LPAIR — A Generator for Lepton Pair Production

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This manual is derived from the publication in [1]. It contains up to date information on the LPAIR program version 2.3 and some information specific to the H1 collaboration.

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Program summary

Title of the program	LPAIR
Computer	SGI (originally developped on IBM)
Programming language	FORTRAN 77
Number of program lines	$\simeq$ 5300
Other programs used	PDFLIB (for parton distributions), AXOHS (for phase space integration), JETSET 7.4 (for hadronic state evolution), H1-routines from H1GEN, H1MCUTIL, H1UTIL, H1NDB FPACK, SHIFT and BOS for file access and data handling CERNLIB
Keywords	QED, two-photon processes, Monte-Carlo simulation
Nature of physical problem	electromagnetic production of lepton pairs in two-photon interactions at high energies
Method of solution	Monte-Carlo event generation
Restrictions	Other than two-photon diagrams are not considered
Typical running time	$\simeq$ 5 ms per event +6 min for VEGAS on IBM ES 9000/720

1 Introduction

The program LPAIR is a Monte-Carlo generator devoted to the process of electromagnetic production of lepton pairs in lepton-lepton, lepton-hadron or hadron-hadron interactions via the two-photon process as is shown in fig. 1a/b).

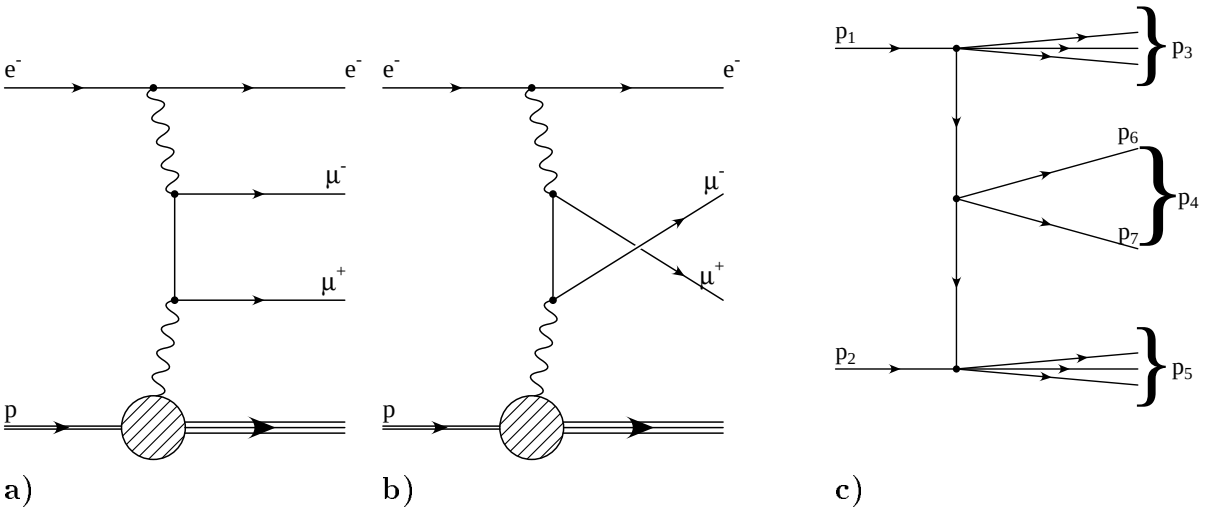

Figure 1:
a), b) *Feynman diagrams of the two-photon mechanism of fermion pair production.*
c) *The kinematics of the process as it is considered in the program.*

The main feature of 2-γ processes is their multiperipheral structure in which there are two photons in the t-channel. This is responsible for the large cross sections and also for the very strong gauge cancellations in the matrix element. Most of the cross section is found at very small values of $|t|$ for both photons. This can cause severe problems for a numerical integration program. Another problem concerns the evaluation of the matrix element of the process. The cancellations between the various terms can be so bad that even the 64 bit accuracy of a CDC computer will not suffice. It was therefore necessary to use a different form for the matrix element.

LPAIR is based on a numerically stable formula for the matrix element of the two-photon production of a pair of fermions in which the beam particles can have arbitrary structure functions. This formula has been obtained using a new method of formulating the matrix element to avoid gauge cancellations. The explicit description of this method is presented in [2].

It should be noted that the two-photon diagrams are not the only ones that contribute to the specified final state, but extra diagrams typically contribute on the level of 1% of the two-photon diagrams or are of importance only in an easily recognizable corner of the phase space. So their contribution can be rather easily separated or estimated with the help of some other programs.

The kinematics of the two-photon reaction is written as a $2 \to 3$ process like in fig. 1c). All the essential two-photon physics properties can be described in this kinematics, independently of the particle contents of the systems denoted by the 4-vectors p_3, p_4 or p_5 (each may represent more than one particle). In the vertex $p_1 \to p_3$ elastic and inelastic interactions are considered in the program.

The basic kinematical variables are: $M_3^2 = p_3^2$, $M_4^2 = p_4^2$ and $M_5^2 = p_5^2$ — the masses squared of the final state systems, $t_1 = q_1^2$ and $t_2 = q_2^2$ — the 4-momenta squared of the virtual photons, $s_2 = (p_4 + p_5)^2$, $\Delta = (p_1p_2)(q_1q_2) - (p_1q_2)(p_2q_1)$ and the angles $\cos\Theta$ and ϕ of the produced leptons p_6 and p_7 in their centre-of-mass (cm) system. This choice of kinematical variables is adjusted to the method (mentioned above) of formulating the matrix element in a numerically stable form.

Since the differential cross section behaves roughly like $t_1^{-1}t_2^{-1}$, by changing the integrals over t_1 and t_2 into integrals over $\log(-t_1)$ and $\log(-t_2)$ the integrand is not so strongly peaked anymore. After this the integration routine VEGAS is used. The combination of VEGAS with a reformulation of phase space yields a good event generator. We do not consider here the principles of VEGAS, since they are described elsewhere [3].

2 The contents of the program

The routines which the program consists of, may be divided into two classes: those essential for the physics, and others concerning the input/output handling. Below, the task of each of them is explained.

Routines essential for the physics of the process

- F(x) — the function to be integrated, which returns the value of the weight of an event, including the matrix element of the process, all the kinematical factors, and the cut restrictions. X — is an array of random numbers used to select a random point inside the phase space.
- PICKIN — describes the kinematics of the process $p_1 + p_2 \to p_3 + p_4 + p_5$ in terms of Lorentz-invariant variables. Fills common blocks to be used in PERIPP (essential for the evaluation of the matrix element).
- ORIENT — calculates energies and momenta of the 1st, 2nd, 3rd, 4th and 5th particle in the overall cm frame.
- GAMGAM — describes the kinematics of a "decay" $p_4 \to p_6 + p_7$ and calculates the energies and momenta of the 6th and the 7th particle in the cm frame.
- PERIPP — contains the expression of the matrix element squared for the process under consideration. It returns the value of the product of the form-factors or structure functions and the matrix element squared. Its two arguments define whether the upper and lower photon vertices are taken to be: 1 — elastic structureless, like in the electron or single quark case; 2 — elastic with nontrivial form factor, like proton [4] ; 3 — inelastic with the structure functions of [5, 6]
- MAPW2, MAPXQ, MAPMX, MAPT1, MAPT2, MAPLA — redefine the variables of integration in order to avoid the strong peaking of the integrand.

Service, input and output routines

The program has been interfaced to H1 software [8]. The most important non-standard routines are the following.

- GMUPA — main steering routine for the generation of e-p events. Called by H1GEN.
- GMUBEG — prepares the event generator. Calls VEGAS [3] and SETGEN [3].
- GMUGNA — reconsiders the generated events and rejects some of them with a definite probability in order to produce unweighted events.

3 User defined parameters

These parameters are transmitted to the program via the steering card (i.e. BOS bank) `GMUP`.

3.1 AXOHS parameters

Keyword	Default	Explanations:
IBEG		the starting step of the program:
	times	1 – to run a completely new job
		2 – to use the grid produced by VEGAS from a previous run
		3 – to use the VEGAS grid and the information about the weights of events produced by SETGEN in a previous run
IEND		the concluding step of the program:
		1 – to estimate the cross-section only
		2 – to save SETGEN information (for further runs)
	times	3 – to produce a complete output event (to be stored)
PRVG	1	Print parameter from VEGAS
NTRT	1	Strategy parameter NTREAT from VEGAS
NCVG	14000	Number of events for VEGAS to perform the integration
ITVG	10	Number of iterations for VEGAS
NCSG	100	Number of events in each bin (for SETGEN)

3.2 Beam, particle and interaction parameters

INPP first incoming particle momentum in GeV/c, default = 820.0

PMOD first incoming particle type and kind of interaction:

1 — electron *(for tests)*

2 — proton elastic = default

11 — proton inelastic with structure functions [5]

12 — proton inelastic with structure functions [6] (for $M_x < 2$ GeV, $Q^2 < 5$ GeV^2)

13 —

101 — proton inelastic in parton model, only valence quarks

102 — proton inelastic in parton model, only sea quarks

103 — proton inelastic in parton model, valence and sea quarks

GPDF	author group code for structure function, default= 5 PDFlib-parameter NGROUP, (cf. PDFLIB [7] for details)
SPDF	set code for structure function, default= 6 PDFlib-parameter NSET, (cf. PDFLIB [7] for details)
QPDF	choice of scattered quark flavour, default = 12 1=up, 2=down, 12=up+down, 3=strange 4=charm, 5=bottom
INPE	second incoming particle momentum in GeV/c, default = 30.0
EMOD	second incoming particle type 1 — electron = default -1 — positron 2 — proton elastic *(for tests)*
PAIR	particle code of produced leptons 11 — e^+e^- 13 — $\mu^+\mu^-$ = default 15 — $\tau^+\tau^-$
MPDF	*Obsolete; overrides selections via* SPDF/GPDF*!* choice of proton structure function via the outdated interface parameter PMODE of PDFlib.

Backward compatibility of the default structure function: From version 2.03 on, the obsolete interface to PDFlib via the MPDF (LPAIR) / PMODE (PDFlib) parameter has been abandoned. The previous (versions 2.02 and below) default value for MPDF/PMODE= 72 corresponds to GPDF/SPDF=5/3 (GRV HO from 1992). However, we made the choice to take the recommended successor set GRV 94 HO by default in the newer versions.

3.3 Cut parameters

Keyword	Default	Explanations:
MCUT	2	0 = No cuts at all (for the total cross section)
		1 = Vermaserens hypothetical detector cuts (see [2])
		2 = Cut with the following parameters for both leptons
		3 = Cut with the following parameters for one lepton only
THMX	175.0	Θ_{max} of lepton (in degrees)
THMN	5.0	Θ_{min} of lepton (in degrees)
ECUT	1.0	minimal energy of lepton (in GeV)
PTCT	0.5	minimal transverse momentum of lepton (in GeV)
Q2MN	0.0	minimal Q^2 at the proton side (in GeV^2)
Q2MX	10000.	maximal Q^2 at the proton side (in GeV^2)
		for PMOD$>$ 10 only :
MXMN	1.070	minimal inv. mass of the hadronic system (in GeV)
MXMX	320.0	maximal inv. mass of the hadronic system (in GeV)

References

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