Ion Sources for Proton Injection into COSY

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Abstract

A survey of the new ion sources proposed for the injection of protons into the COSY ring is given. The performance of an adapted H_2^+-source is discussed in some more detail.

1. INRTRODUCTION

The Cooler Synchrotron COSY, which is under construction at the KFA Jülich [1], shall after some time have four ion sources available for the different particles to be accelerated; three new sources for proton injection and an existing ECR source [2] for heavy ions. The types of source needed are mainly determined by the fact that the injection into the COSY ring will be performed by stripping. The existing cyclotron will be used as an injector for COSY and the sources shall be connected to the cyclotron injection beam line, which has been built a few years ago [2]. Figure 1 shows the

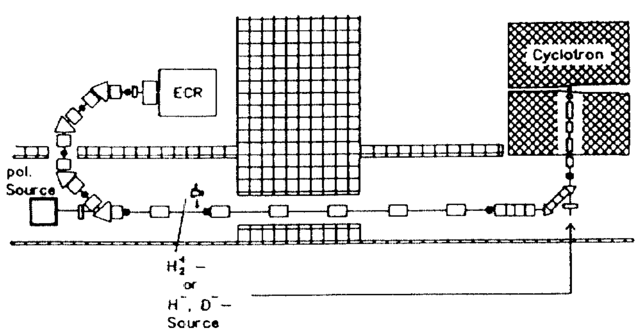

Figure 1:
Arrangement of existing and future ion sources for COSY at the cyclotron injection beamline

four ion sources at their proposed positions in the existing cyclotron injection beam line. The first COSY beams will be delivered by an H_2^+-source connected to the cyclotron injection beam line close to the wall of the cyclotron basement cave. The H_2^+-particles will be accelerated to 80 MeV in the cyclotron and via a stripping foil 40 MeV protons are injected into the COSY ring. The H_2^+-source can be replaced by an H^-, D^--source which has been bought from the IBA company in Louvain-la-Neuve, Belgium. The main reason to get the H^-, D^--source is to study the behaviour of negative ions during the acceleration through the cyclotron. The results are of mayor importance for a future H^-, D^--polarised ion source which provides the only possibility to inject polarised ions into the ring by stripping.

A low emittance medium current H_2^+-source for COSY

Measurements with a "pencil beam" have shown that the transmission through the source beam line and the cyclotron can be increased by reducing the beam emittance much below the expected acceptance of the cyclotron. The results imply that a source with low emittance ($\lesssim$ 35 π mm mrad at 8,2 keV beam energy) and medium high current ($\gtrsim$ 100 μA) in order to avoid space charge effects would probably be the best choice for the H_2^+-source for COSY beams. H_2^+-currents of 10 μA at a beam energy of 80 MeV are requested at the cyclotron exit.

In this context tests have been made to find out how to fulfill these requirements under the additional conditions that the advantage of the ECR sources to contain no destructable parts like for example heater wires should be kept.

Since the emittance of ECR sources increases with the axial magnetic field in the extraction region it is obvious to use a low microwave frequency like 2.45 GHz and lower the field in the extraction as much as possible. Several source versions including magnetic mirror configurations with and without magnetic multipoles have been studied.

The best results have been achieved with a source consisting of a permanent magnetic multipole, which provides zero axial magnetic field in the extraction, and one mirror coil at the source end opposite to the extraction. Figure 2 shows schematically this source version. The parameters to optimise the source performance are the solenoid field, the microwave power, the gas pressure and the puller voltage.

The beam emittance has been measured directly behind the source with a slit-wire system without any optical devices in between it and the source exit except for the extraction system. As expected the lowest emittance for a certain ion current is achieved when the

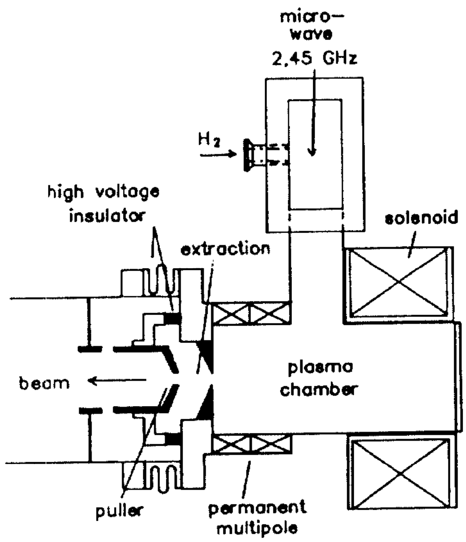

Figure 2:
Scheme of the H_2^+-source

coupling of the microwave power is good ($W_{refl} << W_{forw}$) and the plasma noise is low. In this case the ion current is always almost equal to the current shown on the extraction voltage power supply. It turns out that this is a necessary condition for the best performance. Because of less confinement the source works at higher gas pressure ($\sim 10^{-3}$ mbar) and higher microwave power than a full ECR source, but it is easier to obtain a quiet plasma. One can achieve a stable plasma at a microwave power below 100 watts and in a high power mode above 200 watts where the extracted ion current is about double as high. In the high power mode the ECR resonances of the multipole contribute to the plasma density. The higher mode does not exist when these resonances are covered by a metalic ring. In order to reach both regions of ECR resonances (solenoid and multipole) the micro wave injection has to be connected radially between both (Fig. 2).

One can call this source a multicusp source with an additional on axis ECR resonance which provides easy plasma ignition and stable performance at medium ion current densities of 0.25 to 1 mA/cm^2. The extracted beam contains mainly H_2^+ and H_3^+ ions and a small amount of protons, when the source pressure is optimized to maximum H_2^+ production.

For a current of 100 μA and a beam energy of 8,2 keV the emittance has been determined to be about 30 π mm mrad.

The emittance has been found to be proportional to the radius of the extraction hole as expected for a "thermal" emittance. Increasing the current density from 0.25 mA/cm^2 to 1 mA/cm^2 the emittance increases by 20% due to space charge effects. The lowest achieved emittance of 25 π mm mrad sets an upper level of about 1 eV for the thermal ion energy.

Up to 150 μA of H_2^+ ions with an energy of 8.2 keV - needed for a cyclotron extraction energy of 80 MeV - have been transported from the source to the hyperboloid inflector in the center of the cyclotron with almost 100% transmission.

After acceleration in the cyclotron the H_2^+ beam is now used for the acceptance tests of the transport beamline from the cyclotron to COSY. The influence of the low emittance of the source on the transmission ot the cyclotron could not be checked so far since the whole system is not yet back to the optimum performance. The source has shown reliable and stable performance over several month of operation.

H^--Source

The H^--source is a multicups source and is able to produce about 2 mA of H^- beam at a beam energy of about 25 keV. The H_2^+ source and the H^--source have been mounted on waggons. They can be easily exchanged without disconnecting any electrical cables or cooling hoses. This source exchange would later on not waste COSY beamtime since a switch from positive to negative ions needs much more time for changes at the COSY injection. As soon as the polarised source becomes available, both unpolarised sources have to be out and replaced by a pipe closing the beamline for polarised ions (Fig. 1).

The H^--source has been designed by the company to run at an extraction voltage of 25 to 30 kV. At an extraction voltage of only 4.5 kV needed here some optical problems occurred in the extraction area. It was not possible to achieve an efficient ion extraction and the beam formation with only one electrostatic electrode, the puller. The result was an incomplete matching of the source to the existing beam line, caused by the large divergence of the low energy beam. The matching has been improved remarkably by introducing two additional electrostatic electrodes behind the puller. The source with the full extraction system is schematically shown in Fig. 3. The first new electrode is on negative voltage up to several kV whereas the second one is grounded.

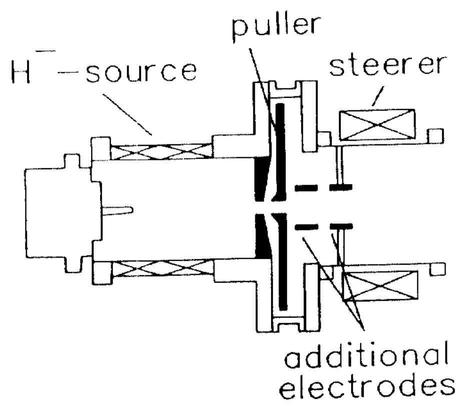

Figure 3:
Modified extraction system at the IBA H^--source

After a period of cyclotron operation with H_2^+ particles, the H^--source shall be connected to the cyclotron to study the cyclotron performance for H^- particles. These tests have to be performed as soon as possible since they may result in changes in the cyclotron extraction region to achieve optimum performance for polarized H^- particles. Finally the H^--source may be placed directly underneath the cyclotron (Fig. 1) allowing a fast change from polarized to unpolarized H^- ions or vice versa.

Polarised Source

A source for polarised H^- and D^- ions for COSY is under construction at the universities Bonn, Erlangen and Köln. It will be a coliding beam source. The three groups are setting up different subsystems of the source in there laboratories. The complete source will be assembled at the final location in Jülich indicated in Fig. 1. The mounting of the source at the Jülich cyclotron is supposed to start in the beginning of 1993.

2. REFERENCES

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