WW scattering in the era of post-Higgs-boson discovery

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안녕하세요

- Collaborators this work: Jung Chang, Kingman Cheung and Tzu-Chiang Yuan
- Reference:PRD 87, 093005 (2013)

Motivation:

- Is the new 125-126 GeV boson a lone player responsible for the full EWSB? (Is the simplest SM enough?)
- May the additional Higgs bosons play a partial role in EWSB as well? (Do we need the "New Physics" ex: 2HDM, Little Higgs model, Strongly-Interacting Light Higgs Model?)

Basic Ideas

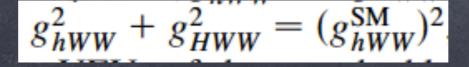
- The WW scattering becomes strong when the extra Higgs bosons are very heavy.
- The modified gauge-Higgs coupling may lead to incomplete cancellation and thus the partial growth in the scattering amplitudes in the intermediate energy range.

Method:

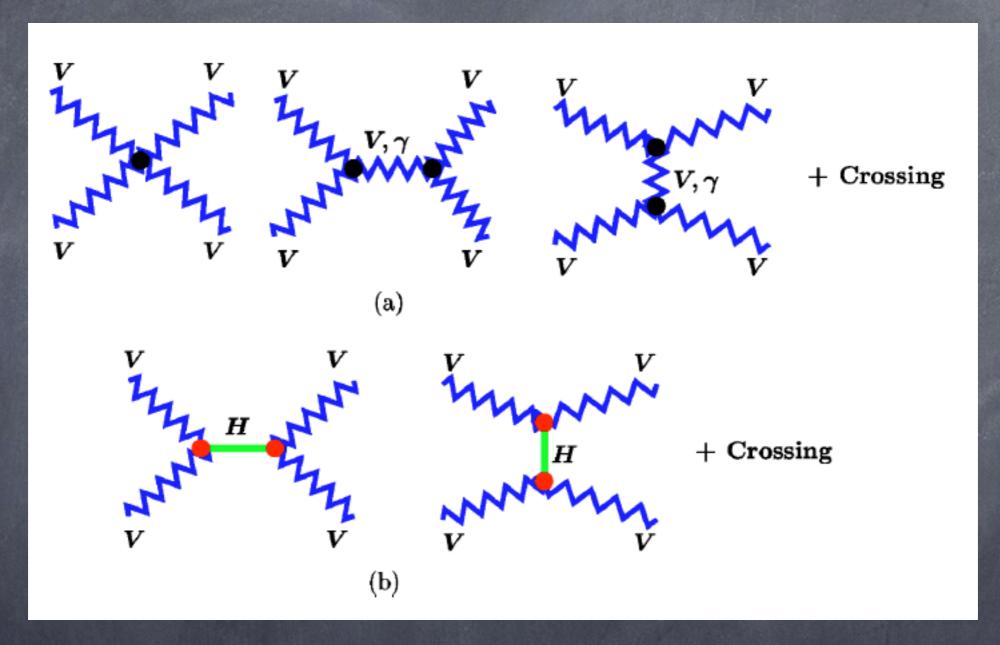
- We use WW scattering to investigate such a possibility, using 2HDM as a prototype.
- We set the light CP-even Higgs boson h is at 125 GeV while the heavy CP-even Higgs boson H is at 2 TeV.
- These 2 CP-even Higgs bosons couple to the vector boson with reduced strengths

$$g_{hWW} = \sin(\beta - \alpha)g_{hWW}^{SM}$$

$$g_{hWW} = \sin(\beta - \alpha)g_{hWW}^{SM}$$
 $g_{HWW} = \cos(\beta - \alpha)g_{hWW}^{SM}$



Feynman diagrams for VV scattering



ø cite: PRD 67, 114024 (2003)

WW SCATTERING AMPLITUDES

$$i\mathcal{M}^{\text{gauge}} = i\mathcal{M}_t^{\gamma+Z} + i\mathcal{M}_s^{\gamma+Z} + i\mathcal{M}_4$$

= $-i\frac{g^2}{4m_W^2}u + O((E/m_W)^0)$.

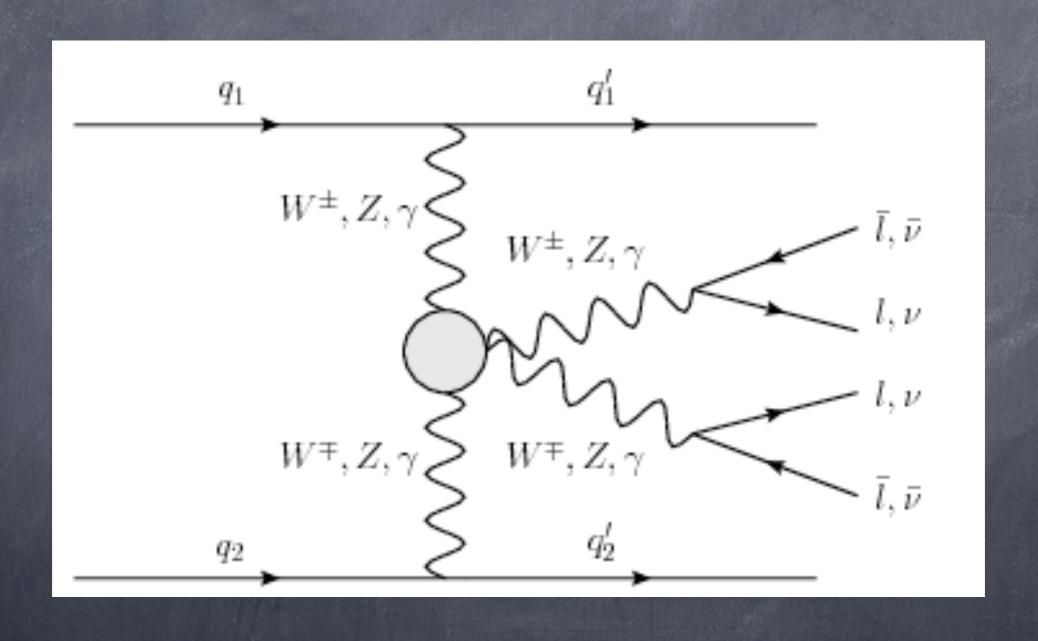
$$\begin{split} i\mathcal{M}^{\rm Higgs} &= -i\frac{C_v^2 g^2}{4m_W^2} \left[\frac{(s-2m_W^2)^2}{s-m_h^2} + \frac{(t-2m_W^2)^2}{t-m_h^2} \right], \\ &\simeq i\frac{C_v^2 g^2}{4m_W^2} u, \end{split}$$

The current data constrain [4]

$$C_v = \frac{g_{hWW}}{g_{hWW}^{SM}} = 0.96^{+0.13}_{-0.15}.$$

Nevertheless, it is not unreasonable that the value of Cv could deviate from the central value by 2 sigma, then the Cv could be as low as 0.66.

Vector Boson Fusion (VBF)



Numerical Results

- Experimental Cuts for VBF:
- (i) The appearance of 2 energetic forward jets with large spatial separation.
- (ii) The leptonic decay products of the W or Z bosons are enhanced at the large invariant mass region.

Cuts for the 2 jets in selecting the VBF events

$$E_{T_{j1,j2}} > 30 \text{ GeV}, \qquad |\eta_{j1,j2}| < 4.7,$$

 $\Delta \eta_{12} = |\eta_{j1} - \eta_{j2}| > 3.5, \qquad \eta_{j1} \eta_{j2} < 0,$ (8)

where $E_{T_{j1,j2}}$ and $\eta_{j1,j2}$ are the transverse energies and pseudorapidities, respectively, of the two forward jets, and

$$M_{jj} > 500 \text{ GeV} \tag{9}$$

on their invariant mass M_{jj} at $\sqrt{s} = 13$ TeV.

0

Cuts for the leptonic decay modes

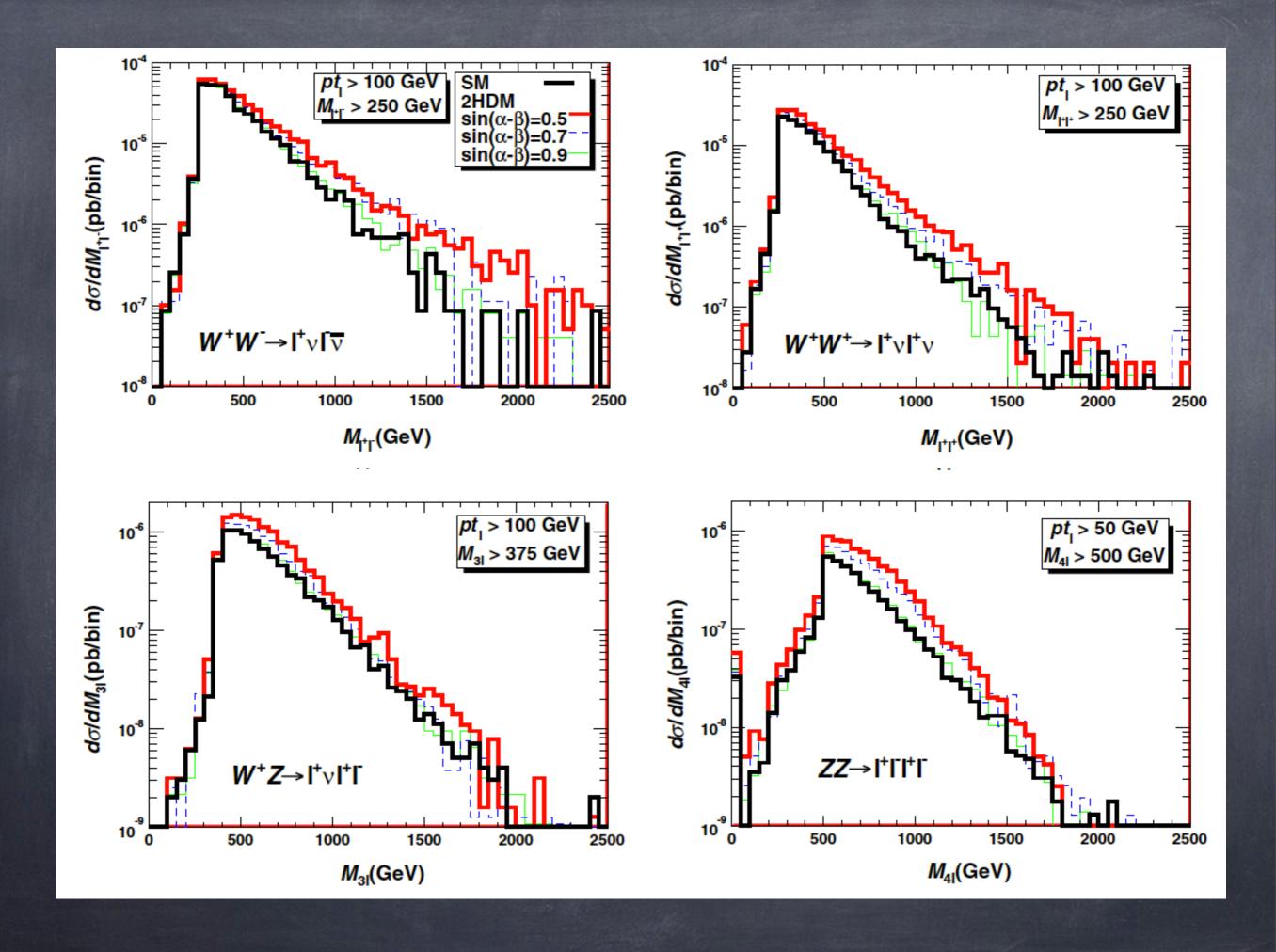
TABLE I. Leptonic cuts on the leptonic decay products of the diboson channels: W^+W^- , $W^\pm W^\pm$, $W^\pm Z$, and ZZ.

| W^+W^- | $W^{\pm}W^{\pm}$ | $W^{\pm}Z$ | ZZ |
|--|---|---|--|
| $\begin{aligned} p_{T_{\ell}} &> 100 \text{ GeV} \\ y_{\ell} &< 2 \end{aligned}$ | $p_{T_{\ell}} > 100 \text{ GeV}$ $ y_{\ell} < 2$ | $p_{T_{\ell}} > 100 \text{ GeV}$ $ y_{\ell} < 2$ | $p_{T_{\ell}} > 50 \text{ GeV}$ $ y_{\ell} < 2$ |
| $M_{\ell^+\ell^-} > 250 \text{ GeV}$ | $M_{\ell^{\pm}\ell^{\pm}} > 250 \text{ GeV}$ | $M_{3\ell} > 375 \text{ GeV}$ | $M_{4\ell} > 500 \text{ GeV}$ |

0

TABLE II. Cross sections in fb in various diboson channels under the jet cuts in Eqs. (8) and (9) and leptonic cuts listed in Table I.

| Channels | Cross sections (fb) $\sin(\beta - \alpha) = 0.5 \qquad 0.7 \qquad 0.9 \qquad \text{SM } (C_v = 1)$ | | | | | |
|--|--|----------------------|----------------------|----------------------|--|--|
| $W^+W^- \rightarrow \ell^+ \nu \ell^- \bar{\nu}$ | 0.51 | 0.46 | 0.40 | 0.39 | | |
| $W^+W^+ \rightarrow \ell^+ \nu \ell^+ \nu$ | 0.20 | 0.17 | 0.14 | 0.14 | | |
| $W^-W^- \longrightarrow \ell^- \bar{\nu} \ell^- \bar{\nu}$ | 0.083 | 0.075 | 0.070 | 0.069 | | |
| $W^+Z \rightarrow \ell^+ \nu \ell^+ \ell^-$ | 0.016 | 0.013 | 0.011 | 0.010 | | |
| $W^-Z \rightarrow \ell^- \bar{\nu} \ell^+ \ell^-$ | 1.0×10^{-2} | 8.5×10^{-3} | 7.6×10^{-3} | 7.4×10^{-3} | | |
| $ZZ \rightarrow \ell^+\ell^-\ell^+\ell^-$ | 8.4×10^{-3} | 6.4×10^{-3} | 4.6×10^{-3} | 4.4×10^{-3} | | |



Conclusion

The detailed studies of longitudinal weak gauge boson scattering at the LHC can provide useful hints of new physics at a higher scale (~2TeV), despite only a light Higgs boson (125~126GeV) has been discovered.

END

- OTHANK YOU!
- 고맙습니다

