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GenEx: A Simple Generator Structure for Exclusive Processes in High Energy Collisions

R. A. Kycia[1,*], J. Chwastowski[2], R. Staszewski[2] and J. Turnau[2]

[1] *Cracow University of Technology, Faculty of Physics, Mathematics and Computer Science, PL-31155 Kraków, Poland.*
[2] *Henryk Niewodniczański Institute of Nuclear Physics, PAN, Kraków, Poland.*

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Abstract. A simple C++ class structure for construction of a Monte Carlo event generator which can produce unweighted events within relativistic phase space is presented. The generator is self-adapting to the provided matrix element and acceptance cuts. The program is designed specially for exclusive processes and includes, as an example of such an application, implementation of the model for exclusive production of meson pairs $pp \to pM^+M^-p$ in high energy proton-proton collisions.

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1 Introduction

A commonly used method of testing hypotheses concerning the structure of matrix elements for inelastic processes in high energy physics is Monte Carlo simulation. One generates random "events" within the kinematic phase space (conserved energy and momentum) and associates with each event a weight which is a product of the square of modulus of the matrix element and a kinematic factor [1,2]. Such properly weighted MC events may be processed in the same manner as real events and may yield theoretical distributions directly comparable to experimental ones. This method becomes inefficient when, for dynamical reasons, a non-negligible weight is observed only in the very limited regions of the phase space. For example, in high energy multi-particle production the transverse momenta of final state particles are small while their longitudinal momenta increase significantly with collision energy. Methods for generation of events within the

*Corresponding author. *Email addresses:* kycia.radoslaw@gmail.com (R. A. Kycia), Janusz.Chwastowski@ifj.edu.pl (J. Chwastowski), rafal.staszewski@ifj.edu.pl (R. Staszewski), Jacek.Turnau@ifj.edu.pl (J. Turnau)

so-called longitudinal phase space were developed long time ago [3–5] and are standard components of any event generator for high energy physics. However, there is growing interest in investigation of the high energy exclusive processes (for recent review see [6]) which are governed by sharply peaked matrix elements and nonzero weight events that occupy an extremely small spot in the available phase space. There exist several event generators specially designed for this type of processes. GenEx (Exclusive Processes Generator), the event generator described in this paper, achieves a high efficiency due to combination of a proper choice of the integration variables with self-adapting Monte Carlo [7] implemented in TFoam class of ROOT [8]. The usage of this self-adapting Monte-Carlo technique and modular C++ structure dedicated to facilitate addition of new phase space generation methods and new processes (matrix elements) make the GenEx distinctive from other available generators for exclusive processes such: DIME [9], FPMC [10], ExHuME [11]. In addition, GenEx, unlike ExHuME and FPMC, does not use the parton structure of the colliding particles from the beginning, what makes it suitable for modelling soft, Regge-like processes. The program extensively uses existing commonly available open source ROOT library developed at CERN [8], in particular TFoam [7] and some other free software. For other general purpose software that uses TFoam see, e.g., [12].

The following sections contain general description of the generation method, implementation and class structure and detailed instruction how to install and use GenEx, including examples and standard tests. In the Appendix some details of the phase space calculation are explained.

2 General description of the event generator

A typical path of a Monte Carlo event generation has the following steps:

- create the vector of random numbers $\mathcal{R}$;
- transform $\mathcal{R}$ into a set of final state particles four-momenta P which fulfil the energy-momentum conservation;
- evaluate the matrix element square and the event total weight;
- use the rejection method to generate events with unit weight.

Random numbers in GenEx are generated by `TRandom3` ROOT class [8] that implements classical Mersenne Twister algorithm [13]. The period for the algorithm is $2^{19937}-1$ and should be taken into account when the large number of samples is generated. The seed of the generator can be set in the main generator configuration file described below.

Using general properties of a certain class of matrix elements, e.g., for multiple particle production in high energy collisions, standard importance sampling methods are usually employed to increase the generator efficiency. The importance sampling is performed either at the level of the first step (non-uniform random number distribution) or