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RESEARCH ARTICLE

Photon Multiplicity Distributions at Heavy Ion Au+Au, Pb+Au, Pb+Pb Interactions

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ABSTRACT

The experimental distributions for Heavy ion interaction, Au+Au, Pb+Au, Pb+Pb have been fitted to polynomial fit of 4th order to look at minor differences in multiplicity distributions for different targets at heavy ion collisions experiment. The multiplicity distributions found similar; except for small differences which may be of statistical in nature. This analysis supports the hypothesis that geometrical aspects play a dominant role in particle production in heavy ion interactions.

Keywords: Photon multiplicity, Heavy ion interaction, Au+Au, Pb+Au, Pb+Pb interactions.

1. Introduction

The quark gluon plasma (QGP) is the primary goal of ultra-relativistic heavy ion experiments in which nuclear matter under extreme conditions are studied, where hadronic matter expected to undergo a phase transition to a new state of matter, QGP. For a thermalized system undergoing a phase transition, the variation of the temperature with entropy density is interesting as the temperature is expected to increase while below the transition, remain constant during the transition, and then increase again [1,2] fluctuations are also a signature of the existence of a critical point in quantum chromodynamics QCD [3]. These behaviours can be studied by two experimentally measured quantities, the mean transverse momentum PT, and the pseudo rapidity density at high temperature T, for varying impact parameter, or max centrality, for a number of colliding systems. These n variables also provide additional information to characterize the evolving system. In addition, the change in shape of the pseudo rapidity distribution should be investigated in detail because it may provide a clue to the formation of the QGP phase [4, 5]. Except for a few measurements of photon multiplicity [6–9].

2. Photon Multiplicity Distributions

Photon multiplicity distributions should also have investigated, where photon multiplicity of produced particles in deferent targets increases Average as we go from Proton-Proton (P-P) interactions to P-Nucleus interactions.; keeping the energy of Proton the same in both cases. Average multiplicity further increases as we go from Proton-Nucleus to Nucleus-Nucleus interactions keeping energy per nucleon the same as that of proton. Although the process of particle production is more complicated; a simple picture can be visualized as Proton-Nucleus is a superposition of many Nucleon-Nucleon interactions. Similarly, Nucleus-Nucleus is a superposition of even large number of Nucleon-Nucleon interactions. In other words, the number of basic Nucleon-Nucleon interactions increases as we go from Nucleon-Nucleon to Nucleon-Nucleus and then to Nucleus-Nucleus interactions; or the number of primary Nucleon-

Nucleon collisions is increased. These ideas have been described in detail elsewhere [10]; where average charged particle multiplicity in P-Nucleus and Nucleus-Nucleus interactions is expressed in terms of charged particle multiplicity in P-P interactions. The number of basic Nucleon-Nucleon interactions can be changed in other ways also i.e. By varying the impact parameter of the Nucleus-Nucleus collisions or by choosing Nucleus-Nucleus collisions of different centrality. Another alternative is to choose the Nuclear interactions of different projectiles and targets. So if we take Nucleus-Nucleus interactions of different nuclei, the number of primary Nucleon-Nucleon interactions would be different, resulting in different average particle multiplicity. These effects, where number of participating nucleons changes are also termed as geometrical effects. As expected, the number of produced particles also changes when the energy of incident proton or nucleus is increased.

In the comparison of multiplicities for various interactions and at different energies, it is advantageous to define normalized or scaled multiplicity as $\frac{N}{<N>}$. Normalized multiplicities are studied by many authors [11,12,13] e.g EMU01 collaboration [11,13] studied variation of normalized shower particle multiplicity (shower particle multiplicity in nuclear emulsions is a measure of produced charged particles in an interaction), Ns/<Ns>, for O-emulsion interactions at 15 A, 60 A and 200 A GeV of different centralities. These observations confirm the advantage of comparing normalized multiplicities instead of usual multiplicities {which change because of energy or number of basic Nucleon-Nucleon interactions}. In this study experimental data for Pb+Pb, Pb+Au and Au+Au interactions at 158 A GeV have been investigated. The normalized photon multiplicity distributions of minimum bias events for Eta range 2.0-4.2 are studied here. Study of normalized multiplicity with increasing η-window size is also made in the case of central events for two targets. The selected η-window sizes are 2.0-3.4, 2.0-3.8, and 2.0-4.2. Gaussian fits as well as Polynomial fits on these multiplicity distributions are also described

3. Event Selection

The selection criterion for the classification of events depends upon many factor like collected energy at a particular angle, multiplicity of the projectile and target fragments and number of created particles etc. Basically, the heavy ion collision can be divided into peripheral, not so central (Quasi central) and central collision. In central collisions the production of heavier fragments reduces drastically due to complete overlapping of the two nuclei. We used data from trigger detectors, i.e. MIRAC and ZDC where MIRAC gives total transverse energy in forward hemisphere and ZDC measures energy in the very forward one. The coverage of MIRAC and PMD is almost same. We used E_T observed in MIRAC as the selection parameter of the events. The ranges for different classes of E_T are given below-

E_T Cuts	Percentage
$E_t \geq 291.65$	10%
$291.65 \geq E_t \geq 212.15$	10-20%
$212.15 \geq E_t \geq 147.75$	20-30%
$147.75 \geq E_t \geq 102.05$	30-40%
$102.05 \geq E_t \geq 50.55$	40-50%
$E_t \geq 50.53$	60-100%

Here we have studied only the first category of events i.e. Et ≥291.65; these events are also termed as central events.

4. Results and Discussion

All the experimental distributions are fitted to polynomial fit of 4th order given as ($Y=A+B_1.X+B_2.X^2+B_3.X^3+B_4.X^4$), Although we tried to fit polynomials of order 3,4,5 and 6, 4th order polynomial fits are closer to the data. The fitted values of A, B_1, B_2, B_3 and B_4 are given in table 1-3. The polynomial fit parameters which are given in Table 1, 2 and 3; for each window, are similar. The data for two target and each window are shown in table 4-6. There is small regular change, when we go from smaller window to larger window. Similarly, small change is observed, when we go from smaller target [Pb] to bigger target [Au]. This change may be statistical in nature; because in both cases actual Nγ values change, although the normalized photon multiplicity distributions do not show appreciable change.

Figure 1-6 shows the distributions, where the mean of simulation is raised to that of experimental data. In Other words, the two distributions are normalized to the same <Nγ>.

Table 1: *Polynomials fit parameter for Au-Au collisions*

Au+Au	**2.0-3.4**		**2.0-3.8**		**2.0-4.2**	
Parameter	**Value**	**Error**	**Value**	**Error**	**Value**	**Error**
A	7.68	1.5	7.9	3	9.2	4.56
B_1	-20.3	10.4	-32.4	13.4	-41.7	14.2
B_2	67	17.4	72.4	18.15	69.24	23.98
B_3	-39.6	11.5	-54.3	11.43	-48.1	15.3
B_4	10.12	3	9.23	3	11.89	4.3

Table 2: *Polynomials fit parameter for Pb-Au collision*

Pb+Au	**2.0-3.4**		**2.0-3.8**		**2.0-4.2**	
Parameter	**Value**	**Error**	**Value**	**Error**	**Value**	**Error**
A	6.78	4.3	8.96	3	67.5	2.34
B_1	-32.5	14.2	-45.3	13.6	-38.3	13
B_2	57.34	20.3	66.3	18.3	68.34	19.23
B_3	-42.4	15.6	-40.5	13.2	-52.5	13.7
B_4	8	1.4	10	3.6	14.7	4.23

Table 3: *Polynomials fit parameter for Pb-Pb collisions*

Pb+Pb	**2.0-3.4**		**2.0-3.8**		**2.0-4.2**	
Parameter	**Value**	**Error**	**Value**	**Error**	**Value**	**Error**
A	4.19	1.7	9.63	3.46	11.24	4.98
B_1	-21.2	7.4	-44.9	14.5	-51.9	20.81
B_2	37.4	11.2	74.2	21.9	85.29	31.53
B_3	-27	7.3	-51.4	14.3	-58.9	20.59
B_4	6.81	1.7	12.7	3.4	14.5	4.9

Table 4: *Mean before and after Gaussian fit for Pb+Pb collisions*

Eta Windows	**<Nγ>**	**Mean**	**RMS**	**X^2/ndf**	**Mean After Gaussian fit**	**Sigma**
2.0---3.4	157.5	0.9984	0.1430	0.8230E-02/7	0.9997	0.1414
2.0---3.8	312.8	0.9989	0.1289	0.2935E-01/7	1.003	0.1250
2.0--4.2	433.7	0.9985	0.1224	0.315E-01/5	1.001	0.1194

Table 5: *Mean before and after Gaussian fit for Pb+Au collisions*

Eta Windows	<Nγ>	Mean	RMS	X^2/ndf	Mean After Gaussian fit	Sigma
2.0---3.4	166.6	0.9975	0.178	0.255E-01/7	0.998	0.132
2.0---3.8	342.1	0.9899	0.1400	0.1109E-01/6	0.999	0.13
2.0---4.2	565.9	0.992	0.1401	0.1812E-01/6	1	0.13

Table 6: *Mean before and after Gaussian fit for Au+Au collisions*

Eta Windows	<Nγ>	Mean	RMS	X^2/ndf	Mean After Gaussian fit	Sigma
2.0---3.4	168.05	0.9927	0.1488	0.1345E-01/5	0.9823	0.16
2.0---3.8	391.5	0.9981	0.1191	0.1575E-01/4	1.000	0.175
2.0--4.2	608.4	0.9969	0.1078	0.1859E-01/4	0.991	0.146

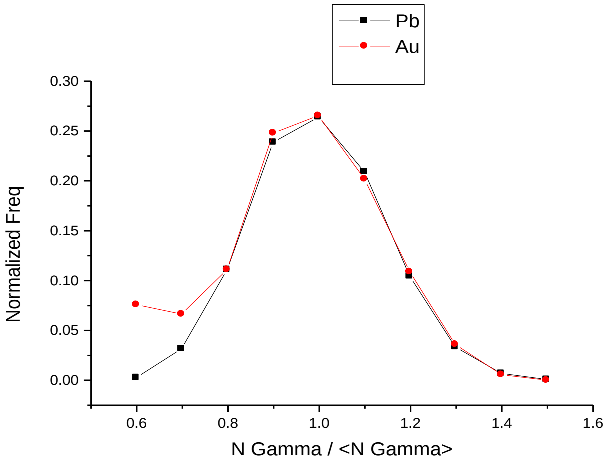

Figure 1: *Normalized photon multiplicity for 2.0-3.4 Eta windows*

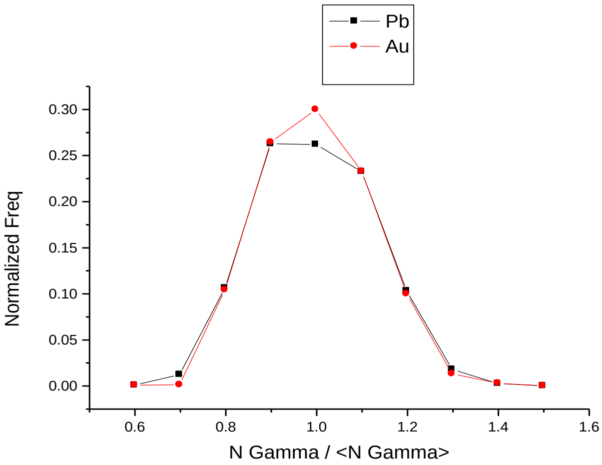

Figure 2: *Normalized photon multiplicity for 2.0-3.8 Eta windows*

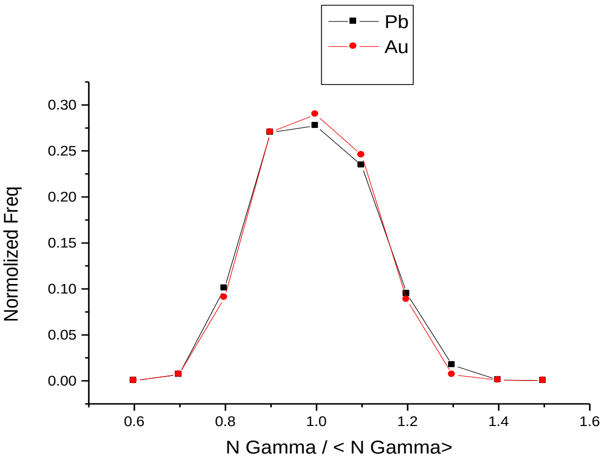

Figure 3: *Normalized photon multiplicity for 2.0-4.2 Eta windows*

5. Conclusions

The normalized photon multiplicity distributions for two targets and three windows are fitted to polynomials of 4th order; the fitted parameters are given in Tables 1,2 and 3. The data for each window and two targets along with polynomial fit are represented by Figure 4-6. Based upon the Tables and Figures we can say that multiplicity distributions are similar; except for small differences which may be of statistical in nature. This analysis also supports the hypothesis that geometrical aspects play a dominant role in particle production in heavy ion interactions.

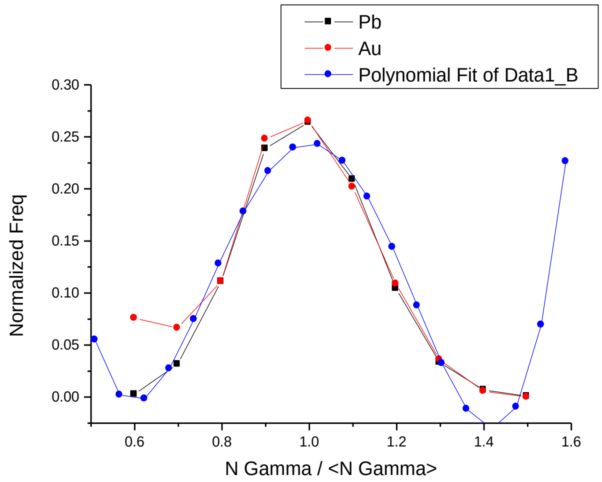

Figure 4: *Normalized photon multiplicity for 2.0-3.4 Eta windows with polynomial fit*

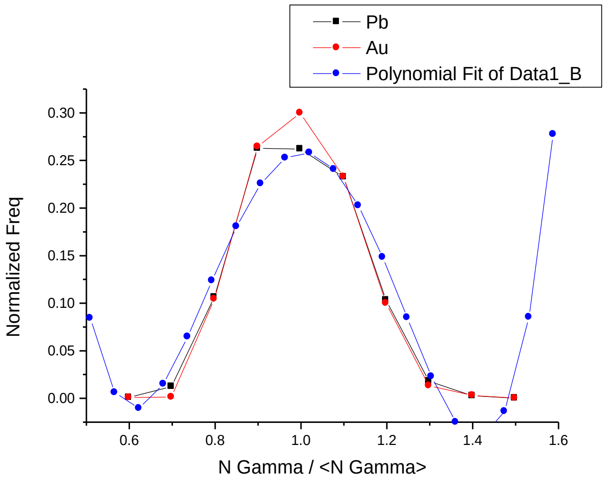

Figure 5: *Normalized photon multiplicity for 2.0-3.8 Eta windows with polynomial fit*

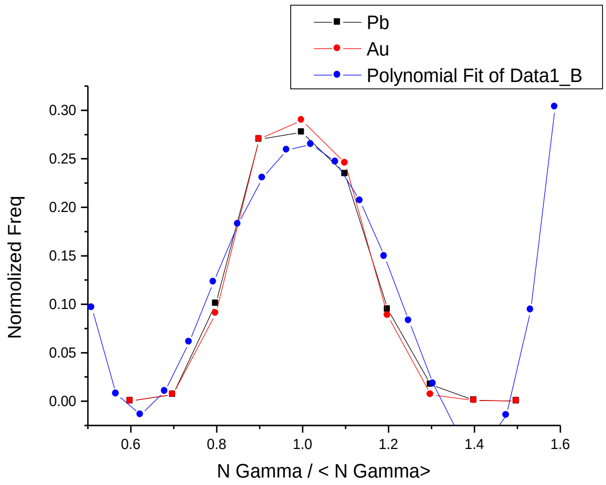

Figure 6: *Normalized photon multiplicity for 2.0-2.4 Eta windows with polynomial fit*

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