

GenEx – Exclusive Meson Generator

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Exclusive light meson production processes possible to be measured at RHIC and LHC accelerators are briefly described. This includes Pomeron and photon induced continuum of pions and kaons as well as f_0 and ρ^0 resonant production. Next, GenEx, a new Monte Carlo generator recently developed in Cracow, is presented. Its purpose is to generate resonant and non-resonant pion and kaon production and diffractive Bremsstrahlung. Its future development will take into account spin (polarization) effects and simulate corrections due to absorption and re-scattering.

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1 Introduction

Collisions at hadron accelerators are dominated by soft processes. Absence of a hard scale in these events prevents one from using perturbation theory. Instead, in order to calculate the properties of the produced particles (*e.g.* energy or angular distributions), one has to use approximative methods.

In about a half of collisions at LHC or RHIC one or both outgoing protons stay intact. Such final state is possible due to the exchange of a colourless object: photon (electromagnetic) or Pomeron (strong interaction). Such an exchange results in a presence of the rapidity gap between the centrally produced system and scattered protons. Thus, such events are of diffractive nature.

Diffractive studies are one of the important parts of the physics programme for the LHC experiments. A particularly interesting classes are exclusive processes, where all centrally-produced particles are detected. An example is the process of pion pair production $pp \rightarrow p\pi^+\pi^-p$, which can be used for studies of low-mass resonances, including searches for glueballs.

In order to include detector effects (acceptance, efficiency) in theory-to-data comparison Monte Carlo generators are needed. There are few MC generators which are specialized in simulation of the soft exclusive processes, *e.g.* SUPERCHIC [1] or DIME [2]. In this paper GENEX [3, 4], a tool complementary to the existing ones in terms of implemented processes and calculation methods, will be briefly described.

2 Soft Exclusive Production at the LHC

Diffractive protons are usually scattered at very small angles (fraction of milliradian). In order to measure them, special devices that allow detector presence in close vicinity of the beam are required. At the LHC Roman pots are commonly used. ATLAS [5] has two systems of such detectors: ALFA [6, 7] and AFP [8]. Similar set is installed around CMS/TOTEM Interaction Point [9]. Roman pots are usually located far away (few hundreds meters) from the Interaction Point (IP). It means that there are several LHC magnets between them and the IP. The settings of these magnets, commonly called *machine optics*, play a key role in the exclusive analysis. The detailed description of the properties of optics sets used at the LHC can be found in [10]. In addition, in this reference a geometric acceptance of AFP and ALFA detectors is presented.

2.1 Non-resonant Pion Pair Production

Diagram for the non-resonant pion pair production (also called continuum) is shown in Fig. 1 (left); a Pomeron is “emitted” from each proton resulting in a four particles present in final state: scattered protons and (central) pions. The object exchanged in the t -channel is an off-shell pion. The model implemented in GenEx is based on

calculations done in Ref. [11]. Feasibility studies for the ATLAS detector are shown in [12].

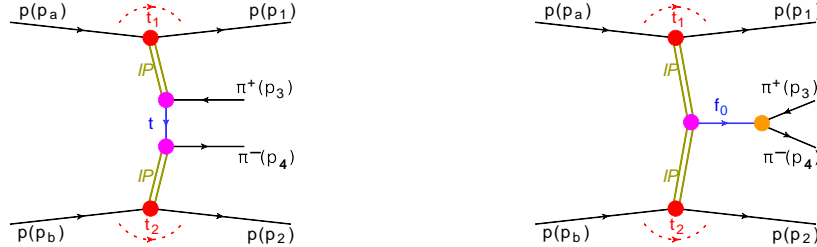


Figure 1: Diagrams of: non-resonant (**left**) and f_0 resonance (**right**) pion pair production.

2.2 Pion Pair Production via f_0 Resonance

Diagram for the exclusive pion pair production via the f_0 resonance is shown in Fig. 1 (right). In order to calculate it, one must know the Pomeron-Pomeron-meson vertices. These elements have been discussed in detail in Ref. [13]. It was shown there that different couplings structures with corresponding orbital angular momentum and spin of two Pomerons are possible.

2.3 Photon-induced Continuum and ρ^0 Photoproduction

The dominant diagram of the exclusive pion pair continuum production is a Pomeron-induced one. However, the production of a photon-induced continuum (see Fig. 2 (left)) is also possible. It should be taken into account in the Monte Carlo generators as it contributes up to the several percent of the exclusive pion pair production, see Ref. [14].

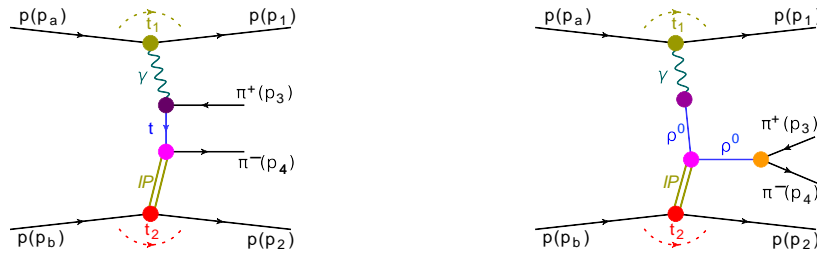


Figure 2: Diagrams of: non-resonant (**left**) and ρ^0 (**right**) pion pair photo-production.

Another interesting class of photon-induced processes is a resonant ρ^0 photoproduction. Feynman diagram is shown Fig. 2 (right) whereas details are discussed in [14].

2.4 Diffractive Bremsstrahlung

Diffractive Bremsstrahlung is typically an electromagnetic process (see Fig. 3 (left)). However, as discussed in [15], high energy photons can be radiated in the elastic proton-proton scattering (Fig. 3 (right)). This idea was extended in [16] by introducing the proton form-factor into the calculations and by considering also other mechanisms leading to the $pp\gamma$ final state, *e.g.* a virtual photon re-scattering. Recently, diffractive Bremsstrahlung was implemented into the GenEx Monte Carlo generator [17].

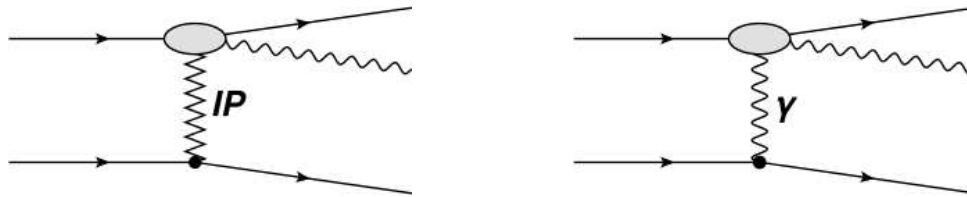


Figure 3: Diagrams of electromagnetic (left) and diffractive (right) Bremsstrahlung. The blobs represent various mechanisms of photon emission.

3 GenEx Generator

GENEX [3] is a C++ class structure for the construction of a Monte Carlo event generators which can produce unweighted events within the relativistic phase space. Generator is self-adapting to the provided matrix element and acceptance cuts. Current version contain resonant and non-resonant exclusive meson production processes with vector and tensor Pomeron as well as diffractive Bremsstrahlung production [18]. In near future spin (polarization) effects and absorption/re-scattering corrections will be added.

Current version of generator is based on several core classes:

- TFOAM – class of adaptive Monte Carlo simulator,
- TDENSITY – class with integrand function (calculated accordingly to a given event),
- TEVENTMAKER2TON – generates two leading particles and a central blob which then is decayed by TDECAY into $N - 2$ remaining particles.

Recently, a significant effort is taken in order to simplify the implementation of new processes. For reference see [19].

4 Summary

Exclusive light meson production should be measurable at LHC and RHIC. A Monte Carlo generator containing continuum and resonances would be useful to understand recorded data. Such tool will be especially needed in order to include detector effects (acceptance, efficiency) in theory-data comparison.

One of such generators is GENEX. Its first version is already available for tests (see [18]) and contains: the generator structure, pion/kaon continuum and diffractive Bremsstrahlung processes. The developments are ongoing – in the near future a new version of GENEX would allow to: generate resonant production ($f_0(500)$, $f_0(980)$, $f_0(1370)$, $f_0(1500)$, $f_2(1270)$, $f_2'(1520)$ and ρ_0), take into account spin (polarization) effects and simulate corrections due to absorption and re-scattering.

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