THE ANGULAR DISTRIBUTIONS OF SECONDARIES
IN PROTON-NUCLEUS INTERACTIONS AT 200 AND 300 GeV

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A B S T R A C T

The angular distributions of shower particles from proton-nucleus collisions at 200 and 300 GeV are investigated and correlated to the nuclear parameters (heavy prong emission), the inelasticity coefficient and the angle of the leading track. A partition is made into two components, the LP component associated with a single collision and the RC component corresponding to the excess from repeated collisions of the impinging proton and the nucleons inside the nucleus. Results from earlier investigations on the multiplicity distributions are confirmed. The LP component exhibits an excess of about 30% as compared to the shower particle emission in proton-proton collisions at the same energy. We find that the excess particles are slow moving in the equal velocity system, i.e., the frame in which the proton and the nucleus have equal but oppositely directed velocities. The opening angle of the cone inside which the proton-nucleus distributions are similar to the proton-proton distributions at the same energy is small ($\lesssim 0.5^\circ$) and is energy dependent. We also find indications of A dependence and a noticeable correlation to the inelasticity coefficient and to the angle of the leading track.

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1. - INTRODUCTION

In a few earlier notes ^{1),2)} we have considered the properties of the multiplicity distributions of the secondaries emitted in proton-nucleus interactions for energies between 6 GeV and the FNAL energy range.

In this note we are going to investigate the angular distributions of the shower particles for the 200 and 300 GeV data assembled in the International Emulsion Study Group ³⁾. A similar investigation has been presented by the Cracow group ⁴⁾. The shower particles correspond to fast moving particles causing lightly ionizing tracks and are composed of about 95% pions.

We will in particular consider :

- i) the partition of the angular distributions into an inner cone with properties similar to proton-proton collisions at the same energy and the remainder of phase space in which there are correlations to the nuclear parameters ⁴⁾ ;
- ii) the partition of the secondaries into two components ^{1),2)}, the RC component (RC for Repeated Collisions) and the LP component (LP for Leading Particle) as well as the comparison of the resulting distributions to those found in hadron-nucleon collisions ;
- iii) the energy dependence of the above-mentioned partitions ;
- iv) the comparison of the results to the predictions of available theoretical models ⁵⁾⁻⁸⁾.

The existence of a partition like the one mentioned in i) is already a well-known phenomenon in the subject ^{4),5)}. We want to consider precise criteria and also to correlate the size of the opening angle to the remaining parameters of the process. The partition according to ii) has been found relevant in the earlier investigations of the multiplicity distributions ^{1),2)}. The precise definitions will be discussed below but the LP component is assumed to account for the case when the impinging proton makes a single collision with one of the nucleons bound in the nucleus while the RC component can be correlated to the repeated collisions.

The indications that the mean multiplicity of the LP component is essentially enhanced ^{1),2)} as compared to free proton-proton collisions are supplemented by the results of this note. We find deviations from proton-proton collisions already at very small angles, in fact much smaller than the ones predicted by most current models, e.g., the Gottfried model ⁵⁾.

We also find a noticeable energy dependence of these deviations and also indications of a dependence on the nuclear number.

Such properties are expected in the framework of the hydrodynamical model ⁷⁾. Qualitative arguments in the Reggeon model based upon "Pomeron coherence distance" are compatible in size with the opening angle ⁶⁾ but more conservative estimates in the model ⁹⁾ lead to predictions close to those of the Gottfried model. More precise predictions would be of value, however.

The enhancement in the number of shower particles occurs for angles corresponding to small velocities in the "equal velocity frame" (evs) defined as the system in which the proton and the nucleus have equal and opposite velocities. This frame is one possible generalization of the centre-of-mass system in single hadron-hadron collisions.

The remainder of this note is partitioned into three sections. In Section 2 we have gathered some earlier results and definitions in order to make the paper self-contained.

In Section 3 we present the experimental material and the analysis performed on it and in Section 4 we compare to the predictions of theoretical models and summarize the main results.

2. - SHOWER PARTICLES AND HEAVY PRONGS

In earlier investigations ^{1),2)} on the correlations of the multiplicity distributions we have made use of the notion of elementary collision in the following sense.

Each elementary collision results in an independent contribution to the multiplicity of both the shower particles (n_s) and the heavy prong particles (N_h)

$$n_s = n_0 + \sum_{j=2}^{\nu} n_j \quad (1)$$

$$N_h = \sum_{j=1}^{\nu} N_j \quad ; \quad \nu > 1 \quad (2)$$

The partition in Eq. (1) into a contribution with index 0 and the remaining contributions of the sum indicates our partition of the distribution into two components, the LP component and the RC component. An operational definition of the LP component is to associate it with the single collisions inside the nucleus. Correspondingly the RC component accounts for the excess from the further collisions. In our treatment we assume that the RC component is built out of independent and equal contributions for each repeated collision. Thus we assume that the elementary RC distribution, corresponding to v collisions, $P_{RC}(n)$, is a convolution of $v-1$ equal distributions P_1 :

$$P_{RC}(n) = \sum_{n_1 + \dots + n_{v-1} = n} P_1(n_1) \dots P_1(n_{v-1}) \quad (3)$$

With $P_0(n_0)$ the probability distribution to find n_0 shower particles stemming from the LP component, the total probability distribution to find n_s shower particles in v collisions is constructed as

$$P_s(n_s) = \sum_{n_0 + n = n_s} P_0(n_0) P_{RC}(n) \quad (4)$$

The probability distribution $\pi(v)$ for a prescribed number of collisions (v) between the impinging proton and the nucleons inside the nucleus is computed from an (incoherent) multiple scattering formula of the Glauber type¹⁰⁾. We make use of a Woods-Saxon density^{10),11)} to describe the nucleon density inside the nucleus and we use a cross-section $\sigma = 32$ mb appropriate to inelastic proton-proton collisions.

It has been argued that phenomena associated with beam diffraction (which accounts for 3-4 mb) do not contribute to the process and that they consequently should be discarded. This change in the cross-section means an increase in the contribution from the single collisions $\pi(1)$. The difference is, however, in general too small to be noticeable within the present experimental uncertainties.

The heavy prong particles are almost entirely composed of nuclear fragments and correspond to slow moving heavily ionizing tracks in emulsion. In most cases, the recoil nucleon will, according to this classification, be counted as a heavy prong particle. It is, accordingly, useful²⁾ to introduce for comparison the notion of "equivalent shower particle multiplicity" $\bar{n}_{eq}$. This is defined as the mean multiplicity of charged secondaries in

in proton-proton collisions with sufficient velocity to be classified as shower particles (i.e., with velocities exceeding 0.7 c).

The main parameters from our investigations on the shower particle multiplicities are then the parameters describing the basic distributions for the LP component (P_0) and the RC component (P_1). The basic LP distribution then exhibits a mean multiplicity $\bar{n}_0$ and a width $\overline{\delta n_0^2}$ which obey (inside the present experimental errors of about 10%) for energies above 6 GeV

$$\begin{aligned}\bar{n}_0 &= 1.3 \bar{n}_{eq} \\ \sqrt{\overline{\delta n_0^2}} &= 0.6 (\bar{n}_0 - 1)\end{aligned}\quad (5)$$

The second relation is the well-known Wroblewski relation ¹²⁾ between the width and the mean multiplicity in hadron-hadron collisions.

Thus the LP component exhibits properties similar to the ones emerging from proton-proton collisions except for an increase of about 30% for the mean multiplicity.

For the corresponding parameters of the basic RC distribution we find that

- 1) the parameter $\bar{n}_1$ is small and close to zero for 6 GeV ;
- 2) the parameter $\bar{n}_1$ rises almost linearly up to Serpukhov energies ;
- 3) and then it stays flat from 69 GeV and through the FNAL energy range at $\bar{n}_1 = 0.4 \bar{n}_{eq}$.

The width $\overline{\delta n_1^2}$ of the distribution is compatible with a Poisson distribution, i.e., $\overline{\delta n_1^2} = \bar{n}_1$.

From the independence and similarity assumptions we get from the mean shower particle multiplicity $\bar{n}_s(\nu)$ for a fixed number of collisions the well-known Gottfried formula ⁵⁾

$$\bar{n}_s(\nu) = \bar{n}_0 + \bar{n}_1(\nu - 1) \quad (6)$$

Each of the above-mentioned collisions inside the nucleus results in a low energetic recoil nucleon, which will traverse the nucleus distributing its energy in repeated collisions with the remaining nucleons. The resulting split-up of the nucleus is in general difficult to describe

on an event-to-event basis because of the large amount of available reaction channels. In case there are several collisions inside the nucleus, we may, however, expect that the ensuing distributions will exhibit the regularity characteristic of statistical equilibrium. The experimental results are compatible with such a picture in which the mean number of heavy prongs $\bar{N}_h(v)$ emitted is a linear function of the number of collisions v :

$$\bar{N}_h(v) = \eta_h^{\text{eff}} \cdot v \quad ; v > 1 \quad (7)$$

The coefficient η_h^{eff} in this relation has the index eff (for effective) in order to stress the fact that qualitatively different nuclei (light, CNO, and heavier Ag and Br) contribute to the results in emulsion. Further the linear relationship is valid only for events corresponding to several collisions.

In a picture of this kind, any one of the multiplicities n_s or N_h is (for values above certain "threshold values" to account for the particular properties of the single collisions) a measure of the number of collisions v . In particular, one finds experimentally that there is a linear relationship between the mean shower particle multiplicity $\bar{n}_s(N_h)$ and the heavy prong multiplicity (as well as the other way around) :

$$\bar{n}_s(N_h) = \alpha + \beta N_h$$

It turns out that the parameters β and $\bar{n}_1$ can be related through the number η_h^{eff} in Eq. (7) :

$$\bar{n}_1 = \eta_h^{\text{eff}} \beta \quad (8)$$

The relationship between the parameters α and $\bar{n}_0$ is more involved and depends upon the precise way to define "single collisions". An empirically valid formula compatible with Eq. (3) is ²⁾

$$\bar{n}_0 = \alpha + \beta N_0 \quad (9)$$

Here the number W_0 is $W_0 \simeq 1$. Equation (9) is valid if we make use of the experimental results for events with $N_h \geq 2$ in order to define the parameters α and β . Among the events corresponding to $N_h = 0.1$ there are noticeable coherent contributions as well as contributions from the hydrogen component in emulsion.

3. - THE ANGULAR DISTRIBUTIONS

The main objects of our investigation are the two integral distributions $\bar{n}_s(\eta, N_h)$ and $\bar{n}_s(\eta, n_s)$. They are defined as the total number of tracks (normalized to one event) with angle smaller than the one characterized by the parameter $\eta = 10 \log(\text{tg} \theta)$ in events corresponding to a fixed number N_h of heavy prong particles or a fixed number n_s of shower particles. We will start to discuss the distribution $\bar{n}_s(\eta, N_h)$.

In Fig. 1 we exhibit the distribution $\bar{n}_s(\eta, N_h)$ for events corresponding to $E = 300$ GeV and some different values of N_h ¹³⁾. We have in that case excluded the track with the smallest angle in each event. We will call this track "the leading track". It turns out that the quantity $\bar{n}_s(\eta, N_h)$ for a fixed value of the parameter η exhibits a linear dependence on the number of heavy prongs N_h . In Fig. 2, we exhibit as an example the quantity $\bar{n}_s(\eta, N_h)$ for a few different values of the parameter η and for both 200 and 300 GeV¹³⁾ (in Fig. 2 the leading track is included). It is then possible to define two functions $\alpha(\eta)$ and $\beta(\eta)$ by

$$\bar{n}_s(\eta, N_h) = \alpha(\eta) + \beta(\eta)N_h \quad (10)$$

In the actual construction of the two functions α and β we have made use of events corresponding to $2 \leq N_h < 20$ in accordance with the discussion after Eq. (9) above. The linear relationship cannot be expected to be valid for $N_h > 20$ when the nucleus is almost completely fragmented. It turns out that the results are almost unchanged if events with $N_h = 1$ are added in the construction of $\alpha(\eta)$ and $\beta(\eta)$. In Figs. 3 and 4 we exhibit the results of such a construction of $\alpha(\eta)$ and $\beta(\eta)$ for $E = 200$ GeV and 300 GeV from proton emulsion data.

It is further possible to construct the differential distributions $d\alpha/d\eta$ and $d\beta/d\eta$ from a knowledge of $\alpha(\eta)$ and $\beta(\eta)$. These quantities are exhibited in Figs. 5a, 5b and 6a, 6b for the same two energies.

Before we continue the discussion, we would like to mention that there are small but systematic deviations from the linear relationship according to Eq. (10). Thus tracks stemming from events with $N_h < 8$ tend to occur more frequently for small angles while tracks in events with $N_h > 8$ exhibit the opposite tendency. The effect is, however, so small that the results from the present experiments cannot certify it.

The partition of the data into those stemming from only the heavy nuclei in emulsion (Ag, Br with $N_h > 8$) and those stemming from the combined contributions of light and heavy nuclei ($N_h \leq 8$) is unreliable unless a large statistical sample is used or the effect that is to be investigated is large. Experiments, which will enable a partition, are, however, presently under way.

It is also possible to investigate the dependence of the angular distributions on the value of the angle of the leading track in each event.

If the leading track is removed from the sample then the differential distribution $d\beta/d\eta$ is unchanged at both energies. The difference in the results for the distribution $d\alpha/d\eta$ is the forward shaded area in Figs. 5a and 5b.

We have also investigated the dependence on the inelasticity coefficient k_{inel} defined for given proton lab. energy E and event (e) by

$$k_{inel} = \frac{1}{E} \sum_{j \in e} \left(\left(\frac{p_L}{\sin \theta_j} \right)^2 + m_\pi^2 \right)^{1/2} \quad (11)$$

Here the parameter p_L is chosen as $p_L = 0.35$ GeV in accordance with the findings in proton-proton collisions. We will consider the properties of k_{inel} in more detail in another publication.

In Figs. 7a and 7b we exhibit the two functions $d\alpha/d\eta$ and $d\beta/d\eta$ at $E = 300$ GeV constructed for events with $k_{inel} < 0.3, 0.4, 0.5$ as well as for the total sample. It is evident that the results are sensitive to a partition according to the values of k_{inel} . The corresponding material for $E = 200$ GeV exhibits a similar general behaviour.

The function $\bar{n}_s(\eta, n_s)$ is exhibited in Fig. 8 for a few different values of n_s . The smooth curves stem from a construction that will be discussed in the next Section. We have finally found notable correlations between the angular distributions and the angle of the leading track. We will, however, leave the details of these correlations for future investigations.

4. - THEORETICAL CONSIDERATIONS

An investigation similar to ours has been presented by the Cracow group ⁴⁾. Except for normalization differences the general behaviour of the distributions coincide in the two investigations.

It is evident that already at angles with $\eta = -1.8$ for $E = 200$ GeV and for angles with $\eta = -2.0$ for $E = 300$ GeV there are correlations to the nuclear parameters, i.e., the functions $\beta(\eta)$ are non-vanishing.

As a matter of fact there may be deviations from proton-proton collisions at still smaller angles. We have made use of the results reported from bubble chamber measurements in the FNAL to compute the angular distributions of charged pions in the variable η . The resulting curves are pointed in Figs. 5a and 5b. The curves are centred at a parameter value corresponding to the origin of the equal velocity system. This value of η is computed from the angle exhibited in the lab. system by a pion moving along the axis at right angles to the beam in equal velocity system with a transverse momentum $p_\perp = 0.35$ GeV. We assume that the leading track is a proton. The leading track distribution is the (forward) shaded area shown in Figs. 5a and 5b.

There are differences between the results for $d\alpha/d\eta$ and for the combined distribution of charged pions from proton-proton collisions and the leading track distribution already at $\eta = -1.8$ (for 200 GeV) and at $\eta = -2.0$ (for 300 GeV). In case only the tracks with $\eta < -0.5$ are counted then the difference is 1.9 for 200 GeV and 2.3 particles at 300 GeV.

There is a noticeable lack of pions in the distribution $d\alpha/d\eta$ for $\eta > -0.5$ as compared to the proton-proton distribution. The difference is, however, almost completely accounted for by Eq. (9). The distributions $N_0(d\beta/d\eta) \simeq d\beta/d\eta$ are added in Figs. 5a and 5b as the (backward) shaded areas. The distributions $d\beta/d\eta$ are much wider than any corresponding hadron-hadron collision distribution. It is possible to compute the energy from the RC component [cf. Eq. (8)] according to the formula

$$E_{RC} = n_h^{\text{eff}} \int d\eta \frac{d\beta}{2\eta} \left(\left(\frac{p_\perp}{\sin\theta(\eta)} \right)^2 + m_\pi^2 \right)^{1/2} \quad (12)$$

We find, with values of the parameters n_h^{eff} and $p_\perp$ in accord with Eqs. (8) and (11), that for $E = 200$ GeV, $E_{RC} = 5.4$ and for $E = 300$ GeV, $E_{RC} = 9.3$ GeV. It is interesting to see that the energy results are close to the values predicted by Gottfried's EFC model but the angular distributions for the RC component is not at all similar to the one predicted by the model (cf. below).

In the Gottfried model the RC component stems from collisions between low energetic mesonic entities and the nucleons inside the nucleus. In other models, the RC component is associated with excited hadronic matter (also with mesonic quantum numbers). It is then of interest to correlate the distribution $d\beta/d\eta$ to relevant hadronic distributions.

In Fig. 6b, we have beside the experimental results for $d\beta/d\eta$ at 300 GeV also plotted the angular distribution of the pions from πp collisions at 7 GeV (dotted curve) normalized to the area under $d\beta/d\eta$. The distribution has been centred around the median of $d\beta/d\eta$ for $\eta = 0.7$. It is evident that the distribution $d\beta/d\eta$ exhibits a much larger width than the pion distribution. The effect can be understood as the result of a convolution between a velocity distribution characteristic for the RC component and an elementary collision distribution like the one mentioned above. In case a Gaussian distribution in η is used for the velocity distribution then the width is energy dependent and is of the order of 0.5 for $E = 300$ GeV and 0.4 for $E = 200$ GeV. Before we discuss the results for the distributions $\bar{n}_s(\eta, n_s)$ we will briefly consider the predictions (if any) of different models. We will use Eqs. (7), (8) and (9) in order to compare the results from our constructed functions $d\alpha/d\eta$ and $d\beta/d\eta$ to the LP and RC components.

The Gottfried model predicts that the RC component stems from "slices" of hadronic matter which, during the (time-dilated) interval between two ensuing collisions, have developed into the "size" of real hadrons. The model predicts a largest value for the rapidity of the RC component. The points have been marked by the letter G in Figs. 6a and 6b. It seems evident that if the identification of the RC component can be done according to Eq. (8) (cf. below) then an upper limit of this kind experimentally corresponds to much smaller angles (larger rapidities) than those achieved in models in which a certain fraction of the rapidity interval is attributed to the RC component. In Gottfried's model this fraction is close to $1/3$ while in others, it is close to $\frac{1}{2}$. We have marked this last-mentioned prediction by the letter L in Figs. 6a and 6b. Models containing more pronounced collective effects also predict larger differences between proton-proton and proton-nucleus collisions both with regard to the size and the shape of the angular distributions. In the Reggeon model ⁵⁾ rather intuitive arguments have been given for a rapidity value $y_p = \ln 2M_p R$ below which nuclear corrections and enhancements should be noticeable. Here M_p is the proton mass and R the nuclear radius. This value is A dependent (and computed for emulsion $\eta \simeq -2.0$) but not energy dependent and it corresponds to rapidities so large that a Pomeron in the theory can act coherently over the whole nucleus. A more conservative estimate leads to the prediction $y'_p = \ln(\frac{4}{2}m_\pi R)(\eta \simeq -1.0)$ ⁹⁾. The predictions of the hydrodynamical model depends in an essential way upon the value which is assumed for the velocity of sound but also upon some boundary conditions of essentially classical nature. More detailed discussions and computations of the model which are relevant to this investigation will be presented elsewhere ¹⁴⁾. We will only mention that for sound velocities smaller than the ones employed in the original model (which is based upon the equation of state of black body radiation), the model exhibits a dependence upon energy and nuclear number which is compatible with our results.

For values of the variable $\eta < -1.8$ (200 GeV) and $\eta < -2.0$ (300 GeV) the distributions $\beta(\eta)$ are (slightly) negative for both energies. This can be understood as an effect of charge exchange, i.e., that there is a non-vanishing probability in each elementary collision that the proton is transformed into a neutron. The effect is centred in the region where the main contributions from the leading track occur and it is not noticeable in the distributions obtained by discarding the leading

track. From the results of Fig. 7 and the discussion in Section 3, we find noticeable correlations between value of the inelasticity coefficient k_{inel} , defined by Eq. (11) and the angular distributions of the secondaries. It would be reasonable to expect that the distribution $\alpha(\eta)$ is more heavily affected by a decreasing value of k_{inel} (the whole construction is difficult to carry through if k_{inel} is too small, however, due to statistical fluctuations in a small sample). This property is due to the small (total) energy value of the RC component [cf. the discussion in connection with Eq. (1)] - the leading particle might not be much influenced by the repeated collisions in case each of them results in (on the average) a small loss of energy. Surprisingly enough, however, both the LP and the RC components seem to be correlated to the value of k_{inel} . There is a decrease of particles in the forward direction with decreasing k_{inel} for both the RC and the LP components.

The construction of this note is based upon the assumption that the Gottfried Eq. (6) can be used also in a "differential" way, i.e., that the angular distribution for a fixed number (ν) of collisions is given by the formulae :

$$n(\eta, \nu) = n_0(\eta) + (\nu-1)n_1(\eta) \quad (13)$$

In case also the relations in Eqs. (8) and (9) can be used in a differential way we know all the quantities in Eq. (13) from the above constructions :

$$n_0(\eta) = \alpha(\eta) + N_0 \beta(\eta) ; N_0 \sim 1 \quad (14)$$

$$n_1(\eta) = n_h^{eff} \beta(\eta) \quad (15)$$

Then the distribution $\bar{n}_s(\eta, n_s)$ should be given by the construction ²⁾

$$\bar{n}_s(\eta, n_s) = \left[\sum_{\nu} \pi(\nu) P_s(n_s, \nu) \right]^{-1} \left(\sum_{\nu} \pi(\nu) n(\eta, \nu) P_s(n_s, \nu) \right) \quad (16)$$

The distributions π and P_s are presented in Section 2 and the parameters of these distributions have been determined from earlier considerations ²⁾. The theoretical predictions from Eq. (16) have been exhibited in Figs. 10 together with the experimental data. It is evident that the predictions are well compatible with the data.

5. - CONCLUSIONS

We have, in this note, made a partition of the angular distributions of the shower particles from 200 GeV and 300 GeV proton-emulsion collisions into one part, called the LP component which is uncorrelated to the emission of heavy prong fragments and one part corresponding to the excess from the repeated collisions (the RC component). We find that the opening angle of the forward cone inside which the angular distributions coincide with the pp collisions at the same energy is very small ($\lesssim 0.5^\circ$), is energy dependent (decreases with the proton energy), possibly A dependent and is dependent upon the angle of the leading track as well as the inelasticity coefficient. The LP component exhibits a mean multiplicity which is $\sim 30\%$ larger than the equivalent pp multiplicity at the same energy. The excess particles are slowly moving in the equal velocity system. The RC component can be described as composed of contributions, one for each collision of the proton inside the nucleon, which are low energetic (only a few per cent of the total energy) and contain a few shower particles each.

Only models with large collective effects are easily compatible with the results of this investigation. More detailed predictions from available models would be of great interest.

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FIGURE CAPTIONS

- Figure 1 The integral distribution $\bar{n}(\eta, N_h)$ for $E_{lab} = 300$ GeV and for a few different groups of values of N_h . The leading track is excluded (the two curves are displaced).
- Figure 2 The linear dependence of $\bar{n}(\eta, N_h)$ on N_h , the number of heavy tracks for $E_{lab} = 200$ GeV and 300 GeV.
- Figure 3 The RC component distribution $\beta(\eta)$.
- Figure 4 The LP component distribution $\alpha(\eta)$.
- Figure 5 The differential LP component distribution $d\alpha/d\eta$ for
a) $E_{lab} = 200$ GeV ;
b) $E_{lab} = 300$ GeV.
The pointed curve is derived from the π distribution in pp collisions at FNAL. The forward shaded area $\eta < -1.3$ is the leading track distribution, the backward shaded area the distribution $\mathcal{N}_0(d\beta/d\eta)$ at the same energy.
- Figure 6 The differential RC component distribution $d\beta/d\eta$ for
a) $E_{lab} = 200$ GeV ;
b) $E_{lab} = 300$ GeV.
The letters G, L and P correspond to predictions of different models according to the discussion in the main text. The pointed curve corresponds to the π distributions stemming from a 7 GeV π^-p collision.
- Figure 7 The correlation of the inelasticity coefficient to the differential distributions at 300 GeV :
a) $d\alpha/d\eta$;
b) $d\beta/d\eta$.
- Figure 8 The differential distributions $d\bar{n}/d\eta(n_s, \eta)$ for a few different values of n_s and both energies. The curves stem from theoretical considerations in Section 4.

FIG. 1

FIG. 2

FIG. 3

FIG. 4

FIG. 5a

FIG. 5b

FIG. 6a

FIG. 6b

FIG. 7a

FIG. 7b

FIG. 8