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Name of Traveler: T. C. Awes

Joint Trip Report

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X No

If so, name of other traveler(s): ____________

MASTER

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ORNL FOREIGN TRIP REPORT

ORNL/FTR-3797

Date: October 19, 1990

Subject: Report of Foreign Assignment of T. C. Awes, Research Staff Member, Physics Division

To: Alvin W. Trivelpiece

From: T. C. Awes

PURPOSE

To oversee and assist with preparations for the WA80 experiment.

SITE VISITED

9/25/1989–10/4/1990 CERN, Geneva, Switzerland H. H. Gutbrod

ABSTRACT

The traveler spent the year at CERN primarily to test, calibrate, and prepare a BGO photon detector system for use in the August 1990 run of WA80 with sulfur beams and for use in future planned runs with an expanded BGO detector. The BGO was used in test-beam runs in December 1989 and April–May 1990 and in the August data-taking run. The Midrapidity Calorimeters (MIRAC) were also prepared in a new geometry for the August run with a new transverse energy trigger. The traveler also continued to refine and carry out simulations of photon detector systems in present and future planned photon detection experiments. The traveler participated in several WA80 collaboration meetings, which were held at CERN throughout the period of stay. Invited talks were presented at the Workshop on High Resolution Electromagnetic Calorimetry in Stockholm, Sweden, November 9–11, 1989, and at the International Workshop on Software Engineering, Artificial Intelligence, and Expert Systems for High-Energy and Nuclear Physics at Lyon, France, March 19–24, 1990. The traveler participated in an experiment to measure particle–particle correlations at 30-MeV/nucleon incident energies at the SARA facility in Grenoble from November 11–24, 1989.

REPORT OF FOREIGN ASSIGNMENT
Geneva, Switzerland, September 25, 1989–October 4, 1990

I. BGO Photon Detector

The traveler went to CERN with the intention of being on site for the acceptance, assembly, calibration, and use in an experiment of an anticipated array of 500 BGO photon detector modules. However, due to delays in the release of U.S. funds and problems with obtaining expected matching German funds, it was only possible to obtain a modest array of 30 BGO modules for prototype tests. In fact, this was not so serious since the initial goal to have 500 modules ready for the 1990 WA80 sulfur run was overly optimistic in light of the fact that the design and construction of the custom readout electronics was not feasible on such a short time scale.

The motivation to develop a BGO photon detector is driven by the fact that, if one is interested to measure the direct photon signal at low transverse momenta, p_T, which is believed to be a likely signature of quark–gluon plasma (QGP) formation, then it is necessary to measure simultaneously the photon contribution from π^0 decays also in the low p_T region. However, simulations have shown that due to the high π^0 multiplicity in heavy-ion-induced reactions, there is a large combinatorial background of photon pairs from which the π^0 yield must be extracted. This problem increases with increasing mass or energy of the colliding system, according to the increase in the π^0 particle density. To combat this problem it is necessary to use a detector system with the best possible energy and position resolution. WA80 initially pursued the possibility of using the newly developing Pb-scintillator spaghetti calorimeters, but found that they did not provide significant improvements in resolution (or cost). Instead, other available options were studied (mainly by Glenn Young), and it was realized that BGO provided the best resolution with the least cost per pixel element. Since this is the solution which was chosen by the L3 experiment at LEP after extensive tests, we have largely followed their design. The WA80 BGO modules are right cylinders of 2.5 cm by 2.5 cm front surface and 22 radiation lengths depth. They are read out by two Hamamatsu photodiodes which nearly cover the back surface (the same diodes as used by L3). In order to exploit the excellent resolution of BGO over the full dynamic range of a few MeV to around 100 GeV, it was necessary to build a custom preamplifier/amplifier/ADC system similar to what has been done by L3 to provide an effective 20-bit readout system. The considerations leading to the design of the WA80 BGO system were carried out by Glenn Young after discussions with Richard Sumner (ORNL/FTR-3491), who was one of the principal persons involved in the L3 design, and with Chuck Britton of the ORNL I&C Division. Although somewhat similar in philosophy to the L3 design, the ORNL design is significantly different in that it follows more closely a nuclear physics spectroscopy approach with pulse-shaping and base-line restore rather than a simple pulse integration. This is partly motivated by the difference between running in a collider geometry with a known interaction time and hence the possibility of a clocked gate, and a fixed-target geometry with a long spill period.

With the 30-module array it was possible to study the response of our BGO detector and to test the electronic readout prototypes at various stages of preparation, the last stage of which is still under design. The on-site work with the BGO consisted of acceptance tests, including measurements of the light transmission using the L3 transmission test bench, resolution measurements with a ^{137}Cs source, and physical dimension measurements. Also, tests were made of different surface coverings to optimize the uniformity and amount of light collection (wrapping with Millipore filter paper was found to be optimum). Measurements were made with the photodiodes using a ^{57}Co source and cosmic rays in the BGO to obtain absolute measurements of the number of electron pairs in the photodiode/MeV of deposited energy to determine the necessary absolute amplification ranges and to study the noise behavior of the diodes to find the optimum amplifier shaping time. At CERN, the BGO team consisted of the traveler, with assistance from Achim Franz of UT; Kyle Pope, an ORAU student research participant; and Mathias Hartig, a University of Münster diploma student, who all came for stays at CERN of various duration.

The BGO array was used in test beams on the X3 beam line in a two-week test period in late December 1989 and in a six-week period in April–May 1990. The experience during these test periods was very unsatisfactory due to the fact that the time was overprescribed. For example, in the December test it was intended to recalibrate all 1275 modules and remeasure the response of the SAPHIR photon detector, make tests of the Lund MSAC detectors, make detailed efficiency measurements of the old streamer tube data needed for analysis of the old data, and to test the BGO prototype detector. Since the BGO detector test was felt to be of the lowest priority, it was left to last, with the result that it only saw beam shortly before the Christmas holidays when nearly everyone at CERN had left; and so, due to problems with the accelerator after a storm and with the acquisition system, it was only possible to obtain a few hours of useful data after calibrating. As a result, this run period was largely a waste of a couple months of the traveler's time since the BGO had been assembled in a rush to prepare for this run with only single photodiodes (which were bought from L3 from their surplus, thanks to the present ORNL L3 connections) and so had to be disassembled and re-prepared with the desired readout. Also a great deal of time was spent to analyze these results since they had suggested a disturbingly poor BGO resolution, which later turned out to be due to the acceptance of the beam line spectrometer, which hadn't been understood at that time and which could not be diagnosed from the BGO data which was recorded then.

The April–May test period was similarly intense since the calibration and response measurements of the two new Pb-glass towers of 1250 modules each to be used in the August 1990 sulfur run [see trip reports of Frank Plasil (ORNL/FTR-3551) and Richard Cumby (ORNL/FTR-3585)] was deemed to have the highest priority and which used all but the last week of the calibration period. To complicate matters, problems had been found with the December calibration and response measurements of SAPHIR, largely due to drifting high voltages, such that it was desired to once again recalibrate SAPHIR. It was discussed to allow only a day for the BGO tests, which would have been entirely inadequate, until a solution was found in which the BGO and SAPHIR detectors could be mounted on the moveable stand in such a way that the two detectors could be put into beam alternatively with little movement of the stand, such that time spent in changing the beam setting was comparable to the data-taking period, making efficient use of the remaining calibration time.

Analysis of the BGO test and calibration data by the traveler proceeded during the remaining period of stay and is continuing. From the analysis so far, it is observed that the electronic noise contribution to the resolution is about 1 MeV. A temperature dependence of the BGO light output has been observed, similar to that quoted by L3, although somewhat smaller. It was observed that part of the observed temperature drift could be attributed to electronic drift as seen by drift of the electronic pulser signal. This contribution is not discussed by L3. The position resolution of the BGO has been found to be extremely good with a value of about 1 mm at 10 GeV, obtained without fitting of the shower, but instead using a simple weighted average method, with logarithmic rather than linear weights. The same procedure used for the higher position moments seems to provide an efficient means to discriminate between photons and hadrons with essentially no hadron contamination above 1 GeV. It raises a question on the need for longitudinal segmentation which was being considered by WA80 as a means to provide improved photon shower identification.

II. WA80 August 1990 Sulfur Run

The traveler participated in the August 1990 sulfur run of WA80, which has been reported in the trip reports of Glenn Young (ORNL/FTR-3491 on preparations and ORNL/FTR-3649 on run period) and of Frank Plasil (ORNL/FTR-3733). Together with H. A. Gustafsson of Lund University, the traveler had prepared the MIRAC detector in its new location, about 11.5 meters downstream of the target. Since the angle locations of the MIRAC towers changed in moving to the new geometry, it was necessary to create a new set of resistor–attenuator weights to be used in the MIRAC transverse energy trigger. This was done by using calculated effective tower angles which take into account the MIRAC detector response, and were provided by Soren Sorensen of the University of Tennessee and ORNL. For the 1990 run, the MIRAC trigger was used as the high centrality trigger as previously, and it was used in a new function to help define the minimum bias trigger by a low threshold to require a minimum amount of transverse energy. This was necessary since the previous charged-particle multiplicity coverage was significantly decreased and asymmetric, and so could no longer be used to provide a minimum multiplicity requirement. There was some initial concern that the transverse energy trigger might be too noisy; but in fact, it was found to be quite sufficient and to provide a less biased trigger than in previous WA80 runs [see also trip reports of Glenn Young (ORNL/FTR-3649 and ORNL/FTR-3743)].

The traveler also prepared the modest 30-element BGO array for the run. Shortly preceding the run, 30 prototype modules of amplifiers, custom designed and built in the ORNL I&C Division by Chuck Britton, Alan Wittenberg, and

Nance Ericson, were received to be used for the run period. These amplifiers provide six different gain ranges with a sample and hold circuit and a multiplexer which selects as output from the module the highest unsaturated gain range to be digitized with a commercial 12-bit ADC. It also provides 3 bits of information to give the selected gain range and to be read with a commercial latch. Thus, the system provides an effective 20-bit dynamic range. These modules were found to perform exactly as designed; however, during the run period it was decided to make several modifications, mainly to lower the low-energy threshold to around 10 MeV and also to allow for a slower WA80 trigger coincidence. These modifications are described in the trip reports of Britton and Wittenberg (ORNL/FTR-3746) and Young (ORNL/FTR-3743). Although this BGO array is of very modest size, it should provide interesting physics information on the inclusive photon spectra, especially at very low energies, which can be compared with the large Pb-glass arrays. It will also provide some early indications of whether it is highly sensitive to low-energy background which might degrade the energy resolution from that obtained in a clean test environment. This information can be studied from the observed resolution for the minimum ionizing peak as compared to that seen under the test conditions and also from the π^0 mass resolution when combined with the Pb-glass detector.

III. Photon Detector Simulations

Throughout the period of stay at CERN, the traveler continued with Monte Carlo simulations of photon detector response and combinatorial backgrounds for different photon detector systems and reactions. These included simulations for the 1990 WA80 sulfur run, which were used to choose the arrangement and geometry of the new Soviet Pb glass used for the run, simulations for the 1991–1992 Light Universal Detector (LUD) upgrade proposal, for the Pb beams at CERN, and also for photon measurements in the RHIC dimuon experiment. The simulation routines were upgraded to include the detailed photon detector geometry, allowing for the individual module locations, including the possibility of dead modules, and to include the effect of the photon reconstruction efficiency based on extrapolations from the results obtained with the SAPHIR photon detector.

IV. Attendance of Meetings

During the period of stay at CERN, the traveler went to Stockholm, Sweden, to attend the Workshop on High Resolution Electromagnetic Calorimetry, November 9–11, 1989, and to Lyon, France to attend the International Workshop on Software Engineering, Artificial Intelligence, and Expert Systems for High-Energy and Nuclear Physics, March 19–24, 1990. At both meetings the traveler presented an invited talk entitled "A Neural-Network Approach to the Problem of Photon Pair Combinatorics" from a work which had recently been published in *Nuclear Instruments and Methods in Physics Research*. Although this topic was somewhat outside the scope of the first meeting, which was mainly concerned with hardware issues relating to electromagnetic calorimetry in the high-rate environment of the SSC and

LHC accelerators, it generated considerable interest as a novel method to combat the increasing multiplicities at these facilities. This meeting was also of interest since it was attended prior to the assembly of our BGO detector. Much of the workshop consisted of discussions of the properties of the candidate high-rate EM calorimeters, which were essentially only BaF and liquid xenon scintillators. However, there were also discussions of new, novel detectors, such as PbF by David Anderson of Fermilab, and by Craig Woody of BNL. It was also learned that there are now several facilities in the Soviet Union beginning to grow BGO crystals, one of which is the Kurchatov Institute, which has joined WA80 with the new Pb glass and which plans to contribute BGO crystals for the possible 1992 run.

The meeting in Lyon was particularly interesting to the traveler since it was the first time to attend such a meeting dealing exclusively with topics on computing in physics. It became clear to the traveler from this meeting that since computing and software has become such an important portion of the present large experiments, that it is absolutely essential to take an engineering approach to computing as well as the detector hardware. It would be wise to follow the developments in computing, as from such meetings in the future. Surprisingly, the traveler was asked to chair a session on expert systems (of which he knew essentially nothing prior to the meeting!), presumably since he was considered to be an authority on the application of neural networks in physics, having been one of the few people to experiment with them. Apart from having the opportunity to meet some of the other people who have experimented with neural networks, such as Brice Denby from Fermilab, the meeting was interesting for several other reasons.

It was learned that for essentially all of the LEP detectors, a substantial software effort has been made to develop expert systems with the intent to allow for the diagnosis of the detectors, even by those experimenters who are not knowledgeable about a particular detector subsystem. The conclusions from the speakers and discussions, however, were that, although the expert systems should work in principle, they actually provided little help in practice. The systems had several problems; first of all, in order to become experts, the expert systems had to obtain the knowledge of the detector subsystems. However, before gaining some experience with the detectors, even the detector experts did not yet have the knowledge to diagnose the detector problems and, therefore, could not provide the deductive rules needed for the expert system. Furthermore, during the initial stages of the experiment when the expert system would be most useful, the experts were usually too busy or uninterested to provide the information for the expert system. Also, the regeneration of the expert system data base with each new piece of knowledge was often extremely slow, as well as the deductive diagnosis process itself. It occurred to the traveler that it might be more productive to simply train a neural-network system with each expected or experienced detector problem and cause. This neural network would then have the ability to quickly diagnose a problem to give a probable solution, although the neural network would not be able to supply the deductive logic which would support its conclusion; however, this is probably also true of the detector experts! As a final blow to the usefulness of these systems, it was remarked by someone that by the time the expert systems had acquired a sufficient knowledge base to be useful, the detector would probably be upgraded or finished. Such systems are apparently only useful for applications with a long expected lifetime.

The other most interesting realization which came from this meeting was the impression that the time may finally have arrived to get away from the FORTRAN language and switch to an object oriented language such as C. It was stressed over and over again that physicists deal mainly with objects — events, magnets, spectra, etc. — and that FORTRAN was an unnatural language to use. A very interesting application was shown by Paul Kunz of SLAC in which an entire physics analysis, from data sorting to histogram manipulation, could be performed in a Macintosh-like mouse environment on a *NeXT* computer.

V. Experiment at SARA Facility in Grenoble

The traveler participated in an experiment to measure light charged-particle correlations in reactions of 30-MeV/nucleon sulfur on Ag at the SARA facility in Grenoble from November 11–25, 1989. The experiment was performed with the AMPHORA Detector Group with Serge Kox as spokesman. The experiment was motivated by results of proton–proton correlations obtained at HHIRF by our group at ORNL which were published in *Physical Review Letters* and had been discussed with Kox during a stay at CERN in the previous year. From the ORNL results it appeared that the nuclear proton-emission volume in space-time was not simply large due to long lifetimes but that it must be physically larger than the compound nucleus system. However, the ORNL experiment suffered from a lack of impact parameter selection, so that the result might be explained by impact parameter averaging. The goal of the SARA experiment was to use the EMRIC detector system, which is a close-packed light-particle detector array, together with the AMPHORA detector, which is a near 4π light-particle detector suitable for event classification and impact parameter selection. The experiment ran successfully and the analysis is being carried out in Grenoble.

VI. P252 Collaboration Meeting, October 1–3, 1990

On October 1–3 the first full meeting of the newly formed Light Universal Detector (LUD) collaboration was held, and included all of the former WA80 collaboration, with the exception of the LBL group, together with the new collaboration members from India, the Soviet Union, and the University of Geneva. This experiment is also known as CERN proposal P252. This proposal had been drafted in the previous collaboration meeting of May 3–14, 1990, which has been described in the trip report of Frank Plasil (ORNL/FTR-3614). Shortly before the meeting it was learned that the proposal had been turned down technically and that a new proposal would need to be submitted. It was reported that the SPS Committee (SPSC) had rejected the proposal on the argument that they felt that the BGO was too expensive an option to pursue with the belief that we would not be able to afford enough BGO coverage to obtain meaningful physics results. On the other hand, it was reported that the SPSC did feel that the pursuit of the photon pad counters and MSAC detectors were interesting ideas which deserved approval. The SPSC, therefore, recommended that the collaboration resubmit the proposal without the BGO. The traveler extended his period of stay to include this collaboration meeting after it was realized that he would be the only participant from ORNL who could attend the meeting.

The meeting was truly a LUD collaboration meeting, with essentially no business relating to the previous WA80 results. It also felt like a different collaboration since most of the WA80 collaborators were wiped out by the August run, so that it was largely only the new collaborators and those of WA80 permanently at CERN who managed to attend. The first day of the meeting dealt with the magnet and the Multiple-Step Avalanche Counters (or MSAC detectors) with optical readout by CCD (also referred to as the Light Chambers, as in the Light Universal Detector) cameras to be used for tracking. The second day concentrated on the photon measurements with the photon pad detector and its readout using the UA2 CCD cameras and the BGO. It was also concerned with data acquisition and simulations. The third day dealt with time scales for preparation for the 1991 run.

A report on field calculations done by the CERN magnet group for the Goliath magnet showed that it should be okay to increase the gap size to 1.6 m and still obtain the required Bdl. There may be a problem to get the necessary increased power supplies though. There did not appear to be any problems in moving the magnet from the North Area, with installation in the West Area being completed by about May. Extensive field mapping would be required since with the large magnet gap, the field would extend quite far out from the magnet. It is of the order of 50 gauss just outside the magnet.

The first MSAC results were reported by the Lund and Geneva groups. Some initial test results were obtained during the August sulfur run when the MSAC detectors (one from Lund University and the other from the Geneva group) were run parasitically independent of the WA80 data taking. The analysis of the Geneva chamber results had progressed quite far while little progress had been made with analyzing the Lund chamber results due to problems reading the data taken with the Geneva group acquisition system. From the results reported by the Geneva group, it was seen that although the CCD event displays looked like trash in raw form, after filtering out the background, basically with only a pixel-by-pixel threshold level, they cleaned up very well, showing very clear hit clusters. The preliminary efficiency number was 70–80%, based on only about 100 events. They expect to improve the light collection by about a factor of 20 with a new camera and image intensifier so that there should be better signal/noise and improved efficiency. The main problem still is sparking. They only get sparks associated with tracks, unlike the Lund MSAC which is not gated and tends to spark at a continuous rate. Right now the chamber voltage is increased until the spark rate is at 1% of the trigger rate for single tracks. It is worried that this will not be acceptable with the actual running, since the number of tracks will be significantly higher, and so the associated increase of the spark rate will lead to an unacceptable dead time of the detectors.

A new Lund collaborator, Harry Whitlow, described the Lund electronics project for pad readout of an avalanche detector with single avalanche gap. This is viewed as an alternative to the optical CCD readout and is felt to have the advantage that it may be less expensive and require less amplification and, hence, have little or no problems with sparking. They are designing a system to read out a 3.5×3.5 m^2 avalanche detector with 5×5 mm^2 pads, or 512K pads. It sounded to be an interesting possibility also for the muon chambers required for the dimuon experiment which ORNL hopes to lead at RHIC. The pad readout will have 4-bit pulse height information with full zero suppression. There will be 3 bytes per pad: 2 and 1/2 for address and 1/2 for the ADC. The estimated cost is 1 Swiss franc/pad. The readout is very parallel and designed to be about 1 ms for readout of the full 512K pad system.

With the magnet in place and at maximum field, it is estimated that the beam deflection will be about 7 cm at MIRAC, meaning that the beam would hit the inner tower of MIRAC with the present geometry. Therefore, the MIRAC hole will need to be opened, to a slit presumably. Also, since it is planned to run both field polarities, the slit will need to be symmetric. The magnetic field will obviously distort the E_T and ZDC measurements, but presumably there will remain a good correlation between impact parameter and ZDC or E_T, but strongly distorted. The question of whether or not to restack the ZDC and replace the damaged scintillator was left to be decided from simulations if it was seen that there is an obvious preference for the ZDC over E_T for trigger purposes. One interesting possibility is that the slit could be chosen so that spectator protons ($Z/A = 1$) hit the inner towers while the beam ($Z/A = 1/2$) and neutrons hit the ZDC.

On the second day of the meeting, progress on the new photon pad detector simulations and construction was reported by the Indian collaborators. The photon pad detector is to consist of roughly 8000 scintillator pads of 2 cm by 2 cm located behind a Pb converter. The scintillators are laid out to overlap like fish scales, to have no dead regions, with the signals carried out on optical fibers which are read out in bundles of about 2000 with CCD cameras as done by UA2. In fact, it is intended to use the CCD cameras of the now completed UA2 experiment. The Indian collaborators have been very busy with EGS simulations of the detector response, the results of which look very promising. It is seen that the energy deposited in a single pad for a photon shower is up to about 5 times the energy of a minimum ionizing particle. Typically, several pads fire. It was shown that a simple cut on the pad pulse height may be used to eliminate the hadrons and provide a hit multiplicity which is directly proportional to the photon multiplicity. The physics objective of this detector system is to provide another means of searching for a direct photon enhancement as seen by a simple increase in the number of photons relative to the number of charged particles. This observable has the advantage that it would be sensitive to an increase in the N_γ/N_C on an event-by-event basis, in contrast to the actual photon p_T spectrum which must be determined on a statistical basis after accounting for the photon contributions from meson decays. However, it is doubtful to the traveler that one would ever be able to claim that you have evidence for QGP formation with such a detector alone, but it should give useful corroborative information with the other Pb-glass and BGO detectors.

During this part of the meeting there was a discussion within the collaboration on the status of the BGO project, the feelings of the SPSC towards future photon measurements at CERN, and the ORNL outlook. It was stated that ORNL had \$1M for BGO from DOE, but would not use it for the BGO without the approval of the SPSC. Also, that without the BGO in the near term and with the unlikely future possibilities for photon measurements at CERN, ORNL would very likely not be involved in the Pb experiments but would concentrate efforts on RHIC development. There was much general discussion and agreement on the bad treatment we have received from the committee, and the collaboration again showed signs of splitting along the photon–nonphoton lines, that is, with clear indications that ORNL, Lund, and Münster would probably not be involved in the Pb experiment.

It was agreed that a clear statement from the SPS management was needed, and so Gutbrod, Martin, and Santo all went immediately to meet with Darriulat, the SPS coordinator, and Donnachie, the SPSC chairman. In this meeting, as it was reported to the rest of the collaboration, CERN management was told of the BGO funds from the U.S. and of the future Soviet BGO, neither of which they were aware. When asked point-blank whether we should abandon plans for photon measurements at CERN, they said that, on the contrary, we should continue to pursue them. There were also two other new pieces of information which were presented and which apparently might have changed their point of view. One is that Satz is now very much for photon measurements, since there are new calculations by Ruuskannen which show that the thermal dilepton signal will not be observable above nonplasma processes, whereas the direct photon signal may be. Also, they were not aware that we are about to publish our oxygen direct photon data. We were encouraged to submit the BGO as an addendum to the revised P252 proposal, pointing out in this given sequence of importance: (1) the new theoretical information showing the importance and needed sensitivity, with our present photon measurement results; (2) a discussion of how the BGO will provide test results useful towards the developments for future measurements; (3) a discussion of physics to be done with the limited amount of BGO in the sulfur setup.

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