MedAustron
Ion Therapy Center

STRATEGIES FOR PATIENT SPECIFIC QA PRE-TREATMENT

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MedAustron Ion Therapy center

OUTLINE

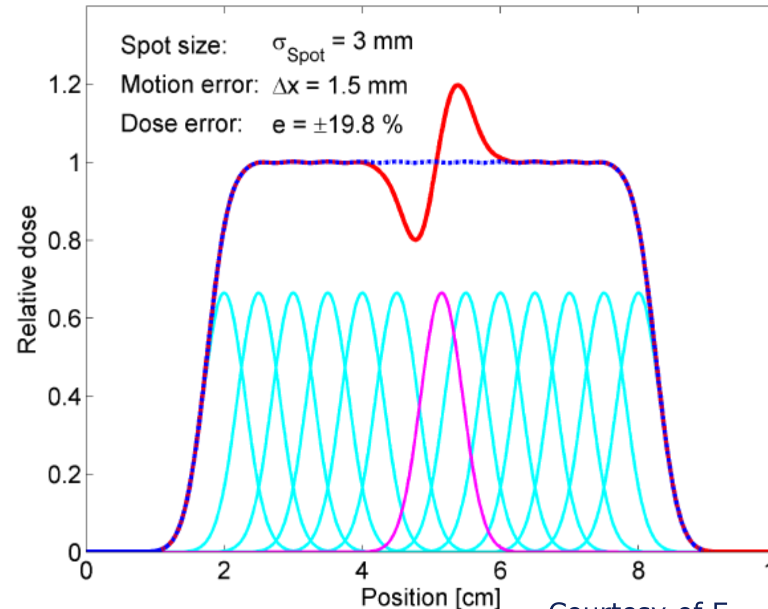
- Motivation
- Dosimetry equipment/methods for PSQA at different Light Ion Beam Therapy (LIBT) facilities
- Characterization of the equipment for PSQA at MedAustron
- PSQA procedures implemented at MedAustron
- PSQA results at MedAustron
- Toward Independent Dose Calculation (IDC) – MedAustron project

Why is patient specific plan verification needed?

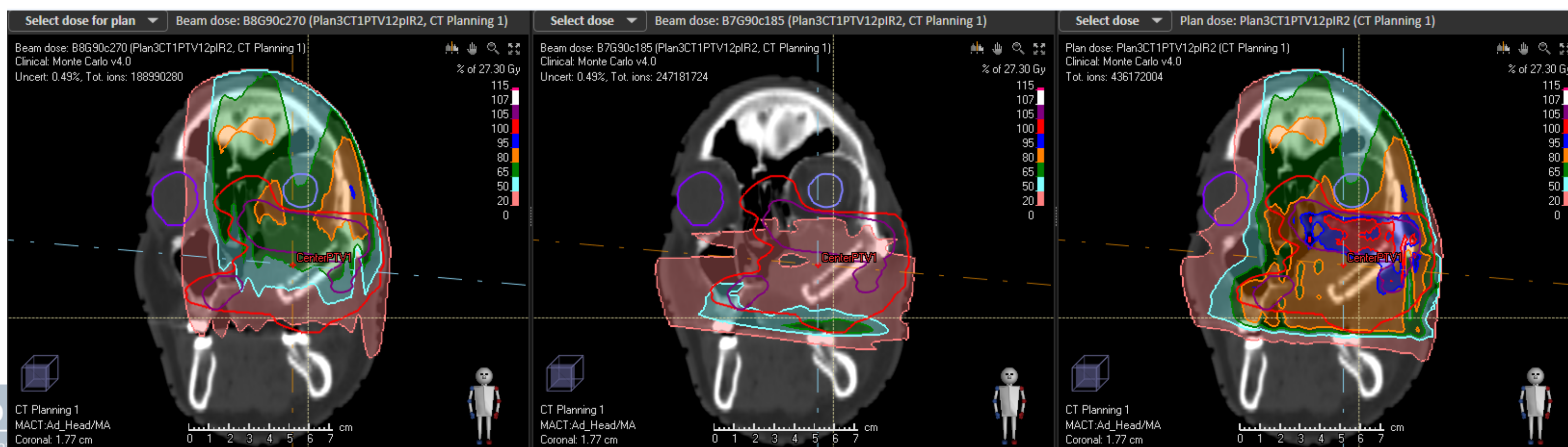
- Complex and non-standard irradiation technique (superposition of thousands of individually placed and weighted pencil beams)

- To verify that the entire treatment plan is delivered without triggering any major interlocks or accelerator failures.

- High dose gradient and inhomogeneous dose distribution (Intensity Modulated Particle Therapy)



Courtesy of E. Pedroni (PSI)



Typical treatment workflow

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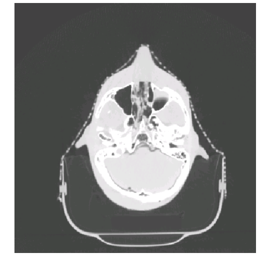


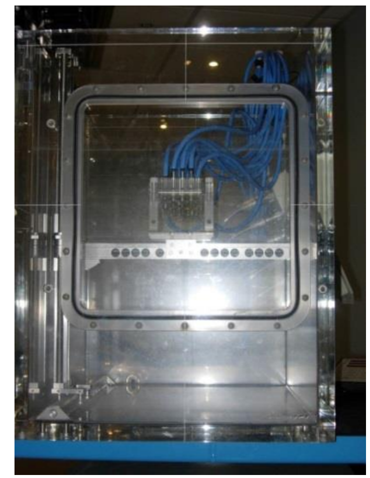
Imaging for planning

Treatment planning

Patient specific plan QA

Patient setup and imaging for positioning

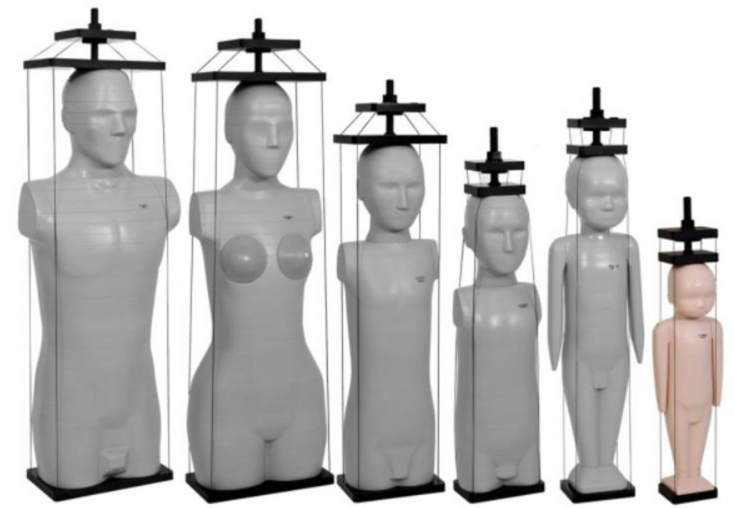
Delivery



Dosimetry Equipment - Phantoms

Water phantoms (e.g. MP3-P PTW)

Slabs- plastic material
(e.g. RW3 1.045 g/cm^3 PTW)



Antropomorphic phantom

Anthropomorphic phantoms

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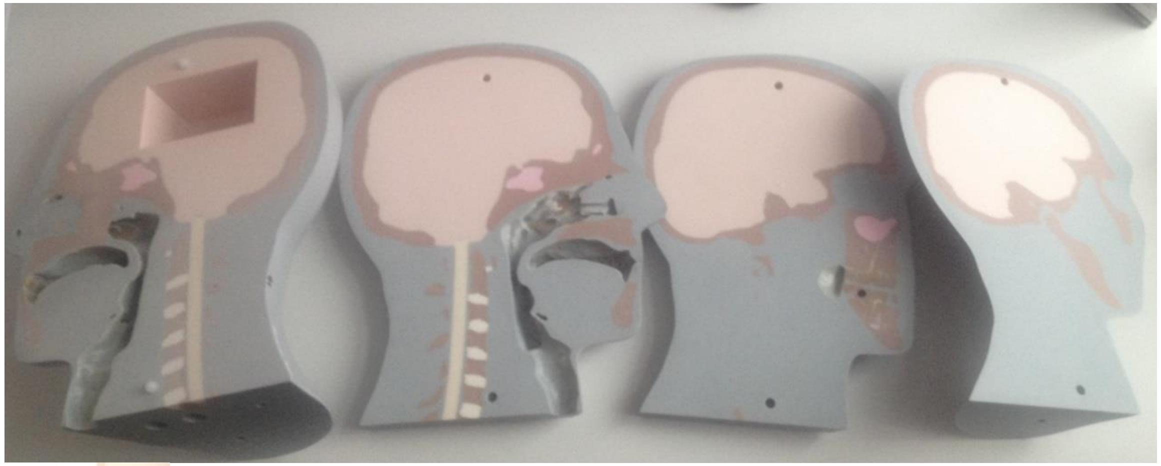
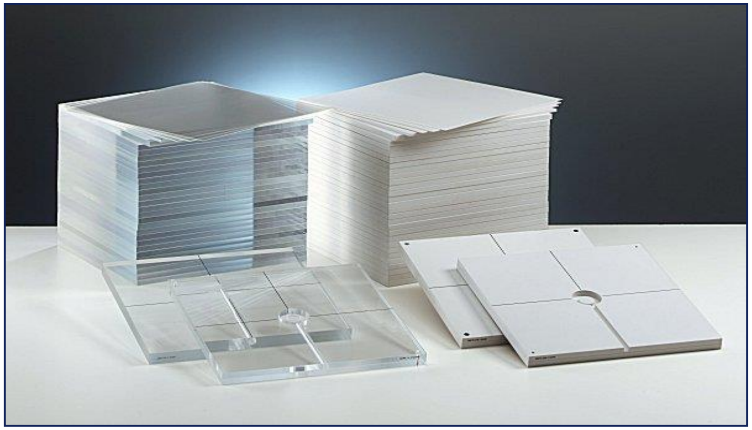


Carlino, A. et al. "**End-to-end tests using alanine dosimetry in scanned proton beams**.", Physics in Medicine and Biology, 2018.

☺ Close to real patient geometry
☺ Reproducing tissue patient heterogeneity
☺ Mainly used for TPS commissioning and end-to-end testing
☹ Time consuming set-up measurement
☹ Measurements at multiple points only with passive dosimeters (films, TLDs, Alanine)

Homogeneous slabs plastic materials

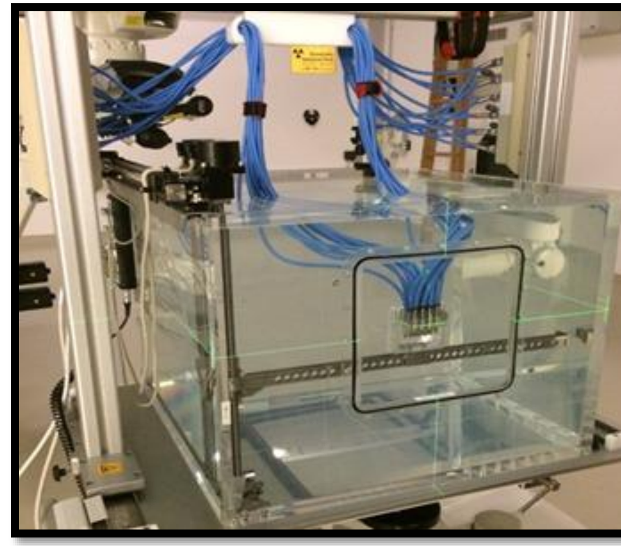


☺ Accurate and reproducible detectors positioning
☹ Relation HU vs Stopping Power is not accurate determined – need to measure WET of the slabs during commissioning phase
☹ Setup is time consuming
☹ Water-to-plastic fluence correction factors to determine (issue mainly for carbon ions)
☹ The beam model included in a commercial TPS is based on water - different fragmentations spectra (issue for ^{12}C) in plastic material which the dose calculation in the TPS doesn't take into account

Water phantoms

MP3-P water phantom (PTW)

MP3-PL water phantom (PTW)



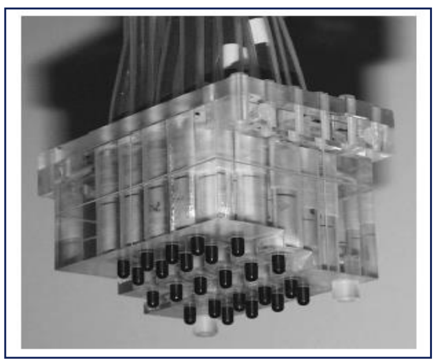
☺ Accurate and reproducible detectors positioning (0.1 mm resolution)
☺ Thin entrance wall window : 5 mm PMMA thickness – 5.8 mm water equivalent thickness (WET)
☺ Water medium – no need of FCF
☺ Alignment and movement remotely control
☹ Expensive devices

Dosimetry techniques

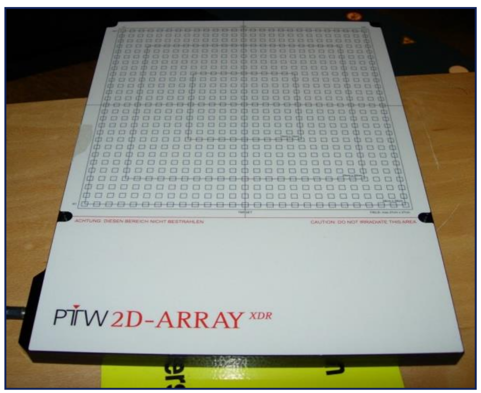
- For passive scattering beam delivery systems a dose measurement at a single point
- For scanned ion beam delivery systems dose measurement at multiple points/depths in the target volume
- Different detector geometries (1D, 2D, 3D?)
- Accuracy and reproducibility
- Physical dimension and spatial resolution
- Negligible dose rate and angular dependency
- Dose linearity response
- On-line or off-line reading
- LET and energy dependence ("quenching effect" mainly for the solid state detectors)

Detectors for plan verification in ion beam therapy

2D and quasi-3D detectors

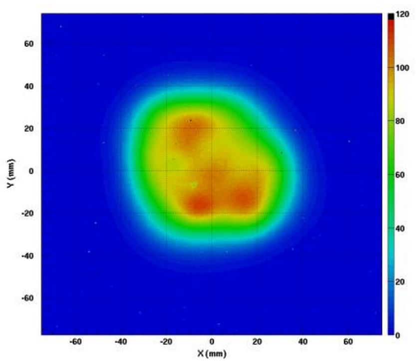


3D Detector Block with 24 PinPoint ICs (PTW-Freiburg)



2D- array of Ionization chambers (IC) (PTW or IBA)

Radiochromic Films (EBT3)



Scintillator + CCD

Radiochromic Films (1)

Gafchromic EBT films are attractive for 2D dosimetry in radiotherapy due to their self-developing behaviour and due to the possibility of their handling in visible light.

☺ High spatial resolution (down to 10µm)
☺ Waterproof
☺ Tissue equivalent in photon (EBT2/EBT3): Z_{eff} = 6.8 close to Z_{eff} = 7.3 for the water
☹ LET dependence (quenching)
☹ Quenching more evident for Carbon ions than protons (A model to predict the quenching effec (Spielberger et al. 2002))

Li Zhao, "**Gafchromic EBT film dosimetry in proton beams**", Phys. Med. Bio., 2010

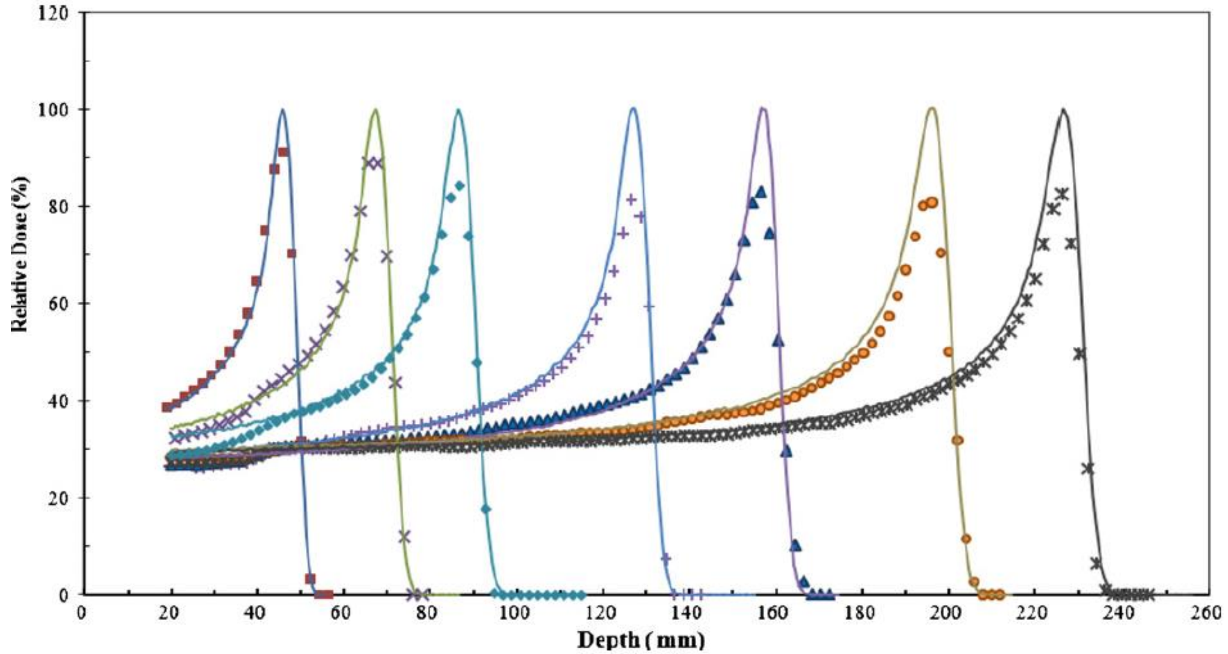
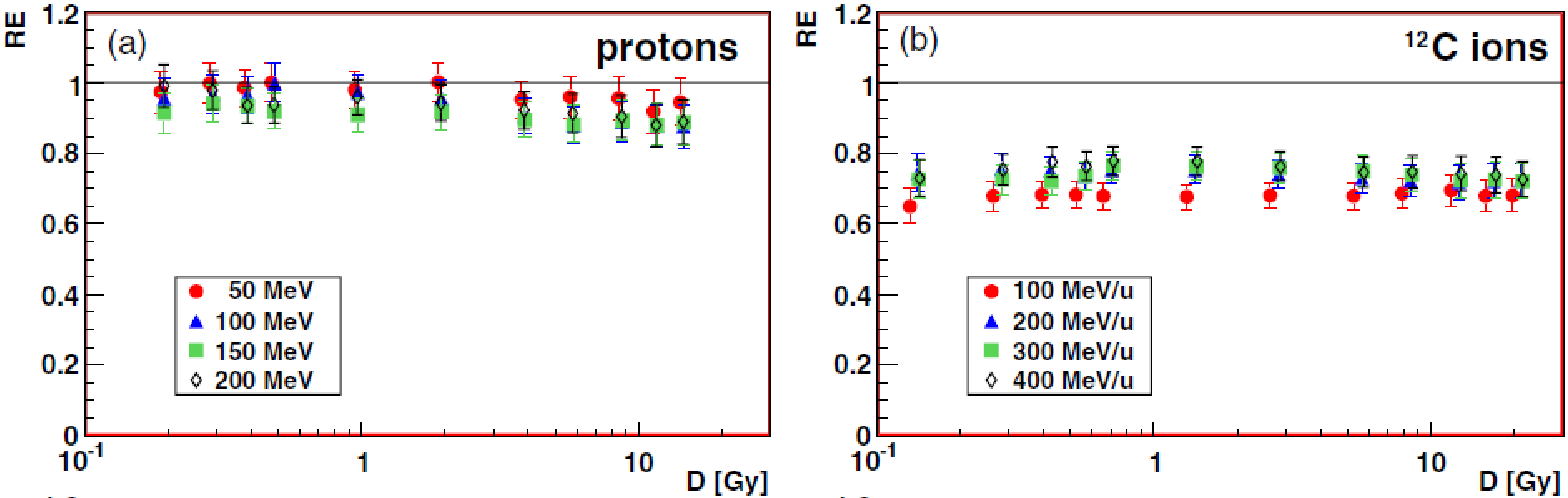


Figure 5. Depth–dose curves for un-modulated proton beams in the central axis as measured in a solid water phantom with Gafchromic EBT film (discrete data points), and a Markus ionization in a water phantom (continuous lines).

Radiochromic Films (2)

To quantify the quenching effect, the measured values of the dose-response relation were used to calculate the relative efficiency of the EBT films. It was defined in accordance to the relative biological effectiveness as

$$\mathrm{RE}(E, Z, F) = \left.\frac{D_\gamma}{D_{\mathrm{ion}}(E, Z, F)}\right|_{netOD}, \qquad (2)$$



M. Martisikova et al. **Dosimetric properties of Gafchromic® EBT films in monoenergetic medical ion beams**. Phys Med. Bio. 2010

Radiochromic Films (3)

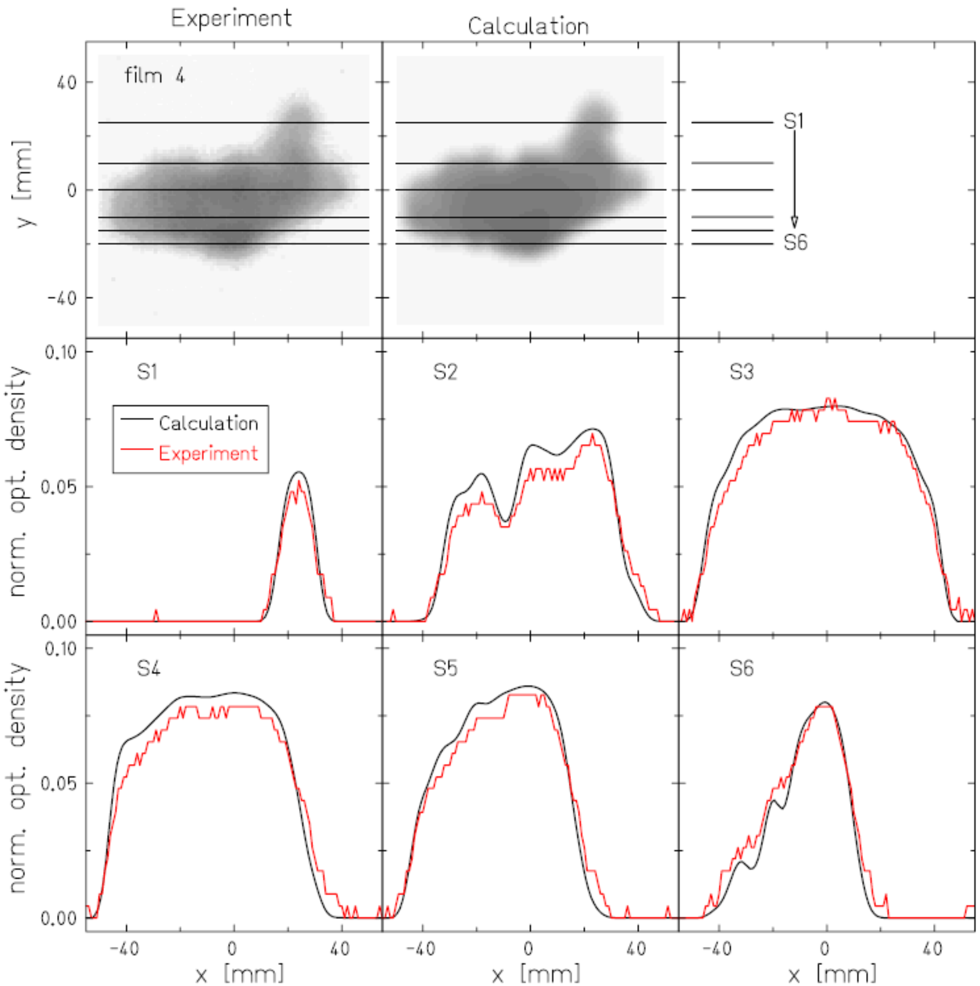


Figure 7. Profiles of a two-dimensional optical density distribution. A comparison between experiment and calculation.

Plan verification with Films in scanned carbon ion beams at GSI (Darmstadt, Germany) : TPS vs measurements

M. Spielberger et al. **Three-dimensional dose verification with x-ray films in conformal carbon ion therapy**. Phys Med. Bio. 2003

2D array of ionization chambers (1)

MatriXX PT detector (IBA dosimetry)

- Sensitive area of measurements 24.4 x 24.4 cm^2
- 1020 Vented parallel ion cambers
- Chamber diameter 4.2mm and height 2mm
- 7.6 mm distance between chambers
- Bias Voltage 500 V
- Dose rate from 0.02 Gy/min to 20 Gy/min

Octavius Detector 1500XR (PTW, Freiburg)

- Sensitive area of measurements 27 x 27 cm^2
- 1045 Vented parallel ion cambers
- Chamber size 4.4 x 4.4 mm^2 and height 3mm
- 7.1 mm distance between chambers
- Bias Voltage 1000 V
- Dose rate from 0.25 Gy/min to 800 Gy/min

2D array of ionization chambers (2)

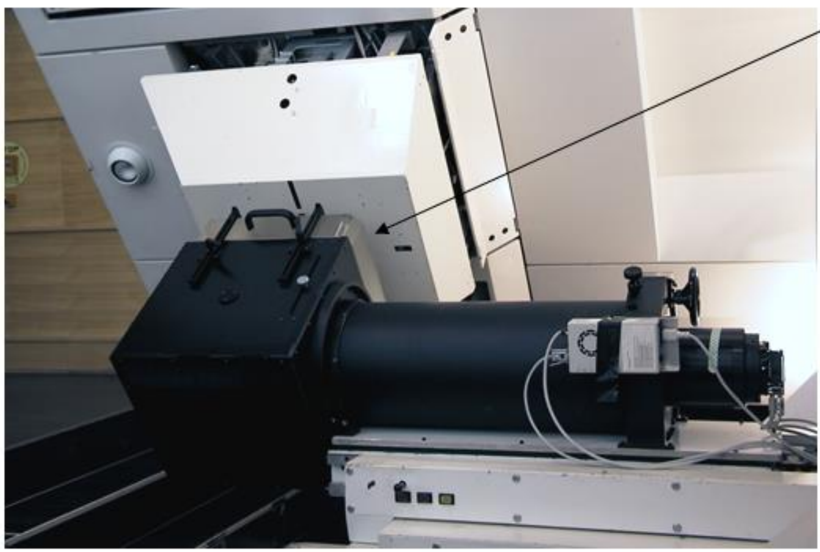
DigiPhant PT (IBA dosimetry)

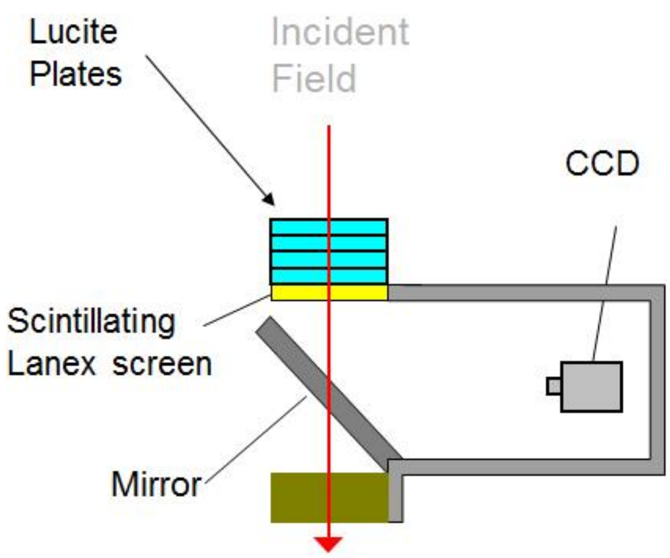
Octavius Detector 1500XR in RW3 @ MedAustron

B. Arjomandy et al. ,**Verification of patient-specific dose distributions in proton therapy using a commercial two-dimensional ion chamber array**, Med. Phys. 37, 2010

Scintillator screen coupled with CCD camera (1)

- ☺ High reproducibility
- ☺ High spatial resolution 0.5 mm
- ☺ Fast data acquisition
- ☹ LET dependence (quenching)
- ☹ Only relative dosimetry



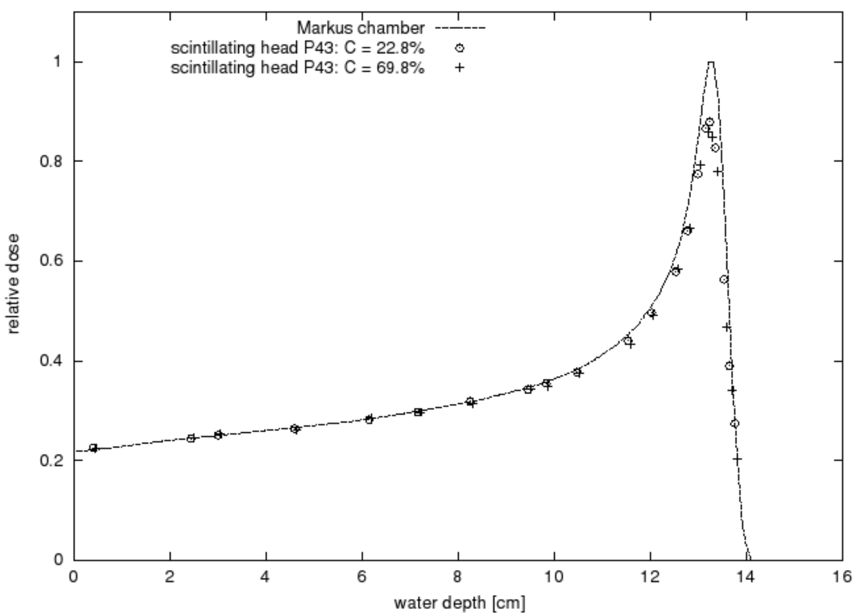


Gantry 2 at Paul Scherrer Institute (PSI, Switzerland)

Applications : beam homogeneity and symmetry as function of depths in water for single monoenergetic layer or SOBP

Scintillator screen coupled with CCD camera (2)

Quenching Effects



- Under-response of scintillator in Bragg peak region (high LET)
- Effect must be considered when dose measurements involve a combination of different beam energies (patient treatment plan)
- More evident for ^{12}C ion than for proton beams
- A model should be develop to predict the quenching effect

INSTITUTE OF PHYSICS PUBLISHING PHYSICS IN MEDICINE AND BIOLOGY
Phys. Med. Biol. **49** (2004) 4637–4655 PII: S0031-9155(04)74989-1

Development of an inorganic scintillating mixture for proton beam verification dosimetry

Sairos Safai, Shixiong Lin and Eros Pedroni

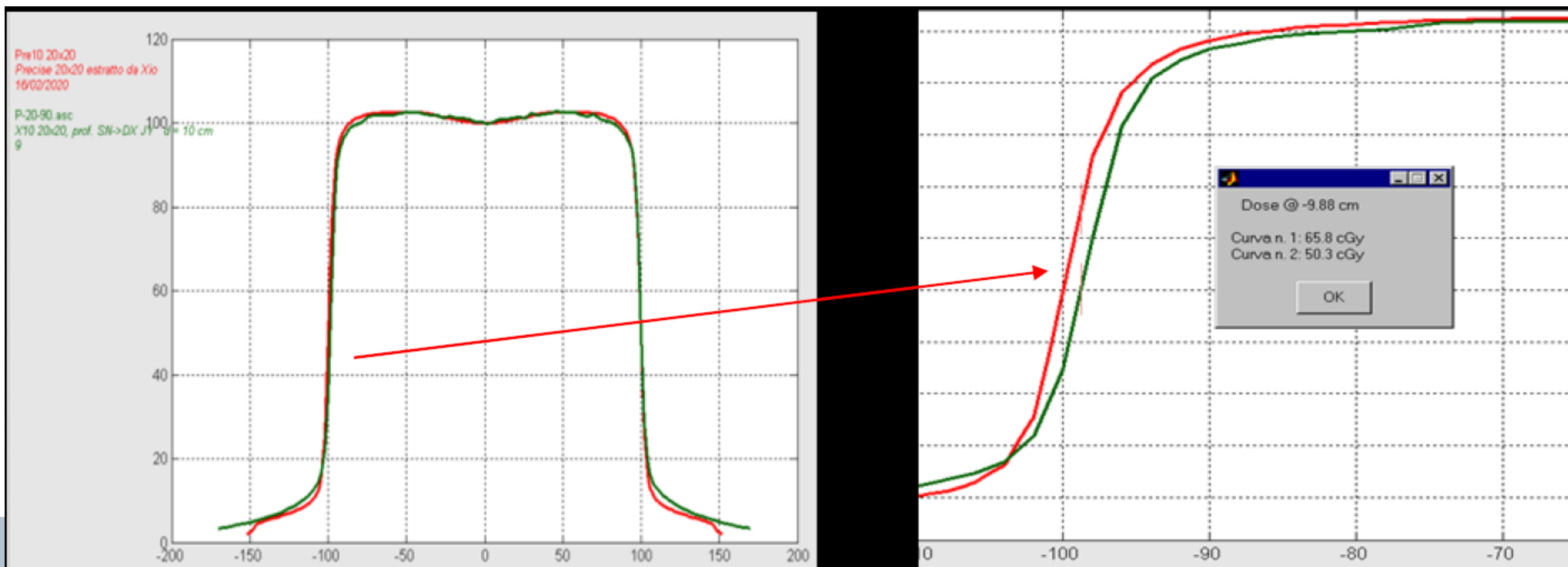
Division of Radiation Medicine, Paul Scherrer Institute, 5232 Villigen-PSI, Switzerland

Evaluation of dose distributions (1)

Quantitative comparisons of dose distributions (computed vs measurements) are needed in patient-specific plan verification measurements.

- ➢ Deviations in absolute or in % between computed and measured dose distributions (DD)
- ☺ Straightforward and simple method
- ☹ Potential large deviations in the high dose gradients due to the misalignment of the two 2D dose maps.

Accuracy of phantom positioning, detector positioning and read-out process



Evaluation of dose distributions (2)

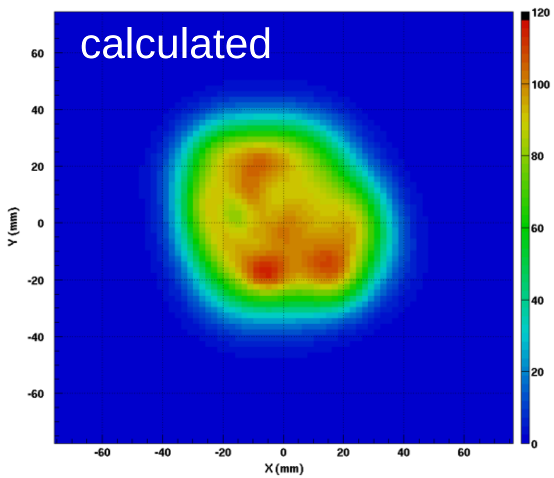
- Distance to agreement (DTA) = distance between a measured data point and the nearest point in the calculated dose distribution that exhibits the same dose.

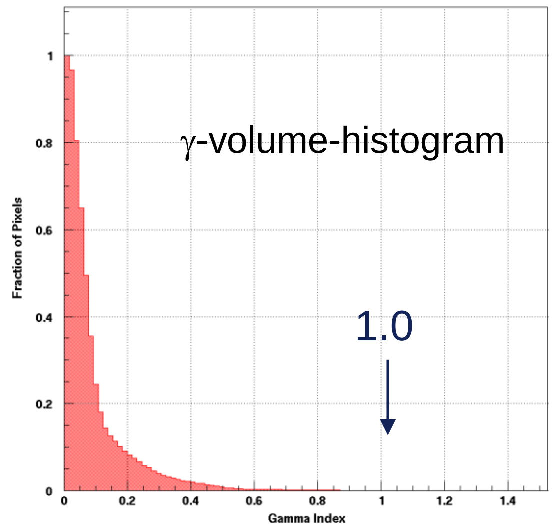
D. Low et al. “**A technique for the quantitative evaluation of dose distributions**” Med. Phys., 1998

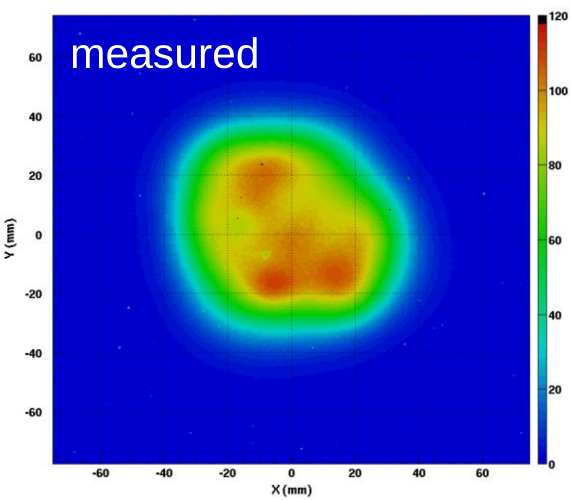
Quality index γ (Gamma) takes into account the DD and the DTA

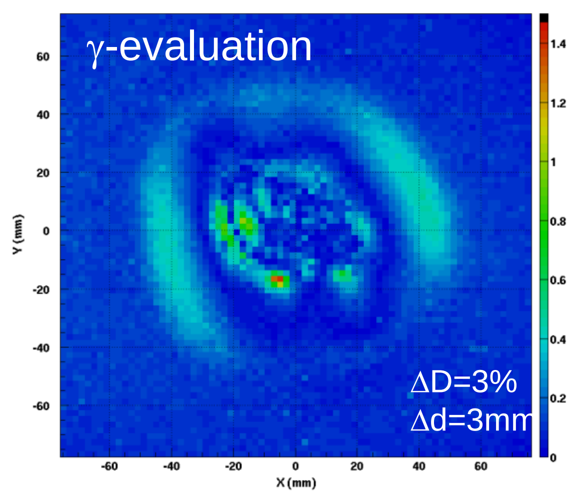
Evaluation of dose distributions (3)

Quality index γ (Gamma) takes into account the DD and the DTA









D. Low et al. "**A technique for the quantitative evaluation of dose distributions**" Med. Phys., 1998

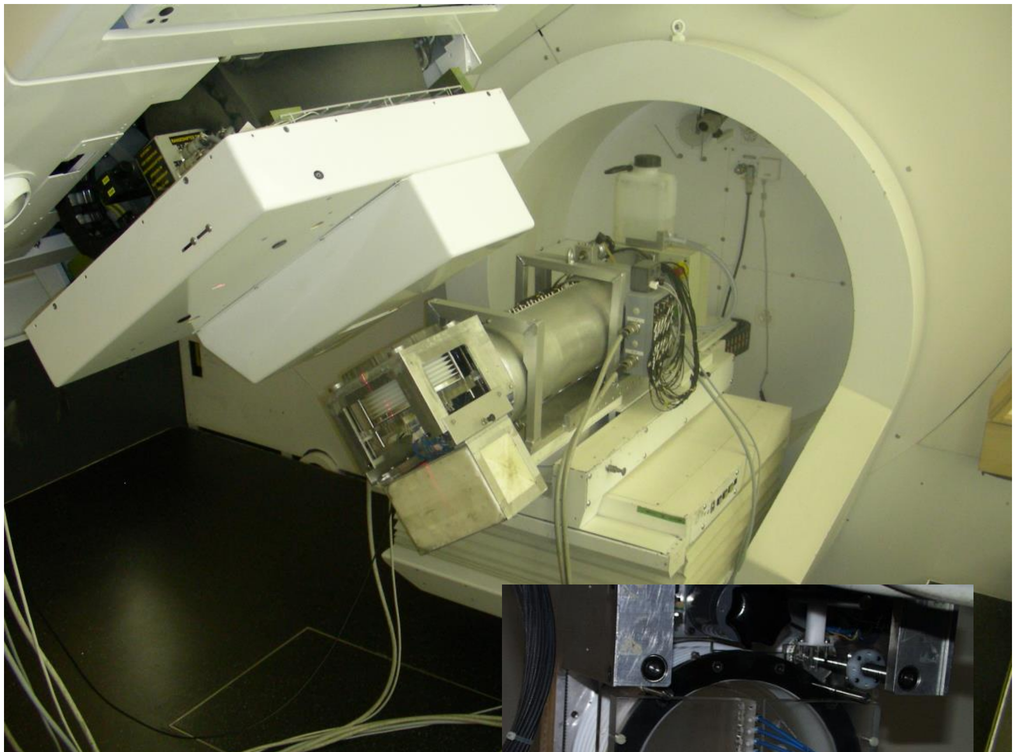
Usually DD and DTA criteria are set to 3% and 3mm for comparison of measured and computed dose distributions

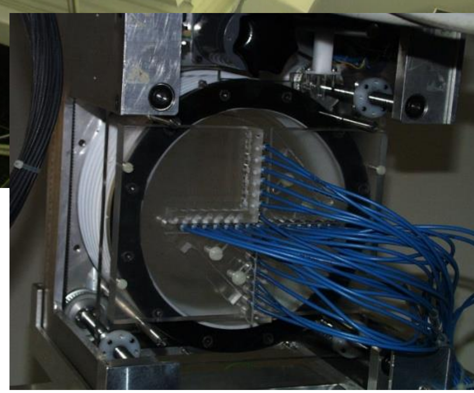
$$\gamma(\mathbf{r}_m) \leq 1, \quad \text{calculation passes,}$$
$$\gamma(\mathbf{r}_m) > 1, \quad \text{calculation fails.}$$

Pass-rate : is the % of measured points which pass the gamma analysis

Patient specific QA at Paul Scherrer Institut PSI @ Gantry1

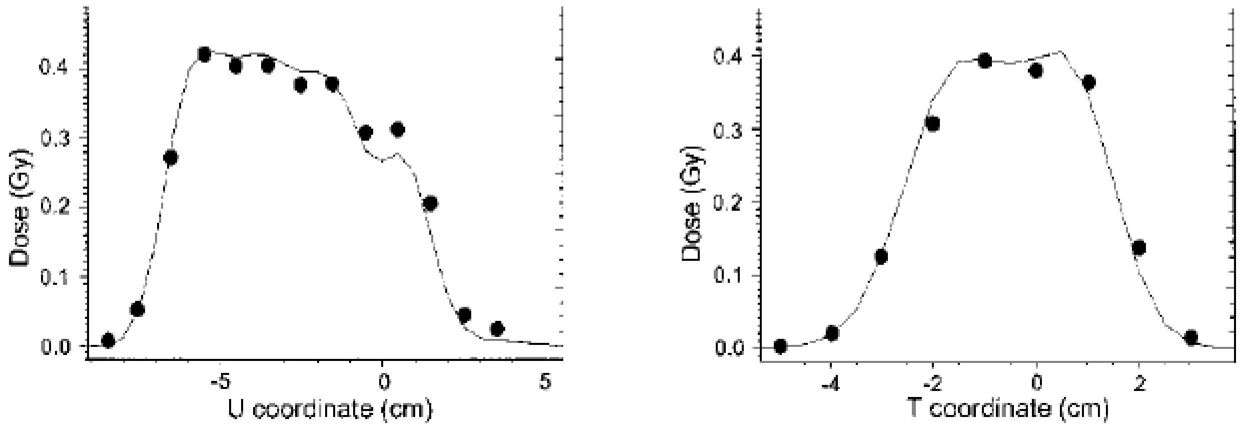
First Gantry in use at PSI since 1996





- Two ionisation chamber arrays
  - → 13 chambers each (0.1 cm^3)
  - → Spacing: 1 cm
  - → Two orthogonal dose profiles
  - → Measures absolute dose in Gy
- Rotatable
  - → Alignment to gantry angle
- Adjustable water column
  - → Measurements at various depths
- Readout interface to planning system
  - → Online analysis of measured profiles against calculation

Patient specific QA at PSI @ Gantry 1



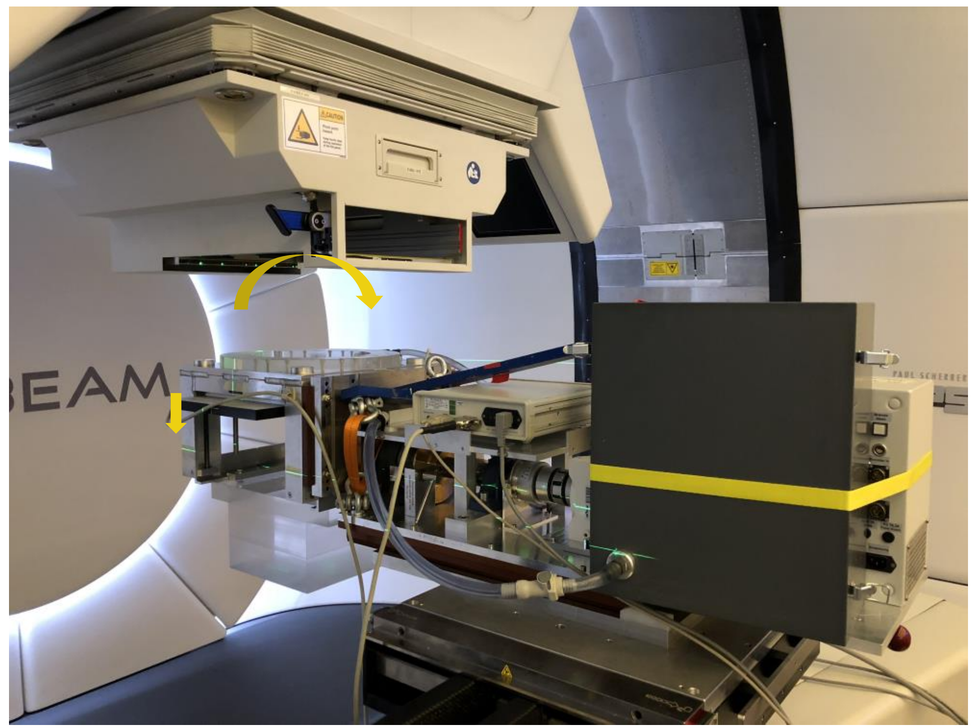
- Measured dose on average 1% lower than the predicted by the TPS.

- Tolerances of ±3% on the average dose.

A.Lomax et al. "**Treatment planning and verification of proton therapy using spot scanning: Initial experiences**", Med. Phys. 31 (11), 2004

Patient specific QA at PSI @ Gantry 3 (1)

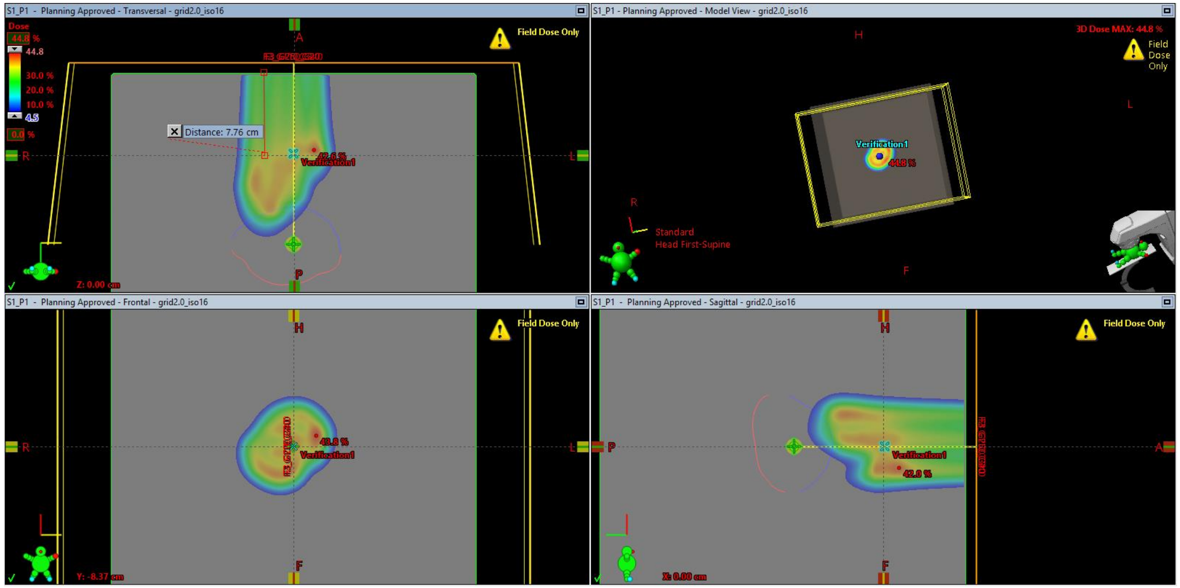
- Dedicated rotateable water-column phantom with adjustable water depth (mounted with a special adapter on Varian ProBeam v3.5 couch)
- Commercial 2D-array of IC (PTW Octavius 1500XDR – customized for ion beam therapy)
- In-house LabView-based software for phantom positioning and data acquisition



Courtesy of T. Boehlen

Patient specific QA at PSI @ Gantry 3 (2)

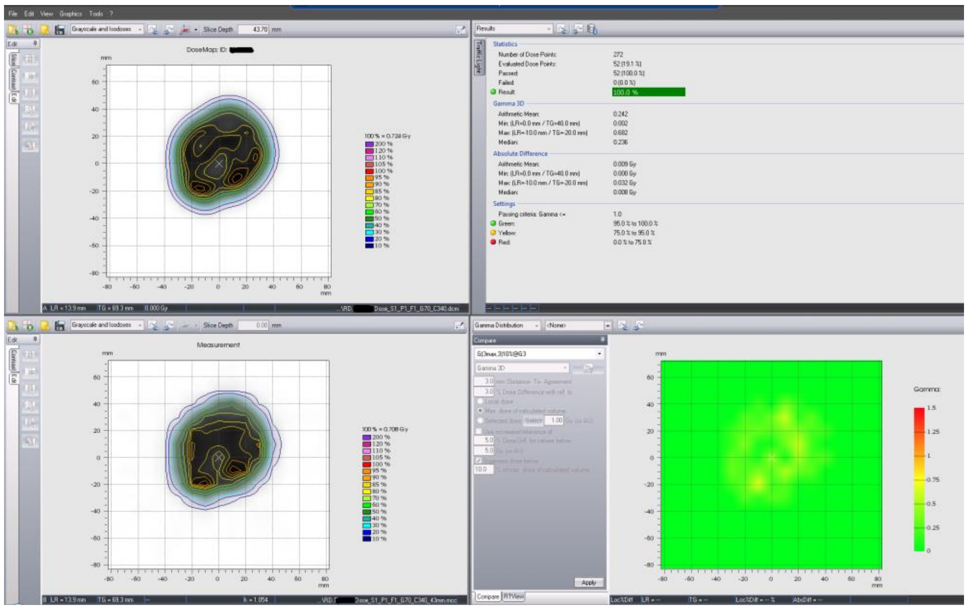
➢ TPS Eclipse (Varian): Dose recomputation of the clinical plan in a water phantom

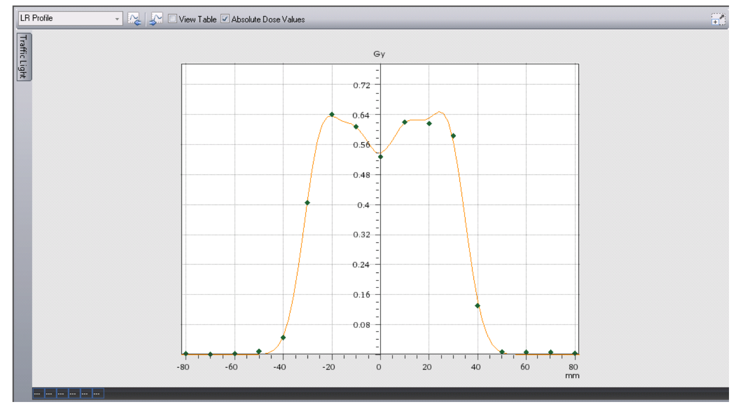


Courtesy of T. Boehlen

Patient specific QA at PSI @ Gantry 3 (3)

- Measurement with the water column (2 depths per field)
- Analysis with Verisoft (PTW)





- passing criteria:
  Gamma analysis (3%,3mm) with pass-rate >90%

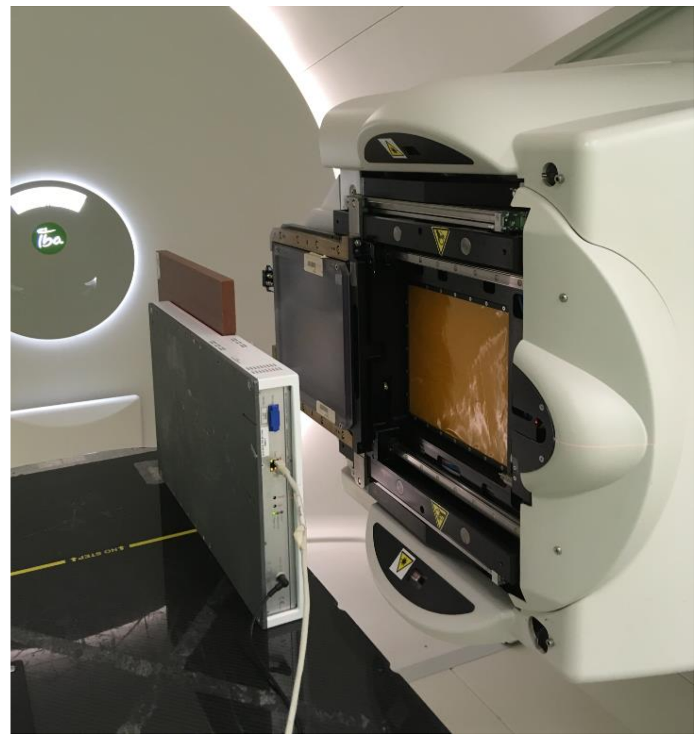
Courtesy of T. Boehlen

Patient specific QA at PTC of Trento (1)

- "IBA proteus plus" machine with 2 Gantry and one experimental fixed beam line

- TPS RayStation v7 (RaySearch Laboratories, Sweden) – Each treatment plan recomputed on a solid water phantom (Gammex® slabs)

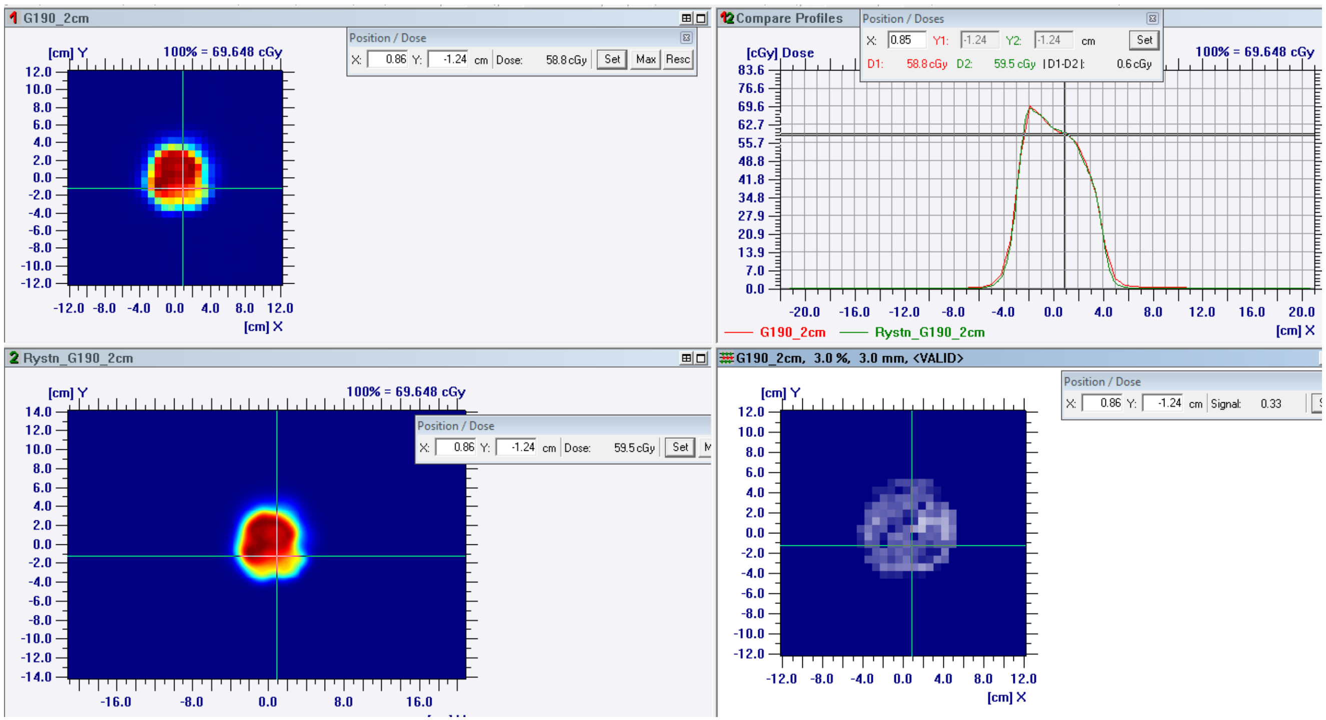
- 2D array of ICs (matrixx PT – IBA dosimetry) – 1020 ICs arranged in a 32 × 32 grid – active area 24.4 x 24.4 cm^2



Courtesy of S. Lorentini

Patient specific QA at PTC of Trento (2)

- Verification only at 1 fix depth (2cm of solid water) – At the beginning of treatments verifications at 3 depths.
- 2D dose planes from the TPS are compared with 2D dose planes measured with 2D array.
- Gamma analysis criteria (3%,3mm), cutting threshold set to 5%, passing rate set to 95%.

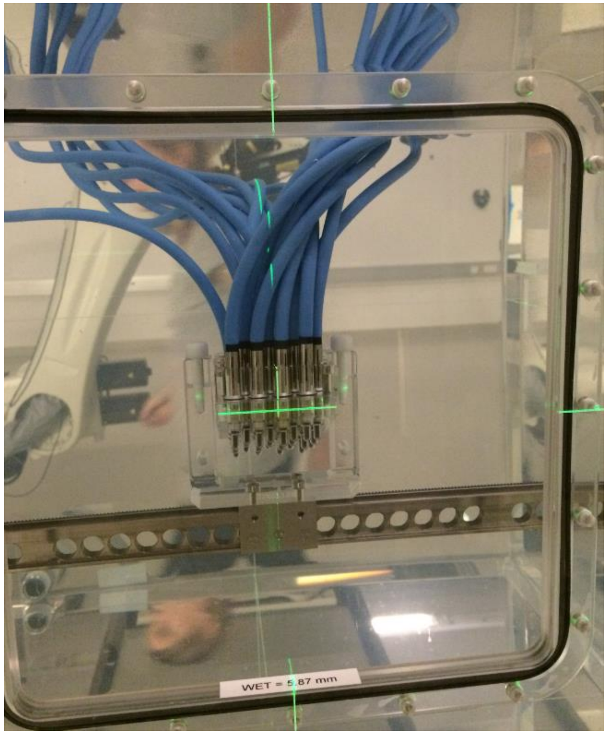


Courtesy of S. Lorentini

Patient specific QA at HIT, CNAO, MedAustron

- At HIT (Heidelberg, Germany) , CNAO (Pavia, Italy) and MedAustron (Wiener Neustadt , Austria) similar equipment and PSQA procedures have been selected mainly driven by GSI experience in Carbon ions

3D Detector Block (PTW, Freiburg)



- 24 cylindrical Pinpoint ionization chambers
- PinPoint model 31015, diameter 2.9mm, volume 0.03cm^3
- Two multichannel electrometers (Multidos)
- Chamber positions staggered in beam's eye view – quasi-3D dosimetry
- Possibility to rotate 90° the block for fixed vertical beam line

C.P. Karger et al. "**A system for three-dimensional dosimetric verification of treatment plans in intensity-modulated radiotherapy with heavy ions**", Med. Phys., 1999

Characterization of dosimetry equipment (1)

- Commissioning of the measurements equipment for clinical use within the clinical range of measurements.
- Definition of a QA program for the equipment to guarantee the performances of the dosimetry equipment and associate phantoms

Water phantoms MP3-P and MP3-PL (PTW, Freiburg)

TABLE I. Maximum mechanical deviations measured using laser tracker over a scanning length of 40 cm.

Parameter	MP3-PL	MP3-P
Linearity of moving mechanism in 1D	0.1 mm	0.1 mm
Maximum deviation of scanning length in 1D	0.3 mm	0.4 mm
Maximum transverse deviations perpendicular to a 1D scanning direction	0.9 mm	0.5 mm
Position reproducibility in 3D	0.1 mm	0.1 mm

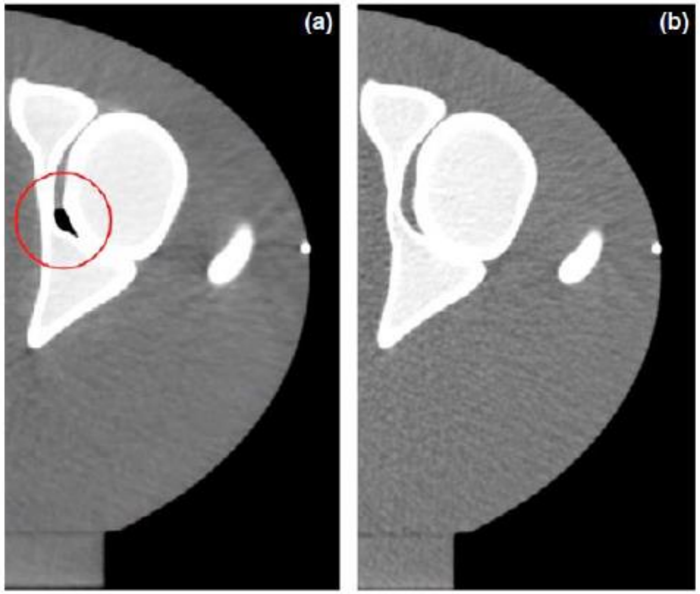


FIG. 6. Pelvis phantom before (a) and after (b) reparation from CIRS. Inside the circle in evidence the air bubble of ≈10 mm in diameter. [Color figure can be viewed at wileyonlinelibrary.com]

L. Grevillot et al. 2018, **Implementation of dosimetry equipment and phantoms at the MedAustron light ion beam therapy facility**, Med. Phys. 45 (1), 2018

Characterization of dosimetry equipment (2)

More specific characterization was done for the 24 PinPoint ion chambers.

The following tests have been carried out on the PinPoint (type TM31015, 0.03 cm^3) ICs at MedAustron:

(i) An x-ray image was made of each PinPoint chamber to verify the integrity of its construction;
(ii) ^{90}Sr check source readings were performed to monitor the stability of the PinPoint chamber response to ionising radiation;
(iii) ion recombination and polarity were studied in a 6 MV high-energy photon beam and in a PBS delivered proton beam;
(iv) the PinPoint chambers were cross-calibrated in a 6 MV high-energy photon beam and in a PBS delivered proton beam.

A. Carlino et al., **Characterization of PTW-31015 PinPoint ionization chambers in photon and proton beams**, Phys. Med. Biol. 63, 2018

Characterization of dosimetry equipment (3) Ion recombination of PinPoint ICs

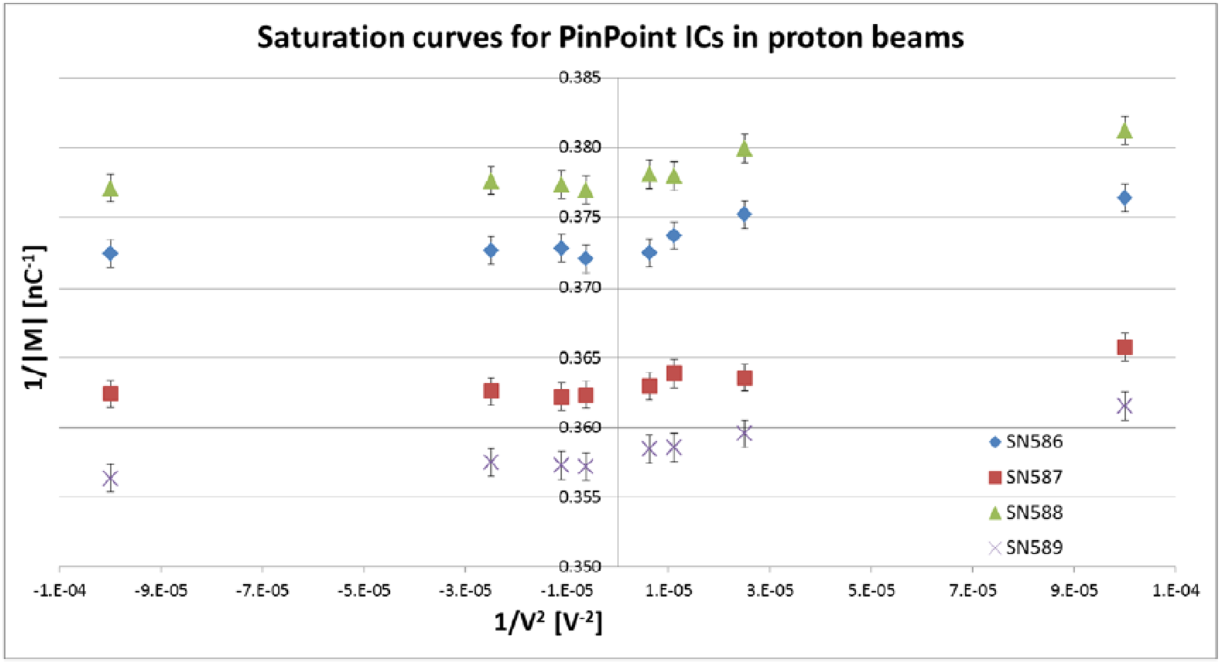
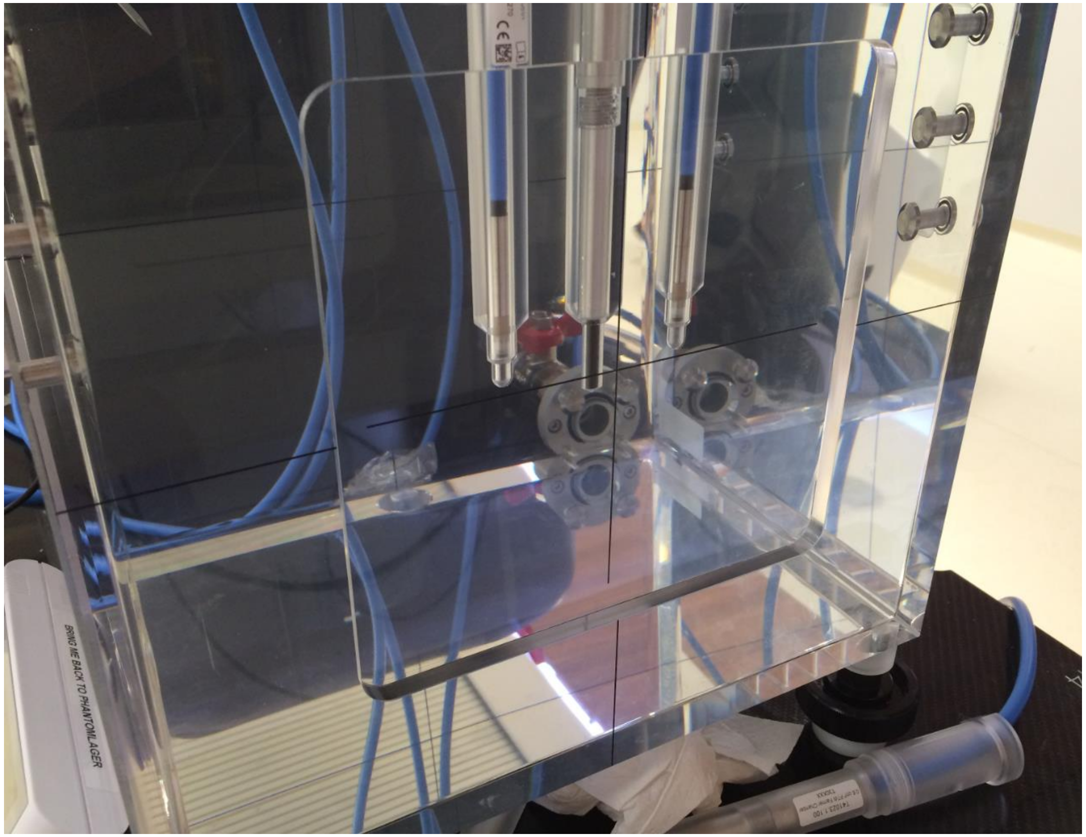


Figure 5. Saturation curves of four Pinpoint ICs placed at a depth of 86.8 mm (peak region) in water for proton beams. The serial number of each PinPoint IC is reported.

- Asymmetric behaviour of the response between positive and negative voltages – typical of PinPoint chambers
- Ion recombination below 0.1% - no corrections are applied for PSQA measurements
- No corrections for polarity as well

A. Carlino et al., **Characterization of PTW-31015 PinPoint ionization chambers in photon and proton beams**, Phys. Med. Biol. 63, 2018

Characterization of dosimetry equipment (4)
Cross-calibration in proton beams



- Cylindrical chamber Farmer type (volume 0.6cm^3) is our reference chamber at MedAustron
- Cross- calibration of PinPoint vs Farmer ionization chamber in proton beams.

Characterization of dosimetry equipment (5)
Cross-calibration in proton beams

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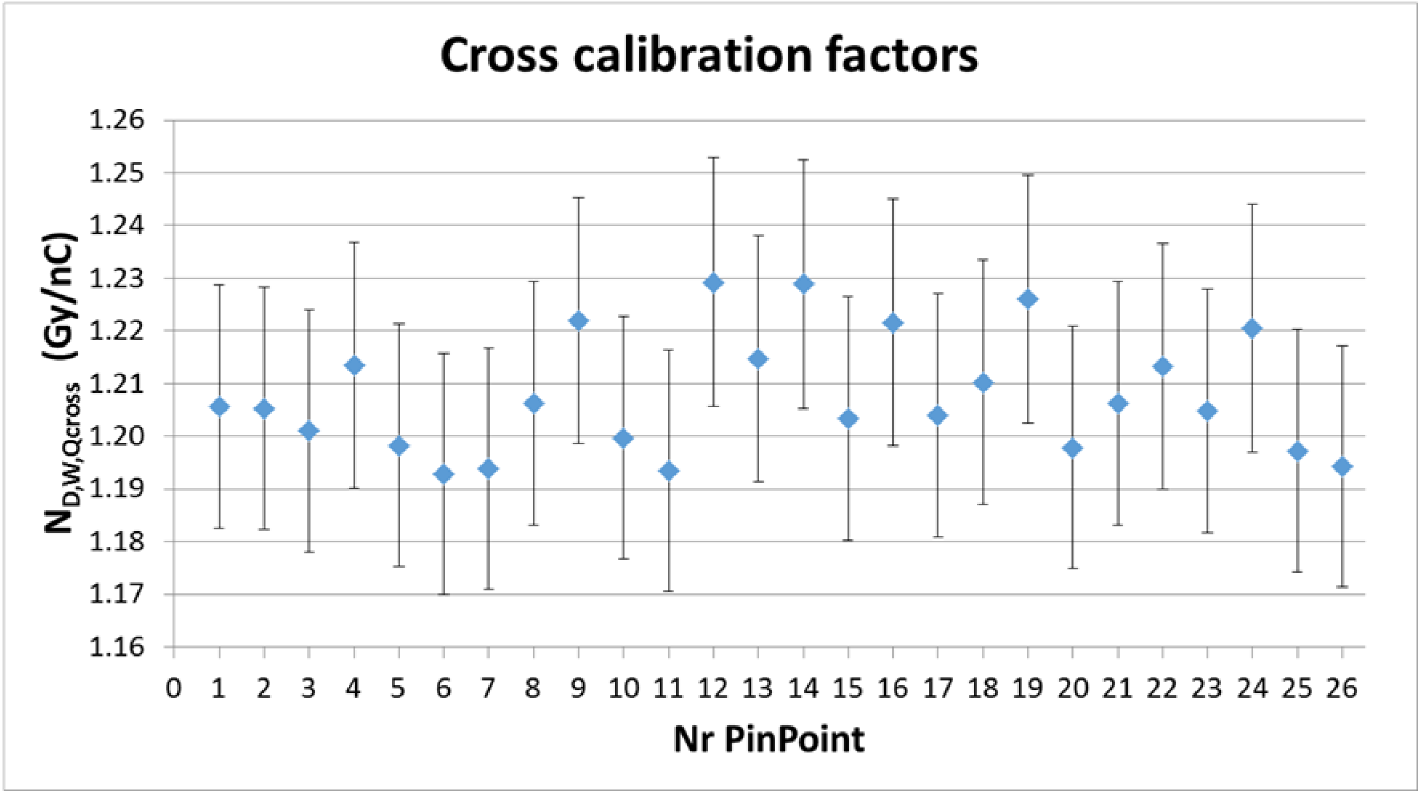


Cross-calibration factors are used to derived the absorbed dose to water from the collected charge for each of the 24 PinPoint chambers used in PSQA (IAEA TRS398)

$$D_{w,Q} = M_Q N_{D,w,Q_{cross}}^{PP} k_{Q,Q_{cross}}$$

where M_Q are the dosimeter readings for the PinPoint chambers corrected for the influence quantities temperature and pressure $k_{T,P}$, polarity effect k_{pol} and ion recombination k_s. $k_{Q,\ Qcross}$ is set to 1.

Workflow of PSQA at MedAustron (1)

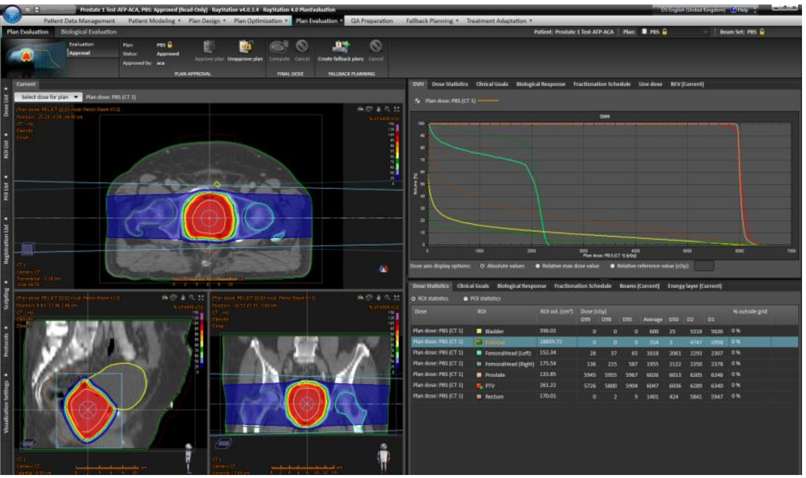
MedAustron Ion Therapy Center

No software available

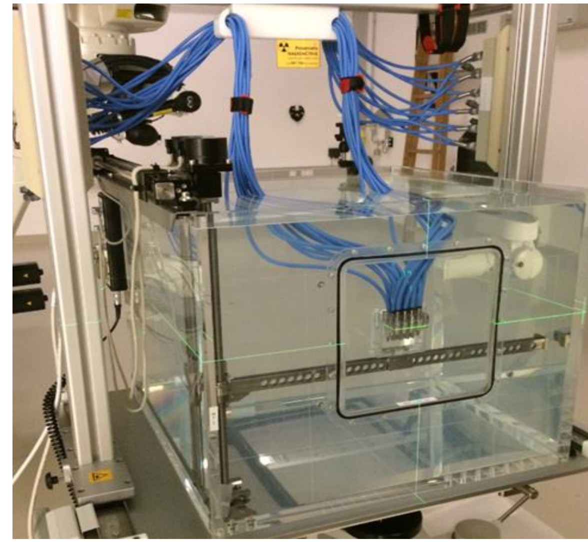
RaySearch Laboratories

Treatment Planning System (TPS)

PTW



Software interface



Script “MA_QA_v4.py“

Software “Plan verificator”

PTW equipment for plan QA

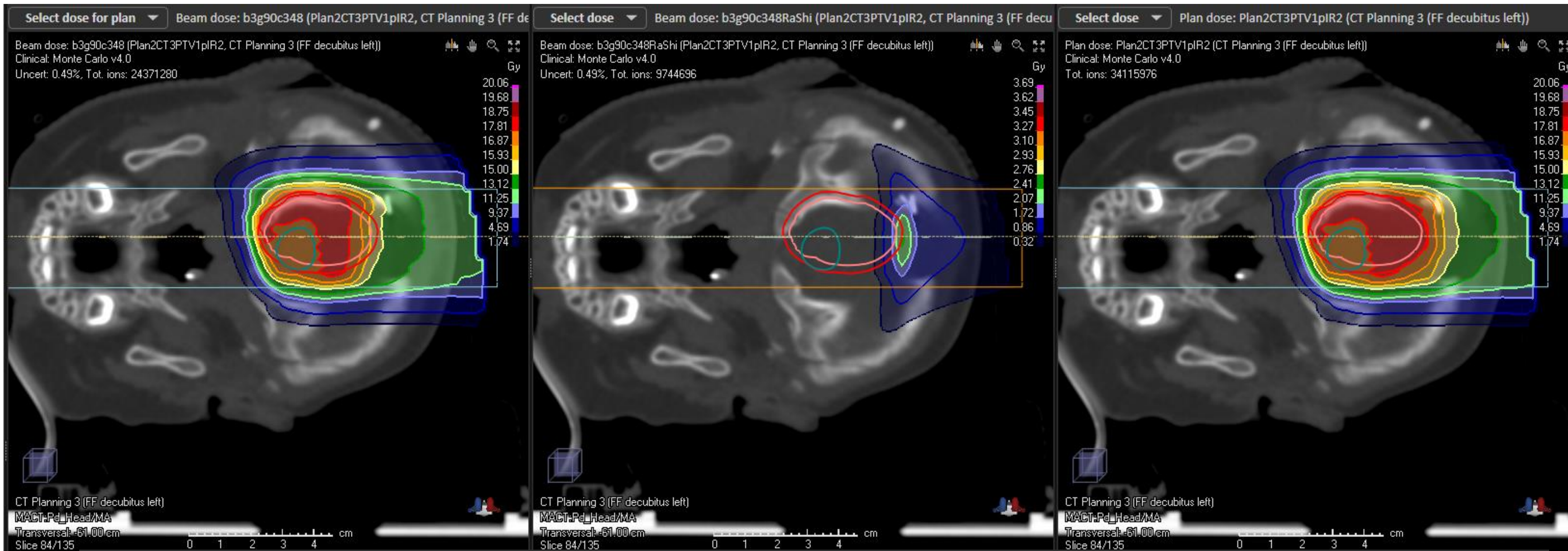
QADatabase

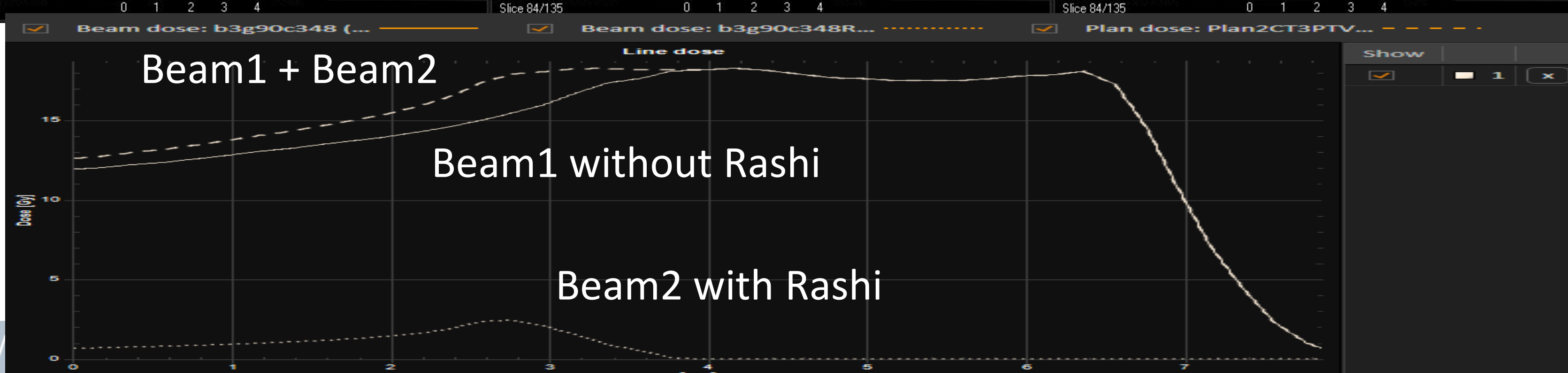
A. Carlino, **Implementation of advanced methodologies in the commissioning of a Light Ion Beam Therapy facility**, PhD thesis, 2017

Workflow of PSQA at MedAustron (2)

Treatment plan of a pediatric tumor in the head. Beam split technique (with and without Range Shifter (RaShi))

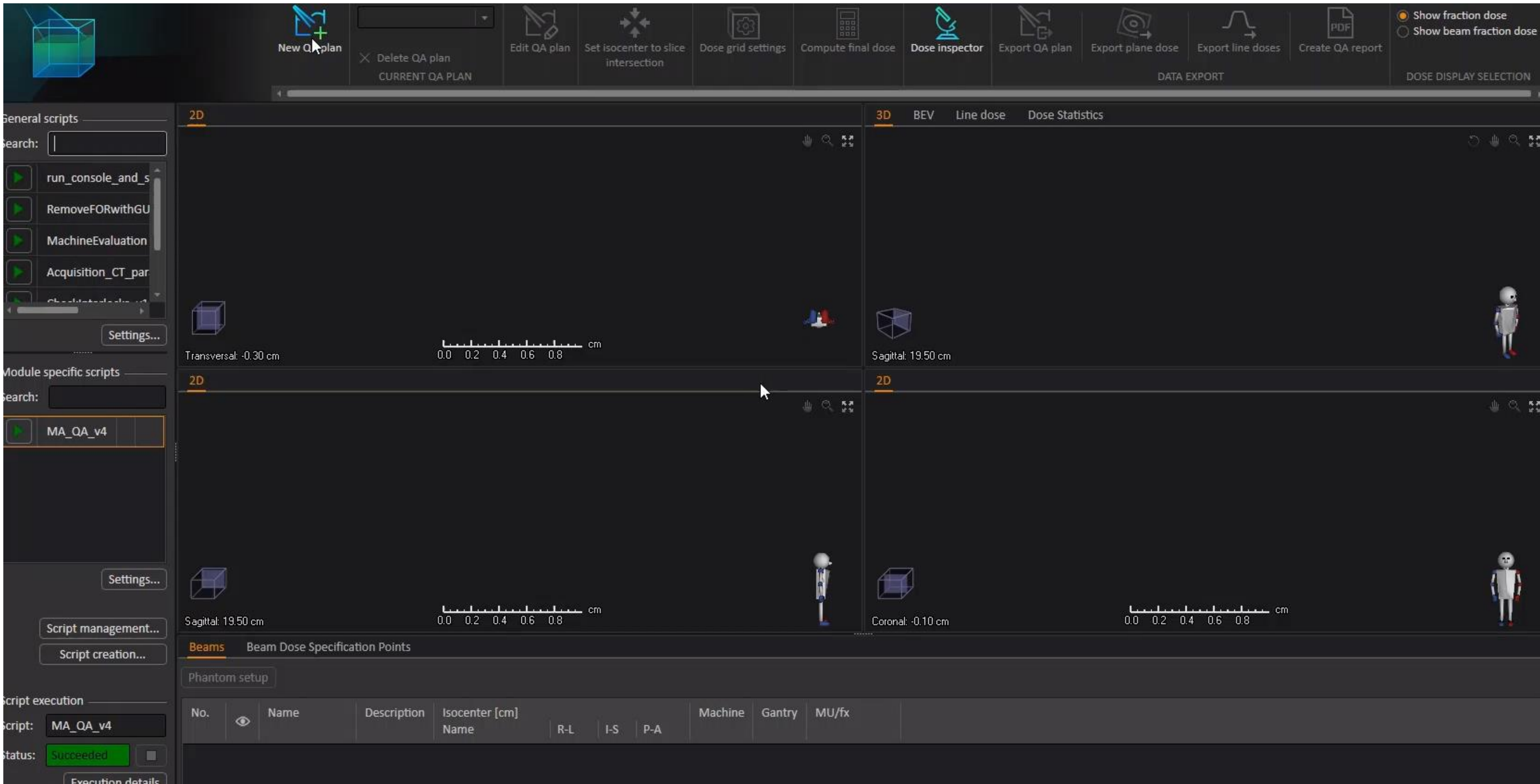
Beam1 without Rashi | Beam2 with Rashi | Beam1 + Beam2





Workflow of PSQA at MedAustron (3)

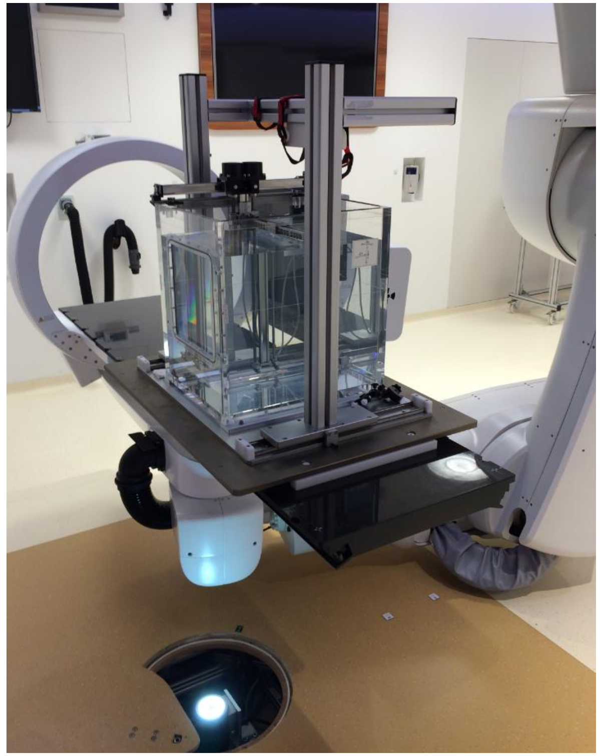
Recalculation of the plan in the virtual water phantom and extraction of the dose at the PinPoint ion chamber position (**Live Demo**)

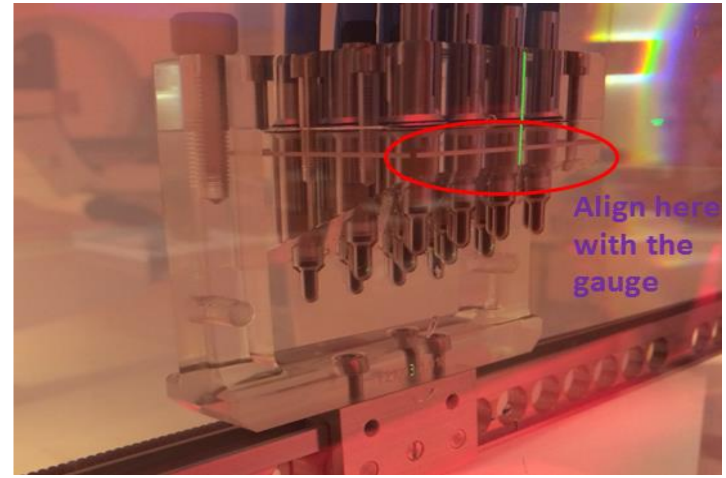


Workflow of PSQA at MedAustron (4)

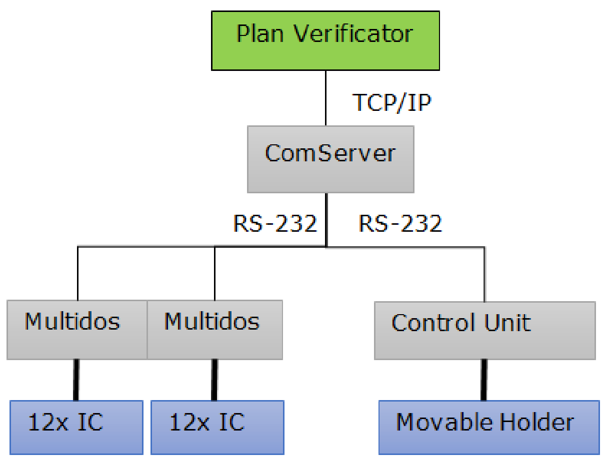
MedAustron
Ion Therapy Center

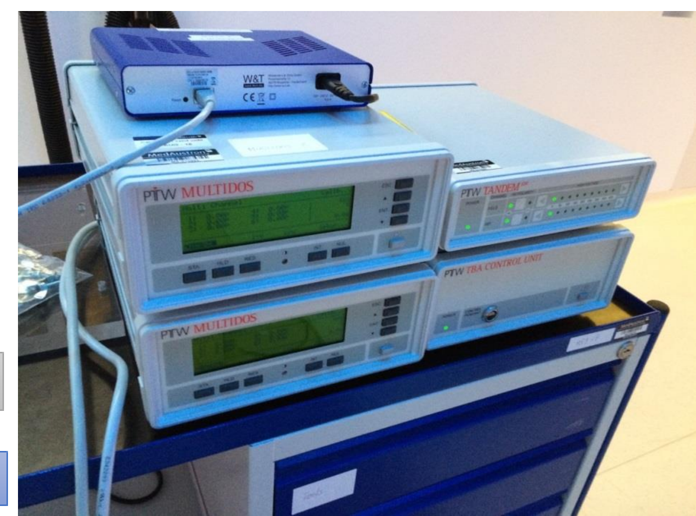
- In-house customized trolley to position the water phantom MP3-P on the robotic couch at MedAustron





- In-house development of "PlanVerificator" software to control the equipment, acquire and analyze on-line the measurements

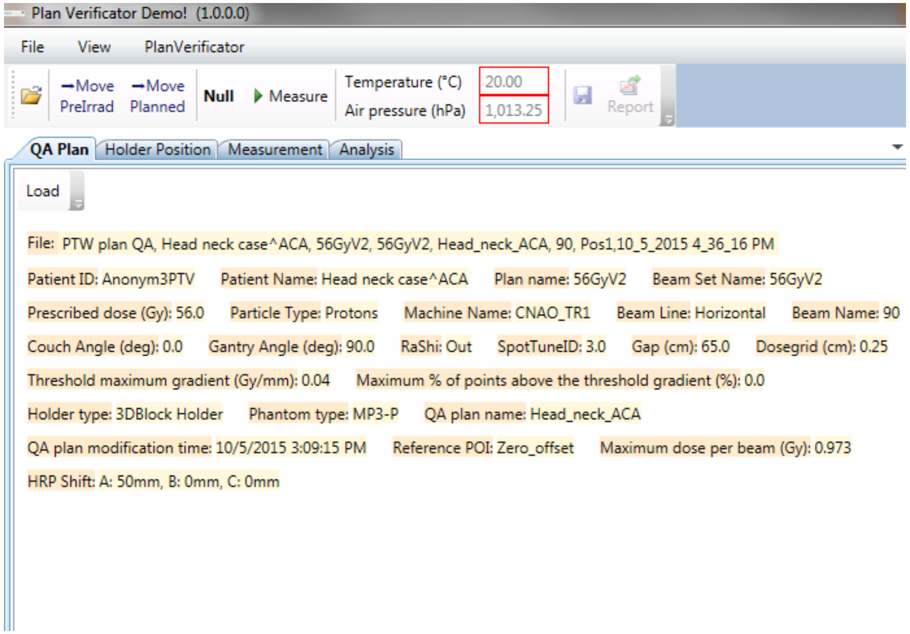




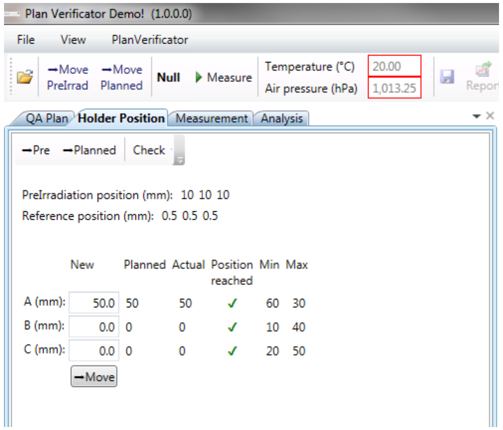
Workflow of PSQA at MedAustron (5)

MedAustron Ion Therapy Center

- Load the plan information from the script



- Move the 3D Detector Block holder with the 24 PinPoint ICs inside the water phantom



Workflow of PSQA at MedAustron (6)

MedAustron Ion Therapy Center

- Acquire the measurements and analyze the results on-line (according to established action levels)

QA Plan | Holder Position | Measurement | **Analysis**

Plot Report

Difference between planned and measured dose

IC	Gradient (Gy/mm)	Planned Dose (Gy)	Measured Dose (Gy)	Local difference (%)	Difference normalized to max dose (%)
1	0.016	0.586	0.575	-1.84	-1.11
2	0.022	0.654	0.635	-2.97	-1.99
3	0.005	0.58	0.574	-0.97	-0.58
4	0.011	0.555	0.544	-1.95	-1.11
5	0.003	0.447	0.444	-0.67	-0.31
6	0.009	0.49	0.476	-2.78	-1.4
7	0.013	0.543	0.561	3.28	1.83
8	0.008	0.576	0.589	2.33	1.38
9	0.017	0.542	0.558	3.03	1.69
10	0.008	0.61	0.619	1.48	0.93
11	0.004	0.637	0.631	-0.88	-0.58
12	0.004	0.65	0.64	-1.51	-1.01
13	0.018	0.602	0.617	2.49	1.54
14	0.012	0.63	0.639	1.37	0.88
15	0.007	0.66	0.649	-1.67	-1.13
16	0.002	0.646	0.65	0.62	0.41
17	0.006	0.667	0.661	-0.9	-0.62
18	0.002	0.629	0.643	2.19	1.42
19	0.004	0.651	0.654	0.52	0.35
20	0.004	0.646	0.657	1.76	1.17
21	0.018	0.6	0.598	-0.4	-0.25
22	0.003	0.621	0.611	-1.64	-1.05
23	0.005	0.638	0.645	1.16	0.76
24	0.009	0.633	0.635	0.32	0.21

IC inactived if dose gradient (Gy/mm) > 0.040 (0.04)

Analysis

Results are normalized to the max planned dose: 0.973 Gy

Measure	Action Level	Result
Number of ionization chambers above the action level	±7%	**0 (Max: -1.99%, IC 2)**
Average difference	±5%	**0.06%**
Std. dev. difference	5%	**1.13%**
Average absolute value difference	5%	**0.99%**
Std. dev. absolute value difference	5%	**0.51%**
Std. dev. of the mean	5%	**0.23%**

Note

(250 characters available)

Workflow of PSQA at MedAustron (7)

➢ Automatic creation of a QA report in pdf format (for documentation purpose)

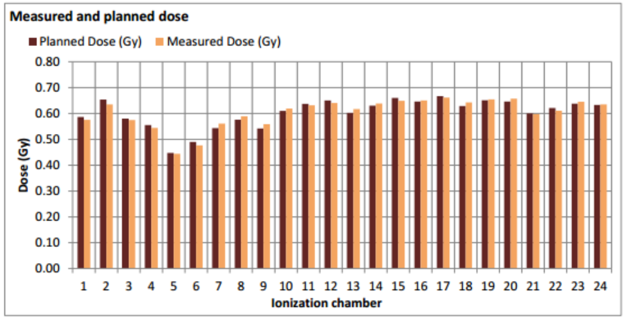
MedAustron

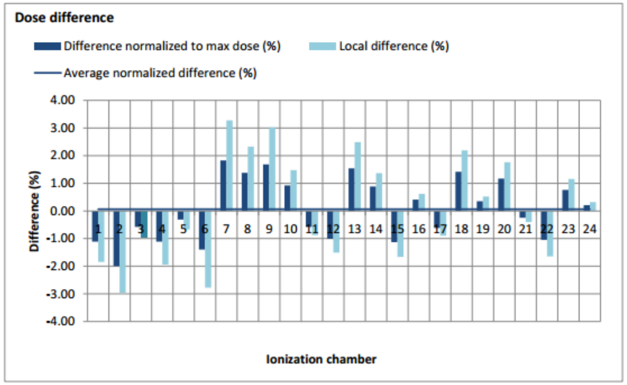
Plan Verificator QA Report

Plan Verificator version: 1.0.0.0
User: ACA
Computer : 10.2.5.171
Report creation: 10/05/2015 18:06:53

Patient, Plan and Beam data

QA Plan file name	PTW plan QA, Head neck case^ACA, 56GyV2, 56GyV2, Head_neck_ACA, 90, Pos1,10_5_2015 4_36_16 PM
Patient ID	Anonym3PTV
Patient Name	Head neck case^ACA
Plan name	56GyV2
Beam Set Name	56GyV2
Prescribed dose (Gy)	56.0
Particle Type	Protons
Machine Name	CNAO_TR1
Beam Line	Horizontal
Beam Name	90
Couch Angle (deg)	0.0
Gantry Angle (deg)	90.0
RaShi	Out





Note

Pass/Fail

Report accepted

Date and Signature

PSQA results at MedAustron (1)

MedAustron Ion Therapy Center

- Analysis of results and tolerances for PSQA

  - ✓ Mean signed global dose difference $$-5\% \leq \sum_{i}^{N} \frac{1}{N} \frac{D^i_{meas} - D^i_{TPS}}{D_{max}} \leq +5\%$$

  - ✓ Maximum deviation for each PinPoint chamber $$-7\% \leq \frac{D^i_{meas} - D^i_{TPS}}{D_{max}} \leq +7\%$$

  - ✓ Pass rate of global dose differences of 3% / 5% / 7%

Filtering of the data based on dose gradient *(<0.04 Gy/mm)* and dose levels *(>0.1Gy)*

PSQA results at MedAustron (2)

Data analysis based on 145 patients treated from December 2016 to April 2018 (**1064 beams** measured)

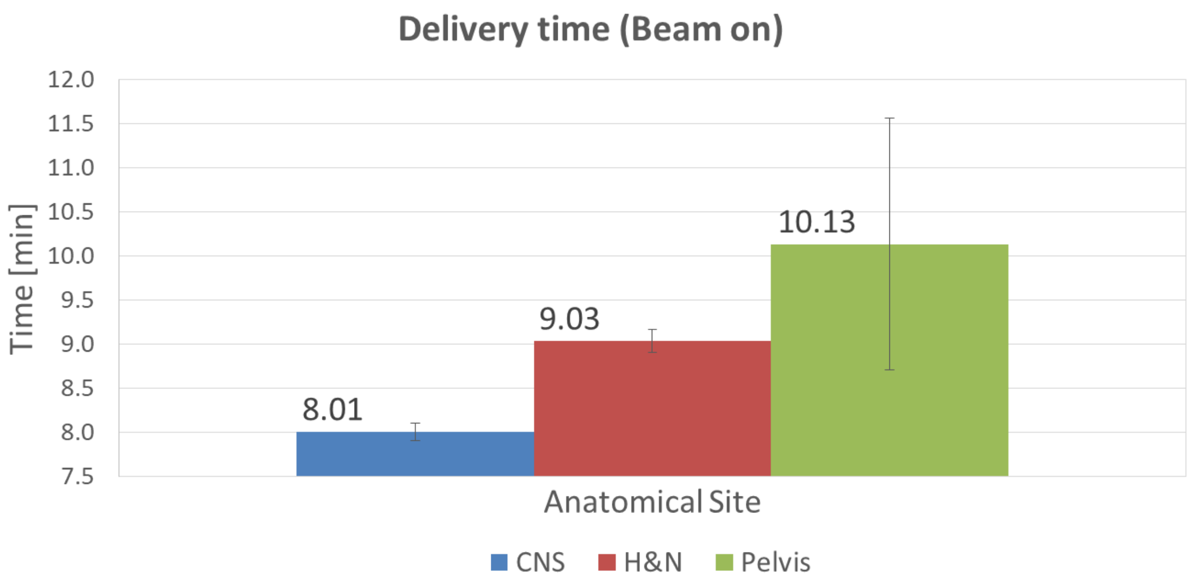
- Analysis of additional patient specific data:
  - ✓ Number of energy layers per beam
  - ✓ Number of spots per beam
  - ✓ Number of protons per beam
  - ✓ Delivery time per beam
  - ✓ PTV volume
  - ✓ Couch angle per beam
  - ✓ Highest energy per beam
- Data extraction and analysis was automatized via scripting (python language)

PSQA results at MedAustron (3)

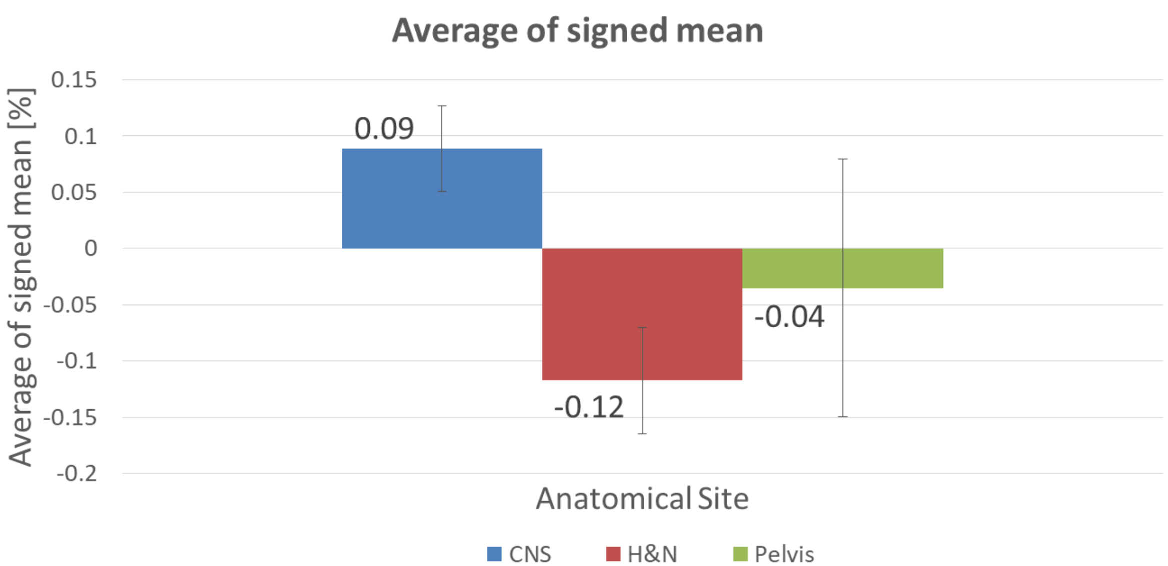
- PSQA carried out at the two horizontal beam lines (IR2HBL and IR3HBL)

- Patient specific data were analyzed versus:
  - ✓ Anatomical site (pelvis, CNS, H&N)
  - ✓ Dose algorithms in RayStation TPS (PBv3.5, PBv4.1, MCv4.0)
  - ✓ Presence of Range Shifter (RaShi) in the beam line
  - ✓ Planning technique (Single Field Optimization SFO vs Multiple Field Optimization MFO)
  - ✓ Irradiation room (IR2HBL and IR3HBL)

PSQA results at MedAustron (4)
PSQA results vs anatomical sites

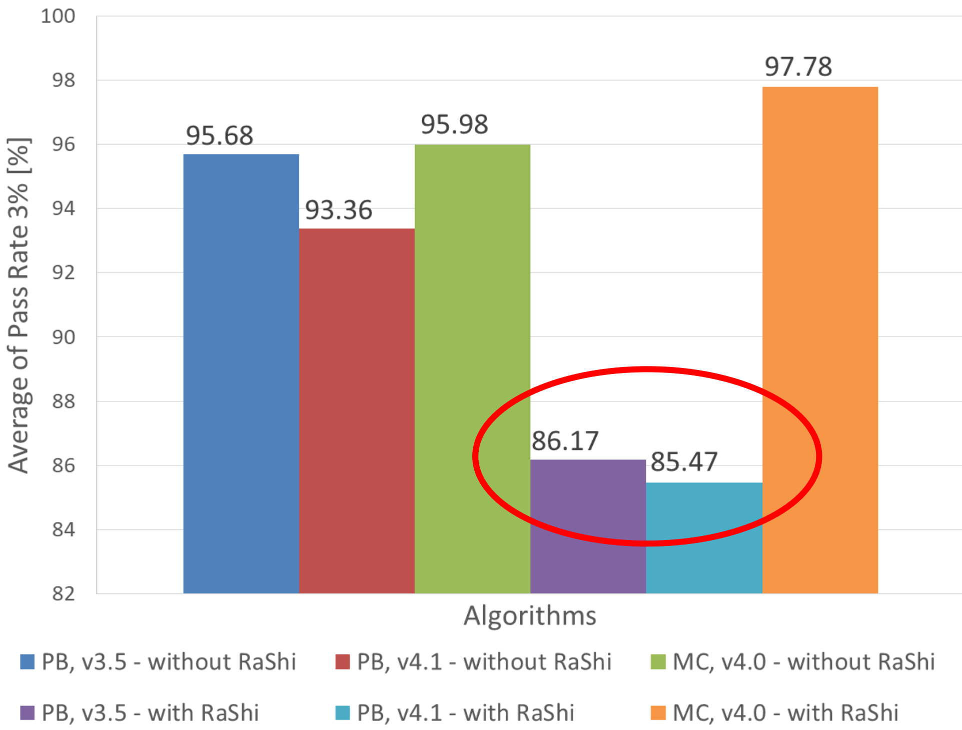


M. Schafasand et al."**Patient specific QA in scanned proton beams: results from the first year of operation at MedAustron**", OEGMP, Wien , 2018

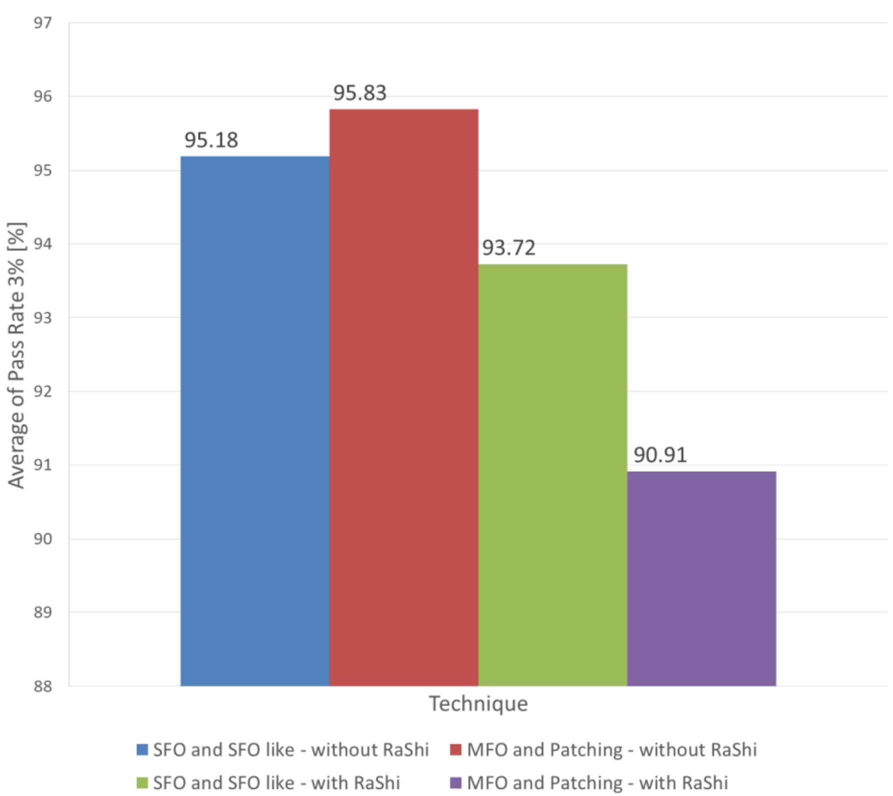


PSQA results at MedAustron (5)

PSQA results vs dose algorithms and vs planning technique

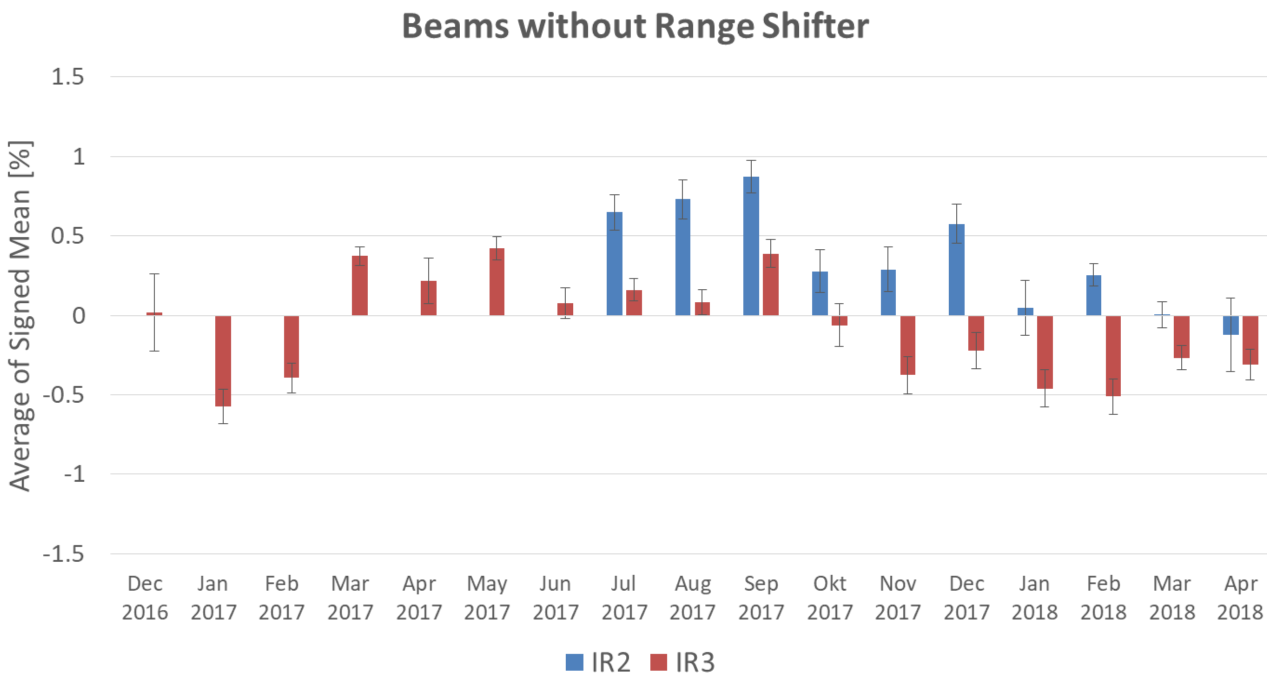


- ➢ Both PB algorithms show lower pass rate at 3% with RaShi



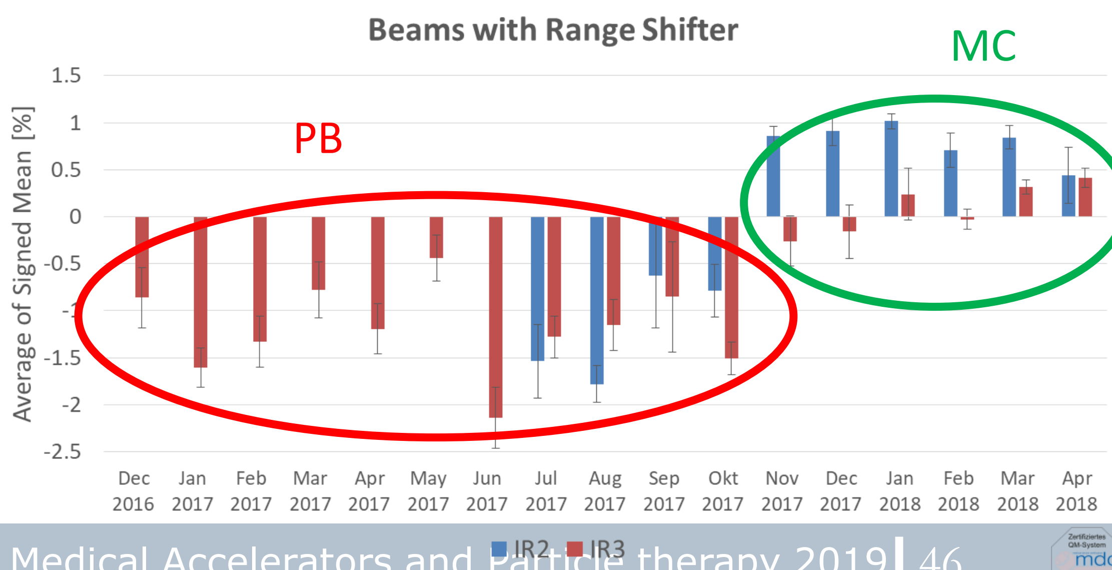
- ➢ SFO and MFO technique without RaShi are comparable.
- ➢ In presence of RaShi MFO shows slightly worse performances than SFO technique

PSQA results at MedAustron (6)
PSQA results in the two HBLs



- Without Range Shifter the PSQA results in the two Horizontal beams lines are comparable

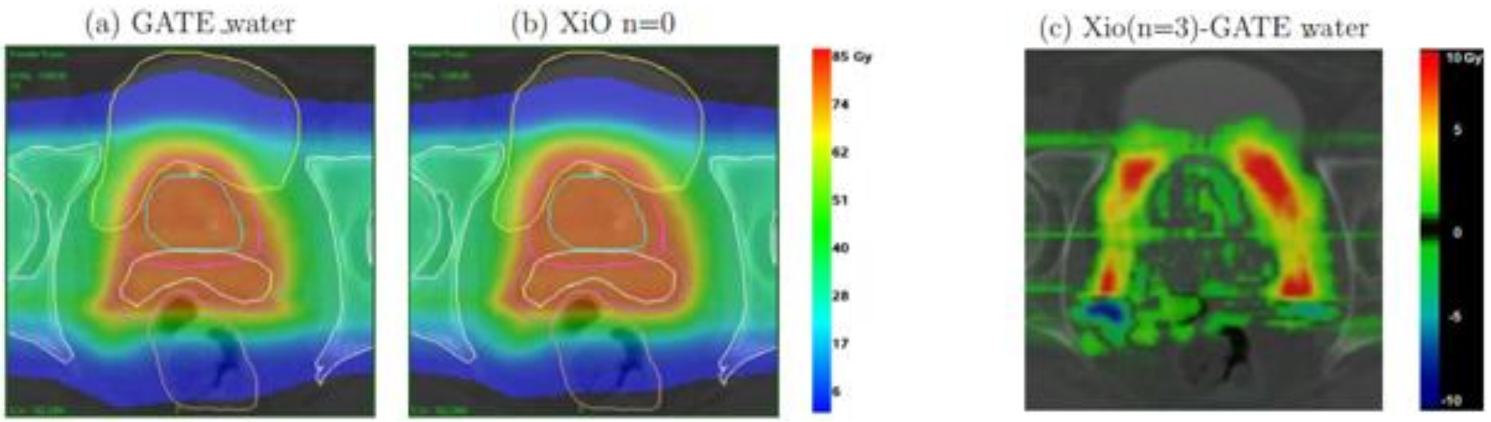
- With Range shifter deviations are larger depending on the dose algorithm used



Independent dose calculation (1)
Motivation

- Monte Carlo is a tool to support Medical Physics commissioning activities
- A way to reduce beam time and increase patient throughput
- At MedAustron:
  - 1 patient treatment ~ 1 hr machine time for PSQA
  - 1000 patients per year ~ 1 month time for PSQA
- Dose distribution in a water phantom is completely different than the dose distribution in the patient.

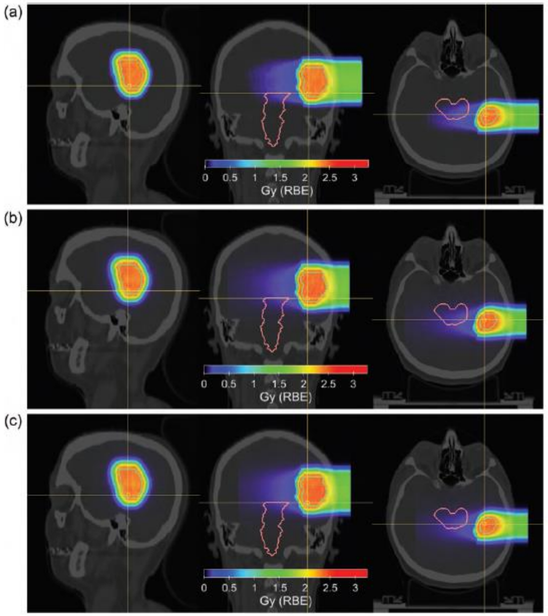
Independent Dose Calculation may reduce the amount of PSQA measurements and provide a reliable comparison in the real patient geometry



Grevillot et al, GATE as a Geant4-based Monte Carlo platform for the evaluation of proton pencil beam scanning treatment plans, Phys. Med. Biol. 57 (2012)

Independent dose calculation (2)

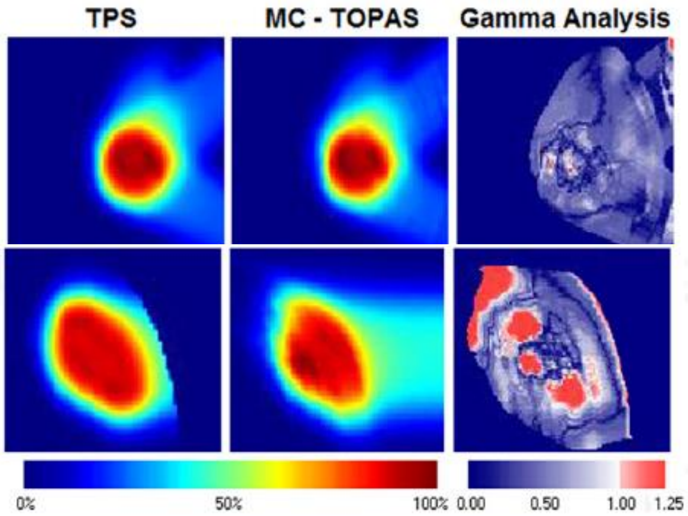
Independent Dose Calculation with different MC codes



TPS optimization (PBA)

Fluka recomputation (MC)

Fluka-based re-optimized plan (MC)



Böhlen et al, A Monte Carlo-based treatment-planning tool for ion beam therapy, J. Rad. Res. 2013

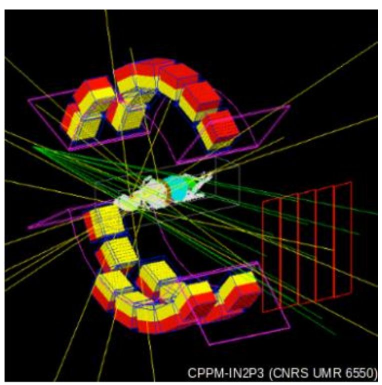
Fracchiolla et al, Characterization and validation of a Monte Carlo code for independent dose calculation in proton therapy treatments with pencil beam scanning, Phys. Med. Biol. 60 (2015)

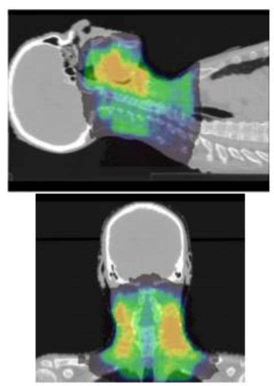
Independent dose calculation (3)

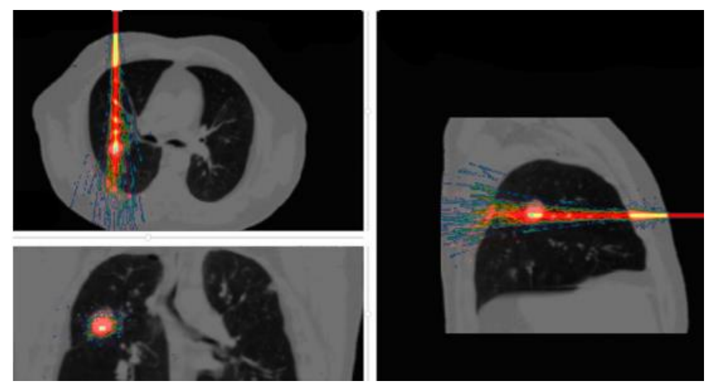
GATE:

- Free and Open source Geant4-based Monte Carlo toolkit
- Covers most fields of medical physics

  with ionizing radiations.
- Simple macro language → no C++ needed!
- A lot of capabilities!







Independent dose calculation (4)

IDEAL

Objective:
To provide a CE marked Independent DosE cALculation (IDEAL) product for scanned ion beam delivery facilities using GATE-RTion dose engine.

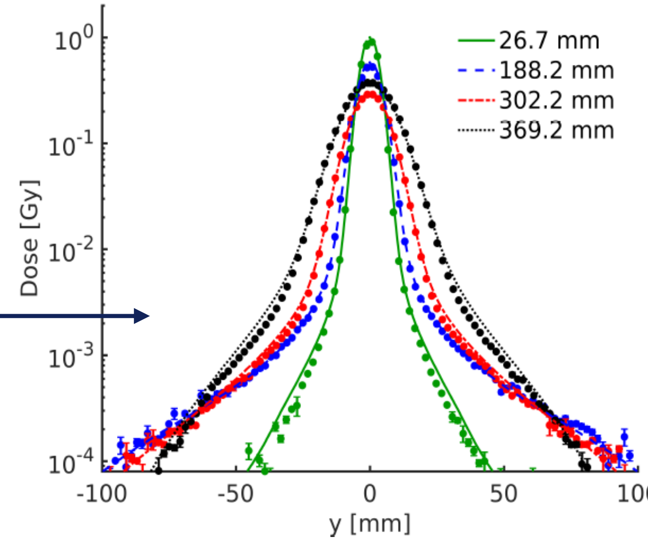
The project is funded within the scope of the Austrian COMET - Competence Centers for Excellent Technologies, in a collaboration between EBG MedAustron GmbH, Medical University of Vienna and ACMIT Gmbh.

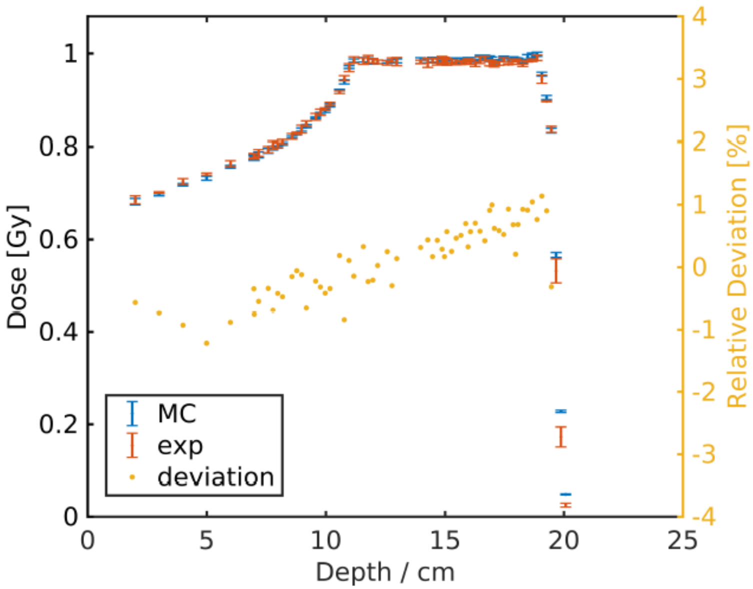
Project started in February 2018 for a duration of up to 8 years.
First version planned to be available at MedAustron in 2019.

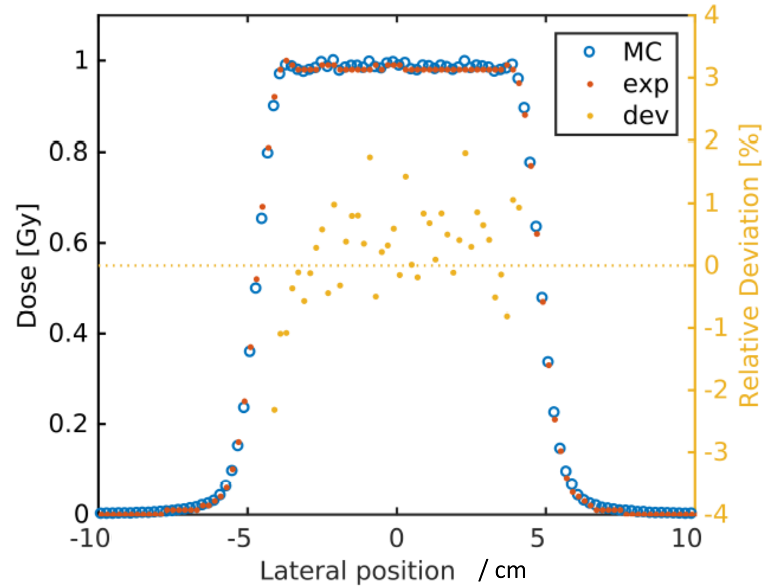
Independent dose calculation (5)

Validation of the IDC is on-going at MedAustron

- **Nuclear halo validation at 252.7 MeV**
- **Full nozzle beam model validation in SOBP in water**







- **Resch A. et al., *Validation of electromagnetic and nuclear scattering models in GATE/Geant4 for proton therapy , Med. Phys., 2019***

Questions ?