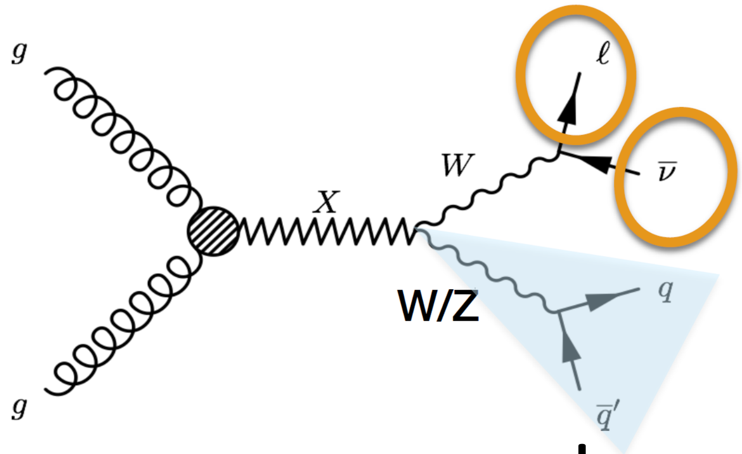


Search for heavy resonances decaying to WV in semileptonic channel at CMS

Huang Huang

(Peking University)

Aug-17-2016

Outline

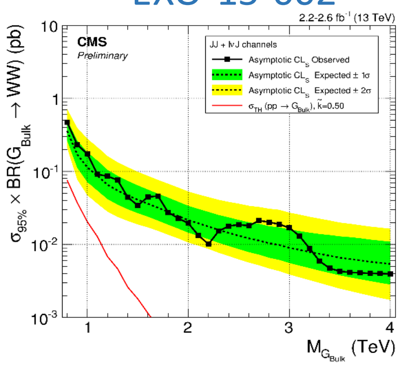
- Motivation
- Analysis Strategy
- Samples and Preselections
- Control plots
- V-tagger validation
- Background estimation
- Systematic uncertainties
- Final limit

Motivation

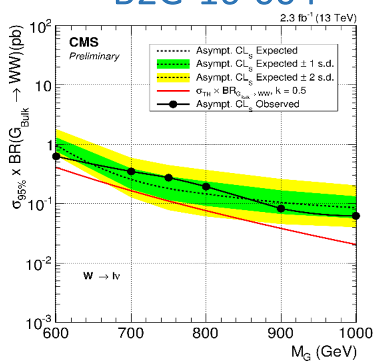
- 2015 data: 2.3/fb, √s=13TeV
- EXO-15-002: 800 - 4000 GeV
- B2G-16-004: 600 - 1000 GeV

	Channel	Models
EXOTIC Resonance X→ Diboson	WW	Spin-2 Bulk Graviton
	WZ	Spin-1 HVT (charged)

EXO-15-002

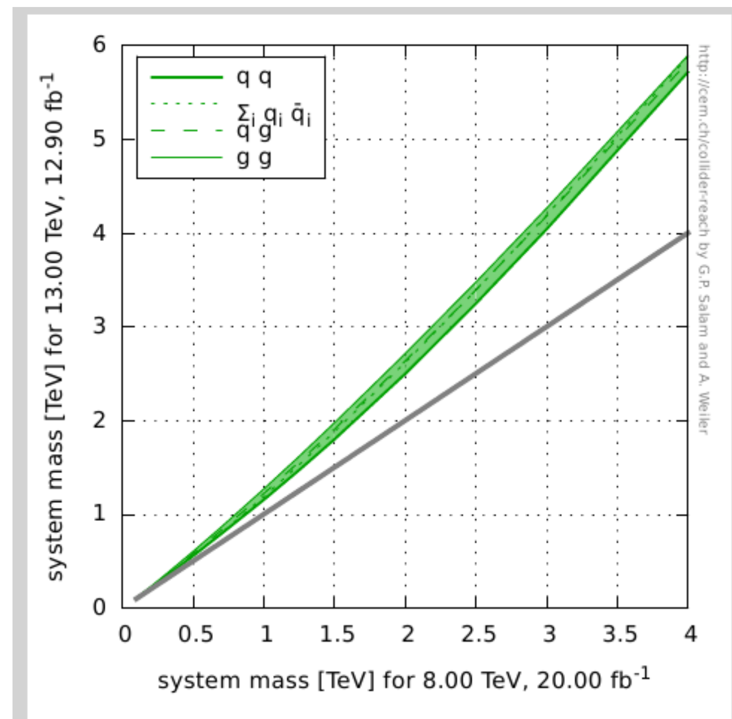


B2G-16-004



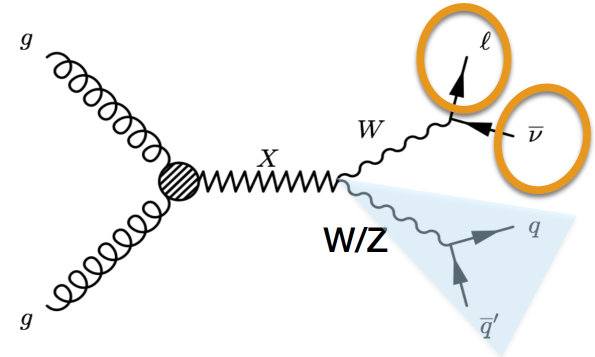
- **2016 data: 12.9/fb, √s=13TeV**
- **B2G-16-020: 600 - 4500 GeV**

http://cds.cern.ch/record/2205880



12.9/fb, √s=13TeV V.S. 20/fb, √s=8TeV

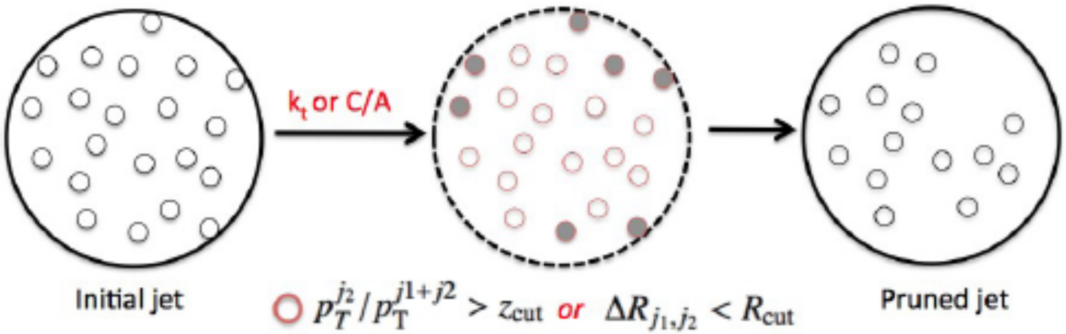
Analysis Strategy



- Heavy Resonance decaying to WW in the semi-leptonic final state
- Boosted hadronic Ws: merged jets, jet substructure
- Signal Model
  - Bulk Graviton to WW to lep+MET+Jet
  - Wprime to WZ to lep+MET+Jet
- Signal Mass coverage: 600 – 4500 GeV
  - Low mass analysis [600-1000] with M_{WW} 600-1500 GeV
  - High mass analysis (1000- 4500] with M_{WW} 0.8-5 TeV

Analysis Strategy

- **“Pruning”** http://arxiv.org/abs/0912.0033 (S. Ellis, C. Vermilion, J. Walsh)
  - Recombine jet constituents with C/A or kt while vetoing wide angle (R_{cut}) and softer (z_{cut}) constituents. Does not recreate subjets but prunes at each point in jet reconstruction



Tuned parameters: R_{cut} and z_{cut}

R_{cut} and z_{cut} are 0.5 and 0.1,

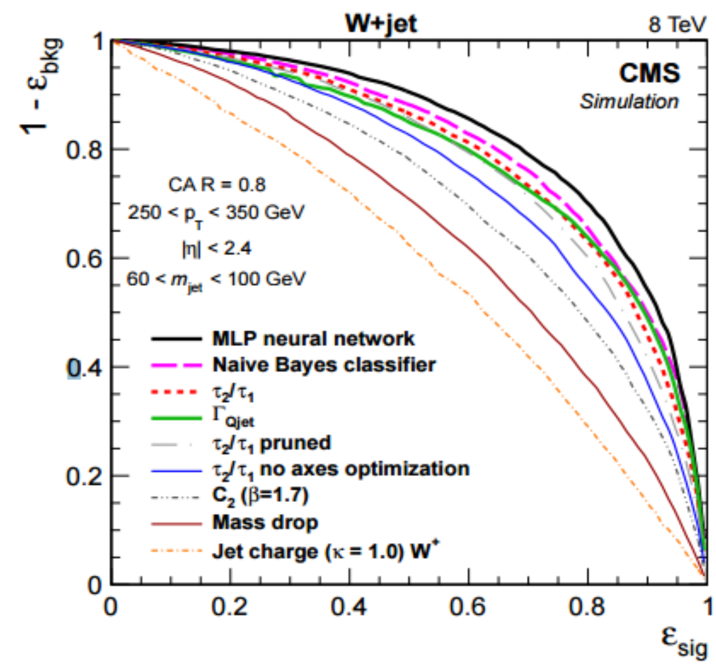
N-subjettiness (arXiv:1011.2268):

how likely is a jet to have “N” subjets

$$\tau_N = \frac{1}{d_0}\sum_k p_{T,k} \times \min(\Delta R_{1,k}, \Delta R_{2,k}, ..., \Delta R_{N,k})$$

$$d_0 = \sum_k p_{T,k} \times R_0$$

Wjet tagger: $\tau_2/\tau_1 = \tau_{21}$



Analysis Strategy

"Bump" search: looking for an excess over the Mvw distributions

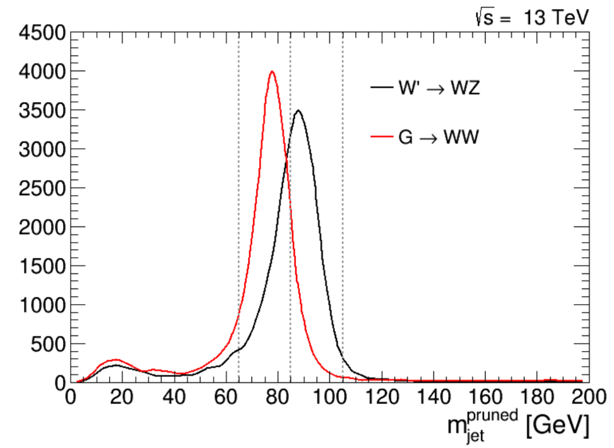
Jet pruning

- V-boson mass window

  BulkGraviton: 65-95GeV

  W': 75-105GeV

  Higgs signal region (105-135 GeV) kept blind



Jet substructure

- N-subjettiness

  Only HP: $\tau_{21} < 0.45$ for low Mass & $\tau_{21} < 0.6$ for high Mass

How to estimate the background contributions

Minor background from simulation, corrected with scale factors from data

Wjets: extracted from data

Samples and Preselections

- Data: 12.9/fb (2016)
- Signal
  - Bulk Graviton
  - Wprime
- Backgrounds
  - WJetsToLNu
  - TTbar
  - Single Top
  - WW/WZ/ZZ

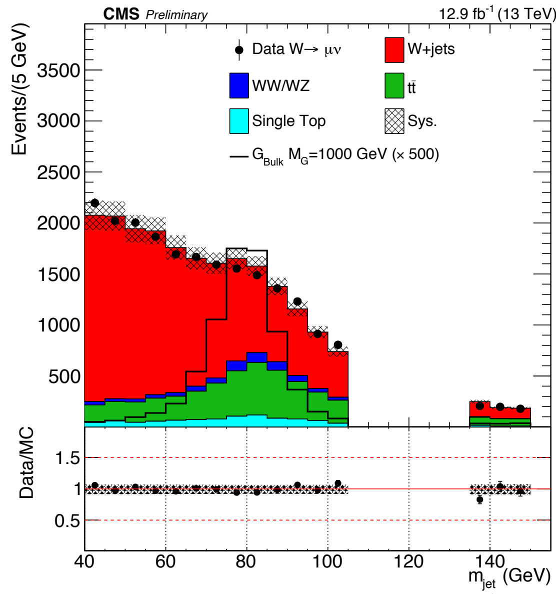
Muon channel
• Tight muon: $p_T > 50$ GeV , $\|\eta\|<2.1$, • Loose muon (for veto): $p_T > 20$ GeV , $\|\eta\|<2.4$ • Missing $E_T > 40$ GeV (type I) • Transverse mass > 40GeV
Electron channel
• Tight electron: $p_T > 55$ GeV • Loose electron: Veto ID • Missing $E_T > 80$ GeV (type I)
Both channels
Noise cleaning filters AK8 jets, $p_T > 200$ GeV, Loose ID AK4 jets (for b-veto), Loose ID Leptonic W pT > 200 GeV
$\Delta R(l,W_{had}) > \pi/2$ $\Delta R(W_{had}, W_{lep}) > 2$ $\Delta R(W_{had}$, missing $E_T) > 2$

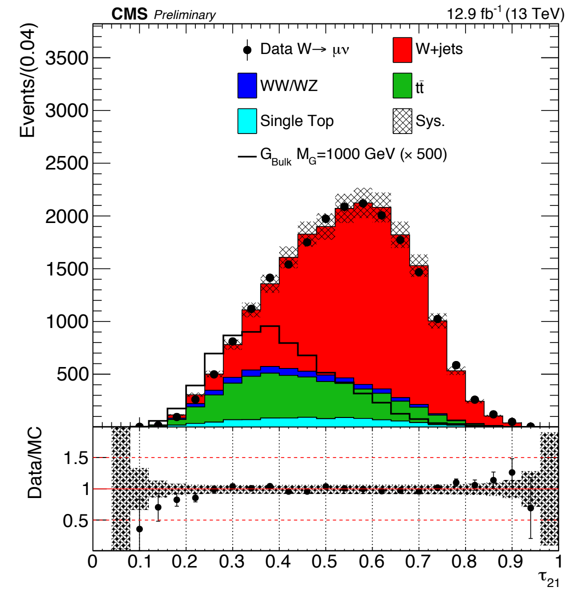
Data/MC Comparison

Sys. uncertainties:
W-jets norm., TTbar SF, lep eff, b-tag SF

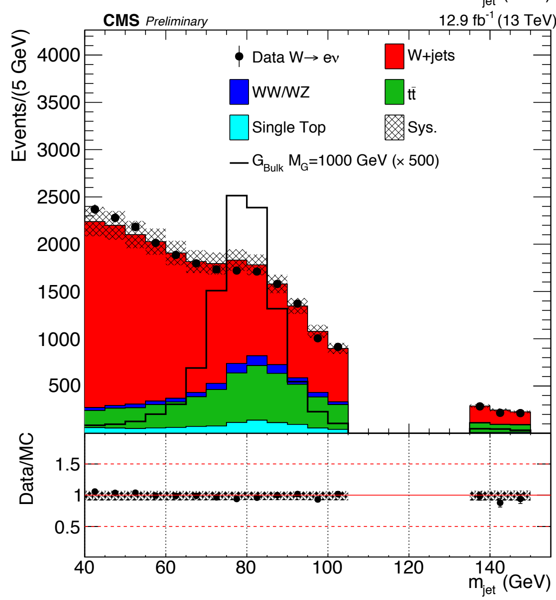
Pruned jet mass | **tau21**

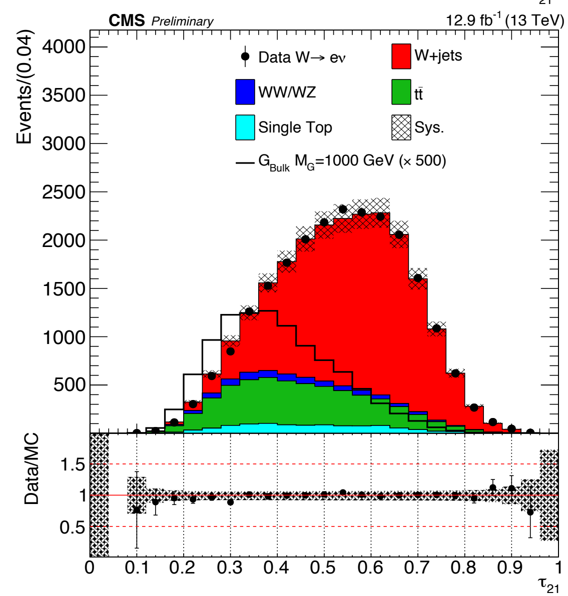
muon



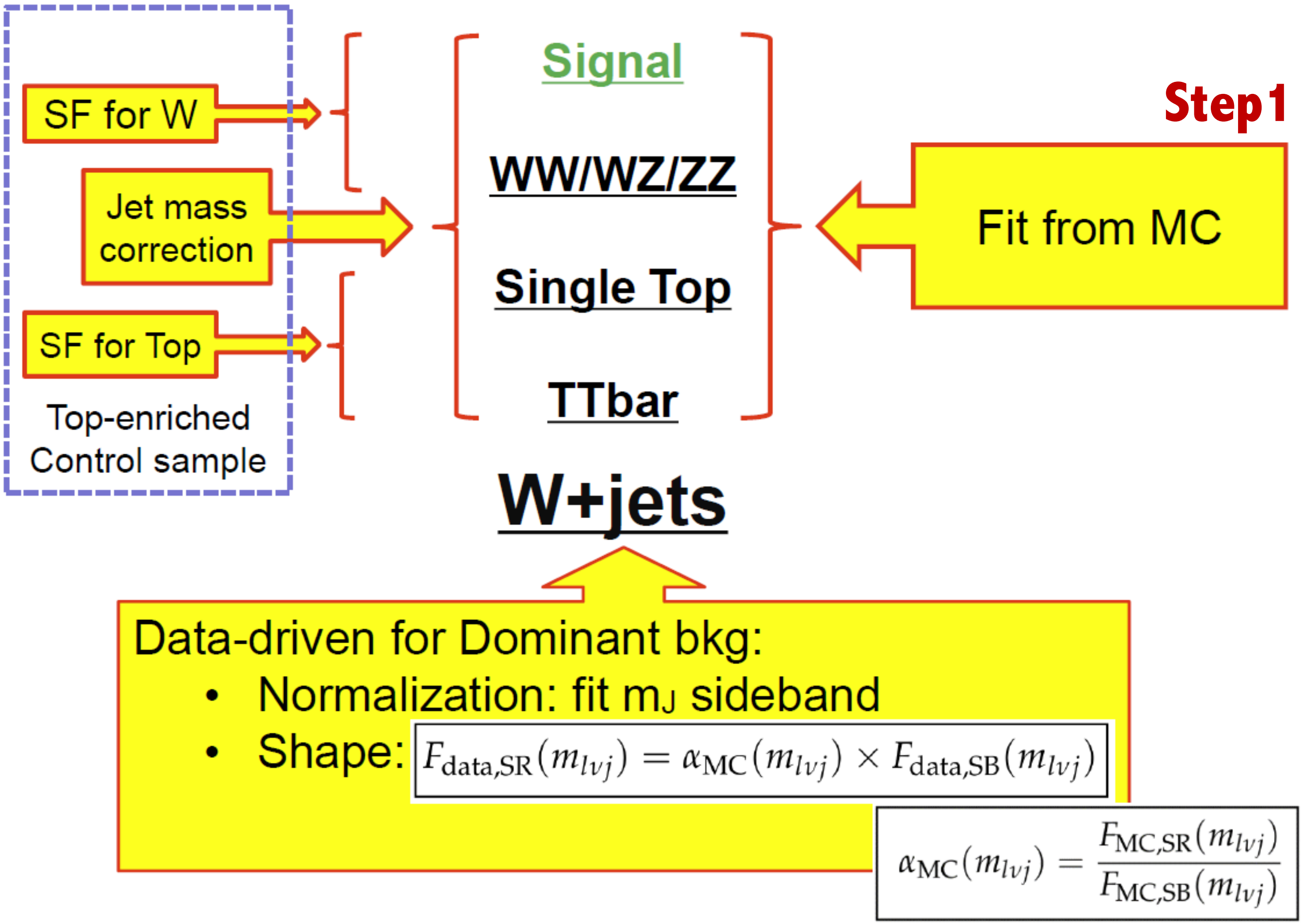


electron

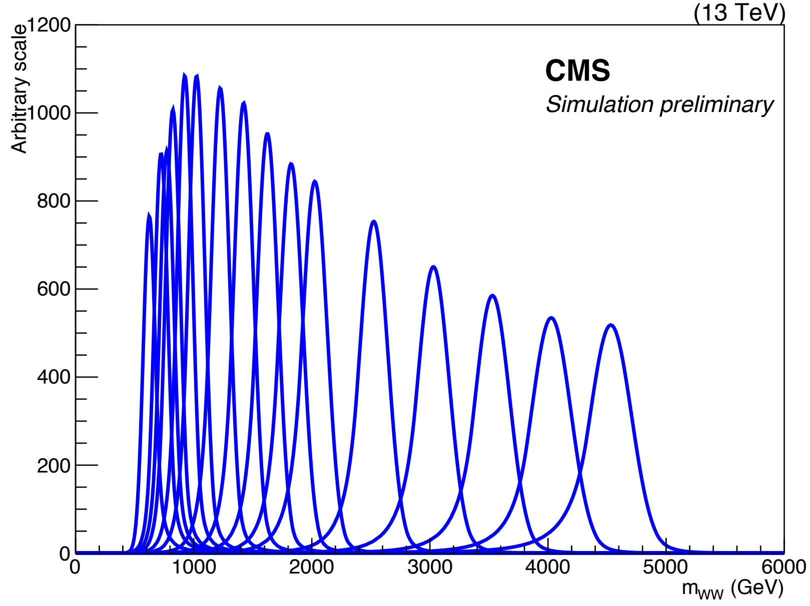




Signal and Bkg Estimation



Signal Modeling

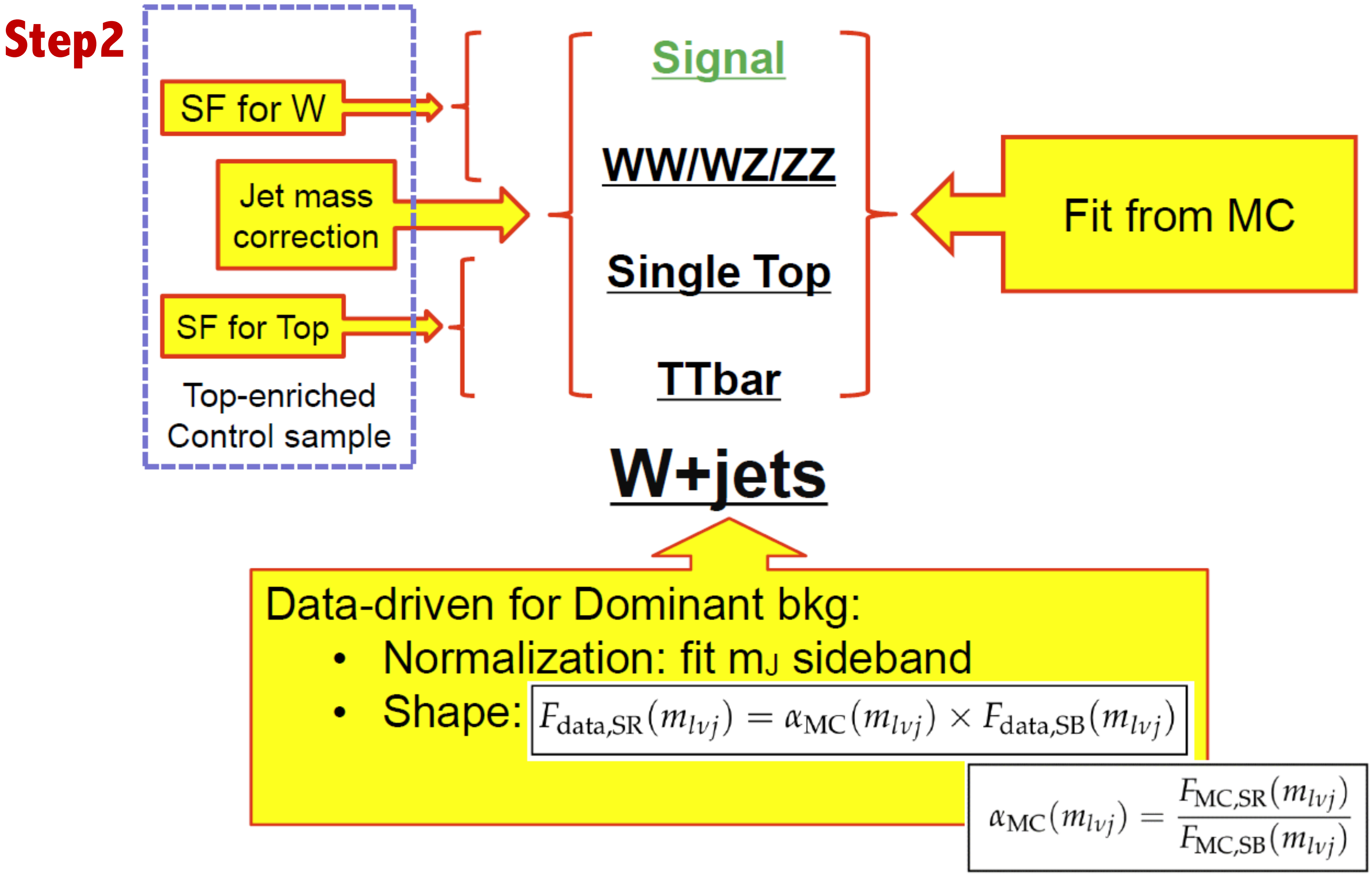


Double CB

The area of each shape is proportional to the total signal efficiency of the corresponding mass point

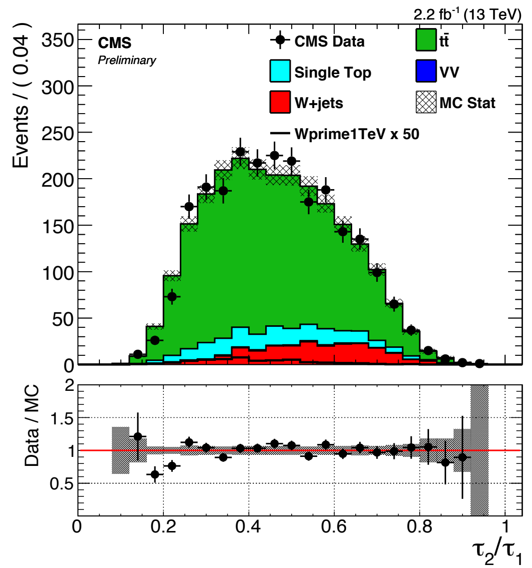
- Signal mass from 600 GeV to 4.5 TeV
- Bulk Graviton (k=0.5) for WW analysis
- Wprime HVT model A for WZ analysis
- Signal shape is modeled with double Crystal-Ball function

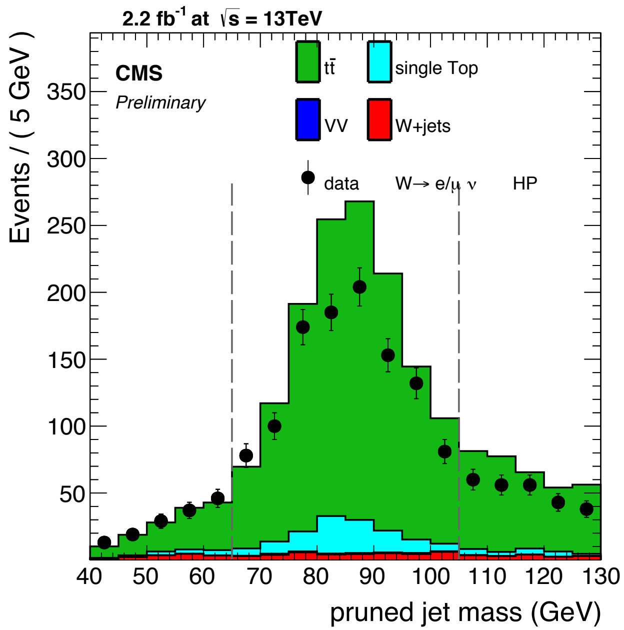
Signal and Bkg Estimation



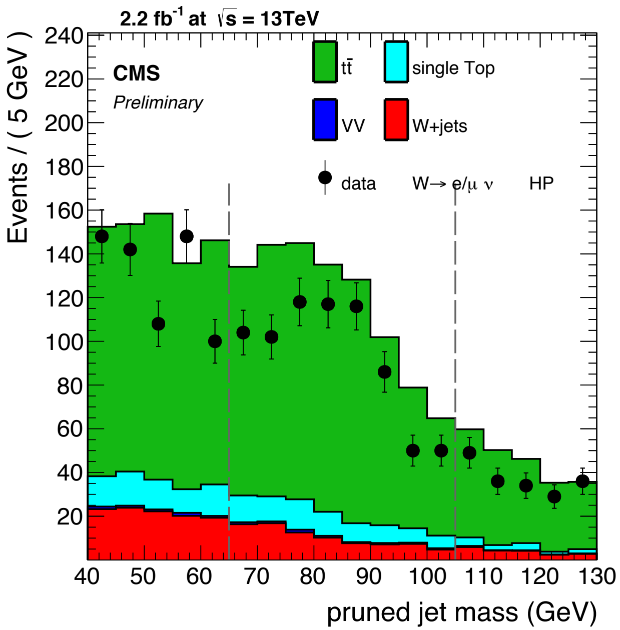
W-Tagging

- Top-Enriched Control Sample:
  - Reverse the b veto selection
  - The back-to-back angular selection is removed





Pass (HP)



Fail (LP)

Plots from EXO-15-002

W-Tagging

High purity

Top SF & **W-tagging SF**

TTbar & Single Top

tau21 0.45: 0.81 ± 0.2
0.6: 0.83 ± 0.1

The **Top scale factors** are just derived by DATA/MC in the signal region.

Cut count method: $Sf_{top} = N_{data}/N_{MC}$ (minor background contribution negligible)

WW/WZ/ZZ

tau21 0.45: 0.976 ± 0.048
0.6: 1.002 ± 0.018

Consider the TTbar made of 'real' W and 'combinatorial'

Background(s-top/ WW/ W+jets) are taken from MC

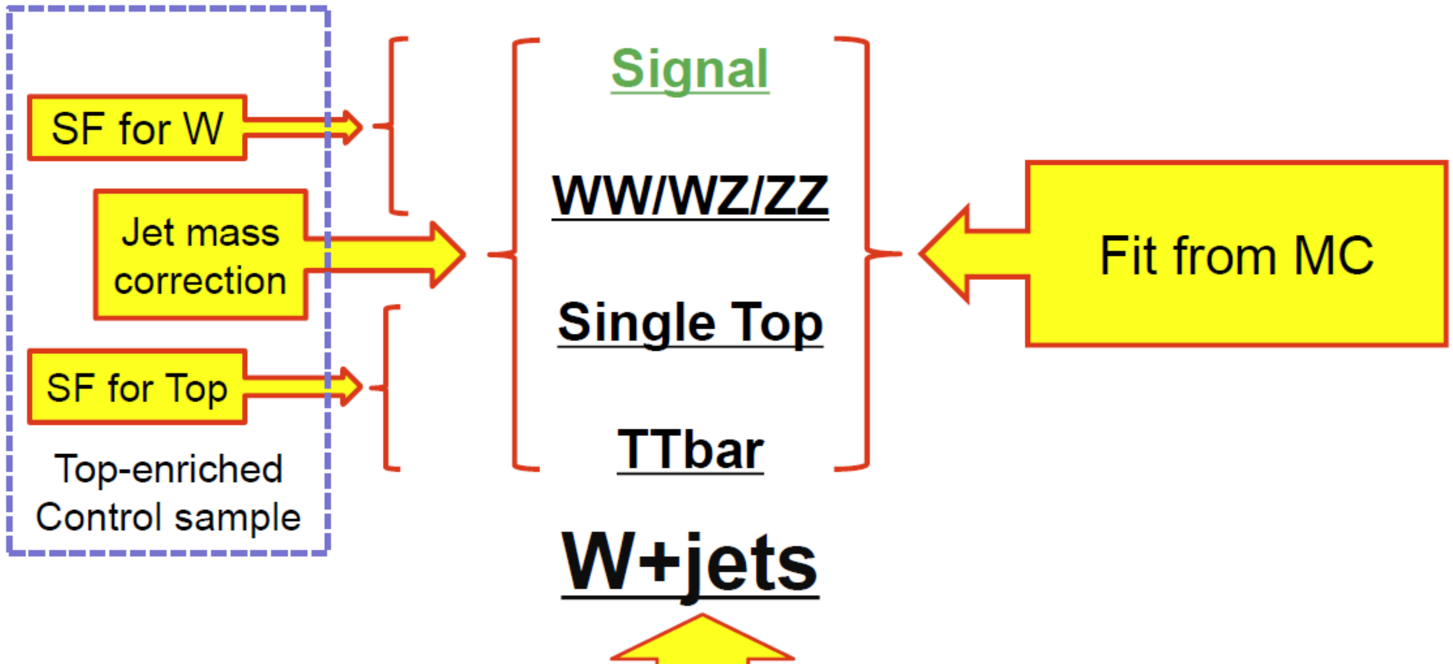
Simultaneous fit data and MC in PASS & FAIL to get SF

Mass peak shift

Peak shape	Mass[GeV]	σ[GeV]
Data	84.9 ± 0.2	7.9 ± 0.2
MC	83.8 ± 0.2	7.5 ± 0.2

CMS Collaboration, "Identification techniques for highly boostedWbosons that decay into hadrons", JHEP 12 (2014) 017, doi:10.1007/JHEP12(2014)017, arXiv:1410.4227.

Signal and Bkg Estimation



Data-driven for Dominant bkg:

- Normalization: fit m_J sideband
- Shape: $F_{\text{data,SR}}(m_{l\nu j}) = \alpha_{\text{MC}}(m_{l\nu j}) \times F_{\text{data,SB}}(m_{l\nu j})$

$$\alpha_{\text{MC}}(m_{l\nu j}) = \frac{F_{\text{MC,SR}}(m_{l\nu j})}{F_{\text{MC,SB}}(m_{l\nu j})}$$

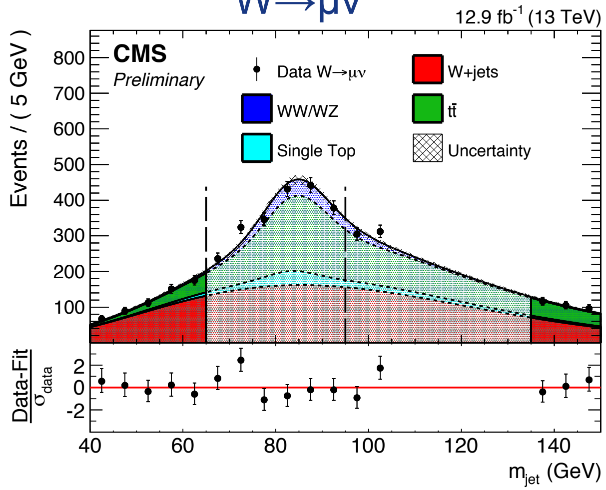
Step3

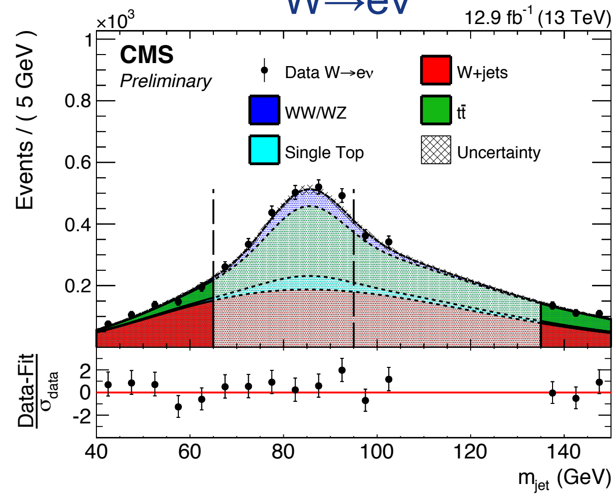
W+Jets Norm: Fit Jet Mass in Sideband

W→μν

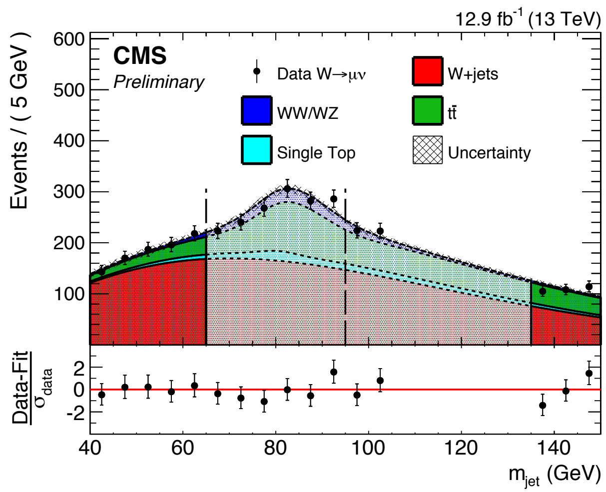
W→eν

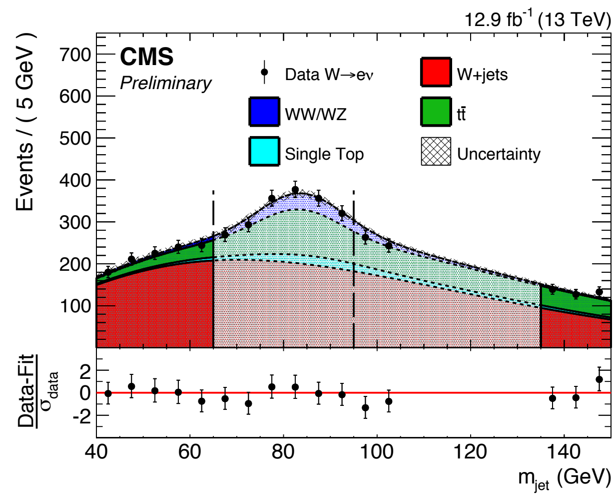
M_{WW}: 0.6-1.5TeV





M_{WW}: 0.8-4.5TeV





- **Fit on data in the sidebands to extract the W+jets normalization**
- **TTbar, VV, Single Top: Norm. and shape in Pruned jet mass from MC, and corrected by Top-enriched control region**

W+Jets Shape: alpha-method

$$\alpha^{MC} = \frac{F_{WW}(SR)^{MC}}{F_{WW}(SB)^{MC}}$$

$$\alpha^{Data} = \frac{F_{WW}(SR)^{Data}}{F_{WW}(SB)^{Data}}$$

- Assuming $\alpha^{Data} = \alpha^{MC}$

$\Rightarrow$ $$F_{WW}(SR)^{Data} = F_{WW}(SB)^{Data} \times \alpha^{MC}$$

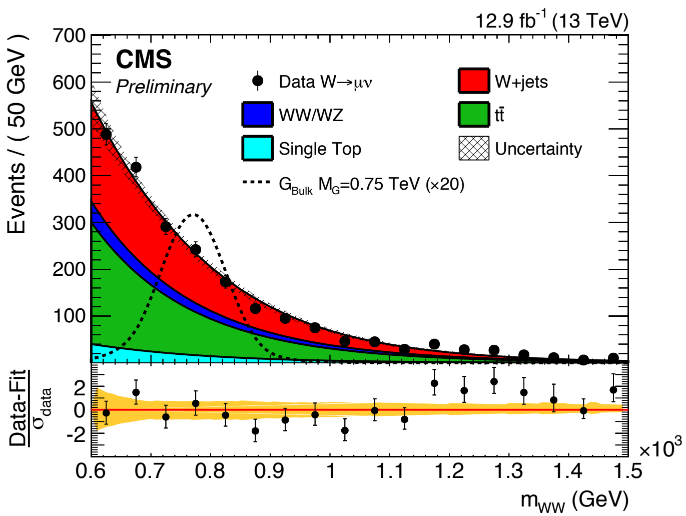
M_{WW} in Signal Region

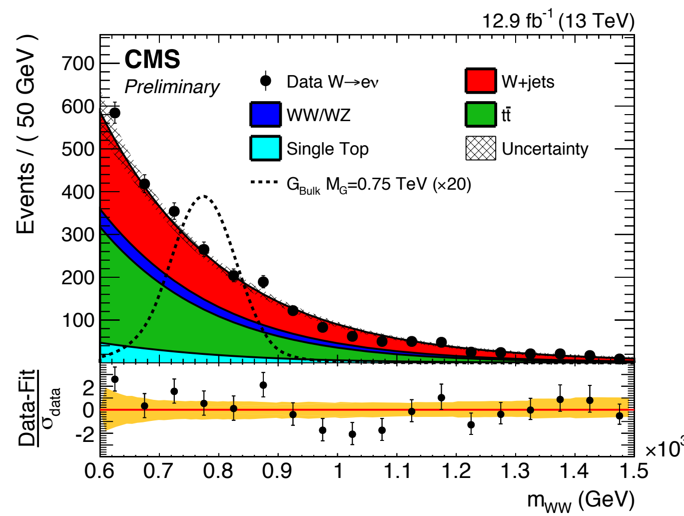
BulkGraviton

W→μν

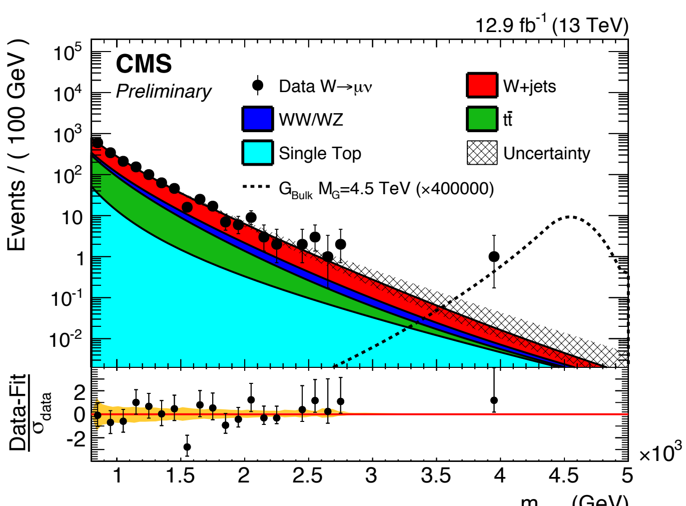
W→eν

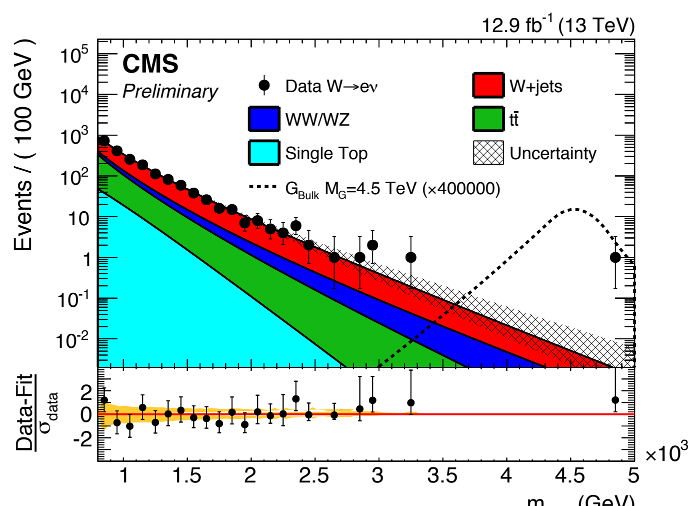
0.6-1.5TeV





0.8-5TeV





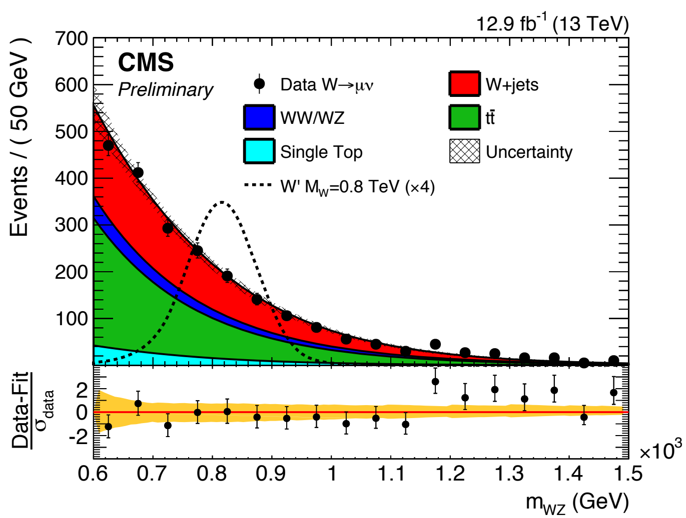
M_{WW} in Signal Region

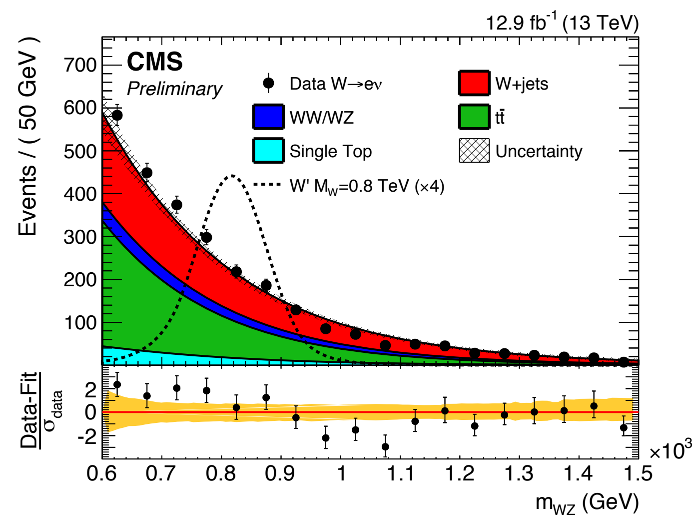
W'

W→μν

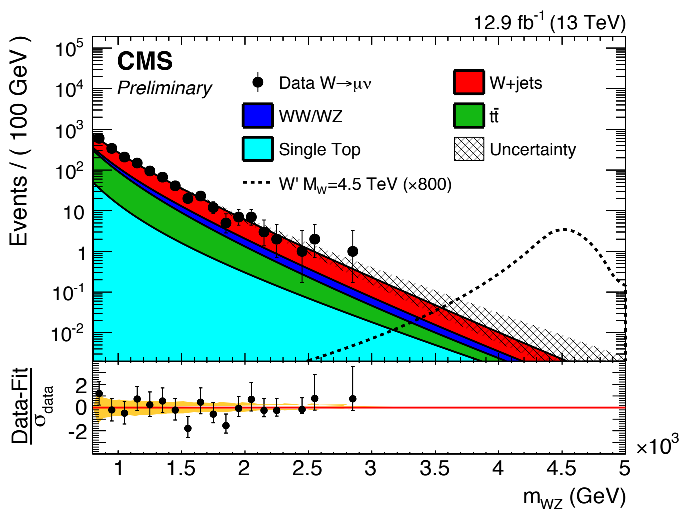
W→eν

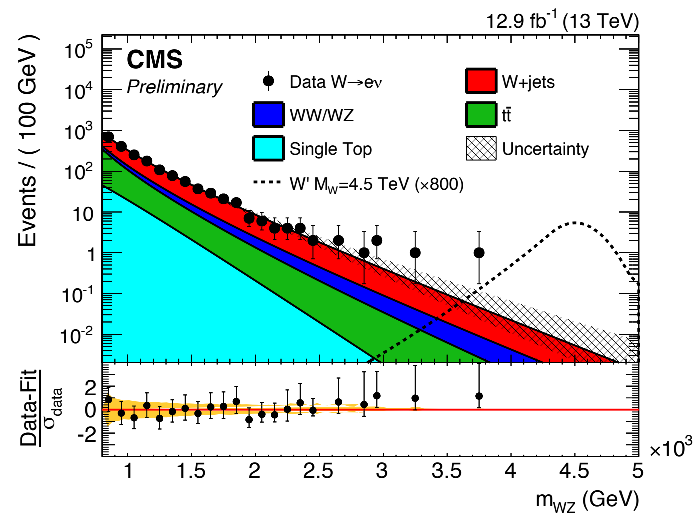
0.6-1.5TeV





0.8-5TeV





Systematic Uncertainties

- Brief summary
  - Common terms for signal and backgrounds
    - Integrated lumi, Theory XS, lepton Trigger and ID, V-tagging
  - Signal
    - lepton energy scale/res, jet energy/mass scale/res, btagging, Scale and PDF uncertainties
  - Backgrounds
    - W+jets norm.: stat. of data in sideband, shape function, TTbar
    - W+jets shape: α and F_{WW}(SB) uncertainties inflating by $\sqrt{2}$
    - TTbar and Single Top norm.: SF from Top-enriched control region

Systematic Uncertainties

- the general and jet-specific uncertainties, respectively, for this analysis

signal

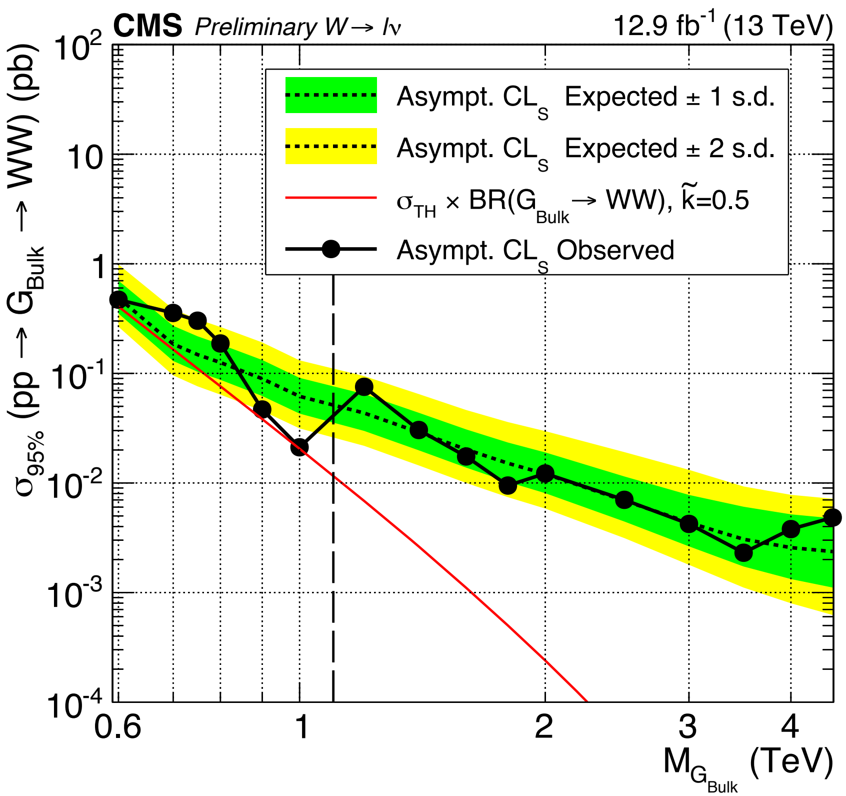
Source	Effect	$\mu\nu$+jet uncertainty	$e\nu$+jet uncertainty
Lepton trigger	Yield	5%	5%
Lepton identification	Yield	5%	5%
b tag	Yield	0.6%	
Jet energy scale	Yield	[1-2]%	
Jet energy scale	Shape (mean)	1.3%	
Jet energy scale	Shape (width)	[2%–3%]	
Jet mass scale	Yield	[1-4]%	
Jet mass resolution	Yield	[0.1-2]%	
Jet energy resolution	Yield	<0.1%	
Jet energy resolution	Shape (mean)	0.1%	
Jet energy resolution	Shape (width)	4%	
Integrated luminosity	Yield	6.2%	
W′ PDF	Yield	[5-30]%	
W′ Scale	Yield	[1-15]%	
Bulk graviton PDF	Yield	[10-100]%	
Bulk graviton Scale	Yield	[10-25]%	
V tagging τ_{21}	Yield	5%	

Background

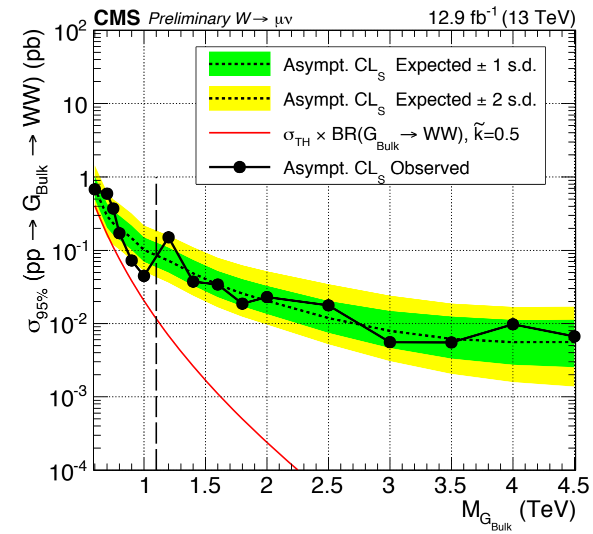
Source	$\mu\nu$+jet uncertainty	$e\nu$+jet uncertainty
Lepton trigger	5%	5%
Lepton identification	5%	5%
Integrated luminosity	6.2%	
Diboson cross section	20%	
$t\bar{t}$ and single top normalization	2%	
W+jets normalization, low (high) mass	5%(4%)	5%(3.5%)
Single top b tag	5%	
$t\bar{t}$ b tag	6%	
Diboson b tag	0.6%	
V tagging τ_{21}	5%	

Bulk Graviton

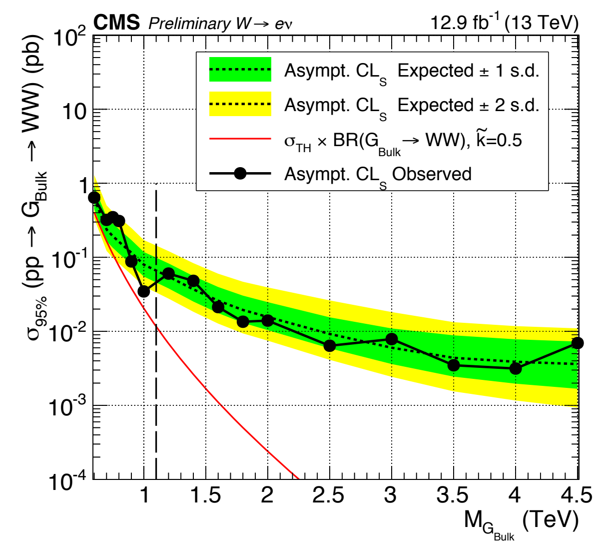
W→lν



W→μν



W→eν

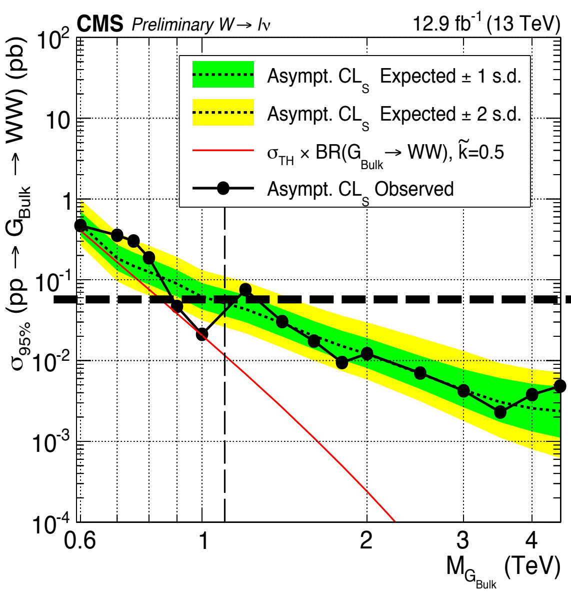


- Higgs Combination Tool and Asymptotic CLs
- No significant excess from 600 GeV to 4.5 TeV

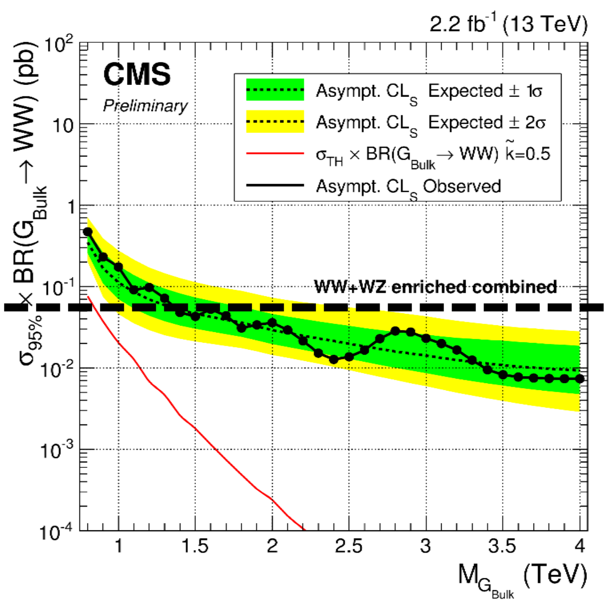
Comparisons

CMS-PAS

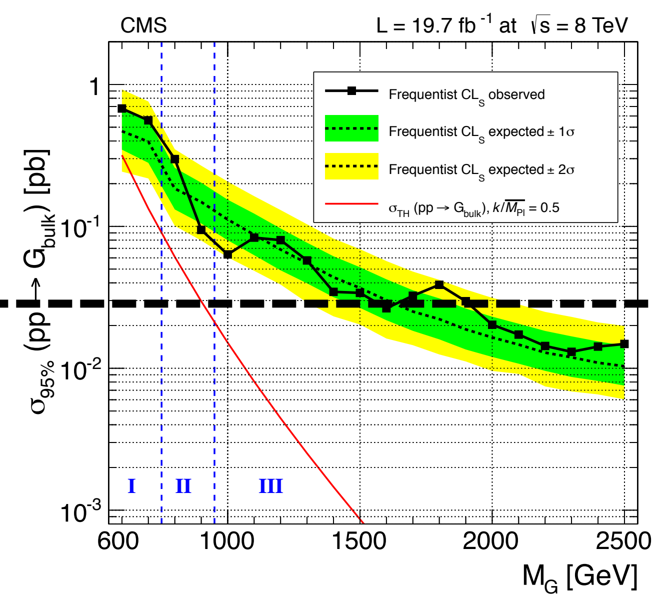
B2G-16-020
RUN II 2016



EXO-15-002
RUN II 2015



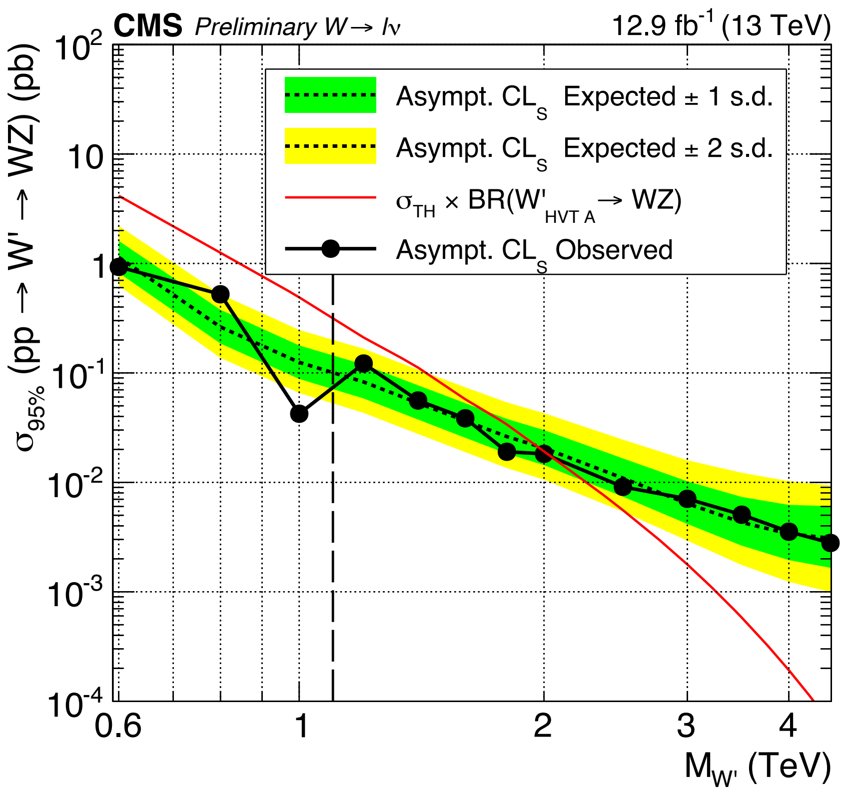
EXO-13-009
RUN I



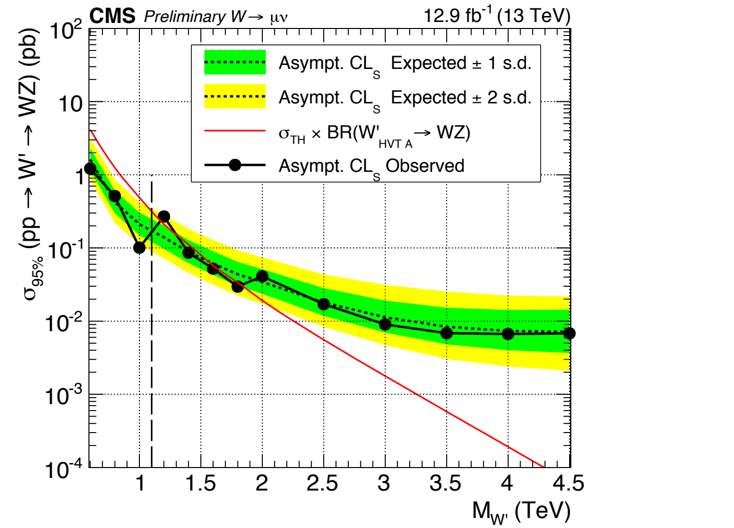
- Better sensitivity than EXO-15-002 & EXO-13-009
- Larger statistics, low W-tagging uncertainty error, ……

Wprime HVT model A

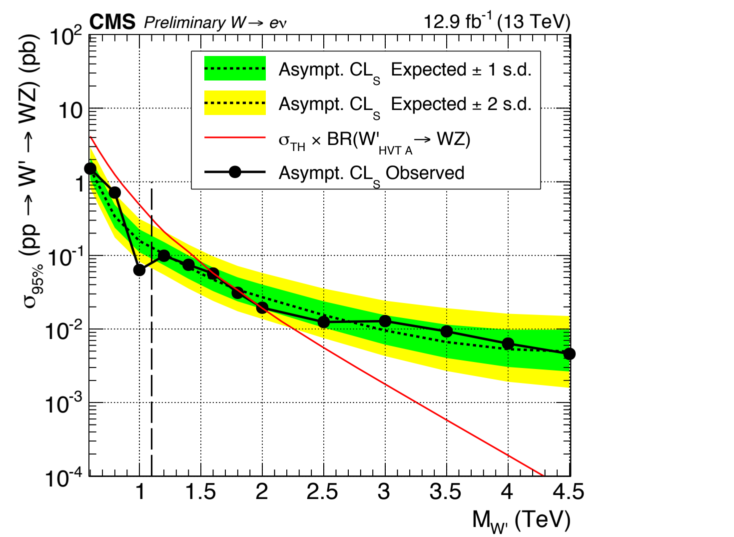
W→lν



W→μν



W→eν

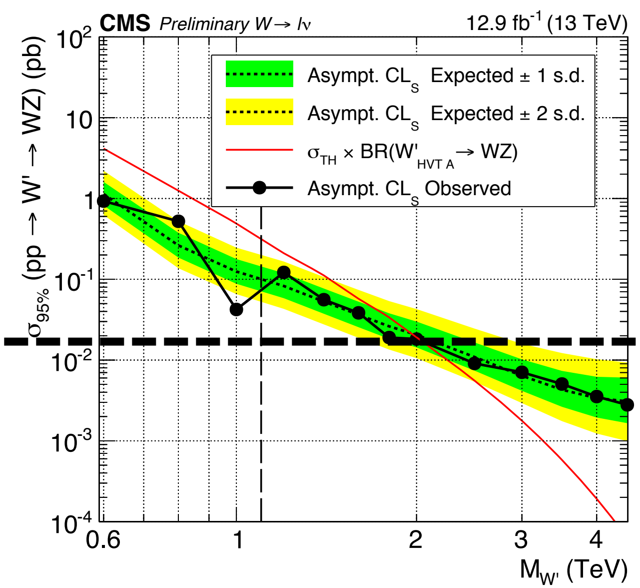


- No significant excess from 600 GeV to 4.5 TeV
- W' is excluded by 2 TeV

Comparisons

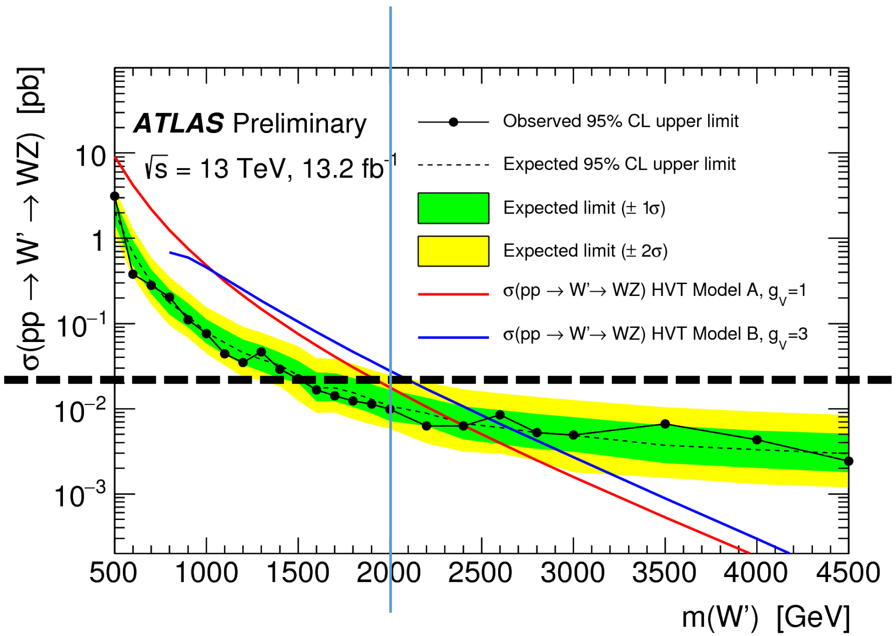
CMS-PAS-B2G-16-020

CMS 2016



ATLAS-CONF-2016-062

ATLAS 2016



- Compare with ATLAS

Summary

- [600-4500 GeV] analysis of the X → WV → lvJ
  - No significant excess from 600 GeV to 4.5 TeV
- Minimal changes from the 2015 analyses:
  - Trigger, offline lepton p_T cuts, tau21 cut
  - No Mass category, different Mass Window for W/Z
- No significant excess. In the model of HVT A, we set a lower limit on the W' mass of 2.0TeV.
- PAS-PUB & ICHEP2016
- **More data will definitely tell us more**

Backup

Results Publication

- **PAS-PUB**
- CMS Collaboration, "Search for new resonances decaying to WW/WZ→ℓνqq", CMS Physics Analysis Summary CMS-PAS-B2G-16-020, 2016.
- **ICHEP2016**
- http://indico.cern.ch/event/432527/contributions/2207066/

Search for new resonances involving Higgs, W or Z boson at CMS (15' + 5')

5 Aug 2016, 15:10
Chicago 7 ()

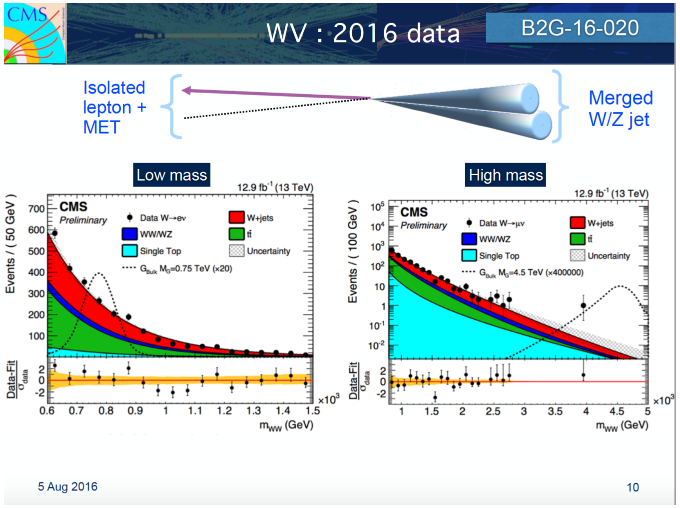
Oral Presentation | Beyond the Standard ... | Beyond the Standard Mo...

Speaker

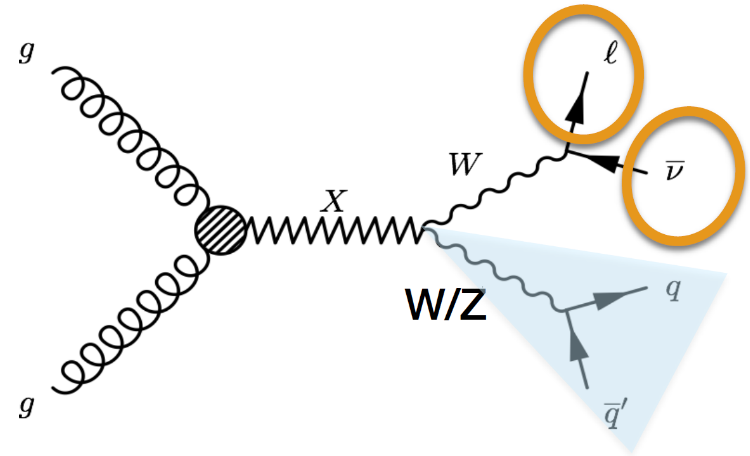
Salvatore Rappoccio (State University of N...)

Description

Beyond the standard model theories like composite Higgs models predict resonances with large branching fractions in a Higgs boson and a vector boson with negligible branching fractions to light fermions. We present an overview of searches for new physics containing a Higgs boson and a W or Z boson in the final state, using proton-proton collision data collected with the CMS detector at the CERN LHC. For high-mass resonances decaying to intermediate bosons, the large boost for hadronic decays gives rise to one single "merged" jet, which can be identified through a study of its substructure consistent with the presence of two quarks, enhancing the sensitivity due to the large branching ratios for hadronic decays. B-quark identification algorithms are used in addition to identify the hadronic H decays.



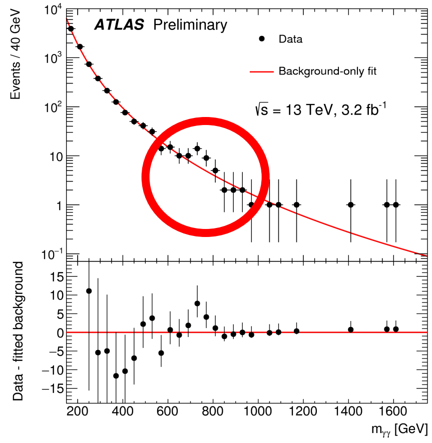
Analysis Selection

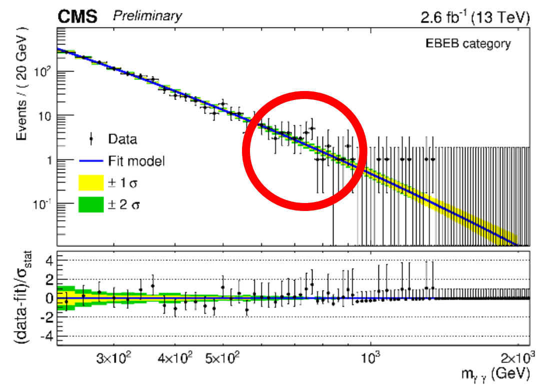


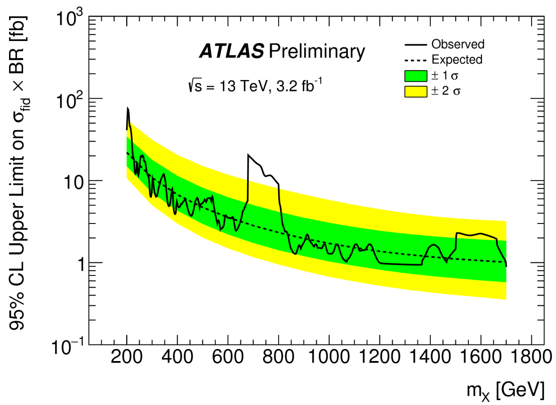
- Leptonic W
  - one charged Lepton
  - Loose lepton veto
  - Large Missing transverse energy: 80(40) GeV for Ele(Mu) channel
  - Leptonic W pT >200 GeV
- Hadronic W/Z
  - Leading AK8 jet pT >200GeV
  - B-tag veto to reduce TTbar and Single Top backgrounds
  - Tau21 0.45(0.60) for low(high) mass analysis
  - Jet mass windows [65-95] for W, [75-105] for Z
- Angular selections for a back-to-back diboson event
  - $\Delta R(\ell, \mathrm{W_{had}}) > \pi/2$
  - $\Delta\phi(\mathrm{W_{had}}, E_{\mathrm{T}}^{\mathrm{miss}}) > 2$
  - $\Delta\phi(\mathrm{W_{had}}, \mathrm{W_{lep}}) > 2$
- Noise Filters from the MET POG

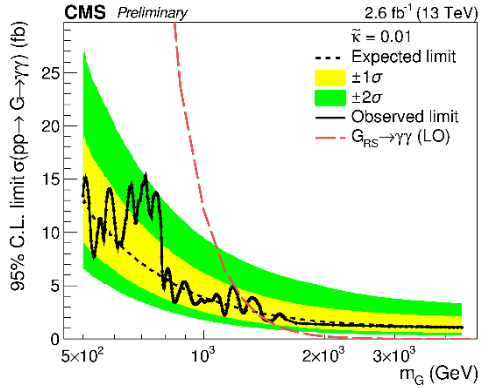
750 GeV Mania

- Diphoton resonance search at CERN 2015 Jamboree









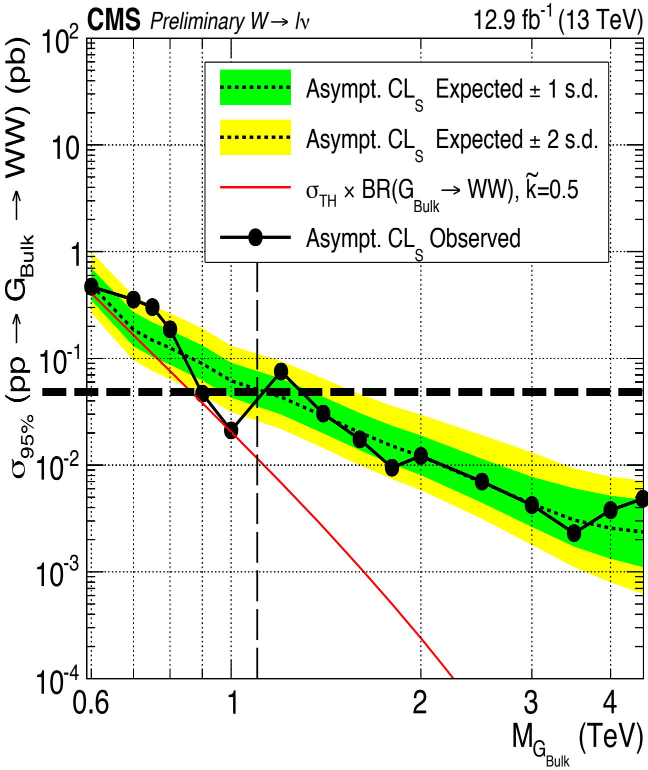
ATLAS-CONF-2015-081

3.6σ local, 2.0σ global

CMS-EXO-15-004

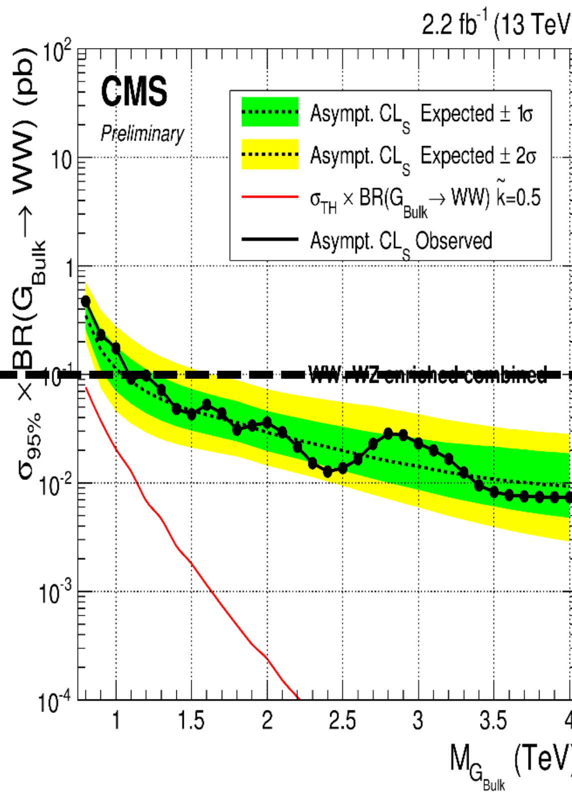
2.6σ local, <1.2σ global

Comparisons



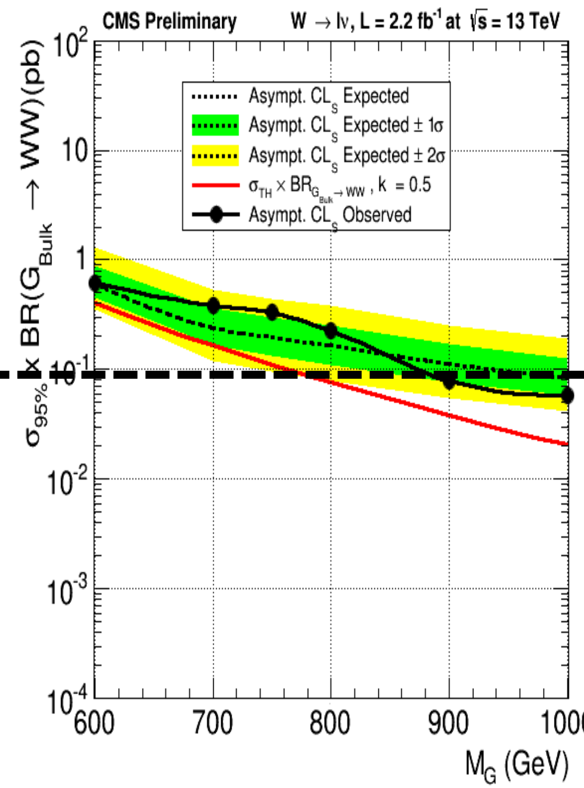
High Mass Analysis

EXO-15-002



Low Mass Analysis

B2G-16-004



- Better sensitivity than EXO-15-002
- Better sensitivity than B2G-16-004 for the 1 TeV mass point (not add BR)
- Larger statistics, low W-tagging uncertainty error, ……