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THE POSSIBILITY OF USING STORAGE RINGS WITH INTERNAL THIN TARGETS

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Storage rings, apart from the colliding-beam experiments, give some unique possibilities for operation with thin internal targets. When one operates with an extracted beam, the choice of the target thickness is a compromise between two contradictory requirements; namely, increase of the reaction total yield and necessity of a high energy resolution. In the storage ring these requirements reconcile naturally. The target thickness may be chosen as small as necessary for a single passage of the particles through the target, but the effective thickness (real thickness multiplied by number of revolutions) is nearly the same as for commonly used targets, and in many cases even much larger. The particles energy losses in the period between two successive passages of the target are compensated by r.f. cavity, and accumulated angular and energy spreads may be stabilized by damping effects (radiation for electrons, artificial beam-"cooling" for protons.[1]

Let us consider the storage-ring operation regime when the losses of particles are determined by processes of their interaction with the target. The beam life-time τ (it is convenient to consider dimensionless time in terms of the periods of revolution) is determined by the cross-sections of the processes δ_i and by the target thickness n_o (number of particles per cm^2)

$$\tau^{-1} = n_o \Sigma \delta_i = \Sigma \tau_i^{-1}$$

The quantity $n_{eff} = n_o \tau$ does not depend explicitly on n_o and is determined by the total cross-section of all processes which result in particle losses: $n_{eff} = (\Sigma \delta_i)^{-1}$.

It is useful to distinguish "single" processes from multiple ones. The latter's influence, being accumulated for many revolutions, results in time-linear increase of the mean squares of corresponding parameters (amplitude of oscillation): $< a_i^2 > = \alpha_i t$. The rising time of $< a_i^2 >$ up to maximum admissible value $\tau_i = (\max a_i)^2/\alpha_i$ determines the beam lifetime connected with a given process. The influence of the "single" processes is different, in principle. They result only in single particle losses but, on the contrary to "multiple" processes, do not influence essentially other beam parameters; namely, angular and energy spreads, transverse beam size. These important parameters may be essentially improved in the "super-thin target" regime when the "multiple" processes are suppressed by damping effects.

Let τ_{di} be the damping time of oscillations a_i. Decreasing the target thickness n_o, one may have lifetime τ to be greater than τ_{di}. In this case, the damping effects limit the rise of amplitude a_i at the equilibrium value $a_i^\circ = <\alpha_i \tau_{di}>^{1/2} < \max a_i$. The effective beam thickness n_{eff} increases by jump in this case because the corresponding "multiple" process (δ_i) ceases to work.

The "super-thin target" regime was investigated in part on the electron storage ring VEP-1 at our Institute in the process of preparation for the operation with the colliding beams. The experimental results (n_{eff} value, stable beam parameters) are in good agreement with the calculations.[2]

For investigation of the transition from the "thin target" regime to the "super-thin target" regime special experiments were performed.[3] Aluminium foils of various thicknesses (thin target) as well as a quartz filament of 1μ thickness (nearly a super-thin target at 135 MeV) were used. At the given target thickness the dependence of the effective thickness on radial aperture was measured. The quantity n_{eff} was characterized by the bremsstrahlung intensity. The bremsstrahlung quanta with the energy of $(0.96 \pm 0.003)E_o$ were selected by coincidence with recoiled electrons of the corresponding energy (E_o-primary electron energy). The electrons were detected by a counter located inside a uniform magnetic field of the storage ring (Fig. 1) so that the 1800-focusing took place[4] (the so-called monochromatic γ-quanta). The calculated curves as well as experimental results for the aluminium and quartz targets are shown in Fig. 2. The straight line I with $n_{eff} \simeq 0.05$ r.l. is for super-thin target. The parabolic curve II is for the thin target (corrections were made on uncompensated energy losses). The transition to the "super-thin target" regime for the quartz target is obvious.

In conclusion we summarize the possibilities and the advantages of the storage rings with the internal target:

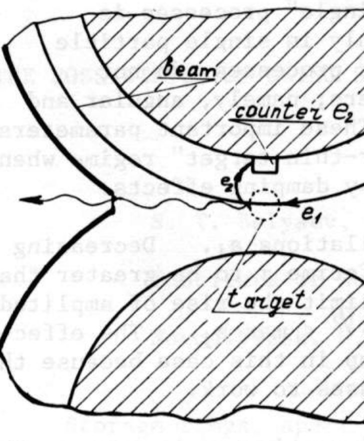

Figure 1

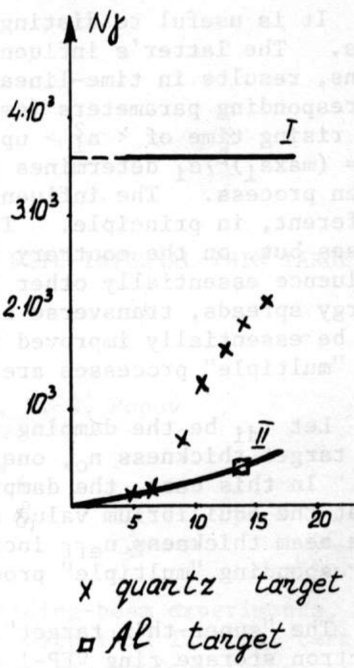

Figure 2

i) The target thickness may be decreased without decrease of the reaction total yield.

Let us consider an example (with the synchrotron B3-M (5) as the injector into the storage ring). The number of injected particles is 2.10^{11} per puls; repetition rate — 5 cps at the energy of 100-500 MeV. In this energy range $n_{eff} \approx 0.2$ r.l. (10^{22} cm^{-2} for Al). The luminosity is of 10^{34} sec^{-1} cm^{-2} at the stable energy spread of 50-150 KeV (the energy resolution is $3\div5.10^{-4}$). The best competitor to the storage ring seems to be a high-current linac. If the average current is of 10 μA, and the energy spread is of the order of 1% (it corresponds to the target thickness of 10^{-2} r.l.) then the luminosity is equal to 3.10^{34} sec^{-1} cm^{-2}. A higher energy resolution demands the decrease of the luminosity. At the energy resolution of 3.10^{-3} the luminosity will be 10^3 times lower.

ii) The advantages for the reactions with particles production near threshold are obvious (for example, pions electroproduction).

iii) For several experiments the advantage of the storage rings is their continuous operation. The intensity of monochromatic quanta for a linac is limited by its repetition rate (50-500 cps) because the electronic equipment practically may detect not more than several tens of recoiled electrons per pulse of 1 μsec duration. On the storage rings (multi-channel modification of the experiment shown in Fig. 2) practically all electrons may be converted into polarized monochromatic quanta.

iv) The storage rings give the possibility, in principle, for experiments with unique primary particles (polarized electrons and positrons[6], antiprotons) as well as with unique targets (polarized gas target, electrons, neutron beams and so on). The possible high energy resolution makes experiments on the proton storage rings with various nuclear targets to be of interest (for example, the missing-mass experiments at 2-3 GeV, accompanied by hyper-nuclei production.

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