

LIGHT ION BEAM THERAPY APPLICATIONS USING GATE

Grevillot Loïc

CONTENT

1. Main talk:

IDEAL presentation

(Switzerland/Germany/Austria, Sept. 2021)

2. Status & Perspectives



1. IDEAL

**The independent dose calculation system
for light ion beam therapy**

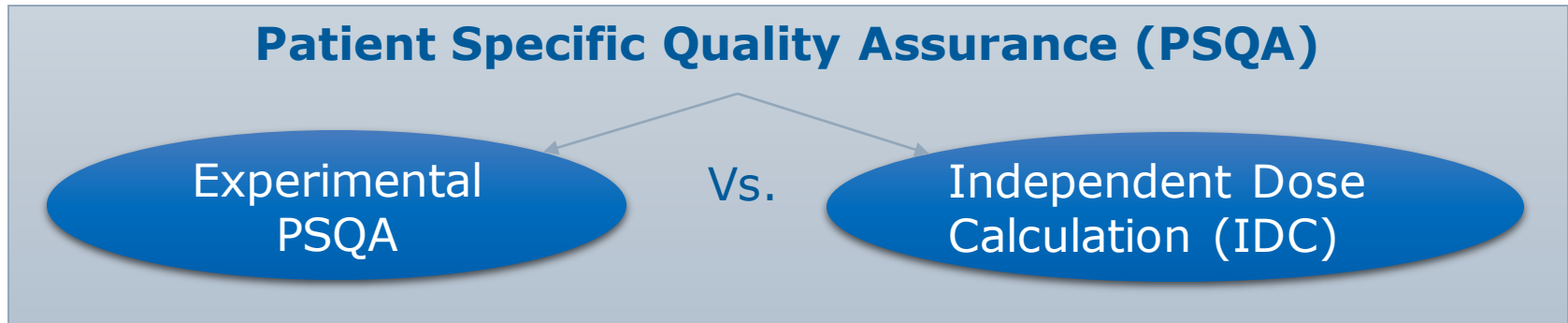
Grevillot L., Boersma D., Fuchs H., Bolsa-Ferruz M., Scheuchenpflug L.,
Georg D., Kronreif G., Stock M.

CONTENT



1. Introduction
2. Materials & Methods
3. Results
4. Summary

INTRODUCTION



What is recommended today?

“Currently, IMRT guidance recommends experimental verification for IMRT patient specific QA” **AAPM Report TG219, 2021.**

Why?

“IDC are recommended and have been used for a long time as a routine QA tool in conventional radiotherapy... (Dutreix *et al.* 1997).... However, the traditional empirical dose calculation models ... are of very limited applicability for advanced treatment techniques ... and may also be of limited accuracy if applicable at all (Georg *et al.*, 2004).” **ESTRO booklet N0 10, 2010.**

Historically, IDC was substituted by experimental PSQA due to technical limitations of the IDC algorithms.

INTRODUCTION

Experimental PSQA has a limited sensitivity!!

- **IMRT:**
IDC was 12 times more sensitive at detecting treatment failures for IMRT than measurement-based PSQA. **Kry et al, Med Phys 2019**
- **Cyberknife:**
similar findings in terms of sensitivity. **Milder et al, J Appl Clin Med Phys, 2020**
- **Protons:**
“The implementation of a Monte Carlo (MC) algorithm in an IDC system was shown to illuminate dose computation issues from analytical algorithms implemented in TPS, which would not otherwise be detected using traditional measurement-based PSQA.” **Jhonson et al, PloSOne 2019**

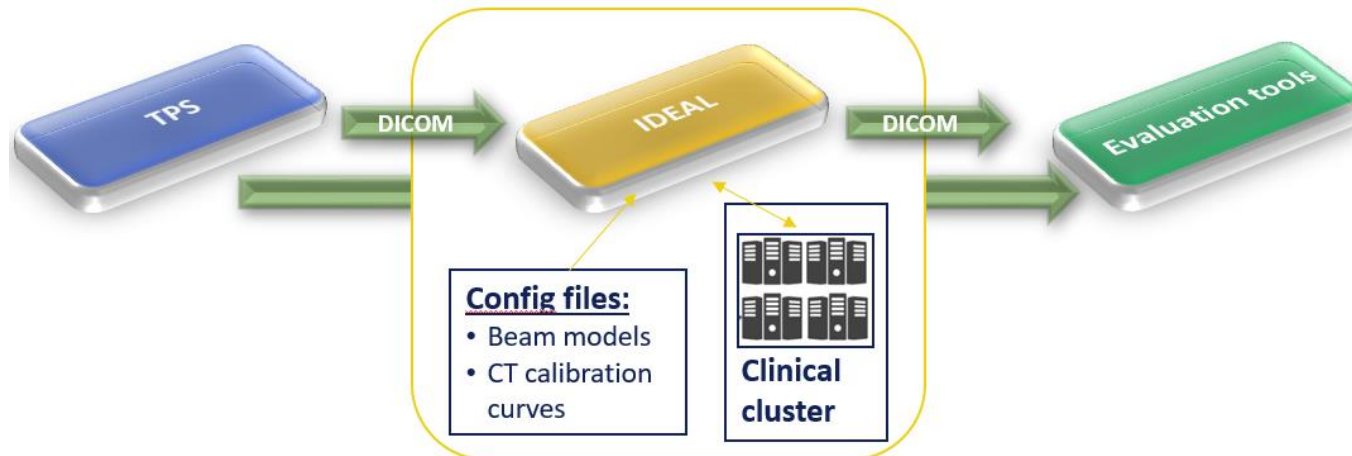
In 2021, there is evidence that IDC should have a place of choice in the PSQA process due to limited sensitivity of experimental PSQA.

MATERIALS & METHODS

IDEAL

(the Independent DosE cAlculation system for Light ion beam therapy)

- **Relies on GATE-RTion V1.0 - Protons and Carbon ions**
Grevillot et al., Med. Phys. 47 (8), August 2020
(A GATE/Geant4 release for clinical applications in scanned ion beam therapy)
- **IDEAL:DICOM-in/DICOM-out workflow**



MATERIALS & METHODS

IDEAL

(the Independent DosE cAlculation system for Light ion beam therapy)

Clinical implementation steps:

- 1. System installation & configuration**
- 2. Acceptance testing**
- 3. Commissioning**
- 4. Clinical use cases**

MATERIALS & METHODS

IDEAL

(the Independent DosE cAlculation system for Light ion beam therapy)

Clinical implementation steps:

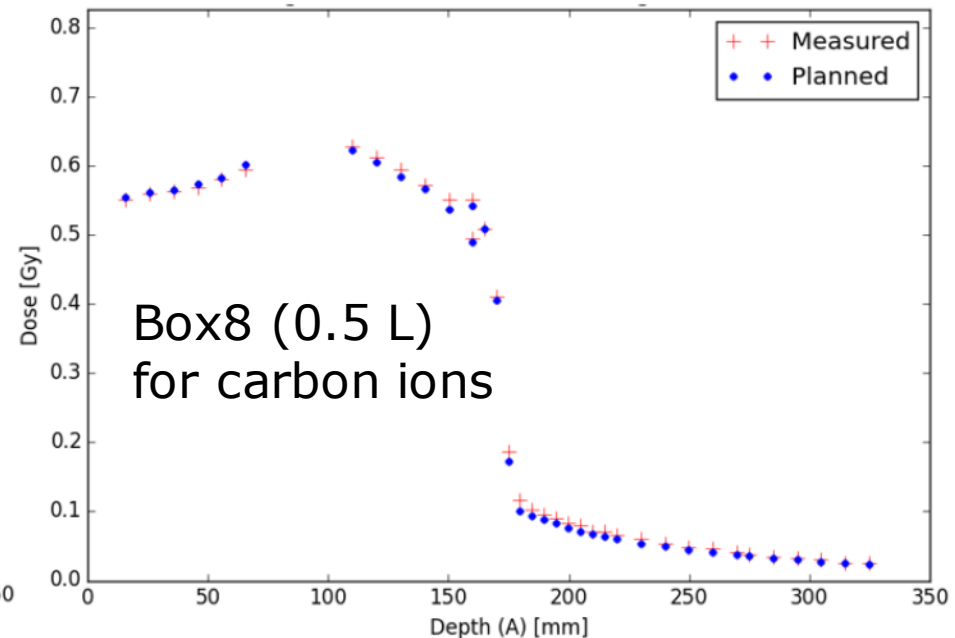
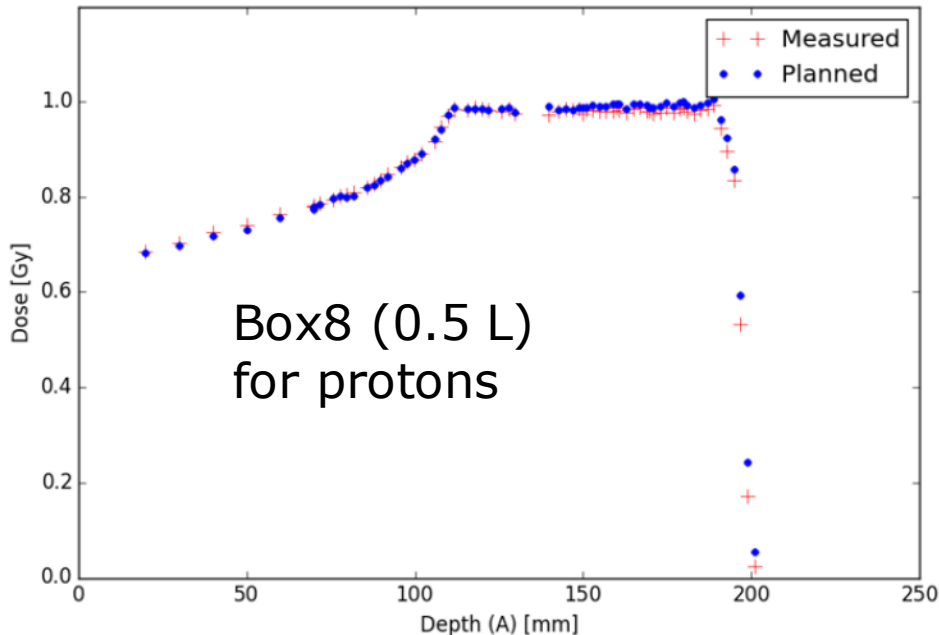
1. System installation & configuration
2. Acceptance testing
3. **Commissioning**
 - a. Dosimetric commissioning (range, spot size, dose)
 - b. CT calibration validation (evaluation of Water Equivalent Thickness (WET))
4. **Clinical use cases**
 1. IDC of proton and carbon ion clinical plans (using 1% uncertainty goal)
 2. Gamma index evaluation using Verisoft Version7.2 (PTW, Freiburg)

RESULTS

Dosimetric commissioning in water

Proton and carbon ion key results:

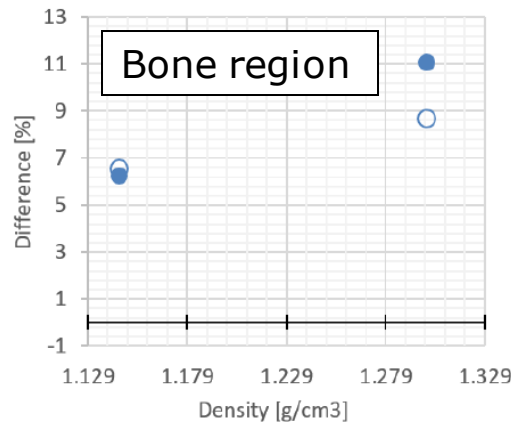
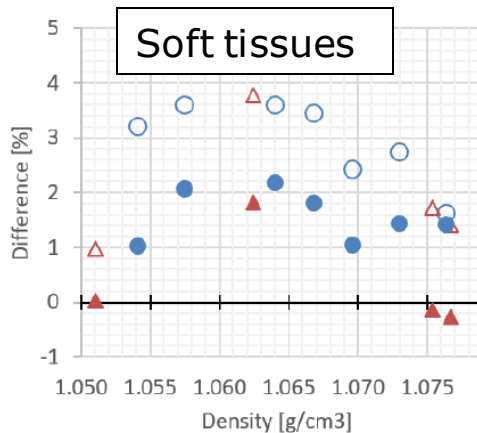
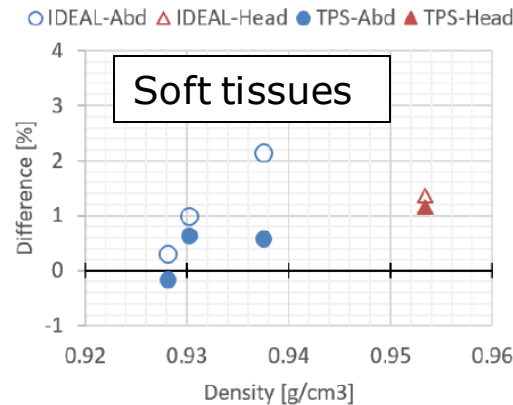
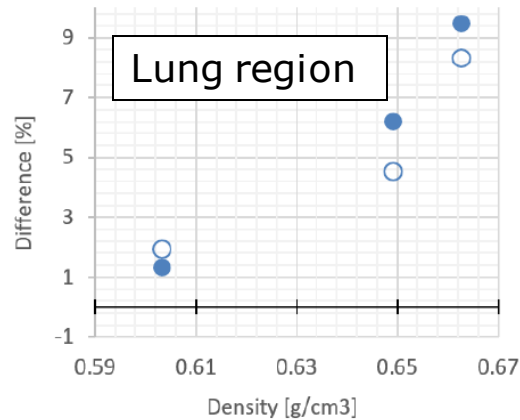
- **Ranges** in water: within **0.2 mm**
- **Beam sizes** in air: within **0.3 mm** (from nozzle exit till isocenter)
- **3D dosimetric pass-rate** at the 5% dose level > **97%** (for 3D reference boxes)



Grevillot L. and Boersma D. J. et al, Frontiers in physics, 2021

RESULTS

CT calibration and validation



Evaluation of Water Equivalent Thickness (WET) differences between measurements and simulations, **using real pig tissue samples** (lung, adipose, brain, kidney, heart, blood, spleen, liver, muscle, bone)

Grevillot L. and Boersma D. J. et al, *Frontiers in physics*, 2021

RESULTS

Carbon ion example

Angiosarcoma

para-nasal region

PTV1 (465cc)

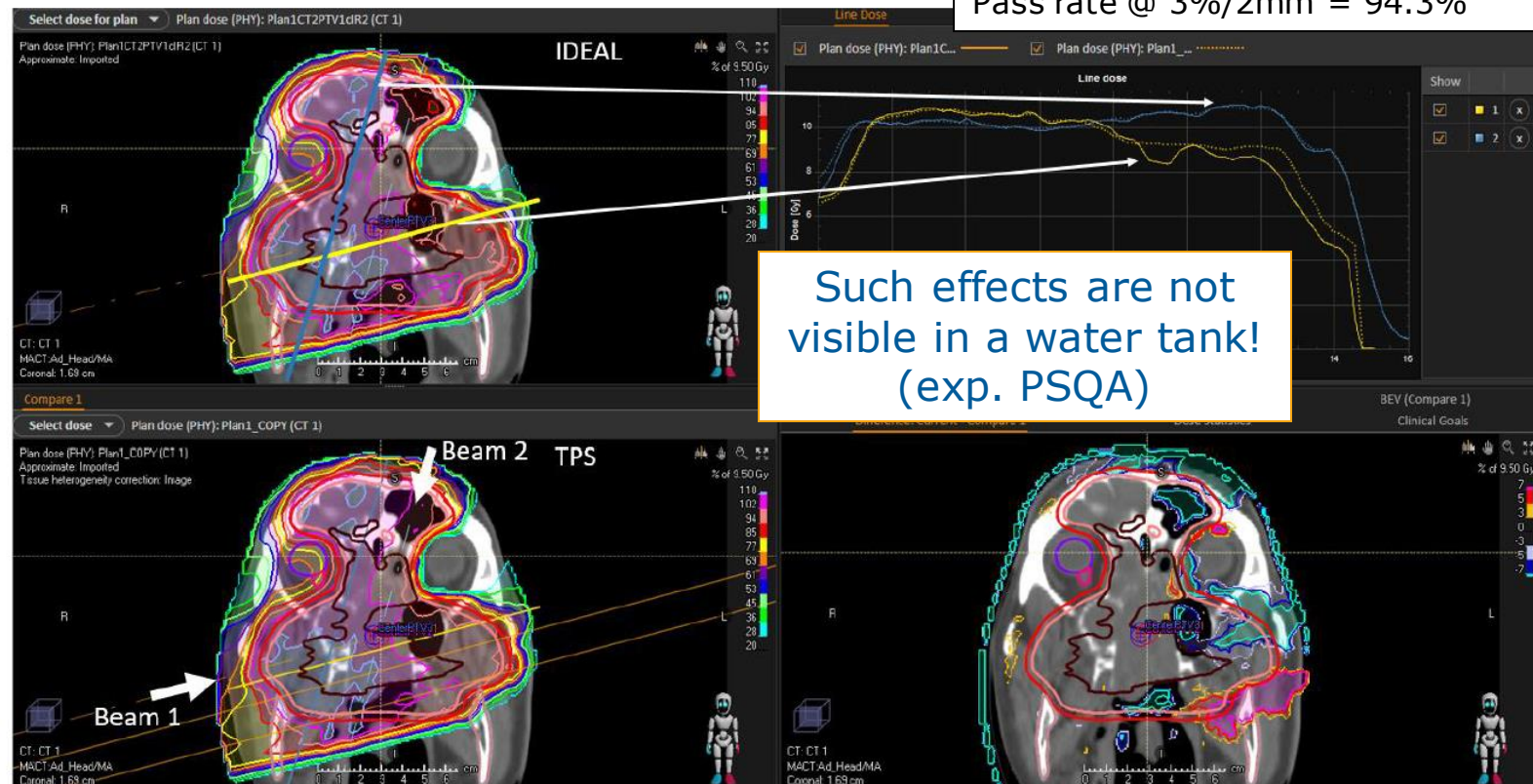
43.2Gy = 9Fx of 4.8Gy/Fx

Differences are visible in the vicinity of the air cavities, probably due to limitations of the TPS pencil beam algorithm against the IDEAL MC algorithm.

Pass rate @ 3%/3mm = 97.4%

Pass rate @ 3%/2mm = 94.3%

Such effects are not visible in a water tank! (exp. PSQA)



Grevillot L. and Boersma D. J. et al, *Frontiers in physics*, 2021

RESULTS

Proton example

Pancreas

PTV1/PTV2 (204/71cc)

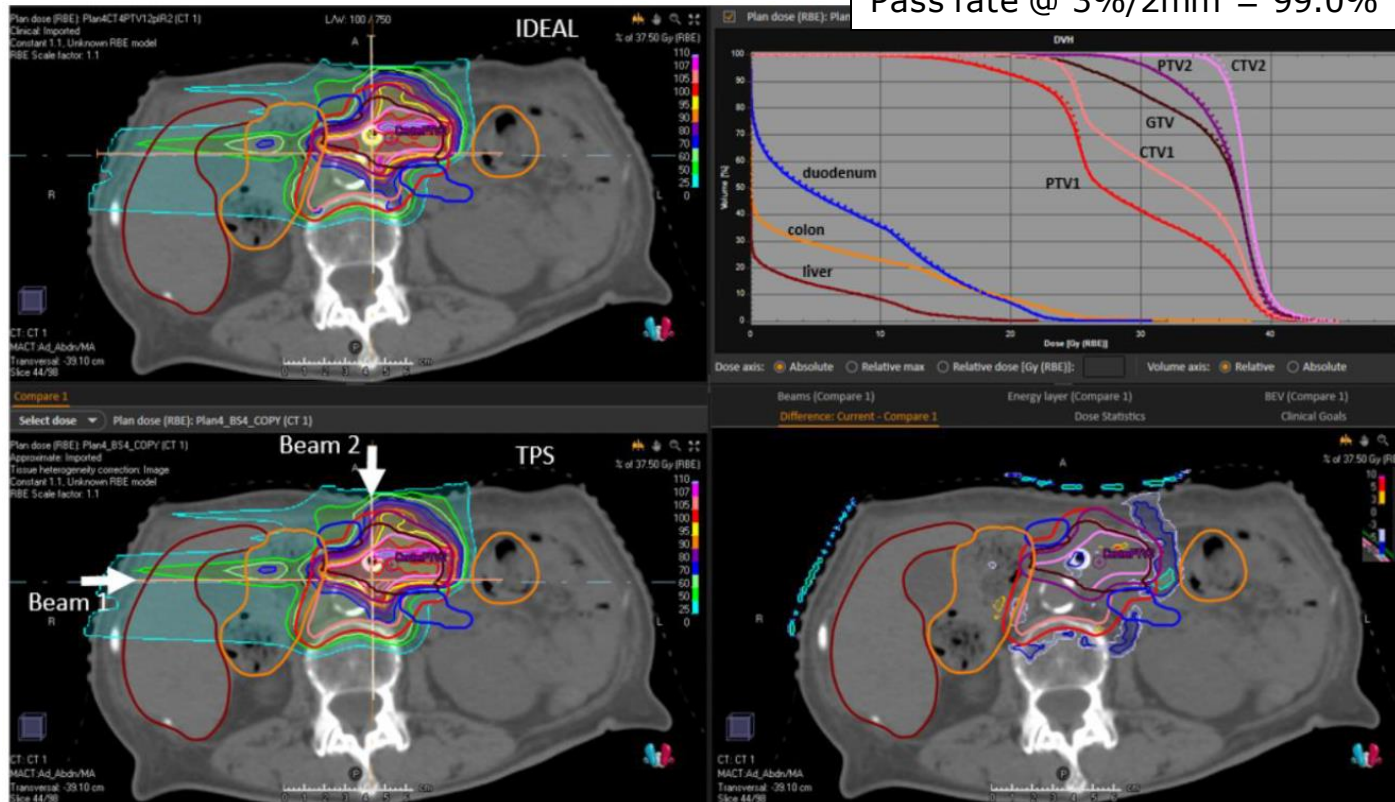
25Gy/37.5 Gy (5 Fx)

5/7.5 Gy/Fx

Very little differences observed between both TPS and IDEAL MC algorithms. Dose difference at end of range are visible due to stopping power differences.

Pass rate @ 3%/3mm = 99.8%

Pass rate @ 3%/2mm = 99.0%



Grevillot L. and Boersma D. J. et al, *Frontiers in physics*, 2021

SUMMARY

- ✱ IDEAL V1.0 was released in April 2021!
- ✱ IDEAL was accepted and partially commissioned at MedAustron:
 - ✱ For scanned proton & carbon ion beams!

PERSPECTIVES

- ✱ Clinical implementation! (*see general perspectives*)

Thank you for your attention!

*This work is the result of national and international collaborations.
Many thanks to all participants!!*

- **David Boersma**: IDEAL main developer
- **Hermann Fuchs, Alessio Elia, Delphine Boucaud, Marta Bolsa, Lukas Scheuchenpflug, Ruben Gonzalo**, for participation in acceptance testing and commissioning of GATE-RTion/IDEAL
- **MedAustron medical physics team**: for providing measurements
- **OpenGate collaboration** for development and maintenance of GATE
- **ACMIT/MUW/MedAustron** for collaboration in the IDEAL project



MP TEAM!



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2. STATUS AND PERSPECTIVES

**GATE applications
for light ion beam therapy**



STATUS

• Accepted papers:

- GATE-RTion (Grevillot, 2020)
- 3D stopping power (Bolsa-Ferruz, 2021)
- IDEAL (Grevillot & Boersma, 2021)
- Impact of beamline-specific particle energy spectra on clinical plans in carbon ion beam therapy (Resch 2021, conditionally accepted)

• Papers in preparation:

- Evaluation of methods to compute water-equivalent thickness for protons and carbon ions using GATE-RTion (Bolsa-Ferruz 2021, to be submitted)

The GATE-RTion/IDEAL Independent Dose Calculation System for Light Ion Beam Therapy

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Frontiers in Physics | www.frontiersin.org

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Technical Note: GATE-RTion: a GATE/Geant4 release for clinical applications in scanned ion beam therapy

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(Received 20 December 2019; revised 15 April 2020; accepted for publication 3 May 2020; published 13 June 2020)

Monte Carlo computation of 3D distributions of stopping power ratios in light ion beam therapy using GATE-RTion

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(Received 26 June 2020; revised 11 December 2020; accepted for publication 20 December 2020; published 27 March 2021)

Purpose: This paper presents a novel method for the calculation of three-dimensional (3D) Bragg–

2580 Med Phys 48 (5), May 2021 0094-2405/2021/48(5)/2580/12 © 2021 American Association of Physicists in Medicine 2580

PERSPECTIVES

- **IDEAL 1.0**

- **Integration into MyQAiON** (*CE medical product for IDC from IBA*) **planned for 2022!**
- **MedAustron/IBA collaboration**

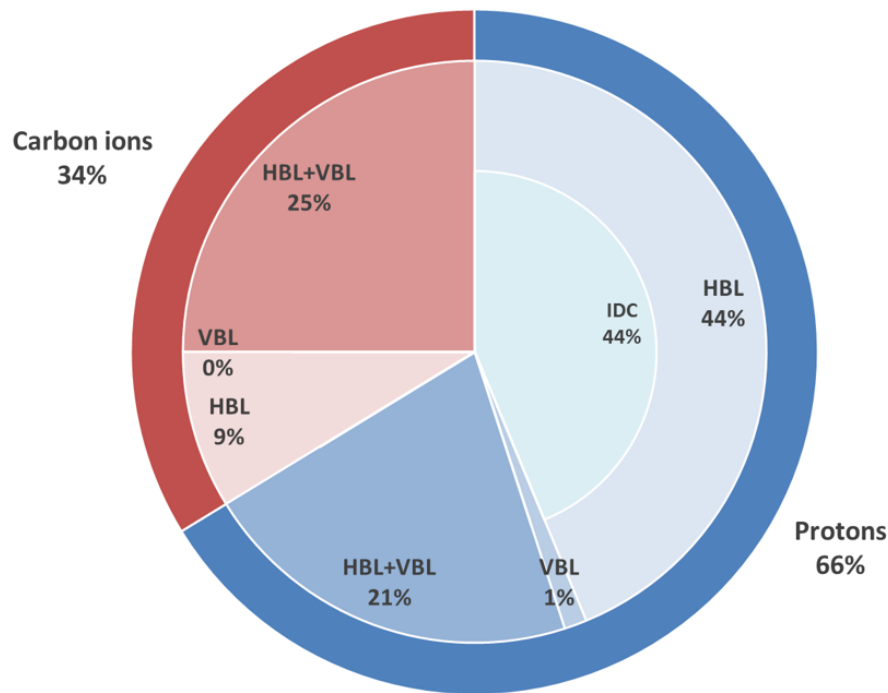
- **IDEAL 2.0:**

- **Project proposal approved** by the region of lower Austria
 - The region contributes to 25-40% of the money
 - MedAustron for the rest (*final budget under approval*)
- **~ 3 year project, starting Q2 2022, including a developer, a medical physicist and a PhD student**
 - Including LET/RBE models
 - Including GATE-RTion 2.0
 - Revival of the GATE-RTion meetings for the next version towards IDEAL 2.0?
⇒ GATE-RTion V2.0 = 2023 ?

PERSPECTIVES

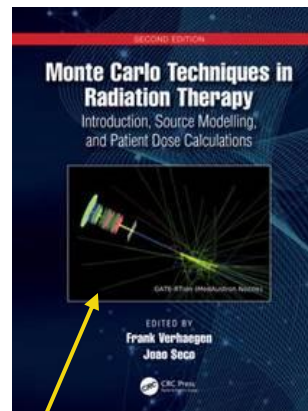
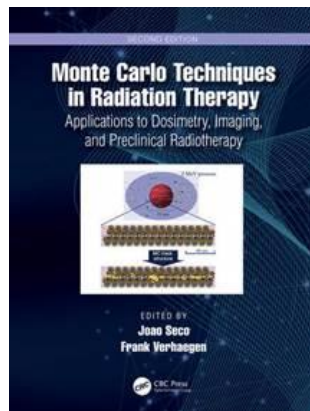
- **MyQAiON** allows to reduce PSQA by about 60-70% for protons.
- **MyDEAL = MyQAiON + IDEAL** (for carbon ions)
may allow to reduce beam time for PSQA for the remaining 30-40%!!

Particle type/Beam line - October 2021



Thank you for your attention!

Finally: If you look for a good book about Monte Carlo!



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Edition	2nd Edition
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Pub. Location	Boca Raton
Imprint	CRC Press
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Subjects	Engineering & Technology, Medicine, Dentistry, Nursing & Allied Health, Physical Sciences

