FeynRules Tutorial

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Tools for HEP tools

- Many tools exist for HEP computations that allow to perform computations in an easy an automated way:

  - ➡ Symbolic tools: FeynArts, FormCalc, ...
  - ➡ Matrix element generators: CalcHep/CompHep, MadGraph, Sherpa, Whizard/Omega...
  - ➡ MC event generators: Herwig, Pythia, Sherpa,...
  - ➡ Spectrum generators: SoftSusy,...
  - ➡ DM relic density: MicrOmegas,...
  - ➡ FastSim: Delphes, PGS, ...
  - ➡ ...

Tools for HEP tools

- Many of these tools are able to handle a generic (renormalizable) QFT model.
- Most of the codes only have only a limited set of models implemented (SM, MSSM, ...).
- For more general models, the information on the model (particles, vertices, ...) must come "from the outside", i.e., must be provided by the user.

Tools for HEP tools

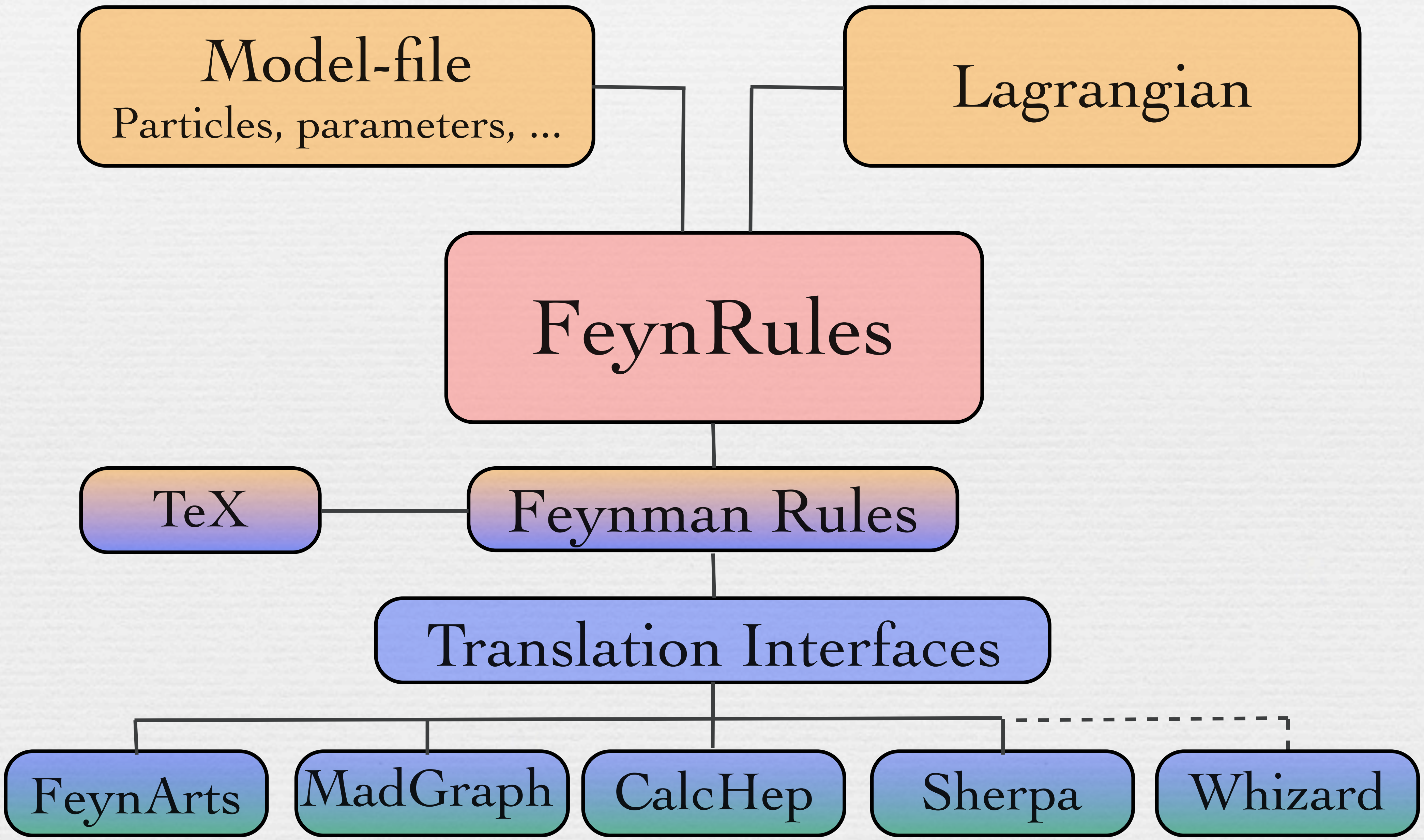
- Implementing a model from scratch into a HEP tool can be a tedious and error prone task:

  ➡ Vertices must be entered one at the time.
  ➡ Each code uses its own conventions (factors of ±1, ±i, ...).
  ➡ Each code uses a different programming language.
  ➡ Painful validation for each model.

FeynRules

- Mathematica package that allows to derive Feynman rules directly form a Lagrangian.
- No special requirements on the form of the Lagrangian (apart from Lorentz and gauge invariance).
- Supported field types:
  - ➡ Scalars
  - ➡ Fermions (Dirac & Majorana)
  - ➡ Vectors
  - ➡ Spin 2
  - ➡ Ghosts

FeynRules


Model-file
Particles, parameters, ...
Lagrangian
FeynRules
TeX
Feynman Rules
Translation Interfaces
FeynArts
MadGraph
CalcHep
Sherpa
Whizard

A simple model of Dark Matter

- During the next four hours, we will implement a very simple model of Dark Matter into FeynRules, and export the model to two different HEP tools to study its phenomenology:

  ➡ **MicrOmegas**:
  Compute the DM annihilation rate and the DM relic density

  ➡ **MadGraph**:
  Generate the matrix element and compute the cross section for DM production at the LHC.

A simple model of Dark Matter

- The model we will consider consists in the addition of a singlet scalar S, protected by a Z_2 symmetry (i.e., S is Z_2-odd, whereas all SM particles are Z_2-even).

$$\mathcal{L} = \mathcal{L}_{SM} + \mathcal{L}_{DM}$$

$$\mathcal{L}_{DM} = \frac{1}{2}\partial_\mu S\,\partial^\mu S - \frac{1}{2}\left(m_S^2 + \lambda_{SH}\,v^2\right) S^2 + \lambda_S S^4 + \lambda_{SH} S^2\,\Phi^\dagger\Phi$$

- Implementing this model into FeynRules means
  - ➡ Defining the new particle.
  - ➡ Defining the new parameters.
  - ➡ Entering the Lagrangian into Mathematica.

A simple model of Dark Matter

- All instructions of how to
  - ➡ Implement the model into FeynRules
  - ➡ Export it from FeynRules to MicrOmegas and MadGraph
  - ➡ Run MicrOmegas
  - ➡ Run MadGraph

  are given in the handout.

- Solutions to all the problems are provided:
  - ➡ for FeynRules in ~/FeynRules1.4.3/Yeti10_Bkup.
  - ➡ for MicOmegas in ~/micromegas_2.2.CPC.i/feynrules_bkup.
  - ➡ for MadGraph in ~/MG_ME_V4.4.32/HiggsStrahlung.

- Feel free to ask as many questions as you like... and have fun!

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- Web pages:
  - ➡ for FeynRules: http://feynrules.phys.ucl.ac.be/
  - ➡ for MicOmegas: http://lappweb.in2p3.fr/lapth/micromegas/
  - ➡ for MadGraph: http://madgraph.phys.ucl.ac.be/
- Feel free to ask as many questions as you like... and have fun!