A C-14 beam monitor using silicon solid state sensor for cultural heritage

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on behalf of the INFN CHNet Lilliput experiment

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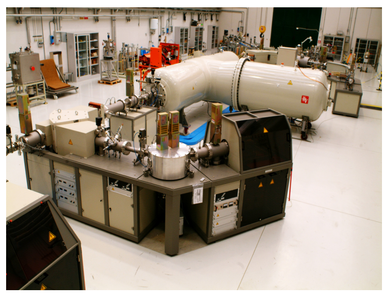
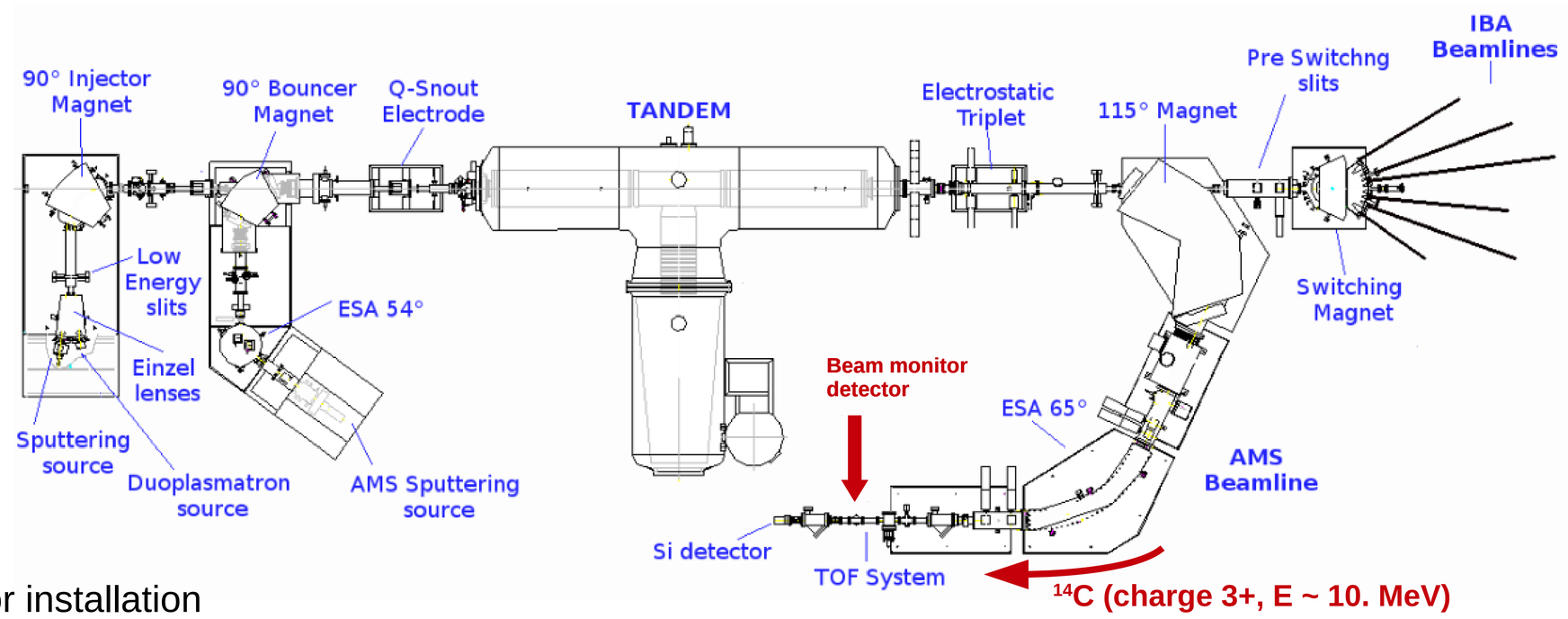
We report the design and preliminary test results of a C-14 beam monitor developed for the online monitoring for radiocarbon dating. The challenge of the INFN CHNet_Lilliput experiment is to measure the amount of carbon in very small samples (down to a few micro-grams) with a very low concentration of radiocarbon. For this purpose, a new dedicate beam monitor for C-14 ions (energy around 10 MeV) uses a silicon solid state detector made of 4 independent sectors, active area 50x50mm^2 and 300micrometer thickness. The detector is preliminary tested in the INFN Laboratory of Bari and then installed on the final part of the Accelerator Mass Spectrometry (AMS) beam line at the INFN-Labec laboratory of Florence (Italy) where since 2004, sample measurements for radiocarbon dating are performed.

CHNet LABEC

Accelerator Mass Spectrometry (AMS) measurements are performed at the Tandem (3 MV maximum terminal voltage) accelerator of LABEC (Laboratorio di tecniche nucleari per l'Ambiente e i Beni Culturali), INFN-Firenze. Three ion sources and 6 beam lines dedicated to Ion Beam Analysis (IBA) and AMS measurements. Schematic layout of the AMS beam line at INFN-LABEC (the ion sources and the different beam lines dedicated to IBA measurements are not shown here. The AMS beam line can be divided in three sections: low-energy side, Tandem Accelerator and high energy side;

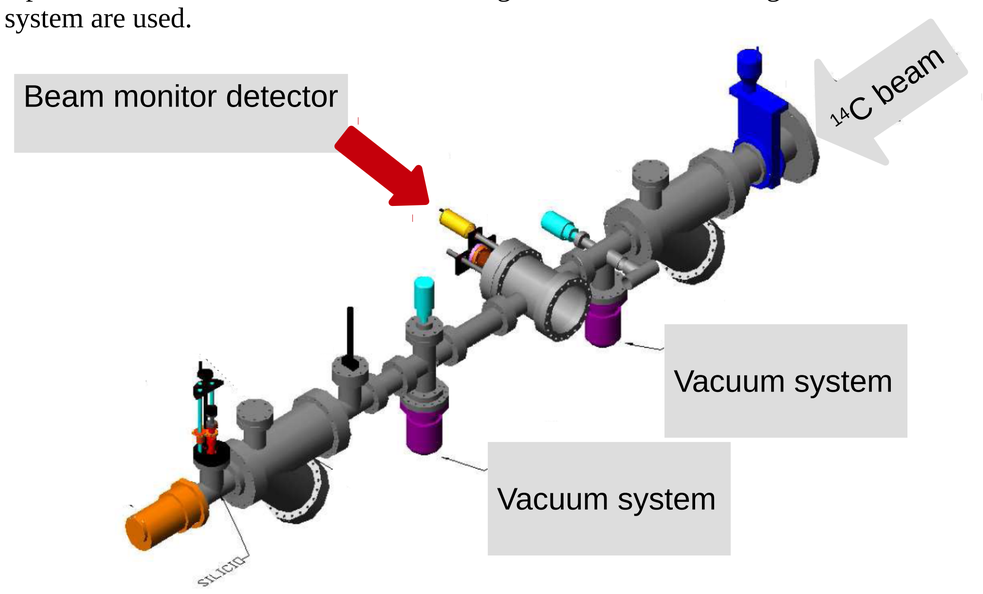




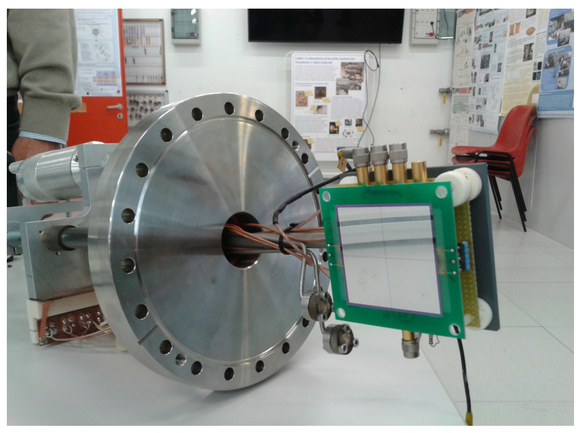
Detector installation

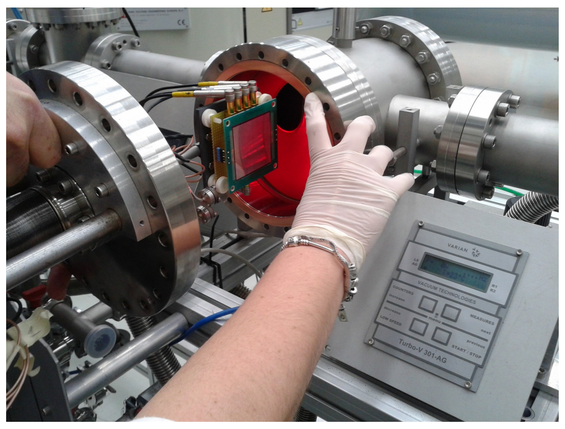
The typical ^{14}C counting rate expected in the case of modern sample ($^{14}C/^{12}C \sim 10^{12}$) is about 15 counts/s. A Faraday cup cannot be used to detect the ^{14}C current as in case of ^{12}C and ^{13}C. The low counting rate allows the use of a solid state detector without a significant deterioration of its performance. For these reasons, a silicon photodiode detector (1 x 1 cm^2, 300 μm) is located at the end of the AMS beam line at LABEC.

An upgrade of this system is based on the use of a larger photodiode detector (5 x 5 cm^2 , thickness 300 μm), made of 4 independent sectors that can allow the counting of ^{14}C and the beam monitoring: it has been installed in the May 2018 close to the Faraday cups. The mechanical drawing of the whole new part of the beam line is shown in figure below. The red arrow shows the exact position of the detector. A schematic diagram for the data taking is shown below. Two parallel system are used.



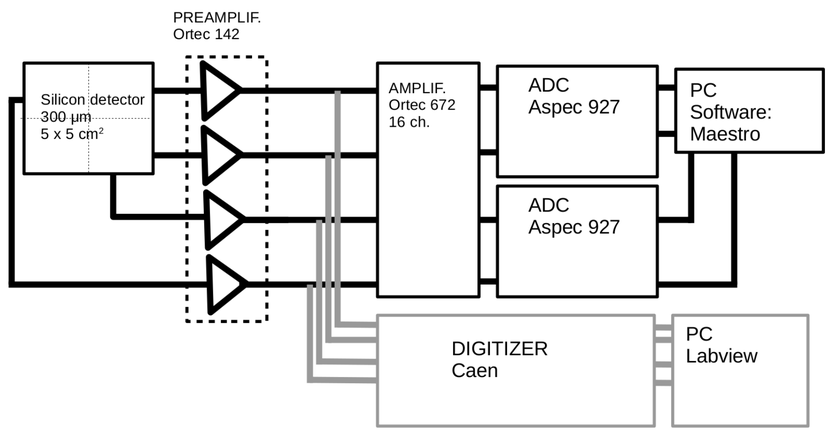
Below (left) a picture of the detector before and during the installation phase (right). The silicon detector has been mounted on a manually movable mechanical arm inserted inside a bellow. The overall excursion of the arm is 65 mm and allows the complete retraction of the detector from the beam line.



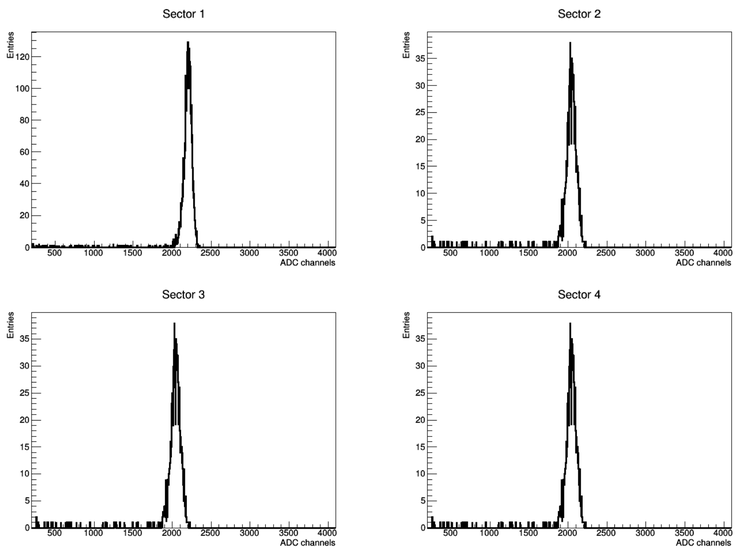


Preliminary results: detecting ^{14}C

After the installation, the detector has been biased applying a different voltage of 140V. Signals coming from the output of the preamplificator were preliminary viewed directly with an oscilloscope (~10 mV).
The detector has been tested using a pulser and radioactive α-emitting source (^{243}Am). The source was placed directly upon the sensitive side of the detector. During the test the vacuum was about 10^{-4} mbar.
A schematic diagram of the DAQ is shown below. Two different DAQ are used:
– preamplificator + amplificator + ADC + Maestro software[1] (black lines)
– preamplificator + digitazer (Caen) + software based on Labview (in phase of developing). The latter will be the default DAQ.
In both cases, the first collected data are analyzed using Root[2].



A standard sample (IAEA-C7 Oxalic Acid with certified radiocarbon concentration is 49.53 ± 0.12 pMC) has been used to test the detector. A typical spectrum collected during the measurements for each sector are shown: the possible interferences are suppressed and only one peak is observed in the spectrum. From the integral under the signal is possible to retrieve the counting rate and also, thanks to a dedicated algorithm (work in progress) it will be possible to monitor the beam position.



REFERENCE

[1] https://www.ortec-online.com/products/application-software/maestro-mca
[2] https://root.cern.ch

PM2018 - 14th Pisa Meeting on Advanced Detectors
from 27 May 2018 to 02 June 2018 (Europe/Rome) - *La Biodola, Isola d'Elba (Italy)*
Europe/Rome timezone