STATUS OF THE INTERNAL TARGET TECHNIQUE AT THE NUCLOTRON

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Abstract

The internal target station used in physics experiments at the Nuclotron, its hardware and software configuration are described. The distance control of the station realized by means of an IBM PC computer is based on an operative presentation of the magnetic field cycle, beam parameters and target location relative to the beam on the monitor. A necessary space-time trajectory of the chosen target in time scale of the accelerator operation, is determined by the operator by means of a mouse and is realized by a step motor. To control the beam-target interaction in time, the light radiation of the target material bombarded by ions is used. The graphical functions, characterizing the luminosities and lifetime of a d, C and Ar nucleus beam with energies of 1 and 6 AGeV for different internal targets, are presented.

At present it is supposed that the range nuclear bombarding energy from some hundred MeV to some GeV per nucleon is very productive from the point of view of studying the transition regimes from proton-neutron to quark-gluon states of nuclear matter [1,2]. At the Nuclotron, a superconducting strong-focusing accelerator of nuclei at the Laboratory of High Energies of the JINR in Dubna there exists the opportunity to conduct this investigation in the unified experimental frames by using, for example, internal targets. First physics experiments on a circulating deuteron beam in energy range of 100 AMeV÷2.5 AGeV [3-4] show the perspectivity of works in this trend and the possibility to perform measurements simultaneously with beam extraction to the base setups.

The linear area of the Nuclotron with an internal target station is an installation which can operate both as part of the beam transfer line and, independently of it, when the accelerator is off. The design of this installation allows one to change its functional possibilities operatively and without an influence on the vacuum and cryogenic systems of the other Nuclotron areas. Here with, mounting the next batch of internal targets or elements for the subsequent irradiation in the internal beam and also the total replacement of the station for another experiment, can be realized. Taking this into account, at this installation one can use various types of internal targets (foils, thread-like, jets, beams etc.), test new methods of beam diagnostics and realize certain experiments analogous to those at a solid angle close to 4π on an external beam.

The internal target station used in physics experiments at the Nuclotron , its hardware and software are described in refs.[5,6] in detail. It is made in the form of two crossing cylinders of the beam transfer line and a larger diameter cylinder with three internal targets. The dimensions, design and wall thickness (0.5 mm) of the station are optimized to detect secondary particles by external detectors at a maximum solid angle and minimum losses. The foil targets of CH_2 ($\approx 1.6\mu$m in thickness), Cu ($\approx 0.55\mu$m) and Au ($\approx 1.7\mu$m) hung up by quartz fibres in the C-shaped frames, are used in experiments. The frames with targets are mounted vertically on the table rotating by means of a step motor. To control the beam-target interaction in time, the radiation of the target material bombarded by ions is used. The radiation is detected through the window by a photomultiplier tube and by a tandem-microchannel-plate detector in vacuum. Extraction of all frames with the targets from the beam transfer line and choice of a necessary target for experiment are realized by means of an electro-optical device connected to the rotation axis of the table and the electron control system of the step motor. The station is controlled by means of an IBM PC, the corresponding hardware and the program TARGET operating in DOS-system. It is based on presentation of necessary information about the accelerator run and beam parameters in real time and also the target position relative to the beam on a monitor. The program interactive down menu is driven and controlled by a mouse. An example of the operating window on the monitor is shown in fig.1. The information on the type of accelerated ions and the internal target used in the experiment is presented at the top of the window under the command menu. The magnetic field of the Nuclotron dipoles (H), the current of the circulating beam (I) and the energy of ions (E_k/A) are shown in the time scale of the accelerator run. The kinetic energy per nucleon is calculated at every point of measuring the magnetic field. The information about the position and beam profile at the station area (horizontal X-profile in fig.1) needed for target control is presented in the middle of the window in the same time scale. In accordance with the command menu, the beam profile can be determined by means of ionization profilometer counters periodically read out for the cycle time of the accelerator run, through the signals from the detectors (D_1 or D_2) of the radiation of the scintillation fibre scanning the beam or assigned by theoretical gaussian with definite dispersion. In the second case the information about the profile averaged for the measurement time is supposed unchangeable in time to the next measurement moment. The theoretical presentaion of the beam

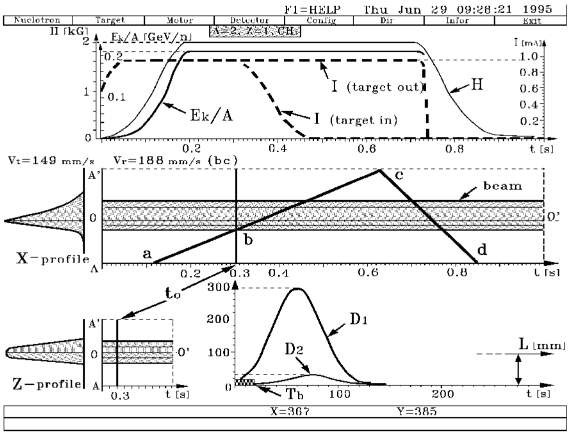

Figure 1: Example of the operating window at the PC-monitor.

profile is used for adjusting the station without a circulating beam. The operator defines the needed space-time trajectory of the used target relative to the beam (in the time scale of the accelerator run) by the broken line consisting of three segments ($a - b - c - d$ in fig.1). This trajectory is realized by a step motor to the next meddling of the operator. Some additional information about the vertical beam pro-

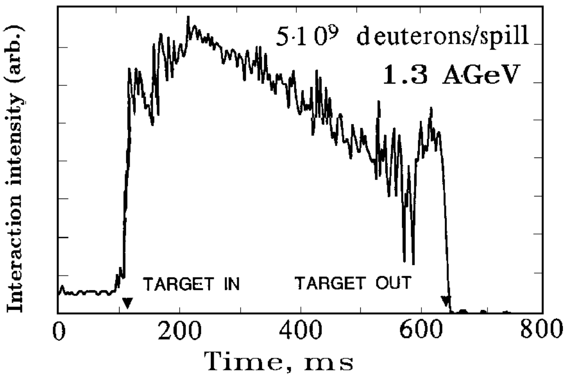

Figure 2: Time structure of deuteron beam-target interaction (1.3 AGeV, 1.6μm CH_2-target).

file (Z-profile), and also amplified analogous signals from the detectors of the target radiation (D_1 and D_2) attached to the time moment (t_o) of beam crossing by the target are presented at the bottom of the window. The time scale of these signals is defined by the operator in the command menu taking into account the needed interval of digitation. The minimum time interval of analog signal digitation during the station control is equal to 100 μs. The lifetime (T_b) of part of the beam interacting with the target is also presented in this scale. The value of T_b is calculated taking into account the information about the beam, accelerator and used internal target. A more detailed presentation of the beam profile through the time signal of the detector (D_1 or D_2) can be realized by transition from time to space scales ($t \leftrightarrow L$).

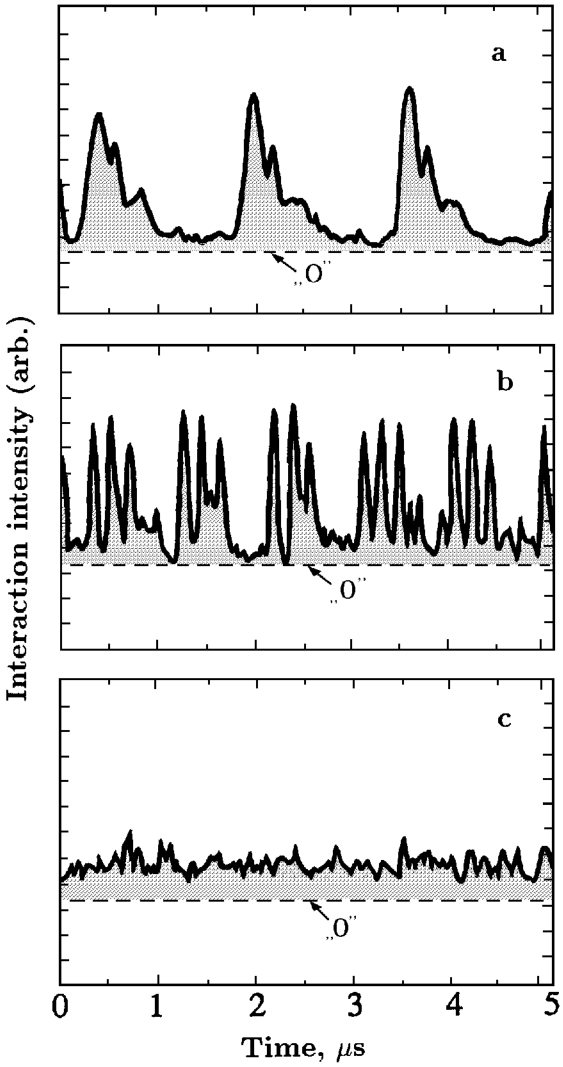

Figure 3: Time microstructure of deuteron beam-target interaction (1.6μm CH_2-target) at different phases of the accelerator run: **a**- start of acceleration, **b**- start of the plateau of the magnetic field (RF is switch off), **c**- middle of the plateau of the magnetic field - disappearance of bunches. Light radiation from the target is detected.

Here with, the speed (V_r) of the target on the bc-segment of the space-time trajectory is taken into account automaticaly. The program TARGET also anticipates an automatic choice of this speed when the time of discrete space motion of the target is equal to T_b. The monitor presentation of information is realized in each cycle of the accelerator run at a stationary or movable target.

When the operator desires, any information presented at the operating window can be removed from the monitor, transferred to a vacant space of the window in the decreased state (see the Z- profile of the beam in fig.1), viewed in time in more detail, returned to the initial position and also writ-

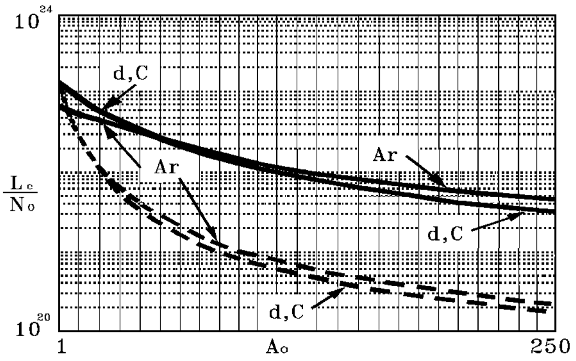

Figure 4: Maximum values of specific luminosities averaged over cycle time (T_c) per one projectile (d, C and Ar nuclei) for different internal targets at the Nuclotron (T_c= 10 s, −− 1 AGeV, — 6 AGeV).

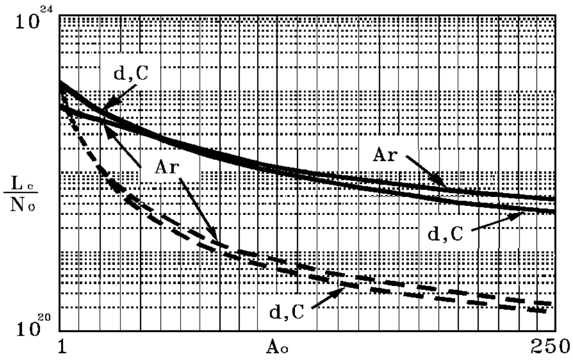

Figure 5: $T_b t_g$- functions vs target mass number A_o for different incident nuclei at the Nuclotron (−− 1 AGeV, — 6 AGeV).

ten as a file or read out from it during the following analysis of experimental data. As an example of the selected information, a light signal from the polyethylene target ($\approx 1.6\mu$m) characterizing the time structure of target interaction with a deuteron beam at an energy of 1.3 GeV/nucleon, is shown in fig.2. The microstructure of the target light radiation (see fig.3) obtained by means of an additional ADC with a minimum time interval of digitation equal to 20 ns shows the interaction with a bunched beam circulating at various phases of the accelerator run.

To estimate the potentialities of experiments on the Nuclotron internal beam, figs. 4 and 5 present the maximum values of luminosities averaged over cycle time (T_c) per one projectile (L_c/N_o [cm^{-2}s^{-1}], N_o is the number of circulating particles before beam-target interaction) and the lifetime (T_b [s]) of a d-, C- and Ar-nuclear beam at energies of 1 and 6 AGeV vs target thickness (t_g [g/cm^2]) and mass number (A_o). For the above targets and the supposed beam intensities at the first stage of the Nuclotron run [1], the values of L_c [cm^{-2}s^{-1}] and T_b [s] are estimated as in table.

Target	C, CH_2	Cu	Au
Part.,	L_c	—	—
Energy	$[T_b]$	—	—
1 AGeV	2×10^{33}	8×10^{31}	10^{31}
d	$[3 \times 10^{-2}]$	$[3 \times 10^{-3}]$	$[2 \times 10^{-4}]$
6 AGeV	4×10^{33}	10^{33}	2×10^{32}
	$[10^{-1}]$	$[4 \times 10^{-2}]$	$[4 \times 10^{-3}]$
1 AGeV	2×10^{32}	10^{31}	2×10^{30}
C	$[3 \times 10^{-2}]$	$[3 \times 10^{-3}]$	$[2 \times 10^{-4}]$
6 AGeV	6×10^{32}	10^{32}	3×10^{31}
	$[10^{-1}]$	$[4 \times 10^{-2}]$	$[4 \times 10^{-3}]$
1 AGeV	8×10^{29}	6×10^{28}	10^{28}
Ar	$[3 \times 10^{-2}]$	$[4 \times 10^{-3}]$	$[3 \times 10^{-4}]$
6 AGeV	2×10^{30}	6×10^{29}	2×10^{29}
	$[6 \times 10^{-2}]$	$[4 \times 10^{-2}]$	$[5 \times 10^{-3}]$

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