Anomalous Higgs couplings @LHC

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LAPTH Annecy

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Outline

- Introduction
  - Effective Theory & New Physics
  - d=6 operators and Higgs
- Modification of SM Higgs properties
  - Decays
  - Constraints from LEP - Tevatron
  - LHC searches
- What can we learn on New Physics
  - Mediators
  - New Physics detection in Higgs physics

Introduction

- The Standard Model (SM) of particle physics suffers several issues:
  - Non zero neutrino masses
  - Dark Matter
  - Baryon asymmetry
  - Hierarchy problem

Call for New Physics (NP) > EW

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- Identifying NP ~ constraining new parameters

  ↳ Calculate every observable stemming from each coefficient in each model

up-to-bottom

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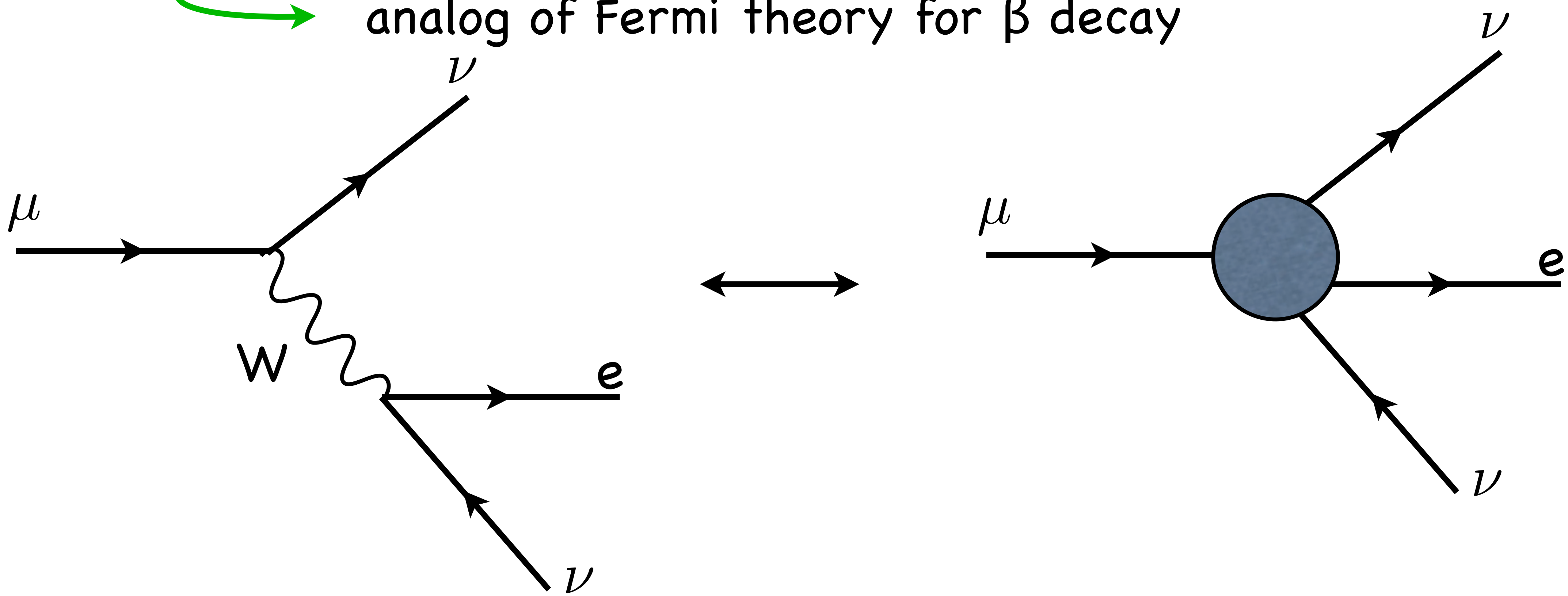
up-to-bottom

- Another approach: bottom-up $\longrightarrow$ SM ~ 1st order Effective theory

Effective theories

- SM viewed as 1st order of an effective theory

  analog of Fermi theory for β decay



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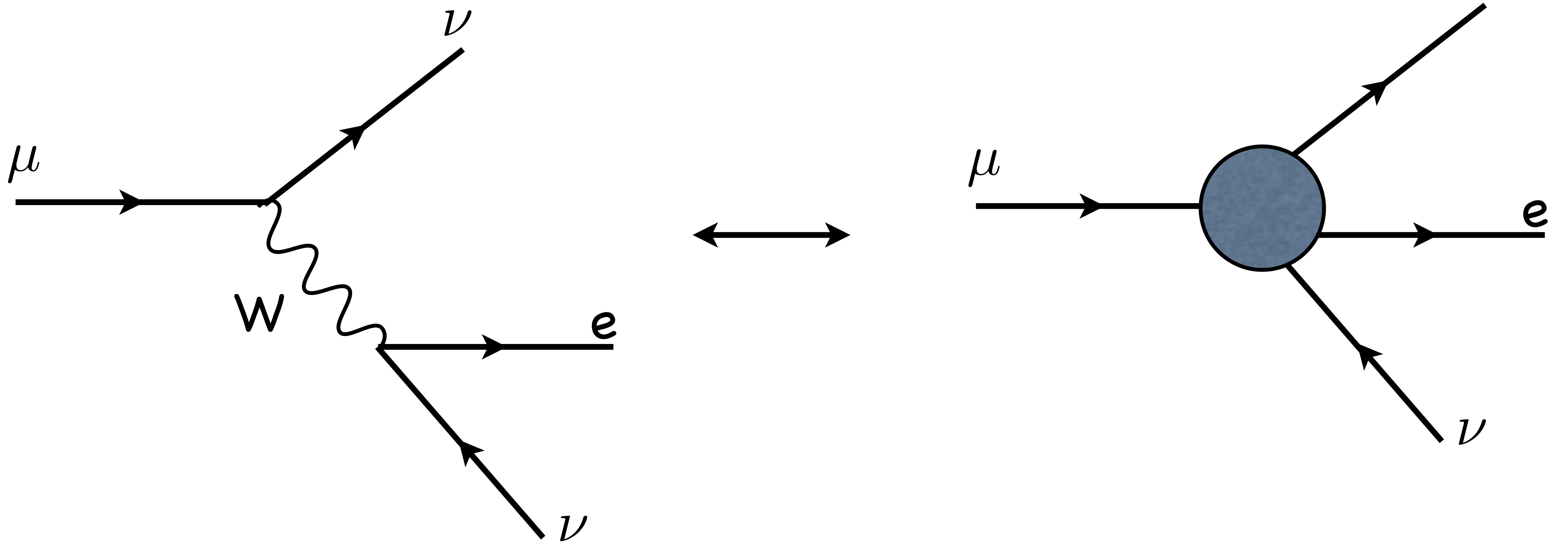

- Effective operators: low-energy remnant of NP

  Build only with SM fields

- Nearly model independent analysis: only the coefficients of the operators are model-dependent

$$\mathcal{L}_{eff} = \mathcal{L}_{SM} + \delta\mathcal{L}^{d=5} + \delta\mathcal{L}^{d=6} + \dots$$

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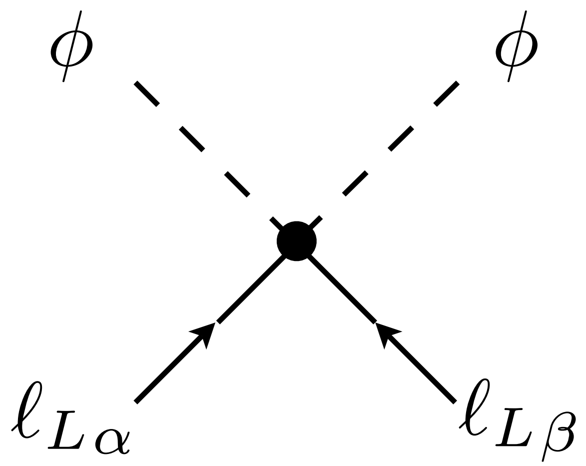
- Lowest order: unique d=5 operator
  - Weinberg operator
  - Neutrino masses

Recent review
A. Abada et al. '07



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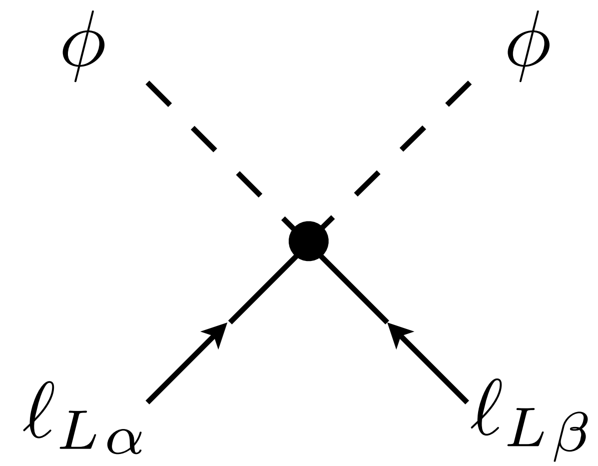

- Next: 81 independent d=6 operators (Buchmuller, Wyler '86)

$$\mathcal{L}_{eff} = \mathcal{L}_{SM} + \sum_i \alpha_i \mathcal{O}_i$$

- Model dependent
- $\propto 1/\Lambda^2$

Operators with Higgs

- Higgs hasn't been observed yet

  → Higgs sector less constrained

- What if the Higgs sector is not SM like? what can be the influence of NP on the Higgs sector?

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loop suppression

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- Modification of SM Higgs properties
  - Decays
  - Constraints from LEP - Tevatron
  - LHC searches
- What NP can generate such operators
  - Mediators
  - Constraints

Modification of the SM Higgs sector

Anomalous Higgs couplings

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Modification of Higgs potential
Shift in vev

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Contribution to Higgs kinetic term
Modification of Higgs-gauge interactions
Modification of Gauge bosons mass

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- Relevant interactions:

$$\begin{aligned}\mathcal{L}_{H,Z,W} \quad \ni \quad & M_W^2 W_\mu^- W^{+\mu} + M_Z^2 Z_\mu Z^\mu + \frac{1}{2}\partial_\mu H \partial^\mu H - M_H^2 H^2 \\ & + \lambda_{HWW} W_\mu^- W^{+\mu} H + \lambda_{HZZ} Z_\mu Z^\mu H - \lambda_{HHH} H^3 \\ & + \lambda_{HHWW} W_\mu^- W^{+\mu} H^2 + \lambda_{HHZZ} Z_\mu Z^\mu H^2 - \lambda_{HHHH} H^4\end{aligned}$$

- New interactions: $H^3 W_\mu W^\mu$, $H^3 Z_\mu Z^\mu$, $H^4 W_\mu W^\mu$, $H^4 Z_\mu Z^\mu$, $H\partial_\mu H \partial^\mu H$, $H^2 \partial_\mu H \partial^\mu H$

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with:
$\alpha_i v^2 \ll 1$

Z-scheme
M_Z, G_F, α, M_H
as inputs

$$\begin{aligned}M_W^2 &= M_{W_{SM}}^2 (1 - \frac{c^2}{c^2 - s^2}\alpha_\phi^{(3)}\frac{v^2}{2})\,, \\ \lambda_{HWW} &= \lambda_{HWW_{SM}} (1 + \alpha_\phi^{(1)}\frac{v^2}{2} - (\frac{1}{2} + \frac{c^2}{c^2 - s^2})\alpha_\phi^{(3)}\frac{v^2}{2} - \alpha_{\partial\phi}\frac{v^2}{2}))\,, \\ \lambda_{HZZ} &= \lambda_{HZZ_{SM}} (1 + \alpha_\phi^{(1)}\frac{v^2}{2} + \alpha_\phi^{(3)}\frac{v^2}{4} - \alpha_{\partial\phi}\frac{v^2}{2}))\,, \\ \lambda_{HHWW} &= \lambda_{HHWW_{SM}} (1 + \frac{5}{2}\alpha_\phi^{(1)}v^2 - (1 + \frac{c^2}{c^2 - s^2})\alpha_\phi^{(3)}\frac{v^2}{2} - \alpha_{\partial\phi}v^2))\,, \\ \lambda_{HHZZ} &= \lambda_{HHZZ_{SM}} (1 + \frac{5}{2}\alpha_\phi^{(1)}v^2 + 2\alpha_\phi^{(3)}v^2 - \alpha_{\partial\phi}v^2))\,, \\ \lambda_{HHH} &= \lambda_{HHH_{SM}} (1 - \alpha_\phi^{(3)}\frac{v^2}{4} - \alpha_{\partial\phi}\frac{v^2}{2} + \frac{1}{3}\alpha_\phi\frac{v^2}{\lambda}) \\ \lambda_{HHHH} &= \lambda_{HHHH_{SM}} (1 - \alpha_\phi^{(3)}\frac{v^2}{2} - \alpha_{\partial\phi}v^2 + 2\alpha_\phi\frac{v^2}{\lambda})\end{aligned}$$

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- Fermions: shift of Higgs field to have canonical kinetic term implies

$$\mathcal{L}_f \ni Y_f \frac{v}{\sqrt{2}} \overline{f} f + Y_f H \overline{f} f\,,$$

with:

$$Y_f = Y_{f_{SM}}(1 + \alpha_\phi^{(3)} \frac{v^2}{2} - \alpha_{\partial\phi}\frac{v^2}{2})$$

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- Electroweak precision tests: $\mathcal{O}_\phi^{(3)}$ modifies differently M_W and M_Z

$$\left.\begin{aligned} \rho &\equiv \frac{M_Z^2 c^2}{M_W^2} = \frac{M_{W_{SM}}^2}{M_W^2} \\ M_W^2 &= M_{W_{SM}}^2\left(1 - \frac{c^2}{c^2-s^2}\alpha_\phi^{(3)}\frac{v^2}{2}\right) \end{aligned}\right\} \longrightarrow \delta\rho = \frac{c^2}{c^2-s^2}\alpha_\phi^{(3)}\frac{v^2}{2}\,.$$

$$\boxed{\alpha_\phi^{(3)} v^2 \lesssim 3\cdot 10^{-4}}$$

we neglect it for the rest of the talk

- Consequences: $M_W = M_{W_{SM}}$

Branching ratios and decay widths

Decays

Fermions: $Y_f = Y_{f_{SM}}(1 - \alpha_{\partial\phi}\frac{v^2}{2})$

$$\Gamma(H \to f\bar{f}) = (1 - \alpha_{\partial\phi} v^2)\Gamma_{SM}(H \to f\bar{f})$$

Gluons: fermions loop

$$\Gamma(H \to gg) = (1 - \alpha_{\partial\phi} v^2)\Gamma_{SM}(H \to gg)$$

Gauge bosons: $\lambda_{HVV} \quad = \quad \lambda_{HVV_{SM}}(1 + \alpha_\phi^{(1)}\frac{v^2}{2} - \alpha_{\partial\phi}\frac{v^2}{2}))\,,$ V=W, Z

$$\Gamma(H \to VV) \quad = \quad (1 + \alpha_\phi^{(1)} v^2 - \alpha_{\partial\phi} v^2)\Gamma_{SM}(H \to VV)$$

Photons: fermion and W loops

$$\frac{\Gamma(H \to \gamma\gamma)}{\Gamma_{SM}(H \to \gamma\gamma)} = \frac{\left|(1 - \alpha_{\partial\phi}\frac{v^2}{2})\frac{4}{3}A^H_{1/2}(\tau_f) + (1 + \alpha_\phi^{(1)}\frac{v^2}{2} - \alpha_{\partial\phi}\frac{v^2}{2})A^H_1(\tau_W)\right|^2}{\left|\frac{4}{3}A^H_{1/2}(\tau_f) + A^H_1(\tau_W)\right|^2}\,,$$

Decays

Two cases

- only $\alpha_{\partial\Phi}$
- only $\alpha_{\Phi}^{(1)}$

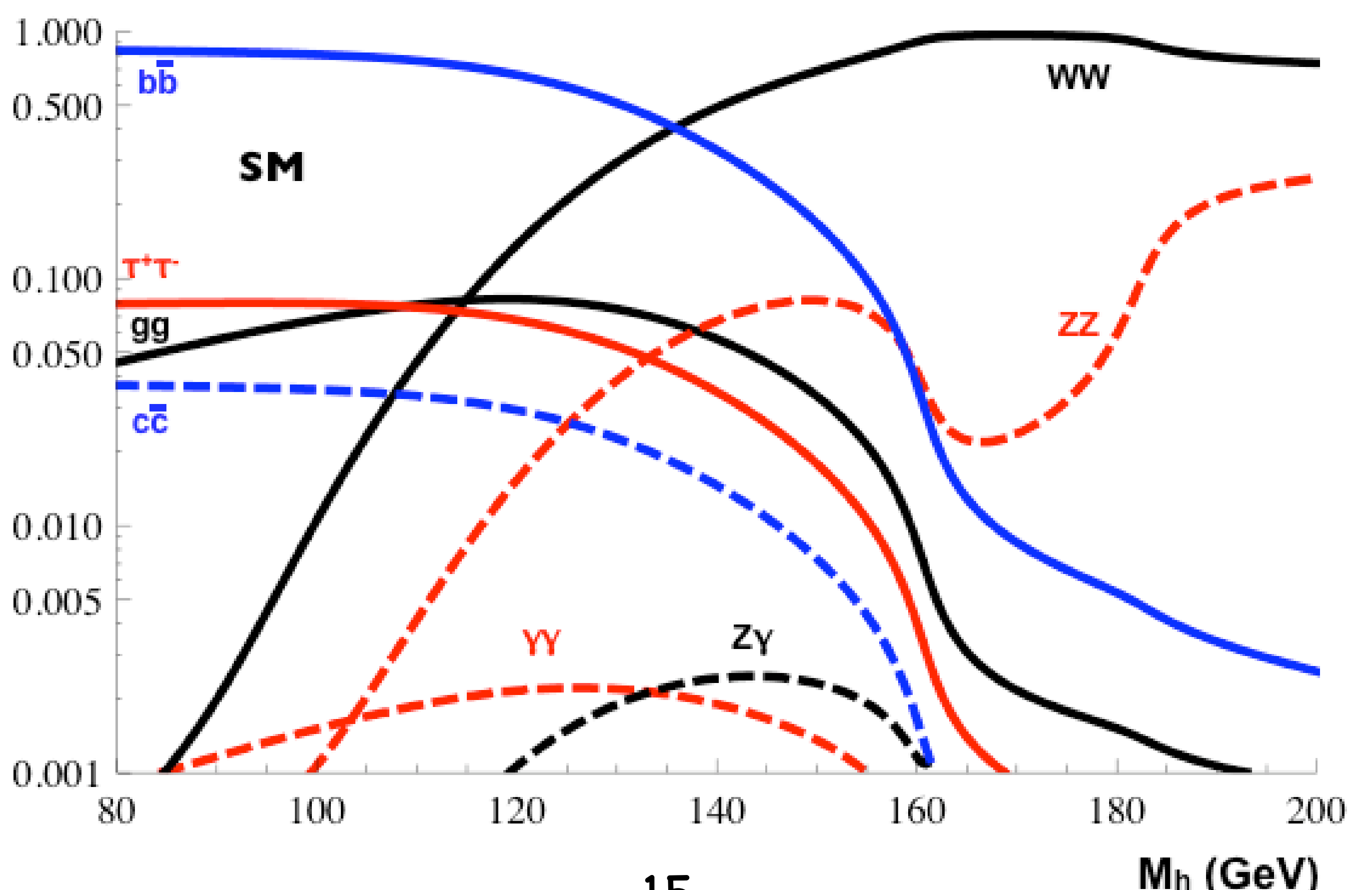
Decays

Two cases

- only $\alpha_{\partial\Phi}$
- only $\alpha_{\Phi}^{(l)}$

$$\Gamma(H \to XX) = (1 - \alpha_{\partial\phi} v^2)\Gamma_{SM}(H \to XX)$$

→ BR as in the SM



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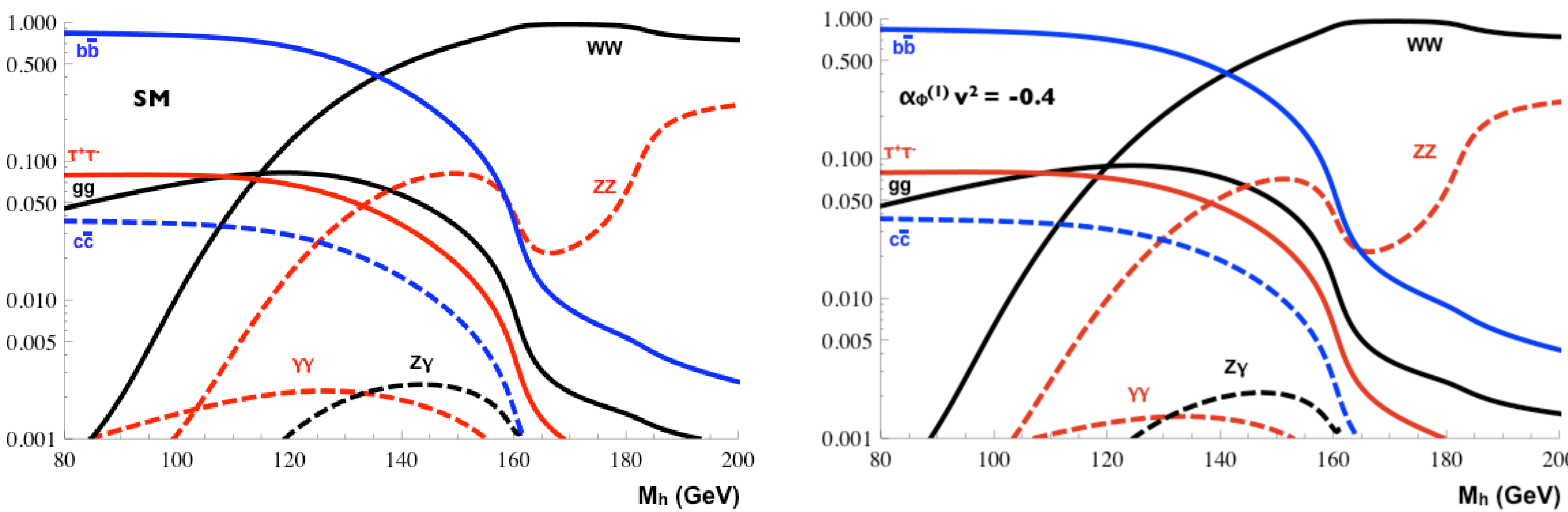

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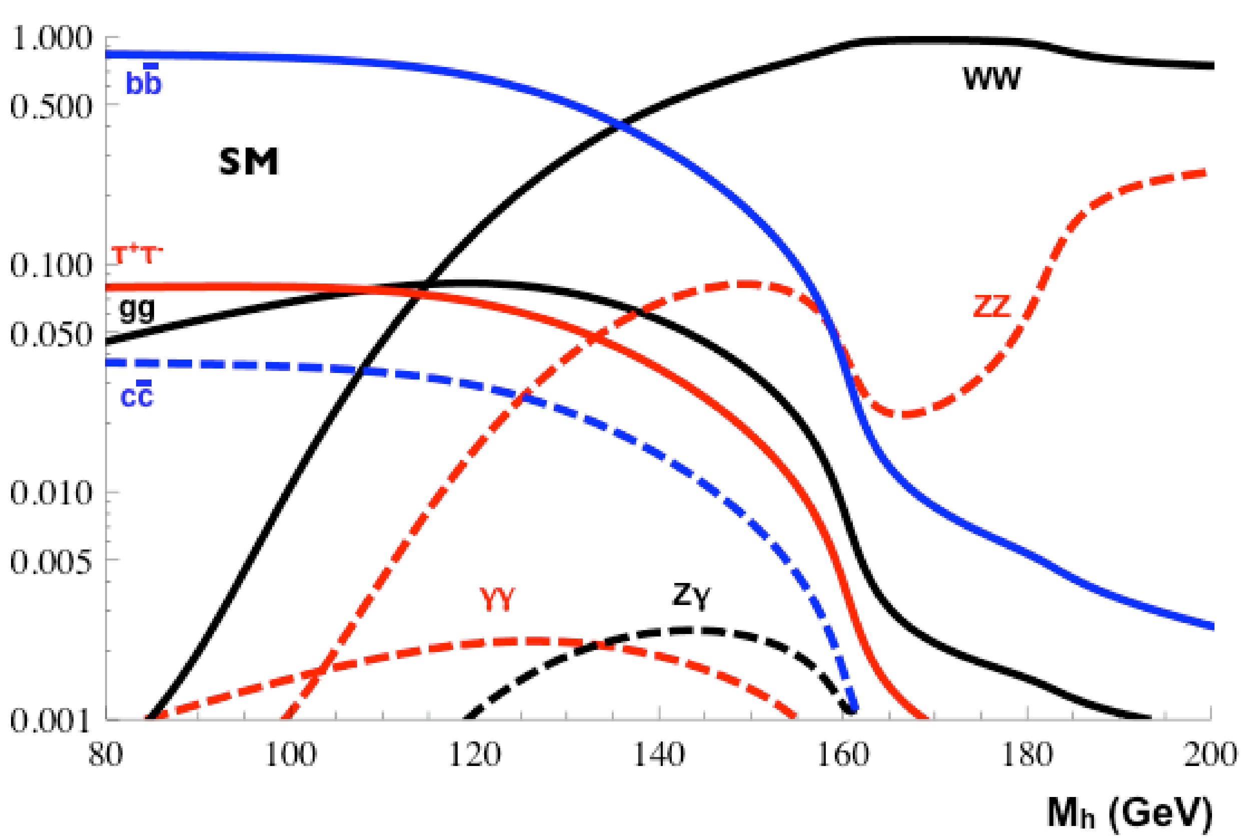

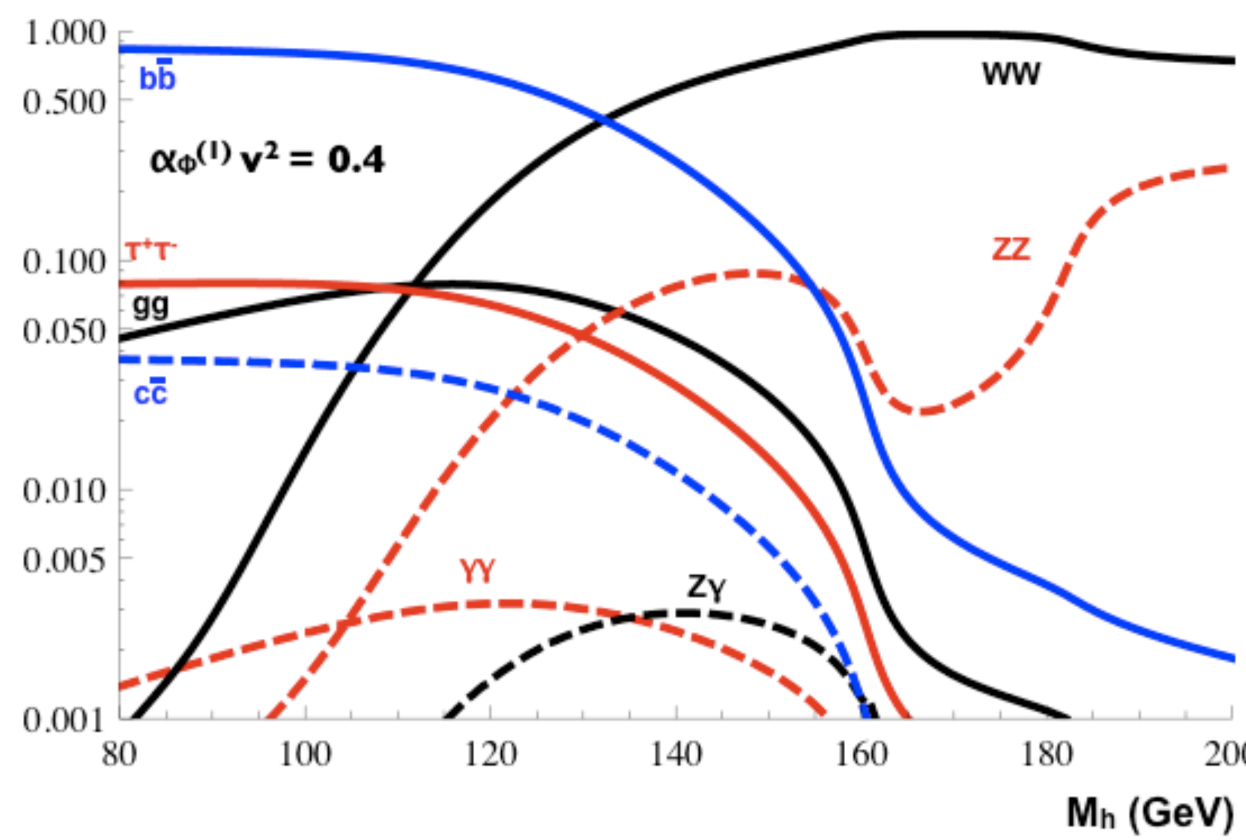

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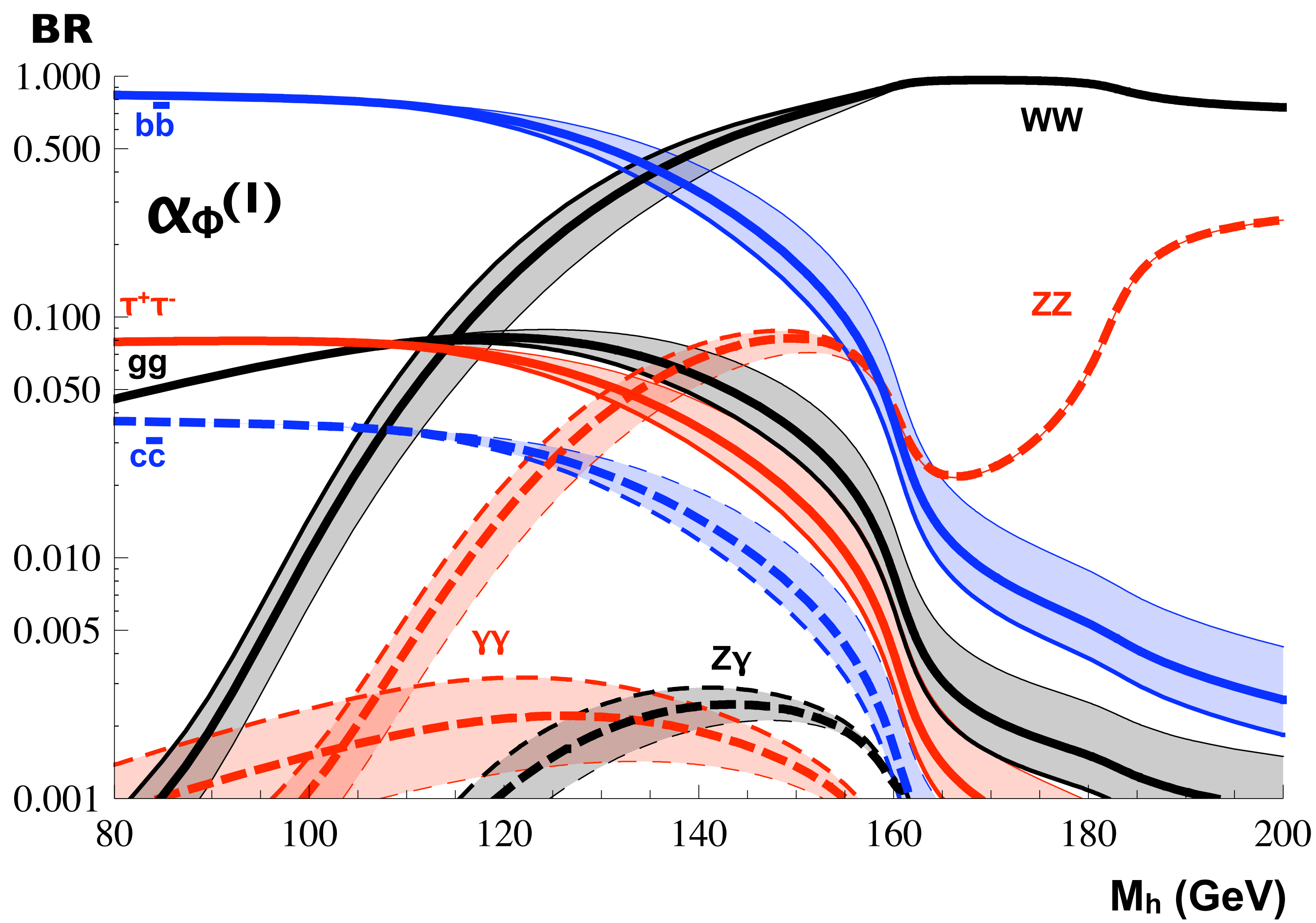

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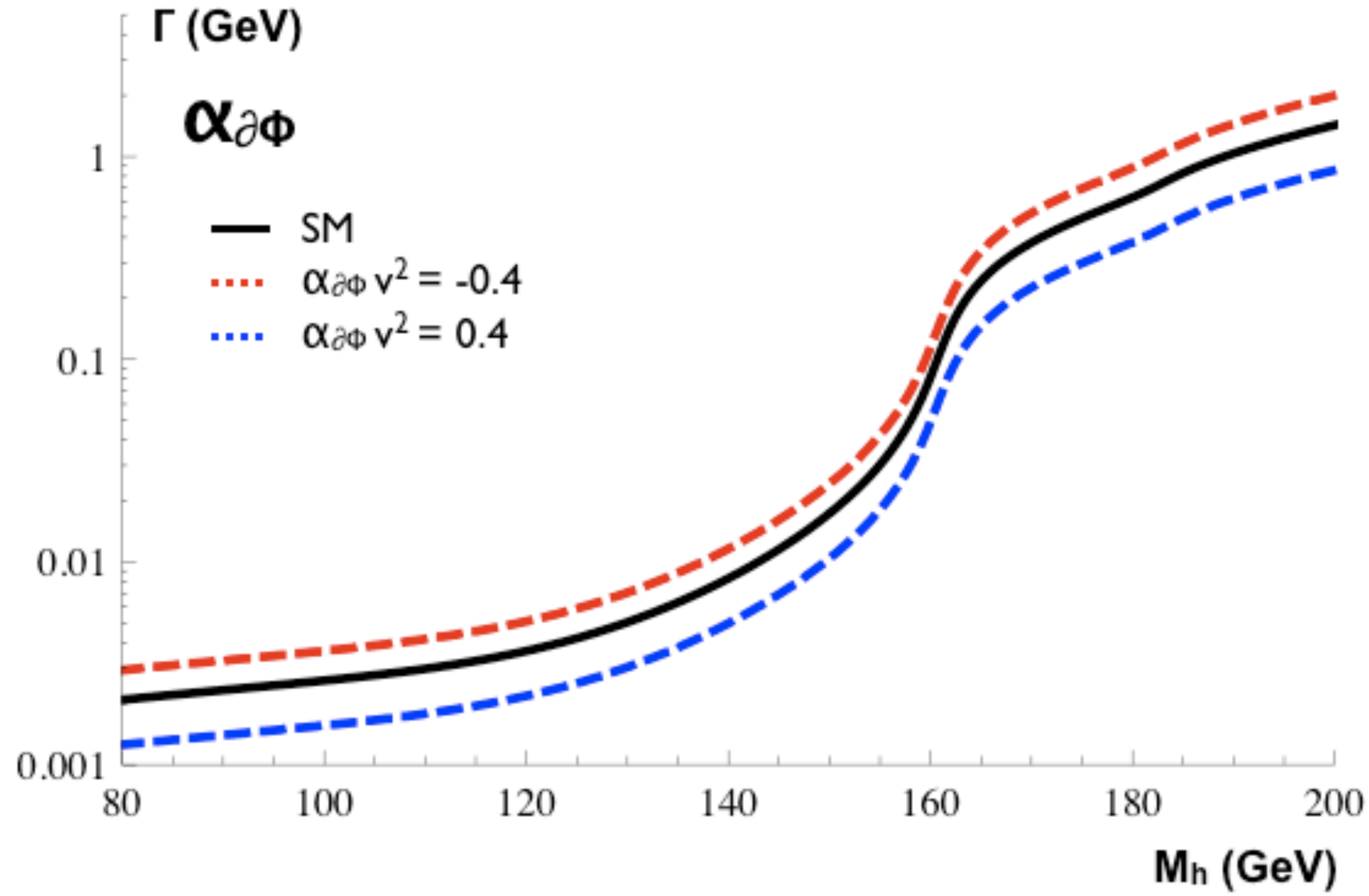
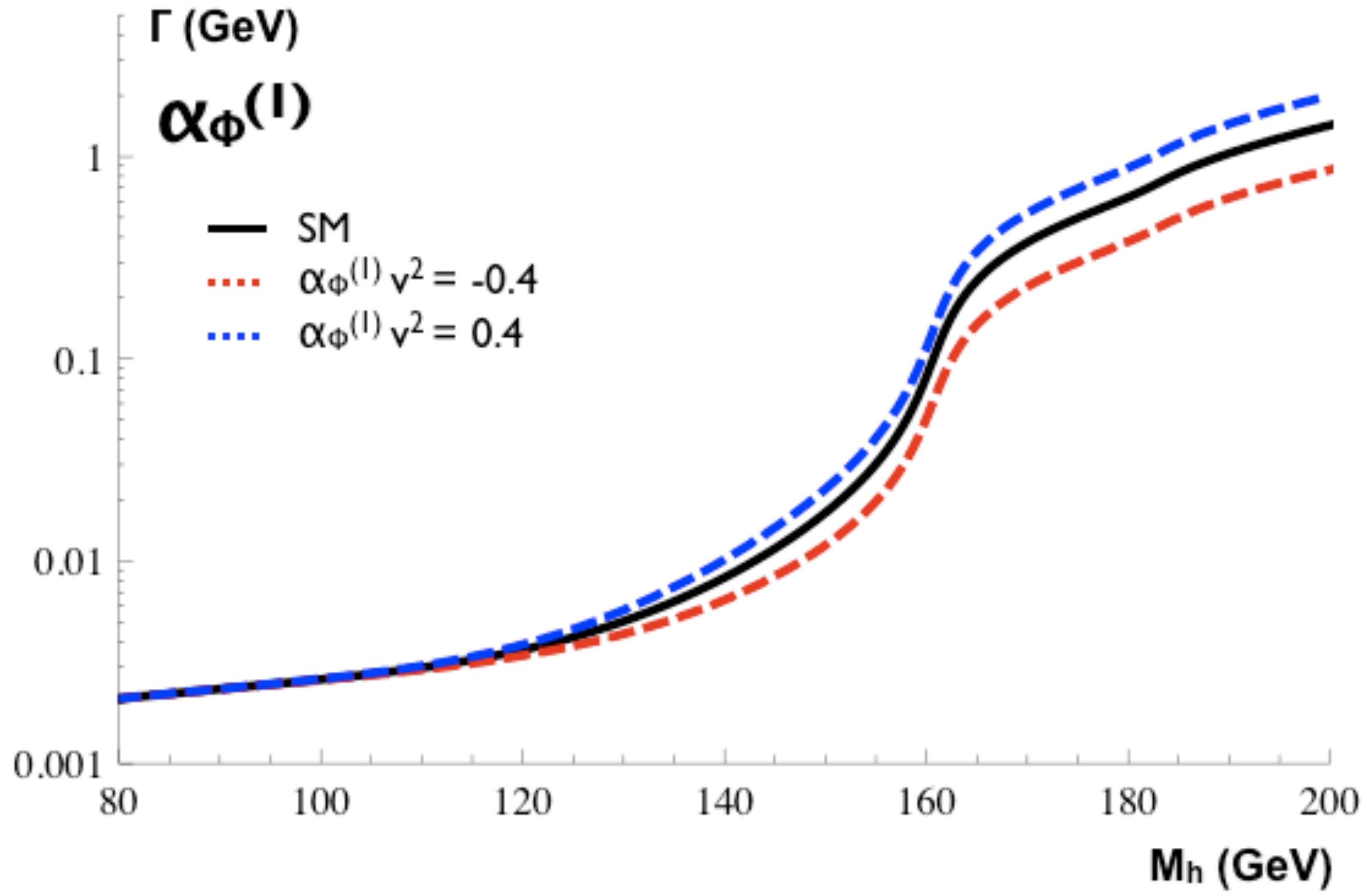


Γ (GeV)
α∂Φ
SM
α∂Φ v2 = -0.4
α∂Φ v2 = 0.4
1
0.1
0.01
0.001
80
100
120
140
160
180
200
Mh (GeV)

Decays



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Constraints from LEP-Tevatron

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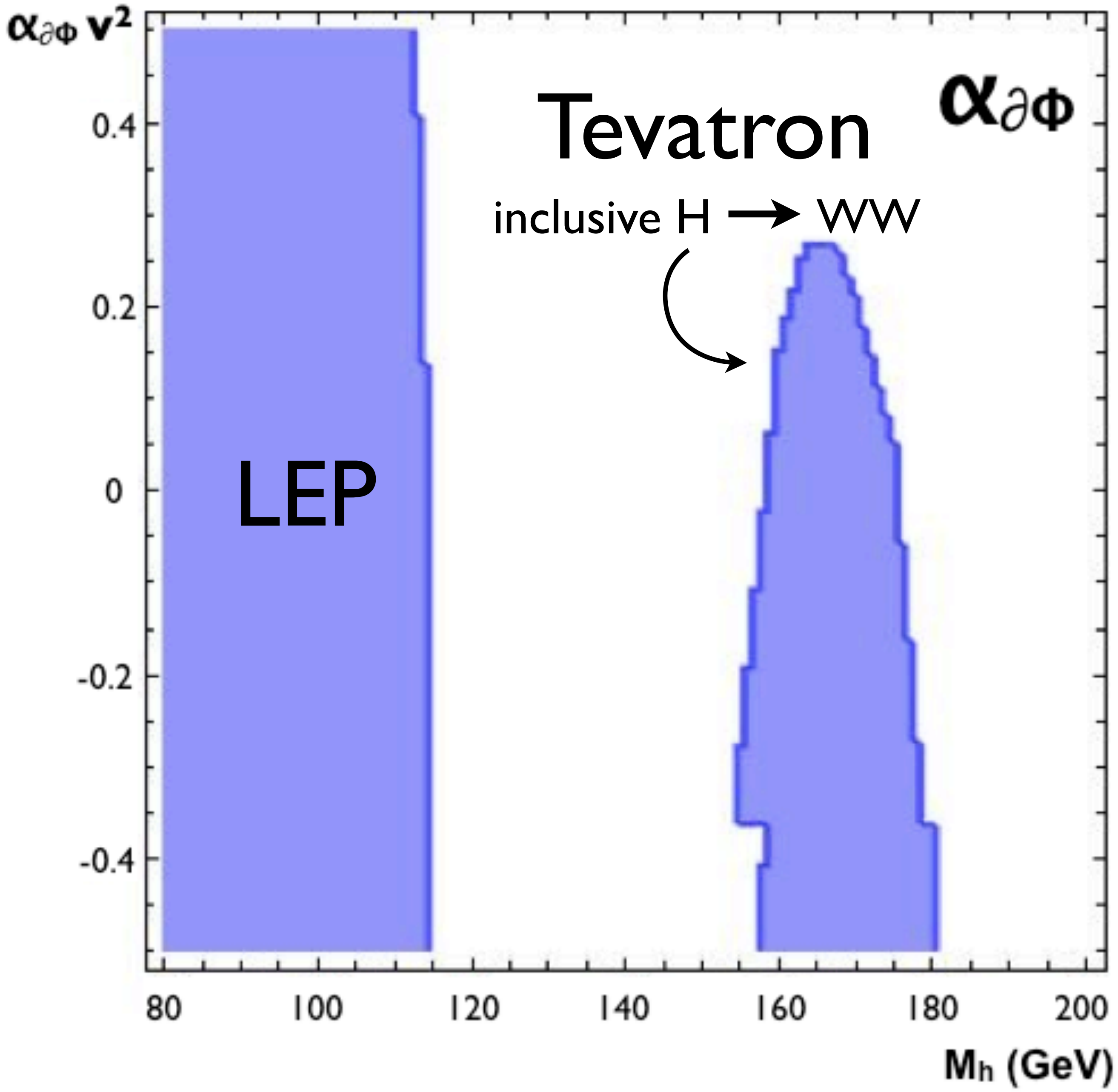

HiggsBounds, Bechtle et al.

LEP: $e^+e^- \to ZH \to Zb\bar{b}$

$$\lambda_{HZZ} = \lambda_{HZZ_{SM}}(1 - \alpha_{\partial\phi}\frac{v^2}{2})$$
$$Y_b = Y_{b_{SM}}(1 - \alpha_{\partial\phi}\frac{v^2}{2})$$

Tevatron:

inclusive production:
gluon fusion, VBF, Higgstrahlung

+

H → WW

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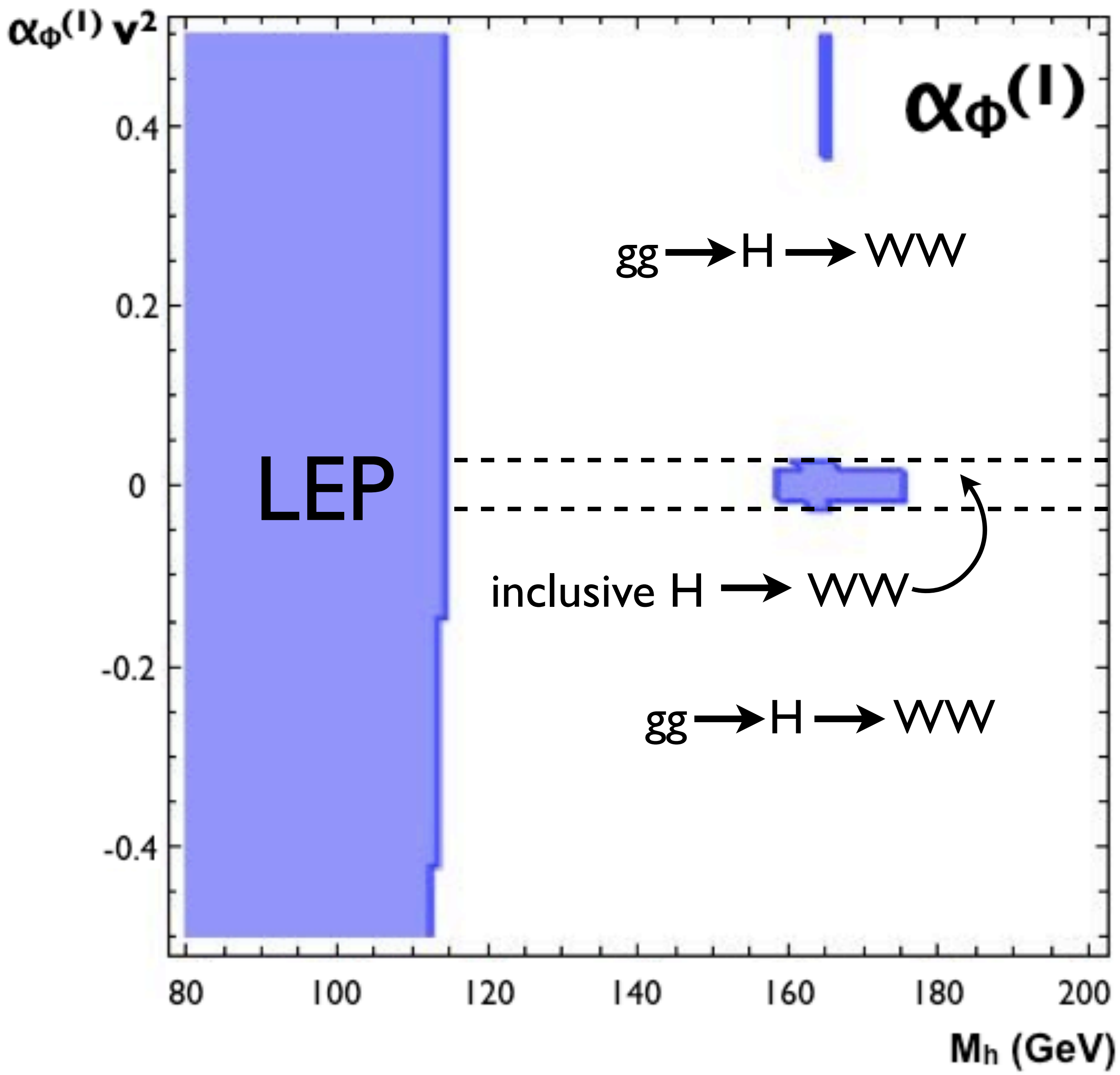

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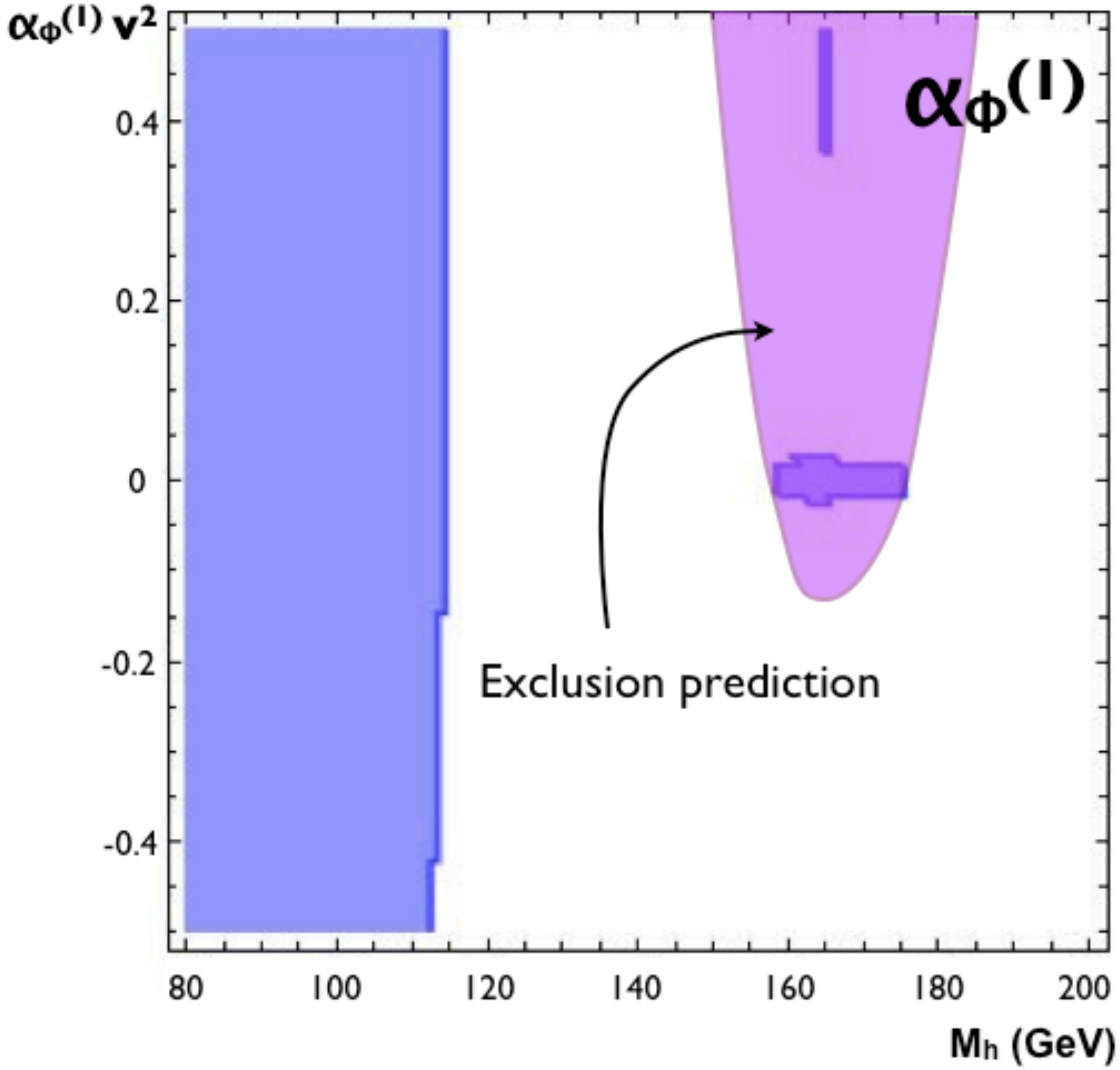

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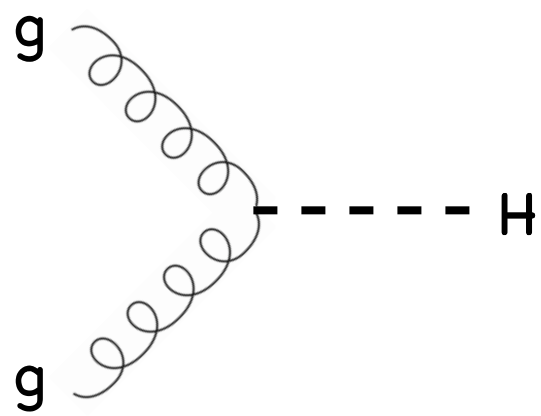
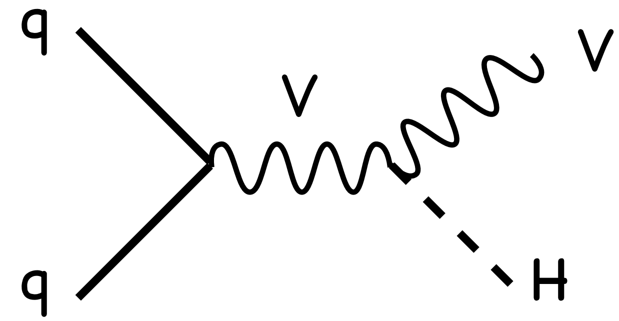
Higgs @ LHC

Production of a Higgs @LHC

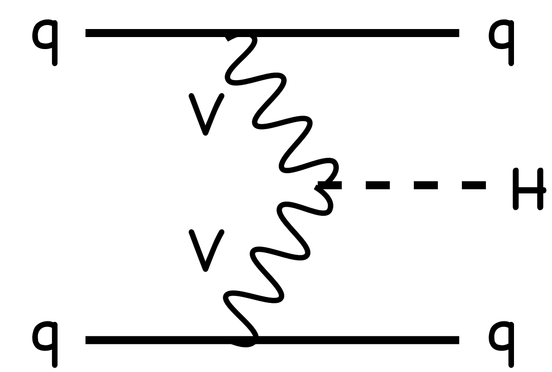
gluon fusion:



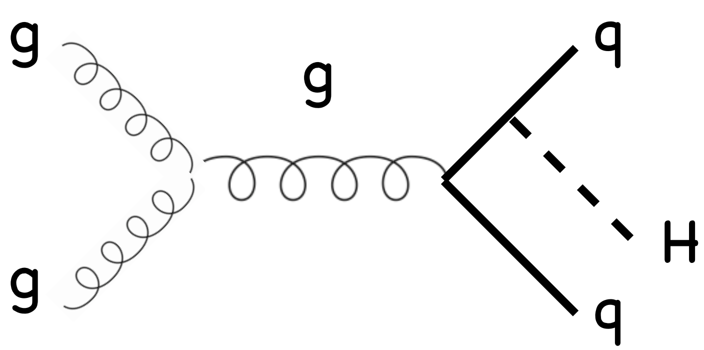
Higgstrahlung:

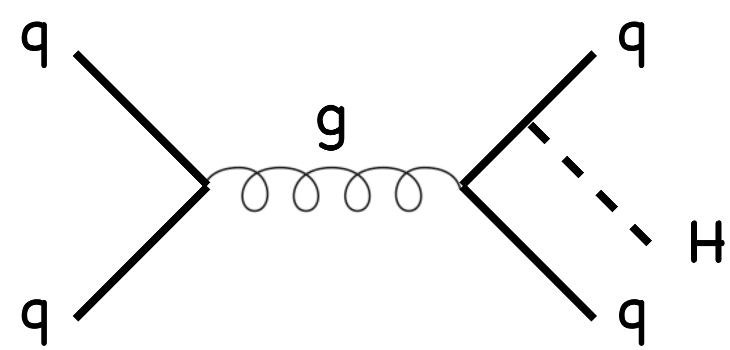


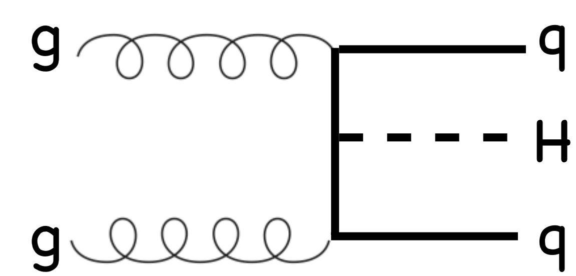
vector boson fusion:



Associated production with top:







Production of a Higgs @LHC

gluon fusion:

$$\sigma_{NLO}(gg \to H) = (1 - \alpha_{\partial\phi} v^2)\sigma^{SM}_{NLO}(gg \to H)$$

vector boson fusion:

$$\sigma_{NLO}(VV \to H) = (1 + \alpha^{(1)}_{\phi} v^2 - \alpha_{\partial\phi} v^2)\sigma^{SM}_{NLO}(VV \to H)$$

Higgstrahlung:

$$\sigma_{NLO}(VH) = (1 + \alpha^{(1)}_{\phi} v^2 - \alpha_{\partial\phi} v^2)\sigma^{SM}_{NLO}(VH)$$

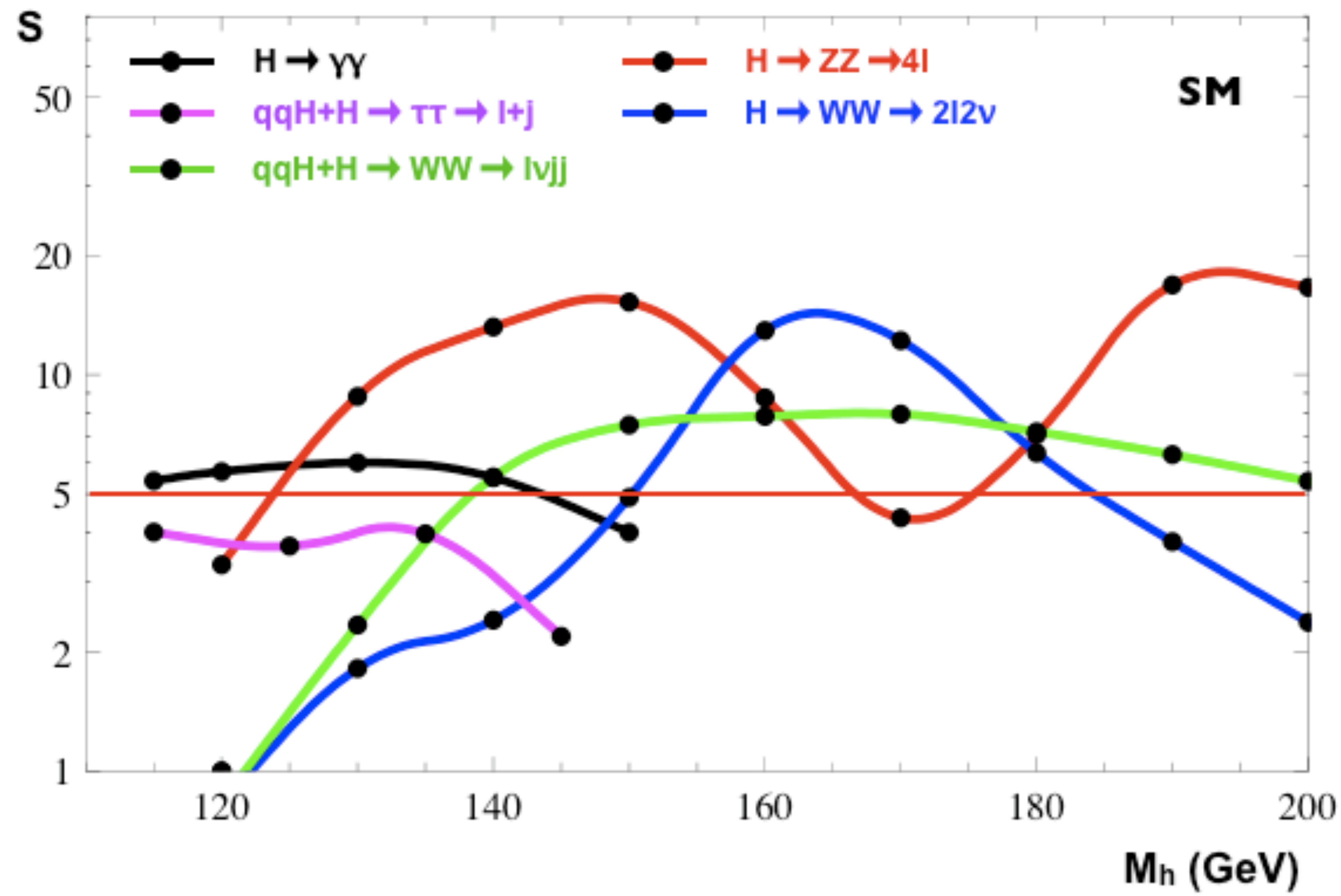
Associated production with top:

$$\sigma_{NLO}(Ht\bar{t}) = (1 - \alpha_{\partial\phi} v^2)\sigma^{SM}_{NLO}(Ht\bar{t})$$

Higgs searches @LHC (CMS: 30 fb^{-1})

14 TeV

- Inclusive search channels:
  - $H \to ZZ \to 4l$
  - $H \to WW \to 2l2\nu$
  - $H \to \gamma\gamma$
- Non inclusive search channels:
  - $VBF + H \to WW \to l\nu jj$
  - $VBF + H \to \tau^+\tau^- \to l+j+\not{E}_T$

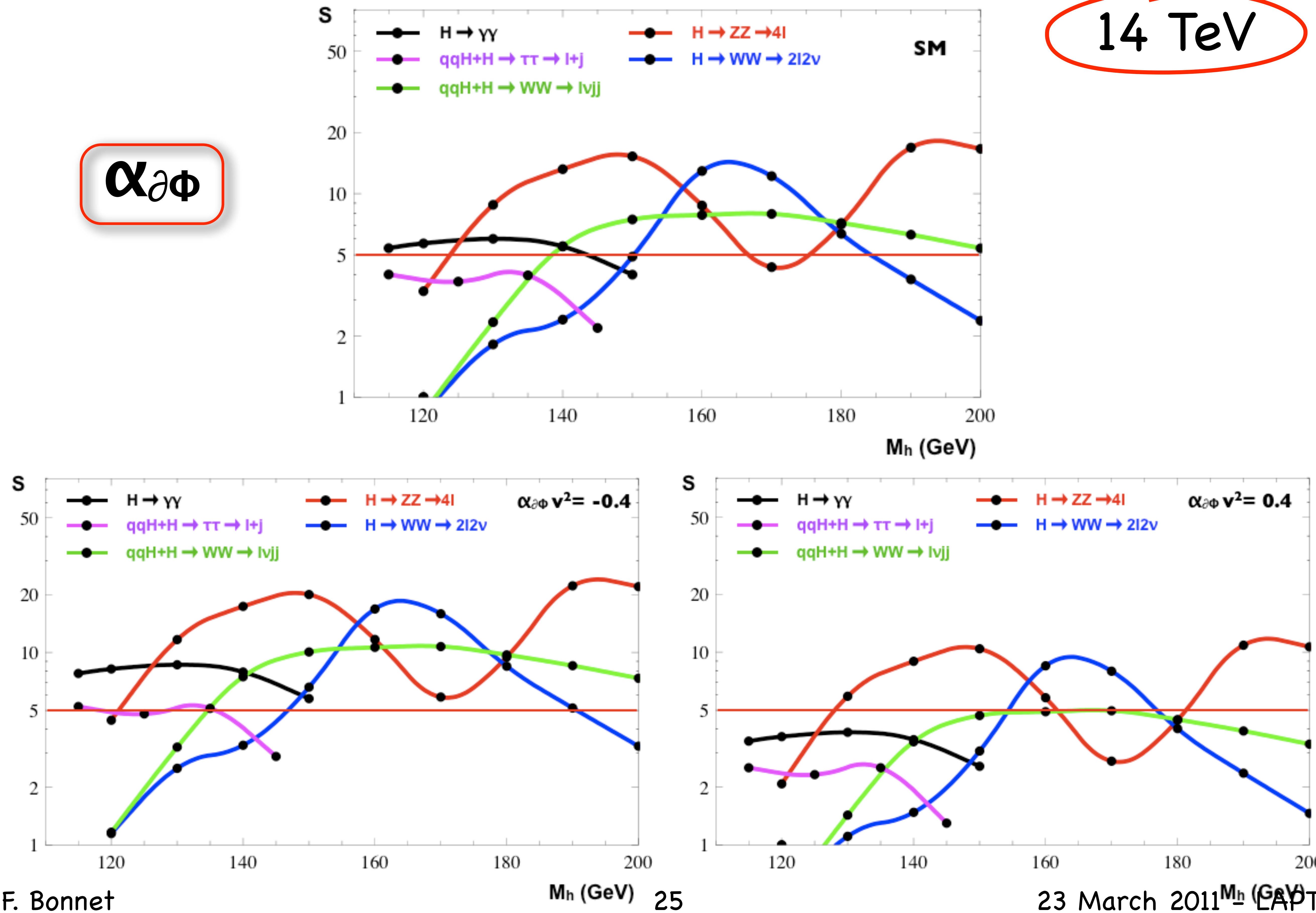


From CMS technical report Vol. II: Physics performance Bayatian et al. '07.

Higgs searches @LHC (CMS: 30 fb^{-1})

14 TeV

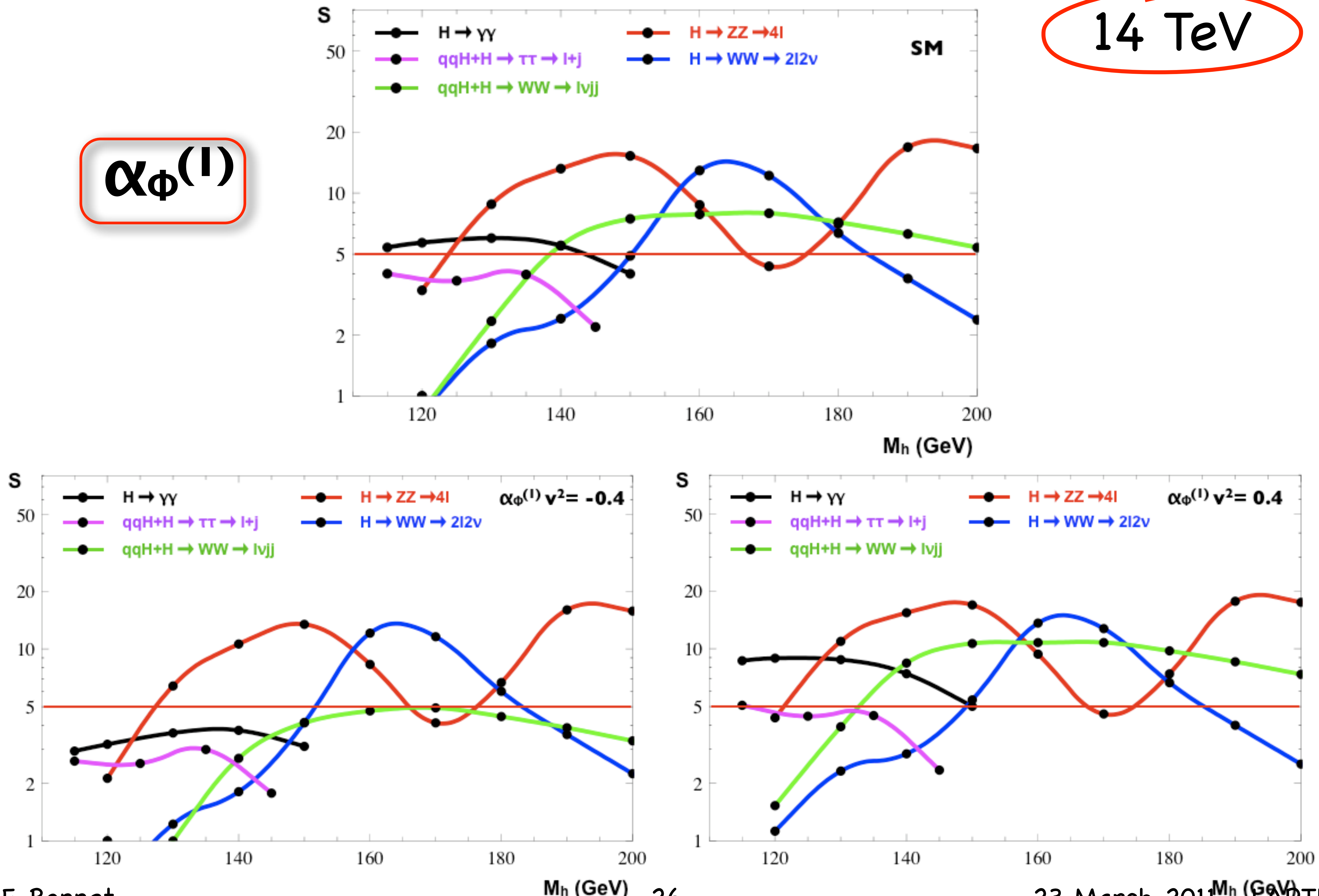
$\alpha_{\partial\Phi}$



Higgs searches @LHC (CMS: 30 fb^{-1})

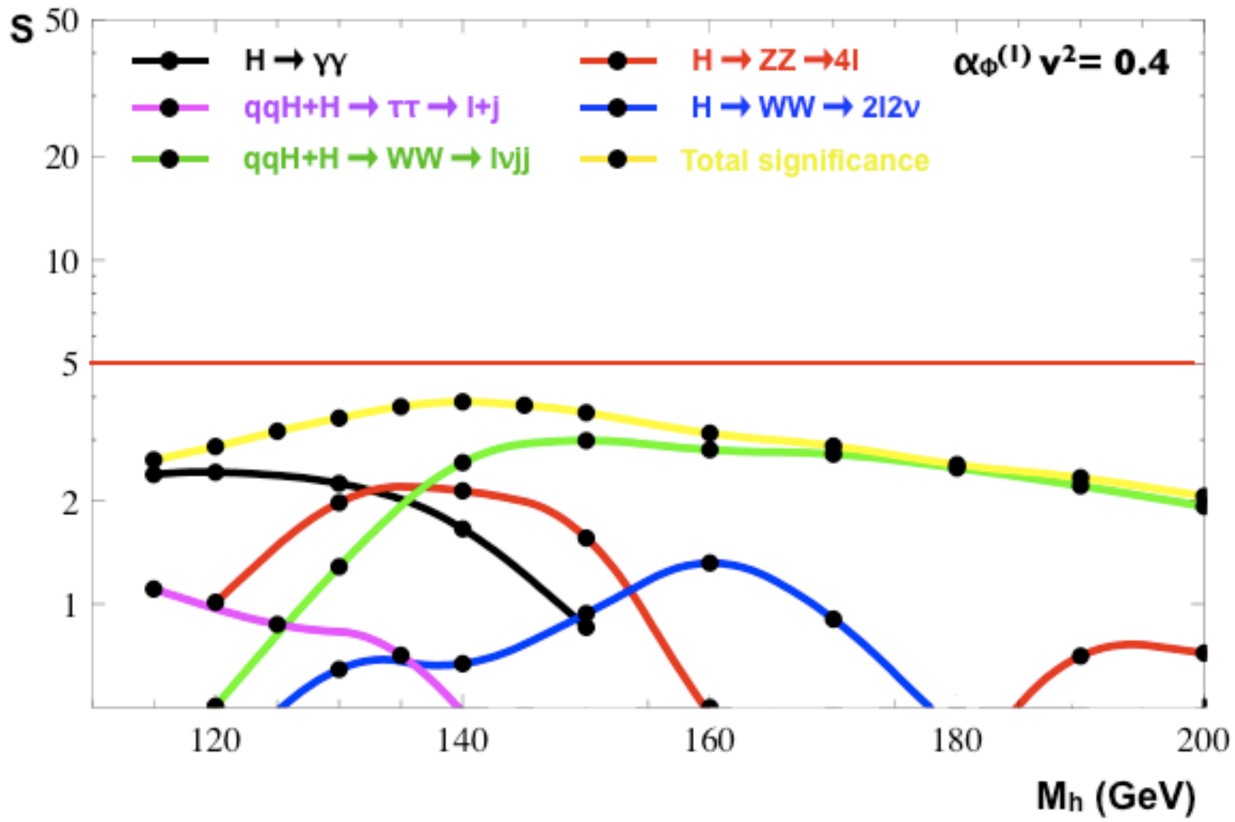
14 TeV

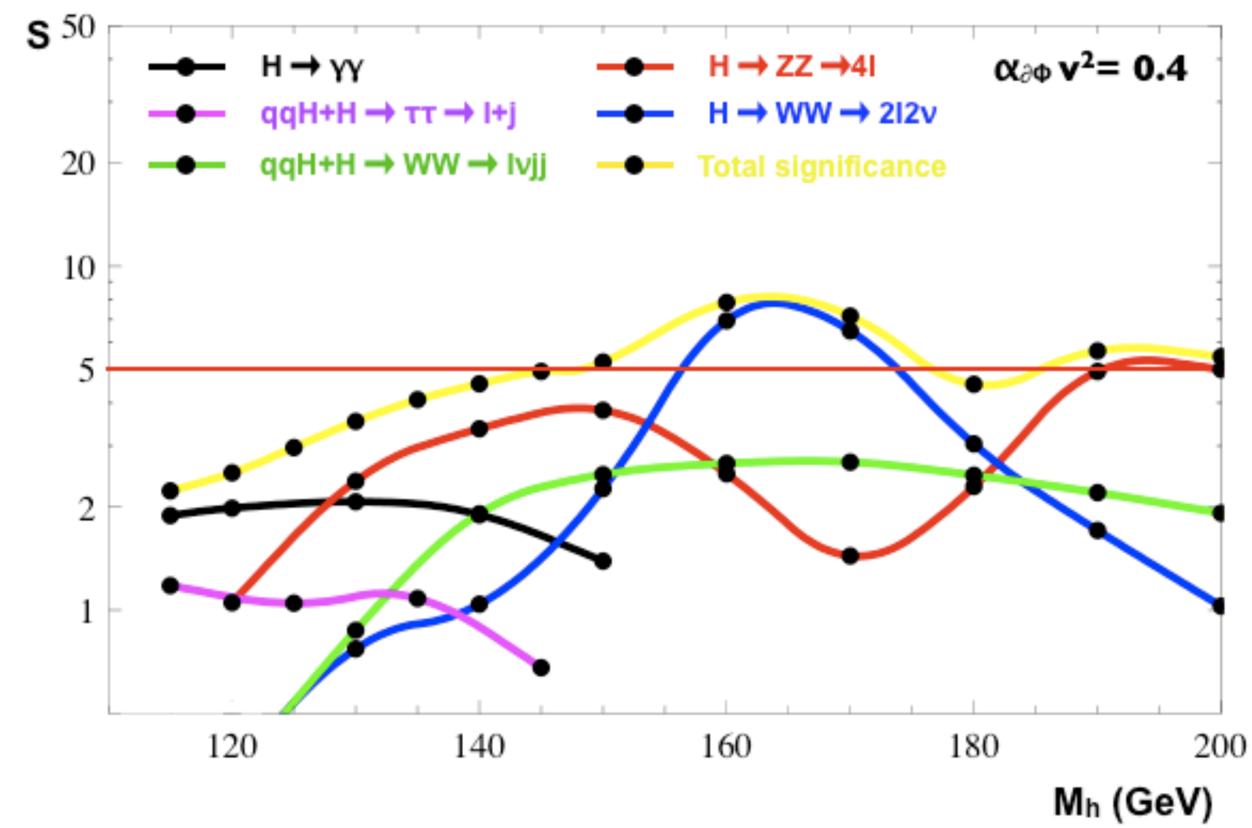
$\alpha_\Phi^{(l)}$



Sensitivity of LHC to α_i

14 TeV





Sensitivity of LHC to α_i

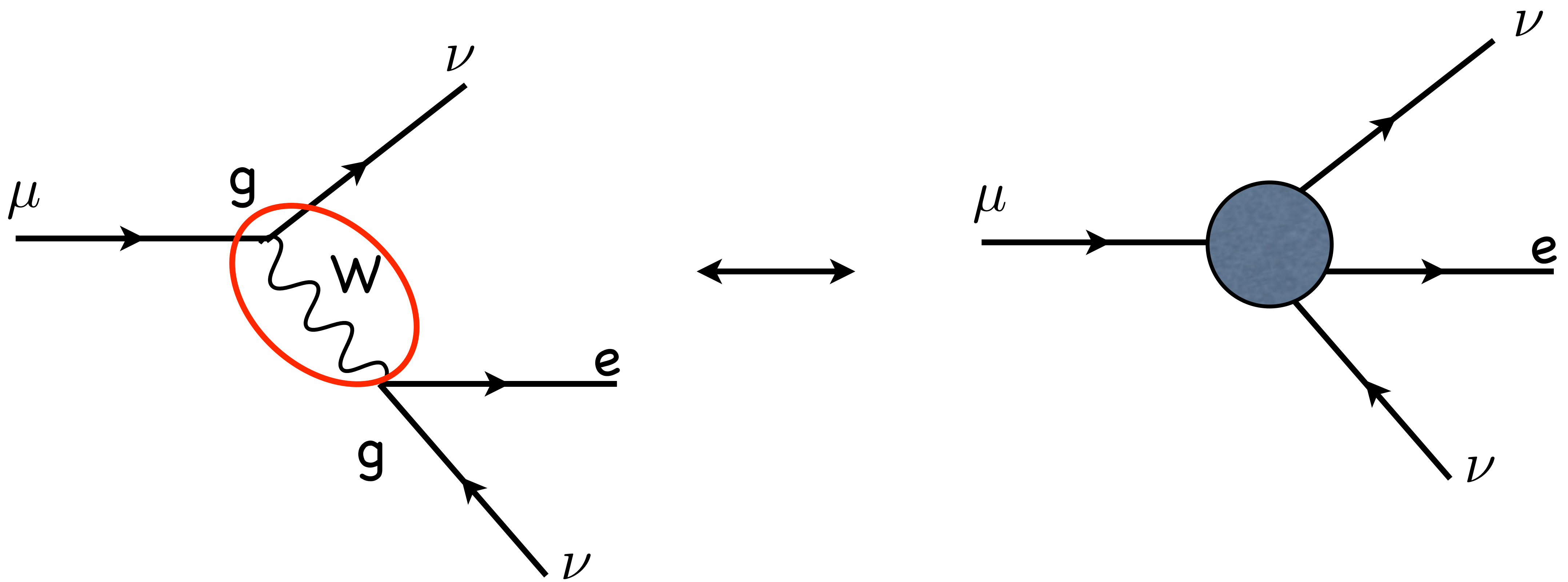
- Detection will need luminosity
- Once α_i dicovered, sign should be easily identified because SM deviations are sign sensitive
- Combinations, ratios of different channels (inclusive Vs non inclusive) will allow a disentanglement of $\alpha_{\partial\Phi}$ and α_{Φ}[(1)]

$$\alpha_i > 0.1$$

From effective Theory to NP

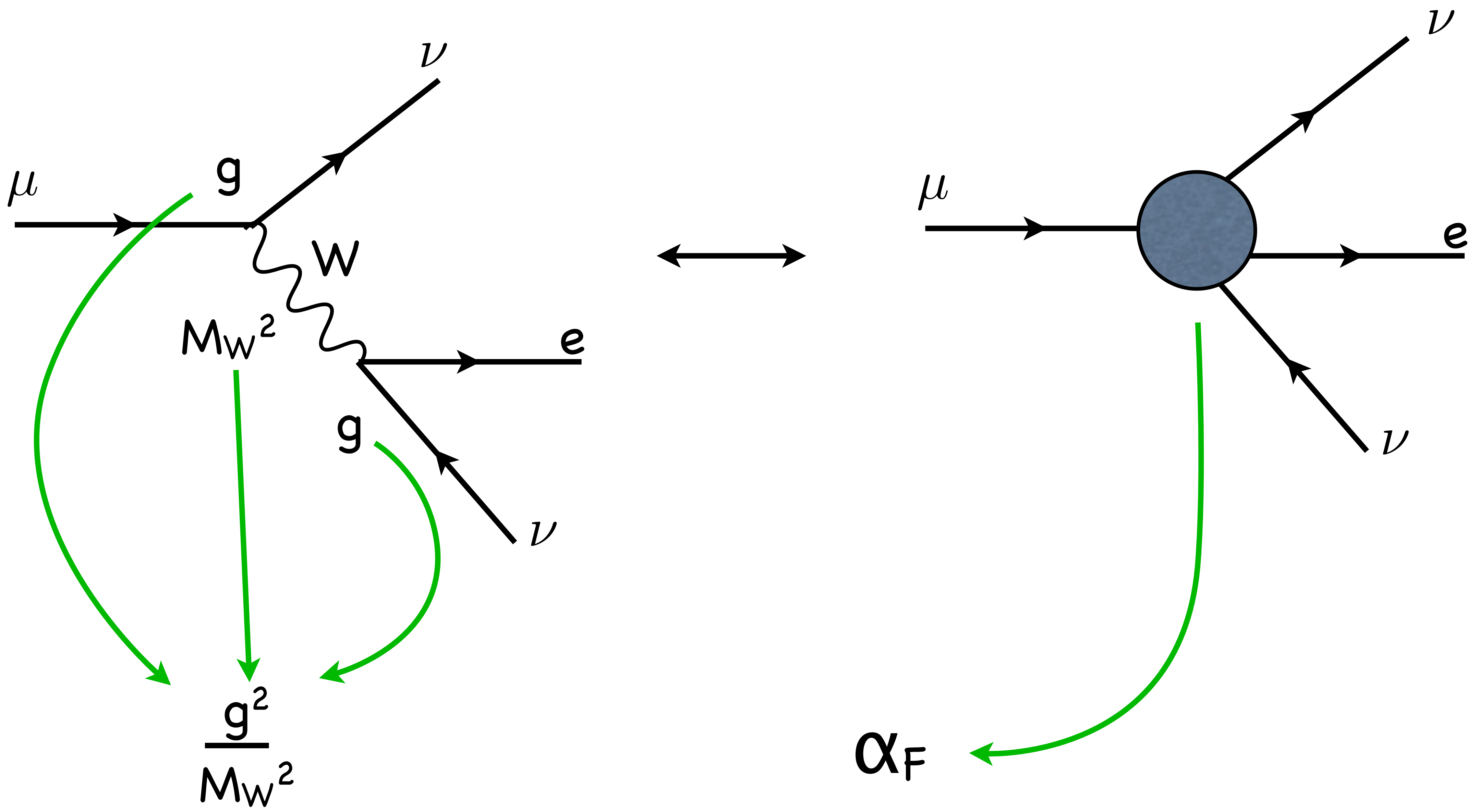
Mediators

Mediator : heavy field generating effective operator once integrated out.



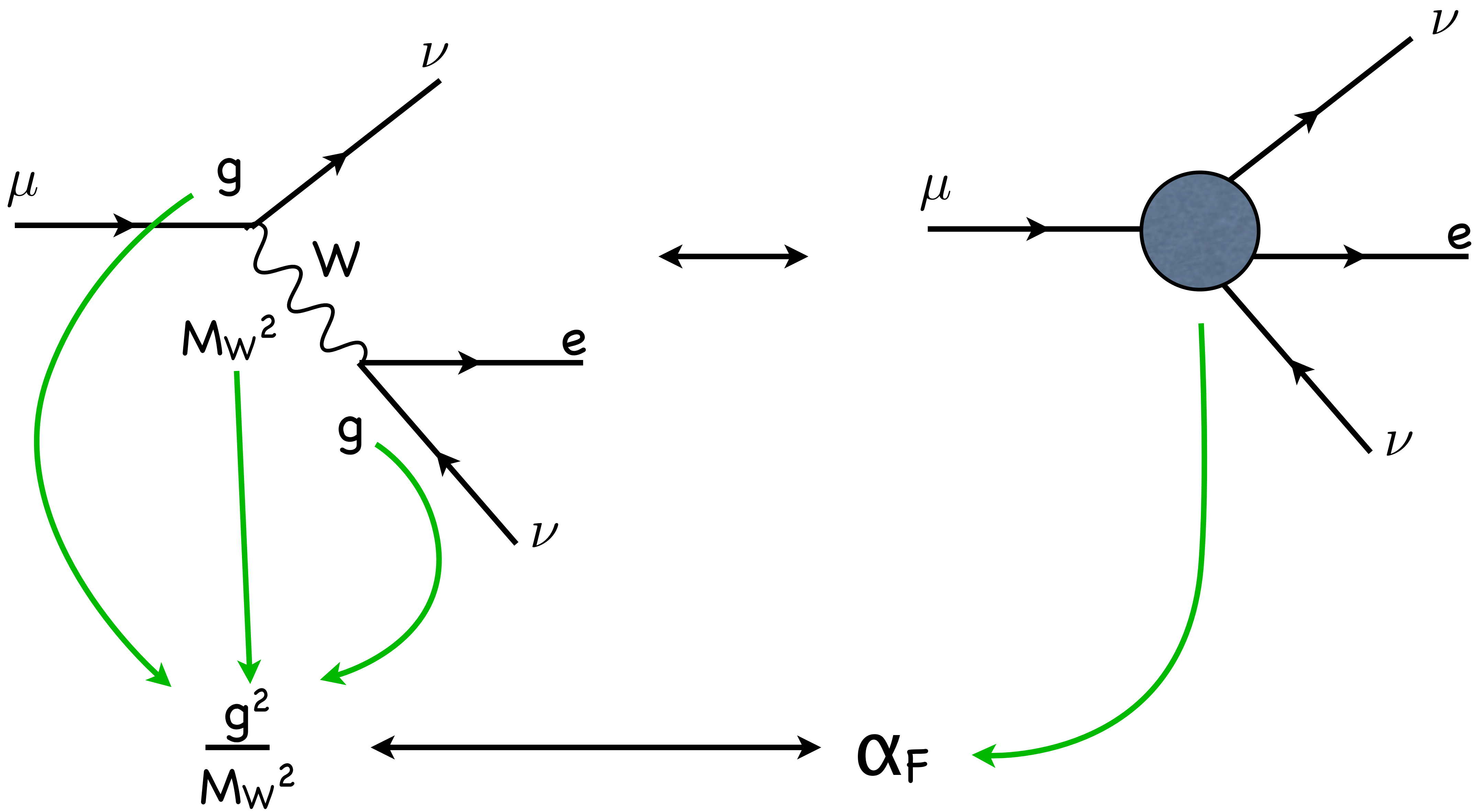
Mediators

Mediator : heavy field generating effective operator once integrated out.



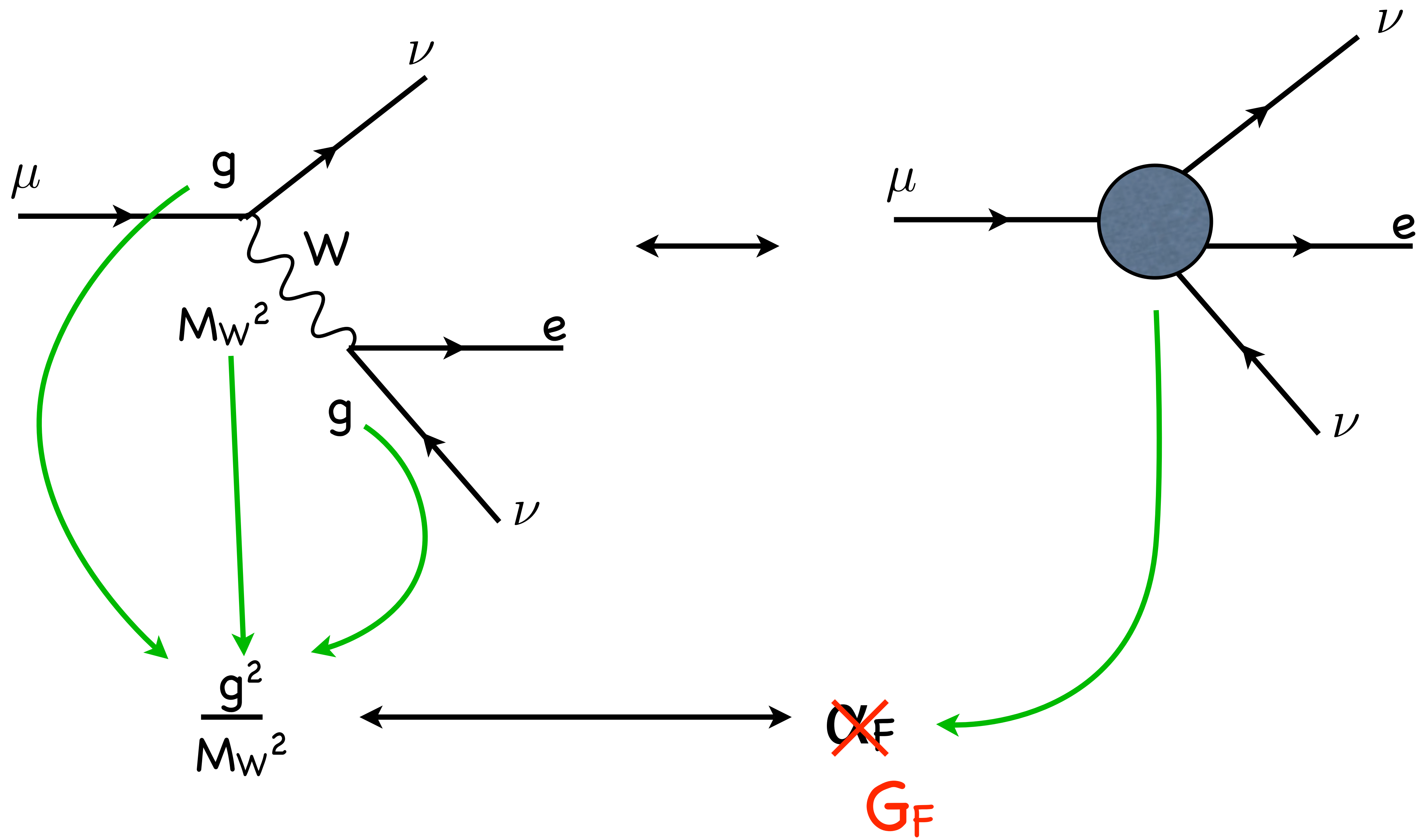
Mediators

Mediator : heavy field generating effective operator once integrated out.



Mediators

Mediator : heavy field generating effective operator once integrated out.



Bounds on α_i ⟶ bounds on high energy parameters

Mediators

Mediator : heavy field generating effective operator once integrated out.

Decomposition of an operator : finding all tree-level mediators

- Bounds on α_i imply bounds on NP parameters
- One mediator can generate several operators

Mediators

Mediator : heavy field generating effective operator once integrated out.

Decomposition of an operator : finding all tree-level mediators

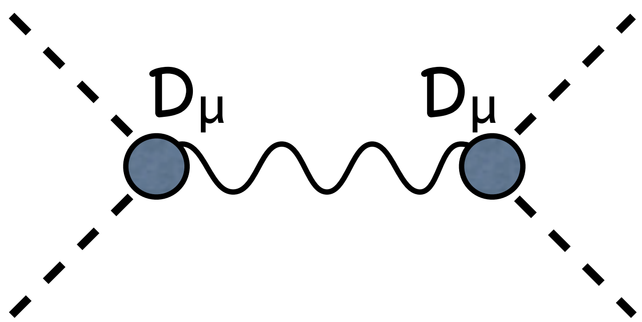
- Bounds on α_i imply bounds on NP parameters
- One mediator can generate several operators

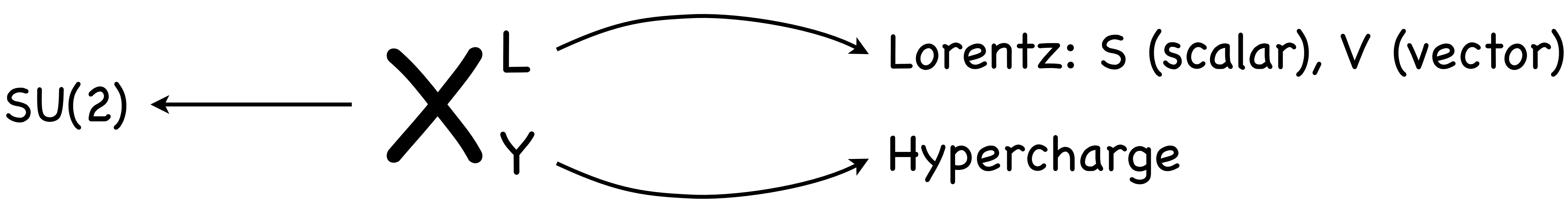
→ Extra constraints on effective operators

Mediators

Mediator : heavy field generating effective operator once integrated out.

Decomposition of an operator : finding all tree-level mediators





Decomposition

α_i \ Med.	S (1_0^S)	Δ (3_0^S)	Δ_1 (3_0^S)	V (1_0^V) (gauge)	U (3_0^V) (gauge)	V (1_0^V) (non gauge)	U (3_0^V) (non gauge)
$\alpha_{\partial\Phi}$	$\frac{\mu_S^2}{M_S^4}$	$\frac{\mu_\Delta^2}{M_\Delta^4}$	0	$\frac{g_V^2}{M_V^2}$	$\frac{g_U^2}{4M_U^2}$	$-\frac{\lambda_V^2}{M_V^2}$	$-\frac{\lambda_U^2}{M_U^2}$
$\alpha_\Phi^{(1)}$	0	$2\frac{\mu_\Delta^2}{M_\Delta^4}$	$4\frac{\|\mu_{\Delta_1}\|^2}{M_{\Delta_1}^4}$	0	$-\frac{g_U^2}{2M_U^2}$	0	$-4\frac{\lambda_U^2}{M_U^2}$
$\alpha_\Phi^{(3)}$	0	$-2\frac{\mu_\Delta^2}{M_\Delta^4}$	$4\frac{\|\mu_{\Delta_1}\|^2}{M_{\Delta_1}^4}$	$-2\frac{g_V^2}{M_V^2}$	0	0	$4\frac{\lambda_U^2}{M_U^2}$

Scalars: $\mu_X X \{\Phi^*,\Phi\}$

Gauge vectors: $g_X X_\mu(D_\mu\Phi^*\Phi-\Phi^*D_\mu\Phi)$

Non gauge vectors: $\lambda_X X_\mu D_\mu\{\Phi^*,\Phi\}$

Decomposition

α_i \ Med.	S (1_0^S)	Δ (3_0^S)	Δ_1 (3_0^S)	V (1_0^V) (gauge)	U (3_0^V) (gauge)	V (1_0^V) (non gauge)	U (3_0^V) (non gauge)
$\alpha_{\partial\phi}$	$\frac{\mu_S^2}{M_S^4}$	$\frac{\mu_\Delta^2}{M_\Delta^4}$	0	$\frac{g_V^2}{M_V^2}$	$\frac{g_U^2}{4M_U^2}$	$-\frac{\lambda_V^2}{M_V^2}$	$-\frac{\lambda_U^2}{M_U^2}$
$\alpha_\phi^{(1)}$	0	$2\frac{\mu_\Delta^2}{M_\Delta^4}$	$4\frac{\vert\mu_{\Delta_1}\vert^2}{M_{\Delta_1}^4}$	0	$-\frac{g_U^2}{2M_U^2}$	0	$-4\frac{\lambda_U^2}{M_U^2}$
$\alpha_\phi^{(3)}$	0	$-2\frac{\mu_\Delta^2}{M_\Delta^4}$	$4\frac{\vert\mu_{\Delta_1}\vert^2}{M_{\Delta_1}^4}$	$-2\frac{g_V^2}{M_V^2}$	0	0	$4\frac{\lambda_U^2}{M_U^2}$

Constrained by EW precision tests

$\Downarrow$

New constraints

Decomposition

α_i \ Med.	S (1_0^S)	Δ (3_0^S)	Δ_1 (3_0^S)	V (1_0^V)	U (3_0^V)	V (1_0^V)	U (3_0^V)
				gauge		non gauge	
$\alpha_{\partial\phi}$	$\frac{\mu_S^2}{M_S^4}$	$\frac{\mu_\Delta^2}{M_\Delta^4}$	0	$\frac{g_V^2}{M_V^2}$	$\frac{g_U^2}{4M_U^2}$	$-\frac{\lambda_V^2}{M_V^2}$	$-\frac{\lambda_U^2}{M_U^2}$
$\alpha_\phi^{(1)}$	0	$2\frac{\mu_\Delta^2}{M_\Delta^4}$	$4\frac{\lvert\mu_{\Delta_1}\rvert^2}{M_{\Delta_1}^4}$	0	$-\frac{g_U^2}{2M_U^2}$	0	$-4\frac{\lambda_U^2}{M_U^2}$
$\alpha_\phi^{(3)}$	0	$-2\frac{\mu_\Delta^2}{M_\Delta^4}$	$4\frac{\lvert\mu_{\Delta_1}\rvert^2}{M_{\Delta_1}^4}$	$-2\frac{g_V^2}{M_V^2}$	0	0	$4\frac{\lambda_U^2}{M_U^2}$

→ Constrained by EW precision tests

⇓

New constraints

Decomposition

α_i \ Med.	S (1_0^S)	Δ (3_0^S)	Δ_1 (3_0^S)	V (1_0^V) (gauge)	U (3_0^V) (gauge)	V (1_0^V) (non gauge)	U (3_0^V) (non gauge)
$\alpha_{\partial\phi}$	$\frac{\mu_S^2}{M_S^4}$	$\frac{\mu_\Delta^2}{M_\Delta^4}$	0	$\frac{g_V^2}{M_V^2}$	$\frac{g_U^2}{4M_U^2}$	$-\frac{\lambda_V^2}{M_V^2}$	$-\frac{\lambda_U^2}{M_U^2}$
$\alpha_\phi^{(1)}$	0	$2\frac{\mu_\Delta^2}{M_\Delta^4}$	$4\frac{\lvert\mu_{\Delta_1}\rvert^2}{M_{\Delta_1}^4}$	0	$-\frac{g_U^2}{2M_U^2}$	0	$-4\frac{\lambda_U^2}{M_U^2}$
$\alpha_\phi^{(3)}$	0	$-2\frac{\mu_\Delta^2}{M_\Delta^4}$	$4\frac{\lvert\mu_{\Delta_1}\rvert^2}{M_{\Delta_1}^4}$	$-2\frac{g_V^2}{M_V^2}$	0	0	$4\frac{\lambda_U^2}{M_U^2}$

Beyond LHC

$$\mathcal{O}_\phi = \frac{1}{3}(\phi^\dagger\phi)^3$$

sensitive to couplings ~ XXΦΦ

$$\begin{aligned}
\mathcal{L}_{\text{new int.}} = & - \left[\lambda_0 v(1+\frac{5}{6}\frac{v^2}{\lambda_0}\alpha_\phi - \frac{3}{4}\alpha_\phi^{(1)}v^2 - \frac{3}{4}\alpha_\phi^{(3)}v^2 - \frac{3}{2}\alpha_{\partial\phi}v^2)\right] H^3 \\
& - \left[\frac{\lambda_0}{4}(1+\frac{5}{2}\frac{v^2}{\lambda_0}\alpha_\phi - \alpha_\phi^{(1)}v^2 - \alpha_\phi^{(3)}v^2 - 2\alpha_{\partial\phi}v^2)\right] H^4 \\
& + \left[g_0^2\frac{v}{2}\alpha_\phi^{(1)}\right] H^3 W_\mu^- W^{\mu+} + \left[\frac{g_0^2+g_0'^2}{4}v(\alpha_\phi^{(1)}+\alpha_\phi^{(3)})\right] H^3 Z_\mu Z^\mu \\
& + \left[\frac{g_0^2}{8}\alpha_\phi^{(1)}\right] H^4 W_\mu^- W^{\mu+} + \left[\frac{g_0^2+g_0'^2}{16}(\alpha_\phi^{(1)}+\alpha_\phi^{(3)})\right] H^4 Z_\mu Z^\mu \\
& + \left[\alpha_\phi^{(3)}\frac{v}{2}+\alpha_{\partial\phi}v\right] H\partial_\mu H\partial^\mu H + \left[\frac{\alpha_\phi^{(3)}}{4}+\frac{\alpha_{\partial\phi}}{2}\right] H^2\partial_\mu H\partial^\mu H \\
& - \left[\alpha_\phi\frac{v}{4}\right] H^5 - \left[\frac{\alpha_\phi}{24}\right] H^6 ,
\end{aligned}$$

Beyond LHC

New interactions

$$
\begin{aligned}
\mathcal{L}_{\text{new int.}} = \; & - \left[\lambda_0 v(1+\frac{5}{6}\frac{v^2}{\lambda_0}\alpha_\phi - \frac{3}{4}\alpha_\phi^{(1)}v^2 - \frac{3}{4}\alpha_\phi^{(3)}v^2 - \frac{3}{2}\alpha_{\partial\phi}v^2)\right] H^3 \\
& - \left[\frac{\lambda_0}{4}(1+\frac{5}{2}\frac{v^2}{\lambda_0}\alpha_\phi - \alpha_\phi^{(1)}v^2 - \alpha_\phi^{(3)}v^2 - 2\alpha_{\partial\phi}v^2)\right] H^4 \\
& + \left[g_0^2\frac{v}{2}\alpha_\phi^{(1)}\right] H^3 W_\mu^- W^{\mu+} + \left[\frac{g_0^2+g_0'^2}{4}v(\alpha_\phi^{(1)}+\alpha_\phi^{(3)})\right] H^3 Z_\mu Z^\mu \\
& + \left[\frac{g_0^2}{8}\alpha_\phi^{(1)}\right] H^4 W_\mu^- W^{\mu+} + \left[\frac{g_0^2+g_0'^2}{16}(\alpha_\phi^{(1)}+\alpha_\phi^{(3)})\right] H^4 Z_\mu Z^\mu \\
& + \left[\alpha_\phi^{(3)}\frac{v}{2}+\alpha_{\partial\phi}v\right] H\partial_\mu H\partial^\mu H + \left[\frac{\alpha_\phi^{(3)}}{4}+\frac{\alpha_{\partial\phi}}{2}\right] H^2\partial_\mu H\partial^\mu H \\
& - \left[\alpha_\phi\frac{v}{4}\right] H^5 - \left[\frac{\alpha_\phi}{24}\right] H^6 \,,
\end{aligned}
$$

New interactions

$$
\begin{aligned}
\mathcal{L}_{\text{new int.}} = \; & - \left[\lambda_0 v \left(1 + \frac{5}{6}\frac{v^2}{\lambda_0}\alpha_\phi - \frac{3}{4}\alpha_\phi^{(1)} v^2 - \frac{3}{4}\alpha_\phi^{(3)} v^2 - \frac{3}{2}\alpha_{\partial\phi} v^2\right)\right] H^3 \\
& - \left[\frac{\lambda_0}{4}\left(1 + \frac{5}{2}\frac{v^2}{\lambda_0}\alpha_\phi - \alpha_\phi^{(1)} v^2 - \alpha_\phi^{(3)} v^2 - 2\alpha_{\partial\phi} v^2\right)\right] H^4 \\
& + \left[g_0^2 \frac{v}{2}\alpha_\phi^{(1)}\right] H^3 W_\mu^- W^{\mu +} + \left[\frac{g_0^2 + g_0'^2}{4} v(\alpha_\phi^{(1)} + \alpha_\phi^{(3)})\right] H^3 Z_\mu Z^\mu \\
& + \left[\frac{g_0^2}{8}\alpha_\phi^{(1)}\right] H^4 W_\mu^- W^{\mu +} + \left[\frac{g_0^2 + g_0'^2}{16}(\alpha_\phi^{(1)} + \alpha_\phi^{(3)})\right] H^4 Z_\mu Z^\mu \\
& + \left[\alpha_\phi^{(3)}\frac{v}{2} + \alpha_{\partial\phi} v\right] H \partial_\mu H \partial^\mu H + \left[\frac{\alpha_\phi^{(3)}}{4} + \frac{\alpha_{\partial\phi}}{2}\right] H^2 \partial_\mu H \partial^\mu H \\
& - \left[\alpha_\phi \frac{v}{4}\right] H^5 - \left[\frac{\alpha_\phi}{24}\right] H^6 ,
\end{aligned}
$$

ILC, CLIC ...

Conclusions

- Effective operators can modify Higgs detection @LHC
  - Enhance or reduce LHC power
  - Especially true in low mass range

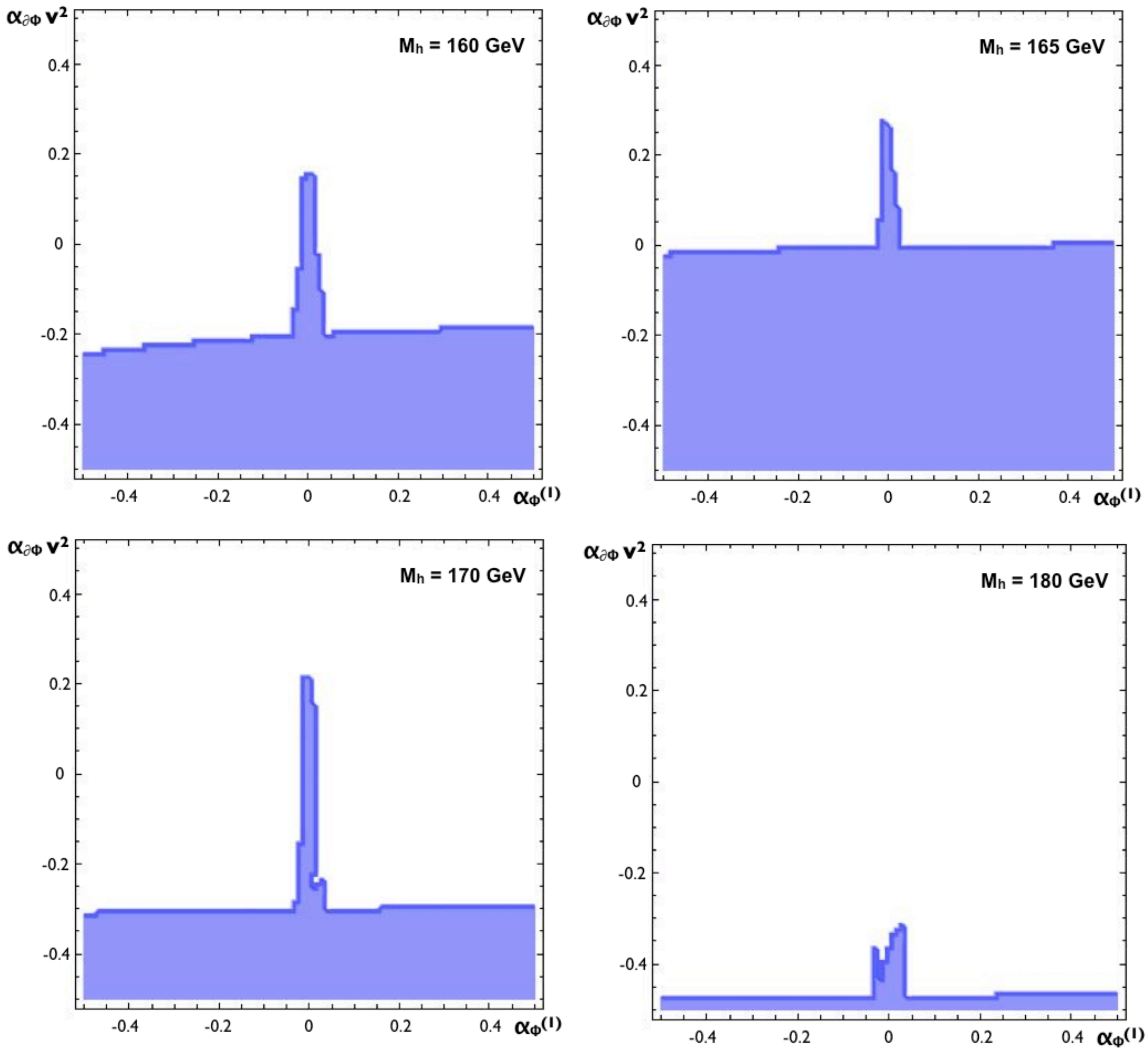
- Measurement of effective coefficient feasible
  - Combination of different channels -> disentanglement
  - $|\alpha_i v^2| \gtrsim 0.1 - 0.2$ achievable

- Effective approach allow to discriminate among NP implementations
  - Correlaton between effective operators

- Special role of O_Φ
  - Triple Higgs coupling and new interactions
  - Useful in multiple mediators cases

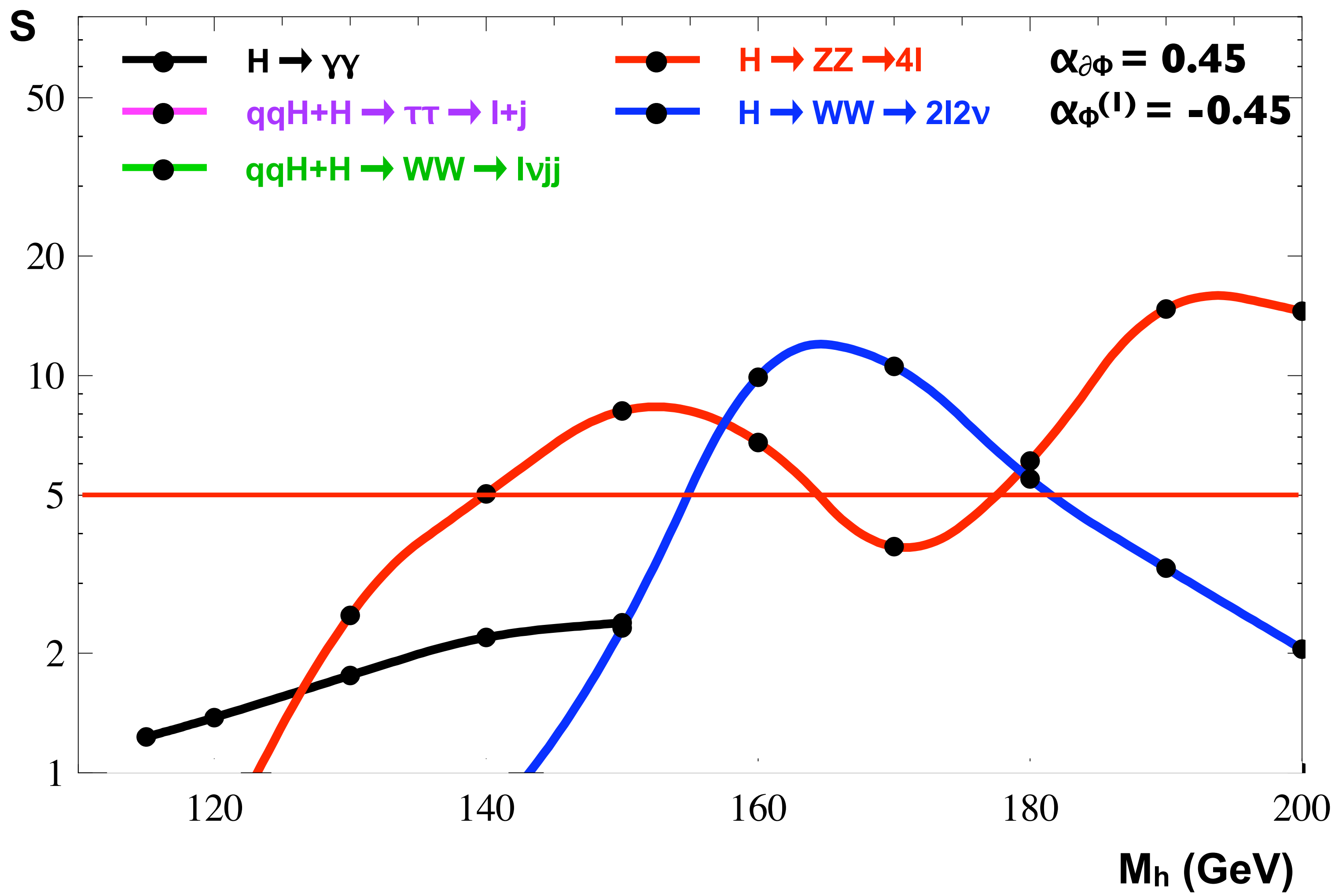
BACKUP SLIDES

Interplay



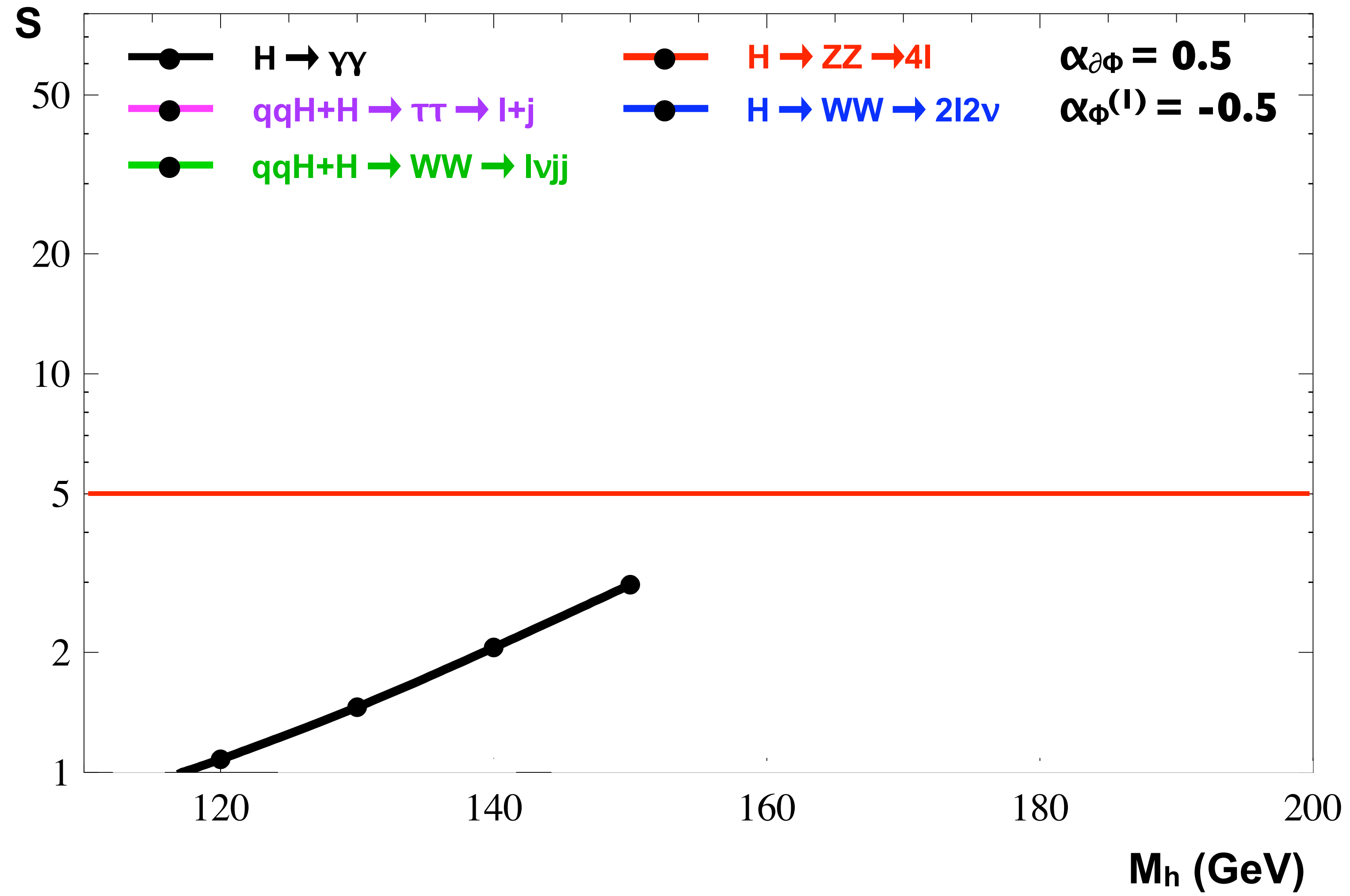
$\alpha_{\partial\Phi}\, v^2$
M_h = 160 GeV
M_h = 165 GeV
M_h = 170 GeV
M_h = 180 GeV
0.4
0.2
0
-0.2
-0.4
$\alpha_{\Phi}^{(1)}$

Interplay



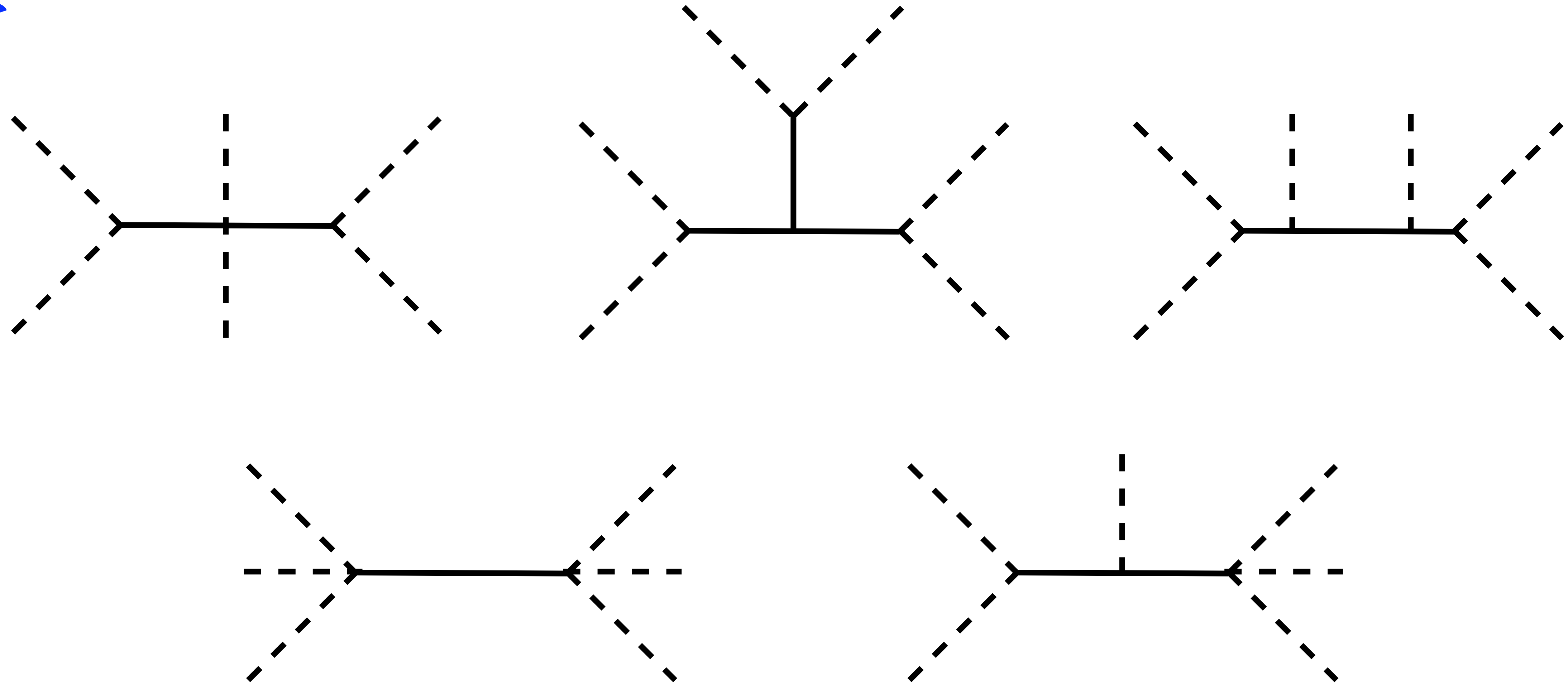
S
H → γγ
qqH+H → ττ → l+j
qqH+H → WW → lνjj
H → ZZ → 4l
H → WW → 2l2ν
$\alpha_{\partial\Phi} = 0.45$
$\alpha_{\Phi}^{(1)} = -0.45$
50
20
10
5
2
1
120
140
160
180
200
M_h (GeV)

Interplay



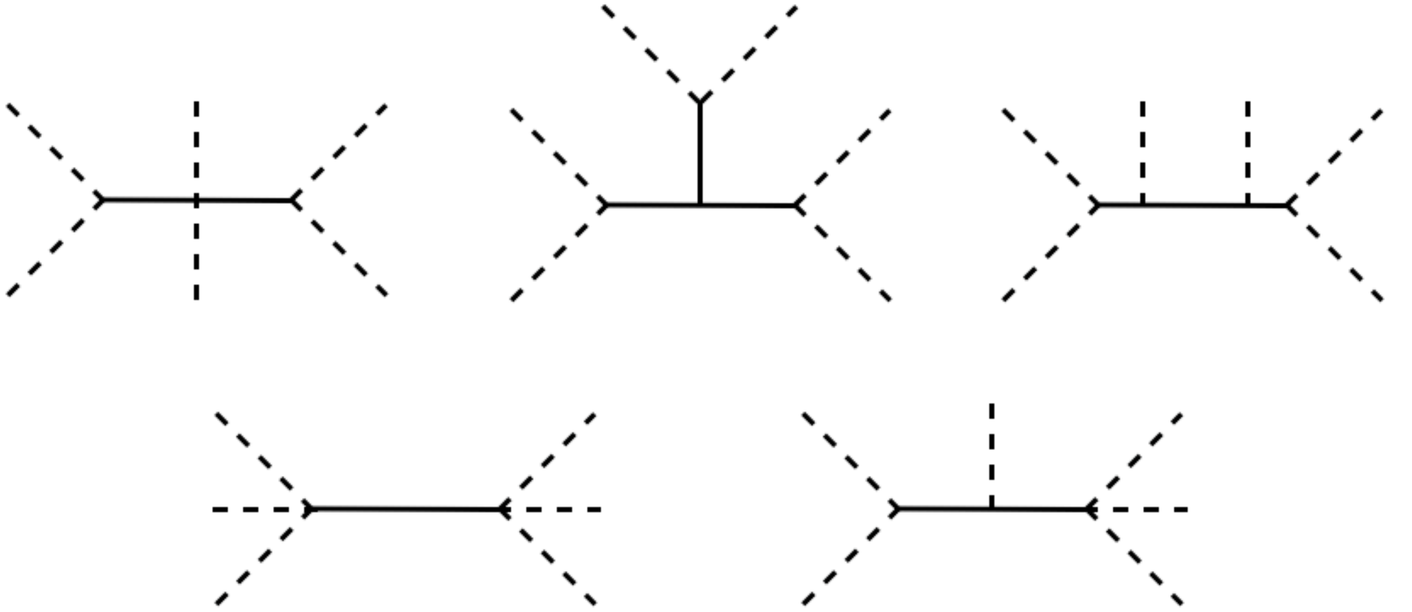
S
H → γγ
qqH+H → ττ → l+j
qqH+H → WW → lνjj
H → ZZ →4l
H → WW → 2l2ν
α∂Φ = 0.5
αΦ(l) = -0.5
50
20
10
5
2
1
120
140
160
180
200
Mh (GeV)

O_ϕ



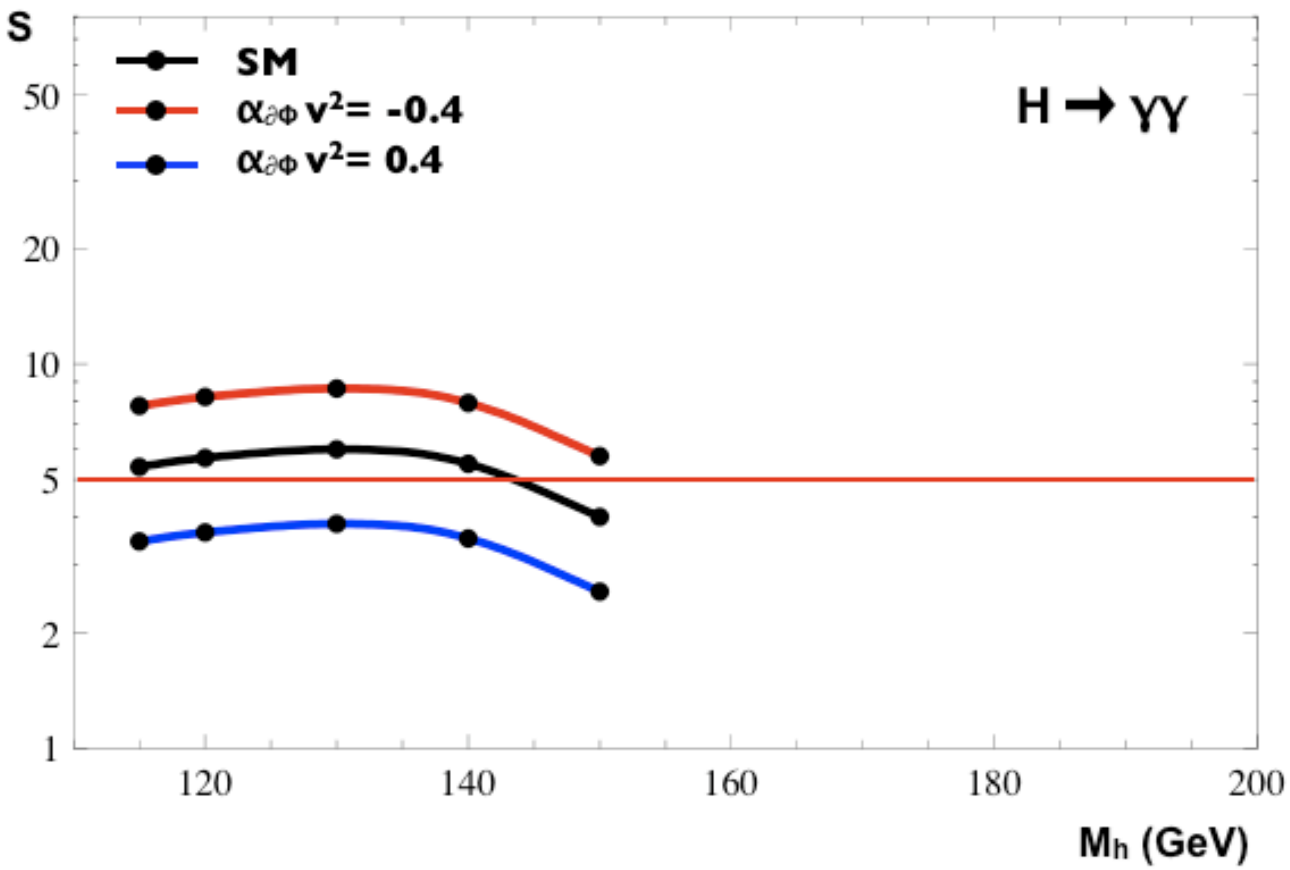
	1_0^S	$2_{1/2}^S$	3_0^S	3_1^S
$3\alpha_\phi$	$\frac{\mu_3\mu_S^3}{3M_S^6}-\frac{\mu_S^2\kappa_S}{2M_S^4}$	$\left(\frac{\lambda_\varphi^2}{M_\varphi^2}+\frac{\widetilde{\lambda}_\varphi^2}{M_\varphi^2}+4\frac{\widetilde{\lambda}_\varphi'^2}{M_\varphi^2}+2\frac{\lambda_\varphi\widetilde{\lambda}_\varphi}{M_\varphi^2}+4\frac{\lambda_\varphi\widetilde{\lambda}'_\varphi}{M_\varphi^2}+2\frac{\widetilde{\lambda}_\varphi\widetilde{\lambda}'_\varphi}{M_\varphi^2}\right)$	$-\frac{\mu_\Delta^2\lambda_\Delta}{2M_\Delta^4}$	$-2\frac{\mu_\Delta'^2}{M_{\Delta_1}^4}(\lambda'_\Delta+\widetilde{\lambda}'_\Delta)$

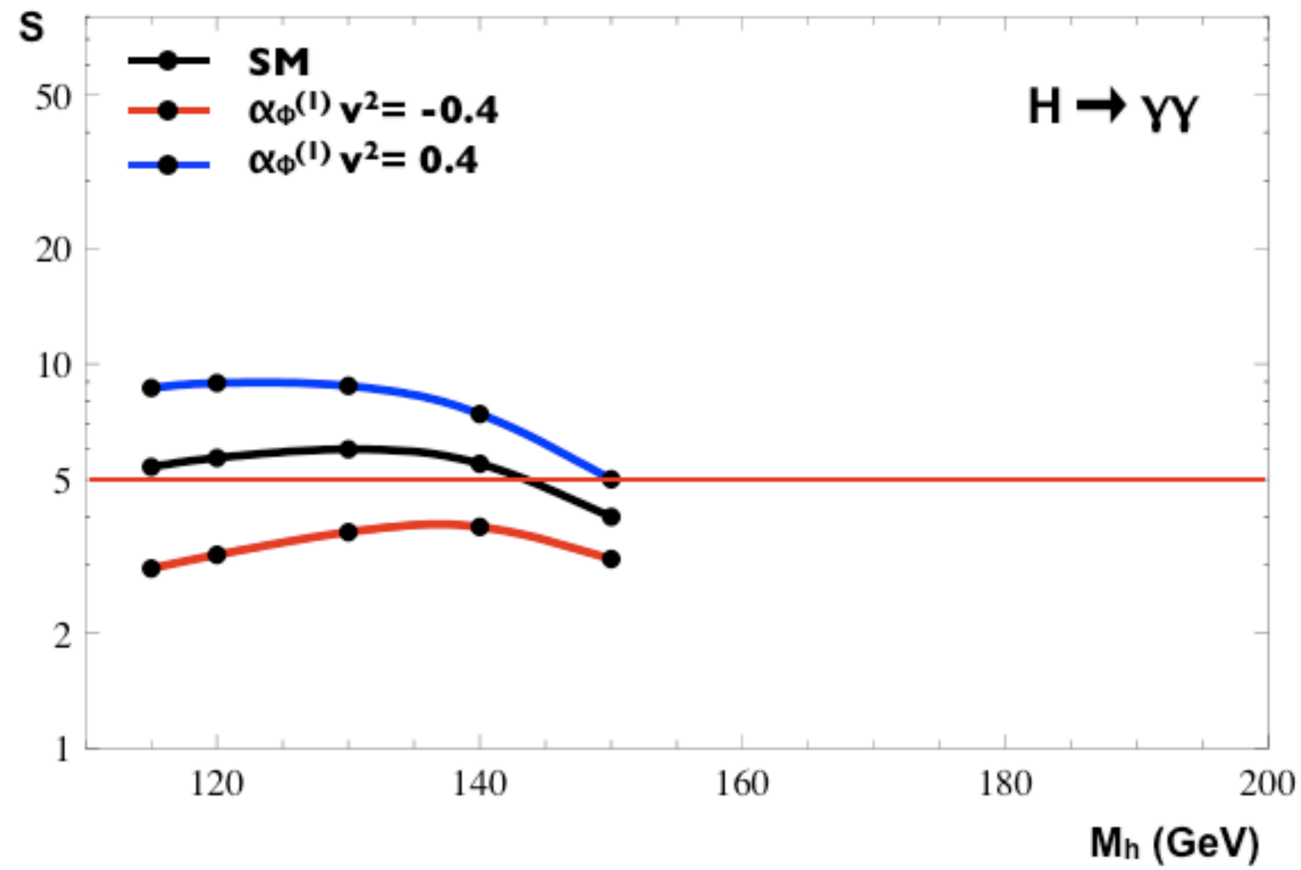
O_ϕ



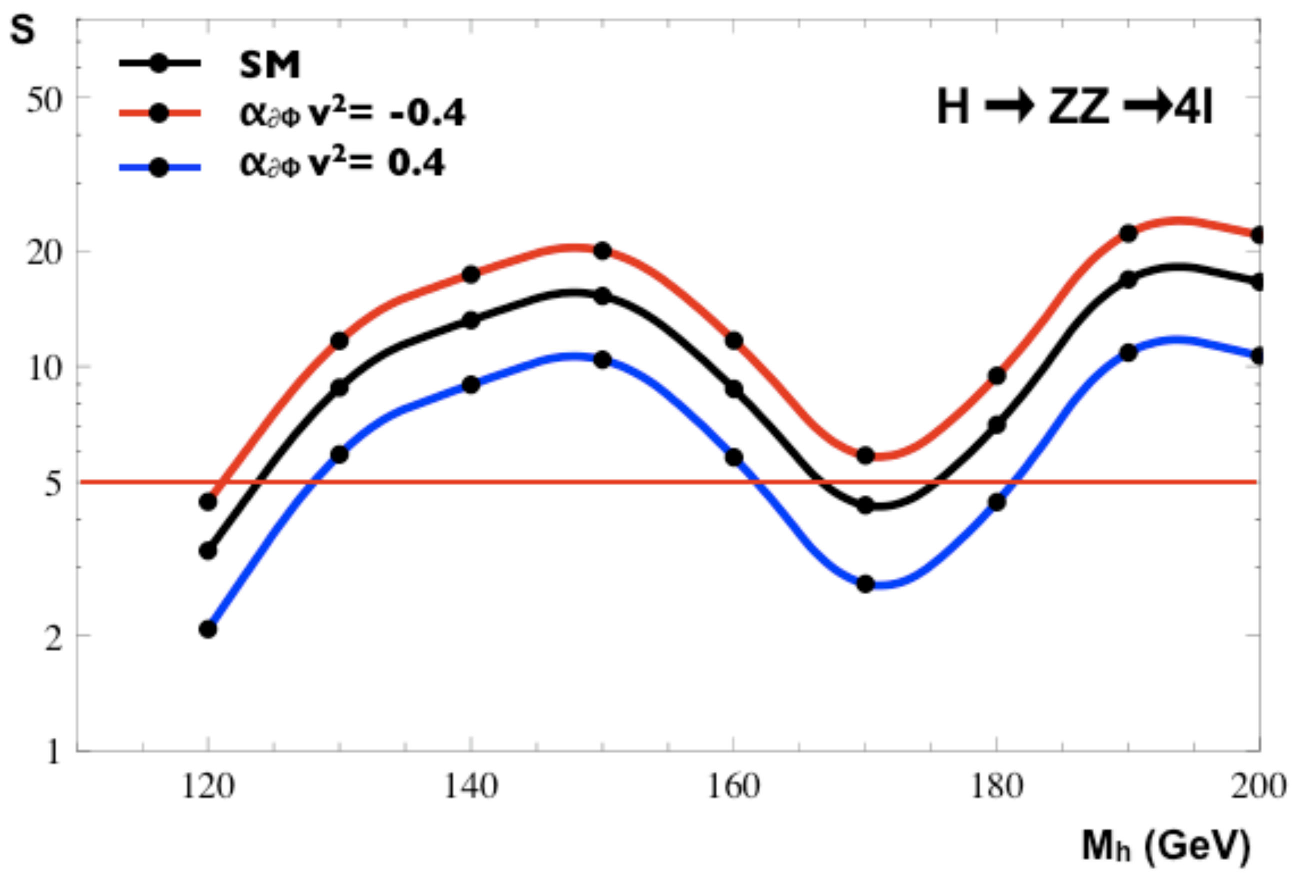
	$3\alpha_\phi$
$1_0^S + 3_S^0$	$-\frac{\mu_\Delta \mu_S}{M_S^2 M_\Delta^2}\left(\lambda_{S\Delta} - \frac{\mu_\Delta \mu_{s\Delta}}{M_\Delta^2}\right)$
$1_0^S + 3_S^1$	$-2\frac{\mu'_\Delta \mu_S}{M_S^2 M_{\Delta_1}^2}\left(2\lambda'_{S\Delta} - \frac{\mu'_\Delta \mu'_{S\Delta}}{M_{\Delta_1}^2}\right)$
$3_0^S + 3_S^0$	$2\frac{\mu_\Delta \mu'_\Delta}{M_\Delta^2 M_{\Delta_1}^2}(2\lambda_{\Delta\Delta} + \frac{\mu_{\Delta\Delta} \mu'_\Delta}{M_{\Delta_1}^2})$
$1_0^S + 2_S^{1/2}$	$\frac{\mu_S^2 \mu_{S\varphi}^2}{M_\varphi^2 M_S^4} - 2\frac{\mu_S \mu_{S\varphi}}{M_S^2 M_\varphi^2}\left(\lambda_\varphi + \widetilde{\lambda}_\varphi + 2\widetilde{\lambda}'_\varphi\right)$
$2_{1/2}^S + 3_S^0$	$\frac{\mu_\Delta^2 \mu_{\Delta\varphi}^2}{M_\varphi^2 M_\Delta^4} - 2\frac{\mu_\Delta \mu_{\Delta\varphi}}{M_\Delta^2 M_\varphi^2}\left(\lambda_\varphi + \widetilde{\lambda}_\varphi + 2\widetilde{\lambda}'_\varphi\right)$
$2_{1/2}^S + 3_S^1$	$4\frac{\mu'^2_\Delta \mu'^2_{\Delta\varphi}}{M_\varphi^2 M_{\Delta_1}^4} - 4\frac{\mu'_\Delta \mu'_{\Delta\varphi}}{M_{\Delta_1}^2 M_\varphi^2}\left(\lambda_\varphi + \widetilde{\lambda}_\varphi + 2\widetilde{\lambda}'_\varphi\right)$
$2_{3/2}^S + 3_S^1$	0

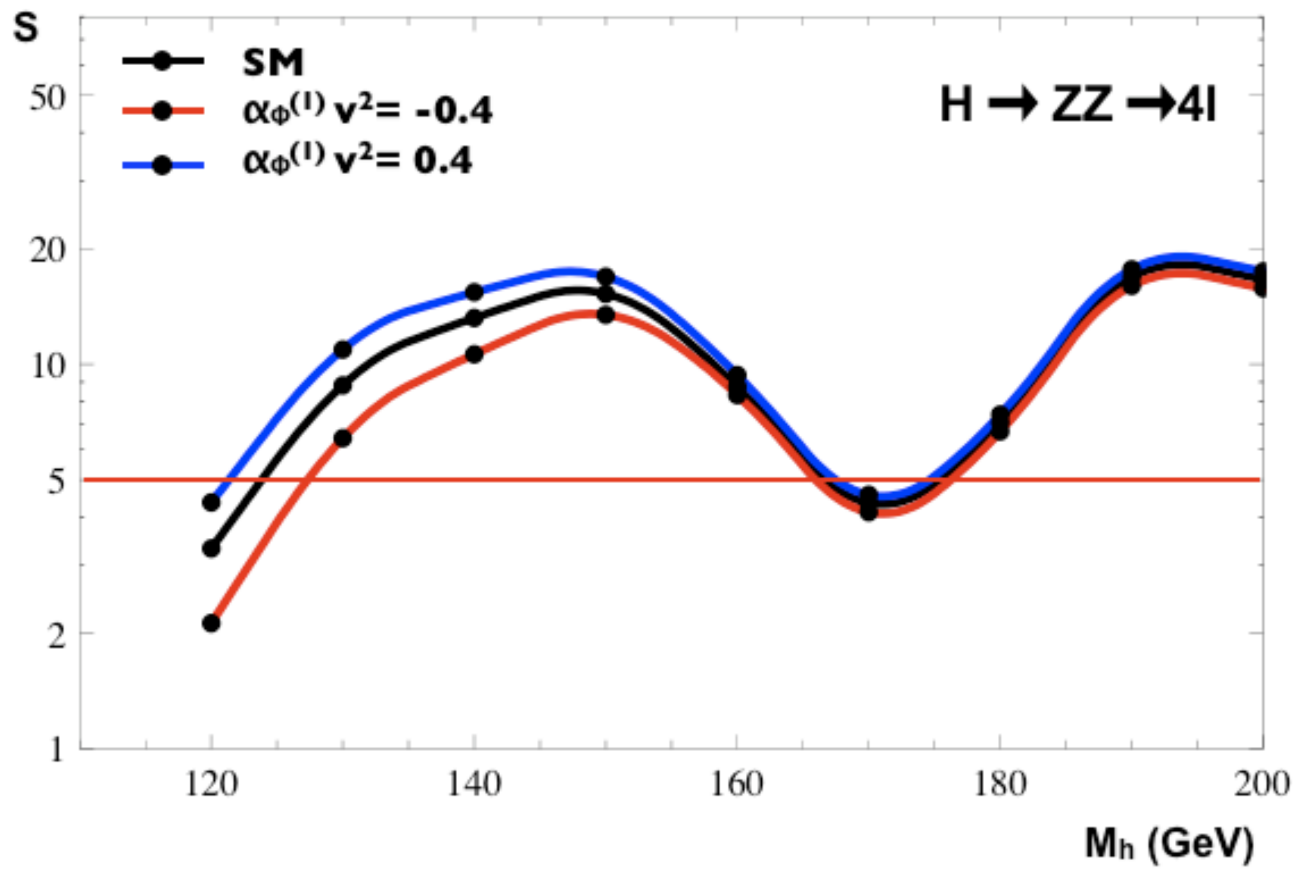
Significance



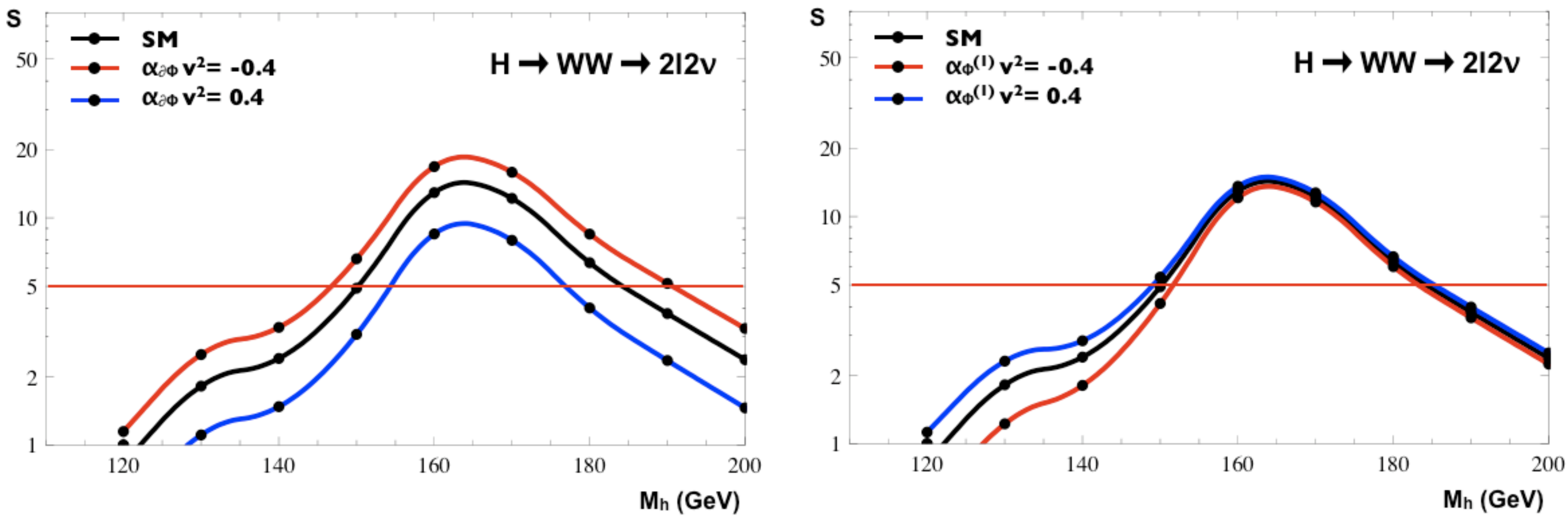


Significance

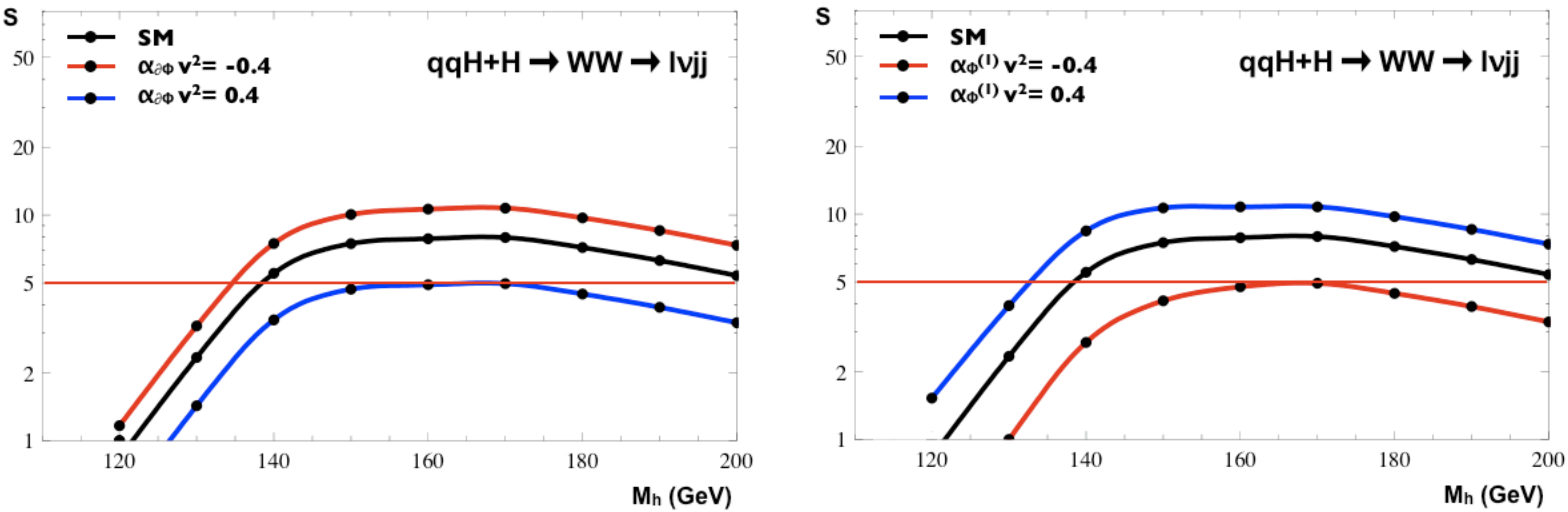




Significance



Significance



Significance