Upgrade of the Accelerator Mass Spectrometer * in Peking University

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Abstract:

To meet the requirements of the Xia-Shang-Zhou Chronology Project, some upgrade has been made at Peking University Accelerator Mass Spectrometer (PKUAMS) since 1996. The injection beam line was reconstructed to reduce the number of Enzel lenses for getting better beam properties. A new ion source made by NEC(MC-SNICS) was put in. The new control system adopting ControlNet production of Group3 used a PC. A new data acquisition system was designed. The main power supplies and beam monitoring systems are improved. The precision of ^{14}C measurements is expected to be better than 0.5% and the system should be easier to operate with higher throughput.

1 INTRODUTION

The chronicle of ancient China begin from 841BC, at the end of West Zhou dynasty. There are different opinions about the dates of Xia, Shang and Zhou dynasties. For instance, there are over 40 versions for the date of which King Wu started the war with King Zhou, the year known as the first year of West Zhou dynasty. Dating from different sources span more than 100 years, from 1127BC to 1018BC. The aim of Project of Xia-Shang-Zhou Chronology[1], one of the most visible scientific projects in China, is to find the correct date of such historical events. This effort encompass the fields of history, archaeology, astronomy and ^{14}C dating.

The date measured by ^{14}C dating is called radiocarbon age. Because the ^{14}C content of the earth's atmosphere has not been constant over the period of time for which ^{14}C dating can be made, used to obtain a calendar age, it is necessary to compare them with tree ring calibration curve[2]. Because tree ring calibration curve presents a saw tooth form, a single calibration value cannot be obtained for one ^{14}C date hence the age uncertainty increases obviously. If one can find a series of samples with known relative calendar years (Although their absolute calendar dates are unknown), the corresponding radiocarbon results can be formed into a floating curve which is subsequently compared with high precision calibration curve to give a precise calendar date. In fact, most of the samples have small content of carbon and can not be measured by conventional ^{14}C dating method, AMS ^{14}C dating with high precision plays an important role in getting radiocarbon date.

2 REQUIRMENT FOR THE XIA-SHANG-ZHOU CHRONOLOGY PROJECT

During recent years progress has been made for archaeological excavation. To study the culture of Xia, Shang and Zhou dynasties, some ruins and graves of these dynasties have been found and they provide sufficient samples including a series of samples of known relative ages for dating.

The first thing to be considered for AMS ^{14}C dating is the measurement precision. The precision of PKUAMS was only 1%, corresponding to 80 of years. Such a precision does not meet the requirements for Xia-Shang-Zhou Chronology. While the precision of ^{14}C dating is 0.3%, the date error will reach 24 years. It is expected that the uncertainty of the measured age should be better than 20 years after tree calibration for a series of samples of known relative date.

Increasing of measurement precision means extension of ^{14}C counting time. For a precision of 1%, 20,000 ^{14}C counts are needed and for 0.5%, 100,000 counts are needed. A precision of 0.3% requires 350,000 of ^{14}C counts. Good long term operating stability, high reliability, high repeatability and high efficiency are also required. For these reasons, the fractionation and background have to be considered. For ease of use with high throughput, ^{14}C measurement process is also automated.

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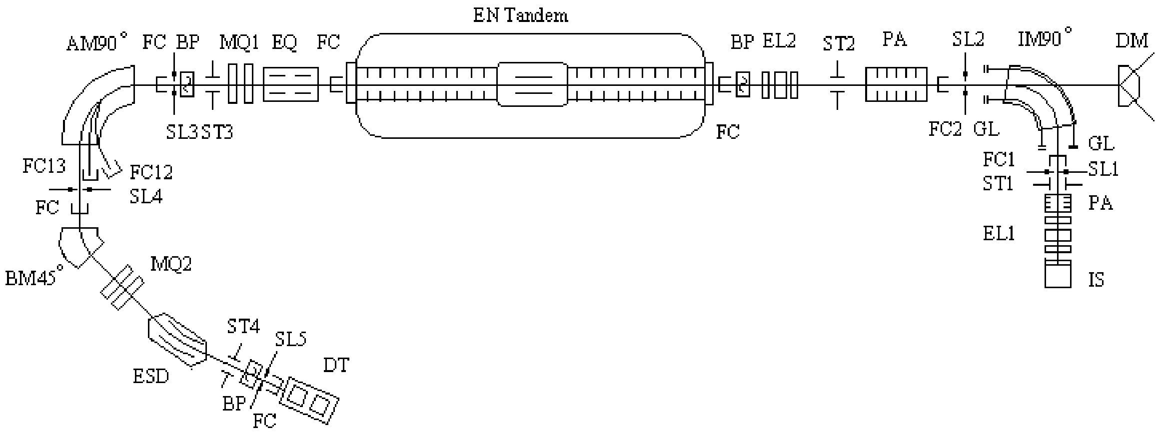

Fig.1. Schematic layout of the AMS facility in Peking University

3 UPGRADE OF PKUAMS

To meet the requirements of this project, some experimental studies have been made for the transportation, fractionation and background of the whole AMS system systematically[3]. The ion source physics, electron stripping mechanism and particle detector techniques are also studied. The upgrade of PKUAMS includes (1) replacement of the old ion source, (2) redesigning and rebuilding the injection line (3) improving the vacuum of the whole system , (4) improving the stability of power supplies used for the beam elements and (5) upgrading the automatic control and data acquisition system.

3.1 Ion Source

The ion source is a crucial element of AMS facility for getting high precision and good efficiency. The original sputter source of PKUAMS (model 860, made by Shanghai Institute of Nuclear Research in 1992) is replaced by a new one made by NEC (MC-SNICS). The new ion source uses a tapered ionizer. It is fitted with a Cesium lens to optimize the focusing of Cs^+ beam spot on the target. To improve the emittance of the ion beam, a small bore diameter of the extract electrode is used. There are 40 positions on the sample tray. The tolerance for the sample to shift position is smaller than 0.05mm. A dedicated cooling system is used for the target.

3.2 Injection System

In order to get high transmission efficiency and flat-top transmission, we redesigned the injection system. It is difficult to optimize the beam properties for the old injection line, which is 12 meters long, using 4 Enzel lenses and two magnets. The layout of the new PKUAMS is shown in Fig.1. There will be only two lenses and one magnet in the injection line.

A triad barrel lens follows the exit of the source to optimize the beam quality. A bypass Faraday cup follows the 90 degree double focusing injection magnet to monitor the abundant isotopes. Two apertures are used before and after the gap lenses to filtrate the ions with high divergence. The resolving power of the injection magnet is 150. Its radius is 350mm. The gap between the poles is 50mm. The maximum magnet rigidity is 6MeV·aum/Q^2 and its mass resolution is 175.

3.3 Automatic control System

All of the power supplies of the beam elements on PKUAMS, the Faraday cups, the beam monitors, ion source target changing system and the Tasla meters are controlled by a Distributed Control System, Group3 Fiber-Optic ControlNet[4]. There are 6 Data-Interfaces (DI) in the Loop, with a baud rate of 10 Mbits/sec.. The capacity of the control system is 58 A/D’s (16-bit), 41 D/A’s (14-bit), 32 DI’s and 4 serial ports (fiber optic). The LabVIEW[5] software (National Instrument, US) is used for automatic control. The whole program is driven by a global data pool. It is possible for all the functional modules to share data. No parameter passing is needed between sub modules. For the main panel, all parameters are displayed with a scan rate of about 10 Hz and they can be saved and "read-back". This feature is convenient for debugging purposes. The controlled values approach their set value in a controlled manner to avoid possible damage to the power supplies.

There are 4 sub modules under the main module. That is, ion source, pre-accelerator, accelerator and high energy part. If one click on one of the icons showing such functions, the working condition will be displayed. One can re-writing on the element fields.

3.4 data Acquisition System

The main control micro-computer of the data acquisition system is Pentium/200. It is operated under Microsoft Windows 3.2 Chinese Edition and LabVIEW is also used. There are hardware interfaces to control the external equipment: ^{14}C counter, dual-parameters acquisition and processing system, MC-SNICS ion source target changing element and alternating injection power supply. The first two equipment are working at front and back platform mode, the ^{14}C counter is connected to the main control computer through GPIB card; and the dual parameter system, through a dedicated communication interface. The main program controls the four external equipment alternately according to the predetermined time series.

The core of the data acquisition system is the dual parameter nuclear spectrum acquisition. It works at DMA (direct memory access) mode. The dead time of every ^{14}C effect event is only 20μs. The measurement of the live time can be accurate to only a few ms. The time precision is 2 ms. The interesting area of the dual parameter spectrum consists of 5 rectangle sub areas to construct ellipse or other special shapes.

3.5 Other Improvements

Because of the subsidence of the foundation, the collimation of the old beam line around the tandem was destruction. The center of the entrance of the tandem was 2mm lower than it used had been and at the injection line it was even lower. We reconstructed and collimated the whole beam line of PKUAMS, and have made sure that the collimation is reliable.

Three beam profile monitors are installed along the entire beam line to observe the beam cross sections. Two 450-liter turbo molecular pumps on the entrance and exit of the tandem have been replaced by 1,500-liter pumps.

4 RESULTS AND DISCUSSION

The installation of the entire beam line is finished and the vacuum of the line is about 10^{-7} torr. The automatic control system for all of the power supplies, ion source and beam monitors are reliable and easy to operate from the control room.

The ion source has been tested. The orientation of the sample target is reliable to ensure the stability and the identity of the extracted beam properties for different target. A stable beam of 25μA with emittance better than $5\pi\cdot mm\cdot mrad\cdot MeV^{1/2}$ can be obtained by selecting appropriate working parameters.

The beam test is under way and we expected to obtain a better measurement precision in April of 1998.

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