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Strangeness Production in pp,pA,AA
Interactions
at SPS Energies. HIJING Approach

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Abstract

In this report we have made a systematic study of strangeness production in proton-proton(pp),proton-nucleus(pA) and nucleus- nucleus(AA) collisions at CERN Super Proton Synchrotron energies, using *HIJING MONTE CARLO MODEL* (version *HIJ.01*).

Numerical results for mean multiplicities of neutral strange particles ,as well as their ratios to negatives hadrons($\langle h^- \rangle$) for p-p,nucleon-nucleon(N-N), p-S, p-Ag, p-Au('min. bias')collisions and p-Au, S-S, S-Ag, S-Au ('central')collisions are compared to experimental data available from CERN experiments and also with recent theoretical estimations given by others models(*QGSM*, *RQMD*, *DPM*, *VENUS* and *FRITIOF*).

Neutral strange particle abundances are quite well described for p-p,N-N and p-A interactions ,but are underpredicted by a factor of two in A-A interactions for Λ , $\bar{\Lambda}$, K_S^0 in symmetric collisions(S-S, Pb-Pb)and for Λ , $\bar{\Lambda}$ in asymmetric ones(S-Ag, S-Au, S-W).

The ratios antistrange/strange are well described for $\frac{\bar{\Lambda}}{\Lambda}$ but the ratios for multistrange particles (Ξ, Ω) and their antiparticle, could not be predicted by the model.A detailed analysis in limited rapidity range is required in order to draw some definite conclusion.

A qualitative prediction for rapidity, transverse kinetic energy and transverse momenta normalized distributions are performed at 200 GeV/Nucleon in p-S,S-S,S-Ag and S-Au collisions in comparison with recent experimental data. HIJING model predictions for coming experiments at CERN for S-Au, S-W and Pb-Pb interactions are given. The theoretical calculations are estimated in a full phase space.

The factor of two can not be explained by considering very central events ($b_{max} = 0.0$) and taking into account minijets. New ideas are necessary in order to improve the comparison with experiment for nucleus - nucleus interactions.

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1 Introduction

Searching for possible exotic states of nuclear matter is one of the currently most interesting and stimulating subjects in high energy nuclear physics (see references [1–10]) To create exotic matter such as the quark-gluon plasma (QGP) [1–4,5] strange matter [4],[10], multi Δ -matter, pion condensate, kaon condensate [4],[9] it is essential to generate extreme states of nuclear matter regarding density, temperature or energy density [10]. Such extreme states are considered to be produced most probably in high energy heavy ion reactions [10–14] or in the annihilation of energetic antiprotons (\bar{p}) on a nucleus [15]

The possibility suggested by Witten [16] that strange quark-matter might be the lowest energy state of large baryon number, would have many consequences in physics and astrophysics and also cosmology relevance [16–20]. Small drops of strange matter (strangelets) may be natural results of the evaporation of a QGP formed in heavy ion collisions.

Enhanced strangeness production [10] in ultrarelativistic heavy ion collisions (URHIC) is one of the most widely discussed signature for creating QGP [21],[114].

Several experiments have been performed to investigate strangeness production in reactions involving relativistic nuclei, particularly at Super Proton Synchrotron (SPS) at CERN : NA35 [22–32], NA36 [33–37], WA85, WA94 [38–45],[128–130], NA44 [132–133], HELIOS Collab. [46–50], and at the Alternating Gradient Synchrotron (AGS) at Brookhaven E802 [51–55], E810 [57],[115] and E814 [116],[134].

These experiments have measured also the yield of several particle species containing one or two strange quarks (K^+ , K_s^0 , Λ , Ξ^- and their antiparticles) or three strange quarks (Ω^-). In all the cases their production relative to pions or negative hadrons and some other ratios are larger in nucleus - nucleus collisions compared to proton - proton .

Now experiments with truly heavy ion projectile have just started (with a gold beam at BNL) [117],[118] or are under way ($Pb(170AGeV) + Pb$ at CERN) [114].

The soft physics data have stimulated a great deal of theoretical activity and in the present introduction it is impossible to give more than a superficial overview of the main types of the Monte Carlo models used. Many models for URHIC have been developed: Dual Partons Models (DPM) [59–66],[120] Quark Gluon String Models (QGSM) [67–69], VENUS models for Very Energetic Nuclear Scattering [70–75] FRITIOF model [76],[77], ATTILA [78] model, relativistic quantum molecular dynamics (RQMD) [79–83][135–138], Parton String Model (PSM) [139], HIJET model [119].

An excellent review and detailed comparison of the models was done by Werner [84].

On the other hand, no unconventional explanation has so far put forward for the observed increase of antihyperons ($\bar{\Lambda}$, $\bar{\Xi}^-$). Actually, it is the old Pomeron exchange picture that is revitalized in some models with a new ingredient that is the Pomeron is made of two colored strings. Thus the problem of interaction of strings becomes important. This interaction may give rise to the fusion of strings [85–88][137,138] making a new string with more color charge. These new objects could explain the strangeness enhancement [89],[90],[137,138] especially $\bar{\Lambda}$ enhancement. Such models can be seen as an interplay between independent string fragmentation and QGP formation. One version of VENUS generator also include such interaction [73], [90].

We note also that an interpretation based on a particular dependence of the cross sections for URHIC was taken into account [58].

In this report we have performed a systematic study of strange particle production in proton-proton (pp), proton-nucleus (pA) and nucleus-nucleus (AA) interactions at SPS-

CERN energies using HIJING(Heavy Ion Jet Interacting Generator) Monte Carlo model [91–97] developed at Berkeley.

The formulation of HIJING is guided by the LUND FRITIOF ([76]–[77]) and DPM [98] models phenomenology for soft nucleus - nucleus reactions at intermediate energies $\sqrt{s} \leq 20 \text{ GeV}/N$ and the successful implementation of perturbative QCD (PQCD) processes in the PYTHIA model [99]–[100] for hadronic interactions.

HIJING incorporate the PQCD to multiple jet processes and the nuclear effects such as parton shadowing and jet quenching. HIJING provide a link between the physics at intermediate CERN–SPS energies and the highest collider energies at Relativistic Heavy Ion Collider(RHIC)($\sqrt{s} \geq 200 \text{ GeV}/N$ and the CERN Large Hadron Collider (LHC) ($\sqrt{s} = 6 \text{ TeV}/N$).

Using HIJING Monte Carlo model [92],[93] a detailed discussion and comparison with a wide variety of data in pp, pA and AA collisions was reported. However no study on the strangeness production at SPS-CERN energies in pp, pA and AA data exist within this approach .

In this paper we present some theoretical calculations for mean multiplicities of strange particle production in the full rapidity range as well as their ratios to negative hadron predicted by HIJING model(HIJ.01 version -see section 2 and 3 for explanation of this version)for pp ,nucleon-nucleon $N - N$, 'minimum bias' collisions pS, pAg, pAu and 'central collisions' $pAu, SS, SAg, SAu, SW, PbPb$ at the energy of 200 AGeV .

Also a qualitative prediction for normalised distributions for rapidity,transverse kinetic energy and transverse momenta are done at $200 \text{ GeV}/N$ ucleon in pp, pS, SS, SAg and SAu collisions and the results are compared with recent experimental data from NA 35 Collaboration[140]. We note that theoretical calculations are done for full phase space. For giving an idea of abundances and spectra in experiments planned in the near future at CERN ,we give some predictions for SW and PbPb interactions.

We note that the version HIJ.01 of the model includes neither the formation of QGP nor some collective dynamics on either the hadronic or string level. Although the existing trends of hadron distributions are quite satisfactorily approximated by the HIJING model [92],[93]and also neutral strange production in pp and pA interactions are quite well described, this version is getting less reliable for strange particle produced in heavy colliding systems. The same result is stressed out and in other models QGSM[101],[102],RQMD[83], FRITIOF[27],PSM[139].

A brief description of the HIJING Monte Carlo model and theoretical background are given in Section 2. Detailed numerical results of this version HIJ.01 for pp, pA and AA reactions especially at CERN-SPS energies $\sqrt{s} \simeq 20 \text{ GeV}/N$ for strangeness production are compared to experimental data and other models predictions like QGSM [101],[102], DPM [65],[141],[142],VENUS [84] ,FRITIOF [27], and RQMD [83],[140] in Section 3. Section 4 concludes with a summary and discussion of future applications.

2 The Monte Carlo HIJING model

A detailed discussion of the HIJING Monte Carlo model was reported in references [91],[92],[94]. The formulation of HIJING was guided by the LUND-FRITIOF and DUAL PARTON MODEL phenomenology for soft nucleus-nucleus reactions at intermediate energies ($\sqrt{s} < 20 \text{ GeV}$)and implementation of perturbative QCD(PQCD) processes in

the PHYTHIA MODEL for hadronic interactions. Comparison between some MONTE CARLO GENERATORS are given in reference [84]

All PQCD models employ initial and final state radiation in an iterative fashion : a parton with a squared mass Q^2 radiates a parton and leaves a remainder parton with reduced Q^2 , the latter one radiating again and so on .The hadronization finally is done by using string model(PYTHIA).A link to the soft semihard models is provided by PYTHIA ,where it was realized that the perturbatively calculated cross section is an inclusive one and may well exceed the total cross section meaning multiple scattering. Therefore the cross sections was eikonalized:for a given impact parameter multiple scattering occurs according to a Poissonian distribution,with the average number of scatterings, being b -dependent,proportional to some profile function $T(b)$.HIJING is based on a particular model of high energy pp inelastic collisions.

We give in this section brief review of the aspect relevants to hadronic interaction:

1. The models includes multiple minijet production with initial and final state radiation along the lines of the PYTHIA model [99],[100] and with cross sections calculated within the eikonal formalism.
2. Soft beam jets are modeled by quark-diquark strings with gluon kinks along the lines of the DPM and FRITIOF models.Multiple low p_T exchanges among the end point constituents are included.
3. Exact diffuse nuclear geometry is used to calculate the impact parameter dependence of the number of inelastic processes [78].
4. An impact parameter dependent parton structure function is introduced to study the sensitivity of observable to nuclear shadowing,especially of the gluon structure functions.
5. A model for jet quenching is included to enable the study of the A-dependence of moderate and high p_T observable on an assumed energy loss of partons traversing the produced dense matter.
6. HIJING does not incorporate the mechanism for final state interactions among low p_T produced particles.

The rate of multiple minijet production in HIJING is constrained by the cross sections in nucleon-nucleon collision .Within an eikonal formalism [103] the total elastic cross sections σ_{el} ,total inelastic cross sections σ_{in} and total cross sections σ_{tot} can be expressed as:

$$\sigma_{el} = \pi \int_0^\infty db^2 (1 - \exp(-\chi(b, s)))^2 \quad (1)$$

$$\sigma_{in} = \pi \int_0^\infty db^2 (1 - \exp(-2 \chi(b, s))) \quad (2)$$

$$\sigma_{tot} = 2 \pi \int_0^\infty db^2 (1 - \exp(-\chi(b, s))) \quad (3)$$

Strong interactions involved in hadronic collisions can be generally divided into two categories depending on the scale of momentum transfer q^2 of the processes. If $q^2 < \Lambda_{QCD}^2$ the collisions are nonperturbative and are considered *soft* and if $q^2 \gg \Lambda_{QCD}^2$ the subprocesses on the parton level are considered *hard* and can be calculated via PQCD [93].

In the limit that the real part of the scattering amplitude is small and the eikonal function $\chi(b, s)$ is real, the factor

$$g(b, s) = 1 - \exp(-2\chi(b, s)) \quad (4)$$

in terms of semiclassical probabilistic model can be interpreted as *the probability for an inelastic event of nucleon–nucleon collisions at impact parameter b , which may be caused by hard, semihard or soft parton interactions.*

To calculate the probability of multiple minijet a main dynamical assumption is that they are independent. This holds as long as their average number is not too large. The independence should apply up to LHC energies [93]

When shadowing can be neglected, the probability of no jets and j independent jet production in an inelastic event at impact parameter b , can be written as :

$$g_0(b, s) = (1 - \exp(-2\chi_s(b, s))) \exp(-2\chi_h(b, s)) \quad (5)$$

$$g_j(b, s) = \frac{[2\chi_h(b, s)]^j}{j!} \cdot \exp(-2\chi_h(b, s)) \quad j \geq 1 \quad (6)$$

where $\chi_s(b, s)$ –is the eikonal function for soft interaction, $2\chi_h(b, s)$ –is the average number of hard parton interactions at a given impact parameter, $\exp(-2\chi_s(b, s))$ –is the probability for no soft interaction. Summing eqs.(5) and (6) over all values of j leads to :

$$\sum_{j=0}^{\infty} g_j(b, s) = 1 - \exp(-2\chi_s(b, s) - 2\chi_h(b, s)) \quad (7)$$

Comparing with eq.(4) one has :

$$\chi(b, s) = \chi_s(b, s) + \chi_h(b, s) \quad (8)$$

If we consider that the parton distribution function is factorizable in longitudinal and transverse directions and the shadowing can be neglected the average number of hard interaction $2\chi_h(b, s)$ at the impact parameter b is given by :

$$\chi_h(b, s) = \frac{1}{2} \sigma_{jet}(s) T_N(b, s) \quad (9)$$

where $T_N(b, s)$ is the effective partonic overlap function of the nucleons at impact parameter b .

$$T_N(b, s) = \int d^2 b' \rho(b') \rho(|b - b'|) \quad (10)$$

with normalization

$$\int d^2 b T_N(b, s) = 1 \quad (11)$$

and σ_{jet} is the is the PQCD cross section of parton interaction or jet production [92],[93]

If we note $\xi = b/b_0(s)$, where $b_0(s)$ provide a measure of the geometrical size of the nucleon

$$\pi b_0^2(s) = \sigma_s(s)/2$$

we get assuming the same geometrical distribution for both soft and hard overlap functions

$$\chi_s(\xi, s) \equiv \frac{\sigma_s}{2\sigma_0} \chi_0(\xi) \quad (12)$$

$$\chi_h(\xi, s) \equiv \frac{\sigma_{jet}}{2\sigma_0(s)} \chi_0(\xi) \quad (13)$$

$$\chi(\xi, s) \equiv \frac{1}{2\sigma_0} [\sigma_s(s) + \sigma_{jet}(s)] \chi_0(\xi) \quad (14)$$

We note that $\chi(\xi, s)$ is a function not only of ξ but also of \sqrt{s} because of the \sqrt{s} dependence on the jet cross section $\sigma_{jet}(s)$. Geometrical scaling implies on the other hand, that $\chi_s(\xi, s) = \chi_0(\xi)$ is only a function of ξ . Therefore geometrical scaling is broken at high energies by the introduction of the nonvanishing $\sigma_{jet}(s)$ of jet production.

Now we can rewrite the cross sections of nucleon - nucleon collisions as :

$$\sigma_{el} = \sigma_0(s) \int_0^\infty d\xi^2 (1 - \exp(-\chi(\xi, s)))^2 \quad (15)$$

$$\sigma_{in} = \sigma_0(s) \int_0^\infty d\xi^2 (1 - \exp(-2\chi(\xi, s))) \quad (16)$$

$$\sigma_{tot} = 2\sigma_0(s) \int_0^\infty d\xi^2 (1 - \exp(-\chi(\xi, s))) \quad (17)$$

The calculation of these cross sections requires specifying $\sigma_s(s)$ with a corresponding value of cut - off momenta P_0 [94],[95]

In the energy range $10 \text{ GeV} < \sqrt{s} < 70 \text{ GeV}$, where only soft parton interactions are important cross sections $\sigma_s(s)$ is fixed by the data on total cross sections $\sigma_{tot}(s)$ directly. In and the above $Spp\bar{p}S$ energy range $\sqrt{s} \geq 200 \text{ GeV}$ we fix $\sigma_s(s)$ at a value of 57 mb with $P_0 = 2 \text{ GeV}/c$, in order to fit the data of the cross sections. Between the two regions $70 \text{ GeV} < \sqrt{s} < 200 \text{ GeV}$, we simply use a smooth extrapolation for $\sigma_s(s)$ [95].

In HIJING a nucleus-nucleus collisions is decomposed into binary collisions involving in general excited or wounded nucleons. Wounded nucleon are assumed to be $q-qq$ string like configurations that decay on a slow time scale compared to the collision time of the nuclei. In the FRITIOF scheme wounded nucleon interactions follow the same excitation

law as the original hadrons. In the DPM scheme subsequent collisions essentially differ from the first since they are assumed to involve sea partons instead of valence ones. The HIJING model adopt a hybrid scheme, iterating string-string collisions as in FRITIOF but utilizing DPM like distributions.

By incorporating the successful multistring phenomenology for low p_T interactions at intermediate energies, HIJING provide a link between the dominant nonperturbative fragmentation physics at intermediate CERN-SPS energies and perturbative QCD physics at the highest collider energies (RHIC; LHC)

3 NUMERICAL RESULTS

3.1 STRANGENESS IN PROTON - PROTON INTERACTION

Strange particle production provide some information about the question of whether or not a quark-gluon plasma occurs in heavy ion collisions. This is major motivation to first study the production of strange particles in pp scattering. In addition, strange particle give some insight into dynamics already for pp collisions.

We run the program HIJING , with default parameters, mainly IHPR2(11)=1 , which means choise of baryon production model with diquark-antidiquark pair production allowed, initial diquark treated as unit ; IHPR2(12)=1 , decay of particle such as $\pi^0, K_s^0, \Lambda, \Sigma, \Xi, \Omega$ are allowed ; IHPR2(17)=1 - gaussian distribution of transverse momentum of the sea quarks ; IHPR2(8)=0 - jet production turned off for theoretical predictions in HIJING model- HIJ.01, and IHPR2(8)=10-the maximum number of jet production per nucleon-nucleon interaction for for theoretical predictions $HIJ.01^{(j)}$.

The energy dependence of average multiplicities for different particle species, gives a first impression about the predictive power of the model and provide an important check of model approach.

In Table 1 we give average multiplicities of particle at $E_{lab} = 200 GeV$ in proton-proton interaction, E_{lab} being the laboratory energy.

The theoretical values $HIJ.01$ are obtained for 10^5 generated events and in a full phase space. The values $HIJ.01^{(j)}$ are for very central pp collisions ($b_{max} = 0.0$) and with minijet production. The experimental data are taken from reference [32].

The large difference between pions and kaons is due to the suppressed strangeness production from string fragmentation. Pions(+) and kaons(+) are more frequent than the negative ones due to charge conservation. We note that the multiplicities for neutral strange particle $\langle \Lambda \rangle, \langle \bar{\Lambda} \rangle, \langle K_s^0 \rangle$ and for antiproton $\langle \bar{p} \rangle$ are quite well described in the limits of three standard error deviations for pp interactions at $200 GeV$. However the values for $\langle \bar{p} \rangle$ and $\langle \bar{\Lambda} \rangle$ are slightly overpredicted by the model.

In order to give some comparison at ultrahigh energy and to test the predictive power of generator we perform calculations at centre of mass energy $\sqrt{s} = 546 GeV$ ($Spp\bar{p}S$ -energies), for $\bar{p}p$ interactions.

By using many pieces of data from the different collider experiments (charge particle K, Λ, Ξ and γ from **UA5** , p from **UA2**), the **UA5** collaboration has attempt to piece together a picture of the composition of a typical soft event at the $Spp\bar{p}S$ [104]. The measurements were made in various different kinematic regions and have been extrapolated in the full transverse momenta (p_T) range and rapidity range for comparison as described

in reference [106]. The experimental data are compared with $HIJ.01^{(j)}$ results in Table 2. The number of generated events was 10^5 .

It was stressed out [104] that the data show a substantial excess of photons compared to the mean $\pi^+ + \pi^-$. It was suggested like explanation the possible emission of gluon Cerenkov radiation in hadronic collision [105]. At this energy the model $HIJ.01^{(j)}$ seems to work fairly well and the data are well described. Our calculations ruled out such hypothesis. Taken into account direct gamma production the agreement with the data is in the limit of experimental errors.

The experimental ratio $\frac{K^+}{\pi^+} = 0.095 \pm 0.009$ are predicted also by $HIJ.01^{(j)}$ model (0.99). We note that a study of the ratios of invariant cross sections of kaons to that of pions as a function of transverse momenta in the central region was done by Wang and Gyulassy [92],[93].

The behaviour of average multiplicities for different particles species as a function of the energy can be reproduced by HIJING model[93] and also by VENUS model(see reference [84]).

Appropriate variable to describe single particle properties are the transverse momentum p_T and the rapidity y

$$y = \frac{1}{2} \ln \frac{E + p_3}{E - p_3} = \ln \frac{E + p_3}{m_T} \quad (18)$$

with E, p_3 , and m_T being energy, longitudinal momentum and transverse mass

$$m_T = \sqrt{m_0^2 + p_T^2} \quad (19)$$

with m_0 being particle mass.

In figures 1a,b and 2a,b we show normalized rapidity (1a,2a) and transverse momentum distributions (1b,2b) for Λ 's (fig.1a,b) and for K_s^0 's for pp scattering at 200 GeV. The theoretical values HIJ.01 are compared with experimental data taken from Jaeger et al.[107] HIJING results and data [107] are very similar, although *HIJING* does not show some structures present in data.

We see the two distinct lambda peaks, being due (in zeroth order) the fragmentation of the forward baryonic string and the backward baryonic string into leading baryons. Therefore lambda distributions are similar to proton distributions, just reduced by some factor and with the diffractive peak missing (see also reference [84]).

The kaons are peaked at mid rapidity and are similar to the pions, though again less in magnitude. The distributions are narrower compared to proton's and pion's.

3.2 STRANGENESS IN PROTON-NUCLEUS AND NUCLEUS-NUCLEUS INTERACTIONS

3.2.1 Multiplicities in pA and AA collisions

In the following we investigate strange particle production in HIJING model approach, for proton-nucleus and nucleus-nucleus collisions. We have studied the production of neutral strange particle $\Lambda, \bar{\Lambda}, K_s^0$ in comparison with recent experimental data from NA35

CERN-experiments,for pp, pA, AA interactions. We investigate the average multiplicities for negative hadrons ($\langle h^- \rangle$),negative pions($\langle \pi^- \rangle$ and neutral strange particles ($\langle K_s^0 \rangle, \langle \Lambda \rangle, \langle \bar{\Lambda} \rangle$) in pp, NN, pS, pAg, pAu 'minimum bias collisions'and SS, SAg, SAu 'central collisions' at $200 \text{ GeV}/N$. The default parameters were used during the simulation and also option JET NO(IHPR2(8)=0). The number of Monte Carlo generated events was 10^5 for pp and pA interactions, $5 \cdot 10^3$ for SS, SAg and 10^3 for SW, SAu and $PbPb$ collisions.

The results are given in Tabel 3 in comparison with experimental data [140].The corresponding data for pp and NN at 200 GeV [32] are also shown in Table 3.

We remark that HIJING model describe quite well neutral strange particle multiplicities for pp and pA interactions, but underestimate by a factor of two the values for nucleus-nucleus interactions for $\langle \Lambda \rangle, \langle \bar{\Lambda} \rangle, \langle K_s^0 \rangle$ in symmetric collisions $SS, PbPb$ (expected values) and for $\langle \Lambda \rangle, \langle \bar{\Lambda} \rangle$ in assymmetric ones (SAg, SAu, SW).

We note also that our theoretical calculations are done for pA 'minimum bias' collisions and the experimental data are for the events with charged particle multiplicity greater than five, which contain a significant fraction (about 90 %) of the 'minimum bias' events [140].

In order to get some idea about the discrepancies between theoretical calculations and experimental data we try to run the program in the limiting condition for very central events ($b_{max} = 0.0$) and jet allowed. The results are given in Table 4 and are compared also with recent theoretical approach in RQMD [140], QGSM [102],[140] and DPM models (DPM^1 are from reference [141], variant of DPM which include additionally $(qq) - (\bar{q}\bar{q})$ production from the sea into the chain formation process, DPM^2 are from reference [142], variant of DPM which include chain fusion, good candidate to explain the anomalous antihyperon production).

In order to study the total production of strangeness in these collisions in a model independent way and to use all available experimental information NA35 Collaboration [140] has studied the ratio defined as :

$$E_S = \frac{\langle \Lambda \rangle + 4 \langle K_s^0 \rangle}{3 \langle \pi^- \rangle} \quad (20)$$

We estimate this ratio in HIJING approach for the above interactions and give the numerical results in Table 5 together with the mean multiplicities for negative pions. We can conclude from this analysis that the factor of two for $\langle K_s^0 \rangle$ which was reclaimed from multiplicities analysis for symmetric interactions are ruled out. Experimental error are to higher and new data with higher statistics are needed for draw a definite conclusions.

Taken into account a factor of two in neutral strange particle production we get a value $0.26 - 0.28$ independent of the target nucleus mass number for AA interaction from SS to $PbPb$. Without factor of two the theoretical E_S values for pA and AA are aproximatively equal to the values for nucleon-nucleon interactions. However the experimental values of E_S are two times higher then the corresponding NN and pA values, a fact established from recent NA35 data. Therefore new ideas are required to modify hadronic models in order to reproduce strange particle production at high energies.

3.2.2 Multiplicity ratios

A different approach of finding signals for QGP is simply to compare nucleus-nucleus (AA) or hadron-nucleus(hA) data with nucleon-nucleon(NN) data.

However, in particular this assumption is certainly not correct, since at high energies AA scattering is not simply a superposition of NN collisions. The time scale between two NN interactions is too small for hadronization and therefore some intermediate object is involved.

Simple theoretical estimates are very unreliable. Comparing AA with NN data or pA and NN data does not help, because new results do not necessarily mean QGP. Calculation based on QCD are not feasible, because we are in domain where PQCD does not apply. Soft interactions involving small transverse momenta transfer should be taken into account.

This ratios for multistrange particles were analysed in terms of thermal models [122],[121], [124], [123]. A constraint between thermal fireball parameters arises from the requirement that the balance of strangeness in a fireball is nearly zero. The impact of this constraint on (multi-)strange (anti-)baryon multiplicities comparing hadron gas and QGP has been analysed. The data are compatible with the QGP hypothesis and appear to be inconsistent with the picture of an equilibrated hadron gas fireball [121],[122].

However the two scenarios (slow and rapid) for the expansion of a QGP were recently studied in detail. Production ratios $\Lambda/\bar{\Lambda}$ and $\Xi/\bar{\Xi}$ for hadron gas at $T = 200 MeV$ and plasma break-up have been compared to experimental data at baryonic chemical potential $\mu_B = 300 MeV$. Present data on strange particle production cannot provide a distinction between the two scenarios [112].

We calculate the ratios of the mean strange particles multiplicities to the mean multiplicities of negative hadrons and we show in Table 6 a comparison with experimental NA35 data [140] for the same interactions like in Table 3. The agreement cannot be obtained without factor of two in neutral strange multiplicities. We note that negative hadrons as well as negative pions are well described even for very complex AA interactions.

In Tabel 7 we give the multiplicity ratios for negative hadrons as well as for neutral strange particle for pA/pp, AA/pp and AA/pA. Results from HIJING (*HIJ.01*) and *DPM* models are compared to NA5 [31] and NA35 [22] experimental data. The calculations on the models *HIJ.01* and *DPM* reproduce the relative increase of the K_s^0 ratios in central *SS* collisions, but cannot describe the data concerning Λ and $\bar{\Lambda}$ generation.

Comparing experimental data with theoretical prediction of the HIJING model we see that these ratios cannot be described without factor of two for *AA/pp* and *AA/pA*.

Data for charge kaon production have already been published by HELIOS Collaboration for $p+W$ and $S+W$ at $200 GeV/N$ in the limited target rapidity region $y = 1.0 - 1.5$ and by NA35 Collab. for $p+S$, $p+Au$ and $S+S$, $S+Au$ collisions at $200 GeV/N$ in a wider rapidity interval. Both experiments have shown an increase of the ratio $\frac{K^+}{\pi^+}$ as compared with the elementary interaction, while no significant increase was observed for $\frac{K^-}{\pi^-}$ ratio.

The experimental values [51],[50] are compared with HIJING results in Tabel 8a and Tabel 8b.

In Table 9 the results on average multiplicities of K^+ and K^- and multiplicities ratios in $S+S$ interactions extrapolated to the full phase space are compared with model

predictions : HIJING (HIJ.01),VENUS and FRITIOF. The experimental data are taken from reference [27]. All models underestimate the $\frac{\langle K^+ \rangle}{\langle \pi^+ \rangle}$ ratio ,but reproduce well the $\frac{\langle K^- \rangle}{\langle \pi^- \rangle}$ ratio. The models seems to overpredict the average $\langle K^- \rangle$ multiplicities in nucleus-nucleus collisions.The secondary collisions induced by the pion and kaon mesons in nuclei may influence the ratios $\frac{\langle K \rangle}{\langle \pi \rangle}$ [108] .

Experimental values for multistrange baryon ratios in nucleus nucleus interactions were recently reported [45], [37], [6].We check if the model could describe these ratios ,but our calculations are for full phase space and experimental data are reported in limited rapidity range. We see from Table 10 that only ratios $\frac{\bar{\Lambda}}{\Lambda}$ are well described by the model.The model overestimate the productions of $\bar{\Xi}^-$ and $\bar{\Omega}^-$.

The ratios are well described for $\bar{\Lambda}/\Lambda$ but the ratios for multistrange particles and their antiparticle could not be predicted by the model.A detailed analysis in limited rapidity range is required in order to draw some definite conclusions (calculations are now in progress). We remark that the ratios for multistrange particle production are not predicted by this version of HIJING model,nor by more sophisticated models like QGSM , RQMD ,DPM,SPM.

3.3 Some distributions for neutral strange particles in pA and AA interactions

A qualitative prediction for rapidity and transverse kinetic energy are performed at 200 GeV/Nucleon in $p-S$, $S-S$, $S-Ag$ and $S-Au$ collisions and are represented in comparison with experimental data from T.Alner et al.,[140].

In Fig.3a,b,c,d we give normalized rapidity distributions for Λ produced in interactions quoted above : Fig.3a for $p-S$; Fig.3b for $S-S$, Fig.3c for $S-Ag$;and Fig.3d for $S-Au$. In Fig.4a,b,c,d and in Fig.5a,b,c,d we give the rapidity distributions for $\bar{\Lambda}$ and K_s^0 respectively.

In Fig.6a,b,c,d ;Fig.7a,b,c,d and in Fig.8a,b,c,d normalized distributions of transverse kinetic energy defined as $T_{kin} = m_T - m_0$,are represented for the same interactions. Theoretical HIJING values (HIJ.01) are multiplied by a factor of two (HIJ.01*2) shown in the figures.The total number of events generated in full phase space are the same as for the results from Table 3(see section 3.1).

Transverse momentum distributions for Λ , $\bar{\Lambda}$ and K_s^0 particles produced in $p+S$ interactions are given in Figures 9a,b,c. The ratio of $\bar{\Lambda}$ to Λ rapidity distributions for $p+S$ collisions are done in Fig.10 .

Analysing the figures (fig.3a,b,c,d – fig.5a,b,c,d) we see that similarly to $p+S$ collisions,the rapidity spectra of K_s^0 and $\bar{\Lambda}$ particles in $S-S$ interactions have a sharp peak centered at mid rapidity and their width are close to the ones for the proton induced case. For Λ particles the distribution is naturally symmetrical and its width is larger due to possible production of strange baryons in the target(projectile) fragmentation region. A detailed discussion of $S+S$ collision system was done also by Werner [84] and Amelin et al. [102], [139].The projectile and target mass asymmetry is reflected in the Λ rapidity distributions which for $p-S$, $S-Ag$ and $S-Au$ interactions reach a maximum at about 1.0 which is compatible with those remarked in experiment (about 1 to 1.5). The $\bar{\Lambda}$ and K_s^0 rapidity distributions are less sensitive to the initial asymmetry of the system.

As follows from figures, the shape of rapidity for kaons, lambdas and antilambdas are reproduced fairly well by HIJING model, but the model underestimates the production of Λ in the central region of rapidity spectra, even for proton-sulphur interaction. New experimental data and also data on proton production in hadron-nucleus and nucleus-nucleus interactions are required in order to draw a definite conclusions.

For transverse kinetic energy distributions (taken into account the factor of two) we obtain a good agreement with the data except the low m_T values and in some cases the values at the tails. The normalised transverse momentum distributions for $p - S$ interactions are well described except some discrepancies seen for Λ (see Fig.9a,b,c).

The ratio of the $\bar{\Lambda}$ and Λ yields is suggested to reflect the net baryon density of the particle source. In Fig.10 the ratio of $\bar{\Lambda}$ to Λ rapidity distributions for $p + S$ is presented in comparison with experimental data. The theoretical values are higher than experimental ones.

It should be stressed out that in the most string models the produced strings do not interact and decay independently. Introduction of some collective effects like string fusion [137],[138] or firecracker model [143] can change the predictions essentially, especially for rapidity plateau heights and high multiplicity distribution tails.

Some analysis was done recently by Sorge [83], [110] in the framework of the RQMD. A doubling of lambda production in the target fragmentation region for collision on heavy targets were found due to nuclear cascading of the produced mesons. Also in RQMD approach the resonances play an important role in creating strange quark pairs. Werner [84] has shown that rescattering should be considered at CERN-SPS energies with the effect of increasing neutral strange particles production especially in the central region. HIJING does not incorporate these ingredients.

No model seems to get a real description of absolute values for neutral strange particle production without additional mechanisms.

Since recently [45] the data on multiple strange particle production (Ξ^- , $\bar{\Xi}^-$) was reported, in figures 11a-b we give rapidity distribution for full phase space Ξ^- (fig.11a) and $\bar{\Xi}^-$ (fig.11b) for $S + S$ interaction. We can see from these figures that the ratio of multiplicities $\frac{\langle \Xi^- \rangle}{\langle \bar{\Xi}^- \rangle}$ has strongly dependence on rapidity bins. Improvement of the statistics and considerations of limited rapidity experimental intervals, are needed in order to due some more toward comparison with experimental data.

For giving an idea about of the abundances of particles produced in the near planed experiments at CERN we have studied $Pb+Pb$ interaction at $170 \text{ GeV}/N$ and in addition to multiplicities given in Tabel 3 and Tabel 5, normalised rapidity distributions are given in figures 12a-b for $(\Lambda, \bar{\Lambda})$. The number of generated events was 10^3 and the results are represented for full phase space.

The dependences rapidity - transvers momentum, which define theoretical values for acceptances as well as their bidimensional projections are also given in figures 13 a-b for Λ , in figures 14 a-b for $\bar{\Lambda}$ and for all negatives charges in $S - S$, $S - W$ and $Pb - Pb$ interactions in figures 15a,b;16a,b and 17a,b (respectively) and for all positives charges in $Pb - Pb$ interactions in figures 18a-b.

We hope that from such kind of correlations we will get more inside the dynamics of the systems and we will find some limits of the model concerning neutral strange particles production.

4 Conclusions

In this report ,we give a systematic study of strange particle production in pp,pA and AA collisions mainly at SPS CERN-energies, using HIJING MONTE CARLO model developed for high energy collisions. We analyse data from CERN experiments (NA35,NA36, WA85) and we give a detailed comparison for mean multiplicities of neutral strange particle for pp,pS,pAg,pW,pAu,SS,SW and PbPb interactions. One should note that HIJING MODEL includes neither hypotheses of QGP. Strange particle abundances are quite well described in pp and pA collisions and are underpredicted by a factor of two in nucleus-nucleus interactions ,by this version (theoretical values for HIJ.01) .The ratios for multistrange particles could not be predicted by the model HIJ.01 .The abundances of Ξ^- and Ω^- are underpredicted and the abundances of Ξ^- and Ω^- are overpredicted . More careful analysis are necessary in limited rapidity interval.

We present also some calculations for the ratios $\frac{\langle K^+ \rangle}{\langle \pi^+ \rangle}$ and $\frac{\langle K^- \rangle}{\langle \pi^- \rangle}$ given by HIJING model compared with other models predictions like VENUS and FRITIOF.All models seems to overpredict $\frac{\langle K^- \rangle}{\langle \pi^- \rangle}$ ratios and underpredict $\frac{\langle K^+ \rangle}{\langle \pi^+ \rangle}$ ratios . Rescattering should be important even at SPS -energies.

A qualitative prediction for rapidity distributions of neutral strange particles in $p + S$, $S + S$, $S - Ag$, $S - Au$ 200GeV per nucleon are done compared also with recent experimental data[140]. The models describes correctly the shapes of the rapidity in central $A - A$ collisions for K_s^0 , Λ and $\bar{\Lambda}$ but absolute numbers for multiplicities are underestimated by a factor of two for $\langle \Lambda \rangle$, $\langle \bar{\Lambda} \rangle$, $\langle K_s^0 \rangle$ in symmetric collisions and for $\langle \Lambda \rangle$, $\langle \bar{\Lambda} \rangle$ in asymmetric ones. Some discrepancies are seen for Λ rapidity distribution and transverse momentum distributions even for $p + S$ interactions.The factor of two can not be explained taken into account minijets and very central events($b_{max} = 0.0fm$).

The theoretical model predictions HIJ.01 presented above for central $S - W$, $S - Au$ and $Pb - Pb$ collisions give an idea for particle abundances in experiments which are under the way or are planned in the near future at CERN.

The HIJING model simulations are however still somewhat too low compared to the data.Also the ratios for multistrange baryons could not be described. New ideas are necessary in order to improve the comparison of theoretical calculations with experimental data.The main goal is to increase the rate of neutral strange particle production by a factor of two in nucleus-nucleus interaction at 200 GeV/nucleon. We remark that other models (QGSM, VENUS ,DPM and PSM) include now some additional hypothesis in order to improve the discrepancies (collective string-string interactions, double or multiple colour exchanges,string fusion).

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Table Captions

Table 1

Particle multiplicities for pp interaction at 200 GeV

Table 2

Particle composition of a typical event at $\sqrt{s} = 546$ GeV

Table 3.

Average multiplicities for negative hadrons, neutral strange particle in pp,pA and AA interactions predicted by HIJING model are compared with experimental data. The values for HIJ.01 are theoretical values for $\Lambda, \bar{\Lambda}$ and K_s^0 multiplied by a factor two and the values for HIJ.01** are theoretical values for $\Lambda, \bar{\Lambda}$ multiplied by a factor two.*

Table 4.

Theoretical predictions of HIJING are compared with others recent theoretical calculations .

Table 5.

The mean multiplicities of negative pions and E_S ratios(see the text for definition) for nuclear collisions at 200 GeV per nucleon .The experimental data are from NA 35 Collaboration(reference[140]) and the NN data are from reference[32].

Table 6.

The ratios of the mean strange particle multiplicity to the mean multiplicity of negative hadrons. The values for HIJ.01 and HIJ.01** have the same meaning as in Table 3.The experimental data are from T.Alner et al. [140]*

Table 7

Multiplicity ratios for negative hadrons as well as for several identified strange particles and diferent reactions at 200GeV/nucleon;results from the HIJ.01 model are compared to DPM model[65], NA5[31] and NA35[22] data.

Tabel 8a

$\frac{K}{\pi}$ RATIOS

Tabel 8b

Some ratios for pW and SW interactions at 200 GeV/N The experimental data are from reference [51]

Table 9

Average multiplicities of K^+ and K^- and multiplicity ratios in $S + S$ interactions extrapolated to the full phase space. The experimental data are from Baechler et al.[27]. The results for p + p interaction [32] are also included for comparison.

Table 10

Multistrange multiplicity ratios at 200 GeV/nucleon. The experimental data are from NA35[22], NA36[127] and WA85[128,129] CERN experiments.

Table 1

pp	Exp.data	HIJ.01	<i>HIJ.01^(j)</i>
$\langle \pi^- \rangle$	2.62 ± 0.06	2.61	2.65
$\langle \pi^+ \rangle$	3.22 ± 0.12	3.18	3.23
$\langle \pi^0 \rangle$	3.34 ± 0.24	3.27	3.27
$\langle h^- \rangle$	2.86 ± 0.05	2.99	3.03
$\langle K^+ \rangle$	0.28 ± 0.06	0.32	0.32
$\langle K^- \rangle$	0.18 ± 0.05	0.24	0.25
$\langle \Lambda + \Sigma^0 \rangle$	0.096 ± 0.015	0.16	0.165
$\langle \bar{\Lambda} + \bar{\Sigma}^0 \rangle$	0.013 ± 0.01	0.03	0.037
$\langle K_s^0 \rangle$	0.17 ± 0.01	0.26	0.027
$\langle p \rangle$		1.43	1.45
$\langle \bar{p} \rangle$	0.05 ± 0.02	0.11	0.12
$\langle \gamma \rangle^*$ (<i>dir</i>)		0.53	0.55
$\langle \Xi^- \rangle$		0.0015	0.0019
$\langle \bar{\Xi}^- \rangle$		0.0021	0.0021

Table 2

Particle type	$\langle n \rangle$	<i>Exp.data</i>	<i>HIJ.01</i> ^(j)
All charged	29.4 ± 0.3	UA5	28.2
$K^0 + \bar{K}^0$	2.24 ± 0.16	UA5	1.98
$K^+ + K^-$	2.24 ± 0.16	UA5	2.06
$p + \bar{p}$	1.45 ± 0.15	UA2	1.55
$\Lambda + \bar{\Lambda}$	0.53 ± 0.11	UA5	0.50
$\Sigma^+ + \Sigma^- + \bar{\Sigma}^+ + \bar{\Sigma}^-$	0.27 ± 0.06		0.23
Ξ^-	0.04 ± 0.01	UA5	0.037
γ	33 ± 3	UA5	29.02
$\pi^+ + \pi^-$	23.9 ± 0.4	UA5	23.29
K_s^0	1.1 ± 0.1	UA5	0.99
π^0	11.0 ± 0.4		13.36

Table 3.

<i>Reaction</i>		$\langle h^- \rangle$	$\langle \Lambda \rangle$	$\langle \Lambda \rangle$	$\langle K_s^0 \rangle$
$p + p$	DATA	2.85 ± 0.03	0.096 ± 0.015	0.013 ± 0.005	0.17 ± 0.01
	HIJ.01	2.99	0.16	0.030	0.26
$N + N$	DATA	3.22 ± 0.06	0.096 ± 0.015	0.013 ± 0.005	0.20 ± 0.03
	<i>HIJ.01</i>	3.29	0.156	0.033	0.267
$p + S$ 'min.bias'	DATA	5.7 ± 0.2	0.28 ± 0.03	0.049 ± 0.006	0.38 ± 0.05
	<i>HIJ.01</i>	4.83	0.255	0.046	0.400
$p + Ag$ 'min.bias'	DATA	6.2 ± 0.2	0.37 ± 0.06	0.05 ± 0.02	0.525 ± 0.07
	<i>HIJ.01</i>	6.28	0.34	0.054	0.505
$p + Au$ 'central'	DATA	9.6 ± 0.2			
	<i>HIJ.01</i>	11.25	0.67	0.090	0.88
$S + S$ 'central'	DATA	95 ± 5	9.4 ± 1.0	2.2 ± 0.4	10.5 ± 1.7
	<i>HIJ.01*</i>	88.8	9.17	1.73	14.47
	<i>HIJ.01**</i>	88.8	9.17	1.73	7.23
	<i>HIJ.01</i>	88.8	4.58	0.86	7.23
$S + Ag$ 'central'	DATA	160 ± 8	15.2 ± 1.2	2.6 ± 0.3	15.5 ± 1.5
	<i>HIJ.01*</i>	164.35	17.2	2.97	26.36
	<i>HIJ.01**</i>	164.35	17.2	2.97	13.20
	<i>HIJ.01</i>	164.35	8.61	1.48	13.20
$S + Au$ 'central'	DATA				
	<i>HIJ.01*</i>	213.2	22.6	3.62	33.10
	<i>HIJ.01**</i>	213.2	22.6	3.62	16.55
$S + W$ 'central'	<i>HIJ.01**</i>	210.0	21.28	3.42	16.05
	<i>HIJ.01</i>	210.0	10.64	1.71	16.05
$Pb + Pb$ 'central'	<i>HIJ.01*</i>	725.15	72.88	11.86	109.7
	<i>HIJ.01</i>	725.15	36.44	5.93	54.86

Table 4.

<i>Reaction</i>		$\langle h^- \rangle$	$\langle \Lambda \rangle$	$\langle \bar{\Lambda} \rangle$	$\langle K_s^0 \rangle$
<i>p + p</i>	DATA	2.85 ± 0.03	0.096 ± 0.015	0.013 ± 0.005	0.17 ± 0.01
	HIJ.01	2.99	0.16	0.030	0.26
	RQMD	2.59	0.11		0.21
	QGSM	2.85	0.15	0.015	0.21
	<i>DPM</i> ¹	3.52	0.155	0.024	0.18
	<i>DPM</i> ²	3.52	0.155	0.024	0.18
	<i>HIJ.01</i> ^(j)	3.03	0.160	0.037	0.27
<i>p + S</i> 'min.bias'	DATA	5.7 ± 0.2	0.28 ± 0.03	0.049 ± 0.006	0.38 ± 0.05
	<i>HIJ.01</i>	4.83	0.255	0.046	0.400
	RQMD				
	QGSM	5.87	0.240	0.023	0.340
	<i>DPM</i> ¹	5.53	0.300	0.043	0.360
	<i>DPM</i> ²	5.54	0.32	0.060	0.360
	<i>HIJ.01</i> ^(j)	6.80	0.37	0.061	0.57
<i>S + S</i> 'central'	DATA	95 ± 5	9.4 ± 1.0	2.2 ± 0.4	10.5 ± 1.7
	<i>HIJ.01</i> *	88.8	9.17	1.73	14.47
	<i>HIJ.01</i> **	88.8	9.17	1.73	7.23
	<i>HIJ.01</i>	88.8	4.58	0.86	7.23
	<i>RQMD</i>	110.2	7.76		10.0
	<i>QGSM</i>	120.0	4.70	0.35	7.0
	<i>DPM</i> ¹	109.8	6.83	0.80	10.6
	<i>DPM</i> ²	107.0	7.18	1.57	10.24
	<i>HIJ.01</i> ^(j)	89.5	9.52	1.76	7.47
<i>S + Ag</i> 'central'	DATA	160 ± 8	15.2 ± 1.2	2.6 ± 0.3	15.5 ± 1.5
	<i>HIJ.01</i> *	164.35	17.2	2.97	26.36
	<i>HIJ.01</i> **	164.35	17.2	2.97	13.20
	<i>HIJ.01</i>	164.35	8.61	1.48	13.20
	<i>RQMD</i>	192.3	13.4		18.30
	<i>DPM</i> ¹	195.0	13.3	1.45	19.40
	<i>DPM</i> ²	186.90	14.06	3.65	15.73

Table 5.

<i>Reaction</i>		$\langle \pi^- \rangle$	$\langle E_S \rangle$	$\langle E_S^* \rangle$	$\langle E_S^{**} \rangle$
$p + p$	DATA HIJ.01	2.62 ± 0.06 2.61	0.153		
$N + N$	DATA <i>HIJ.01</i>	3.06 ± 0.08 2.89	0.100 ± 0.01 0.140		
$p + S$ ' <i>min.bias</i> '	DATA <i>HIJ.01</i>	5.26 ± 0.13 4.3	0.086 ± 0.008 0.144		
$p + Ag$ ' <i>min.bias</i> '	DATA <i>HIJ.01</i>	6.4 ± 0.11 5.59	0.108 ± 0.009 0.141		
$p + Au$ ' <i>central</i> '	DATA <i>HIJ.01</i>	9.3 ± 0.2 10.22	0.073 ± 0.015 0.136		
$S + S$ ' <i>central</i> '	DATA <i>HIJ.01*</i> <i>HIJ.01**</i> <i>HIJ.01</i>	88 ± 5 79.6 79.6 79.6	0.183 ± 0.012 0.140	0.280	0.160
$S + Ag$ ' <i>central</i> '	DATA <i>HIJ.01*</i> <i>HIJ.01**</i> <i>HIJ.01</i>	149 ± 8 147.8 147.8 147.8	0.173 ± 0.017 0.138	0.277	0.158
$S + Au$ ' <i>central</i> '	DATA <i>HIJ.01*</i> <i>HIJ.01**</i> <i>HIJ.01</i>	192.6 192.6 192.6	 0.105	0.268	0.154
$S + W$ ' <i>central</i> '	<i>HIJ.01**</i> <i>HIJ.01</i>	179.84 179.84	 0.139		0.158
$Pb + Pb$ ' <i>central</i> '	<i>HIJ.01*</i> <i>HIJ.01</i>	621.75 621.75	 0.137	0.273	

Table 6.

<i>Reaction</i>		$\langle h^- \rangle$	$\frac{\langle \Lambda \rangle}{\langle h^- \rangle}$	$\frac{\langle \bar{\Lambda} \rangle}{\langle h^- \rangle}$	$\frac{\langle K^0 \rangle}{\langle h^- \rangle}$
$p + p$	DATA	2.85 ± 0.03	0.034 ± 0.005	0.0046 ± 0.0018	0.060 ± 0.004
	HIJ.01	2.99	0.0535	0.010	0.0869
$N + N$	DATA	3.22 ± 0.06	0.030 ± 0.005	0.0040 ± 0.0016	0.062 ± 0.009
	HIJ.01	3.29	0.0483	0.0101	0.0816
$p + S$ 'min.bias'	DATA	5.7 ± 0.2	0.049 ± 0.006	0.086 ± 0.0011	0.067 ± 0.001
	HIJ.01	4.83	0.053	0.0095	0.0820
$p + Ag$ 'min.bias'	DATA	6.2 ± 0.2	0.0597 ± 0.008	0.0081 ± 0.001	0.0847 ± 0.005
	HIJ.01	6.28	0.0537	0.0085	0.0804
$p + Au$ 'min.bias'	DATA	7.0 ± 0.4	0.060 ± 0.007	0.010 ± 0.004	0.0614 ± 0.005
	HIJ.01	7.34	0.0535	0.0084	0.0761
$p + Au$ 'central'	DATA	9.6 ± 0.2			
	HIJ.01	11.25	0.060	0.0080	0.078
$S + S$ 'central'	DATA	95 ± 5	0.099 ± 0.012	0.023 ± 0.004	0.110 ± 0.019
	HIJ.01*	88.8	0.1032	0.0194	0.163
	HIJ.01**	88.8	0.1032	0.0194	0.0814
	HIJ.01	88.8	0.0516	0.0097	0.0814
$S + Ag$ 'central'	DATA	160 ± 8	0.095 ± 0.009	0.016 ± 0.002	0.097 ± 0.011
	HIJ.01*	164.35	0.1048	0.0181	0.0802
	HIJ.01	164.35	0.0524	0.0090	0.0802
$S + Au$ 'central'	DATA				
	HIJ.01*	213.2	0.106	0.0169	0.0776
$S + W$ 'central'	HIJ.01**	210.0	0.1013	0.0163	0.0764
$Pb + Pb$ 'central'	HIJ.01*	725.15	0.1005	0.0163	0.1512

Table 7

Ratio	$\langle h_- \rangle$	$\langle K_s^0 \rangle$	$\langle \Lambda \rangle$	$\langle \Lambda \rangle$
pS/pp	1.72 ± 0.07	1.6 ± 0.2	2.3 ± 0.4	2.2 ± 0.7
HIJ.01	1.61	1.54	1.594	1.533
DPM	1.72	1.91	1.75	1.46
pAr/pp	1.88 ± 0.18	1.4 ± 0.4	2.4 ± 0.8	
HIJ.01				
DPM	1.90	2.14	1.90	1.19
pXe/pp	2.39 ± 0.06	2.1 ± 0.5	4.6 ± 1.3	
HIJ.01				
DPM	2.62	2.94	2.39	1.31
pAu/pp	3.37 ± 0.08	2.3 ± 0.6	4.7 ± 1.2	3.4 ± 1.3
HIJ.01	2.455	2.15	2.456	2.06
DPM	2.81	3.18	2.39	1.23
pW/pp				
HIJ.01	3.61	3.07	3.69	2.43
SS^{cent}/pp	36 ± 2	63 ± 18	86 ± 12	115 ± 47
<i>HIJ.01*</i>	29.70	55.61	57.29	57.56
DPM	36.00	44.4	30.7	21.4
SS^{cent}/pS	21 ± 2	38 ± 10	37 ± 6	54 ± 16
<i>HIJ.01*</i>	18.38	36.16	35.95	37.54
DPM	20.90	23.20	17.60	14.60

Tabel 8a

Interaction	$\% \frac{K^+}{\pi^+} (exp)$	$\% HIJ.01$	$\% \frac{K^-}{\pi^-} (exp)$	$\% HIJ.01$
pp	10.8 ± 0.9	9.98	8.6 ± 0.8	9.40
pW	14.1 ± 0.8	10.41	3.7 ± 0.4	7.14
SW	17.6 ± 1.5	10.23	5.0 ± 0.6	7.52

Tabel 8b

Ratio	$\% \text{ Exp.data}$	$\% \text{ HIJ.01}$
$\frac{\left(\frac{K^+}{\pi^+}\right)_{SW}}{\left(\frac{K^+}{\pi^+}\right)_{pW}}$	1.24 ± 0.09	1.01
$\frac{\left(\frac{K^-}{\pi^-}\right)_{SW}}{\left(\frac{K^-}{\pi^-}\right)_{pW}}$	1.31 ± 0.22	1.42
$\left(\frac{K^+ + K^-}{\pi^+ + \pi^-}\right)_{SW}$	12	8.99
$\left(\frac{K^+ + K^-}{\pi^+ + \pi^-}\right)_{pW}$	8.9	8.77

Table 9

$S + S$	$\langle K^+ \rangle$	$\langle K^- \rangle$	$\frac{\langle K^+ \rangle}{\langle \pi^+ \rangle}$	$\frac{\langle K^- \rangle}{\langle \pi^- \rangle}$	$\frac{\langle K^+ \rangle}{\langle K^- \rangle}$
Exp.data	12.5 ± 0.4	6.9 ± 0.4	0.137 ± 0.008	0.076 ± 0.005	1.81 ± 0.12
HIJ.01	8.43	6.27	0.106	0.0788	1.345
VENUS	10.57	7.48	0.117	0.083	1.41
FRITIOF	9.35	7.02	0.102	0.077	1.33
p+p	0.28 ± 0.06	0.18 ± 0.05	0.087 ± 0.02	0.069 ± 0.02	1.55 ± 0.5
HIJ.01	0.323	0.24	0.101	0.093	1.335

Table 10

Reaction	$\frac{\bar{\Lambda}}{\Lambda}$	HIJ.01	$\frac{\Xi^-}{\Lambda}$	HIJ.01	$\frac{\Xi^-}{\Lambda}$	HIJ.01
pp	0.14 ± 0.005	0.18		0.011	0.06 ± 0.02	0.056
pS	0.175 ± 0.02	0.18		0.007		0.078
pAg	0.135 ± 0.022	0.159				
pW		0.165		0.01	0.27 ± 0.06	0.066
SS	0.18 ± 0.06	0.186		0.009		0.072
SAg	0.171 ± 0.05	0.172				
SW WA85	0.20 ± 0.01	0.163	0.09 ± 0.01	0.008	0.20 ± 0.03	0.070
SW NA36	0.207 ± 0.012	0.163	0.066 ± 0.013	0.008		0.070
PbPb		0.163		0.006		0.067

Figure Captions

Fig.1

Rapidity distributions (Fig.1a) and transverse momentum distributions(Fig.1b) for Λ particles produced in pp interactions at 200 GeV . Experimental data are taken from Jaeger et al.[107].

Fig.2

Rapidity distributions (Fig.2a)and transverse momentum distributions(Fig.2b) for K_s^0 particles produced in pp interactions at 200 GeV . Experimental data are taken from Jaeger et al.[107].

Fig.3

Rapidity distributions for Λ particles produced in minimum bias $p - S$ (a) interactions and central $S - S$ (b), $S - Ag$ (c) and $S - Au$ (d) collisions at 200 GeV per nucleon.The experimental data (full circles) are taken from T.Alner et al.,[140]. The dashed histograms are theoretical values $HIJ.01$ and the solid histograms are theoretical predictions $HIJ.01$ multiplied by a factor of two $HIJ.01 * 2$. The open circles show the distributions for $S - S$ collisions reflected at $y_{cm} = 3.0$

Fig.4

Rapidity distributions for $\bar{\Lambda}$ particles produced in minimum bias $p - S$ (a) interactions and central $S - S$ (b), $S - Ag$ (c) and $S - Au$ (d) collisions at 200 GeV per nucleon. The experimental data (full circles) are taken from T.Alner et al.,[140].The dashed histograms are theoretical values $HIJ.01$ and the solid histograms are theoretical predictions $HIJ.01$ multiplied by a factor of two $HIJ.01 * 2$. The open circles show the distributions for $S - S$ collisions reflected at $y_{cm} = 3.0$

Fig.5

Rapidity distributions for K_s^0 particles produced in minimum bias $p - S$ (a) interactions and central $S - S$ (b), $S - Ag$ (c) and $S - Au$ (d) collisions at 200 GeV per nucleon. The experimental data (full circles) are taken from T.Alner et al.,[140].The dashed histograms are theoretical values $HIJ.01$ and the solid histograms are theoretical predictions $HIJ.01$ multiplied by a factor of two $HIJ.01 * 2$. The open circles show the distributions for $S - S$ collisions reflected at $y_{cm} = 3.0$

Fig.6

Transverse kinetic energy distributions for Λ particles produced in minimum bias $p - S$ (a) interactions and central $S - S$ (b) $S - Ag$ (c) and $S - Au$ (d) collisions

at 200 GeV per nucleon. The experimental data (full circles) are taken from T.Alner et al.,[140]. The solid histograms are theoretical HIJING values ($HIJ.01$) or $HIJ.01 * 2$ shown in the figures.The vertical scale is given in GeV^{-2} .

Fig.7

Transverse kinetic energy distributions for $\bar{\Lambda}$ particles produced in minimum bias $p - S$ (a) interactions and central $S - S$ (b) $S - Ag$ (c) and $S - Au$ (d) collisions at 200 GeV per nucleon. The experimental data (full circles) are taken from T.Alner et al.,[140]. The solid histograms are theoretical HIJING values ($HIJ.01$) or $HIJ.01 * 2$ shown in the figures.The vertical scale is given in GeV^{-2} .

Fig.8

Transverse kinetic energy distributions for K_s^0 particles produced in minimum bias $p - S$ (a) interactions and central $S - S$ (b) $S - Ag$ (c) and $S - Au$ (d) collisions at 200 GeV per nucleon. The experimental data (full circles) are taken from T.Alner et al.,[140]. The solid histograms are theoretical HIJING values ($HIJ.01$) or $HIJ.01 * 2$ shown in the figures.The vertical scale is given in GeV^{-2} .

Fig.9

Transverse momentum distributions for Λ (a), $\bar{\Lambda}$ (b) and K_s^0 (c) particles produced in minimum bias $p - S$ interactions at 200 GeV per nucleon.The solid histograms are theoretical HIJING values ($HIJ.01$).The vertical scale is given in $(GeV/c)^{-1}$.

Fig.10

The ratio of $\bar{\Lambda}$ to Λ rapidity distributions for $p - S$ interactions at 200 GeV per nucleon. The corresponding ratio calculated using HIJING model is shown by solid histogram. The experimental data [140] are represented by full circles.

Fig.11

Rapidity distributions for Ξ^- (a) and for $\bar{\Xi}^-$ (b) particles produced in $S - -S$ interactions at 200 GeV per nucleon. Histograms are HIJING results.

Fig.12

Predicted rapidity distributions for Λ (a) and for $\bar{\Lambda}$ (b) particle produced in central $Pb - Pb$ collisions at 170 $AGeV$

Fig.13

Theoretical values for acceptances are given (a) for Λ particles produced in $Pb - Pb$ collisions at 170 $AGeV$. A bidimensional plot (rapidity y - transverse momentum p_T)

(b) for the same interaction.

Fig.14

Theoretical values for acceptances are given (a) for $\bar{\Lambda}$ particles produced $Pb - Pb$ collisions at $170 AGeV$. A bidimensional plot (rapidity y - transverse momentum p_T) (b) for the same interaction.

Fig.15

Theoretical values for acceptances are given (a) for all negatives charges produced in $S - S$ central collisions at $200 AGeV$. A bidimensional plot (rapidity y - transverse momentum p_T) (b) for the same interaction.

Fig.16

Theoretical values for acceptances are given (a) for all negatives charges produced in $S - W$ central collisions at $200 AGeV$. A bidimensional plot (rapidity y - transverse momentum p_T) (b) for the same interaction.

Fig.17

Theoretical values for acceptances are given (a) for all negatives charges produced in $Pb - Pb$ central collisions at $170 AGeV$. A bidimensional plot (rapidity y - transverse momentum p_T) (b) for the same interaction.

Fig.18

Theoretical values for acceptances are given (a) for all positives charges produced in $Pb - Pb$ central collisions at $170 AGeV$. A bidimensional plot (rapidity y - transverse momentum p_T) (b) for the same interaction.