Activities at CELSIUS

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Abstract

The CELSIUS ring is in operation for storage-ring experiments using very thin internal targets and cooled ion beams. Machine cycles of 2 – 15 minutes are used. Recent developments of the accelerator and the experiments performed there are described.

1. ELECTRON COOLER

During the spring of 1994 CELSIUS's electron cooler [1] has shown its usefulness in accumulating-accelerating-cooling runs of ^{16}O-ions. A stored beam current of 150 µA of O^{8+} was obtained in CELSIUS using stripping injection while 1.5 µA of O^{5+} was received from the cyclotron. Up to 4 mA was accumulated with the electron cooling system and accelerated to different energies up to 470 MeV/u and cooled again to a 1.5 mm wide beam (at the target) with $\Delta p/p \approx 10^{-4}$.

A new collector has been mounted [2]. Measurements show that the collector efficiency is improved in high-voltage, high-current operation.

The electron cooler has also been equipped with new clearing electrodes which also act as collimators to stop secondary electrons that escape from the collector.

2. INSTRUMENTATION

Some new beam diagnostic instrumentation has been added to the basic instrumentation, which has been described previously [3]. The new instrumentation consists of a system of background radiation monitors [4], a H^0 profile monitor, and a magnesium-jet beam profile monitor [5], which has given results in agreement with those previously measured with a carbon fibre [4].

A wall-gap monitor, intended for high sensitivity and high bandwidth observations of the ion beams, is to be installed.

3. CONTROLS

3.1 High bandwidth transverse feedback system

A high bandwidth feedback system (damper) has been constructed in order to be used to damp coherent transverse oscillations of the beam. The position signal from a pickup is amplified and fed with a proper delay to a kicker. Tests show that the oscillations, at the betatron sidebands, are reduced at frequencies up to at least 20 MHz.

3.2 Automatic orbit correction

Developing an acceleration cycle for CELSIUS includes creating vector tables for machine parameters that vary with time during the machine cycles. To optimize the tables that control the position of the closed orbit throughout the cycle, an automated orbit correction system has been installed.

The horizontal beam positions in eight of the pickups are sampled each time the vectors end (up to 64 times per cycle). On request of the operator, the position data for one cycle is transferred to the host computer, which calculates and loads corrections for the vector tables for eight of the back-leg winding power supplies.

3.3 Low bandwidth radial loop

A radial position feed-back loop has been installed. The position signal from a horizontal pickup, which is put where the dispersion is large, is used as input. The error signal is fed back to adjust the magnetic field in the main dipole magnets. Even though it has a bandwidth limitation of 2 Hz (the CELSIUS dipole magnets are not laminated [6]) it makes the vector tables less critical, especially for acceleration of relativistic beams (high energy protons), for which the momentum (and thus the radial position of the beam) depends strongly on the revolution frequency.

4. INTERNAL TARGETS

4.1 Cluster-jet target

The cluster-jet target system installed at CELSIUS [7] is in regular operation for experiments. It is producing target beams of hydrogen, deuterium, nitrogen and the noble gases neon, argon, krypton and xenon in target thicknesses of 10^{13} - 10^{14} atoms/cm^2. Expensive gases will be handled in a gas recirculation and cleaning system which is close to be finished.

4.2 Pellet target

A pellet generator producing frozen droplets of hydrogen has been developed. It gives 40 µm diameter pellets with velocity

60 m/s and rate 6.8×10^4 s^{-1}. The half-width of the pellet stream has been measured to be 2 mm at a distance of 1.37 m from the nozzle during a long-term stability test.

The pellet system is currently being adapted for installation and test at the CELSIUS ring. The influence of the pellet stream on beam life times and vacuum will be measured.

5. EXPERIMENTS

The main experimental activity at CELSIUS concerns the production and decay of light mesons, see e.g. ref [8]. In the studies both light-ion and heavy-ion reactions are being used. So far, the experiments have taken place at the cluster-jet target. Around the wide-angle scattering chamber are mounted a forward spectrometer (FD, fig. 1) consisting of a tracker, (FT) hodoscope (FHD) and a range telescope (FRH), and a wide-angle calorimeter (CEC) of CsI detectors, alternatively a set of plastic scintillator telescopes.

In a series of experiments, a part or all of the magnets of the quadrant following the cluster-jet target are used as a magnetic spectrometer.

The pellet target system will form a vital part of the future second experimental station at CELSIUS intended for high-luminosity light-ion studies.

5.1 Zero-degree spectrometer

In order to study reactions close to threshold, a small size zero-degree spectrometer has been developed by the nuclear physics group at Stockholm University in collaboration with IKP, Jülich. It consists of a charged-particle telescope, made of high-purity germanium, that can be installed at a suitable position, depending on the magnetic rigidity of the particles to be detected, inside the ultra-high vacuum system of CELSIUS. Particles with a magnetic rigidity lower than that of the beam particles will then be deflected out of the beam by the magnetic field of the dipole magnets and possibly reach the particle telescope. For tests and measurements done so far, a port in the second dipole magnet of the first bend following the target straight section, 6.1 m away from the target, has been used. Here rigidities relative to that of the beam of 0.40 to 0.75 are accessible.

In a set of experiments the pion-pion interaction and its modification in the presence of nuclear matter is investigated. In a first experiment the production of two pions in the $d+d\rightarrow {}^4\mathrm{He}+X$ reaction at 570 MeV is studied. The particle telescope, for the detection of the produced alpha particles, is a 1.4 mm thick ΔE detector, which is position sensitive, and a 14.9 mm thick E detector to stop the alpha particles. With particle identification, knowledge of total kinetic energy and position on the detector, the emission angle can be determined. Taking into account the emittance of the cooled CELSIUS beam, the angular resolution is better than 2 mrad at a relative rigidity of 0.50. In a second experiment the two-pion production in the reaction ${}^{14}\mathrm{N}+d\rightarrow {}^{16}\mathrm{O}+X$ at 2047 MeV will be studied. The measurement will be done at a position 7.7 m away from the target where relative rigidities between 0.75 and 0.90 are accessible.

5.2 Studies of giant resonances with heavy ion beams in the CELSIUS ring

The energy region covered by the CELSIUS ring is well suited for studies of giant resonances by Coulomb excitation , and an experiment is now under preparation. The basic idea is now to use the whole quadrant after the target in the ring for momentum selection. Particles scattered from the target through very small angles can be focused in both planes to a point on the straight section following the target straight section (i.e. the injection straight section) by an appropriate choice of working point. This working point is not optimal for injection and acceleration. Therefore, the working point is jumped from its usual $(Q_x,Q_y) = (1.627,\ 1.836)$ to $(1.766,\ 1.795)$ after the acceleration in every cycle.

The tracking of the inelastically scattered particles will be performed by a three-detector telescope placed on the injection straight section. The first two components of the telescope are two-dimensional position-sensitive silicon strip detectors. The third component is a scintillator hodoscope consisting of an array of vertically oriented scintillation fibres. A plastic scintillator counter behind the array of fibres defines the full detector solid angle and serves as the trigger and for particle identification. All detectors are movable in the direction perpendicular to the beam line.

5.3 Meson production in heavy-ion experiments and "CHICSI"

The CHIC collaboration has measured kaon production at CELSIUS in p+Ar collisions at 1.36 GeV and pion production in ^{16}O+Kr reactions at 470 MeV/u using range telescopes. The group is now developing CHICSI, a 500 element multi-detector system for studies of intermediate mass fragments in 100-470 MeV/u heavy-ion reactions. The system will be placed at the cluster-jet target. A detector element is composed of 10, 300 and/or 1000 μm thick silicon detectors. The forward telescopes have an additional 7-10 mm thick scintillation crystal of the new GSO type [9], with photo-diode readout. The GSO emission spectrum peaks at 430 nm, therefore UV sensitive photo diodes are required for the readout.

5.4 WASA/PROMICE

The PROMICE and WASA collaborations, carry out a joint experimental programme using ions in CELSIUS. At present the main points are:

— production of π^0 and η mesons in pp and pd interactions

— studies of mechanisms for deuteron breakup

— proton - proton bremsstrahlung

— searches for dibaryon states

The present detector setup (fig. 1) is situated at the cluster-jet target, and consists of the forward spectrometer mentioned above for measurements of charged particles and the wide-angle calorimeter which is used both for gammas and charged particles.

Recently, near-threshold production of neutral pions has been measured at IUCF in Bloomington [10], and has led to renewed theoretical interest in the field with the purpose to explain the discrepancy in the magnitude of the measured and calculated cross sections.

By taking advantage of the photon detection possibilities of the WASA/PROMICE detector, neutral pions may be detected by detecting the photons from the pion decay. By doing so we are not limited by detector acceptance when approaching the kinematical threshold from above as is the case of the IUCF experiment where the pions are detected indirectly by detecting the two recoiling protons.

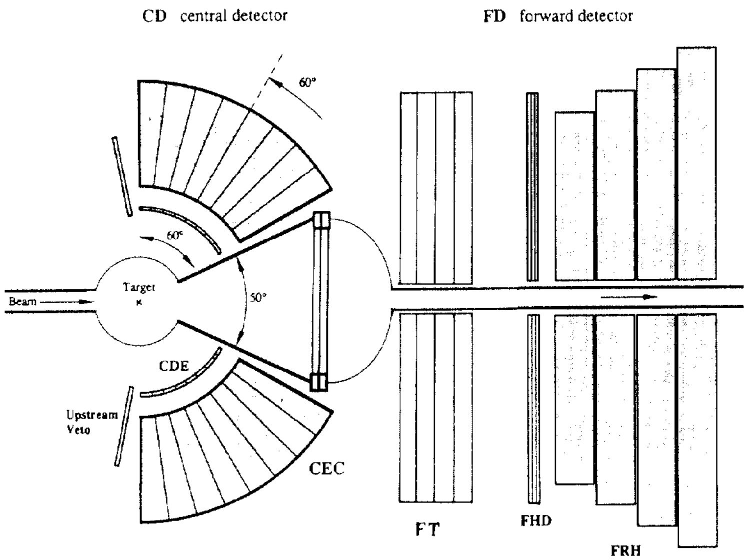

Fig. 1. Cross section of the WASA/PROMICE setup at the cluster-jet target.

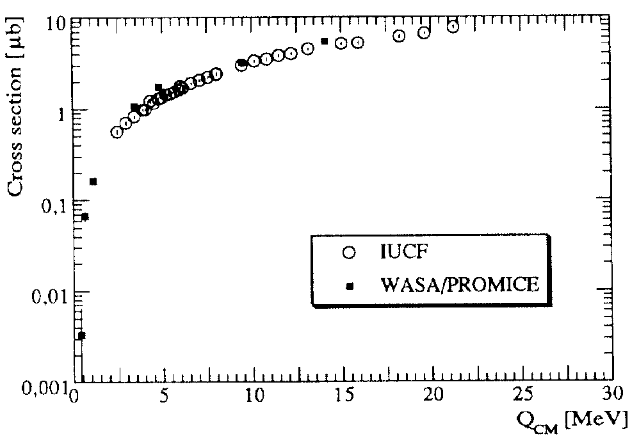

Fig. 2. Preliminary results of the $pp \rightarrow pp\pi^0$ cross section measured at CELSIUS together with data from [10]. The cross section is given as a function of the excess energy in the centre-off-mass system.

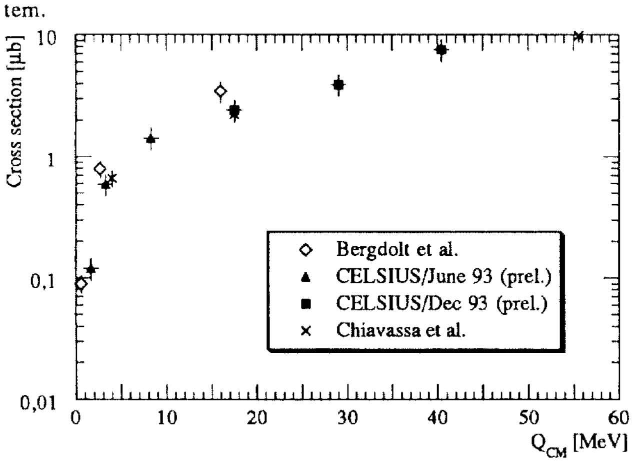

Fig. 3. Preliminary cross sections for the reaction $pp \rightarrow pp\eta$. Two recent measurements from Saturne [11,12] are also shown.

The total cross section has been measured at a number of points from 0.8 MeV to 30 MeV above the kinematical threshold at 279.7 MeV. Preliminary results are shown in fig. 2.

During 1993, 25 eight-hour shifts at CELSIUS were devoted to the study of the reaction $pp \rightarrow pp\eta$ at energies close to the kinematical threshold at 1255 MeV. The etas were detected through their decay into two photons with the two-arm CsI calorimeter. Data were collected at six different proton energies in the range 1259 – 1360 MeV. Preliminary cross sections for the reaction are shown in fig. 3.

The smallest scattering angle that can be measured using the standard WASA/PROMICE setup is 3°. A tagging spectrometer for nuclear recoils emitted at 0° is being developed. Its main goal is to tag mesons produced in $p+A$ interactions by means of detecting outgoing ^3He nuclei. The spectrometer is to be installed inside the first bending magnet of the quadrant following the target. An energy resolution of 1 MeV for 56 MeV ^3He from $pd \rightarrow {}^3He + \pi^0$ at 200 MeV was achieved.

The spectrometer has also been used for beam energy measurement. The energy difference between forward and backward scattered ^3He is very sensitive to the beam energy. The energy difference was 6.4 ±0.5 MeV which gives a beam energy of 200±0.2 MeV.

5.5 CLAMSUD

A spectrometer for detecting low energy kaons from exclusive and inclusive kaon production in proton-nucleus collisions will be installed at CELSIUS in the spring of 1995. The spectrometer is developed by a group at Catania, Italy, and will be further equipped with detectors appropriate for kaon detection at CELSIUS. The spectrometer (CLAMSUD), which is of the clamshell type and has a weight of 20 ton, is oriented with its bending plane vertical. The momentum range is 120 % and a maximum momentum of about 270 MeV/c (kaon energy 70 MeV) can be analyzed. The spectrometer subtends a solid angle of 30 msr, and the total distance between the target and the last trigger detector is about 2.7 m.

6. REFERENCES

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