Higgs decays to jets, or to photons + jets

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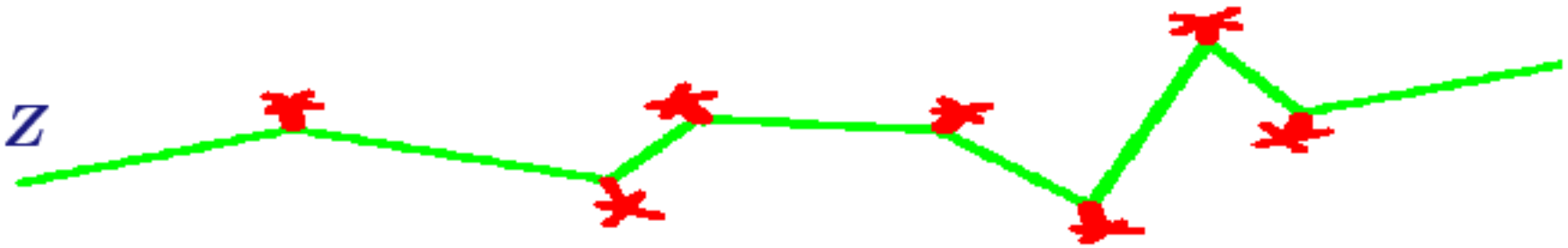
We know that $SU(2)_C \times U(1)_Y \to U(1)_Q$

$\Rightarrow$ $W^{\pm}$ and Z have not only transverse polarizations,

but also longitudinal ones: three spin-0 states have been eaten.



What is the origin of electroweak symmetry breaking?

We do not know:

- what unitarizes $W_L^+ W_L^-$ scattering?
- why is there a VEV that breaks $SU(2) \times U(1)$?
- what has a VEV that breaks $SU(2) \times U(1)$?

Even in the context of the standard model, we know little about the electroweak breaking sector.

Small perturbations of the standard model field content can affect dramatically the Higgs phenomenology:

- *Higgs branching fractions for $M_h < 2M_W$ are set by small couplings $\Rightarrow$ nonstandard Higgs decays expected in the presence of new particles.*

- *electroweak observables depend on $\ln M_h$, whereas they typically depend quadratically on the parameters of new particles.*

Higgs decays to "axions"

Standard model + a scalar singlet S: $cH^\dagger H S^\dagger S$

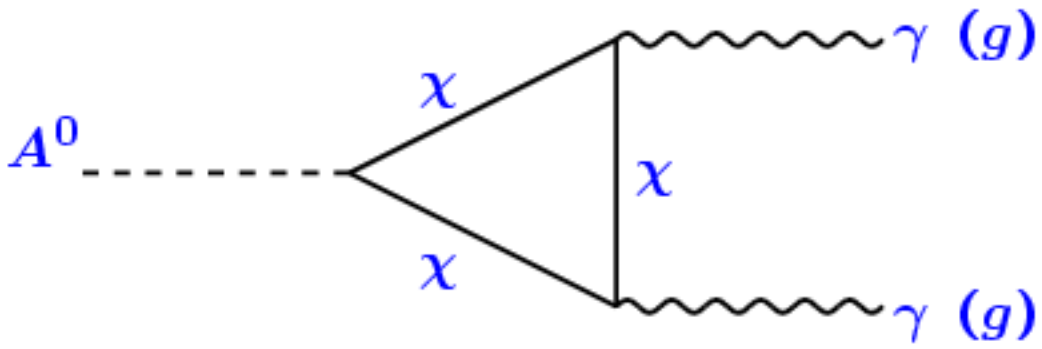
$$S = \frac{1}{\sqrt{2}}\left(\varphi_S + \langle S\rangle\right) e^{iA^0/\langle S\rangle} \quad , \; A^0 \text{ is a CP-odd spin-0 particle (axion)}$$

$$\frac{c\,v}{2} h^0 A^0 A^0 \text{ coupling} \;\Rightarrow\; \Gamma(h^0 \to A^0 A^0) = \frac{c^2\,v^2}{32\pi M_h}\left(1 - 4\frac{M_A^2}{M_h^2}\right)^{1/2}$$

(Dobrescu, Landsberg, Matchev, hep-ph/0005308)

The subsequent decays of A^0 are model dependent.

Example: $\mathcal{L} = \xi S \overline{\chi}_L \chi_R + \text{h.c.} - V(H,S)$, χ is a new fermion



Effective coupling of the axion to pairs of gluons and photons:

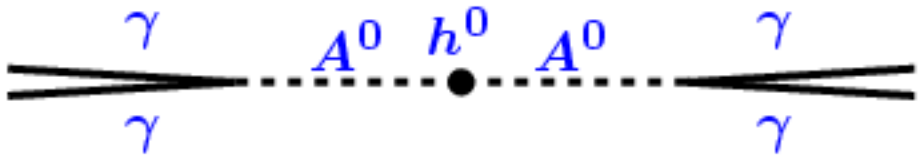
$$\frac{-\sqrt{2}}{16\pi\langle S\rangle} A^0 \epsilon^{\mu\nu\rho\sigma} \left[T_2(\chi) \alpha_s \, \mathrm{G}_{\mu\nu} \mathrm{G}_{\rho\sigma} + N_c e_\chi^2 \alpha \, F_{\mu\nu} F_{\rho\sigma} \right]$$

Case 1) **If χ is electrically-charged color singlet**

$\Rightarrow$ **Br**$(A^0 \to \gamma\gamma) \approx 100\%$

Br$(h \to A^0 A^0 \to \gamma\gamma\gamma\gamma) \approx 100\% \Rightarrow$ **tiny background at the LHC, Higgs boson will be discovered early!**

Note: for $M_A \lesssim 1$ GeV the two photons from a Higgs decay overlap: $h \to A^0 A^0 \to 4\gamma$ decay will appear in the detector as a diphoton resonance



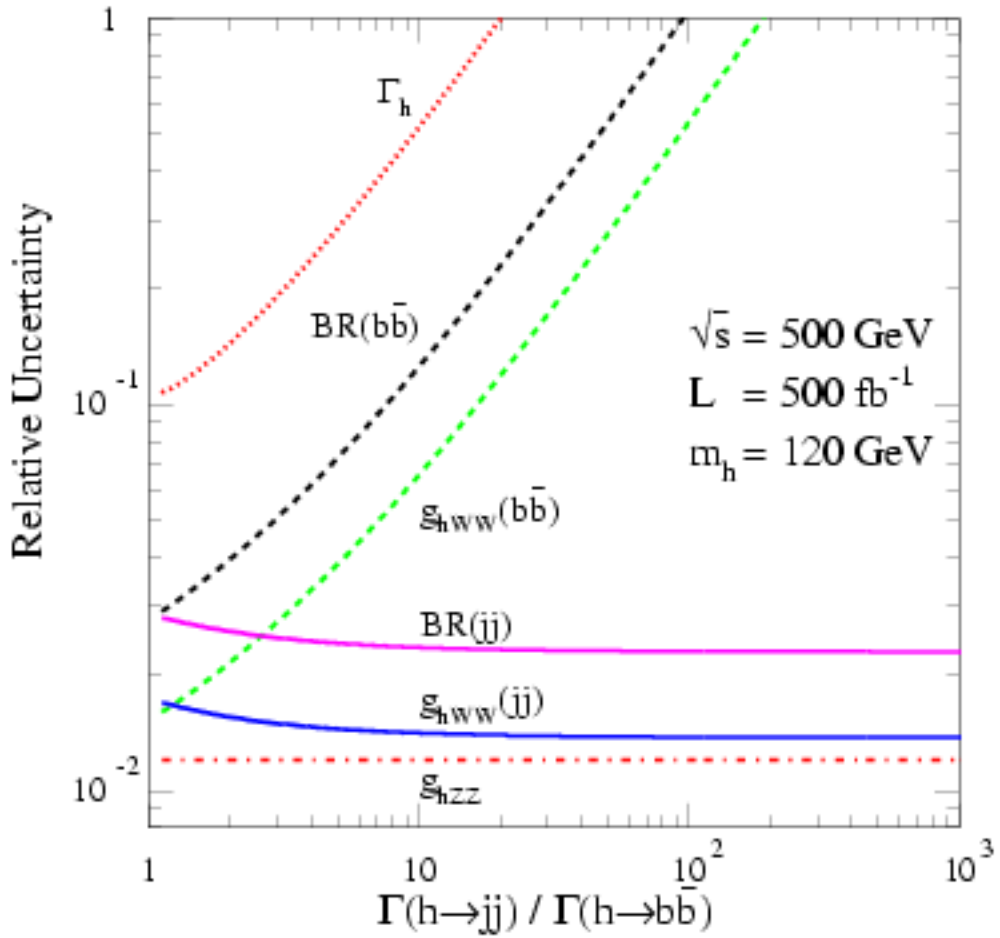
Case 2) **If the fermion χ is colored and electrically neutral,**

$\Rightarrow$ **Br**$(A^0 \to gg) \approx 100\%$

For $M_h < 2M_W$, **Br**$(h \to A^0 A^0 \to 4\,\text{jets}) \approx 100\%$

$\Rightarrow$ **huge background at the LHC.**

ILC required for Higgs discovery!



Berger, Chiang, Jiang, Tait, Wagner, hep-ph/0205342

"Higgs boson decay into hadronic jets,"

based on the observation that the **Higgs** could decay into light sbottoms:

Carena, Heinemeyer, Wagner, Weiglein, hep-ph/0008023

Case 3) **The fermion χ is both colored and electrically charged**

$\Rightarrow$ **competition between Br$(A^0 \to gg)$ and Br$(A^0 \to \gamma\gamma)$**

(S. Chang, P.J. Fox, N. Weiner, hep-ph/0608310)

Best motivated theoretically!