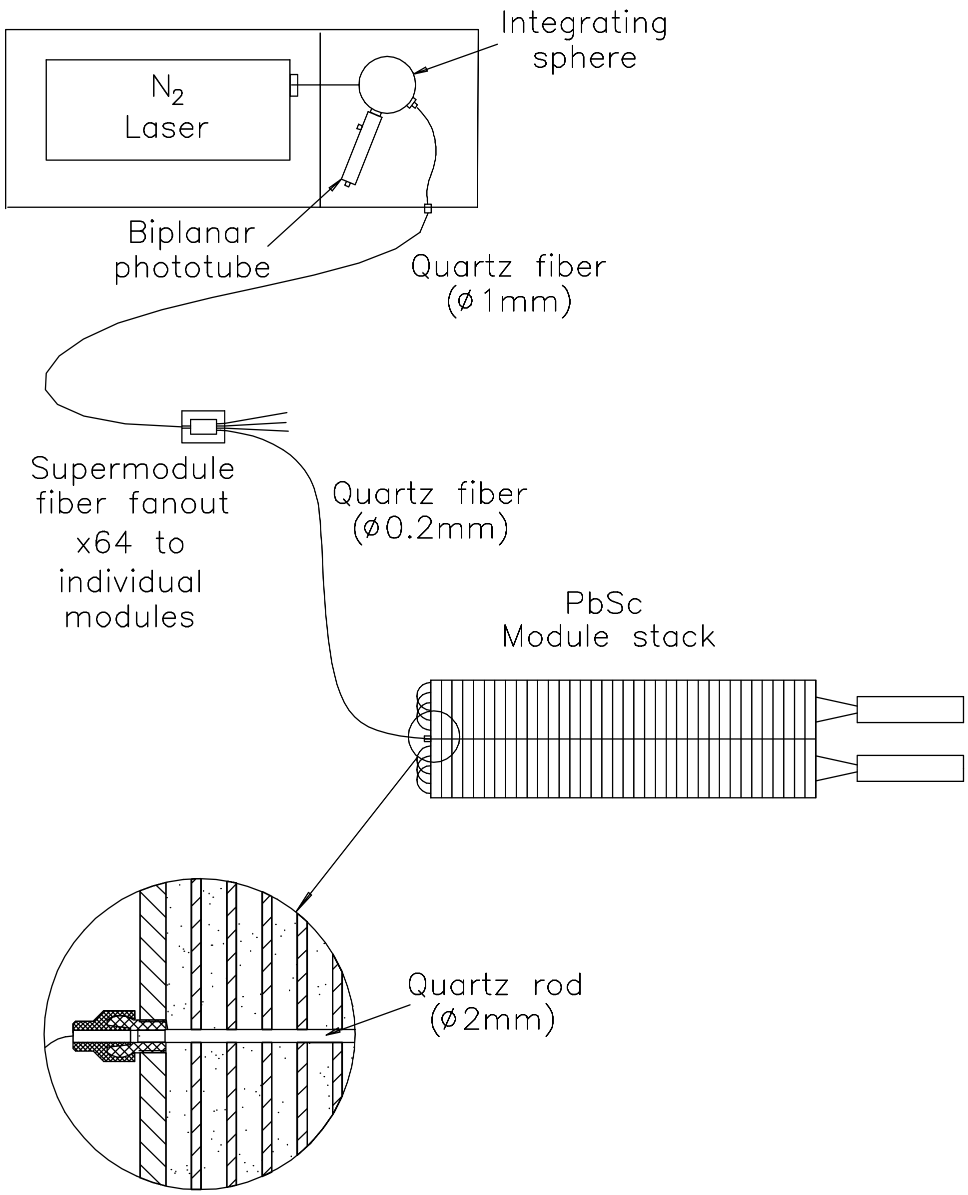

Figure 9.6: Laser-based calibration scheme for lead-scintillator calorimeter.

instantaneous current pulse (up to 300 mA) directly into a 50-ohm load. It has a rise time of about 60 ps and a peak quantum efficiency at about 340 nm. This is well matched to the 337 nm emission of the nitrogen laser. Therefore, the pulse can also be used as a trigger for timing calibration and monitoring the stability of the time-of-flight resolution of the EMCal. Other ports of the integrating spheres are equipped with fiber optics interfaces to provide light distribution to the calorimeter supermodules and auxiliary monitoring devices.

9.3 Electronics and Data Acquisition

A major goal in the development of the readout electronics for the EMCal is the choice of an architecture and design which is consistent with the other major PHENIX subsystems and which could be coherently and cost effectively applied both for the PbSc and PbGl calorimeters. The front-end electronics (FEE) does analog processing of the calorimeter signals, splits the signals between parallel data paths, digitizes the signals, filters them following the strategy chosen for the Level-1 (LVL-1) and Level-2 (LVL-2) triggers, and finally outputs the data to the event stream. Although the choice of components is similar to that of other subsystems, the particular FEE design is specific to PHENIX calorimeter technology.

The EMCal employs photomultipliers to convert scintillation or Cherenkov light to an electrical signal thus involving a number of sequentially coupled processes in the energy to signal conversion. The PMT favored for use in the PbSc calorimeter is the Russian-made photomultiplier FEU115M (described above). Its basic advantages are relatively low cost, linear response up to the value of the peak output current of at least 100 mA, and a rise time of the order of 5 ns.

PMT High Voltage Distribution

The PbGl calorimeter will be redeployed following the WA98 experiment at CERN. It is already equipped with FEU84 (Russian) photomultipliers, which are well tested and well understood; however, they are somewhat slower than the FEU115M (described above). In preparation for the 1994 running of WA98 all 10,000 PbGl modules will be equipped with new HV-generating bases designed and prototyped at CERN for WA98 [6]. These bases, which use a a 43-stage Greinacher voltage multiplier with each stage delivering up to 50 V for a maximum of 2150 V, are similar in design to a system with a similar number of channels being built for ZEUS at DESY. Each base is equipped with a decoder chip which gives an output when its own encoded 9-bit address is received twice in succession. The input is serial, and the address is set by means of nine jumpers allowing the possibility to address up to 512 modules in one group. During the transmission of the code for a particular base, an analog reference voltage, which corresponds to the desired voltage for this base, is set on a separate line. This voltage is set to a value equal to $-1/1000$ of the desired voltage of the base. The output of the decoder triggers a stretch signal, at which time the reference voltage is stored by a sample and hold amplifier. At the same time the actual high voltage is supplied as feedback to a voltage correction circuit via a buffer amplifier with output equal to $-1/1000$ of the actual voltage. The photomultiplier voltage is adjusted by varying the reference voltage. The relative voltage for each of the individual dynodes is fixed by tapping from the appropriate stage of the 43-stage voltage multiplier.

This design makes it possible to connect all bases within one group of 512 channels to a common bus of only six low voltage lines while maintaining individual channel high voltage adjustment. It thereby eliminates the need for individual high voltage supply channels and high voltage cables. Additionally, the power dissipation, typically 65 mW at 1500 V, is considerably less than the one-to-several watts per channel of conventional bases. This reduces power consumption and alleviates temperature stabilization in close-packed geometries. The temperature dependence of the output voltage is measured to be about 60 ppm/°C. The estimated production cost of the complete high voltage base system of base with controller is about $70 per channel. The new system will be produced for WA98 with funds from GSI and the University of Münster.

A similar solution can certainly be employed to supply HV for the PbSc calorimeter if funds are available. As a fall-back alternative the FEU115M equipped with simple resistive bases could be used in series with miniature multiturn potentiometers driven by the computer controlled micromotors. A similar system is currently employed by the 4000 channel GAMS detector at CERN and is reliable and easy to use [7]. Commercial systems based on the same principle are also used in several large experiments, such as CDF.

Readout Electronics

A new set of readout electronics is also presently under design by the ORNL Instrumentation and Controls group for use with the PbGl photon detector in experiment WA98 at CERN. The design of this system makes use of the experience gained from the RHIC RD16 electronics R&D project and is very similar to the readout system intended for the PHENIX calorimeter readout. The elements of the WA98 readout system are: (1) a delay stage for the anode signal, which allows for trigger formation time, (2) a charge integration stage to sum the anode current, (3) a 13-bit equivalent ADC with conversion time of 100 μs or less, (4) a local address generator and output buffer, and (5) a readout controller to assemble individual addresses and outputs and to store the resulting data stream in VME buffers.

A block diagram of the readout system design is shown in Fig. 9.7 which shows the FEE from the anode signal through the ADC. The organization under design is to install eight channels of FEE through ADC and local buffer plus address-tagging on a single microchip. Sixteen chips are mounted on a buffer card that includes an interface to power supplies and the readout bus. Separate readout cards would deal with collecting data from the buffer cards adding further address bits while transferring the entire data stream into a VME buffer.

The front end incorporates an integrating amplifier matched to the signal characteristics of the anode pulse and set to give a 3 V output for a 40 GeV photon striking one detector. The integrating amplifier is followed by a multicorrelated double sampler which stores the observed charge on a capacitor while awaiting the trigger decision. The storage is of the switched capacitor type. One or more *pre* samples are taken of the amplifier output prior to the event arrival and other *post* samples are taken after the output rises to its full value. The difference of these *post* and *pre* samples yields the net charge due to the event. This scheme also provides a good degree of noise rejection. A clock cycle advances a storage pointer that selects the capacitor of the storage array to be switched on for a given cycle. An experiment trigger signal causes the output of the appropriate capacitors to be readout, necessary differences to be taken, and the result stored in a buffer at the ADC input. The trigger also initiates ADC conversion after an appropriate delay.

The analog storage scheme was designed with operation at RHIC in mind. Due to the fixed event arrival times at the collider, the *pre* and *post* signal samples can be taken at precise predetermined times relative to the RF timing. The asynchronous nature of the trigger timing for the CERN fixed target experiments necessitates that the analog storage capacitors be cycled with a free-running clock which continuously samples the integrating-amplifier output. A clock frequency of 20 MHz with a switched capacitor array which is 16 samples deep allows an 800 ns wide window. The occurrence of a trigger, in the fixed target experiment, stops the cycling through the capacitor array and initiates the extraction of the appropriate *pre* and *post* event samples. The digitization will be accomplished with a dual-range system consisting of two gain ranges separated by a factor of eight, or 3-bits. Each channel would have its own section of a multichannel Wilkinson-type 10- or 11-bit ADC meaning that all channels would be converted within 50–100 μs (Fig. 9.7). A constant fraction timing signal will also be derived from a signal split from the analog input and digitized on the same readout chip.

The calorimeter phototube signal for PHENIX will be shaped similarly to that described above for the CERN fixed target experiments. The signal will be integrated and stored in the switched capacitor arrays implemented in custom designed CMOS integrated circuits. See Chapter 11, Section 11.2.2. The sampling frequency will be equal to the beam crossing frequency. Analog-to-digital conversion will occur after the LVL-1 trigger decision, thus allowing a reduction in bandwidth requirements for digitization.

In addition analog signals from the calorimeter towers will be grouped together into trigger towers with a four times coarser granularity. These mixed signals will be digitized at a beam-crossing frequency with a resolution of at least 6-bits and used to form total and local overlapping energy sums to be used in the LVL-1 trigger.

9.4 Operation and Performance

In this section we discuss the expected performance of the calorimeter subsystem based on our test beam experience with small arrays of prototypes. We also used simulation of RHIC events to assess the net effect of detector occupancy on our measured single particle detector response.

9.4.1 Energy Resolution

The energy resolution of the electromagnetic calorimeter will directly affect the sensitivity of our experiment to prompt photons. Good energy resolution is needed to reconstruct π^0 and η decays into photon pairs precisely enough to recognize them above the abundant random combinations and to quantify the excess of photons beyond those from meson decay in each p_T bin.

Energy resolution of about 7–8%/$\sqrt{E}$ can be achieved readily both in PbGl and PbSc calorimeters (see Fig. 9.8 and 9.9). Such resolution is probably the practical limit for relatively low cost calorimetry, and will enable the measurement of π^0 down to p_T of less than or about 1.0 GeV/c. It will also yield calorimetric measurements of the two electron effective masses with information comparable to that provided by tracking at and above the Υ mass.

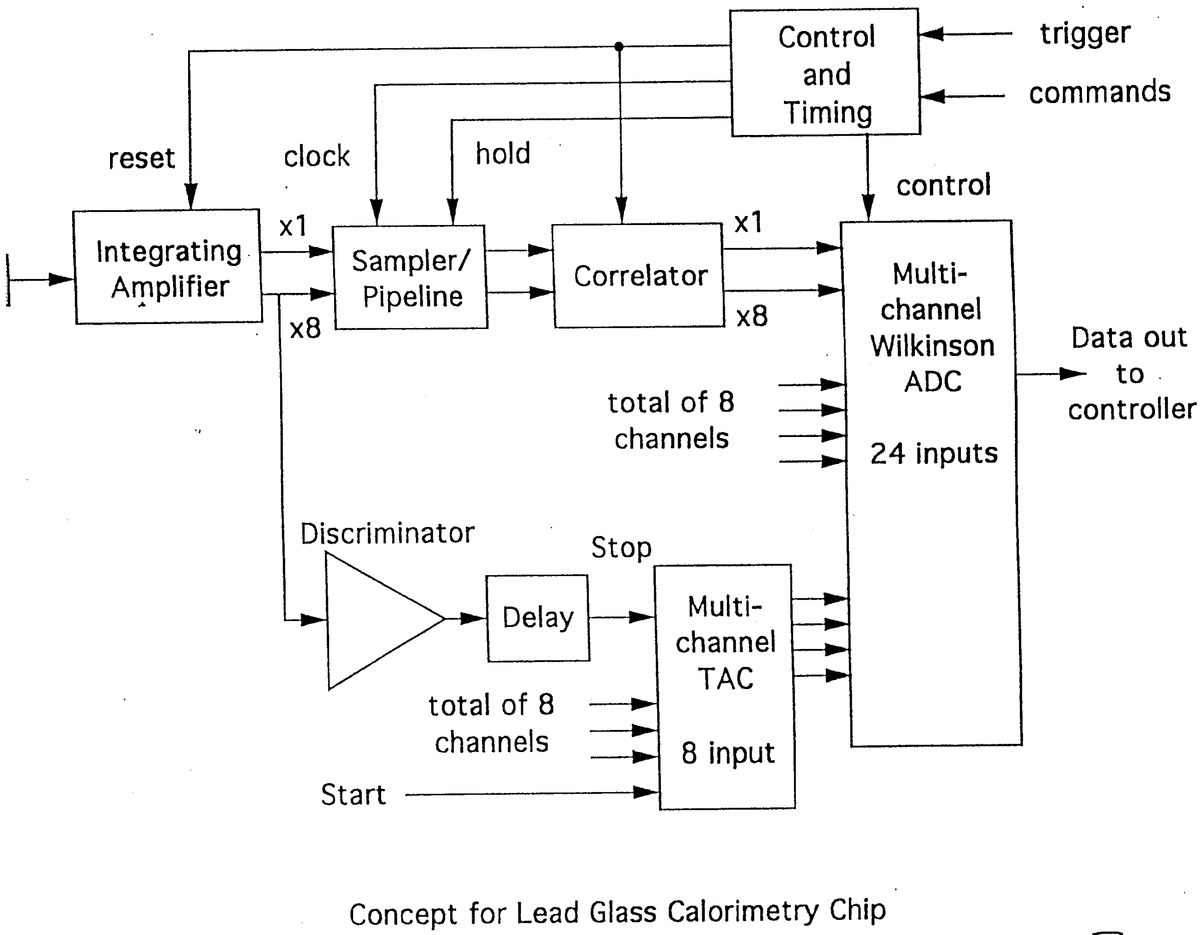

Figure 9.7: Block diagram of the integrating amplifier, correlated sampler, analog memory, and multichannel ADC under design and construction for the PbGl detectors of CERN experiment WA98.

9.4.2 Timing Resolution

The timing response of the PbSc and PbGl electromagnetic calorimeters were studied extensively at the Brookhaven AGS for momenta greater than or equal to 500 Mev/c. The sources of timing uncertainty using these modules are now largely understood. The intrinsic resolutions of both types of detector appear to be quite similar (see Fig. 9.11 and 9.10). The time resolution can be characterized by the form

$$\delta t = \delta t_0 + \delta t_1 / \sqrt{N_{pe} \cdot E_{Dep}}, \tag{9.1}$$

where δt_0 is an intrinsic timing resolution limit, presumably due to fluctuations in the effective localization of the shower. It is dependent on the particle type and on the way the