TANDEM ACCELERATOR BASED AMS SYSTEM AND THE PROJECT AT PEKING UNIVERSTY

Chen Jiaer(陈佳洱), Liu Kexing (刘克新), Guo Zhiyu (郭之虞) and Li Kun(李坤)

(Institute of Heavy Ion Physics, Peking University, Beijing 100871, China)

(Received November 1989)

ABSTRACT

On the basis of general description of AMS, the advantage and development of tandem accelerator based AMS are discussed. The AMS facility at Peking University and its preliminary applications are described.

Key words Tandem accelerator AMS

I . INTRODUCTION

AMS is a technique based on accelerator that makes possible the measurement of isotope ratios in the range 10^{-12}— 10^{-16}. It counts directly the nuclides which are accelerated to high energy by using the developed nuclear instruments and methods.

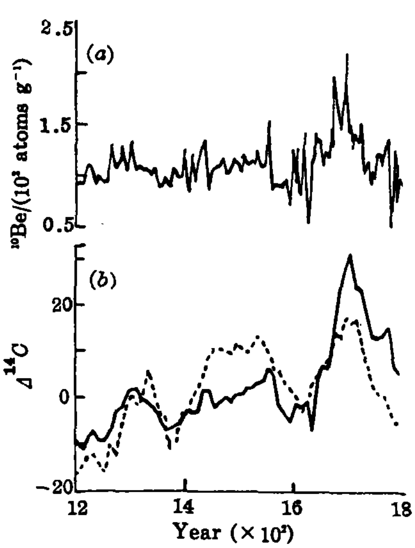

Fig.1 (a)^{10}Be concentration (b) Measured ^{14}C (dotted line) and calculated ^{14}C based on the^{10}Be variation

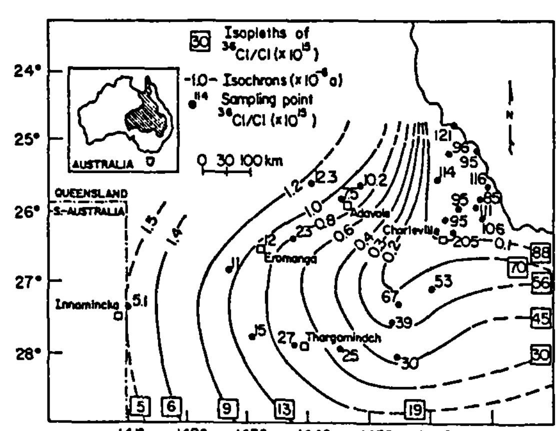

Fig.2 Map of the Great Artesian Basin area with solid lines of isopleths of ^{16}Cl/Cl ratio

Because of the advantages of high sensitivity, small sample size and high efficiency, AMS has been widely used as a powerful method for the measurements of long-lived radioisotopes as well as stable isotopes in earth science, archaeology, physics, biology, environmental chronology, material science etc. A number of achievements has been obtained especially in earth science. The following are some examples.

In 1983, Beer et al.[1] measured the ^{10}Be concentration on an ice core from station Milcent, central Greenland. The result showed in Fig.1 reflects the heliomagnetic shielding of cosmic radiation and the 200 – years period of the solar activity.

In 1986, Bentley et al.[1] measured $^{36}Cl/Cl$ ratio in groundwater of the Great Artesian Basin area of Australia (Fig.2). Therefore, the age of groundwater and its travelling direction(normal direction of Isopleths) were determined.

Three laboratories at Arizona, Oxford and Zurich have made interesting tests to show if the Turin "Shroud of Christ" is true[3]. Only a 10mm × 70mm strip was cut from Shroud. The result indicated that the age of that linen was within 1260 – 1390 A.D (95% confidence). It's medieval forgery rather than the Shroud of Christ.

Table 1 shows the technical level of the measurement of six typical cosmogenic nuclides with AMS[4,5].

Table 1

Nuclides	^{10}Be	^{14}C	^{26}Al	^{36}Cl	^{41}Ca	^{129}I
Half – life(a)	1.5×10^{5}	5730	7.2×10^{5}	3.0×10^{5}	1.0×10^{5}	1.6×10^{7}
Stable isotopes	^{9}Be	^{12}C, ^{13}C	^{27}Al	^{35}Cl, ^{37}Cl	^{40}Ca, ^{41}Ca	^{127}I
Isobars	^{10}Be	^{14}N	^{26}Mg	^{36}Ar, ^{36}S	^{41}K	^{129}Xe
Abundance	10^{-11}	10^{-12}	10^{-14}	10^{-10}	10^{-14}	10^{-14}
Detection limit	7×10^{-15}	3×10^{-15}	10^{-15}	2×10^{-16}	2×10^{-15}	10^{-14}
General accuracy (%)	2 – 3	1	5 – 10	1		

II. DEVELOPMENT OF TANDEM ACCELERATOR BASED AMS

Presently, more than 34 AMS facilities are in operation or being built up, among them 30 are based on tandem accelerator.

Tandem accelerator based AMS has a number of merits. Firstly, it suits best the measurement of isotopic ratios. The fractionation can be reduced effectively by using alternate injection, therefore the accuracy is close to β counting method. For a cyclotron based AMS the alternate injection demands the cycling of radio frequency and magnet field simultaneously, which will cause formidable difficulties. Secondly, it is straight forward to combine with many useful techniques like stripping. Gas filled magnet etc, so as to facilitate the separation of isobars. Another advantage is the flexibility of extending the heavy elements measurements by adding post accelerator. Finally, tandem accelerator has good beam quality and the operation is simple.

Before 1980s, with the original AMS facility, which was simply based on the accelerator and analysis system used for nuclear physics research, the feasibility of

AMS was proved, the main problems involved and their solutions were indicated. The experiments showed[6]. (1) High mass resolution (at least 50) injector is the basis of AMS measurements. (2) Better terminal voltage control (better than 0.025%) is indispensable. (3) Combination of different kinds of analysers (magnetic analyser, electronstatic analyser and velocity selector) is absolutely necessary.

The AMS has been improved continuously since 1980[7]. The intense beam, small emittance, low – memory halogen sputter negative ion sources and the fast switching system have been developed. The complete analysing system for post acceleration analysis was established. Based on those developments, the dedicated AMS facilities such as the TANDETRON AMS system and the ETH AMS system at Zurich were built. The accuracy of the TANDERON AMS in ^{14}C measurement at the University of Arizona is better than 1% with the best of 0.5%.

Around increasing sensitivity, accuracy and efficiency, many techniques related with AMS have been developed.

The Gas – filled magnet[8] is a hopeful technique for isobar separation. It's based on the fact that charge – changing processes of an ion in a gas, if they occur frequently enough in a magnetic field region, leads to trajectories determined by the average charge state q of the ion, which is in turn determined by nuclear charge z. Fig.3 shows the ^{58}Ni – ^{58}Fe isobar separation at Artonne laboratory.

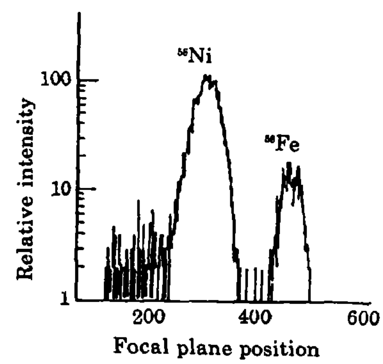

Fig.3 ^{58}Ne– ^{58}Fe isobar separation at Argon

The generation of negative ions through charge exchanging intense positive ion beams which are generated in iodine sputter source is also a developing technique.

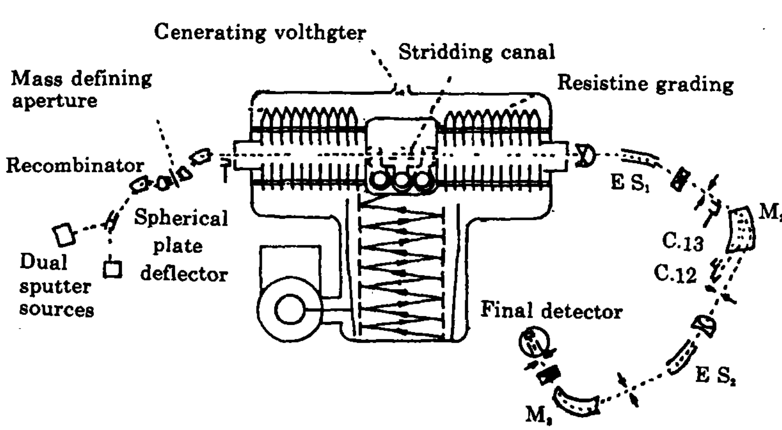

Fig.4 Schematic diagram of "the third generation" AMS

Recently, the design of "the third generation" AMS proposed by US – AMS company and the University of Toronto[9] reflects the systematic efforts for eliminating fractionation (Fig.4). The main consideration are (1). eliminating crater effect by using scanning technique. (2) injecting isotopes simultaneously by using recombinator. (3) beam transmission with large aperture (The aperture of stripper is 1.20 cm.). (4) multi-stage post acceleration analysis system with dispersion compensation.

III. AMS PROJECT AT PEKING UNIVERSITY

With the support of NSF of China, a tandem based AMS facility was designed and under construction at Peking University. The general consideration involved in the design include (*a*) Mass identification of a variety of nuclides e.g. ^{10}Be, ^{14}C, ^{26}Al, ^{36}Cl. (*b*) Minimization of fractionation effect by using fast switching system and flat topping transport system. (*c*) Reduction of contamination and background to as low as 10^{-15}. (*d*) Development of high brightness ion source. (*e*) Provisions for heavier ions AMS by using post accelerator.

Fig.5 shows the general layout of this facility. The sensitivity and accuracy are expected as in table 2.

Table 2

Nuclides	^{10}Be	^{14}C	^{26}Al
sensitivity	10^{-13}	10^{-15}	10^{-15}
accuracy	5%	1%	10%

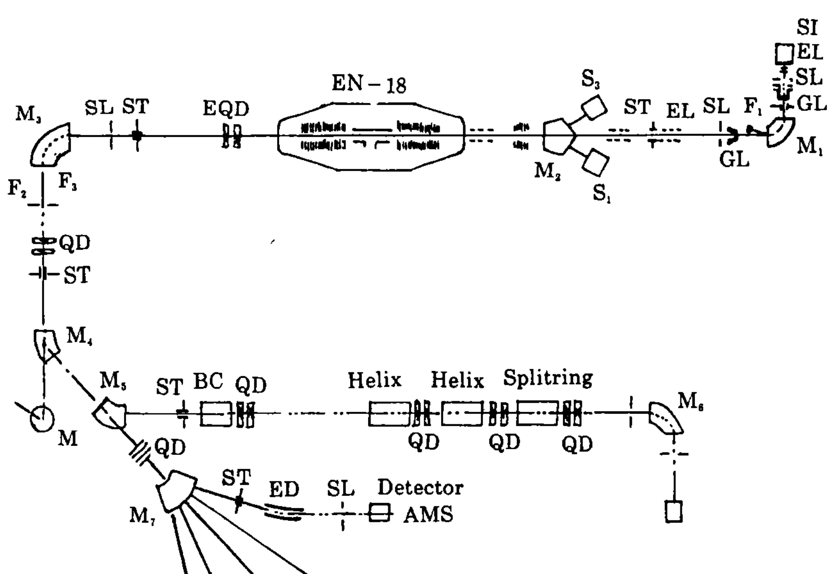

Fig.5 Schematic diagram of the AMS system at Peking University

The ion source is a Cs sputter source with spherical ionizer and multi-sample target wheel. It is expected to get 3—5 μA beam for BeO, 0.5—1 μA beam for Al, emittance of 10 mm · mrad · $MeV^{1/2}$and memory effect smaller than 0.005 per minute.

A 90° double focusing magnet with a gap of 5.0cm and resolution of 160 are used as an injector. The duration of fast switching system are 200 μ s, 2 ms for ^{12}C, ^{13}C respectively, and the cycling frequency is 10 Hz.

The terminal voltage of EN tandem is 6.5MV. The signals used for the stabilization of terminal voltage are picked up from position adjustable Faraday cup which is also used for measuring stable isotopes. A 90° magnet is designed as the first analyser after acceleration. As the second, a 20° electrostatic analyzer with $E/\triangle E$ of 500 is used to reduce the background. A $\triangle E-E$ counter telescope is used for detection and further identification of rare isotope. IBM PC/XT microcomputer dual parameter data acquisition system is to be used to display the $\triangle E-E$ spectrum.

The AMS facililty at Peking University will be applied prelimenarily in following topics:

(*a*) ^{14}C dating of Malain Loess. There is very large loess area in the north-west of China. To measure the ^{14}C age of the organic material in different loess layer can verify the theory of loess forming and know the loess sedimentation rate, which will give the information about the long term variation of the ancient climate, the palaeo-environment and soil erosion process in loess areas.

(*b*) ^{14}C dating of Homo sapiens fossils found in China. It's very important to measure the age of those fossils with AMS method for investigating the evolution and distribution of Chinese primitive man lived in the palaeolithic period.

(*c*) The study of possibility of ^{10}Be dating. The possibility of ^{10}Be dating for deep-sea sediment sample has been identified by a lot of experimental results, but more work is still needed. The goal of the first stage at Peking University is to measure the concentration and distribution of ^{10}Be on suspended particles collected in estuary of Yellow River.

The ratio of $^{26}Al/^{27}Al$ in aerolites also will be measured.

REFERENCES

[1] J.Beer et al., Proc. 10th int. cosmic ray cont., Vol.9, p.317.

[2] H.W.Bentley et al., *Water Resources Res.*, **22** (1986), 1991.

[3] C.R.Bronk et al., *Radiocarbon dating of the shroud of turin*, 1980, in press.

[4] W.Wolfli, *Nucl. Instr. Meth.*, **B29** (1987), 1.

[5] W.Kutschera, *Nucl. Instr. Meth.*, **A268** 1988, 552.

[6] K.H.Purser et al., *Revue Phys. Appl.*, 1977, 1487.

[7] A.E.Litherland, *Nucl. Instr. Meth.*, **B5** (1984), 100.

[8] W.Henniing et al., Proc. workshop on techniques in AMS, Oxford, UK, 1986, p.196.

[9] K.H.Purser et al., *Nucl. Instr. Meth.*, **B35** (1988), 284.