Independent Pair Parton Interactions Model and Multiplicity Distributions at LHC

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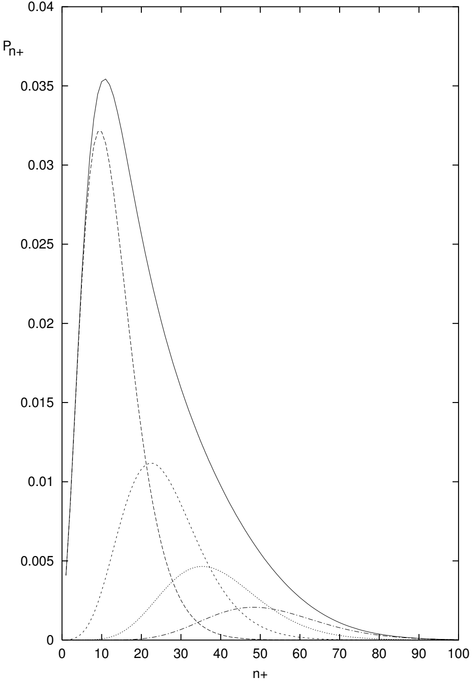
The independent pair parton interactions (IPPI) model:
1. High energy particles are "clouds" of partons.
2. Each pair of colliding partons is independent of others and creates new particles according to NBD-distribution of multiplicity.

The main equation:

$$P(n;m,k) = \sum_{j=1}^{j_{max}} w_j P_{NBD}(n;jm,jk). \qquad (1)$$

$P(n;m,k)$ is the probability to create n particles, m and k are the parameters of the NBD-distribution, w_j is the probability for j parton pairs to be active at a given energy, $\sum_{j=1}^{j_{max}} w_j = 1$, j_{max} is the maximum number of the active parton pairs. The simplest case: $w_j = w_1^j$.

- Experimental indications: single NBD fits at energies up to 200 GeV, then the distributions widen.
- Interpretation: 1 pair of partons is active and leads to NBD at lower energies while their number increases with energy.



The decomposition of the multiplicity distribution at Tevatron $\sqrt{s}$=1.8 TeV into 1, 2, 3 and 4 parton-parton interactions

How one gets the main equation.

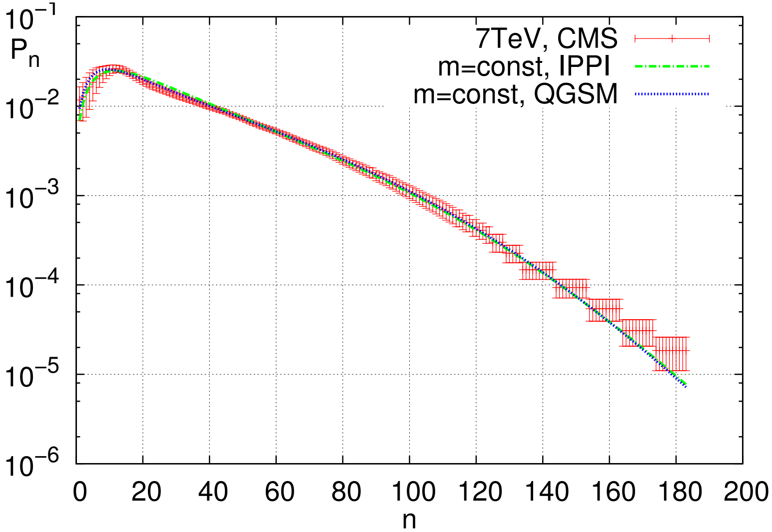
Key property: Convolution of NBDs is again NBD!

$$P(n;m,k) = \sum_{j=1}^{j_{max}} w_j P_j(n;m,k) = \sum_{j=1}^{j_{max}} w_j \sum_{(n_p)} \prod_{p=1}^{j} P_{NBD}(n_p;m,k). \tag{2}$$

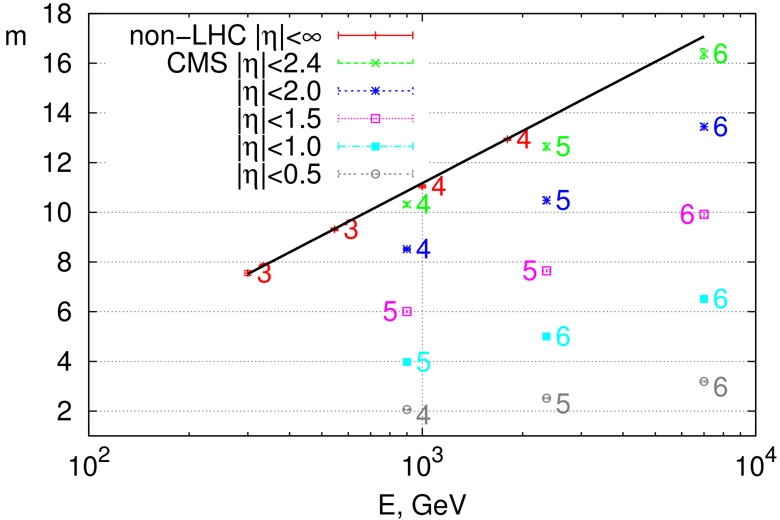
n_p is the number of particles created by the pth pair,
$\sum_{(n_p)}$ denotes the convolution of NBD distributions with the sum of those parton interactions where $\sum_{p=1}^{j} n_p = n$.

The summation in Eq. (2) gives rise to the main equation.
NBD definition:

$$P_{NBD}(n;m,k) = \frac{\Gamma(n+k)}{\Gamma(n+1)\Gamma(k)} \left(\frac{m}{k}\right)^n \left(1+\frac{m}{k}\right)^{-n-k}$$



The fits by the IPPI-model (line) and by the QGSM-model (dots) of the multiplicity distribution at 7 TeV ($|\eta| < 2.4$, CMS-data).



The values of the parameter *m* (i.e. of the effective average multiplicity for a single parton pair) at different energies and rapidity windows.

The number of active pairs (j_{max}) is shown near each point.

IMPORTANT TECHNICALITIES!

The requirement of independence of m on the ranks of moments of the distribution imposes restrictions on the parameter k.

We use the properties of factorial (F_q) and cumulant (K_q) moments of the multiplicity distributions (as well as of their ratio H_q) in fits of experimental data to show how well this requirement is fulfilled.

For more details see the papers in Phys. Rev. or arXiv:hep-ph.

$$F_q = \sum_n P(n)n(n-1)...(n-q+1)$$

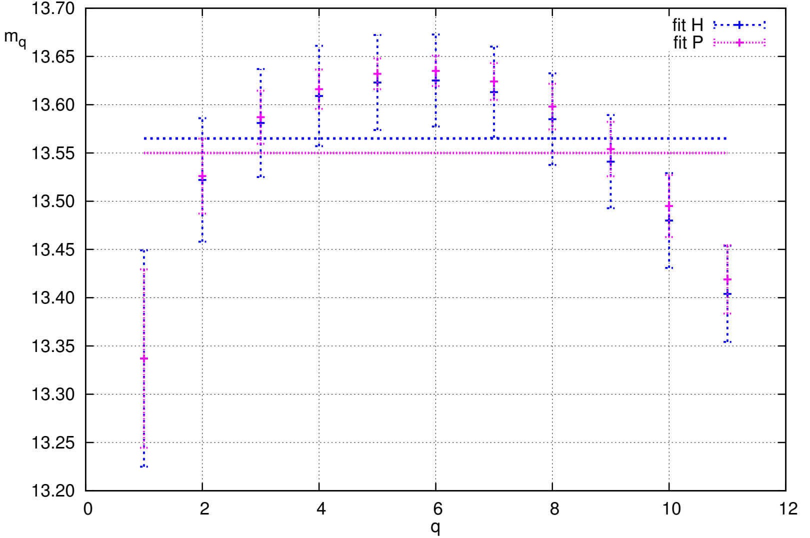
$$= \sum_{j=1}^{j_{max}} w_j \frac{\Gamma(jk+q)}{\Gamma(jk)} \left(\frac{m}{k}\right)^q = f_q(k) \left(\frac{m}{k}\right)^q ; \quad K_q = \kappa_q(k) \left(\frac{m}{k}\right)^q \tag{3}$$

where

$$f_q(k) = \sum_{j=1}^{j_{max}} w_j \frac{\Gamma(jk+q)}{\Gamma(jk)} = k \sum_{j=1}^{j_{max}} w_j j(jk+1)...(jk+q-1). \tag{4}$$

The selfconsistency of the IPPI-model asks for q-independence of m:

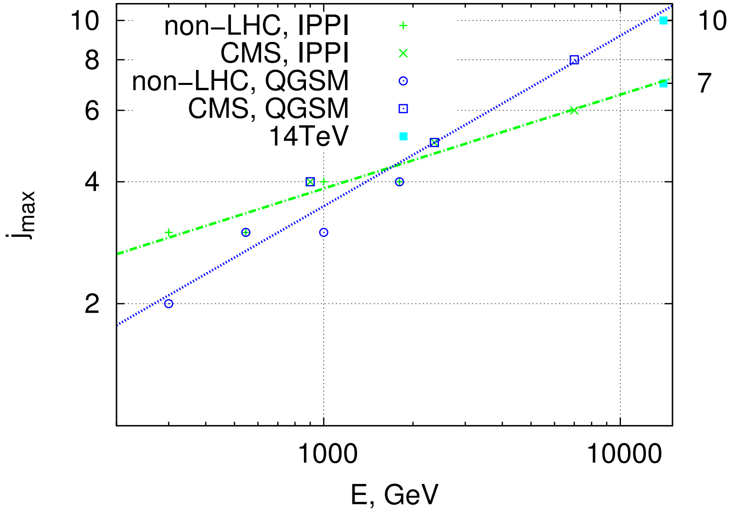
$$m = k \left(\frac{F_q^{exp}}{f_q(k)} \right)^{1/q} = \mathrm{const.} \qquad (5)$$



Conclusions

- The IPPI-model is proposed.
- The pairs of partons from colliding "clouds" are independent and each pair creates particles according to NBD-distribution.
- Experimental distributions are well described at different energies and rapidity windows with only two adjustable parameters k and j_{max}.
- The average multiplicity in collision of a single pair m and the number of active pairs j_{max} increase with energy logarithmically.
- The density of the parton medium increases with energy and asks for account of SOFT (not only HARD) multiparton interactions.
- The predictions at higher energies 14 and 100 TeV have been done.

ADDITIONAL SLIDES



Extrapolation of the maximum number of the active parton pairs (j_{max}) to 14 TeV.

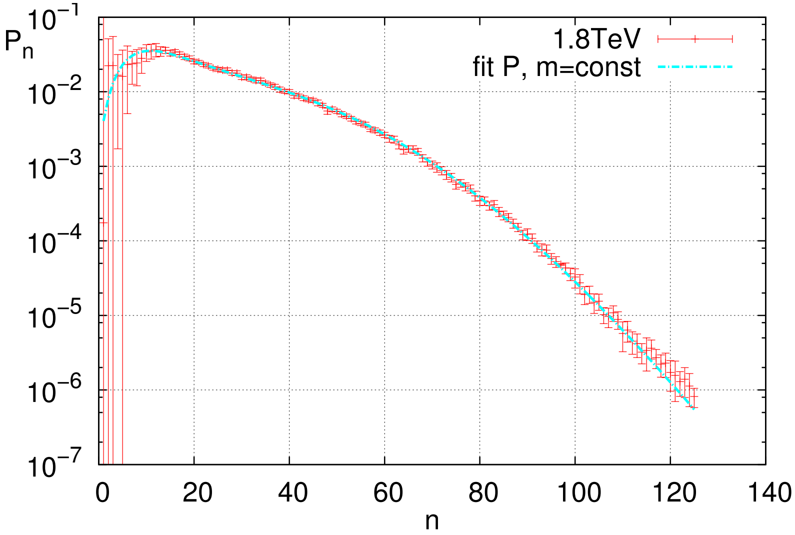
QGSM (A.B. Kaidalov, K.A. Ter-Martirosyan)

$$w_j(\xi_j) = \frac{p_j}{\sum_{j=1}^{j_{max}} p_j} = \frac{1}{jZ_j(\sum_{j=1}^{j_{max}} p_j)} \left(1 - e^{-Z_j} \sum_{i=0}^{j-1} \frac{Z_j^i}{i!}\right) \tag{6}$$

where

$$\xi_j = \ln(s/s_0 j^2), \quad Z_j = \frac{2C\gamma}{R^2 + \alpha'_P \xi_j} \left(\frac{s}{s_0 j^2}\right)^{\Delta} \tag{7}$$

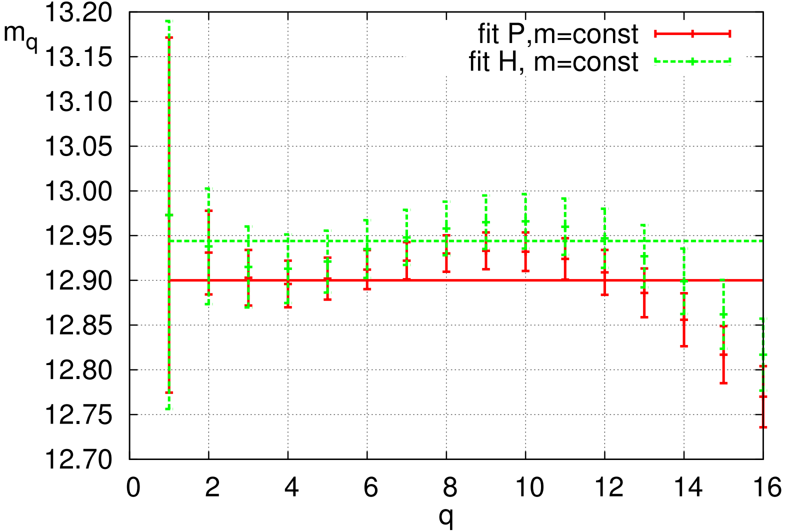
numerical parameters derived from fit of experimental data on total and ilastic scattering $\gamma = 3.64$ GeV^{-2}, $R^2 = 3.56$ GeV^{-2}, $C = 1.5$, $\Delta = \alpha_P - 1 = 0.08$, $\alpha'_P = 0.25$ GeV^{-2}, s_0 =1 GeV^2.



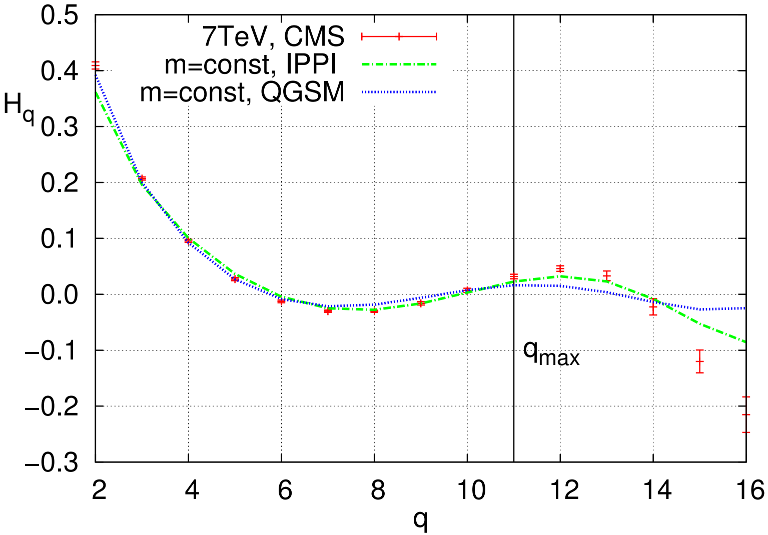
The fit by the IPPI-model (dotted) of the multiplicity distribution at 1.8 TeV.

The selfconsistency of the IPPI-model asks for q-independence of m (1.8 TeV):

$$m = k \left(\frac{F_q^{exp}}{f_q(k)} \right)^{1/q} = \text{const.} \tag{8}$$



$$K_q = F_q - \sum_{r=1}^{q-1} \frac{(q-1)!}{r!(q-r-1)!} K_{q-r} F_r. \tag{9}$$



IPPI-fit (dash-dotted) and QGSM-fit (dotted) for H_q-moments at 7 TeV.