Presentation 13 – Session 4

Nuclear research and education at the Australian National University

Professor Andrew Stuchbery
Head, Department of Nuclear Physics, Australian National University

Biography

Professor Andrew Stuchbery is Head of the Department of Nuclear Physics at the Australian National University, which operates Australia’s Heavy Ion Accelerator Facility for pure and applied nuclear physics research. He is also Convenor of the ANU Master of Nuclear Science program, which covers both science and policy aspects of nuclear technology, and caters to a broad audience, for example giving training relevant for nuclear security, safety and non-proliferation.

He is an internationally engaged experimental nuclear physicist with broad research interests that include nuclear magnetism and nuclear structure, and science at the interface of atomic and nuclear physics. Current projects range from the study Auger electrons emitted by medical radioisotopes, with potential applications for targeted cancer therapy, to dark matter detection based on nuclear-recoil methods.

Abstract

The Department of Nuclear Physics at the Australian National University operates Australia’s Heavy Ion Accelerator Facility (HIAF), which consists of a 15 MV tandem accelerator and superconducting linac booster. It is Australia’s only accelerator facility that supports front-line nuclear physics research, teaching and training at all levels. The accelerator runs 24/7, typically delivering beams for experiments for over 5000 hours per year. Research themes can be classified under the headings of Quantum Physics with Nuclei, Nuclei in the Cosmos, and Nuclei for Society. The ANU policy of research-led education allows undergraduates as well as honours and higher-degree students to engage with nuclear physics research based on the accelerator facility. Our graduates have gone on to take senior positions in government (including the Australian Safeguards and Non-Proliferation Office, ASNO, and the Department of Defence), in academia, in nuclear medicine, industry, and with the International Atomic Energy Agency (IAEA).
HIAF is supported by the National Collaborative Research Infrastructure Scheme (NCRIS) which provides funding for operations, by the Australian National University, and by competitively won grants, including Australian Research Council grants, which fund postdoc and research fellow positions. With six permanent academic staff, and a strong cohort of postdocs, research fellows and research students, HIAF punches well above its weight, attracting top overseas researchers for experiments in Australia. About half of the experiments involve outside users. Across all research themes, HIAF has strong two-way links with leading international laboratories, especially the billion-dollar international radioactive beam facilities such as NSCL (USA), TRIUMF (Canada), GANIL (France), GSI/FAIR (Germany), RIKEN (Japan) and the REX-ISOLDE and n-TOF facilities at CERN (Switzerland). The ANU group has strong collaborations with the IAEA in relation to nuclear data and neutron standards; an important example is the ANU-based development and maintenance of the BrIcc internal conversion coefficient data base.

Nationally, Nuclear Physics at ANU is engaged with ANSTO in a number of applications of nuclear techniques, including Accelerator Mass Spectrometry (AMS), which was pioneered in Australia at ANU, and in a project that is characterizing the emission of Auger electrons from radioisotopes with a view to applications in targeted cancer therapy. We are engaged with the Medical Physics group at the University of Wollongong to improve the physics in the Monte Carlo code GEANT4 for medical applications, and to investigate heavy-ion cancer therapy with a focus on two areas, namely the effect of secondary nuclear reactions induced by the primary beam, and the characterization of energy-transfer in the low-energy regime where most energy is transferred to tissue. Together with the Universities of Melbourne, Adelaide and Swinburne, and ANSTO, ANU Nuclear Physics is taking a leading role in the development of Australia’s Underground Physics Laboratory and the first direct search in the Southern Hemisphere for evidence of dark matter by detecting nuclear recoils. Work to date has focused on detector characterization.

A brief overview of Nuclear Physics education and research at ANU will be given, with one or two examples of recent research highlights.
Nuclear Research and Education at the Australian National University

Andrew Stuchbery
Department of Nuclear Physics, ANU
Heavy Ion Accelerator Facility

Australia’s largest accelerator facility supporting front-line nuclear physics research, teaching and training

Evolved over time responding to new technologies and demands

Demand for beamtime requires 24/7 accelerator operation by researchers

15 million volts

Unique beamline instrumentation supported by ARC, NCRIS, ANU
Heavy Ion Accelerator Facility

HEAVY ION ACCELERATOR FACILITY

14UD Accelerator

AMS Ionization detector: environmental studies
AMS Time of flight detector: environmental, biomedical, geological, safeguards
AMS Enge gas-filled magnet: astrophysics, technology

Superconducting Linear Accelerator

Super-e: conversion electrons and pair spectroscopy

BALIN: break-up mechanisms in weakly bound nuclei

14 m

SOLEROO: radioactive beam production

Solenogam: conversion electron spectroscopy, isomers

CUBE: two-body fission dynamics

CAESAR: time-correlated spectroscopy, nuclear structure

Hyperfine Spectrometer: nuclear magnetism, hyperfine fields
International connections

Major/Radioactive beam facilities
** Two way exchanges **
More than one ANU group/activity

TRIUMF
ANL
NSCL
GANIL France
ORNL
GSI Germany
CERN
RIKEN

International Atomic Energy Agency (IAEA): Nuclear Data Projects e.g. Bricc
Research Areas: Overview

Quantum Physics with Nuclei
- Dynamics, excitations, correlations, decay
- Experiment and theory advancing hand-in-hand
- Nuclear methods in fundamental physics

Nuclei in the Cosmos
- Nucleosynthesis (Supernovae, Li problem, Hoyle State, …)
- Dark Matter search (Stawell Underground Physics Lab)

Nuclei for Society
- Nuclear physics for medicine (Auger electrons, Hadron therapy,…)
- Nuclei and the environment
- Nuclear Safety, Security and Safeguards
- Nuclear data - IAEA engagement
  ✓ Bricc.anu.edu.au website 6000 unique visitors/year
Unique hands-on accelerator-based research-led education at all levels:

- Core Nuclear Physics course in 3rd year
- Research-led education (ASC, Hons, MPhil, PhD)
- Masters by coursework (Master of Nuclear Science)
  - Caters to broad audience
  - Laboratory-based teaching – unique
  - Science to inform policy on nuclear issues
Research projects of the 6 students attending ANA 2017

Dongyun Jeung (Yun)

Matt Gerathy

Ben Coombes

Tim Gray

Brendan McCormick

Jackson Dowie
Quasifission & Making New Elements

Dongyun Jeung (Yun)

Detect fission products with **CUBE** detector

\[ ^{40}\text{Ca} + ^{238}\text{U} \]

Time Dependent Hartree Fock (Cedric Simenel)

- **Quasi-fission**
  - (M_R asymmetric region)

- **Fusion-fission**
  - (M_R symmetric region)

Mass-Angle Distribution \( \theta_{c.m} \)

After Capture
Schematic of Solenogam (above).

Partial level scheme of $^{182}$W and associated spectra (left)

Matthew Gerathy with Solenogam (right).
Application of LaBr$_3$ detectors

$^{98}\text{Mo}(^{12}\text{C,3n})^{107}\text{Cd}$ 48 MeV

The first $10^+$ state in $^{110}\text{Cd}$ has configuration $\nu(h_{11/2})^2$
Spectroscopy and magnetic moment measurements on $^{111}$Cd

$753 \, 5/2^+$

$620 \, 5/2^+$

$342 \, 3/2^+$

Spectrum and electromagnetic properties $\Rightarrow ^{111}$Cd is rotational not vibrational?
Moments in Mg isotopes

ISOLDE@CERN proposal (G. Georgiev, AES et al.)

Proposal to the ISOLDE and Neutron Time-of-Flight Committee

Nuclear moment studies of short-lived excited states towards the Island of Inversion. g factor of $^{28}$Mg (2⁺) using TDRIV on H-like ions.

6 October 2016

**Problem !**

**Projectile excitation**

$^{26}$Mg measured relative to $^{24}$Mg

Precession $10 \times$ old measurement

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Brendan McCormick
Exotic decay modes: double conversion

Jackson Dowie

Super-e Superconducting electron spectrometer

Double Differential Cross Section of Double Internal Conversion of the 662 keV M4 transition in $^{137}$Ba

Next: Search with 10x stronger source from ANSTO

$^{137}$Cs source 662 keV M4 transition
End