Multi-Boson Production to Test Muon-Higgs Interactions at Muon Colliders

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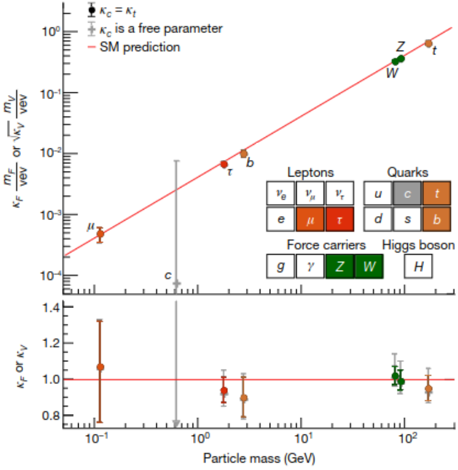
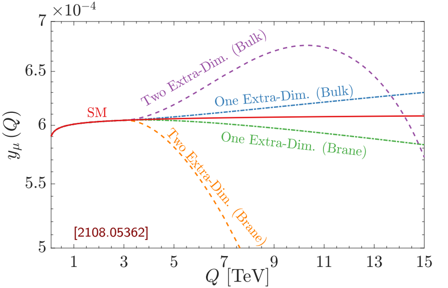
With T. Han, Y. Ma
W. Kilian, N. Kreher, J. Reuter, T. Striegl, 2108.05362
+ E. Celada, F. Maltoni, D. Pagani, 2312.13082

Muon-Higgs Interactions in the EFT

- We still have BSM room for muon-Higgs interactions.



[ATLAS, Nature 607(2022)52; CMS Nature 607(2022)60]



- κ scheme: $y_\mu = \kappa_\mu y_\mu^{\text{SM}}$
- Linear SMEFT

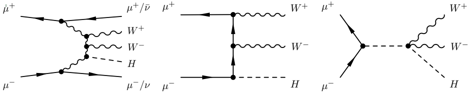
$$\mathscr{L}_6 = \sum_{n=1}^{N} \frac{\tilde{C}_{\ell\varphi}^{(n)ij}}{\Lambda^{2n}} \left(\varphi^\dagger \varphi\right)^n \bar{\ell}_L^i \varphi e_R^j + \text{hc}$$

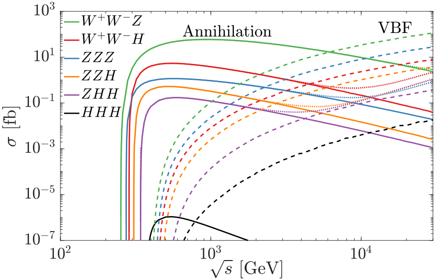
- Nonlinear HEFT

$$\mathscr{L}_U = \frac{v}{\sqrt{2}} \bar{\ell}_L^i \tilde{Y}_\ell^{ij}(H)\, U \frac{1-\tau_3}{2} \ell_R^j + \text{hc}$$

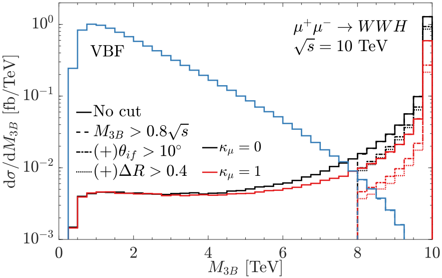
$$\tilde{Y}_\ell^{ij}(H) = \sum_{n\geq 0} \tilde{Y}_{\ell,n}^{ij} \left(\frac{H}{v}\right)^n$$

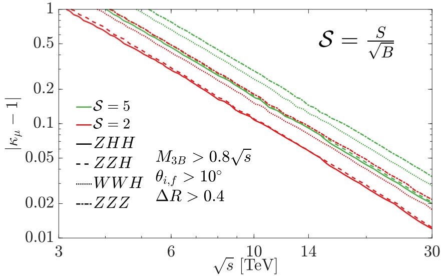
Multi-boson Production to Measure Muon Yukawa





[2108.05362]



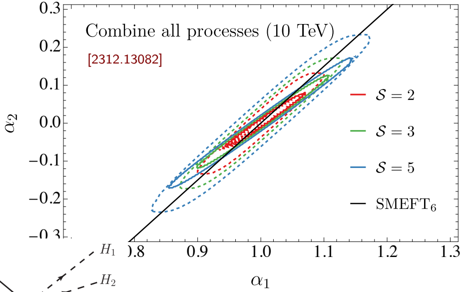


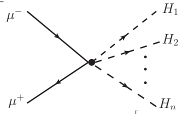
- Annihilation vs Vector-Boson Fusion
- The y_μ deviation (e.g., $\kappa_\mu = 0$) introduces anomalous annihilation.
- VBF is our background, which can be singled out with kinematics.
- We can measure $\Delta\kappa_\mu$ (including sign) up to 10% at a 10 TeV muon collider.

Multi-Higgs coupling in SMEFT and HEFT

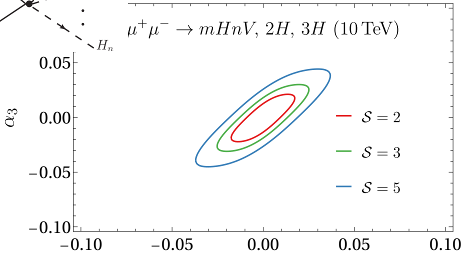
H \ V	0	1	2	3	4	5
0	-	Z	Z^2, W^2	Z^3 W^2Z	Z^4, W^4 W^2Z^2	Z^5, W^2Z^3 W^4Z
1	H	ZH	W^2H Z^2H	W^2ZH Z^3H	W^4H, Z^4H W^2Z^2H	-
2	H^2	ZH^2	W^2H^2 Z^2H^2	W^2ZH^2 Z^3H^2	-	
3	H^3	ZH^3	W^2H^3 Z^2H^3	-	-	
4	H^4	ZH^4	-	-	-	
5	H^5	-	-	-	-	-

α_1, $\alpha_{1,2}$, $\alpha_{1,2,3}$, $\alpha_{1\cdots4}$, $\alpha_{1\cdots5}$





- The hyper coupling can directly contribute to multiple Higgs production.
- Multi-Higgs/Boson to determine the $\alpha_n m_\mu \mu\bar{\mu}\left(\frac{H}{v}\right)^n$ interaction.
- A 10 TeV muon collider can do much better than a 3 TeV machine.



$$\text{SMEFT}_6 : \left| c_{\ell\phi}^{(6)}/\Lambda^2 \right| \lesssim 5\cdot 10^{-10}\ \text{GeV}^{-2},$$

$$\text{HEFT} : |\Delta\alpha_1| \lesssim 0.1,\ |\alpha_2| \lesssim 0.2,\ |\alpha_3| \lesssim 0.03,\ |\alpha_4| \lesssim 0.01,\ |\alpha_5| \lesssim 0.01.$$