New LHC bound on low-mass diphoton resonances

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IN SEARCH OF NEW PARADIGMS

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based on 1710.01743

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Introduction

Resonance Searches

Resonance search, strong discovery method at collider

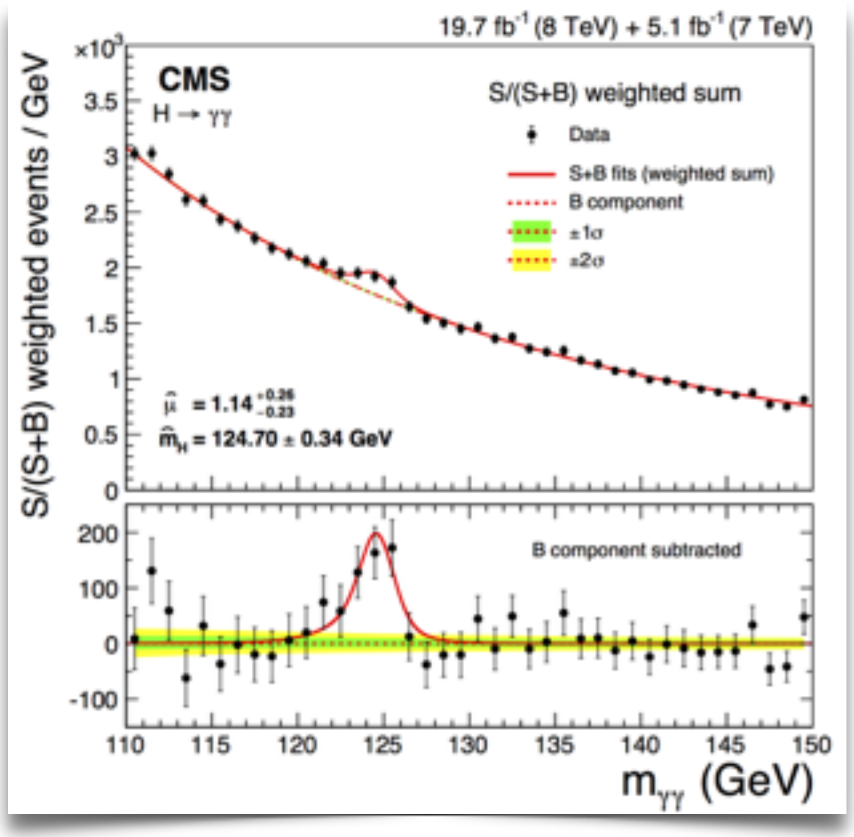
Dilepton

Diphoton

Dijet

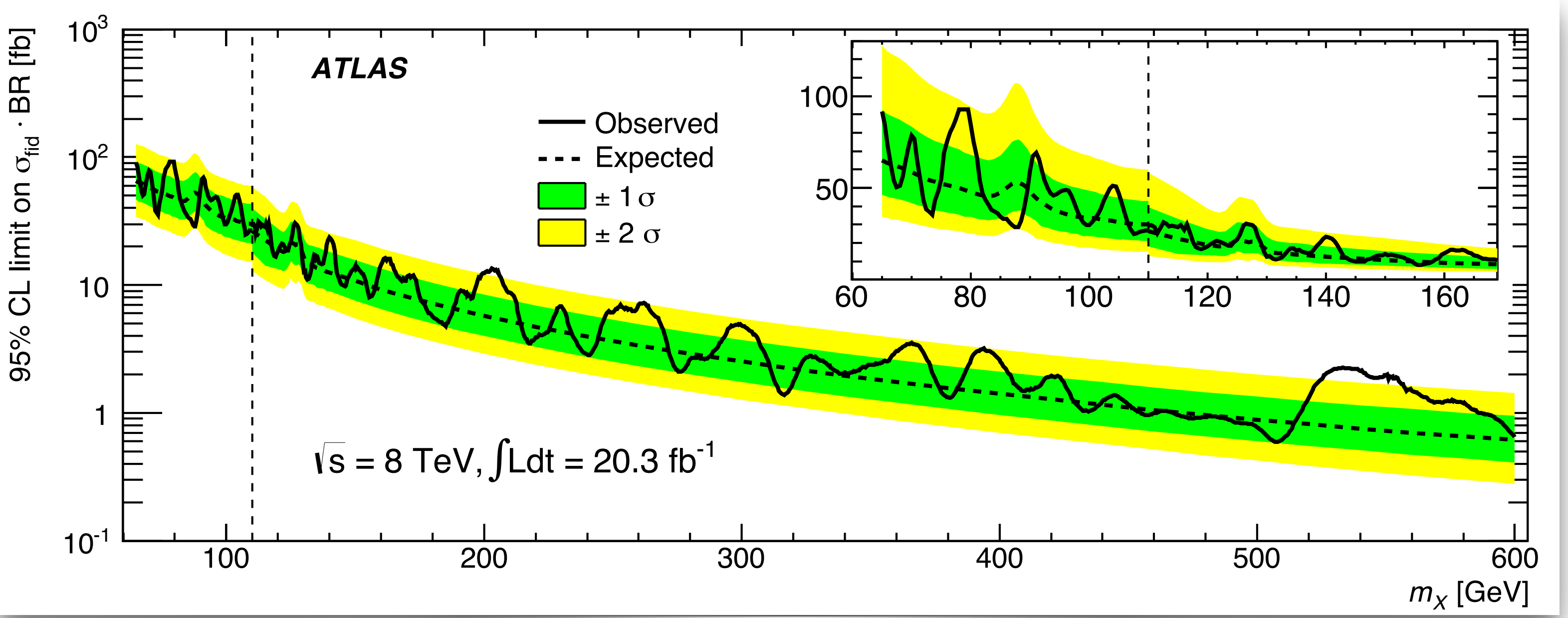
4lepton

Diboson(Z/W) etc.



Success: J/ψ, ϒ, Z, h.., and toward BSM

Typically prove beyond 100GeV



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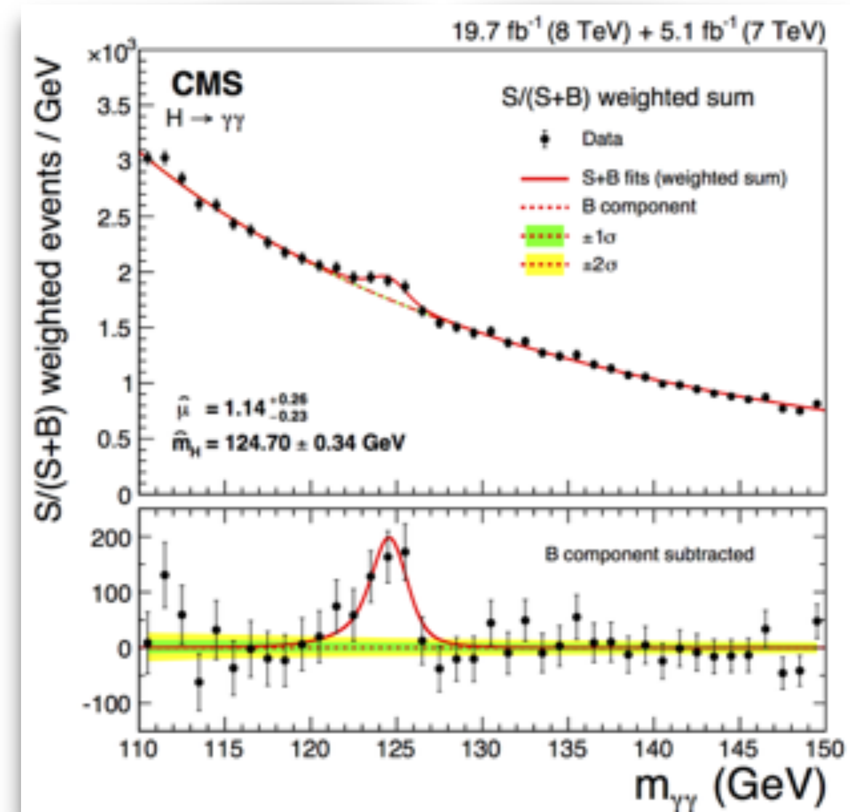

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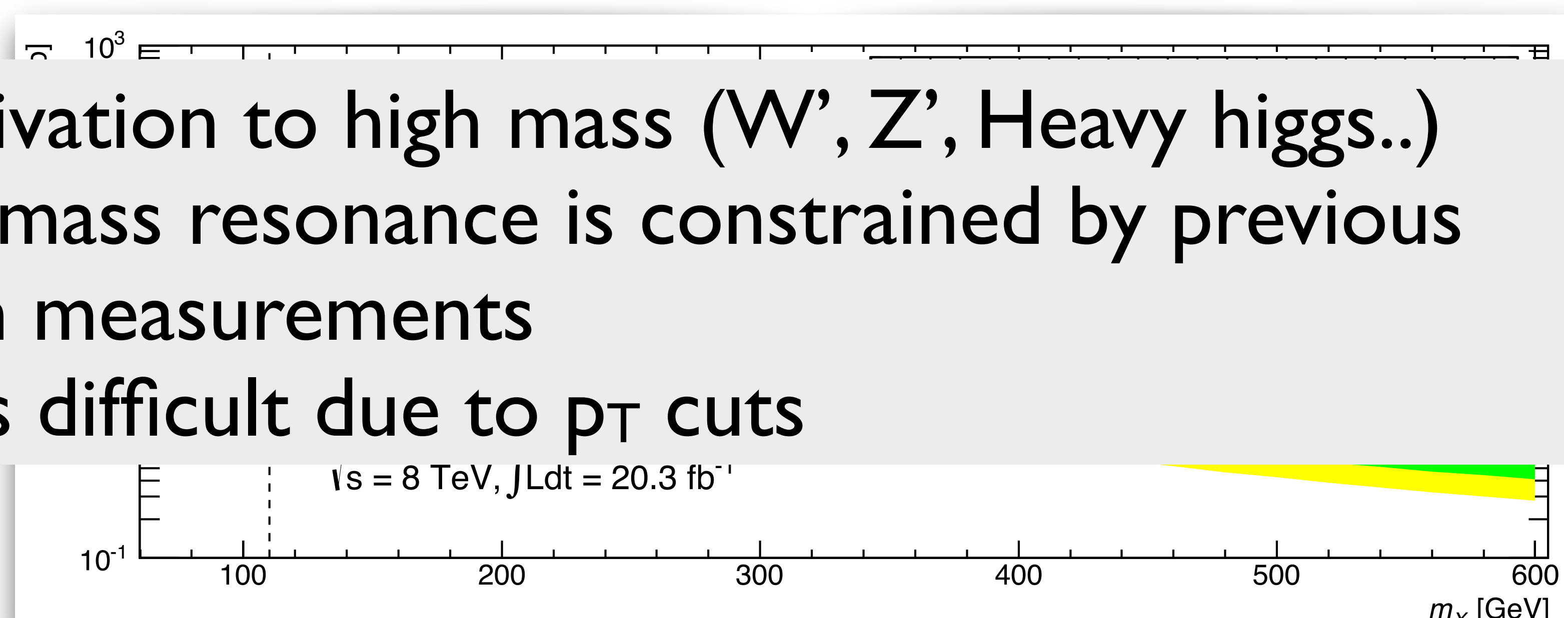
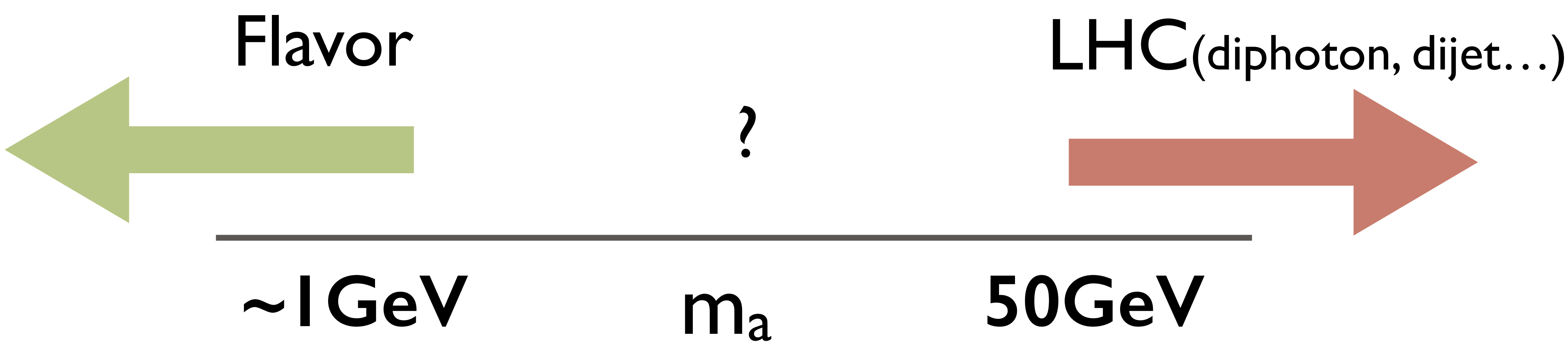


1. Theoretical bias/motivation to high mass (W', Z', Heavy higgs..)
2. Common belief, low mass resonance is constrained by previous colliders or precision measurements
3. For LHC, low mass is difficult due to p_T cuts

Resonance Searches

However, poorly constrained mass range exists



This talk:

Constraint such mass range 10-100GeV

using LHC **diphoton x-section measurements**

Theory perspectives
&
Search Framework

Theory perspective

pNGB: pseudo Nambu Goldstone bosons

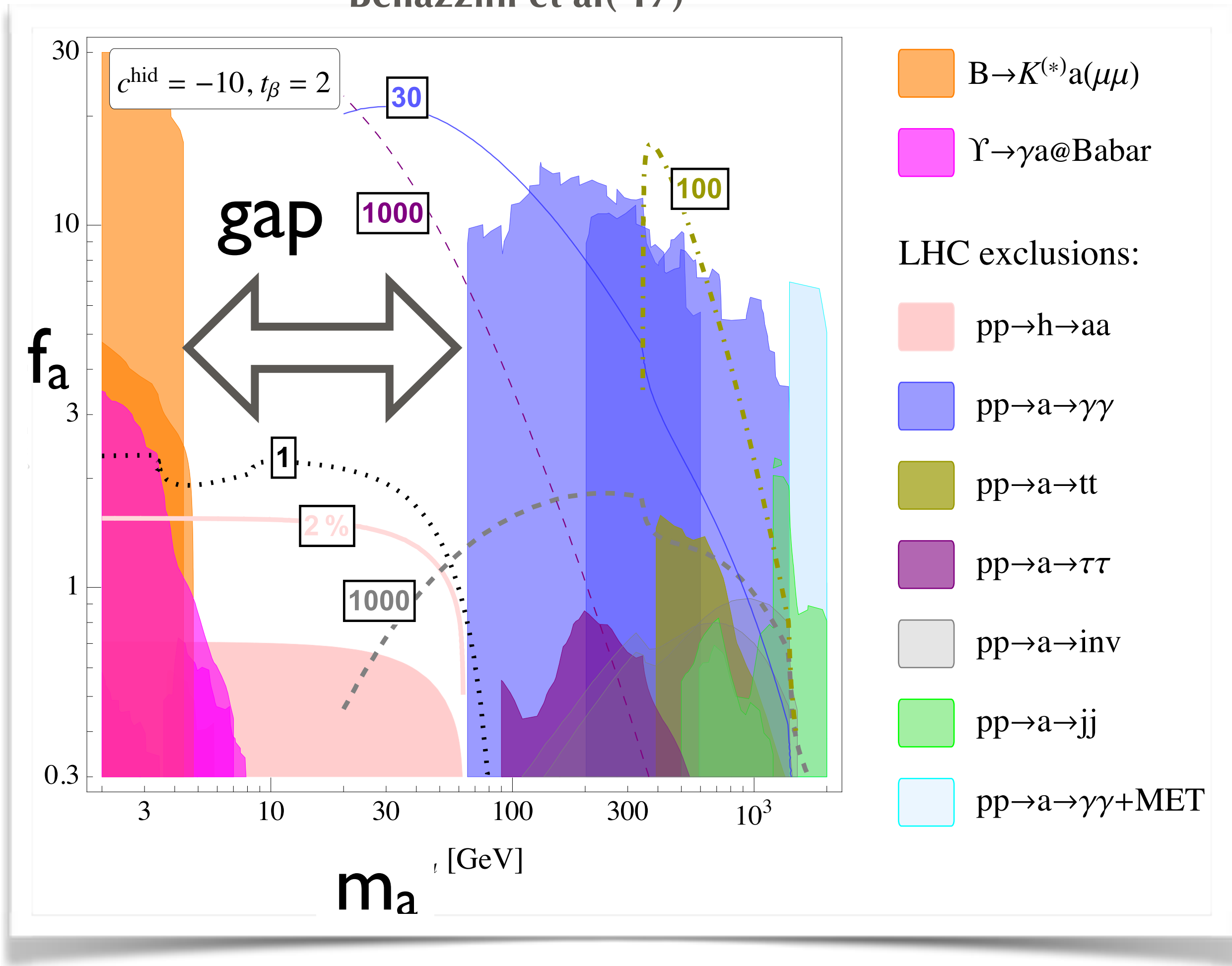
common among BSM models, mass scale is arbitrary light

Axion-like-particle(ALP) e.g.

- R-axion from low-scale SUSY
  Bellazzini, Mariotti, Redigolo, Sala, Serra(1702.02152)
- New pion from TeV QCD'
  Kilic, Okui, Sundrum('09), Nakai, Sato, KT ('16) …
- pNGB from composite Higgs
  Barnard, Gherghetta, Ray('13), Ferretti('16)…

such ALP/pNGB can be the first signal

Bellazzini et al('17)



many previous studies for ALPs:

Photonphilic ALP: LEP[Jaeckel, Spannowsky('15)] Heavy-ion[Knapen et al('16)]
Sub 10GeV, ALP-W int. induces FCNC(B->Ka) [Izaguirre, Lin, Shuve('16)], etc.

ALP Effective Lagrangian

Consider only anomaly/ Wess-Zumino-Wittern terms

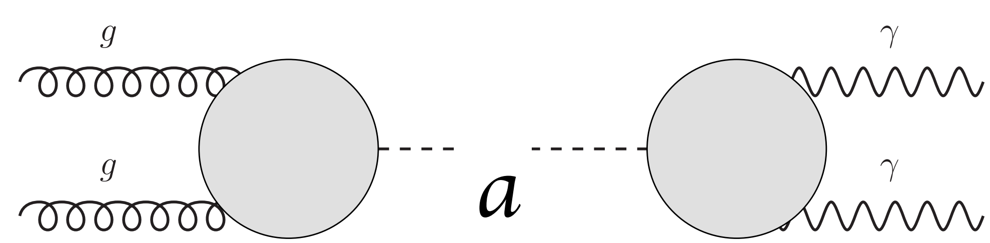
$$\mathcal{L}_{\rm int} = \frac{a}{4\pi f_a}\left[\alpha_s c_3 G\tilde{G} + \alpha_2 c_2 W\tilde{W} + \alpha_1 c_1 B\tilde{B}\right]$$

$\alpha_1 = 5/3\alpha'$

Broad class of models

$f_a \sim 0.1 - 10 \text{ TeV and } c_3 \neq 0$

Take $c_1 = c_2 = c_3 = 10$ for benchmark



- Narrow resonance,
- production@LHC is gluon fusion,
- decay to dijet or diphoton due to kinematics ($m_a < m_Z$)

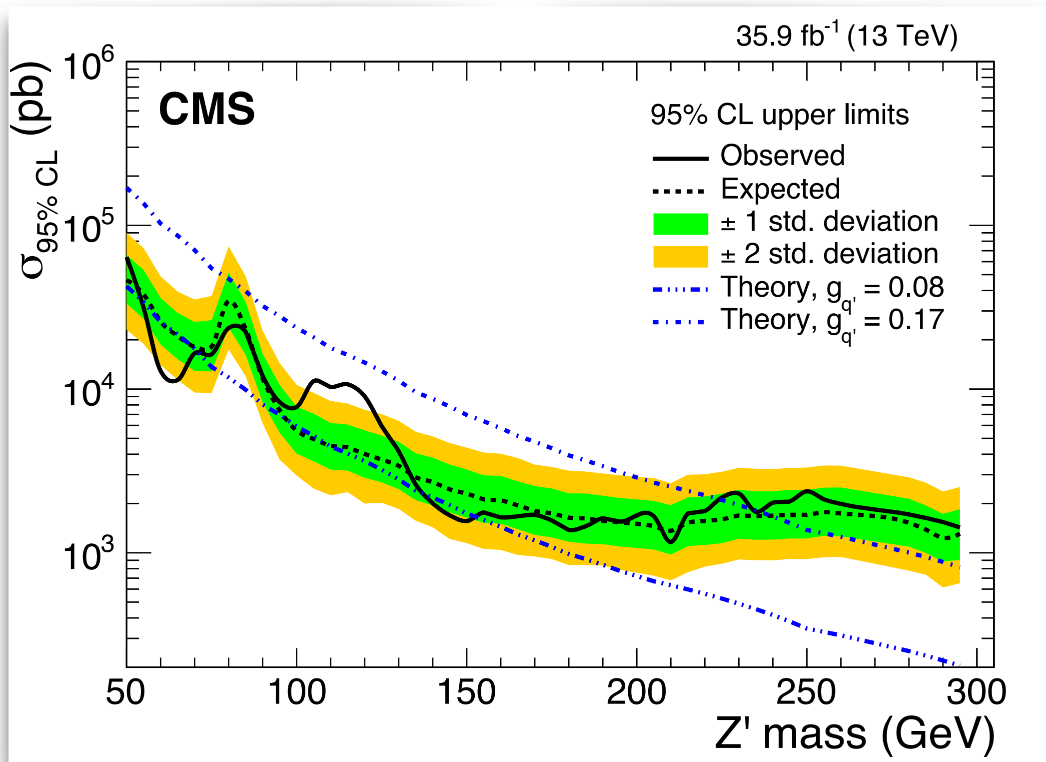
New Bound

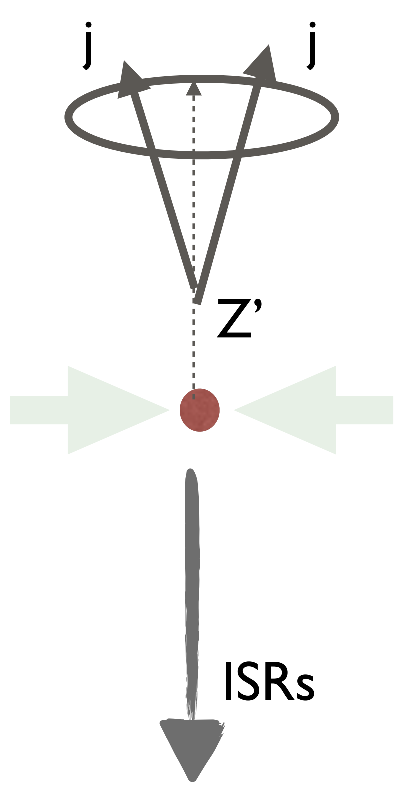
Existing constraints for ma<100GeV

Experiment	Process	Lumi	$\sqrt{s}$	low mass reach	ref.
LEPI	$e^+e^- \to Z \to \gamma a \to \gamma jj$	12 pb^{-1}	Z-pole	10 GeV	[26]
LEPI	$e^+e^- \to Z \to \gamma a \to \gamma\gamma\gamma$	78 pb^{-1}	Z-pole	5 GeV	[27]
LEPII	$e^+e^- \to Z^*, \gamma^* \to \gamma a \to \gamma jj$	9.7,10.1,47.7 pb^{-1}	161,172,183 GeV	60 GeV	[28]
LEPII	$e^+e^- \to Z^*, \gamma^* \to \gamma a \to \gamma\gamma\gamma$	9.7,10.1,47.7 pb^{-1}	161,172,183 GeV	60 GeV	[28, 29]
LEPII	$e^+e^- \to Z^*, \gamma^* \to Za \to jj\gamma\gamma$	9.7,10.1,47.7 pb^{-1}	161,172,183 GeV	60 GeV	[28]
D0/CDF	$p\bar{p} \to a \to \gamma\gamma$	7/8.2 fb^{-1}	1.96 TeV	100 GeV	[30]
ATLAS	$pp \to a \to \gamma\gamma$	20.3 fb^{-1}	8 TeV	65 GeV	[31]
CMS	$pp \to a \to \gamma\gamma$	19.7 fb^{-1}	8 TeV	80 GeV	[32]
CMS	$pp \to a \to \gamma\gamma$	19.7 fb^{-1}	8 TeV	150 GeV	[33]
CMS	$pp \to a \to \gamma\gamma$	35.9 fb^{-1}	13 TeV	70 GeV	[34]

Boosted dijet(Z')+ISR [50,300]GeV

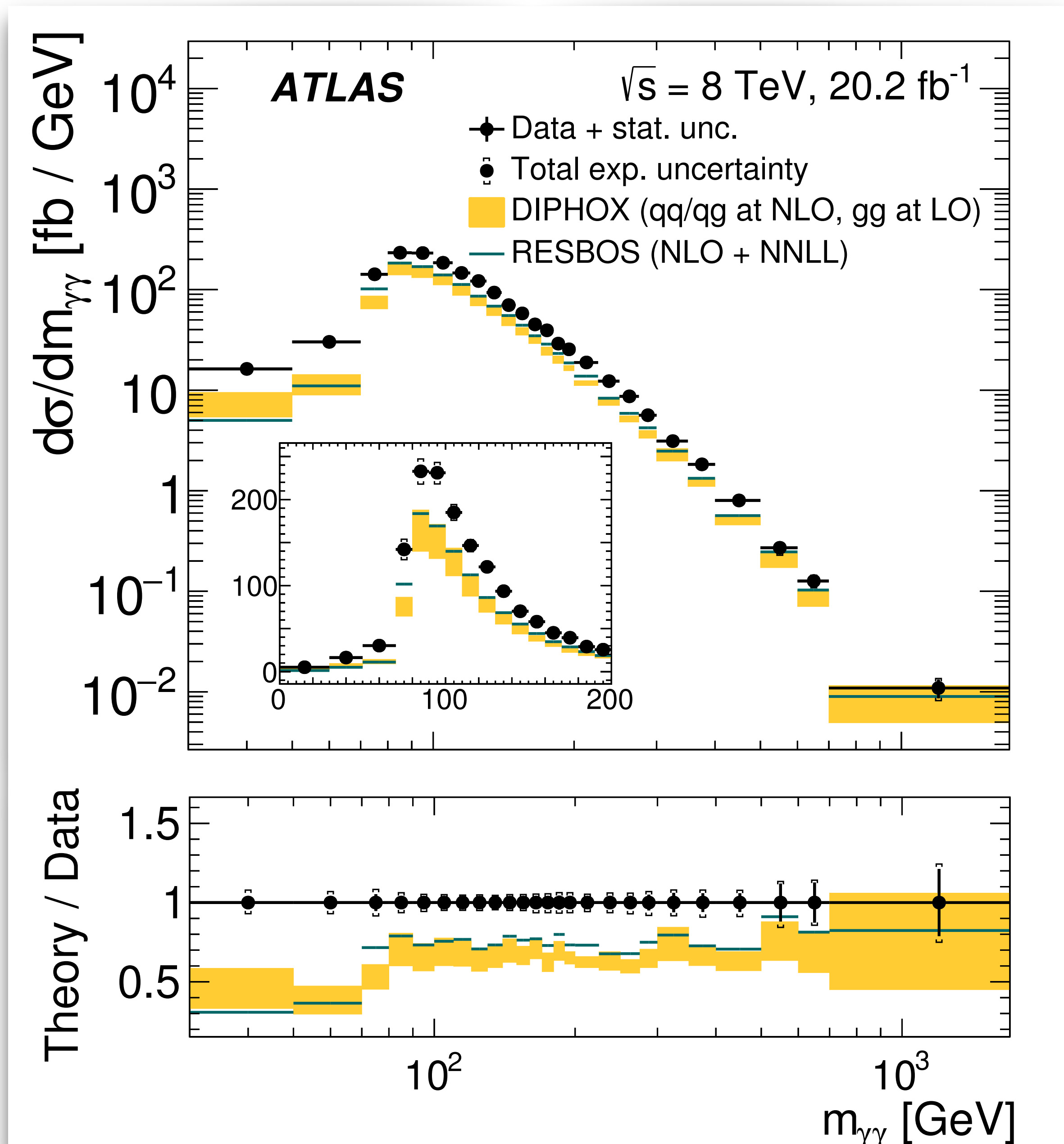
CMS [arXiv:1710.00159]



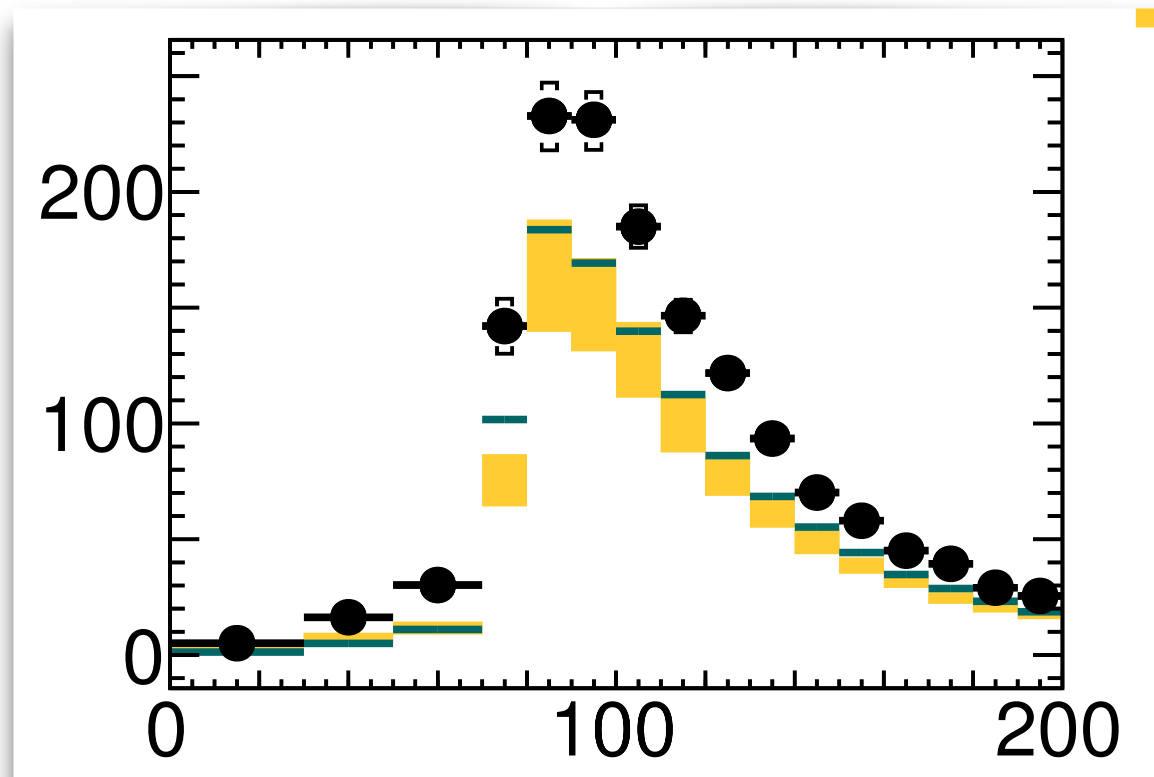


Diphoton x-section measurements

D0 ($\sigma_{\gamma\gamma}$)	$p\bar{p} \to a \to \gamma\gamma$	4.2 fb^{-1}	1.96 TeV	$p_{T_1}, _{T_2} > 21, 20$ GeV	[35]
CDF ($\sigma_{\gamma\gamma}$)	$p\bar{p} \to a \to \gamma\gamma$	5.36 fb^{-1}	1.96 TeV	$p_{T_1}, _{T_2} > 17, 15$ GeV	[36]
ATLAS	$pp \to a \to \gamma\gamma$	4.9 fb^{-1}	7 TeV	$p_{T_1}, _{T_2} > 25, 22$ GeV	[8]
ATLAS	$pp \to a \to \gamma\gamma$	20.2 fb^{-1}	8 TeV	$p_{T_1}, _{T_2} > 40, 30$ GeV	[9]
CMS	$pp \to a \to \gamma\gamma$	5.0 fb^{-1}	7 TeV	$p_{T_1}, _{T_2} > 40, 25$ GeV	[10]

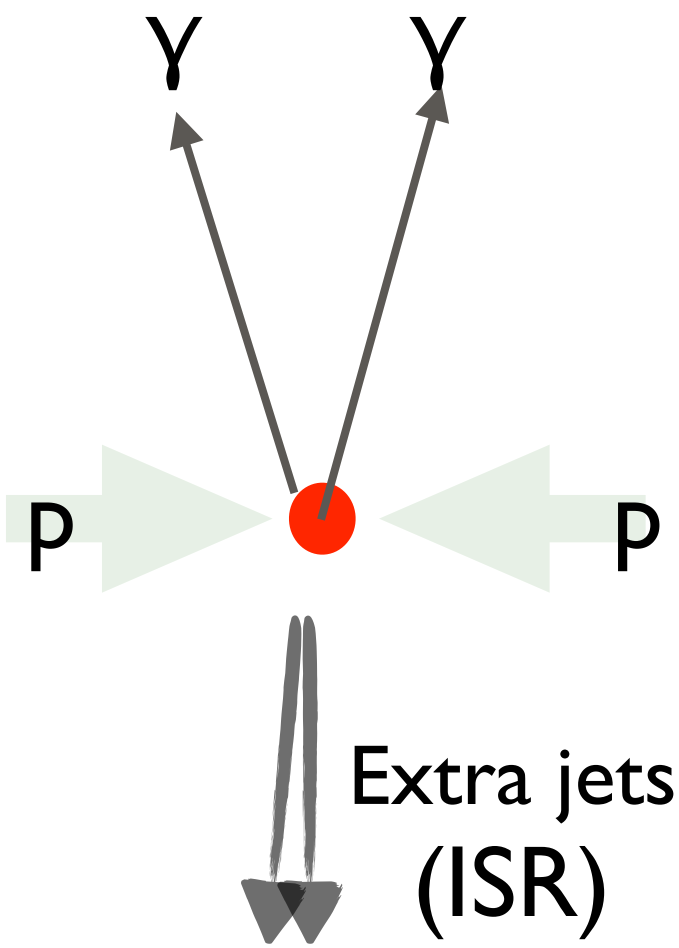


report lower mass

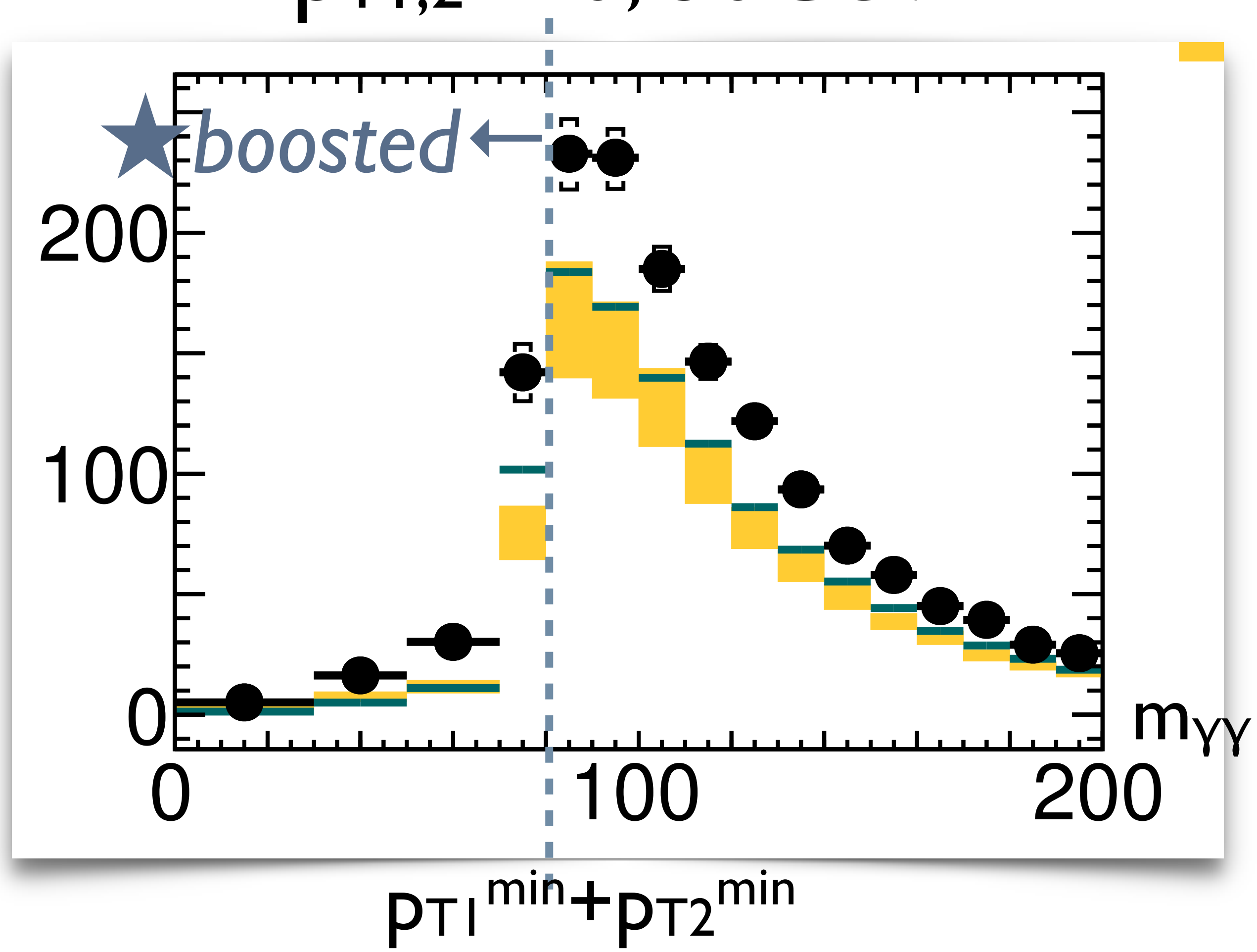


Diphoton x-section measurements

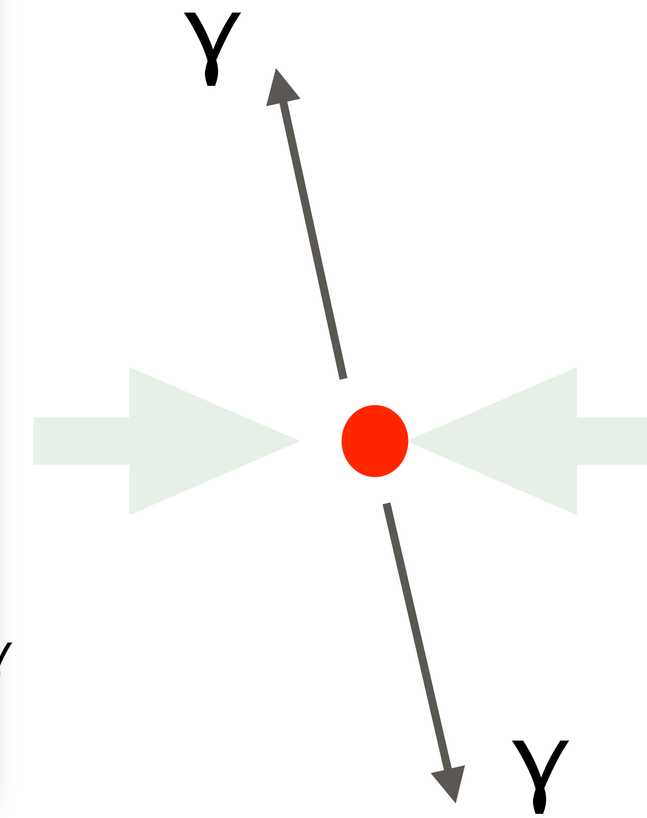
boosted



$p_{T1,2}$>40, 30GeV



at rest



★strict lower bound of $m_{\gamma\gamma}$ from ΔR>0.4

diphoton angular separation

$$m_{\gamma\gamma} > \Delta R \cdot \sqrt{p_{T1}^{\rm min} p_{T2}^{\rm min}}$$ ~13.8GeV

m_a in GeV	10	20	30	40	50	60	70	80	90	100	110	120
ϵ_S for $\sigma_{8\rm TeV}$ ATLAS [9]	0	0.0007	0.008	0.014	0.024	0.037	0.071	0.233	0.347	0.419	0.452	0.484

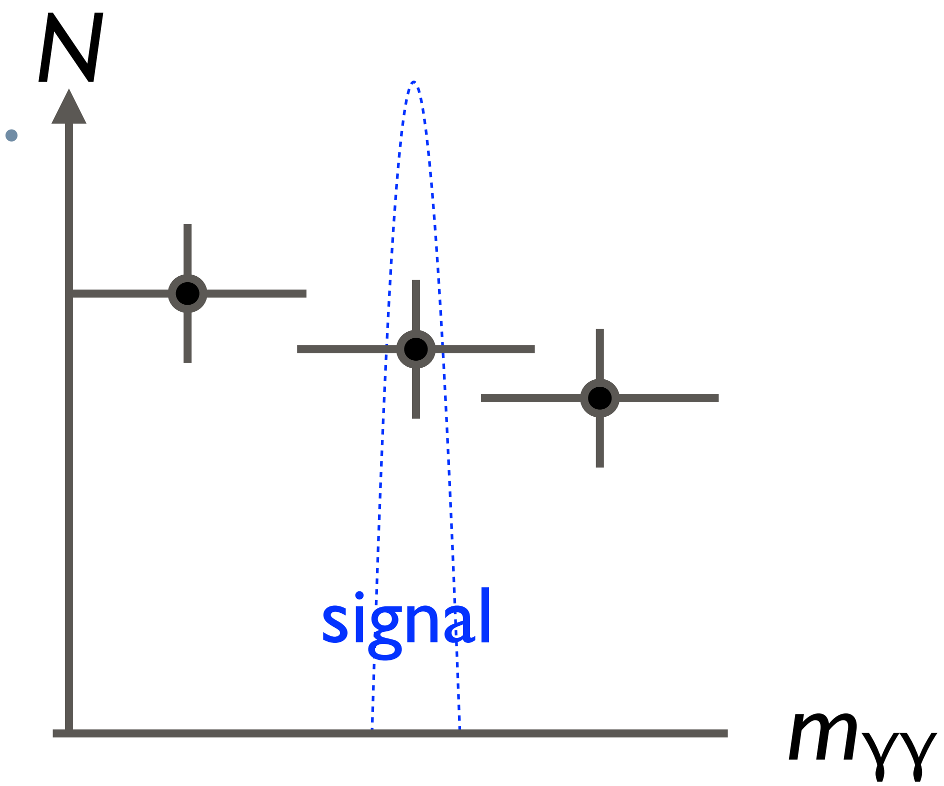
Bound from Diphoton x-section measurement

For this measurement, signal is SMγγ…

1. Conservative bound

data=signal

$N_{bin}+2\Delta N_{bin} > S_a$



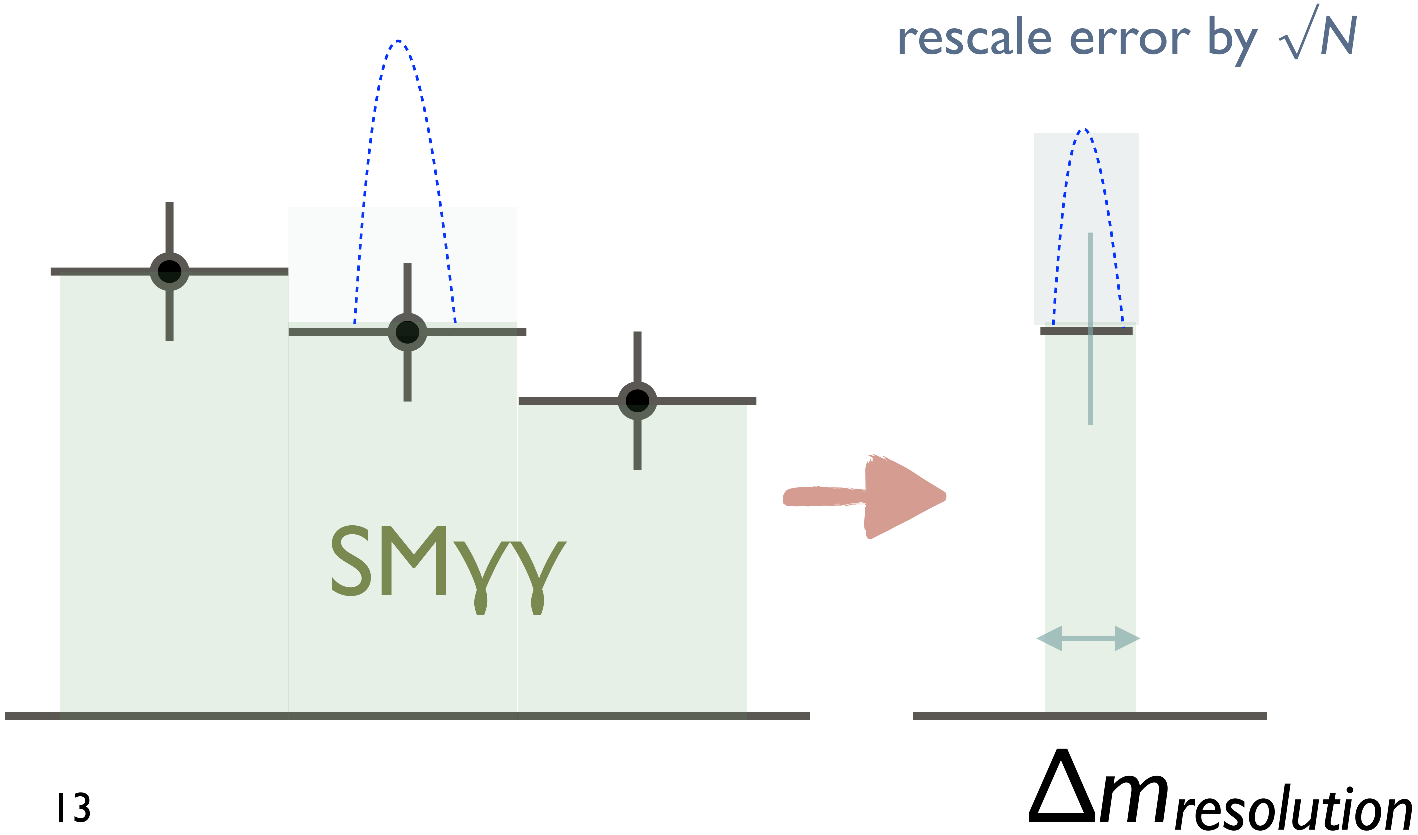
2. Sensitivity(reach)

assume data=SMγγ

$2\Delta N_{bin} > S_a$

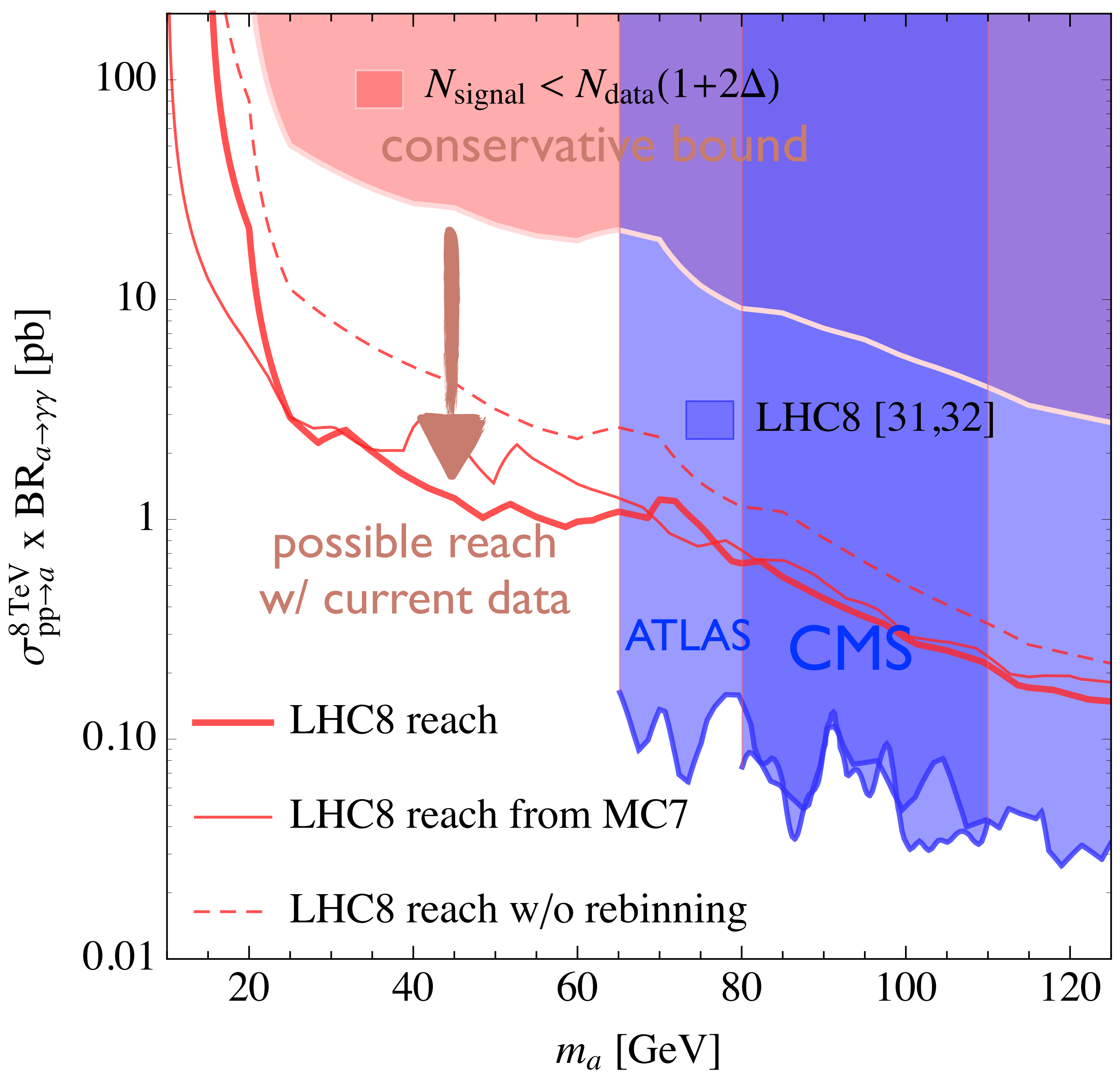
3. Narrow given bin(~10GeV) to mass resolution(~3GeV)

$2\Delta N_{resolution} > S_a$

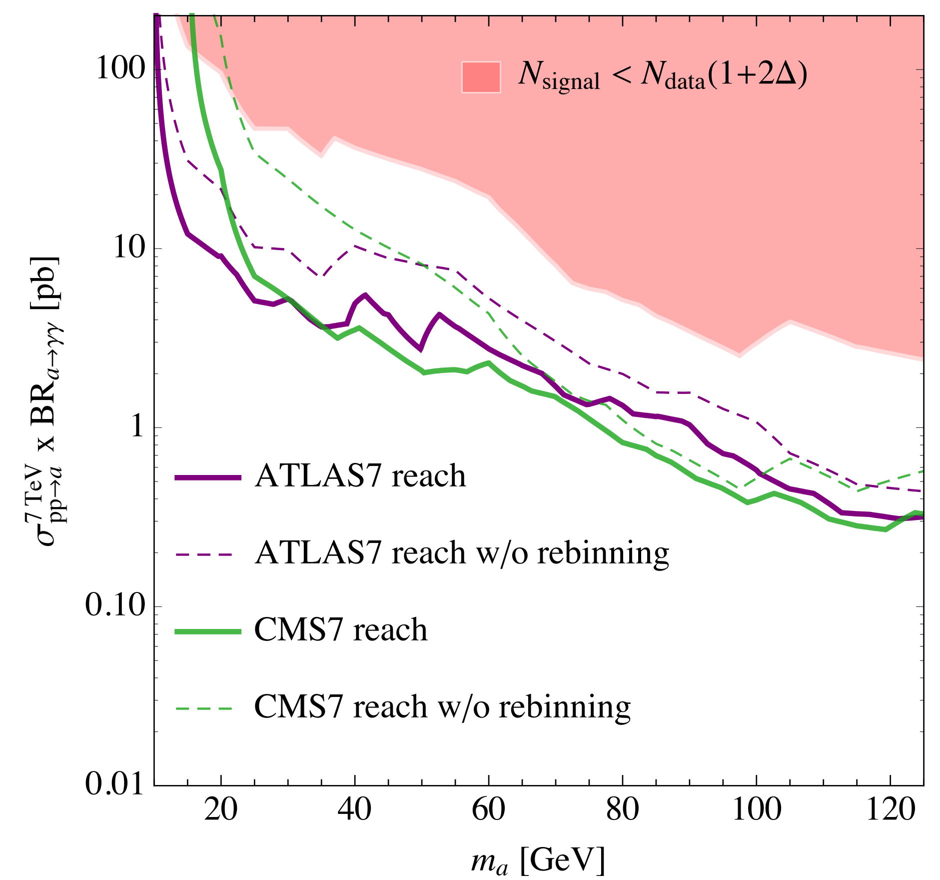


Bound/sensitivity on cross section

8TeV

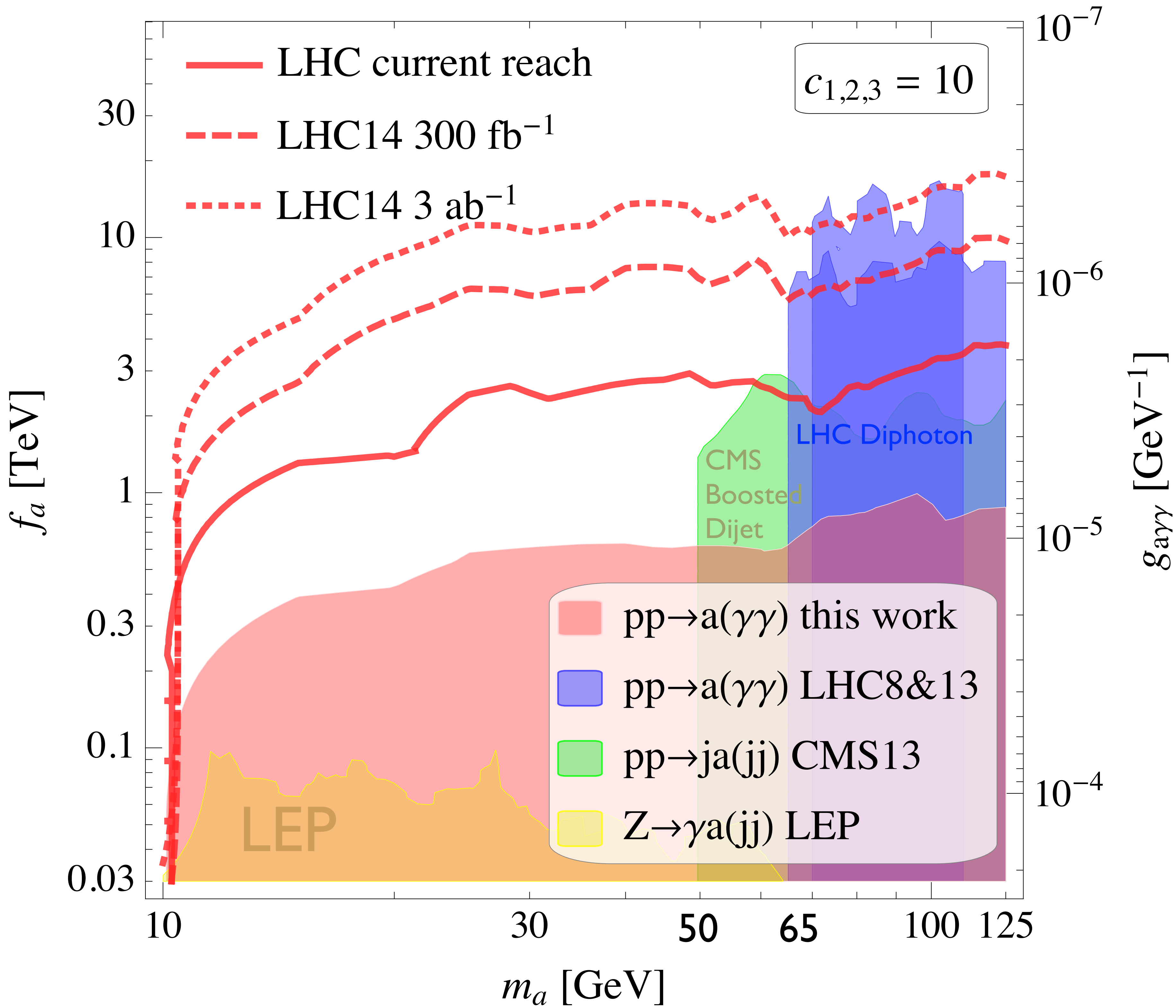


7TeV



ATLAS7 down to 10GeV

ALP parameter space



LHC>>LEP! And, fa<TeV can be covered.

Summary and Prospects

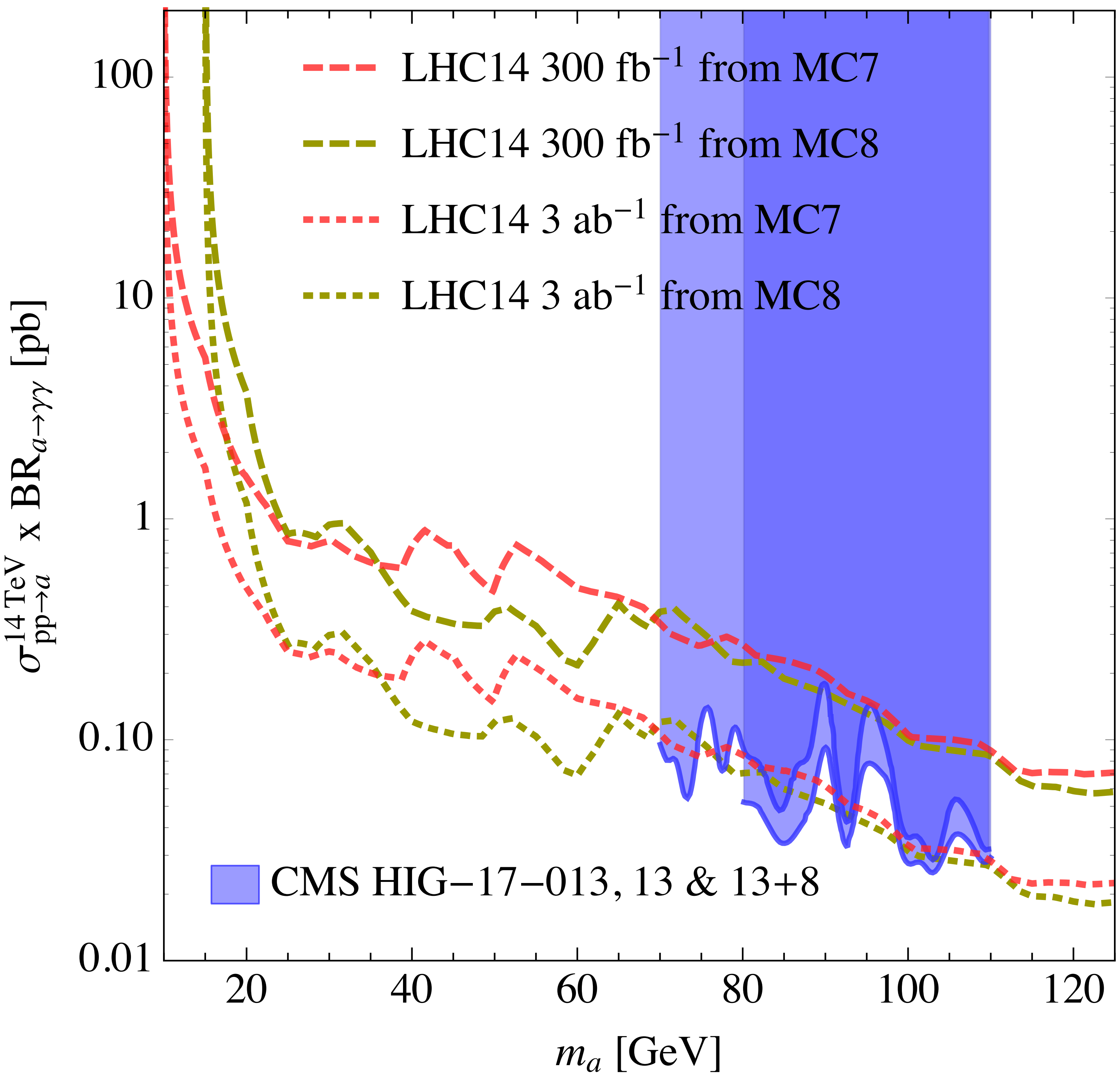
- pNGB/ALP of 1-50GeV was poorly constrained
- 10-100GeV can be covered by x-sec measurement
- Conservative bound is already strongest. Sensitivity with current data can be x10 better(in x-section). Encourage ATLAS&CMS!
- Challenge is **1-10GeV**
  - Lower p_T or ΔR cut. Use trigger level analysis, or data parking (record fraction of data)
  - Substructure technique. Extend boosted dijet+ISR analysis to low mass. Boosted diphoton+ISR is interesting direction

...
meV
eV
keV
MeV
GeV
10GeV
100GeV
TeV
ALPS landscape
pic from http://us.france.fr/en/discover/alps-0

Thank you!

Backup

14TeV Projection from 7TeV and 8TeV



Validation of our MC

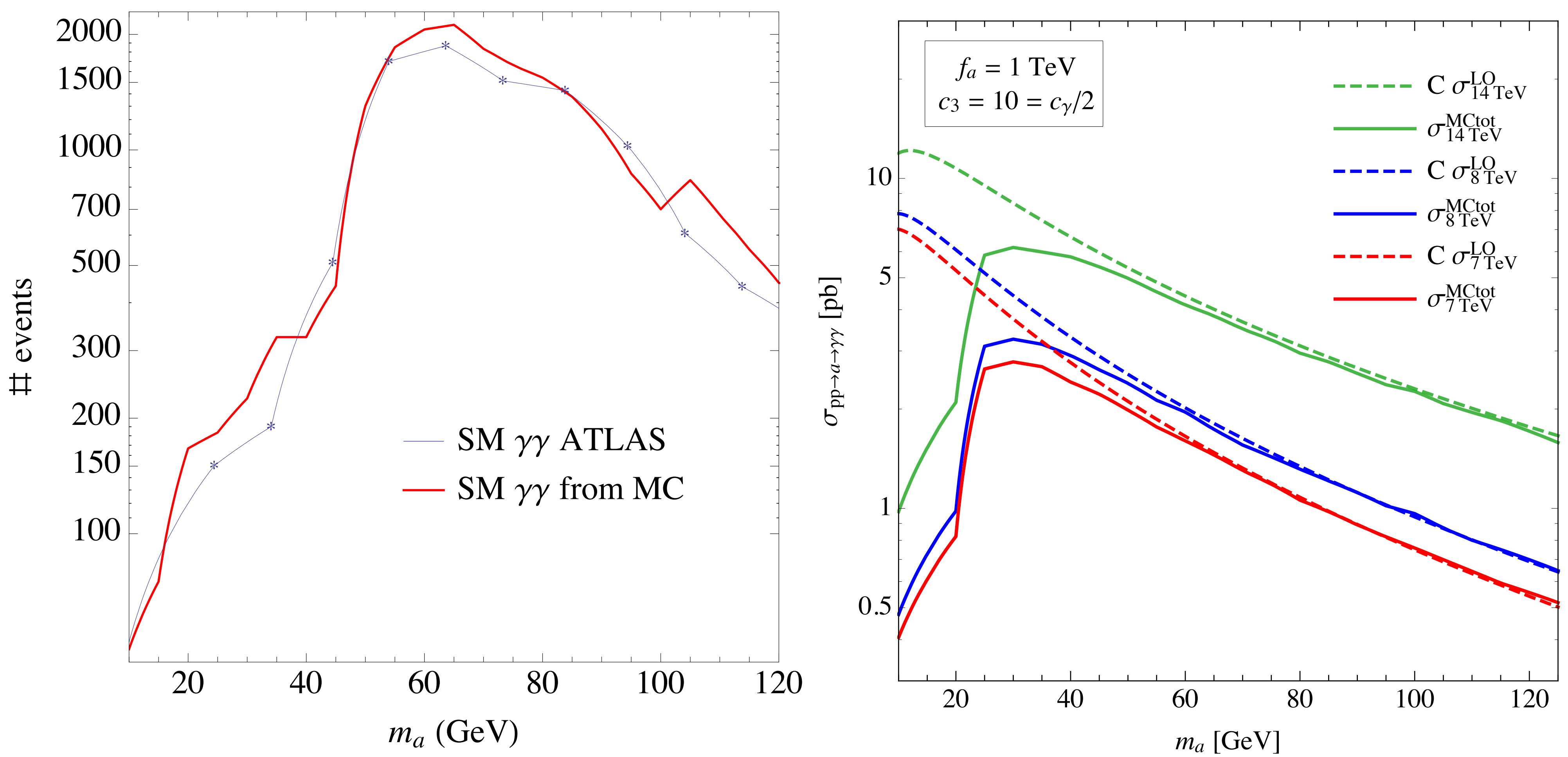


FIG. 3: Left: diphoton background shapes from our MC simulation (solid red) and from ATLAS cross section measurements (light blue) at 7 TeV. Right: Total signal strengths from our MC simulation with minimal cuts (solid lines), compared with the LO theoretical signal strengths (dashed lines). See text for more details.