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THE ISOLDE FACILITY AT THE CERN PS BOOSTER.

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ABSTRACT

The CERN ISOLDE On-Line Mass Separator facility was reconstructed at the 1 GeV PS Booster and is now being commissioned. Protons in very short high intensity pulses (average current $2 \mu\text{A}$) are directed on either one of the targets of the two on-line mass separators. The 60 keV ions from them are fed into a common beam transport system to which most of the experiments will be connected. The facility can supply radioactive beams of about 60 elements from the whole nuclear mass range to a community of more than 250 physicists working in the fields of nuclear, atomic, surface and solid state physics, astrophysics and nuclear medicine. The most interesting features of the facility will be discussed and a few experiments described to illustrate the extent of the experimental programme. An outlook into future developments such as resonant laser ion-sources and plans for post-acceleration of radioactive ions will be given.

(ISOLDE - General)

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1. INTRODUCTION.

On-line isotope separation has a long tradition at CERN. For more than two decades the ISOLDE mass separators were attached to the 600 MeV CERN Synchro-cyclotron (SC). During these years the separator facility was upgraded several times and a wealth of experience and data was obtained [1,2]. In order to run the Laboratory in the most efficient way, CERN closed down the SC two years ago and approved the transfer of the ISOLDE facility to a new site in the array of the CERN high energy accelerators. The ISOLDE target is now on-line to the 1 GeV PS Booster.

2. THE PS BOOSTER

The PS Booster (PSB) is a stack of four small synchrotrons in which protons (or heavier particles) from a linac are preaccelerated to 1 GeV before being injected into the 27 GeV CERN Proton Synchrotron, which, in turn delivers protons to the even more powerful machines or supplies protons for production of antiprotons and other secondary particles.

Although being the most intensely used machine in the complex of CERN accelerators, the PSB produces more protons than required for PS injection. The spare accelerator cycles (about one pulse in two in a 14.4 sec long PS supercycle) are available to isotope production at ISOLDE [3]. The main features of the PS Booster beam are summarized in Table 1.

Table 1: The PS-Booster beam parameters

Beam energy	1 GeV
Max. intensity	$3.2 \cdot 10^{13}$ p/pulse
Pulse length	2.4 μ s
Repetition time (typ.)	1.2 - 2.4 s
Average current on target	2.1 μ A

The time structure of the PSB beam creates a major technological problem but also allows full advantage of a pulsed operation of the facility to be taken.

3. LAYOUT OF THE FACILITY

The main features of the facility can be seen on Fig. 1. The 1 GeV proton beam is delivered (eventually in a pulse-sharing mode) to either one of the two target stations: the General Purpose Separator (GPS) and the High Resolution Separator (HRS). The GPS is conceived as an easy to operate machine with a double focussing 70° magnet and a switchyard which allows one to extract two side beams (in a mass range of $\pm 15\%$ from the central mass) simultaneously with the main beam. The HRS is essentially the slightly modified IS-3 separator with its two magnets (90° and 60°) and several higher order correction elements. All lenses are electrostatic quadrupoles. Both separators feed a common beam transport system via a "merging switchyard", so that most experiments can receive beam from either machine. A detailed description of the facility is given in Ref. [4].

As a result of extensive work on target and ion source techniques over the last 25 years around 600 isotopes of 60 elements from all regions of the nuclidic chart are available today [5]. Radioactive atoms are produced in high-energy fission, spallation and fragmentation reactions in selected target materials, then transferred into an ion source and accelerated as singly charged ions to 60 keV. By a judicious choice of ion source type and temperatures some further chemical selectivity can be obtained [6,7]. Radioactive ion beams with half-lives down to a few milliseconds can be delivered at intensities ranging from 10^{11} to 10^{-1} per second.

Acceleration of the reaction products is achieved by applying a highly stabilized 60 kV potential to the target. One of the most challenging issues of the project was to keep this voltage constant to within a few volts despite the intense ionization in the air around the target due to the very short high intensity proton pulses impinging on it ($3 \cdot 10^{13}$ per burst). To avoid perturbations caused by ionization, this voltage is modulated to zero during the $2.4 \mu\text{s}$ beam impact period [8]. The system brings the voltage back to the stabilized conditions within 5 ms after impact almost independently of the proton beam intensity and proved to work very reliably. During this target voltage modulation a "beam gate"

interrupts the ion beam. The same timing signals can also be used to gate the data taken in the experiments.

Another new development was the economic and user friendly control system of the separators. The architecture is based on the well-known concept of front end computers connected to the equipment (about 2000 parameters), console computers for the operator and a file server, all linked together by the CERN wide Ethernet. Ordinary office type personal computers running under MS-DOS/Windows and commercial software such as Excel and Visual Basic were used to create the ISOLDE-specific applications [9,10].

The installation of the GPS and its three beam lines is completed and the physics programme could be successfully started. At present the construction of the beam distribution system advances rapidly. The HRS will be commissioned in 1994.

4. EXPERIMENTS AT ISOLDE

In a first run in June this year radioactive Ne beams from a MgO target were produced. Already in this experiment the pulsed structure of the Booster beam was fully exploited. There is evidence of an enhancement of release of the reaction products caused by the high power density deposited in the target during the short proton bursts. In this first run the β -decay of ^{17}Ne to the 1st excited state in ^{17}F was studied in order to establish that this state is a proton halo [11].

When the facility starts full operation in the fall of 1992 about 3000 hours of beam per year will be used by more than 300 physicists for a vast experimental programme in nuclear, atomic, surface and solid state physics, nuclear medicine and astrophysics. At present 22 ISOLDE experiments are approved by the CERN Research Board. A few of them will be described here in order to illustrate the programme.

The wide range of available nuclei and their relatively high production yields has not only allowed systematic studies of nuclear level schemes, but also led to the investigation of exotic phenomena such as neutron halos in ^{11}Li and β -delayed particle emission in some nuclei far from

stability. Actually, β -delayed emission of $2n$, $3n$, tritons and, in a recent experiment, of deuterons in the decay of ${}^6\text{He}$ was discovered at ISOLDE [12].

With an exciting new technique, masses of nuclei far away from the line of β -stability can be directly determined by measuring their cyclotron frequency in a Penning trap. Only a few atoms from ISOLDE need to be captured in the trap and accuracies of better than 20 keV can be achieved. This method has already been applied to Rb, Cs, Fr and Ra isotopes [13].

Detailed studies of ground state properties of long series of isotopes were carried out by collinear laser spectroscopy [14]. Recently these measurements could be extended to low-yield nuclei very far from stability by application of ultra sensitive resonance detection techniques based on optical pumping, charge exchange and atom or ion counting. The latest measurements at ISOLDE include isotopic chains of Yb, Lu, Ca, Sr and Kr [15].

In the NICOLE experiment [16] the technique of nuclear orientation of ions implanted in a ferromagnetic host at temperatures of typically 10 mK combined with NMR yields information concerning nuclear spins and moments of short lived isotopes. This information is complementary to data from laser spectroscopy. Inversely, this technique allows the study of the solid state properties of the host lattice itself.

The combination of various nuclear methods and the wide choice of pure, radioactive implants opens access to investigations of problems in solid state physics, in particular concerning impurities and defects in semiconductors. Due to the decay of the implant to its daughter, Deep Level Transient Spectroscopy (DLTS) with radioactive ions, first done at ISOLDE, has become a unique tool for unambiguous identification of electronic levels of impurities in semiconductors [17].

5. OUTLOOK

In order to take full advantage of the features of the new facility an intense target and ion source development program is planned [18]. It is expected that higher yields will be obtained due to the higher cross sections and thicker targets possible at the 1 GeV proton energy. Following an earlier development at ISOLDE [19] we intend to implement pulsed laser ion sources where use is made of stepwise resonant excitation to autoionizing states. This type of ion source would allow efficient production of ion beams, and in particular give high element selectivity. The increasing astrophysical interest in experiments with high energy radioactive ion beams makes a post-acceleration scheme at ISOLDE, where high production yields are available, an attractive option. At present, a proposal is being prepared for an RFQ/Linac accelerator to provide radioactive beams in the energy range of 0.2 -5.0 MeV/u for masses up to $A=80$.

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FIGURE CAPTIONS:

Figure 1:

A view of the new ISOLDE facility. The protons from the Booster are delivered to the targets via a 100 m long transfer line. Handling of the highly radioactive targets is done with a robot on rails. The whole area, except the experimental hall, is buried under up to 8 m of earth for radiation protection purposes.

Figure 1