Working Group: QCD and MC Simulation

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9.2.00

Monte Carlo programs, event generators

→ Tools to be used in physics analyses:

- low x
- photon structure
- high Q^2
- searches ....

→ requests from other groups

→ provide reliable tools

→ invite MC authors to contribute

→ contribute to physics analyses of other group

Technical reliability of MC programs

$E_e = 30$ GeV $\Longrightarrow$ $E_e = 250\,(500)$ GeV

HERA factor 10/20 TERA

extend kinematic range ($x, Q^2, E_T, x_{IP}, \ldots$)
by one order of magnitude

- gain:
  - example: Leading-Log Approximation
    (LO, NLO in QCD,
    WWA for γ-flux)
    keep $O(\ln Q^2/M^2)$, neglect $O(1)$
    → <u>LLA is better at higher energies</u>
  - example: Higher twist, finite mass effects
    neglect $O(M^2/Q^2)$
    → is better at higher energies

- Loss:
  - example: Cancellation between different contributions
    - e.g. many different Feynman diagrams for l^+l^--pair production
      (separate diagrams may increase like s^n, sum of all diagrams $\sim 1/s$, gauge invariance)
    - e.g. radiative corrections, contain $\ln^2(Q^2/m_e^2)$ from virtual corrections, cancel against similar terms from real radiation (QED, QCD)

    → Loose precision at higher energies (numerical stability)
  - example: Choice of variables
    - e.g. fix "interesting" kinematic range by $Q^2 < 4\ \mathrm{GeV}^2$

      → $\theta_e \gtrsim$ 176° at HERA, $\theta_e \gtrsim$ 179.8° at TERA(50

    → Loose efficiency (if wrong variable is used)
    - e.g. separation of soft and hard bremsstrahlu in HERACLES by

      $E_\gamma \lesssim \Delta(\kappa,\gamma) \sim O(1\text{-}100\ \mathrm{MeV})$

      $\frac{\Delta}{\sqrt{s}}$ decreases by factor ~ 10

    → "efficiency" for soft-photon contribution ?

DESY workshop on Monte Carlo Generators for HERA Physics

List of Monte Carlo Programs

Last update: September 2, 1999 http://www.desy.de/~heramc/mclist.html

ARIADNE	A program for simulation of QCD cascades implementing the color dipole model.
AROMA	*Heavy quark* production in boson-gluon fusion using full electroweak LO cross-sections (with quark masses) in ep collisions, DIS and photoproduction. Parton showers and Lund hadronization gives full events.
COMPTON	Event generator of quasi-real QED Compton events in ep collisions.
DIFFVM	DIFFVM is a program to simulate soft diffractive processes in ep-collisions in the framework of Regge phenomenology and the vector meson dominance model. It includes a detailed simulation of the diffractive dissociation of the proton.
DIPSI	A Monte Carlo generator for elastic vector meson production in charged lepton-proton scattering
DISENT	DISENT is a program for (1+1)- and (2+1)-jet events in deep inelastic scattering in NLO.
DISASTER	DISASTER is a program for (1+1)- and (2+1)-jet events in deep inelastic scattering in NLO.
DJANGO	Interface between HERACLES (QED corrections to order alpha_QED) and LEPTO/ARIADNE (QCD matrix elements and parton showers/colour dipole radiation) to give complete ep events.
EPJPSI	EPJPSI is a program to simulate elastic and inelastic vector meson production in photo production and deep inelastic scattering.
GRAPE-Dilepton	This program is an event generator for dilepton production in ep collisions. It is based on exact matrix elements calculated automatically by GRACE. The program is interfaced to PYTHIA to generate a complete final state.
HERACLES	NC and CC ep interactions (using parameterizations of structure functions or parton densities) with radiative corrections: single photon emission from the lepton line, self energy corrections and the complete set of one-loop weak corrections can be included.
HERWIG	General purpose generator for Hadron Emission Reactions With Interfering Gluons; based on matrix elements, parton showers including colour coherence within and between jets, and a cluster model for hadronization.
HITVM	A Monte Carlo program of calculations of Forshaw and Ryskin for diffractive vector meson production using a gluon ladder in pQCD using BFKL formalism.
JETSET	The Lund string model for hadronization of parton systems.
JETVIP	NLO program for calculating one and two-jet cross sections for electron-protron and electron-positron collisions. The virtuality of the photon emitted by the electron can be chosen in a continuous region, ranging from on-shell photons

	(photoproduction) up to very large virtualities (deep-inelastic scattering region). The program enables to calculate the direct and resolved photon processes in NLO QCD. Special attention is given to the resolved virtual photon component.
JBFKL	A Monte Carlo generator for J/psi meson production by off-shell gluons (get the program source here).
LDCMC	A program which implements the Linked Dipole Chain (LDC) model for deeply inelastic scattering within the framework of ARIADNE. The LDC model is a reformulation of the CCFM model.
LEPTO	Deep inelastic lepton-nucleon scattering based on LO electroweak cross sections (incl. lepton polarization), first order QCD matrix elements, parton showers and Lund hadronization giving complete events. Soft colour interaction model gives rapidity gap events.
LPAIR	This event generator is devoted to the process of electromagnetic production of lepton-pairs in lepton-lepton, lepton-hadron or hadron-hadron interactions via the two-photon process.
MAJOR	Production and decay of *heavy Majorana neutrinos* in ep collisions, via mixing or exchange of righthanded W-bosons. Parton showers and Lund hadronization added to give complete events.
MEPJET	NLO Monte Carlo program to study jet cross sections for arbitrary jet algorithms and arbitrary event shapes in deep inelastic e- p and e+ p scattering.
PHOJET	Multiparticle production in high energy hadron-hadron, photon-hadron, and photon-photon interactions (hadron = proton, antiproton, neutron, or pion).
POMPYT	Diffractive hard scattering in pp, gamma-p and ep collisions, based on pomeron flux and pomeron parton densities (several options included). Also pion exchange is included. Parton showers and Lund hadronization to give complete events.
PYTHIA	General purpose generator for e+e-, pp and ep-interactions, based on LO matrix elements, parton showers and Lund hadronization.
QCDINS	QCDINS is a Monte Carlo package for simulating QCD-instanton induced scattering processes in deep-inelatic lepton-nucleon scattering. It is designed as an 'add-on' hard process generator for the Monte Carlo generator HERWIG. Optionally, an interface to JETSET is also available for the final hadronization step. This allows to examine the effects of different hadronization schemes on the instanton-induced final state.
RAPGAP	A full Monte Carlo suited to describe Deep Inelastic Scattering, including diffractive DIS and LO direct and resolved processes.
RIDI	A Monte Carlo generator for inelastic diffraction dissociation of virtual photon in ep scattering, based on a model by M. Ryskin.Transverse and longitudinal cross sections are simulated. Processes implemented: ep -> epX with X = q+qbar or X = q+qbar+gluon. Fragmentation and parton shower done with JETSET.
SUSYGEN 3	Event Generator for SUSY processes in e+e-, mu+ mu-, ep and pp collisions. In ep collisions, allows to simulate the resonant production of R-parity violating squarks undergoing any (direct or cascade) decay. SUSY processes at hadronic colliders are not included in this pre-release of SUSYGEN 3.
WABGEN	An event generator for the simulation of elastic and inelastic wide angle

bremsstrahlung, including the simulation of the complete final state.

Programs for calculating diagrams:

COMPHEP The *CompHEP* package was created for calculation of multiparticle final states in collision and decay processes. The main idea in *CompHEP* was to enable one to go directly from the Lagrangian to the cross sections and distributions effectively, with a high level of automation. For a short description of updates see here.

GRACE Grace system.

MadGraph MadGraph automatically generates postscript Feynman diagrams and Fortran code to calculate arbitrary tree level helicity amplitudes by calling HELAS subroutines

Tools:

HzTool HzTool consists of a set of routines allowing to compare published HERA data to Monte Carlo generator predictions. It contains most of the data available on the hadronic final state in DIS and photoproduction from H1 and ZEUS. It is currently beeing extended to contain also data from gamma-gamma collisions at LEP. Its development began within the 1995/96 workshop 'Future Physics at HERA'.

PDFLIB Nucleon, Pion and Photon Parton Density Functions and alpha(s) Calculations.

Physics:

Suggestions for some specific improvements

- low x

  need improvements of existing MC generators to include BFKL, CCFM evolution saturation

  ARIADNE
  LDCMC
  RAPGAP
  → CASCADE

  & hadronic final states
  e.g. forward jets

  hard diffraction

  need more physics models implemented in MC progr

  DIFFVM, HITVM (for VM productio
  POMPYT, RAPGAP

  diffraction in weak neutral & charged scattering ?

- Large Q^2

  electroweak physics o.k

  PDFLIB: valid parametrizations up to $Q^2 \sim 10^6 GeV^2$?
  down to $x \sim 10^{-6}$?

  do all existing programs have an option for polarized beams ?

- NLO programs for jet production !
  at large Q^2 → include Z-exchange (NC)
  → NLO jet production in CC

- Generator for (single) top production ?
  (Wb→t, rate probably too small)

  Generator for (non-standard) Higgs production ?
  (probably no simulation needed)

  Generators for non-SM physics / searches o.k. ?

- HZTool: routine to describe
  simplified acceptance cuts
  (lepton, hadronic final state)