Advancing Soft QCD Understanding
Revisiting Multi-Pomeron Exchange in String Models with U-Matrix Solutions

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Monday, July 15, 2024
IJCLab, Orsay

Hadron interaction and QCD

- Hadronic interactions : Involve particles that undergo strong interactions.

- QCD : Widely recognized as the theory of strong interactions.

- QCD is most applicable to processes in which the coupling constant is small.

$\alpha = (Q^2)$

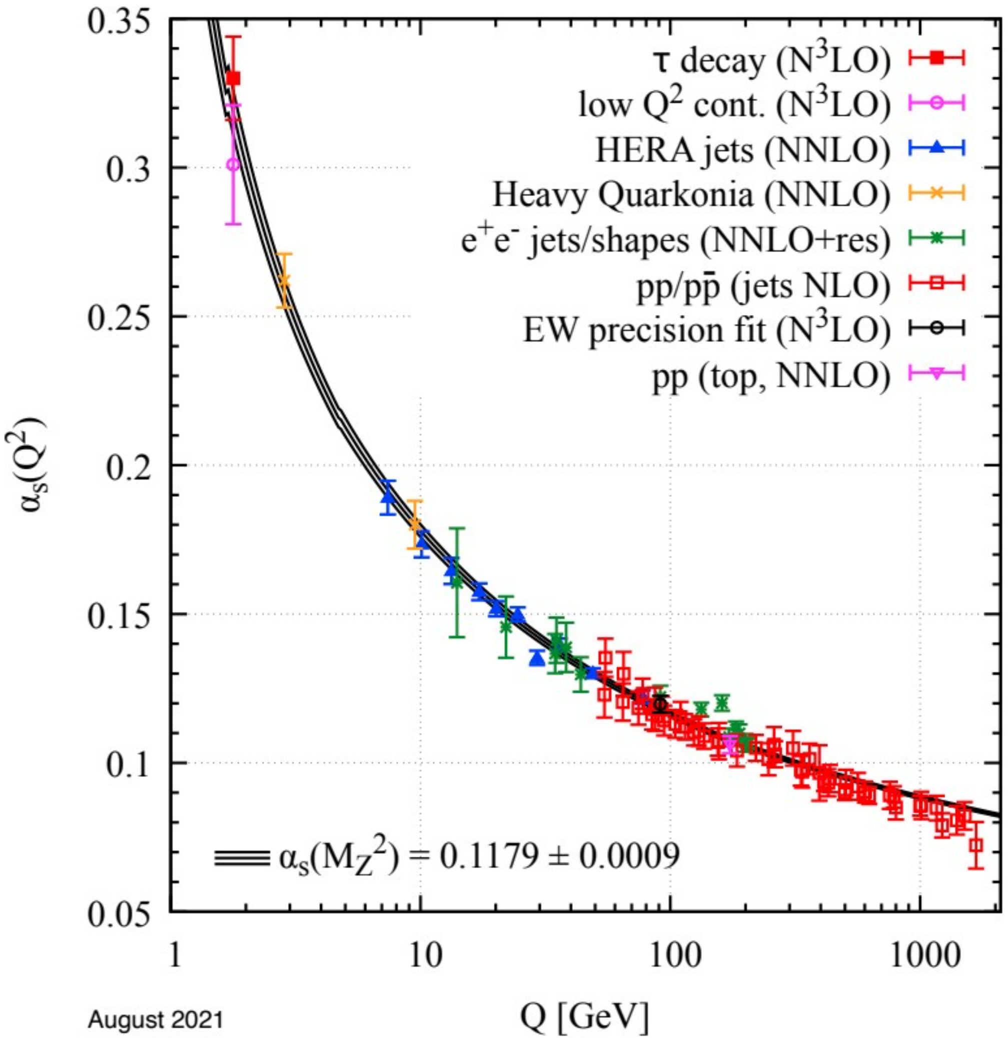
- Two QCD processes :

- At large Q ⇒ α small

⇒ Hard QCD

- for small Q ⇒ α large

⇒ Soft QCD



Problem : soft qcd : perturbation theory breaks down

- Solution : Pheno. models

- abundant in the literature :

    - based on the Gribov-Regge phenomenology.

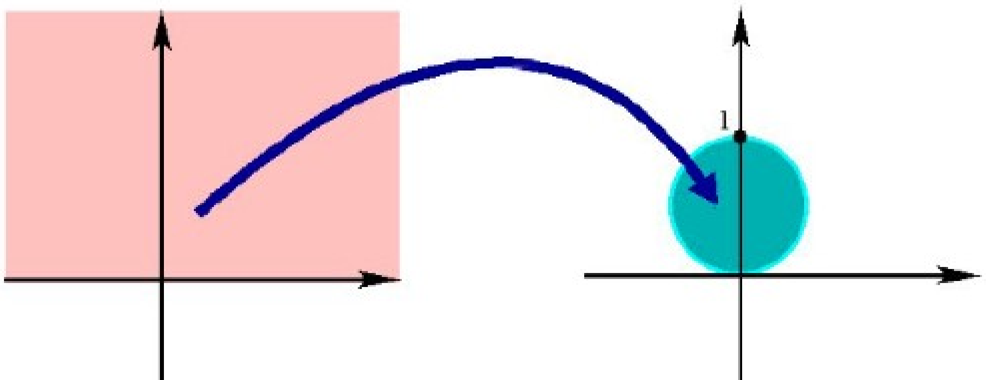
      hinge on fundamental principles of S matrix theory : unitarity, analyticity and crossing

      empirical parameterizations

Unitarity Problem

$$S(s, \mathbf{b}) = 1 + iG(s, \mathbf{b})$$

Unitarity demands that $|S(\mathbf{b})|^2 \leq 1$ $\Longrightarrow$ Unitarity circle: the amplitudes must lay on the circle to satisfy the unitarity condition for elastic scattering.



Several ways to represent the unit circle

- one can map the upper complex plane into a circle via a complex exponential

$$S(s,\mathbf{b}) = \exp(iz(s,\mathbf{b})) \quad \text{with} \quad \text{Im } z(s,\mathbf{b}) \geq 0.$$

$$\Longrightarrow \qquad G(s,\mathbf{b}) = i(1 - \exp(i\chi(s,\mathbf{b}))).$$

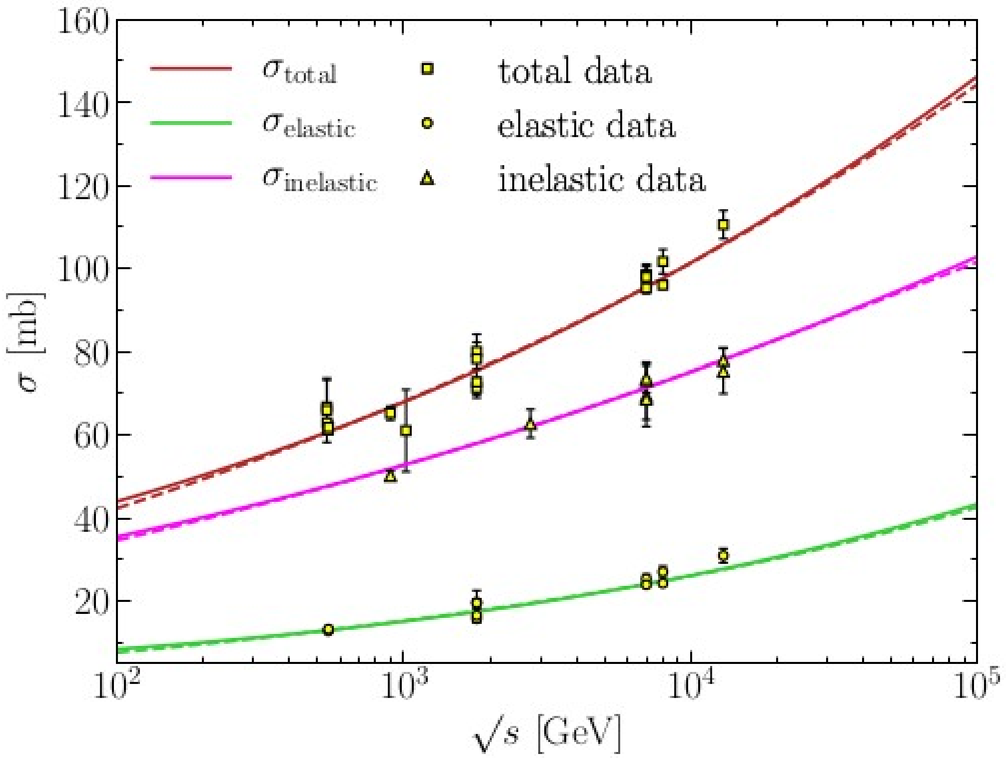
- Use a one-to-one map through a Möbius transform

$$S(s,\mathbf{b}) = \frac{1 + iz'(s,\mathbf{b})}{1 - iz'(s,\mathbf{b})}, \quad \text{with} \quad \text{Im } z'(s,\mathbf{b}) \geq 0.$$

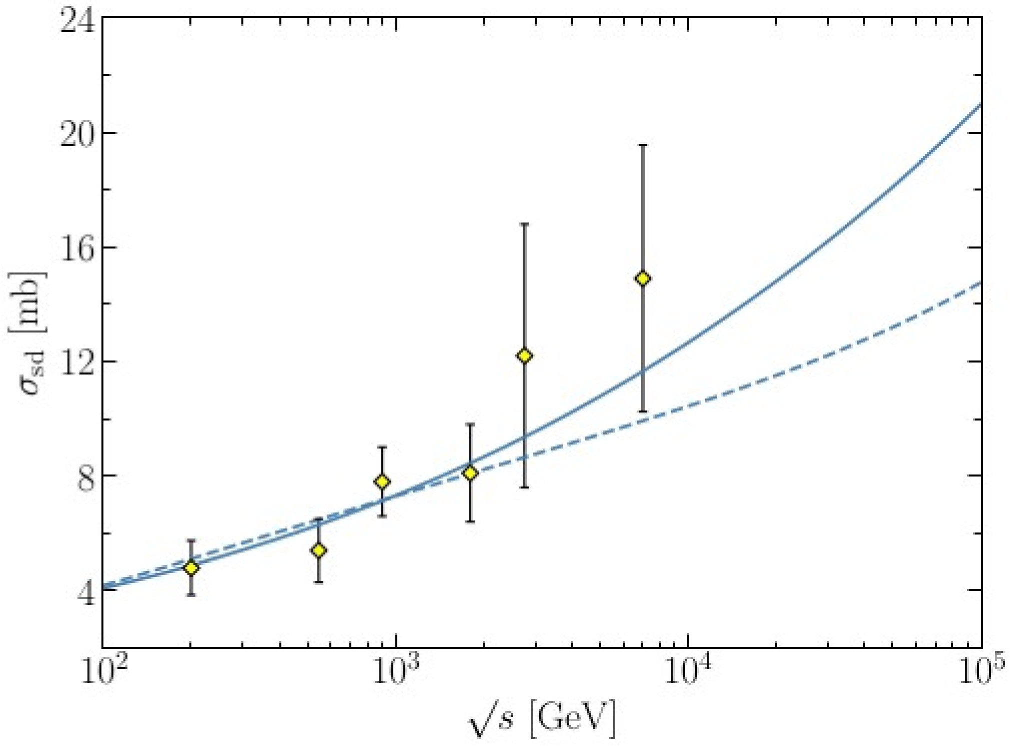
$\Longrightarrow$ U Matrix scheme

$$G(s,\mathbf{b}) = \frac{\chi(s,\mathbf{b})}{1 - i\chi(s,\mathbf{b})/2}.$$

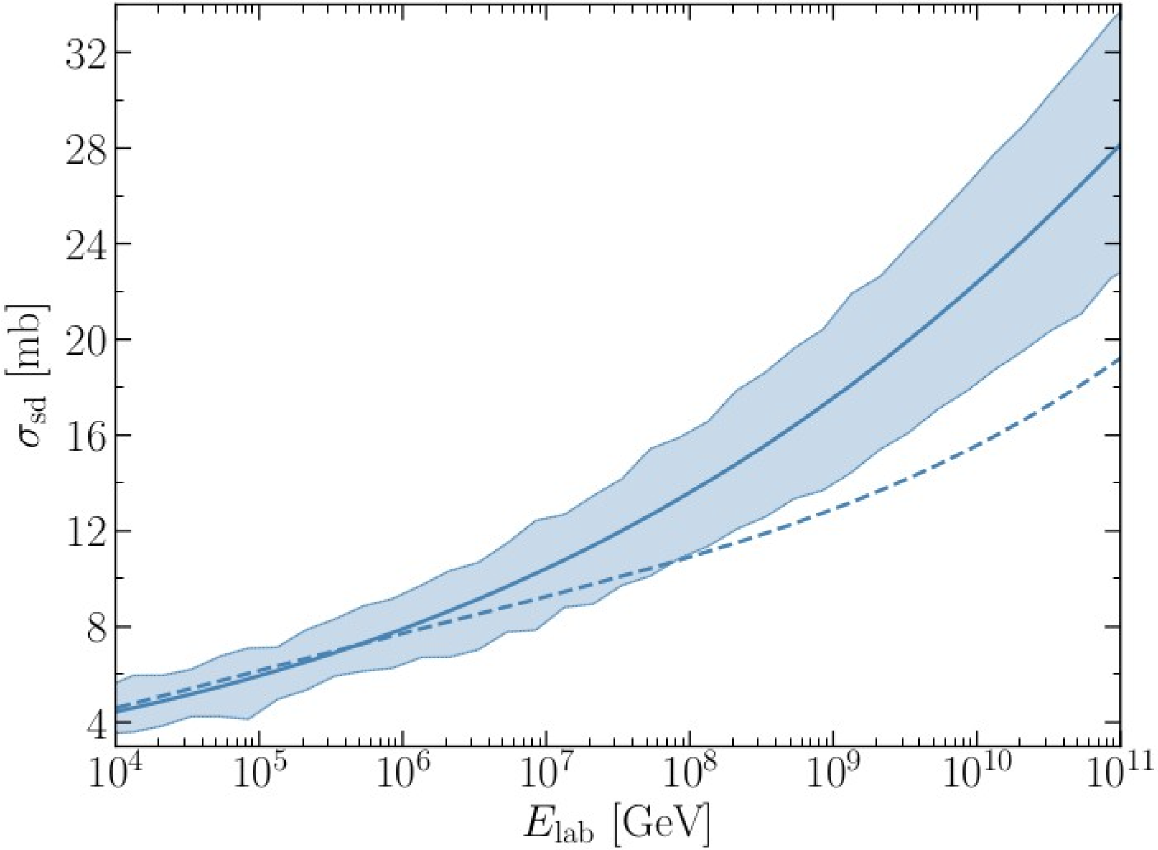
High-energy collider data for pp and p$\bar{p}$ scattering



Single diffractive cross-sections



Single-diffractive cross section at ultra-high energy



Unitarisation and multi-particle production

- Slight better description for cross-sections with the U matrix scheme than the eikonal

- What about the multiplicity distribution

- Probability of producing n char $P_n(s) = \frac{\sigma_n(s)}{\sigma_{\text{in}}(s)}$ elastic p + p(p̄) collision at the energy s

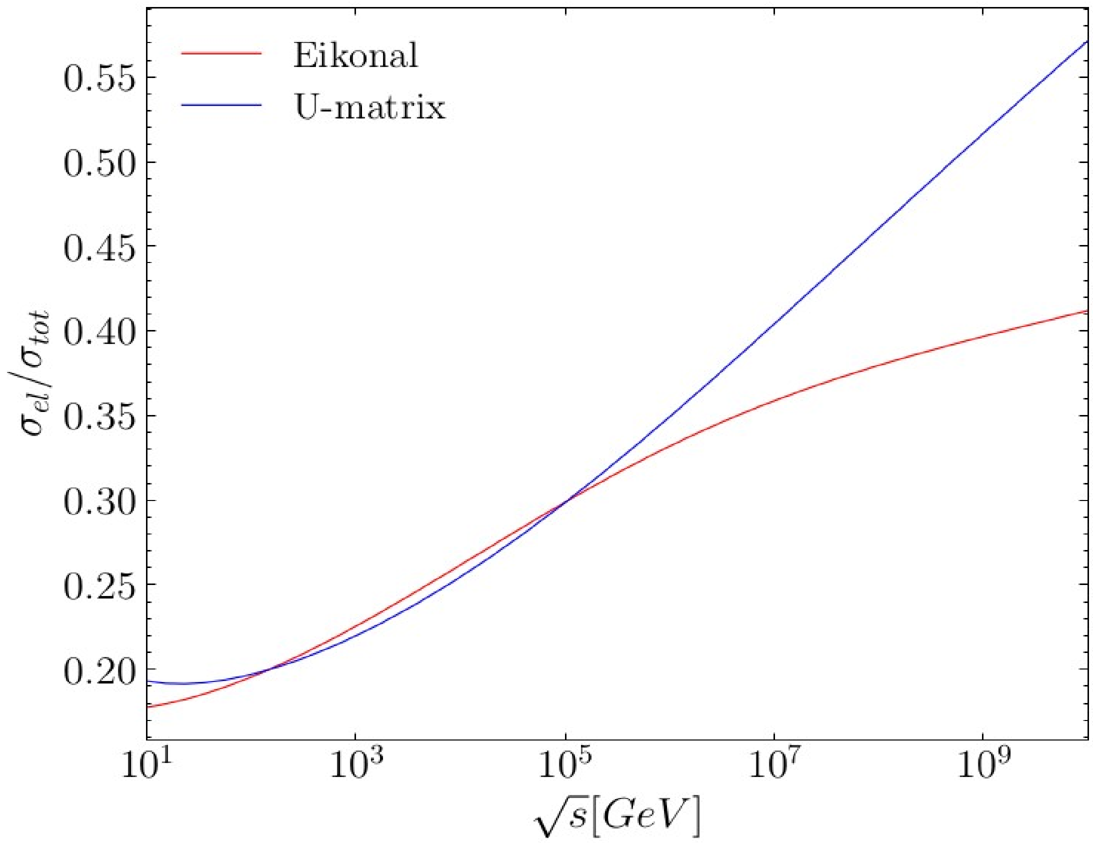
The model

$$P_n(s) = \frac{1}{\langle n(s)\rangle \int d^2b\, G_{\rm in}(s,b)} \int d^2b\, \frac{G_{\rm in}(s,b)}{f(s,b)}\, \phi^{(1)}\left(\frac{z}{f(s,b)}\right),$$

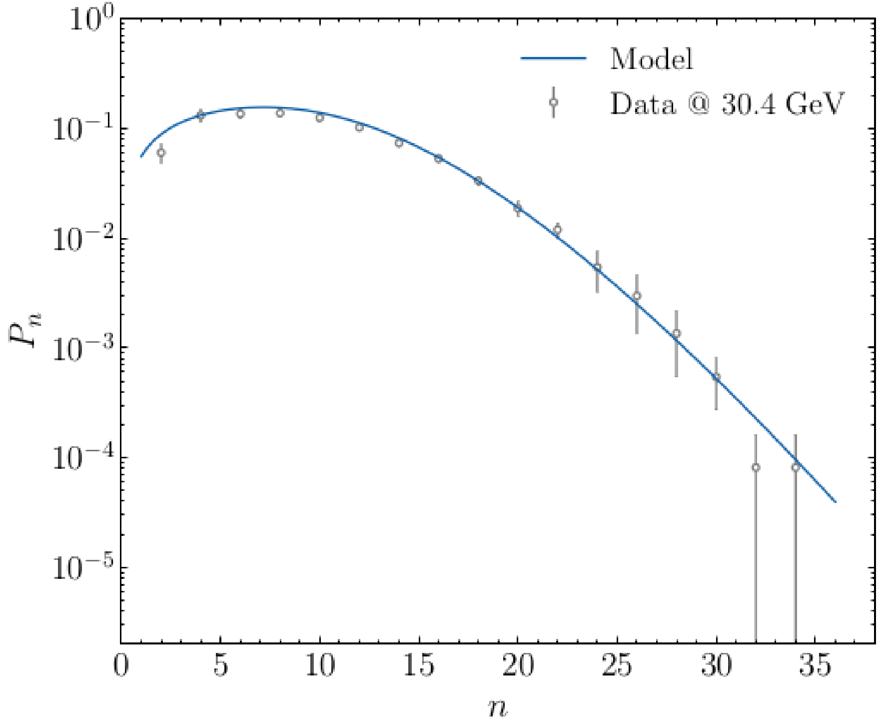
- Superposition procedure : summing contributions from parton-parton collisions occurring at each impact parameter weighted by the inelastic overlap function, which dictates the unitarisation scheme.

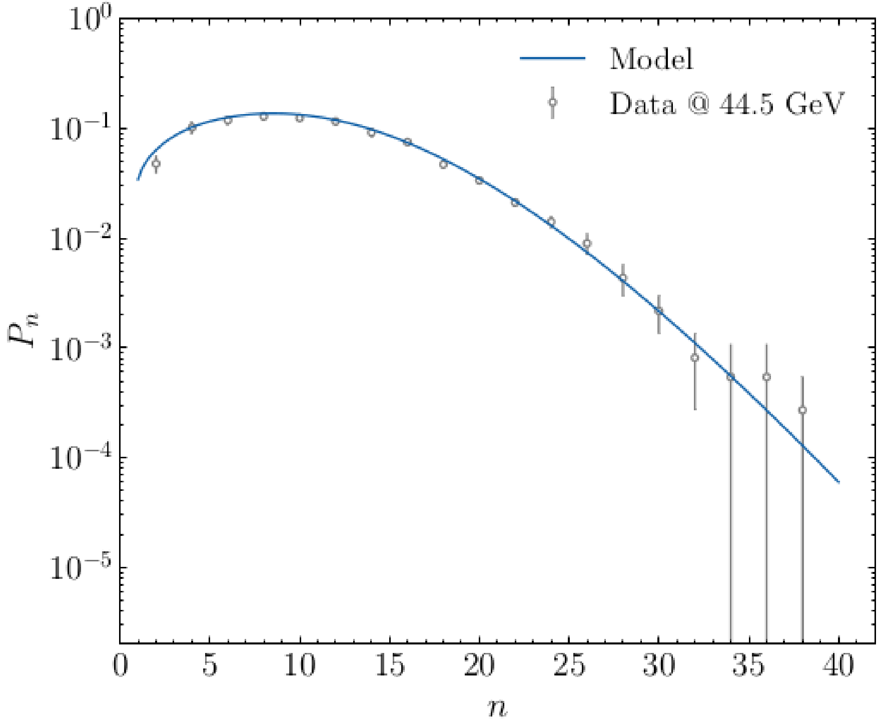
- picture : the KNO scaling violation viewed as an extension of the geometrical scaling violation

Geometrical scaling violation

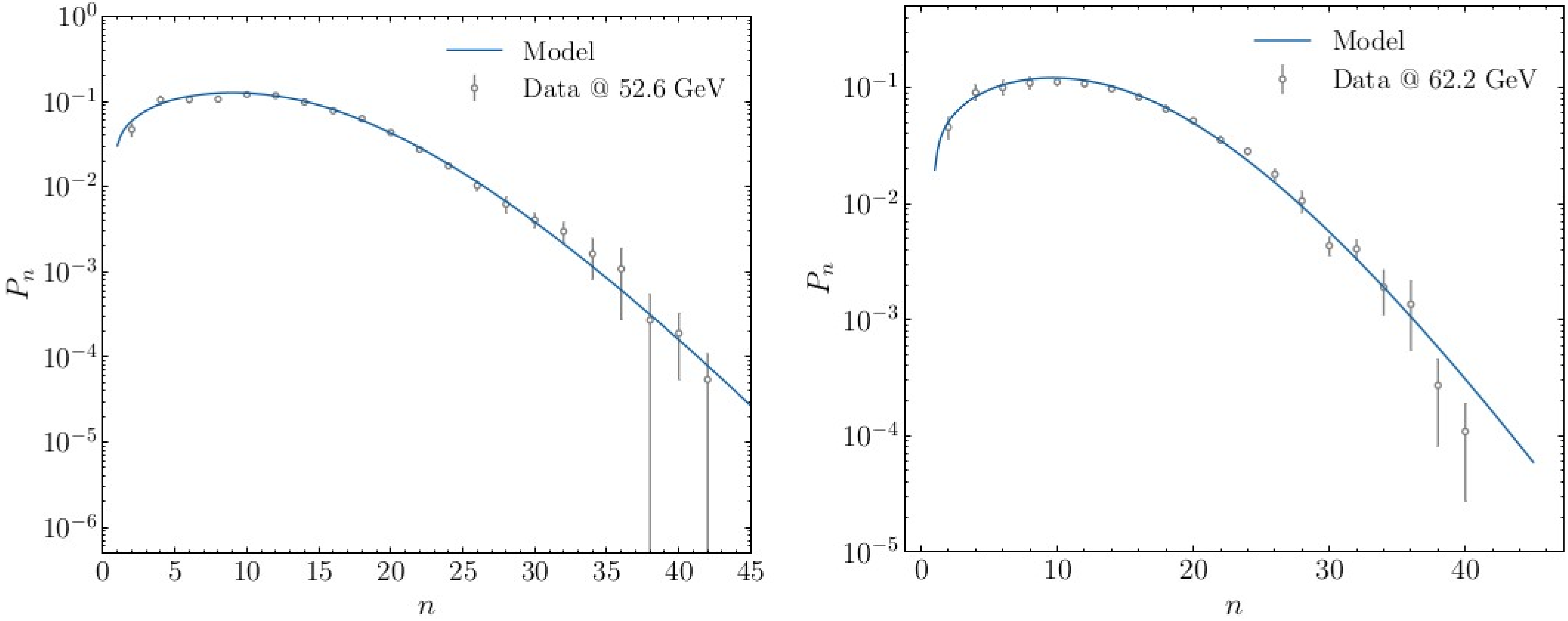


Multiplicity distributions for inelastic pp collision

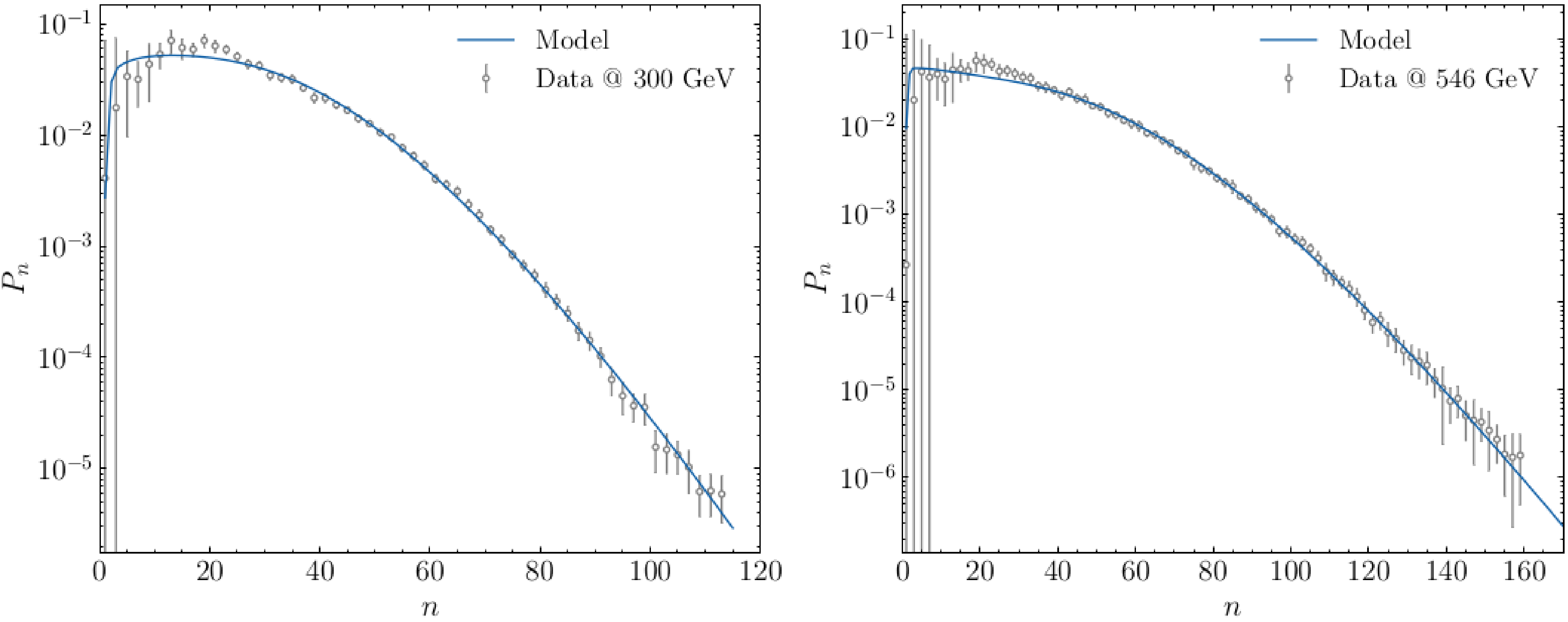




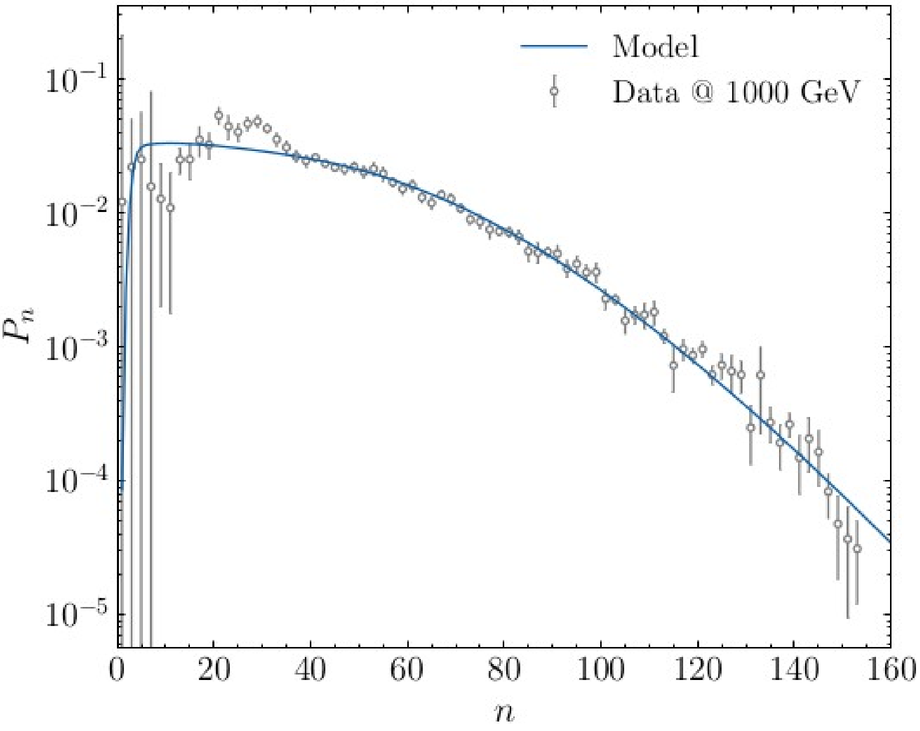
Multiplicity distributions for inelastic pp collision

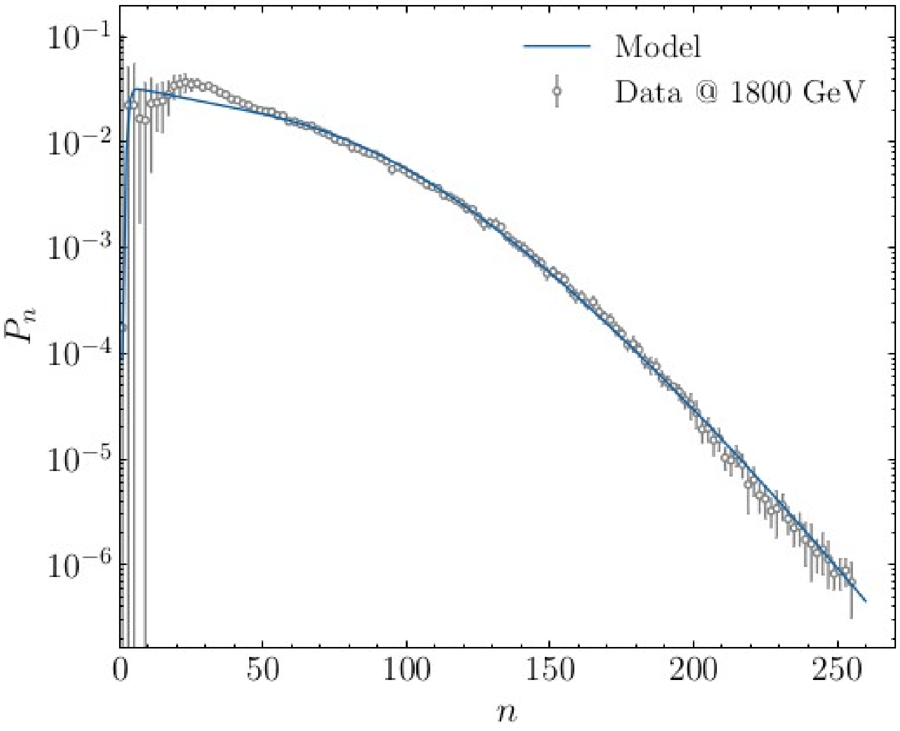


Multiplicity distributions for inelastic p̄p data



Multiplicity distributions for inelastic p̄p data



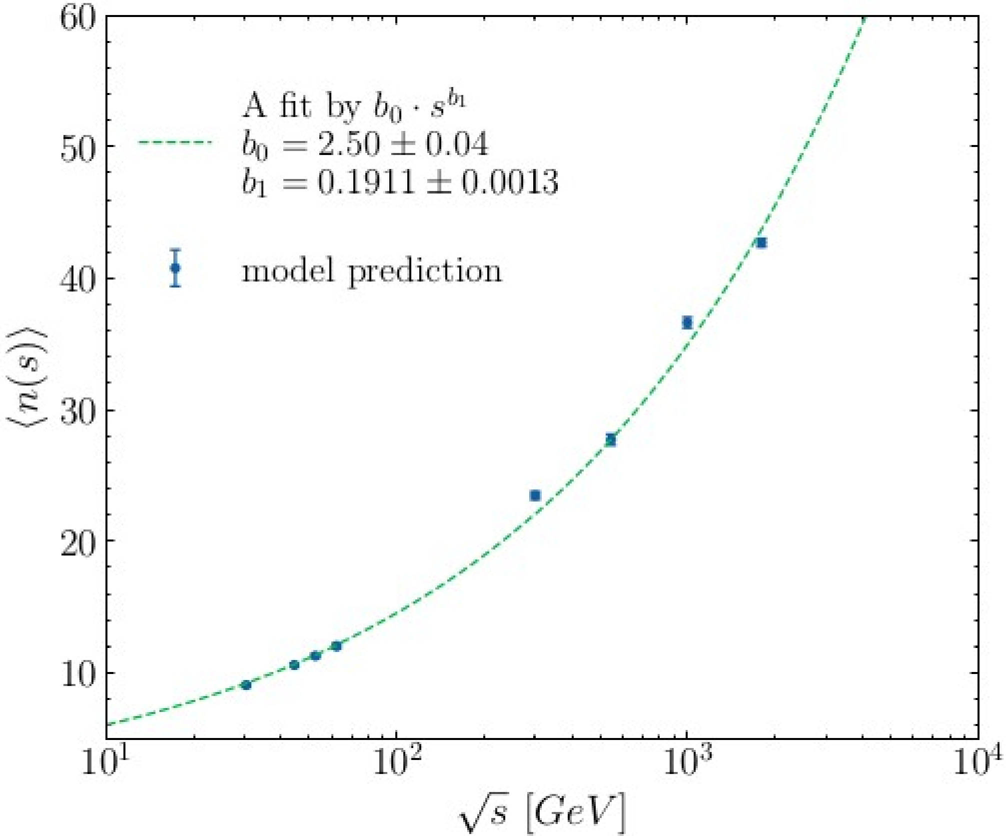


Hadron mean multiplicity

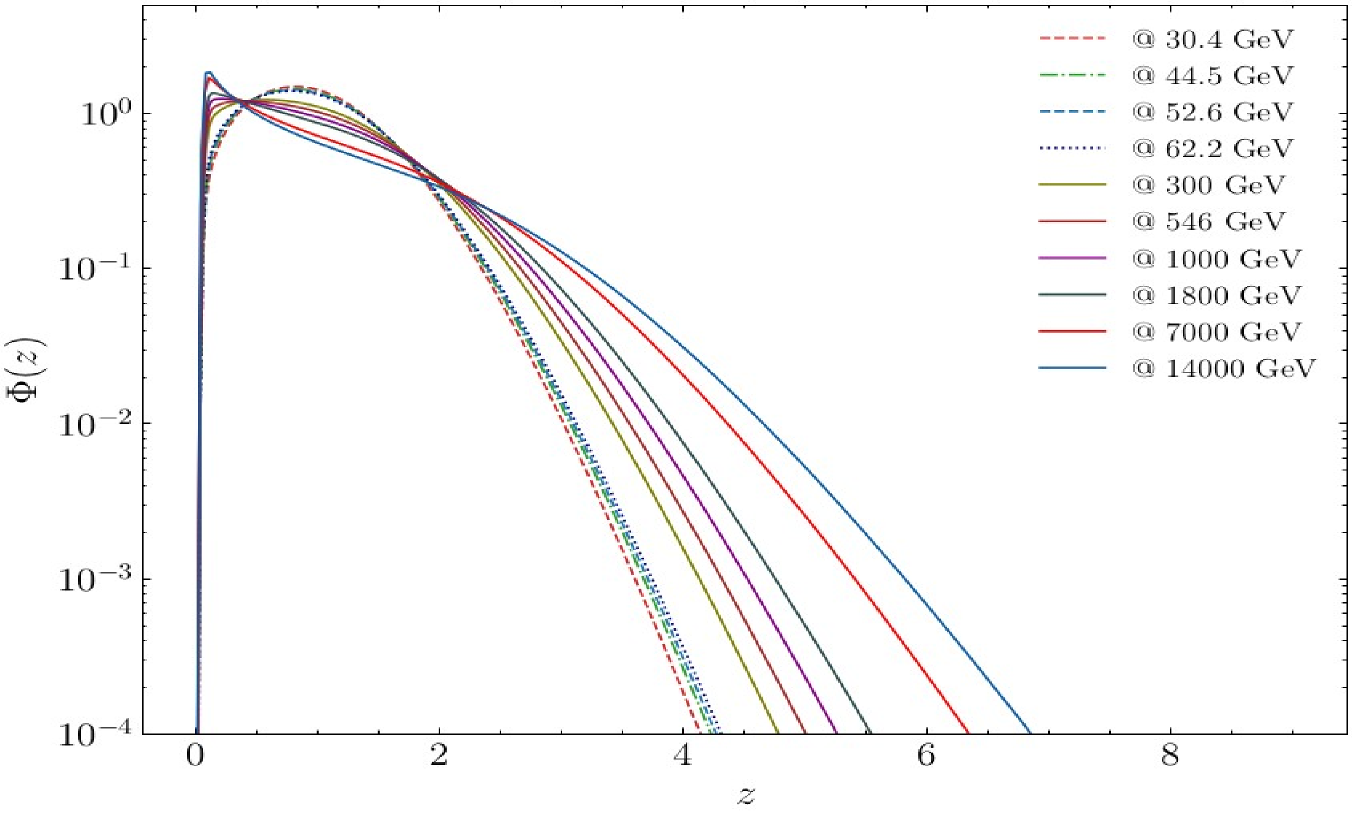
- In line with Troshin and Tyurin :

$$\langle n(s) \rangle = 2.328\ s^{0.201},$$

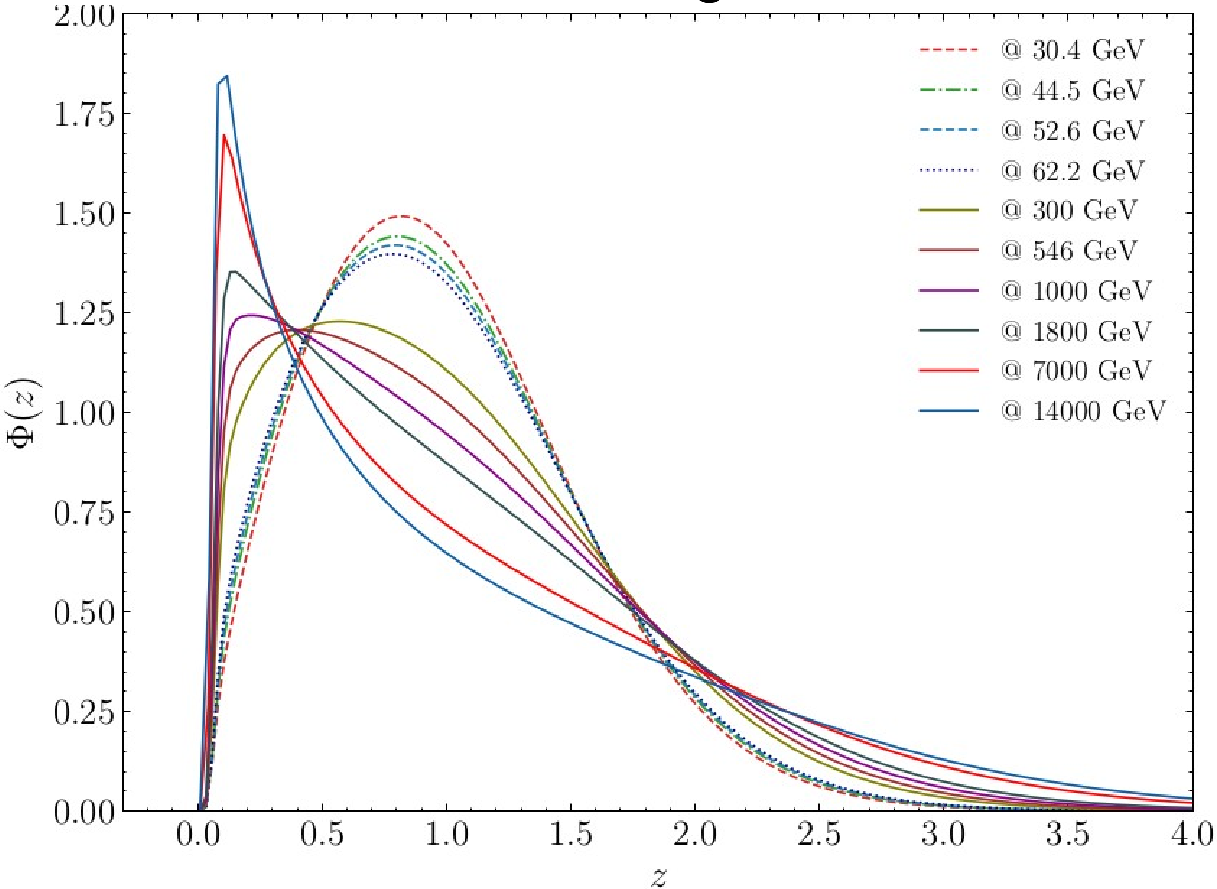
- this alignment further support the use of The U Matrix scheme



KNO scaling violation



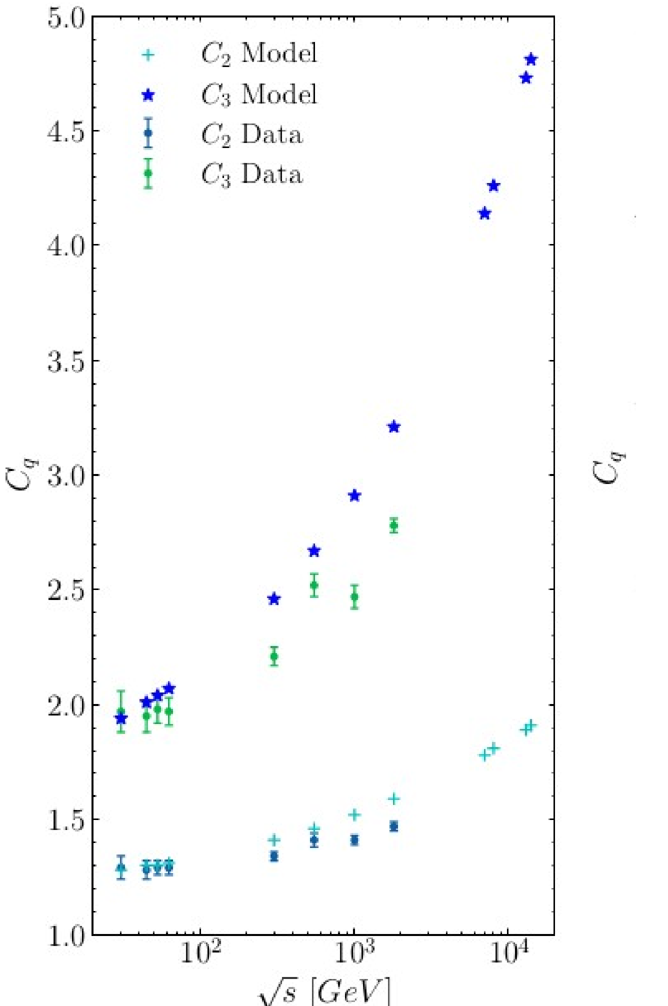
KNO scaling violation



Particles correlation and fluctuation

$$C_q = M_q / M_1^q,$$

$$M_q = \sum_{n=0}^{\infty} n^q P_n,$$



Particles correlation and fluctuation

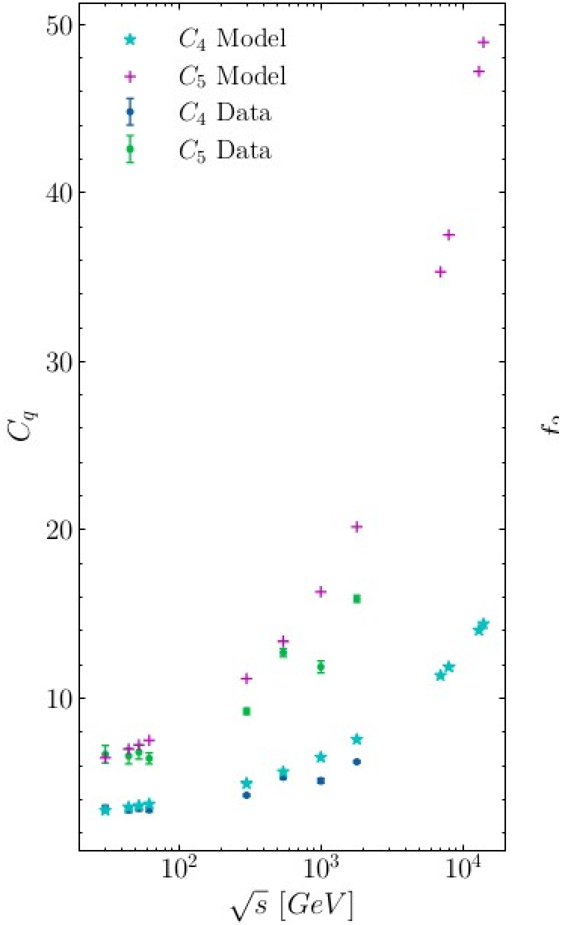
- Predictions match with the data points

within the ISR energy range

- Overestimates the fluctuations and correlations

  in the multiplicity distribution with rising energy

  notably above LHC energy.



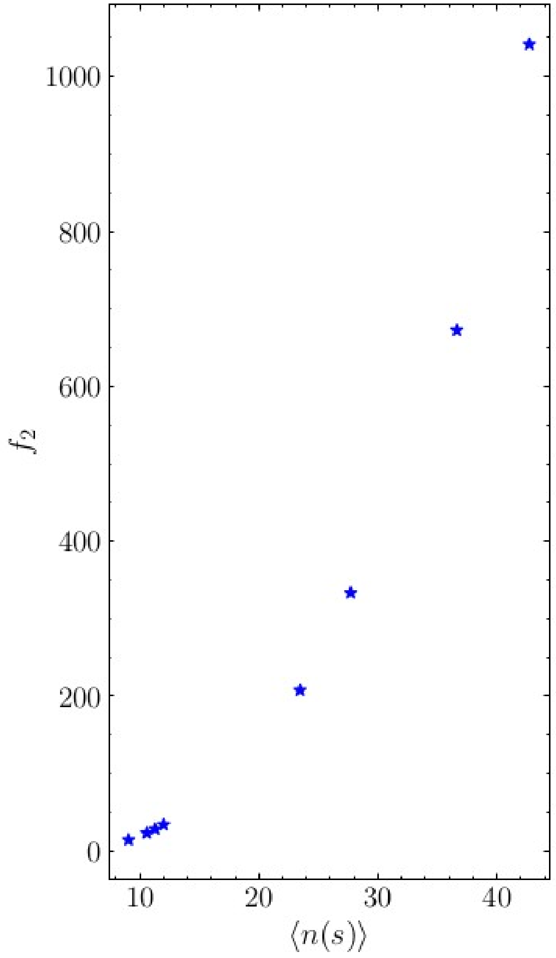
Particles correlation and fluctuation

- In order to further illustrate this overestimation

- The f2 moment

  (or the two-particle correlation parameter)

$$f_2 = < n(n-1) > - < n >^2$$



Model’s Outcomes

- Pronounced KNO scaling violation resulting from a strong Geometrical scaling violation

- Unexpected overestimation of the fluctuations and correlations with increasing energy

- Attributed to statistical fluctuations related to the inelastic overlap function and hence to the U Matrix scheme

- What is the distribution of pomerons in the U-Matrix scheme ?

Thank you for your attention