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Tools and facilities of the Milan section of the INFN

F. Broggi
INFN-Sezione di Milano Laboratorio LASA, via f.lli Cervi 201, 20090 Segrate, MI, Italy

Abstract

In this note the main tools, experimental capabilities, and intellectual know-how of the Milan section of the INFN are listed. The main purpose is to spread out informations outside INFN and especially to the productive world, as a starting point towards future collaborations with the industries.

PACS: 01.52.+r National and international laboratory facilities

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1 INTRODUCTION

The activity and institutional dues of the INFN is to perform basic research in nuclear and particle physics. To this aim strong synergic contact with the University is well established. In addition to the University collaboration, contacts with industries occur. The industrial know-how and technologies are often used to set up experimental apparatus or particle accelerators for INFN experiments, the inverse process seldom or never occurs, despite the fact that INFN develops high and innovative technology solutions to realize his research projects.

It will be useful both for the industries and for the INFN to share this frontier knowledge and technology solutions, eventually protected by patent process, in order to gain in commercial competitions (for industries) and increase the exchange between the basic and industrial applied research. This can lead to a more dynamic market for personnel too.

More career opportunities in industrial research can help institutions like INFN to overcome (even partially) the problem of temporary researchers that cannot become definitive staff, or turnover replacements. In addition a more dynamic job-market can stimulate young students to start a scientific course of studies.

In this note the apparatus and competences of the Section of Milano of the INFN, that could be useful to industry, are illustrated.

2 SECTION STRUCTURE

The Milan section of INFN has two locations, one in Via Celoria (c/o the physics department of the University of Milan) and the LASA laboratory in Segrate, a group of INFN associated researcher is located at Politecnico di Milano. According to the national structure, the section of Milan of INFN is divided into five research groups, referring to the specific research field.

- Group I : Is dedicated to the study of high energy physics through the use of accelerator beams (LHC at CERN, Tevatron at Fermilab, Stanford Linear Collider).
- Group II : Is dedicated to the study of high energy physics and astroparticle physics, without accelerator, mainly performed in underground laboratories (Gran Sasso National Laboratory). This group includes the studies on neutrinos produced at CERN and sent to the Gran Sasso National Laboratory.
- Group III : Performs nuclear physics studies.
- Group IV : It is the theoretical group
- Group V : It includes all the applied and interdisciplinary physics, spanning from accelerators to particle detectors, to medical physics.

In addition to the research group and administrative services, general utility services are present, i.e.:

- Protection and prevention service : dedicated to the care of the safety working conditions.
- Design and workshop : is a general purpose service to help experimental groups in designing and machining.
- Electronics : provides assistance and electronic design to the experiments.
- Calculus : is related to the data analysis of the various experiments.

In addition to the activities of the five groups other activities are developed in the frame of an extra-group, the so-called “Progetti Speciali” or under external funds resources and projects, typically from EU.

In the following the main activities of each group are illustrated, and links with industries, are outlined.

3 GROUP ACTIVITIES

3.1 Group I

To this group belong the experiments and activities related to high energy/particle physics, done with beams from accelerators.

The research is done mainly at CERN with the LHC beam at the ATLAS experiment. Other experiments are/were set at Fermilab (Chicago) and at Stanford Linear Collider.

All the experiments use the know-how from the design service, together with the workshop experience and collaboration, to design custom and original solutions to realize and install the experimental apparatus.

The main activity done in collaboration with industry is the one related to the ATLAS experiment, more precisely the technique of the “Bump Bonding”. This activity is performed in collaboration with the SELEX, to realize bonding with Indium between the pixel sensors (that detect the particles) and the electronics that read the signal generated by the particles in the sensors.

The chip dimensions are 2 x 2 cm^2, the pixel dimensions are 50 x 250 μm while the dimensions of the Indium bumps (drops) before/after the bonding are 15 μm/10 μm.

The peculiarity of this activity, because of the dimensions of the pixel, is the precision needed, both in the setting the mask with the holes were the Indium will be deposed, and in the alignment between the pixel and the electronic board.

Another activity is connected with the SuperB experiment. In this experiment electronics components for particle detectors (the vertex detector), and fast electronics to handle the signals from the detectors (in connection with the electronics service) are developed.

3.2 Group II

The activity in group II are related to high energy/particle physics, without using beams from accelerators. The primary particles come from the cosmic rays and from secondary neutrino beams produced at CERN. The experiments are located at National Laboratory of Gran Sasso (BOREXINO, ICARUS, OPERA) and in the Argentina Pampa (AUGER).

The main activity/process developed (or that can be in some way useful to the industry) are in the BOREXINO project where the phototubes (detectors of the light emitted by the events from neutrino interactions) are immersed in water and in scintillating liquid (pseudo-cumene).

Technological innovative solutions to insulate the phototubes have been developed, both because of the chemical characteristics of the pseudo-cumene, and because all the insulating materials must have a very low residual radioactivity.

In the frame of the Borexino experiment, water purification has been studied for the removal of radioactive contaminants. This research program could produce benefits for the technology of ultrapure water in electronics industry.

In the frame of the same experiment a general purpose detector of environmental radioactivity (especially for building materials) has been developed, together with KIMIA Company.

3.3 Group III

The activities and experiments included in Group III are related to the nuclear physics. Many experiments are active: GAMMA, AEGIS, EXOTIC, LUNA, EXOCHIM, KAONNIS.

Common feature of all the experiments is the development of fast electronics, (both analog and digital), used to read the detector signals, and the related data acquisition systems. In addition there are competences in the measurement of gamma radiation, X rays and charged particles.

As a matter of fact there is interest from electronic industries to acquire and commercialize the electronics developed.

The competences present are:

- Development of custom and top level electronic solutions, especially in the field of analog-digital and digital-analog converters.
- Development of electronics dedicated to radiation spectroscopy (from optical wavelength to gamma radiation).
- Characterization and repair of electronic and microelectronic “front-end” circuits, both on normal and integrated circuits, for detector for X, gamma and laser spectroscopy.
- Development of multi-parameters Data acquisition systems

- Spectroscopic measurement of X and gamma radiation
- Measurement of charged particles

3.4 Group IV

Group IV is dedicated to the theoretical physics, so it has no implication in applied physics or technological applications.

3.5 Group V

Group V includes the applied and interdisciplinary physics experiments and activities.

It is divided into four subgroups:

- Detectors : where the particle and radiation detector technology is developed
- Electronics and Software :
- Accelerators :
- Interdisciplinary Applications: spanning from environmental measurements to medical applications, radio-dating of cultural heritage etc.

Competences in radioprotection, radiobiology radiation detectors and imaging techniques are well established.

A new technique for optical imaging in transmitted light for GAFCHROMIC® films has been developed, together with analysis techniques and instruments for thermoluminescence radiation detectors; both the systems have compact dimensions and are transportable.

In the radiobiology field, quantitative studies on the biological effects induced by mutagens and carcinogens (ionizing or non-ionizing) on cell cultures are routinely made.

Radiobiological studies on particle beams for radiotherapy (protons, Carbon ions) from Centro Nazionale di Adroterapia Oncologica (CNAO) are done, in order to determine the biological effectiveness.

To this aim experimental apparatus are used:

- Production of ultra-pure water (18MΩ.cm).
- Laminar flow hoods
- Incubators for cell cultures
- Sterilizers
- Counter of particles (of micrometers size) in suspension

Semiconductor detection systems for position and energy, measurements of X, gamma and optical photons (e.g. spectroscopy and imaging systems with resolution of 130 eV FWHM at 6 keV, without liquid Nitrogen cooling and transportable) are developed by the Politecnico di Milano group.

In addition electronics for radiation detectors with custom dedicated hardware and software design is developed, together with the interfacing to instrumentation and control. VLSI electronics for mixed signals is developed.

3.6 Special and External funded Projects

3.6.1 Accelerator Physics

General problems about accelerator physics together with problems related to all components of an accelerator or to the beam (both hadronic and leptonic or photon beam) are well in competence with the groups working on accelerator physics.

Accelerator physics has a long tradition and is still a very important activity in the Milan section of INFN. As a matter of fact between 1960 and 1965 a 45 MeV cyclotron was designed, built and installed in the laboratory located in the Physics Department of the University of Milan (Via Celoria). The cyclotron was funded by industries of the Milan area (the most important among them were Pirelli for the coils, Franco Tosi for the iron of the magnet, and the mechanical machining) for about 2/3 of the total cost, while the remaining cost was provided by the Milan municipality, the Minister for Education and by the National Council of Research (CNR). The cyclotron was dedicated to nuclear physics experiments and to the production and studies on radio-tracers for medical applications.

The group that built and managed the cyclotron then designed and built a Superconducting Cyclotron, the first of this type in Europe, the fifth in the world, but it is worth noting that the Milan group actively participated in the design and construction of the first one at the Michigan State University. The Milan Superconducting Cyclotron is now operating in the INFN Laboratory of Catania (LNS), for nuclear physics, medical application, medical treatments of oncologic patients.

The deep experience in the accelerator and beam physics, make possible many collaborations with accelerator laboratories, either for linear accelerators or for circular colliders. The main collaboration in the field of hadronic accelerators is with CERN for LHC. In the past many projects have been carried out to develop accelerators or components of them for medical applications, among which the most important is the synchrotron of the Centro Nazionale di Adroterapia Oncologica (CNAO) located in Pavia.

In the field of proton accelerators and beams, in the framework of FP European Programs a high current proton accelerator for waste transmutation has been studied and research activities on dedicated components are ongoing with involvement of Italian companies.

Regarding electron accelerator, collaboration with Deutsches Elektronen SYncrhrotro (DESY) laboratory in Hamburg was established since ‘80s. INFN has contributed on components for the TESLA Test Facility (now FLASH) with cryomodules for superconducting cavities, photocathode production and handling system for the high brightness electron sources and many ancillaries (Wire Position Monitors, tuner developments, etc.). More recently, INFN is involved in the production process of 1.3 GHz superconducting RF cavities, tuners, cryomodules and the 3.9 GHz complete accelerating section for the upcoming European X-ray Free Electron Laser (XFEL). INFN is also involved in the worldwide activities related to the feasibility studies of the International Linear Collider (ILC).

Electron beams of high quality (brightness), free electron lasers, monochromatic x and gamma ray beam generation for physics, interdisciplinary and medical applications are studied, in collaboration with the INFN Laboratory of Frascati (LNF) and the most important institutions and universities (among them CEA-France, UCLA-USA).

Theoretical aspects are mainly done by the group located in via Celoria, while experimental activities are mostly carried out at LASA laboratory (see next sections).

3.6.2 Medical applications

Medical applications of physics (and of accelerator physics as outlined in the previous paragraph) are developed in the frame of the Group V. Here the treatment plans and all the aspects of the medical applications (both diagnostics and therapy) of physics, including the design of special accelerators or beam sources are developed.

3.6.3 External Funding Projects

Some activities are funded partially by external source, mainly from European Union.

The subject of these activities are related to the collaborations among different foreign or international institutions focused to the realization of big infrastructures or facilities, like the International Linear Collider, or the upgrade of the LHC accelerator.

3.7 Electronic Service

Hardware and infrastructures:

- Cleanroom (30 m^2) class 10000 with some zones class 1000 with pre-cleanroom with instruments to be used inside the cleanroom.
- Machines for bonding and for inspection of wire bonding for custom applications.
- Micropositioners for electronic components for testing on “naked” devices.
- Thermostatic chamber for testing electronic components in controlled temperature environment.

- Possibility of characterization of electronics components at cryogenic temperatures.
- Systems for characterizing transmission lines.

Specific know-how and competence:

- Know-how and competences in designing custom applications in discrete, hybrid and integrated circuits.
- Software for programmable logics.

3.8 Computing Service - Grid and Cloud facilities in Milan

In Milan there is an ATLAS Tier2 center (coordinated by Prof. L Perini) with about 600 CPU cores and 850 TB disk by end of 2011, (about 750 core e 1050 TB in June 2012). The center is part of the grid of WLCG and is included in the European infrastructure of the EGI-InSPIRE project via IGI.

IGI is in consortium with a structure similar to the one of the GARR which operates the network for the Italian research, and for the second consecutive year, has been directly funded by MIUR with the aim of establishing this new independent body. In this transition phase that will end in 2012, IGI is structured as INFN Special Project, and the management of the INFN Grid is demanded to the two "Progetti Speciali" IGI and GRID. INFN is expected to be the main member of the IGI Consortium, which will include among its members also CNR, INAF, ENEA, ELETTRA, ISAS, GARR (non-exhaustive list).

Hardware resources are the property of INFN, purchased specifically for the ATLAS experiment, but in the "Progetto Speciale" GRID a long standing policy dictates that up to 10% of CPU resources are available to users other than the experiment for usages with low priority or agreed with the primary user.

Recently, the development of cloud computing by the commercial world has expanded the domain of distributed computing based on Grid by introducing a new paradigm, the virtualization of resources, and a new model allocation of resources via WEB, thus allowing a relationship between user and provider of computing and storage much more flexible and automated. Thanks to Cloud services physical resources become a multitude of virtual computing and storage environments that can be provided on demand in a flexible and timely way, according to the specific requirements of users and for the time strictly necessary.

Within the IGI WnoDES as a tool for virtualization-cloud has been developed, and it is currently in tests at CNAF, with ATLAS (one of the experiment running at CERN LHC) as one of the early testers; Milan for IGI will be a geographic aggregation pole, at the beginning providing access to Grid resources users of the Sciences Faculty (physics and others) and then, still in the first half of 2012, by using WnoDES as a support for a Cloud offering, which may also be directed to users outside the universities and research institutes members of IGI.

Additional hardware resources in 2012 will not come from IGI (this possibility exists for the following years, but IGI should never be the main source) but may be provided by users interested in having guaranteed access to resources on the Grid, while maintaining priority access its own resources, without having to directly manage them, or by EU or national (in the IGI framework) or regional projects (to be found independently, IGI involved more weakly).

In three years from now, the physical space necessary to expand the current installation will be ensured in the new building that will rise in the Physics department, where a 300 square meters room will be available.

3.9 Workshop and Design Service

Here the machines and instruments in the workshop are listed.

- Milling machine **Fidia:** PC controller with CAD/CAM software, working on three axes, the fourth is manual type. Operating range: x= 1650mm; y= 450mm; z= 400mm. IT works with electro-spindle with max velocity 15.000 turns/min.
- Milling machine **Rambaudi**: with control Heidenhain 510 elaboration unit. Ranges: x= 800mm; y= 350mm, z= 300mm.
- Milling machine **Tiger**: with Heidenhain control, 155 elaboration unit. Ranges. x= 900mm; y= 250mm, z= 350mm. Inclinable head in two directions (line Y and line X). Spindle with horizontal axis available.
- Manual milling machine, range x= 700mm; x= 250mm, z= 300mm.
- Lathe **Momac** with numerical control and auto-learning, maximum working diameter Ø 200 mm.
- n° 2 Lathe **Ursus 300** for manual operations up to Ø 300mm
- Lathe **Anselmi** for manual operations up to Ø 150mm
- Desktop micro-lathe **Valex** for small operations
- Desktop micro-lathe **C3** for micro machining
- Column drill with automatic progression **Bimuk** mod. 32au/p
- Drill **Bimuk** 13 daN
- Drill M118W
- Drill IM 103N
- Cutting-off machine **Fendo** (350mm)
- Cutting-off machine **Thomas** mod.310
- Endless saw **Opus**
- Pneumatic shears: maximum cut length 1000mm, maximum thickness 5mm.
- Manual shear

- Pneumatica notching
- Sanding belt
- Abrasive wheel
- Deburring sheet
- Beveling
- Pneumatic threading from M3 a M10

4 LASA LABORATORY (Laboratorio Acceleratori e Superconduttività Applicata)

The infrastructures of the INFN Section of Milan are the ones located at the Physics Department of the University of Milan, and the LASA laboratory, a separated structure, located in Segrate (about 5 km from the physics department) with mechanical workshop, together with a large experimental area, cryogenic plant, chemical and radio-chemical laboratory.

4.1 STRUTTURA GENERALE DEL LASA

Here the main activities on superconductivity, accelerator physics and applied physics are developed.

The LASA infrastructure characteristics are:

- 2000 m^2 surface (offices, laboratory, workshop and experimental area)
- 50 tons crane
- 40 l/h He liquefier
- 16 MVA Installed Electrical power
- 100 Mbit Local area Network
- Optical microscope for metallography in transmission/reflection, the resolution is up to 0.1 μm, magnification 100x – 1000x.
- Optical microscope "stereozoom", magnification 1x – 100x, for large samples (≈10 cm).
- Digital camera for image acquisition from microscopes.
- Class B Radiochemical Laboratory (it is a lab. of the University of Milan, managed by university professors, with the partial support of INFN technicians, and partial funding of INFN).

In addition to these common utilities, others are dedicated to specific experiments and applications.

4.1.1 Superconductivity for Magnets and Material Science

This activity is dedicated to the development of the magnet technology for accelerators and detectors.

To this aim 3 CC power supply with maximum current of 30000 A, 6V are available.

Both series and parallel connection are available.

In the following table the magnet available are listed.

NAME	MAGNET TYPE	POWER	MAX. FIELD (T)	AVAILABLE SPACE (cm)
SOLEMI-1	Solenoid NbTi	CC	8	55*
SOLEMI-2	Solenoid NbTi/Nb_3Sn	CC	12	24**
SOLEMI-3	Solenoid NbTi/Nb_3Sn	CC	15****	10**,7.5***
SUPER COMPATTO	Solenoid NbTi/Nb_3Sn	CC	13.5	5.3**
DIPOLO	Resistive Dipole	CC	1.6, 1.2, 0.9, 0.8	42 (Φ poli) 6,8,10,12 (gap)

* available space at room temperature
** available space at T=4.2 K
*** available space in gas between 2 e 300 K
**** in SOLEMI2+SOLEMI3 configuration

Critical current measurements on superconducting wires up to 2000 A in the sample are possible.

4.1.2 Mechanical Measurement Laboratory

Measurements of yield strength, Young's modulus, section reduction, elongation, ultimate stress e strain are possible.

To this aim the following testing machines are used:

- **INSTRON mod. 6027**, tensile and compression tests, according to the guidelines of ASTM EN-85, at room and cryogenic temperatures.
- **MTS mod. 810**, toughness test according to the guidelines ASTM EN-85, at room and cryogenic temperatures.

Characteristics of the INSTRON testing machines mod. 6027

TENSILE TEST

Max load capacity	Load Cells	Testing speed	Control
+/- 200 kN	+/- 200 kN +/- 10 kN +/- 100 kN	0.002 mm/min – 0.5 m/min	Load/strain/position

Cryostat

Max. load in tension	Max. load in compression	Temperature range	He consumption
100 kN	50 kN	3-5 K (in liquid He) 77 k (in liquid N2) 3-300 K (in He gas flow)	3 l/h

Specimen

Typical Dimensions	Max. stroke	Working Space
Φ=8 mm, l=109 mm	130 mm	Φ=150 mm x 109 mm, tension Φ=50 mm x 65 mm, compression

Characteristics of the MTS mod. 810 testing machine

TOUGHNESS TEST

Possible tests:

a) plane strain fracture toughness (Ki,c) following ASTM E399 e UNI 7969

b) thoughtness at the initiation of the crack growth (Ji,c) following ASTM E813

c) fatigue crack growth rate (da/dN) following ASTM E647, using C(T) type specimens.

Max. Frame load	Load cells	Specimen cage	Specimen dimensions
+/- 250 kN	+/- 250 kN	250 kN in tensione +/- 125 kN LCF	62.5 x 60 x 25 mm

Cryostat

Temperature range	He consumption
2 – 300 K	1.5 l/h

Hydraulic circuit

Hydraulic power supply flow	Hydraulic power supply pressure	Stroke, max.	Displacement – Frequency at 100 kN
63 l/min	210 bar	+/- 250 kN	2.5 mm a 10 Hz

4.1.3 Thermal Conductimeter

Thermal conductivity measurements on insulating, composite and pure material can be done in the temperature range 4-300 K (providing a form factor giving a thermal conductance between $5x10^{-3}$ - $20x10^{-3}$ W/K).

4.1.4 Ancillary Equipments

Two ovens for thermal treatments (impregnations etc.) are operating:

- Oven for thermal treatment in controller atmosphere and in vacuum with maximum temperature of 1200° C; available space is 14.5 cm diameter and 110 cm length.
- Oven for impregnation; the available volume is 50x60x70 cm^3.

4.1.5 Superconductivity for Accelerating Cavities

- **Clean Room ISO4 Class**: Room with laminar flow without particulate according to the guidelines ISO-16644-1, class 4. The surface available is about 9 m^2 equipped with particulate counter, nitrogen, helium and ultra-pure water. Cleaning of objects with ultra-pure water at 100 bar, filtered at 20 nm, is possible inside the room

- **Ultra-pure water production**. For the needs of treatment of superconducting components, an ultra-pure water plant is available to produce water with resistivity at 18 MΩ cm. The water, from the public distribution system, is filtered with an Elix system, and then with a Millipore SuperQ. The rate of production of ultra-pure water is 10 l/min, while the Elix system provides 70 l/h. A 6000 l tank is a buffer to produce the 18 MΩ cm water.

- **Vertical Cryostat:** A vertical cryostat (4 m deep, 700 mm wide) allows tests in liquid or superfluid He down to 1.8 K. The cooling power available is about 17 W at 2.0 K.
- **RF Laboratory :** To test the RF cavities, many RF instruments are available : amplifiers in different frequency:
    - 500-800 MHz (650 W)
    - 1.3 GHz (100W)
    - 3.9 GHz (200 W).

  Spectrum analyzers, function generators, network analyzers.

4.1.6 Photocathode Laboratory

The photocathode laboratory utilizes some laser systems:

- **Femtosecond Laser "TWINKLE":** It is an Nd:Glass laser generating 1 ps pulses on the fundamental wavelength (1055 nm), using a passive mode locking and a regenerative amplifier. By a pulse compression process during the second harmonic generation, the pulse length is reduced to about 400 fs in second fourth and fifth harmonic, whose wavelength are, respectively, 527nm, 264nm and 211nm. The energy on the fundamental is 1.5 mJ and the repetition rate is 12.5 Hz.

- **Nanosecond Laser "QUANTEL":** It is a Nd:YAG Q-switched generating 5 ns pulses. The fundamental wavelength is 1064 nm, the second and the fourth harmonics (532 nm and 266 nm). The energies of the various harmonics are 350 mJ, 125 mJ and 30 mJ respectively. The repetition rate is variable.

- **Laser Ar+ :** It is a laser at Argon ions, with variable wavelength from UV to visible (457.9 nm, 465.8 nm, 476.5 nm, 488.0 nm, 496.5 nm, 501.7 nm, 514.5 nm) through a Littrow prism. The total power is 100 mW with 40 mW at 514 nm and 488 nm and about 6 mW at 457.9 nm and 465.8 nm.

- **Monochromatic light source** : The source is a continuous mercury or deuterium high pressure vapour lamp. The light can be filtered by interference filters to obtain light on the wavelength 254 nm, 297 nm, 334 nm, 365 nm, 403 nm, 436 nm, from UV to the typical mercury visible. The deuterium lamp gives light up to about 200 nm. A monochromator allows the selection of the wavelength in a continuous way.

- **Oscilloscope** : A Tektronics TDS 7154B oscilloscope is used in the laboratory. It has 4 channels with 1.5 GHz bandwidth and 20GS/s sampling on the single channel and 4 GS/s on four channels.

4.1.7 Radiochemical and Radioprotection

The activity of radiochemical and radioprotection at LASA utilizes the following laboratories:

- Radiochemical B type (or class 2) according to the IAEA/62 and UNI7815 guidelines. It is a laboratory with classified as "controlled zone" with permission from the authority (Nulla Osta Prefettizio) to possess and manipulate radioactive sealed or not sealed sources, neutron source and tagged compounds (composti marcati) and radiopharmaceuticals.

  Here radiochemical separation techniques are optimized, by treating radioactive samples produced by accelerator/cyclotron or nuclear reactors, to produce tagged compounds, radiopharmaceuticals, or radioactive elements to be used as tracer for medical, biological, or environmental applications. In addition separation methods for low concentration of radioactive isotopes, in environmental matrices are developed. Long lifetime calibration radioactive sources are available.

- Physical Measurements Lab : Here nuclear measurements on low-activity samples (usually prepared in the radiochemical laboratory) by using high sensitivity and energy resolution are done. The detection systems are:
  - 8 chains with HPGe (15% - 40% relative efficiency) shielded with lead;
  - Liquid scintillator, with anticoincidence system and correction with number of Horrocks;
  - Liquid scintillator with PSA circuit to discriminate alpha signal from beta one.
  - Two high resolution alpha spectrometry chains with surface barrier Si and PIPS.
  - Two chains with fixed NaI(Tl); one chain with portable probe NaI(Tl).
  - Many chains for neutron spectrometry, standard Bonner chamber, modified Bonner chamber for high energy neutrons, a dose calibration ionization chamber (a pozzetto).
  - Radiochemical hood with filtering system according to UNI guidelines.
  - Various fixed and portable radioprotection instrumentation.

- "Cold" Chemistry Laboratory : Here chemical and radiochemical measurements with atomic absorption spectrophotometers, liquid and gaseous phase radiochromatographic (HPLC), eluition systems, polarography, stripping voltammetry. In one of the laboratories a test plant for production of ultra-pure water (in collaboration with Centro di Ricerca per l'Ambiente e l'Impresa, University of Milan).

Both the Radiochemical and the “Cold” Chemistry laboratories are laboratories of the University of Milan, managed by university professors. INFN provide support to them by technical people and partial funding for experiments.

- Radon and didactic laboratory : Here NaI scintillating detectors for reading the passive dosimeters are installed. Active detectors ZnS scintillators and reading system for reading track dosimeter to determine the environmental radon concentration are present too. A sealed glove-box to create a controller radon concentration, allowing the calibration of the didactic radon detectors, is available.

- Calibration monitor and neutronics : There is a delimited zone equipped for calibrating instruments for radiation, neutrons and electromagnetic radiation detectors. A motorized calibrating desk at 3 m from the floor (to avoid reflection from the floor of the radiation emitted by the radiation sources). The calibration sources available are :

  - Am-Be with activity $3.7x10^{10}$ Bq (1 Ci) and $3.7x10^{9}$ Bq (0.1 Ci) neutron sources;
  - ^{60}Co with activity $3.7x10^{9}$ Bq (0.1 Ci) and $3.7x10^{8}$ Bq (10 mCi).

- Target production and optical microscopy: Here the targets to be irradiated are prepared and mechanically and optically characterized. The microscope available are are :
  - Optical microscope for metallography in transmission/reflection, the resolution is up to 0.1 μm, magnification 100x – 1000x.

  - Optical microscope “stereozoom”, magnification 1x – 100x, for large samples (≈10 cm)

External users can access:

a. Neutron spectrometry and dosimetry;
b. Advanced gamma spectrometry , hifh resolution alfa spectrometry, liquid scintillation beta spectrometry;
c. Setup of methods of Quality Control for radiopharmaceuticals, both conventional and in testing phase, in collaborations with hospitals;
d. Learn techniques to setup non conventional productions of radionuclides with *high specific activity* for radiodiagnostics and/or metabolic radiotherapy;
e. Calibration of radiation protection instrumentation;
f. Environment contamination measurements;
g. Evaluation of the radon-222 gas concentration, according to D.Lgs 230/241.
h. Operative radioprotection procedures.

4.1.8 Workshop

Here the machines and instruments in the workshop are listed.

- Milling machine **Rambaudi:** mod. KVO, spindle ISO 50, numerical control Heidenhain. Operating range x=1300 mm, y= 3050 mm, z= 300 mm.
- Milling machine **Rambaudi:** mod. M3, spindle ISO 30 with dimension visualizer. Operating range x=800 mm, y= 350 mm, z= 300 mm.
- Lathe **Ursus** 250 , mandrel hole diameter 100 mm. Working range up to Φ=350 mm.
- Lathe **Grazioli** 250 mandrel hole diameter 60 mm
- Lathe **Gildemeister** automatico, mandrel hole diameter 50 mm
- Automatic bending machine **Colgar** for stainless steel 5 mm thick.
- Automatic bender **Colgar** for calendering diameters 120 mm – 500 mm, maximum thickness 5 mm
- Saw **Opus** semiautomatic
- Saw **Opus**
- Cutting-off machine **Thomas** 260
- Welding machine TIG **Miller** 300 A (aluminum – stainless steel)
- Welding machine TIG **Miller** 250 A (aluminum – stainless steel)
- Plasma cutter (aluminum up to 10 mm thickness, stainless steel up to 5 mm)
- Optical machine 3D Alpha Mod. Venture 3d CNCN : measurement field 300x300x150 mm.
- Roughness meter SM mod. RT-80; range 30-300 μm.

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