EDDE Monte Carlo event generator.

Petrov V.A., Ryutin R.A., Sobol A.E.
Institute for High Energy Physics
142 281 Protvino, Russia
and
Guillaud J.-P.
LAPP, Annecy, France

Abstract
EDDE is a Monte Carlo event generator, under construction, for different Exclusive Double Diffractive Events. The program is based on the extended Regge-eikonal approach for "soft" processes. Standard Model and its extensions are used for "hard" fusion processes. An interface to PYTHIA, CMSJET and CMKIN is provided.

Keywords
Exclusive Double Diffractive Events – Pomeron – Regge-Eikonal model – event generator
1 Introduction

Usually High Energy Physics is considered as the synonym of ”physics of particles”. New phenomena in this area are related to discoveries of new particles or to the typical ”particle-like” effects, such as ”Bjorken scaling” in DIS or high-\(p_T\) jets and so on. In the space-time language these kinematical regimes correspond to small distances.

However there is an area in High Energy Physics, which is related to rather large distances, even at high energies. These phenomena are similar to the scattering of hadrons to small angles. The wellknown feature of such processes is that the angle distribution gives the typical diffractive pattern with zero-angle maximum and one or, sometimes, two dips. Here wave properties of hadrons play the main role. From this distribution we can make the conclusion about size and shape of the scatterer, or the ”interaction region”.

Experiments at the LHC which aim to study low (TOTEM,-) and high (CMS,)-\(p_T\) regimes, related to typical undulatory (diffractive) and corpuscular (point-like) behavior of the corresponding cross-sections, may offer a very exciting possibility to observe an interplay of both regimes. In theory the ”hard part” can be (hopefully) treated with perturbative methods while the ”soft” part is definitely nonperturbative.

Large number of event generators are devoted to partonic processes of the Standard Model and its extensions, i.e. work at small distances. It is wellknown, that perturbation theory has some problems in the description of processes at large distances. That is why diffractive processes are usually considered as special cases which description is based on different phenomenological approaches. The most popular approach is the Regge-eikonal model.

In the present paper a brife description of the generator EDDE (Exclusive Double Diffractive Events) is given.

2 Physics of EDDE.

For calculation of cross-sections we use the method developed in Refs. [1],[2]. It is based on the extension of the Regge-eikonal approach, and succesfully used for the description of the HERA [3],[4] and \(p + p(\bar{p}) \rightarrow p + p(\bar{p})\) [5] data.

Generator works in the kinematical region:

\[
0.01 \text{GeV}^2 \leq |t_{1,2}| \leq 1 \text{GeV}^2 ,
\]

\[
\xi_{\text{min}} \simeq \frac{M^2_X}{s} \leq \xi_{1,2} \leq \xi_{\text{max}} = 0.1 ,
\]

The amplitude of the process \(p + p \rightarrow p + X + p\) can be obtained in the following way (see Fig. 1). The first step is to calculate the ”bare” amplitude \(T_X\), which is depicted in Fig. 1a.

The ”hard” part of \(T_X\) is the usual gluon-gluon fusion process calculated by perturbative methods in the Standard Model or its extensions. In the first version EDDE1.1 three different processes are included:

- Standard model Higgs boson (H) production [6].
Figure 1: a) The process $p+p \rightarrow p+X+p$. Absorption in the initial and final pp-channels is not shown. b) The full unitarization of the process $p+p \rightarrow p+X+p$.

- Randall-Sundrum model with one extra dimension [7]. Higgs boson ($H^*$) and Radion ($R^*$) production.

- Standard model $b\bar{b}$ production.

For all the processes total cross sections and distributions are calculated.

The more recent version EDDE1.2 is available. There are some additional processes:

- Improved calculations for $b\bar{b}$ production, including corrections to background for Higgs or Radion production.

- Standard model di-jet production.

- Cross-sections for heavy quarkonia production at LHC.

- Some azimuthal angular distributions.

"Soft" amplitudes $T_{1,2}$ are obtained in the extended Regge-eikonal approach. Parameters and formulae can be found in Ref. [1]. The second step is the unitarization procedure, that takes into account initial and final state interactions (see Fig. 1b).

3 Program procedures and limits.

There are several procedures and functions in the generator.

EDDE1.1:

- function $\text{EDDECSHST}(MH)$ returns the total cross-section of Standard model Higgs boson production in fb. $MH$ is the Higgs boson mass in GeV. Typical values of the cross-section are $3.6 \rightarrow 0.1$ fb in the mass region $100 \rightarrow 500$ GeV.
• function EDDECSRS1(XI, GAM, HMASS, RMASS, NP) returns the total cross-section for $H^*(\text{NP}=1)$ or $R^*(\text{NP}=2)$ production. $\text{XI}$ is the mixing parameter of the RS1 model [7]. Typical values are $-0.5 \to 0.5$. $\text{GAM}$ is the scale parameter of the model, which is equal to $246 \text{ GeV}/\Lambda$. $\Lambda$ is the Radion vacuum expectation value, which is directly related to the radius of compact extra-dimension. Usually $\Lambda = 1 \to 5 \text{ TeV}$. 

• EDDECSBBBG(Mcut) is the total cross-section for the leading order QCD $b\bar{b}$ production in the EDDE at LHC. $\text{Mcut}$ is the lower cut on the invariant mass of the $b\bar{b}$ system. $\text{Mcut} = 2 \text{MTcut}$, where $\text{MTcut}$ is the jet ”transverse mass” cut, which is used in other subroutines. $\text{MTcut} = \sqrt{E_{T,cut}^2 + m_b^2}$.

• procedure EDDETTPHI(GT1, GT2, GPHI0) generates the distribution

$$\frac{1}{\sigma} \frac{d\sigma}{dt_1dt_2d\phi_0},$$

where $\phi_0$ is the azimuthal angle between final protons.

• $\xi$-distribution ($\xi = 1 - x_F$) is generated by the function EDDEX(HMASS), where $\text{HMASS}$ is the invariant mass of the central system.

• procedure EDDEMXUBB(MTcut, UG, MXG) generates the distribution for the ”hard” process $ggPP \to b\bar{b}$. $\text{MTcut}$ is the lower cut on the ”transverse mass” of $b(\bar{b})$ quark.

EDDE1.2:

• new procedure EDDECS0(NX, MTcut) is introduced instead of EDDECSBBBG which returns total cross-sections of $b\bar{b}$ or $gg$ di-jets and heavy quarkonia production at LHC.

$$\begin{align*}
\text{NX} &= 1 \to b\bar{b} \\
\text{NX} &= 2 \to gg \\
\text{NX} &= 3 \to \chi_{c,0} \\
\text{NX} &= 4 \to \chi_{b,0}
\end{align*}$$

Parameter $\text{MTcut}$ is used for di-jet production only. In the STAGEN interface $\text{MTcut} = \text{Rpar}(107)$. Default value is 25 GeV.

• procedure EDDEMXUGG(MTcut, UG, MXG) generates the distribution for the ”hard” process $ggPP \to gg$. $\text{MTcut}$ is the lower cut on the transverse momentum of gluon (see above comment).

• additional modification of the procedure EDDETTPHI(GT1, GT2, GPHI0) which is transformed to the more general one EDDETTPHI(NX, GT1, GT2, GPHI0), where $\text{NX}$ is the code number of produced particle or system of particles.
Other states will be added in the forthcoming version.

4 Results.

Here some samples from the work of the generator with PYTHIA [8] are presented (see Figs. 3a)-d).

For both versions the interface to the last version of PYTHIA is provided.

The updated version of the generator EDDE1.2 will be available on the web-page:

\[http://sirius.ihep.su/cms/higgsdiff/diff.html\]

Interface to CMKIN will be provided soon.

For the first version EDDE1.1 with interface to CMKIN and CMSJET [9] (in the STAGEN package) see the page

\[http://cmsdoc.cern.ch/cms/generators/www/geners/collection/stagen/stagen.html\]

Someone can use the new source file for STAGEN (see the webpage) to update EDDE1.1 until the new interface is provided.

Aknowledgements

This work is supported by grants CNRS-PICS-2910 and RFBR-04-02-17299.

Thanks to Andrey Sobol for the first version of the generator \texttt{DPEHiggs}, to Sergei Slabospitsky, who helped to correct the interface to PYTHIA and CMSJET, to Kreiton Hogg and Marek Tasevsky for helpful discussions concerning the work of the generator EDDE1.1.

References

[1] V.A. Petrov and R.A. Ryutin, \textit{JHEP 0408 (2004) 013}.

[2] V.A. Petrov and R.A. Ryutin, \textit{Eur. Phys. Journ. C 36 (2004) 509}.

[3] V.A. Petrov and A.V. Prokudin, \textit{Phys. Atom. Nucl. 62 (1999) 1562}.

[4] V.A. Petrov, A. V. Prokudin and R. A. Ryutin, hep-ph/0404116.
[5] V.A. Petrov and A. V. Prokudin, *Eur. Phys. J. C* 23 (2002) 135.

[6] A. Kniehl, Phys. Rept. 240 (1994) 211.

[7] L. Randall and R. Sundrum, *Phys. Rev. Lett.* 83 (1999) 3370;
   M. Chaichian, A. Datta, K. Huitu and Zenghui Yu, *Phys.Lett. B524* (2002) 161.

[8] T. Sjostrand et al., *Comp. Phys. Commun.* 135 (2001) 238, hep-ph/0108264; hep-ph/0308153 (recent version).

[9] S. Abdulin, A. Khanov and N. Stepanov, CMS Note 1994/180.
Figure 2: Some distributions from EDDE1.2. (90 signal and 660 background events. \(MTcut = 25\) GeV). Solid curve represent signal+background, dashed one is the background, and dash-dotted is the signal. a) azimuthal angle distribution for Higgs boson production; b) rapidity and c) pseudorapidity distributions; d) integrated t-distributions.