

Calibration of Measurement of Absolute Dee Voltage for U-400M Isochronous Cyclotron at FLNR JINR

<u>A.T. Issatov^{1, 2}, R.K. Kabytayeva^{1, 2}, I.A. Ivanenko¹, I.V. Kalagin¹, S.V. Mitrofanov¹, Yu.G. Teterev¹.</u> 1 - Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research, Dubna, Russia. 2 - L.N.Gumilyov Eurasian National University, Astana, Kazakhstan.

e-mail: issatov@jinr.ru

Abstract

Results of measurement of absolute dee voltage of the isochronous cyclotron U-400M at FLNR JINR are presented. X-ray technique was applied for measurements. Measurements were made at the following frequencies of the resonance system: 12.8, 13.317, 15.012, 15.1 and 17.5 MHz. To accurately determine the maximum energy of Xray spectrum, a modeling of X-ray spectrum was carried out by the software package FLUKA. An influence of the absolute dee voltage on the capture factor was estimated by the program Center.

Introduction

The direct measurement of dee voltage on cyclotrons by the method of adding additional measuring circuits to the resonant circuit is convenient for operational work, but it does not give reliable results for the all frequency range of RF-system of cyclotrons. To adjust a cyclotron to the ion acceleration mode with minimal losses in the central region (the maximum capture factor of the beam acceleration) and to ensure the centering of the accelerated beam, the amplitude of the RF voltage on dees must correspond to the calculated value. The measuring circuits must be calibrated to determine the actual dee voltage. For calibration, a technique for measuring the spectrum of bremsstrahlung X-rays can be used. Electrons escaping from the surface of DEE and liner are accelerated in the RF field and emit a bremsstrahlung spectrum when hitting a metal surface. The endpoint energy of the spectrum is a measure of peak DEE voltage.

The FLUKA simulation of the X-ray spectrum

JINR

14 Flerovium

Dubna

Accurately determining of the maximum energy of X-ray spectrum was difficult because of background radiation from the induced activity of the internal elements of the cyclotron. The FLUKA simulation of X-ray spectrum was done to accurately determine the maximum energy of X-ray spectrum. An electron beam in the FLUKA model was monoenergetic.





The control of dee voltage by pick-up electrodes

- The frequency range of the accelerating voltage: fa = $11.5 \div 24$ MHz. - The calculated value of the RF voltage amplitude on the dees is up to 130 kV. - The operational control of the dee voltage on the U-400M is made by 8 pick-up electrodes on each dee, located 4 on the top and 4 on the bottom. -A sketch of the location of the pick-up electrodes is shown in Figure 1.





Fig. 1. The sketch of dee and pick-up electrodes for controlling of dee voltage.

Fig. 2. The electrical scheme of dee voltage controlling by using pick-up electrodes.

X-ray spectrum measuring

- The XR-100CdTe detector was used to measure X-ray from dees of U-400M. The digital pulse processor PX5 was used to data acquisition.

- The XR-100CdTe is a high performance x-ray and gamma ray detector, preamplifier, and cooler system using 5 x 5 x 1 mm Cadmium Telluride (CdTe) diode detector mounted on a two-stage thermoelectric cooler. The XR-100-CdTe is capable of detecting energies from a few keV to several hundreds of keV, with an efficiency that peaks from 10 to 100 keV.

- The PX5 includes Digital pulse shaping amplifier, Integrated multichannel analyzer and Power supplies. http://amptek.com

- The XR-100CdTe was calibrated with radioactive isotope of ¹⁸⁰Ta. The energy resolution is 1.1 keV for 103.6 keV.



Fig. 3. Photo of XR-100CdTe detector and PX5.





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Fig. 11. The dependence of voltages measured by the pick-up electrodes on the maximum energy of the X-ray spectrum for different frequencies.



Fig. 12. The dependence of the calibration factor $(E_{max} (x-ray)/U_{pick-up})$ on the frequency/ of the RF-system.

An estimation of dee voltage influence on the capture coefficient

- A simulation of the capture in the acceleration of 15N5 + ions (A / Z = 3, fa = 17.5 MHz) was made to estimate the influence of the amplitude of the RF voltage on the dees.

- The trajectory analysis of the capture and acceleration of ion beams in the central region of the cyclotron was carried out by the Center program.

- An experimental check of the influence of the dee voltages on the capture coefficient is carried out.





Fig. 13. The dependence of the capture coefficient on the acceleration on the initial phase of the beam at different voltages on the dees at the first 6 revolutions.



radioactive isotope of ¹⁸⁰Ta.

X-ray measurement from dee of U-400M

X-ray spectrum was measured through a titanium window. A thickness of the window is 70 um. The window was installed near the resonator №3 of U-400M. Therefore, X-ray was measured from the dee №3.



Fig. 5. Photo of resonator №3 of U-400M.



Fig. 6. Photo of the XR-100CdTe detector and titanium window.

Fig. 14. The motion of the injected 15N5 + ion beam on the first turn at the voltage on dees 85 kV (black) and 120 kV (red).

Conclusions

The absolute dee voltage of the isochronous cyclotron U-400M at FLNR JINR was measured. It was noted that the voltage measurement circuit by pick-up electrodes is sensitive to the frequency of the resonance system.

The modeling of the X-ray spectrum by the software package FLUKA was carried out to accurately determine the maximum energy of the bremsstrahlung spectrum.

The influence of the absolute dee voltage on the capture factor was estimated by the program Center.