Particle physics going 'gaga'.

Kai Schmidt-Hoberg

Overview of theoretical interpretations of the diphoton excess

Current count ~ 170 papers

~165	spin-0 resonance
~5	spin-2 resonance
~1	spin-1 resonance
~5	parent resonance/kinematic edge

HELMHOLTZ ASSOCIATION

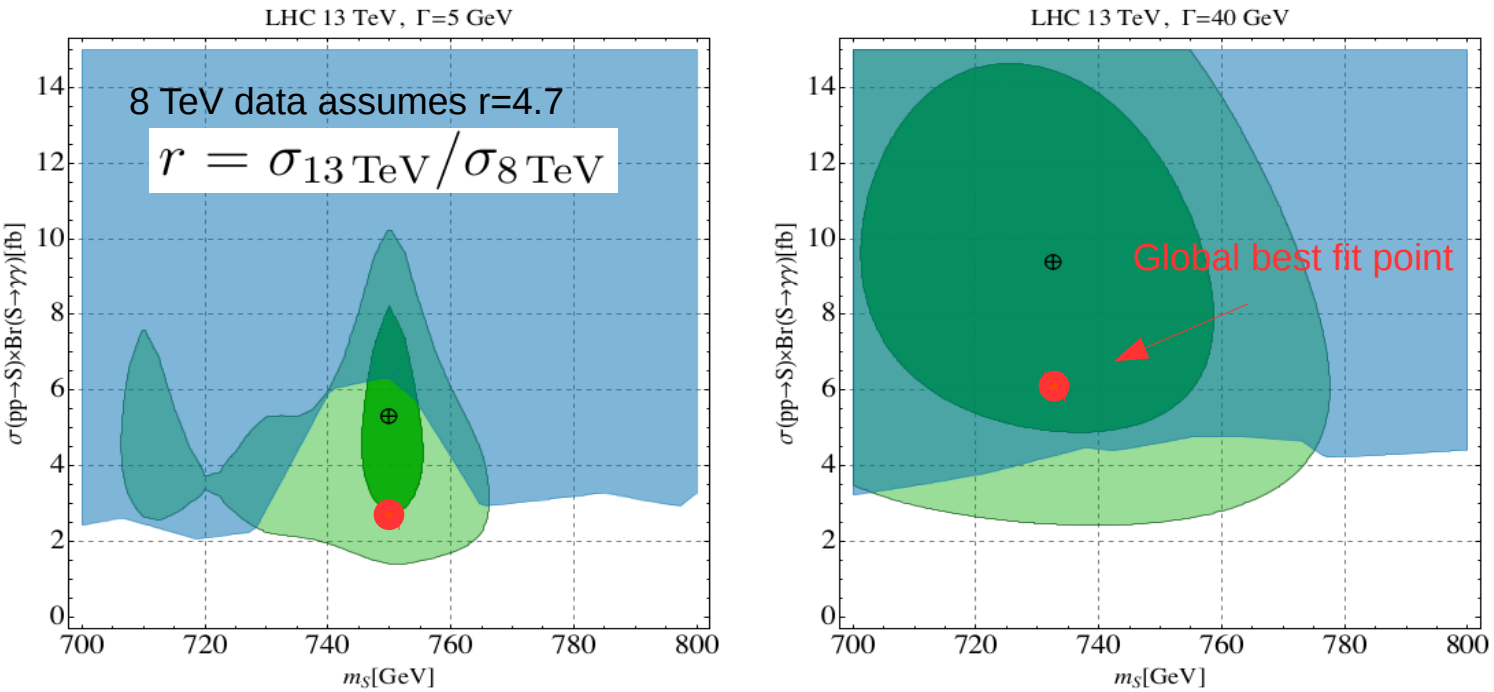
erc

DESY

Observation (ATLAS + CMS).

Inferred **cross section** (combined):

1512.05777



Some tension with run 1 data...

Signal cross section should grow significantly to be consistent

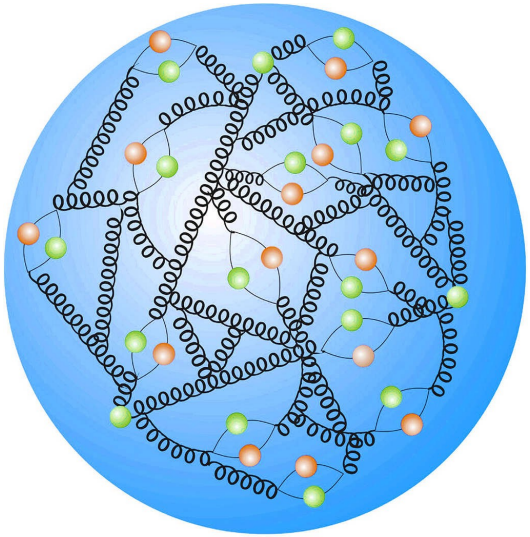
Width: largish width of ~ 40 GeV slightly preferred (not significant)

A resonance at 750 GeV.

Simplest explanation: A **resonance at 750 GeV**

Narrow width approximation OK

$$\sigma(pp \to \gamma\gamma) \approx \sigma(pp \to \Phi) \cdot BR(\Phi \to \gamma\gamma)$$



Possible parton initial states are qq, gg, VV

Increase in cross section depends on initial state:

$r_{b\bar{b}}$	$r_{c\bar{c}}$	$r_{s\bar{s}}$	$r_{d\bar{d}}$	$r_{u\bar{u}}$	r_{gg}	$r_{\gamma\gamma}$
5.4	5.1	4.3	2.7	2.5	4.7	1.9

<3.9 from finite size

Other resonance searches at 8 TeV.

1512.04933

final state f	σ at $\sqrt{s} = 8\,\text{TeV}$ observed	implied bound on $BR(S \to f)/BR(S \to \gamma\gamma)$
$e^+e^- + \mu^+\mu^-$	< 1.2 fb	$< 0.6\ (r/5)$
$\tau^+\tau^-$	< 12 fb	$< 6\ (r/5)$
$Z\gamma$	< 4.0 fb	$< 2\ (r/5)$
ZZ	< 12 fb	$< 6\ (r/5)$
Zh	< 19 fb	$< 10\ (r/5)$
hh	< 39 fb	$< 20\ (r/5)$
W^+W^-	< 40 fb	$< 20\ (r/5)$
$t\bar{t}$	< 550 fb	$< 300\ (r/5)$
$b\bar{b}$	$\lesssim 1\,\text{pb}$	$< 500\ (r/5)$
jj	$\lesssim 2.5$ pb	$< 1300\ (r/5)$

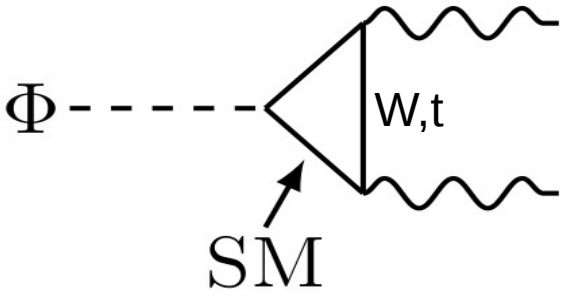
$$BR(\Phi \to \gamma\gamma)/BR(\Phi \to \text{SM SM})) \gtrsim 10^{-3}$$

Could it be the SM + 750 GeV resonance?

1512.04928

Is it possible to have **only** SM states contributing to the effective couplings?

Decay: loop induced!



Decay to WW, tt, open:

Can estimate:

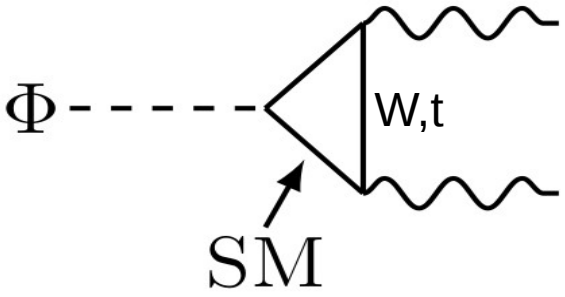
$$\frac{BR(\Phi \to \gamma\gamma)}{BR(\Phi \to W^+W^-/t\bar{t})} \sim \left(\frac{\alpha}{4\pi}\right)^2 \sim 5 \times 10^{-5}$$

Could it be the SM + 750 GeV resonance?

1512.04928

Is it possible to have **only** SM states contributing to the effective couplings?

Decay: loop induced!



Decay to WW, tt, open:

Can estimate:

$$\frac{BR(\Phi \to \gamma\gamma)}{BR(\Phi \to W^+W^-/t\bar{t})} \sim \left(\frac{\alpha}{4\pi}\right)^2 \sim 5 \times 10^{-5}$$

Excluded by bounds from resonance searches in WW, tt, …

Need additional BSM states!

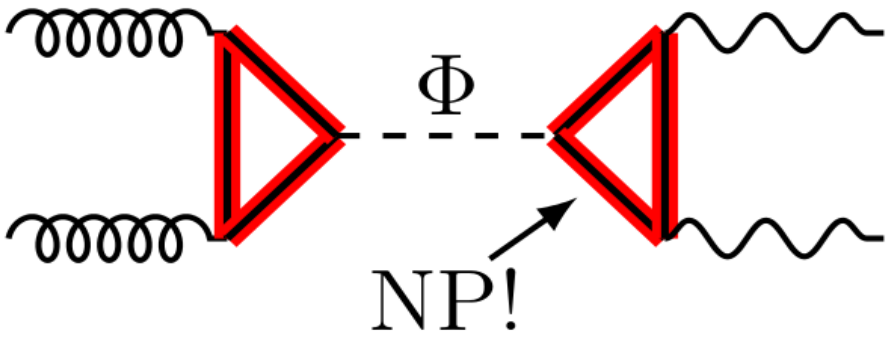
What is the spin of the resonance?

Landau-Yang theorem:

For a two photon final state the resonance could have **spin 0 or spin 2**.

98% of papers have considered spin 0

Natural production process: gluon fusion



Very simple working model (narrow width): Resonance + vector-like fermions
M > 375 GeV

Colored states typically below TeV → large production cross section!

What about the MSSM?

How does this fit into known models?

$$BR(\Phi \to \gamma\gamma)/BR(\Phi \to \text{SM SM})) \gtrsim 10^{-3}$$

Large BR into photons - **problematic for 2HDM, MSSM!**

For **R-parity conservation**, candidates are heavy Higgses H,A

→ does not work 1512.05332

Again need additional states…

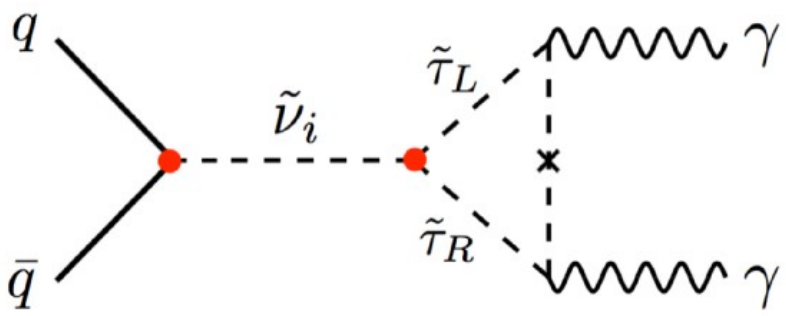
If you love SUSY and signal genuine→ beyond MSSM ?!

A MSSM solution?

G Weiglein: with R parity violation everything possible :-)

Possible interpretation in the MSSM with R parity violation:

1512.07645



Large enough rate: Mass of stau 375 GeV < m < 388 GeV

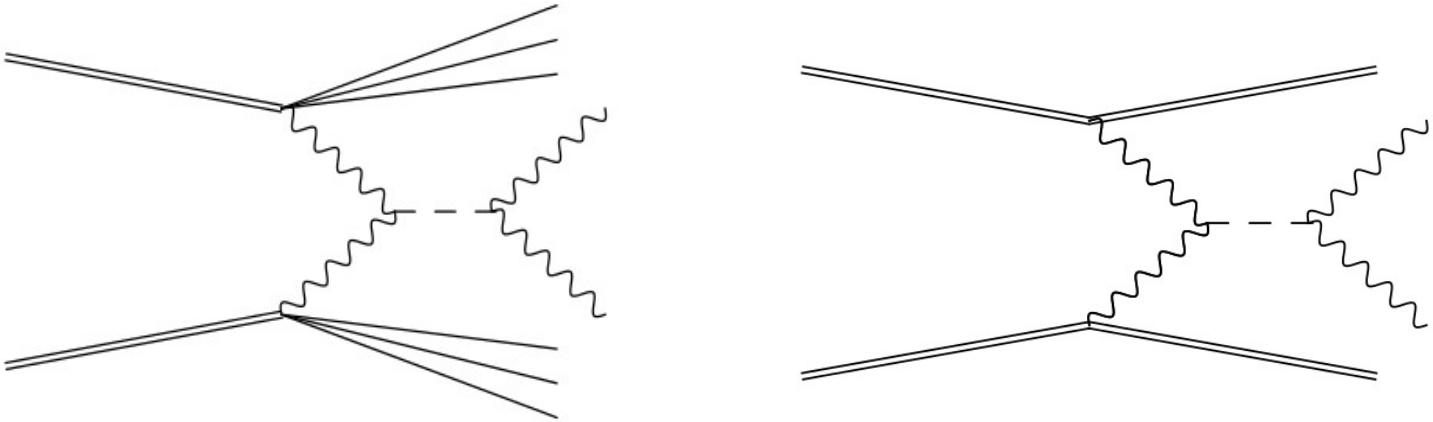
In the given model: dd initial state → strong tension with run 1 data

Even with R parity violation challenging to explain in MSSM!

The minimal model

- The minimal case: only effective couplings to photons

1512.05751



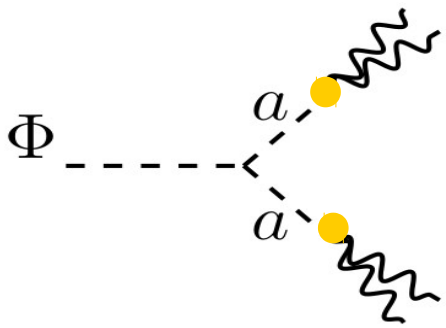
- No new colored states needed
- possible detection of forward protons from elastic photoproduction
- Tension with run 1 data

What if the width is large?

Large width is difficult to achieve in the simple model with gg initial state (only loop induced decay modes)

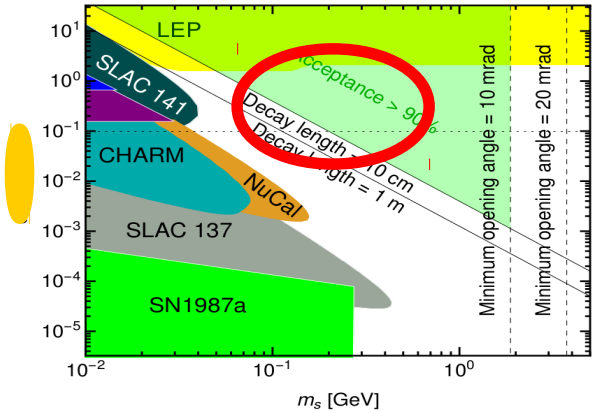
Option for a large width (if not several states at 750 GeV):

- New strong dynamics (similar to QCD) 1512.04850
- Large invisible width ('dark matter mediator')?
  → Significant constraints from monojet searches, but not excluded 1512.06842
- Tree-level decays 1512.04928



Could be very collimated photons (not resolved)

Depends on mass and coupling of a



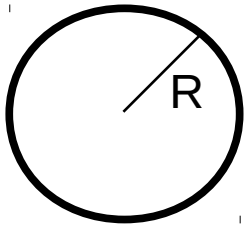
Spin-2

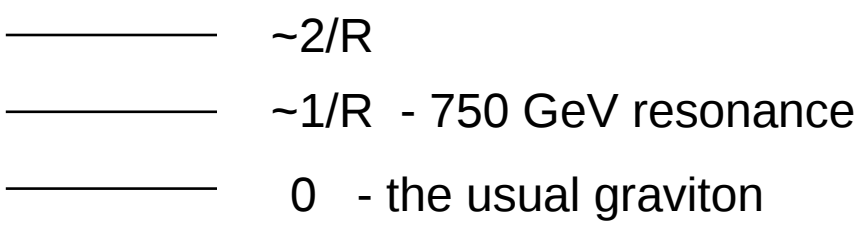
1512.06376

Spin-2 resonance much less studied

Only fundamental spin-2 particle: graviton

Candidate: KK excitation of graviton in extra dimensions



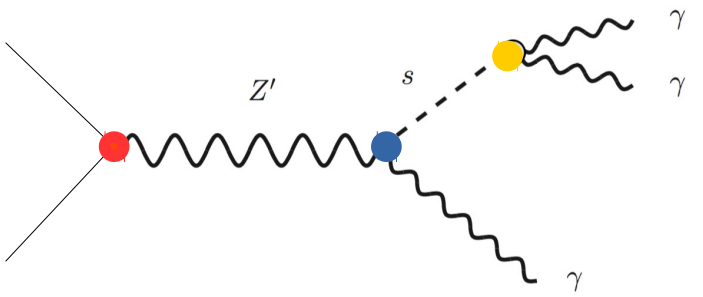


Couplings to SM states depend on localization in extra dimensions

Difference to spin 0 → different angular distributions

Spin 1 - Evading Landau-Yang

Could it be a vector resonance despite Landau-Yang? 1512.06833



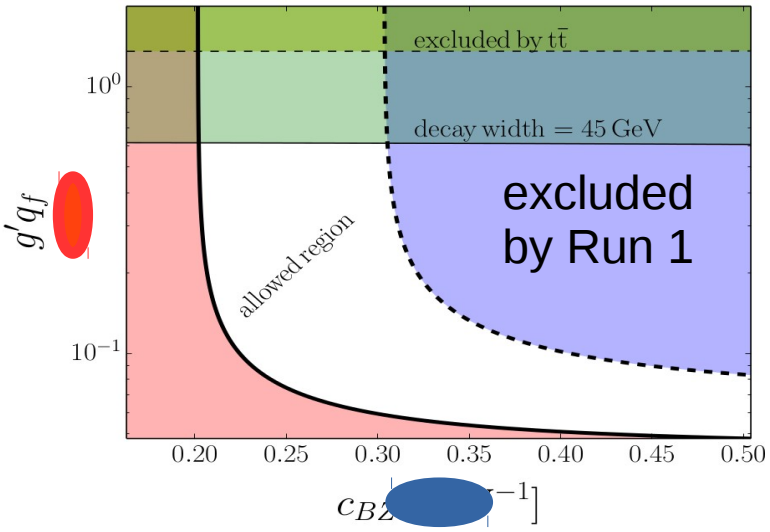
collimated

Ingredients naturally present in Z' models:

- Higgs boson to break the U(1)'
- Anomalies: Extra fermions (non-colored) will generate couplings

3rd generation couplings (bb initial state)

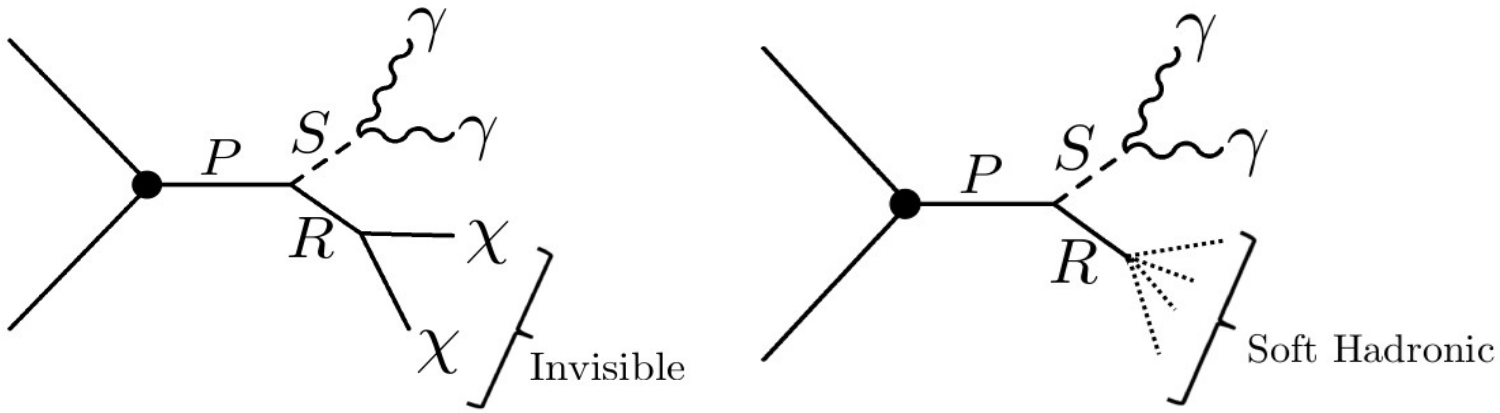
Naturally large width (strongest constraint)



A parent resonance

1512.04933

A parent resonance would allow for better Run-1/Run-2 compatibility



Naturally additional signatures such as etxra jets, MET, …

Search is inclusive, but nothing suspicious seen...

To suppress MET need $\Delta = m_P - m_S - m_R$ small

Summary

- Large number of possible interpretations of the 750 GeV excess
- Spin 0,1,2 resonance as well as non-resonant physics could work
- Almost too simple to write down a working model (unlike a number of other anomalies - say top forward backward asymmetry)

- However, vanilla MSSM or 2HDM don't work
- Need additional new states, which should be accessible!

- Overall: many theorists in excited state (at least until summer)

Thank you!