Radiation hardness of the RHIC Zero Degree Calorimeters

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The Relativistic Heavy Ion Collider, RHIC, [1] is designed to reproduce the conditions present in the early universe about one microsecond after the big bang. It does this by Colliding gold ions energies of up to 100GeV/nuclean each. The main luminosity measurement at RHIC will be provided by Zero Degree Calorimeters, ZDCs that measure correlated neutrons emitted along the collision axis due to electromagnetic dissociation. They can also measure non interacting neutrons in central events and thus give information about nuclear stopping. Such neutrons have a very soft emission spectrum, $P_T \approx 100MeV$ and at RHIC will be almost completely contained in a 2mr cone along the beam axis. The calorimeters may also provide information on "beam-gas" background events since their energy deposition should be very asymmetric. By looking at time differences between the two calorimeters the shape and size of the interaction diamond can be mapped out. In order to provide for identical luminosity monitoring and event characterization among the four RHIC experiments it was proposed, [2], to install identical ZDCs in each experiment.

The ZDCs consist of three modules, each two interaction lengths thick. Each module consists of 29 layers of 5mm tungsten plates followed by a ribbon of 0.5mm PMMA fibers. The plates are 187.5mm high and 100mm wide and are tilted at 45 degrees with respect to the beam. A prototype tungsten module was tested at CERN, [3]. The calorimeter modules were intercalibrated with muons. The energy resolution at 100GeV was 20% and the calorimeter response increased linearly with energy. This will give us a good separation between one and two neutrons at RHIC. The time resolution of the first module was 115ps and 229ps in the second module. This implies that the calorimeters should be able to locate z position of the interaction with a resolution of 5cm, which will help reject beam-gas background.

During AuAu running the calorimeters should suffer a radiation dose of 220^{+220}_{-100} Gray/year [4], from electromagnetic dissociation, beam gas and beam-beam interactions. This should cause an attenuation of 2 dB/m according to [5] and may force us to replace the PMMA fibers by quartz ones. The calorimeters may also suffer from "accidental" radiation damage. The tevatron at Fermilab has dumped about 10% of the total beam energy into a single magnet, twice in the last 13 years. This would probably damage the PMMA fiber and tubes as well as the magnet. However in such a case it should be possible to repair the calorimeter within a couple of weeks during which time cause of such a dump would be under investigation.

To understand the effect of radiation

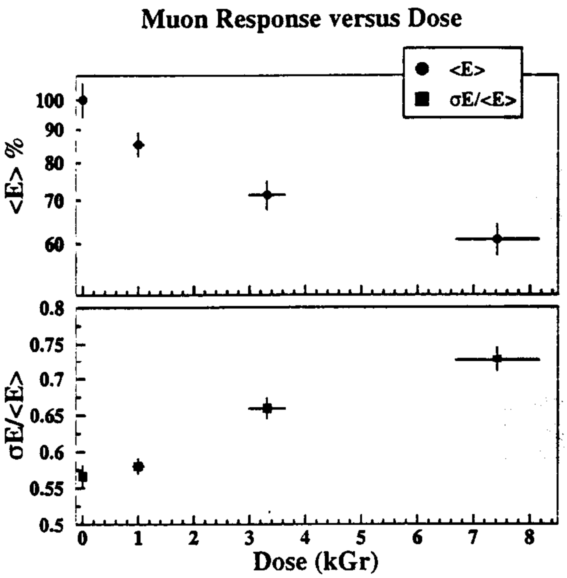

Figure 1: The muon signal and its fractional width versus dose.

damage on the fibers we looked at the signal produced by cosmic ray muons in the calorimeter. The variation in response to cosmic ray muons is less than 3% for the 6 modules constructed at TAMU. A measurement was done before exposing the fibers to radiation and then two measurements were taken after each subsequent exposure. The difference in these two measurements was an estimate of our systematic errors. They were found to be less then 1% of the signal height. Figure 1 shows the effect of radiation dose on the signal produced by muons passing through the fiber bundle. As the dose is increased the mean signal height decreases with the fractional width of the distribution increases. This is because the number of photo-electrons generated by each muon decreases and therefore the relative fluctuations get worse. The dose was approximately 7% neutrons and 25% photons. Note that 1KGy is equivalent to 5 years of RHIC running. After such a dose the the fiber response drops by only 15%. The plastic PMMA fibers needed for the zero degree calorimeters have ample radiation hardness for RHIC.

The central elements of these calorimeters, plastic PMMA fibers were tested at the TAMU reactor and found to have ample radiation hardness for RHIC. The calorimeters have already been installed and will be ready for the start up of RHIC in June. A workable interface between the RHIC controls group and BRAHMS has been developed. The first calorimeter was installed in BRAHMS on March 19th. Both ZDCs will be used in the commissioning run in June of 1999. and they should allow BRAHMS to make several interesting physics measurements as soon as the first AuAu collisions occur at RHIC.

References

[1] "The Relativistic Heavy Ion Collider" www.rhic.bnl.gov

[2] qCal Collaboration, www.rhich.bhl.gov/~swhite/zcal/index.html

[3] S. White et al, www.rhich.bhl.gov/≈swhite/zcal/index.html

[4] A. J. Stevens, *RICH Detector Note* 25, December 1997

[5] J.P. de Brion CEN-Saclay report DPHPE 86-07 (1986)"