FRITIOF EXTENDED

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ABSTRACT

We extend the original FRITIOF model for low-P_T hadronic collisions to include the effect of Rutherford parton scattering (RPS). RPS together with gluon bremsstrahlung radiation contribute an increasingly large part to the collision processes at higher energies. By properly treating the dominant properties of these effects, we arrive at a FRITIOF implementation of RPS which is infrared stable. The resulting model provides an excellent description for all available experimental data up to the highest energies.

INTRODUCTION In this paper we report some progress made in the Lund FRITIOF model for hadronic interactions. The original FRITIOF [1] was constructed for low-P_T hadronic reactions. The aim of our current work is to build the large-P_T dynamics into the model and so to push the applicability of the model up into the TeV energy regime. At high energies there are growing contributions in the collision from gluon radiation and Rutherford Parton Scattering (RPS). By properly treating the dominant properties of RPS and gluon radiation we arrived at an improved FRITIOF model which gives excellent descriptions to available hadron collision data.

We will not re-present the basic constructions in FRITIOF (cf ref. [1]) here other than writing down a few basic equations to establish notations. Two incoming hadrons of masses m_1 and m_2 with light-cone momenta

$$P_1^i = (p_+^0, \frac{m_1^2}{p_+^0}, \vec{0}_T), \quad P_2^i = (\frac{m_2^2}{p_-^0}, p_-^0, \vec{0}_T) \tag{1}$$

will emerge out of the interaction as two excited string states with new momenta

$$P_1^f = (p_+^0 + \frac{m_2^2}{p_-^0} - P_+^f, P_-^f, \vec{Q}_T), \quad P_2^f = (P_+^f, p_-^0 + \frac{m_1^2}{p_+^0} - P_-^f, -\vec{Q}_T). \tag{2}$$

The two variables P_-^f and P_+^f are related to the total momentum transfer and are assumed to follow the distribution

$$dP \propto \frac{dP_-^f}{P_-^f}\frac{dP_+^f}{P_+^f}. \tag{3}$$

The transverse momentum transfer $\vec{Q}_T$ is in the absence of RPS taken as a Gaussian distribution.

TREATMENT OF GLUON RADIATION AND RUTHERFORD PARTON SCATTERING In FRITIOF gluon radiation is treated with the Soft Radiation Model (SRM) [2] in the dipole cascade scenario [3], and RPS is treated with the probabilistic QCD parton model. A RPS with large P_T would dominate over its underlying gluon bremsstrahlung, and there is no ambiguities in this case. But in the region of phase space where RPS can not be so distinguished from bremsstrahlung, care must be taken to identify the dominant behaviour.

In SRM gluon bremsstrahlung in a h-h collision is treated similar to that in an e^+e^- annihilation, with special assumptions made in connection with the fact that hadrons are extended objects. In analogy to a radiating antenna, only a fraction of the extended emitting source is available for radiation, and the size of this fraction is about the same as the radiation wavelength $\lambda \sim 1/k_T$. If the extension of the source is characterised by the inverse of a momentum scale parameter μ, then only a piece of the source with energy fraction $a(k_T) = (\mu/k_T)^\alpha$ can radiate coherently. We will take the dimensionality parameter α to be 1, consistent with the one dimensional character of assumed hadronic strings. Using two symbols μ_1 and μ_2 to denote the inverse extensions of two string ends in a generic string with mass M, the (reduced) phase space for the radiation is in its rest frame

$$k_T^2 e^{-y} \lesssim \mu_1 M, \quad k_T^2 e^{y} \lesssim \mu_2 M. \tag{4}$$

If the string has been acted upon by only many low P_T momentum transfers (soft collision), the string as a whole should act as a coherent emitter, and so we expect $\mu_1 = \mu_2 = \mu_0$ where $\mu_0 \sim 0.7$ GeV is a parameter in the model characterising the inverse of the hadron transverse size. The presence of RPS will break down the coherence along the string, and we expect μ_1 and μ_2 to be larger than μ_0 (in practice we have used $\mu_1 = \mu_2 = 2\mu_0$).

For the RPS cross section we use the well-known QCD parton model expression $d\sigma_{QCD} \sim F(x_1, Q^2) \otimes F'(x_2, Q^2) d\hat{\sigma}$. This perturbative expression is ill-defined at low P_T and a cut off is normally needed. We wish to treat this cut off dynamically in FRITIOF and make the model infrared stable, meaning that the model should not be sensitive to a few soft parton scatterings. We note that for a Feynman diagram with two incoming partons and a set of produced partons, the propagator with the *largest* transverse momentum $k_\perp$ appears in the cross section with the power $k_\perp^4$. This propagator corresponds to the momentum transfer in the Rutherford scattering. The remaining propagators with *smaller* $k_\perp$ appear in the cross section with the power $k_\perp^2$. They determine the transverse momentum for the associated bremsstrahlung radiation. We then use a procedure that RPS-partons will be included in the outgoing string states only if they are found to be harder than the associated gluon bremsstrahlung. Since soft parton scattering will most likely be irrelevant in this scenario, we need only to generate the RPS with the largest-possible P_T by

$$Prob(p_T) = \rho(p_T) \exp\left(- \int_{p_T}^{\sqrt{s}/2} dp'_T \rho(p'_T) \right), \tag{5}$$

where $\rho(p_T) = (d\sigma_{QCD}/dp_T)/\sigma_{nd}(s)$ with $\sigma_{nd}(s)$ being the hadron-hadron non-diffractive inelastic cross section. In Fig. 1 we show the effects of the dynamical cutoff on this RPS P_T-spectrum.

RESULTS With the implementation of gluon radiation and RPS, combined with string fragmentation [4], FRITIOF gives excellent description to available hadronic collision data. We only have space here to show a few examples for $\bar{p}p$ collisions. In Fig. 2 and Fig. 3 we show respectively the multiplicity and total-event-E_T distributions at 900 GeV. Fig. 4 shows the E_T-distribution of jet clusters (minijets), compared with the UA1 data. (Data are from ref. [5]. Refer to ref. [6] for details of the FRITIOF simulation program.)

References

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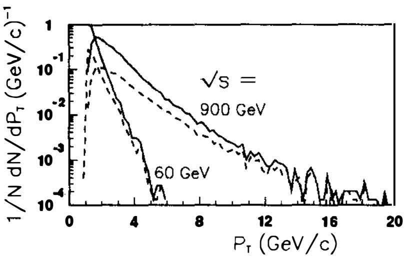

Fig.1 RPS transverse momentum distributions. The solid and dashed lines correspond to the RPS before and after comparison to gluon bremsstrahlung.

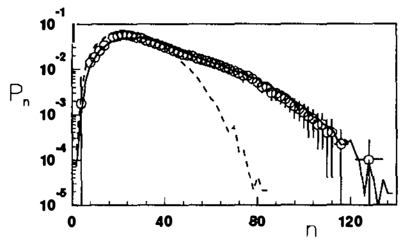

Fig.2 Multiplicity distributions for p-pbar collisions at 900 GeV. Dashed line: FRITIOF with gluon radiation but without RPS. Solid line: including RPS.

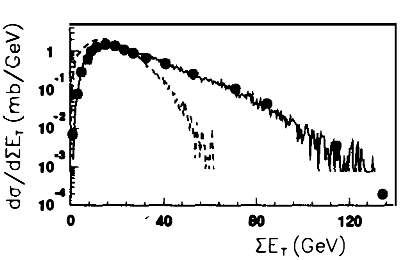

Fig.3 Transverse energy differential cross sections. Notation as in fig. 2.

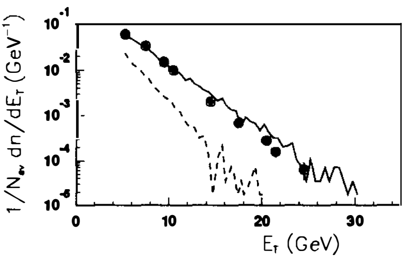

Fig.4 Number of clusters (minijets) per event as a function of the cluster transverse energy. Notation as in fig.2.