Particle Identification in the PHENIX Experiment at RHIC (present and future)

E. Kistenev (for the PHENIX Collaboration) [a]

[a] *Brookhaven National Laboratory, Upton, NY 11973-5000, USA*

The PHENIX[1] detector at the Relativistic Heavy Ion Collider, BNL is designed to perform a broad study of A-A, p-A and p-p collisions to investigate nuclear matter under extreme conditions. The charged particle identification is currently provided for kaons and pions to a momentum of 2.4 GeV/c and protons to 5 GeV/c. These limits would be greatly extended by the now under construction Aerogel Threshold Cherenkov detector (refractive index n=1.012).

1 Charged Particle Identification in the PHENIX Central Arms

The Particle Identification Component of the PHENIX experiment incorporates tracking system (drift- and pad-chambers), Time-of-Flight and Ring Imaging Cherenkov detectors, Time Expansion Chambers and Electromagnetic Calorimeters. The PHENIX ToF subsystem consists of 10 panels of ToF modules with dimensions of 38 cm x 200 cm, each panel houses 96 slats of 1.5 cm x 1.5 cm plastic scintillation counters (Bicron BC404) with 3/4" diameter PMT's attached at both ends[2]. A resolution of 96 ps was already achieved. The primary device for electron identification is RICH[3] - threshold gas Cherenkov detector with a high angular segmentation to cope with the high particle density. RICH can be filled with ethane (pion threshold of $3.5GeV/c$) or CO2 (pion threshold of $4.9GeV/c$. The EMCal system consists of a total of 24768 individual detector modules divided between the Pb-Scintillator calorimeter which provides 75% of azimuthal coverage and Pb-glass calorimeter in the rest of the acceptance. Both energy and timing measurements in EMCal are critical for the electron and photon identification and for the triggering. Time Expansion Chambers contribute both to low momentum hadron (via dE/dx measurements) and to the electron (via TRD measurements) identification.

The exiting new research program which opened up with the discovery[4] of jet quenching[5] requires measuring transverse momentum spectra of identified hadron species above 2 GeV/c currently accessible to PHENIX. To alleviate this problem the Aerogel Čerenkov detector covering the surface area of $\sim 4m^2$ will be installed for the next RHIC run with colliding Au ions. The detector consists of 160 identical cells of a $11 \times 22 \times 20\text{cm}^3$ packaged with aerogel (refractive index of ~ 1.012) to the half of the depth. An empty space in the cell is an integrating box which works following the principles similar to those of a standard "integrating sphere". Cells are built of mylar-Goretex paper laminate where Goretex serves as a diffuse reflector.

2 Performace of the PHENIX Aerogel Detector (test beam results)

A number of prototype aerogel counters differed in the refractive indices of aerogel, configuration of aerogel cells, number, kind and location of the photomultipliers were tested in the test beam lines $\pi2$ and T1 at the KEK proton synchrotron in Japan. The light yield was measured in the configurations shown in the Fig.1. Block of aerogel tiles ($12 \times 12 \times 12$ cm^3 in size, n=1.017) was viewed by two 3" PMT's (R6233 HAMAMATSU, 30% peak quantum efficiency at 420 nm) either in direct contact with aerogel or through the integration box. The total depth of the block (in the direction orthogonal to PMT axis) was adjustable. Light yield dependence on the aerogel block depth is shown in Fig.2. When block is viewed at a center line the light yield is proportional to the total depth of the block up to the maximum depth studied of 26 cm. When light is collected through the integrating box the saturation is reached at around 13 cm depth. In the final design the depth of aerogel compartment is set to 12 cm, the lateral cell size set to double the aerogel tile size (11×22 cm^2), the light collection scheme "via integration box" with two photomultipliers on the narrow sides of the cell facing each other. Fig.3 illustrates light yield uniformity in a such a cell. Light yield per PMT varies less then 30% over the whole cell surface, the total light yield is constant to better then 15%. We observed less then 30% difference between two extreme cell orientations: PMT's downstream or upstream.

Requiring a coincidence between signals from both PMT's in the cell with two photomultipliers sharing in the light collection largely solves the background problem due to charged particle hits in the PMT windows. An additional background rejection will be provided measuring time of the pulses from aerogel counters for which the subnanosecond timing resolution was reached triggering timing discriminator on the first photoelectron (no slewing correction). The measured dependence of the timing peak position in both PMT's on the impact point position is plotted in Fig.4. In this picture time '0' is set equal to measured when signal is due to charged particle hitting PMT window. Hits close to one of the PMT's result in timing nearly 2 ns different as measured by individual PMT's. They are also delayed compared to the direct hit timing

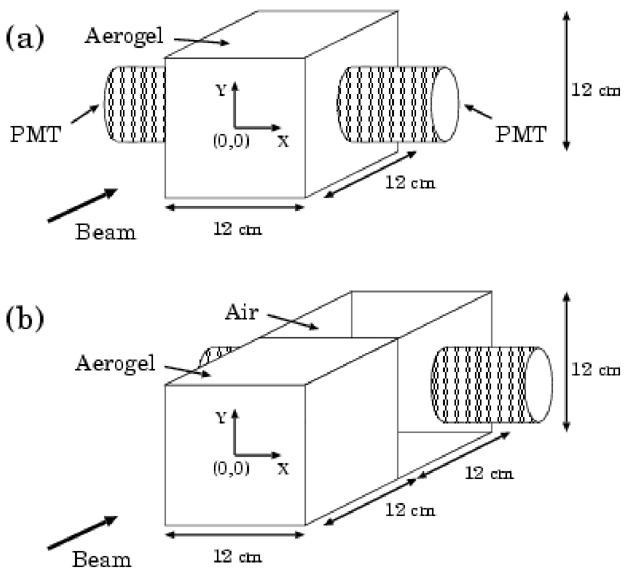

Fig. 1. Schematic drawing of prototypes; (a)PMT's in direct contact with aerogel, (b)Light collection through integration box.

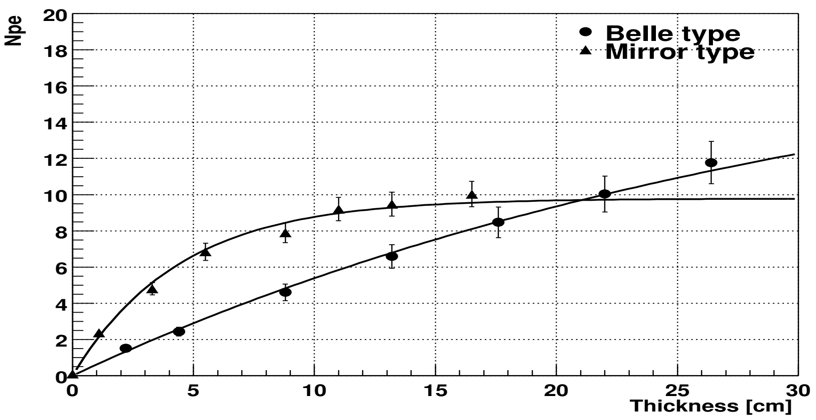

Fig. 2. N_{pe} per PMT as a function of the aerogel block depth. Circles are for the PMT in direct contact with the block at half depth, triangles are the integration box.

by nearly 8 ns.

3 Summary

Particle identification in PHENIX in the current configuration allows for explicit track-by-track identification of pion and kaon up to $\sim 2GeV/c$, and proton up to $\sim 4GeV/c$. Upgrading the system with high granularity Aerogel detector will extend the range for kaon identification to nearly $5GeV/c$.

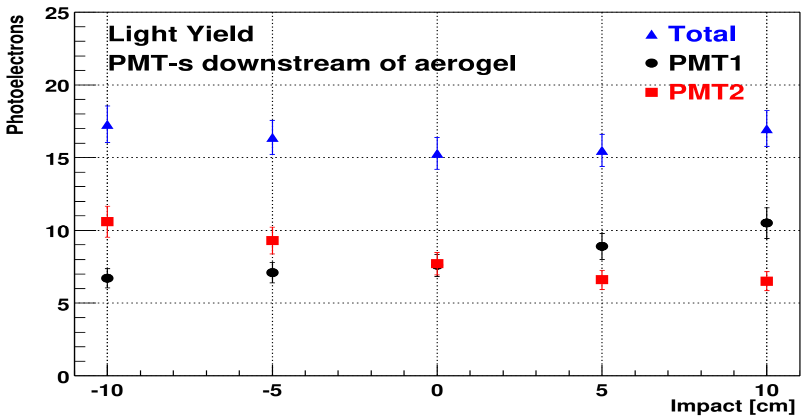

Fig. 3. Light Yield from a single aerogel cell as a function of the impact position in the cell. Data for the cell with PMT's downstream of aerogel are shown.

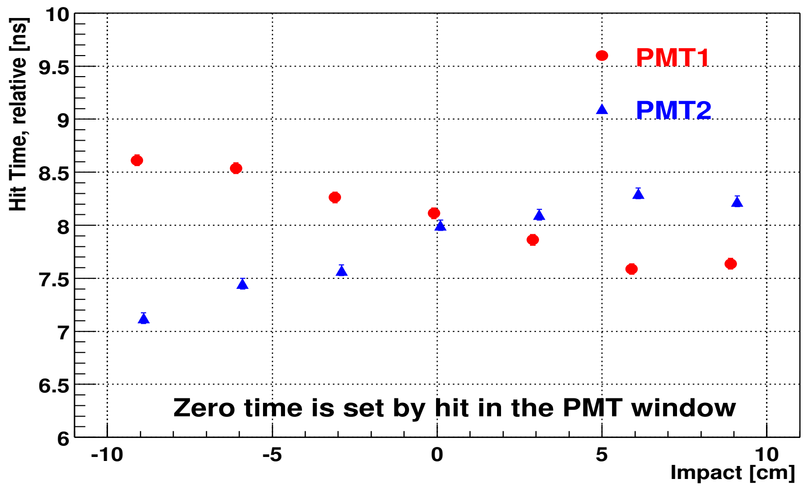

Fig. 4. Timing difference between signals in two photomultipliers as function of the impact point position

References

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