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ELEMENTARY PARTICLES AND FIELDS
Theory

Scaling of Semi-inclusive Events in *pp* Interactions

A. I. Golokhvastov*

Joint Institute for Nuclear Research, Dubna, Moscow oblast, 141980 Russia

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Abstract—The normalized single-particle semi-inclusive double-differential spectrum of π^- mesons from pp interactions at 6.6–400 GeV/c and the relative concentration of π^0 and K_S^0 mesons in such events of fixed multiplicity of π^- mesons are completely determined by specifying any feature of this spectrum—for example, $\langle y^2 \rangle_n$ or $\langle E \rangle_n$. Therefore, a two-parameter sample of semi-inclusive events that depends on the energy and the multiplicity reduces to a one-parameter sample.

Sasha Golokhvastov
Dubna, ≈1980

Dedicated idealist in physics and life

Proponent of ''slow science'' [AB] (= thinking about and discussing your idea before publishing in 10 papers)

AB – Andrzej Bialas, SQM 2011, Krakow After dinner talk

The term "semi-inclusive" was introduced by Koba, Nielsen, and Olesen [1], who studied the scaling of semi-inclusive spectra (this is so-called KNO-II scaling, which was not confirmed, however, in experiments [2, 3]). A semi-inclusive spectrum is a kinematical spectrum of particles of some sort in events where the number of these particles is fixed.

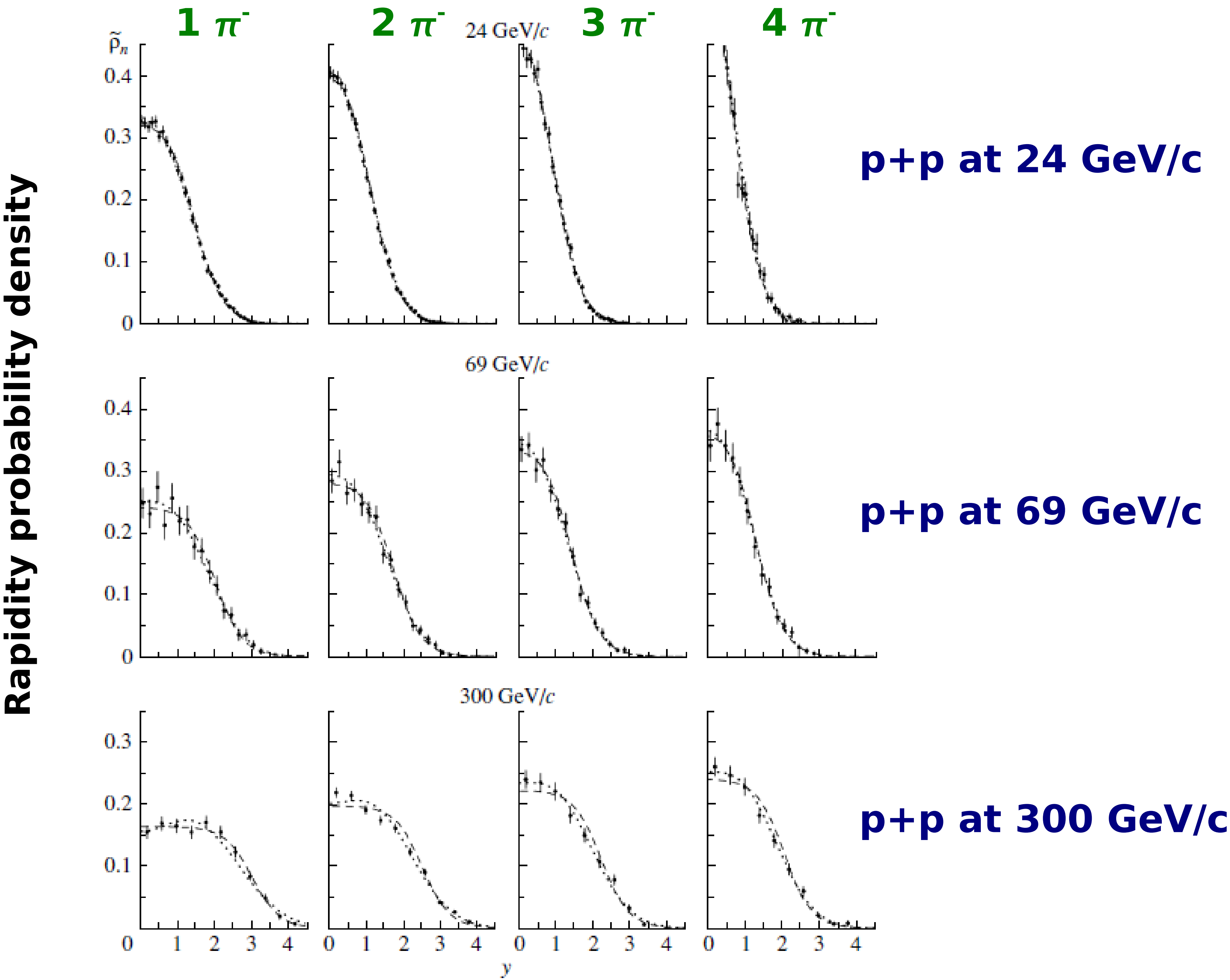
e.g., **π^- rapidity spectrum in**
$p+p \rightarrow n\ \pi^- + X$ processes
at a given collision energy

The richest data on semi-inclusive spectra concern rapidity distributions of negatively charged pions (or hadrons) in p+p interactions at the SPS (NA61/SHINE) energies.

Data at higher collision energies are poor as collider experiments have typically small acceptance.

$$P(y \mid \sqrt{s},\ n) = \tilde{\rho}_n(y) = \frac{1}{n\sigma_n}\frac{d\sigma_n}{dy}, \qquad \int \tilde{\rho}_n(y)dy = 1 \qquad (1)$$

(the tilde symbol is used here to indicate that ρ is normalized to unity [4, 11]). Thus, the quantity $\tilde{\rho}_n(y)$ is the density of the probability that an arbitrarily chosen π^- meson in any event featuring n π^- mesons has a rapidity y.



1 π⁻
2 π⁻
3 π⁻
4 π⁻
24 GeV/c
69 GeV/c
300 GeV/c
Rapidity probability density
p+p at 24 GeV/c
p+p at 69 GeV/c
p+p at 300 GeV/c
y

Obviously semi-inclusive spectra depend on both experimental parameters,
- particle multiplicity and
- collision energy.

Sasha Golokhvastov found that the two parameter dependence can be reduced to a single parameter dependence:

Golokhvastov scaling of semi-inclusive spectra

$$P(\, y \mid \sqrt{s},\, n\,) \;=\; P(\, y \mid f(\sqrt{s},\, n)\,)$$

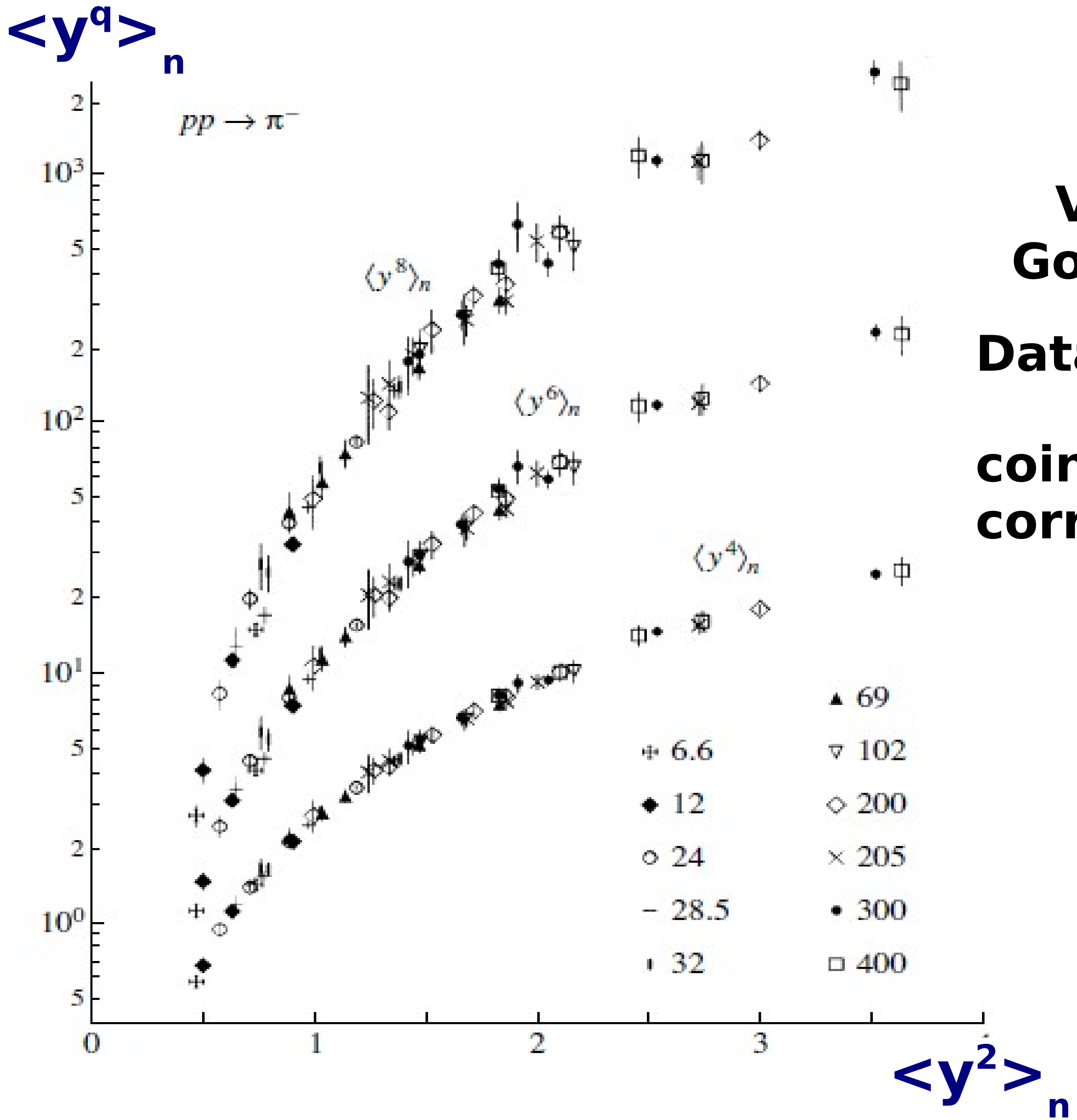
Golokhvastov scaling of semi-inclusive spectra

P(y | √s, n) = P(y | f(√s, n))

In particular f(√s, n) can be selected as any parameter characterizing rapidity spectrum, e.g., its variance $<y^2>$

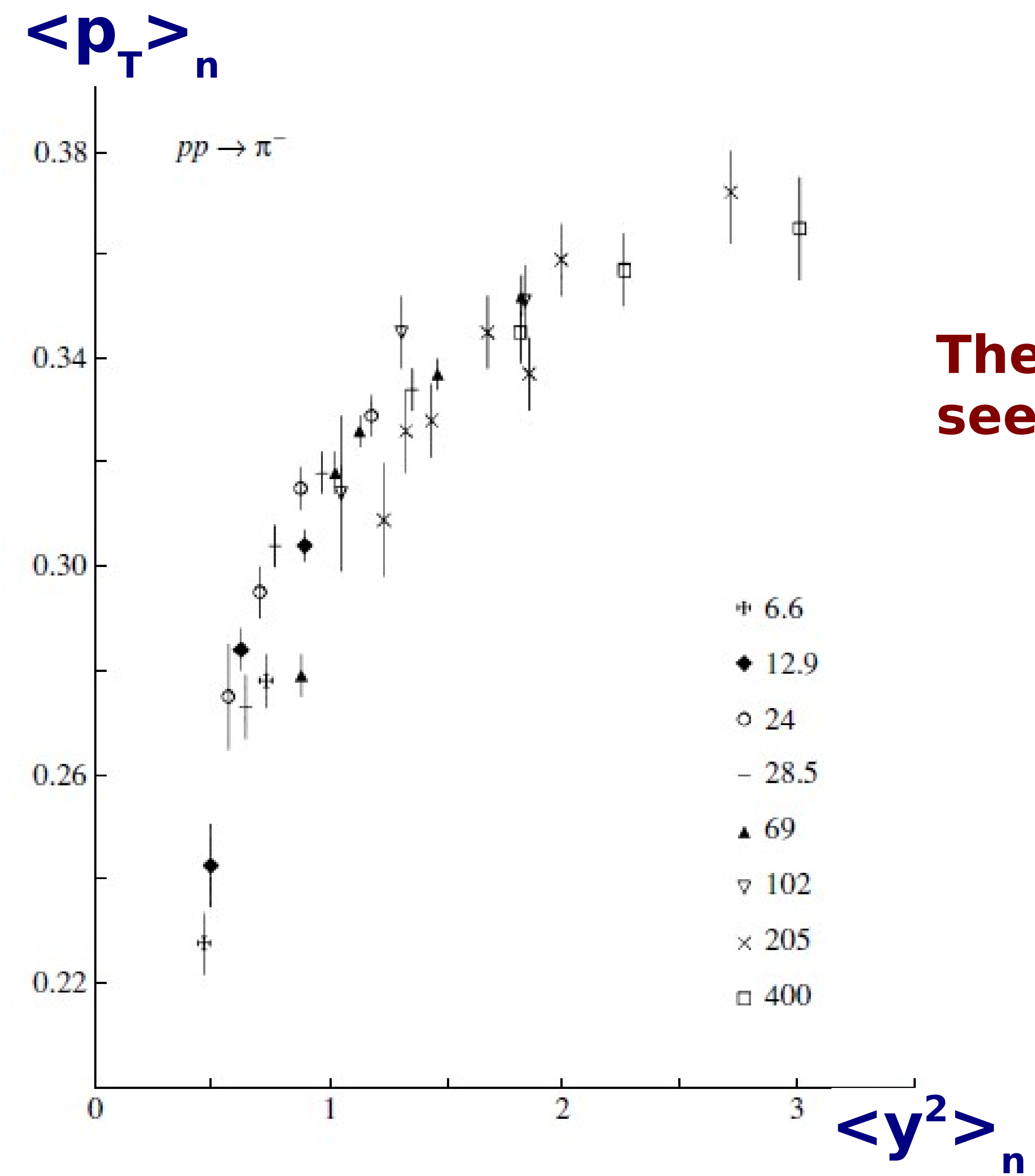
and the scaling can be tested using higher moments of y

$$\langle y^q \rangle_n \equiv \int y^q \bar{\rho}_n(y) dy. \qquad (2)$$



Verification of the Golokhvastov scaling:

Data points for various $\sqrt{s}$ and n coincide providing they correspond to the same $\langle y^2 \rangle_n$



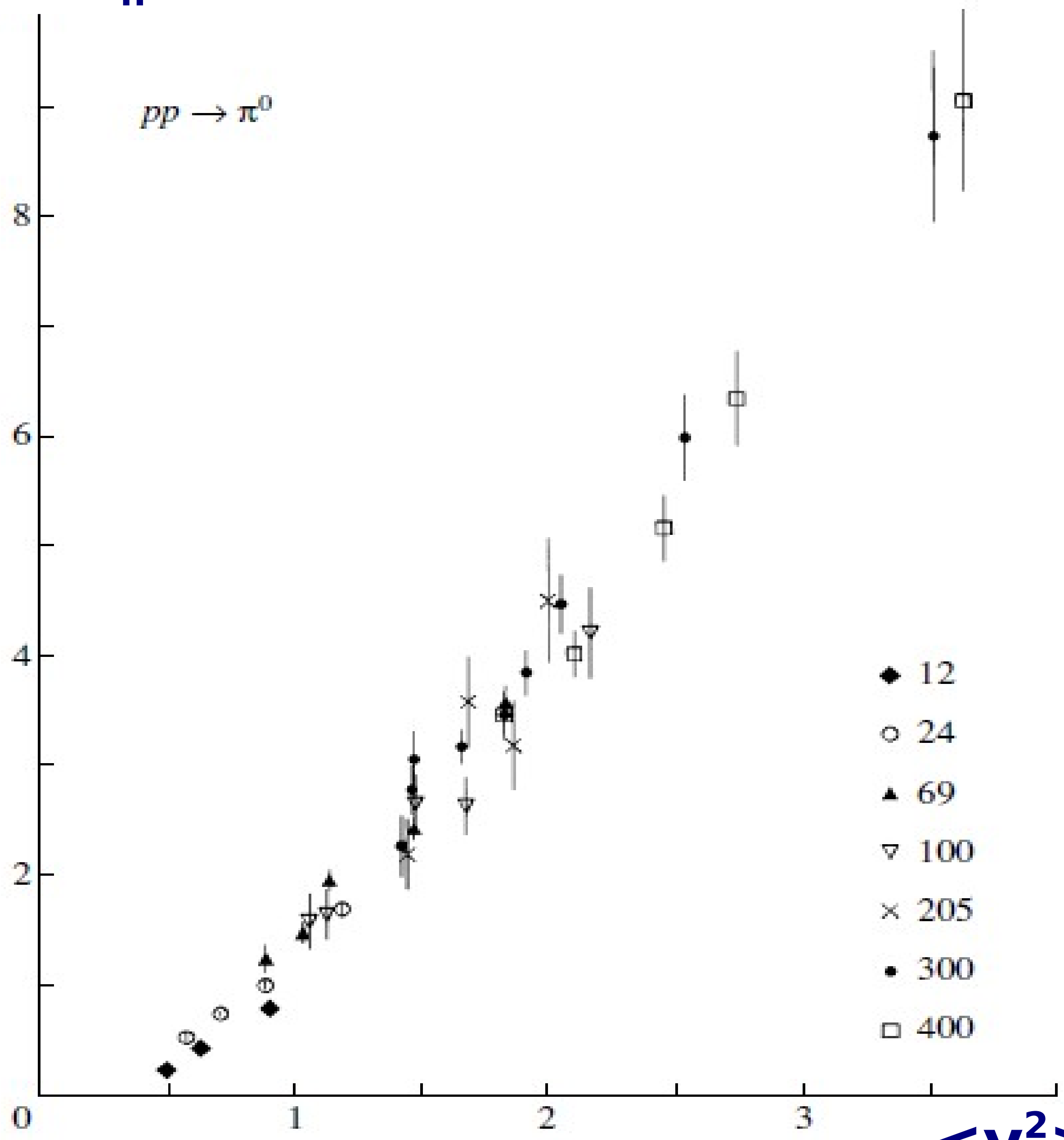
The Golokhvastov scaling seems to be valid also for p_T spectra

Thus Sasha formulated the hypothesis of the scaling validity for the two-dimensional y, p_T spectrum:

$$\frac{1}{n\sigma_n}\frac{d^2\sigma_n}{dydp_T}(\sqrt{s},n) = \frac{1}{n\sigma_n}\frac{d^2\sigma_n}{dydp_T}[f(\sqrt{s},n)]. \quad (3)$$

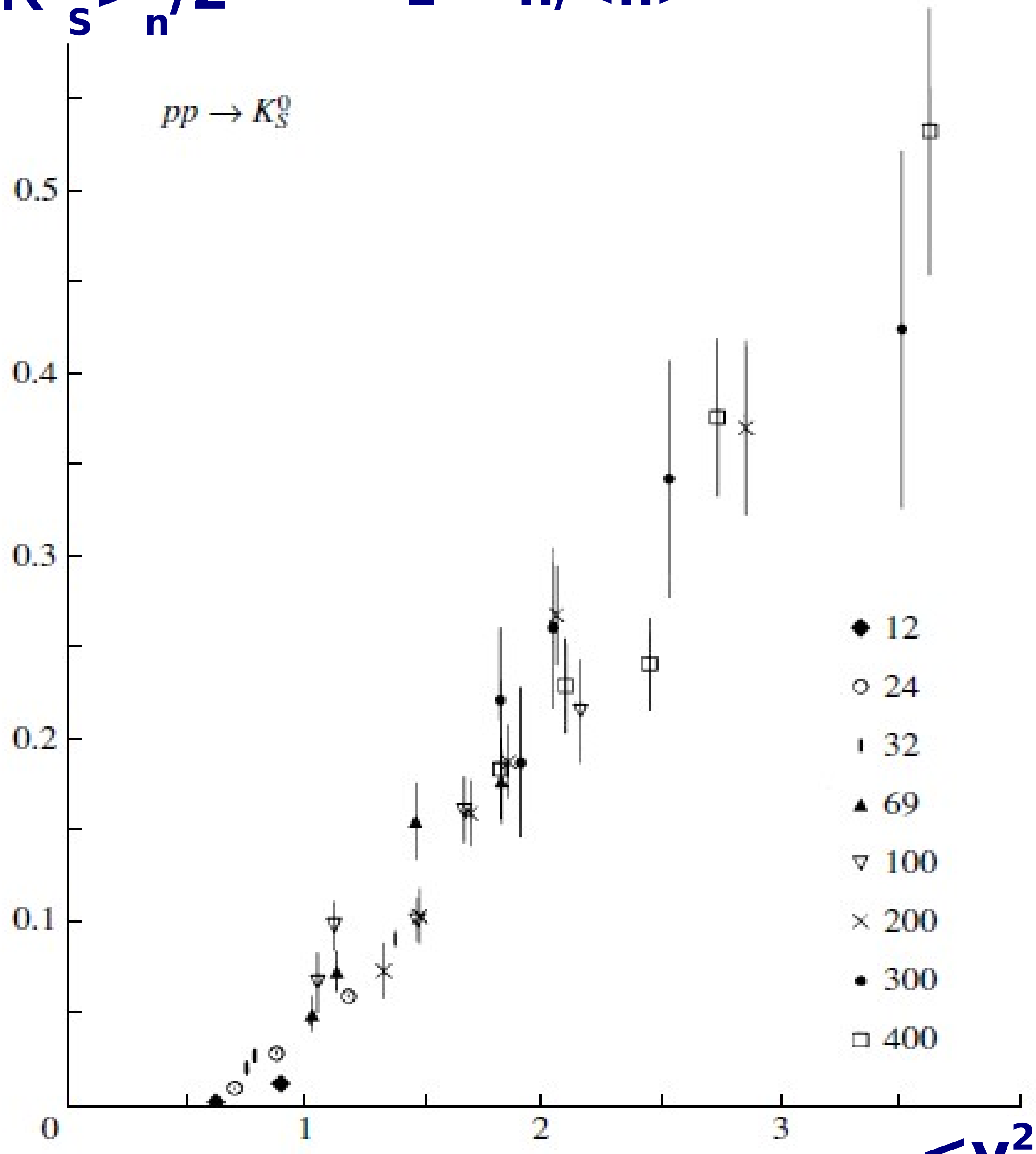
and possibly, for other properties of hadron production e.g., mean multiplicity of neutral pions and kaons.

$<\pi^0>_n/z$ $z = n/<n>$



$<y^2>_n$

$<K^0_S>_n/z$ $z = n/<n>$



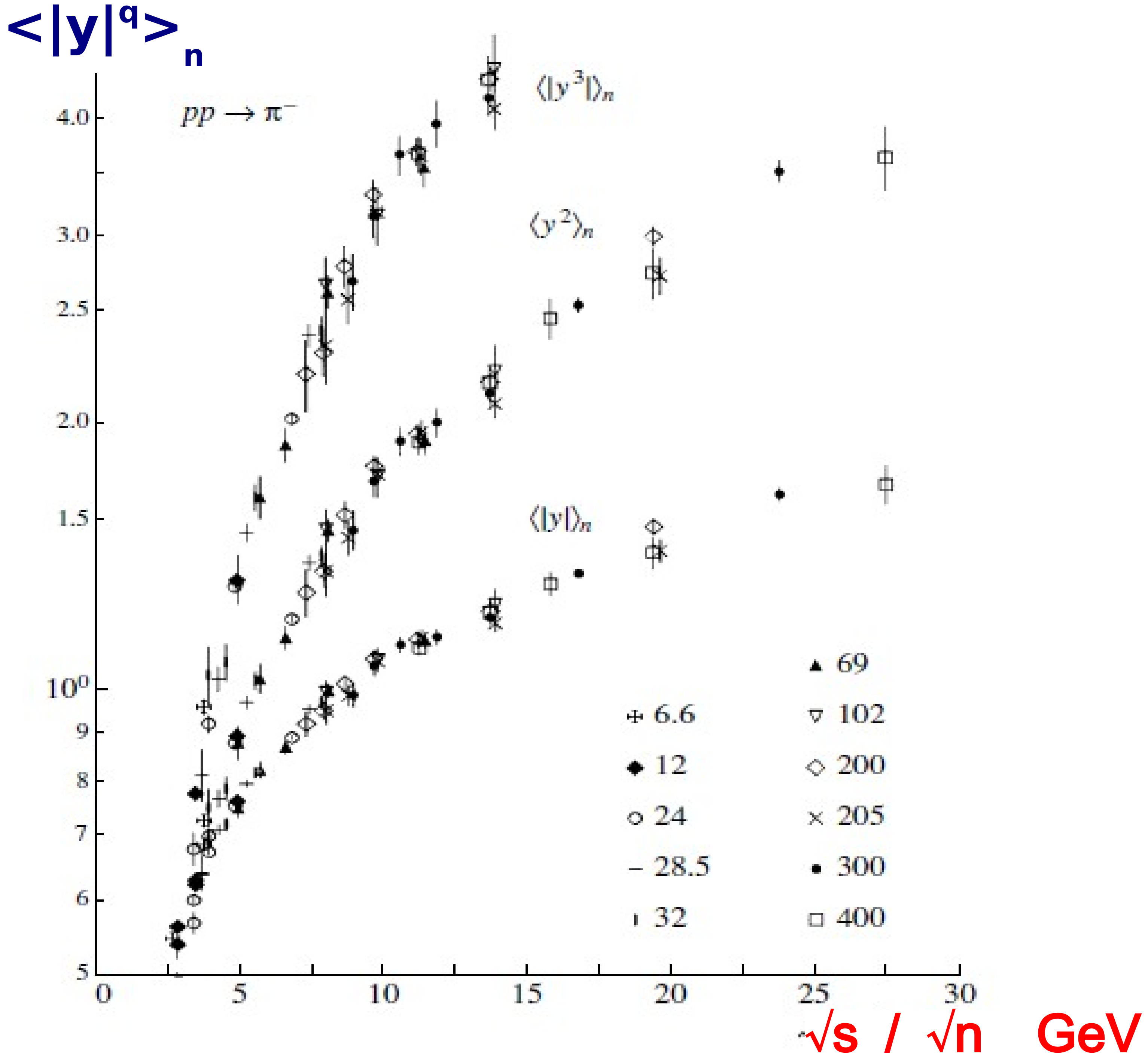
$<y^2>_n$

Golokhvastov scaling of semi-inclusive spectra

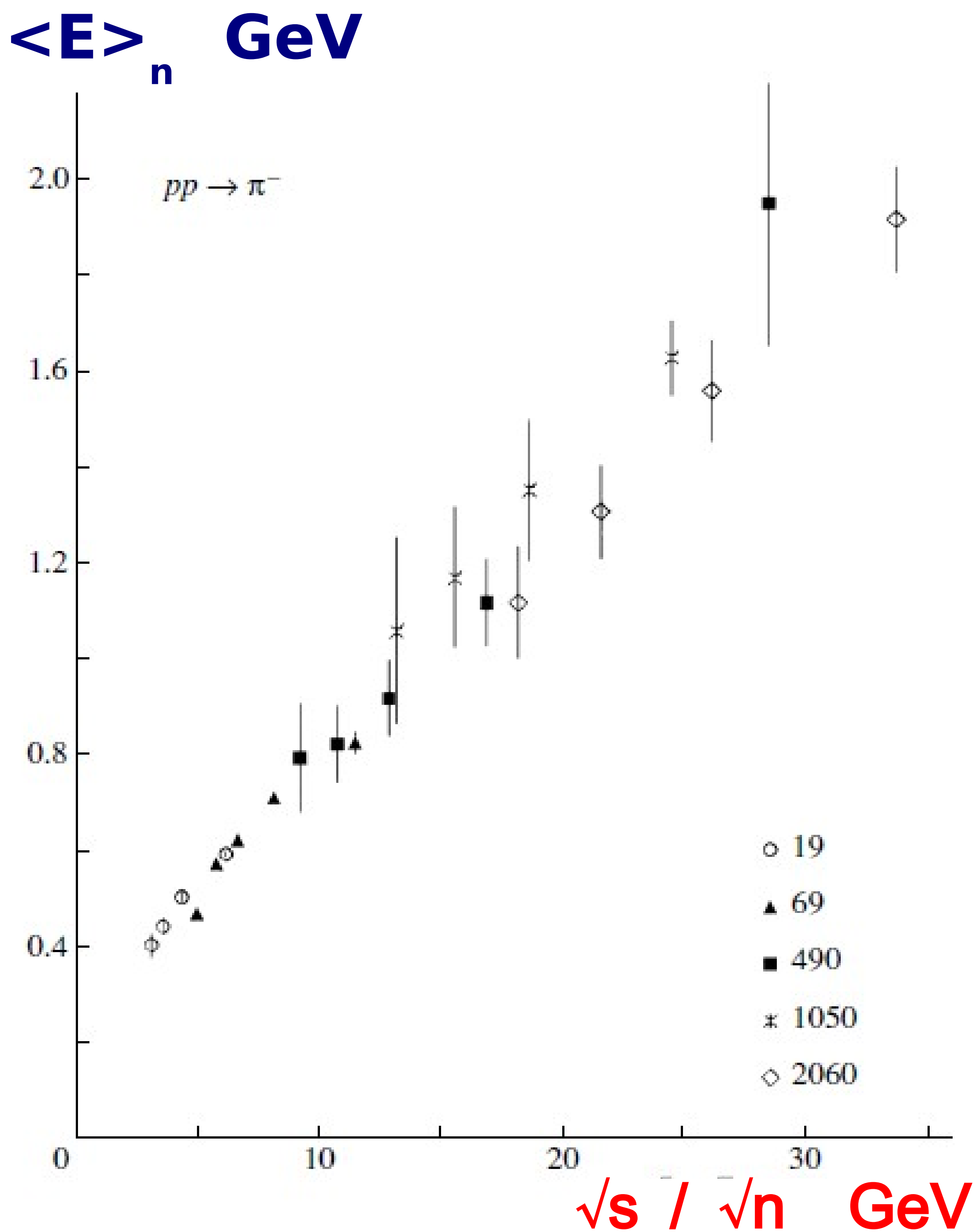
$$P(\, y, \ldots \mid \sqrt{s}, n \,) = P(\, y, \ldots \mid f(\sqrt{s}, n) \,)$$

Finally Sasha proposes a simple form of the $f(\sqrt{s}, n)$ function:

$$f(\sqrt{s}, n) = \sqrt{s} \,/\, \sqrt{n}$$



<|y|^q>_n
pp → π⁻
⟨|y³|⟩_n
⟨y²⟩_n
⟨|y|⟩_n
4.0
3.0
2.5
2.0
1.5
10⁰
9
8
7
6
5
0
5
10
15
20
25
30
6.6
12
24
28.5
32
69
102
200
205
300
400
√s / √n GeV


<E>n GeV
pp → π⁻
2.0
1.6
1.2
0.8
0.4
0
10
20
30
19
69
490
1050
2060
√s / √n GeV

Possible next steps:

- understanding origin of the scaling within statistical models – clearly it reflects conservation laws, thus the MCE-based models should be considered,

- based on the Golokhvastov and the KNO-Golokhvastov scalings construct a Monte Carlo model which should allow for precise predictions of negatively charged pion spectra in p+p interactions.

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