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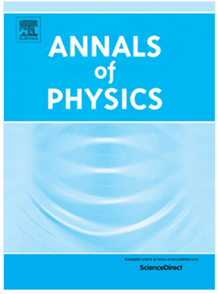

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Regimes of the Pomeron and its Intrinsic Entropy

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We suggest that the perturbative and non-perturbative descriptions of the Pomeron can be viewed as complementary descriptions of different phases in the Pomeron phase diagram, with a phase boundary where the proper description of the produced systems are "string balls". Their intrinsic entropy is calculated and turned out to be the same, as the recently reported perturbative entanglement entropy. The distribution of large multiplicities stemming from the string balls is also wide, with its moments close to those reported for hadrons in *pp* collisions at the LHC. At low-x, the quantum string is so entangled that sufficiently weak string self-attraction can cause it to turn to a string ball dual to a black hole. We suggest that low-x saturation occurs when the density of wee-strings reaches the Bekenstein bound, with a proton size that freezes with increasing rapidity. Some of these observations maybe checked at the future eIC.

I. INTRODUCTION

Already in the 1960's high energy hadronic collisions were described using "Reggeon exchanges" with various quantum numbers. The *Pomeron*, named after Pomeranchuck who introduced the leading exchange with vacuum quantum numbers, dominates hadronic collisions at high energies. Phenomenological descriptions of weakly interacting Pomerons have been developed by Gribov and collaborators, see [1, 2].

In the 1970's, with the advent of QCD in its weak coupling form, a lot of work has been devoted to describe high energy collisions by re-summing certain gluonic Feynman diagrams. This program has been, to leading order, completed by Balitsky, Fadin, Kuraev and Lipatov [3] and is known as the BFKL Pomeron. Reformulation of it in terms of Wilson loops, and the addition of the nonlinar effects leading to saturation, has lead to the so called BK equation, due to Balitsky and Kovchegov [4].

While the perturbative description is valid at small distances, hadronic collisions deal with object sizes and impact parameters $\sim 1\,\mathrm{fm}$, where nonperturbative effects due to confinement are dominant. Therefore multiple efforts have been made to develop a "non-perturbative Pomeron". In this work we discuss one of such approaches, developed using semiclassical tunneling and an effective long string action by Basar, Kharzeev, Yee and Zahed [5], for brevity to be called BKYZ Pomeron. Its main elements will be presented in the next section.

(We will not review other versions of non-perturbative Pomerons, and just note in passing that a holographic idea relating the Pomeron to a dual graviton exchange [6] has evolved into a rather successful theory of double-diffractive production [7, 8] in a framework of AdS/QCD.)

In a previous paper by the two of us [10], to be referred to below as I, it was pointed out that the stringy Pomeron possesses an *intrinsic temperature and entropy*. It happens because the classical world-volume of the exchanged string, for brevity to be called a "tube", possesses a periodic coordinate, which can be identified with a Matsubara time. Therefore quantum oscillations of the tube have the form of a thermal theory. This temperature depends on the location along the tube, its maximal value is

$$\frac{1}{T} = \beta = \frac{2\pi b}{\chi}, \tag{1}$$

where b is the impact parameter (the length of the tube) and $\chi = \ln(s/s_0)$ is the relative rapidity of the beams. In the standard way, this temperature defines the energy, entropy and other thermodynamic quantities of the system.

Further arguments in I point out that since the QCD strings are well known to exhibit the so called Hagedorn transition as a function of temperature, real or "effective", at a certain temperature T_H. As $T \to T_H$ from below,