1 Event Generators for $\gamma - \gamma$ Physics

1.1 GGPS1, GGPS2

1.1.1 Basic Facts

Program name: GGPS1, GGPS2
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Program size: (in source lines) 2213 (ggps1), 2841 (ggps2), common routine 3034 (pool)
Program location: Anonymous ftp lapphp8.in2p3.fr in pub/keklapp/ggps
get ggps.tar.gz and README.

1.1.2 Program description

This generator simulates jet productions in two-photon process based on the leading-log (LL) parton shower (PS) technique[1]. Two cases are separately treated, namely, the deep inelastic scattering of the photon (**GGPS1**) and the scattering of two quasi-real photons (**GGPS2**)[2]. Both processes begin by the PS space-like evolution, then takes place the hard scattering of partons followed by the time-like evolution of the final state partons.

The non-singlet quark distribution in the photon, $q_{NS}(x,Q^2)$, obeys[3]

$$\frac{dq_{NS}(x,Q^2)}{d\ln Q^2} = \frac{\alpha_s}{2\pi}\int_x^1 \frac{dy}{y} P_{qq}^{(0)}(x/y) q_{NS}(y,Q^2) + \frac{\alpha}{2\pi} k_{NS}^{(0)}(x), \tag{1}$$

The inhomogeneous term, $k_{NS}^{(0)}(x)$, is proportional to $x^2+(1-x)^2$. α is the QED coupling constant, the QCD coupling constant α_s is defined as: $\alpha_s(Q^2) = 4\pi/(\beta_0 \ln Q^2/\Lambda^2) = \alpha_0/(\ln Q^2/\Lambda^2)$ with $\beta_0 = 11-(2/3)N_F$. N_F is the number of flavours. Eq.(1) can be brought into the integral equation

$$q_{NS}(x,Q^2) = \int_x^1 \frac{dy}{y} K_{NS}^{(0)}(x/y,\bar{s}) q_{NS}(y,Q_0^2) + \int_{Q_0^2}^{Q^2} \frac{dK^2}{K^2} \int_x^1 \frac{dy}{y} K_{NS}^{(0)}(x/y,\eta(K^2)) \frac{\alpha}{2\pi} k_{NS}^{(0)}(y), \tag{2}$$

where $\bar{s} \equiv \ln(\alpha_s(Q_0^2)/\alpha_s(Q^2)) = \ln(\ln(Q^2/\Lambda^2)/\ln(Q_0^2/\Lambda^2))$ and $\eta = \ln(\ln(Q^2/\Lambda^2)/\ln(K^2/\Lambda^2))$. The first term represents the vector meson dominant part (VDM) while the second corresponds to the perturbative photon. Here $K_{NS}^{(0)}(x,\bar{s})$ is the QCD kernel function[4] defined by the inverse Mellin transformation

$$K_{NS}^{(0)}(x,\bar{s}) = \int_{r_0-i\infty}^{r_0+i\infty} \frac{dn}{2\pi i} x^{-n} e^{\alpha_0 d(n)\bar{s}}, \tag{3}$$

where $d(n)$ is the moment of $P_{qq}^{(0)}(x)/(2\pi)$.

The singlet distribution is handled in the similar manner.

Due to the inhomogeneous term in Eq.(1), the total energy is conserved *only if* the photon energy is included,

$$\int_0^1 dxx[\sum_f(q_f(x,Q^2)+\overline{q}_f(x,Q^2))+G(x,Q^2)] = \int_{Q_0^2}^{Q^2}\frac{dK^2}{K^2}\frac{\alpha}{2\pi}\int_0^1 dxxk_{NS}^{(0)}(x). \tag{4}$$

In the generation the right-hand side is used as *the weight of the event.*

Let us summarize the main steps present in the algorithm generating the partons in the course of the evolution.

1. Selection of a Q^2.
2. Calculation of the energy of the VDM part (independent of Q^2) and of the energy of the perturbative photon part by using Eq.(4). The sum of these energies is used as the weight of the event.
3. Selection of the actual process, either VDM or perturbative photon, according to the ratio of energies.
4. If VDM is chosen, the usual QCD evolution from Q_0^2 (the cut-off momentum) to Q^2 is performed.
5. In the case of a perturbative photon, the virtual mass squared K^2 according to the probability dK^2/K^2 is determined. Then the flavour of the partons are selected according to the ratio of charges squared.
6. For each quark or anti-quark, the usual QCD evolution from K^2 up to Q^2 is performed.

This algorithm is common to the deep inelastic photon scattering and to the two quasi-real photon scattering with large p_T^2. The hard scattering parts are, however, different. In quasi-real photon collision the initial states q-q, q-$\overline{q}$, q-G, G-G, q-γ G-γ and γ-γ are taken into account for the hard scattering, although in the virtual-quasi-real case only the γ^*-q and γ^*-G subprocesses are considered.

The reference cross section used to select events is the differential cross-section:

$$d\sigma^0/dp_T^2 = \pi/p_T^4. \tag{5}$$

The ratio of the hard cross section to Eq.(5) is counted as the weight of the event. The argument of α_s in the hard cross section is set to be p_T^2, because there are some processes whose cross section is dominated by the t-channel contribution. After the time-like evolution of the produced partons has been performed, the energy of the initial photons is fixed and thus the four-momenta of all partons are determined.

Events are generated with a weight whose maximum is unknown at the beginning of a run. A maximum value is arbitrary fixed by the user, overweight events are rejected and counted. At the end of the run, if the number of overweight events is too large, compromising the generation accuracy, the user must increase the maximum weight, reducing consequently the generation efficiency.

Finally the generated partons are hadronized following the JETSET[5] mechanism. Colour flows are properly matched and adopt the JETSET definition. Two types of colour singlet exist: a string beginning and ending with quarks possibly embedding one or many gluons or a closed colour loop of gluons.

1.1.3 General generator parameters

Definition of all generator adjustable parameters:

`LIST`

Definition: Request a listing of the input parameters on the output file

`BEAM` *beam* `(D=90.0 GeV) [real*4]`

Definition: Beam energy = *beam* GeV

`TRIG` *trig* `(D=1000) [integer]`

Definition: Number of events (triggers) = *trig*

`DEBU` *p1 p2 p3* `(D=-1 10 10) [integers]`

Definition: Debugging tool

`p1`: First event to print, if negative initialization printout is also performed.
`p2`: Last event to print.
`p3`: Printing frequency.

`RNDM` *rndm* `(D=12345678) [integer]`

Definition: Seed of random number generator *rndm*. (for generating different set of events, the seeds must be different.

`COND` *cond* `(D=0) [integer]`

Definition: Run condition, *cond* should be read as a list of digit in base 10. Each digit corresponds to a run condition, any combination is valid.

cond = `001` Event are converted to the standard HEPEVT common.
cond = `0n0` Event MUST comply with the specific user defined cuts to be accepted.
n = 1: at least 1 particle in the acceptance cut
n = 2: at least 1 jet
n = 3: at least 1 jet in the jet cuts

n = 4: like n = 3 but the event should comply with the global event cuts

cond = `100` Event are generated with weight=WGHT in common:
COMMON/QCWGHT/ WGHT0,FAIL,WGHT,ACCPTX
This is more efficient, but the user has to deal with weighted events

`PROC` *proc* `(D=2) [integer]` **FOR GGPS1:**

Definition: Mode type selection

proc = `0`: calculate parton distributions in photon

proc = `1`: process of real photon and electron scattering

proc = `2`: process of virtual photon and real photon of electron positron scattering

FOR GGPS2:

Definition: Process type selection

proc = `0`: $\gamma - \gamma$ scattering with fixed $p_T^2 = q2xm$

proc = `1`: $\gamma - \gamma$ scattering with $p_T^2 > q2xm$

proc = `2`: $e^+e^- \rightarrow \gamma - \gamma$, the γ being quasi-real

`MINV` *minv* `(D=0.0 GeV) [real*4]`

Definition: Minimum $\gamma - \gamma$ invariant mass $= minv$ GeV

`Q2XM` *q2xm* `(D=10.  GeV`^{2}`) [real*4]`

Definition: FOR GGPS1:
q2xm is the minimum value of the virtual photon virtuality. The resolving photon is assumed to be real. **FOR GGPS1:**
q2xm is the minimum value of jets Pt^2.
The following relationship must hold: $\lambda_{QCD} = lamb^2 < q2cu < q2mi << q2xm$.

`Q2MI` *q2mi* `(D=0.25 Gev`^{2}`) [real*4]`

Definition: *q2mi* is the virtual mass squared at the start of the evolution. This value is strongly correlated with the initial parton distributions. *q2min* is of the order of hadronic scale ($q2mi < 1 - 5\ GeV^2$). See Q2XM.

`Q2CU` *q2cu* `(D=0.1 Gev`^{2}`) [real*4]`

Definition: *q2cu* is the minimum P_t^2 in the parton shower branching ($\frac{1+x^2}{1-x}$. Needed to cut off the infrared singularities. This is supposed to be of the hadronic scale ($q2cu < 1 - 3$ GeV^2). This is unphysical so that physical distributions should not depend on *q2cu*. See Q2XM.

`LAMB` *lamb* `(D=0.23 GeV) [real*4]`

Definition: $\Lambda_{QCD} = lamb$ (0.1 - 0.5 GeV)

Warning: the Λ_{QCD} value depends on the number of flavor *nfla*. See Q2XM. For a given set of *nfla* and *lamb*, $\Lambda^{(5)}$ is computed and compared to the world average value Average $\Lambda^{(5)} = 195 + 65 - 50$ MeV [6]. See the output file.

`NFLA` *nfla* `(D=4) [integer]`

Definition: Number of flavor *nfla*. See LAMB.

`KZAP` *kzap* `(D=0) [integer]`

Definition: In the branching $q(K^2, 1) \rightarrow q(Q^2, x) + gluon(0, 1 - x), (Q^2 >> K^2)$ the running α_s depends on the kinematics..

`kzap = 0` $\alpha_s(Q^2)$ is used

`kzap = 1` $\alpha_s(x(1-x)Q^2)$, where $P_t^2 = x(1-x)Q^2$ is used to account for next-to-leading contributions, the so-called K_t ordering.

`NREM` *nrem* `(D=1) [integer]`

Definition: In the VDM sector, the remnant part of a photon emitting a gluon can be a gluon or a pair $q - \bar{q}$.

`nrem = 0` a gluon

`nrem = 1` a pair $q - \bar{q}$

`POIN` *poin* `(D=0) [integer]`

Definition: The $\gamma - \gamma$ process can be restricted to the case where one or both photons are point-like.

`poin = 0` No restriction

`poin = 1` One photon is point-like

`poin = 2` Both photons are point-like

`WMAX` *wmax* `(D=10.)  [real*4]`

Definition: Maximum weight *wmax*

All event weight, if smaller than *wmax*, are normalized to *wmax*. If event weight is larger than *wmax*, the event is discarded.

The larger *wmax* the more accurate is the cross-section and the smaller the generation efficiency. Precision versus efficiency are shown on the print out to guide the user.

1.1.4 Specific user defined parameters

Definition of some analysis parameters, if the digit (2) of COND is set to 1 event are selected according to the following parameters, otherwise only the analysis is uses this information.
ACCEPTANCE CUTS:

`TCMI` *tcmi* `(D=0.34906585 (20`^{0}`)) [real*4]`

Definition: Polar angle θ minimum for charged particles

`GEMI` *gemi* `(D=1.  Gev) [real*4]`

Definition: Minimum energy of γ's

`PCMI` *pcmi* `(D=0.4 Gev/c) [real*4]`

Definition: Minimum momentum (absolute value) of charged particles

`TNMI` *tnmi* `(D=0.17453293 (10`^{0}`) ) [real*4]`

Definition: Polar angle θ minimum for neutral particles

`ENMI` *enmi* `(D=1.  Gev) [real*4]`

Definition: Minimum energy of neutral particles.

JETS CUTS:
`PRMA` *prma* `(D=1.)  [real*4]`

Definition: Maximum pseudo-rapidity of jets

`PJMA` *pjma* `(D=100.  Gev/c) [real*4]`

Definition: Maximum jet p_t

GLOBAL EVENT CUTS:
`PTMA` *ptma* `(D=10.  Gev/c) [real*4]`

Definition: Maximum P_t of the event.

`PZMA` *pzma* `(D=20.  Gev/c) [real*4]`

Definition: Maximun P_z of the event.

`RMMA` *rmma* `(D=50.  Gev) [real*4]`

Definition: Maximum event invariant mass.

1.1.5 Example of Control cards

```
LIST
TRIG  1000
BEAM 87.5
DEBUG 1 5 10
c 001 convert to HEPEVT
c 010 comply with user cuts
```

```
c 100 weighted event
COND 000
c Minimum value for the transverse momentum squared of jets
Q2XM 20.0
Q2MI 0.25
Q2CU 0.1
c Minimum gamma-gamma invariant mass
MINV 20.0
c        process to be generated
c        nprc = 0 : gamma-gamma scattering with fixed p_T^2
c        nprc = 1 : gamma-gamma scattering
c        nprc = 2 : two quasi-real photon process in e+e- scattering
c
PROC 2
C lambda qcd
LAMB 0.23
C Nb of flavor
NFLA 4
c      Remnant of the photon after emitting a gluon is
c      quark-antiquark pair NREM = 1 or is a gluon NREM  = 0
NREM 1
c     POIN = 1 RESTRICT ONE PHOTON  to be POINT-LIKE
c     POIN = 2 RESTRICT TWO PHOTONS to be POINT-LIKE
POIN 0
C Maximum weight
WMAX 10.0
C User analysis cuts
c   Acceptance cuts
C THCMIN Theta min for charged particles
TCMI 0.34906585
c GEMIN Gamma energy minimum
GEMI 1.
c PCMIN momentum minimum for charged particles
PCMI 0.4
c THNMIN Theta min for neutral particles
TNMI 0.17453293
c ENMIN Minimum energy for neutral particles
ENMI 1.
C  Jets cuts
c PRJMAX Pseudo-rapidity cut
PRMA 1.0
c PTJMAX Transverse PT of the jet
PJMA 100.
```

```
C Global event cuts
C PTMAX cut
PTMA 10.
c PZMAX cut
PZMA 20.
C RMMAX Invariant mass cut
RMMA 50.
c Pawfile
PAWF 'ggps2.n1.paw'
END
```

1.1.6 Output results

```
 ****************************************************
                RUNNING STATISTICS
 ****************************************************

  NB. OF EVENT REQUESTED :  1000

 EVT GENERATED:      100 EFFICIENCY:  3.66% OVERWGHT:   .42% LUEXE ERR.:   .00%
 EVT GENERATED:      200 EFFICIENCY:  3.61% OVERWGHT:   .42% LUEXE ERR.:   .00%
 EVT GENERATED:      300 EFFICIENCY:  3.59% OVERWGHT:   .40% LUEXE ERR.:   .00%
 EVT GENERATED:      400 EFFICIENCY:  3.66% OVERWGHT:   .38% LUEXE ERR.:   .00%
 EVT GENERATED:      500 EFFICIENCY:  3.71% OVERWGHT:   .38% LUEXE ERR.:   .00%
 EVT GENERATED:      600 EFFICIENCY:  3.73% OVERWGHT:   .37% LUEXE ERR.:   .00%
 EVT GENERATED:      700 EFFICIENCY:  3.74% OVERWGHT:   .36% LUEXE ERR.:   .00%
 EVT GENERATED:      800 EFFICIENCY:  3.67% OVERWGHT:   .37% LUEXE ERR.:   .00%
 EVT GENERATED:      900 EFFICIENCY:  3.68% OVERWGHT:   .38% LUEXE ERR.:   .00%
 EVT GENERATED:     1000 EFFICIENCY:  3.64% OVERWGHT:   .38% LUEXE ERR.:   .00%

***********  END OF GENERATION *******************
            WEIGHTED      WEIGHTED    ERROR       %
            NO OVERWEIGHT INCL. OVERW
 XSECT (pb) 100.86        134.69      33.835     25.120 <-------+
 XSECT AFTER GG INV MASS CUT (pb) : 93.864                      |
                                                                |
 **************************************************             |
                                                  ----------------------------------
                                                 | But due to rejection of overweight
                                                 | events, the generated cross-section
                                                 | is 100.86 pb. a 28.7 % error.
                                                 | To reduce the error increase the WMAX
```

```
                                                  | parameters
UNWEIGHTING STATISTICS

EVENT GENERATED           :  39426
EVENT ACCEPTED            :  1435
GENERATION EFFICIENCY (%):   3.64
EVENT REJECTED            :  37843
EVENT OVERWEIGHT          :  148
EVENT OVERWEIGHT (%)      :    .38
ERR. DUE TO OVERWEIGHT(%):  19.07
TOTAL CROSS-SECTION (pb) :   .13469E+03
ERR. ON CROSS-SECTION pb):   .25682E+02
MEAN OVERWEIGHT           :   .22667E+02      <- mean weight for the event over WMAX
SIGMA OVERWEIGHT          :   .20983E+02      <- Essentially a measure of the
                                                 width of the overweight
MAXIMUM WEIGHT ASSUMED   :   .10000E+02      <- Set by the user
MAXIMUM WEIGHT SEEN       :   .16933E+03      <- Maximum weight recorded


HADRONIZATION  STATISTICS

EVENT with LUEXEC ERROR  :  0

*************** END GGPS2 *****************************
HISTOGRAMS STORED IN:
 ggps2.n1.paw
```

References

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