TANDEM AND SUPERCONDUCTING CYCLOTRON ACCELERATORS ACTIVITY AT INFN-LNS CATANIA

D. Rifuggiato on behalf of the LNS Accelerator staff

INFN Laboratori Nazionali del Sud, Catania, Italy

Abstract

The LNS accelerator activity during the year 2005 is described with details on the Cyclotron and Tandem beam time distribution. A status report of the Cyclotron upgrading is also given. Statistics of the running year 2006 is not here reported, while the related activity is shortly reported in the last paragraph .

1 BEAM OPERATION

In 2005, an intense experimental activity was accomplished with the Tandem and the Superconducting Cyclotron. Beams were delivered to users for a total time of 5 months, according to a schedule that included consistent periods of machine stops dedicated to advances of Excyt. In this 5 months period, 1750 hours of Cyclotron beams and 1442 hours of Tandem beams were delivered. These numbers demonstrate that thanks to a significant reduction of failures and to the good reliability level reached, the target of increasing the overall efficiency of accelerators, set 5 years ago, has been achieved.

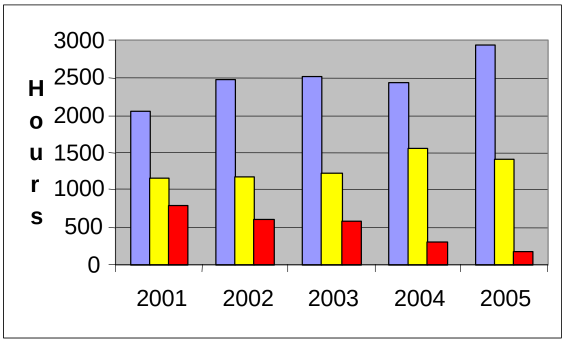

Figure 1: 2001-2005 Cyclotron beam statistics scaled for 8 months

All the experiments with stable beams approved in the meeting of the Program Advisory Committee were accomplished, except the ones to be performed with the MAGNEX spectrometer, whose commissioning was made at the beginning of 2006 due to the complexity of the experimental set-up.

In 2005 the new experimental hall was completed with everything needed to operate the three new halls. Therefore the commissioning of the new beam lines was accomplished, transporting the beam to the three new experimental points: Catana, Magnex and Chimera. As a consequence, in April the first patient was irradiated in the new Catana location and the spectrometer Magnex received its first Tandem beam for a preliminary test. The availability of the new Catana hall made free an additional experimental area, which is now dedicated to interdisciplinary experiments using small experimental set-up.

In 2005, 3 sessions of proton therapy of ocular tumors (Catana) were accomplished, using the 62 MeV proton beam from the Superconducting Cyclotron, for a total of 16 treated patients. Moreover 2 test sessions were accomplished to test the 3 meters long line in air in the new location. In total the protontherapy activity took approximately 420 Cyclotron hours.

In figures 1 and 2 the beam statistics for the years 2001 through 2005, scaled for a period of 8 months, are shown. The first column, in blue, displays the delivered hours, the second, in yellow, gives the preparation time, the third, in red, the number of failures. As evident from figure 1, the number of failures has a clearly decreasing trend, which demonstrates the achieved good reliability, quite important for the experimental activity as well as for the development of new projects. The amount of setting hours is still big, demonstrating that the Cyclotron is a quite complicated machine. As for the Tandem, the delivered beam time is less than the previous 2 years. In fact, the time made free by the Magnex experiments not performed was not allocated so as to allow for access in the Tandem area, speeding up the completion of Excyt.

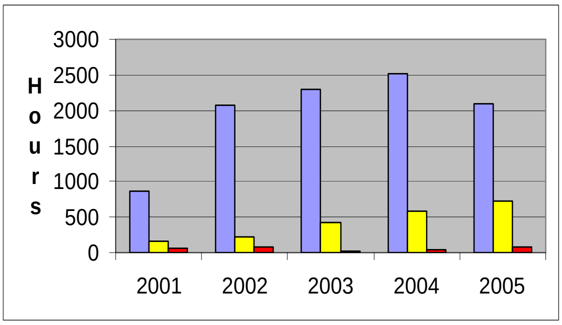

Figure 2: 2001-2005 Tandem beam statistics scaled for 8 months

2 SUPERCONDUCTING CYCLOTRON

In 2005 the Superconducting Cyclotron delivered beams in a quite reliable way and with the usual good timing quality, i.e. FWHM 1 nsec and interburst separation 100-150 nsec, very much appreciated for nuclear physics experiments carried out with large array detectors   Table 1 shows the Cyclotron beam types delivered in 2005.

In 2005 Cyclotron beams were used for Nuclear Physics experiments (56%), proton-therapy (20%) and interdisciplinary experiments (12%) mainly investigating on interaction of ion beams with biological matter and on new superconducting materials. The remaining part of beam time was used for high intensity beam tests of the Cyclotron.

In figure 3 a plot of the experiments performed in 2005 with Cyclotron beams is presented, showing the beam time distribution among different experiments.

Table1: Cyclotron beams delivered in 2005

Beam	Time
Protons 62 MeV	516 h
Deuterons 62 MeV	32 h
^{12}C 62 AMeV	115 h
^{13}C 45 AMeV	270 h
^{20}Ne 21 AMeV	32 h
^{20}Ne 45 AMeV	594 h
^{40}Ar 40 AMeV	16 h
^{58}Ni 35 AMeV	96 h
^{62}Ni 35 AMeV	32 h
^{112}Sn 35 AMeV	127 h
^{124}Sn 35 AMeV	127 h
^{197}Au 21 AMeV	63 h
Total	**2020 h**

During the periods of machine stops, high intensity tests were accomplished to continue the program started in the previous years of upgrading of the Cyclotron, aiming to increase the extracted beam current to be used for radioactive ion beam production in Excyt. The primary beam was 13C 45 AMeV.

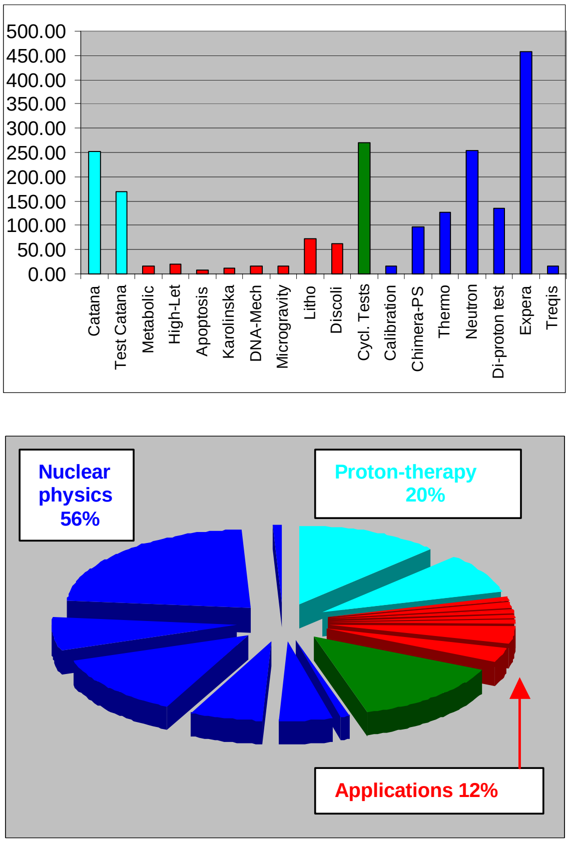

Figure 3: Cyclotron beam time distribution

The deflector used was a new prototype: in addition to the new more efficient cooling circuit, further improvements were introduced: the septum was now made of tungsten instead of tantalum, which improves the thermal conductivity and the mechanical stability, and is twice thicker than before, now being 0.3 mm. Beam tests gave very positive results: extraction efficiency was now 63% instead of 50%, and the conditioning time under beam was significantly reduced, which implies a better beam stability. The 100 watt beam power is now more reliable and is expected to be increased very soon.

In Table 2 a list of the experiments performed at the Cyclotron in 2005 is given.

Table2: Experiments performed in 2005 at the Cyclotron

Experiment	Research field
Catana	**Hadrontherapy**
Metabolic	**Biology**
High-Let	**Biology**
Apoptosis	**Biology**
Karolinska	**Biology**
DNA-Mech	**Biology**
Microgravity	**Biology**
Litho	**Lithography**
Discoli	**Superc. material**
Cyclotron tests	**Accelerators**
Calibration	**Nuclear physics**
Chimera-PS	**Nuclear physics**
Thermo	**Nuclear physics**
Neutron	**Nuclear physics**
Di-proton test	**Nuclear physics**
Expera	**Nuclear physics**
Treqis	**Nuclear physics**

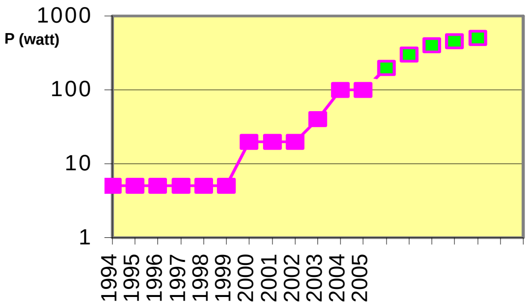

Figure 4: Beam power evolution at the Cyclotron

In figure 4 the beam power evolution at the Superconducting Cyclotron is shown, starting from 1994, the commissioning year, to nowadays. The increased values were due to axial injection in 2000, and to the upgrading of the electrostatic deflectors in 2003 and 2004. There are good chances to reach 500 watt, which is the target set by Excyt, but it is difficult to imagine to go beyond this value, considering the present extraction efficiency.

3 TANDEM

Tandem beams have been delivered mainly to the 60° and 80° beam lines, the so-called by-pass area allowing the complete decoupling of the two accelerators, with two beams contemporarily sent to two different experimental areas.

Table 3 displays the Tandem beam types delivered in 2005.

Table 3: Tandem beams delivered in 2005

Beam	Time
Proton 22-26 MeV	154 h
Deuterons 20 MeV	40 h
^{6}Li 20-50 MeV	316 h
^{7}Li 20 MeV	68 h
^{9}Be 10-40 MeV	245 h
^{12}C 60 MeV	237 h
^{16}O 80 MeV	110 h
^{79}Br 230 MeV	272 h
Total	**1442 h**

Table 4: Tandem experiments performed in 2005

Experiment	Research field
Litho	**Ion lithography**
Diamond	**Detectors**
DPAA	**Archaeology**
Piramide	**Rad. hardness**
Damage	**Rad. hardness**
Detector tests	**Detectors**
Astro	**Nuclear physics**
E0	**Nucl. astrophysic**
Chimera-PS	**Nuclear physics**
Calibration	**Nuclear physics**
S-factor	**Nucl. astrophysic**
Test-Magnex	**Nuclear physics**
Clad	**Nuclear physics**

Tandem beams were used for Nuclear Physics experiments (53%) and applicative experiments (47%) covering several inter-disciplinary fields: ion lithography, radiation hardness, archaeology, and detector development. In figure 5 a plot of the experiments performed in 2005 with Tandem beams is presented, showing the beam time distribution among different experiments.

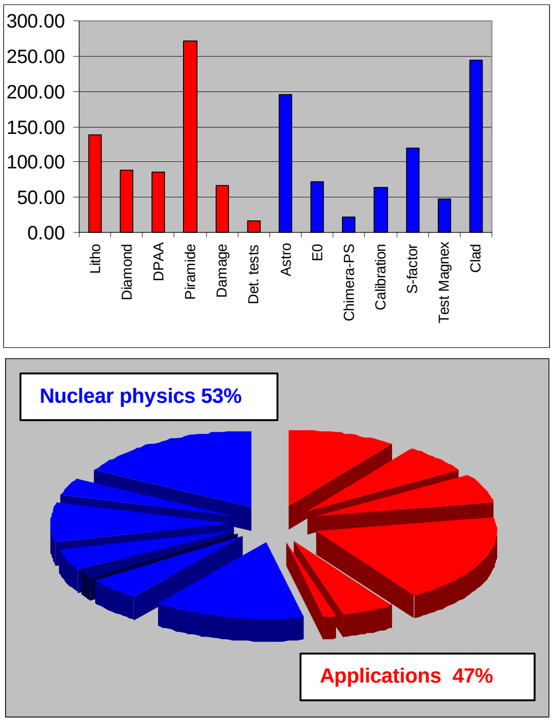

Figure 5: Tandem beam time distribution

4 CONCLUSIONS

In 2005 the LNS accelerators proved to be quite reliable, allowing to carry out a significant amount of experiments in a reduced time, approximately 5.5 months. The remaining part of the year was dedicated to complete the Excyt installation, and as a consequence the commissioning of the new facility started. Proton-therapy was accomplished as usually with 16 patients treated in the final Catana location in the new experimental area. The Cyclotron upgrading went ahead with the installation of a new electrostatic deflector (see figure 6) with a direct cooled septum, which yielded an increased extraction efficiency (from 50% to 63%). In 2006, experiments have been carried out with stable beams at the Cyclotron and at the Tandem, together with proton-therapy sessions, but a big amount of beam time has been allocated to EXCYT tests in order to complete the commissioning already begun at the end of 2005. Since this commissioning has been effectively finished, experiments with unstable beams are planned to be performed in the next weeks. Beam delivery has been accomplished with the same reliability as in the past four years. Special attention has been paid also to the primary beam production from the Cyclotron for the EXCYT tests. The total number of proton-therapy sessions planned to be accomplished in 2006 is 5.

Figure 6: Deflector with cooling circuit in contact with the septum