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Europe/Rome timezone

Application of a Monte Carlo algorithm in dosimetric verification of pencil beam scanning proton therapy treatments

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Introduction

What's the aim of this verification?

1. Verify the correct DATA TRANSFER from Treatment Planning System to Therapy Control System
2. Verify TPS dose calculation (?)

How to perform it?

1. Measurements (array of ionization chambers, IC, Fluence detectors etc.)

2. Independent dose calculation algorithm: three AAPM reports ([TG100], [TG114] and [TG219])
   "*[…]any valid dosimetric calculation system, up to and including a second TPS or* ***Monte Carlo*** *simulation, can be used to perform a verification MU calculation*" [TG100]

MC parameters

Welcome to TOPAS MC Inc., a non-profit organization created to support and extend the TOPAS Tool for Particle Simulation.

Geant 4

Proud user of the Geant4 Simulation Toolkit

New: TOPAS Version 3.1.p2 Released 7 October 2017

- TOPAS can model a passive scattering or scanning beam treatment head
- model a patient geometry based on computed tomography (CT) images
- score dose, fluence, LET ecc.
- provides advanced graphics,
- TOPAS let user to implement his own code and recompile the whole code in order to improve the tool flexibility.
- is fully four-dimensional (4D) to handle variations in beam delivery and patient geometry during treatment

TOPAS: An innovative proton Monte Carlo platform for research and clinical applications

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Perl J, Shin J, Schumann J, Faddegon B, Paganetti H. **TOPAS: an innovative proton Monte Carlo platform for research and clinical applications.** Med Phys. 2012 Nov; 39(11):6818-37

Physics Modules optimized for protontherapy:

G4em-standard_opt3
G4h-phy_QGSP_BIC_HP
G4decay
G4ion-binarycascade
G4h-elastic_HP
G4q-stopping

d:Ph/Default/CutForAllParticles= 0.5 mm
(it is 10 times the TOPAS default value)

Beam Model

IOP Publishing | Institute of Physics and Engineering in Medicine
Physics in Medicine & Biology
Phys. Med. Biol. 60 (2015) 8601–8619
doi:10.1088/0031-9155/60/21/8601

Characterization and validation of a Monte Carlo code for independent dose calculation in proton therapy treatments with pencil beam scanning

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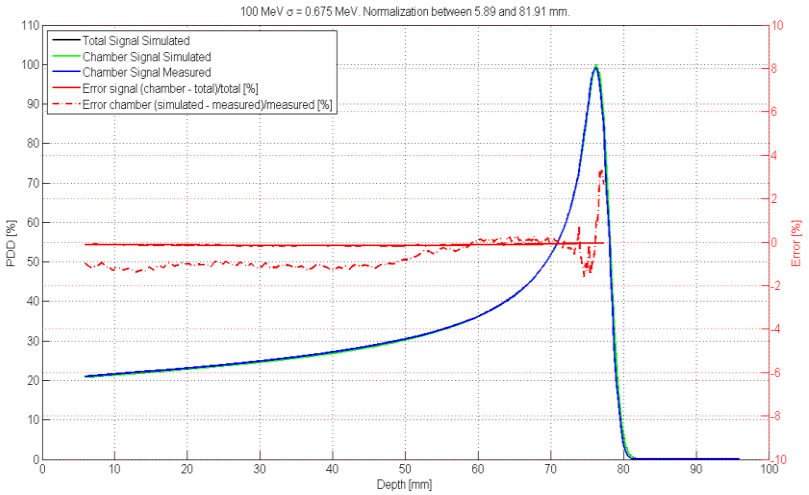
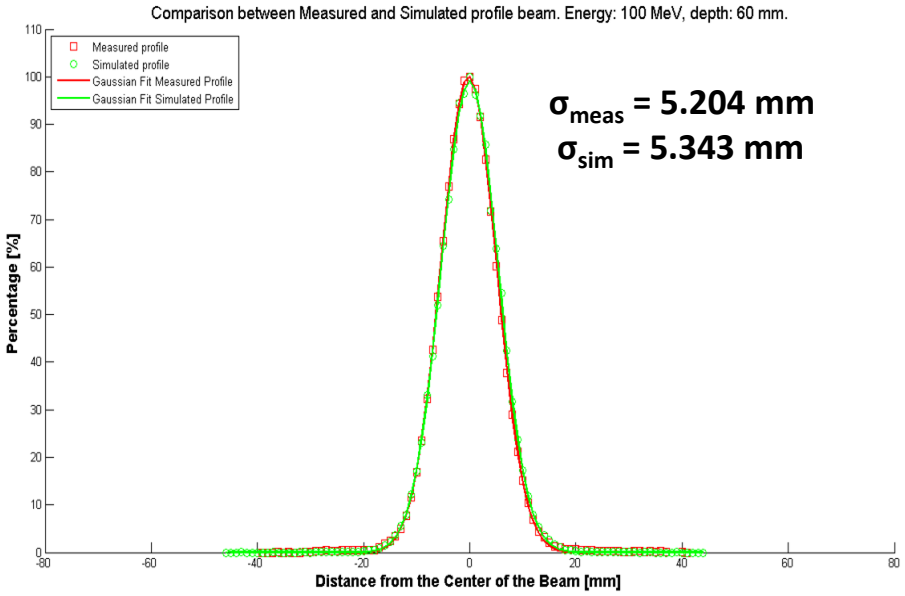
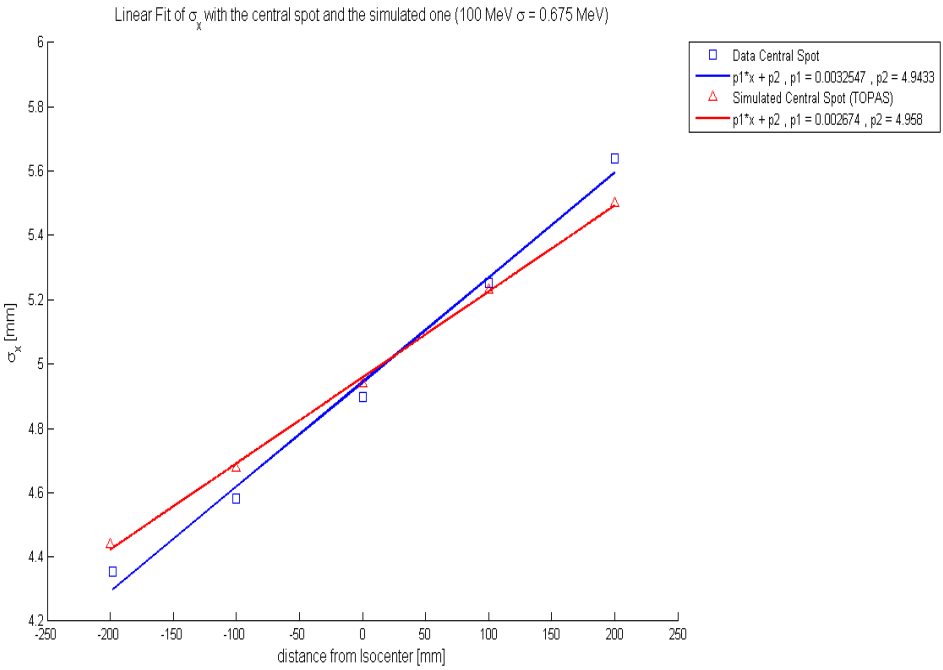
CrossMark

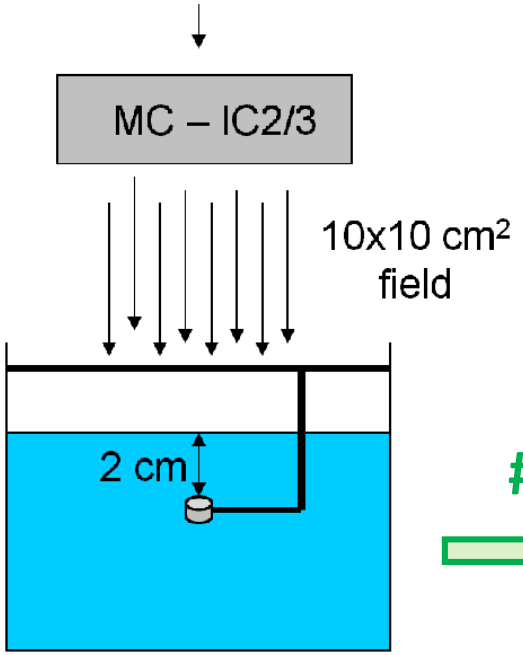




σ_{meas} = 5.204 mm
σ_{sim} = 5.343 mm



The strength of this Beam Model



Comparison between **Faraday Cup** measurements of # of p+ and **MC+IC** determination

# of p+/MU

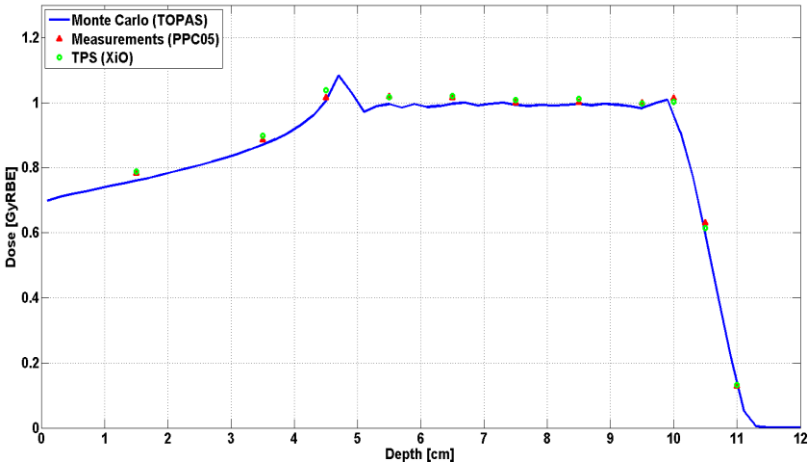
PTC data			
E	number of p/MU		
(MeV)	Simulated	Measured and Corrected for FC efficiency	Percentage Differences
70	6,05E+07	6,07E+07	0,30%
80	6,74E+07	6,75E+07	0,09%
90	7,36E+07	7,33E+07	0,42%
100	7,95E+07	7,89E+07	0,79%
110	8,48E+07	8,53E+07	0,59%
120	9,03E+07	9,06E+07	0,29%
130	9,57E+07	9,48E+07	0,99%
140	1,01E+08	1,01E+08	0,41%
150	1,06E+08	1,07E+08	0,16%
160	1,11E+08	1,11E+08	0,39%
170	1,17E+08	1,17E+08	0,02%
180	1,22E+08	1,21E+08	0,54%
190	1,26E+08	1,26E+08	0,03%
200	1,31E+08	1,31E+08	0,24%
210	1,35E+08	1,36E+08	0,74%
220	1,39E+08	1,41E+08	1,28%
mean differences			0,50%

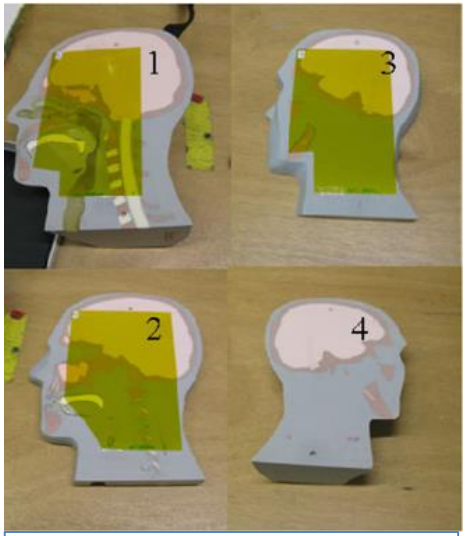
# of p+/MU

Code Validation

HOMOGENEOUS PHANTOM

Three SOBPs were planned, delivered and simulated
with different Range and Modulation

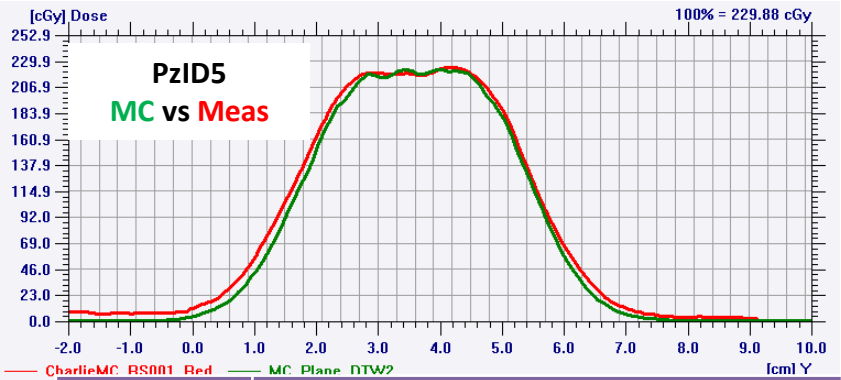




Pic. From: Albertini et al., Phys. Med. Biol. 56 (2011) 4415–4431

ANTROPOMORPHIC PHANTOM

- Five different intra cranical plans were created, delivered, simulated and measured
- EBT3 GAFCHROMIC between phantom slab



	Gamma Analysis results – Passing Rate (%)	
PlanID	MC vs Measurement	TPS vs Measurement
PzID1	93,50	92,22
PzID2	97,73	98,95
PzID3	97,54	97,57
PzID4	96,54	94,41
PzID5	**95,99**	**88,95**
PzID6	**93,65**	**81,20**

MC Plan Verification

THE QUESTION:

Does this Monte Carlo code allow to replace QA measurements while maintaining the same treatment quality and safety standards?

Patients cohort:

Number of patients: **28**
Number of verification plans: **187**

	PTV Volume (cc)	MU	dose/fraction (GyRBE)	total dose (GyRBE)
min	2,14	27,24	1,70	10,00
max	498,90	905,70	2,00	60,00
mean	140,83	210,00	2,00	54,00
stdv	121,04	194,81	0,10	16,25

The method

Gold Standard

Patient Specific QA measurements

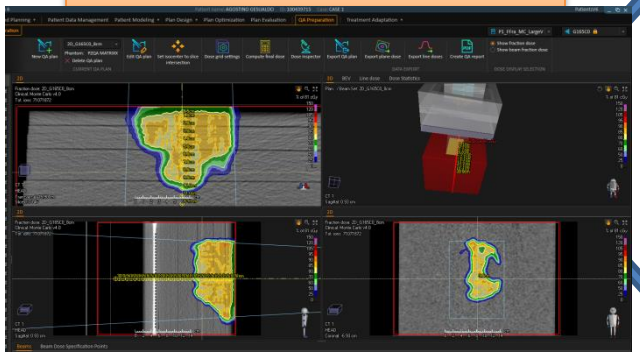
Measurements vs **TPS**

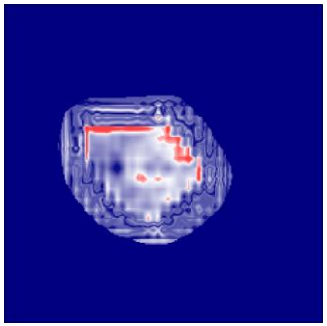
Gamma Passing Rate (3%,3mm)

Threshold = 90%

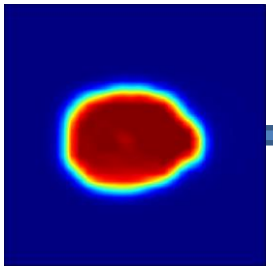
Plan Approved

Verification plan in TPS

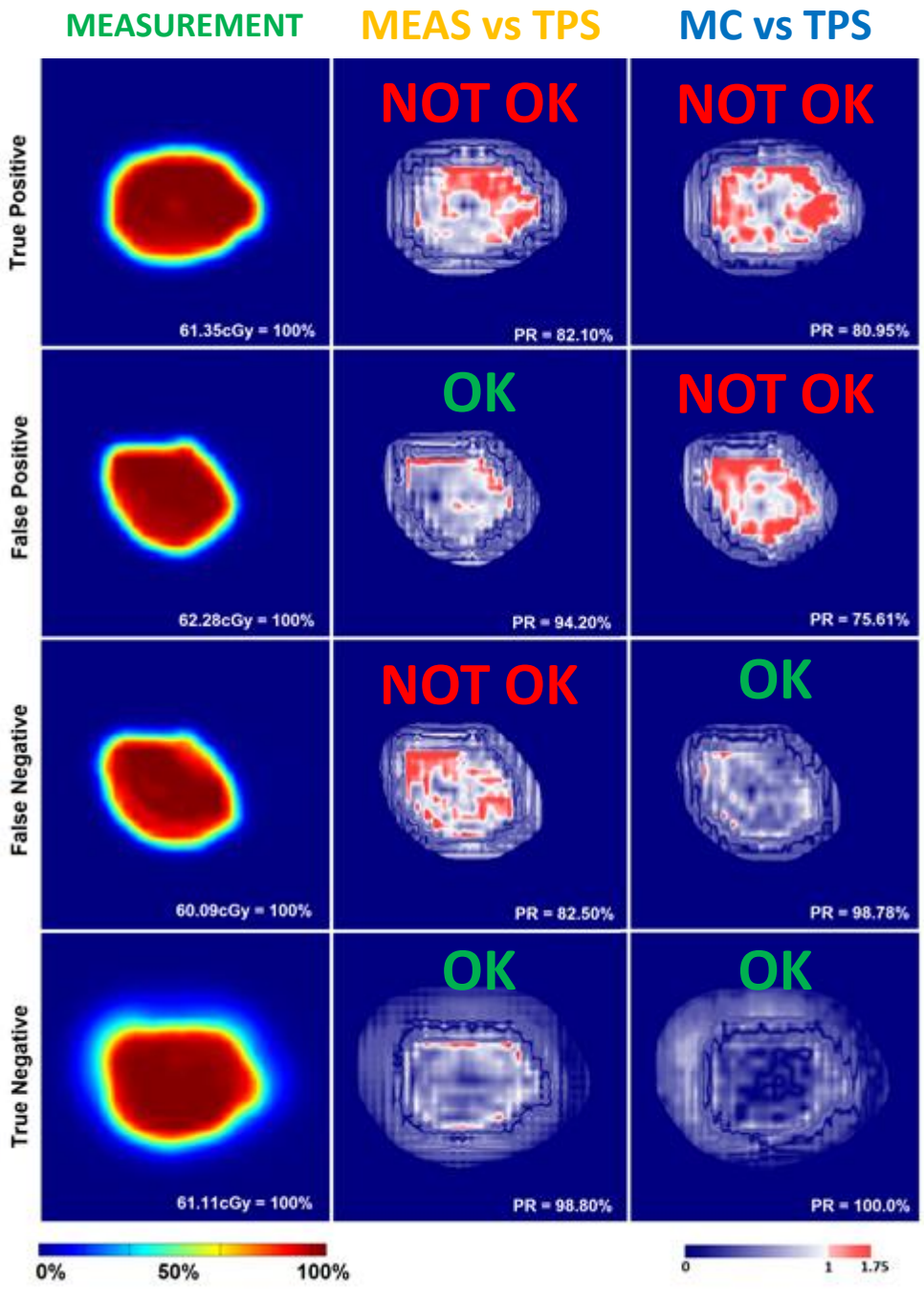




MC simulation of PSQA



MC vs **TPS**



Results

1

0

0

186

Accuracy = (TP + TN) / total = 100,0%

1. Average Time per simulation: **20min**
2. Average Time per measurements: **2h and half**
3. **High Accuracy** of the test on a large sample of verification plans
4. The suggested workflow is **compliant** with international guidelines

Summary and Perspectives

- We **characterized** and **validated** a MC code for independent calculation of pencil beam scanning protontherapy treatments
- We performed a **sensitivity/specificity** test of the code in PSQA applications obtaining the best results in terms of accuracy
- With this code we are able to drastically **reduce the occupation time of gantry rooms** without loosing anything in terms of quality
- It is compliant with international radiotherapy guidelines

Coming Soon…

- Independent dose calculation will be performed on patient anatomy
- High gradient dose distributions can be simply verified (MatriXX spatial resolution is 7,6mm)