Operation of scanning irradiation system at NIRS-HIMAC

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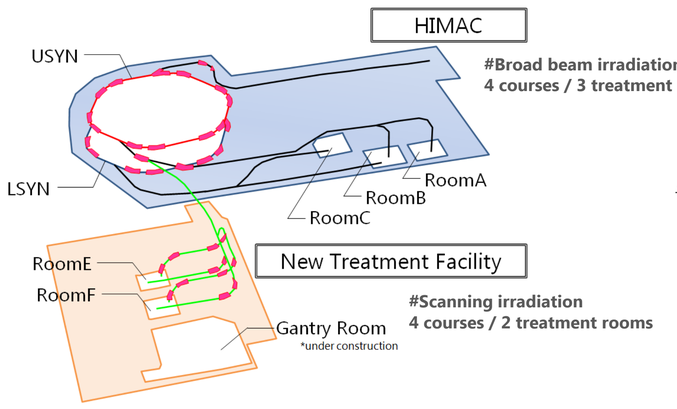
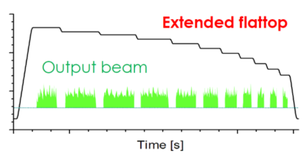
Introduction

HIMAC outline

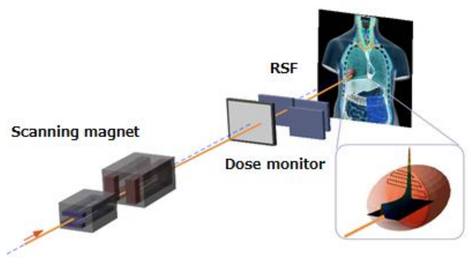
Two synchrotrons are called the upper synchrotron (USYN) and the lower synchrotron (LSYN). The new treatment facility has been utilized for treatment since 2011. HIMAC mainly supplies carbon-ion beam for cancer therapy during the daytime from Monday to Friday. The USYN shares time with vertical direction of room A&B and the new treatment facility. Therefore, in short limited time, the operators need to perform QA for the therapeutic beam efficiently.



Multiple-energy operation



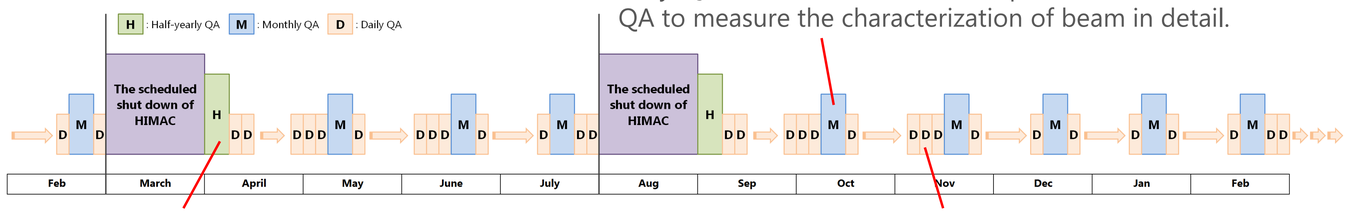
In the scanning irradiation, the 3D dose distribution is achieved by superimposing doses of individually weighted pencil beams. The beam is scanned transversely by a pair of deflection magnets and is shifted in the longitudinal direction by changing the 11 step beam-extraction energy of a synchrotron and by inserting degraders such as range shifters. Any changes in the scanned beam will cause a significant impact on the irradiation dose.



QA program

Purpose of QA programs

It is important to periodically acquire a reference data for daily QA checks. Once a month, perform additional beam QA to measure the characterization of beam in detail.



After the scheduled half-yearly shut down, we check the condition of the scanning system in detail. Additionally, we newly measure the characterization of beam to determine a reference for daily QA and monthly QA and re-tune the current of magnets from the measured results.

Before starting patient treatment, the reproducibility of beam should be checked. Therefore, daily QA procedures require not only adequate but also simple to not skilled operator.

	Half-yearly QA	Monthly QA	Daily QA
Beam position			
at common transport line	O		
at each course transport line	O	O	
at position monitor in treatment room	O	O	
at isocenter	O		
Beam size			
at isocenter	O	O	
Stability of the unscanned-beam positon and size			
at isocenter	O	O	
Beam spill shape and extraction efficiency	O	O	
Irradiation dose			
Irradiation dose of 11-stepwise energy	O		O
Calibrate Monitor	O		O
Beam range	O		O
Standard 3Ddose distribution	O		O
Check Particles/count	O		
Verification of 3D dose distribution for a patient plan	O		
Scanning irradiation system			
Flux monitors	O		O
Position monitor	O		O
Scanning control	O		O
Feedback control	O		O
Operating safety interlock system during irradiation	O		
Not operating safety interlock system during irradiation	O		O

Ref *1 (Half-yearly QA → Monthly QA); Ref *2 (Monthly QA → Daily QA); Ref *3 (Half-yearly QA → Daily QA); Ref *4 (Half-yearly QA → Daily QA)

*1 After the shut down, check the reproducibility of the extraction beam from USYN and the condition of the scanning system. Additionally, determine a reference for daily QA and monthly QA to carry out by the next scheduled shut down of HIMAC.

*2 Once a month, periodically acquire a reference data for daily QA checks and compare the last results of monthly QA checks.

*3 Carry out the measurement same as daily QA checks. Furthermore, dose distribution is measured by using the IC in a water phantom and compare the measured and planned dose. As a result, determine a reference for daily QA checks.

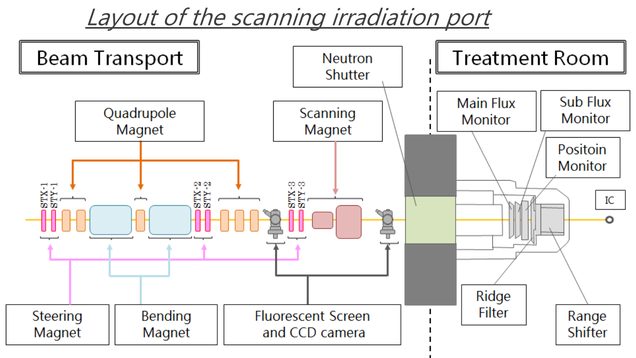
*4 After the shut down, check the soundness of the system

Daily QA procedure

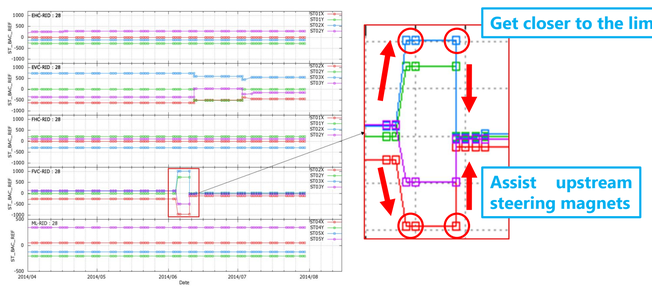
Old Method - Beam auto centering (BAC)

The beam position is automatically tuned by the two pairs steering magnets with the measurement at two fluorescent screen monitors every morning. However, if the electric current of steering magnet get closer to the limits (±12 A), we adjust located more upstream of one pair steering magnets.

Layout of the scanning irradiation port

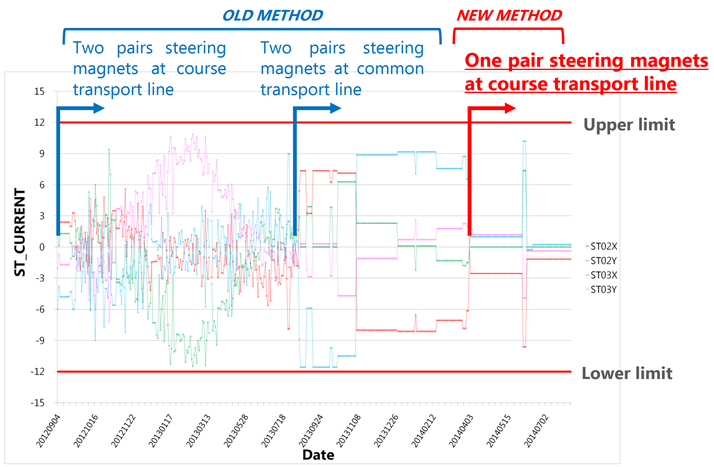


Set points trend of the steering magnets

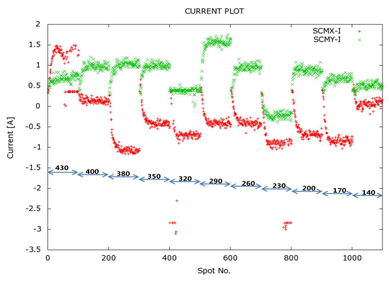


New method (PRNCHK)

The scanning delivery system uses a position feedback control system consisting of scanning magnets and position monitor in order to keep the beam position stable. For tuning the beam position more effectively, new method uses in combination with the feedback control system. The using electric current for feedback control convert into an electric current of one pair steering magnets and create a setting file of magnets.



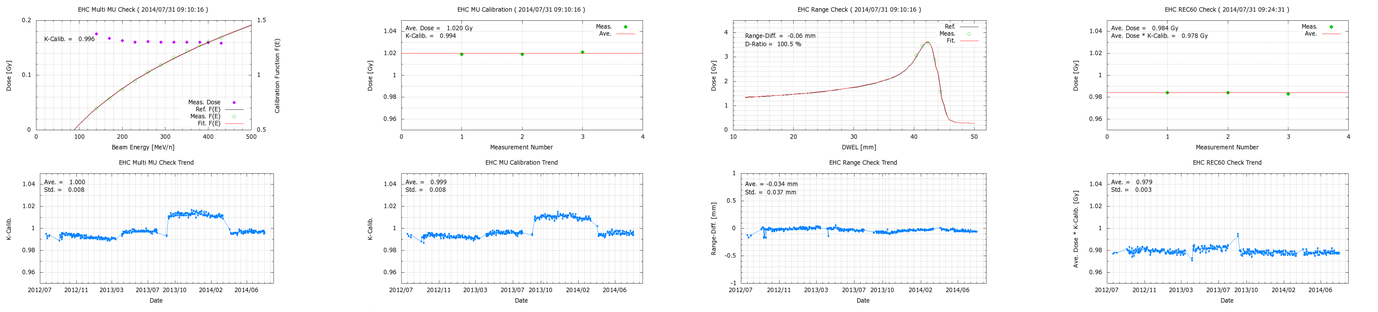
The electric current for position feedback control



Check beam position method		
	Old method (Called BAC)	**New method (Called PRNCHK)**
Place to check beam position	Two fluorescent screen monitors	Position monitor in treatment room
Magnets to adjust	Two pairs steering magnets (STY-2, STY-2, STX-3, STY-3)	One pair steering magnets (STX-3, STY-3)
Position check sequence time	6 ~ 10 minutes	1 ~ 2 minutes

Check irradiation dose

We carry out regular irradiation pattern and confirm that there is not large fluctuation in irradiation dose and range.



(a) 11-stepwise energy irradiation dose and trend

(b) Calibrated MU constant of the flux monitor and trend

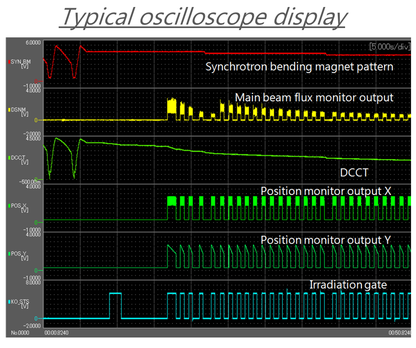
(c) Beam range and trend

(d) Standard 3D dose distribution and trend

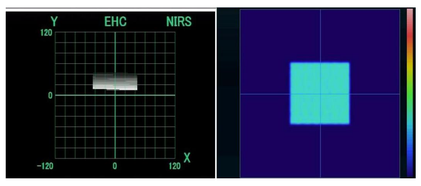
Check scanning irradiation system

We confirm the scanning irradiation system such as flux monitors and position monitor can work during irradiation normally.

Typical oscilloscope display

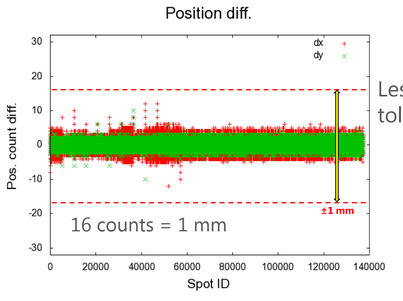


Display of position measurement



Left: online display of beam position.
Right: measured fluence map for each slice

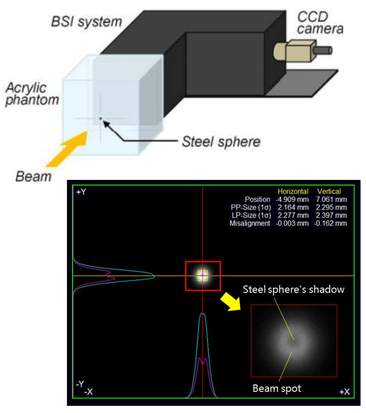
The difference of the beam position at position monitor during scanned irradiation



Less than the tolerance of 2 mm

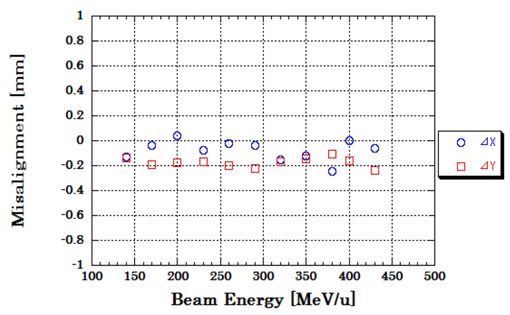
Monthly QA procedure

Check beam position at isocenter

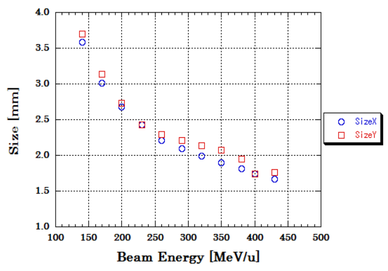


We periodically acquire a reference data using for daily QA checks and confirm the misalignment of beam is less than the tolerance of ±0.5 mm at isocenter.

Measurement results of the beam misalignment



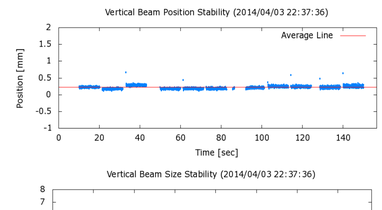
Check beam size at isocenter



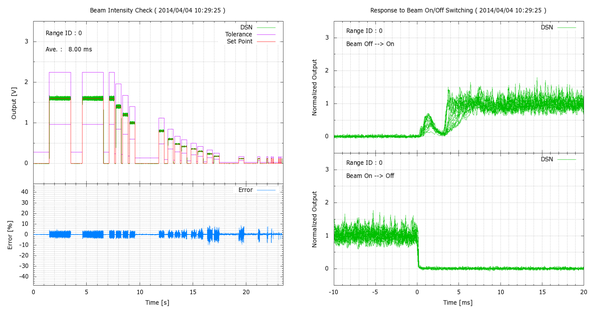
Check stability of the unscanned-beam position and size at isocenter

The beam size variation due to emittance growth, therefore, should be cared during a long extraction period.

The beam position drift is also cared although the beam position is controlled with the feedback system integrated into the control system of the scanning magnet power supply.



Check beam spill shape and extraction efficiency



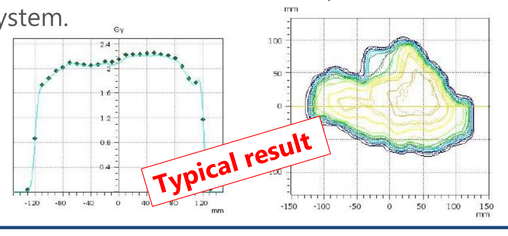
The high overshoot of the beam spill is capable of bringing dose hot spot inside the target volume. Therefore, we check the intensity.

Half-yearly QA procedure

Verification of 3D dose distribution for patient plan

After the scheduled shut down, we check the condition of the whole scanning system including synchrotron in detail. Additionally, we newly measure the characterization of beam to determine a reference for daily and monthly QA.
Conclusively, irradiation is performed in the same manner as in the patient treatment and check the comprehensive scanning system.

We use a 2D-array ionization chamber with a water phantom



Summary

We introduced some examples of the current operating. In near future, it shifts from 11-stepwise energy irradiation to 201-stepwise energy irradiation without range shifter. Additionally, rotating gantry and respiration gated irradiation with 3D scanning is starting. Consequently, it is expected the spending time of daily QA increases. Therefore, it is important to efficiently perform the QA checks.