13. The beam of Warsaw Cyclotron for radiobiological studies

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In recent years the application of beams from heavy ion accelerators for biophysical experiments has been gaining increasing importance [1]. The understanding of radiobiological effects of charged heavy particles are of fundamental importance both for radiation protection and radiotherapy, where the number of patients treated with heavy ions is increasing [2]. The physical environment of the sample is the major problem in biological studies of living cells under irradiation by the uniform beam of heavy ions. The temperature and humidity of the sample can influence the survival of the biological sample. In order to ensure a high humidity of the cell environment the vertical beam facility are usually used to irradiate the sample [3]. The vertical beam allows keeping the sample in the medium or in the solution placed in petri dishes in horizontal position.

However, thin sample (< 400\(\mu\)m) should be kept in vertical position during irradiation without influence on the humidity of the cells. In the experiment carried out at the Warsaw Cyclotron the 120MeV \(^{12}\)C ions were extracted to the atmosphere from the vacuum tube through an exit window made from the Havar foil 2.5mg/cm\(^2\) thick. The exit window of a size of 14 \(\times\) 14 mm was used. The Au scattering foil of thickness 20mg/cm\(^2\) was used to produce a beam directed to exit the window placed at 15\(^0\) and to the monitor at 20\(^0\) (Fig. 1). The spatial distribution of the beam intensity at the exit window is not uniform, and determined by the Rutherford scattering. The cell containers fastened to an X-Y sliding table (Fig. 2) was moved along the X and Y axes in order to ensure a uniform dose distribution at the irradiated target (see Fig. 1).

![Fig. 1. Sketch of the set up for cell irradiation at Warsaw cyclotron](image)

The intensity of the beam scattered at the gold foil was measured by a barrier silicon detector placed at 20\(^0\). To reduce the count rate, a collimator with 2mm diameter was placed in front of the detector monitoring beam intensity. The detector was placed at a distance of 125mm from the center of the scattering chamber, where the scattering foil was mounted. Appropriate
calculation of Rutherford scattering ratios \( \frac{d\sigma_R}{d\Omega}(\theta) \bigg/ \frac{d\sigma_R}{d\Omega}(\theta = 20^0) \) allowed us to determine the intensity of the scattered beam and the spatial distribution at the target position.

Before irradiation with the beam of the Warsaw Cyclotron, the radiation field at the position of the target was simulated. A two-dimensional intensity distribution was calculated assuming X-Y scanning of the target field with the beam transmitted through the exit window. A combination of the Rutherford scattering and the displacement of the beam on the target area ensured that the homogeneity of the beam was better than 5% across the target area (see Fig. 3).

Data acquisition system is registering time dependence of the beam intensity as well as the energy spectrum of the scattered beam. A selected number of counted particles initiates the programmed shift of the sliding table with the sample.

In order to perform uniform irradiation of biological samples, which are spread over 6 to 8cm in diameter, the moving sample was scanned by the beam passively smeared by the scattering foil. The required flux of the particles \( 10^7/s \) of \(^{12}\text{C} \) at incident energy 100MeV corresponds to the dose rate 10 Gy/min. The scanning in the horizontal and vertical direction was performed to obtain a homogeneity of the beam in the order of <5%. The dose determination based on the counting of ions scattered at 20° leads to the determination of number of particles reaching the sample. To verify the dose a set of thermoluminescence detectors, as well as an X-
ray film were irradiated. The results of irradiation of the X-ray film irradiated with doses 0.25Gy, 0.5Gy, and 1.0Gy respectively are shown in Fig. 5.

![Fig. 5](image1.png)

**Fig. 5.** The result of irradiation of the X-ray film irradiated with doses 4.7 Gy (left), 9.5 Gy (center) and 18.9 Gy (right).

V79 Chinese hamster fibroblasts were grown on thin foils for 24 hours, transported to the Heavy Ion Laboratory on ice and irradiated for different time periods in order to determine the optimal doses and exposure times that yield enough mitotic cells for scoring of chromosomal aberrations. Following irradiation the cells were transported on ice back to the laboratory where they were incubated at 37°C for 16 hours. Colcemid was added for the last 3 hours in order to block cells in mitosis. Cells were harvested as described elsewhere and aberrations were scored under a light microscope [4]. An example of a cell with chromosomal aberrations is shown in figure 6. A good yield of mitotic cells was observed after exposure times of 10-15 minutes and doses of 0.5-1 Gy. These exposure conditions will be used in future experiments.

![Fig. 6](image2.png)

**Fig. 6.** An example of a mitotic cell with chromosomal aberrations.

**References:**