A Les Houches Interface for BSM Generators

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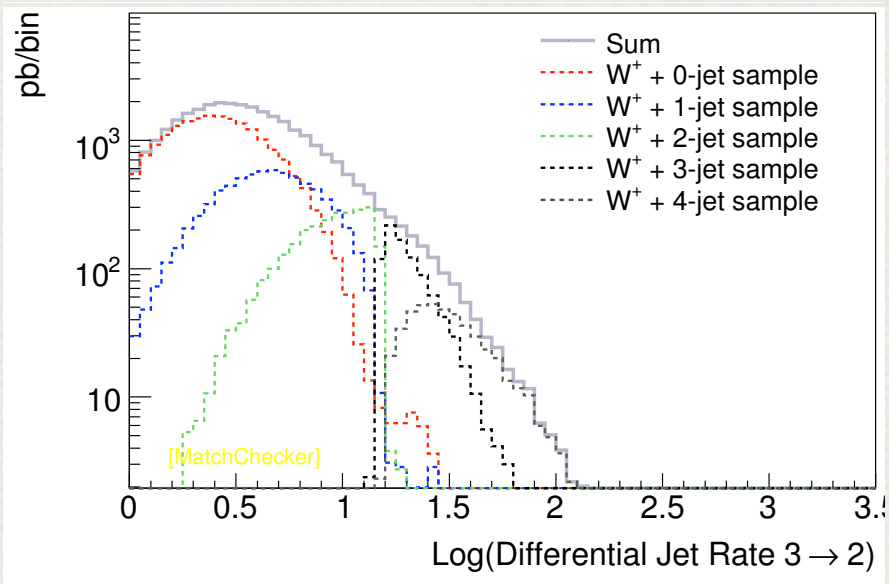
Yet another interface ?

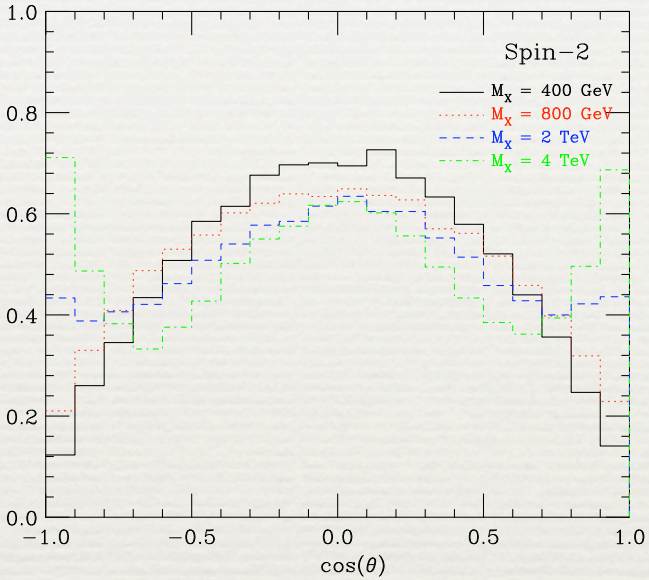
Outline

- The need for interfacing BSM generators
- Definition of the LH interface
- Implementations in MG/ME *4* & Pythia 6
- A practical example
- Conclusion

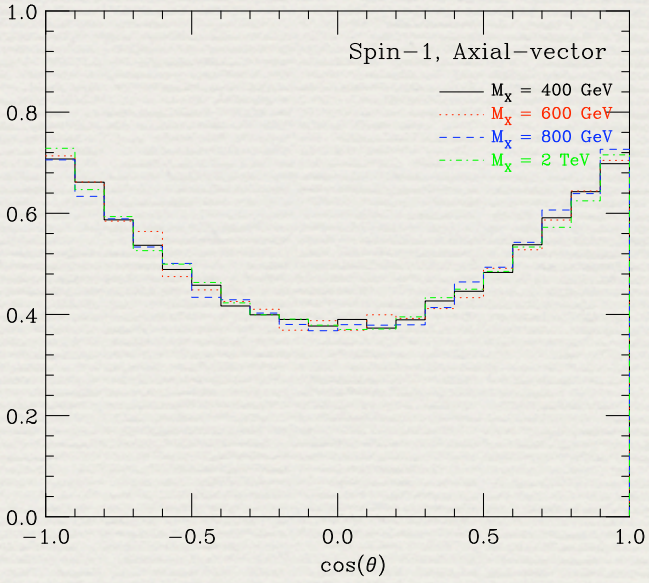
BSM simulation

- Different tools for different needs
  - Matrix Elements generators : Hard interactions, Spin correlations, ...
  - Parton Shower generators: Soft physics, Fast, ...
- Matching methods allows for consistent merging of events simulated at different levels





(b)



Decay of new particles

1. **Exact ME**. Very precise, very slow & limited to <6 particles final states
2. ME + **no interference approx**. Precise, slow & limited to <~8 particles final states
3. Decay after event production using **dedicated tools**. Rather precise, moderately slow & need to deploy an extra tool compatible with the BSM model.
4. Decay with **parton shower**. Fast, flat phase space (as a default), new model need to be implemented in the PS software → Not necessary, could be improved !

Requirements

- Pass effortlessly all the required model parameters from ME to PS generators
- "Inspired" & compatible with previous LH standards:
  - **SLHA2** for SUSY models parameters files
  - **LHEF2** XML format for event files

3 points proposal

1. Introduce new SLHA like blocks `QNUMBERS` for each BSM particle containing PDG code, spin, electric charge, colour representation and particle/antiparticle distinction
2. Use the existing `MASS` and `DECAY` blocks for new particles
3. Include the above information bewteen `<slha>` tags in the header of the LHEF2 file

Implementation in MG4

- MG/ME4 already uses SLHA like files (`param_card.dat`) for mass & decay widths
- From version 4.1.43: the particle content of BSM models generated with the USRMOD or with FeynRules (see Claude's talk tomorrow) is transcribed as `QNUMBERS` blocks in the `param_card.dat`
- From version 4.1.47: the `param_card.dat` is stored between the special tags `<slha>` in the LHE file header

Implementation in Pythia 6

- Starting from version 6.414, Pythia is able to:
  - read the `QNUMBERS`, `MASS` & `DECAY` information from the LHE file header for any model
  - decay accordingly BSM particles in the final state. 2- and 3- body decays with flat phase space and simple colour flows are available

Example

- Toy model containing
  - a “michelon”, symbol `mi`, a new heavy top quark decaying with BR=0.5 into a top quark and a “sabrinon”
  - a “sabrinon”, symbol `sa`, a new heavy scalar decaying into two gamma
- Implemented using the USRMOD (in the internal MG file `particles.dat`)

```
#MODEL EXTENSION
mi       mi~        F        S      MIMASS MIWIDTH  T    mi    3000001
sa       sa         S        D      SAMASS SAWIDTH  S    sa    3000002
# END
```

Example

- Output of the USRMOD scripts

```
BLOCK QNUMBERS 3000001 # mi
         1  0 # 3 times electric charge
         2  2 # number of spin states (2S+1)
         3  3 # colour rep (1: singlet, 3: triplet, 8: octet)
         4  1 # Particle/Antiparticle distinction (0=own anti)
BLOCK QNUMBERS 3000002 # sa
         1  0 # 3 times electric charge
         2  1 # number of spin states (2S+1)
         3  1 # colour rep (1: singlet, 3: triplet, 8: octet)
         4  0 # Particle/Antiparticle distinction (0=own anti)

Block MASS       #  Mass spectrum (kinematic masses)
   3000001     1.00000000e+02   # MIMASS
   3000002     1.00000000e+02   # SAMASS

DECAY   3000001     1.00000000e+00   # MIWIDTH
DECAY   3000002     1.00000000e+00   # SAWIDTH
```

Example

- After manual modifications

```
BLOCK QNUMBERS 3000001 # mi
         1  2 # 3 times electric charge
         2  2 # number of spin states (2S+1)
         3  3 # colour rep (1: singlet, 3: triplet, 8: octet)
         4  1 # Particle/Antiparticle distinction (0=own anti)
BLOCK QNUMBERS 3000002 # sa
         1  0 # 3 times electric charge
         2  1 # number of spin states (2S+1)
         3  1 # colour rep (1: singlet, 3: triplet, 8: octet)
         4  0 # Particle/Antiparticle distinction (0=own anti)

Block MASS       #  Mass spectrum (kinematic masses)
   3000001     5.00000000e+02   # MIMASS
   3000002     2.00000000e+02   # SAMASS

DECAY   3000001     1.00000000e+01   # MIWIDTH
   0.50000000e+00     2     3000002    6
DECAY   3000002     1.00000000e+00   # SAWIDTH
   1.00000000e+00     2          22   22
```

Example

- Passing the LHE event file from MG

```
<event>
 4 100  0.8624900E-02  0.9118800E+02  0.7818608E-02  0.1300000E+00
       21   -1    0    0  502  501  0.00000000000E+00  0.00000000000E+00  0.40122922055E+03
0.40122922055E+03  0.00000000000E+00 0. -1.
       21   -1    0    0  501  503  0.00000000000E+00  0.00000000000E+00 -0.77132817073E+03
0.77132817073E+03  0.00000000000E+00 0.  1.
  3000001    1    1    2  502  0 -0.16615260591E+03  0.17005836180E+03 -0.12778172790E+03
0.56820304896E+03  0.50000000000E+03 0. -1.
 -3000001    1    1    2  0  503  0.16615260591E+03 -0.17005836180E+03 -0.24231722227E+03
0.60435434232E+03  0.50000000000E+03 0. -1.
</event>
```

to Pythia 6 gives

```
*  PYSLHA:  Last Change 05 Nov 2007 - P.Z. Skands
* (PYSLHA:) Reading in QNUMBERS for KF =  3000001
* (PYSLHA:) Reading in QNUMBERS for KF =  3000002
* (PYSLHA:) Reading in MASS entry for KF =  3000001, pole mass =     500.000
* (PYSLHA:) Reading in MASS entry for KF =  3000002, pole mass =     200.000
* (PYSLHA:) Reading in SLHA decay table for KF = 3000001: mi
* (PYSLHA:) Reading in SLHA stable particle KF = 3000002: sa
```

and the decay chain is simulated accordingly in the STDHEP output

Perspectives

- CalcHEP and CompHEP will include the same information in their LHEF output
- HERWIG++ and PYTHIA8 will read this information in their LHEF interface
- Evolution of the SLHA format towards a more generic, XML compliant format is envisaged
- First step towards a uniform format for BSM model parameters exchange ?

Conclusion

- A simple LH interface to easily pass particle information between different generators has been defined
- It can be used to decay any BSM particles at the parton shower level
- It has already been implemented in *MG/ME4* and Pythia6, and will be available soon in other generators

Thanks for your attention !