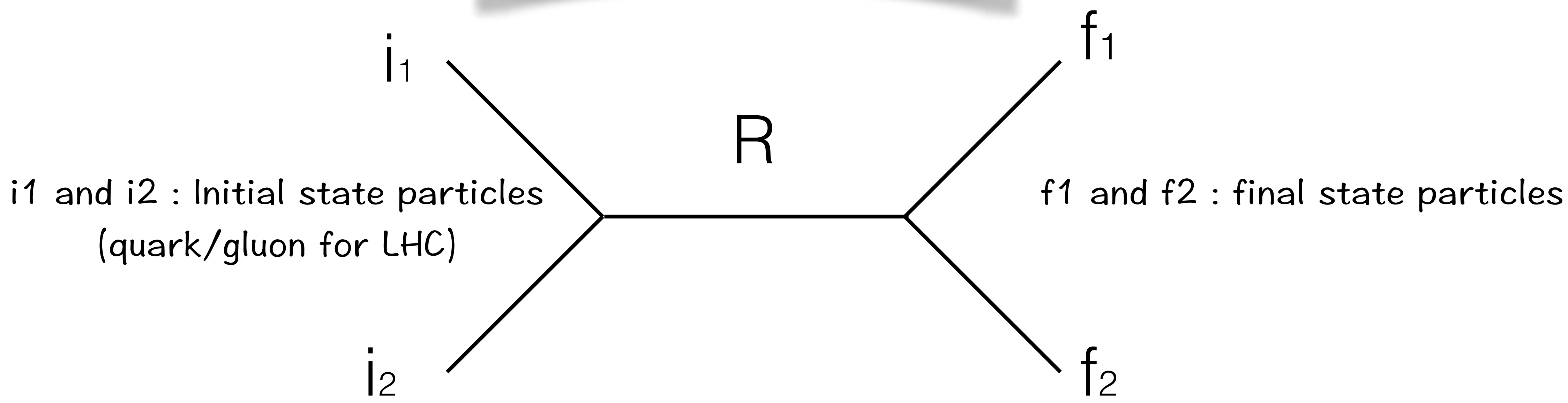
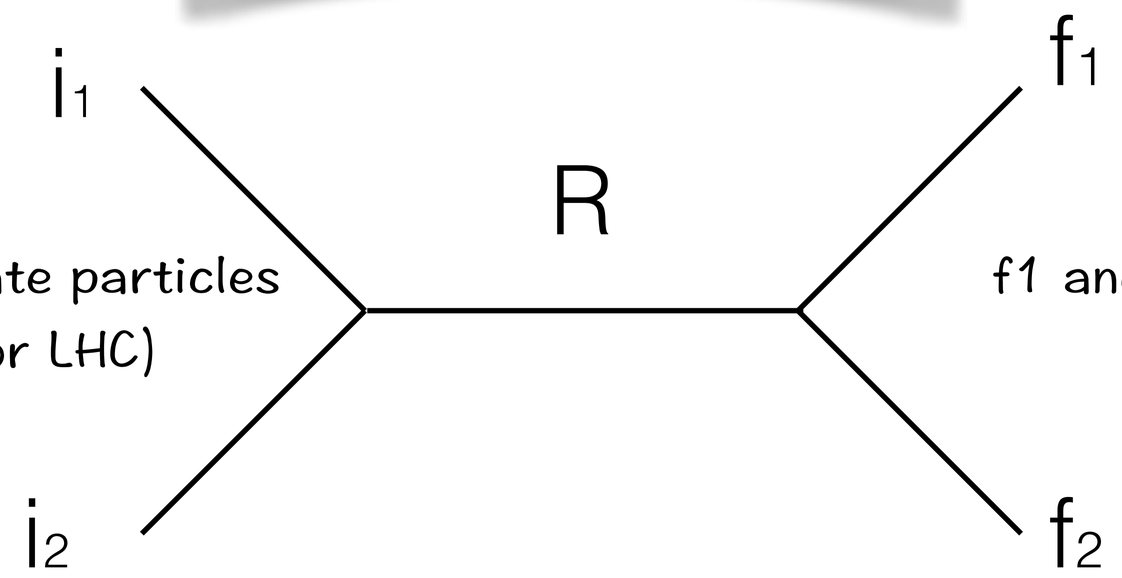
The Status of 750 GeV di-photon resonance

Biplob Bhattacherjee
Centre for High Energy Physics
Indian Institute of Science
5th May 2016

Resonance search



Resonance search



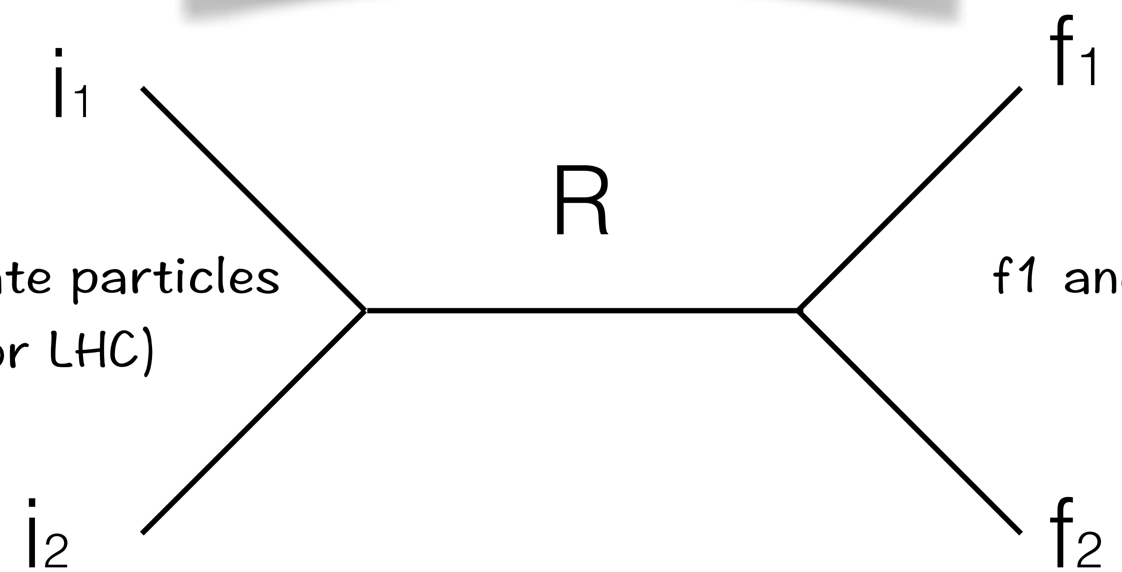
i1 and i2 : Initial state particles (quark/gluon for LHC)

f1 and f2 : final state particles

invariant mass of f_1 and f_2 = Mass of R

$$M^2_{f_1 f_2} = (P_{f_1} + P_{f2})^2 = M^2_R$$

Resonance search



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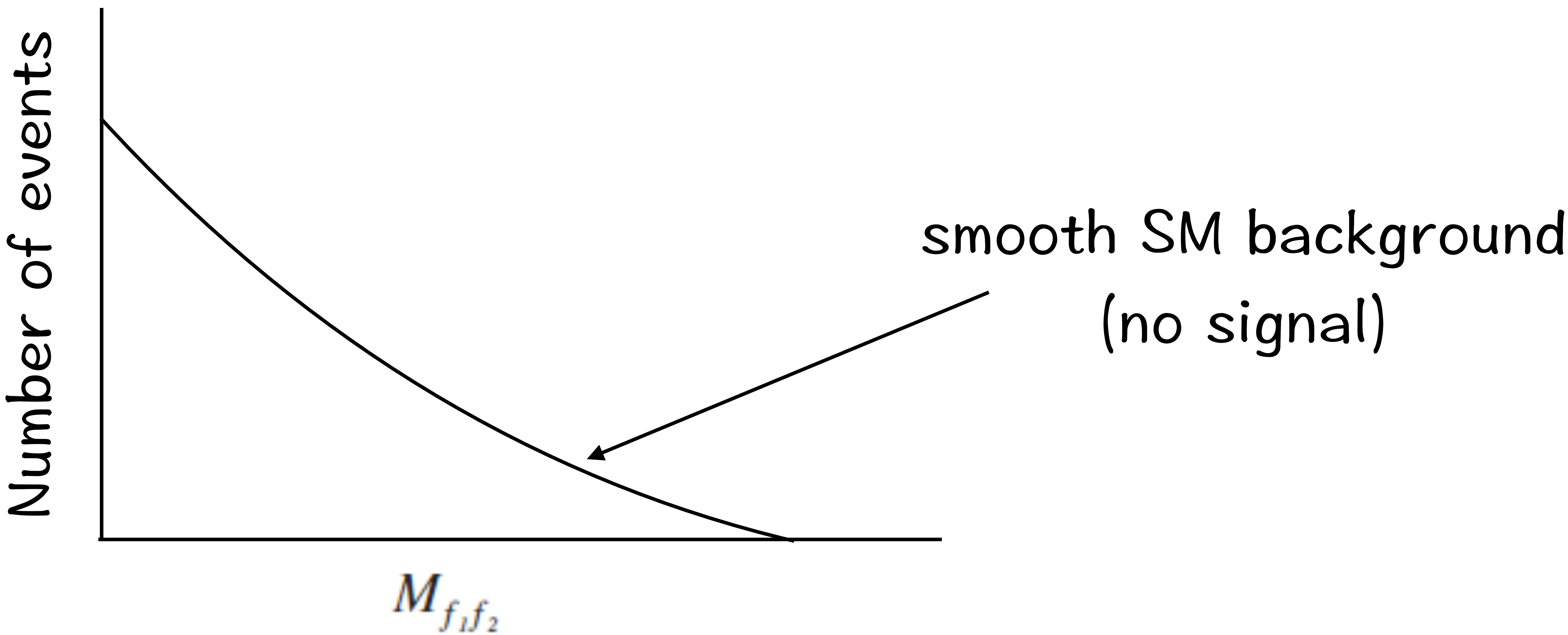
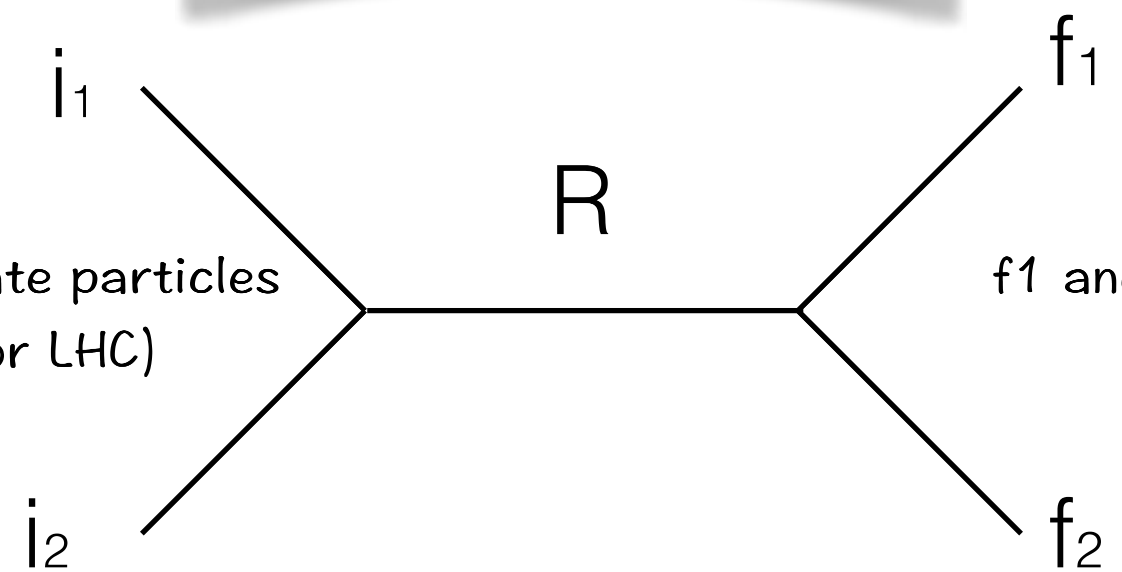


Resonance search

i1 and i2 : Initial state particles (quark/gluon for LHC)



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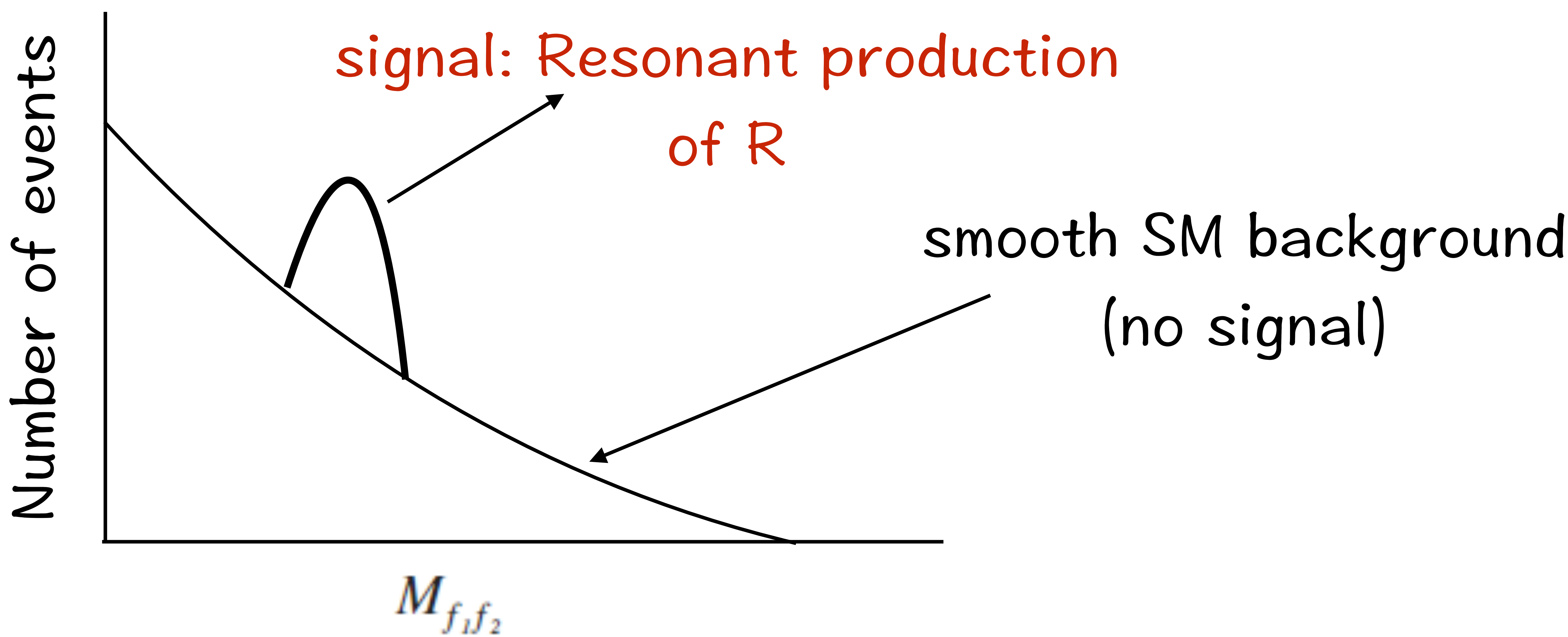
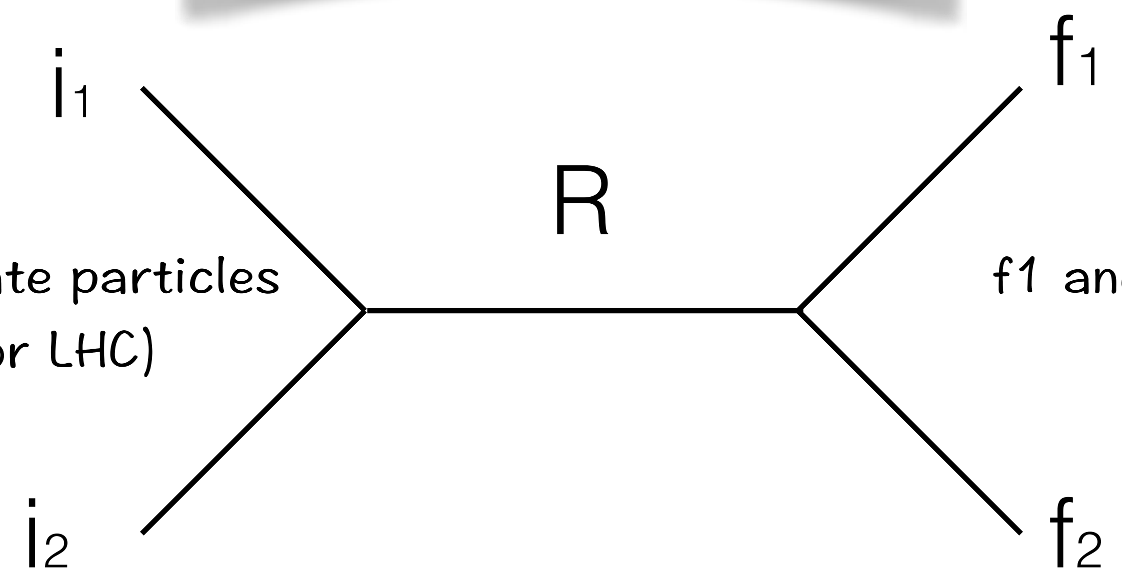


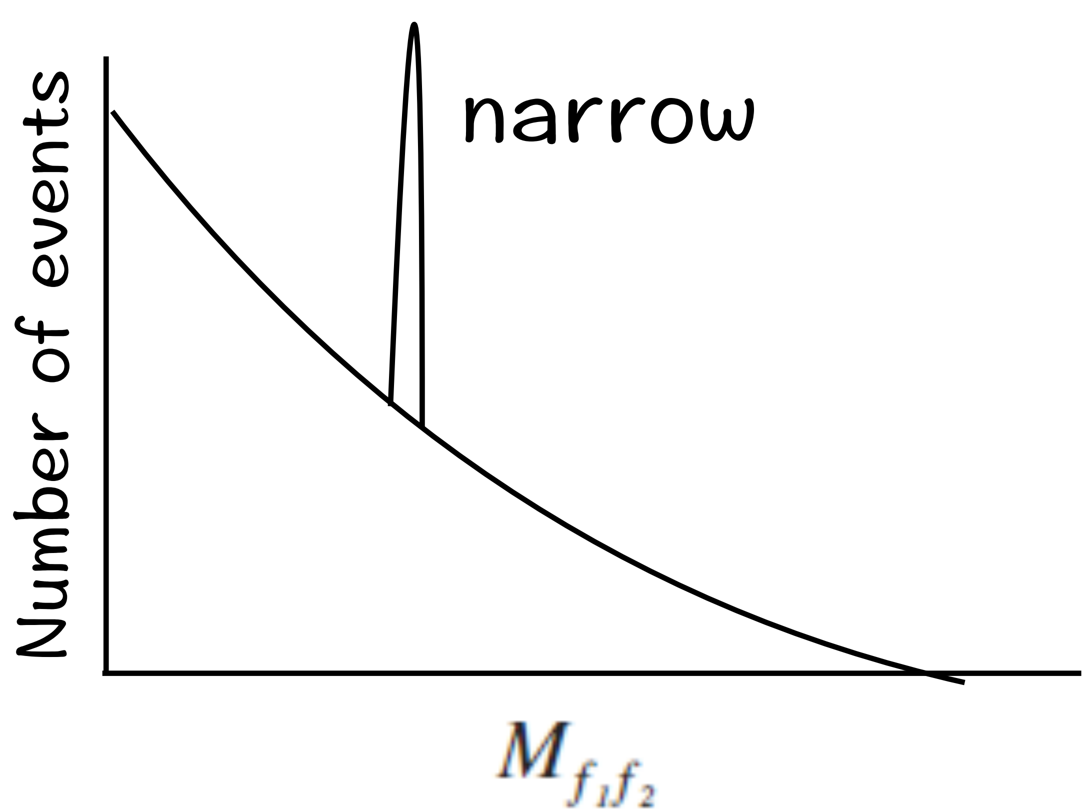
Resonance search

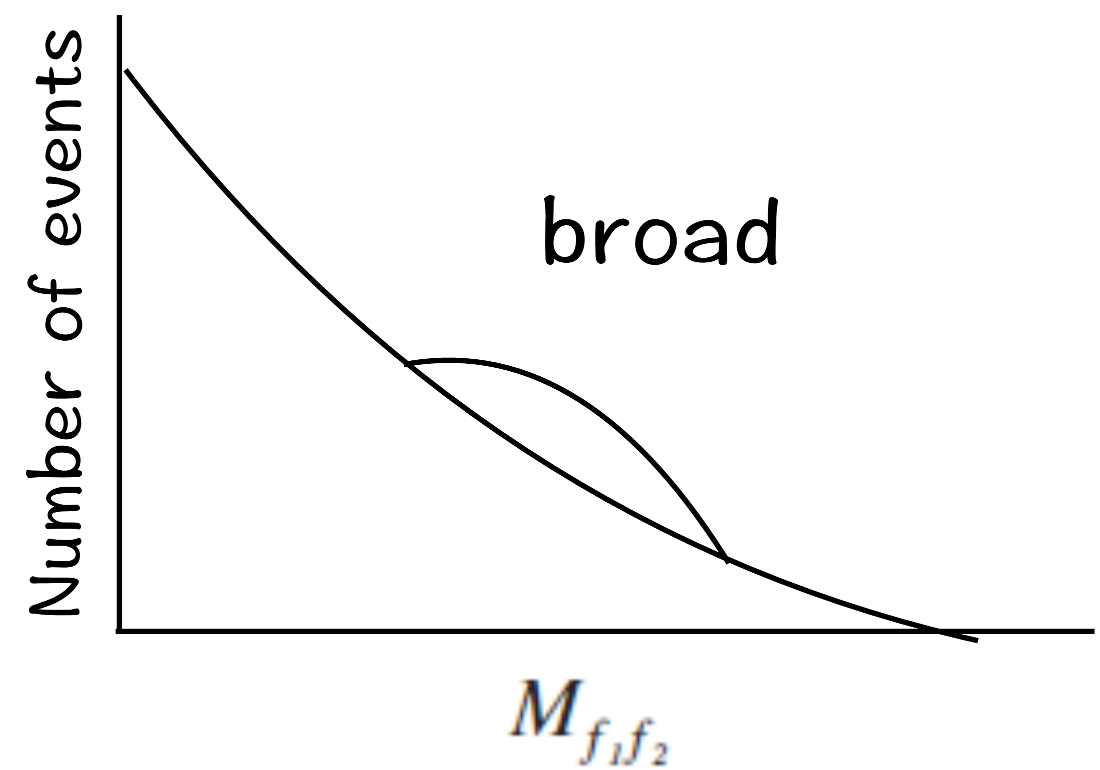


i1 and i2 : Initial state particles (quark/gluon for LHC)

f1 and f2 : final state particles

Narrow or broad => depends on particle width and detector resolution



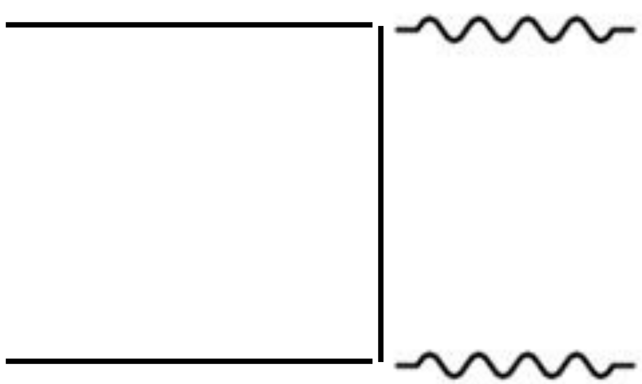


Di-photon Resonance search

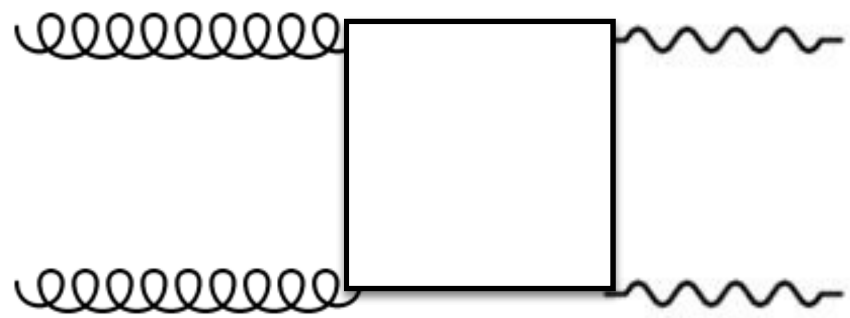
Signal $pp \rightarrow X \rightarrow \gamma\gamma$

backgrounds

irreducible



dominant



reducible(jets mis-tagged as photon)

$pp \rightarrow \gamma + jet$

$pp \rightarrow jet + jet$

Back

Summary : LHC di-photon searches

Search for di-photon resonances in the mass range from 150 to 850 GeV in pp collisions at sqrt(*s*) = 8 TeV

The CMS Collaboration (1506.02301)

Abstract

Results are presented of a search for heavy particles decaying into two photons. The analysis is based on a 19.7 fb^{-1} sample of proton-proton collisions at $\sqrt{s} = 8$ TeV collected with the CMS detector at the CERN LHC. The diphoton mass spectrum from 150 to 850 GeV is used to search for an excess of events over the background. The search is extended to new resonances with natural widths of up to 10% of the mass value. No evidence for new particle production is observed and limits at 95% confidence level on the production cross section times branching fraction to diphotons are determined. These limits are interpreted in terms of two-Higgs-doublet model parameters.

Summary : LHC di-photon searches

Search for di-photon resonances in the mass range from 150 to 850 GeV in pp collisions at sqrt(*s*) = 8 TeV

The CMS Collaboration (CMS-HIG-14-006)

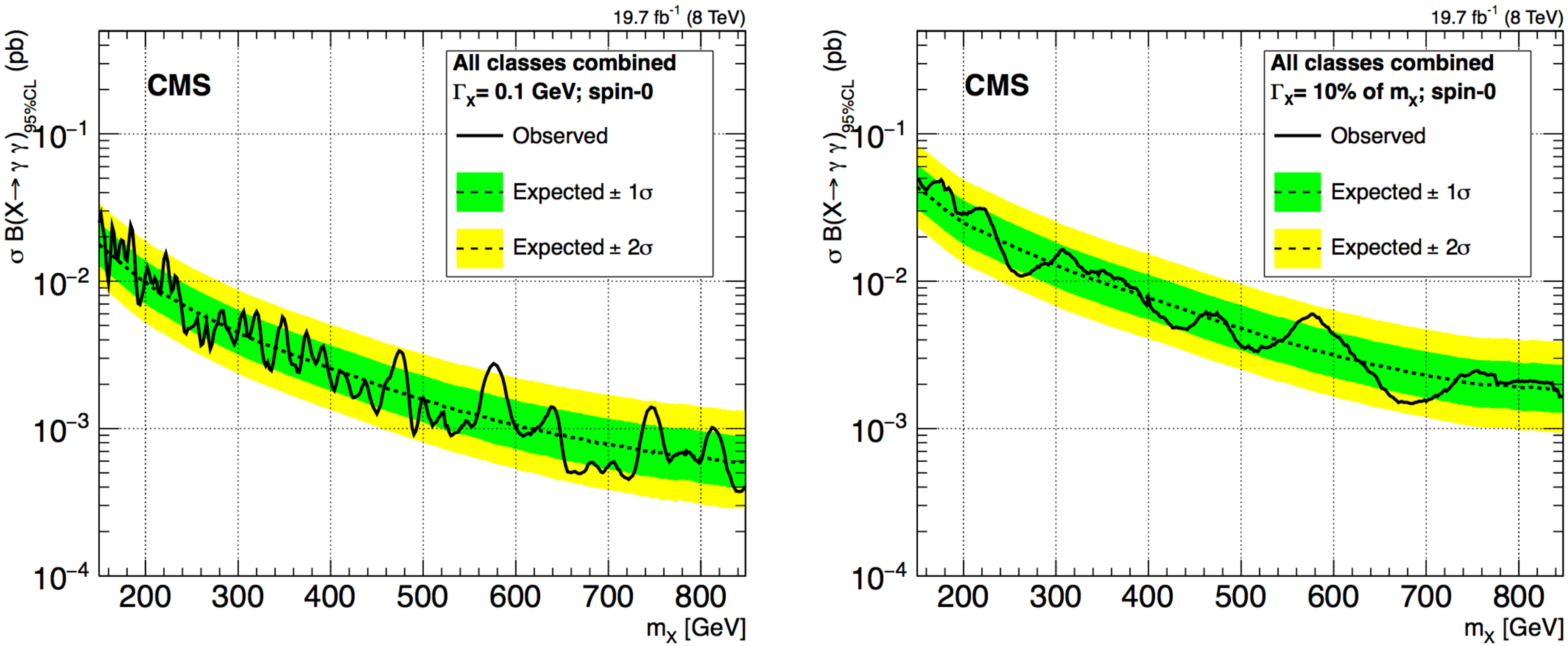


Figure 7: Exclusion limit at 95% CL on the cross section times branching fraction of a new, spin-0 resonance decaying into two photons as a function of the resonance mass hypothesis, combining the four classes of events. The results for a narrow resonance hypothesis ($\Gamma_X = 0.1\,\text{GeV}$) (left) and for a wide resonance hypothesis ($\Gamma_X = 0.1 m_X$) (right) are shown.

Summary : LHC di-photon searches

Search for High-Mass Diphoton Resonances in pp Collisions at $\sqrt{s} = 8$ TeV with the CMS Detector

The CMS Collaboration

Abstract

A search for high-mass diphoton resonances is performed in proton-proton collisions at $\sqrt{s} = 8$ TeV, with data corresponding to an integrated luminosity of 19.5 fb^{-1}, collected by the CMS detector at the CERN Large Hadron Collider. Such a diphoton resonance could be a signature of an excited state of the graviton in the Randall-Sundrum scenario with a warped extra dimension of space. The background to this signal comes from real standard model diphoton production, and from photon+jet or dijet processes where one or two jets produce a fake photon signature in the detector. The observed diphoton mass distribution is compared to the background prediction, and no significant excess of events over the background is found. 95% confidence level limits are set in the parameter space of the Randall-Sundrum model: masses below $1450 - 2780$ GeV are excluded for the first excited state of the Randall-Sundrum graviton, for values of the coupling parameter k/M_{Pl} in the range $0.01 \leq k/M_{\mathrm{Pl}} \leq 0.1$.

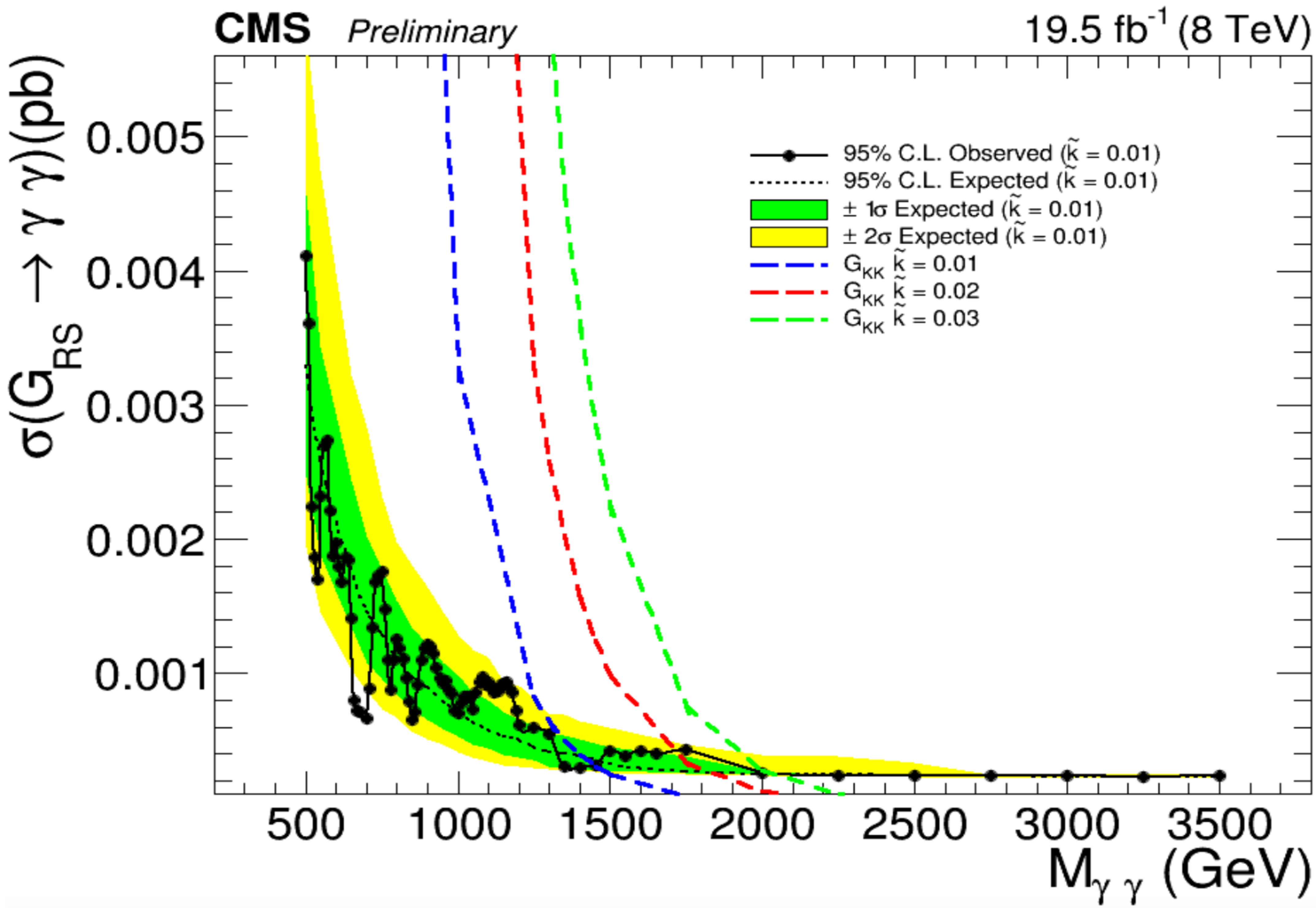
CMS PAS EXO-12-045

Summary : LHC di-photon searches

Search for High-Mass Diphoton Resonances in pp Collisions at $\sqrt{s} = 8$ TeV with the CMS Detector

CMS PAS EXO-12-045

The CMS Collaboration



Summary : LHC di-photon searches

Search for Scalar Diphoton Resonances in the Mass Range 65–600 GeV with the ATLAS Detector in *pp* Collision Data at $\sqrt{s} = 8$ TeV

ATLAS Collaboration

A search for scalar particles decaying via narrow resonances into two photons in the mass range 65–600 GeV is performed using 20.3 fb^{-1} of $\sqrt{s} = 8$ TeV *pp* collision data collected with the ATLAS detector at the Large Hadron Collider. The recently discovered Higgs boson is treated as a background. No significant evidence for an additional signal is observed. The results are presented as limits at the 95% confidence level on the production cross-section of a scalar boson times branching ratio into two photons, in a fiducial volume where the reconstruction efficiency is approximately independent of the event topology. The upper limits set extend over a considerably wider mass range than previous searches.

1407.6583

Summary : LHC di-photon searches

Search for high-mass diphoton resonances in *pp* collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector

The ATLAS Collaboration. **[arXiv:1504.05511]**

Abstract

This article describes a search for high-mass resonances decaying to a pair of photons using a sample of 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8$ TeV recorded with the ATLAS detector at the Large Hadron Collider. The data are found to be in agreement with the Standard Model prediction, and limits are reported in the framework of the Randall-Sundrum model. This theory leads to the prediction of graviton states, the lightest of which could be observed at the Large Hadron Collider. A lower limit of 2.66 (1.41) TeV at 95% confidence level is set on the mass of the lightest graviton for couplings of $k/\overline{M}_{\text{Pl}} = 0.1$ (0.01).

Summary : LHC di-photon searches

Search for high-mass diphoton resonances in *pp* collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector

The ATLAS Collaboration. [arXiv:1504.05511]

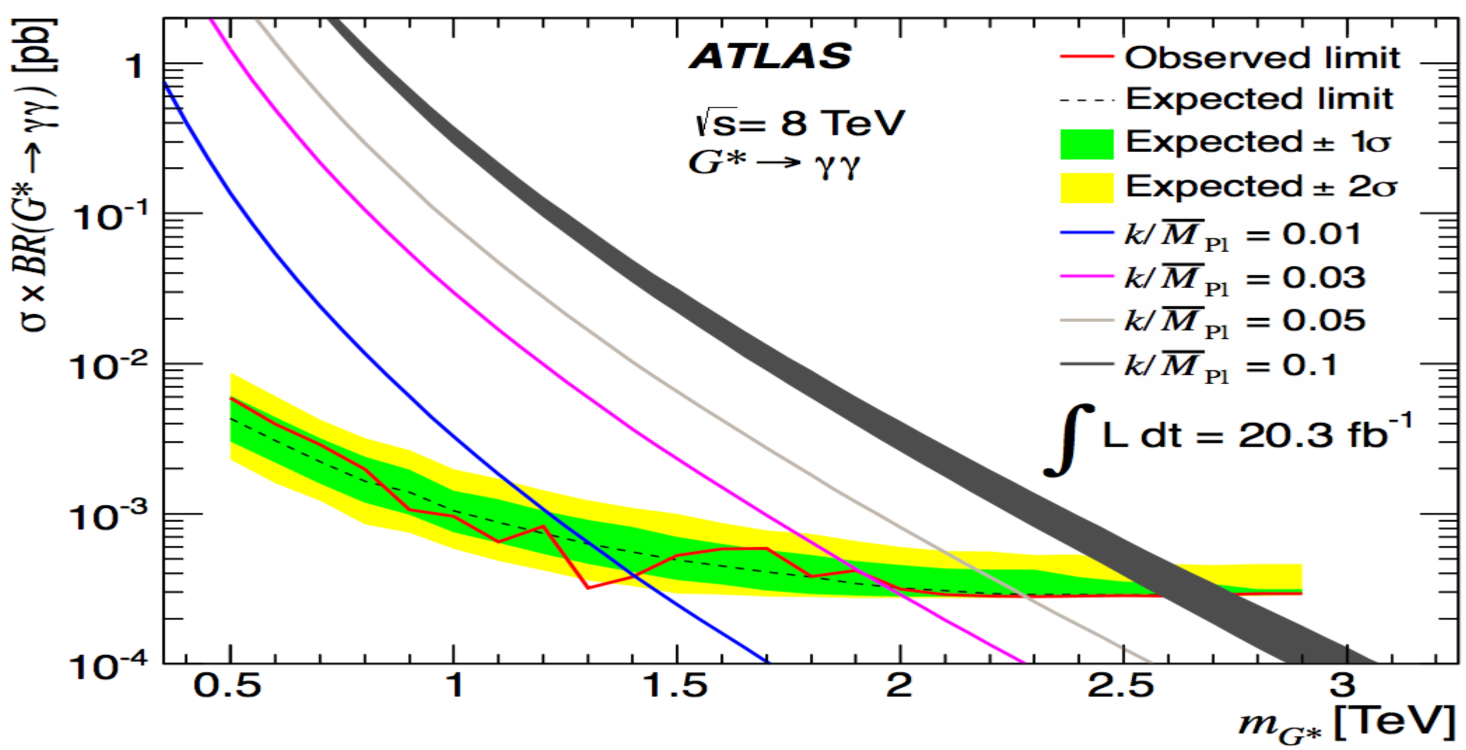


Figure 4: Expected and observed upper limits on $\sigma \times BR(G^* \to \gamma\gamma)$ expressed at 95% CL, as a function of the graviton mass. At large m_{G^*}, the -1σ and -2σ variations of the expected limit tend to be particularly close to the expected limit. This is expected, since signals with high m_{G^*} would appear in regions of $m_{\gamma\gamma}$ where the background expectation is small and the Poissonian fluctuations around the mean expected background are highly asymmetric. The curves show the RS model prediction for given values of $k/\overline{M}_{\rm Pl}$ as a function of m_{G^*}. They are obtained using the Pythia generator plus a K-factor to account for NLO corrections (see text). The thickness of the theory curve for $k/\overline{M}_{\rm Pl} = 0.1$ illustrates the PDF uncertainties expressed at 90% CL.

Summary : LHC di-photon searches

Search for new physics in high mass diphoton events in proton-proton collisions at

sqrt(*s*) = 13 TeV

The CMS Collaboration (CMS PAS EXO-15-004)

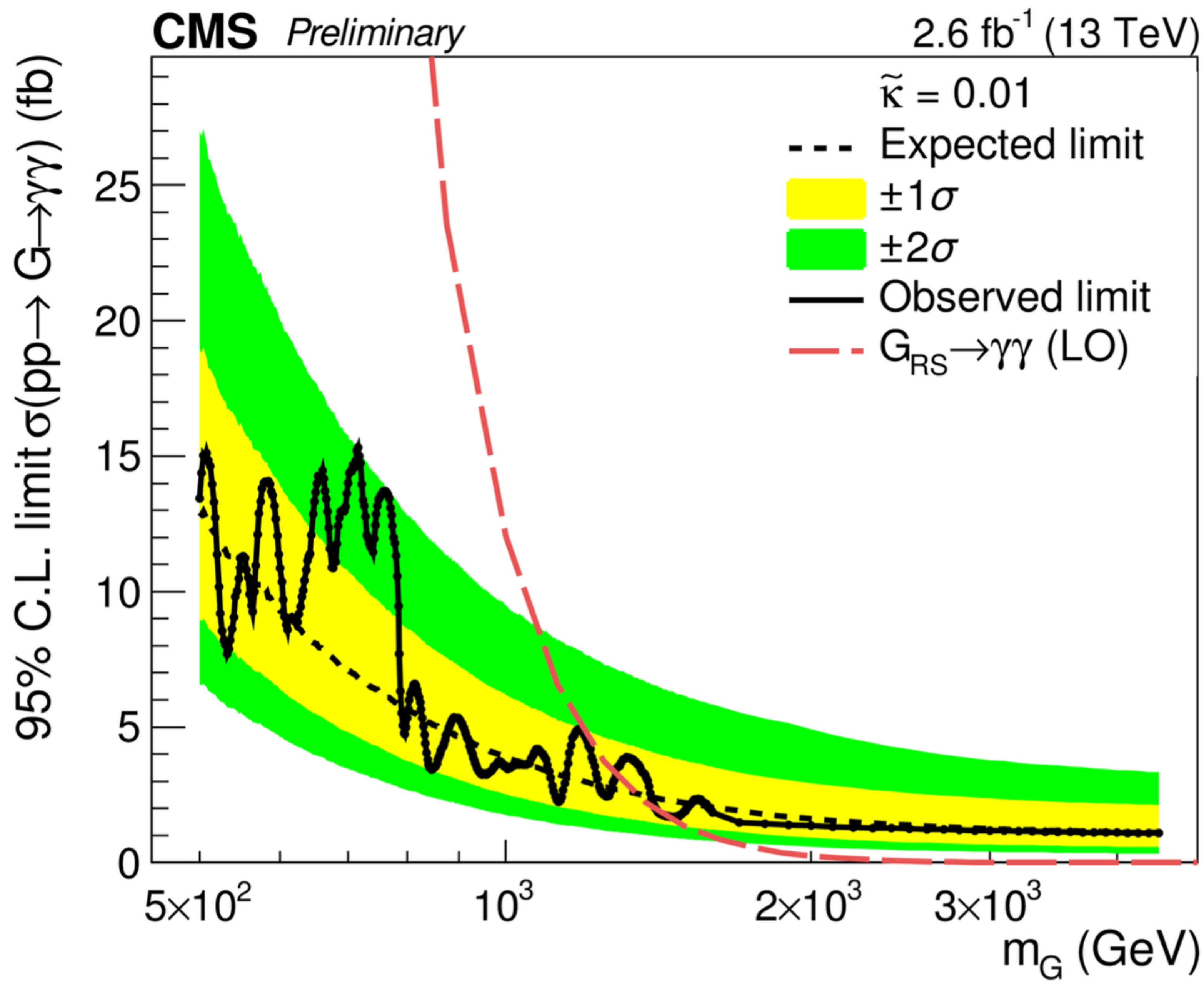
Abstract

We report on a search for new physics using high mass diphoton events. The search employs 2.6 fb^{-1} of pp collision data collected by the CMS experiment in 2015 at a center-of-mass energy of 13 TeV and it is aimed at extradimensional models leading to resonant production of two photons. Limits on the production cross section of Randall-Sundrum gravitons decaying to two photons are obtained in the range 500-4500 GeV.

Summary : LHC di-photon searches

Search for new physics in high mass diphoton events in proton-proton collisions at sqrt(*s*) = 13 TeV

The CMS Collaboration (CMS PAS EXO-15-004)



Summary : LHC di-photon searches

Search for resonances decaying to photon pairs in 3.2 fb^{-1} of pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector

The ATLAS Collaboration

Abstract

This note describes a search for new resonances decaying to two photons, with invariant mass larger than 200 GeV. The search is optimized for scalars such as those expected, for example, in models with an extended Higgs sector. The dataset consists of 3.2 fb^{-1} of pp collisions at $\sqrt{s}$ = 13 TeV recorded with the ATLAS detector at the Large Hadron Collider. The data are consistent with the expected background in most of the mass range. The most significant deviation in the observed diphoton invariant mass spectrum is found around 750 GeV, with a global significance of about 2 standard deviations. A limit is reported on the fiducial production cross section of a narrow scalar boson times its decay branching ratio into two photons, for masses ranging from 200 GeV to 1.7 TeV.

ATLAS-CONF-2015-081

Summary : LHC di-photon searches

ATLAS-CONF-2015-081

Search for resonances decaying to photon pairs in 3.2 fb^{-1} of pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector

The ATLAS Collaboration

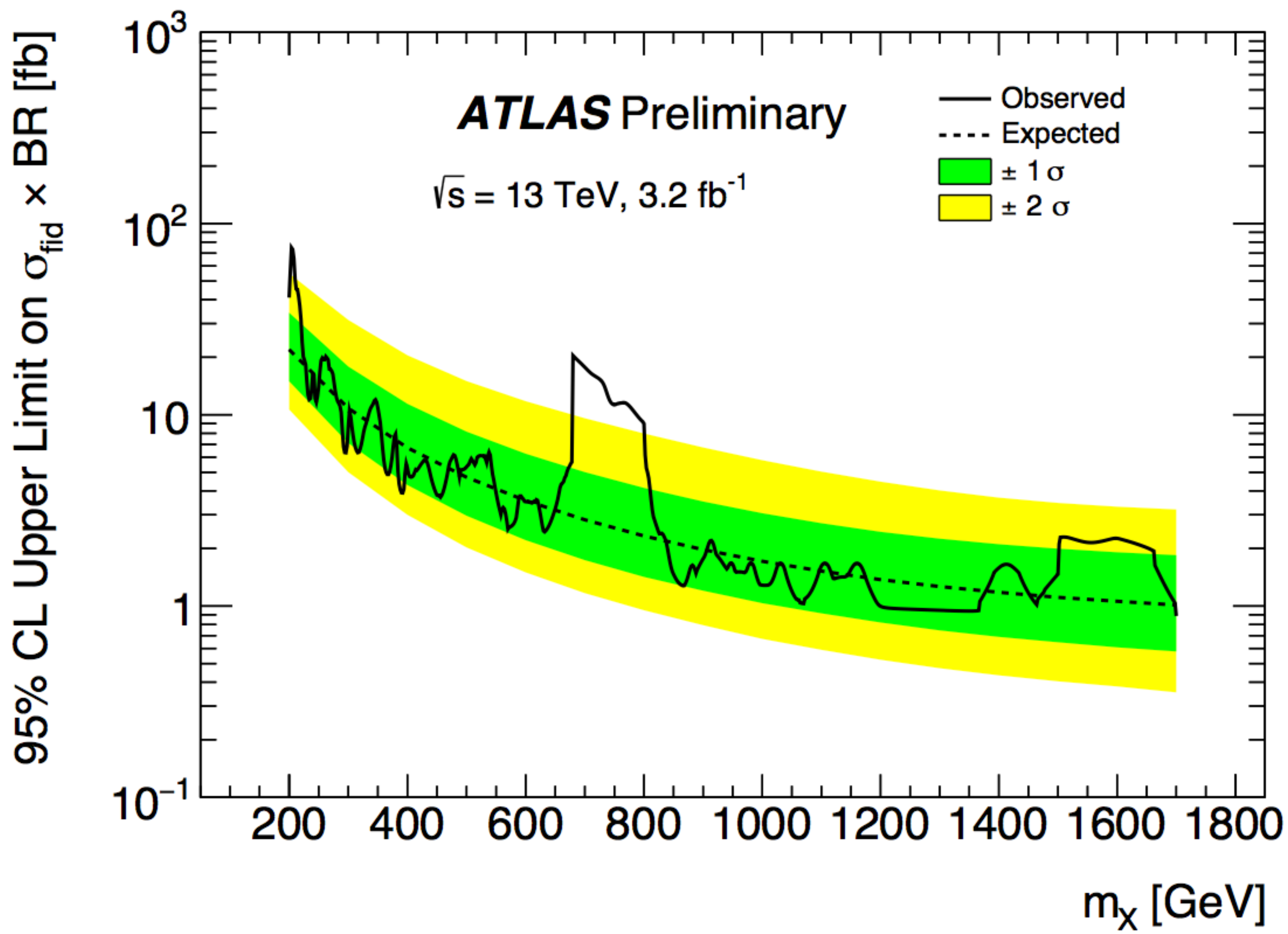


Figure 3: Expected and observed upper limits on $\sigma_{\text{fiducial}} \times \text{BR}(X \to \gamma\gamma)$ expressed at 95% CL, as a function of the assumed value of the narrow-width scalar resonance mass.

Experimental Summary page

Analysis	Cuts	Model	upper limit on cross section in fb(M=750 GeV)
CMS 8 TeV $\mathcal{L} = 19.7\ fb^{-1}$ 1506.02301	$E_{T1} > 33$ GeV, $E_{T2} > 25$ GeV $E_{T1}/m_{\gamma\gamma} > 0.33$, $E_{T2}/m_{\gamma\gamma} > 0.25$	2HDM + Spin 2	1.5-2
CMS 8 TeV $\mathcal{L} = 19.5\ fb^{-1}$ CMS PAS EXO-12-045	$E_{T1} > 80$ GeV, $E_{T2} > 80$ GeV	Spin 2	1-1.5
ATLAS 8 TeV $\mathcal{L} = 20.3\ fb^{-1}$ 1504.05511	$E_{T1} > 50$ GeV, $E_{T2} > 50$ GeV	RS model	~ 2
CMS 13 TeV BB and EE $\mathcal{L} = 2.6\ fb^{-1}$ CMS PAS EXO-15-004	$E_{T1} > 75$ GeV, $E_{T2} > 75$ GeV	RS Model	~ 12
ATLAS 13 TeV $\mathcal{L} = 3.2\ fb^{-1}$ ATLAS-CONF-2015-081	$E_{T1} > 40$ GeV, $E_{T2} > 30$ GeV $E_{T1}/m_{\gamma\gamma} > 0.4$, $E_{T1}/m_{\gamma\gamma} > 0.3$	2HDM	~ 20

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required cross to explain the excess

$$\sigma(pp \to \gamma\gamma) \approx \begin{cases} (0.5 \pm 0.6)\,\text{fb} & \text{CMS [2]} \quad \sqrt{s} = 8\,\text{TeV}, \\ (0.4 \pm 0.8)\,\text{fb} & \text{ATLAS [3]} \quad \sqrt{s} = 8\,\text{TeV}, \\ (6 \pm 3)\,\text{fb} & \text{CMS [1]} \quad \sqrt{s} = 13\,\text{TeV}, \\ (10 \pm 3)\,\text{fb} & \text{ATLAS [1]} \quad \sqrt{s} = 13\,\text{TeV}. \end{cases}$$

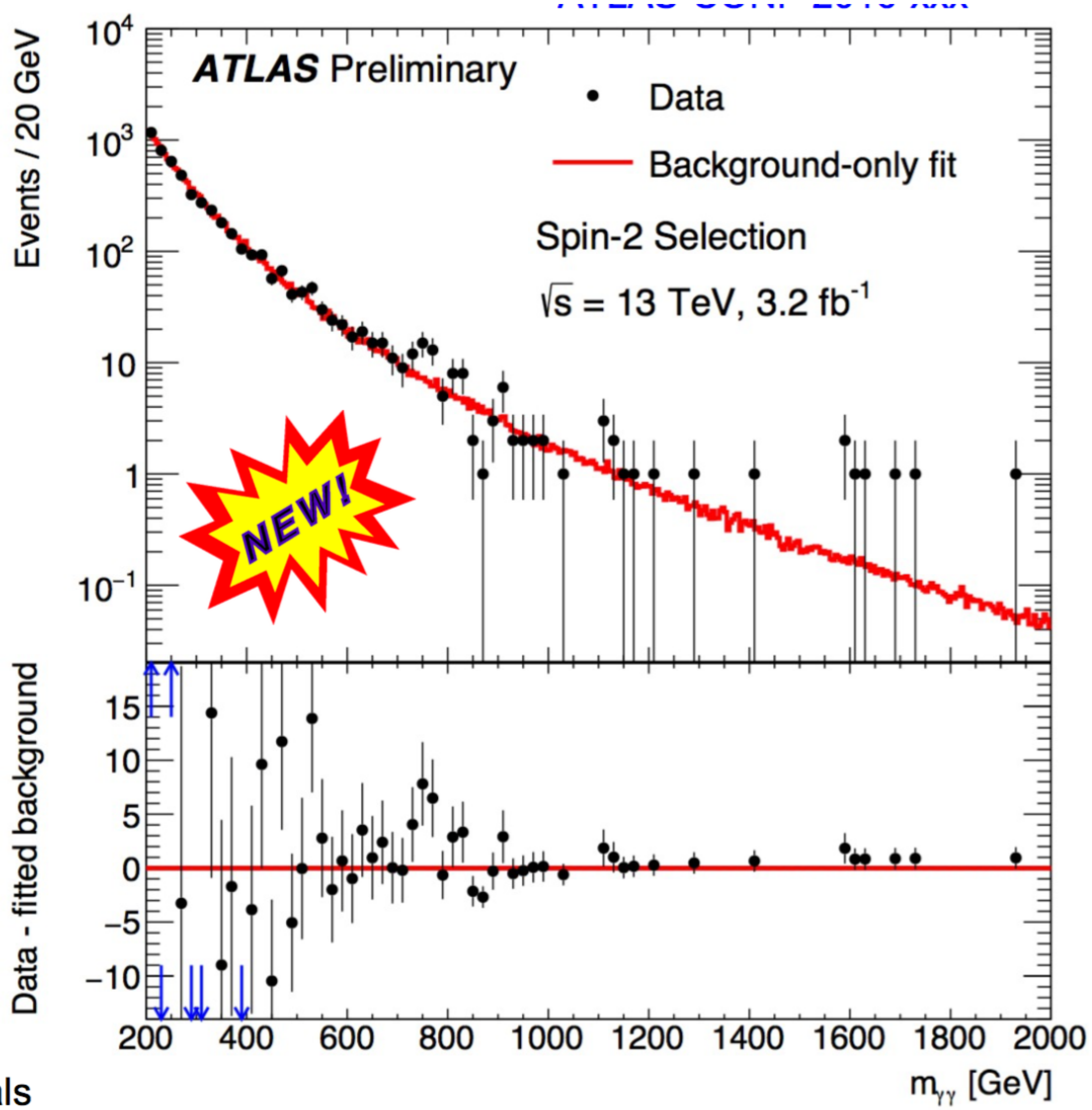
1512.04933 (R. Franceschini et.al.)

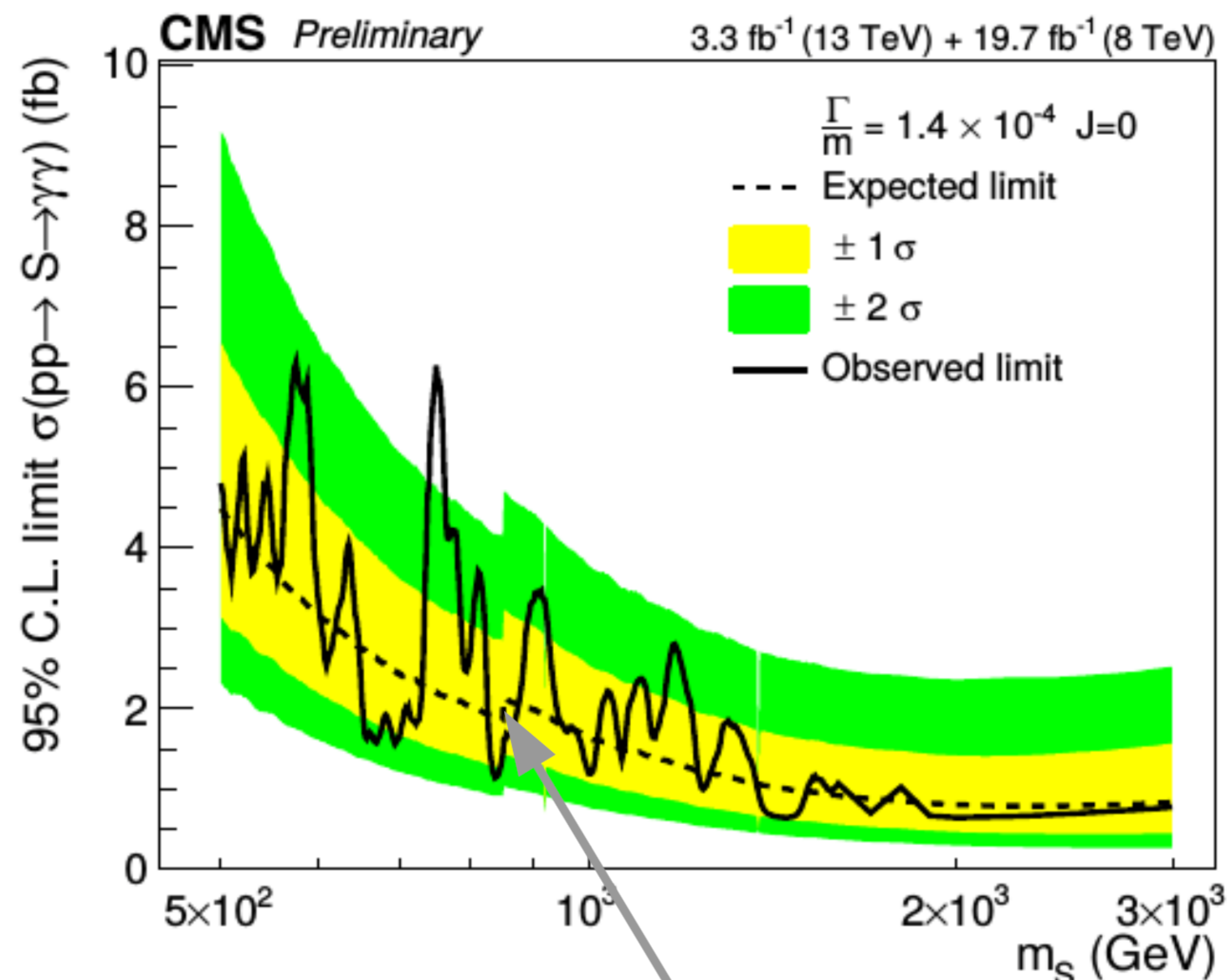
13 TeV new analysis : ATLAS and CMS

relaxed cuts

additional 0.6 ifb data (B=0)
both spin=0 and 2 analysis

$\Gamma/m = 1.4\times10^{-4}$



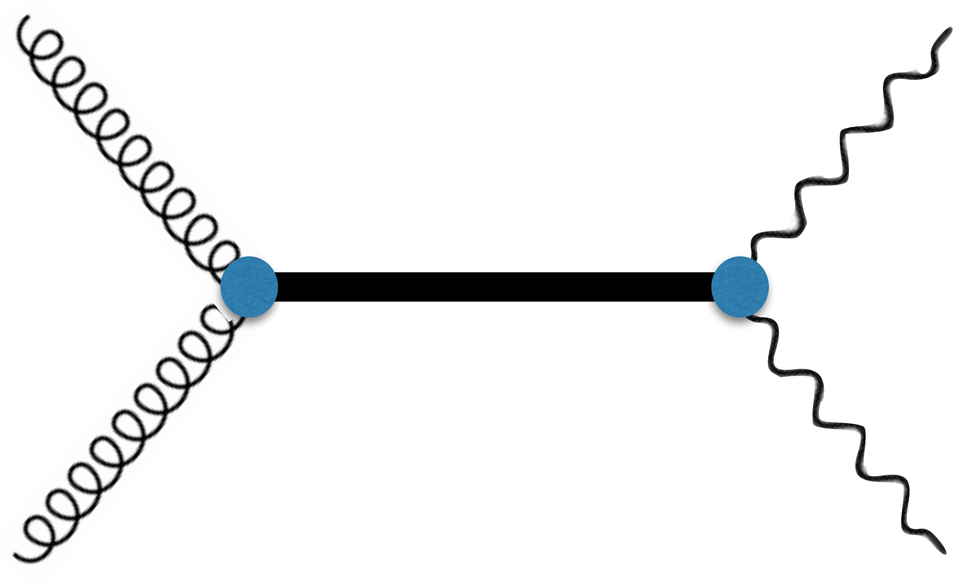


spin 2 hypothesis : local significance 3.6 sigma
spin 0 hypothesis : local significance 3.3 sigma

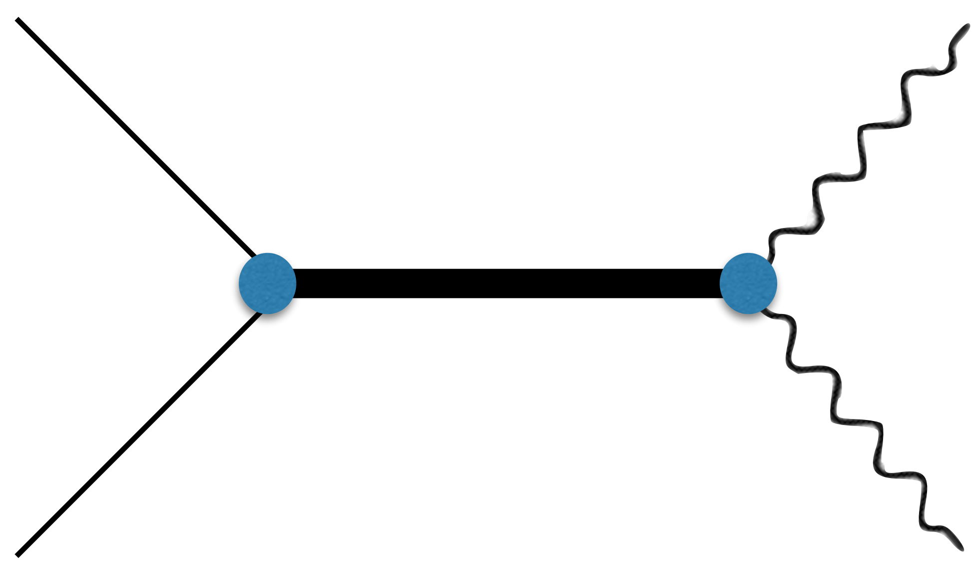
combined significance =3.4 sigma(8+13 TeV)

production process

gluon initiated ?



quark initiated ?



production: qq vs gg

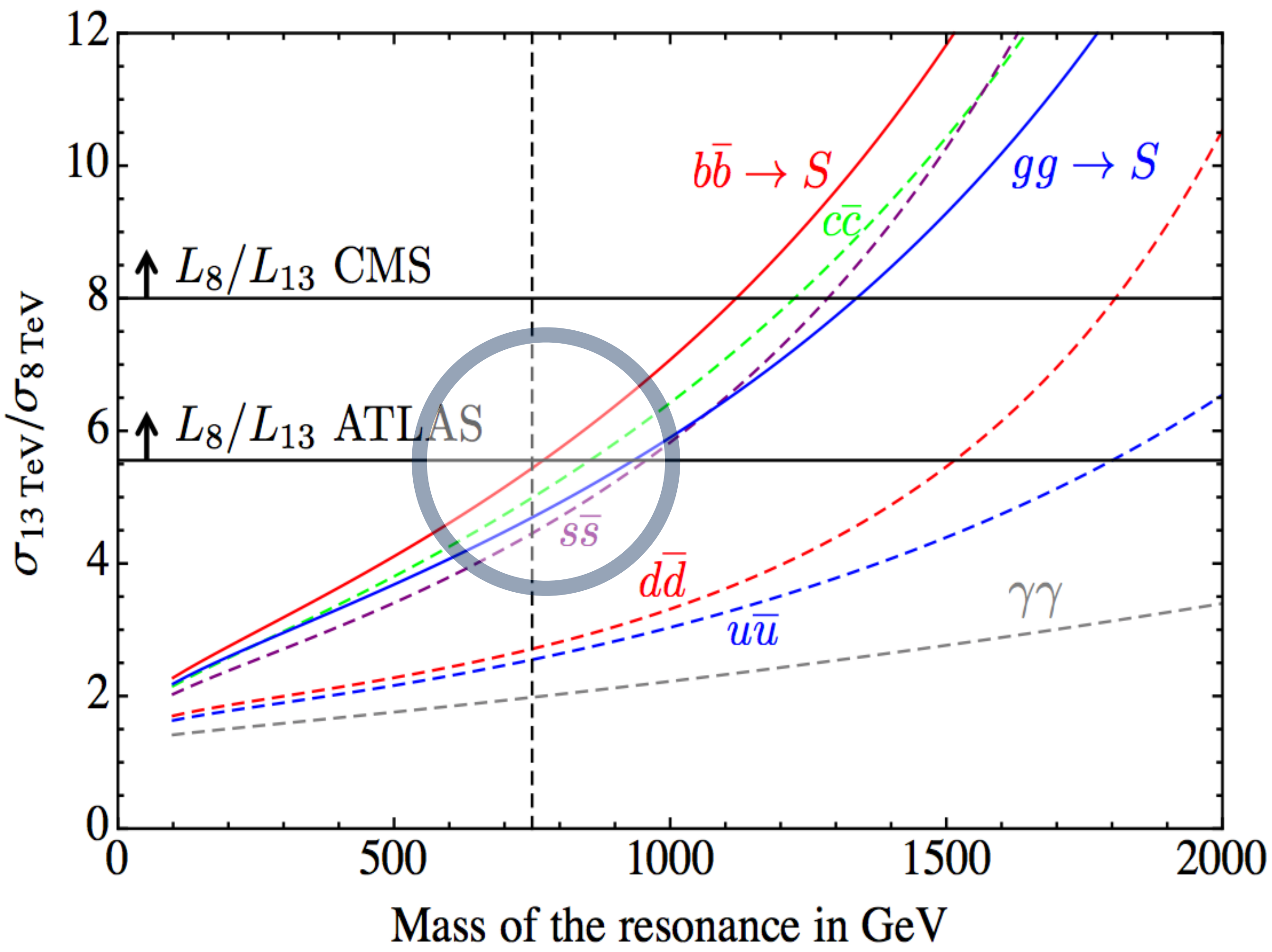


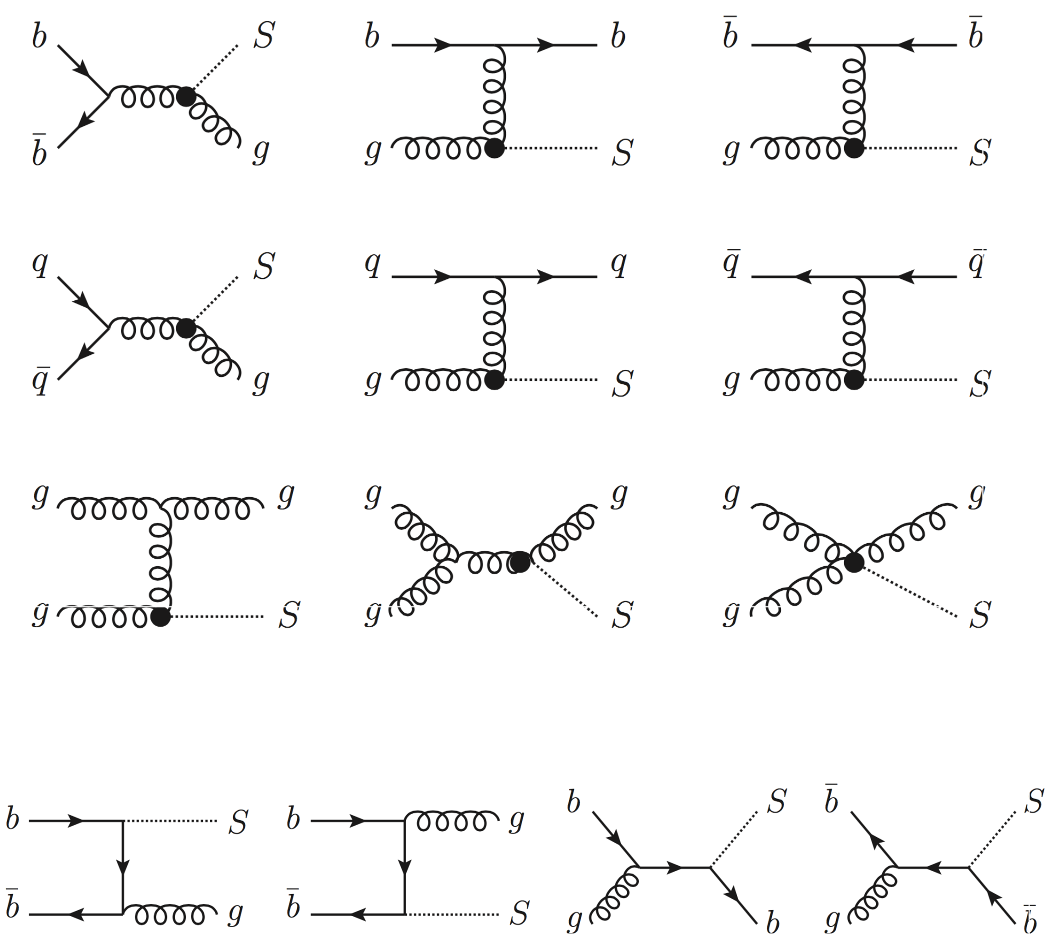
Figure 10: *Ratio of pp cross sections at* $\sqrt{s} = 13\,\mathrm{TeV}$ *and* $8\,\mathrm{TeV}$ *for producing a narrow resonance* S *with mass* M *computed for different initial partons, compared to the inverse ratio of luminosities accumulated by CMS (upper) and ATLAS (lower). This reflects the relationship of the total number of events observed between 8 and 13 TeV, but does not reflect the significance, which depends additionally on the background at the two energies.*

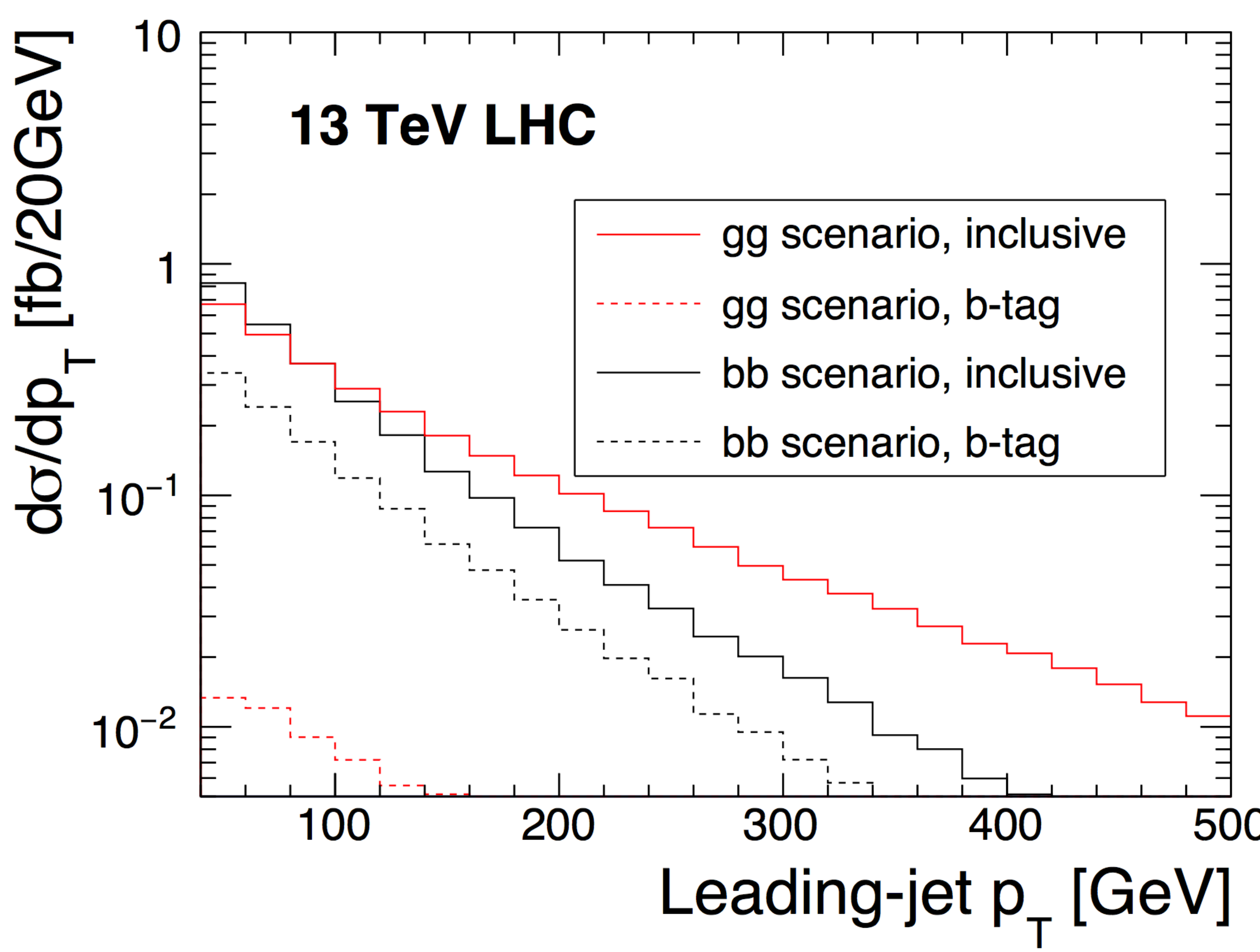
1512.04933 (R. Franceschini et.al.)

production: qq vs gg

1512.08478 (Gao, Zhang and Zhu)

$$pp \to X + q/g \to \gamma\gamma + q/g$$





Other distributions can also be helpful

1601.00638(C. Cs´aki, J. Hubisz, S. Lombardo, J. Terning)

production of electroweak gauge boson ia association with di-photon resonance may be another possibility ??

Mass , Spin and cross section compatibility

2 possibilities : spin-0 vs spin-2

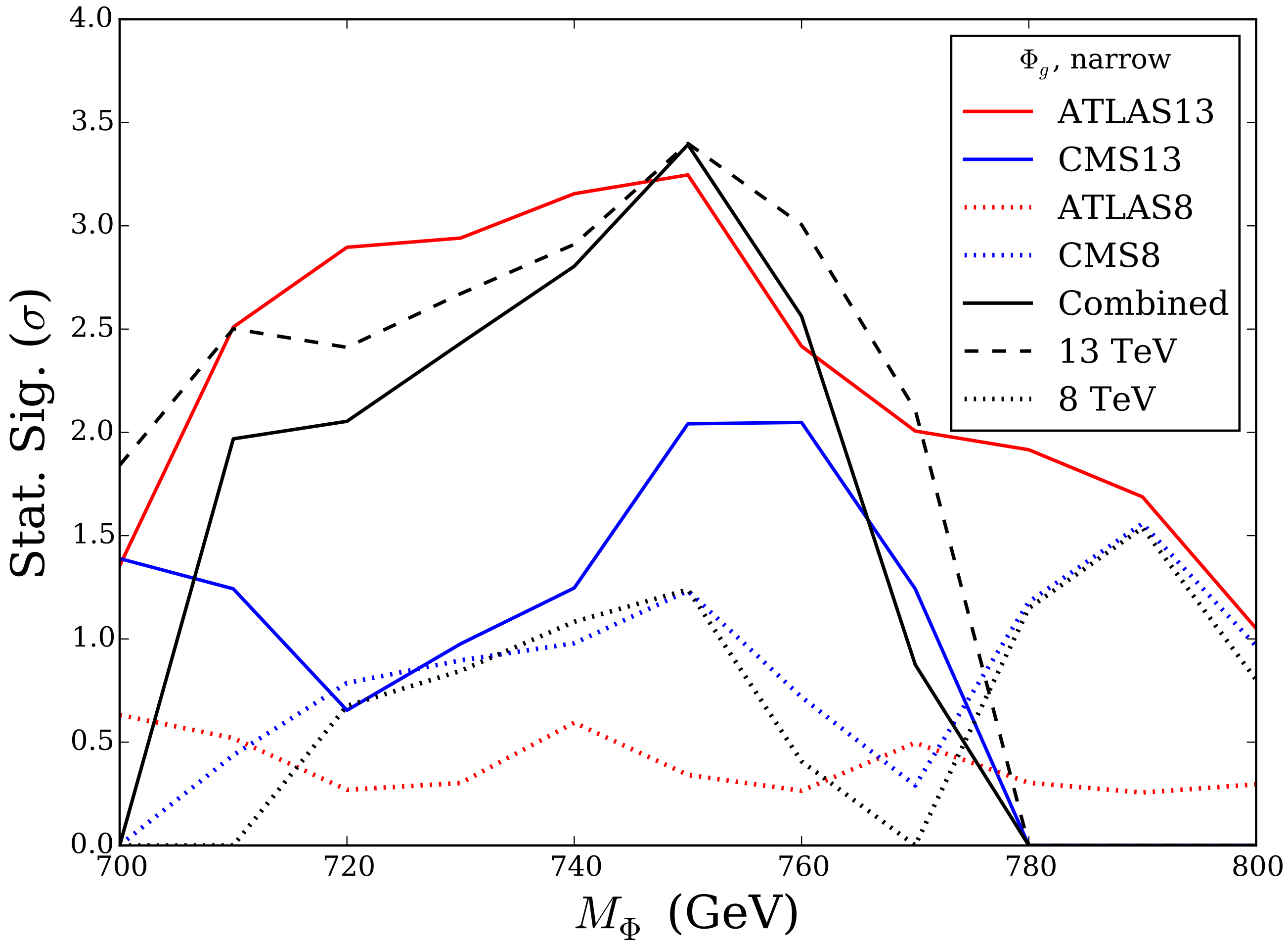
ATLAS TALK by JOHN STARK, MORIOND QCD 2016

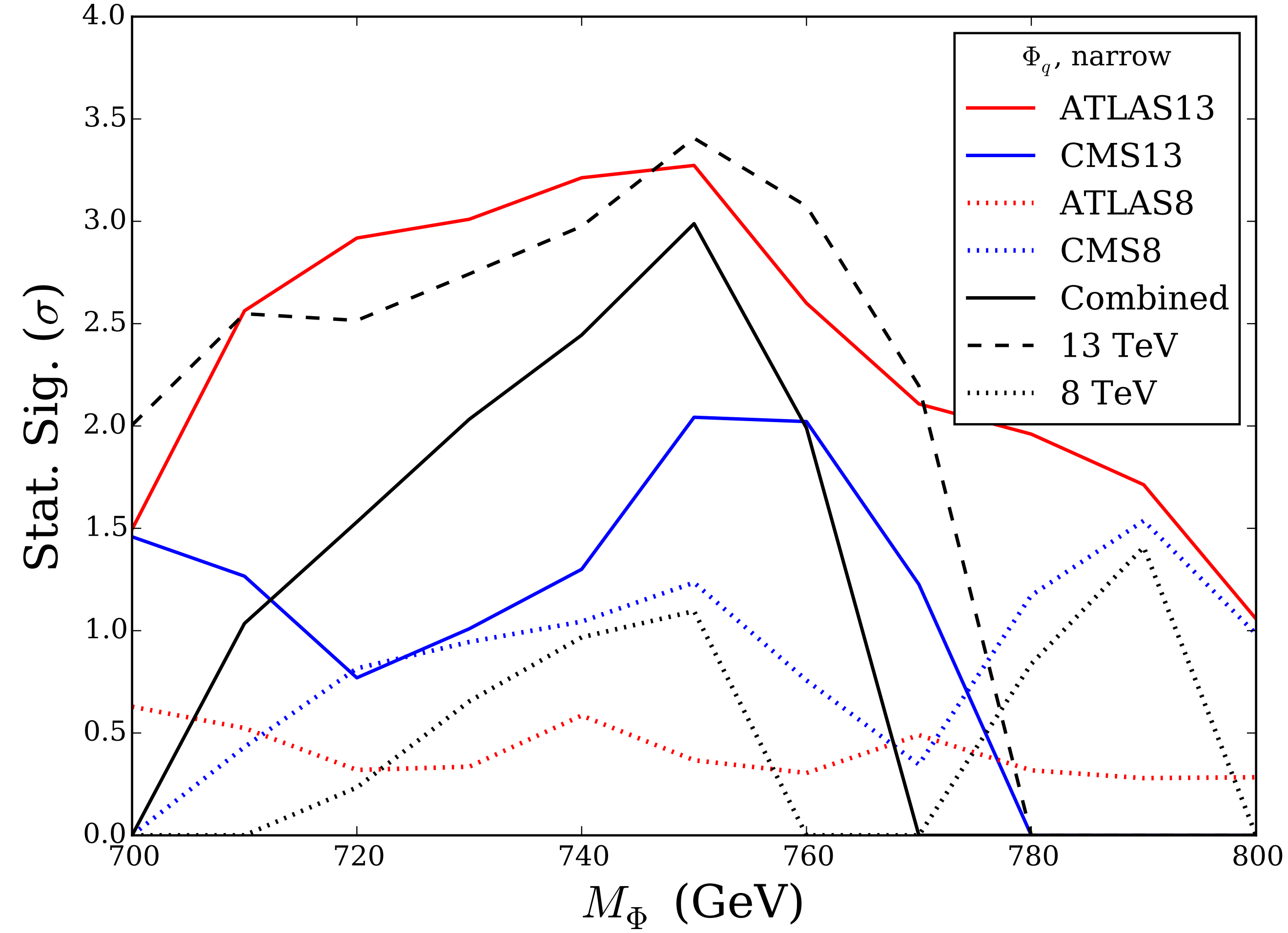
Spin 0	Spin 2
8 TeV data: 1.9σ deviation from B-only hypothesis at $m_X = 750$ GeV, $\Gamma_X/m_X = 6\%$	8 TeV data: no excess in the region of interest
Assuming common signal model; production cross-section scales like Parton luminosities gg s-channel = 4.7 qq s-channel = 2.7	
Compatibility 8 TeV ↔ 13 TeV (gg hypothesis): 1.2σ Compatibility 8 TeV ↔ 13 TeV (qq hypothesis): 2.1σ	Compatibility 8 TeV ↔ 13 TeV (gg hypothesis): 2.7σ Compatibility 8 TeV ↔ 13 TeV (qq hypothesis): 3.6σ

Standard RS type model can not explain, no peak in di-lepton distributions

Mass

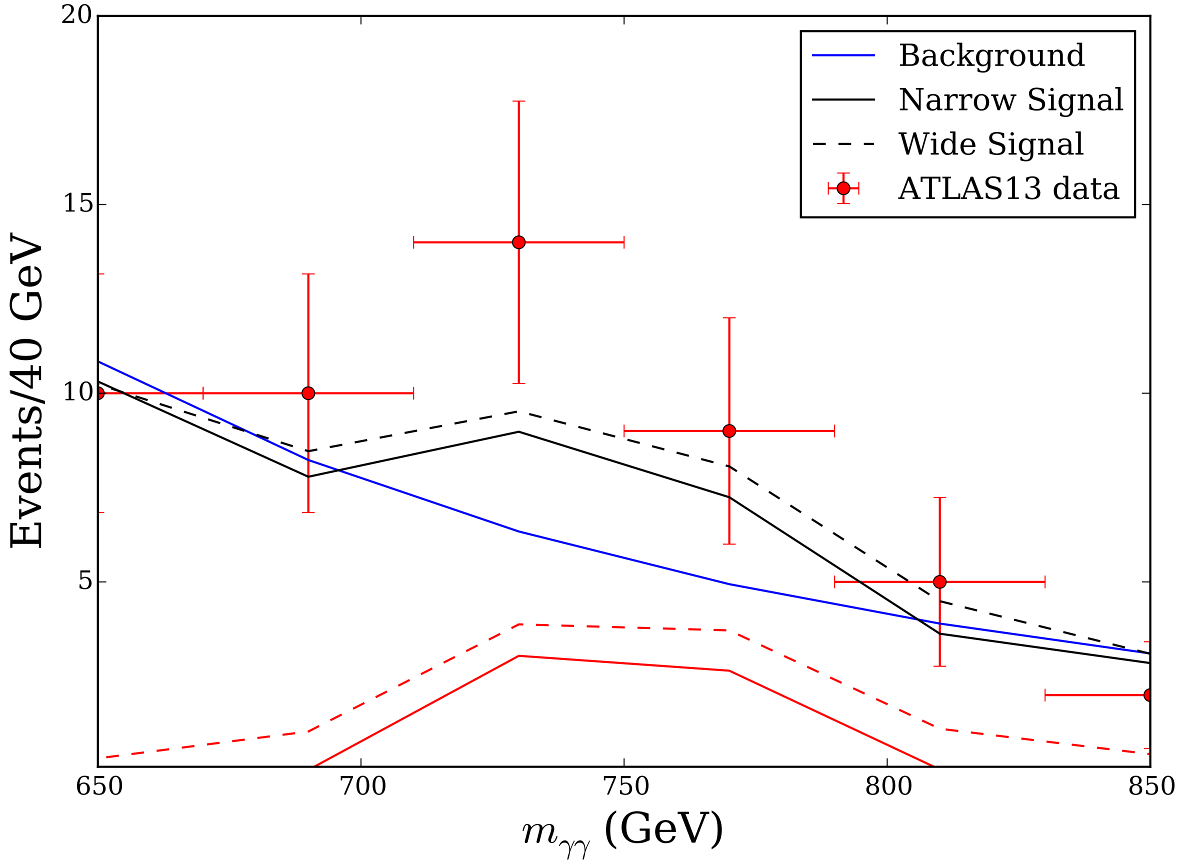
1601.04751(M R. Buckley)

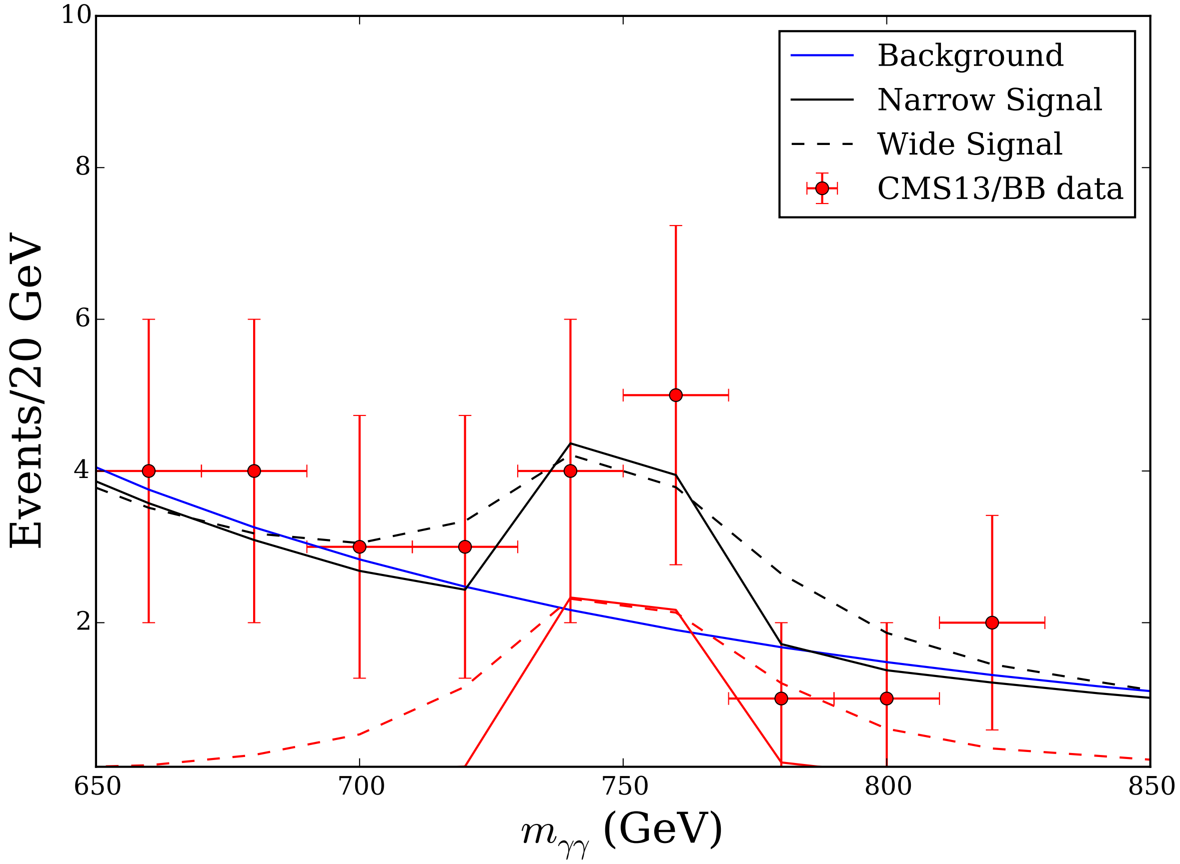




Width

1601.04751(M R. Buckley)





Summary of conclusions

1601.04751(Matthew R. Buckley)

1. Explaining the anomaly through a spin-0 resonance is preferred over a spin-2 mediator, though this preference is less than 1σ in most cases.
2. The cross sections needed for the ATLAS13 and CMS13 data sets are incompatible at the one sigma level, though they agree in mass.
3. When considering only the 13 TeV data, the CMS13 data does not share the ATLAS13 preference for a 45 GeV width. I find that the "wide" interpretation of the resonance has a statistical significance in the COMBO13 data set which is approximately 0.5σ less likely than the "narrow" interpretation.

Reducible vs irreducible backgrounds

CMS PAS EXO-15-004

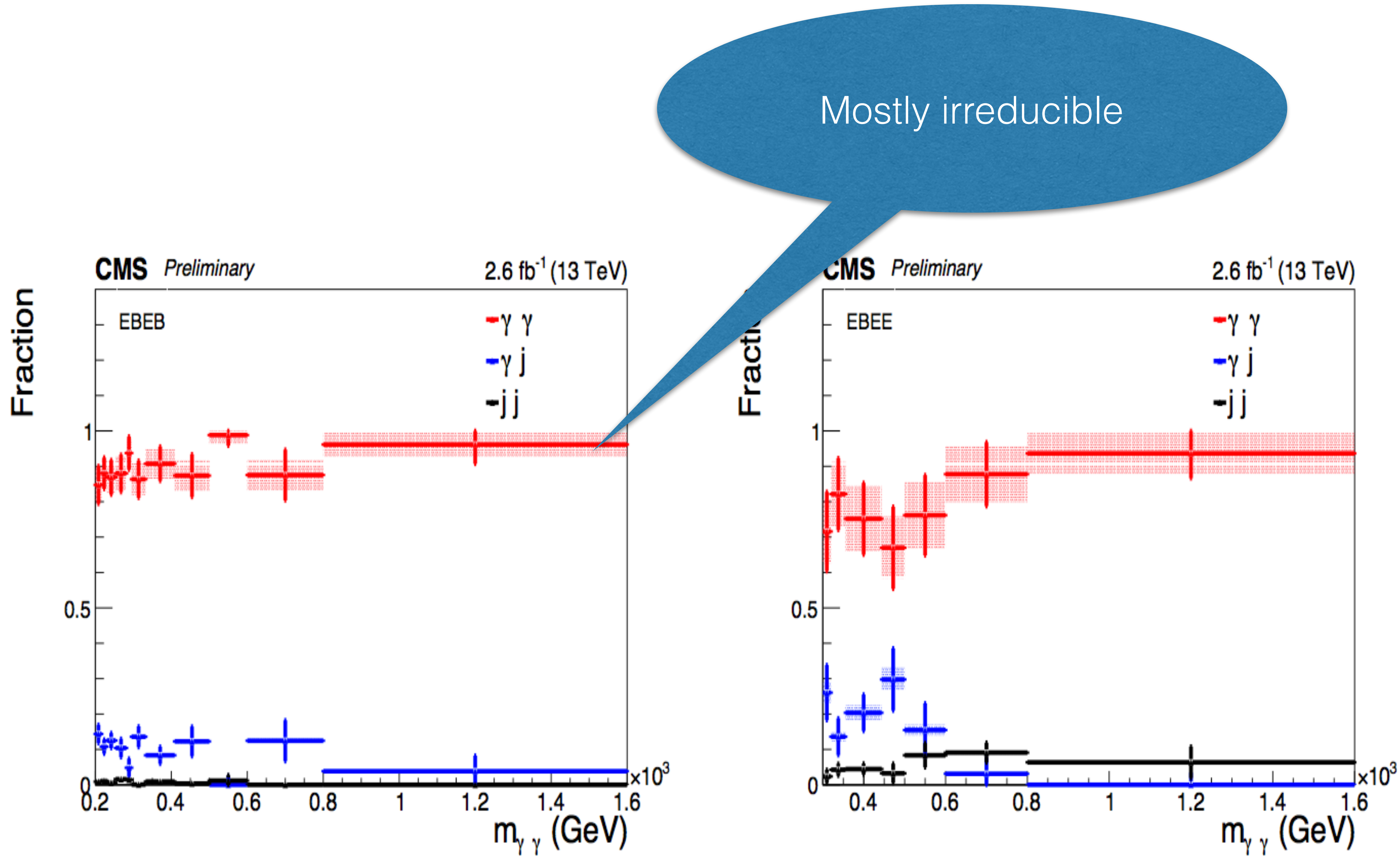


Figure 4: Measured composition of the background for the EBEB (left) and EBEE (right) categories.

More info

diphoton bkg estimation and fitting

Background fitting function

$$\textsc{Atlas}8/13: f(m_{\gamma\gamma}; a_0, b) = \left(1 - \left(\frac{m_{\gamma\gamma}}{\sqrt{s}}\right)^{1/3}\right)^b \left(\frac{m_{\gamma\gamma}}{\sqrt{s}}\right)^{a_0},$$

$$\textsc{Cms}13: f(m_{\gamma\gamma}; a, b) = m_{\gamma\gamma}^{a+b\log m_{\gamma\gamma}},$$

$$\textsc{Cms}8: f(m_{\gamma\gamma}; p_1, p_2) = e^{-p_1 m_{\gamma\gamma}} m_{\gamma\gamma}^{-p_2}.$$

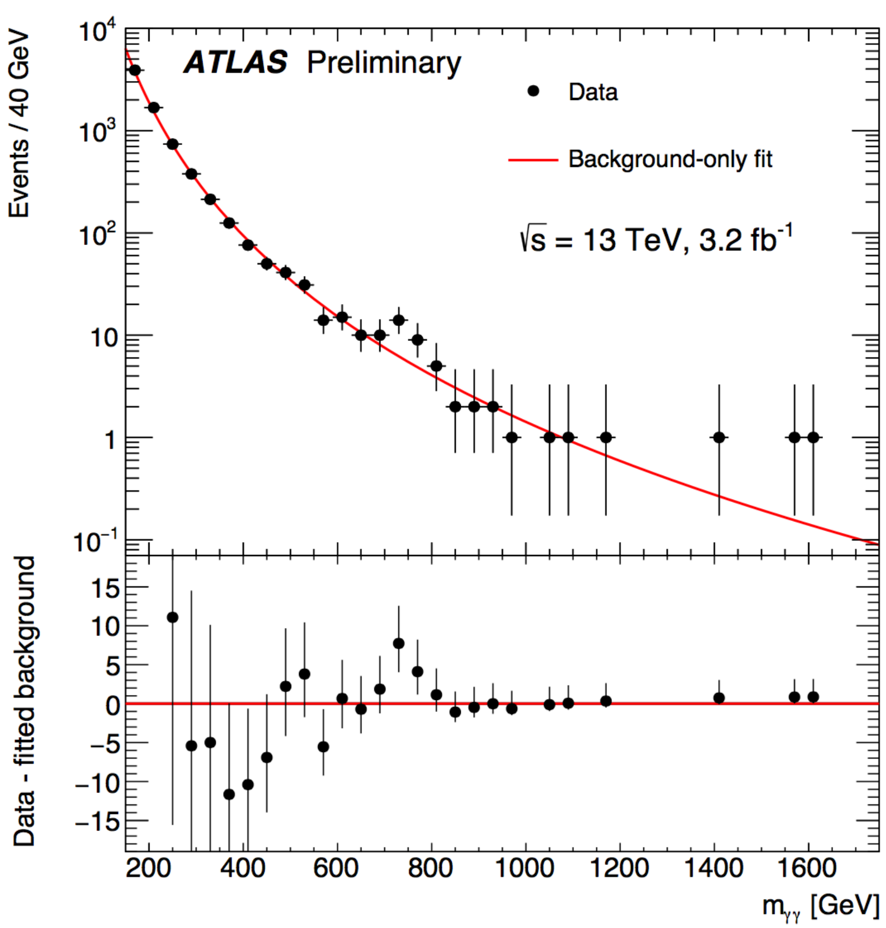
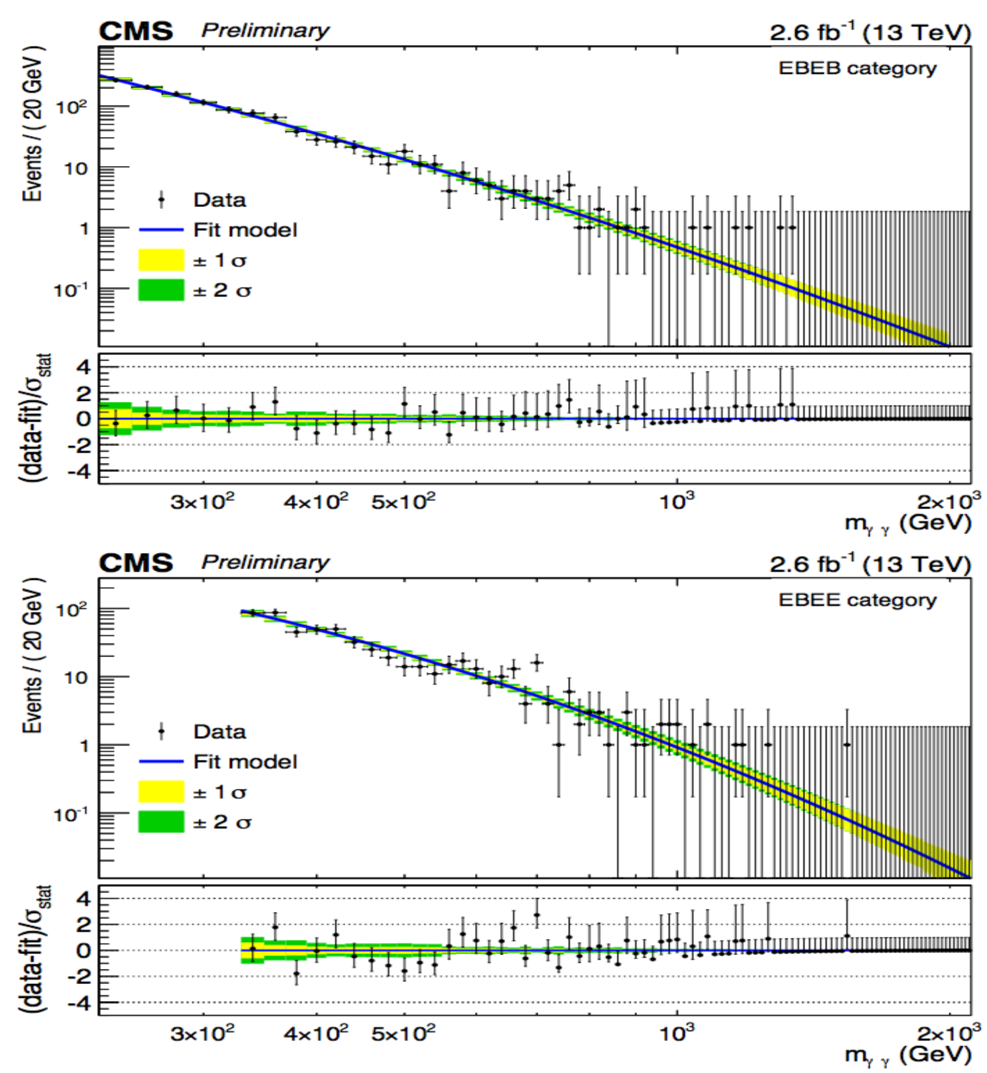


Figure 1: Invariant mass distribution of the selected diphoton events. Residual number of events with re
fit result are shown in the bottom pane. The first two bins in the lower pane are outside the vertical plot



diphoton bkg estimation and fitting

1601.03153(J H. Davis, M. Fairbairn, J Heal and P. Tunney)

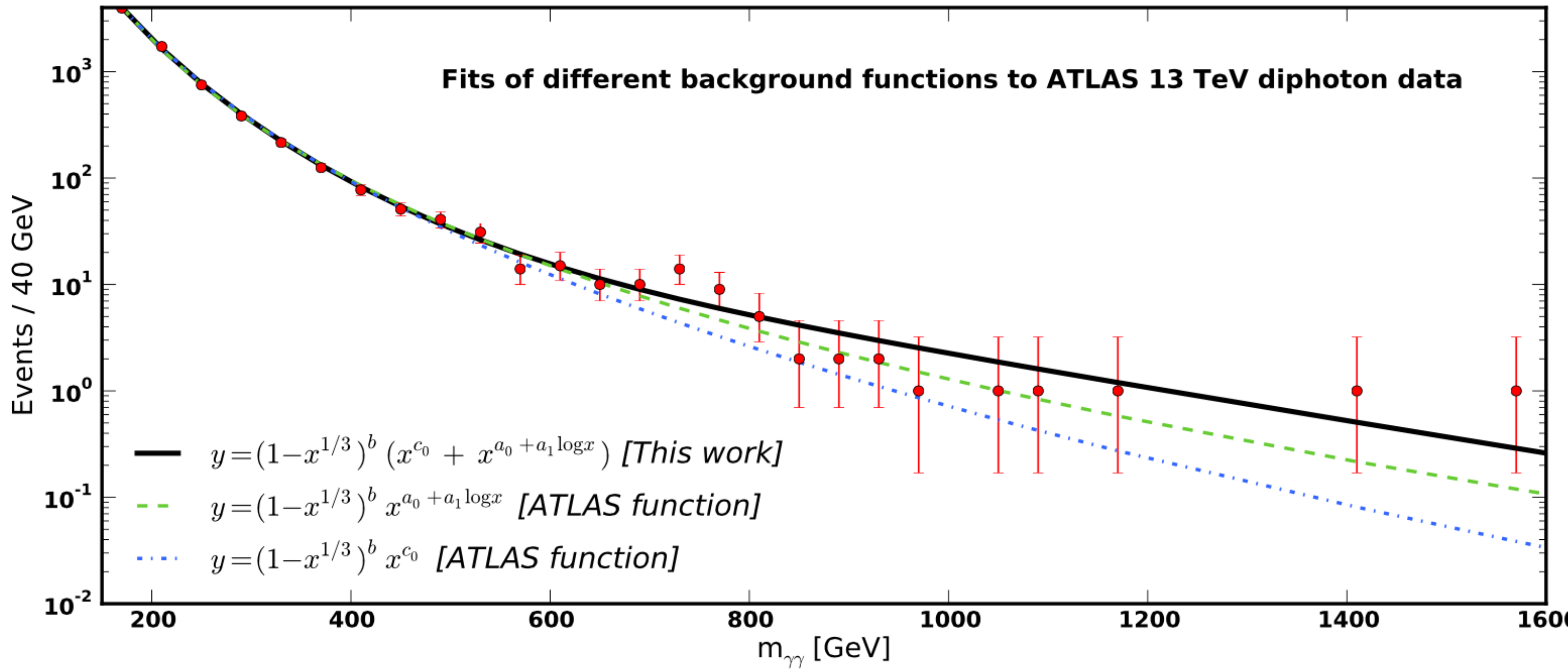


FIG. 1. Comparison of empirical functions for the continuum diphoton background which best fit to the data. We consider the fit function used by the ATLAS collaboration with and without the log x exponent, and also our own empirical function.

Background function	Free width	NWA
$y=(1-x^{1/3})^b x^{a_0}$	3.9σ	3.6σ
$y=(1-x^{1/3})^b x^{a_0+a_1 \log x}$	2.9σ	2.6σ
$y=(1-x^{1/3})^b (x^{c_0}+x^{a_0+a_1 \log x})$	2.0σ	2.0σ

TABLE I. Local significance for a resonance-like signal at $m_{\gamma\gamma} \sim 750$ GeV under different assumptions for the functional dependence of the smooth background. The first function is the one used by ATLAS in their analysis. We either allow the width of the resonance to vary freely, or keep it fixed in the case of the Narrow Width Approximation (NWA).

diphoton bkg estimation and fitting

1601.07330(Bradley J. Kavanagh)

Background function	NWA	Free-width
Fixed normalisation		
$k = 0$	4.2σ	4.9σ
$k = 1$	3.4σ	3.7σ
$k = 2$	3.4σ	3.7σ
Free normalisation		
$k = 0^\dagger$	3.4σ	3.6σ
$k = 1$	3.5σ	3.8σ
$k = 2$	3.4σ	3.6σ
ATLAS reported	3.6σ	3.9σ

TABLE III. Estimated local significance of the ATLAS 750 GeV diphoton excess obtained in this work using each of the background functions described in Eq. 2, assuming a freely varying resonance width (free-width) and under the narrow width approximation (NWA). The background function used by the ATLAS collaboration in Ref. [1] is marked with a dagger. For comparison, we also give the local significance reported by the ATLAS collaboration.

It is of course necessary to point out that the significances we report are only estimates and care must be taken when comparing with the official ATLAS analysis. In particular, the results reported by ATLAS use the full unbinned data set, while we consider here only binned data. Furthermore, this data was obtained by digitising the results released in Ref. [1]. However, we have investigated the possible impact of digitisation error on our analysis. In order to do this, we added random noise to the first 10 bins in $m_{\gamma\gamma}$ (distributed uniformly between -3% and $+3\%$ of the number of events in each bin) in order to simulate digitisation errors.[3] Ten such 'randomised' datasets were generated and the peak significance for each was calculated assuming the $k = 0$, free-$\mathcal{N}$ background. The resulting local significances were in the range:

$$\begin{aligned} \text{NWA:} &\quad 3.3\sigma\text{–}3.5\sigma \\ \text{Free-width:} &\quad 3.5\sigma\text{–}3.8\sigma\,. \end{aligned} \tag{6}$$

These tests indicate that digitisation could have induced an error of order 0.2σ in the analysis, and may also explain some of the discrepancy between our results and those reported by ATLAS.

May be addressed at the time of "critical discussion"

diphoton bkg estimation: Theory vs data

1603.02663

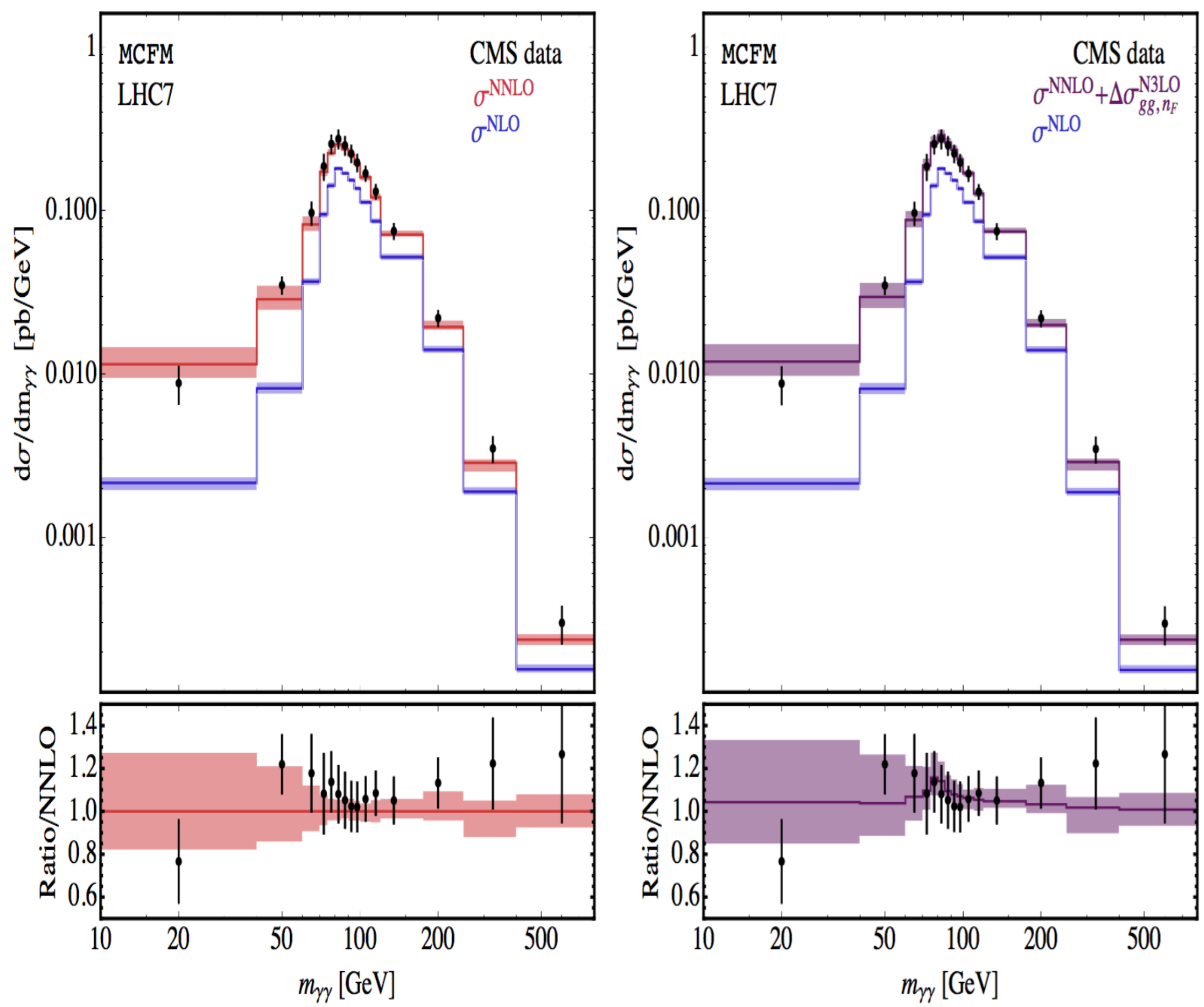


Figure 7. The invariant mass of the photon pair $m_{\gamma\gamma}$ at NLO and NNLO, compared with the CMS data from ref. [15]. The pure NNLO prediction is shown in the left panel, while the result that also includes $gg\ n_F$ contributions that enter at N^{3}LO is depicted in the right panel. The lower panels present the ratio of the data and NNLO scale variations to the NNLO theory prediction obtained with the central scale.

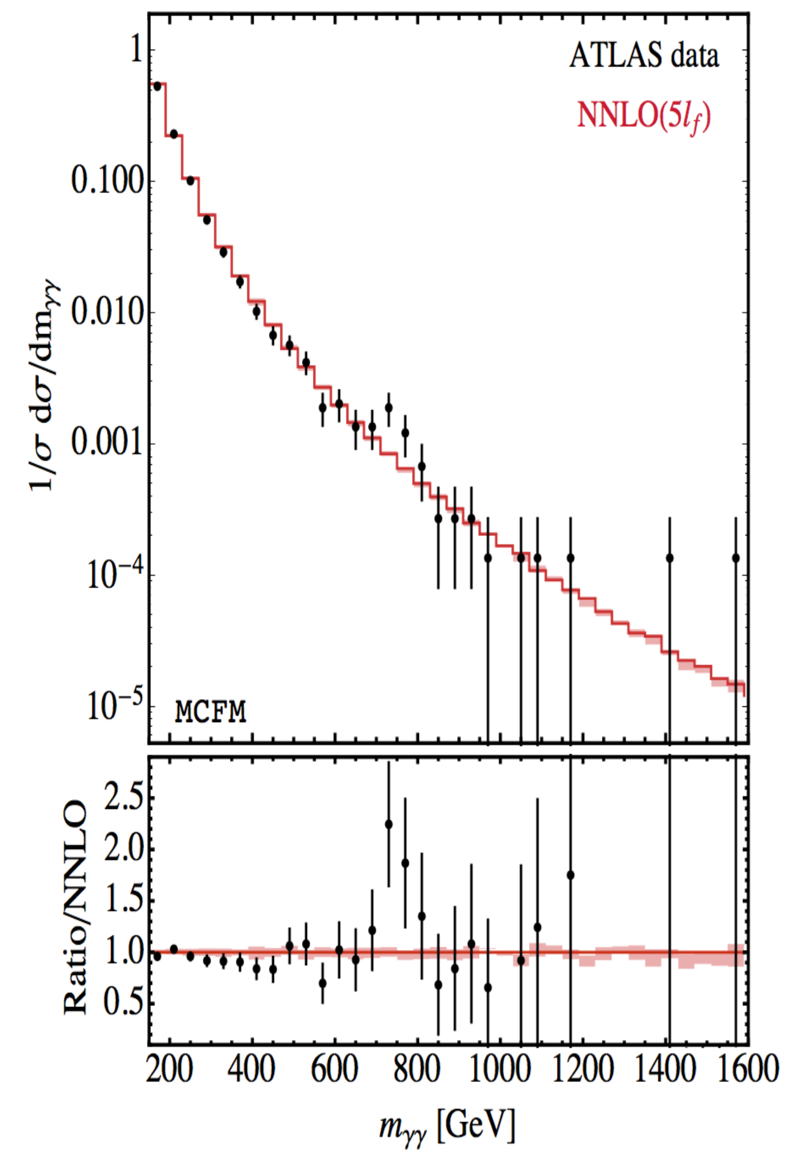
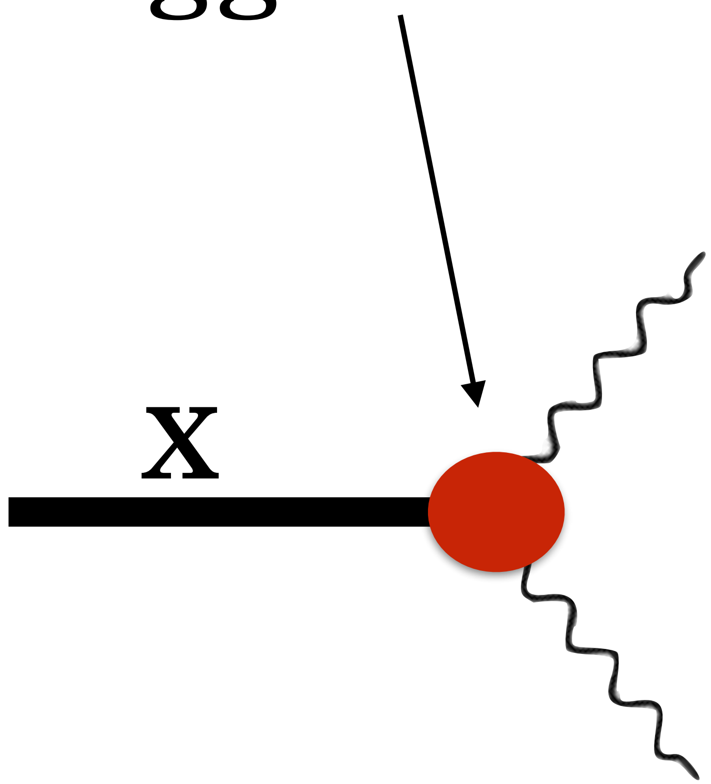


Figure 11. The rate-normalized shapes of the $m_{\gamma\gamma}$ distribution from the ATLAS collaboration and the MCFM NNLO prediction for $\mu = m_{\gamma\gamma}$. The lower panel indicates the ratio of the data to the NNLO prediction.

1603.02663(J. M. Campbell, R. K. Ellis , Y.Li and C. Williams)

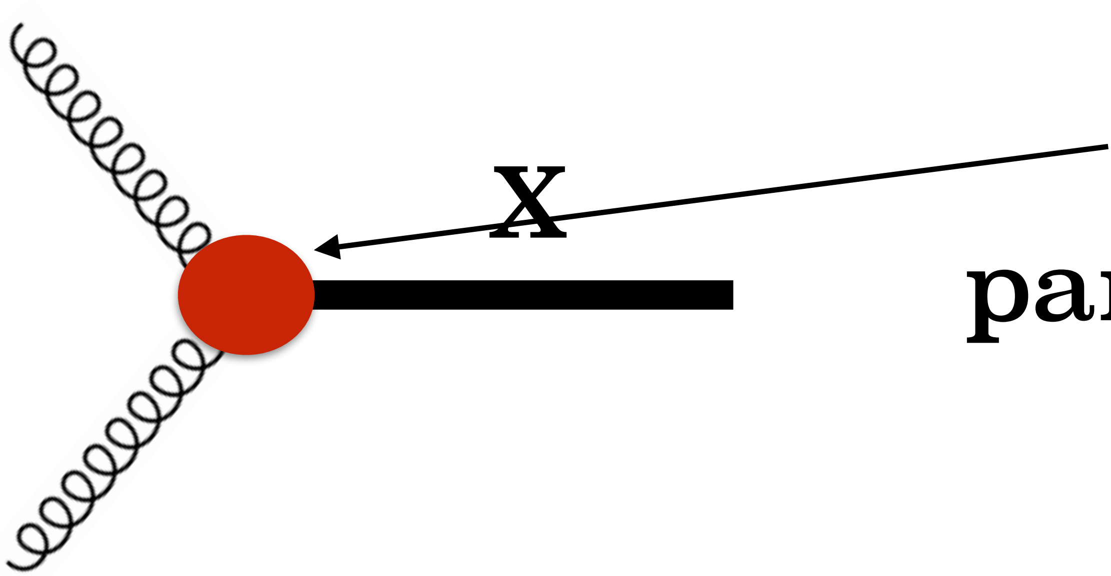
Model building

Charged particle loop (For SM Higgs -> W and top quark loop)

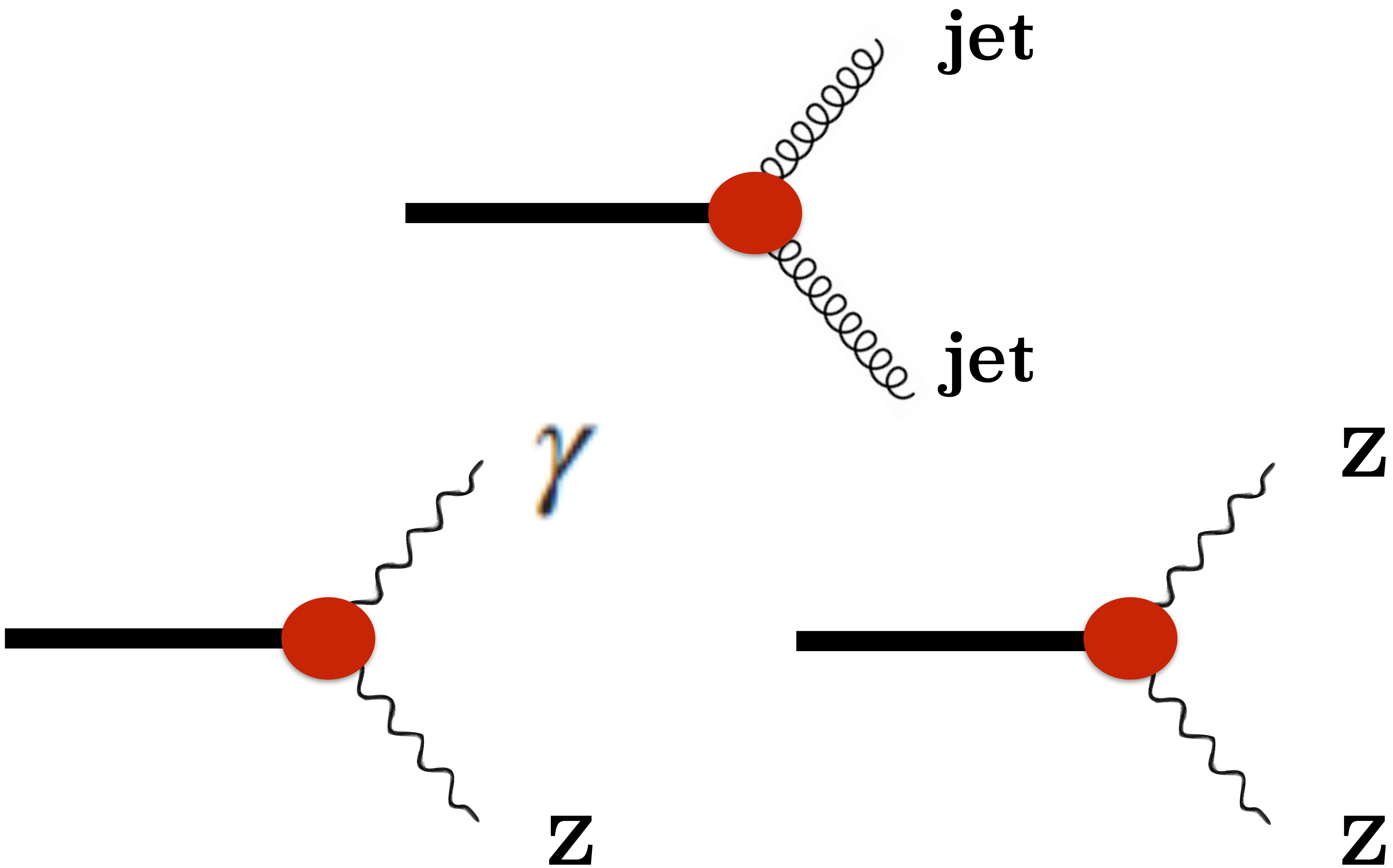


Cross section~ a few fb equivalent to ~ tens of pb WW/ ttbar cross section should be new particle loop

Coloured particle loop may need new coloured particles to enhance cross sec



Interesting channels



Model building challenges : current bounds

1512.04933 (R. Franceschini et.al.)

final state f	σ at $\sqrt{s} = 8\,\text{TeV}$ observed	expected	ref.	implied bound on $\Gamma(S \to f)/\Gamma(S \to \gamma\gamma)_{\text{obs}}$
$\gamma\gamma$	< 1.5 fb	< 1.1 fb	[6, 7]	$< 0.8\ (r/5)$
$e^+e^- + \mu^+\mu^-$	< 1.2 fb	< 1.2 fb	[8]	$< 0.6\ (r/5)$
$\tau^+\tau^-$	< 12 fb	< 15 fb	[9]	$< 6\ (r/5)$
$Z\gamma$	< 4.0 fb	< 3.4 fb	[10]	$< 2\ (r/5)$
ZZ	< 12 fb	< 20 fb	[11]	$< 6\ (r/5)$
Zh	< 19 fb	< 28 fb	[12]	$< 10\ (r/5)$
hh	< 39 fb	< 42 fb	[13]	$< 20\ (r/5)$
W^+W^-	< 40 fb	< 70 fb	[14, 15]	$< 20\ (r/5)$
$t\bar{t}$	< 550 fb	-	[16]	$< 300\ (r/5)$
invisible	< 0.8 pb	-	[17]	$< 400\ (r/5)$
$b\bar{b}$	$\lesssim 1$ pb	$\lesssim 1$ pb	[18]	$< 500\ (r/5)$
jj	$\lesssim 2.5$ pb	-	[5]	$< 1300\ (r/5)$

Table 1: *Upper bounds at 95% confidence level on pp cross sections at* $\sqrt{s} = 8\,\text{TeV}$ *for various final states produced through a resonance with* $M = 750\,\text{GeV}$ *and* $\Gamma/M \approx 0.06$. *Assuming that the production cross section grows as* $r = \sigma_{13\,\text{TeV}}/\sigma_{8\,\text{TeV}} \approx 5$, *and that* $S \to \gamma\gamma$ *fits the central value of the* $\gamma\gamma$ *anomaly, we show in the last column the upper bounds on the partial widths in different channels. Similar analyses claim a bound on the jj cross section which is weaker by a factor of few, and with a surprisingly large dependence on the assumed width and shape.*

ttbar bound is more tricky : See Rohini's talk

Model building challenges : current bounds

p p -> di-jet

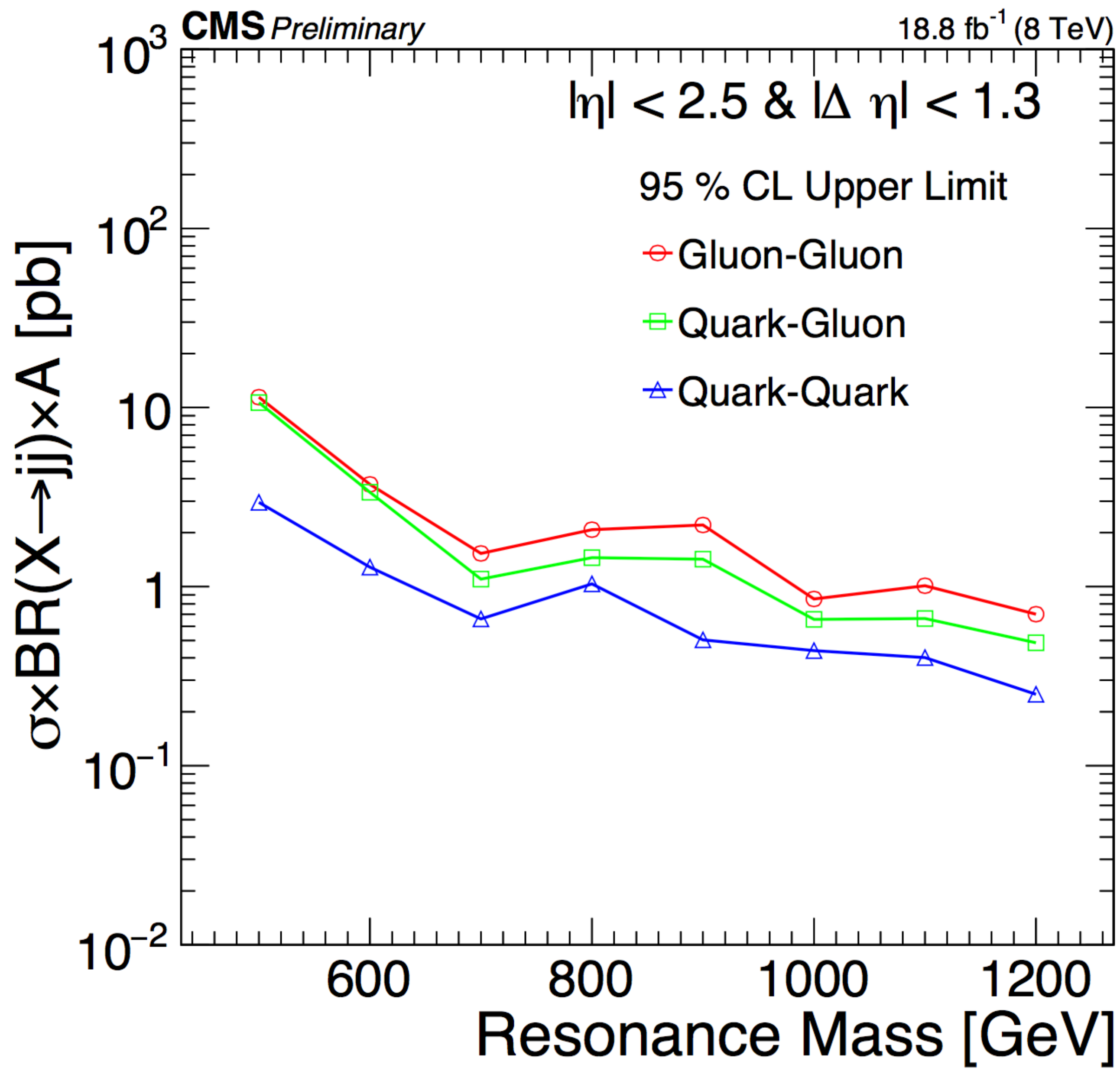


Figure 3: 95% CL upper limits on $\sigma \times \mathrm{BR} \times \mathrm{A}$ for a narrow resonance decaying to gg final states (open circles), gq final states (open squares), and qq final states (open triangles).

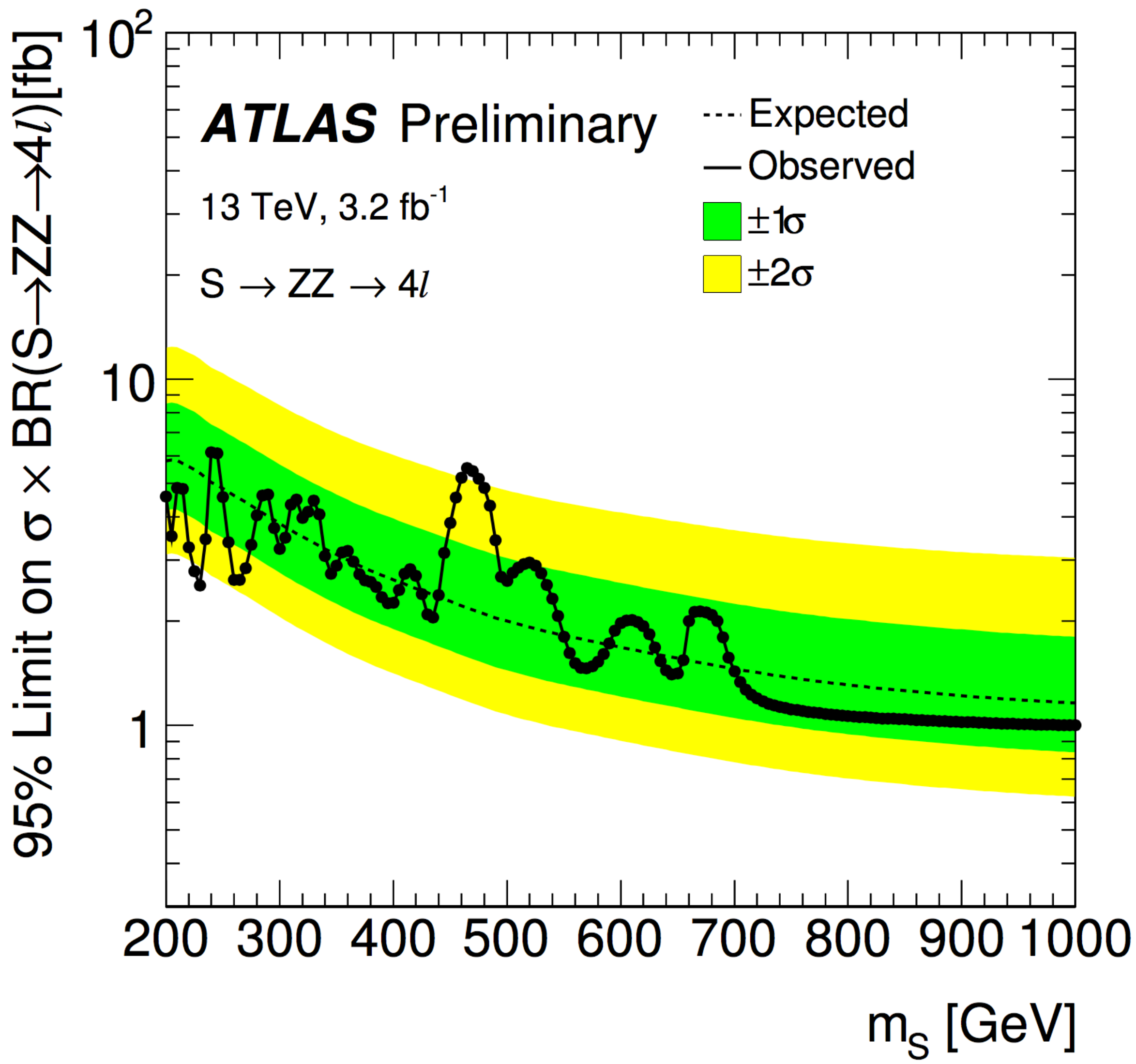
CMS EXO-14-005-PAS

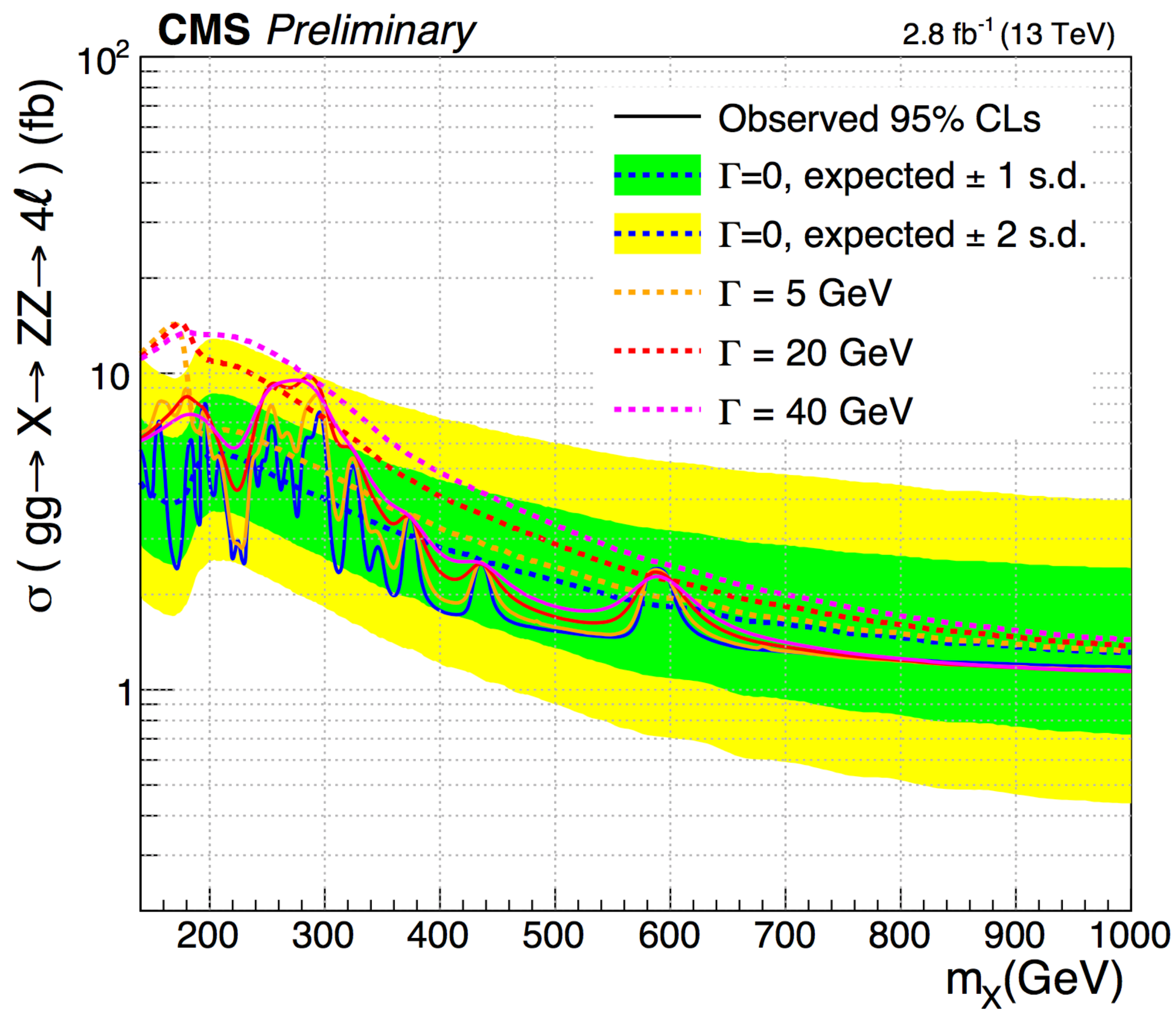
Neural Higgs to ZZ(13 TeV)

ATLAS-CONF-2015-059, CMS-PAS-HIG-15-004
CMS-PAS-HIG-16-001 , ATLAS-CONF-2016-012

2HDM H -> ZZ

$Br(H \to ZZ \to 4l) \sim 0.5\%,$ (small but clean)
$Br(H \to ZZ \to qqll) \sim 4.7\%,$ (better for high mass)
$Br(H \to ZZ \to ll\nu\nu) \sim 1.35\%,$ (better for high mass)



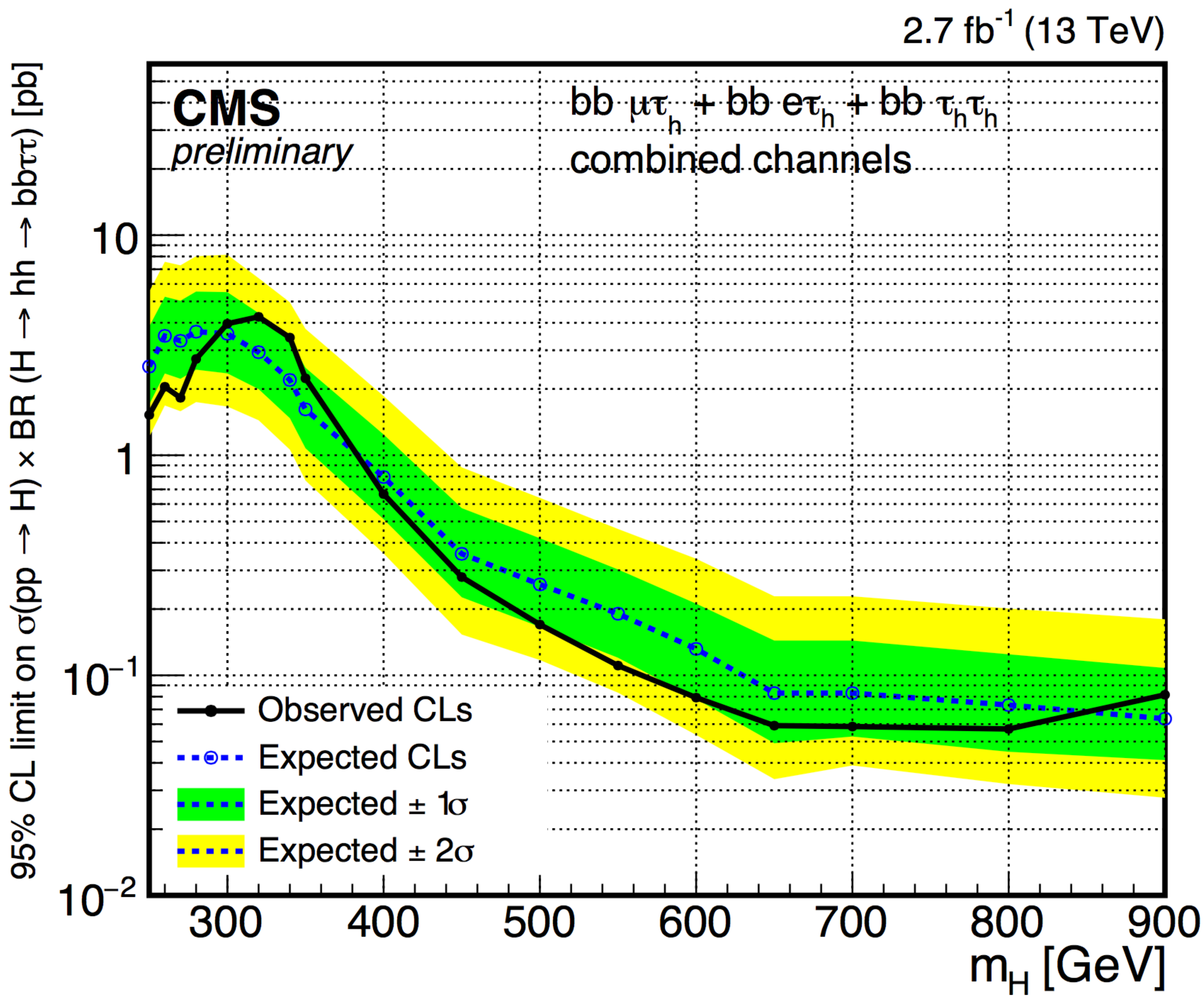


Typical upper limit on H prod X Br (H to ZZ) ~ pb

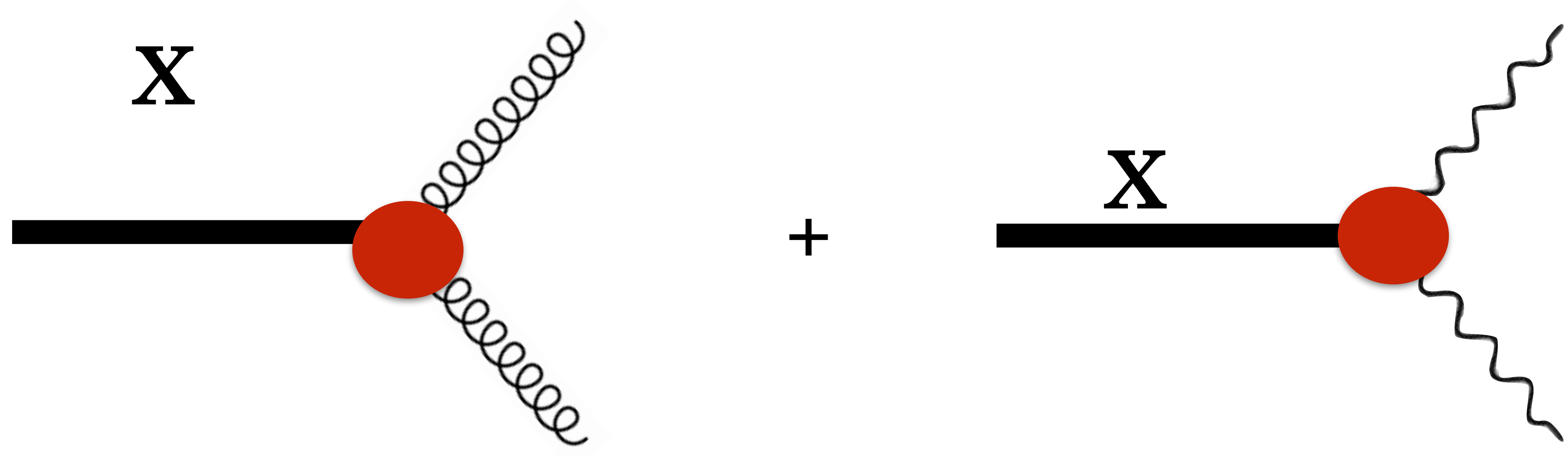
Also see 13 TeV H→ZZ→2ℓ2ν CMS-PAS-HIG-16-001

H decaying to 125 GeV Higgs (13 TeV)

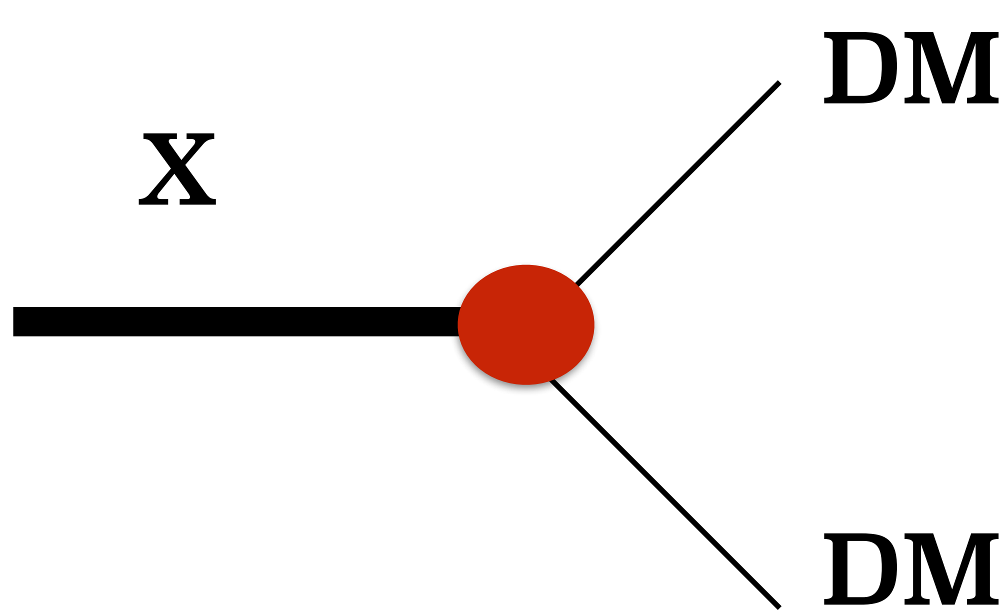
H -> bb tau tau



Model building challenges : small or large width ?



Large width: may require additional decay modes except di-photon and di-jet

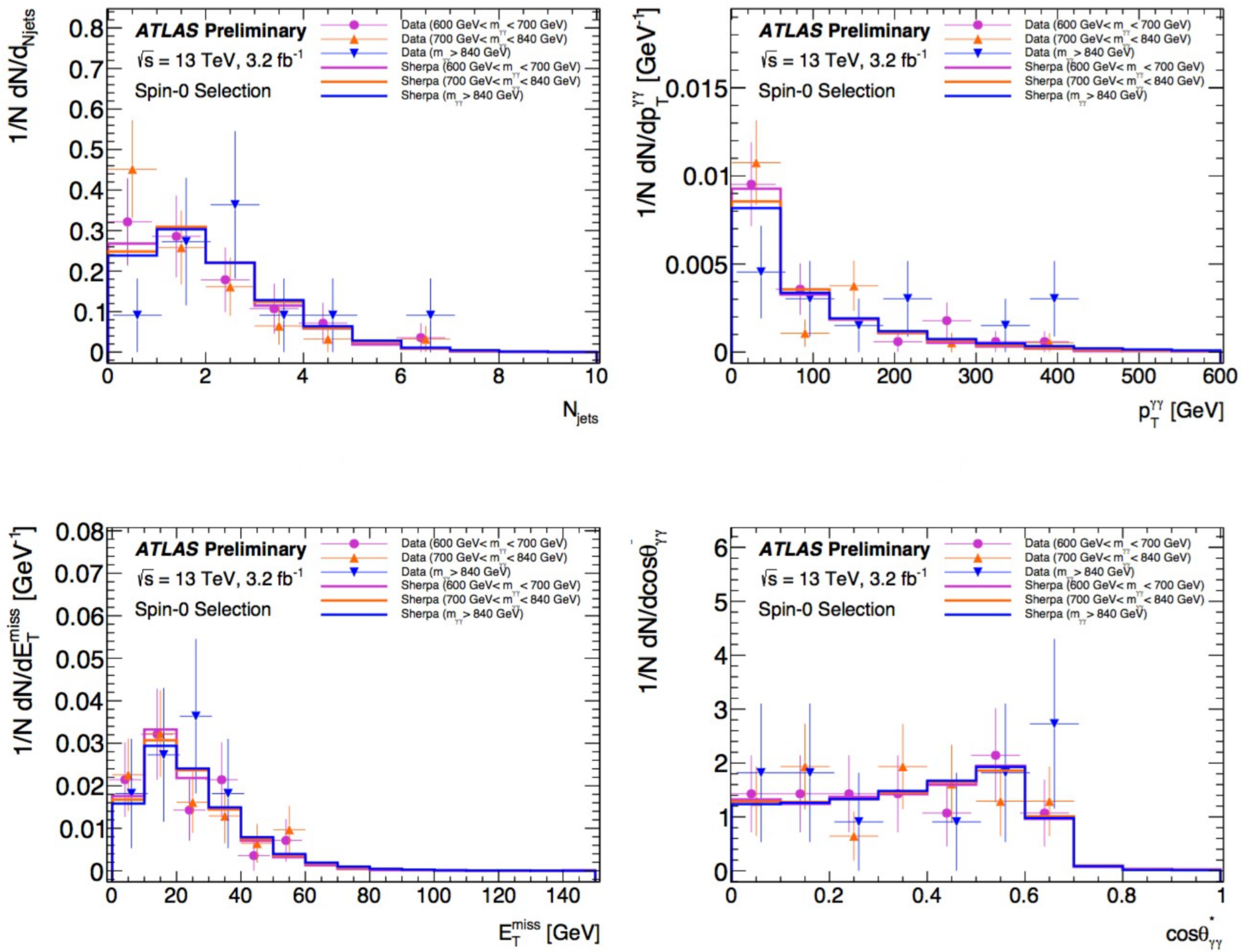


Possible ?

(See Yann's talk)

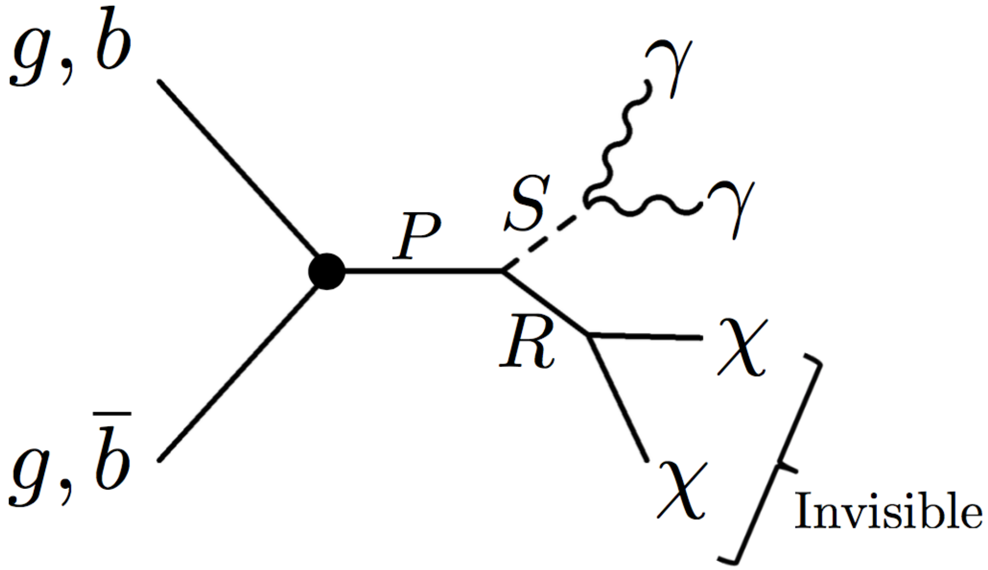
Model building challenges : additional distributions

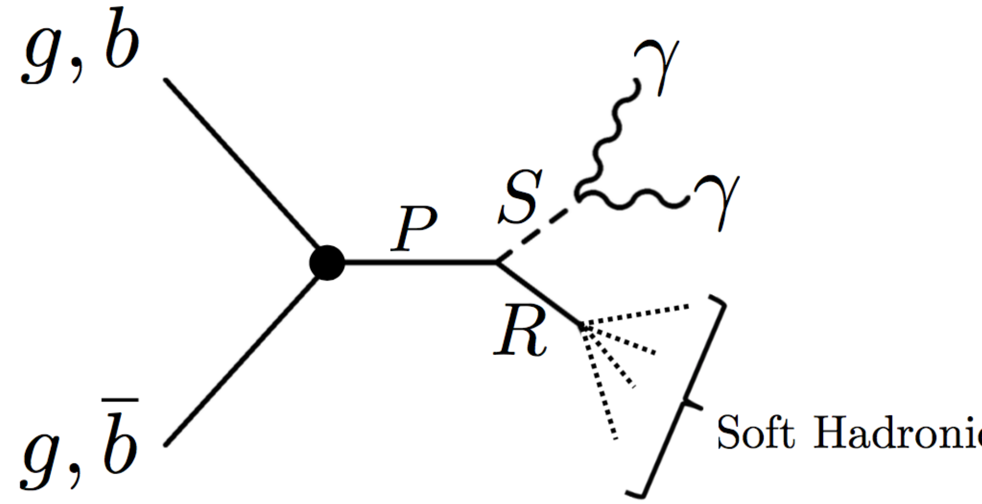
ATLAS TALK by JOHN STARK, MORIOND QCD 2016



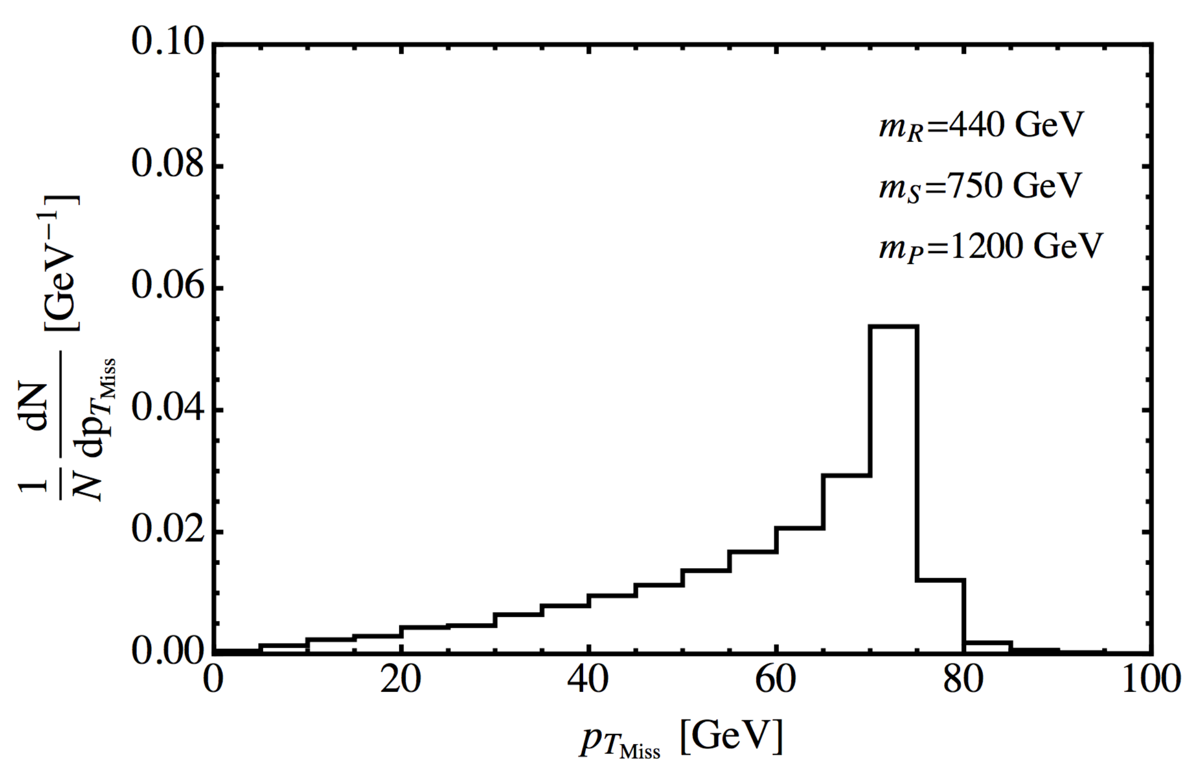
possibility 2 :decay of heavy particle

1512.04933 (R. Franceschini et.al.)





more cross section enhancement (8/13 TeV)



possibility 3 : peak or edge ?

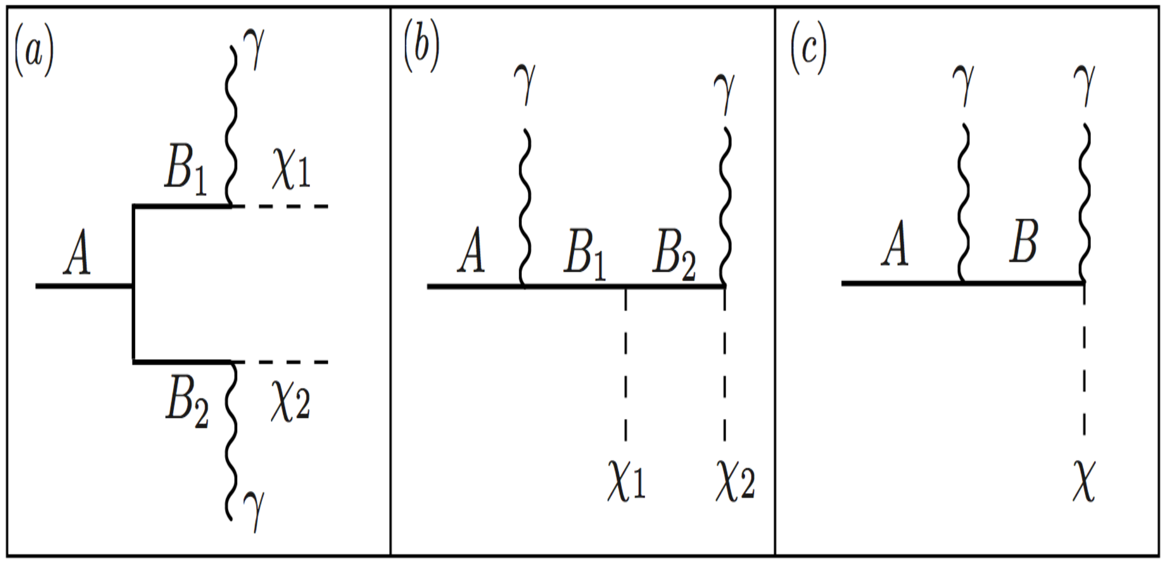
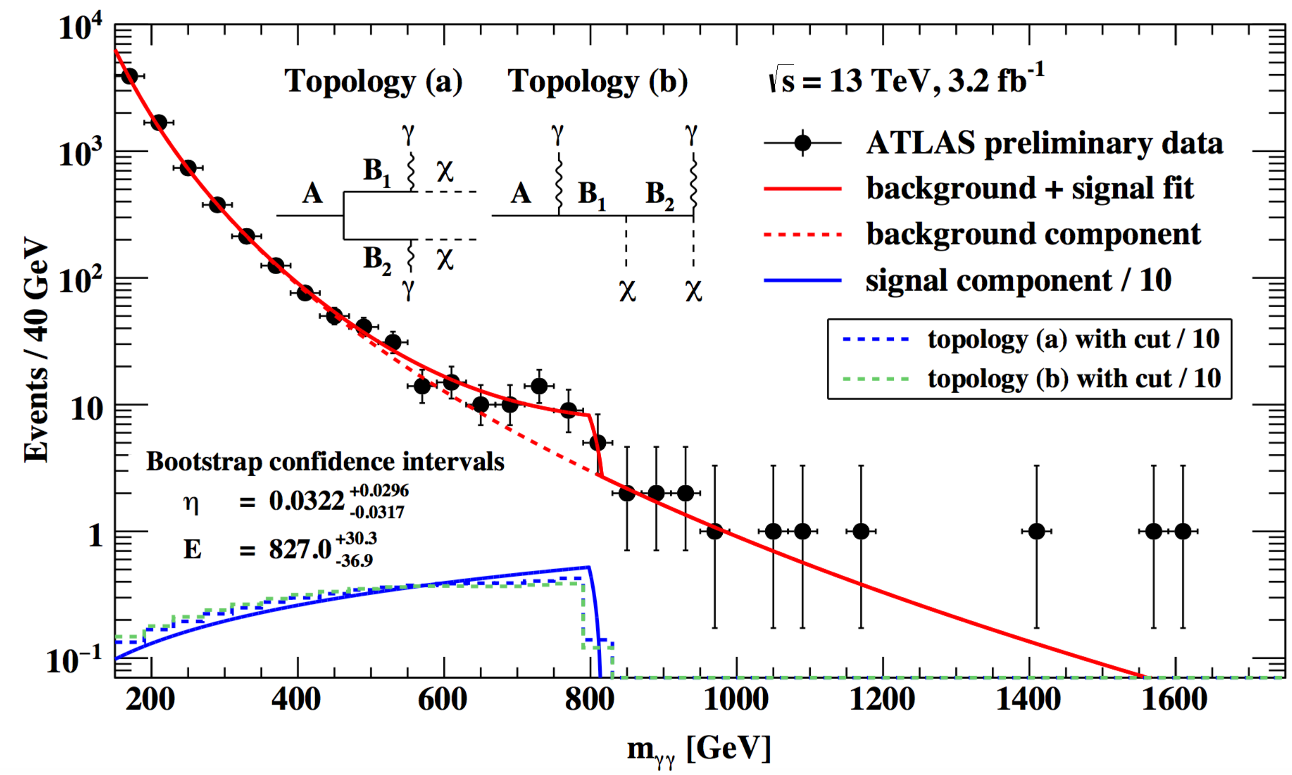
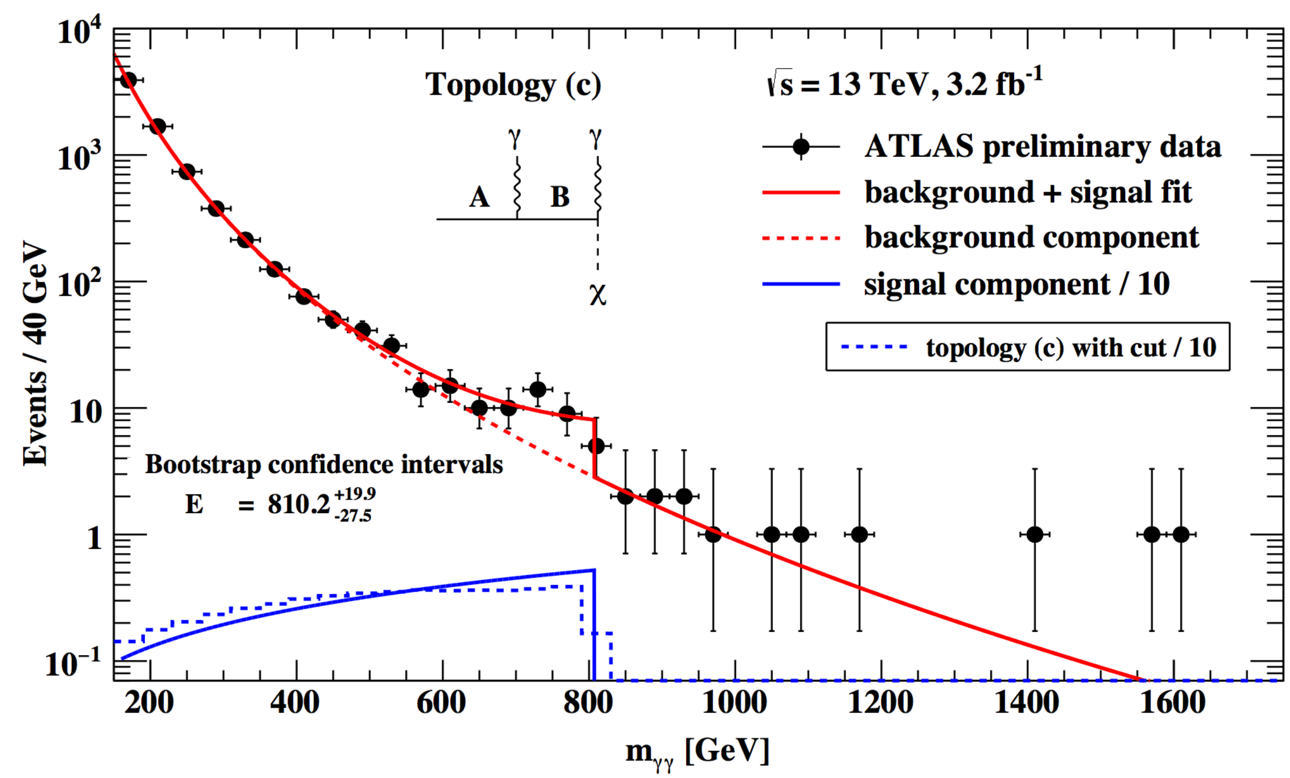


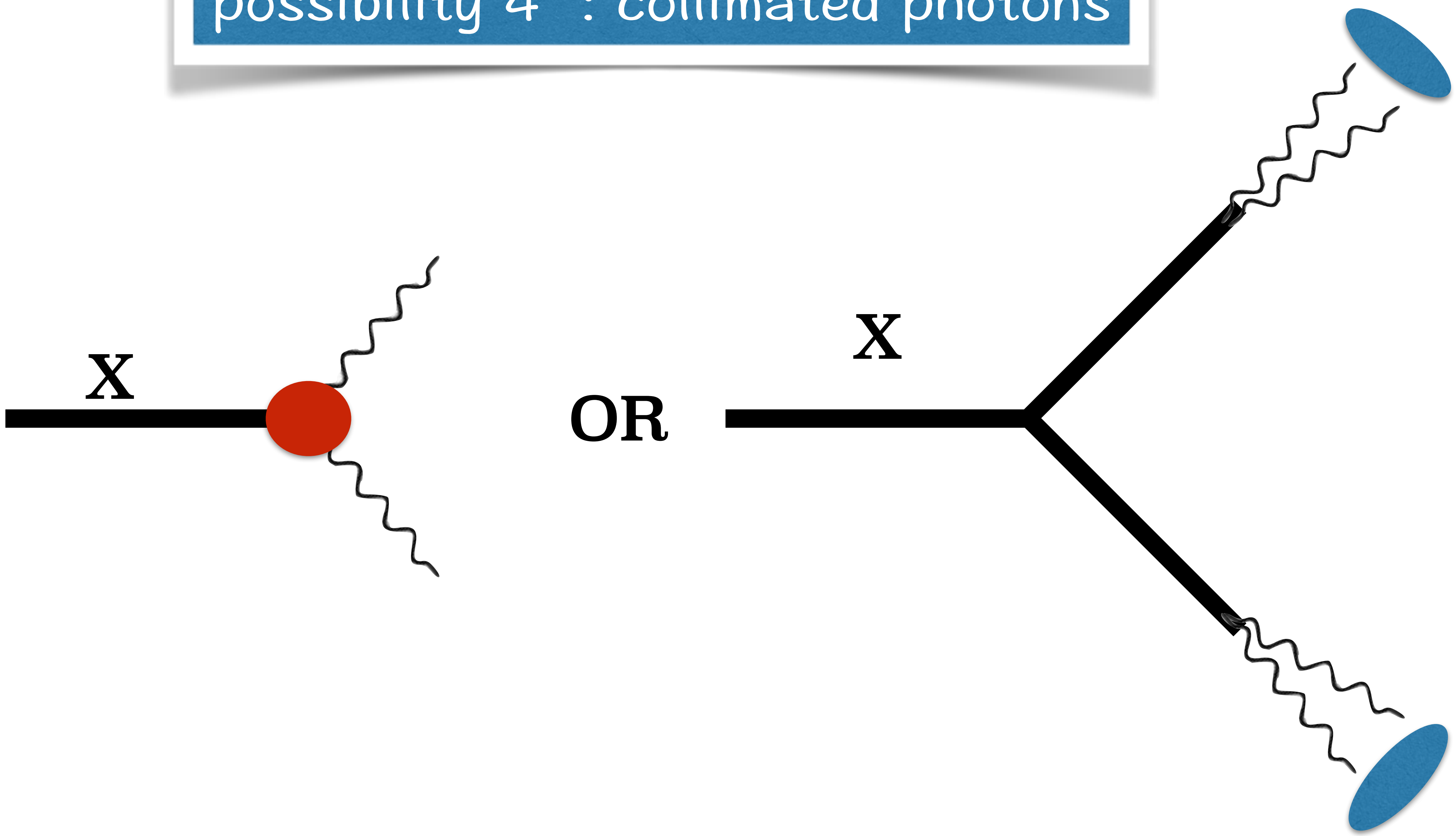
FIG. 1: The event topologies with two photons γ (wavy lines) and up to two additional particles χ_i (dashed lines) under consideration in this letter: (a) antler, (b) sandwich, and (c) 2-step cascade decay. Solid lines correspond to heavier resonances (A, B_i).



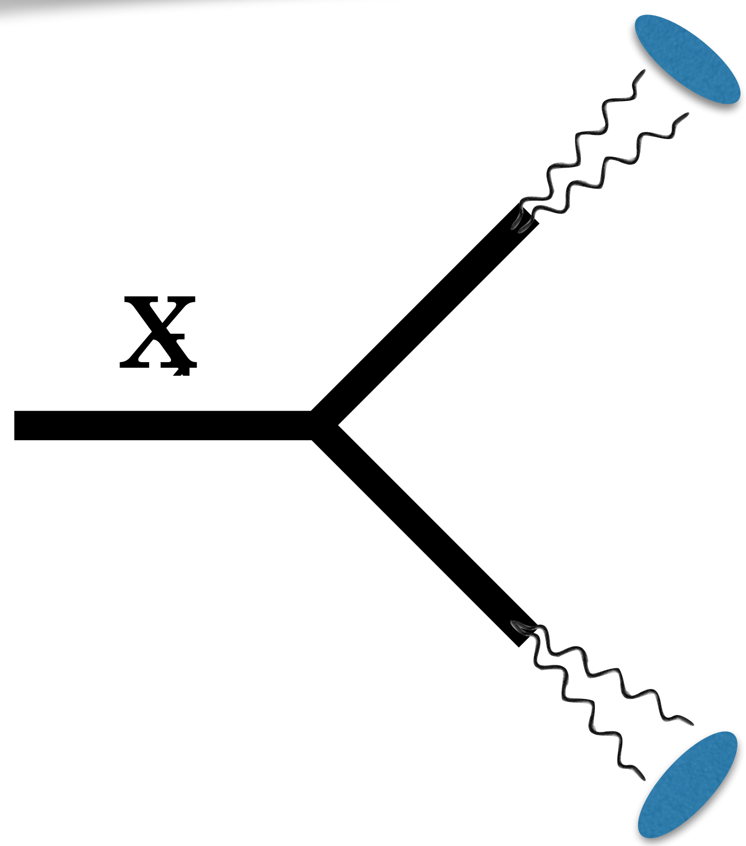


1512.06824(W. S. CHO et.al.)

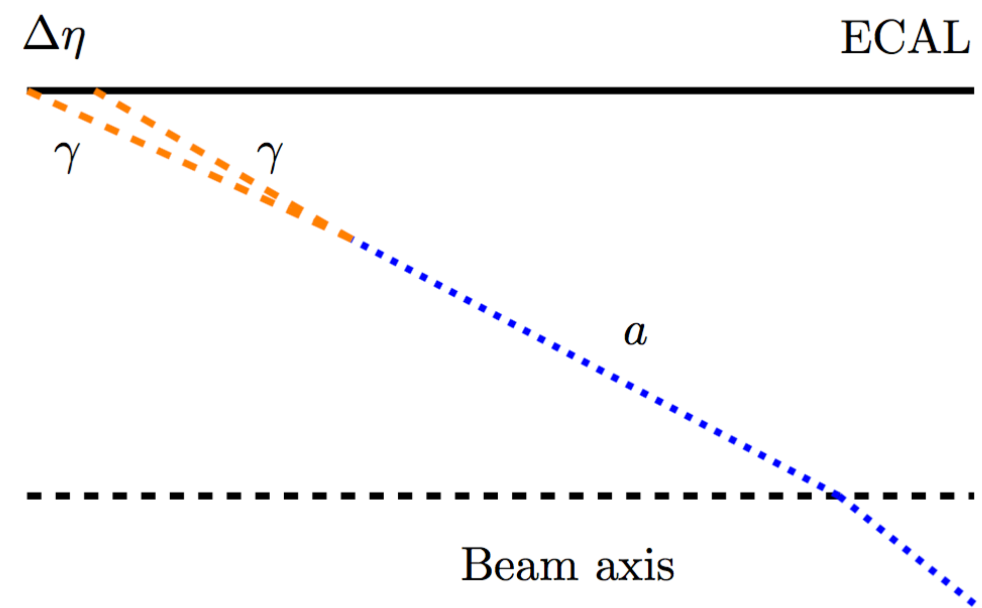
possibility 4 : collimated photons

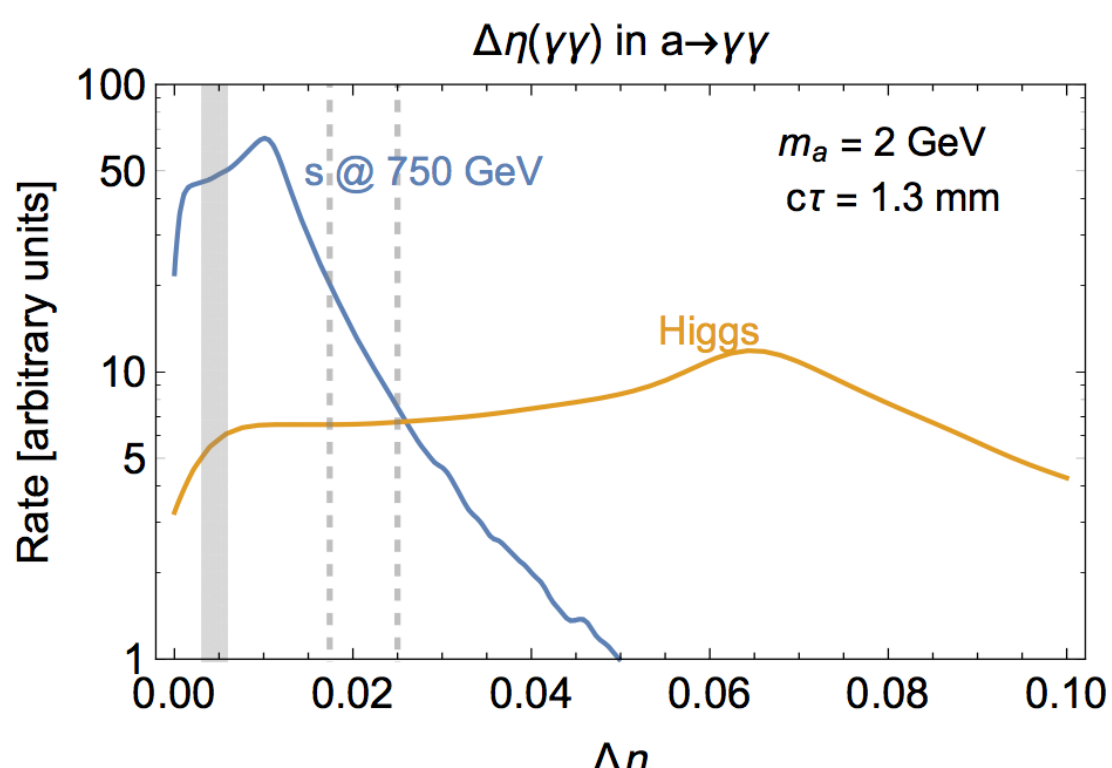


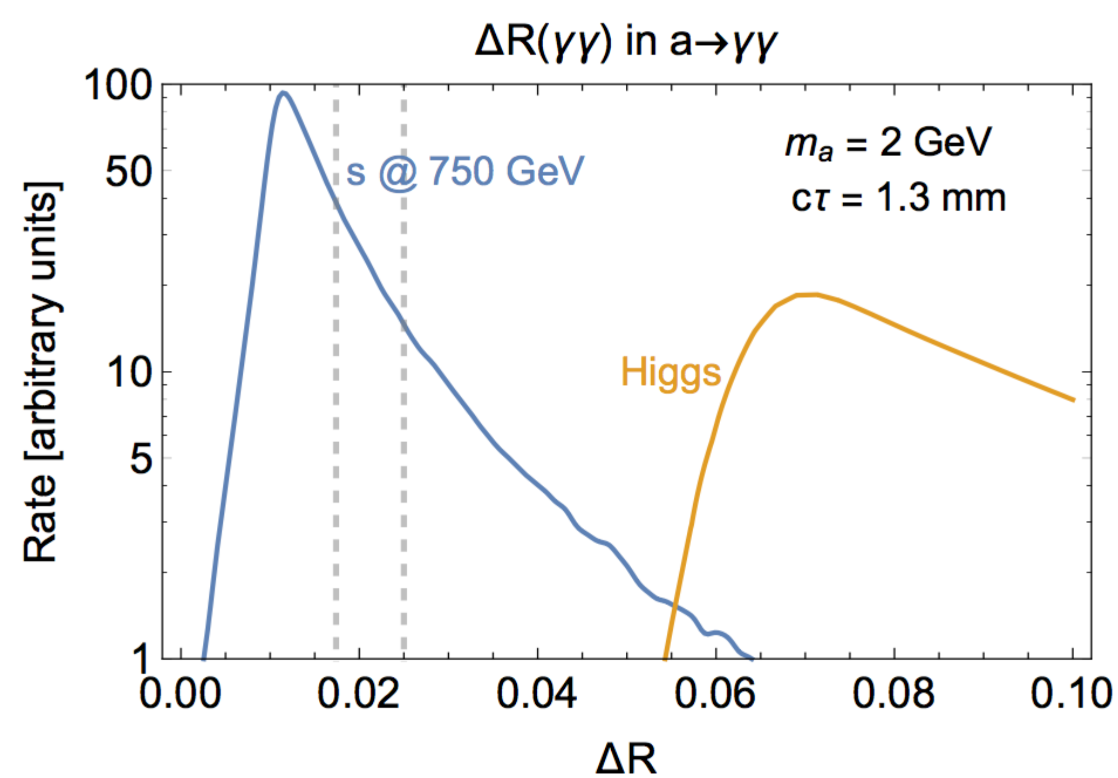
possibility 4 : collimated photons



collimated photons







1512.05775(P. Agarwal et.al.)

Summary

Many possible models that can explain the excess, may be connected to other small excesses.
Connection with dark matter ?

Future searches : Z gamma , ZZ and dijet, top quark resonance + additional particle searches

Many open questions :

Large vs small width
single vs double /N resonances
spin-0 vs spin-2
750 GeV vs Heavy resonance
interference with SM background
single photon vs collimated photons
peak vs edge
fitting functions

Thank you

…….