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Quality Assurance of Proton Beam Profile Using Phosphor Screen and TE-Cooled CMOS CAMERA

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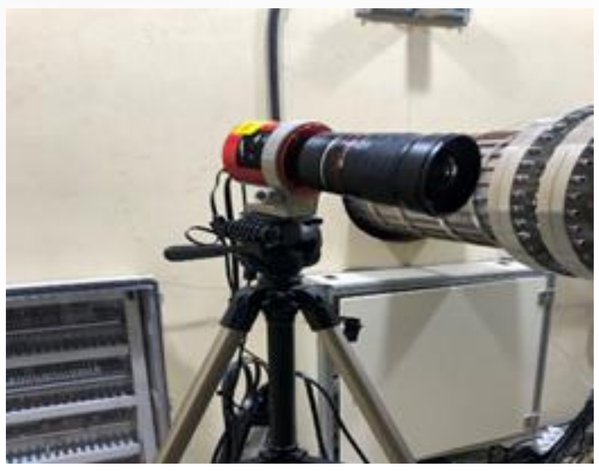
Motivation

- A KOMAC has operated 100-MeV proton linear accelerator since 2013.
- TR103, a genral purpose irradiation facility, has generally analyze beam profile with Gafchromic film™
- Recently, for in-situ proton beam profile monitoring, P43 phosphor screen and cooled CMOS camera were introduced.
- A software for post-processing of image data and calculation of beam profile uniformity was developed using Python.
- In this study, we will introduce the procedure of the beam profile analysis and its quality assurance using phosphor screen and cooled CMOS camera.

Materials & Methods

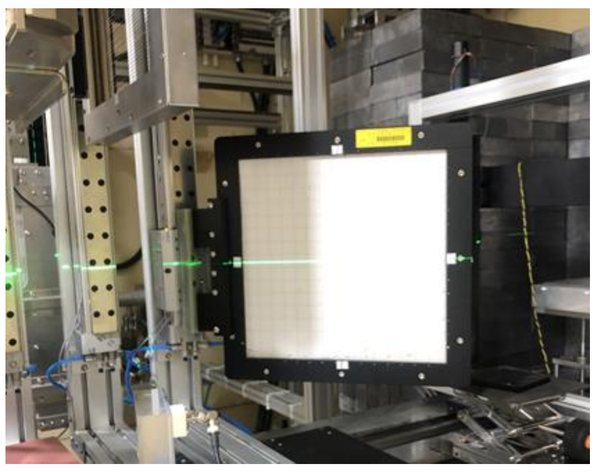
❑ TE-cooled CMOS camera

- ASI183MC Pro, ZWO
- Sensor sizeof 13.2 × 8.8 mm
- Thermoelectric cooler (up to -10 ℃)
- Leakage current of defective sensor is proportional to the temperature.



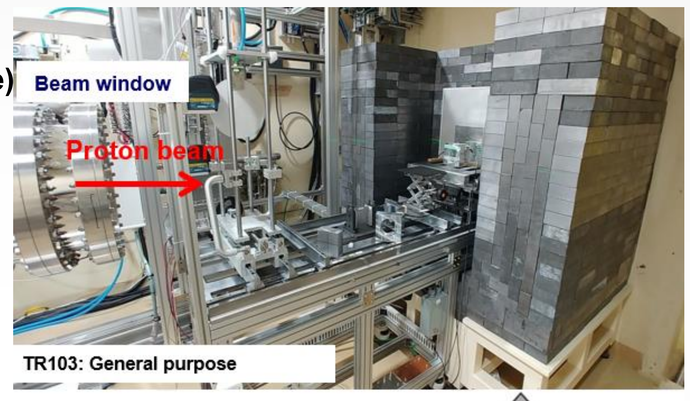
❑ P43 Phosphor Screen

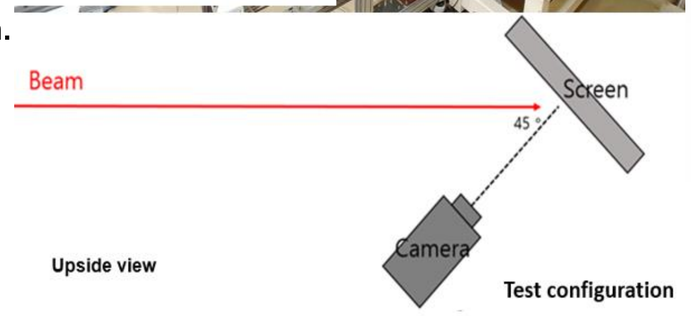
- P43 (Gd_2O_2S:Tb) layer on Al substrate
- Detection area of 310 mm × 310 mm
- Peak wavelength of 545 nm
- Decay time of 1.5ms to 10%
- High light efficiency



❑ Test conditions

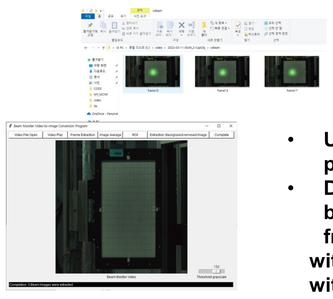
- Irradiation facility: TR103
- Flux: 10^{10}~10^{11} #/(cm^2 · pulse)
- Beam energy: 100 MeV
- Pulsed beam (1 Hz)
- Beam profile measurement at DUT.
- Phosphor screen was irradiated by beam under and angle of 45°.
- Cooled camera was placed perpendicular to the screen.





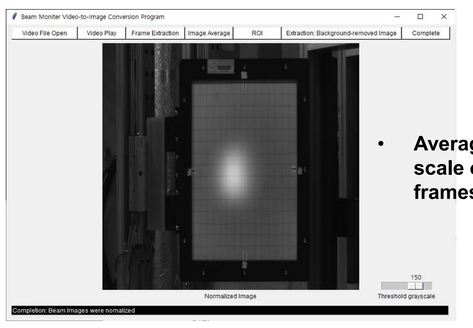
Beam Profile Analysis Procedure

1. Video uploading & Frame extraction



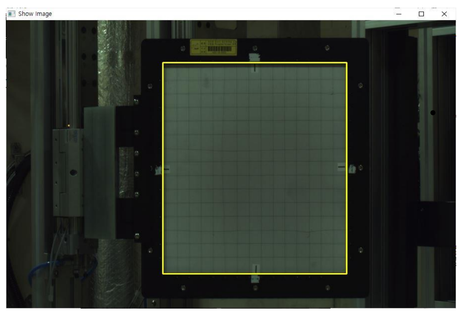
- Upload beam profile video
- Distinguish between frames with beam and without beam

2. Image average



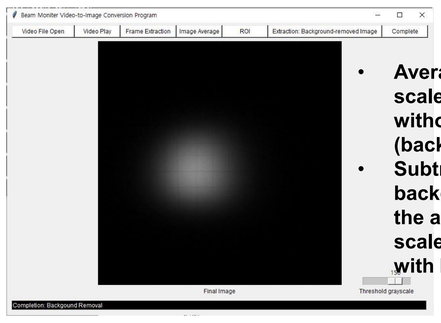
- Average the gray scale of the frames with beam

3. 1st ROI selection



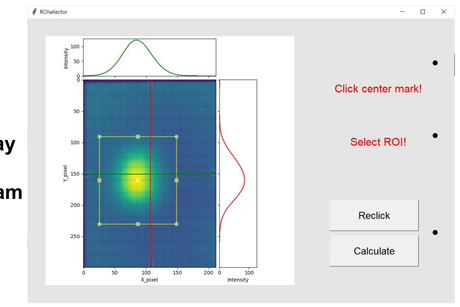
Select the first ROI for the detection area of the phosphor screen

4. Background subtraction



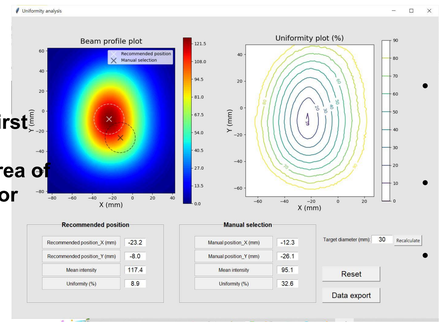
- Average the gray scale of the frames without beam (background)
- Subtract the background from the averaged gray scale of the frames with beam

5. (0,0) & 2nd ROI selection



- Select (0,0) for X-Y coordination
- Select second ROI for uniformity calculation
- Geometrical correction

6. Uniformity calculation



- Calculate the minimum uniformity and its location
- Manual select and calculate uniformity
- Data export

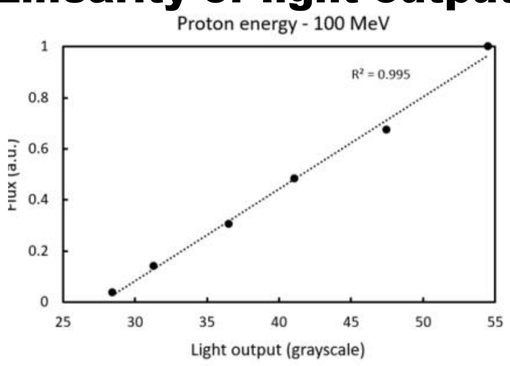
Quality Assurance of Proton Beam Profile

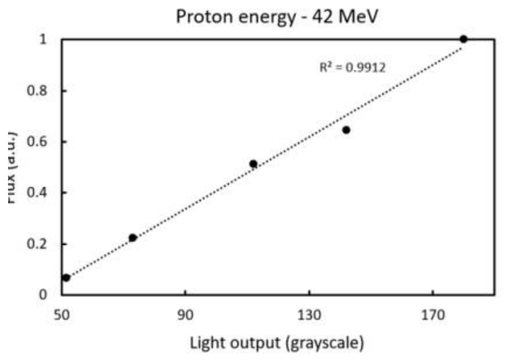
❑ Uniformity QA (vs Gaf.film)

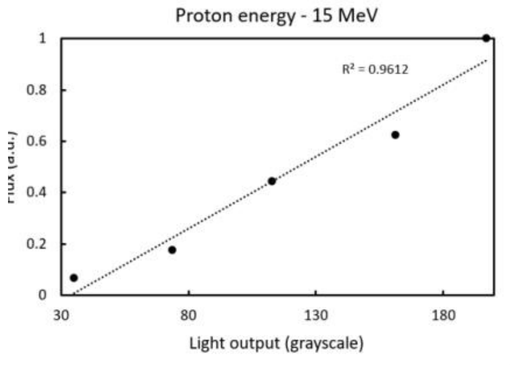
Table 1. Minimum uniformity, FWHM and sigma of the beam profile measured by phosphor screen and film for each incident proton energy.

	15 MeV		42 MeV		100 MeV	
	HD-V2	Screen	HD-V2	Screen	HD-V2	Screen
Uniformity in 30 mm-Ø (%)	11.9	9.8	7.5	7.3	6.2	6.5
Uniformity in 50 mm-Ø (%)	31.1	25.6	20.2	19.8	16.1	17.1
FWHM-her (mm)	25.3	28.4	34.5	34.8	36.1	37.1
FWHM-ver (mm)	33.7	34.5	33.6	34.5	38.7	37.1
σ-hor (mm)	21.5	24.2	29.3	29.5	30.4	31.9
σ-ver (mm)	33.7	34.5	34.5	34.5	38.7	37.1

❑Linearity of light output







Conclusion

- Beam profile monitoring system using P43 phosphor screen and TE-cooled CMOS camera was introduced.
- Comparison of beam uniformity measured using the phosphor screen and fim revealed that incidents with energies of 42 MeV and 100 MeV dsplayed differences within 10% in both diameters, while the incident energy of 15 MeV exhibited a difference of approximately 20% in both diameters.
- The linearity between light output and beam flux was found to be excellent, demonstrating a consistent relationship throughout the entire range without any indication of saturation.

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