Scalar hint from the diboson excess?

Aldo Deandrea
Université Lyon 1 & IUF

Rencontres de Moriond
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based on hep-ph/1507.03098 with G.Cacciapaglia and M.Hashimoto

Introduction

- Diboson searches as a test for BSM physics
- Which models, which resonances can be tested?
- Strong composite dynamics and a spin zero pseudoscalar
- WZW couplings from the fundamental dynamics: models
- Results and perspectives for Run 2

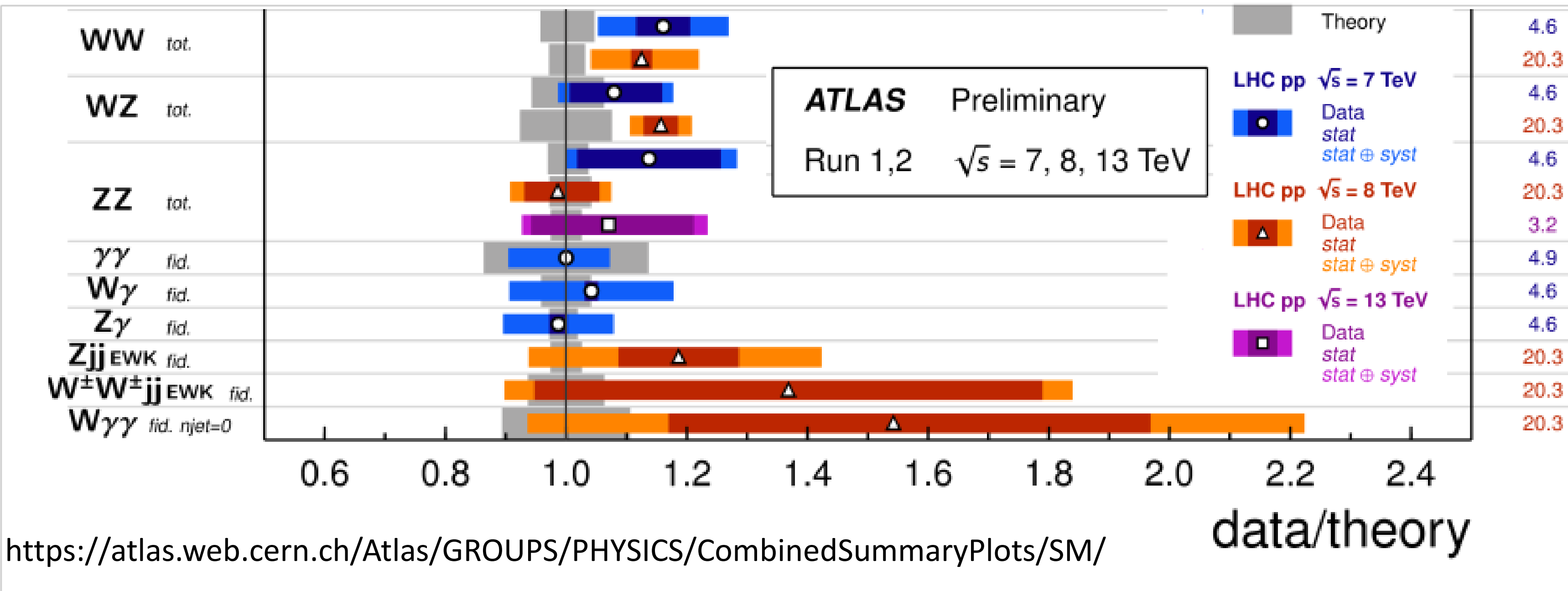
Diboson and BSM

- search for heavy resonances around 2 TeV in both ATLAS and CMS
  2015 due to excesses in the hadronic diboson channels

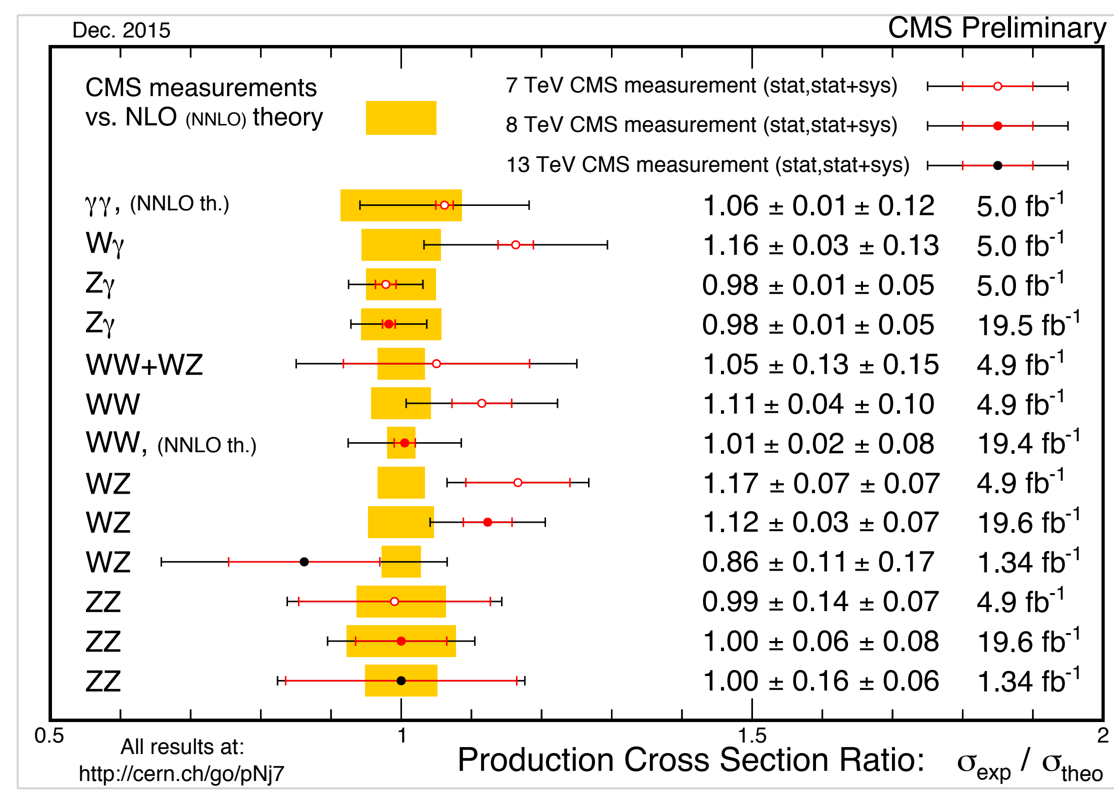
- BSM models with new resonances coupling to SM gauge bosons are constrained by these searches (excess or not)

- Firm theoretical predictions?Yes in a class of models with a scalar coupling to the gauge bosons via the anomaly.

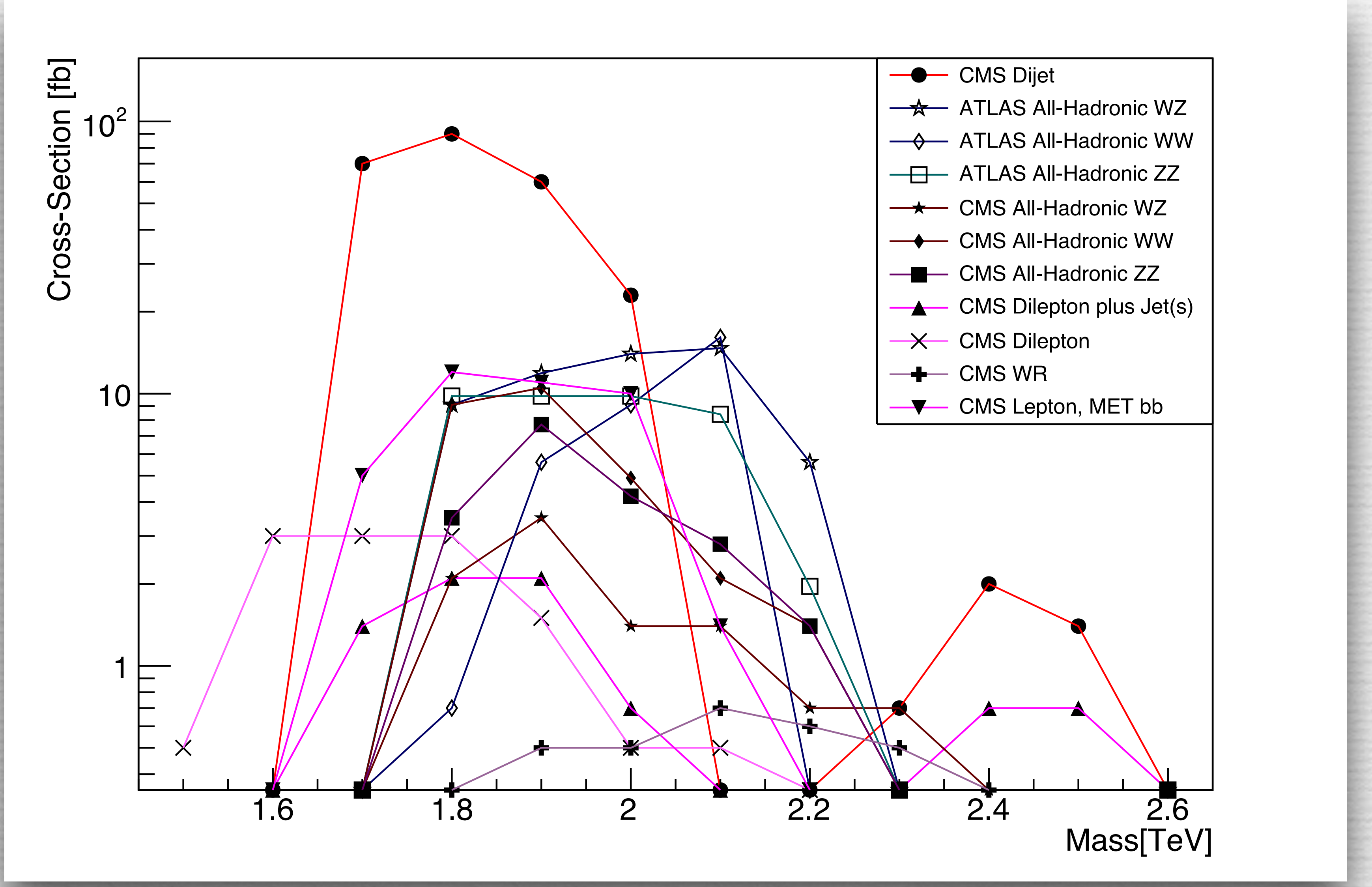
Diboson status 7/8/13 TeV



- few measurements @8 TeV higher than SM expectation
- see Tuesday talk by Tiesheng Dai and the one by M.Pierini today for details & updates



Cross-section estimates



from Les Houches working group, hep-ph/1512.04357

Phenomenological description

- Assuming some s-channel narrow resonance:

$$\sigma_R(pp \to VV) \simeq \mathcal{N} \times BR(R \to partons) \times BR(R \to VV)$$

- and with cross-section in the range 1-100 fb:
    - Vector-Boson-Fusion (VBF) is subdominant at 8 TeV
    - Drell-Yan (DY) production can accommodate an excess from a spin 1 vector in this range
    - Gluon fusion (GGF) is relevant for spin 0 and spin 2

Which models, which resonances?

- Strong dynamics for the EW sector:
  - spin 1 (popular guess but S parameter needs extra contribution (axial-vector, …), via Drell-Yan mainly
  - spin 0, spin 2 from gluon fusion
- Extended SM scalar sector
- Extended gauge sector
- …..

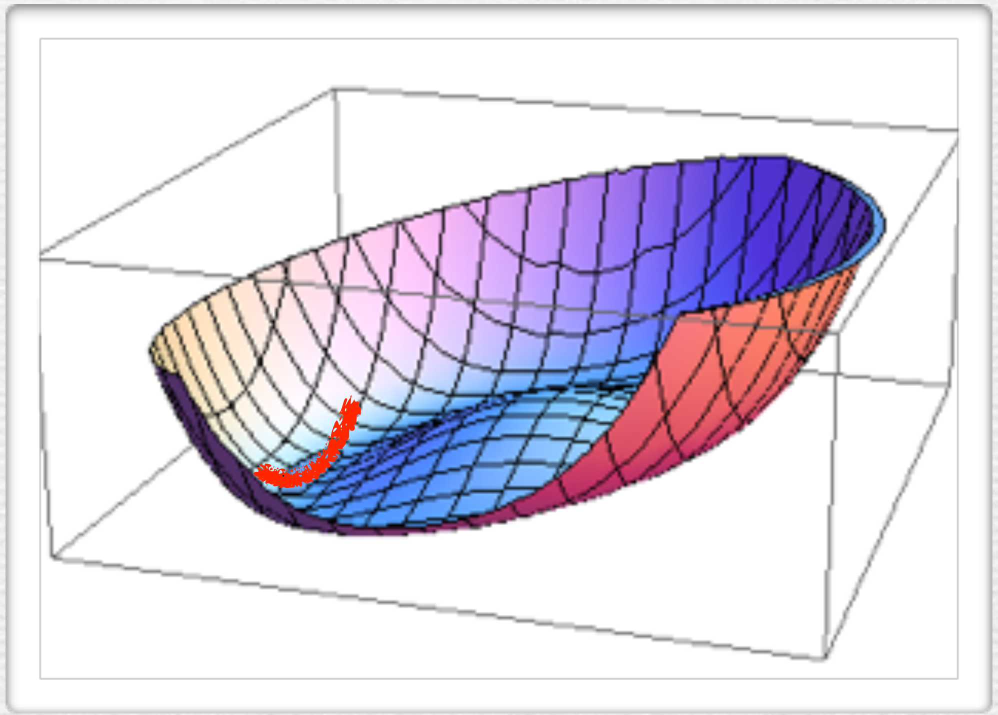
Strong dynamics in the EW sector

Global symmetry:

G → H

SU(2)xU(1) → U(1)

SM gauge symmetry



"pions"   h, WL, ZL

Higgs boson light as pNGB of the broken symmetry of the strong sector, parameterisation with an effective chiral Lagrangian, detailed computations in terms of the fundamental fermionic states

Scalars in TeV strong dynamics

- Higgs: pNGB or mixture pNGB-Composite (see 1402.0233)
- Composite scalars can be lighter than vectors (indications from lattice calculations with specific strong dynamics)
- A pseudo-scalar η with WZW anomaly couplings is present in the spectrum and can be in the TeV range.
  - Couplings are calculable in terms of the dynamics
  - Fermiophobic η is a realistic case in composite models

See hep-ph/1502.04718 for details of the scalar sector in minimal SU(4)/Sp(4) case and hep-ph/0809.0713 for the model.

η effective couplings

$$\mathcal{L}_{\eta gg} = \kappa_g^\eta \frac{g_3^2}{32\pi^2} \frac{\eta_{\rm WZ}}{F_\eta} \epsilon^{\mu\nu\rho\sigma} G^a_{\mu\nu} G^a_{\rho\sigma},$$

$$\mathcal{L}_{\eta WW} = \kappa_W^\eta \frac{g_2^2}{32\pi^2} \frac{\eta_{\rm WZ}}{F_\eta} \epsilon^{\mu\nu\rho\sigma} W^i_{\mu\nu} W^i_{\rho\sigma},$$

$$\mathcal{L}_{\eta BB} = \kappa_B^\eta \frac{g_Y^2}{32\pi^2} \frac{\eta_{\rm WZ}}{F_\eta} \epsilon^{\mu\nu\rho\sigma} B_{\mu\nu} B_{\rho\sigma},$$

κ_g^η, κ_W^η and κ_B^η are calculable if the dynamics is specified

A toy vector-like model

	$SU(N)$	$SU(3)_c$	$SU(2)_W$	$U(1)_Y$
$Q_L = (Q_1, Q_2)_L$	$\square$	**3**	**2**	0
$Q_R = (Q_1, Q_2)_R$	$\square$	**3**	**2**	0
$L_L = (L_1, L_2)_L$	$\square$	**1**	**2**	0
$L_R = (L_1, L_2)_R$	$\square$	**1**	**2**	0
N_L	$\square$	**1**	**1**	0
N_R	$\square$	**1**	**1**	0

$$N_f = 2N_c n_Q + 2n_L + 1,$$

$$N_f < 11N/(4T(R))$$

to keep asymptotic freedom

η pNGB is in the U(1) part of SU(N)

$$\kappa_B^\eta = \kappa_{WB}^\eta = 0,$$

$$\kappa_g^\eta = \frac{1}{2}N(N-1)\cdot 2n_Q,$$

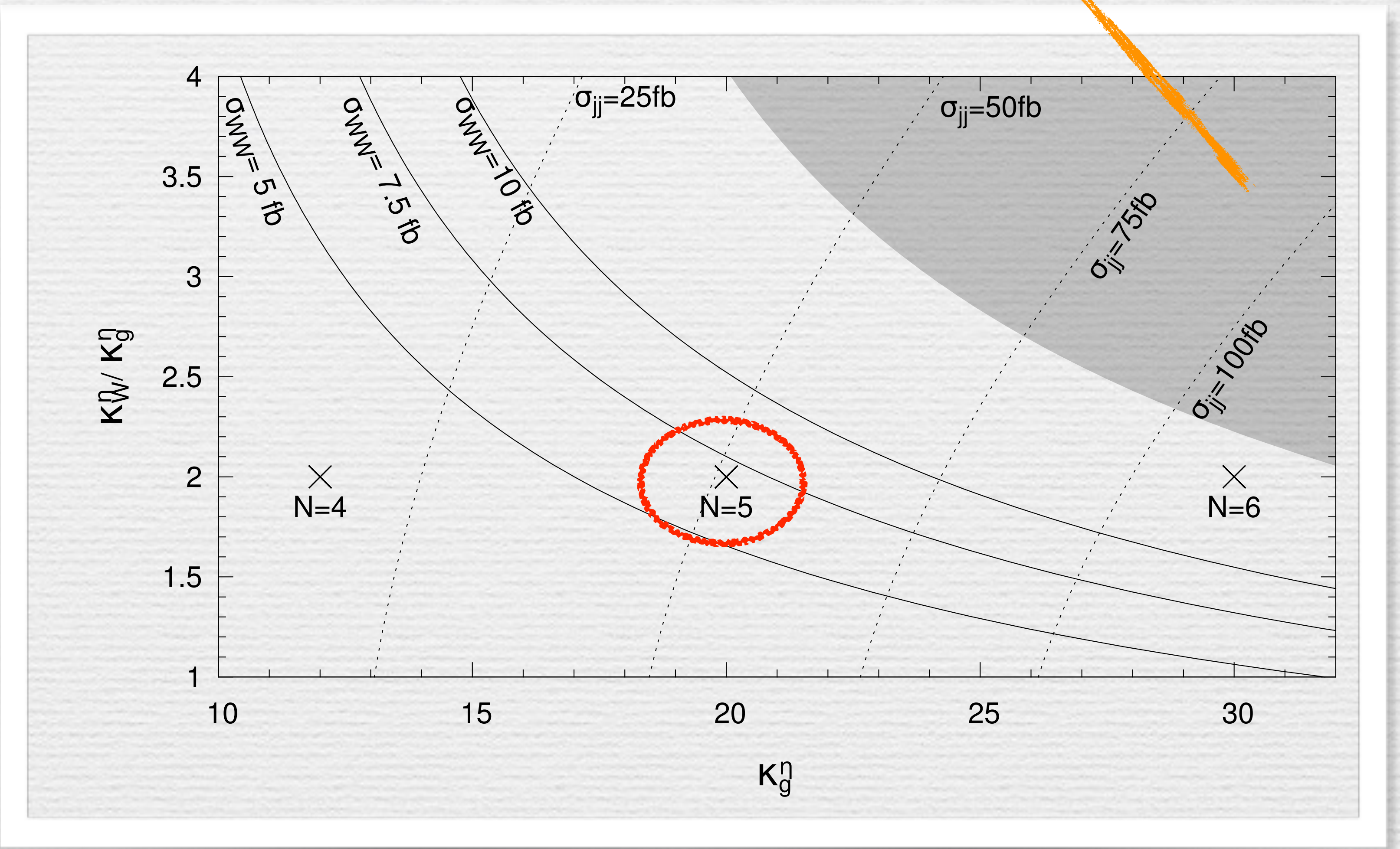
$$\kappa_W^\eta = \frac{1}{2}N(N-1)\cdot (N_c n_Q + n_L),$$

Numerical results

shaded area excluded by γγ > 0.5 fb

decay mode	BR
gg	83%
WW	11.2%
ZZ	3.2%
$Z\gamma$	2%
$\gamma\gamma$	0.4%

BR for η of 2 TeV and $\kappa_W^\eta/\kappa_g^\eta = 2.$



A more realistic model

	$\mathrm{Sp}(2N_c)$	$\mathrm{SU}(3)_c$	$\mathrm{SU}(2)_L$	$\mathrm{U}(1)_Y$	$\mathrm{SU}(4)$	$\mathrm{SU}(6)$	$\mathrm{U}(1)$
Q_1 Q_2	$\square$	$\mathbf{1}$	$\mathbf{2}$	0	$\mathbf{4}$	$\mathbf{1}$	q_Q
Q_3	$\square$	$\mathbf{1}$	$\mathbf{1}$	$1/2$			
Q_4	$\square$	$\mathbf{1}$	$\mathbf{1}$	$-1/2$			
χ_1 χ_2 χ_3	$\begin{smallmatrix}\square\\\square\end{smallmatrix}$	$\mathbf{3}$	$\mathbf{1}$	$2/3$	$\mathbf{1}$	$\mathbf{6}$	q_χ
χ_4 χ_5 χ_6	$\begin{smallmatrix}\square\\\square\end{smallmatrix}$	$\bar{\mathbf{3}}$	$\mathbf{1}$	$-2/3$			

Two types of fermions: 4 Q in the fundamental and 6

	σ
κ_g/f_σ	$(2N_c+1)(N_c-1)/f_\sigma$
κ_W/f_σ	$-6N_c(N_c-1)/f_\sigma$
κ_B/f_σ	$\left[\frac{8}{3}(2N_c+1)(N_c-1) -6N_c(N_c-1)\right]/f_\sigma$

The neutral scalar sector contains 2 pNGB σ and η and a massive σ'.
η does not couple to gluons and σ' has a too large decay to γγ.
σ can reproduce the excess at 2 TeV.

see 1311.6562, 1507.02283 1512.04508

Conclusions and perspective for Run 2

- Strong dynamics: other resonances?
- charged/neutral: role of WZ vs WW and ZZ
- $Z\gamma$ and $\gamma\gamma$ channels
- Channels with a Higgs boson (Vh)
- Determine production modes (DY, VBF, GGF) as much as possible exploiting kinematical differences
- Production balance different: @13 TeV DYx5-7, VBFx10 vs 8 TeV