MadGraph/MadEvent v4

Building bridges between theory(ies) and experiment(s)

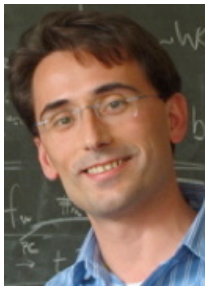
Michel Herquet & Simon de Visscher

+

The MG/ME development team

Core team

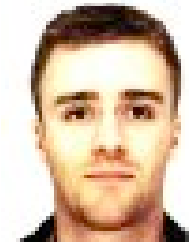
T. Stelzer (UIUC)
Original author



F. Maltoni (Louvain)
Original author

J. Alwall (SLAC)
Matching, Pythia, MSSM

P. Denim (Louvain)
ExRootAnalysis, Grid



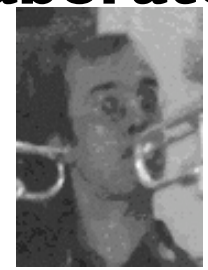
S. de Visscher (Louvain)
Matching, usrmod, mass production

R. Frederix (Louvain)
New models, HELAS, Grid

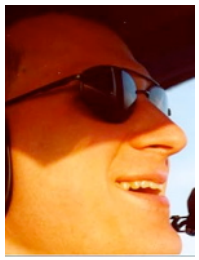
M. Herquet (Louvain)
New models, web & clusters

Long-standing collaborators

S. Mrenna (FNAL)
Matching, Pythia



T. Plehn (Edinburgh)
MSSM



D. Rainwater (Rochester)
MSSM, HELAS

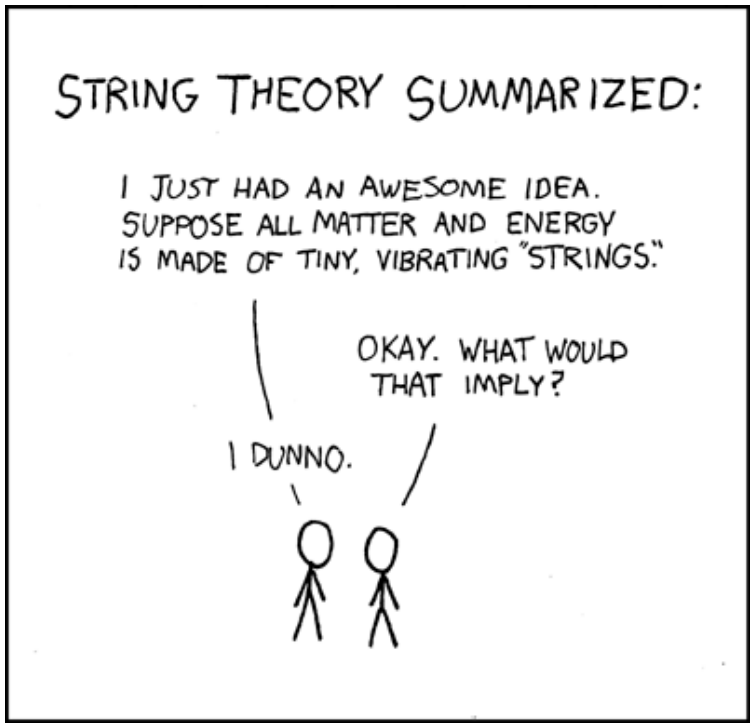
New directions

P. Artoisenet (Louvain)
MadOnia, ME methods

O. Mattelaer (Louvain)
ME methods

C. Duhr (Louvain)
FeynRules

Building bridges ?

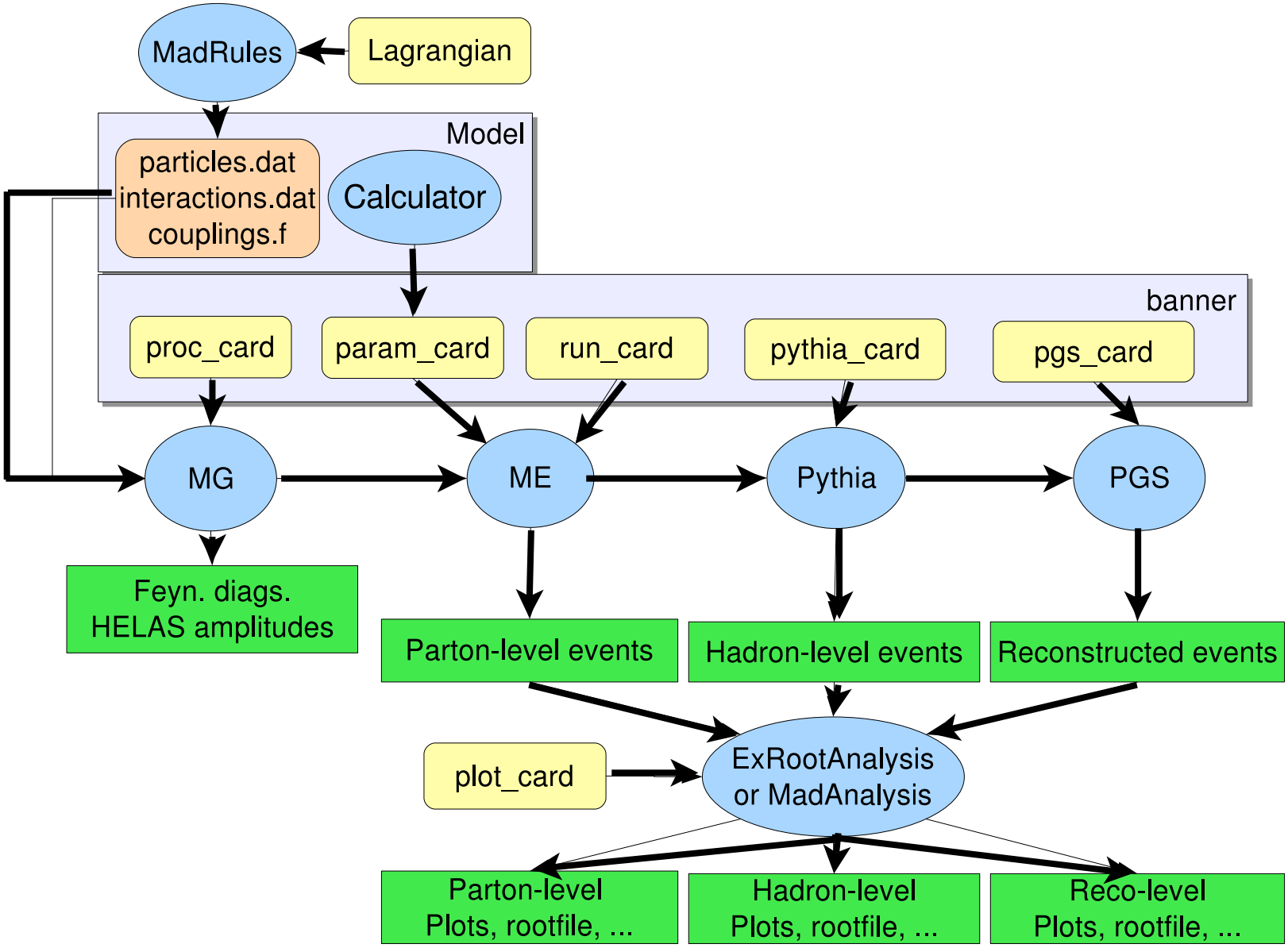


Before the linear accelerator

Plan

- Global picture
- Usrmod & FeynRules: From an idea to a model
- MadGraph: From a model to amplitudes
- MadEvent: From amplitudes to events
- Mass production of event samples with MG/ME
- Conclusion

MG/ME: global picture



Part 1:
From a theoretical idea to a model

New models (1)

- MG/ME deals with different physical models as directories containing:
  - **particles.dat** : particle list with name, PDG codes, properties, ...
  - **interactions.dat** : list of all possible 3- and 4-vertices
  - **couplings.f** : analytic expressions for Feynman rules couplings
- MG/ME comes with several predefined models: MSSM, 2HDM, HEFT, BSM top, ...

New models (2)

- **Calculators**: generic name for tools generating **param_card.dat** files (text files with all model parameters compliant with the Les Houches Accord format). Exist for MSSM, 2HDM, ...
- **USRMOD**: script allowing users to implement their own models by modifying the SM default

New models (3)

- **FeynRules** : new package to compute Feynman rules from Lagrangian
  - Theorist friendly Mathematica package
  - Completely generic, zeroth level output is TeX!
  - Interfaces for **MG/ME**, but also for **Sherpa** and **CalcHEP**
  - Still in beta testing, but first stable version to be release soon!

Part 2:
From a model to amplitudes

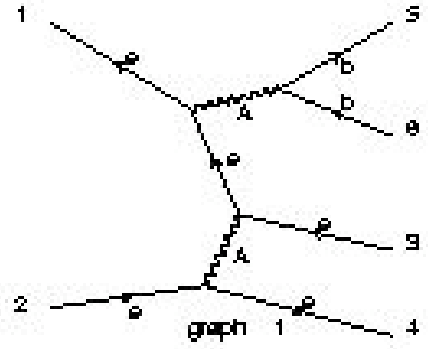
MadGraph

- Basic building blocks : Feynman diagrams
  - Generates "empty" topologies for m>n diagrams and "fill" them using valid interaction vertices
  - Knowing particles properties (listed in the particles.dat file), produces Feynman diagrams and suitable f77 calls to the HELAS library
  - User friendly web interface

MG output sample

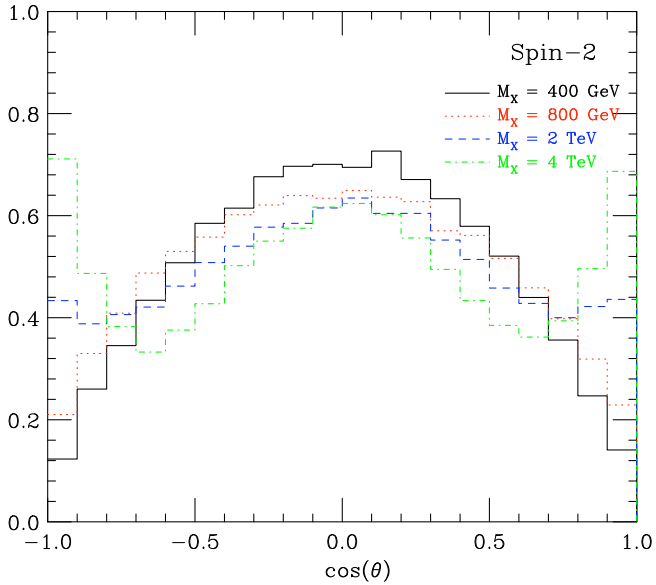
- Sample matrix.f file (for the $e^+e^- \to e^+e^-b\bar{b}$ process)

```
CALL OXXXXX(P(0,1   ),ZERO ,NHEL(1   ),-1*IC(1   ),W(1,1   ))
CALL IXXXXX(P(0,2   ),ZERO ,NHEL(2   ),+1*IC(2   ),W(1,2   ))
CALL IXXXXX(P(0,3   ),ZERO ,NHEL(3   ),-1*IC(3   ),W(1,3   ))
CALL OXXXXX(P(0,4   ),ZERO ,NHEL(4   ),+1*IC(4   ),W(1,4   ))
CALL OXXXXX(P(0,5   ),BMASS ,NHEL(5   ),+1*IC(5   ),W(1,5   ))
CALL IXXXXX(P(0,6   ),BMASS ,NHEL(6   ),-1*IC(6   ),W(1,6   ))
CALL JIOXXX(W(1,2   ),W(1,4   ),GAL ,ZERO    ,AWIDTH  ,W(1,7   ))
CALL FVIXXX(W(1,3   ),W(1,7   ),GAL ,ZERO    ,ZERO    ,W(1,8   ))
CALL JIOXXX(W(1,8   ),W(1,1   ),GAL ,ZERO    ,AWIDTH  ,W(1,9   ))
CALL IOVXXX(W(1,6   ),W(1,5   ),W(1,9   ),GAD ,AMP(1   ))
CALL JIOXXX(W(1,8   ),W(1,1   ),GZL ,ZMASS   ,ZWIDTH  ,W(1,10  ))
CALL IOVXXX(W(1,6   ),W(1,5   ),W(1,10  ),GZD ,AMP(2   ))
CALL JIOXXX(W(1,2   ),W(1,4   ),GZL ,ZMASS   ,ZWIDTH  ,W(1,11  ))
CALL FVIXXX(W(1,3   ),W(1,11  ),GZL ,ZERO    ,ZERO    ,W(1,12  ))
CALL JIOXXX(W(1,12  ),W(1,1   ),GAL ,ZERO    ,AWIDTH  ,W(1,13  ))
CALL IOVXXX(W(1,6   ),W(1,5   ),W(1,13  ),GAD ,AMP(3   ))
CALL JIOXXX(W(1,12  ),W(1,1   ),GZL ,ZMASS   ,ZWIDTH  ,W(1,14  ))
CALL IOVXXX(W(1,6   ),W(1,5   ),W(1,14  ),GZD ,AMP(4   ))
CALL JIOXXX(W(1,3   ),W(1,1   ),GAL ,ZERO    ,AWIDTH  ,W(1,15  ))
```

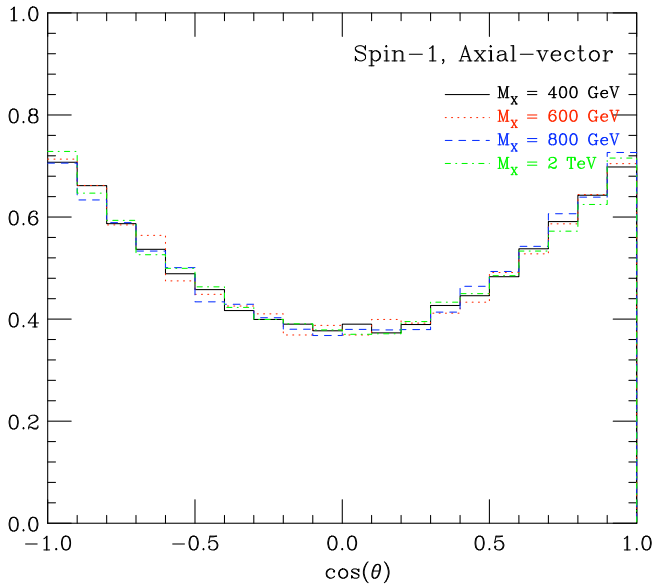


Advantages of ME

- "Natural" approach for phase space regions where perturbative expansion is effective (hard, high angle, ...)
- Take into account all possible interferences
- Simulate correctly spin correlations
- Can be used for new analysis techniques



(b)



Technical aspects

- Written in F77, does not require any external library
- "Limited" to ~100k Feynman diagrams (~10000 per SubProcess), essentially because of F77 limitations
- Produces summary files and a self containing MadEvent package (can be done online)
- Can be used in "StandAlone" mode by theorists

Part 3:
From amplitudes to events

MadEvent

- Adaptive methods like VEGAS adjust a "grid" to numerically flatten peaks
  - But : time expensive, peaks must lie on integration variables
- Solutions exist : Multi-Channel Integration (Amegic,Nextcalibur,Whizard), **Single Diagram Enhanced MCI** (MadEvent) :

$$|\sum_i A_i|^2 = \sum_i \left(\frac{|A_i|^2}{\sum_j |A_j|^2} |\sum_k A_k|^2 \right)$$

- One peaked function per diagram
- Parallel in nature

Hadron collision

- Parton distribution functions (**PDFs**) must be taken into account when calculating cross sections :

$$\sigma = \frac{1}{2s} \sum_{p_1, p_2} \int f_{p_1}(x_1) f_{p_2}(x_2) |M|^2 \mathrm{d}\Phi \mathrm{d}x_1 \mathrm{d}x_2$$

- MadGraph automatically deals with **summations over multiple partons** (p, j and l symbols)
- MadEvent automatically integrates over PDFs
- MG/ME can deal with several processes inclusively, e.g.

$$pp \to X, X + 1j, X + 2j, \ldots, X + nj$$

Technical aspects

- MadEvent: self containing (process dependent) F77 package, no external library + Bash & Perl scripts
- **Online event generation** available on our 3 public clusters
  - madgraph.phys.ucl.ac.be : Louvain (30 CPU, 500Go)
  - madgraph.hep.uiuc.edu : UIUC (36 CPU, 2To)
  - madgraph.roma2.infn.it : Roma (32 CPU, 500 Go)
- CVS version of server CGI scripts available
- PBS (Torque, OpenPBS, PBSPro) and Condor (through "translation" scripts) are supported

Let’s go online!

Part 4:
Mass production

Why ?

- To provide **public reference samples** of parton level events for "**standard processes**"
  - To be used by the **TH/PH** community
  - To be used as a **reference by EXP** collaboration(s) doing full simulation of these processes

What ?

- **First stage: SM processes** (V+jets, VV+jets, tt +jets, H+jets, VVV, ...)
  - Only cuts required for production and matching validation
  - One sample per jet multiplicity
- **Second stage**: Other SM processes (photon + jets, only jets, ...) and standard MSSM processes
- **Third stage**: other BSM processes, biased SM samples, ...

Who ?

- **MG/ME team + collaborators**
  - Production of ~100K **test samples** and the associated **Grid code** to produce more (+ sanity checks)
  - **Validation** of these samples by matching with Pythia (see Simon's talk)
- **"Interested people"** (i.e. help needed here...)
  - **Production** and **storage** of the large samples
  - **Full simulation** using collaboration tools

When ?

- **First stage** (SM samples definition and validation) to be finished at the end of **February**
- **Second and (part of) third stage** expected for **April/May**
- **Mass production** and **collaboration(s) simulations** to be started in **March ???**

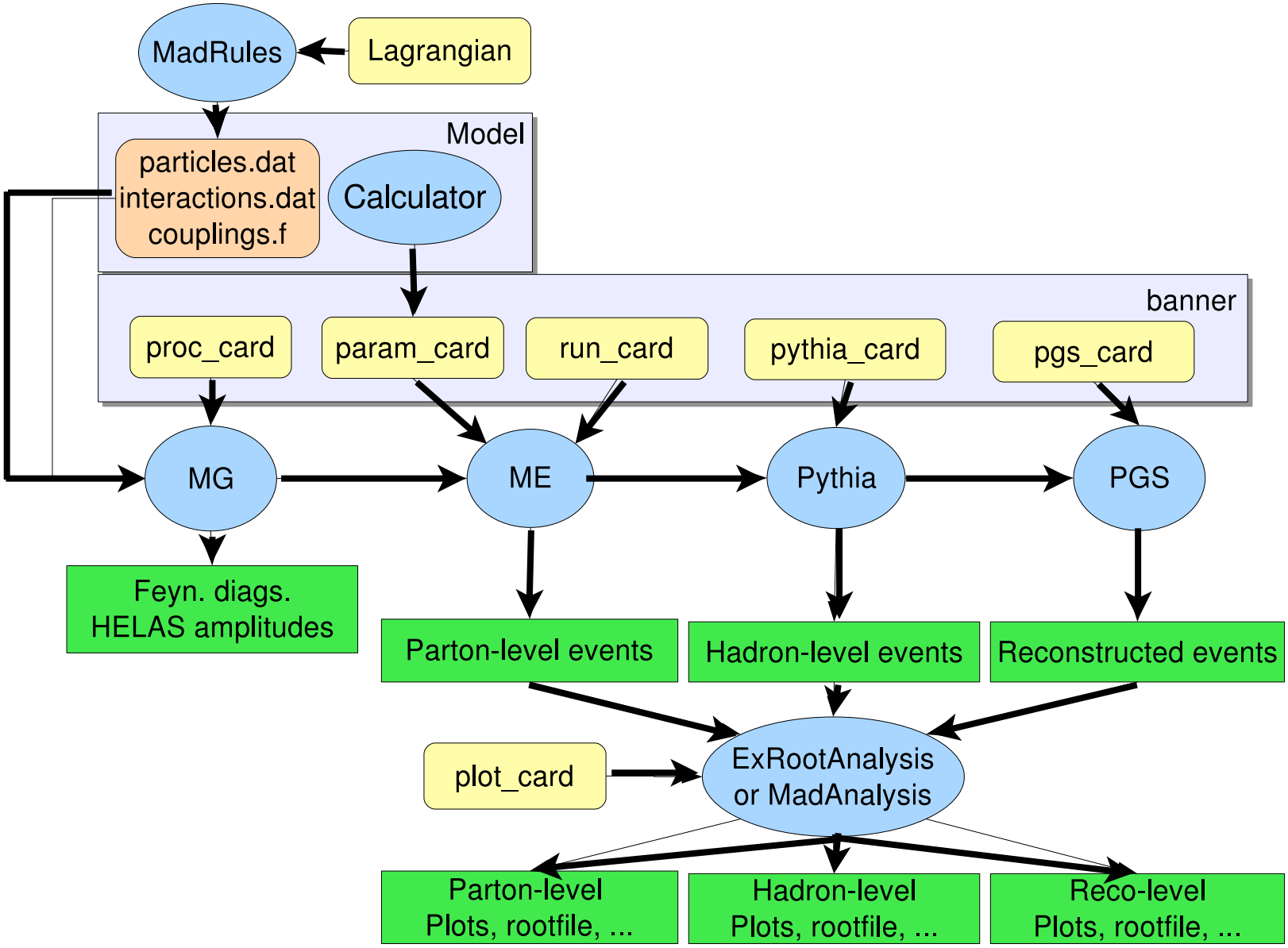
How ?

- Test samples **validation and grid packages production** on our clusters **by the team**
- "**Grid package**": self containing, "plug and produce", frozen tarball
  - **Step 1**: "warming up" phase on our clusters
  - **Step 2**: compilation on a Grid standard machine
  - **Step 3**: run over the Grid for a specific random seed and a specific number of events
- Each step is driven by **one single script**

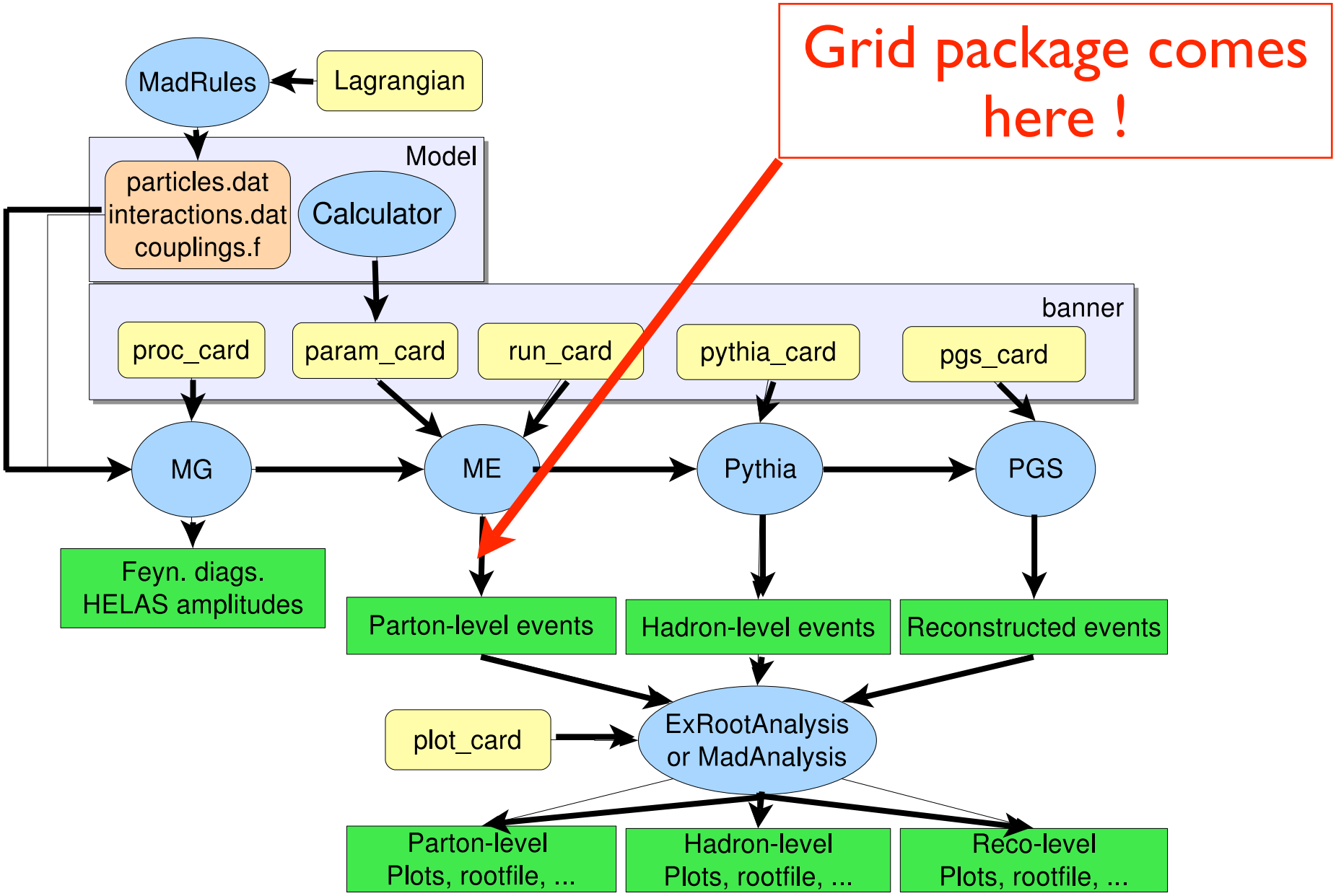
How ?

- Test samples **validation and grid packages production** on our clusters **by the team**
- "**Grid package**": self containing, "plug and produce", frozen tarball
  - **Step 1**: "warming up" phase on our clusters
  - **Step 2**: compilation on a Grid standard machine
  - **Step 3**: run over the Grid for a specific random seed and a specific number of events
- Each step is driven by **one single script**

Grid version



Grid version



Let’s go wiki!

Conclusion

To bring back home ...

- MG/ME v4 is out since 6 months and has been **well received by the community** :
  - **User friendly** (web interface, cards, wiki support, ...)
  - **New physics models** are available and easy to implement
  - **Open** framework (many side projects/tools), compatible with all standard formats (LH, ...)
  - Ready for **mass production**: clusters, Grid version, interfaces to other tools (PS, collaboration tools, ...)
- "It's time to move on!": We are **willing to** and **ready** to start a **collaborative project** for the massive production of partonic event samples useful for TH/PH & EXP

Thanks for your attention!