Proc. of IVth Int'l. Conf. on Calorimetry in
High Energy Physics, LaBiodola, Elba, Italy
Sept. 27 - Oct. 2, 1993, in press.

PX61
BNL-61511
Conf-9309166--6

The PHENIX Electromagnetic Calorimeter

presented by Sebastian White

E.Kistenev and S.White
Brookhaven National Laboratory
Upton, N.Y. 11973

and

S. Belikov and V. Kochetkov
IHEP, Protvino, Russia

ABSTRACT

The main features of the Phenix EM calorimeter are presented. This is a Pb/scintillator calorimeter with "shish-kebab" fiber readout, designed for low energy electron and photon measurements. Prototype calorimeters have been built with longitudinal segmentation,~ 100 psec time of flight resolution and 8% energy resolution at 1GeV/c. The laser based monitoring system which has been incorporated into large scale prototypes is described. The dependence of light yield on fiber choice and scintillator surface preparation has been studied.

1. INTRODUCTION

Construction of a large (15552 channel) electromagnetic calorimeter for the PHENIX experiment at RHIC will begin during 1994.

The PHENIX experiment at RHIC has been designed to have the capability of studying, simultaneously, many possible signatures of quark-gluon plasma formation within a limited geometric aperture. The measurement of direct (not due to meson decay) photons and electron pairs is a central element in the PHENIX physics program. The main role of the PHENIX EM calorimeter is to make a precision measurement of the energy of electrons and photons.

Since the most central collisions of Au ion beams are expected to produce a very high particle multiplicity (about 700 charged particles per unit rapidity - corresponding to about 200 in the calorimeter area) the calorimeter is highly segmented. The transverse dimension of each calorimeter tower is 5.5cm and the radial distance from the ineraction point is 5.0 m.

The PHENIX experiment is primarily concerned with the measurement of particles of 1 GeV/c momentum or less, hence calorimeter energy resolution is mostly governed by statistical (i.e. 7% from sampling fluctuations @ 1GeV) contributions. Energy independent effects from non-uniformity, etc. are of secondary importance. Also, because of the 5 m. flight path to the calorimeter, a time of flight measurement with 100-200 psec resolution can be used to identify particles on the

*Work performed under U.S. Dept. of Energy contract No. DE-AC02-76CH00016.

basis of their energy and velocity.

Since hadrons will be more copiously produced than electrons, approximately 10^5 rejection against hadrons is required. The PHENIX EM calorimeter provides about a factor of 100 rejection from lineshape alone at 1 GeV/c [1] ,but this tool becomes less effective at lower energies. We studied ways to obtain additional hadron rejection with the calorimeter using both longitudinal shower shape measurement and time of flight measurement[1]. Timing performance of this calorimeter is largely determined by photostatistics, decay constants of the scintillator and waveshifters and by the speed of the phototube.

The maximum radiation dose at the calorimeter is expected to be ≤ 100 rads/yr due to the large distance from the interaction point and the luminosity(particle fluxes are equivalent to a pp luminosity of $10^{30} cm^{-2} s^{-1}$ during heavy ion running). The most radiation sensitive component of our calorimeter is expected to be the waveshifter fiber [2].

2. Construction of the Calorimeter

The calorimeter is built up out of non-projective modules, each segmented into 4 optically independent towers. Each tower is made up of 66 alternating layers of 1.5 mm lead and 4 mm thick injection molded polystyrene based scintillator. On each face of the scintillating plates there is a white paper reflector . This assembly is held under compression by 0.12 mm thick steel sheets that are tack welded to the end plate of the module.

One end plate of the module has an optical fiber connector allowing a specially prepared quartz fiber to be inserted through the center of the module and thereby illuminate ,simultaneously, all scintillator plates in each of the four towers with UV light from the monitoring system (fig. 1).

Each tower is read out by 36 waveshifter optical fibers which penetrate through holes in the scintillator, are bundled in a dry collet, then cut and polished. The light from the 7mm fiber bundle is viewed by a 30 mm diameter vacuum photomultiplier. In most of our tests we have used a 12 stage, green enhanced PMT (average q.e.= 16% @ 500 nm.) developed within the PHENIX collaboration and manufactured in Russia, in other cases we have used a Phillips XP2081B which has similar characteristics.

3. Summary of Calorimeter R&D program during '92-'93

During the last year we focused on the following topics:

- light yield optimization
- monitoring system development
- time of flight optimization and characterization of non-gaussian tails
- longitudinal segmentation
- scintillator tile edge preparation

DISCLAIMER

4.Optical system components

Table 1 summarizes the properties of the waveshifter fibers used in our beam and cosmic ray tests at BNL. BCF99-29a is a waveshifter fiber manufactured by Bicron Corp. using the fast decay constant fluor G-2. It yields a faster risetime pulse from the calorimeter and hence better leading edge time resolution. We requested that the manufacturer make special runs with 1/2 and 2 times the fluor concentration in order to determine the sensitivity of light yield and module uniformity to the fluor concentration.

Fiber	BCF92	BCF99-29a	BCF99-29b	K27
Diameter (mm)	1 and 1.2	1	1	1.2
Core index	1.59	1.59	1.59	1.59
Cladding ind.	1.49	1.49	1.49	1.49/1.42
Fluor	G2, x mg/l	G2, 2x mg/l	G2, 4x mg/l	K27
Decay time (ns)	2.8	2.8	2.8	6.7
L_{att} (m)	3.1	2.67	2.1	2

Table 1: Characteristics of the WLS fibers

The K-27 doped fibers were manufactured at the Institute of Nuclear Research in Moscow and have 2 layers of cladding with outermost index=1.42.

We studied the light yield dependence on waveshifter fluor concentration and fiber diameter using a cosmic ray exposure of a single calorimeter module in which fibers were replaced in successive runs. Typically, the cosmic ray muon peak had a spread of about $\sigma = 13\%$ so the change in average light yield is easily determined.

The results of our measurements are summarized in Table 2. We see a 10% increase in light yield for every factor of 2 in fluor concentration. Module longitudinal non-uniformity increases with fluor concetration but in all cases tested results in less than 0.5% contribution to the enrgy resolution. We plan to use the highest fluor concentration tested. The light yield also increases linearly with fiber diameter and a 1.2 mm diameter has been chosen for the final design.

Fiber type	K27(1.2 mm)	BCF92 (1mm)	BCF99-29a	BCF99-29b
N_{phe}/MIP	268	285	310	342

Table 2: Number of photoelectrons per MIP measured in a segmented module with different WLS fibers

The dependence of the calorimeter light yield on scintillator surface preparation and reflective wrapping has also been studied. White paper reflectors on the scintillator face locally increase the light yield by 12% and can be used to trim the response uniformity. Various edge reflectors ranging from wrappings to vacuum deposited Al coatings have been tried and are being evaluated for total light yield and their effect on tile uniformity. Roughly 20% more light yield can be obtained using edge reflectors. The transverse uniformity of tile response is evaluated for different wrapping configurations by scanning the monitoring system UV fiber accross the midplane of 2 adjacent towers. One such scan is shown in Figure 2 where one tile is paper wrapped and the other is aluminized. Our goal is to achieve $\leq 5\%$ nonuniformity with a point source.

Fig. 1: Monitor Syatem.

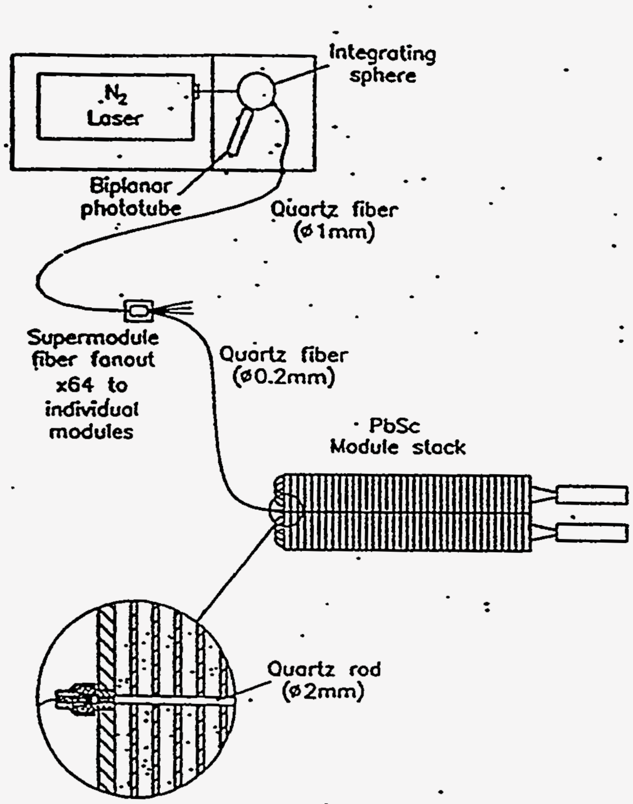
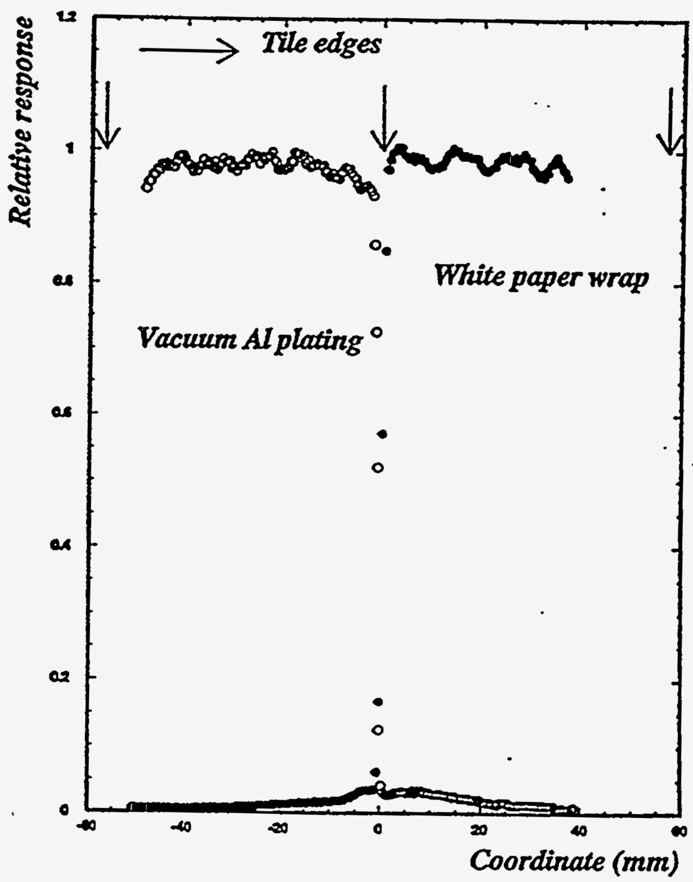


Fig. 2: *Shish-Kebab EMCal - Lateral scan 10/19/93*



5.Monitoring system

Our goal for calibrating the calorimeter is to obtain a 10% initial energy normalization of individual towers, prior to the start of data taking. This initial calibration will be performed either with cosmic ray calibration or with a radioactive source. Because intrinsic variations in scintillator output and coupling to the fibers turn out to be small (typically we find ~3.5% tile-to-tile fluctuation within a calorimeter tower) and since the overall module response averages over many layers, we expect module to module variations to also be small.

The monitoring system is based on a fast pulsed nitrogen laser [3] with peak emission at 337 nm and a 3 nsec wide output pulse. The monitoring system produces a signal in the calorimeter by exciting the scintillator directly. Pusle shape and color spectrum are the same as those produced by electromagnetic showers. The laser output varies by less than 4% and, in our system, this variation is corrected for pulse by pulse by simultaneously observing the light output with a unity gain biplanar phototube (Hamamatsu R1328U).

Our monitoring system has been built into a 256 channel prototype calorimerter currently under test at BNL and was used in smaller arrays during test beam and cosmic ray runs in our lab. Fiber fanouts for the laser light distribution system , including a commercial 72-channel [4] device had up to a factor of 4 variation (max/min) among output channels. Overall efficiency was ~ 30%.

"Leaky fibers" have been made for distributing light inside the calorimeter modules using either 2mm quartz or 1mm PMMA fiber scored along its length.

6. Timing measurement and Longitudinal Segmentation

Measurements of timing resolution, using leading edge timing [1] have shown that hadrons depositing $\geq$ 200 MeV equivalent energy in a calorimeter cell have 200 psec TOF resolution. For electromagnetic showers the resolution decreases further with energy to 100psec. The difference in limiting resolution for electromagnetic showers and penetrating hadrons is completely accounted for by geometrical effects. Since light propagation in the calorimeter has velocity ($\sim \frac{c}{2}$) different from the particle velocity , shower fluctuations lead to an irreducible resolution for normally incident particles.

A further contribution to the timing resolution at the "straight through peak" in our earlier measurements has now been identified in further beam tests[5]. In a fraction of events (~ 1% @ 1GeV/c) where μ 's orπ's penetrate the calorimeter Cerenkov light was produced in the original PMT windows. The light produced has negligible effect on energy measurement (equivalent 10 Mev of deposited energy) but caused non-gaussian tails in the timing resolution. Our new PMT's are modified to reduce this effect.

Our beam tests showed that a longitudinal segmentation scheme we developed in which a second (longer) decay time constant scintillator is used in the rear part of the calorimeter achieves ideal e/ π discrimination without any mechanical changes in the construction. Discrimination was accomplished using a dual gated current integrator and gave the same performance as a Monte Carlo simulation with ideal segmentation [1]. This work was supported, in part, by DOE contract DE-AC02-CH7600016.

7. References

1. E.Kistenev et al. *Proceedings of the III Int. Conf. on Calorimetry in High Energy Physics*(1992) 663.
2. V.Hagopian et al. *ibid.* 575.
3. Laser Sciences VSL-337ND.
4. C-Technologies, Inc. Short Hills, N.J.
5. PHENIX internal note 87