MadGraph

The new physics side and more...

Fabio Maltoni- CP3 (Belgium)

MC4BSM 2010

Getting ready for the LHC...

Getting ready for the LHC...

Getting ready for the LHC...

NLO

Exp. software integration

Very exotic models

Multi-jet samples

Effective theories

Exotic models

Advanced analysis techniques

DECAY CHAINS

Cluster/Grid computing

Real corrections

Merging ME/PS

DECAY PACKAGES

Testing / robustness

NNLO

MATRIX ELEMENTS

User Interface

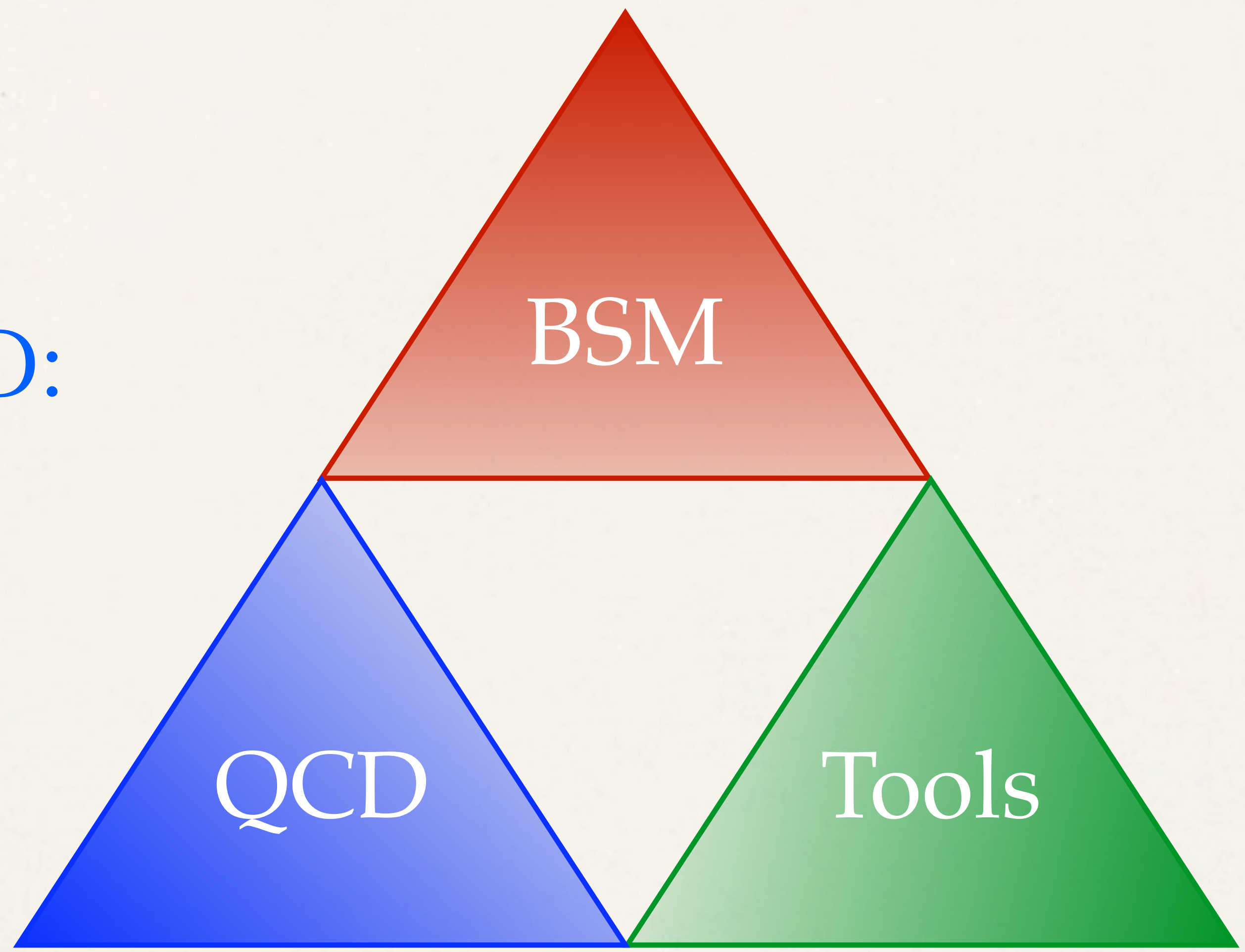
Organizing the work...

Effective theories

Exotic models

DECAY PACKAGES

DECAY CHAINS



Automatic NLO:

Real corrections

Loops

Subtractions

Automatic NLOwPS

Merging ME/PS

MATRIX ELEMENTS 4

EXTERNAL APPS

Advanced analysis techniques

Testing / robustness

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BSM special features

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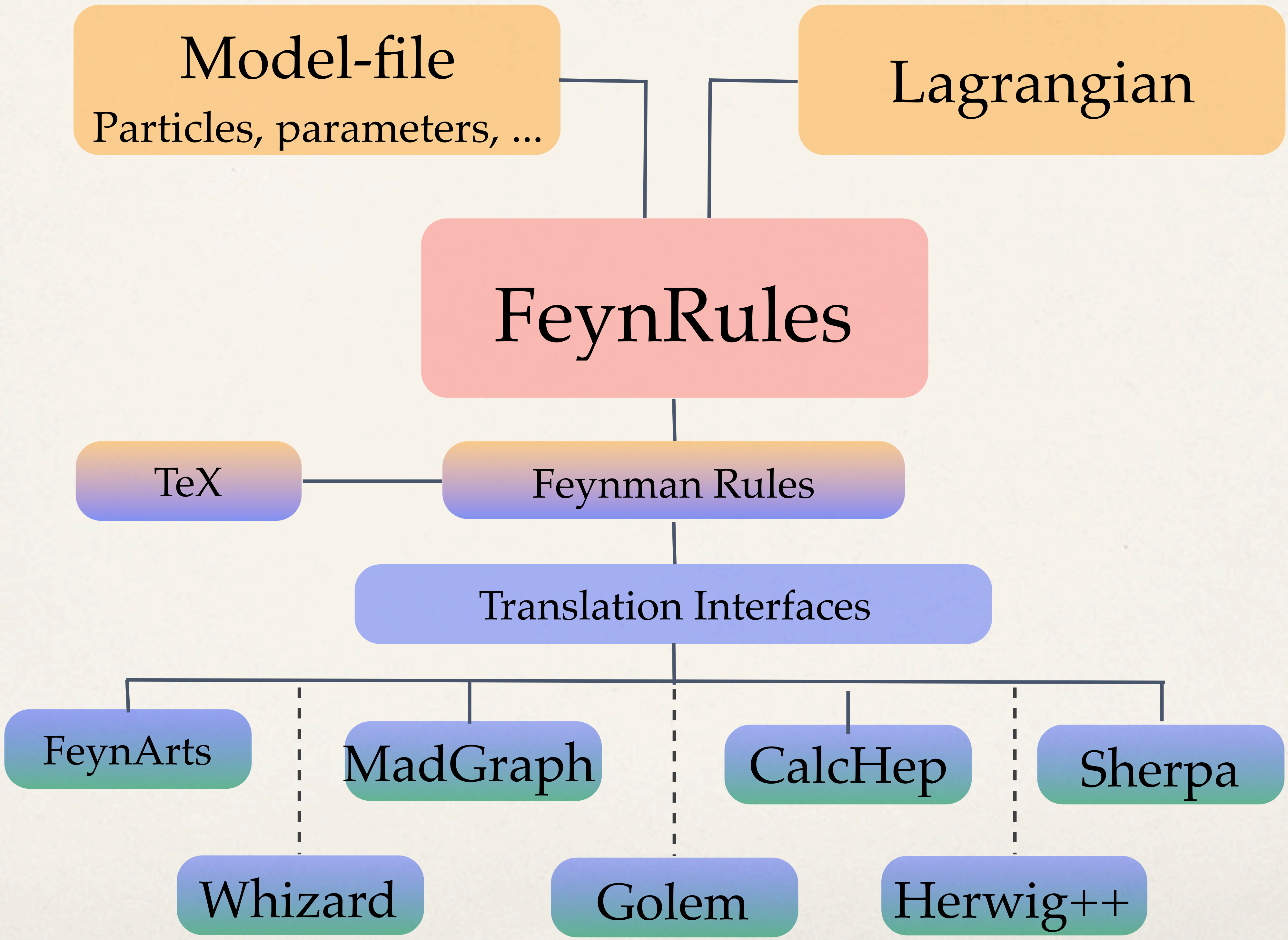
- What more....?

Full automatization from Model Builder to MC!

FeynRules

[Christensen, Duhr, Fuks, + many collaborators now]

[See talks by Speckner and Degrande]



FeynRules 2010 Workshop

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Idea: Lock 13 experts in a (very nice) Monastery for one week.

Exceptional interactions with MC's developers/TH tools.

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Many results/plans also related to MC's:

* A new set of models available
* The UFO
* LH Validation scheme
* Design of SBM model DB

The new UFO (Universal FeynRules Output)

[C. Duhr, D. Grellscheid, M. Herquet, W. Link, O. Mattelaer,...]

- Full use of Object Oriented notation (in Python)
- Lists of particles, interactions, coupling expressions, parameters (internal and external), but also color and Lorentz algebra and structures!
- Initially thought with MadGraph v5 in mind, but already now fully general.
- The most ambitious Lagrangian-to-MC interface up-to-date, first step towards unprecedented BSM possibilities.

FeynRules : towards a DB...

[FR2010 + All the interested people...]

- Ambition : Build a web database of BSM models

- Authors can upload their implementation of a model and make it public to the community.

- Many interesting and possibly "revolutionary" aspects:
  - new minimal quality standard introduced (see LH grading)
  - full traceability and reproducibility of the generated event samples (legacy)
  - best way to organize proper credit
  - many more..and above all...fun!

- The final result might look like this...

FeynRules : Les Houches validation scheme

★ Documentation:

References to the original papers,operating system, ...

★ Basic theory sanity checks:

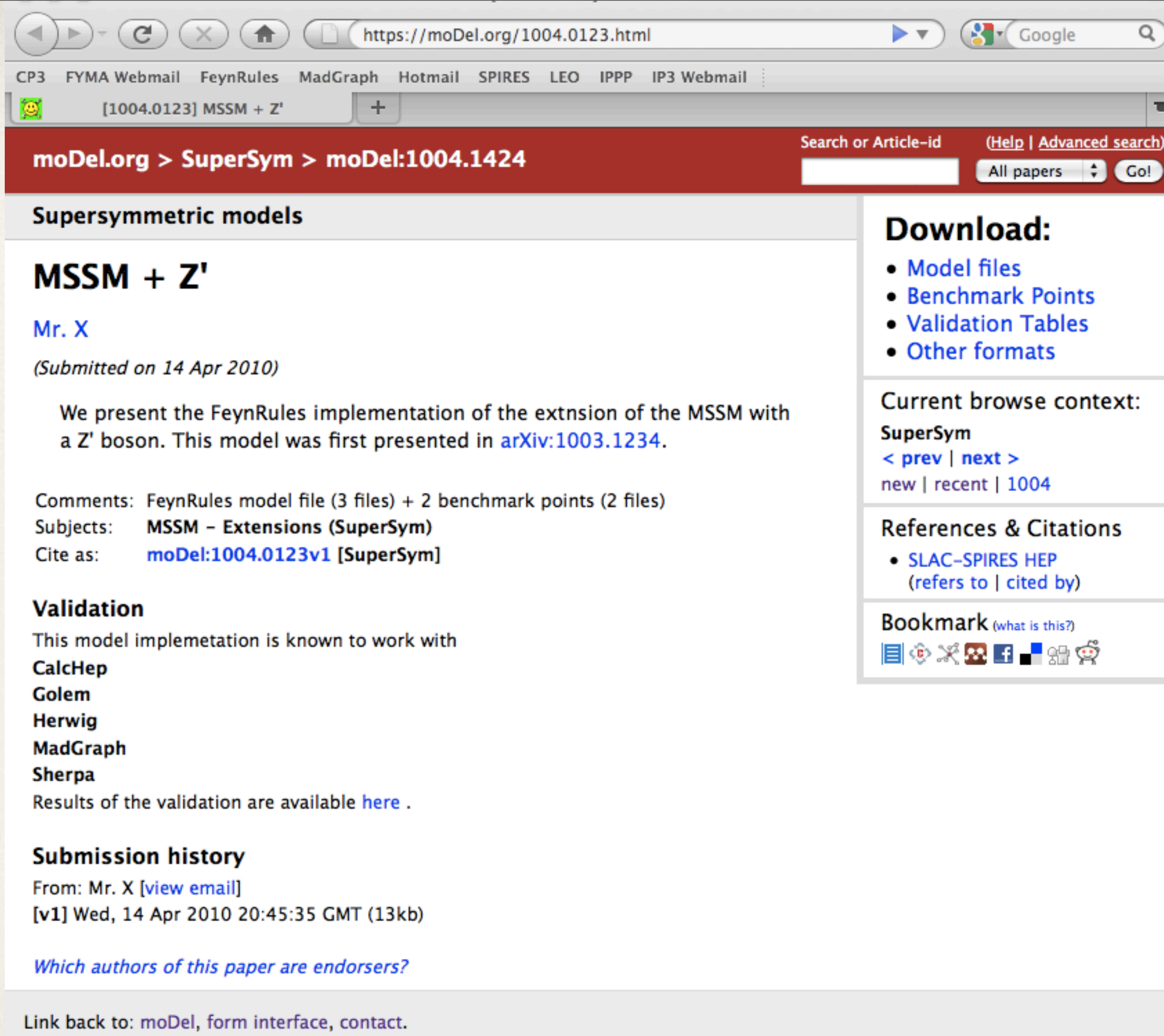
Hermiticity, gauge invariance, 2-to-2 cross section,...

★ Testing one ME generator:

All possible 2-to-2 cross sections, in different gauges, HE behavior, ...

★ Testing several ME generators

Process	MG-FR	MG-ST	CH-FR	CH-ST	SH-FR	SH-ST	WO-FR	WO-ST	Comparison
e+,e->sd1,sd1~	2.85002×10^{-3}	2.85011×10^{-3}	2.8501×10^{-3}	2.8501×10^{-3}	2.85007×10^{-3}	2.85007×10^{-3}	2.85013×10^{-3}	2.85013×10^{-3}	$\delta = 0.00394796$ %
e+,e->sd2,sd2~	4.34049×10^{-4}	4.34207×10^{-4}	4.3415×10^{-4}	4.3415×10^{-4}	4.34145×10^{-4}	4.34145×10^{-4}	4.34155×10^{-4}	4.34155×10^{-4}	$\delta = 0.0364994$ %
e+,e->sd1,sd2~	2.85795×10^{-4}	2.85759×10^{-4}	2.8578×10^{-4}	2.8579×10^{-4}	2.85825×10^{-4}	2.85825×10^{-4}	2.8579×10^{-4}	2.8579×10^{-4}	$\delta = 0.0229397$ %
e+,e->n1,n1	7.45909×10^{-2}	7.45813×10^{-2}	7.4637×10^{-2}	7.4637×10^{-2}	7.46268×10^{-2}	7.46266×10^{-2}	7.463×10^{-2}	7.46338×10^{-2}	$\delta = 0.0746855$ %
e+,e->n1,n2	2.5541×10^{-2}	2.55366×10^{-2}	2.5555×10^{-2}	2.5555×10^{-2}	2.55523×10^{-2}	2.55516×10^{-2}	2.55521×10^{-2}	2.55535×10^{-2}	$\delta = 0.0719985$ %
e+,e->n1,n3	2.08218×10^{-3}	2.08034×10^{-3}	2.081×10^{-3}	2.081×10^{-3}	2.08093×10^{-3}	2.08089×10^{-3}	2.0811×10^{-3}	2.081×10^{-3}	$\delta = 0.0880299$ %
e+,e->n1,n4	3.73046×10^{-3}	3.73254×10^{-3}	3.7325×10^{-3}	3.7325×10^{-3}	3.73208×10^{-3}	3.7321×10^{-3}	3.73223×10^{-3}	3.73238×10^{-3}	$\delta = 0.0555803$ %



https://moDel.org/1004.0123.html

CP3 FYMA Webmail FeynRules MadGraph Hotmail SPIRES LEO IPPP IP3 Webmail

[1004.0123] MSSM + Z'

moDel.org > SuperSym > moDel:1004.1424

Search or Article-id (Help | Advanced search)

All papers Go!

Supersymmetric models

MSSM + Z'

Mr. X

(Submitted on 14 Apr 2010)

> We present the FeynRules implementation of the extnsion of the MSSM with a Z' boson. This model was first presented in arXiv:1003.1234.

Comments:	FeynRules model file (3 files) + 2 benchmark points (2 files)
Subjects:	**MSSM - Extensions (SuperSym)**
Cite as:	**moDel:1004.0123v1 [SuperSym]**

Validation

This model implemetation is known to work with

CalcHep
Golem
Herwig
MadGraph
Sherpa

Results of the validation are available here .

Submission history

From: Mr. X [view email]
[v1] Wed, 14 Apr 2010 20:45:35 GMT (13kb)

Which authors of this paper are endorsers?

Download:

- Model files
- Benchmark Points
- Validation Tables
- Other formats

Current browse context:
SuperSym
< prev | next >
new | recent | 1004

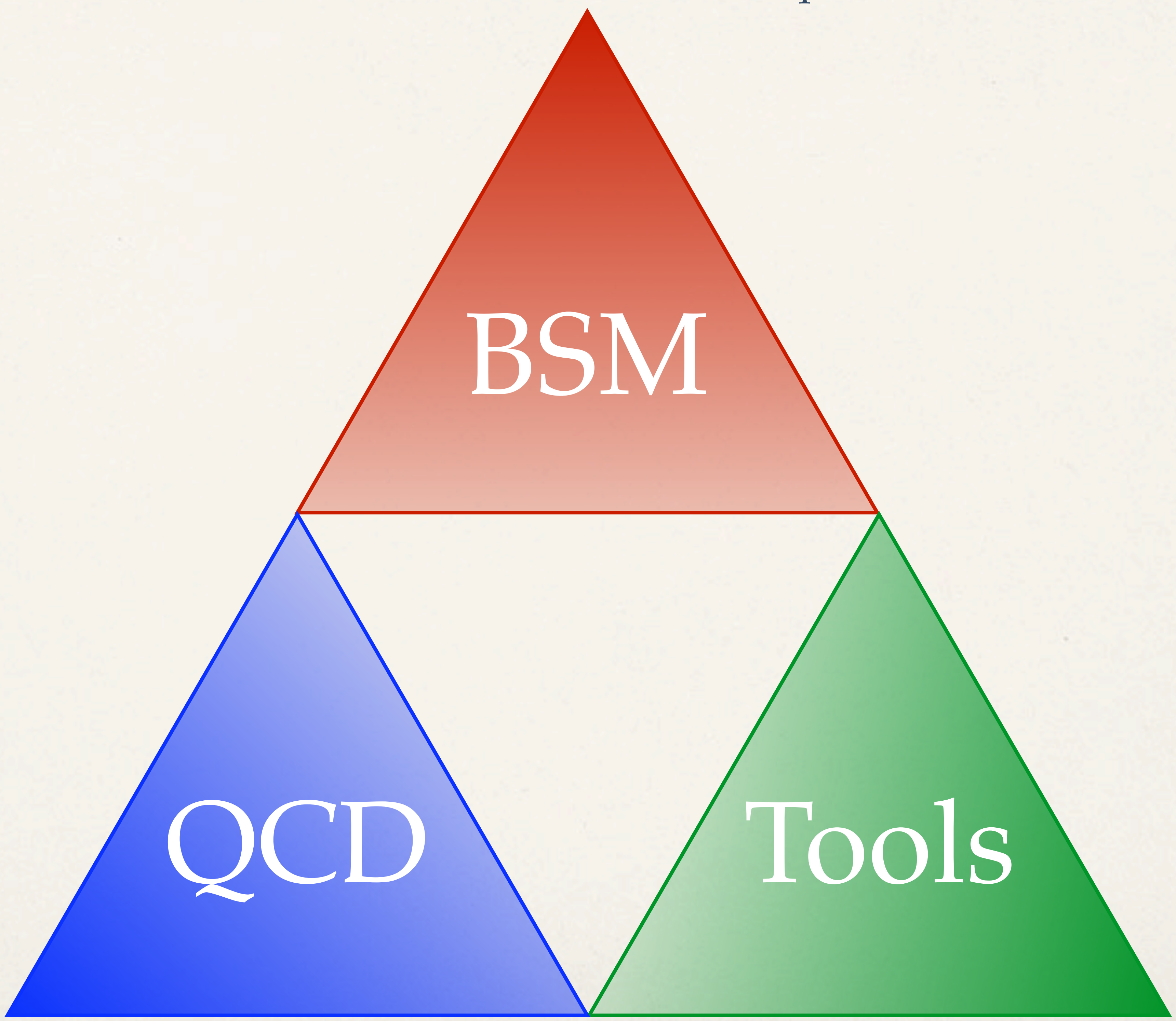
References & Citations
- SLAC-SPIRES HEP (refers to | cited by)

Bookmark (what is this?)

Link back to: moDel, form interface, contact.

MadGraph v5

[J. Alwall,M. Herquet, F. M., O. Mattelaer, T. Stelzer]



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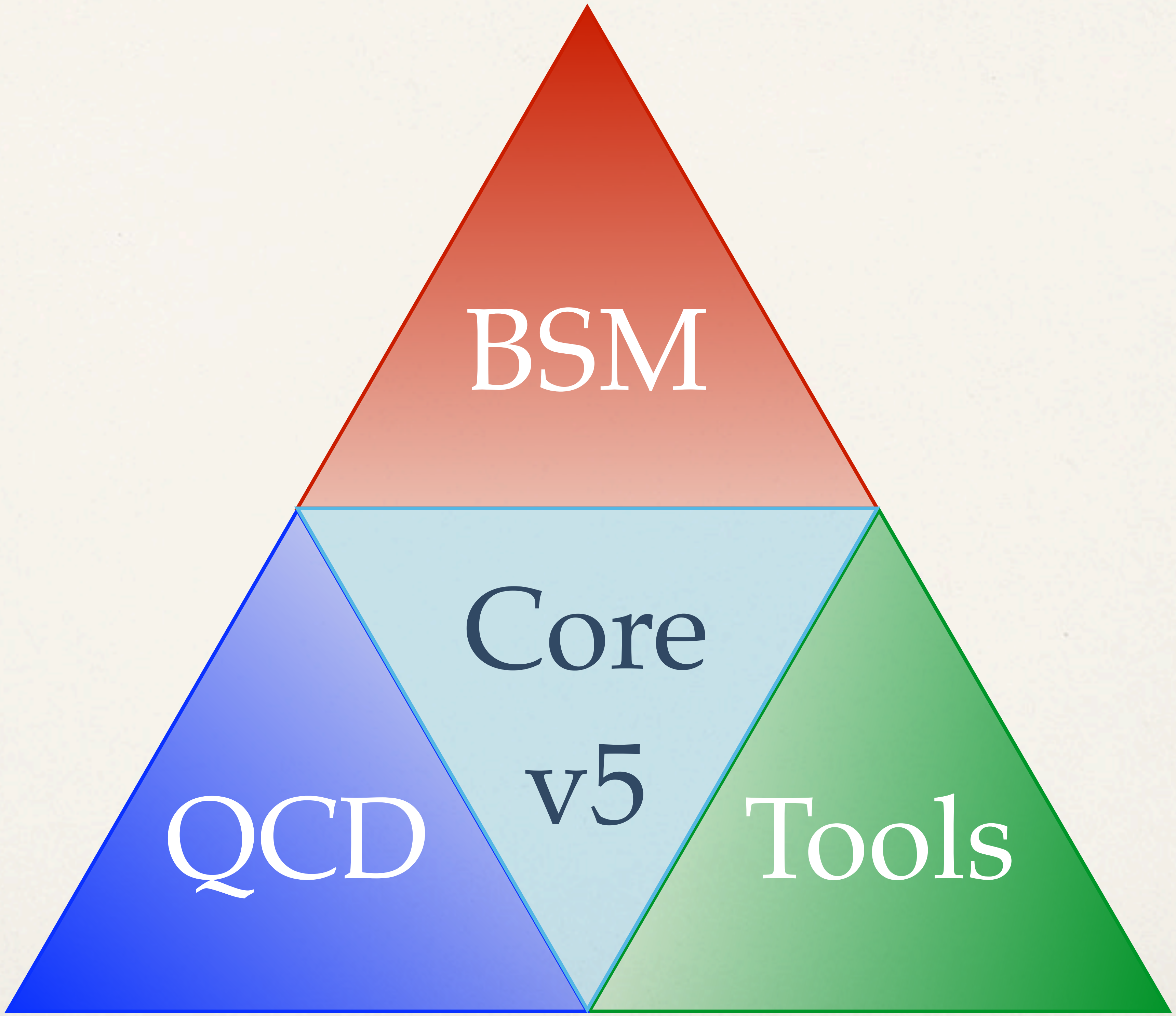

MadGraph v5 : Innovations

- Main EVOLUTION of Philosophy
  - Focus on our main expertises : matrix elements and phase space integration (=parton-level event generation)
  - Extend and Develop

    1. the core expertise by including NLO;
    2. interoperability and support to other codes, up-stream (FeynRules) and down-stream (HERWIG and Pythia). E.g., by providing libraries to be linked for matrix elements, Feynman rules;
    3. provide ME's to any tool.

MadGraph v5 : Innovations

- Main EVOLUTION of Philosophy is reflected in the tech choices:
    - Python flexibility
    - Open and modular structure for independent contributions..
    - Many functionalities accessible in a kind of SHELL environment (a la ROOT).
    - Output for Matrix element generation for a large set of applications: not only MadEvent, MadWeight, MadFKS, MadDipoles, but also Standalone in Fortran or C(++), GPU's, possibly HERWIG++ or PYTHIA8.

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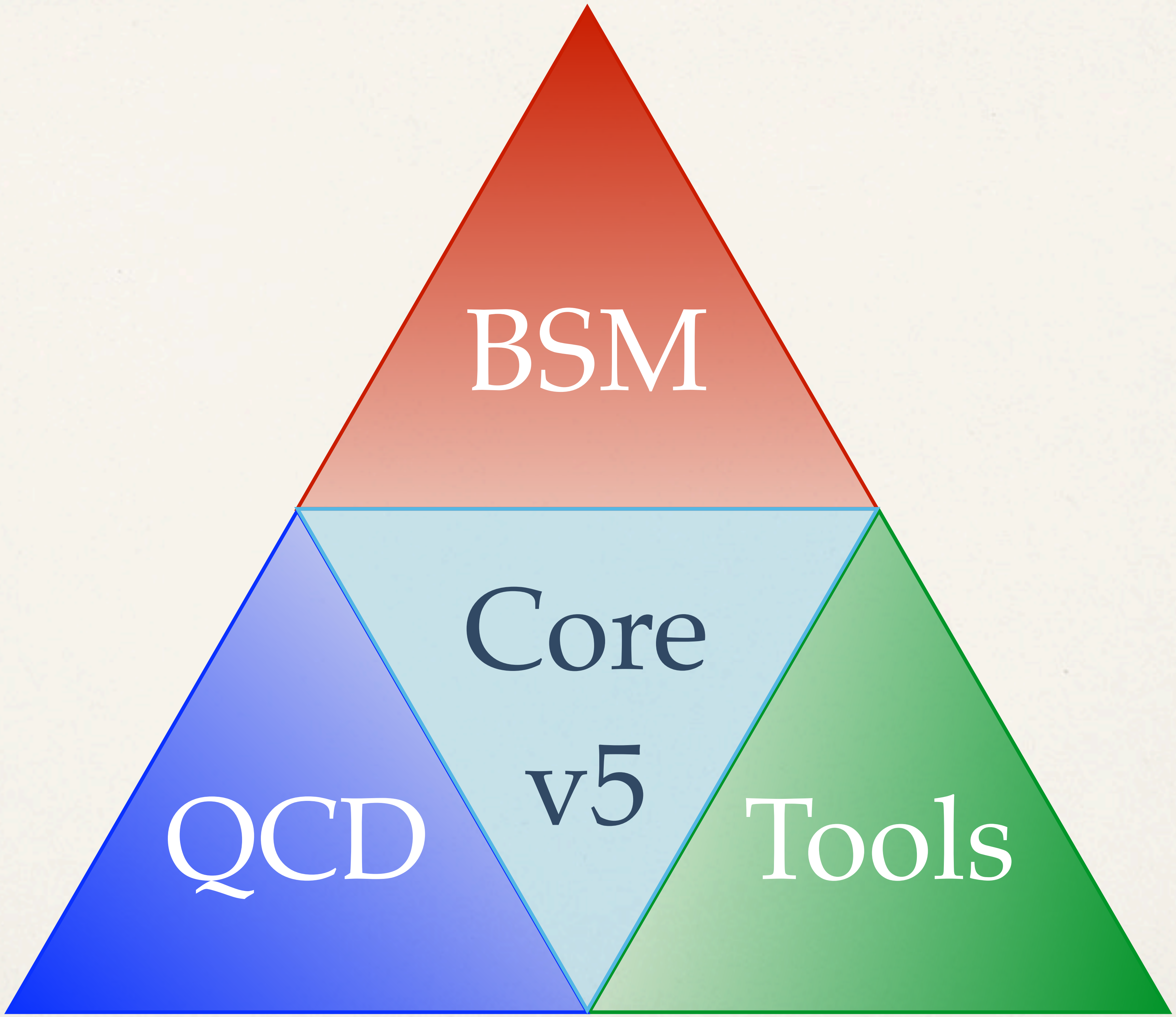
  - Ready for recursive approaches (for multi-gluon amps..)
- New HELAS call generation algorithm (90% less calls for critical cases!)
- Generic and "smart" new color calculation library (MC..)
- New, faster and generic diagram drawing library (Easy to extend it to loops...)

Short term plan



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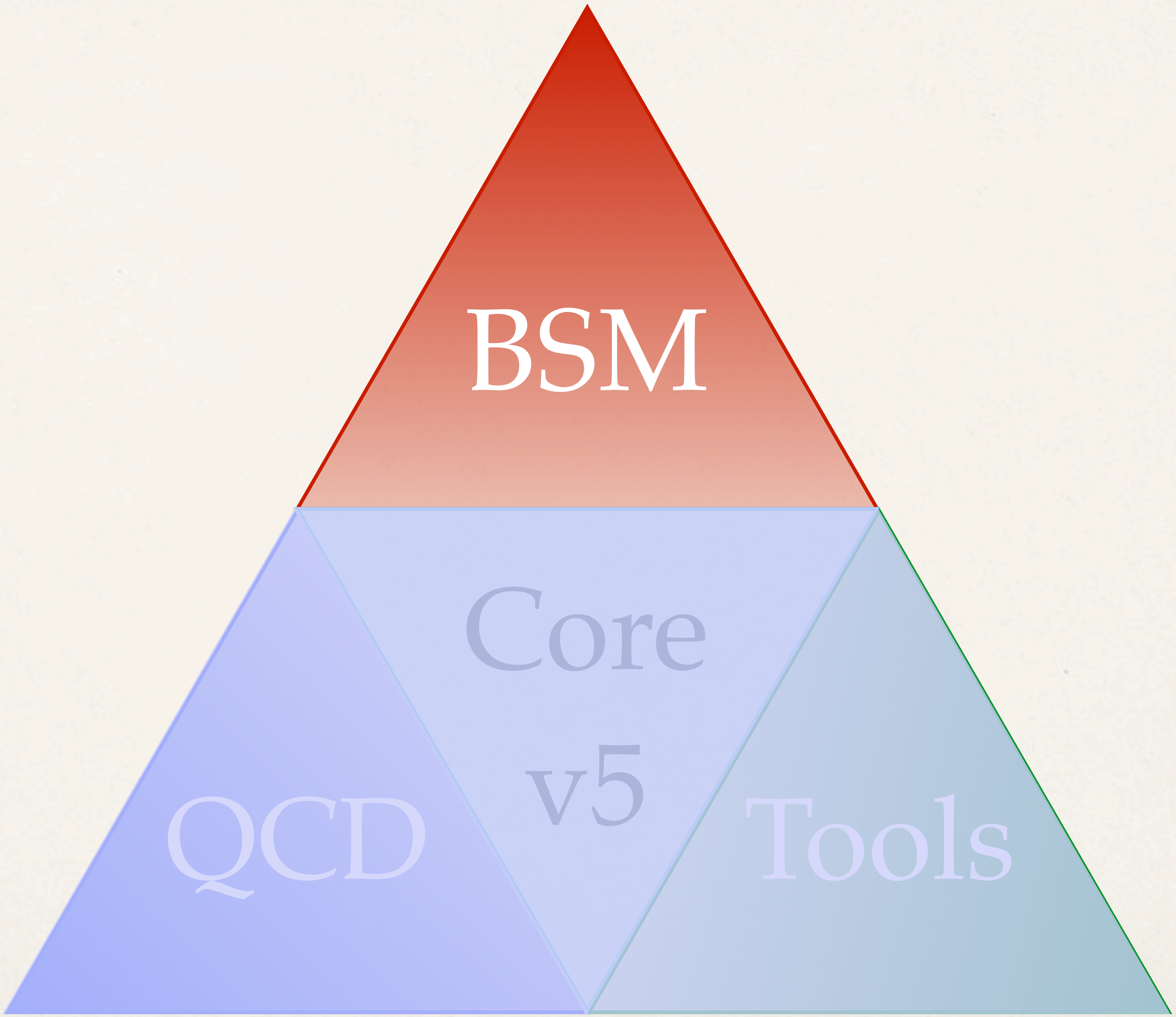

BSM

- FeynRules interface
- Generic color structures
- Generic Lorentz structures

Generic color structures

- Color is now completely generic:
  - The color structure of a vertex is described inside the model using a textbook notation, e.g.:

```
'color':[[f(0, 1, -1),f(2, 3, -1)],
         [f(2, 0, -1),f(1, 3, -1)],
         [f(1, 2, -1),f(0, 3, -1)]]
```

  - The full color factor associated with a diagram is simplified using (easy to implement and modify) simple rules, e.g.,

```
f(a,b,c) = -2 I Tr(a,b,c) + 2 I Tr(c,b,a)

Tr(a,x,b)T(c,x,d,i,j) = 1/2(T(c,b,a,d,i,j)
                         -1/Nc Tr(a,b)T(c,d,i,j))
```

    to build the color basis and color matrices for squared amplitudes

Generic Lorentz structures

[P. de Aquino, W. Link, O. Mattelaer]

- Lorentz is now completely generic (tested SM 2→ 2 and 2 → 3 last week):
  - The color structure of a vertex is described inside the model using a textbook notation, e.g.:

```
'Structure':[complex(0,1)*Gamma(1,2,'a')*ProjM('a',3)]
```

  - The corresponding optimized "HELAS" routines are produced automatically

```
 SUBROUTINE VERTEX1_111(C,V1,F2,F3,VERTEX)
 IMPLICIT NONE
 DOUBLE PRECISION C
 DOUBLE COMPLEX V1(6)
 DOUBLE COMPLEX F2(6)
 DOUBLE COMPLEX F3(6)
 DOUBLE COMPLEX VERTEX
 VERTEX = C*((F3(4)*V1(1)gra*F2(2))+(F3(4)*V1(4)*F2(2))+(F3(4)*V1(2)
$ *F2(1))+1.*(0,1.)*(F3(4)*V1(3)*F2(1))+(F3(3)*V1(2)*F2(2))
$ +-1.*(0,1.)*(F3(3)*V1(3)*F2(2))+(F3(3)*V1(1)*F2(1))+-(F3(3)
$ *V1(4)*F2(1))+(F3(2)*V1(1)*F2(4))+-(F3(2)*V1(4)*F2(4))
$ +-(F3(2)*V1(2)*F2(3))+-1.*(0,1.)*(F3(2)*V1(3)*F2(3))+-(F3(1)
$ *V1(2)*F2(4))+1.*(0,1.)*(F3(1)*V1(3)*F2(4))+(F3(1)*V1(1)*F2(3))
$ +(F3(1)*V1(4)*F2(3)))
 END
```

BSM special features: status in MG

✓

✓✗

✗✍

✍

✓✍

✓

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- Long decay chains (SUSY, UED,LH, WTC) ✓

✓✗

✗✍

✍

✓✍

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✗✍

✍

✓✍

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✍

✓✍

✓

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- Majorana particles (See-saw at LHC, SUSY, ...) ✓

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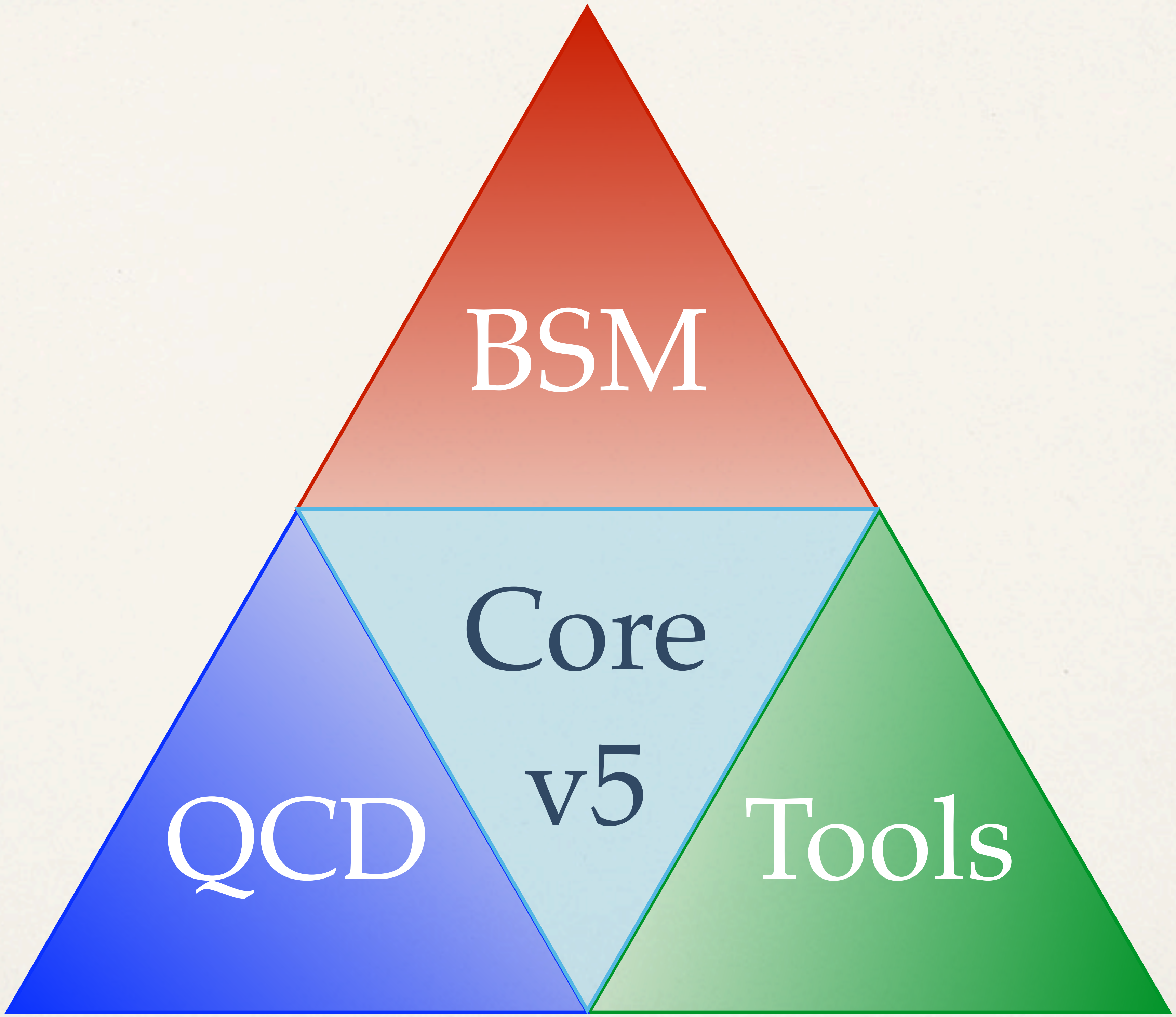

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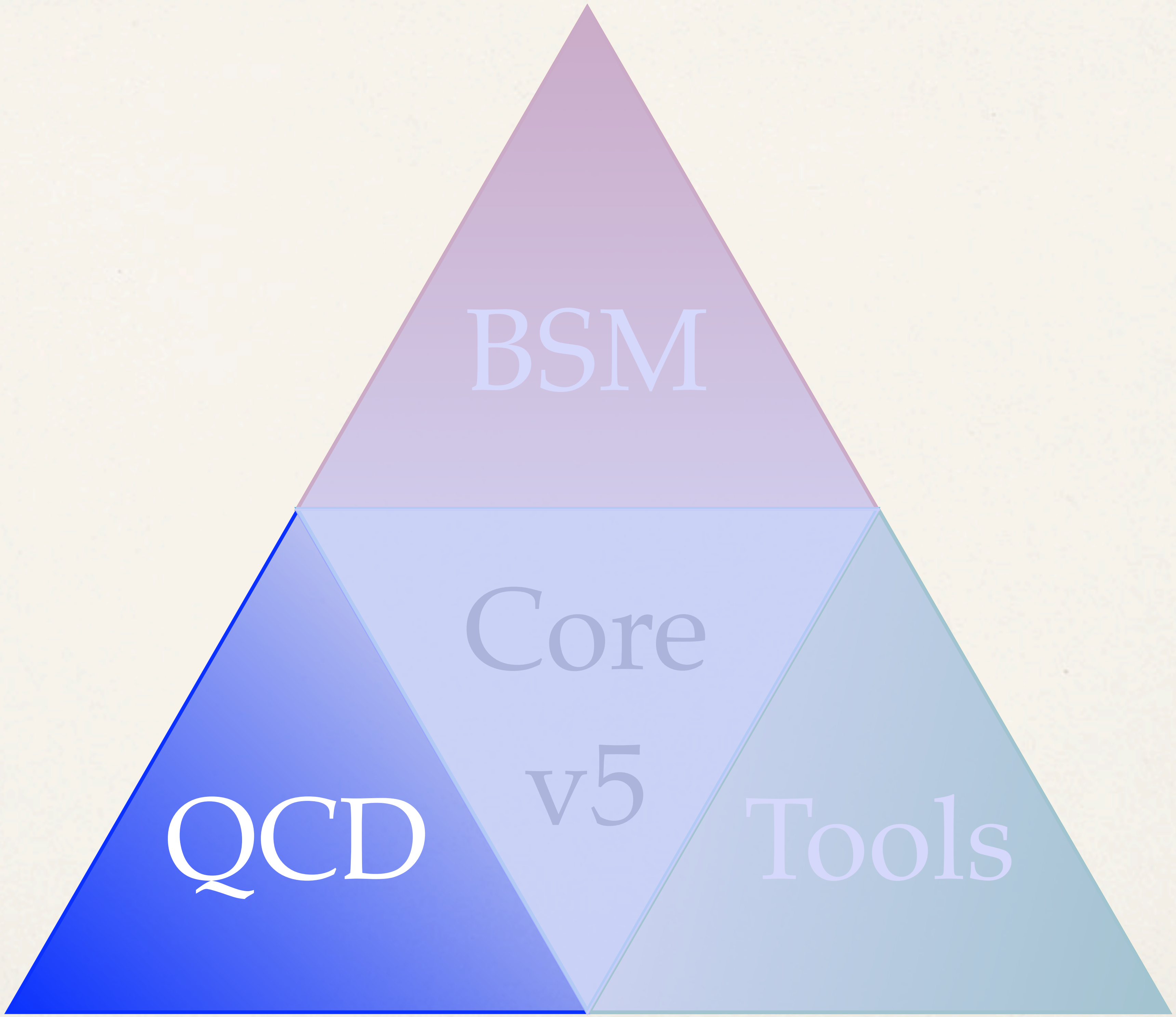
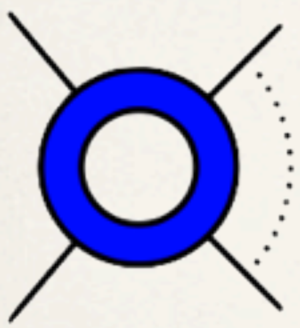


QCD : desiderata

- Same capabilities as SM procs OUT OF THE BOX:
  - Automatic NLO
  - Merging with PS for multijet final states (non-trivial)
  - Automatic NLO+PS

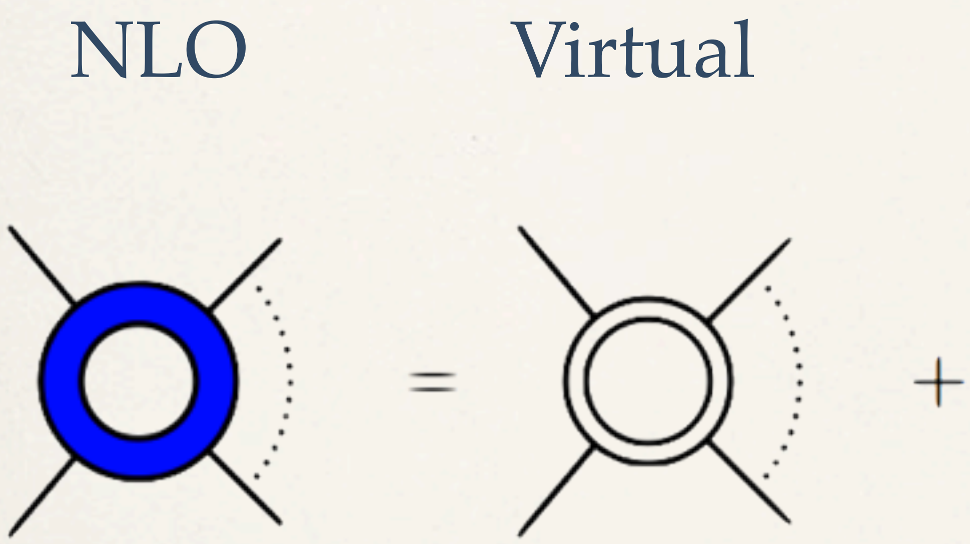
NLO: the problem

NLO

 $=$

$$\sigma^{\rm NLO} =$$

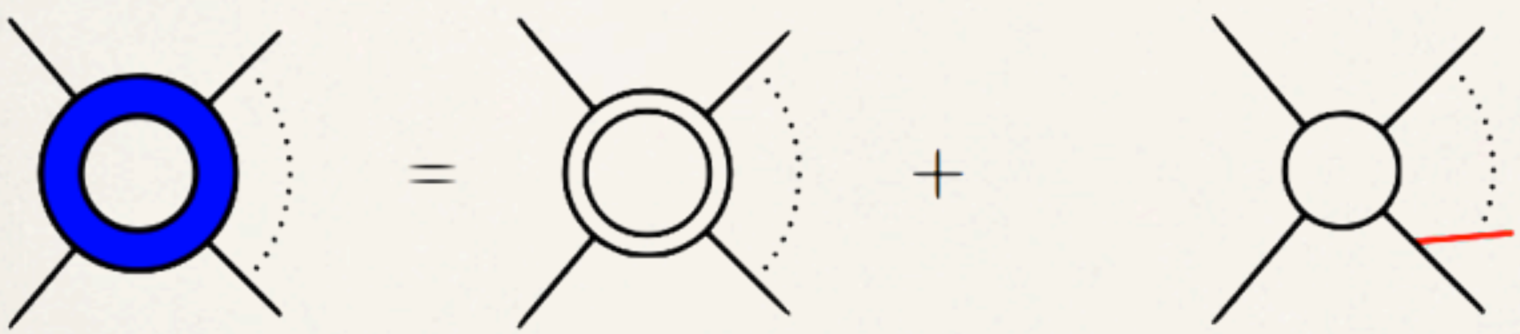
NLO: the problem



$$\sigma^{\text{NLO}} = \int_m d^{(d)}\sigma^V +$$

NLO: the problem

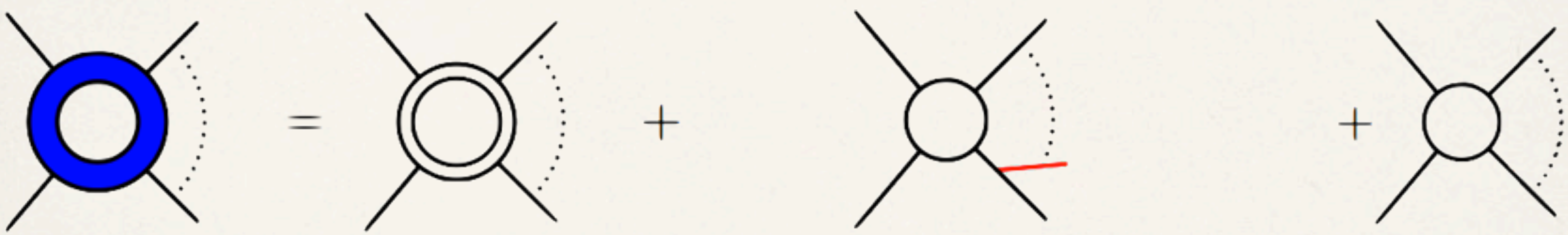
NLO Virtual Real



$$\sigma^{\mathrm{NLO}} = \int_m d^{(d)}\sigma^V + \int_{m+1} d^{(d)}\sigma^R +$$

NLO: the problem

NLO Virtual Real Born



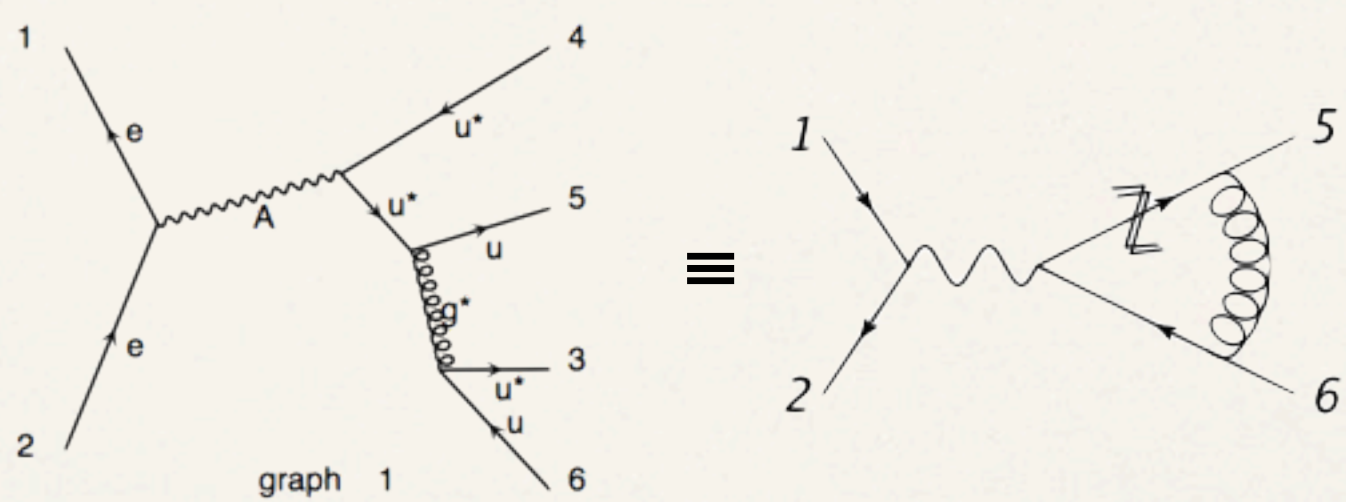
$$\sigma^{\mathrm{NLO}} = \int_m d^{(d)}\sigma^V + \int_{m+1} d^{(d)}\sigma^R + \int_m d^{(4)}\sigma^B$$

NLO: virtual contributions

[R. Frederix, S. Frixione, V. Hirschi, R. Pittau, M. V. Grazielli,]

- Two (complementary) approaches:

  - Use MG to generate diagrams and calculate n+2 amplitudes to build the NLO result (CutTools technique), e+e- → 2 and 3 jets already checked. Advantages: valid for any BSM model



  - Rely on external tool(s) (BlackHat, Rocket, Golem, ...) using the Binoth-LHA accord (see Rikkert's talk). Various e+e- and hadronic processes checked. Advantage: strong optimization possibilities.

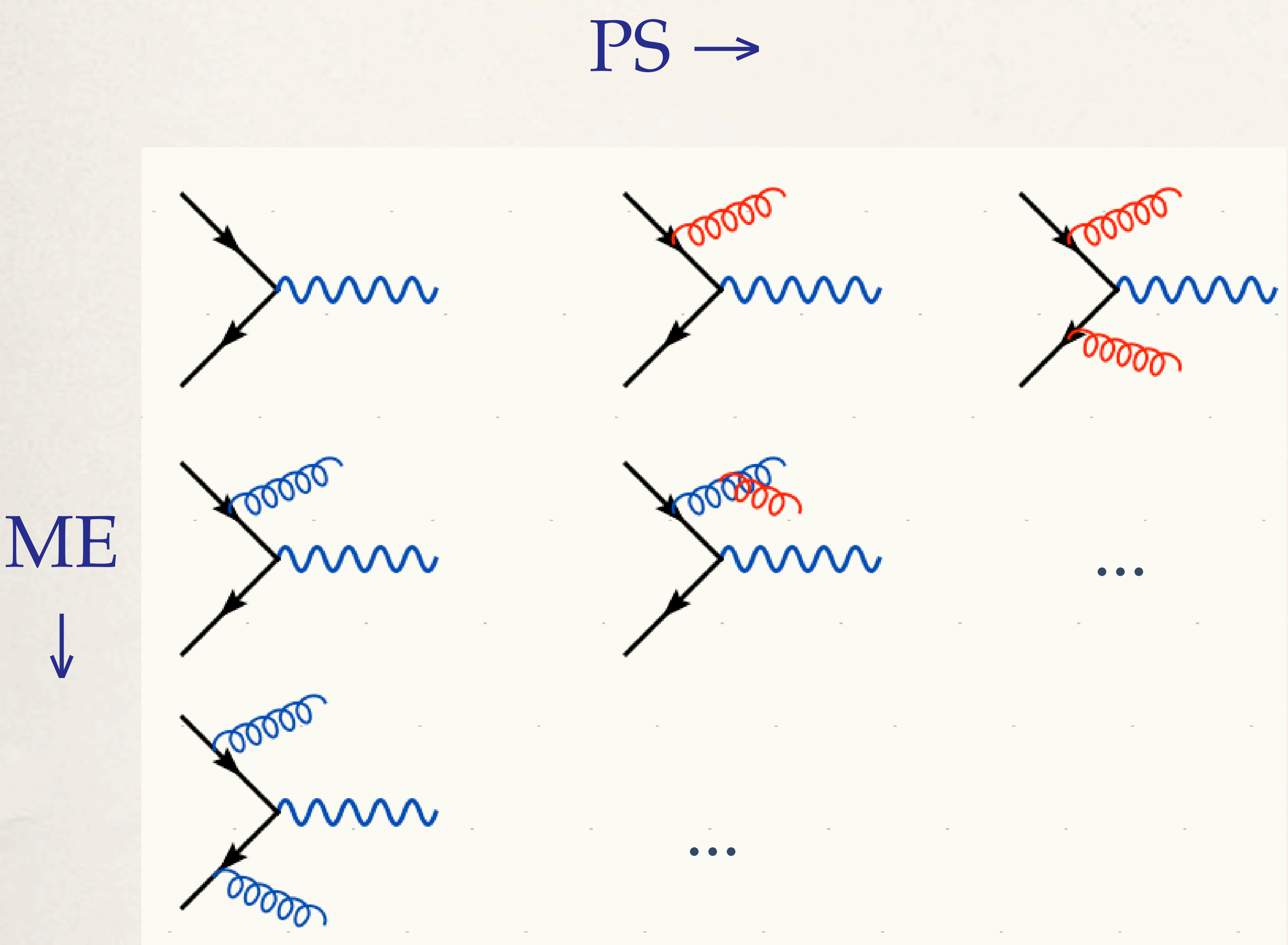
NLO: real contributions

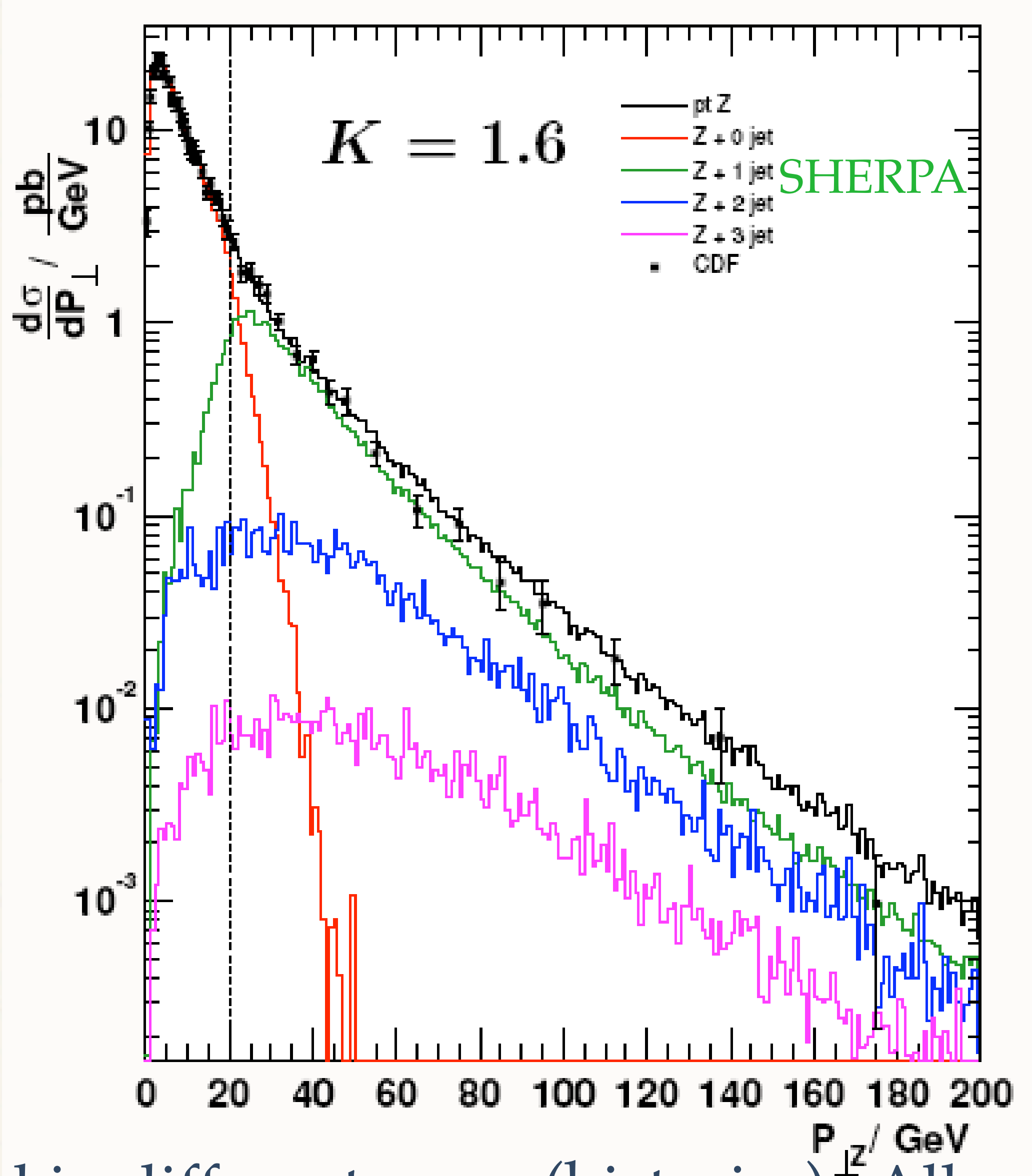
[R. Frederix, S. Frixione, F. Maltoni, T. Stelzer; R. Frederix, T. Gehrmann, N. Greiner,]

- Two approaches:
  - MadDipole: Catani-Seymour dipole substraction scheme, standalone implementation (TH), cancellation of singularities checked, and dipoles checked against MCFM
  - MadFKS: Frixione-Kunszt-Signer substraction scheme, integration is available (TH+PH), cancellation of singularities checked.
  - Both: usable both for SM and BSM processes, and for massless and massive external particles

ME/PS Matching

[Mangano, 2003] [Catani, Krauss, Kuhn, Webber,2003]





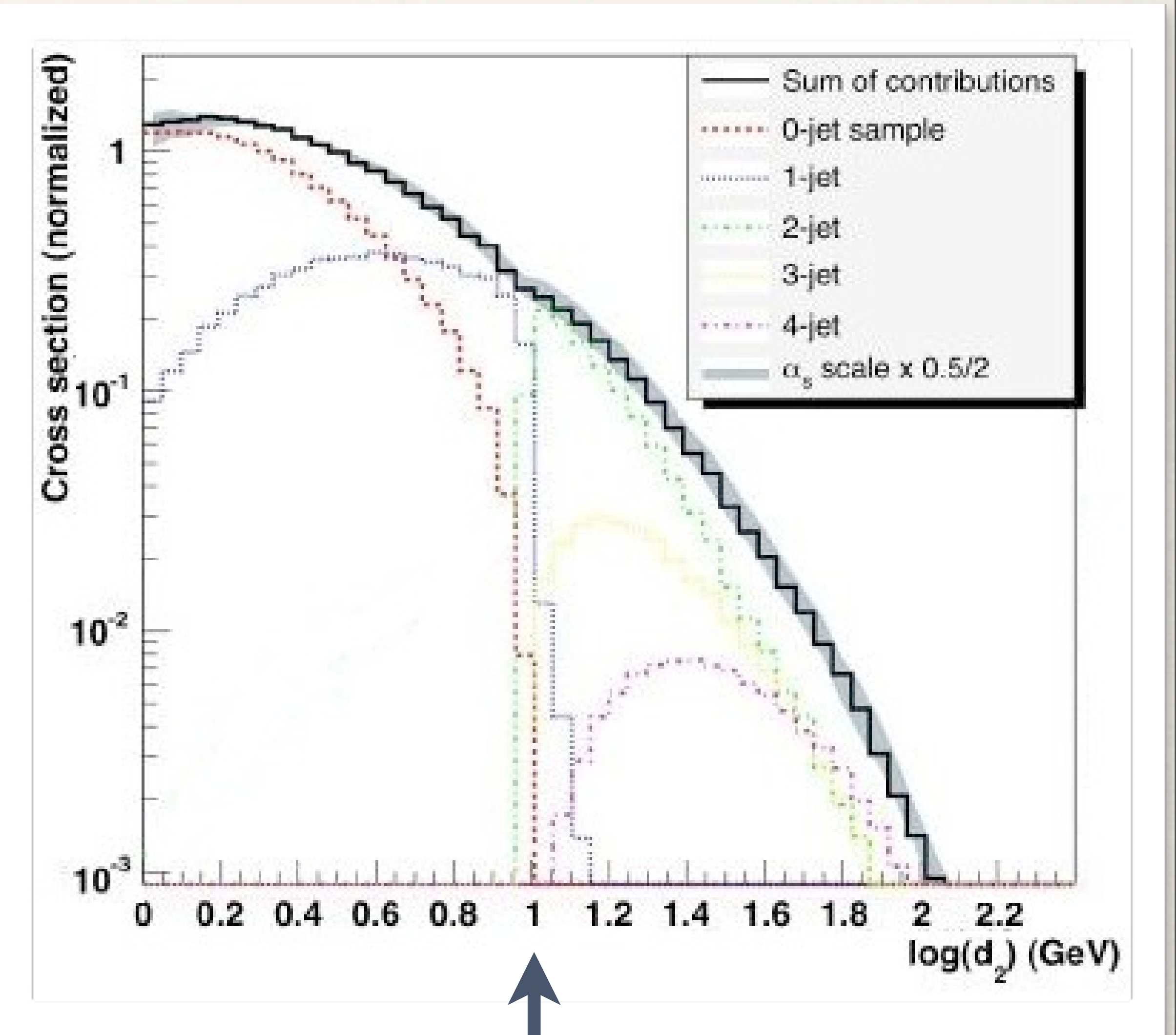
Double counting of configurations that can be obtained in different ways (histories). All the matching algorithms (CKKW, MLM,...) apply criteria to select only one possibility based on the hardness of the partons. As the result events are exclusive and can be added together into an inclusive sample. Distributions are accurate but overall normalization still leading order.

ME/PS Matching

[Alwall et al.]

- 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 and Tevatron data
- Allows matching in most SM and BSM processes

Jet resolution for 1 to 2 jets

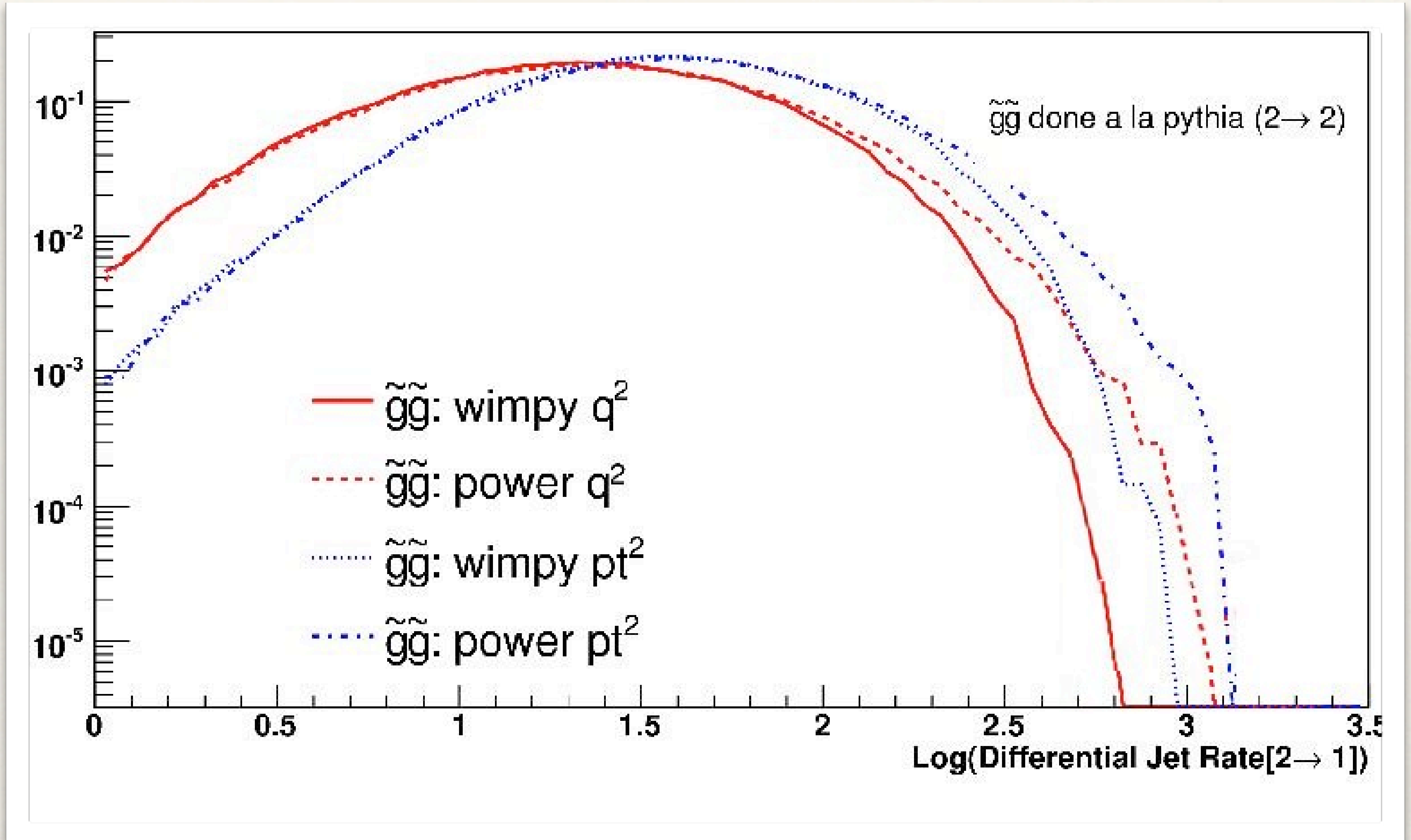


Cutoff (unphysical)

Matching for BSM processes

[J. Alwall, S. de Visscher, F. Maltoni]

600 GeV gluino pair production at the LHC



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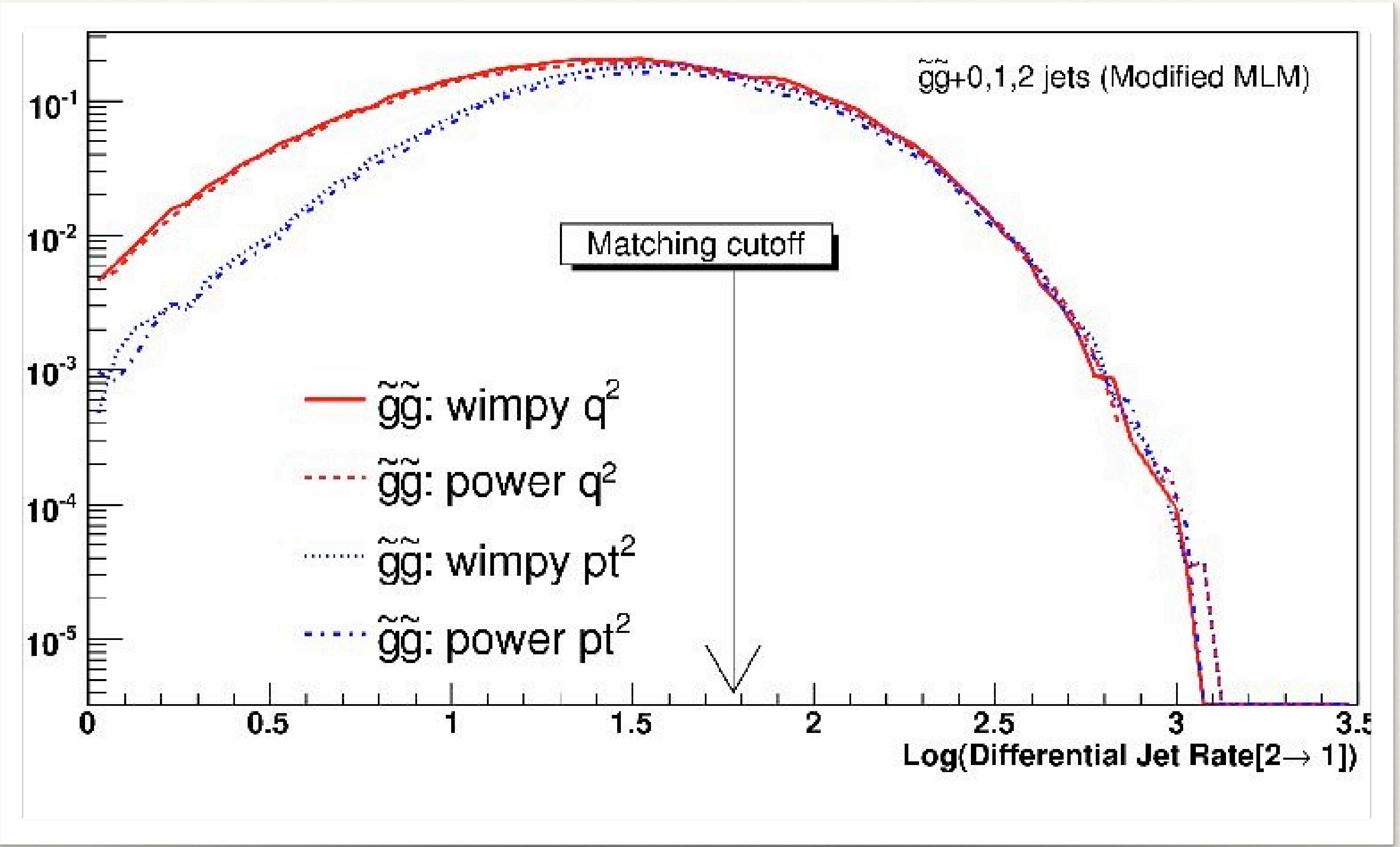
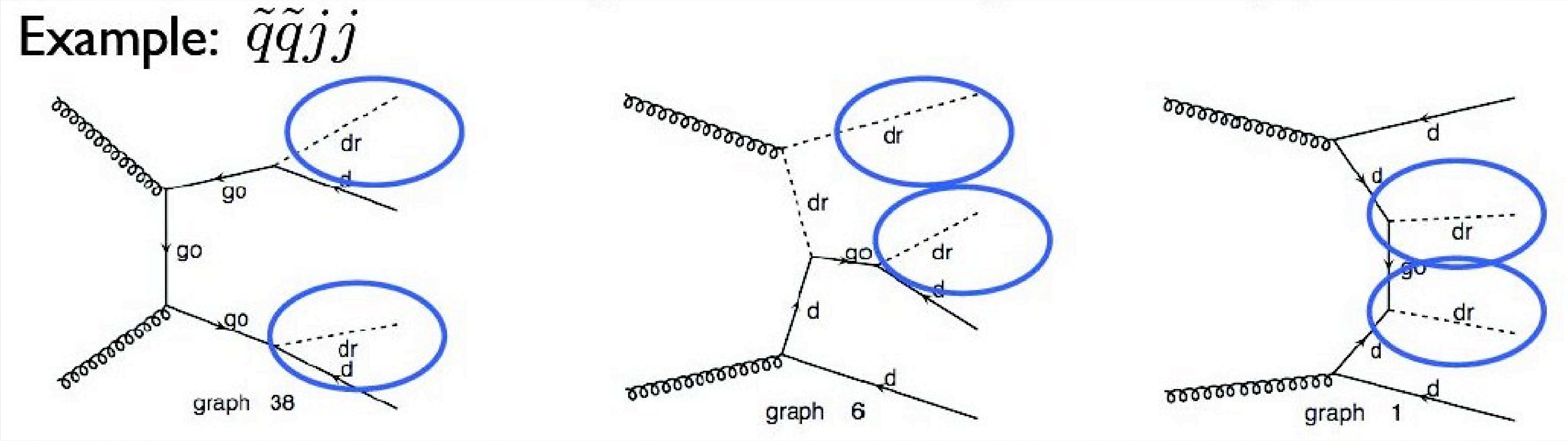


Resonances double counting

[Alwall, de Visscher, FM, 2009]

A new* kind of problem arises when trying to combine samples with more partons.



Resonances double counting

[Alwall, de Visscher, FM, 2009]

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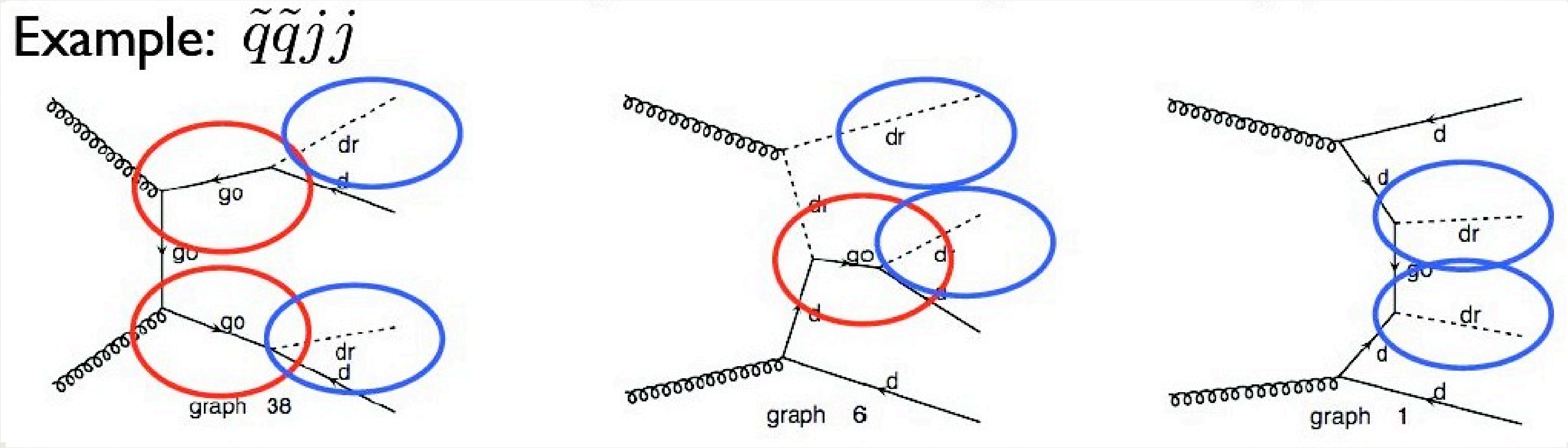

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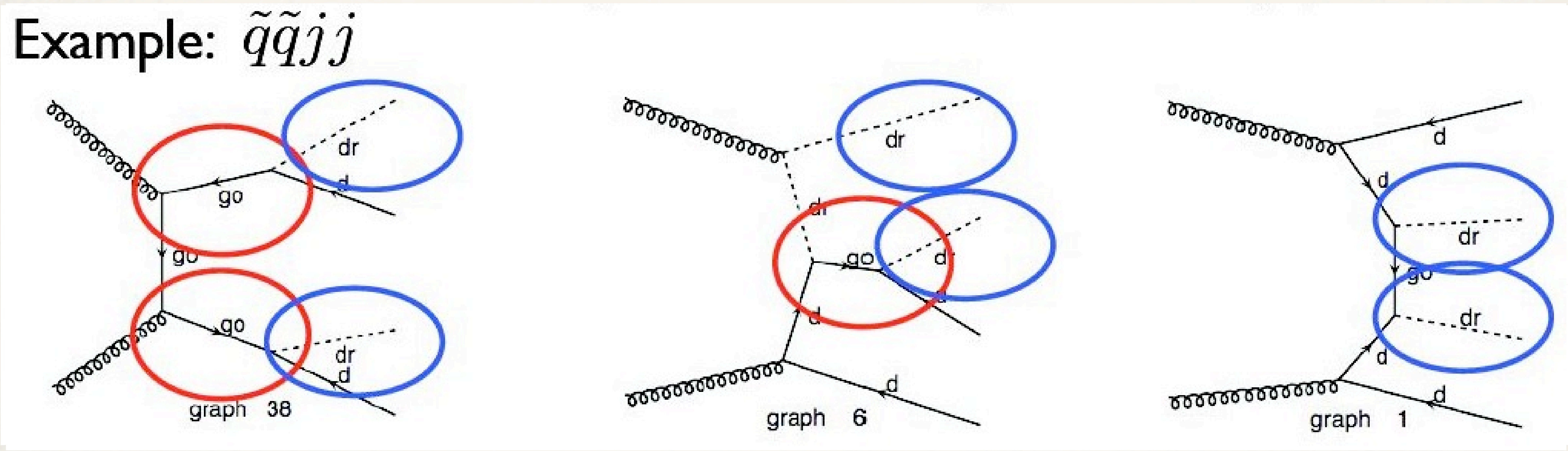

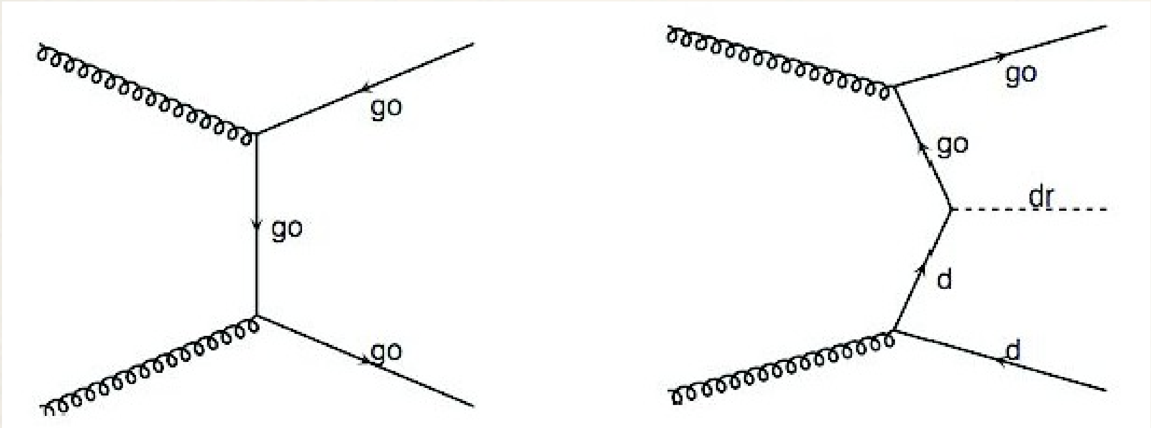

Double counting with gluino-gluino production and sucessive decays. Physics is clear, but technical problem.

Resonances double counting

Two solutions implemented and tested, which are exact in the NWA:

Resonances double counting

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1. Resonant event removal


```
<event>
 6   0  0.7992762E-04  0.9118800E+02  0.7816531E-02  0.1300000E+00
       21   -1    0    0  502  503  0.00000000000E+00  0.00000000000E+00  0.38916243784E+03  0.38916243784E+03  0.00000000000E+00 0.  1.
        1   -1    0    0  501    0  0.00000000000E+00  0.00000000000E+00 -0.16355197391E+04  0.16355197391E+04  0.00000000000E+00 0.  1.
  1000021    2    1    2  501  503 -0.22162854802E+03 -0.24366260777E+03 -0.12022753376E+04  0.13861620323E+04  0.60620830799E+03 0.  0.
       -1    1    3    3    0  503  0.18372150189E+02  0.27121177112E+02 -0.34707630298E+02  0.47725399437E+02  0.00000000000E+00 0. -1.
  2000001    1    3    3  501    0 -0.24000069821E+03 -0.27078378488E+03 -0.11675677073E+04  0.13384366329E+04  0.54522846200E+03 0. -1.
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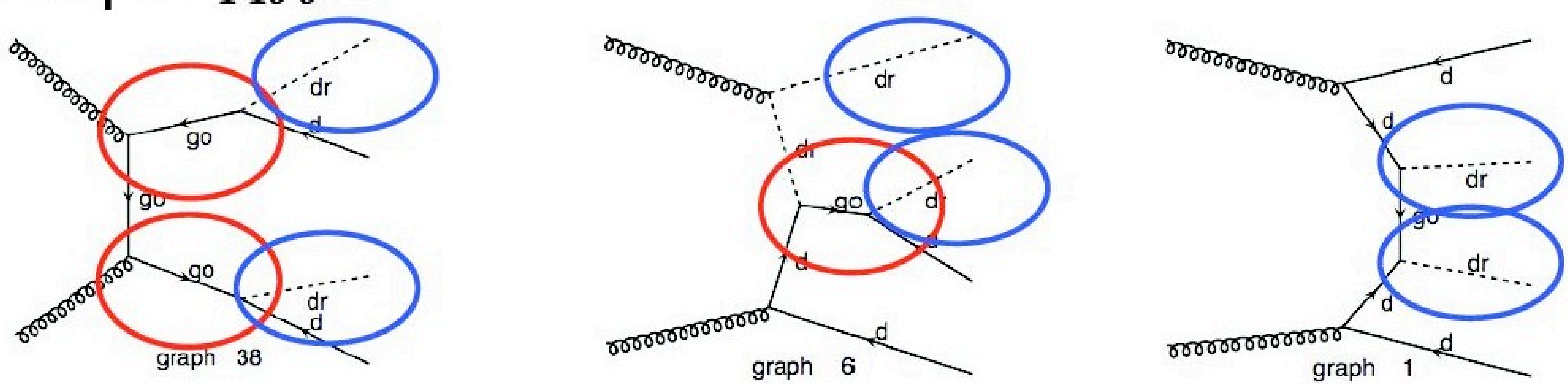
</event>
```

2. Resonant diagram removal

Example: $\tilde{q}\tilde{q}jj$



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         1    -1     0     0   501     0   0.00000000000E+00   0.00000000000E+00  -0.16355197391E+04   0.16355197391E+04   0.00000000000E+00 0.   1.
   1000021     2     1     2   501   503  -0.22162854802E+03  -0.24366260777E+03  -0.12022753376E+04   0.13861620323E+04   0.60620830799E+03 0.   0.
        -1     1     3     3     0   503   0.18372150189E+02   0.27121177112E+02  -0.34707630298E+02   0.47725399437E+02   0.00000000000E+00 0.  -1.
   2000001     1     3     3   501     0  -0.24000069821E+03  -0.27078378488E+03  -0.11675677073E+04   0.13384366329E+04   0.54522846200E+03 0.  -1.
   2000001     1     1     2   502     0   0.22162854802E+03   0.24366260777E+03  -0.44081963594E+02   0.63852014456E+03   0.54522846200E+03 0.  -1.
</event>
```

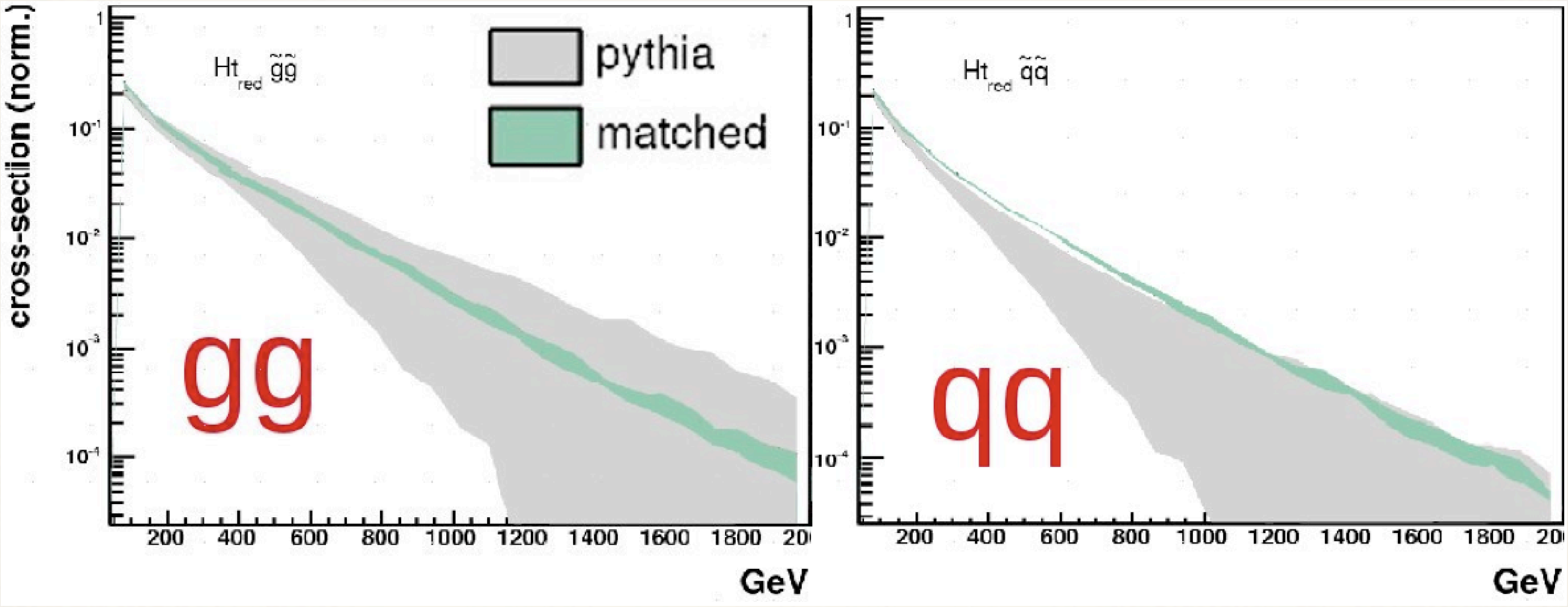

2. Resonant diagram removal

Example: $\tilde{q}\tilde{q}jj$

Results are very much independent on the subtraction method.

Initial state dependence: gg vs qq

600 GeV gluino vs squark pair production at the LHC



No single tune for the shower can reproduce both channels.

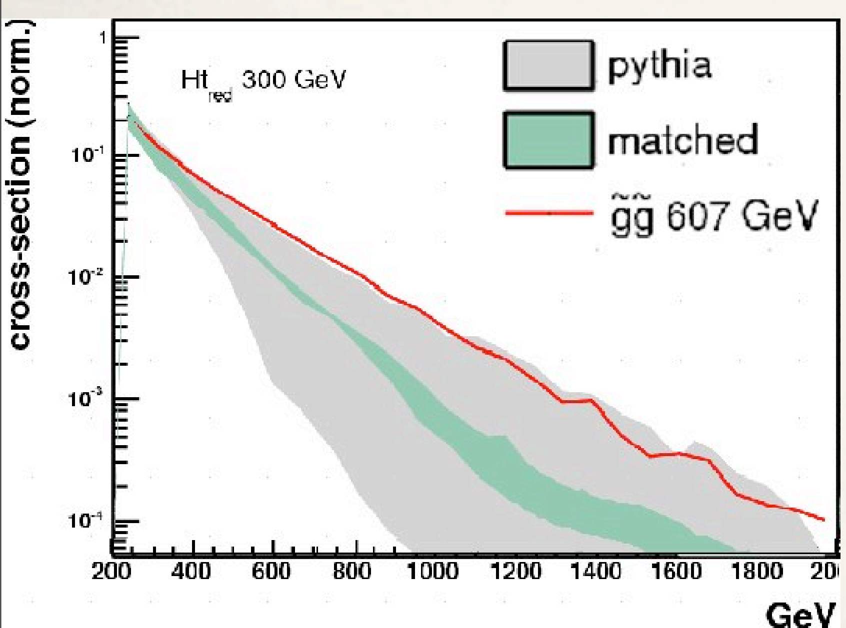
Mass scale dependence of the radiation

1. Overall scale of SUSY can be difficult to measure in presence of missing E_T.
2. The “amount” of radiation depends on the overall scale of the event as expected.

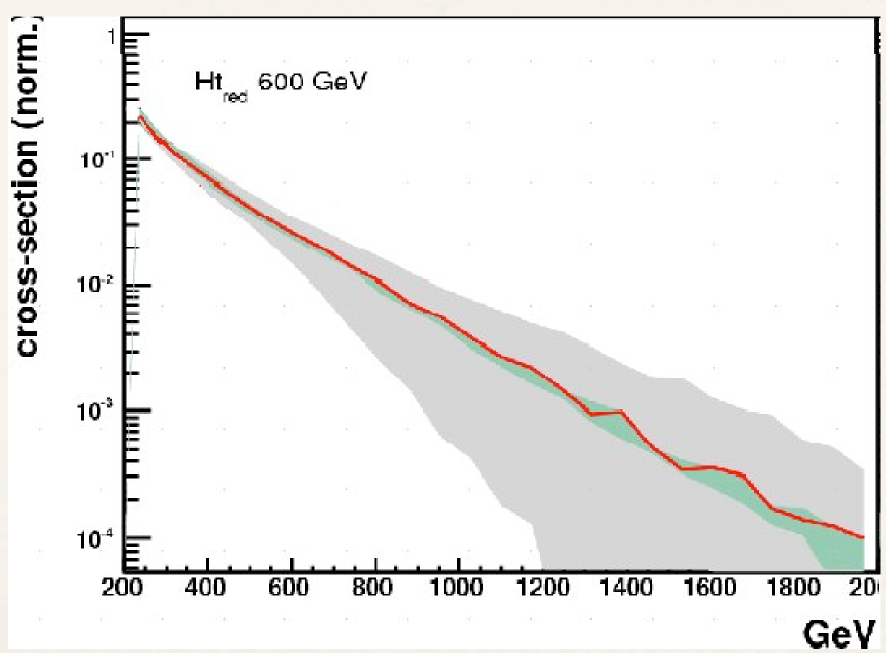
Q: can we use the “amount of radiation” to measure the overall scale?

Example: (Stable) gluino pair production at the LHC. The hard jets H_T.

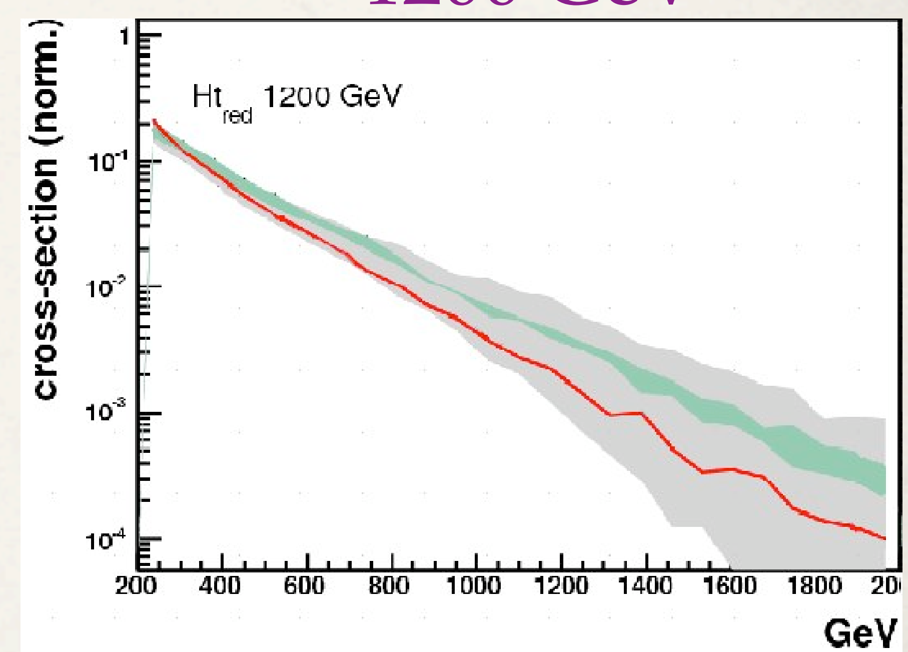
300 GeV



600 GeV

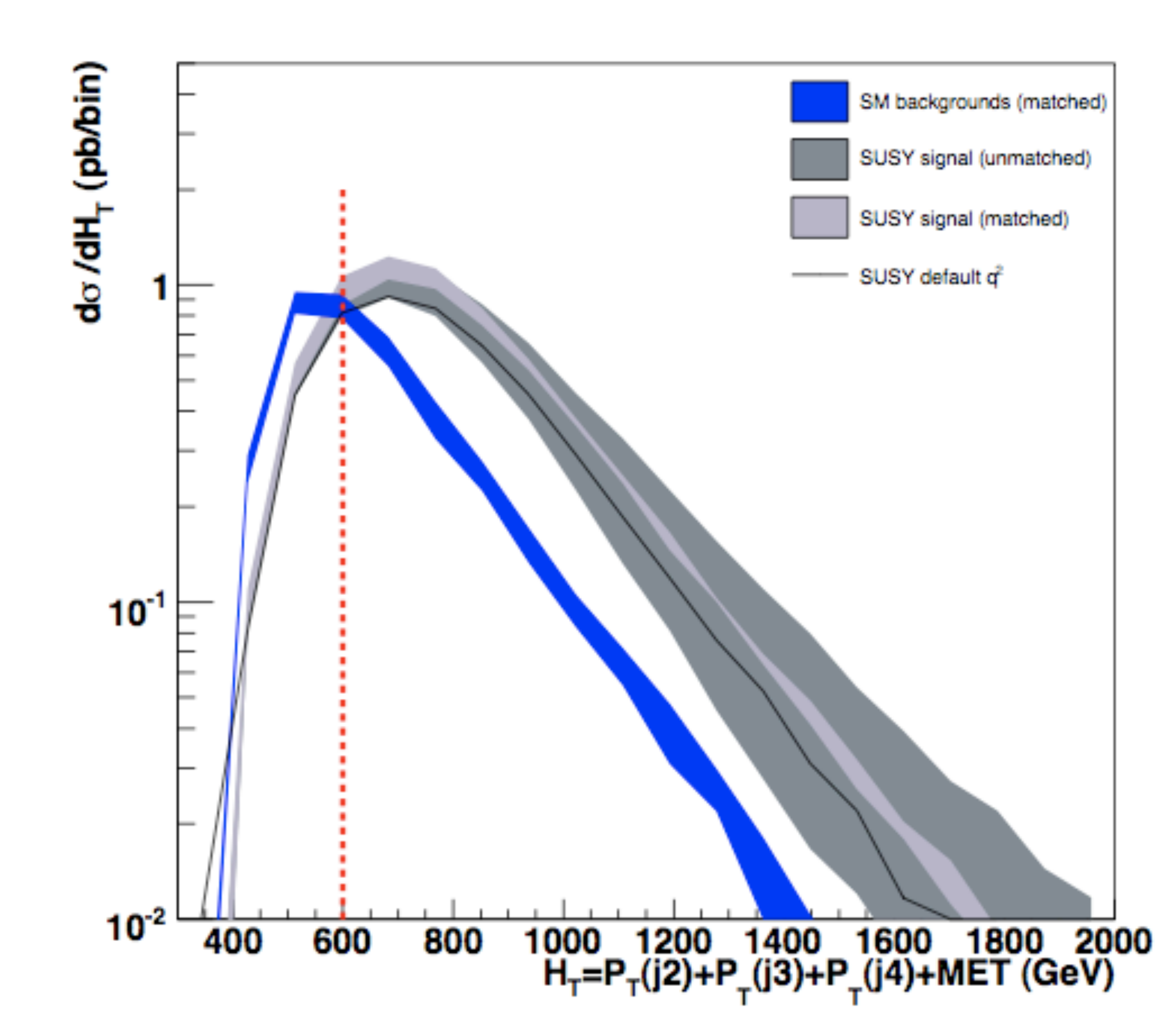


1200 GeV



Matched predictions are in principle predictive enough to allow such a study.

MSSM @ LHC : present



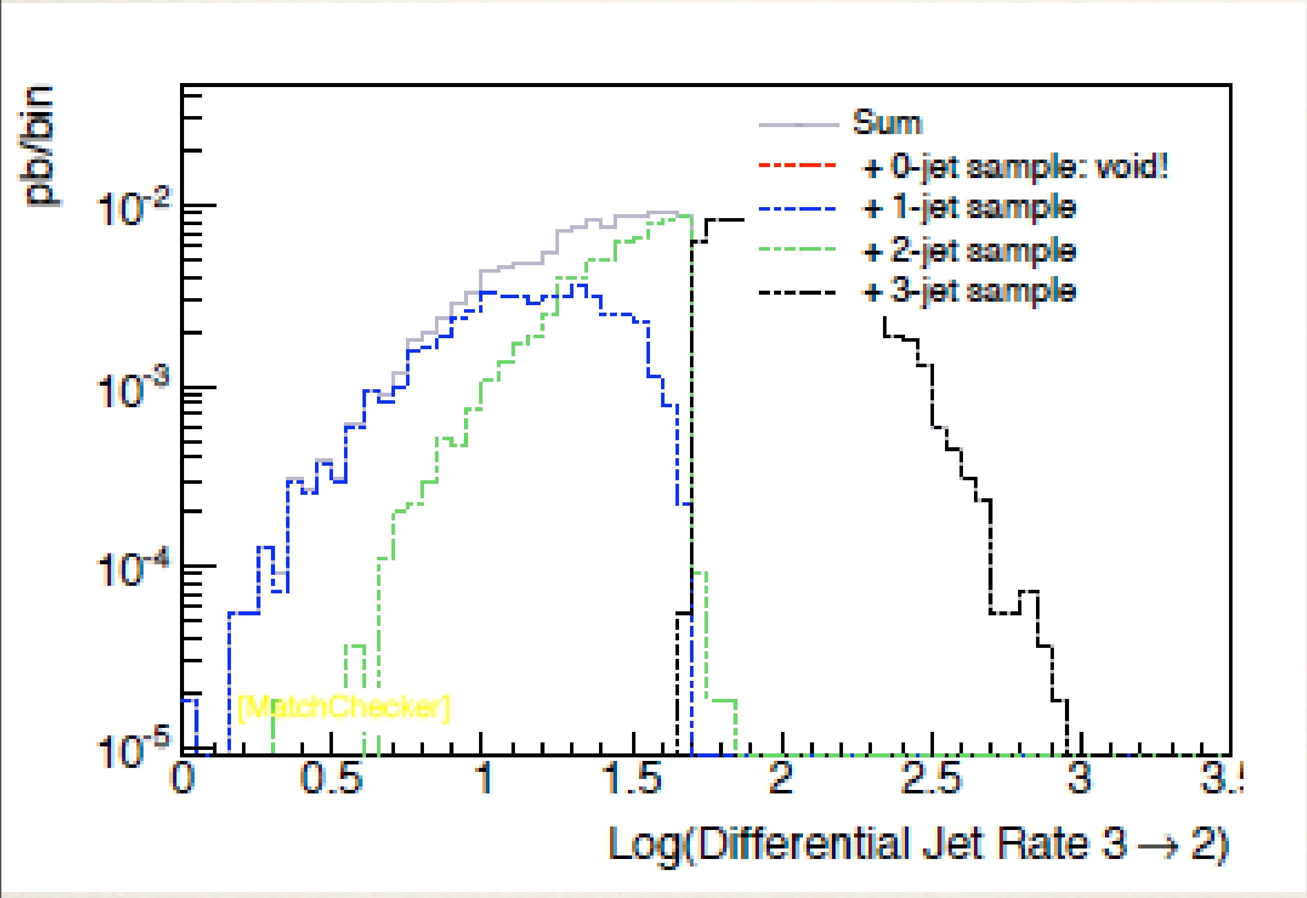
Both signal and background matched!

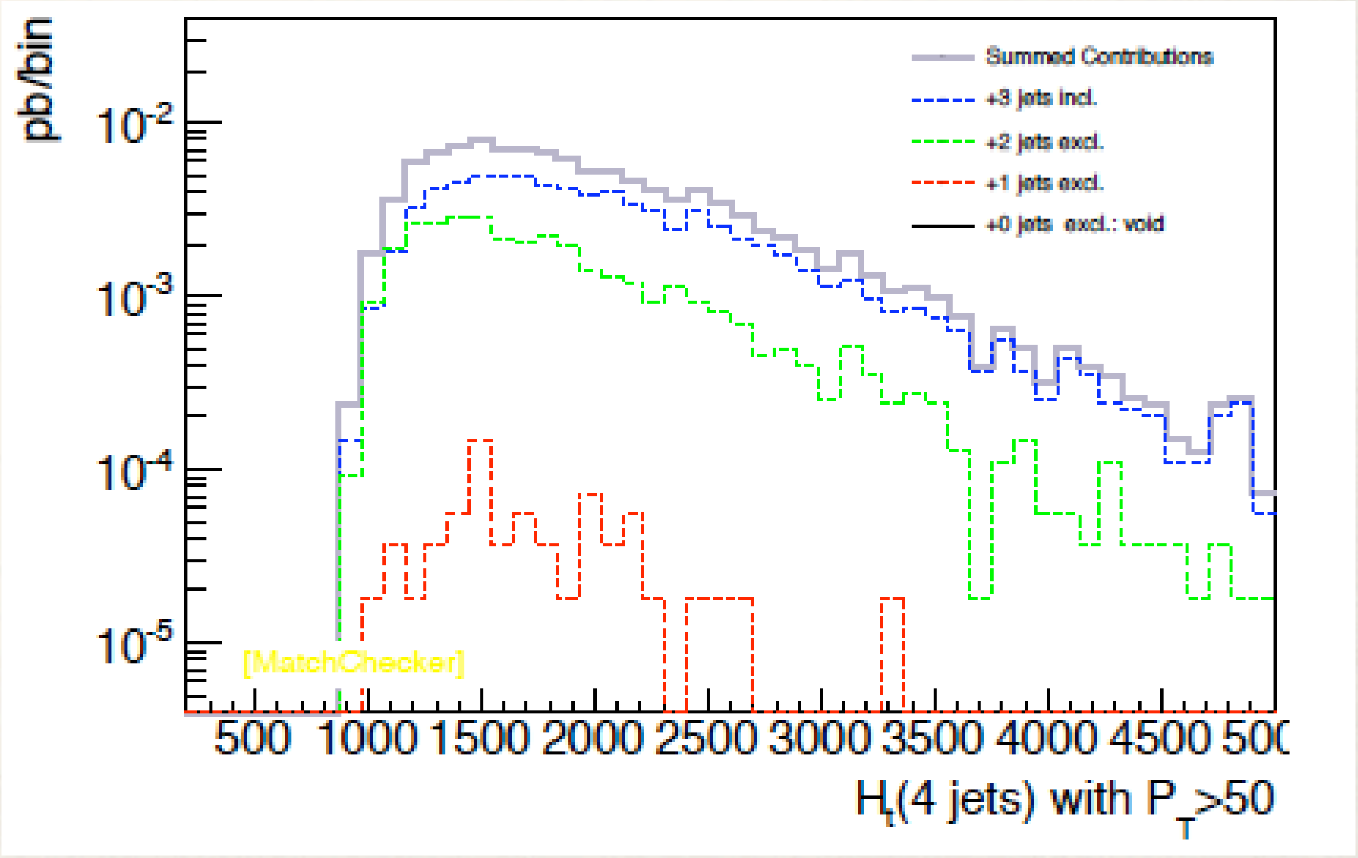
Sizable reduction of the uncertainties. Overall picture unchanged for SPS1a.

Gravitons

[K. Hagiwara, J. Kanzaki, Q. Li and K. Mawatari]
[P. de Aquino, K. Hagiwara, Q. Li, F. M.]

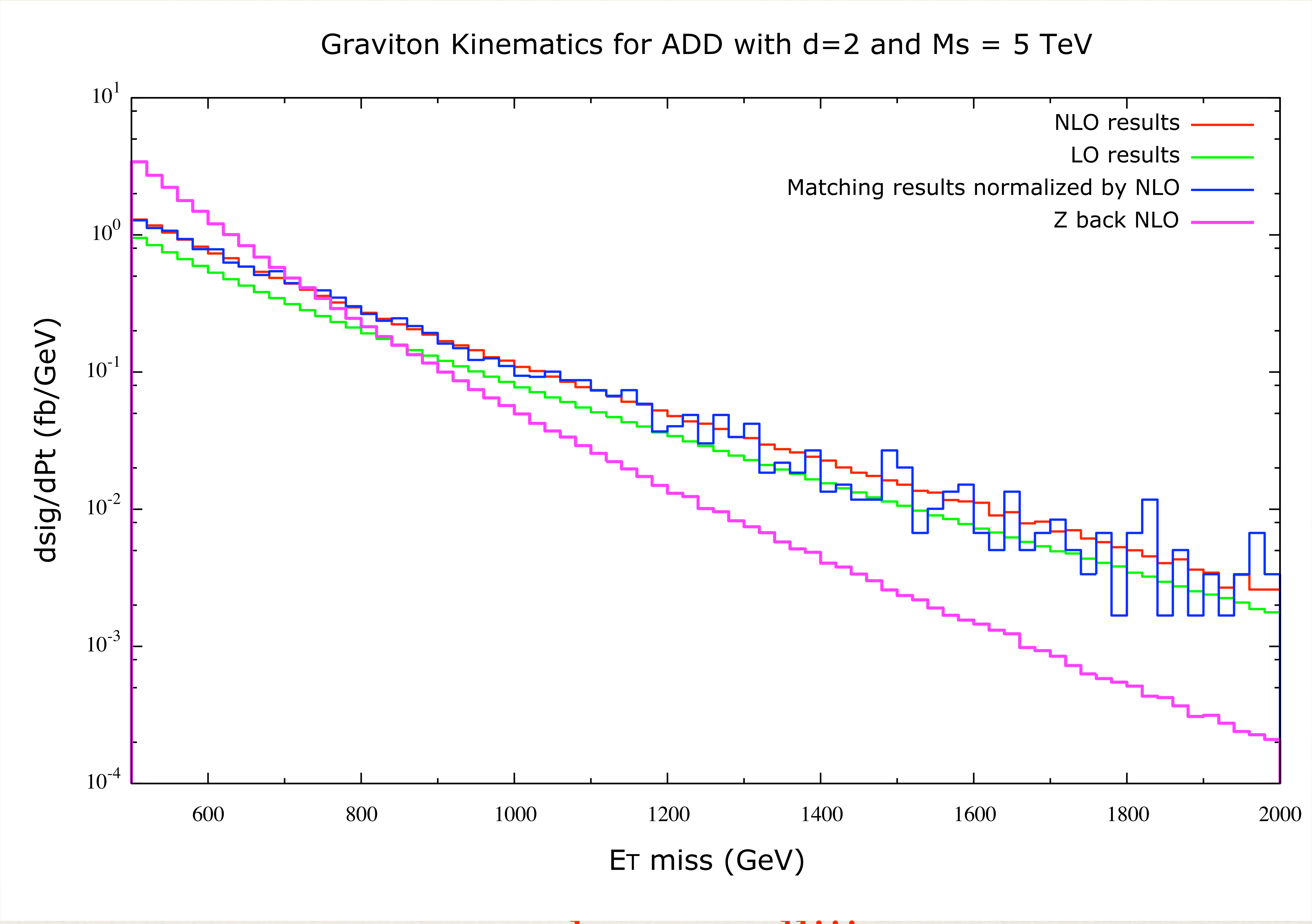
- Fixed mass gravitons (RS and also mG=0)
- ADD gravitons also available : challenging due peculiar "propagator" : this is automatically handled in MG now.





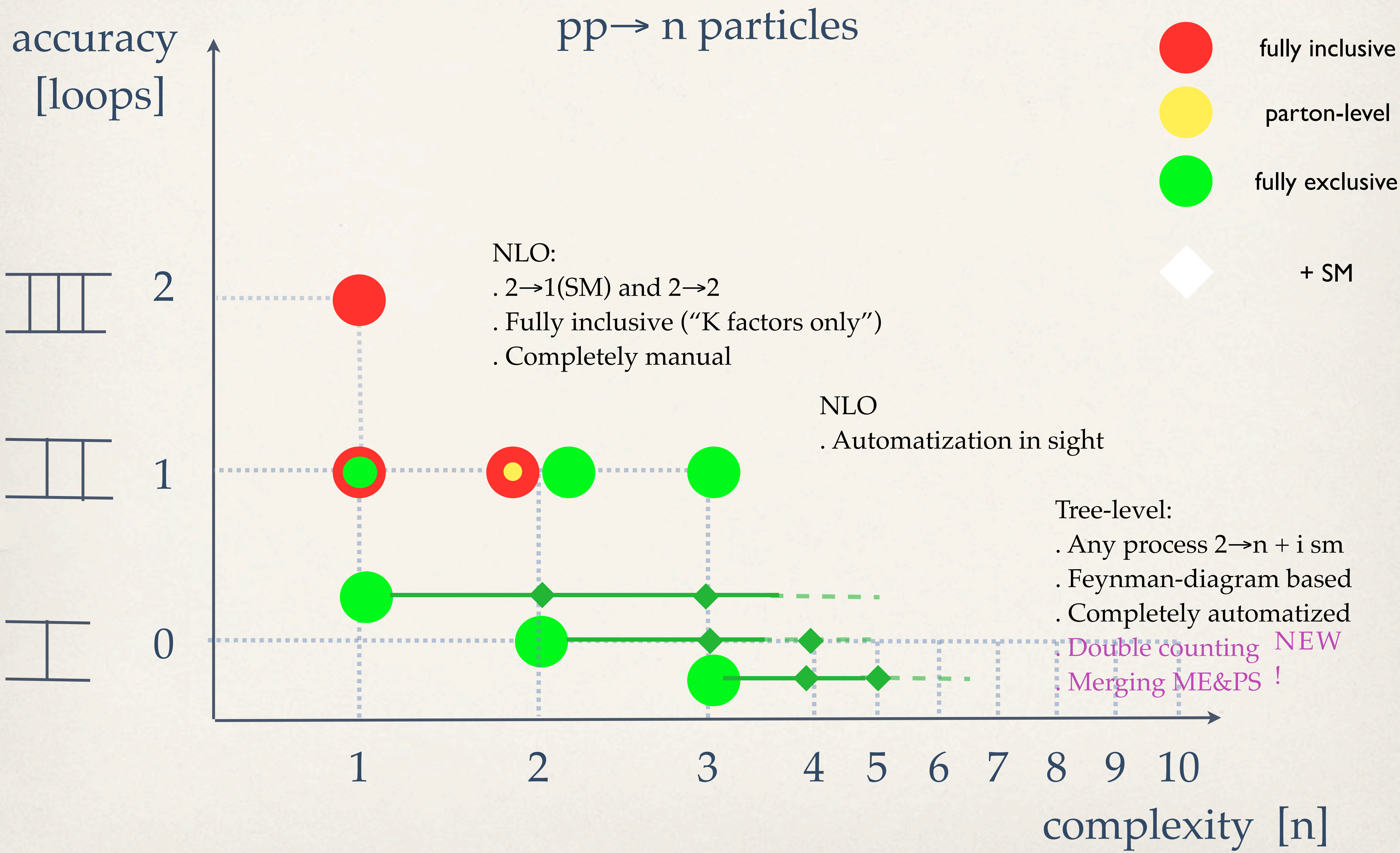
Works out of the box..

Gravitons

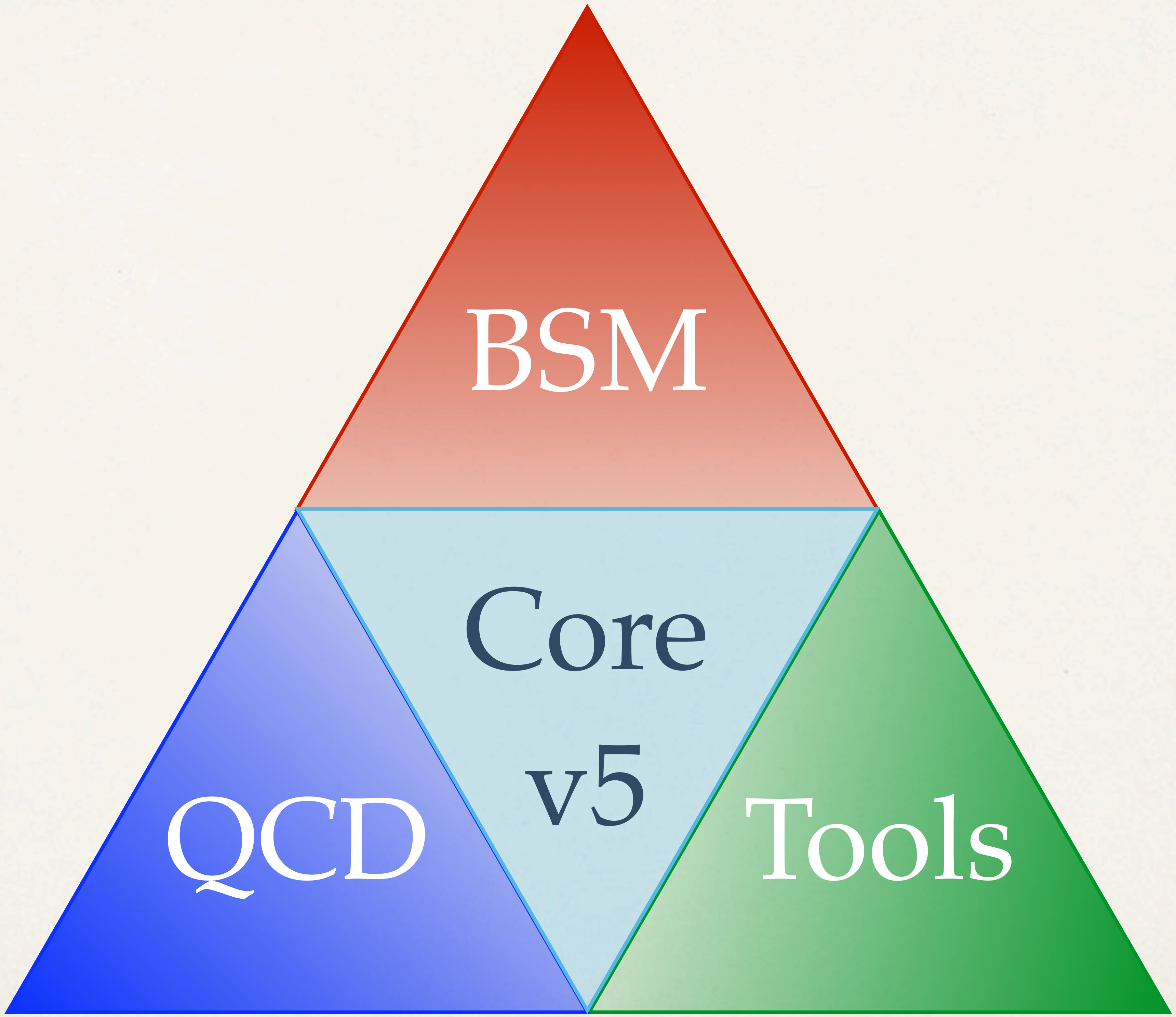


and very well!!!

BSM : status and outlook



Short term plan



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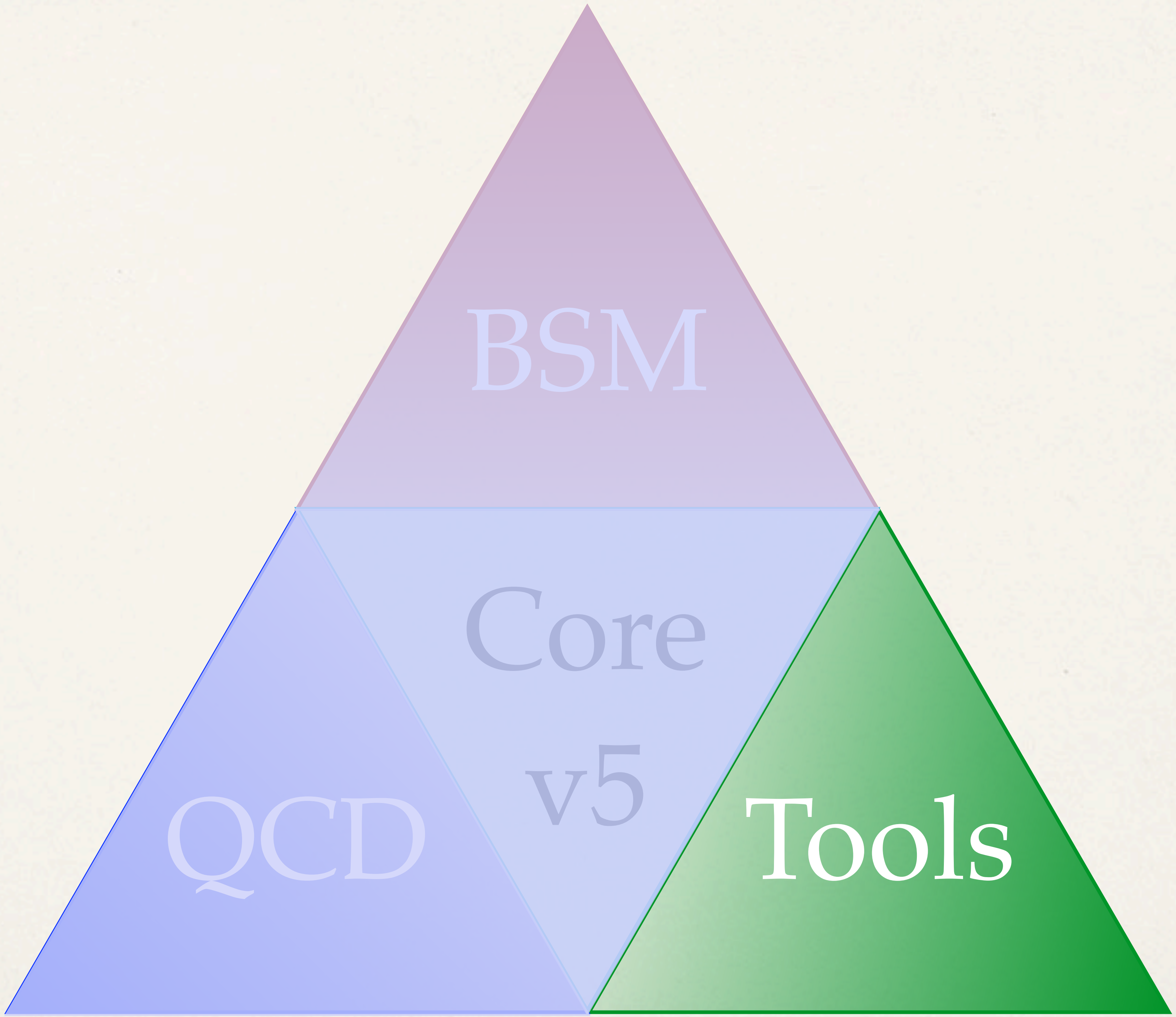


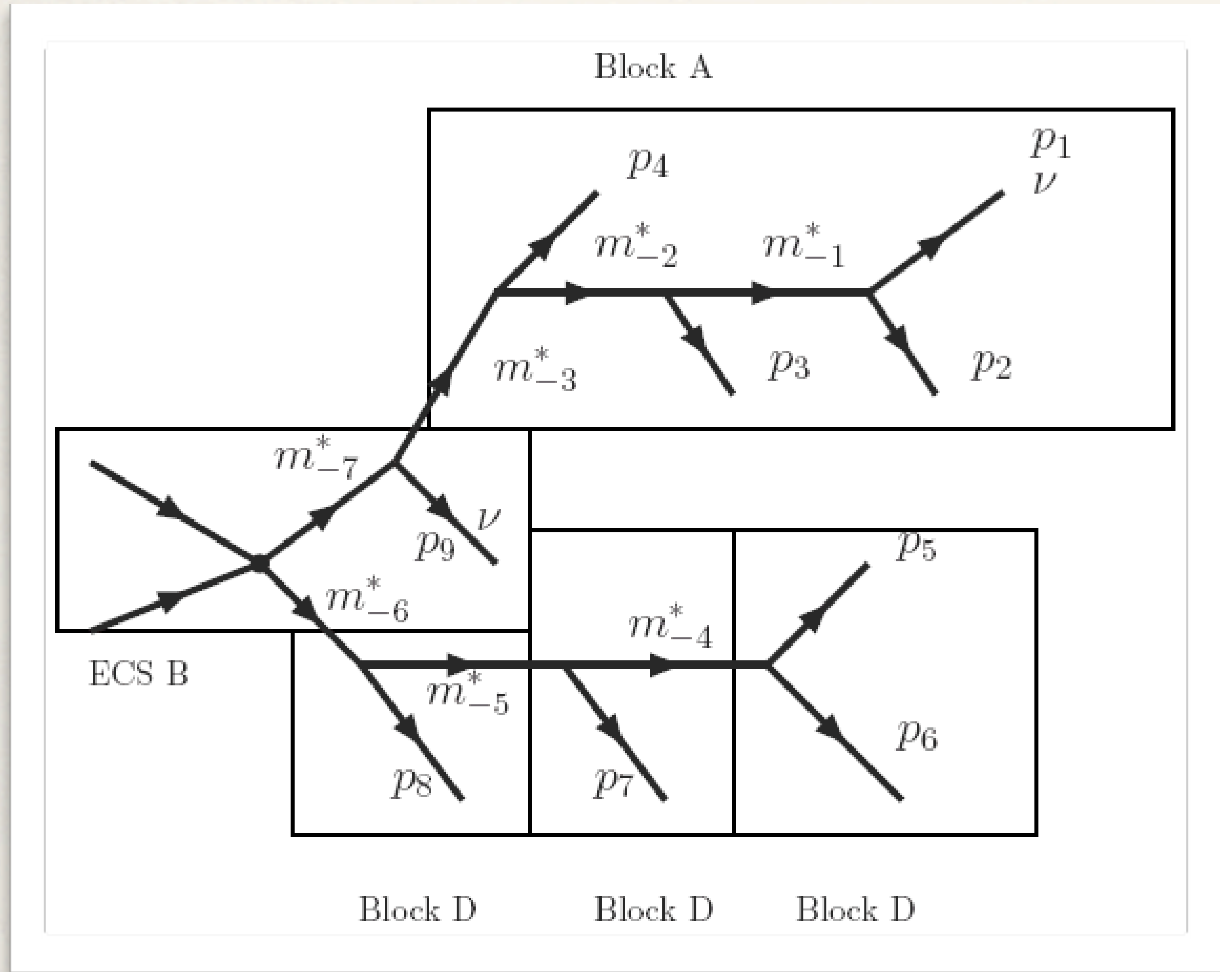
Tools

- MadWeight: Matrix Element methods
- MadOnia: Onium production
- GPU : MadGraph on a graphic card
- GridPacks: Mass production
- ...

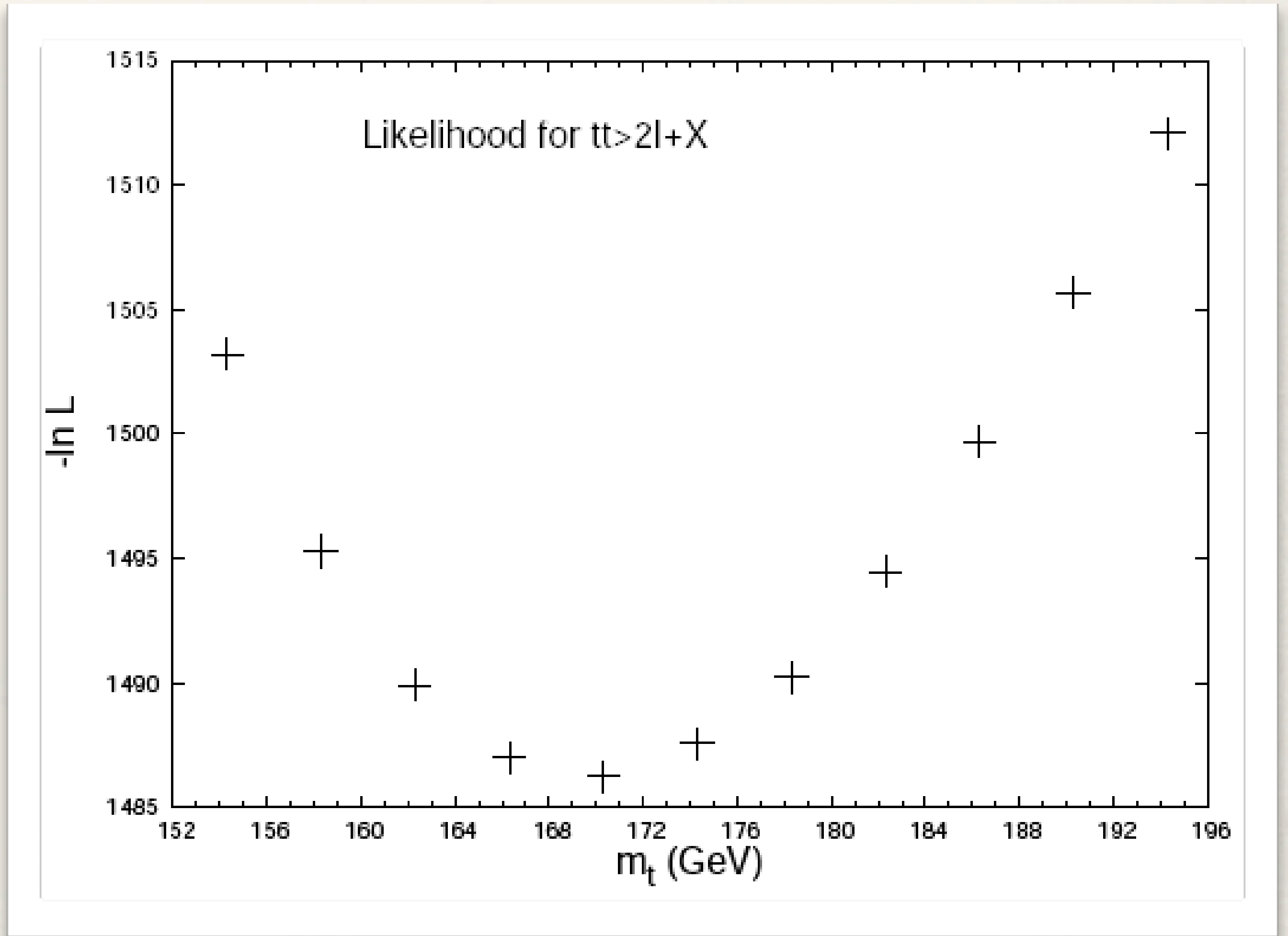
MadWeight

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

- Tool to find matrix element weight of exp. events for (almost) any process in any model:



Phase space integration using automatic change of variables aligned with peaks

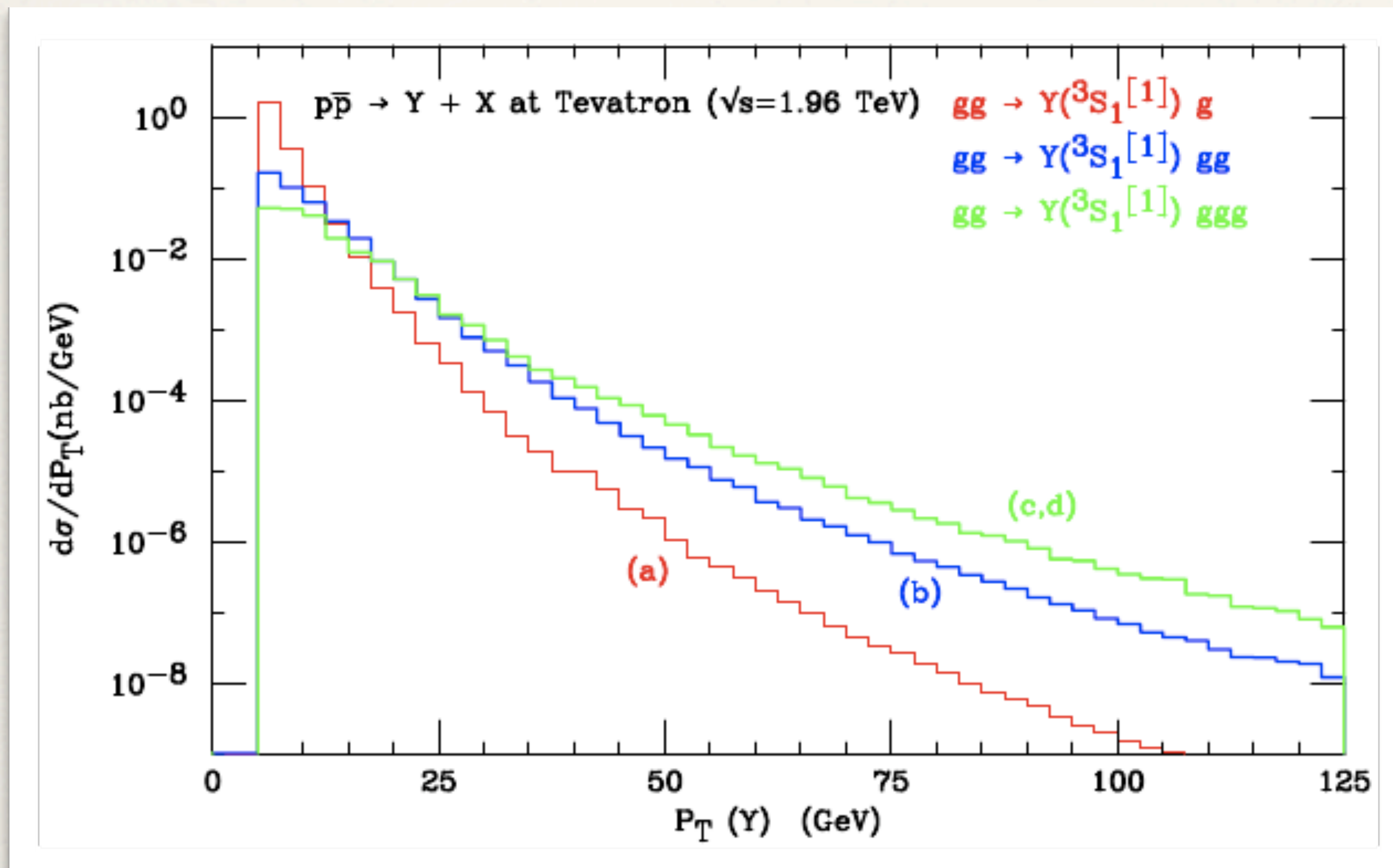


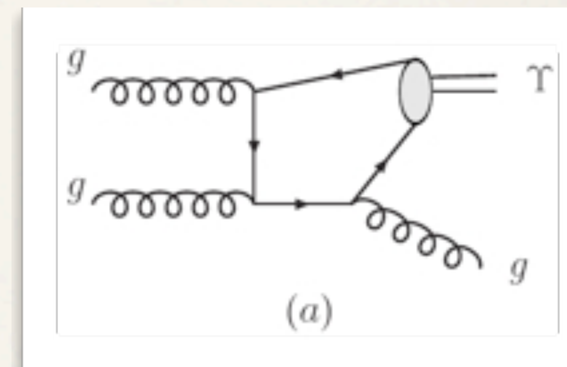
Find likelihood for model parameters (here top mass)

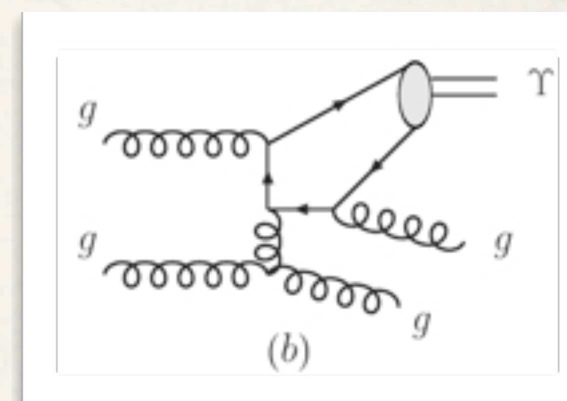
MadOnia

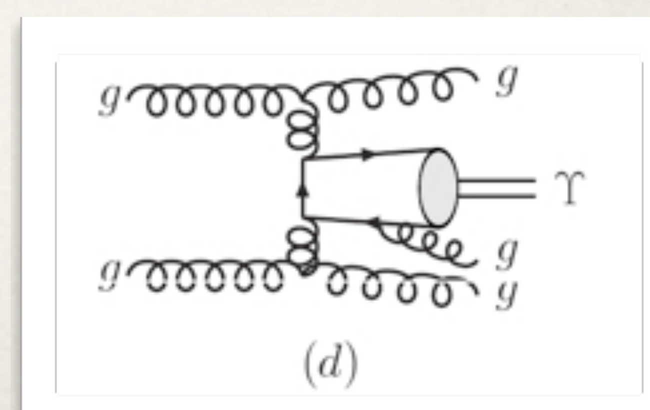
[P. Artoisenet, F. M., T. Stelzer]

- Production of bound states of heavy-quark bound states events at tree level within non relativistic QCD.
- Extendable to squark/gluinos/sextets...
- Example of application: Υ+ jets in hadron collisions









MadGraph on a graphic card

[K. Hagiwara, J. Kanzaki, N. Okamura, D. Rainwater, T. Stelzer]

- Use a graphics processing unit (GPU) for fast calculations of helicity amplitudes
- New HELAS in CUDA library, HEGET, and convertor for MG
- First studies for QED and QCD processes
- Impressive speed improvements (x 20-150)

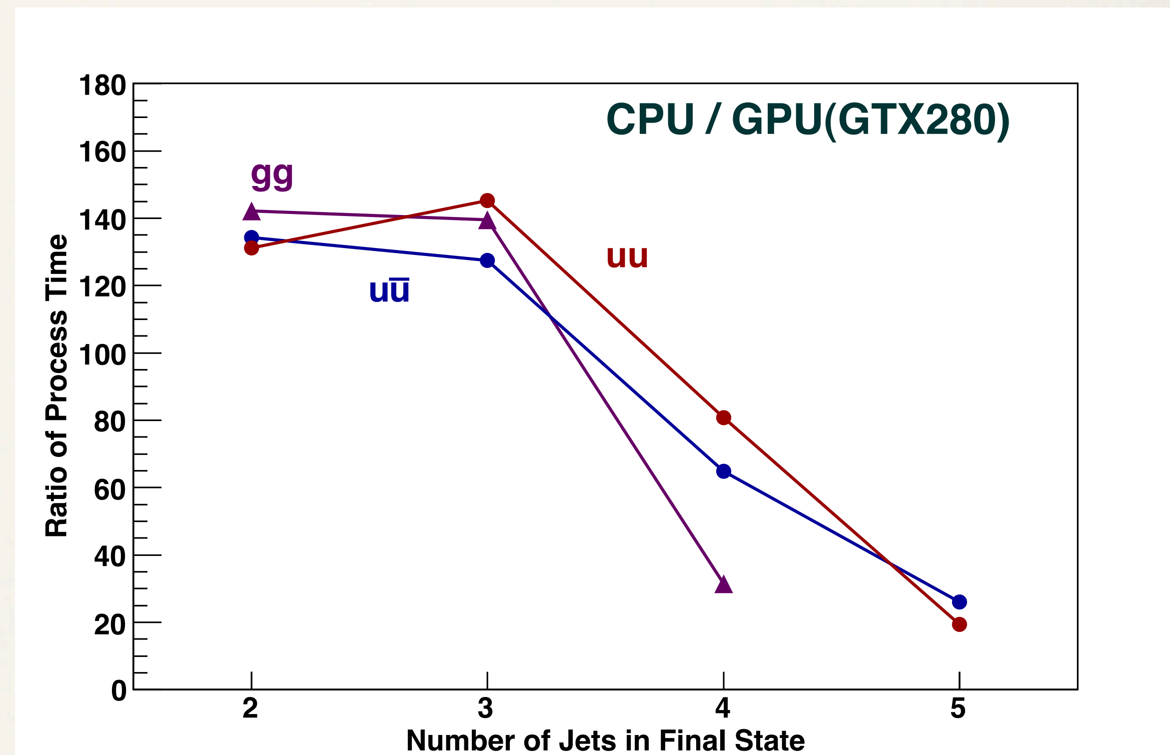


Fig. 2. Ratio of processing time. Time on CPU divided by time on GPU.

agrams and 720 color basis vectors. In order to compile the program for the computation of this process, we use the technique developed in the previous study [1]. By dividing the program into about 140 pieces we were able

MadGraph on the Grid

- "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,...).
- Used for massive production of SM backgrounds by the CMS collaboration

Summary

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- MG/ME v4 is now a mature, well established and stable code coming with several features for BSM and QCD physics, and numerous tools.

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- MG/ME v4 is now a mature, well established and stable code coming with several features for BSM and QCD physics, and numerous tools.
- MG/ME v5 is behind the corner, with several key improvements in all directions. Stable release of core MadGraph v5 by summer.

Feel free to join our (food) club...

Timeline

V4 V5

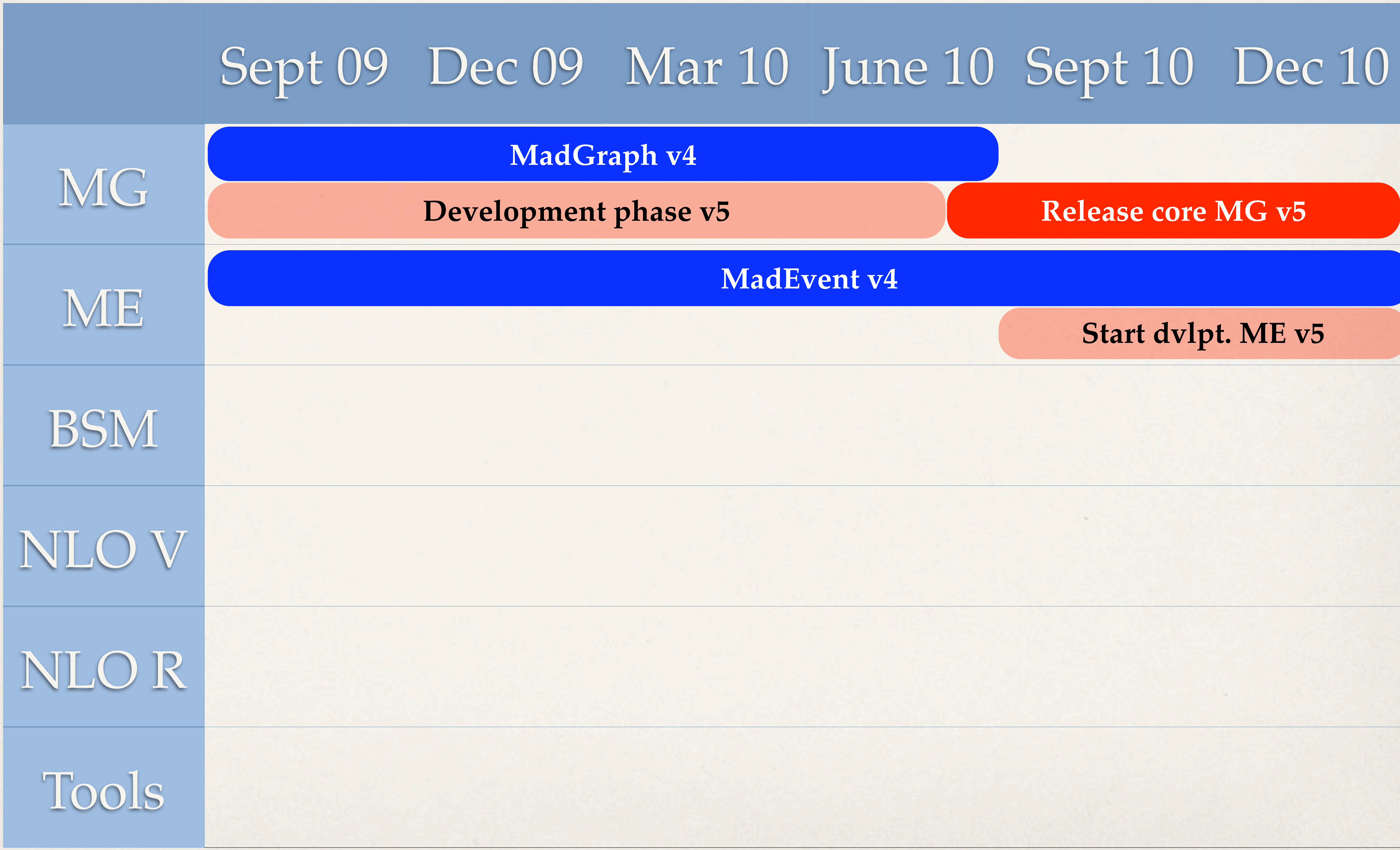
	Sept 09	Dec 09	Mar 10	June 10	Sept 10	Dec 10
MG						
ME						
BSM						
NLO V						
NLO R						
Tools						

Timeline

V4 V5

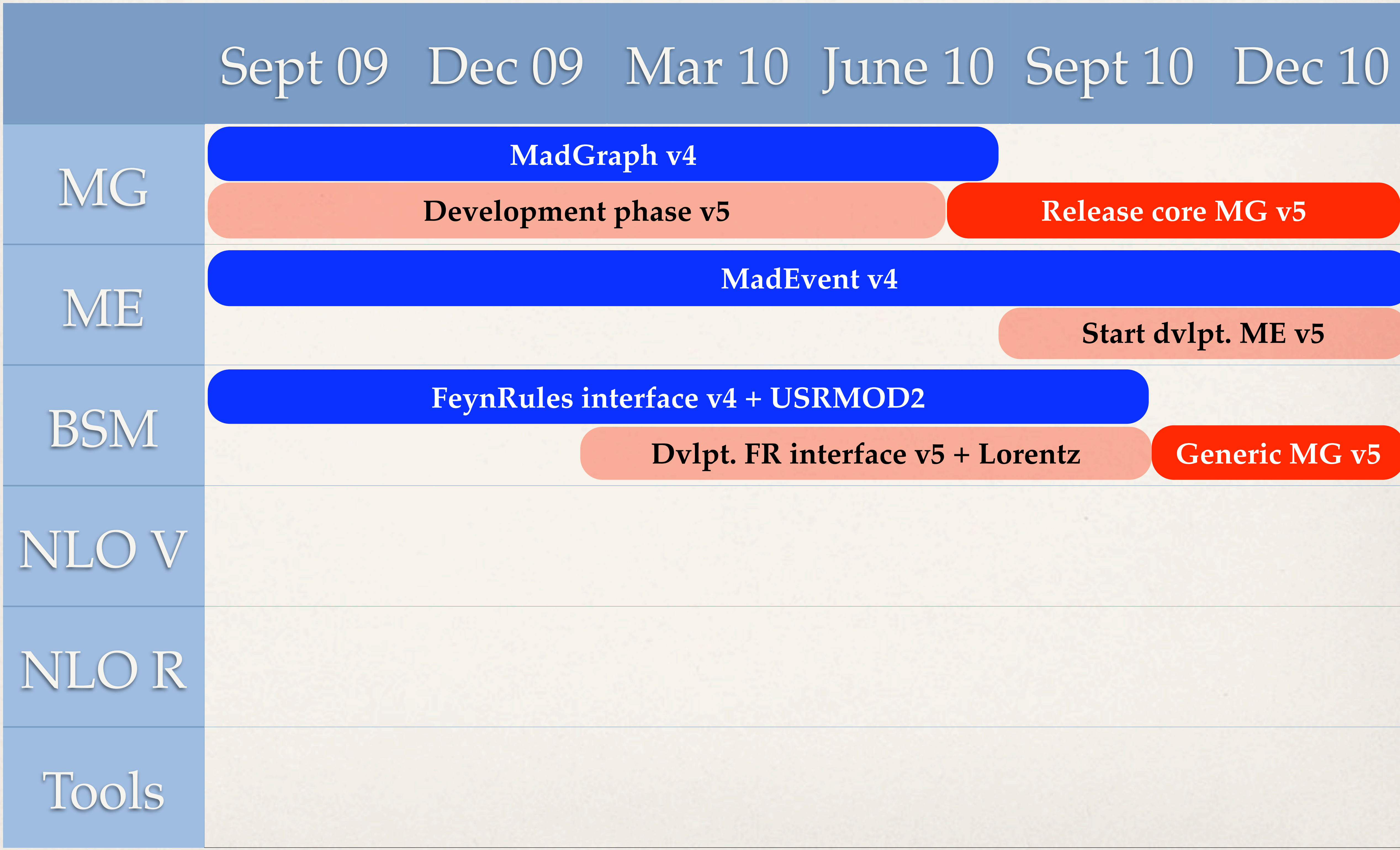
Timeline

V4 V5



Timeline

V4 V5



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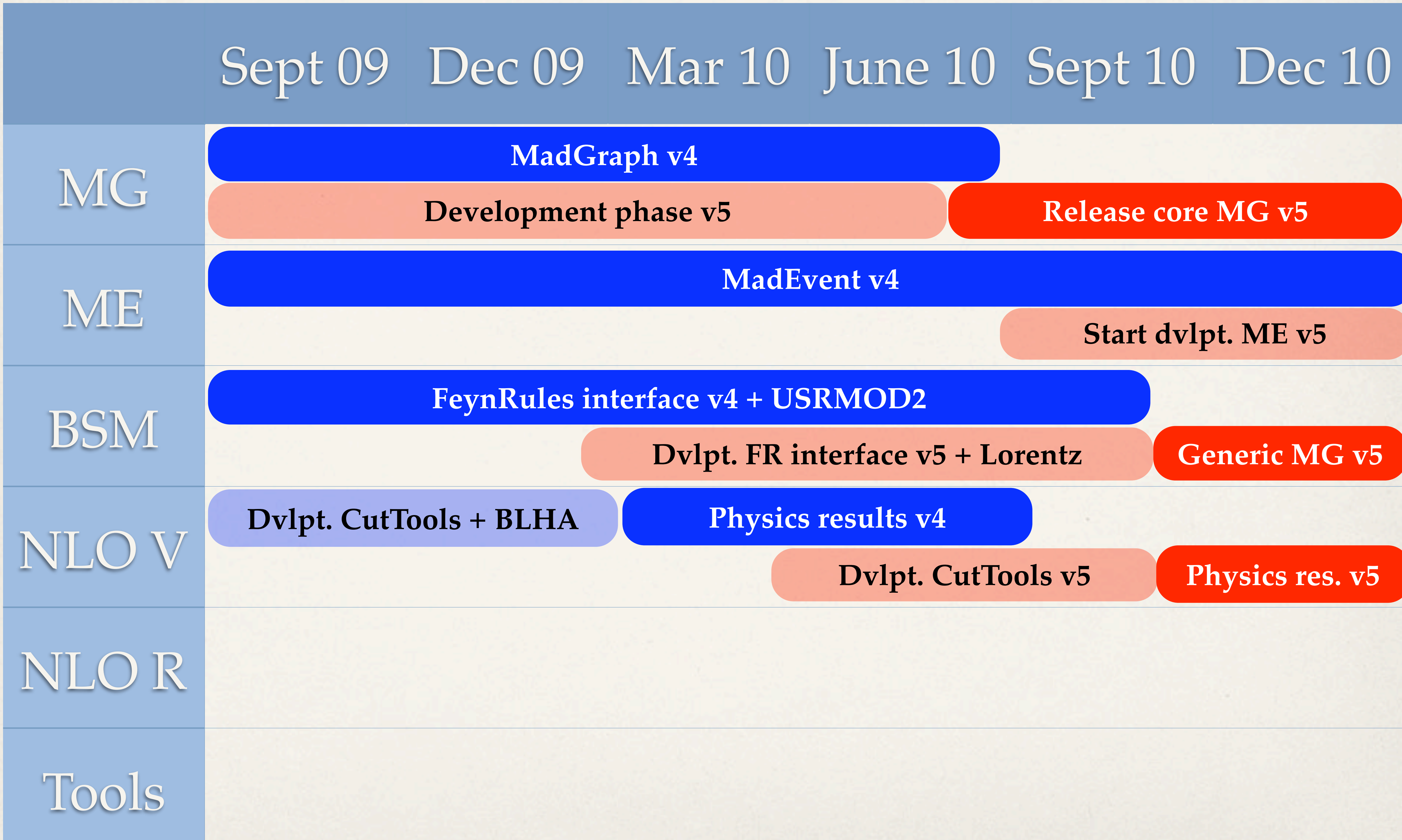
V4 V5



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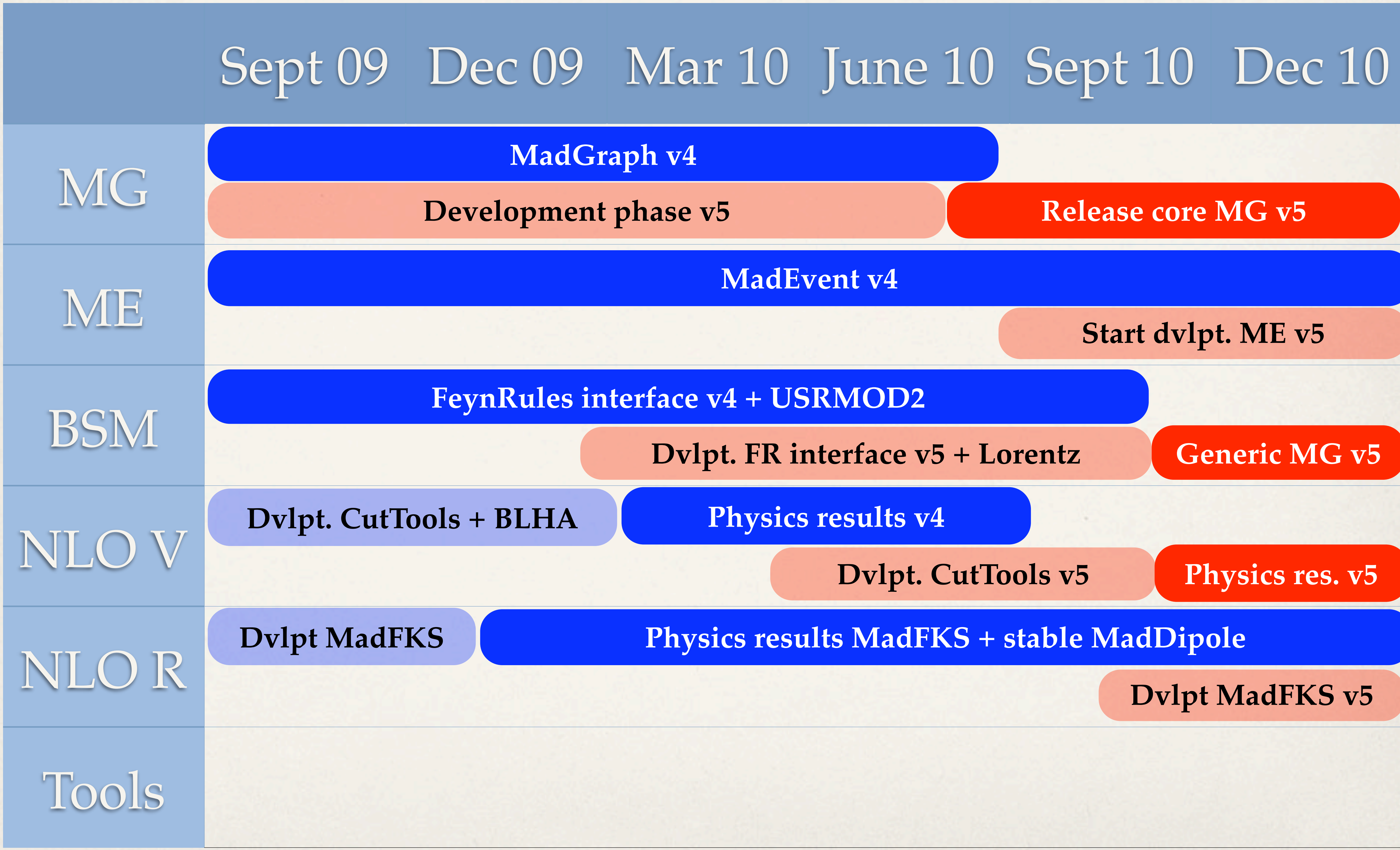

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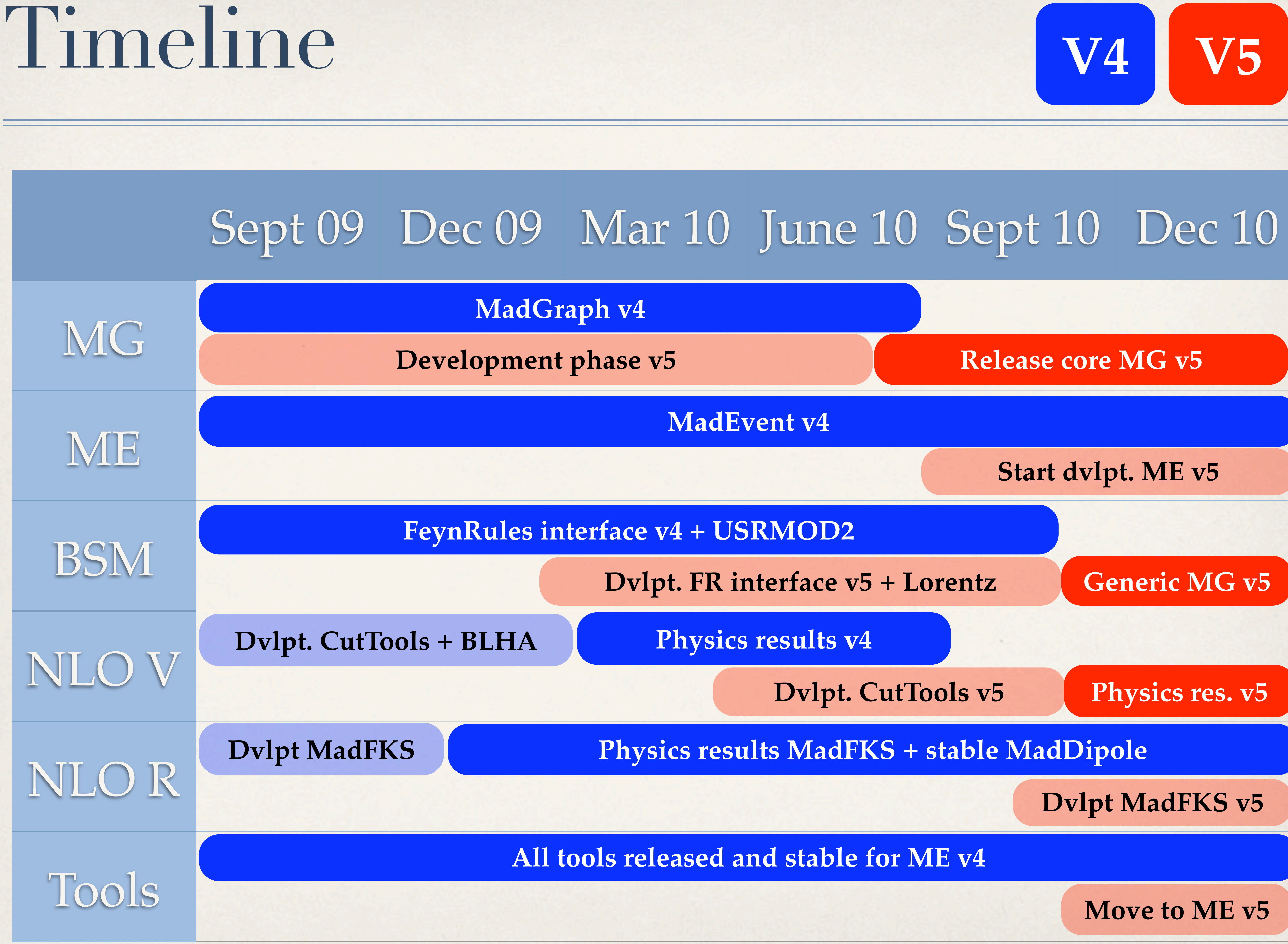
V4
V5
Sept 09
Dec 09
Mar 10
June 10
Sept 10
Dec 10
MG
MadGraph v4
Development phase v5
Release core MG v5
ME
MadEvent v4
Start dvlpt. ME v5
BSM
FeynRules interface v4 + USRMOD2
Dvlpt. FR interface v5 + Lorentz
Generic MG v5
NLO V
Dvlpt. CutTools + BLHA
Physics results v4
Dvlpt. CutTools v5
Physics res. v5
NLO R
Dvlpt MadFKS
Physics results MadFKS + stable MadDipole
Dvlpt MadFKS v5
Tools
All tools released and stable for ME v4
Move to ME v5

Timeline

V4 V5