Oblique corrections from Light Composite Higgs

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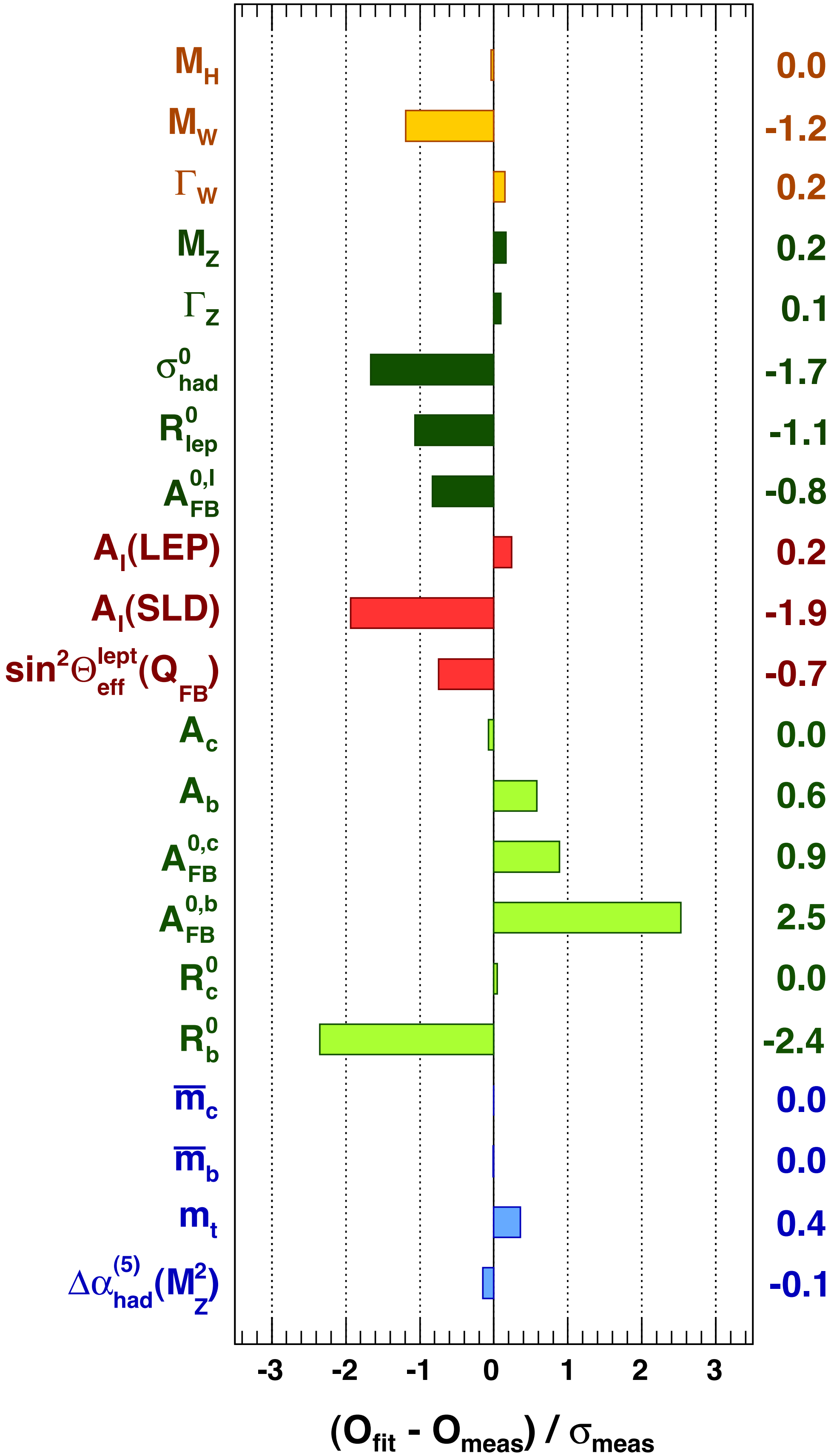
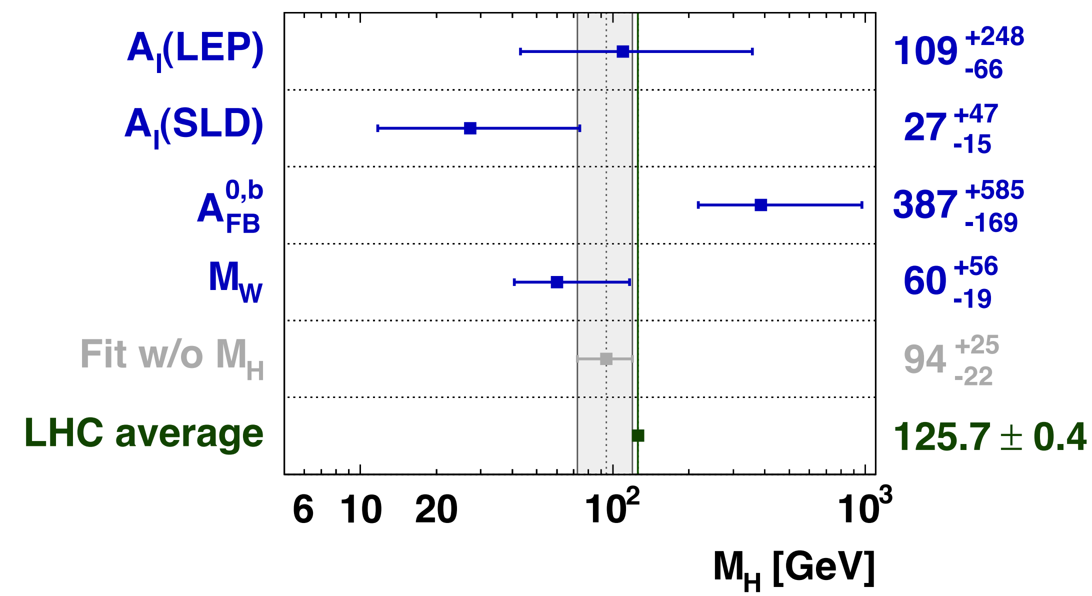
with Axel Orgogozo
1111.3534 & work in progress

EWPT in Standard Model





GFitter

EWPT in BSM

- With light fermion universality, 3 most important observables: $\Delta\rho, \Delta\kappa, \Delta r_W$

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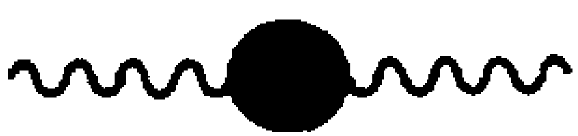
- Most often new effects only in gauge boson propagators (**oblique**):



The epsilons

Altarelli, Barbieri

$$\varepsilon_1 = \Delta\rho$$

$$\varepsilon_3 = c^2\Delta\rho + (c^2 - s^2)\Delta k$$

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Have simple parametrization in terms of self-energies:

$$\varepsilon_1 = e_1 - \quad e_5$$

$$\varepsilon_2 = e_2 - c^2 e_5 - s^2 e_4$$

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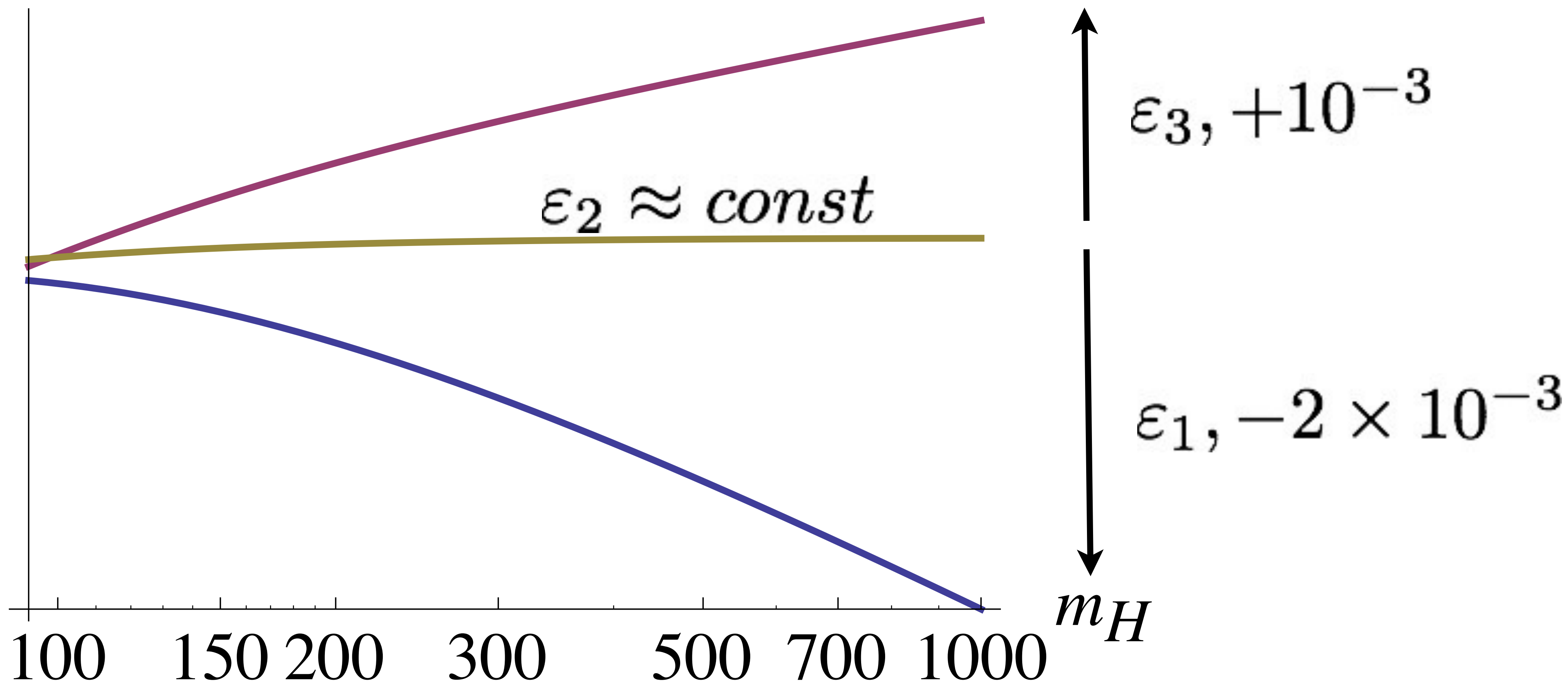
$$\boxed{\begin{aligned} e_2 &= \Pi'_{WW}(m_W^2) - \Pi'_{33}(m_Z^2) \\ e_4 &= \Pi'_{\gamma\gamma}(0) - \Pi'_{\gamma\gamma}(m_Z^2) \\ e_5 &= m_Z^2 \Pi''_{ZZ}(m_Z^2) \end{aligned}}$$

Dependence on Higgs mass



Experimental determination

$$\hat{T} = \varepsilon_1 - \varepsilon_1(SM, m_{H,ref}) = (0.4 \pm 1) \times 10^{-3}$$
$$\hat{S} = \varepsilon_3 - \varepsilon_3(SM, m_{H,ref}) = (0.3 \pm 0.8) \times 10^{-3}$$
$$\hat{U} = \varepsilon_2 - \varepsilon_2(SM, m_{H,ref}) = (-0.3 \pm 0.8) \times 10^{-3}$$

$$\rho = \begin{bmatrix} 1 & 0.9 & 0.83 \\ * & 1 & 0.54 \\ * & * & 1 \end{bmatrix}$$

GFitter

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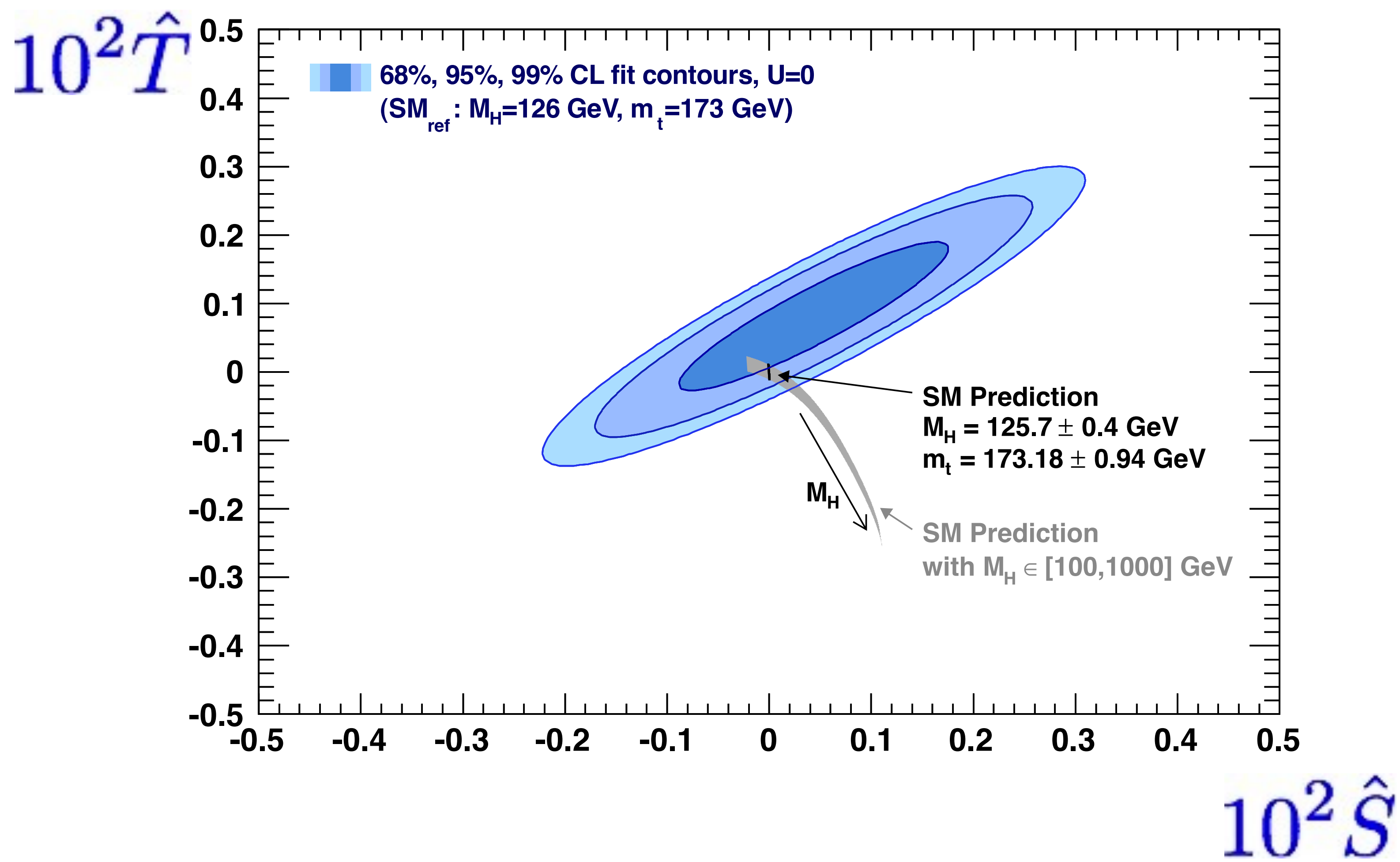
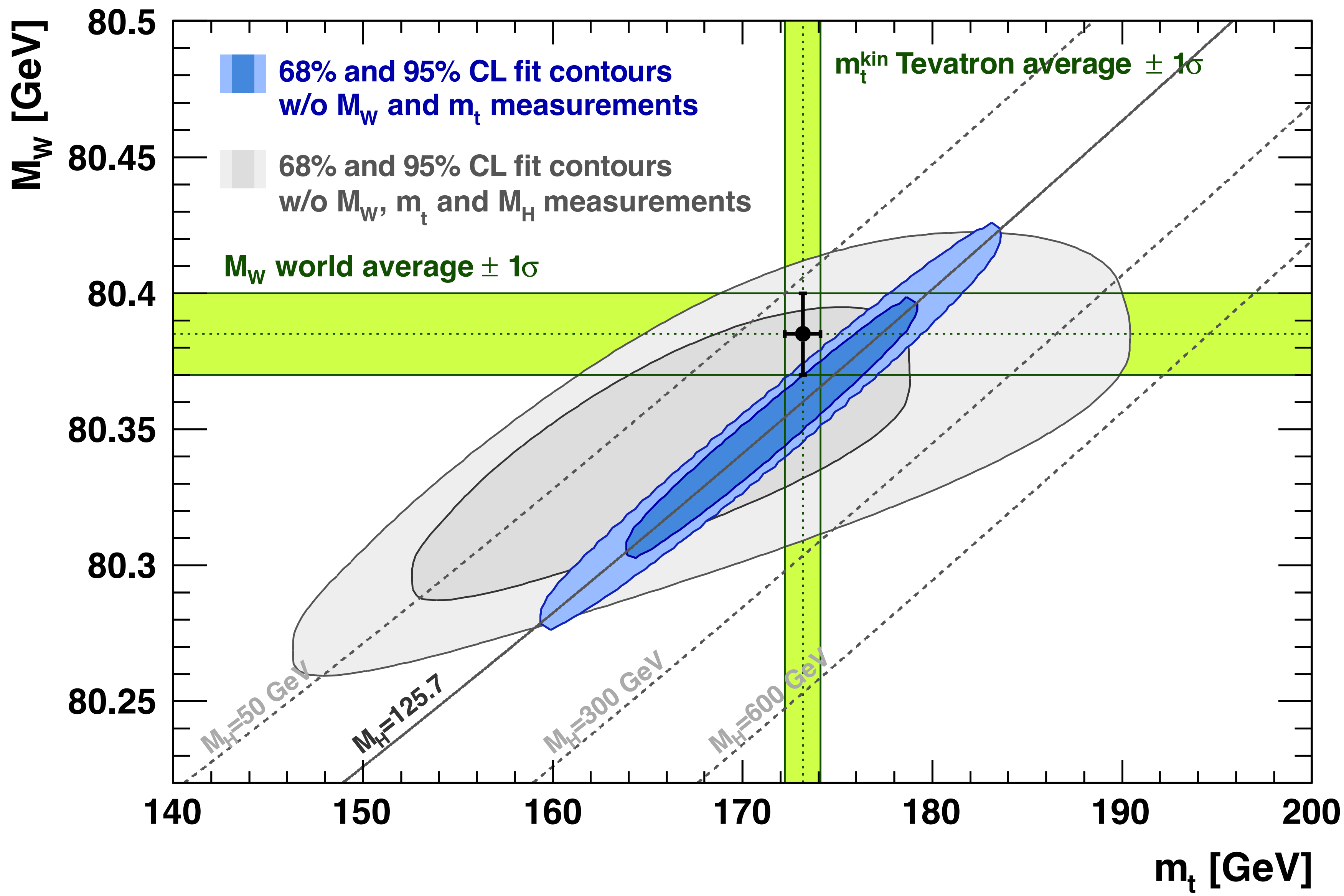
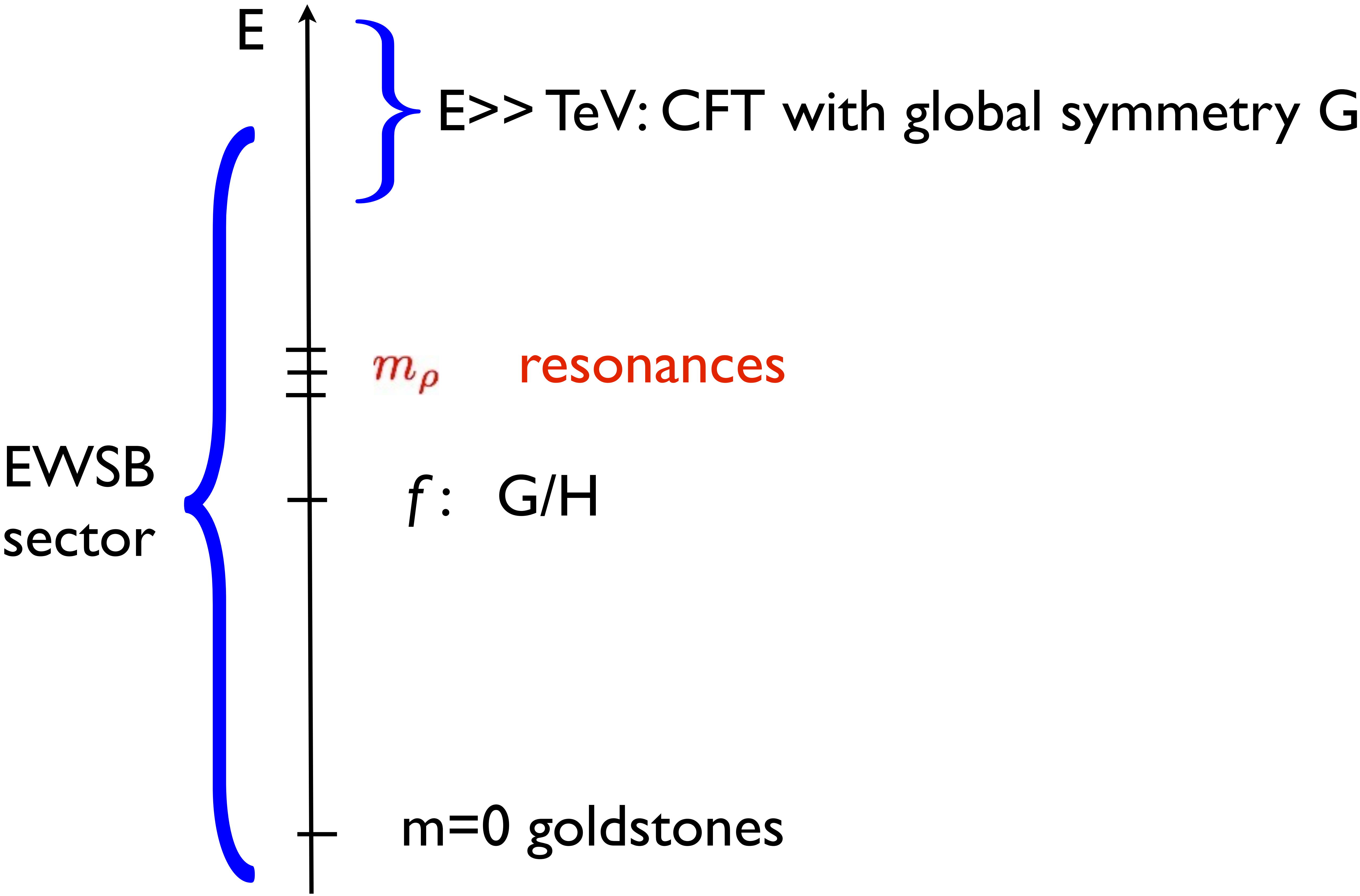
Since ε2 insensitive to heavy NP, makes sense to condition on U=0:



Thus: better W measurements improve determination of ε1,ε3. Studying consistency directly in terms of mW seems rather awkward.



EWPT in composite Higgs models



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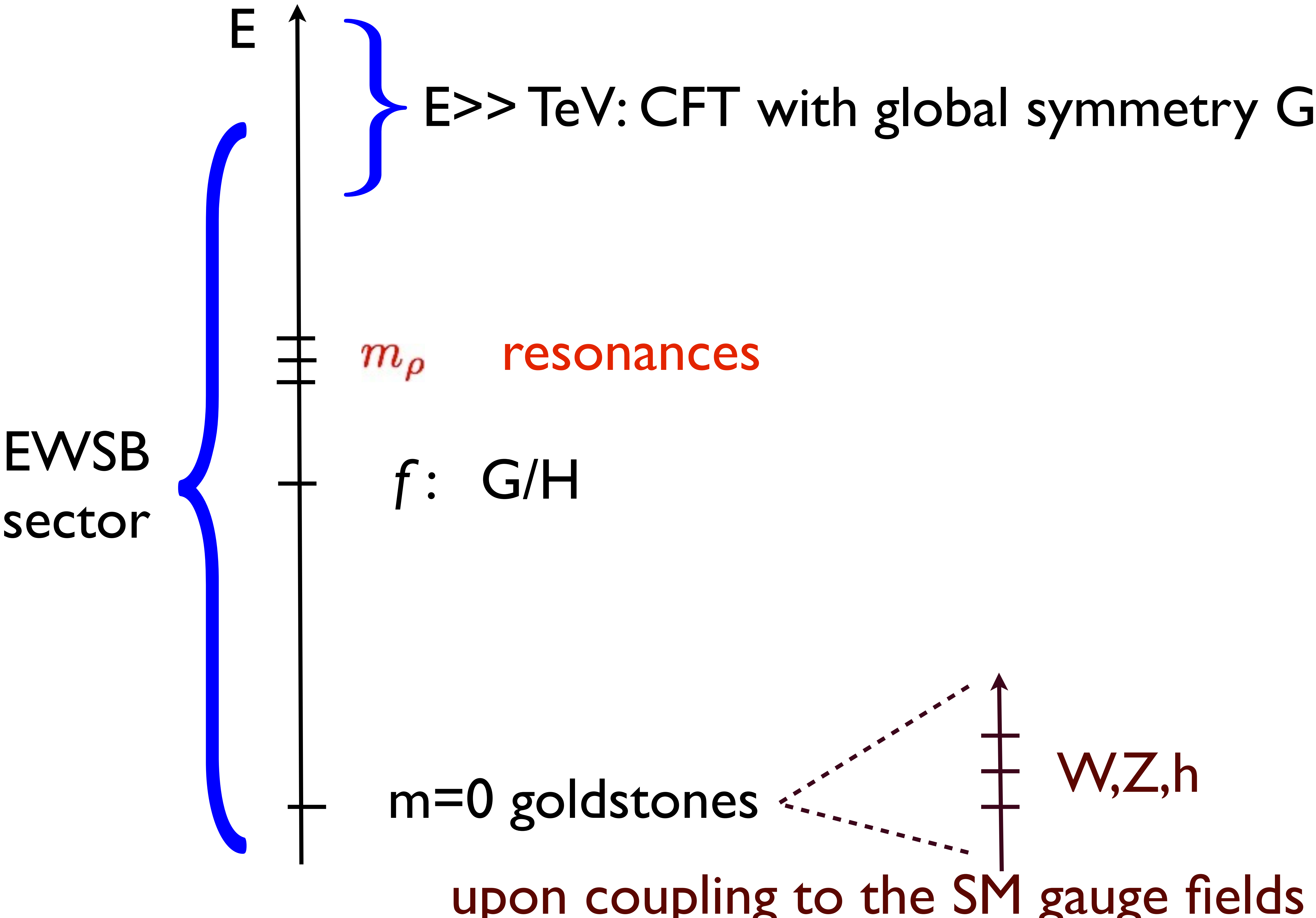

Problem:

$$\hat{S} = O(g^2) = ?$$

$$\hat{T} = O(g'^2, y_t^2) = ?$$

Which CFT observable controls them?

Case study: Higgsless case

Peskin, Takeuchi 1991

G=SU(2)$_L$xSU(2)$_R$ → H=SU(2)$_V$

$$\langle J^{3L} J^{3R} \rangle = \Pi'_{30}(q^2) = \int_0^\infty ds \frac{\rho_{LR}(s)}{s - q^2 + i\epsilon}$$

$$\hat{S} = g^2 \int_{\mu^2}^{\infty} \frac{ds}{s} [\rho_{LR}(s) - \rho_{LR}^{SM}(s)]$$

strong sector

heavy Higgs SM

$$\mu^2 \ll m_\rho, m_{h,ref}$$

$$\varepsilon_3 = e_3 - c^2 e_5 + c^2 e_4$$

$$\hat{S} = g^2 \int_{\mu^2}^{\infty} \frac{ds}{s} \rho_{LR}(s) + \frac{g^2}{96\pi^2} (\log \frac{\mu}{m_{h,ref}} + \frac{11}{12})$$

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μ independence:

$$\rho_{LR} = \rho_V - \rho_A \approx \rho_{\pi\pi} = \frac{1}{192\pi^2} \qquad (s \ll m_\rho^2)$$

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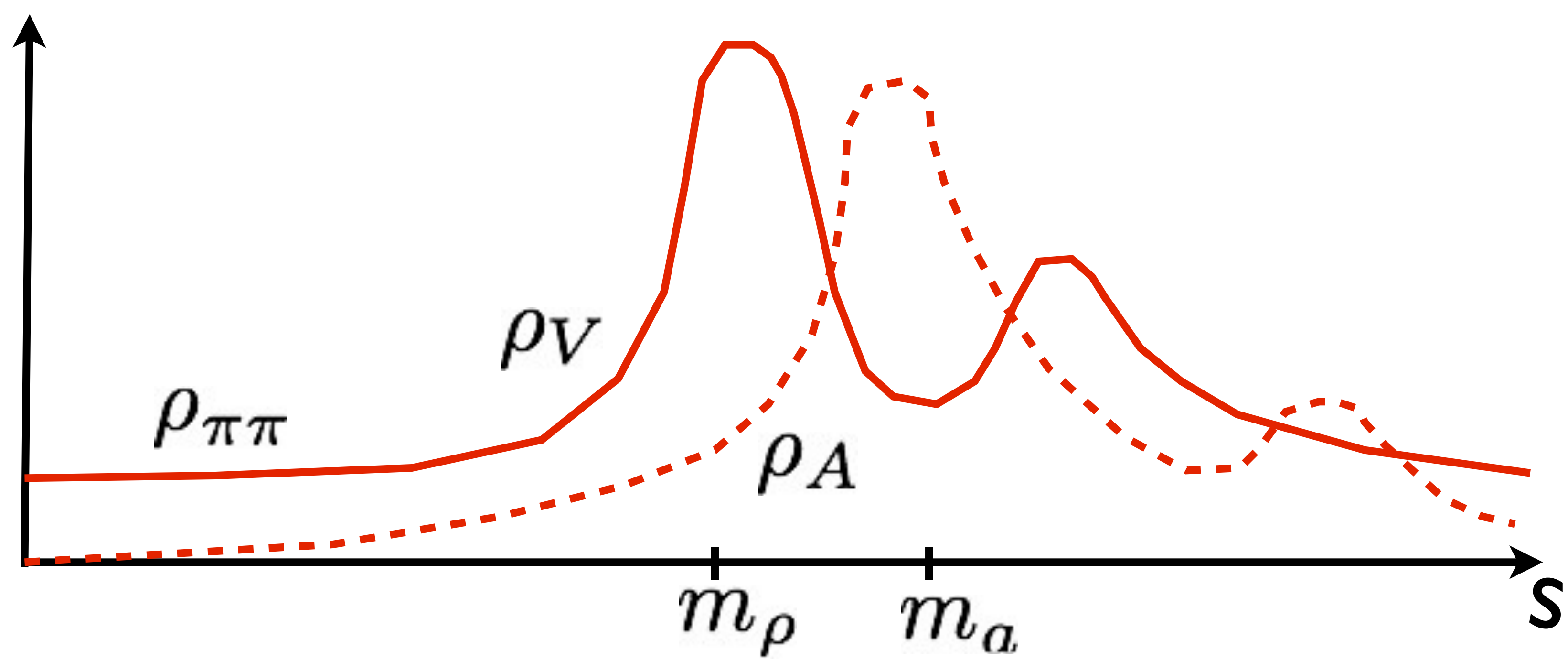
Relative accuracy:

$$\Delta \hat{S}_{\mathrm{theor}} / \hat{S} = O(m_W^2 / m_\rho^2)$$

- If spectral densities are known (like in scaled-up QCD), then S parameter can be computed reliably

- If unknown, still allows modelization (Vector Meson Dominance, Weinberg sum rules, etc)



For composite Higgs:

$$S = S_{UV} + S_{IR} + S_{matching}$$

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From resonances & CFT,
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From pseudo-Goldstone Higgs
(mH=125 GeV => must go beyond heavy Higgs approximation)

Aim for m_h^2/m_ρ^2 rel. accuracy

For concreteness, consider Minimal Comp. Higgs Model, i.e. SO(5)/SO(4)

SO(5) Current correlators:

$$\langle J^A_\mu(q) J^B_\nu(-q)\rangle = \left(\eta_{\mu\nu} - \frac{q_\mu q_\nu}{q^2}\right)\left[\delta^{AB}\,\Pi_0(q^2) + \Phi^t T^A T^B \Phi\,\Pi_1(q^2) + \epsilon^{ijklm}\Phi^m\,\Pi_2(q^2)\right]$$

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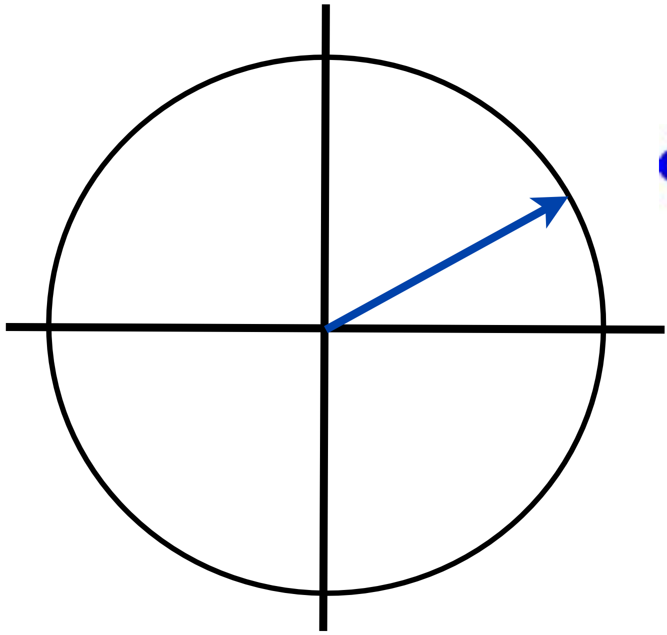

$$\Phi = (0, 0, 0, \sin\theta, \cos\theta)$$

v/f

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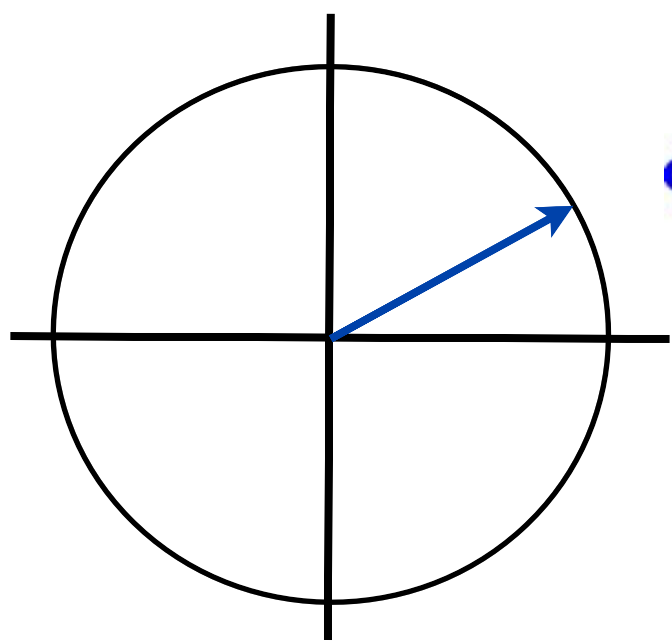

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parity breaking term

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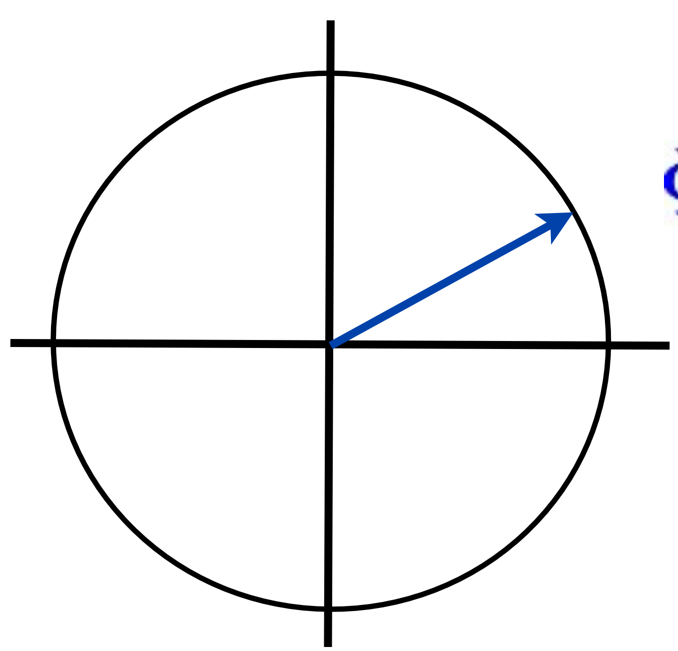

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v/f

term responsible for S(UV)

OPE analysis in the UV

$$J_\mu^A(x) J_\nu^B(0) = (\eta_{\mu\nu}\partial^2 - \partial_\mu \partial_\nu)\left[\frac{1}{(x^2)^2} + \sum_{\mathcal{O}} \frac{\Gamma_C^{AB}\mathcal{O}^C(0)}{(x^2)^{2+\Delta_{\mathcal{O}}/2}} + \ldots\right]$$

$(x \ll m_\rho^{-1})$

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$$\langle \mathcal{O} \rangle \sim m_\rho^{\Delta_{\mathcal{O}}} \times \begin{cases} 1\,, & \mathcal{O} \in \mathbf{1}, \\ \Phi^i\Phi^j - \frac{1}{5}\delta^{AB}\,, & \mathcal{O} \in \mathbf{14}, \\ \Phi^i\,, & \mathcal{O} \in \mathbf{5}, \end{cases}$$

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These operators control formfactor asymptotics:

$$\Pi_i(q^2) \sim q^2 \left(-q^2/m_\rho^2\right)^{-\Delta_{\mathcal{O}_i}/2}, \qquad \mathcal{O}_0 \in \mathbf{1}, \mathcal{O}_1 \in \mathbf{14}, \mathcal{O}_2 \in \mathbf{4}$$

Focus on Π_1

$$\Pi_1 = \Pi_a - \Pi_{\hat{a}} \equiv f^2 + q^2 \Pi_1'(q^2)$$

$$\Pi_1'(q^2) = \int_0^\infty ds \, \frac{\rho(s)}{s - q^2 + i\epsilon}$$

Spectral density dominated by two-goldstone state at small s:

$$\rho(s) \approx 1/(192\pi^2) \qquad (s \ll m_\rho^2)$$

Digression about Weinberg sum rules

$$\int_0^\infty ds\, \rho(s) = f^2$$

$$\int_0^\infty ds\, s\, \rho(s) = 0$$

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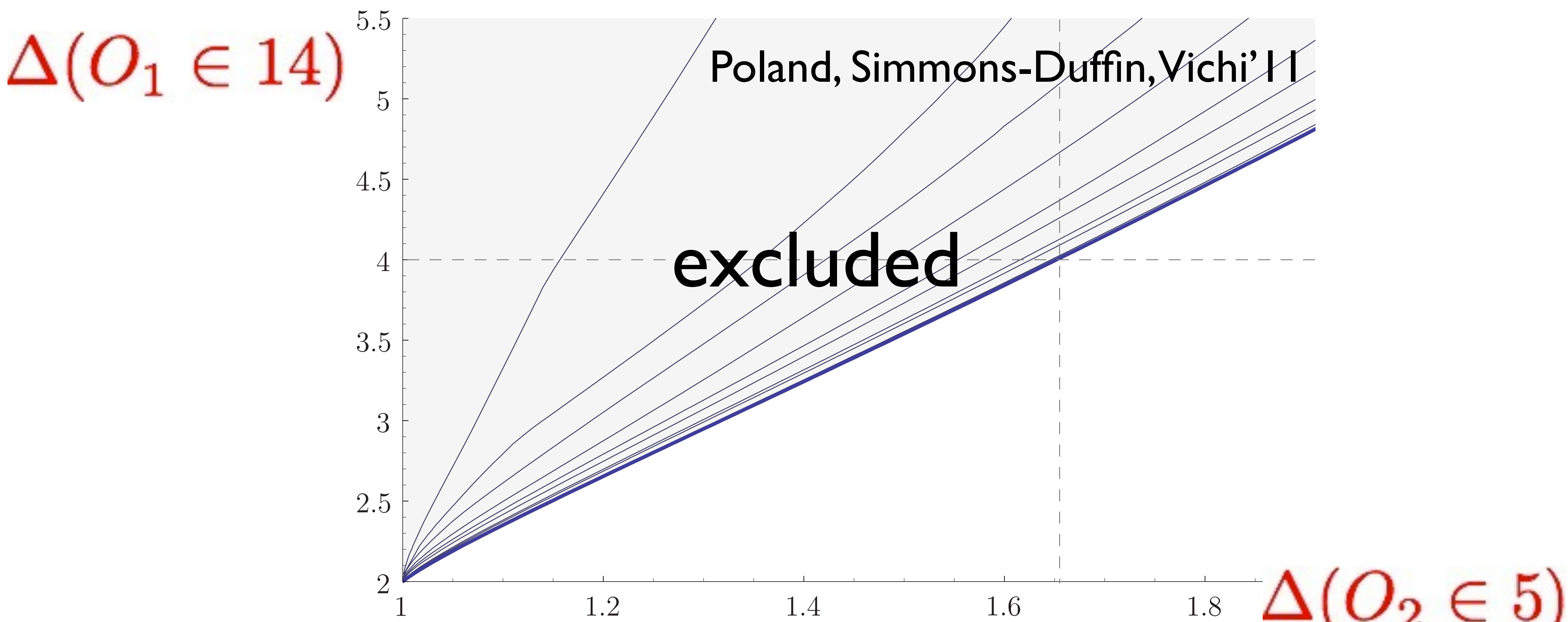

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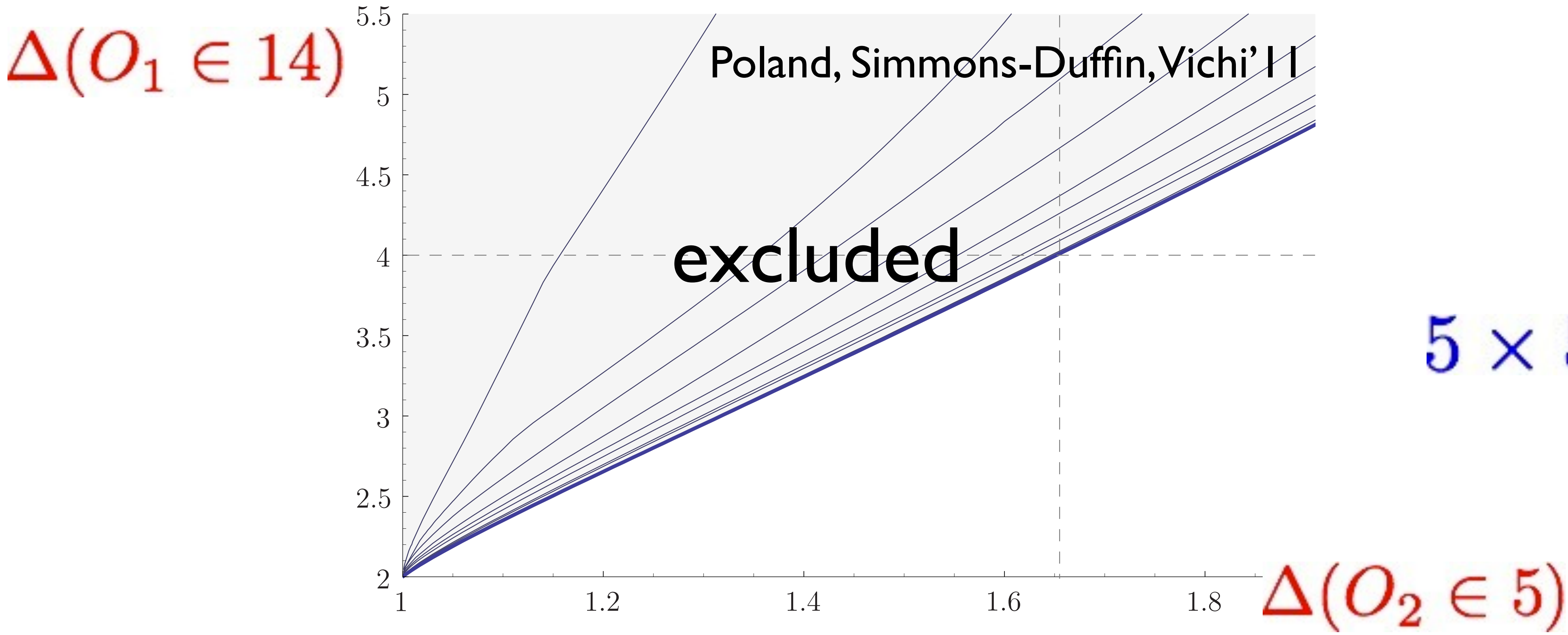

$$5 \times 5 \ni 14$$

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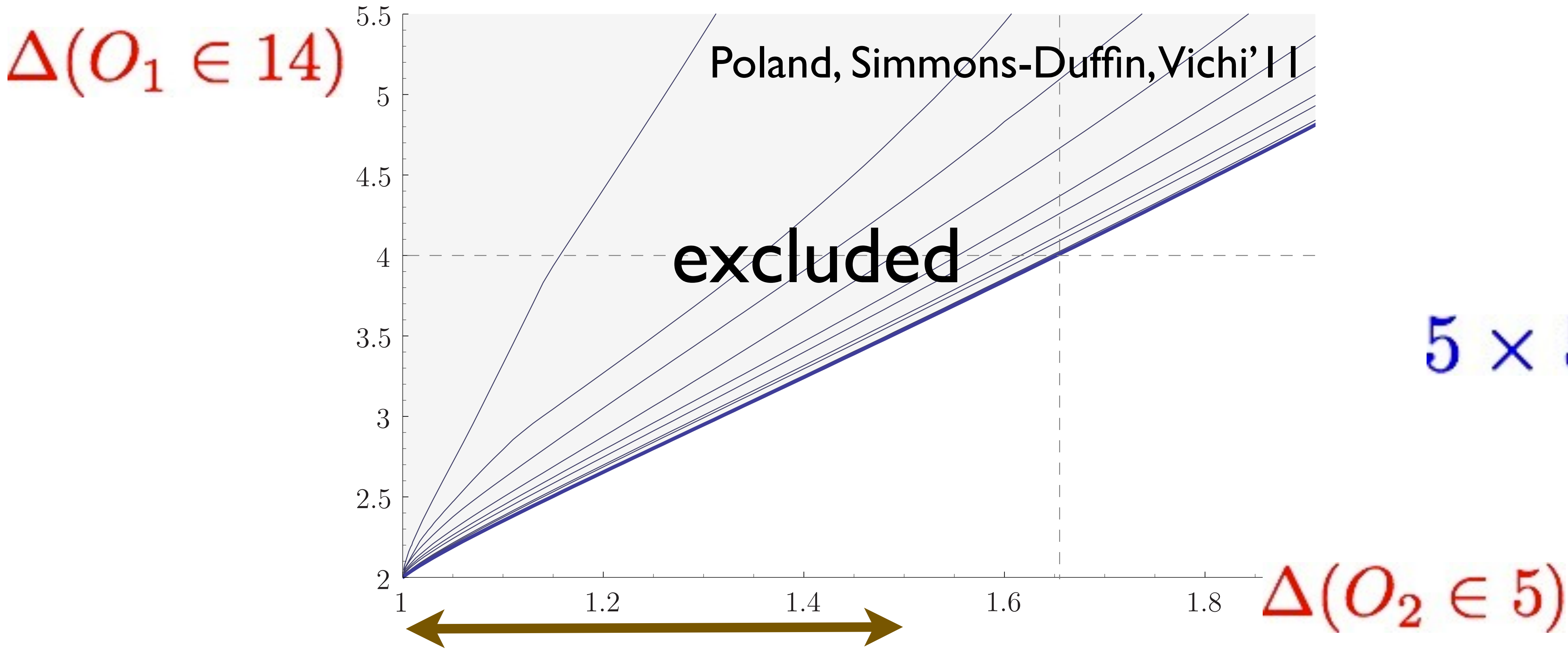

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Conformal Technicolor® range

Back to computing S

Step 1. Match UV theory to

$$\mathcal{L}_{eff} = \frac{f^2}{2}(D_\mu\Phi)^2 + c(\mu^2)B_{\mu\nu}W^a_{\mu\nu}\Phi^t T^a_L T^3_R \Phi \qquad m_h \ll \mu \ll m_\rho$$

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In UV theory:

$$\Pi'_{LR}(q^2) = \frac{v^2}{f^2} \Pi'_1(q^2)$$

Agashe,Contino,Pomarol

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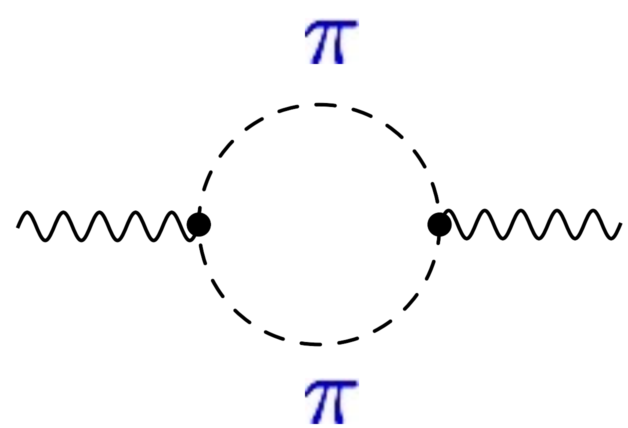
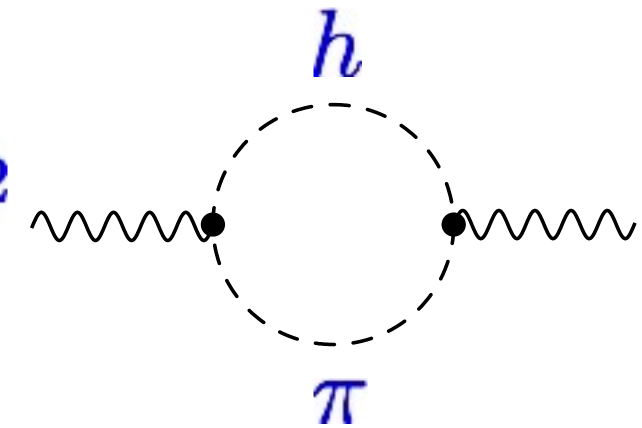
Agashe,Contino,Pomarol

In effective theory:

$$\Pi'_{LR}(q^2) = \frac{v^2}{f^2}c(\mu^2) +$$



$$-a^2$$



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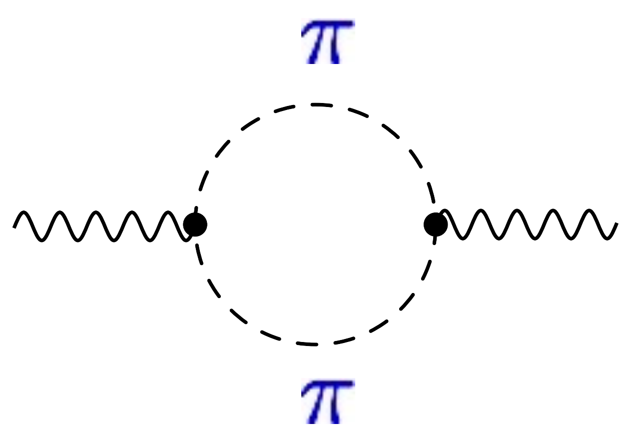

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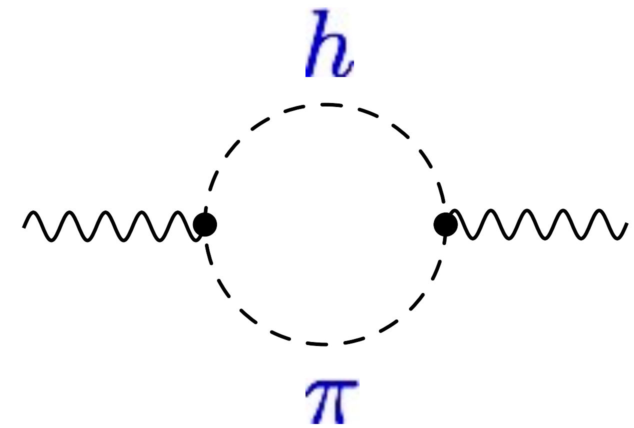

$$= \frac{v^2}{f^2}\left[c(\mu^2) + \frac{1}{192\pi^2}\left(\frac{2}{\epsilon} + \log\frac{\mu^2}{-q^2} + \frac{5}{3}\right)\right]$$

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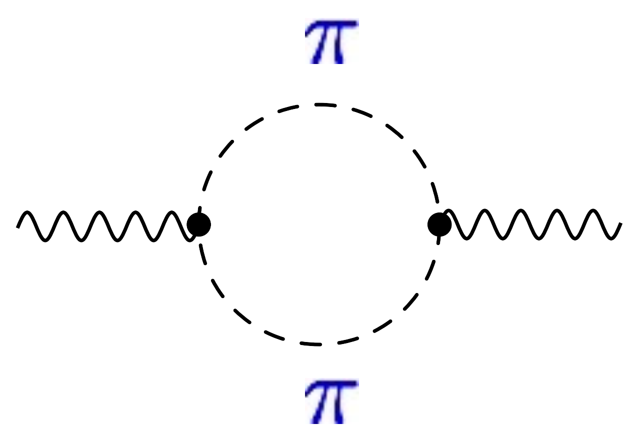

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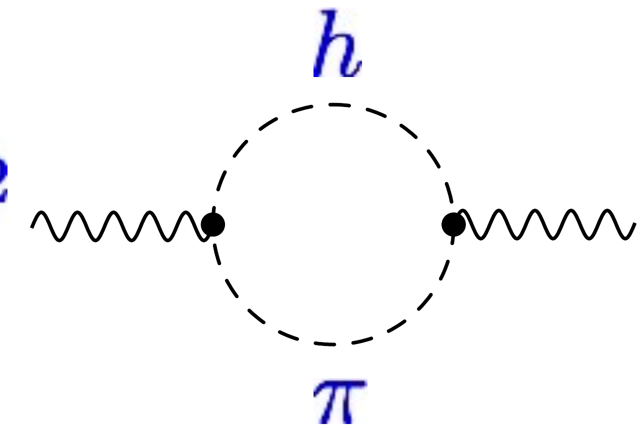

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Matching UV to effective determines:

$$c(\mu^2) = \int_{\mu^2}^{\infty} ds\, \frac{\rho(s)}{s} - \frac{1}{192\pi^2}\left(\frac{2}{\epsilon} + \frac{5}{3}\right)$$

Step 2. Compute S from effective theory

Recall SM:

$$\varepsilon_{3,Higgs} = \frac{c}{s}\Pi'_{30} - c^2 m_Z^2 \Pi''_{ZZ}|_{q^2=m_Z^2}$$

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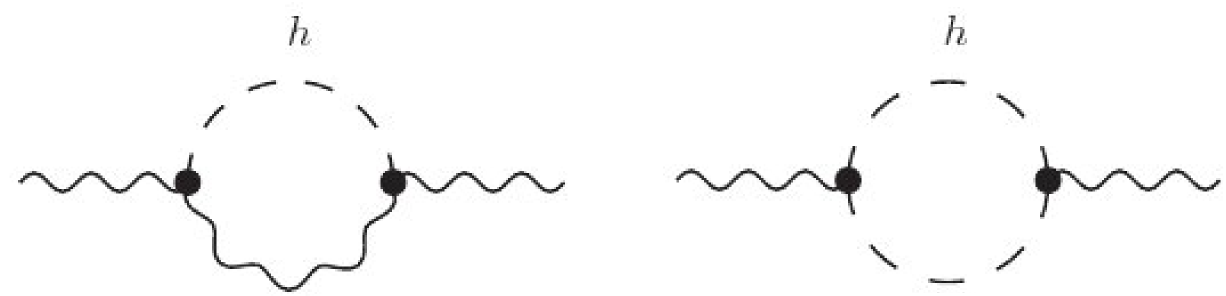

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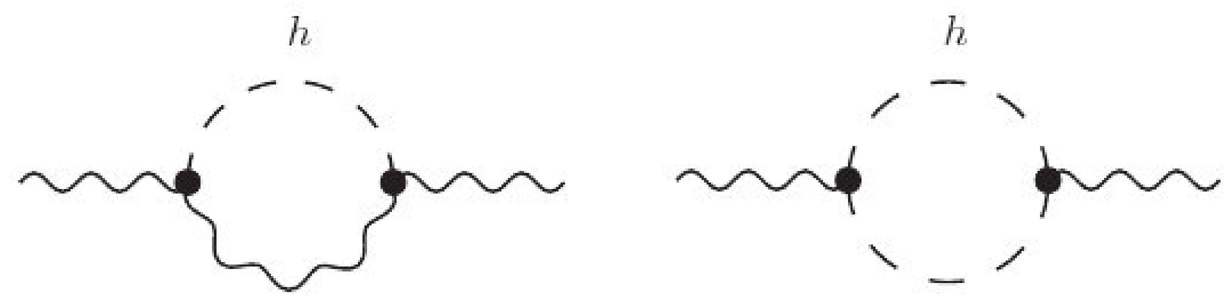

$$= \frac{3g^2}{64\pi^2}\left[H_A(h) - H_R(h)\right] - \frac{g^2}{192\pi^2}\left(\frac{2}{\epsilon} + \log\frac{\mu^2}{m_Z^2} + \frac{2}{3}\right)$$

e.g. Novikov, Okun, Vysotski

$$H_A(h) = \frac{hc^2}{h-c^2}\log\frac{h}{c^2} - \frac{8h}{9(h-1)}\log h + \left(\frac{4}{3} - \frac{2}{3}h + \frac{2}{9}h^2\right)F_h(h) - \left(\frac{4}{3} - \frac{4}{9}h + \frac{h^2}{9}\right)F_h'(h) - \frac{h}{18}$$

$$H_R(h) = -\frac{h}{18} + \frac{c^2}{1-\frac{c^2}{h}}\log\frac{h}{c^2} + \left(\frac{4}{3} - \frac{4}{9}h + \frac{1}{9}h^2\right)F_h(h) + \frac{h}{1-h}\log h\,,$$

$$F_h(h) = 1 + \left(\frac{h}{h-1} - \frac{1}{2}h\right)\log h + \begin{cases} h\sqrt{1-\frac{4}{h}}\log\left(\sqrt{\frac{h}{4}-1} + \sqrt{\frac{h}{4}}\right), & h > 4\,, \\ -h\sqrt{\frac{4}{h}-1}\,\arctan\sqrt{\frac{4}{h}-1}\,, & h < 4\,, \end{cases}$$

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$$h = m_h^2/m_Z^2 \qquad \approx 1.89 \text{ for } m_h = 125 \text{ GeV}$$

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$$\varepsilon_3(\mathrm{MCHM}) = \varepsilon_{3,W/Z} + a^2 \varepsilon_{3,\mathrm{Higgs}} + g^2 \frac{v^2}{f^2} c(\mu^2)$$

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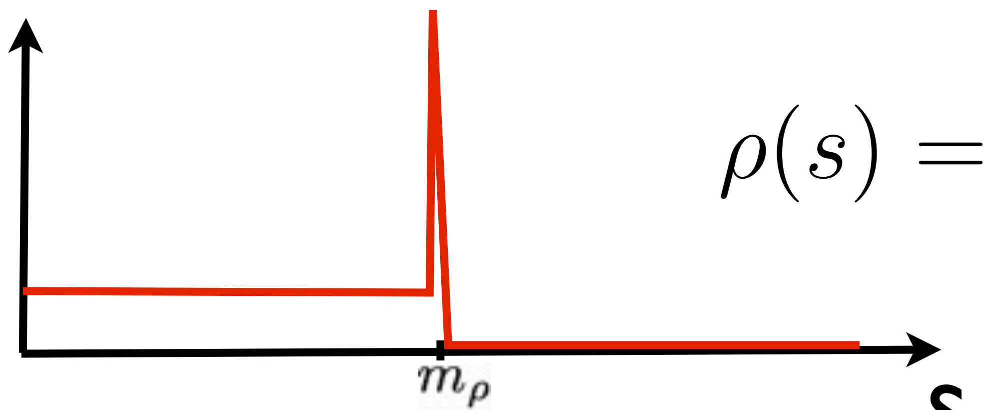
$$\frac{\Delta \hat{S}_{theor}}{\hat{S}} = O\left(\frac{m_h^2}{m_\rho^2}\right)$$

Toy model spectral density



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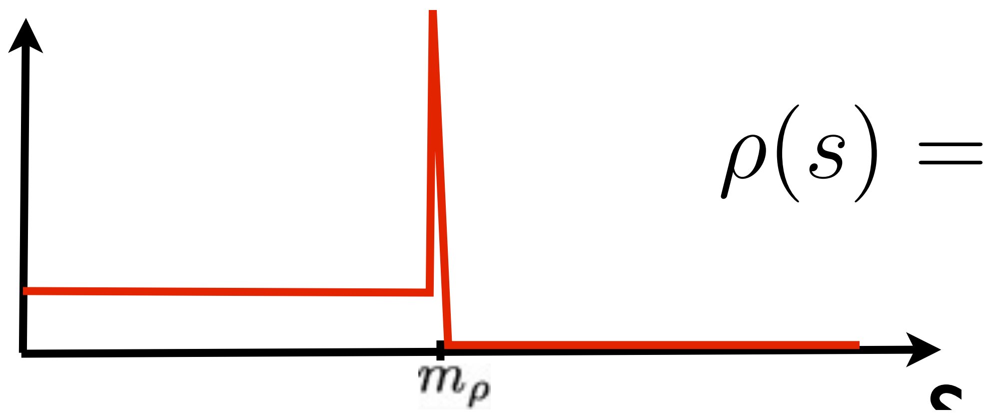

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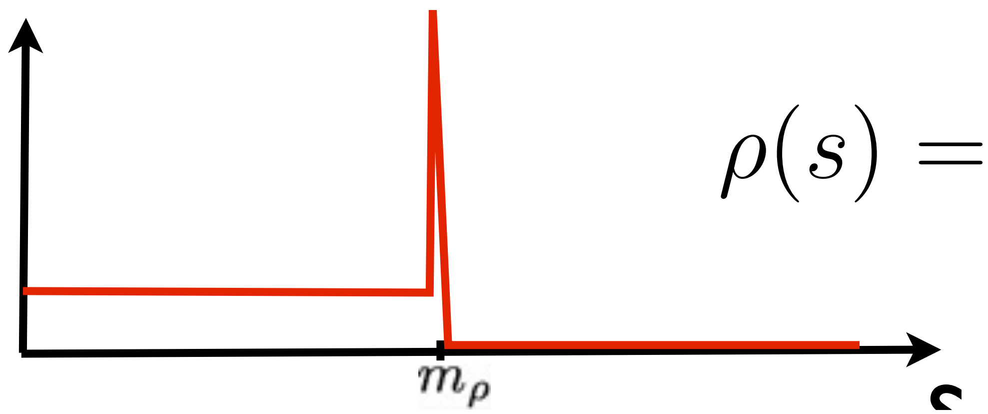

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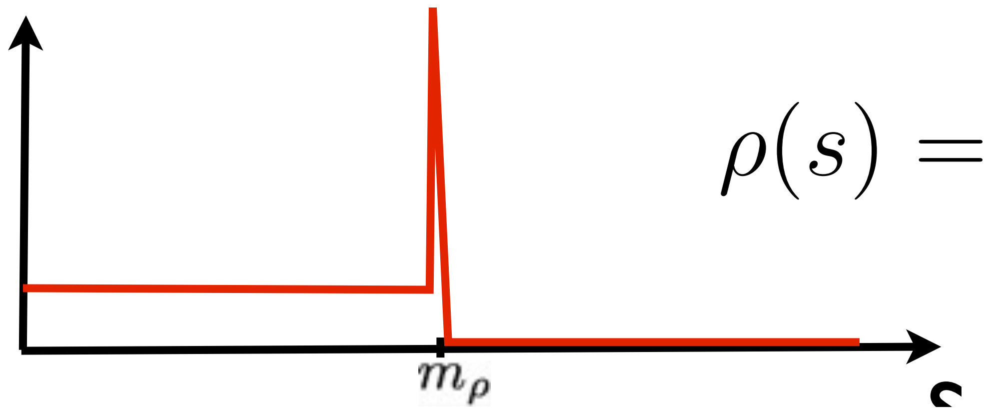

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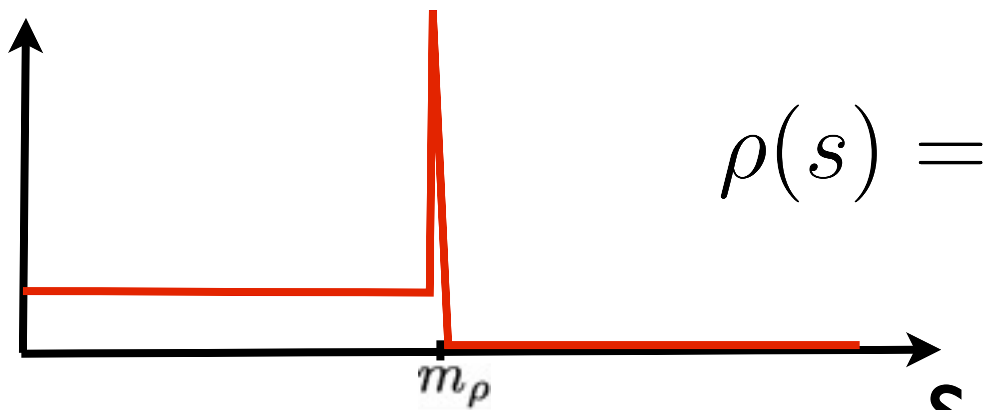

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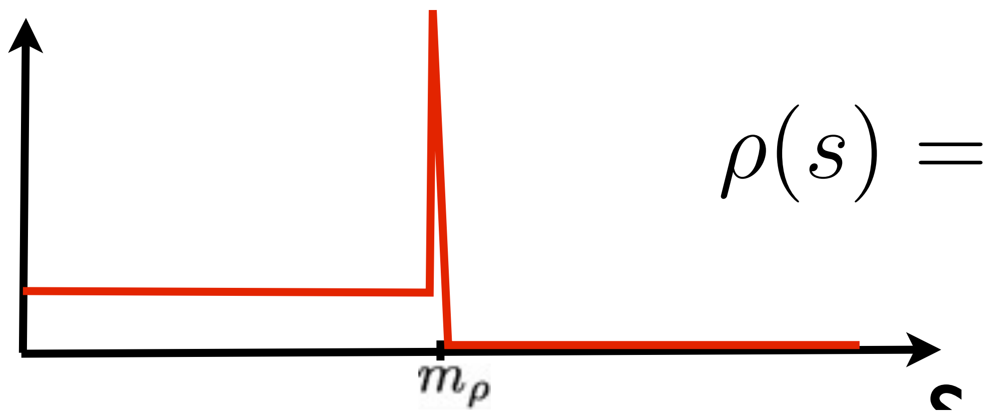

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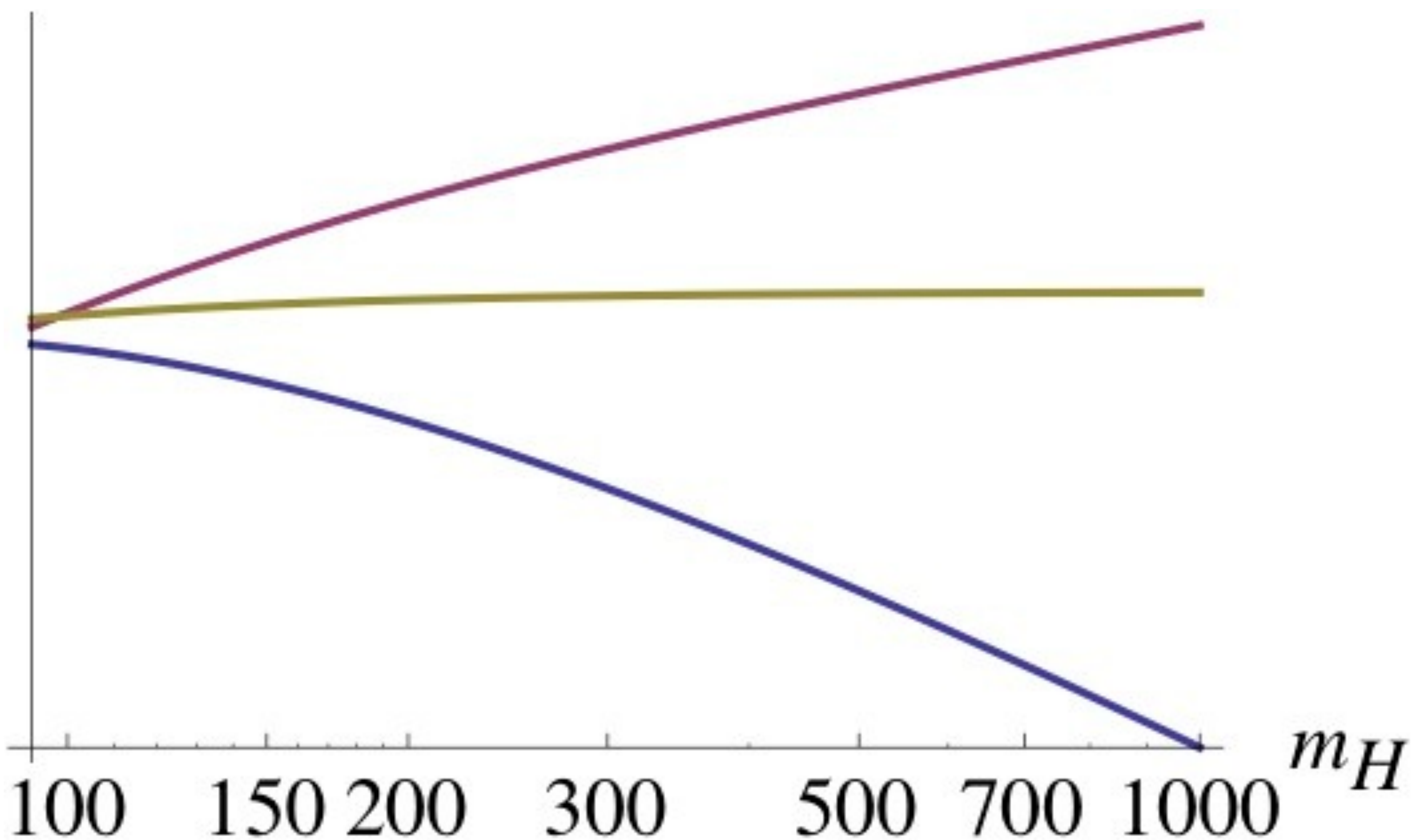
But which dispersion relation, if any, controls UV?


100
150
200
300
500
700
1000
m_H