Brief Summaries of Detector Systems

GlueX-doc-323

The GlueX Collaboration

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This document provides a set of one-page summaries for each of the major systems in the GlueX detector. These are not meant to be detailed, complete discussions, but rather a quick overview of the entire detector. These summaries briefly outline the purpose of the system, the requirements placed on the system by physics goals of GlueX, and a brief description including channel count. This continues with a discussion of the expected raw signals as well as needed amplification and final readout of the detector. A brief discussion of the current stage of R& D is given with outstanding questions pointed out. Finally, the groups and manpower needed for final construction of the element are identified as well as an estimate of the required construction time.

It should be pointed out that due to the availability of both manpower and interest within the collaboration, some systems are much further along than others. In particular, the Lead-glass Calorimeter is being built out of glass blocks from an existing device and a great deal of experience exists. The Forward Drift Chambers were taken on by the Ohio University group in late 2002, while the collaboration is currently in discussions with the University of Tennessee and Oak Ridge groups about taking responsibility for the Cherenkov system. Independent of this, the collaboration believes that assuming timely funding of the detector, a viable plan exists for getting physics out of the detector in a timely fashion.

The Tagger System

Purpose, Resolution Requirements, Description, Mass, Channel count

The purpose of the Tagger system is to provide a flux of $\sim 10^8$ Hz of linearly polarized photons from coherent bremsstrahlung in a thin, orientated diamond crystal. This is achieved by measuring the energies of the energy degraded bremsstrahlung electrons in the spectrometer. The photon energy resolution is required to be less than 0.1% r.m.s. of E_0 for E_γ between 70 % and 75 % of E_0, which corresponds to 12 MeV r.m.s. energy resolution for a 12 GeV electron beam. The Tagger system consists of a quadrupole and 2 dipole magnets, a vacuum chamber and the associated focal plane detectors. The dipoles are two identical magnets that will be run at 1.5 T and at present the pole shoe surfaces will be part of the vacuum chamber. The focal plane detector array is located just outside the vacuum chamber. It consists of a set of 128 fixed scintillation counters spanning the full energy range from 25 % to 92% of E_0 and is required for the alignment of the diamond. A movable "microscope" of 64 narrow counters is required to measure accurately the photon energies in the energy range of 70 to 75% of E_0. The total mass of the tagger system will be $\sim$ 90 tons.

Raw Signals, Stages of Amplification, Final readout

Since individual detectors in the focal plane array will have to count at rates in excess of 5×10^6 Hz, a *plastic scintillator/photomultiplier* combination is appropriate. A detailed design which specifies the precise geometry of the scintillators and their support frame still has to be finalized. The signal readout from the focal plane detectors will be standard.

R&D Issues, Simulations and Other Considerations

The Glasgow and Catholic Universities groups have calculated the tagger optics separately, the results of which can be found in Hall D note 70[1] and the GlueX/Hall D Design Report (Nov 2002). The Design Report tagger is different from the design described above. It has a single long, narrow dipole which is 6.1 m in length and weighs $\sim$ 100 tons. Due to concerns about the mechanical stiffness, the availability of sufficiently large pieces of iron of the necessary quality and the availability of suitable manufacturers, Glasgow and Jlab investigated the possibility of a tagger consisting of two identical magnets in series[2]. By careful positioning of the two magnets it is possible to obtain a design that is equivalent, and in some respects superior, to a single magnet configuration. The two magnet design concept was accepted by the collaboration at the Indiana meeting in May 2004. Glasgow has studied the design in more detail and has produced drawings of the two magnet assembly, including a possible vacuum system, which should contain sufficient details for budget prices to be obtained from potential manufacturers. It is also relevant to mention that prior to version 4 of the Design Report, Glasgow and Jlab investigated the feasibility of a tagger with superconducting coils[3] with a magnetic field of 5T and main beam bend angles of 15, 30 and 45 degrees, for both curved and straight output edges - the room temperature tagger bend is 13.4 degrees. After careful consideration, the superconducting option was rejected since there are several distinct disadvantages and no clear advantages.

Manpower, R&D and Production Schedules

The Tagger system has been the responsibility of groups from Glasgow University, JLab and Catholic and Connecticut Universities. More work is required to investigate alternative vacuum system designs - we have already considered a vacuum chamber which, (i) is external to the tagger dipole magnets, or (ii) uses the pole shoe surfaces as an integral part of the chamber. Vacuum systems which are either completely welded or use a combination of O-ring seals and welds have also been examined. It should be realistic to obtain cost estimates for the magnets and vacuum system in the near future. The Moscow group using ISTC financing could provide the necessary manufacturing skill and manpower to produce the magnets and the vacuum chamber. Basic R&D is required for the focal plane assembly, and a decision on which group or groups should take on this responsibility should be made in the near future, bearing in mind manpower requirements.

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[1] Optics calculation for the Hall D tagging spectrometer for a 12 GeV electron beam. G. Yang, January 2004.

[2] Optics calculation for a two magnet tagged photon spectrometer for GlueX. G. Yang, July 2004.

[3] Possible designs for a 12 GeV superconducting Tagger. J. Kellie, November 2001.

The Superconducting Solenoid

Purpose and Requirements

The Solenoid is the magnetic element selected for the GLueX Experiment to provide momentum analysis in the central tracking chambers. The Solenoid is a large (73 inch) warm bore super conducting (SC) device that produces a nominal maximum central field of 2.2 Tesla at 1800 Amps. The Magnet is 195 inches long and weighs approximately 300 tons. The solenoid was originally designed as a highly reliable and thermally stable SC magnet. The typical field quality of the solenoid is consistent with GlueX requirements for momentum resolution. The Solenoid - as originally designed - had a slotted yoke and separately cooled SC coils, with the upstream end closed and the downstream end with a full aperture opening. There were several problematic areas related to both construction and design: the specific magnetic geometry had the unfortunate side effect of creating large external magnetic fields, particularly in regions where phototubes would likely be present; many of the solenoid systems were inconsistent with JLAB operations; the Solenoid had a persistent history of internal leaks and had accumulated a substantial amount of wear and tear - as well as failed instrumentation - during its 30 year history. Despite these problems, the robust design and the good state of preservation made selection of the Lass/MEGA solenoid a cost effective choice for Hall D, even after the necessary costs of modernization and maintenance were taken into consideration.

Status of Upgrading, Modernization and Repair.

The Solenoid was originally designed in 1970 as the LASS spectrometer at SLAC and was subsequently used as the MEGA spectrometer at LANL. The Solenoid was mothballed in place in 1995 and first inspected by JLAB Hall D in 2000. The first task performed after the initial evaluation of the Solenoid was to redesign the yoke magnetic geometry to match the Solenoid to the requirements of Hall D and to reduce substantially the external fields. The modifications entailed filling the yoke slots and adding steel at the end to reduce yoke saturation and the escape of internal fields, thus reducing the external fields by creating a symmetric yoke with a large upstream opening. This modification also changed the solenoid to a clear bore from end to end. There are obvious benefits to detector access and installation, while the redesign of the yoke supports now allows the magnet installation at the beam elevation of 3.5 Meters in Hall D.

New Solenoid systems were proposed and planned that include a new DC power supply and energy dump system recently purchased from Danfysik for GlueX, a new cryogenic interface with JLAB compatible automatic valves and connections and a new control and instrumentation package. The new control package is to be based upon the current control upgrade for the HMS spectrometer for JLAB Hall C. The new cryogenic interface is based on the proven designs currently in use on seven different SC magnets at JLAB.

At the completion of the visual inspections, the Solenoid was dismantled and shipped to IUCF where it has been undergoing some long needed maintenance and repairs. Following a series of detailed coil tests, the first two of the four coils were dismantled, repaired and modernized. The repairs consisted of finding and repairing the numerous leaks that have plagued the solenoid for 30 years. Three of the coils had leaks in the LN2 shields while the fourth had a leak in the coil LHe vessel. The shield thermometry, which originally was based on thermalcouples, was replaced with more accurate and modern PT-102 Pt resistance thermometers - now the industry standard. The coil support strain gauges were all replaced, since many of the originals had failed over the years. Finally, the multi layer super insulation, which had deteriorated due to previous maintenance practices and the operation with oil diffusion pumps, was replaced. During the course of this maintenance work, corrosion was discovered in some internal plumbing and all four 18 inch coil junction bellows. These have all been replaced.

Starting in July of 2004, the two completed coils were cooled down with LN2 to perform a final leak proof test and quality check and were determined leak-free. At the completion of work at IUCF early in 2005 on coils 3 and 4, all four coils will have been repaired and modernized.

Manpower, R&D and Production Schedules

Current plans are to ship the solenoid to JLab's test lab beginning in Jan. 2005 and perform single coil cryogenic tests there to prove out all systems. The coils will be integrated with the new cryogenic interface, controls and DC system and be fully tested prior to installation in Hall D.

The Liquid Hydrogen Target

Purpose, Resolution Requirements, Description, Mass, Channel Count

The main physics program for the GlueX experiment will be conducted with a low-power liquid hydrogen target. The planned target is $30\,cm$ long and somewhere between 3 and $6\,cm$ in diameter. Such targets normally employ mylar target cells. The mylar cell will be mounted on a metal base to provide for liquid entry ports and a reliable means of positioning the cell. The beam enters through a thin window mounted on a reentrant tube at the base of the cell. The target cell is connected to a condenser located upstream of the cell.

R&D Issues, Simulations, Monitoring and Other Considerations

The maximum power deposited in the target by the beam is $100\,mW$. In such low-power targets, natural convection is sufficient to remove heat from the target cell and a circulation pump is not required. A system such as this, containing a few hundred cm^3 of liquid hydrogen, would be considered "small" by Jefferson laboratory standards and the safety requirements would not place any significant constraints on the target design or operation.

Manpower, R&D and Production Schedules

The target will be built by the JLab target group. It is estimated that approximately one year will be required to design, construct, test and certify the target. This target is very similar to other targets that have been built at JLab, partcularly for Hall B.

The Start Counter

Purpose, Resolution Requirements, Description, Mass, Channel Count

The start counter is used to provide a start signal for time of flight measurements and to identify the beam pulse associated with the observed event. In order to be independent of particle momenta and trajectories, the start counter is located as close to the target as possible. To be able to identify beam pulses the detector needs a minimal time resolution of 300 ps.

The detector will consist of an array of 30 to 60 scintillators cylindrically surrounding the target. The inner diameter of the cylinder is 10 cm. Each scintillator element will have a thickness of 3 to 5 mm and a length between 45 cm and 70 cm. The optimal dimension will be determined from simulation. The detectors can be read out either via high magnetic field PMT's or other detection methods based on solid state detectors.

Raw Signals, Stages of Amplification, Final Readout

¿From studies using cosmic rays we have determined that high field PMT's such as the Hamamatsu R5942 (H6614-01 system) can provide a time resolution of 250 ps which makes is suitable for our application. For minimum ionizing particles we obtained signal sizes of about 0.4 V with a rise time of about 5-8 ns.

R&D Issues, Simulations, Monitoring and Other Considerations

The timing performance of the Hamamatsu tube his to be determined in various magnetic field configurations. Other readout methods including VLPC and SiPM will also be studied to investigate the feasibility of a double ended readout system. Further simulations are needed to finalize the detector geometry.

Manpower, R&D and Production Schedules

FIU is responsible for the start counter. In its current form without the need of high resolution position information the available man power at FIU is sufficient. Once R&D work using VLPCs is completed, we expect that the counter can be built on the time scale of two years.

The Straw-tube Chamber

Purpose, Resolution Requirements, Description, Mass, Channel count

The purpose of the CDC is to accurately measure (r, ϕ, z) coordinates along charged-particle tracks. In conjunction with the FDC, it will then reconstruct the momentum, $\vec{p}$ of each track and the primary and secondary vertices's of the event. The exact momentum resolution is a function of particle momentum and the number of hits in both the CDC and FDC. Monte Carlo studies indicate that an $r\phi$-spatial resolution, $\sigma_{r\phi}$, on the order of 150 to $200\mu m$ is sufficient to satisfy the physics goals of the experiment. The z-coordinate is obtained using 6° stereo layers. The resolution is given as $\sigma_z = \sigma_{r\phi}/\sin 6^\circ$. The CDC also needs to provide dE/dx information sufficient for separating Ks and πs for particle momentum under $0.500\,GeV/c$.

The chamber is built using 23 layers of $1.6\,cm$ diameter, 100μ thick aluminized kapton, $2\,m$ long straw tubes. The signal is measured using a 20μ diameter gold-plated tungsten wire strung under $55\,g$ of tension. Layers 5, 6, 14 and 15 are $+6^\circ$ stereo while layers 7, 8, 16 and 17 are -6° stereo. Due to the packing of the tubes, the exact channel count depends on the exact specifications of the final chamber. It will be 3240 channels.

Raw Signals, Stages of Amplification, Final readout

A minimum ionizing track produces about 30 primary ionizations per centimeter of traversed gas. Path length in a straw-tube depends on both the distance away from the wire as well as the polar-angle θ of the track, but typical values vary between about $0.5\,cm$ to a few cm. The chamber will be run such that the gas amplification is about 10^4. The signals will be read out using capacitively coupled preamps mounted directly on the upstream end plate of the detector and then fed into 10+ bit FADC and digitized at 125 MHz. Due to the $2.25\,T$ magnetic field, the maximum drift times will be on the order of 800 ns for a typical gas mixture.

R&D Issues, Simulations, Monitoring and Other Considerations

The group is currently stringing wires in a $\frac{1}{4}$-chamber, full-scale prototype. We have currently identified several design changes that will facilitate easier construction. Apart from construction technique, the main issues to be resolved with the prototype are gas distribution and electronic hook-ups.

Manpower, R&D and Production Schedules

The CDC is the responsibility of the Carnegie Mellon University group. Assuming that a team of stringers is hired during the actual fabrication phase (as has been done with other chamber projects), the group has sufficient manpower to build the final device on a time scale of three and a half years from the time that funds become available. The group expects to work with the FDC team and the JLab electronics group to build a preamp that is common to all chambers in the experiment.

The Forward Drift Chambers

Purpose, Resolution Requirements, Description, Mass, Channel Count

The FDCs include 4 separate packages of disk-shaped horizontal drift chambers to measure the momenta of all charged particles emerging from the target at angles of up to 30° relative to the photon beam line. Each package consists of 6 planes of alternating anode and field-shaping wires with a wire-to-wire separation of 5 mm (119 anode wires per plane) and with 150 μm spatial resolution from the drift time readout. Each wire plane is sandwiched between 2 planes of cathode strips (238 strips per plane with 5 mm pitch). By charge interpolation of the electron avalanche image charge in the cathode strip readout, spatial resolutions at the cathode planes are expected of better than 150 μm. The strips are arranged in a U and V geometry with respect to the wires (at $\pm 45°$) allowing for separation and assignment of multiple hits within a chamber to the different tracks. Adjacent chamber elements will be rotated by 60° with respect to each other in order to improve track reconstruction decisions on the corresponding anode wire left/right ambiguities, hence improving the overall resolution. The wires that cross through the beam line will be deadened out to a radius of 3.5 cm to reduce the rates. Each FDC package has a channel count of 3570, leading to a total channel count for the full FDC system of 14280 (2856 A, 11424 C).

Raw Signals, Stages of Amplification, Final Readout

Each signal from the FDCs (anodes and cathodes) will be sent to a chamber-mounted charge-sensitive preamplifier that drives a pulse-shaping amplifier. The signals from the anode wires that are above some pre-determined voltage threshold will be discriminated and then digitized by 40 MHz F1 TDCs. The signals from the cathodes will be digitized with 250 MHz 8-bit flash ADCs.

R&D Issues, Simulations, Monitoring and Other Considerations

The primary development issues that must be addressed for the FDC system are factors affecting the intrinsic resolution of the chambers, along with the mechanical and electronics layout. The goal is to construct a tracking detector that meets the required design specifications and has a long life time, a uniform and predictable response, a high efficiency, and is serviceable in case of component failure.

Two detector prototypes will be completed and studied over the course of the next two years. The first will be employed to study the optimal electrode configuration for the system. A second full-scale prototype will be completed to test mechanical support designs for the chamber cathode planes and wire planes, which is necessary to avoid electrostatic instabilities and non-uniformities that are known to affect resolution. This second prototype will also be essential to complete the final design of the FDC circuit boards. A significant aspect of the design work includes development and study of Monte Carlo of the GlueX detector system focussing on the properties of the FDC system that will enable us to meet or exceed the required design specifications.

The detector group at Jefferson Laboratory is developing the gas system for the entire GlueX experiment. The Ohio University group will work to ensure that this design is adequate for the control and monitoring of the FDC system.

Manpower, R&D and Production Schedules

The FDC prototyping and design is primarily the responsibility of the Ohio University group, with important support from the detector group at Jefferson Laboratory. The manpower available is adequate to complete the detector R&D within 2 years and to complete the detector construction with 4 years pending availability of funds.

The Time-of-flight Wall

Purpose, Resolution Requirements, Description, Mass, Channel Count

The purpose of the TOF is to serve as part of the particle identification system in conjunction with a Cerenkov counter for forward-going charged particles. The goal is to separate $\pi^{\pm}$ from $K^{\pm}$ for momenta up to 2 GeV/c and for the given geometry a 95% separation efficiency is achieved at the highest momentum with a time resolution of 80 ps. The TOF will use two planes of scintillator bars located immediately upstream of the lead glass detector (LGD). Based on simulations and prototype studies the bars will be 250 cm long, 6 cm wide and 1.5 cm thick. Thus the mass presented by the detector immediately before the LGD corresponds to 3 cm of scintillating plastic. Each bar is read out at both ends with a photomultiplier. The channel count is 168.

Raw Signals, Stages of Amplification, Final Readout

Prototype studies with a cosmic ray test facility at Indiana U and extensive tests in a hadron beam at IHEP (Protvino, Russia) included various scintillating bars of different thickness (1.5 cm, 2.5 cm and 5.0 cm) with various photomultipliers (Russian FEU-115, Hamamatsu R5506 and R5946, and Philips XP2020). The XP2020 was chosen. The typical pulse has a rise-time of less than 5 ns and an amplitude of about 0.5 V. Constant fraction discriminators will be used and a TDC with a least count of 25 ps.

R&D Issues, Simulations, Monitoring and Other Considerations

The performance of the prototype TOF in a 5 GeV/c hadron beam at IHEP has been described in three NIM publications[4]. For the 1.5 cm thick TOF bar, a time resolution for a two-bar system of 77 ps at the bar center and 40 ps near the ends was achieved. Magnetic shielding studies were also carried out and are described in a NIM publication[5]. Further R&D measurements with an array of scintillator bars in a hadron beam at IHEP are planned within the next year.

Manpower, R&D and Production Schedules

The TOF is the responsibility of the groups from Indiana University and the Institute for High Energy Physics (IHEP) in Protvino, Russia. This manpower is adequate to complete remaining R&D in six months and to complete the detector construction in two years from availability of funds.

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[4] Nucl. Instr. & Meth. **A478** 440 (2002); Nucl. Instr. & Meth. **A494** 495 (2002); Nucl. Instr. & Meth. **A525** 183 (2004)

[5] Studies of magnetic shielding for phototubes; accepted and available online at www.sciencedirect.com 10 Aug 2004

The Barrel Calorimeter

Purpose, Resolution Requirements, Description, Mass, Channel count

The purpose of the BCAL is the detection and energy determination of photons and charged particles from the decays of the neutral π, the η and other mesons decaying into photons. All charged particles that fall within its volume as they are swept by the magnetic field, mostly in the momentum range of $300 - 1000\,MeV/c$, will also be detected. Some spatial information can also be extracted from the timing information relative to the two read-out ends of the BCAL. The design of the BCAL is based on that of the KLOE calorimeter at LNF in Italy. The expected energy resolution for photons is $\sigma(E) \approx 0.05 + -0.05/\sqrt{E}$, while the expected timing resolution is $\sigma(t) \approx 200\,ps$. The physical layout of the BCAL is a ring consisting of 48 modules (segments) at an inner radius of $67\,cm$ and an outer radius of $92\,cm$. Thus, its approximate thickness is $25\,cm$ corresponding to approximately 16 radiation lengths. The nominal length of each module is $400\,cm$. Each module is constructed as a matrix of 96 double clad scintillating fiber optic strands (SciFi+IBk-s), embedded on grooved Pb sheets of $0.5\,mm$ thickness.Thus, each module consists of approximately 220 layers of Pb/SciFi and special optical epoxy composite. The high magnetic field and limited space available for read out, is an area of particular concern with several emerging technologies, such as SiPM's, offering the most attractive solutions. Extensive R&D is still needed to finalize the type of readout devices and the required channels.

Raw Signals, Stages of Amplification, Final readout

It is clear that a large number of SciFi+IBk-s will be read out by any of the selected PM's. The exact number depends on PM window size and its saturation properties. Assuming $1\,mm^2$ to $3\,mm^2$ SiPM window area and a $5\,cm \times 5\,cm$ matrix area viewed, approximately 1600 SciFi's will be viewed by a number of SiPM's. The optimum number of SiPM's required will depend on the nature and geometry of the light concentrator and diffuser and the light collection efficiency of the optical fibers that will transport the light to the SiPM's. This requires R&D and testing of various configurations, however early studies indicate between a number 10 and 20 SiPM's. Each group will be coupled to provide one (fast) analog signal similar to that from vacuum PMT's, which are thus subject to standard ADC and TDC processing.

R&D Issues, Simulations, Monitoring and Other Considerations

The R&D on the actual construction of the BCAL has been almost completed with the full scale 4 m Module 1 prototype 80% completed as this is written. The read-out requires significant R&D and MC simulations, more so because the SiPM technology is still not yet mature and specifications and performance improve with demand and experience. This R&D has already started and most likely will result in collaboration with DESY, CERN, KLOE and Russian groups to custom tailor the devices to our needs. The monitoring system of the read-out devices can be done by using a pulsed laser-fiber optic combination.

Manpower, R&D and Production Schedules

The BCAL is the responsibility of the UofR SPARRO group. For the construction of Module 1 and subsequent production modules, as well as radiation damage studies of the SciFi's, the CSR group at the University of Alberta is also assisting. This combined manpower is adequate to complete the R&D phase by the end of 2005. It is also adequate to complete the construction of the BCAL subject to external funding and adequate construction timelines. The high-energy physics group at the University of Athens will be assisting with the SiPM R&D, as the European component of this emerging technology effort.

The Lead-glass Calorimeter

Purpose, Resolution Requirements, Description, Mass, Channel Count

The purpose of the LGD is to detect and measure the energy and position of photons from the decays of π^0, η and other mesons. LGD's of similar construction were used in experiments at Brookhaven (E852 - using a pion beam) and JLab (Radphi -using a photon beam). The energy resolution given by $\sigma(E)/E = 0.036 + 0.073/\sqrt{E}$. Shower positions at the LGD plane are reconstructed with a resolution of $\sigma_r = \sqrt{(7.1/\sqrt{E})^2 + (X_0 \sin\theta)^2}$ mm where X_0 is the radiation length of the lead glass (30 mm) and θ is the photon angle measured with respect to the normal to the LGD (energies in GeV). This leads to mass resolutions of 10 MeV/c^2 and 30 MeV/c^2 for the π^0 and η respectively. The detector consists of 2300 lead glass blocks of dimensions $4 \times 4 \times 45$ cm^3 arranged in a nearly circular stack of radius $\approx$1 m. The Cerenkov light from each block is viewed by a FEU-84-3 Russian phototube. The phototube bases are of a Cockcroft-Walton (CW) design. The phototubes are resigtered with respect to the glass using a cellular wall that includes soft-iron and μ-metal shielding. Since the LGD is the furthest downstream subsystem in the overall GlueX detector, the mass presented to particles is not an issue. The channel count is 2300.

Raw Signals, Stages of Amplification, Final Readout

A 1 GeV photon produces about 800 photoelectrons corresponding to a phototube signal of about 0.5 V and a rise-time of 10 ns. No further amplification is required. The signal will be digitized with an 8-bit 250 MHz FADC.

R&D Issues, Simulations, Monitoring and Other Considerations

The performance of the LGD has been described in two NIM publications for E852 experiment[6] and a a submitted NIM article for Radphi. An earlier version of the CW base is described in another NIM publication[7]. GlueX R&D has concentrated on construction of 100 prototype improved CW bases, evaluation of lead glass and FE-84-3 phototubes used in E852 and Radphi to determining suitability for use in GlueX and various curing techniques to repair radiation damage of lead glass. Simulations of detector response is based on extensive experience with E852 and Radphi data analysis. Raphi experience is particularly important as it involved operating an electromagnetic calorimeter in an bremsstrahlung photon beam. The monitoring system consists of a plastic scintillator sheet covering the up stream end of the glass stack and illuminated by fibers connected to a pulsed laser.

Manpower, R&D and Production Schedules

The LGD is the responsibility of the groups from Indiana University and the Institute for High Energy Physics (IHEP) in Protvino, Russia. This manpower is adequate to complete remaining R&D in six months and to complete the detector construction (including CW bases) in two years from availability of funds.

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[6] Nucl. Instr. & Meth. **A332** 419 (1993); Nucl. Instr. & Meth. **A387** 377 (1997)

[7] Nucl. Instr. & Meth. **A414** 466 (1998)

The Upstream Photon Veto

Purpose, Resolution Requirements, Description, Mass, Channel count

The purpose of the UPV is to detect backward going photons of energy greater than 20 MeV emerging from the target region. The UPV provides the upstream coverage of the hermetic photon detection. The design of the UPV employs a traditional lead-scintillator sampling calorimetry. The detector is able to detect multiple photons with fast detection and with timing information that may be utilized at the trigger level.

The UPV consists of 18 layers of scintillator alternating with first 12 layers of lead sheets (0.36 radiation length thick) then 6 layers of lead sheets (0.72 radiation length thick). The expected energy resolution for incident photons is $\sigma(E)/E = 5\% + 8\%/\sqrt{E}$ at a 24% sampling fraction. Each scintillator layer consists of seven 34cm x 238 cm paddles forming a plane. The central paddle has a 10 cm hole to allow for the passage of the beam. The effective area of each plane is approximately 238 cm x 238 cm. The total counter thickness is 8.91 radiation lengths. The layers are arranged into 3 alternating orientations: x, u, and v ($\pm 45^o$, respectively).

The scintillation light is collected at one end of each paddle only. For each orientation, the light collecting ends of the scintillators are join together via a wavelength shifter which is oriented perpendicular to the scintillators. The wavelength shifter is used to redirect the light through 90^o and out the upstream end of the solenoid to photomultipliers tubes (PMT). Each PMT is protected from fringe magnetic field with soft steel casing and mu-metal shield. The channel count is 21.

Raw Signals, Stages of Amplification, Final readout

A typical pulse has a signal of 500 mV and a rise time of 10 nSec corresponding to about 10^3 photoelectrons at 10^7 PMT gain. The signal will be digitized using standard FADC and TDC modules.

R&D Issues, Simulations, Monitoring and Other Considerations

Initial R&D on the construction and building techniques of a prototype module is near completion. Measurements of prototype performance in a low energy electron beam are planned for later this year. These results will be compared to Geant4 simulations. R&D continues on optimizing light collection, channel segmentation, and read-out. SiPM's, an emerging technology which is being studied for use in the BCAL, offer an attractive read-out solutions along with potential benefits in light collection and in minimizing high magnetic field effects. The monitoring system of the UPV read-out can be tied into the system utilized for the BCAL detector. A pulsed laser-fiber optic system is planned BCAL read-out devices.

Manpower, R&D and Production Schedules

The UPV is the responsibility of the group from Florida State University. This manpower is adequate to complete remaining R&D and to complete the detector construction in two years from availability of funds.

Electronics

Purpose, Description

The electronics must amplify and digitize raw detector signals and store them for later readout at level 1 trigger rates of 200 kHz without incurring deadtime. Note that the detector includes approximately 12,500 ADC channels and 8,200 TDC channels.

A pipelined approach is required due to the high trigger rate. The digitized information must be stored for many μs while the level 1 trigger is formed. Multiple events must be buffered within the digitizer modules and read while the front ends continue to acquire new events. The raw data rate from the detector is 1 Gbyte/second. A sophisticated timing system is required to synchronize the pipelines in the front-end modules.

Current Status, R&D issues

Since no currently available commercial solutions exist the preamps, digitizer modules, and timing system will be designed by GlueX.

JLab has designed a multi-channel TDC module based on the ACAM TDC-F1 chip, and 50 units have been produced for use in halls B and C. A single-channel prototype 8-bit 250 MHz FADC, suitable for the barrel and lead glass calorimeters, has been constructed at Indiana University. Only preliminary work has been done on the preamps and the timing system.

Review

The GlueX electronics system was reviewed in July of 2003. The reviewers concluded the basic design is sound and appropriate assuming adequate human and fiscal resources.

The reviewers recommended that the work on the TDC and FADC should continue. A multi-channel FADC needs to be prototyped and evaluated. As part of the level-1 trigger, the digitized calorimeter signals are summed in a pipelined adder tree; the prototype FADC needs to demonstrate this capability at the module, crate, and detector levels. Work begun on high speed links should continue.

Analog front-end requirements need to be settled. Prototype work needs to begin, especially on the tracking chamber electronics to be located inside the magnet. The pipelined level-1 trigger, timing, synchronization, and calibration systems all need further development in preparation for the CDR and Lehmann review.

Manpower, Management, and Schedule

The reviewers concluded that current manpower resources are inadequate. The University of Alberta has recently joined the collaboration, but additional institutions possessing electronics expertise are needed.

The reviewers concluded that a rudimentary management plan exists, but that it needs further development.

The reviewers estimated that the GlueX electronics effort could require 6 years to complete after CD-3; the collaboration hopes to reduce this time.

Data Acquisition

Purpose, Description

The data acquisition system must:

- support a deadtimeless front-end system at a 200 kHz trigger rate
- collect data from the front-end modules at 1 GB/sec
- build event fragments into a single event record
- pass built events to a level 3 farm
- write level 3 accepted events to mass storage at 100 MB/sec
- deliver a small subset of the events to calibration and monitoring systems

We expect a level 3 reduction of 90%, which reduces the 1 GB/sec raw rate to an accepted event data rate of 100 MB/sec.

GlueX expects to have 50-100 readout crates (depending on the choice of readout technology) containing approximately 12,500 ADC channels and 8,200 TDC channels.

Current Status, R&D issues

GlueX will use CODA, the standard DAQ system developed at JLab, but at higher trigger and data rates than have been achieved so far. We note that the high rate makes it impossible to interrupt the front-end processors for every event, parallel event building will be required, and that CODA has not been run with a high-rate level 3 farm.

CODA is under active development by the DAQ group at JLab.

Manpower, Further R&D, Production

Primary responsibility for developing CODA belongs to the DAQ group at JLab. This includes all the software needed to program and collect data from the front-end boards, build events, deliver and analyze events in a level 3 farm, and write events to local mass storage. The JLab computer center is responsible for moving the data (100 MB/sec) from local mass storage to permanent storage at the central computing facility.

Note that the DAQ group will develop the software infrastructure required to run the level 3 farm, while GlueX will build and run the farm, and develop the level 3 trigger algorithm. We further note that the DAQ group must be intimately involved with the GlueX electronics, trigger, and online efforts.

A prototype DAQ system needs to be available two to three years before start of data taking, and the production system must be ready one year before the start of data taking.

The Online System

Purpose, Description

The online effort is the umbrella under which all efforts related to taking data and writing it to mass storage will be organized, and includes overall responsibility for designing, installing, and maintaining everything related to controlling and running the experiment. This effort covers

- electronics and trigger installation
- experiment network design and installation
- counting house and operator environment
- DAQ installation and customization
- run management and control
- construction and maintenance of level 3 farm
- online event monitoring
- online event display
- electronic logs and bookkeeping
- slow controls
- alarm systems
- online calibration farm

Current Status, R&D issues

Most of the R&D needed here is being done by other groups, especially the Electronics, DAQ, and Trigger groups. For the remainder we will adapt existing or soon to exist technology (from JLab, CERN, Fermilab, SLAC, industry, etc.) as needed. The main effort will go into customizing the chosen technologies and integrating them into a coherent and usable online system.

Manpower, Further R&D, Production

GlueX will take primary responsibility for the online effort, and we expect that a large fraction of the work will be done by experimenters residing at JLab. The online software effort is substantial, involving customization and integration of a wide variety of outside packages. The online hardware effort is also substantial, involving integration of a large number and wide variety of electronics, computing, and monitoring equipment. Careful planning for dedicated manpower is necessary for successful implementation of the online effort.

Much of the online hardware and software needs to be available two to three years before the beginning of data taking to allow for detector and electronics commissioning.

Computing

Purpose, Description

GlueX is a compute-intensive experiment and will require a substantial computing infrastructure at JLab. This involves:

- design and implementation of a fast backbone network at the lab
- design and implementation of system to transfer 100 MB/sec from the counting house to the central computing facility
- purchase and installation of adequate offline storage media (approx. 1 PB/year raw data, 3 PB/year generated data)
- creation of large offline analysis farms (hundreds of cpu's)
- implementation of grid services to allow transparent access (OC 24 or better) to JLab and university computing facilities by GlueX collaborators

Current Status, R&D issues

Much of the above will not be needed for a number of years. Some of the items involve extension and/or upgrade of existing facilities, while others are completely new (e.g. grid services). JLab is a member of PPDG (a major grid collaboration) and is actively involved in grid R&D. We note that these all efforts are a continuation of current computer center activities.

Manpower, Further R&D, Production

Development and maintenance of the systems mentioned above will be the primary responsibility of the JLab Computing Center, although GlueX collaborators will need to be involved with the planning effort to ensure GlueX needs are met.

We estimate that prototypes of the items above will need to be in place three to five years before the beginning of data taking, and that production versions should be working one to three years before data taking (depending on system). We reconize that the purchase of many components (e.g. farm processors, switches, etc.) must be postponed for as long as possible for economic reasons, and that what needs to be in place early is the infrastructure within which these reside.

We note that the CEBAF Center extension currently under construction has dedicted space to house the offline farms and tape storage facilities needed to support GlueX.

Software

Purpose, Description

This effort includes development all software needed to analyze GlueX data, and includes:

- detector calibration
- full event reconstruction
- simulation
- partial wave analysis
- creation of data summary files
- level 3 trigger algorithm

Current Status, R&D issues

GlueX has developed a preliminary simulation suitable for experiment design and acceptance studies, and has begun work on an offline analysis framework and on the experiment data model. GlueX is also a leader in the world-wide effort to develop new PWA tools and algorithms.

Manpower, Further R&D, Production

Most of the GlueX analysis and simulation algorithms and software remains to be developed. This is a very large effort that has already begun, and it will continue for years after experiment startup. The work will be done by the GlueX collaboration, and a large fraction of GlueX members are expected to contribute.

Preliminary calibration software must be ready about a year before startup, and the final system must be ready by the time the experiment begins.

A full-featured event simulation, analysis framework, and preliminary reconstruction and analysis software needs to be available two to four years before the start of data taking. Final reconstruction and analysis software needs to be ready about six months before data taking for GlueX to succeed in publishing preliminary results within a year of startup.

The production level 3 trigger algorithm is needed about a year after startup, as initial data taking will be at a reduced rate, but a prototype must be available about one year before startup for testing.