Institut Curie - Centre de Protonthérapie

How to minimize and model the collimator scatter in Double Scattering and Uniform Scanning.

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Introduction

The Institut Curie - Centre de Protonthérapie d'Orsay (ICPO), currently uses the passive beam spreading (Double Scattering DS) technique in 2 horizontal fixed beam lines and in the new IBA gantry treatment room also equipped with Uniform Scanning (US) technology. Personalized collimators are routinely used to tailor the field to the tumor shape in proton therapy with DS and US beam lines. Some protons interact with the collimator and create an undesired additional amount of dose which can reach up to 10 % of the prescribed dose. This collimator contamination perturbs the determination of the dose at the calibration point [1], and thus has to be included in the TPS dose calculation. The aim of this study is to reduce and compute the remaining aperture contamination with a fast analytical model.

Material and Methods

Measurements:

Measurements are performed at the 230 MeV IBA gantry of ICPO in Double Scattering and Uniform Scanning. 2D dose profiles are acquired with **divergent and non-divergent** half-block collimators for pristine Bragg peaks at different ranges. Dose distributions are then compared to investigate the reduction of aperture contamination. 2D dose distributions are also measured for circular and half-block divergent collimators to assess the accuracy of the analytical model presented below which takes into account the **Remaining Scatter Contamination** (RSC) for several ranges and aperture sizes, as shown in Fig. 1.

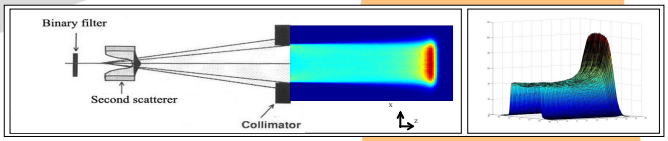

Fig.1: Measurements of 2D dose distribution for a pristine Bragg peak through a 3 cm diameter circular aperture (DS).

Analytical model:

❶ The analytical model takes into account only the contamination due to protons which interact with the **collimator entrance face**, since the dose distribution in the treatment field is mainly disturbed by those [2].

❷ The Remaining Scatter Contamination function is defined as a **scatter dose component** calculated right after the collimator and depends on energy and distance between the aperture edge and the dose calculation point. It is reconstructed for Spread Out Bragg Peaks. The total dose is then computed in adding the RSC function to the dose primary component already evaluated in the TPS ISOGRAY (DOSIsoft) [3]:

$$Dose(r,z) = D_1(r,z) + RSC(r,z)$$

❸ For each dose calculation point the Clarkson and Cunningham algorithm is applied to reconstruct the total dose for circular and **complex apertures**.

Results

Reduction of collimator contamination: Use of divergent collimators

Divergent and non divergent collimators in US and DS are compared. In both modalities, with divergent half-block collimators the dose outside the treatment field coming from the collimator inner face is much lower than with non-divergent apertures. The entrance face scattered protons (EF) which contaminates the treatment field dose distribution is also reduced.

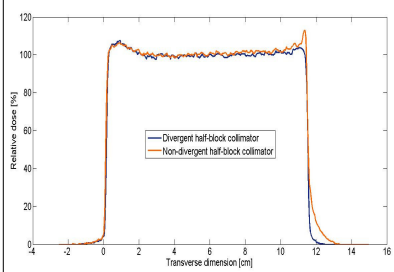

Fig.2: Comparison of dose profiles acquired in Uniform Scanning for divergent and non-divergent half-block collimators for a range of 20 cm in water and 4 cm air-gap.

The table sums up the results for US and DS for half-block collimators for range equals to 20 cm at 4 cm air-gap.

Double Scattering		Uniform Scanning	
Divergent	Non Divergent	Divergent	Non Divergent
P_{90-10} = 2 mm	P_{90-10} = 6.2 mm	P_{90-10} = 1.5 mm	P_{90-10} = 5.4 mm
EF = 3%	EF = 8%	EF = 4%	EF = 13%

The enlargement of the lateral penumbra P_{90-10} is mainly due to the inner face contamination amount.

Characterization of the remaining contamination: Analytical model

Gamma index for space tolerance Δd_{max}= 1 mm and the dose tolerance ΔD_{max}=2% computed between the analytical model of RSC and measurements in DS shows that the percentage of pixels for which $\gamma < 1$ reaches 99%.

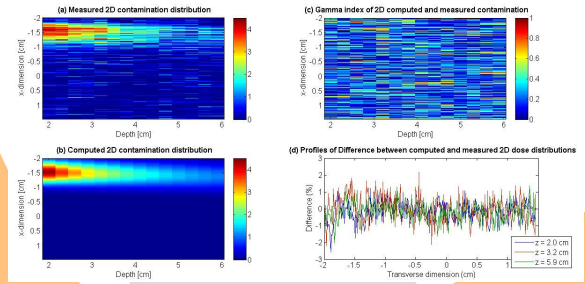

Fig.3: Comparison of the measured (a) and calculated (b) entrance face collimator contamination for a half-block collimator at range of 16.9 cm in Double Scattering. (c) 2D Gamma index computation. (d) Mean difference 1D profiles between the both distributions show 0.18% in average of difference.

Discussion and Conclusion

- **Employing divergent collimators** in Double Scattering and Uniform Scanning drastically reduces the inner face collimator contamination amount and reduce lateral penumbra P_{90-10} of almost 4 mm compared to non-divergent collimators, therefore in better sparing organs at risk. The entrance face contamination is also reduced of about 60%. As for **Pencil Beam Scanning** the use of collimators is still of interest to improve the lateral penumbra [4], this study is now in progress for this delivery technique.
- The proposed analytical model allows now to take into account the remaining collimator dose contamination in the dose calculation with less than 2% of accuracy. It is now being **implemented in the TPS Isogray** (DOSIsoft) for dose calculation and Monitor Units computation.

References

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