SERVIZIO SANITARIO REGIONALE
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# QA Tools

*EPID, Independent Dose/MU calculation, Logfiles, Patient QA*

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# Strategies and Guideline (i.e. Independent Dose/MU Calculation vs. EPID QA)

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AAPM SCIENTIFIC REPORT

MEDICAL PHYSICS

## Report of AAPM Task Group 219 on independent calculation-based dose/MU verification for IMRT

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**Abstract**

Independent verification of the dose per monitor unit (MU) to deliver the prescribed dose to a patient has been a mainstay of radiation oncology quality assurance (QA). We discuss the role of secondary dose/MU calculation programs as part of a comprehensive QA program. This report provides guidelines on calculation-based dose/MU verification for intensity modulated radiation therapy (IMRT) or volumetric modulated arc therapy (VMAT) provided by various modalities. We provide a review of various algorithms for "independent/second check" of monitor unit calculations for IMRT/VMAT. The report makes recommendations on the clinical implementation of secondary dose/MU calculation programs; on commissioning and acceptance of various commercially available secondary dose/MU calculation programs; on benchmark QA and periodic QA; and on clinically reasonable action levels for agreement of secondary dose/MU calculation programs.

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AAPM SCIENTIFIC REPORT

MEDICAL PHYSICS

## AAPM Task Group Report 307: Use of EPIDs for Patient-Specific IMRT and VMAT QA

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**Abstract**

**Purpose:** Electronic portal imaging devices (EPIDs) have been widely utilized for patient-specific quality assurance (PSQA) and their use for transit dosimetry applications is emerging. Yet there are no specific guidelines on the potential uses, limitations, and correct utilization of EPIDs for these purposes. The American Association of Physicists in Medicine (AAPM) Task Group 307 (TG-307) provides a comprehensive review of the physics, modeling, algorithms and clinical experience with EPID-based pre-treatment and transit dosimetry techniques. This review also includes the limitations and challenges in the clinical implementation of EPIDs, including recommendations for commissioning, calibration

# Vendors available (MU Calculation)

TABLE 2 Commercially available 2nd MU verification software

| Software | Algorithm | Supported | Input | Output |
|---|---|---|---|---|
| RadCalc (LifeLine Software, Inc.) | Modified Clarkson | IMRT<br>VMAT<br>TomoTherapy<br>CyberKnife<br>Halcyon | Effective depth<br>Patient external contour<br>Plan parameters | One point/2D |
| MUCheck (Oncology Data Systems, Inc.) | Modified Clarkson | IMRT<br>VMAT<br>TomoTherapy<br>CyberKnife | Effective depth<br>Average depth<br>Average SSD<br>Plan parameters | One point |
| IMSure (Standard Imaging, Inc.) | Three Source Model | IMRT<br>VMAT | Effective depth<br>Plan parameters | Multiple points |
| Diamond (PTW Freiburg GmbH) | Modified Clarkson | IMRT<br>VMAT | Effective depth<br>Plan parameters | One point |
| DoseCHECK (Sun Nuclear, Corp) | Collapsed Cone Convolution/ Superposition | IMRT<br>VMAT<br>TomoTherapy<br>Halcyon | Patient geometry<br>Plan parameters | 3D dose calculation |
| DosimetryCheck (Math Resolutions LLC) | Collapsed Cone Convolution/ Superposition | IMRT<br>VMAT | Plan parameters<br>EPID measurements | 3D dose calculation |
| Mobius 3D (Varian Medical Systems, Inc) | Collapsed Cone Convolution/ Superposition | IMRT<br>VMAT<br>TomoTherapy | Plan parameters<br>EPID measurements | 3D dose calculation |

# Algorithms available

**TABLE 3** 2D algorithms and evaluation methods available in various second dose/MU calculation system and the specifics of various algorithm types

| Alg. types | Hetero. Corr. Methods | Head Scatter Models | Pat. Geom. | # Calc. points | Eval. Method |
|---|---|---|---|---|---|
| 1. Factor based | A. RTAR[1] | a. HS central axis meas. | 2D contour/CT | α. one point | (a). % err. |
| 2. Model based | B. Batho power[2] | b. HS off-axis meas.[3] | | β. 2 – 10 points | (b). Gamma Index (or DTA) |
| 3. Monte Carlo (MC) | C. ETAR[4] | c. Model: flattening filter[3] | | γ. Planar dose | (c). DVH |
| 4. Deterministic (GBBS) | D. FFT[5-7] | d. Model: ff+cs+ps[a] | | | |
| | E. Material Z | | | | |

[a]This refers to three source headscatter model composed of flattening filter (ff), collimator scattering (cs), and primary-collimator scattering (ps)

**TABLE 4** 3D algorithms and evaluation methods available in various second MU calculation system and the specifics of various algorithm types

| Alg. types | Hetero. Corr. Methods | Head Scatter Models | Pat. Geom. | # Calc. points | Eval. Method |
|---|---|---|---|---|---|
| 1. Factor based | A. FFT[5] | a. HS off-axis meas.[3] | | β. 2 – 10 points | (a). % err. |
| 2. Model based | B. Collapsed cone[8,9] | b. Model: flattening filter[3] | 3D contour/CT | γ. Planar dose | (b). Gamma Index (or DTA) |
| 3. Monte Carlo (MC) | C. Material Z | c. Model: ff+cs+ps[a] | | η 3D dose cloud | (c). DVH |
| 4. Deterministic (GBBS) | D. Secondary electron transport | d. Model: source obscuring[3] | | | |
| | | e. Model: monitor backscattering[3] | | | |

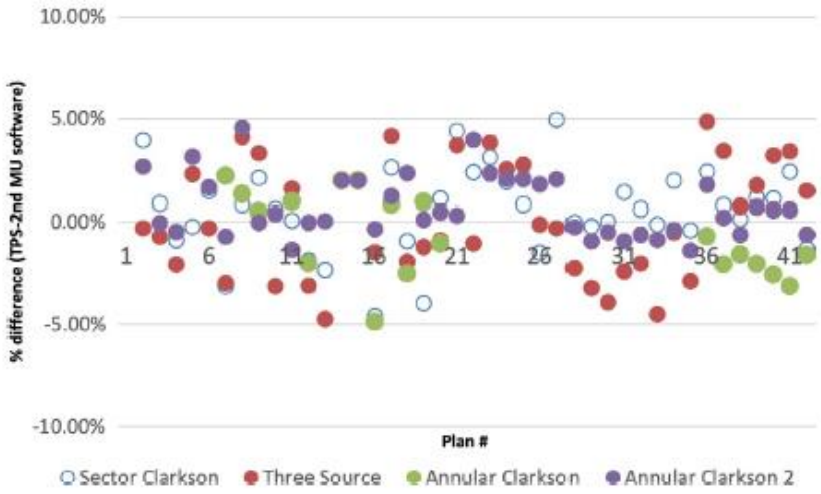
[a]This refers to three-source head scatter model composed of flattening filter (ff), collimator scattering (cs), and primary-collimator scattering (ps).

# Dose algorithm, acceptance and commissioning

TABLE 7 Key tasks for dose algorithm check, acceptance, and commissioning for the secondary MU calculation program

| Tasks | Data required |
|---|---|
| Dose algorithm check | |
| Linac Physics Model | Energy, SAD, Dmax, size/angle range (Jaw, gantry, collimator, couch) |
| Linac Dosimetry Model/ Beam Data | PDD/TMR(open, wedge), Profile(open, wedge), Output Factor (open Sc/Sp, wedge), transmission factors (Jaw, block tray, comp tray, couch, immobilization, etc.), reference MU definition |
| MLC Physics Model | MLC type, leaf number, size, etc. |
| MLC Dosimetry Model | Attenuation (inter and intra leaf), dosimetric leaf gap, etc. |
| **Tasks** | **Test required** |
| Acceptance* | |
| Software | Software running<br>Import-export<br>PDD and profile comparisons<br>Test cases |
| Hardware | Printing |
| **Tasks** | **Test required** |
| Commissioning | |
| Open beam<br>Homogenous phantom | SSD setup, various Jaw size and depth<br>SAD setup, various Jaw size and depth<br>SAD setup, various Off axis point with representative jaw size and depth |
| Static field<br>Homogenous phantom | Blocked field (Block/MLC)<br>Compensator field<br>Wedge field (CAX and Off axis)<br>Field edge<br>Skin Flash<br>Surface slope |
| Dynamic field<br>Homogenous phantom | Dynamic wedge (CAX and Off axis)<br>Step and shoot<br>Sliding window<br>VMAT |
| Heterogeneous phantom | Different density tissue internal (lung/bone, etc)<br>Different density tissues interface<br>Different density field edge |
| Real patient plan | Statistic evaluation between real patient plans and MU calculation program results. |
| Criteria | Percentage, Gamma index or DVH (based on plan type, site, etc.) |
| Benchmark points | Dose/MU points, see Table 8 |

*We recommend following the manufacturer's recommendation for acceptance tests.




you should not expect to be perfect, but to verify compliance with your standards and best practice standards in your clinical conditions

# Vendors available (EPID Dosimetry)

**TABLE 1** Summary of current EPID technology and dosimetry products.

| Software | Version | Compatible linac | Characteristics | | Comparison calculation | Reference (derived from EPID images) |
|---|---|---|---|---|---|---|
| Portal Dosimetry (Varian) | 1.7 | Varian | Pre-treatment | 2D | Vendor algorithm | Image |
| Adaptivo (Standard Imaging) | 1.5 | Varian | Pre-treatment | 2D | Vendor algorithm | Image |
| | | Varian | Transit | 2D | Vendor algorithm | Image |
| SOFTDISO (Best Medical) | 1.0 | Varian | Pre-treatment | 2D | Vendor algorithm | Image (non-dosimetric) |
| | | Elekta | | | | |
| | | Varian | Transit | 0D | TPS | Dose in patient (at isocenter) |
| | | Elekta | | | | |
| Epiqa (EPIdos) | 5.0 | Varian | Pre-treatment | 2D | TPS | Dose in water slab |
| | | Elekta | | | | |
| EPIbeam and EpiGray (DOSIsoft) | 1.0.6 and 2.0.10 | Varian | Pre-treatment | 2D | Vendor algorithm | Dose in water slab |
| | | Elekta | | | | |
| | | Varian | Transit | 0D | TPS | Dose in patient |
| | | Elekta | | | | |
| EPIDose (Sun Nuclear) | 8.4 (SNC patient) | Varian | Pre-treatment | 2D | TPS | Dose in water slab |
| | | Elekta | | | | |
| PerFRACTION SunCHECK Patient (Sun Nuclear) | 2.11.0 | Varian | Pre-treatment | 2D | Vendor algorithm | Dose in water slab |
| | | Elekta | | | | |
| | | Varian | Pre-treatment | 3D | TPS | Dose in patient (non-dosimetric) |
| | | Elekta | | | | |
| | | Varian | Transit | 2D | Vendor algorithm | Dose in water slab |
| | | Elekta | | | | |
| | | Varian | Transit | 3D | TPS | Dose in patient (non-dosimetric) |
| | | Elekta | | | | |
| RadCalc EPID (LAP) | 7.2 | Varian | Pre-treatment | 3D | TPS | Dose in patient |
| | | Elekta | | | | |
| | | Varian | Transit | 3D | TPS | Dose in patient |
| | | Elekta | | | | |
| 3DVH (Sun Nuclear) | 3.3 | Varian | Pre-treatment | 3D | TPS | Dose in patient |
| | | Elekta | | | | |
| iViewDose (Elekta) | 1.0.1 | Elekta | Transit | 3D | TPS | Dose in patient |

0D, zero dimensional; 2D, two dimensional; 3D, three dimensional; EPID, electronic portal imaging device; TPS, treatment planning system.

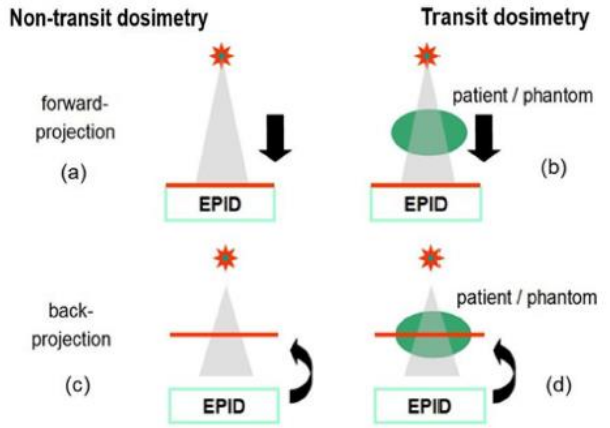



**FIGURE 2** Schematic representation of the various electronic portal imaging device (EPID)-based patient-specific quality assurance (PSQA) techniques. (a, b) Forward methods compare measured two-dimensional (2D) images or dose distributions with predicted images or dose distributions at the EPID level. Back-projection methods, both (c) non-transit and (d) transit, provide dose distributions in a phantom or patient. (Reproduced from ref. 45).

Some Hybrid Machine allow to calculate the transit dose, directly from the detectors, during the delivery (i.e. Tomotherapy)

# EPID Characteristic

**TABLE 2** Characteristics of the currently available EPID systems.

| | Varian aS1000 (C-Series and Truebeam)[a] | Varian aS1200 (Truebeam) | Varian aS1200 (Halcyon/ Ethos) | Elekta iViewGT (AL panel) | Elekta iViewGT (AP panel) | Elekta Unity (AP panel)[b] |
|---|---|---|---|---|---|---|
| Moveable lateral, sup-inf | Yes | Yes | No | Yes | Yes | No |
| Moveable up-down | Yes | Yes | No | No | No | No |
| SID (cm) | 100–180 | 100–180 | 154 | 160 | 160 | 265.3 |
| Dimensions ($cm^2$) lateral × superior-inferior | 40 × 30 | 43 × 43 (40 × 40) dosimetry mode | 43 × 43 | 41 × 41 | 41 × 41 | 41 × 41 |
| Dimensions at isocenter ($cm^2$) | 40 × 30 | 43 × 43 | 27.9 × 27.9 | 25.6 × 25.6 | 25.6 × 25.6 | 22.3 × 22.3[c] |
| Pixel size ($mm^2$) | 0.392 × 0.392 | 0.336 × 0.336 | 0.336 × 0.336 | 0.400 × 0.400 | 0.400 × 0.400 | 0.400 × 0.400 |
| Frame rate (Hz) | Up to 20[d] | Up to 20 | Up to 20 | 3 | Up to 15 | Up to 15 |
| DICOM image Format export (including DPS[e]) | Yes[f] | Yes | Yes | [g] | [g] | [g] |
| Other dosimetric format | | | | Image data in HIS or lossless JPEG format- Gantry/DPS info in text XML file (license required)[h] | Image data in HIS or lossless JPEG format- Gantry/DPS info in text XML file (lice nse required)[h] | Image data in HIS or lossless JPEG format- Gantry/DPS info in text XML file (license required)[h] |
| Dosimetric cine mode acquisition (including DPS[e]) | Yes C-Series[i] No Truebeam | No[j] | No[j] | Yes[h,k,l] | Yes[h,k,l] | Yes[h,k,l] |
| Support for FFF imaging | Yes[m] | Yes | Yes | No | Yes | Yes |

No-coplanar beams?

# Achievable passing rate vs. Metrics and Tolerance

**TABLE 8** Achievable $\gamma$ passing rates and dose agreement obtained from QA measurement results reported in the literature when using EPIDs for pretreatment and transit dosimetry.

**2D Pre-treatment techniques**

| First author year | Delivery technique | Metric: $\gamma$ criteria | Average gamma pass rate ($\%\gamma < 1$) |
|---|---|---|---|
| Howell, 2008[100] (Varian Portal Dosimetry) | IMRT | 3%G[a]/3 mm | 95.9% ±10% |
| Nelms 2012[42] (SNC EPIDose) | IMRT | 3%G/3 mm | 99.7% ± 0.1% (Range 94.0–100) |
| | | 2%G/2 mm | 97.8% ± 0.4% (Range 82.0–100) |
| Bailey 2012[95] (EPIDose, Portal Dosimetry) | IMRT, VMAT | 3%G/3 mm | >95% (Range 95–99) |
| Wu 2012[98] (RadCalc EPID) | IMRT, VMAT | 3%G/3 mm | IMRT: 97.2% ±3.0% (range 89.8–100) |
| | | | VMAT: 95.5% ± 6.0% (range 69.3–100) |

**Transit dosimetry techniques**

| First author year | Delivery technique | Anatomical site(s) | Metric | Average achieved agreement |
|---|---|---|---|---|
| François 2011[136] (EPIgray) | IMRT | Prostate | $\Delta Dose_{Iso}$[b] | 1.6% ± 1.4% |
| Ricketts 2016[124] (EPIgray) | 3DCRT | Breast | $\Delta Dose_{Iso}$, mean $\gamma$[c] | –0.6% ± 7.4% (2SD), 0.38 (range 0.03–1.17) |
| | IMRT | Prostate | $\Delta Dose_{Iso}$, mean $\gamma$ | –4.4% ± 8.2% (2SD), 0.80 (range 0.36–1.34) |
| | IMRT | H&N | $\Delta Dose_{Iso}$, mean $\gamma$ | –5.4% ± 24% (2SD), 0.89 (range 0.54–1.38) |
| Celi 2016[126] (EPIgray) | 3DCRT/IMRT/VMAT | Various | $\Delta Dose_{Iso}$ | 1.9% ± 5.2% |
| Cilla 2016[20] (SOFTDISO) | VMAT | H&N | $\Delta Dose_{Iso}$ | 0.2% ± 1.9% |
| | | | 2D 3%G/3 mm[d] | 93%; $\gamma_{mean}$: 0.42 |
| Consorti 2017[92] (SOFTDISO) | SBRT | Lung | $\Delta Dose_{Iso}$ | ±4% |
| | | | 2D 3%G/3 mm[e] | 96%; $\gamma_{mean}$: 0.6 |
| Piermattei 2018[128] (SOFTDISO) | 3DCRT/IMRT/VMAT | HN, brain | 2D 3%G/3 mm | 99% |
| | | Breast, abdomen, thorax, pelvis 2D | 5%G/5 mm | 96%, 96%, 93%, 95% |
| Nailon 2019[129] (RadCalc EPID) | 3DCRT/VMAT | Nine sites | $\Delta Dose_{Iso}$ | 1.9% ± 4.5% |
| Sterckx 2019[137] (iViewDose) | VMAT | Prostate | 3D 3%G/3 mm | 99.0% ± 1.0% (1SD); $\gamma_{mean}$: 0.33 ± 0.03 (1SD) |
| Yedekci 2019[114] (iViewDose) | VMAT | Prostate | 3D 3%G/3 mm | 97.2% ± 2.6% (1SD) (range 92.7–100) |

2D, two-dimensional; 3D, three-dimensional; 3DCRT, 3D conformal radiation therapy; EPID, electronic portal imaging device; H&N, head and neck; IMRT, intensity modulated radiation therapy; QA, quality assurance; SD, standard deviation; VMAT, volumetric modulated arc therapy.
[a] G: global.
[b] $\Delta Dose_{Iso}$: dose deviation at the isocenter.
[c] Mean g: the mean gamma of the comparison.
[d] 2D 3%G/3 mm: 2D dose distribution in the global gamma analysis and 3 mm distance to agreement.
[e] 3D 3%G/3 mm: 3D dose distribution in the global gamma analysis and 3 mm distance to agreement.

**TABLE 9** Metrics and tolerance limits reported in the literature when using EPIDs for PSQA.

**Pre-treatment techniques**

| First author year | Delivery technique | Anatomical site(s) | Metric | Tolerance limits[a] |
|---|---|---|---|---|
| van Zijtveld 2006[109] | IMRT | Various | 2D $\gamma$: 3% local/3 mm | $P_{min}$ ($\gamma < 1$): 85%; area $\gamma > 1$: <1 cm$^2$ |
| Howell 2008[100] | IMRT | Various | 2D $\gamma$: 3% local/3 mm | $P_{min}$ ($\gamma < 1$): 89.6%; $\gamma_{max}$: 3.20; $\gamma_{mean}$: 0.47 |
| Wu 2012[98] | IMRT | Various | 2D $\gamma$: 3% local/3 mm | $P_{min}$ ($\gamma < 1$): 90% |
| Wu 2012[98] | VMAT | Various | 3D $\gamma$: 5% local/3 mm | $P_{min}$ ($\gamma < 1$): 90% |

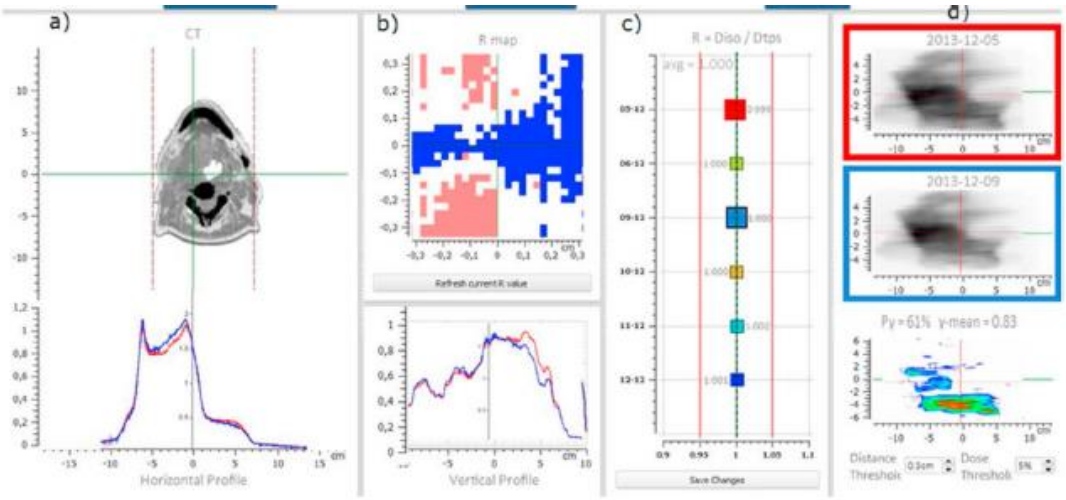
**Transit dosimetry techniques**

| First author year | Delivery technique | Anatomical site(s) | Metric[b] | Tolerance limits[a] |
|---|---|---|---|---|
| Hanson 2014[125] | 3DCRT | All, except CNS and TBI | $\Delta Dose_{Iso}$ | ±5% |
| Mijnheer 2015[16] | 3DCRT/IMRT/VMAT | Most | 3D $\gamma$: 3% global/3 mm/50% | $P_{min}$ ($\gamma < 1$): 85%; $\gamma_{max}$: 2.0; $\gamma_{mean}$: 0.5; $\Delta Dose_{Iso}$: ± 3% |
| | | H&N/rectum/gynecology | 3D $\gamma$: 3% global/3 mm/50% | $P_{min}$ ($\gamma < 1$): 80%; $\gamma_{max}$: 2.5; $\gamma_{mean}$: 0.7; $\Delta Dose_{Iso}$: ± 4% |
| | | Breast | 3D $\gamma$: 3% global/3 mm/50% | $P_{min}$ ($\gamma < 1$): 50%; $\gamma_{max}$: 5.0; $\gamma_{mean}$: 0.5; $\Delta Dose_{Iso}$: ± 3% |
| Ricketts 2016[124] | 3DCRT | Breast | $\Delta Dose_{Iso}$ | ±7% |
| | IMRT | H&N | $\Delta Dose_{Iso}$ | –6% ± 7% |
| | IMRT | Prostate | $\Delta Dose_{Iso}$ | –4% ± 8% |
| Celi 2016[126] | 3DCRT/IMRT/VMAT | Most | $\Delta Dose_{Iso}$ | ±7.5% |
| | | Breast—lateral | $\Delta Dose_{Iso}$ | ±6.7% |
| | | Int. mammary lymph nodes | $\Delta Dose_{Iso}$ | ±10.0% |
| Cilla 2016[20] | VMAT | H&N | $\Delta Dose_{Iso}$ | ±5% |
| | | | 2D $\gamma$: 3% global/3 mm | $P_{min}$ ($\gamma < 1$): 90%; $\gamma_{mean}$: 0.67 |
| Piermattei 2018[128] | 3DCRT/IMRT/VMAT | Six sites | $\Delta Dose_{Iso}$ | ±5% |
| | | | 2D $\gamma$: 3% global/3 mm | $P_{min}$ ($\gamma < 1$): 90%; $\gamma_{mean}$: 0.67 |
| Nailon 2019[129] | 3DCRT/VMAT | Nine sites | $\Delta Dose_{Iso}$ | ±10% |
| Bossuyt 2020[119] | 3DCRT/IMRT/VMAT | Breast | 2D $\gamma$: 7% local/6 mm/ 20% threshold | $P_{min}$ ($\gamma < 1$): 90% |
| | | Whole brain radiotherapy | 2D $\gamma$: 7% local/3 mm/20% threshold | $P_{min}$ ($\gamma < 1$): 90% |
| | | Palliative treatments | 2D $\gamma$: 7% local/5 mm/20% threshold | $P_{min}$ ($\gamma < 1$): 93% |
| | | H&N and brain | 2D $\gamma$: 3% global/3 mm/20% threshold | $P_{min}$ ($\gamma < 1$): 95% |
| | | Rectum | 2D $\gamma$: 5% global/5 mm/20% threshold | $P_{min}$ ($\gamma < 1$): 93% |
| | | Other treatment sites (with mask) | 2D $\gamma$: 5% global/3 mm/20% threshold | $P_{min}$ ($\gamma < 1$): 95% |
| | | Other treatment sites (without mask) | 2D $\gamma$: 5% global/5 mm/20% threshold | $P_{min}$ ($\gamma < 1$): 95% |
| | | Stereotactic | 2D $\gamma$: 10% local/1,2,3 mm/20% threshold | $P_{min}$ ($\gamma < 1$): 95% |

CNS, central nervous system; 2D, two-dimensional; 3D, three-dimensional; 3DCRT, 3D conformal radiation therapy; EPID, electronic portal imaging device; H&N, head and neck; IMRT, intensity modulated radiation therapy; PSQA, patient-specific quality assurance; TBI, total body irradiation; VMAT, volumetric modulated arc therapy.
[a] $P_{min}$ ($\gamma < 1$): minimum pass rate; $\gamma_{max}$: maximum $\gamma$; $\gamma_{mean}$: mean $\gamma$.
[b] $\Delta Dose_{Iso}$: dose deviation at the isocenter.

# Challenges and issues

EPID




**3.3 | Limitations, applications, and challenges in clinical implementation of EPIDs**

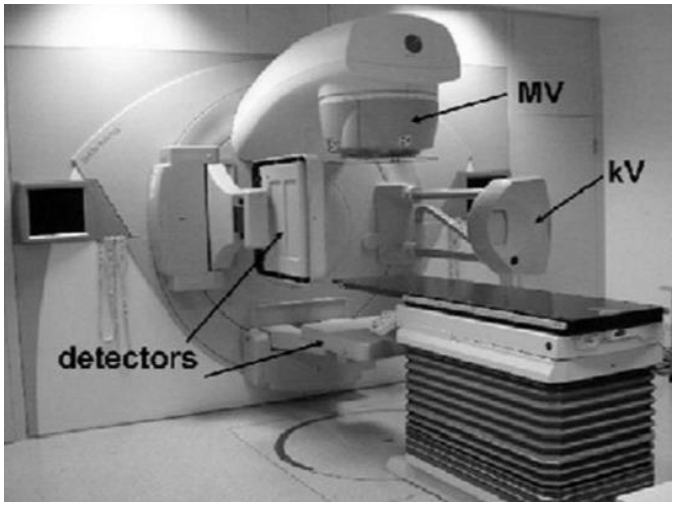
Independent Dose/MU Calculation

### 3.4.4 | High-Z heterogeneities

Dose accuracy is particularly challenging to achieve near high-Z interfaces and is exacerbated for higher energy beams and higher Z materials.[77,86] At the vicinity of both upstream and downstream metal interfaces, dose errors in C/S are often in the range of 10–15% compared to measurement (underestimating dose at the upstream interface and overestimating it at the downstream), but these errors can easily exceed 20%.[87-89] GBBS has been shown to agree within 1%–2% with MC,[86] which in turn agrees reasonably well (within ~5%) with measurement.[86,90] These effects can extend several cm from the implant; even 2 cm away, C/S algorithms can still show residual dose error of 6%–12%.[87-89,91]

namic MLC, and/or VMAT. If the secondary calculation system includes heterogeneity corrections, a heterogeneous benchmark should also be evaluated. Assuming all the benchmark plans calculated in the planning system agree with measurements, the secondary calculation software should agree with the TPS. Reasonable agreement is within 5% (for both field-by-field or composite), and this should be achieved for the benchmark cases. Failure to achieve this level of agreement should result in either (a) improved commissioning of the secondary calculation system such that appropriate agreement is achieved, or (b) identification of the limitations of the secondary system, particularly in the case of challenging benchmarks, and establishment of alternate criteria for treatment plans of a similar nature.

# EPID QA



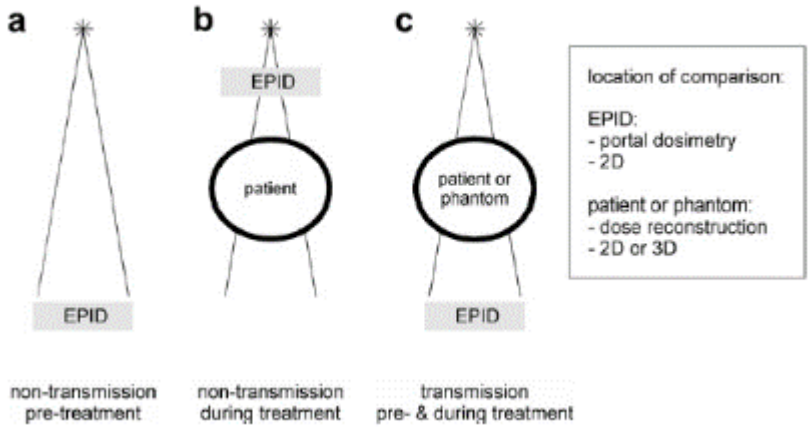




Table 2
List of key references on non-transmission based dose verification methods

| Verification procedure | Type of verification | Key references | Objective of verification or subject of the study |
|---|---|---|---|
| QA of treatment machine | QA | Prisciandaro [93] | Radiation-light field congruence |
| | QA | Dirkx [52,53], Budgell [80,87] | Linac output, beam profile flatness and symmetry |
| | QA | Baker [84], Yang [95], Samant [96], Parent [97] | MLC leaf position for step-and-shoot fields |
| | QA | Vieira [86] | MLC leaf position and absolute output for low MU segmented fields |
| | QA | Vieira [98], Partridge [99], Chang [88] | MLC leaf position during dynamic treatment |

*How do you support a No-Coplanar beam using EPID/CBCT?*
*Why do we not support the transit dosimetry for those patients?*

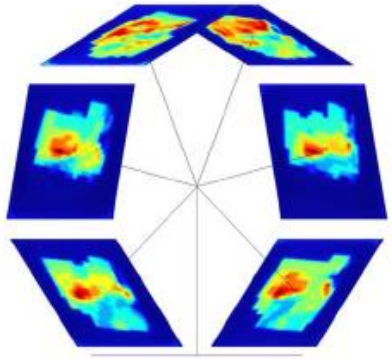
# Begin of the EPID Pre-Treatment verification

Pre-treatment dose verification

## Verification I: Pre-treatment dose verification

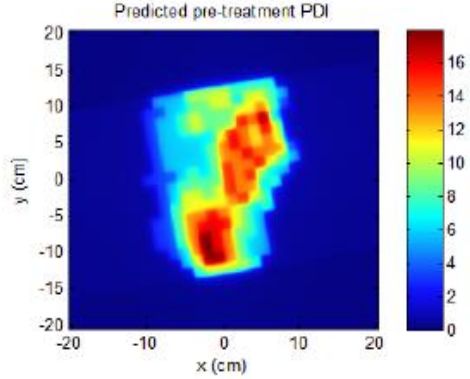
*(S.M.J.J.G. Nijsten, W.J.C. van Elmpt et al., Med. Phys. 34, 2007)*

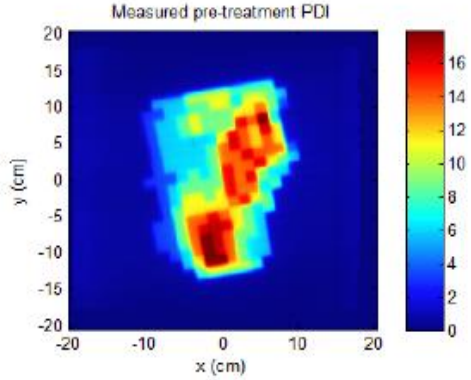
MAASTRO

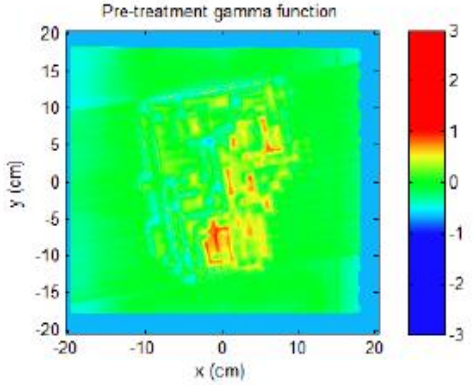


Before the start of treatment, the treatment fields for every patient are delivered and measured with the EPID.

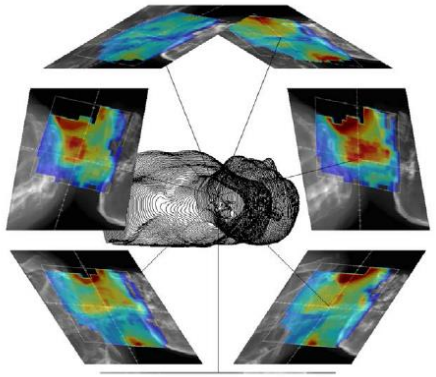
- allows for detection of errors made during transfer of treatment parameters between TPS and LINAC
- allows for detection of malfunctioning of treatment machine (e.g. machine output variations, leaf positioning errors)

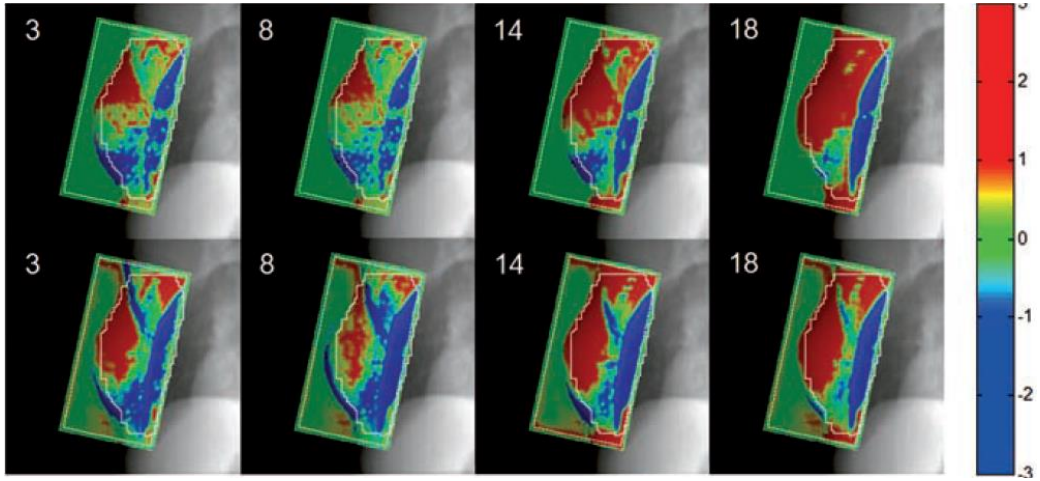


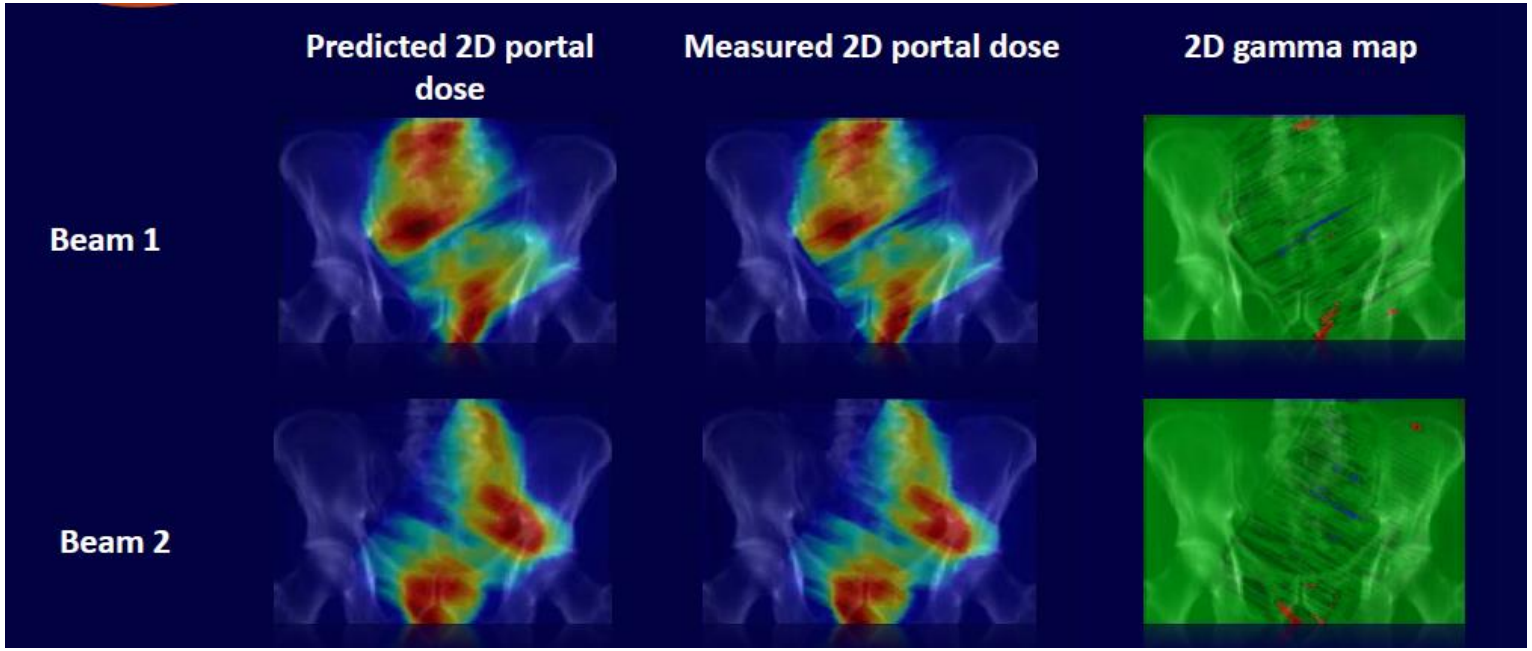



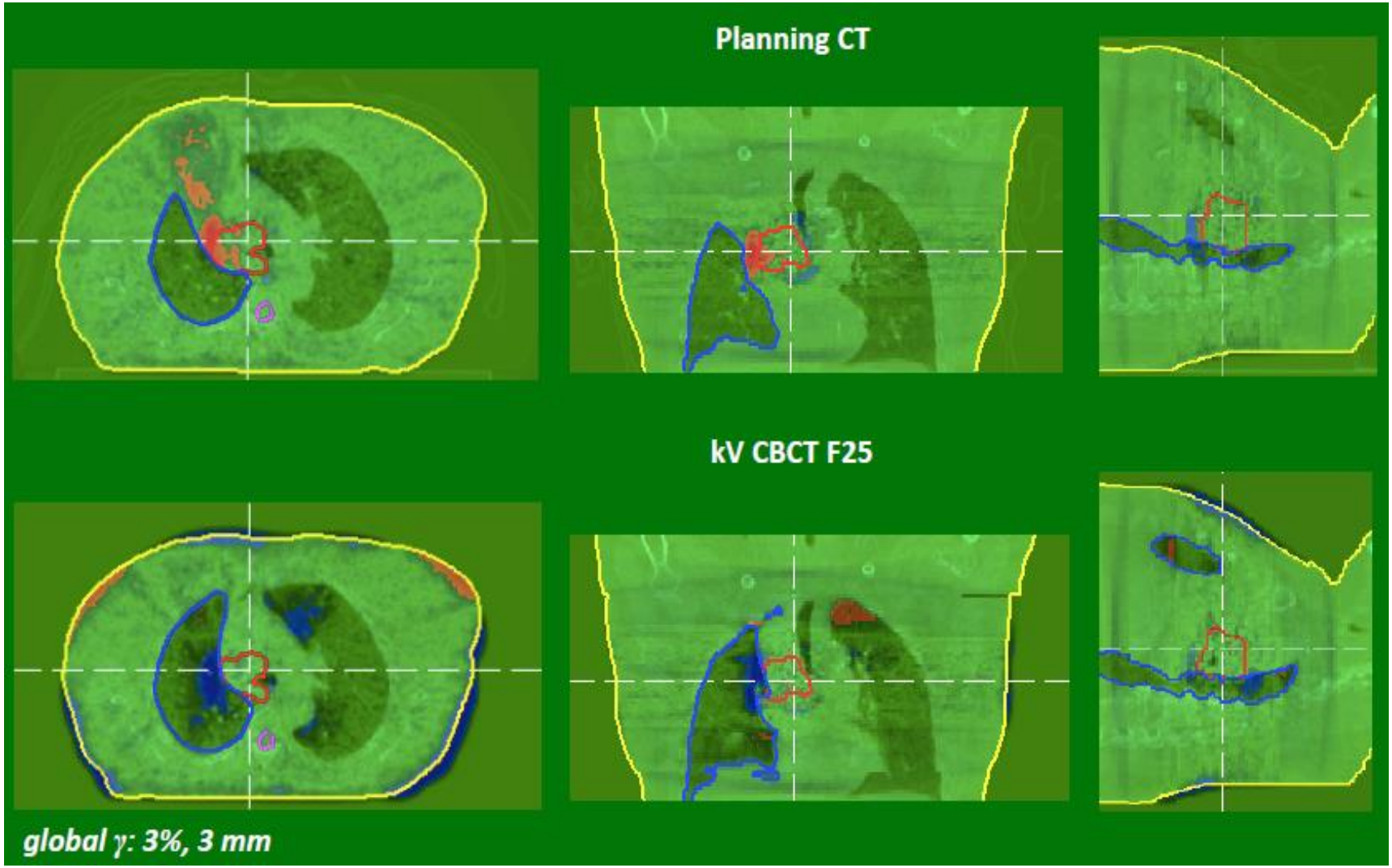
# 2D or 3D? Single o End-To-End errors assessment





# CBCT Recalculation: Issues




*Today we have notice of possible issues related to Image Quality, ED Table, Resolutions, Reconstruction, Artefacts, Non-Homogeneity, High-Z, Dose algorithm*

# i.e. Potential QA and error detected

Table 4
Overview of the various errors that can be detected with EPID dosimetry

| Potential errors | Pre-treatment verification | | | | Treatment verification | | | |
|---|---|---|---|---|---|---|---|---|
| | 2D/3D | 2D | | 3D | 2D | | | 3D |
| | No phantom | Behind phantom | Inside phantom | Inside phantom | Before patient | Behind patient | Inside patient | Inside patient |
| *Machine* | | | | | | | | |
| Wedge presence and direction | Yes (systematic errors) | | | | Yes (systematic and random errors) | | | |
| Presence of segment | Yes (systematic errors) | | | | Yes (systematic and random errors) | | | |
| MLC leaf position/speed | Yes (systematic errors) | | | | Yes (systematic and random errors) | | | |
| Leaf sequencing | Yes (systematic errors) | | | | Yes (systematic and random errors) | | | |
| Collimator angle | Yes (systematic errors) | | | | Yes (systematic and random errors) | | | |
| Beam flatness and symmetry | Yes (systematic errors) | | | | Yes (systematic and random errors) | | | |
| Linac output during treatment | No | | | | Yes | | | |
| Gantry angle | No | Possible | Possible | Possible | No | Possible | Possible | Possible |
| *Plan* | | | | | | | | |
| Transmission through leaves | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Steep dose gradients | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| TPS modelling parameters for MLC | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Delivery of wrong patient plan | Yes (if same plan is used for verification and treatment) | | | | Yes | Yes | Yes | Yes |
| Dose calculation in phantom or patient | No | No | Yes | Yes | No | No | Yes | Yes |

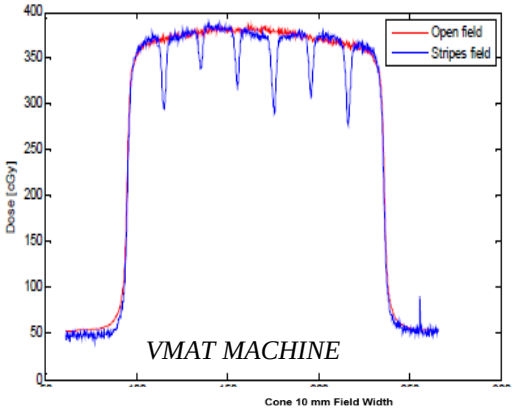
# …DURING THE COMMISSIONING YOU NEED TO VERIFY THE TOLERANCE….
# ….. AND DEFINE THE FUTURE BASELINE

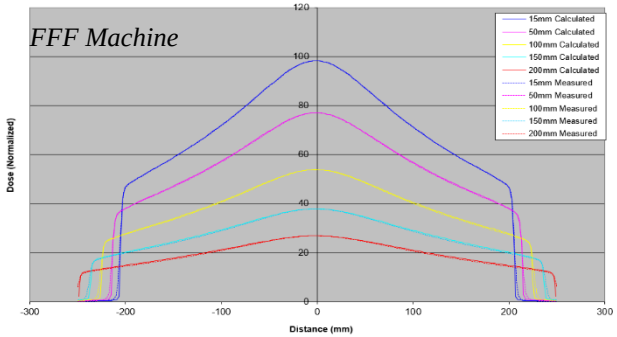


**Code of Practice for the Quality Assurance and Control for Volumetric Modulated Arc Therapy**

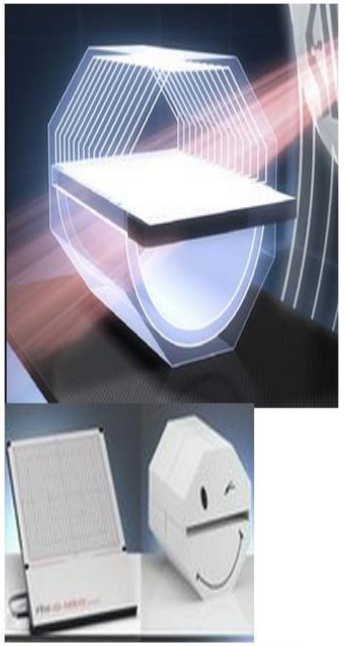
**NEDERLANDSE COMMISSIE VOOR STRALINGSDOSIMETRIE**

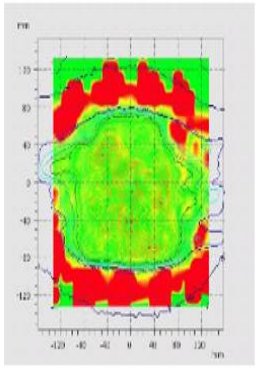
Report 24 of the Netherlands Commission on Radiation Dosimetry
February 2015

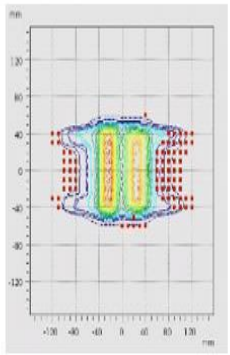


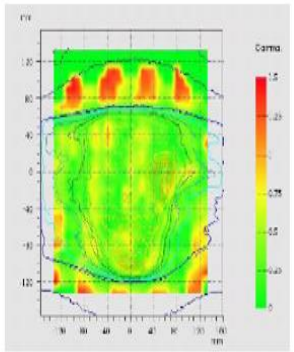




| Riepilogo misure eseguite con 2DArray in Solido (RW3) e Octavius | | | | | | | Local dose | Selected dose | Selected dose |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | % | % | Dose prescriz. (Gy) |
| | | TPS | Tecnica | Fantoccio | Piano | N°Fascio/Gantry Angle | | | |
| ID | Paziente | | | | | | | | |
| | TG119HN | MONACO | IMRT | Octavius | | 11 | 97,7 | 100 | 0,33 |
| | TG119HN | MONACO | IMRT | Octavius | | 12 | 94 | 98,7 | 0,29 |
| | TG119HN | MONACO | IMRT | Octavius | | 13 | 95 | 98,6 | 0,22 |
| | TG119HN | MONACO | IMRT | Octavius | | 14 | 99,2 | 100 | 0,45 |
| | TG119HN | MONACO | IMRT | Octavius | | 15 | 89,4 | 89,4 | 0,28 |
| | TG119HN | MONACO | IMRT | Octavius | | 16 | 91,5 | 99,2 | 0,53 |
| | TG119HN | MONACO | IMRT | Octavius | | 17 | 89,5 | 92,3 | 0,13 |
| | TG119HN | MONACO | IMRT | Octavius | | 18 | 87,7 | 98,1 | 0,30 |
| | TG119HN | MONACO | IMRT | Octavius | | 19 | 90,1 | 97,5 | 0,38 |
| | TG119HN | MONACO | IMRT | Octavius | | ALL | 97,8 | 91,6 | 2,91 |
| | F…… | MONACO | dMLC | RW3 | | 1 | 100 | 100 | 2,43 |
| | F…… | MONACO | dMLC | RW3 | | 2 | 100 | 100 | 2,09 |
| | F…… | MONACO | dMLC | RW3 | | 3 | 100 | 100 | 3,27 |
| | F…… | MONACO | dMLC | RW3 | | 4 | 99,5 | 100 | 2,21 |
| | F…… | MONACO | dMLC | RW3 | | 5 | 100 | 100 | 3,88 |
| | F…… | MONACO | dMLC | RW3 | | 6 | 98,5 | 100 | 2,29 |
| | F…… | MONACO | dMLC | RW3 | | 7 | 100 | 100 | 1,67 |
| | F…… | MONACO | dMLC | RW3 | | 8 | 100 | 100 | 2,90 |
| | F…… | MONACO | dMLC | RW3 | | 9 | 98,9 | 100 | 1,69 |
| | F…… | MONACO | dMLC | RW3 | | ALL | 99,1 | 100 | 22,42 |
| | TG119 Cshape | MONACO | VMAT | RW3 | | 41 | 64 | 63,7 | 0,16 |
| | TG119 Cshape | MONACO | VMAT | RW3 | | 42 | 78,9 | 98,6 | 0,14 |
| | TG119 Cshape | MONACO | VMAT | RW3 | | 43 | 75,9 | 92,7 | 0,16 |
| | TG119 Cshape | MONACO | VMAT | RW3 | | ALL | 66,1 | 67 | 0,45 |
| | S…… | MONACO | VMAT | RW3 | | 31 | 80,6 | 98,6 | 0,79 |
| | S…… | MONACO | VMAT | RW3 | | 32 | 86,8 | 98,9 | 0,75 |
| | S…… | MONACO | VMAT | RW3 | | ALL | 83,9 | 95,8 | 1,53 |
| | 68229 | MONACO | VMAT | Octavius | | 51 | 79,3 | 96,1 | 0,56 |
| | 68229 | MONACO | VMAT | Octavius | | 52 | 72,6 | 90,2 | 0,56 |
| | 68229 | MONACO | VMAT | Octavius | | 53 | 76,2 | 95 | 0,49 |










*Agreement TPS vs. Plan delivery*

*What can happen if the instruments are not calibrated*

# Logfile Experiences

***Integrated server-based web application, access from ANY networked PC***


***Secondary independent Dose Calculation:***

- *Double Dose Check;*
- *Algorithm Validation*

***Pre-Treatment & In-Vivo Dosimetry:***

- *Patient Follow Up during Treatment;*
- *Detailed Analysis of Treatment Plan;*
- *Detection of Errors & Uncertainties;*
- *Action Plan for their reduction;*

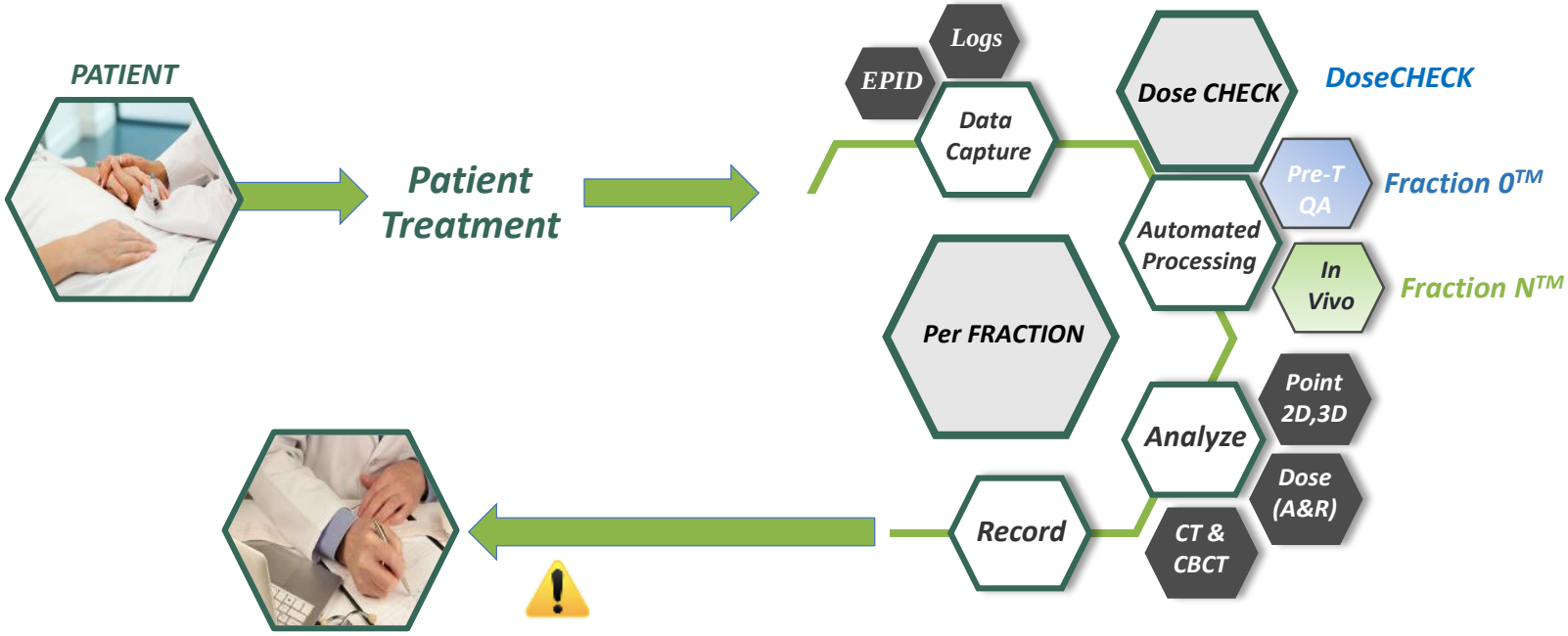
***Check Machine QA:***

- *Imaging; MLC & VMAT;*
- *TG 142 templates;*
- *Phantoms for tests.*


✓ ***Independent Dose Check*** ✓ ***Pre-Treatment QA*** ✓ ***Patient Monitoring***

# Log-Files Platform – How does it works?

***How does it work?***

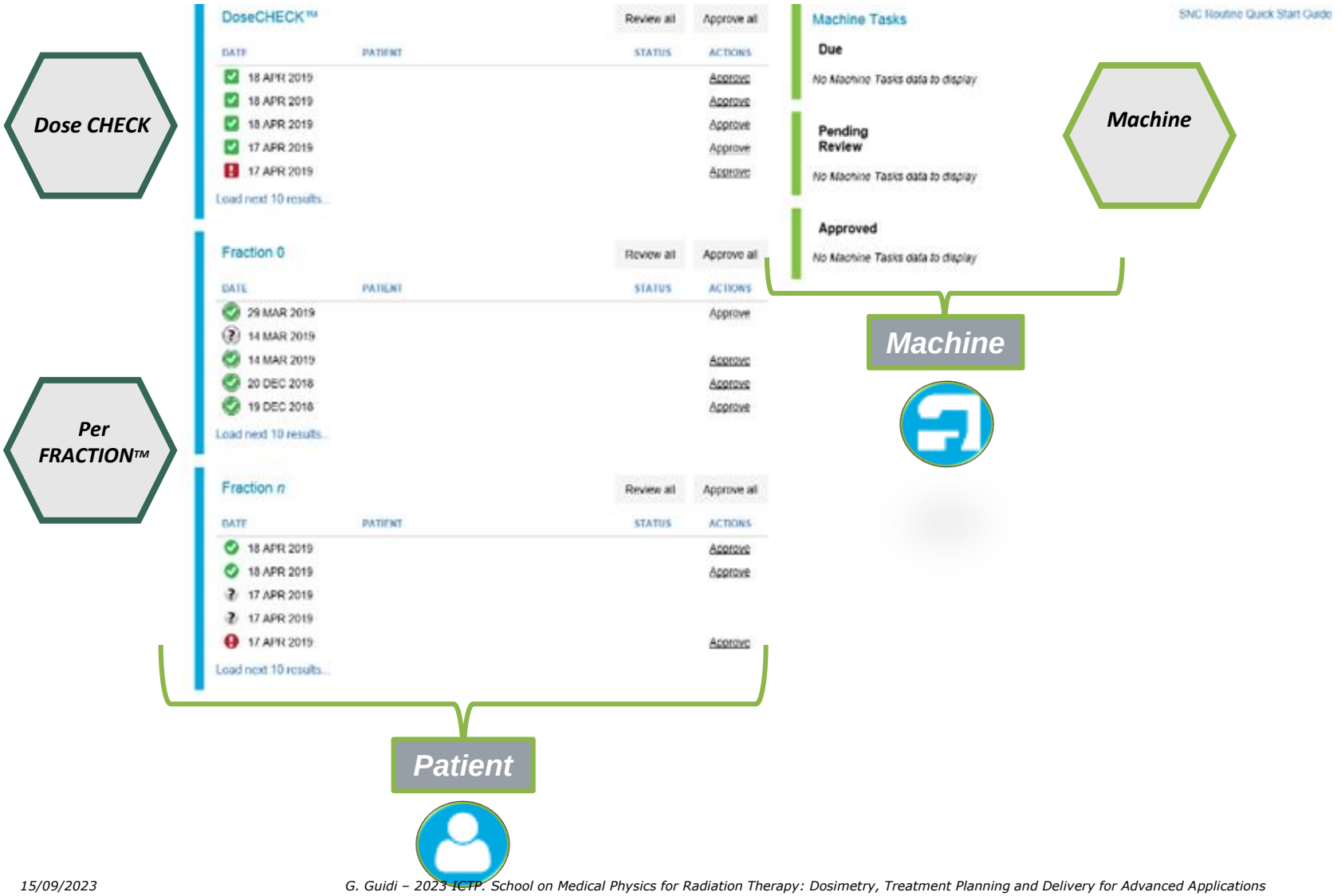



***Machine QA***

***TG #142***

- ✓ *Picket Fence*
- ✓ *Wiston Lutz*
- ✓ *Gantry & leaf Speed*
- ✓ *Dose Rate & Gantry Speed*
- ✓ *Uniformity*
- ✓ *Flatness & Symmetry*
- ✓ *…*

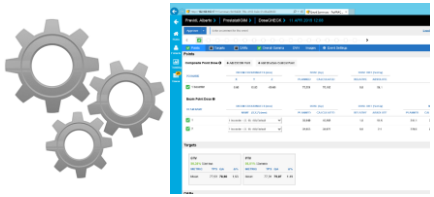
# Patient QA – Machine QA



# Dose Check –Independent Calculation

*TPS Dose Calculation vs. Independent Dose Calculation using RT files & Convolution/Superposition Algorithm.*

***RT Plan + RT Images + RT Structures***



***TPS Dose*** ***Dose Calculation***

- ✓ ***Raystation***
- ✓ ***Monaco***

*Information of VersaMO#1 and VersaMO#2 was sent to Logfiles Platform (plans in phantom)*

*They provide the adjusted **beam models…***

- ✓ ***More Accurate DoseCHECK™***

*Isocenter Point **ΔD[%] = (0,1 ± 0,5) %***

*Overall Gamma **ΔD[%] = (0,5 ± 0,8)%***
*(3% / 3mm – Pass:95%)*

# EPID vs. Log Files

***Log-Files Platform***

***Analysis Type?***

| Analysis type | | EPID Integrated | EPID Cine | Machine log |
|---|---|---|---|---|
| Fraction 0– 2D | | ✔ | | |
| Fraction 0 – 3D | EPID based | | ✔ | ✔ |
| | Log only | | | ✔ |
| Fraction N – 2D | Tansit Dosimetry | ✔ | | |
| | Relaive | ✔ | | |
| Fraction N – 3D | EPID based | | ✔ | ✔ |
| | Log only | | | ✔ |

***EPID vs Log?***

| Analysis Type | EPID | Log-files |
|---|---|---|
| **Fraction 0– 2D** | • 2D Absolute Dose (Inherently includes MLC, Dose Rate, Collimator, Jaws) | No data from Logs |
| **Fraction 0 – 3D** | • MLC positions | • Dose Rate – from Linac monitor chamber<br>• Gantry Angle (instantaneous)<br>• Collimator position |
| **Fraction N – 2D** | • 2D Absolute Transit Dose or 2D Relative Fluence (Inherently includes Patient, MLC, Dose Rate, Collimator, Jaws) | No data from Logs |
| **Fraction N – 3D** | ~~• MLC positions~~ | • Dose Rate – from Linac monitor chamber<br>• Gantry Angle (instantaneous)<br>• Collimator position |

# 2D-3D Calculation or CT/CBCT Calculation?

***Log-Files Platform***

***What are we comparing?***

| Analysis Type | Reference Data | Measured Data | Calculated On |
|---|---|---|---|
| **Fraction 0– 2D** | Dose in water phantom at EPID panel generated by SDC | EPID | EPID |
| **Fraction 0 – 3D** | TPS data | EPID and/or Log-file data | CT-Sim |
| **Fraction N – 2D** | Dose in water phantom at EPID plane generated by SDC or Baseline data (usually 1st fraction) | EPID Absolute Transit Dose Measurement or Relative Fluence Measurement | EPID |
| **Fraction N – 3D** | TPS data/SDC | EPID and/or Log-file data | CT-Sim or CBCT |

***A Modena…***

| | Reference Data | Measured Data | Calculation | Analysis |
|---|---|---|---|---|
| **Fraction 0 – 3D** | TPS Data | EPID / Log-File data<br>MLC Positions - Dose Rate - Gantry Angle - Collimator position | CT-Sim | Analysis 2D/3D<br>NO Absolute |
| **Fraction N – 3D** | TPS data/SDC | Log File data<br>Dose Rate - Gantry Angle - Collimator position | CT-Sim or CBCT | Analysis 3D<br>NO Absolute |

# Instruction and QA Programme



**SOFTWARE PERFRACTION**

Aprire Internet Explorer o un altro Browser disponibile sul PC della barra delle applicazioni in basso (*Figura 1):*

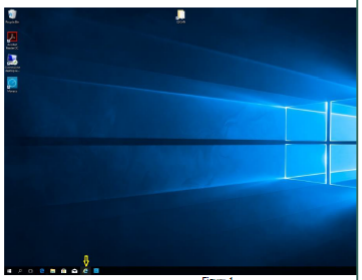


Figura 1

Inserire nella barra degli indirizzi: http://192.168.160.17

All'apertura di Internet Explorer occorre effettuare il login uti
parametri (*Figura 2*):
**Username:** admin@sncsever **Password:** Password#1


Figura 2



Si visualizza la seguente immagine dove compare la lista degli ultimi pazienti calcolati, sia per **DoseCHECK**; **Fraction 0**; e **Fraction n** (*Figura 3* ).
I pazienti che sono stati appena importati dal TPS compaiono nella sezione del DoseCHECK con una pallina gialla 12 SEP 2018 : è necessario preparare questi



**Modality / Details:** Selezionare la modalità e il tipo di terapia

**Pre-Treatment QA:** Viene già selezionato in automatico dal Sistema.

**Structure Type:**

**Target:** Solo una struttura: **PTV** del piano di trattamento.
(Solo nel caso sia un SIB, mettere multipli PTV)

**OAR or External:** Inserire tutti gli organi a rischio che devono essere valutati nel QA giornaliero.

**Ignore:** Inserire le strutture che, se ben saranno considerati nel calcolo, non è necessario il follow up giornaliero. Ad esempio: Strutture dummies; Espansioni; Lettino; Bolus; etc.

IMPORTANTE: è necessario mettere lo spuntino di Pass/Fail:

- Obbligatoriamente per il PTV.
- Obbligatoriamente per il External: Body.
- Per gli OAR's che si vogliono includere nel Gamma Analisi.

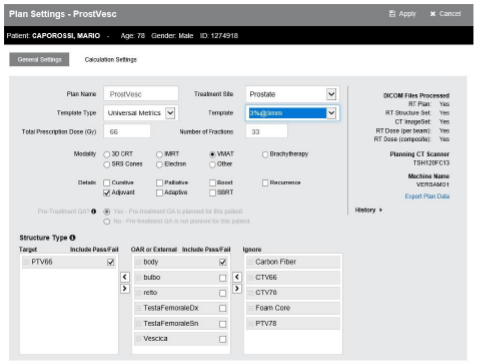



Figura 7

Pagina 3 di 6



Dopo aver modificato i parametri del **Plan Settings**, si conferma con **Apply**.

Di seguito, viene aperta automaticamente la seguente finestra dove si dovranno selezionare le seguenti opzioni per applicare i cambiamenti anche alle future frazioni che verranno importate dall'acceleratore (*Figura 8*)

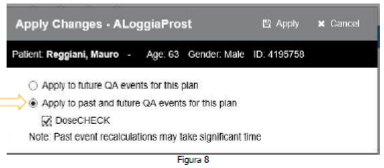
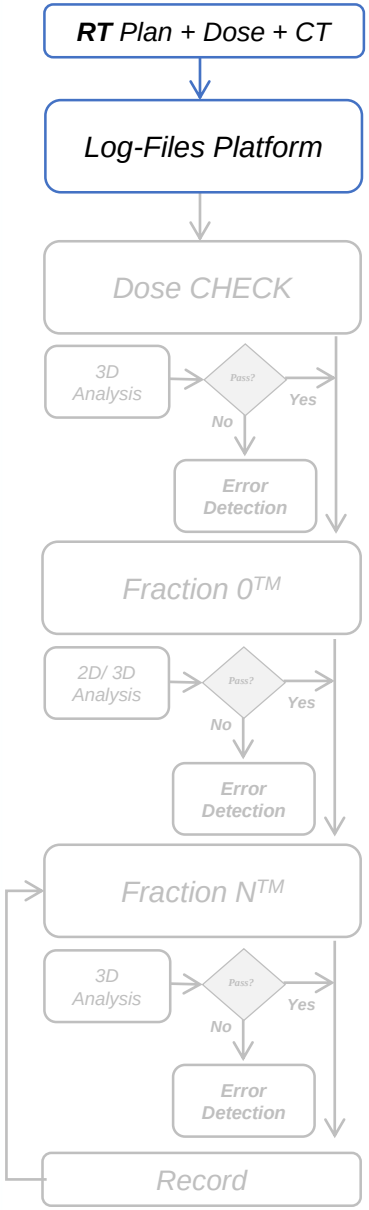


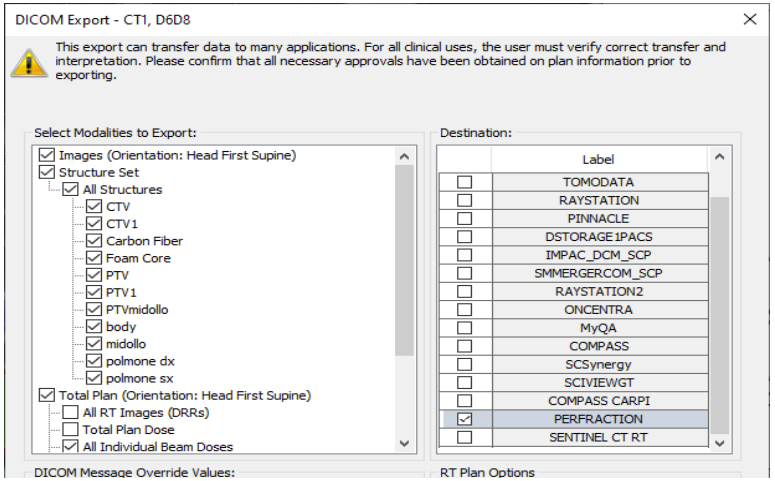

Figura 8

Pagina 4 di 6

# Treatment Planning System Connectivity




***TPS Export…***

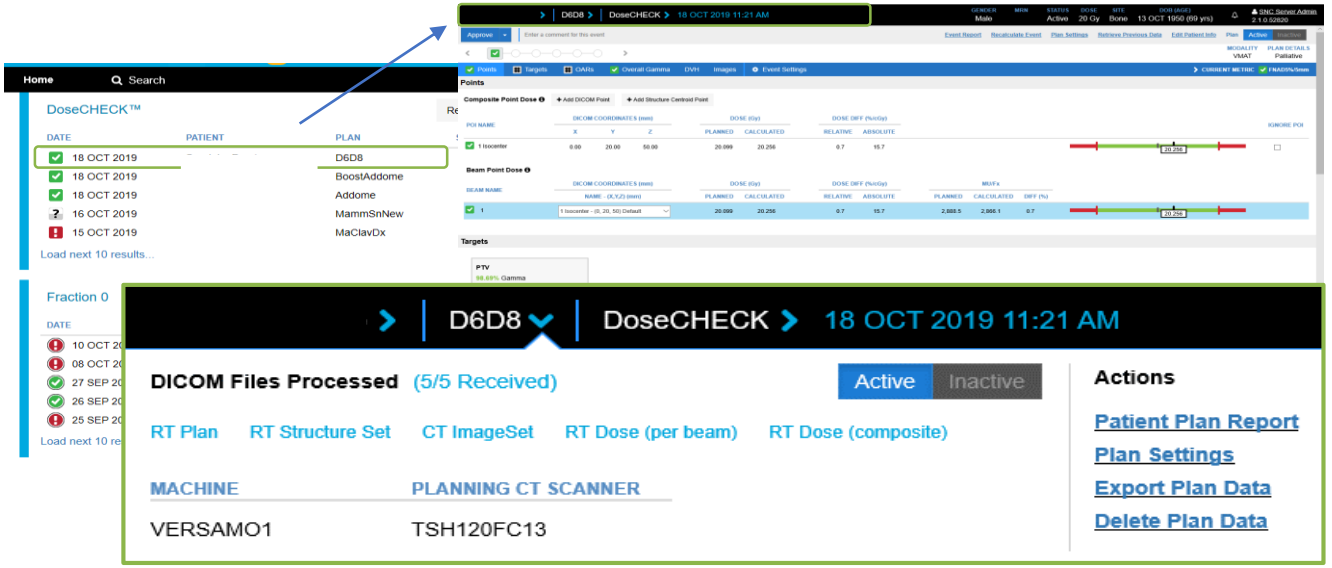



- ✓ *Images*
- ✓ *Structure Set*
  - ✓ *All Structures*
- ✓ *Total Plan*
  - ✓ *All Individual Beam Doses*

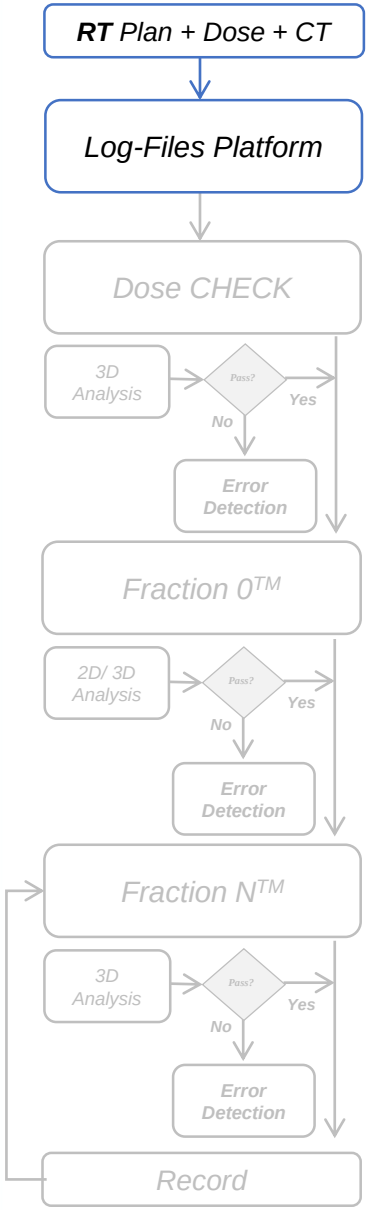
↓

- ✓ *Calculate dose per FRACTION*

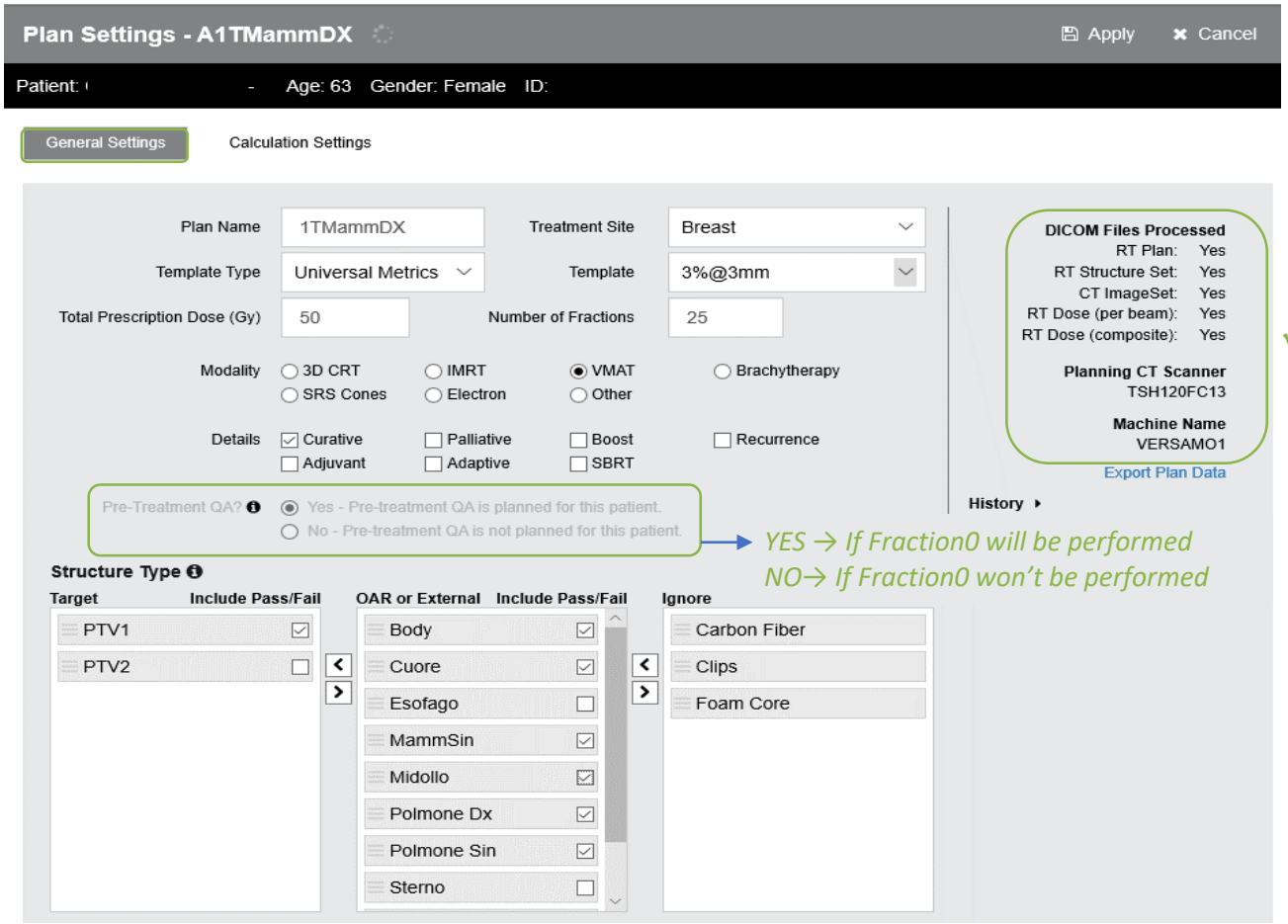
***Fraction Import…***



# Plan Setting, Target, OARs




*Plan Settings… General Settings…*



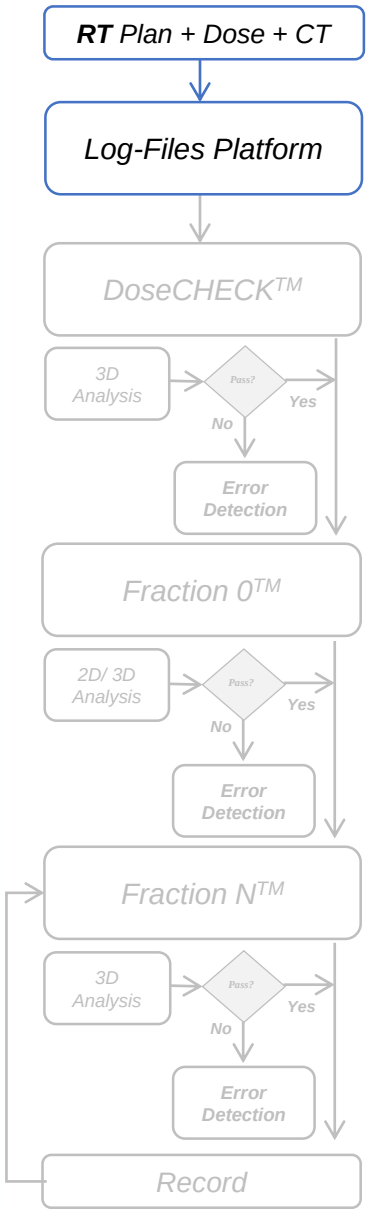

***Plan Name…***

*Has to be the same name as the plan that will be treated in the machine (MOSAIQ).*

***Total Prescription Dose…***

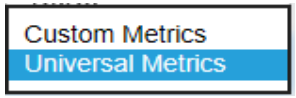
*Has to be completed manually, only Number of Fractions came automatically.*

# Metrics

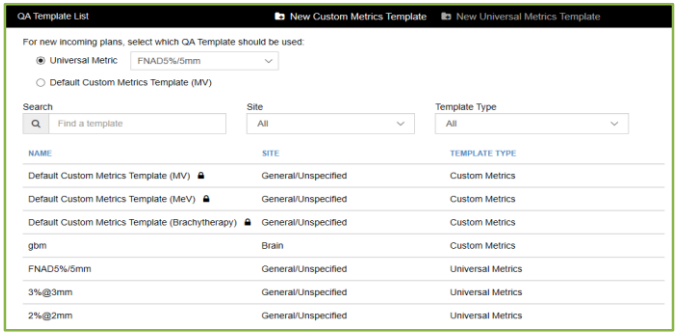



***Plan Settings… General Settings…***

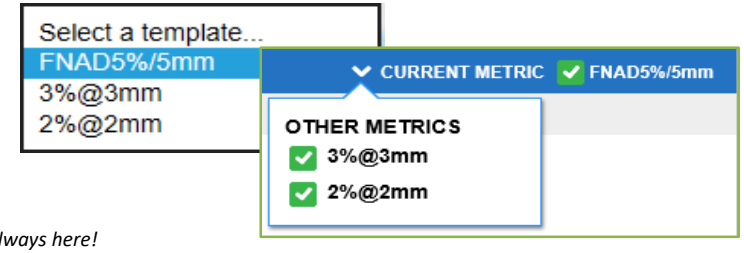
***Template Type…***



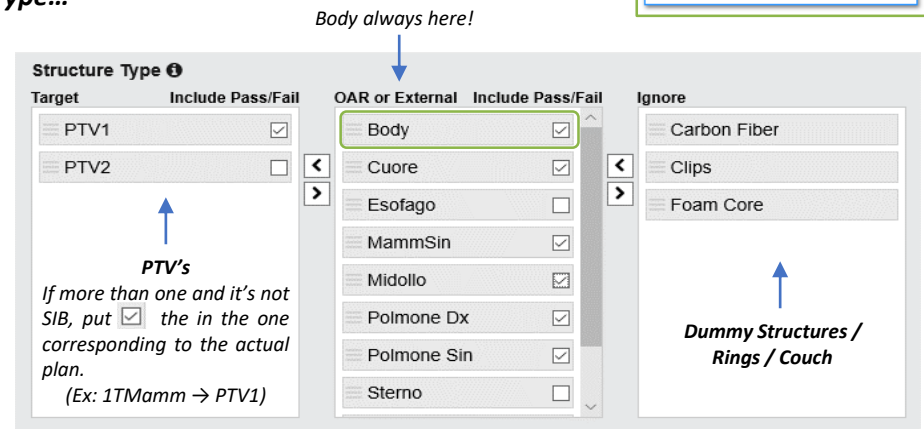

*Metrics can be defined* →




*Independent of the Template we choose, the calculation will be performed in all fractions*

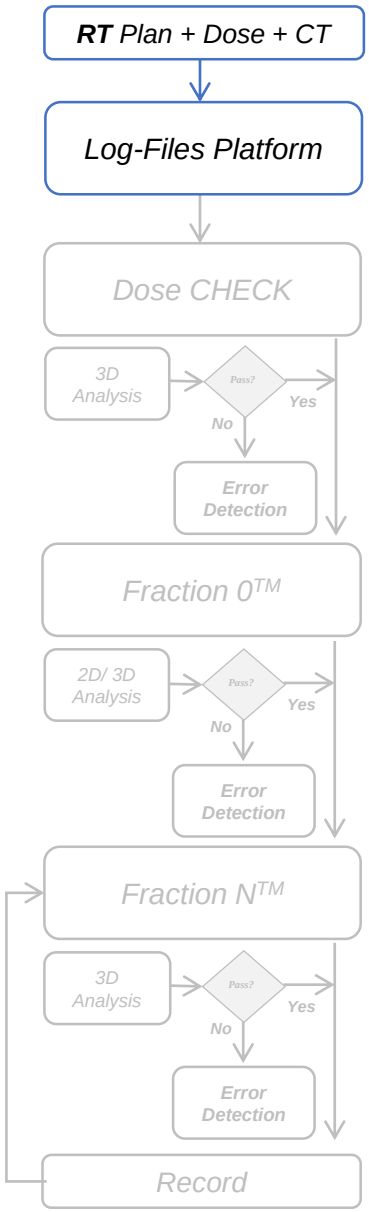



***Structure Type…***

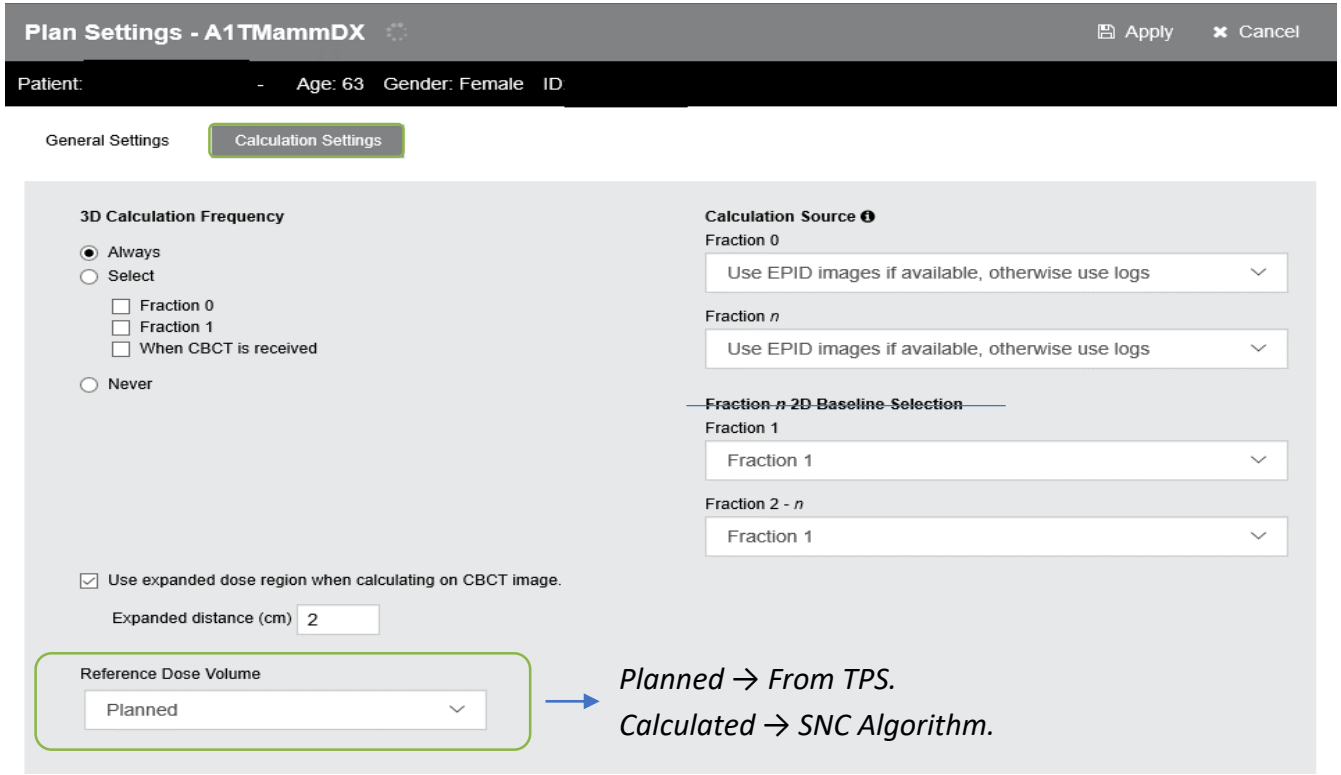



*Clicks has to be putted in the organs we are interesting on follow and/or that we want them to be part of Overall Gamma Calculation.*

# Calculation Settings



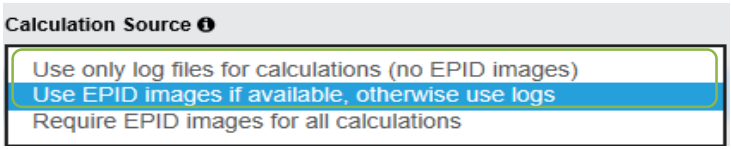

***Plan Settings… Calculation Settings…***




*Planned → From TPS.*

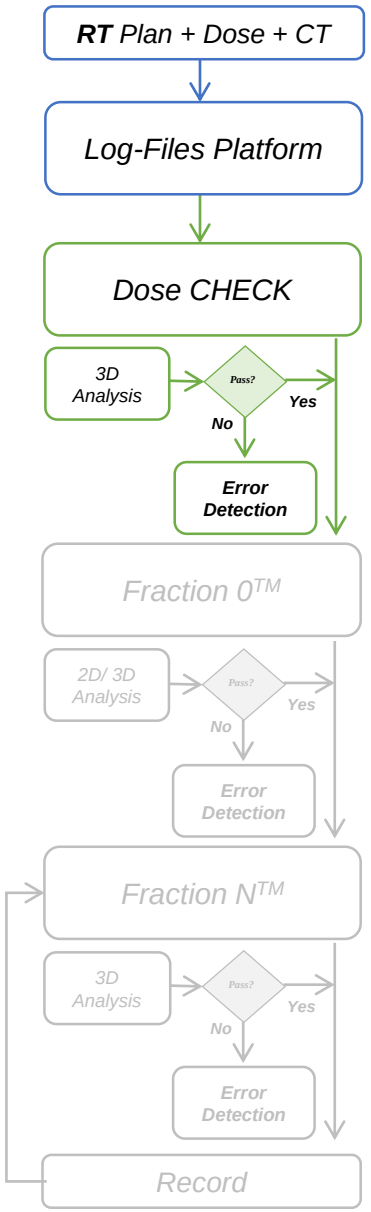
*Calculated → SNC Algorithm.*

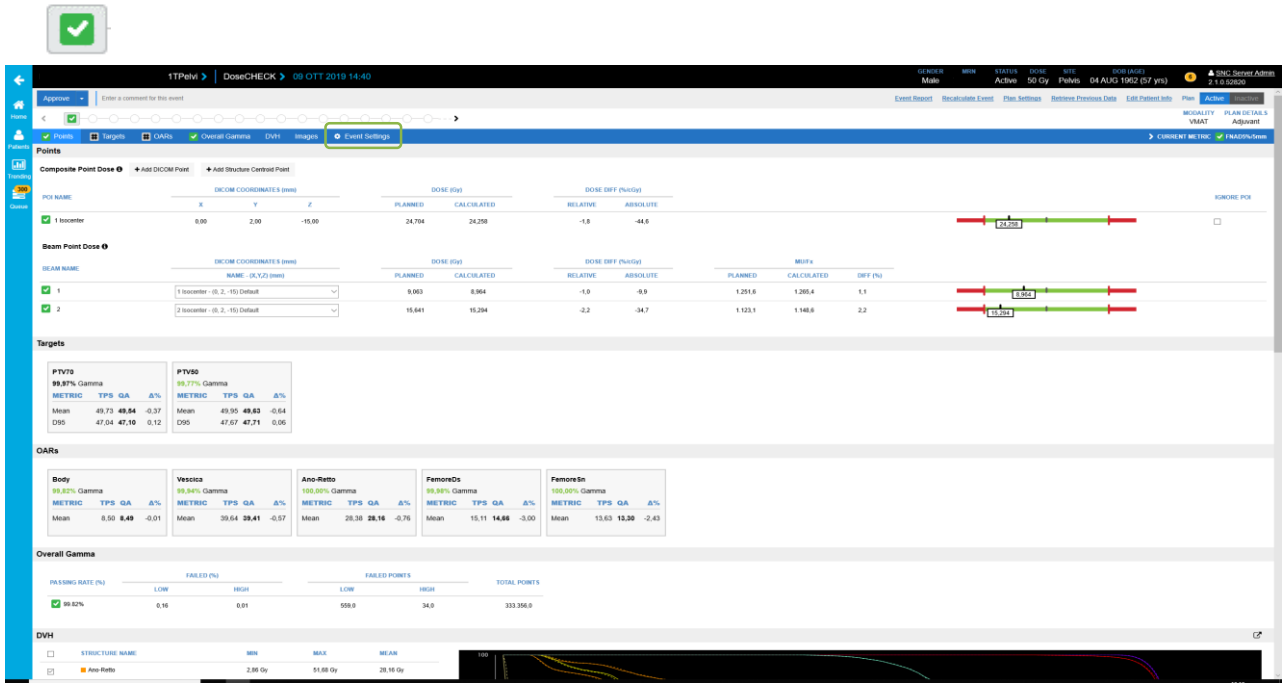
***Calculation Source…***



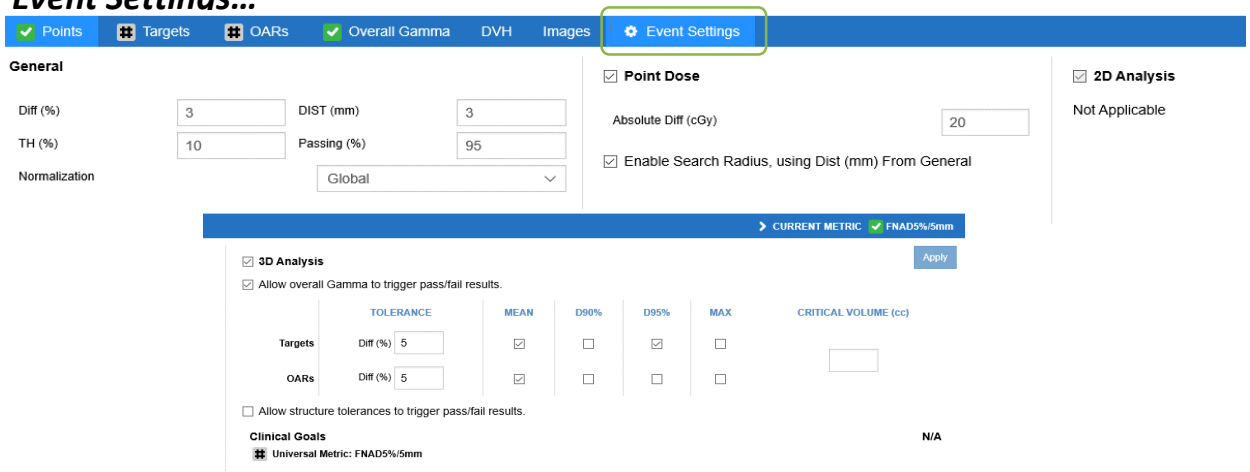

*Any of these two ones is possible. The difference is in the time the system will be "expecting" the information.*

# Dose Check: Patients QA



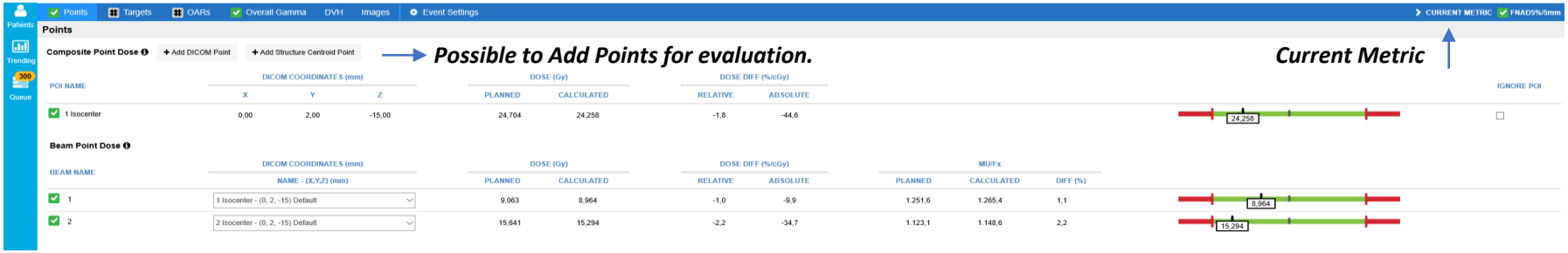




## Event Settings...



# 3D Analysis

***3D Analysis…***




*Composite Dose Point:*
*Beam Dose Point:*

**Targets**

**PTV70**
**99,97%** Gamma

| METRIC | TPS | QA | Δ% |
|---|---|---|---|
| Mean | 49,73 | **49,54** | -0,37 |
| D95 | 47,04 | **47,10** | 0,12 |

**PTV50**
99,77% Gamma

| METRIC | TPS | QA | Δ% |
|---|---|---|---|
| Mean | 49,95 | **49,63** | -0,64 |
| D95 | 47,67 | **47,71** | 0,06 |

***Targets & OARs***
- ✓ *Gamma Analysis (%);*
- ✓ *Metric: Mean, D90, D95, Dmax;*
- ✓ *TPS Dose Value;*
- ✓ *QA Dose Value;*
- ✓ *Δ%.*

**OARs**

**Body**
99,82% Gamma

| METRIC | TPS | QA | Δ% |
|---|---|---|---|
| Mean | 8,50 | **8,49** | -0,01 |

**Vescica**
99,94% Gamma

| METRIC | TPS | QA | Δ% |
|---|---|---|---|
| Mean | 39,64 | **39,41** | -0,57 |

**Ano-Retto**
100,00% Gamma

| METRIC | TPS | QA | Δ% |
|---|---|---|---|
| Mean | 28,38 | **28,16** | -0,76 |

**FemoreDs**
99,98% Gamma

| METRIC | TPS | QA | Δ% |
|---|---|---|---|
| Mean | 15,11 | **14,66** | -3,00 |

**FemoreSn**
100,00% Gamma

| METRIC | TPS | QA | Δ% |
|---|---|---|---|
| Mean | 13,63 | **13,30** | -2,43 |

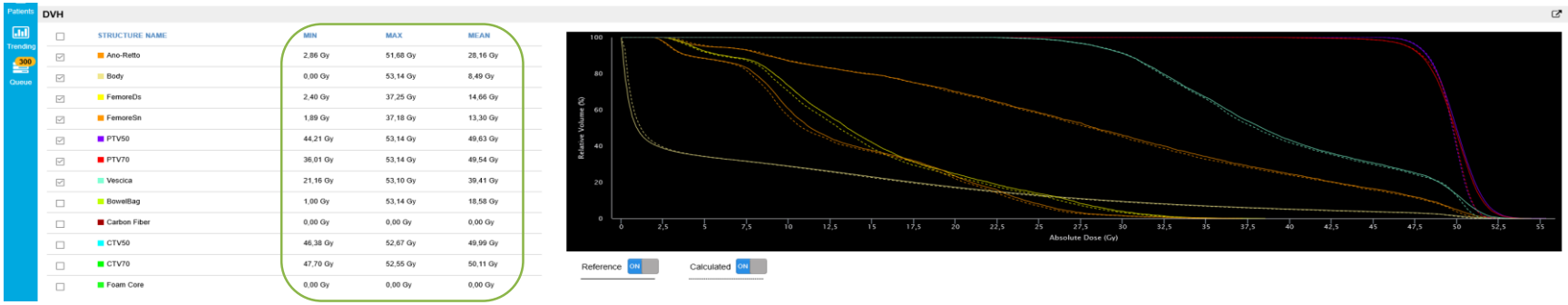
**Overall Gamma**

| PASSING RATE (%) | FAILED (%) | | FAILED POINTS | | TOTAL POINTS |
|---|---|---|---|---|---|
| | LOW | HIGH | LOW | HIGH | |
| ☑ 99.82% | 0,16 | 0,01 | 559,0 | 34,0 | 333.356,0 |

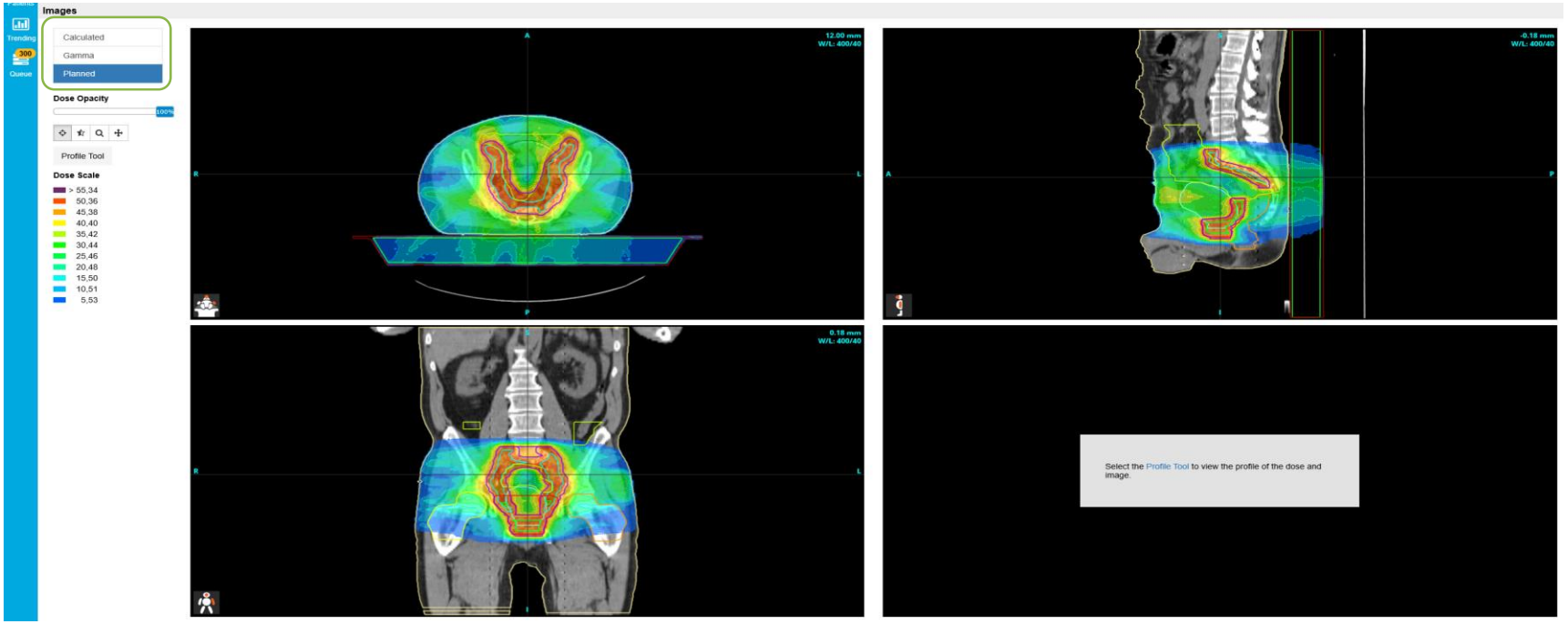
***Overall Gamma***
- ✓ *Passing Rate (%);*
- ✓ *Total Points;*
- ✓ *Failed Points.*

# DVH estimation and comparison

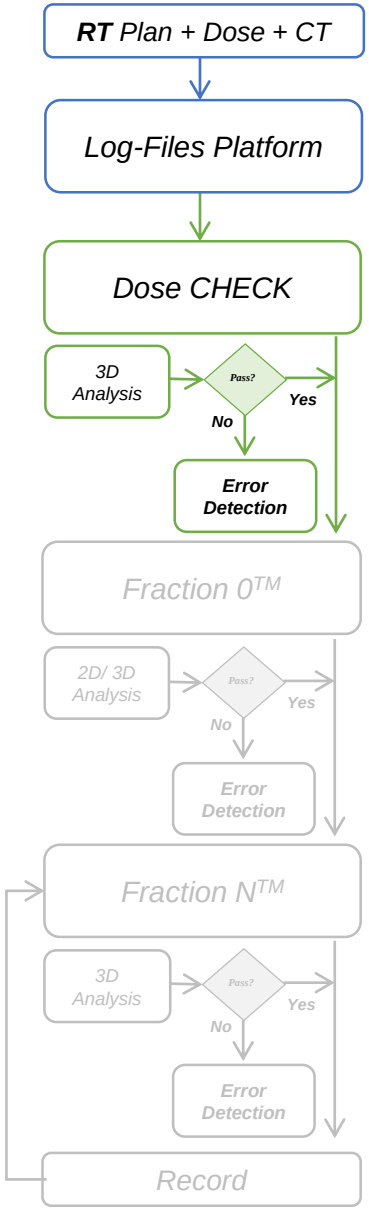
***DVH**: Min, Max, Mean of each Structure. Reference & Calculated Dose.*




***Images**: Calculated, Planned & Gamma Comparison*

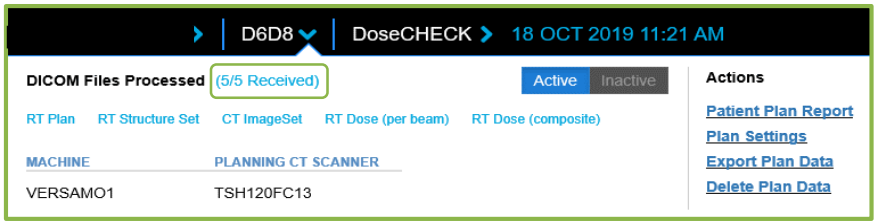


# Error Detections - Case




Error Detection

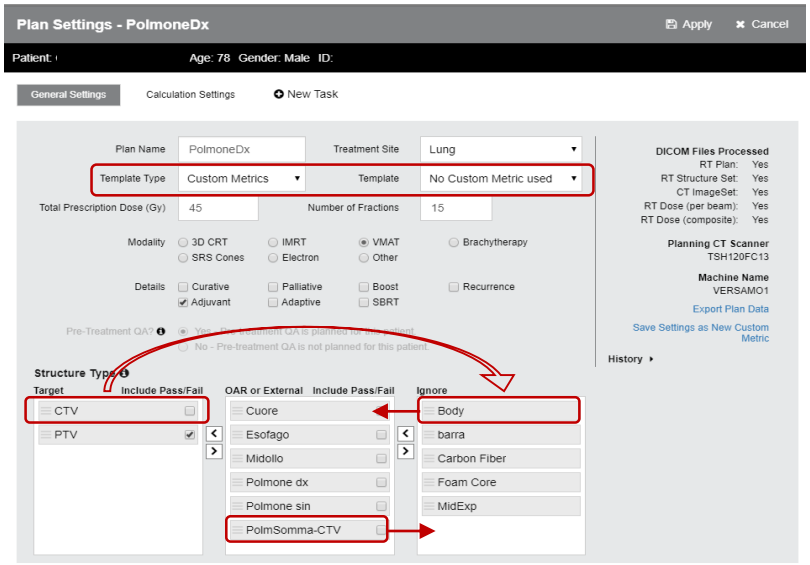
***Verify all Data arrived correctly from TPS:***




*If Less/5 it's possible to export missing data.*

***Verify Plan Settings:***

- X *No Template Type;*
- X *CTV in wrong position;*
- X *Body in wrong position;*
- X *Dummys in wrong position.*




***Evaluate Beam Model:***

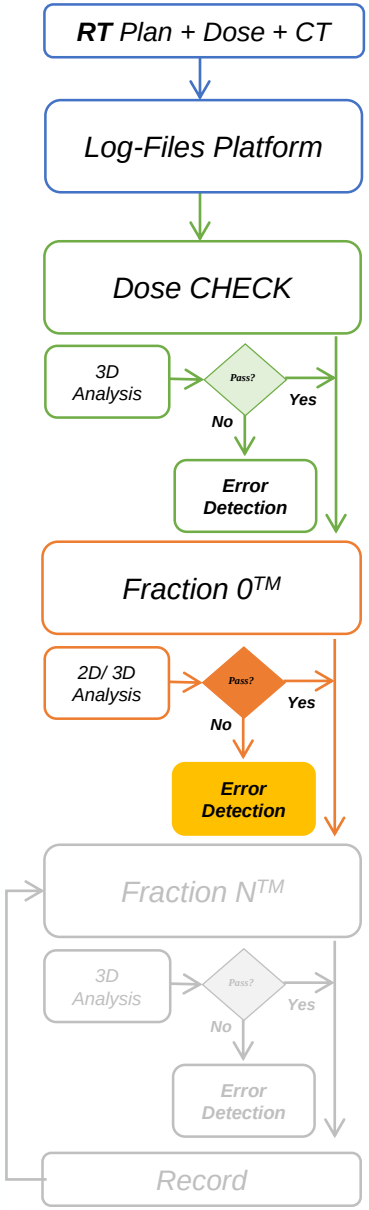
*VersaMO#1: Beam model performed with plans sent to Log-Files Platformfrom Monaco TPS*
*VersaMO#2: Beam model performed with plans sent to Log-Files Platformfrom Raystation TPS*

*Patients planned in Monaco → VersaMO#1* ✓ *Versamo#2* !

*Patients planned in Raystation → VersaMO#1* ! *Versamo#2* ✓

***This issue it's being solved with an integrated model for both TPS.***

# Fraction 0: Pre-Treatment Patient QA

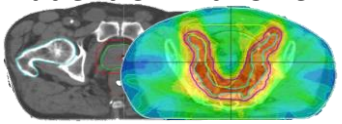


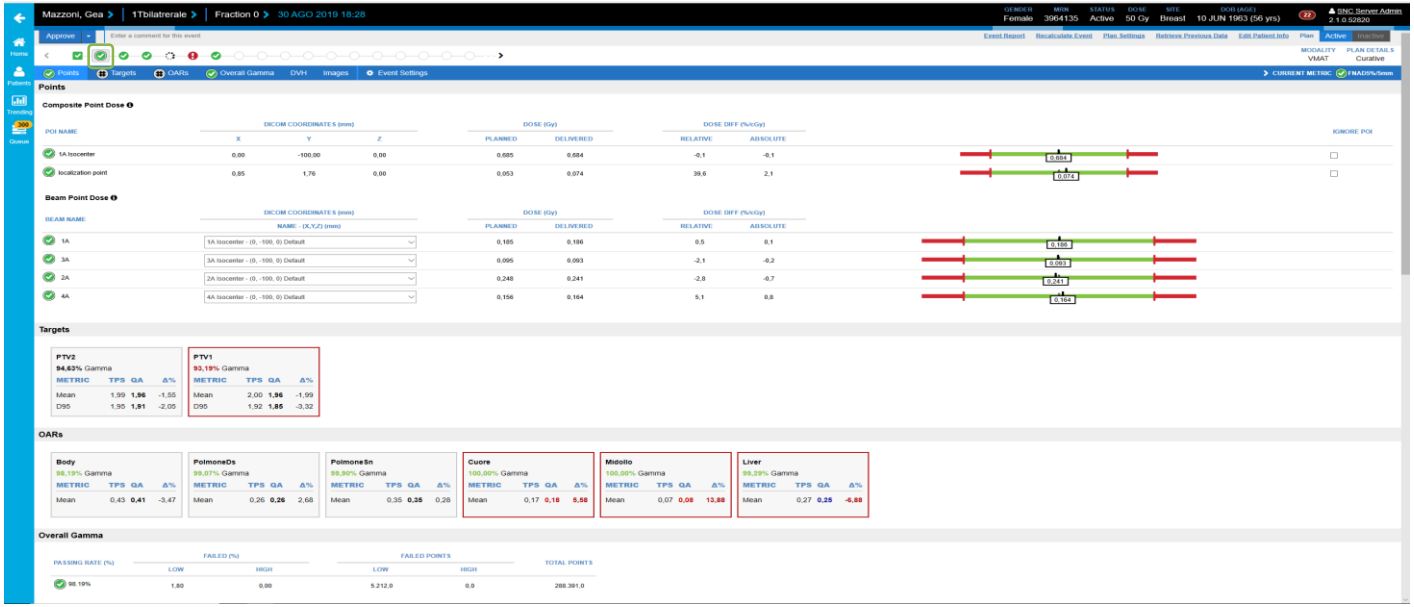

***Pre-Treatment QA…***

*QA Plan in Matrix*

*Log File*

*Calculation using Logfiles in Patient CT with SNC Algorithm*





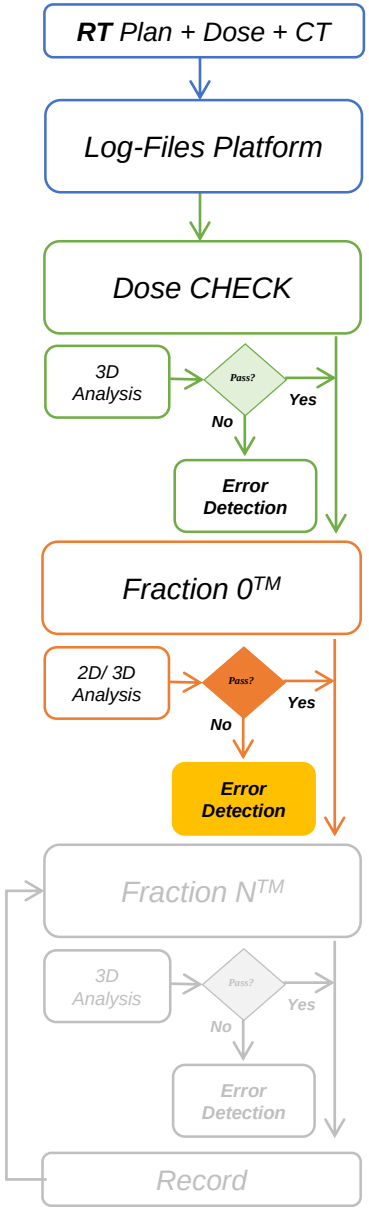
***3D Analysis…***

- ✓ ***Composite Dose Point***
- ✓ ***Beam Dose Point***
- ***Overall Gamma***
- ✓ *Passing Rate (%);*
- ✓ *Total Points;*
- ✓ *Failed Points.*

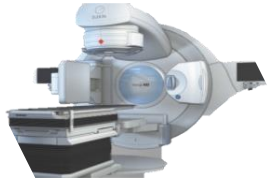
***Targets & OARs***

- ✓ *Gamma Analysis (%);*
- ✓ *Metric: Mean, D90, D95, $D_{max}$;*
- ✓ *TPS Dose Value;*
- ✓ *QA Dose Value;*
- ✓ *Δ%.*

# Fraction 0: Pre-Treatment QA




***Pre-Treatment QA…***

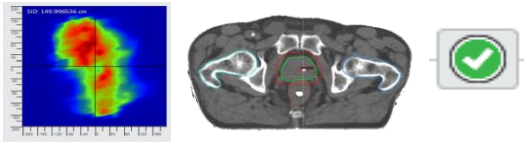


*QA Plan in EPID*

*Log File +*

*EPID Images*

*Calculation using Logfiles & EPID Images in Patient CT with SNC Algorithm*

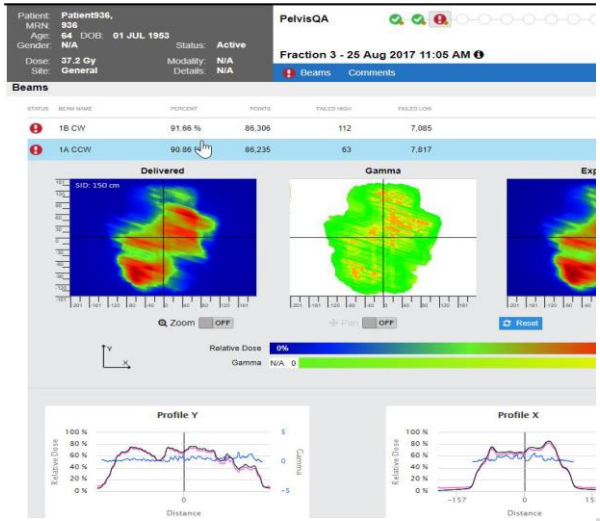


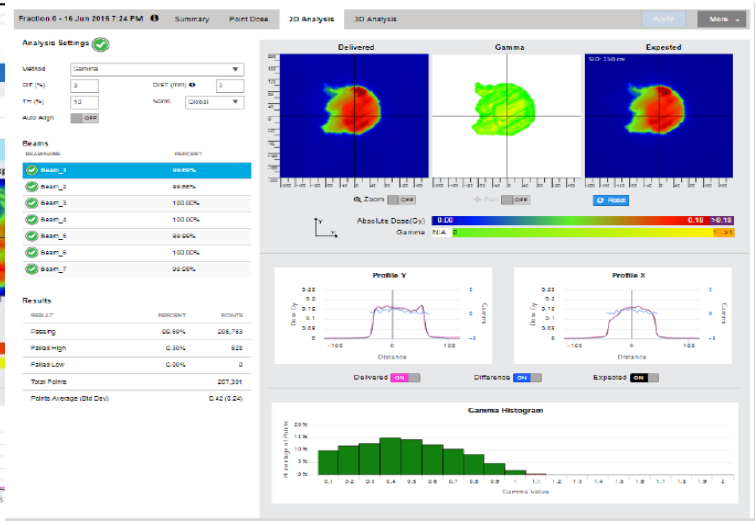
***2D / 3D Analysis…***

- ✓ ***Composite Dose Point***
- ✓ ***Beam Dose Point***
- ***Overall Gamma***
- ✓ *Passing Rate (%);*
- ✓ *Total Points;*
- ✓ *Failed Points.*

***Targets & OARs***

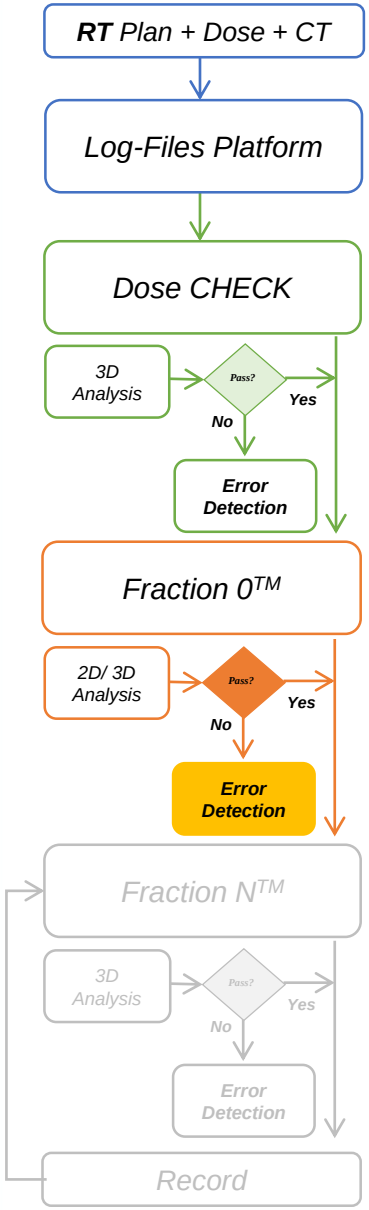
- ✓ *Gamma Analysis (%);*
- ✓ *Metric: Mean, D90, D95, $D_{max}$;*
- ✓ *TPS Dose Value;*
- ✓ *QA Dose Value;*
- ✓ *Δ%.*



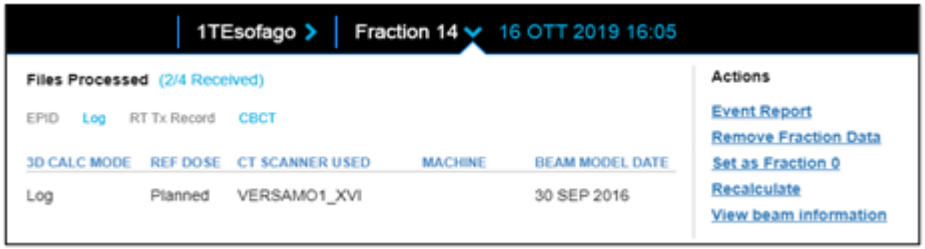

***Measurements with EPID can ONLY be used to verify MLC movements.***
***NO Absolute Dose can be evaluated with EPID measurements since calibration is missed!***

# Error Detection: Fraction 0



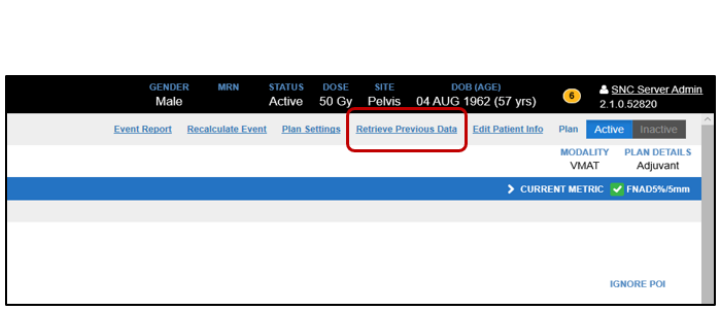


***Verify all Data arrived correctly from the Machine:***

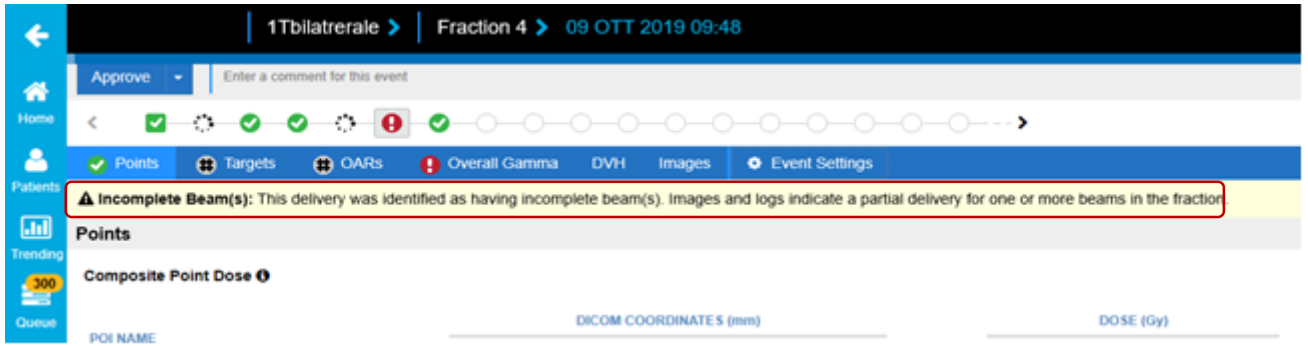



✓ *LogFile,*

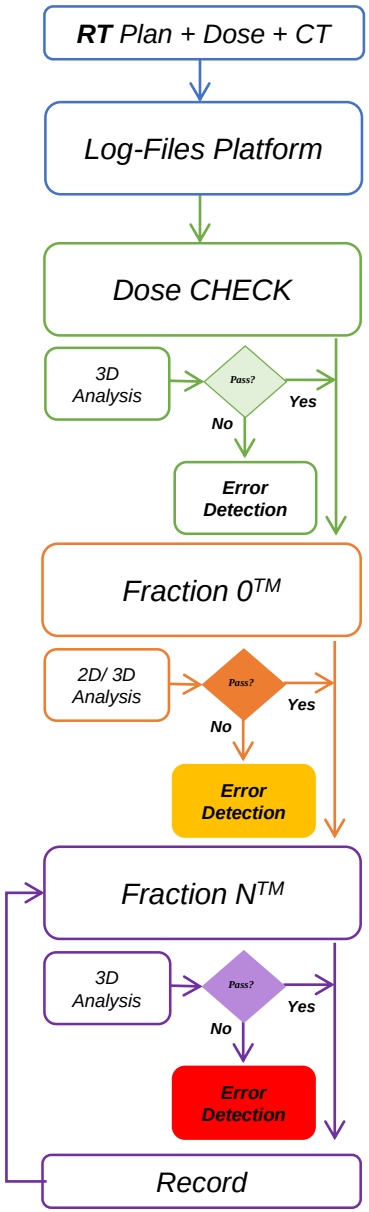
*If not, a Retrieve of the LogFiles can be performed.*




***Verify Fraction Data arrived correctly:***



# Error Detection: Fraction 1,2,3…..n




**Fractions: 1, 2, 3,…,N** → **Fractions in Calculation**

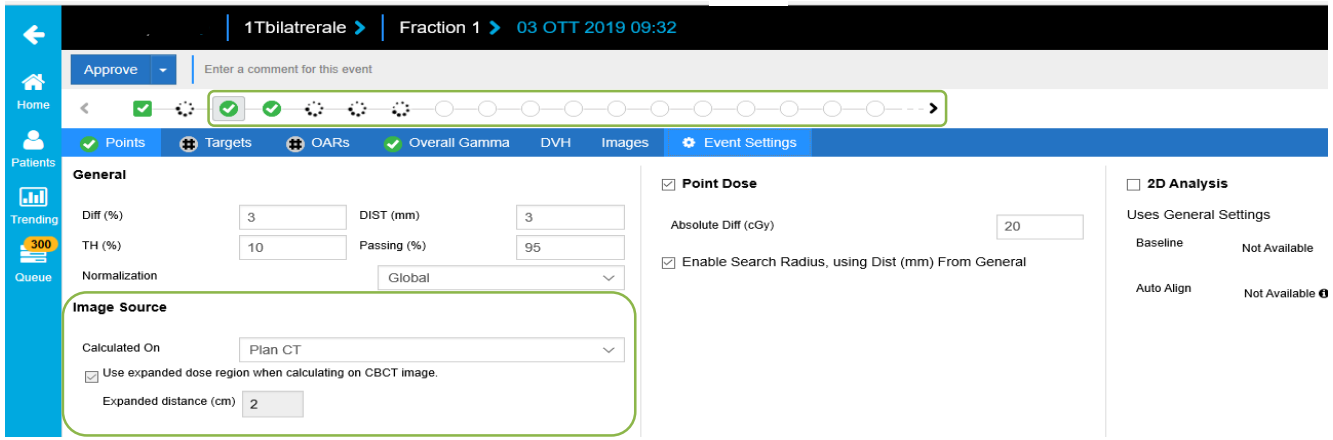
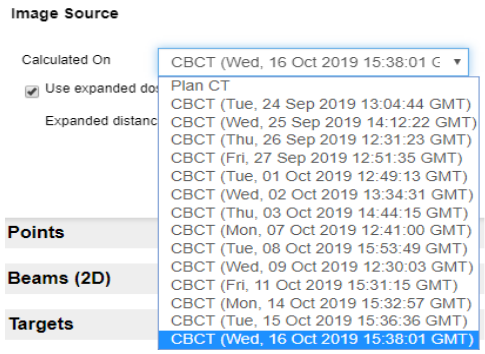



***Image Source…***




*The image source for the calculation can be selected between Plan CT or CBCT from any day.*

*<u>Be Careful:</u> If CBCT is pre-imposed, Log-Files platform will take the last CBCT performed on the patient, independent of the data!*

***3D Analysis…***

***Results compared with Plan CT or with CBCT***

- ✓ ***Composite Dose Point***
- ✓ ***Beam Dose Point***

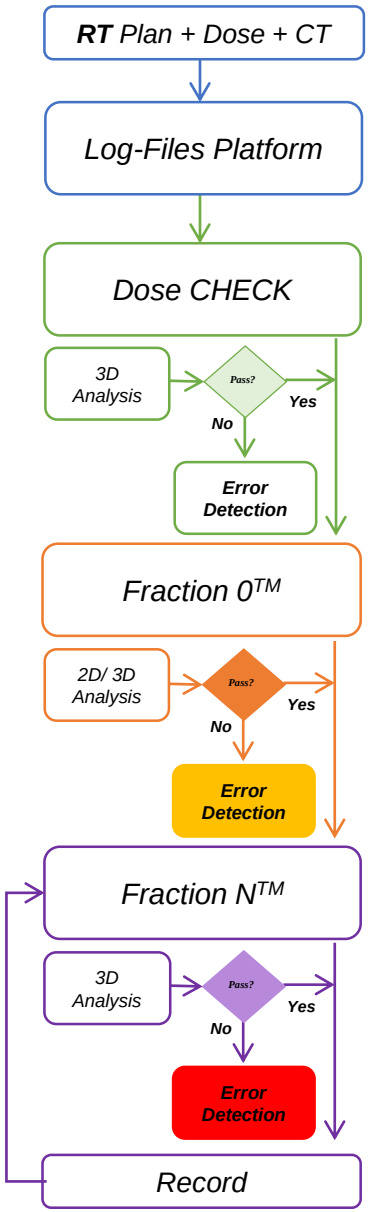
***Overall Gamma***

- ✓ *Passing Rate (%);*
- ✓ *Total Points;*
- ✓ *Failed Points.*

***Targets & OARs***

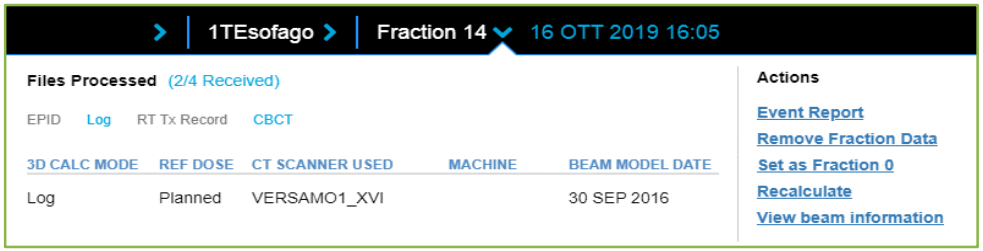
- ✓ *Gamma Analysis (%);*
- ✓ *Metric: Mean, D90, D95, $D_{max}$;*
- ✓ *TPS Dose Value;*
- ✓ *QA Dose Value;*
- ✓ *Δ%.*

# Combination of information.
# Issues for multiple Treatment Planning Systems




Error Detection

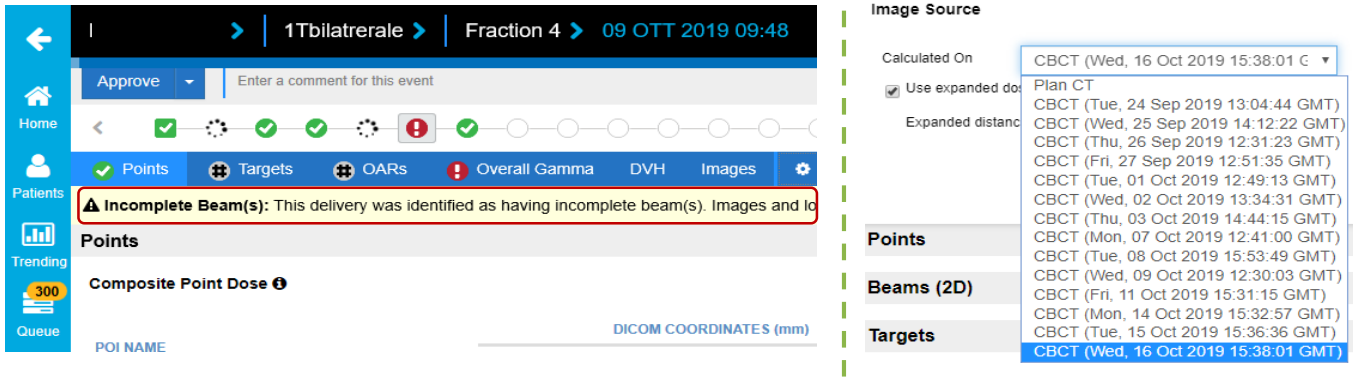
***Verify all Data arrived correctly from the Machine:***




- ✓ *LogFile,*
- ✓ *CBCT + shift*
- ✓ *DIBH Interruptions*

*If some data do not arrive, a Retrieve Data can be performed.*

***Verify Fraction Data arrived correctly:***




***Evaluate Beam Model:***

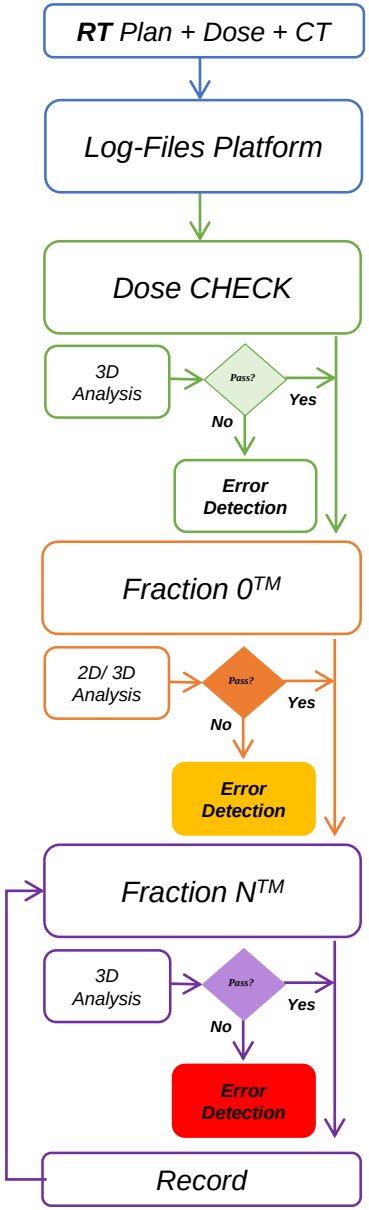
*VersaMO#1: Beam model performed with plans sent to Log-Files Platform from Monaco TPS*
*VersaMO#2: Beam model performed with plans sent to Log-Files Platform from Raystation TPS*

*Patients planned in Monaco → VersaMO#1* ✓ *Versamo#2* !

*Patients planned in Raystation → VersaMO#1* ! *Versamo#2* ✓

***This issue it's being solved by SNC with an integrated model for both TPS.***

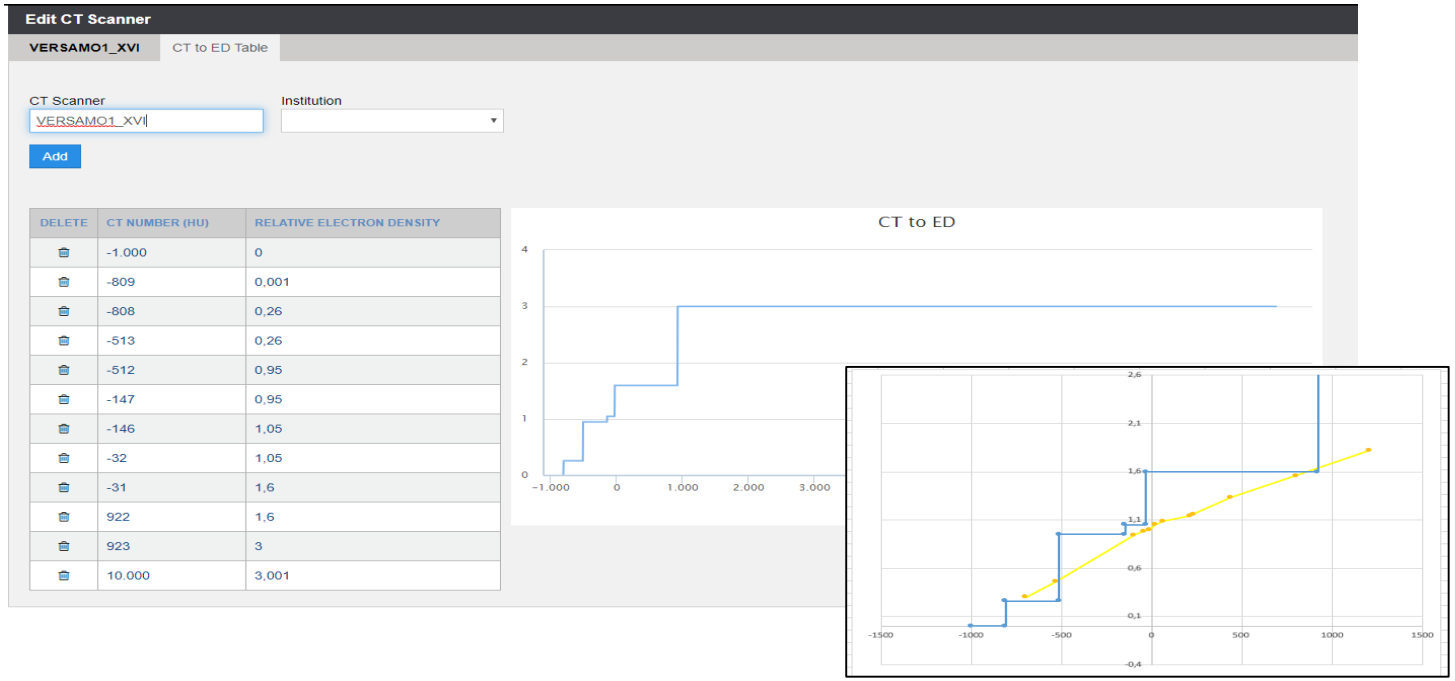
# CBTC Calculation and Issues




**Error Detection**

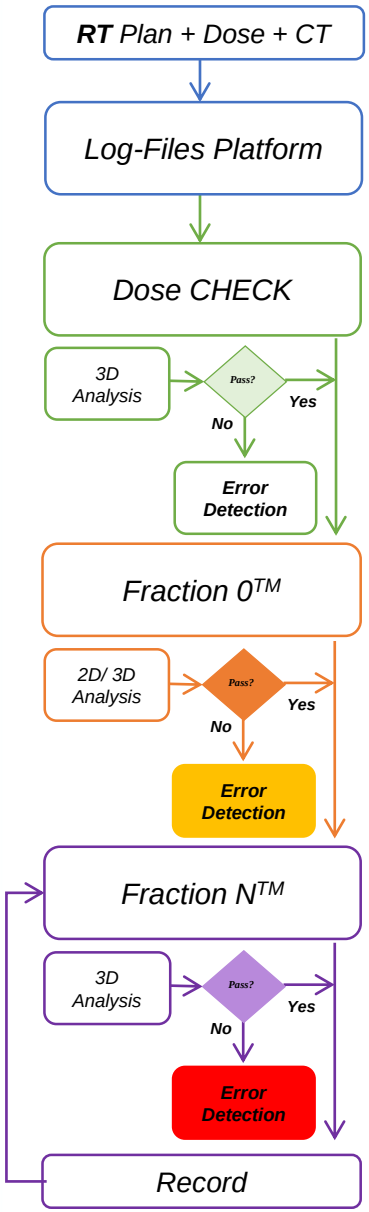
***In CBCT:***

*Daily, CBCT's are being performed to patients with different acquisition protocols.*
*CBCT should be calibrated in Hounsfield Units for each one of the clinical protocols.*
*But… Platfomr allows only one Calibration Curve for the CBCT: the calibration curve implemented nowadays is one measured with the Gammex phantom with protocol: Fast Prostate Seed S10: S10 (120KV; 16mA; 16ms).*




*LIMITATION: due to the multiple protocols of acquisition the image quality and ED Table could be different, but the systems could record only one ED Table?*
*A mean ED table could not be a solutions, might you have to find the appropriate tolerance or thresholds*

# Investigate the issues and find a workaround acceptable for the center



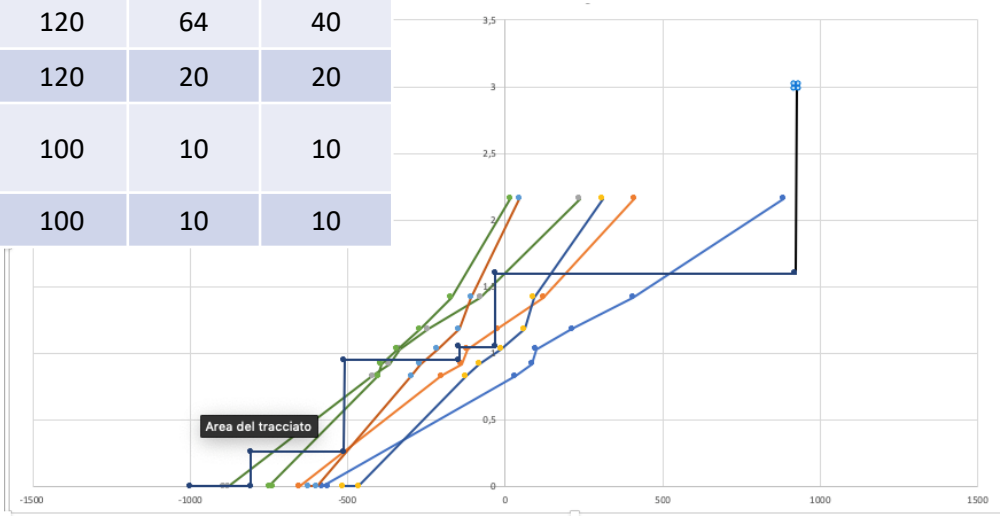

***In order to overcome this limitation…***

*A universal curve that contemplate all protocols is under study*

*CT of **Catphan Phantom** was acquired (Water bags were positioned around the phantom to evaluate not only the change of the CBCT calibration curve according to the protocol, but also if there is scatter influence on CBCT calibration curves).*

***No.5 CBCT with different Protocols were measured in order to obtain No.5 calibration curves:***

| | Filter | KV | mA | ms |
|---|---|---|---|---|
| Pelvis M20 | F1 | 120 | 40 | 40 |
| Slow Prostate M20 | F1 | 120 | 64 | 40 |
| Half CBCT Dx S20 | F1 | 120 | 20 | 20 |
| Fast Head & Neck S20 | F0 | 100 | 10 | 10 |
| Head & Neck S10 | F0 | 100 | 10 | 10 |




*To continue… a PTV will be contoured in the catphan phantom and a treatment plan will be performed in order to obtain the correspond DVH. The same treatment plan will be calculated in each one of the CBCT's and DVH will be analysed.*

# Ideally a Workflow

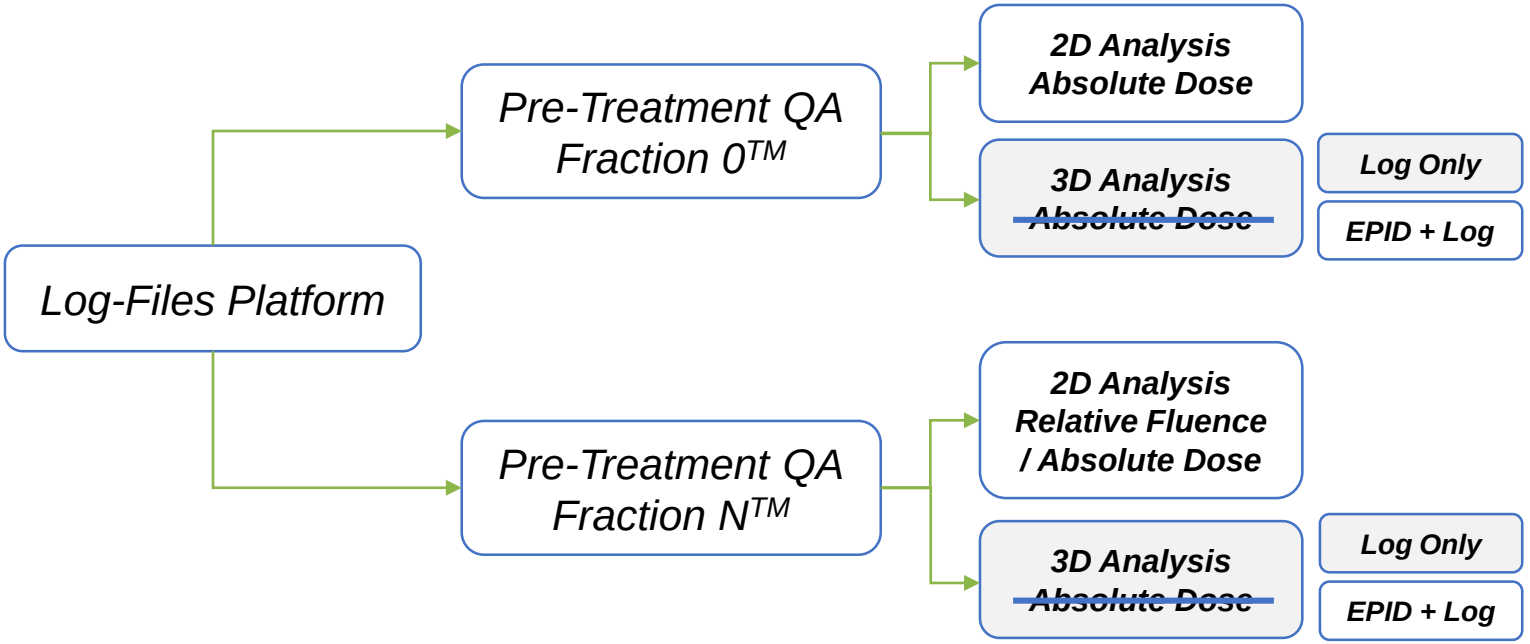
***Types of Analysis***

***Pre-Treatment QA: Fraction 0$^{TM}$***

- ✓ *Used for 3DCRT, IMRT, VMAT, SRS/SBRT;*
- ✓ *2D/3D analysis QA with EPID &/or LogFile*

***In-Vivo Monitoring: Fraction N$^{TM}$***

- ✓ *2D/3D analysis Quality Assurance with EPID &/or LogFile;*
- ✓ *Transmission measured during treatment delivery*
- ✓ *Dose reconstruction based on patient positioning/anatomy;*
- ✓ *MLC movements & delivered MU during patient treatment.*

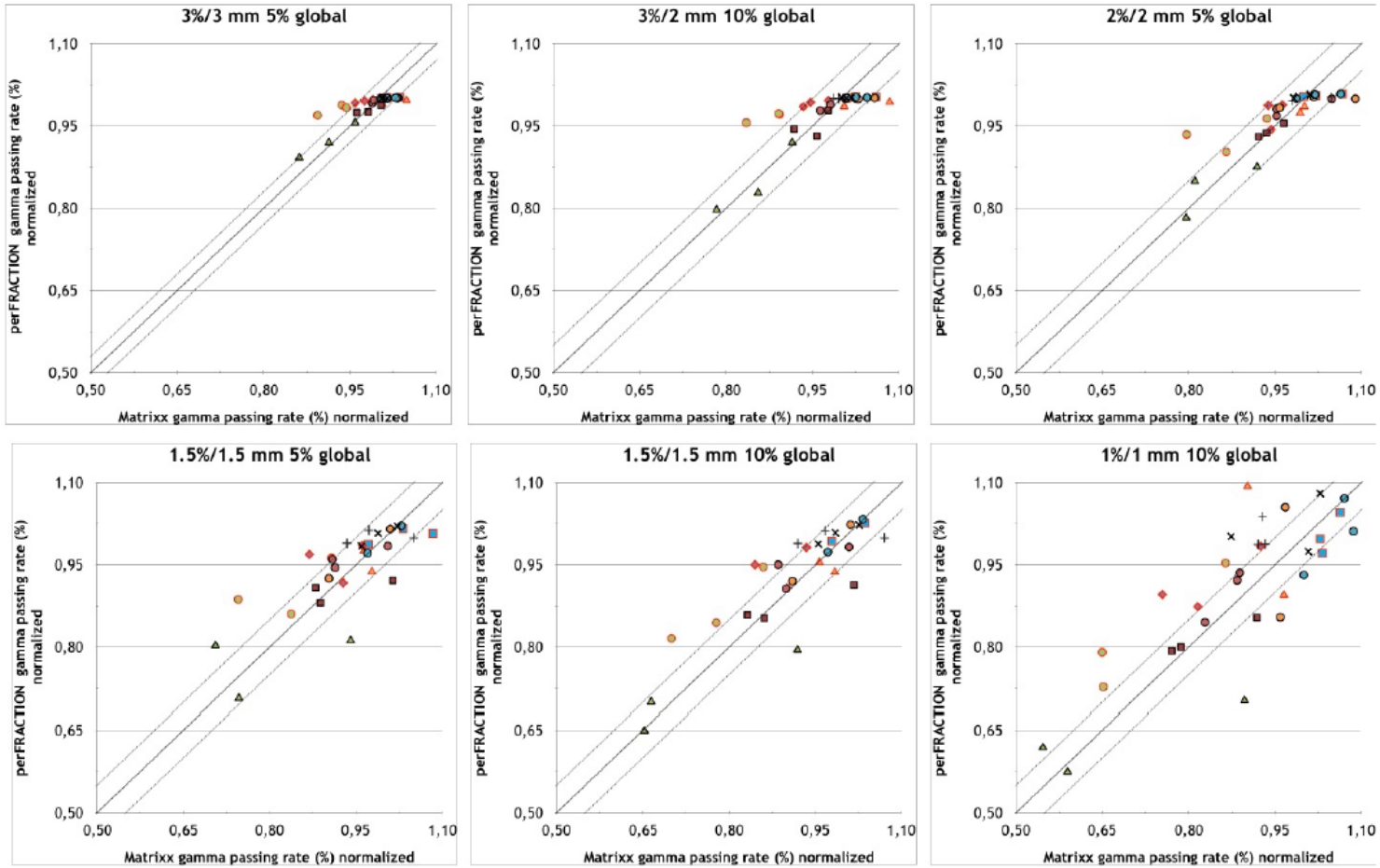


# Dose Matrixx vs. Log-Files accuracy

## Enhancing patient safety with log file analysis : perFRACTION® optimal gamma criteria for VMAT QA

F. Itta[1], GM. Mistretta[1], P. Ceroni [1], V. Gutierrez [1], F. Campanaro [1], L. Morini [1], F. Marino [1], S. Koubegnery [2], E. D'Angelo [3], G. Guidi [1]

(1) University Hospital of Modena, Medical Physics Unit, Modena, Italy; (2) International Centre for Theoretical Physics & University of Trieste, Master in Medical Physics Student, Trieste, Italy; (3) University Hospital of Modena, Radiotherapy Unit–Oncology and Hematology department, Modena, Italy



# Patients QA: Daily monitoring

Fractions to be checked

Approved

Acquire Device Measurement | Event Report | Recalculate Event

Points | Beams (2D) | Targets | OARs | Overall Gamma | DVH | Images | Event Settings

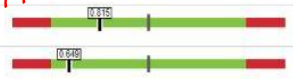
⚠ Incomplete Beam(s): This delivery was identified as having incomplete beam(s). Images and logs indicate a partial delivery for one or more beams in the fraction.

## Points

Composite Point Dose

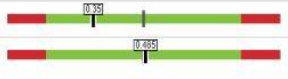
| POI NAME | DICOM COORDINATES (mm) X | Y | Z | DOSE (Gy) PLANNED | DELIVERED | DOSE DIFF (%/cGy) RELATIVE | ABSOLUTE |
|---|---|---|---|---|---|---|---|
| 3 Isocenter | -1,00 | 1,00 | 20,00 | 0,915 | 0,815 | -10,9 | -10,0 |
| Localization | -1,00 | 1,00 | 0,00 | 0,812 | 0,649 | -20,0 | -16,3 |

Dose in a point is partially corrected, but requires attentions




Beam Point Dose

| BEAM NAME | DICOM COORDINATES (mm) NAME - (X,Y,Z) (mm) | DOSE (Gy) PLANNED | DELIVERED | DOSE DIFF (%/cGy) RELATIVE | ABSOLUTE |
|---|---|---|---|---|---|
| 3 ⚠ | 3 Isocenter - (-1,00, 1,00, 20,00) Default | 0,453 | 0,350 | -22,7 | -10,3 |
| 4 | 4 Isocenter - (-1,00, 1,00, 20,00) Default | 0,461 | 0,465 | 0,8 | 0,4 |




## Beams (2D)

## Targets

PTV New
5,97 % Gamma

| METRIC | TPS | QA | Δ% |
|---|---|---|---|
| Mean | 1,79 | 1,51 | -15,69 |
| D95 | 1,75 | 1,30 | -25,92 |

Gamma Rate in Volume is uncorrected

## OARs

Sigma
15,53 % Gamma

| METRIC | TPS | QA | Δ% |
|---|---|---|---|
| Mean | 1,44 | 1,23 | -14,64 |

Intestino
60,04 % Gamma

| METRIC | TPS | QA | Δ% |
|---|---|---|---|
| Mean | 0,79 | 0,71 | -10,28 |

External
47,51 % Gamma

| METRIC | TPS | QA | Δ% |
|---|---|---|---|
| Mean | 0,36 | 0,30 | -15,61 |

Vescica
8,26 % Gamma

| METRIC | TPS | QA | Δ% |
|---|---|---|---|
| Mean | 1,05 | 0,83 | -20,85 |

retto
60,21 % Gamma

| METRIC | TPS | QA | Δ% |
|---|---|---|---|
| Mean | 1,20 | 1,06 | -11,60 |

Testa femore dx
30,10 % Gamma

| METRIC | TPS | QA | Δ% |
|---|---|---|---|
| Mean | 0,35 | 0,29 | -19,22 |

testa femore sx
16,53 % Gamma

| METRIC | TPS | QA | Δ% |
|---|---|---|---|
| Mean | 0,35 | 0,27 | -22,81 |

## Overall Gamma

| PASSING RATE (%) | FAILED (%) LOW | HIGH | FAILED POINTS LOW | HIGH | TOTAL POINTS |
|---|---|---|---|---|---|
| ! 47,51% | 52,49 | 0,00 | 222.748 | 1 | 424.347 |

# Patients QA: might something needs a verification

Fractions to be checked

Approve | Acquire Device Measurement | Event Report | Recalculate Event

Points | Beams (2D) | Targets | OARs | Overall Gamma | DVH | Images | Event Settings

## Points

Composite Point Dose

| POI NAME | DICOM COORDINATES (mm) X | Y | Z | DOSE (Gy) PLANNED | DELIVERED | DOSE DIFF (%/cGy) RELATIVE | ABSOLUTE |
|---|---|---|---|---|---|---|---|
| 1 Isocenter | 80,00 | -80,00 | 10,00 | 1,359 | 1,368 | 0,6 | 0,9 |
| DSP | 100,83 | -115,18 | 15,00 | 2,016 | 2,045 | 1,4 | 2,9 |
| localization | 1,00 | -1,00 | 0,00 | 0,082 | 0,097 | 18,2 | 1,5 |

Dose in a point is corrected

Beam Point Dose

| BEAM NAME | DICOM COORDINATES (mm) NAME - (X,Y,Z) (mm) | DOSE (Gy) PLANNED | DELIVERED | DOSE DIFF (%/cGy) RELATIVE | ABSOLUTE |
|---|---|---|---|---|---|
| 1 | 1 Isocenter - (80,00, -80,00, 10,00) Default | 0,694 | 0,701 | 1,0 | 0,7 |
| 2 | 2 Isocenter - (80,00, -80,00, 10,00) Default | 0,665 | 0,667 | 0,3 | 0,2 |

## Beams (2D)

## Targets

PTV
96,90 % Gamma

| METRIC | TPS | QA | Δ% |
|---|---|---|---|
| Mean | 2,00 | 1,98 | -0,99 |
| D95 | 1,93 | 1,88 | -2,89 |

Gamma Rate in Volume is uncorrected

## OARs

External
99,21 % Gamma

| METRIC | TPS | QA | Δ% |
|---|---|---|---|
| Mean | 0,21 | 0,21 | 1,42 |

Polmone sn
99,94 % Gamma

| METRIC | TPS | QA | Δ% |
|---|---|---|---|
| Mean | 0,30 | 0,32 | 5,24 |

Cuore
99,83 % Gamma

| METRIC | TPS | QA | Δ% |
|---|---|---|---|
| Mean | 0,16 | 0,17 | 6,21 |

Mammella controlaterale
100,00 % Gamma

| METRIC | TPS | QA | Δ% |
|---|---|---|---|
| Mean | 0,12 | 0,12 | 2,45 |

Midollo
100,00 % Gamma

| METRIC | TPS | QA | Δ% |
|---|---|---|---|
| Mean | 0,07 | 0,08 | 12,82 |

Testa omero sn

| METRIC | TPS | QA | Δ% |
|---|---|---|---|
| Mean | 0,01 | 0,01 | 0,00 |

Polmone dx
100,00 % Gamma

| METRIC | TPS | QA | Δ% |
|---|---|---|---|
| Mean | 0,12 | 0,13 | 9,59 |

Protesi
1,37 % Gamma

| METRIC | TPS | QA | Δ% |
|---|---|---|---|
| Mean | 2,00 | 1,81 | -9,63 |

## Overall Gamma

| PASSING RATE (%) | FAILED (%) LOW | HIGH | FAILED POINTS LOW | HIGH | TOTAL POINTS |
|---|---|---|---|---|---|
| 99,21% | 0,73 | 0,05 | 980 | 72 | 133.953 |

# Patients QA: something goes wrong

Approve | Enter a comment for this event | Acquire Device Measurement | Event Report | Recalculate Event

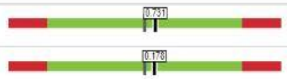
Points | Beams (2D) | Targets | OARs | Overall Gamma | DVH | Images | Event Settings

## Points

Composite Point Dose

| POI NAME | DICOM COORDINATES (mm) X | Y | Z | DOSE (Gy) PLANNED | DELIVERED | DOSE DIFF (%/cGy) RELATIVE | ABSOLUTE |
|---|---|---|---|---|---|---|---|
| 1 Isocenter | -86,00 | -82,00 | 15,00 | 0,709 | 0,731 | 3,1 | 2,2 |
| localization | -1,00 | 3,00 | 0,00 | 0,158 | 0,178 | 12,6 | 2,0 |

Dose in a point is corrected




Beam Point Dose

| BEAM NAME | DICOM COORDINATES (mm) NAME - (X,Y,Z) (mm) | DOSE (Gy) PLANNED | DELIVERED | DOSE DIFF (%/cGy) RELATIVE | ABSOLUTE |
|---|---|---|---|---|---|
| 1 | 1 Isocenter - (-86,00, -82,00, 15,00) Default | 0,279 | 0,291 | 4,3 | 1,2 |
| 2 | 2 Isocenter - (-86,00, -82,00, 15,00) Default | 0,430 | 0,439 | 2,0 | 0,9 |


## Beams (2D)

## Targets

**PTV 40.05** — 99,83 % Gamma

| METRIC | TPS | QA | Δ% |
|---|---|---|---|
| Mean | 2,72 | 2,72 | 0,00 |
| D95 | 2,61 | 2,60 | -0,19 |

**PTV 48** — 99,97 % Gamma

| METRIC | TPS | QA | Δ% |
|---|---|---|---|
| Mean | 3,19 | 3,20 | 0,18 |
| D95 | 3,10 | 3,11 | 0,25 |

Gamma Rate is uncorrected

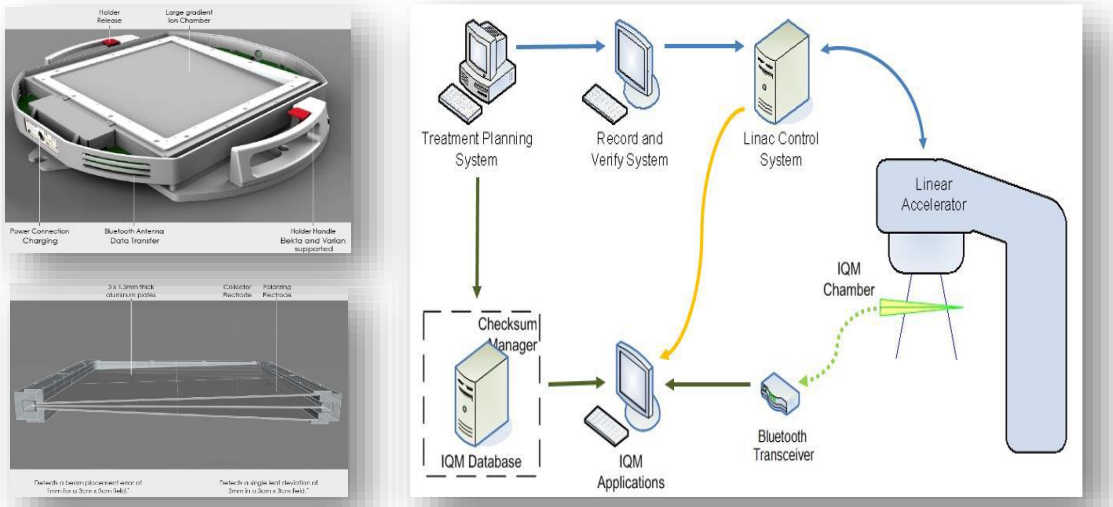
## OARs

| External | Lung (Left) | Lung (Right) | SpinalCord (Thorax) | Mammella Dx | cuore | fegato | omero dx | Mammella controlaterale |
|---|---|---|---|---|---|---|---|---|
| 99,78 % Gamma | 100,00 % Gamma | 100,00 % Gamma | 100,00 % Gamma | 76,51 % Gamma | 100,00 % Gamma | 100,00 % Gamma | 100,00 % Gamma | 100,00 % Gamma |
| METRIC TPS QA Δ% | METRIC TPS QA Δ% | METRIC TPS QA Δ% | METRIC TPS QA Δ% | METRIC TPS QA Δ% | METRIC TPS QA Δ% | METRIC TPS QA Δ% | METRIC TPS QA Δ% | METRIC TPS QA Δ% |
| Mean 0,31 0,32 2,52 | Mean 0,13 0,15 15,03 | Mean 0,46 0,48 3,62 | Mean 0,15 0,17 8,28 | Mean 1,88 2,23 18,88 | Mean 0,21 0,23 10,74 | Mean 0,10 0,12 12,96 | Mean 0,13 0,12 -7,51 | Mean 0,19 0,21 8,76 |

## Overall Gamma

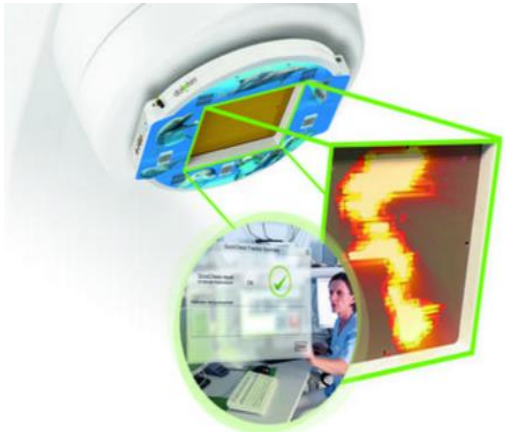
| PASSING RATE (%) | FAILED (%) LOW | HIGH | FAILED POINTS LOW | HIGH | TOTAL POINTS |
|---|---|---|---|---|---|
| 93,22% | 0,03 | 6,75 | 70 | 16.742 | 248.036 |

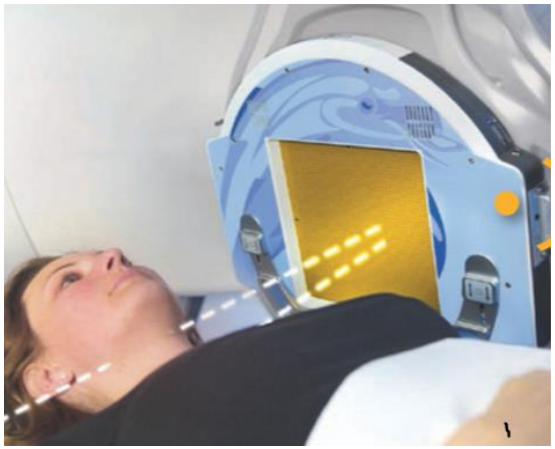
# ALTERNATIVE - INDEPENDENT REAL-TIME BEAM MONITOR SYSTEM



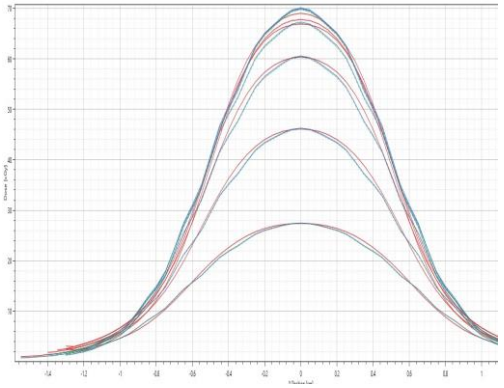

*Courtesy of Andrew Jongho Jung Princess Margaret Cancer Centre (Toronto)*

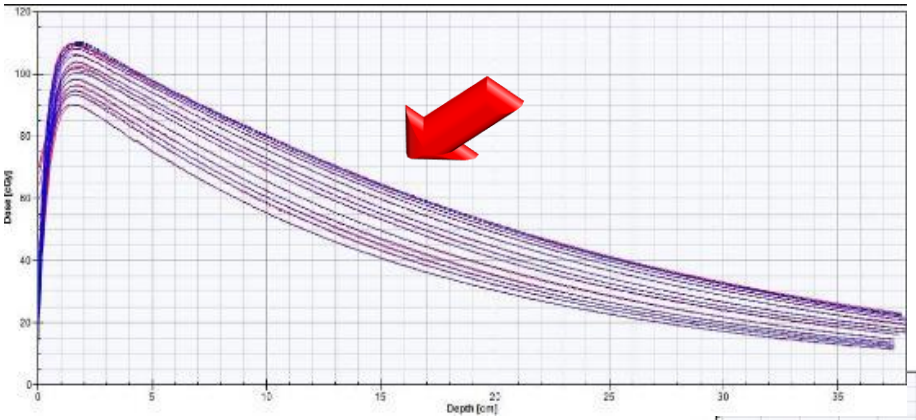
- Possible QA of the LINAC
- Pre-Treatment QA activities
- Error prevention instead of error management
- Intra-fractional verification system
- Real-Time user interaction
- Automated monitoring of every single treatment fraction
- Patient delivery and safety improved in real-time
- In-Vivo evaluation



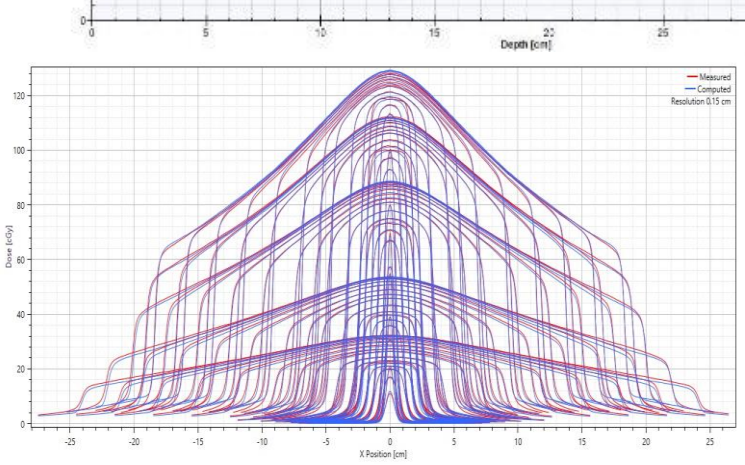


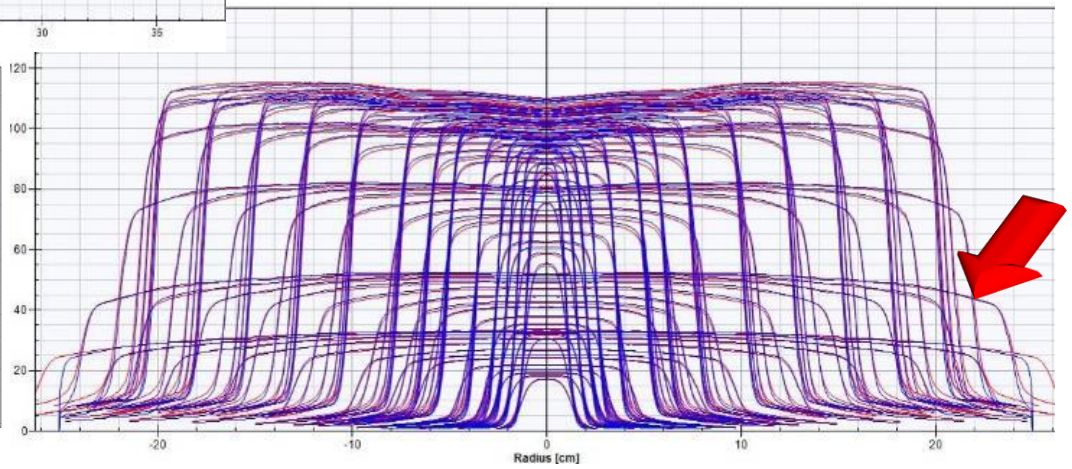
# Gold Model and Beam Matching – No.4 LINAC



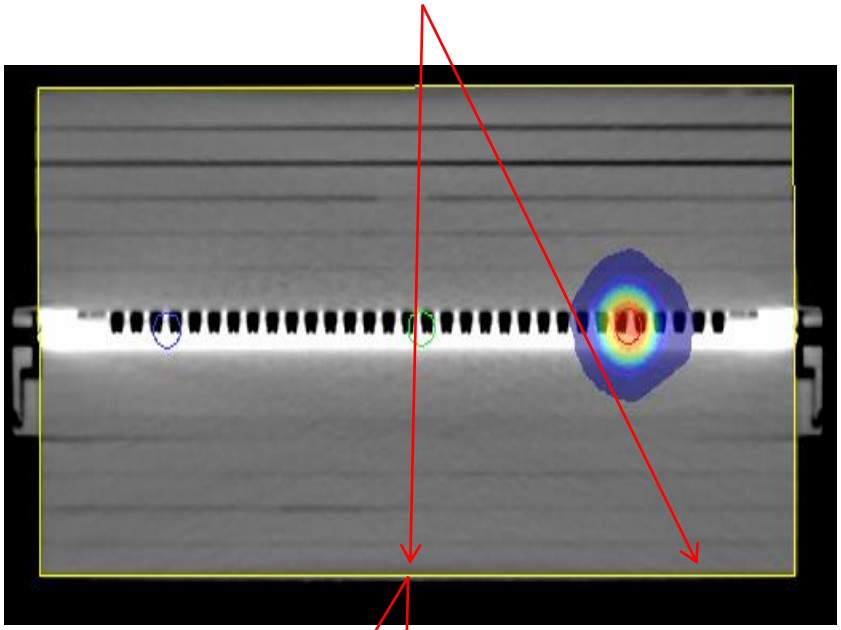


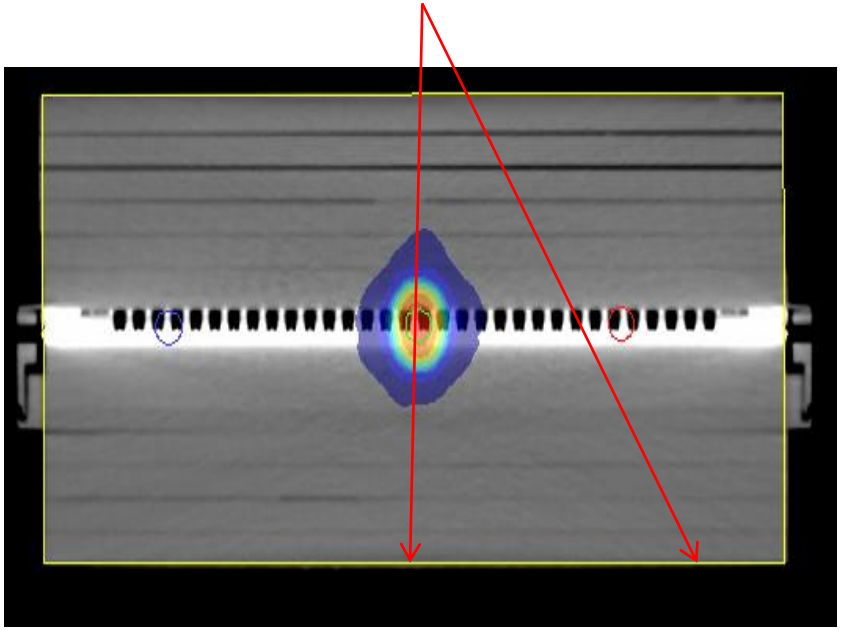

All in one is a BIG Issue
Might a compromise be necessary
Vendors commonly impose their own standards, but these standards may not be compatible with clinical needs (e.g. SBRT, RS).
There are still no clear indications and guidelines

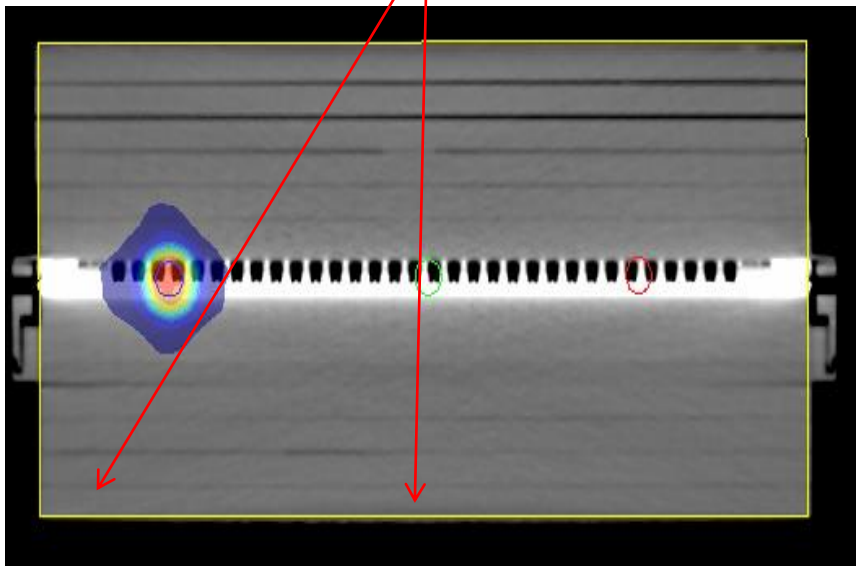


# On-Axis vs. Off-Axis



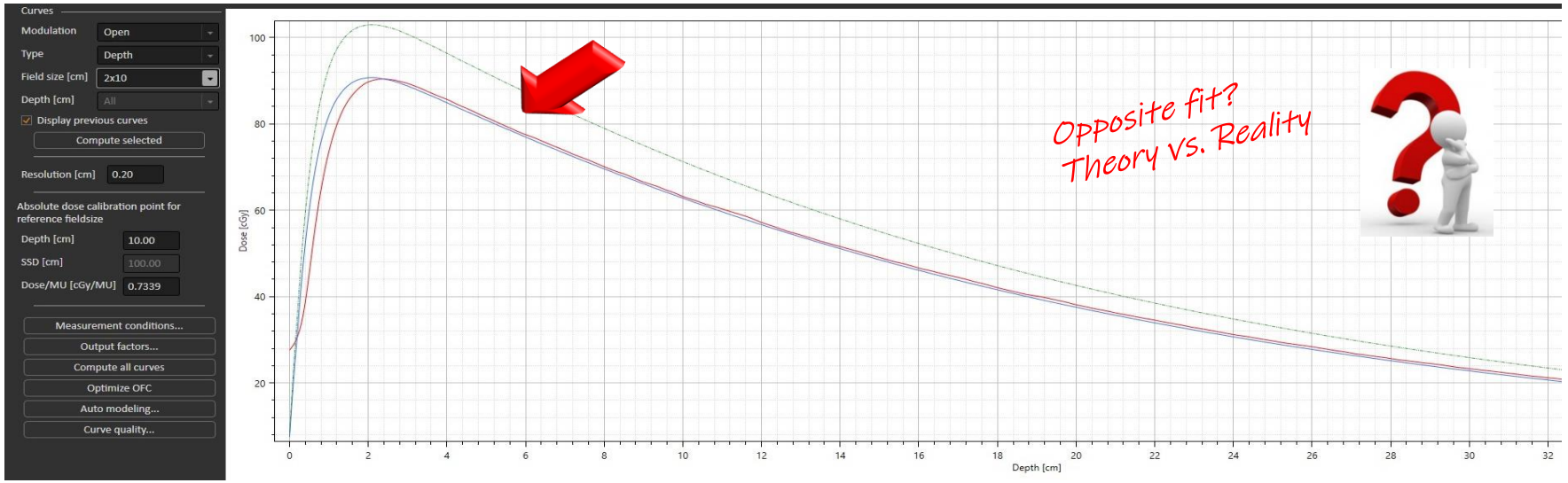


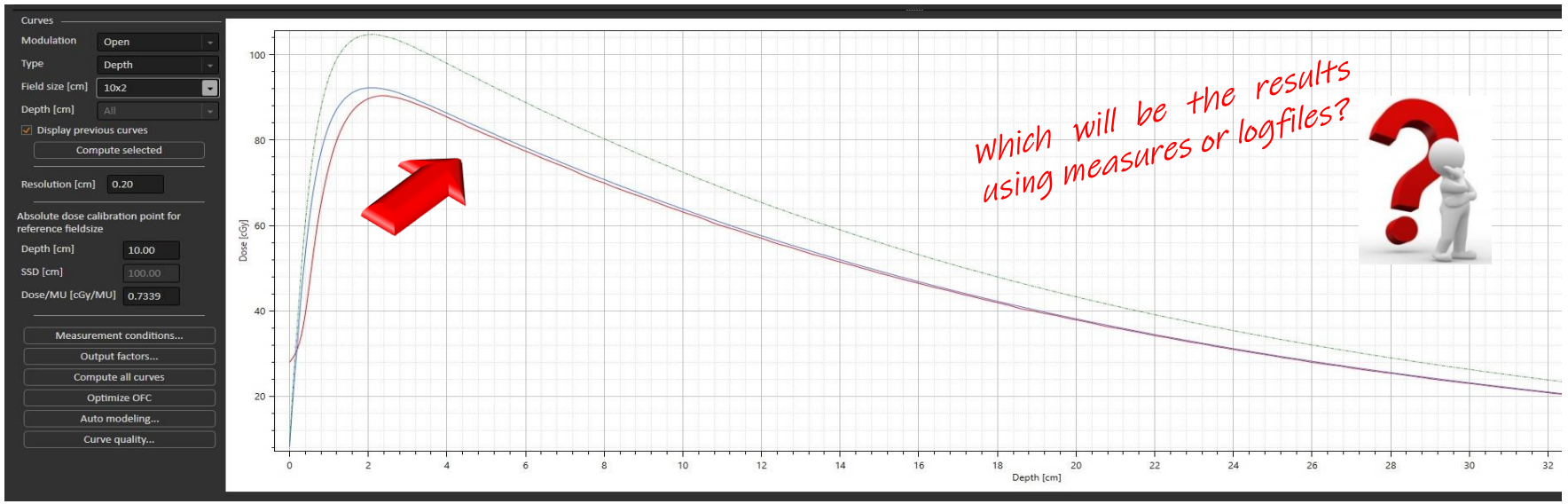


Mostly of the tests are done at the central axis
but many parameters should be investigated an
measured in different condition.
Lack of time is not an excuse!

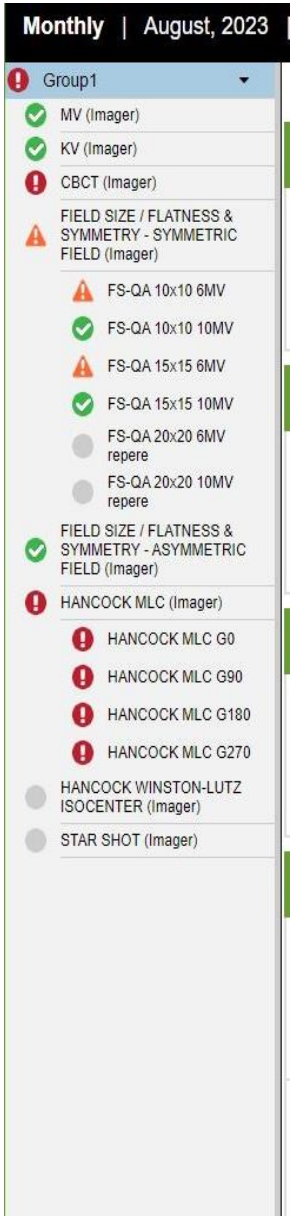
Will you expect the same answer from the EPID?
(independent dose distribution along the EPID)

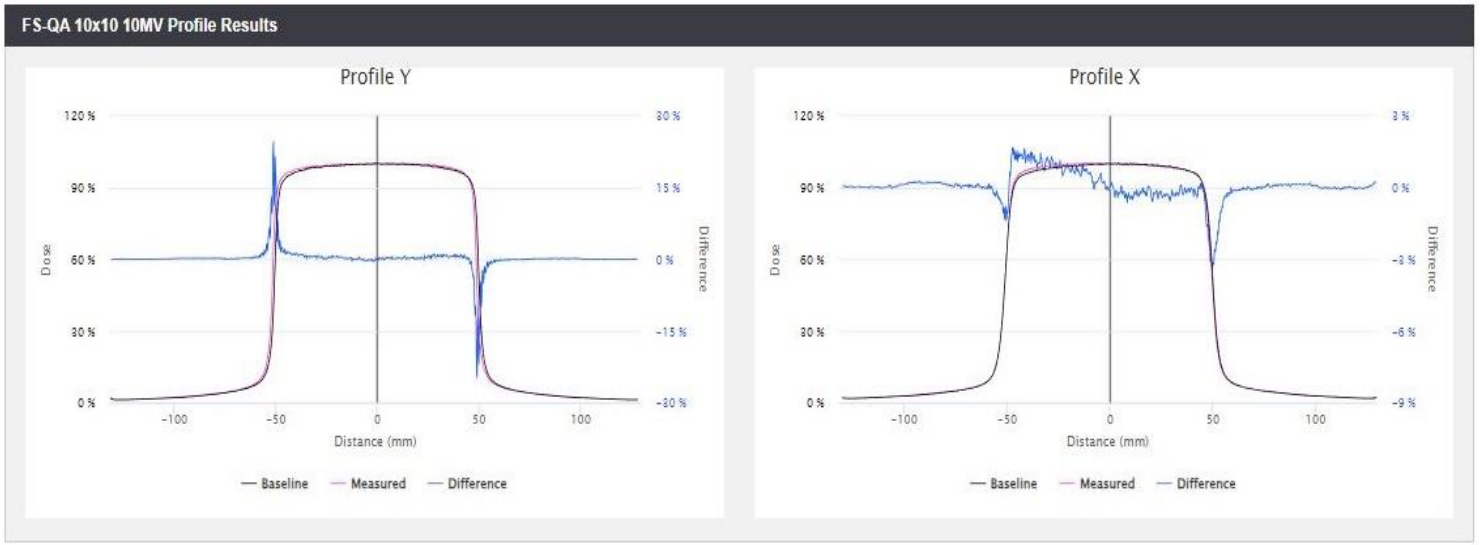
# Rectangular Fields (i.e. 10x2 and 2x10) Model Fi



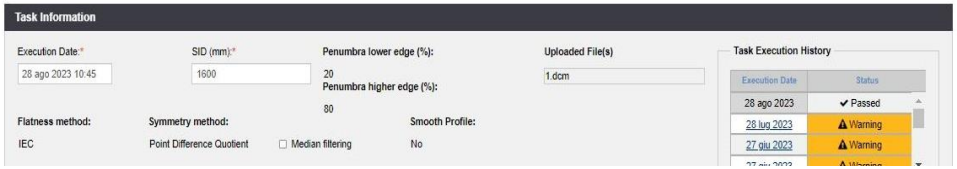



# Machine QA – Dosimetrical Details



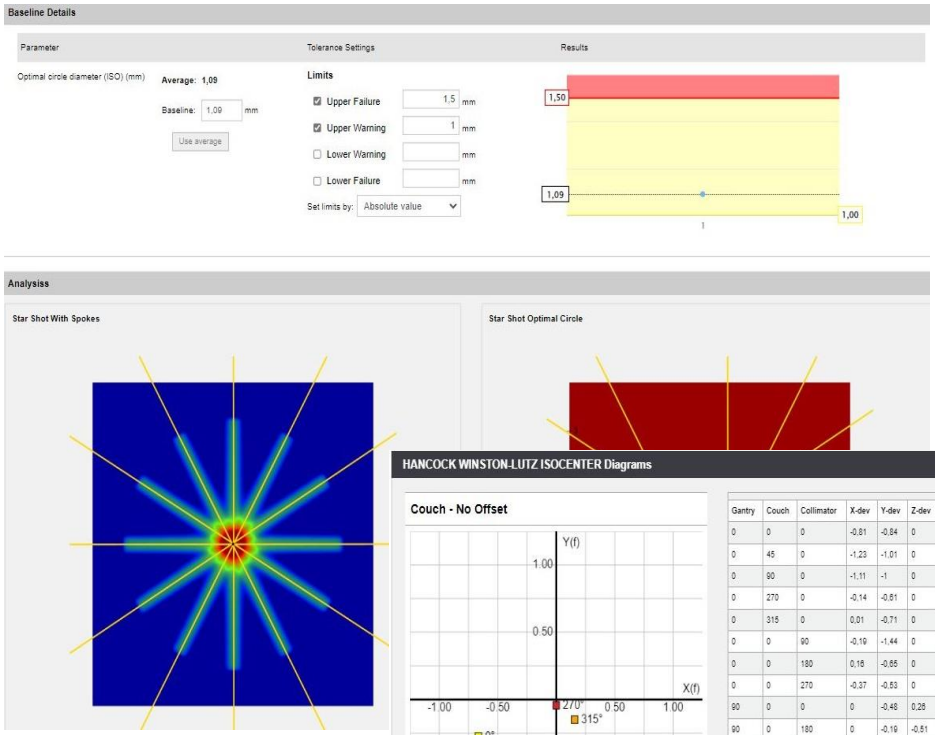



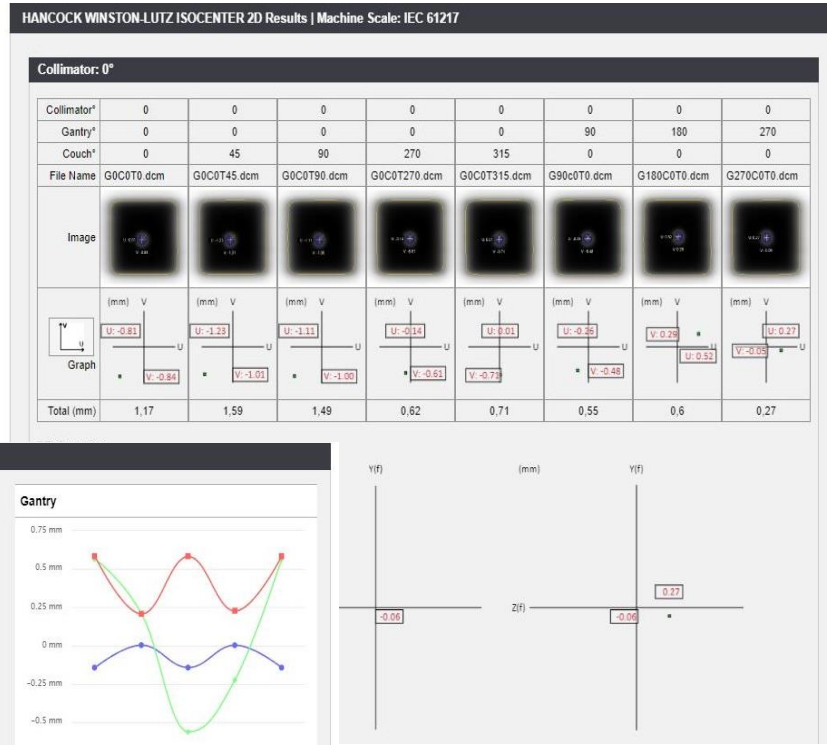


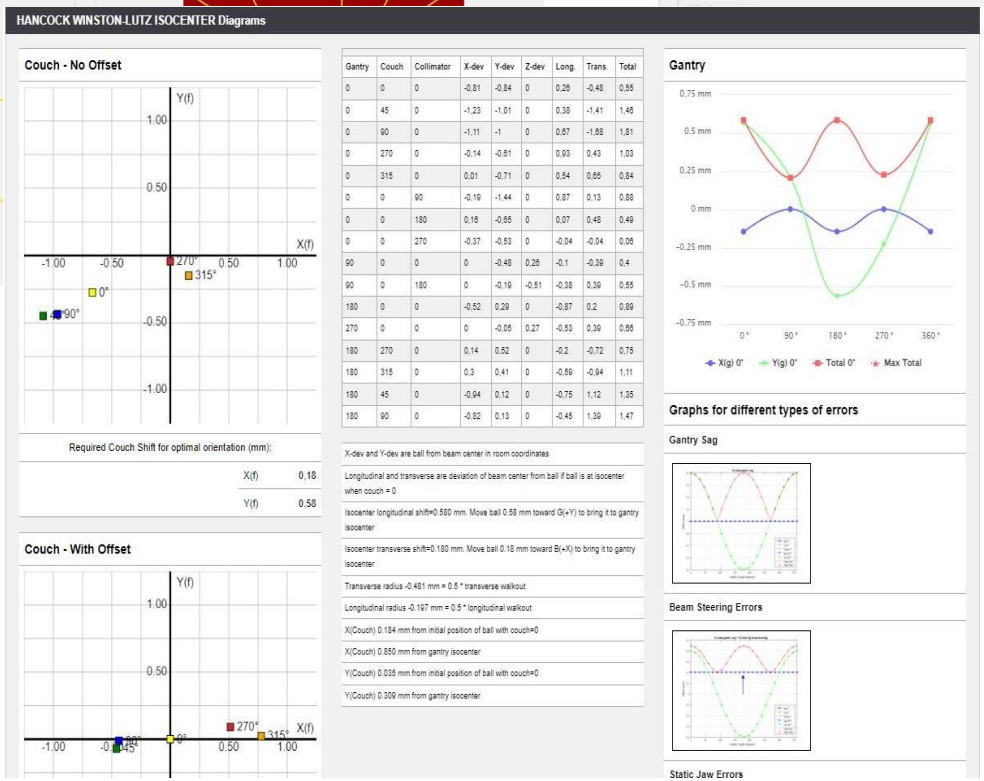



*Real-Time monitoring of the data after QA Sessions*

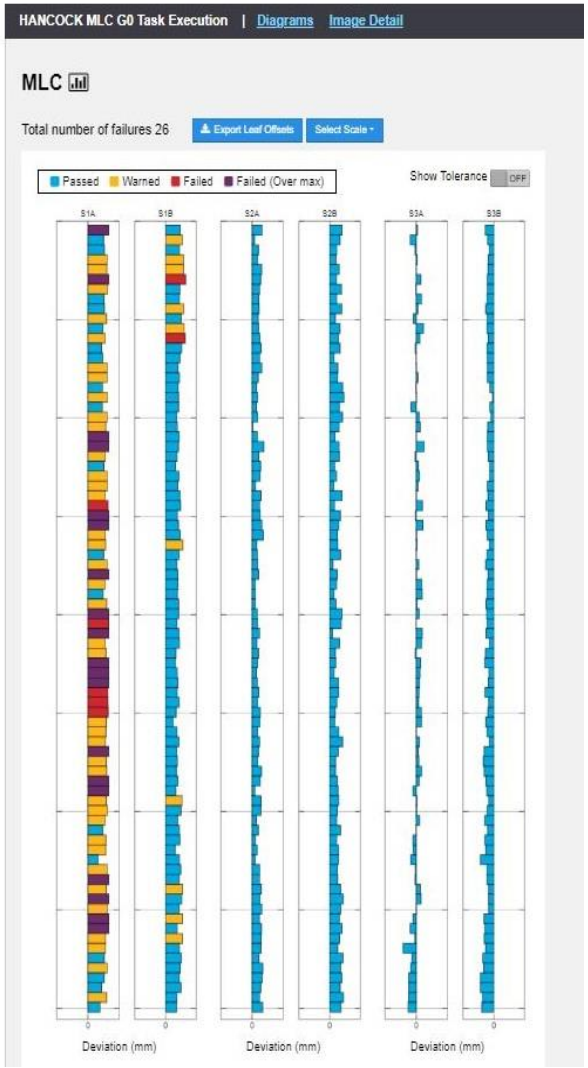
# Machine QA – Geometrical Details



# Machine QA – MLC Details





MLC Details after QA Sessions

# Machine QA – Imaging

**MV Task Execution** | Image Registration

| Parameter | Measurement | Baseline | Difference | Status | Tolerances |
|---|---|---|---|---|---|
| Scaling (mm) | 0,10 | 0,00 | -0,10 | ✔ Passed | -2 -1 0,1 1 2 |
| Spatial resolution (lp/mm) | 0,18 | 0,18 | 0,00 | ✔ Passed | 0,07 0,12 0,18 |
| Uniformity (%) | | | | | |
| Contrast (units) | | | | | |
| Noise (units) | | | | | |

**Task Information**

Execution Date:* 28 ago 2023 10:49

Phanton: SNC MV

Machine: VERSAMO2

Approval Status: Approved by cadioli, cecilia on

**KV Task Execution** | Image Registration

| Parameter | Measurement | Baseline | Difference | Status | Tolerances |
|---|---|---|---|---|---|
| Scaling (mm) | 0,01 | 0,00 | -0,01 | ✔ Passed | -2 -1 0,01 1 2 |
| Spatial resolution (lp/mm) | 0,82 | 0,82 | 0,00 | ✔ Passed | 0,72 0,77 0,82 |
| Uniformity (%) | | | | | 101,11 |
| Contrast (units) | | | | | |
| Noise (units) | | | | | |

**Task Information**

Execution Date:* 28 ago 2023 11:20

Phantoms: SNC kV-QA

Machine: VERSAMO1

Approval Status: Approved by cadioli, cecilia on 30 ago 2023 1

**CBCT Task Execution** | Image Registration

| Parameter | Measurement | Baseline | Difference | Status | Tolerances |
|---|---|---|---|---|---|
| Geometric distortion (mm) | -0,32 | -0,65 | -0,33 | ✔ Passed | -2,65 -1,65 -0,32 0,35 1,35 |
| Spatial resolution (lp/mm) | 0,21 | 0,19 | -0,02 | ✔ Passed | 0,09 0,14 0,21 |
| Uniformity (HU) | -29,36 | -21,28 | 8,08 | ! Failed | -26,28 -14,28 -29,36 -16,28 |
| Contrast (units) | 1,16 | 1,18 | 0,02 | ✔ Passed | 1,14 1,16 1,2 1,22 |
| Noise (units) | 4,04 | 4,07 | 0,03 | ✔ Passed | 4,04 4,46 4,88 |
| Air (HU) | -881,58 | -878,86 | 2,72 | ✔ Passed | -900 -890 -881,58 -860 -850 |
| Teflon 'R' (HU) | 520,92 | 502,03 | -18,89 | ! Failed | 480 490 510 520,92 |
| Delrin 'R' (HU) | 104,19 | 87,44 | -16,75 | ▲ Warning | 70 90 104,19 110 |
| Acrylic (HU) | -73,94 | -85,50 | -11,56 | ▲ Warning | -105 -95 -73,94 -65 |
| Polystyrene (HU) | -185,56 | -201,58 | -16,02 | ▲ Warning | -220 -210 -185,56 -160 |
| Low density polyethylene (LDPE) (HU) | -228,79 | -240,88 | -12,09 | ▲ Warning | -260 -250 -228,79 -210 |
| Polymethylpentene (PMP) (HU) | -290,97 | -300,50 | -9,53 | ✔ Passed | -320 -310 -290,97 -280 |

Imaging Status

# Conclusions & Future Challenges

- Software is a useful tool for Machine QA & Patient QA follow trends during treatment;
- All connections & links for implementation works properly for multiple LINACs;
- Beam Model of each Linac was performed, some extra adjustments were requested;
- Some patient's results are being manually extracted from the SW and analysed;
- A Query Retrieve is under development for automatic extraction of results and DB construction.
- Implementation of Results in Clinical decision is still under complete
- The final goal is the beam-matching of No.4 LINACs and Automatic Calculations.....
- ... but the most important is a complete Daily Vision of the Patients Treatment in Real-Time

SERVIZIO SANITARIO REGIONALE
EMILIA-ROMAGNA
Azienda Ospedaliero - Universitaria di Modena

# "That's too much!!!"

(Praha 2009)