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The Adaptive Monte Carlo Toolbox for Phase Space Integration and Generation

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Abstract. An implementation of the Monte Carlo (MC) phase space generators coupled with adaptive MC integration/simulation program FOAM is presented. The first program is a modification of the classic phase space generator GENBOD interfaced with the adaptive sampling integrator/generator FOAM. On top of this tool the algorithm suitable for generation of the phase space for an reaction with two leading particles is presented (double-peripheral process with central production of particles). At the same time it serves as an instructive example of construction of a self-adaptive phase space generator/integrator with a modular structure for specialized particle physics calculations.

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1 Introduction

The need for an efficient phase space generation of multiparticle final states resulted in a large number of programs. These tools offers various degree of generality of the application that improve the integration of the differential cross sections. In addition, they allow for efficient generation of events with the unit weight. Such feature is needed especially when major time consuming detector simulation is involved. These programs employ

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the sampling methods which aim at the minimisation of the integrand variance. One example of efficient strategy is described in [5]. The n-body phase space parametrised by $3n-4$ independent variables is divided adaptively into the cells, and techniques which reduce the variance of the result are applied (e.g. importance sampling [12] or [3] and the references therein, or the adaptive integration like VEGAS [11] or FOAM [4]). This strategy described in [5] was implemented as the parton level Monte Carlo Event Generator AcerMC [12] with interfaces to PYTHIA 6.4 [14] and other hadronisation programs. Program described in this paper follows in principle the same strategy but it employs the non-perturbative, e.g. Regge, hadron level amplitudes. Moreover, it is designed to efficiently generate the exclusive final states produced in the diffraction processes at very high energy as measured for example at RHIC or at LHC. To illustrate our approach the program GenExLite, discussed in this paper, has been applied to the reaction

$$p+p\to 2p+2\pi^+ +2\pi^-, \tag{1.1}$$

that represents the continuum production of the pion pairs for which one sets restrictive bounds on the transverse momenta of the final state protons – the leading particles. For a thorough physics discussion of the above reaction see [6].

The matrix elements for reactions described by the Regge model are strongly localised in a small volume of the phase space. Therefore the event generation process applying the adaptive scanning of the integrand function gives one of the best, most general and flexible approach to solve such problems. To the class of the most general adaptive MC integrators belong VEGAS [11] and FOAM [4]. In our toolbox FOAM was selected as it is easily available within the ROOT [17] framework. However, the generators presented here can be easily adapted to use other MC integrators such as e.g. VEGAS – the control flow is similar, classes that describe generation of phase space and possible matrix element are unchanged, and the only difficulty is to implement interfaces for other adaptive MC integrators.

The paper is organized as follows. Section 2 outlines the augmented algorithm of the phase space generation based on the Raubold-Lynch spherical decay algorithm [2] implemented in the TDecay class and interfaced with the external program FOAM for adaptive Monte-Carlo integration. In Section 3 a test of the considered spherical decay tool for efficiency is presented. In Section 4 an example of the specialized self-adapting phase space generator (employing the TDecay class as a basic module, which is also described there) called GenExLight is shown. This code designed for the efficient generation of the double-peripheral processes with two leading particles. A test of its efficiency is presented in Section 5. The kinematical formulae derivations and the program technical details are described in the Appendices A, B and C.

The paper is the continuation of the description of algorithms, tools and their tests started in [7] and used in simulations of diffractive processes in High Energy Physics. However in [7] the emphasis was put on the class structure of expanded GenEx (the Generator for Exclusive processes) MC generator. In the present paper we present simplified version of the generator with completely new design principles that are aimed