Quick User Guide for HELAC-Onia (v0.0.1 20/10/2018)

Collision parameters

```
# beam 1 energy (GeV)
energy_beam1 real

# beam 2 energy (GeV)
energy_beam2 real

# colliding particles: 1=pp, 2=ppbar, 3=e+e-, 4=e+p, 5=e-p, 6=e+pbar, 7=e-pbar
colpar integer

# Fixed-target collision (T) or not (F)
fixtarget boolean
```

Monte Carlo/Integration parameters

```
# Monte Carlo generator: 0 PHEGAS (recommended for event generation) 1 RAMBO 2 DURHAM 3 VEGAS -1 Single Phase Space
gener  integer

# unweighting on/off
unwgt boolean

# n. of pre-unweighted events (used when unwgt=T)
preunw integer

# number of unweighted events in .lhe file (always set unwevt=nmc)
unwevt integer

# number of total phase space points
nmc integer

# technical parameters for PHEGAS (gener = 0)
# always set it to be nmc/10
nopt integer
# always set it to be nmc/10
nopt_step integer
# always set it to be nmc
noptlim integer

# Do Monte Carlo over helicities
# recommended value is 4
ranhel integer
```

Output parameters

```
# topdrawer output file (T) or not (F)
topdrawer_output boolean

# gnuplot output file (T) or not (F)
gnuplot_output boolean

# root output file (T) or not (F)
root_output boolean

# hwu output file (T) or not (F)
hwu_output boolean
```

PDF parameters

```
# Use the Les Houches accord PDF library (only valid when lhapdf are installed)
lhapdf boolean

# PDF number (as in file pdf/pdf_list.txt(uselhapdf=F), PDFsets.index(uselhapdf=T));
# enter 0 to run without PDFs e.g.pdf=10000 cteq6m,pdf=10041 cteq61, pdf=10042 cteq611
pdf integer

# Whether one wants to automatically get the PDF uncertainty (Yes (T), No (F))
# it only works when lhapdf = T
reweight_pdf boolean

# first of the error pdf sets when lhapdf=T and reweight_pdf=T
# e.g. when pdf=21100 (MSTW2008), pdf_min=21101 and pdf_max=21140
#(check PDFsets.index in LHAPDF)
pdf_min integer
# last of the error pdf sets when lhapdf=T and reweight_pdf=T
pdf_max integer
```

Theory parameters

 # interactions : 0=only electroweak, 1=electroweak and QCD, 2=only QCD, 3=only QED, 4=QCD and QED
qcd **integer**

Running of alphas : 0=alpha QCD not running, 1=alpha QCD running
alphasrun **integer**

Gauge (for Z/W propagators only) : 0=Feynman gauge, 1=unitary gauge
gauge **integer**

 # Fixed (0) or complex (1) scheme for the introduction of the width of W and Z
widsch **integer**

The renormalisation/factorisation scale choices
0 means fixed scale; 1 means Sqrt(m1**2+pt1**2); 2 means Sqrt(sum(mi,i=3,n)**2+pt1**2); [others check src/setscale.f90]
Scale **integer**

The value of fixed scale (relevant when Scale = 0)
FScaleValue **real**

The multiplication factor for the central renormalisation/factorisation scale
the true scale is FScaleValue*ScalarFactor (Scale=0),Sqrt(m1**2+pt1**2)*ScalarFactor #(Scale=1),etc
ScaleFactor **real**

The additional multiplication factor for the central renormalisation scale
the true scale is FScaleValue*muR_over_ref (Scale=0),Sqrt(m1**2+pt1**2)*muR_over_ref #(Scale=1),etc
muR_over_ref **real**

The additional multiplication factor for the central factorisation scale
the true scale is FScaleValue*muF_over_ref (Scale=0),Sqrt(m1**2+pt1**2)*muF_over_ref #(Scale=1),etc
muF_over_ref **real**

Whether one wants to automatically get the scale uncertainty (Yes (T), No (F))
reweight_Scale **boolean**

When reweight_Scale = T, the renormalisation/factorisation scale uncertainty will be # calculated via
rw_Rscale_down<mu_R/mu_0<rw_Rscale_up,
rw_FScale_down<mu_F/mu_0<rw_FScale_up
rw_RScale_down **real** 0.5
rw_RScale_up **real** 2.0
rw_FScale_down **real** 0.5
rw_FScale_up **real** 2.0

Kinematical cuts
 # The cuts on the absolute rapidity and absolute pseudorapidity if absoluterap = T
 # Otherwise, the cuts on the rapidity and pseudorapidity
 # e.g. if minyrapconia = 0.0 and maxyrapconia=2.0, the cut 0.0<|y|<2.0 on charmonium #is imposed when absoluterap=T and 0.0<y<2.0 is imposed when absoluterap=F
absoluterap **boolean**

 # transverse momentum cuts

 # minimum lepton pt
minptl **real**

minimum quark pt
minptq **real**

minimum charm pt
minptc **real**

minimum bottom pt
minptb **real**

minimum top pt
minptt **real**

minimum photon pt
minptp **real**

minimum charmonium pt
minptconia **real**

minimum bottomnium pt
minptbonia **real**

minimum Bc pt
minptBconia **real**

maximum lepton pt, negative no such cut
maxptl **real**

maximum quark pt, negative no such cut

```
maxptq real

# maximum charm pt, negative no such cut
maxptc real

# maximum bottom pt, negative no such cut
maxptb real

# maximum top pt, negative no such cut
maxptt -1.0d0

# maximum photon pt, negative no such cut
maxptp real

# maximum charmonium pt, negative no such cut
maxptconia real

# maximum bottomnium pt, negative no such cut
maxptbonia real

# maximum Bc pt, negative no such cut
maxptBconia real

# (pseudo) rapidity cuts

# maximum lepton rapidity
maxrapl real
# maximum lepton y rapidity
maxyrapl real
# minimum lepton y rapidity
minyrapl real

# maximum quark rapidity
maxrapq real
# maximum quark y rapidity
maxyrapq real
# minimum quark y rapidity
minyrapq real

# maximum charm rapidity
maxrapc real
# maximum charm y rapidity
maxyrapc real
# minimum charm y rapidity
minyrapc real

# maximum bottom rapidity
maxrapb 2.d0 real
# maximum bottom y rapidity
maxyrapb real
# minimum bottom y rapidity
minyrapb real

# maximum top rapidity
maxrapt real
# maximum top y rapidity
maxyrapt real
# minimum top y rapidity
minyrapt real

# maximum photon rapidity
maxrapp real
# maximum photon y rapidity
maxyrapp real
# minimum photon y rapidity
minyrapp real

# maximum charmonium rapidity
maxrapconia real
# maximum charmonium y rapidity
maxyrapconia real
# minimum charmonium y rapidity
minyrapconia real

# maximum bottomnium rapidity
maxrapbonia real
# maximum bottomnium y rapidity
maxyrapbonia real
# minimum bottomnium y rapidity
minyrapbonia real

# maximum Bc rapidity
maxrapBconia real
# maximum Bc y rapidity
```

```
maxyrapBconia real
# minimum Bc y rapidity
minyrapBconia real

# separation cuts

# minimum delta R (lepton-lepton)
mindrll real

# minimum delta R (lepton-quark)
mindrlq real

# minimum delta R (quark-quark)
mindrqq real

# minimum delta R (quark-b)
mindrqb real

# minimum delta R (b-b)
mindrbb real

# minimum delta R (photon-fermion)
mindrpf real

# invariant-mass cuts

# minimum lepton-lepton mess
minmll  real

# minimum lepton-quark mass
minmlq  real

# # minimum photon-fermion mass
minmpf  real

# minimum quark-quark mass in the pp(bar) case
minmqqp real

# minimum quark-b mass in the pp(bar) case
minmqb  real

# minimum b-b mass in the pp(bar) case
minmbb  real

# additional cuts

# minimum pt of the first final particle in VEGAS(gener 3)
minpt1c real

# maximum pt of the first final particle in VEGAS(gener 3), negative no cut
maxpt1c real

# maximum rapidity (not pseudo!) for the first final particle
maxy1c  real

# minimum rapidity (not pseudo!) for the first final particle
miny1c  real

# minimum mass u,d,s quarks and gluon with partonic beam in the pp(bar) case
minmqbeam real

# minimum missing transverse momentum
minptmiss real

# Technical kinematical cuts for the first final particle
# minimum Pt of the first final particle
Pt1 real
# maximum rapidity of the first final particle
maxy1c real
# minmum rapidity of the first final particle
miny1c real

# (parton) jet related cuts in pp or ppbar

# minimum jet pt
minptjet real  0d0

# maximum jet pt, negative no such cut
maxptjet real -1.0d0

# maximum jet rapidity, negative no such cut
maxrapjet real  1d0

# 1: kt; 0: C/A; -1: anti-kt
```

```
jet_alg integer -1

# jet radius R
jet_radius real  0.5d0

# number of quark flavour included in jet
jet_n_flavour integer 3

# max number of parton jet, negative no such cut
max_n_jet integer -1

# min number of parton jet, negative no jet related cuts applied
min_n_jet integer -1

# ee cuts
cutoffe 1.0d-3         # cutoff (e+e- case)
minenl 10.0d0          # minimum lepton energy
minenq 10.0d0          # minimum quark energy
minenp 10.0d0          # minimum photon energy
minanglb 5.0d0         # minimum angle (degrees) between lepton and beam
minangqb 5.0d0         # minimum angle (degrees) between quark and beam
minangpb 5.0d0         # minimum angle (degrees) between photon and beam
minangll 5.0d0         # minimum angle (degrees) between lepton and lepton
minanglq 5.0d0         # minimum angle (degrees) between lepton and quark
minangqq 5.0d0         # minimum angle (degrees) between quark and quark
minangpf 5.0d0         # minimum angle (degrees) between photon and fermion
minmqqe 10.0d0         # minimum mass quark with quark in the e+e- case

# decay cuts
decay_minptl  0d0      # minimum pt of lepton from decay
decay_maxycl  1d9      # maximum y rapidity of lepton from decay
decay_minycl  0d0      # minimum y rapidity of lepton from decay
decay_maxrapl 1d9      # maximum pesudo rapidity of lepton from decay
decay_minel   0d0      # minimum energy of lepton from decay
decay_maxcl   1d0      # maximum cos angle between beam and lepton from decay

Theory Constants
# Fermi coupling constant
gfermi real  1.16639d-5
# not running value of the strong coupling (used only if alphasrun is 0)
alphas2 real  0.118d0
# Z mass
zmass real  91.188d0
# Z width
zwidth real 2.446d0
# W mass
wmass real  80.419d0
# W width
wwidth real  2.048d0
# squared sinus of Weinberg angle; if set to -1, sin2thetaw = 1-(wmass/zmass)**2
sin2thetaw real -1
# fine structure constant; if set to -1, alphaem = sqrt(2)*gfermi*(wmass**2)*sin2thetaw/pi
alphaem real -1
# Higgs mass
higmass real  126.0d0
# Higgs width
higwidth real  4.291d-3
# electron mass
emass real  0.0d0
# muon mass
mumass real  0.0d0
# tau mass
taumass real  0.0d0
# electronic neutrino mass
nemass real  0.0d0
# muonic neutrino mass
nmumass real  0.0d0
# tau neutrino mass
ntaumass real  0.0d0
# up quark mass
umass real  0.0d0
# down quark mass
dmass real  0.0d0
# strange quark mass
smass real  0.0d0
# charm quark mass
cmass real  0.0d0
# bottom quark mass
bmass real  0.0d0
# top quark mass
tmass real  174.3d0
# top quark width
twidth real  1.6d0
```

Quarkonium specific parameters

```
# If one wants to get 3pj (j=0,1,2) individually (usually used for calculating 3PJ[1] for chi_{QJ}), please # set exp3pjQ=T.
Otherwise, it will calculate the sum of 3pj (j=0,1,2), which is usually used for
# calculating 3PJ[8] with heavy quark spin symmetry).
exppjQ  boolean

# Long Distance Matrix Element For Heavy Quarkonia
# Long Distance Matrix Element <O(3S1[1])>=|R(0)|^2/4/Pi
# in JHEP 02 (2008) 102  <O(3S1[1])>=(2J+1)*2Nc*|R(0)|^2/4/Pi,
# i.e. LDME****1=<O(2S+1)LJ[1]>/2Nc/(2J+1)
# For P-wave <O(3P0[1])>=<O(3P1[1])>=<O(3P2[1])>=3*|R'(0)|^2/4/Pi
# in JHEP 02 (2008) 102 LDME****8=<O((2S+1)LJ[8])>/(Nc^2-1)/(2J+1)

# Charmonium System
LDMEcc1S01 0.0644578d0   # LDME for 1S0[1] charmonium
LDMEcc3S11 0.0644578d0   # LDME for 3S1[1] charmonium
LDMEcc1P11 0.0179049d0    # LDME for 1P1[1] charmonium
LDMEcc3P01 0.0179049d0    # LDME for 3P0[1] charmonium
LDMEcc3P11 0.0179049d0    # LDME for 3P1[1] charmonium
LDMEcc3P21 0.0179049d0    # LDME for 3P2[1] charmonium
LDMEcc1S08 0.95d-2       # LDME for 1S0[8] charmonium
LDMEcc3S18 0.265d-2      # LDME for 3S1[8] charmonium
LDMEcc1P18 0.134287d-2   # LDME for 1P1[8] charmonium
LDMEcc3P08 0.134287d-2   # LDME for 3P0[8] charmonium
LDMEcc3P18 0.134287d-2   # LDME for 3P1[8] charmonium
LDMEcc3P28 0.134287d-2   # LDME for 3P2[8] charmonium

# Bottomnium System
LDMEbb1S01 0.515556d0    # LDME for 1S0[1] bottomnium
LDMEbb3S11 0.515556d0    # LDME for 3S1[1] bottomnium
LDMEbb1P11 0.515556d0    # LDME for 1P1[1] bottomnium
LDMEbb3P01 0.515556d0    # LDME for 3P0[1] bottomnium
LDMEbb3P11 0.515556d0    # LDME for 3P1[1] bottomnium
LDMEbb3P21 0.515556d0    # LDME for 3P2[1] bottomnium
LDMEbb1S08 0.386667d-2   # LDME for 1S0[8] bottomnium
LDMEbb3S18 0.386667d-2   # LDME for 3S1[8] bottomnium
LDMEbb1P18 0.386667d-2   # LDME for 1P1[8] bottomnium
LDMEbb3P08 0.386667d-2   # LDME for 3P0[8] bottomnium
LDMEbb3P18 0.386667d-2   # LDME for 3P1[8] bottomnium
LDMEbb3P28 0.386667d-2   # LDME for 3P2[8] bottomnium

# Bc System
LDMEbc1S01 0.122667d0    # LDME for 1S0[1] Bc
LDMEbc3S11 0.122667d0    # LDME for 3S1[1] Bc
LDMEbc1P11 0.0478333d0   # LDME for 1P1[1] Bc
LDMEbc3P01 0.0478333d0   # LDME for 3P0[1] Bc
LDMEbc3P11 0.0478333d0   # LDME for 3P1[1] Bc
LDMEbc3P21 0.0478333d0   # LDME for 3P2[1] Bc
LDMEbc1S08 0.920004d-3   # LDME for 1S0[8] Bc
LDMEbc3S18 0.920004d-3   # LDME for 3S1[8] Bc
LDMEbc1P18 0.35875d-3    # LDME for 1P1[8] Bc
LDMEbc3P08 0.35875d-3    # LDME for 3P0[8] Bc
LDMEbc3P18 0.35875d-3    # LDME for 3P1[8] Bc
LDMEbc3P28 0.35875d-3    # LDME for 3P2[8] Bc

# P-wave LDME subtraction counterterm via RG in NRQCD (check arXiv:1809.02369)
# a flag to determine whether calculate the subtraction counterterm via MSbar subtraction
calc_LDME_RG_CT  F
# the NRQCD renormalization scale
muNRQCD  1.5d0
```

Nuclear effects in pA or AA collisions

```
# nuclear PDF id; 0: proton, 1: EPS08, 2: EPS09, 3: EPS09LO, 4: EPS09NLO 301-331: EPS09LO,n, 401-431: EPS09NLO,n, 5: EKS98,
1000: use the faked nuclear PDF in LHAPDF6 (make sure the last two are proton PDF).
# It can be used only when using LHAPDF and set lhapdf=T
nPDF_id  integer

# reweight to get nPDF uncertainty, only works when lhapdf = T
reweight_npdf boolean

# the first of the error npdf sets (relevant only when reweight_npdf=T and lhapdf=T)
# if nPDF_id=1000 (and one uses LHAPDF6), its LHAID should be (pdf (central one)+npdf_min-1000)
# usually it is 1001
npdf_min integer

# the last of the error npdf sets (relevant only when reweight_npdf=T and lhapdf=T)
# if nPDF_id=1000 (and one uses LHAPDF6), its LHAID should be (pdf (central one)+npdf_max-1000)
npdf_max integer

# the isospin symmetry should be taken into account by EPS08, EPS09 (in LHAPDF5) and nCTEQ15_*_* (in
# LHAPDF6) but not by nCTEQ15FullNuc_*_* (with 'FullNuc' tag in LHAPDF6) as it has already been taken into
# account by PDF itself.
npdf_isospin boolean


# include reference collision (pp for pA/Ap, (pp,pB,Ap) for AB)
include_ref boolean

# A of nuclear of beam 1, 0: it is proton/(anti-)proton
nuclearA_beam1  integer

# A of nuclear of beam 2, 0: it is proton/(anti-)proton
nuclearA_beam2  integer

# A model for fermion motion

# To include the fermion motion effect (T) or not (F) in pA mode
fermion_motion  boolean

# The default value is 0.26 GeV of pF for fermion_motion
pmax_fermion_motion real
```

Jet-like cuts to mimic some NNLO topologies for quarkonia cuts in pp or ppbar collisions, see arXiv:1809.02369

```
use_stop_cut F        # whether use stop cuts (following cuts will be ignored if it is F)
stop_minptjet 5d0     # minimum jet pt cut (include onium in the jet clustering)
stop_maxrapjet 5d0    # max jet rapidity, negative no such a cut
stop_zcut  0.1d0      # zcut in the soft drop
stop_beta  -1d0       # beta in the soft drop (negative to make it collinear safe)
stop_jet_alg -1        # 1: kt; 0: C/A; -1: anti-kt
stop_jet_radius 1.0d0  # jet radius R
stop_jet_dyn_radius -1d0 # if it is > 0, it will use dynamical jet radius
R=max[stop_jet_radius,stop_jet_dyn_radius*M_{onium}/P_T^{onium}]
                        # the recommendated one is 2d0 if one wants to use dynamical jet radius.
stop_min_n_jet 2     # min number of jet (should be n hard jet + 1 onium jet), negative no such a cut
stop_max_n_jet -1    # max number of jet, negative no such a cut
stop_n_frag_gluon 0  # minimal number of final gluon in the LO fragmentation process
stop_n_frag_quark 0  # minimal number of final bare quark in the LO fragmentation process
stop_zsoftcut 0.2d0  # z_{s,cut} for the soft cut applied to (stop_n_frag_gluon+stop_n_frag_quark)==0
                     # It will be divided by number of partons inside the onium jet
stop_zasymcut 0.3d0  # asymmetric cut for the parton jets if the number of parton jets are >= 2
```

Parton Shower

```
# A switch for ISR shower in e+e- (check arXiv:1402.5840)
# 0: no ISR shower; 1: ISR by QEDPS
emep_ISR_shower integer

# Do parton shower with general-purpose Monte Carlo PYTHIA8 when Les Houches Event file is generated
# 0: no shower (one can do it manually with the generated Les Houches Event file)
# 1: shower by PYTHIA8
parton_shower integer
```