Curriculum Vitae
Luciano Calabretta

Dr. Luciano Calabretta is a senior scientist of National Institute for Nuclear Physics (INFN). He works at Laboratori Nazionali del Sud (LNS) in Catania since 1981.

Positions of responsibilities

- October 2016 reviewer of the project "Superconducting Cyclotron SC200 for proton therapy in HeFei (China);
- March 2016, member of the scientific Advisory Board of IPAC17;
- January 2016, reviewer for the "RISP ISOL Driver at RISP" Daejeon, South Korea;
- January 2016 reviewer for the "Research Activities of the RIKEN Accelerator Group", Wako Campus, Saitama, Japan;
- Since 1995, member of the International Organizing Committee of International Cyclotron Conference and their Applications (ICCA);
- Since November 2007 up to December 2015, in charge of the INFN-LNS Research Division;
- Since December 2014 member of the project group ELIMED, which has to build a therapy beam line for the facility ELI-beamlines of Praga (check republic);
- Since may 2015 consultant for the Rare Isotope Science Project (RISP) founded by the Institute of Base Science (IBS, Daejeon, Korea) for a new cyclotron able to deliver 1 mA deuteron beam at 80 MeV;
- June 2012 to December 2014, in charge to coordinate the test experiment CAPEN supported by the 5th Scientific Committee of INFN, in the frame of the collaboration among the INFN, MIT of Boston and Best Cyclotron Co.;
- May 2012, member of a committee to evaluate the private company BEST Cyclotrons Inc. of Vancouver (Canada);
- 2011/12 and 2012/13, in charge of a 48 hours lesson course on "Particle Accelerators and their Applications" at Physics department of Catania University;
- June 2007 to December 2012 in charge of task "Target and Beam Transport and Purification" of SPES project (LNL-INF);
- 2009 up to now, member of the committee in charge to select the supplier of the 70 MeV proton cyclotron for the SPES project and for the acceptance tests;
- November 2008 to December 2011, member of the committee INFN-MED and in charge of the section "Accelerators for Hadron Therapy";
- September 2002 to November 2007, LNS coordinator for the activity of 5th Scientific National Commission of INFN;
- 2004 to 2007, chairman of the International Conference on Cyclotrons and their Applications";
- 2006-2009, in charge of the SCENT group to design a 300 AMeV cyclotron to deliver protons and Carbon ions for therapy, in the frame of the collaboration agreement between INFN and IBA Company;
- 2003 to 2005, in charge of the project SCENT (Superconducting Cyclotron for Exotic Nuclei production and Therapy) supported by the 5th Scientific Committee of INFN;
- 2002, member of evaluation panel of the superconducting cyclotron for the project TRADE of ENEA;
- 1995 to 2001, in charge of INFN-LNS Accelerator Division;
- 1989 to 1995, assistant to the Leader of "Superconducting Cyclotron" project with the charge to coordinate the assembling and commissioning of the superconducting cyclotron of the LNS-Catania.

Scientifics activities

- December 2015, Expert of the IAEA for the project "Developing Human Resource Capabilities in the Area of Advanced Radiotherapy", Buenos Aires,;

- From 2014, Member of the group in charge to upgrade the Superconducting Cyclotron of the LNS-INFN Catania to deliver beam power higher than 5 kW;

- since 2010 up to now, member of the DAEdALUS collaboration, for the measure of the CP violation in the neutrino sector. He is studying the cyclotron complex to produce a proton beam with maximum energy of 800 MeV and peak intensity of 10 mA. He has studied a 60 MeV/amu normal conducting cyclotron and a 6 sectors superconducting cyclotron ring.

- May 2015, Consultant of the RISP project (DAEJEON, Korea) to evaluate the feasibility of a cyclotron for the production of a Deuteron beam at 40 MeV/amu with intensity of 1 mA. On June 2015 a workshop was organized at RIKEN in Tokyo to evaluate the feasibility of this project.

- October 2007 up to now, on request of the LNS and Laboratori Nazionali di Legnaro (LNL) , He is co-working with the team group for the SPES project and he was the spoken person for the task "Target & Beam Transport" until dec. 2012. He has studied the beam transport line and the High Resolution Mass Separator with a mass resolving power > 40.000.

- 2009-2010, study, design and realization of the new extraction beam line of the LNS superconducting cyclotron to increase of a factor 10 the production and transport of the radioactive beams produced with the in-flight technique.

- 2003 to 2009, study and design of a superconducting cyclotron able to deliver a 300 MeV/n carbon beam and proton beam at energy of 260 MeV. This cyclotron could be used mainly for the hadron therapy. According to the good result of these studies on July 2006 a cooperation agreement was signed between the INFN and Belgian company IBA (Ion Beam Accelerators), world leader in the construction of commercial cyclotron. The IBA company has to promote the INFN cyclotron project and will build the machine when a contract will be signed. The cooperation agreement gives the responsibility of the project and of the commissioning to the INFN. on June 2008, an addendum to the previous cooperation agreement was signed between INFN and IBA. According to this addendum, the working team lead by Dr. Calabretta start the executive design of cyclotron while the IBA company support this project with an amount of money equivalent to three annual contract for scientists.

The high scientific level of the project was recognized by the invitation to present the project at the XII International Conference on Cyclotron and their Application, held at Tokyo on October 2004. On the year 2006, Dr. Calabretta was invited by CIAE (Chinese Institute for Atomic Energy) to present the SCENT project at Beijing. On the year 2007 He was also invited by the University of Valencia and Warsaw to present the SCENT project.

He is patent holder, presented on 2004 August 11th , on the subject "Method to design a radiofrequecy cavity, in particular to be used for a cyclotron, and radiofrequency cavity build using this method, and cyclotron using this cavity".

Since 2007 to 2009 he was involved in the experiments MOBIDIC and FRAG, supported by the scientific commission of INFN 5th and 3rd respectively. The goal of these experiments was to improve the knowledge around the use of carbon ion beam for the oncology therapies. In particular:

- **to understand if and how design a beam line to purify a carbon beam after that its energy has been decreased by the crossing through a target absorber;**
- **To measure the yields for the different fragments produced by the carbon nuclei which strike the nuclei inside the human tissues;**

These data are very interesting to improve the simulation code and also the so called TPS "Treatment Planning System" computer code used to define the treatment procedure . The measure of fragmentation cross section are also interesting for the NASA program in the perspective of the future space voyages. The preliminary results have been presented in different international conference.

Dr. Calabretta was "Team Leader" of the LNS group which worked to the project "Dynamic of Fusion-Fission and Fission-Scission Phenomena", supported by the European Union in the framework of the program INTAS for the period 2005-2007. In the year 2007 an experiment to investigate the superasymmetric fission mode A=78 in 238U(d, pf) reaction at intermediate energy was performed at the LNS in Catania. With the same group of DUBNA some years before were performed similar experiment to study the fission induced by carbon and Oxigen ions at energy subthreshold of fission in nuclei neutrons deficient ^{220,224,226}Th, to measure the amount of the contributes of symmetric and asymmetric fission for the thorium and Radium isotopes. The experiment results were useful to validate the nuclear complex model developed by Dubna group.

On 1998 the INFN management asked to Dr. Calabretta to work with the Italian company Ansaldo Energia to develop a project to build an accelerator complex cyclotron based, able to feed a subcritical reactor of about 80 MW. This preliminary design was a preliminary step towards the executive project for an Accelerator Driven system full scale dedicated to the transmutation of the nuclear waste and/or to the energy production. On the years 1998 and 1999 He joint the 1st and 2nd workshop on "Utlilisation and reliability of high Power Proton Accelerators" organised by NEA-OECD (Nuclear Energy Atomic – Organization for Economic Co-operation and Development) and he presented oral contributions which were published in workshop proceedings.

Triggered by this activity He studied the opportunity to use superconducting cyclotrons to accelerate molecular beam of H_2^+. Indeed, in this case is possible to extract the beam from the accelerator using the so called stripping method. This method being generally used in commercial cyclotron and also in research cyclotrons to extract the H- beams. The studies preformed have underlined the feasibility to deliver high proton current beam up to 10 mA at energies in the territory 110–150 MeV using compact superconducting cyclotrons. Was also investigated the feasibility of a superconducting ring cyclotron, separated sector, to achieve energies up to 1 GeV.

In the year 1999 He asked at the AIMA company (Accelerators for Industrial and Medical Application) a preliminary study and a budgetary quotation to build a superconducting cyclotron for the acceleration of ion beam with charge to mass ratio q/A=0.5 up to the energy of 110 MeV/amu. This cyclotron should be a good driver for the EXCYT facility of LNS. On the 2002 Dr. Calabretta was called by the General Director of ENEA, Prof. Carlo Rubbia, to be member of a scientific committee in charge to evaluate the project of AIMA for a superconducting cyclotron for the project TRADE.

Since the 1997 Dr. Calabretta was involved in the study, design, realization and commissioning of the EXCYT (EXotic ion beams at CYclotron and Tandem) facility for the production and acceleration by the tandem accelerator of the exotics beam produced by fragmentation of the beam delivered by the cyclotron of the LNS. The EXCYT project is based on the production of radioactive ions by fragmentation induced by ions beam

with medium-light mass delivered by the LNS cyclotron at energy 50-70 MeV/amu on a graphite target. The radioactive nuclei are then extracted by the target and ionized inside a proper source to be accelerated by the LNS tandem accelerator. In the framework of the EXCYT project Dr. Calabretta has coordinate the assembling and the commissioning of the axial injection line for the cyclotron, the so called beam line for the primary beam and the system for the beam attenuation by pepper pot collimator and by the low energy chopper. In particular in the year 2003-2005 he has also studied a diagnostic device to monitor the right beam position and current intensity of the beam on-line and of the commissioning of the transport line from the cyclotron to the EXCYT target. He participated at the beam extraction with power of about 100 W. This result was also achieved thank to the low energy chopper designed just by Dr. Calabretta and which allow to change the beam intensity with continuity and without change the beam space charge density and without the insertion of physical object that often modified the beam features.

In the years 2000-2006 he designed a new transport optic for the extraction beam line to use this line like a Fragment separator for Radioactive Ions Beam (FRIB) produced at an intermediate target station. This new configuration joint with a tagging detector allow the experimental group to perform experiment using radioactive nuclei in flight selected. With this technique was performed an experiment which has demonstrated the existence of a new kind of nuclear de-excitation by the emission of two strongly correlated proton.

In the years 2000-2003 he participated to the study and realization of the experimental device to perform the experiment called "Big Bang". The experiment goal was to measure the cross section of the process 8Li(alfa, n)11B to have indication on the two model of homogeneous and inhomogeneous Big Bang. The measure performed by the experiment were in agreement with other data already measured and thanks to a lower statistical error our experiment help to discriminate between the two model.

In the years 2000-2001 he was involved in the working test and characterization of the accelerator prototype module LIBO (LInac BOoster). The working test of the module demonstrate its ability to increase the beam energy of the 62 MeV proton beam up to 72 MeV, [16]. A useful tool for the working test was also the use of a low energy chopper designed and realized by Dr. Calabretta some year before. This chopper allows to fit the duty cycle of the cyclotron to the duty cycle of the LIBO module and to synchronize the two accelerators.

In the years 1999-2000 he studied a new chopper for the cyclotron beam, called "Chopper-500", to reduce the beam bunch delivered by the cyclotron from the original length of 1-3 nsec to the short length of 500 psec, according to the request of the multi array detector CHIMERA and by other experimental set-up.

In the same period, he has designed a new beam line called "By-Pass" which allow the operators to deliver the tandem beam to two experimental beam line at the same time that the cyclotron beam is delivered in other experimental rooms. The By-Pass line is in operation since the 2003.

In April 1998 he was invited to present a talk on "Effects of INFN Scientific Activities on Technological Advances of Small & Medium Industries" at the convention "R&D INDIA'98" on the item "Converting Research into Development" which was held in Kolkata. It is relevant that the other only two foreign peoples invited to participate to convention were the Director of the IN2P3, at that time Prof. Claude Detraz, and

Dr. David Jacobs, at that time deputy leader of the CERN Technological information division.

In the years 1997-1998 he participated to the design study of the injection beam line and of the central region of the cyclotron. These improvements allow to operate the cyclotron in the stand alone mode avoiding the beam injection from the tandem. He proposed also the insertion of moveable slit placed inside the RF cavity to perform a roughly longitudinal cut of the beam.

On July 1997 on behalf of the LNS Director, presented to the INFN management the proposal of the LNS development for the years 1999-2003.

Dr. Calabretta together with Dr. Cuttone proposed on the 1996 to start the project CATANA (Center for Applied Therapy and Advanced Nuclear Application), to use the proton beam accelerated up to 62 MeV by the LNS Cyclotron to treat the ocular melanoma and other similar pathologies.

From 1995 up to 2002 he designed and commissioned the new beam line complex to deserve the beam at the new experimental area of the LNS. Moreover, he designed and commissioned a new bunching system for the axial injection of the cyclotron and a chopper device to satisfy the request of the experimental users.

From 1992 up to the 1996 he has designed and commissioned the superconducting solenoid SOLE. This solenoid is used to collect the reaction products emitted inside a solid angle of 30 mster., with momentum dispersion of ±10% and with magnetic rigidity up to 4.5 Tm inside a detector placed at a distance of 15 m ahead. The simulation shown that it is possible to achieve a precision of impulse measurement of about 0.2%.

From 1987 to 1991 he designed and commissioned the magnetic spectrometer for charged pions CLAMSUD. This spectrometer have a big solid angle of about 35 mster, a good energy resolution of about 0.1% and a large momentum acceptance ±30 %. The optical properties of the spectrometer were measured using alfa source and the tandem beam of the LNS. The CLAMSUD spectrometer was transported in different European laboratories to perform many experiments. An important role in the use of the spectrometer was the develop of the code CARO (Computer Aid for Reconstruction and Optimization) which allow to optimize the reconstruction function on the base of a preliminary experimental measurement data. The reconstruction function allow to fix the energy of a particle from the parameter (x,theta,y, phi) measured on the focal plane of the spectrometer.

From 1984 to 1995 He also studied, designed and commissioned:

- **the injection and extraction beam line for the LNS superconducting cyclotron;**
- **the system of beam transfer line from the accelerators room to the experimental rooms;**
- **the bunching system for the proper injection of the tandem beam into the cyclotron.**

From 1977 to 1988 he worked both in the field s of nuclear physics and of accelerators. In particular, he participated to the experimental measurement of the:

- **photo-fission cross section of ^{238}U with the goal to put in evidence the effects due to a second minimum in to the fission barrier of ^{238}U;**

- **photo-fission cross section of ^{232}Th, more difficult of the previous due to the lower yield, but scientifically very appealing due to the theoretical indication for a triple bump fission barrier;**
- **gamma radiation emitted by nuclei highly deformed at high spin using a multiplicity filter in the reaction ^{124}Sn (^{28}Si ,5n) ^{147}Gd.**

Dr. L. Calabretta started his working activity on January 1979 as fellow of EURATOM at the BCMN (Central Bureau of Nuclear Measurements) of Geel, Belgium, where he worked up to march 1980. In that period he made a measure of cross section of neutron capture and fission in the reaction n(235U, gamma), n(235U,f).

Dr. L. Calabretta has been member of many examiner boards for public employments for senior scientist, scientist and technicians of INFN;

He has been invited to present the results of his studies in many national and international conferences;

He was co-examiner of 17 thesis for Physics or Engineer degree and for 2 Ph.D. thesis;

He hold lesson courses on accelerators for the Physics Specialization school of Catania University and for the INFN scientist and technicians.

Past Students of Luciano Calabretta:

- Dott . Cuttone is now director of National laboratory of South, this is the laboratory where I work.

- Dott. Tuvè is a scientist of INFN she works at the physics department of Catania, near to LNS-INFN laboratory

- Dott. Santo Gammino and Ing. Luigi Celona are experts in ECR ion source, they both work at LNS-INFN laboratory Catania. Gammino is in charge of the LEBT and Ion source for the European Spallation Source (ESS).

- Celona is in charge for the construction of a new ECR ion source for Hadron therapy center called AISHA.

- Alberto Rovelli, is work in the research division as responsible of the service submarine infrastructures.

Other two past students, Mario Maggiore and Daniela Campo, are now working in Legnaro Laboratory INFN, for the installation and commissioning of the 70 MeV proton Cyclotron build by company BEST cyclotron.

Another engineer, Leandro Piazza, now work with a permanent position at Best Cyclotron company in Vancouver.

Alessandra Calanna, has worked at IBA company, and in the last 6 years she has worked with me to design the Daedalus superconducting cyclotron and now she is involved in the design of the new superconducting magnet for the upgrading of Catania Cyclotron.

Grazia D'Agostino is a Ph. D. Student, at Catania University and She is working with me at the project to upgrade the LNS-INFN Superconducting Cyclotron.