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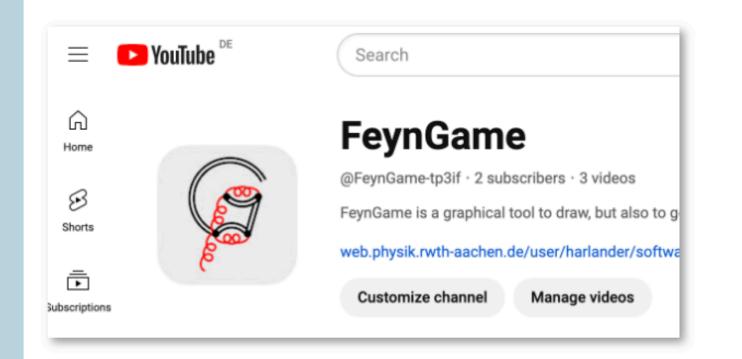
collaborations:

LHC and Philosophy

P H

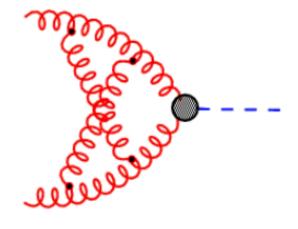
DFG RTG

Welcome! (deutsche Version)



What's new? (older news)

- Topics for bachelor theses
 25 Jan 2024
- FeynGame-2.1 released
- New preprint on quark bilinears in the gradient-flow scheme
 Nov 2023



Submit

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 <u>Brief CV</u>, and details about my <u>Research</u> and <u>Teaching</u> activities.

It is important to try to convey some of our excitement about physics to the general public, high-school students, or politicians. As you can see in the <u>Outreach</u> section of this page, I have been quite active in this field. If you are

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Bachelor Topics for summer term 2024

Click on the titles to see more details, or have a look at the slides of my short presentation on Friday, 26 January 2024.

To discuss in person, meet me in my office on Friday, 26 January 2024, at 3pm.

To apply, follow the instructions here, where you can also find topics from the other members of our institute.

- ▶ Renormalization of effective field theories
- ► The gradient flow for massive quarks
- ► Monte-Carlo speed-up for cross-section predictions
- ► Playing with Feynman diagrams

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Brief CV

Bachelor Topics for summer term 2024

Research

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Teaching

▼ Renormalization of effective field theories

Outrea

Effective Field Theories (EFTs) are used to describe physics beyond the Standard Model in a generic way. However, Confer already in the simplest case, the EFT derived from the Standard Model contains around 100 field operators. A proper analysis requires the renormalization of these operators, by which they can mix with each other. However, not all Softwa operators mix with one another if one is only interested in the first few terms of perturbation theory.

Press

The goal of this project is to systematically determine the sectors among the operators which mix with one another under renormalization.

collabor

LHC ar In this project, you will learn the basic concepts of Effective Field Theories and renormalization.

024 by RH

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Standard Model:

$$\mathcal{L} = -\frac{1}{4} F_{NN} F^{NN}
+ i \not F \not N \not Y
+ \chi_i y_{ij} \chi_j \not P + h.c.
+ |D_N \not P|^2 - V(\not P)$$

	$1: X^{3}$	2: E	I^6		3 : E	H^4D^2		5:	$\psi^2 H^3 + \text{h.c.}$	
Q_G	$f^{ABC}G^{A\nu}_{\mu}G^{B\rho}_{\nu}G^{C\mu}_{\rho}$	Q_H (E	$H^{\dagger}H)^3$	$Q_{H\square}$	$(H^{\dagger}$	$H)\Box(H^{\dagger}H)$	<i>!</i>)	Q_{eH}	$(H^\dagger H)(ar{l}_p e_r H)$	
$Q_{\widetilde{G}}$	$f^{ABC}\widetilde{G}_{\mu}^{A\nu}G_{\nu}^{B\rho}G_{\rho}^{C\mu}$	·		Q_{HD}	$\left(H^{\dagger}D_{\mu}\right)$	$_{\iota}Hig)^{st}\left(H^{\dagger}I ight)$	$O_{\mu}H$	Q_{uH}	$(H^{\dagger}H)(\bar{q}_{p}u_{r}\widetilde{H}%)=0$	
Q_W	$\epsilon^{IJK} W_{\mu}^{I\nu} W_{\nu}^{J\rho} W_{\rho}^{K\mu}$			•				Q_{dH}	$(H^{\dagger}H)(\bar{q}_{p}d_{r}H$	
$Q_{\widetilde{W}}$										
	$4:X^2H^2$	6	$: \psi^2 X F$	H + h.c.			7	$: \psi^2 H^2 I$	D	
Q_{H0}	$H^{\dagger}HG_{\mu\nu}^{A}G^{A\mu\nu}$	Q_{eW}	$(\bar{l}_p\sigma^{\mu u}$	$(e_r) au^IHV$	$W^I_{\mu u}$	$Q_{Hl}^{(1)}$		$(H^{\dagger}i\overleftarrow{I}$	$\overrightarrow{\partial}_{\mu}H)(\overline{l}_{p}\gamma^{\mu}l_{r})$	
$Q_{H\tilde{c}}$	$\widetilde{G} = H^\dagger H \widetilde{G}^A_{\mu u} G^{A \mu u}$	Q_{eB}	$(ar{l}_p\sigma^\mu$	$^{\iota\nu}e_r)HB$	$Q_{Hl}^{(3)}$			$(H^{\dagger}i\overleftrightarrow{D}_{\mu}^{I}H)(\bar{l}_{p}\tau^{I}\gamma^{\mu}l_{r})$		
Q_{HV}	$W = H^{\dagger}H W^I_{\mu u} W^{I \mu u}$	Q_{uG}	$(\bar{q}_p\sigma^{\mu u})$	$T^A u_r)\widetilde{H}$	$G^A_{\mu u}$	Q_{He}		$(H^{\dagger}i\overleftrightarrow{D}_{\mu}H)(\bar{e}_{p}\gamma^{\mu}e_{r})$		
$Q_{H\widetilde{V}}$	$_{\widetilde{V}}$ $H^{\dagger}H\widetilde{W}_{\mu u}^{I}W^{I\mu u}$	Q_{uW}	$(\bar{q}_p \sigma^{\mu\nu})$	$u_r)\tau^I\widetilde{H}$	$W^I_{\mu u}$	$Q_{Hq}^{(1)}$		$(H^{\dagger}i\overleftarrow{D}$	$(\bar{q}_p \gamma^\mu q_r)$	
Q_{HI}	$H^{\dagger}HB_{\mu\nu}B^{\mu\nu}$	Q_{uB}	$(\bar{q}_p\sigma^\mu$	$u^{\nu}u_r)\widetilde{H}H$	$B_{\mu u}$	$Q_{Hq}^{(3)}$		$(H^{\dagger}i\overleftrightarrow{D})$	$(\bar{q}_p \tau^I \gamma^\mu q_r)$	
Q_{HI}	$_{\widetilde{\mathbf{B}}} = H^{\dagger}H\widetilde{B}_{\mu u}B^{\mu u}$	Q_{dG}	$(\bar{q}_p \sigma^{\mu\nu})$	$T^A d_r) H$	$G^A_{\mu u}$	Q_{Hu}		$(H^{\dagger}i\overleftarrow{D}$	$(\bar{u}_p \gamma^\mu u_r)$	
Q_{HW}	· · · · · · · · · · · · · · · · · · ·	Q_{dW}	$(\bar{q}_p \sigma^{\mu\nu})$	$(d_r)\tau^I H$	$W^I_{\mu u}$	Q_{Hd}		$(H^{\dagger}i\overleftarrow{D}$	$(\bar{d}_p \gamma^\mu d_r)$	
$Q_{H\widetilde{W}}$	$\epsilon_B \mid H^\dagger \tau^I H \widetilde{W}_{\mu\nu}^I B^{\mu\nu}$	Q_{dB}	$(\bar{q}_p\sigma^\mu$	$u^{\nu}d_r)H B$	$B_{\mu u}$	Q_{Hud} +	h.c.	$i(\widetilde{H}^{\dagger}D$	$(\bar{u}_p \gamma^\mu d_r)$	
	$8:(\bar{L}L)(\bar{L}L)$		8:($\bar{R}R)(\bar{R}R)$?)		8:	$(\bar{L}L)(\bar{R}L)$	R)	
Q_{ll}	$(\bar{l}_p \gamma_\mu l_r)(\bar{l}_s \gamma^\mu l_t)$	Q_{ee}	$(\bar{e}$	$(\bar{e}_p \gamma_\mu e_r)(\bar{e}_r)$	$(e_s \gamma^\mu e_t)$	Q_{le}	($ar{l}_p \gamma_\mu l_r) (ar{d}_p \gamma_\mu l_r)$	$\bar{e}_s \gamma^\mu e_t)$	
$Q_{qq}^{(1)}$	$(\bar{q}_p \gamma_\mu q_r)(\bar{q}_s \gamma^\mu q_t)$	Q_{uu}	(\bar{u}_i)	$_p\gamma_\mu u_r)(\bar{u}_r)$	$\bar{u}_s \gamma^\mu u_t)$	Q_{lu}	($ar{l}_p \gamma_\mu l_r) (ar{\imath}$	$\bar{u}_s \gamma^\mu u_t)$	
$Q_{qq}^{(3)}$	$\left (\bar{q}_p \gamma_\mu \tau^I q_r) (\bar{q}_s \gamma^\mu \tau^I q_t) \right $	Q_{dd}	$(\bar{d}$	$(p\gamma_{\mu}d_r)(d_r)$	$\bar{l}_s \gamma^\mu d_t)$	Q_{ld}	($ar{l}_p \gamma_\mu l_r) (a$	$ar{d}_s \gamma^\mu d_t)$	
$Q_{lq}^{(1)}$	$(\bar{l}_p \gamma_\mu l_r)(\bar{q}_s \gamma^\mu q_t)$	Q_{eu}	(\bar{e}_i)	$_{p}\gamma_{\mu}e_{r})(\bar{u}% _{r})$	$(s_s \gamma^\mu u_t)$	Q_{qe}	($\bar{q}_p \gamma_\mu q_r)($	$\bar{e}_s \gamma^{\mu} e_t)$	

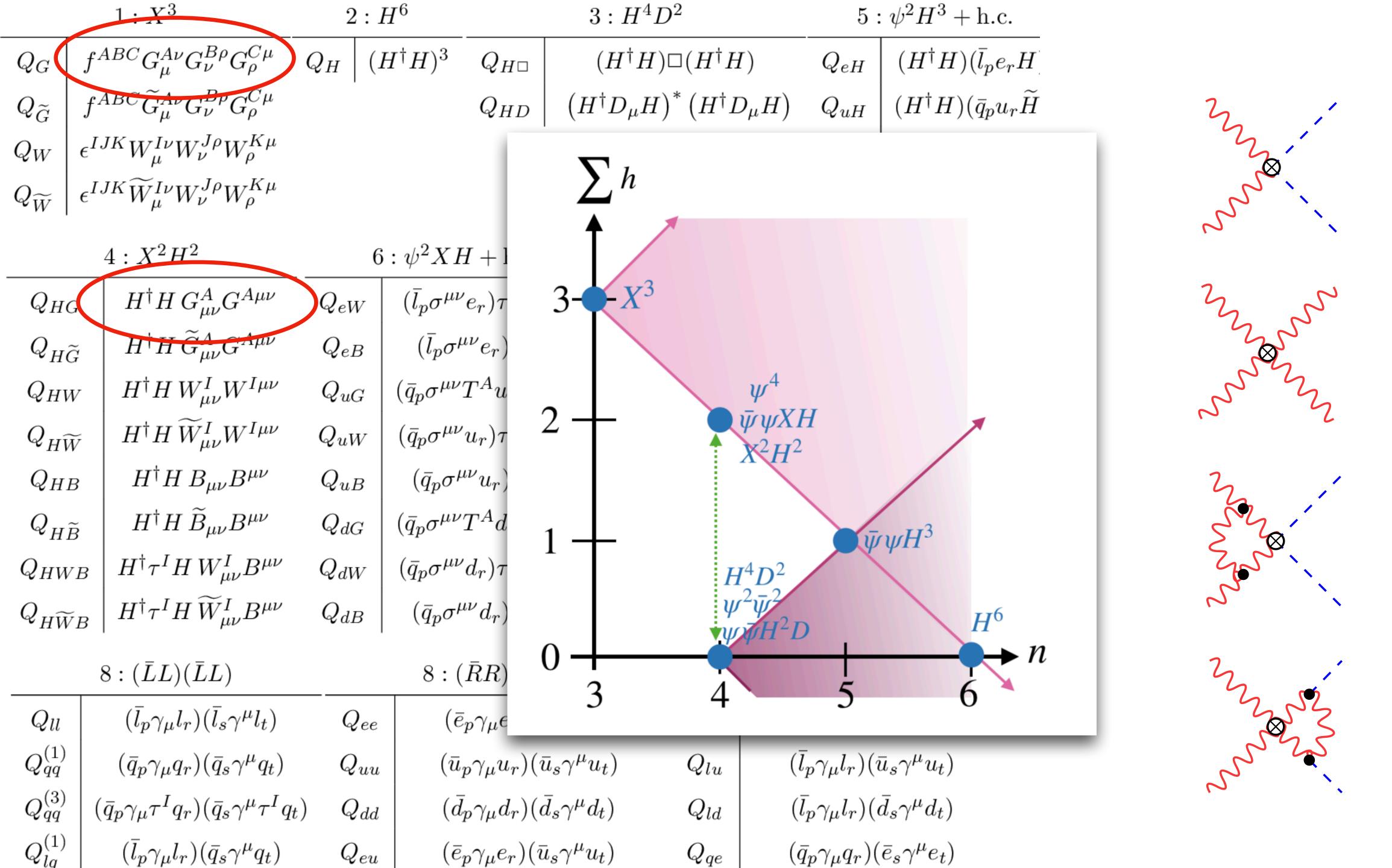
	$1: X^3$	2: E	I^6		3:I	H^4D^2		5:	$\psi^2 H^3 + \text{h.c.}$
Q_G	$f^{ABC}G_{\mu}^{A\nu}G_{\nu}^{B\rho}G_{\rho}^{C\mu}$	Q_H (E	$(I^{\dagger}H)^3$	$Q_{H\square}$	(H)	$^{\dagger}H)\Box(H$	$(T^{\dagger}H)$	Q_{eH}	$(H^\dagger H)(ar{l}_p e_r H)$
$Q_{\widetilde{G}}$	$f^{ABC}\widetilde{G}_{\mu}^{A\nu}G_{\nu}^{B\rho}G_{\rho}^{C\mu}$			Q_{HD}	$(H^{\dagger}D$	$_{\mu}H)^{*}(H$	$H^\dagger D_\mu H ig)$	Q_{uH}	$(H^{\dagger}H)(\bar{q}_{p}u_{r}\widetilde{H}%)=0$
Q_W	$\epsilon^{IJK} W_{\mu}^{I\nu} W_{\nu}^{J\rho} W_{\rho}^{K\mu}$							Q_{dH}	$(H^{\dagger}H)(\bar{q}_{p}d_{r}H$
$Q_{\widetilde{W}}$	$\epsilon^{IJK}\widetilde{W}_{\mu}^{I\nu}W_{\nu}^{J\rho}W_{\rho}^{K\mu}$								
	$4: X^2H^2$	6	$: \psi^2 X F$	H + h.c.			7	$: \psi^2 H^2 I$)
Q_{HG}	$H^{\dagger}HG_{\mu\nu}^{A}G^{A\mu\nu}$	Q_{eW}	$(\bar{l}_p \sigma^{\mu\nu}$	$(e_r) au^I H V$	$W^I_{\mu u}$	Q	(1) Hl	$(H^{\dagger}i\overleftarrow{I}$	$(\bar{l}_p \gamma^\mu l_r)$
$Q_{H\widetilde{G}}$	$H^{\dagger}H\widetilde{\widetilde{G}}_{\mu\nu}^{A}G^{A\mu u}$	Q_{eB}	$(ar{l}_p\sigma^\mu$	$^{\iota\nu}e_r)HB$	$8 \mu u$	Q	(3) Hl		$_{\mu}^{I}H)(\bar{l}_{p} au^{I}\gamma^{\mu}l_{r})$
Q_{HW}	$H^\dagger H W^I_{\mu u} W^{I \mu u}$	Q_{uG}	$(\bar{q}_p\sigma^{\mu\nu})$	$T^A u_r)\widetilde{H}$	$G^A_{\mu u}$	Q	He	$(H^{\dagger}i\overleftarrow{D}$	$(\bar{e}_p \gamma^\mu e_r)$
$Q_{H\widetilde{W}}$	$H^\dagger H \widetilde{W}^I_{\mu u} W^{I \mu u}$	Q_{uW}	$(\bar{q}_p\sigma^{\mu u}$	$u_r)\tau^I\widetilde{H}$	$W^I_{\mu u}$	Q	Hq	$(H^{\dagger}i\overleftarrow{D}$	$(\bar{q}_p \gamma^\mu q_r)$
Q_{HB}	$H^\dagger H B_{\mu u} B^{\mu u}$	Q_{uB}	$(\bar{q}_p\sigma^\mu$	$u^{\nu}u_r)\widetilde{H}H$	$B_{\mu u}$	Q	Hq	$(H^{\dagger}i\overleftrightarrow{D})$	$(\bar{q}_p \tau^I \gamma^\mu q_r)$
$Q_{H\widetilde{B}}$	$H^\dagger H\widetilde{B}_{\mu u}B^{\mu u}$	Q_{dG}	$(\bar{q}_p\sigma^{\mu\nu})$	$T^A d_r) H$	$G^A_{\mu u}$	Q_{\perp}	Hu		$(\bar{u}_p \gamma^\mu u_r)$
Q_{HW}	'	Q_{dW}	$(\bar{q}_p \sigma^{\mu\nu})$	$(d_r)\tau^I H$	$W^I_{\mu u}$	Q	Hd	$(H^{\dagger}i\overleftarrow{D}$	$(\bar{d}_p \gamma^\mu d_r)$
$Q_{H\widetilde{W}}$	$_{B} \mid H^{\dagger} \tau^{I} H \widetilde{W}_{\mu\nu}^{I} B^{\mu\nu}$	Q_{dB}	$(\bar{q}_p \sigma^\mu$	$d^{\mu}d_r)HE$	$B_{\mu u}$	Q_{Hud}	+ h.c.	$i(\widetilde{H}^{\dagger}D$	$(\mu H)(\bar{u}_p \gamma^\mu d_r)$
	$8:(\bar{L}L)(\bar{L}L)$		8:($\bar{R}R)(\bar{R}R)$	R)		8:	$(\bar{L}L)(\bar{R}L)$	R)
Q_{ll}	$(\bar{l}_p \gamma_\mu l_r)(\bar{l}_s \gamma^\mu l_t)$	Q_{ee}	$(\bar{e}$	$(p\gamma_{\mu}e_r)(ar{e}$	$(\bar{e}_s \gamma^\mu e_t)$	Q_i	le ($ar{l}_p \gamma_\mu l_r) (ar{\epsilon}$	$ar{e}_s \gamma^\mu e_t)$
$Q_{qq}^{(1)}$	$(\bar{q}_p \gamma_\mu q_r)(\bar{q}_s \gamma^\mu q_t)$	Q_{uu}	$ $ (\bar{u}_{l})	$_{p}\gamma_{\mu}u_{r})(\bar{\imath}% _{p})$	$\bar{u}_s \gamma^\mu u_t)$	Q_l	u ($\overline{l}_p \gamma_\mu l_r) (\overline{\imath}$	$(u_s \gamma^\mu u_t)$
$Q_{qq}^{(3)}$	$\left (\bar{q}_p \gamma_\mu \tau^I q_r) (\bar{q}_s \gamma^\mu \tau^I q_t) \right $	Q_{dd}	$ $ (\bar{d}_{j})	$(\gamma_{\mu}d_r)(d_r)$	$ar{l}_s \gamma^\mu d_t)$	Q_l	dd ($ar{l}_p \gamma_\mu l_r) (ar{d}_p)$	$ar{l}_s \gamma^\mu d_t)$
$Q_{lq}^{(1)}$	$(\bar{l}_p \gamma_\mu l_r)(\bar{q}_s \gamma^\mu q_t)$	Q_{eu}	$(ar{e}_i$	$_{p}\gamma_{\mu}e_{r})(\bar{u}% _{\mu})$	$u_s \gamma^\mu u_t)$	Q_{ϵ}	$_{qe}$ ($ar{q}_p \gamma_\mu q_r) ($	$\bar{e}_s \gamma^{\mu} e_t)$

	$1:X^3$	2:H	76		3 : E	H^4D^2		5:	$\psi^2 H^3 + \text{h.c.}$	
Q_G .	$f^{ABC}G^{A\nu}_{\mu}G^{B\rho}_{\nu}G^{C\mu}_{\rho}$	$Q_H \mid (H$	$(H^{\dagger}H)^3$	$Q_{H\square}$	$(H^{\dagger}$	$H)\Box(H^{\dagger}H$	<i>[</i>)	Q_{eH}	$(H^\dagger H)(ar{l}_p e_r H)$	
$Q_{\widetilde{G}}$.	$f^{ABC}\widetilde{G}_{\mu}^{A u}G_{ u}^{B ho}G_{ ho}^{C\mu}$			Q_{HD}	$(H^\dagger D_\mu$	$_{\iota}H\big)^{st}\left(H^{\dagger}L\right)$	$O_{\mu}H$	Q_{uH}	$(H^{\dagger}H)(\bar{q}_{p}u_{r}\widetilde{H}%)=0$	
$Q_W \mid \epsilon$	$\epsilon^{IJK}W_{\mu}^{I u}W_{ u}^{J ho}W_{ ho}^{K\mu}$							Q_{dH}	$(H^{\dagger}H)(\bar{q}_{p}d_{r}H$	
$Q_{\widetilde{W}} \mid \epsilon$	$\epsilon^{IJK}\widetilde{W}_{\mu}^{I u}W_{\nu}^{J ho}W_{ ho}^{K\mu}$									
	$4: X^2H^2$	6 :	$\psi^2 X H$	I + h.c.			7	$: \psi^2 H^2 I$	D	
Q_{HG}	$H^{\dagger}HG_{\mu\nu}^{A}G^{A\mu\nu}$	Q_{eW}	$(\bar{l}_p\sigma^{\mu u}$	$(e_r)\tau^I H$	$W^{I}_{\mu\nu}$	$Q_{Hl}^{(1)}$		$(H^{\dagger}i\overleftarrow{I}$	$\overrightarrow{\partial}_{\mu}H)(\overline{l}_{p}\gamma^{\mu}l_{r})$	
$Q_{H\widetilde{G}}$	$H^{\dagger}H\widetilde{\widetilde{G}}_{\mu\nu}^{A}G^{A\mu u}$	Q_{eB}	$(ar{l}_p\sigma^{\mu}$	$e^{\nu}e_r)HE$	$3\mu u$	$Q_{Hl}^{(3)}$		$(H^{\dagger}i\overleftrightarrow{D}$	$_{\mu}^{I}H)(\bar{l}_{p} au^{I}\gamma^{\mu}l_{r})$	
Q_{HW}	$H^\dagger H W^I_{\mu u} W^{I \mu u}$	Q_{uG}	$(ar{q}_p\sigma^{\mu u})$	$(\Gamma^A u_r)\widetilde{H}$	$G^A_{\mu u}$	Q_{He}		$(H^{\dagger}i\overleftarrow{L}$	$(\bar{e}_p \gamma^\mu e_r)$	
$Q_{H\widetilde{W}}$	$_{7} \mid H^{\dagger}H \widetilde{W}_{\mu u}^{I} W^{I \mu u} \qquad Q_{uW} \mid Q$			$(\bar{q}_p \sigma^{\mu\nu} u_r) \tau^I \widetilde{H} W^I_{\mu\nu}$			$Q_{Hq}^{(1)}$		$(H^{\dagger}i\overleftrightarrow{D}_{\mu}H)(\bar{q}_{p}\gamma^{\mu}q_{r})$	
Q_{HB}	$H^\dagger H B_{\mu u} B^{\mu u}$	Q_{uB}	$(\bar{q}_p\sigma^\mu$	$^{\nu}u_{r})\widetilde{H}$ I	$B_{\mu u}$	$Q_{Hq}^{(3)}$		$(H^{\dagger}i\overleftrightarrow{D})$	$(\bar{q}_p \tau^I \gamma^\mu q_r)$	
$Q_{H\widetilde{B}}$	$H^\dagger H\widetilde{B}_{\mu u}B^{\mu u}$	Q_{dG}	$(\bar{q}_p\sigma^{\mu u})$	$T^A d_r) H$	$G^A_{\mu u}$	Q_{Hu}		$(H^{\dagger}i\overleftarrow{D}$	$(\bar{u}_p \gamma^\mu u_r)$	
Q_{HWB}	'	Q_{dW}	$(\bar{q}_p\sigma^{\mu\nu})$	$d_r)\tau^I H$	$W^I_{\mu u}$	Q_{Hd}		$(H^{\dagger}i\overleftarrow{D}$	$(\bar{d}_p \gamma^\mu d_r)$	
$Q_{H\widetilde{W}B}$	$H^{\dagger} au^I H \widetilde{W}^I_{\mu u} B^{\mu u}$	Q_{dB}	$(ar{q}_p\sigma^\mu$	$^{\nu}d_r)HI$	$B_{\mu u}$	Q_{Hud} + 1	h.c.	$i(\widetilde{H}^{\dagger}D$	$(\bar{u}_p \gamma^\mu d_r)$	
	$8:(\bar{L}L)(\bar{L}L)$		8:(.	$\bar{R}R)(\bar{R}I$	R)		8:	$(\bar{L}L)(\bar{R}L)$	R)	
Q_{ll}	$(\bar{l}_p \gamma_\mu l_r)(\bar{l}_s \gamma^\mu l_t)$	Q_{ee}	$(\bar{e}_{l}$	$_{p}\gamma_{\mu}e_{r})(ar{\epsilon}% _{p})$	$\bar{e}_s \gamma^\mu e_t)$	Q_{le}	($(ar{l}_p\gamma_\mu l_r)(ar{l}_p\gamma_\mu l_r)$	$\bar{e}_s \gamma^\mu e_t)$	
$Q_{qq}^{(1)}$	$(\bar{q}_p \gamma_\mu q_r)(\bar{q}_s \gamma^\mu q_t)$	Q_{uu}	(\bar{u}_p)	$\gamma_{\mu}u_{r})(i$	$\bar{u}_s \gamma^\mu u_t)$	Q_{lu}	($(ar{l}_p\gamma_\mu l_r)(ar{l}_p)$	$\bar{u}_s \gamma^\mu u_t)$	
$Q_{qq}^{(3)}$	$(\bar{q}_p \gamma_\mu \tau^I q_r)(\bar{q}_s \gamma^\mu \tau^I q_t)$	Q_{dd}	$(ar{d}_{p}$	$(\gamma_{\mu}d_r)(d_r)$	$\bar{d}_s \gamma^\mu d_t)$	Q_{ld}	($(ar{l}_p\gamma_\mu l_r)(a$	$\overline{d}_s \gamma^\mu d_t)$	
$Q_{lq}^{(1)}$	$(\bar{l}_p \gamma_\mu l_r)(\bar{q}_s \gamma^\mu q_t)$	Q_{eu}	$(\bar{e}_p$	$(\gamma_{\mu}e_r)(ar{u}$	$u_s \gamma^\mu u_t)$	Q_{qe}	($\bar{q}_p \gamma_\mu q_r)($	$\bar{e}_s \gamma^{\mu} e_t)$	

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	$1: X^3$	2: H	I^6		3 : F	H^4D^2	2		5:	$\psi^2 H^3 + \text{h.c.}$
Q_G	$f^{ABC}G^{A\nu}_{\mu}G^{B\rho}_{\nu}G^{C\mu}_{\rho}$	Q_H (E	$(I^{\dagger}H)^3$	$Q_{H\square}$	$(H^{\dagger}$	$H)$ \Box	$\Im(H^\dagger H$)	Q_{eH}	$(H^\dagger H)(ar{l}_p e_r H)$
$Q_{\widetilde{G}}$	$f^{ABC}\widetilde{G}_{\mu}^{A\nu}G_{\nu}^{B\rho}G_{\rho}^{C\mu}$			Q_{HD}	$(H^\dagger D_\mu$	$_{u}H)^{*}$	$(H^{\dagger}D)$	(μH)	Q_{uH}	$(H^{\dagger}H)(\bar{q}_{p}u_{r}\widetilde{H}%)=0$
Q_W	$\epsilon^{IJK}W_{\mu}^{I\nu}W_{\nu}^{J\rho}W_{\rho}^{K\mu}$								Q_{dH}	$(H^{\dagger}H)(\bar{q}_{p}d_{r}H$
$Q_{\widetilde{W}}$	$\epsilon^{IJK}\widetilde{W}_{\mu}^{I\nu}W_{\nu}^{J\rho}W_{\rho}^{K\mu}$									
	$4: X^2H^2$	6	$: \psi^2 X H$ -	+ h.c.				7	$\psi^2H^2H^2$	D
Q_{HG}	$H^\dagger HG^A_{\mu u}G^{A\mu u}$	Q_{eW}	$(\bar{l}_p \sigma^{\mu\nu} e_r$	$() au^IHV$	$W^I_{\mu\nu}$		$Q_{Hl}^{(1)}$		$(H^{\dagger}i\overleftarrow{I}$	$(\bar{l}_p \gamma^\mu l_r)$
$Q_{H\widetilde{G}}$	$H^{\dagger}H\widetilde{\widetilde{G}}_{\mu u}^{A}G^{A\mu u}$	Q_{eB}	$(\bar{l}_p\sigma^{\mu u}\epsilon$	$e_r)HB$	$B_{\mu u}$		$Q_{Hl}^{(3)}$			$_{\mu}^{I}H)(\bar{l}_{p} au^{I}\gamma^{\mu}l_{r})$
Q_{HW}	$H^{\dagger}HW_{\mu\nu}^{I}W^{I\mu\nu}$	Q_{uG}	$(\bar{q}_p\sigma^{\mu\nu}T^p)$	$^{4}u_{r})\widetilde{H}$	$G^A_{\mu u}$		Q_{He}			$(\bar{e}_p \gamma^\mu e_r)$
$Q_{H\widetilde{W}}$	$H^{\dagger}H\widetilde{W}_{\mu\nu}^{I}W^{I\mu\nu}$	Q_{uW}	$(\bar{q}_p \sigma^{\mu\nu} u_r$	$\cdot) \tau^I \widetilde{H}$	$W^I_{\mu u}$		$Q_{Hq}^{(1)}$			$(\bar{q}_p \gamma^\mu q_r)$
Q_{HB}	$H^{\dagger}HB_{\mu\nu}B^{\mu\nu}$	Q_{uB}	$(\bar{q}_p\sigma^{\mu\nu}u$	$(u_r)\widetilde{H} B$	$B_{\mu u}$		$Q_{Hq}^{(3)}$			$(\bar{q}_p \tau^I \gamma^\mu q_r)$
$Q_{H\widetilde{B}}$	· ·	Q_{dG}	$(\bar{q}_p\sigma^{\mu\nu}T^2)$	$^{A}d_{r})H$	$G^A_{\mu u}$		Q_{Hu}			$(\bar{u}_p \gamma^\mu u_r)$
Q_{HWI}	,	Q_{dW}	$(\bar{q}_p \sigma^{\mu\nu} d_r$	$(\tau^I H)$	$W^I_{\mu u}$		Q_{Hd}		$(H^{\dagger}i\overleftarrow{D}$	$(\bar{d}_p \gamma^\mu d_r)$
$Q_{H\widetilde{W}I}$	$_{B} \mid H^{\dagger} \tau^{I} H \widetilde{W}_{\mu \nu}^{I} B^{\mu \nu}$	Q_{dB}	$(\bar{q}_p\sigma^{\mu\nu}\epsilon$	$d_r)H E$	$B_{\mu u}$	Q_H	Iud + 1	ı.c.	$i(\widetilde{H}^{\dagger}D$	$(\bar{u}_p \gamma^\mu d_r)$
	$8:(\bar{L}L)(\bar{L}L)$		$8:(\bar{R}.$	$R)(\bar{R}I$?)			8:	$(\bar{L}L)(\bar{R}L)$	R)
Q_{ll}	$(\bar{l}_p \gamma_\mu l_r)(\bar{l}_s \gamma^\mu l_t)$	Q_{ee}	$(\bar{e}_p \gamma$	$(\mu e_r)(ar{e}$	$(\bar{e}_s \gamma^\mu e_t)$		Q_{le}		$(ar{l}_p\gamma_\mu l_r)(ar{l}_p\gamma_\mu l_r)$	$ar{e}_s \gamma^\mu e_t)$
$Q_{qq}^{(1)}$	$(\bar{q}_p \gamma_\mu q_r)(\bar{q}_s \gamma^\mu q_t)$	Q_{uu}	$(\bar{u}_p \gamma_p)$	$(u_{\mu}u_{r})(\bar{u}_{\mu}u_{r})$	$\bar{u}_s \gamma^\mu u_t)$		Q_{lu}	($(ar{l}_p\gamma_\mu l_r)(ar{l}_p)$	$\bar{u}_s \gamma^\mu u_t)$
$Q_{qq}^{(3)}$	$(\bar{q}_p \gamma_\mu \tau^I q_r)(\bar{q}_s \gamma^\mu \tau^I q_t)$	Q_{dd}	$(\bar{d}_p \gamma$	$(\mu d_r)(a$	$\bar{l}_s \gamma^\mu d_t)$		Q_{ld}	($(ar{l}_p\gamma_\mu l_r)(a$	$\bar{d}_s \gamma^\mu d_t)$
$Q_{lq}^{(1)}$	$(\bar{l}_p \gamma_\mu l_r)(\bar{q}_s \gamma^\mu q_t)$	Q_{eu}	$(\bar{e}_p \gamma$	$(u_{\mu}e_r)(\bar{u}$	$u_s \gamma^{\mu} u_t)$		Q_{qe}	($(\bar{q}_p \gamma_\mu q_r)($	$\bar{e}_s \gamma^{\mu} e_t)$

	$1: X^3$	2: E	H^6	3:H	I^4D^2	5:	$\psi^2 H^3 + \text{h.c.}$
Q_G	$f^{ABC}G^{A\nu}_{\mu}G^{B\rho}_{\nu}G^{C\mu}_{\rho}$	Q_H (E	$(H^{\dagger}H)^3$ $Q_{H\Box}$	$(H^{\dagger}$	$H)\Box(H^{\dagger}H)$	Q_{eH}	$(H^\dagger H)(ar{l}_p e_r H)$
$Q_{\widetilde{G}}$	$f^{ABC}\widetilde{G}_{\mu}^{A\nu}G_{\nu}^{B\rho}G_{\rho}^{C\mu}$		Q_{HD}	$(H^{\dagger}D_{\mu}$	$(H)^* (H^\dagger D_\mu H)$	Q_{uH}	$(H^{\dagger}H)(\bar{q}_{p}u_{r}\widetilde{H})$
Q_W	$\epsilon^{IJK}W_{\mu}^{I u}W_{ u}^{J ho}W_{ ho}^{K\mu}$					Q_{dH}	$(H^{\dagger}H)(\bar{q}_{p}d_{r}H$
$Q_{\widetilde{W}}$ \mid ϵ	$\epsilon^{IJK}\widetilde{W}_{\mu}^{I u}W_{\nu}^{J ho}W_{ ho}^{K\mu}$						
	$4: X^2H^2$	6	$: \psi^2 X H + \text{h.c.}$			$7:\psi^2H^2I$	D
Q_{HG}	$H^{\dagger}HG_{\mu\nu}^{A}G^{A\mu\nu}$	Q_{eW}	$(\bar{l}_p \sigma^{\mu\nu} e_r) \tau^I H$	$W^I_{\mu u}$	$Q_{Hl}^{(1)}$	$(H^{\dagger}i\overleftarrow{I}$	$\overrightarrow{\partial}_{\mu}H)(\overline{l}_{p}\gamma^{\mu}l_{r})$
$Q_{H\widetilde{G}}$	$H^{\dagger}H\widetilde{\widetilde{G}}_{\mu\nu}^{A}G^{A\mu u}$	Q_{eB}	$(\bar{l}_p\sigma^{\mu\nu}e_r)HE$		$Q_{Hl}^{(3)}$	$(H^{\dagger}i\overleftrightarrow{D})$	$(\bar{l}_p T^I \gamma^\mu l_r)$
Q_{HW}		Q_{uG}	$(\bar{q}_p \sigma^{\mu\nu} T^A u_r) \widetilde{H}$	$G^A_{\mu u}$	Q_{He}		$(\bar{e}_p \gamma^\mu e_r)$
$Q_{H\widetilde{W}}$	$H^{\dagger}H\widetilde{W}_{\mu\nu}^{I}W^{I\mu\nu}$	Q_{uW}	$(\bar{q}_p \sigma^{\mu\nu} u_r) \tau^I \widetilde{H}$	$W^I_{\mu u}$	$Q_{Hq}^{(1)}$		$(\bar{q}_p \gamma^\mu q_r)$
Q_{HB}	$H^{\dagger}HB_{\mu\nu}B^{\mu\nu}$	Q_{uB}	$(\bar{q}_p\sigma^{\mu u}u_r)\widetilde{H}$	$B_{\mu\nu}$	$Q_{Hq}^{(3)}$	$(H^{\dagger}i\overleftrightarrow{D})$	$_{\mu}^{I}H)(\bar{q}_{p} au^{I}\gamma^{\mu}q_{r})$
$Q_{H\widetilde{B}}$	$H^\dagger H\widetilde{B}_{\mu u}B^{\mu u}$	Q_{dG}	$(\bar{q}_p \sigma^{\mu\nu} T^A d_r) H$	$G^A_{\mu u}$	Q_{Hu}		$(\bar{u}_p \gamma^\mu u_r)$
Q_{HWB}	· '	Q_{dW}	$(\bar{q}_p \sigma^{\mu\nu} d_r) \tau^I H$	$W^I_{\mu\nu}$	Q_{Hd}	$(H^{\dagger}i\overleftarrow{D}$	$(\bar{d}_p \gamma^\mu d_r)$
$Q_{H\widetilde{W}B}$	$_{\rm B} \mid H^{\dagger} \tau^I H \widetilde{W}_{\mu\nu}^I B^{\mu\nu}$	Q_{dB}	$(\bar{q}_p\sigma^{\mu\nu}d_r)H$ I	$B_{\mu u}$	$Q_{Hud} + \text{h.c}$	$i(\widetilde{H}^{\dagger}D)$	$(\bar{u}_p \gamma^\mu d_r)$
	$8:(\bar{L}L)(\bar{L}L)$		$8:(\bar{R}R)(\bar{R}R)$	R)		$8:(ar{L}L)(ar{R})$	R)
Q_{ll}	$(\bar{l}_p \gamma_\mu l_r)(\bar{l}_s \gamma^\mu l_t)$	Q_{ee}	$(\bar{e}_p \gamma_\mu e_r)(\bar{e}_p \gamma_\mu e_r)$	$ar{e}_s \gamma^\mu e_t)$	Q_{le}	$(\bar{l}_p\gamma_\mu l_r)(c$	$\bar{e}_s \gamma^{\mu} e_t)$
$Q_{qq}^{(1)}$	$(\bar{q}_p \gamma_\mu q_r)(\bar{q}_s \gamma^\mu q_t)$	Q_{uu}	$(\bar{u}_p \gamma_\mu u_r)(\bar{u}_p \gamma_\mu u_r)$	$\bar{u}_s \gamma^{\mu} u_t)$	Q_{lu}	$(ar{l}_p\gamma_\mu l_r)(ar{l}_p)$	$\bar{u}_s \gamma^\mu u_t)$
$Q_{qq}^{(3)}$	$(\bar{q}_p \gamma_\mu \tau^I q_r)(\bar{q}_s \gamma^\mu \tau^I q_t)$	Q_{dd}	$(\bar{d}_p \gamma_\mu d_r)(d_p \gamma_\mu d_r)$	$\bar{d}_s \gamma^\mu d_t)$	Q_{ld}	$(ar{l}_p\gamma_\mu l_r)(\epsilon$	$\bar{d}_s \gamma^\mu d_t)$
$Q_{lq}^{(1)}$	$(\bar{l}_p \gamma_\mu l_r)(\bar{q}_s \gamma^\mu q_t)$	Q_{eu}	$(\bar{e}_p \gamma_\mu e_r)(\bar{\imath}$	$(u_s \gamma^{\mu} u_t)$	Q_{qe}	$(\bar{q}_p \gamma_\mu q_r)($	$(\bar{e}_s \gamma^{\mu} e_t)$



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Click on the titles to see more details, or have a look at the slides of my short presentation on Friday, 26 January 2024.

To discuss in person, meet me in my office on Friday, 26 January 2024, at 3pm.

To apply, follow the instructions here, where you can also find topics from the other members of our institute.

- ▶ Renormalization of effective field theories
- ► The gradient flow for massive quarks
- ► Monte-Carlo speed-up for cross-section predictions
- ► Playing with Feynman diagrams

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▼ The gradient flow for massive quarks

The gradient flow formalism provides a way relate perturbative calculations to lattice calculations in QCD. Up to now, the perturbative calculations have been mostly restricted to massless quarks. However, quark mass effects can become important for large flow times.

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The goal of this project is to study the gradient flow of QCD with massive quarks. At lowest order, this can be studied analytically, which shall then be cross-checked with a numerical and an approximate analytical approach.

You will learn:

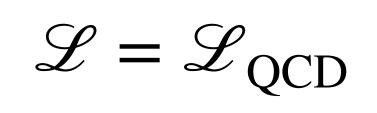
- The general method of the gradient flow.
- Approaches to calculating non-standard Feynman integrals.

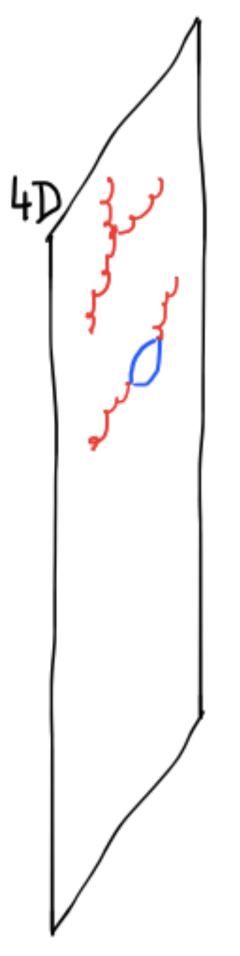
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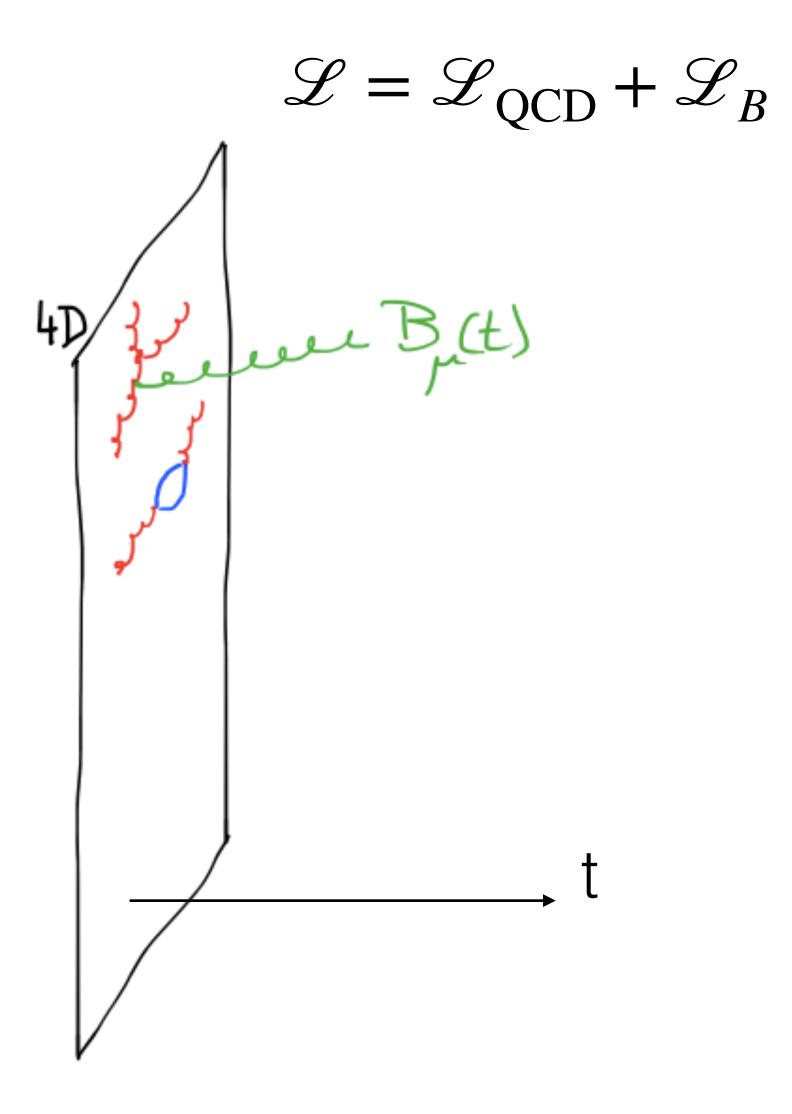
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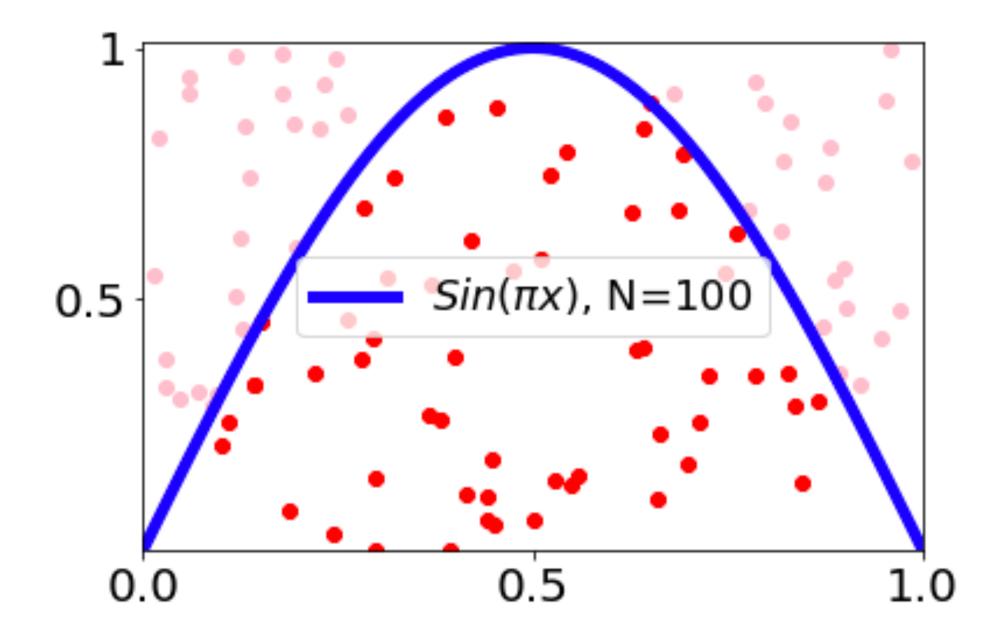
▼ Monte-Carlo speed-up for cross-section predictions

Cross-section calculations play a central role in particle physics. Numerical integration is vital for making these Conference prediction. The most commonly used method for integration is the Monte-Carlo integration. As the integrals get more and more complicated, the basic Monte-Carlo integration comes to its limits and has to be improved by variance reduction. Commonly used are importance sampling techniques like the VEGAS algorithm but recently also Machine Learning methods in the form of density estimators began to gain attention in the community.

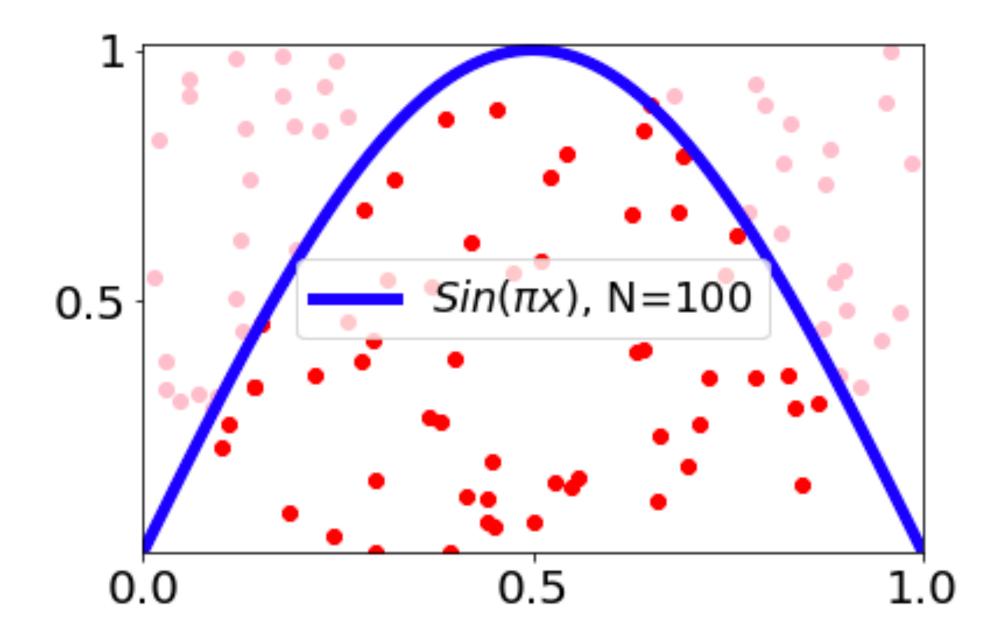
The goal of this project is to study and implement variance reduction methods into our Monte-Carlo integrator. You will learn the basics of Monte-Carlo integration and variance reduction and gain insights into how cross sections are calculated. Here, an affinity to computer programming and familiarity with C or C++ is helpful.

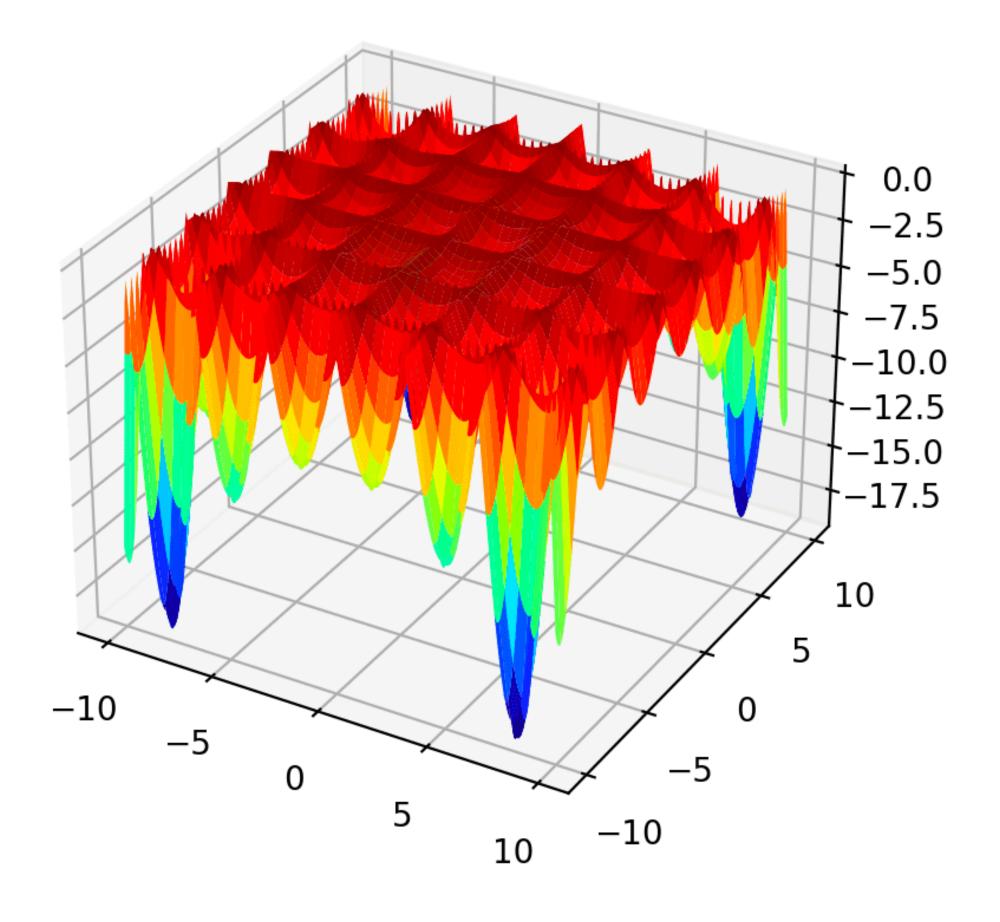
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Research **▼ Playing with Feynman diagrams**

<u>FeynGame</u> is a tool to learn about the concept of Feynman diagrams in a playful way. It allows to easily produce high-quality images of Feynman diagrams. In this project, you will design and implement a new type of game into FeynGame, where the player must construct valid Feynman diagrams from a given set of vertices.

You will learn:

• The algorithmic structure of Feynman diagrams.

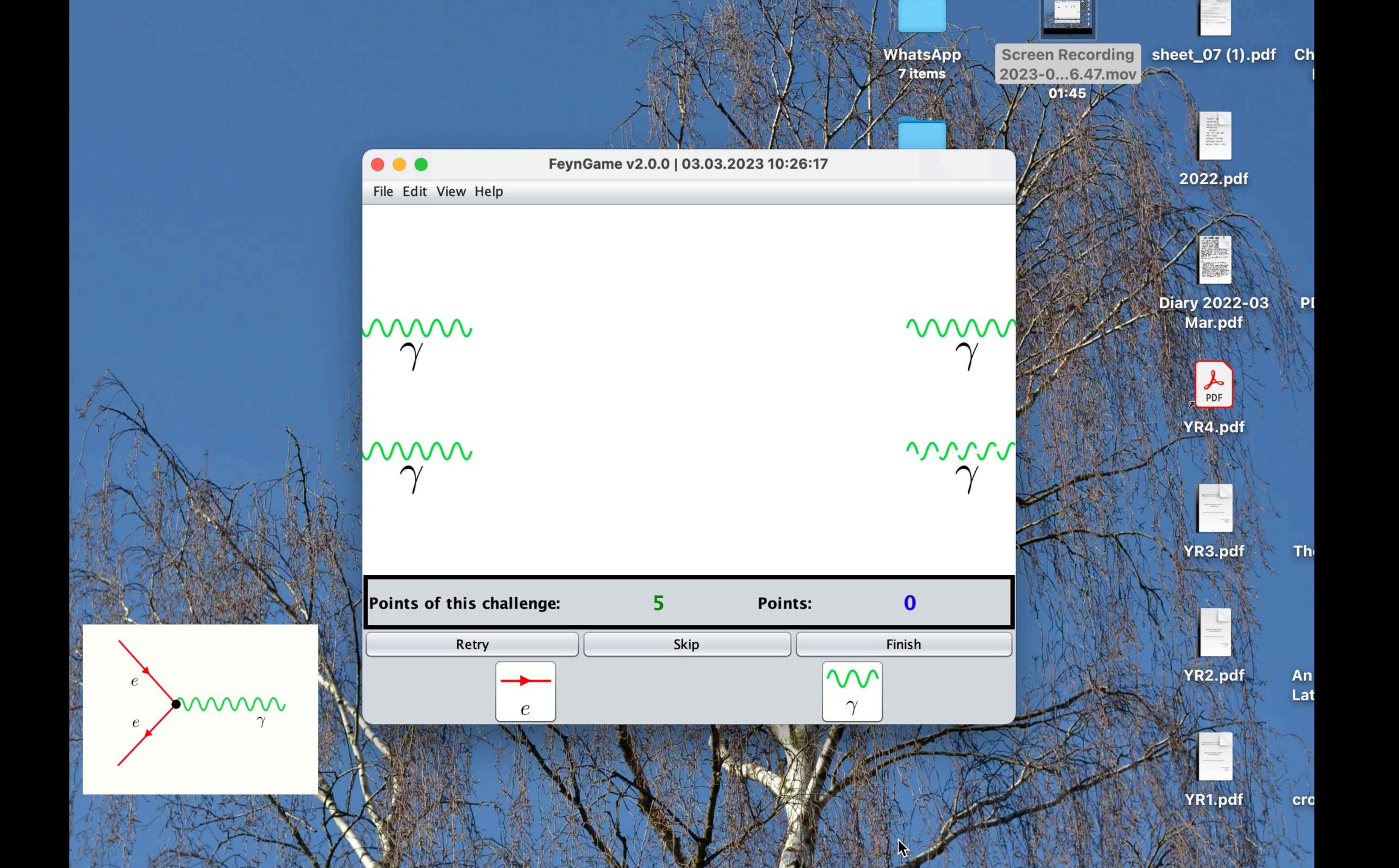
Requirements:

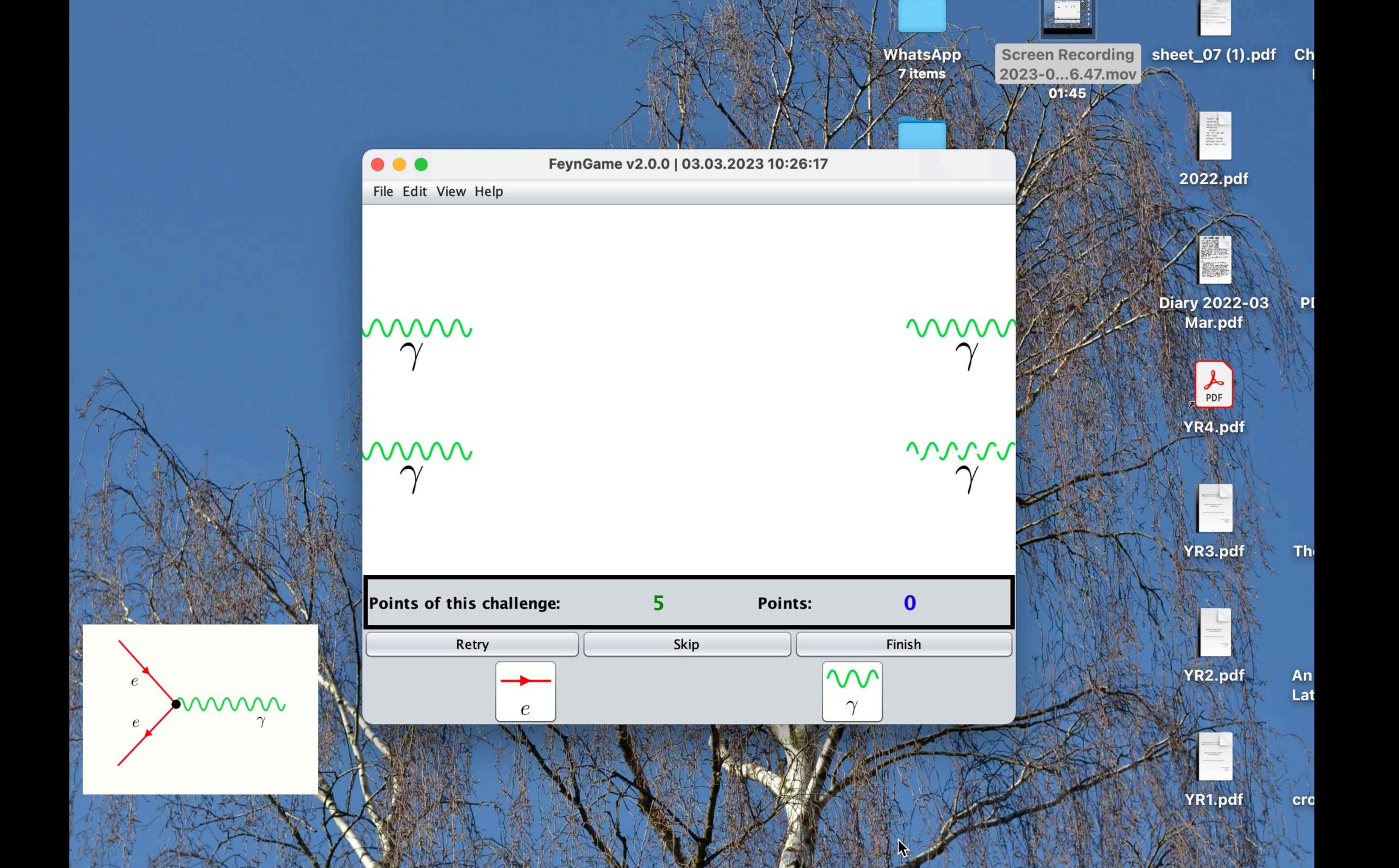
- Interest in Feynman diagrams.
- Affinity to computer programming.

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@FeynGame-tp3if · 10 subscribers · 3 videos

FeynGame is a graphical tool to draw, but also to get acquainted with Feynman diagrams. I...

web.physik.rwth-aachen.de/user/harlander/software/feyngame and 1 more link

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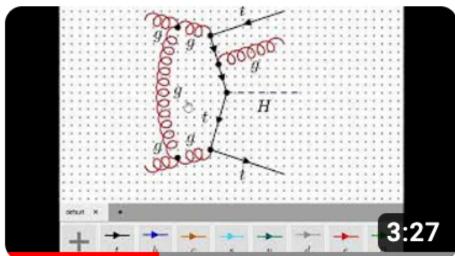
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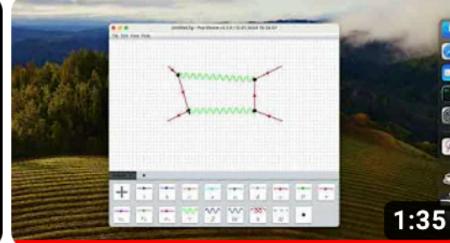
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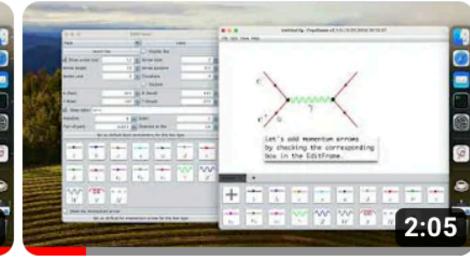
FeynGame - teaser video

62 views • 2 days ago



The first diagram(s) with FeynGame.

115 views • 9 days ago



FeynGame: labels, momentum arrows and more

27 views • 9 days ago

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