Some comments on pseudorapidity distribution density in Au-Au collisions at $\sqrt{s_{NN}} = 130\ GeV$ *and* $\sqrt{s_{NN}} = 200\ GeV$

- brief report -

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Introduction

One of the goals of the BRAHMS experiment is to gather information on the interesting physical quantities characterising the various emitted particles in heavy ion reactions as functions of transverse momentum, p_T, and rapidity, y.

The yields as function of rapidity offer information on the nuclear density in the given collision, as well as on the produced entropy. Therefore, an estimation of the experimental rapidity distribution density is useful to compare with simulation code predictions.

In this short report, some experimental results obtained for Au+Au collisions at $\sqrt{s_{NN}} = 200\ GeV$ will be used.

Pseudorapidity distribution

The experimental pseudorapidity distribution obtained in Au+Au collisions at $\sqrt{s_{NN}} = 200\ GeV$ is presented in the Fig.1 [1]. The average charged particle multiplicity for the most central collisions (0-6%) is *5100±300*. The charged particle pseudorapidity density at η = *0.0* is $\frac{dN_{ch}}{d\eta}\Big|_{\eta=0.0} = 610 \pm 50$.

Using HIJING simulation code [2] for an impact parameter $b < 3.5\ Fm$ around *5.5%* most central collisions are obtained, and the average impact parameter for these collisions is *around 2.0 Fm*. Using a phenomenological geometric picture [3] the average number of participant nucleon, weighted on the considered impact parameter range, is $Q_N = 385.2$. The average number of participant protons is $<Q> = 154.5$.

Taking into account the fact that some information on the collision dynamics and the thermalisation degree is obtained from the spectral shapes of the interesting physical quantities and their dependencies on rapidity we used the dependence of the average transverse momentum on the rapidity densities.

Two simulation codes have been used: HIJING (Fig.2) and UrQMD (Fig.3). From both codes dependencies "like-plateau" are observed. The UrQMD code suggests a larger "plateau", at an average transverse momentum under 390 MeV/c, and HIJING code suggests a narrow "plateau", but at higher average transverse momentum (425 MeV/c). This "plateau" appears in the same dependence for negative pions . If we use the pseudorapidity densities (Fig.4 and Fig.5) the "plateau" appears again, but we cannot observe the increase at very high values of the pseudorapidity densities, as in the rapidity density case.

Energy density estimation

Important information on the collision dynamics is obtained from collision centrality measurements, and the information from the times in the reaction is included in the high p_T parts of the particle spectra.

The rapidity density, respective, pseudorapidity density can be used to estimate energy density [4]. Taking into account the rapidity range, namely [-4.7, 4.7], and the number of charged particle (*5100±300*) we can use the following relation for energy density estimation:

$$\varepsilon = \frac{dN}{dy}\Big|_{y=0} < M_T > \frac{1}{\tau\pi R^2} \quad . \qquad (1)$$

Here $<M_T>$ is the average transverse mass of the secondary particles, τ is the proper time, $\frac{dN}{dy}$ is the rapidity density, and R is the nucleus radius.

From the Fig.1 and Fig.6 [1] we can estimate the energy density for the pions, supposing different proper time. For proper times between *10 Fm/c* and *50 Fm/c* the energy density varies from $1.17\ GeV/Fm^3$ to $0.24\ GeV/Fm^3$.

The energy density can be estimate, also, using the phenomenological geometric picture. For example, at $b = 0.0\ Fm$ the energy density at the initial time moment (maximum compression) is $\varepsilon_{in} = 3.27\ GeV/Fm^3$ (without selection in rapidity). For pion emission the estimated value of the energy density is only $0.44\ GeV/Fm^3$, corresponding at a proper time of $26.6\ Fm/c$.

Thermalisation, particle ratios, and collision centrality

The different lengths of the "plateaus" in the mean transverse momentum dependence on the rapidity (pseudorapidity) densities could justify the assumption of the effect of the hot and dense nuclear matter on the behaviours of the different interesting physical quantities. For example, in Au-Au collisions at $\sqrt{s_{NN}} = 200\ GeV$ the $\frac{\bar{p}}{p}$ ratio – at $y = 2.0$ – have the following experimental value: $\frac{\bar{p}}{p}\Big|_{\exp} = 0.48 \pm 0.08$. This value is different by the predictions of the two simulation codes. The values predicted by the simulation codes are: $\frac{\bar{p}}{p}\Big|_{HIJING} = 0.66$, respectively, $\frac{\bar{p}}{p}\Big|_{UrQMD} = 0.30$.

The effect of the nuclear medium is not evident for particles related to the later collision stages. For pions the values for the $\frac{\pi^-}{\pi^+}$ ratio are the following: $\frac{\pi^-}{\pi^+}\Big|_{\exp} = 0.98 \pm 0.04$, $\frac{\pi^-}{\pi^+}\Big|_{HIJING} = 1.03$, respectively, $\frac{\pi^-}{\pi^+}\Big|_{UrQMD} = 1.01$.

It is important to stress here that a similar behaviours are observed for Au-Au collisions at $\sqrt{s_{NN}} = 130\ GeV$. For the same rapidity, $y = 2.0$, the values of the $\frac{\bar{p}}{p}$ ratio are the following: $\frac{\bar{p}}{p}\Big|_{\exp} = 0.81 \pm 0.04$, $\frac{\bar{p}}{p}\Big|_{HIJING} = 0.824$, respectively, $\frac{\bar{p}}{p}\Big|_{UrQMD} = 0.73$. The influences are smaller, because de density energy is smaller, namely: $\varepsilon_{in} = 1.74\ GeV/Fm^3$, respectively, $\varepsilon_{\pi} = 0.29\ GeV/Fm^3$ (using the phenomenological geometric picture), respectively, in the range 0.54

GeV/Fm^3 and *0.11 GeV/Fm*^{3} from the relation (1), with the same proper times. The corresponding proper time for the first case is *18.6 Fm/c*.

To have additional information on the influence of the possible new interaction mechanisms in the participant region it is important to analyze the behaviour of the $\frac{\bar{p}}{p}$ ratio at the same rapidity, but with different average transverse momenta. In the Table I are included the $\frac{\bar{p}}{p}$ ratio values, for $y = 1$, obtained in Au-Au collisions at $\sqrt{s_{NN}} = 130\,GeV$. Some new aspects can be taken into account at higher transverse momenta (the two simulation codes suggest similar values of the ratio for high transverse momenta).

<u>*Table I*</u>

$\langle p_T \rangle$ *[GeV/c]*	$\left.\frac{\bar{p}}{p}\right\|_{\exp}$	$\left.\frac{\bar{p}}{p}\right\|_{HIJING}$	$\left.\frac{\bar{p}}{p}\right\|_{UrQMD}$
0.500	*0.65*	*0.68*	*0.27*
0.800	*0.76*	*0.79*	*0.26*
1.100	*0.60*	*0.69*	*0.26*
1.500	*0.66*	*0.67*	*0.50*

<u>*Different regions*</u>

BRAHMS experiment offers the opportunity to study particle production mechanisms and the properties of the highly excited nuclear matter in two different regimes, namely: (i) a baryon poor region with a high energy density, created at mid-rapidity; (ii) a region near the initial nuclei, at high rapidities, very rich in baryons at relatively high temperature.

Therefore, seems useful to compare experimental results on average/mean transverse momenta over a wide range of rapidity and transverse momenta at the energies available today at RHIC. In Table II and Table III are included the two simulation code predictions in three rapidity ranges, at two energies, namely: $\sqrt{s_{NN}} = 130\,GeV$ and $\sqrt{s_{NN}} = 200\,GeV$.

Table II. *HIJING and UrQMD predictions at* $\sqrt{s_{NN}} = 130\ GeV$

Y	*All HIJING*	*[-4.5,+4.5] HIJING*	*[-2.2,+2.2] HIJING*	*All UrQMD*	*[-4.5,+4.5] UrQMD*	*[-2.2,+2.2] UrQMD*
$p_T(ch)$	0.354	0.412	0.426	0.550	0.589	0.626
$p_T(\pi^+)$	0.364	0.368	0.382	0.504	0.507	0.629
$p_T(\pi^-)$	0.364	0.368	0.383	0.509	0.513	0.629
$p_T(K^+)$	0.463	0.464	0.484	0.747	0.748	0.799
$p_T(K^-)$	0.456	0.457	0.470	0.691	0.692	0.732
$p_T(p)$	0.232	0.607	0.658	0.524	1.118	1.268
$p_T(\bar{p})$	0.582	0.582	0.594	0.997	0.998	1.028

Table III. *HIJING and UrQMD predictions at* $\sqrt{s_{NN}} = 200\ GeV$

y	*All HIJING*	*[-4.5,+4.5] HIJING*	*[-2.2,+2.2] HIJING*	*All UrQMD*	*[-4.5,+4.5] UrQMD*	*[-2.2,+2.2] UrQMD*
$p_T(ch)$	0.386	0.415	0.425	0.379	0.400	0.389
$p_T(\pi^+)$	0.367	0.371	0.382	0.349	0.352	0.348
$p_T(\pi^-)$	0.367	0.371	0.384	0.350	0.353	0.348
$p_T(K^+)$	0.467	0.469	0.486	0.484	0.485	0.474
$p_T(K^-)$	0.461	0.462	0.474	0.475	0.475	0.470
$p_T(p)$	0.353	0.638	0.653	0.383	0.748	0.707
$p_T(\bar{p})$	0.582	0.582	0.591	0.723	0.741	0.787

Final remarks

The new experimental data could give the selection criteria for mechanisms. A lower stopping power in Au-Au collisions at $\sqrt{s_{NN}} = 200\ GeV$ is expected. A deeper analysis of the experimental results at different angles is necessary. Estimations of the slope parameter for transverse momentum spectra will be available soon.

References

[1]. J.J.Gaardhoje – Meeting at Ecole Polytechnique, Paris, France, 4.IX.2001

[2]. M.Gyulassy, Xian-Nian Wang – Preprint LBL, LBL-34246(2000) - HIJING Code; S.Bass et al – Prog.Part.Nucl.Phys.41(1998)225-370

[3]. Al.Jipa et al – Romanian Reports in Physics 52(8-9)(2001) – in press

[4]. Bjorken – Phys.Rev.D27(1983)140

Figure captions

Fig.1. Pseudorapidity distribution in Au-Au collisions at $\sqrt{s_{NN}} = 200\ GeV$ for different collision centralities

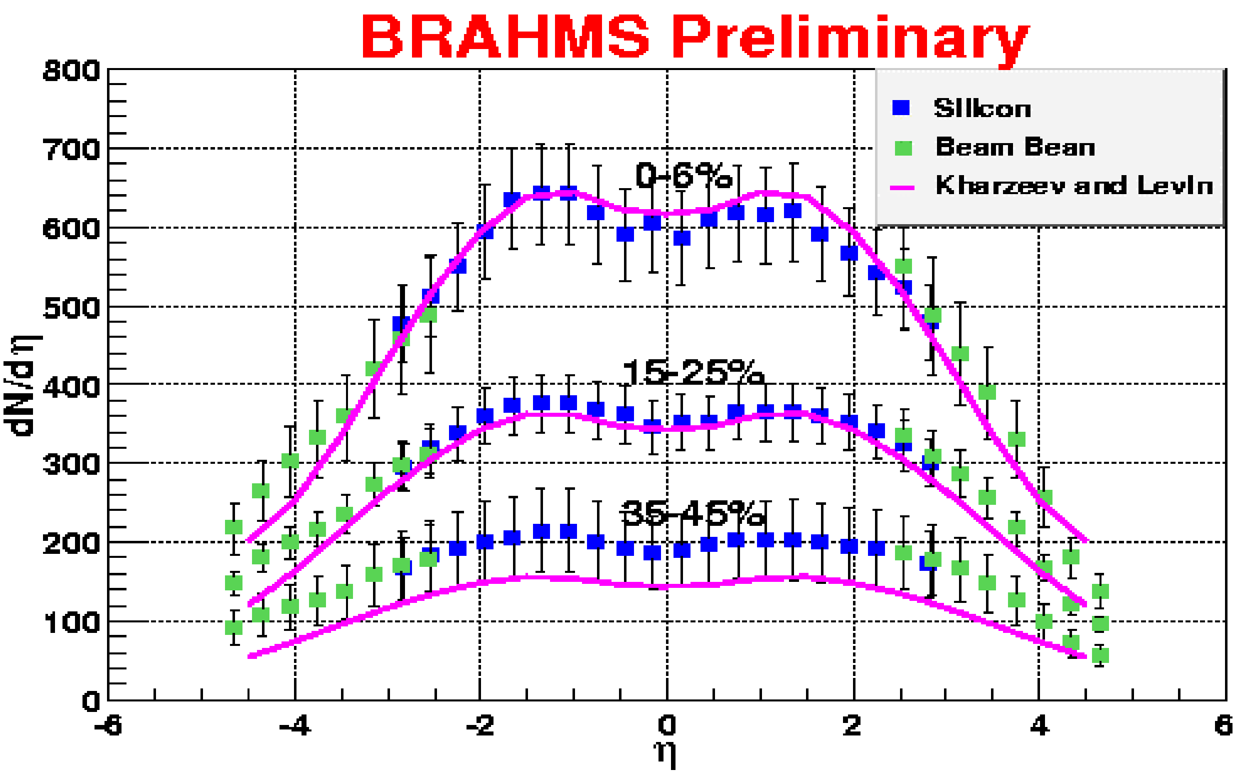
Fig.2. The dependence of the mean transverse momentum on the rapidity density in Au-Au collisions at $\sqrt{s_{NN}} = 200\ GeV$; estimation with HIJING code

Fig.3. The dependence of the mean transverse momentum on the rapidity density in Au-Au collisions at $\sqrt{s_{NN}} = 200\ GeV$; estimation with UrQMD code

Fig.4. The dependence of the mean transverse momentum on the pseudorapidity density in Au-Au collisions at $\sqrt{s_{NN}} = 200\ GeV$; estimation with HIJING code

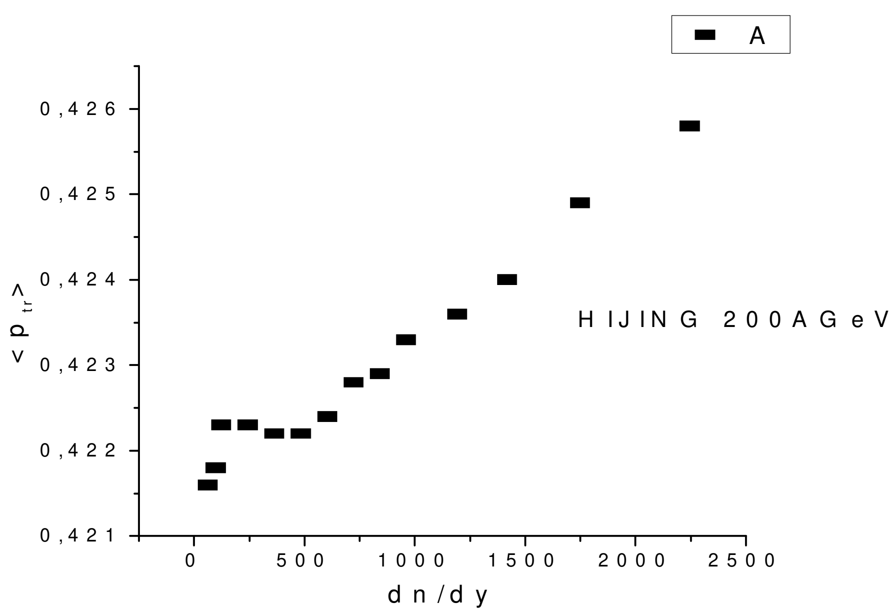
Fig.5. The dependence of the mean transverse momentum on the pseudorapidity density in Au-Au collisions at $\sqrt{s_{NN}} = 200\ GeV$; estimation with UrQMD code

Fig.6. The experimental negative pion transverse momentum spectrum at y = 2 in Au-Au collisions at $\sqrt{s_{NN}} = 200\ GeV$



BRAHMS Preliminary
Silicon
Beam Bean
Kharzeev and Levin
0-6%
15-25%
35-45%
dN/dη
η

Fig.1.



A
HIJING 200AGeV
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dn/dy

Fig.2.

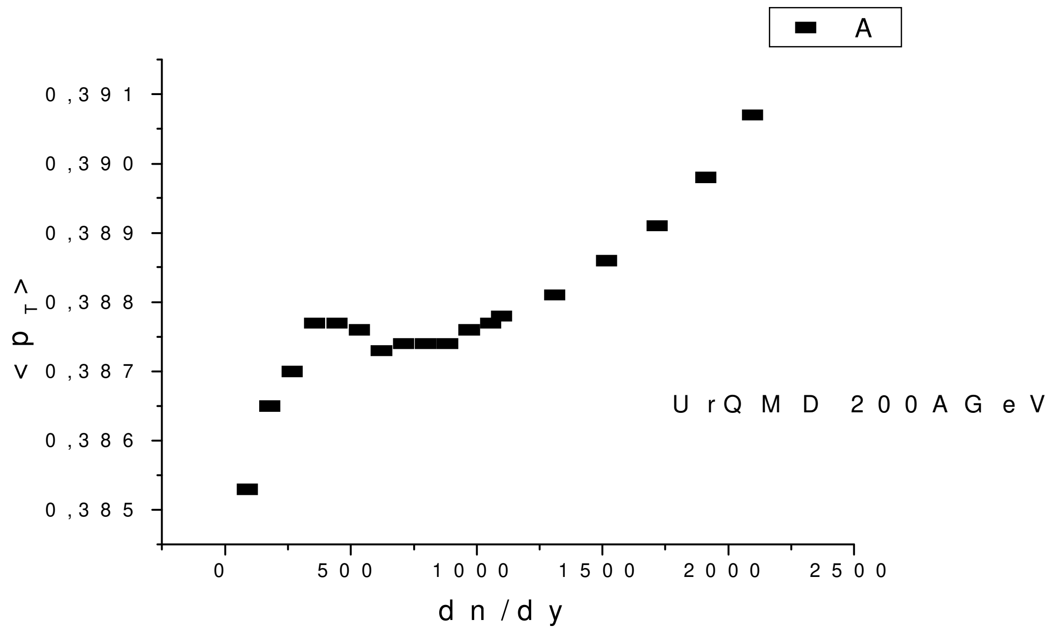


Fig.3.

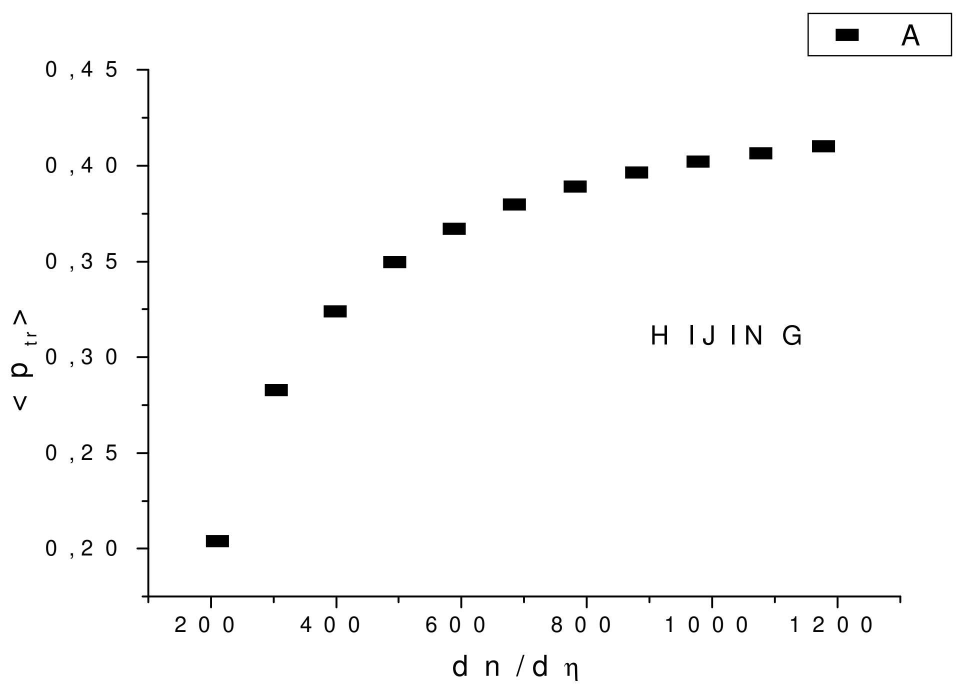
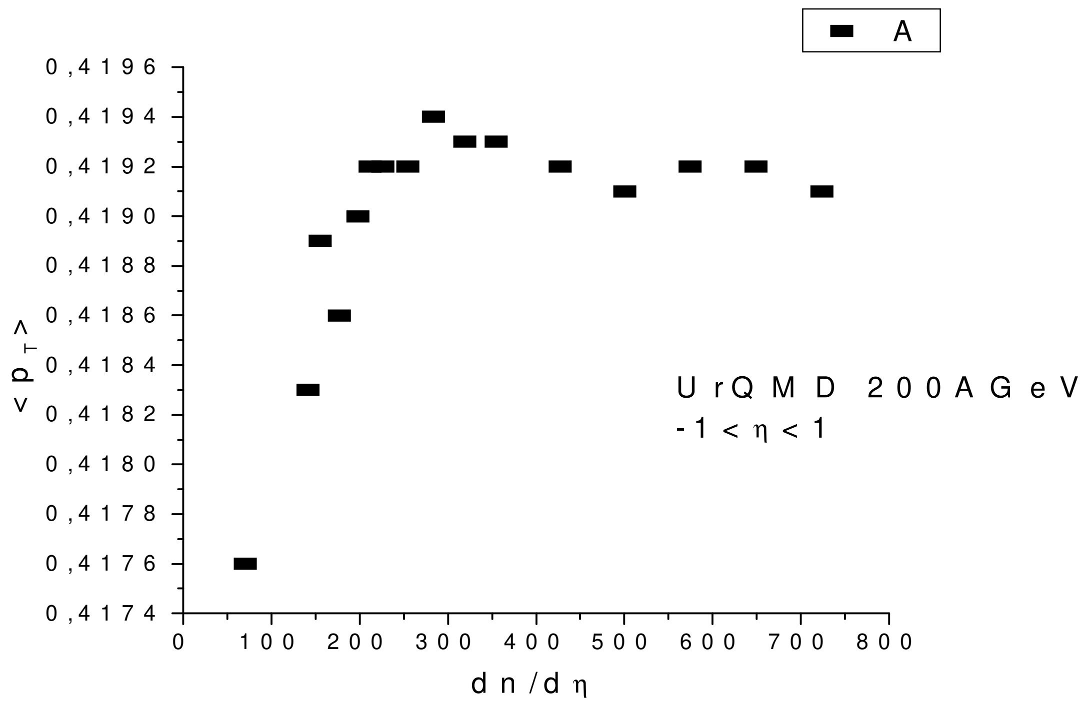


Fig.4.



A
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0,4188
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0,4182
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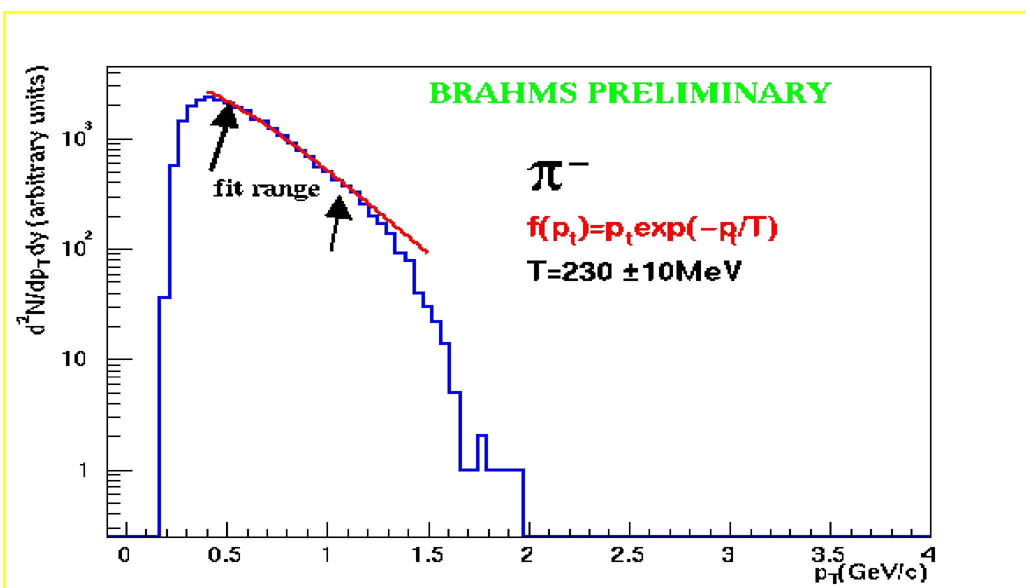
0,4178
0,4176
0,4174
< p_T >
UrQMD 200AGeV
-1 < η < 1
0
100
200
300
400
500
600
700
800
dn/dη

Fig.5.



BRAHMS PRELIMINARY
π⁻
f(p_t)=p_t exp(-p_t/T)
T=230 ±10MeV
fit range
d²N/dp_T dy (arbitrary units)
10³
10²
10
1
0
0.5
1
1.5
2
2.5
3
3.5
4
p_T(GeV/c)

Fig.6.