

# FeynGame

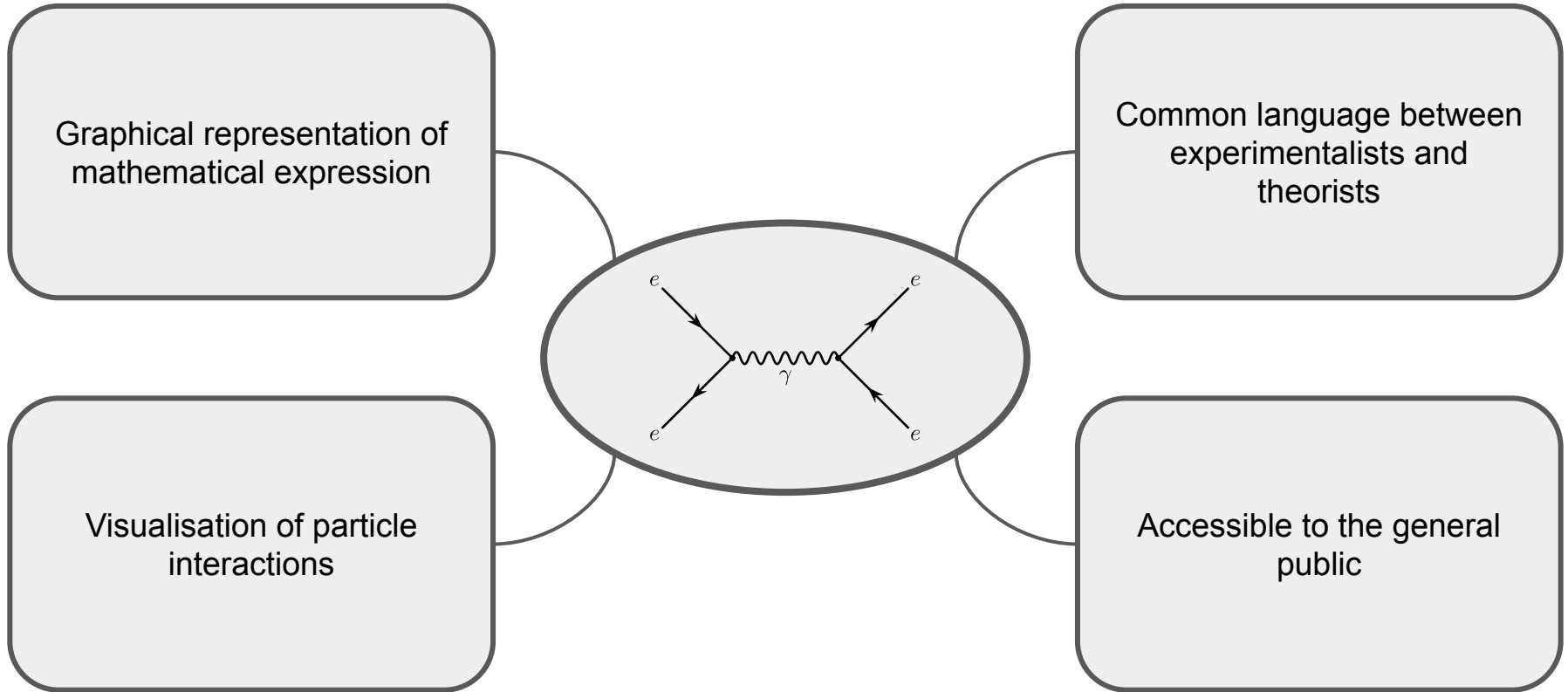
Feynman Diagrams for Everyone

ROBERT HARLANDER, SVEN YANNICK KLEIN, and •MAGNUS SCHAAF

DPG-Frühjahrstagung 2024 – Karlsruhe

06.03.2024

# Feynman Diagrams



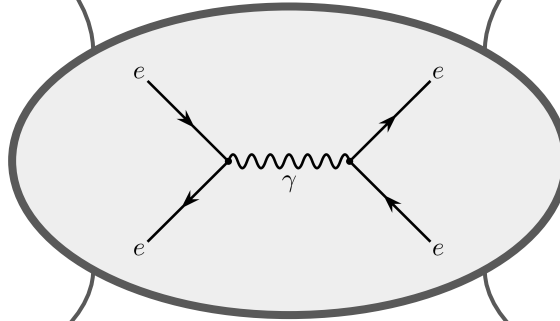
# Feynman Diagrams



$$\bullet \xrightarrow{e} \bullet = \frac{\gamma^\mu p_\mu + m}{p^2 - m^2}$$

$$\bullet \text{---} \gamma \text{---} \bullet = \frac{-ig_{\mu\nu}}{p^2}$$

$$\begin{array}{l} e \\ \swarrow \\ \bullet \\ \nearrow \\ e \end{array} \text{---} \gamma = ie\gamma^\mu$$



Common language between  
experimentalists and  
theorists

Visualisation of particle  
interactions

Accessible to the general  
public

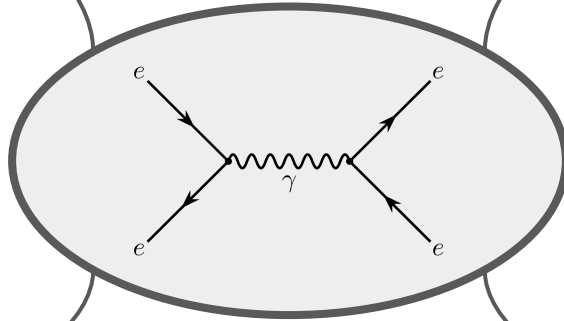
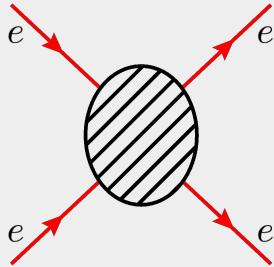
# Feynman Diagrams



$$\bullet \xrightarrow{e} \bullet = \frac{\gamma^\mu p_\mu + m}{p^2 - m^2}$$

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$$\begin{array}{l} e \\ e \end{array} \text{---} \bullet \text{---} \gamma = ie\gamma^\mu$$



Common language between  
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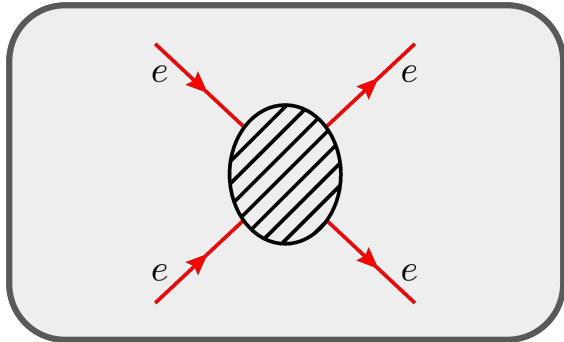
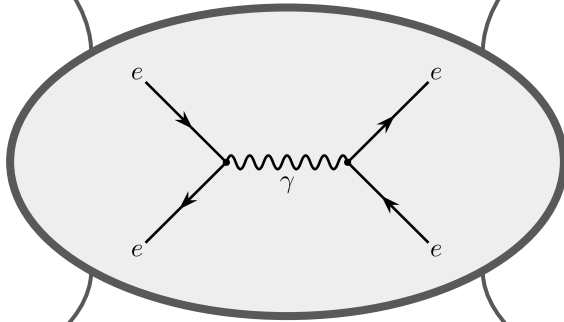
# Feynman Diagrams



$$\text{Feynman diagram for fermion } e \text{ propagator} = \frac{\gamma^\mu p_\mu + m}{p^2 - m^2}$$

$$\text{Feynman diagram for photon } \gamma \text{ propagator} = \frac{-i g_{\mu\nu}}{p^2}$$

$$\text{Feynman diagram for fermion } e \text{ vertex} = ie\gamma^\mu$$



$$\text{Feynman diagram for } gg \rightarrow H \text{ via top quark loop}$$

$$\text{Feynman diagram for } H \rightarrow \gamma\gamma \text{ via top quark loop}$$

Accessible to the general public

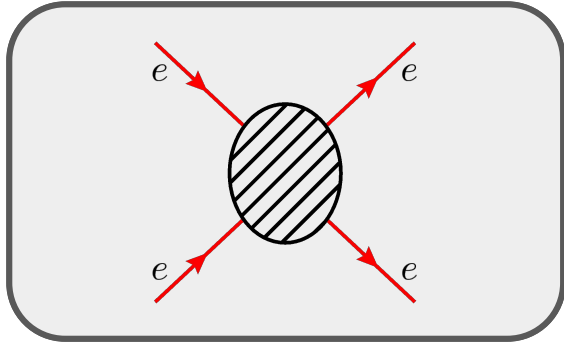
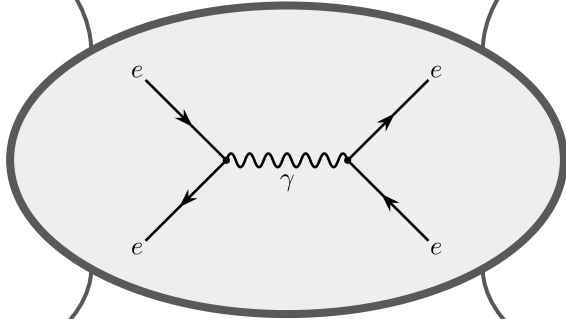
# Feynman Diagrams



$$\text{Feynman diagram for } e \text{ propagator} = \frac{\gamma^\mu p_\mu + m}{p^2 - m^2}$$

$$\text{Feynman diagram for } \gamma \text{ propagator} = \frac{-ig_{\mu\nu}}{p^2}$$

$$\text{Feynman diagram for } e\text{-}\gamma \text{ vertex} = ie\gamma^\mu$$



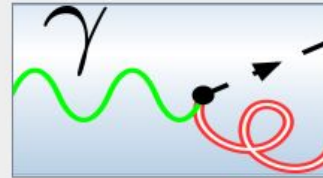
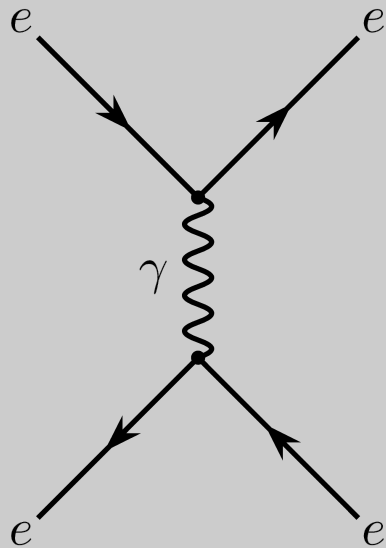
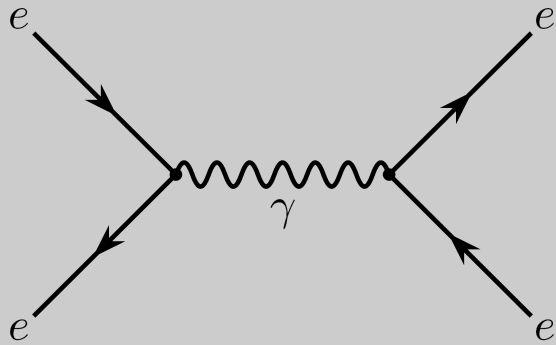
**CMS**  
 $19.7 \text{ fb}^{-1} (8 \text{ TeV}) + 5.1 \text{ fb}^{-1} (7 \text{ TeV})$   
 $H \rightarrow \gamma\gamma$   
 $S/\text{B}$  weighted events / GeV  
 $\mu = 1.14^{+0.10}_{-0.10}$   
 $m_H = 124.79 \pm 0.34 \text{ GeV}$



# Feynman Diagrams for Everyone

How to make Feynman diagrams accessible for **everyone**?

Introducing: **FeynGame**



Drawing mode



InFin mode

# Acquiring Feynman Diagrams in a Playful Way



InFin mode

FeynGame v2.1.0 | 12.01.2024 09:53:51

File Edit View Help

Points of this challenge: **5** Points: **0**

Retry			Skip			Finish				
$t$	$b$	$c$	$s$	$u$	$d$	$e$	$\mu$	$\tau$	$\nu_e$	$\nu_\mu$
$\nu_\tau$	$\gamma$	$Z$	$W$	$g$	$H$					



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File Edit View Help

Respect! It is all correct.  
OK

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File Edit View Help

$g$   $t$   
 $g$   $t$

Points of this challenge: **5** Points: **5**

Retry						Skip			Finish		
$t$	$b$	$c$	$s$	$u$	$d$	$e$	$\mu$	$\tau$	$\nu_e$	$\nu_\mu$	
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Retry Skip Finish

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File Edit View Help

Respect! It is all correct.  
OK

Points of this challenge: 5 Points: 5

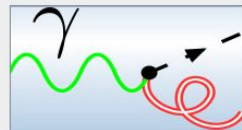
Retry						Skip				Finish		



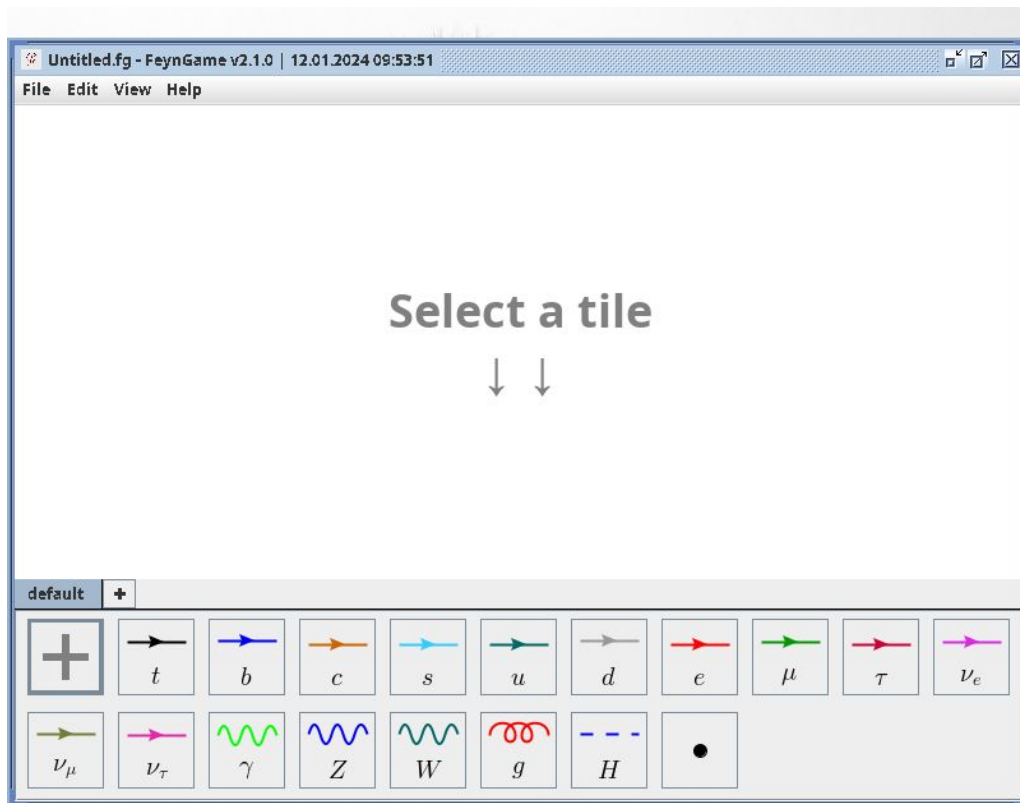
# Drawing Feynman Diagrams



InFin mode



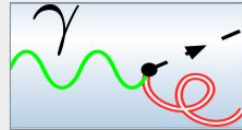
Drawing mode



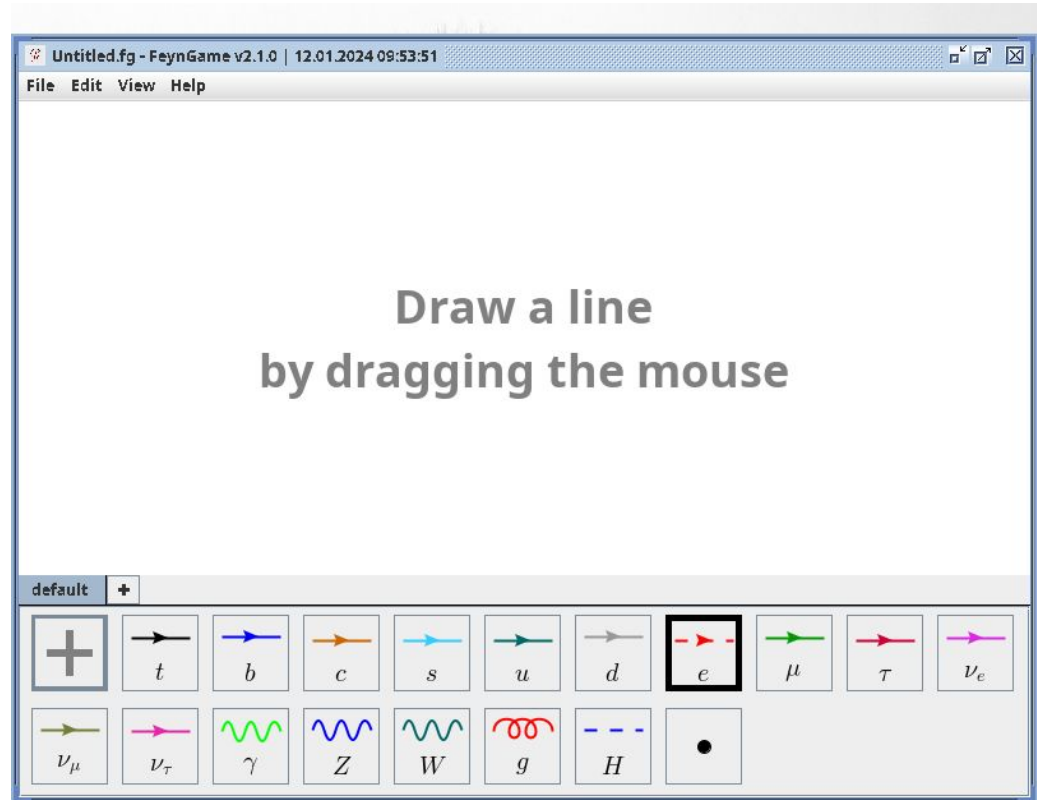
# Drawing Feynman Diagrams



InFin mode



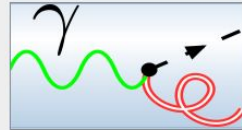
Drawing mode



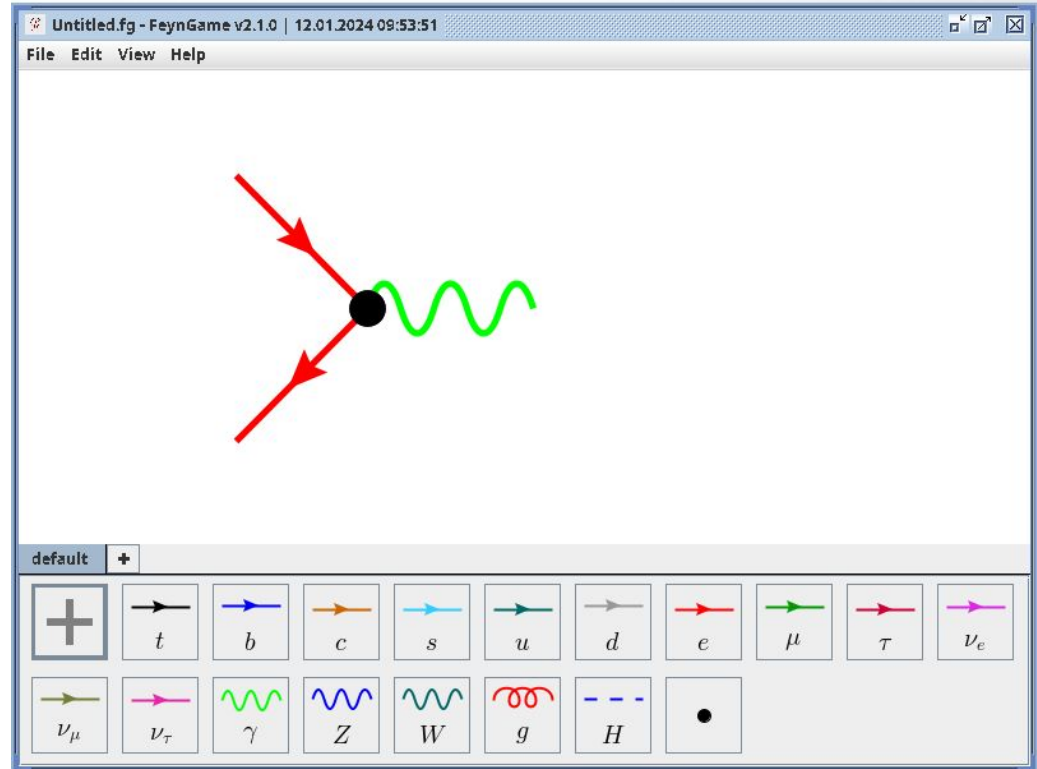
# Drawing Feynman Diagrams



InFin mode



Drawing mode

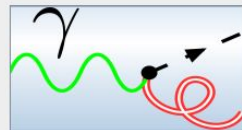




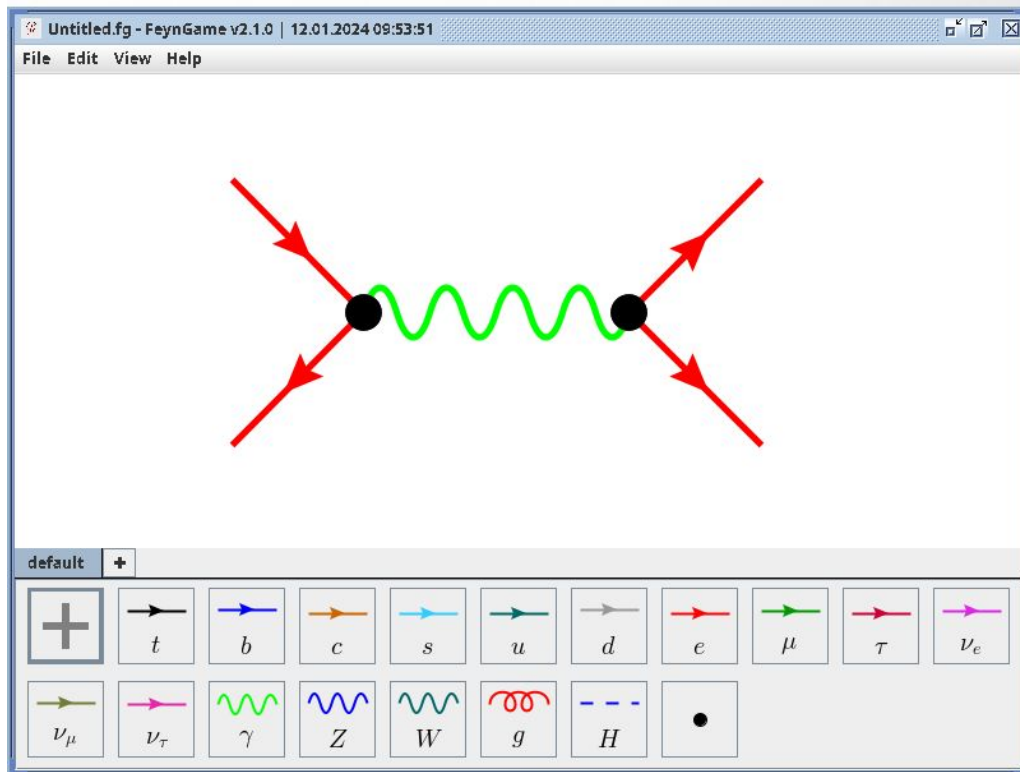
# Drawing Feynman Diagrams



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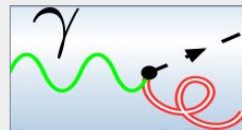




# Drawing Feynman Diagrams



InFin mode



Drawing mode

Checking 5 Lines and 2 Vertices:  
- Vertex {e, e, ph} is not in model file.

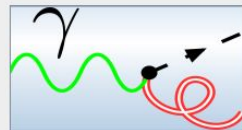
DK



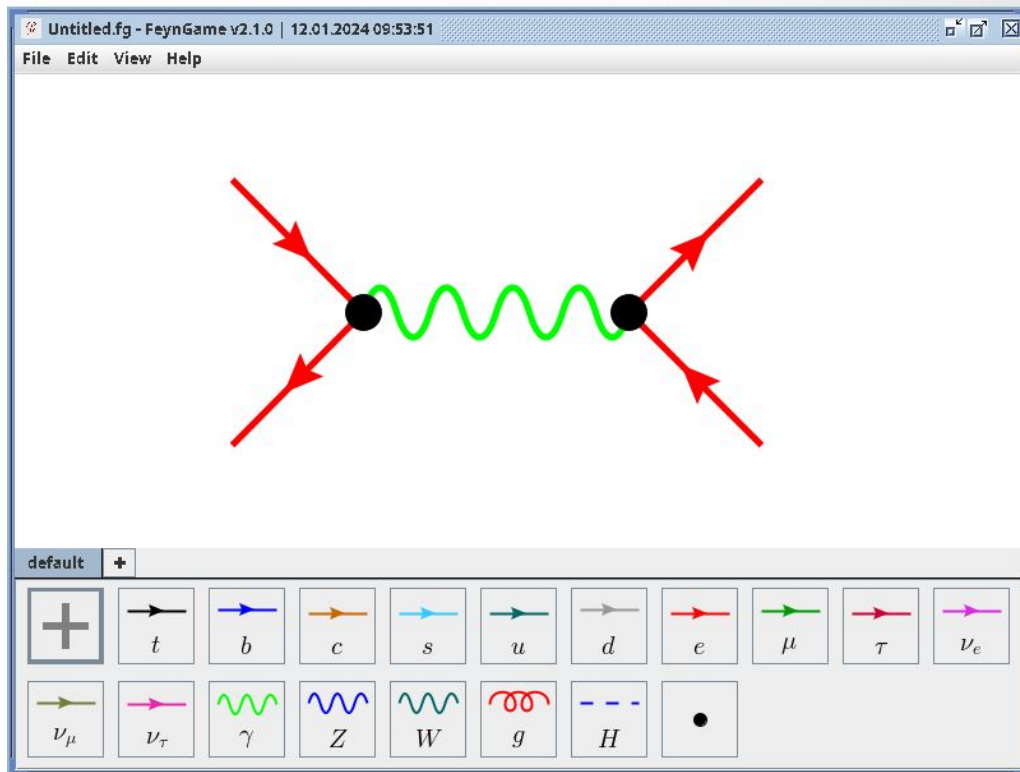
# Drawing Feynman Diagrams



InFin mode



Drawing mode



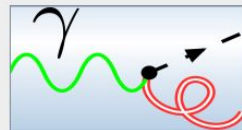




# Drawing Feynman Diagrams



InFin mode



Drawing mode

Untitled.fg - FeynGame v2.1.0 | 12.01.2024 09:53:51

File Edit View Help

Respect! It is all correct.

Show Amplitude

Copy Amplitude to Clipboard

Distribute Momenta

Reset Momenta

OK

default +

$t$   $b$   $c$   $\mu$   $\tau$   $\nu_e$

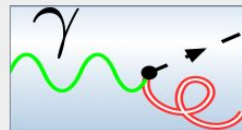
$\nu_\mu$   $\nu_\tau$   $\gamma$   $Z$   $W$   $g$   $H$   $\bullet$



# Drawing Feynman Diagrams



InFin mode



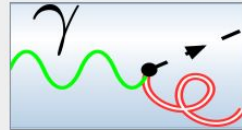
Drawing mode

e^2 u\_{\alpha\_1}(\vec{p}\_1) \bar{v}\_{\beta\_1}((- \vec{p}\_2)) (-iQ\_e \gamma\_{\beta\_1 \alpha\_1}^{\mu\_1}) i \left[ \frac{-g\_{\mu\_1 \nu\_1}}{(-p\_2 + p\_1)^2 + i\epsilon} + (1 - \xi\_\gamma) \frac{(-p\_2 + p\_1)\_{\mu\_1} (-p\_2 + p\_1)\_{\nu\_1}}{((-p\_2 + p\_1)^2)^2} \right] (-iQ\_e \gamma\_{\delta\_1 \gamma\_1}^{\nu\_1}) v\_{\gamma\_1}((- \vec{q}\_1)) \bar{u}\_{\delta\_1}((- \vec{p}\_2 + \vec{q}\_1 + \vec{p}\_1)) Below the formula are buttons: 'OK', 'Show Amplitude', 'Copy Amplitude to Clipboard', 'Distribute Momenta', and 'Reset Momenta'. At the bottom is a toolbar with icons for particles: fermions (t, b, c, mu, tau, nu\_e), bosons (nu\_mu, nu\_tau, gamma, Z, W, g, H), and a vertex (black dot)."/&gt;

# Drawing Feynman Diagrams



InFin mode



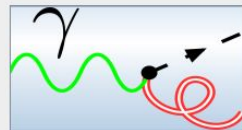
Drawing mode



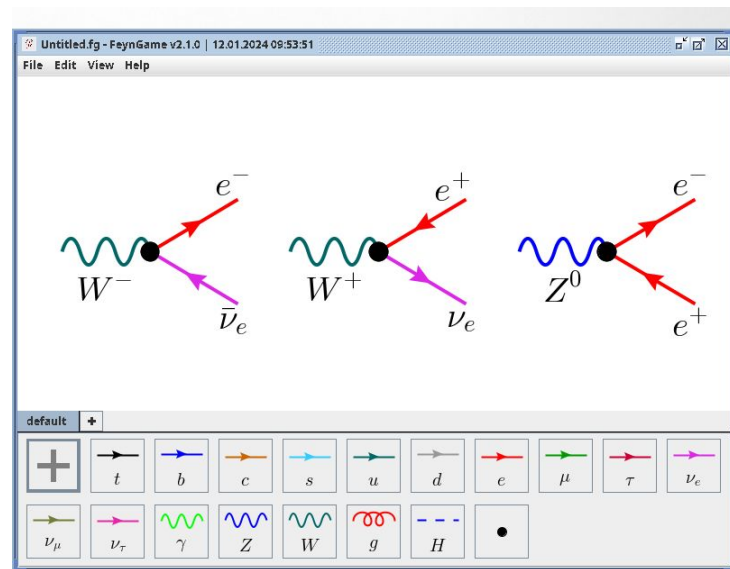
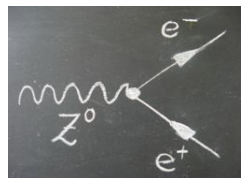
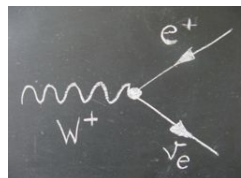
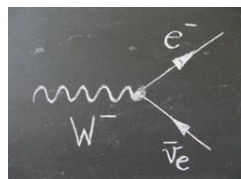
# FeynGame in Outreach



InFin mode



Drawing mode

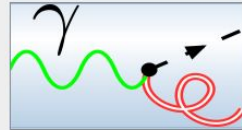




# FeynGame in Outreach



InFin mode

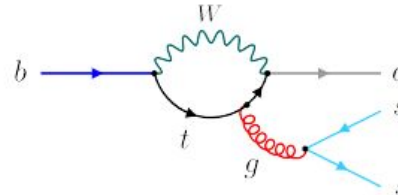


Drawing mode



## Aufgabe 3 Diagramme

Das folgende Diagramm wird unter Physikern auch „Pinguin Diagramm“ genannt:



Zeichne das Diagramm in *FeynGame* nach. Versuche das Diagramm durch verschieben der Vertices und krümmen der Linien so zu verändern, dass der Name „Pinguin Diagramm“ einen Sinn ergibt.

Es gibt weitere Diagrammbezeichnungen, wie z.B.

- Sonnenaufgangs Diagramm
- Kaulquappen Diagramm
- Leiter Diagramm
- Tennisplatz Diagramm
- Mercedes Diagramm

Versuche zu jeder Bezeichnung ein passendes Diagramm zu entwerfen.

# Summary



**FeynGame**

Current developers:  
Robert Harlander, Sven Yennick Klein, Magnus Schaaf

Authors:  
Robert Harlander, Sven Yennick Klein, Maximilian Lipp, Magnus Schaaf

Other contributors:  
Erik de Huy, Lars Moninger

Quick Start   Model Files   GitLab Repository   Citation   YouTube   License

### Quick Start

- Download [FeynGame.jar](#), then type `java -jar FeynGame.jar` (or double-click FeynGame.jar). This opens a dialog window where you can choose to just draw diagrams, or to play a game.
- On MacOS, you can also download [FeynGame.dmg](#), double-click it, and move the FeynGame.app to your /Applications folder
- If you only have an ancient version of Java, you can also use [this FeynGame.jar](#), or [this FeynGame.dmg](#).

### Model Files

By default, FeynGame assumes the Standard Model as the underlying theory, with pre-defined line and vertex styles. Here we collect a number of alternative model files. This list will be regularly updated.

model file	Name	Remarks	Style
<a href="#">standard_model</a>	Standard Model	full Feynman rules; default model after 03. Jun 2024	
<a href="#">qed_model</a>	QED	full Feynman rules	
<a href="#">sqed_model</a>	Scalar QED	full Feynman rules	

### GitLab Repository

The source code of FeynGame is available at [this gitlab repository](#)

### Citation

If you use FeynGame in a publication, please refer to

- R. Harlander, S.Y. Klein, M. Schaaf, FeynGame 2.1 – Feynman diagrams made easy, [\[arXiv:2401.12778\]](#)
- R. Harlander, S.Y. Klein, M. Lipp, FeynGame, [Comput. Phys. Commun. 256 \(2020\) 107465](#) [\[arXiv:2003.00896\]](#)

### YouTube

See the [FeynGame YouTube channel](#)

### License

FeynGame is published under the [GNU General Public Licence 3](#)



# Summary



## FeynGame:

- Program:
  - open source
  - Java (works on almost any machine)
  - active development
- Outreach:
  - simplified models
  - checks for validity
- Research:
  - diagrams completely customizable
  - exportable for slides and papers

## Outlook:

- extend *InFin* mode
- add *tutorial* mode

Feynman diagrams for  
**everyone**: *beginners*,  
*intermediates*, and  
*experts*



**Magnus Schaaf**

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Kosmologie

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