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Study of the radiation damage on a scintillating fibers based beam profile monitor

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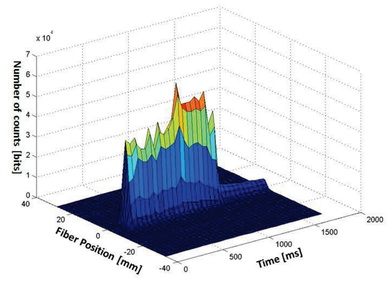
Abstract

The **Scintillating Fibers Harp (SFH)** monitors are the beam profile detectors used in the extraction lines of the **CNAO (Centro Nazionale di Adroterapia Oncologica, Pavia, Italy)** machine. The use of scintillating fibers coupled with a high-resolution CCD camera makes the detector of simple architecture and with high performances; on the other hand, fibers radiation damage shall be faced after some years of operation. The work presents measurements and analysis performed to understand the phenomenon. A procedure for data correction is fixed in such a way to compensate radiation damage effects and make the SFH usable, before the major intervention of fibers replacement.

SFH Monitors [1]

General description

•Two horthogonal harps of scintillating fibers making up the detector active area;
• CCD camera (12-bit digital output signal) for the luminous signal read out.



Example of one extracted spill longitudinal profile reconstructed on the horizontal plane from one set of SFH measurement.

SFH active area

CCD camera

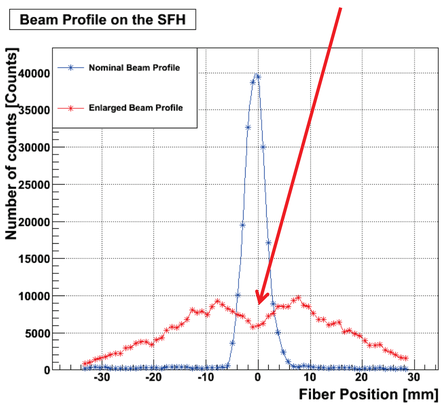
Beam profile reconstruction

• Output signal proportional to the number of particles crossing the detector active area, to their energy and dependent on the camera configuration parameters;
• Output signal off-line processing for beam profile reconstruction;
• Longitudinal beam profile reconstruction by means of the acquisition of consecutive frames.

Radiation damage on scintillating fibers

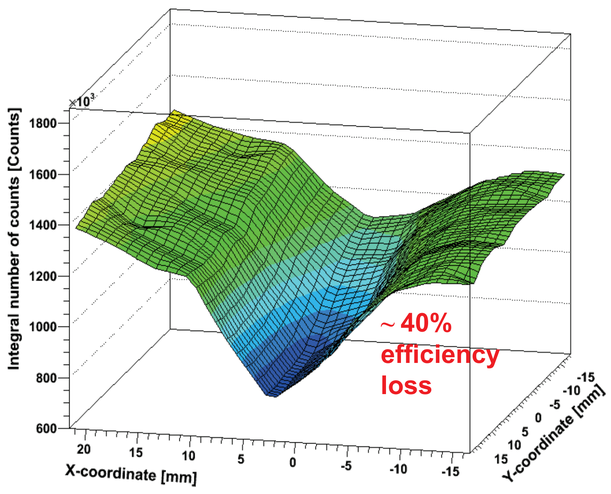
Radiation effects

1. <u>Reduction of fibers light production power</u> involving central fibers (mainly hit by the beam)



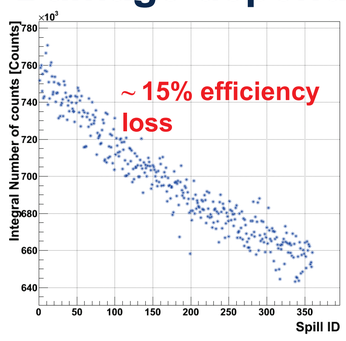
Nominal (blue line) and enlarged (red line) beam profiles reconstructed on the horizontal plane from one SFH measurement.

2. <u>Fibers transparency loss</u>: due to the detector geometry the light produced on the positive region of the vertical plane has to cross the more damaged area (about the active area center) before being read out by the camera.



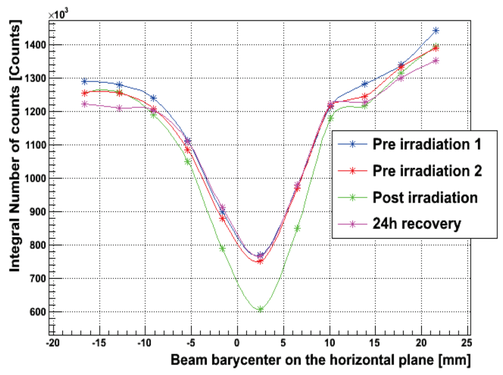
SFH response on the horizontal plane (i.e. integral number of counts in function of beam barycenter position) to a Proton beam with 8E+08 particles per spill, 10 mm FWHM, 60 MeV kinetic energy, moved up to 121 different positions equally spaced on the detector active area.

Damage dependence on the amount of dose



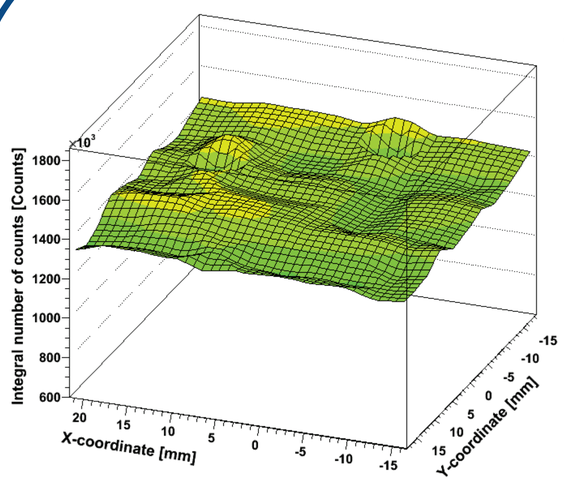
SFH response during the irradiation of the detector active area with a total dose of 115 Gy delivered to the active area center by means of 360 consecutive Proton spills.

SFH response on the horizontal plane at fixed coordinate on the vertical plane (Y = 0 mm) to a Proton beam with fixed parameters (8E+08 particles per spill, 10 mm FWHM, 60 MeV kinetic energy) before and after (immediately after and 24 hours after) the irradiation with 115Gy total dose.



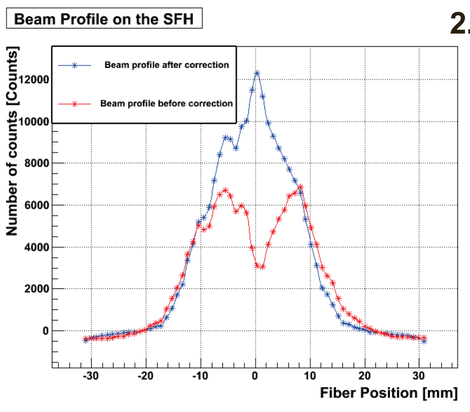
Data correction

Data correction procedures



SFH intensity map, on the horizontal plane, extracted after the application, to raw data, of the correction factors 2D map.

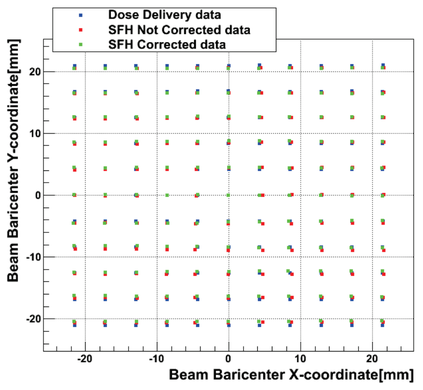
1. **Elaboration of a 2D map of correction factors per each plane, extracted from data manipulation, and depending on beam barycenter position on the horizontal/vertical plane of the detector active area. Detector response correction from radiation damage effects by means of correction factors application on raw data after a rough beam barycenter estimation.
<u>Robust and reliable procedure, but demanding and time consuming, implying the SFH dismantlement from the beam line</u>.**



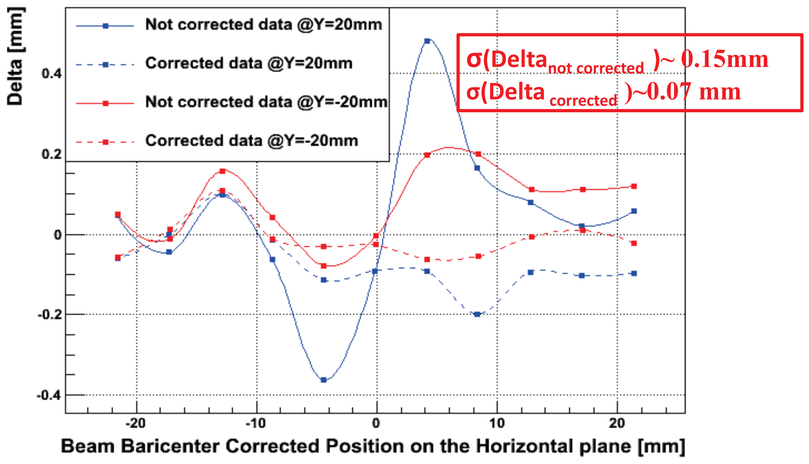
Horizontal beam profiles acquired before and after the 1D set of correction factors application to profiles reconstruction parameters.

2. **Elaboration on 1D set of correction factors involving 4-5 central fibers for each plane. Correction factors used to modify profiles reconstruction parameters for damaged fibers response equalization.
<u>Not very rigorous procedure and usable only for a beam centered on the detector active area. At the same time quick and easy to apply to all the installed SFH detectors.</u>**

Beam parameters computation before and after data correction



Beam barycenter values on the horizontal and vertical plane extracted from one SFH measurement before and after data correction (with the 2D correction factors map application) and compared to reference values acquired with the Dose Delivery, a ionization monitor installed at the end of the extraction line.



Differences (Delta[mm]) on the horizontal plane between reference barycenter values (from Dose Delivery measurement) and barycenter values from one SFH measurement before (solid line) and after (dashed line) data correction (with the 2D correction factors map application) for the two outer positions on the vertical plane (Y = -20 mm and Y = 20 mm)

Conclusion

A robust procedure has been implemented to manage the radiation damage effects on the scintillating fibers based on the determination of a 2D map of correction factors per each plane of one detector. Tests on profiles reconstruction have demonstrated that the correction allows the beam barycenter reconstruction with a major accuracy. Although reliable and efficient, this procedure presents a few operational difficulties. Consequently a less robust, but quicker and easier method to compute correction factors, has been implemented. It can be applied on all the SFH detectors. The goal of radiation damage handling and managing has been reached in both cases.

Acknowledgements to M.Haguenauer and to J.Bosser for their valuable technical support and for their suggestions in facing up to the radiation damage phenomenon.

[1] E. Rojatti et al., "Scintillating fibers used as profile monitors for the CNAO HEBT lines", in Proc. of IPAC, Richmond, Virginia, USA (2015).