Short update on the topic around the EFT model

Ryuta Kiuchi

09/05/2019

Recall of the EFT model

Resolving the tensor structure of the Higgs coupling to Z-bosons via Higgs-strahlung

Shankha Banerjee, Rick S. Gupta, Joey Y. Reiness and Michael Spannowsky[1]

[1] *Institute for Particle Physics Phenomenology, Durham University, South Road, Durham, DH1 3LE*

(Dated: May 9, 2019)

We propose differential observables for $pp \to Z(\ell^+\ell^-)h(bb)$ that can be used to completely determine the tensor structure of the $hZZ^*/hZ\bar{f}f$ couplings relevant to this process in the dimension-6 SMEFT. In particular, we propose a strategy to probe the anomalous $hZ_{\mu\nu}Z^{\mu\nu}$ and $hZ_{\mu\nu}\tilde{Z}^{\mu\nu}$ vertices at the percent level. We show that this can achieved by resurrecting the interference term between the transverse Zh amplitude, which receives contributions from the above couplings, and the dominant SM longitudinal amplitude. These contributions are hard to isolate without a knowledge of the analytical amplitude, as they vanish unless the process is studied differentially in three different angular variables at the level of the Z-decay products. By also including the differential distributions with respect to energy variables, we obtain projected bounds for the two other tensor structures of the Higgs coupling to Z-bosons.

arXiv:1905.02728v1 [hep-ph] 7 May 2019

I read it as . . .

(1) Anomalous HZZ couplings

$$\Delta\mathcal{L}_6^{hZ\bar{f}f} \supset \delta\hat{g}^h_{ZZ}\frac{2m_Z^2}{v}h\frac{Z^\mu Z_\mu}{2} + \sum_f g^h_{Zf}\frac{h}{v}Z_\mu\bar{f}\gamma^\mu f + \kappa_{ZZ}\frac{h}{2v}Z^{\mu\nu}Z_{\mu\nu} + \tilde{\kappa}_{ZZ}\frac{h}{2v}Z^{\mu\nu}\tilde{Z}_{\mu\nu}. \quad (1)$$

(2) Helicity amplitude

ff -> ZH

(here, Z->ll is not assumed yet)

$$\mathcal{M}_\sigma^{\lambda=\pm} = \sigma\frac{1+\sigma\lambda\cos\Theta}{\sqrt{2}}\frac{gg_f^Z}{c_{\theta_W}}\frac{m_Z}{\sqrt{\hat{s}}}\left[1+\left(\frac{g^h_{Zf}}{g^Z_f}+\kappa_{ZZ}-i\lambda\tilde{\kappa}_{ZZ}\right)\frac{\hat{s}}{2m_Z^2}\right]$$

$$\mathcal{M}_\sigma^{\lambda=0} = -\sin\Theta\frac{gg_f^Z}{2c_{\theta_W}}\left[1+\delta\hat{g}^h_{ZZ}+2\kappa_{ZZ}+\frac{g^h_{Zf}}{g^Z_f}\left(-\frac{1}{2}+\frac{\hat{s}}{2m_Z^2}\right)\right],$$

I read it as . . .

Here, Z->ll decay is combined

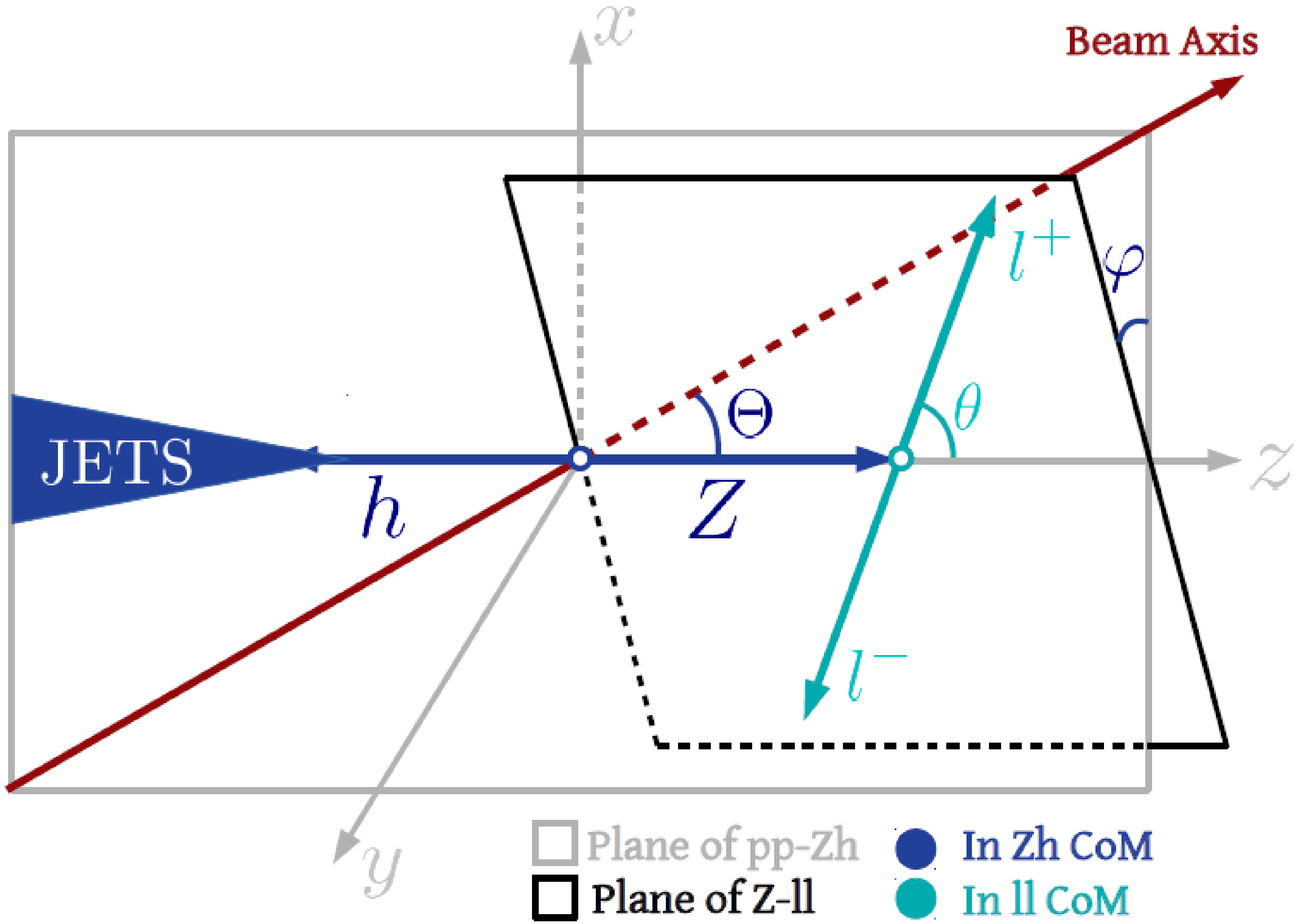
(3) Taking into account Z->ll

$$\sum_{L,R} |\mathcal{A}(\hat{s},\Theta,\theta,\phi)|^2 = a_{LL}\sin^2\Theta\sin^2\theta + a_{TT}^1\cos\Theta\cos\theta$$
$$+ a_{TT}^2(1+\cos^2\Theta)(1+\cos^2\theta) + \cos\varphi\sin\Theta\sin\theta$$
$$\times (a_{LT}^1 + a_{LT}^2\cos\theta\cos\Theta) + \sin\varphi\sin\Theta\sin\theta$$
$$\times (\tilde{a}_{LT}^1 + \tilde{a}_{LT}^2\cos\theta\cos\Theta) + a_{TT'}\cos 2\varphi\sin^2\Theta\sin^2\theta$$
$$+ \tilde{a}_{TT'}\sin 2\varphi\sin^2\Theta\sin^2\theta. \quad (7)$$

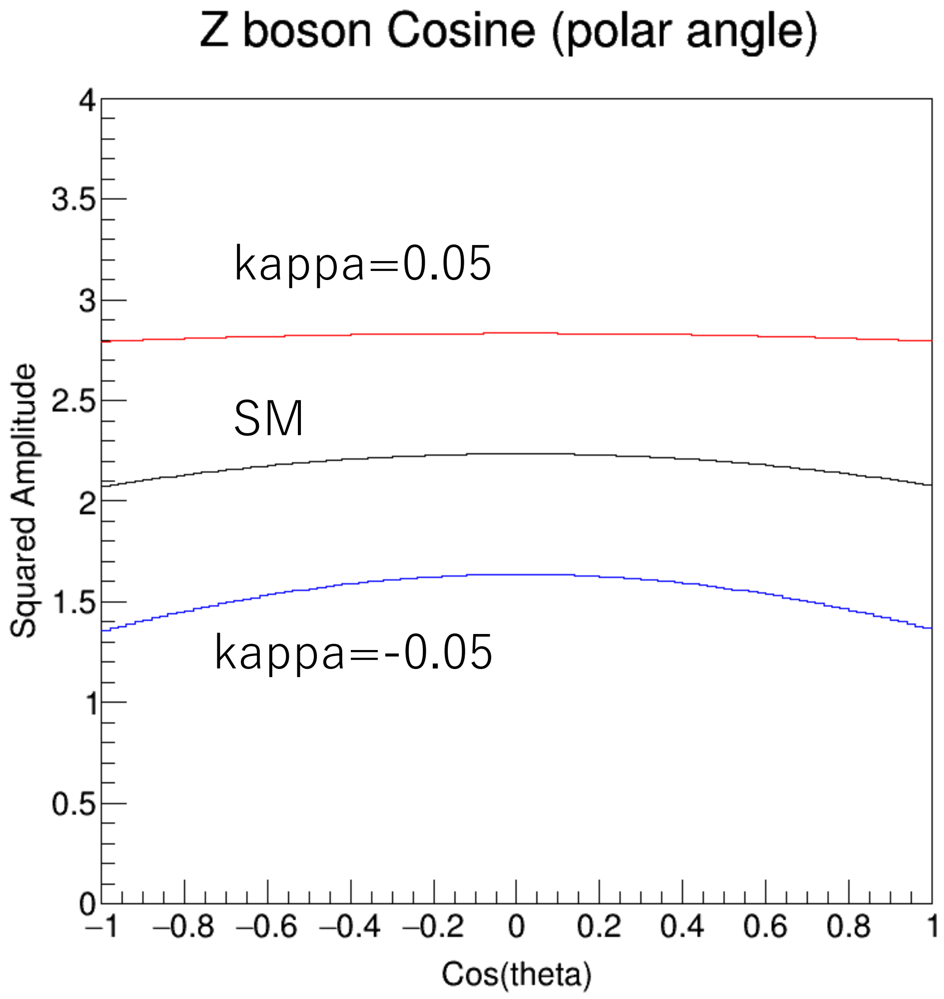
a_{LL}	$\frac{\mathcal{G}^2}{4}\left[1+2\delta g_{ZZ}^h + 4\kappa_{ZZ} + \frac{g_{Zf}^h}{g_f^Z}(-1+4\gamma^2)\right]$
a_{TT}^1	$\frac{\mathcal{G}^2\sigma\epsilon_{LR}}{2\gamma^2}\left[1+4\left(\frac{g_{Zf}^h}{g_f^Z}+\kappa_{ZZ}\right)\gamma^2\right]$
a_{TT}^2	$\frac{\mathcal{G}^2}{8\gamma^2}\left[1+4\left(\frac{g_{Zf}^h}{g_f^Z}+\kappa_{ZZ}\right)\gamma^2\right]$
a_{LT}^1	$-\frac{\mathcal{G}^2\sigma\epsilon_{LR}}{2\gamma}\left[1+2\left(\frac{2g_{Zf}^h}{g_f^Z}+\kappa_{ZZ}\right)\gamma^2\right]$
a_{LT}^2	$-\frac{\mathcal{G}^2}{2\gamma}\left[1+2\left(\frac{2g_{Zf}^h}{g_f^Z}+\kappa_{ZZ}\right)\gamma^2\right]$
$\tilde{a}_{LT}^1$	$-\mathcal{G}^2\sigma\epsilon_{LR}\tilde{\kappa}_{ZZ}\gamma$
$\tilde{a}_{LT}^2$	$-\mathcal{G}^2\tilde{\kappa}_{ZZ}\gamma$
$a_{TT'}$	$\frac{\mathcal{G}^2}{8\gamma^2}\left[1+4\left(\frac{g_{Zf}^h}{g_f^Z}+\kappa_{ZZ}\right)\gamma^2\right]$
$\tilde{a}_{TT'}$	$\frac{\mathcal{G}^2}{2}\tilde{\kappa}_{ZZ}$

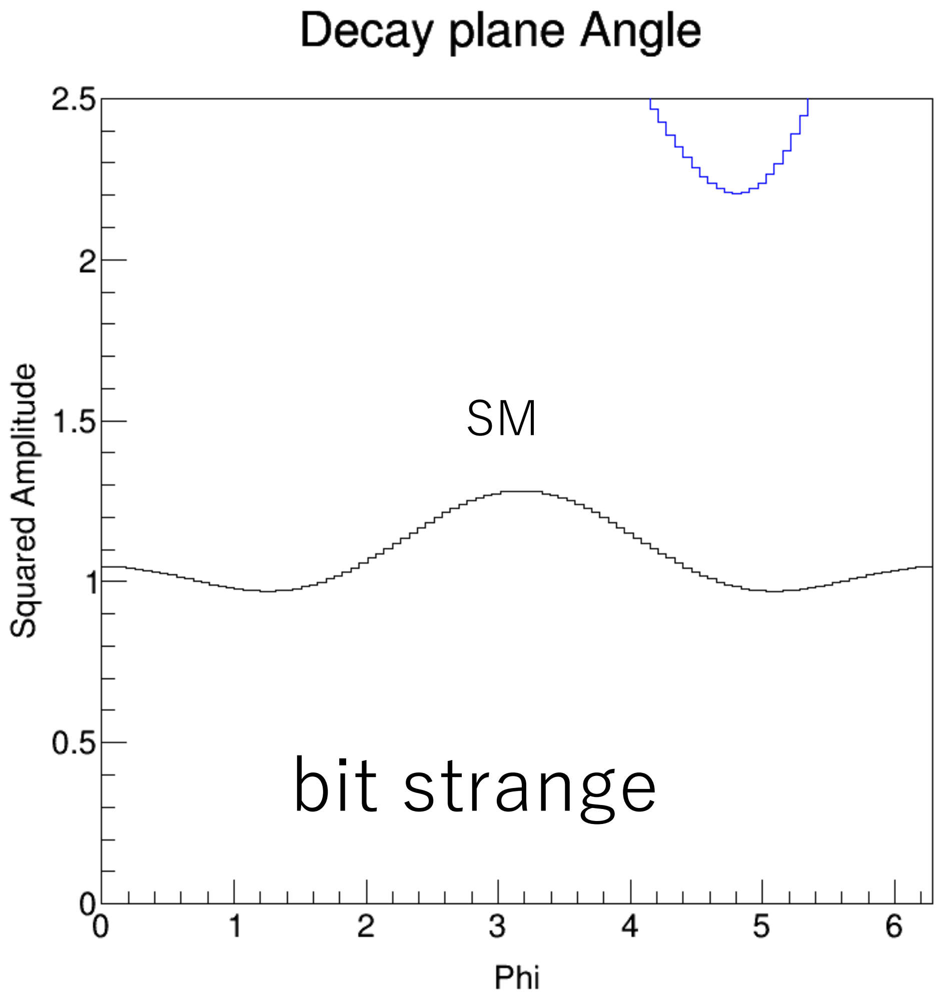
each coefficient is given in Table II.

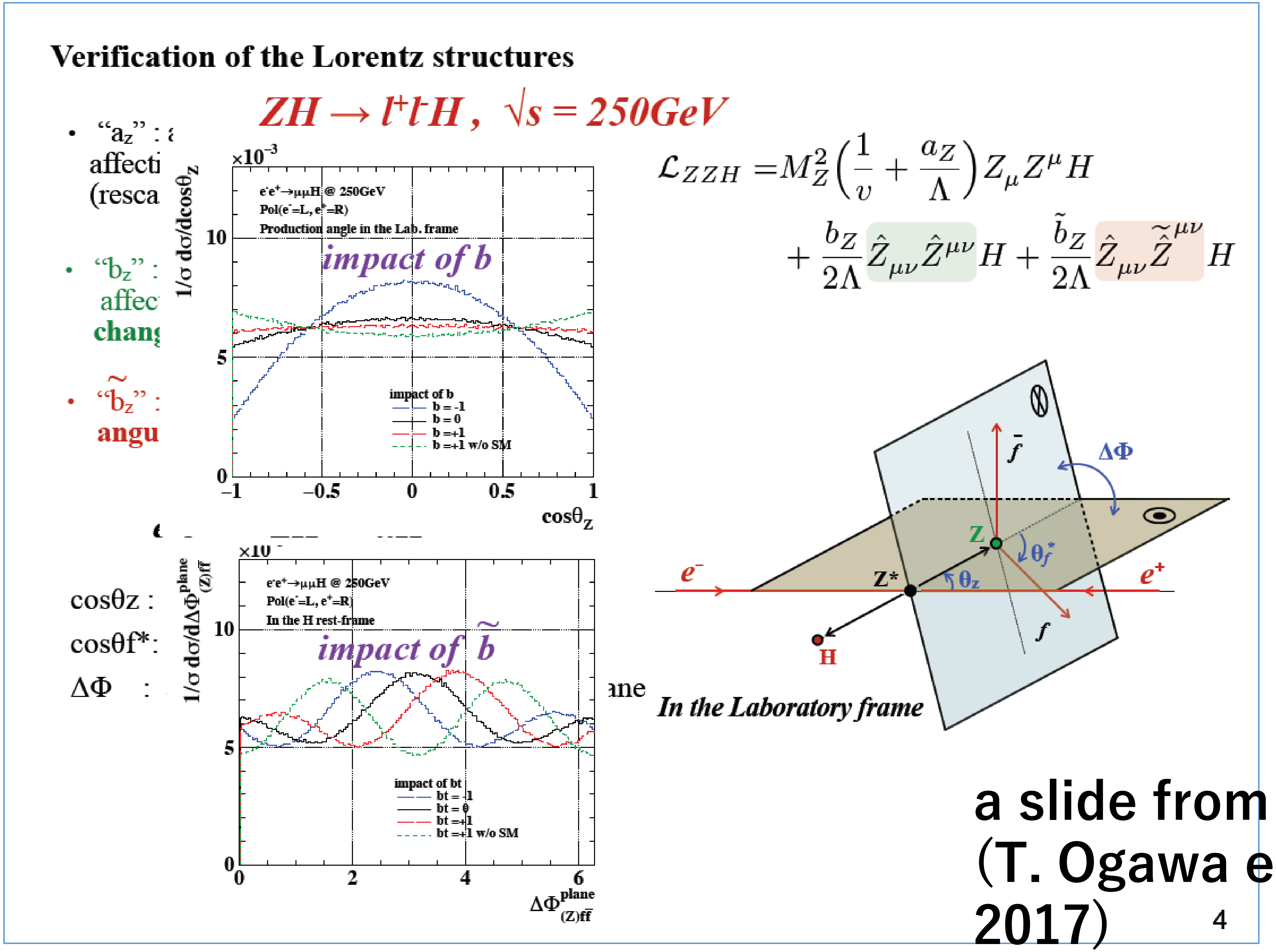
Definition of angles



A trial to follow the squared amplitude







a slide from ILC (T. Ogawa et.al. 2017)

Issue

-- the total value (integrated with $\theta[0, \pi]$, $\phi[0, 2\pi]$) becomes ~ 50 nbarn, with several input values , such as width of Z boson …

I expected that it should be ~6.7fb (ee->ZH->Z(->$\mu\mu$)H), I need to check the input values , but possible that there is another factors not written --> right now, I normalized it.

a_{LL}	$\frac{\mathcal{G}^2}{4}\left[1+2\delta g^h_{ZZ}+4\kappa_{ZZ}+\frac{g^h_{Zf}}{g^Z_f}(-1+4\gamma^2)\right]$
a^1_{TT}	$\frac{\mathcal{G}^2\sigma\epsilon_{LR}}{2\gamma^2}\left[1+4\left(\frac{g^h_{Zf}}{g^Z_f}+\kappa_{ZZ}\right)\gamma^2\right]$
a^2_{TT}	$\frac{\mathcal{G}^2}{8\gamma^2}\left[1+4\left(\frac{g^h_{Zf}}{g^Z_f}+\kappa_{ZZ}\right)\gamma^2\right]$
a^1_{LT}	$-\frac{\mathcal{G}^2\sigma\epsilon_{LR}}{2\gamma}\left[1+2\left(\frac{2g^h_{Zf}}{g^Z_f}+\kappa_{ZZ}\right)\gamma^2\right]$
a^2_{LT}	$-\frac{\mathcal{G}^2}{2\gamma}\left[1+2\left(\frac{2g^h_{Zf}}{g^Z_f}+\kappa_{ZZ}\right)\gamma^2\right]$
$\tilde{a}^1_{LT}$	$-\mathcal{G}^2\sigma\epsilon_{LR}\tilde{\kappa}_{ZZ}\gamma$
$\tilde{a}^2_{LT}$	$-\mathcal{G}^2\tilde{\kappa}_{ZZ}\gamma$
$a_{TT'}$	$\frac{\mathcal{G}^2}{8\gamma^2}\left[1+4\left(\frac{g^h_{Zf}}{g^Z_f}+\kappa_{ZZ}\right)\gamma^2\right]$
$\tilde{a}_{TT'}$	$\frac{\mathcal{G}^2}{2}\tilde{\kappa}_{ZZ}$

$$\sum_{L,R}|\mathcal{A}(\hat{s},\Theta,\theta,\phi)|^2 = a_{LL}\sin^2\Theta\sin^2\theta + a^1_{TT}\cos\Theta\cos\theta + a^2_{TT}(1+\cos^2\Theta)(1+\cos^2\theta) + \cos\varphi\sin\Theta\sin\theta \times (a^1_{LT}+a^2_{LT}\cos\theta\cos\Theta) + \sin\varphi\sin\Theta\sin\theta \times (\tilde{a}^1_{LT}+\tilde{a}^2_{LT}\cos\theta\cos\Theta) + a_{TT'}\cos 2\varphi\sin^2\Theta\sin^2\theta + \tilde{a}_{TT'}\sin 2\varphi\sin^2\Theta\sin^2\theta. \quad (7)$$

Issue

-- Usually, those estimation is done using a generator to which the anomolus couplings are implemented as well

-- Here, I just rely on the derived equation, which only show the first-order and of course, no detector/generator effect is included. Therefore, it might be too course estimation.

Next steps

-- Check again the equation, since I just started this.

-- Try to use Z->mm though Z(->$\mu\mu$)H(->ZZ) sample and try to overplot on theoretical line.
Maybe I need to scale the SM model .

-- Consider to use H->ZZ side . Definitely statistics would be a matter. Different $\sqrt{s}$ is a small advantage.

-- Contact authors about the equation etc.