The CCFM Monte Carlo generator \texttt{CASCADE}

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Abstract

\texttt{CASCADE} is a full hadron level Monte Carlo event generator for $ep$, $\gamma p$ and $p\bar{p}$ processes, which uses the CCFM evolution equation for the initial state cascade in a backward evolution approach supplemented with off-shell matrix elements for the hard scattering. A detailed program description is given, with emphasis on parameters the user wants to change and common block variables which completely specify the generated events.

1 Tabular Summary

| program name      | \texttt{CASCADE} |
|-------------------|------------------|
| version           | 1.00/01          |
| date of latest version | July 2001        |
| author            | Hannes Jung (Hannes.Jung@desy.de) |
| program size      | $\sim$ 8000 lines of code |
| input files needed | ccfm.dat (kms.dat, kmr.dat) |
| computer types    | any with standard Fortran 77, tested on SGI, HP-UX, SUN, PC |
| operating systems | Unix, Linux |
| applicability     | Deep Inelastic $ep$ Scattering  
|                   | Photo-production in $ep$ Scattering  
|                   | $\gamma p$ Scattering  
|                   | heavy quark production in $pp$ and $p\bar{p}$ Scattering |
| hard sub-processes included | $\gamma^* g^* \rightarrow q\bar{q}, Q\bar{Q}$  
|                   | $\gamma g^* \rightarrow J/\psi g$  
|                   | $g^* g^* \rightarrow q\bar{q}, Q\bar{Q}$ |
| QCD cascade       | initial state parton shower according to CCFM |
| fragmentation model | LUND string |
| other programs called | \texttt{PYTHIA} 6.1, \texttt{BASES}/\texttt{SPRING} 5.1 |
| availability      | http://www.quark.lu.se/~hannes/cascade/ |
2 The CCFM evolution equation

The formulation of the CCFM [1, 2, 3, 4] parton evolution for the implementation into a full hadron level Monte Carlo program is described in detail in [5, 6]. Here only the main results are summarized and discussed for the case of lepton production.

Figure 1 shows the pattern of QCD initial-state radiation in a small-\(x\) DIS event, together with labels for the kinematics. According to the CCFM evolution equation, the emission of partons during the initial cascade is only allowed in an angular-ordered region of phase space. The maximum allowed angle \(\Xi\) for any gluon emission sets the scale \(\bar{q}\) for the evolution and is defined by the hard scattering quark box, which connects the exchanged gluon to the virtual photon. In terms of Sudakov variables the quark pair momentum is written as:

\[
p_q + p_q = Y(p_p + \Xi p_e) + Q_t
\]

where \(p_p\) and \(p_e\) are the proton and electron momenta, respectively and \(Q_t\) is the transverse momentum of the quark pair and \(Y\) is its light-cone momentum fraction. The scale \(\bar{q}\) is related to the maximum angle \(\Xi\) via \(\bar{q} = x_n \sqrt{\Xi s}\), with \(s\) being the squared center of mass energy \(s = (p_e + p_p)^2\).

The CCFM evolution equation can be written in a differential form [4], which is best suited for a backward evolution approach adopted in the Monte Carlo generator CASCADE [5, 6]:

\[
\frac{q^2}{d\bar{q}^2} \frac{d}{dx} \frac{x A(x, k_t, \bar{q})}{\Delta_s(\bar{q}, Q_0)} = \int dz d\phi \frac{\tilde{P}(z, \bar{q}/z, k_i)}{2\pi \Delta_s(\bar{q}, Q_0)} x' A'(x', k'_t, \bar{q}/z)
\]

Figure 1: Kinematic variables for multi-gluon emission. The \(t\)-channel gluon four-vectors are given by \(k_i\) and the gluons emitted in the initial state cascade have four-vectors \(p_i\). The maximum angle for any emission is obtained from the quark box, as indicated with \(\Xi\).
where $A(x, k_t, \bar{q})$ is the unintegrated gluon density, depending on $x$, $k_t$ and the evolution variable $\bar{q}$. The splitting variable is $z = x/x'$ and $\vec{k}_t' = (1 - z)/z\vec{q} + \vec{k}_t$, where the vector $\vec{q}$ is at an azimuthal angle $\phi$. The Sudakov form factor $\Delta_s$ is given by:

$$\Delta_s(\bar{q}, Q_0) = \exp \left( - \int_{Q_0}^{q_2^2} \frac{dq^2}{q^2} \int_0^{1-Q_0/q} dz \frac{\bar{\alpha}_s(q^2(1-z)^2)}{1-z} \right)$$

(3)

with $\bar{\alpha}_s = \frac{4\alpha_s}{\pi} = \frac{3\alpha_s}{\pi}$. For inclusive quantities at leading-logarithmic order the Sudakov form factor cancels against the $1/(1 - z)$ collinear singularity of the splitting function.

The splitting function $\tilde{P}_g(z_i, q_i, k_{ti})$ for branching $i$ is given by:

$$\tilde{P}_g(z_i, q_i, k_{ti}) = \bar{\alpha}_s(q_i^2(1-z_i)^2) + \frac{\bar{\alpha}_s(k_{ti}^2)}{z_i} \Delta_{ns}(z_i, q_i^2, k_{ti}^2)$$

(4)

where the non-Sudakov form factor $\Delta_{ns}$ is defined as:

$$\log \Delta_{ns} = -\bar{\alpha}_s(k_{ti}^2) \int_0^{z_i} \frac{dz'}{z'} \int dq^2 \Theta(k_{ti} - q) \Theta(q - z'q_{ti})$$

(5)

The splitting function $\tilde{P}(z, q, k_t)$ in eq.(4) contains only the singular parts in $z$ and $(1 - z)$. The finite terms in the splitting function are neglected, since they are not obtained in CCFM at the leading infrared accuracy [3, p.72]. As soon as they become available they can be easily implemented into the Monte Carlo generator.

### 3 Backward evolution: CCFM and CASCADE

The idea of a backward evolution [4, 5] is to first generate the hard scattering process with the initial parton momenta distributed according to the parton distribution functions. This involves in general only a fixed number of degrees of freedom, and the hard scattering process can be generated quite efficiently. The initial state cascade is generated by going backwards from the hard scattering process towards the beam particles.

According to the CCFM equation the probability of finding a gluon in the proton depends on three variables, the momentum fraction $x$, the transverse momentum squared $k_t^2$ of the exchanged gluons and the scale $\bar{q} = x_n \sqrt{s\Xi}$, which is related to the maximum angle allowed for any emission $\Xi$. To solve eq.(2) the unintegrated gluon distribution $A(x, k, \bar{q})$ has to be determined beforehand.

Given this distribution, the generation of a full hadronic event is separated into three steps, as implemented in the hadron-level Monte Carlo program CASCADE:

- The hard scattering process is generated,

$$\sigma = \int dk_t^2 dx_g A(x_g, k_t, \bar{q}) \sigma(\gamma^* g^* \rightarrow X) ,$$

(6)
with $X$ being $q\bar{q}$, $Q\bar{Q}$ or $J/\psi g$ states. The hard cross section is calculated using the off-shell matrix elements given in [9, p. 178 ff] for $q\bar{q}$ and $Q\bar{Q}$ or for the case of $\gamma g^* \rightarrow J/\psi g$ in [10]. The gluon momentum is given in Sudakov representation:

$$k = x_gp_p + \bar{x}_gp_e + k_t \approx x_gp_p + k_t.$$  

(7)

where the last expression comes from the high energy approximation ($x_g \ll 1$), which then gives $-k^2 \approx k_t^2$.

- The initial state cascade is generated according to CCFM in a backward evolution approach.
- The hadronization is performed using the Lund string fragmentation implemented in PYTHIA /JETSET[11].

The backward evolution there faces one difficulty: The gluon virtuality enters in the hard scattering process and also influences the kinematics of the produced quarks and therefore the maximum angle allowed for any further emission in the initial state cascade. This virtuality is only known after the whole cascade has been generated, since it depends on the history of the gluon evolution (as $\bar{x}_g$ in eq.(7) may not be neglected for exact kinematics). In the evolution equations itself it does not enter, since there only the longitudinal energy fractions $z$ and the transverse momenta are involved. This problem can only approximately be overcome by using $k^2 = k_t^2/(1 - x_g)$ for the virtuality which is correct in the case of no further gluon emission in the initial state.

The Monte Carlo program CASCADE can be used to generate unweighted full hadron-level events, including initial-state parton evolution according to the CCFM equation and the off-shell matrix elements for the hard scattering process. It is applicable for $p\bar{p}$, photo-production as well as for deep inelastic scattering. The typical time needed to generate one event is $\sim 0.03$ sec on a Pentium II (266 MHz), which is similar to the time needed by standard Monte Carlo event generators such as LEPTO [12] or PYTHIA [11].

### 3.1 The unintegrated gluon density

The CCFM unintegrated gluon density $x\mathcal{A}(x, k_t, \bar{q})$ is obtained from a forward evolution procedure as implemented in SMALLX [13, 14] by a fit to the measured structure function $F_2$ as described in [5, 6]. From the initial gluon distribution a set of values $x$ and $k_t$ are obtained by evolving up to a given scale $\log \bar{q}$ using the forward evolution procedure. This is repeated $10^8$ times thus obtaining a distribution of the unintegrated gluon density $x\mathcal{A}(x, k_t, \bar{q})$ for the slice of phase space with a given $\bar{q}$ ($\bar{q} > q_{n}$). To obtain a distribution in $\log \bar{q}$, the above procedure is repeated from the beginning 50 times for the different grid points in $\log \bar{q}$ up to $\bar{q} = 1800$ GeV. Due to the complicated structure of the CCFM equation, no attempt is made to parameterize the unintegrated gluon density. Instead, the gluon density is calculated on a grid in $\log x$, $\log k_t$ and $\log \bar{q}$ with $50 \times 50 \times 50$ points and a linear interpolation is used to obtain the gluon density for values in between the grid points. The data file (ccfm.dat) containing the $50 \times 50 \times 50$ grid points is read in at the beginning of the program.

The parameter IGLU offers the possibility to compare the CCFM unintegrated gluon density $x\mathcal{A}(x, k_t, \bar{q})$ (IGLU=1) with other unintegrated gluon densities published: a simple numerical
derivative of a standard integrated gluon density \( \frac{dG(x,Q^2)}{dq^2} \) taken from [15] (IGLU=2), the one in the approach of Blümelin [16] and coded by [17, 18] (IGLU=3), the unintegrated gluon density of KMS [19] (IGLU=4, stored in kms.dat), the one of the saturation model by [20] (IGLU=5) and the one of KMR [21] (IGLU=6, stored in kmr.dat).

Except for the default CCFM unintegrated gluon density with (IGLU=1), no initial state parton shower can be generated, because the angular variable, essential for angular ordering in the initial state cascade, is not present. However, the transverse momenta of the incoming partons are properly treated.

3.2 \( \alpha_s \) and the choice of scales

The strong coupling \( \alpha_s \) is calculated via the PYTHIA [11] subroutine PYALPS. Maximal and minimal number of flavors used in \( \alpha_s \) are set by MSTU(113),MSTU(114), \( \Lambda_{QCD} = \text{PARU}(112) \) with respect to MSTU(112) flavors and stored in the PYTHIA common COMMON/PYDAT1/. In the initial state cascade according to CCFM, the transverse momenta of the \( t \)-channel gluons are allowed to perform a random walk for small \( z \) values and \( k_t \) can become very small. In the \( 1/z \) part of the splitting function we use \( \mu = k_t \) as the scale in \( \alpha_s(\mu) \) and in the \( 1/(1-z) \) part \( \mu = (1-z)q_t \) is used. In addition we require \( \mu > Q_0 = 1.4 \text{ GeV} \), resulting in \( \alpha_s(\mu > Q_0) < 0.6 \). The parameter \( Q_0 = 1.4 \text{ GeV} \) was determined from the requirement to describe the structure function \( F_2 \) as described in [5, 6].

The scale \( \mu \) which is used in \( \alpha_s \) in the hard scattering matrix element can be changed with the parameter IQ2, the default choice is \( \mu^2 = p_t^2 \).

3.3 Quark masses

The quark mass for light quarks (\( u,d,s \)) is fixed to \( m_q = 0.140 \text{ GeV} \). This, together with the treatment of \( \alpha_s \) at small scales \( \mu \), gives also a reasonable total cross-section for photo-production at HERA energies. The masses for heavy quarks are given by the JETSET / PYTHIA defaults (\( m_c = 1.5 \text{ GeV}, m_b = 4.8 \text{ GeV} \)) and can be changed according to the PYTHIA prescription.

3.4 Leptoproduction

CASCADE can be used to simulate leptoproduction events over the whole \( Q^2 \) range. By fixing the light quark masses to \( m_q = 0.140 \text{ GeV} \) and \( \alpha_s \) for small \( \mu \), the hard scattering matrix element remains finite over the full phase space. The total cross section is simulated by selecting IPRO=10 and NFLAV=4(5). With IPRO=10 light quarks (\( u,d,s \)) are selected and with NFLAV>3 the program automatically includes heavy flavor production via the process IPRO=11 and IHFLA=4 up to IHFLA=NFLAV.

Heavy flavor production can be generated separately via IPRO=11. The value of IHFLA determines the heavy flavor to be generated.

The matrix element for \( \gamma g^* \to J/\psi g \) calculated in [10] is available for quasi-real \( \gamma \)'s via the process IPRO=2.

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1A. Stasto kindly provided the program.
2M. Kimber kindly provided the program.
3.5 **Photoproduction**

CASCADE can be used to simulate real photoproduction events by using \( KE=22 \). The same options as for leptoproduction are available.

3.6 **Hadroproduction**

CASCADE can be used to simulate heavy quark production in \( pp \) or \( p\bar{p} \) collisions (\( IPR0=14 \) for heavy flavor production, and \( IHFIA=4(5) \) for charm (bottom) quarks). The flavor code (\( KE \)) for beam 1 can be chosen as \( KE=2212 \) for proton or \( KE=-2212 \) for anti-proton, beam 2 is always a proton.

3.7 **Initial and final state parton shower**

Initial state parton showers are generated in a backward evolution approach described in detail in [3, 4]. The initial state parton shower consists only of gluon branchings and is generated in an angular ordered region in the laboratory frame. In the present version, the gluons emitted during the branchings are treated on-mass shell, and no further time-like branching occurs.

All parameters (like the scale \( \mu \) in \( \alpha_s \), the collinear cut-off \( Q_0 \)) for the initial state cascade are fixed from the determination of the unintegrated gluon density. The transverse momenta of the partons which enter the hard scattering matrix element are already generated in the beginning and are not changed during the whole initial and final state parton showering (in contrast to standard DGLAP type parton shower Monte Carlo generators like PYTHIA [11] or LEPTO [12]).

The final state parton shower uses the parton shower routine PYSHOW of PYTHIA with the scale \( QMAX=(m_1\perp + m_2\perp)/2 \), with \( m_{1(2)}\perp \) being the transverse mass of the hard parton 1(2).

3.8 **Remnant treatment**

The proton remnant is built in subroutine CAREMN, which is a slightly modified version of the PYTHIA / LEPTO subroutine PYREMN. In the present version no intrinsic transverse momentum, in addition to the transverse momentum from the initial state cascade, is included.

4 **Description of the program components**

In CASCADE all variables are declared Double Precision. The Lund string model is used for hadronization as implemented in PYTHIA 6.1 [1]. The final state QCD radiation is performed via PYSHOW from PYTHIA 6.1. The treatment of the proton remnant follows very closely the ones in LEPTO[12] for the leptoproduction case and the one in PYTHIA 6.1 for the proton-proton case. However slight modifications were needed to adapt to the cascade treatment here.

The unintegrated gluon density is stored on data files (ccfm.dat, kms.dat, kmr.dat), and is read in at the beginning of the program.

The program has to be loaded together with PYTHIA 6, to ensure that the double precision code of JETSET is loaded.
4.1 Random number generator

Since the variables are declared in double precision, also a double precision random number generator has to be used to avoid any bias. The function `DCASRN` gives a single random number, the function `DCASRNV` returns an array of length `LEN` of random numbers. The default random number generator is `RM48` (called in `DCASRN` and `DCASRNV`) from CERNLIB. The user can change this to any preferred Double Precision random number generator.

4.2 Integration and event generation

The integration of the total cross section and the generation of unweighted events is performed with the help of BASES/SPRING [22].

4.3 Subroutines and functions

The source code of CASCADE and this manual can be found under:
http://www.quark.lu.se/~hannes/cascade/

- **CAMAIN** main program.
- **CASINI** to initializes the program.
- **CASCADE** to perform integration of the cross section. This routine has to be called before event generation can start.
- **CAEND** to print the cross section and the number of events.
- **CAUNIGLU(KF,X,KT,P,XPQ)** to extract the unintegrated gluon density \( x, A(x, k_t, \bar{q}) \) for a proton with \( KF=2212 \), as a function of \( x = X, k_t = KT \) and \( \bar{q} = P \). The gluon density is returned in \( XPQ(0) \), where \( XPQ \) is an array with \( XPQ(-6:6) \).
- **EVENT** to perform the event generation.
- **ALPHAS(RQ)** to give \( \alpha_s(\mu) \) with \( \mu = RQ \).
- **PARTI** to give initial particle and parton momenta.
- **FXN1** to call routines for selected processes: **XSEC1**.
- **CUTG(IPRO)** to cut on \( p_t \) for \( 2 \rightarrow 2 \) process in integration and event generation.
- **MEOFFSH** matrix element for \( \gamma^* g^* \rightarrow q \bar{q} \) and \( g^* g^* \rightarrow q \bar{q} \) including masses. \( q \) can be light or heavy quarks.
- **DOT(A,B)** four-vector dot product of \( A \) and \( B \).
- **DOT1(I,J)** four-vector dot product of vectors \( I \) and \( J \) in PYJETS common.
- **PHASE** to generate momenta of final partons in a \( 2 \rightarrow 2 \) subprocess according to phase space
- **P_SEMIH** to generate kinematics and the event record for \( ep, \gamma p \) and \( p \bar{p} \) processes.
- **CAREMN(IPU1,IPU2)** to generate the beam remnants. Copied from LEPTO 6.1 [12] and updated for the use in CASCADE.
- **CASPLI(KF,KPA,KFSP,KFCH)** to give the spectator \( KFSP \) and \( KFCH \) partons when a parton \( KPA \) is removed from particle \( KF \). Copied from LEPTO 6.1 [12] and updated for the use CASCADE.
- **CAPS** to generate color flow for all processes and prepare for initial and final state parton showers.
- **CASCPS(IPU1,IPU2)** to generate initial state radiation.
- **GADAP** Gaussian integration routine for 1-dim and 2-dim integration. Copied from LEPTO 6.1 [12].
4.4 Parameter switches

BASES/SPRING Integration procedure.

NCAL: (D:=20000) Nr of calls per iteration for bases.
ACC1: (D:=1) relative precision (in %) for grid optimization.
ACC2: (D:=0.5) relative precision (in %) for integration.

4.4.1 Parameters for kinematics

PLEPIN: (D:=−30) momentum \( p \) [GeV/c] of incoming electron (/INPU/).
PIN: (D:=820) momentum \( p \) [GeV/c] of incoming proton (/INPU/).
QMI: (D:=5.0) (/VALUES/) minimum \( Q^2 \) to be generated.
QMA: (D:=10\(^8\)) (/VALUES/) maximum \( Q^2 \) to be generated.
YMI: (D:=0.0) (/VALUES/) minimum \( y \) to be generated.
YMA: (D:=1.0) (/VALUES/) maximum \( y \) to be generated.
THEMA,THEMI (D: THEMA = 180., THEM = 0) maximum and minimum scattering angle \( \theta \) of the electron (/CAELEC/).
NFLAV (D: = 5) number of active flavors, can be set by user (/CALUCO/).

4.4.2 Parameters for hard subprocess selection

IPRO: (D:=10) (/CAPAR1/) selects hard subprocess to be generated.

=2: \( \gamma^*g \rightarrow J/\psi g \)
=10: \( \gamma^*g \rightarrow q\bar{q} \) for light quarks.
=11: \( \gamma^*g \rightarrow Q\bar{Q} \) for heavy quarks.

PT2CUT(IPRO): (D=0.0) minimum \( \hat{p}_\perp^2 \) for process IPRO (/CAPTCUT/).

4.4.3 Parameters for parton shower and fragmentation

NFRAG: (D:=1) switch for fragmentation (/CAINPU/).

= 0 off
= 1 on

IFPS: (D:=3) switch parton shower (/CAINPU/).

= 0 off
= 1 initial state
= 2 final state
= 3 initial and final state

ICCFM: (D:=1)

= 1 CCFM evolution.

4.4.4 Parameters for structure functions \( \alpha_s \) and scales

IRUNAEM: (D:=0) (/CAPAR1/) select running of \( \alpha_{em}(Q^2) \).

=0: no running of \( \alpha_{em}(Q^2) \)
=1: running of \( \alpha_{em}(Q^2) \)

IRUNA: (D:=1) switch for running \( \alpha_s \).

=0: fixed \( \alpha_s = 0.3 \)
=1: running $\alpha_s(\mu^2)$

**IQ2:**

(D: = 3) select scale $\mu^2$ for $\alpha_s(\mu^2)$.
=1: $\mu^2 = 4 \cdot m_q^2$ (use only for heavy quarks!)
=2: $\mu^2 = \hat{s}$ (use only for heavy quarks!)
=3: $\mu^2 = 4 \cdot m^2 + p_\perp^2$
=4: $\mu^2 = Q^2$
=5: $\mu^2 = Q^2 + p_\perp^2$

**IGLU:**

(D: = 1) select unintegrated gluon density/GLUON/.

Note for IGLU > 1, all initial state parton showers are switched off.
=1: CCFM unintegrated gluon (ccfm.dat).
=2: derivative of GRV [15] $dx_g(x,Q^2)$.
=3: approach of Blümlein [16].
=4: KMS [19] (kms.dat).
=5: saturation model [20].
=6: KMR [21] (kmr.dat).

### 4.4.5 Accessing information

**AVGI**

integrated cross section (/CAEFFIC/).

**SD**

standard deviation of integrated cross section (/CAEFFIC/).

**SSS**

squared center of mass energy $s$ (/CAPARTON/).

**PBEAM**

energy momentum vector of beam particles (/CABEAM/).

**KBEAM**

flavor code of beam particles (/CABEAM/).

**Q2**

in leptoproduction: actual $Q^2$ of $\gamma$ (/CAPAR4/).

**YY**

negative light-cone momentum fraction of parton 1 ($\gamma^*, g^*$) (/CASGKI/).

**YY_BAR**

positive light-cone momentum fraction parton 1 ($\gamma^*, g^*$) (/CASGKI/).

**XG**

positive light-cone momentum fraction of parton 2 ($g^*$) (/CASGKI/).

**XG_BAR**

negative light-cone momentum fraction of parton 2 ($g^*$) (/CASGKI/).

**KT2_1,KT2_2**

transverse momenta squared $k_{1,2}^2$ [GeV$^2$] of partons 1(2) which enter to the matrix element.

**YMAX,YMIN**

actual upper and lower limits for $y$ =YY (/CAPAR5/).

**Q2MAX,Q2MIN**

actual upper and lower limits for $Q^2$ (corresponding to KT2_1) of $\gamma$ (/CAPAR5/).

**XMAX,XMIN**

upper and lower limits for $x$ (/CAPAR5/).

**AM(18)**

vector of masses of final state particles of hard interaction (/CAPAR3/).

**SHAT**

invariant mass $\hat{s}$ [GeV$^2$] of hard subprocess (/CAPAR5/).

**NIA1,NIA2**

position of partons in hard interaction in PYJETS event record (/CAHARD/).

**NF1,NF2**

first and last position final partons/particles of hard interaction in PYJETS (/CAHARD/).

**Q2Q**

hard scattering scale $\mu^2$ used in $\alpha_s$ and structure functions (/CAPAR4/).

**ALPHS**

actual $\alpha_s$ (/CAPAR2/).

**ALPH**

$\alpha_{em}$ (/CAPAR2/).

**NIN**

number of trials for event generation (/CAEFFIC/).

**NOUT**

number of successful generated events (/CAEFFIC/).
4.5 List of COMMON blocks

COMMON/CABEAM/PBEAM(2,5),KBEAM(2,5),KINT(2,5)
COMMON/CAHARD/ NIA1,NIA2,NIR2,NF1,NF2
COMMON/CAHFLAV/ IHFLA
COMMON/CAINPU/PLEPIN,PPIN,NFRAG,ILEPTO,IFPS,IHF,INTER,ISEMIH
COMMON/CALUCO/KE,KP,KEB,KPH,KGL,KPA,NFLAV
COMMON/CAEFFIC/AVGI,SD,NIN,NOUT
COMMON/CAELEC/THEMA,THEMI
COMMON/CAGLUON/IGLU
COMMON/CAPAR1/IPRO,IRUNA,IQ2,IRUNAEM
COMMON/CAPAR2/ALPHS,PI,ALPH,IWEI
COMMON/CAPAR3/AM(18),PCM(4,18)
COMMON/CAPAR4/Q2,Q2Q
COMMON/CAPAR5/SHAT,YMAX,YMIN,Q2MAX,Q2MIN,XMAX,XMIN
COMMON/CAPAR6/LST(30),IRES(2)
COMMON/CAPARTON/SSS,CM(4),DBCMS(4)
COMMON/CAPTCUT/PT2CUT(20)
COMMON/CASKIN/YY,YY_BAR,XG,XG_BAR,KT2_1,KT2_2,PT2H,SHH
COMMON/VALUES/QMI,YMI,QMA,YMA

5 Example Program

PROGRAM CASMAIN
Implicit None
Integer N1,N2
REAL PLEPIN,PPIN
INTEGER KE,KP,KEB,KPH,KGL,KPA,NFRAG,ILEPTO,IFPS,IHF
INTEGER INTER,ISEMIH
INTEGER NIA1,NIR1,NIA2,NIR2,NF1,NF2,NFT,NFLAV
COMMON/CALUCO/KE,KP,KEB,KPH,KGL,KPA,NFLAV
COMMON/CAINPU/PLEPIN,PPIN,NFRAG,ILEPTO,IFPS,IHF,INTER,ISEMIH
COMMON/CAHARD/ NIA1,NIA2,NIR2,NF1,NF2
INTEGER IHFLA
COMMON/CAHFLAV/ IHFLA

DOUBLE PRECISION THEMA,THEMI,PT2CUT
INTEGER IRUNA,IQ2,IRUNAEM
INTEGER IPRO
COMMON/CAPAR1/IPRO,IRUNA,IQ2,IRUNAEM
COMMON/CAELEC/ THEMA,THEMI
COMMON/CAPTCUT/PT2CUT(20)
REAL ULALPS,ULALEM
EXTERNAL ULALPS,ULALEM
DOUBLE PRECISION QMI,YMI,QMA,YMA
COMMON/VVALUES/QMI,YMI,QMA,YMA

Integer Iglu
Common/CAGLUON/Iglu

Integer ISEED,I

ISEED = 124567
n1=0
n2=0
C initialize random number generator
   CALL RM48IN(ISEED,N1,N2)
C initialize PYTHIA 6 parameters
   CALL GPYINI
C initialize CASCADE parameters
   CALL CASINI

C Select parton shower (IPS=1 initial, =2 final, 3 initial+final PS )
   IFPS = 3
C scale for alpha_s
C I2Q =1 mu^2 = m_q^2 (m_q = light quark or heavy quark depending on IPRO)
C I2Q =2 mu^2 = shat
C I2Q =3 mu^2 = m_q^2 + pt^2 (m_q = light quark or heavy quark depending on IPRO)
C I2Q =4 mu^2 = q^2 (q^2 of virtual photon)
C I2Q =5 mu^2 = q^2 + pt^2 (q^2 of virtual photon)
   IQ2=3
C select process (IPRO=10 for light quarks, IPRO=11 for heavy quarks)
   IPRO= 10
C total number of flavors involved
   NFLAV = 4
C select unintegrated gluon density (D=1)
   Iglu = 1
C minimum Q^2 of electron to be generated
   QMI = 0.5d0
C maximum Q^2 of electron to be generated
   QMA = 10D8
C minimum y of electron to be generated
   YMI=0.0d0
C minimum y of electron to be generated
   YMA=1.0d0
C maximum theta angle of scattered electron
   THEMA = 180.0D0
C minimum theta angle of scattered electron
   THEM = 0.0D0
C momentum of beam 1 (electron, proton, antiproton)
PLEPIN = -27.5
C Lund flavor code for beam 1 (electron=11, photon=22, proton=2212, antiproton=-2212)
KE = 11
C momentum of beam 2 (proton)
PPIN = 820.
C perform fragmentation NFRAG=0/1
NFRAG = 1
c for IPRO = 11 which flavor is produced
IHFLA = 4
c Start integration of x-section
c
    CALL CASCADE

c Print out result of integration of x-section
c
    CALL CAEND(1)
c Start event loop
c
    Do I=1,100
    c generate an event
    CALL EVENT
    Enddo
c Print out of generated events summary
c
    CALL CAEND(20)
STOP
END

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