Multiplicity Characteristics of Fragments Produced in 4.5A GeV/c ^{24}Mg–Emulsion Interaction

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ABSTRACT

This work is concerned with the analyses of relativistic, fast, and slow hadrons production in 4.5A GeV/c ^{24}Mg collision with emulsion nuclei. The highest particle production occurs in the region of low impact parameters. While the multiplicity of the shower particles emitted in the forward direction depends on the projectile mass number and energy, the multiplicity of the backward ones shows a limiting behaviour. The source of the emission of the forward shower particles is completely different from that of backward ones. The target fragments are produced from the thermalization of their emitting system.

Keywords: ***^{24}Mg Interactions with Emulsion / Forward and Backward Emission of Hadrons / Projectile and Target Dependence.***

INTRODUCTION

One of the interesting subjects in nucleon-nucleus and nucleus-nucleus interactions at high energy, is the emission of relativistic and fast hadrons in the backward hemisphere (BHS)[(1-15)]. This interest comes from the fact that in free nucleon–nucleon collisions such production is kinematically forbidden. Therefore, the observation of such hadrons beyond the kinematic limit may then be evidence for exotic production mechanisms such as production from clusters[(1-3, 16-18)]. The authors of Ref. (3) argued that simple Fermi motion of the nucleons in the nucleus could not account for such backward production. They stated that the dominant mechanism for production such relativistic hadron was the interaction between the incident nucleon and multi-nucleon clusters in the target, referring to this mechanisms as cumulative production. Fredriksson[(17)] supported the model in which the nucleon interacts collectively with all matter with in 1 Fm in its rest frame at the time of collision. The LBL data[(2, 5)] supported a model called the "effective target model"[(16)].

The aim of this paper is to investigate the multiplicity characteristics of the forward and backward shower, grey and black particles emitted in ^{24}Mg – emulsion interactions at 4.5A GeV/c. A systematic comparison is made with studies of different projectiles interact with emulsion nuclei at the same momentum per nucleon.

EXPERIMENTAL TECHNIQUE

In this experiment, a stack of NIKFI-BR-2 nuclear emulsion type of size 10 cm $\times$ 20 cm $\times$ 0.06 cm is used.

This stack was exposed to 4.5A GeV/c ^{24}Mg beam at Dubna Synchrophasotron. The pellicles were doubly scanned along the beam tracks starting from the beam entrance, fast in the forward direction and coming back slowly to the starting point.

Through a total scanned length of 103.06 meters of beam tracks, 1094 inelastic interactions were observed, such that the experimental mean free path and inelastic interaction cross section are"λ_{exp}" = 9.42 ± 0.25 cm and 1330.29 ± 35.8 mb, respectively. These values are found to be in a good agreement with the empirical ones deduced using the Bradt - Peters formula following "Glauber multiple scattering theory"[19].

For each detected event, following the rules[20] identifying the type of the emitted secondaries as well as the projectile fragments P.F's,[21] (shower (s), grey (g) and block (b)), the number of each type (n_s, N_g, N_b) was counted.

RESULTS AND DISCUSSION

Multiplicity Characteristics of Secondary Particles

This work devoted to study the characteristics of all types of secondary charged particles produced in 4.5A GeV/c ^{24}Mg - Em inelastic interactions. The present average multiplicities values, $<n_s>$, $<N_g>$, $< N_b>$ and $< N_h>$ where ($N_h = N_g + N_b$) are calculated and compared with the corresponding ones for different projectiles[22-28] at nearly the same incident momentum per nucleon. Table (1) illustrates such comparison which indicates that $<n_s>$, increases, as expected, with increasing the projectile's mass number (A_P). However, the average values of the heavily ionizing particles, $<N_h>$, appear to be nearly constant for all the compared incident projectiles with $A_p \geq 6$. This is could be attributed to the fact that the light projectiles have no sufficient energy to excite the heavy Ag nuclei of the emulsion. The observed constancy of $<N_h>$, at $A_p \geq 6$ reflects the validity of the limiting fragmentation hypothesis at high energy[9, 29, 30].

Table (1): The average multiplicity values of shower, grey, black and heavily ionizing particles emitted from the interactions with emulsion nuclei of different projectiles at nearly the same incident momentum per nucleon (4.5A GeV/c).

Projectile	$< n_s >$	$< N_g >$	$< N_b >$	$< N_h >$	Ref.
P	1.63±0.02	2.81±0.09	3.75±0.08	6.53±0.13	(25)
D	2.77±0.02	3.90±0.10	4.60±0.20	8.50±0.30	(25)
^{4}He	3.37±0.09	3.14±0.12	4.68±0.15	7.82±0.30	(24)
^{6}Li	5.09±0.29	4.23±0.21	4.91±0.30	9.14±0.37	(22)
^{12}C	8.50±0.50	4.60±0.40	4.50±0.30	9.10±0.40	(26)
^{22}Ne	9.98±0.35	5.63±0.24	4.45±0.20	10.08±0.36	(27)
^{24}Mg	10.39±0.27	4.02±0.13	7.00±0.19	11.02±0.30	Present Work
^{28}Si	12.90±0.40	6.90±0.20	4.70±0.10	11.60±0.13	(28)
^{32}S	13.06±0.45	3.43±0.15	6.72±0.25	10.15±0.40	(23)

Now, it is required to investigate the effect of the projectile's mass number A_p on the average multiplicity values of shower and grey particles emitted in both the forward and backward hemispheres, FHS and BHS. For this purpose, the present $< n_s^f >$, $< N_g^f >$, $< n_s^b >$, and $< N_g^b>$ values are listed in Table (2) together with the corresponding results obtained for different projectiles[9-12, 14, 29-30], having nearly the same incident momentum per nucleon. From this table one can notice that, the average values of the forward shower particles multiplicity $<n_s^f >$ increases with the increasing of the projectile's size. On the other hand, for projectiles with $A_p \geq 6$, the values of $<n_s^b>$ are nearly constant

(~ 0.4) which means that A_p of the incident projectile has no effect on the backward shower particle production. These results strongly support the assumption that while the creation of the forward hadrons is due to the energy transferred from the participant nucleons, the backward ones originate from a completely different source.

As for grey particles, the values of both $\langle N_g^f \rangle$ and $\langle N_g^b \rangle$ seem to be unaffected by the size of the incident projectile.

Table (2): The values of the average multiplicities of the emitted shower and grey particles in the FHS and BHS for different interactions.

Projectile	Incident Momentum (**GeV**/c/A)	$\langle n_s^f \rangle$	$\langle N_g^f \rangle$	$\langle n_s^b \rangle$	$\langle N_g^b \rangle$	Ref.
p	4.5	1.51±0.01	2.06±0.06	0.11±0.02	0.74±0.04	(9, 29, 30)
^{6}Li	4.5	5.30±0.15	2.08±0.08	0.41±0.01	0.98±0.05	(14)
^{12}C	4.5	7.11±0.02	4.52±0.20	0.45±0.01	1.38±0.07	(10)
^{22}Ne	4.1	9.85±0.04	4.80±0.20	0.45±0.01	1.42±0.08	(11)
^{24}Mg	4.5	10.00±0.27	3.17±0.11	0.40±0.03	0.86±0.05	Present Work
^{28}Si	4.5	11.36±0.09	4.98±0.18	0.44±0.01	1.42±0.07	(12)
^{32}S	4.5	14.58±0.48	3.17±0.14	0.46±0.01	0.82±0.05	(31)

Dependence on the Impact Parameter

The dependence of the average values of shower, grey and black particles on interactions centrality degrees is also studied in this work. This degree could be sufficiently indicated by the value of N_h [31-34] such that as the interaction becomes more central, the value of N_h increases. Consequently, the present interactions are classified into five main groups with N_h ranges; 0 – 1, 2 – 7, 8 – 15, 16 – 27, and = 28.

Table (3) shows the present average multiplicity values ($\langle n_s \rangle$, $\langle N_g \rangle$, and $\langle N_b \rangle$) at different centrality degrees. According to this table, the average values of shower, grey and black particles increase with increasing the N_h value. When the colliding system moves towards more central regions, the maximum possible number of nucleons present in the overlapping region between the target and projectile will participate in the interaction. In the overlap region, the colliding objects lose their identity after the collision and form a compound system which is the source of the secondary charged particles. The relatively large energy and momentum transfers in such region manifest themselves producing particles which are isotropically distributed over in space with large transverse momentum and/or in creating more particles and pions.

Table (3): The average values of shower, grey, and black particles at different centrality degrees (N_h–ranges) in 4.5A GeV/c ^{24}Mg–Em interaction.

N_h–Ranges	$\langle n_s \rangle$	$\langle N_g \rangle$	$\langle N_b \rangle$
0–1	4.17±0.33	0.22±0.04	0.31±0.041
2–7	6.00±0.27	1.38±0.07	2.70±0.07
8–15	9.20±0.43	4.00±0.16	7.21±0.20
16–27	16.58±0.48	7.20±0.20	13.47±0.21
= 28	26.58±1.16	13.85±0.46	13.85±0.46

Therefore, the highest multiplicities of target fragments and created particles will be obtained at the region of violent (head on) collision, where the overlap region has its maximum size. Such state can be observed in Table (3) at $N_h \geq 28$, where the complete destruction of AgBr nuclei is expected to occur.

Forward – Backward Ratios

Next, it is aimed to check the effect of both the interaction centrality degree and the projectile's mass number, A_p, on the forward – backward ratios for shower and grey particles [$(F/B)_s$ and $(F/B)_g$], respectively. Table (4) illustrates that the $(F/B)_s$ increases rapidly with A_p. At the region of more central collisions, It is concluded by many author(10, 31, 35-38) that the backward shower particle production is a consequence of a decay of highest excited target system after the emission of the forward particles and hence, such production depends mainly on the target. This results shown in Table (4) agree with the previous conclusion where the $(F/B)_s$ ratios decrease with the increase of N_h, i.e. as the interactions become more central, such that this ratios have their minimum values at $N_h \geq 28$. This indicates that the multiplicities of n_s^b attain their greatest values at the most central events. The values of $(F/B)_g$ are found to be nearly around 3.50 irrespective of the either the size of the projectile or the impact parameter. This limiting value reflects the isotropy in the behavior of the system emitting grey particles in both the forward and backward hemispheres.

Table (4): The forward–backward ratio for different projectiles interacting with emulsion nuclei at different centrality degrees (N_h–values).

Projectile		N_h(1–7)	N_h(8–17)	N_h(18–27)	N_h = 28	Total Sample	Ref.
^{12}C	$(F/B)_s$	44.20	27	22.50	18.50	16.93	(10)
	$(F/B)_g$	4.08	3.41	3.20	3.30	3.51	
^{22}Ne	$(F/B)_s$	48.04	27.54	21.21	16.58	21.89	(11)
	$(F/B)_g$	4.80	3.30	3.10	2.90	3.30	
^{24}Mg	$(F/B)_s$	36.65±5.08	24.58±3.42	21.65±2.69	20.16±2.25	24.95±1.81	Present Work
	$(F/B)_g$	7.34±1.00	4.00±0.34	3.44±0.25	2.83±0.28	3.70±0.24	
^{28}Si	$(F/B)_s$	62.40	44.04	23.64	17.88	25.82	(11)
	$(F/B)_g$	4.40	3.50	2.90	3.10	3.52	
^{32}S	$(F/B)_s$	95.50	32.53	20.20	21.47	31.76	(12)
	$(F/B)_g$	6.70	3.51	3.06	4.13	3.91	

Table (5) displays the $(F/B)_b$ ratios of the black particle multiplicity observed in the interaction of p, ^3He, ^4He, ^6Li, Li, ^{12}C, and ^{24}Mg with emulsion nuclei(13, 39, 40) at 4.5A GeV/c. This table shows that, the isotropy factor $(F/B)_b$ has a nearly constant value for all interactions. Therefore, it can be concluded that the system emitting black particles is independent of the projectile masses.

Table (5): The isotropy factor $(F/B)_b$ for the system emitting black particles from different projectiles interactions in nuclear emulsion at 4.5A GeV/c.

Projectile	$(F/B)_b$	Ref.
p	1.33±0.03	(39)
^3He	1.45±0.05	(40)
^4He	1.33±0.07	(40)
^6Li	1.29±0.06	(13)
^{12}C	1.27±0.10	(39)
^{24}Mg	1.48±0.05	Present Work

Target and Projectile Effect on the Backward Particle Production

In order to study the target and projectile effect on the backward particles production, the present percentage probabilities of the events characterized by backward emission of shower (n_s^b), grey (N_g^b) and compound ($N_c^b = n_s^b + N_g^b$) particle multiplicities were determined. Table (6) illustrates a comparison between the present results and the corresponding ones for ^{32}S[31] projectile at the same momentum per nucleon. The probabilities of events with $n_s^b > 0$, $N_g^b > 0$ and $N_c^b > 0$ are found to increase with increasing the centrality degree. On the other hand, the probabilities (at different ranges of N_h) seem to be independent of the projectile's mass number confirming the previous observation. The percentage of the present events accompanied by the emission, in the BHS, of both shower and grey particles together (i.e. $n_s^b > 0$ and $N_g^b > 0$) was calculated and found to be agree with the corresponding values determined for the interactions with emulsion nuclei of 4.5A GeV/c ^6Li[14] and ^{32}S[31]. This indicates that the projectile size has no effect on this percentage. These calculations confirm that the backward particle production (shower and grey) is a target source and independent of the projectile size. Consequently, it can be concluded from the above experimental data that the backward emitting grey particle may be produced by a mechanism which is different from that of forward ones. Such conclusion reveals the existence of the limiting fragmentation hypothesis according to which both the projectile and target may be fragmented irrespective of each other.

Table (6): The probability (in percent) of the interactions accompanied by the emission of shower, grey and compound particle in the BHS at different impact parameters.

Interaction Group	Projectile	$n_s^b > 0$	$N_g^b > 0$	$N_c^b > 0$	Ref.
$N_h = 8$	^{24}Mg	11.90±1.43	13.10±1.50	22.00±1.93	Present Work
	^{32}S	8.10	14.88	22.47	(31)
$N_h = 8$	^{24}Mg	41.25±2.83	71.78±3.74	76.65±3.86	Present Work
	^{32}S	57.00	76.80	84.30	(31)
$N_h = 28$	^{24}Mg	71.80±9.59	96.15±11.10	97.43±11.18	Present Work
	^{32}S	73.50	92.64	100	(31)

Dependence on Target Size

Now, it is aimed to investigate the dependence of the average multiplicity of shower particles, $<n_s>$ on the target size. For this purpose, it is necessary to consider the composition of the used emulsion. In addition to free hydrogen H, this emulsion contains two groups of nuclei; the light group (CNO) and the heavy one (AgBr). In order to separate the experimental events due to the interactions of the present ^{24}Mg projectile with either hydrogen or light group or heavy one, the method of Florian et al[41] is used. This method suggested that:

- All events due to hydrogen interactions are characterized by N_h =0, 1.

- The events with N_h >7 belong to interactions with the heavy group (AgBr).

- The events with $2 \leq N_h \leq 7$ are due to the interactions with light (CNO) and heavy (AgBr) groups.

- The events having $2 \leq N_h \leq 7$ and belonging to the (AgBr) group can be separated by drawing the integral N_h distribution for all events with all values of N_h and then this distribution is extrapolated for events with $N_h > 7$ in the region of $2 \leq N_h \leq 7$. The extrapolated region would exactly contain a number of events equal to the difference between the total number of events due to the interactions with the heavy (Ag, Br) group and the number of events having $N_h > 7$. Consequently, it becomes easily to determine for each value of N_h, the number of events due to the (CNO) group. The numbers of events, and hence the corresponding percentage, due to H, CNO and AgBr are obtained from the best fitting of the integral N_h distribution to be (143 events or 13.07 %), (356 events or 32.54%) and (595 events or 54.39%), respectively. These values are found to be in a good agreement with the corresponding empirical ones calculated according to Ref. (31) [(142, 13%), (354, 32.37%) and (598, 54.65%), respectively].

The present average multiplicities of the shower and heavily ionizing particles emitted in the interaction with hydrogen, light and heavy emulsion nuclei and the corresponding values for ^{12}C(42) and ^{28}Si(29) at the same incident momentum per nucleon are shown in Table (7). One can notice that for a specific target, while the average multiplicity of the heavy particles, $\langle N_h \rangle$, (which are target fragments) is not affected by the mass number of the incident projectile (A_{Proj}), the average multiplicity of the shower particles, $\langle n_s \rangle$, (which are created pions) increases with the increase of A_p. Although the shower particle multiplicity depends mainly in its creation behavior on the projectile mass and energy, however this table, again, confirms that $\langle n_s \rangle$ depends also on the size of the target nuclei. This may be interpreted according to the work of Dabrowska et al(43) who observed a decrease in the number of target fragments with increasing centrality for interactions of projectiles with masses comparable or greater than the mass of the target nucleus. As the collision becomes more central, a significant number of participating protons from the target nucleus get enough momentum to become relativistic due to intranuclear interactions.

Table (7): The average values of shower and heavily ionizing particles for different groups of events detected in the interactions with emulsion nuclei of 4.5 A GeV/c ^{24}Mg in comparison with the corresponding results for ^{12}C and ^{28}Si.

Projectile	Target	$\langle n_s \rangle$	$\langle N_h \rangle$	Ref.
^{12}C	H	0.66±0.05	0.4±0.07	(42)
	CNO	4.80±0.14	2.83±0.12	
	AgBr	10.80±0.19	16.10±0.34	
^{24}Mg	H	3.83±0.31	0.57±0.04	Present Work
	CNO	5.15±0.20	4.00±0.08	
	AgBr	14.92±0.38	17.75±0.34	
^{28}Si	H	4.77±0.39	0.41±0.03	(29)
	CNO	7.06±0.38	3.77±0.22	
	AgBr	21.29±0.88	17.39±0.72	

Table (8) displays the percentage probabilities of the events characterized by the backward emission of shower, grey and compound particles multiplicities in the interactions of 4.5A GeV/c ^{24}Mg with different emulsion components (CNO and AgBr) as well as with the emulsion as a whole. For comparison, the corresponding results for 4.5A GeV/c ^{32}S are also shown in this table. Table (8) clarifies that, for both 4.5A GeV/c ^{24}Mg and ^{32}S, the increase of target size has a great effect on the probability of having events accompanied by the emission in the BHS of shower, grey and compound particles. It can be seen also that nearly 30 % of the total number of events due to the interaction with emulsion as a whole are characterized by backward emission of shower particles. This percentage value is consistent with the corresponding ones observed by the authors of Ref. (3) of ^{6}Li, ^{12}C and ^{22}Ne at 4.1–4.5A GeV/c (28.1, 30.2 and 28.04, respectively). This indicates that the probability of interactions having backward relativistic hadrons, is nearly independent of the projectile mass number.

The values of the average multiplicity of forward and backward emission of shower and grey particles ($<n_s^f>$, $<n_s^b>$, $<n_g^f>$, $<n_g^b>$, respectively) in the interaction of 4.5A GeV/c ^{24}Mg (present work), ^{3}He, ^{4}He[40, 44] and ^{32}S[31] with different group of emulsion nuclei (CNO and AgBr) are listed in Table (9). From this table, one can see that the average number of shower and grey particles in each of the forward and backward hemispheres increases with increasing the target size. This table confirms the conclusion obtained from Table (2) that while the value of $< n_s^f>$ depends on the projectile's mass number A_p, the value $<n_s^b>$ is nearly not affected by A_p. Therefore, it is possible to assume that while the relativistic hadrons flying in the forward hemisphere are created as a result of energy transferred from participant nucleons, those emitted in the backward hemisphere are originated from a completely different source.

Table (8): The probability (in percent) of the interactions accompanied by the emission of shower, grey and compound particles in the BHS due to different emulsion nuclei.

Interaction Group	Projectile	$n_s^b > 0$	$N_g^b > 0$	$N_c^b > 0$	Ref.
CNO	^{24}Mg	12.64±1.90	12.40±1.86	22.00±2.50	Present Work
	^{32}S	11.55	18.68	28.75	(31)
Em	^{24}Mg	26.32±1.55	40.70±1.93	47.44±2.08	Present Work
	^{32}S	30.20	42.80	50.38	(31)
AgBr	^{24}Mg	39.00±1.58	67.23±3.36	73.00±3.50	Present Work
	^{32}S	44.34	60.64	78.60	(31)

Table (9): The values, for different projectiles, of the average multiplicities of the emitted shower and grey particles in the FHS and BHS for CNO and AgBr groups of emulsion nuclei.

Interaction Group	Projctile	$< n_s^f >$	$< n_s^b >$	$< N_g^f >$	$< N_g^b >$	Ref.
CNO	^{3}He	2.63±0.07	0.13±0.02	0.91±0.02	0.18±0.01	(40)
	^{4}He	2.97±0.09	0.17±0.02	0.77±0.04	0.18±0.01	(44)
	^{24}Mg	5.01±0.24	0.15±0.02	1.10±0.06	0.14±0.02	Present Work
	^{32}S	8.91±0.41	0.09±0.02	1.11±0.06	0.16±0.02	(31)
AgBr	^{3}He	5.31±0.12	0.53±0.03	2.63±0.08	0.85±0.03	(40)
	^{4}He	6.70±0.18	0.71±0.05	3.36±0.13	0.93±0.04	(44)
	^{24}Mg	14.54±0.37	0.63±0.05	5.14±0.15	1.49±0.08	Present Work
	^{32}S	18.15±0.91	0.69±0.02	4.47±0.22	1.23±0.06	(31)

Multiplicity Distribution of Forward and Backward Particles

The experimental multiplicity distributions of shower and grey particles in both the FHS and BHS ($P(n_s^f)$, $P(N_g^f)$, $P(n_s^b)$, and $P(N_g^b)$ respectively) for the present interaction with CNO, AgBr and emulsion as a whole (Em) are shown in figures (1), (2), (3) and (4). From these figures one can notice that, the distributions of shower and grey particles detected in the FHS (Figs. (1) and (3)) extend to much higher multiplicity values than those in the BHS (Figs.(2) and (4)). This is due to the fact that in the FHS the particles are produced with no kinematical restrictions.

The present multiplicity distributions of the backward shower and grey particles can be fitted by the following exponential forms:

$$P(n_s^b) = P_s e^{-l_s^b n_s^b} \qquad \text{and} \qquad P(N_g^b) = P_g e^{-l_g^b N_g^b}$$

This relation represents the fundamental equation of the decay of an excited system. The decay constants $?^b_s$ and $?^b_g$,as obtained from the best fit of the present experimental data, are listed in Table (10) with the corresponding ones for different projectiles[31, 40]. From this table, one can be seen that, for the interaction with emulsion as a whole (Em) the shower particle decay constant $?^b_s$ seems to be independent of the projectile mass number. This result supports the effective target model[16] where the incident nucleus is assumed to interact with and hence excite, in a collective fashion, with the row of nucleons along its paths. During de-excitation, the emission of pions occurs in a manner similar to that in the thermal models. Such conclusion is also consistent with the model drawn by Fredriksson[17] according to which the incident nucleus interact collectively with all matter within 1 fm (in the rest frame) at the line of collision. On the other hand, the value of the decay constant $?^b_s$ decreases with increasing the target size. The relationship between the grey decay constant $?^b_g$ and both the projectiles mass number and target size are observed to be similar to those for the shower decay constant $?^b_s$. The above results for the shower and grey particles emitted in the BHS confirm the limiting fragmentation hypothesis at the incident momentum used. Therefore, the shower particles which are flying above the kinematic limit (in the BHS) may be thought to be due to the decay of an exciting system (cluster) at a fixed temperature in the first step. Then the backward grey particles as expected to emitted in the second step.

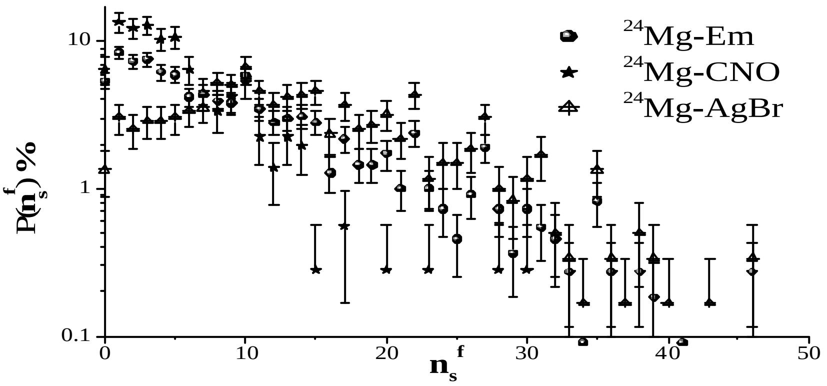

Fig. (1): The normalized multiplicity distributions of shower particles emitted in FHS due to the interactions of ^{24}Mg with CNO, AgBr, and emulsion at 4.5A GeV/c.

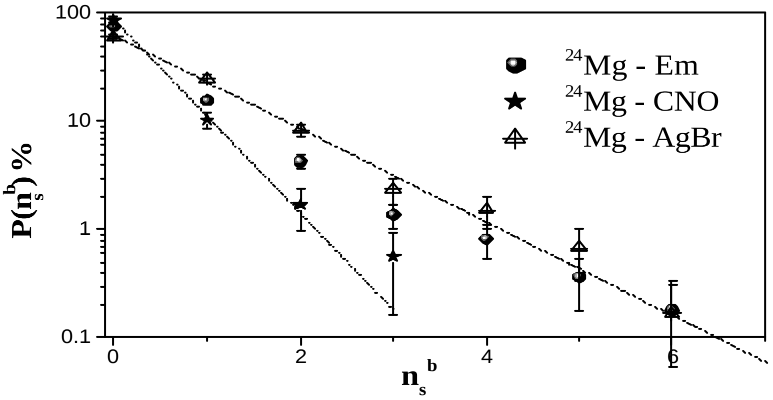

Fig. (2): The normalized multiplicity distributions of shower particles emitted in BHS due to the interactions of ^{24}Mg with CNO, AgBr, and emulsion at 4.5A GeV, together with the exponential decay lines.

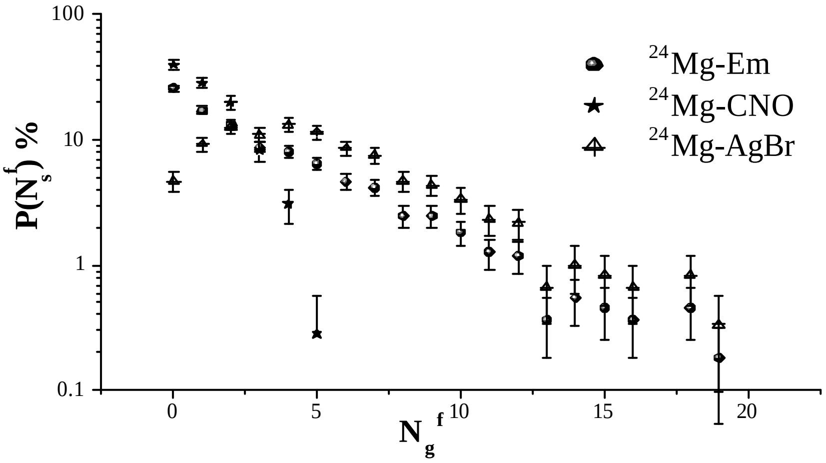

Fig. (3): The normalized multiplicity distributions of grey particles emitted in FHS due to the interactions of ^{24}Mg with CNO, AgBr, and emulsion at 4.5A GeV/c.

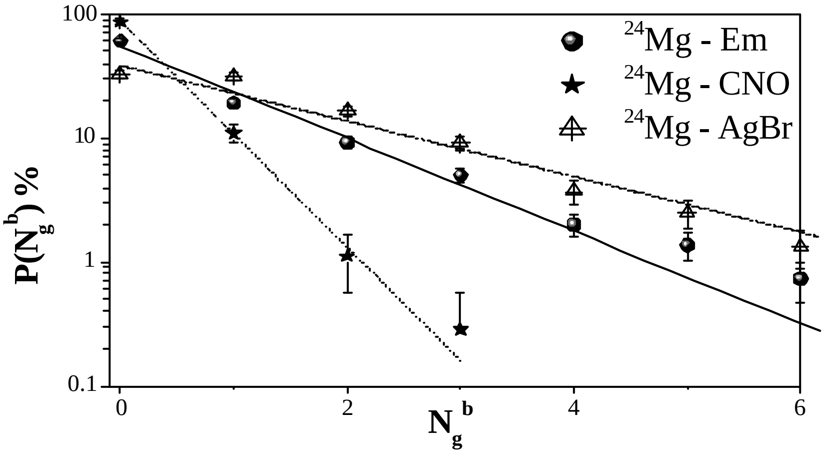

Fig. (4): The normalized multiplicity distributions of grey particles emitted in BHS due to the interactions of ^{24}Mg with CNO, AgBr, and emulsion at 4.5A GeV/c, together with the exponential decay lines.

Table (10): The fitting parameters of the backward shower and grey particle distributions fitted in an exponential decay form.

Projectile	Target	$?_s^b$	P_s	$?_g^b$	P_g	Ref.
^{12}C	Em	1.09±0.04	63.22±7.75	0.75±0.06	45.92±11.56	(35)
^{22}Ne	Em	1.06±0.04	58.52±6.98	0.66±0.04	40.91±7.58	(35)
^{24}Mg	Em	1.17±0.04	74.55±2.28	0.86±0.04	55.89±2.13	Present Work
	CNO	2.05±0.03	86.89±4.92	2.10±0.03	87.72±4.92	
	AgBr	0.99±0.05	62.26±3.01	0.52±0.08	40.00±2.03	
^{28}Si	Em	1.02±0.08	54.93±13.14	0.67 0.04	42.11±8.88	(35)
^{32}S	Em	1.05±0.05	62.67±7.06	0.76±0.02	50.88±5.23	(31)
	CNO	2.38±0.10	86.86±11.22	1.81±0.04	83.07±6.64	
	AgBr	0.89±0.05	61.68±6.97	0.67±0.03	52.77±7.68	

CONCLUSION

On the basis of the present study of ^{24}Mg–Em interaction at 4.5A GeV/c, the following items can be obtained:

- The average multiplicity values of the forward shower particles, $<n_s^f>$, (which are mostly created pions) increase with the increase of projectile's size (i.e. with the increase of the number of projectile's interacting nucleons). On the other hand, the values of $<n_s^b>$ are nearly independent of the projectile's size ($<n_s^b> \sim 0.40$, starting from ^{6}Li).

- The values of both $<N_g^f>$ and $<N_g^b>$ seem to be unaffected by the size of the incident projectile.

- The average multiplicity value of shower particles increases with the increase of the target size.

- The ratio $(F/B)_s$ increases rapidly with the mass number of the projectile. At the regions of more central collisions (i.e. those with the highest N_h values), the multiplicities of n_s^b will attain their greatest values, such that they contribute more in $(F/B)_s$. Accordingly, the value of $(F/B)_s$ is found to decrease gradually by a factor of at least ~ 1.2 as the centrality increases. This decrement factor shows constancy with the projectile mass number of $N_h \geq 28$ (complete destruction of Ag and Br nuclei).

- The values of $(F/B)_g$ are found to be nearly around 3.5 irrespective of the change of the projectile or the impact parameter. This limiting value reflects the isotropy in the behavior of the system emitting grey particles in both FHS and BHS.

- The $(F/B)_b$ ratios of the black particle multiplicity have a constant value for different projectiles. Therefore, this ratio is considered as an isotropically factor for the system exciting evaporated particles.

- The probabilities of events with $n_s^b > 0$, $N_g^b > 0$ and $N_c^b > 0$ are found to increase with increasing the centrality degree. On the other hand, the probabilities (at different ranges of N_h) seem to be independent of the projectile's mass number.

- The percentage of the present events accompanied by the emission, in the BHS, of both shower and grey particles together (i.e. $n_s^b > 0$ and $N_g^b > 0$) was calculated and found to agree with the corresponding values determined for 4.5A GeV/c ^{6}Li[(11)] and ^{32}S[(20)]. This indicates that the projectile size has no effect on this percentage. i.e. the backward particle production of shower with grey particles is a target source and independent of the projectile size.

- The backward emitting grey particle may be produced by a mechanism which is different from that of forward ones.

- As the target size increases, the average number of shower particles in each of the forward and backward hemispheres increases.

- The multiplicity distributions of shower and grey particles detected in the FHS (see Figs. (1) and (3)) extend to higher values than those in the BHS (see Figs. (2) and (4)). This is due to the fact that the particles produced in the FHS are resulting from the contributions of both projectile and target participates while in the BHS, the target size is the only affecting parameter.

- The results presented in this work strongly support the assumption that while the creation of the forward hadrons is due to the energy transferred from the participant nucleons, the backward ones originate from a completely different source.

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