Consistency and interpretation of the LHC dijet excesses

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ATLAS observed a limit for the cross section of dijet resonances, which is weaker than expected for a mass slightly below ≈1 TeV. In addition, CMS reported hints for the (nonresonant) pair production of dijet resonances X via a particle Y at a very similar mass range with a local (global) significance of 3.6σ (2.5σ) at $m_X \approx 950$ GeV. In this article, we show that, using the preferred range for m_X from the ATLAS analysis, one can reinterpret the CMS analysis of didijets in terms of a resonant search with $Y \to XX$, with a significantly reduced look-elsewhere effect, finding an excess for $m_Y \approx 3.6$ TeV with a significance of 4.0σ (3.2σ) locally (globally). We present two possible UV completions capable of explaining the (di)dijet excesses, one containing two scalar diquarks, the other one involving heavy gluons based on an $SU(3)_1 \times SU(3)_2 \times SU(3)_3$ gauge symmetry, spontaneously broken to $SU(3)$ color. In the latter case, nonperturbative couplings are required, pointing toward a composite or extradimensional framework. In fact, using 5D anti–de Sitter space-time, one obtains the correct mass ratio for m_X/m_Y, assuming the X is the lowest-lying resonance, and predicts a third (di)dijet resonance with a mass around ≈2.2 TeV.

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I. INTRODUCTION

Since the discovery of the Higgs boson in 2012 [1,2], the main focus of the LHC has been on the discovery of new particles and new interactions beyond the ones included in the Standard Model (SM) of particle physics. While intriguing indirect signs emerged (see, e.g., Refs. [3–5] for recent reviews of lepton flavor universality violation), no new resonance has been discovered yet. However, recently, the number of hints for new physics (NP) in direct LHC searches increased. In particular, ATLAS [6] observed a weaker limit than expected in resonant dijet searches[1] in a mass region slightly below 1 TeV, while CMS [8] found hints for the (nonresonant) pair production of dijet resonances with a mass of ≈950 GeV (see the Appendix) with a local (global) significance of 3.6σ (2.5σ) when integrating over the didijet mass.

While the ATLAS analysis by itself does not constitute a significant hint for beyond the SM physics once the look-elsewhere effect (LEE) is taken into account, the compatibility of the suggested dijet mass with the one of the (nonresonant) CMS didijet analysis is very good. This agreement suggests that both excesses might be due to the same new particle X, once directly (resonantly) produced in proton-proton collisions ($pp \to X \to jj$), once pair produced via a new state Y [$pp \to Y^{(*)} \to XX \to (jj)(jj)$]. While the CMS Collaboration in their analysis interprets the didijet excess as the nonresonant production of XX (with $m_X \approx 950$ GeV) via a heavy new particle Y, with

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[1]The analogous CMS dijet search [7] does not display an excess in the same region. However, the sensitivity is significantly lower, such that the signal suggested by the ATLAS analysis is not excluded.

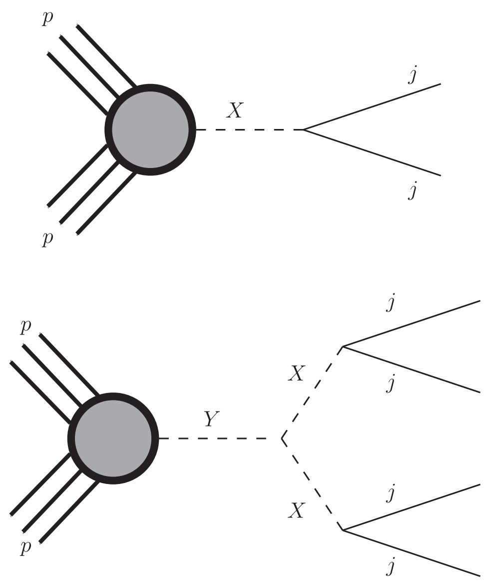

FIG. 1. Feynman diagrams showing the resonant production of dijets via the particle X (upper panel) and didijets via the decay chain $Y \to XX \to (jj)(jj)$ (lower panel). Note that X and Y could be scalar or vector bosons in our setup. As we show in the main text, $m_X \approx 950$ GeV and $m_Y \approx 3.6$ TeV are preferred by the combination of the ATLAS and CMS analyses.

$m_Y \approx 8$ TeV, resulting in a local (global) significance of 3.9σ (1.6σ) [8], it is also possible that the two X particles are resonantly produced from the decay of an on-shell Y particle. In fact, the CMS results suggest 3 TeV $\lessapprox m_Y \lessapprox$ 4 TeV (see the Appendix) for such a resonant scenario, once m_X is assumed to be within the preferred range of the ATLAS dijet analysis.

In order to evaluate this option more quantitatively, a (at least simplified) model is necessary such that the experimental resolution and acceptance can be simulated. We will do this in Sec. II using a simplified model with new vector bosons in order to derive the significance resulting from the CMS analysis for such a scenario with an on-shell Y resonance decaying to two X particles, as illustrated in Fig. 1. Next, we will examine possible UV completions that can provide a common explanation of the (di)dijet excesses. As we will discuss in Sec. III, two scalar diquarks or new massive gluons seem to be the most plausible candidates. Concerning the latter, we will consider a specific example based on an $SU(3)_1 \times SU(3)_2 \times SU(3)_3$ gauge group, broken down to $SU(3)$ color via two bitriplets. We then conclude and present an outlook in Sec. IV.

II. (DI)DIJETS

As outlined in the introduction, the preferred value for the dijet invariant mass of ATLAS and CMS analyses strongly suggest that both signals are due to the same particle X, i.e., that $pp \to X \to jj$ and $pp \to Y \to XX \to (jj)(jj)$ account for the dijet and the didijet excess, respectively (see Fig. 1). In this section, we consider this setup within a simplified model with a vector boson Y decaying into two vector bosons X.[2] We will assume that the vectors have a $Y-X-X$ coupling, depending on the momenta in the same way as the SM $Z-W-W$ coupling, with $m_Y > m_X$ and $\mathrm{Br}[Y \to XX] = 100\%$. In addition to this triple gauge boson interaction, only X and Y couplings to SM quarks, which we assume to be flavor universal, are relevant.

First of all, we fix 900 GeV $\lessapprox m_X \lessapprox$ 1050 GeV from the invariant mass preferred by the dijet analysis of ATLAS [6] which is based on 29.3 fb^{-1} integrated luminosity at 13 TeV.[3] Note that we do not include the significance of the ATLAS measurement in our fit but rather use it to confine ourselves to this range, which reduces the LEE with respect to the dijet invariant mass. We then employ $m_X = 950$ GeV, which corresponds to the best value obtained in the nonresonant analysis by CMS. As such, we move on to the didijet mass m_Y for which the CMS search for pairs of jets was performed with 139 fb^{-1} integrated luminosity at 13 TeV center of mass energy [8]. In this analysis, CMS selected four high transverse momentum jets, including both the cases of resonant $pp \to Y \to XX \to 4j$ and nonresonant $pp \to XX \to (jj)(jj)$ production. The observable

$$\alpha = \frac{m_1 + m_2}{2 \cdot m_{4j}} \tag{1}$$

is defined, where m_1 and m_2 are the dijet invariant masses and m_{4j} is the invariant mass of the four-jet system. The search is then performed in bins of α, and in the nonresonant case an excess at $m_Y \approx 8.5$ TeV with a local (global) significance of 3.9σ (1.6σ) is reported. However, also a resonantlike excess in the four-jet invariant mass spectrum around 3–4 TeV, i.e., for $\alpha = 0.27$, 0.29, 0.31 with $m_X \approx 950$ GeV, is visible. The cross section of this four-jet excess can naively be estimated to be of the order of $O(\mathrm{fb})$.

The dominant background for dijet resonance searches in proton-proton collisions is QCD production of multijets. For both ATLAS and CMS, Monte Carlo simulations of this background are used for signal optimization and to provide an approximate comparison with the observed data. The generation of multijet background is realized by simulating the leading-order QCD $2 \to 2$ processes of jet production,

[2]In the next section, we will consider models that could provide a common explanation of the (di)dijet excesses. There, we will also consider a model with scalars. We did not explicitly simulate this setup; however, the differences compared to the case with gauge bosons is expected to be small, as the decay kinematics are very similar.

[3]See, e.g., Refs. [9–11] for theory accounts of (di)dijet searches.

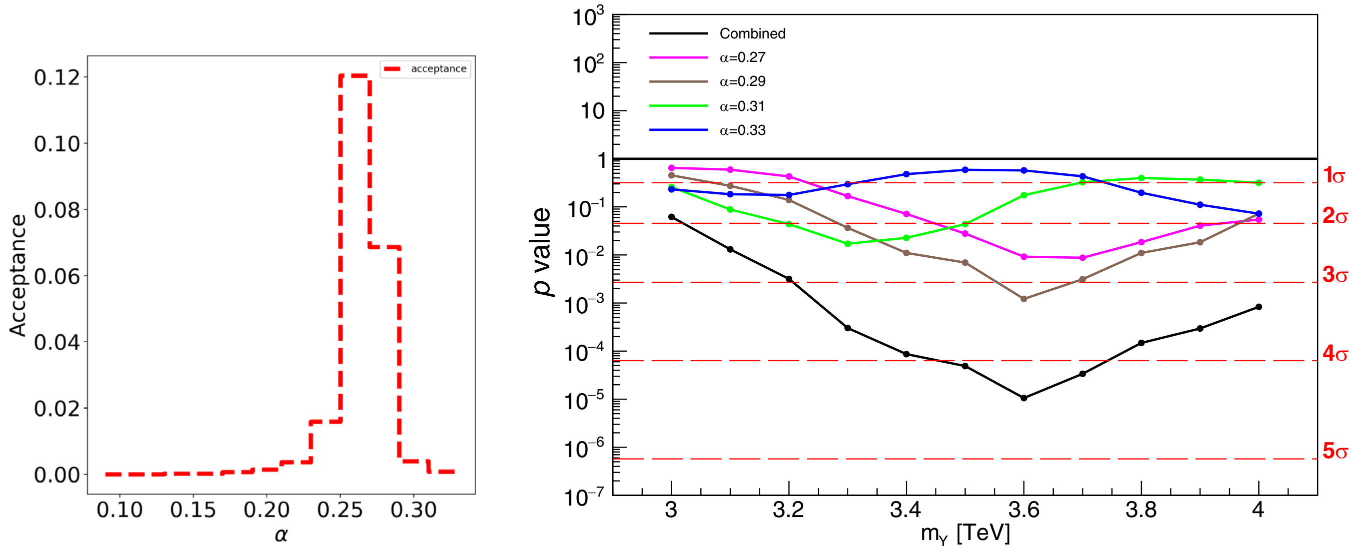

FIG. 2. Left: acceptance obtained from our simulation of $pp \to Y \to XX \to 4j$ for $m_X = 1$ TeV and $m_Y = 3.5$ TeV. Right: p value as a function of m_Y, obtained by combining the two leading bins in α, i.e., $\alpha = 0.27$ and $\alpha = 0.29$.

including extra jets from QCD initial and final state radiation in the parton shower level. In order to avoid the mismodeling of the multijet background, which is closely connected to the detector identification and isolation requirements, the final normalization and shape of this background are estimated from data by ATLAS and CMS using a data-driven method, described and detailed in Refs. [12,13].

In order to evaluate this possibility of a resonant production of $X(950)$ more quantitatively, we use our simplified model to simulate $pp \to Y \to XX \to (jj)(jj)$ events using MadGraph5_aMC@NLO2.6.7 with leading-order (LO) accuracy in QCD [14]. The parton showering and hadronization are simulated with PYTHIA 8.2 [15] using the NNPDF2.3 LO parton distribution function set [16]. The events were processed with DELPHES 3 [17], which provides an approximate fast simulation of the CMS detector. Jets were reconstructed using the anti-kt algorithm [18] with the radius parameter $R = 0.4$, as implemented in FASTJET 3.2.2 [19]. Jets with $p_T > 80$ GeV and $|\eta| < 2.5$ are considered. Reconstructed jets overlapping with photons, electrons, or muons in acone of size $R = 0.4$ are then removed. The four jets with the highest p_T are considered as the leading jets. Then the most probably dijet pair combinations are created by minimizing the $\eta - \phi$ space separations of the jets in each event:

$$\Delta R = |(\Delta R_1 - 0.8)| + |(\Delta R_2 - 0.8)|, \qquad (2)$$

where ΔR_1 and ΔR_2 are the $\eta - \phi$[4] space separations between the two jets within the respective systems. The offset of 0.8 is chosen to avoid the pairings with overlapped jets. In addition, we require the $\Delta R_{i;i=1,2}$ to be less than 2, in order to reject contribution from hard jets produced by QCD processes, while the pseudorapidity separation $\Delta\eta_{jj}$ between the two jets of each dijet system is required to be below 1.1, to remove contribution of backgrounds from the QCD t channel. In the end, we required the asymmetry in the dijet mass between the dijet systems to be small $(\frac{|m_1 - m_2|}{m_1 + m_2} < 0.1)$ which essentially select the dijets of equal mass taking into account the energy resolution. This, in turn, is the property of a pair of equal mass resonances, which is unlike QCD jets that constitute the SM background.

The most significant signal in the CMS analysis is found in the bins with the central values $\alpha = 0.27$ and $\alpha = 0.29$. We therefore evaluated the acceptance and the resolution by simulating the process $pp \to Y \to XX \to (jj)(jj)$. The results for $m_Y = 3.5$ TeV and $m_X = 1$ TeV is shown in left panel in Fig. 2. Because the number of NP events in the two bins is correlated, as given by the acceptance, we can write the p value[5] of the weighted average of the two dominant bins as

$$p = 2 \times \left[1 - \Phi\left(\frac{\sum_{i=1}^{2} w_i S_i}{\sqrt{\sum_{i=1}^{2} w_i^2}}\right)\right], \qquad (3)$$

where S_i is the significance for the ith bin (given in standard deviations) and the weight w_i is equal to the acceptance of each bin, while $\Phi(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} e^{-x'^2/2} dx'$

[4]The distance ΔR between two jets in the $\eta - \phi$ space is defined as $\Delta R = \sqrt{(\Delta\eta_{jj})^2 + (\Delta\phi_{jj})^2}$.

[5]See, e.g., Ref. [20] for the statistical combination of the results from two or more measurements.

denotes the standard normal cumulative distribution function. From the right panel in Fig. 2, we can see that the best agreement with data is found for $m_Y \approx 3.6$ TeV, with a total cross section for $pp \to Y \to XX \to jjjj$ of ≈ 5 fb. The corresponding local (global) significance is 4σ (3.2σ). Note that the global significance of our resonant excess is higher than the nonresonant effect of CMS mainly due to the smaller LEE, as we fixed the range of the dijet mass *a priori* with the help of the ATLAS data. The LEE effect evaluated here includes the range m_Y used in the search.

III. INTERPRETATION

A. Vector bosons based on $SU(3)^3$

A model with new vector bosons seems a natural possibility for providing a common explanation of the didijet excesses, as such states can have sizable couplings to valence quarks without breaking $SU(2)_L$ (similar to the SM gauge bosons), and, in fact, already coupling of the order 10^{-1} turns out to be sufficient to obtain suitable cross sections. Since self-interactions are required to give rise to $Y \to XX$, this suggests that the new heavy vector bosons originate from a non-Abelian gauge group. Furthermore, if one wants all new vectors to couple to quarks, they must have the same quantum numbers as the $SU(2)_L$ or $SU(3)_c$ gauge bosons of the SM, since otherwise the operators $V^a_\mu \bar{q}\gamma^\mu T^a q$, where V^a_μ are the new vector bosons and T^a the corresponding generators, would not be invariant under the SM gauge group. In addition, in order to avoid couplings to leptons, which are strongly constrained from dilepton searches [21,22], as well as bounds from electroweak precision observables [23,24], we will opt for a gauge group based on, and related to, $SU(3)_c$.

Models with such additional heavy colored states based on an extended group for the strong interactions, whose spontaneous symmetry breaking reduces it to its diagonal subgroup, then identified with $SU(3)_c$, were proposed and studied in Refs. [25–30]. Furthermore, such a setup emerges in the context of extra space-time dimensions where Kaluza-Klein excitations of gluons exist [31–34] and a similar picture arises in composite and technicolor models [35–37].

As we need heavy resonances with (at least) two different masses, we consider the gauge group

$$SU(3)_1 \times SU(3)_2 \times SU(3)_3 \times SU(2)_L \times U(1)_Y, \quad (4)$$

broken down to the SM one $SU(3)_c \times SU(2)_L \times U(1)_Y$ via two bidoublets charged under two nonidentical $SU(3)$ groups, each. Here, we use

	$SU(3)_1$	$SU(3)_2$	$SU(3)_3$
Ω_{12}	3	$\bar{3}$	1
Ω_{23}	1	3	3

with

$$\langle\Omega_{12}\rangle = v_{12}\begin{pmatrix}1&0&0\\0&1&0\\0&0&1\end{pmatrix}, \qquad \langle\Omega_{23}\rangle = v_{23}\begin{pmatrix}1&0&0\\0&1&0\\0&0&1\end{pmatrix}, \quad (5)$$

which constitutes a choice of basis; i.e., any other combination (12,13 or 13,23) would lead to the same physical results. The spontaneous symmetry breaking via the vacuum expectation values v_{12} and v_{23} leads to the following mass matrix for the $SU(3)$ gauge fields $G_i^{\mu a}$ ($i = 1, 2, 3$) in the interaction basis:

$$L_M^G = \frac{1}{2}\begin{pmatrix}G_1^{\mu a}\\G_2^{\mu a}\\G_3^{\mu a}\end{pmatrix}^T \begin{pmatrix} v_{12}^2 g_1^2 & v_{12}^2 g_1 g_2 & 0\\ v_{12}^2 g_1 g_2 & (v_{12}^2+v_{23}^2)g_2^2 & v_{23}^2 g_2 g_3\\ 0 & v_{23}^2 g_2 g_3 & v_{23}^2 g_3^2\end{pmatrix} \times \begin{pmatrix}G_1^{\mu a}\\G_2^{\mu a}\\G_3^{\mu a}\end{pmatrix}, \quad (6)$$

where each block corresponds to $a = 1, \ldots, 8$ gauge bosons with the corresponding generators T^a and equal masses.

We can now diagonalize this mass matrix to obtain the mass eigenstates $g_1^{a\mu}$, $g_2^{a\mu}$, and $g_3^{a\mu}$ and identify the state with the zero eigenvalue $g_1^{a\mu}$ with the SM gluons and the corresponding coupling with the strong coupling constant g_s. The mass of $g_2^{a\mu}$ ($g_3^{a\mu}$) should correspond to the X (Y) resonance, i.e., 950 GeV (3.6 TeV). We can, furthermore, determine the couplings of $g_2^{a\mu}$ and $g_3^{a\mu}$ by demanding that the correct signal strengths are obtained. Since ATLAS finds a preferred value of $g_q \approx 0.07$ (in their conventions where quarks couple only to the axial-vector current) for the X resonance, and in our model we have eight $g_2^{a\mu}$ fields which couple each vectorially and flavor universal to quarks, we find that the production cross section is 4 times larger (for equal couplings) resulting in $g' \approx 0.035$, where g' (g'') is the (effective) coupling of $g_2^{a\mu}$ ($g_3^{a\mu}$) to SM quarks. The preferred value for the didijet cross section obtained in the last section is $\approx$5 fb. From this, we find $g'' \approx 0.07/\sqrt{\mathrm{Br}[g_3^{a\mu} \to g_2^{a\mu} g_2^{a\mu}]}$, by using the total production cross section for a sequential SM Z' of this mass (20 fb [38]) and taking into account the Z' branching ratio and the parton distribution function (PDF) scaling, using the PDF of Ref. [39] implemented in ManeParse [40], in order to rescale the cross section to the one of our model.

We can now attempt to solve this system of equations if one specifies under which $SU(3)_i$ gauge factors the SM quarks transform as a triplet. There are seven possibilities for such charge assignments [$SU(3)_1$, $SU(3)_2$, $SU(3)_3$, $SU(3)_1 \vee SU(3)_2$, $SU(3)_1 \vee SU(3)_3$, $SU(3)_1 \vee SU(3)_3$, and $SU(3)_1 \vee SU(2)_1 \vee SU(3)_3$] among which only the option that the SM quarks are $SU(3)_1$ triplets, but uncharged under both other $SU(3)$ gauge factors, provides a solution. In fact, we find $g_1 \approx 1$, $g_2 \approx 10$, and $g_3 \approx 15$, which is clearly in the nonperturbative regime. Therefore, these values should not be taken at face value but rather show only that the system of equations has a solution. These large values for the couplings g_2 and g_3 can be traced back to the smallness of the $g_2^{a\mu}$ and $g_3^{a\mu}$ couplings to SM quarks which requires small mixing among the colored gauge bosons. Nonetheless, as the decay width to SM fermions is small and the right masses and couplings can be obtained, this suggests that the gauge group $SU(3)_1 \times SU(3)_2 \times SU(3)_3$, broken to $SU(3)_c$ via the described breaking, can, in fact, explain the (di)dijet excesses. Furthermore, the sizable couplings g_2 and g_3 point toward an extradimensional or composite realization of this setup.

B. Scalar diquarks

Alternatively to the vector-boson model proposed above, one could try to find a perturbative explanation of the (di) dijet excesses using scalar bosons. Because the suggested cross sections are too large to originate from a scalar produced via gluon fusion (with perturbative couplings) [41], relevant couplings to valence quarks are needed. Since $SU(3)_c$ singlet scalars can interact with quarks only in the same way as the SM Higgs boson, the couplings are naturally related to the respective Yukawa couplings, rendering them tiny for valence quarks, thus resulting in too small cross sections.

However, $SU(3)_c$ triplet or sextuplet (symmetric 3×3) scalars can couple to quarks of the same $SU(2)_L$ representation such that their couplings are unrelated to electroweak symmetry breaking and, therefore, also unrelated to quark Yukawa couplings. Searches for such diquarks via dijet and didijet signatures were proposed in Refs. [42–49].

The choice of quantum numbers for diquarks is restricted to five possibilities:

	$SU(3)_c$	$SU(2)_L$	$U(1)_Y$
Φ_u	$\bar{6}$	1	$-4/3$
Φ_d	$\bar{6}$	1	$2/3$
$\Phi_q^{(1)}$	3	1	$-1/3$
$\Phi_q^{(3)}$	$\bar{6}$	3	$-1/3$
Φ_{ud}	$\bar{6}$	1	1

(7)

if we restrict ourselves to the cases which allow couplings symmetric in flavor space. Note that antisymmetric couplings would, in general, cause problems with $\Delta F = 2$ processes. In this case, we have the coupling to fermions

$$\mathcal{L}_{\rm int} = \lambda_u \bar{u}_R^c \Phi_u u_R + \lambda_d \bar{d}_R^c \Phi_d d_R + \lambda_q^{(3)} \Phi_q^{(3)I} \bar{q}_L^c i\sigma_2 \tau^I q_L + \lambda_q^{(1)} \epsilon \Phi_q^{(1)} \bar{q}_L^c i\sigma_2 q_L + \lambda_{ud} \bar{u}_R^c \Phi_{ud} d_R + \text{H.c.}, \quad (8)$$

where u_R, d_R, and q_L are the SM right-handed $SU(2)_L$ singlet quarks and left-handed $SU(2)_L$ doublet quarks, respectively. ϵ is the totally antisymmetric tensor in three dimensions which contracts the implicit color indices of the color triplets, and we suppressed flavor indices.

We can, thus, attempt to construct a scenario which has the potential to reproduce the experimental signals. Assuming that Φ_u is the 3.6 TeV resonance decaying into two Φ_d scalars with a mass of 950 GeV each, the interaction term $A\epsilon\epsilon\Phi_u\Phi_d\Phi_d$ is needed where the first (second) ϵ contracts the first (second) $SU(3)_c$ index of the symmetric 3×3 representations. Since both scalars couple to right-handed $SU(2)_L$ singlet quarks, we can assume that they have flavor diagonal couplings, both in the interaction and in the mass basis. However, as the couplings to first-generation quarks are constrained by neutron-antineutron oscillations [50], one has to assume that the couplings to second-generation quarks are dominant (at least for either Φ_u or Φ_d). These couplings are then determined by requiring that the correct signal strengths are obtained.[6] The ATLAS dijet analysis gives $|\lambda_{d(s)}| \simeq 0.05(0.2)$. In addition, assuming $\mathrm{Br}(\Phi_u \to \Phi_d \Phi_d) \simeq 100\%$, which is natural for $A = O(\mathrm{TeV})$, we find $|\lambda_{u(c)}| \simeq 0.02(1.1)$ from the didijet cross section of ≈ 5 fb.

In principle, also the option that Φ_d is the 3.6 TeV resonance and $\Phi_q^{(3)}$ or $\Phi_q^{(1)}$ the 950 GeV one is possible. In this case, it has to be assumed that the couplings to quarks are universal, such that the Cabibbo-Kobayashi-Maskawa rotation between the interaction and the mass eigenbasis does not generate flavor-changing couplings that would contribute to $\Delta F = 2$ processes.

IV. CONCLUSIONS AND OUTLOOK

In this article, we pointed out that the ATLAS dijet excess with a mass slightly below 1 TeV is perfectly consistent with the preferred dijet mass of 950 GeV of the CMS didijet analysis. We then used the suggested range for m_X from ATLAS to recast the CMS didijet analysis in terms of a resonant search for $Y \to XX \to (jj)(jj)$. This significantly reduces the LEE and results in a local (global)

[6]Note that neither the CMS nor the ATLAS analysis is sensitive to the electric charge of the vector, because the jet charge is not measured. In addition, the differences in efficiencies between scalar and vector resonances are expected to be small for the analyses under investigation.

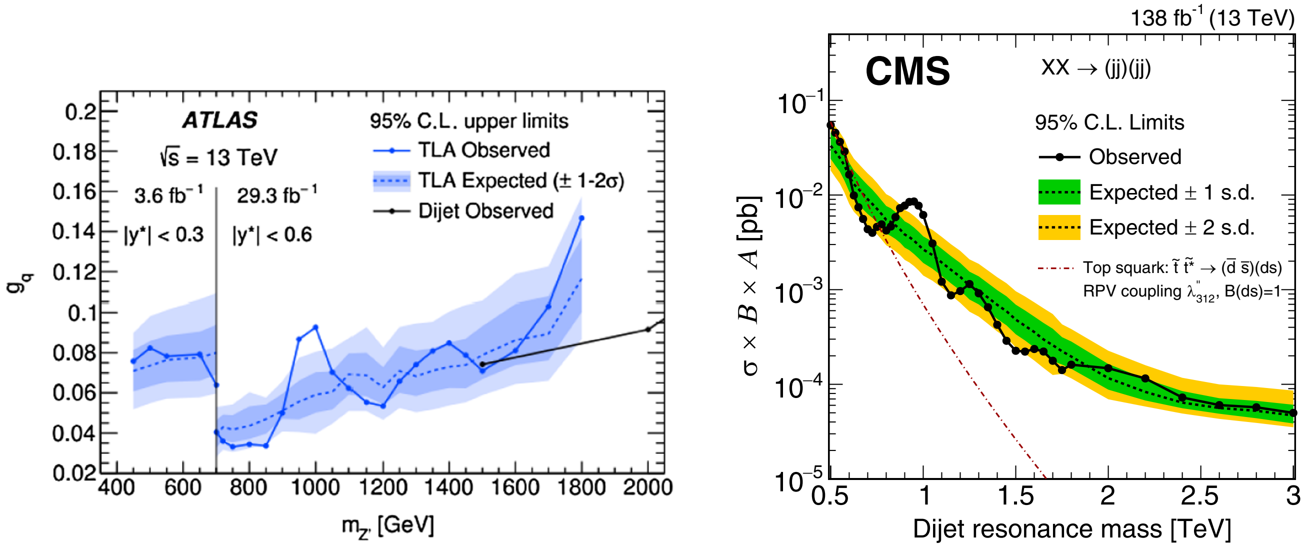

FIG. 3. Left: dijet search of ATLAS [6] showing the expected and observed limits on the axial coupling g_q of a Z' boson to quarks. Right: cross section times branching ratio times acceptance in units of picobarns as a function of the dijet invariant mass obtained in the CMS didijet analysis [8].

significance of $4.0\sigma(3.2\sigma)$ for a resonance Y with mass $m_Y \approx 3.6$ TeV.

We then examined possible combined explanations of the (di)dijet excesses and proposed both a model with scalar diquarks and a model with new heavy colored vector bosons based on an $SU(3)_1 \times SU(3)_2 \times SU(3)_3$ gauge symmetry spontaneously broken to $SU(3)_c$. While the scalar diquark model has couplings that are at most the order of one, the $SU(3)^3$ model requires large nonperturbative couplings, pointing toward an extradimensional or composite realization. Interestingly, interpreting this model in a Randall-Sundrum (RS) framework [51], the ratio of the masses of the gauge boson excitations is predicted to be [52]

$$m_n/m_1 = 4(n - 1/4)/3, \tag{9}$$

where m_1 is the first gluon excitation with a nonvanishing mass. This means if the first resonance ($n = 1$) is at $\approx$950 GeV, the second one ($n = 2$) should be at $\approx$2.2 TeV, while the third ($n = 3$) is at $\approx$3.5 TeV. While the latter value fits nicely the (di)dijet data, this RS framework predicts the existence of another (di)dijet resonance with a mass around 2.2 TeV. Note that such a resonance, if it has similar couplings to quarks as the $n = 1$ and $n = 3$ resonances, is not excluded by current dijet searches due to the PDF scaling with respect to the 950 GeV resonance. Furthermore, the CMS didijet data even point toward a slight excess in this region of the didijet invariant mass m_Y (see the Appendix).

In light of the intriguing hints for NP in semileptonic B decays [53,54], $g-2$ of the muon [55–57], the W mass [58,59], the Cabibbo angle anomaly [60–62], the 96 [63], 151 [64], and 680 GeV [65] excesses, the multilepton anomalies [66–69], and the di-Higgs [70] excess as well as the hint for nonresonant dielectrons [22,71],[7] the (di)dijet excesses constitute one more very interesting sign of physics beyond the SM. While the other signals for NP are, in general, related electroweak processes within the SM, the (di) dijet signals point toward colored new particles. This broadens the range of interactions for which the anomalies suggest NP and has important consequences for collider searches and model building in the collaborative search for the next SM of particle physics.

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APPENDIX: ATLAS AND CMS PLOTS

Here, we quote the main results of the ATLAS and CMS searches for (di)dijet searches for the convenience of the reader. The result of the dijet resonance search of ATLAS is shown in the left plot in Fig. 3. The dijet invariant mass m_X of the CMS didijet analysis is given in the right plot in Fig. 3, while the relevant plots for the didijet mass m_Y are displayed in Fig. 4.

[7] See Ref. [5] for a recent review of anomalies.

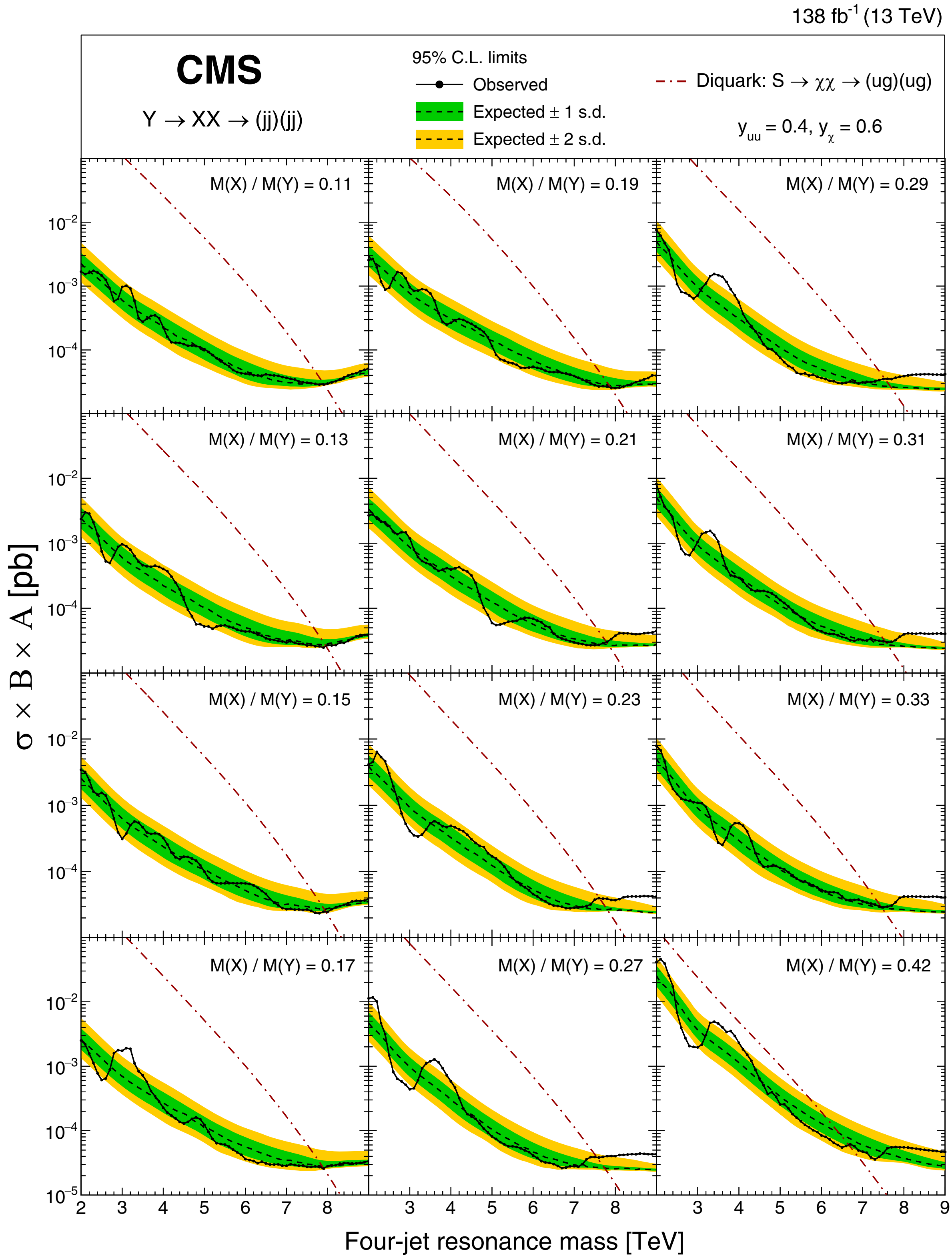

FIG. 4. Observed and expected limit on cross section times branching ratio times acceptance in units of picobarns as a function of the didijet invariant mass for different values of $\alpha = m_X/m_Y$ [8].

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