tion, for single and double HIJET multiplicities there is no observable deterioration in the resolution for 500 MeV photons in the EMCal, but for triple HIJET multiplicities there is about a 10 MeV deterioration. The loss of efficiency for single, double, and triple HIJET multiplicities is 13%, 24% and 37%, respectively. Both the deterioration of resolution and the efficiency loss depend on the photon energy. The absolute values of both resolution and efficiency decrease with with decreasing photon energy. Although the average background from the event is constant, the transverse size of photon showers (consequently the number of cells to be added up by the clustering routine) decreases with decreasing photon energy.

9.4.5 Electromagnetic Calorimeter Trigger Information

The electromagnetic calorimeter will provide information for three different types of trigger filters. Event characterization information is provided at LVL-1 through regional or total-calorimeter-energy sums of the analog signals. This is used to trigger on events with jetlike structures or events with large neutral transverse energy flow, and also provides local-energy sums to be used in identifying single showers as being produced by either high energy photons or electrons.

The electromagnetic calorimeter provides the sole means to trigger on high p_T photons. This is needed to ensure that all such events are written to tape in order to extend the photon measurement as far into the high p_T region of hard QCD photons as allowed by the interaction rate. The p_T threshold for this trigger will depend on the desired trigger rate suppression factor, which will in turn depend on the interaction rate and the DAC bandwidth to tape. Figure 9.18 shows the average multiplicity of photons in the EMCal acceptance which exceed a given energy threshold for central Au + Au reactions. Thus to obtain a trigger suppression factor of the order of 10^{-2} it is necessary to trigger on photons of 3.0–4.0 GeV energy.

The electromagnetic calorimeter also provides an important component of the electron trigger system. However, the formation of an electron trigger from the electromagnetic calorimeter is much more difficult. It is complicated by the fact that photon showers will be more prevalent by about two orders of magnitude (see Fig. 9.18). Although it might be possible to identify individual showers as electromagnetic (based on shower profile), this would not provide electron trigger information alone, because such identified showers would be dominated by photons. Much of this photon background would be eliminated by the requirement of a charged hit in an overlapping region projected from pad chamber PC3. However, a few percent of the photons would be falsely tagged as charged due to chance overlap at the occupancies expected for central Au + Au. In addition, it will be difficult to discriminate between electrons and pions in energy bins near to 250 MeV, because this is the energy of the minimum ionizing peak due to non-interacting charged particles (see Fig. 9.14).

As a result, the electromagnetic calorimeter mainly provides candidate electron hits for a LVL-2 trigger, which would then be matched with another detector such as the RICH. A more complete analysis of these candidate electrons would then be performed using the fully digitized information to confirm the candidate as an electron.

For electron trigger purposes it is not desirable to trigger only on high energy electrons,

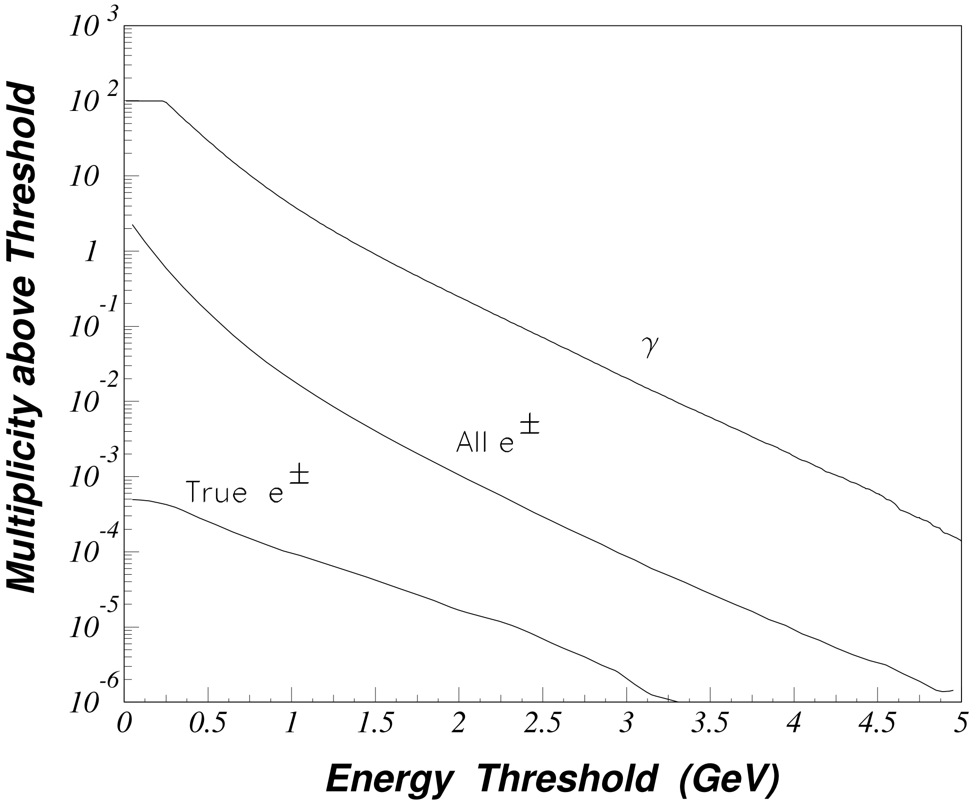

Figure 9.18: Multiplicity of photons or electrons in the EMCal acceptance as a function of the energy threshold for central Au + Au collisions (dN^{π^0}/dy =375). The multiplicity is shown for electrons from true resonance pairs ($\rho, \omega, \phi, and J/\psi$) and for all electron sources including π^0 and η Dalitz decays, as well as 0.5% photon conversions.

because this would compromise the low mass, low p_T electron-pair acceptance (which suffers from low rate). On the other hand, it may not be possible to trigger on low mass electron pairs for central Au + Au reactions, because such a condition might always be satisfied due to the large multiplicity of background electrons. In this case, a trigger which selected events with a high energy electron of above 1.0 GeV is desired to provide event rate suppression and to enhance the sample of events which contain a pair from J/ψ decay. The electromagnetic calorimeter provides essential particle energy information for such a trigger without the need for track reconstruction.

To provide an accurate electromagnetic shower identification and energy measurement it is necessary to perform local cluster sums. This will eliminate pulse-height variations due to energy sharing when crossing module boundaries. Because the electromagnetic calorimeter cell size is approximately one Molière radius, a minimal cluster size would consist of four modules belonging to a local 2×2 array of adjacent modules. To completely eliminate module boundary effects all possible overlapping 2×2 module sums must be formed. Such a procedure was investigated using the recent PbGl A2 test beam data with the results shown in Fig. 9.19.

The results indicate that a 2×2 module sum of signals digitized with 6- to 8-bit precision can be used to provide a photon trigger with an energy threshold resolution which is close to the intrinsic energy resolution of the detector. Furthermore, at the energies of interest for a photon trigger there is very little contamination from charged pions. This indicates that a charged particle veto is not necessary for photon trigger purposes.

Based on the results of simulation and the above tests, the EMCal trigger is to provide all 2×2 energy sums of adjacent modules. The overlapping 2×2 sums are performed in a trigger processor (see Chapter 11) using the analog energy information which is split from the main signal and digitized with at least 6-bit precision. The 2×2 sums are further summed in increasing sequence until the full EMCal energy signal is obtained. Regional energy sums are available at intermediate sum levels. The photon trigger is obtained from a simple threshold on the first level of 2×2 sums. Ideally, it would be desirable to have a series of threshold levels for the photon trigger, with the highest threshold required for the most central collisions, in order to maintain a similar level of rate suppression for all impact parameters. For cost reasons the trigger system is being designed to provide two programmable photon energy thresholds with the lower threshold required for peripheral collisions and a higher threshold for central collisions. For the electron trigger an additional programmable threshold will be applied to the 2×2 sums. Clusters satisfying this threshold will be masked with an overlapping region in the PC3 chamber to determine if they are charged. Those clusters satisfying the charge requirement will be promoted to a list of electron candidates for further evaluation in LVL-2.

In order to lower the cost of the EMCal trigger, an analog sum of non-overlapping 2×2 adjacent modules is performed on the readout board. This sum is then digitized and passed to a trigger processor to form overlapping 2×2 sums of the non-overlapping sums to eliminate boundary effects as in the scheme outlined above. The resulting 4×4 module sums are the basis for the trigger thresholds. There is a factor of four decrease in the number of digitized signals which must be summed in the first step of the trigger processor. Due to the more complete energy collection, for isolated showers the energy threshold is slightly improved. However, due to the problem of overlapping showers, for high multiplicity events the energy threshold becomes more susceptible to an increased trigger rate.

9.5 Cost

The cost of the EMCal and associated electronics is broken down by WBS item and is shown in Table 9.5. The total cost to DOE is \$3420k, of which \$762k is for the FEE, which is considered to be a part of the calorimeter subsystem.

The cost of the PbSc assumes an active IHEP (Russian Federation) involvement in all stages of the design, production and commissioning of this calorimeter.

The cost of the PbGl includes only what is required for the PHENIX collaboration to disassemble, ship and reassemble an existing WA98 lead-glass wall. The front-end electronics costs for the PbGl is included in the EMCal FEE cost.

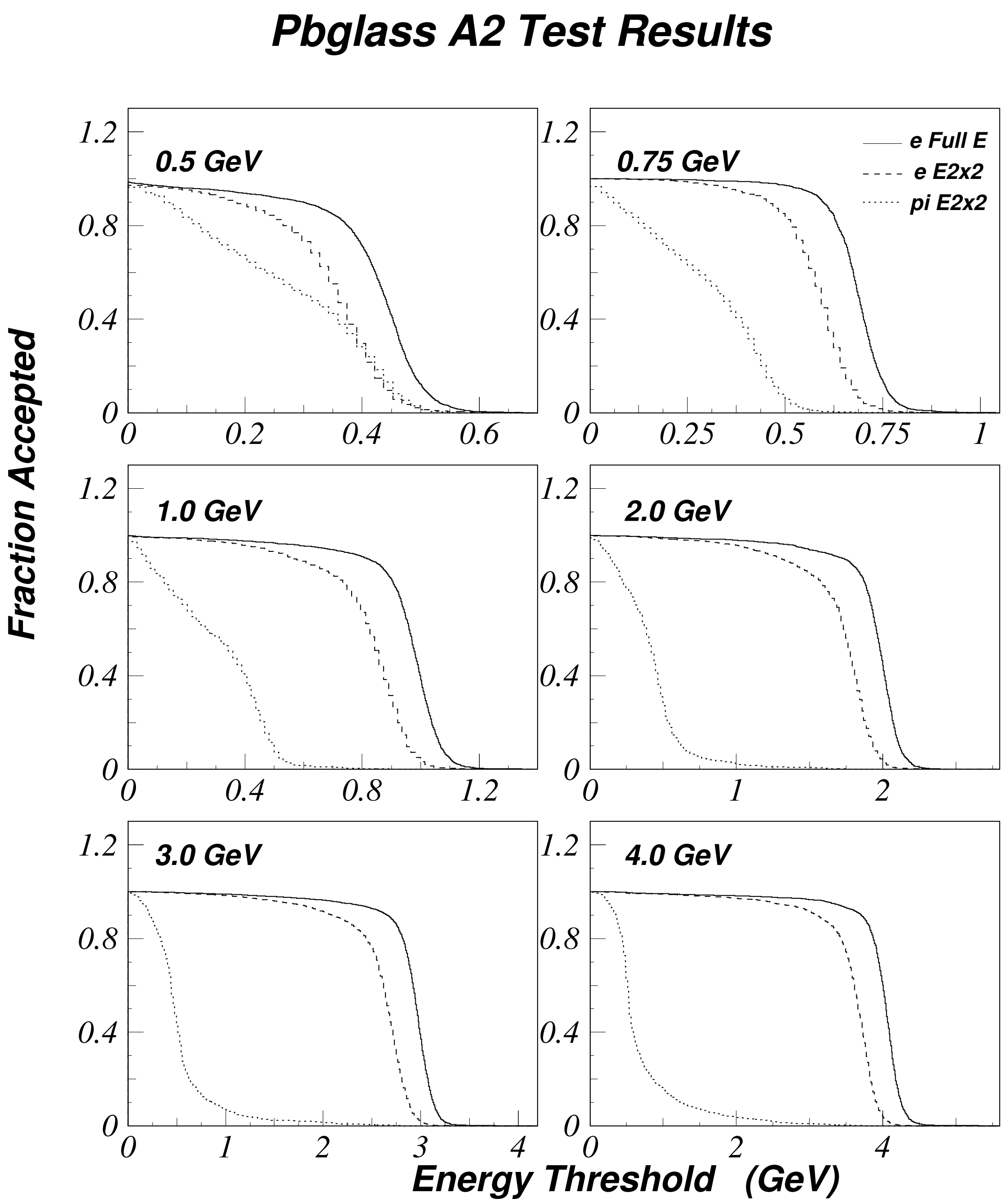

Figure 9.19: Comparison of the response of the PbGl calorimeter to electrons (photons) and pions for trigger purposes. The results show the fraction of electrons or pions which would be accepted as a function of the energy threshold. The beam was nearly uniformly distributed over the front surface of the central module. The results are obtained from A2 test beam data taken with full resolution but analyzed as envisaged for an EMCal cluster trigger with a simulated 8-bit digitization set to 4.0 GeV fullscale using only the maximum 2×2 module sum. The smooth solid curve indicates the electron result summing all modules with full resolution.

Table 9.5: Cost Estimate for PHENIX EMCal Subsystem

EMCalorimeter

		Amounts in FY93 k$					
W B S	Description	Total	M&S	EDIA	Labor	Cont%	Cont(k$)
5. 6	**EM Calorimeter System**	**3420**	**3074**	**298**	**49**	**29**	**999**
5 6. 1	**Pb Sc Calorimeter**	**2624**	**2500**	**84**	**40**	**30**	**775**
5. 6. 1 0	EDIA	84	0	84	0		21
5. 6. 1. 1	Preproduction Prototypes	33	26	0	7		10
5. 6. 1. 2	Fabrication	2467	2464	0	3	30	740
5. 6. 1. 3	Beam calibration	40	10	0	30		4
5. 6. 2	**Pb Glass EM Cal**	**34**	**11**	**14**	**9**	**30**	**10**
5. 6. 2. 0	EDIA	14	0	14	0		1
5. 6. 2. 2	Fabrication	11	11	0	0		
5. 6. 2. 3	Beam calibration at CERN	0	0	0	0		
5. 6. 2. 4	Wall assembly and Calibration	9	0	0	9	10	1
5. 8. 1. 6	**EMCal FEE**	**762**	**562**	**200**	**0**	**28**	**214**
5. 8. 1. 6. 0	EDIA	168	0	168	0	24	41
5. 8. 1. 6. 1	Prototypes	20	20	0	0	50	10
5. 8. 1. 6. 2	Fabrication	534	502	32	0	28	151
5. 8. 1. 6. 3	Testing for FEE	20	20	0	0	36	7
5. 8. 1. 6. 4	Assembly/Installation	20	20	0	0	25	5

9.6 Schedule

The proposed schedule for the EMCal construction is shown in Fig. 9.20. It shows the projected time required for design, prototyping, construction and commissioning of both the calorimeter itself and of the FEE. The most important feature is the completion of the

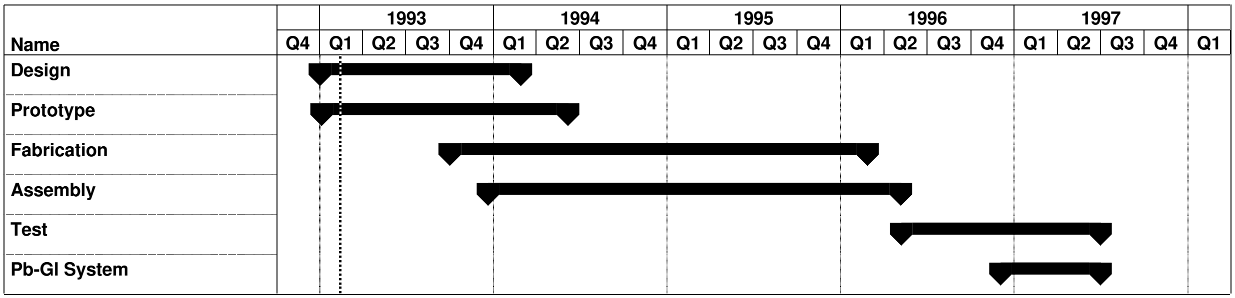

Figure 9.20: Overall schedule for the PHENIX EMCal subsystem.