Correction of the cyclotron RIC-30 magnetic field

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Cyclotron RIC-30 (development of SPA "D.V.Efremov Scientific Research Institute of Electrophysical Equipment" is in operation from 1993. RIC-30 is isochronous cyclotron with sector's focusing and one-dee (180 degree) RF system. Compact magnet has 150 cm pole diameter. Cyclotron is used for the production of the PET-isotopes using internal and extracted beam with maximal energy of protons ~28 MeV. At earlier periods of exploitation some parameters of cyclotron (beam intensity and energy) were in disagreement with designed ones. It was decided to carry out the magnetic field measurements to understand the causes of such misalignment. This was done in 2006.

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Common view of RIC-30 cyclotron

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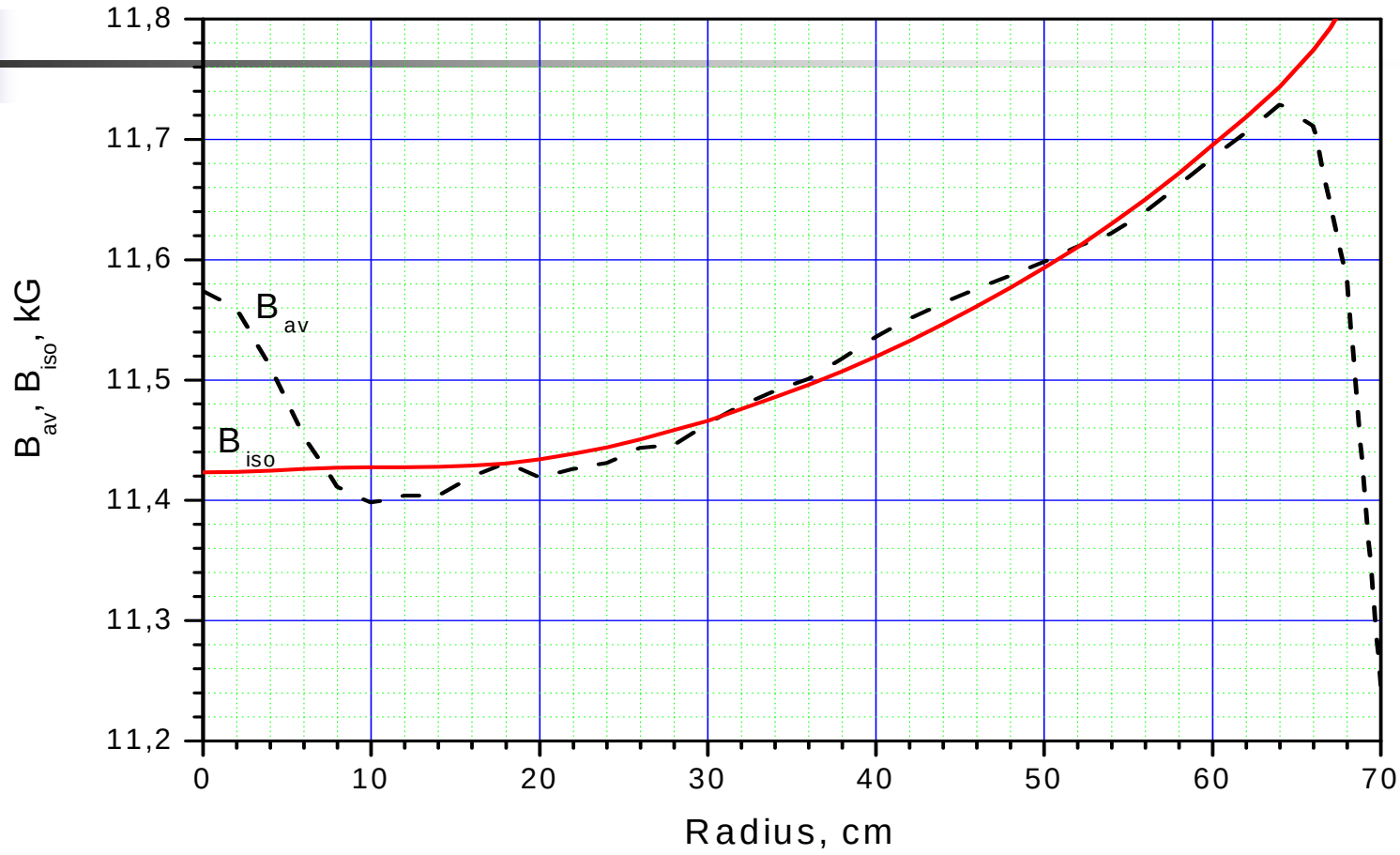

Fig. 1. Average magnetic field B_{av} and isochronous one B_{iso} for the resonance frequency of protons f=17.415 MHz

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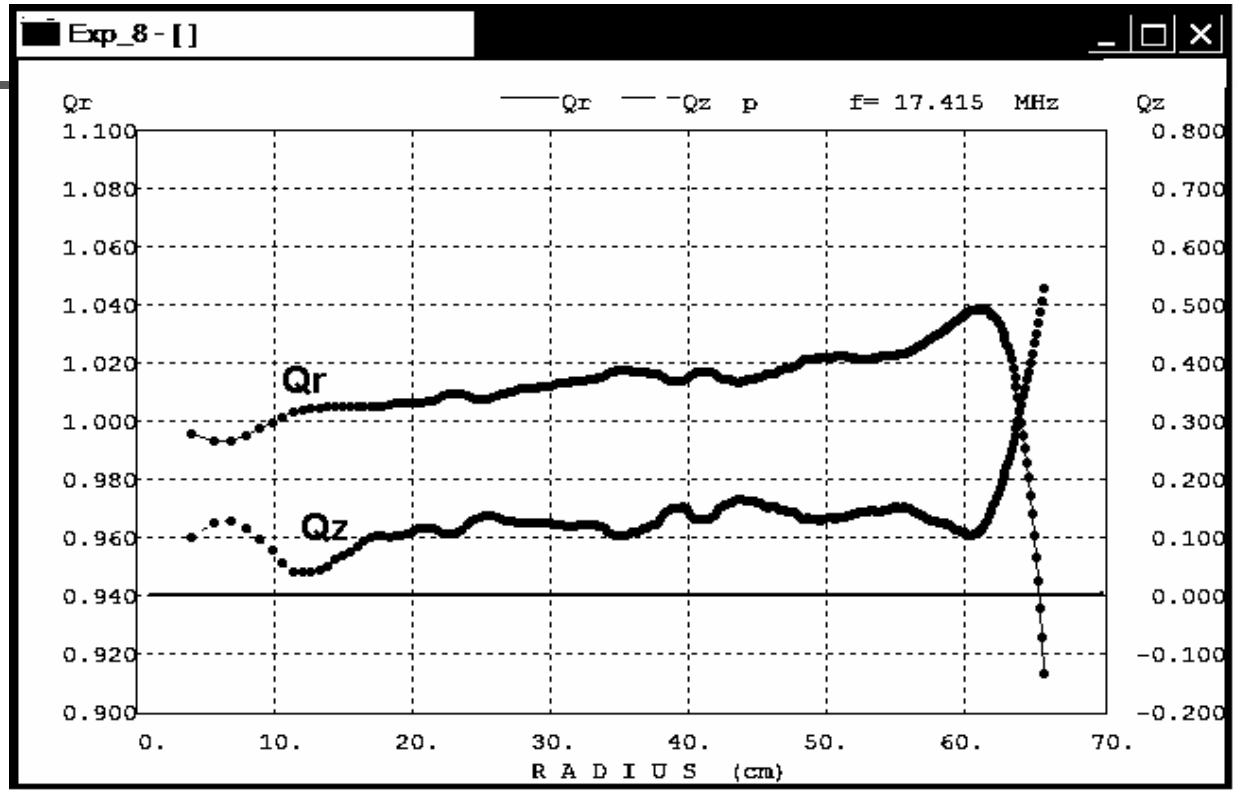

- **Betatron frequencies (average magnetic field from Fig. 1)**

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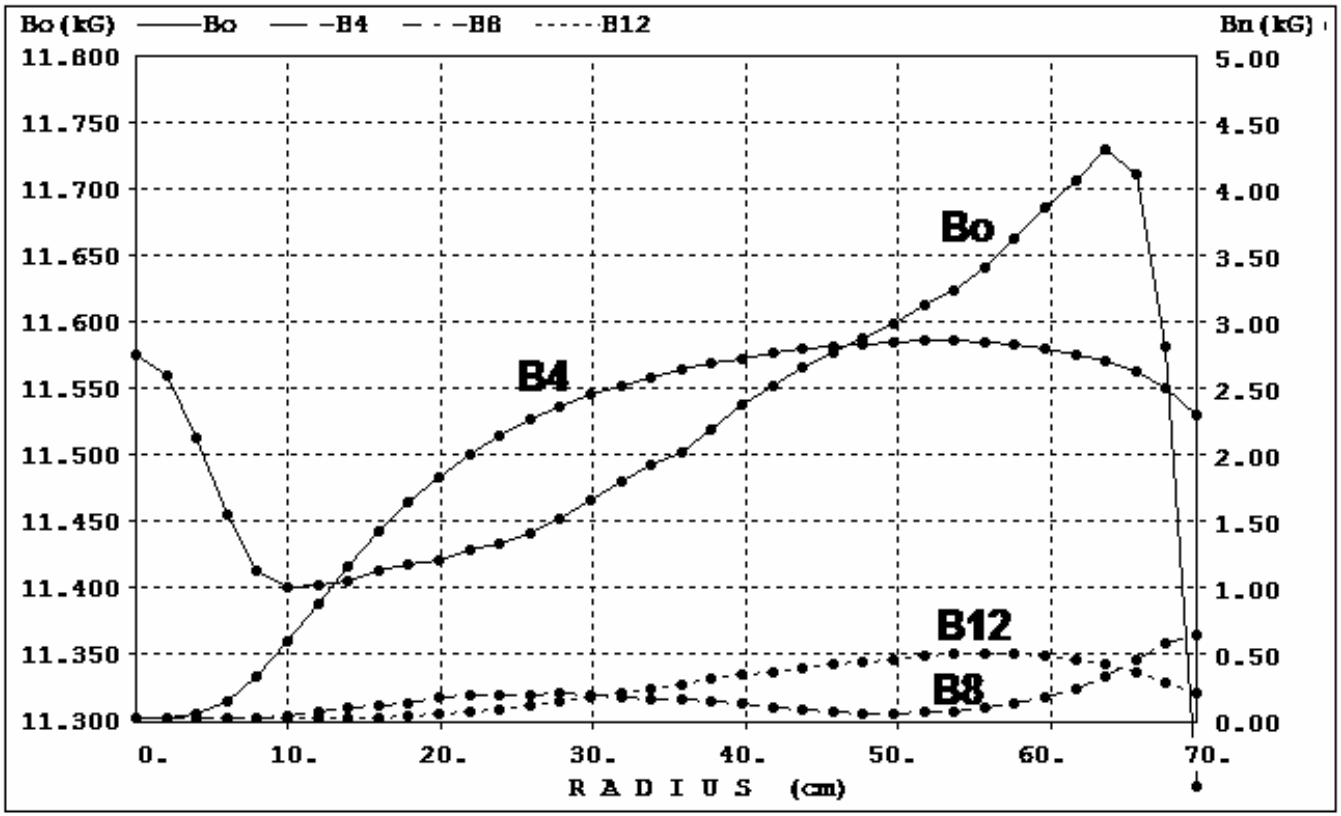

Fig. 2. Average magnetic field *Bo* (smoothed) and amplitudes of harmonics *B4, B8* and *B12* (not smoothed) which were used in the beam acceleration calculations

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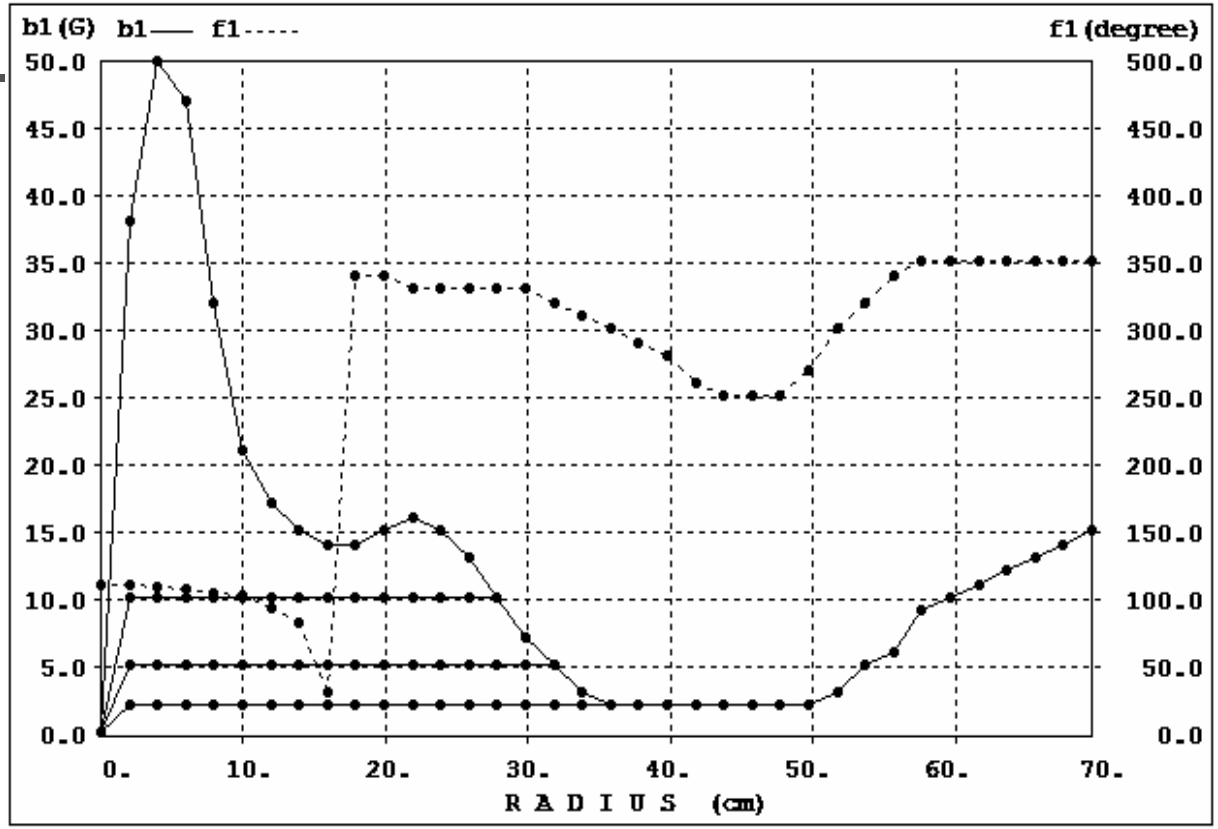

Amplitude *B1* and phase f1 (smoothed) of 1st harmonic of the magnetic field that were used in the beam dynamics calculations. Dependence *B1(r)* were used in range of radii 0-30 cm: experimental

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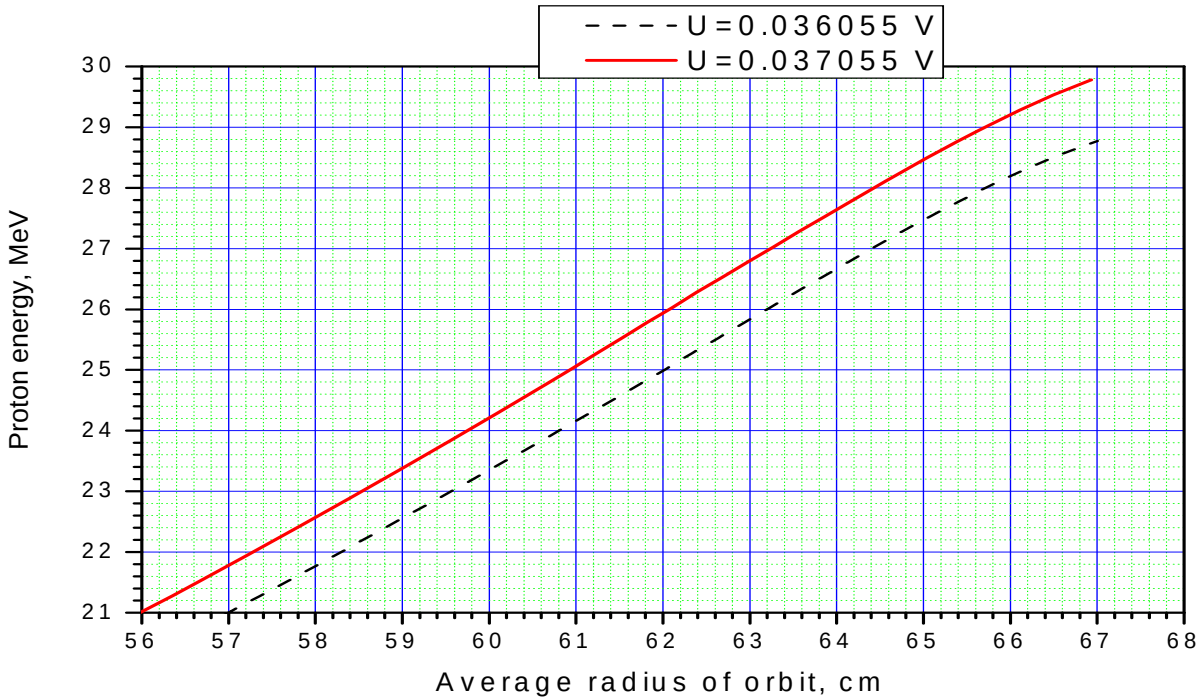

Energy of proton versus average radius of the orbit for two values of the main coil current. Dash line is working regime of cyclotron with RF-frequency 17.415 MHz, red line – corresponds to possible regime with RF-frequency 17.755 MHz.

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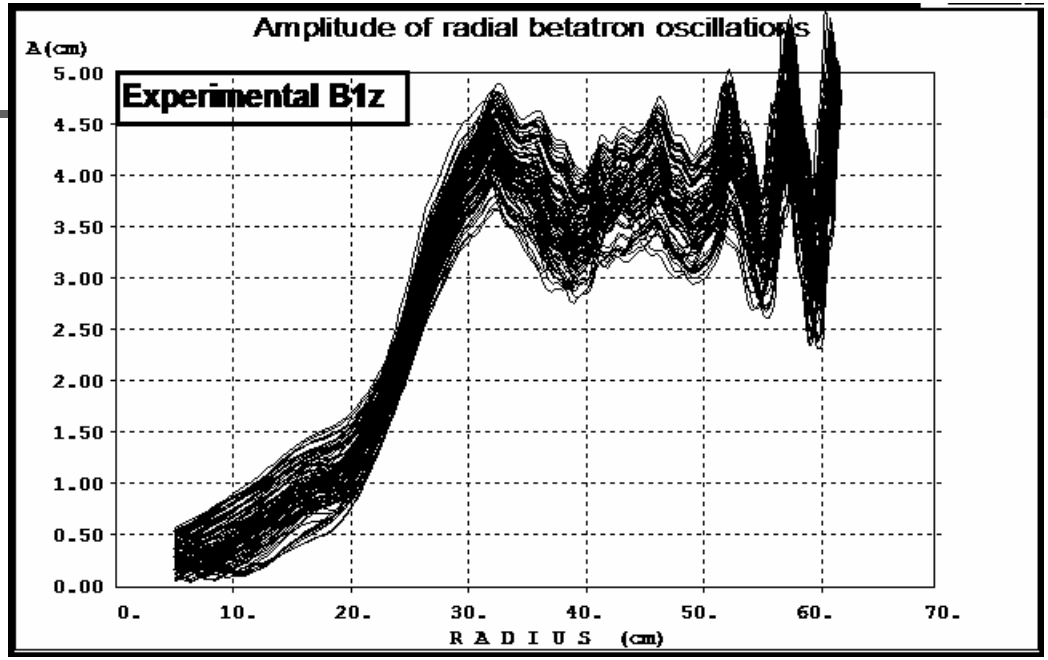

Amplitudes of radial oscillations of protons versus average radius of the orbit with in the case of experimental *B1(r)*

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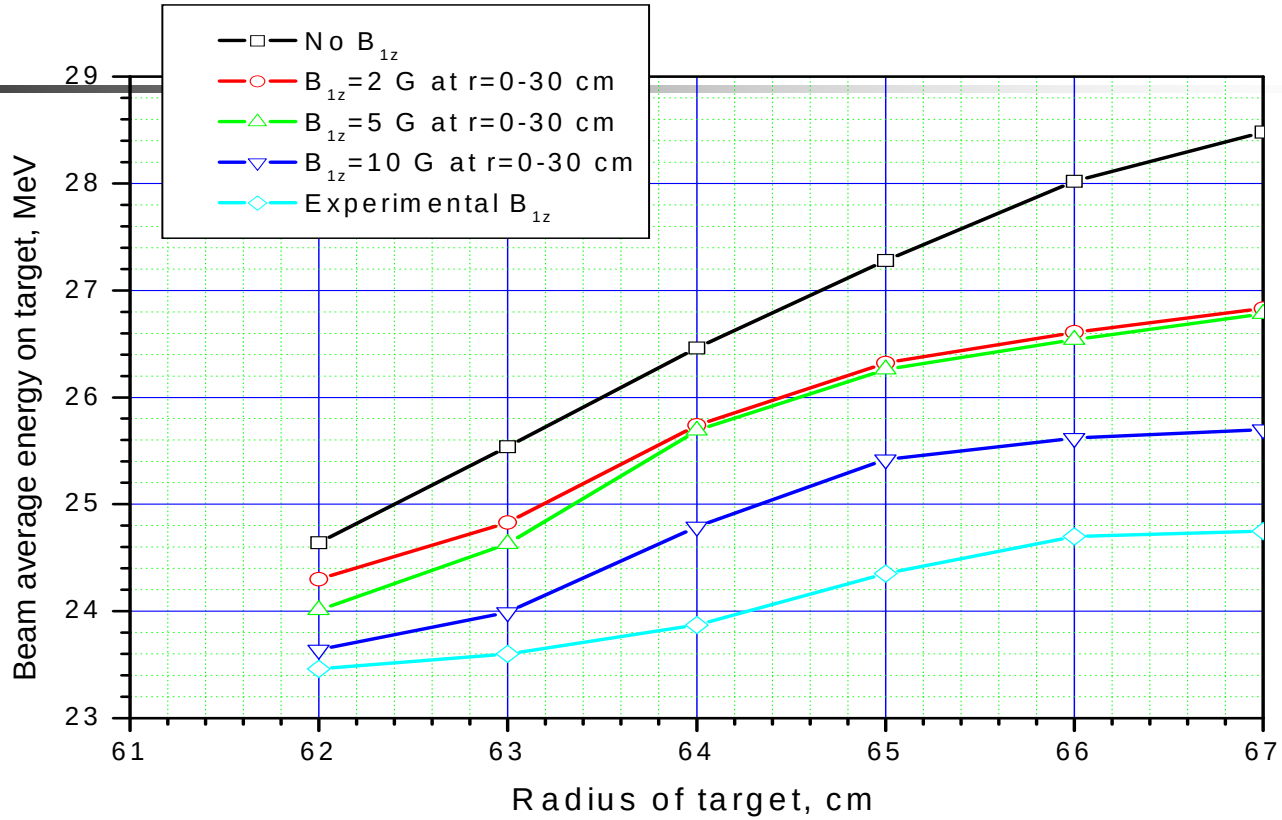

- **Average beam energy on the target (azimuth 235°) versus its radial position for different distributions of *B1(r)***

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- Dependences of the beam energy on inner target for the different shapes of *B1(r)* in the center are shown in Fig.7. With existing 1st harmonic of magnetic field the beam energy equals 24 MeV on radius of a 64 cm. Reaction $^{45}Sc(p,2n)^{44}Ti$ confirm this fact.
- Central steel plug with two symmetrical relatively a center holes with diameters of 20 mm was installed into the machine. In one of the holes an ion source is arranged. The magnetic field with new plug is not measured so far, but it is possible to suppose that 1st harmonic of the magnetic field in the center is essentially decreased. Value of protons energy at the extraction radius (64 cm) was estimated by amount of $^{45}Sc(p,2n)^{44}Ti$ isotope and equals ~26 MeV.

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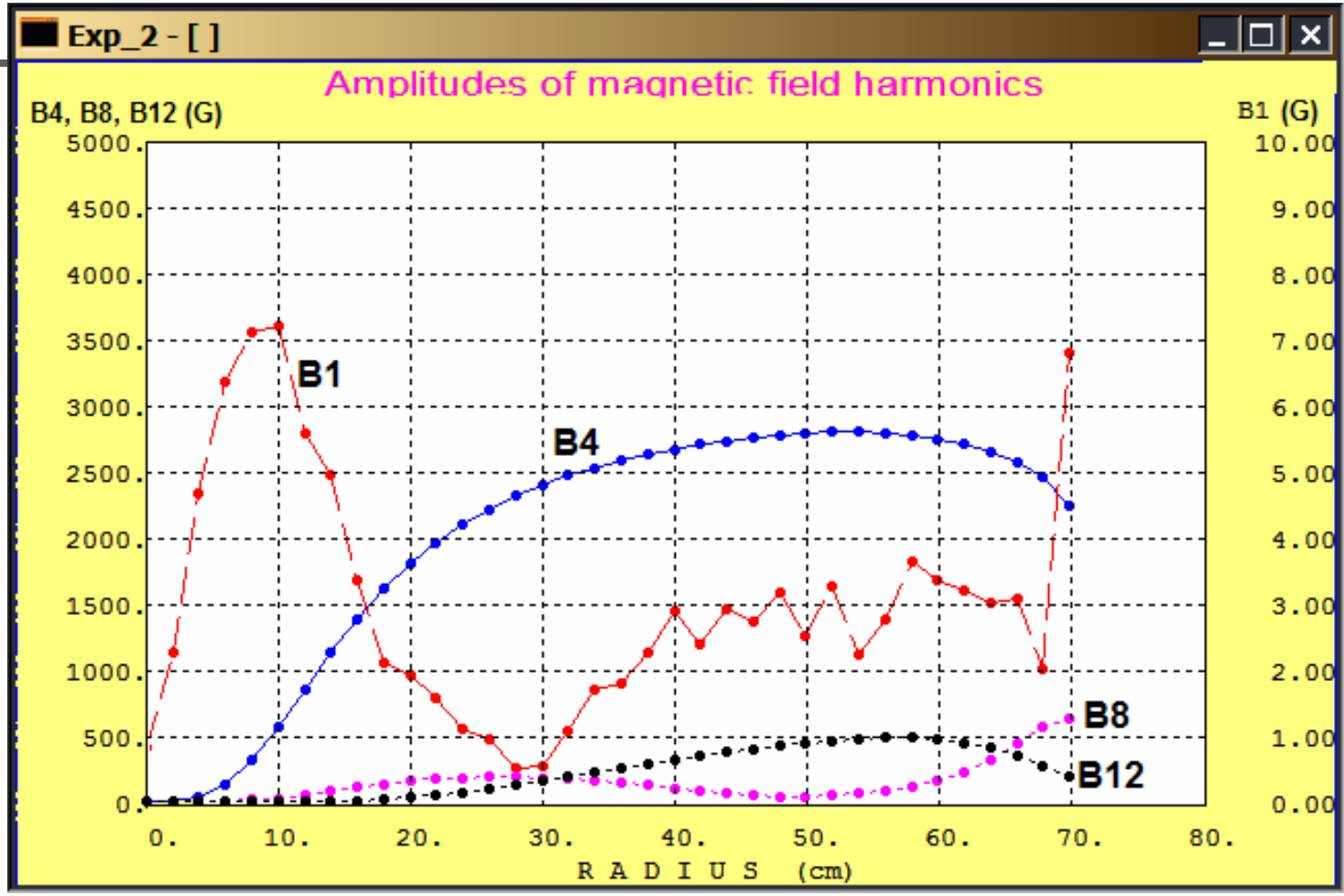

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- **Conclusions**
- The proton beam energy at the final radii was increased due to new steel central plug with two holes which does not create 1st harmonic of the magnetic field and essential beam radial oscillations (this plug was installed instead of plug with one unsymmetrical hole).
- The intensity of the accelerated beam can be essentially increased by the change of the average magnetic field shape in the central region of cyclotron.
- If the body of target is thin surface layer of any material the angle of beam hitting the inner cyclotron target becomes an important characteristic. Orbit of protons in the isochronous cyclotron is not a circle. Thus, angle of beam hitting the target depends on azimuth and radial position of the target. Technical solution of this question is under studying.

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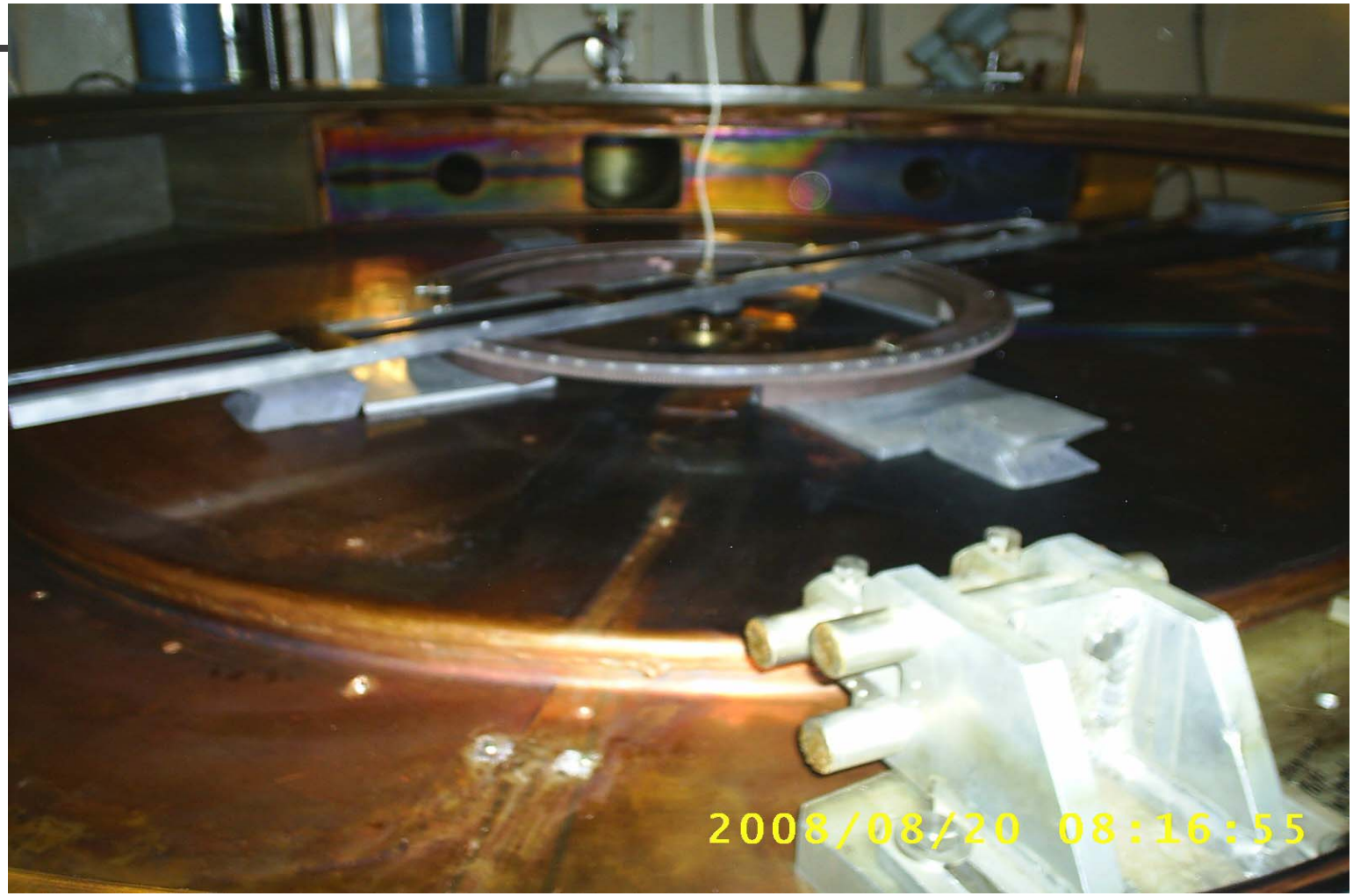

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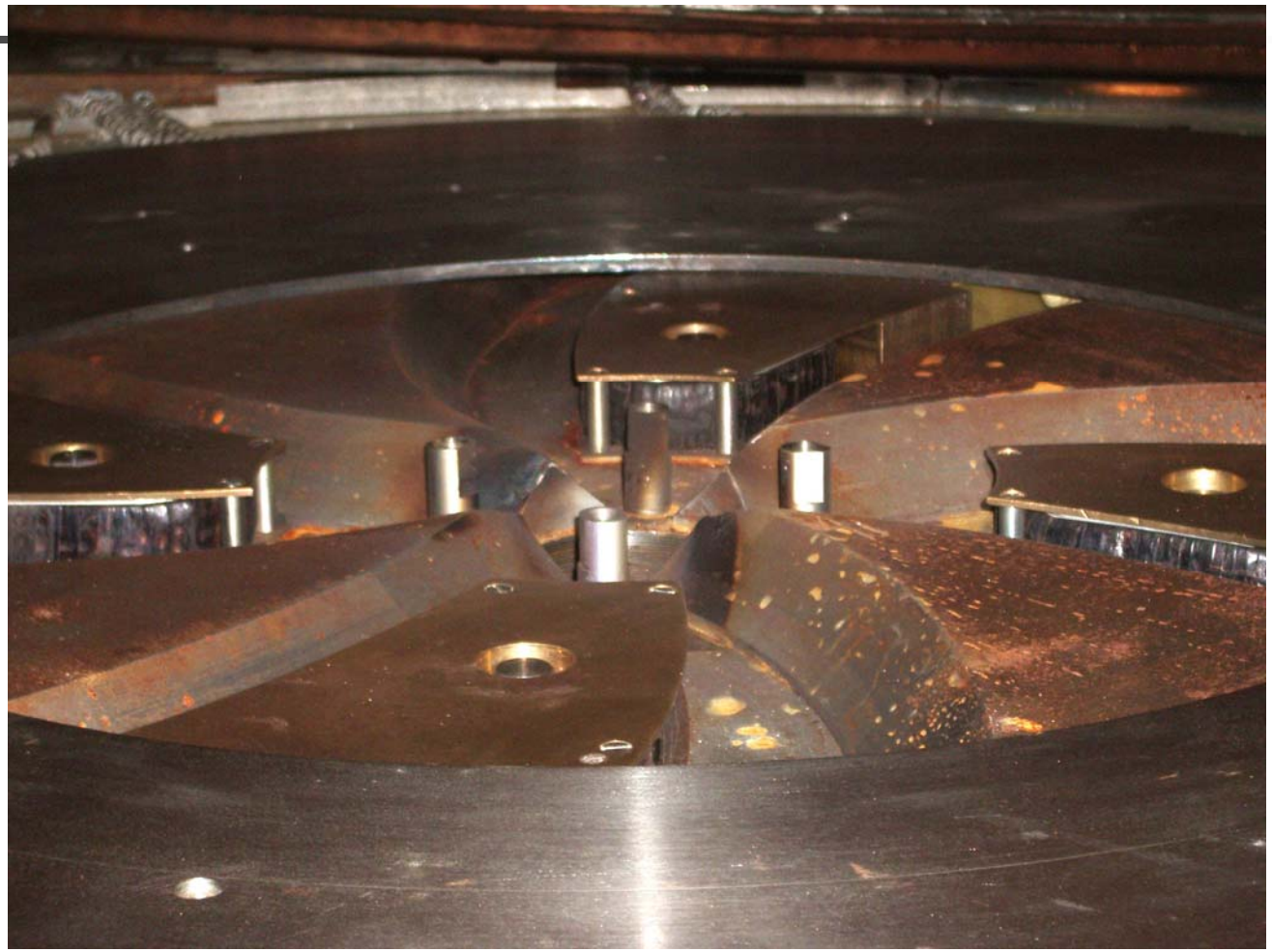

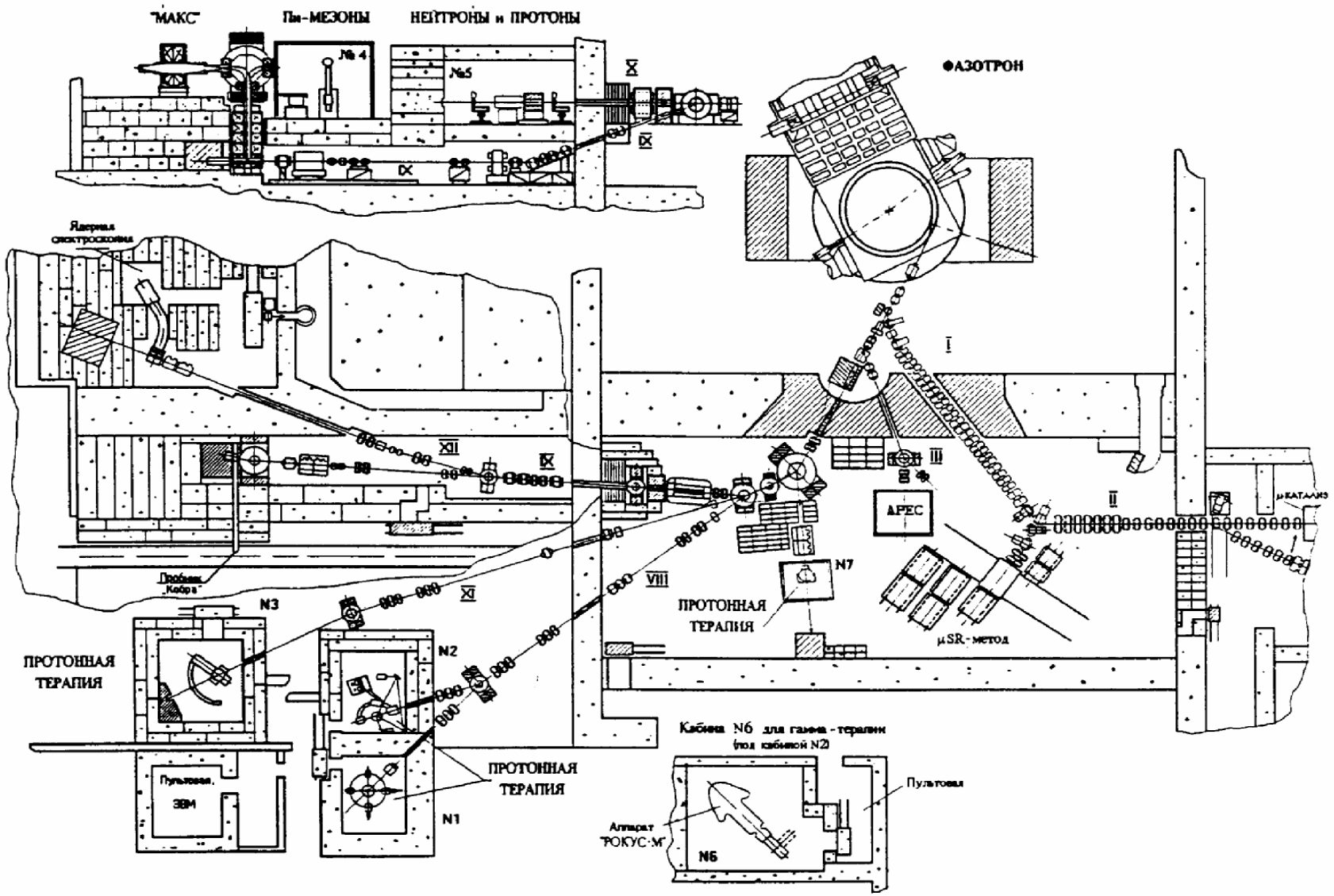

Рис.7. СХЕМА ПУЧКОВ ●АЗОТРОНА ЛЯП ОИЯИ