Design Status of the Antiproton Polarizer Ring

A. Garishvili[a,b], A. Lehrach[a], B. Lorentz[a], S. Martin[a], and F. Rathmann[a]

At the core of the PAX proposal [1] is to polarize antiprotons by spin filtering of stored antiproton beam via multiple passage through an internal polarized storage cell hydrogen target. A storage ring is ideal to efficiently achieve a high degree of beam polarization. Therefore, PAX collaboration aims to build a dedicated Antiproton Polarizer Ring (APR).

In this report the preliminary result on the lattice design study for such type of ring is presented. In fig. 1 a floor plan of the suggested APR is shown, for preparation of which the computer code WinAgile [2] has been used. Following the known requests [1], 4 straight sections are required for the insertions: (a) injection and extraction of the antiproton beam, (b) a low β–section for the gas target, (c) the opposite section reserved for the Siberian snake (to longitudinally align the antiproton spin), and (d) electron cooling in the straight section opposite to the injection. Various ion optical conditions have to be met in the four straight sections: (*i*) in the target, e–cooler, and Siberian snake sections the beam cross section has to be circular and the beams phase space ellipse has to be upright, (*ii*) in all straight sections the dispersion should be zero, (*iii*) the antiproton beam in the e–cooling should be parallel and variable in order to match the size of the electron beam, (*iv*) and the radius of the beam spot at the target should be around 10 mm.

As a first exploration, the following main parameters has been choosen: beam energy - 250 MeV, beam emittance - 250 π mm mrad, and magnetic rigidity - 2.4 Tm. The quadrupole arrangements in the straight sections enable tuning of the beam within a wide choice of optical conditions. Total circumference of the APR is 86.5 m, with each of the four straight sections of about 12 m long. In addition, APR contains two symmetrical arcs and length of each arc is about 19 m. In the current design of the APR, 46 quadrupole magnets has been used with length of 30 cm and 4 bending magnets with the length of 25 cm.

In the target straight section, a free space of 1 m is provided, for design of which the three and five quadrupoles cases was compared. Distribution for beta function ($\beta_{x,y}$) was calculated by equation (1) and beam radius ($R_{x,y}$) with equation (2):

$$\beta_{x,y}(s) = \beta_{x,y}(0)\left(1+\frac{s^2_{x,y}}{\beta^2_{x,y}(0)}\right) \quad (1)$$

$$R_{x,y}(s) = \sqrt{\varepsilon_{x,y}\times\beta_{x,y}(s)} \quad (2)$$

The minimum beta function for three quadrupoles case is 21 m and beam radius is 7.25 mm in the center. However, in this case we have very high spikes for beta function along the quadrupole section (dashed line in fig. 2).

For the five quadrupoles case, the beta function behavior is much flat (solid line) in the target cell region, than for three quadrupoles case. The minimum beta function is 0.31 m and beam radius is 8.8 mm in the center (fig. 2). This numbers is still acceptable for APR optics. This was a reason to choose design with five quadrupoles.

Since the antiprotons should be also longitudinally polarized [1], the ring has to contain a Siberian snake, which is located in the opposite side of the target (see fig. 1).

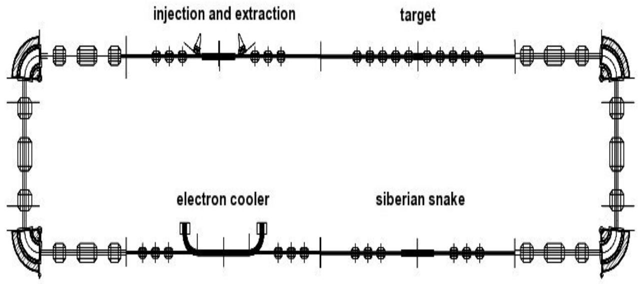

Fig. 1: Floor plan of the APR lattice.

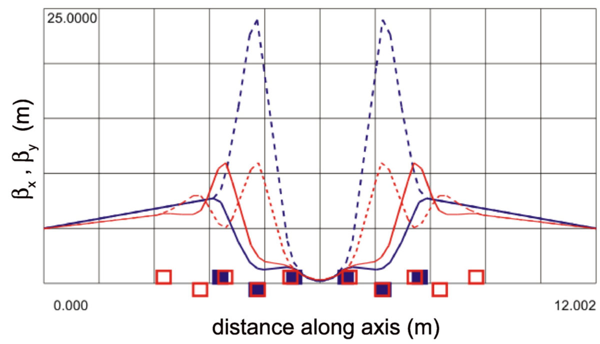

Fig. 2: Beta functions of APR (β_x - solid, β_y - dashed) along the target section. Blue and red colors corresponds to 3 and 5 quadrupole cases, respectively.

To provide longitudinally polarized beam at the position of the storage cell, integrated field strength should be roughly 2.74 Tm. This can be done with 1.1 T solenoid of 2.5 m length. The space between quadrupole triplets in this straight section is 4.1 m and it is enough for this solution. To calculate solenoid field Thomas BMT equation [4] has been used: $\chi = (1+G)/B\rho \cdot \int B\,dL$, where χ is the precession angle in solenoid, G is the anomalous magnetic moment $G = (g-2)/2$, while g is the gyromagnetic ratio.

The beam degradation, the geomatrical blow–up and the subsequent smearing of the beam energy needs to be corrected by phase–space cooling, preferably by electron cooling. For the electron cooling (located next to the Snake straight section), a free space of 6.2 m is reserved. The antiproton beam in the electron cooling section should be parallel and it's cross section should be variable in order to match the size of the electron beam.

Efficient system for injection and extraction of the antiproton beam has to be provided in the ring as well. For the injection and extraction of antiproton beam (located in the opposite side to the electron cooling section), the free space of 4.1 m is foreseen. In this straight section two septums and one kicker are placed.

Finally in the APR we have two symmetrical arcs. In each arc two bending magnet and triplet of quadrupole magnets has been used. Triplets was choosen because of: less aberrational errors, large acceptance ring requires multipole correctors, and dispersion in such design is zero by symmetry.

In more detail the other characteristics of this ring can be found in the talk [3].

References:

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[4] V. Bargmann et al., PRL, 435 (1959).

[a] IKP FZJ, Jülich, Germany
[b] HEPI TSU, Tbilisi, Georgia