Chapter 3

Detector Overview

In this chapter we present the design of the BRAHMS experimental setup which will measure inclusive and semi–inclusive $p^{\pm}$, $\pi^{\pm}$, and $K^{\pm}$ spectra in the pseudorapidity interval $0 \leq \eta \leq 4$ ($2^{\circ} \leq \theta_{lab} \leq 90^{\circ}$). The quite different experimental conditions at midrapidity and at forward rapidity lead to a natural division into two regions. The region 30°-90° (or 20°-90° for lighter ions) will be measured with a simple, rather short spectrometer covering the momentum region up to 5 GeV/c, while the region from 2° to 30° will be measured with a small solid angle device which can measure momenta and identify particles up to ≈25 GeV/c.

The same technology will be used for detector components in the two spectrometers wherever possible.

Figure 3.1 shows the floor plan of the spectrometers, which are both freely rotating, with the forward arm placed at the 2° angle setting and the mid-rapidity arm placed at 75°. The labeled detector components are described in the following paragraphs. Considerations of rates for inclusive measurements are given in Appendix C.

3.1 Forward Spectrometer

The forward spectrometer arm will contain four magnets, D1–D4, for sweeping and analyzing primary particles emerging from the reaction. In order to fit in the space by the beampipe at the most forward setting of 2°, D1 is of a septum design; in order to bend 25 GeV/c particles, it will have a field of up to 1.2 T. The other magnets, D2–D4, as well as D5 on the midrapidity arm, are of conventional design. All the movements of the magnet platforms will be remotely controlled, and absolutely positioned to better

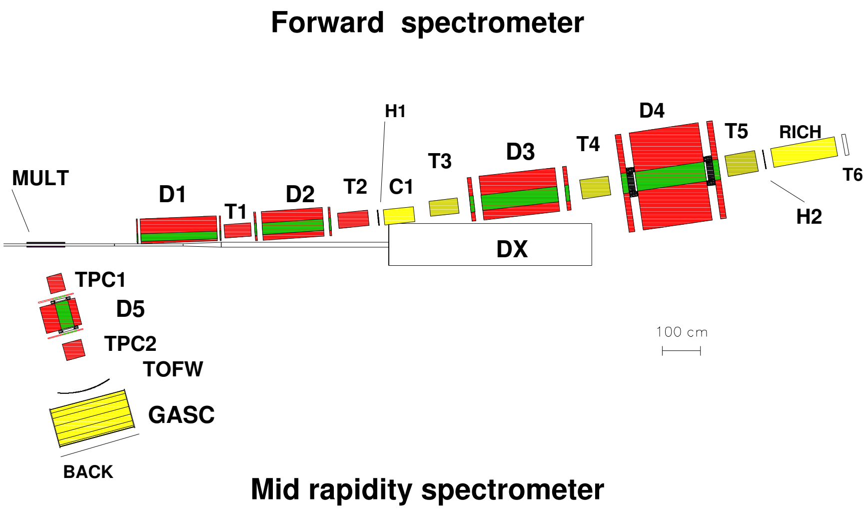

Figure 3.1: Layout of the BRAHMS spectrometers. Both spectrometers are freely rotating: the forward arm is shown at $\theta = 2°$ and the midrapidity arm at 75°. Further details concerning the individual components labeled here are given in the text.

than 1 mm.

The forward arm tracking detectors T1 and T2 are small time projection chambers (TPC's) which provides good three-dimensional track recognition and rejection of background. The TPC's operate outside the magnetic field and have quite small drift distances (≈20 cm) . The requirements for T1 are the most stringent since it has to deal with estimated particle densities up to the order of order 0.2 particles/cm^2. For T2 the estimated number can be up to 0.05 particles/cm^2. The tracking detectors T3–T5 will be conventional drift chambers with $\approx 16 - 22$ planes per detector. The results from recent tracking simulations indicates that T3 might also be a TPC. The positions of tracks are determined locally to better than 0.3 mm and their direction to better than 0.5 mrad.

The lower momentum part of the particle identification for the forward arm is based on two time-of-flight hodoscopes, H1 and H2. Each of the 60 staves (40 for H1 and 20 for H2) will be instrumented with a fast photomultiplier at both ends, with a time resolution of $\sigma \leq 75$ ps. The H1 array at 9 m from the vertex will provide 4σ separation of π and K to 3.3 GeV/c and K/p to 5.7 GeV/c. The H2 array at 20 m, after D4 will have 4σ separation of π/K to 5.0 GeV/c and K/p to 8.5 GeV/c.

High momentum particles will be identified at two places in the forward spectrometer: namely after D2, covering the range of 2.5–6 GeV/c, and behind D4 with coverage from 4 to 25 GeV/c. The first region, behind D2, will be instrumented with a conventional segmented Čerenkov tank, C1. A ring-imaging Čerenkov detector (RICH) with C_4F_{10} as the radiator gas will sit behind H2 to perform K/π separation up to ≈ 25 GeV/c

and K/p separation to much higher momentum. This is accomplished by determining the ring radius with an accuracy of $\Delta r/r \approx 2\%$. A readout scheme using four large (10×10 cm^2), highly segmented photomultiplier tubes will be used for this detector. T6 is a back counter to confirm hits behind the RICH counter.

3.2 Midrapidity Spectrometer

The midrapidity arm is a single-dipole magnetic spectrometer of 8 msr solid angle designed to cover the angular region from $\theta = 30°$ up to $90°$ and to measure and identify particles with momenta in the range of $p \sim 0.2$ GeV/c to 5 GeV/c. The limitation of $30°$ is set by the maximum allowable particle density in the front TPC for central Au-Au events; for lighter beams the spectrometer can cover down to $20°$. The magnet D5 will have a gap of $\sim 10 \times 35$ cm^2 (h$\times$w) at a distance of 190 cm from the nominal interaction point, with the width of the opening chosen so as to accept particles from a significant part of the interaction "diamond".

Since many particles detected behind the magnet arise from decays and secondary interactions, it is necessary to have tracking in front of the magnet. This purpose will be served by a time-projection chamber, TPC1, read out by approximately 1200 pad channels. A second time-projection chamber behind the magnet, TPC2, will have to deal with fewer particles than TPC1, but will be physically larger, resulting in 1000 channels. The front TPC will also provide a vertex determination to approximately 1 mm.

The time-of-flight detection will be done with TOFW, an array of 225 plastic scintillators placed at 4 m. Each element will be 22 cm high with a cross section of 0.6×0.6 cm^2 and will be instrumented with two fast tubes with a time resolution of $\sigma \leq 75$ ps. This will give π/K separation up to 2 GeV/c, and K/p to about 3.5 GeV/c. A pressurized gas Čerenkov threshold detector with segmentation $\approx$15 will give π/K separation up to $\approx$6 GeV/c. This will be augmented with a suitable back counter (BACK) to measure K conversions in the Čerenkov tank.

3.3 Rapidity Coverage

The overall coverage in y-p_t of the spectrometers is shown in Fig. 3.2 for π, K, and p. Such coverage will fully enable the experiment to follow the baryon and meson distributions from the midrapidity region to the onset of the fragmentation region and thus establish strong constraints on the physics at RHIC. The specific acceptance with all the various cuts imposed by the particle identification in y-p_t for pions and kaons using all the PID detectors is described in more detail in the chapter on particle identification. Note that

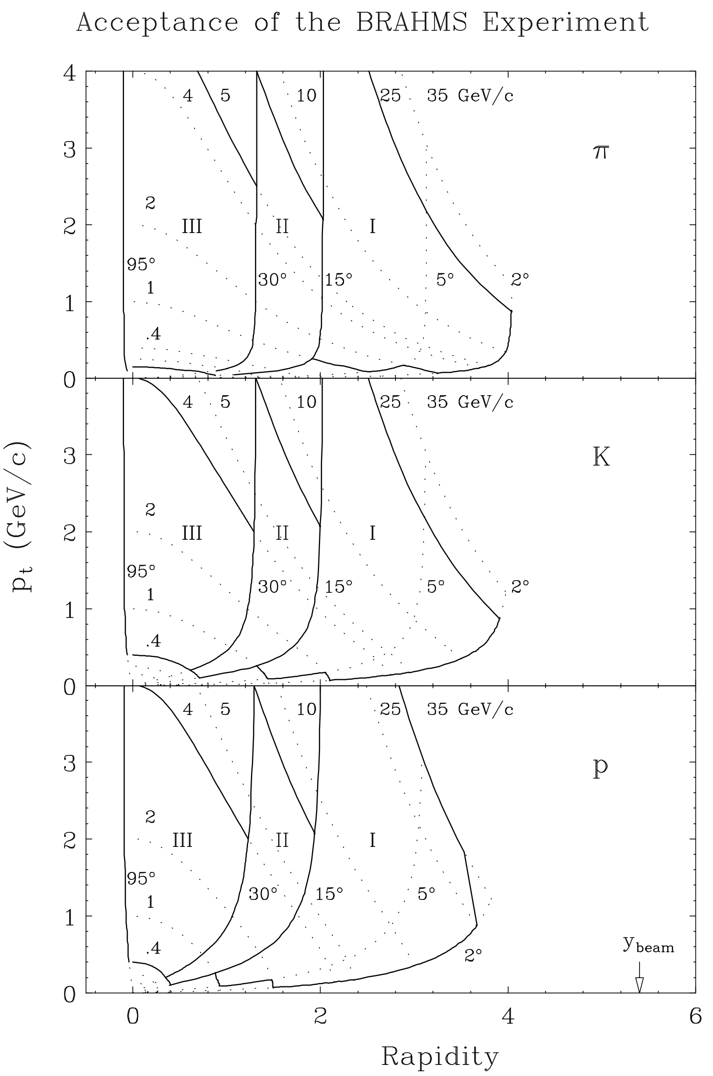

Figure 3.2: Acceptance of BRAHMS experiment for pion, kaon and protons. Region I is measured with the full forward arm, Region II with the D1-D2 complex alone, and Region III with the mid-rapidity arm.

the proton identification does not extend from p=25 GeV/c to 35 GeV/c at the 2° due to a limitation on the bending power of the magnets at that setting.

3.4 Global detectors

A charged-particle multiplicity counter (MULT) with nominal pseudorapidity coverage $|\eta| \leq 2.5$ will provide a global trigger, determining the degree of centrality of the event. The detector will also provide a measure of the $dN/d\eta$ for charged particles. An array of beam-beam counters at 2.25 m backwards and forwards of the beam vertex will provide a start-time for the time-of-flight counters, and will determine the vertex position to roughly 1 cm. The beam-beam counters will provide additional coverage in pseudo-rapidity for the charged particle multiplicity. The beam-beam counters will be phototubes with Čerenkov radiators in front.