# ATLAS + CMS Other heavy "Higgs" bosons

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on behalf of ATLAS + CMS collaborations

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# Aka searches for heavy resonances in di-boson and $t\bar{t}$ final states free from extended Higgs sector interpretation, from 2014

- What are we talking about?!
  - One additional spin-0 EW singlet (Dark portal, ... see S. Dawson talk)
  - Extra dimensions / Strong-like theories (spin-0/2 resonances) *
  - Extended gauge sector (spin-1 resonances) *

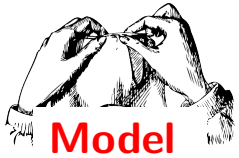
    * Asking for poetic licence with respect to the original talk title

- Why this is a separated talk?
  - Extended mass range hypothesis
    no naturality arguments limiting expectations up to TeV range
    Boosted searches included
  - The large natural with of 2HDM or MSSM Higgs bosons is not considered
    results usually derived negligible width approximation ($\Gamma_X/M_X \lll\lll\lll 0.1$)

# Final states mentioned in this talk

- $X \to VV$ hadronic
- $X \to VV$ semi-leptonic
- $X \to VV$ leptonic
- $X \to \gamma\gamma/\gamma Z/\gamma W$
- $X \to t\bar{t}$
- $X \to hh$ (the 125 GeV one)

- signal extraction method
- object reconstruction techniques
- model dependencies

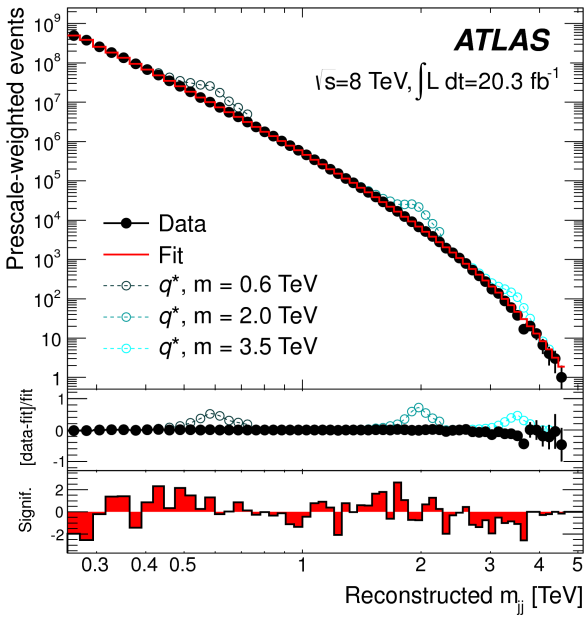



You are invited to go to the references (and backup) for **sensitivity results** and other many interesting details.

(There is no excess bigger than $2\sigma$ in the analyses mentioned in this talk)

# $X \to VV$ hadronic - boosted regime

**$W'(WZ)$, $q^*(jj)$ and bulk/RS1 KK-graviton (CMS, $WW/ZZ$).**



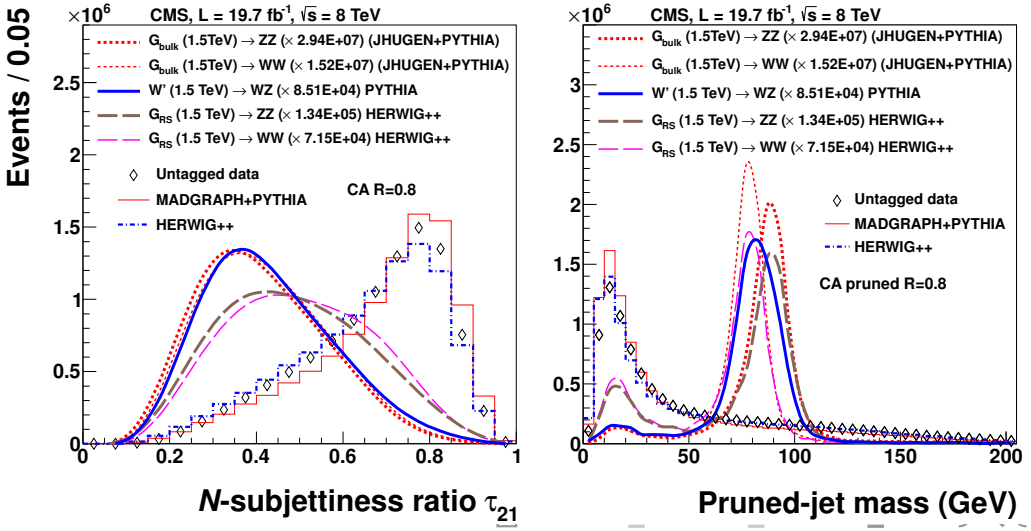

Bump in di-jet mass spectra ($p_T^{jet} > 50(30)$ GeV), $\Delta\eta_{jj} < 1.2(1.3)$ prevents $t$–channel events

ATLAS: $m_X \subset [0.8, 3.2]$ TeV

CMS: $m_X \subset [1, 3]$ TeV

Uses jet substructure to V-tag

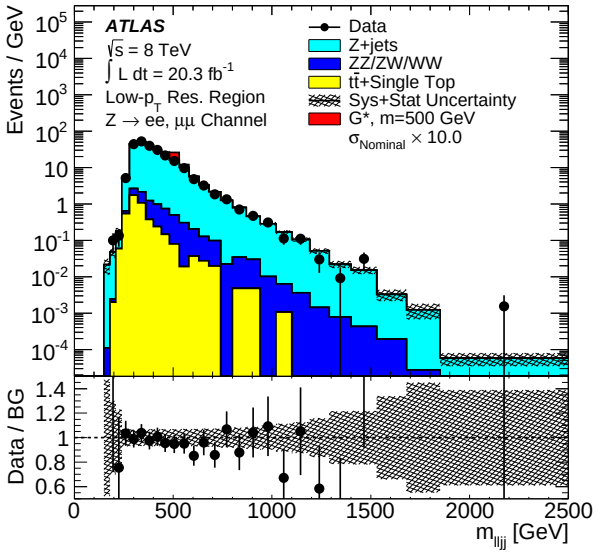
$\Rightarrow$ acentuate results model dependency.




arXiv:1407.1376 + Twiki
JHEP08(2014)173 + Twiki

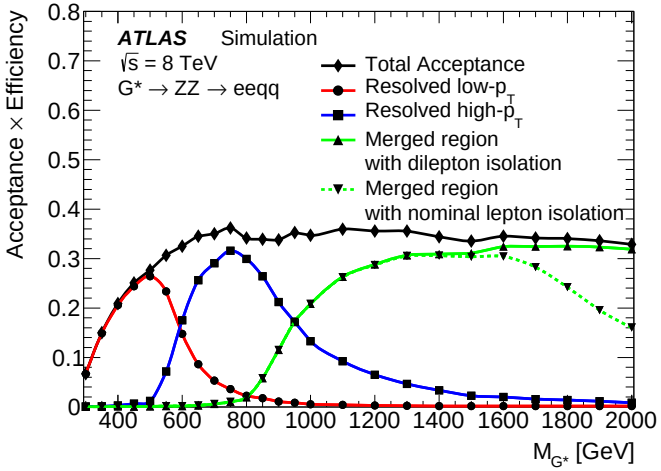
# $X \to VV$ semi-leptonic - resolved + boosted regimes

## $W'$ $(Z(ll)W(qq))$ and bulk KK-graviton $(Z(ll)Z(qq))$




Single lepton trigger ($p_T > 24$ GeV)
with tracker+calo isolation ($\Delta R > 0.2$)
Drop calo lepton isolation if 2 leptons w/ $\Delta R_{ll} < 0.25$

Hadronic V tag by Fat-jet mass
= filter in CA1.2 recluster of AkT04 jets



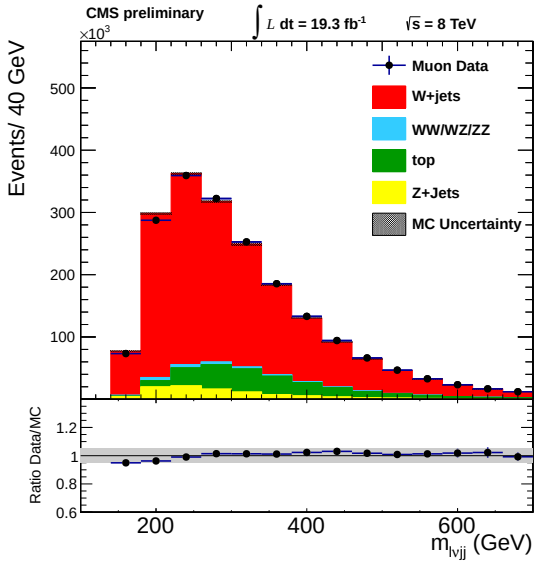

arxiv:1409.6190 + Twiki

# $X \to VV$ semi-leptonic -resolved and boosted regimes

Fit in reconstructed resonance mass.

**GF spin-0 $\to W(l\nu)W(qq)$**

Single lepton HLT ($\Delta R > 0.3$)
+ 2 AkT05 jets
$m_X \subset [160, 600]$ GeV

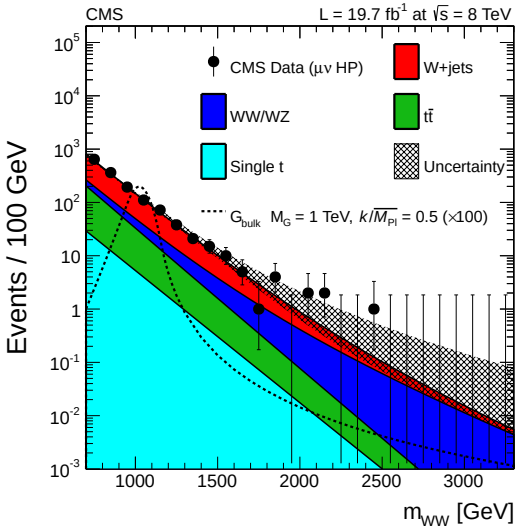


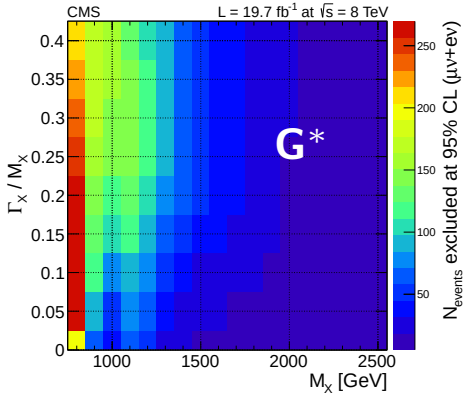

CMS-HIG-13-027 + Twiki

**bulk KK-graviton ($ZZ, WW$) and $W'$ ($WZ$)**

Single and Di-lepton trigger,
no isolation and loose definition

Uses jet substructure to V-tag (as slide 4)




Boosted results given beyond narrow-width approximation.

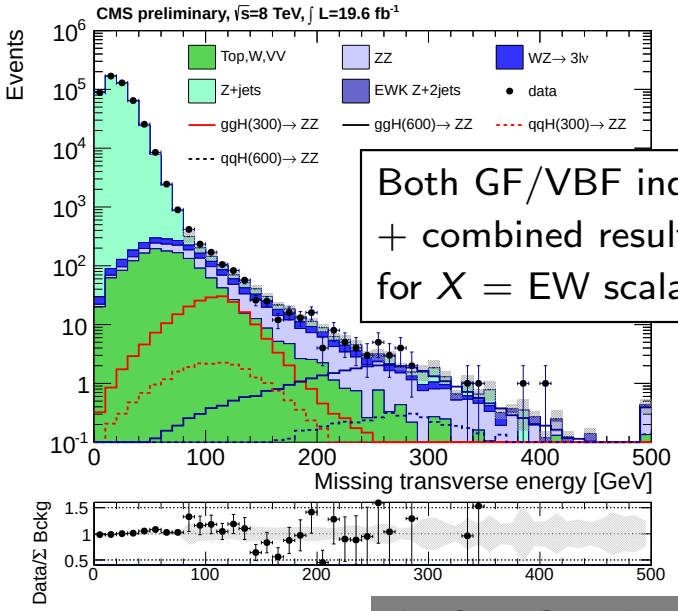
JHEP**08**(2014)174 + Twiki

# $X \to VV$ leptonic - resolved

## GF and VBF spin-0 ($Z(ll)Z(\nu\nu)$)

Two well-identified, isolated same flavour leptons
Signal extraction in transverse plane
$m_X \subset [0.2, 1]$ TeV

$N_{jets}$ define GF and VBF categories:
- VBF: $\Delta\eta_{jj} > 4$ and $m_{jj} > 500$ GeV.



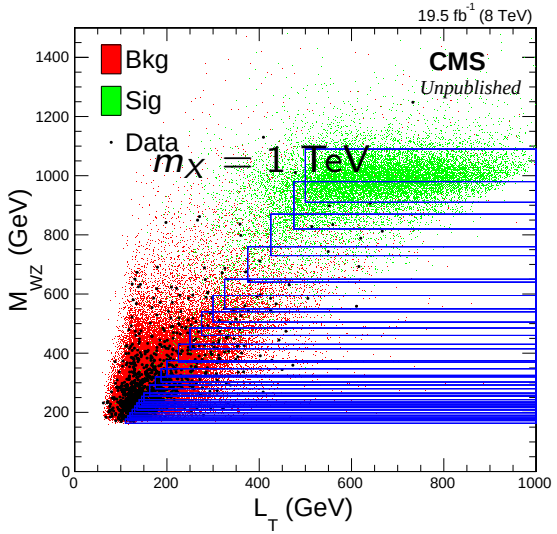

Both GF/VBF individual limits,
+ combined results in terms of $\Gamma_{inv}$,
for $X$ = EW scalar singlet.

CMS-PAS-HIG-13-014 + Twiki

## W' ($W(l\nu)Z(ll)$)

Pair of same-flavor, opposite-charge, isolated leptons with $m_{ll} \sim m_Z$

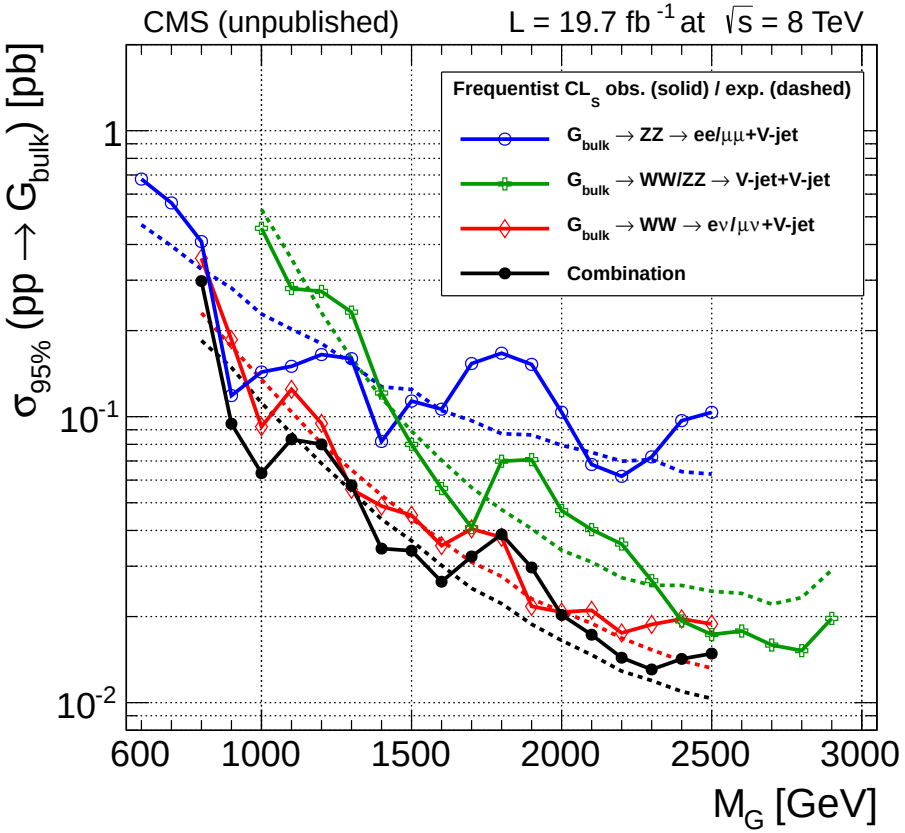
Both reco mass and total tranverse momenta used to extract signal.



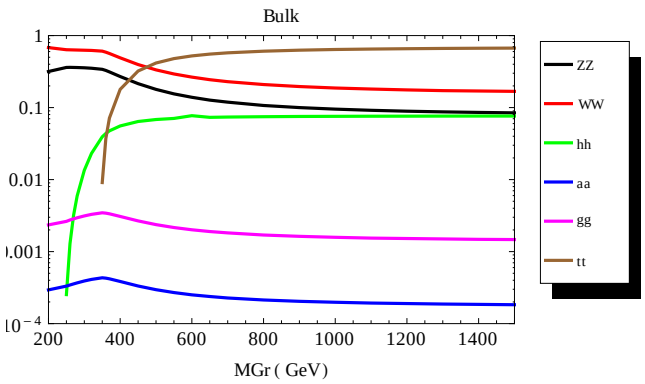

arXiv:1407.3476 + Twiki

# $X \to VV$ combinations in selected benchmark scenarios

hadronic + semileptonic channel
bulk KK-graviton benchmark




Assuming TeV localized RH top



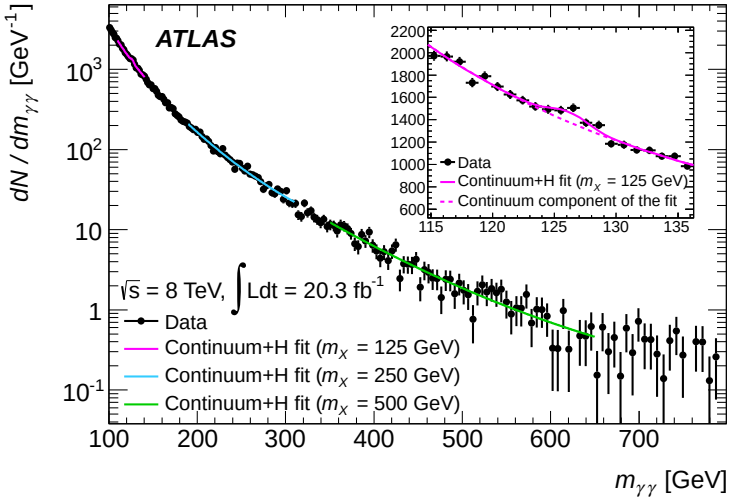

JHEP08(2014)174 + Twiki

Work ongoing on spin-1 hypotheses combination

# $X \to \gamma\gamma$

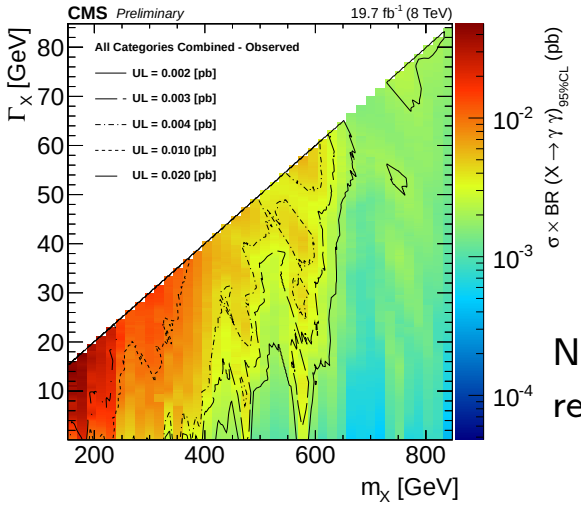
## GF and VBF spin-0 resonance and GF bulk KK-graviton (CMS)

SM-like search for a bump in $m_{\gamma\gamma}$




Extended range for bkg extimation,
di-photon spectra is not like di-jet one:

- ATLAS fit 2th order polinomial in different mass ranges
- CMS uses $f(m) = e^{-p_1 m} m^{-p_2}$ in all range




Narrow width results in terms of $\Gamma_X$

PRL**113**,171801 + Twiki
CMS-PAS-HIG-14-006 + Twiki

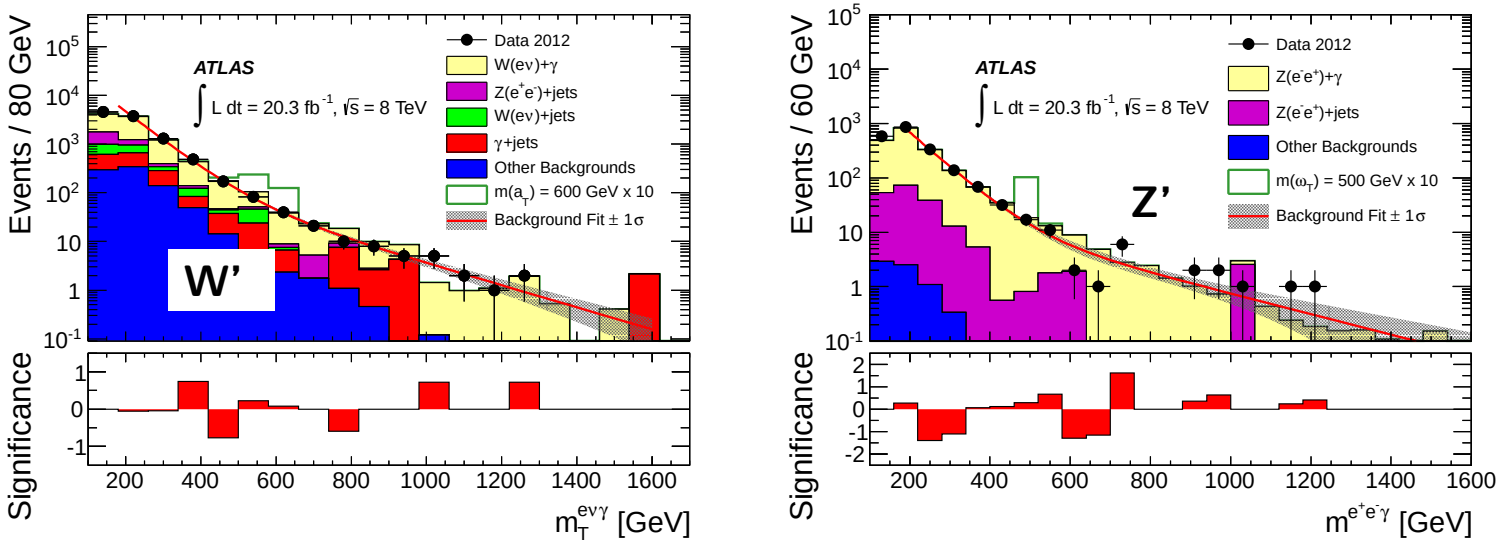
Work ongoing for 2HDM interpretations.

# $X \to \gamma Z/\gamma W$ leptonic

**GF spin-0 resonance, W' and Z'**

PLB**738**(2014)428-447 + Twiki

Single lepton trigger + hard photon ($p_T^\gamma > 40$ GeV)
fit in reconstructed resonance mass

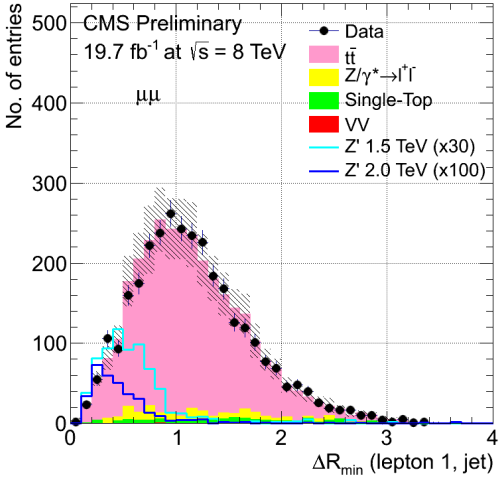


# $X \to t\bar{t}$

## $Z'$ and KK-gluon

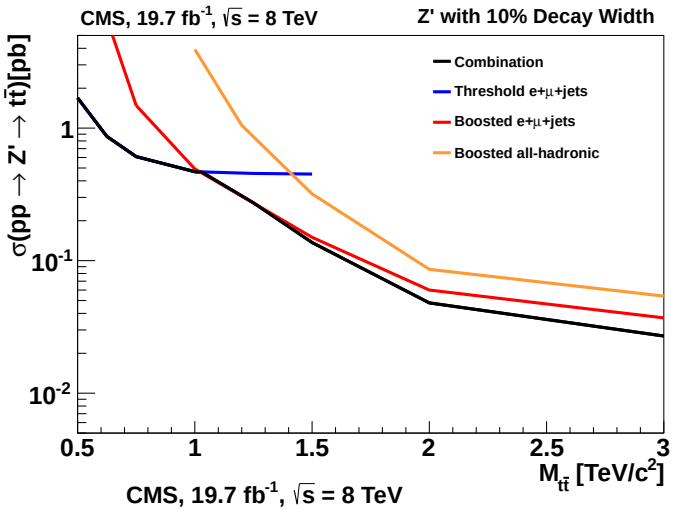
**Di-lepton ($m_X \subset [0.8, 3]$ TeV)**
Non isolated single lepton trigger
+ at least two ($b$)jets + MET.

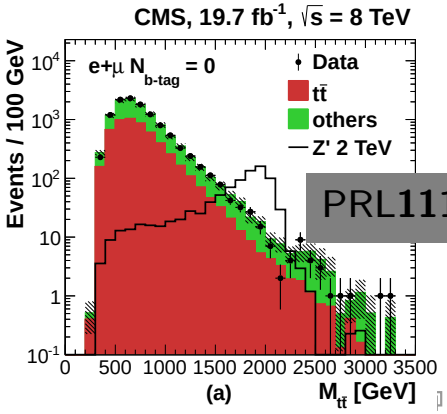
Boosted = $\Delta R_{jl}$ used for BKG rejection.
Signal from reconstructed $m_X$




CMS-PAS-B2G-12-007 + Twiki

**Semi-leptonic + hadronic**

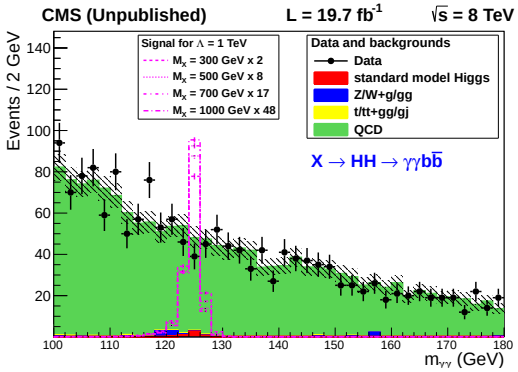


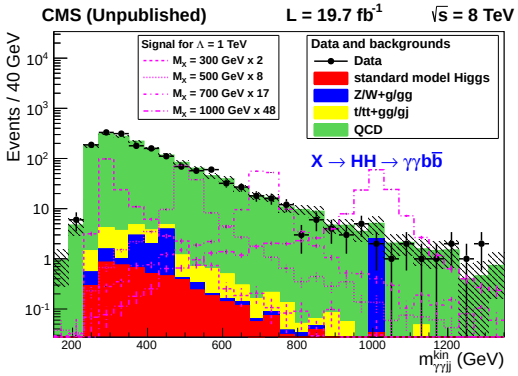




PRL**111**(2013)211804 + Twiki

# $X \to h(\gamma\gamma)h(b\bar{b})$ (the 125 GeV one)

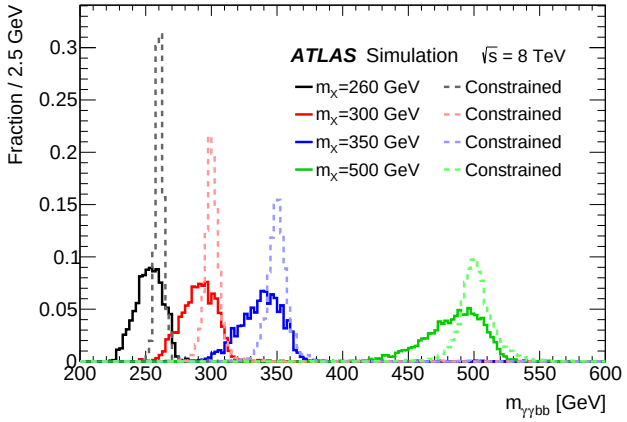
## GF spin-0 and KK-graviton (CMS)




ATLAS: fit in $m_{\gamma\gamma\, b\bar{b}}$ mass spectra, select in Higgses for resonant and non-resonant results

CMS, two strategies:
- same of ATLAS for $m_X > 400$ GeV
- for $m_X < 400$ GeV fit in $m_{\gamma\gamma}$, select $H(b\bar{b})$ and 4-body

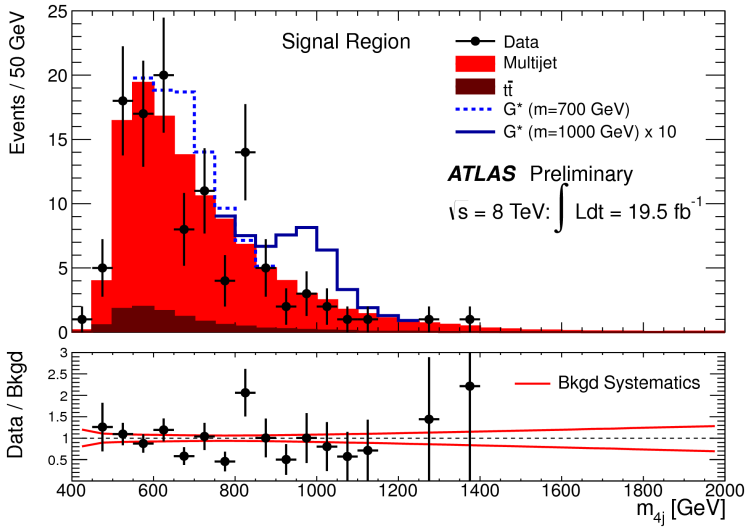



arXiv:1406.5053 + Twiki
CMS-PAS-HIG-13-032 + Twiki

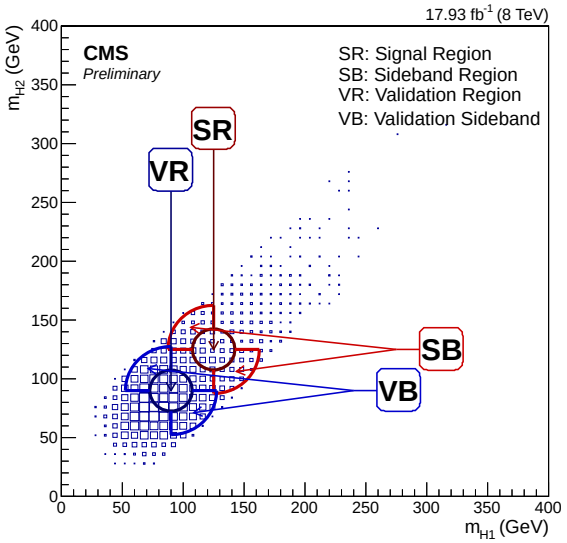
Keep tuned for BSM non-resonant results from CMS!

# $X \to h(b\bar{b})h(b\bar{b})$ (125 GeV) - resolved analyses

**GF spin-0 (CMS) and KK-graviton**




ATLAS: combination of multi-jet triggers (AkT04)
CMS: multijet + $2b$–tag at HLT (AkT05)
$\Rightarrow$ lower threshold aceptance.




Signal extraction in $m_{HH}$ by sidebands in the reconstructed higgses

Boost of Higgses defines jet pairing in intemediate mass regime.

ATLAS-CONF-2014-005 + Twiki
CMS-PAS-HIG-14-013 + Twiki

Keep tuned for boosted regime from both collaborations!

# Conclusions

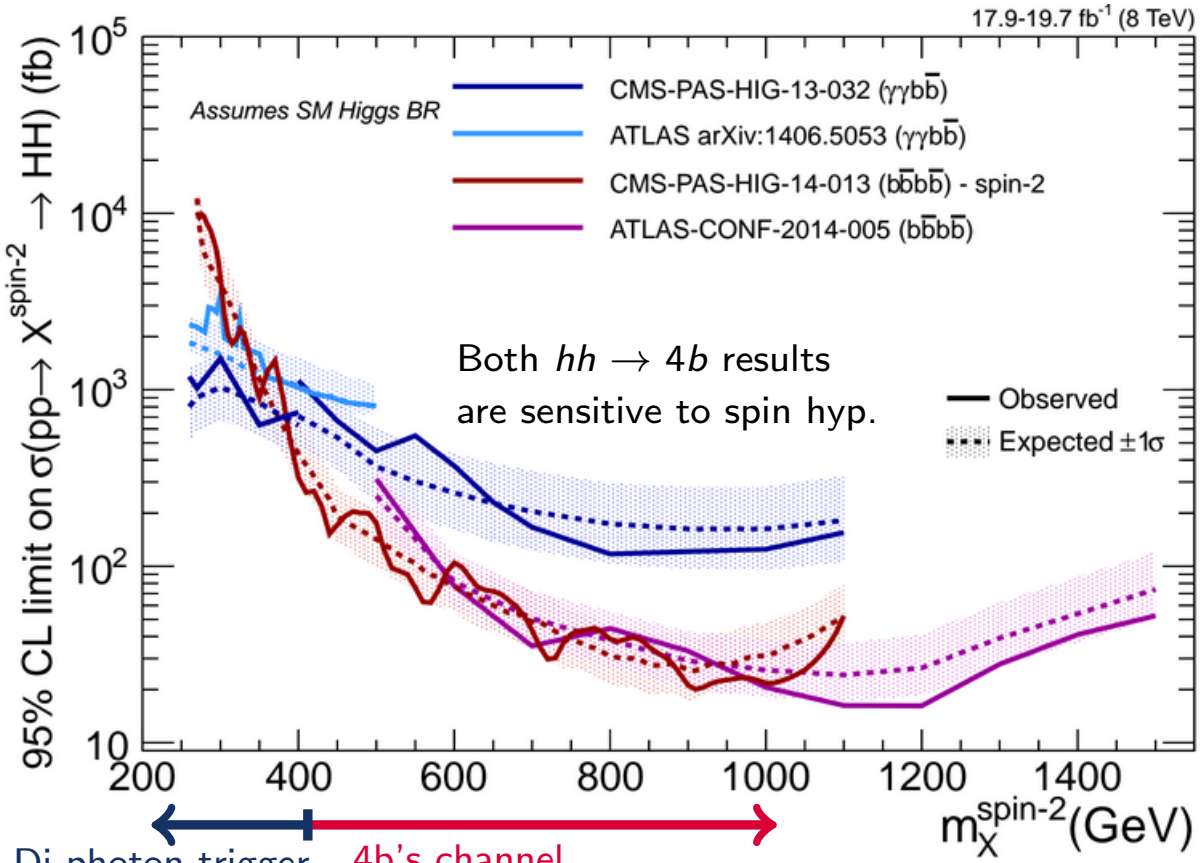
- Very fruitful Run I for resonant searches in di-boson channels
  - No discovery yet
  - Hints for Run II exploration
  - Therefore it is still not finished



The next few months will be full of (8 TeV) news!
And, in any results case, full of interpretation work...

# Thanks for attention!

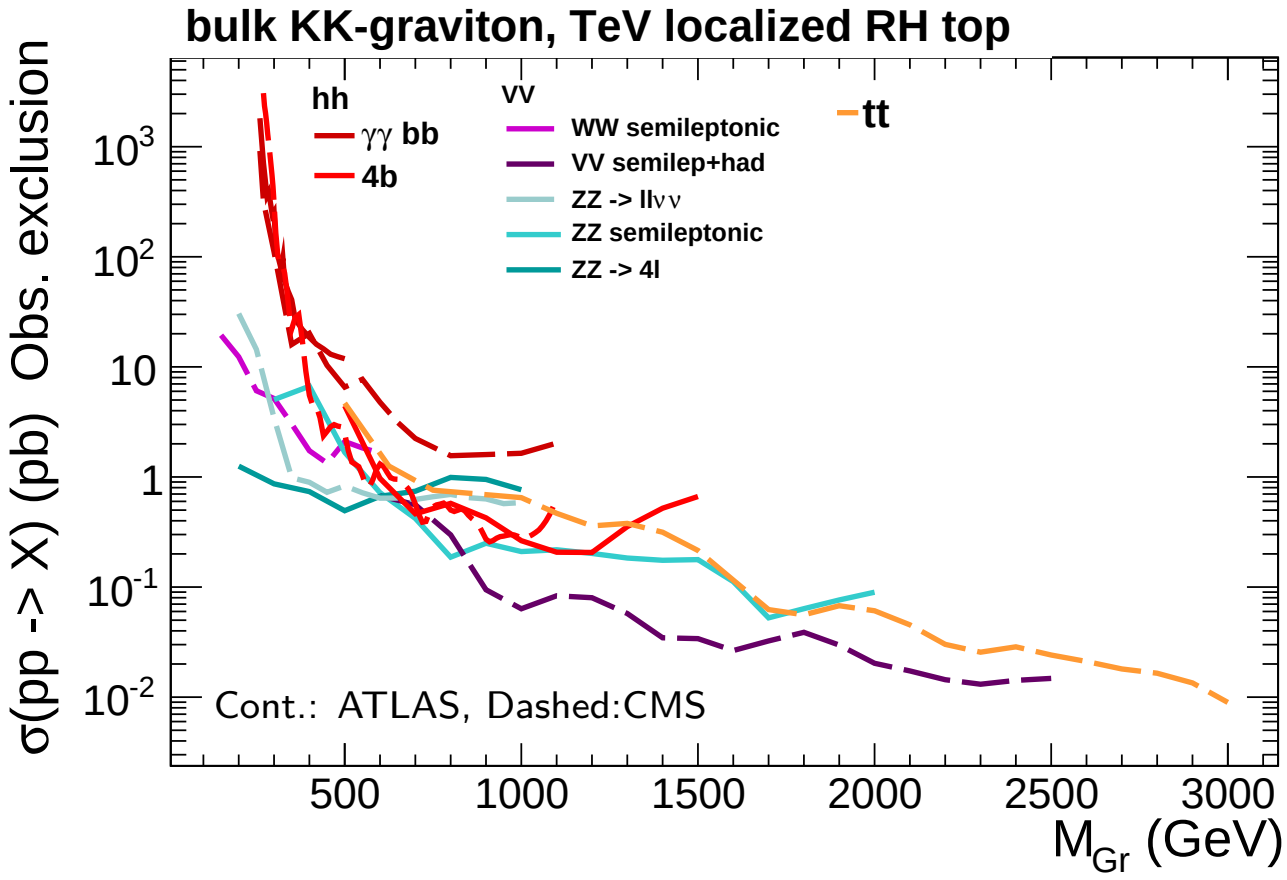

# If we assume the 125 GeV boson to be THE neutral higgs boson



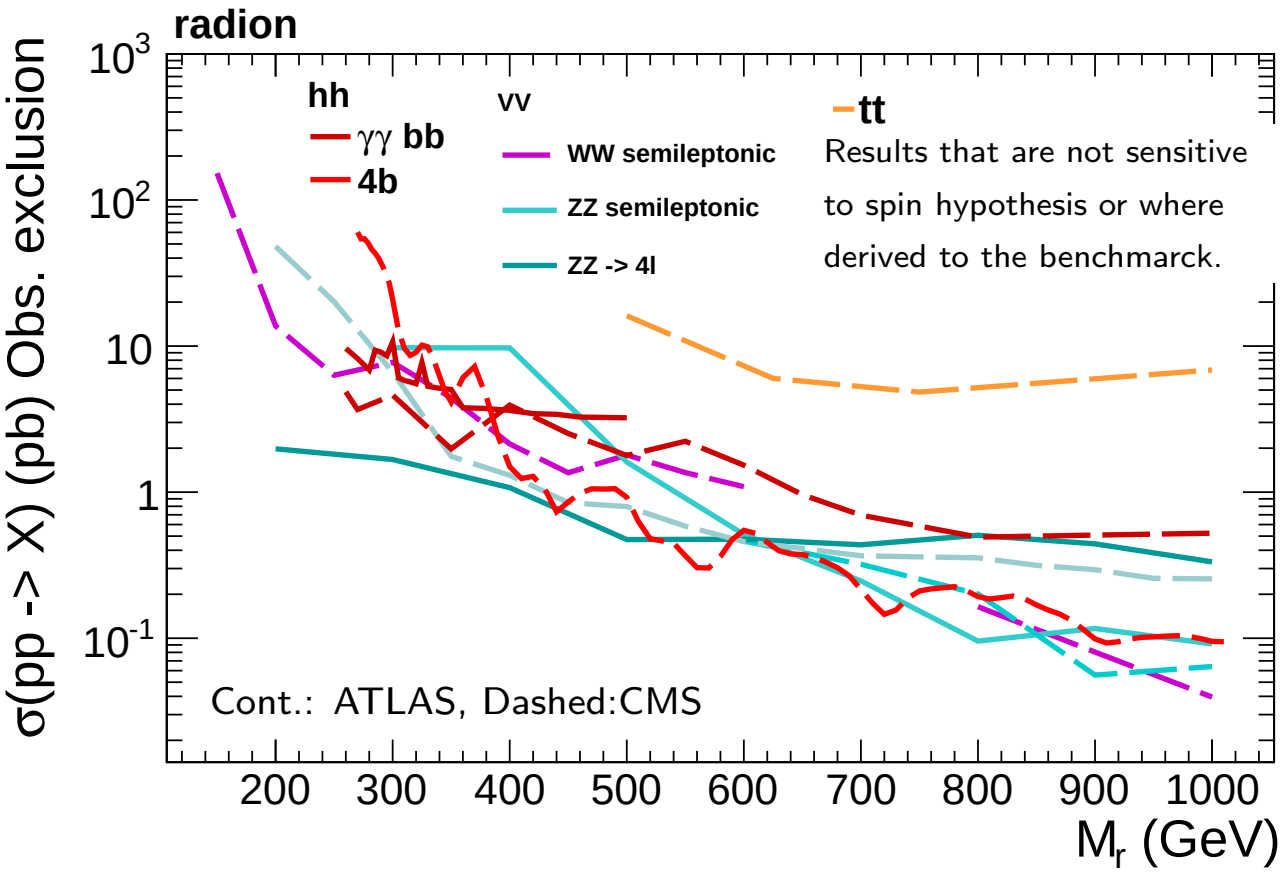

Keep tuned for $h(\tau\tau)h(b\bar{b})$ and $h(WW^*)h(b\bar{b})$ !

# Comparing channels for bulk KK-graviton

Results that are not sensitive to spin hypothesis or where derived to the benchmark.



# Comparing channels for radion benchmark




**Di-higgs channel start to be competitive with VV in all search range**

Thanks to V.Barger an M.Ishida for calculate the NLO radion BFs to 125 GeV higgs case.