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HSRWGT: A Program for Reweighting HERACLES events

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1 Purpose of the program

Since a full event simulation including detector performance is very time consuming, it is often desirable to describe the effect of modified physics input to a Monte Carlo by assigning weights to the events of an already existing event sample. The program HSRWGT is a tool to calculate these weights for event samples obtained from DJANGOH (HERACLES and DJANGO6). It allows to simplify data analyses for cases where a limited list of input options relevant for the overall description of the cross section has to be changed. These input options comprise parameters describing parton distribution or structure functions and electroweak parameters. It does not allow to calculate weights for specific events when parameters relevant for the simulation of the hadronic final state are to be changed. The reweighting method is expected to provide meaningful results in those cases where modifications of the differential cross sections are moderate. For large changes it will remain necessary to repeat the full simulation with adjusted parameters.

One should keep in mind that a modification of parton distributions, in particular of the gluon distribution, will not only affect the cross section, but also the properties of the hadronic final state (e.g., initial state parton showers, the ratio of $eq \rightarrow eqg$ and $eg \rightarrow eq\bar{q}$ events). This effect cannot be recovered by the reweighting technique implemented in HSRWGT.

2 Technical description

The program performs the following steps:

1. For the initialization of the program one has to provide the relevant part of the input options as has been used for the generation of the event sample over which the reweighting program should run. To simplify the prescription, it was decided to keep the full list of input options, although a large part will not be used for reweighting. The user is recommended to provide exactly the same input as was used for the event generation. As for event sampling with HERACLES, this part of the input file has to end with the code word `'START'`.

2. The program has to know which parameter modifications should be used to define reweighting factors. The list of allowed input options is given below. The section of the input file containing this information has to end with the code word `'CONTINUE'`.

3. Then the program reads the events from an existing file. The default file name is `event.dat` and can be changed in the subroutine `HSRWRD`. It is sufficient to provide a reduced event record. The relevant information is contained in the 4-momenta of the scattered lepton, the scattered quark and, for radiative events, the emitted photon. Also, one has to provide the channel number `ICHNN` as given by HERACLES and the flavor of the struck quark. An example of how to read in the necessary information is given in the subroutine `HSRWRD`. The program then calls the appropriate functions to calculate the weights for each event and writes the weight to a file called `eventw.dat` (subroutine `HSRWWR`).

4. Some distributions of average weights are generated with the help of `HBOOK`. Initialization is performed in `HSRWHB`, histogram filling in the subroutine `HSRWHF` and the histograms are saved to the file `reweig.paw` in `HSRWHP`. These routines may be changed or replaced by dummy routines by the user according to his own needs.

3 Calculating weights

The reweighting factors (simply called weights in the following) are calculated from the ratio of the differential cross sections for the two sets of input parameters in the following way: for a given point in the phase space[1], characterized by independent kinematic variables v_i ($i = 1, 2$ for non-radiative events, $i = 1, \cdots, 5$ for radiative events), the weight ω_i is defined by

$$\omega_i = \frac{d\sigma_{\rm new}(v_i)}{d\sigma_{\rm old}(v_i)} \tag{1}$$

where $d\sigma_{\rm new}$ ($d\sigma_{\rm old}$) is the differential cross section for the new (old) parameter set. For non-radiative events the computation of ω_i is straightforward and obtained for each single event correctly. For radiative events, ω_i can be computed only on the average with HSRWGT since the calculation relies on the separation of the cross section into partial cross sections (channels):

$$d\sigma(v_i) = \sum_c d\sigma_c(v_i). \tag{2}$$

[1] In practice, cross sections and event numbers will be defined in bins "v_i".

The subscript c denotes the channel (initial state radiation, final state radiation, Compton contribution, quarkonic radiation for neutral current scattering). The number of events which have been generated by HERACLES in each channel is determined by the partial cross sections $d\sigma_c(v_i)$:

$$N_c(v_i) = \frac{d\sigma_{c,\mathrm{old}}(v_i)}{d\sigma_{\mathrm{old}}(v_i)} N(v_i), \qquad N(v_i) = \sum_c N_c(v_i). \tag{3}$$

Each event is assigned a weight $w_{c,i}$ according to the corresponding partial cross section:

$$w_{c,i} = \frac{d\sigma_{c,\mathrm{new}}(v_i)}{d\sigma_{c,\mathrm{old}}(v_i)}. \tag{4}$$

The weight ω_i is then obtained as the average at a given phase space point:

$$\begin{aligned} \omega_i &= \frac{1}{N(v_i)} \sum_c N_c(v_i) w_{c,i} \\ &= \sum_c \frac{d\sigma_{c,\mathrm{old}}(v_i)}{d\sigma_{\mathrm{old}}(v_i)} \frac{d\sigma_{c,\mathrm{new}}(v_i)}{d\sigma_{c,\mathrm{old}}(v_i)} \\ &= \frac{\sum_c d\sigma_{c,\mathrm{new}}(v_i)}{d\sigma_{\mathrm{old}}(v_i)} \\ &= \frac{d\sigma_{\mathrm{new}}(v_i)}{d\sigma_{\mathrm{old}}(v_i)}. \end{aligned} \tag{5}$$

It is therefore essential that the event sample is large enough, not only to cover the phase space region under investigation with a reasonably high density of events, but also to have a good representation of the partial cross sections $d\sigma_c(v_i)$ by the corresponding partial event numbers $N_c(v_i)$ in each bin.

Apart form the fact that weights for radiative events are obtained on average only, no other approximation is made. In particular there is no need to treat the kinematics of radiative events approximately and, e.g., to invoke a collinear approximation.

4 Input for reweighting

- `'GSW-PR-NEW'`
  data: `LPARIN_new(1:11)`
  for redefining electroweak parameters and switches for the inclusion of different virtual corrections corresponding to the HERACLES code word `'GSW-PARAM'`.
  Note: The effect of QED radiative corrections cannot be obtained by reweighting since it requires the inclusion of channels for radiative events. In particular, this is also true for the effect of quarkonic radiation and the interference of leptonic-quarkonic radiation. One will profit from the reweighting technique in cases where the effect of virtual corrections has to be studied (i.e., `LPARIN(7)` $\cdots$ `LPARIN(11)`).

- `'GSW-M-NEW'`
  data: `MW_new`, `MZ_new`, `MH_new`, `MT_new`
  for redefining the electroweak mass parameters corresponding to the HERACLES code word `'GSW-MASS'`.

- 'STRFC-NEW'
  data: ISTRFC_new
  for redefining the parametrization of parton densities or structure functions corresponding to the HERACLES code word 'STRUCTFUNC'.
  Note: An event sample which has been generated with ILQMOD = 0 or = 1 (i.e., using parton distribution functions) cannot be used to obtain weights for ILQMOD $\geq$ 2 (i.e., using structure functions) and vice versa.

- 'FL-NEW'
  data: IFLOPT_new, PARL11_new, PARL19_new
  for redefining parameters for the inclusion of the longitudinal structure function F_L corresponding to the HERACLES code word 'FLONG'. Note that the values LTM = 1 or LQCD = 1 are not allowed and reset to 2, i.e. the integrals required for the calculation of F_L are computed for each event. This results in larger CPU time, better accuracy and a simplified code.

- 'ALFAS-NEW'
  data: MST111_new, MST115_new, PAR111_new, PAR112_new
  for redefining α_s needed for the calculation of F_L corresponding to the HERACLES code word 'ALFAS'.

- 'CONTINUE'
  to continue execution of the main program, i.e. start reading events and calculating reweighting factors.

The program can be obtained from my www-site: http://www.desy.de/~hspiesb/. It consists of the two files hsrwgt_m.f and hsrwgt_u.f. The latter part contains those subroutines which may be modified by the user to adjust in- and output of events and weights.