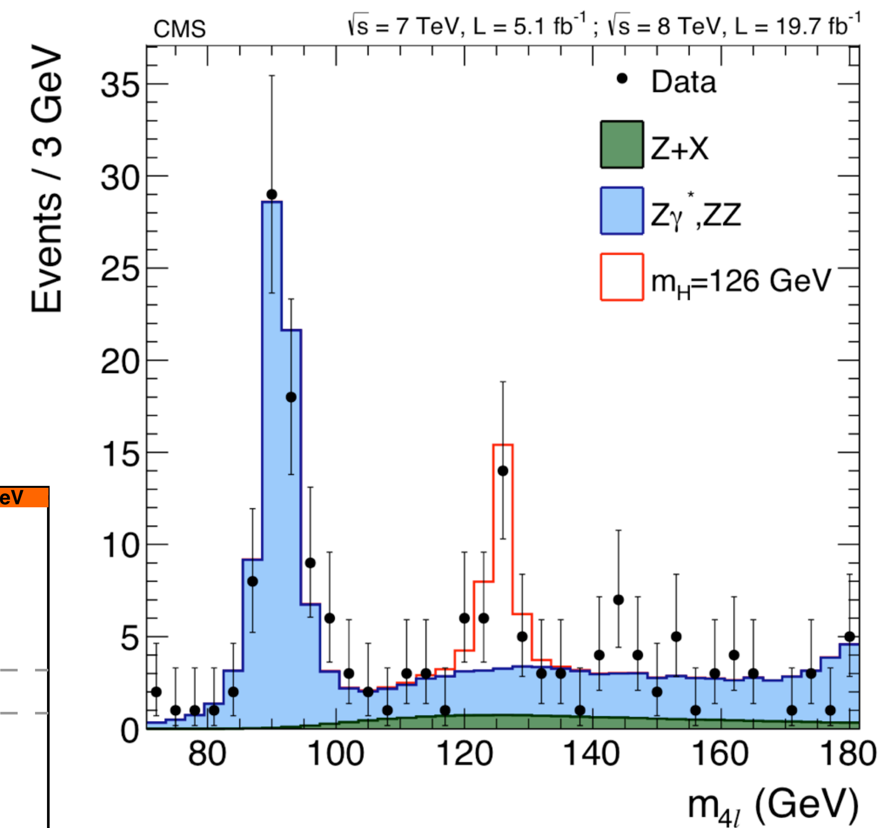
Susy2014 Conference, Manchester

Observed vs Not Observed

- SM Like Higgs Boson (125 GeV) has been observed.
- No SUSY has been observed so far… (see all the other talks)
- But many questions still remain unanswered!





In this talk, non-susy based signatures that are candidates to solve some of the remaining mysteries will be discussed.

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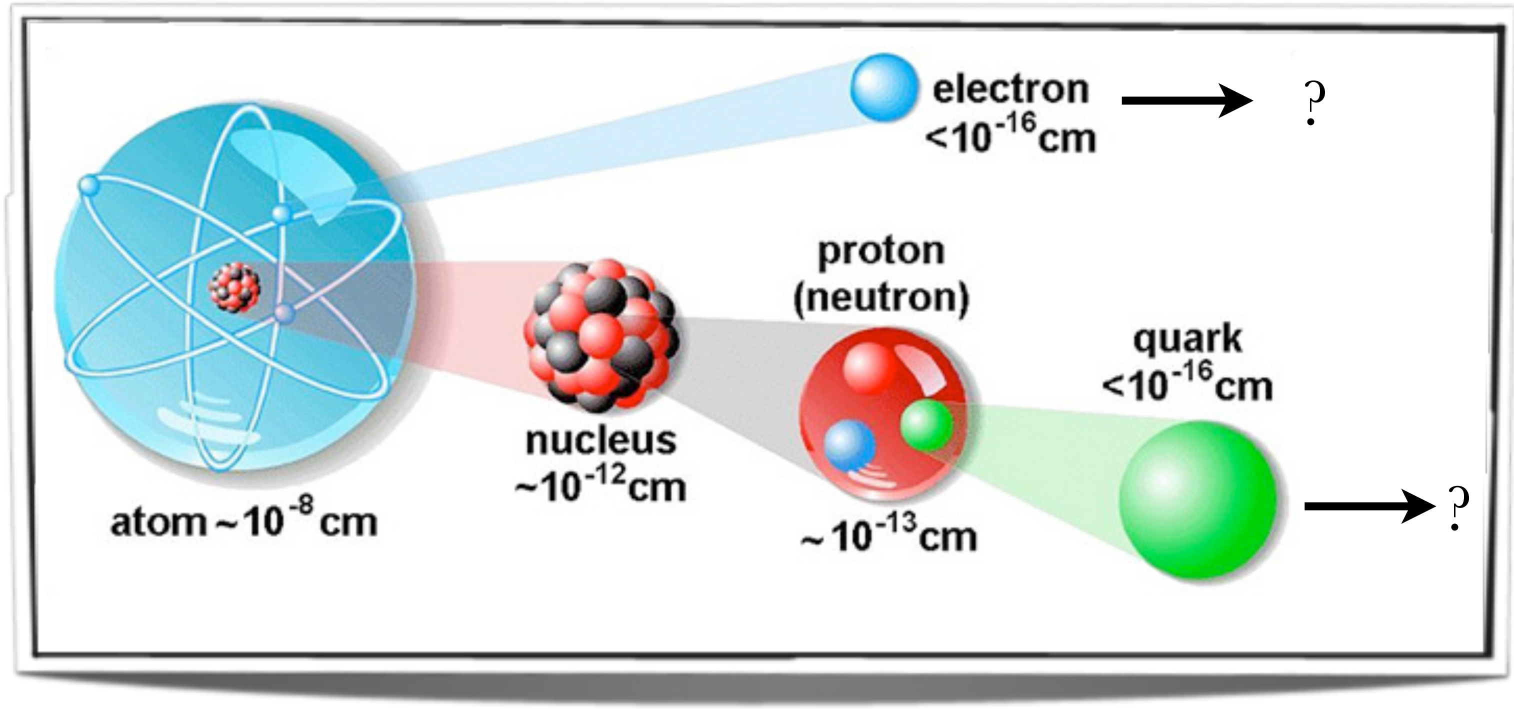
at·om : Greek átomos (noun) undivided

- Looking for substructure has worked great in the past. Why stop now?
- Why are there 3 families of quarks and leptons?
- Are quarks and leptons composed of more fundamental constituents?



COMPOSITENESS : If quarks or leptons are not fundamental, then we should see new interactions between quarks and leptons at the scale of constituent binding energies!

Effects of compositeness could be observed through:

- Contact Interactions (exchange of common constituents or binding quanta
- Excited Quarks (heavy quark with the same quantum numbers)

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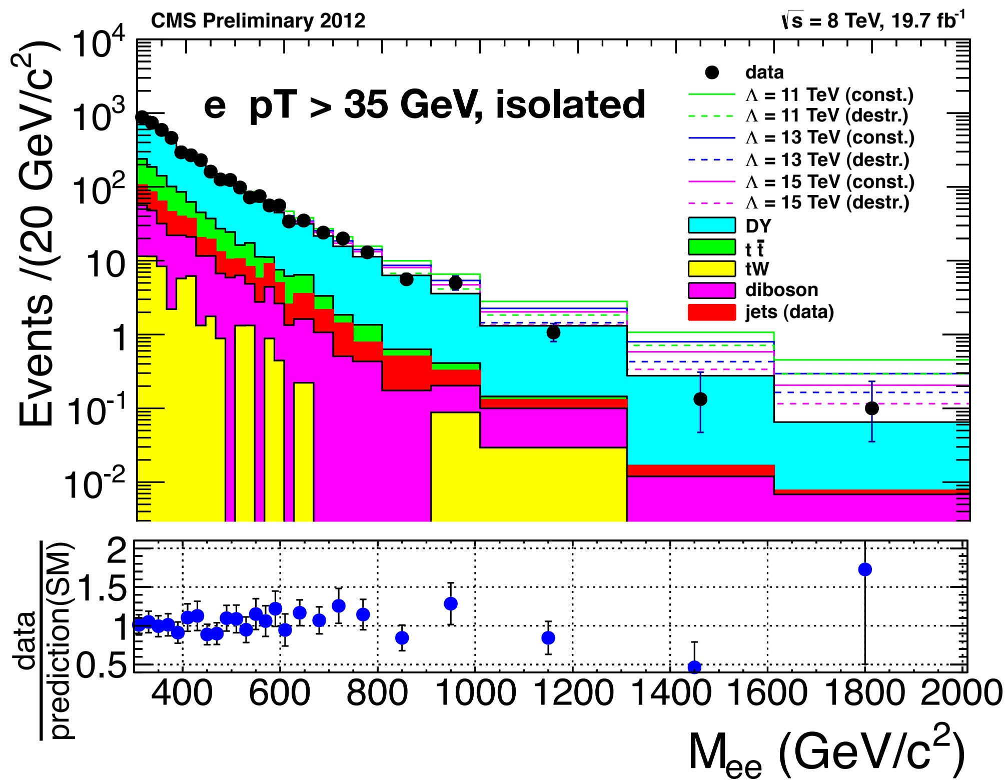
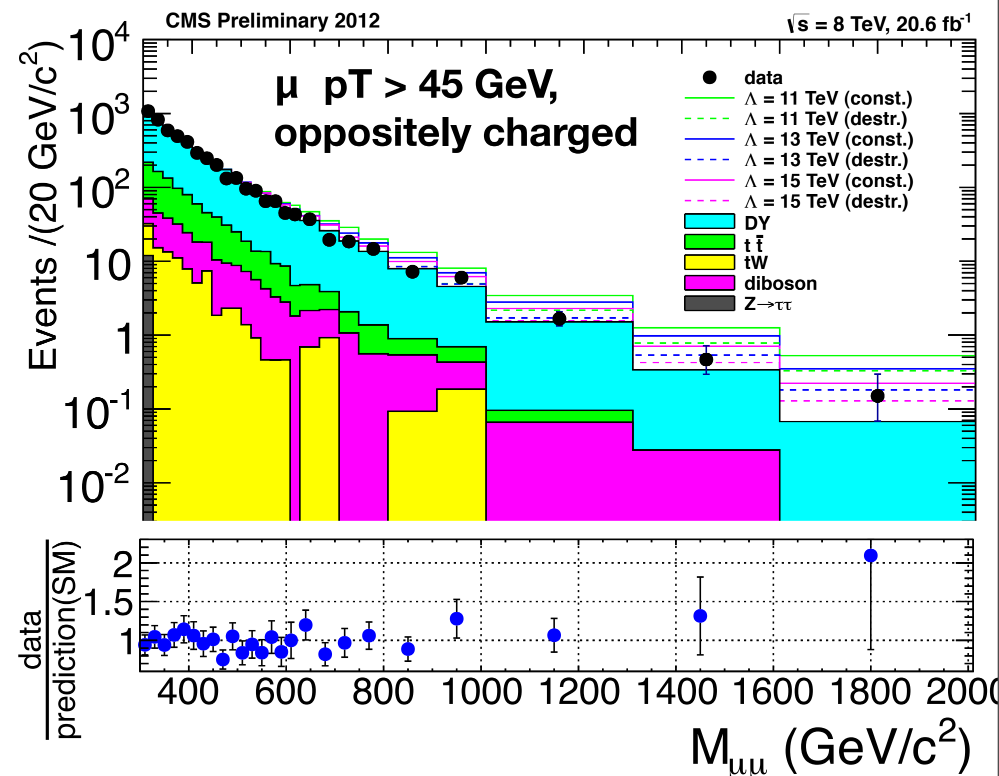
Search for Contact Interactions in Dilepton Mass Spectra

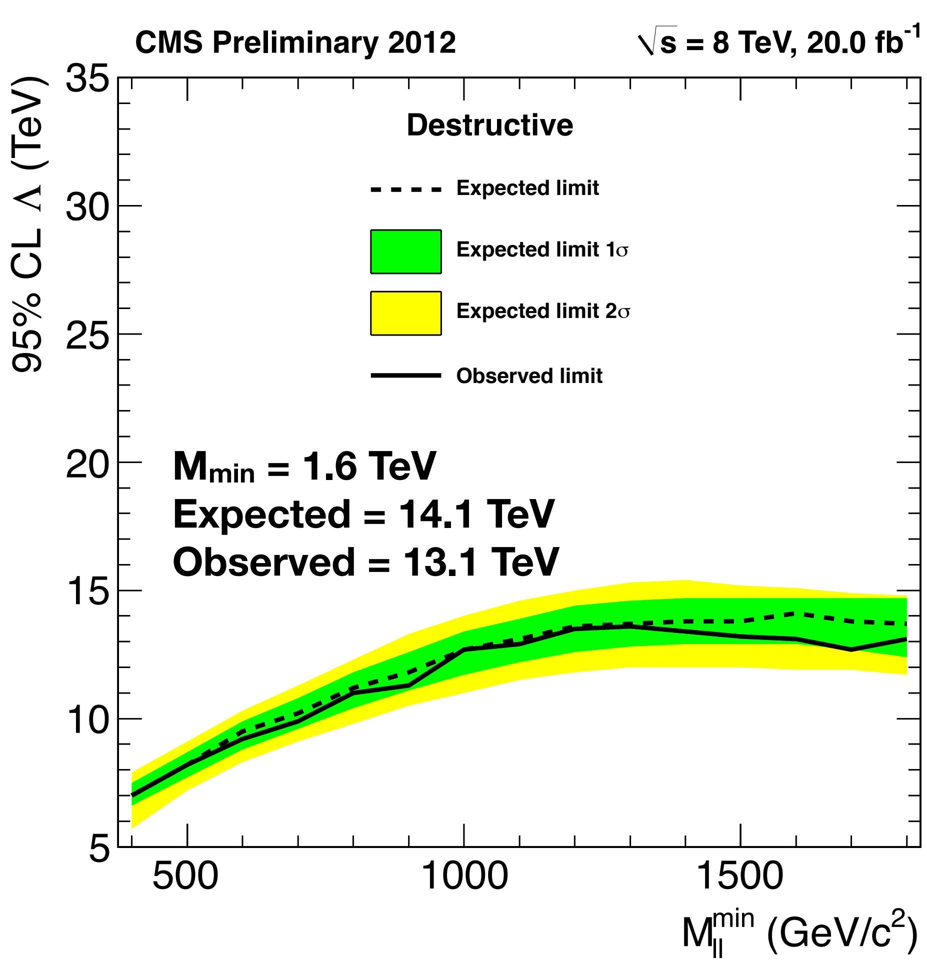
Assumption:
if Λ >> √s then compositeness appear as contact interactions.

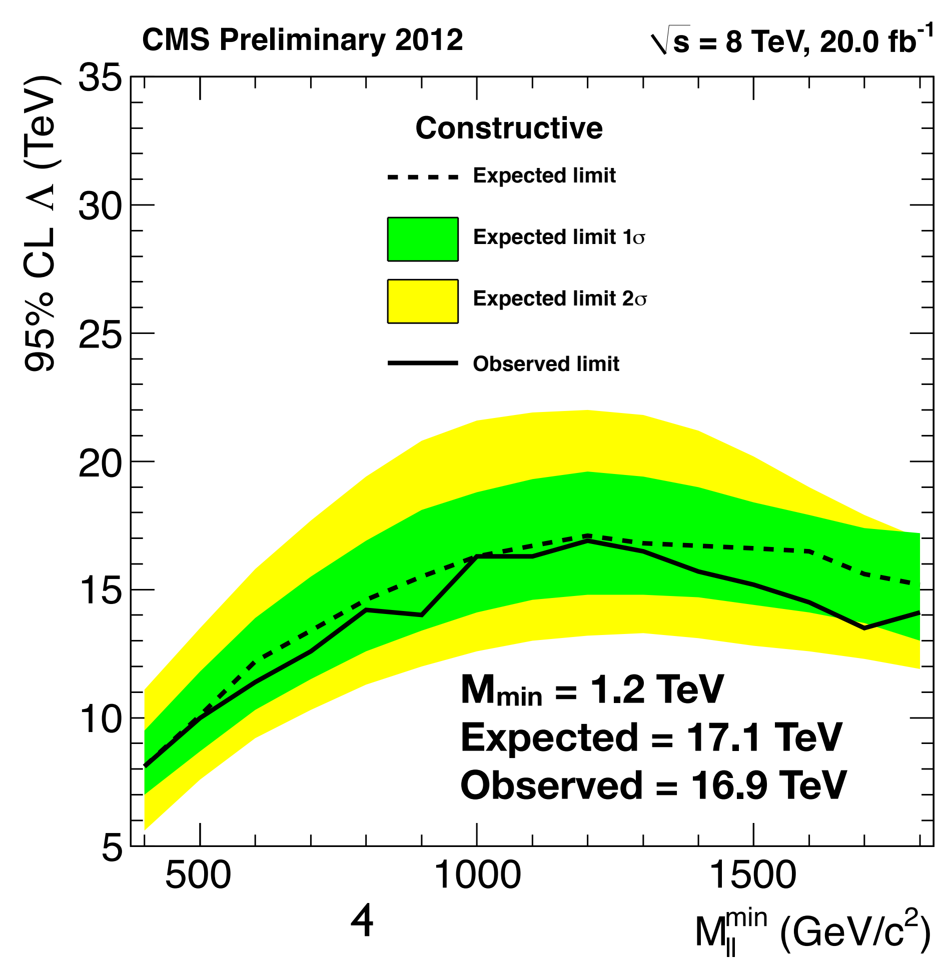
Expectation:
Enhancement to the dilepton cross section.

CMS-EXO-12-020









Observation:
No deviation from the SM

MOST STRINGENT
limits on Λ
[14 (17) TeV] to date.

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Search for Excited Quarks in photon+jet final state

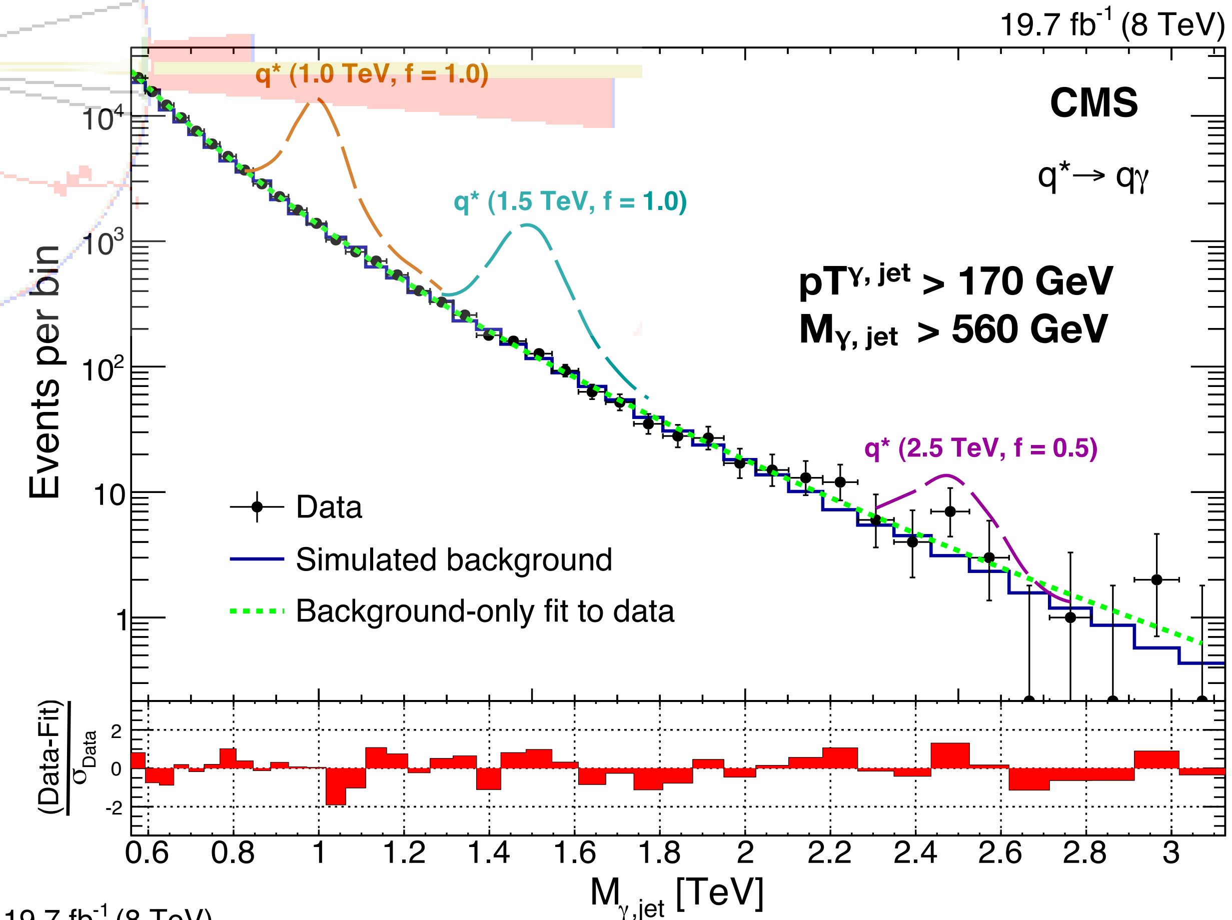
Assumption:
if $\Lambda << \sqrt{s}$ then a narrow resonance of excited particles can be observed

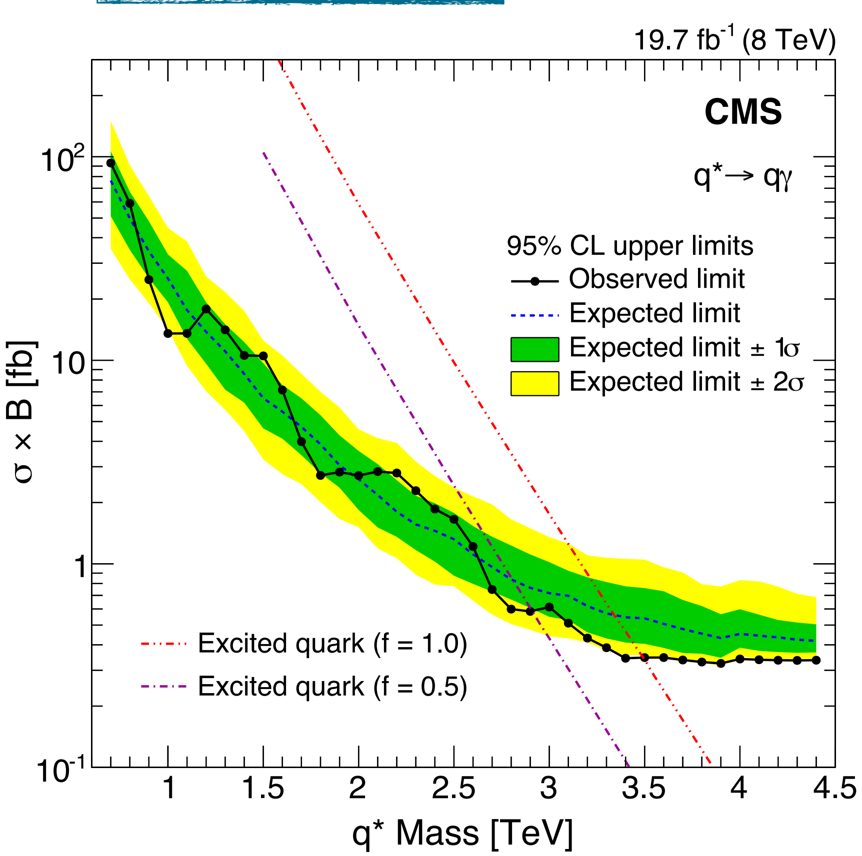
Expectation:
Resonance bump on a smoothly falling spectrum.

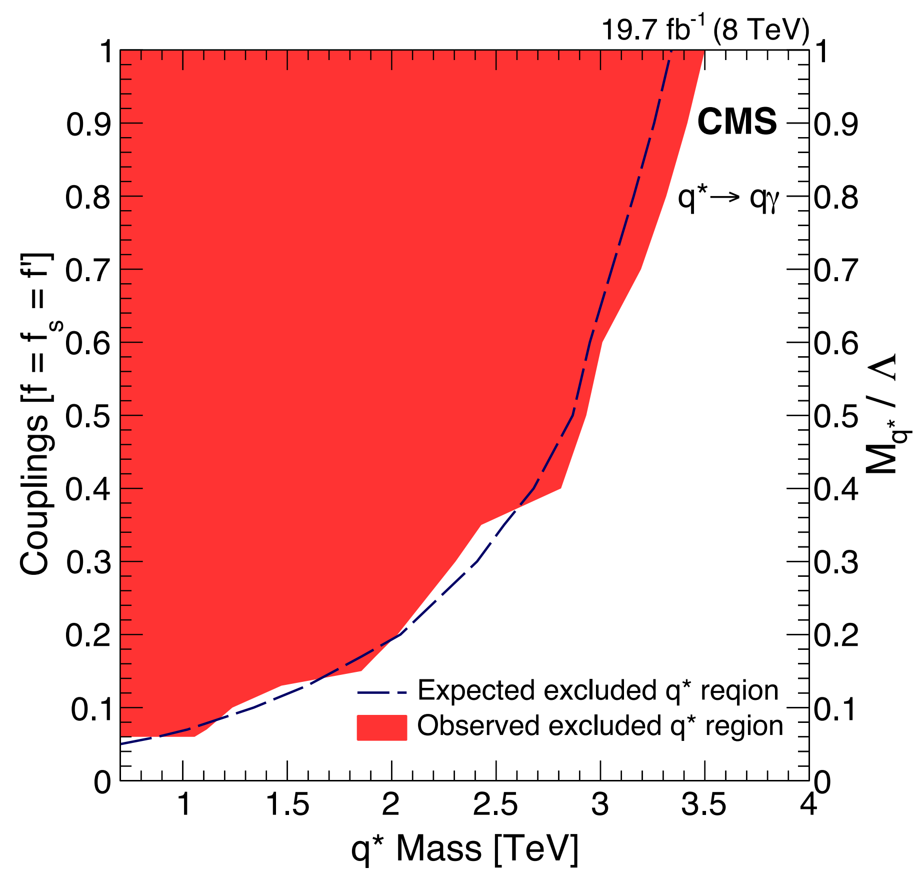
$$\frac{d\sigma}{dm} = \frac{P_0(1 - m/\sqrt{s})^{P_1}}{(m/\sqrt{s})^{P_2 + P_3 ln(m/\sqrt{s})}}$$

Describe the background with an analytic function

arxiv:1406.5171







Observation:
No significant deviation from the SM expectation

$0.7 < M_{q^*} < 3.5$ TeV excluded

First in LHC: Sensitivity for coupling strengths < 1 was investigated!

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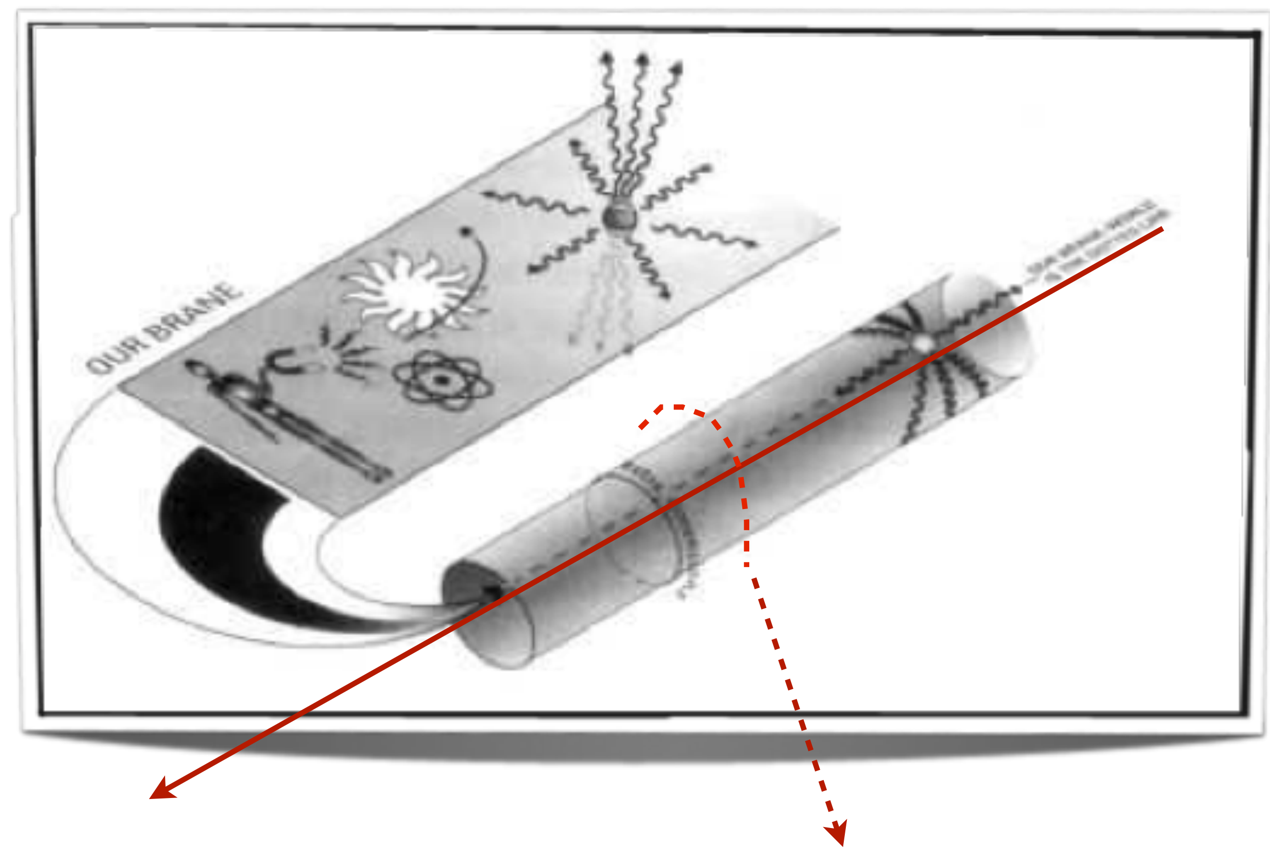
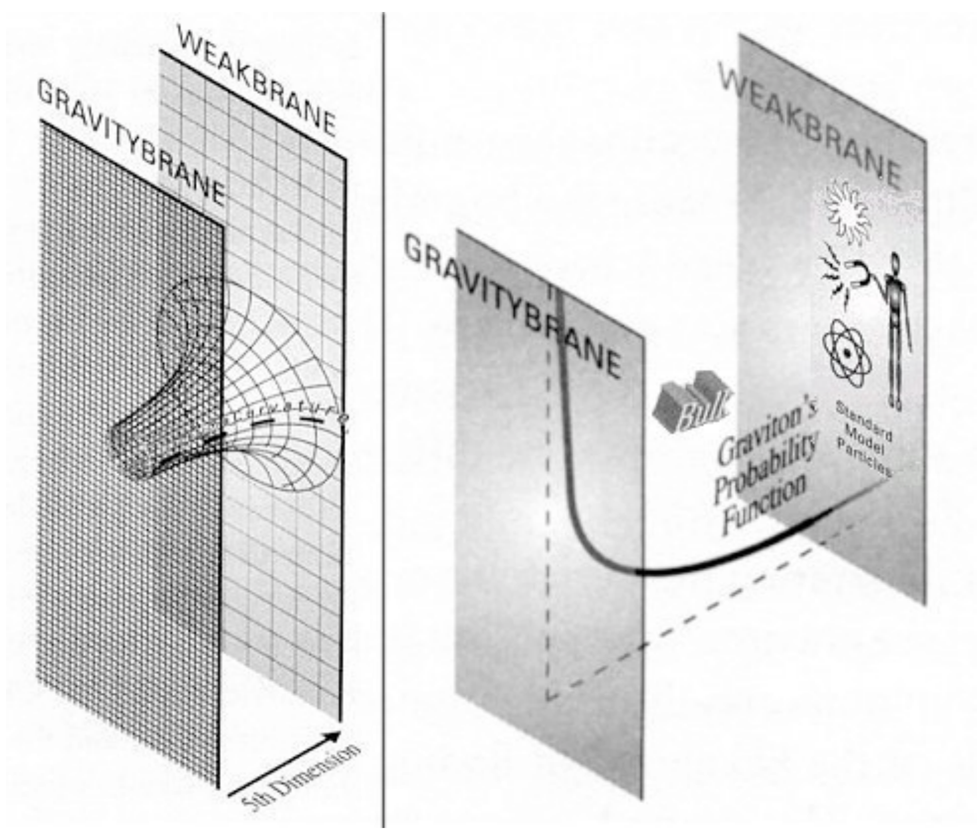
Why is Gravity so weak?

Could be explained by the existence of extra spatial dimensions. Most common benchmark models are:

ADD Model: Postulates two or more extra dimensions in which only gravity could propagate. For two extra dimensions, their size should be ~millimeters to explain the hierarchy between the Planck and Weak scales





Randall and Sundrum Model: A single extra dimension with a warped geometry and compactification scale of order of TeV. Graviton is localized towards the UV boundary (Planck Brane)

Bulk Graviton Model: Extension of RS Model addresses the flavor structure of the SM, decays through vector bosons (couplings to fermions and photons are highly suppressed)

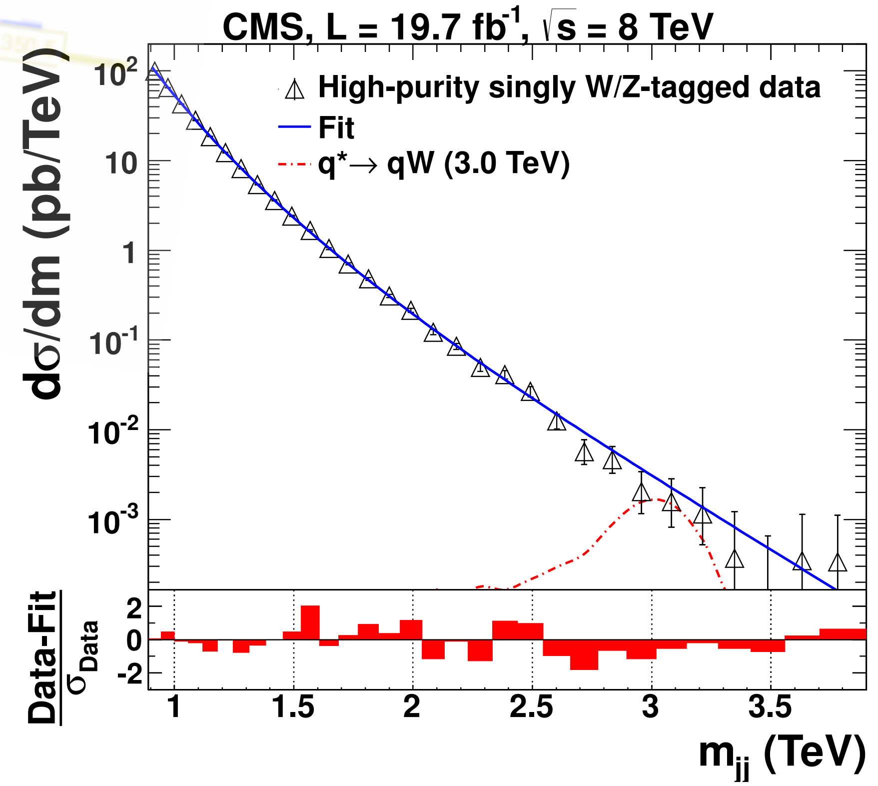
Search for massive resonances decaying into pairs of boosted bosons in all-hadronic final states

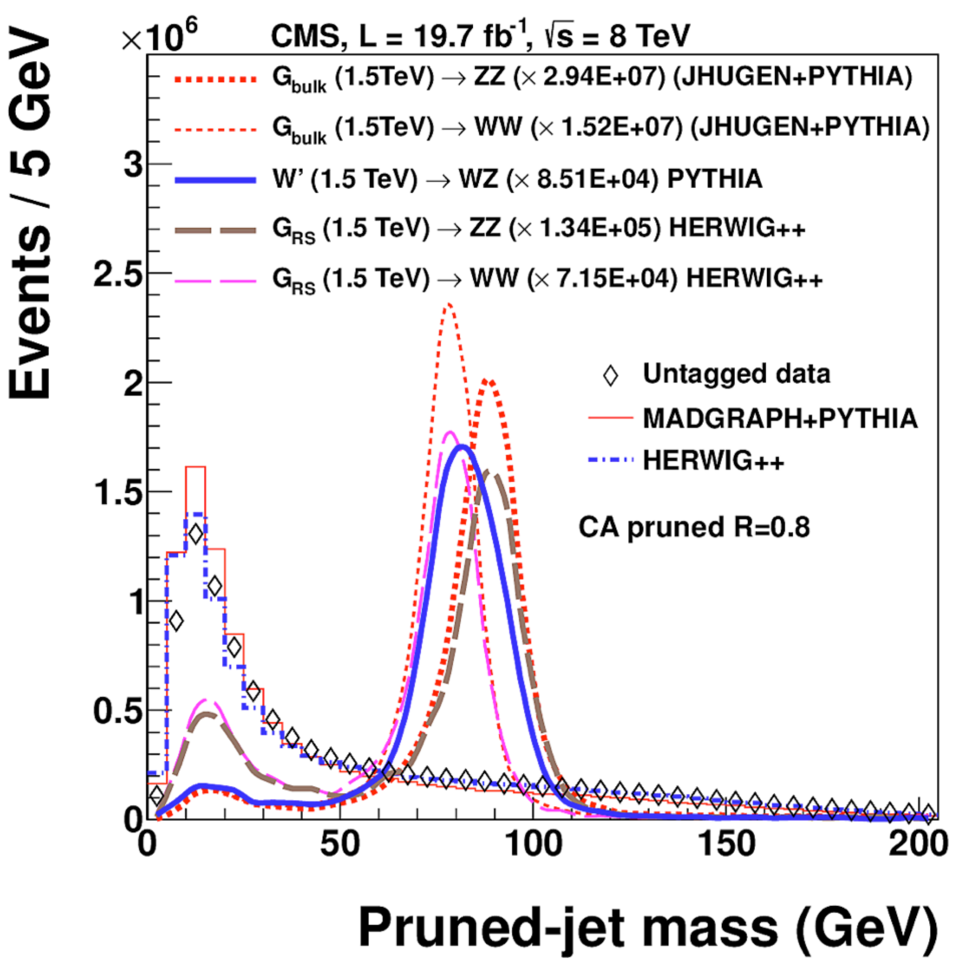
arxiv:1405.1994

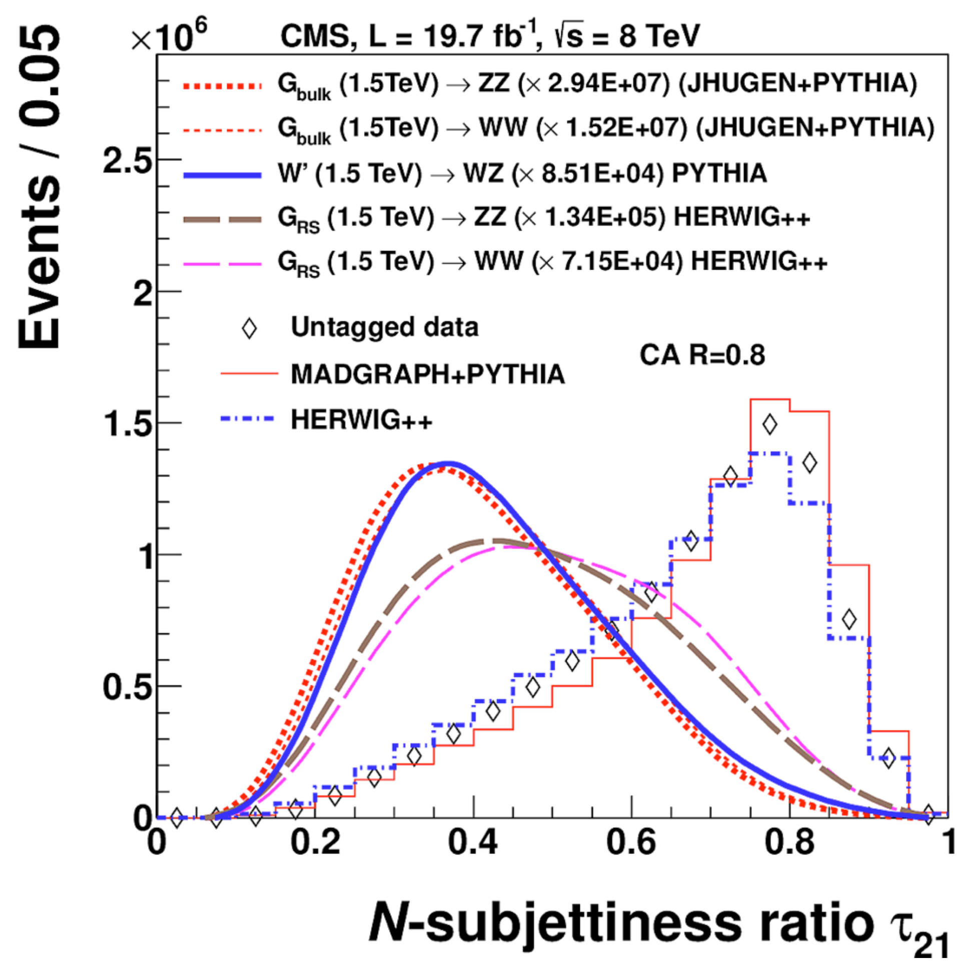
Jet Pruning: Reclusters the jet constituents, removing soft QCD radiation from the underlying event.

70 < Pruned Jet Mass < 100

N-subjettiness (τ_n): Capability of clustering the jet constituents in exactly N subjets. Ratio between 1 subjettines and 2 subjettines is a powerful tool to identify boosted Z and W!







Strategy: Search for a peak in the dijet mass spectrum using different categories:

1 or 2 V-Tags

τ_{21} < 0.5 (High Purity)

0.5 < τ_{21} < 0.75 (Low Purity)

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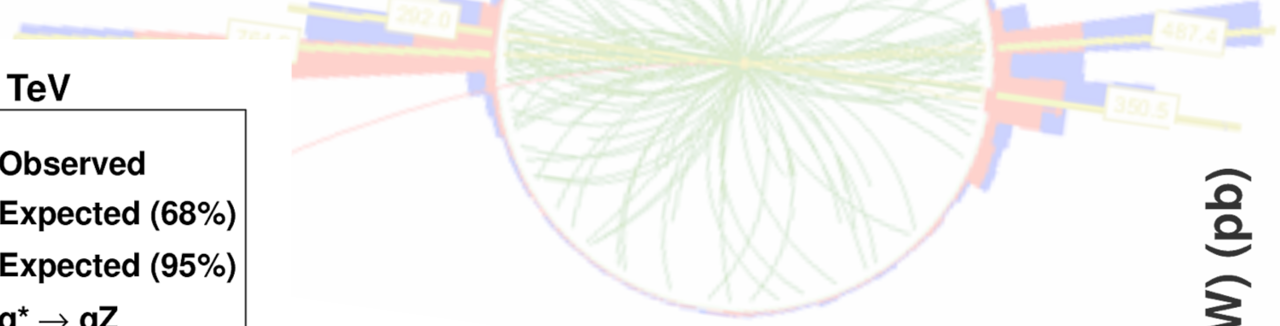
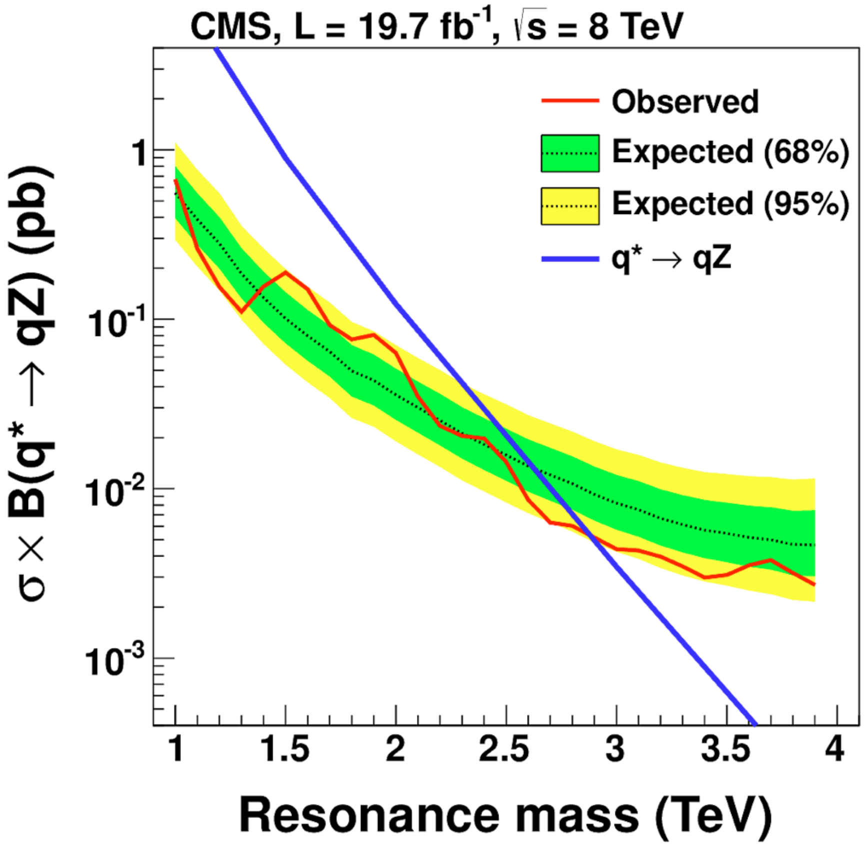
Search for massive resonances decaying into pairs of boosted bosons in all-hadronic final states

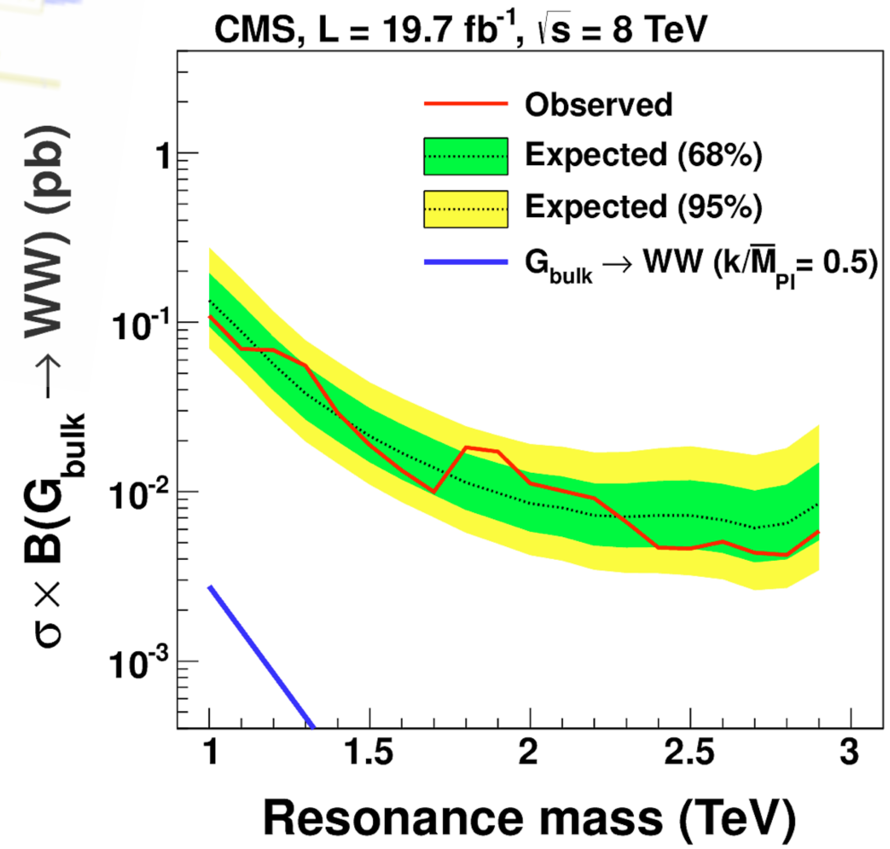


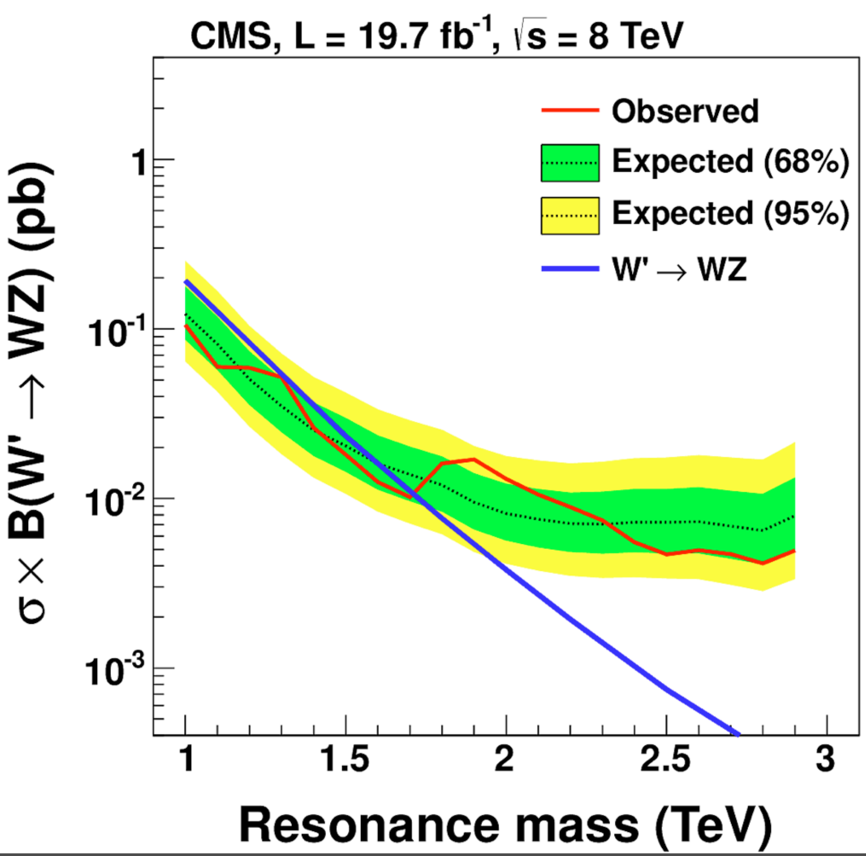


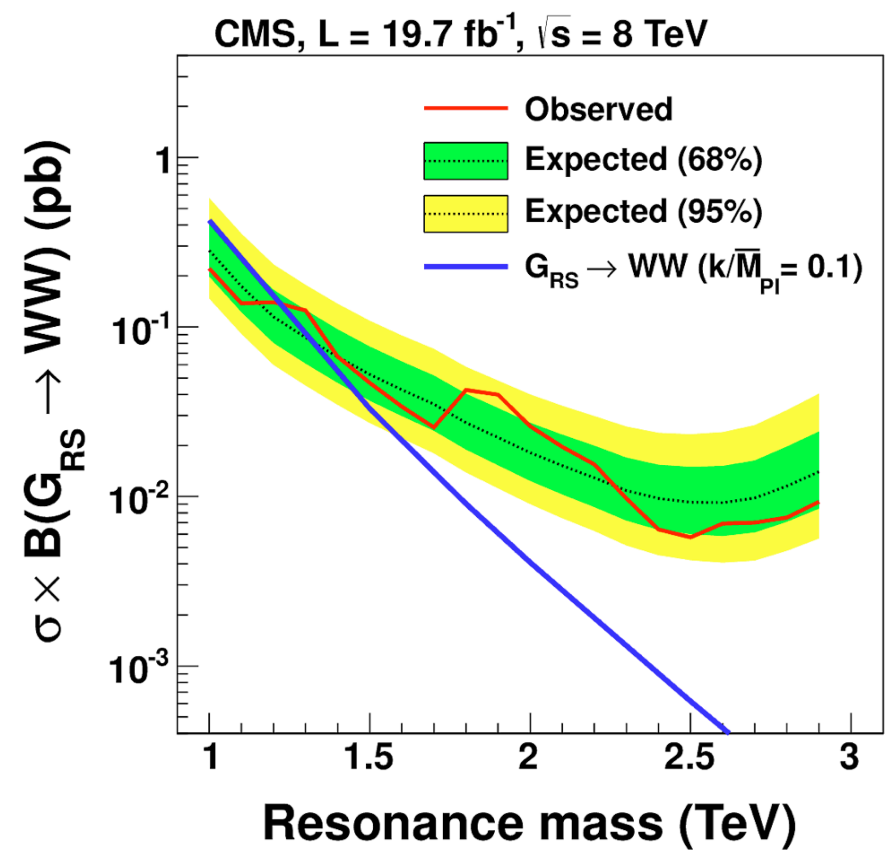
Results: No deviations from the standard model observed.

Process	Observed	Expected
$q^* \to qW$	3.2 TeV	3.0 TeV
$q^* \to qZ$	2.9 TeV	2.6 TeV
W’	1.7 TeV	1.6 TeV
$G_{RS} \to WW$	1.2 TeV	1.3 TeV

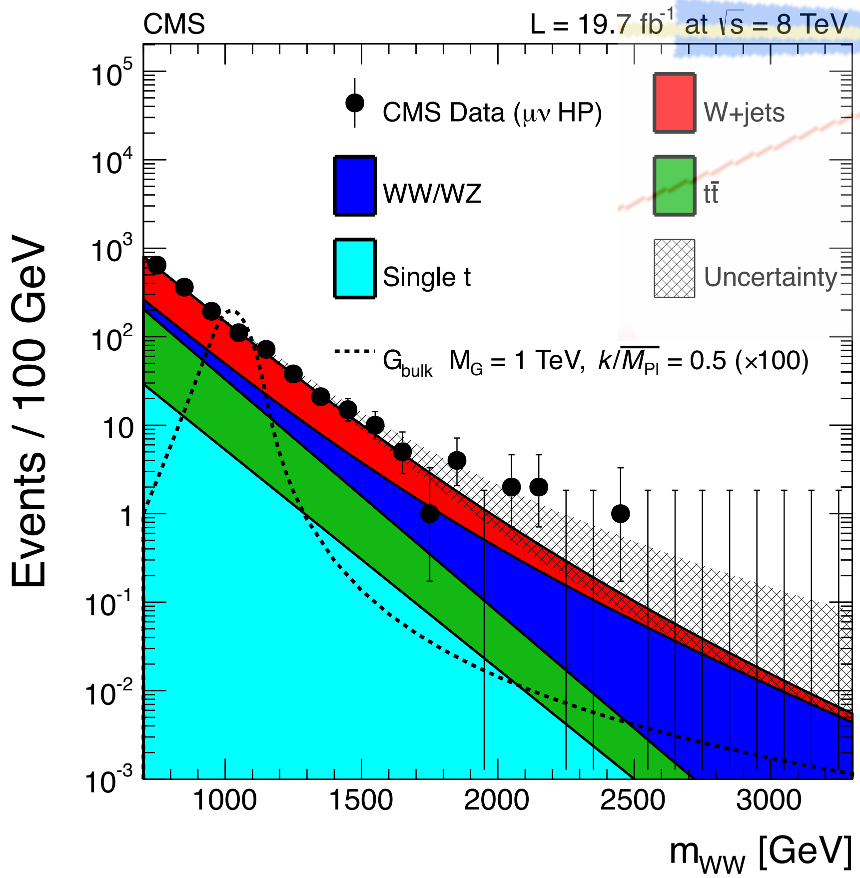
arxiv:1405.1994

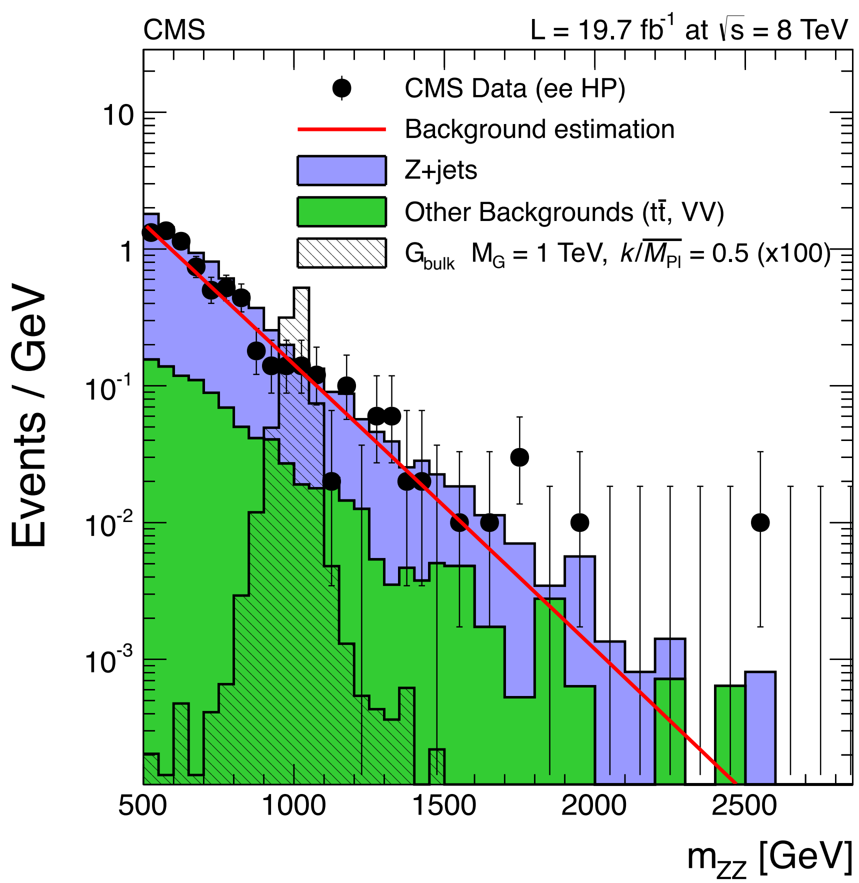






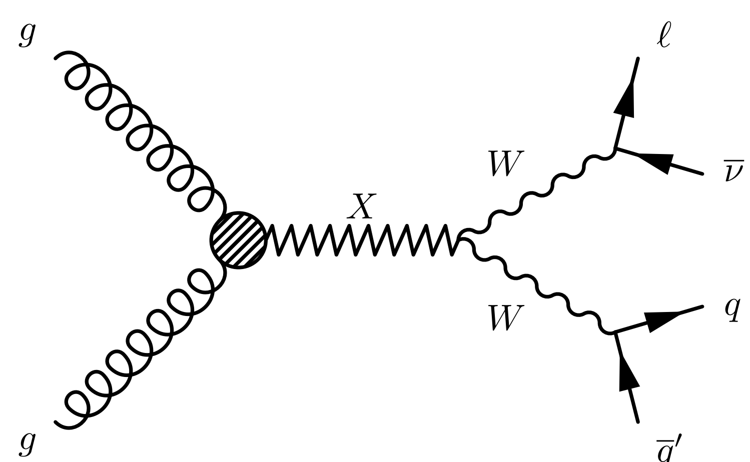
Search for massive resonances decaying into pairs of boosted bosons in semi-leptonic final states





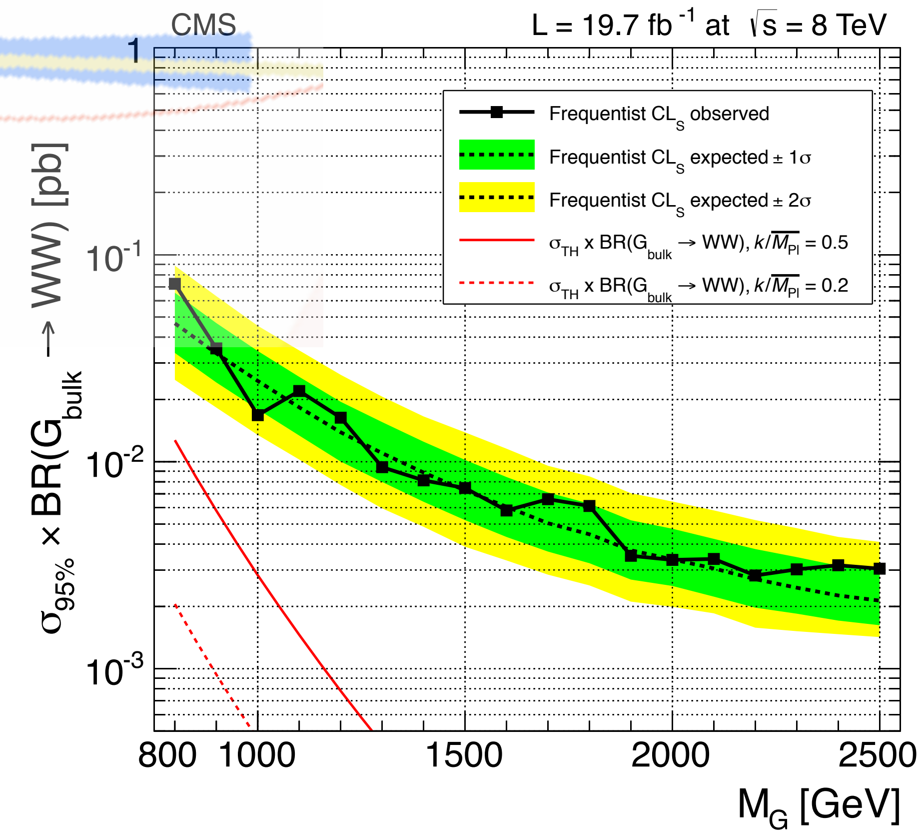
Strategy: Similar jet substructure techniques for identifying a boosted hadronic W or Z

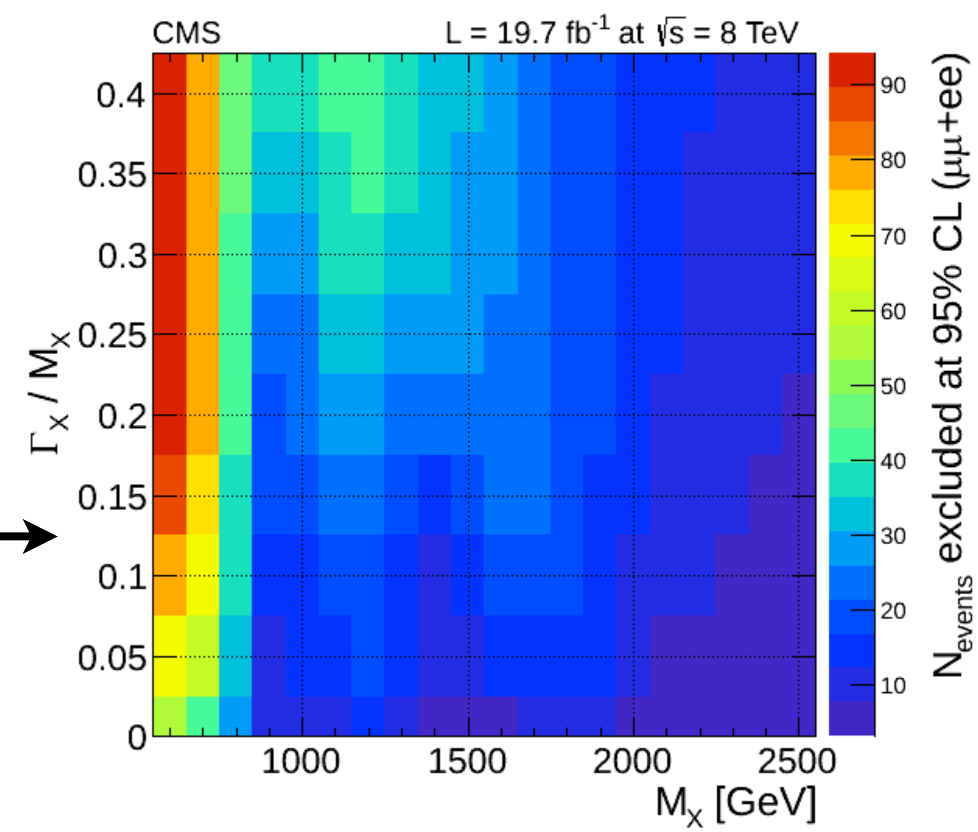
Also require presence of leptons and/or MET.



arxiv:1405.3447

With a simplified analysis, possibility to set limits as a function of both mass and natural width →





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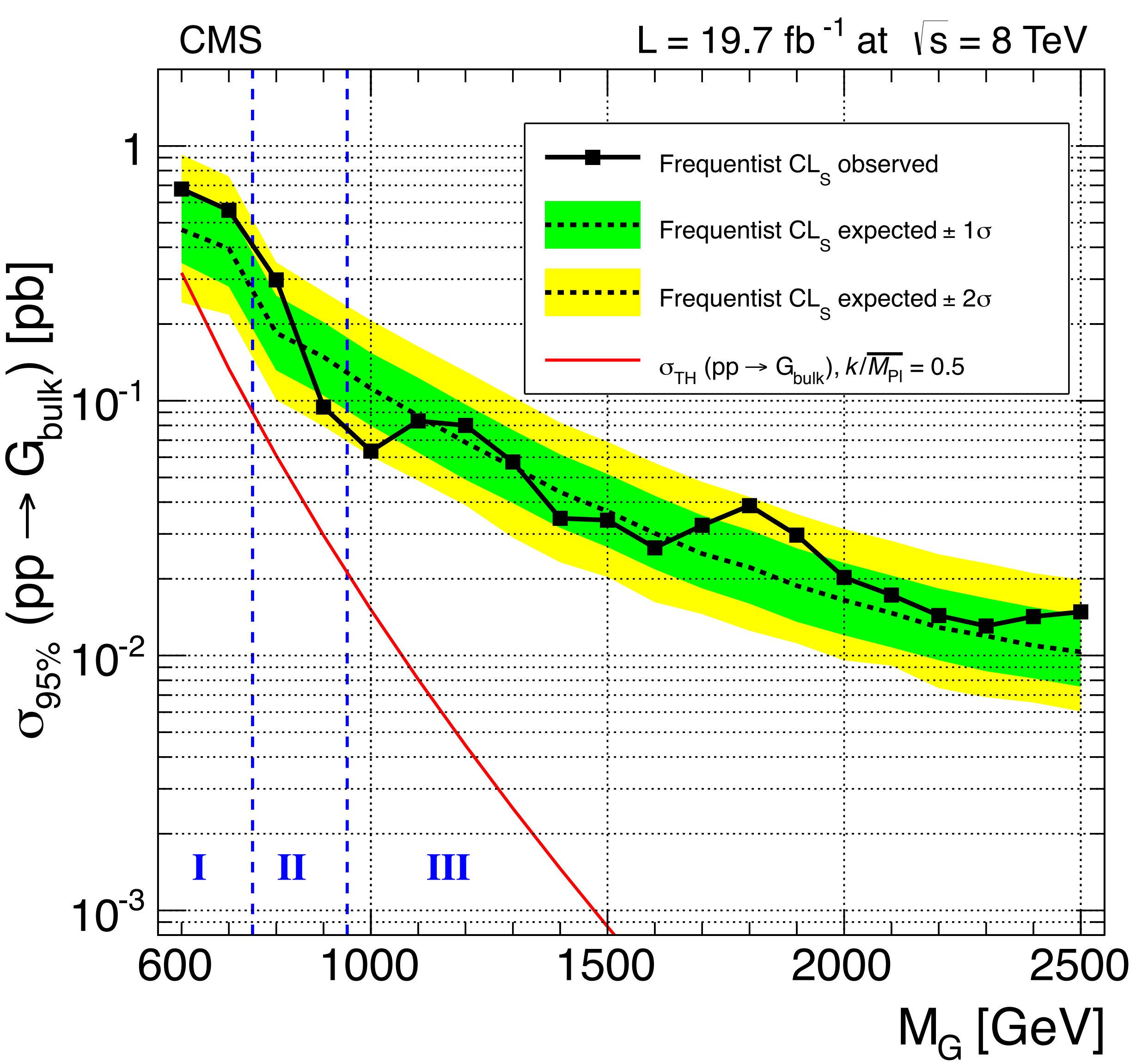
Combination for the search for massive resonances decaying into pairs of boosted bosons in all channels

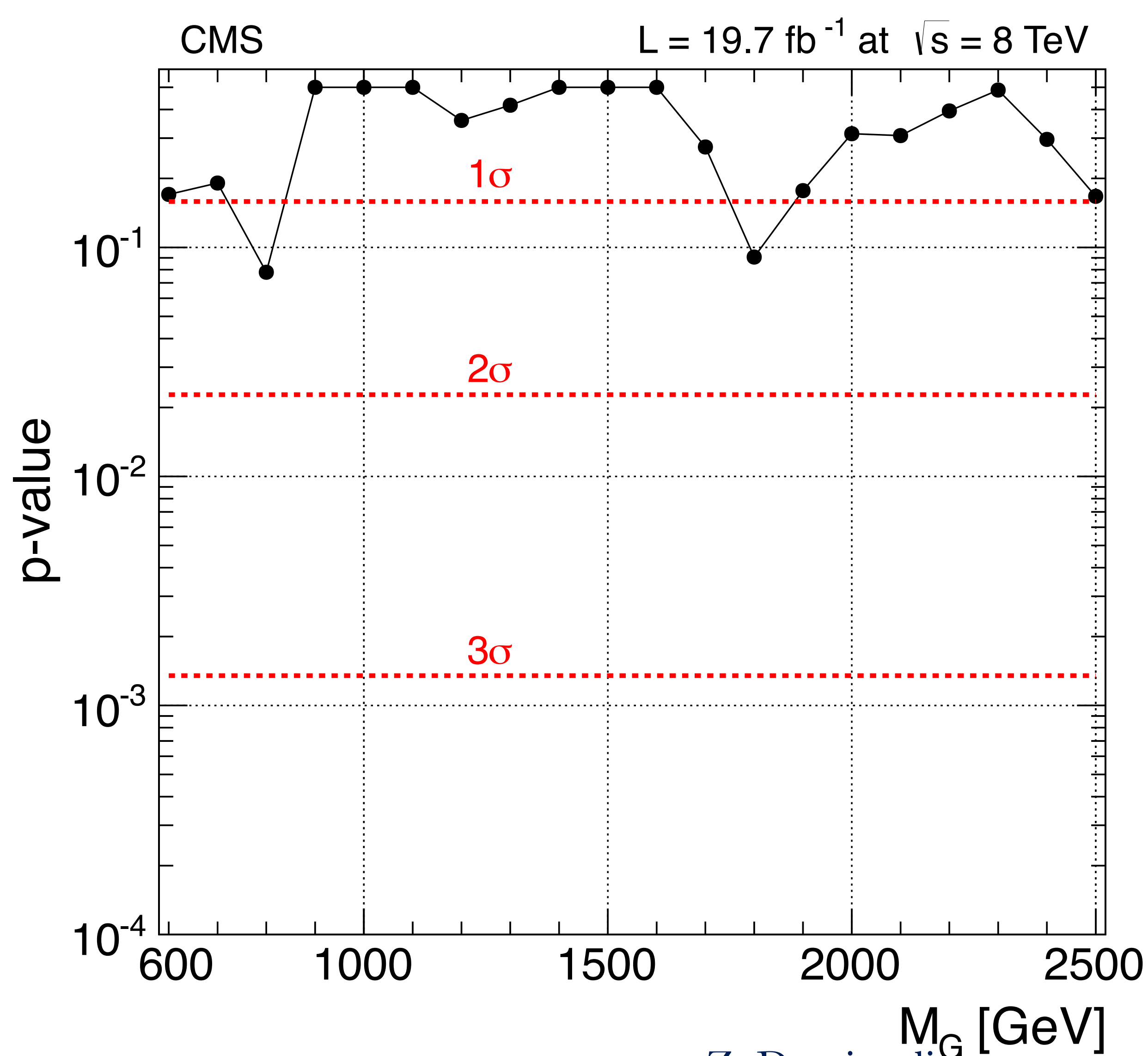
The **lν + V-jet** , **ll + V-jet** along with a complementary **VV → 2V-jets** searches are combined together to maximize the sensitivity for the search for Bulk Graviton.

lν + V-jet : Only contributing to the limit for resonance masses below 800 GeV

ll + V-jet : Dominates the sensitivity in the range of 800 - 2500 GeV

2V-jets : Contributes to the limits above 1300 GeV





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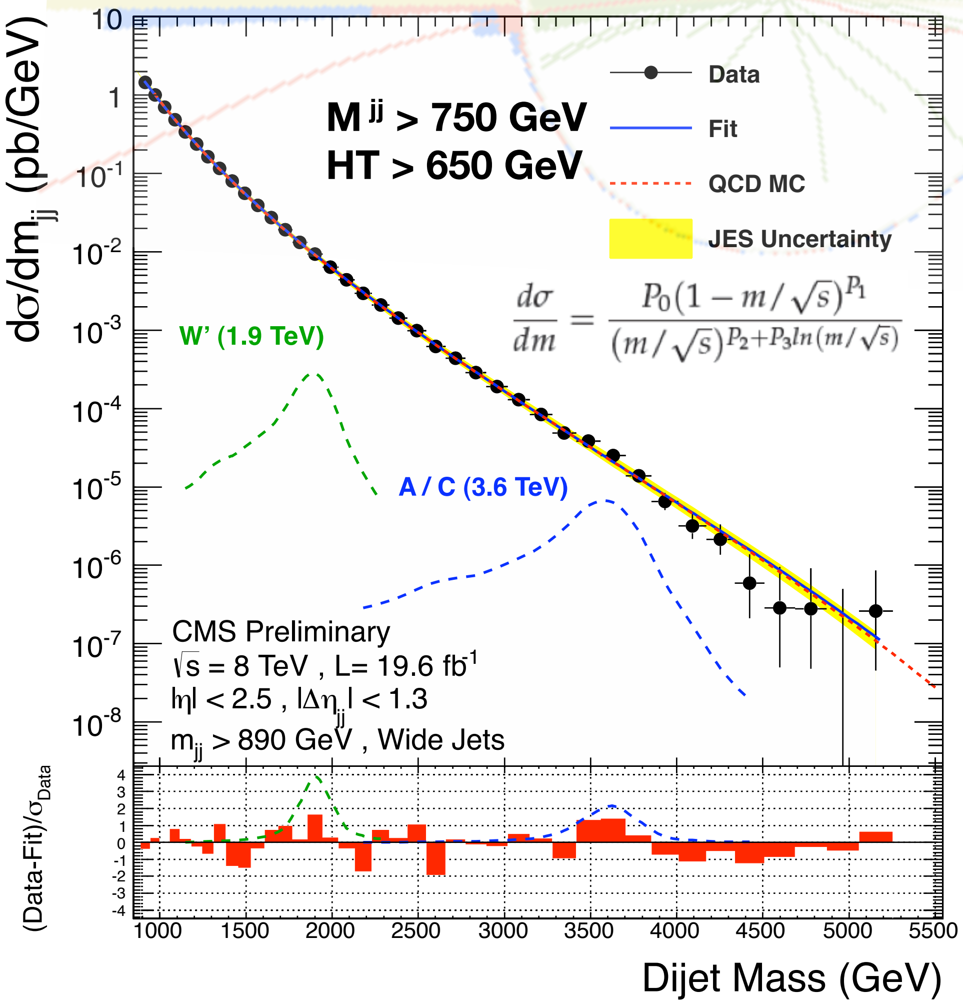
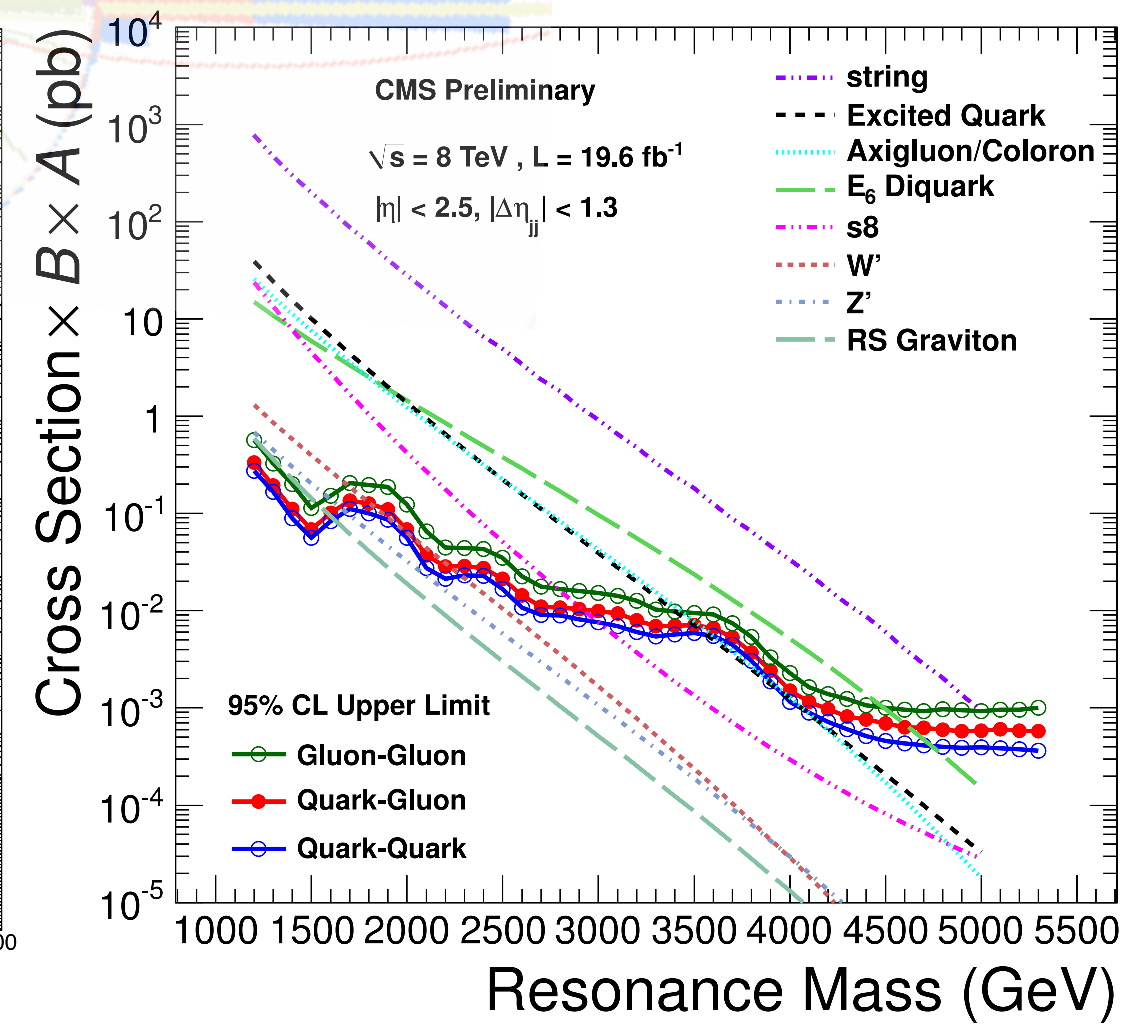
Search for Narrow Resonances using the Dijet Mass Spectrum

CMS-EXO-12-059

Wide Jets: Goal is to reduce sensitivity to gluon radiation.

Recipe: Select the 2 leading jets, combine all other jets within a radius of 1.1 into the leading jets.





No deviations from the SM observed!

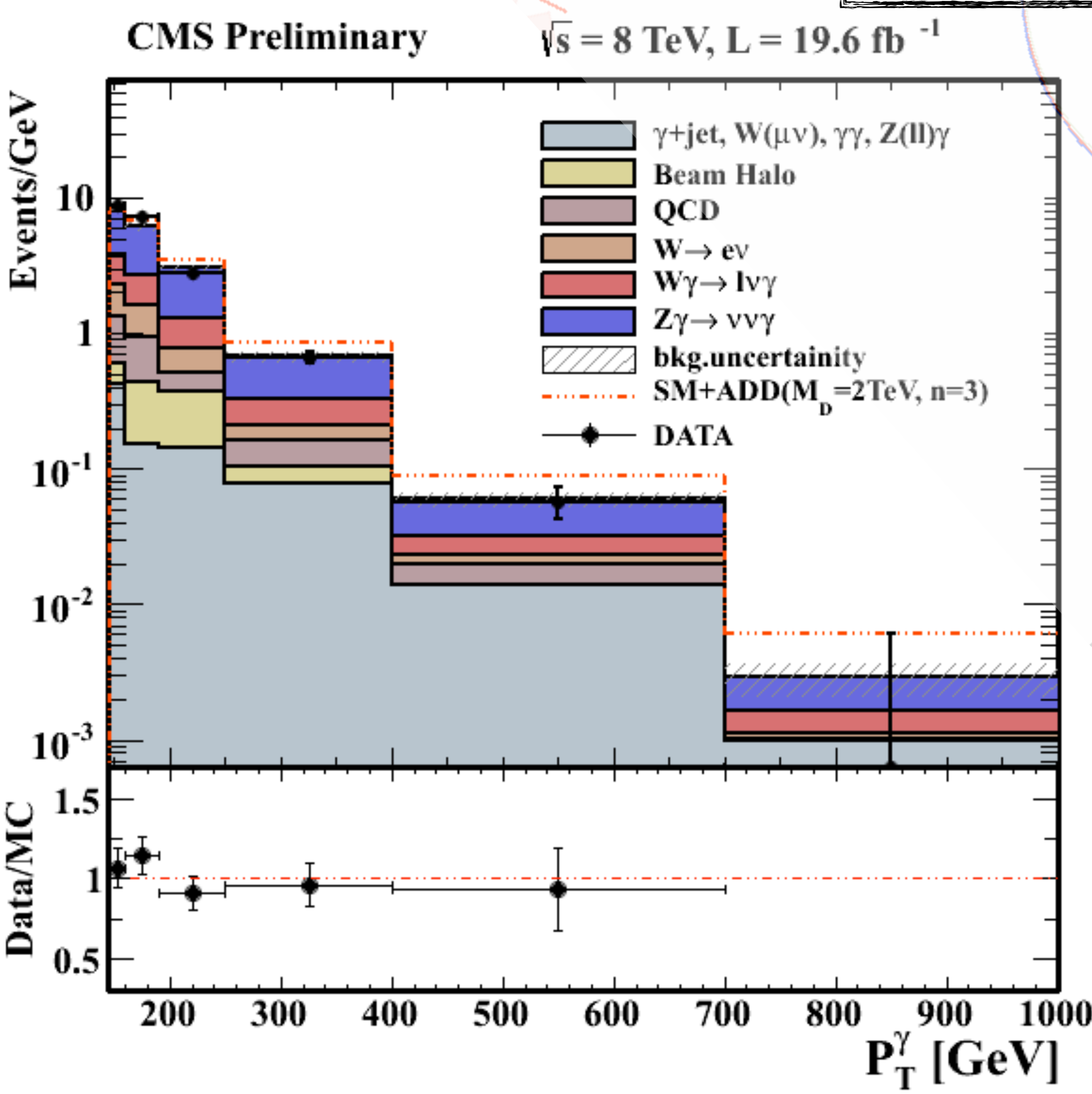
A **separate limit** is needed for each final state because of **dependence** of the dijet resonance shape **on the number of gluons**

Model	Final State	Obs. Mass Excl. [TeV]	Exp. Mass Excl. [TeV]
String Resonance (S)	qg	[1.20,5.08]	[1.20,5.00]
Excited Quark (q*)	qg	[1.20,3.50]	[1.20,3.75]
E_6 Diquark (D)	qq	[1.20,4.75]	[1.20,4.50]
Axigluon (A)/Coloron (C)	$q\bar{q}$	[1.20,3.60] + [3.90,4.08]	[1.20,3.87]
Color Octet Scalar (s8)	gg	[1.20,2.79]	[1.20,2.74]
W′ Boson (W′)	$q\bar{q}$	[1.20,2.29]	[1.20,2.28]
Z′ Boson (Z′)	$q\bar{q}$	[1.20,1.68]	[1.20,1.87]
RS Graviton (G)	$q\bar{q}$+gg	[1.20,1.58]	[1.20,1.43]

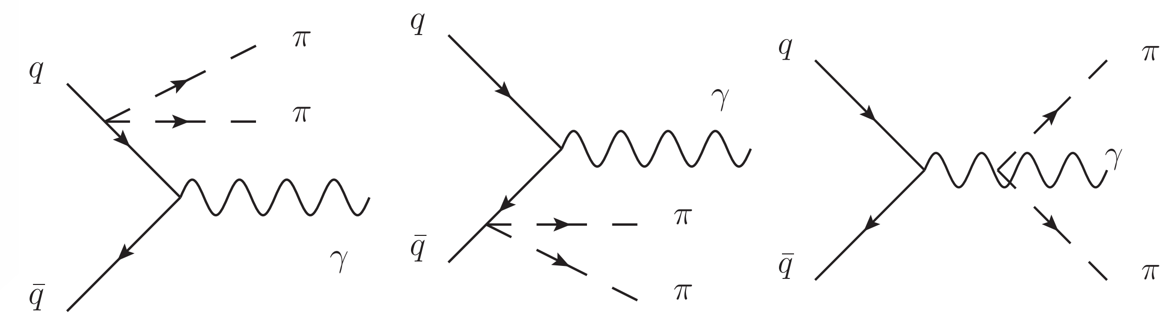
Search for Branons in Photon + MET Final State

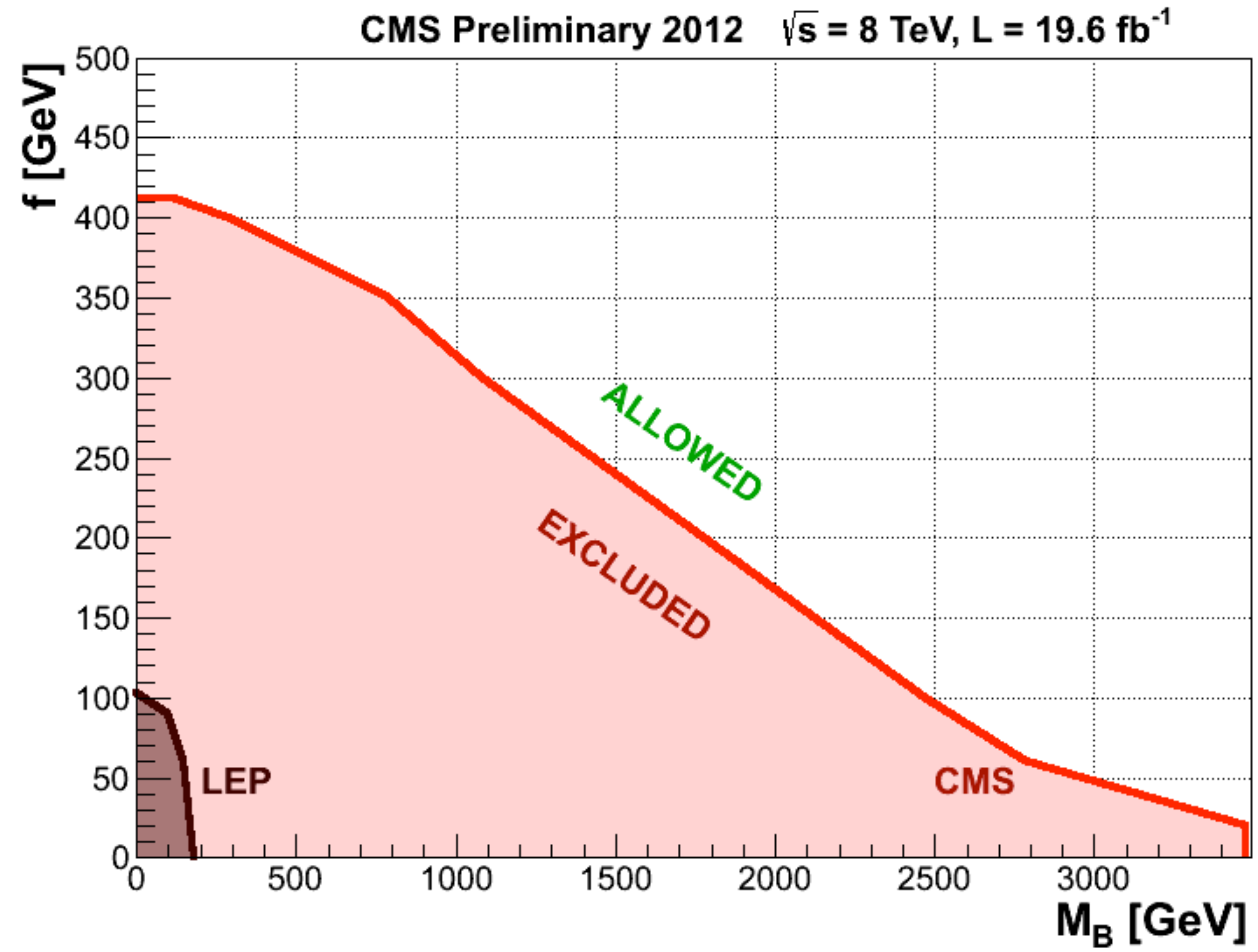
First Branon search at the LHC!

CMS-EXO12-047



Assumption: If the brane in the extra dimension is allowed to fluctuate it will give rise to Branons which are detectable in the LHC through qq → γππ





For massless branons: **Brane Tension > 412 GeV.**

For low brane tension: **Branon Mass > 3.5 TeV.**

First experimental constraints on the branon model since the LEP experiment!

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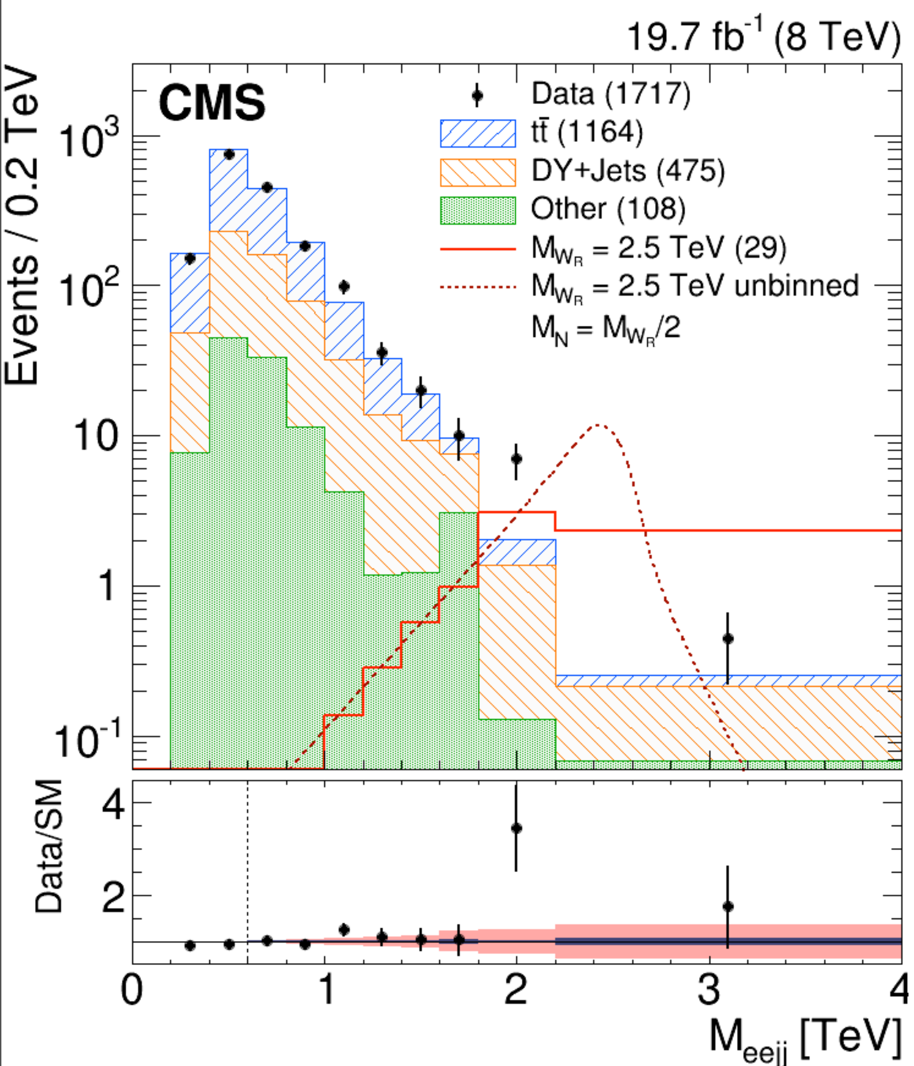
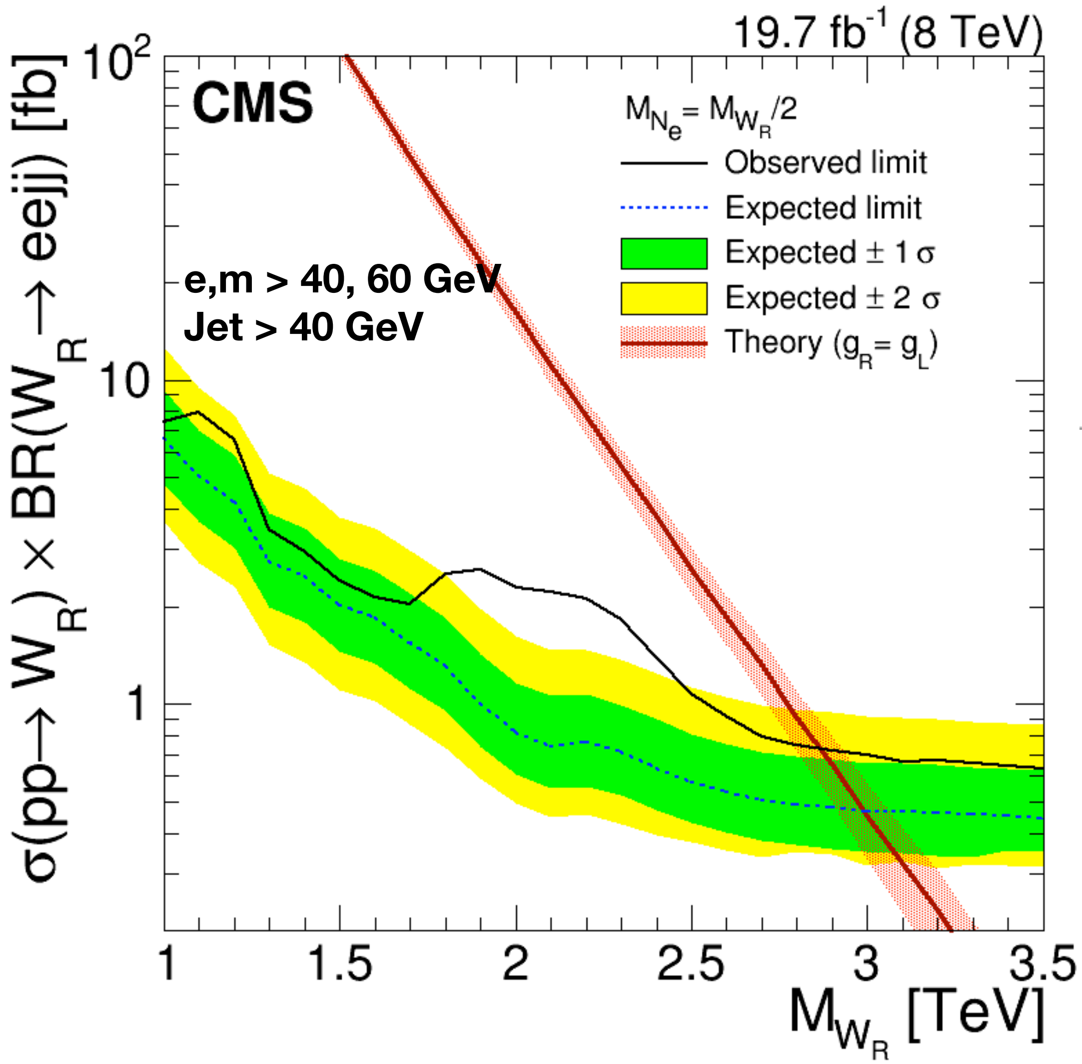
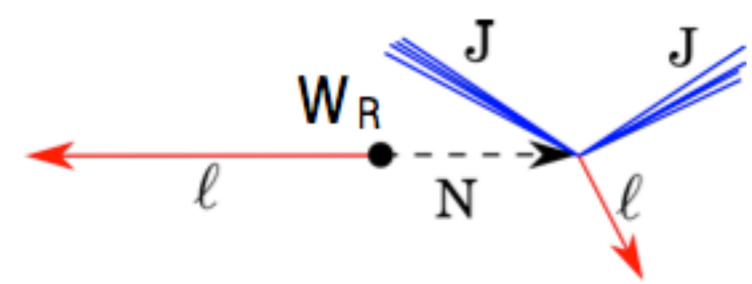
Search for Heavy Neutrinos

arxiv:1407.3683

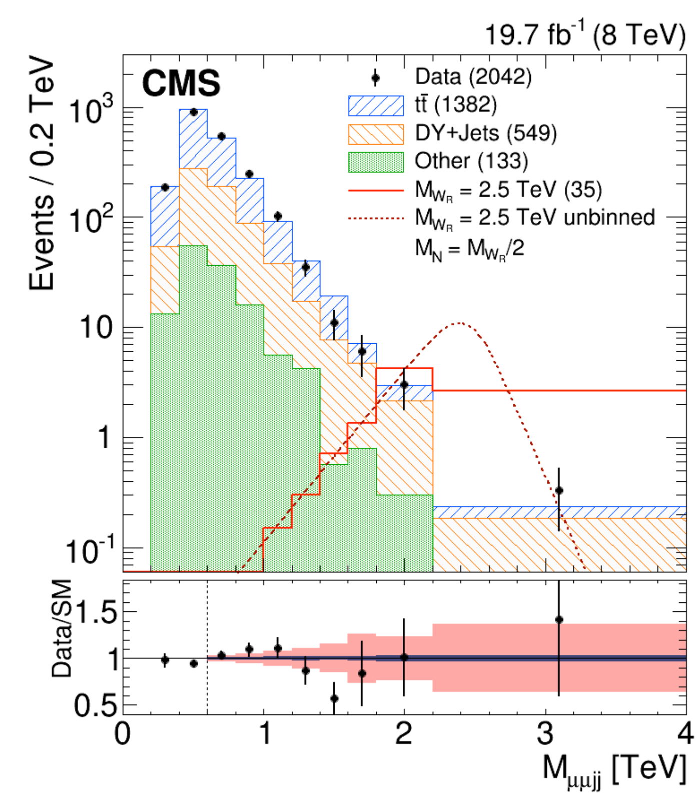
$$W_R \to \ell_1 N_\ell \to \ell_1 \ell_2 W_R^* \to \ell_1 \ell_2 q\bar{q}.$$







no excess seen in muon channel



This excess does not appear to be consistent with WR → eNe decay.

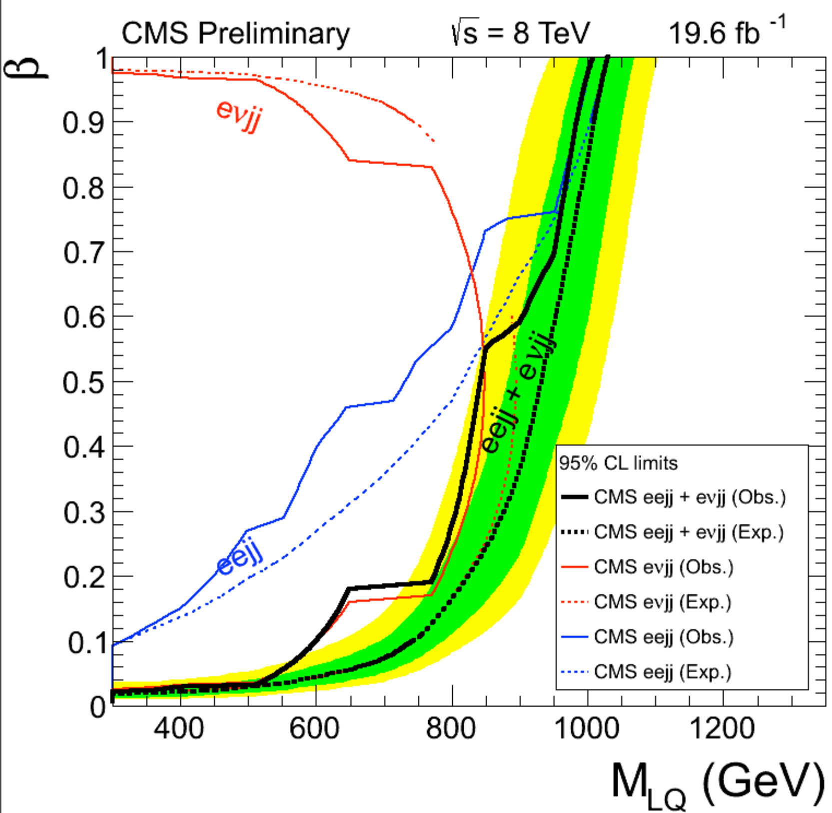
No localized excess in other distributions associated with these events.

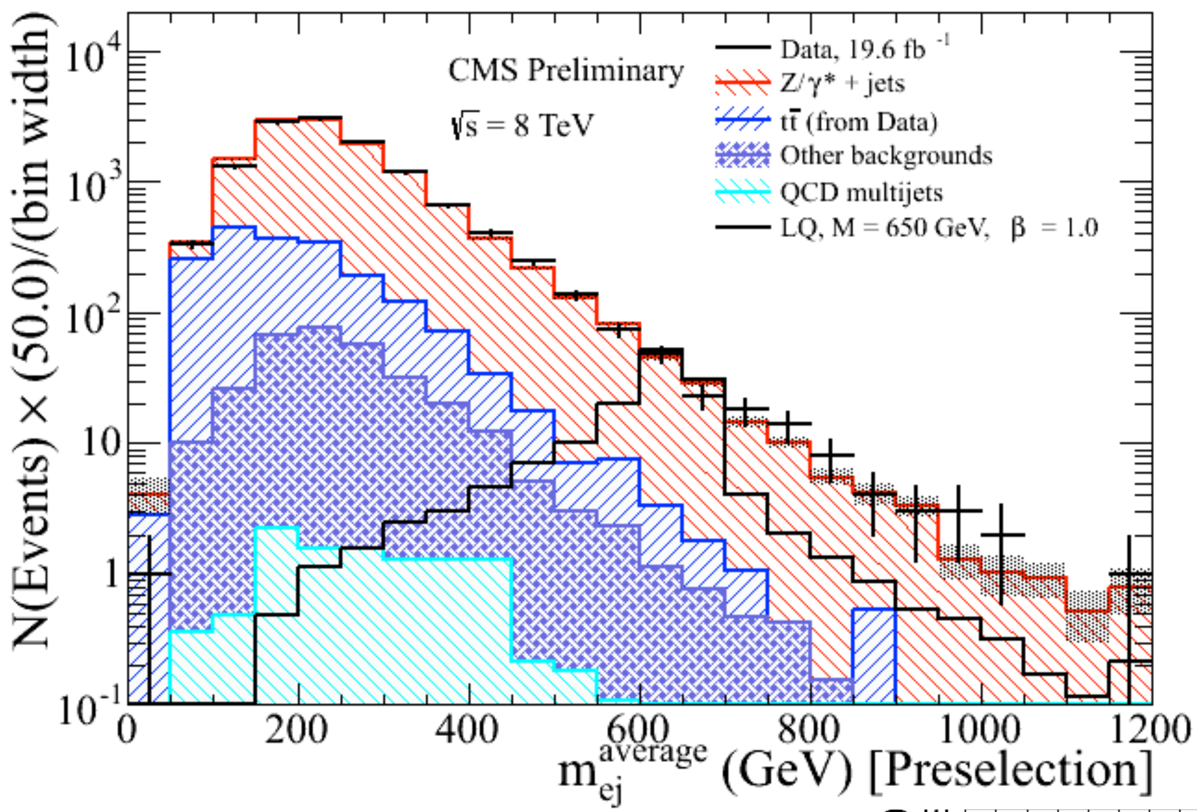
From an earlier parallel / plenary talk:
1st Generation LeptoQuarks

- 2 search regions:
  - $\beta = 1$ [eejj] : $ee + \geq 2j$
  - $\beta = 0.5$ [eνjj] : $e + \geq 2j + E_T^{miss}$>55 GeV

electron	$p_T > 45$ GeV	$\|\eta\| < 2.5(2.1)^{\ddagger}$
jet	$p_T > 125(45)^{\dagger}$ GeV	$\|\eta\| < 2.4$
muon*	$p_T > 10$ GeV	$\|\eta\| < 2.4$

* muon veto † subleading jets ‡ eνjj channel

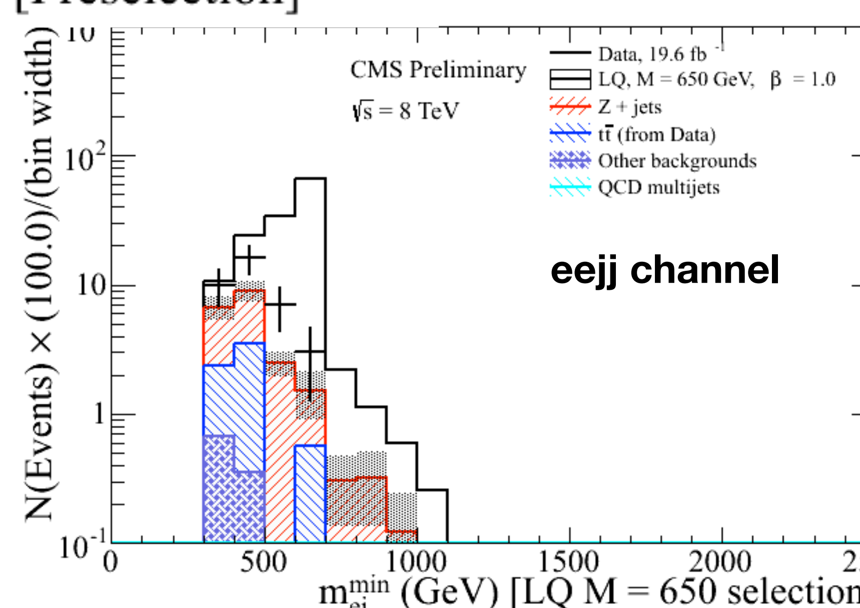




CMS-EXO-12-041

Optimize S_T , M_{ej}^{min} and M_{ee} after eejj selection

Mass 650 Selection: →



	LQ mass (eejj)														
	300	350	400	450	500	550	600	650	700	750	800	850	900	950	≥ 1000
S_T [GeV]	435	485	535	595	650	715	780	850	920	1000	1075	1160	1245	1330	1425
m_{ee} [GeV]	110	110	115	125	130	140	145	155	160	170	175	180	190	195	205
m_{ej}^{min} [GeV]	50	105	160	205	250	290	325	360	390	415	435	450	465	470	475

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Conclusion

Amazing work has been done in CMS so far. Since 2010 in Exotica Physics Program 74 papers are published! (with more to come!)

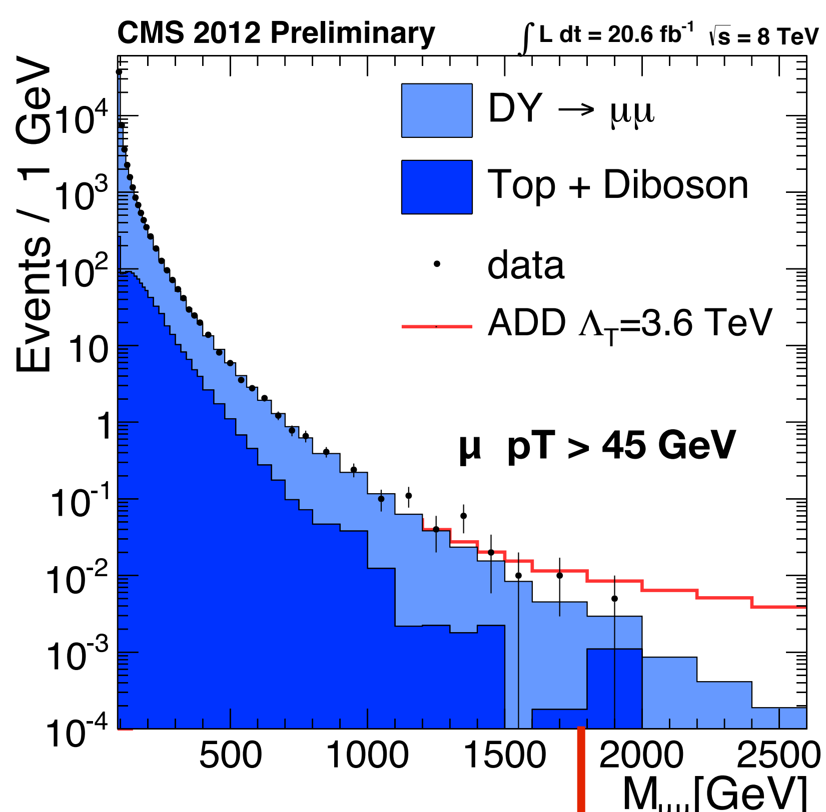
Searching for signs of exotic physics is an important part of the LHC program

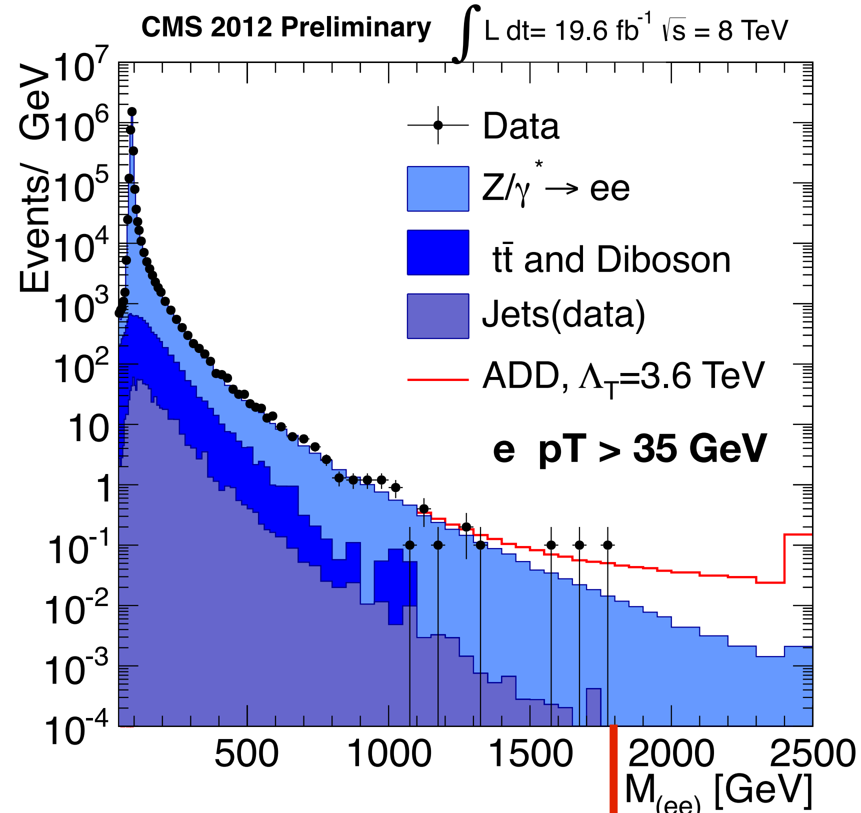
No signs for exotic models so far, but Run 2 is upon us!

Search for Large Extra Dimensions in Dilepton Events

CMS-EXO12-027

CMS-EXO-12-031

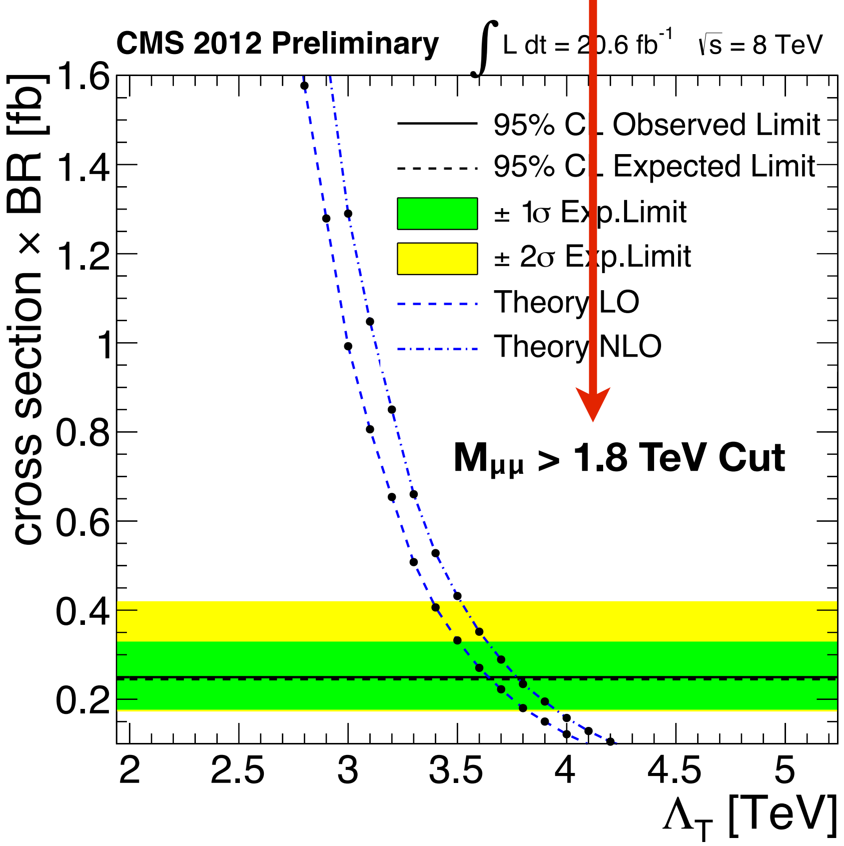


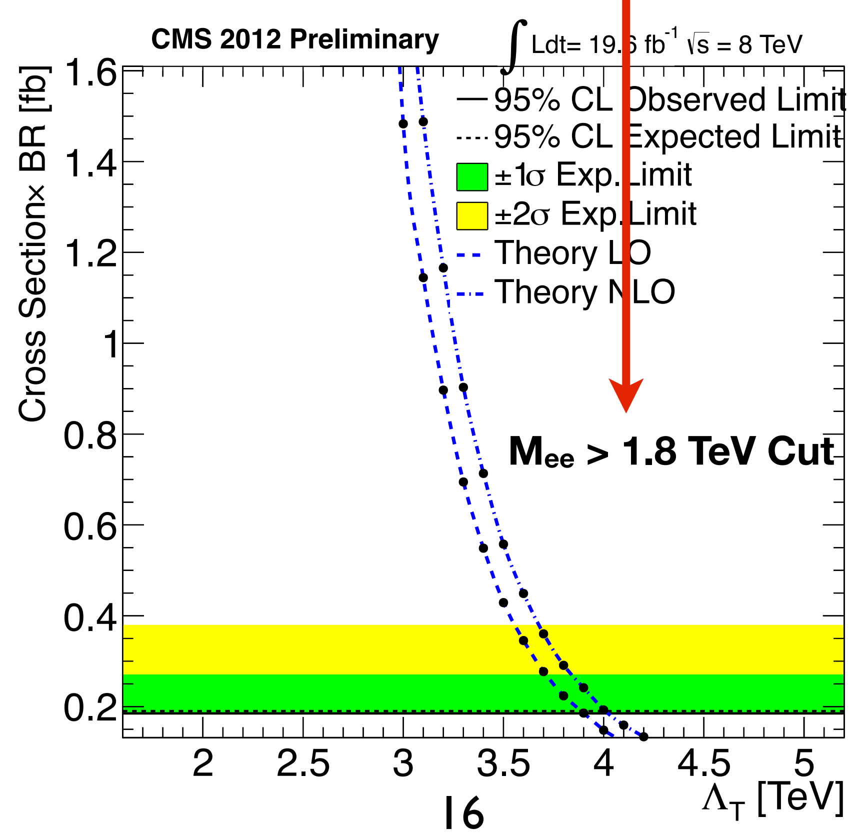


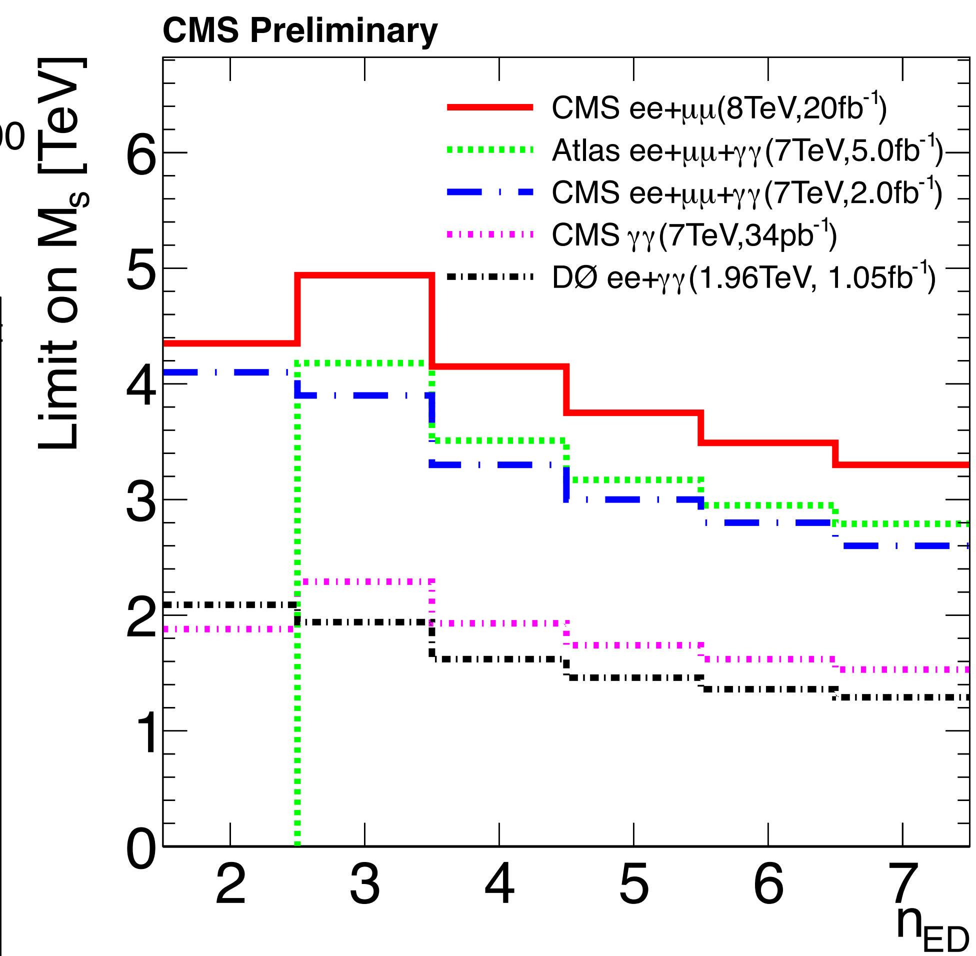
Assumption: Manifestation of extra dimensions through presence of G_{KK}.

Expectation: Enhancement to the dilepton xsec in high invariant masses.

Observation: No deviation from SM







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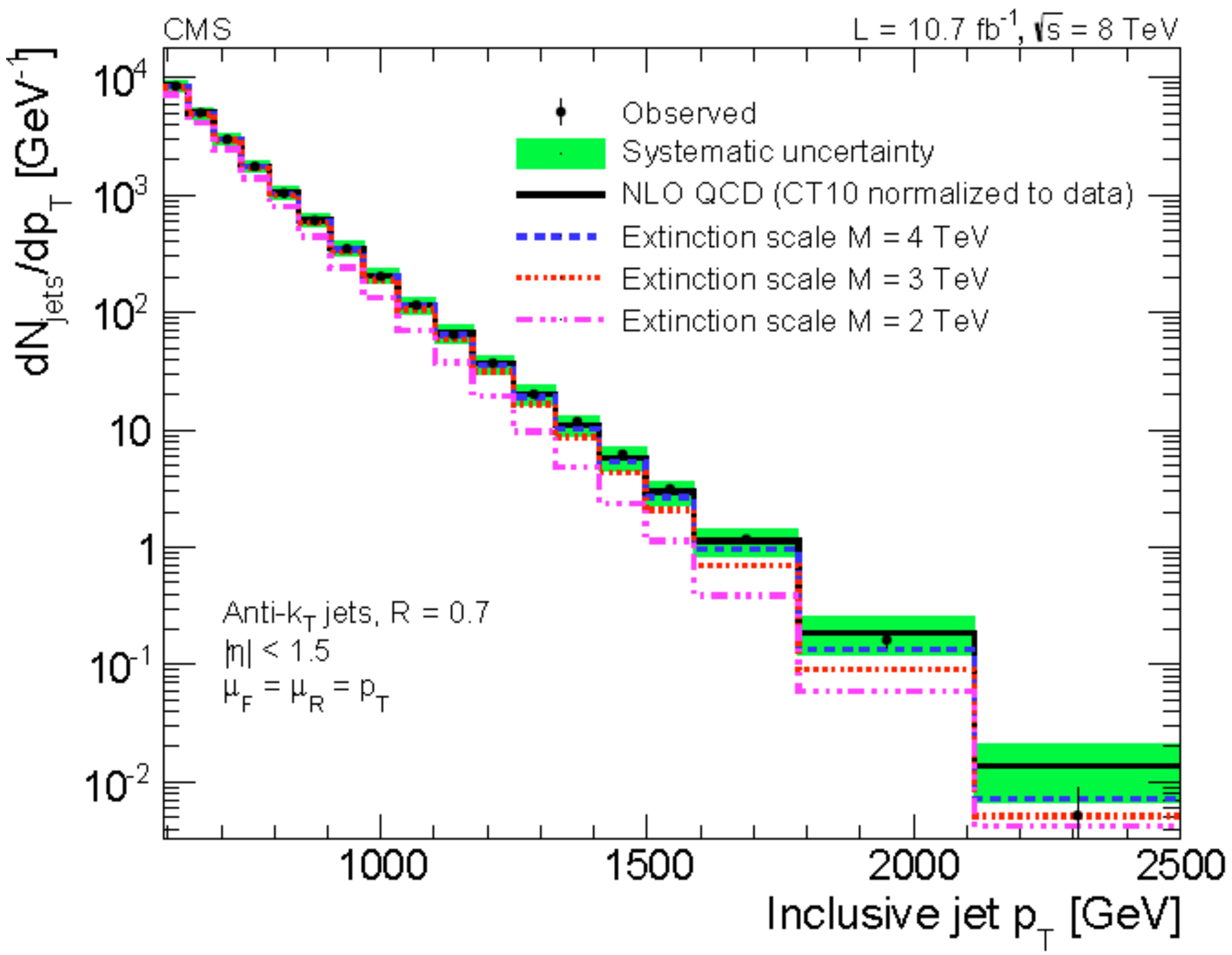
Search for jet extinction in the inclusive jet-pt spectrum

arxiv:1405.7653

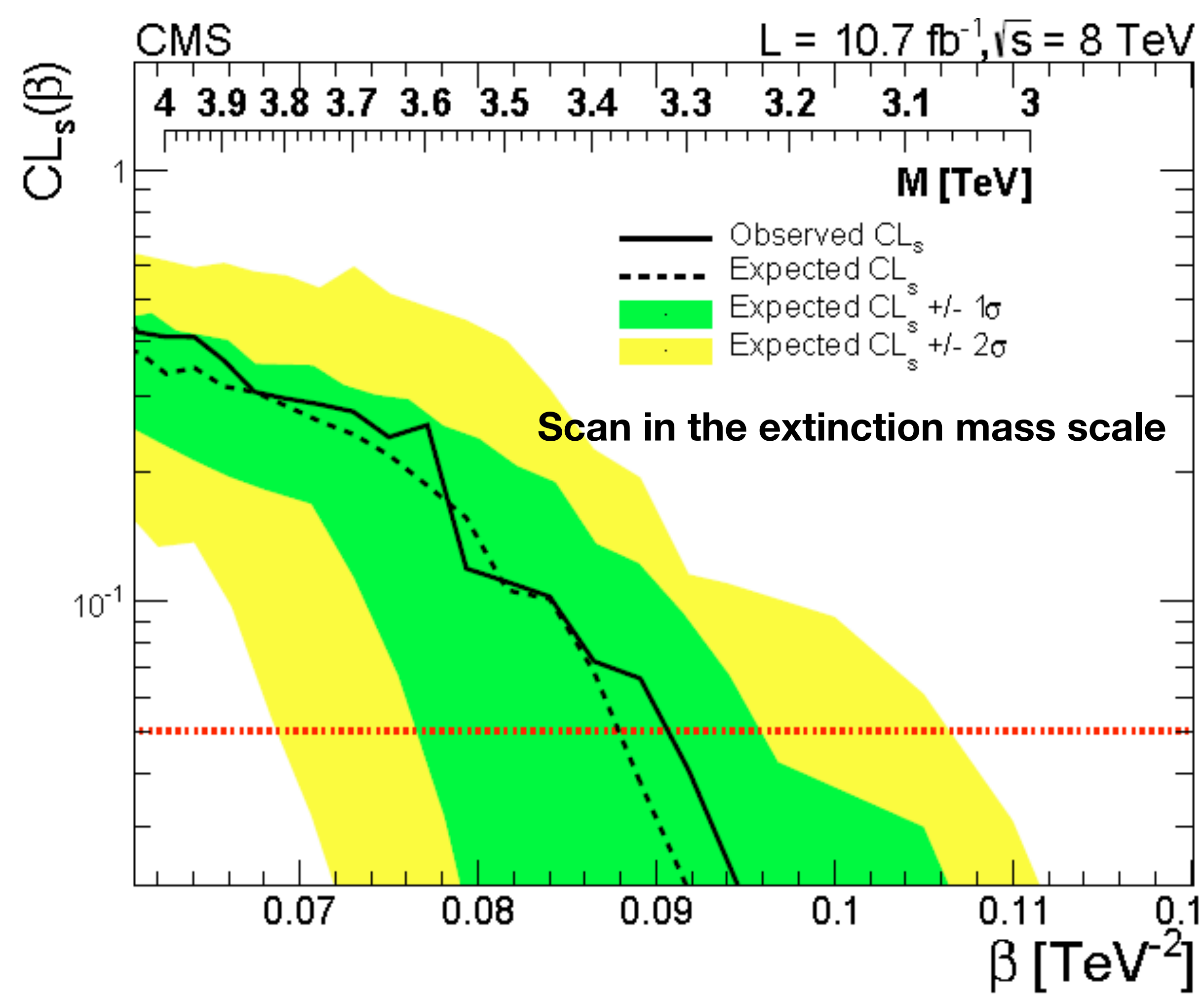
First search at the LHC!



Assumption: Search for signatures of strong gravity at TeV scale. Assumes the existence of string couplings in the strong-coupling limit.

Expectation: Model predicts suppression of all high pT SM processes (no jet production at high energies)

as $\beta \rightarrow 0$ (signal strengh) where $\beta = M^{-2}$, the extinction model $\rightarrow$ the SM prediction



Observation: No deficit of events observed.

The best-fit value of **β** is **0.008 ± 0.033 TeV^{-2}** . Fully consistent with SM!

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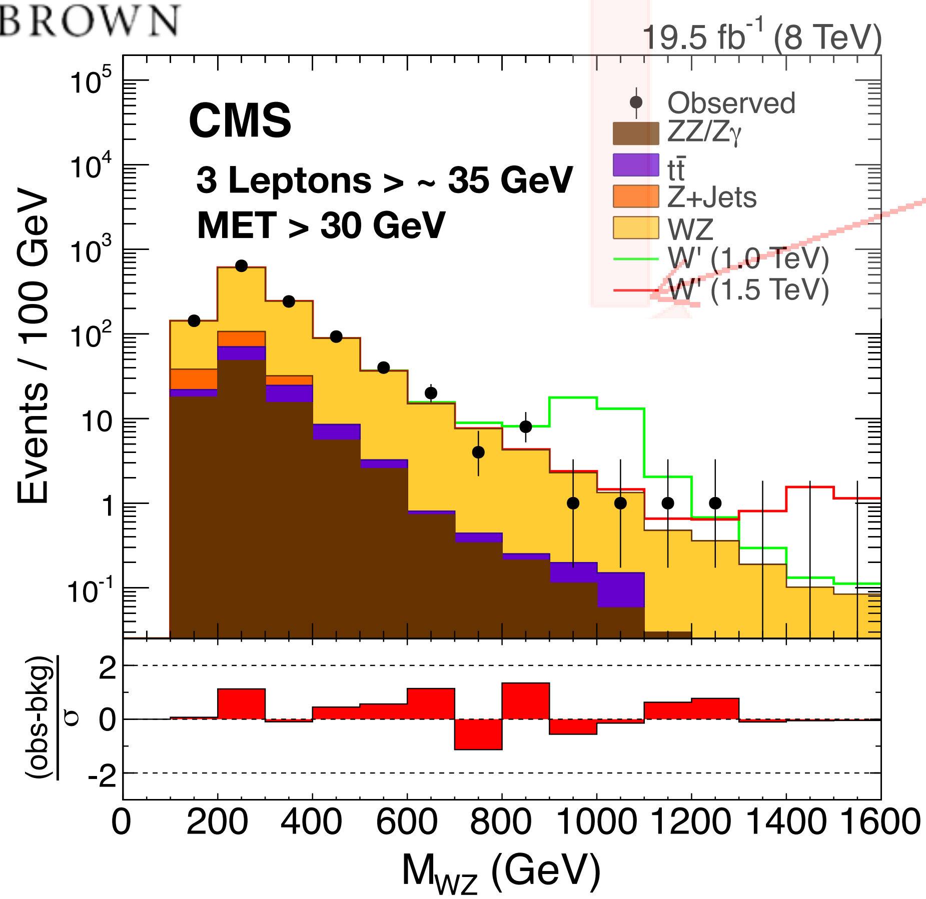
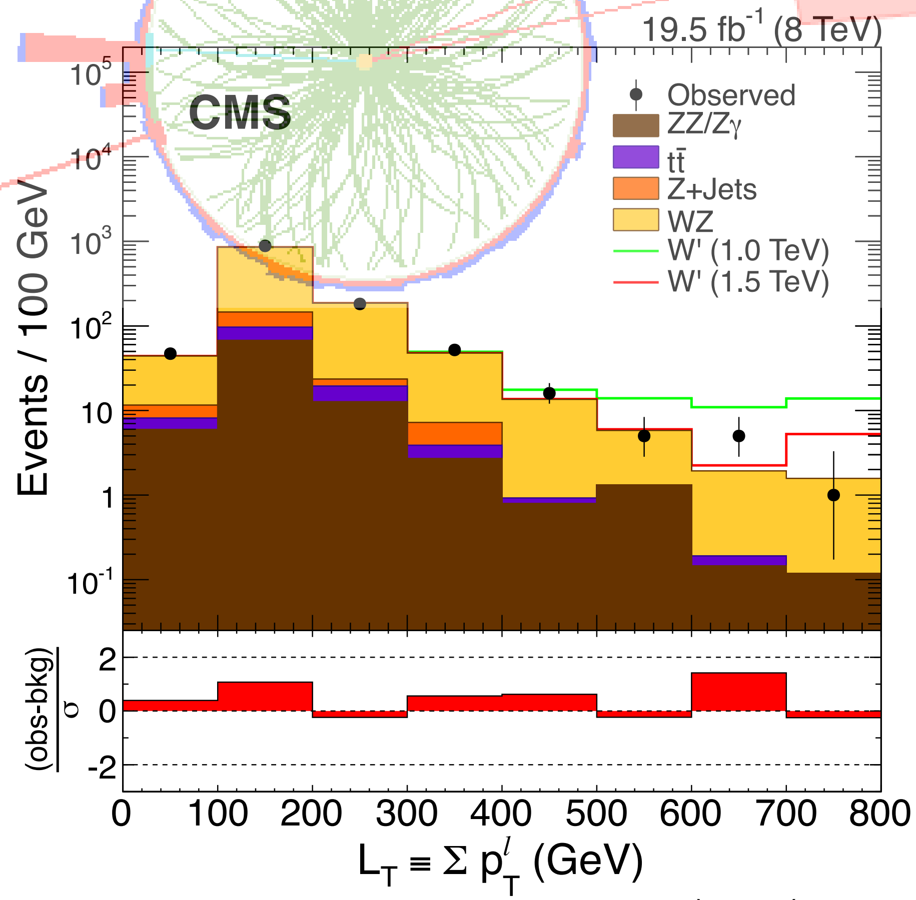
Search for new resonances decaying via WZ to leptons





arxiv: 1407.3476

Discriminators

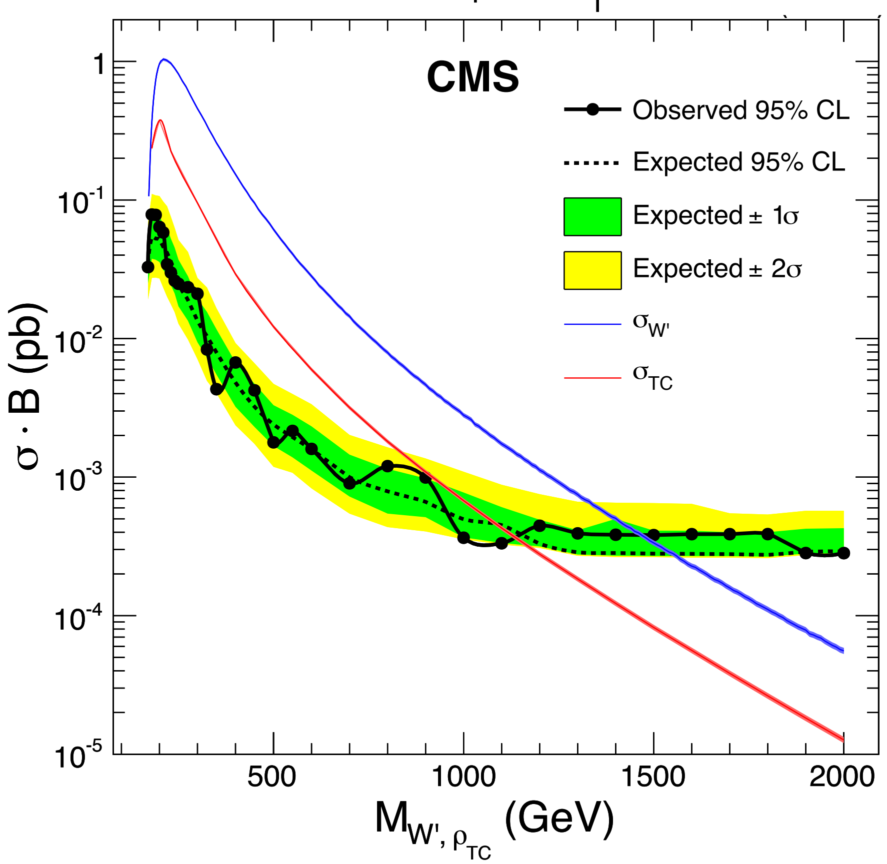
WZ Mass: Mass cannot be determined uniquely without p^{ν}_z Constrain the p^{ν}_z using true W mass.

L_T : $P_T^{l1} + P_T^{l2} + P_T^{l3}$

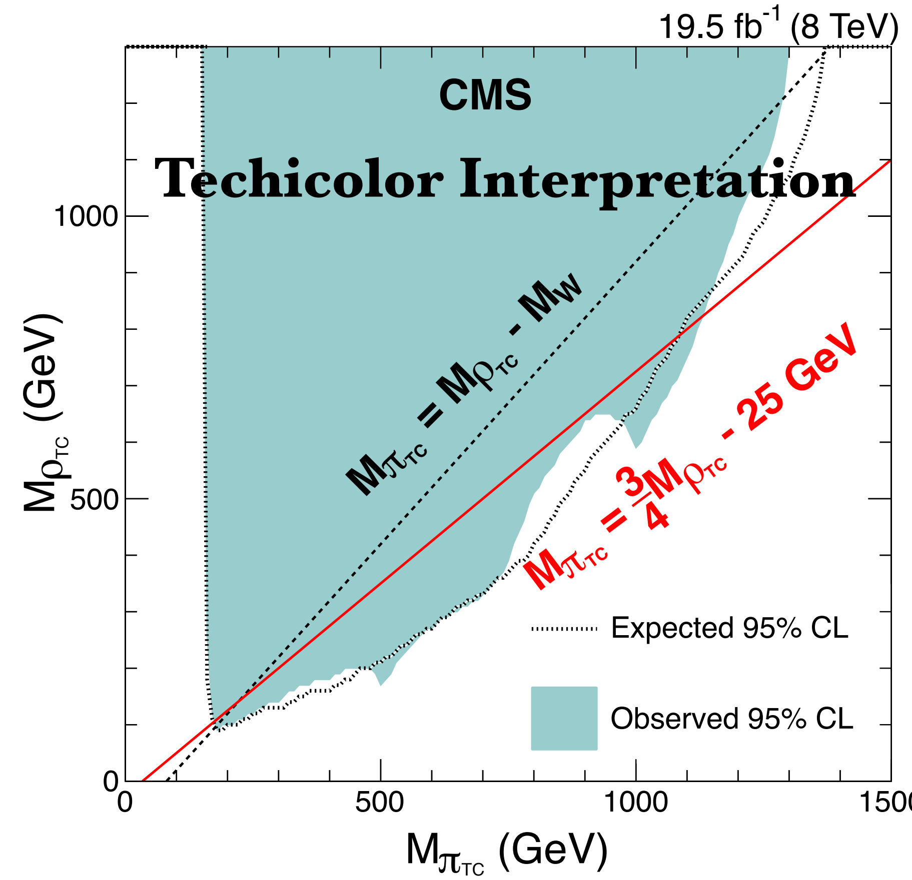
Strategy: Minimum L_T and M_{WZ} window optimized for each mass hypothesis.

No deviation from the SM observed.

Results interpreted in terms of SSM **W'** and **Technicolor**



Techicolor Interpretation



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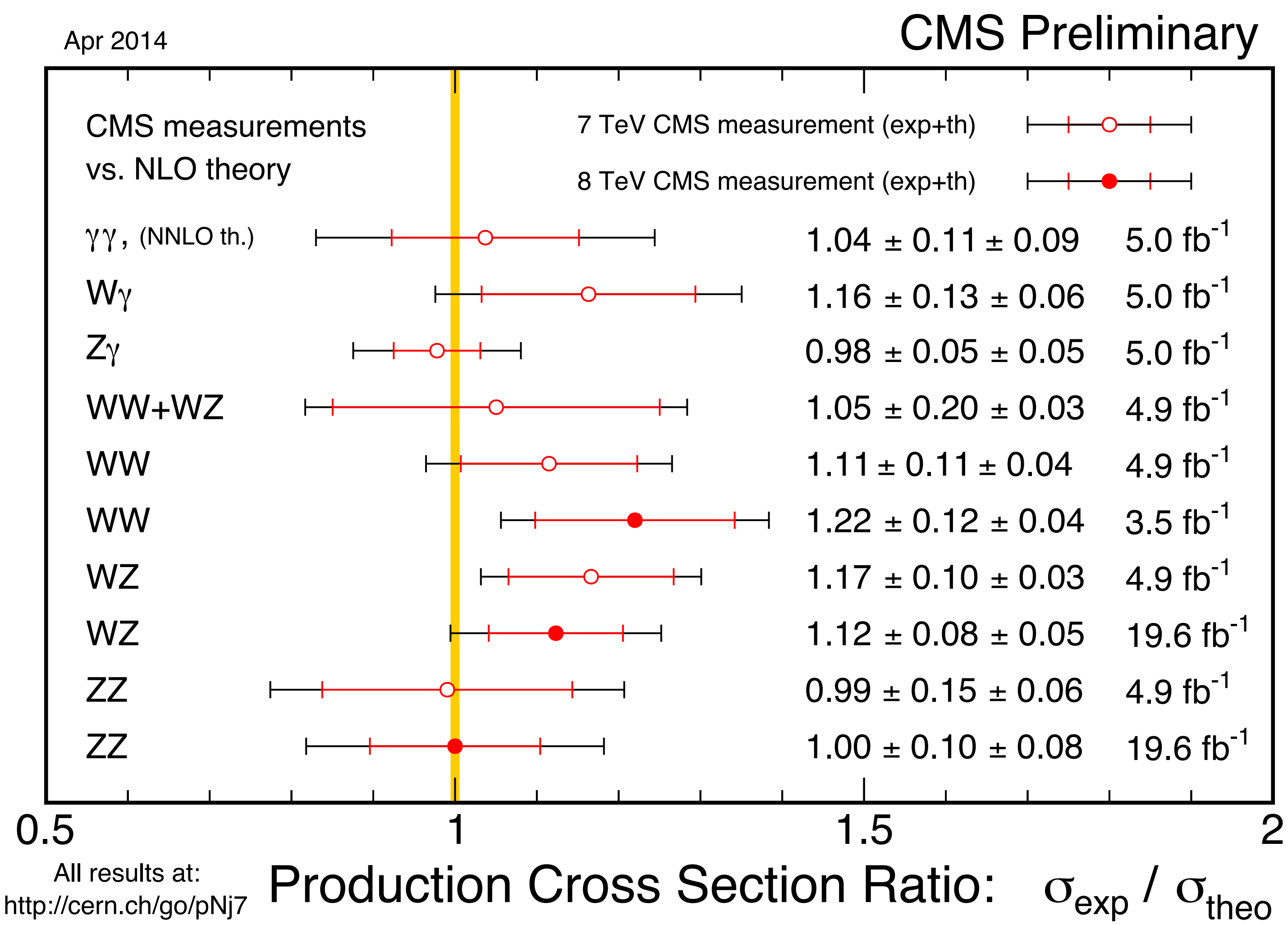
What about the WW xsec Measurement?



Physics Letters B

Excess in WW xsec measurement..

However the selection is:

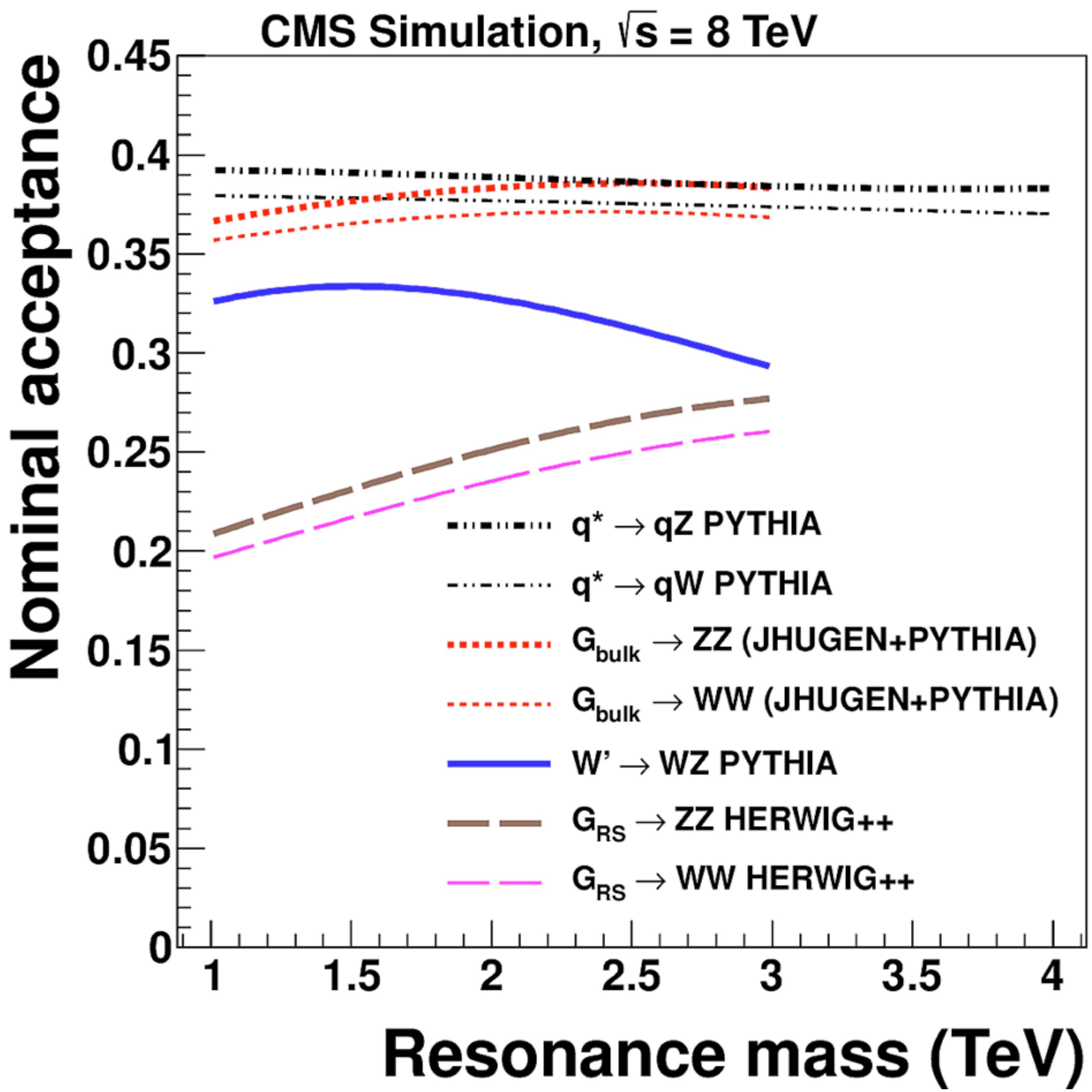
Increase purity of data sample

- p_T > 20 GeV on both leptons
- no jets with p_T > 30 GeV

This excess does not appear to be consistent with what is observed in LQ and Heavy Neutrino Searches due to the orthogonal event selection.

Note that excess also seen in Wgamma. (may be related to radiation zero in these two channels.) NLO calculations have been done 20 years ago and haven't been updated with the latest techniques and also with EW corrections. Channels with radiation zero are know to have "giant K-factors". Perhaps an excess is not so surprising?

Acceptance and Efficiency for some Signal Models



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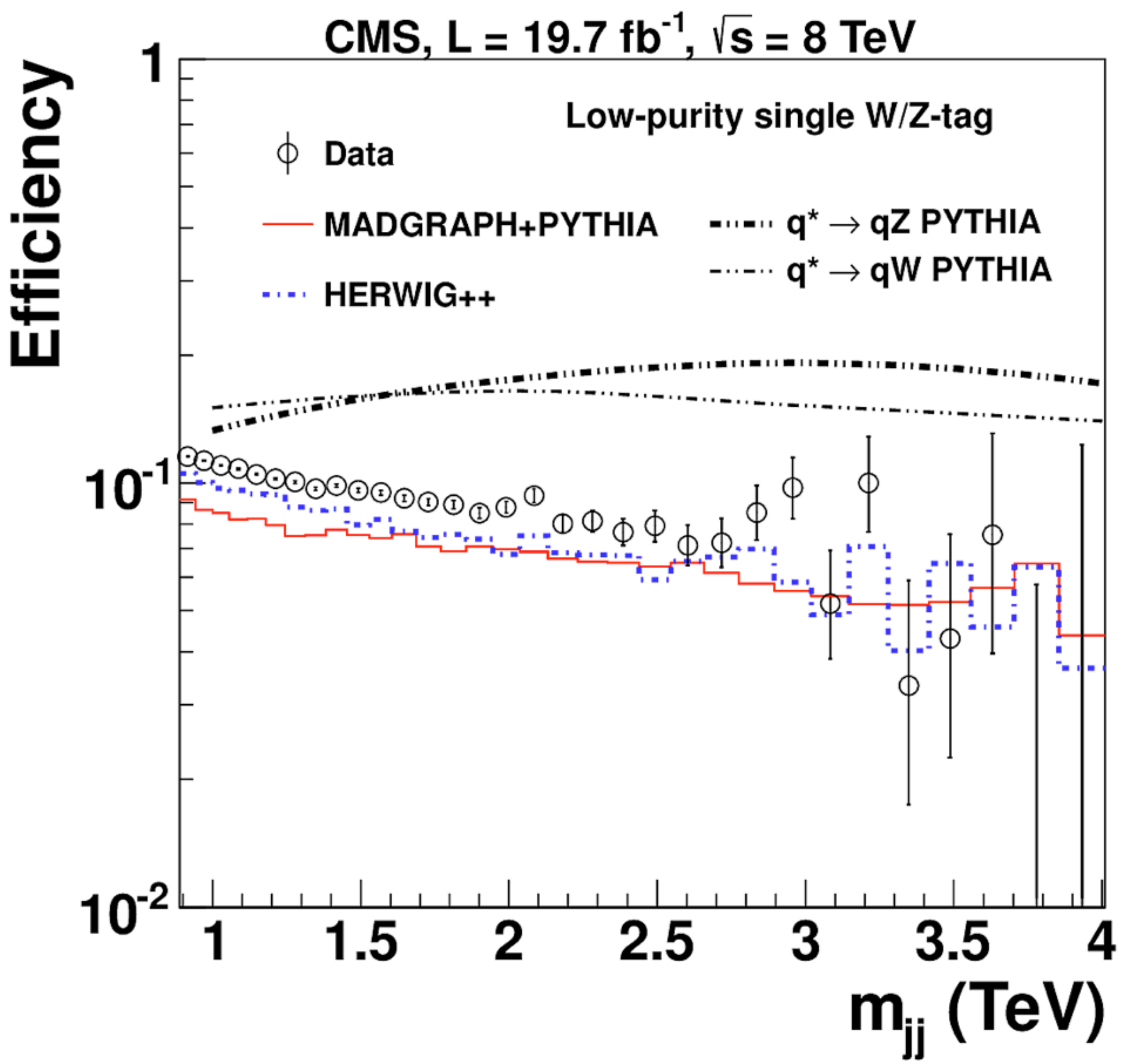
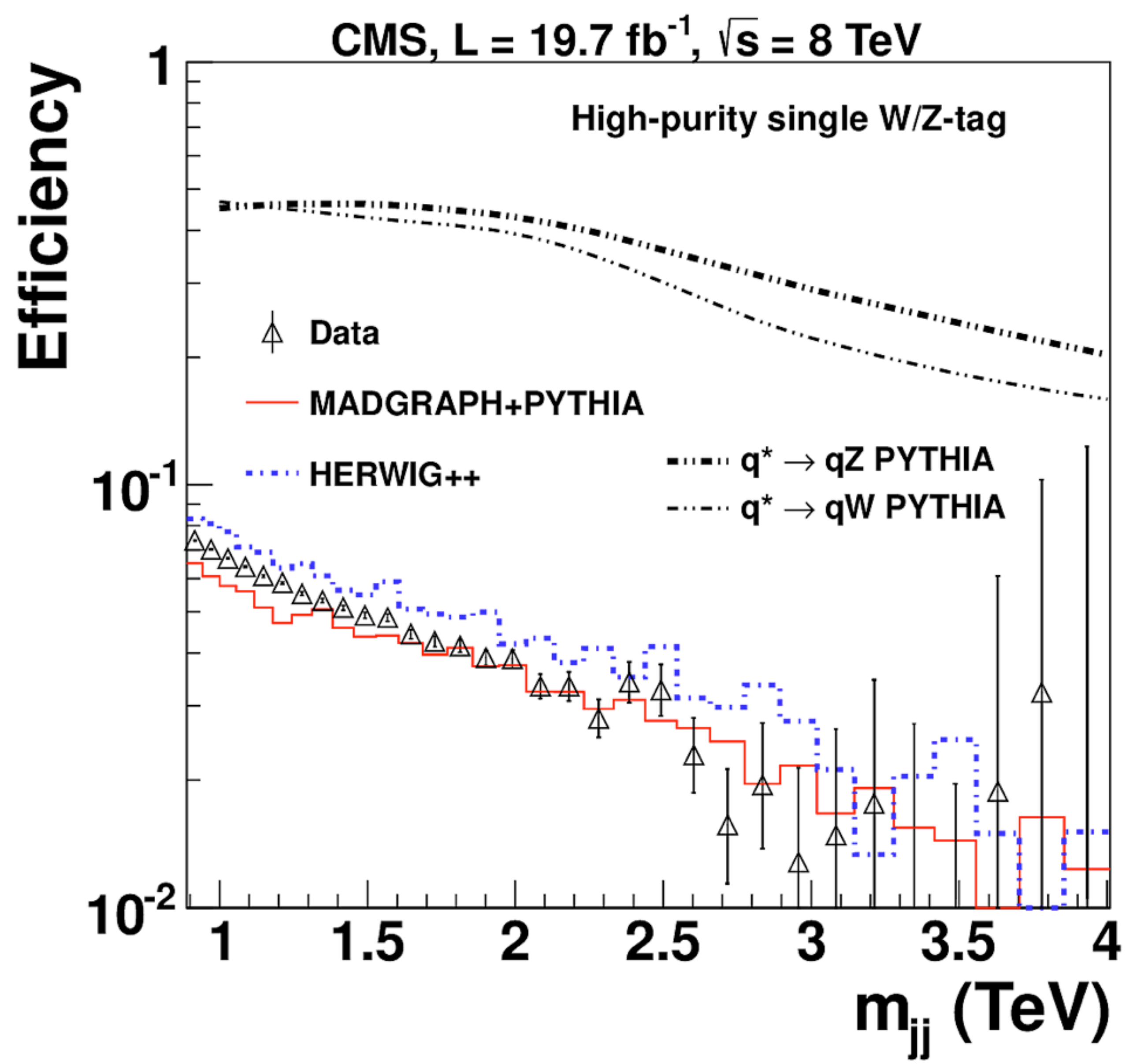
Efficiency of W and Z selection

Efficiency of W and Z selections as a function of mjj in data, and in simulations of signal and background events, with one high and low-purity W/Z tag. The efficiency is computed for W/Z → qq' → jets events, where the jets have $|\eta| < 2.5$, $|\Delta\eta| < 1.3$. MADGRAPH/PYTHIA and HERWIG++ refer to QCD multijet event simulations.





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