Fast energy modulation within the beamline momentum acceptance: a clinical feasibility study

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Fast energy modulation within the beamline momentum acceptance: a clinical feasibility study

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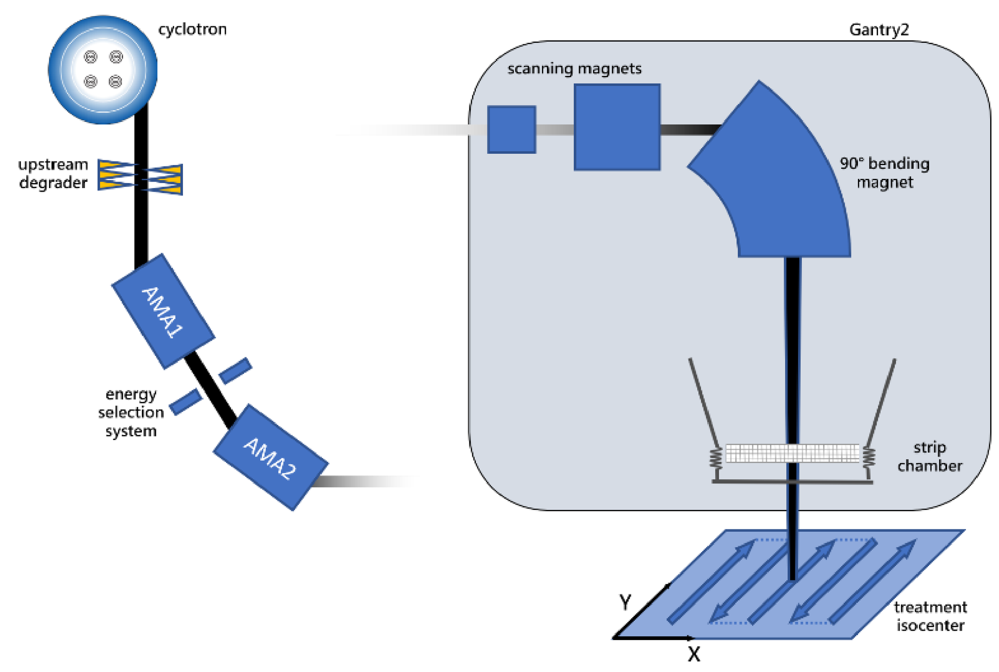
INTRODUCTION

Pencil beam scanning proton therapy is delivered as a sequence of iso-energy dose layers, changing progressively while scanning across the target. [1]

Changing energy requires changing magnetic fields in several slow-settling beamline magnets.

We investigated into modulating proton energy within the beamline momentum acceptance with an upstream degrader to minimise dead time during beam delivery.



MATERIALS AND METHODS

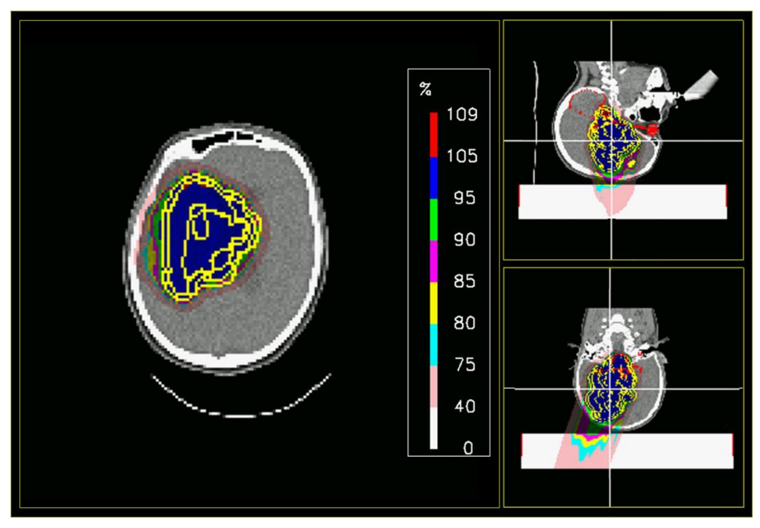
Beam properties

For a relevant set of particles off-momentum between 150 and 230 MeV, we analysed clinically significant parameters:

Beam position, Shape, Range, Transmission.

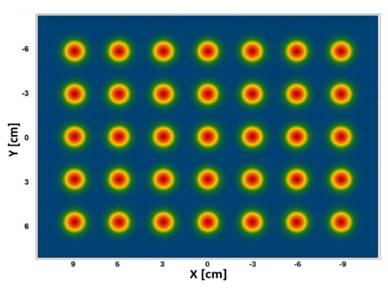
Clinical case

Indication:	cranial glioma
Prescribed dose:	1.8 GyRBE
CTV volume:	183.9 cm^3
PTV volume:	279.6 cm^3
Plan optimization:	SFUD
Energy layers:	48

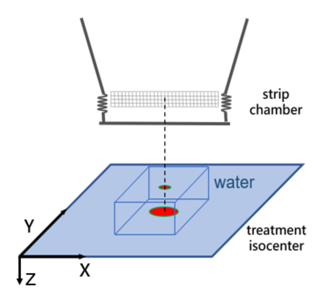


RESULTS

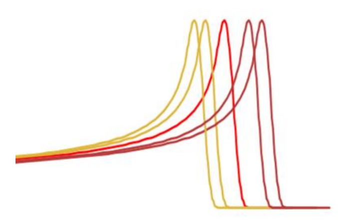
Beam properties characterisation



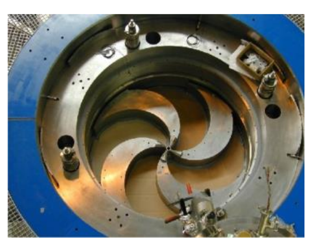
Spot position
median error < 1mm



Spot shape
median error < 1mm



Dept-dose profile
γ (1%/1mm) > 90%
Range
median error 1.16 mm



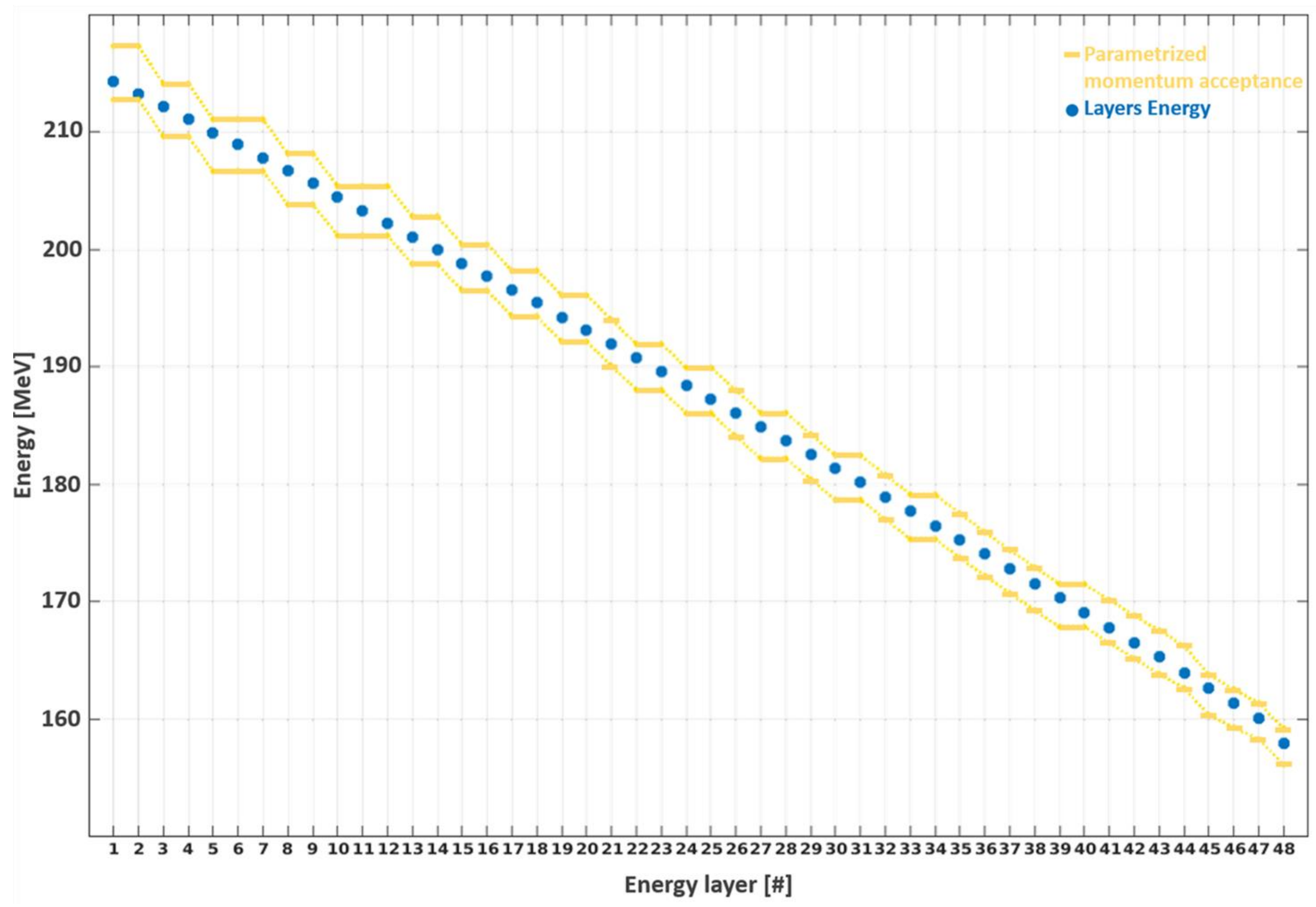
Transmission
14% median decrease compared to clinical settings

Clinical plan energy modulation within the beamline momentum acceptance

The plan's 48 energy layers are represented (from high to low energy) as **blue dots**.

The **yellow lines** represent the beamline momentum acceptance calculated around specific proton energies to ensure continuous coverage of the beam ranges used in the plan.

Overall, 16 beamline re-tunes could be avoided by associating consecutive energy layers to acceptance bands. Delivery time was reduced by 12%, on a machine with nominal energy switching time about 100 ms.

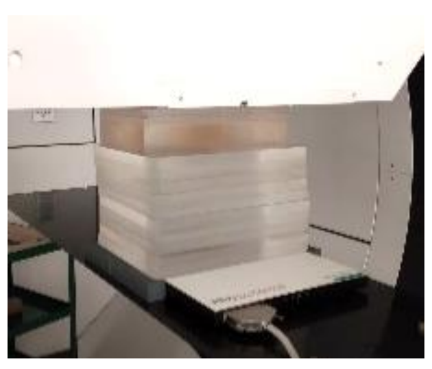


Clinal plan verification at target depth

Treatment has been verified in a similar manner as our clinical plans [2] using a cross-calibrated array of ionisation chambers (PTW Octavius 1500XDR, Freiburg, D) aligned at isocenter.

The plan has been delivered twice, using the standard settings for clinical treatments or making use of the beamline acceptance to reduce the number of full beamline tuning.

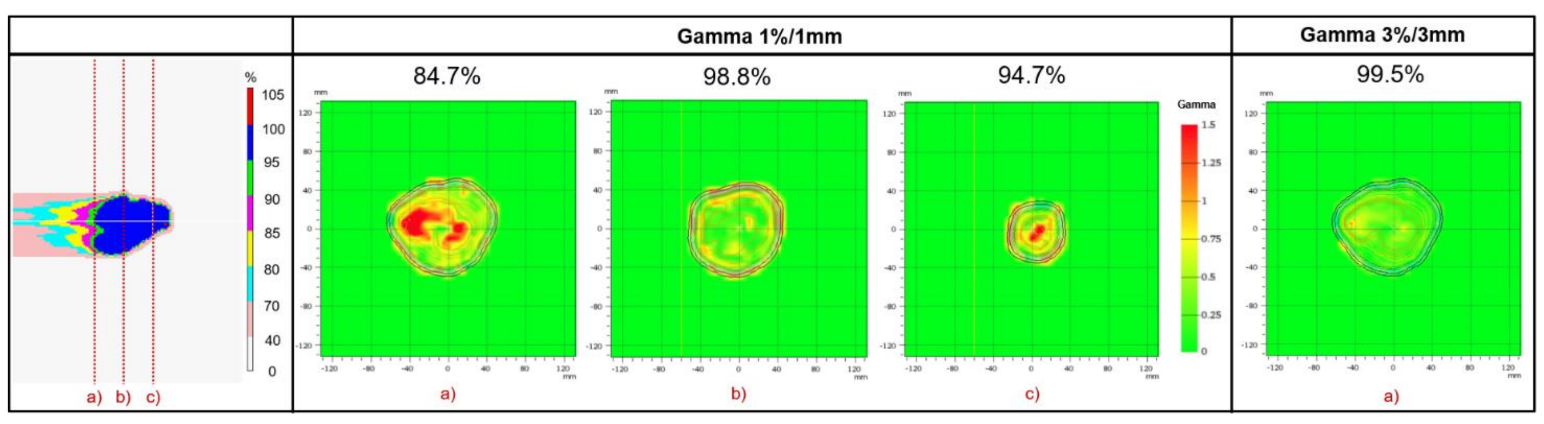
The measurement was performed at three depths located proximally, roughly in the middle and distally in the field using a stack of Polymethyl Methacrylate (PMMA) slabs.



Clinal plan analysis

The two deliveries have been compared using Gamma (1%,1mm) - standard settings considered as reference. Gamma maps and pass rates are reported for three verified planes located respectively at 19.6 cm (a), 23.7 cm (b) and 28.2 cm (c) water equivalent depths.

Largest discrepancies with respect to clinical settings were measured for a proximal layer (a) located in a region of steep dose gradients. The distortions were however below the (3%,3mm) Gamma criteria that is commonly used in the clinic (rightmost panel).



CONCLUSIONS

The potential of energy regulation within momentum acceptance has been investigated on a gantry based medical beamline. Provided that range errors and transmission losses introduced by the distortion of the beam spectra are compensated for, fast energy changes could be achieved under experimental settings with negligible distortions in the delivered dose distribution and without ad-hoc beamline modifications.

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