THE COMPACT FARADAY CUP FOR RADIOBIOLOGICAL RESEARCHES IN IHEP ACCELERATORS BEAMS

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Abstract

IHEP's experts are currently working on the creation of a medical irradiation centre with beams of protons and carbon ions on the basis of IHEP acceleration complex. Already existing IHEP accelerators I-100 - U-1,5 - U-70 are forming a complete chain capable of accelerating not only protons, but also, due to certain modifications, light ions: deuterons and carbon. The compact autonomic Faraday cup which works in the atmospheric environment has been developed to measure currents in the accelerators beams. The device has a good electromagnetic protection. It is compact and allows to make measurements on any (from 600 mm long) open site of a beam line. Vacuum tests and work with biological samples on a beam of protons of I-100 accelerator have proved that the Faraday cup is meeting all the requirements.

INTRODUCTION

IHEP's experts are currently working on the creation of a medical irradiation centre with beams of protons and carbon ions on the basis of IHEP acceleration complex. Already existing IHEP accelerators I-100 - U-1,5 - U-70 are forming a complete chain capable of accelerating not only protons, but also, due to certain modifications, light ions: deuterons and carbon.

In collaboration with scientists of the Medical radiological scientific centre (MRSC, Obninsk, Kaluga region), IHEP experts make biological researches in IHEP accelerators, with existing beams. Possible places of making researches on complex IHEP are shown on fig. 1 by red colour.

The parameters of beams in these sections [2] are shown in the Table 1.

Table 1: Parameters of beams at 3 points of IHEP accelerators

	Ions	Kinetic energy, MeV/u	Range in water, mm	Z/A	Pulse duration, current	
I-100 (point 1)	${}_{1}H^{+1}$	72	43	1	1÷50 µs	1-50 mA
	${}_{2}H^{+1}$	16,7	4	1/2	1÷50 µs	15 mA
	${}_{12}C^{+6}$	16,7	1,0	1/2	3 µs	1.5 mA
U-1,5 (point 2)	${}_{1}H^{+1}$	<1320	<4700	1	≈0.2 µs	400 mA
	${}_{2}H^{+1}$	<440	<2000	1/2		80 mA
	${}_{12}C^{+6}$	<440	<300	1/2		8 mA
U-70 (point 3)	${}_{1}H^{+1}$	<1320	<4700	1	Slow extraction	
	${}_{2}H^{+1}$	<440	<2000	1/2		
	${}_{12}C^{+6}$	<440	<300	1/2		

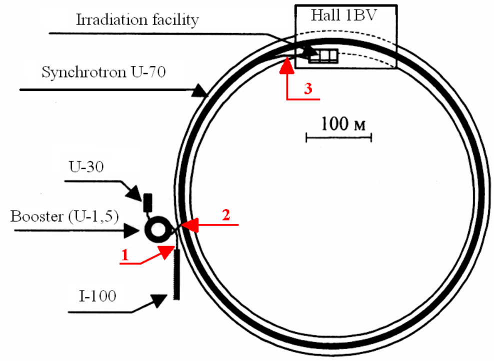

Figure 1: The layout of linear accelerator I-100, synchrotron-booster U-1.5, main ring U-70 and experimental hall 1BV.

THE FARADAY CUP`S DESIGN

The device (Fig. 2) has been made with the classical scheme of Faraday Cup (FC) [3, 4]. It has following features:

- works under atmospheric conditions;
- working aperture - Ø 69 mm;
- external dimensions of pipe: diameter - 100 mm, length - 550 mm;
- weight - 11 kg;
- weight of magnetic system (3) – 12 kg;
- entrance window is made of 0.1 mm thickness mylar, covered with aluminum from two sides;
- the carbon (density of ~2 g/sm3) core's (8) of length 200мм provides full absorption of different beams of tab. 1;
- induced activity from an absorber, because of nuclear interactions with a beam, has a half-life period of ~20 minutes that is important for the portable device;
- aluminum collimator (5), attached to FC`s body, can be fast replaced with an other one in case of need.

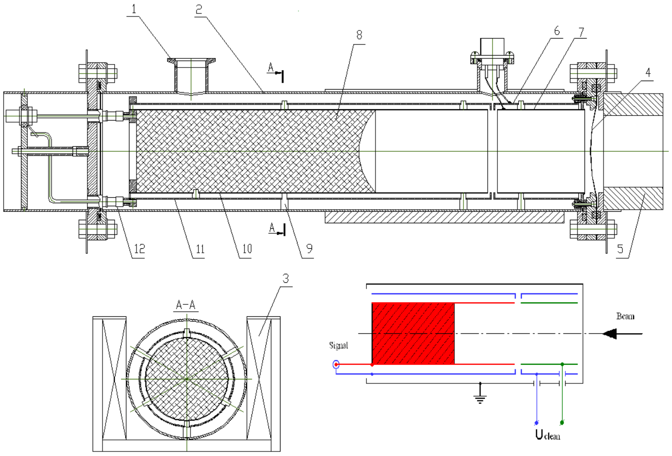

Figure 2: Compact autonomic Faraday cup.

Because of strong electromagnetic hindrances there has been chosen 3-cylinder coaxial design, for minimizing influence of hindrances and breakthroughs. All cylinders are made from stainless steel. The external cylinder (2) forms a closed and grounded vacuum volume. Two inner pipes are divided on length on two unequal parts and are suspended on ceramic insulators (9). The beam enters to the cylinder from the right side (in the drawing). The first parts of cylinders (on a course of a beam) form "clearing" electrodes (6, 7) length of 70 mm. The internal cylinder has positive potential. The purpose of this part of FC is to gather secondary electrons which been emitted with a beam from an entrance window. The second parts of pipes (10, 11) form "the measuring" section. Inner pipe is covered from inside with a copper and electrically contacted to the 70 mm diameter carbon core (8). The charge, formed by a beam of ions in a core is read out through vacuum ceramic-metal feedthrough (12) and HF socket. The stream of secondary electrons, arising from the core and moving back (towards to a beam), is going to the internal surface of the same "measuring" pipe (10). Such effect is caused by a cross-section constant magnetic field from external system (3) on the basis of SmCo. The same magnetic system helps to improve a gathering of secondary electrons, arising from an entrance window, on "clearing" electrode (7). Vacuum inside the cylinder is $3*10^{-3}$ torr. It prevents ionization effect.

FC TESTS AND RESULTS

Manufacturing, clearing of details and vacuum tests of FC were spent in IHEP at the high- vacuum stand [5]. One of the important specificities of the device is ability to work without pumping out for a long time. Changing of pressure in the device from time has been measured with different entrance windows.

FC has been tested for tightness with leak founder with sensitivity $\sim 1 \cdot 10^{-12}$ L·mbar/s. No leaks has been found during the test. It means, that pressure changing inside FC is defined by gas evolution from internal surfaces of cylinders, mylar window and graphite. Pumping out for working during the day was made at the vacuum stand. Then the device was transferred to the beam. For longer period of work FC has been constantly attached to the ceolitic sputter pump.

Electric tests of FC have confirmed high quality of used ceramic insulators and a socket: leakage currents have not exceeded 1 pA.

Working tests of FC were made in accelerator I-100 with a proton beam with energy of 72 MeV (fig. 3) at small (duration of a current's impulse is 1.5 µs) and big (20 µs) irradiation doses.

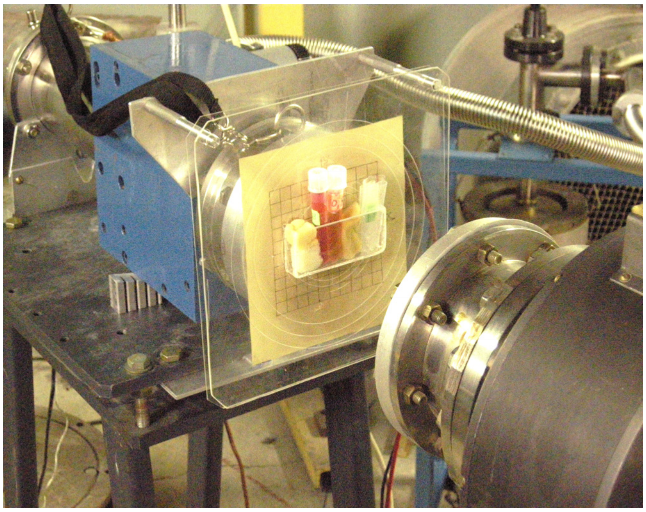

Figure 3: FC with biological samples is mounted on a beam of I-100

On the following fig. 4 there are oscillograms of a beam current from the Beam Current Transformer (BCT) mounted in vacuum system of the accelerator and from FC, standing in atmosphere on exit of I-100.

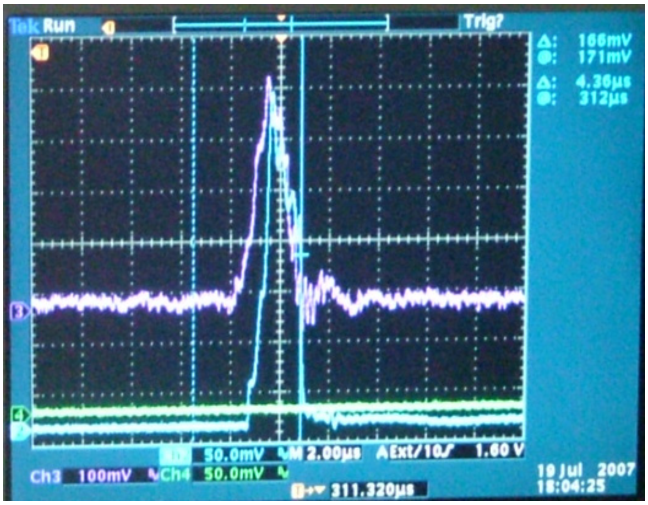

Figure 4: Oscillograms of signals from BCT (the top ray) and FC (the bottom ray). Coincidence within 10 %.

Signal's monotonous dependence from "clearing" electric field (in limits ±200 V), has smooth character and can change indications of FC for 4 %. The "correct" value of a clearing bias voltage is +200 V.

Installation of a constant magnet in a forward part of the cylinder increases a signal for 4 %.

In the end of tests there has been made irradiation of thermo luminescent dosimeters, which were fixed on a target flange in front of the cylinder. The range of measurements of doses was from 1 to 10 Gray (through 1 Gray) and further 20, 50, 150, 300, 500 and 1000 Gray.

Results of measurements of these dosimeters have been compared with FC`s indications. The data are correlated with 10 %.

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