Inclusive distributions in p-p collisions at LHC energies compared with an adjusted DPMJET-III model with chain fusion

Fritz W. Bopp and J. Ranft

Univ. Siegen
bopp@physik.uni-siegen.de

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Monte Carlo codes based on the two–component Dual Parton Model involving soft and hard hadronic collisions producing chains of particles are available **since a long time**:

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Multiparticle production in a two-component dual parton model

P. Aurenche
Laboratoire de Physique des Particules, Institut Nacional de Physique Nucléare et de Physique des Particules, Annecy, France

F. W. Bopp
Fachbereich Physik, Universität Siegen, Siegen, Federal Republic of Germany

A. Capella
Laboratoire de Physique Théorique et Hautes Energies, Université de Paris XI, Orsay, France

J. Kwiecinski
Institute of Nuclear Physics, Krakow, Poland

M. Maire
Laboratoire de Physique des Particules, Institut Nacional de Physique Nucléare et de Physique des Particules, Annecy, France

J. Ranft* and J. Tran Thanh Van
Laboratoire de Physique Théorique et Hautes Energies, Université de Paris XI, Orsay, France
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The initial DTUJET was not updated. The present codes are:

PHOJET	for h–h, γ–h and γ-γ collisions
DPMJET-III	for h–h, h–A and A–A collisions

DPMJET-III is based on PHOJET for its h–h collisions.
For h–h collisions it is - except for a few additions discussed below - identical to PHOJET.
PHOJET describes the production of strings. For the string decay it calls PYTHIA version 6.412 . For a few special cases we found it necessary to change the PYTHIA fragmentation.

The changes were done in the DPMJET part, leaving the PYTHIA and the PHOJET code itself untouched.

Since the DPMJET-III program was published in 2000 a number of changes were introduced.

The main additions to DPMJET III prior to LHC are:

(1) Comparing DPMJET-III to RHIC heavy ion data it was learned that a ***decrease in the particle density*** was needed.

As the strings are quite dense in impact parameter space interactions between strings are plausible. The expected "percolation" was implemented in DPMJET-III in 2004 as ***fusion of geometrically close hadronic chains***

The obtained reduction was very essential for central collisions of ***heavy ions***,
but fusion also changes the particle production in ***very high energy p–p collisions*** when the number of contributing chains obtained by a Glauber / eikonal formalism gets sizable.

RHIC and Fermilab data also contain interesting information about particle antiparticle ratios .

(2) For the baryon/antibaryon distribution the string fusion mentioned above can be significant (p.e. two quark-antiquark strings can fuse to a diquark-antidiquark string yielding baryons and antibaryons).

(3) In the diquark string decay used in PYTHIA one observes a forward dip in the ratio of the $\Omega/\bar{\Omega}$ spectra not seen in the data. A solution of the problem is to include a small contribution of diquark-antidiquark mesons production in the first rank so that Ω can appear in the second rank. The idea is that such tetra-quark mesons are always produced but decay too fast to be identified in mass plots.

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Essentially three additional modifications of DPMJET-III where implemented to get better agreement with LHC data on particle production in p–p collisions.

(1) The first modification concerns ***collision scaling***. DPMJET-III uses an eikonal formalism to determine the size of various multiple scattering contributions $P_{n,\{\alpha_i^f\},\{\alpha_i^b\}}$

Ignoring diffraction there are two kinds of chains in the two component model.

- ***Hard chains*** produced by hard collisions of partons from the colliding hadrons (typically large $p_\perp$) and
- ***soft chains*** representing soft hadron production in the collisions.

Let us consider the forward direction. The attributed energy fractions $\{x_i\}$ to these partons are then chosen with

$$P_{n,\{\alpha_i\}} \int \prod_i^n x_i^{\alpha_i - 1} \delta(1 - \sum_j^n x_j)$$

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In the factorizing formalism soft processes affect the energy sampled in hard processes!

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With an extra parameter hard collisions are enhanced in a way that collision scaling is obtained. Eventually this should be replaced by a better method of sampling the energy fractions.

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This is not unreasonable. The time scale of the initial scattering is inversely proportional to the energy. This causes a more localized string and a widening of the $p_\perp$ distribution of the string ends.

Such a widening was observed as on contribution to the multiplicity dependence of the average transverse momentum $< p_\perp >_{n(ch)}$.

For the moment our strategy is to just allow for an energy-dependent tuning of string decay parameters.
It is meant as a first step.

PHOJET contains a mildly energy dependent cutoff between soft and hard scattering processes. It somehow defines what is meant with "soft" and our initial plan was to attach the string parameter to this quantity.

It became apparent that there are some results which cannot be obtained with purely energy-dependent parameters. So we left it like this.

Presumably a differentiation between softer and harder strings within one scattering will be necessary.

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$$PARJ(41) = \begin{cases} 0.2 & \text{for } E_{cm} \leq 3\,\text{TeV} \\ 0.2 + 0.1(E_{cm}-3)/4 & \text{for } E_{cm} \in [3\,\text{TeV}, 7\,\text{TeV}] \\ 0.3 + 0.05(E_{cm}-7)/7 & \text{for } E_{cm} \in [7\,\text{TeV}, 14\,\text{TeV}] \\ 0.35 & \text{for } E_{cm} \geq 14\,\text{TeV} \end{cases}$$

$$PARJ(42) = \begin{cases} 0.8 & \text{for } E_{cm} \leq 3\,\text{TeV} \\ 0.8 - 0.2(E_{cm}-3)/4 & \text{for } E_{cm} \in [3\,\text{TeV}, 7\,\text{TeV}] \\ 0.6 - 0.1(E_{cm}-7)/7 & \text{for } E_{cm} \in 7\,\text{TeV}, 14\,\text{TeV}] \\ 0.5 & \text{for } E_{cm} \geq 14\,\text{TeV} \end{cases}$$

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Hyperon and strange meson production is controlled by the Lund parameters PARJ(1), PARJ(2), PARJ(3), PARJ(5) and PARJ(6).

The following new energy-dependent values were implemented:

$$
\begin{array}{lcl}
PARJ(1) = & 0.1 & \text{for } E_{cm} \leq 0.5\,\text{TeV} \\
& 0.1 + 0.1(E_{cm} - 0.5)/0.4 & \text{for } E_{cm} \in [0.5\,\text{TeV}, 0.9\,\text{TeV}] \\
& 0.2 & \text{for } E_{cm} \geq [0.9\,\text{TeV}] \\
PARJ(2) = & 0.3 & \text{default value untouched} \\
PARJ(3) = & 0.4 & \text{for } E_{cm} \leq 0.5\,\text{TeV} \\
& 0.4 + 1.6(E_{cm} - 0.5)/0.4 & \text{for } E_{cm} \in [0.5\,\text{TeV}, 0.9\,\text{TeV}] \\
& 2.0 & \text{for } E_{cm} \geq [0.9\,\text{TeV}] \\
PARJ(5) = & 0.5 & \text{for } E_{cm} \leq 3.0\,\text{TeV} \\
& 0.5 - 0.05(E_{cm} - 3.0)/4.0 & \text{for } E_{cm} \in [3.0\,\text{TeV}, 7.0\,\text{TeV}] \\
& 0.45 & \text{for } E_{cm} \geq [7.0\,\text{TeV}] \\
PARJ(6) = & 0.5 & \text{for } E_{cm} \leq 1.0\,\text{TeV} \\
& 0.5 + 0.55(E_{cm} - 1.0)/6.0 & \text{for } E_{cm} \in [1.0\,\text{TeV}, 7.0\,\text{TeV}] \\
& 1.05 & \text{for } E_{cm} \geq [7.0\,\text{TeV}]
\end{array}
$$

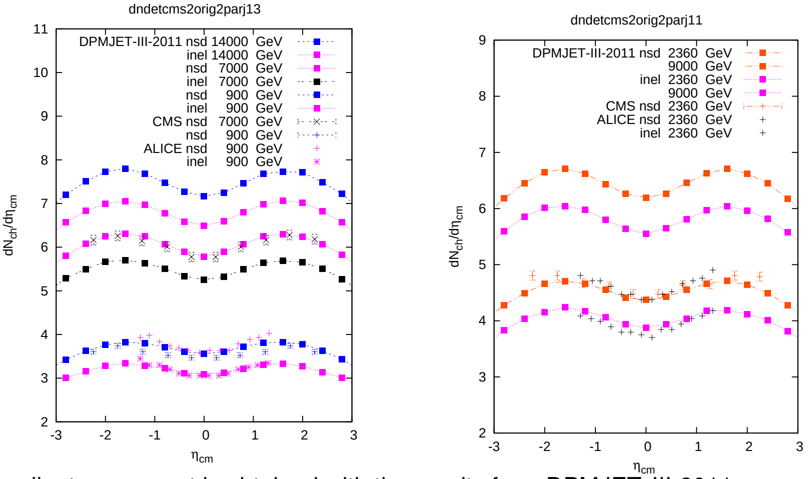
We now compare results of this DPMJET–III–2011 with data.

The energies shown are 900, 2360, 7000 and 14000 GeV. For 14000 GeV the distributions are expected to be be measured in future.

The result of the

nsd (non single diffractive) and *inel* (inelastic) distribution, $dN_{ch}/d\eta_{cm}$,

measured by the CMS and ALICE Collaborations is:

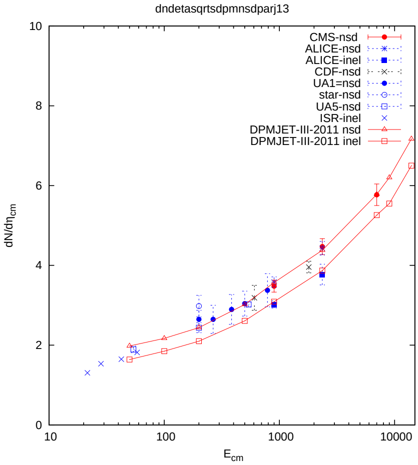


Excellent agreement is obtained with the results from DPMJET–III-2011.

The energy-dependence of the central density

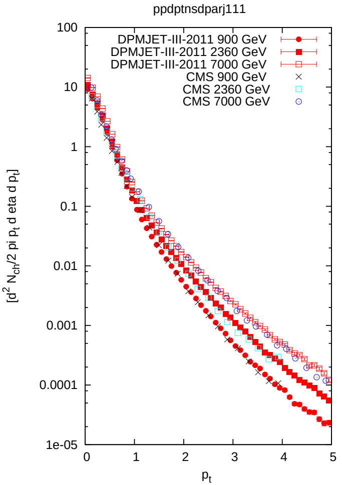
$$dN/d\eta_{cm} \text{ at } \eta_{cm} = 0$$

is presented for p–p collisions of *nsd* and *inel* events.
The DPMJET–III-2011 results are compared with data from various energies of various collaborations.
In all cases a good agreement is obtained.

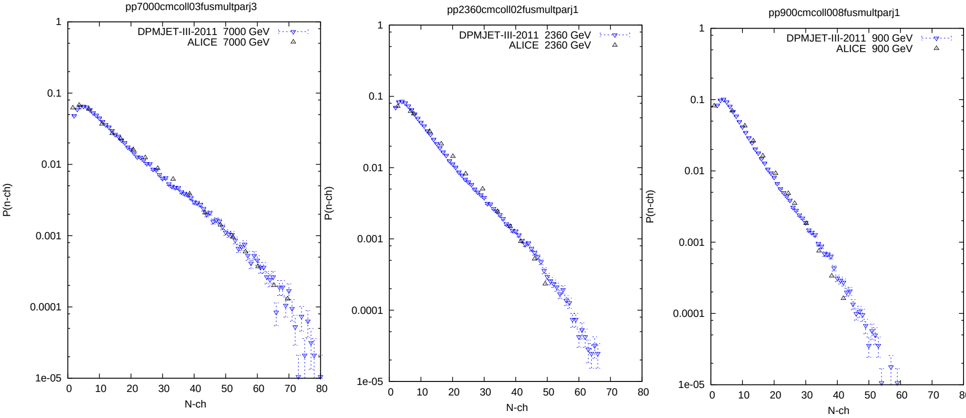


Next we compare the $p_\perp$ distributions

in p–p collisions at $\sqrt{s}$ = 900, 2360 and 7000 GeV.
The agreement between the DPMJET–III-2011 and the CMS data points is again good.



Next we compare the multiplicity distributions for $|\eta| < 1.$ with ALICE data. Again a reasonable agreement is obtained with DPMJET–III-2011 results.



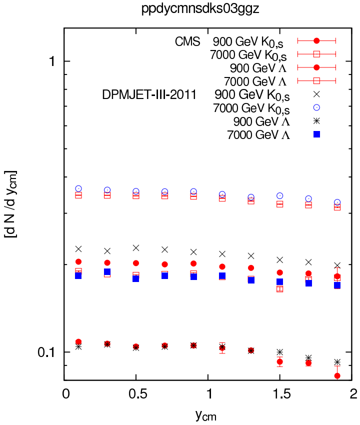
We now turn to strange particle production.

The production of K_s^0 mesons and that of Λ and Ξ^- hyperons was measured by CMS.

Similar data on the production of strange hadrons were also given by the ALICE Corporation. We did not include them so far as they do not affect the consideration discussed below.

First we compare the rapidity distribution dn/dy_{cm} of K_s^0 mesons & Λ hyperons:

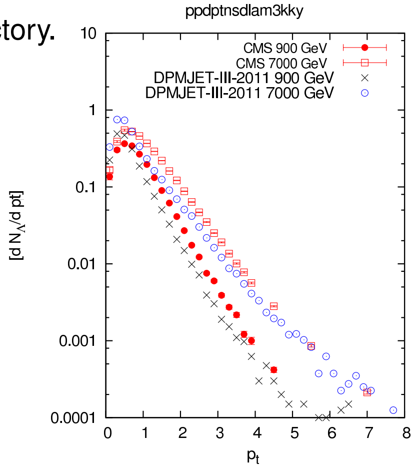
With energy-dependent parameters good agreement of the DPMJET-III-2011 and the CMS measurements is obtained.



But the situation is not satisfactory.

Comparing the Λ and $\bar{\Lambda}$ transverse momentum distributions obtained with DPMJET-III-2011 to CMS data we find the shape of the distributions to differ.

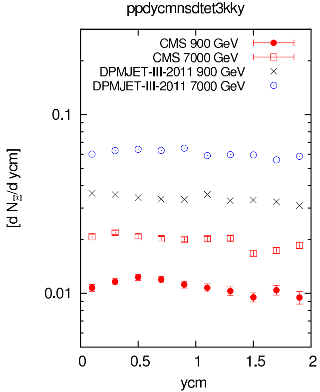
The transverse momentum distributions of Λ hyperons. Above 1 GeV the model is below the data. A similar problem seems to appear in many other model calculations .



If we would also adjust the parameters in such a way, that the agreement between the transverse momentum distributions is optimal in this region, we would obtain a disagreement in the dn/dy_{cm} distributions.

Unfortunately here the situation becomes even more problematic for the Ξ hyperons.

The dn/dy_{cm} distributions of Ξ hyperons in the DPMJET-III-2011 compared with the measurements of CMS.



DPMJET-III-2011 predicts Ξ and $\bar{\Xi}$ distributions about three times as large as measured by CMS.

We have modified the parameters in such a way, that the Λ hyperons agree with the CMS data. The same parameters should also lead to agreement for the Ξ hyperons. They do not.

We so far do not fully understand the production of Ξ hyperons in DPMJET-III.

Conclusion

LHC data require energy-dependent parameters for string decays. With ad hoc adjustments agreement of DPMJET-III with the new LHC data was obtained.

It is meant as a temporary solution. Eventually such a dependence should be an intrinsic property of the hadron production models.

Some problems remained unsolved. A more permanent solution will require deeper changes in the program.

Presumably string parameter should depend on the hardness of the individual strings.

We conclude that we need a new version of the model.

Thank you!

Backup

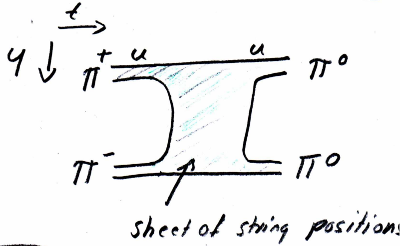
Lund's "PARJ" used:

			default:	s-dependent:
LUND-PARJ	11	0.38	D=0.5	
LUND-PARJ	18	0.3	D=1	
LUND-PARJ	42	0.60	D=0.58	*
LUND-PARJ	1	0.200	D=0.1	*
LUND-PARJ	2	0.2	D=.3	
LUND-PARJ	3	3.1	D=0.4	*
LUND-PARJ	5	0.45	D=0.5	*
LUND-PARJ	6	1.05	D=0.5	*
LUND-PARJ	21	0.34	D=0.36	
LUND-PARJ	41	0.30	D=0.3	*

History of Dual Parton Model

(1)

Dual
Topological
Unification
(Chew et ....)

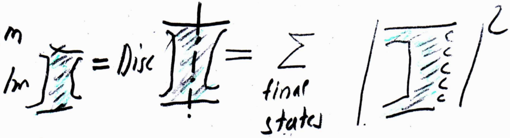


s-channel resonance
2 t-channel Regge exchanges
→ unified dual amplitude (Veneziano ..)

with oposite C Parity

"parton-dynamics"
forward quark stays forward

② Optical Theorem

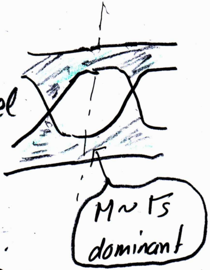


Iteration ⇒ Pomeron

2 Possibilities

t channel

s channel



⇒ Pomeron ≈ Odderon

not seen ↓

⇒ 2 independent stri

(parton dynamics

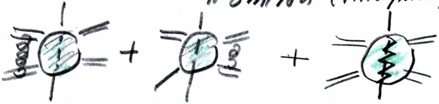
(Avenche.., Capella

③ **A & K Cancelation** — Abramovskii Gribov Kancheli

Iteration?

Pomeron (imaginary)

disc A =

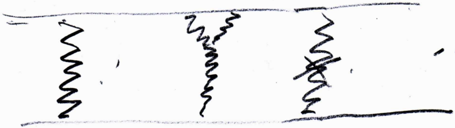


$\text{extra}(-A_P + A_P^*)$ $\quad$ $\text{extra}(2\,\text{Im}\, A_P)$ $= 0$

$\Rightarrow$ **no increase in $\frac{d\sigma}{dp}$**

(4)

Energy-effects → Iteration

$\sum$  .... + all possible cuts

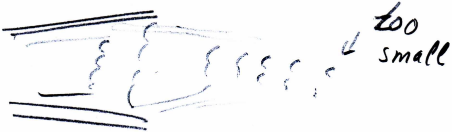
$\Longrightarrow$ $\sigma_{n\text{-Pomeron},\ n\text{-Diffraction} \ldots}$

Capella, Kaidalov ....

X-section fits σ [vs s] —success!→ P_n, ρ, c ...

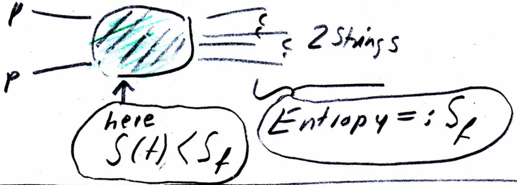
(5) **Problem 1:** $m_{String} < m_{cut\,off}$

$\sigma_{n_1 n_2 \dots} \longrightarrow$



Logic: $\exists$ or $\nexists$ final state $\Rightarrow \exists$ or $\nexists$ path

<u>no time ordering</u>:



6 Problem 2:

Color-electric ✱ color magnetic

$E_{QCD}\downarrow$ string $q\bar{q}$ production

$\dot{B}_{QCD}$ → $q\bar{q}$ local $q\bar{q}$ production

charge clusters ✓

neutral clusters

Charge corrlation **data**

→ charge cluster dominate

the end