The Di-Boson Menagerie

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Recent Bumps

There has been recent experimental interest in di-boson resonant signatures , *e.g.*

- $\gamma\gamma$ di boson resonance at 750 GeV
- WW/ZZ/WZ/resonance at ~2 TeV

Di-boson resonant signatures yield generic interesting possibilities for search topologies

This talk will systematically explore models and signatures for such physics

This Talk:General exploration of final states in models with di-boson resonances. Consider all possible ways a particle can couple to 2 gauge bosons

Here we consider general set of gauge/Lorentz invariant EFT's under assumptions

-Spin:Models with spin 0 particle

-couplings:Only to to 2 SM gauge bosons

-gauge quantum numbers: begin with fundamental scalar and adjoint rep of SM gauge groups

EFT's

In order to systematically categorize possible decays of exotic scalars, I will write the most generic possible effective field theory Lagrangian.

- The assumption is that these operators are generated by integrating out some heavy 'mediator 'fields. The operators are useful as a catalog but EFT analysis will be invalid for certain calculations if the mediator scale is too light.

Consider Fields S, T, X

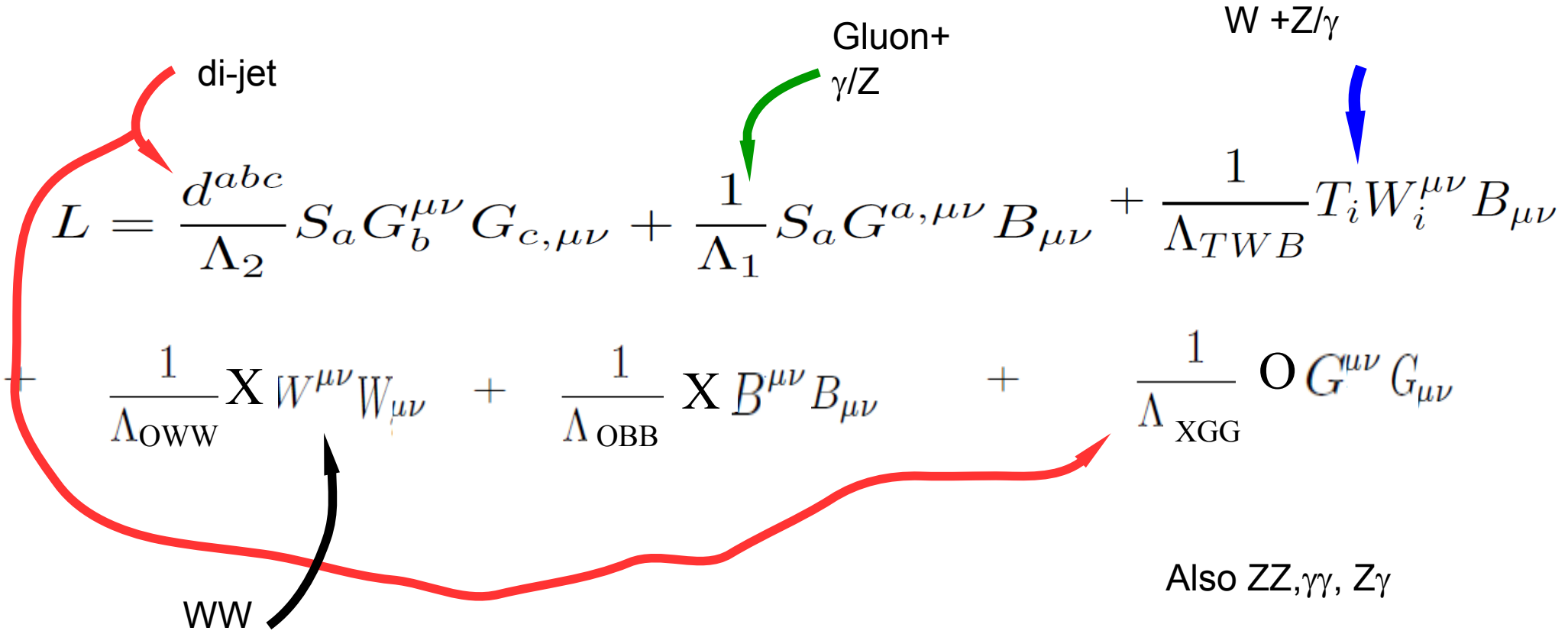
X in SM singlet, T is SU(2) adjoint, S is SU(3) adjoint

$$L = \frac{d^{abc}}{\Lambda_2} S_a G_b^{\mu\nu} G_{c,\mu\nu} + \frac{1}{\Lambda_1} S_a G^{a,\mu\nu} B_{\mu\nu} + \frac{1}{\Lambda_{TWB}} T_i W_i^{\mu\nu} B_{\mu\nu}$$

$$+ \frac{1}{\Lambda_{\mathrm{OWW}}} \mathrm{X} W_i^{\mu\nu} W_{\mu\nu} + \frac{1}{\Lambda_{\mathrm{OBB}}} \mathrm{X} B^{\mu\nu} B_{\mu\nu} + \frac{1}{\Lambda_{\mathrm{OGG}}} \mathrm{X} G^{\mu\nu} G_{\mu\nu}$$

Dim 5 Operators

Some Decay Signatures



- Dim 7 Operators

WW

$$L = \frac{1}{\Lambda^3_{TBB}}[H^\dagger T H]B^{\mu\nu}B_{\mu\nu} + \frac{1}{\Lambda_{TWW^3}}[H^\dagger T H]W^{\mu\nu}W_{\mu\nu}$$

$$\frac{1}{\Lambda^3_{TGG}}[H^\dagger T H]G^{\mu\nu}G_{\mu\nu} + \frac{1}{\Lambda^3_{SGW}}S^a G^{\mu\nu}_a [H^\dagger W^i_{\mu\nu} H]$$

di-jet

Also $\gamma\gamma$, ZZ, $Z\gamma$

Searches for resonant pairs of all gauge bosons are possible. Depending on operator production mechanisms are manifold,eg S field, color adjoint production mechanisms

- gluon fusions g g > S
- Associated production with g
- Associated production with photon/Z

Monohar-Wise Model, scalar color octet SU(2) doublet

We can be even more creative by considering fields charged under multiple gauge groups

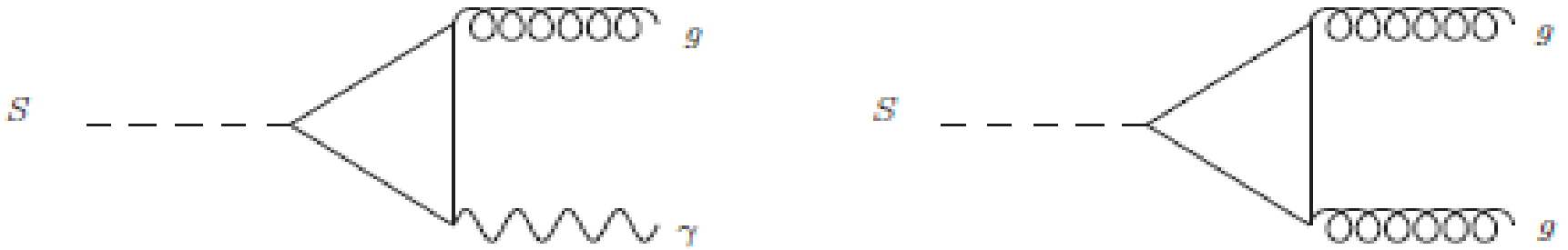
$$L = \frac{1}{\Lambda^2_{gg1}} d^{abc} H^\dagger S_{ua} G^{\mu\nu}_b G^{\mu\nu}_c + \frac{1}{\Lambda^2_{gg2}} d^{abc} H S_{da} G^{\mu\nu}_b G^{\mu\nu}_c + \frac{1}{\Lambda^2_{gb1}} H^\dagger S^a_u G^{\mu\nu}_a B^{\mu\nu} + \frac{1}{\Lambda^2_{gb2}} H S_d G^{\mu\nu}_a B^{\mu\nu}$$
$$+ \frac{1}{\Lambda^2_{gw1}} [H^\dagger W^{\mu\nu} S_u] G^{\mu\nu}_a + \frac{1}{\Lambda^2_{gw2}} [H W^{\mu\nu} S_d] G^{\mu\nu}_a$$

Dim 6 operators

Completions

EFT operators may be completed in a variety of models with similar phenomenology

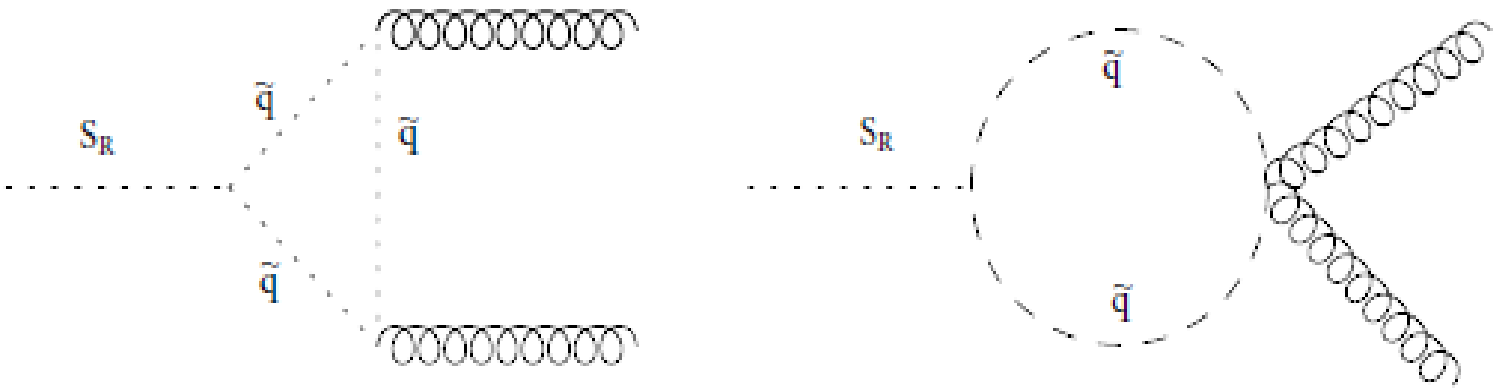
- Arbitrary model with fundamental scalars mediated to SM by some heavy vector-like fermions



- Models of strong coupling in which scalar fields S,T,X are composite. (technicolor -like theories) predict existence of a spectrum of fields in various representations of the SM.

Supersymmetry

- Models with Dirac gauginos already predict the existence of scalar and pseudo-scalar fields in adjoint representation of SM gauge groups. These are the partners of the gauginos.



- These couple to squarks and sleptons as well as possible messengers which mediate SUSY breaking

- This theory naturally contains a complex SM adjoint superfield that “marries” the SM gaugino

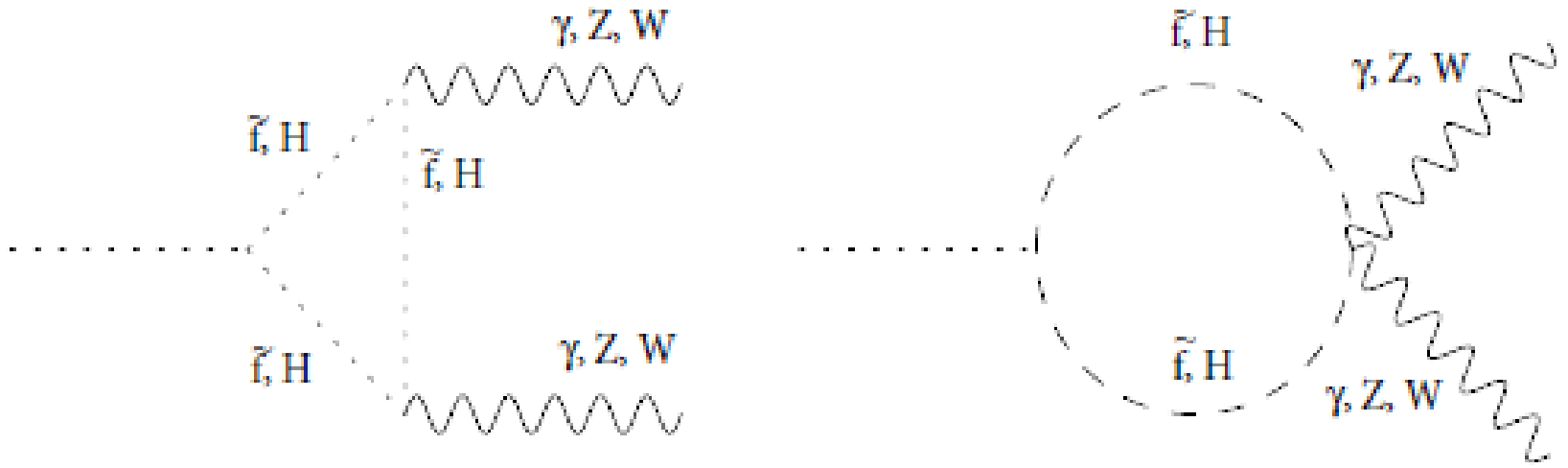
$$W = \int d^2\theta \frac{W'_\alpha W^\alpha A}{\Lambda} = \frac{D\lambda\psi_A}{\Lambda}$$

The gauge field and adjiont couple to a broken U(1) superfield creating a Dirac mass. In a similar fashion, couplings between the adjoint and 2 SM gauge fields may occur

$$W = \int d^2\theta \frac{W^Y_\alpha W^\alpha A}{\Lambda} \qquad W = \int d^2\theta \frac{d^{abc} W_3^a W_3^b S^c}{\Lambda'}$$

As examples

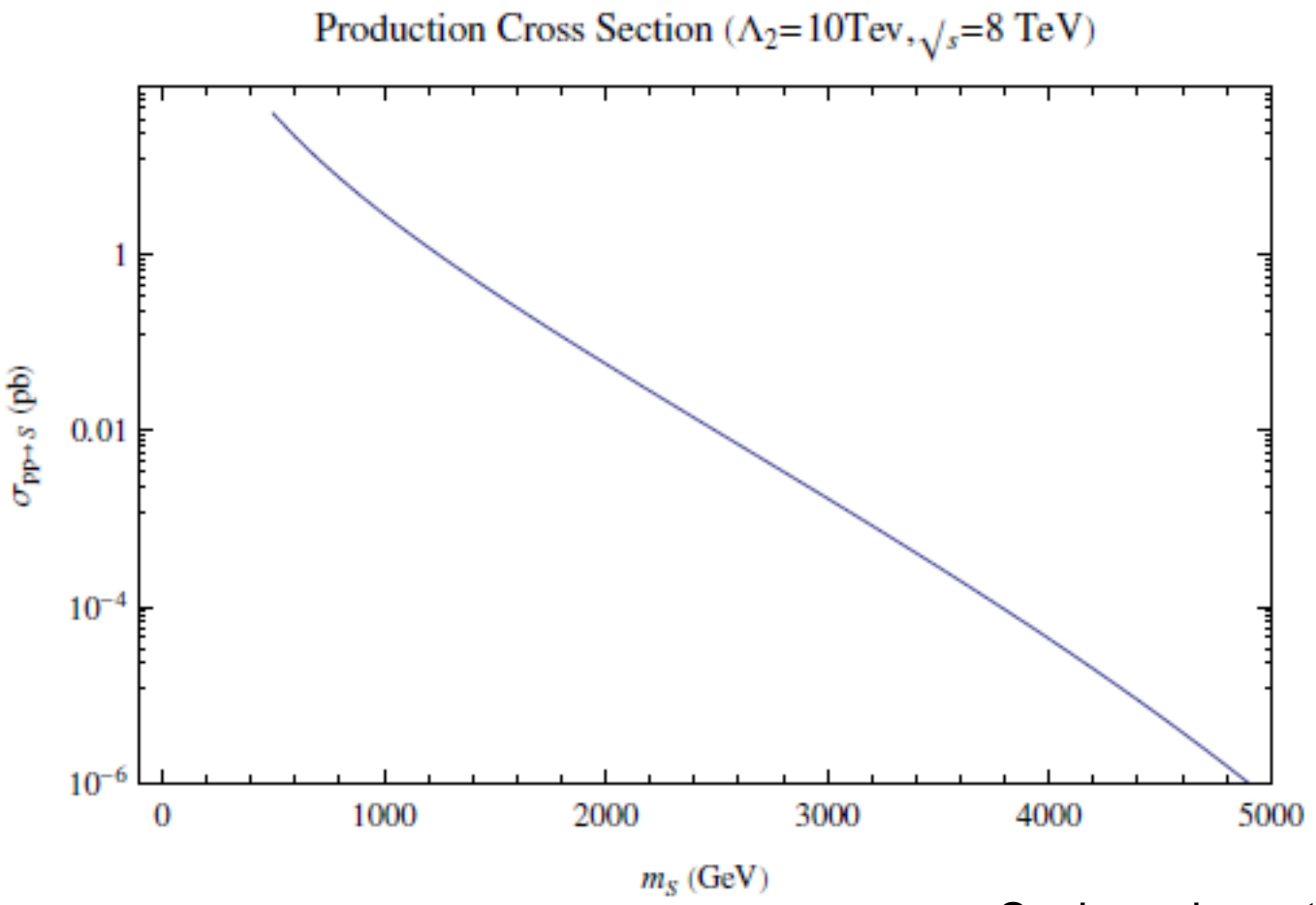
Also useful for explaining mysterious 750 GeV particles



Candidate particle could be real or imaginary part of Bino partner or real or imaginary Wino partner with appropriate Higgs vevs inserted

Just one example of search possibilities

- A single production mode of 1 possible state

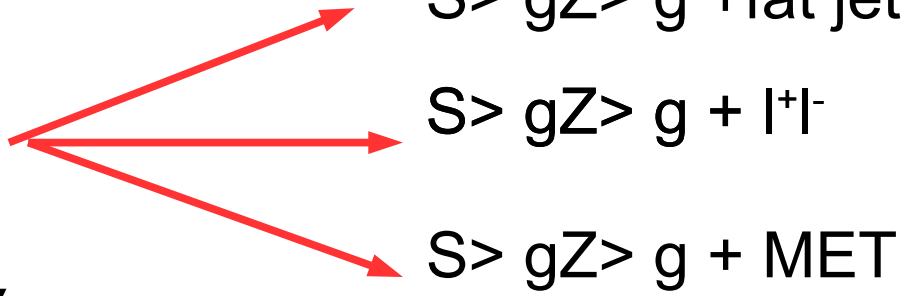


Scalar color octet

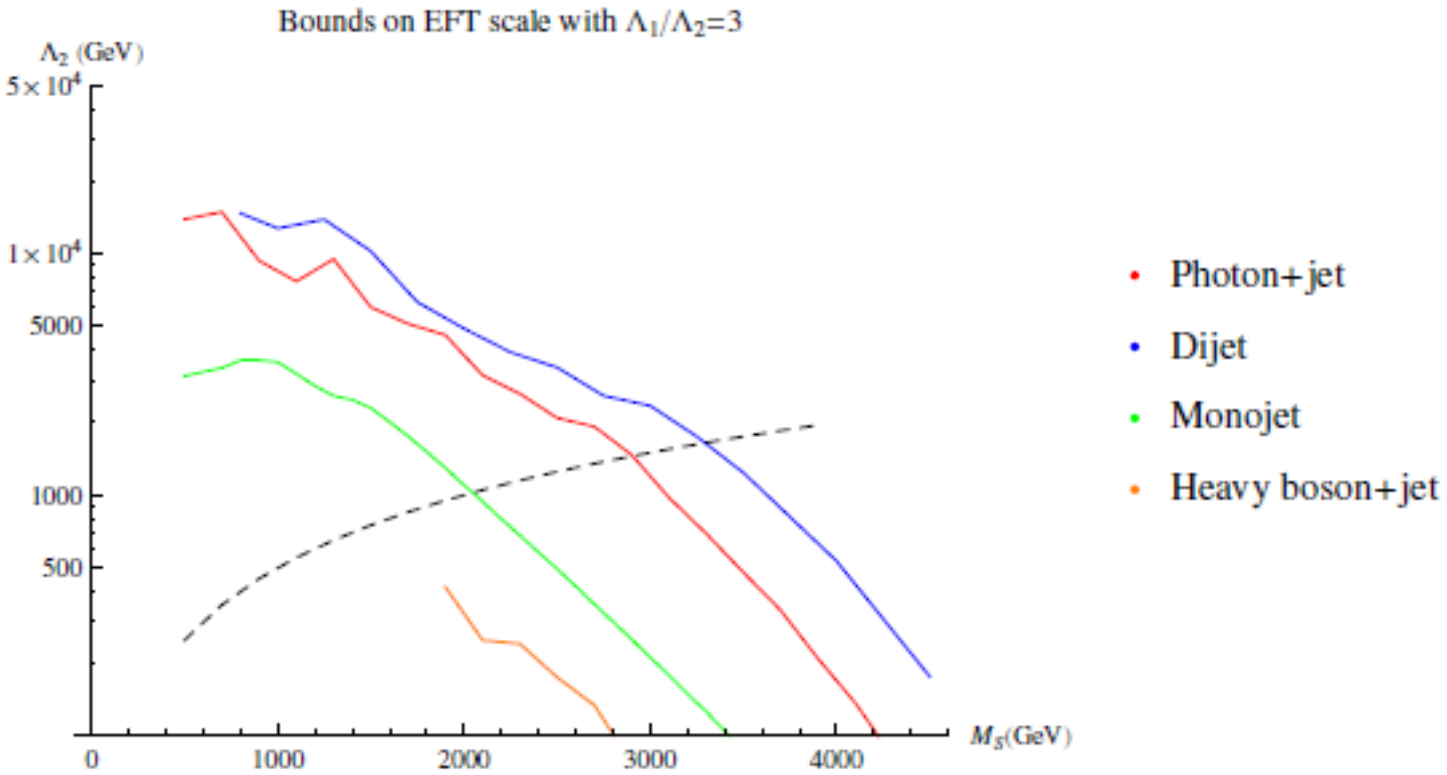
Dim 5 decay to gluons or g+Z/γ

Now 5 distinct search topologies apply to single S production

- gg>S>gg
- gg>S>gZ
- gg>S>g γ

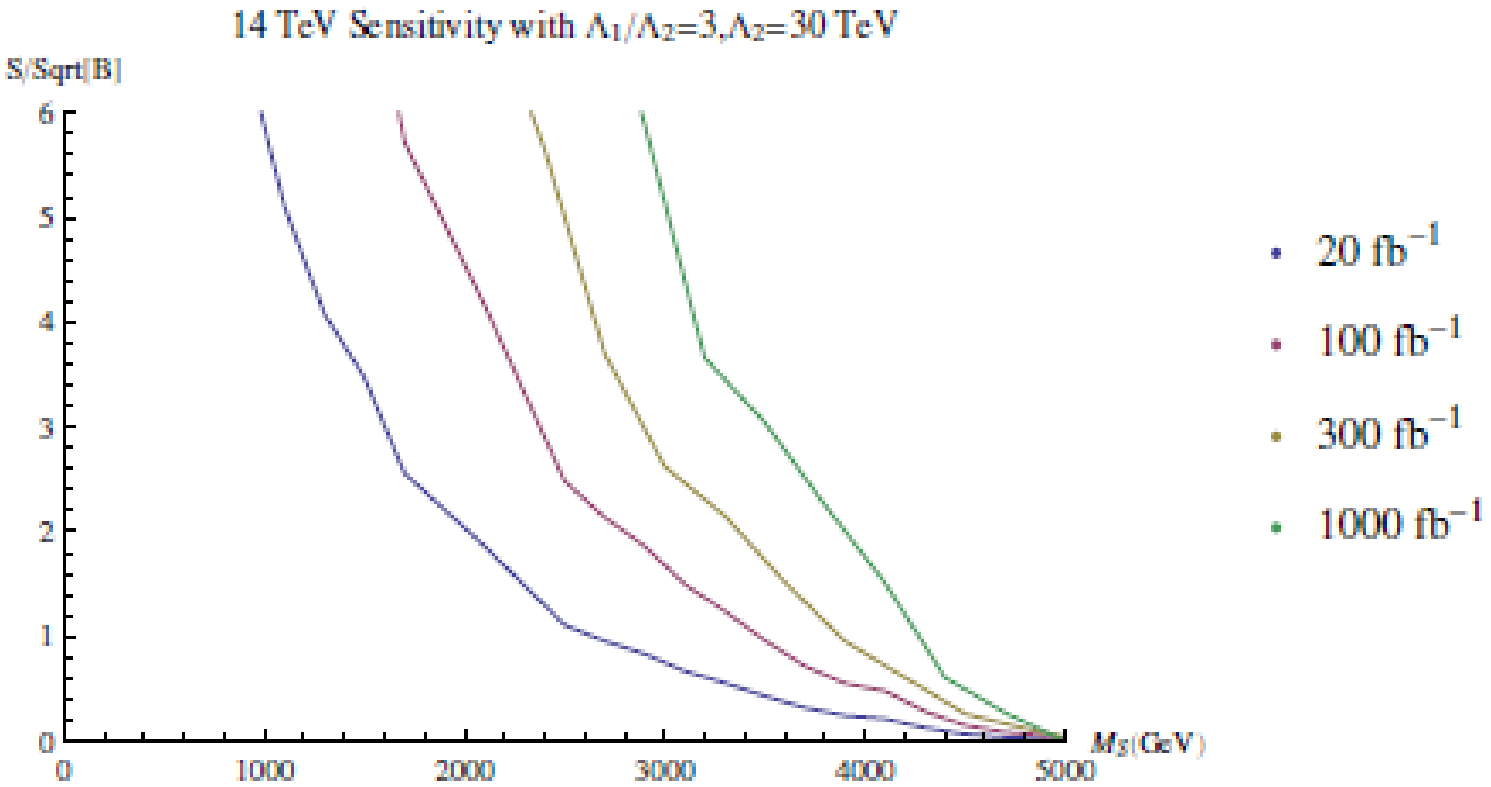


8 TeV bound



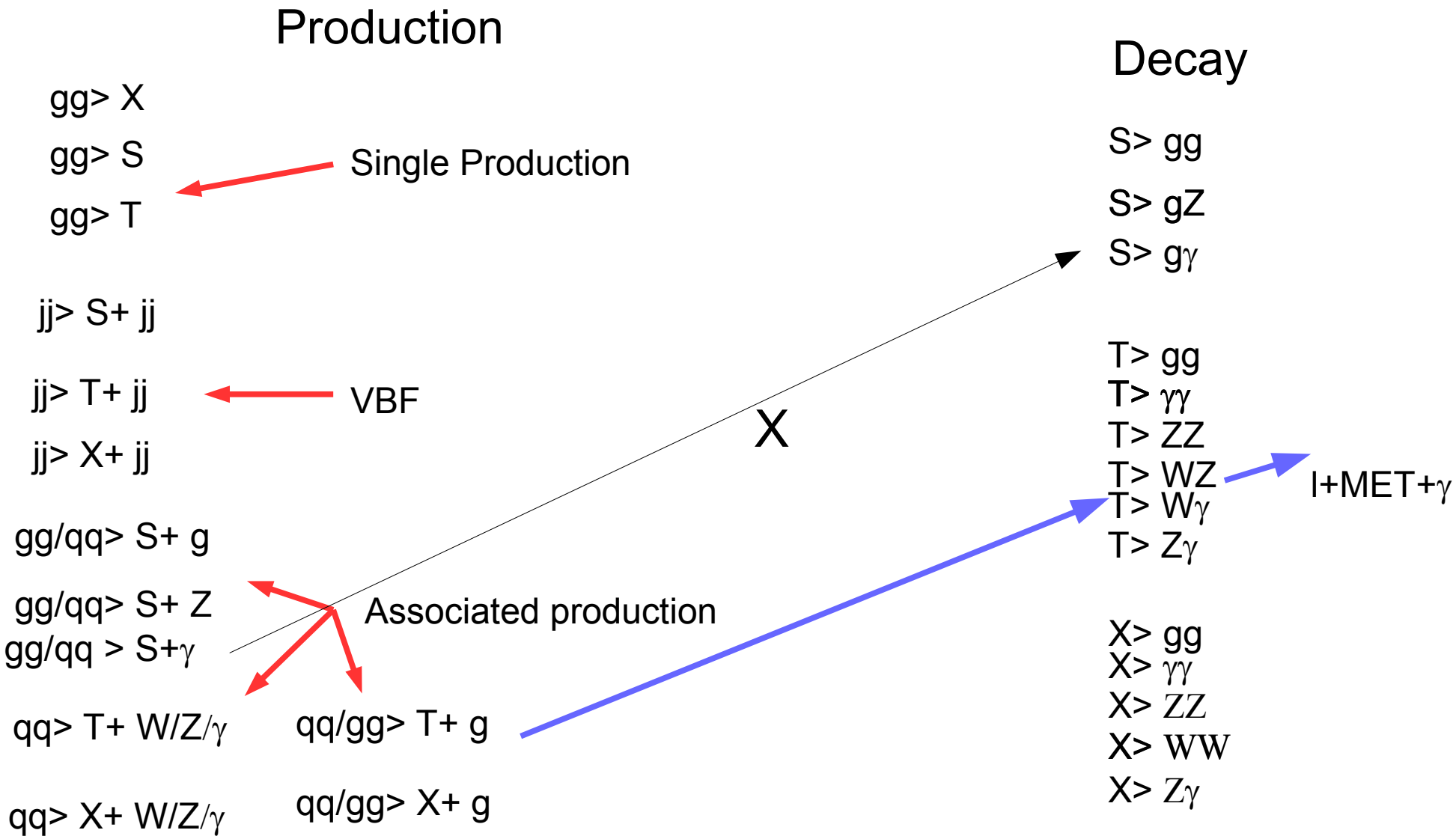
Combined 95% confidence level bound on EFT scale from all the channels considered for the choice $\Lambda_2 = .1\Lambda_1$. The black dashed line corresponds to where the validity of the EFT framework breaks down $m_S > 2\Lambda_i$.

High Energy Run Sensitivity

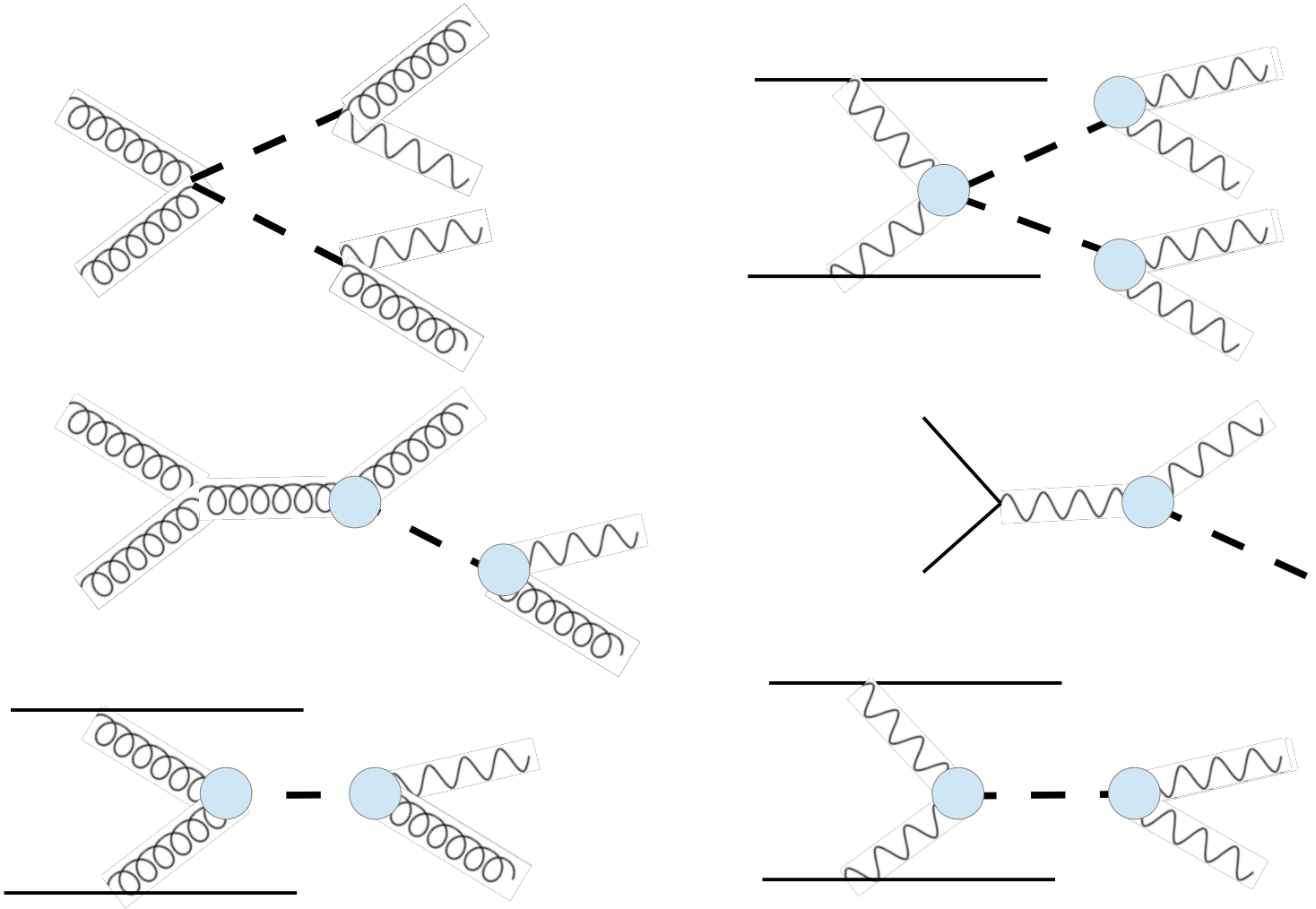


- At least one isolated photon with $p_T > 125$ GeV
- At least one hard jet with $p_T > 125$ GeV.
- Photon required to have angular separation $\Delta R(\gamma, j) > 1.0$ between leading photon and all other jets with $p_T > 30$ GeV.
- Photon and jet required to be in the central region of the detector with $|\eta_\gamma| < 1.37$ and $|\eta_j| < 2.8$.
- Pseudo-rapidity separation between jet and photon of $|\Delta\eta(\gamma, j)| < 1.6$.
- Highest p_T γ and jet candidates used to compute $m_{\gamma j}$, which is binned.

Production and Decay Menagerie



These are correlated



A menagerie of possible event topologies may exist in models where new fields couple to pairs of dibosons

Completeness compels us to consider a full set of possible operators, which may be correlated by theoretical consideration in full UV models

If current hints remain a complete exploration of theory space requires correlating measurements of these possible events