ION-OPTICS OF ANTIPROTON SEPARATOR AT FAIR

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Abstract

In the framework of antiproton program at FAIR project [1], the large acceptance Antiproton Separator (AS) [2] is dedicated for the effective separation of the secondary antiprotons from the primary protons and the secondary beams of other particle species and subsequent transportation to the Collector Ring (CR) [3]. Here we present the latest ion-optical layout of the antiproton separator and possible second-order correction scheme.

Collimation

High energy antiprotons (3 GeV) will be produced by inelastic collision of 29 GeV proton beam ($2 \cdot 10^{13}$ particles within 50 ns bunch and a repetition rate of 5-10 s) with the thick 110 mm nickel-iridium target, subsequently focused in the magnetic horn lens and then transported to the Antiproton Separator, which is illustrated in Fig. 4. About 50-60% of the primary protons will undergo a reaction in the production target. The other part of the proton beam will be dumped in the target hall after separation in the first 15^0 dipole magnet.

The AS is designed to operate with a maximum magnetic rigidity of 13 Tm and to have ±3% momentum acceptance. The transverse acceptance is 240 mm mrad in both planes. The beam envelope is presented in Fig. 1. The distribution of the antiprotons after the horn (295124 particles) has been calculated with the MARS code using 10^9 protons at the target [4, 5].

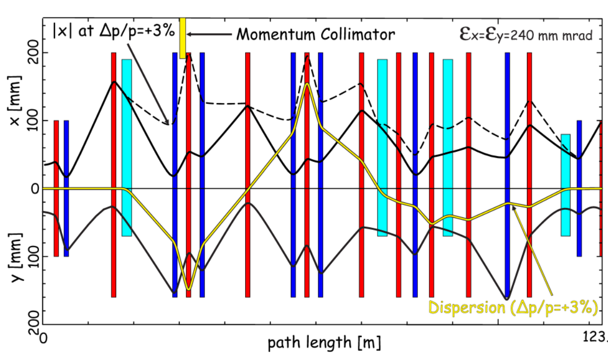

Figure 1: The calculated beam envelope in horizontal (upper part) and vertical (lower part) directions of the AS starting after the horn and till the CR symmetry point. The dispersion (yellow curve) is shown for a momentum deviation of +3%. Dashed black curve represents the horizontal envelope with the dispersion influence. Dipole, horizontal and vertical focusing quadrupole apertures are shown by cyan, red and blue boxes respectively. The position of the momentum collimator is indicated by the yellow box.

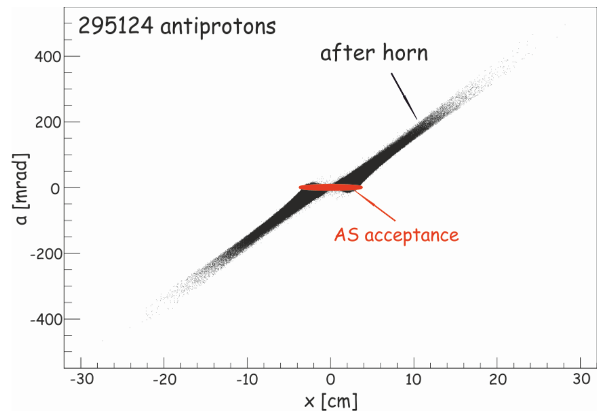

Figure 2: Horizontal phase space of antiprotons after the horn lens (black distribution) and the AS acceptance (red ellipse).

It is symmetrical in both transverse directions and is much large than the separator acceptance, as can be seen in Fig. 2. In order to protect the separator from the shower of unwanted antiprotons and other secondary species coming from the target, the fixed 1.6 m cylindrical collimator with the radius of 3.5 cm is proposed to install at a distance of 0.5 m after the horn lens (H/V-Col. in Fig. 4). To estimate the transmission

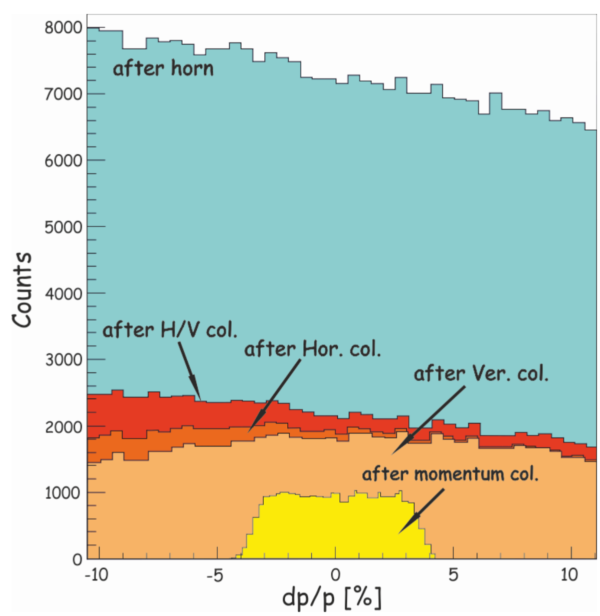

Figure 3: Momentum distribution of antiprotons after horn lens (blue), cylindrical collimator (red), horizontal and vertical collimators (two orange distributions) and after desired momentum collimation (yellow). The aperture of momentum collimator is 200 mm.

of antiprotons to the CR and their phase space evolution,

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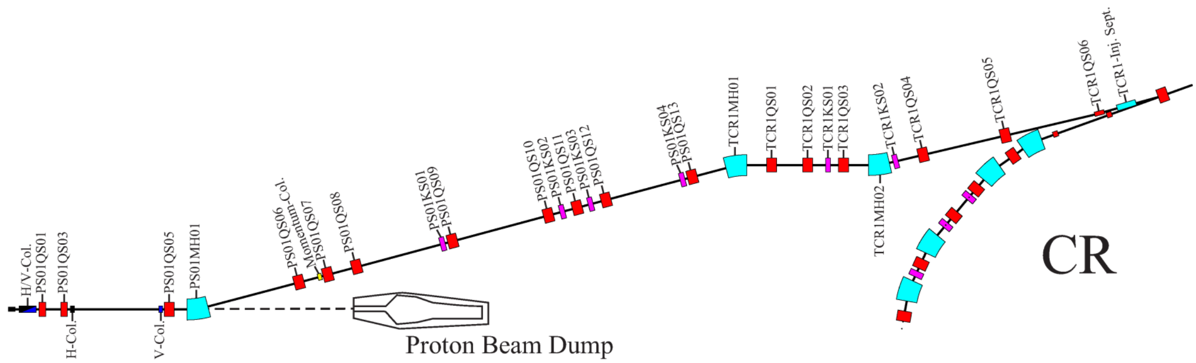

Figure 4: Layout of the antiproton separator with part of the CR.

the dedicated Monte-Carlo simulation has been performed with the MOCADI code [6]. In this program an ion-optical system can be described by up to fifth-order transfer matrices which have been calculated with the GICOSY code [7]. About 73% of all injected antiprotons will be cut in the first collimator. The further transverse collimation will be done within 2 additional (1 horizontal and 1 vertical) collimators with movable apertures installed in the first straight section of the AS (see H-Col. and V-Col. in Fig. 4). The result of these collimations is shown in Fig. 5. In addition, one horizontal collimator with movable aperture (Momentum-Col. in Fig. 4) will be installed in the place with the maximum dispersion (see Fig. 1), in order to cut particles with the momentum larger ±3% and therefore match the momentum acceptance of the CR, as can be seen in Fig. 3. After all

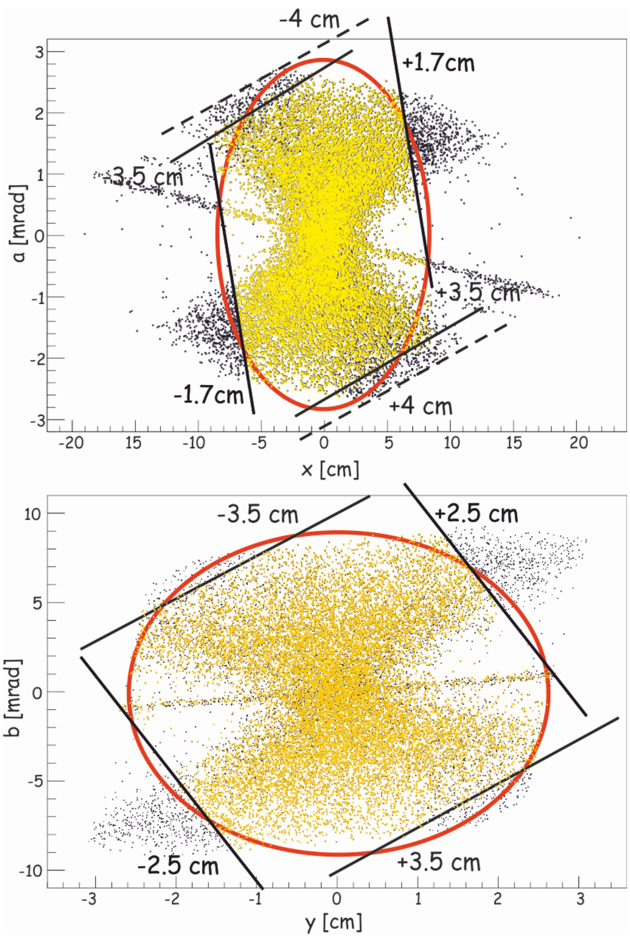

Figure 5: Horizontal (upper picture) and vertical (lower picture) phase space of antiprotons at the symmetry point of the CR. The CR acceptance is marked by red ellipse. The desired collimation of the phase space is shown by the yellow distribution whereas antiprotons cut by only the first collimator with radius of 4 cm are shown by the black distribution.

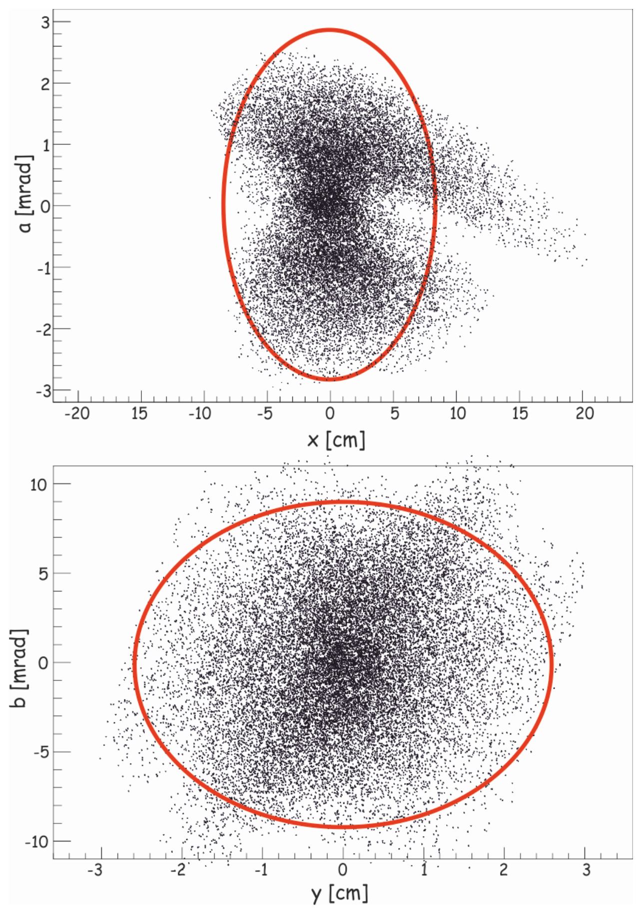

Figure 6: Horizontal (upper picture) and vertical (lower picture) nonlinear phase space of antiprotons at the symmetry point of the CR after the sextupole correction.

collimators only 8.3% of antiprotons (24419 particles) will reach the CR. The uncut particles, which are however out of the CR acceptance will be lost after several revolutions in the ring. In a linear approximation, only 0.3% of the particles were lost and about 8% of antiprotons (23569 particles) were stored after 100 turns.

Second-Order Correction

Due to the large momentum spread the second-order chromatic aberrations play significant role, especially in the horizontal plane. The excitation of the second-order dispersion and a strong deformation of the transverse phase space will lead to the ion-optical mismatch between the AS-CR system and correspondingly to the additional losses, which mostly occur during circulation in the ring. Around $1.5 \cdot 10^4$ particles will survive after 100 turns, which is about 30% losses of initial 24419 antiprotons injected in the CR.

There are 10 (4 horizontal, 4 vertical) nonzero second-order chromatic aberrations at the end of the AS. Due to the relatively small dispersion in the AS (the maximum is about 5 m, see Fig. 1), the strengths of sextupoles used for their correction would be so strong, that excite high-order aberrations and the correction would be useless. However, there are only 6 sextupoles are foreseen to be installed in the AS, and all 10 second-order chromatic aberrations cannot be minimized separately but one can try to compensate their common effect. In our approach we have minimized with 5 sextupoles the aggregate contribution from two horizontal angular chromatic aberrations and minimized the second-order angular dispersion keeping the second-order dispersion, vertical and remaining horizontal chromatic aberrations uncorrected. It allowed us to have quite week sextupoles strengths and to not excite strongly higher orders. After correction 17529 antiprotons survived after 100 turns in the CR, which is about 25% losses. Therefore, $1.75 \cdot 10^{-5}$ antiprotons per incident proton (antiproton rate) are expected in the CR, that agrees quite well with the result calculated by another programs [2].

The phase space at the symmetry point of the CR after the sextupole correction can be seen in Fig. 6. The tails in the horizontal plane obviously correspond to the excited geometric aberrations. They could be corrected with special sextupoles installed in the dispersion free regions, but the necessity of such correction and the further sextupole correction scheme is under investigation.

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