Discrimination possibility between composite and fundamental multi-Higgs doublet models with derivative interactions

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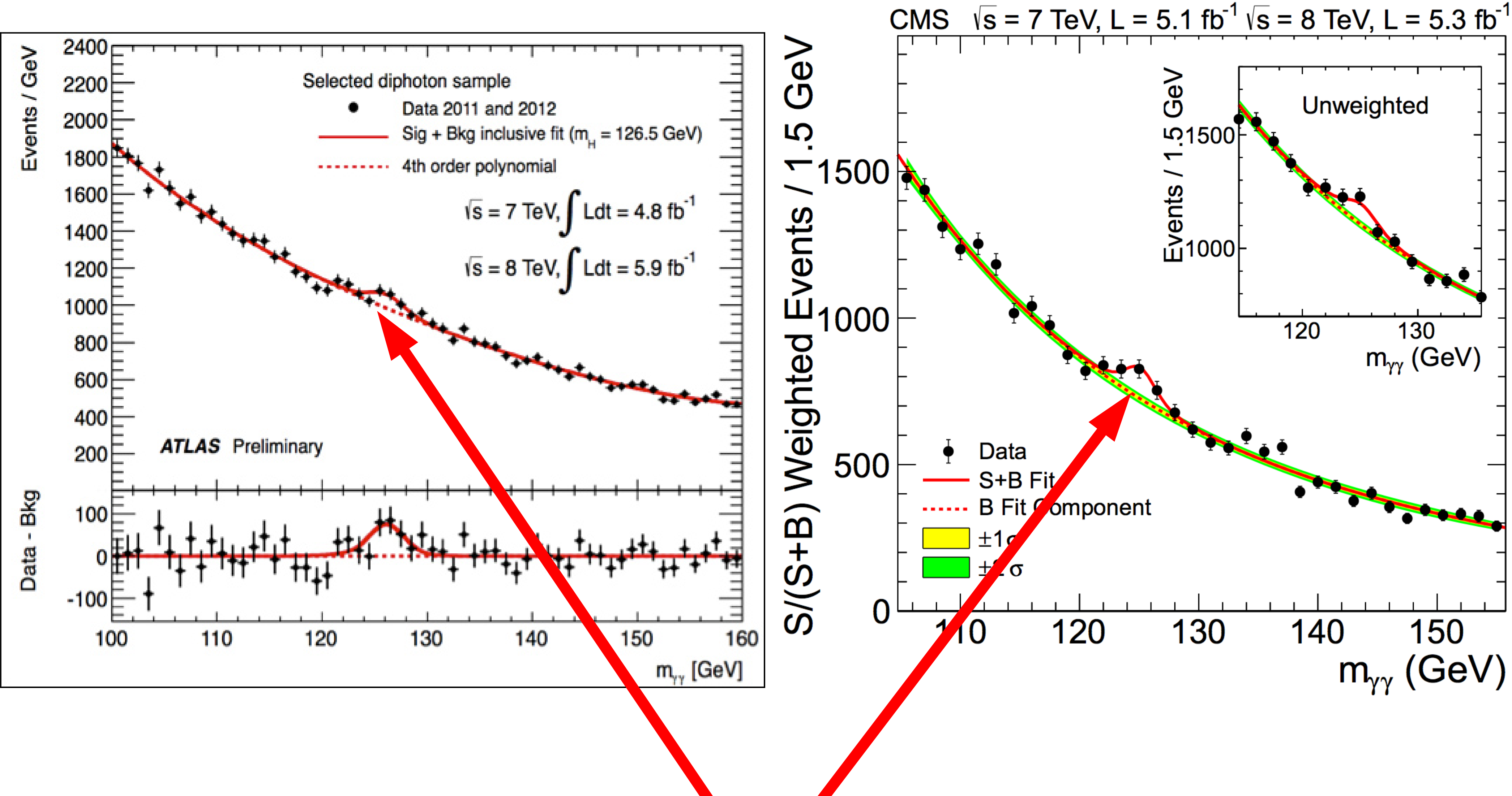
Based on
arXiv:1111.2120 with Y. Kikuta and Y. Okada
and succeeding works with Y. Kikuta

@ Workshop on Multi-Higgs Models,
Aug. 2012, Lisbon

The Higgs (?) boson is discovered!!

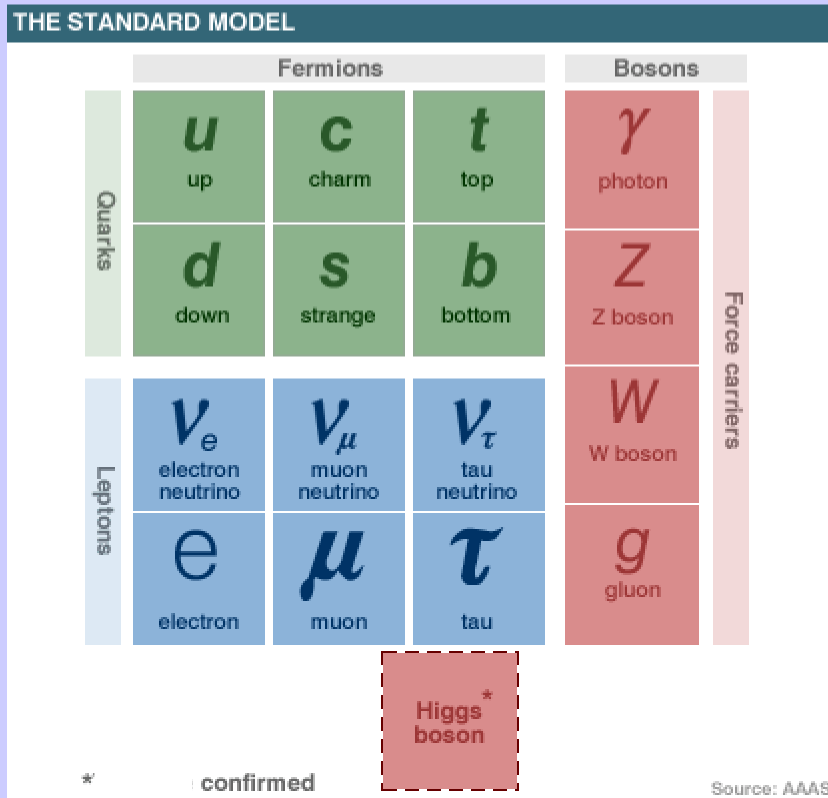


SM Higs like resonance

The Standard Model is established!!

DM?

Axion?



GUT?

Majorana ν?

Baryogenesis?

Beyond the Standard Model

Where is the new scale?

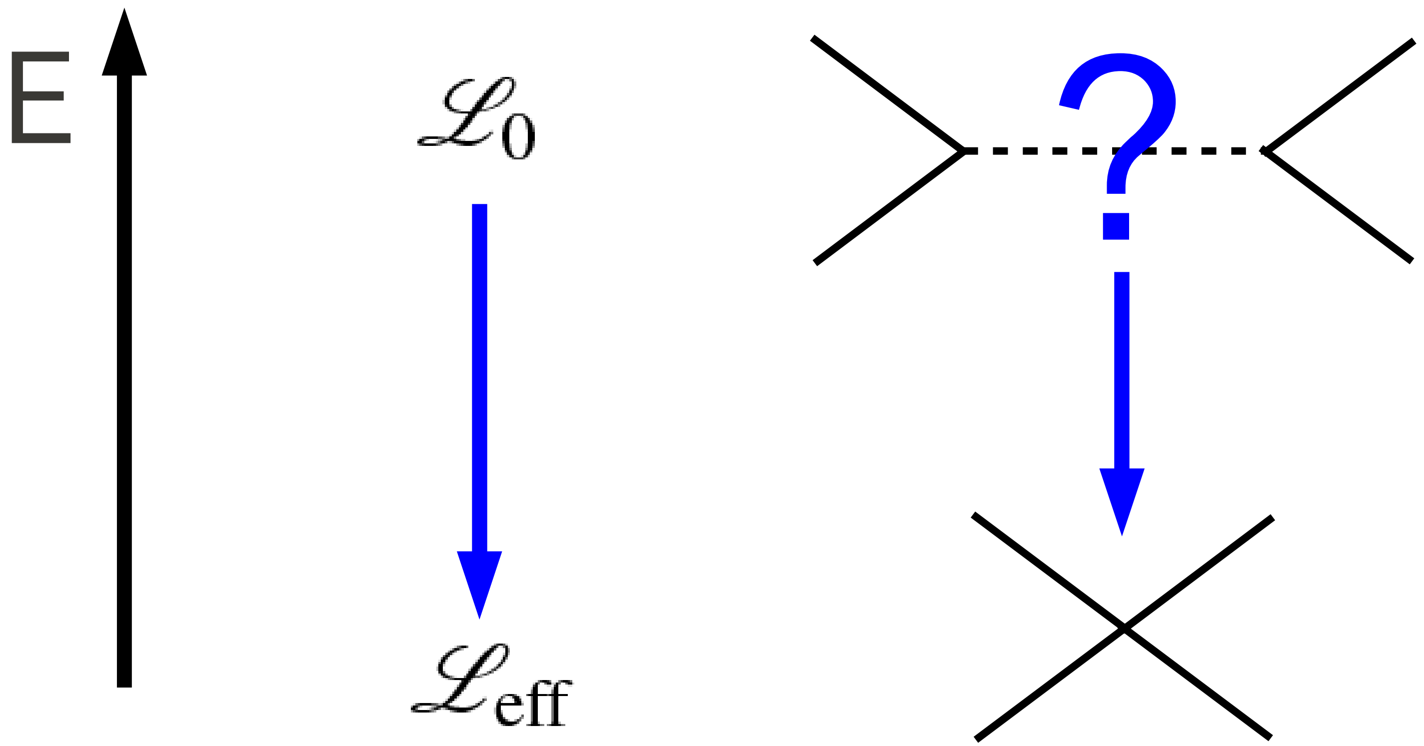
How to break the EW symmetry.

By hand in the SM

$$V = -\mu^2 H^\dagger H + \frac{\lambda}{2}(H^\dagger H)^2$$

A mechanism in the BSM

TeV



Higgs doublet

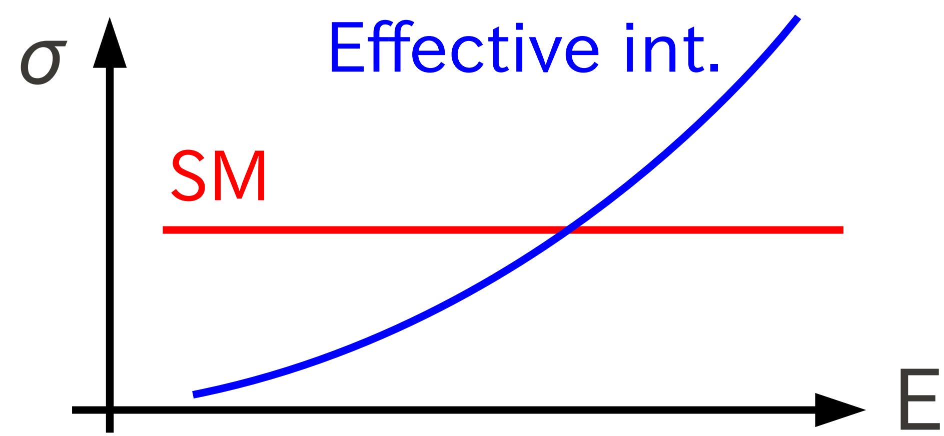
$$\partial(H^\dagger H)\partial(H^\dagger H), \ldots \quad (H^\dagger \overleftrightarrow{\partial} H)(H^\dagger \overleftrightarrow{\partial} H), \ldots$$

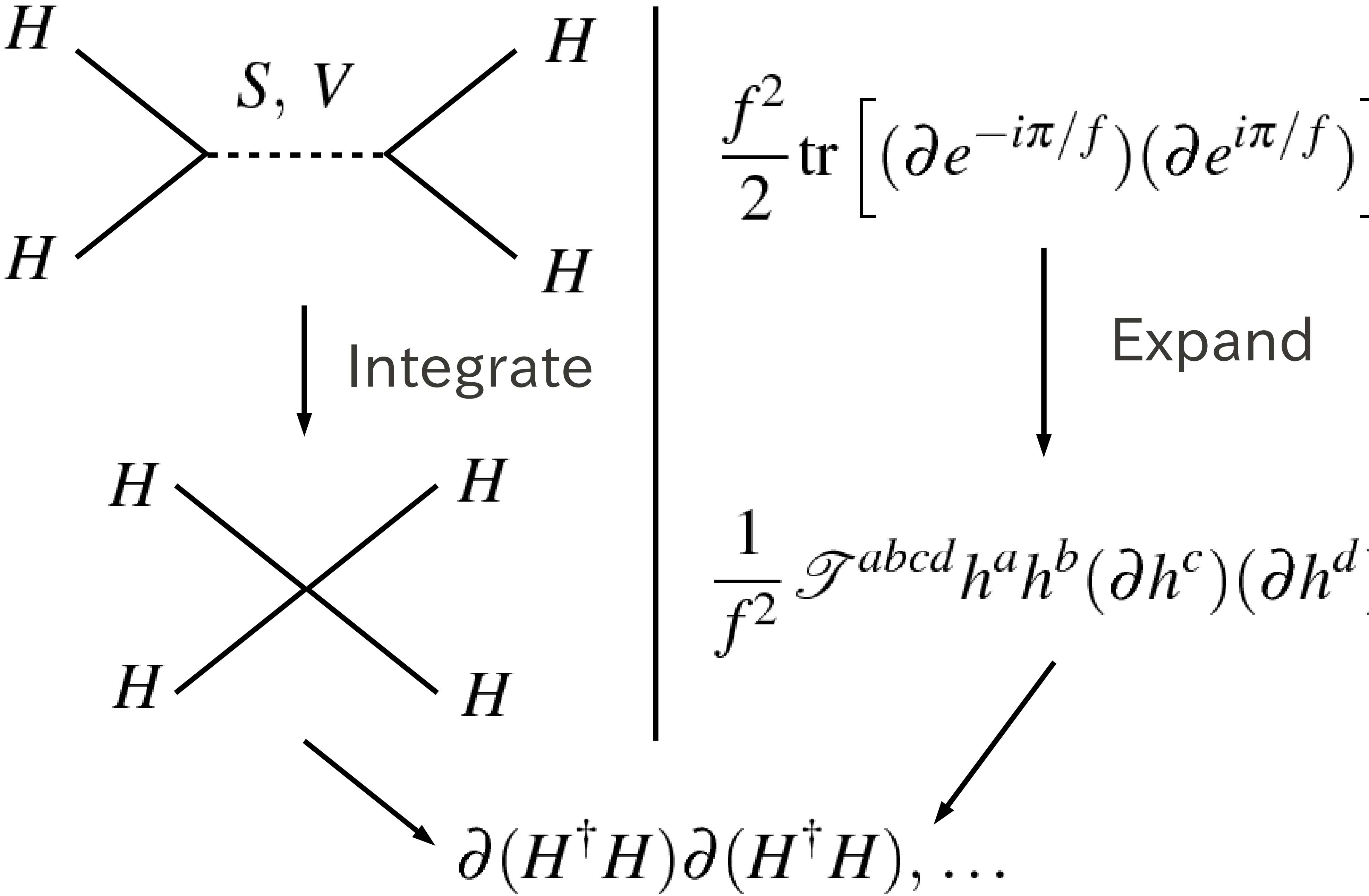
$$\frac{c^H}{2f^2}\partial(H^\dagger H)\partial(H^\dagger H), \ldots$$

$$\frac{1}{2}\left(1 + c^H \frac{v^2}{f^2}\right)(\partial h)^2$$

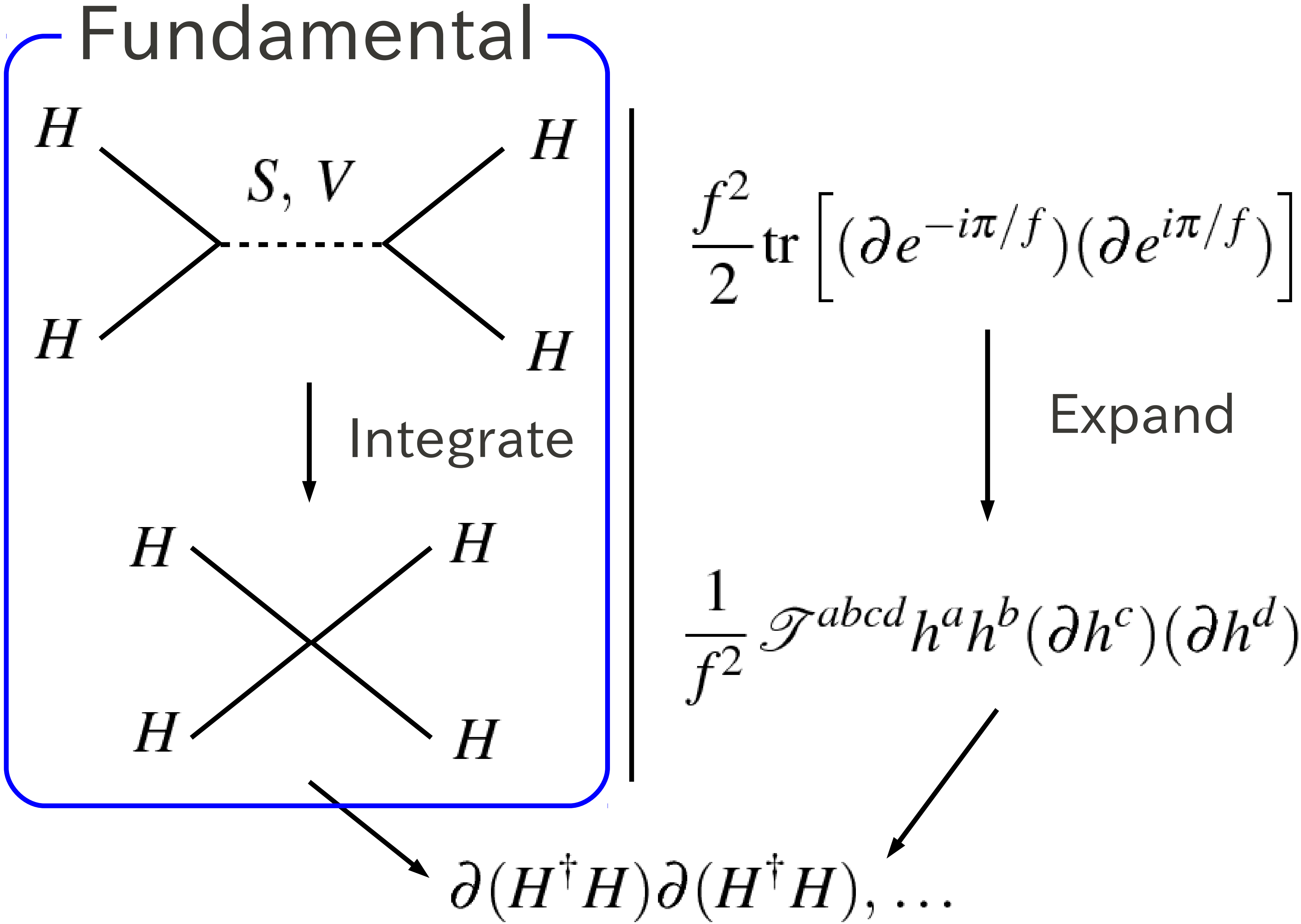
$$h \to \frac{h}{\sqrt{1 + c^H \frac{v^2}{f^2}}}$$

$$\frac{c^H}{f^2} h(\partial h)\phi(\partial\phi)$$

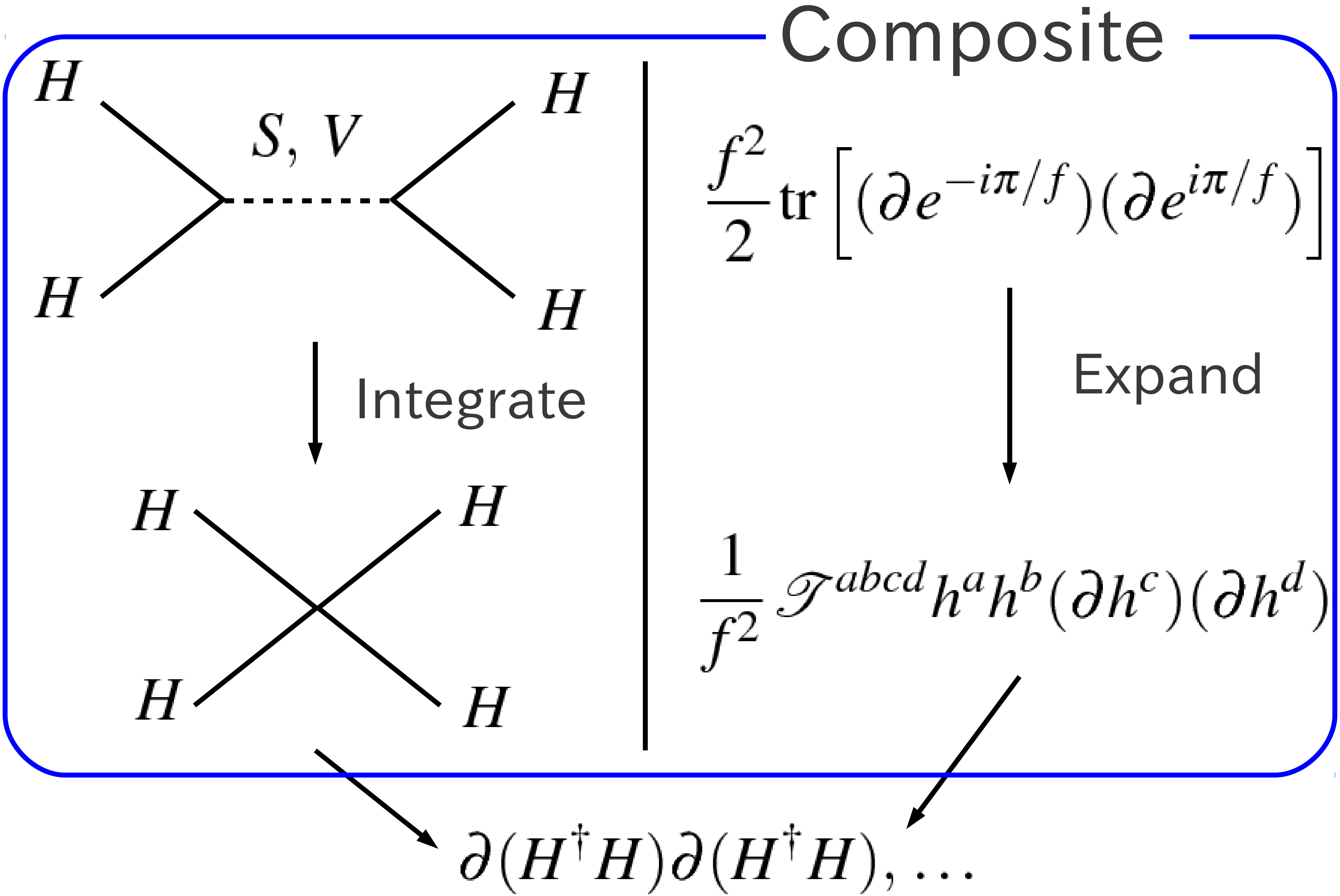




H
S, V
H
H
H
Integrate
H
H
H
H
$\frac{f^2}{2}\mathrm{tr}\left[(\partial e^{-i\pi/f})(\partial e^{i\pi/f})\right]$
Expand
$\frac{1}{f^2}\mathscr{T}^{abcd}h^a h^b(\partial h^c)(\partial h^d)$
$\partial(H^\dagger H)\partial(H^\dagger H), \ldots$



Fundamental
H
H
S, V
H
H
Integrate
H
H
H
H
$\frac{f^2}{2}\mathrm{tr}\left[(\partial e^{-i\pi/f})(\partial e^{i\pi/f})\right]$
Expand
$\frac{1}{f^2}\mathscr{T}^{abcd}h^a h^b(\partial h^c)(\partial h^d)$
$\partial(H^\dagger H)\partial(H^\dagger H), \ldots$



Composite
H
S, V
H
H
H
Integrate
H
H
H
H
$\frac{f^2}{2}\mathrm{tr}\left[(\partial e^{-i\pi/f})(\partial e^{i\pi/f})\right]$
Expand
$\frac{1}{f^2}\mathcal{T}^{abcd}h^a h^b(\partial h^c)(\partial h^d)$
$\partial(H^\dagger H)\partial(H^\dagger H), \ldots$

Why multi Higgs doublets?

Fundamental : 2HDM, SUSY, ...

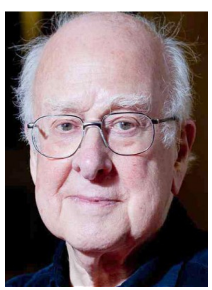
Composite : large global symmetry breaking

$$\boldsymbol{\pi} = \begin{pmatrix} & h_1 & h_2 & h_3 & \cdots \\ h_1^T & \ddots & & & \\ h_2^T & & \ddots & & \\ h_3^T & & & \ddots & \\ \vdots & & & & \ddots \end{pmatrix}$$

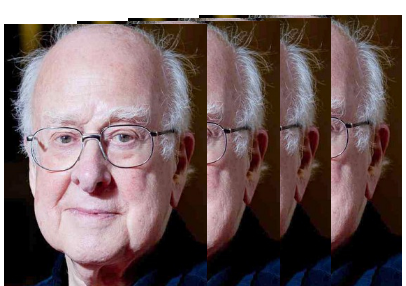
Fundamental　　　Composite

$$\partial(H^\dagger H)\partial(H^\dagger H), \ldots$$

Can we discriminate them?



Difficult ← '09 Low et. al.



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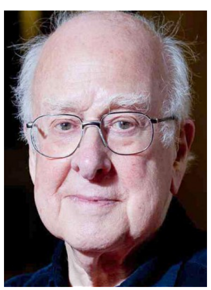
Possible ← This talk

DOF	Fundamental		Composite
1HDM	$\phi_0,\ \phi_L^a$	$>$	$\partial(H^\dagger H)\partial(H^\dagger H)$
2HDM	EWPM: 4~6	$<$	6, 8



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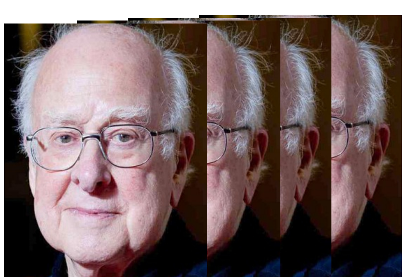


...

Possible ← This talk

$$\mathscr{L}_{\mathrm{NG}} = \frac{f^2}{2}\mathrm{tr}\left[(\partial e^{-i\pi/f})(\partial e^{i\pi/f})\right]$$

$$\supset -\frac{1}{24f^2}\left(4f^{aci}f^{bdi} + f^{ace}f^{bde}\right)h^a h^b(\partial h^c)(\partial h^d)$$

4 real scalars

Generators of SO(4)

$$= a_L(hT_L^{\alpha}\partial h)(hT_L^{\alpha}\partial h) + a_R(hT_R^{\beta}\partial h)(hT_R^{\beta}\partial h)$$
$$+ a_Y(hT_R^{3}\partial h)(hT_R^{3}\partial h)$$

$$\rightarrow \partial(H^\dagger H)\partial(H^\dagger H),\ (H^\dagger \overleftrightarrow{\partial} H)(H^\dagger \overleftrightarrow{\partial} H)$$

Even in NHDM,

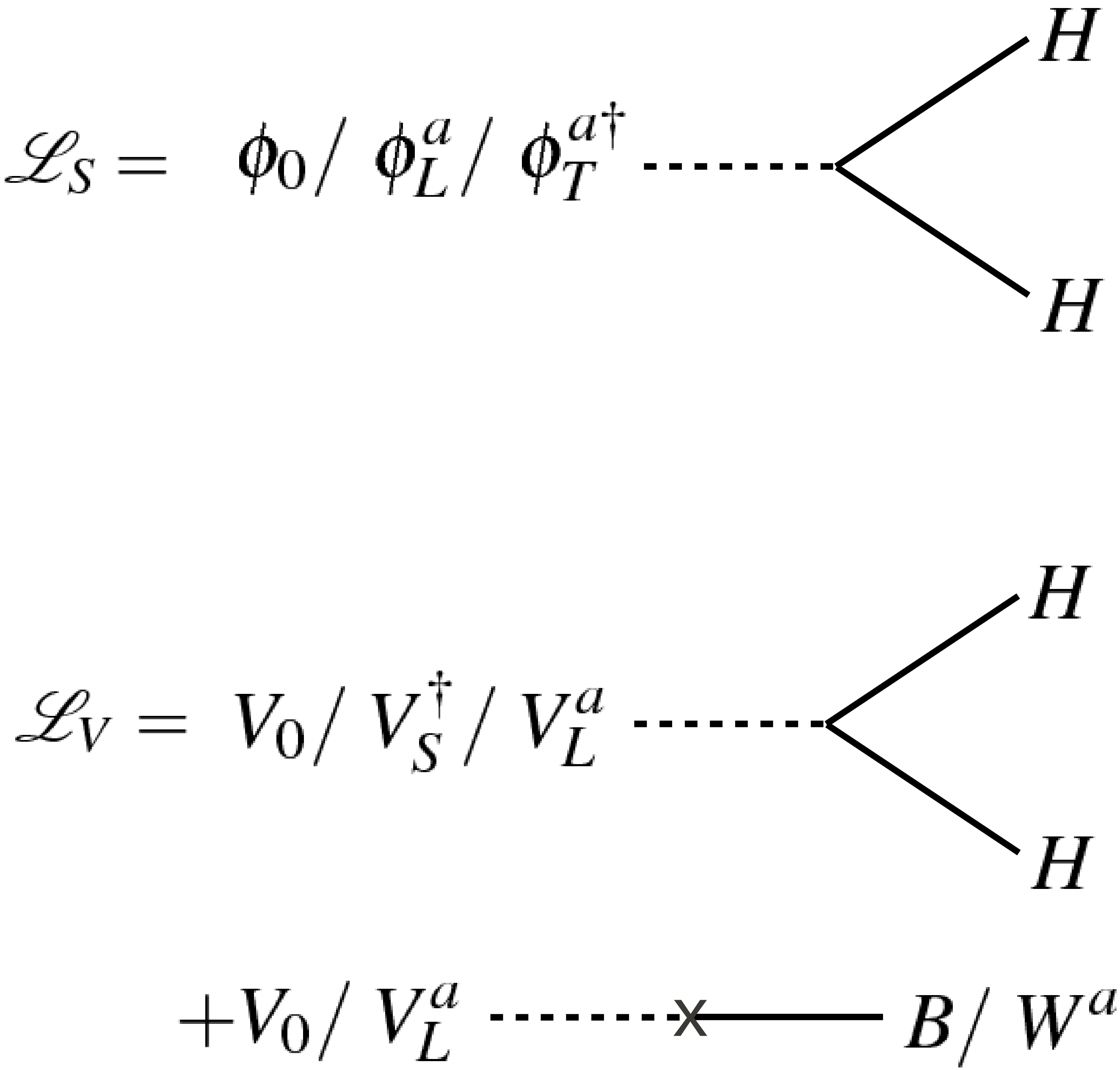
DOF(composite) = DOF(general)

arXiv:1111.2120

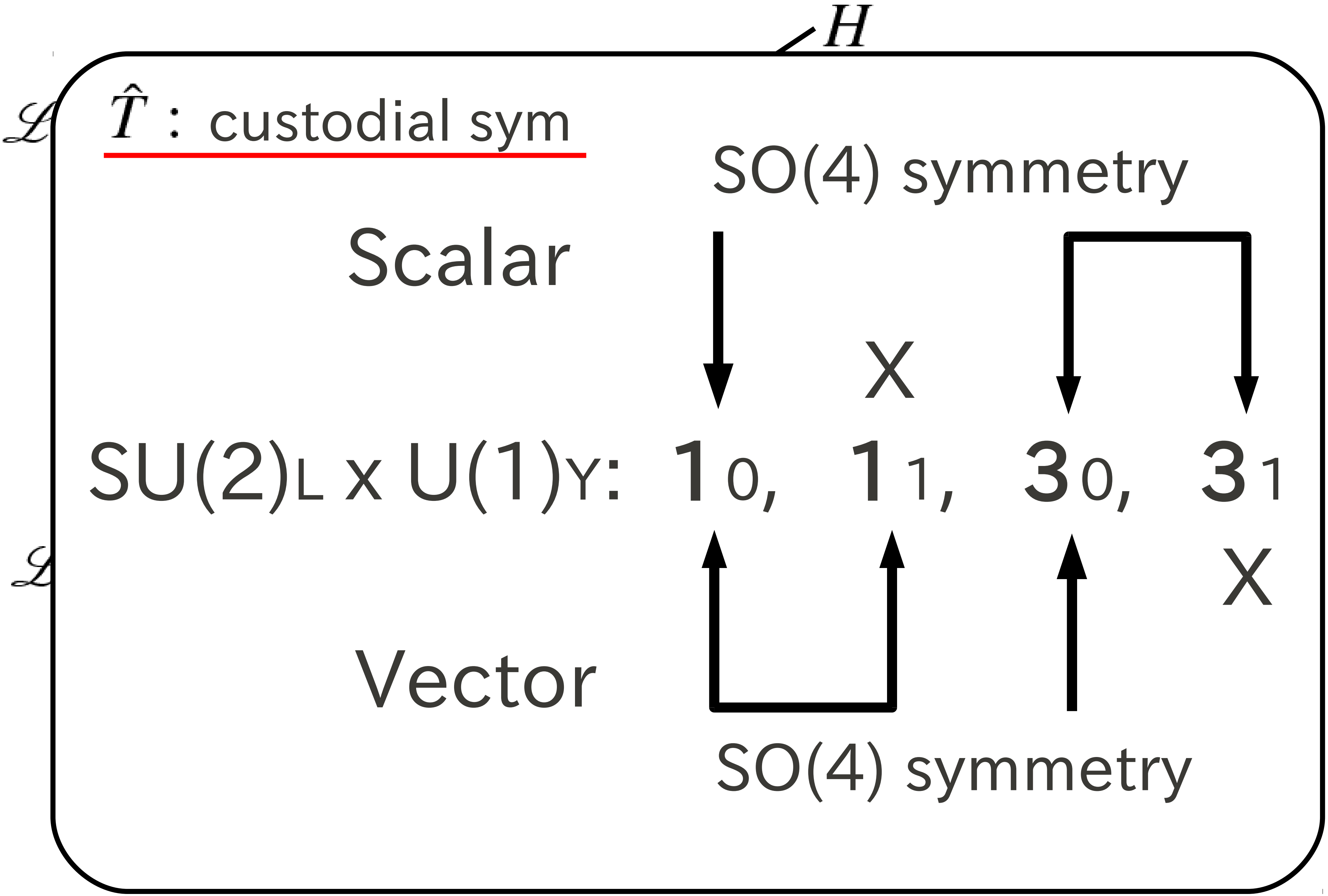
Lagrangian

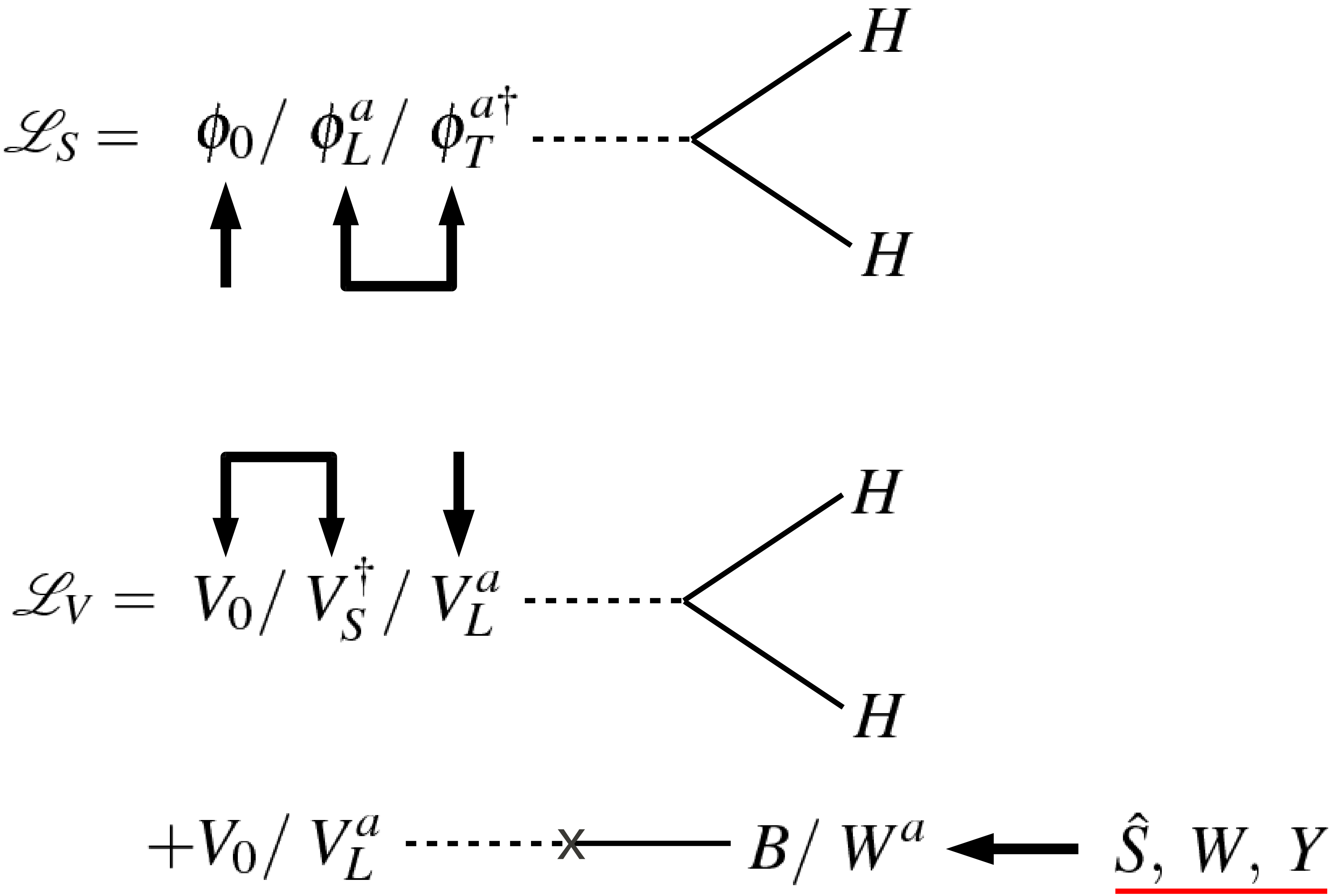
$$\mathscr{L}_S = -\frac{m_{S0}^2}{2}\phi_0^2 + \lambda_0 f \phi_0 (H^\dagger H) - \frac{m_{SL}^2}{2}\phi_L^a \phi_L^a + \lambda_L f \phi_L^a (H^\dagger \sigma^a H) - m_{ST}^2 \phi_T^{a\dagger}\phi_T^a + \left(\frac{\lambda_T}{2} f \phi_T^{a\dagger} (\tilde{H}^T \sigma^a H) + \mathrm{H.c.}\right)$$

$$\mathscr{L}_V = \frac{m_{V0}^2}{2} V_0 \cdot V_0 + V_0 \cdot \left(i g_0 \left(H^\dagger \overleftrightarrow{\partial} H \right) + g' \gamma_0 \partial \cdot B \right) + m_{VS}^2 V_S^\dagger \cdot V_S + \left(\frac{i g_S}{2} V_S^\dagger \cdot \left(\tilde{H}^T \overleftrightarrow{\partial} H \right) \right) + \frac{m_{VL}^2}{2} V_L^a \cdot V_L^a + V_L^a \cdot \left(i g_L \left(H^\dagger \overleftrightarrow{\partial} \sigma^a H \right) + g \gamma_L (\partial \cdot W)^a \right)$$

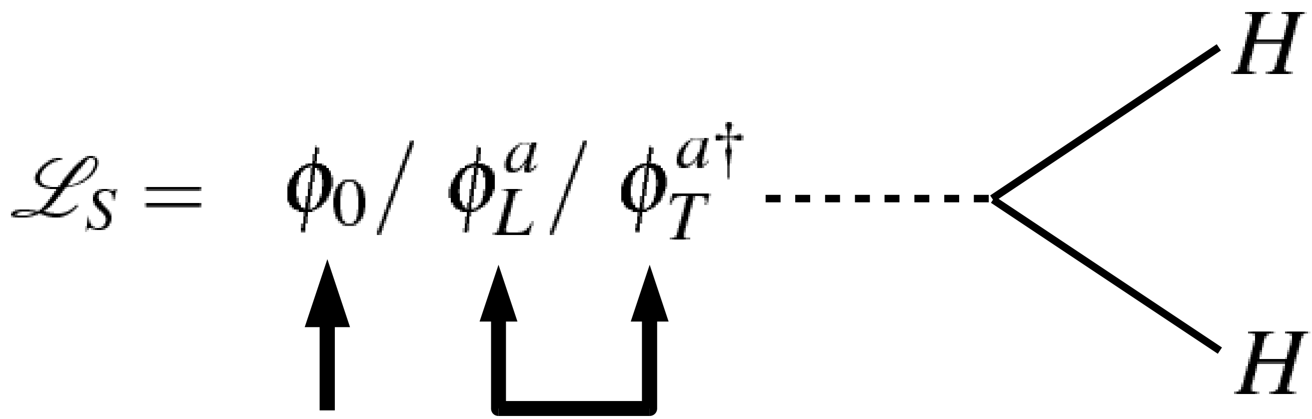


$\mathscr{L}_S = \phi_0 /\ \phi_L^a /\ \phi_T^{a\dagger}$
H
H
$\mathscr{L}_V = V_0 /\ V_S^\dagger /\ V_L^a$
H
H
$+V_0 /\ V_L^a$
$B /\ W^a$


H
$\hat{T}$: custodial sym
SO(4) symmetry
Scalar
X
SU(2)L x U(1)Y: 1 0, 1 1, 3 0, 3 1
X
Vector
SO(4) symmetry



Vectors should be decoupled.

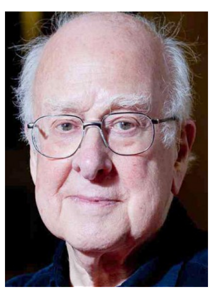


$$\Rightarrow f^2 \left(\frac{\lambda_0^2}{m_{S0}^4} - \frac{3\lambda_L^2}{m_{SL}^4} \right) \partial(H^\dagger H) \partial(H^\dagger H)$$

DOF(fund.)=2 > DOF(comp.)=1

It is difficult to discriminate them.

DOF	Fundamental		Composite
1HDM	$\phi_0,\ \phi_L^a$	$>$	$\partial(H^\dagger H)\partial(H^\dagger H)$
2HDM	EWPM: 4~6	$<$	6, 8



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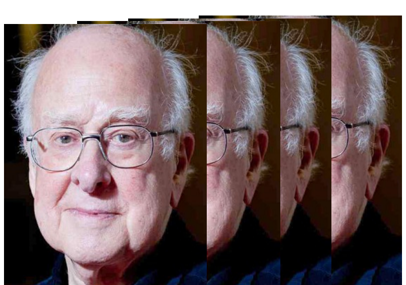
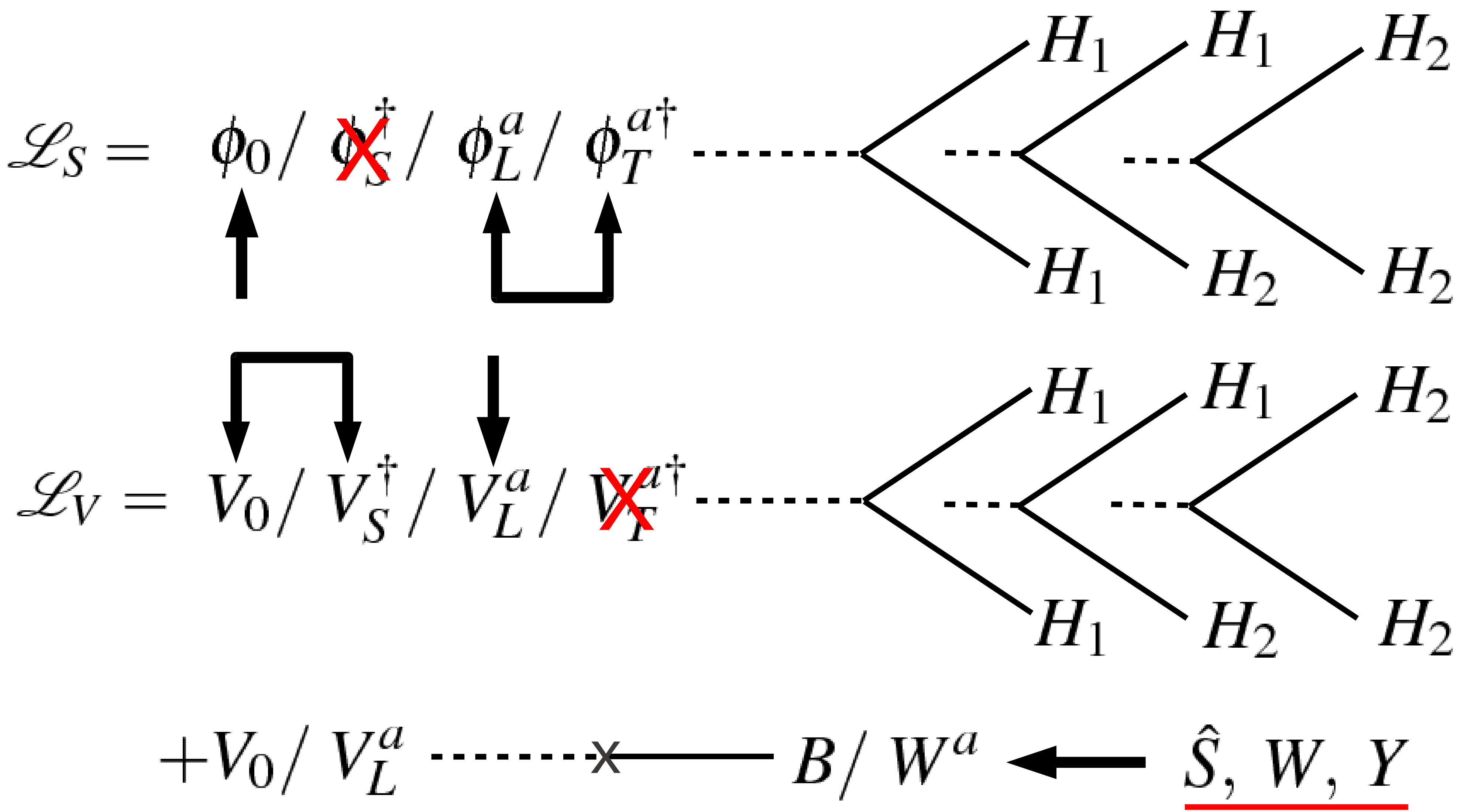


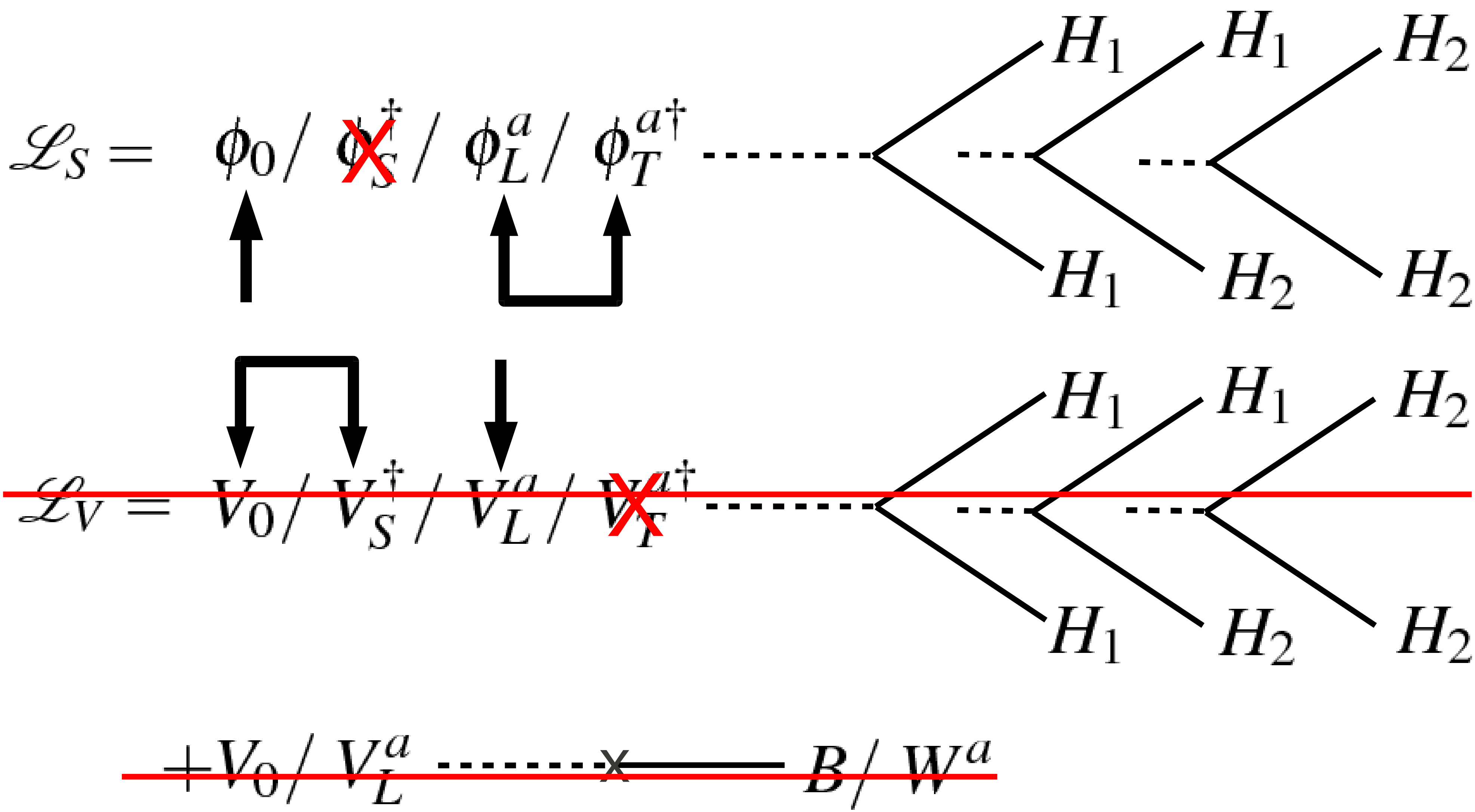
...

Possible ← This talk



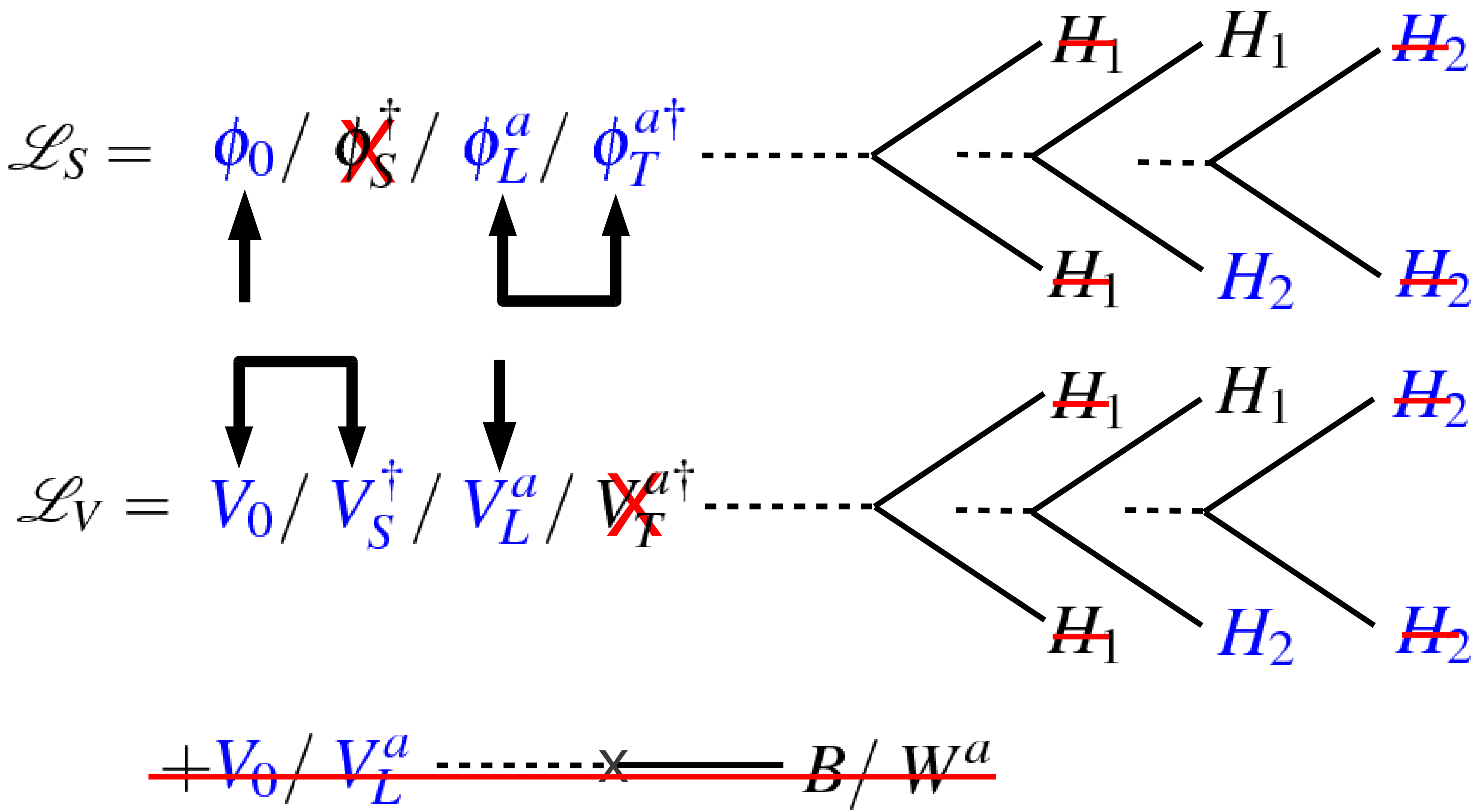
Oblique operators are suppressed by

large M_V/ additional Z_2



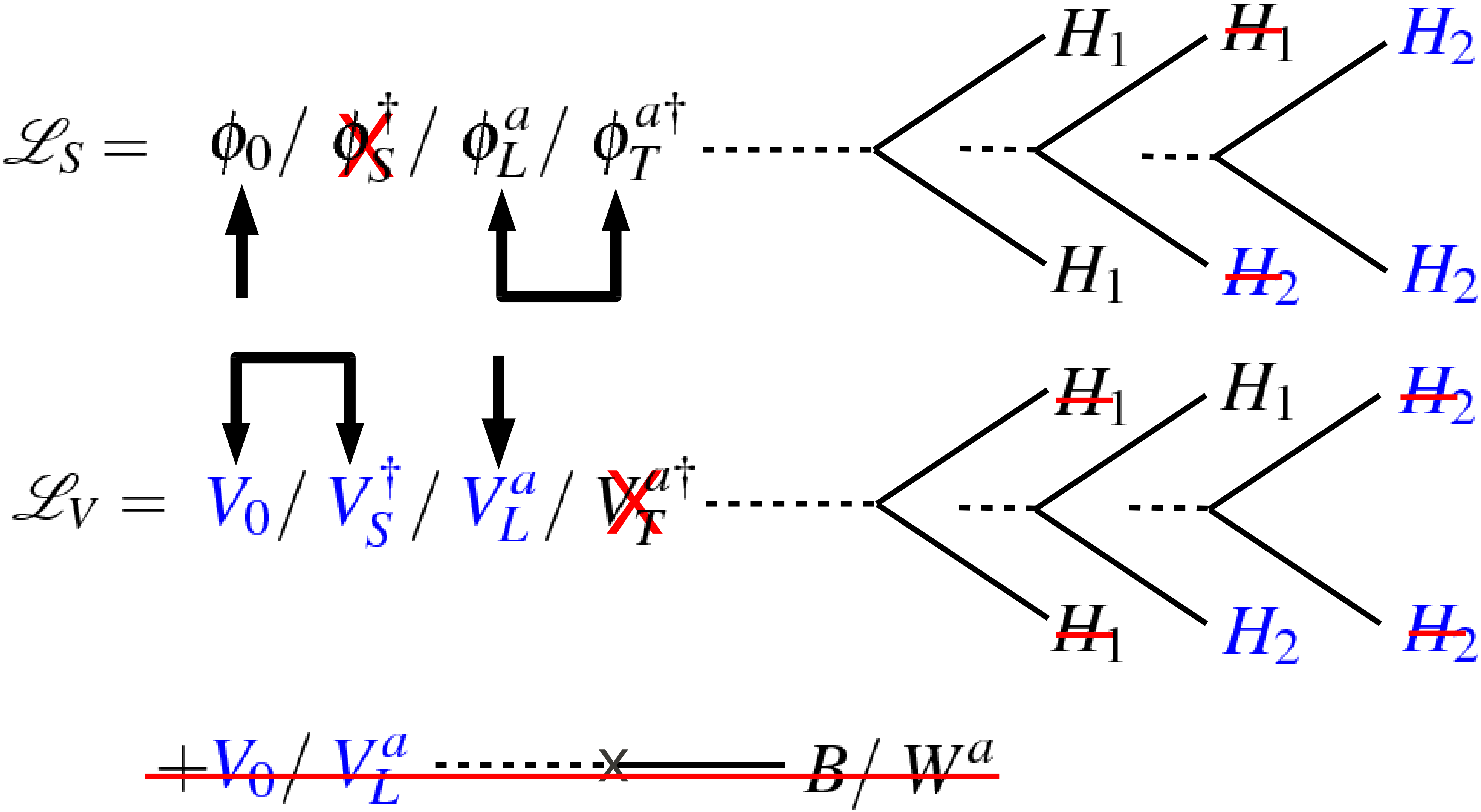
Decouple:

DOF(fund)=6 < DOF(comp.)=8



Z_2 symmetry (odd scalar):

DOF(fund.)=4 < DOF(comp.)=6



Z2 symmetry (even scalar):

DOF(fund.)=6 = DOF(comp.)=6

$$\partial(H^\dagger H)\partial(H^\dagger H), \ldots$$

Integrating out   Nonlinear sigma model

Is the Higgs fundamental or composite?

Suppression of oblique corrections

SO(4) symmetry

Large M_V/ Additional Z_2

For N > 1,

DOF(Fundamental) ≦ DOF(Composite)

Complete results for NHDM will appear arXiv:1209.xxxx