COLLIDER PHENOMENOLOGY OF HIGGS EFFECTIVE FIELD THEORY

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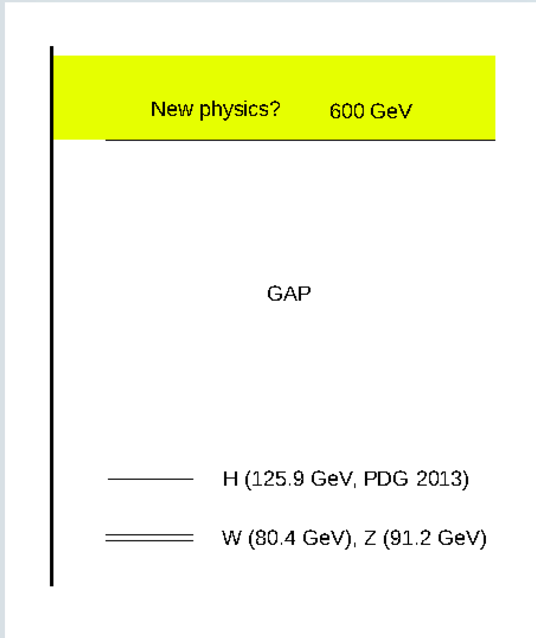
ABSTRACT

We report computations of the production cross-section of longitudinal electroweak boson pairs within Effective Field Theory for the Electroweak sector (including the Higgs). Particularly, we focuse on photon-photon production, as this is a very clean process allowing access to scalar and tensor resonances. We also employ LEP results on the oblique S,T parameters to constrain the HEFT parameter space.

1) LHC findings: the Higgs... and nothing else yet



Spectrum of the Electroweak Symmetry Breaking Sector

What to do next @LHC?

New physics would be great!!

Otherwise, contrain the Effective Field Theory of the particles that we do see.

Empirical science after all...

SMEFT (Standard Model EFT)
*) Linear realization of spontaneous symmetry breaking
*) The Higgs h is part of a complex doublet Φ
*) Constraints among coefficients

HEFT (Higgs EFT)
*) Non-Linear realization of spontaneous symmetry breaking
*) The Higgs h is an independent scalar field
*) Most general possible EFT for the electroweak sector ✔

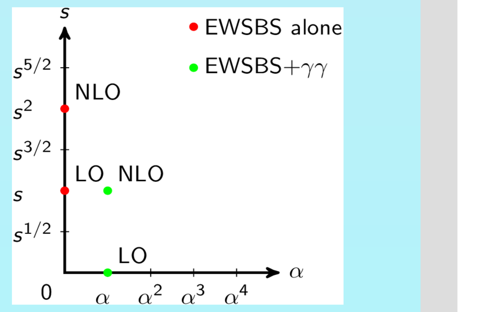
2) Lagrangian with chiral (derivative) counting

$$\mathcal{L} = \frac{1}{2}\left(1 + 2a\frac{h}{v} + b\left(\frac{h}{v}\right)^2\right)\partial_\mu\omega^a\partial^\mu\omega^b\left(\delta_{ab} + \frac{\omega^a\omega^b}{v^2}\right) + \frac{1}{2}\partial_\mu h\partial^\mu h + \frac{4a_4}{v^4}\partial_\mu\omega^a\partial_\nu\omega^a\partial^\mu\omega^b\partial^\nu\omega^b + \frac{4a_5}{v^4}\partial_\mu\omega^a\partial^\mu\omega^a\partial_\nu\omega^b\partial^\nu\omega^b + \frac{g}{v^4}(\partial_\mu h\partial^\mu h)^2 + \frac{2d}{v^4}\partial_\mu h\partial^\mu h\partial_\nu\omega^a\partial^\nu\omega^a + \frac{2e}{v^4}\partial_\mu h\partial^\nu h\partial^\mu\omega^a\partial_\nu\omega^a .$$

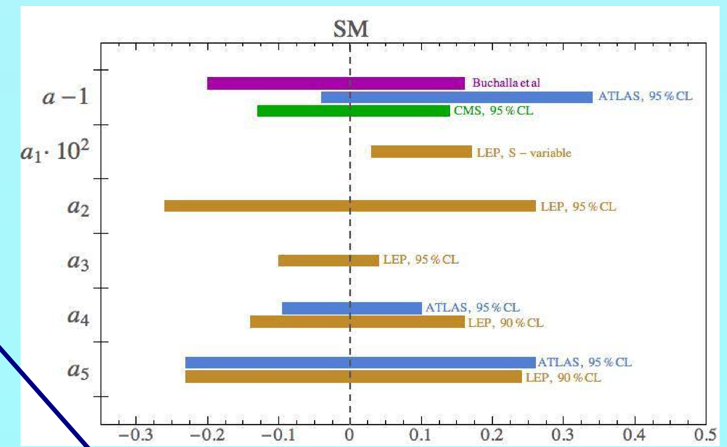
*) In the SM, $a^2=b=1$; all others vanish various BSM parameters can be studied

*) New strong interactions: separations from those values strong ww, hh rescattering

*) Coupling to γγ or tt (not part of EW symmetry sector) controlled by perturbation theory



Existing constraints on the HEFT parameters



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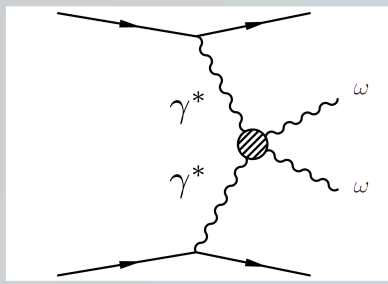
*) Oblique S, T parameter constraints from LEP.

*) Obtained by spectral representation of S,T in terms of spectral functions

How to make further progress at the LHC and at future e-e+ colliders?

5) Particularly clean: γγ collisions

Typical experimental problem: large, uncontrolled backgrounds rely on Monte Carlo simulations? Trust sideband fits? Try less noisy channels (low statistics is also low noise)



$$\frac{d\sigma_{pp\to ppW^+W^-}}{ds_{\gamma\gamma}} = \int dx dy E_p^2 \frac{f(x)}{E_p x}\frac{f(y)}{E_p y}\sigma_{\gamma\gamma\to W_L^+W_L^-}\delta(s_{\gamma\gamma} - 4xyE_p^2) = \int dx \frac{1}{s_{\gamma\gamma}}\frac{f(x)}{x} f\left(\frac{s_{\gamma\gamma}}{4E_p^2 x}\right)\sigma_{\gamma\gamma\to W_L^+W_L^-}$$

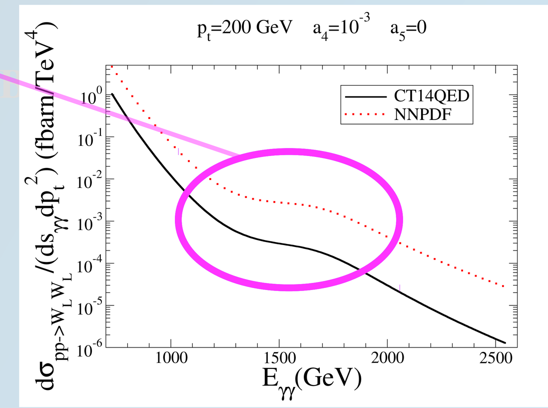
Soon to be published...

The IAM provides the parton-level cross-section

ABSENCE OF RESONANCES? CONSTRAIN PARAMETERS

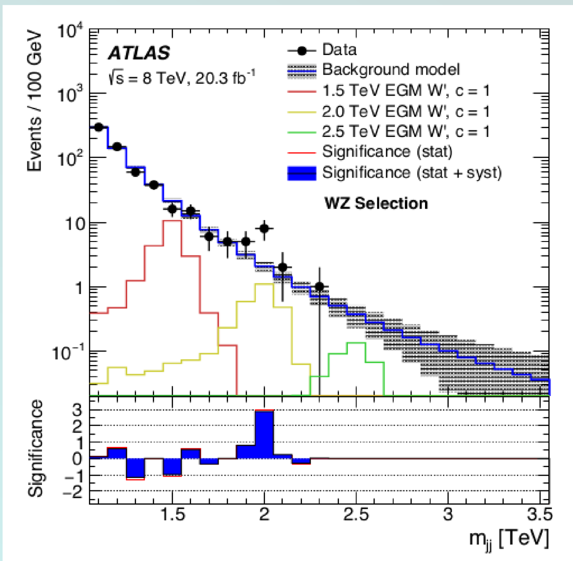
$$\mathcal{L}_4 = \frac{e^2 a_1}{2v^2}A_{\mu\nu}A^{\mu\nu}\left(v^2 - 4\omega^+\omega^-\right) + \frac{2e(a_2 - a_3)}{v^2}A_{\mu\nu}\left[i\left(\partial^\nu\omega^+\partial^\mu\omega^- - \partial^\mu\omega^+\partial^\nu\omega^-\right)\right. \left. + eA^\mu\left(\omega^+\partial^\nu\omega^- + \omega^-\partial^\nu\omega^+\right) - eA^\nu\left(\omega^+\partial^\mu\omega^- + \omega^-\partial^\mu\omega^+\right)\right] - \frac{c_\gamma}{2}\frac{h}{v}e^2 A_{\mu\nu}A^{\mu\nu}$$

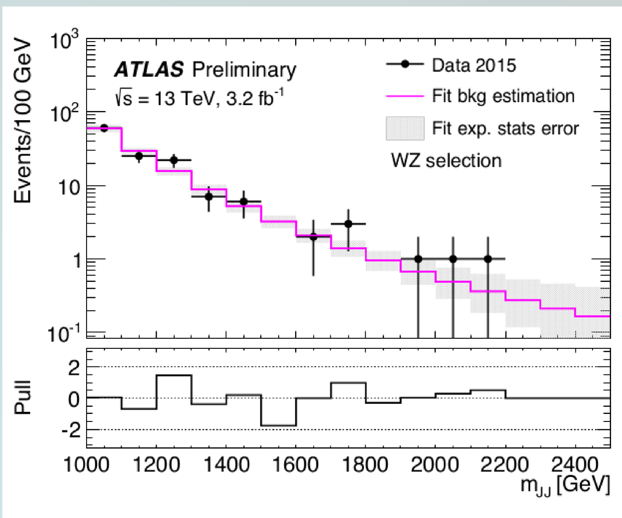
Additional terms in the Lagrangian coupling the photon



Access to $J^P = 0^+, 2^+$ resonances

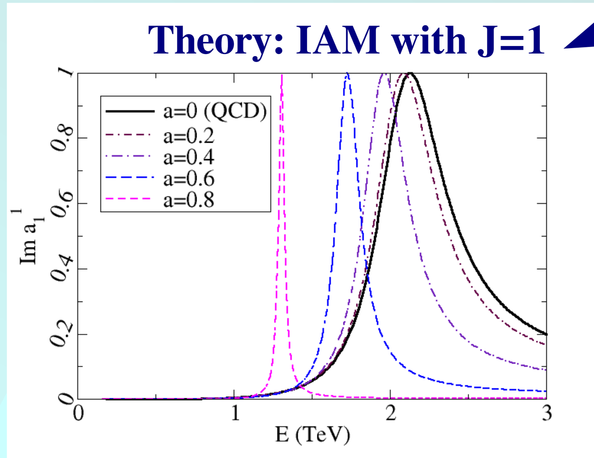
4.c) Search for vector resonances

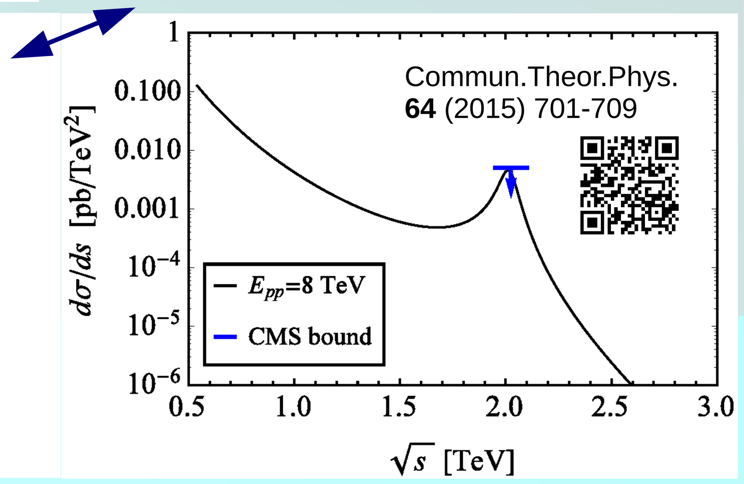




Experiment: ATLAS diboson

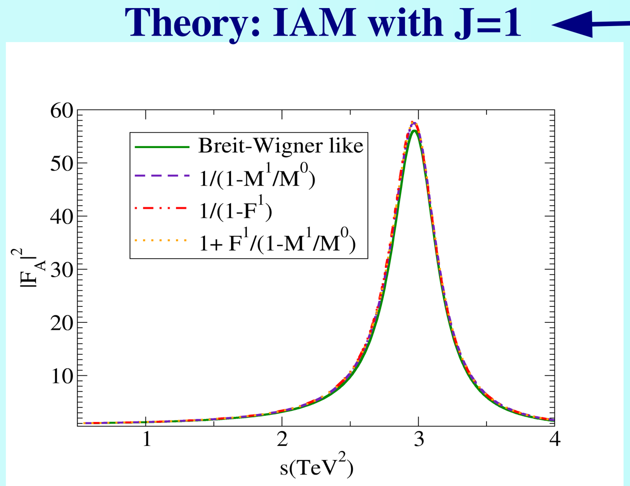
Theory: IAM with J=1



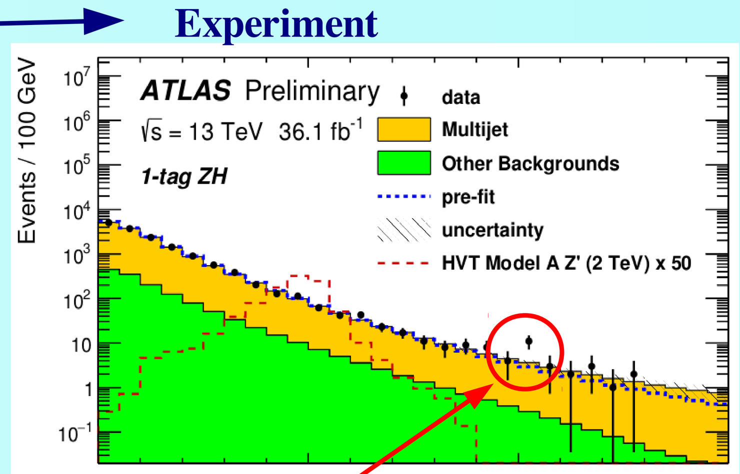


4.b) Searches for axial resonances: 3 TeV wh at ATLAS

Theory: IAM with J=1



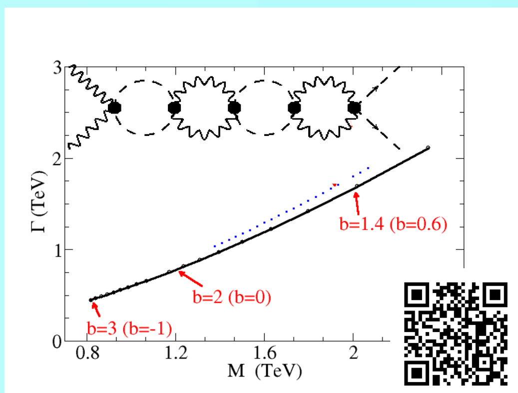
Experiment



Is that anything but a fluctuation?

4) Examples from recent LHC data

4.a) Absence of $W_L W_L$ resonance to constrain b (hh-$W_L W_L$ coupling)



from our PRL **114** (2015) 221803
-1 < b < 3
(because no $W_L W_L$ resonance seen at low energy, it cannot be too strongly coupled to hh)

3) Use resonance searches

Perturbative amplitudes grow polynomially in s (and violate unitarity)

$$A_{IJ}(s) = A_{IJ}^{(0)}(s) + A_{IJ}^{(1)}(s) + \cdots$$

$$A_{IJ}^{(0)}(s) = Ks,$$

$$A_{IJ}^{(1)}(s) = \left(B(\mu) + D\log\frac{s}{\mu^2} + E\log\frac{-s}{\mu^2}\right)s^2$$

Unitarized pert. Theory "Inverse Amplitude Method" produces resonances with M and Γ related to the Lagrangian parameters.

$$A(s) \simeq A^{\rm IAM}(s) = \frac{[A^{(0)}(s)]^2}{A^{(0)}(s) - A^{(1)}(s)}$$

Method: compare experimental resonance searches to IAM and use it to constrain parameters of HEFT