MadGraph/MadEvent

(Recent) Past, Present & Future

Michel Herquet - NIKHEF TH

IPMU LHC Focus Week - Kashiwa - March 18th 2009

A Mad Team...

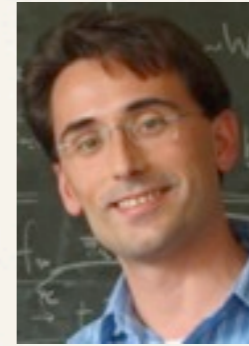# A Mad Team...

J. Alwall
(SLAC)
Matching,
PS interfaces

P. Artoisenet
(CP3)
MadOnia
MadWeight

P. Demin
(CP3)
ROOT inter.
Grid, clusters

S. de Visscher
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Matching &
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R. Frederix
(CERN)
HELAS in MG,
NLO dvlpt

M. Herquet
(NIKHEF)
BSM,
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F. Maltoni
(CP3)
MG/ME

O. Mattelaer
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T. Stelzer
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MG/ME

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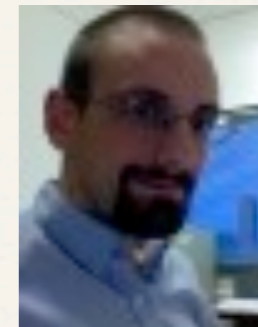
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MG/ME**

- ✤ More expected (very) soon!
- ✤ Long standing collaborators: K. Hagiwara, T. Plehn, S. Mrenna, …
- ✤ Feynrules team and model authors: C. Duhr, N. Christensen, B. Fuks, P. Aquino, C. Degrande, …
- ✤ All the MG/ME users, from beginners to "experts"

... working (really) hard!

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(Except this guy who is **<u>not</u>**
part of the MG team)

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From BSM to data: a problem
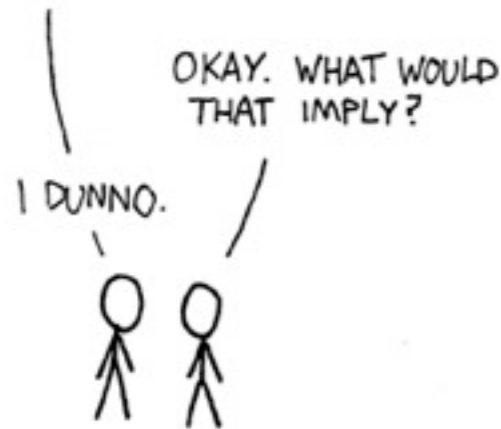
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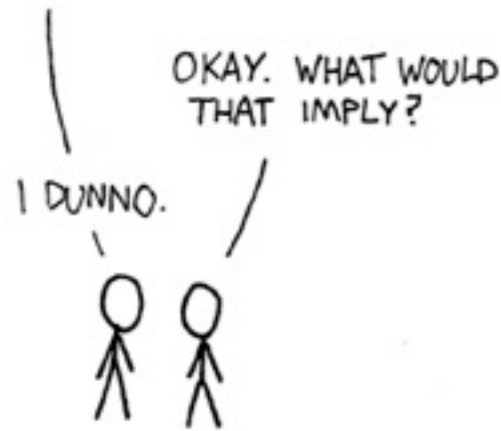
Model builders do not want:
• To loose their time in dirty coding and MC validation
• Their creativity to be limited
• To spend their time "translating" model dependent results

From BSM to data: a problem

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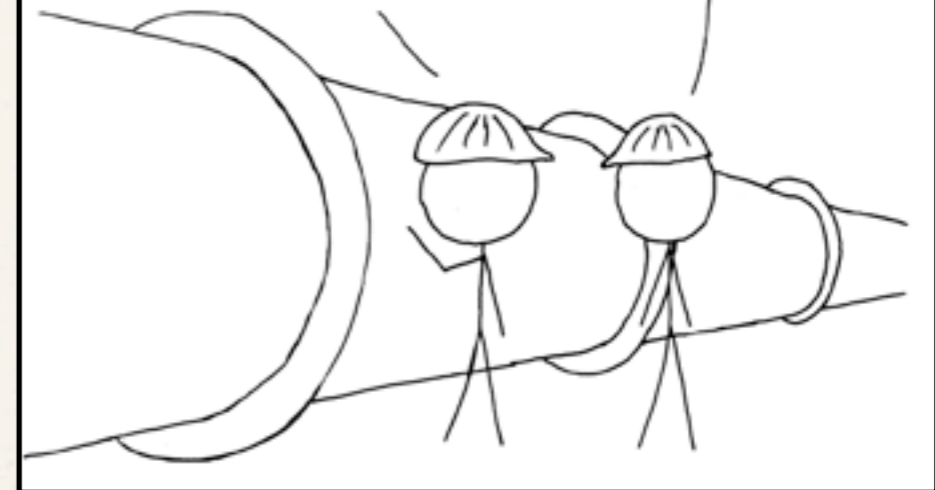- To loose their time in dirty coding and MC validation
- Their creativity to be limited
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Experimentalists do not want:
- To screw up large collaboration softwares with home-made codes or use external MC events
- To (over)simplify data
- To spend their time scanning excluded parameter space regions

From BSM to data: a problem

Need for a "communication gate"…

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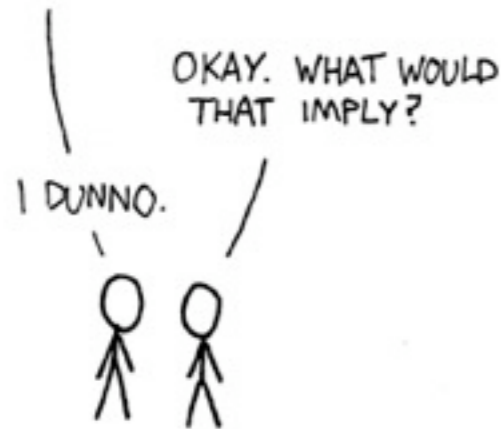- To spend their time "translating" model dependent results

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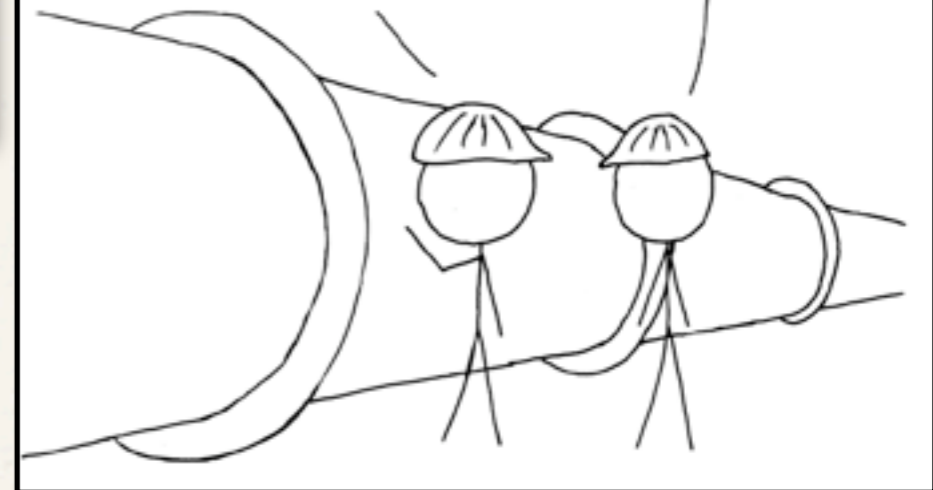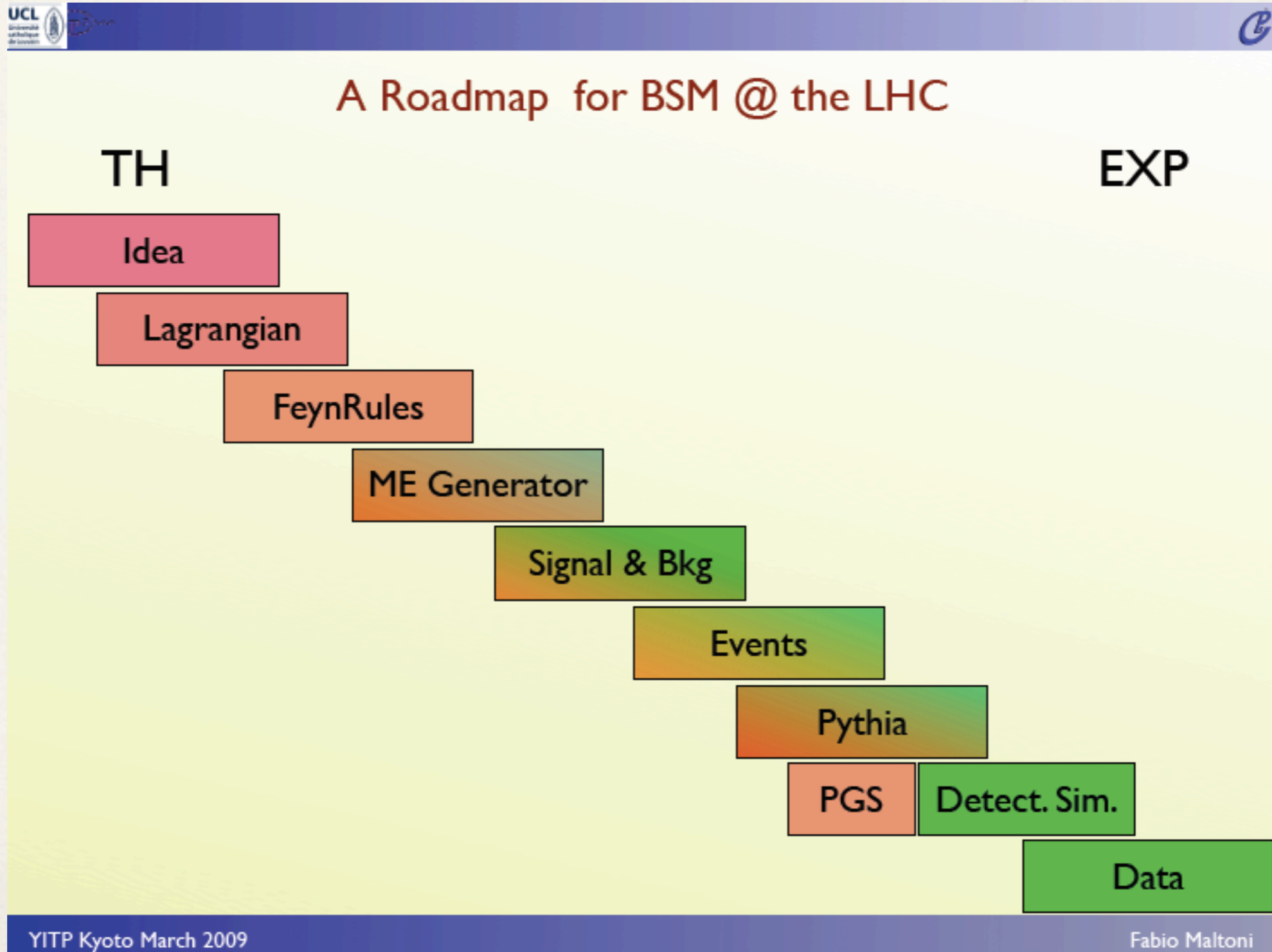
From BSM to data: a solution

* A recent proposal (see Fabio Maltoni's talk last Wednesday at YITP):

A Roadmap for BSM @ the LHC

TH   EXP

Idea

Lagrangian

FeynRules

ME Generator

Signal & Bkg

Events

Pythia

PGS   Detect. Sim.

Data

YITP Kyoto March 2009   Fabio Maltoni

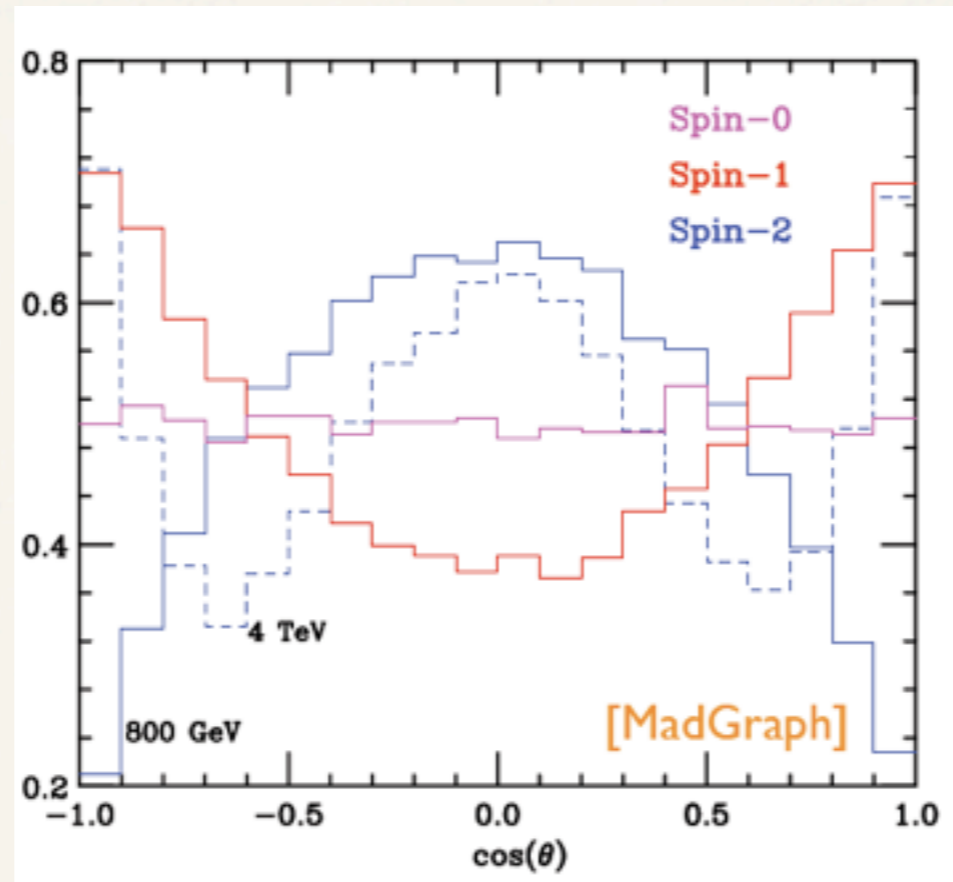# From BSM to data: a solution

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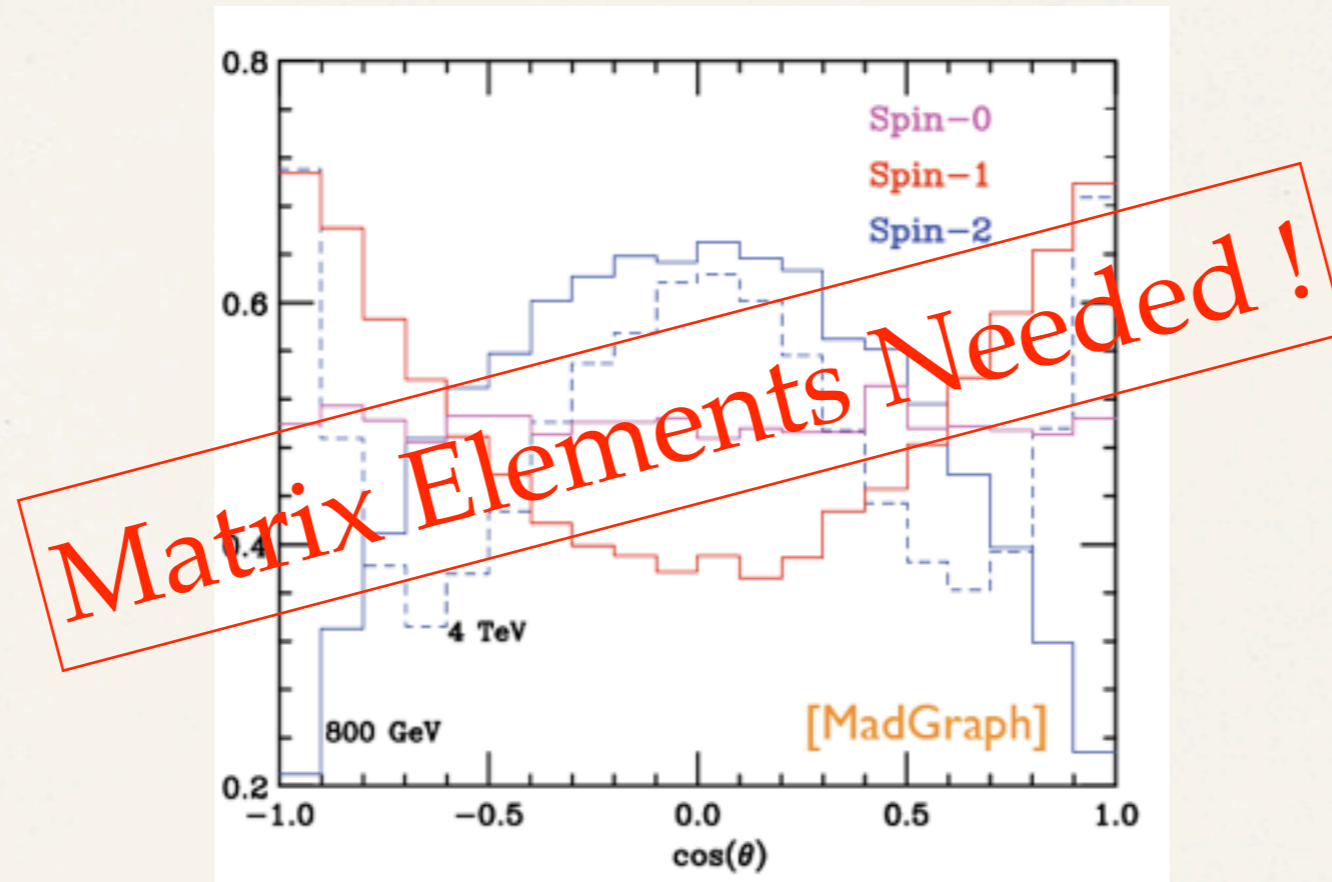# Spin and mass measurement ?

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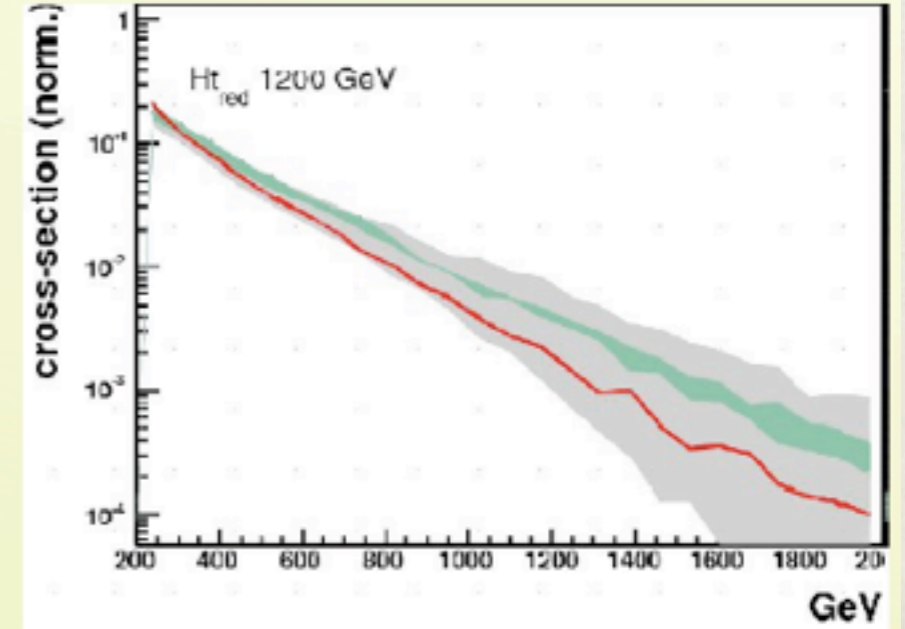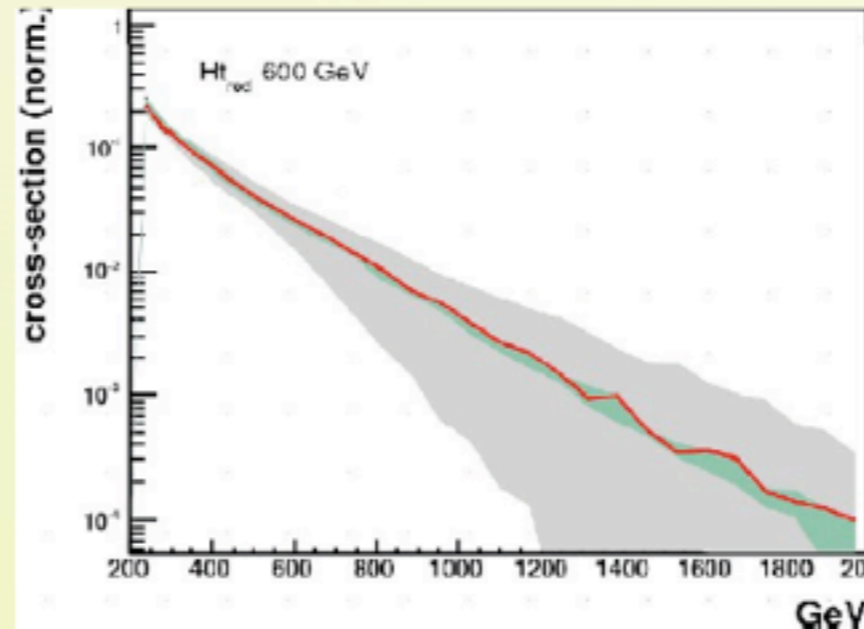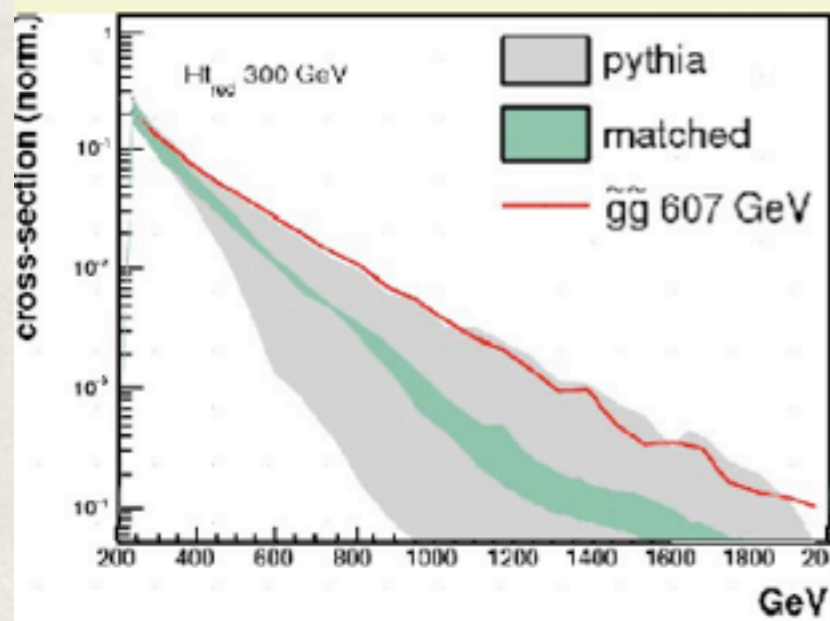
* Spin:
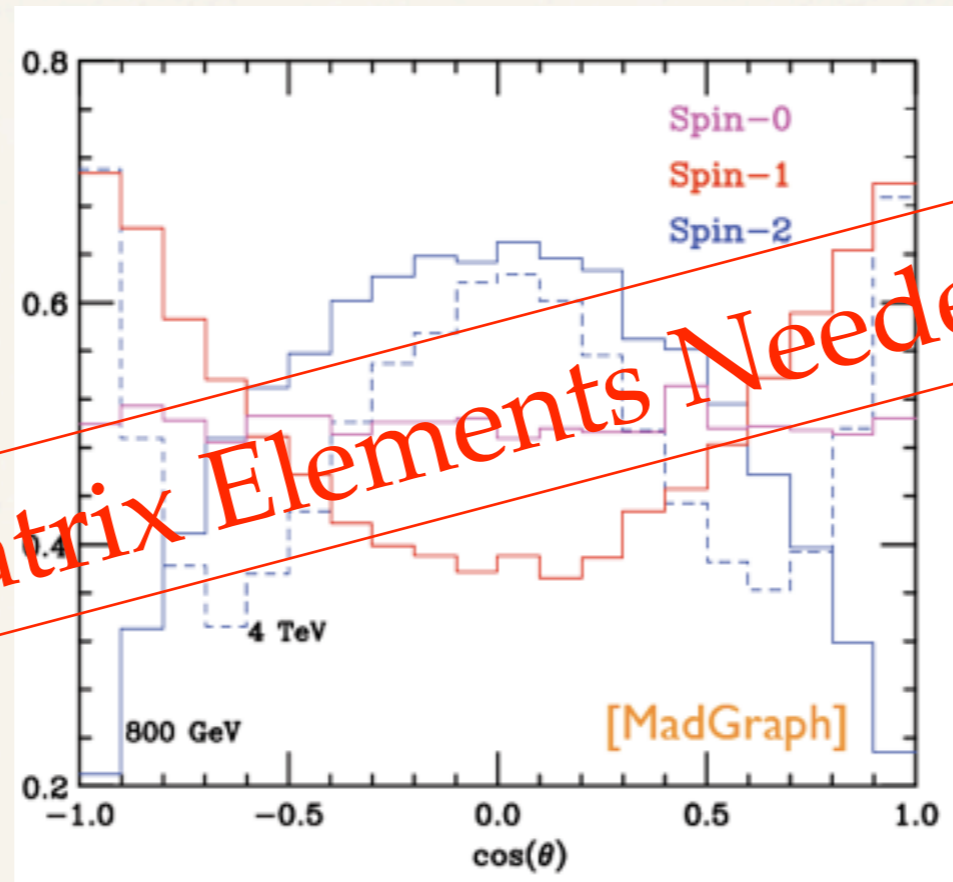
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* Mass scale:

Spin and mass measurement ?

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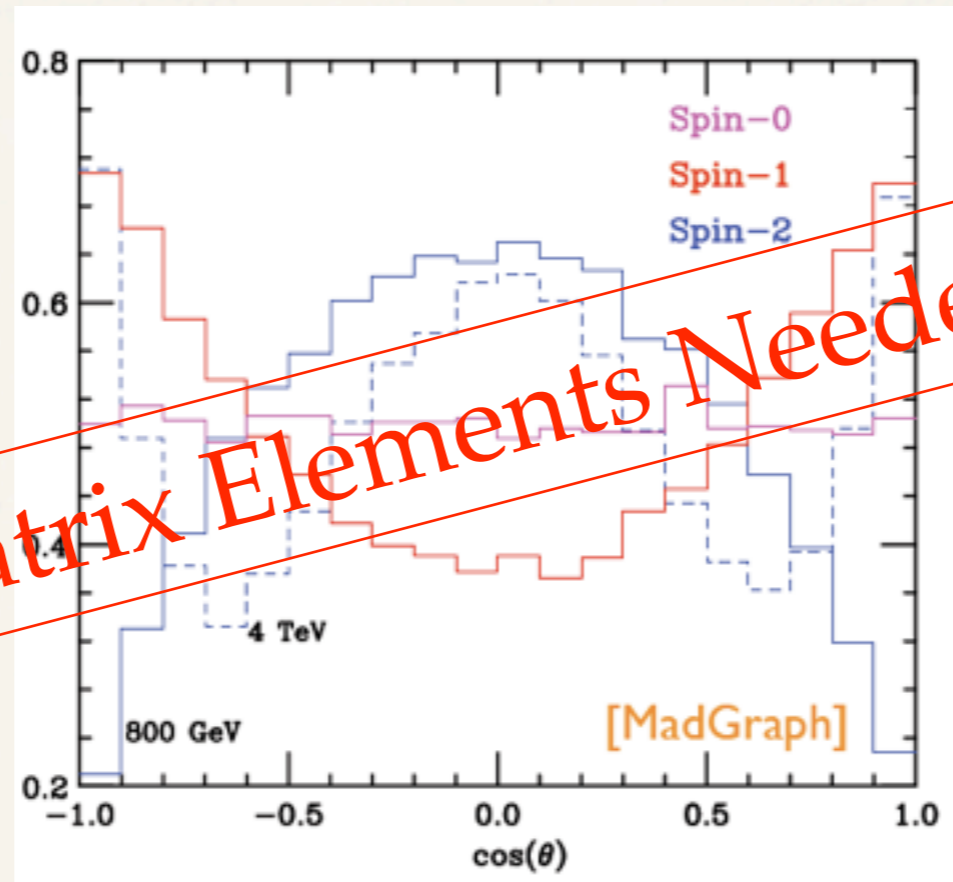
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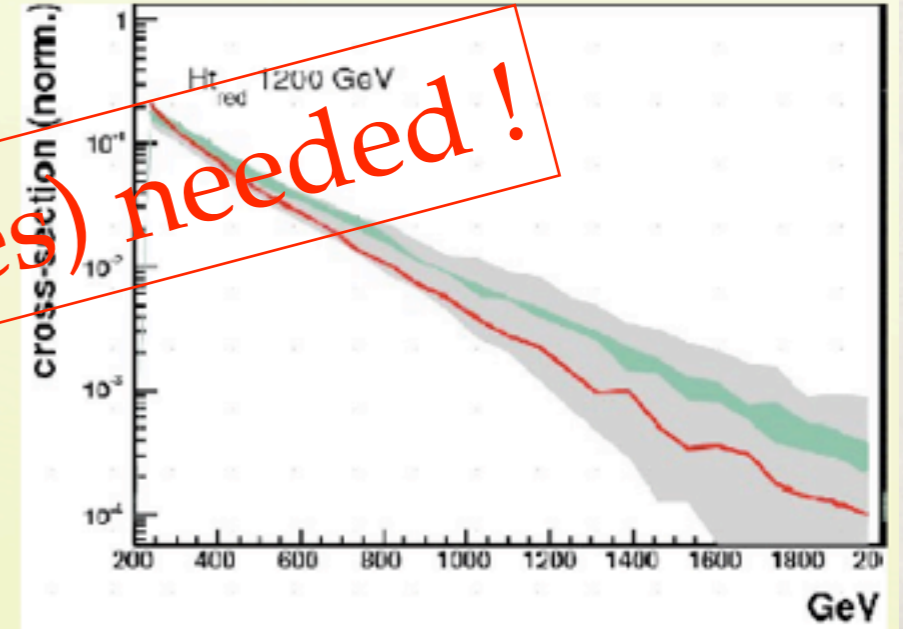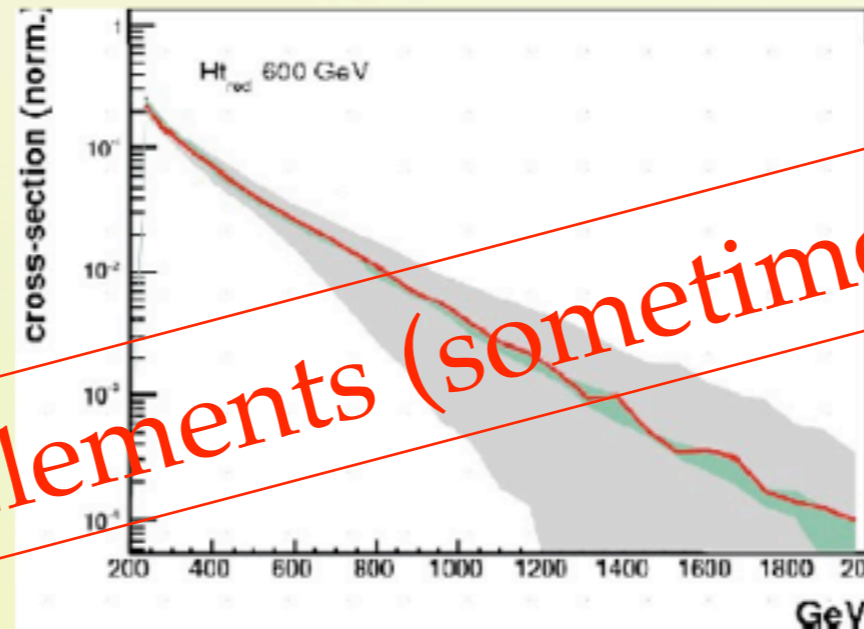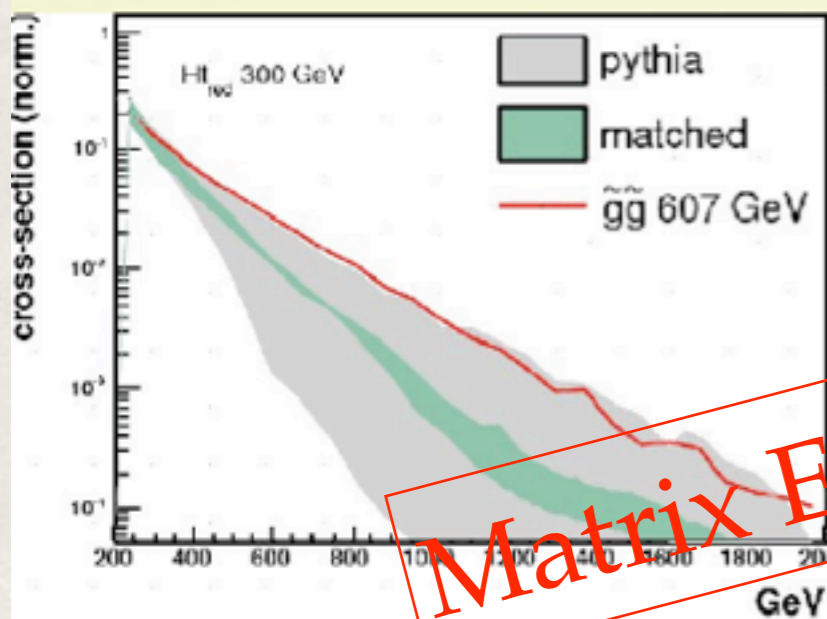
Plan

* (Recent) past

* Present

* Future

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MadGraph

- ✤ Basic building blocks : Feynman diagrams

- ✤ Generates "empty" topologies for m to n diagrams and "fill" them using valid interaction vertices

- ✤ Knowing particles properties, produces Feynman diagrams and suitable calls to the HELAS library
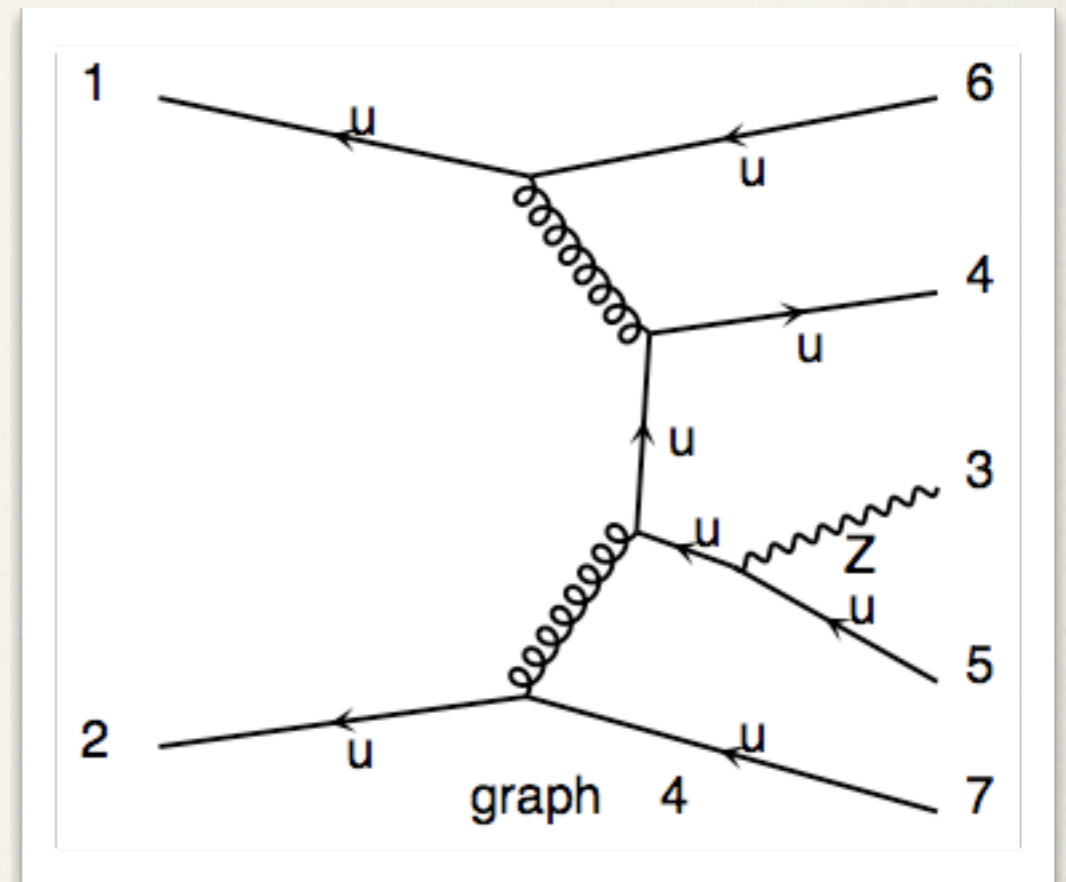
One diagram among 39276 for Z+4 jets

MadEvent

* Integrates the MEs from MadGraph to generate events. Uses adaptive methods like VEGAS to 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) :

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

    * Each peak is mapped onto a single phase-space variable

    * Parallel in nature

Online interface

* Complete web generation:

    * User inputs model/parameters/cuts.

    * Code runs in parallel on one of our farms (UCL, UIUC, Roma)

    * Returns cross section, plots, parton-level events.

    * Returns also Pythia and PGS events if needed

* Advantages:

    * Reduces overhead to getting results

    * Events can easily be shared/temporarily stored

Online interface

* Compl

  * User

  * Cod   oma)

  * Retu

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* Advan

  * Redu

  * Ever

BSM models in MG/ME v4

- ✤ MG/ME v4 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 rule couplings

- ✤ MG/ME v4 comes with several predefined models: MSSM (SMadGraph), 2HDM, HEFT, BSM top, ...

BSM models in MG/ME v4

* 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

  * Limitation 1: computing Feynman rules by hand is a hard task

  * Limitation 2: only start from the SM

  * Limitation 3: limited number of possible modifications

ME/PS Matching

* Difficulties combining the Matching Element and Parton Shower descriptions:

    * Same phase space configuration can be described by both n+1-parton ME event and n-parton event + PS → Double counting

    * Transition between ME and PS should be smooth

    * Cross section should not be affected

    * Minimize dependence on highest ME multiplicity

* Solutions: Catani, Krauss, Kuhn, Webber [2001], Lönnblad [2001], M.L. Mangano [2002, 2006]

ME/PS Matching

* Matching schemes implemented with Pythia: kT and cone jet MLM schemes, new "shower kT" scheme

* Both Q^2- and pT-ordered Pythia parton showers

* Extensively validated, W+jets compared with other generators

* Allows matching in most SM and BSM processes

Jet resolution for 1 to 2 jets

Cutoff (unphysical)

ME/PS Matching

* Comparison with Tevatron data for W+jets
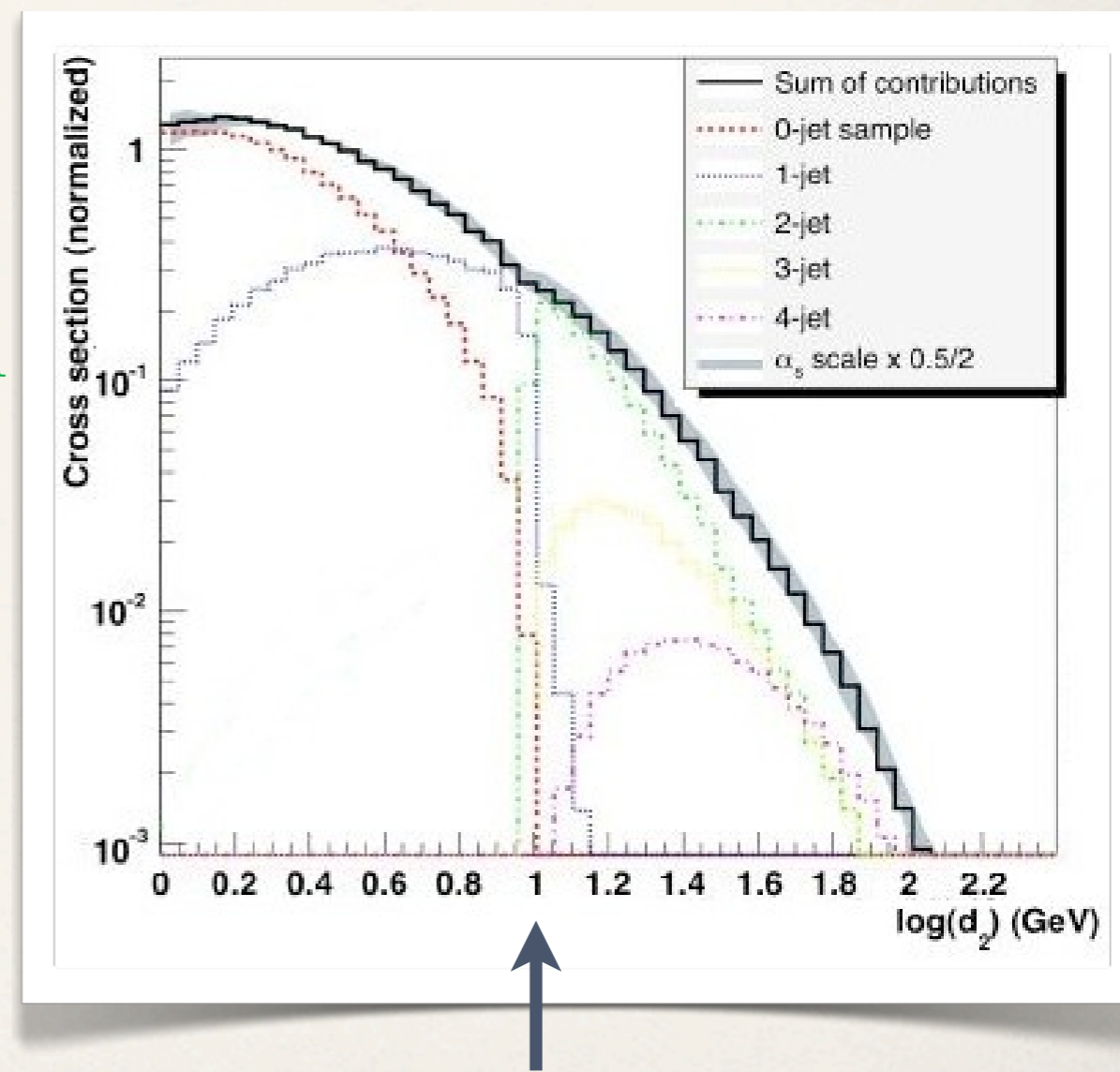
HEP community standards

* Standardization of formats for HEP data files is crucial for theorists-theorists and theorists-experimentalists communication

* MadGraph/MadEvent v4 implements:

  * SLHA2 for SUSY parameters and a straightforward generalization of this format for all model parameters

  * XML Les Houches Event File format (and interface to ROOT)

  * QNUMBERS scheme for new particle description

* We will support all the forthcoming standards defined and used by the whole community

The "big" picture of MG/ME v4
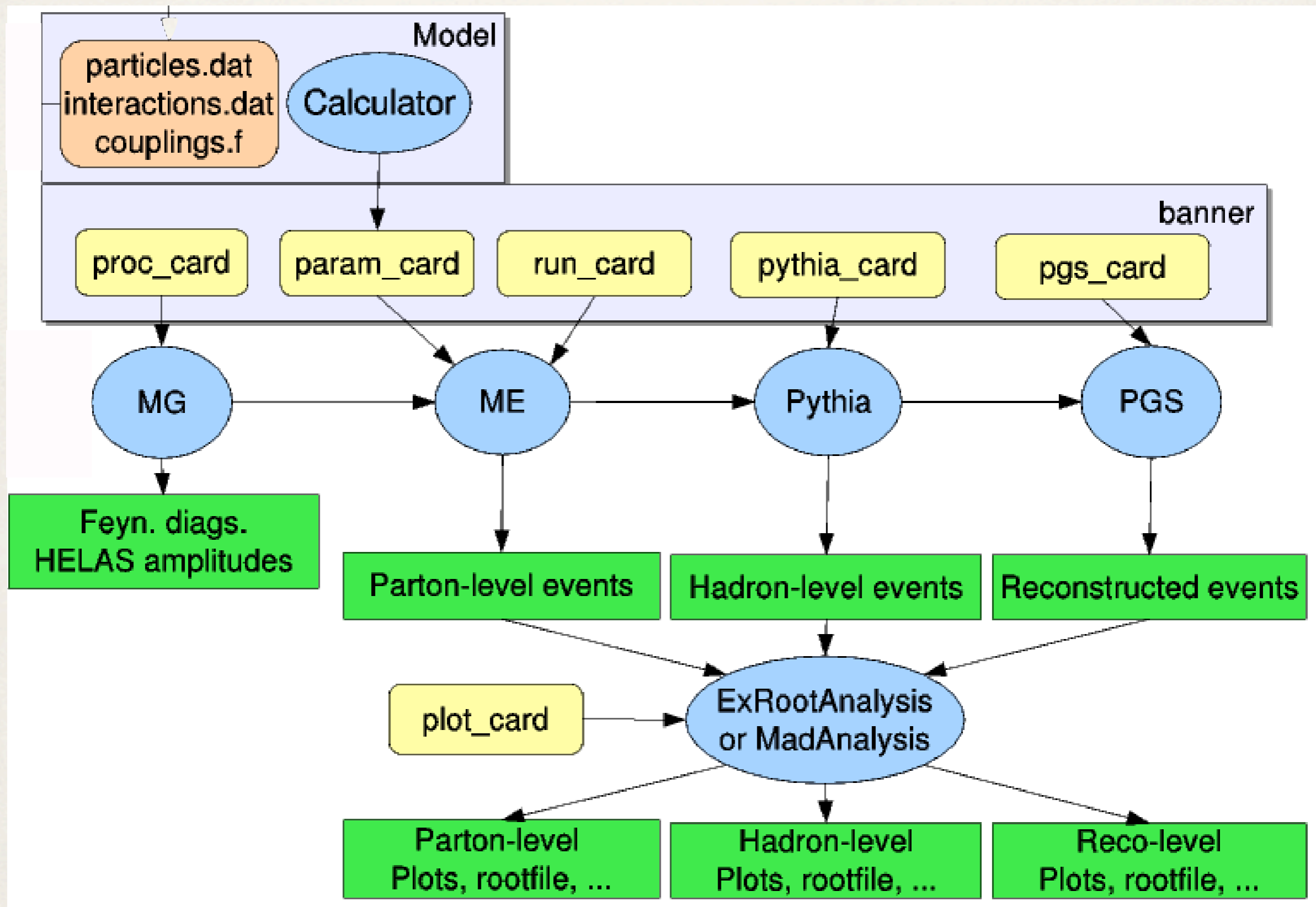
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New models: FeynRules interface

* **FeynRules**: new Mathematica package to compute automatically Feynman rules from any QFT Lagrangian: See C. Duhr's presentation

* User friendly MG/ME interface available and has already been tested intensively

* In a (very) short future, all the MG/ME existing "official" models will be replaced by their FeynRules equivalent (general MSSM, 2HDM, ...)

* Several other models will also be added (UED, 3-sites, Littlest Higgs, ...)

* Best implementation method for realistic models (consistency, validation,...)

New models: FeynRules interface
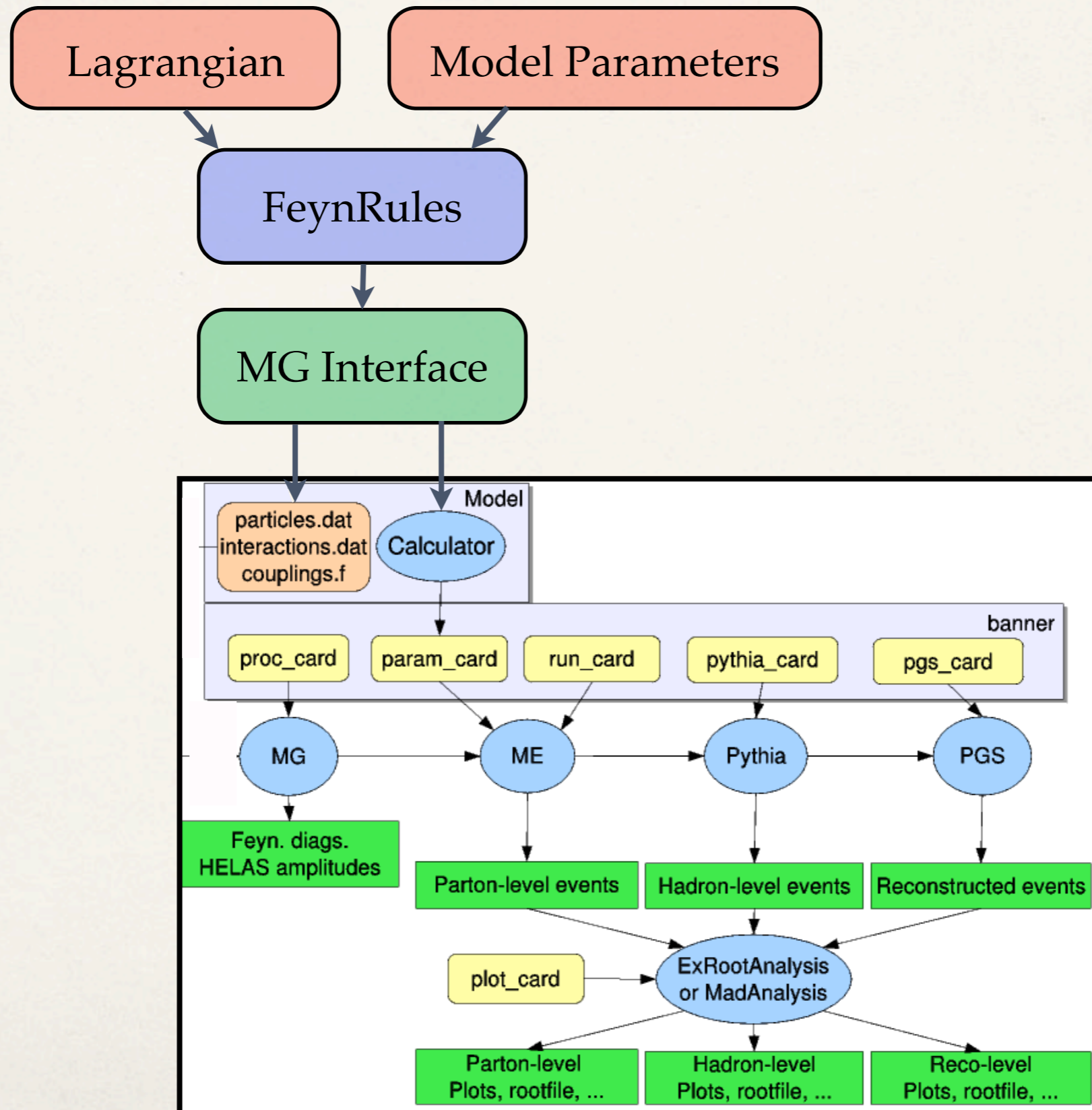
New models: USRMOD2

✤ USRMOD2: set of Python scripts to allow users to implement easily a few modifications to an existing MG/ME model (add particles, interactions, …)

✤ Full support of all models produced with FeynRules

✤ Best implementation method for minor changes, i.e. for the study of a given BSM signature, or when Mathematica is not available

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```
z      z     v    w     mz    wz     s    z    23
w+     w-    v    w     mw    ww     s    w    24
g      g     v    c     zero  zero   o    g    21
h+     h-    s    d     mhc   whc    s    hc   37
h      h     s    d     mh    wh     s    h    25
```

```
w+     w-    h    h     MGVX12   DUM1   QED   QED
z      z     h    h     MGVX22   DUM1   QED   QED
b      t     h-   HMCOUP    QED
t      b     h+   HPCOUP    QED
```

```
gg(1) = -g
gg(2) = -g
hmcoup(2) = -(a+b)
hmcoup(1) = -(a-b)
hpcoup(2) = -(a+b)
hpcoup(1) = -(a-b)
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Decay chains

```
gg>(go>u~(ul>u n1)))(go>b~(b1>(b(n2>mu+(mul->mu- n1)))))
```
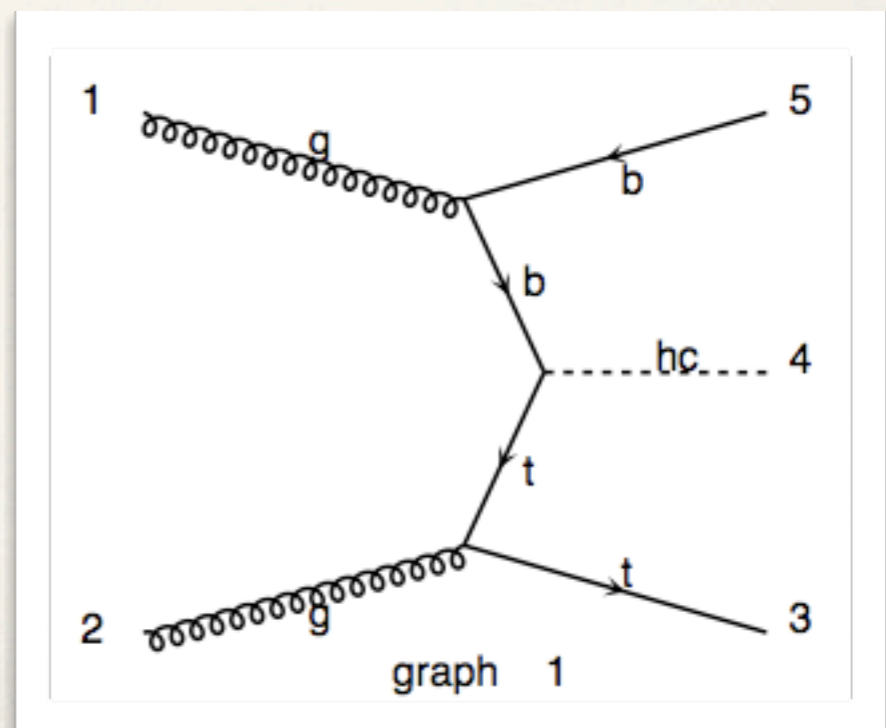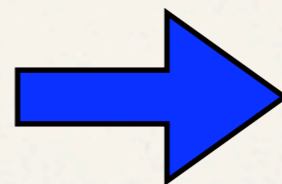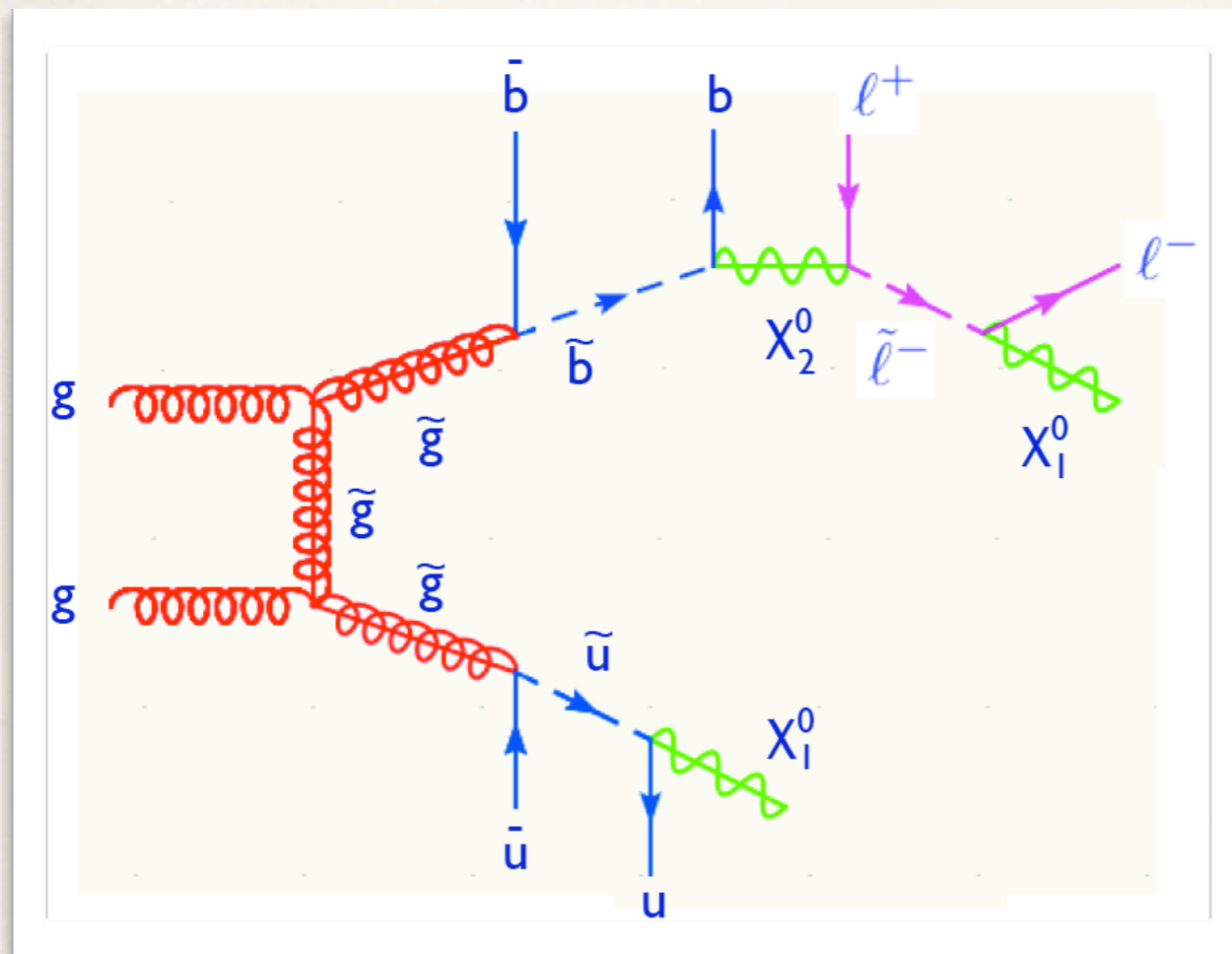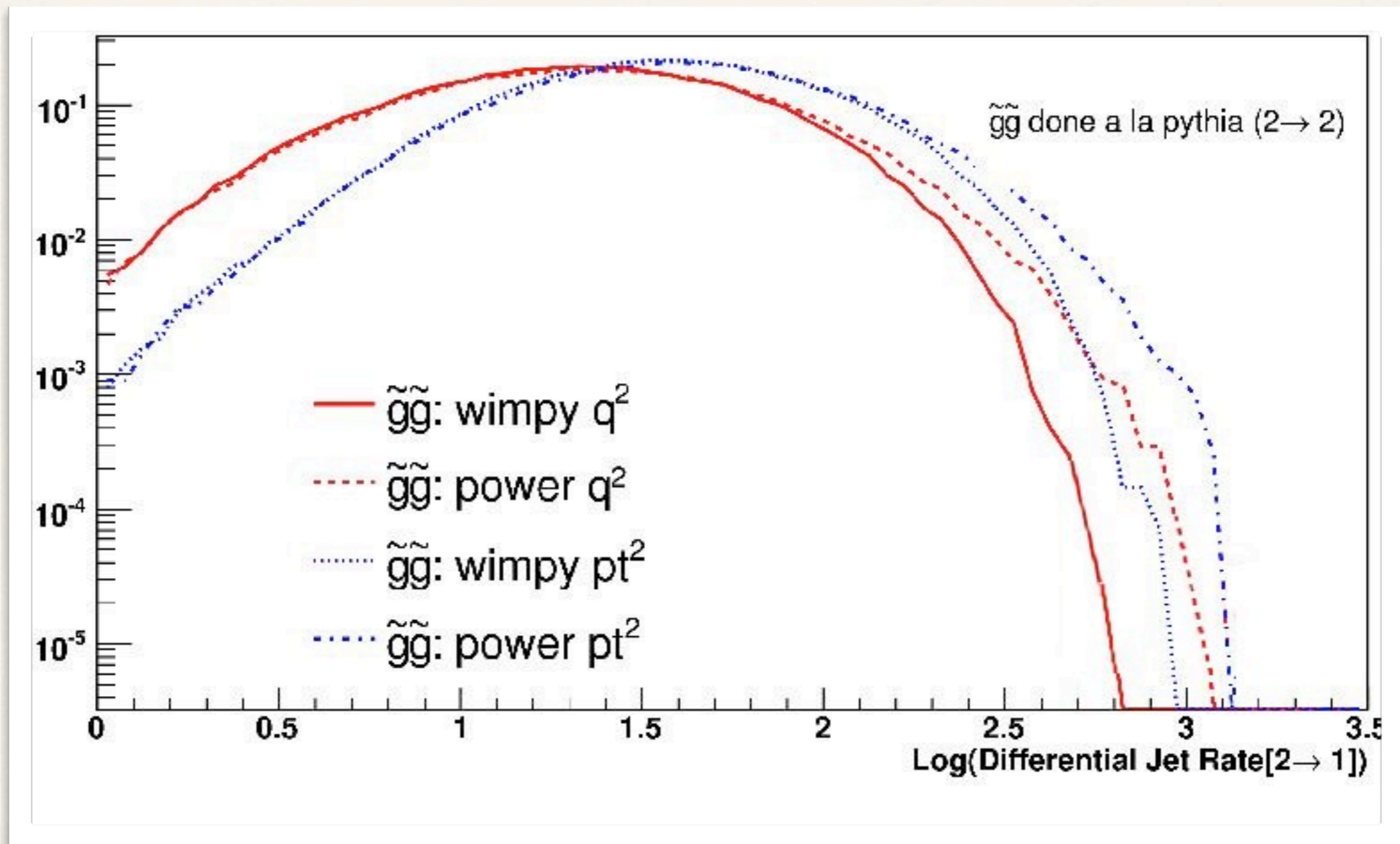

* ✤ Full matrix element with all correlations between production and decay

* ✤ 1 → N decays possible

* ✤ BW for all resonances

* ✤ Non-resonant contributions can be included only where relevant
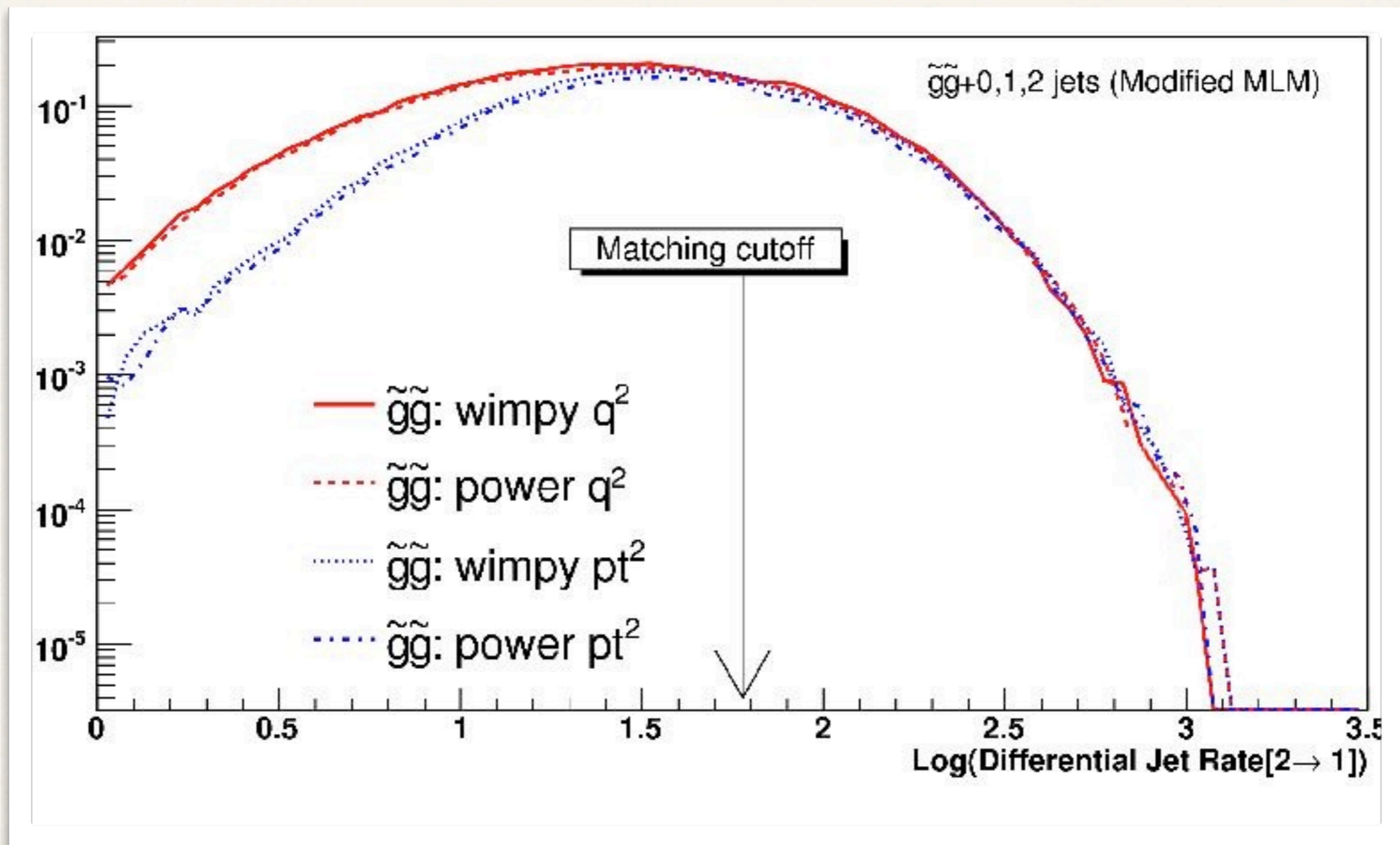
Matching for BSM processes

[Alwall,de Visscher,Maltoni]

600 GeV gluino pair production at the LHC

Matching for BSM processes

600 GeV gluino pair production at the LHC

Mass production

- ✤ "Gridpack" version of MG/ME:

    - ✤ Completely frozen, self contained package for a given process/set of cuts (only inputs: number of events and random seed)

    - ✤ Designed to be sent over the Grid

- ✤ Public library of several SM backgrounds (jets, W,Z+jets, tops+jets,...) available and validated (matching,...). Currently ~100 gridpacks for 10 and 14 TeV.

- ✤ Currently used for massive production of SM backgrounds by the CMS collaboration

MadWeight

[P. Artoisenet, V. Lemaitre, F. Maltoni, O. Mattelaer]

✤ Tool to find matrix element weight of exp. events for (almost) any process in any model: see J. Alwall's talk
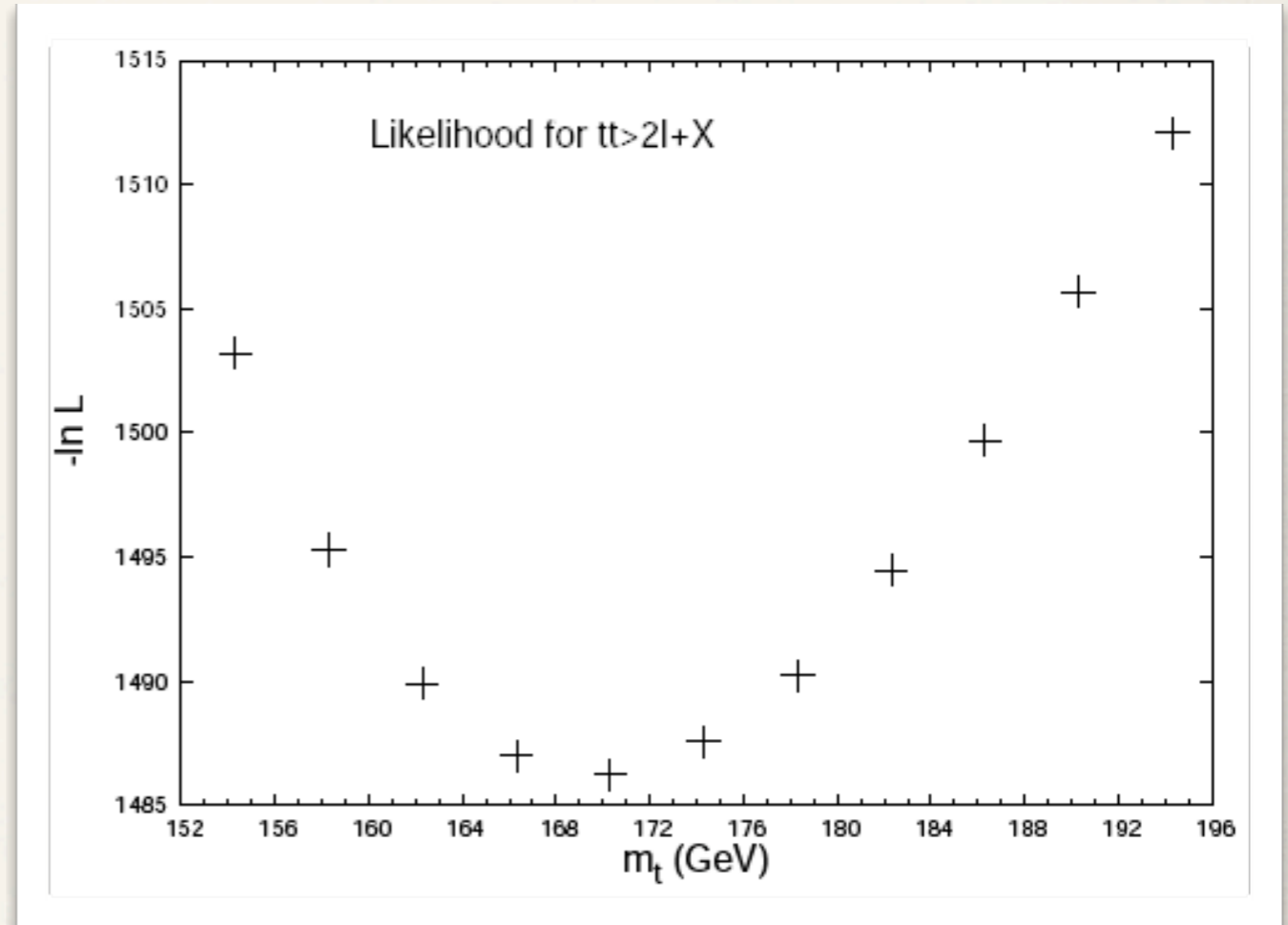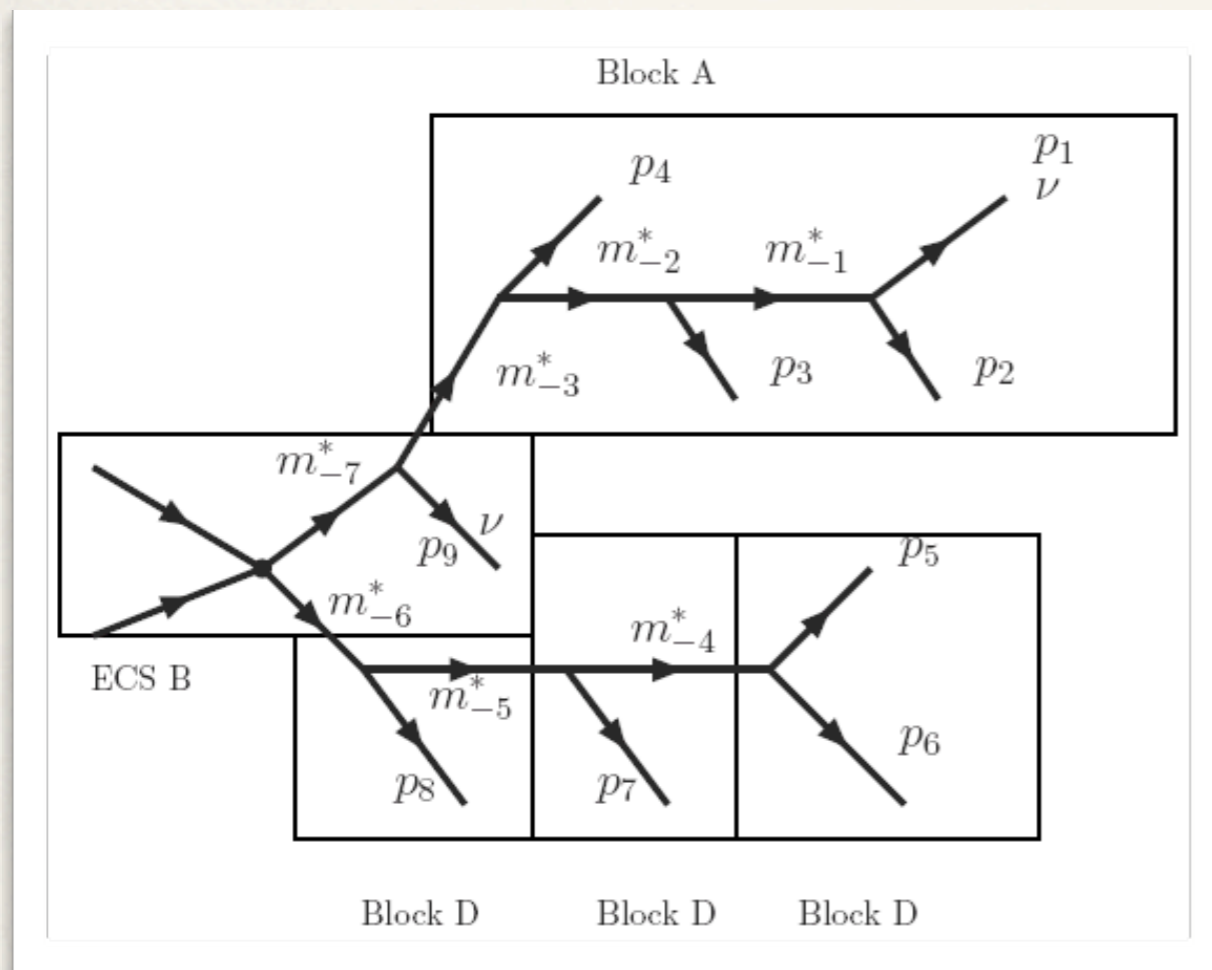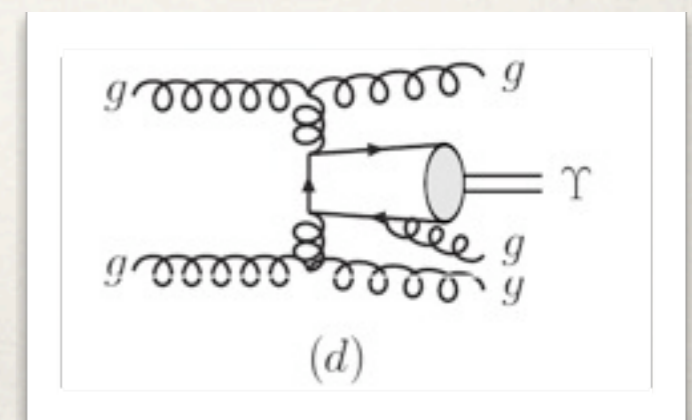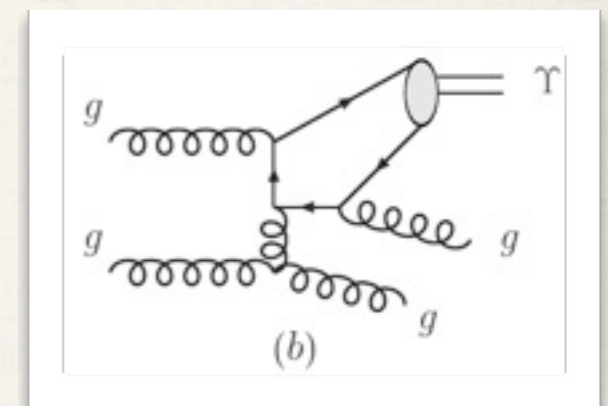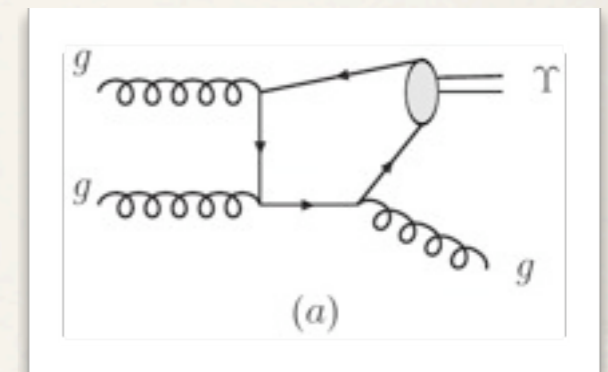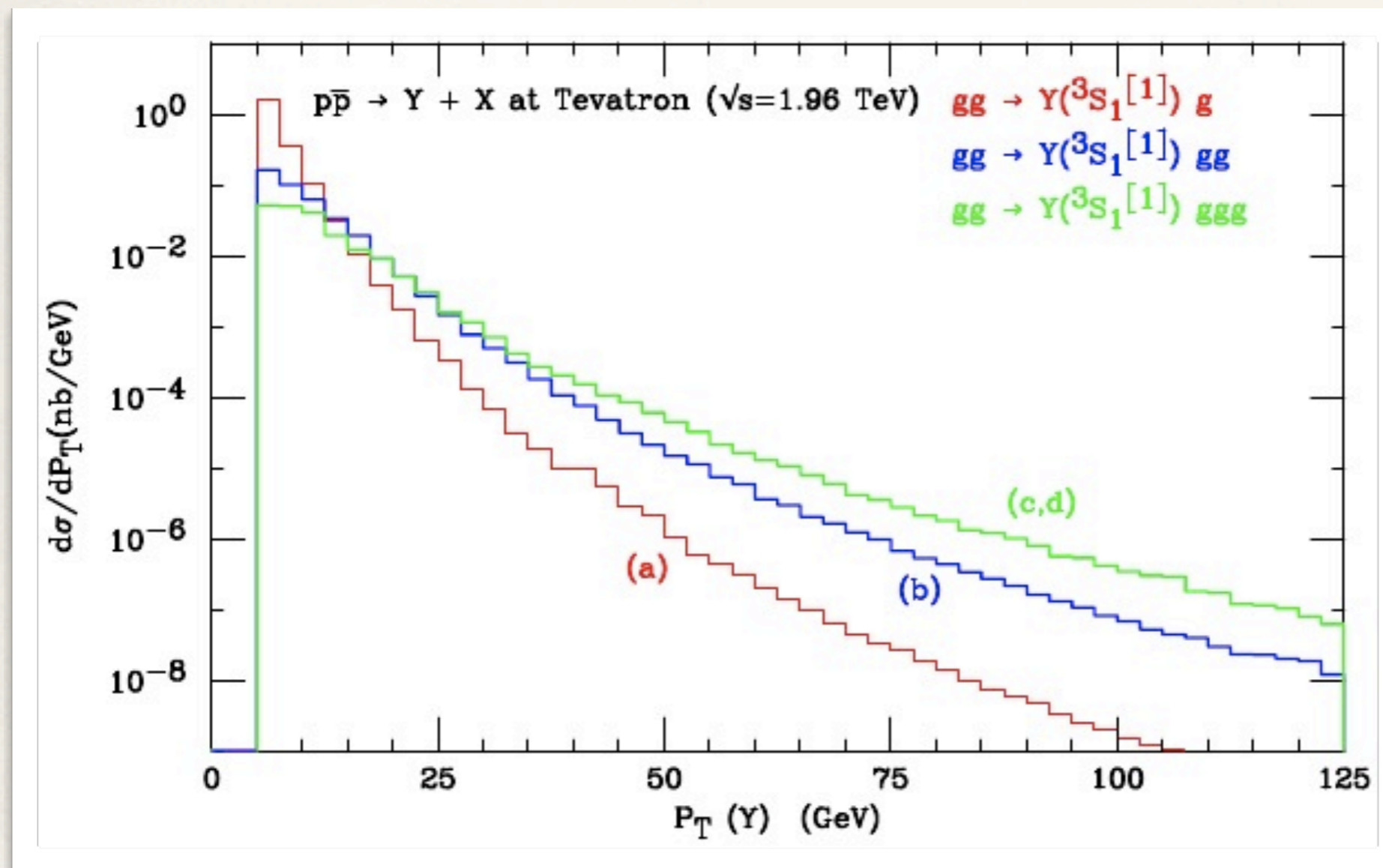

Phase space integration using automatic change of variables aligned with peaks

Find likelihood for model parameters (here top mass)

MadOnia

[P. Artoisenet, F. Maltoni, T. Stelzer]

* **Production of quarkonium** events at tree level within non relativistic QCD

* Example of application: Υ+ jets in hadron collisions

MadDipole

[R. Frederix et al.]

$$\sigma^{\mathrm{NLO}} = \int_{m+1} \left[d^{(4)}\sigma^R - d^{(4)}\sigma^A \right] + \int_m \left[\int_{\mathrm{loop}} d^{(d)}\sigma^V + \int_1 d^{(d)}\sigma^A \right]_{\epsilon=0}$$

✤ Automatic divergence subtraction for the real contributions of any QCD NLO calculation:

  ✤ Catani-Seymour subraction scheme

  ✤ Standalone implementation

  ✤ Both for SM and BSM

  ✤ Massless and massive external particles

Plan

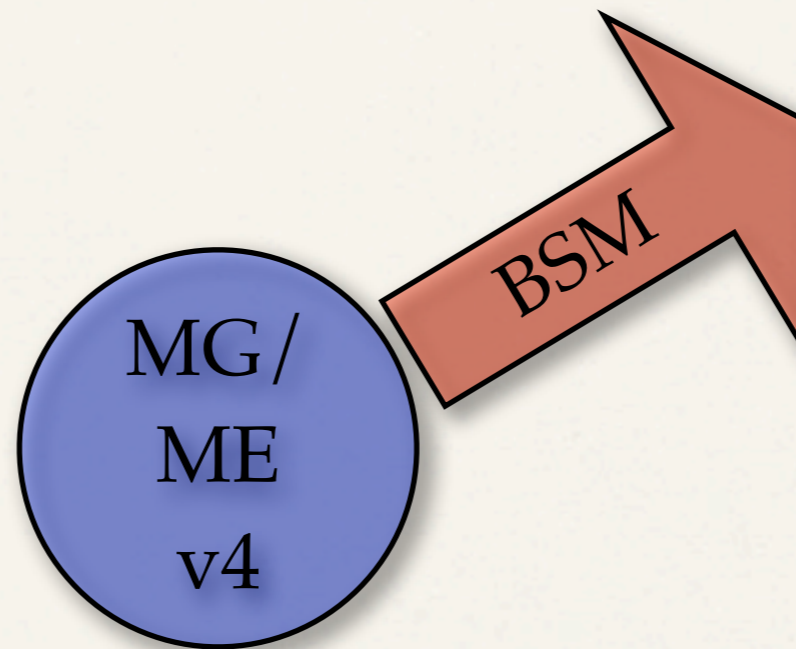* (Recent) past

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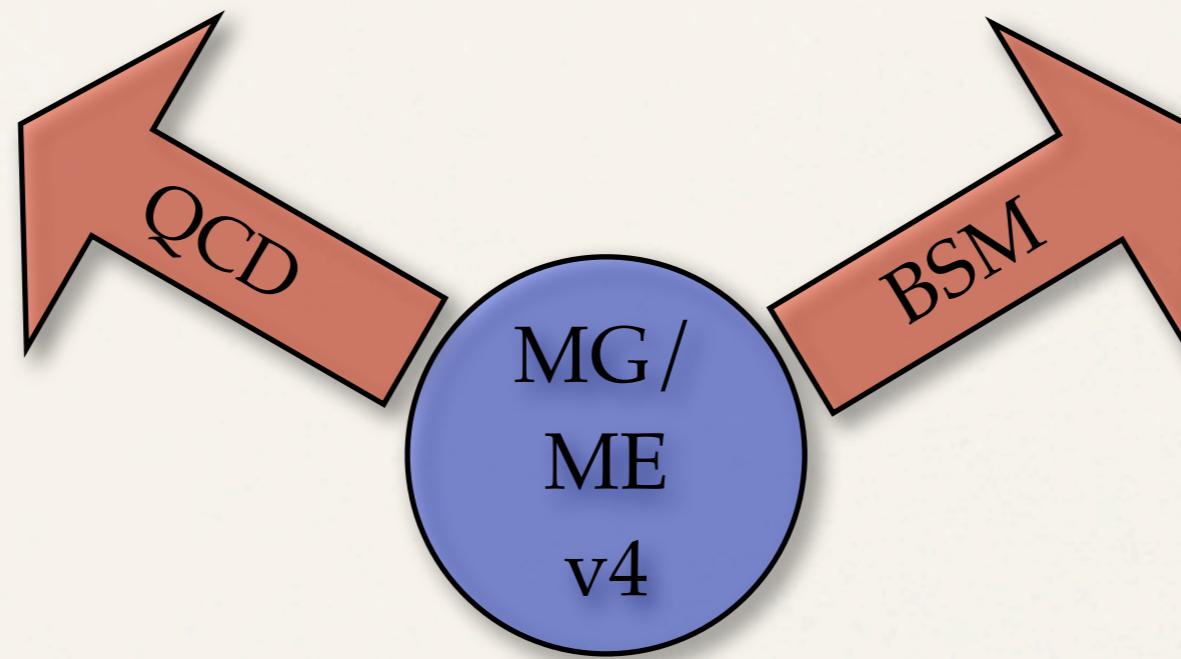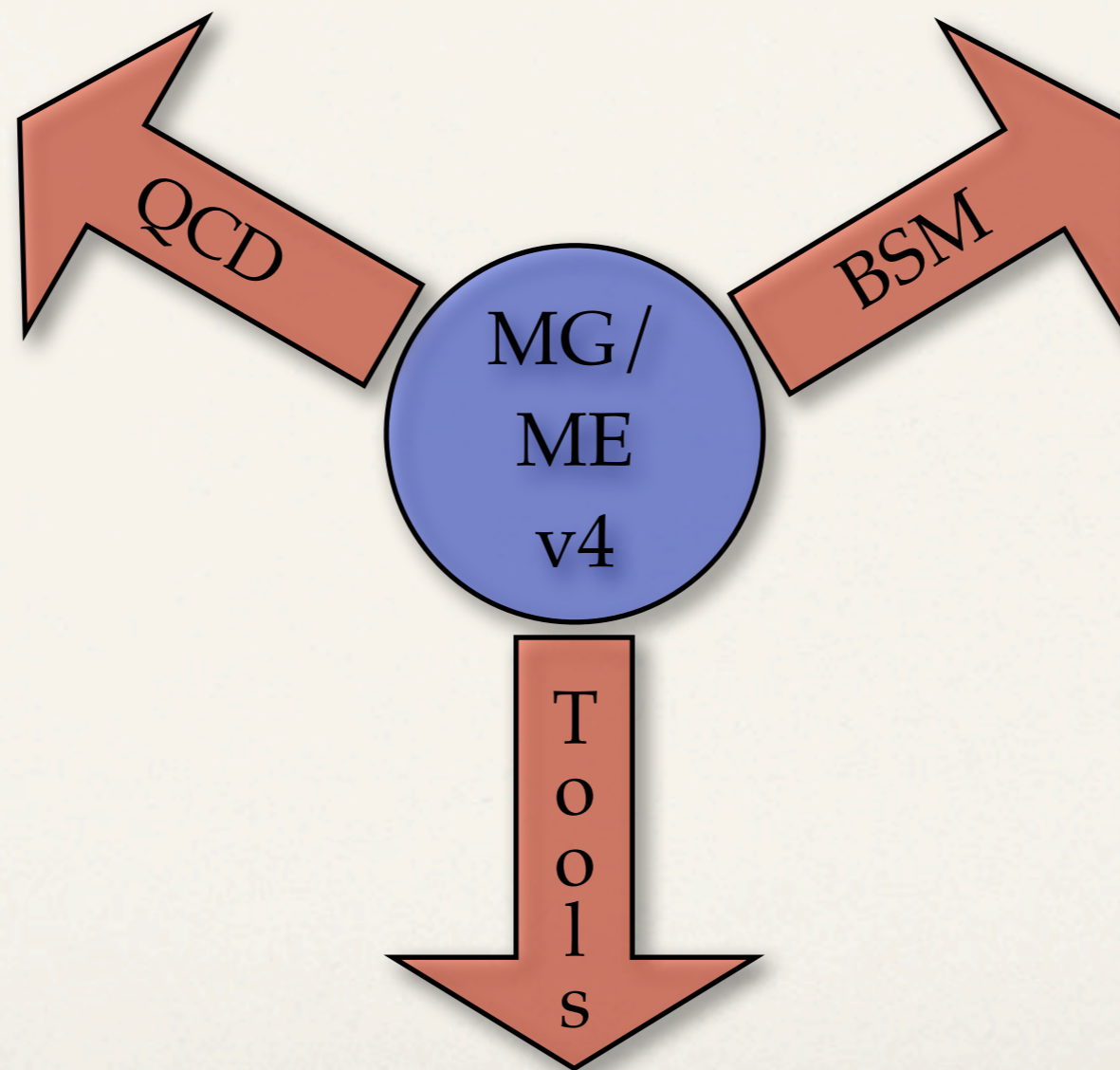# 3 development directions

MG /
ME
v4

3 development directions

3 development directions

QCD

MG/ ME v4

BSM

3 development directions

BSM direction

* Models [FR team, Model authors, MH, ...]:

  * New model implementation (FeynRules and/or USRMOD2)

  * Online documented "Model library" to structure communication between theorists, phenomenologists and experimentalists

* HELAS+MadGraph [Stelzer, Link, MH,...]:

  * New HELAS routines for BSM and automatic method to generate them with FeynRules

  * Improved topology generation algorithm taking into account model information

  * Improved ME element generation for complex final states and generalized color structure
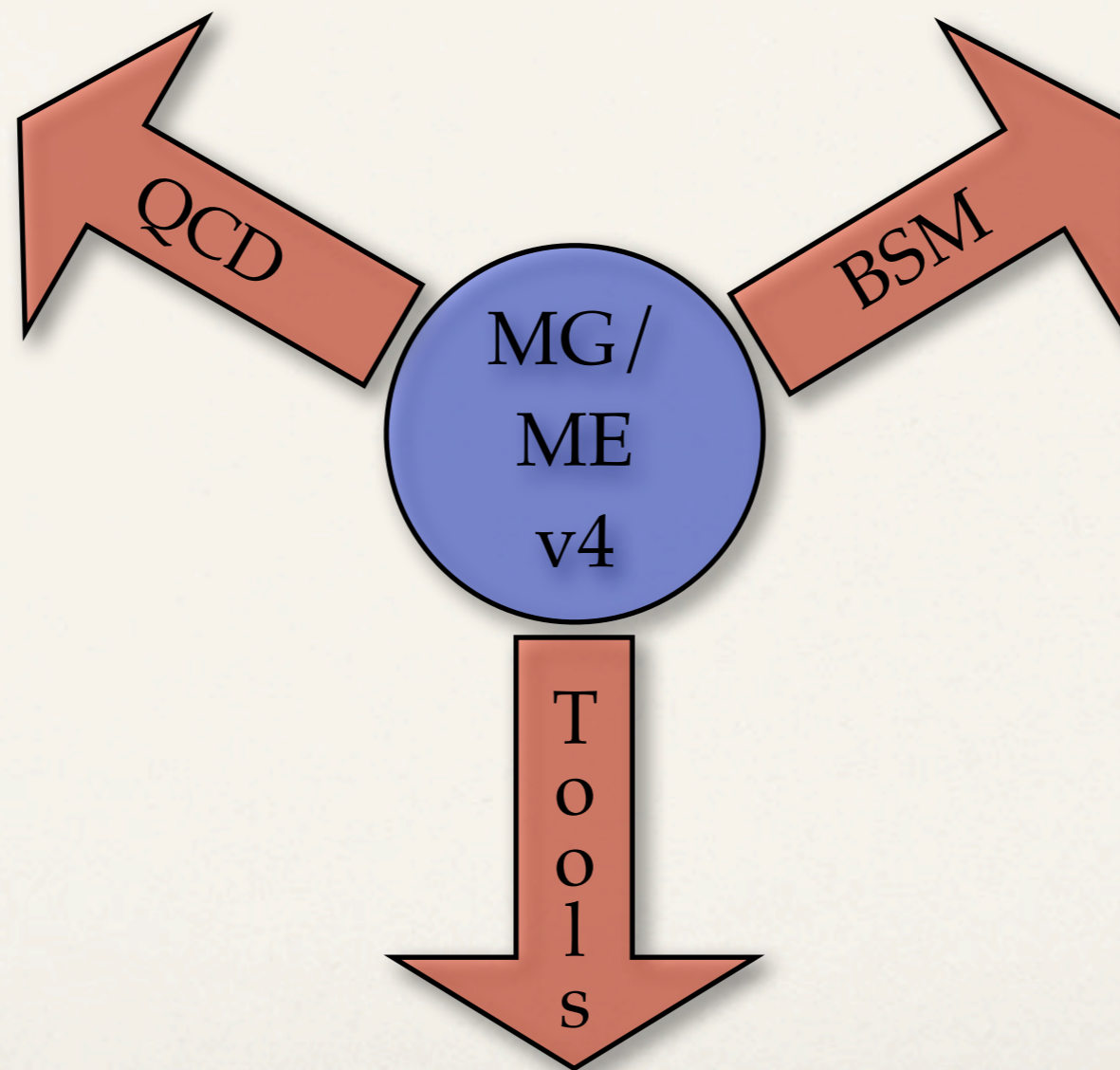
QCD direction

* **MadDipole** [R. Frederix,...]:

  * Final goal: consistent treatment of NLO corrections in MG/ME with interface to input virtual amplitudes

* **Matching ME/PS** [J. Alwall,...]:

  * CKKW matching scheme in MG/ME + Pythia

  * Matching for processes @ NLO

* **MadGraph** [MG Team]:

  * Improved routines for the multi-gluon part of any final state

Tools direction

✤ MadWeight: Include ISR + Sudakov reweighting:
see J. Alwall's talk

✤ MadOnia: ME/PS matching for quarkonium + jets

✤ Full support to any project using MG/ME as a
development platform (user support, improved code
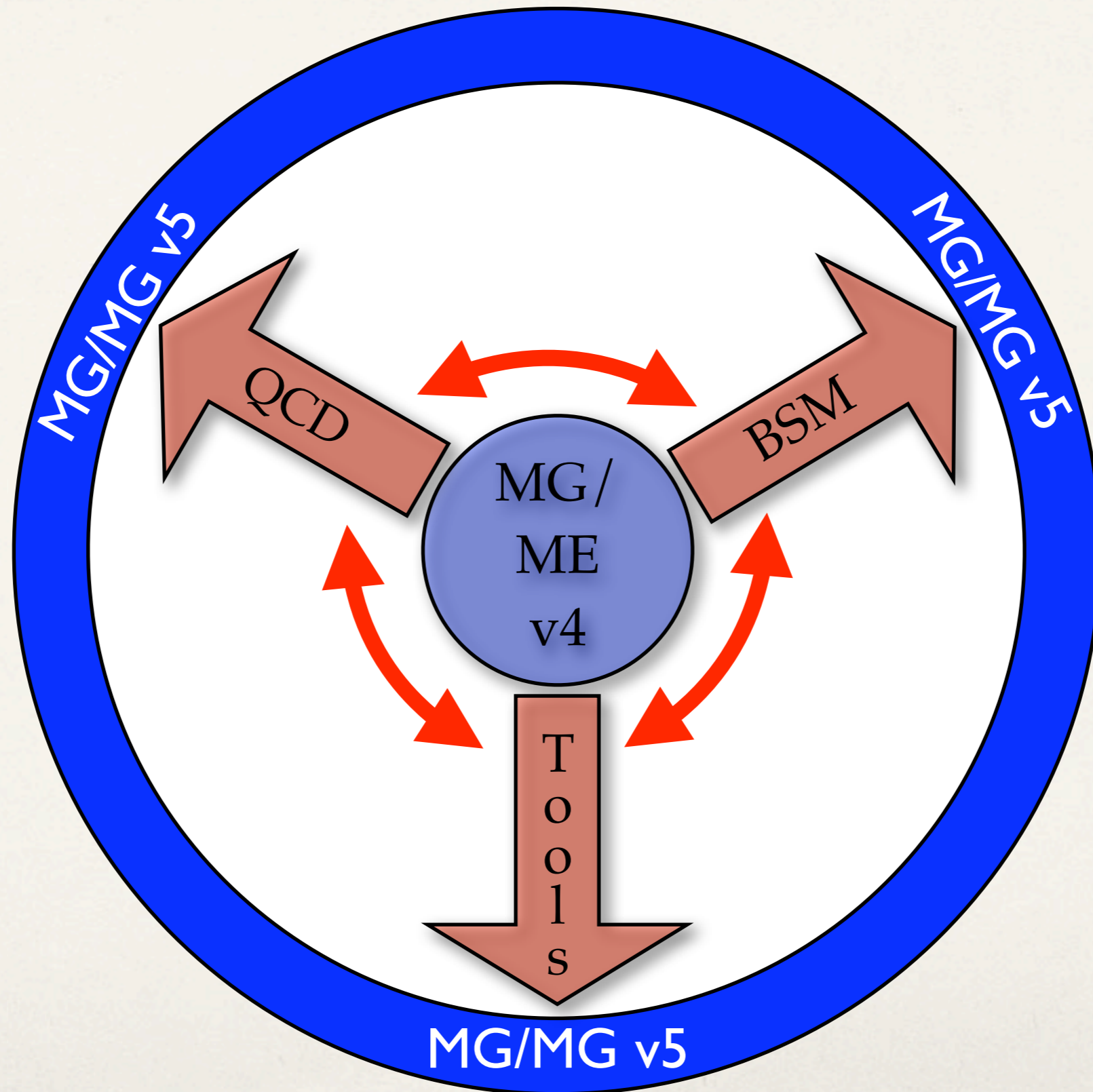structure, documentation framework, ...)

3 development directions

3 development directions
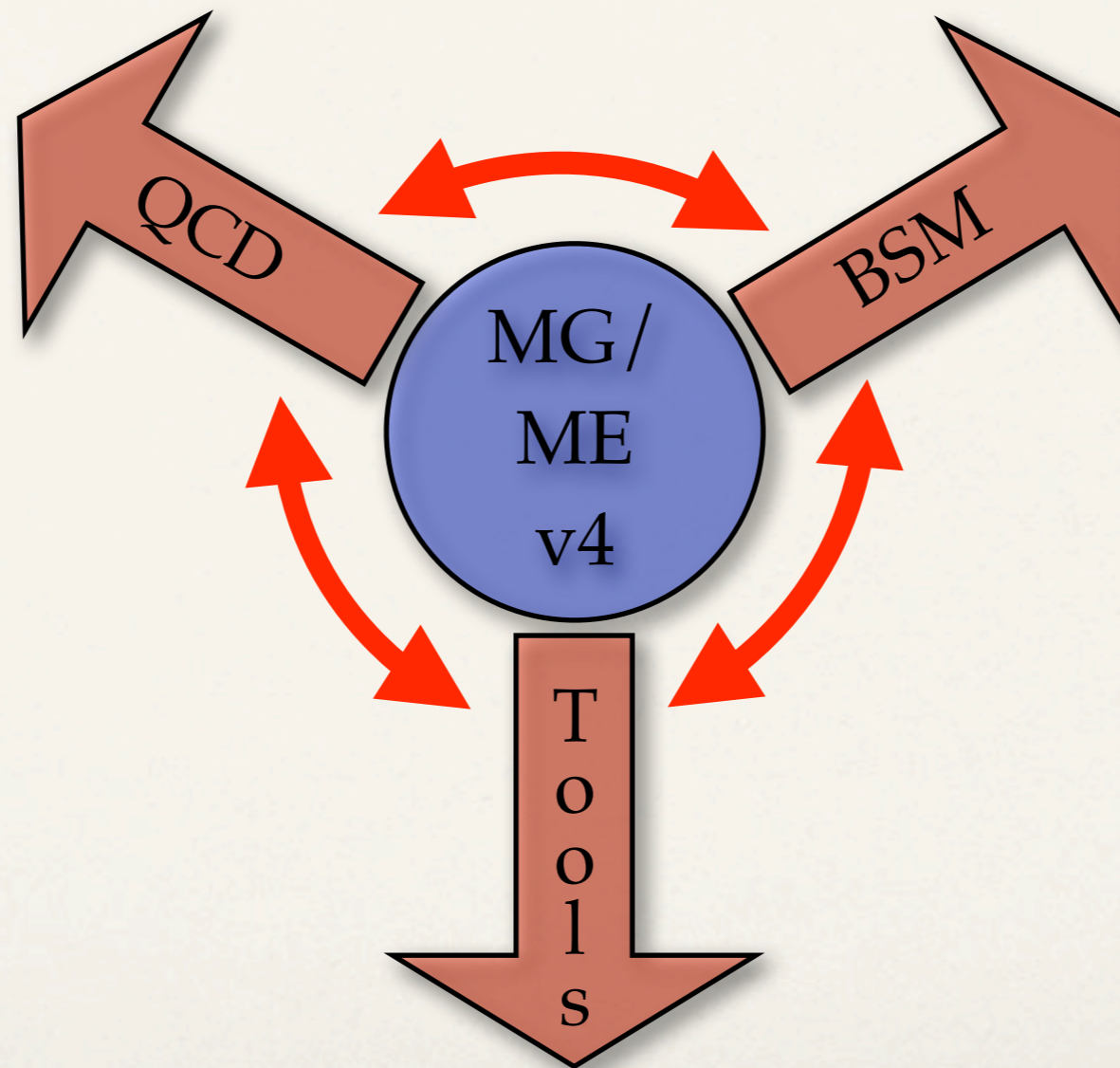
3 development directions

MadPhilosophy

MadPhilosophy

✤ We are ourselves our first users!

MadPhilosophy

* We are ourselves our first users!

* Users and their continuous feedback is our greatest asset

MadPhilosophy

* We are ourselves our first users!

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* Open and public framework

Conclusion

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* Present: MG/ME belongs to complete chain of tools going from a BSM Lagrangian to collider data, with useful peripheral tools available

* Future: Ambitious developments along three directions: BSM, QCD/NLO and new tools. Stay tuned!