IMPROVEMENTS OF THE DIAGNOSTICS OF THE GUSTAF WERNER CYCLOTRON

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A new low energy polarimeter is used in the injection beam line for polarised protons and deuterons. The cyclotron has been equipped with phase probes, a TV probe is used to detect picoampere currents of heavy ions and a stopping probe with a variable angle of incidence has been developed to better measure protons with energies exceeding 100 MeV. In the external beam lines beam position pick-ups are being installed. Emittance measurements are performed using a movable collimator and measurement of the beam current on a movable rod. An energy measurement device based on thermal heating using a wedge shaped absorber is under installation, and new Faraday cups with higher precision have been developed.

1 General

When the Gustaf Werner cyclotron[1] was restarted in 1987 the only diagnostics available were two internal probes and fluorescent screens and simple Faraday cups in the external beam lines. Today the cyclotron is used in several modes of operation (external or internal ion sources, isochronous or synchrocyclotron mode) and with ions ranging from protons to ^{123}Xe of varying energies, often with many different particles/energies during the same week or even during the same day. This has made the development of the diagnostics necessary to make the tuning of a new case possible within a reasonable time.

2 Low energy polarimeter

The POLIS polarised ion source[2] has been tested with measured polarisation at 80 MeV protons of only 65% at the B-line POLMAN polarimeter and with similar results at the Celsius gas target. To determine if the source delivers the expected polarisation or not a low energy (20 keV) polarimeter has been developed at INR, Moscow and is now installed below the POLIS source. The principle[3] is neutralisation in a sodium charge exchange cell to metastable H or D atoms in 2S½-state, quenching of β-states by a Helmholtz coil and crossed electric field and detection by Secondary Electron Multiplying Tube (SEMT) and a Faraday cup. The first results indicated that the polarised proton beam is contaminated by other particles (probably nitrogen ions with low charge states), which led to the insertion of a 10 degree bending magnet and a slit system before the polarimeter to reduce the background. This was briefly tested in June this year, but no conclusive results are yet available.

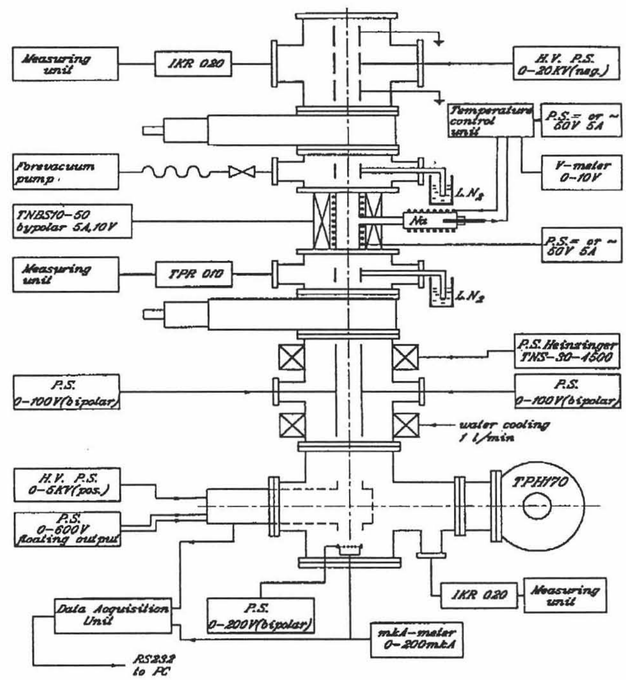

Fig.1. Block schematic of the polarimeter

3 Phase probes

The large turn number (up to approx. 2000) in isochronous mode makes the isochronisation of the field very critical. In 1994 a set of 11 capacitive beam pick-up probes (20x48 mm) were installed symmetrically 27 mm above and below the median plane at positions determined mainly by the position of the trim coils. Through matched coaxial lines the signals are transported through vacuum feedthroughs to a 16 to 1 multiplexer where one of the 11 pairs (or a signal from a similar movable pick-up set mounted on main probe no.2) is selected and summed and fed to the control room, where the 2nd (or 4th) harmonic of the beam signal is compared in a HP network analyser to a frequency doubled RF signal from one of the Dee voltage RF pickups. The network analyser and the multpilexer are controlled by GP-IB from the SUN Sparcstation of the control system where the result is displayed as phase difference for each pick-up set from an arbitrary reference phase.

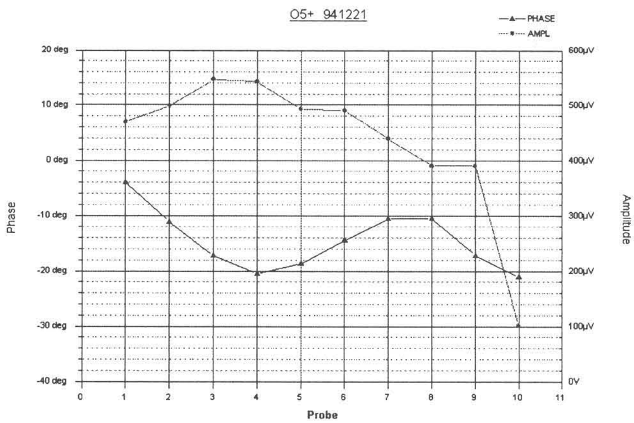

Fig. 2. Result from phase probe measurement

4 TV probe

A CCD TV camera with a 200 mm tele lens is used to observe heavy ions hitting a fluorescent screen[4)] mounted on the tip of main probe no. 1. This is used to detect pA-currents of beams entering the cyclotron through the electrostatic inflector. The inflector and Dee voltages can be adjusted to obtain a well centered beam in the median plane. The turn pattern can be observed from the very first turns out to ca. 400 mm radius, and by counting the number of turns per vertical oscillation an estimation of ν_z can be obtained.

5 Main probe with variable angle of incidence

All synchrocyclotrons have problems measuring proton beam accurately with a beam stopping probe. The turn separation is very small, and parts of the beam are scattered out from the probe. Also, the limited diameter of the probe makes it difficult to fit a sufficiently thick beam stop inside the probe. When the cyclotron is equipped with spiral sectors the problem is even worse, since the angle of incidence of the particles vary with radius and also with the magnetic field (the "scalloping" effect is more pronounced at lower fields). In the GW cyclotron the original probe measures accurately to approx. 100 MeV, where a gradual decrease of the measured beam starts and when the probe is moved out the beam vanishes completely to return again (due to better angle of incidence) and disappear again as energy is increased further, and is not measurable again until it has passed through the deflector and the beam hits the probe far from its inner end. This led to the development of a new main probe with a 40 mm copper beam stopping head that can be tilted ±3 degrees around a vertical axis by rotation of an axis inside the probe tube which extends of the cyclotron where a motor and position sensor are placed. Thus it is possible to first find the angle where highest beam current is measured at each radius for a given magnetic field, and then later automatically set this angle when the probe is moved. The improved probe additionally has one set of plates above and below the probe designed to collect secondary electrons, which also disturb the measurement. A pair of beam phase pick-ups are also included in the probe head.

6 Beam position monitors in the external beam lines

The alignment of the beam in the beam transport system is crucial for several beam users. The PACMAN experiment in beam line B requires very low background, which means there must be no beam losses in the beam line, and the biomedical line must repeatedly be set to exactly the same position and direction and Celsius requires variation of focusing without any change in position or direction of the beam. For those purposes it was found necessary to have measurements of beam position with results directly available to the control system. Prototypes have been produced for electrostatic beam position monitors (fig. 3). The first tests of the system have shown it to be useful in isochronous mode with high beam currents, but in FM mode the sensitivity for the biomedical beam line (beam currents are usually of the order of 3 nA) must be improved. A solution under study is resonant beam position monitors[5)] working on harmonic no. 4 with respect to the RF frequency of the cyclotron. The resonant BPM consists of four capacitive pick-up plates (approx. 19 pF) in series with capacitance diodes and brought to resonance by an inductor. A signal from the RF is converted to a voltage used to control the capacitance diodes and a phase locked loop is used to ensure that the cavity tracks the RF of the cyclotron.

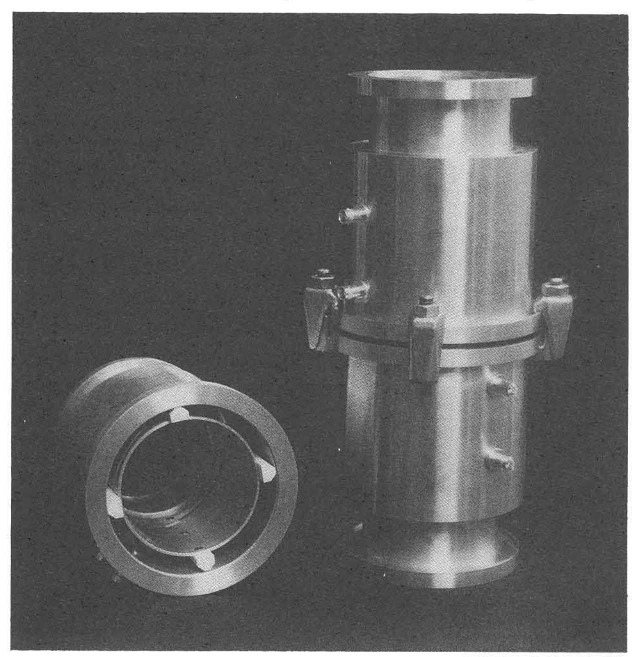

Fig.3 Prototype of electrostatic beam position monitor

7 Emittance measurements

Emittance measurements are performed using a movable collimator and measurement of the beam current on a movable rod. A simple procedure[6)] has been established to within a short time obtain an estimate of the emittance. For a fixed opening in the x direction of the collimator two positions are chosen, one with max. total beam current measured on a Faraday cup after the moving rod, one with 25 % of max. beam current. For those two positions the rod positions in x for max. beam and 10 % of max. beam measured by the rod are determined. This gives the four matrix elements and the emittance is approximatively determined. This is of course repeated in the y direction. An emittance value can be obtained within ten minutes.

8 Relative energy measurement using a wedge shaped absorber

An energy measurement device based on thermal heating using a wedge shaped absorber[7)] is under installation. The principle is that the beam is collimated in a hole collimator, goes through a first copper sheet with a thermocouple, then through a set of one fixed and one movable wedge giving a variable absorber with parallel outer surfaces perpendicular to the beam. The absorbers are made from copper, and the total thickness is variable between 2.5 and 40 mm. After passing through the wedge system the beam passes through a second copper sheet with a thermocouple. The two thermocouple units are placed in a symmetrical way (they are suspended identically and the leads from the thermocouples are identical in length to the vacuum feedthroughs). The wedge is adjusted until the temperature on the two thermocouples is the same. The system should be possible to use for 40-180 MeV protons but has to be calibrated against time-of-flight measurements.

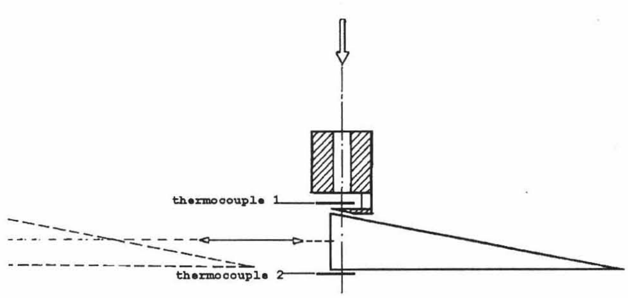

Fig. 4. Principle of the thermal (relative) beam energy measurement device

9 New Faraday cups with higher precision

The original Faraday cups employed no biased secondary electron suppression rings. This is installed in a new version, which also has permanent magnets to deflect secondary electrons. Another problem was bias in the measurement due to the cooling water. This is eliminated by using a kapton sheet between the carbon beam stop and the water cooled copper can into which the beam stop is inserted. The temperature difference between the copper and the carbon is less than 55 degrees for a beam power of 2 kW.

References

1. S.Holm, Status report of the Gustaf Werner Cyclotron in Uppsala, Proc. 13th Int. Conf. on Cycl. and their Appl. (Vancouver 1992) 106
2 .TSL Progress Report 1992-1993 p.10
3. W. Heberle, Helv.Phys.Acta Suppl. 6(1960)140
4. F. Marti et al, Internal beam dynamics studies with a TV probe, Proc. 13th Int. Conf. on Cycl. and their Appl. (Vancouver 1992)435
5. Yan Yin, Resonant beam position monitors for TSL beam transport lines, TSL-Note 94-18
6. A.Ingemarson and J.Hölling, Rapid emittance, TSL internal note
7. E. Bollman et al: A simple probe for relative measurement of beam energy, KfK Karlsruhe, IEEE 1984 p.419