Robert Harlander

Institute for Theoretical Particle Physics and Cosmology
Faculty of Mathematics, Computer Science and Natural Sciences
RWTH Aachen University
52056 Aachen, Germany

phone: +49-241-80-27045
fax: +49-241-80-22187
harlander(at)physik.rwth-aachen.de
Office: 28A414, Campus Melaten

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Welcome! (deutsche Version)

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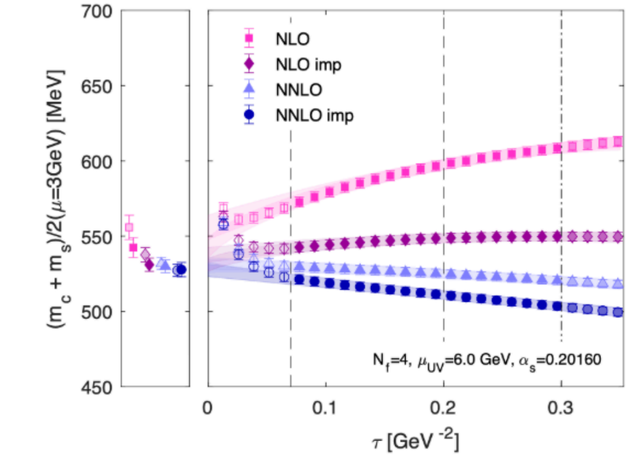
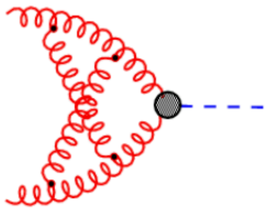


What's new? (older news)

- Topics for Master Theses in winter term 2025
  02 Jul 2025
- Another preprint on *quark mass determination*
  23 Jun 2025
- New preprint on *quark mass determination*
  12 Jun 2025
- New podcast episode: Siegen mit Exzellenz
  28 May 2025



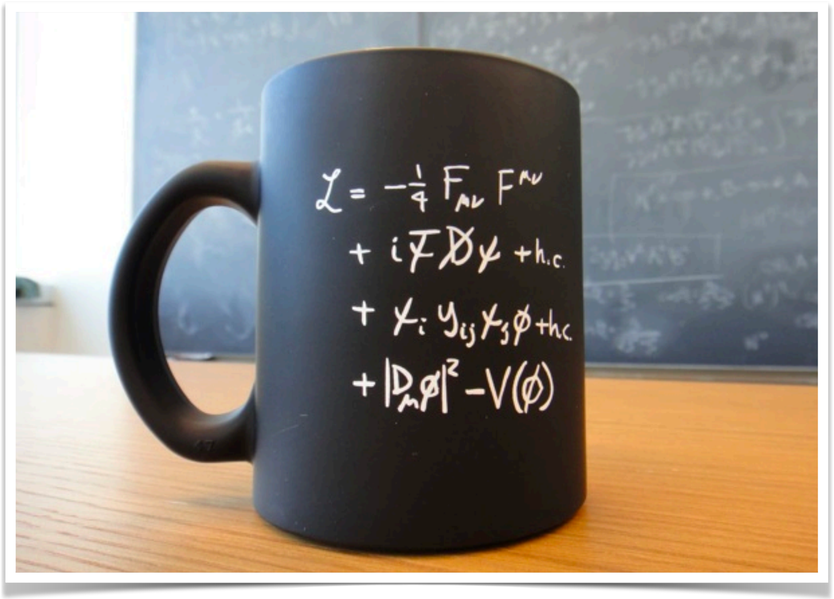
One of my favorite Feynman diagrams

I am a professor for theoretical particle physics at RWTH Aachen University.

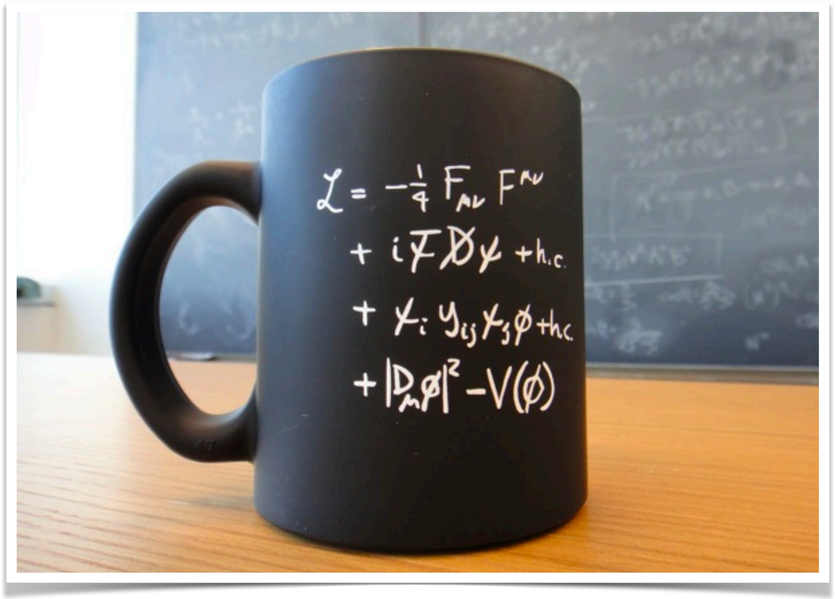
My main research field is to understand and predict phenomena at particle colliders. Within the last few years, I have been mostly interested in the physics of Higgs bosons in and beyond the Standard Model. Recently, I have also become interested in improving the connection between the perturbative and the lattice approach to quantum field theory through the gradient-flow formalism.

The menu on the left should help you navigate through this page. In particular, you can find a Brief CV, and details about my Research and Teaching activities.

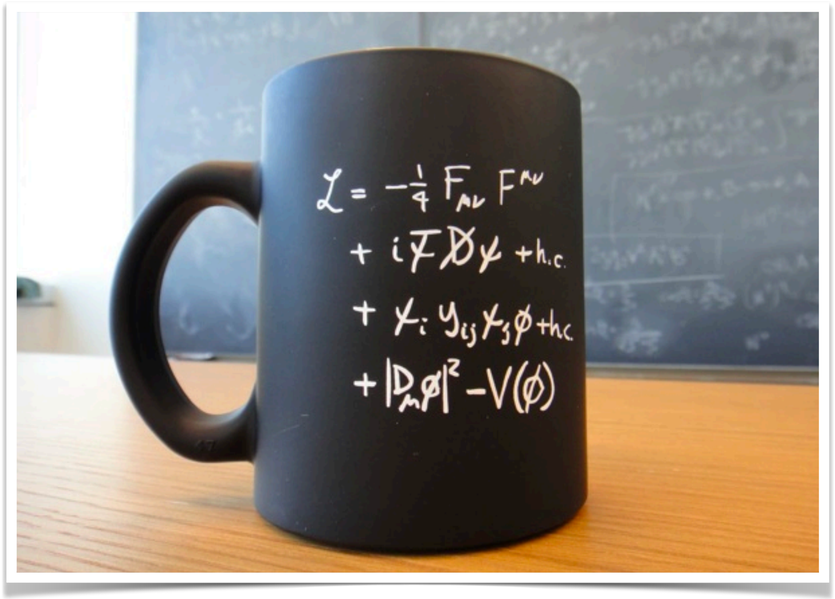
It is important to try to convey some of our excitement about physics to the general public, high-school students, or


$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu}$
$+ i\bar{\mathcal{F}} \not{D} \mathcal{F} + h.c.$
$+ \chi_i y_{ij} \chi_j \phi + h.c.$
$+ |D_\mu \phi|^2 - V(\phi)$

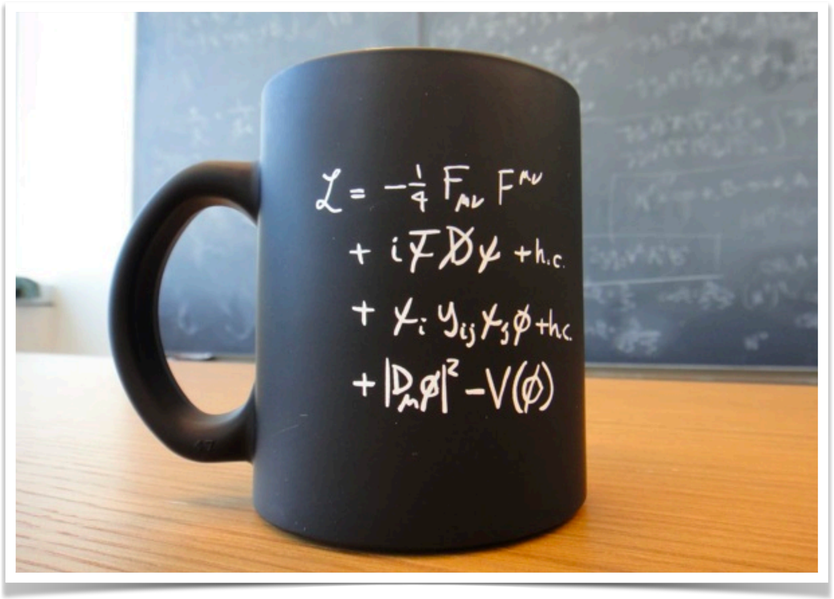
ψ
$\psi^{(1)}$
$\psi^{(2)}$
$\psi^{(3)}$
$\psi^{(4)}$
$\psi^{(5)}$



ψ	I	Y
$\psi^{(1)}$	0	4/3
$\psi^{(2)}$	0	−2/3
$\psi^{(3)}$	1/2	1/3
$\psi^{(4)}$	0	−2
$\psi^{(5)}$	1/2	−1



ψ	I	Y
$\psi^{(1)}_{1,2,3}$	0	4/3
$\psi^{(2)}_{1,2,3}$	0	−2/3
$\psi^{(3)}_{1,2,3}$	1/2	1/3
$\psi^{(4)}_{1,2,3}$	0	−2
$\psi^{(5)}_{1,2,3}$	1/2	−1



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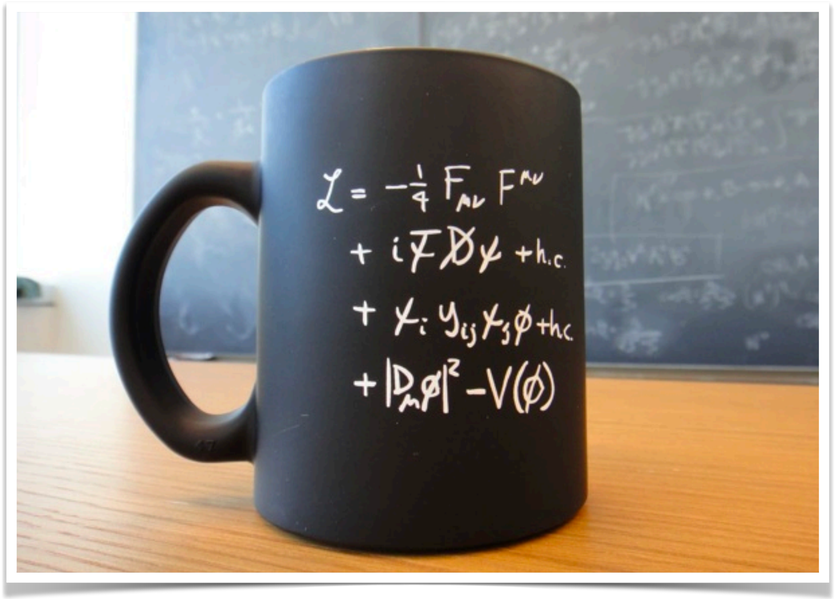
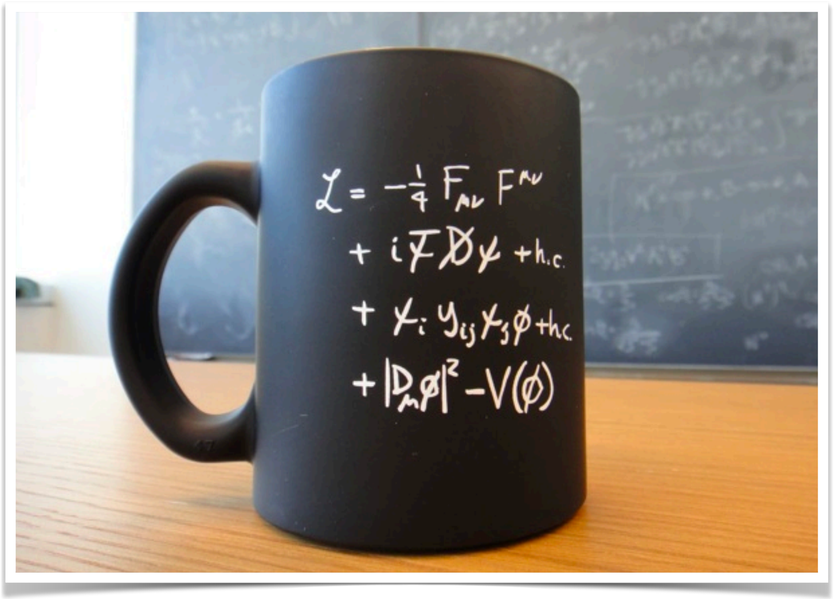


$$Y_\phi = 1$$

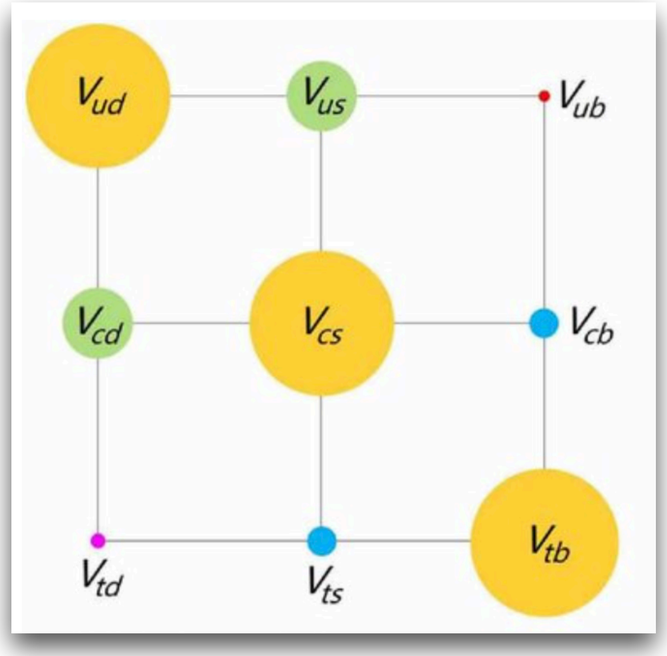
			ψ	I	Y
t_R	c_R	u_R	$\psi^{(1)}_{1,2,3}$	0	4/3
b_R	s_R	d_R	$\psi^{(2)}_{1,2,3}$	0	$-2/3$
$\begin{pmatrix} t_L \\ b_L \end{pmatrix}$	$\begin{pmatrix} c_L \\ u_L \end{pmatrix}$	$\begin{pmatrix} u_L \\ d_L \end{pmatrix}$	$\psi^{(3)}_{1,2,3}$	1/2	1/3
τ_R	μ_R	e_R	$\psi^{(4)}_{1,2,3}$	0	-2
$\begin{pmatrix} \nu_{\tau L} \\ \tau_L \end{pmatrix}$	$\begin{pmatrix} \nu_{\mu L} \\ \mu_L \end{pmatrix}$	$\begin{pmatrix} \nu_{eL} \\ e_L \end{pmatrix}$	$\psi^{(5)}_{1,2,3}$	1/2	-1

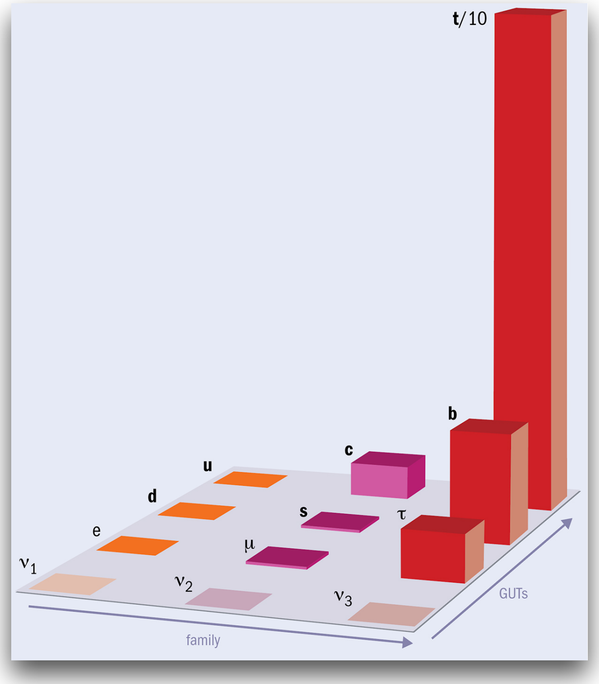


$$Y_\phi = 1$$

Flavor Hierarchies

Flavor hierarchies:

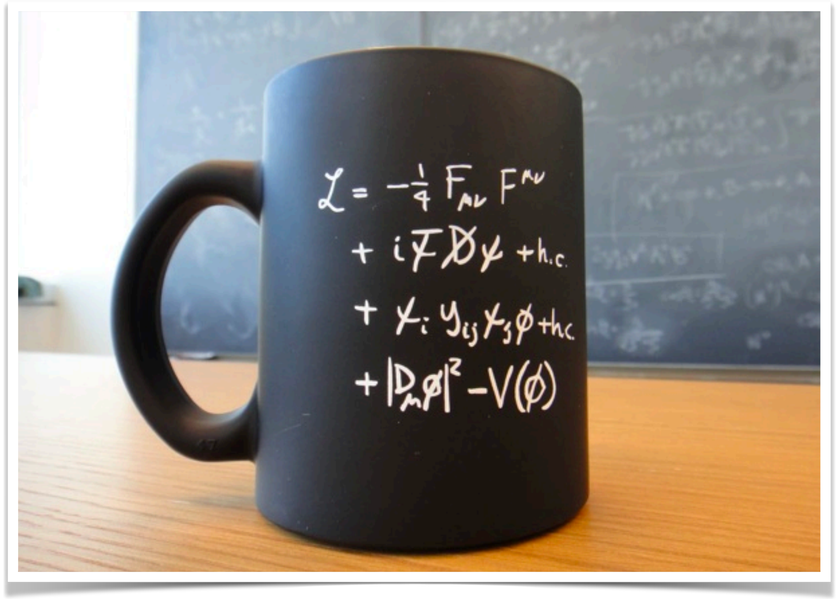




Reflected in SMEFT parameters?

Flavor structures in Effective Field Theories

Standard Model:



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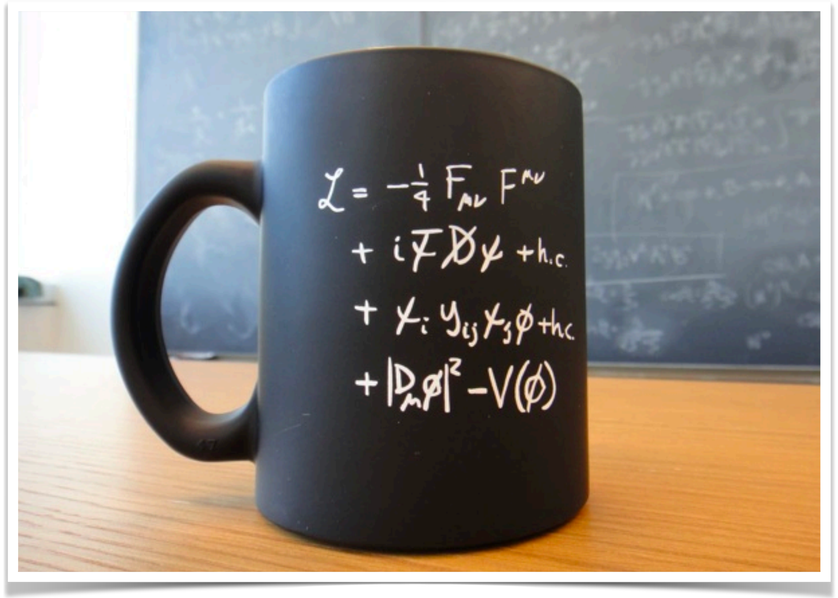

SMEFT

$1: X^3$		$2: H^6$		$3: H^4D^2$		$5: \psi^2H^3 + \text{h.c.}$	
Q_G	$f^{ABC} G^{A\nu}_{\mu} G^{B\rho}_{\nu} G^{C\mu}_{\rho}$	Q_H	$(H^\dagger H)^3$	$Q_{H\Box}$	$(H^\dagger H)\Box(H^\dagger H)$	Q_{eH}	$(H^\dagger H)(\bar{l}_p e_r H)$
$Q_{\widetilde{G}}$	$f^{ABC} \widetilde{G}^{A\nu}_{\mu} G^{B\rho}_{\nu} G^{C\mu}_{\rho}$			Q_{HD}	$\left(H^\dagger D_\mu H\right)^* \left(H^\dagger D_\mu H\right)$	Q_{uH}	$(H^\dagger H)(\bar{q}_p u_r \widetilde{H})$
Q_W	$\epsilon^{IJK} W^{I\nu}_{\mu} W^{J\rho}_{\nu} W^{K\mu}_{\rho}$					Q_{dH}	$(H^\dagger H)(\bar{q}_p d_r H)$
$Q_{\widetilde{W}}$	$\epsilon^{IJK} \widetilde{W}^{I\nu}_{\mu} W^{J\rho}_{\nu} W^{K\mu}_{\rho}$						

$8: (\bar{L}R)(\bar{R}L) + \text{h.c.}$		$8: (\bar{L}R)(\bar{L}R) + \text{h.c.}$	
Q_{ledq}	$(\bar{l}^j_p e_r)(\bar{d}_s q_{tj})$	$Q^{(1)}_{quqd}$	$(\bar{q}^j_p u_r)\epsilon_{jk}(\bar{q}^k_s d_t)$
		$Q^{(8)}_{quqd}$	$(\bar{q}^j_p T^A u_r)\epsilon_{jk}(\bar{q}^k_s T^A d_t)$
		$Q^{(1)}_{lequ}$	$(\bar{l}^j_p e_r)\epsilon_{jk}(\bar{q}^k_s u_t)$
		$Q^{(3)}_{lequ}$	$(\bar{l}^j_p \sigma_{\mu\nu} e_r)\epsilon_{jk}(\bar{q}^k_s \sigma^{\mu\nu} u_t)$

$4: X^2H^2$		$6: \psi^2XH + \text{h.c.}$		$7: \psi^2H^2D$	
Q_{HG}	$H^\dagger H\, G^A_{\mu\nu} G^{A\mu\nu}$	Q_{eW}	$(\bar{l}_p \sigma^{\mu\nu} e_r)\tau^I H W^I_{\mu\nu}$	$Q^{(1)}_{Hl}$	$(H^\dagger i \overleftrightarrow{D}_\mu H)(\bar{l}_p \gamma^\mu l_r)$
$Q_{H\widetilde{G}}$	$H^\dagger H\, \widetilde{G}^A_{\mu\nu} G^{A\mu\nu}$	Q_{eB}	$(\bar{l}_p \sigma^{\mu\nu} e_r) H B_{\mu\nu}$	$Q^{(3)}_{Hl}$	$(H^\dagger i \overleftrightarrow{D}^I_\mu H)(\bar{l}_p \tau^I \gamma^\mu l_r)$
Q_{HW}	$H^\dagger H\, W^I_{\mu\nu} W^{I\mu\nu}$	Q_{uG}	$(\bar{q}_p \sigma^{\mu\nu} T^A u_r)\widetilde{H}\, G^A_{\mu\nu}$	Q_{He}	$(H^\dagger i \overleftrightarrow{D}_\mu H)(\bar{e}_p \gamma^\mu e_r)$
$Q_{H\widetilde{W}}$	$H^\dagger H\, \widetilde{W}^I_{\mu\nu} W^{I\mu\nu}$	Q_{uW}	$(\bar{q}_p \sigma^{\mu\nu} u_r)\tau^I \widetilde{H}\, W^I_{\mu\nu}$	$Q^{(1)}_{Hq}$	$(H^\dagger i \overleftrightarrow{D}_\mu H)(\bar{q}_p \gamma^\mu q_r)$
Q_{HB}	$H^\dagger H\, B_{\mu\nu} B^{\mu\nu}$	Q_{uB}	$(\bar{q}_p \sigma^{\mu\nu} u_r)\widetilde{H}\, B_{\mu\nu}$	$Q^{(3)}_{Hq}$	$(H^\dagger i \overleftrightarrow{D}^I_\mu H)(\bar{q}_p \tau^I \gamma^\mu q_r)$
$Q_{H\widetilde{B}}$	$H^\dagger H\, \widetilde{B}_{\mu\nu} B^{\mu\nu}$	Q_{dG}	$(\bar{q}_p \sigma^{\mu\nu} T^A d_r) H\, G^A_{\mu\nu}$	Q_{Hu}	$(H^\dagger i \overleftrightarrow{D}_\mu H)(\bar{u}_p \gamma^\mu u_r)$
Q_{HWB}	$H^\dagger \tau^I H\, W^I_{\mu\nu} B^{\mu\nu}$	Q_{dW}	$(\bar{q}_p \sigma^{\mu\nu} d_r)\tau^I H\, W^I_{\mu\nu}$	Q_{Hd}	$(H^\dagger i \overleftrightarrow{D}_\mu H)(\bar{d}_p \gamma^\mu d_r)$
$Q_{H\widetilde{W}B}$	$H^\dagger \tau^I H\, \widetilde{W}^I_{\mu\nu} B^{\mu\nu}$	Q_{dB}	$(\bar{q}_p \sigma^{\mu\nu} d_r) H\, B_{\mu\nu}$	$Q_{Hud} + \text{h.c.}$	$i(\widetilde{H}^\dagger D_\mu H)(\bar{u}_p \gamma^\mu d_r)$

$8: (\bar{L}L)(\bar{L}L)$		$8: (\bar{R}R)(\bar{R}R)$		$8: (\bar{L}L)(\bar{R}R)$	
Q_{ll}	$(\bar{l}_p \gamma_\mu l_r)(\bar{l}_s \gamma^\mu l_t)$	Q_{ee}	$(\bar{e}_p \gamma_\mu e_r)(\bar{e}_s \gamma^\mu e_t)$	Q_{le}	$(\bar{l}_p \gamma_\mu l_r)(\bar{e}_s \gamma^\mu e_t)$
$Q^{(1)}_{qq}$	$(\bar{q}_p \gamma_\mu q_r)(\bar{q}_s \gamma^\mu q_t)$	Q_{uu}	$(\bar{u}_p \gamma_\mu u_r)(\bar{u}_s \gamma^\mu u_t)$	Q_{lu}	$(\bar{l}_p \gamma_\mu l_r)(\bar{u}_s \gamma^\mu u_t)$
$Q^{(3)}_{qq}$	$(\bar{q}_p \gamma_\mu \tau^I q_r)(\bar{q}_s \gamma^\mu \tau^I q_t)$	Q_{dd}	$(\bar{d}_p \gamma_\mu d_r)(\bar{d}_s \gamma^\mu d_t)$	Q_{ld}	$(\bar{l}_p \gamma_\mu l_r)(\bar{d}_s \gamma^\mu d_t)$
$Q^{(1)}_{lq}$	$(\bar{l}_p \gamma_\mu l_r)(\bar{q}_s \gamma^\mu q_t)$	Q_{eu}	$(\bar{e}_p \gamma_\mu e_r)(\bar{u}_s \gamma^\mu u_t)$	Q_{qe}	$(\bar{q}_p \gamma_\mu q_r)(\bar{e}_s \gamma^\mu e_t)$
$Q^{(3)}_{lq}$	$(\bar{l}_p \gamma_\mu \tau^I l_r)(\bar{q}_s \gamma^\mu \tau^I q_t)$	Q_{ed}	$(\bar{e}_p \gamma_\mu e_r)(\bar{d}_s \gamma^\mu d_t)$	$Q^{(1)}_{qu}$	$(\bar{q}_p \gamma_\mu q_r)(\bar{u}_s \gamma^\mu u_t)$
		$Q^{(1)}_{ud}$	$(\bar{u}_p \gamma_\mu u_r)(\bar{d}_s \gamma^\mu d_t)$	$Q^{(8)}_{qu}$	$(\bar{q}_p \gamma_\mu T^A q_r)(\bar{u}_s \gamma^\mu T^A u_t)$
		$Q^{(8)}_{ud}$	$(\bar{u}_p \gamma_\mu T^A u_r)(\bar{d}_s \gamma^\mu T^A d_t)$	$Q^{(1)}_{qd}$	$(\bar{q}_p \gamma_\mu q_r)(\bar{d}_s \gamma^\mu d_t)$
				$Q^{(8)}_{qd}$	$(\bar{q}_p \gamma_\mu T^A q_r)(\bar{d}_s \gamma^\mu T^A d_t)$

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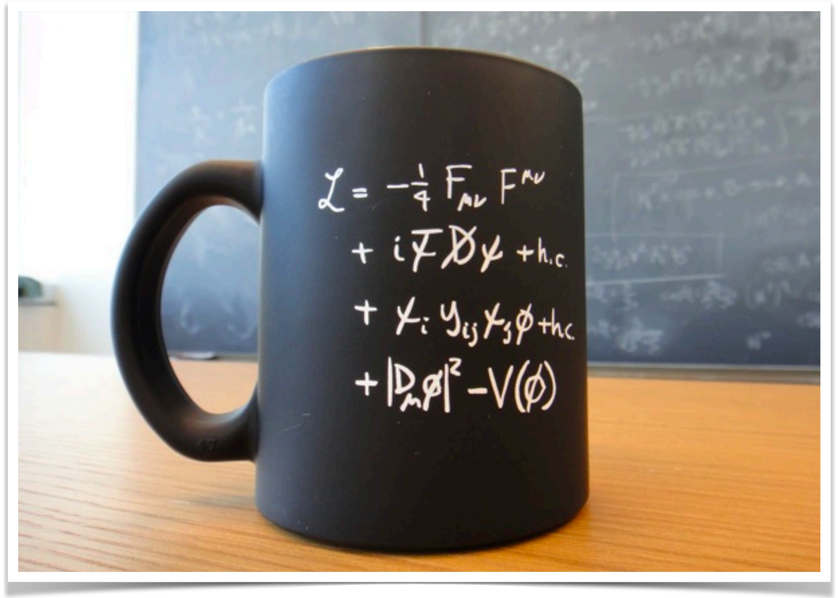
Flavor structures in Effective Field Theories

Standard Model:



SMEFT

$1: X^3$		$2: H^6$		$3: H^4D^2$		$5: \psi^2H^3 + \text{h.c.}$	
Q_G	$f^{ABC} G^{A\nu}_{\mu} G^{B\rho}_{\nu} G^{C\mu}_{\rho}$	Q_H	$(H^\dagger H)^3$	$Q_{H\Box}$	$(H^\dagger H)\Box(H^\dagger H)$	Q_{eH}	$(H^\dagger H)(\bar{l}_p e_r H)$
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2499 parameters

$4: X^2H^2$		$4: X^2H^2$		$4: X^2H^2$		$4: \psi^2XH + \text{h.c.}$	
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$Q_{H\widetilde{G}}$	$H^\dagger H\, \widetilde{G}^A_{\mu\nu} G^{A\mu\nu}$	Q_{eB}	$(\bar{l}_p \sigma^{\mu\nu} e_r) H B_{\mu\nu}$	$Q^{(3)}_{Hl}$	$(H^\dagger i \overleftrightarrow{D}^I_\mu H)(\bar{l}_p \tau^I \gamma^\mu l_r)$		
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$Q_{H\widetilde{B}}$	$H^\dagger H\, \widetilde{B}_{\mu\nu} B^{\mu\nu}$	Q_{dG}	$(\bar{q}_p \sigma^{\mu\nu} T^A d_r) H\, G^A_{\mu\nu}$	Q_{Hu}	$(H^\dagger i \overleftrightarrow{D}_\mu H)(\bar{u}_p \gamma^\mu u_r)$		
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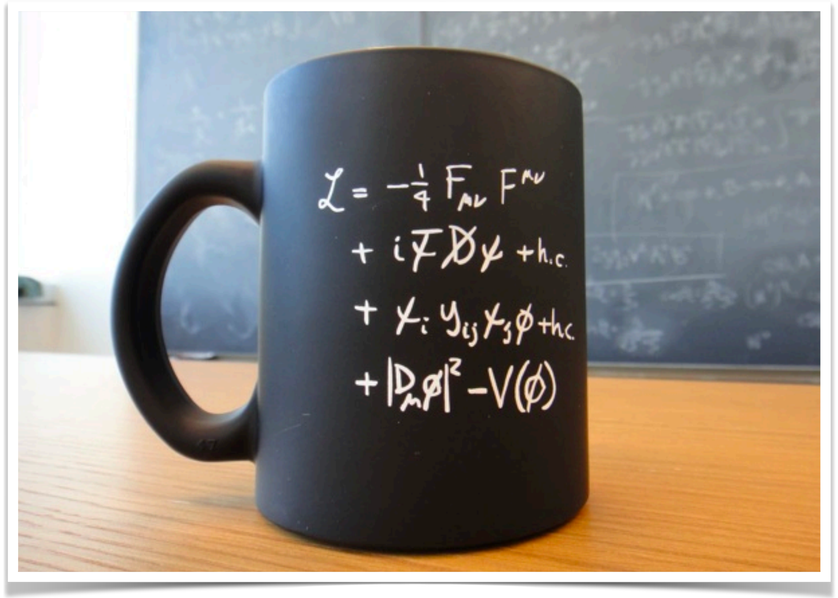

SMEFT

$1: X^3$		$2: H^6$		$3: H^4D^2$		$5: \psi^2H^3 + \text{h.c.}$		$8: (\bar{L}R)(\bar{R}L) + \text{h.c.}$		$8: (\bar{L}R)(\bar{L}R) + \text{h.c.}$	
Q_G	$f^{ABC} G^{A\nu}_{\mu} G^{B\rho}_{\nu} G^{C\mu}_{\rho}$	Q_H	$(H^\dagger H)^3$	$Q_{H\Box}$	$(H^\dagger H)\Box(H^\dagger H)$	Q_{eH}	$(H^\dagger H)(\bar{l}_p e_r H)$	Q_{ledq}	$(\bar{l}^j_p e_r)(\bar{d}_s q_{tj})$	$Q^{(1)}_{quqd}$	$(\bar{q}^j_p u_r)\epsilon_{jk}(\bar{q}^k_s d_t)$
$Q_{\widetilde{G}}$	$f^{ABC} \widetilde{G}^{A\nu}_{\mu} G^{B\rho}_{\nu} G^{C\mu}_{\rho}$			Q_{HD}	$\left(H^\dagger D_\mu H\right)^* \left(H^\dagger D_\mu H\right)$	Q_{uH}	$(H^\dagger H)(\bar{q}_p u_r \widetilde{H})$			$Q^{(8)}_{quqd}$	$(\bar{q}^j_p T^A u_r)\epsilon_{jk}(\bar{q}^k_s T^A d_t)$
Q_W	$\epsilon^{IJK} W^{I\nu}_{\mu} W^{J\rho}_{\nu} W^{K\mu}_{\rho}$					Q_{dH}	$(H^\dagger H)(\bar{q}_p d_r H)$			$Q^{(1)}_{lequ}$	$(\bar{l}^j_p e_r)\epsilon_{jk}(\bar{q}^k_s u_t)$
$Q_{\widetilde{W}}$	$\epsilon^{IJK} \widetilde{W}^{I\nu}_{\mu} W^{J\rho}_{\nu} W^{K\mu}_{\rho}$									$Q^{(3)}_{lequ}$	$(\bar{l}^j_p \sigma_{\mu\nu} e_r)\epsilon_{jk}(\bar{q}^k_s \sigma^{\mu\nu} u_t)$

2499 parameters

2452 related to flavor!

$4: X^2H^2$					
Q_{HG}	$H^\dagger H$				
$Q_{H\widetilde{G}}$	$H^\dagger H \widetilde{G}^A_{\mu\nu} G^{A\mu\nu}$	Q_{eB}	$(\bar{l}_p \sigma^{\mu\nu} e_r) H B_{\mu\nu}$	$Q^{(3)}_{Hl}$	$(H^\dagger i \overleftrightarrow{D}^I_\mu H)(\bar{l}_p \tau^I \gamma^\mu l_r)$
Q_{HW}					
$Q_{H\widetilde{W}}$					
Q_{HB}					
$Q_{H\widetilde{B}}$					
Q_{HWB}	$H^\dagger \tau^I H W^I_{\mu\nu} B^{\mu\nu}$	Q_{dW}	$(\bar{q}_p \sigma^{\mu\nu} d_r) \tau^I H W^I_{\mu\nu}$	Q_{Hd}	$(H^\dagger i \overleftrightarrow{D}_\mu H)(\bar{d}_p \gamma^\mu d_r)$
$Q_{H\widetilde{W}B}$	$H^\dagger \tau^I H \widetilde{W}^I_{\mu\nu} B^{\mu\nu}$	Q_{dB}	$(\bar{q}_p \sigma^{\mu\nu} d_r) H B_{\mu\nu}$	$Q_{Hud} + \text{h.c.}$	$i(\widetilde{H}^\dagger D_\mu H)(\bar{u}_p \gamma^\mu d_r)$

$8: (\bar{L}L)(\bar{L}L)$		$8: (\bar{R}R)(\bar{R}R)$		$8: (\bar{L}L)(\bar{R}R)$	
Q_{ll}	$(\bar{l}_p \gamma_\mu l_r)(\bar{l}_s \gamma^\mu l_t)$	Q_{ee}	$(\bar{e}_p \gamma_\mu e_r)(\bar{e}_s \gamma^\mu e_t)$	Q_{le}	$(\bar{l}_p \gamma_\mu l_r)(\bar{e}_s \gamma^\mu e_t)$
$Q^{(1)}_{qq}$	$(\bar{q}_p \gamma_\mu q_r)(\bar{q}_s \gamma^\mu q_t)$	Q_{uu}	$(\bar{u}_p \gamma_\mu u_r)(\bar{u}_s \gamma^\mu u_t)$	Q_{lu}	$(\bar{l}_p \gamma_\mu l_r)(\bar{u}_s \gamma^\mu u_t)$
$Q^{(3)}_{qq}$	$(\bar{q}_p \gamma_\mu \tau^I q_r)(\bar{q}_s \gamma^\mu \tau^I q_t)$	Q_{dd}	$(\bar{d}_p \gamma_\mu d_r)(\bar{d}_s \gamma^\mu d_t)$	Q_{ld}	$(\bar{l}_p \gamma_\mu l_r)(\bar{d}_s \gamma^\mu d_t)$
$Q^{(1)}_{lq}$	$(\bar{l}_p \gamma_\mu l_r)(\bar{q}_s \gamma^\mu q_t)$	Q_{eu}	$(\bar{e}_p \gamma_\mu e_r)(\bar{u}_s \gamma^\mu u_t)$	Q_{qe}	$(\bar{q}_p \gamma_\mu q_r)(\bar{e}_s \gamma^\mu e_t)$
$Q^{(3)}_{lq}$	$(\bar{l}_p \gamma_\mu \tau^I l_r)(\bar{q}_s \gamma^\mu \tau^I q_t)$	Q_{ed}	$(\bar{e}_p \gamma_\mu e_r)(\bar{d}_s \gamma^\mu d_t)$	$Q^{(1)}_{qu}$	$(\bar{q}_p \gamma_\mu q_r)(\bar{u}_s \gamma^\mu u_t)$
		$Q^{(1)}_{ud}$	$(\bar{u}_p \gamma_\mu u_r)(\bar{d}_s \gamma^\mu d_t)$	$Q^{(8)}_{qu}$	$(\bar{q}_p \gamma_\mu T^A q_r)(\bar{u}_s \gamma^\mu T^A u_t)$
		$Q^{(8)}_{ud}$	$(\bar{u}_p \gamma_\mu T^A u_r)(\bar{d}_s \gamma^\mu T^A d_t)$	$Q^{(1)}_{qd}$	$(\bar{q}_p \gamma_\mu q_r)(\bar{d}_s \gamma^\mu d_t)$
				$Q^{(8)}_{qd}$	$(\bar{q}_p \gamma_\mu T^A q_r)(\bar{d}_s \gamma^\mu T^A d_t)$

Effective Field Theories: AutoEFT

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PHYSICAL REVIEW D **108,** 055020 (2023)

Standard model effective field theory up to mass dimension 12

R. V. Harlander, T. Kempkens, and M. C. Schaaf

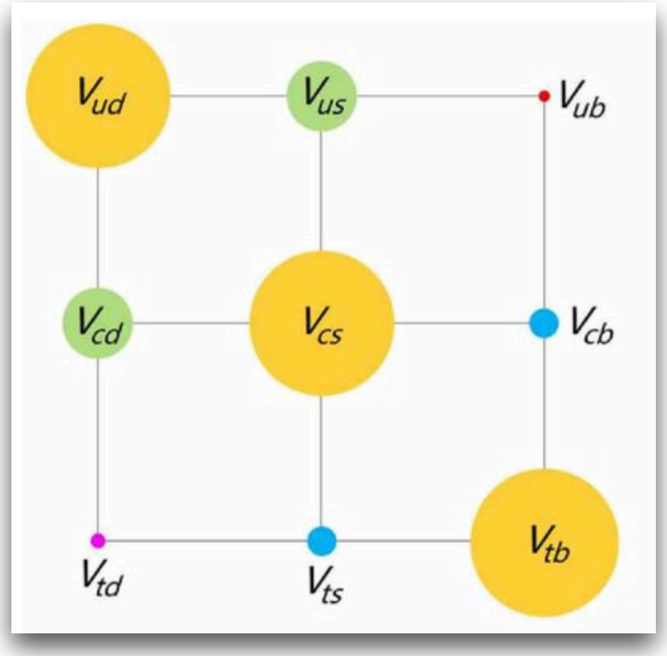
Institute for Theoretical Particle Physics and Cosmology, RWTH Aachen University, 52056 Aachen, Germany

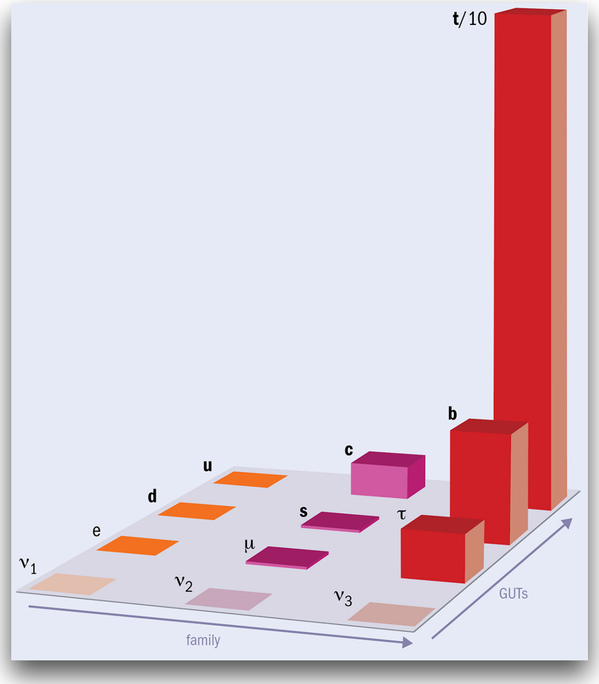
(Received 13 June 2023; accepted 14 August 2023; published 21 September 2023)

We present a complete and nonredundant basis of effective operators for the Standard Model effective field theory up to mass dimension 12 with three generations of fermions. We also include operators

Flavor Hierarchies

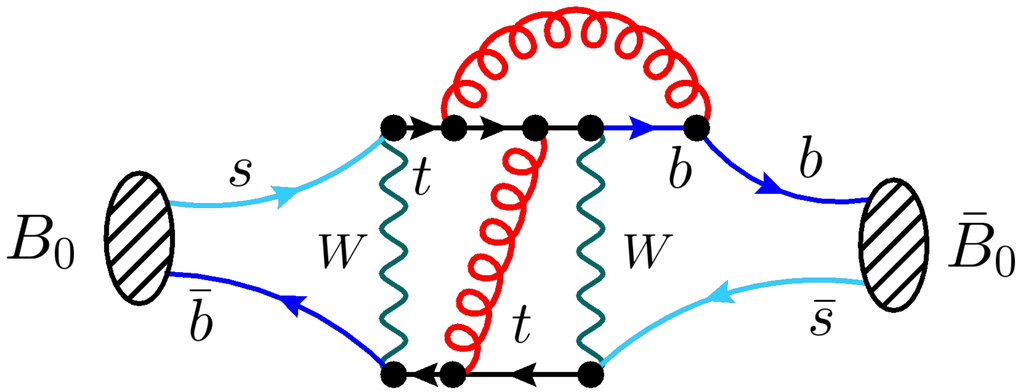
Flavor hierarchies:



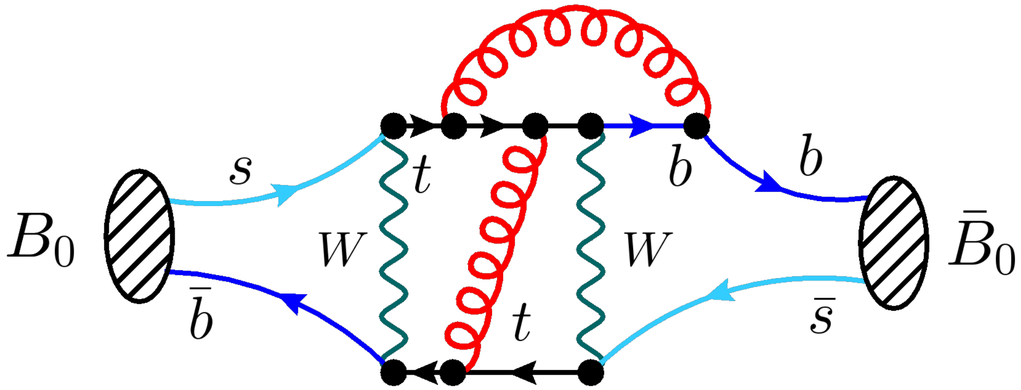


Reflected in SMEFT parameters?

Heavy-flavor hadrons

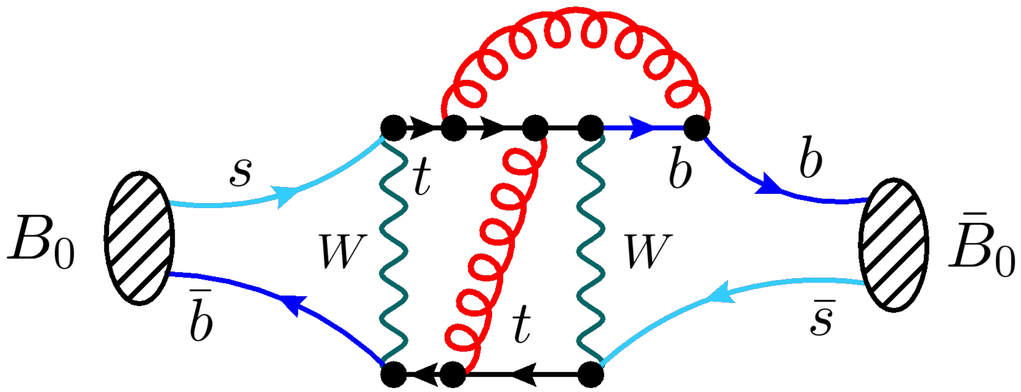


Heavy-flavor hadrons



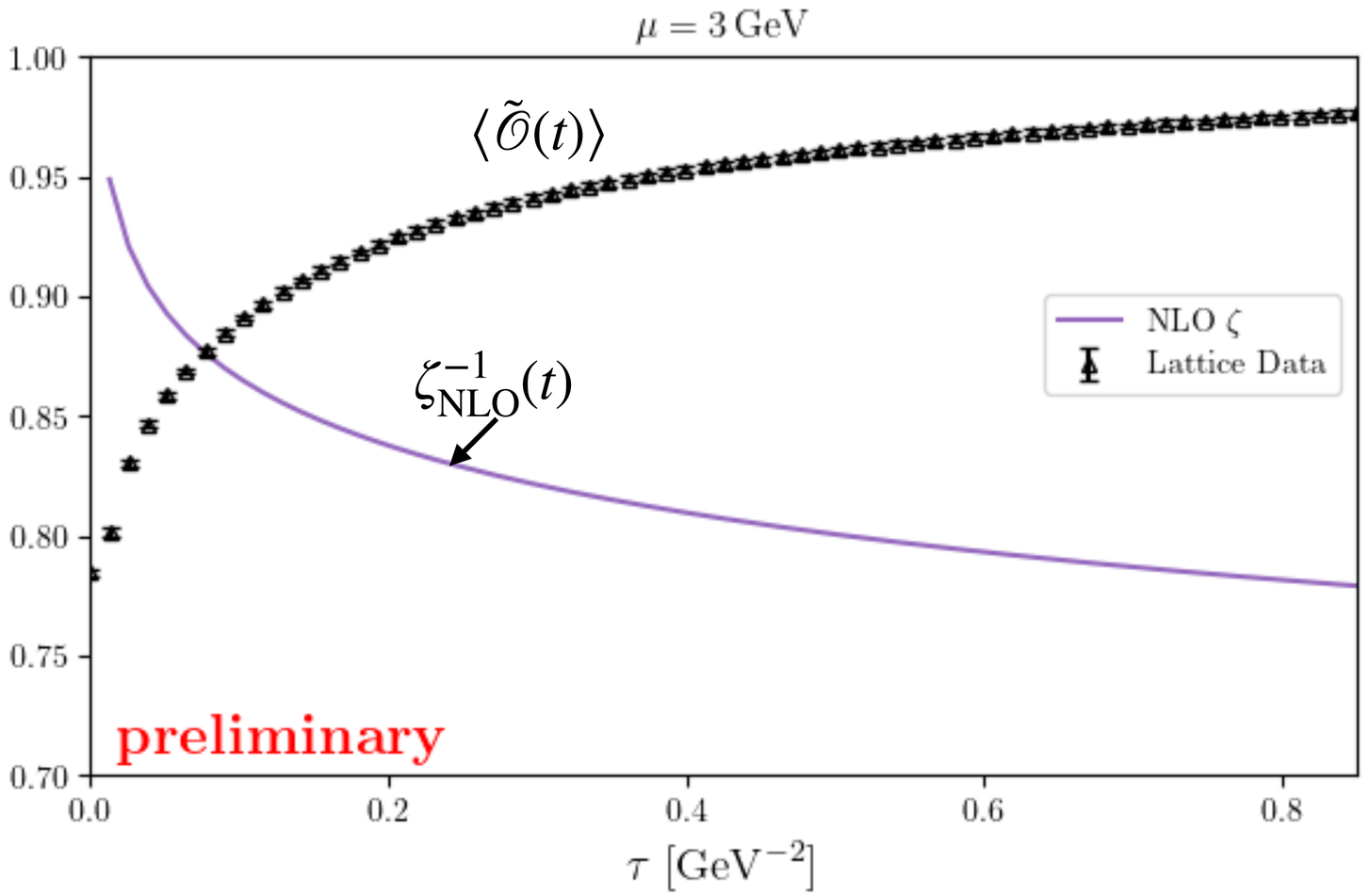
non-perturbative ⊗ perturbative

Heavy-flavor hadrons

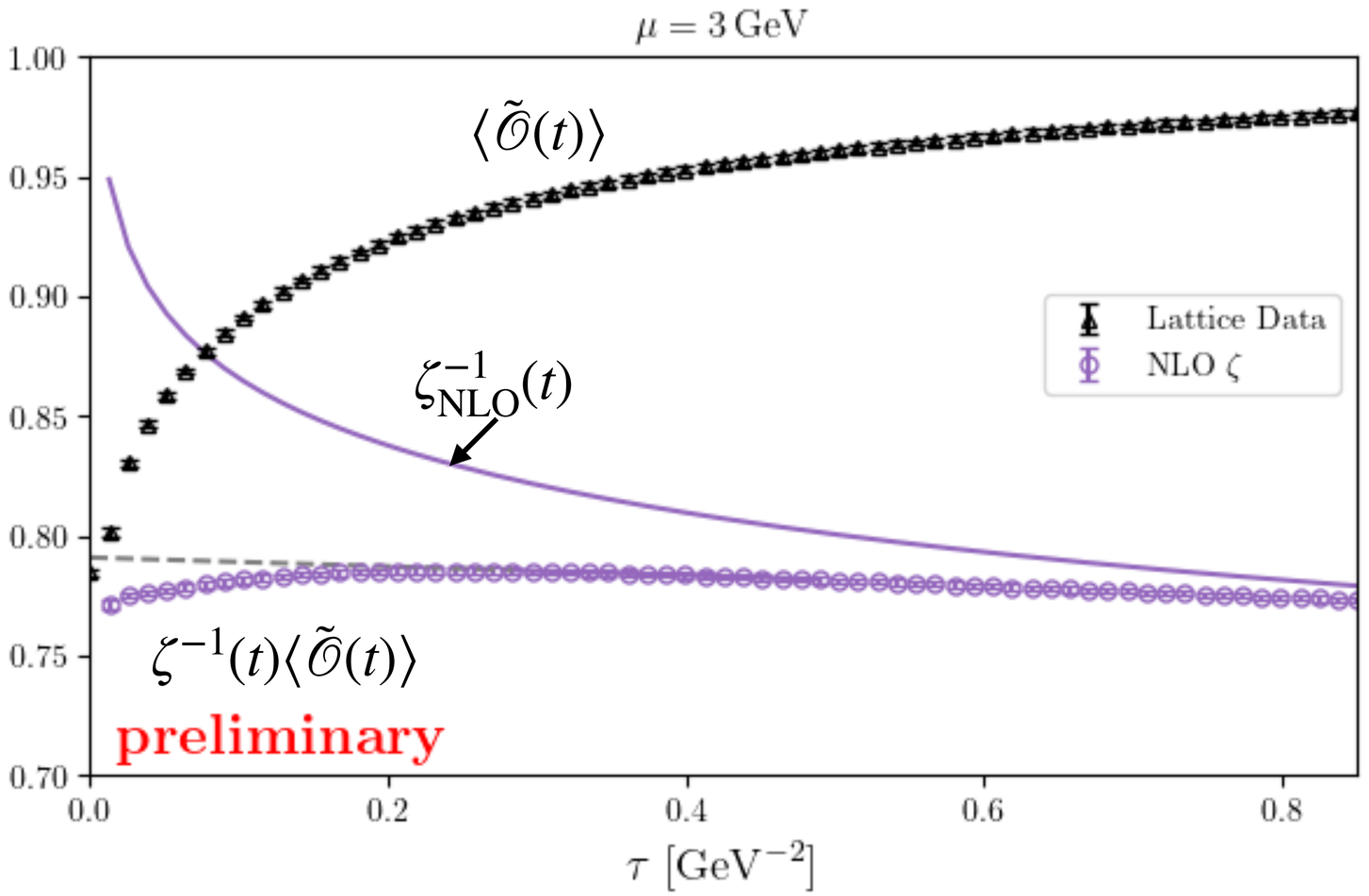


lattice ⊗ perturbative

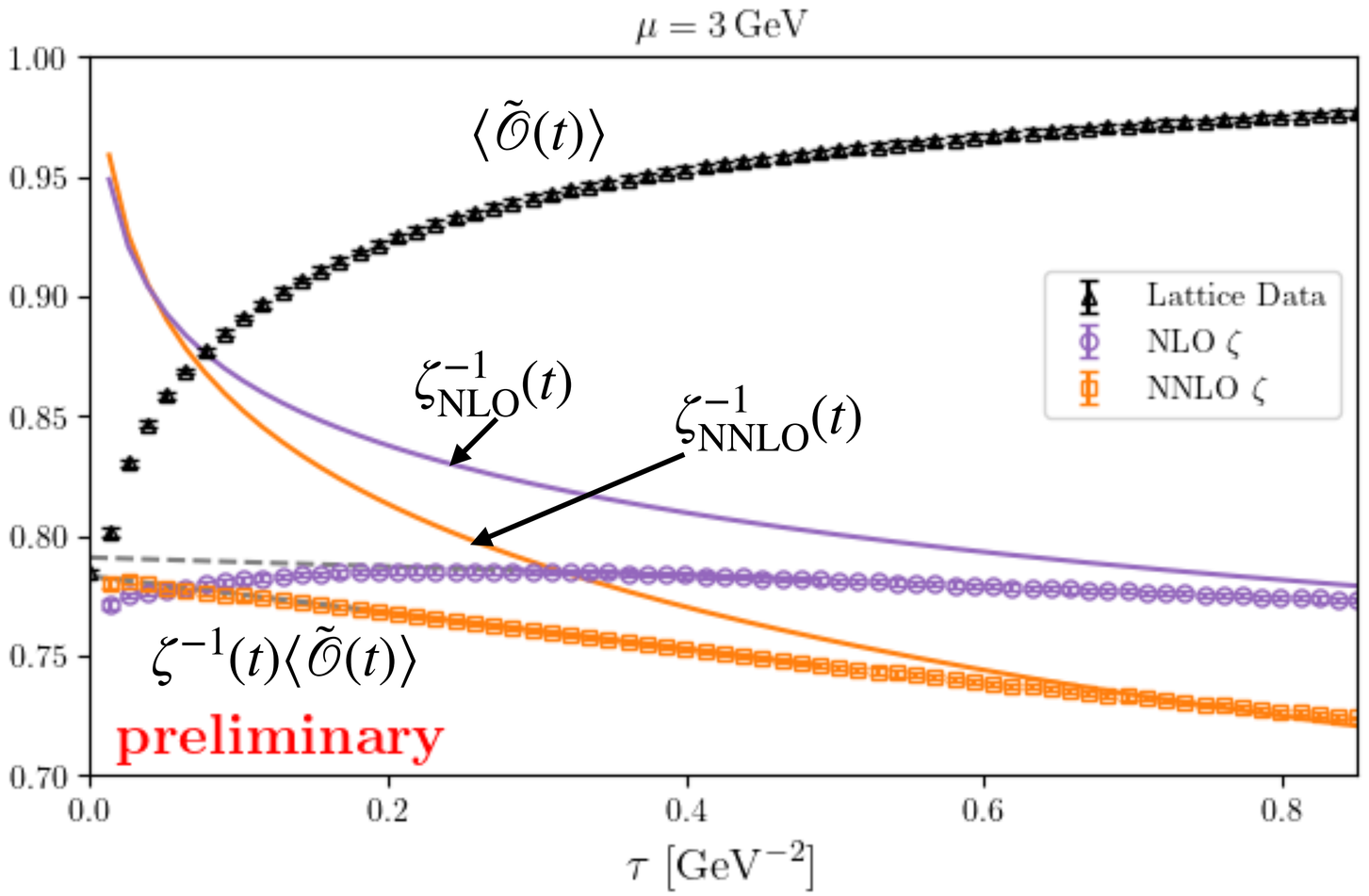
Bag parameter

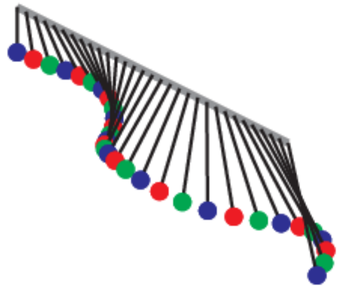


Bag parameter

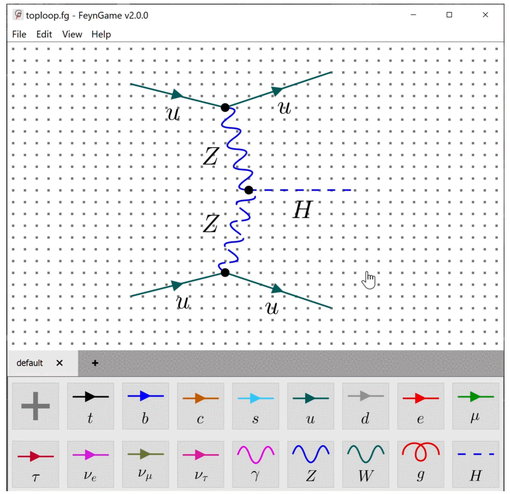


Bag parameter





aximate



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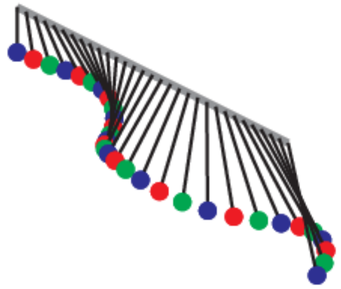
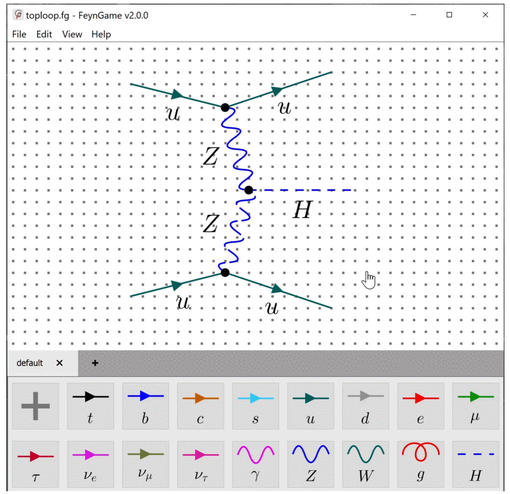
Podcast



aximate



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Podcast