Les Houches Accords

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Introduction: Monte Carlo event generators

- Matrix element event generators (MEG): CompHEP, CalcHEP, MadGraph5, Pythia, Sherpa, Herwig, VBFNLO, ...
- Hadronization event generators (SHG): Pythia, Sherpa, Herwig, ...
- Detector simulation event generators: Geant4, Delphes, PGS, ...

Generators mostly used for analysis: MadGraph5 $\rightarrow$ Pythia $\rightarrow$ Geant4, MadGraph5 $\rightarrow$ Herwig $\rightarrow$ Geant4, Sherpa $\rightarrow$ Geant4.

Motivation

The beginning of 2000th:

• Modularization of High Energy Particle Physics event generation is becoming increasingly useful as the complexity of Monte Carlo programs grows.

• The communication of simulation parameters between stages can be complicated and program-specific.

Therefore, it is necessary to standardize output files which should be transferred between different MC generators. It can both reduce the number of files that need to be passed around and minimize the possibility for error by keeping all relevant model information together with the actual events.

• HEPEVT — standard interface between generators and analysis/detector simulation.

• Interface between different MC generators (MEG and SHG)?

Les Houches Accords (LHA)

Workshop "Physics at TeV Colliders", Les Houches, France.

Several authors of popular Monte Carlo and matrix element programs attending the Physics at TeV Colliders Workshop in Les Houches, 2001 have agreed on a generic format for the transfer of parton level event configurations from matrix element event generators (MEG) to showering and hadronization event generators (SHG).

Experience of an interface of WbbGen with Herwig and an interface of CompHEP with Pythia is exploited here.

In the course of a normal event generation run, communication between MEG and SHG occurs at two stages: (1) At initilization, to establish the basic parameters of the run as a whole. (2) For each new event that is to be transferred from the MEG to the SHG. Each of these two stages here corresponds to its own Fortran common block.

https://arxiv.org/pdf/hep-ph/0109068.pdf.

Les Houches Accords events file (LHEF): run common block

```
      integer      MAXPUP
      parameter ( MAXPUP=100 )
      integer      IDBMUP, PDFGUP, PDFSUP, IDWTUP, NPRUP, LPRUP
      double precision EBMUP, XSECUP, XERRUP, XMAXUP
      common /HEPRUP/ IDBMUP(2), EBMUP(2), PDFGUP(2), PDFSUP(2),
     +                IDWTUP, NPRUP, XSECUP(MAXPUP), XERRUP(MAXPUP),
     +                XMAXUP(MAXPUP), LPRUP(MAXPUP)
```

HEPRUP 'User Process' Run Common Block

The most interesting variables:

- integer IDBMUP(2) : ID of beam particle 1 and 2 according to the Particle Data Group convention;
- double EBMUP(2) : energy in GeV of beam particles 1 and 2;
- integer PDFSUP(2) : the PDF set ID for beam 1 and 2, according to the Cernlib PDFlib specification.

Les Houches Accords events file (LHEF): event common block

```
 integer MAXNUP
 parameter ( MAXNUP=500 )
 integer NUP, IDPRUP, IDUP, ISTUP, MOTHUP, ICOLUP
 double precision XWGTUP, SCALUP, AQEDUP, AQCDUP,
+                 PUP, VTIMUP, SPINUP
 common /HEPEUP/ NUP, IDPRUP, XWGTUP, SCALUP, AQEDUP, AQCDUP,
+                IDUP(MAXNUP), ISTUP(MAXNUP), MOTHUP(2,MAXNUP),
+                ICOLUP(2,MAXNUP), PUP(5,MAXNUP), VTIMUP(MAXNUP),
+                SPINUP(MAXNUP)
```

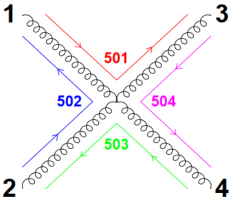
HEPEUP 'User Process' Event Common Block

The most interesting variables:

- integer NUP : number of particle entries in this event;
- double XWGTUP : event weight;
- integer IDUP(I) : particle ID according to Particle Data Group convention;
- integer ISTUP(I) : status code;
- double PUP(5,I) : lab frame momentum (P_x, P_y, P_z, E, M) of particle in GeV.

Example 1

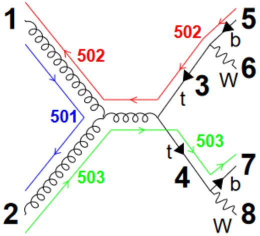
Example: $gg \to gg$



I	ISTUP(I)	IDUP(I)	MOTHUP(1,I)	MOTHUP(2,I)	ICOLUP(1,I)	ICOLUP(2,I)
1	−1	21 (g)	0	0	501	502
2	−1	21 (g)	0	0	502	503
3	+1	21 (g)	1	2	501	504
4	+1	21 (g)	1	2	504	503

Example 2

Example: hadronic $t\bar{t}$ production



I	ISTUP(I)	IDUP(I)	MOTHUP(1,I)	MOTHUP(2,I)	ICOLUP(1,I)	ICOLUP(2,I)
1	–1	21 (g)	0	0	501	502
2	–1	21 (g)	0	0	503	501
3	+2	–6 ($\bar{t}$)	1	2	0	502
4	+2	6 (t)	1	2	503	0
5	+1	–5 ($\bar{b}$)	3	3	0	502
6	+1	–24 (W^-)	3	3	0	0
7	+1	5 (b)	4	4	503	0
8	+1	24 (W^+)	4	4	0	0

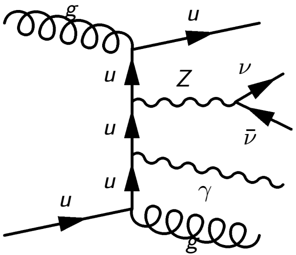
LHA update

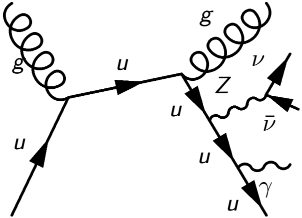
https://arxiv.org/pdf/hep-ph/0609017.pdf.
The original standard was in terms of two Fortran common blocks where information could be stored, while the actual usage has tended to be mainly in terms of files with parton-level events, and increasingly will be used by C++ generators. Since the format of such event files is not specified by the standard, several different formats are in current usage. This leads to a duplication of effort when such files are to be parsed, a problem that may increase when more programs are developed for different LHC physics aspects.

```
<LesHouchesEvents version="1.0">
  <!--
    # optional information in completely free format,
    # except for the reserved endtag (see next line)
  -->
  <header>
    <!-- individually designed XML tags, in fancy XML style -->
  </header>
  <init>
    compulsory initialization information
    # optional initialization information
  </init>
  <event>
    compulsory event information
    # optional event information
  </event>
  (further <event> ... </event> blocks, one for each event)
</LesHouchesEvents>
```

Present-day LHEF


```
<event>
 8      1 +1.0803033e-01 4.00377500e+02 7.81860800e-03 1.04364900e-01
       21 -1    0    0  503  502 +0.0000000000e+00 +0.0000000000e+00 +2.5542627084e+02 2.5542627084e+02 0.0000000000e+00 0.0000e+00 -1.0$
        1 -1    0    0  502    0 -0.0000000000e+00 -0.0000000000e+00 -8.7206165037e+02 8.7206165037e+02 0.0000000000e+00 0.0000e+00 -1.0$
       23  2    1    2    0    0 -5.0062590497e+01 -2.1293460726e+01 -3.3731171118e+02 3.5381160076e+02 9.1890064174e+01 0.0000e+00 0.00$
       16  1    3    3    0    0 -7.3853101660e+01 -1.9268782172e+01 -2.9965980477e+02 3.0922736811e+02 0.0000000000e+00 0.0000e+00 -1.0$
      -16  1    3    3    0    0 +2.3790511164e+01 -2.0246785539e+00 -3.7651906406e+01 4.4584232646e+01 0.0000000000e+00 0.0000e+00 1.00$
       22  1    1    2    0    0 +1.3849191341e+02 -3.1066691058e+02 -5.4215557372e+01 3.4443180177e+02 0.0000000000e+00 0.0000e+00 -1.0$
       21  1    1    2  503  501 -2.1711139566e+01 +2.6500640755e+02 -1.3314172202e+02 2.9736591561e+02 0.0000000000e+00 0.0000e+00 -1.0$
        1  1    1    2  501    0 -6.6718183347e+01 +6.6953963749e+01 -9.1966388968e+01 1.3187860308e+02 0.0000000000e+00 0.0000e+00 -1.0$
<mgrwt>
<rscale>  2 0.40037747E+03</rscale>
<asrwt>0</asrwt>
<pdfrwt beam="1">  1       21 0.39296349E-01 0.40037747E+03</pdfrwt>
<pdfrwt beam="2">  1        1 0.13416333E+00 0.40037747E+03</pdfrwt>
<totfact> 0.13034132E+03</totfact>
</mgrwt>
</event>
```



Information about mother particles can be used for determine which diagram was realized in any event. Here the second diagram was realized.

LHEF size

Example: 40k events of $pp \to \nu\bar{\nu}\gamma jj$.

- Number of particles in the event: 2 (initial) + 5 (final) + 1 (intermediate Z) = 8.
- Zipped LHEF size: 11.8 Mb $\to$ 0.3 kb/event.
- Unzipped LHEF size: 57.7 Mb $\to$ 1.4 kb/event.
- Corresponding root file size: 19.8 Mb $\to$ 0.5 kb/event.
- Size of the root file after hadronuzation and detector simulation with Delphes (for comparison): 3.2 Gb $\to$ 80 kb/event.

Additional things

- SLHA — SUSY Les Houches Accords: https://arxiv.org/pdf/0712.3311.pdf.
- LHAPDF — Les Houches Accords PDF: https://arxiv.org/pdf/hep-ph/0508110.pdf.

Conslusion

- Motivation for LHA creating was reviewed;
- First LHA (Fortran) and some examples was considered;
- Update LHA (Fortran $\rightarrow$ C++) was considered;
- Present-day example of LHEF was reviewed.