20 MEV CYCLOTRON FOR ISOTOPE PRODUCTION.

A.Glazov, Ju.Alenitskiy, S.Chesnova, A.Chesnov, V.Kochkin, D.Novikov,
E.Samsonov, M.Semenov, A.Vasilenko, E.Zaplatin, N.Zaplatin
Joint Institute for Nuclear Research,
Head Post Office, P.O. Box 79, 101000 Moscow, Russia
and
I.Gulamov, O.Iljasov, A.Rylov.
Institute of Nuclear Physics, 702132 Tashkent, Uzbekistan

ABSTRACT

The $20MeV$ fixed-energy proton cyclotron was constructed based on the conventional magnet with pole diameter $115cm$, which is the standard equipment of physical laboratories in Russia. It is proposed to use an internal target for isotope production. A special two-element magnetic system to increase the size of the beam on the target in the axial and radial directions will be used. The cyclotron was designed and constructed at the JINR (Dubna), but will be used at the INP (Tashkent)

1. BASIS CHARACTERISTICS OF THE ACCELERATOR

The cyclotron is intended for acceleration of protons to fixed energy 20 MeV with current up to $400\mu A$. The design and construction of the accelerator were started simultaneously at the beginning of 1991, and from May 1992 commissioning period began. The cyclotron was designed based on a conventional magnet with dimensions : $3 \times 1.5m^2$ in plane and $2.12m$ high (weight $48T$). The necessary magnetic rigidity and focusing conditions are reached in the magnetic structure with fourfold symmetry and $8.2cm$ gap in the hill of spiral shims. The maximum working radius is $48cm$, the maximum magnetic field is $1.35T$. This structure was chosen not only to solve the main problem, but to be a model for reconstruction of the cyclotron U-150 at INP, Tashkent.[1]

The leading idea in designing the accelerator was to decrease the cost of the production and to simplify and make cheaper the exploitation. So we chosen a standard magnet, forming the magnetic field by iron shims, a self-excited single-tube oscillator to generate rf power, an internal ion source, an internal target for isotope production and a passive magnetic regenerative system to decrease the density of the beam on the target.

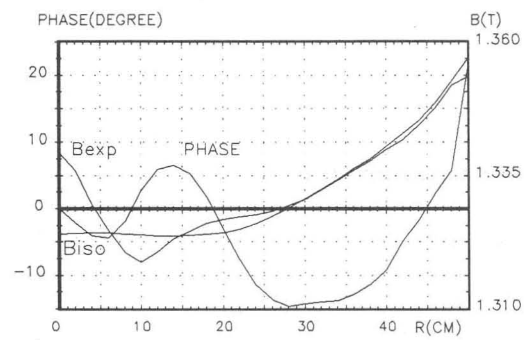

Figure 1: Radial dependence of the isochronous field (Biso), measured average field (Bexp) and phase motion of the beam

2. MAGNETIC SYSTEM

An isochronous magnetic field of the cyclotron is formed with the help of four pairs of spiral and sector shims. For simplicity and precision in production, the edges of the spiral shims are arcs of circumference. The spiral angle varies from 10 to 50 degrees. An increase of the magnetic field along the radius is produced by increasing the azimuthal length of spiral shims and the thickness of the sector ones placed in valleys starting from the radius $18cm$. The radial dependence of the isochronous field, measured average field, and the phase motion of the beam are shown in Fig. 1.

The focusing properties of the magnetic field are illustrated in Fig. 2. The values obtained for frequencies of free oscillations correspond to stability of the particle motion. The low harmonics of the magnetic field amplitudes are quite small. In the central region ($R < 30cm$) the amplitude of the first harmonic is less then $0.3mT$, on the radii $30 - 45cm \sim 0.7mT$. To regulate their value, if necessary, in the central region ($4cm \leq R \leq 14cm$) and at the periphery ($32cm \leq R \leq 46cm$) there are four pairs of harmonic coils placed in the valleys.

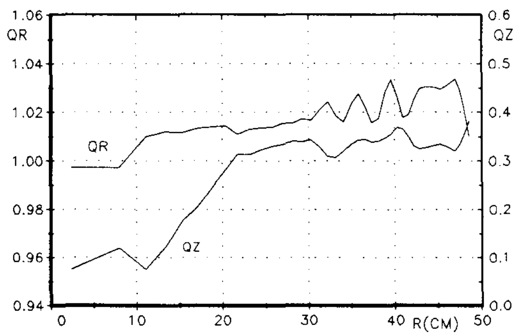

Figure 2: Frequencies of free oscillations

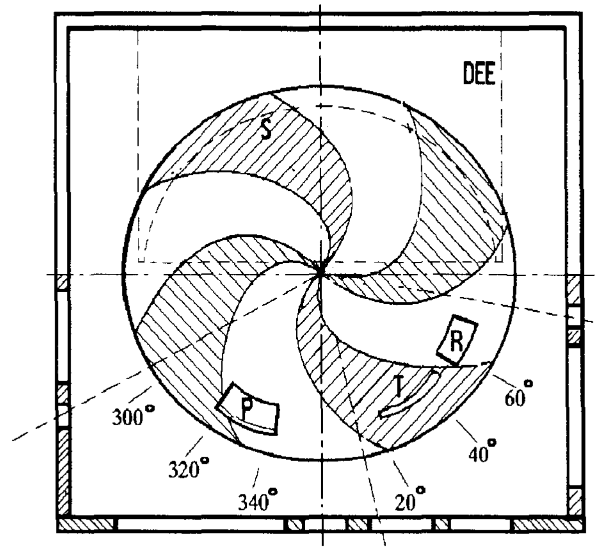

Figure 3: Beam spread system : P-peeler, R-regenerator, T-target

3. ACCELERATION SYSTEM

In a formed magnetic field the revolution frequency for protons is $20.2MHz$. A conventional scheme with one 180^o dee and a quarter -wavelength resonant line on the revolution frequency was chosen for the acceleration. Dee aperture is $20mm$. To increase the mean axial gap between the dee and the chamber the cooling tubes were soldered outside the aperture. The minimal gap is $22mm$, the accelerating voltage is $50kV$.

Dee and resonant line were made flat rectangular in plane like it is proposed for convertion of Tashkent cyclotron.[1] The vertical distance "d" between inner and external electrode resonant line outside the magnet were chosen as compromise between convenience for installation of vacuum pumps and rf power consumption .

The calculation of parameters was made by conventional formula for the resonance line. The expression for the wave impedance was taken from.[2] The experimental value of the resonant frequency became 5% less than a calculated one. The rf losses are $12kW$ at the accelerating voltage $50kV$. For generation rf power a triode oscillator with the selective feedback circuit is used. There is a possibility of pulse work of the oscillator by means of a grid modulation. Initial coarse tuning of the resonator is made by changing the distance d in some limits. For fine automatic tuning two trimmer capacitors on both sides of the dee are used.

4. THE TARGET AND THE BEAM SPREAD SYSTEM

For isotope production internal target with dimension $2cm$ in the axial direction and $17cm$ in the azimuthal one will be used. The surface of the target has an inclination 6^o to the beam orbit. The internal water-cooled side was made with ribs to increase the possible power dissipation up to $10kW$.

The beam spread system must produce the radial deflection of the beam by $1.5cm$ and the extension of its axial dimension up to $1.5 - 2cm$. For this purpose it was decided to use a passive regenerative system.[3] It consists of two ferromagnetic elements: a peeler with the gradient $-5T/m$ and a regenerator with the gradient $2T/m$. The position of the elements in the accelerating chamber is shown on fig 3. The field disturbance on the working radii ($35 - 45cm$) is less then $0.5mT$ (first harmonic).

The results of computation of the beam behavior in the regenerating system are shown in fig 4. Approximately at 20 turns the turn separation increases from 0.1 to $1.5cm$ at the azimuth of the target. In computation it is also seen that the amplitude of the axial oscillation increases by a factor of ~ 2.

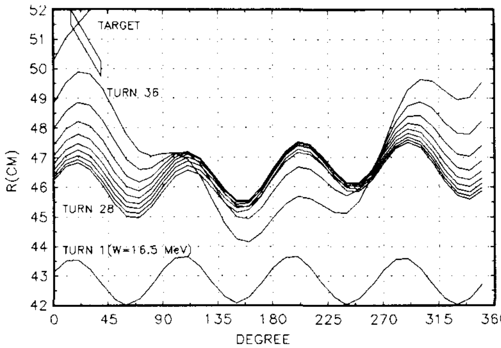

Figure 4: Turns separation in the regenerative system

5. THE BEAM GENERATION AND DIAGNOSTIC ELEMENTS

For ion production an internal ion source of the Penning type with a hot cathode and an insulated anticathode is used. The extraction and selection of the beam on the first turn is realized by means of a puller, turned at the angle 16^o to dee edge.

There are three water-cooled probes to control the beam. One of them goes through the dee along the axis. When adjusting the accelerator, low current multielectrode targets on the probes can be installed. The accelerating voltage is measured by means of capacitive probes.

6. STATUS

At present time the cyclotron was assembled at the test stand at the JINR (Dubna). Most systems and devices were tuned independently and ready to work. Two weeks ago we began the vacuum pumping of the accelerator and the struggle with leaks. Soon we plan to study the beam behavior in the central region. The full-scale experiments will be possible only in Tashkent where a proper radiation shielding is provided.

7. REFERENCES

1) Alenitskij Yu.G et al., **"Convertion Project of the AS Uzbekistan Cyclotron"**, JINR, P9-91-82, Dubna, 1991
2) Glazov A.A. et al.,**"Study acceleration system of U-200T isocchronous cyclotron"**, JINR, P9-91-84, Dubna, 1991
3) Dmitriewskij W.P. et al., **"The choise of system for beam deflection on the inside target of syclotron U-120"**, JINR, P9-91-480, Dubna, 1991