PRELIMINARY TEST SETUP OF THE METU DEFOCUSING BEAM LINE, AN IRRADIATION TEST FACILITY IN TURKEY

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Abstract

METU-Defocusing Beam Line (METU-DBL) Project has been started in August 2015 and aims to construct a beam line at Turkish Atomic Energy Authority (TAEA) Sarayköy Nuclear Education and Research Center (SANAEM) Proton Accelerator Facility (PAF) to perform Single Event Effect (SEE) tests for the first time in Turkey. The METU-DBL is an 8m-long beam line which has quadrupole magnets to enlarge the beam size and collimators to reduce the flux. When complete, the METU-DBL will provide a beam that is suitable according to the ESA ESCC No. 25100 Single Event Effects Test Method and Guidelines standard. The final METU-DBL beam size at the target area will be 15.40 cm x 21.55 cm and the flux setting will be selectable between 10^5 p/cm^2/s and 10^{10} p/cm^2/s. The METU-DBL will serve space, particle, nuclear and medical physics communities starting from 2018 by performing irradiation tests. A preliminary test setup is being constructed towards first tests in May 2017. The beam size will be 6 cm x 8 cm and the flux will be 3.4×10^9 p/cm^2/s for preliminary test setup. The METU-DBL project construction status for the preliminary test setup is presented in this proceedings.

METU-DBL PROJECT

Radiation affects electronic components that are intended to be used in high radiation environments. These electronic components must be radiation tolerant or hard and must be tested before being employed in such environments. Total Ionising Dose (TID), Displacement Damage (DD) and Single Event Effects (SEEs) are effects that result from the radiation interaction with the materials in components.

METU-Defocusing Beam Line (METU-DBL) project is being constructed at the Turkish Atomic Energy Authority (TAEA) Sarayköy Nuclear Research and Education Center (SANAEM) Proton Accelerator Facility (PAF) in order to perform SEE tests for the first time in Turkey. 30 MeV protons are produced at the PAF and used for radioisotope production with a beam current variable between 0.1 µA to 1.2mA [1]. One room is dedicated for research purposes as shown in Figure 1 and has adjoining technical and control rooms. The beam size at the entrance of the R&D room is approximately 1 cm in diameter. METU-DBL has three quadrupole magnets, scattering foils, helium cooling section and collimators to satisfy the requirements of the ESA ESCC No. 25100 standard [2]. The beam kinetic energy must be between 20 MeV and 200 MeV with a beam size of 15.40 cm x 21.55cm. Also the proton flux must be 10^5 p/cm^2/s to at least 10^8 p/cm^2/s while having a uniformity of ±10% across the irradiation area. The fluence must be reached 10^{11} p/cm^2 for one irradiation.

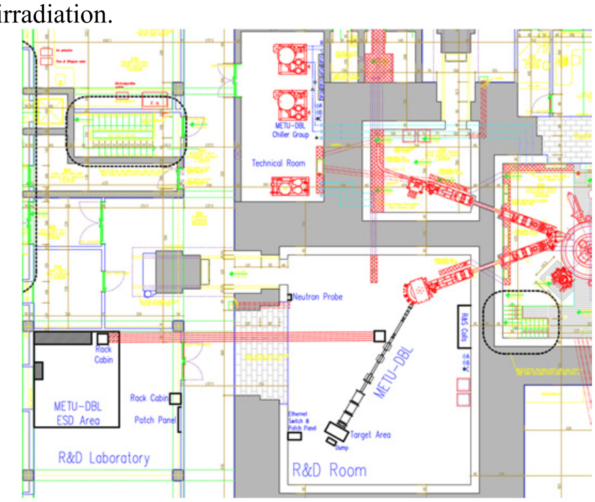

Figure 1: Drawing of R&D room, technical room and R&D laboratory at the PAF. METU-DBL is in the R&D room while the chiller group is shown in the technical room and the control of the METU-DBL will be done from the ESD area in the R&D laboratory.

The beam kinetic energy at the PAF is suitable but even the minimum beam current give a too high flux according to the aforementioned standard. The beam size must be enlarged and the flux must be reduced. Figure 2 shows the schematic of the METU-DBL. The METU-DBL will start from the exit of the 5-port switching magnet, which will be an important component for the R&D room of the PAF in order to have more experimental stations in the room. The first elements are a beam stopper and a vacuum valve connected to an interlock system. The first and the second quadrupole magnets were procured commercially from Scanditronix and the third quadrupole has been designed specially for the METU-DBL and will be produced in Turkey. The conic collimator will have a variable aperture to serve different fluxes to the users. The beam line will be under vacuum and the irradiations will be performed in air therefore a vacuum window is necessary at the end of the beam line.

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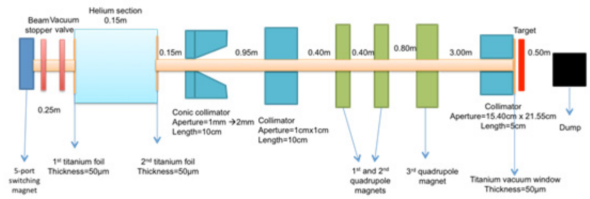


Figure 2: Schematic of the METU-DBL.

TURTLE program [3] is being used for the particle tracking simulations that is necessary to check the beam uniformity. Figure 3 shows the beam size after the vacuum window and Figure 4 shows the beam kinetic energy change along the METU-DBL generated by a TURTLE simulation. The required beam size is satisfied and the proton beam kinetic energy is lowered when passing through the scattering foils while keeping the final beam kinetic energy within the standard. The expected distance between the vacuum window and the target position is 7 cm and this distance is not shown in Figure 4 which is not affected beam size, beam distributions and kinetic energy of the beam significantly.

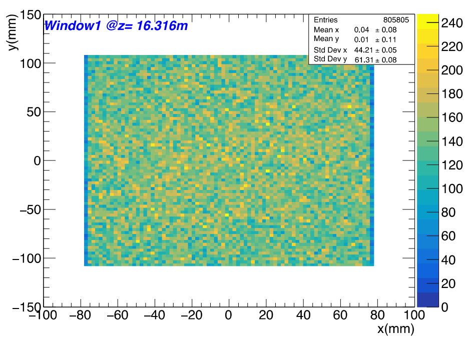


Figure 3: The beam size at the target position generated by a TURTLE simulation. Required beam size is satisfied.

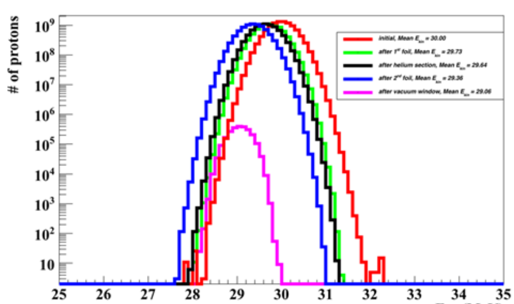


Figure 4: The beam kinetic energy change along the METU-DBL generated by a TURTLE simulation using an initial 30MeV with 1% dispersion. The final proton beam kinetic energy is still within the standard.

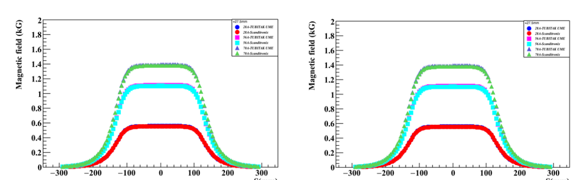
Table 1 lists the different apertures for the conic collimator and the corresponding fluxes and uniformities. The input beam current is taken to be 1 μA for these flux calculations. There is a factor of 50 in flux between the smallest and largest aperture setting of the conic collimator. The beam current can be lowered to 0.1 μA and the cooling system of the METU-DBL is designed for 100 μA therefore there is a factor of 50000 between the lowest and the highest flux of the METU-DBL.

Table 1: Different apertures for the conic collimator and the corresponding flux and uniformities. The input beam current is taken to be 1 μA for the flux calculations.

Conic collimator aperture (mm)	Flux (p/cm^2/s)	Uniformity in x and y axes
1→2	1.5 x 10^6	4.6% and 7.5%
2→3	6.0 x 10^6	2.1% and 4.8%
3→4	1.3 x 10^7	2.1% and 4.2%
4→5	2.2 x 10^7	1.9% and 4.0%
5→6	3.2 x 10^7	1.8% and 3.0%
6→7	4.3 x 10^7	1.3% and 2.7%
7→8	5.3 x 10^7	2.5% and 2.8%
8→9	6.3 x 10^7	1.4% and 1.8%
9→10	7.3 x 10^7	1.1% and 1.7%
30	1.4 x 10^8	3.9% and 3.3%

PRELIMINARY TEST SETUP FOR METU-DBL

METU-DBL will start from the exit of the 5-port switching magnet, which has been procured recently. The magnet production and installation will take nine months. The quadrupole magnets procured commercially can be used to build a preliminary test setup for the METU-DBL. These quadrupole magnets were tested by TUBITAK National Metrology Institute. Figure 5a and Figure 5b show the magnetic field measurement results that were performed at -27.5mm and +27.mm on the x axis of the magnet for the results both TUBITAK National Metrology Institute and Scanditronix. These results are consistent within error bars.



(a) (b)

Figure 5a-5b: The magnetic field measurement results at -27.5mm and +27.mm on the x axis of the magnet for the results both TUBITAK National Metrology Institute and Scanditronix. These results are consistent within error bars.

The preliminary test setup will start from the end of the existing beam line in the R&D room of the PAF. Figure 6 shows the schematic of the preliminary test setup of the METU-DBL. A collimator is necessary to protect the magnets. 2 mm of graphite layer will be placed at the end of the collimator in order to reduce the scattered particles from the collimator. A long drift distance at the end will enable to blow up the beam.

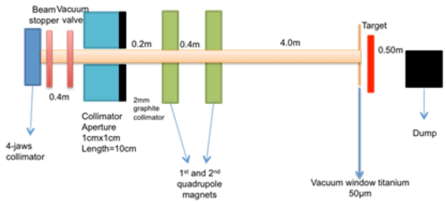


Figure 6: The schematic of the preliminary test setup of the METU-DBL. A collimator is necessary to protect the magnets.

The final beam size after the vacuum window is 8 cm x 6 cm. The beam size is small but is still suitable for performing SEE tests for some components. The flux is 3.4 x 10^9 p/cm^2/s at the central 8 cm x 6 cm. There are similar tests performed for electronic components in literature [4, 5].

The technical drawing of the preliminary test setup is shown in Figure 7 as well as the test and measurement table at the target position. The METU-DBL has a turbomolecular and mechanical pump in order to have vacuum level below 10^{-5} mbar along the beam pipe.

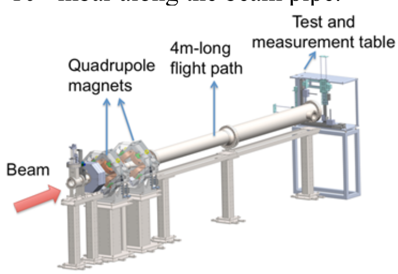


Figure 7: The technical drawing of the preliminary test setup with the test and measurement table at the target position.

The cooling system for the METU-DBL has been constructed at the PAF technical room with a water tank, heat exchangers and pumps as shown in Figure 8. The cooling system uses water from the PAF's chiller and after a heat exchanger distributes water to the beam elements through collectors.

Figure 8: The cooling system installed for the METU-DBL in the technical room. The cooling system has a tank, heat exchangers and pumps.

The critical beam elements, which receive a high dose, must be shielded. Especially the collimators which reduce the total dose in the R&D room, sensitive electronic components used in the cooling system and beam diagnostic system must be shielded. These studies are performed with FLUKA program [6].

The flux and uniformity of the beam will be measured with three different detectors: a Timepix3 pixel detector, a diamond detector and scintillator fibers. Figure 9 shows the table for the detectors and the mounting for the device under test. These detectors must scan the beam area in order to check the uniformity of the beam distributions. The table has moveable x-y stages for this purpose.

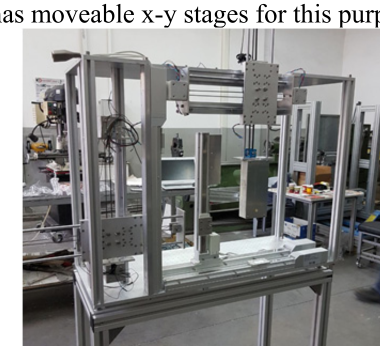


Figure 9: The table for the detectors and the mounting for the device under test. The detectors must scan the beam area in order to check the uniformity of the beam distributions.

The control of the METU-DBL will be done from the R&D laboratory that is located opposite the R&D room. There is a cable trench between the R&D room and the R&D laboratory which will enable having the power supplies and the PLC modules at there. The control software is written in the LabView program. All the electronic and electromechanical components can be controlled from the control computer.

CONCLUSION

The preliminary test setup construction of the METU-DBL will be finished in May and the first irradiation tests will be performed shortly. The METU-DBL construction will start after the installation of the 5-port switching magnet and the METU-DBL will start serving the particle, nuclear, space and medical physics communities in August 2018. This research is funded by Ministry of Development of Turkey. We want to thank our colleagues from TAEA SANAEM Proton Accelerator Facility.

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