THE POTENTIALITIES OF H^- BEAM DIAGNOSTICS BY DETACHED PARTICLES

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Abstract

A comparative analysis of proposed methods of H^- beam diagnostics by secondary particles, which are produced from the detachment of a part of the ions in thin probing particle or photon targets, is presented. The estimate of the measurement accuracies for various beam parameters and used targets is made. As shown, using a photon target, wider potentialities of nonperturbative beam diagnostics can be achieved from the viewpoint of accuracies and the spectrum of compact diagnostic apparatus.

1. INTRODUCTION

For measuring the profile and phase-structure of ion beams, the emission of electrons from a probing particle target, is broadly used [1-4]. Using some analogous devices separated by a drift distance allows one to measure the transverse [5] and longitudinal [6] emittances of a beam. Broader potentialities of the diagnostics by means of one measuring device are opened up for negative ion beams, in particular H^-. Due to the atomic structure of these particles, it is possible to fulfil the conditions when the flux of electrons and neutral atoms, which are produced on a thin target probing the beam, follows the ion distribution in the $(Y_i^{'}, Y_i)$- transverse and $(\Delta p/p, \varphi)$- longitudinal phase-spaces with a high accuracy. Using these particles as a transmitter of information on beam parameters, it is possible to realize the beam diagnostics by means of the corresponding measurements on the flux of the noted particles beyond the beam limits [7-13]. In this paper we consider the physics limits, which determine maximum accuracies of this diagnostics with reference to H^--ion beam with various energy.

2. H^o-ATOM AND ELECTRON PERTURBATIONS IN THE H^--ION DETACHMENT

Maximum accuracies of the coincidence of the H^- ion, H^o atom and electron distributions in a beam at angle $(\Delta\theta_{o,e})$ and relative energy ($\Delta E_{o,e}/E_{o,e}$, where $E_e = E \cdot m_e/M$, $E_o = E$, m_e is the electron mass, M and E are the mass and energy of H^- ion) are determined by the value and nature of the perturbation that the atoms and electrons get in elementary acts of their creation as a result of ion detachment, and depend on the type of the used probing target. A comparative analysis of these accuracies can be realized by means of the experimental [14-23] and theoretical [24-28] dependences for electrons and H^o atoms presented respectively in figs. 1 and 2. The half-amplitude widths of the corresponding distributions

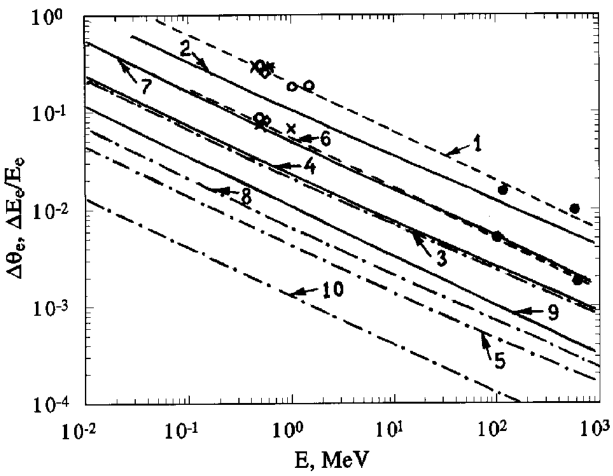

Figure 1: The maximum accuracies of the coincidence of the H^- ion and electron distributions at relative energy ($\Delta E_o/E_o$, 1-5 curves) and angle ($\Delta\theta_o$, 6-10) for different particle (1,6 - $\diamond$ $Kr[14]$, $*$ $Ne, CH_3Cl[15]$, $\circ$ $He[15,16,18]$, $\times$ $Ar[17,19]$, $\bullet$ $C[24]$) and photon ($\lambda = 10600\AA$ - 2,3,7,8; $\lambda = 16300\AA$ - 4,5,9,10 [26-28]) targets versus ion energy.

of the noted particles during their creation are shown for particle targets. The distributions measured in refs.[14-19] are used for electrons. The experimental results for hydrogen atoms (dependence 1 in fig.2) are obtained by means of ribbon-type beams of H^- ions [20] and taking into account the influence of the geometry of the experiment on its result [29]. For comparison fig.2 also present the results of refs.[20] (segment a-c), [21] (curve 2), [22] ($\star$) and [23] ($\times, \diamond$) obtained in uncorrect analisis of the experimental material. In case of a photon target, the theoretical values of maximum angular and energy spreads for electrons and H^o atoms, that are created at the single-photon detachment of H^- ions, are shown by the solid curves [26-28]. The dash-dotted lines correspond to the half-amplitude widths for the same photon energy, but at the optimum direction of the momentum and polarization plane of the photon. The polarization in the plane of photon-ion interaction and mutual perpendicularity of their momenta, are optimum for the angular measurements. On the contrary, for the energy (momentum) distributions the polarization must be perpendicular to the interaction plane. The experimental results of ref.[23] for photon target, which polarization is perpendicular ($\times$) or parallel ($\diamond$) to the interaction plane, are obtained by means of the method of ref.[20] and correspond to the half-amplitude widths of the angular distributions of H^o atoms.

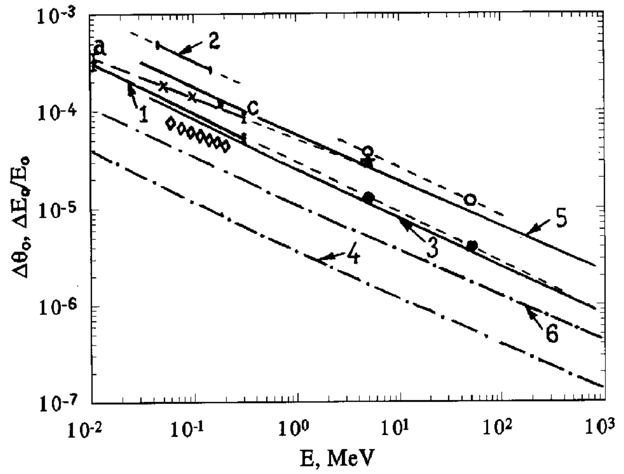

Figure 2: The maximum accuracies of the coincidence of the H^- ion and H^o atom distributions at angle ($\Delta\theta_o \rightarrow 1, 2, \star, \times, \diamond$ - exp.; $\bullet$,3,4 - theor.) and relative energy ($\Delta E_o/E_o \rightarrow$ $\circ$,5,6 - theor.) for different particle (1 - $He, Ar, H_2, N_2, CO_2, Kr, Xe$; $\star$ $-$ $K[22]$; 2 $-$ $H_2[21]$; $\bullet, \circ$ $-$ $C, Ar, Ne, He[25]$) and photon ($\lambda = 10600\AA \rightarrow \times, \diamond[23], 3-6[28]$) targets versus ion energy.

As the dependences presented in figs. 1 and 2 show, the type of particle target practically unaffects the maximum accuracy of the coincidence of the ion and secondary particle (H^o, e) distributions. In this connection, for diagnostic purposed one can use the most suitable, from the view point of target formation, gas chamber, type of gas or foil. A significant improvement of the accuracies of the distribution coincidence can be achieved by converting to photons. At an optimum target polarization the reached accuracies are estimated by the expressions [26-28]

$$\Delta\theta_e = \frac{M_{H-}}{m_e} \cdot \Delta\theta_o \approx \frac{0.25}{\gamma\beta}\sqrt{\frac{2(\omega - \varepsilon_t)}{m_e C^2}}, \ \ \eta = \pi/2; \ (1)$$

$$\Delta E_e/E_e = \frac{M_{H-}}{m_e} \cdot \Delta E_o/E_o \approx \frac{0.4\beta\gamma}{\gamma - 1}\sqrt{\frac{2(\omega - \varepsilon_t)}{m_e C^2}}; \ (2)$$

where β and γ are relativistic beam parameters, $\omega = \omega_o\gamma(1 - \beta \cdot cos\eta)$, ω_o is the photon energy in the laboratory frame, η is the angle between the ion and photon momenta, C is the speed of light, ε_t= 0.754 eV is the photodetachment threshold of the H^- ion. For measuring the ion distributions in a certain $(Y_i^{'}, Y_i)$- phase space, where Y_i is perpendicular to the interaction plane, expression (1) is correct for $\Delta Y_i^{'}$ at any angle η.

High monochromaticy and orientation of laser radiation, relative simplicity of its space control allow one to exploit the Doppler-effect efficiently for the realization of the distribution coincidence with a maximum accuracy on high energy beams, and also to form photon targets with small sizes in space-time and to develop compact multifunctional devices. Compactness of these devices is achieved by using the photoelectrons produced as a result of near-threshold photodetachment of H^- ions or intermediate H^o atoms, at the final stage of beam information readout [10,13].

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