BEAM-TARGET INTERACTIONS AT AmPS

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4 Conclusions

We are presently able to successfully operate a 15 mm diameter, 40 cm long storage-cell target within the ring vacuum environment. Backgrounds are manageable and a good fraction of them is removed during off-line analysis provided track reconstruction with a sufficient resolution is possible. In the future, the cell diameter might even be decreased and a parallel improvement program for $\beta$-function and emittance reduction is underway. As for denser targets the intrinsic gas lifetime contribution is expected to be considerably smaller (of the order of 80 s at $10^{16}$ He-At cm$^{-2}$), improvements are planned for the ring vacuum. More pumping capacity through NEG strips will be added and a systematic investigation of clearing mechanisms will be pursued. Also, the impact of the gas flow on the ring vacuum will be minimized by larger pumping speeds in the target region.

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collimators only at very inner positions, while the single rates produced by the beam halo are rapidly growing much earlier. Therefore, very aggressive cell diameters like 10 – 12 mm could be chosen, provided one can still operate the detector system. As the beam dimension out of the machine plane is expected to be much smaller than the one in plane, one could also, in the absence of intra-beam \( x - y \) coupling, consider elliptically shaped cells. The slits system itself, when placed in a far away section of the ring, is extremely helpful in cutting away part of the beam halo at every turn and is one of the experimental parameters by which one can tune or minimize the wall events background.

The cell diameter ultimately depends also on the type of detector and what particles one is looking for. Indeed heavy recoil detection (\( \Lambda = 4 \) or \( \Lambda = 3 \)) poses less stringent limits, as a trigger for a helium isotope is not likely to originate from a wall event. At present, for a 15 mm diameter cell with tensor-polarized deuterium we find a raw wall events rate of \( \approx 700 \) Hz/mA , which by imposing conditions on the event reconstruction and vertex, drops to a fraction of nearly 30% of the total data and can be monitored by taking data on an empty storage cell\(^5\). Of course by having a more powerful target source available, this ratio will drop down to a negligible fraction, for the same cell diameter.
lifetimes from theoretical expectations taking into account this effective target thickness along the ring, are shown for different residual gas compositions.

A possible explanation for the missing strength could be ion trapping in the beam potential of ionized residual atoms or molecules. This could create a pressure gradient in the beam pipe, such that the actual gas density at the beam spot was larger than the one measured, thus explaining the smaller lifetime. In order to compensate for such an effect, ion-clearing electrodes were installed at various ring positions and operated at a maximum voltage of 3.5 kV.

This could have been insufficient at the highest current, as at 100 mA and for a beam core of a few mm the electrical field created by the circulating current could be larger than the constant field gradient produced by the electrodes: consequently the ion-clearing mechanism was not guaranteed and the rapid beam neutralization made possible. Other major effects associated with ion trapping are the possible introduction of incoherent tune shifts, emittance growth and resonance (wake fields) excitations.

3 Slits studies

The density in a storage cell is proportional to the inverse cube of its diameter. Therefore one should aim at reducing this aperture to the minimal tolerable value, whilst not affecting the beam lifetime and keeping detector background at an acceptable level.

Very little is known about spatial distributions of stored electron beams: it is expected that after damping (which occurs within a second at these energies) the beam profile should follow a gaussian shape with a \(\sigma\)-value of the order of 1 mm. Scattering with residual gas and wake fields excitations, however, will start populating the tails of the distribution thus creating a non-gaussian beam halo, which extends down to about \(8 - 10\ \sigma\). It is the interaction of particles in this halo with the target cell walls which is responsible for background events not coming from the target gas.

In order to obtain information on the beam in the presence of a very small aperture, lifetime data have been taken while placing 4 movable 1 cm thick tungsten slits at known positions inside the beam pipe. The slits could be positioned as close as 1.4 mm to each other. Data for such measurements are shown in fig. 3. Intersecting the beam with a movable collimator should not affect the lifetime until the actual beam core is reached. Then the effect of such a restricted aperture should become dominant in determining \(\tau_0\) which will therefore become inversely proportional to the aperture squared. Indeed one observes once more that the beam lifetime starts being affected by the
factor $Z(Z + 1)$, whereas for elastic single or multiple scattering the scaling would have been proportional to the atomic charge $Z$ only. This indicates that the radiative energy loss of particles in the target is dominant in this energy region, although it is true that given the lower than predicted values of $\tau_{\text{gas}}$, bremsstrahlung might have been excessively weighted by imperfections in the RF system of the ring.

A rather puzzling behaviour was observed for $\tau_0$. In fig. 2 the ring instantaneous lifetime is shown: there is a clear decreasing trend towards higher beam currents, which collapses in a beam blow up above 100 mA. The gradual decrease in lifetime in the low current region is correlated to an increase of the ring residual pressure which was observed only in the curved sections and was independent of gas flow in the internal target area. Therefore this effect can be attributed to synchrotron radiation induced gas desorption from the pipe walls.

It has to be noted that an average pressure of few $\times 10^{-8}$ mbar over the 212 m ring circumference, corresponds to a total thickness of $\approx 10^{13}$ at cm$^{-2}$ of, in principle, unknown atomic species with probably a high contamination of high $Z$ materials (e.g. $CO, CO_2$), therefore contributing non-negligibly to the lifetime during data taking on polarized deuterium. Also in fig. 2, extrapolated
2 Beam lifetime during the experiment

In a storage ring particles interacting with the residual gas in the vacuum line or with the target materials, may leak out of the machine stable phase space because of scattering beyond the ring geometrical or energy acceptance. The insertion of a storage tube as a target amplifies these effects, as the beam is forced to be recirculated through a region of high gas density and very limited aperture. Under the assumption that particle loss in the target region and elsewhere in the ring are statistically independent, the total lifetime $\tau$ can be written as:

$$\frac{1}{\tau} = \frac{1}{\tau_0} + \frac{1}{\tau_{gas}}$$  \hspace{1cm} (1)

with an intrinsic contribution coming from the ring and another one from the target gas itself. While $\tau_{gas}$ is a direct consequence of the density chosen, one would like to keep the ring intrinsic storage time $\tau_0$ as large as possible in order not to play an important role in eq. 1. In fig. 1 the measured $\tau_{gas}$ at 565 MeV is shown for $H_2$ and $N_2$. The lifetime scales inversely proportional to the target thickness in the cell. Furthermore in going from one gas species to another, it scales almost exactly with the bremsstrahlung cross section, i.e. with a

![Figure 1: The inverse of the intrinsic gas lifetime for $H_2$ and $N_2$ as a function of equivalent target densities at 565 MeV and 40 mA circulating current.](image-url)
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Specific design aspects of the storage cell in internal-target electron-scattering experiments, such as beam lifetimes, impact on ring vacuum, beam halo studies and detector backgrounds, are discussed. Experience on such issues gained during the 91-12 experiment at NIKHEF is presented and will serve as a guideline for future experiments and future targets.

1 Introduction

A strong internal-target physics program at the 900 MeV 100% duty factor AmPS electron storage ring of NIKHEF-K is presently being pursued. The storage cell technique has proven to be extremely useful for experiments with polarized targets and/or polarized beams. Recently, target thicknesses$^1$ of $2 \times 10^{13}$ at cm$^{-2}$ at a flow of $2 \times 10^{10}$ at s$^{-1}$ tensor polarized deuterium atoms have been successfully reached into a 15 mm diameter, 40 cm long storage cell without running into major obstacles on the machine side. We presently find that the ring vacuum is the major factor limiting the experimentally observed lifetime, while backgrounds induced by the 25 μm cell walls are kept at a tolerable level. This indicates that a further reduction of the cell aperture might be possible. Still, it is necessary to gain an understanding of the limitations which might occur for future denser targets and of different nuclear species (e.g. $^3$He and polarized $^3$He$^2$).