

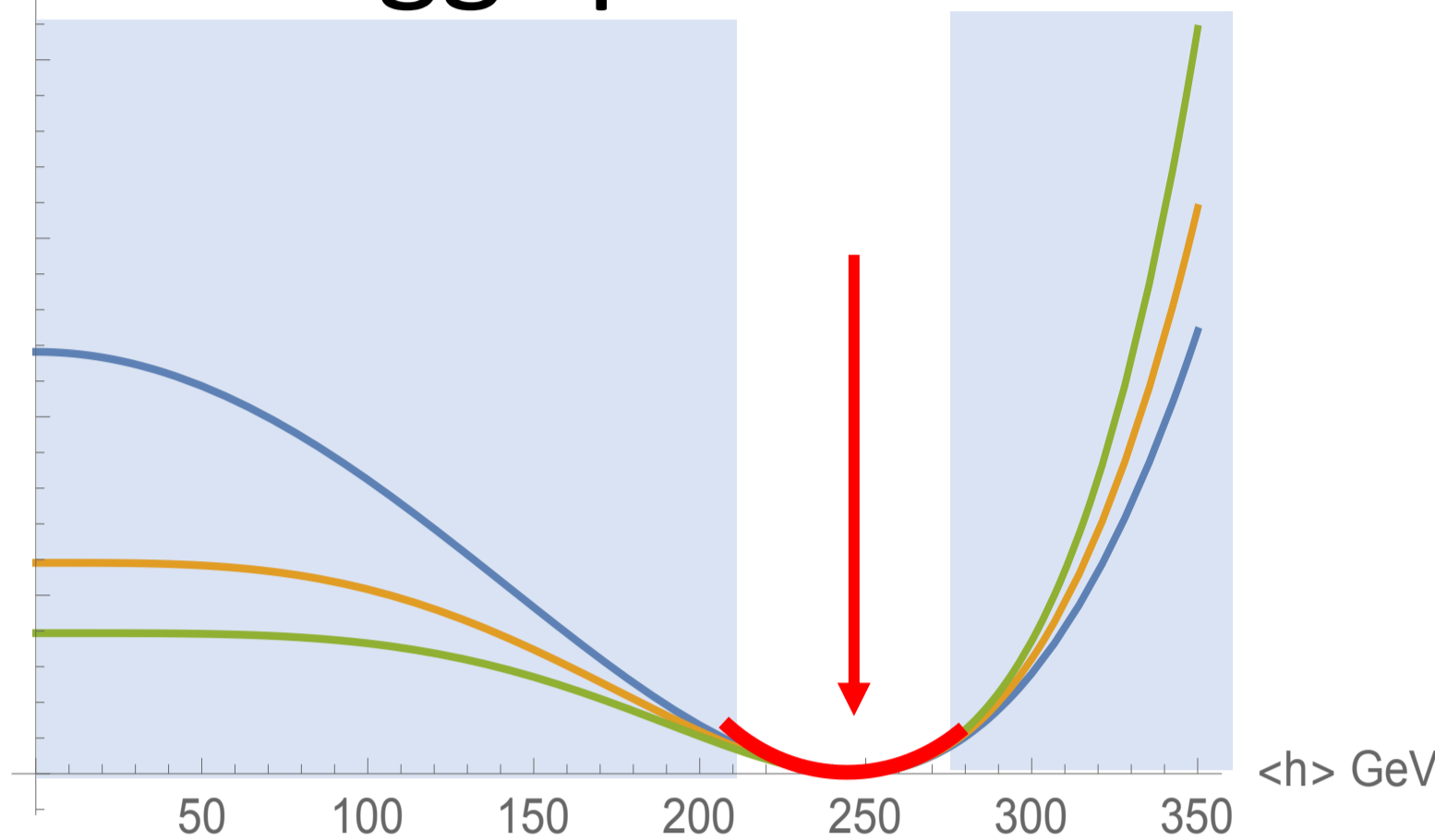
arXiv:1710.08096 and paper in preparation

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introduction

We know "2" things about Higgs potential

$\frac{dV}{dh}$: the EW vac.
 $\frac{d^2V}{dh^2}$: the Higgs mass



We don't know the global structure of potential

Model

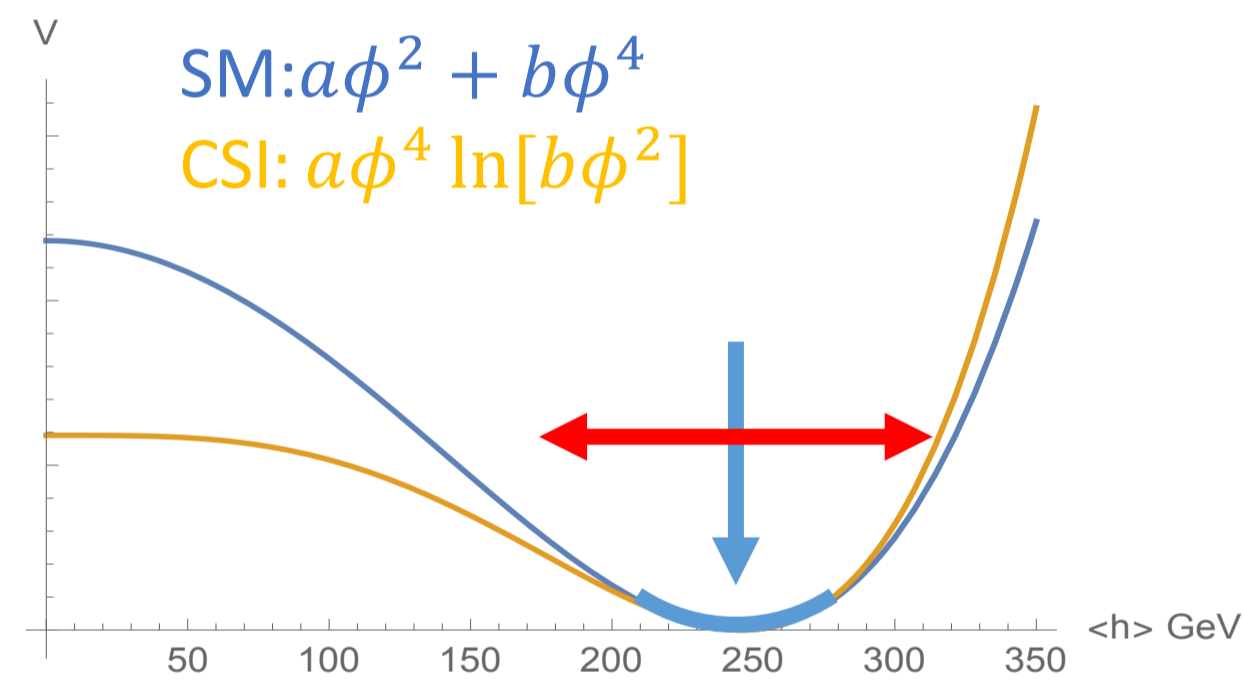
Classically scale invariant model (CSI model)

$$\mathcal{L} = \mathcal{L}_{SM} \mu^2 \rightarrow 0 + \frac{1}{2} (\partial_\mu \vec{S})^2 - \lambda_{HS} (H^\dagger H) (\vec{S} \cdot \vec{S}) - \frac{\lambda_S}{4} (\vec{S} \cdot \vec{S})^2$$

Foot et.al., 2007; Endo, Sumino 2015

$\mu^2 H^\dagger H - \lambda_H (H^\dagger H)^2$ SM singlet scalar w/ $O(N)$ sym. Higgs portal coupling

- Radiative vacuum
- LO is tree + 1loop ξ expansion $\rightarrow \xi^2 \lambda_h, \xi \lambda_{hs}, \xi^{1/2} y_t$



Typical observables

Effective action

$$\Gamma[H] = -V(H) + H^\dagger (D^2 H) \Gamma^1[H] + \dots$$

$$\frac{\delta^2 \Gamma}{\delta H \delta H} = m_h^2 + \Sigma(q^2) \quad \frac{\delta^3 \Gamma}{\delta H \delta H \delta H} = \lambda_{hhh}(q^2; k_1, k_2)$$

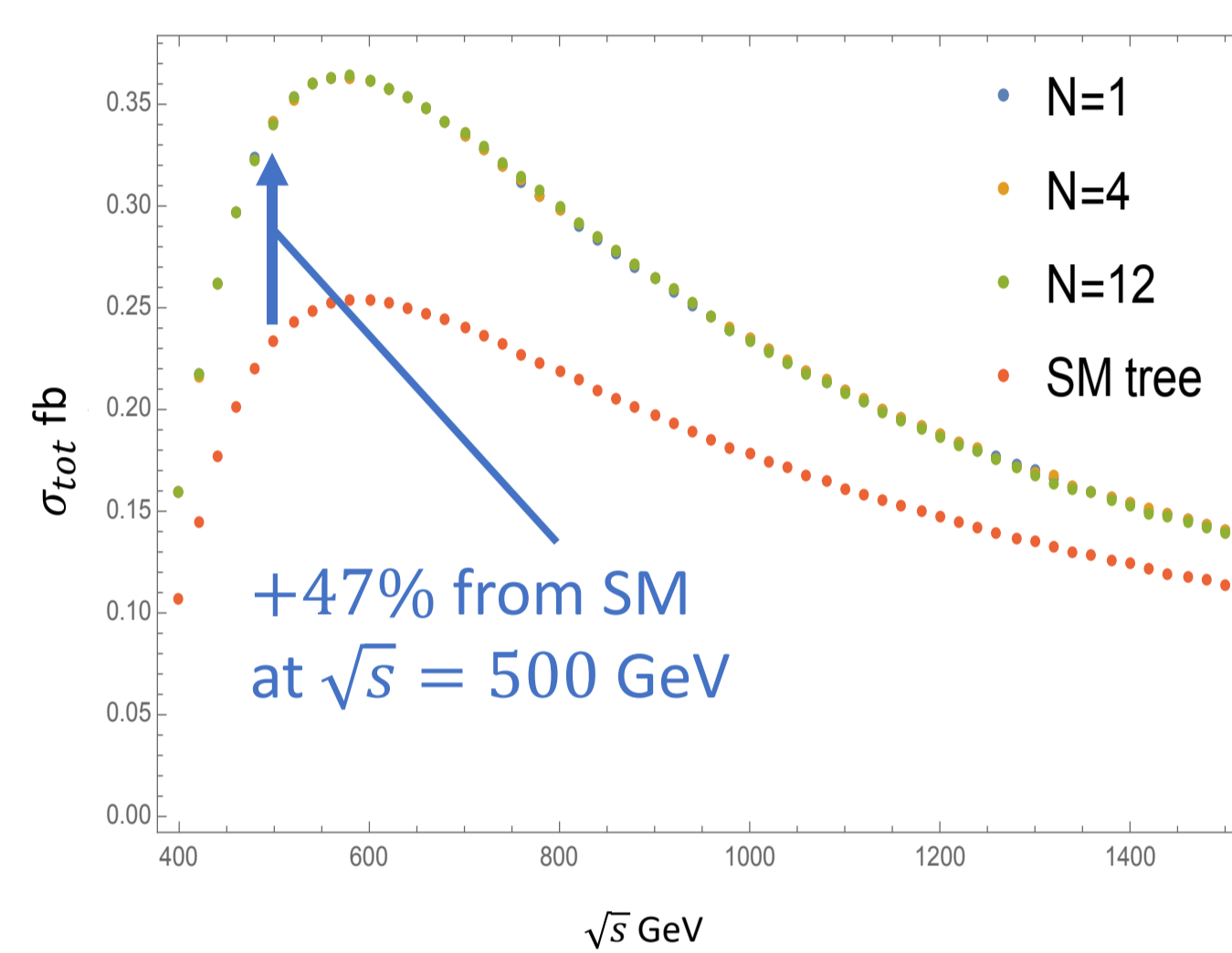
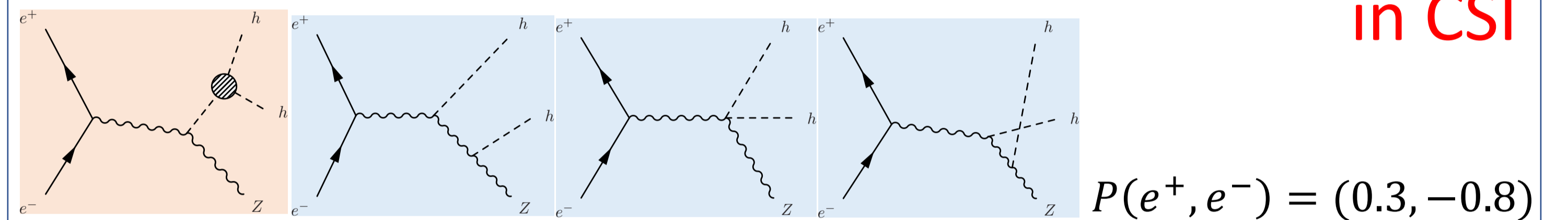
- Lower terms of δH and ∂H
- d^3V/dh^3
 - Γ^1
 - $\delta \Gamma^1 / \delta H$
- \rightarrow
- $\lambda_{hhh}^{q^2 \rightarrow 0}$
 - $d\Sigma/dq^2$
 - $d\lambda_{hhh}/dq^2$

Typical obs. appear in Higgs off-shell processes

λ_{hhh} in $e^+e^- \rightarrow Zh h$

$$\lambda_{hhh}(q^2) = \lambda_{hhh}^{q^2 \rightarrow 0} + \frac{q^2 d\lambda_{hhh}}{dq^2} \dots$$

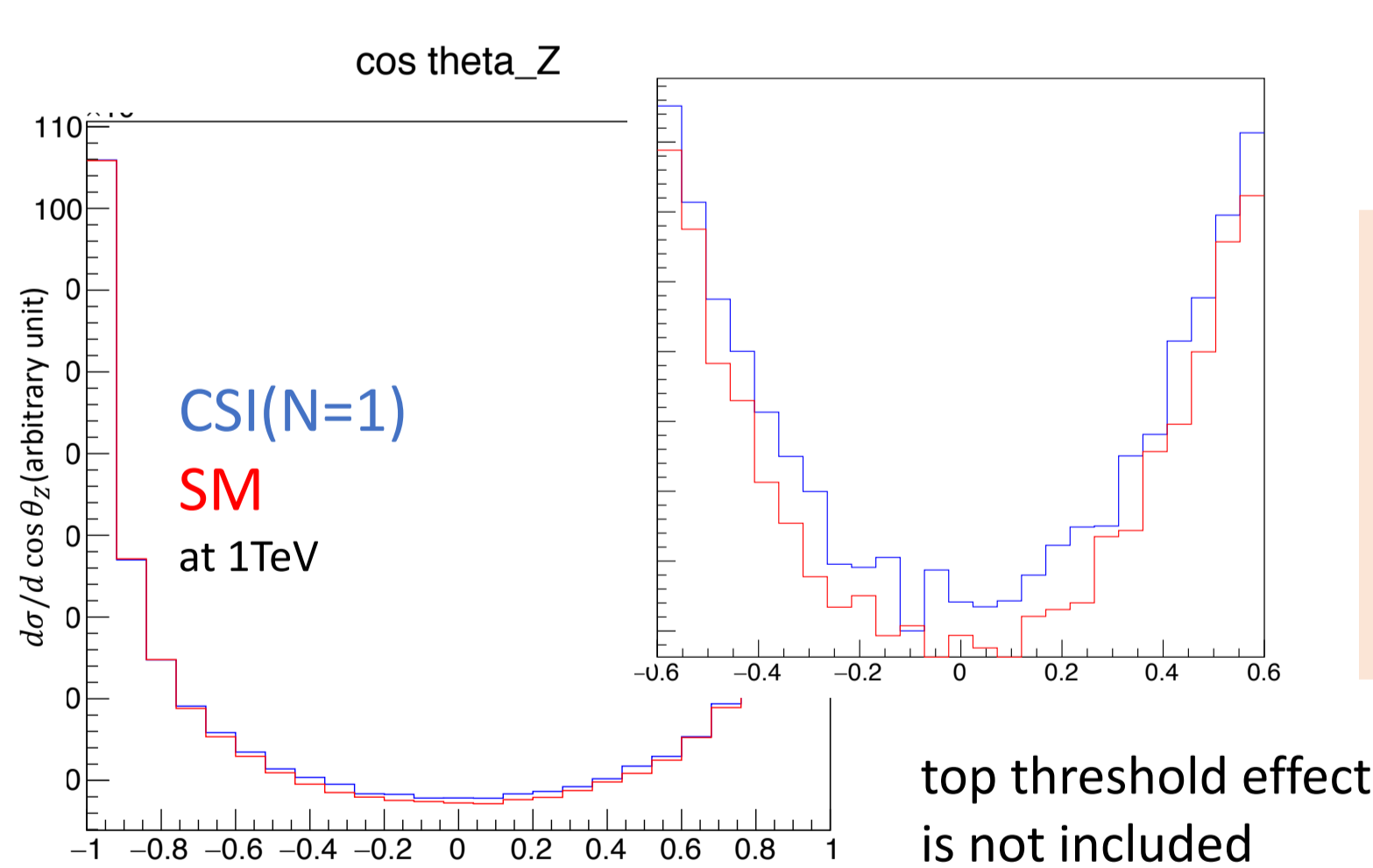
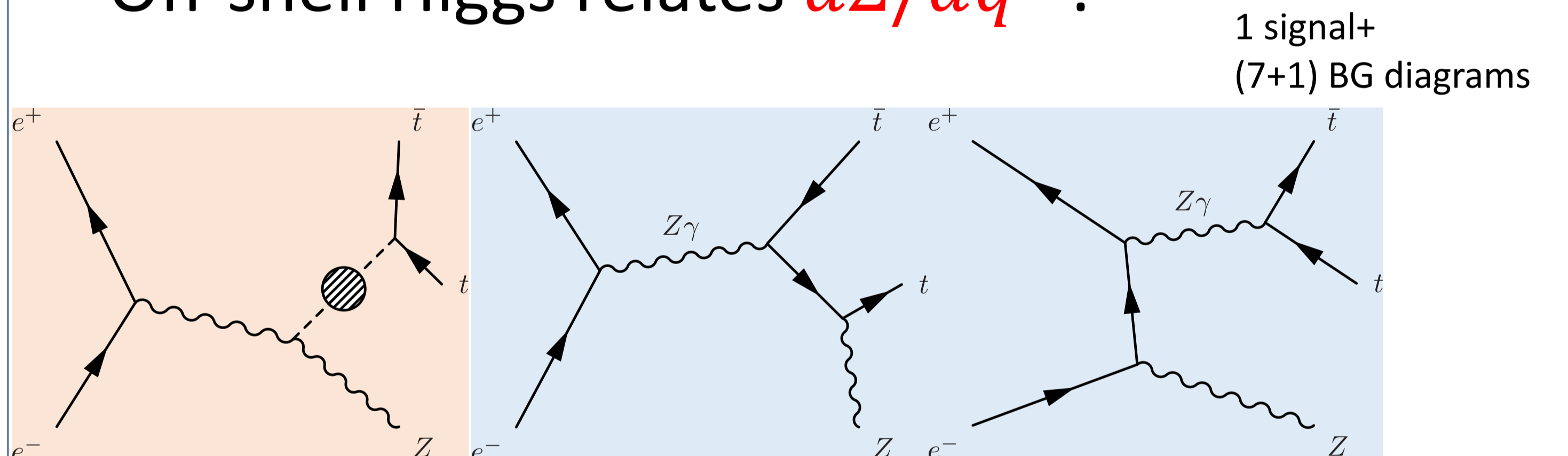
Large enhancement Accidental cancellation in CSI



Integrated Luminosity to discover 5σ /exclude 3σ
 $710/260 \text{ fb}^{-1}$
Based on LC-REP-2013-003, $1\sigma \approx N_{sig}/\sqrt{N_{BG}}$

$d\Sigma/dq^2$ in $e^+e^- \rightarrow Zt\bar{t}$

Off-shell Higgs relates $d\Sigma/dq^2$.



$\sigma_{|\cos \theta_Z| < 0.6}^{e^+e^- \rightarrow Zt\bar{t}} = 3.922 \text{ fb}$,
+3.4% from SM tree at 1TeV

Summary

- The structure of the EW vac. is still unknown.
- CSI model has a radiative vac. and anomalous phenomena.
- In portal like models, there are three observables to classify the model.
- The Higgs triple coupling is testable by 47% enhancement of $\sigma^{e^+e^- \rightarrow Zh h}$.
- The off-shell effects of the Higgs propagation appear +3.4% anomaly in $\sigma^{e^+e^- \rightarrow Zt\bar{t}}$