The 750 GeV Diphoton Resonance: A Chiral Composite Model

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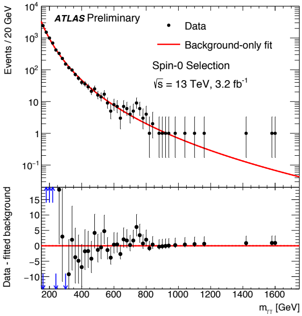
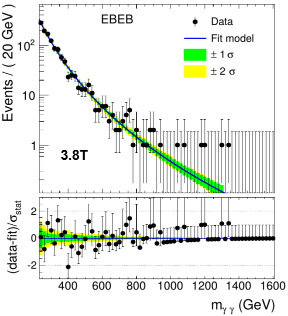
Introduction

Both ATLAS and CMS observe a diphoton excess at $m_{\gamma\gamma} \sim 750$ GeV with 3.9σ and 2.8σ local significance.





$$\sigma(pp \to X) \times \text{Br}(X \to \gamma\gamma) \sim 5 \text{ fb}.$$

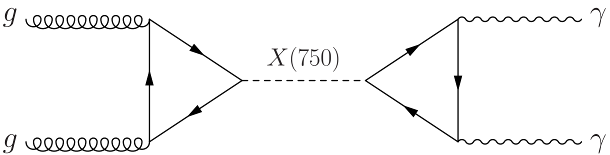
51st Rencontres de Moriond: M. Delmastro (ATLAS) & P. Musella (CMS)

Introduction

What the data tells us:

- A SM gauge singlet is preferred to avoid current constraints from other decay modes.
- gg (or alternatively $b\bar{b}$, $c\bar{c}$, $s\bar{s}$) is the preferred production mechanism to alleviate tension with 8 TeV results.
- Neither spin-0 nor spin-2 signal hypotheses have been completely ruled out.
- ATLAS data suggests a wide width, but combined results do not exclude a narrow width interpretation.

Introduction



- One might introduce a scalar singlet that couples to new vector fermions, generating loop level couplings to *gg* and $\gamma\gamma$.
- However, the large effective couplings may require large gauge or Yukawa couplings with nearby Landau poles.
- Theories of composite resonances can avoid this issue.

Introduction

Even in a composite theory, what explains the light fermion masses which accommodate a composite X near 750 GeV?

Ingredients for a **chiral composite psuedo-scalar** resonance:

- New fermions, vector-like under the SM, charged under a new confining $SU(N_b)$ with confinement scale Λ_b at $\mathcal{O}(TeV)$.
- Let these fermions be chiral under a new $U(1)'$ gauge symmetry, forbidding vector-like mass terms.
- Introduce a new scalar charged under the $U(1)'$ symmetry which develops a VEV, providing masses for the fermions.

The Model

GUT model:

	$SU(N_b)$	$SU(5)_{\mathrm{GUT}}$	$U(1)'$
$\left(\psi^{\mathrm{T}}_{1,L},\ \psi^{\mathrm{D}}_{1,L}\right)$	N_b	5	q_1
$\left(\psi^{\mathrm{T}}_{1,R},\ \psi^{\mathrm{D}}_{1,R}\right)$	N_b	5	q_2
$\left(\psi^{\mathrm{T}}_{2,L},\ \psi^{\mathrm{D}}_{2,L}\right)$	N_b	$\overline{5}$	$-q_1$
$\left(\psi^{\mathrm{T}}_{2,R},\ \psi^{\mathrm{D}}_{2,R}\right)$	N_b	$\overline{5}$	$-q_2$
φ	1	1	$q_1 - q_2$

The Model

$$\mathcal{L}_{\text{Yukawa}} \supset - y_1^{\mathrm{T}}\, \varphi\, \overline{\psi}{}_{1,L}^{\mathrm{T}}\, \psi_{1,R}^{\mathrm{T}} - y_1^{\mathrm{D}}\, \varphi\, \overline{\psi}{}_{1,L}^{\mathrm{D}}\, \psi_{1,R}^{\mathrm{D}} - y_2^{\mathrm{T}}\, \varphi^*\, \overline{\psi}{}_{2,L}^{\mathrm{T}}\, \psi_{2,R}^{\mathrm{T}} - y_2^{\mathrm{D}}\, \varphi^*\, \overline{\psi}{}_{2,L}^{\mathrm{D}}\, \psi_{2,R}^{\mathrm{D}} + \mathrm{h.c.}$$

- We will take $y_1^{\mathrm{T}} = y_2^{\mathrm{T}}$, $y_1^{\mathrm{D}} = y_2^{\mathrm{D}}$.

$$V(\varphi) = \overline{m}_\varphi^2\, \varphi^*\varphi + \lambda_\varphi\, (\varphi^*\varphi)^2\,, \quad \overline{m}_\varphi^2 = m_\varphi^2 + \lambda_{\varphi h} v_{\mathrm{EW}}^2/2\,.$$

- We will take $\overline{m}_\varphi^2 > 0$ and break the $U(1)'$ symmetry via confinement.
- This has the additional effect of tying the Z' boson mass to the confinement scale Λ_b, typically with $m_{Z'} < \Lambda_b$.

The Model

Spontaneous symmetry breaking:

$$SU(10)_L \times SU(10)_R \times U(1)_V \times U(1)_\varphi \to SU(10)_V \times U(1)_V \,.$$

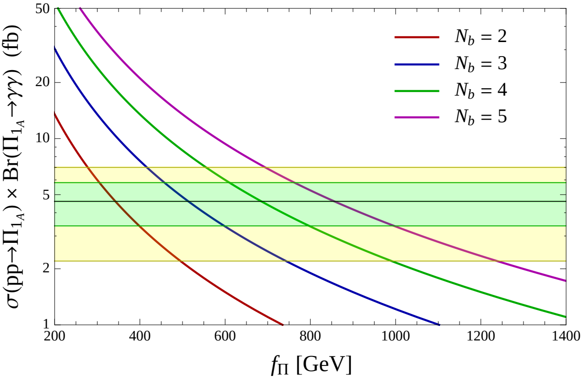
There are a total of 100 PNGBs, including four SM-singlet Π.

- Π_{1_A} will refer to the 750 GeV resonance candidate.
- One combination of singlet Π and φ will be eaten by the Z' boson.
- All singlet pions receive masses due to the explicit symmetry breaking of the Yukawa interactions.

Residual approximate parity symmetries further suppress the coupling of the other singlet PNGBs to SM gauge bosons.

PNGB Spectrum

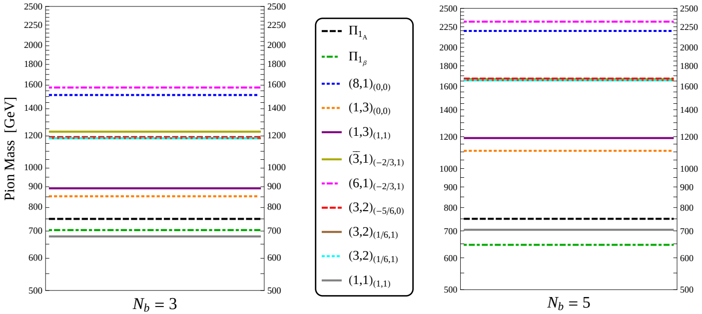
Identifying Π_{1_A} as the 750 GeV resonance fixes the pion decay constant, $f_\Pi \approx \Lambda_b/4\pi$, and sets the pion mass spectrum.



This sets the confinement scale at $5 - 10$ TeV, setting the scale for heavier states like the vector mesons and baryons.

PNGB Spectrum

Pion mass spectrum ($g' = 0.2$).



- $m_\varphi \sim 5 - 10$ TeV.
- $m_{Z'} \sim 200 - 400$ GeV.

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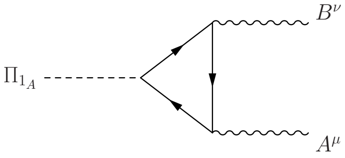
750 GeV decay modes:

$g' = 0.2,\ m_{Z'} = 294$ GeV,
$f_\Pi = 657$ GeV, $N_b = 4$.

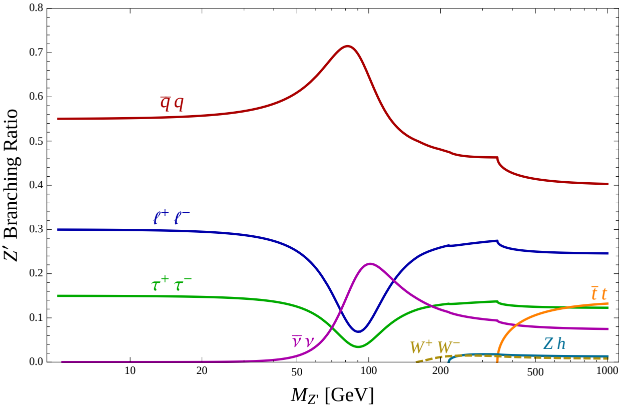


Mode	gg	$\gamma\gamma$	$Z\gamma$	ZZ	WW	$Z'\gamma$	$Z'Z$
Branching ratio	0.91	0.0045	0.0075	0.019	0.059	0.0025	0.0007
$\Gamma_{\rm tot}$	80 MeV $\left(\frac{N_b}{4}\right)^2 \left(\frac{657\ \mathrm{GeV}}{f_\Pi}\right)^2$						

- Decay modes satisfy current constraints.
- Model prefers narrow width.

Phenomenology

Z' decay modes:



- Larger leptonic branching fraction predicts excess in $\ell^+\ell^-\gamma$ final states relative to models with no Z'.

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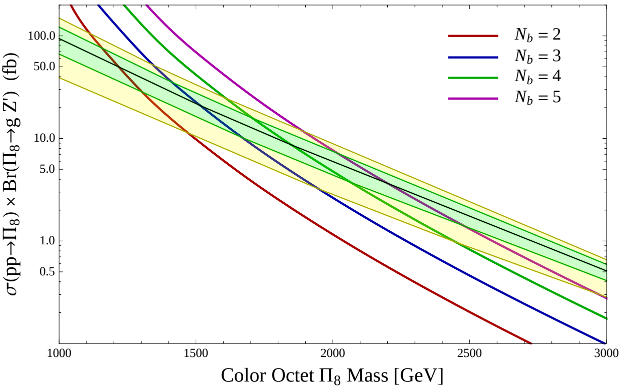
Colored pions:

- Color triplet/sextet pions could show up in future searches for stopped long-lived particles.
- Color octet pions should be produced, and have interesting decay modes such as $\Pi_8 \to Z' g$.



Conclusion

Chiral completions of the 750 GeV diphoton excess are both well-motivated and provide testable predictions.

- Chiral composite models can help to alleviate the coincidence of scales between the 750 GeV excess and the mass of new fermions by relating them both to a new strong confinement scale.
- These models predict a Z' boson with mass also related to (and lighter than) the confinement scale. This can open novel search channels.
- Color octet resonances could be within easy reach of the LHC, suggesting for instance dilepton + jet searches.

Thank you.