Is the Higgs composite?

Kenneth Lane, Boston University,
with
Lukas Pritchett, PL B753,211 (2016),
Will Shepherd, PRD99,05515 (2019),
Eric Pilon, PRD101,055032 (2020),
Estia Eichten, PRD103,115022 (2021).

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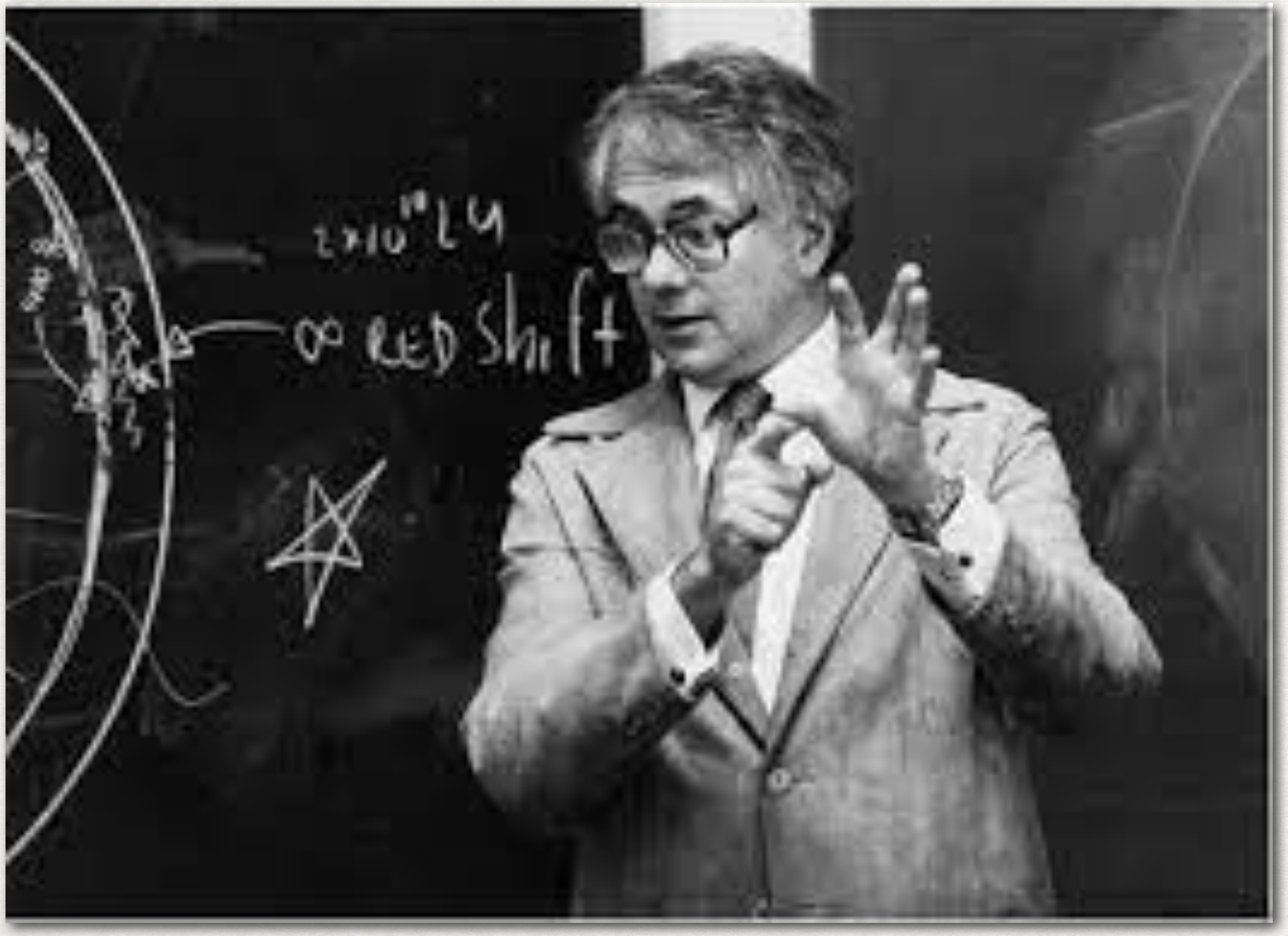

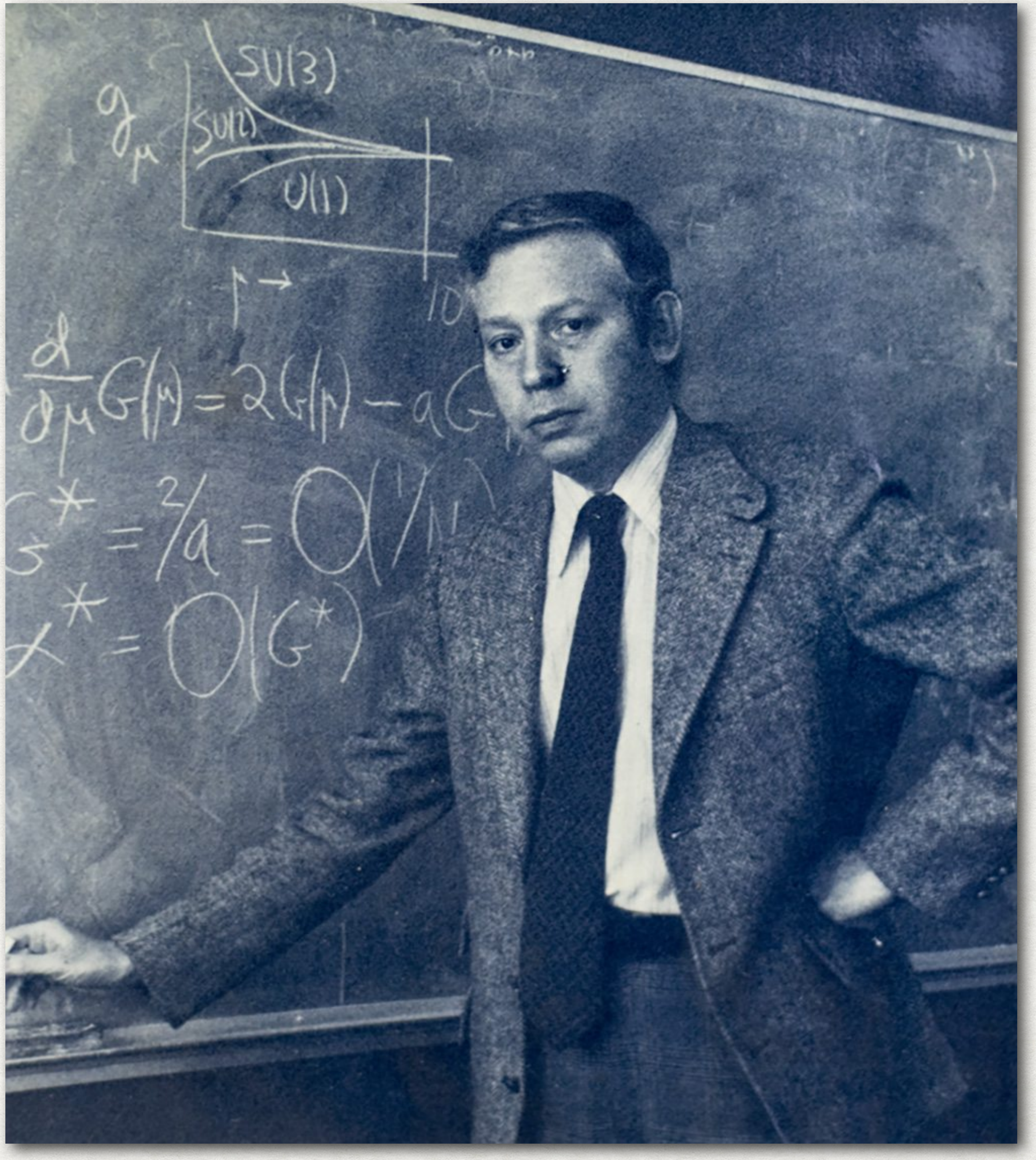

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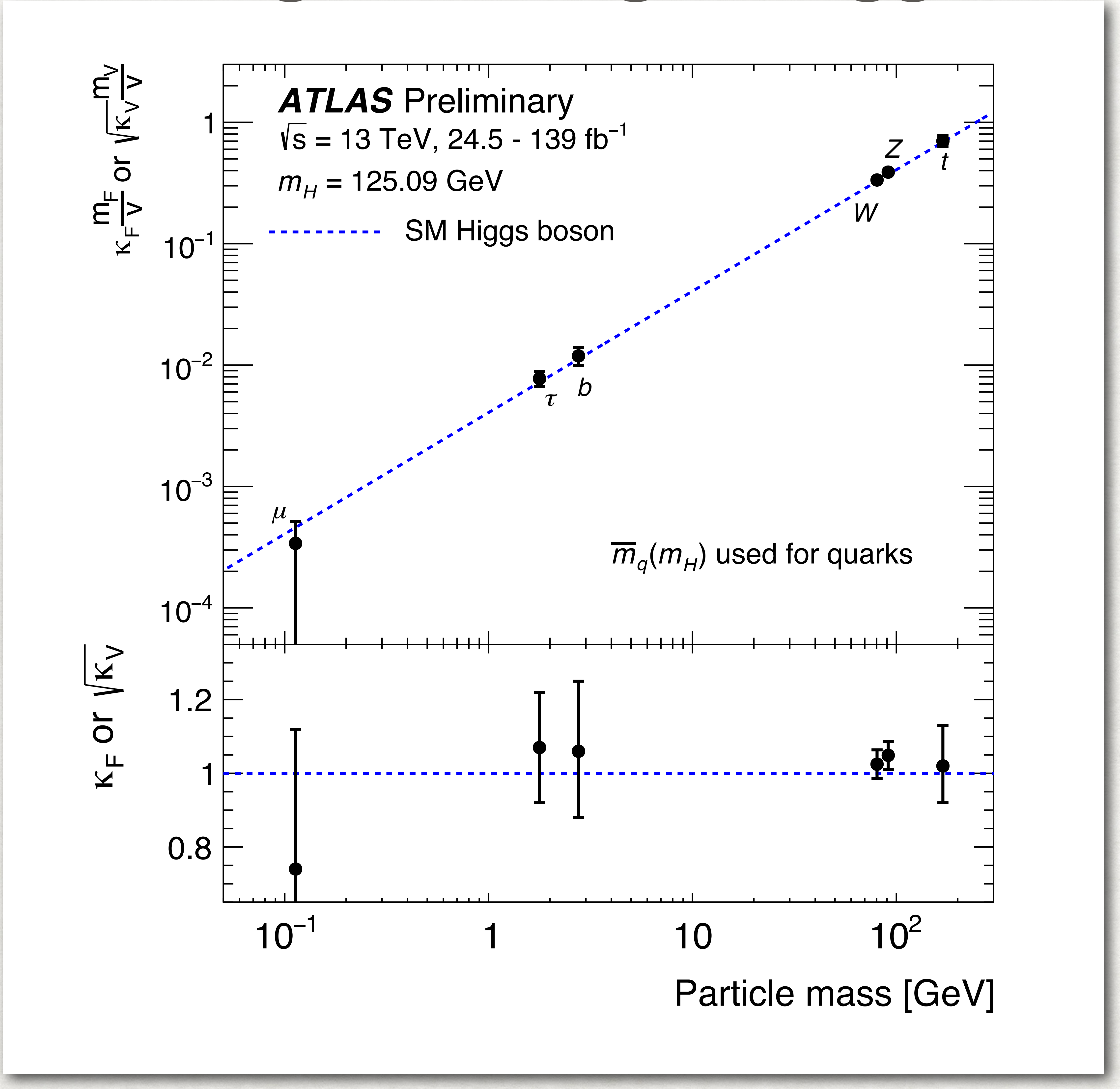

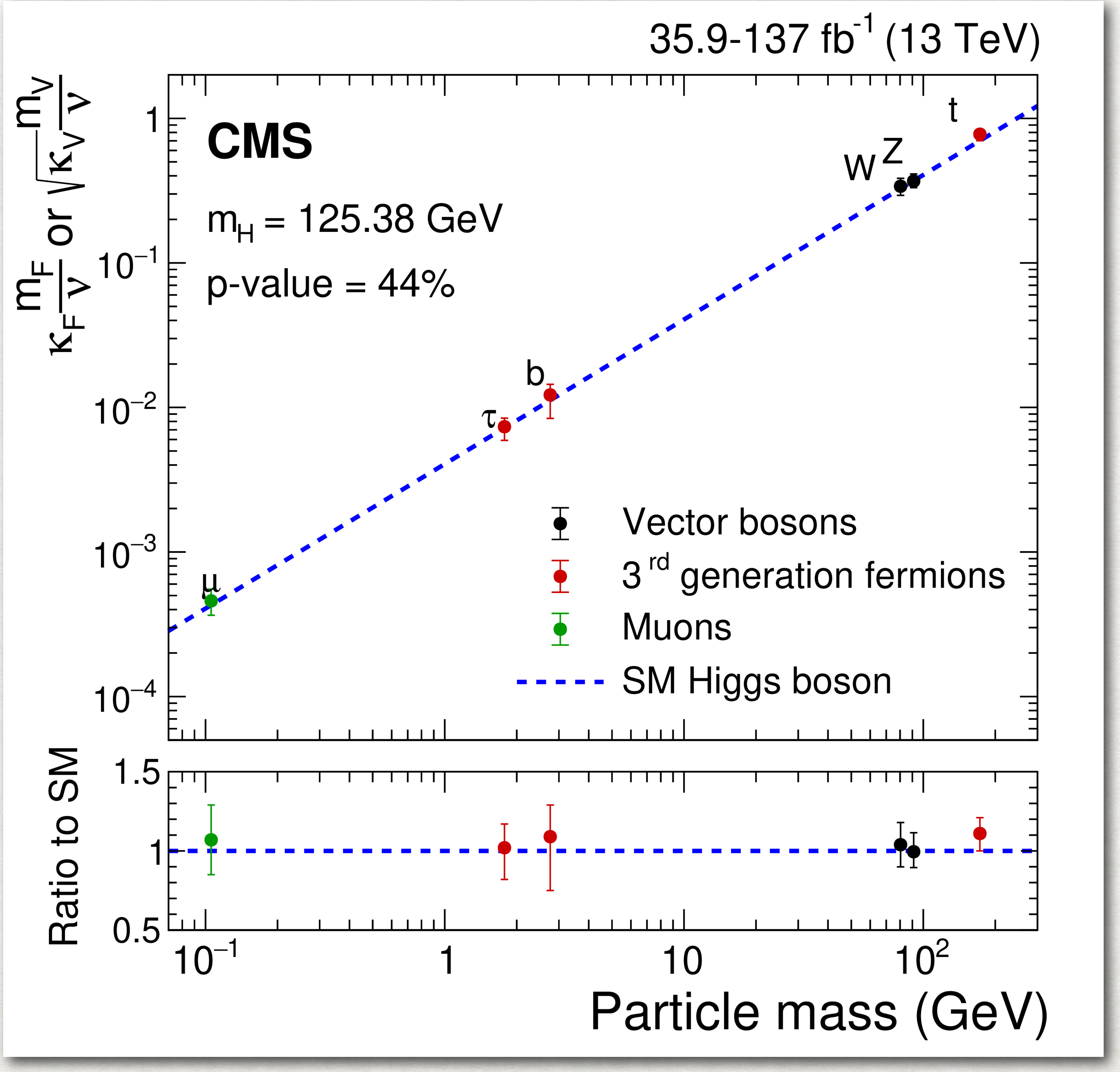

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If this is all there is, particle physicists might as well call it a day…or **NOT!**

Let's assume that H(125) is composite.

H is a product of new strong interactions (S.I.) at

$$\Lambda_H \gtrsim 1\,\mathrm{TeV}$$

These S.I. are also responsible for EWSB, so that there are also the composite Goldstone bosons

$$W_L^{\pm}, Z_L$$

What are they composites of? Who knows…?
But their constituents must be fermions, with a chiral symmetry that contains EW SU(2) x U(1), now <u>spontaneously broken</u> to EM U(1).

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…and does it Naturally!!

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- The S.I. coupling is near, but just barely beyond, the critical value for spontaneous breaking of the fermions’ chiral symmetry, again $\sim$ a TeV. (This is a version of walking TC.) **But**, again, it is fine-tuning.

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  This idea was proposed 45 years ago by E. Gildener and S. Weinberg (GW) in PR**D13**, 3333 (1976)! Furthermore, in the GW scheme, the dilaton scale f = v (246 GeV) and H is **aligned**, i.e., its couplings to W,Z and to fermions are $\simeq$ exactly as in the SM!

There are many signals of the GW Higgs. But almost all of them appear to be much more accessible at the "low-energy" LHC and its "modest" upgrades.
(See the papers on the title page).

BUT, there is one signal that **must** be somewhere above a TeV <u>and</u> which is GW-model independent.

Heavy VV-diboson resonances w/ $\boldsymbol{V = W^{\pm}, Z}$

- These are spin-one bound states of the S.I. fermions with isospin I = 1 (and 0) and accessible via Drell-Yan production (also VBF):

$$\bar{q}q' \to W^{\pm}, Z, \gamma \to X_{\bar{V}V'} \to \boldsymbol{\bar{V}V'}$$

(<u>Math note:</u> Chiral symmetry of S.I. fermions $\boldsymbol{\subseteq (2_L, 2_R) = (1, 3)}$ of weak isospin.)

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- Their mass $M_X = \mathcal{O}(\Lambda_H)$ is unknown… but we look where we can!

Heavy VV-diboson resonances w/ $\boldsymbol{V = W^{\pm}, Z}$

- I =1 vectors decay to pairs of S.I. "pions"

$$\rho_H^{\pm} \to W_L^{\pm} Z_L,\ \rho_H^0 \to W_L^+ W_L^- \quad - \text{but } \underline{\text{not}}\ Z_L Z_L$$

- I =1 axial-vectors decay like the a_1 :

$$a_H^{\pm} \to W_L^{\pm} H,\ a_H^0 \to Z_L H$$

(**N.B.**: This is **<u>not</u>** the HVT model: $\boldsymbol{a_H \neq \rho_H}$!!)

(See also Appelquist, et al., JHEP 1601 (2016) 109; also K.L. and L. Pritchett, PLB753, 211.)

ρ_H, a_H decay rates

$$\Gamma(\rho_H^0 \to W^+W^-) \cong \Gamma(\rho_H^\pm \to W^\pm Z) \cong \frac{g_{\rho_H}^2 M_{\rho_H}}{48\pi}$$

$$\Gamma(a_H^0 \to ZH) \cong \Gamma(a_H^\pm \to W^\pm H) \cong \frac{g_{\rho_H}^2 M_{a_H}}{48\pi}$$

$$\Gamma(a_H^0 \to W^+W^-) \cong \Gamma(a_H^\pm \to W^\pm Z) \cong \frac{g_{\rho_H}^2 M_W^2 M_{a_H}^3}{24\pi M_{\rho_H}^4} = \mathcal{O}(g^2)$$

$(g_{\rho_H} = \mathcal{O}(1),\ M_{\rho_H, a_H} \simeq g_{\rho_H} \Lambda_H)$

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$$\Gamma(a_H^0 \to ZH) \cong \Gamma(a_H^\pm \to W^\pm H) \cong \frac{g_{\rho_H}^2 M_{a_H}}{48\pi}$$

$\Big\}$ $\simeq 200\,\mathrm{GeV}$ at $M \simeq 2\,\mathrm{TeV}$

N.B.: These decays are dominated by W_L, Z_L.

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N.B.: These decays aren't ! $\lesssim 1\,\mathrm{GeV}$ at $M \simeq 2\,\mathrm{TeV}$

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$\sigma(pp \to \rho_H^{\pm,0}) \simeq 2\sigma(pp \to a_H^{\pm,0}) \simeq 2$–$10$ fb at LHC(14 TeV)

$\boldsymbol{\rho_H, a_H}$ decay rates

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What about $\boldsymbol{\sigma(e^+e^- \to \rho_H^0, a_H^0)}$ at $\boldsymbol{\sqrt{s} \simeq 2\,\mathrm{TeV}}$?


BUMP HUNTERS
BU physicists sift through the shrapnel of proton collisions made by the biggest machine on Earth, searching for new physics

The End