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TWO-BEAM OPERATION IN DESIREE

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Abstract

The current status of DESIREE is described, with special emphasis on the setup for collision experiments with ions in both the two electrostatic rings - negative ions in one ring and positive in the other. By measuring in 3D the kinetic energy released in mutual neutralization reactions between the two ions at collision energies close to zero eV, the population of different reaction channels has been obtained. The different steps necessary to set up the beams to get well controlled experimental properties are described as well as the principles behind our automatic optimization routines, which are extensively used with consistent result.

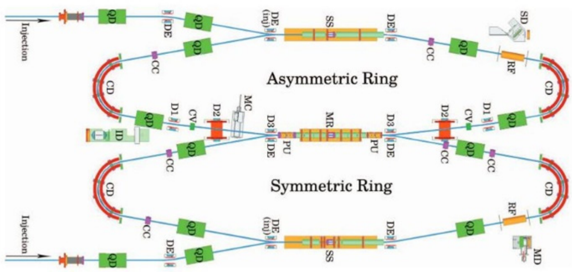

Figure 1: Layout of DESIREE.

INTRODUCTION

The DESIREE storage ring facility at the Physics Department at Stockholm University consists of two electrostatic storage rings with one common straight section. The rings are cooled to around 13 K. The excellent vacuum which results from the low temperature allows very long storage times to be used, up to more than 1000 s. Experiments are performed both with ions stored in only one of the rings as well as utilizing the unique possibility of the double-ring design of DESIREE to study mutual neutralization between positive and negative ions in the straight section which is common for the two rings. The beams stored in the two rings with close to the same velocity but different masses, can be merged in the common straight section with the help of two extra pairs of horizontal steerers in ring A (asymmetric). The space needed for these steerers requires two quadrupole pairs to be displaced compared with ring S (symmetric). The design allows a maximum mass ratio between the two beams of 20. The schematic layout of DESIREE is shown in Fig. 1. An overview of DESIREE can be found in ref [1] and a report on a single ring storage experiment in ref [2].

AUTOMATIC OPTIMIZATION

An automated, model independent process is used to maximize the intensity of the ion beams. It consists of the following steps:

1) Choose a list of optical elements to be used for the optimization.
2) Read the current signal, usually averaging over a few cycles. Input is either the current in a beam line Faraday cup, the spectrum analyzer signal from an electrostatic pick-up at injection, or the stored beam current which is dumped in a Faraday cup inside DESIREE at the end of each cycle.
3) Change one or sometimes two parameters up and down (same direction for pairs of quadrupoles, opposite for pairs of correctors) and read the current signal again for each value of the parameter.
4) If the signal is improved, keep that setting of the parameter and continue the procedure in 2) as long as the signal improves.
5) Go to the next parameter in the list and repeat from 2).
6) At the end of the list(s), go to the beginning of the list again and start another round of optimizations with slightly reduced step sizes and an increased number of averages.

Different sets of parameters can be selected from the different input files. Typical sets of parameters are the elements in the beamline, the injection, the main ring and the correction parameters in the ring. The step sizes are given in the input files individually for each parameter and are adjusted from the experiences of many tries using the optimization procedure.

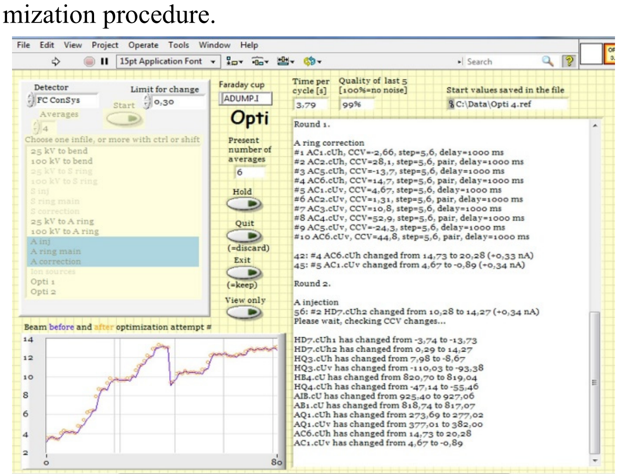

Figure 2: Example of an optimization run. The beam curent, as measured at the end of the cycle, is increased from 4 nA at the end of a 0.24 s cycle to 12 nA after a 4.24 s cycle. The decrease in current half-ways through the op-timization is due to the increase of the cycle length. 12 out of 28 parameters have been changed.

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The parameters are tried in the same order as they appear in the beam line. In the shortest transport, LE-ring S, we have 23 parameters in the beam line, 6 in injection, 5 in ring main and 16 ring corrections. Of these 50 parameters 19 are also optimized in pairs, and it takes 0.3 seconds to change one parameter. As an example, with 0.14 s cycle length and 3 averages it takes (50+19+n)×3×(3×014+0.3) = 149+2.16n seconds to optimize all parameters where n is the number of improvements. Often, however, the optimiation takes much longer, i.e. when optimizing the storage life time in a ring by maximizing the current in the beam dump with cycle times of 2-5 seconds. In this case only changing the few ring parameters could take an hour or more. While this optimization procedure can be made by hand, the automated process is mostly faster and more reliable and it does not depend on the endurance of the operator. In Fig. 2 an example of an optimization run is shown.

POSITION AND ENERGY MATCHING OF TWO BEAMS

To make it possible to merge the beams, the heavier ions have to be stored in ring A and the lighter ones in ring S. The ion source platform normally used for negative ions is placed on the S ring side of DESIREE and the positive ion source on the A side. Thus, when the negative ions are the lighter ones, we can inject both beams at the same time, but when the negative ions are the heavier ones the beams need to **cross** in the beamline between the 90-degree bends into the rings. In this case 0,7 s is needed between the injections to have time to switch the settings of this part of the beamline as well as the 90-degree bends. In Fig 3 the layout of the beamlines is shown.

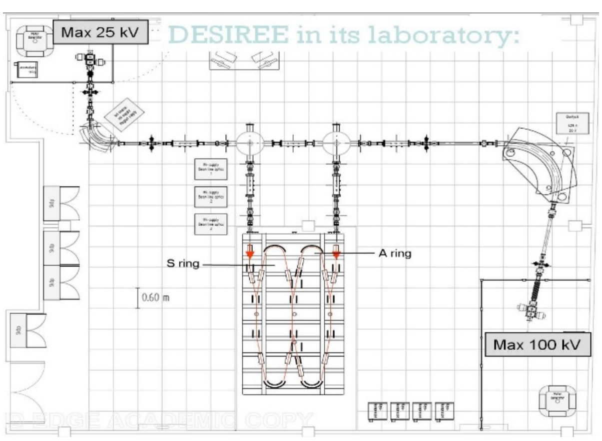

Figure 3: Layout of the DESIREE lab showing the two ion source platforms and the beamlines transporting the beams to the two rings from either platform.

Horizontal and Vertical Positions

Two horizontal and vertical pickups are placed at each end of the common straight section. By making Fourier transforms of the eight signals from the pickups, the positions of the two beams can simultaneously be extracted from the amplitudes at the two revolution frequencies. No RF is used to bunch the beams, only the initial bunching of the single turn injection which can be seen for up to a few thousand turns. An example of such a measurement is shown in Fig. 4

The figure shows the intensity of a pickup signal and the calculated positions of the beams in the two pairs of

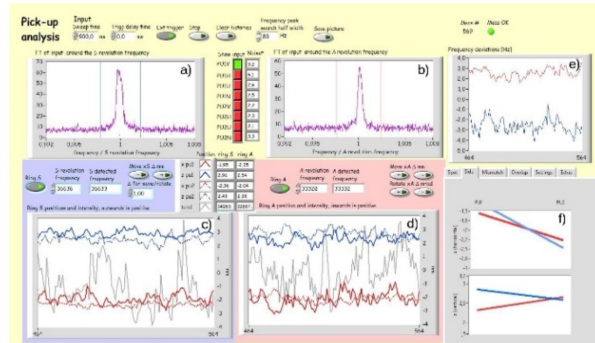

Figure 4: Screen dump from a PU measurement of 15 keV F^+ in ring S and 10 keV Cl^- in ring.

pickups. Panels a) and c) show the results for the S ring and b) and d) for the A ring. In e) the revolution frequencies in the two rings is shown while f) gives a graphical representation of the beam positions in the pickups to aid the adjustments to align the two beams. To align the beams, both the main bending elements and the steerers in both rings are used.

Velocity Matching

A voltage can be applied to one or more of the seven drift tubes in the common straight section to decelerate one beam and accelerate the other to bring them to the same velocity. Often three tubes are used. More tubes give a higher count rate, while fewer tubes give a better precision for the measurement of the kinetic energy release since the origin of the reaction is more well defined.

To find the correct voltage, the count rate on the neutral particle detector after the drift tubes is maximized by scanning the drift tube voltage. The resolution is limited by the momentum spread of the ions and the angle between the beams. Fig. 5 shows the result of such a scan where the different voltages on the drift tubes have been converted to relative energy between the beams.

KINETIC ENERGY RELEASE MEASUREMENT

In the mutual neutralization reaction

$$A^+ + B^- \rightarrow A + B + \text{kinetic energy}$$

kinetic energy is released and carried away by the neutrals. The amount of energy released depends on the quantum states populated after the reaction. By measuring both the position of where the neutrals hit the detector and the timing between their arrivals, a full 3D reconstruction of the

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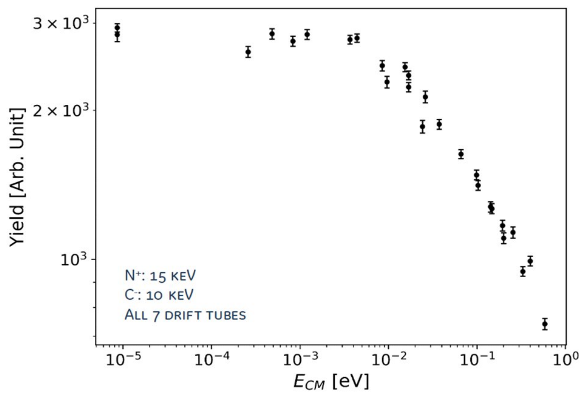

Figure 5: Result of a scan of the drift tube voltage. The voltages have been converted to relative energy between the two beams. The cross section is largest for zero collision energy, but the momentum spread in the beams limit the resolution to 10 meV in the center-of-mass system.

reaction can be performed and the branching ratio between the populated states can be measured.

In Fig. 6 results of a test measurement of the mutual neutralization of N^+ and C^- is shown. The different values of distances correspond to the final-state channels indicated in the figure. So far, we have studied among others C_{60}^+ + Au^-, $H^+ + D^-$, $Li^+ + D^-$, $F^+ + Cl^-$ and $C^+ + CN^-$. Very recently, we managed to introduce an improvement in the data processing and analysis, which will lead to a significantly improved resolution in kinetic energy release. After that, the next step is to develop the ability to determine reaction cross sections on an absolute scale.

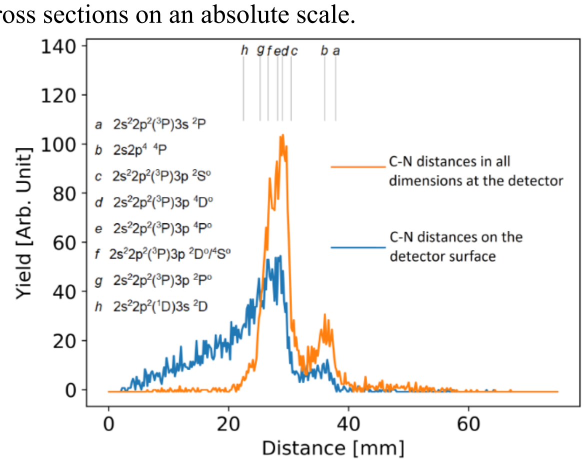

Figure 6: Measured distances between pairs of neutrals hitting the detector. By measuring both the distances on the detector surface (blue curve) and the time difference for each pair of neutrals a 3D reconstruction is made resulting in the orange curve. Several channels in the mutual neutralization of C^- and N^+ contribute.

ACKNOWLEDGEMENTS

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