Measurement Inputs in the EFT study

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DESY & IHEP

Higgs physics toward CDR Meeting
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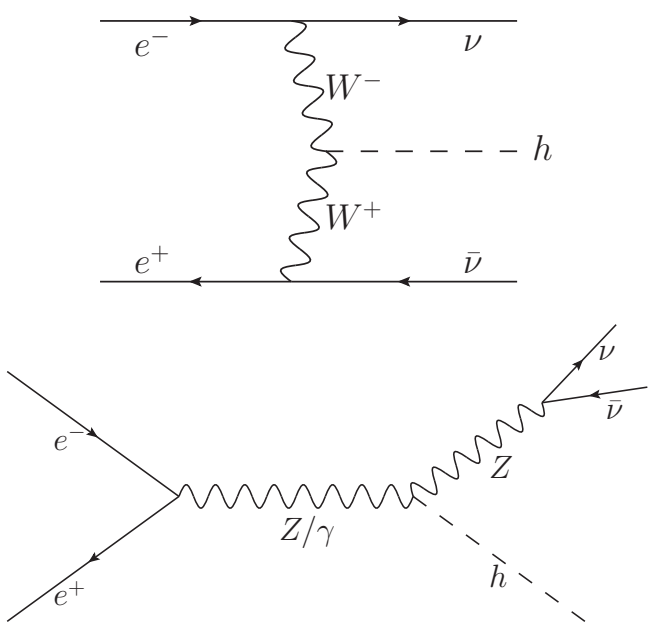
based on [arXiv:1704.02333] G. Durieux, C. Grojean, JG, K. Wang

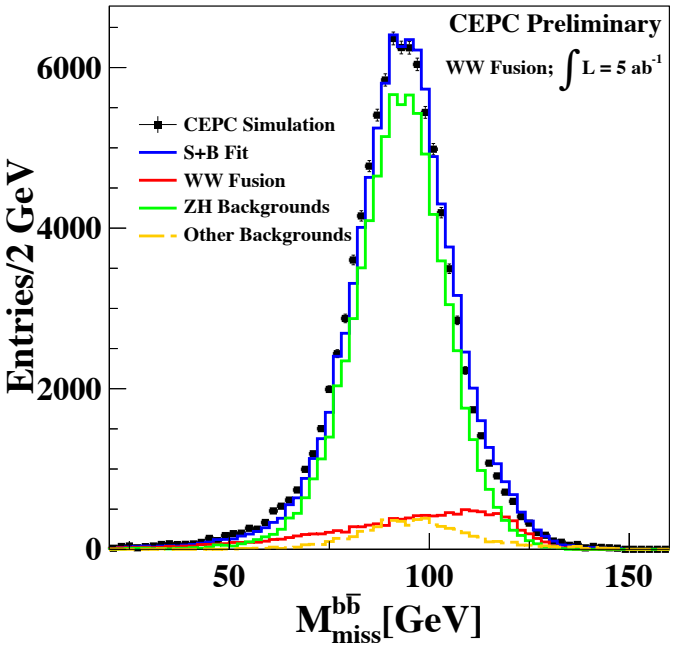
Higgs rate measurements

	CEPC 240 GeV, 5 ab^{-1}	
production	$e^+e^- \to hZ$	$e^+e^- \to \nu\bar{\nu}h$
σ	0.50%	-
	$\sigma \times \text{BR}$	
$h \to b\bar{b}$	0.21%*	0.39%$^\diamond$
$h \to c\bar{c}$	2.5%	-
$h \to gg$	1.2%	-
$h \to \tau\tau$	1.0%	-
$h \to WW^*$	1.0%	-
$h \to ZZ^*$	4.3%	-
$h \to \gamma\gamma$	9.0%	-
$h \to \mu\mu$	12%	-
$h \to Z\gamma$	25%	-

- $\sigma(hZ)$, $\sigma(hZ) \times \text{BR}$ and $\sigma(\nu\bar{\nu}h) \times \text{BR}$
- Would be good to have the correlations among $\sigma(hZ) \times \text{BR}(h \to b\bar{b}/c\bar{c}/gg)$, if they are significant. (currently assumed to be zero in our study)
- Be careful on the $\nu\bar{\nu}h$ measurement! ($^\diamond$ and * explained in the next two pages)

$e^+e^- \to \nu\bar{\nu}h$





- It is hard to separate the *WW* fusion process from $e^+e^- \to hZ, Z \to \nu\bar{\nu}$ at 240 GeV.
- It is not consistent to focus on one process and treat the other one as SM-like!
- For CEPC/FCC-ee 240 GeV, we analyze the combined $e^+e^- \to \nu\bar{\nu}h$ process, assuming new physics can contribute to both processes.

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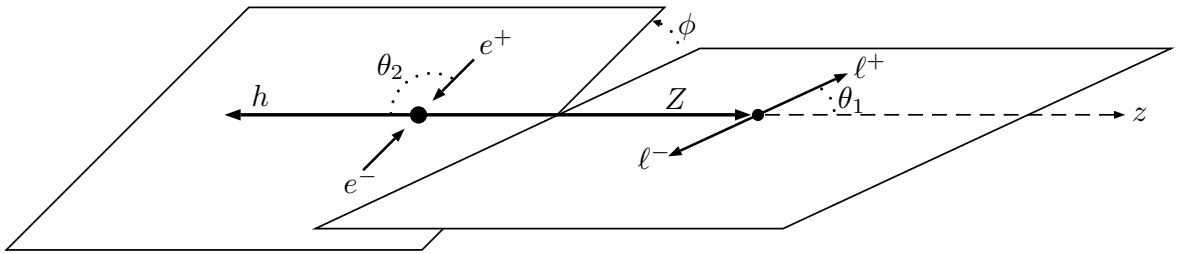
- $^\diamondsuit$: The precision is normalized to the total cross section including both WW fusion and $e^+e^- \to hZ, Z \to \nu\bar{\nu}$.

$$\frac{\Delta\sigma_{\text{tot}}}{\sigma_{\text{tot}}^{\text{SM}}} = \frac{2.8\% \times \sigma_{WW\to H}^{\text{SM}}}{\sigma_{WW\to H}^{\text{SM}} + \sigma_{\text{inv}Z}^{\text{SM}}} \approx 0.39\%\,, \tag{1}$$

- $^\bigstar$: The precision of $\sigma(hZ) \times \text{BR}(h \to b\bar{b})$ reduces to 0.24% if one excludes the contribution from $e^+e^- \to hZ, Z \to \nu\bar{\nu}, h \to b\bar{b}$ to avoid double counting.

angular observables in $e^+e^- \to hZ$

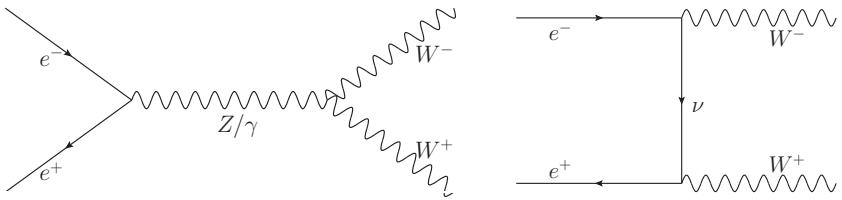


- We focus on the channel $e^+e^- \to hZ,\ Z \to \ell^+\ell^-,\ h \to b\bar{b}$.
  - The angular observables we have do not rely on the Higgs decay product.
  - We use the $b\bar{b}$ channel because it has less background.
- Good resolution, very small background $\Rightarrow$ statistical uncertainty dominates $\Rightarrow$ the most important input is the efficiency!
- A preliminary version of the preCDR suggest the efficiency is about $\sim$ 50-60%.
  - We fix it to 60% for simplicity.

angular observables in $e^+e^- \to hZ$, ways to improve

- Include additional Higgs decay channel
  - May need to worry about background and combinatorial problems.
- Include hadronic decays of Z
  - EFT calculation not available (but it won't be hard to do).
  - May need to worry about jet resolution, and also hard to discriminate q and $\bar{q}$.
- Extending the hZ angular observable analysis may not be our top priority. (but who knows?)

$e^+e^- \to WW$ (TGC measurements)



ILC 500 GeV				
	uncertainty	correlation matrix		
		$\delta g_{1,Z}$	$\delta\kappa_\gamma$	λ_Z
$\delta g_{1,Z}$	6.1×10^{-4}	1	0.634	0.477
$\delta\kappa_\gamma$	6.4×10^{-4}		1	0.354
λ_Z	7.2×10^{-4}			1

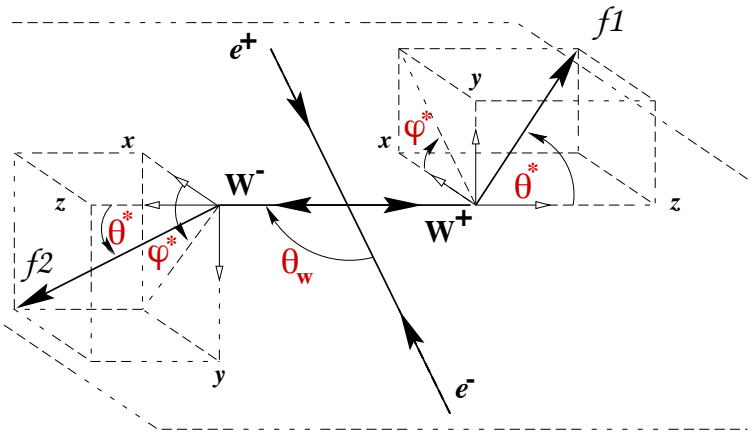
- Important, and also difficult.
- Ideally, it would be best if the constraints on the aTGCs can be directly provided by experimentalists.
  - ILC study: I. Marchesini, PhD thesis, Hamburg U. (2011), assuming $500\,\mathrm{fb}^{-1}$ data at 500 GeV with $P(e^-, e^+) = (\pm 0.8, \pm 0.3)$.
- Other people are also doing it.
  - ILC may release an updated document on TGC analysis soon (and there will also be some results for the 250 GeV run obtained by scaling).
  - CLIC's TGC analysis may also come out soon.

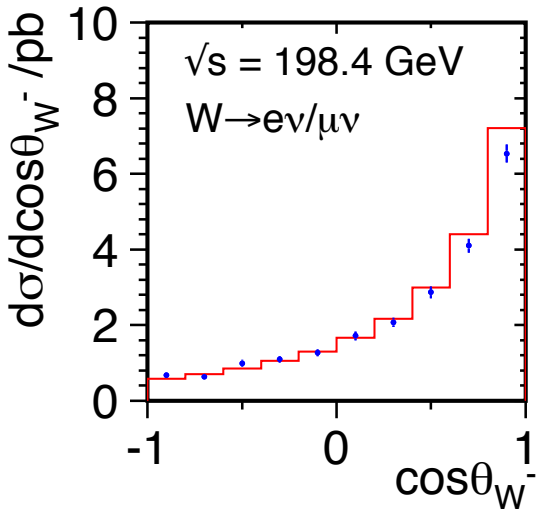
What we did (which wasn't good enough)

- We follow a previous TGC study for CEPC by theorists.
  ([arXiv:1507.02238] Bian, Shu, Zhang)
- Some optimistic assumptions are made.
  - 100% cut efficiency. Backgrounds are ignored.
  - All channels are used. Optimistic assumptions are made for the event reconstruction.
  - All the angular distributions are used (1 production angle, 2 decay angles for each W). The correlation among them are ignored.
- Different from [arXiv:1507.02238], we added by hand a fixed 1% in each bin (while the distribution in each angle is divided into 20 bins).
  - Probably too conservative!

CEPC 250 GeV (5/ab), our estimations				
	uncertainty	correlation matrix		
		$\delta g_{1,Z}$	$\delta\kappa_\gamma$	λ_Z
$\delta g_{1,Z}$	0.0064	1	0.068	-0.93
$\delta\kappa_\gamma$	0.0035		1	-0.40
λ_Z	0.0063			1

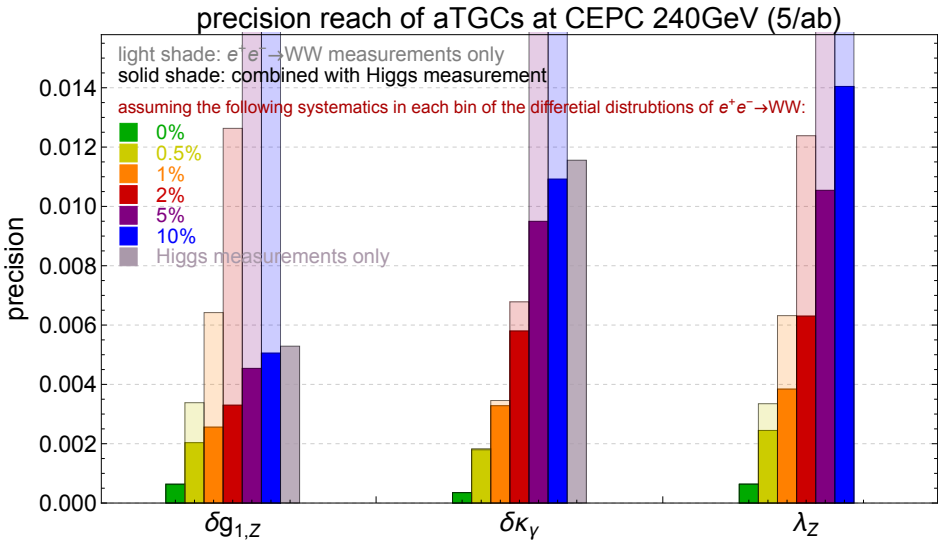
$e^+e^- \to WW$ (TGC measurements)

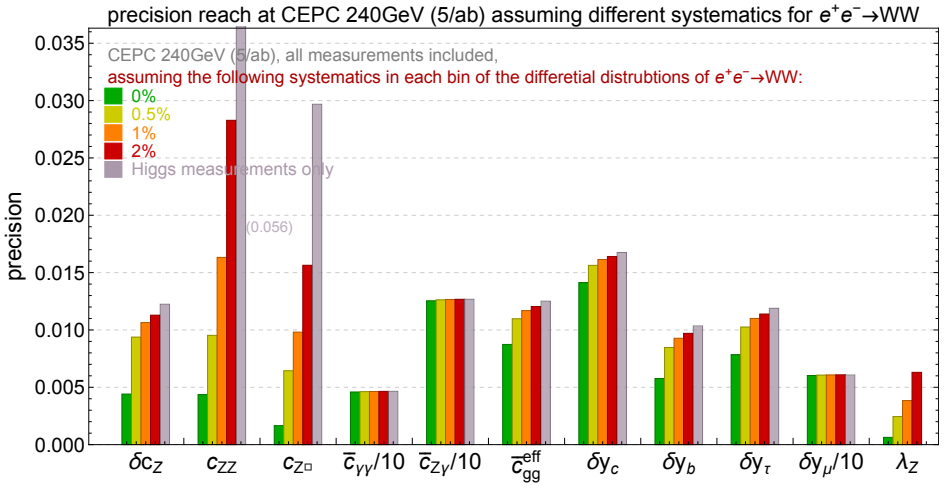




- Maybe we should focus on the semi-leptonic channel?
- The angular distributions are important!
- Would it be possible for experimentalist to provide the uncertainties for the binned distribution of the production polar angle? (An example from LEP is shown on the top right.)
- It would be better to also include the decay angles.

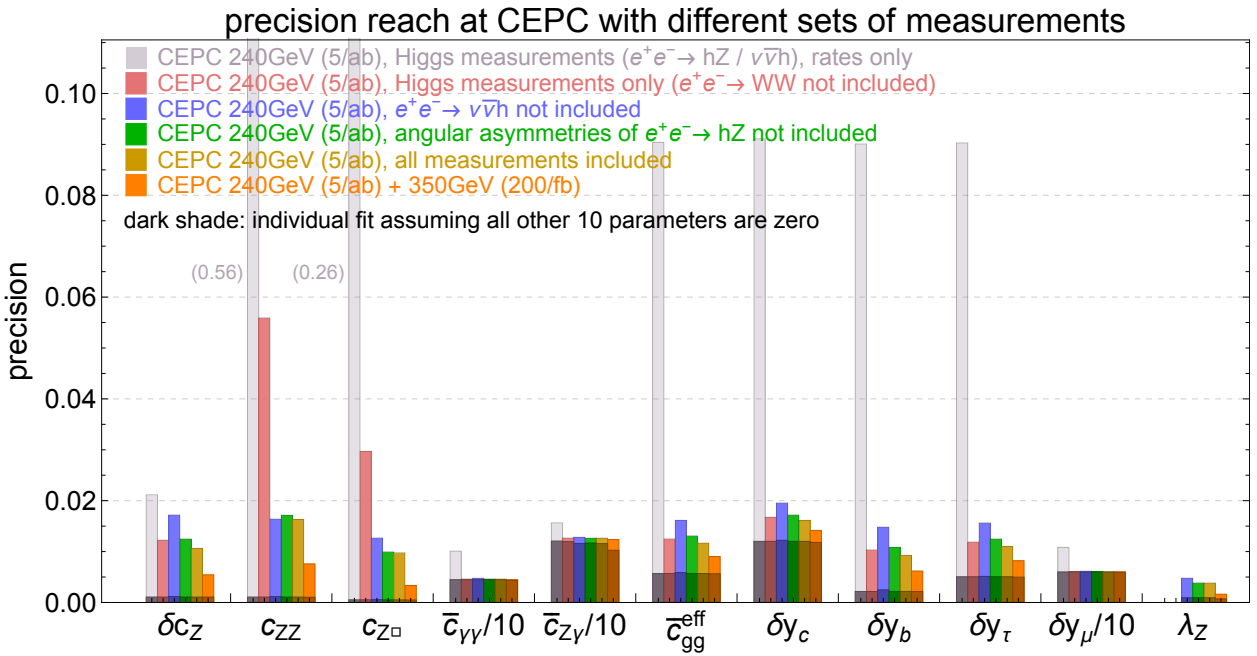
The interplay between Higgs and TGC





- $\delta g_{1,Z}$, $\delta\kappa_\gamma$ $\leftrightarrow$ c_{ZZ} , $c_{Z\Box}$, $c_{\gamma\gamma}$, $c_{Z\gamma}$
- We try different assumptions on the systematic uncertainties (in each bin with the differential distribution divided into 20 bins).
- Detailed study of $e^+e^- \rightarrow WW$ required to estimate the systematic uncertainties!

The importance of combining all measurements



- The results are much worse if we only include the rates of Higgs measurements alone!
- There is some overlap in the information from different measurements.
- Measurements at different energies can be very helpful.