A Roadmap for communication of BSM models for the LHC

Johan Alwall, SLAC

with
Fabio Maltoni, Louvain
and the FeynRules team

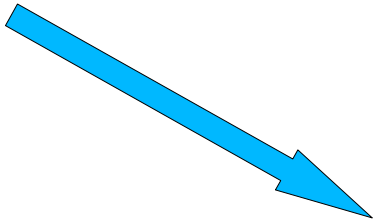
Davis, 1 Apr 2009

Communication TH-EXP

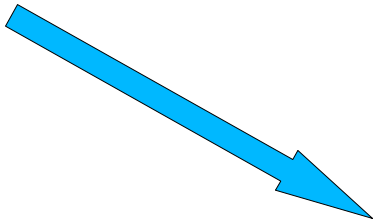
TH

EXP

Idea



?



Data

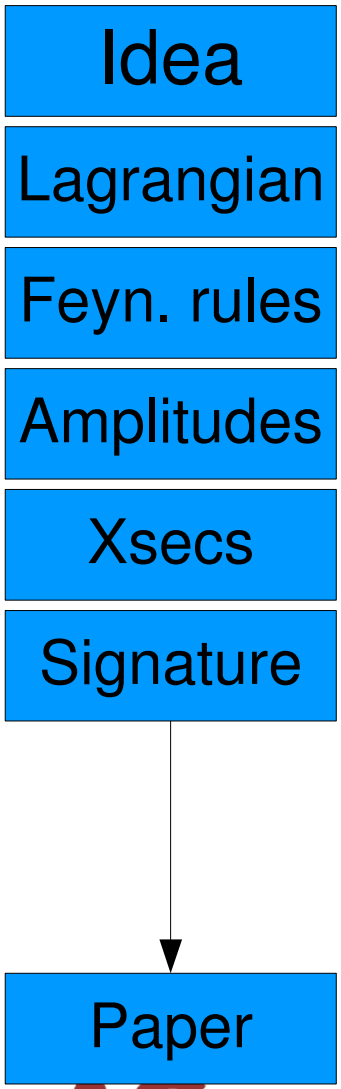
Communication today

TH

Idea

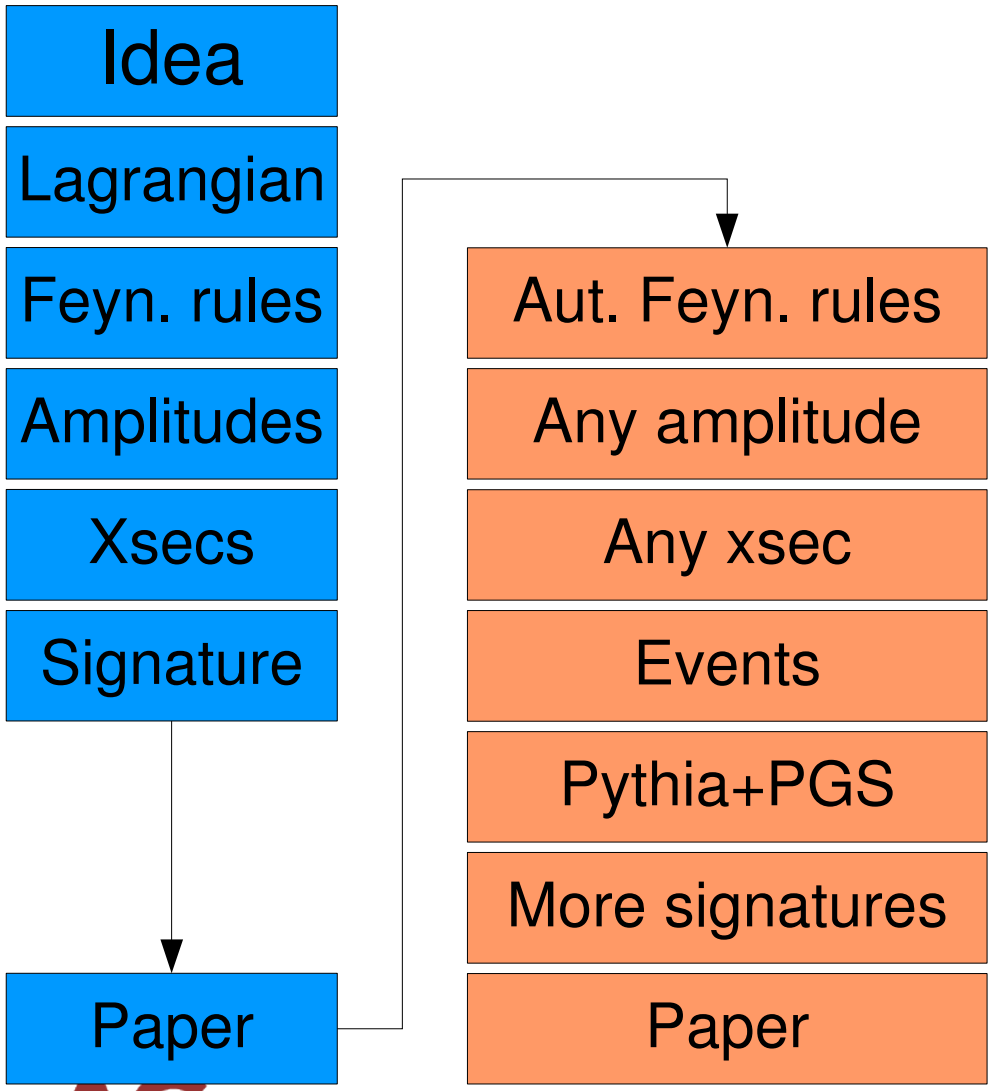
Communication today

TH



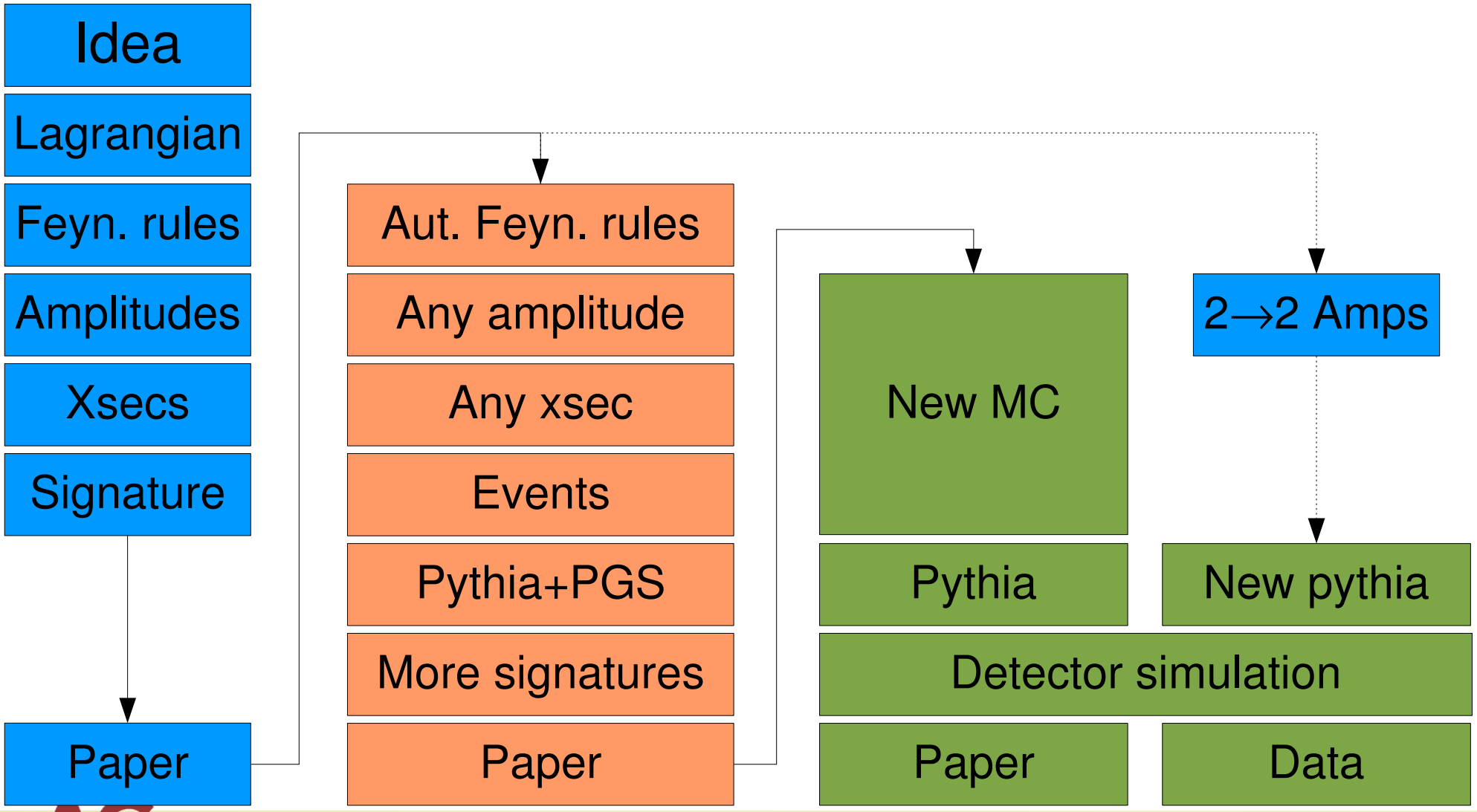
Communication today

TH PHENO



Communication today

TH PHENO EXP

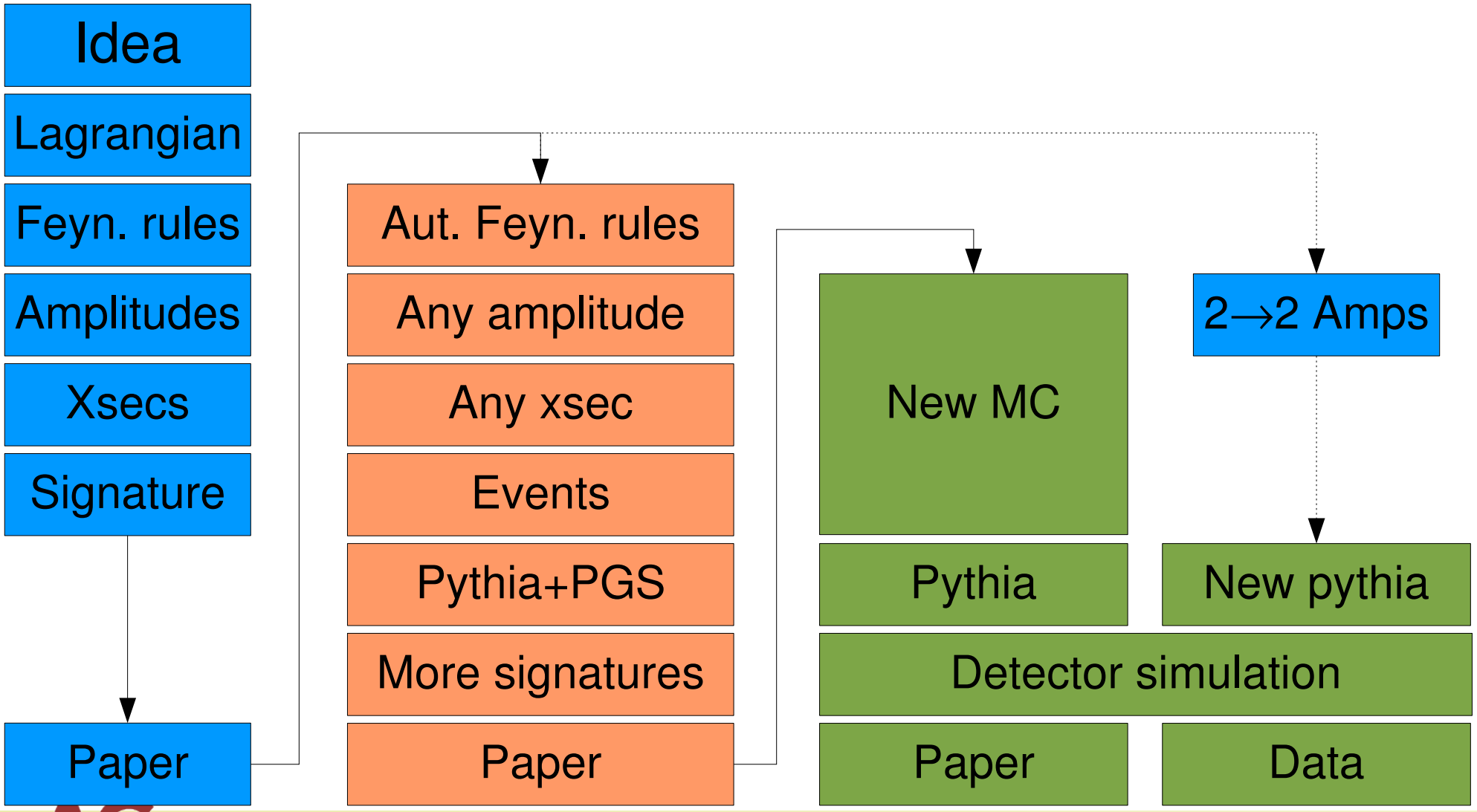


Communication today

- Workload tripled
- Long delays between stages
- Painful validations needed in every step
  - Still error prone
  - Very time/work-consuming
- Proliferation of MC tools, difficult to document/ maintain, difficult to reproduce in the long term

Roadmap for direct communication

TH PHENO EXP



Roadmap for direct communication

TH PHENO EXP

Idea

Lagrangian

Aut. Feyn. rules

Any amplitude

Any xsec

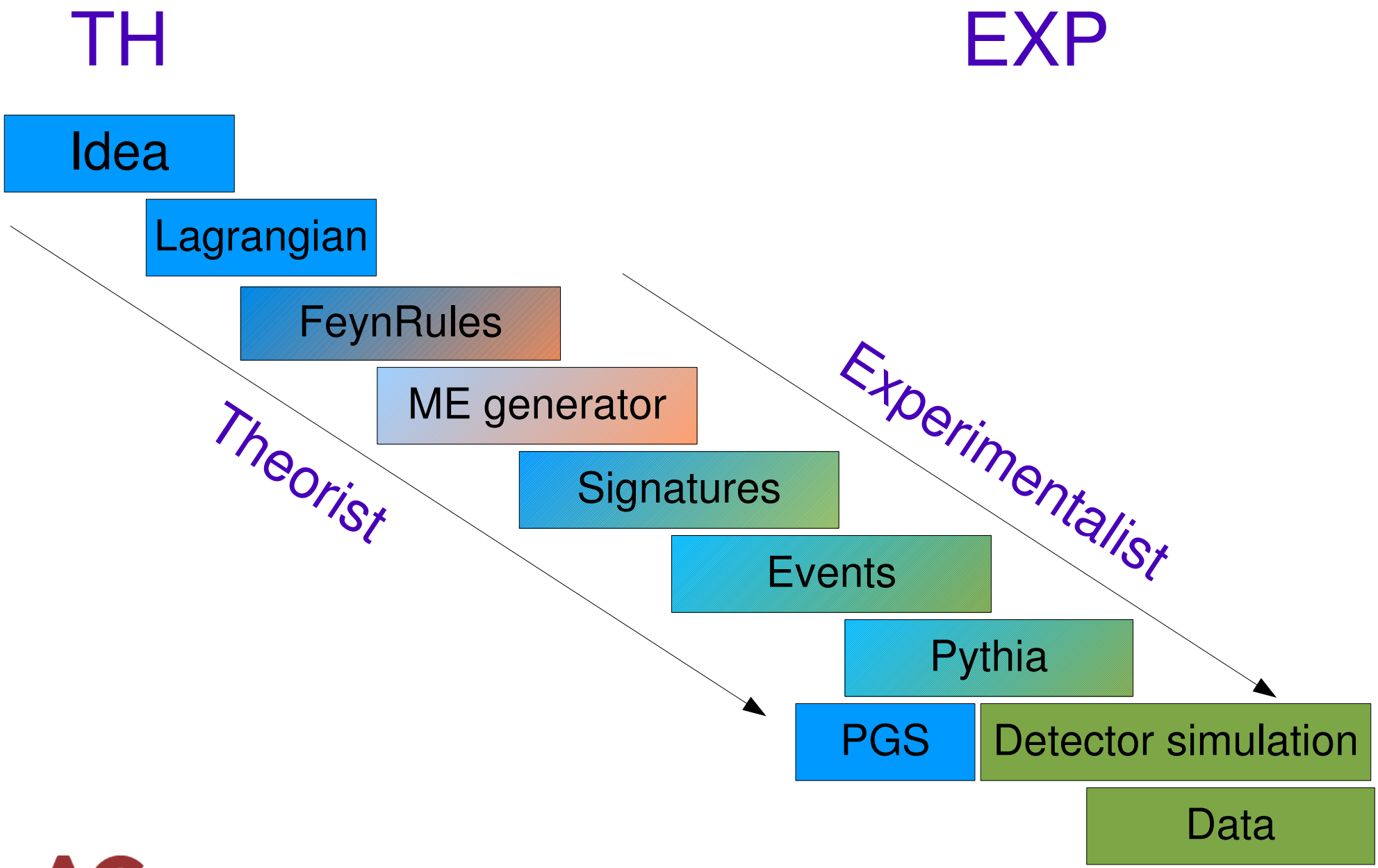
Events

Pythia

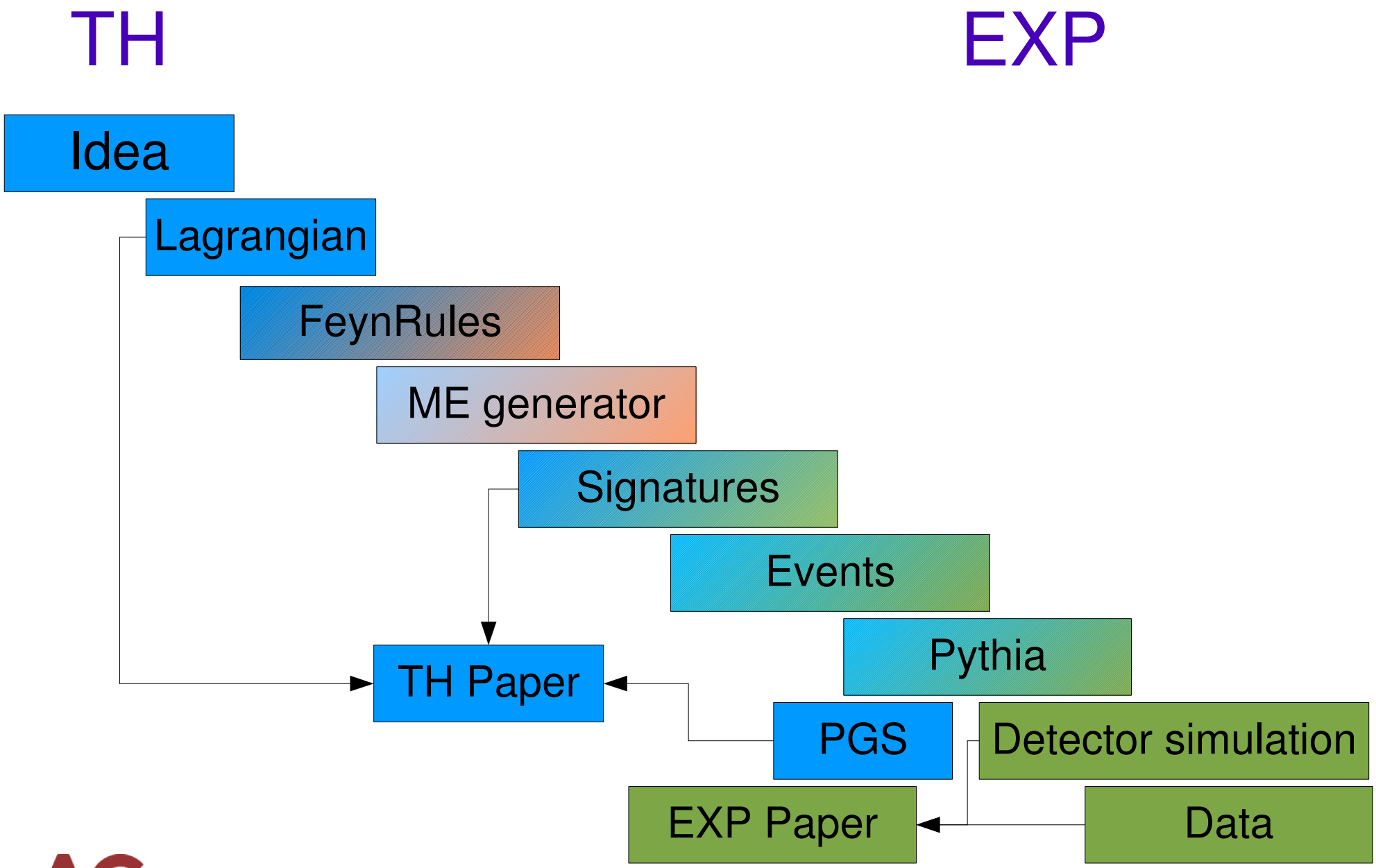
Detector simulation

Data

Roadmap for direct communication



Roadmap for direct communication

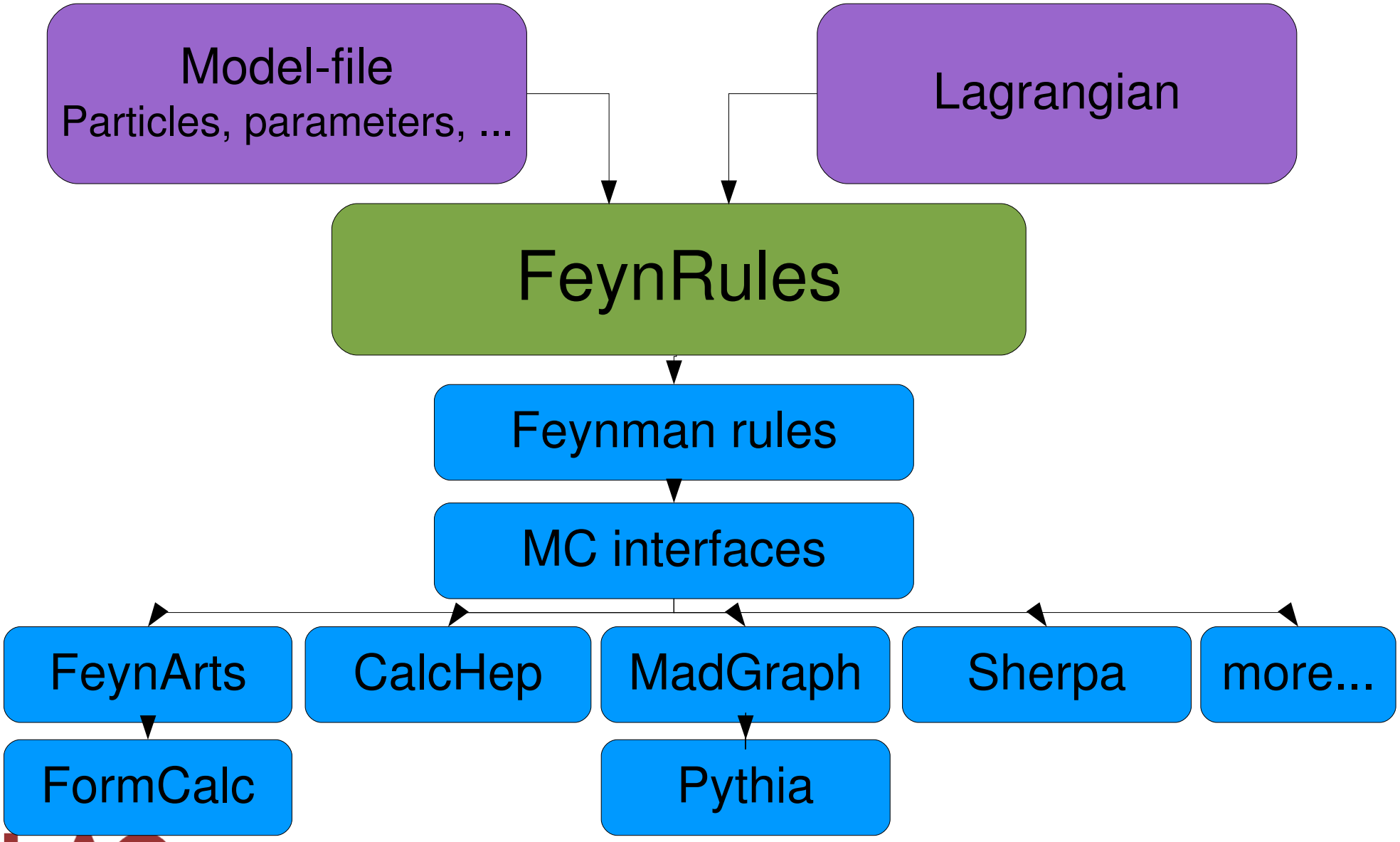


Roadmap for direct communication

- Communication between theory and experiment using Lagrangian + parameters
  - Easy to document, easy to reproduce
- Nobody wastes time building Monte Carlos
- All Monte Carlos already in exp. framework
  - Inclusion of new model automatic
  - No re-validation of tools necessary
- Completely parallel simulation chains
  - Validation of amplitudes and parton-level by theorist
  - Validation of complete simulation by experiment

FeynRules

[Christiansen, Duhr, arXiv:0806.4194]



FeynRules

[Christiansen, Duhr, arXiv:0806.4194]

- Mathematica package for derivation of Feynman rules from any Lagrangian
- Interfaces to multiple MC tools
  - Theory tools: FeynArts/CalcHep/MadGraph (loops, DM constraints, parton level MC/plots)
  - Exp. tools: MG/ME, Sherpa (already in exp. Frameworks)
- Tutorial on Friday (Claude Duhr et al)
- Please ask Claude for details

Conclusions

- How to avoid double (or triple) efforts and time in creation and validation of MC's for comparison of new models with data?
- We suggest using automatic tools all the way
  - Effortlessly from Lagrangian to simulation
  - Identical/parallel simulation chains for TH and EXP
  - Validation of theory by theorist, full sim. by exp.
  - Streamlined documentation, reproduction
- Allows for standardized framework for communication of new models, e.g. via web

Backup slides

The Hill model

SM SCALAR AND EXTRA SINGLET(S)

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[arXiv:0707.0359]

$$L = -\frac{1}{2}(D_\mu \Phi)^\dagger (D_\mu \Phi) - \frac{\lambda_0}{8}(\Phi^\dagger \Phi - f_0^2)^2$$
$$- \frac{1}{2}(\partial_\mu H)^2 - \frac{\lambda_1}{8}(2 f_1 H - \Phi^\dagger \Phi)^2$$

Slides contributed by C. Duhr

Model building with FeynRules

- Step 1: Add all the parameters of the new sector to the model file:

```
f1 == {Value -> 600,
       InteractionOrder -> {QED, -1}},

l1 == {Value -> 0.25,
       InteractionOrder -> {QED, 2}},

ca == {Value -> 0.896242},
```

Cosine of the mixing angle

$$L = -\frac{1}{2}(D_\mu \Phi)^\dagger (D_\mu \Phi) - \frac{\lambda_0}{8}(\Phi^\dagger \Phi - f_0^2)^2 - \frac{1}{2}(\partial_\mu H)^2 - \frac{\lambda_1}{8}(2 f_1 H - \Phi^\dagger \Phi)^2$$

Slides contributed by C. Duhr

Model building with FeynRules

- Step II: Add all the particles of the new sector to the model file:

```
S[1] == {
  ClassName -> h1,
  SelfConjugate -> True,
  Mass -> {Mh1, 78.5}},

S[2] == {
   ClassName -> H,
   SelfConjugate -> True,
   Unphysical -> True,
   Definitions -> {H -> sa h1 +ca h2}}
```

Mass eigenstate

Mixing

$$L = -\frac{1}{2}(D_\mu \Phi)^\dagger (D_\mu \Phi)$$

$$- \frac{\lambda_0}{8}(\Phi^\dagger \Phi - f_0^2)^2$$

$$- \frac{1}{2}(\partial_\mu H)^2$$

$$- \frac{\lambda_1}{8}(2 f_1 H - \Phi^\dagger \Phi)^2$$

Slides contributed by C. Duhr

Phenomenology with FeynRules

- Now we are ready to do some phenomenology...
- Let's consider the following process in the framework of Hill model

$$e^+e^- \to Zb\tilde{b} \quad \to \quad \mu^+\mu^- b\tilde{b}$$

At a CoM energy of 500GeV.

- Let's first have a look at the one-loop corrections.

Use FeynArts

Slides contributed by C. Duhr

Phenomenology with FeynRules

- The results obtained by FeynRules can be easily exported to FeynArts:

```
WriteFeynArtsOutput["HillModel.mod",{LSM + LHill}, FlavorExpand → SU2W]
```

– – – FeynRules interface to FeynArts – – –

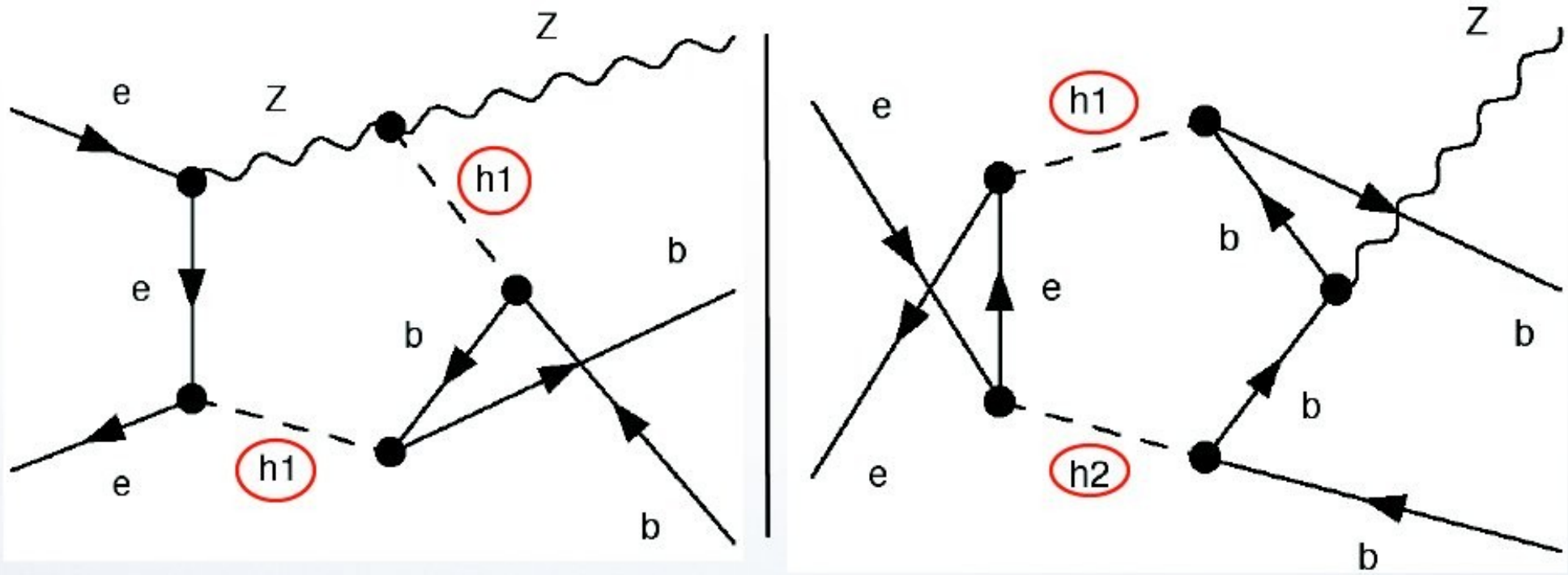
C. Duhr, 2007

- This produces a FeynArts model-file which can be read by FeynArts.

```
topo = CreateTopologies[1, 2 → 3,
    ExcludeTopologies → Internal];
Amp = InsertFields[topo,
        {F[2, {1}], -F[2, {1}]} → {V[2], F[4, {3}], -F[4, {3}]},
        Model → HillModel];
```

Slides contributed by C. Duhr

Phenomenology with FeynRules



Slides contributed by C. Duhr

Phenomenology with FeynRules

- The results obtained by FeynRules can be easily exported to MadGraph:

```
WriteMGOutput[LSM + LHill]
```

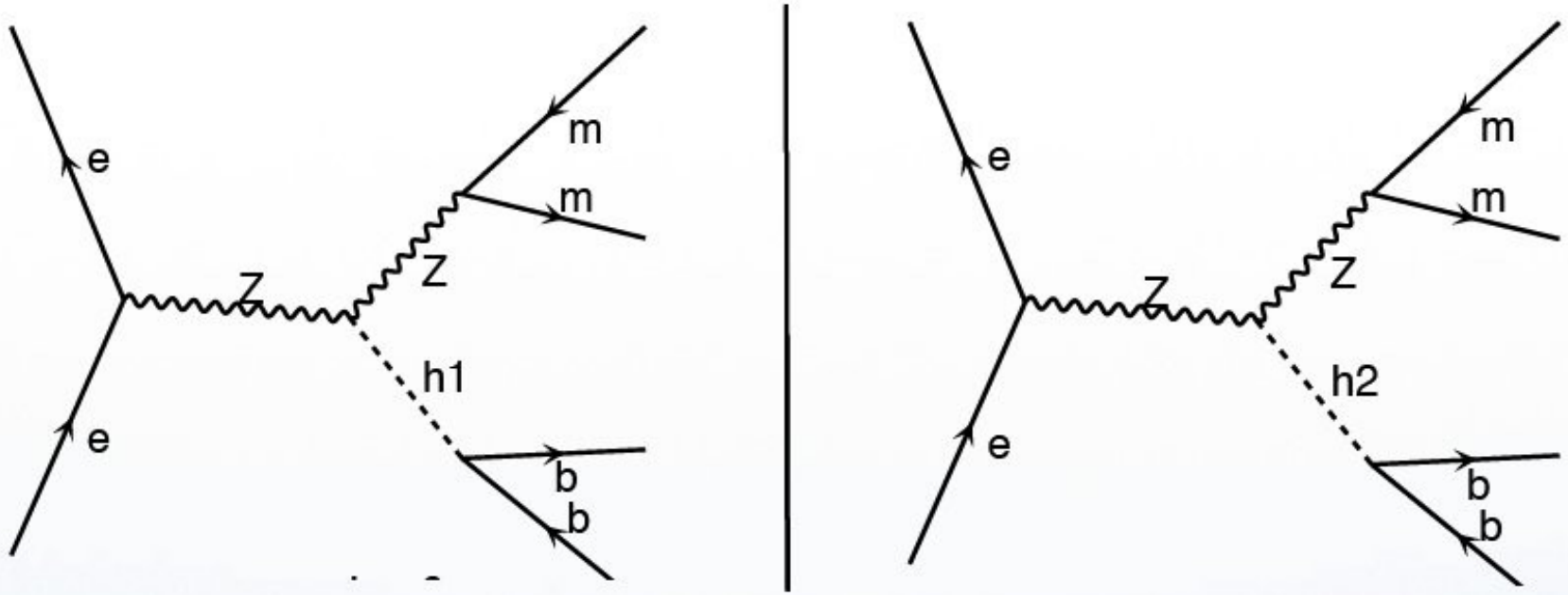
– – – FeynRules interface to MadGraph – – –

C. Duhr, M. Herquet, 2007

- This produces all the files needed to implement the Hill model into MadGraph. Let's have a look at our process!

Slides contributed by C. Duhr

Phenomenology with FeynRules



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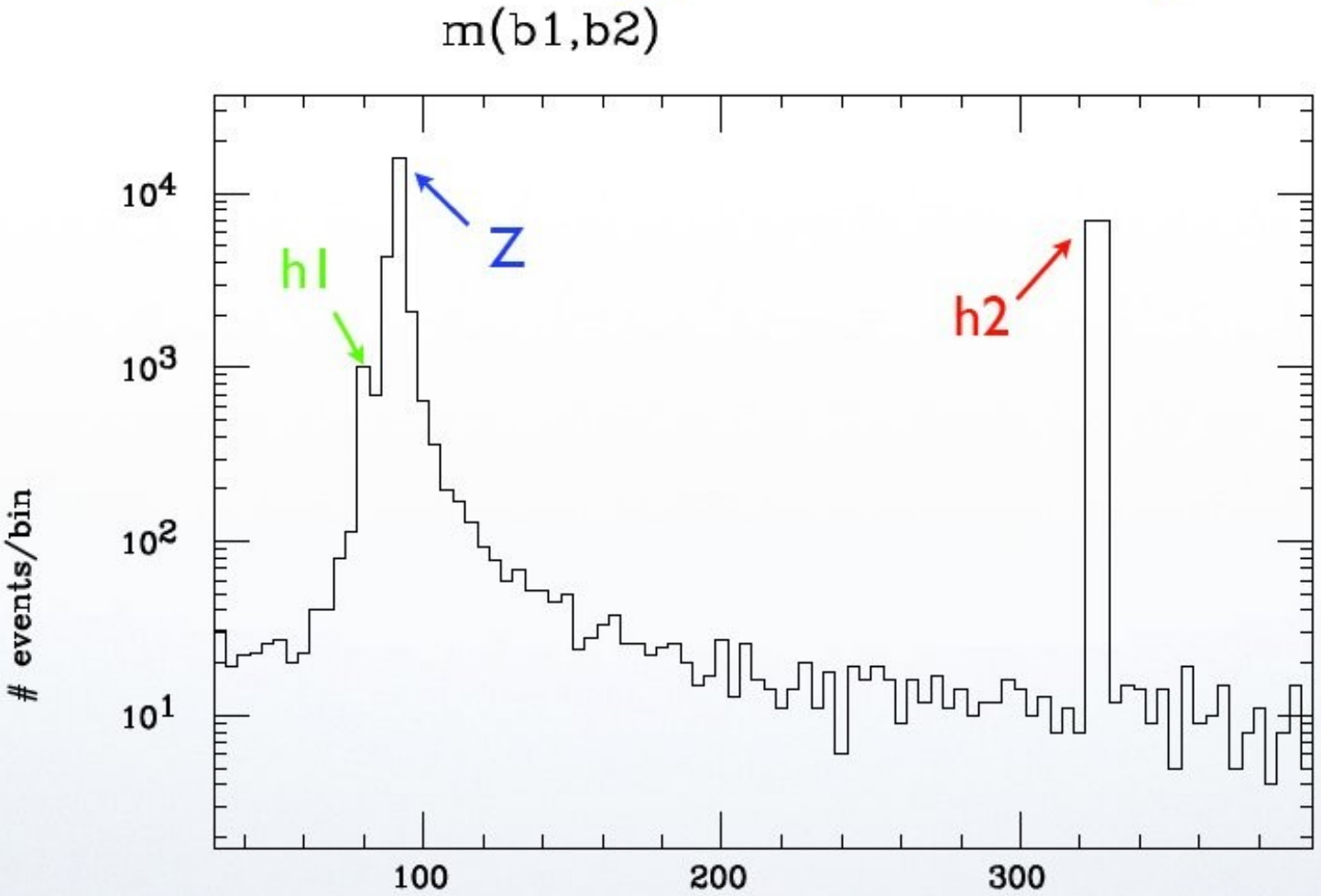
Phenomenology with FeynRules



Slides contributed by C. Duhr