

Report on the
GRETINA Physics Working Group Workshop

**“Optimizing GRETINA Science:
A workshop dedicated to planning the first rounds of operation”**

October 14 + 15, 2007
University of Richmond, Richmond, Virginia



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1. Introduction

The GRETINA Advisory Committee (GAC) together with the Contractor Project Manager organized and hosted a GRETINA/GRETA Physics Working Group workshop entitled “Optimizing GRETINA Science: A workshop dedicated to planning the first rounds of operation” This workshop was held on October 14 and 15, 2007 at the University of Richmond immediately following the Fall DNP meeting in Newport News.

The meeting was focused on how to best optimize the discovery potential and physics impact of GRETINA with unstable and stable beams at various sites once GRETINA will be completed with seven quad clusters by February 2011. It was agreed that GRETINA will be assembled, tested, and commissioned at LBNL and then it will be rotated among the national laboratories ANL, ORNL and MSU. At the workshop we also discussed in detail the physics opportunities at each laboratory and unanimously converged on a sequence order for the first rotation cycle. We also discussed in detail infrastructure issues at each of the laboratories.

Prior to the meeting a letter (see Appendix 1) was sent to the GRETINA Management Advisory Committee (MAC) and each of the laboratory directors at ANL, LBNL, MSU and ORNL requesting their ideas on with how to best move forward on these issues and developing a coherent scientific plan for GRETINA. In our letter we asked several questions, which included:

- What interest does your laboratory have in hosting GRETINA?
- What site preparation do you need (including manpower and funding needs)?
- Is there a preferred timetable after 2010 for GRETINA to come to your facility?
- How long would you feel is optimal for GRETINA to stay at your facility?
- What beam-time allocation might be envisioned for this device?
- What rotation period do you think would be sensible for its next return?
- By what mechanism or through what process should we make siting decisions?
- Are there other issues or concerns that need addressing?

Responses from all four laboratories are contained in Appendix 1.

Each of the speakers at the meeting representing the various host laboratories was requested to focus on:

- What new opportunities does GRETINA bring to the program at your laboratory and what are the specific details of the initial experiments or campaigns that will have the greatest physics impact?
- Auxiliary detectors will play a key role. What are you planning to use?

In addition to these major sessions, the meeting also included presentations on the status of the GRETINA project, the status of signal decomposition efforts and a detailed discussion on the assembly, testing and initial engineering runs at LBNL. A report on auxiliary detectors for GRETINA was given along with a presentation of a new neutron detector being built in Canada as part of the TIGRESS project but which could also be used with GRETINA. A representative from Japan discussed the scientific program at RIKEN and their interest in possibly hosting GRETINA at some point in the future. We were also fortunate to have representatives of the parallel AGATA project in Europe who enlightened us with regard to their current status as well as their plans for rotation of the “early demonstrator” system among several stable and unstable beam laboratories.

The meeting was carefully organized such that there was plenty of opportunity for open discussion of all issues. At the end of the meeting our initial objective was met in that a plan of the early science campaigns and rotation order among the individual laboratories was unanimously agreed upon.

In Section 2 a brief review of the exciting scientific plans at each individual laboratory is presented. Section 3 contains a summary of answers to the questions we posed in our original letter to the laboratory Directors. Section 4 contains the main outcome of the meeting, namely the initial rotation plan for GRETINA and several “action items” from the meeting are also outlined. The Appendix contains (i) our original letter to the MAC, (ii) laboratory responses to this letter, (iii) the workshop schedule and (iv) a list of attendees along with a group photograph.

2. The frontier science plans at each laboratory

GRETINA will have a broad and rich scientific program wherever it is situated. However, for the first cycle of operations, experiments focusing on high profile “Home Run” science, seizing the major unique opportunities at each site, must be the priority. Thus a large fraction of the meeting was devoted to the discussion of the exciting science opportunities at each of the possible host facilities. As mentioned above each laboratory brings unique qualities in terms of beam capabilities and auxiliary systems that can be used with GRETINA. The scientific initiatives and areas of investigation discussed below are fully consistent and indeed constitute a driving force within the scientific goals expressed in the current 2007 Long Range Plan exercise. They also form a natural evolutionary path of physics objectives towards those expressed in the GRETA White Paper which can be found at

http://fsunuc.physics.fsu.edu/~gretina/GRETA_WP_Jan07_4.pdf

(a) Argonne National Laboratory: Benchmarking the new key physics opportunities at Argonne has been performed by identifying the limitations of current Gammasphere research. We can see three promising categories; Coulomb excitation of neutron-rich beams from our new CARIBU ion source, research in very heavy elements and near ^{101}Sn , and exploitation of multi-nucleon transfer reactions.

Coulomb excitation has long been a key spectroscopic tool for nuclear structure investigation, as the reaction mechanism is purely electromagnetic. Studies of very neutron-rich nuclei, for example the highly deformed zirconium isotopes from CARIBU, are expected to show new collective features. Traditional Coulomb excitation on high-Z targets favors multi-step excitation, ideal for investigating band structures. Near barrier excitation on low-Z targets is ideal for identifying single-step non-yrast collective strength connected to the groundstate. For both of these applications, the excellent Doppler reconstruction power of GRETINA will enhance sensitivity. This is critical as radioactive beams will have low intensities, 10^5 - 10^6 particles per second, and will be traveling at up to 10% of the speed of light. A new auxiliary detector “Super-CHICO” will match the higher angular resolution of GRETA and is a cost-effective device for enhancing sensitivity.

In super heavy nuclear research, Gammasphere has led the way in developing a new paradigm for understanding the formation and stabilization of the heaviest elements. This research can be enhanced with GRETINA by exploiting its compact size and fast-counting abilities. At ANL, replacing Gammasphere with an optimized GRETINA at the Fragment Mass Analyzer (FMA) increases the experiments efficiency by about a factor 20, allowing “in-beam” studies on nuclei produced below 5 nanobarn (nb) in cross-section. Locating neutron states from above the N=184 “magic” spherical gap, through observing backbending, would be one of the main goals, as would be the enhanced spectroscopy of odd-A nuclei. This setup will be ideal for other far-from-stability research, such as investigating nuclei near ^{100}Sn . The ^{100}Sn region, lying right at the proton dripline, plays a critical role in understanding the evolution of shell gaps in exotic nuclei.

Access to neutron-rich nuclei is difficult. Multi-nucleon transfer from beams with large N/Z ratios, like lead and uranium, has proven to be a powerful tool for spectroscopy of exotic nuclei, due to the high resolving power of large gamma-ray arrays. This approach has been very successful in populating exotic nuclei in the neutron-rich fp-shell, where new shell model interactions are being developed to describe the new landscape. Operating GRETINA with Super-CHICO, masked to only select reaction products near the grazing angle, appears to offer the potential for pushing one or two isotopes further from stability and approaching new shell closures. This application exploits both the superior Doppler reconstruction and the high-count rate capability of the device.

(b) Lawrence Berkeley National Laboratory: The 88-Inch Cyclotron is able to provide the full range of stable beams at the energies and intensities required for many experiments with GRETINA/GRETA. Many interesting cases for GRETINA science, using stable beams, have been presented both in the GRETINA Proposal (June 2003) and the GRETA White Paper (December 2006). For example, dipole resonances such as the pygmy resonance and the giant-dipole built on superdeformed states in heavy nuclei can be studied in great detail, thanks to the improved efficiency for high-energy gamma-rays of GRETINA. Another example involves deep-inelastic experiments using SuperCHICO in the mass $A > 100$ Mo-Zr to study, for instance, shape evolution and symmetries in n-rich heavy nuclei that will benefit from GRETINA’s angular resolution for Doppler correction.

However, it is in the area of heavy elements research that a major impact is possible by combining GRETINA with the Berkeley Gas-filled Separator (BGS) - the best γ -ray

detector system with a highly efficient heavy element separator. The compactness, efficiency, and count-rate capability of GRETINA together with the superb performance of the BGS will provide an optimal facility to carry out a new generation of experiments on the structure of transfermium nuclei. Of particular interest here is the study of the relevant single-particle and collective degrees of freedom. It will be possible to perform detailed prompt spectroscopy of odd-A nuclei such as ^{251}Md , ^{255}Lr , and $^{253,255}\text{No}$. In even-even nuclei it will be possible to identify the first band crossing in the ground state sequences and search for structures built on high-K multi-quasiparticle states. This type of information will allow us to identify and characterize the single-particle orbitals, some of which originate near the spherical super heavy shell gaps and get close to the Fermi surface at $Z \sim 100$ $N \sim 150$ due to the quadrupole deformation. We will also obtain important information on the collectivity and pairing properties of these heavy nuclei.

With a BGS efficiency of $\sim 60\%$ for reactions of Ca/Ti Beams on Pb/Bi targets and the high count rate capabilities of GRETINA, we estimate improvement factors ≥ 10 over current setups. We will be able to study the prompt spectroscopy of ^{256}Rf ($Z=104$ $\sigma_{\text{max}} \sim 18\text{nb}$) and possibly even ^{260}Sg ($Z=106$, $\sigma_{\text{max}} \sim 1\text{nb}$). In addition, a $\sim 15\%$ BGS efficiency for reactions induced by light beams on actinide targets opens up a broader range of isotopes which can be studied.

(c) NSCL at Michigan State University: GRETINA will have an immediate impact on the scientific discovery potential at NSCL. The scientific program at the NSCL addresses key questions at the forefront of nuclear structure physics and nuclear astrophysics in experiments that combine gamma-ray spectroscopy and event-by-event particle detection for a variety of experimental approaches. GRETINA will be used in conjunction with the high-resolution, large-acceptance S800 spectrograph and provide an improvement in sensitivity of more than an order of magnitude over the currently used Segmented Germanium Array (SeGA).

The reach of projectile Coulomb excitation measurements and direct reactions in inverse kinematics, e.g. one- and two-nucleon knockout experiments, single-nucleon pickup, fragmentation reactions and charge-exchange reactions, will be immediately enhanced by the superior efficiency and resolution of GRETINA relative to SeGA. In-beam gamma-ray experiments with beam rates of a few ions per second will allow extending the study of the evolution of shell structure to new exotic regions of the nuclear chart and closer to the nucleon drip lines. Excitation level schemes, $B(E2)$ excitation strengths, single-particle spectroscopic strengths, $B(GT)$ values, excited-state g -factors and level lifetimes will be accessible observables. Experiments on nuclei beyond ^{42}Si , ^{54}Ca , ^{78}Ni and ^{64}Cr will be feasible and provide crucial input for model calculations aimed at predictive theories for nuclear structure and nuclear astrophysics. The geometry of GRETINA is ideally suited for detecting the forward-focused gamma-ray distribution emitted by nuclei at velocities exceeding 30% of the speed of light.

More than 600 different isotopes have been delivered as radioactive ion beams to experiments at NSCL during the first five years of Coupled Cyclotron Operations.

(d) Oak Ridge National Laboratory: The combination of GRETINA with beams available at the HRIBF will allow the community to address critical questions at the frontier of nuclear structure and nuclear astrophysics in a unique and powerful way, and will significantly enhance the productivity of the HRIBF research program. The scientific

questions addressed by GRETINA at the HRIBF coincide with the main scientific nuclear structure thrusts of GRETA at FRIB described in the GRETA White Paper for the 2007 Long Range Plan, in particular those described in Sec. 3.1:

- 3.1 How do extreme proton-to-neutron asymmetries affect nuclear properties, such as shell structure and collectivity?
 - 3.1.1 Doubly magic nuclei far from stability
 - 3.1.2 The alteration of shell structure far from stability
 - 3.1.3 Symmetries and excitation modes in exotic nuclei
 - 3.1.4 The nucleus as an open quantum system

With an expected emphasis on experiments with neutron-rich beams, GRETINA experiments at the HRIBF may be expected to include:

- Measurements of Coulomb excitation in the regions of crucial magic and doubly magic rare isotopes such as ^{132}Sn and ^{78}Ni , including multiple excitation, and magnetic dipole and electric quadrupole moments.
- Single-particle transfer reactions in inverse kinematics to locate and perform detailed studies of crucial single-particle states, including angular correlation and lifetime measurements.
- Two-nucleon transfer reactions to measure symmetries, correlations and excitation modes in neutron-rich systems.
- (p,γ) capture studies, recoil-isomer-decay tagging experiments, etc.

The HRIBF has the capability to accelerate approximately 175 radioactive isotopes including 140 neutron-rich species, to energies above the Coulomb barrier for all species. More than 50 of these beams, including ^{132}Sn , are available at intensities of 10^6 ions/s or greater. With the IRIS-2 completion expected in mid-FY09, substantial improvements in facility efficiency, reliability and predictability will be realized. We envision GRETINA to be coupled with the Recoil Mass Spectrometer (RMS).

3. Laboratory answers to the questions asked in our letter

While the Appendix contains the full response from each of the laboratory Directors we summarize here the general consensus on each of the questions which we asked in our original letter. It was interesting to note that there was very broad agreement on almost all of these issues.

- What interest does your laboratory have in hosting GRETINA?

All the laboratories responded in a very positive way as evidenced by the exciting science programs documented in the previous section.

- What site preparation do you need (including manpower and funding needs)?

Here the one time site preparation costs varied between the different laboratories ranging from \$125k to \$450k. Most of the manpower needs can be met by the present staff although the need for extra scientists was noted. Funds to support post-docs were

identified as a critical issue for growing our community for the future. In addition it is clear that an appropriate operations budget for GRETINA close to \$1.5M/year (similar to that originally allocated for Gammasphere after inflation is taken into account) will be necessary.

- Is there a preferred timetable after 2010 for GRETINA to come to your facility?

Both LBNL and MSU are ready to begin GRETINA running as soon as possible while ORNL require the IRIS-2 upgrade to be in place and ANL's science program requires CARIBU to be operational. These requirements are fully compatible with the operation rotation plan agreed upon.

- How long would you feel is optimal for GRETINA to stay at your facility?

Interestingly each laboratory felt a shorter length of time than the ~2 years that had been typical for Gammasphere was more appropriate. All the labs felt focused campaigns of about 6 months would be best with about one month each for setup and breakdown including shipping.

- What beam-time allocation might be envisioned for this device?

Here numbers between 60–80% were mentioned which are consistent with experience from running Gammasphere. Also similar to the latter operationally was the consensus that the Program Advisory Committee (PAC) at each host laboratory should add one or more “expert” members to enhance their PAC when evaluating GRETINA based experimental proposals.

- What rotation period do you think would be sensible for its next return?

In the letters and from discussions at the meeting about 24 months seemed sensible in order to allow time for the first round of GRETINA experiments to be analyzed and new proposals developed.

- By what mechanism or through what process should we make site selection decisions?

It was agreed that a community based consensus should be reached. It was felt that the present procedure initiated by the GRETINA Advisory Committee (GAC) fulfills this criterion and has been successfully executed. It could therefore be used as a basis for future rotation decisions although in the future the GAC will likely be replaced by a GRETINA Users Executive Committee. About 15 months before the end of the first rotation cycle was judged as a reasonable time for planning the next round.

4. Main summary and outcomes from the meeting

A unanimous view of how best to proceed with the optimization and science planning of GRETINA after the end of the engineering runs in February 2011 was agreed upon. This plan is outlined below:

(i) Commissioning runs at LBNL for a period of 2-3 months. These runs with GRETINA coupled to the BGS would be coordinated by the GAC. Primarily they will serve as the major debugging phase for GRETINA under real battle conditions with the critical benefit that most of the experts who had built up the various systems would be available locally. These runs would also provide the opportunity to obtain important physics results on the spectroscopy of super heavy elements (SHE). Indeed SHE studies have featured heavily in all GRETINA and GRETA (and recent Long Range Plan) documents. These runs would be contingent on (a) a study of the n-damage rate for detectors in the BGS environment, and (b) that site preparation be completed on time. After these commissioning runs GRETINA would be ready for moving to another laboratory to begin official PAC-approved physics campaigns.

(ii) The first physics campaigns of approximately 6 months duration would follow the initial rotation cycle:

1. MSU
2. ORNL (contingent on IRIS-2 being fully functional)
3. ANL (contingent on CARIBU being fully functional)

We expect an approximate time of 2 months as a take down and set up period for each initial move. A subcommittee of the GAC to evaluate the detailed costs and issues involved has been setup.

Other outcomes and action items included:

- That a GRETINA Users Executive Committee would be formed at the time GRETINA becomes operational. This organization would follow along the lines of the Gammasphere model.
- The continued development of auxiliary detectors to be used with GRETINA was to be greatly encouraged.
- We look forward to further discussions with our Japanese colleagues and are excited about the possibility of future collaborations.
- Our continued interactions with the AGATA project have been mutually beneficial and will continue to be developed.

Appendix (i): Letter to the Management Advisory Committee

Dear Member of the GRETINA Management Advisory Committee:

We are writing to discuss with you how best to proceed with formulating the initial science, siting and rotation plan for GRETINA at the national laboratories of LBNL, ORNL, ANL and MSU. We request your help in determining how we can best optimize the discovery potential and physics impact of GRETINA (expected to be completed with 7 quadruple clusters by the end of 2010) using unstable and stable beams. Prior to this we believe that GRETINA should be assembled, tested, and commissioned at LBNL.

We have several questions which we would like to ask about GRETINA and your laboratory, which will help us develop a coherent plan. These include:

- What interest does your laboratory have in hosting GRETINA?
- What site preparation do you need (including manpower and funding needs)?
- Is there a preferred timetable after 2010 for GRETINA to come to your facility?
- How long would you feel is optimal for GRETINA to stay at your facility?
- What beam-time allocation might be envisioned for this device?
- What rotation period do you think would be sensible for its next return?
- By what mechanism or through what process should we make siting decisions?
- Are there other issues or concerns that need addressing?

By answering these questions you will help us converge on a specific plan in order to give potential sites and their users enough lead time to not only prepare to house GRETINA but also to organize a coherent scientific plan. We most certainly welcome your thoughts on related issues and request a brief written response by September 21.

With these important thoughts in mind the GRETINA Advisory Committee together with the Contractor Project Manager (I.Y. Lee) are planning to host a GRETINA/GRETA Physics Working Group workshop entitled “Optimizing GRETINA Science: A workshop dedicated to planning the first rounds of operation” to be held October 14,15 2007 at the University of Richmond immediately following the Fall DNP meeting at Newport News. The University of Richmond is a 1.5 hour drive from Newport News. The workshop will begin at 9:00 am on Sunday morning (14th Oct.) and end at lunch time (12:30 pm) on Monday (15th).

The program of the meeting will include discussion of the following:

- What new opportunities does GRETINA bring to the program at each national laboratory and what are the specific details of the initial experiments or campaigns that will have the greatest physics impact?
- Auxiliary detectors will play a key role. What are people planning to use?
- What infrastructure needs to be in place at a potential site?
- What is a reasonable timetable for the rotation of GRETINA among the labs and exactly what is needed to make these transitions safe and smooth?

Our aim is for a reasonably small and intense meeting but with sufficient opportunity for open discussion.

We therefore seek your valued participation and input into this meeting on how we may best compose the future physics themes of GRETINA and equally importantly how this spectacular device should be transitioned between the various national facilities in order to maximize its physics discovery potential.

Yours sincerely:

The GRETINA Advisory Committee and Contractor Project Manager

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Appendix (ii): Laboratory responses to the GAC letter

(a) Argonne National Laboratory:



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September 20, 2007

Dr. David Radford
Chair, GRETINA Advisory Committee
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Dear David,

This letter is in response to the request for input by the GRETINA Advisory Committee of August 6, 2007. Below, you will first find the answers to the eight questions included in your request. This will be followed by a number of other remarks specific to the situation at ATLAS.

What interest does your laboratory have in hosting GRETINA?

ATLAS is the premier User facility in the U.S. for physics in the vicinity of the Coulomb barrier with stable beams. In addition, the facility currently also accelerates radioactive beams produced in flight or via the two-accelerator method. Capabilities in the area of radioactive beams will increase in a major way once the CARIBU project is completed in FY 2009. The Users of ATLAS are most certainly interested in seeing GRETINA come to the facility. A research program with the instrument would exploit the unique beam and instrumentation capabilities of the facility. It would presumably span a large range of topics, from nuclear structure investigations at the proton drip line and in heavy nuclei (exploiting the coupling to the Fragment Mass Analyzer), to investigations of neutron-rich nuclei via deep inelastic reactions and Coulomb Excitation with heavy beams (exploiting the high count rate capability and the precise Doppler correction capability of the device). In a way, a GRETINA program at ATLAS would represent an extension of the very successful on-going GAMMASPHERE program. However, one of the largest impacts GRETINA will make will be with the CARIBU beams. CARIBU will deliver a large number of the exotic beams that cannot be obtained at ISOL facilities and the combination of GRETINA and CARIBU will provide first structure information on, for example, neutron-rich Pd, Mo and Ru isotopes where recent calculations predict drastic changes in structure associated with the large neutron excess.

What site preparation do you expect to require (including manpower and funding needs)?

For the 2007 Science and Technology Review of ATLAS, we were requested by DOE to present a plan for the equipment and manpower needs of the facility for the next five years. In the document with our response, Physics Division management indicated its intention to carry out site preparation activities with funding out of so-called base equipment funds, starting in FY 2011 and totaling about \$400k for hosting GRETINA. The manpower plan indicated our intention to request that the scientific staff be augmented by one additional scientist who would be in charge of site preparation for GRETINA. All other technical and scientific support required to install GRETINA at ATLAS will be made available from existing resources.

Is there a preferred timetable after 2010 for GRETINA to come to your facility?

In the short term future, our primary responsibility at ATLAS is the successful completion and subsequent operation of the CARIBU project. For the coming 2-3 years, investments in new equipment will be directed towards new instrumentation to take advantage of the CARIBU beams. As stated above, the ATLAS equipment plan anticipates funding for site preparation in FY 2011. Thus, we do not envision ATLAS to be the first host of GRETINA unless additional resources can be made available on an earlier timescale. Fortunately, the facility will benefit from the presence of GAMMASPHERE for a first round of measurements with CARIBU beams. Hence, the opportunity exists for the user community to use the next few years at ATLAS as a means to thoroughly optimize the scientific program with stable and radioactive beams prior to GRETINA's arrival, hopefully in FY 2012.

How long would you feel is optimal for GRETINA to stay at your facility?

This is an issue that would be best answered by the users of GRETINA rather than by the management of the Physics Division. We are certainly prepared to host the device for as long as the users feel that the science warrants it. On the other hand, it is likely that GRETINA will run scientific campaigns at the various host laboratories. It seems to us that a first scientific campaign of 6 months to 1 year (not including installation and packing) would provide the user community with the opportunity to complete a first round of experiments which would have to be thoroughly analyzed before a return of the instrument to the facility.

What beam-time allocation might be envisioned for this device?

Beam time at ATLAS is granted solely on the basis of scientific merit as evaluated by the Program Advisory Committee. There is a priori no reason for this situation to change with the presence of GRETINA. On the other hand, since GRETINA is likely to be located at any given facility only for a relatively short time, it is probably more appropriate to think in terms of GRETINA campaigns during which the device would be granted as much beam time as possible, taking into account the time required to change set-ups, etc. We are certainly willing to operate ATLAS in such a mode while the instrument is at ANL. Furthermore, we would like to remind the community that, during its first stay at ATLAS, experiments with GAMMASPHERE were granted between 65 and 70% of the available beam time, based on their scientific merit.

What rotation period do you think would be sensible for its next return?

At first consideration, a campaign of six months every second year may well be a realistic scenario. This would allow a regular rotation between 3 host laboratories with occasional siting elsewhere. This issue will obviously become clearer as experience is gained from a first round of experiments at each of the user facilities interested in hosting the device. In addition, criteria related to the relevance of the scientific output and the urgency of the new scientific questions to be addressed should play a major role in siting considerations.

By what mechanism or through what process should we make siting decisions?

It seems obvious that science should be the driving force behind any decision. Since science is driven by the users of the instrument, it also stands to reason that the GRETINA user community be involved in the siting process. The GAMMASPHERE model could serve as a good example on how to proceed. Every move of GAMMASPHERE took place only after the interested facility and its users had written a proposal detailing the physics program to be carried out. This proposal was reviewed both by external reviewers and by the executive committee of the GAMMASPHERE user group. A similar procedure might well prove useful in the case of GRETINA.

Are there other issues and concerns that need addressing?

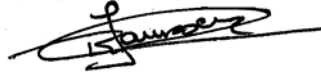
Our experience with GAMMASPHERE makes it clear that institutions and individuals need to have clear designated responsibilities for the maintenance, operation and upgrade of an instrument like GRETINA. Our model is that GRETINA may move more frequently than GAMMASPHERE, and do rather different

physics at each host institution. One could consider naming a "mother institution" that would supervise all transfers and repairs and maintain documentation.

We hope that the considerations above address the issues the Advisory Committee had in mind. As the present host of GAMMASPHERE, we would like to add that we are convinced that this spectrometer remains an extremely important tool for the low-energy nuclear physics community. At ANL we remain as committed as ever to its maintenance and its upgrade as, in many ways, the two spectrometers will be complementary instruments, at least until to full GRETA array enters into operation.

If you need any further information, please do not hesitate to contact us again.

Sincerely,



Robert V. F. Janssens
Acting Division Director
Scientific Director of the ATLAS Facility
Physics Division

RVFJ/jmb

(b) Lawrence Berkeley National Laboratory:



Nuclear Science Division

October 2, 2007

Dear GRETINA Advisory Committee,

As the lead lab for the construction of GRETINA, we very much hope that the detector will have maximum scientific impact for the nuclear science community, and look forward to working with the GRETINA users, its advisory committee, and funding agencies to achieve this goal. Our reply to your questions on the science, siting, and rotation of GRETINA are given below in the order they were asked.

What interest does your laboratory have in hosting GRETINA?

The Nuclear Science Division is very interested in hosting GRETINA. We believe there is strong scientific merit for a campaign at the 88-Inch Cyclotron with GRETINA coupled to the Berkeley Gas Filled separator (BGS), and that the GRETINA community as a whole would benefit from such a campaign.

The study of heavy elements is at the frontier of research in low-energy nuclear science and it generates considerable interest and recognition outside our field. The BGS is a superb separator for heavy element studies; its excellent beam rejection and transport efficiency are second to none. GRETINA's compactness and efficiency make it the ideal device to couple to the BGS. We recognize that a focused GRETINA science campaign at the BGS target position is likely to provide an optimal facility to study actinide and trans-actinide nuclei, providing the US nuclear physics community with a unique capability.

The 88-Inch Cyclotron has a world class operations staff that develops and operates some of the most advanced ECR ion sources worldwide. In FY07 the Cyclotron provided 4864 beam hours (with 96% reliability) for its applied and local research scientists. While we are no longer a National User Facility, we have many active users of our accelerator. In FY07, for example, 161 applied users made 338 separate visits to run 79 experiments using the BASE, space effects facility. All necessary EH&S, training, and other programs are in place at LBNL to accommodate and support GRETINA users during a science campaign.

What site preparation do you expect to require (including manpower and funding needs)?

GRETINA will be assembled and tested in cave 4C at the 88-Inch Cyclotron. Additional site preparation to locate GRETINA at the BGS target position in cave 1 include: modifying the BGS beam line; installing custom rails; relocating the electronics shack; installing an LN line. An initial cost estimate for cave 1 site preparation is ~\$250k. NSD has the technical and scientific support to host a GRETINA science campaign. We assume GRETINA operating funds will be available.

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Is there a preferred timetable after 2010 for GRETINA to come to your facility?

We believe that the timetable to site GRETINA at any facility is best based on science impact, but should also take account of technical feasibility, readiness, and project/facility costs. We are looking forward to the Richmond meeting, where these issues will be discussed with the community.

The 88-Inch Cyclotron could host a GRETINA campaign anytime after completion of the engineering runs. The keen international interest, high science impact, and competition in the heavy element physics program support an early GRETINA campaign at LBNL. From a local perspective an early campaign is more efficient; it minimizes risk and makes best use of existing GRETINA expertise (e.g. software and electronic engineering) built up during the project construction phase.

How long would you feel is optimal for GRETINA to stay at your facility?

Within the framework of our current mission, six months is probably the longest period that could be accommodated without undue disruption of our applied customers.

It has been suggested that GRETINA operates in shorter campaigns (of order 6 months); this seems to be a sensible proposal. It can allow more flexibility to respond to scientific opportunities and will limit the disruptive effects of GRETINA running on other parts of the scientific program at the various likely sites.

What beam-time allocation might be envisioned for this device?

Based on current operation the Nuclear Science Division could provide, in a 6 month period, ~1500-2000 hours of beam time at the 88-Inch Cyclotron specifically for GRETINA experiments. Beam time for GRETINA will be allocated on science merit by a PAC.

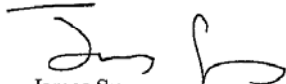
What rotation period do you think would be sensible for its next return?

From an operational point of view GRETINA campaigns at the 88-Inch Cyclotron could be carried out on an 18-24 month cycle. However, this question is best answered in the context of the science that emerges from the initial campaigns.

By what mechanism or through what process should we make siting decisions?

Organizing such a dynamic schedule for GRETINA and providing the necessary peer review is a challenge. We understand that many factors have to be considered in siting a detector like GRETINA: scientific merit of the proposed experiments, cost, technical difficulty, uniqueness, reliability of the accelerator, etc.. However, we hope that, as far as possible, siting decisions will be based on peer-reviewed consideration of all these issues.

Sincerely,



James Symons
Division Director
Lawrence Berkeley National Laboratory

(c) National Superconducting Cyclotron Laboratory:

**MICHIGAN STATE
UNIVERSITY**

September 21, 2007

David Radford, GAC Chair, ORNL
I-Yang Lee, Contractor Project Manager, LBNL
Con Beausang, University of Richmond
Douglas Cline (University of Rochester)
Thomas Glasmacher (MSU/NSCL)
Kim Lister (ANL)
Augusto Macchiavelli (LBNL)
Mark Riley (Florida State University)
Demetrios Sarantites (Washington University)
Kai Vetter (LLNL)

Dear GRETINA Advisory Committee and Contractor Project Manager,
NSCL and its users are excited about the GRETINA project and the science opportunities that become available by combining GRETINA, NSCL rare isotope beams, and the S800 spectrograph. Hence, NSCL is very interested in hosting GRETINA.



Dr. Claus-Konrad Gelbke
University Distinguished
Professor and Director

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As you know, NSCL and LBNL have jointly developed the conceptual design for a rail car system that allows placement of GRETINA in front of the S800 spectrograph. This system makes use of the tracks of an existing rail car system for the S800 scattering chamber. Preparation of fabrication packages, fabrication, installation and test of operation will require material and effort of the order of \$125k. Clean power, liquid nitrogen, ventilation, oxygen level sensors, and fiber connections exist in the experimental vault and power and cooled forced air for the computer farm exist in a room adjacent to the data taking area.

The types of experiments envisioned for GRETINA at NSCL are currently being performed with SeGA. Replacement of SeGA in these experiments with GRETINA will immediately add significant scientific reach and increased discovery potential. The scientific risk for such experiments is small (since they work now) and the risk of integrating GRETINA and the S800 is mitigated by the successful test of one GRETINA detector, where both data acquisition systems were successfully tied together. In addition, gamma-ray multiplicities and data rates in experiments at NSCL will be smaller than the PEP performance criteria for GRETINA. Thus we believe that operating GRETINA at NSCL at the earliest possible date after CD4 is both feasible and highly beneficial; it will yield outstanding physics results very quickly while the community gains experience in operating GRETINA at optimum levels.

*The Michigan State
University/DEA is Institutional
Diversity:Excellence in Action*

*MSU is an affirmative-action,
equal-opportunity employer.*

NSCL operates with a highly predictable schedule and, when feasible, in “campaign mode” – running experiments with similar setup in close succession to minimize set-up and take down time and provide for more efficient utilization of expensive detectors. Campaigns typically last for 2-4 months and receive most (or all) of the beam time. We can run campaigns for about 2 months without scheduled interruption, followed by a one-week maintenance shutdown, followed by another 2-month running period. We envision that GRETINA would fit well into such a campaign model. Thus we suggest that the optimal time for GRETINA to be at NSCL would be 3-4 months of running, plus the time needed for setup and takedown.

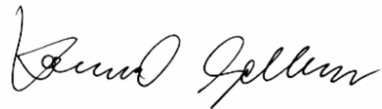
Beam-time is allocated for proposed experiments that are approved by NSCL’s Program Advisory Committee (PAC), which meets approximately twice a year. While we cannot prejudice the PAC approval process, past PAC recommendations may provide insight. In the past five PAC cycles, 30-40% of the approved experiments required gamma-ray detection that would have greatly benefited from GRETINA. This fraction will likely increase rather than decrease for experiments with GRETINA, translating into an annual beam time allocation of 1,500-2,000 hours assuming funding for NSCL operations consistent with our present cooperative agreement. To take advantage of emerging scientific opportunities we prefer a relatively quick return of GRETINA after about 12-15 months for another intensive campaign.

A consensus agreement on siting between the GRETINA Advisory Committee, the Contractor Project Manager, and the GRETINA Management Advisory Committee would be preferable. Alternatively, a review committee that evaluates scientific opportunities and site readiness chartered by the funding agency could be empanelled.

It would be helpful to prepare a site interface document, which describes the interface needs in detail. Prior to coming to NSCL, our EHS office will need to analyze hazards and possible impacts on the environment. From an organizational point of view, it would be beneficial to determine and document how GRETINA operates. Is the model closer to that of a detector collaboration at RHIC or CEBAF or to that of Gammasphere? From a facility point of view, this will make interactions more defined and avoid miscommunications.

In summary, NSCL users and management are excited about the prospects of GRETINA and committed to realizing the scientific opportunities of GRETINA at NSCL. Several of our faculty and staff will attend the Richmond workshop. Please feel free to contact Thomas Glasmacher (who coordinates the GRETINA effort at NSCL) or me at any time. I wish you much success with your wonderful project.

Sincerely,



C. Konrad Gelbke
Director, NSCL

(d) Oak Ridge National Laboratory:

OAK RIDGE NATIONAL LABORATORY

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September 28, 2007

GRETINA Advisory Committee
GRETINA Contactor Project Manager

Ref: Your letter of August 6 2007 regarding GRETINA Science, Siting, and Rotation Plan

Dear GRETINA Advocates:

We received your letter regarding the science, siting and rotation plan for GRETINA. Our reply follows. We address your questions to us in the order posed.

1) Interest in hosting GRETINA

The HRIBF and ORNL Physics Division are very interested in hosting GRETINA. We believe that the combination of GRETINA with beams available at the HRIBF will allow the community to address critical questions at the frontier nuclear structure and nuclear astrophysics in a unique and powerful way, and will significantly enhance the productivity of the HRIBF research program.

The HRIBF has the capability to accelerate approximately 175 radioactive isotopes including 140 neutron-rich species; more than 50 of these, including ^{132}Sn , are available at intensities of 10^6 ions/s or greater. The tandem post-accelerator delivers beams at continuously variable energies up to approximately 5 MeV/nucleon for most ions. The ability of the HRIBF to deliver reaccelerated beams of neutron-rich fission fragments at energies above the Coulomb barrier is currently unique worldwide. With IRIS-2 online in mid-FY09, substantial improvements in facility efficiency, reliability and predictability will be realized. GRETINA will enable high-resolution gamma-gamma spectroscopy to be performed on exotic nuclei, with an expected emphasis during the first period on experiments with neutron-rich RIBs. We envision GRETINA to be coupled with the Recoil Mass Spectrometer (RMS), which has several auxiliary detectors that could be used in conjunction with GRETINA.

The scientific questions addressed by GRETINA at the HRIBF coincide with the main scientific nuclear structure thrusts of GRETA at FRIB described in the brochure on "THE FUTURE OF GAMMA-RAY SPECTROSCOPY: GRETA, THE GAMMA-RAY ENERGY TRACKING ARRAY" (December 2006), in particular those described in Sec. 3.1 of the Brochure. GRETINA experiments with neutron-rich beams at the HRIBF may be expected to include:

- Measurements of Coulomb excitation in the regions of crucial magic and doubly magic rare isotopes such as ^{132}Sn and ^{78}Ni , including multiple Coulex and static moment measurements;
- Single-particle transfer reactions in inverse kinematics to study crucial single-particle states;

- Multi-nucleon transfer reactions with re-accelerated neutron-rich beams to measure symmetries, correlations and excitation modes in neutron-rich systems;
- Decay spectroscopy of neutron-rich nuclei approaching the r-process path.

The HRIBF currently has and will maintain a diverse research program concentrating on nuclear astrophysics, nuclear reactions, and decay spectroscopy. Our hosting of GRETINA has the potential of enhancing research in all these fields, and should not significantly impact them adversely.

2) Site preparation

We plan to install GRETINA at the target position of the Recoil Mass Spectrometer (RMS), on the present CLARION support structure. We will do a mechanical engineering analysis and any work needed to ensure that the crystal locations are known to within 1 mm. Sufficient HVAC and clean power are available at the RMS to accommodate the electronics and HV power supplies. The planned 70-node CPU farm will most likely be housed in a shack on existing concrete planks above the RMS beam line, and cooled either by water-cooled cabinets or through forced air cooling. Alternatively, a mezzanine could be installed in the center of the RMS vault and the CPU farm installed close to the array. Typically, this area is not a radiation area when beam is on target.

A 900-gallon liquid nitrogen (LN) tank is just outside the RMS vault and currently supplies the CLARION Ge detector array with LN through a vacuum-jacketed line. In addition, our Clover Ge detectors may be used in experiments at the RMS focal plane, which also has a vacuum-jacketed LN hose.

We expect to need at least \$100k for design and implementation of modifications to the existing support structure, plus up to \$200k for the electronics/CPU shack and its HVAC system, depending on the implementation (water or air cooling) chosen. Other miscellaneous requirements increase the total estimated cost for site preparation to around \$400k. DOE were informed of these estimated costs during the most recent S&T review of the HRIBF.

Other comments specific to our site:

- A target chamber with a 10-20 degree exit port is compatible with radioactive ion beam experiments. GRETINA experiments at the HRIBF must be concerned with radioactive beam scattering in the target and deposited on the walls of the chamber which contributes to high background and random coincidences. Experience has shown that even with inverse kinematics, targets of a few mg/cm² can produce significant background due to scattered beam particles.
- A charge reset foil (typically 10 cm downstream of the target) is necessary for use with the Recoil Mass Spectrometer (RMS). This foil is used to provide a normal charge distribution of fusion-evaporation products prior to injection into the RMS. An abnormal charge distribution can result when excited states undergo decay by electron conversion.
- Presently at the HRIBF, we have the ability to change targets and charge reset foils without letting the chamber up-to-air. This capability minimizes down time particularly when, for example,, internal detectors must be turned off and out-gassed, when radioactive beam is excessively stopped in the target or inadvertently strikes the target frame, and when using hydroscopic targets.

3) Time table

GRETINA should be sited at HRIBF after the IRIS-2 project is completed and fully operational. This project will provide the HRIBF with a second operational radioactive ion beam injector providing optimum operational efficiency for RIB delivery. By using both RIB sources and our stable ion injector, the HRIBF should be able to deliver beams 24/7. Assuming GRETINA is available to come to the HRIBF in FY11 or later, we would propose that the HRIBF be second in position for each rotation.

4) Optimal stay at the HRIBF

We believe that the optimal operational stay at HRIBF is around 6 months. We anticipate that the initial setup of GRETINA at the HRIBF would take approximately 2 months, and the disassembly and shipment to the next laboratory will take an additional 1 month. On subsequent rotations of GRETINA at the HRIBF we would expect the installation period to be shortened to 1 month.

5) Beam-time allocation

Beam time allocation at the HRIBF is recommended by the PAC, and it is rare for the Scientific Director to disregard their recommendations. GRETINA experiments would be expected to go through our established beam allocation process. However, we intend to enhance the HRIBF PAC with GRETINA-physics experts for the relevant period. We expect that the combination of our radioactive ion beams with GRETINA will present exciting research opportunities such that approximately 80% of the 6-month operational stay would be devoted to GRETINA experiments. We would then plan to schedule a full campaign of GRETINA experiments during the 6-month operation period, with expected beam delivery to GRETINA at about 80%. The remaining 20% would be related to changes in set-up, particularly with regard to the auxiliary detectors and RIB ion source changeovers.

6) Rotation period

The rotation to the HRIBF should be approximately every 2 years. The breadth of our research program, which includes nuclear astrophysics, reactions, and nuclear decay (radioactivity) experiments, suggests that a 6-month stay every two years is optimal. With the expected heavy demand on our limited staff during the 8 months of installation, operation, and disassembly, a 16-month break should allow sufficient time to digest, analyze, and disseminate the accumulated data.

7) Mechanism for siting process

We recommend that GRETINA use a fixed sequence of sites and equal durations at each site. The period of operation should be 6 months. Installation, disassembly, and shipping should take an additional month before and after the 6 month operational period. We expect that installation during the first rotation would require an extra month. We also suggest that consideration be given for the initial siting proposals to cover 2-3 rotational periods.

8) Other concerns and issues

- We have an established users program with roughly 90-120 on-site users per year. GRETINA operations should boost this number by at least 50%. One should expect some additional help in the Users Office primarily because of existing duties of other division support staff.

- We will have to observe all DOE requirements regarding access by foreign nationals and for computer usage. These apply to all DOE sites and we currently comply with them for the HRIBF program. These requirements have become significantly more restrictive.
- Cyber security controls within DOE and the federal government are growing in rapid and difficult-to-anticipate ways. The cyber resource usage and communications requirements of GRETINA should take this into account. We particularly would like to know of access requirements to files stored remotely.
- We would like to know of any hazards, hazardous material, or other safety issues with regard to GRETINA and its associated detectors. For example, the Rochester detector CHICO uses isobutane. We currently limit the use of isobutane in all counting rooms and we will need to have adequate lead time and resources to deal with relevant safety issues.

If you require any further information in this matter, please do not hesitate to contact us.

Yours truly,



Glenn R. Young
Director, Physics Division, Oak Ridge National Laboratory

Appendix (iii): Meeting schedule

GRETINA Physics Working Group Workshop
“**Optimizing GRETINA Science:**
A workshop dedicated to planning the first rounds of operation”
October 14 + 15, 2007
University of Richmond, Richmond

Sunday 14 October:

Session: Scientific Opportunities

Chair: Con Beausang

- 9:00 - Welcome and Outline of Meeting Objectives (Con Beausang)
- 9:15 - Status of GRETINA and GRETA (IY Lee)
- 9:35 - Status of Signal Decomposition (David Radford)
- 9:55 - The Initial Engineering Runs (Augusto Macchiavelli)
- 10:20 - Discussion

10:35 – 11:00 BREAK

- 11:00 - Scientific Opportunities and Operational Plan at MSU (Thomas Glasmacher)
- 11:25 - Discussion
- 11:40 - Scientific Opportunities and Operational Plan at ANL (Kim Lister)
- 12:05 - Discussion

12:20 – 1:30 LUNCH

Session: Future Physics Opportunities continued

Chair: Mark Riley

- 1:30 - Scientific Opportunities and Operational Plan at ORNL (David Radford)
- 1:55 - Discussion
- 2:10 - Scientific Opportunities and Operational Plan at LBNL (Rod Clark)
- 2:35 - Discussion

2:50 – 3:10 BREAK

- 3:10 - Scientific Opportunities at RIKEN (Susumu Shimoura)
- 3:30 - Discussion
- 3:40 - Auxiliary Detectors (Doug Cline and Walter Reviol)
- 4:10 - Discussion
- 4:20 - Detectors from Canada (James Wong)
- 4:30 - Discussion
- 4:35 - Status of AGATA (Andy Boston)
- 5:05 - Discussion
- 5:15 - Thoughts for the evening

5:30 – END OF DAY

Monday 15th October:

Session: Bringing it all together:

Chair: Con Beausang and Mark Riley

9:00 - Open Discussion: What did we learn from yesterday? Any open questions?

9:30 - Suggested Scenarios. Converging on a coherent science, siting and rotation plan

10:30 BREAK

11:00 - Convergence on Summary Points and Action Item bullets for meeting report.

12:30 WORKSHOP END

Appendix (iv): List of attendees and group photo



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