STATUS AND FUTURE OF THE JUELICH CV28 COMPACT CYCLOTRON

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The parameters of compact cyclotron with changeable energy CV28 and modernization of its systems and possible applications of the accelerated protons, deuterons, ^{3}He and alpha particles is described.

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1. FACILITY LAYOUT

The building comprises four heavily shielded rooms, a number of peripheral rooms such as experiment preparation, control and power supply rooms. The cyclotron room, in addition to the cyclotron itself, houses the complete beam transport system, consisting of a main beam line for the external beam with steering systems S1 and S2 and the 2,5" quadrupole Q0, the switching magnet SM, and seven beam lines between the switching magnet and the target stations T1 to T7.

The target stations T1 and T2, T4 and T5 as well as T7 are situated in individually shielded target rooms to allow the set up of experiments during cyclotron operation. These long beam lines (6 m distance between switching magnet and targets) are equipped with 2" quadrupole doublets Q1 to Q7. The short beam lines, 3 and 6, end in the cyclotron room. Target station 3 is equipped with an automatically operated pneumatic transfer system which allows receiving and returning targets from and to laboratories in the nearby building. Target station T6 is mainly used for nuclide production in continuous flow gas targets. The target stations TI, T2 and T7 are presently used for nuclide production target development. T4 and T5 are used with specially designed targets for radiation damage studies [1].

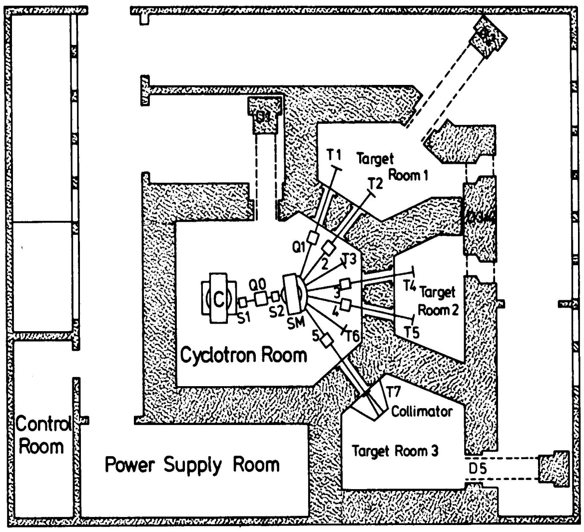

Fig.1. Facility layout

2. THE CYCLOTRON

The cyclotron CV28 is a variable energy AVF isochronous cyclotron with the performance data given in the Table.

Particle performance data

Particle	Min. energy, MeV	Max. energy, MeV	Int. beam, μA	Ext. beam, μA
p	2	24	500	70
d	3	14	500	100
^{3}He	5	36	150*	70
α	6	28	100*	50

*At maximum energy; at minimum energies 15μA ^{3}He and 10μA α external currents, rising with $U^{3/2}$

Some of its main features are shown in the median plane cross section Fig.2,3.

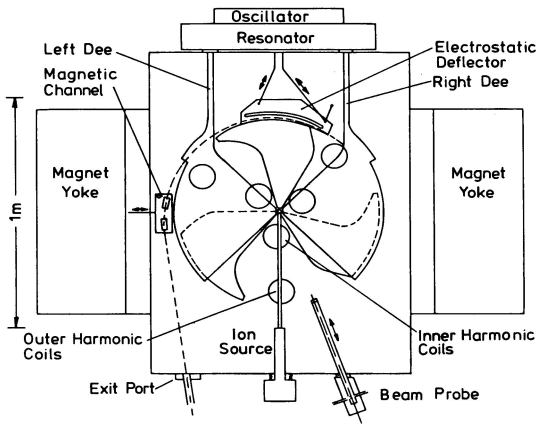

Fig.2. Median plane cross section

The azimuthally variable field is provided by three spiral shaped hills. The average maximum field is 1.7 T. The necessary field gradient adjustment to account for relativistic mass changes is achieved by 4 concentric profile coils (not shown) on the pole tips underneath the hills. Two sets of harmonic coils allow adjustment of beam centering and harmonic content for optimum beam extraction. A radial mounted "cold cathode" type hooded arc ion source is adjustable in three dimensions, allowing also tilting the source, for optimum beam production. The ion source is adjustable in four independent coordinates, namely, horizontal, radial, vertical and finally the axial rotation. The method to adjust the cross

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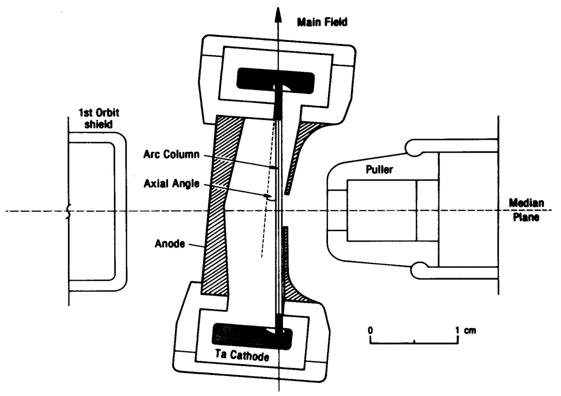

Fig.3. Cross section of the ion source head

section of the arc column has been developed by T.Y.T. Kuo and J.S. Laughlin [2] to increase the ion production extracted by the puller electrode. With these variable parameters and the possibility of accelerating voltage adjustment, beams between a few nanoamperes and the full specified output can be produced routinely. The ions extracted from the ion source are accelerated in the fundamental mode by high voltage radio frequency (typ. 5…25 kV) applied to two 60° dees. The two dees are connected by a variable inductor (movable shorting plane inside the resonator box). This variable inductor together with two variable capacitors allows tuning the resonant frequency between 6.5 and 26 MHz. This resonant circuit is driven by an equally tunable power oscillator.

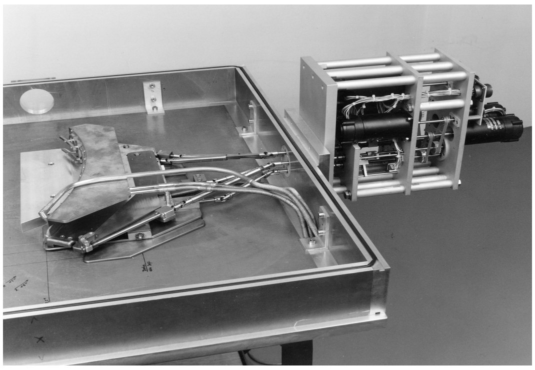

Fig.4. Test bench for the new deflector drive

An internal beam probe allows to monitor and optimize the internal beam between a radius of 10 cm to the extraction radius of 40 cm.

The beam is extracted by an electrostatic deflector, followed by a magnetic channel, both being mechanically adjustable. As an additional way of freedom a radial movement has been installed [3], to allow better tuning for extraction (Fig.4.). Extraction efficiencies of 70% at high, 40 to 50% at low energies are routinely being achieved.

3. BEAM TRANSPORT AND DIAGNOSTICS

The good quality of the external beam, approximately 15 mm mrad were achieved, does not require a very sophisticated beam transport system. A 2½" quadrupole doublet between cyclotron exit and switching magnet provides the necessary waist for the beam to pass the 30 mm gap of the switching magnet. With this quadrupole alone, the beam can be focused to a 5 mm diameter spot on targets 3 and 6 inside the cyclotron room.

The long beam legs, leading to the separate target rooms, require an additional 2" doublet about halfway between switching magnet and target.

Two X, Y steering systems were installed in the main beam line, to allow parallel shifts, to steer all extracted beams onto the optical axis.

Two types of diagnostic instruments are used in the beam transport system: beam shutters and helical wire beam scanners.

4. RADIATION SHIELDING AND SAFETY

The primary radiation shielding consists of 1.8 m thick walls of normal concrete (density 2.4 g/cm^3). The roof above the cyclotron room and the target rooms consist of 0.60 m concrete and a 1.2 m thick water-gravel layer in a watertight basin. This shielding has proved satisfactory under worst-case conditions. It was tested with thick beryllium targets at target stations T_2, T_6, and T_7, The targets were bombarded with 50 μA of 14 MeV deuterons; neutron dose rates at measuring points outside the shielding closest to the respective target positions were in the order of 0.1 mR/h throughout. Cyclotron and target rooms have equivalent shielded doors -the plug doors D1 and D5 and the sliding door D3/4 (Fig.1.). In order to make the target rooms really independent of any possible mode of cyclotron operation, special safety features have been developed (Fig.5). Failsafe beam plugs (self-closing when compressed air and/or power fail) are mounted in the switching magnet vacuum chamber in front of each of the seven beam line exits. These beam plugs are electrically interlocked with their corresponding target room doors such that no beam can enter a target room with its door open. The beam line (100 mm id. aluminum pipe) is fed through the shielding wall with interlacing polyethylene discs of two different sizes such that the beam line can still be mechanically adjusted without changing the shielding efficiency. To close the beam line itself (under worst conditions, with 100 μA 14-MeV deuterons on the safety beam plug, the dose rate delivered in the collimated neutron beam inside the target room is 20 R/h), a "pearl string" made of polyethylene balls is automatically rolled into the beam line when the target room door is opened. In this way a full protection from direct radiation by the running cyclotron is achieved.

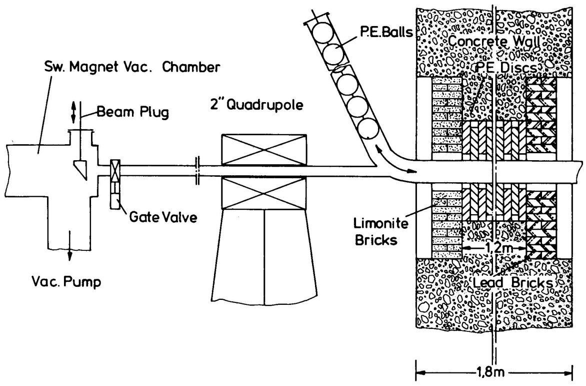

Fig.5. Beam feed through and shielding

5. DEVELOPMENTS AND ADDITIONS

5.1. INTERNAL TARGET SYSTEM

An automatic target System for high current irradiations, up to 5 kW beam power, using the internal beam of the cyclotron has been developed [4].

5.2. MEAN BEAM ENERGY MEASURING SYSTEM

A new method and apparatus for measuring the mean energy of the cyclotron beam has been developed [5].

The absolute energy of the beam from the CV28 cyclotron has been determined by measuring the temporal distance between the particle bunches in the transport system. The method uses two capacitive pickups inserted in the straight line in such a way that the downstream one can be moved longitudinally along the beam axis. The measurement is performed completely on-line, a PC controls the position of the probe and evaluates the signal produced by the HF detector electronics. Applying a moderate distance of about 2.5 m between the pickups, an accuracy of better than $3*10^{-3}$ has been achieved with different beams in the intensity range of 1...20 μA (Fig.6).

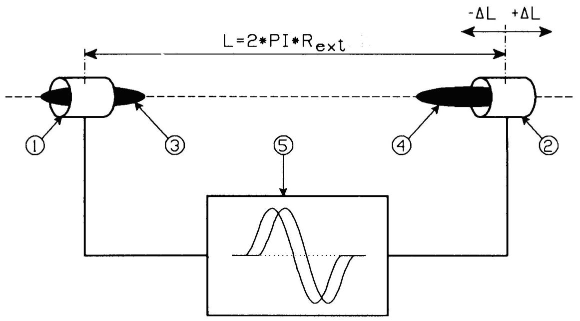

Fig.7. Measurement scheme: 1 – fixed probe; 2 – movable probe; 3 – particle bunch; 4 – neighboring bunch; 5 – oscilloscope

6. APPLICATIONS OF THE CYCLOTRON

6.1. INSTITUTE OF NUCLEAR CHEMISTRY

Fundamental radiochemical studies on complex particle emission and isomer distribution in nuclear reactions. Measurement of reaction cross sections and excitation functions via the activation technique, with reference to problems of nuclear technology and medicine. Production of short-lived cyclotron radionuclides (^{11}C, ^{13}N, ^{15}O, ^{18}F, ^{82m}Rb, ^{86}Y, ^{94m}Tc, ^{124}I, ^{55}Co, ^{75}Se, ^{76}Br, ^{120}I, ^{140}Nd) especially for emission tomography methods (PET, SPECT) in medicine. Production of monoenergetic neutrons in the energy range 5 to 12 MeV using a deuterium target and their use in measurement of fusion energy related cross section data.

Radiopharmaceutical Chemistry. Development of tracers for studies on regional metabolic functions, especially in the brain, using emission tomography (PET und SPECT). Methods for fast labeling of biomolecules with short-lived radionuclides for medical diagnostic and pharmacological investigations.

6.2. MATERIAL SCIENCE

The Jülich Compact Cyclotron is used in the framework of the European Fusion Programme (EFDA) and in the European Spallation Source (ESS) project for the investigation of irradiation induced changes of material properties and the resulting microstructures. Light ions in the5 to 36 MeV range are employed to simulate the damage by neutrons or high energy protons. Advantages of the light ion irradiations are better control on irradiation parameters and conditions, e.g. temperature, stress, dose rate, etc. Topics which are especially apt to be studied in cyclotrons are effects of high gas production (hydrogen, helium), time-dependent property changes (irradiation creep, fatigue, etc.) and effects of non-stationary irradiation conditions (pulsed irradiation, cyclic changes of temperature and/or stress). So far a large variety of materials have been tested under various conditions, mainly austenitic and martensic steels, but also pure metals, intermetallic alloys, ODS steels, precipitation harden materials, ceramics and glasses. The latter two classes of materials still allow a wealth of interesting experiments, when problems of specimen preparation are solved, which are caused by the limited range of the light ions of Jülich Compact Cyclotron.

7. FUTURE PLAN

The cyclotron will be shut down at the end of December 2005. The disassembly starts March 2005 and it will be reinstalled at the National Science Center „Kharkov Institute of Physics & Technology“.

REFERENCES

1. J. Hemmerich, R. Hölzle, W. Kogler // *Kerntechnik*. 1977, 19. Jahrgang, №.2.
2. T.Y.T. Kuo and J.S. Laughlin. Sloan-Kettering Institute, New York, N.Y. USA
3. K. Beverung. service@zyklotron.beverung.de
4. W. Stellmacher, W. Kogler, W. Bolten, G. Blessing. IFF/INC, Forschungszentrum Jülich
5. Z. Kormany // *Nucl. Instrum. and Methods*. 1994, v.A337, p.258-264.

СТАТУС И БУДУЩЕЕ ЮЛИХСКОГО КОМПАКТНОГО ЦИКЛОТРОНА CV28

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Приведены параметры компактного циклотрона CV28 с изменяемой энергией. Описаны модернизация его систем и возможные применения ускоряемых протонов, дейтронов, ^{3}He- и альфа-частиц.

СТАТУС І МАЙБУТНЄ ЮЛИХСЬКОГО КОМПАКТНОГО ЦИКЛОТРОНУ CV28

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