SIMION simulations for microchannel plate detectors

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Introduction

To understand the reaction dynamics, it is required to measure the energy, velocity and scattering angle of reaction products to characterize a nuclear reaction. For identification of the particles produced in a nuclear reaction, a detector system with good energy, timing and position resolutions is required. The Z value (atomic number) of the reaction products can be identified by using ΔE-E detector, while mass identification can be performed by time-of-flight (ToF) measurements. To obtain the ToF information of the reaction products, microchannel plate (MCP) detectors are the best suited due to their fast timing response. Timing resolution as good as ∼100 ps can be obtained. In the low-energy domain, ToF of the particle can be used to extract the mass information using the expression

$$M = 2ET^2/d^2 \quad (1)$$

where M is the mass number of the nucleus, E is the energy of the nucleus, T is ToF and d is the flight path. The mass resolution ($\Delta M/M$) is related to time resolution ($\Delta T/T$) (if uncertainty in d is ignored) as

$$\Delta M/M = \sqrt{(2\Delta T/T)^2 + (\Delta E/E)^2} \quad (2)$$

Hence, continuous efforts are there to develop ToF set-ups with detectors having excellent timing resolution.

ToF set-ups based on MCPs are being used routinely in various labs worldwide for different types of nuclear physics experiments [1–3]. A ToF spectrometer, CORSET, consisting of two ToF arms based on MCP detectors, was developed at JINR, Dubna, to identify the nuclear reaction products [1]. The timing resolution for this ToF set-up was reported to be 150 ps. A transmission-type MCP detector system is being developed based on the principle of secondary electron emission for the transfer reaction measurements in the General Purpose Scattering Chamber (GPSC), Inter University Accelerator Centre (IUAC), New Delhi. This requires designing and fabrication of an electrostatic mirror [4] for focusing the secondary electrons on the MCP. Theoretical simulations were carried out using the SIMION code [5] to optimize the trajectories of secondary electrons.

SIMION simulations

When reaction products pass through the carbon foil, the secondary electrons are emitted. SIMION simulations are performed to obtain the timing and trajectory information of the secondary electrons when they reach MCP. The trajectories of the simulated electrons are shown in figure 1a for ten thousand electrons. The electrons are accelerated from carbon foil (at -2.5 kV) towards the electrostatic grid, which is kept at ground potential. Inside the grid, electrons move in a constant field. When electrons come out of the grid, they are repelled by the electrostatic mirror (at -3 kV) and are deflected by 90° towards the MCP. The point of emission of electrons was taken randomly, and only one electron was emitted perpendicular to the foil from a particular point. The initial electron beam emitted from the carbon foil was taken as emerging in a circular form having a diameter of 10 mm. The kinetic energy (KE) of the electrons was taken as a single value of 0.1 eV. The ToF and position spectra of electrons when they reach MCP are shown in figure 1b and 1c, respec-

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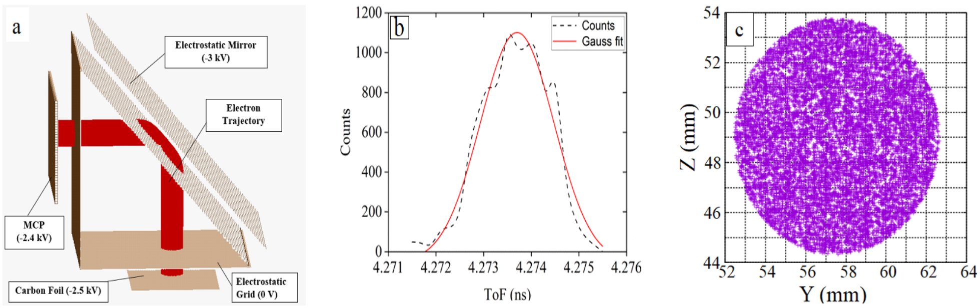

FIG. 1: a) Three-dimensional view of set-up, b) ToF spectrum, c) position spectrum for ten thousand electrons when they reach MCP.

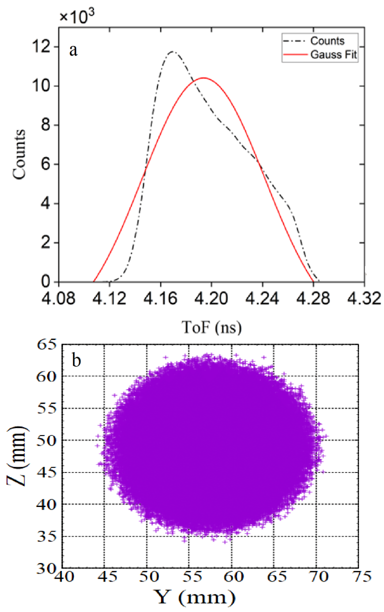

FIG. 2: a) ToF and b) position spectrum for one lakh electrons when they reach MCP.

tively. Negligible time and position spread were observed. Further simulations were performed by varying parameters such as applied potentials and relative position of the emissive foil w.r.t. MCP position. The number of electrons emitted per ion; the angle at which the electrons are emitted at a particular point of the foil, distribution of the kinetic energy of the emitted electrons were also varied. In one such simulation, the number of the emitted electrons from each point was assumed to be 25 in the conic distribution having a half angle of 45°. The KE was taken as the Gaussian distribution having mean = 30 eV and FWHM = 10 eV. One lakh electrons were simulated, and the corresponding timing and position spectra are shown in figure 2a and 2b, respectively. The position and ToF spectra of this simulation were drastically different from the earlier one. The timing resolution was found to be around $\sim$ 110 ps. There was a significant spread in the position of the electrons when they reached the MCP. Further simulations are being performed to optimize the design for the best possible detection efficiency, timing and position resolution. The detailed design of the set-up and simulation results will be presented.

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