

SOME REMARKS ABOUT SIMULATION OF COSMIC RAY PHENOMENA
WITH USE OF NUCLEAR INTERACTION MODELS BASED ON THE
CURRENT SPS PROTON-ANTIPROTON DATA

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We demonstrate, that claims about "models based on SPS collider particle distributions" do not unambiguously predict properties of EAS generated by Monte Carlo simulation.

One of the main difficulties in interpreting extensive air shower data to derive the properties of particle production in the elementary act is that the data available at the highest accelerator energies (SPS proton-antiproton collider) do not include the features of interaction most essential in air shower propagation (e.g. x -distributions).

Therefore, one could think of different models of particle production, each of them adequately fitting the measured pseudo-rapidity distributions at SPS $p\bar{p}$ energies, but possessing different properties in other variable, for example the \bar{d} distributions in x .

In addition to this x - y ambiguity, there are some other degrees of freedom in utilizing the collider data in a phenomenological model of nuclear interaction:

- * distribution in inelasticity,
- * the fact that nucleon-air and (especially) meson-air interactions may differ from nucleon-nucleon interaction,
- * the extrapolation of scaling violation at interaction energies above 155 TeV.

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However, in this study we will limit ourselves just to the x-y controversy, introducing models with as many features (except for x- and y-distributions) in common, as possible; to avoid the extrapolation problem, we consider only primary energies of 500 TeV (2*485 GeV in the CMS).

To prove our point, we have performed Monte Carlo simulations of EAS generated by 500 TeV vertical primary protons; four different nuclear interaction models were used. Two of them are described elsewhere in this volume [1] (also, a detailed writeup of models and the general simulation scheme in which they were immersed is available [3]); here we will only name them:

- @ Model M-Y00 - with inclusive x- and y-distributions behaving in a "scaling" way (except for the rise in the total inelastic cross-sections, see below),
- @ Model M-F00 - at and below ISR energies (1 TeV in Lab) exactly equivalent to the above, then gradually changing to provide the distributions in rapidity at 155 TeV as given by SPS p \bar{p} [4]. This was achieved by gradual decrease in the "scale unit" in x-distributions of produced secondaries (see [1]), as interaction energy increases.

In addition to this pair, we modified the M-Y00 model by removing secondaries at x around and above 0.1 (this energy was used for production of low-x particles, to keep the inelasticity distribution unchanged). The probability of this removal was changed logarithmically between 0 at 1 TeV and 1 at 100 TeV. The resulting rapidity distribution at 150 TeV is much closer to that for M-F00 than for M-Y00. Thus, one could say that - at least as far as the rapidity distributions are considered - the modification resulted in

- @ Model M-T00 (T standing for "truncated"), together with M-F00 reasonably well describing the rapidity distributions at ISR and SPS p \bar{p} energies.

To check the effect of charge exchange (about which we know nothing from the collider data, either), a modification of M-T00 was introduced:

- @ Model M-T01 - similar to M-T00, but 1/3 of interacting charged pions may emerge from the collision as pi-zeros.

Except for the differences mentioned above, all remaining simulation assumptions (including mean free paths and inelasticity) were the same for four models [1,3].

The x- and y-distributions for our four models at 1.5 TeV (ISR) and at 150 TeV (SPS p \bar{p}) are shown in Figs.1 and 2. At 1 TeV the distributions for all of them are exactly the same.

(Rapidity for M-Y00 at 150 TeV, not shown, behaves just like it should).

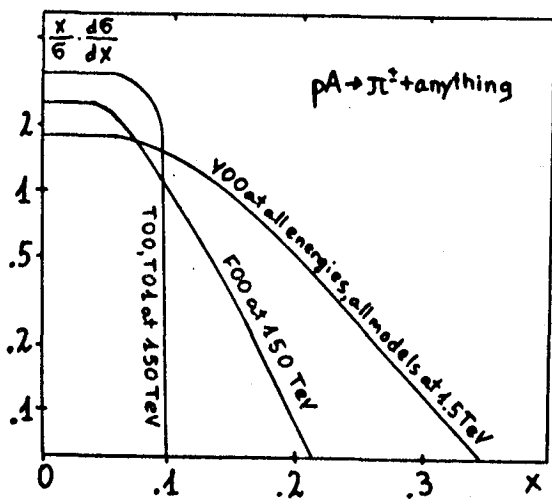


Fig.1 The distributions in x (in high energy approximation: $E/E[\text{inter}]$) for four models used in our study.

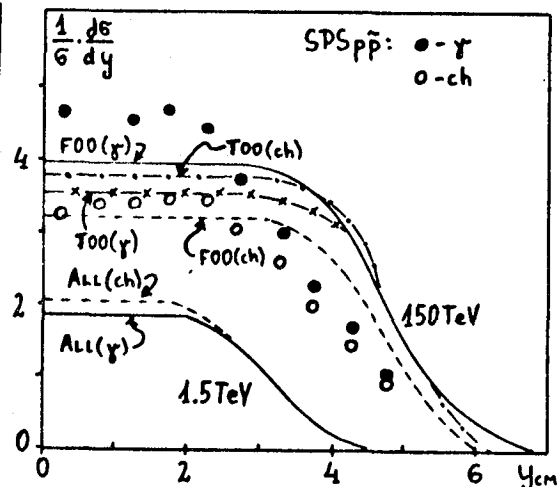


Fig.2 The distributions in rapidity for our models compared with the SPS $p\bar{p}$ data [4] on pseudorapidity.

We are limiting the scope of this paper only to demonstration of the validity of the statement made in the abstract above; more detailed and systematic study of extensive air showers for a variety of models (including two of these) is presented by us in another contribution to this Conference [1,2].

The Table below presents a brief sample of Monte Carlo results for extensive air showers predicted by our four models (numbers in brackets denote mean square statistical errors in last decimal digit units).

Model :		M-Y00	M-T00	M-T01	M-F00
N_e at maximum		$288(3) \cdot 10^3$	$284(3) \cdot 10^3$	$316(4) \cdot 10^3$	$310(3) \cdot 10^3$
at 1000 g/cm ²	N_e	$80(3) \cdot 10^3$	$61(3) \cdot 10^3$	$75(4) \cdot 10^3$	$64(3) \cdot 10^3$
	$N_\mu (> 2 \text{ GeV})$	$6.5(1) \cdot 10^3$	$7.1(1) \cdot 10^3$	$5.0(1) \cdot 10^3$	$6.1(1) \cdot 10^3$
	$N_\mu (> .2 \text{ TeV})$	30(1)	36(1)	31(1)	32(1)
	$N_h (> 2 \text{ GeV})$	237(11)	194(9)	109(9)	168(8)
	$N_h (> .2 \text{ TeV})$	12.3(4)	9.7(4)	6.4(3)	7.9(4)

One can notice, that the average shower size at maximum for M-T00 is basically the same as for M-Y00 (and not for M-F00, in spite of the similarity in rapidity distributions), the transfer of energy into the electromagnetic component had to be speeded up by charge exchange (M-T01) for maximum to reach the M-F00 level. The situation at 1000 g/cm^2 is just reversed. The increase in number of low-energy muons for M-T00 may be understood easily, though for high-energy ones it is not so obvious. For hadrons M-T00 gives results half way between M-Y00 and M-F00. Hadrons are affected to a greater degree than muons by introduction of charge exchange.

Therefore, statements about "models fitting the SPSpp data" may be often misleading; as the comparison of M-F00 and M-T00 shows, the shape of rapidity distribution (especially with the smallest angles excluded from the collider data) does not determine the interaction features most relevant to EAS development (and lack of information on inelasticity and on meson-nucleus interactions makes situation significantly worse).

Such statements may lead to a false belief, that one knows, what to expect from a nuclear interaction at a few hundred TeV, so (this factor fixed) the extensive air showers supply us with unequivocal information on other subjects: inelastic free path, primary composition. This is clearly not the case; air showers still remain one of basic information sources on the multiple production phenomenology in this energy region.

References

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