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## The Rating Quality for Theoretical Description of Experimental Data

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### The Rating Quality for Theoretical Description of Experimental Data

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1. *Introduction.* A new multi-parameter score-rating methodology for assessing the quality of theoretical description of experimental data in heavy-ion physics [1-11] is proposed. The approach overcomes the limitations of the traditional single-value criterion  $\chi^2/\text{ndf}$ , which provides only an integral measure of agreement between theory and experiment.

The methodology is based on dividing the phase space into seven physically motivated kinematic regions of transverse momentum  $p_T$  distributions and particle ratios, corresponding to different underlying physical regimes. For each region, the quality of agreement is quantified by a score  $Q_i \in [10; 1000]$  defined on a scale, ranging from very poor to excellent agreement.

A comprehensive rating  $R$  is constructed through a systematic procedure that includes region definition, weighting according to physical significance, aggregation of local scores, uncertainty estimation, stability checks, and visualization. This framework enables a transparent and comparative assessment of theoretical models, revealing their region-specific performance and complementarity.

2. *Methodology.* The phase space is divided into seven kinematic regions corresponding to different physical regimes: thermal spectra ( $p_T < 0.8$  GeV/c), radial flow, hard processes relevant to QGP formation (2.5–4.0 GeV/c), medium-energy jets, high-energy jets with quenching, and the perturbative QCD regime ( $p_T > 10$  GeV/c).

For each region, the local statistic is defined as:

$$R_i = \frac{\chi_i^2}{\nu_i}, \quad \nu_i = N_i - k \text{ where } N_i \text{ is the number of data points and } k \text{ is the number of model parameters.}$$

3. *Score Assignment.* Based on the value of  $R_i$ , a quality score  $Q_i$  is assigned using a scale, ranging from  $Q_i = 1000$  for excellent agreement to  $Q_i = 10$  for very poor agreement.

4. *Weighting and Aggregation.* Weight coefficients reflect the physical significance of different kinematic regions. The aggregated quality measures include weighted averaging, geometric mean, minimum score, and dispersion penalties.

5. *Results and Discussion.* The methodology was applied to LHC data for  $K_S^0$  mesons and  $\Lambda$  hyperons in  $p$ -Pb collisions at  $\sqrt{s_{NN}} = 5.02$  TeV. The analysis demonstrates model complementarity and sensitivity to nuclear shadowing effects.

6. *Conclusions.* The proposed score-rating methodology provides a transparent and robust framework for ranking theoretical models in heavy-ion physics and is well suited for systematic studies of LHC Run 3 data and beyond.

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