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The KN3000 Accelerator and the History of the Nuclear Physics in Florence in the Last Three Decades of the Past Century through a Museum Itinerary

Mariaelena Fedi - Istituto Nazionale di Fisica Nucleare, sezione di Firenze - mariaelena.fedi@fi.infn.it
Samuele Straulino - Dipartimento di Fisica e Astronomia dell'Università di Firenze - samuele.straulino@unifi.it

Abstract: The "Garbasso" building housed the Institute (later Department) of Physics of the University of Florence from 1921 to the early 2000s. It was built on the hill of Arcetri, close to the Astronomical Observatory and to the Villa that many years earlier had hosted Galileo. Among many research activities developed here during almost the entire 20th century, the history of the KN3000 accelerator is really interesting. In fact, the electron injector of the *electrosynchrotron* installed by CNEN in Frascati, once dismissed, was assigned in 1971 to the nuclear physics group in Florence and here was converted to a positive-ion accelerator, exploiting the locally available technological expertise. Afterwards, it has been used for research in pure and applied nuclear physics for three decades. After the installation in 2003 of a 3 MV Tandem accelerator in the new Physics Department of the University, in Sesto Fiorentino, thanks to a special funding by INFN, the KN3000 was decommissioned and left in the room where it has been in operation for years. After a long period of inactivity, part of the original staff suggested to restore the accelerator and the associated equipment to create a museum exhibition. In the planned museum, the accelerator is one of the stages of a wider route which, together with Villa Galileo, also includes two institutions whose operations are still based on the hill of Arcetri: Observatory (OAA-INAF) and National Institute of Optics (INO-CNR). The accelerator project, mainly funded by Fondazione Cassa di Risparmio di Firenze and the University of Firenze (UNIFI) and receiving significant support from INFN, will be completed by the first half of 2023.

Keywords: Particle Accelerator, Nuclear Physics, Galileo Galilei.

1. Arcetri

The hill of Arcetri represents a place of natural beauty, history and science, as the aerial photo taken in 1985 (Fig. 1) suggests. Four main buildings can be identified: the so-called Garbasso building (A), which housed the University's Physics Department, the CNR – National Institute of Optics (B), the Solar Tower (C) and the Arcetri Observatory (D) of the National Institute of Astrophysics (INAF). Since the early 2000s, the Physics Department (currently Physics and Astronomy Department) has moved to the new University scientific area, located in Sesto Fiorentino. However, the hill remains a living place of science, as activities are still ongoing at CNR – INO and INAF. Moreover, the Garbasso building houses now the Galileo Galilei Institute (GGI) for theoretical physics, a national center for advanced studies of the National Institute of Nuclear Physics (INFN), while some rooms of the same building are kept by University members working at the nearby Observatory. “Villa il Gioiello”, where Galileo stayed in the last years of his life, is a few hundred meters away from the Department. The Villa has recently undergone restoration and rearrangement interventions; it is at present one of the interest points of the “Sistema Museale” of the University of Florence. On May 17, 2013 the hill of Arcetri was declared a historic site of the European Physical Society because of the history of the Institutes, the significance of the research carried out in the past decades and the high level of the scientists who worked there.

Fig. 1. Old aerial photo (1985) of the hill of Arcetri (Florence).

At the beginning, the leading actor of this story of the Physics Department was Antonio Garbasso, who got the idea of making a new building to house the Physics Institute, which in the early 20th century was located in the center of Florence. Garbasso offered the local scientific community a more comfortable and suitable environment for the research that was developing in those years. The building was inaugurated on November 7, 1921. Garbasso was an undisputed protagonist not only from a logistical and architectural point of view, but also because he recruited many important figures for the nascent university, including people of absolute importance, such as Rita Brunetti, Vasco Ronchi, Franco Rasetti, Enrico Fermi, Enrico Persico, Bruno Rossi, Beppo Occhialini, Gilberto Bernardini, Daria Bocciarelli, Giulio Racah: for this reason, historians of science refer to the “school of Arcetri” when speaking about scientists working there in that period. Several photos illustrate those years’ life in Arcetri, such as the one reported in Fig. 2, showing a moment of ease during a lunch among colleagues. The activities carried out in Arcetri in 1920's and 1930's can be reconstructed through many testimonies. As an example, Michele Della Corte reports when, as a high school student, went with his class to the hill of Arcetri in the early 1930's: "Basically there were two fields of research: some problems of nuclear physics concerning, if I remember correctly, the interactions of alpha particles with nuclei, and cosmic radiation. It was the first time I had heard of this topic and I was fascinated by it. With great clarity Bernardini explained to us the structure and functioning of the Geiger counters and the coincidence records recently devised by Bruno Rossi" (Della Corte 1999). A complete picture of the activities carried out in that period at the Institute of Physics is outlined in (Casalbuoni *et al*. 2021).

Fig. 2. A lunch in Arcetri around 1935. From left to right: Lorenzo Emo Capodilista, Beatrice Crinò, Gilberto Bernardini, Attilio Colacevich, Daria Bocciarelli.

2. Nuclear Physics with accelerators in Florence

In the following years, research activities in nuclear and subnuclear physics became increasingly differentiated. In the specific case described here, the installation of the first particle accelerator, named PN400, is worth to be mentioned. The PN400 accelerator, which is now on display in the entrance hall of the Department of Physics and Astronomy in Sesto Fiorentino, was installed in a small bunker connected to the main building. It had a terminal voltage of 400 kV and, being equipped with a source for hydrogen ions, was capable of accelerating protons and deutons. By using this accelerator, nuclear physics studies were carried out, in particular production of isomeric states, measurements of decay times and cross sections. The research group initially included Manlio Mandò (leader), Tito Fazzini, Piergiorgio Bizzeti, Anna Maria Bizzeti-Sona, Mario Bocciolini, Giuliano di Caporiacco, Pietro Sona, Paolo Maurenzig, Nello Taccetti, Paolo Blasi.

At the end of the 1960s, this accelerator was not powerful enough for the planned researches and the nuclear group faced the problem of purchasing or acquiring a new machine. Some years before, in the INFN National Laboratories of Frascati, the *electro-synchrotron* had been assembled; its injector was an accelerator for electrons (KS3000) built in 1956 by High Voltage Engineering Corporation (Massachusetts), which had remained in operation until the end of the 1960s. When the KS3000 in Frascati was going to be dismissed, the Florence group applied for the assignment of this accelerator and this was moved to Arcetri in the early seventies. Here, with a great deal of work by technicians and researchers, it was converted into a positive ion accelerator and renamed KN3000. In the meantime, the laboratory was also expanded: a larger bunker was built with a new measurement room. In Fig. 3 the location of the accelerator in the period 1982–2003 is shown. At the beginning, only nuclear spectroscopy measurements were made with the KN3000 machine. However, the group composed of Piergiorgio Bizzeti, Maurizio Bini, Tito Fazzini, Paolo Maurenzig, Andrea Perego, Giacomo Poggi, Pietro Sona, Nello Taccetti was dedicated to measurements of parity violation of nuclei (FWEIN and WEIN2 experiments) (Taccetti 2017). The FWEIN apparatus is shown in Fig. 4: in this picture we can see some people who today promote the recovery of the accelerator as a museum.

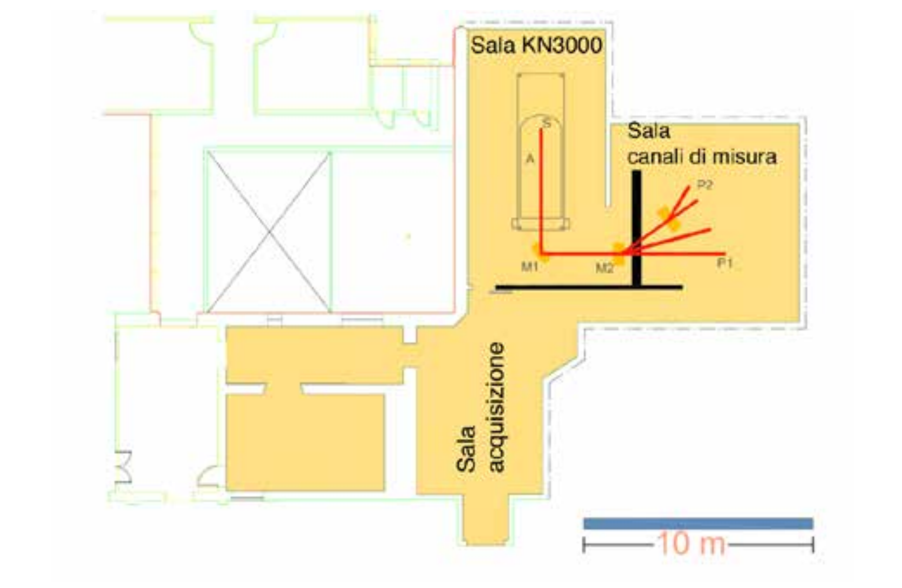

Fig. 3. Set-up of the KN3000 in the period 1982-2003. Red lines represent the beam lines (four in the last period of activity), while black lines are concrete shields.

In the subsequent years, further developments took place, especially from the mid-1980s. Mainly thanks to the initiative of Pier Andrea Mandò, the accelerator began to be used also for measurements in the fields of environmental physics and cultural heritage, with a measurement channel dedicated to these studies (Mandò 2013). Over time, such activities became prevalent among those carried out at the accelerator, since the nuclear group has moved to other experimental themes, such as the dynamics of collisions among nuclei, which required larger accelerators in other experimental sites in Italy and abroad. In Fig. 5, the external beam set-up to study artworks and environmental samples is shown: this is one of the first miniatures analyzed using the PIXE technique around 1986. PIXE (Particle Induced X-ray Emission) allows us to obtain information about the elements present in an object or a sample, analyzing the characteristic X-rays emitted from the material under study after irradiation by the accelerated protons. This method can be used to study the composition of any material that can be brought to the laboratory, such as the atmospheric particulate matter collected on filters or the pigments in ancient miniatures, as in the example shown in the figure. A great technological advance of those years was the achievement of the external beam: this made irradiating the object under study much easier and safer, basically removing the need to collect samples, thus contributing to enhance the non-invasivity and non-destructivity characteristics of PIXE.

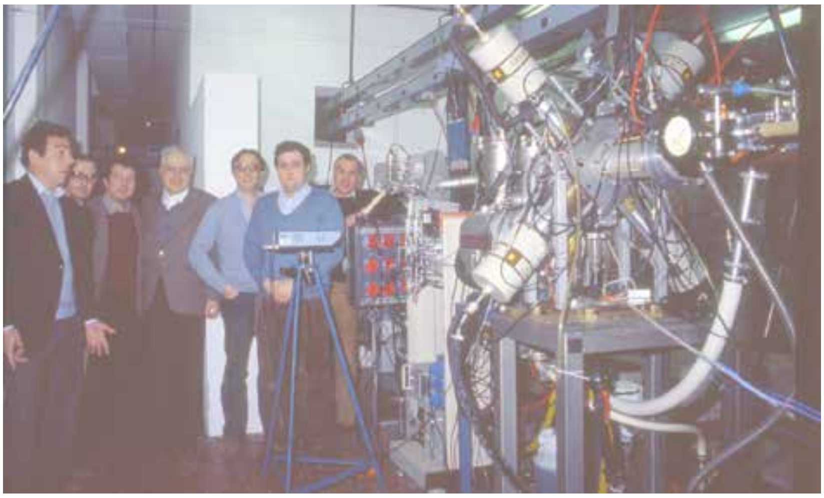

Fig. 4. A picture of the FWEIN experiment in the 1980's. From left to right: N. Taccetti, P. Calonaci, M. Bini, T. Fazzini, P. Del Carmine, G. Poggi and A. Pecchioli.

These studies have continued until 2003, when the definitive transfer to the Sesto Fiorentino new site took place. Here, in the laboratory called LABEC, Laboratory of Nuclear Techniques for the Environment and Cultural Heritage, a new Tandem accelerator funded by INFN was installed. In continuity with what have been started in Arcetri, but also expanding the experimental capabilities and the fields of application, many techniques are today commonly applied and developed, such as Ion Beam Analysis (IBA), including PIXE, Accelerator Mass Spectrometry (AMS), implantations, detector tests.

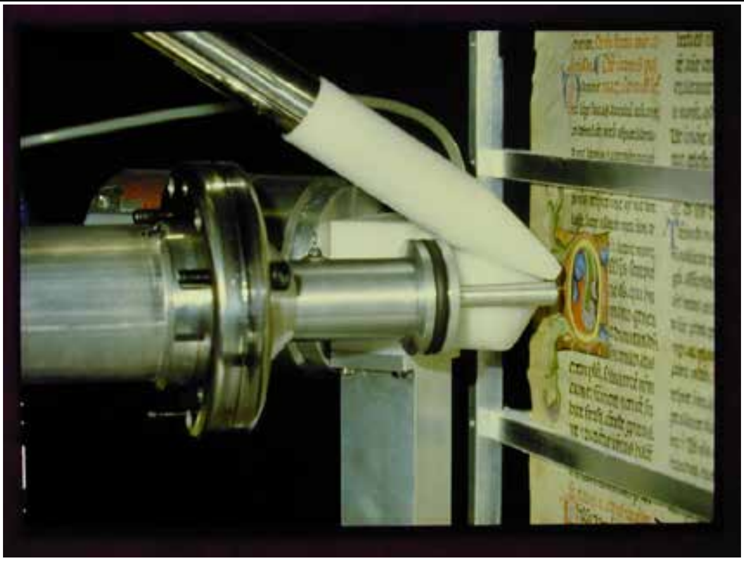

Fig. 5. The PIXE technique applied on a miniature, around 1986.

3. The "route of science in Arcetri"

The laboratories in Arcetri thus remained empty and rapidly deteriorated due to some infiltration of water from the ceiling. Despite the apparent decay, the people who had worked on the KN3000 facility had the idea to enhance the accelerator in a museum sense, to reconstruct a part of the Florentine physics of the 20th century. In 2016, the proposal of creating an educational-scientific itinerary on the hill of Arcetri was born, involving all the institutions there present (UNIFI, INFN, INO-CNR, OAA-INAF).

There were several reasons promoting this idea: the intense dissemination activity of the Observatory, which has ever welcomed many school classes until the beginning of the pandemic emergency in 2020, the renewed attendance of "Villa Il Gioiello" for scientific meetings, the proposal of the restoration of the accelerator by old users and the existence, starting from 2011, of a collaboration agreement ("Il Colle di Galileo") among the aforementioned institutions that are present in loco. In 2018, the proposed "route of science in Arcetri" has really started, thanks to the availability of funding from the Cassa di Risparmio di Firenze Foundation. It represents a scientific and educational path consisting of various stages, located in those buildings that one can meet along the internal road of the Campus (the KN3000 accelerator within the Garbasso building, the National Institute of Optics, the Arcetri Astrophysical Observatory), also including "Villa il Gioiello" for its valuable historical significance.

For the accelerator stage, a restoration of the laboratories, financed by the University of Florence, will start shortly, and a subsequent museum installation will be created (a project has been prepared and discussed in detail and is in the final approval stage).

The set-up will be of educational type, to allow visiting students and general public to discover and understand basics of radioactivity and how the machine worked.

In the entrance corridor, the history of nuclear physics research in the building is highlighted through portraits of scientists and the main achievements reached by the Florentine school. Then visitors enter a first room dedicated to natural radioactivity, where we plan to show simple radiation detection by Geiger counters and more advanced measurements using germanium detectors. In the same room, a detector will count the incoming cosmic rays using the coincidence circuit by Bruno Rossi. In the next room, a small Van de Graaff generator, as an example of an electrostatic machine capable of reaching high potential differences, and a fine beam tube, to show the magnetic deflection of an electron beam in a low pressure tube, are placed: these devices explain the fundamental working principles of the accelerator. Then visitors enter the accelerator room: here they find a large room, as the dividing walls serving as shields, drawn in black in Fig. 3, will be demolished. Two measurement points will be reconstructed, even though without obviously restoring the functionality of the particle accelerator. One channel will be dedicated to the experiments carried out in the past on fundamental physics studies and the other one to measurements in the applied physics field.

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