

A Monte Carlo Pencil Beam Scanning model towards TPS Quality Assurance using GATE/GEANT4



Protect, enhance and save lives



L. Grevillot (1,2), D. Bertrand (2), F. Dessy (2), N. Freud (1) and D. Sarrut (1)
loic.grevillot@iba-group.com

1 Université de Lyon, CREATIS ; CNRS UMR5220 ; Inserm U1044 ; INSA-Lyon ; Université Lyon 1 ; Centre Léon Bérard, Lyon, France.
 2 IBA, B-1348, Louvain-la-Neuve, Belgium.

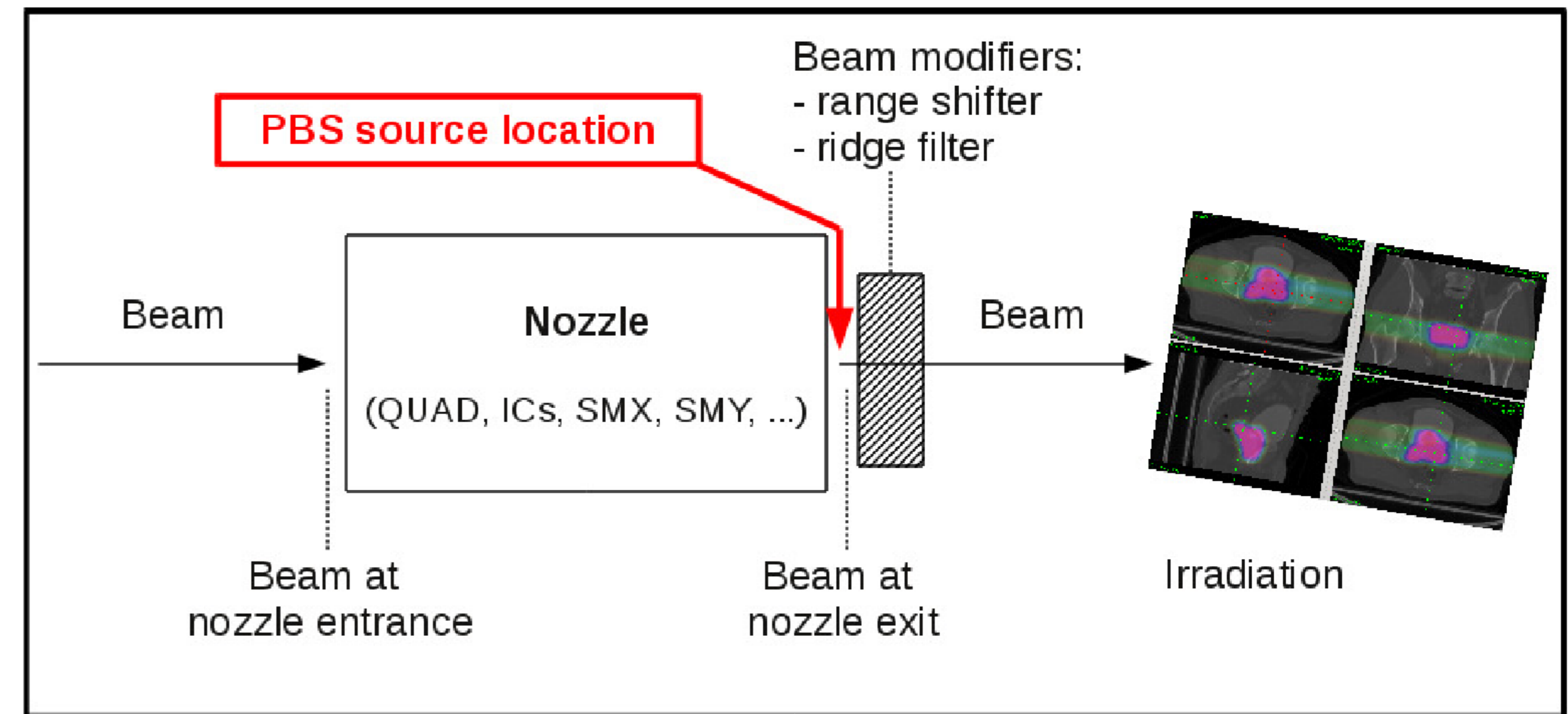


Purpose

We propose an original method for **Monte Carlo modeling of Pencil Beam Scanning (PBS) systems**, without simulating the treatment nozzle and based exclusively on the beam data library measurements. The method is applied and validated for an IBA proton-therapy system dedicated to PBS delivery. **Preliminary comparisons between the XiO TPS (Elekta) and GATE/GEANT4** are presented.

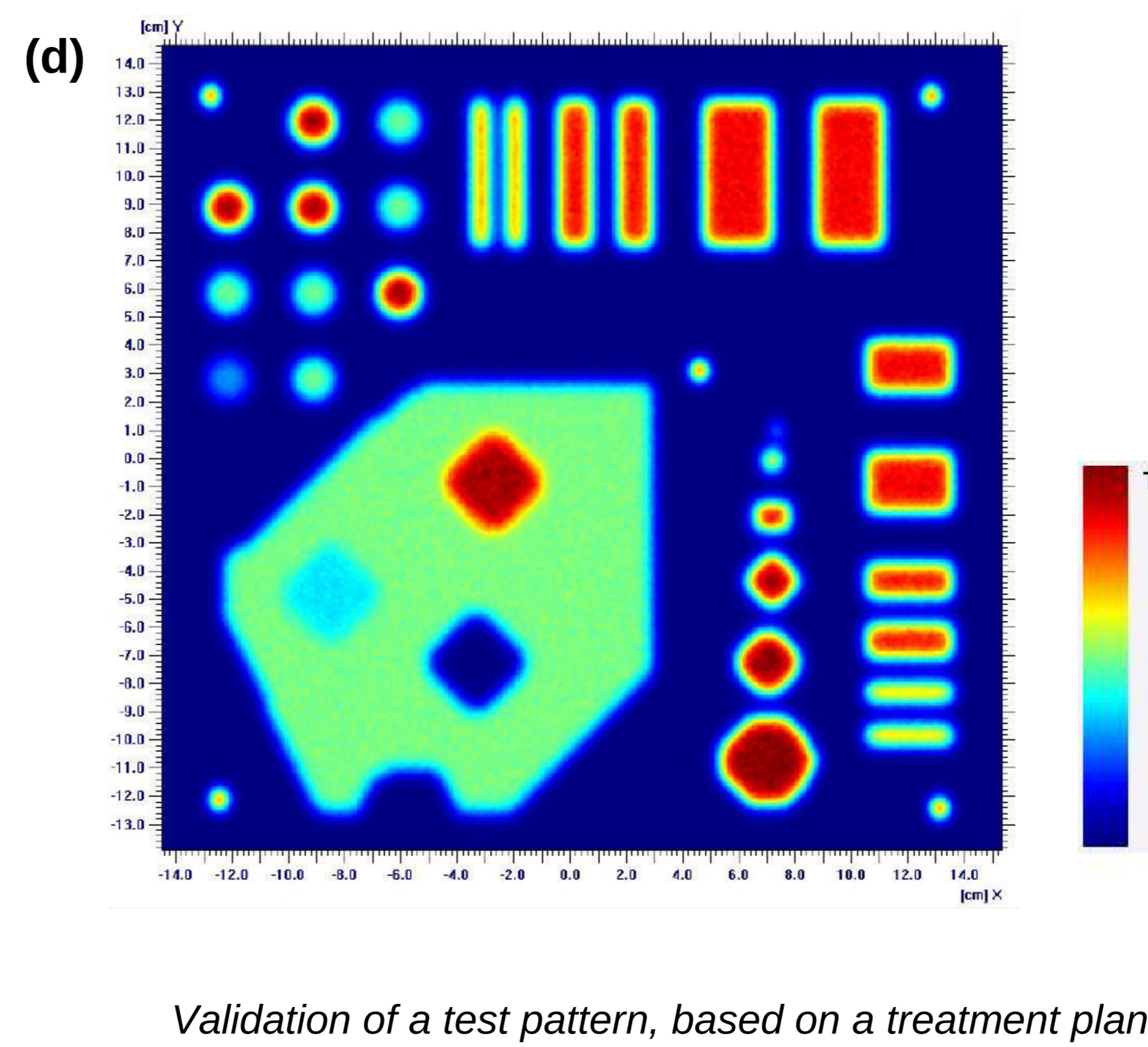
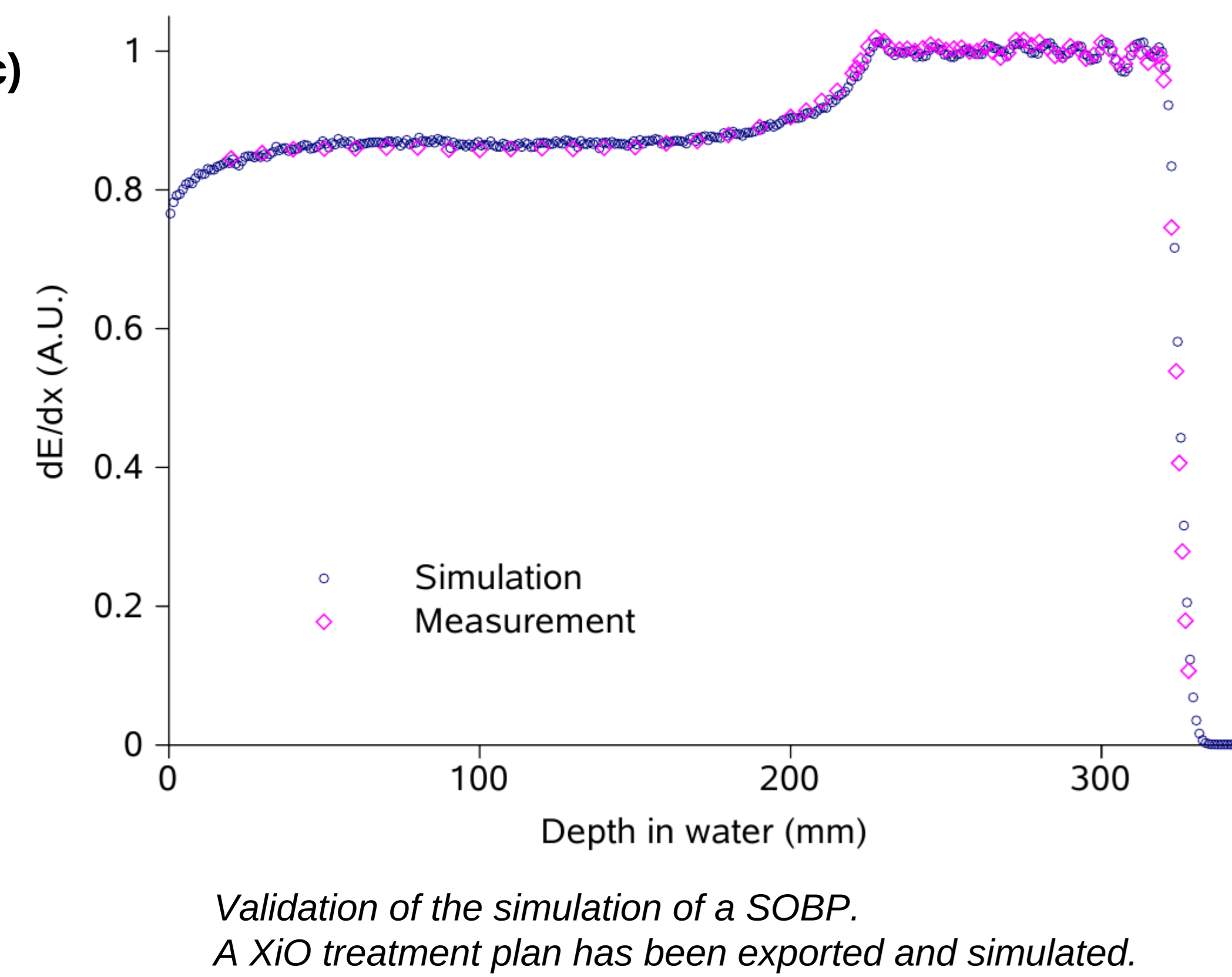
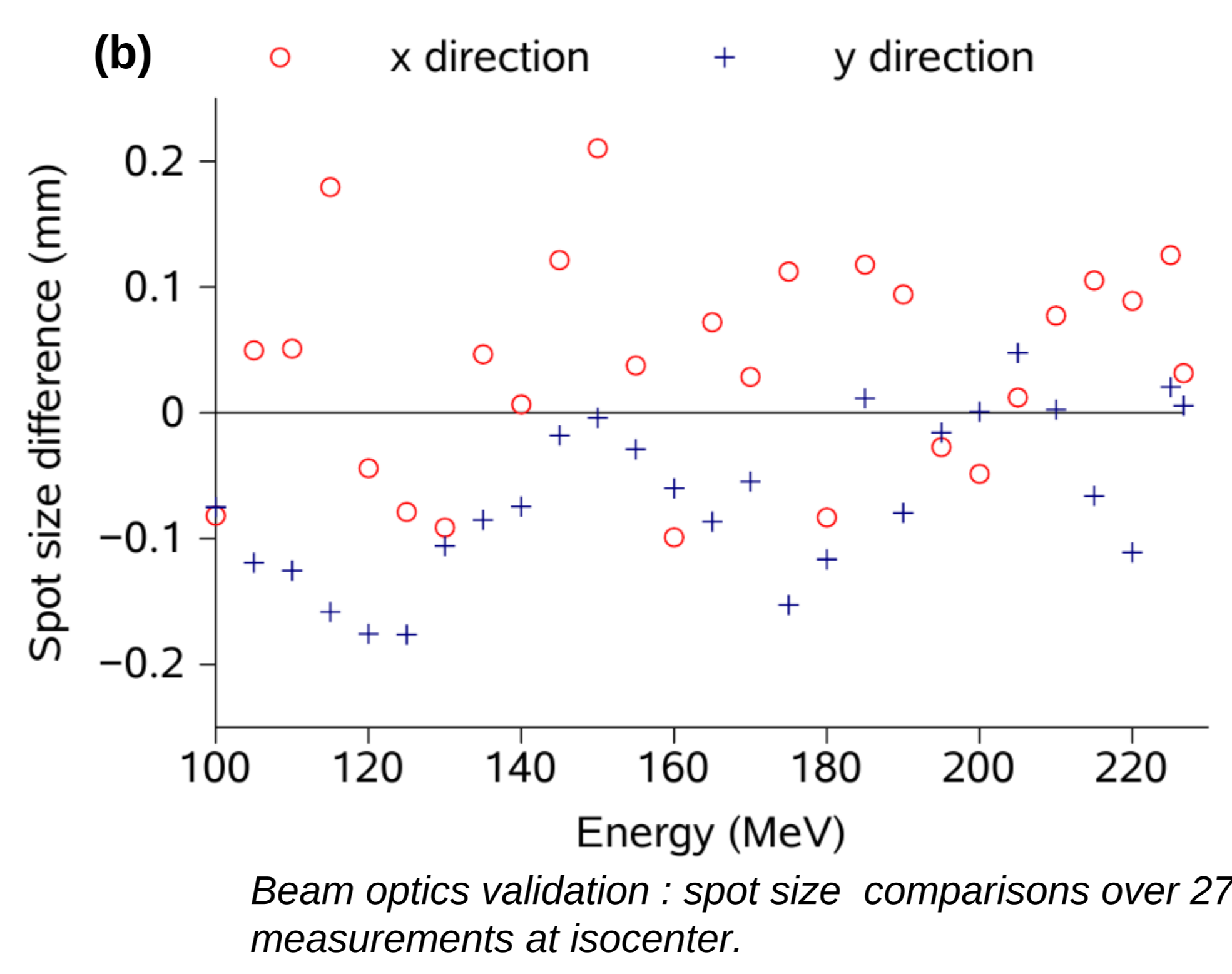
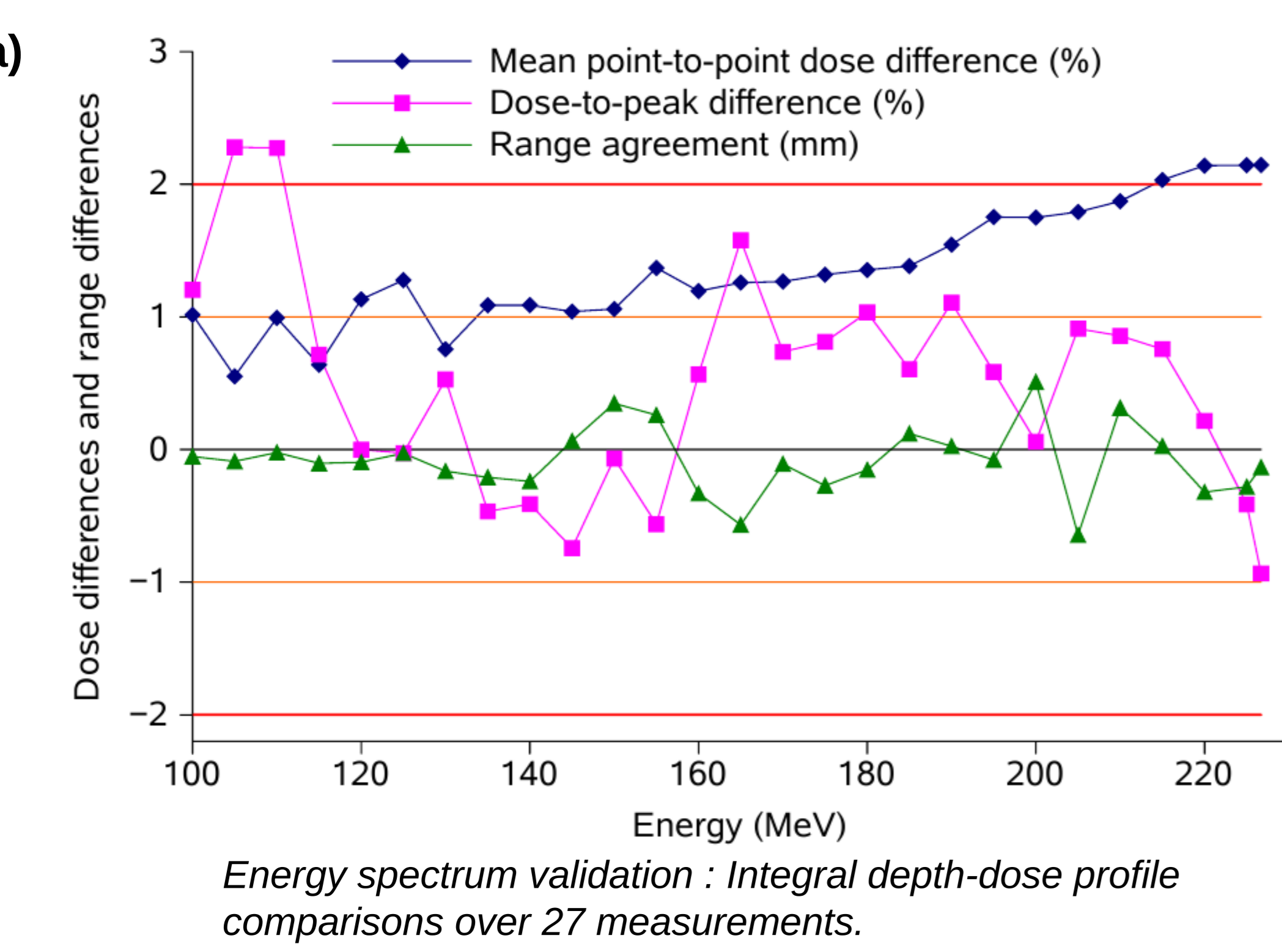
Materials and Methods

Optical and energy parameters of the system are modeled using a set of proton depth-dose profiles and spot sizes measured at 27 therapeutic energies. Pristine Bragg peak simulations are evaluated in terms of mean point-to-point, dose-to-peak, range and spot size differences. **The beam model accuracy is further validated by simulating complex 2D and 3D plans.** Gate V6.0, V6.1[1] and Geant4 9.2, 9.4 releases were used. Physics-list and parameters were selected according to [2].



Schematic view of the treatment delivery.

Beam model validation



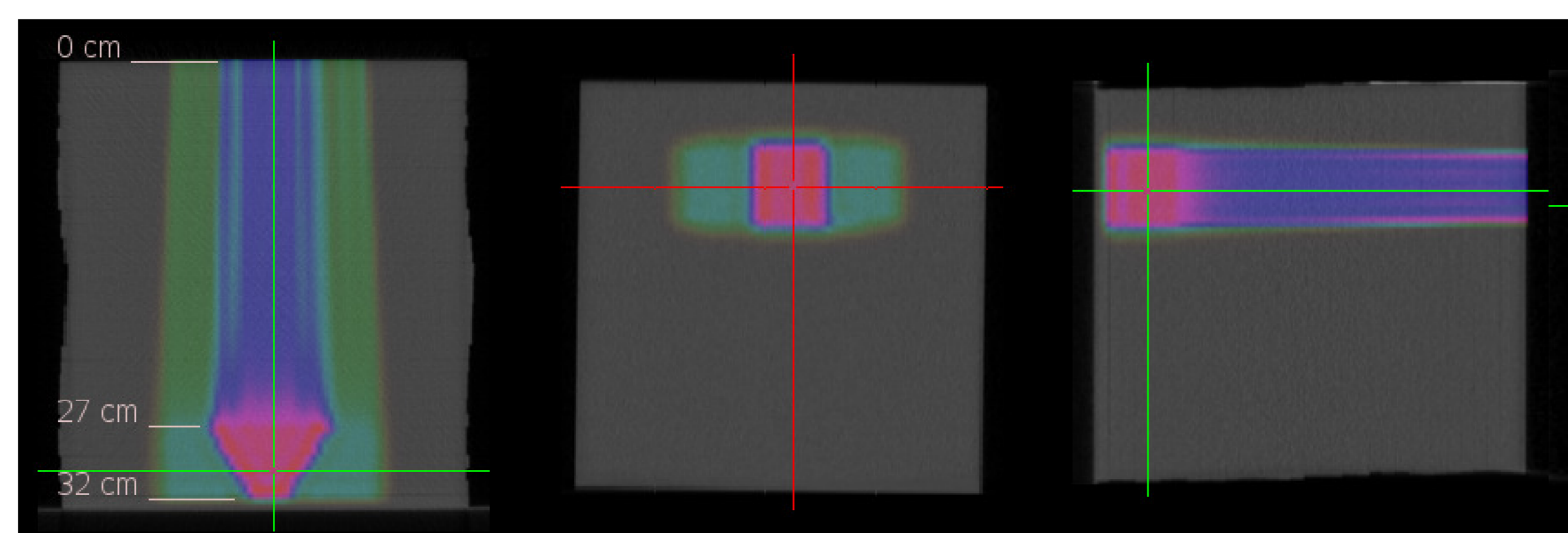
Details of the beam model:

The beam model starts at the nozzle exit and is characterized by energy parameters (mean energy, energy spread) and optical parameters (spot size, beam divergence, beam emittance).

Details of the presented results:

- (a) We evaluated the simulation of 27 depth-dose profiles in terms of range and dose difference.
 - A **2%/1mm agreement** is obtained for most of the points.
 - (b) We evaluated the spot size simulation at isocenter for 27 energies.
 - The spot size (standard deviation) is reproduced within 0.2 mm.
 - (c) We evaluated the simulation of a SOBP modulated between 22 and 32 cm, by simulating the cylindrical geometry of a 1 cm PPC05 (IBA-dosimetry) ionization chamber, using the proposed beam model.
 - A **2%/1mm agreement** is obtained up to the distal fall-off.
 - (d) We evaluated the simulation of a test pattern at isocenter for 3 energies (117, 181, 226 MeV) using the proposed beam model over measurements obtained with the LynX (FIMEL) scintillating screen.
 - **Gamma indexes** calculated using OmniPro-ImRT (IBA-Dosimetry) are better than **95% using a 2%/2mm criterion**.
- => **These results validate the proposed beam model in homogeneous media in view of further comparisons with TPS.**
 => **The proposed beam model has been submitted to Phys. Med. Biol. in March 2011.**

Treatment plan comparisons between measurements, XiO and Gate/Geant4



Details of the experiment:

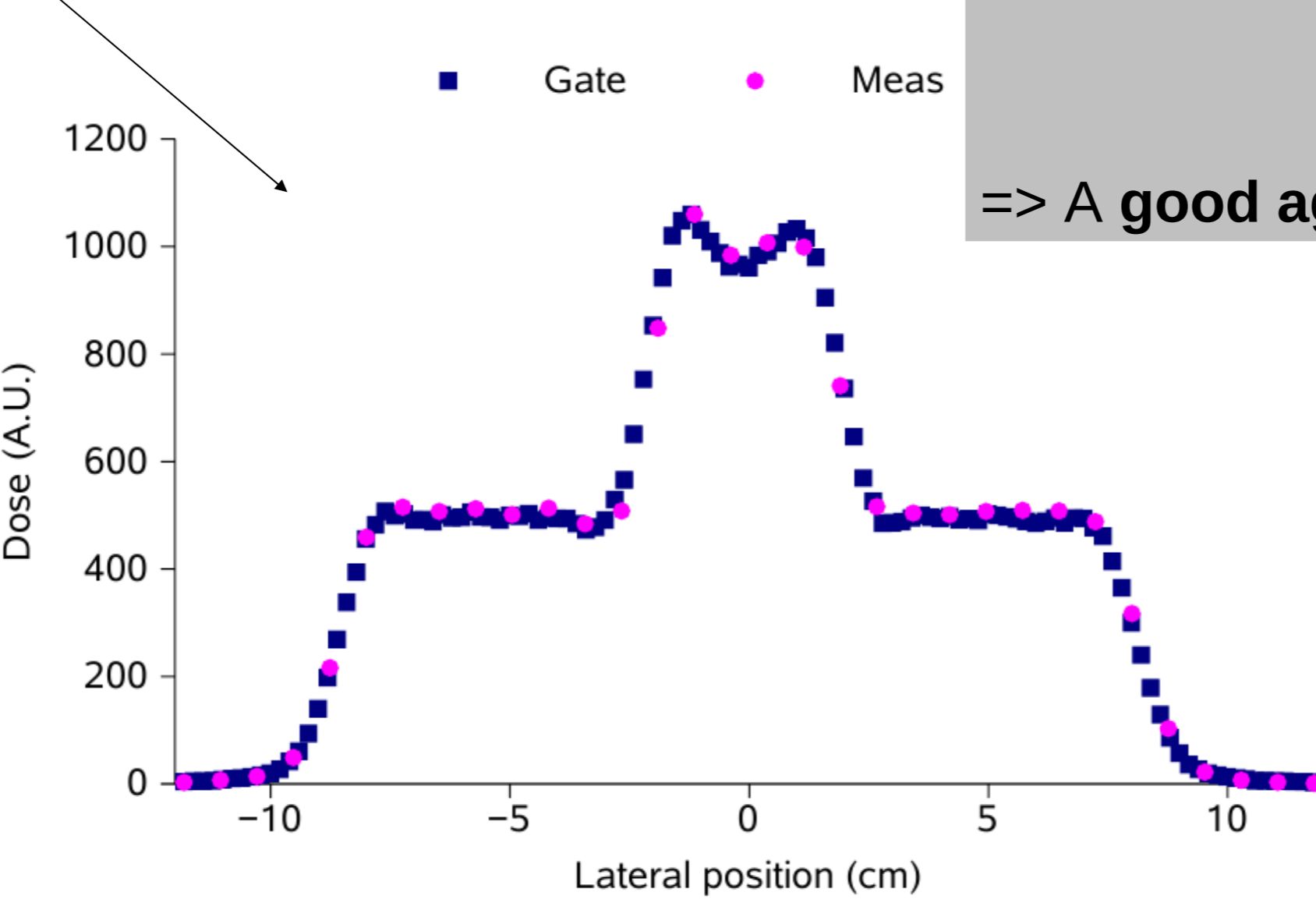
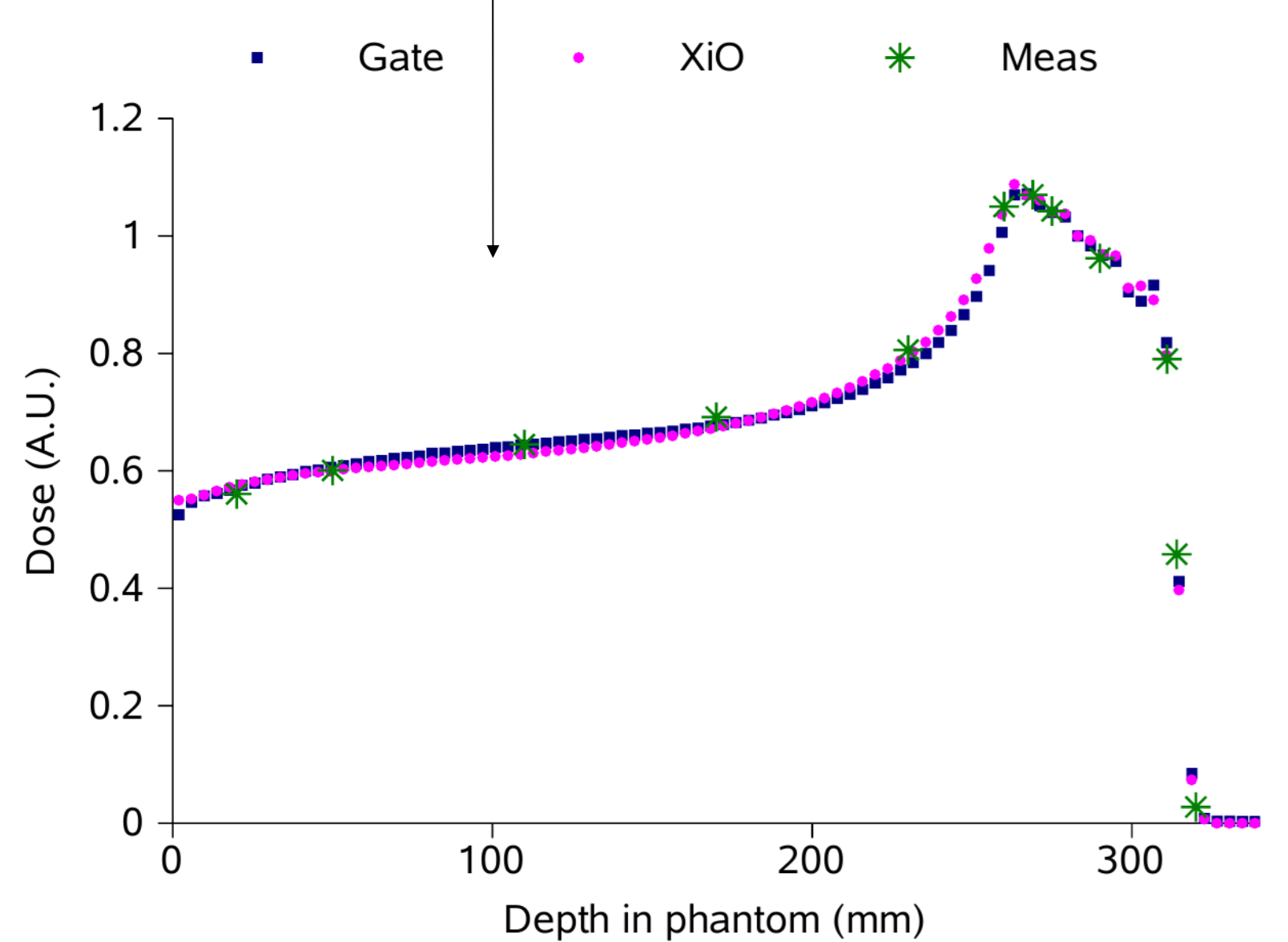
A tissue equivalent phantom was scanned. A treatment plan was generated using XiO, exported and simulated using the Gate platform. Measurements were acquired at various depths using the MatriXX (IBA-Dosimetry) tool, which is a matrix of ionization chambers with a resolution of 7.6 mm.

(e) Integral depth-dose profiles were reconstructed.

(f) Transverse profiles were evaluated for 7 depths between the entrance and the distal fall-off:

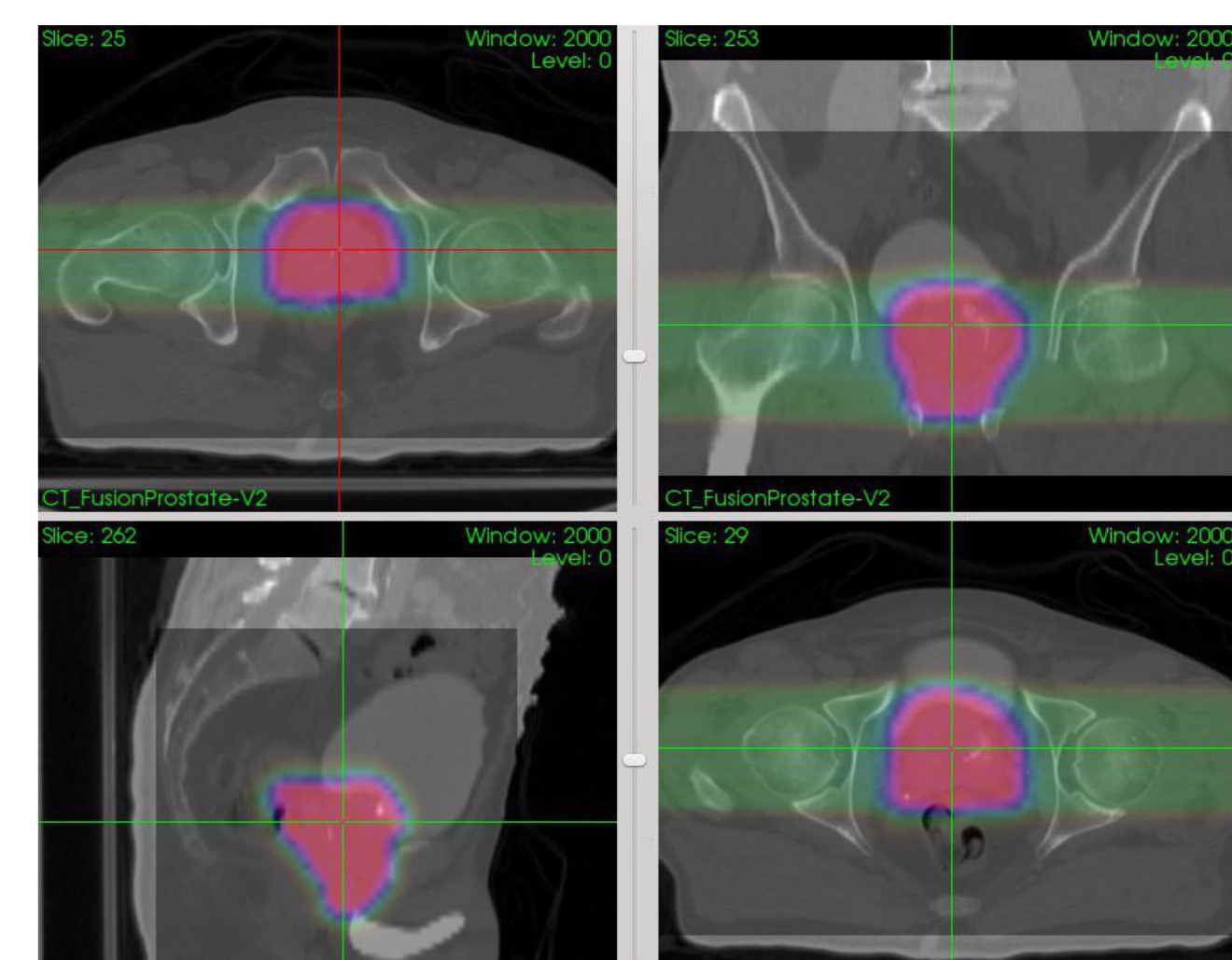
Gate Vs. Meas (3%/3mm)	> 95%
XiO Vs. Meas (3%/3mm)	> 95%
XiO Vs. Gate (2%/2mm)	> 99%

=> **A good agreement in homogeneous phantoms is obtained between Gate, measurements and XiO.**



Perspectives

- We are currently working on **3D dose comparisons between XiO and Gate/Geant4 in patients** for various treatment plans.
- Validations with measurements using sandwiches of heterogeneous materials are also contemplated.



References

- [1] Jan et al. 2011, GATE V6: a major enhancement of the GATE simulation platform enabling modelling of CT and radiotherapy. Physics in Medicine and Biology, 56(4):881, 2011.
- [2] Grevillot et al. 2010, Optimization of GEANT4 settings for Proton Pencil Beam Scanning simulations using GATE. Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms, 268(20):3295 - 3305, 2010.

www.iba-worldwide.com

The research leading to these results has received funding from the [European Community's] Seventh Framework Programme ([FP7/2007-2013] under grant agreement n° 215840-2.

Conclusions

- A Monte Carlo pencil beam scanning model has been validated for the IBA dedicated system.
- **The Gate/Geant4 Monte Carlo platform has been upgraded and allows for active ion beam scanning simulations.**
- Preliminary comparisons between the XiO TPS and Gate/Geant4 simulations showed a good agreement in homogeneous media.
- Further studies in heterogeneous media like patient are on-going.