RESULTS FROM THE PHOBOS EXPERIMENT ON Au+Au COLLISIONS AT RHIC

KRZYSZTOF WOZNIAK
Institute of Nuclear Physics
ul. Kawiory 26A, 30-055 Kraków, Poland
E-mail: krzysztof.wozniak@ifj.edu.pL

for the PHOBOS Collaboration
B.B.Back[1], M.D.Baker[2], D.S.Barton[2], S.Basilev[5], R.Baum[8],R.R.Betts[1,7], A.Białas[4], R.Bindel[8], W.Bogucki[3], A.Budzanowski[3], W.Busza[5], A.Carroll[2], M. Ceglia[2], Y.-H.Chang[6], A.E.Chen[6], T.Coghen[3], C. Conner[7], W.Czyż[4], B.Dąbrowski[3], M.P.Decowski[5], M.Despet[3], P.Fita[5], J.Fitch[5], M.Friedl[5], K.Gałuszka[3], R.Ganz[7], E.Garcia-Solis[8], N.George[1], J.Godlewski[3], C.Gomes[5], E.Griesmayer[5], K.Gulbrandsen[5], S.Gushue[2], J.Halik[3], C.Halliwell[7], P.Haridas[5], A.Hayes[9], G.A.Heintzelman[2], C.Henderson[5], R.Hollis[7], R.Hołyński[3], B.Holzman[7], E.Johnson[9], J.Kane[5], J.Katzy[5,7], W.Kita[3], J.Kotuła[3], H.Kraner[2], W.Kucewicz[7], P.Kulinich[5], C.Law[5], M.Lemler[3], J.Ligocki[3], W.T.Lin[6], S.Manly[9,10], D.McLeod[7], J.Michałowski[3], A.Mignerey[8], J.Mülmenstädt[5], M.Neal[5], R.Nouicer[7], A.Olszewski[2,3], R.Pak[2], I.C.Park[9], M.Patel[5], H.Pernegger[5], M.Plesko[5], C.Reed[5], L.P.Remsberg[2], M.Reuter[7], C.Roland[5], G.Roland[5], D.Ross[5], L.Rosenberg[5], J.Ryan[5], A.Sanzgiri[10], P.Sarin[5], P.Sawicki[3], J.Scaduto[2], J.Shea[8], J.Sinacore[2], W.Skulski[9], S.G.Steadman[5], G.S.F.Stephans[5], P.Steinberg[2], A.Strączek[3], M.Stodulski[3], M.Stręk[3], Z.Stopa[3], A.Sukhanov[2], K.Surowiecka[5], J.-L.Tang[6], R.Teng[9], A.Trzupek[3], C.Vale[5], G.J.van Nieuwenhuizen[5], R.Verdier[5], B.Wadsworth[5], F.L.H.Wolfs[9], B.Wosiek[3], K.Woźniak[3], A.H.Wuosmaa[1], B.Wysłouch[5], K.Zalewski[4], P.Żychowski[3]

[1] *Physics Division, Argonne National Laboratory,* [2] *Chemistry and C-A Departments, Brookhaven National Laboratory,* [3] *Institute of Nuclear Physics, Poland,* [4] *Department of Physics, Jagellonian University, Poland,* [5] *Laboratory for Nuclear Science, Massachusetts Institute of Technology,* [6] *Department of Physics, National Central University, Taiwan,* [7] *Department of Physics, University of Illinois at Chicago,* [8] *Department of Chemistry, University of Maryland,* [9] *Department of Physics and Astronomy, University of Rochester,* [10] *Department of Physics, Yale University*

PHOBOS is one of four experiments studying the Au-Au interactions at RHIC. The data collected during the first few weeks after the RHIC start-up, using the initial configuration of the PHOBOS detector, were sufficient to obtain the first physics results for the most central collisions of Au nuclei at the center of mass energy of 56 and 130 AGeV. The pseudorapidity density of charged particles near midrapidity is shown and compared with data at lower energies and from pp and $p\overline{p}$ collisions. The progress of the analysis of the data is also presented.

1 Introduction

In June 2000 the Relativistic Heavy Ion Collider (RHIC) in Brookhaven National Laboratory became operational and delivered first collisions of gold nuclei at the center of mass energy several times larger than that available from accelerators so far. This opened a new frontier in particle physics, with a potential to study the behavior of strongly interacting matter under the conditions of extreme energy densities. Theoretical predictions of creation of the Quark-Gluon Plasma (QGP) define the main goal for all RHIC experiments: search for this new state of matter.

PHOBOS experiment was designed to measure global properties of the Au+Au interactions (multiplicity and angular distribution of charged particles in almost full solid angle) and combine them with detailed data on particles emitted at large angles, which may carry information on the early stage of the interaction. This enables to correlate the total multiplicity and centrality of the collision with several proposed QGP signals (particles ratios, transverse momentum distribution, fluctuations).

2 The PHOBOS experiment

The PHOBOS detector [1] consists of three main subsystems: the multiplicity detector, the spectrometer extended by a time of flight wall (TOF) and the trigger system (Fig. 1).

The multiplicity detector, covering almost full solid angle, is divided into octagonal, barrel like, part surrounding the nominal interaction point and six rings placed along the beam pipe on both sides of the interaction point. Above and below the nominal interaction point a part of the octagonal multiplicity detector is substituted by top and bottom vertex detectors used to precise measure the interaction point.

The two arm spectrometer consists of several layers of silicon sensors placed inside a conventional magnet (2 Tesla field). It covers pseudorapidity range approximately between 0 and 2 and about $10°$ in azimuth (each arm). Using the information from the spectrometer on particles trajectories and the ionization energy losses we can measure momenta of charged particles and identify them.

The trigger system consists of two identical sets of counters placed on both sides of the interaction point. The scintillator paddle counters (PP and PN) detect charged particles emitted in pseudorapidity range 3-4.5 and the Zero Degree Calorimeters (ZDCP and ZDCN) measure the energy deposited by spectator neutrons from the colliding nuclei.

During the first few weeks of RHIC running only a part of the PHOBOS

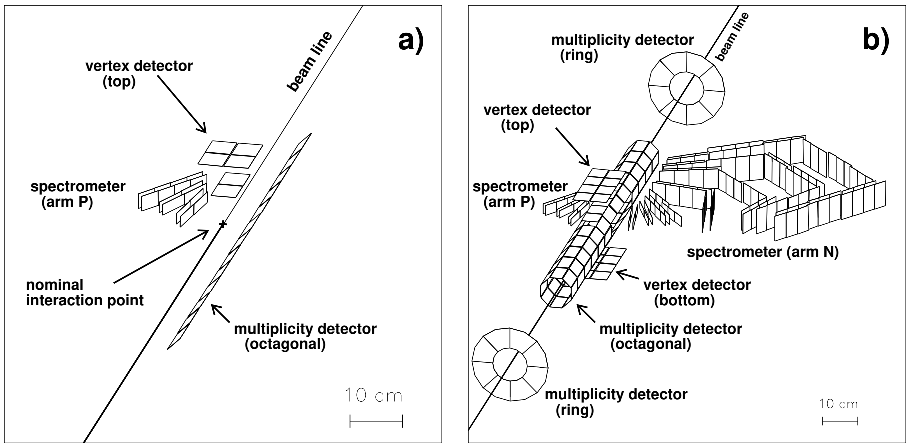

Figure 1: Comparison of the initial (a) and final (b) detector set-up during the RHIC 2000 run. Only active elements in central part of the detector are shown, more distant elements (trigger counters, TOF and 4 out of 6 ring multiplicity detectors) are not visible.

detector was installed and the magnet was switched off. Trigger system was operational from the very beginning but only a small fraction of silicon sensors was present (Fig. 1a). As the highest luminosity was achieved at the end of the RHIC run, almost all of 3.5 million events collected by PHOBOS were measured with the later detector set-up.

3 Selection of central events

The PHOBOS trigger is sensitive both to neutral fragments of interacting projectile nuclei registered in ZDC and to produced charged particles detected by paddle trigger counters. To reject the background, mostly from the beam-gas interactions, we require coincidence of the signals from at least one particle in each of the two paddle counters. For the events with low or moderate number of hits in paddle counters a coincidence of the signals in the ZDC counters is also demanded.

Each of 16 scintillator counters in PP and PN registers also the energy deposited by charged particles and the total signal in paddle trigger counters is proportional to the number of particles produced in the Au+Au collision. We extract the most central events by selecting 6% of the events with largest total signal in PP and PN. For the first physics analysis [2] we used only the data measured with the initial detector setup. Two samples of central events, 382 events at $\sqrt{s_{nn}} = 56$ GeV and 724 events at $\sqrt{s_{nn}} = 130$ GeV were analyzed.

The centrality of the nucleus-nucleus collision can be characterized by the number of nucleons participating in the interactions. Using detailed description of the detector and GEANT based simulation program we are able to reproduce satisfactorily the detector response for the generated Au+Au collisions (from HIJING generator [3]). The MC events with largest simulated signal in the paddle counters selected by 6% cut are indeed the most central ones. The distribution of the number of participating nucleons, N_{part}, for MC events is restricted to highest values (Fig. 2). We can estimate the mean number of participating nucleons with about 5% systematic uncertainty (Table 1).

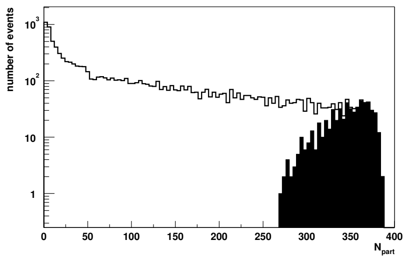

Figure 2. Distribution of the number of nucleons participating in the Au+Au collisions for inclusive (histogram) and central HIJING events (shaded area).

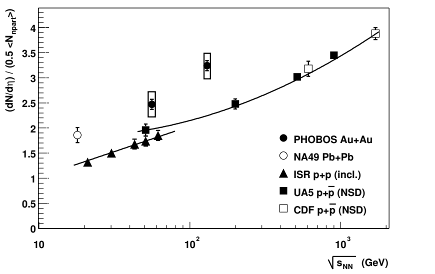

Figure 3. Charged particles pseudorapidity density normalized per participant pair. For PHOBOS systematic uncertainties are shown as boxes around data points.

4 Charged particle multiplicity near mid-rapididty

For both central event samples we performed reconstruction of the straight line tracks passing at least 4 layers of the spectrometer. The position of the primary collision vertex was then determined as the point of closest approach of the found tracks. We further restricted our analysis to the events with reconstructed vertex positions within -25< z_{vtx} <15 cm from the nominal collision point along the beam direction.

To measure the charged particle multiplicity, pairs of hits in two consecutive layers of spectrometer or vertex detector, consistent with a track emitted from the collision vertex, were formed (tracklets). The relation between the number of tracklets and the number of primary charged particles is approximately linear and was derived applying the same reconstruction procedure to the MC events processed by GEANT based simulations of PHOBOS detector. The proportionality factors $\alpha(z_{vtx})$ agree better than 5% for the MC events obtained from HIJING and VENUS [4], eventhough the total multiplic-

Table 1: Charged particle pseudorapidity density for central events.

	$\sqrt{s_{nn}}$ = 56 GeV	$\sqrt{s_{nn}}$ = 130 GeV
$< N_{part} >$	330 ±4 (stat.) $^{+10}_{-15}$ (syst.)	343 ±4 (stat.) $^{+7}_{-14}$ (syst.)
$dN/d\eta\|_{\|\eta\|<1}$	408 ±12 (stat.) ±30 (syst.)	555 ±12 (stat.) ±35 (syst.)
$\frac{dN/d\eta\|_{\|\eta\|<1}}{0.5<N_{part}>}$	2.47 ±0.1(stat.) ±0.25(syst.)	3.24 ±0.1(stat.) ±0.25(syst.)

ities in these models differ by a factor 2-3. The extracted values of $\alpha(z_{vtx})$ contain corrections for the tracklets finding inefficiency, contributions from secondary particles, decay products and noise hits, stopping of primary particles in the beam pipe and, the most important, geometrical acceptance. Overall systematic uncertainty of $\alpha(z_{vtx})$ is less than 8%. Integrated values of the charged particle pseudorapidity density in the η range -1 to 1, $dN/d\eta|_{|\eta|<1}$, are given in Table 1. The densities normalized per pair of participant nucleons, $(dN/d\eta|_{|\eta|<1})/(0.5 < N_{part} >)$ are directly compared to results obtained in other experiments [5,6,7] (Fig. 3). For central Au+Au collisions we observe a significantly larger particle density per participant pair than for pp or $p\overline{p}$ interactions at similar energies. The increase of the particle density in nucleus-nucleus collisions with energy is also faster than in elementary interactions. At RHIC energies, $\sqrt{s_{nn}}$ = 56 GeV and 130 GeV, this increase is 31%. The presented results impose restrictions on particle production models, ruling out simple superposition models [8].

5 Work in progress

The first results presented in the previous section were obtained using only a small fraction of the data collected by PHOBOS. Analysis of the full data set collected later with the complete detector set-up will provide much more detailed information on the properties of Au+Au collisions. The normalized charged particle densities can be measured in a wide range of N_{part}, also for semi-peripheral collisions for which some models give significantly different predictions [9] (Fig. 4). With a complete arm N of spectrometer placed in the magnetic field we can measure particle momenta and identify them (Fig. 5) and thus obtain anti-particles to particles ratios. Using full multiplicity detector we can measure pseudorapidity density of primary particles in 11 rapidity units. Data from multiplicity detector will be used to study elliptic flow of charged particles and fluctuations in angular distribution.

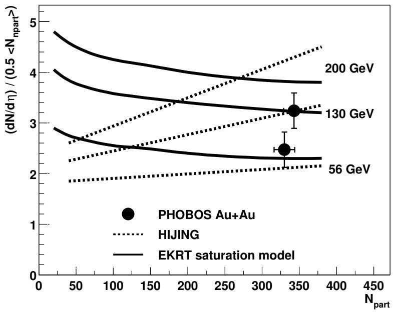

Figure 4. Dependence of the charged particle pseudorapidity density on the centrality of the Au+Au collision for HIJING model and EKRT saturation model.

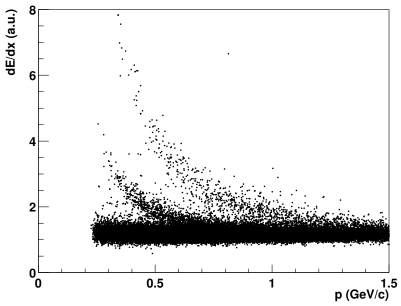

Figure 5. Identification of the particles in PHOBOS spectrometer. Proton and kaon bands start to separate from horizontal pions band at about 1.1 and 0.6 GeV/c respectively.

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References

1. B.Back *et al.*, (PHOBOS), Nucl. Phys. **A661** (1999) 690.
2. B.B.Back *at al.*, (PHOBOS), Phys. Rev. Lett. **85** (2000) 3100.
3. M.Gyulassy and X.N.Wang, Phys. Rev. **D44** (1991) 3501.
4. K.Werner, Phys. Rep. **232** (1993) 87.
5. J.Bächler et al., Nucl. Phys. **A661** (1999) 45.
6. W.Thome et al., Nucl. Phys., B129 (1977) 365.
7. F.Abe et al., Phys. Rev. **D41** (1990) 2330.
8. A.Białas, B.Bleszyński and W.Czyż, Nucl. Phys. **B111** (1976) 461.
9. X.N.Wang and M.Guylassy, nucl-th/0008014 (2000).