Reports from the Working Groups

ATLAS Users Meeting

August 8-9, 2009-09-16

Report of working group on Nuclear Structure – Focus on Physics

Convenors: D. Hartley, P. Fallon and M.P. Carpenter

The working group which focused on nuclear structure physics had 14 presentations by users with regards to future work at ATLAS. These presentations were subdivided into four general categories labeled proton-rich, CARIBU, heavy elements and high-spin.

The nuclear structure studies of proton-rich nuclei at ATLAS have been a major avenue of research for over a decade. Recently, an excited state in ^{101}Sn was identified using Gammasphere coupled to the FMA. The techniques used in this experiment to isolate gamma-ray transitions associated with ^{101}Sn are highly selective and can be extended to other nuclei in the region; *e.g.*, ^{100}Sn. However, the production cross-sections for many nuclei of interest are prohibitive and would require very extended beam times, on the order of months, using current accelerator and detector capabilities. Proposed upgrades in both accelerator capabilities and experimental equipment could increase data taking capabilities by 5-10 times for these type of measurements. Such an improvement would allow access to many new nuclei in the ^{100}Sn region, including ^{100}Sn itself.

With regards to CARIBU, many of the programs discussed by users at the workshop would concentrate on precision measurements of nuclear states. For example, reduced matrix elements could be obtained from Coulomb excitation measurements or lifetime measurements using DSAM, a plunger, or fast scintillators such as LaBr(Ce). Several groups are also interested in building up a program using CARIBU beams to measure g-factors. With regards to the g-factor program it was stressed that isobaric purity of the beam in excess of 90% is important to carry out these measurements. It remains to be seen whether this challenging requirement can be met. Beta decay studies using Gammasphere could greatly extend our knowledge of neutron-rich isotopes. The 4π coverage of Gammasphere will allow precise determination of the angular distributions of emitted gamma rays which in turn will allow for spin determination of excited states.

Studies of super-heavy elements at ATLAS have concentrated on nuclei with $Z<105$. Both in-beam gamma-ray and decay spectroscopy have been utilized. All these measurements have utilized the FMA in order to isolate the fusion-evaporation products from dominating fission background. These groups would like to continue their studies at ATLAS, but they are severely limited by available beam intensities, although there are additional limitations associated with the transmission of the FMA and the count rate capabilities of the focal plane detectors.

With Gammasphere at ATLAS, studies of high-spin states will continue to be an area of interest to users. This program will be pursued using stable beams and complimented in certain situations with CARIBU beams. For the latter cases, this would involve beams delivered to target with the highest intensities. A major theme common to the presentations on high-spin programs involved the study of exotic shapes at high spin. For example, studies of Hf, Lu and Ta nuclei have provided evidence for stable triaxial shapes through the identification of so-called wobbling rotation bands. Such structures are also predicted in neutron-rich Mo-Ru nuclei which could be studied with beams from CARIBU. Studies of ^{240}Pu at ATLAS have brought into question the existence of stable octupole shapes and a competing explanation based on surface vibrations has emerged. Recent searches for exotic shapes have included experiments looking for nuclei with tetrahedral shapes. In general, high-spin measurements would benefit greatly by a digital Gammasphere.

Beam Intensities

It was clear from the user presentations that the increase in-beam intensities afforded by the phase I upgrade would benefit the physics reach for both stable and CARIBU beams. For experiments involving stable beams, the phase I upgrade will allow for beams with intensities up to 1 pμA to be delivered to the experimental stations. Such beam intensities would benefit the programs involved in the study of nuclei near the proton drip-line as well as super-heavy nuclei. It was recognized that while ATLAS has been able to deliver certain beam species to the target area at up to 500 pnA, it appears to be difficult to sustain the beam at these intensities for a typical 5-7 day run. Thus, it is not only the beam current which is important to the users, but also, the ability to sustain the intensity for the entire length of the experiment. It was also pointed out that the beam intensities from phase II could be utilized to make radioactive ion beams using the in-flight technique. These secondary beams if produced with enough intensity could be used for fusion evaporation reactions to produce proton-rich nuclei e.g., ^{100}Sn using a ^{56}Ni beam.

With regards to CARIBU physics, the phase I upgrade would be beneficial. Many of the proposed programs would require beam intensities on target to be >$5x10^4$. Examples of such experiments are Coulomb excitation and g-factor measurements. The Phase I upgrade has the potential to increase current beam intensities by a factor of 10 when one considers both the implementation of an EBIS source and improved transmission through ATLAS. Such an increase would significantly increase the physics reach of CARIBU with regards to nuclear structure studies. The phase II upgrade would not impact CARIBU studies as much, at least if the EBIS source is built.

Equipment Needs:

Many of the programs discussed would require Gammasphere. With regards to stable beams, a digital Gammasphere with a modern day data acquisition system would allow for the Ge detectors to run at up to 50,000 counts/sec with pileup at < 10% and at the same time maintain an intrinsic energy resolution of ~3 keV for a 1 MeV gamma ray. Such capabilities would be able to take advantage of increased beam intensities afforded by the Phase I upgrade. In addition, the distributed architecture of the new data acquisition should allow events to be recorded to disk at rates exceeding 100,000 events/sec. This is in contrast to the current limit of ~20,000 events/sec for a typical high-spin measurement. While count rates in individual Ge detectors will not be an issue using CARIBU beams due to the limited beam intensities, throughput rates of analog Gammasphere could be prohibitive if the experiment is required to trigger on a single Ge hit. Such a trigger would be appropriate for Coulomb excitation and even beta decay measurements. The proposed digital Gammasphere data acquisition in principle could record in excess of 250,000 Ge singles/sec.

Many of the other detector systems discussed here were also covered in the instrumentation section such as Chico (PPAC Array), DSSD's (160x160), and plungers. One item of equipment not discussed in the instrumentation section was the use of LaBr(Ce) detectors for fast timing measurements. These detectors have been shown to measure nuclear lifetimes down to 40 picoseconds and have an energy resolution of ~3%. A small array of such detectors used in conjunction with Gammasphere could prove to be quite powerful in measuring lifetimes of individual states down to 10ps.

In terms of major equipment for ATLAS, it was pointed out that a gas-filled separator would be a complementary device to the FMA. While the FMA does provide mass information, its efficiency for most experiments is ~10%. A properly designed gas filled separator could provide transmission efficiencies in excess of 50% and would greatly enhance the ability to extend study super heavy nuclei.

Report of working group on Nuclear Structure – Focus on Instrumentation

Convenors: W. Reviol, D. Seweryniak, P.J. Woods

Studies of nuclear structure remain an active research area at ATLAS judging by the strong interest in the session devoted to upgrades of existing experimental equipment and new equipment initiatives relevant to structure studies. There is also large overlap and common interest between the nuclear structure, reactions, astrophysics and fundamental symmetries groups both in terms of physics and equipment.

One of the recurring themes was the need to make sure that one can take full advantage of the intense stable beams which will be available after the ATLAS upgrade is completed. More intense beams will allow studies of ever more exotic effects, but, inevitably, will pose new experimental challenges due to higher counting and event rates, and more severe radiation doses. Gammasphere alone, in combination with the FMA, and/or with a variety of ancillary detectors will offer unparalleled sensitivity and selectivity provided that required modifications are implemented. The same is true for Gretina at ATLAS. Secondly, the portfolio of detection techniques available at ATLAS needs to be expanded as well so that the most optimum approach can be used for each experimental challenge. Aspects specific to experiments with radioactive CARIBU beams were also discussed throughout the session.

This session was the first occasion to discuss among users opportunities and challenges related to the ATLAS high intensity upgrade. Follow-up consultations will help to further crystallize and prioritize ideas for experimental equipment which need to be implemented in near future for nuclear structure experiments at ATLAS.

The following list contains topics which were discussed during the session:

1) Gammasphere upgrades:
    a. Digital DAQ - replacing the existing analogue acquisition system with digital pulse processors would allow an increase in the Ge counting rates by a factor of at least 5 without significant losses due to pile-up.
    b. VME readout - implementing readout from VME based high-density digitizers would help to reduce dead time and facilitate optimal use of multi-detector arrays with Gammasphere.
2) FMA upgrades:
    a. New beam dump – currently the un-reacted beam is deposited on the inside of the anode of the first electric dipole and on the wall of the tank at the exit from the first electric dipole; in the planned more open geometry the beam would be stopped in a suppressed Faraday cup placed outside of the tank to avoid charging up the anode and knocking out electrons from the wall of the tank and inducing sparking between the wall and the anode.
    b. New entrance quads – shorter first quad capable of generating stronger magnetic fields will result in 50% larger angular acceptance.
    c. Implantation station upgrades
        i. Digital DSSD – digitizing signals from the DSSD will allow studies of fast activities which currently obscured by the pile up with implants.

ii. Plastic beta detectors – these detectors will facilitate beta-decay tagging and optimize gamma-ray detection at the FMA focal plane.

3) Gas-filled separator - recoil separators are at the forefront of nuclear structure research worldwide as exemplified by the FMA. The FMA offers excellent mass resolution which is required to study weak reaction channels in the presence of large backgrounds. However, the M/Q acceptance of the FMA limits its efficiency. This limitation is circumvented in gas-filled separators which collect all charge states. It is proposed to build a gas filled separator and use it in conjunction with Gammasphere or Gretina to study heavy nuclei and fast proton and α emitters. Consequently, a gas-filled separator would be complementary to the FMA. It could also be used at FRIB.
4) Gammasphere ancillary detectors
   a. SuperHercules – the proposed successor of Hercules, possessing higher granularity, due to Multianode-PMT readout and position tracking, and, thus, higher count rate capability.
   b. NanoBall – the anticipated successor of Microball which uses TransStilbene crystals, capable of running at about 10 times higher rates (compared to the currently used in CsI crystals) and possibly providing additional particle-ID by ToF measurement.
   c. SuperChico – the proposed successor of Chico; it supersedes the present detector in azimuthal angle resolution.
   d. Conversion-electron detection devices – capability for prompt (with Gammasphere/Gretina) and delayed (behind the FMA) conversion electron detection would greatly enhance heavy-element spectroscopy.
   e. Arrays of position-sensitive Si detectors – several arrays were discussed in the context of particle-gamma coincidence measurements, particularly for transfer reactions.
      i. STARS – the Livermore-Berkeley-Richmond Si telescope array; (p,t) reaction studies in normal kinematics are proposed.
      ii. ORRUBA - the Oak Ridge-Rutgers Barrel Array; (d,p) reaction studies in inverse kinematics with CARIBU beams are proposed.
      iii. Position-sensitive avalanche photo diodes from University of Massachusetts at Lowell and Radiation Monitoring Devices in Boston – it is currently in the testing stage.
   f. Plunger devices – several options were discussed to facilitate ps life time measurements with Gammasphere.
      i. The Gammasphere plunger built at Notre Dame University.
      ii. The New Yale Plunger Device.
      iii. The Tigress Integrated Plunger proposal – the design concept involves usage with a 4π CsI(Tl) charge-particle detector.
5) CARIBU
   a. Moving-tape collector β-decay stations – several such stations are being designed for diagnostics of and β-decay studies with CARIBU beams
      i. Low-energy area – β decay and diagnostics
      ii. ATLAS tape station - diagnostics
      iii. Gammasphere tape station – β decay

Report of working group on Nuclear Reactions and Nuclear Astrophysics – Focus on Physics

Convernors: A. Wuosmaa, K.E. Rehm

In this section we had contributions from six speakers, followed by a general discussion. The talks discussed possible future experiments that could be done with higher-intensity and higher-energy beams from ATLAS. The speakers and the titles of their contributions were:

- .Phillipe Collon - Possibilities for AMS experiments at ATLAS
- .Livius Trache - Single-nucleon transfer between p-shell nuclei around 10 MeV/u
- .William Peters - (d,pγ) as a surrogate for (n,γ)
- .Lee Sobotka - Decay spectroscopy - next up ^{14}C
- .Catherine Deibel - Studying the (α,p) process at ATLAS
- .Xiaodong Tang - The ^{12}C+^{12}C fusion reaction

The need for high-resolution transfer experiments, which are possible with the new HELIOS spectrometer, was the topic of several talks. Livius Trache discussed the need for high-quality unstable beams of sd-shell nuclei at ~10 MeV/u for ANC studies, which are important for nuclear astrophysics. He also pointed out that for many applications using radioactive beams good optical model parameters are needed. Neutron-transfer reactions were also at the center point Bill Peters' contribution. He discussed (d,p) reactions as a surrogate tool for the measurement of (n,γ) cross sections which are needed in nuclear astrophysics or for stockpile stewardship applications. Inelastic scattering, populating excited (cluster) states in more exotic nuclei was discussed by Lee Sobotka. Again HELIOS would be the ideal tool in these experiments. Astrophysical applications for HELIOS, in particular (α,p) reactions were discussed by Catherine Deibel. The large acceptance of HELIOS would open many possibilities in this field, once beams of neutron-deficient nuclei will become available. New opportunities will also open up with higher-intensity, higher-energy beams from ATLAS using the AMS technique. This was discussed by Phillipe Collon. Building on our previous experience with ^{40}Ca beams the higher energies will allow us to extend the production and later identification via AMS, to A~150 p-process nuclei, which thus far are inaccessible.

In the following some of the new opportunities that are possible with an upgraded ATLAS facility are discussed in more detail.

Possibilities with Higher Energies from ATLAS:

Nuclear transfer reactions as a tool for nuclear structure studies have seen a revival in recent years with the possibility to study few-nucleon transfer processes away from the valley of stability. The history of these experiments using stable beams has shown that this field quickly moved from the (low) energy region (~5 MeV/u) to higher energies, because of the cleaner reaction mechanism and the ability to study transitions to higher-lying states or reactions with more negative Q-values. First reaction studies with radioactive beams at ~3-5 MeV/u are presently being performed at various places. Argonne has, with the HELIOS spectrometer, the optimum device for these experiments. To hold a unique position worldwide in this field we need high-quality beams with energies exceeding 10 MeV/u, which would open many new opportunities even when the (lower energy) beams from FRIB will be available. As an additional advantage the higher-energy particles available from ATLAS will improve our abilities to identify the heavy recoils in ΔE-E detectors, a crucial point in experiments with beams that have contaminations from stable or unstable beam components. Higher energies are especially important for planned AMS experiments of medium and heavier nuclei using the gas-filled magnet technique which are presently hampered by the low velocities of the particles from ATLAS. These reactions are critical for nuclear structure studies, for reactions of interest to nuclear astrophysics as well as for studies of importance in stockpile stewardship and nuclear reactor design and waste handling.

Possibilities with Higher Intensities from ATLAS:
Many of the experiments at ATLAS using radioactive beams have been done with very low beam intensities. While these measurements have given us important insight into nuclei away from the valley of stability and taught us how to design and built high-efficiency detector systems, they are still difficult and very time-consuming. A timely intensity upgrade of ATLAS would be a giant step forward for these studies. The biggest gain for this field could be made with a dedicated separator of high acceptance that separates the secondary beam particles from the production beam. The present system uses existing 22^{o} or 30_{o} bending magnets of the ATLAS beam line system. The measured transfer efficiencies under these conditions are typically 0.5%.

The low intensities (< 1 ppA) that can be achieved with this setup permit us to transport these beams only to experimental stations which are in close proximity to the production target. With a dedicated separator, and making use of the excellent time structure of the ATLAS beams this efficiency can be increased by a factor of 10-100. This improvement will open many new opportunities to study reactions with smaller cross sections (e.g. (d,^{3}He) or (d,t) reactions with neutron-rich or neutron-deficient beams), or to use other beam lines with detectors that so far have not been used but which have unique particle identification features (e.g. Gammasphere). Also, the In-flight Technique could then be extended to nuclei which are further away from the valley of stability and are produced with more exotic transfer reactions and smaller production cross sections.

Other topics that were mentioned in the discussions and were not included above are:

- Advantages of studying (d,n) reactions in inverse kinematics as a surrogate for the astrophysically important (p,γ) reactions. For this purpose an array of low-energy neutron detectors would be needed. It was recognized, however, that the domain of applicability of the approach remains open to discussion.
- Many interesting nuclear properties could be studied with a triton target. It was mentioned that, due to the safety issues involved, a National Laboratory would be the ideal place for setting up such a target.
- The possibility of 'harvesting' (longer-lived) isotopes from the CARIBU sources for reactor and stockpile stewardship applications.

Report of working group on Nuclear Reactions & Nuclear Astrophysics – Focus on Instrumentation

Convenors: I. Wiedenhoever and B.Back

The deliberations of the working group was initiated by six invited presentations as listed below:

1. Steve Pain, Paisley	“ORRUBA + GammaSphere"
2. Ingo Wiedenhoever, FSU	"The ANASEN Si array"
3. Ken Gregorich, LBNL	"Gas-filled spectrometer design"
4. Aby Bickley, NSCL	"The NSCL Active Target TPC"
5. Nick Scielzo, LLNL	"Surrogate reactions"
6. Greg Chubarian, Texas A&M	“SHE Mass Measurements”

These presentations all had relevance for future instrumentation at ATLAS by discussing various possible developments that may allow the user community to take full advantage of the existing and planned beam capabilities of the facility.

The coupling of the ORRUBA particle detector array with large solid angle coverage with Gammasphere was presented by Steve Pain as a complementary option for studying single particle states in exotic nuclei as compared to the existing HELIOS instrument. The possibility of gating on specific γ-ray transitions is expected to allow for the study of states and transitions in heavy nuclei where the energy resolution of HELIOS is insufficient to perform such studies.

The physics reach and design parameters of the ANASEN array were presented by Ingo Wiedenhoever. This is an active target-gas detector, which is especially well suited for studying nuclear reactions of astrophysical interest, such as (α,p) reactions, proton scattering, and transfer reactions. The system consists of a cylindrical gas target/ ionization detector surrounded by a barrel consisting of position sensitive Si ΔE detectors backed by 2cm thick CsI E detectors for light particle identification and energy measurement. The intended facilities for this detector are FSU and the ReA3facility at NSCL.

Another active-target device, namely the Active-Target Time-Projection Chamber (ATTPC) being built at NSCL, was presented by Aby Bickley, NSCL. It consists of a moderate size TPC of 70cm diameter, which will be inserted into a 2T superconducting solenoid magnet in order to produce curved tracks for particle momentum/charge measurements. The instrument will be used at the ReA3 and fragmentation beam-lines at the NSCL and is intended to address a wide range of physics topics in nuclear astrophysics, nuclear structure and nuclear equation of state using both stable and radioactive beams.

The discussion on gas-filled spectrometers was led by Ken Gregorich, LBNL, who described the present Berkeley Gas-filled Spectrometer (BGS) as well as future designs using only dipole magnets, either in-plane or in a perpendicular plane arrangement. These new configurations would allow for a substantial increase of the acceptance (~x2) while cutting the flight path through the spectrometer in half, relative to the present BGS, with clear beneficial implications for measuring small cross sections and short half-lives.

The use of surrogate reactions to estimate cross sections for neutron-induced processes is a topic of contemporary interest. By using inverse kinematics reactions with radioactive beams it is possible to obtain some of the information required for advanced reactor design, stockpile stewardship, and rprocess studies. This method, as well as a specific experiments carried out at LBNL, were discussed by Nicholas Scielzo, LLNL.

The final talk was presented by Greg Chubarian, Texas A&M. The planned facility at Dubna will couple the Dubna gas-filled recoil separator (DGFRS) with the Mass Analyzer of Super-Heavy Atoms (MASHA), which will be possible by stopping heavy products in the DGFRS focal plane in an Argonne-built gas cell, extracting and re-accelerating the ions for mass analysis in MASHA. This scheme is intended to circumvent one of main draw-backs of gas-filled spectrometers, namely that they do not provide information on the mass of the recoils.

Discussion:

The presentations were followed by an in-depth on various aspects of the instrumentation ideas presented as well as other topics suggested by the participants.

It was pointed out (J. Kolata) that the present and planned ATLAS instrumentation does not include a facility for efficient neutron detection. One possibility is to utilize the excellent time resolution of ATLAS beams to detect low energy neutrons from e.g. (d,n) reactions in backward angles. The working group recommends that the physics case for such a device and its technical feasibility be considered.

It was also emphasized that recoil detection in light-ion transfer reactions (HELIOS) provides important background suppression and additional information about the decay patterns of high-lying states. There was general agreement that this aspect should be considered to determine whether new instrumentation, in addition to the existing Si telescope and future PPAC/ionization chamber, is required for such studies.

Finally, the instrumentation required to take full advantage of the ongoing efficiency and intensity upgrade of ATLAS was considered. With this upgrade, and concurrent development of high-intensity targets, it was emphasized that the ATLAS facility will be placed well for the study of processes with extremely small cross sections. For example, ongoing programs on the study of nuclear structure of (super)-heavy elements and the quest for measuring nuclei near the doubly-magic N=Z=50 shell closure will both benefit from these developments. In order to take full advantage of these capabilities it is recommended that ATLAS management explore optimal designs for a large acceptance recoil separator, possibly of the gas-filled type, that will also be able to accommodate γ-detectors (Gammasphere/Gretina) at the target position and a full range of γ- and particle detectors at the focal plane.

Fundamental Interaction Working Group – Recommendations

Convenors: N. Scielzo, P. Mueller and G. Savard

Short term:

Fully utilize low energy beams from CARIBU for mass measurements, laser spectroscopic studies and decay experiments. Ideally, the space available for low energy experiments at CARIBU should be expanded to fully exploit these possibilities (NA6).

Utilize ATLAS intensity upgrade (Phase I) for improved beta decay correlation experiments and weak interaction studies by increased production rate of light isotopes close to stability (e.g. ^{6}He, ^{8}Li, ^{14}O, ^{18}Ne) (FI4). Phase II upgrade, in particular the recoil separator, would significantly improve production and separation of these isotopes.

Medium term:

Improve isotope separation and overall transmission of the ion transfer line after the gas catcher into the triangle room. This would enable mass measurements closer to the proton drip line (^{65}As) once the CPT is moved back to its previous location (NA2). This upgrade also would improve correlation studies or decay experiments possible at that location (FI4).

Long term:

Add gas catcher and low-energy beam-line behind recoil separator for studies of very proton rich isotopes (e.g. around ^{100}Sn, requires Phase II). Provide experimental area to accommodate low-energy beam experiments, e.g., in the ATSCAT area.

Support high precision measurements of basic nuclear properties of isotopes close to stability (on the proton rich side) to enable future high precision measurement far off stability at FRIB, e.g., measurements of T=2 superallowed beta decays.

Find a stronger source for ^{225}Ra for improved EDM experiment that will be truly statistics limited (FI9).