IL NUOVO CIMENTO Vol. 33 C, N. 6 Novembre-Dicembre 2010
DOI 10.1393/ncc/i2011-10766-4

Colloquia: IFAE 2010

MCSTHAR++, a Monte Carlo code for the microcanonical hadronization

C. Bignamini(1)(*), F. Becattini(2) and F. Piccinini(3)

(1) *Dipartimento di Fisica Nucleare e Teorica, Università di Pavia and INFN, Sezione di Pavia Pavia, Italy*

(2) *Dipartimento di Fisica, Università di Firenze and INFN, Sezione di Firenze Firenze, Italy*

(3) *INFN, Sezione di Pavia - Pavia, Italy*

(ricevuto l'8 Ottobre 2010; pubblicato online il 2 Febbraio 2011)

Summary. — `MCSTHAR++` is a new Monte Carlo code implementing the Statistical Hadronization Model. This model assumes that hadronization proceeds through the microcanonical decay of massive extended clusters. Unlike other hadronization models, in this approach very few free parameters are needed, as has been demonstrated in previous studies. The tuning of the model and the comparison with the data is ongoing.

PACS `12.40.Ee` – Statistical models.
PACS `13.66.Bc` – Hadrons production in e^-e^+ interaction.

1. – Introduction

The transition from the partonic state to the confined state is described using various phenomenological models like the *Cluster Models* [1, 2] and the *String Model* [3]. A completely independent model, based on a statistical formulation and known as *Statistical Hadronization Model* [4], has been studied in the literature but it is not available in any official release of the Monte Carlo event generators for High Energy Physics. In this paper a short overview of the microcanonical formulation of the Statistical Hadronization Model will be given and a new Monte Carlo code performing the hadronization process according to that model, `MCSTHAR++`, and its interface to the event generator `HERWIG6.510` [5] will be described, showing also some preliminary results obtained for the hadronization of light quarks only.

(*) Speaker.

2. – The Statistical Microcanonical Hadronization Model: a short overview

As described in [4], the statistical model is based on the hypothesis that in a high energy collision some extended objects made of pre-hadronic matter, called *clusters* or *fireballs*, are produced. These objects are supposed to be colorless and characterized by well defined physical quantities like energy, momentum and abelian charges. Each one of these clusters hadronizes according to a pure statistical law, which for the microcanonical formulation is the following: *every multihadronic state confined inside the cluster and conserving all the physical quantities of the cluster itself is equally likely*. In this picture of the hadronization process the cluster is treated as a microcanonical ensemble, whose partition function Ω is given by [6]

$$\Omega = \sum_{(N_j)} \langle (N_j) \, | P_{\mathbf{Q}} P_V P_{\mathbf{Q}} | \, (N_j) \rangle, \quad \text{where} \;\; P_V = \sum_{h_V} |h_V\rangle\langle h_V| \tag{1}$$

is the sum over all the multihadronic states $|h_V\rangle$ confined inside the cluster, while the sum on the left equation is over all possible channels, corresponding to the asymptotic states, which are identified by the K-tuple of integer $(N_j) = (N_1, N_2, \ldots, N_K)$, one for each hadron species j, and where $P_{\mathbf{Q}}$ is the projector on the conserved set of charges.

The above partition function is then modified introducing the strangeness suppression parameter γ_s and multiplying the weight of each channel by the factor $\gamma_s^{N_s}$, where N_s is the total number of strange and antistrange quarks contained in the hadrons of the channel itself. At this point this hadronization model requires only *two* parameters, which need to be tuned on the experimental data: the γ_s parameter and the energy density of the clusters ρ, which is taken to be equal for each cluster and which is used to convert the mass of a cluster into its volume, a quantity which appears in Ω, as can be seen in [6].

3. – `MCSTHAR++`: code description and preliminary results

`MCSTHAR++` (**M**onte **C**arlo **ST**atistical **HA**dronization in high energy **R**eactions) is a Monte Carlo code implementing the Statistical Hadronization Model in its microcanonical formulation. It is written in Object Oriented `C++` and it is built to take as input a set of clusters and to give in output a set of hadrons (stable and unstable), coming from the microcanonical hadronization of each one of the incoming clusters. For the hadronization of these objects the exact conservation of energy-momentum, electric charge, strangeness, baryonic number, charm and beauty charge is imposed.

In the present case, `MCSTHAR++` is interfaced to `HERWIG6.510` [5], the clusters used as input for `MCSTHAR++` are the "standard" `HERWIG`'s clusters (allowed to have non-zero baryonic number) and the primary hadrons produced during the hadronization are decayed using the `HERWIG`'s routines for the strong and electroweak hadron decay.

Even if a full tuning of the model is mandatory, it is already possible to see the good behavior of the hadronization code in the preliminary results shown in this section. The theoretical predictions are obtained with no tuning at all of the `HERWIG`'s parameters and with a reasonable choice of the `MCSTHAR++`'s parameters: $\gamma_s = 0.65$ and $\rho = 0.35\,\text{GeV/fm}^3$. The charged-particle scaled momentum distributions of fig. 1 and the multiplicity values of table I show a comparison among `MCSTHAR++`, `HERWIG6.510` and LEP (OPAL [7] and DELPHI [8]) data for the process $e^+e^- \to \gamma/Z^0 \to u\bar{u}, d\bar{d}, s\bar{s}$ at 91.2 GeV center-of-mass energy.

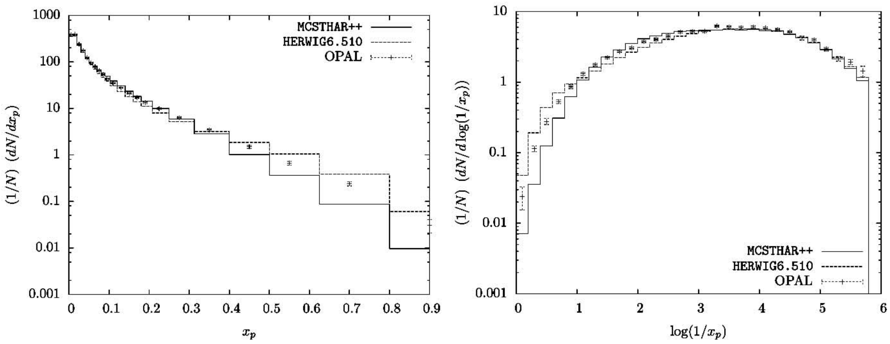

Fig. 1. – Charged-particle scaled momentum $x_p = 2p/\sqrt{s}$ and $\log(1/x_p)$ distribution.

Table I. – *Mean values of the charged-particle multiplicity and of the production rate of charged pions, charged kaons and (anti)protons, for the hadronization of light quarks only.*

	$N_{\rm ch}$	$N_{\pi^\pm}$	$N_{K^\pm}$	$N_{p,\bar{p}}$
MCSTHAR++	19.53 ± 0.14	16.64 ± 0.11	1.65 ± 0.04	0.98 ± 0.07
HERWIG6.510	18.601 ± 0.006	15.022 ± 0.006	1.628 ± 0.002	1.736 ± 0.002
DELPHI	19.94 ± 0.34	16.84 ± 0.87	2.02 ± 0.07	1.07 ± 0.05

4. – Conclusions

MCSTHAR++, a new Monte Carlo code for the Statistical Microcanonical Hadronization, has been presented. This code, written in C++, will be soon available to be used with the Monte Carlo event generators alternatively to the standard hadronization modules, as it has been shown in this paper, where MCSTHAR++ has been interfaced to HERWIG6.510.

The next steps of this work will be focused on the tuning of MCSTHAR++, completed with the hadronization of c and b quarks, on LEP and Tevatron data, and on the comparison with other available hadronization models.

* * *

One of us (CB) would like to thank S. Gieseke for support and useful discussions and the ITP of the Karslruhe University for warm hospitality. Work supported in part by the EU Marie Curie Research Training Network MCnet (MRTN-CT-2006-035606).

REFERENCES

[1] Webber B. R., *Nucl. Phys. B*, **238** (1984) 492; Marchesini G. and Webber B. R., *Nucl. Phys. B*, **310** (1988) 461.
[2] Winter J. C., Krauss F. and Soff G., *Eur. Phys. J. C*, **36** (2004) 381.
[3] Andersson B., Gustafson G., Ingelman G. and Sjöstrand T., *Phys. Rep.*, **97** (1983) 31.
[4] Becattini F., arXiv:0901.3643 [hep-ph] (2009) and references therein.

[5] Corcella G., Knowles I. G., Marchesini G., Moretti S., Odagiri K., Richardson P., Seymour M. H. and Webber B. R., *JHEP*, **0101** (2001) 010.
[6] Becattini F. and Ferroni L., *Eur. Phys. J. C*, **35** (2004) 243; **38** (2004) 225.
[7] Ackerstaff K. *et al.*, *Eur. Phys. J. C*, **7** (1999) 369.
[8] Abreu P. *et al.*, *Eur. Phys. J. C*, **5** (1998) 585.