First Results from Photon Multiplicity Detector at RHIC

B. Mohanty (for STAR Collaboration\(^1\))
Variable Energy Cyclotron Centre, 1/AF, Bidhan Nagar, Kolkata - 700064
E-mail: bmohanty@veccal.ernet.in

Abstract. We present the first measurement of multiplicity and pseudorapidity distributions of photons in the pseudorapidity region \(2.3 \leq \eta \leq 3.7\) for different centralities in Au + Au collisions at \(\sqrt{s_{NN}} = 62.4\) GeV. The pseudorapidity distribution of photons, dominated by neutral pion decays, has been compared to those of identified charged pions, photons, and inclusive charged particles from heavy ion and nucleon-nucleon collisions at various energies. Scaling of photon yield with number of participating nucleons and limiting fragmentation scenario for inclusive photon production has been studied.

1. Introduction
Inclusive charged particle multiplicity measurements at RHIC have so far revealed a lot of information on the nature and dynamics of particle production in heavy ion collisions \([1, 2]\). It has been observed that the charged particle pseudorapidity density at mid rapidity scales with the number of participating nucleons and the number of collisions. However, the total charged particle multiplicity is found to scale with number of participant nucleons only. Limiting fragmentation (LF) \([3]\) behaviour of inclusive charged particles have been studied at RHIC. It has been observed that inclusive charged particles follow a energy independent and centrality dependent limiting fragmentation scenario \([1, 2]\). It will be interesting to study the above physics aspects with inclusive photon multiplicity measurements \([4]\) at RHIC. In this paper we present the first photon multiplicity measurements in the forward rapidity at RHIC for the Au + Au collisions at \(\sqrt{s_{NN}} = 62.4\) GeV in the STAR experiment.

2. Experiment and data analysis
The photon multiplicity measurements were done in the STAR experiment \([5]\) at RHIC by a highly granular gas based photon multiplicity detector (PMD) in pseudorapidity region \(2.3 \leq \eta \leq 3.7\). The details of the construction and design of PMD can be found in the following Ref. \([6]\). The data presented here corresponds to 0 to 80% of Au+Au hadron cross section. The minimum bias trigger was obtained from the information of the following trigger detectors. An array of scintillator slats arranged in a barrel surrounding the Time Projection chamber (TPC), called central trigger barrel (CTB), which measures charged particles and two zero degree hadronic calorimeters (ZDCs) at \(\pm 18\) m from the detector center \([7]\). The charged particles from TPC

\(^1\) Complete author list can be found at the end of this proceeding.
| η | < 0.5 was used for the centrality selection for data and simulation in the present paper.

![Figure 1](image1.png)  ![Figure 2](image2.png)

**Figure 1.** Minimum bias $N_{\gamma}$ distribution. Comparison with HIJING and AMPT models are shown. The solid curve is the fit to a Gaussian.

**Figure 2.** $dN_{\gamma}/d\eta$ for various event centrality classes compared to HIJING and AMPT model calculations.

In the present analysis, only the data from the preshower plane of the PMD has been used. The data analysis proceeded through the following steps: (a) Calibration of gain of all cells of PMD, (b) clustering of hits on PMD and (c) photon-hadron discrimination. Details of each of the above steps of analysis can be found in Ref. [4].

### 3. Results

#### 3.1. Multiplicity and Pseudorapidity distributions

Fig. 1 shows the minimum bias distribution of $N_{\gamma}$ along with results from HIJING [8] and AMPT [9] models. We observe that HIJING underpredicts the measured photon multiplicity. AMPT slightly overpredicts the total measured photon multiplicity for central collisions. However, within the systematic errors [4] it is difficult to make a firm conclusion. The top 5% central multiplicity distribution (open circles) is fitted to a Gaussian with a mean of 252.

Fig. 2 shows the pseudorapidity distribution of photons for various event centrality classes. The errors shown are systematic and statistical. The results from HIJING are systematically lower compared to data for mid-central and peripheral events. The results from AMPT compare well to the data.

#### 3.2. Scaling of photon multiplicity with number of participating nucleons

Fig. 3 shows the variation of total number of photons per participant pair in the PMD coverage as a function of the number of participants. $N_{\text{part}}$ is obtained from Glauber calculations [10]. We observe that the total number of photons per participant pair is approximately constant with centrality. The values from HIJING are lower compared to the data. The values from AMPT agree fairly well with those obtained from the data.

#### 3.3. Limiting fragmentation scenario for photons

Fig. 4 compares the photon spectra in Au + Au collisions at $\sqrt{s_{NN}} = 62.4$ GeV, with the top SPS energy photon data for Pb + Pb collisions [11] and charged particle data at $\sqrt{s_{NN}} = 130$ and
200 GeV [1, 2] for Au+Au as a function of $\eta - y_{beam}$ for central collisions. The SPS and RHIC photon results are consistent with each other, suggesting that photon production follows the LF behavior. However, the photon multiplicity values are lower compared to charged particles.

In Fig. 5 we study the centrality dependence of the LF behavior for inclusive photons and compare the photon spectra with those for charged particles. In the forward $\eta$ region, the photon production cross section as a function of $\eta - y_{beam}$ is independent of centrality. The dependence of LF spectra on the collision system is established by the comparison of charged particles spectra from $pp$ and $p\bar{p}$ collisions at $\sqrt{s_{NN}} = 53$ and 200 GeV, respectively, and $\gamma$ at 546 GeV [12]. We observe that the photon results in the forward rapidity region from $p\bar{p}$ collisions at $\sqrt{s_{NN}} = 546$ GeV are in close agreement with the measured photon yield in Au+Au collisions at $\sqrt{s_{NN}} = 62.4$ GeV within the LF scenario.

Fig. 6 shows the total charged pion rapidity density from SPS [13] and scaled photon rapidity density at $\sqrt{s_{NN}} = 62.4$ GeV as a function of $y - y_{beam}$. HIJING calculations indicate that about 93-96% of the photons are from $\pi^0$ decays. The photon results in Fig. 6 have been scaled down accordingly to reflect approximately twice the $\pi^0$ spectrum. The results show that pion production in heavy ion collisions in the fragmentation region agrees with the LF picture.

**4. Summary**

In summary, we have presented the first results of photon multiplicity measurements at RHIC in the pseudorapidity region $2.3 \leq \eta \leq 3.7$. The pseudorapidity distributions of photons have been obtained for various centrality classes. Photon production per participant pair is found to be approximately independent of centrality in this pseudorapidity region. Comparison with photon and charged pion data at RHIC and SPS energies shows, for the first time in heavy ion collisions, that photons and pions follow an energy independent limiting fragmentation behavior, as has been previously observed for inclusive charged particles. However photons, unlike charged particles, follow a centrality independent limiting fragmentation scenario.
Figure 5. Centrality dependence of limiting fragmentation for inclusive photons and charged particles. Comparison to \( p\bar{p} \) and \( pp \) collisions. The error bars shown are systematic errors.

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