BSM in MadGraph5

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UCL

MG5: J. Alwall, M. Herquet, F. Maltoni, T. Stelzer
UFO: C. Degrande, C.Duhr, B. Fuks,
D. Grellscheid,T.Reiter
ALOHA: P. Aquino,W. Link, F.Maltoni, T.Stelzer

Plan

- Introduction / MadGraph5
- UFO
- ALOHA
- Color
- Model

Why simulating BSM?

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- Dedicated research

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- If we observe something unexpected

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- If we don't observe anything
  - We want a model independent way to constraint the possible new physics

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- Dedicated research
- If we observe something unexpected
- If we don't observe anything
  - We want a model independent way to constraint the possible new physics
  - Dimension 6 Operator formalism

From Theory to Detector

Lagrangian

Detector events

From Theory to Detector

Lagrangian

FeynmanRules

Detector events

From Theory to Detector

Lagrangian

FeynmanRules

matrix-element

Detector events

From Theory to Detector

Lagrangian

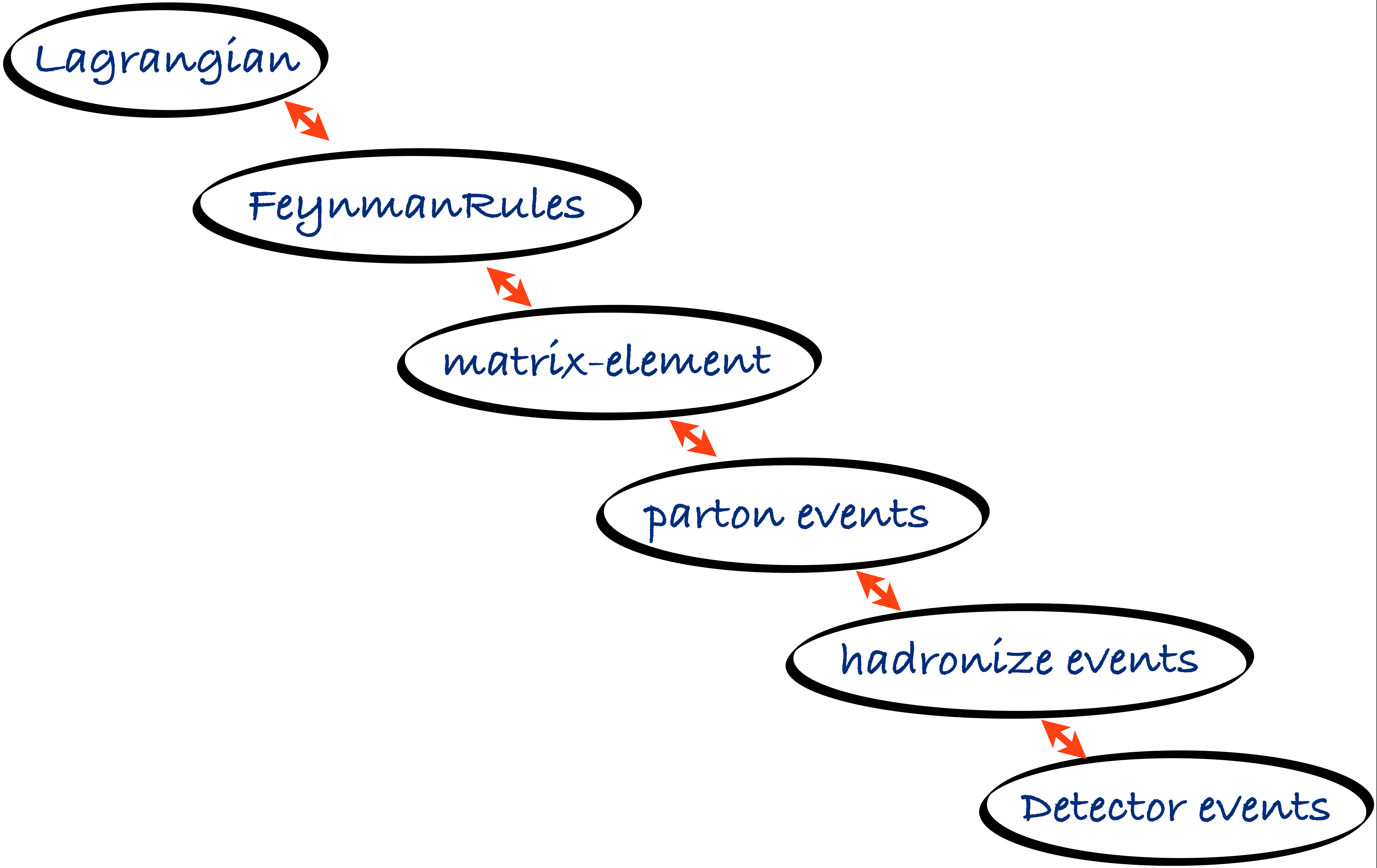
FeynmanRules

matrix-element

parton events

Detector events

From Theory to Detector



From Theory to Detector

Lagrangian

FeynRules

FeynmanRules

MODEL: UFO

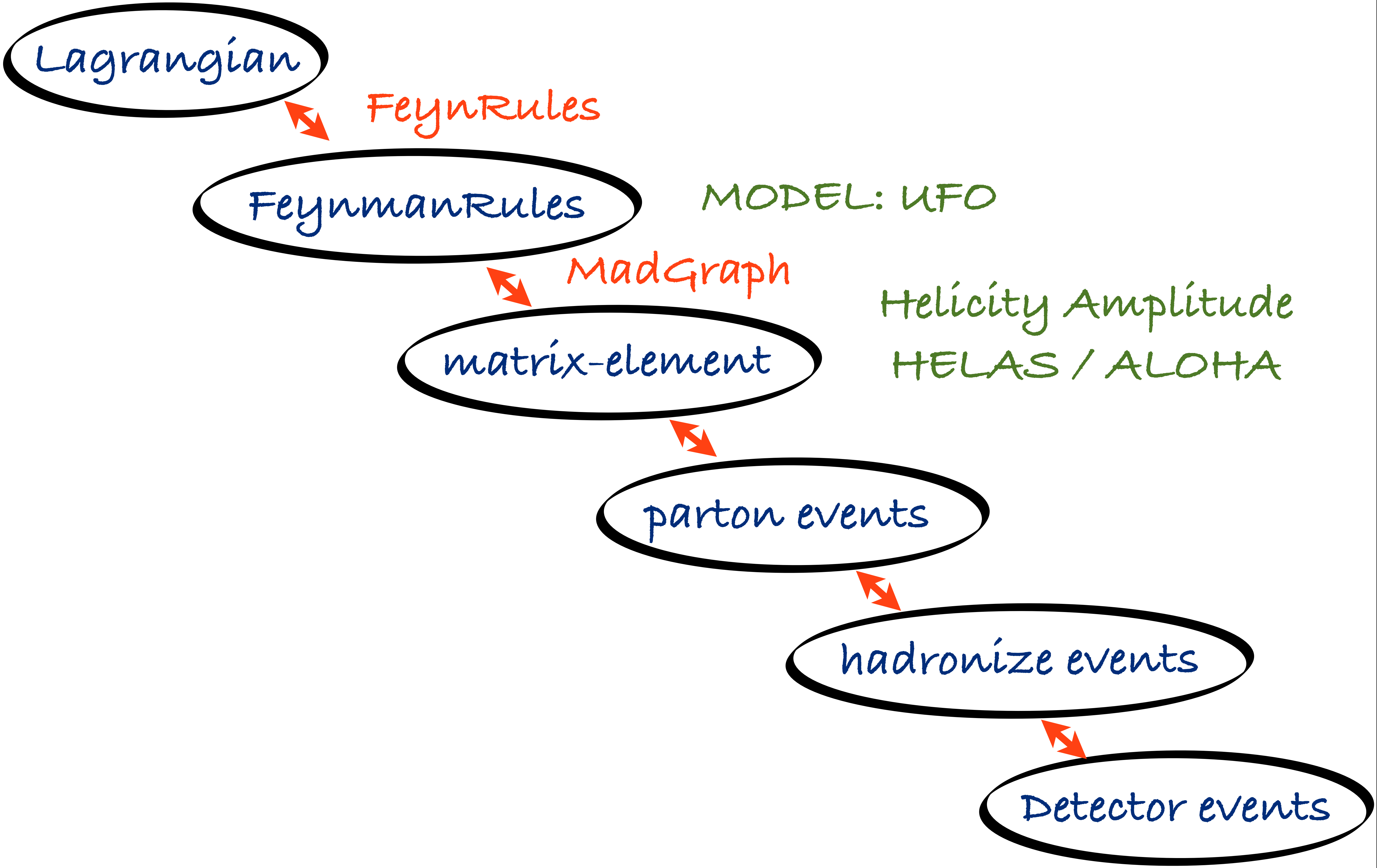
matrix-element

parton events

hadronize events

Detector events

From Theory to Detector



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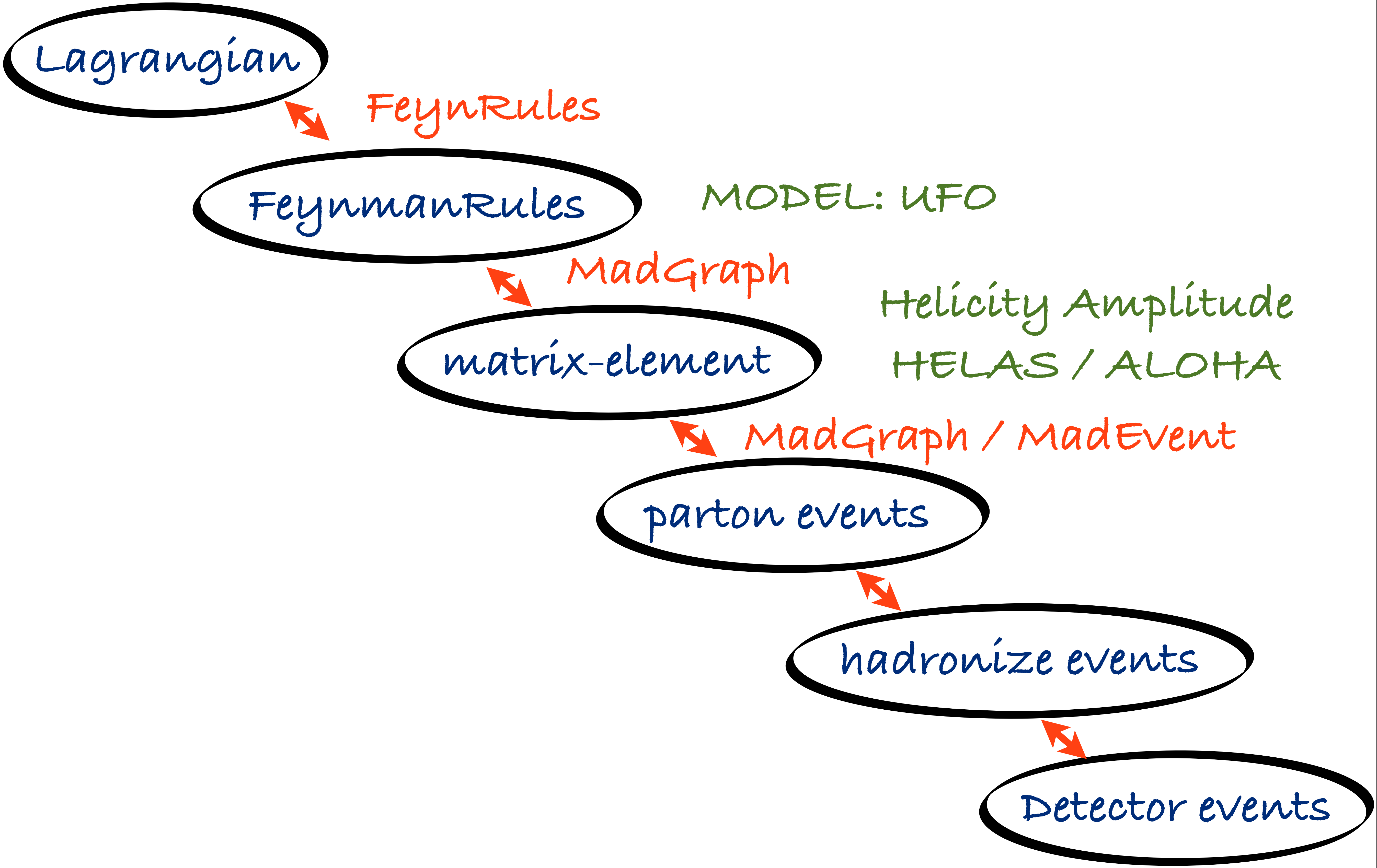

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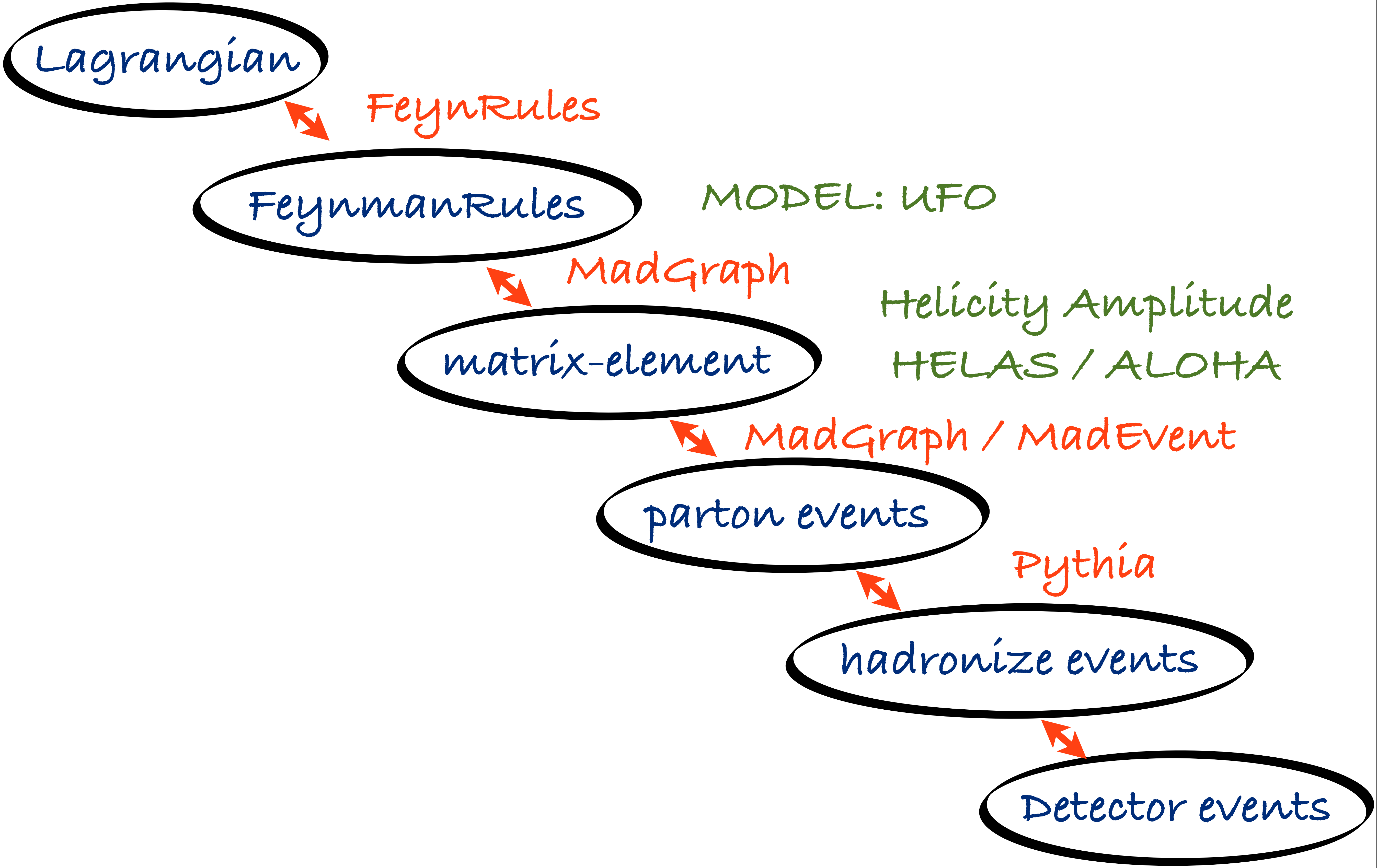


From Theory to Detector

Lagrangian

FeynRules

FeynmanRules

MODEL: UFO

MadGraph

Helicity Amplitude

HELAS / ALOHA

matrix-element

MadGraph / MadEvent

parton events

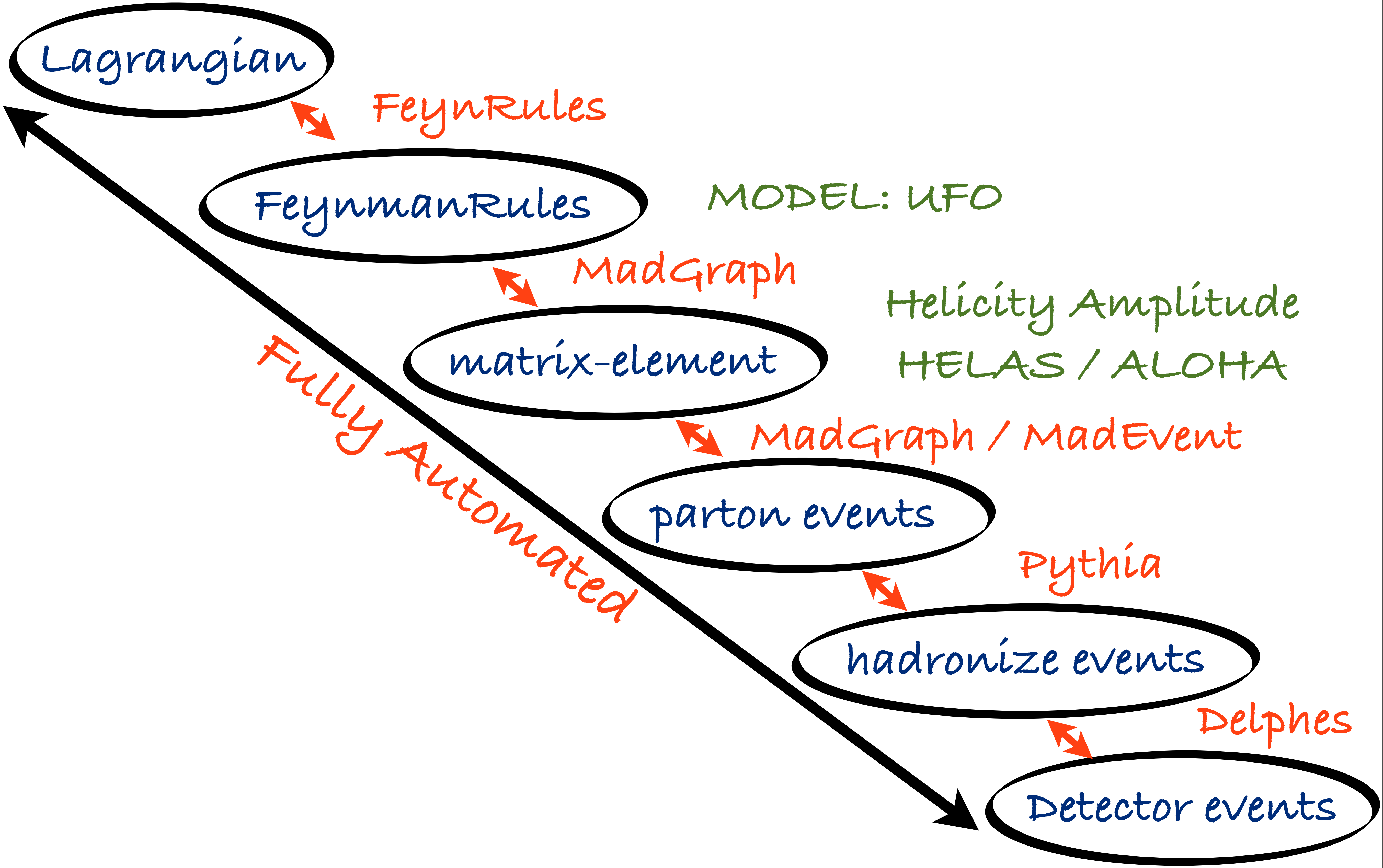
Pythia

hadronize events

Delphes

Detector events

From Theory to Detector



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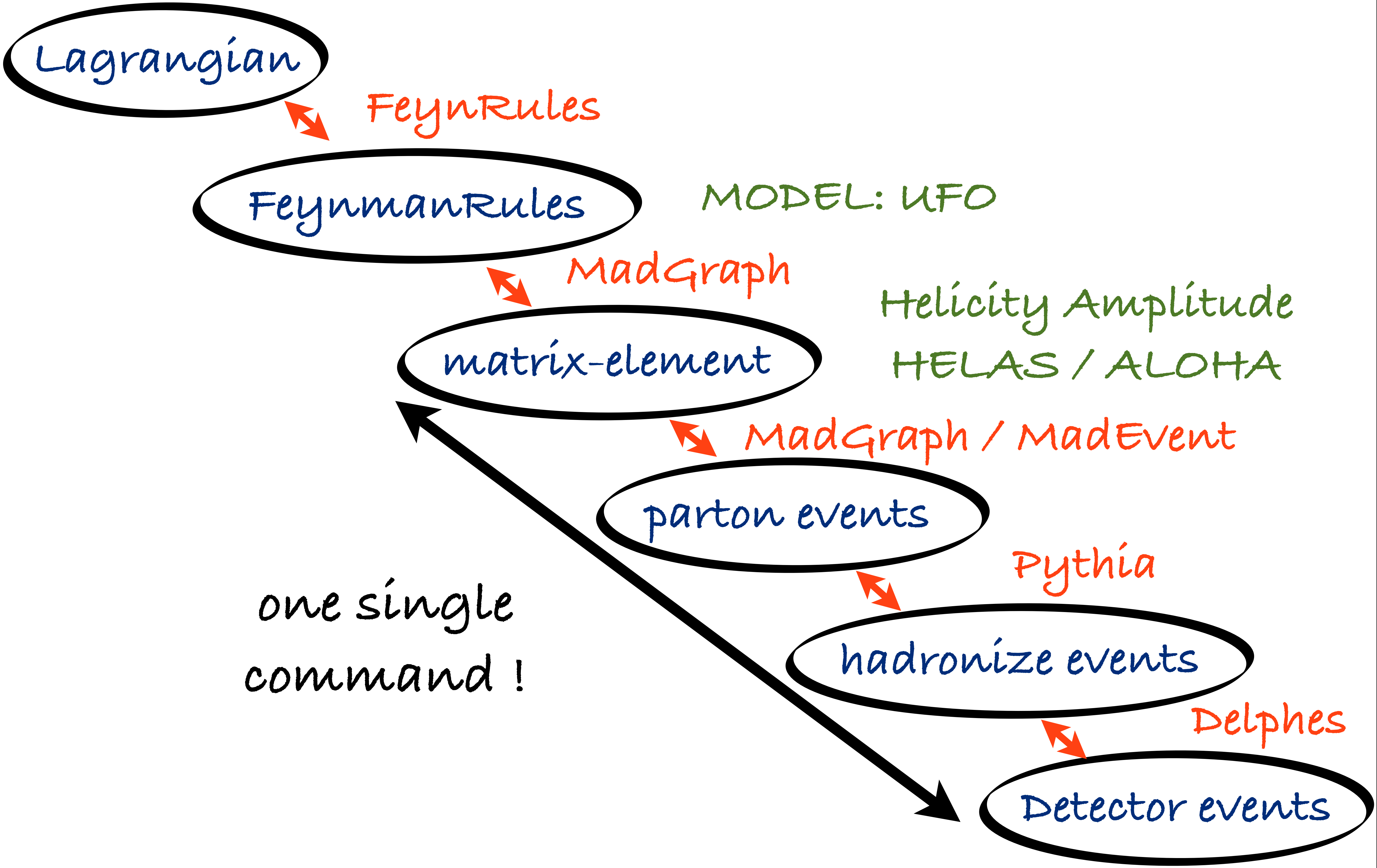
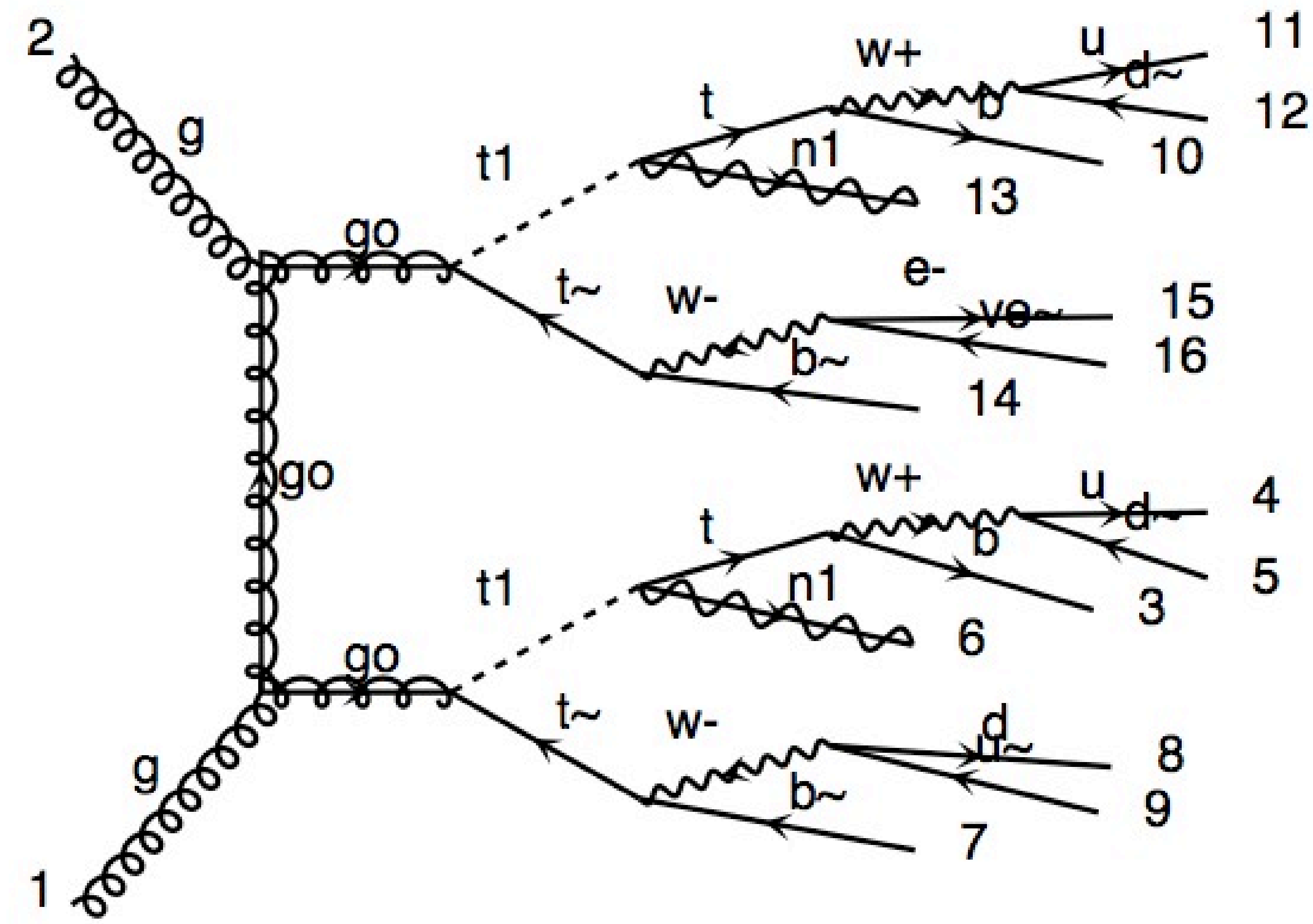


MadGraph5 Goal

- Remove ALL limitations of MadGraph4
  - speed
  - type of interactions
  - number of particles
  - nicer interface

number of particles



Command Interface

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*         VERSION 1.3.16               2011-09-11          *
*                                                          *
*    The MadGraph Development Team - Please visit us at    *
*    https://server06.fynu.ucl.ac.be/projects/madgraph     *
*                                                          *
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```

Command Interface

- Nice interactive session

```
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Command Interface

- Nice Interactive session
  - Auto-completion

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If You test it, you are going to like it !

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Command Interface

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- Simple command set

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Command Interface

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- Simple command set
  - import model sm
  - generate p p > e+ e-
  - output FORMAT MY_DIR
  - launch

```
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Plan

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- UFO
- ALOHA
- Color
- Model

UFO: Motivations

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- Avoid multiple output model written by FR.

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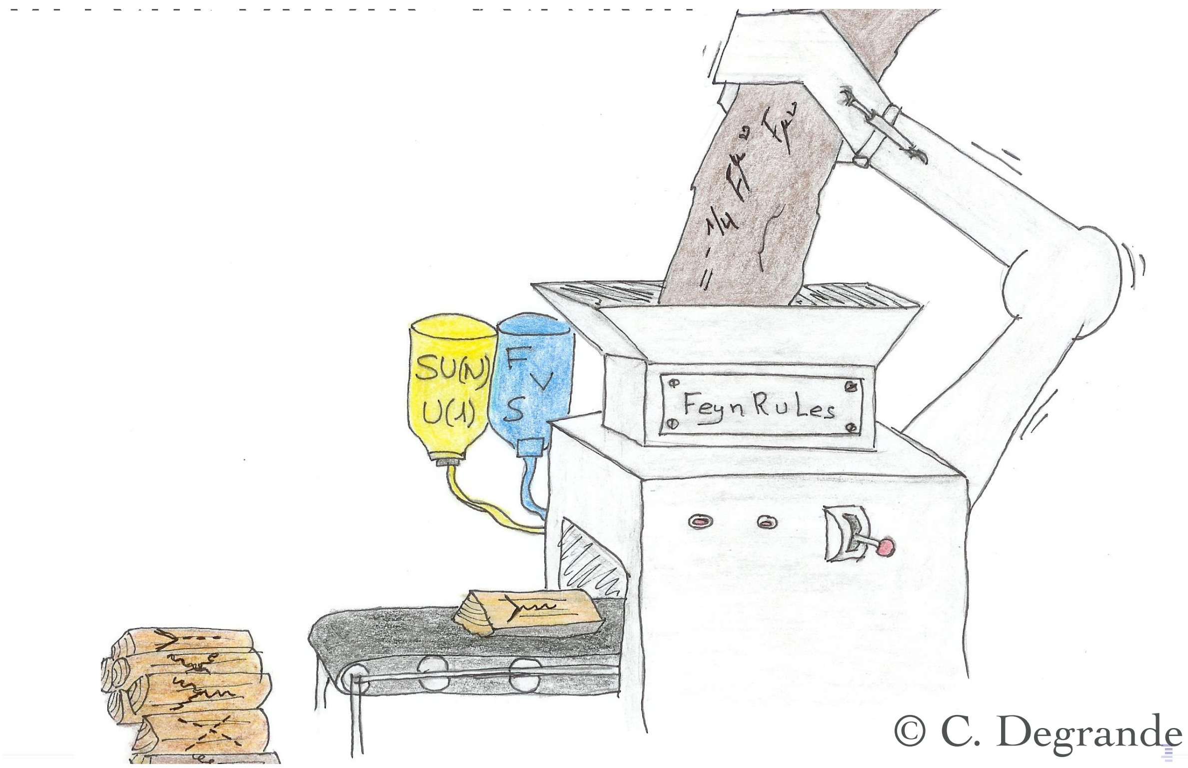

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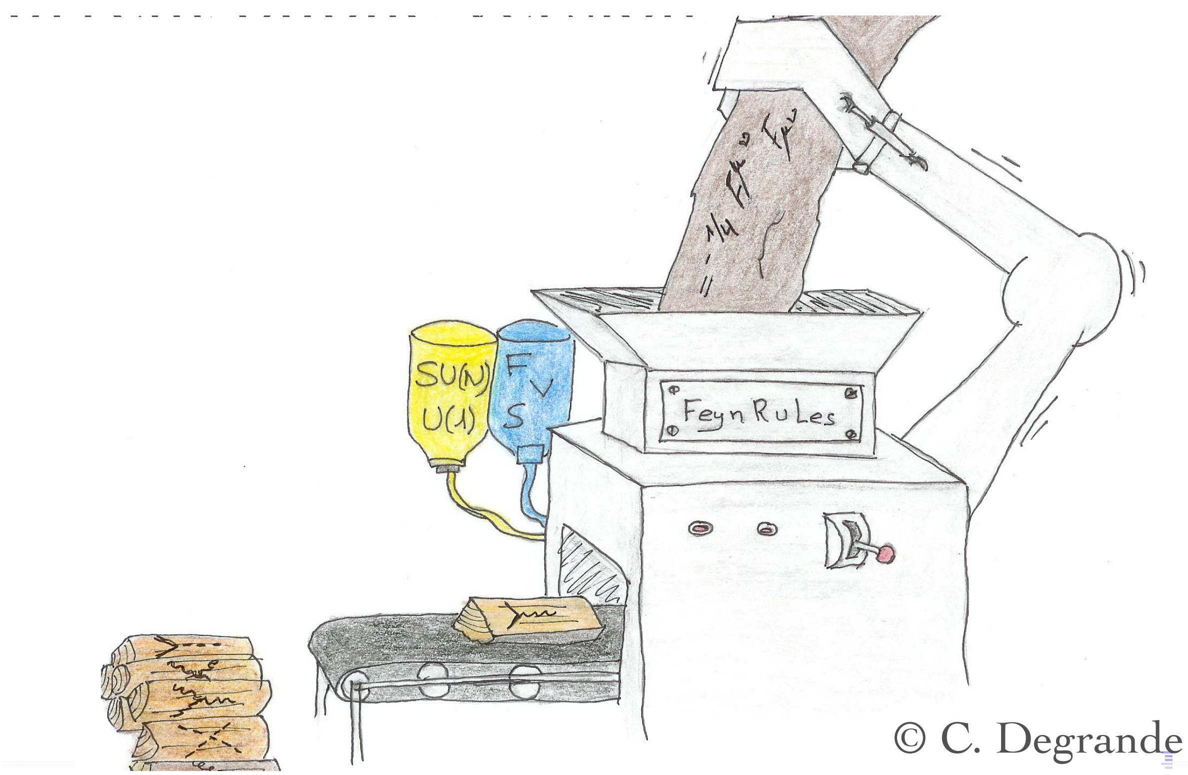

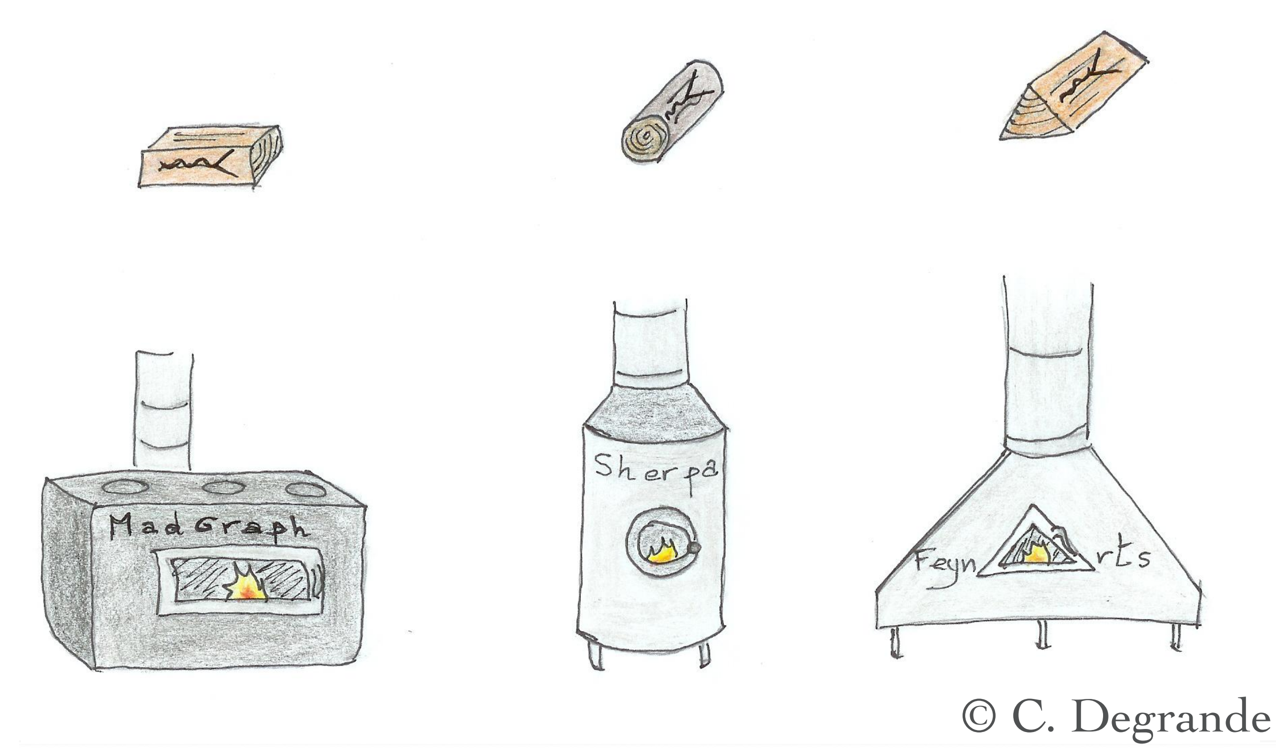

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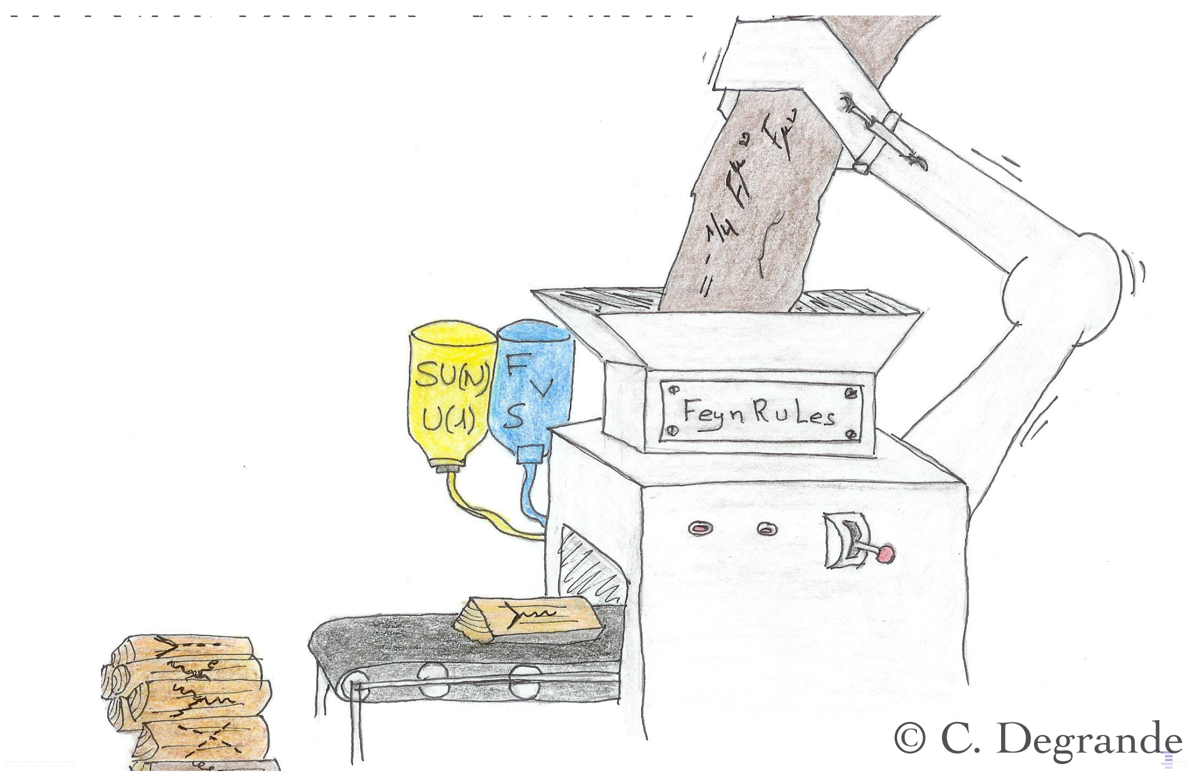

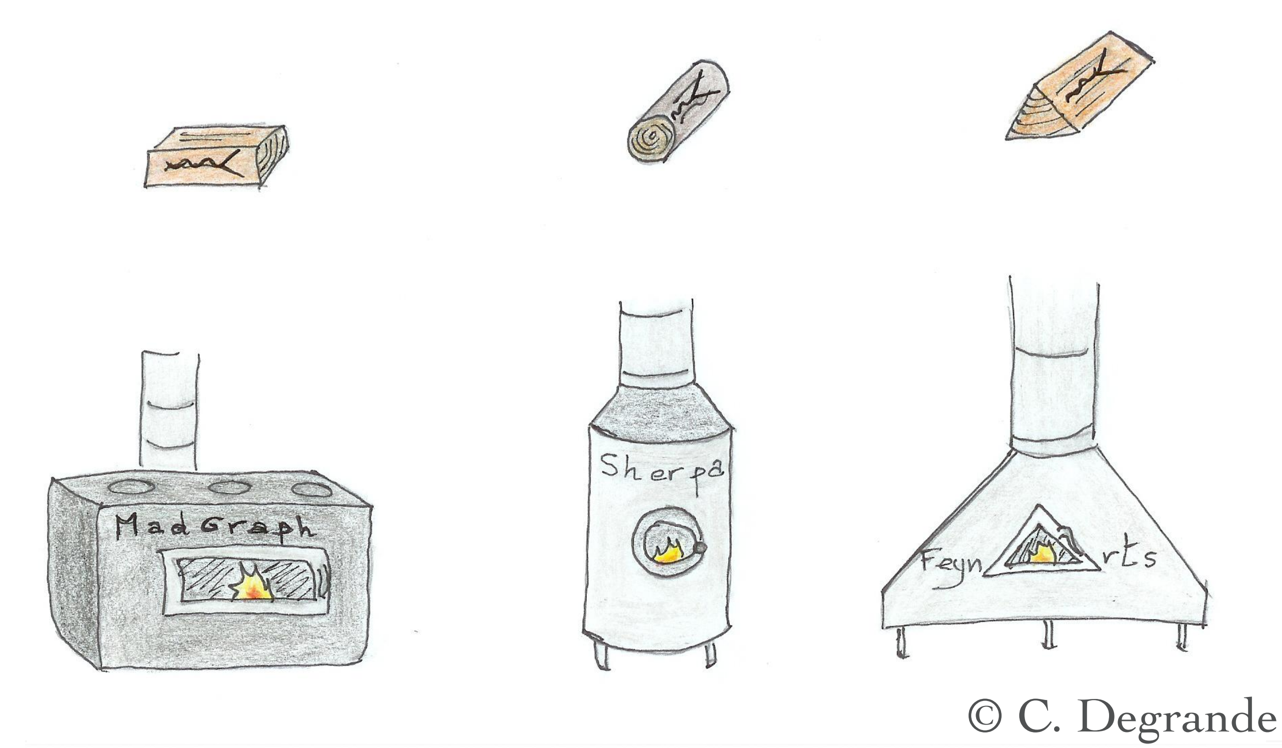

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  - color
  - lorentz structure
  - number of particles in a vertex
  - gauge

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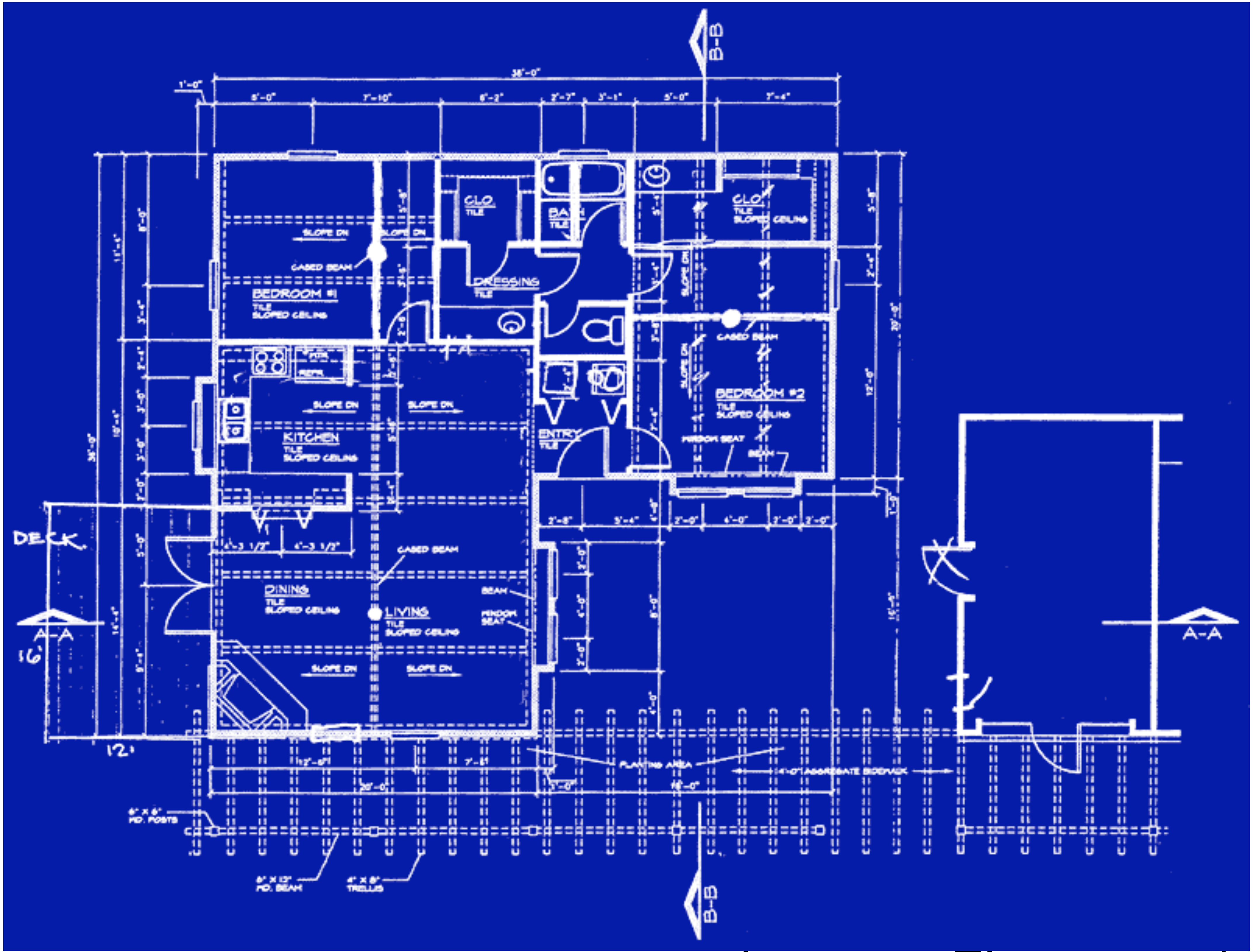
- Joint model for MG5 / GOLEM / Herwig++
- Python Object Oriented Model

FORMAT



BEDROOM #1
KITCHEN
DINING
LIVING
DRESSING
BEDROOM #2
ENTRY
DECK
A-A
B-B
PLANTING AREA

Universal FeynRules Output (UFO)

particles.py:

```
G = Particle(pdg_code = 21,
         name = 'G',
         antiname = 'G',
         spin = 3,
         color = 8,
         mass = 'ZERO',
         width = 'ZERO',
         texname = 'G',
         antitexname = 'G',
         line = 'curly',
         charge = 0,
         LeptonNumber = 0,
         GhostNumber = 0)
```

lorentz.py:

```
VVV1 = Lorentz(name = 'VVV1',
         spins = [ 3, 3, 3 ],
         Structure =
               'P(3,1)*Metric(1,2) -
               P(3,2)*Metric(1,2) -
               P(2,1)*Metric(1,3) +
               P(2,3)*Metric(1,3) +
               P(1,2)*Metric(2,3) -
               P(1,3)*Metric(2,3)')
```

couplings.py:

```
GC_4 = Coupling(name = 'GC_4',
         value = '-G',
         order = {'QCD':1})
```

vertices.py:

```
V_2 = Vertex(name = 'V_2',
         particles = [ P.G, P.G, P.G ],
         color = [ 'f(1,2,3)' ],
         lorentz = [ L.VVV1 ],
         couplings = {(0,0):C.GC_4})
```

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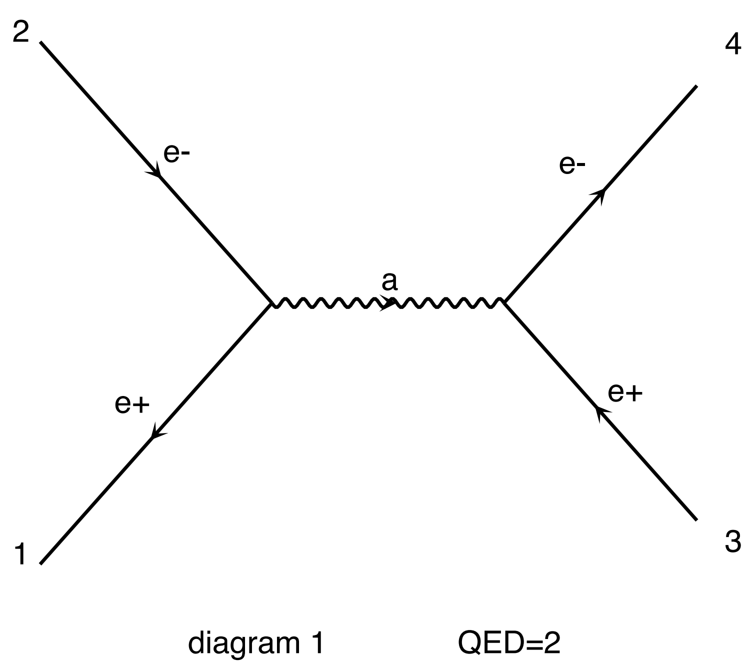
- **Idea:** Evaluate $\mathcal{M}$ for fixed helicity of external particles.



$$M = \bar{u}\gamma^{\mu} v \; P_{\mu\nu} \; \bar{u}\gamma^{\nu} v$$

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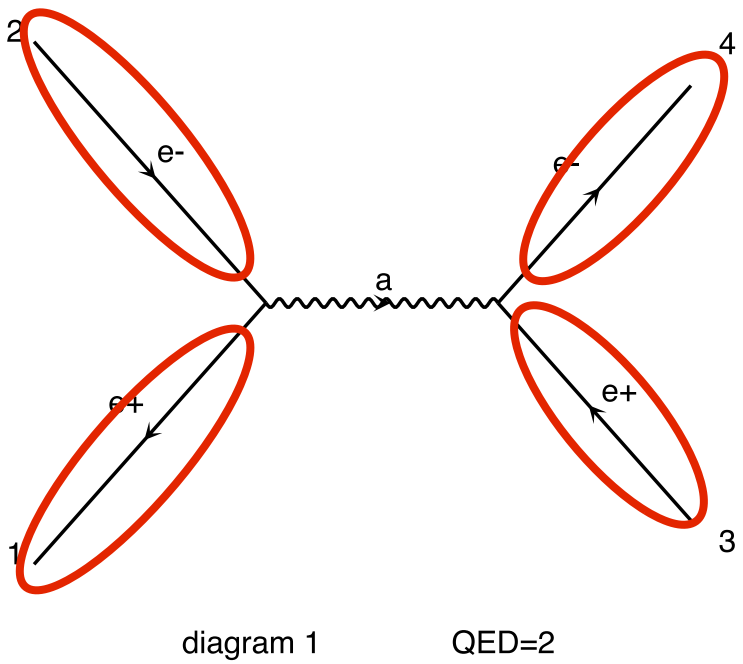

$$M = \bar{u}\gamma^\mu v \, P_{\mu\nu} \, \bar{u}\gamma^\nu v$$

→ Number for a given helicity

HELAS

- Idea: Evaluate $\mathcal{M}$ for fixed helicity of external particles.

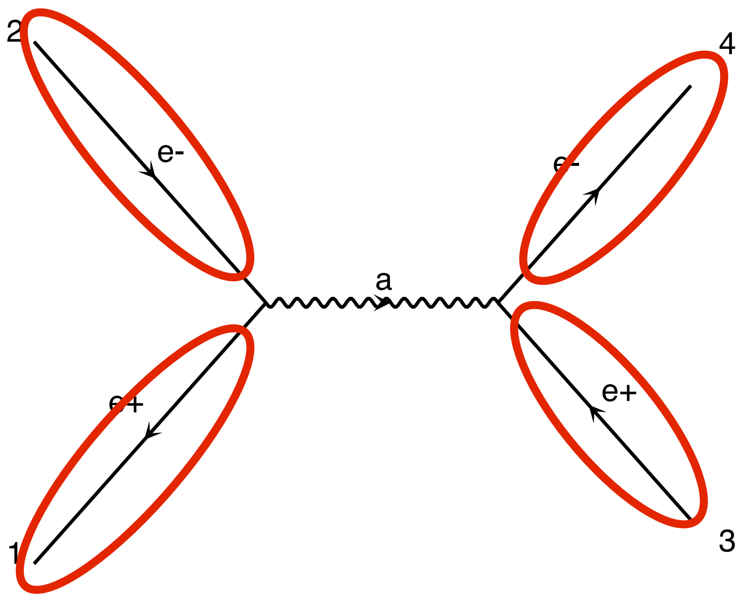

diagram 1 QED=2

$$M = \bar{u}\gamma^{\mu} v \, P_{\mu\nu} \, \bar{u}\gamma^{\nu} v$$

→ Number for a given helicity

```
CALL IXXXXX(P(0,1),ZERO,NHEL(1),+1*IC(1),W(1,1))
CALL OXXXXX(P(0,2),ZERO,NHEL(2),-1*IC(2),W(1,2))
CALL OXXXXX(P(0,3),MT,NHEL(3),+1*IC(3),W(1,3))
CALL IXXXXX(P(0,4),MT,NHEL(4),-1*IC(4),W(1,4))
```

HELAS

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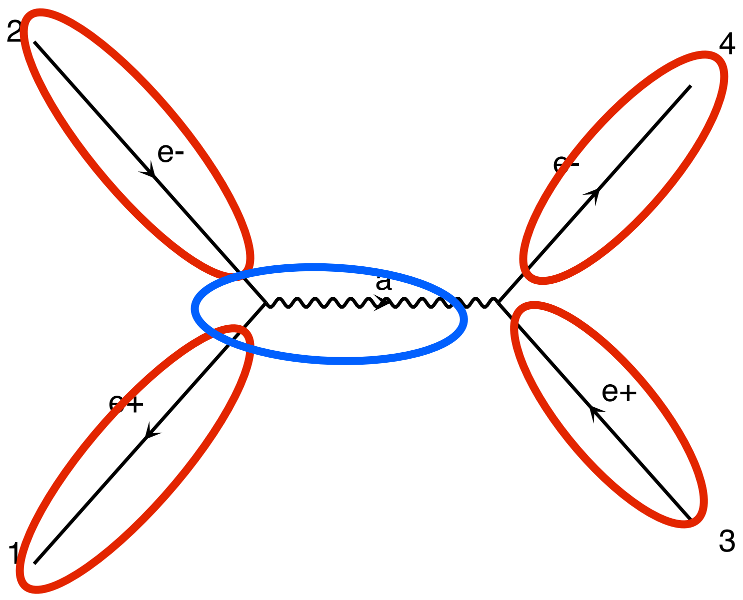

diagram 1 QED=2

$$M = \bar{u}\gamma^{\mu} v \, P_{\mu\nu} \, \bar{u}\gamma^{\nu} v$$

→ Number for a given helicity

→ Evaluate Interaction by interaction

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CALL IXXXXX(P(0,1),ZERO,NHEL(1),+1*IC(1),W(1,1))
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CALL OXXXXX(P(0,3),MT,NHEL(3),+1*IC(3),W(1,3))
CALL IXXXXX(P(0,4),MT,NHEL(4),-1*IC(4),W(1,4))
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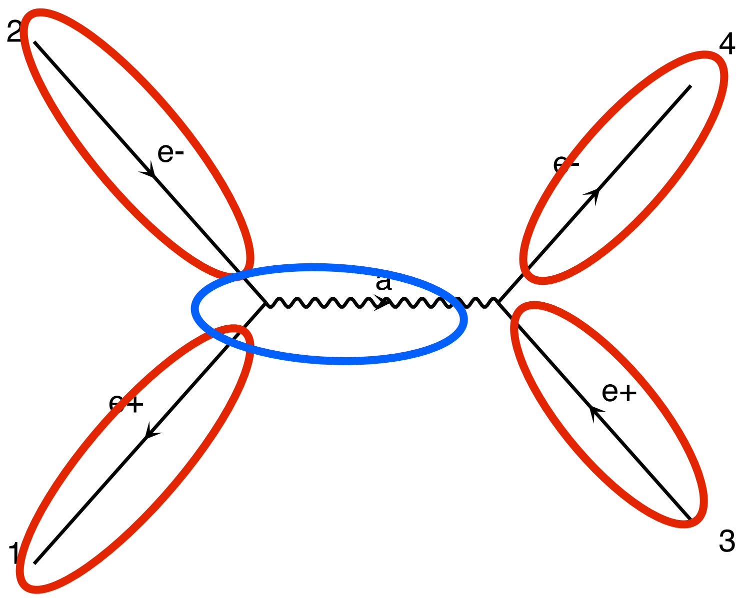

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CALL IXXXXX(P(0,4),MT,NHEL(4),-1*IC(4),W(1,4))
CALL JIOXXX(W(1,1),W(1,2),GG,ZERO,ZERO,W(1,5))
```

HELAS

- **Idea:** Evaluate $\mathcal{M}$ for fixed helicity of external particles.

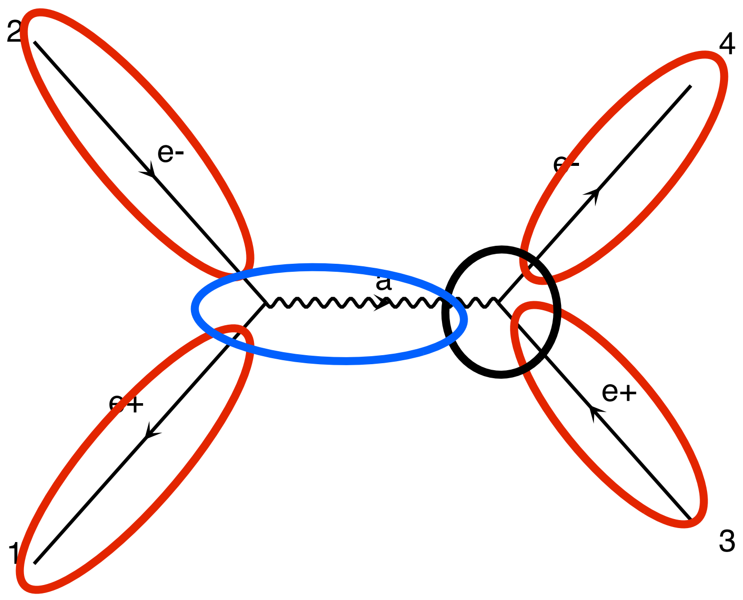

diagram 1 QED=2

$$M = \bar{u}\gamma^\mu v \, P_{\mu\nu} \, \bar{u}\gamma^\nu v$$

→ Number for a given helicity

→ Evaluate Interaction by interaction

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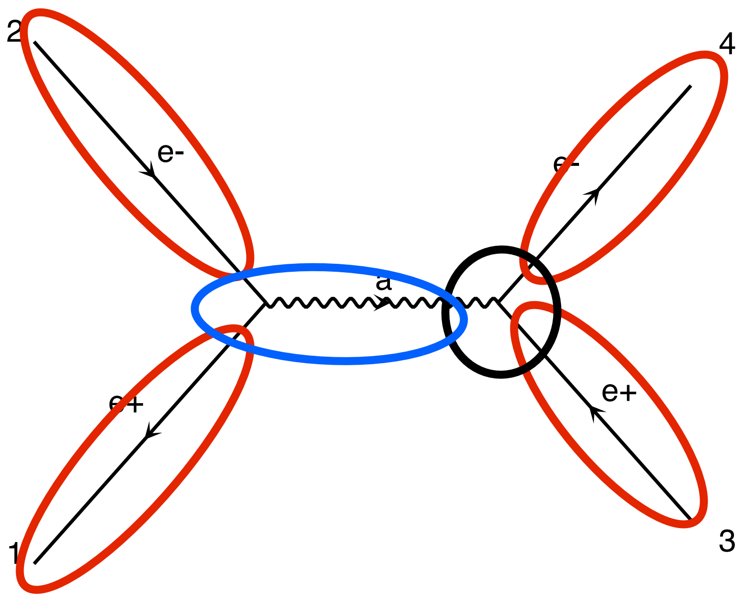

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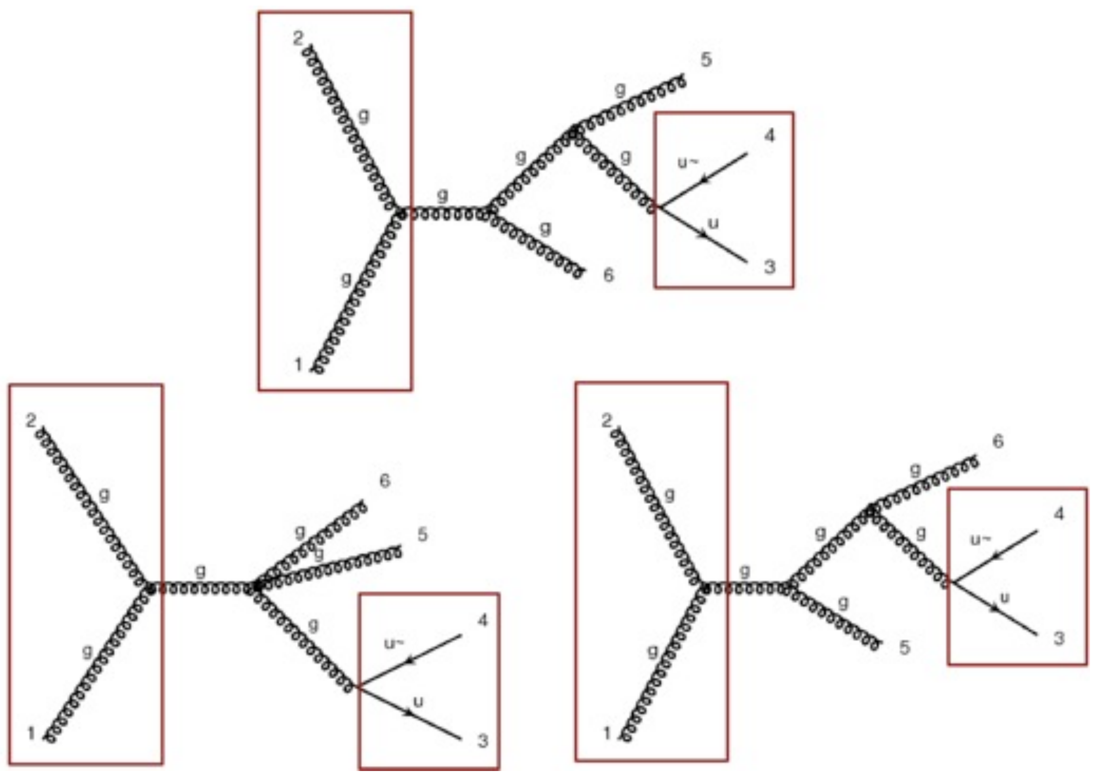
CALL JIOXXX(W(1,1),W(1,2),GG,ZERO,ZERO,W(1,5))
CALL IOVXXX(W(1,4),W(1,3),W(1,5),GG,AMP(1))
```

HELAS

- Speed:
  - The complexity grows linearly with the number of diagram
  - recycling between diagram (so reduces the factorial growth)



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- This requires an automation!!

ALOHA

[O.M, al]

- Automatic Creation of HELAS routine for ANY BSM theory
- Output
  - Fortran
  - C++
  - Python

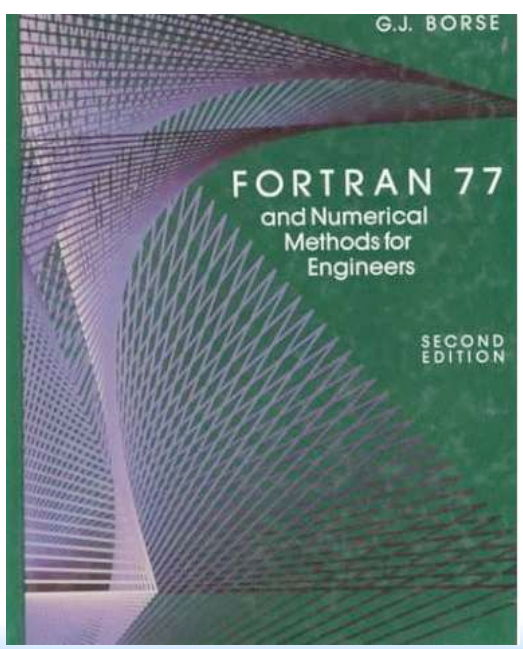
The Helas routine for BSM without the pain to write it.

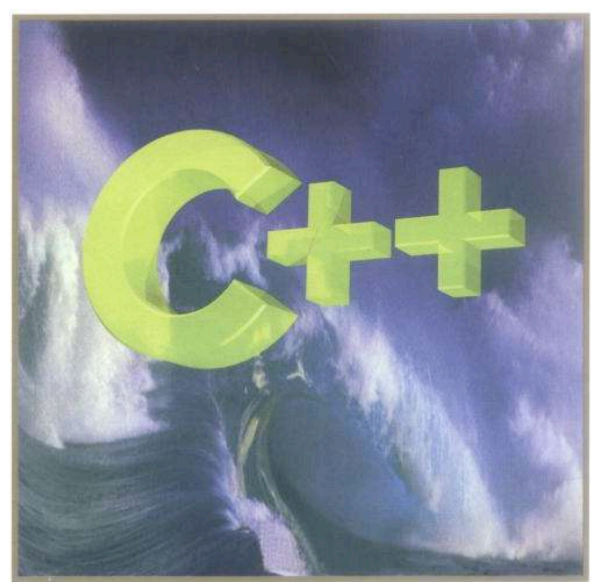
ALOHA

ALOHA ~~Google~~ translate

From: UFO To: Helicity Translate

Type text or a website address or translate a document.





ALOHA

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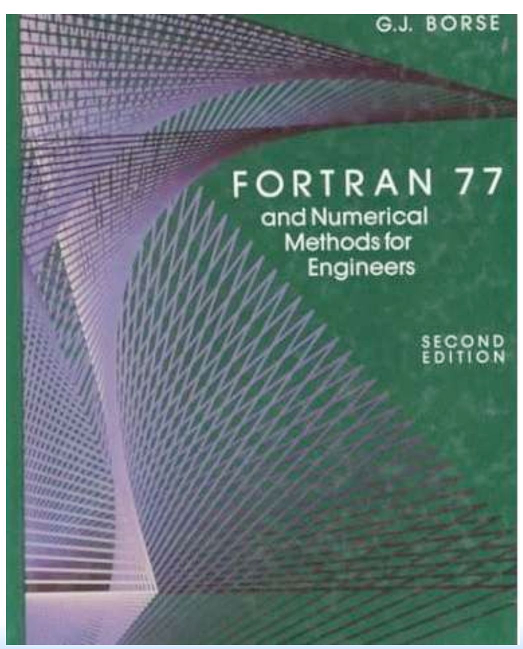
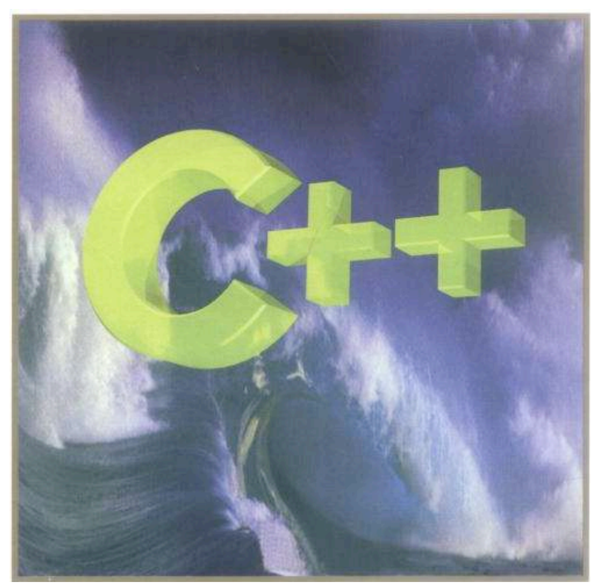
From: UFO ▾ To: Helicity Translate

Options: Standard (HELAS)
Unitary gauge
Complex-mass scheme
Loop

Type text or a website address or translate a document.





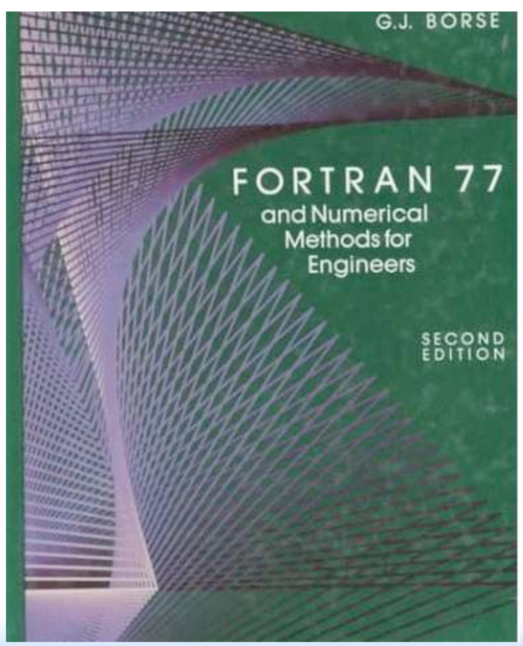
ALOHA

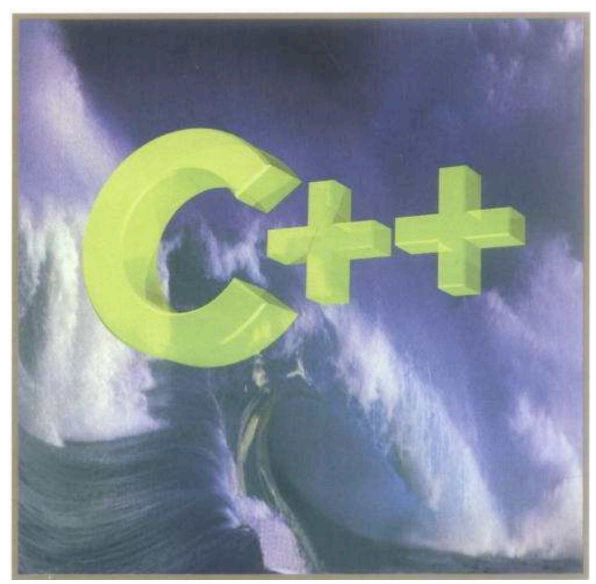
ALOHA ~~Google~~ translate

From: UFO To: Helicity Translate

Options: Standard (HELAS)
Unitary gauge 1.5
Complex-mass scheme 1.5
Loop 2.0

Type text or a website address or translate a document.





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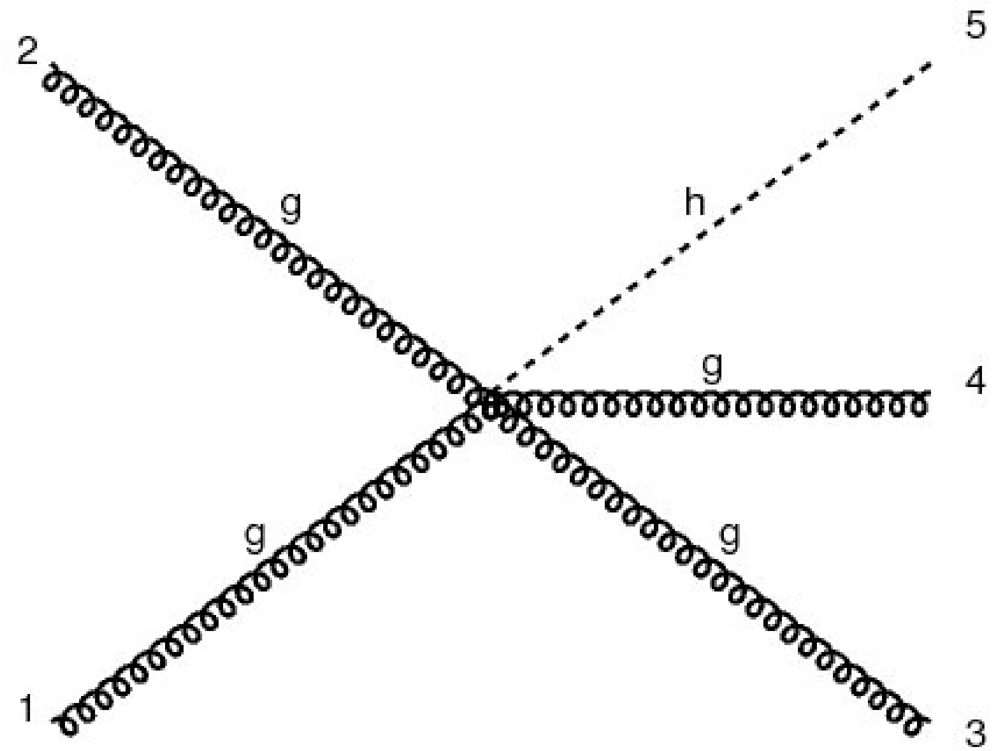
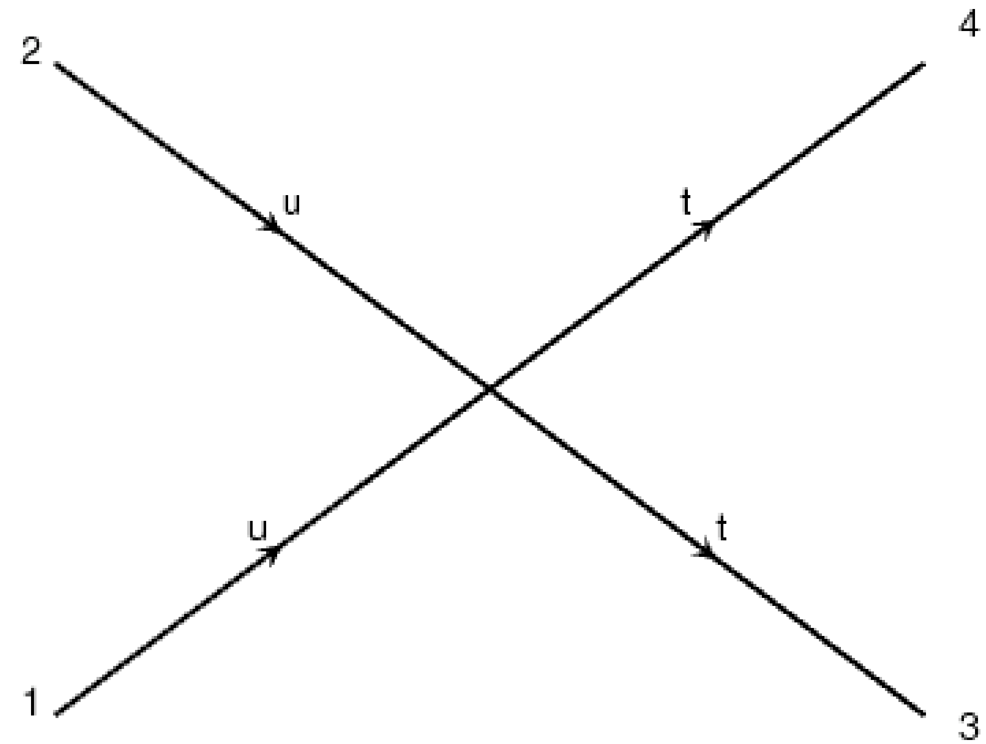
- spin implemented
  - Scalar
  - Fermion
  - Vector
  - Spin2

Type of Interactions



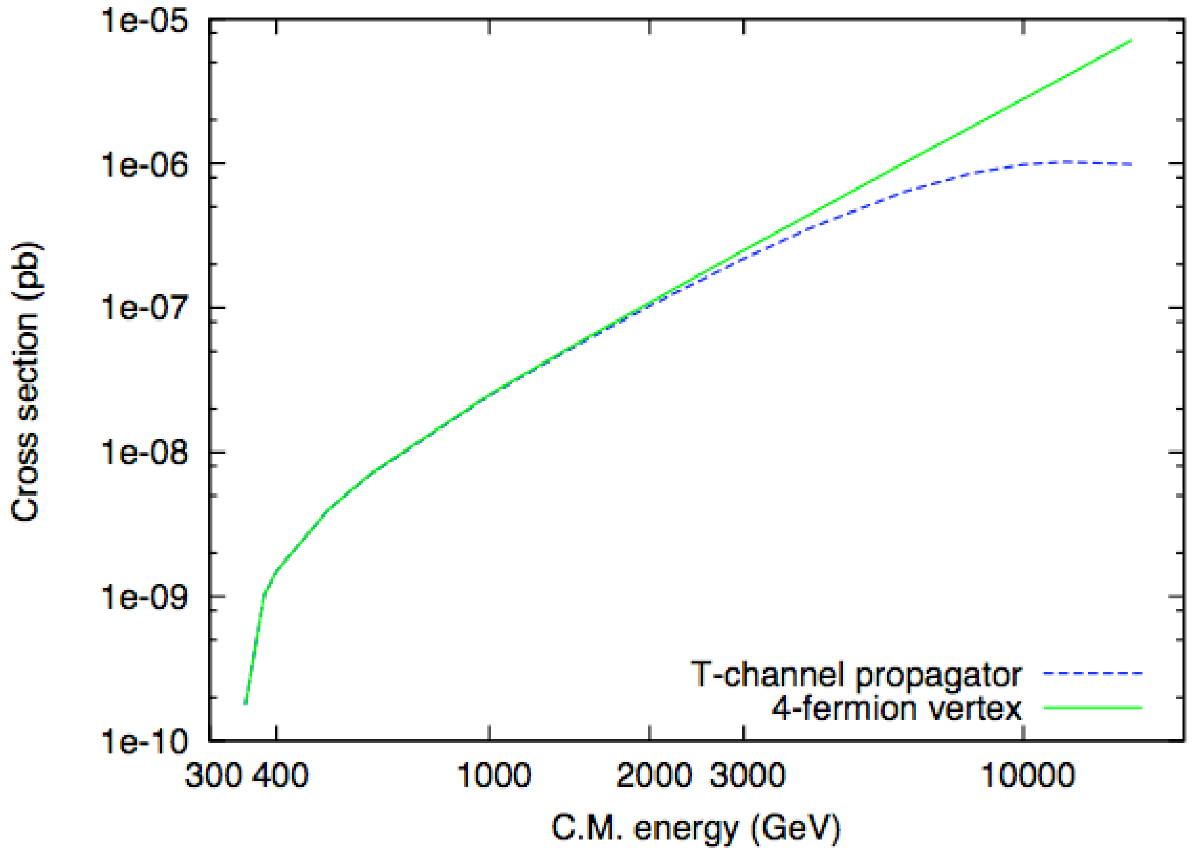
Effective Theory



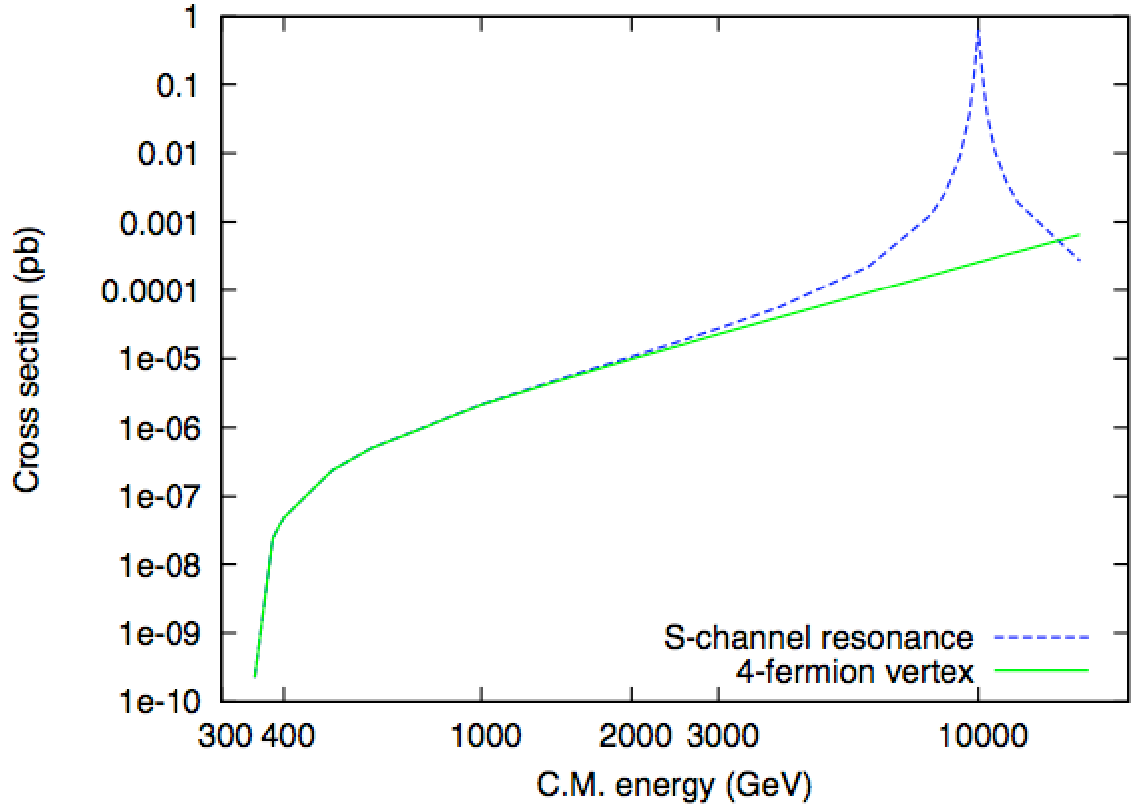
multi fermion interactions

Type of Interactions

Comparisons between explicit propagators and 4-fermion vertex



t-channel u u > t t



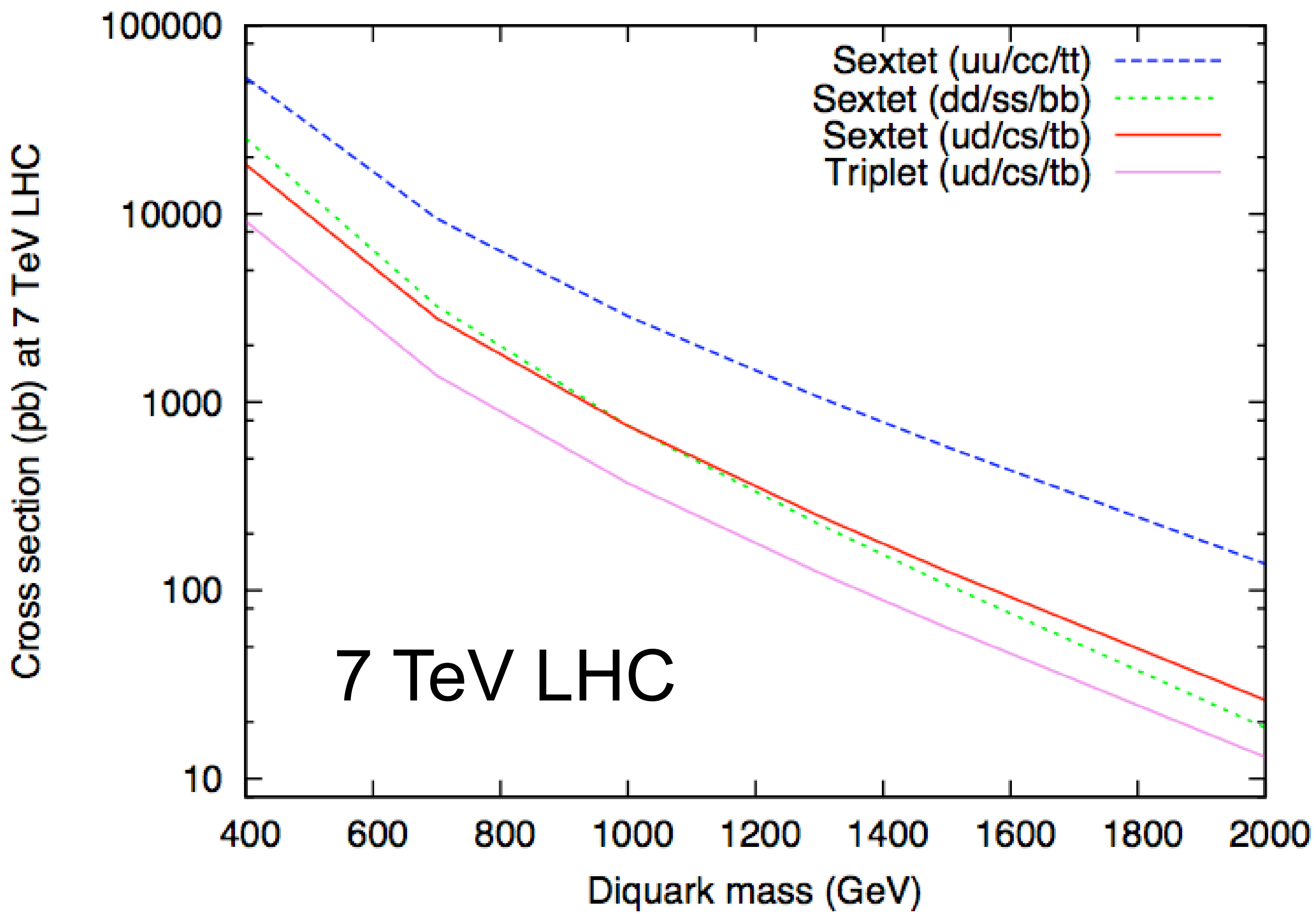
s-channel u u > t t

Plan

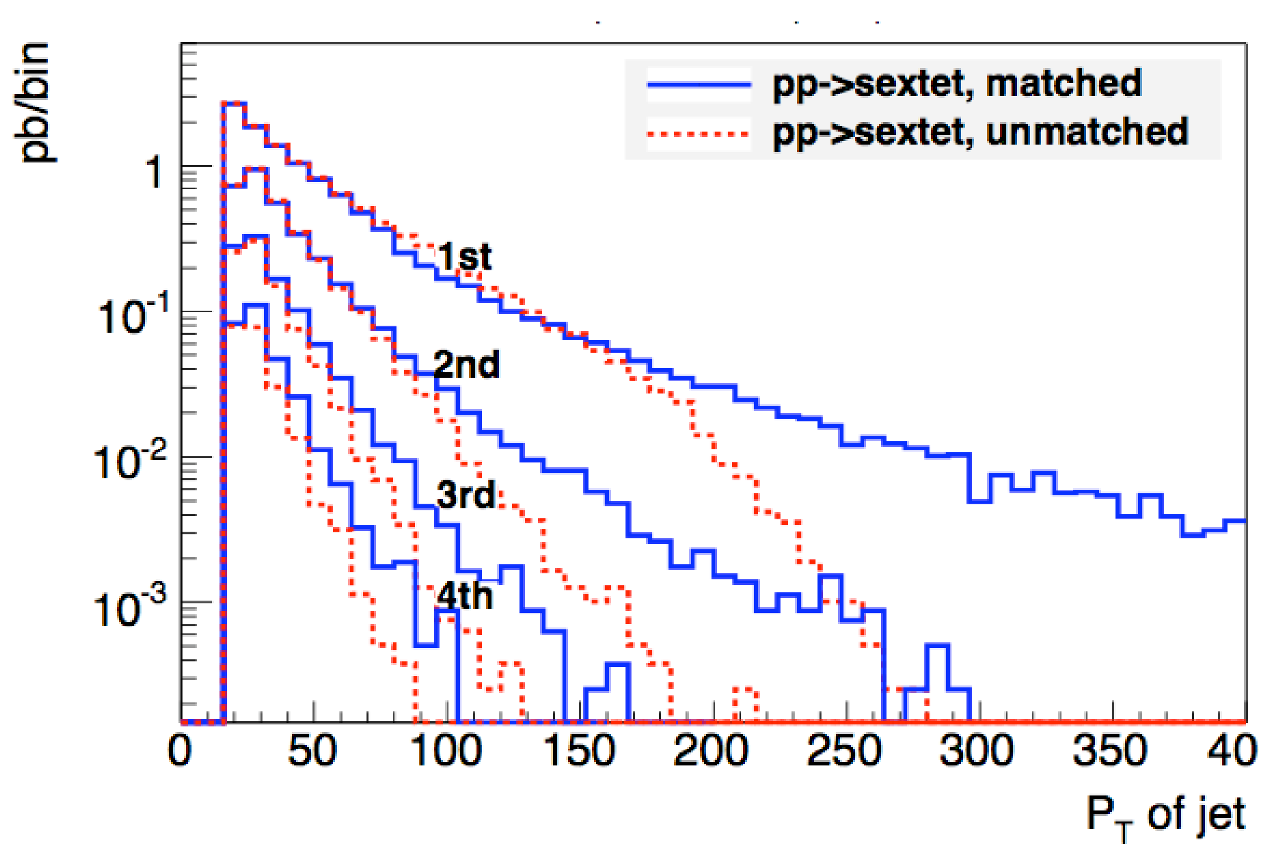
- Introduction / MadGraph5
- UFO
- ALOHA
- Color
- Model

Type of Interactions

Color sextet and ε^{ijk} implementations



Diquark cross sections with coupling 0.01



Jet p_T:s, fully matched

$pp \rightarrow D + 0,1,2$ jets

Plan

- Introduction / MadGraph5
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FAQ about the Model

- You can still use v4 model (but not C++ output possible) -- import model_v4 --
- This model is too large? MG5 can simplify it.
  - set masses/couplings to zero
- You can check that your model is valid by
  - checking the gauge invariance
  - checking the lorentz invariance
  - checking consistency of ALOHA output -- check PROCESS --
- The usermod (v4) is still working. A new one for the UFO model is on its way.

Any BSM should be possible in a fully automatic and efficient way!

If you need anything else, please let us know

Conclusion

MadGraph 5 is ready for production
both for SM and for BSM
https://launchpad.net/madgraph5