SNOWMASS21-EF2_EF1-209 LOI
HIGGS COUPLINGS MEASUREMENTS AND MODEL INDEPENDENT BOUNDS ON THE SCALE OF NEW PHYSICS

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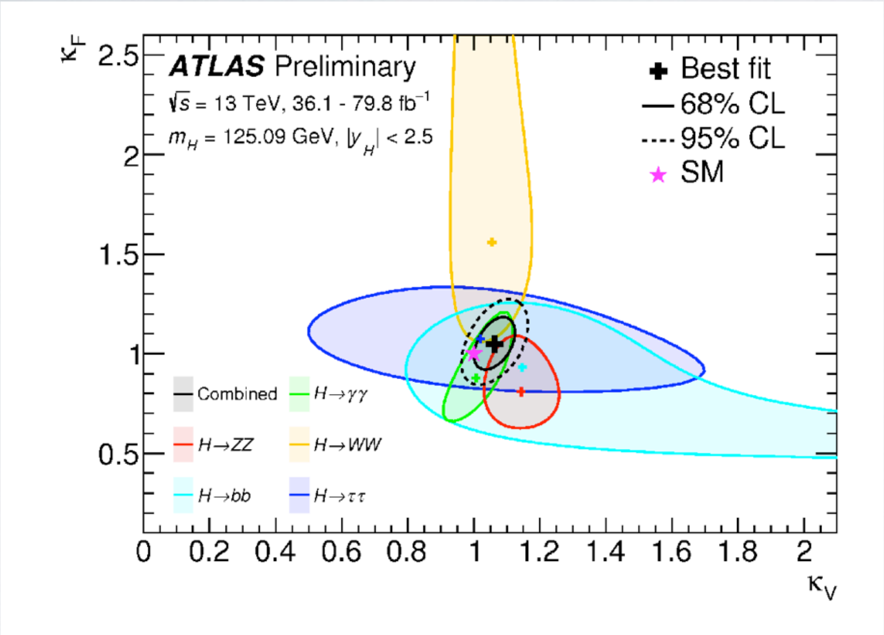
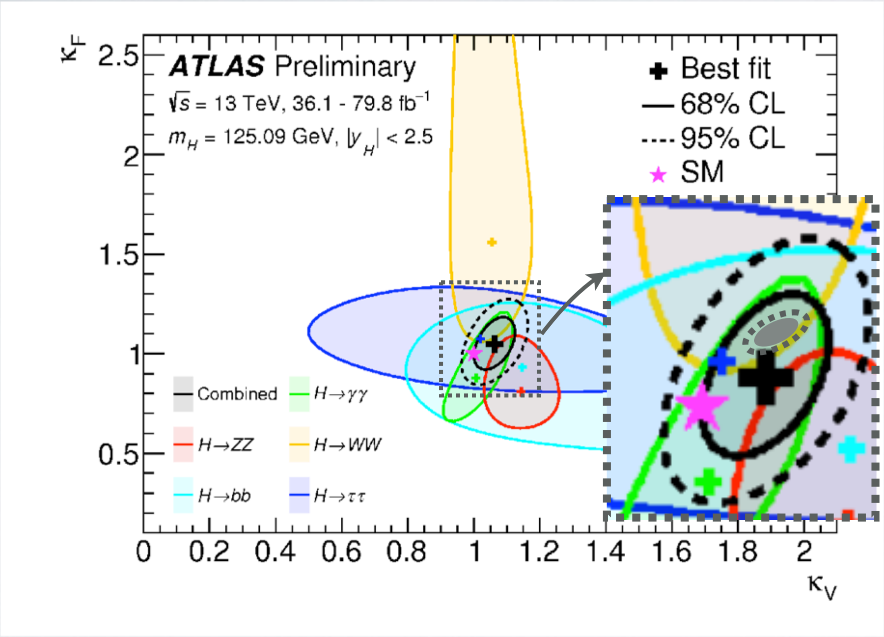
EF02 Nov. 12th, 2020 Meeting

PRECISION HIGGS



What are the new physics implications of a Higgs coupling deviation?

PRECISION HIGGS



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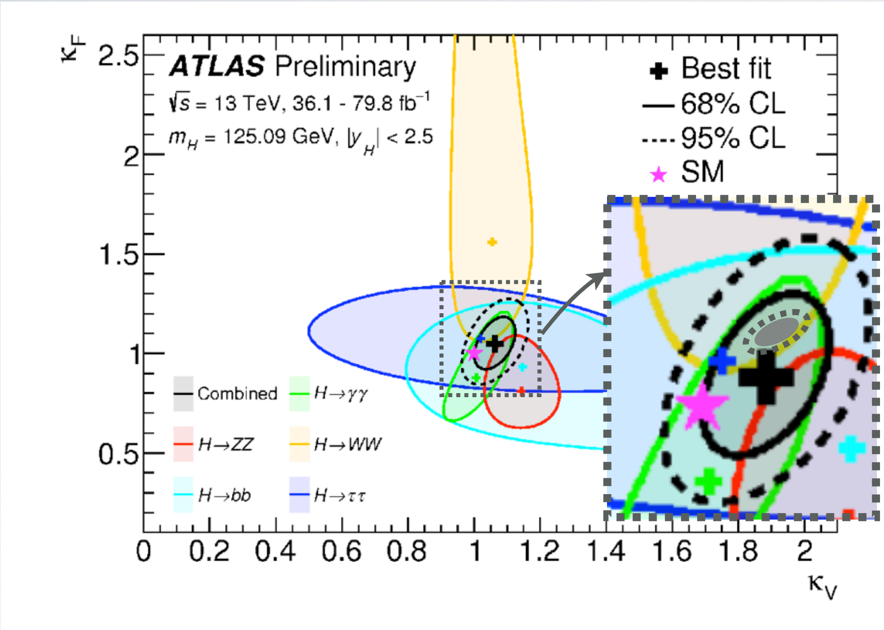

What are the new physics implications of a Higgs coupling deviation?

Any Higgs coupling deviation from SM prediction leads to unitarity violation at high energies, placing an upper bound on new physics. Also, leads to interesting processes to measure (see Henning et.al. 1812.09299 & Stolarski, Wu 2006.09374)

GENERAL HIGGS COUPLINGS

$$
\begin{aligned}
\mathcal{L} = \mathcal{L}_{\mathrm{SM}} &- \delta_3 \frac{m_h^2}{2v} h^3 - \delta_4 \frac{m_h^2}{8v^2} h^4 - \sum_{n=5}^{\infty} \frac{c_n}{n!} \frac{m_h^2}{v^{n-2}} h^n + \cdots \\
&+ \delta_{Z1} \frac{m_Z^2}{v} h Z^\mu Z_\mu + \delta_{W1} \frac{2m_W^2}{v} h W^{\mu +} W_\mu^- + \delta_{Z2} \frac{m_Z^2}{2v^2} h^2 Z^\mu Z_\mu + \delta_{W2} \frac{m_W^2}{v^2} h^2 W^{\mu +} W_\mu^- \\
&+ \sum_{n=3}^{\infty} \left[\frac{c_{Zn}}{n!} \frac{m_Z^2}{v^n} h^n Z^\mu Z_\mu + \frac{c_{Wn}}{n!} \frac{2m_W^2}{v^n} h^n W^{\mu +} W_\mu^- \right] + \cdots \\
&- \delta_{t1} \frac{m_t}{v} h \bar{t} t - \sum_{n=2}^{\infty} \frac{c_{tn}}{n!} \frac{m_t}{v^n} h^n \bar{t} t + \cdots
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GENERAL HIGGS COUPLINGS

$$\mathcal{L} = \mathcal{L}_{\rm SM} - \delta_3 \frac{m_h^2}{2v} h^3 - \delta_4 \frac{m_h^2}{8v^2} h^4 - \sum_{n=5}^{\infty} \frac{c_n}{n!} \frac{m_h^2}{v^{n-2}} h^n + \cdots$$ Higgs Potential Couplings

$$+ \delta_{Z1} \frac{m_Z^2}{v} h Z^\mu Z_\mu + \delta_{W1} \frac{2m_W^2}{v} h W^{\mu+} W_\mu^- + \delta_{Z2} \frac{m_Z^2}{2v^2} h^2 Z^\mu Z_\mu + \delta_{W2} \frac{m_W^2}{v^2} h^2 W^{\mu+} W_\mu^-$$

$$+ \sum_{n=3}^{\infty} \left[\frac{c_{Zn}}{n!} \frac{m_Z^2}{v^n} h^n Z^\mu Z_\mu + \frac{c_{Wn}}{n!} \frac{2m_W^2}{v^n} h^n W^{\mu+} W_\mu^- \right] + \cdots$$ W/Z Couplings

$$- \delta_{t1} \frac{m_t}{v} h \bar{t} t - \sum_{n=2}^{\infty} \frac{c_{tn}}{n!} \frac{m_t}{v^n} h^n \bar{t} t + \cdots$$ top Couplings

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Any nonzero **δ** or **c** coupling is a sign of new physics, which leads to unitarity violation at high energies, giving an upper bound on this new physics

BEST CHANNELS FOR HIGGS TRILINEAR

$$hW_L^+W_L^- \to W_L^+W_L^- \ : \ E_{max} = \frac{6.4 \text{ TeV}}{\left|\frac{\delta_3}{11}\right|}$$

$$W_L^+W_L^+W_L^- \to W_L^+W_L^+W_L^- \ : \ E_{max} = \frac{4.3 \text{ TeV}}{\sqrt{\left|\frac{\delta_3}{11}\right|}}$$

(Normalized to largest deviation consistent with ATLAS and CMS di-Higgs 95%CL constraints)

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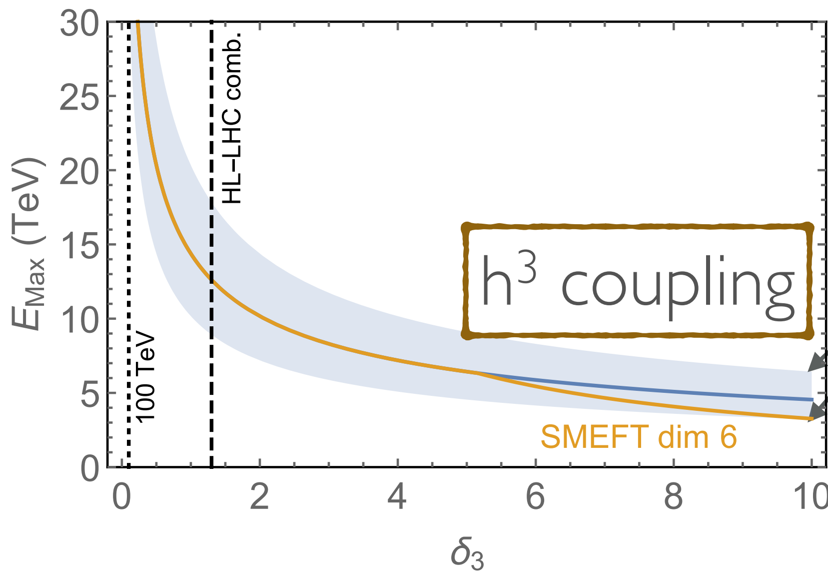
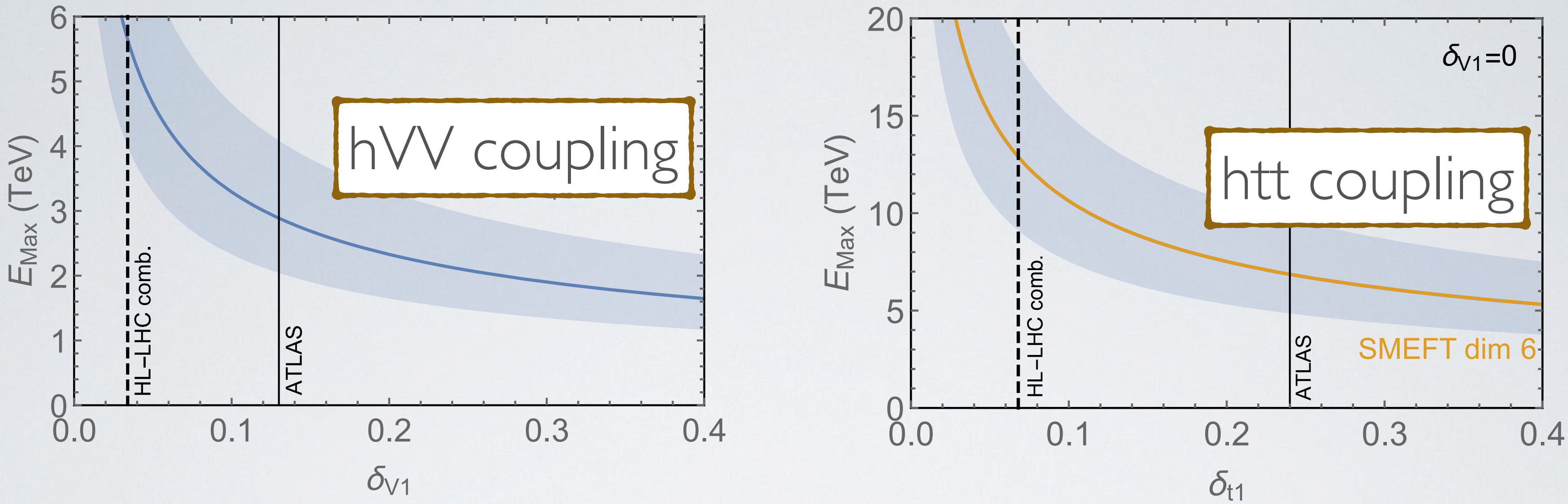


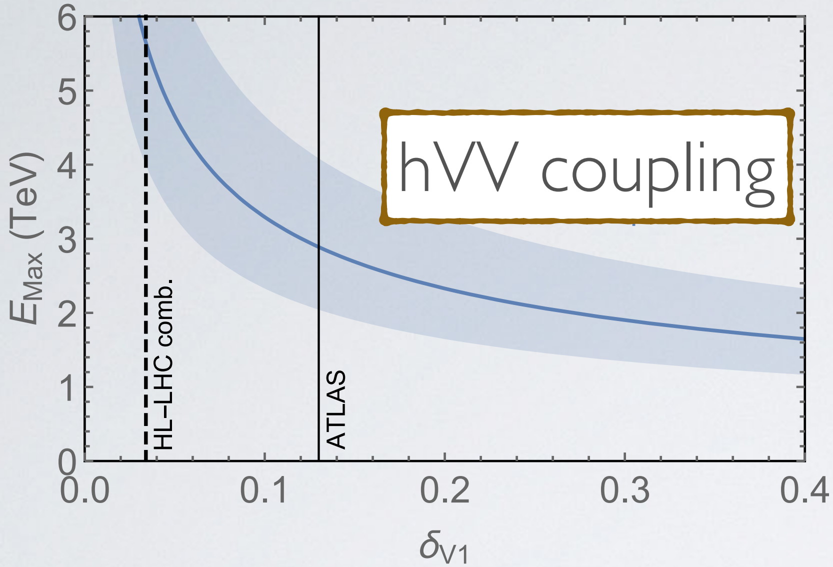
Estimated
Theoretical uncertainty of
Unitarity violating scale

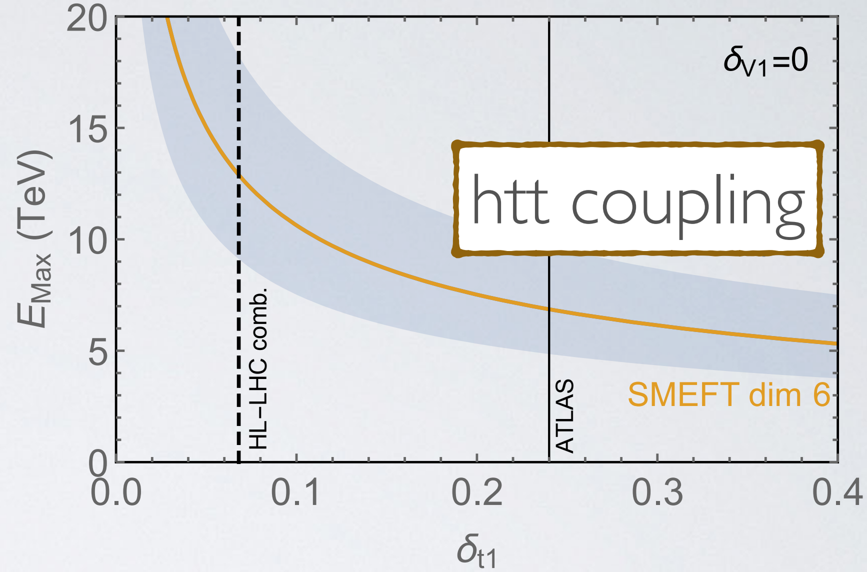
Current bound allows new physics below ~ 4 TeV

W/Z AND TOP COUPLINGS



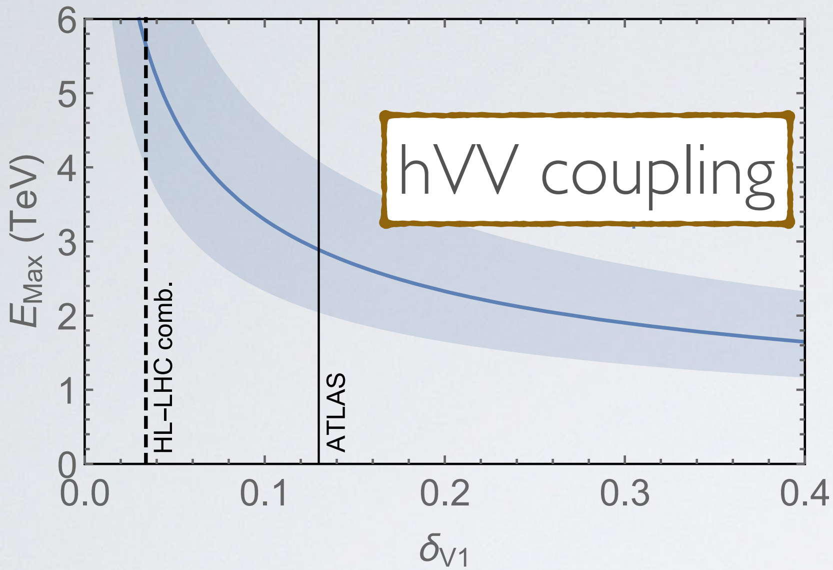
W/Z AND TOP COUPLINGS

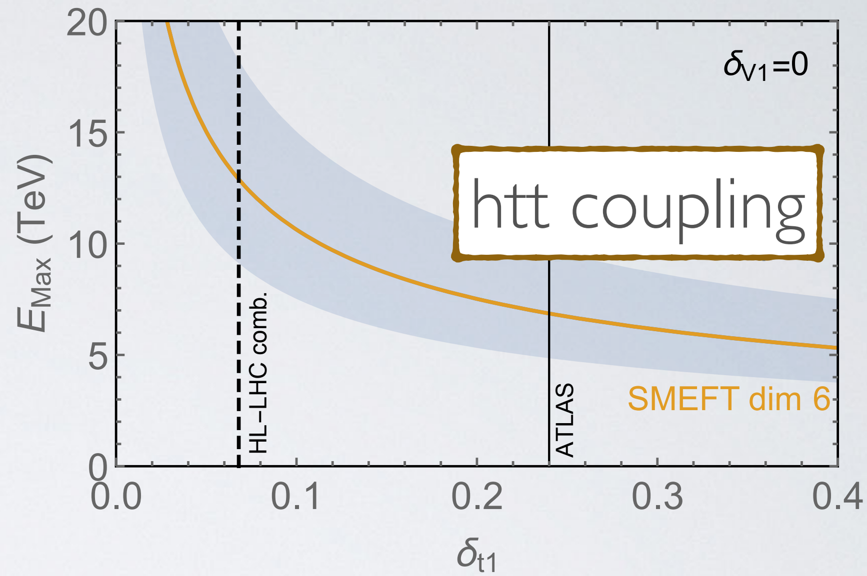




Existing strong bounds on these couplings still allow future deviations where new physics has to appear below ~ 3-8 TeV. In fact, hVV is more powerful than h^3!

W/Z AND TOP COUPLINGS





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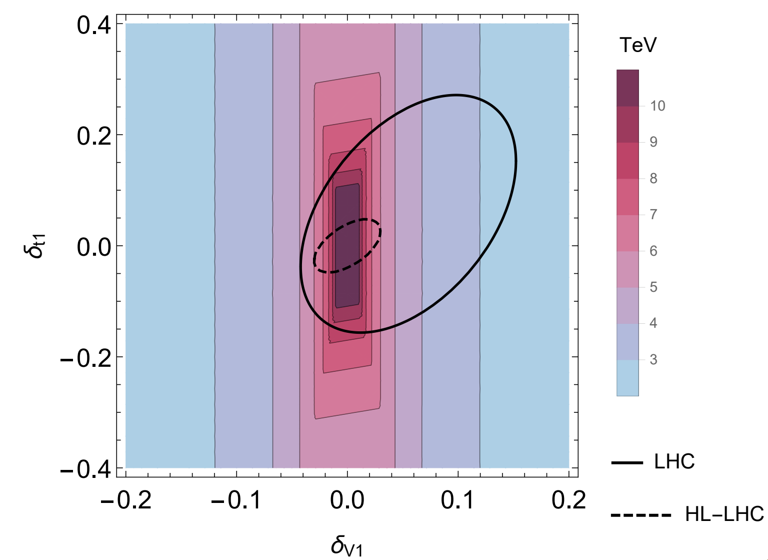

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If you're interested in discussing or collaborating, please let us know!

THANK YOU FOR YOUR ATTENTION!