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The ALPGEN Generator

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M.L. Mangano, M. Moretti, F. Piccinini, R. P., A.D. Polosa, JHEP07(2003)001

- Collection of MC codes for many processes relevant in hadron–hadron collisions (TEVATRON and LHC)
- Exact LO matrix element calculations of $d\hat{\sigma}$ based on the ALPHA algorithm
- Parton-level event generation (weighted and unweighted)
- Interface to Herwig/Pythia for the evolution of the partonic final state through parton shower with matching à la MLM
- ALPGEN can be downloaded from the code home page http://mlm.home.cern.ch/mlm/alpgen/ where a detailed documentation is also available

Up to now available processes

- $W + N$ jets, $Z/\gamma + N$ jets, $N \leq 6$
- $WQ\bar{Q} + N$ jets, $Z/\gamma Q\bar{Q} + N$ jets $(Q = b, t)$, $N \leq 4$
- $W + c + N$ jets, $N \leq 5$
- $n\ W + m\ Z + p$ Higgs $+\ l$ photons $+\ N$ jets, $n + m + p + l \leq 8$, $N \leq 3$
- $Q\bar{Q} + N$ jets, $(Q = b, t)$, $N \leq 6$
- $Q\bar{Q}Q'\bar{Q}' + N$ jets, $(Q, Q' = b, t)$, $N \leq 4$
- N jets, $N \leq 6$
- $Q\bar{Q}H + N$ jets, $(Q = b, t)$, $N \leq 4$
- N photons $+\ M$ jets, $N > 0$, $N + M \leq 8$ and $M \leq 6$

NEW processes

- single top production: tq, tb, tW, tbW, No extra jets
- $H + N$ jets, $N \leq 3$, effective ggH coupling
- W + photons + N jets, up to 2 γ's
- W + photons + $Q\bar{Q}$ + N jets, up to 2 γ's
- $Q\bar{Q} + N$ photons + N jets, $(Q = b, t)$, $M + N \leq 6$

Tutorial (How to use ALPGEN)

- Go to `http://mlm.home.cern.ch/mlm/alpgen/` and download in an empty directory the file `v210.tgz` by clicking:

  NEW: The source code for version V2.10

- Then give the command:

> tar -xzvf v210.tgz

resulting in the following directory structure:

```
2Qlib      compare      Makefile   QQhlib      vbjetwork  wphqqlib   zqqwork
2Qphlib    compile.mk   Njetlib    QQhwork     wcjetlib   wphqqwork
2Qphwork   DOCS         Njetwork   toplib      wcjetwork  wqqlib
2Qwork     ft90V.tar.gz phjetlib   topwork     wjetlib    wqqwork
4Qlib      herlib       phjetwork  v210.tgz    wjetwork   zjetlib
4Qwork     hjetlib      prc.list   validation  wphjetlib  zjetwork
alplib     hjetwork     pylib      vbjetlib    wphjetwork zqqlib
```

- It is possible to validate the whole package by giving the command:

$>$ make validate

It will compile *all* processes and will run them with few points, comparing then the results with a library of results to see if the installation worked or whether there are differences.

Then change directory:

$>$ cd validation

to see the result of the check:

$>$ more val.summary

Let us now show how to run a specific process (e.g. $Wb\bar{b} + 1$ jet).

- Go to the corresponding directory:

> cd wqqwork

that looks like

```
alpgen.inc   cnfg.dat   input   Makefile   pdflnk   wqq.inc   wqqusr.f
```

- Then complile the code with the command

> make gen

that will generate the executable file

wqqgen

- Run it by giving the command

> wqqgen < input

(the default `input` file corresponds to $Wb\bar{b} + 1$ jet)

- The result of the run is stored is a series of files contained in the directory, that now looks like

```
alpgen.inc  Makefile    wbbj.grid2  wbbj.stat  wqqgen     wqqusr.o
cnfg.dat    pdflnk      wbbj.mon    wbbj.top   wqq.inc
input       wbbj.grid1  wbbj.par    wbbj.wgt   wqqusr.f
```

Before discussing the output we show how to prepare

the input file

```
1           ! imode
wbbj        ! label for files
0 ! start with: 0=new grid, 1=previous warmup grid, 2=previous generation grid
10000 2     ! Nevents/iteration,  N(warm-up iterations)
100000      ! Nevents generated after warm-up
*** The above 5 lines provide mandatory inputs for all processes
*** (Comment lines are introduced by the three asteriscs)
*** The lines below modify existing defaults for the hard process under study
*** For a complete list of accessible parameters and their values,
*** input 'print 1' (to display on the screen) or 'print 2' to write to file
ihvy 5
njets 1
ickkw 0
ptjmin  20
ptbmin  20
etajmax 1
etabmax 1
drjmin  0.7
drbmin  0.7
```

- There are hidden parameters, with default values. To see the entire list type:

> ./wqqgen

- Then it appears on the screen:

```
Input RUN generation mode:
0: generate weighted events, no evt dumps to file
1: generate wgtd events, write to file for later unweighting
2: read events from file for unweighting or processing
or documentation modes:
3: print parameter options and defaults, then stop
4: write to par.list parameter options and defaults, then stop
5: write to prc.list complete list of processes, parameter
   options and defaults, scale choices, PDF, etc., then stop
```

- Now write

> 4

- to genarate the file `par.list`, that reads:

```
------
hard process code (not to be changed):
ihrd= 1
------
Select pp (1) or ppbar (-1) collisions:
ih2= -1
------
beam energy in CM frame (e.g. 7000 for LHC):
ebeam=  980.
------
parton density set:
ndns= 5
NDNS     Set          Lambda_4    Lambda_5_2loop   Scheme

   1     CTEQ4M        .298        .202                MS
   2     CTEQ4L        .298        .202                MS
   3     CTEQ4HJ       .298        .202                MS
   4     CTEQ5M        .326        .226  (as=0.118)    MS
   5     CTEQ5L *      .192        .144  (asLO=0.127)  MS
   6     CTEQ5HJ       .326        .226  (as=0.118)    MS
```

```
   7     CTEQ6M       .326         .226  (as=0.118)  MS
   8     CTEQ6L       .326         .226  (as=0.118)  MS
   9     CTEQ6L1      .215         .165  (asLO=0.130)  MS
10-50    CTEQ6xx      .326         .226  (as=0.118)  MS
 101     MRST99 COR01 .321         .220              MS
 102     MRST2001     .342         .239  (as=0.119 ) MS
 103     MRST2001     .310         .214  (as=0.117 ) MS
 104     MRST2001     .378         .267  (as=0.121 ) MS
 105     MRST2001J    .378         .267  (as=0.121)  MS
 106     MRST2002LO * .22          .167  (asLO=0.13) MS

  PDF sets followed by * are obtained from a 1-loop analysis,
  and the relative values of Lambda  refer to 1-loop.
  The MSbar scheme is used by default with 1-loop
  structure functions.
  In all cases the values of Lambda and loop order are set
  automatically by the code, The user only needs to input ndns

------
scale option (process dependent):
```

```
iqopt= 1
Options for Factorization/renormalization scale Q:
iqopt=0 => Q=qfac
iqopt=1 => Q=qfac*sqrt{m_W^2+ sum_jets(m_tr^2)}
iqopt=2 => Q=qfac*mW
iqopt=3 => Q=qfac*sqrt{m_W^2+ pt_W^2}
iqopt=4 => Q=qfac*sqrt{sum_jets(m_tr^2)}
where:
- m_tr^2=m^2+pt^2, summed over heavy quarks and light jets
To select CKKW scale input 'ickkw 1'
(mandatory for later use of jet matching)
In imode=2 select clustering option 'cluopt':
cluopt=1: kperp propto pt(cluster) (default)
cluopt=2: kperp propto mt(cluster)
kperp is then rescaled by ktfac
------
Q scale rescaling factor:
qfac=  1.
------
CKKW scale option: set to 1 to enable jet-parton matching:
```

```
ickkw= 0
------
scale factor for ckkw alphas scale:
ktfac=  1.
------
number of light jets:
njets= 0
------
heavy flavour type for procs like WQQ, ZQQ, 2Q, etc(4=c, 5=b, 6=t):
ihvy= 5
------
charm mass:
mc=  1.5
------
bottom mass:
mb=  4.7
------
top mass:
mt=  174.3
------
```

```
minimum pt for light jets:
ptjmin=  20.
------
ptmin for bottom quarks (in procs with explicit b):
ptbmin=  20.
------
ptmin for charm quarks (in procs with explicit c):
ptcmin=  20.
------
minimum pt for charged leptons:
ptlmin=  0.
------
minimum missing et:
metmin=  0.
------
max|eta| for light jets:
etajmax=  2.5
------
max|eta| for b quarks (in procs with explicit b):
etabmax=  2.5
```

```
------
max|eta| for c quarks (in procs with explicit c):
etacmax=  2.5
------
max abs(eta) for charged leptons:
etalmax=  10.
------
min deltaR(j-j), deltaR(Q-j) [j=light jet, Q=c/b]:
drjmin=  0.699999988
------
min deltaR(b-b) (procs with explicit b):
drbmin=  0.699999988
------
min deltaR(c-c) (procs with explicit charm):
drcmin=  0.699999988
------
min deltaR between charged lepton and light jets:
drlmin=  0.
------
first random number seed (5-digit integer):
```

```
iseed1= 12345
------
second random number seed (5-digit integer):
iseed2= 67890
------
W decay modes, in imode=2:
iwdecmod= 1
------
kt scale option. 1:kt propto pt, 2:kt propto mt:
cluopt= 1
------
first random number seed for unweighting (5-digit integer):
iseed3= 12345
------
second random number seed for unweighting (5-digit integer):
iseed4= 67890
```

• All these default values can be changed by writing in the input file, *in any place*, the changed values

• For example, in our input file, the default value `etajmax= 2.5` has been changed by the statement

```
etajmax 1
```

We are now ready to discuss

<u>the output files</u>

wbbj.stat

```
W b bbar + 1 jets
W-> ell nu
=======================================
 b mass:  4.7
Generation cuts for the partonic event sample:
     Light jets:
ptmin=  20. |etamax|=  1. dR(j-j),dR(Q-j)>  0.7
 b quarks:
ptmin=  20. |etamax|=  1. dR(QQ)>  0.7
     Leptons:
ptmin(lep)=  0. |etamax|=  10. Et(miss)>  0. dR(l-j)>  0.

 RUNNING PARAMETERS
-------------------


        Electroweak parameters:
iewopt= 3:
input mW, mZ, GF calculate the rest
```

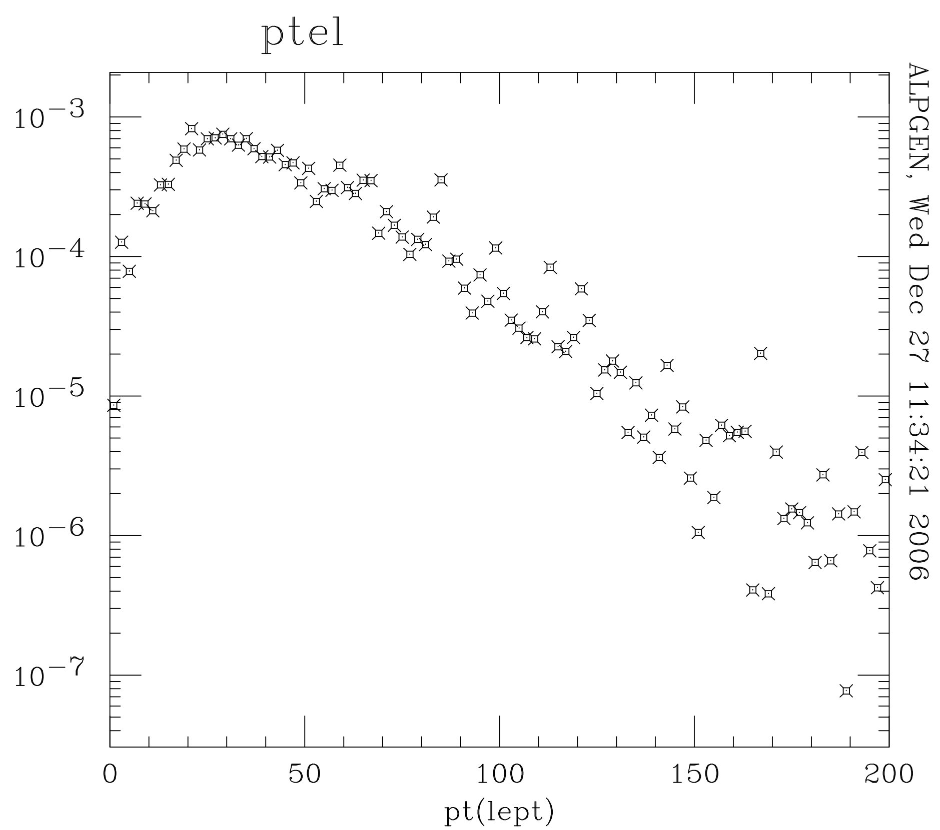
```
M(W)=  80.419 Gamma(W)=  2.04807653
M(Z)=  91.188 Gamma(Z)=  2.44194427
M(H)=  120. Gamma(H)=  0.
 gW=  0.65323291; sin^2(thetaW)=  0.222246533; 1/aem(mZ)=  132.50698

        Quark masses:
m(top)=  174.3 m(b)=  4.7

       Beams' parameters:
beam1=proton, beam2=antiproton
Ebeam=  980. PDF set=CTEQ5L
as(MZ)[nloop= 1] =   0.127003172


starting generation of  10000. events
average ph-space eff=  0.342536138
avgwgt(pb)=  0.0152015651+-  0.00187552134 maxwgt=  7.65766369
unwgt eff =  0.00198514399

 sub-processes:
```

```
jproc= 1 total(pb):   0.0108255596+-  0.0017552771
jproc= 2 total(pb):   0.00236215767+-  0.000554153443
jproc= 3 total(pb):   0.00201384775+-  0.000374062198

cumulated cross-section:
avgwgt(pb)=  0.0152015651+-  0.00187552134

starting generation of  10000. events
average ph-space eff=  0.436891083
avgwgt(pb)=  0.019895344+-  0.00268578981 maxwgt=  14.9961835
unwgt eff =  0.00132669383

 sub-processes:

jproc= 1 total(pb):   0.0136988128+-  0.00249145625
jproc= 2 total(pb):   0.00288165339+-  0.000481786113
jproc= 3 total(pb):   0.00331487788+-  0.000890439387

cumulated cross-section:
```

```
avgwgt(pb)=  0.0167401609+-  0.00153770483

starting generation of  100000. events
average ph-space eff=  0.409294254
avgwgt(pb)=  0.017476239+-  0.000574471343 maxwgt=  26.1532933
unwgt eff =  0.000668223264

 sub-processes:

jproc= 1 total(pb):   0.0114901936+-  0.000490463401
jproc= 2 total(pb):   0.00322185443+-  0.000225250821
jproc= 3 total(pb):   0.00276419101+-  0.000200695731

cumulated cross-section:
avgwgt(pb)=  0.0173860873+-  0.000538143309
```

wbbj.top

• The pre-defined histograms of any variable, loaded by the user in `wqqusr.f` before the run, are stored here, in the Topdrawer format. For example



wbbj.mon

- Stores intermediate information. It is rewritten each 10^5 points:

```
   processed=       100000.0 events

 average ph-space eff=  0.409294254
 avgwgt(pb)=  0.017476239+-  0.000574471343 maxwgt=  26.1532933
 unwgt eff=  0.000668223264

  sub-processes:

 jproc= 1 total:   0.0114901936+-  0.000490463401
 jproc= 2 total:   0.00322185443+-  0.000225250821
 jproc= 3 total:   0.00276419101+-  0.000200695731
```

• The files `wbbj.par`, `wbbj.grid1` and `wbbj.grid2` are for internal use

What shown up to now is enough to produce results at the parton level. If, instead, one needs to produce actual events (e.g. to perform detector simulations of more realistic studies), the following is also needed

• The file `wbbj.wgt` contains the weighted events generated during the run. To generate unweighted events do the following 4 steps

1) Run again the code:

> ./wqqgen

Output:

```
Input RUN generation mode:
0: generate weighted events, no evt dumps to file
1: generate wgtd events, write to file for later unweighting
2: read events from file for unweighting or processing
or documentation modes:
3: print parameter options and defaults, then stop
4: write to par.list parameter options and defaults, then stop
5: write to prc.list complete list of processes, parameter
   options and defaults, scale choices, PDF, etc., then stop
```

2) Input:

> 2

Output:

```
Input string labeling output and input files
(e.g. w2j to output files w2j.stat, etc.)
```

3) Input:

> wbbj

Output:

```
Parameters and results written to wbbj_unw.par
Topdrawer plots (if any) written to wbbj_unw.top
Wgted events are read from wbbj.wgt
Unwgted events are written to wbbj.unw

read in generation parameters:
ihvy    =  5.
njets   =  1.
ickkw   =  0.
```

```
ptjmin  =  20.
ptbmin  =  20.
etajmax =  1.
etabmax =  1.
drjmin  =  0.7
drbmin  =  0.7

Input decay params to replace defaults: type and value
(input 'print 1' to display the list of parameter types and  their current values)
(input 'ctrl-D' to terminate the input sequence)
```

4) Input:

> ctrl-D

Output:

```
starting scan/unweighting of  5450. events
Crosssection(pb)=  0.0173861+-  0.000538143
Generated  176 unweighted events, lum=  10123.0293pb-1
```

• The generated unweigted events can be found in the file `wbbj.unw` and are written in a format that can be easily translated to the standard *Les Houches Accord*

E. Boos *et al.*, hep-ph/0109068

• For example the first of the 176 generated unweighted events reads

```
   1     1   7 0.100000E+01 0.118382E+03
   2     3     0    118.206
  -1     0     1   -147.774
   5     2     0       12.285     -33.814     -16.966       4.700
  -5     0     1       40.632     -48.437      14.085       4.700
  21     3     2      -19.046      42.996      24.373       0.000
  12     0     0        3.867      44.875      -0.971       0.000
 -11     0     0      -37.738      -5.619     -50.088       0.001
```

Showering and Hadronizing events (with Herwig)

• Compile `Herwig` by going to the appropriate directory (it takes a while...):

> cd herlib

> make hwuser

• Return to the working directory and run from the the `Herwig` executable file (`hwuser`). Input:

> cd ../wqqwork

> ../herlib/hwuser

Output:

```
          HERWIG 6.510  31st Oct. 2005

          Please reference:  G. Marchesini, B.R. Webber,
          G.Abbiendi, I.G.Knowles, M.H.Seymour & L.Stanco
          Computer Physics Communications 67 (1992) 465
                             and
          G.Corcella, I.G.Knowles, G.Marchesini, S.Moretti,
          K.Odagiri, P.Richardson, M.H.Seymour & B.R.Webber,
          JHEP 0101 (2001) 010
 INPUT NAME OF FILE CONTAINING EVENTS
 (FOR "file.unw" ENTER "file")
```

• Input:

> wbbj

• The 176 unweihted events are now fully showered and hadronized. They can be analyzed on line, during the running of `Herwig`, from `SUBROUTINE HWANAL` in `hwuser.f` (see the `Herwig` Manual for more details).