

Irradiation setup at the U-120M cyclotron facility

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We present a setup that is used for tests of radiation hardness at the U-120M cyclotron facility at the Nuclear Physics Institute of the Czech Academy of Sciences (NPI CAS). Methods which are used for on-line monitoring of beam parameters and total ionizing dose are discussed. The facility is extensively used for tests of radiation hardness of various electronic components for high-energy physics experiments including silicon sensors and FPGAs.

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1 Electronic components of high-energy physics detectors are often exposed to intensive fluxes
 2 of ionization radiation. This radiation deteriorates properties of materials and can introduce false
 3 signals in complex electronic circuits. Successful operation of these detectors thus requires to
 4 perform tests which show that all sensitive components are radiation hard enough.

5 The setup for radiation hardness studies, described in this proceeding, uses a 30 MeV proton
 6 beam provided by the isochronous cyclotron U-120M of the NPI CAS in Rez [1]. The cyclotron
 7 can be operated in positive and negative modes. In the positive mode, the cyclotron accelerates
 8 positive ions H^+ , D^+ , ${}^3He^{2+}$, and ${}^4He^{2+}$. They are extracted from the cyclotron by means of
 9 a three section electrostatic deflection system with a magnetic kicker. In the negative mode, the
 10 cyclotron can accelerate negative ions H^- and D^- . The output beam is extracted by an 1 μm
 11 thick carbon stripping foil. A negative ion loses both valence electrons by passing through the foil
 12 and the positively charged ion is directed by a magnetic field to a beamline. The energies of the
 13 extracted proton beam varies in the range from 6 to 37 MeV with the maximal current up to 50 μA .
 14 Tests of radiation hardness are carried out with the negative mode proton beam.

15 The beam current is controlled via modulation by a 150 Hz macropulsed signal. A duty cycle
 16 of the macropulse signal determines the frequency of proton microbunches injection to the cy-
 17 clotron and can be adjusted in the range from 5 to 65%. The microbunch structure of the beam is
 18 given by the cyclotron radiofrequency which is tunable from 10 MHz to 26 MHz [3].

19 A simplified scheme of the experimental setup which is used for radiation hardness tests is
 20 shown in Fig. 1. The end of the beamline is equipped with an energy degrader unit which allows
 21 for insertion of aluminum plates with different thickness to the beam. The plates can be used to
 22 absorb the proton beam or to change its parameters like energy or width, see Fig. 2.

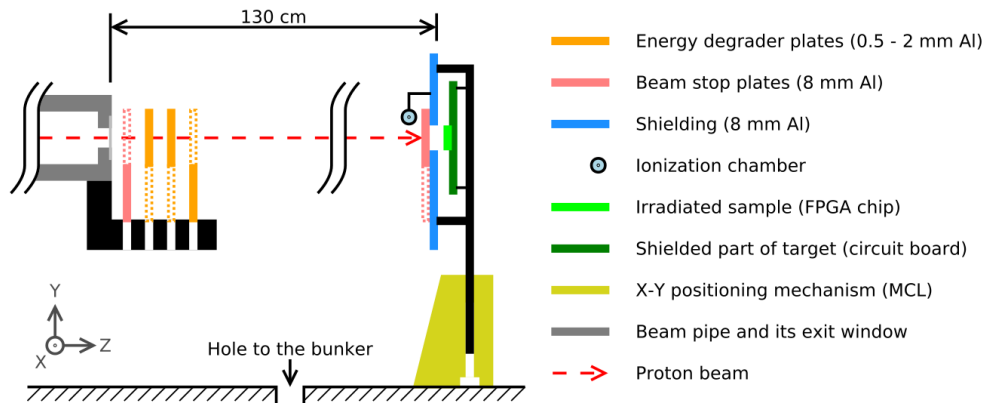


Figure 1: Scheme of the irradiation setup

23 The irradiated sample is placed on a remotely controlled X-Y positioning mechanism which
 24 is located 130 cm from the beamline. The arm of the setup with the tested sample is movable in
 25 transverse plane w.r.t. the beam. The arm further carries another remotely controlled beam shutter
 26 to shield the sample, and an ionization chamber which is fixed next to the tested sample and which
 27 is used for online monitoring of the proton flux. The chamber provides a linear response to the
 28 incoming proton flux up to 10^9 proton $cm^{-2}s^{-1}$ [1].

29 During irradiation, sample is placed to the beam center and the ionization chamber measures
 30 beam intensity at the beam periphery. When estimating the proton flux experienced by the sample,

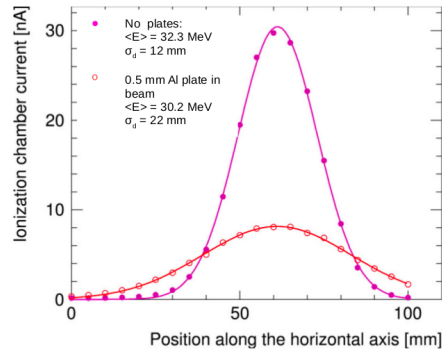


Figure 2: Profile of the proton beam for two energy degrader configurations as measured along the horizontal axis.. The beam profiles measured along the vertical axis look similar. The legend quotes the mean energy of the proton beam at the sample position and the Gaussian width of the beam.

31 we correct for this displacement by a scaling factor that we know from the measured Gaussian
 32 beam profile. The proton flux is monitored each 1 s and integrated in time to obtain proton fluence.
 33 The dose accumulated by the irradiated sample is calculated online using the formula:

$$D [\text{krad}] = 1.602 \times 10^{-8} \times S [\text{MeV cm}^2 \text{mg}^{-1}] \times F [\text{cm}^{-2}], \quad (1)$$

34 where S is the stopping power of the irradiated material and F is the proton fluence. Estimated
 35 systematic uncertainty of absorbed doses is about 10% [1].

36 In summary, the presented setup works at the open access irradiation facility CANAM [2] of
 37 the NPI CAS and it is suitable to perform radiation hardness studies for various electronic com-
 38 ponents. The facility was used in several studies, including characterization of FPGAs [4] for the
 39 readout unit of the new Inner Tracking System [5] of the ALICE experiment and radiation hardness
 40 study of the silicon ALPIDE pixel sensor [6].

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