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Acceptance Tests for AMS Radiocarbon Measurements at iThemba LABS, Gauteng, South Africa

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Abstract

The accelerator mass spectrometer was commissioned recently at the iThemba LABS 6 MV tandem accelerator. Improvements in the vacuum system, requiring procurement of cryo-pumps and the reducing the tank pressure of the $N_2 + CO_2$ insulation gas mixture below the level used for IBA measurements, were necessary. This resulted in the reduction of the nitrogen background and improved the resolution of ^{14}C from ^{14}N background in the ionisation chamber. The nitrogen was leaking to the stripping canal because of inadequate sealing. The analysing magnet was scaled to detect C^{3+} ions, at 3 MV terminal potential. The first sensible spectra allowed for the pin-pointing of many persistent issues. This resulted in measurements with a precision better than 1 pMC, and current blank levels correspond to 12 half-lives of ^{14}C or ~68000 years. The radiocarbon sample preparation laboratory has reached production status. A brief outlook of the work towards the implementation of the measurement and chemical preparation protocols for radionuclides ^{10}Be and ^{26}Al is also summarised in the conclusion

Keywords: Accelerator mass spectrometry; AMS; IBA; South Africa; radiocarbon; beryllium; aluminium, tandem; accelerator

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1. Introduction

It has long been thought that research programmes at iThemba LABS should be extended to include Accelerator Mass Spectrometry (AMS). The idea dates to the times the branch of iThemba LABS at the University of the Witwatersrand, Johannesburg was part of the university, and known as WITS-CSIR Schonland Research Centre for Nuclear Sciences (SRCNS). To this end, Prof J. P. F. Sellschop, who founded the SRCNS originally known as the Nuclear Physics Research Unit as part of the department of physics in 1958, attended and gave the closing remarks at the Fourth International Symposium on Accelerator Mass Spectrometry held at Niagara-on-the-Lake, Canada in 1987 (Sellschop 1987). After the SRCNS had been donated to (South African) National Research Foundation in 2004, the first head of department of this new era went on an IAEA funded fact finding trip to ETH-Zurich. When SMM became the head of department and, following repeated applications to funding agencies, the proposal was picked for funding, and preparation for the procurement of the AMS detection systems began in earnest.

In anticipation of the inclusion of the AMS various changes were made to the accelerator, beamlines and the vault. These changes were not only meant to benefit the AMS but also looked to improve detection limits in the Ion Beam Techniques and Nuclear Physics detection beamlines. Summaries on the states of these particle experiments can be found in various publications (Andeweg, et al., 1997; Msimanga, et al., 2013, 2016; Przybylowicz, et al., 1993). Some of these articles demonstrate the thought, towards the expansion of the research themes of the SRCNS, and eventually iThemba LABS, which was originally a nuclear physics research facility, to a more inclusive institute with research interests extending to geology, archeology and possibly paleaontology. The AMS would then be at the centre of operations.

The AMS development started with the preparation. Implementation of ^{14}C, will, in the near future extend to ^{10}Be and ^{26}Al, followed by the other radionuclides. These developments will be in response to research imperatives in the region. The design of the system follows closely the Scottish Universities Environmental Research Centre (SUERC) 5 MV AMS system. We hope in the long run, to measure a similar spectrum of isotopes to SUERC (Freeman, et al., 2004; Maden, et al., 2007). The ^{14}C for which capability has been established and is the subject of this report, will be measured, together with the radionuclides ^{10}Be and ^{26}Al in chronological dating applications ranging from commercial to academic research. Academic research will include assessments of landscape evolution in Southern Africa (Bierman and Caffee 2001) and the continent (Brown, et al. 1994). We are looking to implement exposure (Bierman and Caffee 2001) and burial dating (Owen, et al. 2011) of cosmogenic radionuclides. We further hope to contribute to the knowledge of species evolution by dating, in partnership with local and international colleagues, caves and fossil sites in the region and the continent (Granger and Muzikar 2001). The context of southern African paleoscience places the iThemba LABS AMS facility in a good position to contribute towards answering unique localized research opportunities such as African human origins (Tattersal 2009).

2. The spectrometer

The improvements that preceded the installation of AMS spectrometer included better alignment of the injection and extraction beam line optics. In the detection lines the changes included, but were not limited to, optical alignment of the entire beamlines and detection lines, the upgrade of compressed air and cooling water systems, vacuum system placed under computer control, the redesign and upgrade of the IBA injection source, refurbishment and installation of larger beam line magnets, replacing the belt charging system by a Pelletron charging system, installing new high-voltage grading resistors, installing new axial electric field and spiraled magnetic field accelerator tubes, installing a new terminal potential stabiliser system (TPS), converting the gas stripper to a recirculating gas with HV terminal pumping.

Changes were made to the building housing the accelerator. These included compartmentalising the accelerator building into an accelerator vault, experiments hall for all detectors, electronics room, control room, and offices for engineers and the technical staff. The installation of the AMS system included the low and high energy spectrometers. The low energy spectrometer comprised the installation of the 64 cathode ion source, einzel lenses, electrostatic