BRAHMS MRS Threshold Cherenkov Proposal

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The principal physics goal of the BRAHMS experiment is to explore the dynamics of relativistic heavy-ion reactions and the properties of the highly excited nuclear states formed in these reaction. This is done by measuring spectra of identified particles over a broad range of pseudorapidity and transverse momentum using two magnetic spectrometer arms, one for measuring spectra at forward angles corresponding to the fragmentation region of the reaction, and the second for measuring spectra a mid-rapidity. The high transverse momentum part of the spectrum, with $p_t > 2$ GeV, is particularly important to study since this is the range where the influence of partonic processes are most likely to be seen. Indeed, evidence has been presented for $\sqrt{s_{NN}} = 130\ \mathrm{GeV}$ data of a reduction in the number of hadrons at high transverse momentum near mid-rapidity, thus hinting at a suppression of hadronic jets at high matter densities[2]. Unfortunately, the BRAHMS experiment is currently limited in the range for which particles can be identified at mid-rapidity by the fundamental limitation that the speed of light imposes on the time-of-flight system used for particle identification at these angles.

The overall layout of the BRAHMS experiment is shown in Fig. 1. With the two spectrometer arms, labeled as the Forward Spectrometer (FS) and Mid-Rapidity Spectrometer (MRS) in Fig. 1, we obtain an acceptance plot for identified pions as shown in Fig. 2. Particle identification is accomplished in the forward spectrometer by either time-

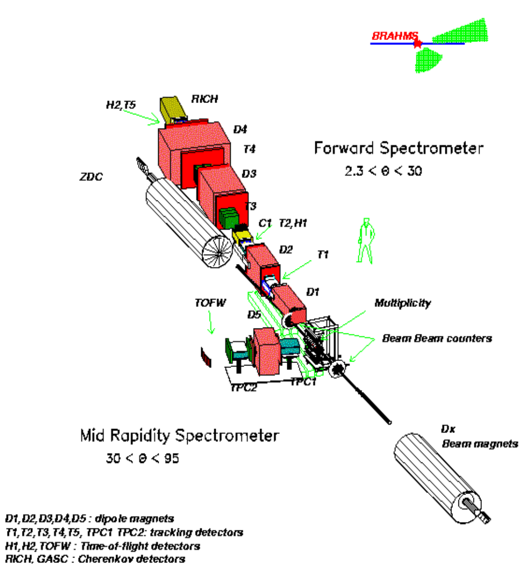

Fig. 1 — Experimental layout of BRAHMS.

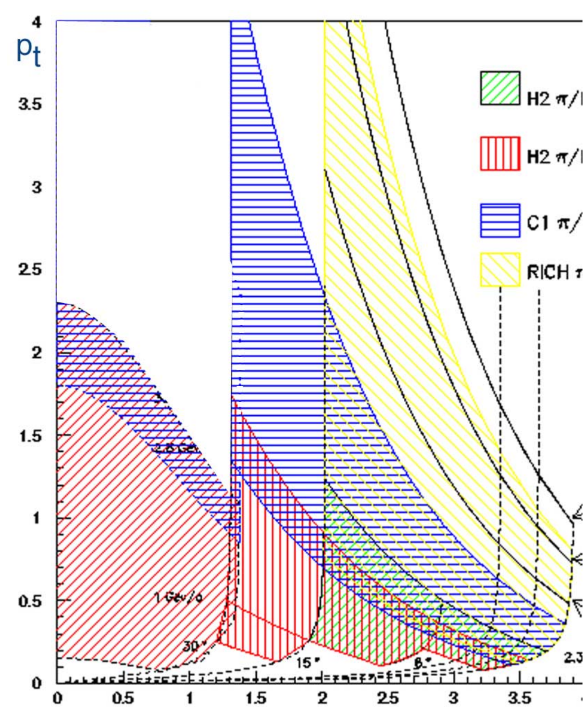

Fig. 2—Current acceptance plot of BRAHMS for π/K separation.

of-flight measurement (H1, H2) or by Cherenkov radiation detection (C1, RICH), with high momentum particles identified using the ring-imaging Cherenkov detector at the end of the FS (RICH). The MRS relies on time-of-flight measurement for particle identification (TOFW), leading to a restricted range in transverse momentum for which identification is possible and preventing us from accumulating spectra of "hard" scattering processes with good particle identification.

We have been exploring what we believe will be a highly cost effective program to significantly extend the p_t range at mid-rapidity where we can achieve particle ID. The layout that is currently being considered is shown in Fig. 3. A gas threshold Cherenkov counter (C4) will be located immediately behind the time-of-flight wall (TOFW) of the mid- rapidity spectrometer. This counter will be backed by two additional threshold Cherenkov counters (C5 and C6) using Aerogel radiators of increasing refraction indices. The full angular acceptance of the mid-rapidity spectrometer is preserved. Fig. 4 shows the transverse momentum thresholds for Cherenkov radiation as a function of pseudorapidity for pions, kaons, and protons in the

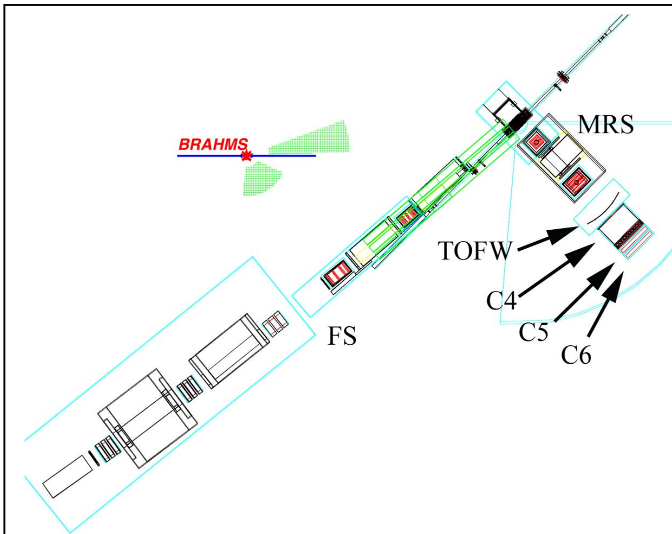

Fig. 3—Proposed layout of new Cherenkov elements (C4-C6) at the back of the MRS. The existing TPFW is also labeled.

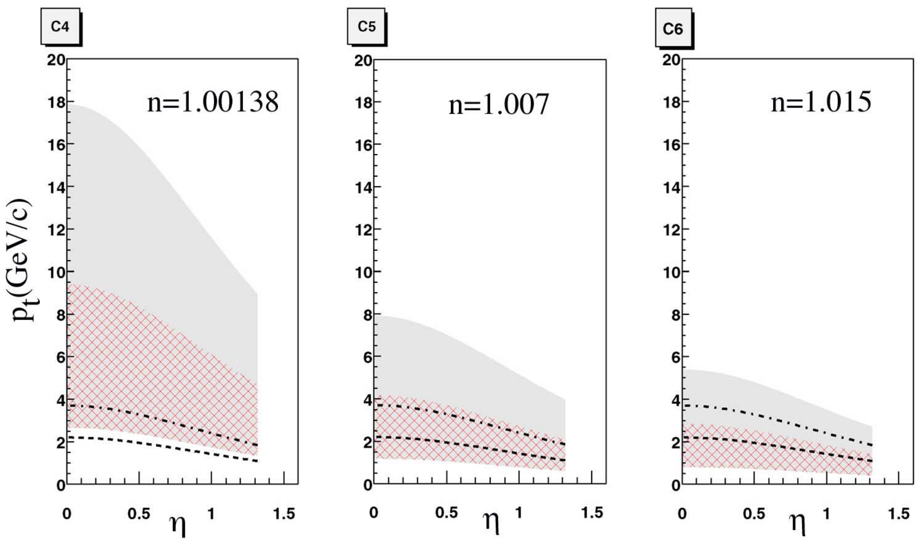

Fig. 4—Particle identification regions for the C4, C5, and C6 threshold Cherenkov detectors. The bottom of the cross hatched region marks the Cherenkov threshold for pions. The top of this region is the kaon threshold, and the top of the solid fill region is the proton threshold. Also shown by the dashed and dot-dashed curves are the limits where π/K and K/p identification can be achieved using the TOFW.

three Cherenkov volumes. The lower edge of the cross hatched regions indicate the threshold for Cherenkov radiation for pions. The upper edge of this region is the kaon threshold and the upper edge of the solid filled region indicates the proton threshold. For each of the three volumes we also indicate the highest p_t value for which π/K (lower, dashed lines) separation and K/p (upper, dash-dot lines) can be achieved using the TOFW.

With this arrangement it should be possible to achieve unambiguous π and kaon identification up to the K threshold in the first, C4, gas volume. For lower p_t values, time-of-flight identification is used. Once π/K identification is no longer possible using time-of-flight, the presence of Cherenkov radiation for the pions and lack of the radiation for the kaons and protons in the C5 volume is used together with the TOFW for π/K/p identification up to the point where K/p separation can no longer be achieved with the TOFW. From this point up to the C5 proton threshold, π/K separation is achieved, with the absence of a signal in C4 and corresponding presence of a signal in first C6 and then C5 signifying a kaon. In this range, the absence of a signal in C4 and C5 (or C6 at the low end of the range) would signify a proton. Although it will not be possible to separate pions from kaons above the C4 kaon threshold, it should be possible to separate protons from the lighter pions and kaons up to the proton threshold in C4. It will not be possible to separate kaons and protons in the limited range between the C5 proton threshold and the C4 kaon threshold.

Fig. 5 shows a possible design for the C4 gas Cherenkov volume that has been incorporated into GEANT for more extensive simulations. Based on simulations using the HIJING event generator for central Au+Au collisions at $\sqrt{s_{NN}} = 130\,\mathrm{GeV}$ we find an event rate for primary pions at mid-rapidity above threshold of 0.4% , with the rate of secondary pions having tracks directed towards the mirrors about half that of the primary rate. Table 1 shows the fraction of each type of particle that the GEANT simulations predicts in the counter. In this table “primary” refers to particles from the interaction vertex that track through the MRS. “Secondary” particles arise from interactions away from the vertex, including interactions within the Cherenkov volume itself. With the segmentation shown in Fig. 5, the probability of an electron or

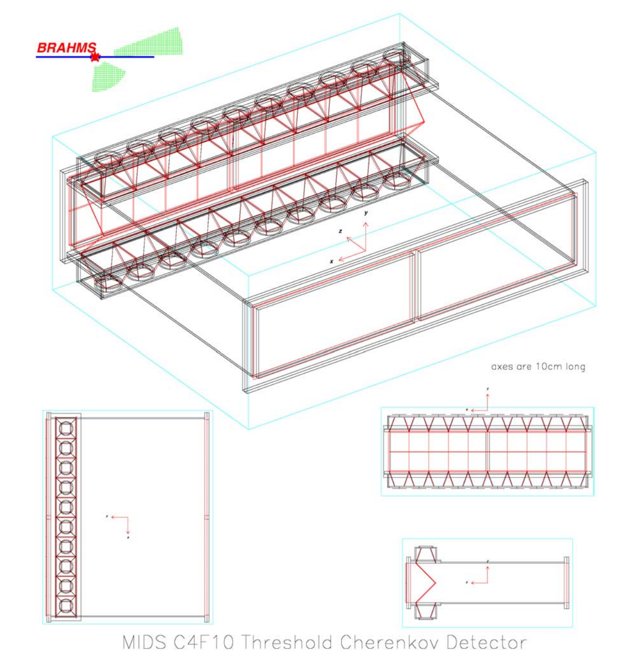

Fig. 5—Initial design study for C4 threshold Cherenkov detector.

	Fractions		Cnts/Event		Cnts/Event/20	
	Primary	Secondary	Primary	Secondary	Primary	Secondary
e+	0.0000	0.3970	0.0000	0.0636	0.0000	0.0032
e-	0.0130	0.5240	0.0001	0.0841	0.0000	0.0042
μ+	0.0000	0.0200	0.0000	0.0032	0.0000	0.0002
μ-	0.0000	0.0140	0.0000	0.0022	0.0000	0.0001
π+	0.3210	0.0120	0.0025	0.0019	0.0001	0.0001
π-	0.3970	0.0140	0.0031	0.0023	0.0002	0.0001
K+	0.0380	0.0000	0.0003	0.0000	0.0000	0.0000
K-	0.0260	0.0000	0.0002	0.0000	0.0000	0.0000
p	0.1410	0.0170	0.0011	0.0027	0.0001	0.0001
pbar	0.0640	0.0000	0.0005	0.0000	0.0000	0.0000
Σ_+	0.0000	0.0010	0.0000	0.0001	0.0000	0.0000
d	0.0000	0.0020	0.0000	0.0003	0.0000	0.0000

Table 1 – Particle yields in C4 detector with tracks directed towards mirrors. Primary/Secondary refers to whether or not the particle is produced at the interaction vertex. The last two columns assume a C4 volume with 20 phototube readout.

positron causing Cherenkov light in a given phototube is ~0.7% per event. Fig. 6 shows a simulation for the expected number of photoelectrons within a typical phototube frequency bandwidth (350 nm – 550 nm) as a function of momentum for pions emitted in a one degree range about 90^o with respect to the beam axis. A quantum efficiency of 20% is assumed. A 90% reflectivity of the mirrors is also assumed. The design shown in Fig. 5 is such that the detector box can be constructed in the Kansas shops, allowing for a significant cost savings. Moreover, the phototubes that would be used in this design are already available at BNL. Smaller phototubes may also be available at BNL, so it may be possible to increase the segmentation, thus helping with the electron background, without significantly increasing the cost. Further study is also needed to decide on an optimal depth for the C4 detector. It is expected that the Aerogel detectors, C5 and C6, will be designed and tested at BNL (R. Debbe) and Texas A&M University (M. Murray). Assuming collaboration support, the construction of the MRS Cherenkov detectors should be completed well before the beginning of the next period of RHIC running in late 2002.

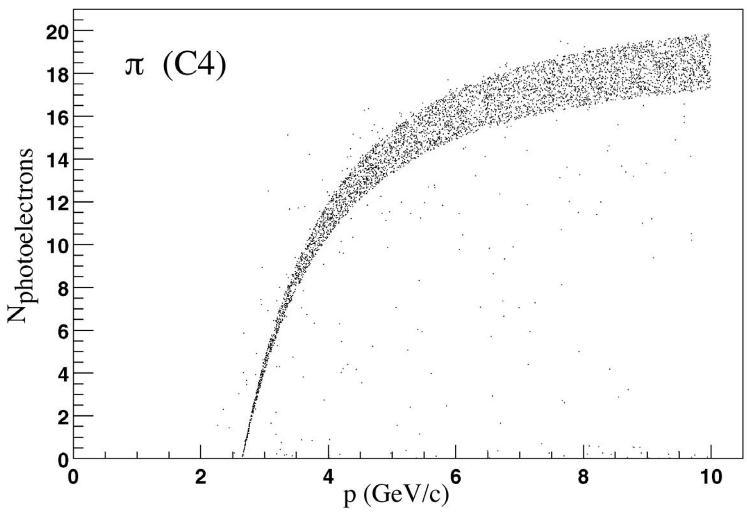

Fig. 6 —Predicted number photoelectrons in the C4 detector. The simulation is for pions emitted within a 1º angular range about 90º with respect to the beam axis

References:

[1] **X. N. Wang and M. Gyulassy, Physical Review D 44, 3501 (1991).**

[2] **K. Adcox and S. S. Adler and N. N. Ajitanand, et al., Physical Review Letters 8705, 2301 (2001).**