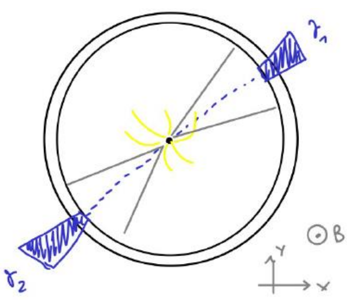
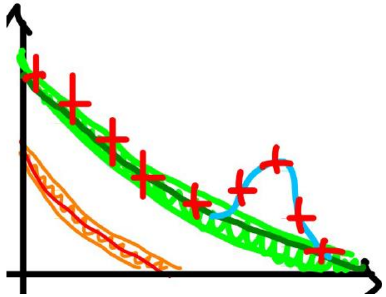
750GeV diphoton excess and some explanations

Jin Min Yang

ITP, Beijing / TUHEP, Tohoku





IPMU, Tokyo U

2016.3.9

Outline

1 Introduction

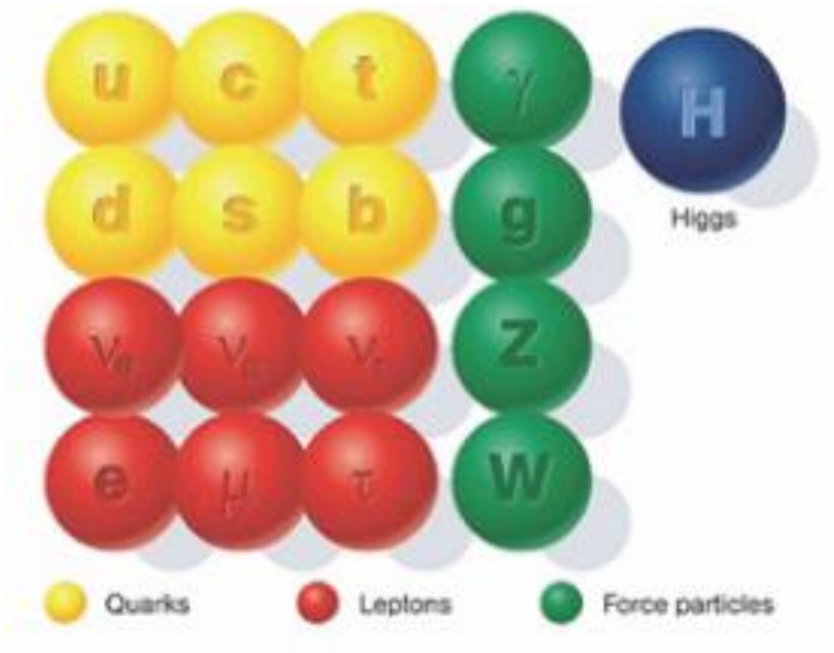
2 750GeV diphoton excess

3 Some explanations

4 Conclusion & outlook

1. Introduction

With the Higg boson, SM is complete



Reminds us of some words said 100 years ago:

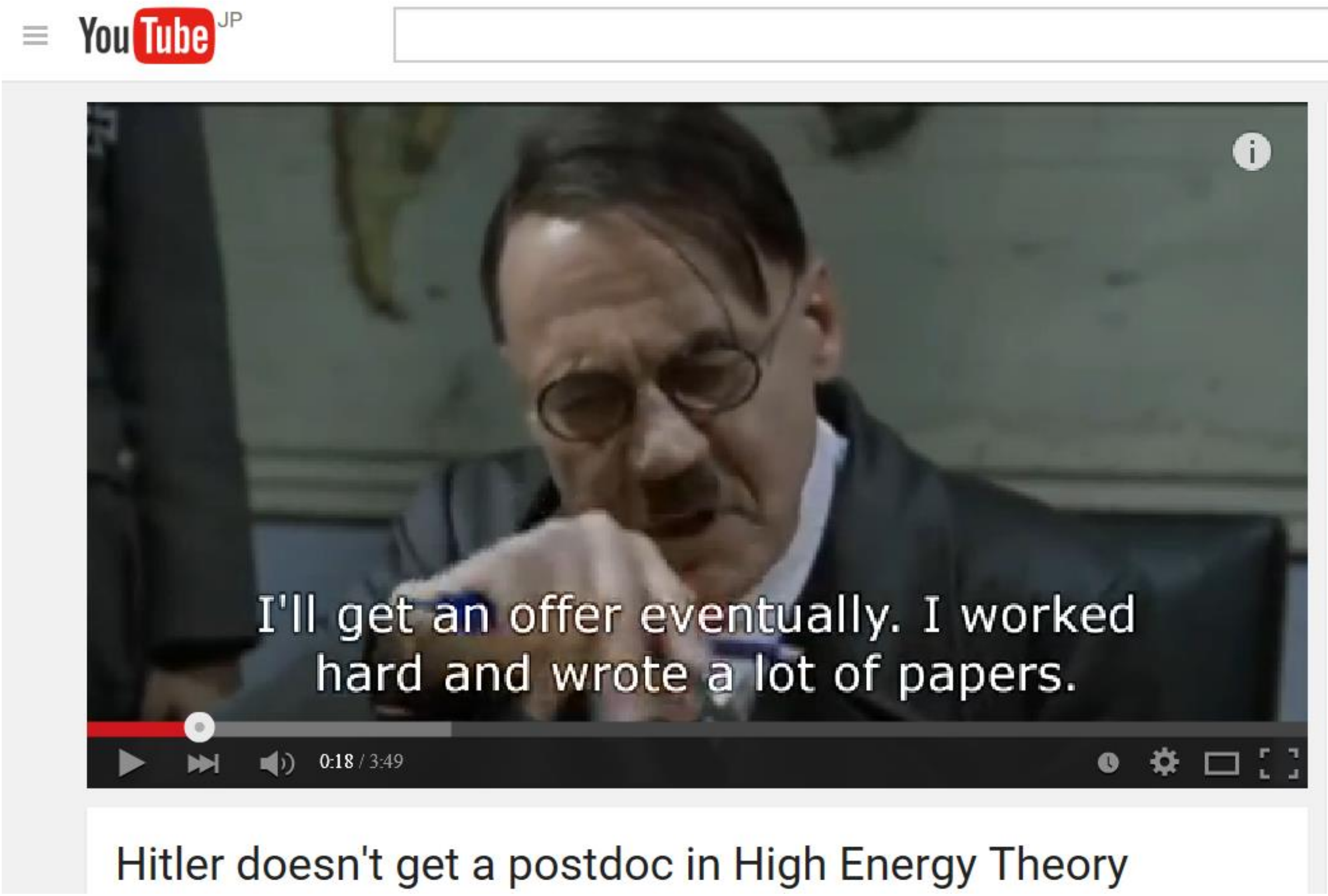
“The more important fundamental laws and facts of physical science have all been discovered”

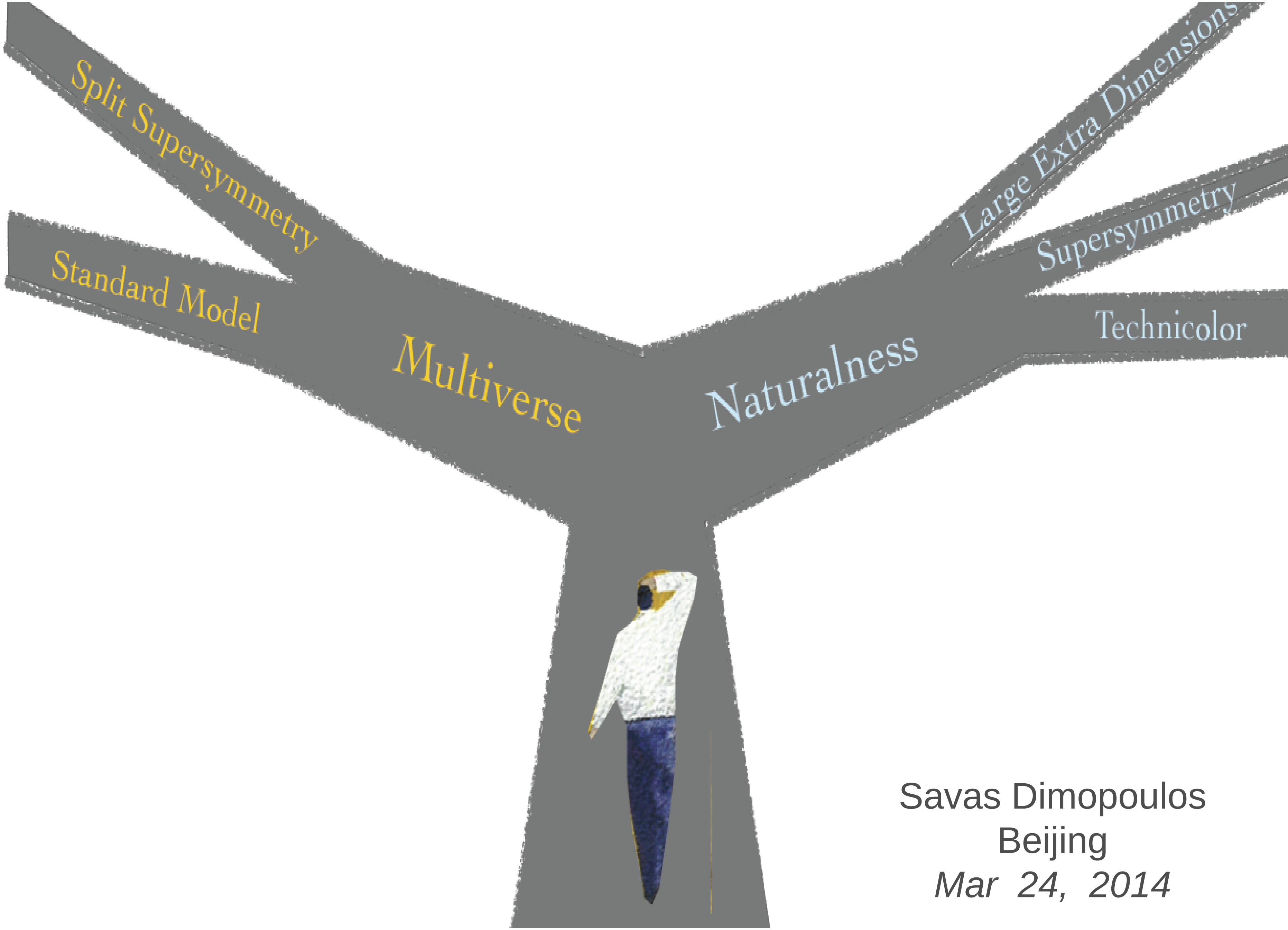
Albert Michelson (1894)

“There is nothing new to be discovered in physics now, all that remains is more and more precise measurement”

Lord Kelvin (1900)

HEP is at a critical moment





Savas Dimopoulos
Beijing
Mar 24, 2014

To move on from the SM, we need:

- **Theoretical crisis (fine-tuning, quantize gravity, ….)**
- **Phenomenological crisis (some hints….)**

We need new physics evidence from colliders !

2. 750GeV diphoton excess

Jester @Resonaances · 16小时

Don't miss: Tuesday 15h ATLAS and CMS present first 13 TeV results, including 750 GeV diphoton excess. Webcast here indico.cern.ch/event/442432/

23 6

Jester @Resonaances · 12月7日

Very nice popular article on gravitational waves searches, theguardian.com/commentisfree/...

2 6 查看摘要

Jester @Resonaances · 12月6日

First LHC 13 TeV rumor: modest excess in di-photon spectrum at 700 GeV in both ATLAS and CMS

37 24

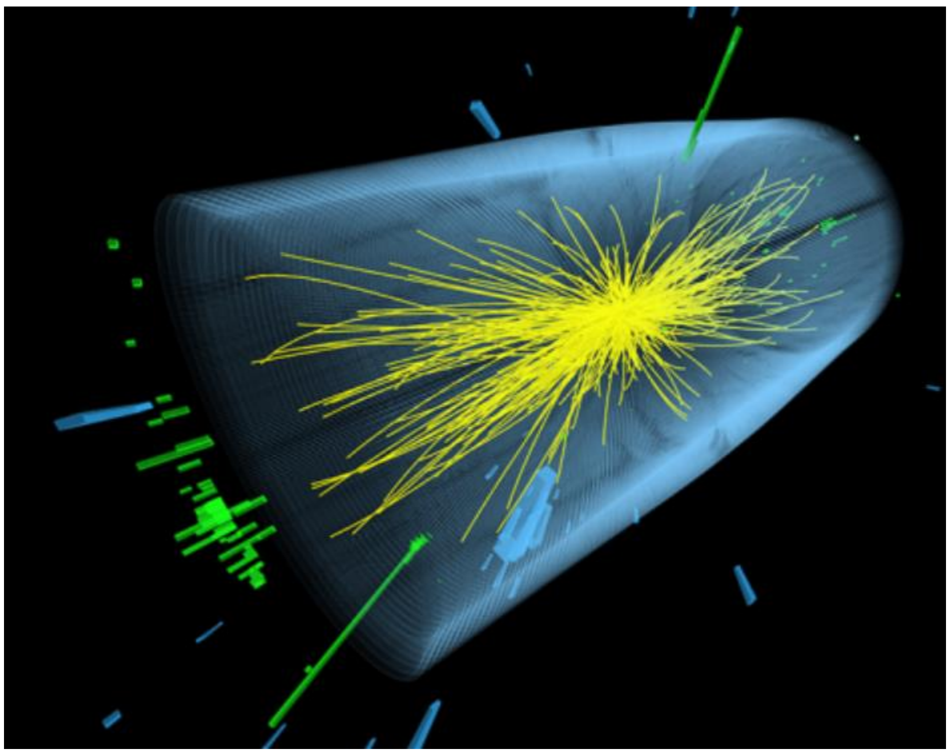
nature International weekly journal of science

NATURE | EDITORIAL

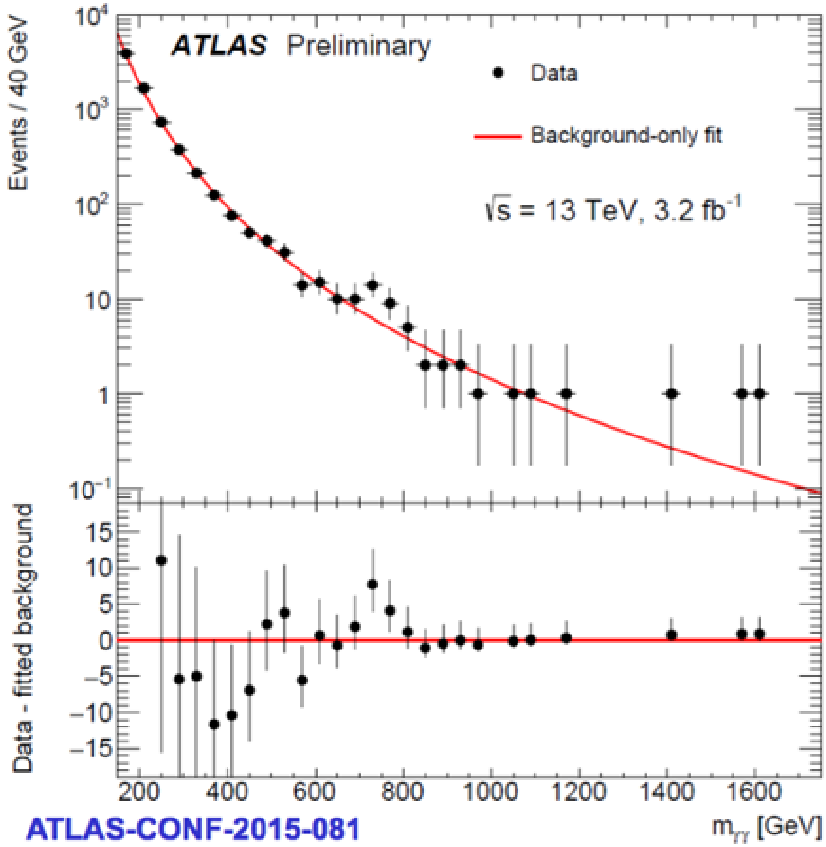
Who ordered that?

An unexpected data signal that could change everything has particle physicists salivating.

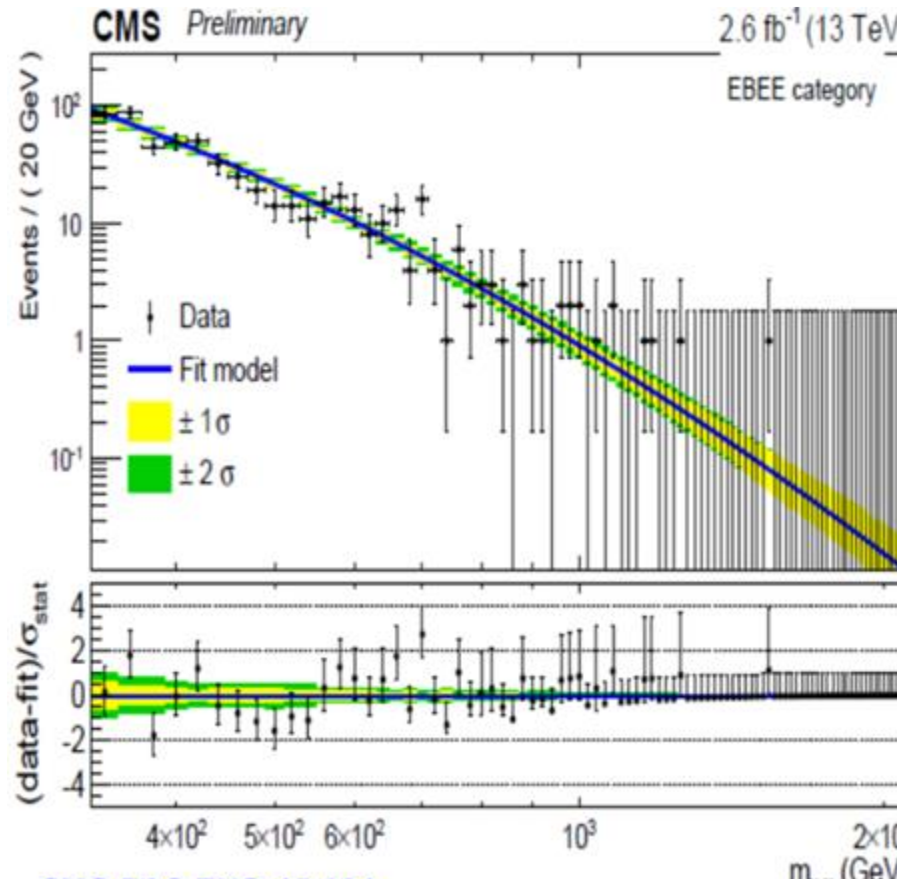
08 March 2016



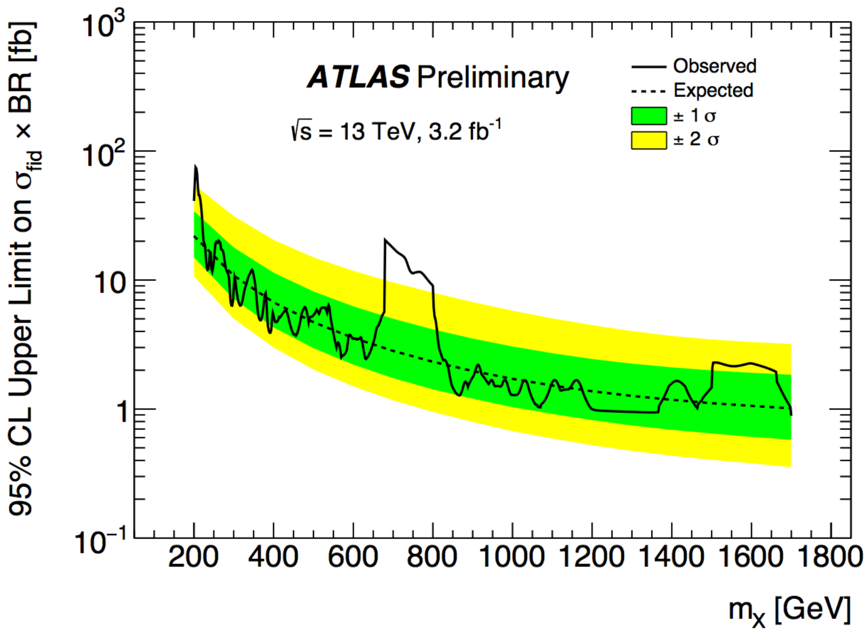
> "The LHC is now providing the opportunity of a lifetime to break entirely new ground."



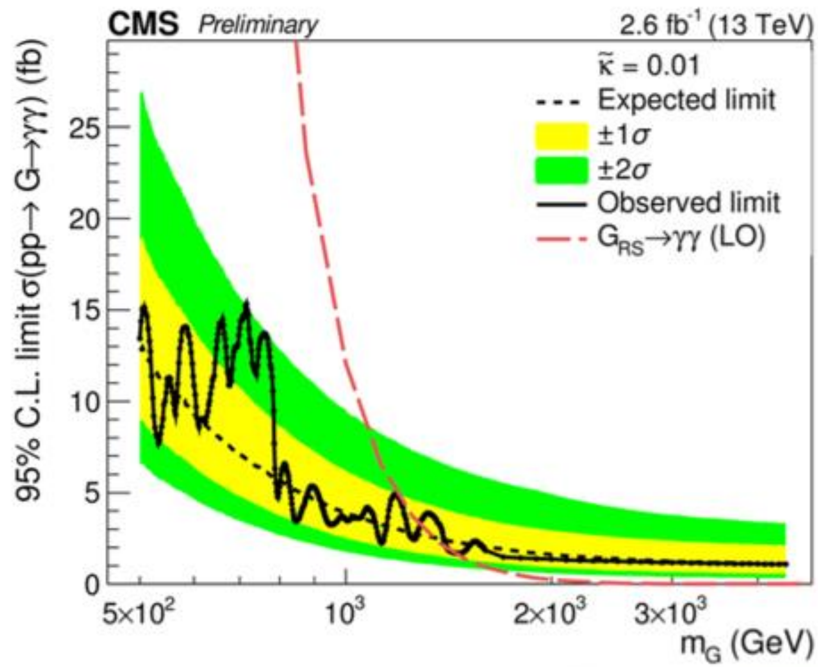
ATLAS-CONF-2015-081



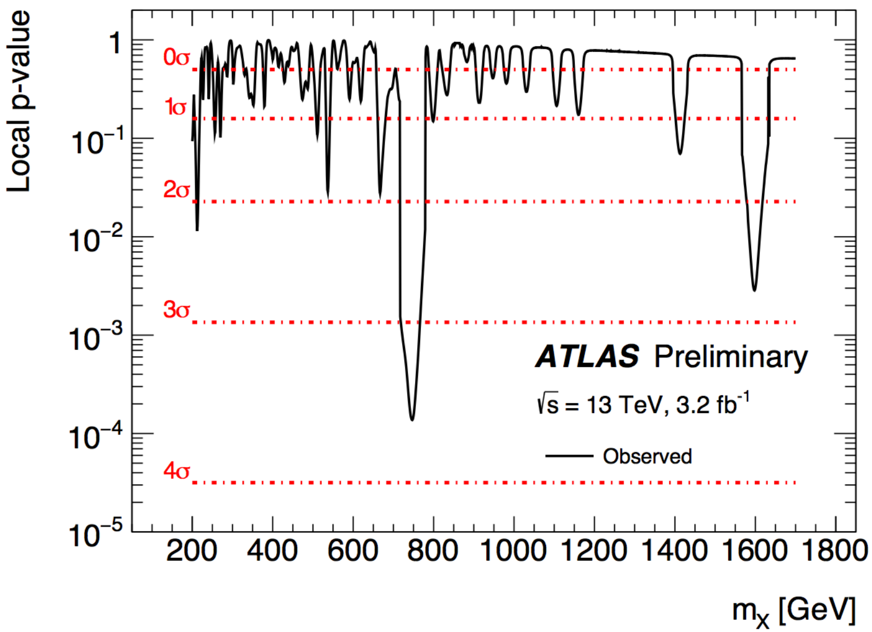
CMS-PAS-EXO-15-004



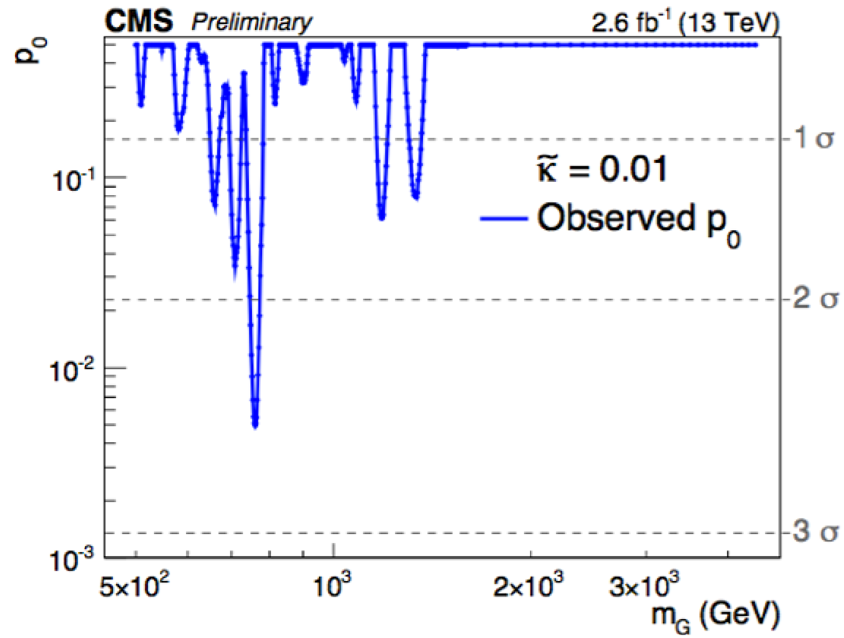
ATLAS Preliminary
√s = 13 TeV, 3.2 fb-1
Observed
Expected
± 1 σ
± 2 σ
95% CL Upper Limit on σfid × BR [fb]
mX [GeV]



CMS Preliminary
2.6 fb-1 (13 TeV)
κ̃ = 0.01
Expected limit
±1σ
±2σ
Observed limit
GRS→γγ (LO)
95% C.L. limit σ(pp→ G→γγ) (fb)
mG (GeV)



Local p-value
ATLAS Preliminary
$\sqrt{s}$ = 13 TeV, 3.2 fb^{-1}
Observed
0σ
1σ
2σ
3σ
4σ
m_X [GeV]



CMS Preliminary
2.6 fb^{-1} (13 TeV)
p_0
$\tilde{\kappa}$ = 0.01
Observed p_0
1 σ
2 σ
3 σ
m_G (GeV)

ATLAS

Bin[GeV]	650	690	730	770	810	850
N_{events}	10	10	14	9	5	2
$N_{\mathrm{background}}$	11.0	8.2	6.3	5.0	3.9	3.1

CMS

Bin[GeV]	700	720	740	760	780	800
N_{events} (EBEB)	3	3	4	5	1	1
$N_{\mathrm{background}}$ (EBEB)	2.7	2.5	2.1	1.9	1.6	1.5
N_{events} (EBEE)	16	4	1	6	2	3
$N_{\mathrm{background}}$ (EBEE)	5.2	4.6	4.0	3.5	3.1	2.8

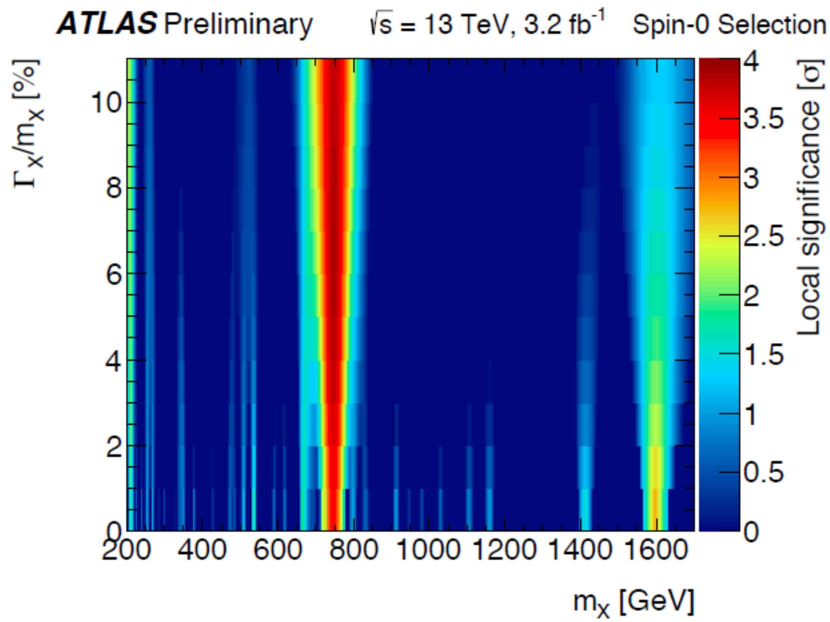
1512.04933 (R. Franceschini et al.)

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

1512.04929 (Buttazzo, Greljo, Marzocca)

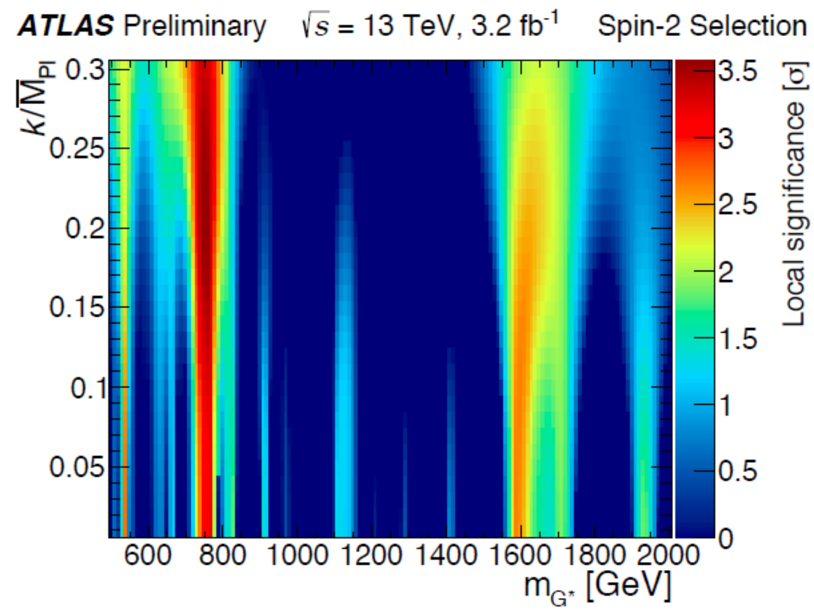
$$\sigma(pp \to \gamma\gamma) = \begin{cases} 0.63 \pm 0.25\ \text{fb} & \text{CMS} & \text{at}\ \sqrt{s} = 8 & \text{TeV}, \\ 0.46 \pm 0.85\ \text{fb} & \text{ATLAS} & \text{at}\ \sqrt{s} = 8 & \text{TeV}, \\ 5.6 \pm 2.4\ \text{fb} & \text{CMS} & \text{at}\ \sqrt{s} = 13 & \text{TeV}, \\ 6.2^{+2.4}_{-2.0}\ \text{fb} & \text{ATLAS} & \text{at}\ \sqrt{s} = 13 & \text{TeV}. \end{cases}$$

SPIN-0 ANALYSIS



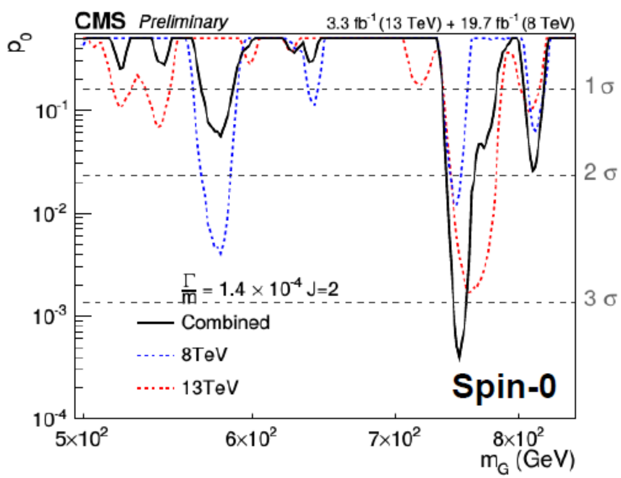
- Largest deviation from B-only hypothesis
  - ✓ m_X ~ 750 GeV, Γ_X ~ 45 GeV (6%)
  - ✓ Local Z = **3.9 σ**
  - ✓ Global Z = **2.0 σ**

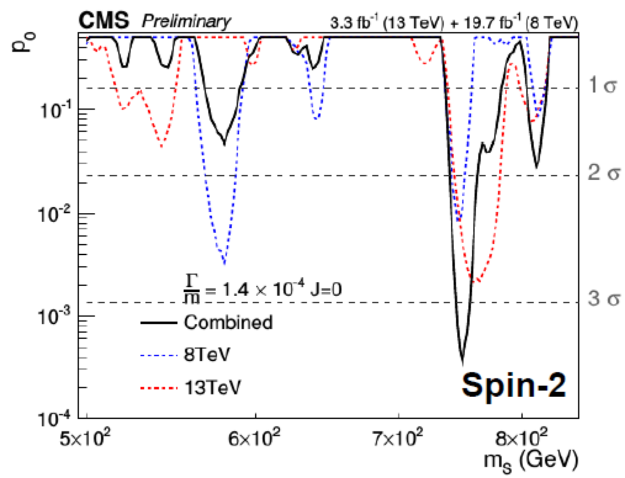
SPIN-2 ANALYSIS



- Largest deviation from B-only hypothesis
  - ✓ m_G ~ 750 GeV, κ/M_{Pl} ~ 0.2 (Γ_G ~ 7% m_G)
  - ✓ Local Z = **3.6 σ**
  - ✓ Global Z = **1.8 σ**

- Largest excess observed at **m_X = 750GeV** and for **narrow** width.
  - **Local** significance: **3.4σ**
  - Taking into account mass range 500-3500GeV (and all signal hypotheses), "**global**" significance becomes **1.6σ**





- **Modest excess** of events observed at **m_X = 750(760)GeV** for the 8+13TeV(13TeV) dataset.
- **Local** significance is **3.4(2.9)σ**, **reduced to 1.6(<1)σ** after accounting for look-elsewhere-effect.

Summary on 750 diphoton

Cross section: 5-10 fb

Events: $\sim$10

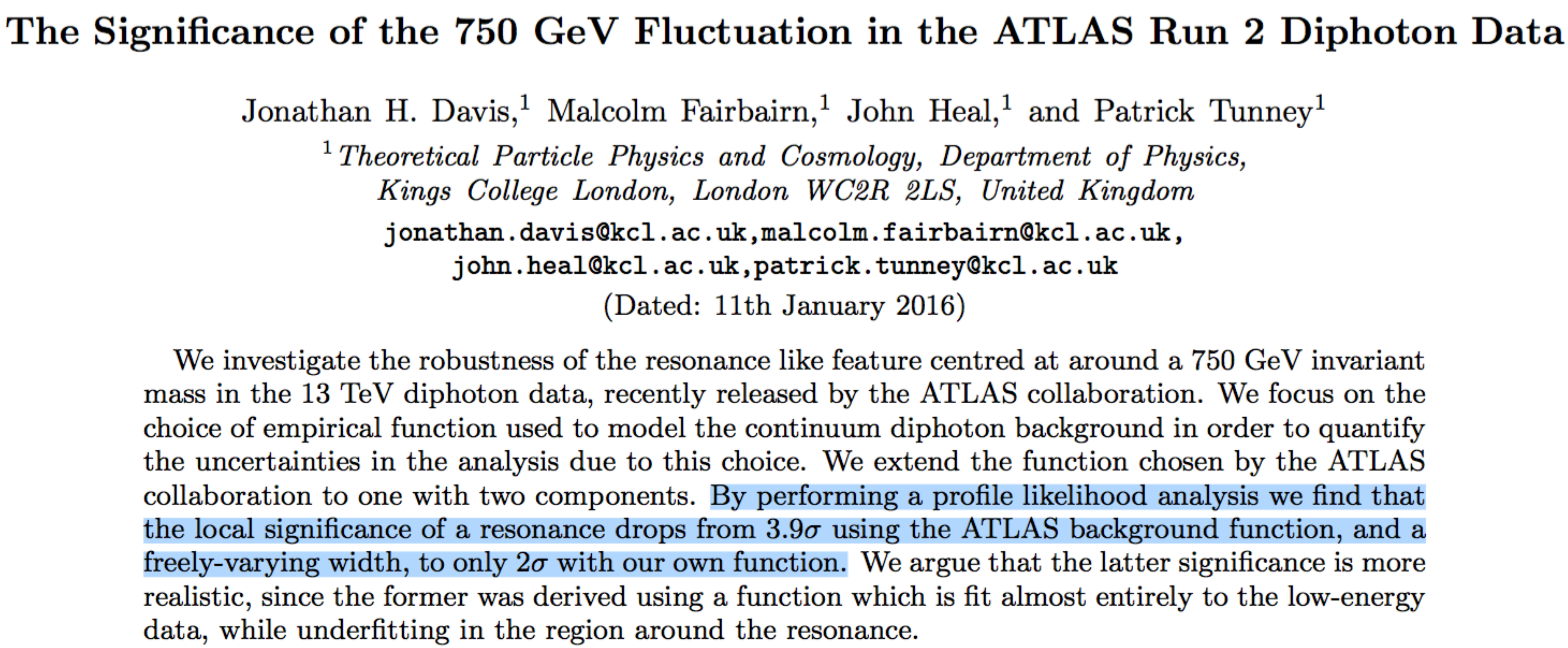
Significance (local)
- ATLAS : 3.9σ
- CMS : 3.4σ

Width
- ATLAS : $\sim 40\ \mathrm{GeV}$
- CMS : narrow

However, we note:

"The more extraordinary a claim, the stronger the proof required to support it" --Laplace

(1) Background analysis is important



The Significance of the 750 GeV Fluctuation in the ATLAS Run 2 Diphoton Data

Jonathan H. Davis,[1] Malcolm Fairbairn,[1] John Heal,[1] and Patrick Tunney[1]

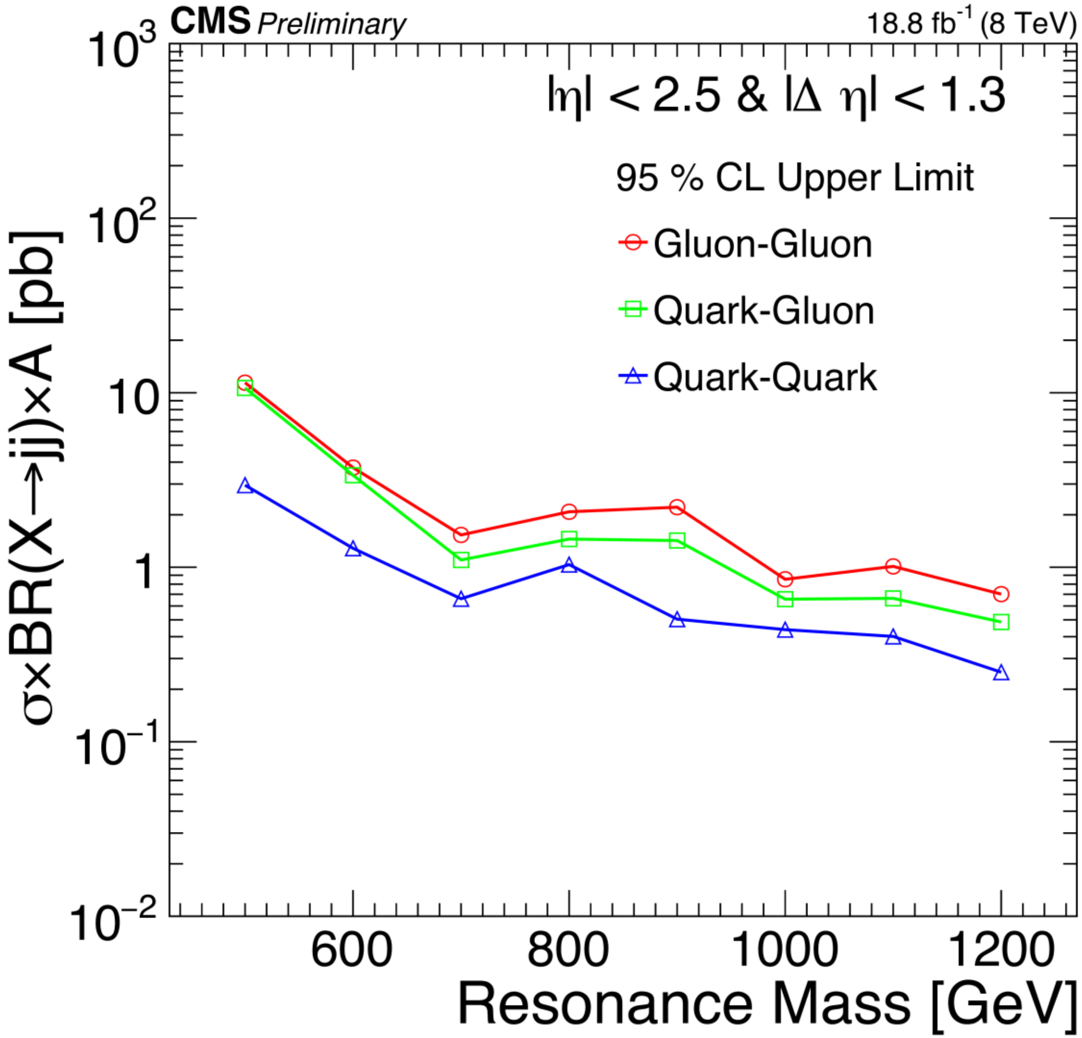
[1] *Theoretical Particle Physics and Cosmology, Department of Physics, Kings College London, London WC2R 2LS, United Kingdom*

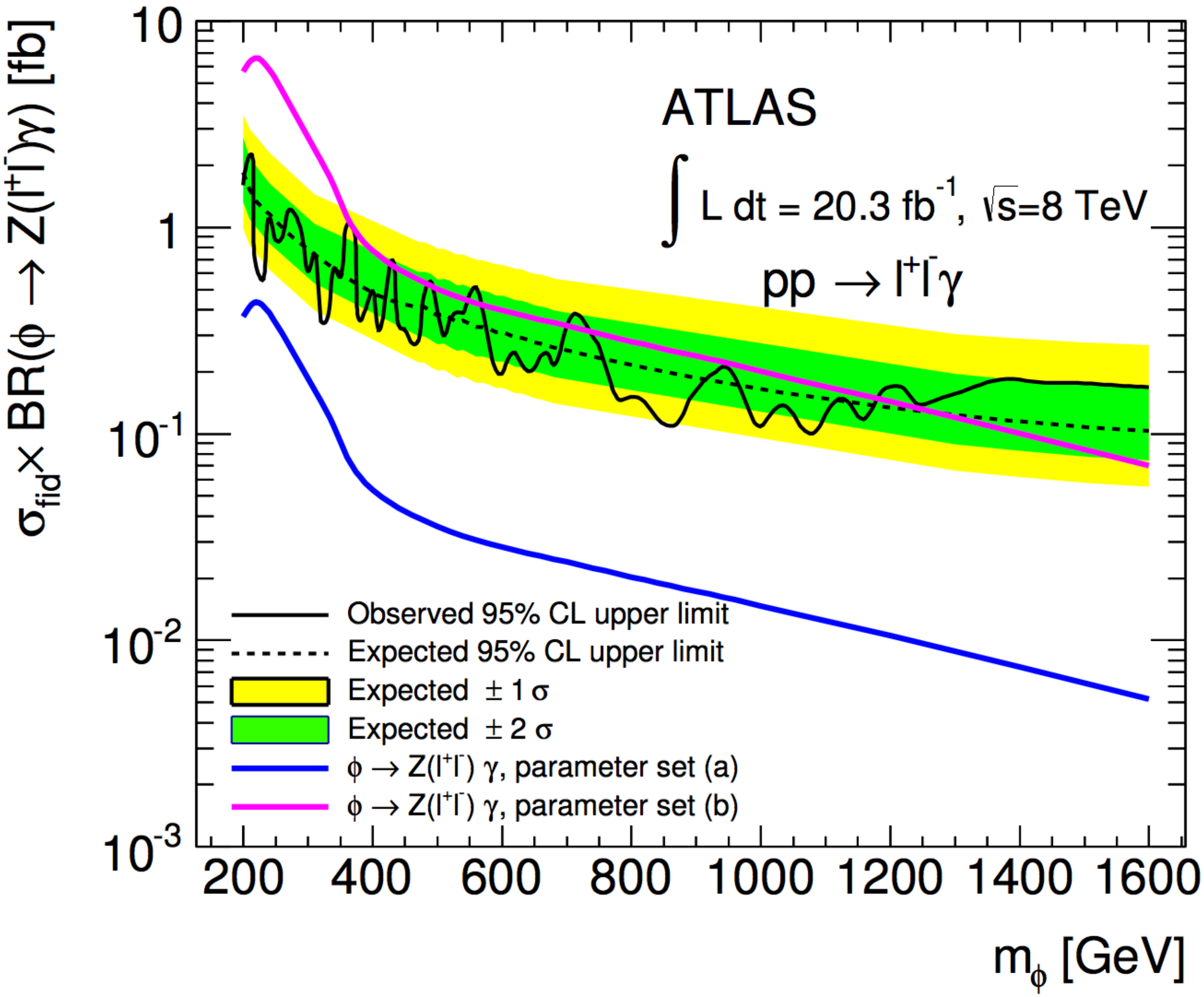
jonathan.davis@kcl.ac.uk, malcolm.fairbairn@kcl.ac.uk, john.heal@kcl.ac.uk, patrick.tunney@kcl.ac.uk

(Dated: 11th January 2016)

We investigate the robustness of the resonance like feature centred at around a 750 GeV invariant mass in the 13 TeV diphoton data, recently released by the ATLAS collaboration. We focus on the choice of empirical function used to model the continuum diphoton background in order to quantify the uncertainties in the analysis due to this choice. We extend the function chosen by the ATLAS collaboration to one with two components. By performing a profile likelihood analysis we find that the local significance of a resonance drops from 3.9σ using the ATLAS background function, and a freely-varying width, to only 2σ with our own function. We argue that the latter significance is more realistic, since the former was derived using a function which is fit almost entirely to the low-energy data, while underfitting in the region around the resonance.

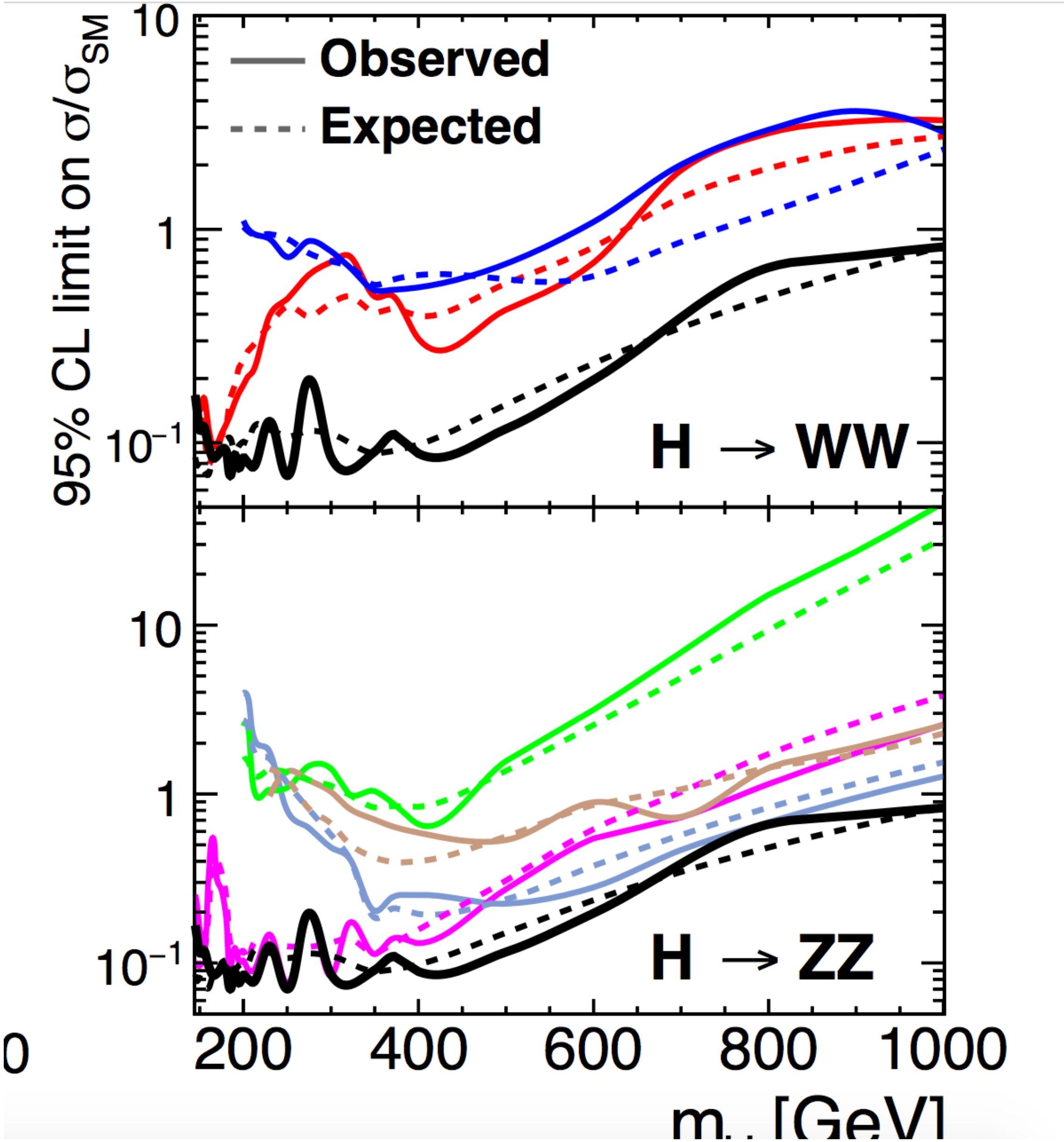
(2) No-excesses for dijet, diboson, top pair, …



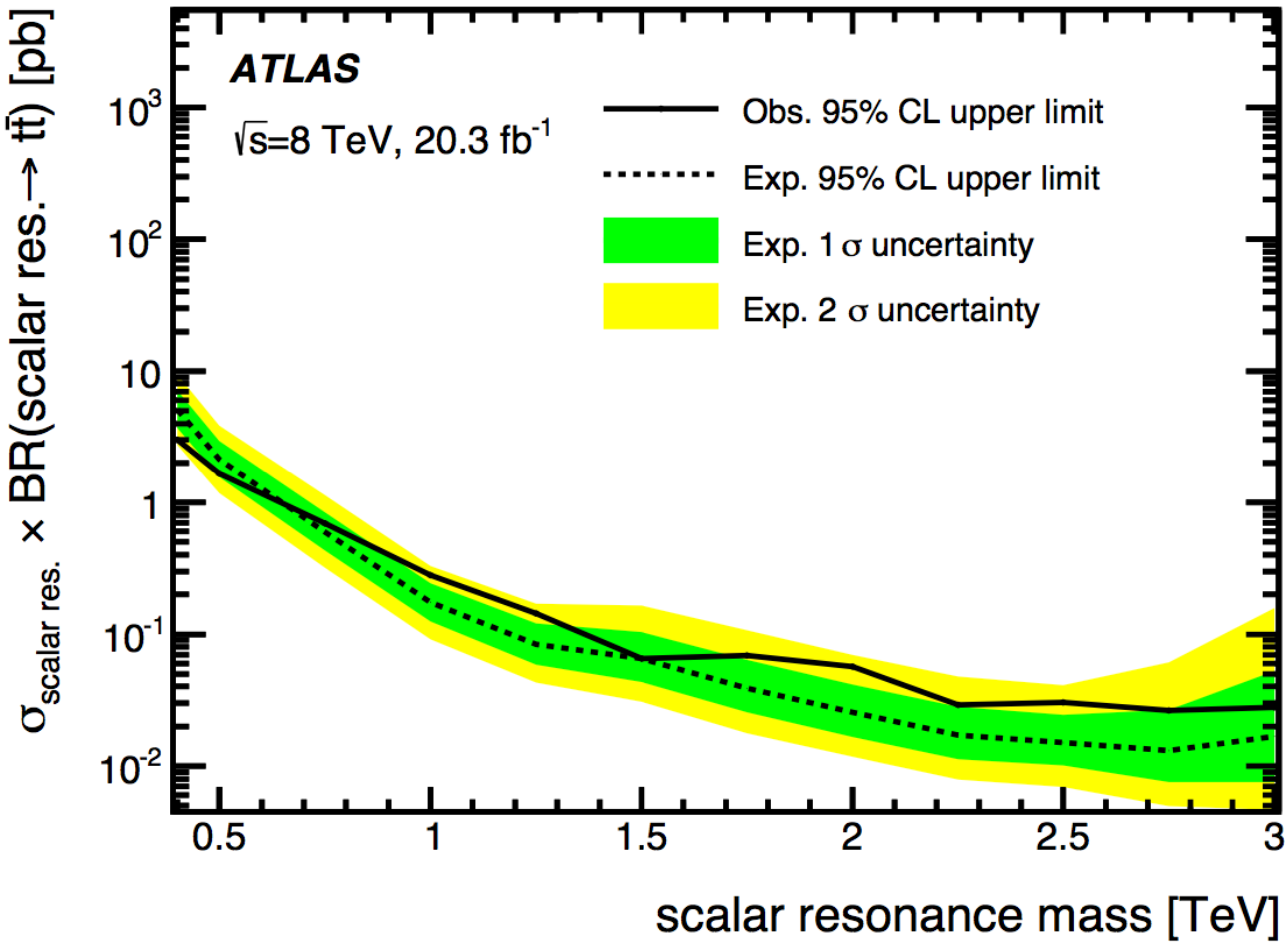


ATLAS
$\int L\,dt = 20.3\ \mathrm{fb}^{-1}$, $\sqrt{s}$=8 TeV
$pp \rightarrow l^+l^-\gamma$
$\sigma_{fid} \times BR(\phi \rightarrow Z(l^+l^-)\gamma)$ [fb]
m_ϕ [GeV]
10
1
10^{-1}
10^{-2}
10^{-3}
200
400
600
800
1000
1200
1400
1600
Observed 95% CL upper limit
Expected 95% CL upper limit
Expected $\pm 1\sigma$
Expected $\pm 2\sigma$
$\phi \rightarrow Z(l^+l^-)\gamma$, parameter set (a)
$\phi \rightarrow Z(l^+l^-)\gamma$, parameter set (b)

(c)



95% CL limit on σ/σ_SM
Observed
Expected
H → WW
H → ZZ
10
1
10^{−1}
200
400
600
800
1000
m_H [GeV]



(d) Scalar resonance, resolved and boosted combination.

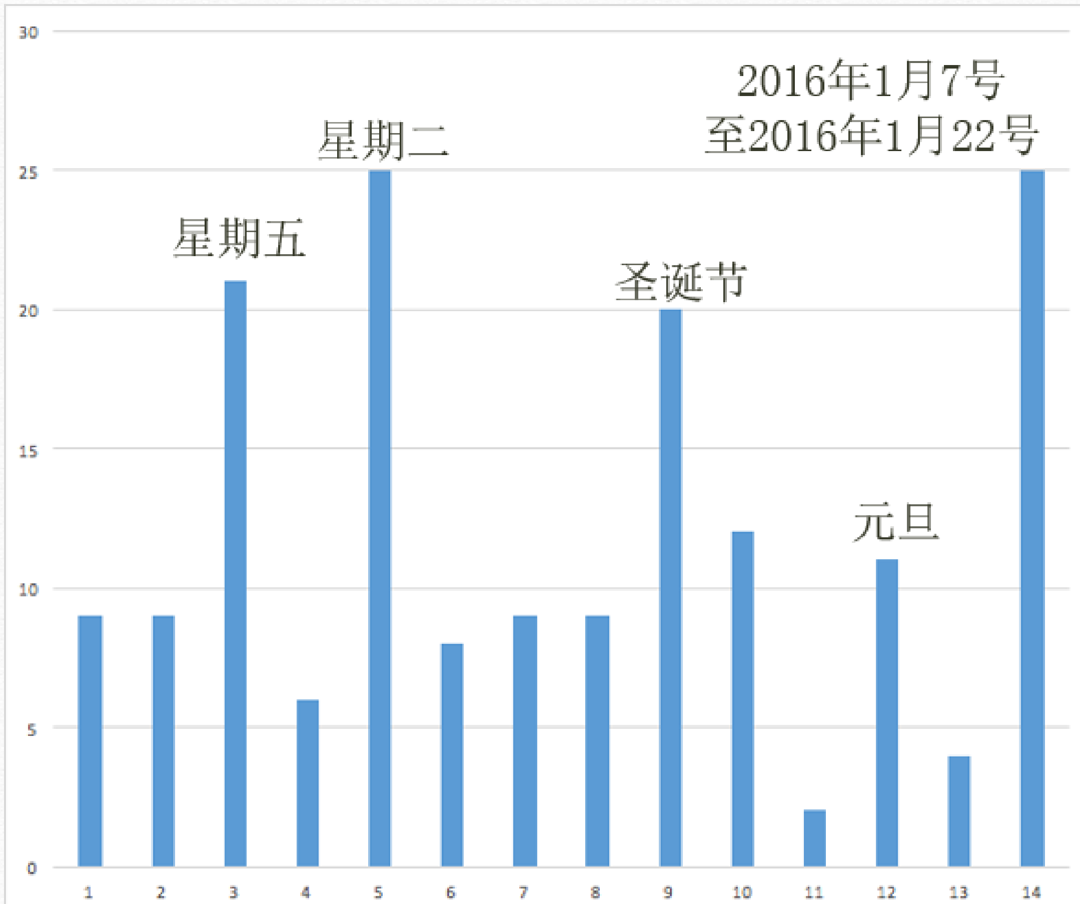
Anyway,

we theorists are

“allowed to be a little excited”

F. Gianotti, talk to CERN staff, Jan 18, 2016

3. Some explanations



38天共170篇

Studies based on Complete models

My apologies if I missed your paper here

Strong dynamics (9+)

Harigay, Nomura, 1512.04850;Nakai, Sato, Tobioka, 1512.04924; Molinaro et al, 1512.05334; Matsuzaki, Yamawaki, 1512.05564; No, Sanz, Setford, 1512.05700; Curtin, Verhaarer, 1512.05735; Bian, Chen, Liu, Shu, 1512.05759; Liao, Zheng, 1512.06741; Cline, Liu, 1512.06827; Belyaev et al, 1512.07242; Craig, et al, 1512.07733

Axion:

Higaki, Jeong, Kitajima, Takahashi, 1512.05295
Chiang, Fukuda, Ibe, Yanagida, 1602.07909

SUSY or SUSY motivated (13+)

Dutta, Gao, Ghosh, Gogoladze, Li, 1512.05439; Bellazzini et al, 1512.05330; Peterson, Torre, 1512.055333; Demidov, Gorbunov, 1512.05723; Gabrielli, et al, 1512.05961; Carpenter et al, 1512.06107;Ding, Huang, Li, Zhu, 1512.06560; Luo, Wang, Xu, Zhang, Zhu, 1512.06670; Feng, Li, Zhang, Zhao, 1512.06696; Wang, Wu, Yang, Zhang, 1512.06715; Chakraborty, et al, 1512.07527;Allanach, et al, 1512.07645; Cases et al, 1512.07895; Hall et al, 1512.07904

Han, Yanagida, Yokozaki,1602.04204

2HDB (7+)

Angelescu, et al, 1512.04921; Becirevic et al, 1512.05623; Han, Wang, 1512.06587; Huang, Tsai, Yuan, 1512.07268; Moretti, Yagyu, 1512.07462; Badziak, 1512.07497; Altmannshofer, 1512.07616

Top-seesaw

Kobakhidze, Wang, Wu, Yang, Zhang, 1512.05585

Manohar-Wise Model

Cao, Han, Shang, Wu, Yang, Zhang, 1512.06728

Extra dimension (6+)

Cox et al, 1512.05618; Ahmed et al, 1512.05771; Arun, Saha, 1512.06335; Barchan et al, 1512.06674; Heckman, 1512.06773; Cvetic et al, 1512.07622

EFT (10+)

Ito, Moroi, Takaesu, 1601.01144
Bae, Endo, Hamaguchi,Moroi, …

Gauge Extension (10+)

Wide or Narrow? The Phenomenology of 750 GeV Diphotons

Matthew R. Buckley[1]

[1] *Department of Physics and Astronomy, Rutgers University, Piscataway, NJ 08854, USA*

I perform a combined analysis of the ATLAS and CMS diphoton data, using both Run-I and Run-II results. I find combining the ATLAS and CMS results from Run-II increases the statistical significance of the reported 750 GeV anomaly, assuming a spin-0 mediator coupling to gluons or heavy quarks with a width much smaller than the detector resolution. This significance does not decrease when including the 8 TeV data. A spin-2 mediator is disfavored compared to the spin-0 case. A spin-0 resonance with a width of 45 GeV is mildly disfavored when considering only 13 TeV results. The cross section required to fit the ATLAS anomaly is in tension with the aggregate data, all of which prefers a smaller value. The best fit for all models I consider is a 750 GeV spin-0 mediator coupling to gluons with a cross section of 4 fb at 13 TeV (assuming narrow width) or 10 fb (assuming $\Gamma = 45$ GeV).

General remarks:

- This 750 resonance better be produced via gg fusion than $\bar{q}q$ annihilation since no $\gamma\gamma$ execess at 8 TeV LHC (PDF) 2.5 4.7
- Spin-0 scalar is favored over spin-2 particle because spin-2 particle usually couples universally to SM particles (no other excess of SM particles)
- Spin-0 scalar is favored not to couple at tree-level with quarks (because of dijet, $\bar{t}t)$ or WW, ZZ (no such excesses)
- Spin-0 scalar is then favored to be a SM singlet, coupling with gg and $\gamma\gamma$ through loops
- In the loops Sgg and $S\gamma\gamma$, the particles must be some colored and charged new particles (vector-like fermions, bosons) . These particles better be SU(2) singlets (no WW, ZZ excess)

This 750 resonance is not so welcome by SUSY

BBC News

Nov 19, 2012

SUSY may not be dead, but these latest results have certainly put it into hospital

Our own works:

We are maniacs of 750

- An extension of two-Higgs-doublet model and excesses of 750 GeV diphoton, muon g-2 and $h \to \mu\tau$, X. Han, L. Wang, JMY, 1601.04954
- Explaining 750 GeV diphoton excess from top/bottom partner cascade decay in 2HDM extension, X. Han, L. Wang, L. Wu, JMY, M. Zhang, 1601.00534
- Interpreting 750 GeV Diphoton Resonance in NMSSM with Vector-like Particles F. Wang, W. Wang, L. Wu, JMY, M. Zhang, 1512.08434
- Interpreting the 750 GeV diphoton excess by the singlet extension of Manohar-Wise Model, J. Cao, C. Han, L. Shang, W. Su, JMY, Y. Zhang, 1512.06728
- 750 GeV diphoton resonance, 125 GeV Higgs and muon g-2 anomaly in deflected AMSB, F. Wang, L. Wu, JMY, M. Zhang, 1512.06715
- 750 GeV diphoton resonance explained as a heavy scalar in top-seesaw, A. Kobakhidze, F. Wang, L. Wu, JMY, M. Zhang, 1512.05585

[1] 750 as a heavy scalar in top/bottom seesaw

A. Kobakhidze, F. Wang, L. Wu, JMY, M. Zhang, 1512.05585

topcolor, top-condensation, top-seesaw

If top quark feels a new strong interaction (topcolor), we may have a top-quark condensate

$$\langle \bar{t}t \rangle \neq 0$$

Use it for EWSB: topcolor scale is too high or top mass is too large

- top seesaw

  a heavy partner quark T forms the condensate; the top quark mass eigenstate that we observe is a seesaw mixture between T and top quark gauge eigenstate

Top and bottom seesaw from SUSY strong dynamics

C. Balazs, T. Li, F. Wang, JMY, 1208.3767

We propose a top and bottom seesaw model with partial composite top and bottom quarks. Such composite quarks and topcolor gauge bosons are bound states from SUSY strong dynamics by Seiberg duality. SUSY breaking also induces the breaking of topcolor into the QCD gauge coupling. **The low energy description of our model reduces to a complete non-minimal extension of top seesaw model with bottom seesaw.** The non-minimal nature is crucial for Higgs mixings and the appearance of light Higgs fields. The Higgs fields are bound states of partial composite particles with the lightest one **compatible with a 125 GeV Higgs** field which was discovered at the LHC.

Top partner

$$\chi_L, \chi_R : (\ 3,\ 1,\ 2/3)\ ,$$

Bottom partner

$$\omega_L, \omega_R : (\ 3,\ 1, -1/3)$$

Top seesaw

$$\begin{pmatrix} \bar{t}_L & \bar{\chi}_L \end{pmatrix} \begin{pmatrix} 0 & \mu_1 \\ m_{t\chi} & m_\chi \end{pmatrix} \begin{pmatrix} t_R \\ \chi_R \end{pmatrix}$$

Bottom seesaw

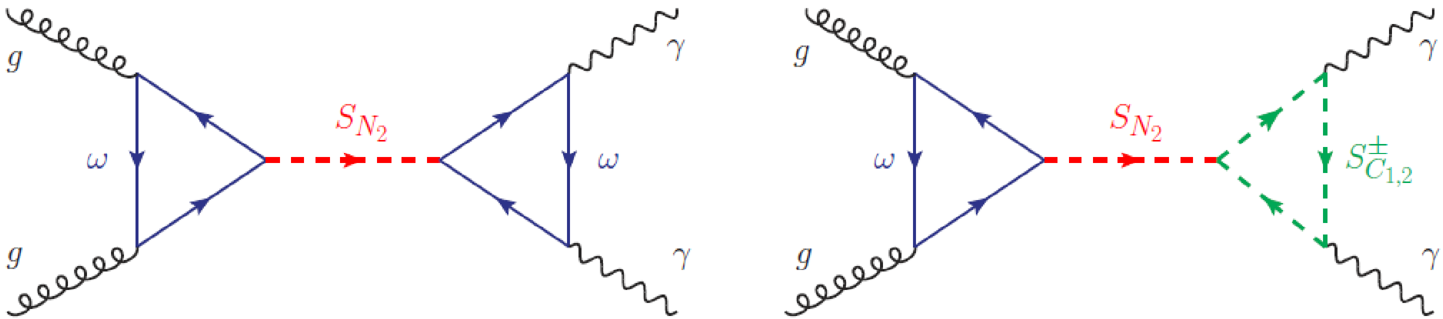
$$\begin{pmatrix} \bar{b}_L & \bar{\omega}_L \end{pmatrix} \begin{pmatrix} 0 & \mu_2 \\ m_{b\omega} & m_\omega \end{pmatrix} \begin{pmatrix} b_R \\ \omega_R \end{pmatrix}$$

$$\mathcal{L}_\Lambda \supseteq \quad [m_{0\chi}\bar{\chi}_L\chi_R + m_{0\omega}\bar{\omega}_L\omega_R + h.c.] + G_\chi(\bar{\chi}_L\chi_R)(\bar{\chi}_R\chi_L) + G_\omega(\bar{\omega}_L\omega_R)(\bar{\omega}_R\omega_L)$$
$$+G_{\chi\omega}(\bar{\omega}_L\chi_R)(\bar{\chi}_R\omega_L) + G_{\omega\chi}(\bar{\chi}_L\omega_R)(\bar{\omega}_R\chi_L).$$

$$S_{N_1} \sim \bar{\chi}_L\chi_R, \quad S_{N_2} \sim \bar{\omega}_L\omega_R,$$
$$S^+_{C_1} \sim \bar{\omega}_L\chi_R, \quad S^+_{C_2} \sim \bar{\omega}_R\chi_L, \quad S^-_{C_1} \sim \bar{\chi}_L\omega_R, \quad S^-_{C_2} \sim \bar{\chi}_R\omega_L$$

$$\mathcal{L}_{\mu<\Lambda} \supseteq \quad y_{N_1}S_{N_1}\bar{\chi}_L\chi_R + y_{N_2}S_{N_2}\bar{\omega}_L\omega_R + y_{C_1}S^+_{C_1}\bar{\omega}_L\chi_R + y_{C_2}S^+_{C_2}\bar{\omega}_R\chi_L$$
$$+m_{0\chi}\bar{\chi}_L\chi_R + m_{0\omega}\bar{\omega}_L\omega_R + h.c. + V(S_{N_i}, S^\pm_{C_i}),$$

$$V(S_{N_i}, S^\pm_{C_i}) \supseteq \sum_{i=1}^{2}\frac{1}{2}m^2_{S_{N_i}}S^2_{N_i} + \sum_{i=1}^{2}\frac{1}{2}m^2_{S^\pm_{C_i}}S^+_{C_i}S^-_{C_i} + \sum_{i,j=1}^{2}\lambda_{C_{ij}}\mu' S_{N_i}S^+_{C_j}S^-_{C_j}$$



$$gg \to S_{N_2}(750\ \mathrm{GeV}) \to \gamma\gamma$$

Constraints:

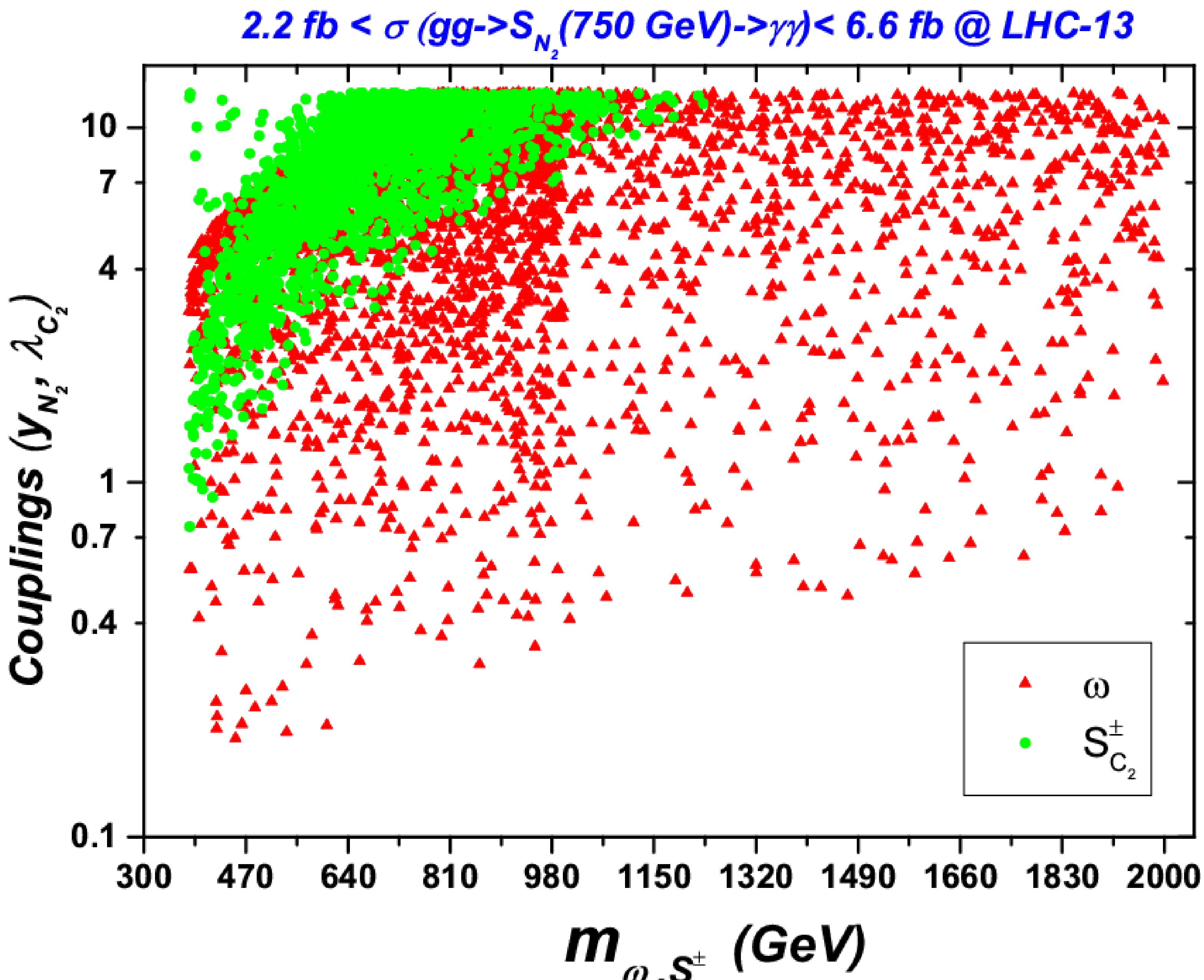
$$\sigma(pp \to X)_{8\,\mathrm{TeV}} \times Br(X \to gg) < 1.8\ \mathrm{pb}$$

$$\sigma(pp \to X)_{8\,\mathrm{TeV}} \times Br(X \to ZZ) < 22\,\mathrm{fb}\,_{(\mathrm{ATLAS})}\,,\ \ 27\,\mathrm{fb}\,_{(\mathrm{CMS})}$$

$$\sigma(pp \to X)_{8\,\mathrm{TeV}} \times Br(X \to t\bar{t}) < 0.7\,\mathrm{pb}\,_{(\mathrm{ATLAS})}\,,\ \ 0.6\,\mathrm{pb}\,_{(\mathrm{CMS})}$$

$$\sigma(pp \to X)_{8\,\mathrm{TeV}} \times Br(X \to \gamma\gamma) < 2.2\,\mathrm{fb}\,_{(\mathrm{ATLAS})}\,,\ \ 1.3\,\mathrm{fb}\,_{(\mathrm{CMS})}$$

$$\sigma(pp \to X)_{8\,\mathrm{TeV}} \times Br(X \to Z\gamma) < 4\,\mathrm{fb}\,_{(\mathrm{ATLAS})}$$



2.2 fb < σ (gg->S_N2(750 GeV)->γγ)< 6.6 fb @ LHC-13
Couplings (y_N2, λ_C2)
m_ω, S± (GeV)
ω
S±_C2
0.1
0.4
0.7
1
4
7
10
300
470
640
810
980
1150
1320
1490
1660
1830
2000

[2] 750 GeV diphoton, 125 Higgs, mu g-2 anomaly in deflected AMSB

F. Wang, L. Wu, JMY, M. Zhang, 1512.06715

Deflected anomaly mediation of SUSY breaking naturally predict a coupling between a singlet field and vector-like messengers.

The singlet scalar (S) serve as 750 GeV resonance.

The messenger fields (10 TeV) induce $S\gamma\gamma$ and Sgg couplings via loops

Mixed gauge and anomaly mediation from new physics at 10 TeV

K. Hsieh and M. A. Luty hep-ph/0604256

In the context of anomaly-mediated supersymmetry breaking, it is natural for vectorlike fields and singlets to have supersymmetry breaking masses of order 10 TeV, and therefore act as messengers of supersymmetry breaking.

- **minimal AMSB: tachyonic slepton**
- **introduce messengers (gauge mediation) + anomaly mediation**

⇓

deflected anomaly mediation

[3] NMSSM with Vector-like Particles

F. Wang, W. Wang, L. Wu, JMY, M. Zhang, 1512.08434

In this work, we explain the recent observed 750 GeV diphoton resonance in the Next-to-Minimal Supersymmetric Standard Model (NMSSM) by introducing vector-like chiral superfields. Such an extension is well motivated from the top-down view since some grand unified theories usually predict the existence of singlet scalars and vector-like particles at weak scale. In our model, the 750 GeV resonance can be interpreted as two nearly degenerate singlet-like Higgs bosons ($m_{h_2} \approx m_{a_1} \approx 750$ GeV). The decays of $h_2/a_1 \to \gamma\gamma$ are dominated by the vector-like squarks with large mixing, which can also enhance the production cross section of $gg \to h_2/a_1$. Under the constraints from the Higgs data and dark matter detection, we scan the parameter space and find that such a model can successfully accounts for the diphoton excess.

arXiv:1603.00718

Date: Wed, 2 Mar 2016 14:16:08

Title: Higgs mass and unified gauge coupling in NMSSM with Vector Matter

Authors: R. Barbieri, D. Buttazzo, L. J. Hall, D. Marzocca

We consider the NMSSM extended to include one vector-like family of quarks and leptons. If (some of) these vector-like matter particles, as the Higgs doublets, have Yukawa couplings to the singlet S that exceed unity at about the same scale $\Lambda < 10^3$ TeV, this gives the order 40% enhancement of the tree level Higgs boson mass required in the MSSM to reach 125 GeV. It is conceivable that the Yukawa couplings to the singlet S, although naively blowing up close to Λ, will not spoil gauge coupling unification. In such a case the unified coupling α_X could be interestingly led to a value not far from unity, thus providing a possible explanation for the number of generations. The characteristic signal is an enhanced resonant production of neutral spin zero particles at LHC, that could even explain the putative diphoton resonance hinted by the recent LHC data at 750 GeV.

[4] The singlet extension of Manohar-Wise Model

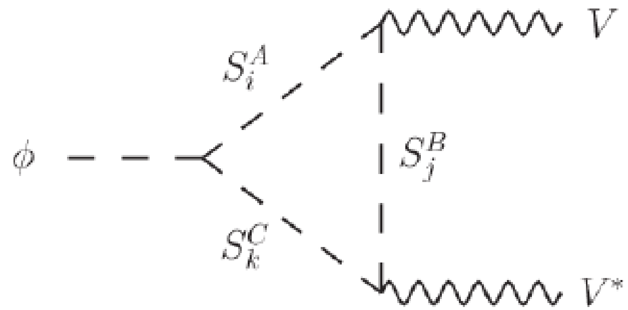
J. Cao, C. Han, L. Shang, W. Su, JMY, Y. Zhang, 1512.06728

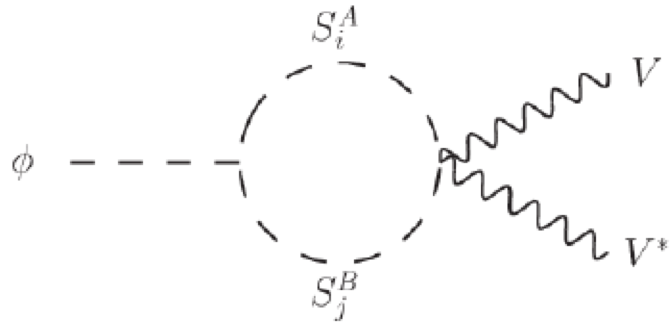
Motivated by minimal flavor violation,

Manohar-Wise model extends the SM:

Manohar, Wise
hep-ph/0606172

$$S^A = \begin{pmatrix} S_+^A \\ \frac{1}{\sqrt{2}}(S_R^A + iS_I^A) \end{pmatrix}$$





[5] Top/bottom partner cascade decay in 2HDM extension

X. Han, L. Wang, L. Wu, JMY, M. Zhang, 1601.00534

In this paper, we interpret the 750 GeV diphoton excess in the Zee-Babu extension of the two-Higgs-doublet model by introducing a top partner (T)/bottom partner (B). In the alignment limit, the 750 GeV resonance is identified as the heavy CP-even Higgs boson (H), which can be sizably produced via the QCD process $pp \to T\bar{T}$ or $pp \to B\bar{B}$ followed by the decay $T \to Ht$ or $B \to Hb$. The diphoton decay rate of H is greatly enhanced by the charged singlet scalars predicted in the Zee-Babu extension and the total width of H can be as large as 7 GeV. Under the current LHC constraints, we scan the parameter space and find that such an extension can account for the observed diphoton excess.

[6] An extension of 2HDM: 750 GeV diphoton, mu g-2, $h \to \mu\tau$

X. Han, L. Wang, JMY, 1601.04954

In this paper we simultaneously explain the excesses of the 750 GeV diphoton, muon g-2 and $h \to \mu\tau$ in an extension of the two-Higgs-doublet model (2HDM) with additional vector-like fermions and a CP-odd scalar singlet (P) which is identified as the 750 GeV resonance. This 750 GeV resonance has a mixing with the CP-odd scalar (A) in 2HDM, which leads to a coupling between P and the SM particles as well as a coupling between A and the vector-like fermions. Such a mixing and couplings are strongly constrained by $\tau \to \mu\gamma$, muon g-2 and the 750 GeV diphoton data. We scan over the parameter space and find that such an extension can simultaneously account for the observed excesses of 750 GeV diphoton, muon g-2 and $h \to \mu\tau$. The 750 GeV resonance decays in exotic modes, such as $P \to hA$, $P \to HZ$, $P \to HA$ and $P \to W^{\pm}H^{\mp}$, and its width can be dozens of GeV and is sensitive to the mixing angle.

4 Conclusion & Outlook

- **750 diphoton excess caused excitement in HEP (170 papers in 2 months)**
- **750 diphoton excess needs further confirmation (may be in June)**
- **If 750 diphoton excess is true**

Spin-0 or spin-2 new particle ?

Other new colored and/or charged particles ?

A new era of HEP is coming ?

A new era of HEP is coming

We are planning some big colliders

- **ILC (in Japan)**
- **HL-LHC, FCC-ee/TLEP/LEP3 (in Europe)**
- **CEPC, SPPC, super Z-factory (in China)**

Test the Higgs property and probe new physics

Thanks for your attention !