SEPARATED ANTIDEUTERON BEAM AT IHEP ACCELERATOR

V.V.Vasiliev, N.A.Galyaev, K.I.Gubrienko, V.N.Zapol'sky, V.G.Zarucheysky, V.I.Kotov, V.N.Lyamin, V.A.Maisheev, V.P.Sakharov, Yu.M.Sapunov, B.A.Serebryakov, B.V.Prosin, Yu.S.Khodyrev, S.A.Chernyj

IHEP, Serpukhov, USSR

V.Vrba, B.V.Batyunya, I.V.Boguslavsky, I.M.Gramenitsky, Yu.D.Zernin, R.Lednitsky, V.A.Kuznetsov

JINR, Dubna, USSR

S.V.Livanyan

FIAS, Moscow, USSR

I.R.Yampol'sky

Kurchatov's IAE, Moscow, USSR

ABSTRACT

The principle of a method of separation of antideuterons is discussed in this article. The first results on pure antideuteron beam with momentum 12.2 GeV/c for the "Lyudmila" bubble chamber are presented. The intensity of 63 GeV primary proton beam is equal to 10^{12} per cycle, the mean quantity of $\bar{d} \sim 0.7$ per frame with hadronic background $\sim 30\%$.

RF separators have widely been used to get pure beams of pions, kaons, antiprotons and deuterons for bubble chambers [1-6]. Below we discuss the problem of using RF separators to select antideuterons.

This problem is complicated by a rather low yield of antideuterons, which makes up about 10^{-6} of the number of pions [7]. To make the conditions of the experiment on the bubble chamber close to the standard ones, at least one antideuteron per frame should be provided in the beam. The hadronic background in this should not be higher than some tens of one percent.

In a usual Panofsky-Montague-Schnell separator the suppression factor for the unwanted particles is not more than 10^4 [1,3,4]. It is explained by the "halo" accompanying the beam, which cannot be suppressed with the given separation procedure. When separating antideuterons with the quoted procedure the flux of the background particles will be not less than two orders higher than the antideuteron one.

The special two-stage beam separator (see fig. 1a) may be used in order to suppress unwanted particles more effectively. In the first stage a usual two-cavity separator is used. The RF phase difference between the cavities RF1 and RF1' is set so that the resulting

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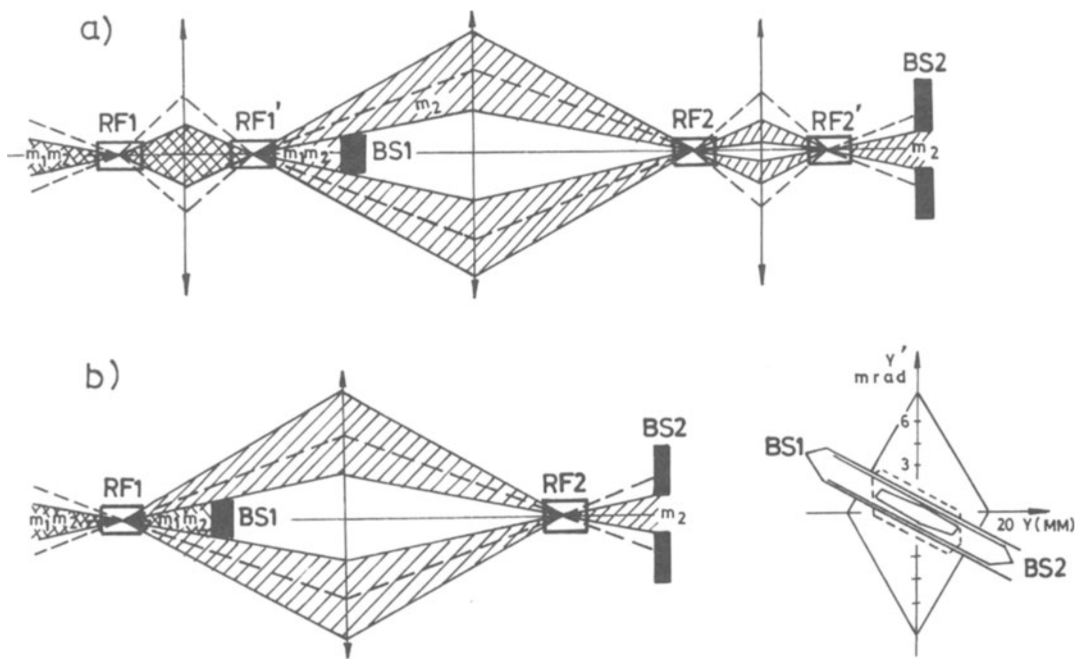

Fig. 1. a) General layout of two-stage RF separator.
b) Two-stage RF separator for low energy particles. Dotted line corresponds to the trajectories of unwanted particles m_1. Phase space diagram corresponds to the centre of the first deflector in the separation plane. The figure in the centre of the diagram defines the undeflected beam. Dotted line limits the phase space of wanted particles m_2 with RF1 on.

transverse momentum for unwanted particles m_1 would be equal to zero, and wanted particles m_2 would be additionally deflected in the deflector RF1'. If the deflection is big enough the part of m_2 particles would pass missing the beam stopper BS1, placed on the beam axis. The main particle flux m_1 will be intercepted in the beam stopper, but the "halo" can pass missing it and cause the background. The "halo" is suppressed in the second stage, which is similar to the first one, but the beam stopper is replaced with a collimator BS2. Both stages are fed by a common RF signal source. The RF phase difference between the first and second stages is equal to 180°. In this case the deflection of wanted particles at output of the second stage is cancelled and they will pass through the slit of the collimator BS2, and the "halo" remains undeflected as with the first stage and will be intercepted in the collimator BS2.

The angular dimensions δ_{BS1} of the beam stopper as well as those of the collimator BS2 when total absorption of unwanted particles is provided, are defined in a general case by the relation

$$\delta_{BS1} = \delta_V + D_a$$
$$\delta_{BS2} = \delta_V \, , \qquad (1)$$

where δ_V is the angular dimension of the undeflected beam, D_a is the angular deflection of unwanted particles at the output of the first stage.

For separation of (8-15) GeV/c antideuterons one may use one cavity in each stage [6].

The problem was realized in the beam channel[8] that produces secondary beams for the "Lyudmila" bubble chamber. The layout of the equipment and the beam optics are shown in fig. 2. Antideuterons were separated with two cavities RF1 and RF2 of the separator installed in the beam[9], the main deflector parameters are listed in Table 1.

To get a pure antideuteron beam one should suppress three kinds of unwanted particles, i.e. pions, kaons, antiprotons. The calculated momentum-dependent angular deflections of particles at the deflector output are given in fig. 3a. The minimal deflection was realized for the most intense particles, i.e. for pions. Antiproton angular deflection, which is the largest for unwanted particles, determined the choice of the beam stopper (BS1) thickness from relation (1).

The calculated values for the transmission factor (the ratio between the number of wanted particles at the output and input of the separator) for the beam with $\delta_V = 0.7$ mrad and particle spread $\Delta p/p = \pm 1\%$ are given in fig. 3b. From the figure it follows that the resulting transmission factor η_Σ is about 0.4 in the (9-13) GeV/c momentum range and is rather close to those of a standard separation scheme. To provide the bubble chamber with the required antideuteron flux one should have a flux of secondaries $\sim 10^7$ per cycle in the beam channel. When the level of intensity is so high, the background problem becomes

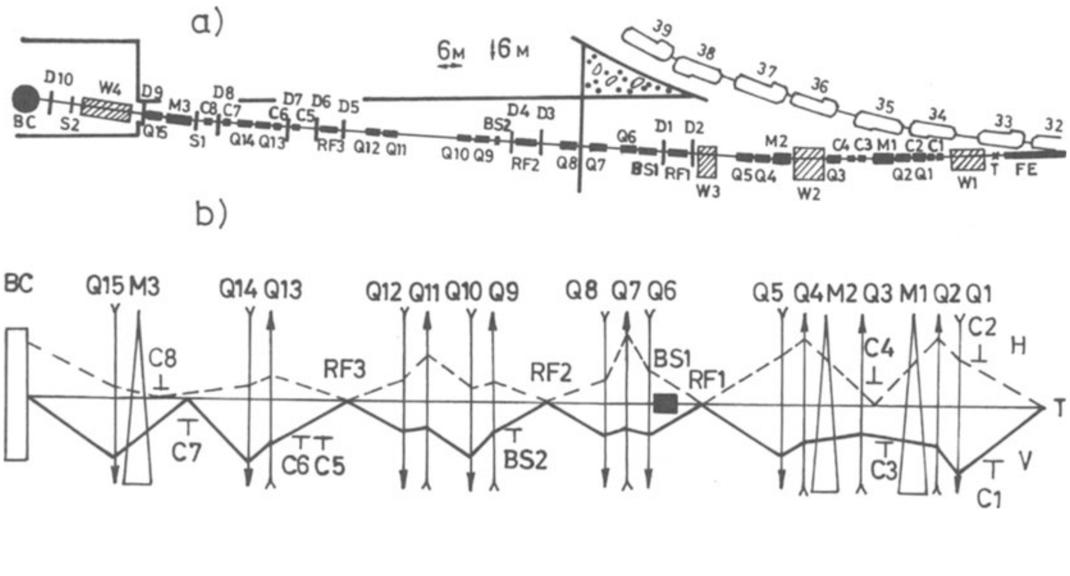

Fig. 2. a) General layout of the beam transport system.
b) Beam optics of the channel. T - target, C - collimators, Q - quadrupoles, M - magnets, RF - deflectors, BS - beam stoppers, BC - "Lyudmila" bubble chamber.

Table 1

Main parameters of RF separator cavity

1. Working frequency in vacuum at 32° C (MHz)	2795
2. Phase shift per cell	$\pi/2$
3. Voltage attenuation (Np/m)	0.084
4. Power with feedback (MW)	30
5. Maximum transverse momentum given to particle (MeV/c)	30.7
6. RF pulse duration (μsec)	5
7. Aperture, 2a (mm)	46
8. Length (m)	4

essential. To reduce the background we optimized the passing of the proton beam which did not interact with the target. This was done at the beginning of the beam channel with the help of two double-coordinate detectors of secondary emission, installed at the entrance to the beam channel and in front of the proton beam stopper W_2. Having measured the fluxes of background particles we put additional shielding W_3 and improved the shielding W_4 before the bubble chamber to suppress soft diffuse background.

The beam channel was tuned by means of ten wire proportional chambers D_{1-10}. The information from these chambers was fed into the TPA-1001/1 computer and then displayed on a VDU[10]. In the operating conditions the proportional chambers were withdrawn from the

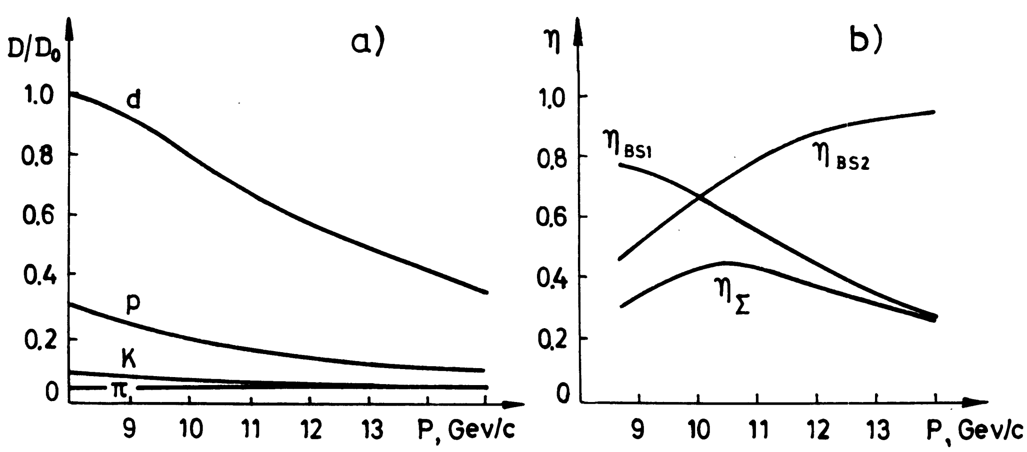

Fig. 3. a) Normalized particle deflection at the output of the deflector as a function of momentum.
b) Calculated beam stopper transmission.

beam channel aperture to avoid beam scattering. The beam parameters were monitored by scintillation profilometer consisting of three finger counters, installed in front of the beam stopper BS1.

The RF phase difference between the cavities was chosen by the following procedure. Since antiprotons have some deflection (see fig. 3a) they may be separated by reducing the thickness of the beam stopper BS1. Then varying the RF phase difference between the deflectors, one can find the phase corresponding to the maximum antiproton flux on the scintillation counter S_2, installed at the entrance to the bubble chamber. The beam stopper thickness may be reduced in such a way, that the antiproton intensity peak might be distinguished at increasing flux of background particles. The transition to antideuteron separation foresees the installation of the beam stoppers of the designed thickness and an increase of RF phase difference by the value determined by the relation

$$r = \frac{2\pi L}{\lambda}\left[\sqrt{1+\left(\frac{E_{02}}{pc}\right)^2} - \sqrt{1+\left(\frac{E_{01}}{pc}\right)^2}\right], \qquad (2)$$

where E_{01}, E_{02} are the rest energies of antiprotons and antideuterons, respectively, and L is the interdeflector distance. A more precise phase difference can be chosen by the results of processing the test pictures, fig. 4. A corrected phase difference plus relation (2) makes it possible to find a more precise value of the particle momentum. A similar procedure was carried out for deuteron separation, fig. 4.

Table 2 gives the results on separation of deuteron and antideuteron beams.

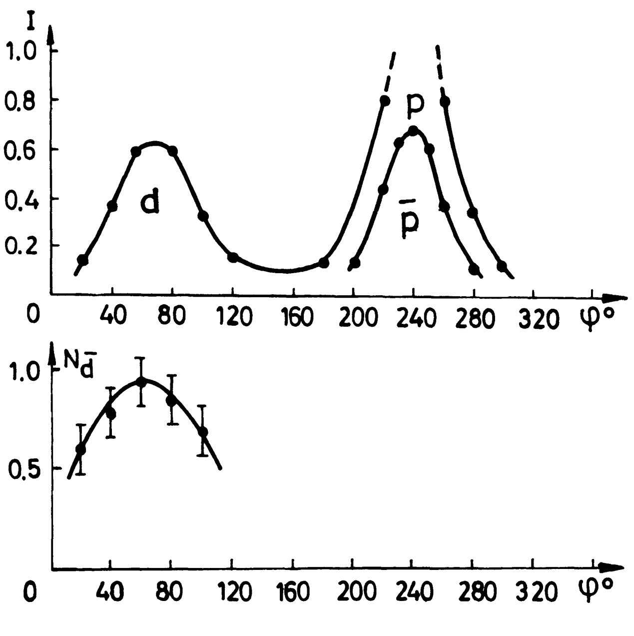

Fig. 4. The fluxes of deuterons and protons, antideuterons and antiprotons in front of the bubble chamber depending on phase difference between RF1 and RF2. (Deuteron flux normalized on proton intensity.)

Table 2

Results of d and $\bar{d}$ separation

Kinds of Particles	d	$\bar{d}$
1. Proton beam energy, GeV	63	63
2. Target (Fe), mm	2x1.5x80	2x1.5x80
3. Proton intensity on the target	6×10^{10}	10^{12}
4. Production angle	0°	0°
5. Solid angle, μster	18	18
6. Secondary particle momentum, GeV/c	12.2	12.2
7. Relative momentum bite, $\Delta p/p$, %	±0.25	±1
8. Number of wanted particles per cycle	3.2 ± 0.2	0.7 ± 0.1
9. Hadronic background, particle per cycle	0.06	0.2
10. Muonic background, particle per cycle	0.8	3.0

With this antideuteron beam one can carry out a number of physical investigations of reactions ($\bar{d}$p) and (d$\bar{d}$). At present about 100 thousand frames have been obtained in the "Lyudmila" bubble chamber exposed in the antideuteron beam.

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