Systematic analysis of hadron spectra in p+p collisions using Tsallis distribution

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Using the experimental data from the STAR, PHENIX, ALICE, and CMS programs on the rapidity and energy dependence of the pT spectra in p+p collisions, we show that a universal distribution exists. The energy dependence of temperature, T, and parameter, n, of the Tsallis distribution are also discussed in detail. A cascade particle production mechanism in p+p collisions is proposed [1].

Recently, the Tsallis distribution has attracted many theorists' and experimentalists' attention in high energy heavy-ion collisions. The excellent ability to fit the spectra of identified hadrons and charged particles in a large range of pT up to 200 GeV/c is quite impressive. From the phenomenological view, there may be real physics behind the prominent phenomenology work, e.g. Regge trajectory for particle classification. p+p collision experiments have been performed and measured under different energies. Since p+p collision is very simple compared to nucleus-nucleus collision, the measurements of p+p collisions are used to understand the particle interaction, particle production mechanism and as a baseline for nucleus-nucleus collisions. Many efforts have been put to study the particle spectra produced in p+p collisions using Tsallis distribution. Different versions of the Tsallis distribution are used in the literature. The parameter T in the Tsallis distribution was interpreted as temperature. All of them can fit the particle spectra very well but they give different temperatures. We would like to study the connections and differences among different versions of the Tsallis distribution. We collected p+p collisions data with different p_T ranges and different rapidity cuts from different experiment groups at RHIC and LHC and did a systematic study of the particle spectra using one of the Tsallis distributions. We adopted

$$\left(E\frac{d^3N}{dp^3}\right)_{|N|<n} = A\left(1+\frac{E_T}{nT}\right)^{-n},$$

where A, n and T are fitting parameters. E_T is the transverse energy of the particle.

We collect the spectra data for different particles with different p_T ranges and different rapidity cuts from p+p collisions at 62.4, 200, 900, 2760, and 7000 GeV. In Fig. 1, we showed the prominent fitting power of the Tsallis distribution. This is for charged particles. As we can see, the excellent fitting can cover 15 orders of magnitude up to 200 GeV/c for p_T. This spectacular result was first shown by Wong et al [2]. After performing the systematic analysis of the particle spectra. We found that T is not dependent on the beam energy for pions, while for kaons and protons it increases with increasing energy. Furthermore, we notice that T is higher for the particle whose mass is larger. This is probably due to the particle produced time. In the cascade particle production mechanism, this result is perfectly understandable. The behavior of n for kaons is not the same as pions and protons, which is related to the

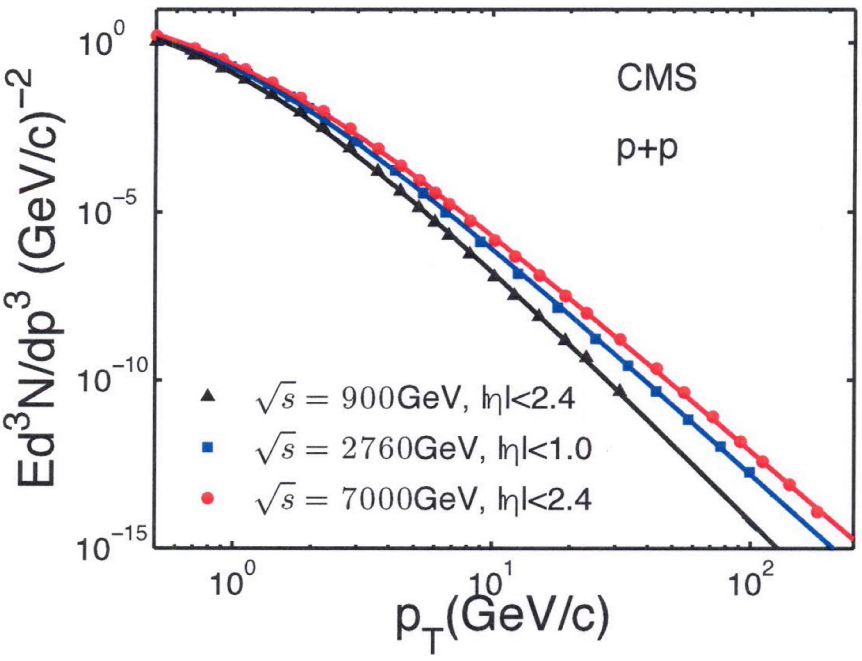

FIG. 1. Fitting results using the Tsallis distribution for charged particles in p+p collisions at 900, 2760, and 7000 GeV, respectively. Data are taken from CMS.

particle production process. From the properties of T and n, we get more information about particle production mechanism in p+p collision.

[1] H. Zheng, Lilin Zhu, and A. Bonasera, Phys. Rev. D **92**, 074009 (2015).

[2] Cheuk-Yin Wong and G. Wilk, Acta Phys. Pol. B **43**, 2047 (2012).