The rapidity spectra of protons, deuterons, tritons produced in379

collisions L 22-26: I suggest removing this sentence.

Reply : Done

L 43: specify the beam rapidity

Reply : Done

L 60: give a reference for the "penalty factor"; this is not a so well-known term.

Reply : Done

L 91-94: I suggest removing this sentence. The issue is not addressed in this paper.

Reply : Done

L 102: specify the models and give refs.

Reply : Done

L 140-143: "The analysis...[46]": this sentence can be erased.

Reply : Done

L 146: what is meant by relative? I suggest erasing the word.

Reply : Done

L 166-167: erase the sentence. The same information is repeated below with more details.

Reply : Done

L 177-179: There is no figure. Erase the sentence.

Reply : Done

Figs. 2a and 2b: Since you claim that the m2 windows and the background shape depend on target, rapidity, p interval..., you should specify the values of these parameters used to generate Fig. 2a and 2b.

Answer, add to the text: with all the targets are shown …Particles which satisfy the selection criteria specified above contribute to the M2 spectra.

L 213-216: The sentence and procedure are not clear. If you separate d from He4 using the dE/dx, then you set a window to select d. Why do you need to calculate the fraction of He4? How do you calculate it?

Answer: A dedicated dE/dx analysis of signal amplitudes in the GEM detectors was performed to separate He4 (Z>=2) from deuterons (Z=1) for all the targets. To improve the amplitude resolution, narrow ranges along the boundaries of the GEM HV sectors were excluded from the amplitude analysis. These spatial cuts reduce the number of tracks for the dE/dx analysis to ~80% of the full sample. Tracks excluded from the dE/dx analysis are equivalent to tracks accepted for the analysis. We do not want to reduce the data statistics to 80% and introduce additional inefficiency in MC. The result for the He4/(d+he4) ratio is applied to the whole data set to exclude the He4 fraction in the d+He4 sample. It was found that the He4/(d+he4) ratio is consistent for all the targets.

Fig 7: I am confused with this figure. From panels a), it appears that N(tracks) and N(BDhits) are correlated, in the sense that in peripheral collisions, both N(tracks) and N(BDhits) are dominated by low values, and in central collisions, both are dominated by high values. I don't see that correlation in the panels b). Am I missing something?

Answer: The upper (red) plot in the panel b) shows the fraction of events with centrality < 40% in the two-dimensional bins of N(tracks) vs N(BD). It is seen that events with <40% centrality are concentrated at large values of N(BD) and N(tracks). The boundary between events with low fraction and high fraction is shifted towards lower N(BD) values at larger values of N(tracks). It means that the two-dimensional distribution gives an additional constrain to the centrality selection relative to the one-dimensional distribution of N(BD) or N(tracks),

The lower plot in the panel b) shows the fraction of events with centrality > 40%, i.e. the value of (1 – Upper plot).

Section 5 is a verbatim copy from ref. [8]. This is bad practice. I suggest you rewrite using your own words or reduce the text referring as much as possible to ref. [8].

Answer: Section 5 is new. We made sections 4 and 6 shorter and gave references to paper [8].

L 326: "half of the difference": difference between what and what?

Answer, add to the text: Systematic uncertainty calculated as half of the difference between the p/d/t yield measured in the ToF-400 and ToF-700 detectors in bins of rapidity y

L 375: Why you are not showing the mT spectra for the peripheral collisions?

Answer: We select figures which we discuss in the text. Otherwise the paper would contain too many figures. We will provide tables with all the measured values of yields, dN/dy and mT. at a dedicated web-page (and make a reference to it in the paper).

L 382-3: The text in the first paragraph of p. 15 is a bit chaotic. For example, the sentence in L 382-3: "It is seen that the spectra are softer in interactions with heavier targets." appears right after mentioning Fig. 16. However, I believe that this sentence refers to the mT spectra. If so, this sentence refers to Fig. 15 and should be moved to L 379. The same is true for the sentence in L 381-2. I reshuffled the text of this paragraph, as you can see in the attached file.

Answer: Here we discuss the behavior of the dN/dy spectra, but not mT. To clarify the message we added to the text: "The dN/dy spectra of protons, deuterons, tritons produced in collisions …" and ":" It is seen that the particle rapidity spectral shapes vary strongly with the target mass."

L 381-2: From the fit, you extract not only dN/dy but also T0. Why is this not mentioned? I think that the values of the fit should be listed in a table or quoted inside the figures. A figure (or two) collecting all the values measured might be interesting not only in its own right but also in the context of the discussions made later in Sections 9 and 10. I also think that these values should be discussed/compared with values obtained in other experiments.

Answer: All the measured values (yields in (y,pT) points, dN/dy, T0, <mT>-m values) will be provided at a dedicated web-page (and make a reference to it in the paper).

Add to the text: The T0 values are used to calculate the mean transverse kinetic energy <E_T> according to equation N.

L 433-435: The sentence: "Assuming ... value." is not clear to me, not the dependence and not the quoted 2% value. In any case, this sentence should be moved to the end of the paragraph.

Answer, text changed to : "To cross-check the result of this averaging, the rapidity dependence of <E_T> for each particle sort in Fig. 11 was fitted with a functional form E_T(0)/cosh{y*} with the midrapidity transverse energy E_T(0) being the fit parameter. We found that the difference between E_T(0) and <E_T(y*=0)> is less than 2\% and it was disregarded."

L 450-458: This discussion needs to be seriously revised:

-the results in Table 3 show that within the experimental uncertainties there is no significant variation of beta (and also of T) with the target mass. On the other hand, the FOPI results reported in L 453-456 say the opposite and in the following sentence you claim that the BM@N results are consistent with "the general tendency of the thermal temperature and radial flow to rise with the collision system size"

Answer: Unfortunately, we used wrong numbers for <mT>-m for Ar+Al reactions in the version of the paper draft given to experts. Now, Figure 12 and Table 3 are updated. New results indicate a weak system size dependence for <\beta> (see Fig. 1 below) and small (if any) variation for T.

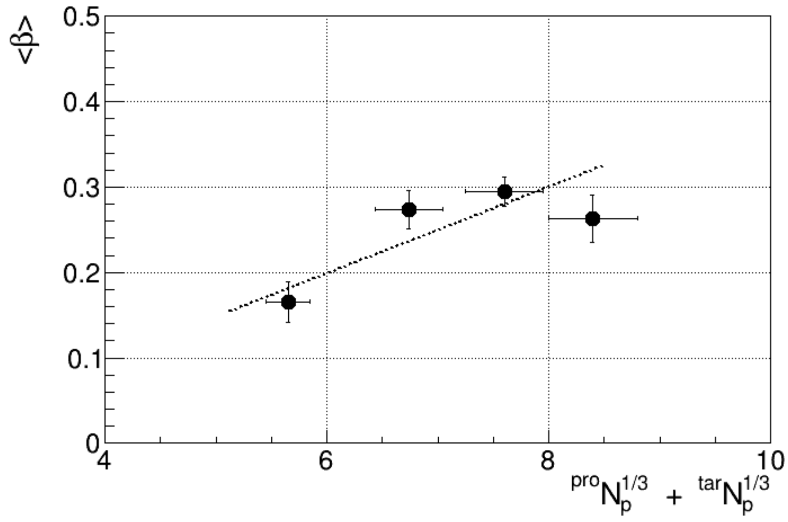


Fig.1 Average radial velocity as a function of the longitudinal dimension of the overlap region for Ar+Al, Cu, Sn, Pb collisions. The dashed line is only used to guide the eye.

The text of the paper draft has changed accordingly. Now it reads:

"One finds a flow velocity consistent with zero in central Ar+C collisions. Nuclear collisions of such small systems can be considered as a superposition of the independent nucleon-nucleon interactions, therefore, the density of participants that has been reached in these reactions is probably not high enough to create a fireball with strong collective behavior. In contrast, for larger colliding systems (Ar+Al,Cu,Sn,Pb) the particle density and the re-scattering rate inside the reaction zone are higher, giving rise to the mean expansion velocity. It appears that the observed mass dependence for T and <\beta> is weak at BM@N energies: the fits give nearly the same temperature and a slight increase of the flow velocity. It might be an indication that the increase of the reaction volume and the number of collisions with the target mass does not accompanied by a significant compression of nuclear matter (note also discussion about the degree of nuclear stopping in Section~\ref{section_stopping})"

Regarding the overall energy and system size dependence for the radial velocity and how the current BM@N results are fit with those:

The BM@N measurements are done for medium-size collision systems (Ar+A). HADES, FOPI, STAR and NA49 measured radial flow for heavier collision system (Au+Au, Pb+Pb). Figure 2 shows a collection of world data [1-5] indicating a rise of the radial flow velocity <\beta> with the collision energy in central heavy-ion collisions Au+Au, Pb+Pb, and Ar+A. The BM@N data point is an average of the Ar+Cu, Ar+Sn and Ar+Pb results (see Fig.1). To get a hint about the centrality (system size) dependence of radial flow in Au+Au at STAR/BES energies, Fig.2 also shows the results for 50-60% collisions where the system size in terms of the number of participants is approximately equal to 0-40% Ar+Al collisions (note that the size of the system in 0-10% central Au+Au, Pb+Pb is a factor of 2 bigger than in 0-40% Ar+Pb).

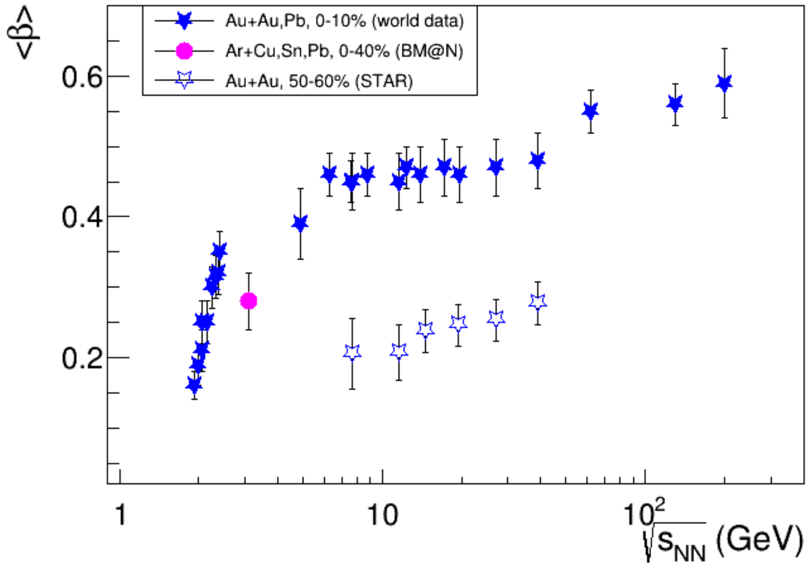


Fig.2 Energy dependence of <\beta> in Au+Au (EOS [1], FOPI [2] and STAR [3,4]), Pb+Pb (NA49 [5]) and Ar+Cu,Sn,Pb (BM@N, this study). The STAR results [3,4] are shown for 0-10% and 50-60% centrality bins.

The degree of the rise of <\beta> with charged particle multiplicity (prop. to centrality / system size) in collisions of small systems at RHIC energies is indicated in the plot below (Fig.37).

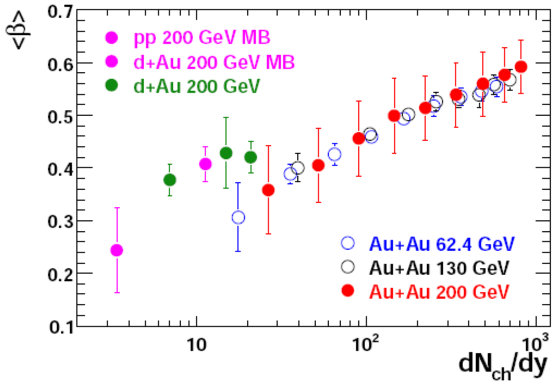


FIG. 37: (color online) Average transverse radial flow velocity extracted from blast-wave model fit to *pp* and d+Au at 200 GeV, and to Au+Au collisions at 62.4 GeV, 130 GeV, and 200 GeV as a function of the charged hadron multiplicity. Errors shown are the total statistical and systematic uncertainties. The 200 GeV *pp* and Au+Au data are taken from Ref. [17].

At low beam energies the FOPI experiment states that both the radial flow (<\beta>) and temperature T0 are rising with the beam energy (see the plots below, Fig.32).

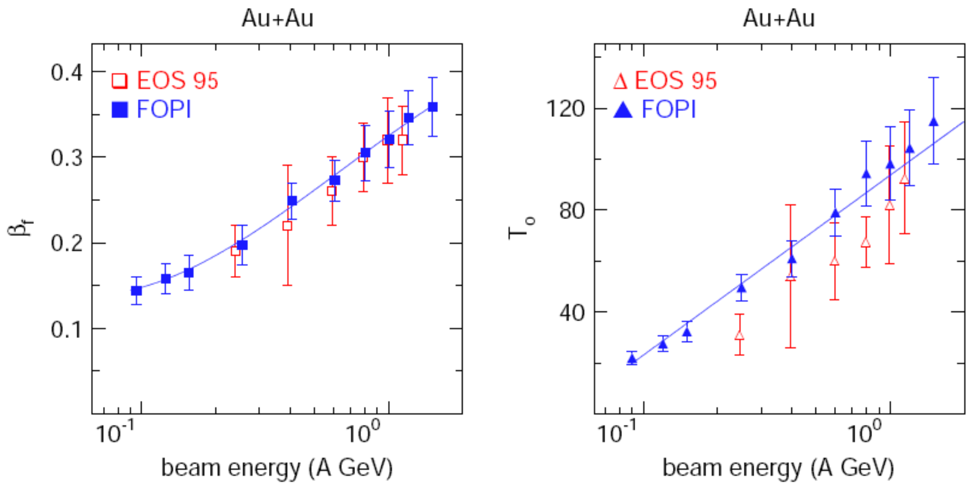


Fig. 32. Radial flow velocities β_f (left panel) and offset temperatures T_o (right panel) for Au+Au collisions deduced from 90° kinetic energies of mass 1-3 ejectiles ($A3$ method). The present data (blue full symbols) are compared to data from ref. [45]. The smooth curves are fitted to the present data only and serve to guide the eye.

At low beam energies FOPI also states the rise of the radial flow energy (which is correlated with <\beta>) with the collision system size (see Fig. 34 below).

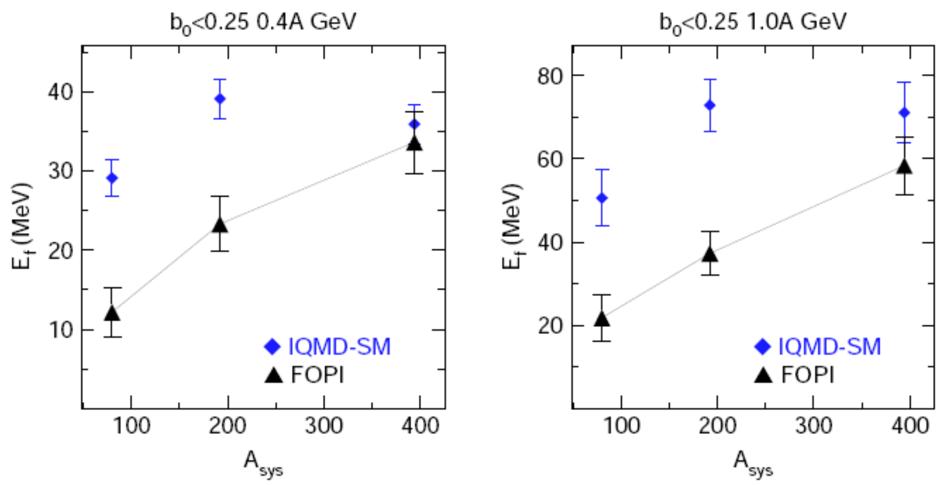


Fig. 34. System size dependence of radial flow in central ($b_0 < 0.25$) collisions. The experimental data (black full triangles joined by straight lines) are compared with IQMD-SM predictions for 0.4A Gev (left) and 1.0A GeV (right) incident energies.

work of ref. [61].

<u>Finally</u>, one might conclude that our result for <\beta> from 0-40% central Ar+Cu,Sn,Pb collisions at 3 GeV (shown in Fig.2) is in accordance with the both energy and system size dependence for the radial velocity.

[1] EOS Collaboration, Phys. Rev. Lett. 75, 2662 (1995)
[2] FOPI Collaboration, arXiv:1005.3418v2 [nucl-ex]
[3] STAR Collaboration, Phys. Rev. C 96, 044904 (2017)
[4] STAR Collaboration, Phys. Rev. C 101, 024905 (2020)
[5] NA49 Collaboration, Phys. Rev. C 94, 044906 (2016)

- How is the temperature T derived here related to the parameter T_0 obtained earlier in this section?

Answer: Parameter T0 is used to calculate the mean transverse kinetic energy <E_T> according to equation 4 (corrected version) . Temperature T is evaluated from the fit to <E_T> according to equation (3) and then additional boost correction (5).

It means, that temperature T is a free parameter (independent of the particle mass) in the linear fit of <E_T> on the particle mass. Parameter T0 is extracted from the exponential fits for particles with different masses, i.e. it depends on the particle mass.

From equation (4) we get <E_T> \sim T0 for heavy particles (m >> T0) and get

<E_T> \sim 3/2 T0 for low mass particle m = T0.

-Could you make a plot comparing the BM@N results with those of NA49, FLOPI and STAR?

Answer: from the plots given above, the <beta> and temperature depend as on the energy so as on the system size.

-Figs. 22, 23 and 24: in all these comparisons, the other experiments are for Au+Au or Pb+Pb or Au+Pb. These are all heavy and almost symmetric systems. Maybe it is more appropriate to show in these plots the BM@N values obtained in almost symmetric systems like Ar+Al or Ar+Cu or the average of these two?

Answer: In Fig.22,23,24 the BM@N values averaged for Ar + Al,Cu,Sn,Pb interactions are compared with other experiments. Ar+C interactions are excluded because the collision system is too small. It is not obvious why the deuteron and triton results for symmetric systems should be different from those for non-symmetric systems.

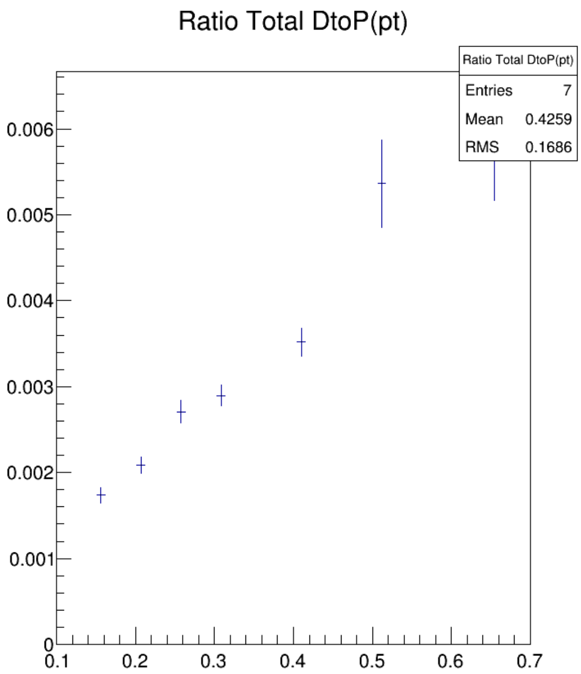
In all these figures you should add references for the other experiments either in the caption or in the legend.

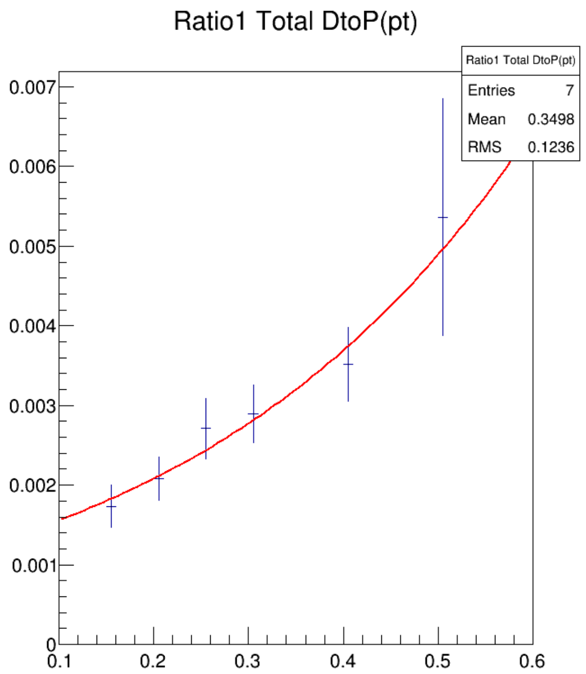
Answer: done

L 487-488: why don't you show these exponential fits in Fig. 21?

Answer: The data are better described by the linear dependence on pT. From the other side, the exponential function is predicted by the coalescence model. In the exponential fit we have to scale up the experimental errors by the Chi2/Ndf value to get reasonable estimation of the uncertainty for the fit result. We do not think it is worth to show the extended errors of the fitted data points which are not taken from the measurements but from the fit adjustment.

Example for the D to P ratio (B2) for the Pb target is shown in figure below. The left plot gives the B2 measurement as a function of pT/A. The right plot gives the B2 fit by the exponential function of pT/A. The errors are increased by a factor of chi2/Ndf.





L 523: is there any reason for this functional form?

Reply: I followed the procedure of the analysis of baryon rapidity spectra suggested by the BHAHMS Collaboration in Ref. [1]. They found that: “A six order symmetric polynomial (pol6) f(y) which is the simplest polynomial that describes the data points, has the correct integral, and f(y_b)=0.”

The reference to the BRAHMS paper [1] is added to the text.

1. I.G. Bearden et al (BRAHM Collaboration) “Nuclear Stopping in Au +Au Collisions at sqrt{s}=200 GeV”, Phys. Rev. Lett. 93, 102301, 2004.

L 526: what is the value of y_b used in this section?

Reply: y_b = 1.08 (center-of-mass beam rapidity). The used value is specified in the text.

L 535: specify the microscopic models.

Reply: Done

Fig. 9: give a reference for the data points from other experiments in the caption or in the legend.

Reply: Done

L 545 "(despite of the different collision centrality)": the centralities are very similar. I suggest erasing this.

Reply: Agree. This phrase had erased.

L 551 "surprisingly": why is this surprising?

Reply: see explanations below

L 553-558: This discussion should be reworded: there is no contradiction if one makes an apples-to-apples comparison. Fig. 9 shows that the rapidity loss in central collisions does not vary significantly from mid-size to heavy systems and the BM@N central collision results shown in Table 5 are fully consistent with that. The 65% increase in the BM@N results comes by considering the lightest system Ar+C in peripheral collisions. This extreme case is not included in the data from other experiments.

Paragraph L 540-558: The common feature of all the data compiled in Fig. 9 is that they are from symmetric or almost symmetric systems. Could this be the relevant parameter and not so much the distinction between mid-size and heavy systems? This paragraph might need some revisions to reflect this and the previous comment.

Reply: I am afraid that I couldn't get your point about "apples" and the difference between symmetric and asymmetric collisions for the rapidity loss effect. Thus, in what follows I am trying to explain again what is puzzling me in the collection of the results on rapidity losses in nucleus-nucleus collisions (shown in Fig.9 that is Fig.8 in the new draft version) and to suggest some modifications in the paper draft in this respect...

In A+A reactions at a given collision energy, the loss in rapidity by a single projectile nucleon is defined by the average number of inelastic nucleon-nucleon interactions it experiences in the target. So, rising of $<\delta y>$ with centrality or/and in reactions with heavier targets is likely to be due to a larger probability for multiple interactions. It is still being debated in literature whether the amount of energy lost by the nucleon in each interaction is independent of the rank of this interaction (the first one or any subsequent) and on the collision energy (namely, is it the same mechanism or it is different, like a string-based String Junction - SJ at high energies and a resonance-based in the cascade mode at low energies). Figure 1 shows $<\delta y>$ from Ar+A (BM@N) and Au+Au (STAR) collisions at 3 GeV as a function of the number of collisions per participant in the projectile. The STAR data are preliminary (they are taken from a presentation at the QM'22 conference [1]), so I do not like the idea of including this comparison in the paper draft – it is just for consideration. The observation from this figure is that for symmetric Au+Au collisions the rise in the $<\delta y>$ value is a factor of 1.6 going from the most peripheral (40-80%) to the most central (0-10%) bin. Here the number of collisions per participant in the most central bin is twice as big as one in the most peripheral bin and the number of participants N_part (i.e. system size) increases from ~40 to ~311 [2].

The situation in asymmetric collision can, in principle, be different, and the observed rapidity loss in collisions of light nuclei with heavy targets can even be larger than that in symmetric A+A for the same number of participants (as discussed in ref. [3]). Nevertheless, in general, asymmetric and symmetric collisions at the same collision

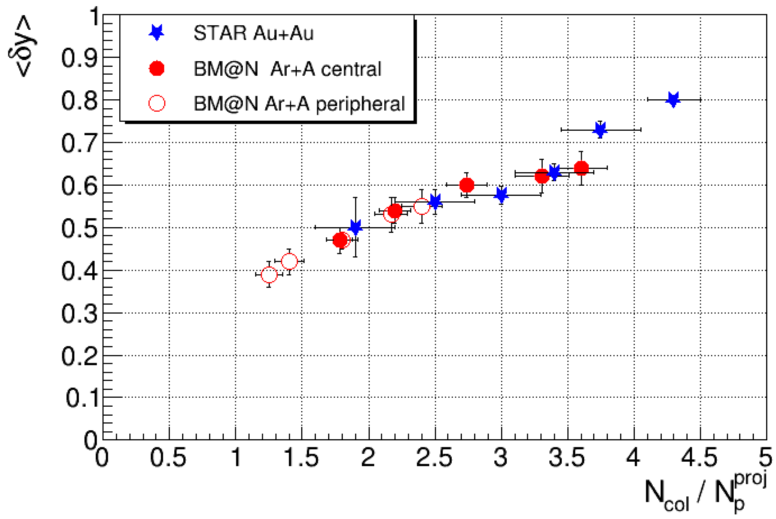


Fig.1 Rapidity loss as a function of the number of collisions per participant in Ar+A and Au+Au collisions at 3 GeV. The BM@N data are from this study, the STAR data are from [1], N_col and N_p are from a Glauber model calculations.

energy should follow a quite similar system size dependence (again, as Fig.1 indicates). Thus, the question of the ‘base line’ for the <δy> system size dependence from BM@N (i.e. is it a 65% rise relative to peripheral Ar+C or just a 27% one comparing central Ar+C and Ar+Pb) – has from my point of view a minor importance.

Let’s now switch to energy dependence of the stopping process. The excitation function of the rapidity loss is studied in terms of the scaled rapidity loss, namely, as the ratio of <δy> to the beam rapidity y_b (in the center of mass). Figure 2 shows the excitation function of the relative rapidity loss in A+A collisions. This is a replica of Fig. 9 from the draft with a larger range of collision energies and two additional points from the RHIC/BRAHMS experiment [4,5].

What is puzzling me in this figure?

First, I assume that at each collision energy the system size dependence is defined by the average number of inelastic collisions suffered by a nucleon from the projectile and characterized by the N_coll/N_part ratio (in the projectile). Second, the discussed system size dependence has a shape like the one in Fig.1, despite of symmetry (or asymmetry) of the collision system. Thus, a rather small difference between the losses in small and large collision systems observed at AGS and SPS:

AGS/E802 (triangles) - Si+Al (N_coll/N_part ~ 2.5) and Au+Au (N_coll/N_part ~ 4.5)
SPS/NA49/NA35 (squares) - S+S (N_coll/N_part = 2.6) and Pb+Pb (N_coll/N_part~4.7)

forces me to think that some another process(es) makes the rapidity loss less efficient in multiple collisions as the collision energy grows. These potential processes (color transparency, formation time, etc..)) start play a role even before the top SPS energy (not after ~20 GeV as one can guess from Fig.2). This problem has been discussed for a long time (see for example [6] and reference therein), but, I had not found a commonly accepted interpretation of it. Moreover, the baryon number transfer mechanism can have a different origin at low and high collision energies: resonance production in cascade interactions determined by isospin-dependent in-medium cross-sections at NICA and string formation + quark/diquark fragmentation or some exotica (like SJ) at AGS/SPS/RHIC.

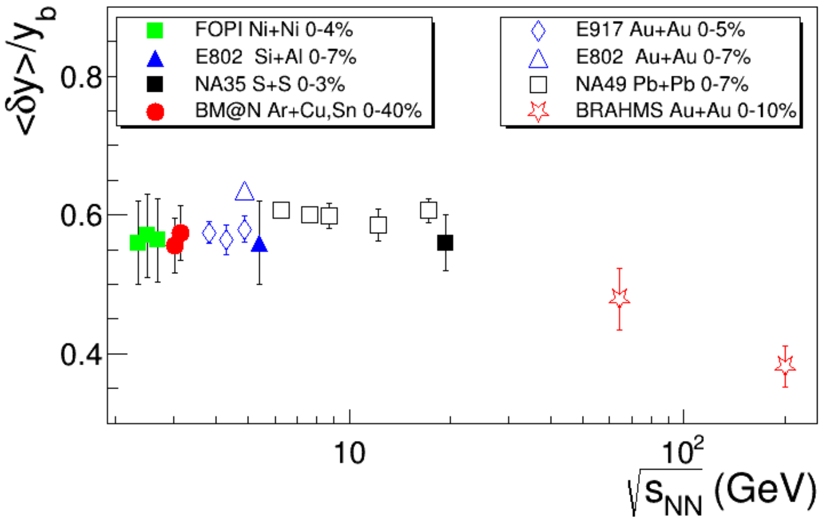


Fig.2 The excitation function of the scaled average rapidity loss ⟨δy⟩/yb in A+A collisions. Medium-size colliding systems are drawn by solid symbols, while heavy systems are shown by open ones. Centrality intervals are indicated in the legends. BM@N points for Ar+Cu and Ar+Sn reactions are displaced horizontally for clarity. of the scaled rapidity loss for medium size A+A collisions (solid symbols) and for central Au+Au and Pb+Pb interactions (open symbols).

Finally, I guess that too much focus given to the discussion of the energy dependence of the scaled rapidity loss in the paper draft without a solid background from theory or models (as Richard correctly pointed out) can have a negative impact on the referee's decision about the BM@N results on the stopping. Moreover, it requires providing a large amount of additional information (plots, references to theory predictions, etc..), that from my point of view and for the current volume of available results is out of the scope of our draft. So, I suggest the following modification in the text and in Fig. 8:

1) An extra sentence is added to the text:
   After "The final <δy> values for central and peripheral collisions are listed in Table 5. A clear trend is observed: <δy> increases with the target mass and with centrality."
   The following text has added "This behavior is expected because the probability of multiple interactions in the projectile-target overlap region is also rises with centrality and the target mass."
2) As Itzhak suggested earlier, Fig.8 now shows the average of BM@N results for the scaled rapidity loss obtained in Ar+Al and Ar+Cu ('almost symmetric system'). The text has changed accordingly.
3) Text in lines 481-496 had revised considerably. Now it states:
   "Fig.8 shows the energy dependence of the scaled average rapidity shift <δy>/y_b in ion-ion collisions as a function of $\sqrt{s_{NN}}$. Results from medium-size almost symmetric colliding systems from [57,59,60] are shown by solid symbols and those from heavy colliding systems [57,61,62] are depicted by open symbols. The corresponding centrality intervals are indicated in the legends. Here, the average of BM@N results obtained in Ar+Al and Ar+Cu reactions is shown. As one can see, the scaled rapidity loss does not vary over a broad energy range."

[1] Benjamin Kimelman for the STAR Collaboration, Quark Matter 2022, Krakow, Poland.
[2] The STAR Collaboration, arXiv: 2311.11020v1
[3] F.Videbaek and Ole Hansen, Phys. Rev. C 52 (1995) 2684
[4] I.G. Bearden et al (BRAHMS Collaboration) Phys. Rev. Lett. 93, 102301 (2004)
[5] I.C. Arsene et al (BRAHMS Collaboration) Phys. Lett. B 677 (2009) 267
[6] A. J. Baltz, Phys. Rev C 43, 1420 (1991)

L 569: specify where the dN_B/dy values are coming from.

Reply: These values are from BM@N data and obtained from the fits of Fig.7. An explanation is added.

L 612-613 "the contribution of π^-, π^0, ... was obtained from the UrQMD model." How different is that from the assumption that the 3 pion species are equal?

Reply: According to UrQMD, the total yield of pions N_total is underestimated by 21% in central Ar+Pb and by 11% in Ar+C if N_total = 3 x N_piplus.

L 625: where are the dN/dy values taken from? Are these the values extracted from the fits of Fig. 15? If so, please say it in the text.

Reply: Yes, indeed, they are taken from these fits. Explanations are added to the text.

L 640: Could you give a ref. for eq. 14?

Reply: Done

L 648 "surprisingly": why is that surprising? Is this the first time that the baryochemical potential at freeze-out is extracted from the penalty factors?

Reply: “Surprisingly” erased from the text of the draft. Extraction of the baryochemical potential value from the penalty factor was, indeed, done for the first time. Usually, the penalty factor is calculated [1-3] according to Eq.14 using μ and T values taken from HGM-based (Hadron Gas Model) statistical model fits of hadron abundances, for example, using the numbers provided by F. Becattini et al in ref. [7].

During the recent BM@N Collaboration meeting, Itzhak also asked me to show an excitation function for the penalty factor in A+A collision. Figure 1 shows results from the E864 Experiment [1,2], NA49 [3], and STAR [4-6] To extract penalties, the midrapidity dn/dy values are used. The yields are also corrected by the spin degeneracy factor (2J+1). Two lines of corresponding color (green for NA49 and red for STAR) are linear fits to the NA49 and STAR data. The fits are obtained in the region (6-27) GeV and then extrapolated to low energies (the AGS/E864 point was not used in fits!). As one can see, the trend from STAR is slightly different from the NA49 one, that is expected since a lead nucleus is heavier than a gold nucleus and the NA49 data are for more central collisions (i.e. in more central collisions of heavier nuclei the density of nucleons is greater, thus, the probability of forming bound nucleon systems is larger and the penalty is smaller). The right panel is the same figure with a log-axis to see better how the penalties from BM@N (this study) and from STAR [4] behave at sqrt{s}=3 GeV. The shaded area indicates the results of calculations for the penalty factor according to eq. 14 and using T and μ from [7]. Though the HGM fits are for the total 4pi yields, the difference between the HGM model predictions and the penalties from dn/dy values vanishes toward BM@N energies.

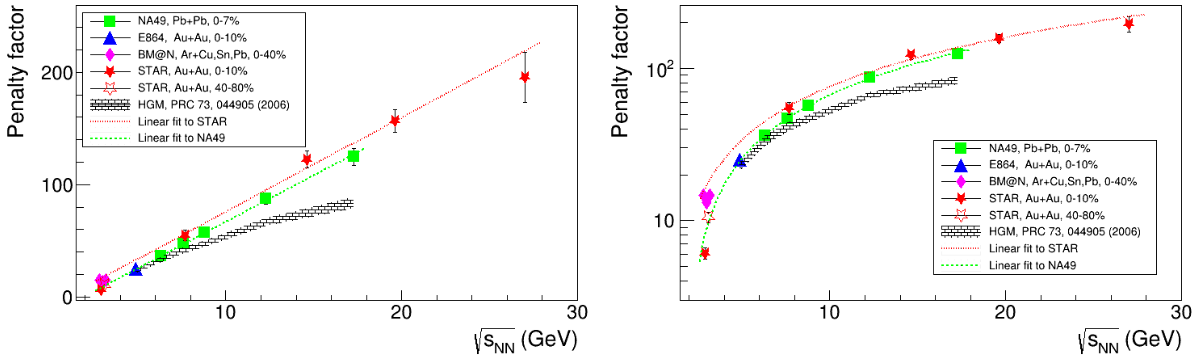


Fig.1 Left: Energy dependence of the penalty factor in A+A collisions [1-6]. Right: The same in log-scale. The red-dashed line is a linear fit in the (7-27) GeV range to the STAR Au+Au results [5,6], the green line is the linear fit in the (6-17) GeV range to the NA49 Pb+Pb data [3].

[1] T.A. Armstrong et al (E864 Collaboration) Phys. Rev. Lett. 83, 5431 (1999)

[2] T.A.Armstrong et al. (E864 Collaboration), Phys. Rev. C 61, 064908 (2000)

[3] T.Anticic et al. (NA49 Collaboration) Phys. Rev. C 94, 044906 (2016)

[4] The STAR Collaboration, arXiv:2311.11020v1

[5] The STAR Collaboration, Phys. Rev. C 96, 044904 (2017)

[6] The STAR Collaboration, Phys. Rev. Lett. 130, 202301 (2023)

[7] F. Becattini et al, Phys, Rev. C 73, 044905 (2006).

L 689-90 "We have....collisions": erase this sentence. It has been said in the preceding paragraph.

Reply: Done

L 694-5: This interpretation was not even mentioned in the main text. So it cannot be in the "Summary".

Reply: Done

Some technical remarks:

- Figures do not appear always in a sequential order
- Remove Preliminary in the legend of figures
- Fonts need to be increased in many figures.

Reply: In progress