First CQ Measurements and Skin Dose Measurements with Radiochromic Films

SYRMA-3D Collaboration Meeting

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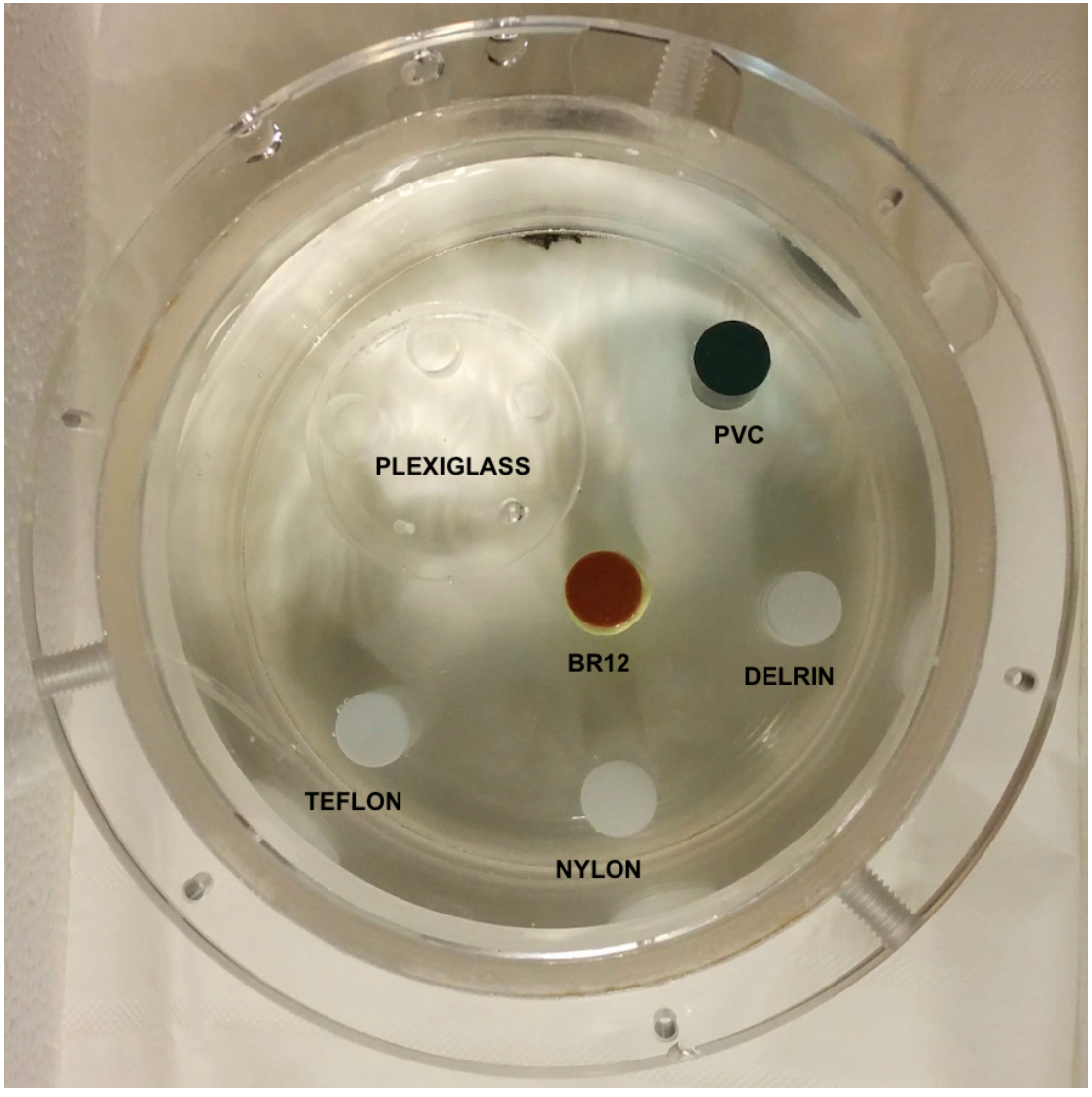
17 February 2017

QC PHANTOM MATERIALS



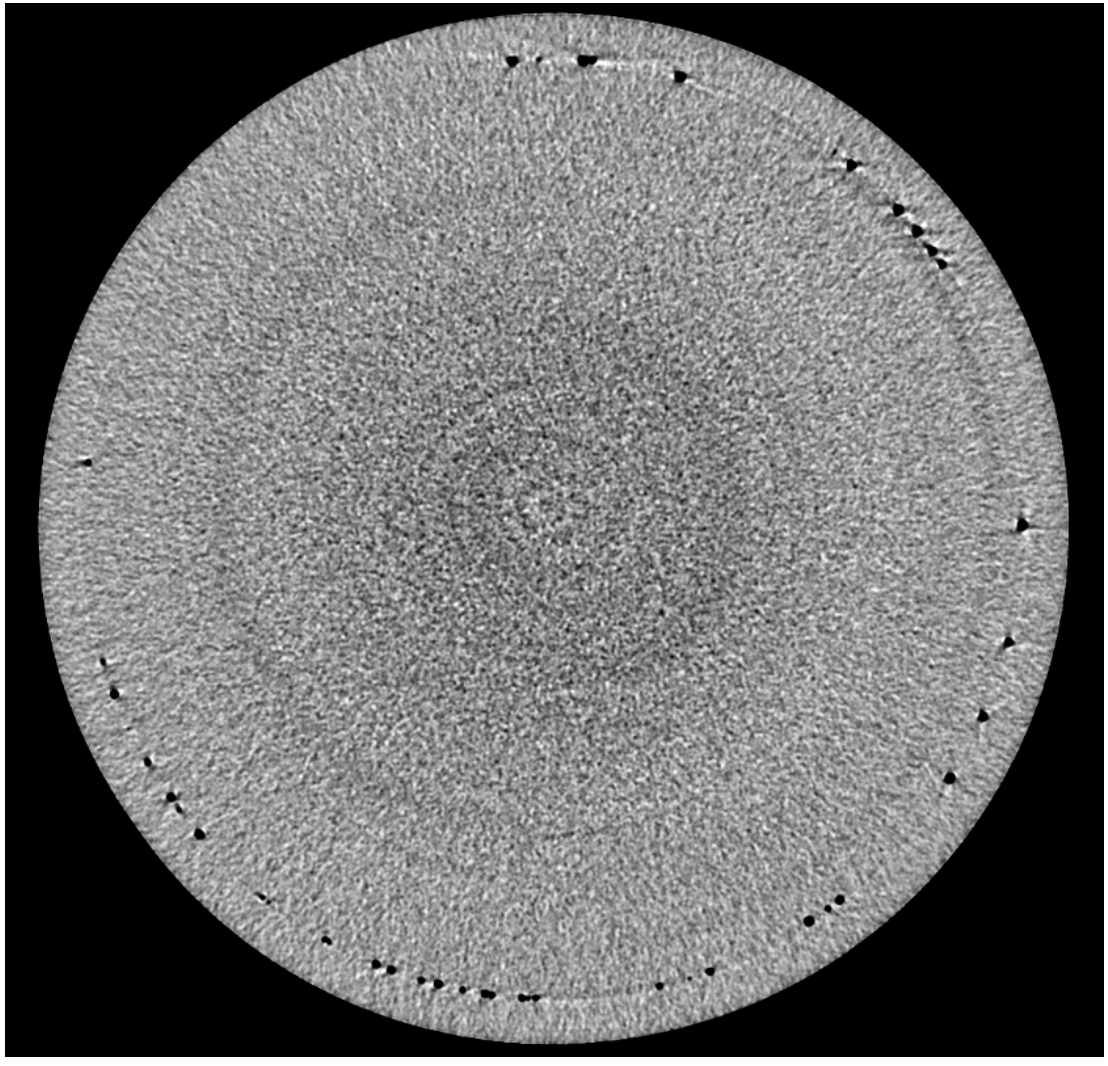
QC PHANTOM

Acquisition and Reconstruction Parameters:

MODALITA' DI ACQUISIZIONE														
Modalità	Velocità (deg/s)	Irradiation Time (s)	Filtri Al (mm)	IOC_1 (A.U.)	Lx	Altezza Irraggiata (mm)	Air Kerma at Breast Position	MGD_t (mGy)	MGD_v (mGy)	Dead Time	Proiezioni	Shutter (ms)	Threshold	Pixel Ricostruzione
Alta Dose	4,5	40	3	16000	16,373	3	36,5	28,9	15	DTF	1250	33	3	60
Bassa Dose	4,5	40	7,875	8190	16,373	3	13,47	10,6	5,53	DTF	1250	33	3	60

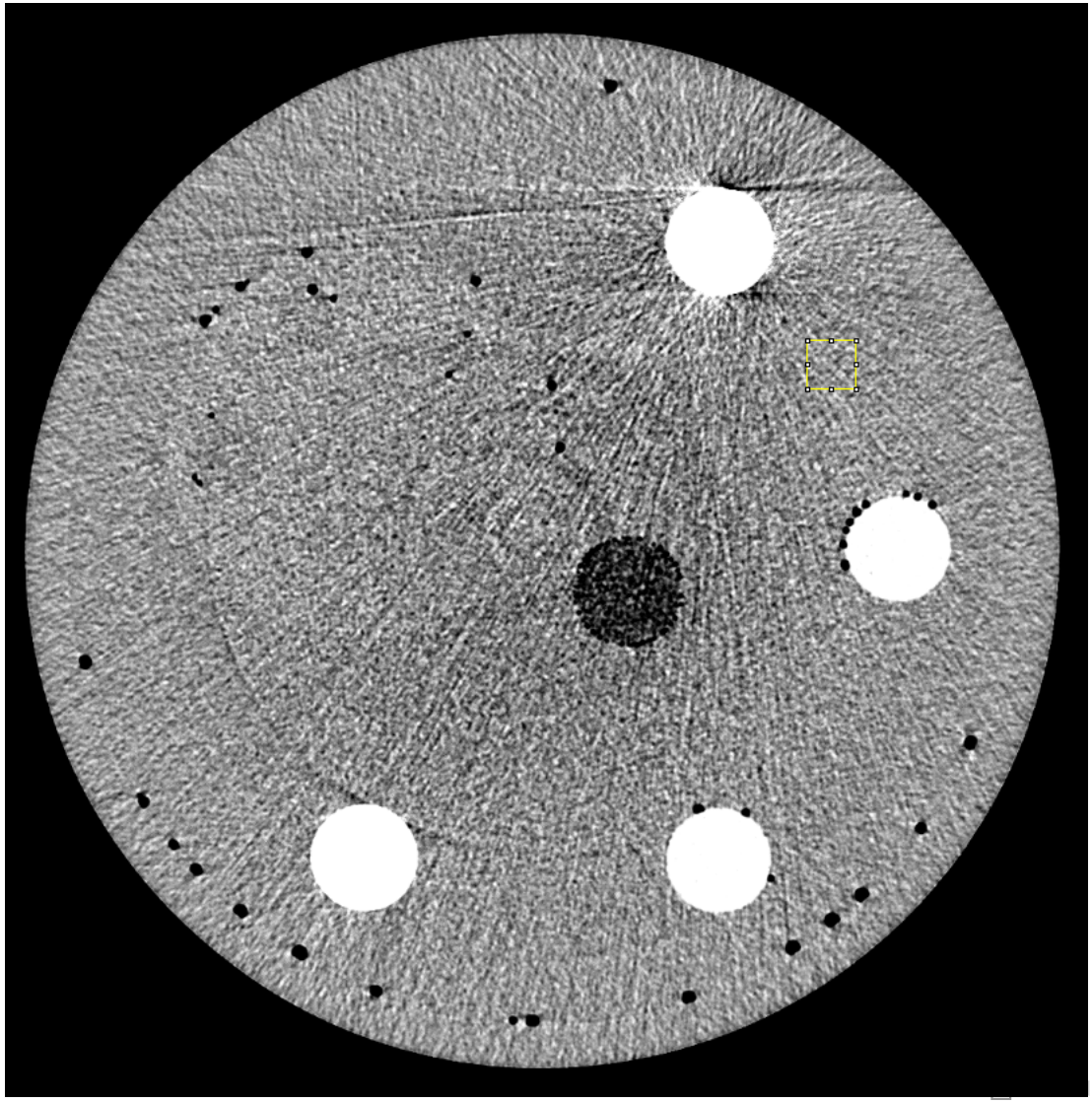
QC Phantom Images

35 keV High Dose:



QC PHANTOM IMAGES

35 keV High Dose:



QC PHANTOM MEASUREMENTS

Average CT number of water:

PARAMETRO	DEFINIZIONE	DISPOSITIVO	PROCEDURA	VALUTAZIONE
Numero CT medio	Il numero CT rappresenta l'attenuazione media associata a ciascuna area elementare dell'immagine.	Fantoccio CQ Zona solo Acqua	Selezionare una regione di interesse al centro dell'immagine e determinare il valore medio dei pixel considerati. La ROI deve contenere almeno 100 pixel; il diametro non deve superare il 10% dell'immagine del dispositivo di prova	Il CT medio ottenuto deve essere confrontato con il numero CT di riferimento

QC PHANTOM MEASUREMENTS

Average CT number of water:

35 keV HIGH DOSE

Misura 1	0,281
Misura 2	0,28
Misura 3	0,278
Media	0,27966667

Mu H20	0,307

Diff %	8,90336591

Area ROI	50x50 pixel

QC PHANTOM MEASUREMENTS

Noise and Uniformity:

PARAMETRO	DEFINIZIONE	DISPOSITIVO	PROCEDURA	VALUTAZIONE
Rumore	Il rumore è definito come la variazione dei numeri CT rispetto a un valor medio in un'area definita dell'immagine di una sostanza uniforme. Il valore è espresso dalla deviazione standard dei numeri CT della sostanza in una ROI	Fantoccio CQ Zona solo Acqua	Selezionare una regione di interesse al centro dell'immagine e determinare il valore medio dei pixel considerati. La ROI deve contenere almeno 100 pixel; il diametro non deve superare il 10% dell'immagine del dispositivo di prova.	Il rumore deve essere valutato confrontando la deviazione standard dei numeri CT nella regione di interesse con il valore di riferimento
Uniformità	L'uniformità è la costanza dei numeri CT dell'immagine in un materiale omogeneo attraverso il campo d'esame	Fantoccio CQ Zona solo Acqua	Selezionare una regione di interesse al centro dell'immagine e determinare il valore medio dei pixel considerati. Ripetere su altre quattro ROI non sovrapposte poizionate a 1 cm dal bordo del dispositivo di prova.	L'uniformità si ottiene dalle differenze tra il numero CT medio della ROI centrale e il numero CT medio delle ROI ai bordi

QC PHANTOM MEASUREMENTS

Noise and Uniformity:

ORE	CT # Medio	STD Dev
Centro	0,28	0,015
12	0,288	0,012
3	0,28833333	0,012
6	0,28733333	0,01166667
9	0,28833333	0,011

Uniformità
0,00833
Uniformità %
2,976190476

CENTRO			
	Misura 1	Misura 2	Misura 3
CT medio	0,281	0,28	0,279
STD dev	0,016	0,015	0,014
Media CT	0,28		
Media std_dev	0,015		

Rumore Centro %
5,357142857

QC PHANTOM MEASUREMENTS

CT Number Linearity:

PARAMETRO	DEFINIZIONE	DISPOSITIVO	PROCEDURA	VALUTAZIONE
Linearita`	E' la relazione tra il numero CT ed i coefficienti di attenuazione lineare	Fantoccio CQ Zona con Rods	Acquisire l'immagine e leggere il valore del numero CT in corrispondenza dei materiali. Fittare con una retta.	Si registrano l'equazione della retta e di R^2 e si verifica che non ci siano significative variazioni nel tempo
Scala di Contrasto	La scala di contrasto è definita come: (mu1-mu2)/(CT1-CT2) dove 1 e 2 sono due materiali simili all'acqua	Fantoccio CQ Zona con Rods	Acquisire l'immagine e leggere il valore del numero CT in corrispondenza dei materiali. Calcolare il valore della scala di contrasto.	Si registra il valore della scala di contrasto e si verifica che non ci siano significative variazioni nel tempo

QC PHANTOM MEASUREMENTS

CT Number Linearity:

35 keV HIGH DOSE

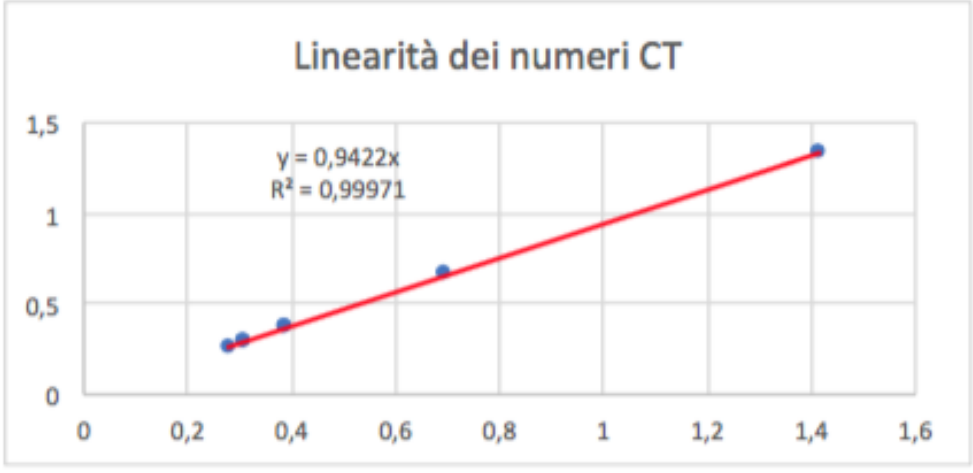
Materiale	Water	BR12	Nylon	PVC	Plexiglass	Delrin	Teflon
μ (a 35 KeV)	0,307	0,279	0,387	1,414	0,309	0,387	0,692
CT#	0,288	0,247	0,366	1,334	0,289	0,364	0,656

	μ	CT#
Nylon	0,387	0,366
Plexiglass	0,309	0,289
Delrin	0,387	0,364
BR12	0,279	0,247
Water	0,307	0,288
Teflon	0,692	0,656
PVC	1,41	1,334

y = 0,8943x +0,054

R^2 = 0,97618

Sc. ctr. = 104,000



QC PHANTOM MEASUREMENTS RESULTS

Synthesis of the Results:

SINTESI DEI RISULTATI						
Modalità	Linear. CT#	Scala contr.	CT# medio %	Rumore centro %	Unif. spaz.	Unif. spaz. %
Alta Dose	0,97618	106,7	8,9	5,3	0,0083	2,98
Bassa Dose						

QC PHANTOM MEASUREMENTS RESULTS

Synthesis of the Results:

	RIFERIMENTI E TOLLERANZE				
			35 keV High Dose		
Parametri	Toll. Hospital	Toll. Koning	Misura	Compatibilità Hospital	Compatibilità Koning
Rumore: limite di allarme	±10%	8 HU	5,3	SI	NO
Rumore: limite di sospensione	±25%	-	5,3	SI	-
Uniformità	±8 HU	±15 HU	0,0083	NO	NO
Numero CT medio	±4 HU	±10 HU	0,280	NO	NO
Linearità: H20 allarme	rif ± 5 HU	-	0,288	NO	-
Linearità: H20 sospensione	rif ± 20 HU	-	0,288	NO	-
Linearità: BR12 allarme	rif ± 10 HU	-	0,247	NO	-
Linearità: BR12 sospensione	rif ± 30 HU	-	0,247	NO	-
Linearità: Plexiglas allarme	rif ± 10 HU	-	0,289	NO	-
Linearità: Plexiglas sospensione	rif ± 30 HU	-	0,289	NO	-
Linearità: Delrin allarme	rif ± 10 HU	-	0,364	NO	-
Linearità: Delrin sospensione	rif ± 30 HU	-	0,364	NO	-
Linearità: Teflon allarme	rif ± 10 HU	-	0,656	NO	-
Linearità: Teflon sospensione	rif ± 30 HU	-	0,656	NO	-
Linearità: PVC allarme	rif ± 10 HU	-	1,334	NO	-
Linearità: PVC sospensione	rif ± 30 HU	-	1,334	NO	-

QC PHANTOM MEASUREMENTS RESULTS

What we learned:

- Nylon isn't Nylon... It's Delrin!
- Plexiglas absorbs $\approx$ water @ 35 keV;
- Low Contrast Details are unresolved;
- Ring artefacts affect uniformity especially in the central area;
- PVC generated streaking artefacts: is it too absorbing?

Skin Dose Measurements using Radiochromic Films

Aim:

- Measure the dose to the patient's skin;
- Different irradiation modalities.

Radiochromic Films:

- GafChromic™ XR-QA2;
- Sensitive 1-200 mGy;
- Properly Calibrated.

MEASUREMENTS AT THE SYRMEP BEAMLINE

SYRMEP Beamline @Elettra:

- Elettra @ 2.4 GeV;
- Laminar SR beam 3 mm height (@slits);
- Energy 38 keV;
- IOC gives the air-Kerma.

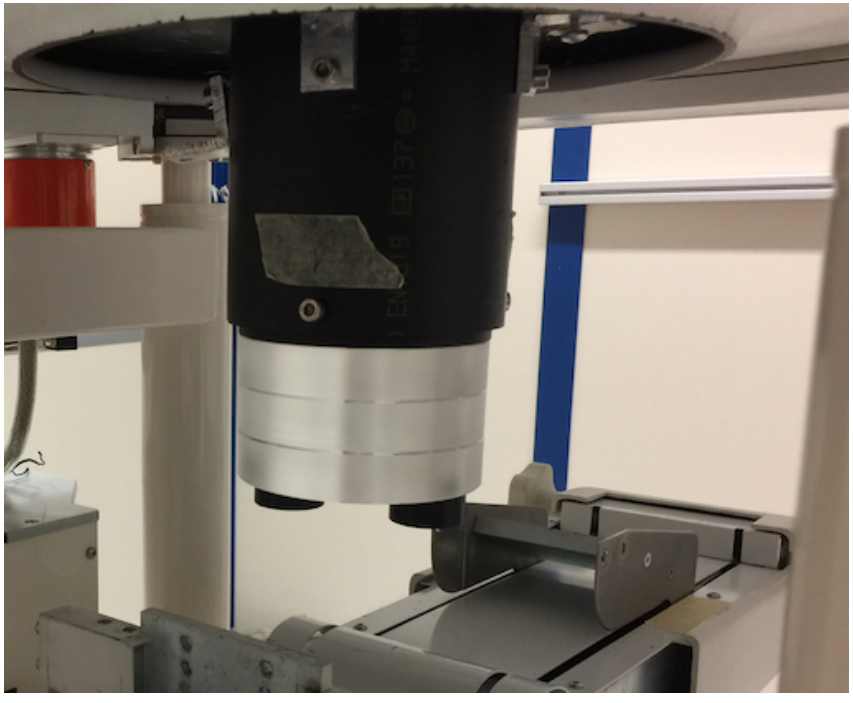
(a)

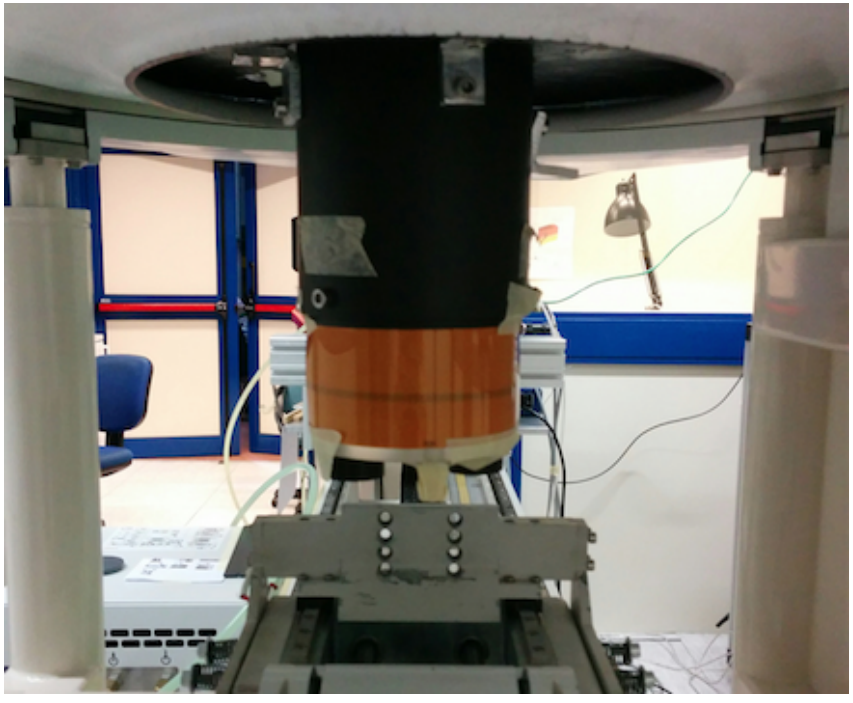
(b)

MEASUREMENTS AT THE SYRMEP BEAMLINE

Cylindrical Phantom 10 cm in diameter on patient's support:

- diameter, symmetry and μ similar to breast;
- two pieces of films tightly wrapped around it to simulate patient's skin.





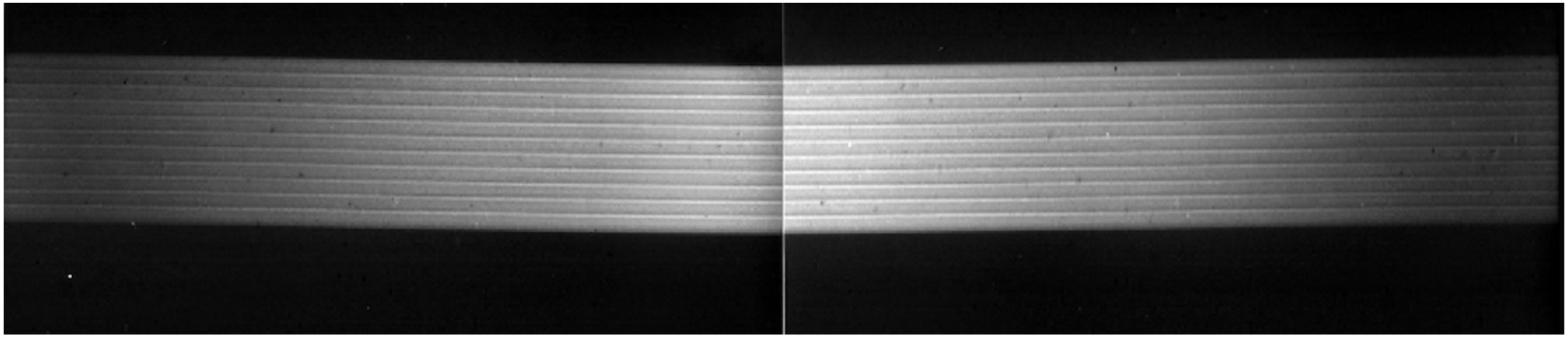
MEASUREMENTS AT THE SYRMEP BEAMLINE

Four different irradiation modalities on different pieces of film:

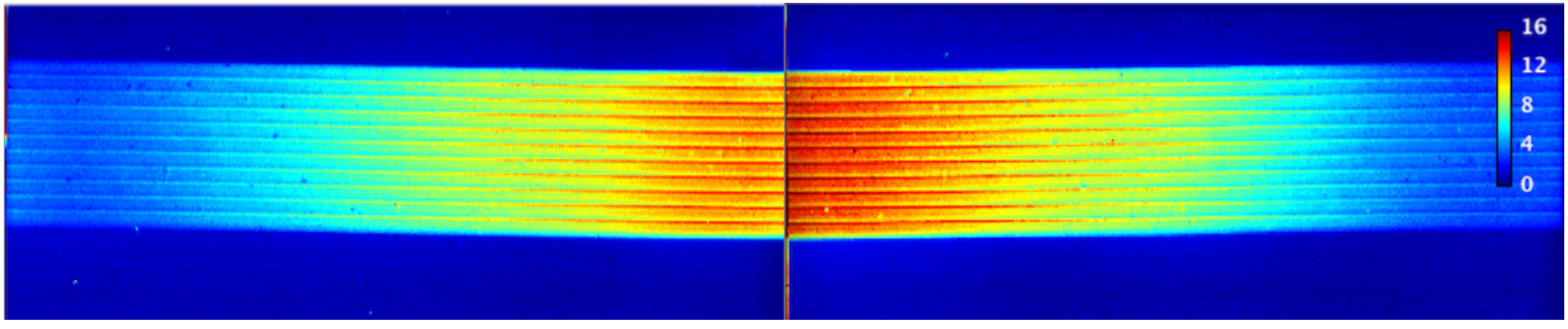
- 180°
- 360°
- 0°-180°- step - 0°-180°
- 0°-180°- step - 180°-360°

0°-180°- STEP - 0°-180°

Radiochromic film scan:



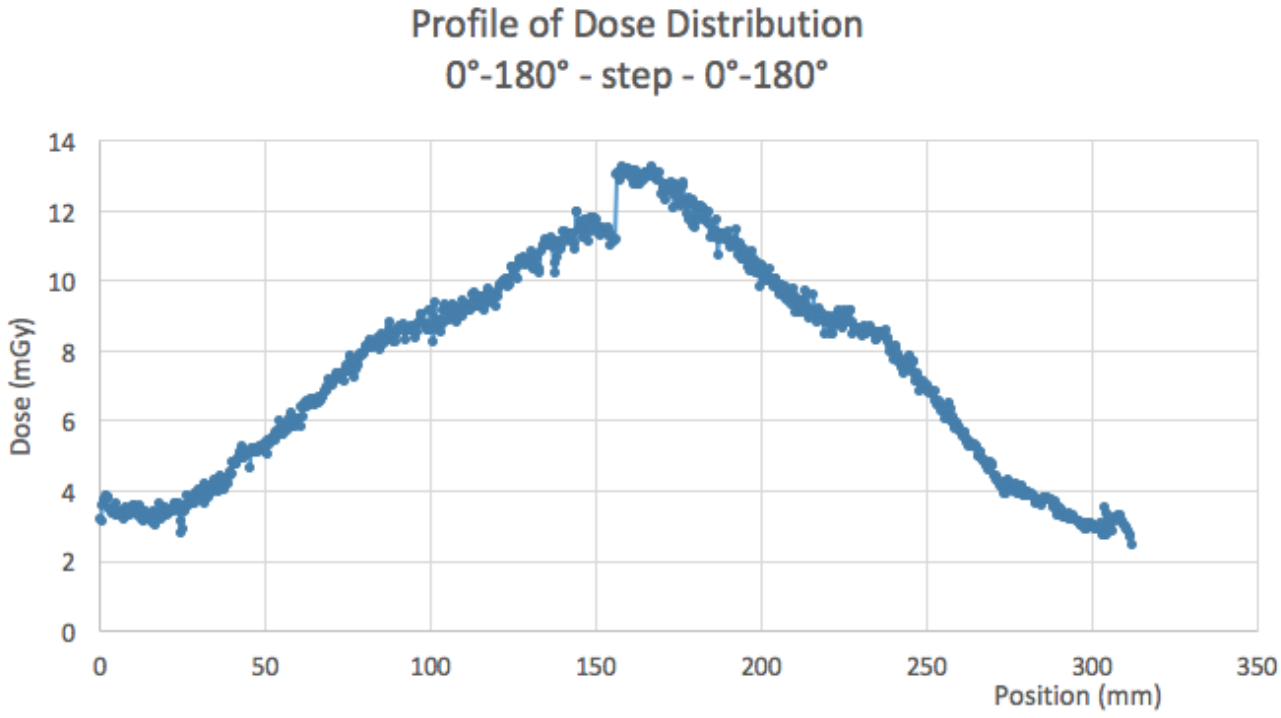
(c)



(d)

0°-180°- STEP - 0°-180°

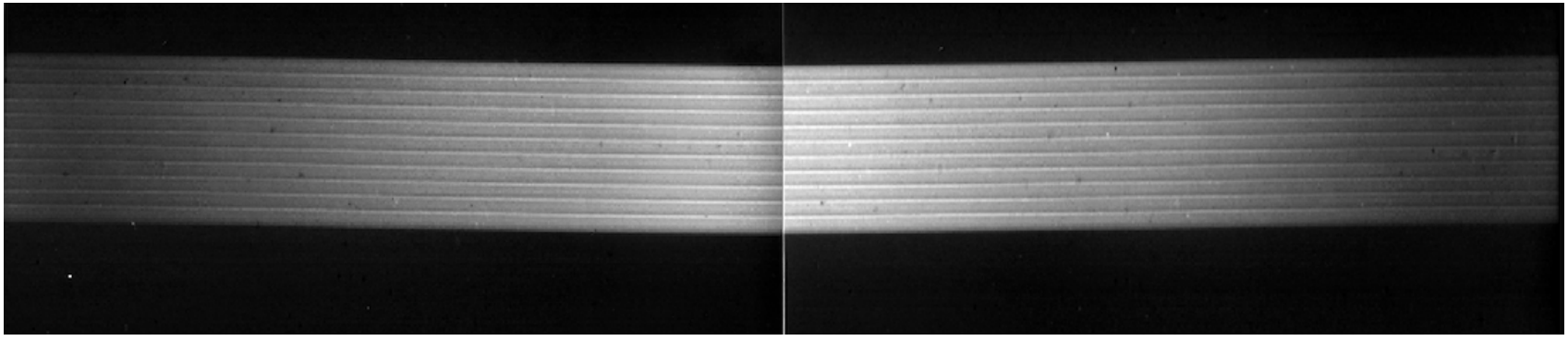
Profile of horizontal dose distribution:



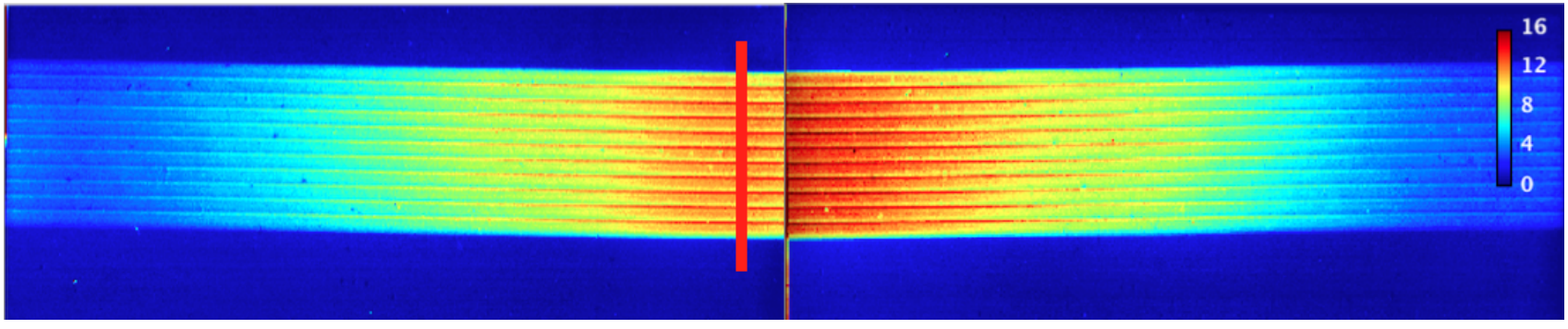
- Minimum dose: 18% of the maximum dose;
- $MGD_t = 6.9$ mGy $\rightarrow$ Dose up to 205% of MGD_t.

0°-180°- STEP - 0°-180°

Profile of vertical dose distribution:



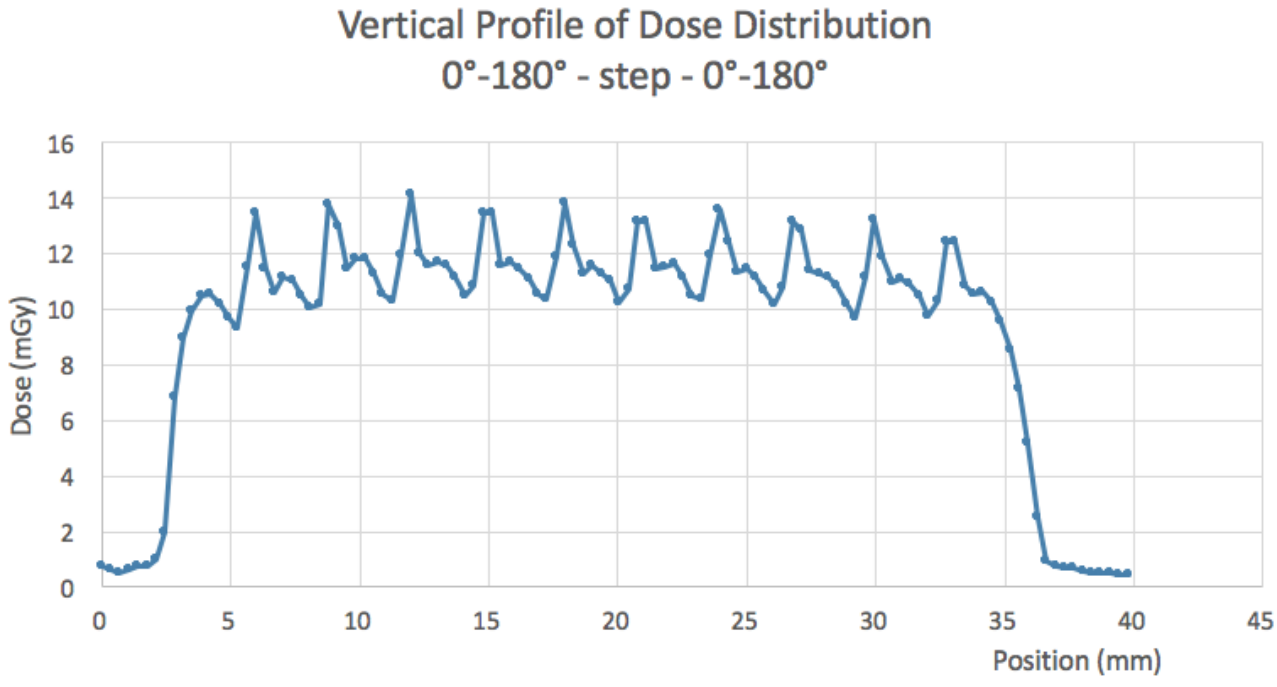
(e)



(f)

0°-180°- STEP - 0°-180°

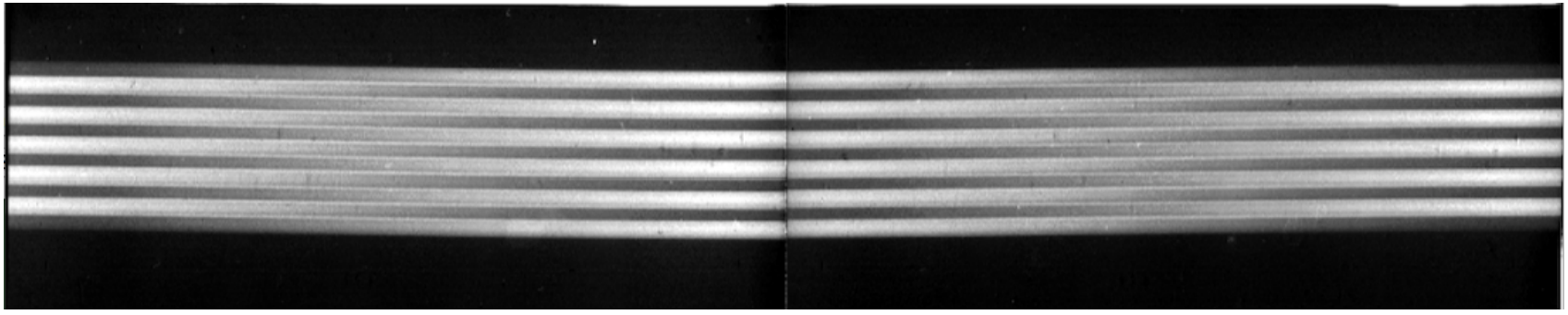
Profile of vertical dose distribution:



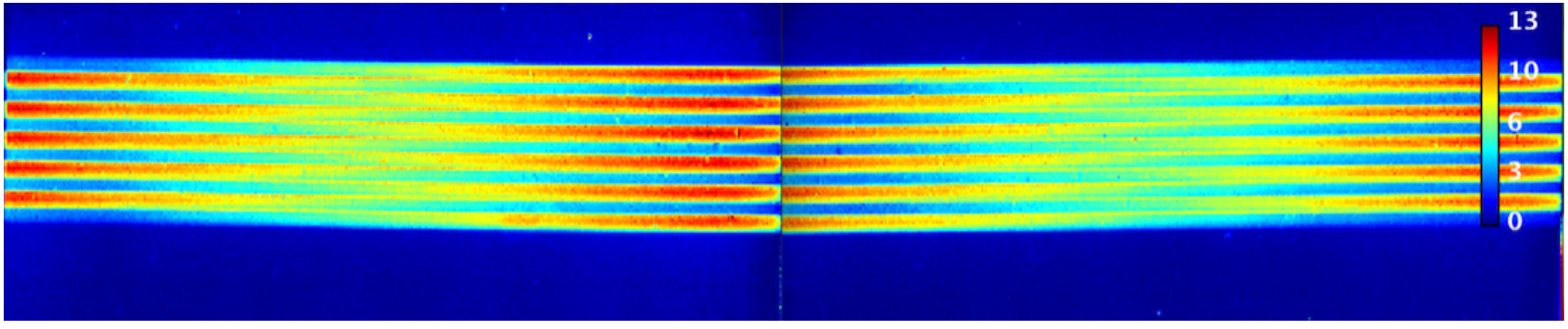
- Maximum peak-to-valley difference: 33% of the maximum dose.

0°-180°- STEP - 180°-360°

Radiochromic film scan:



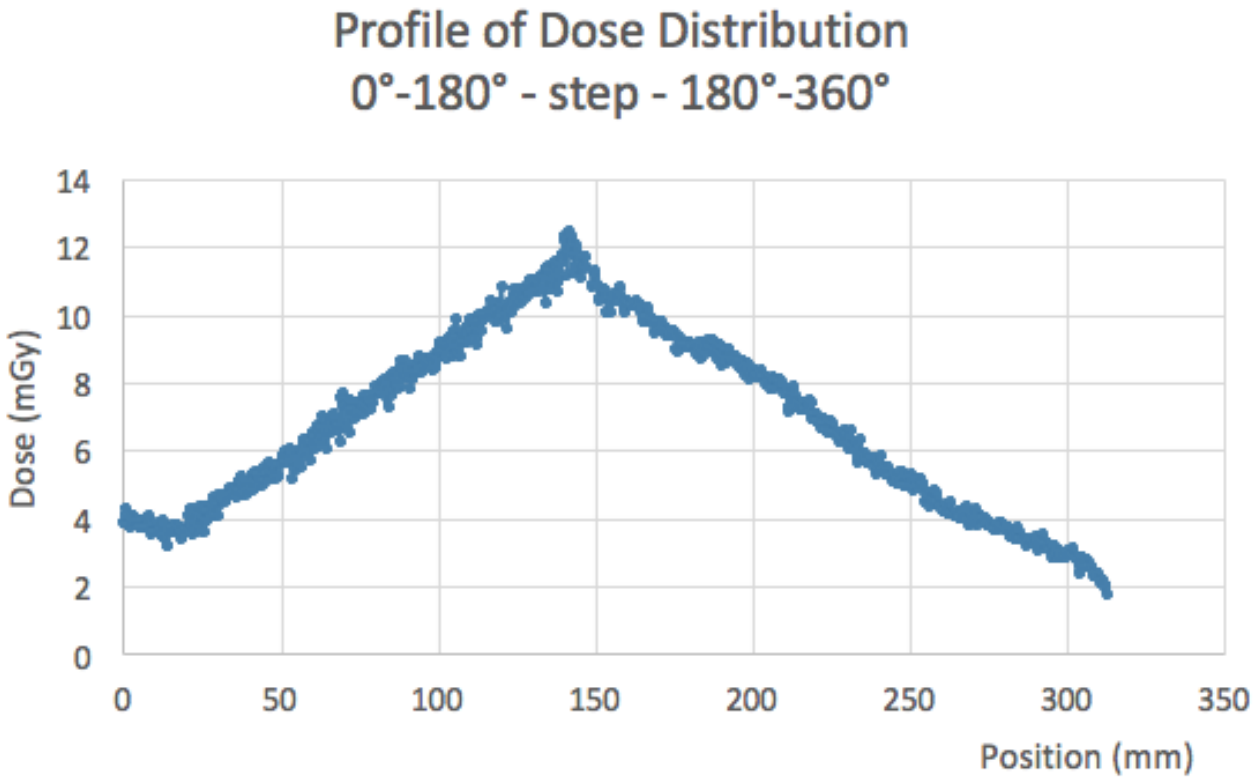
(g)



(h)

0°-180°- STEP - 180°-360°

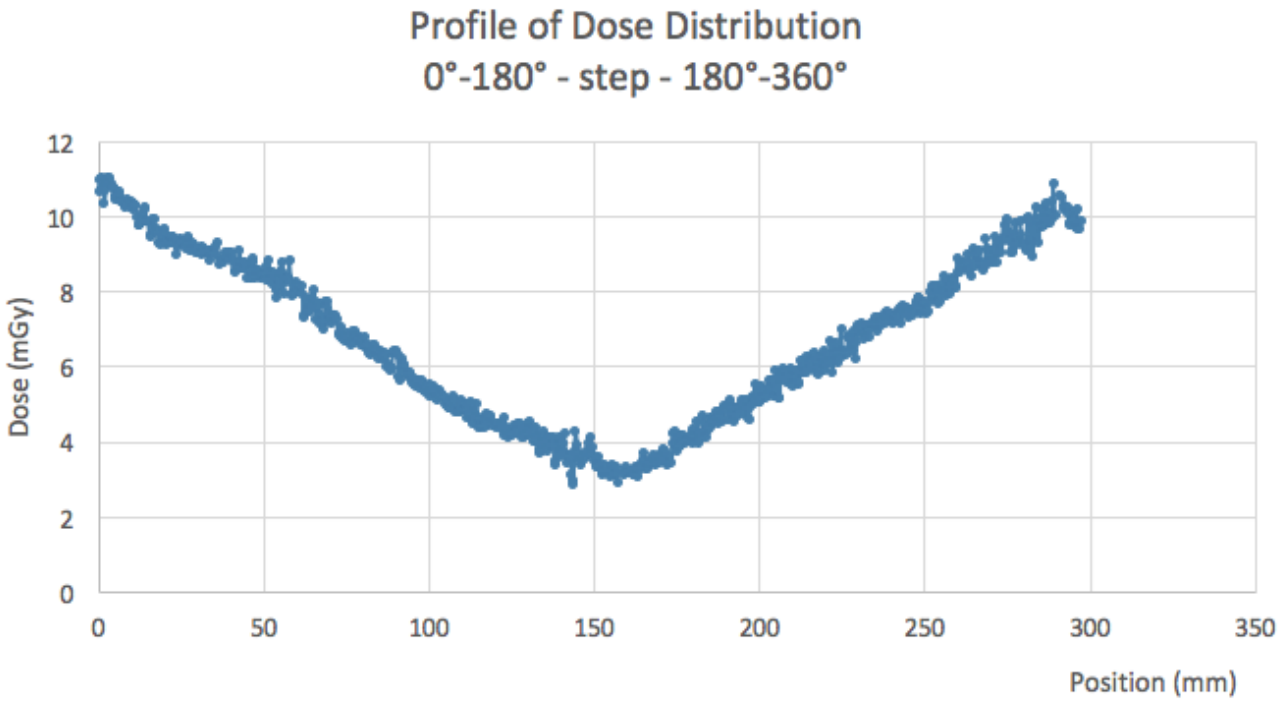
Profile of horizontal dose distribution for odd slices:



- Minimum dose: 20% of the maximum dose.

0°-180°- STEP - 180°-360°

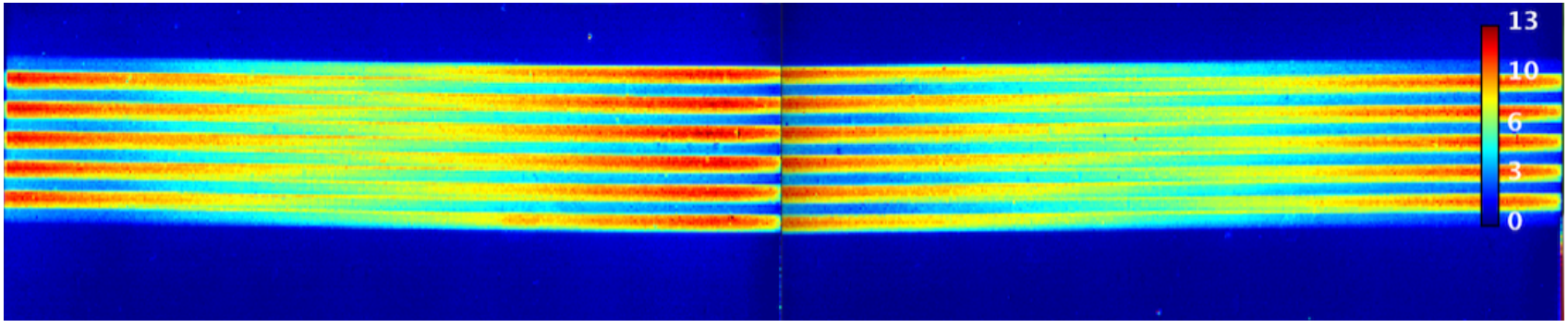
Profile of horizontal dose distribution for even slices:



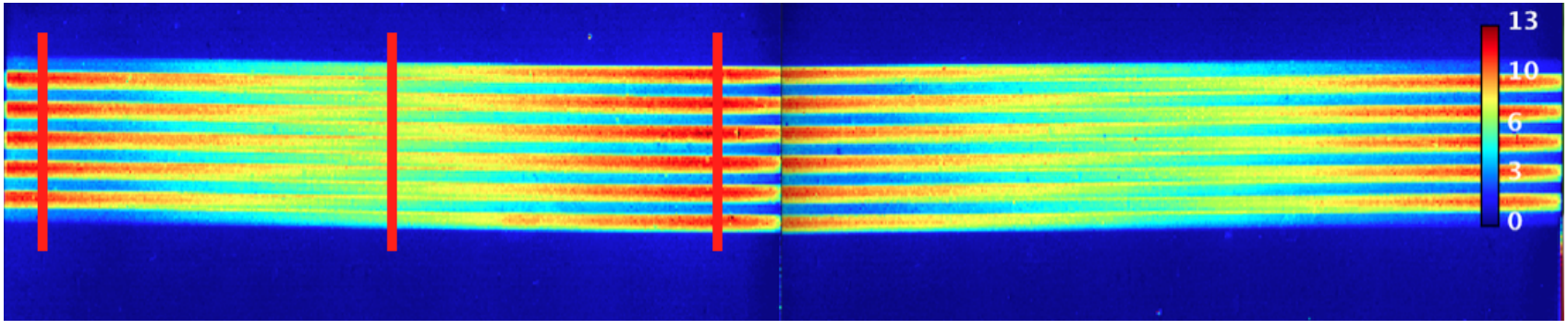
- Minimum dose: 20% of the maximum dose.
- $MGD_t = 6.9$ mGy $\rightarrow$ Dose up to 170% of MGD_t.

0°-180°- STEP - 180°-360°

Profile of vertical dose distribution: we see three different patterns



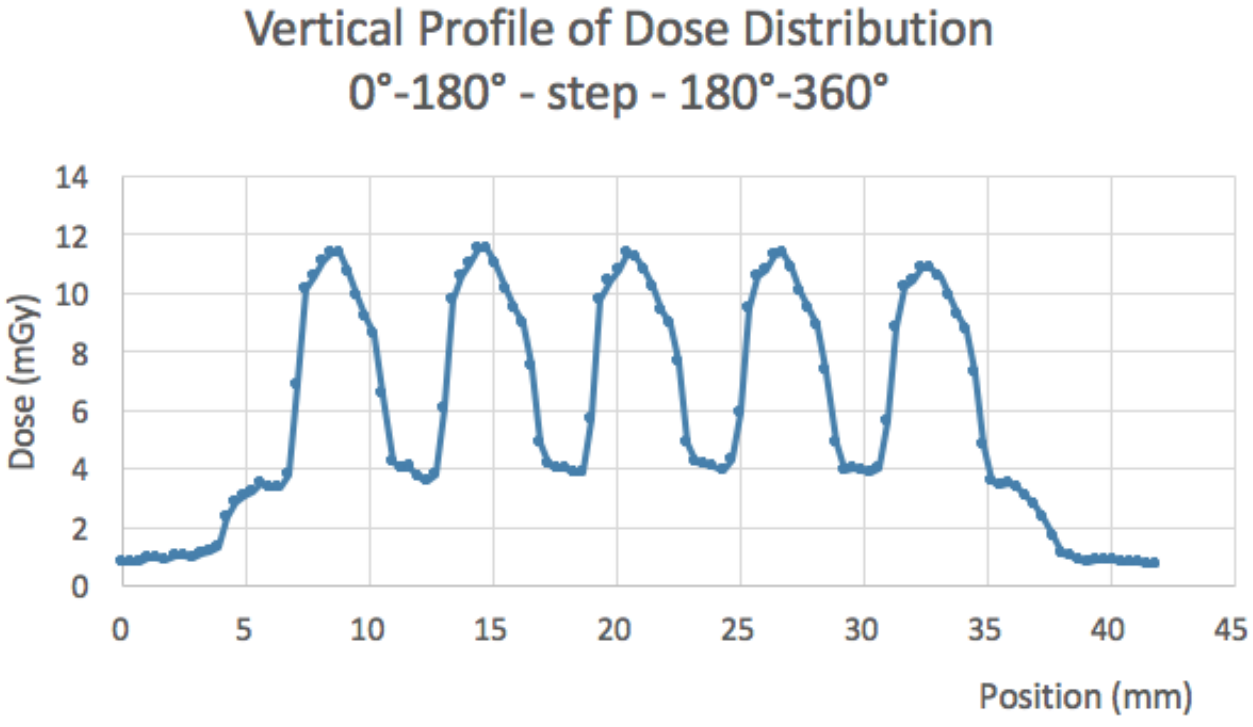
(i)



(j)

0°-180°- STEP - 180°-360°

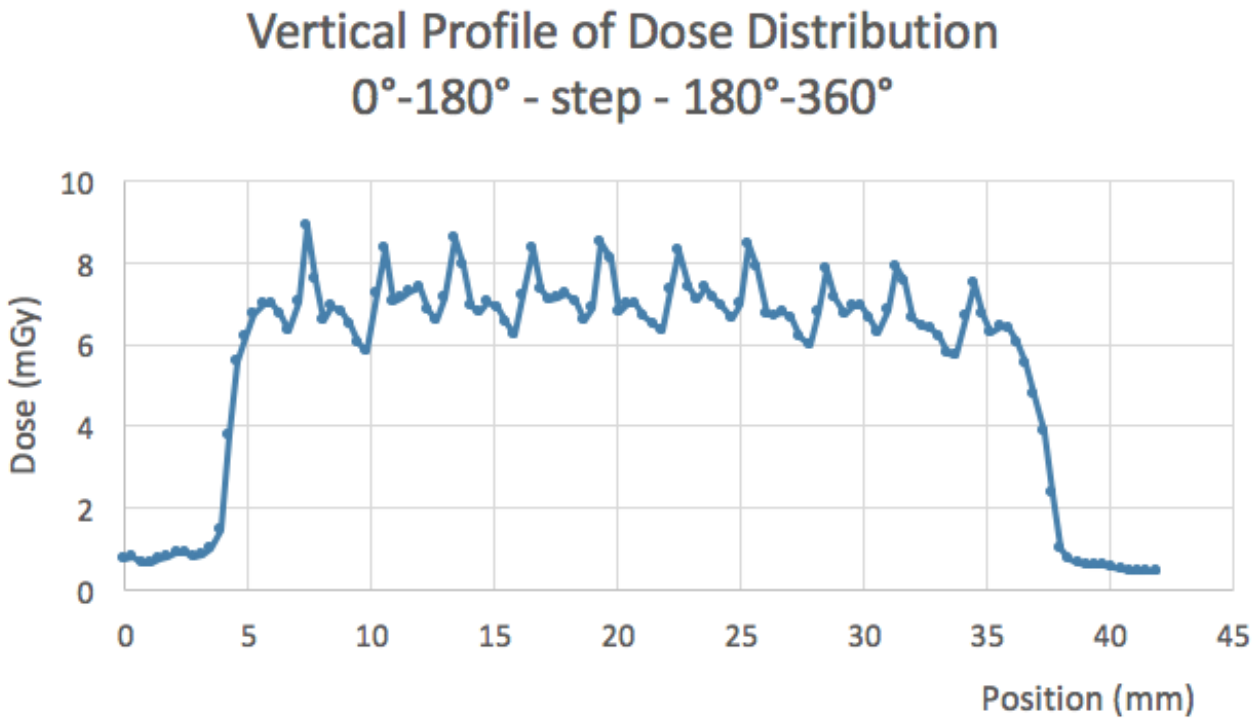
Profile of vertical dose distribution:



- Maximum peak-to-valley difference: 80% of the maximum dose.

0°-180°- STEP - 180°-360°

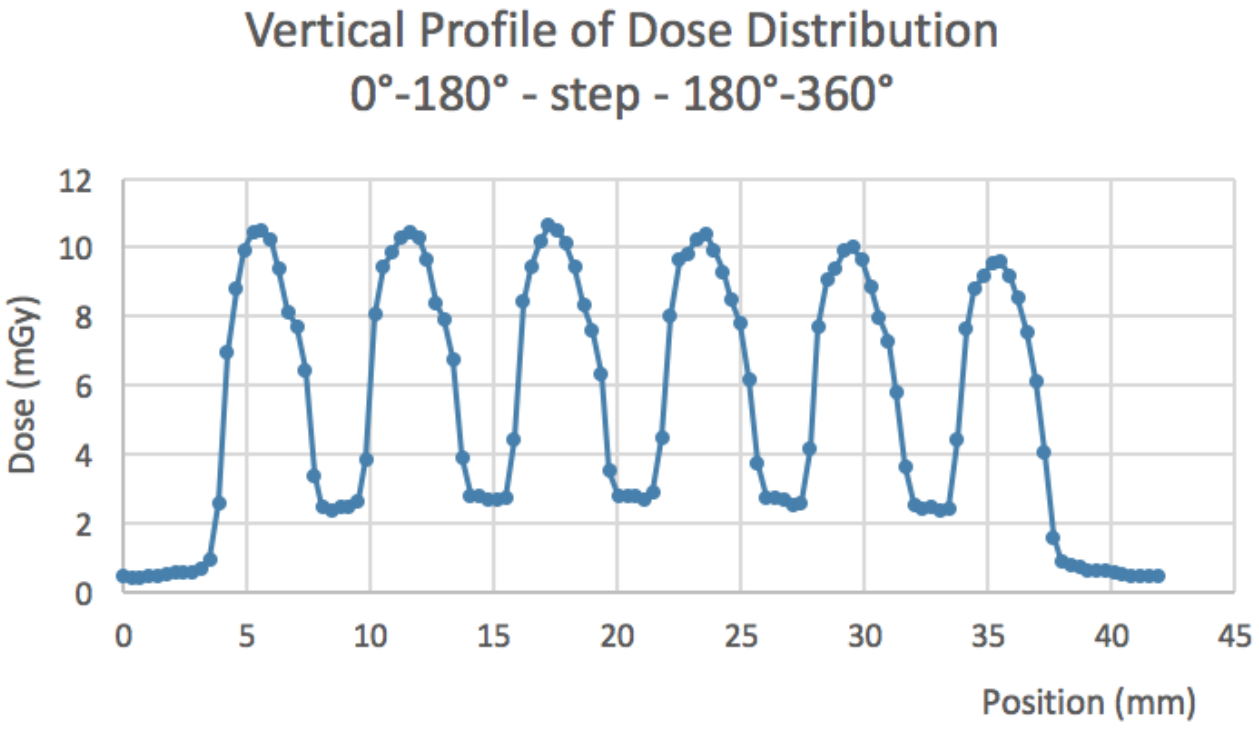
Profile of vertical dose distribution:



- Maximum peak-to-valley difference: 34% of the maximum dose.
- $MGD_t = 6.9$ mGy $\rightarrow$ Dose up to 120% of MGD_t.

0°-180°- STEP - 180°-360°

Profile of vertical dose distribution:



- Maximum peak-to-valley difference: 77% of the maximum dose.

CONCLUSIONS AND COMMENTS

We were able to measure the dose to the skin in different irradiation conditions:

- In 180°the non irradiated skin receives $> 10\%$ of the maximum dose;
- 0°-180°- step - 0°-180°gives high areas of superposition (with this step);
- 0°-180°- step - 180°-360°is a good intermediate irradiation (less superposition).

FUTURE MEASUREMENTS

In the future we would like to repeat the measure with...

- Different step between slices to study the superposition;
- Different energies;
- Different doses.

The End

Thank you for you kind attention!

WHAT IS THE MEAN GLANDULAR DOSE (MGD)?

- For the whole volume irradiated, MGD(mGy) is calculated from the total energy deposited (E_g) in the total glandular mass of the breast (M_g), as:

$$MGD = {}^{E_g}/_{M_g}$$

- For a partial irradiation, MGD_v (mGy) can be calculated from the energy (e_g) deposited only in the glandular mass of the directly irradiated breast volume (m_g), as:

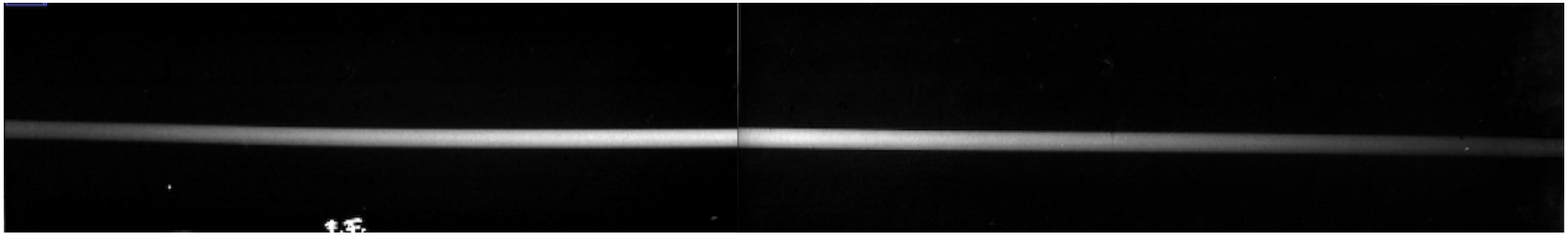
$$MGD_v = {}^{e_g}/_{m_g}$$

- Considering the scattered radiation coming outside of the irradiated volume, MGD_t is the ratio between the total energy deposited in the whole breast (E_g) and the glandular mass in the irradiated volume (m_g):

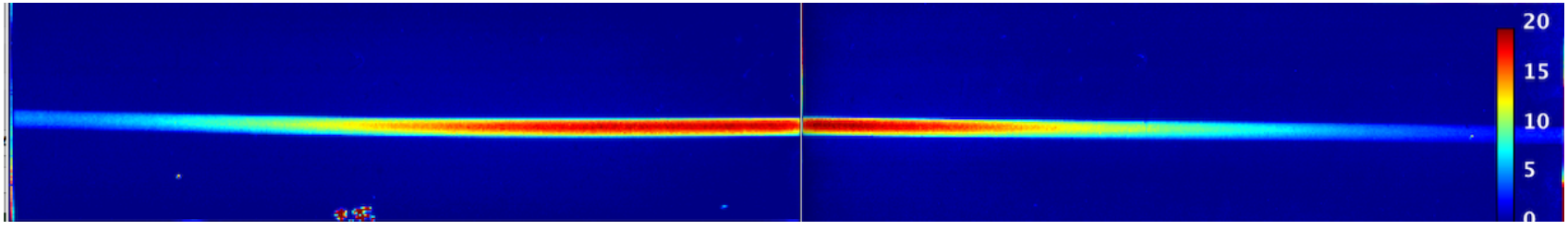
$$MGD_t = {}^{E_g}/_{m_g}$$

180°

Radiochromic film scan:



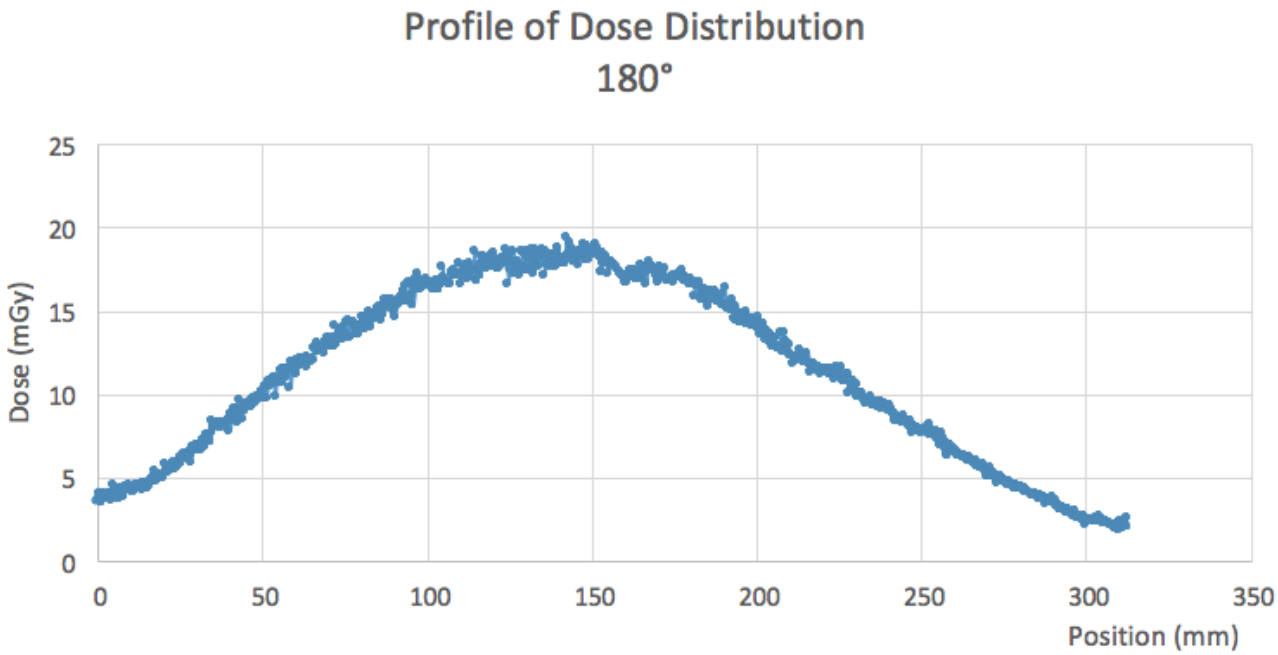
(k)



(l)

180°

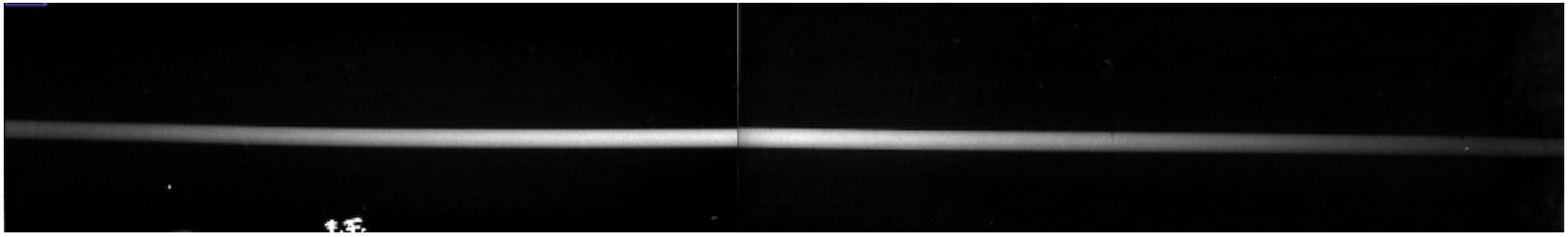
Profile of horizontal dose distribution:



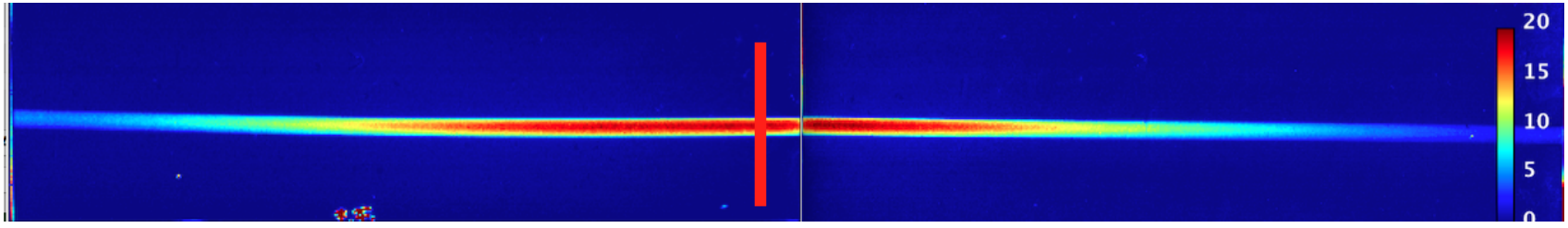
- Minimum dose: 9.5% of the maximum dose;
- MGD_v = 7,8 mGy $\rightarrow$ Dose up to 240% of MGD_v.

VERTICAL BEAM PROFILE

Profile of vertical dose distribution:



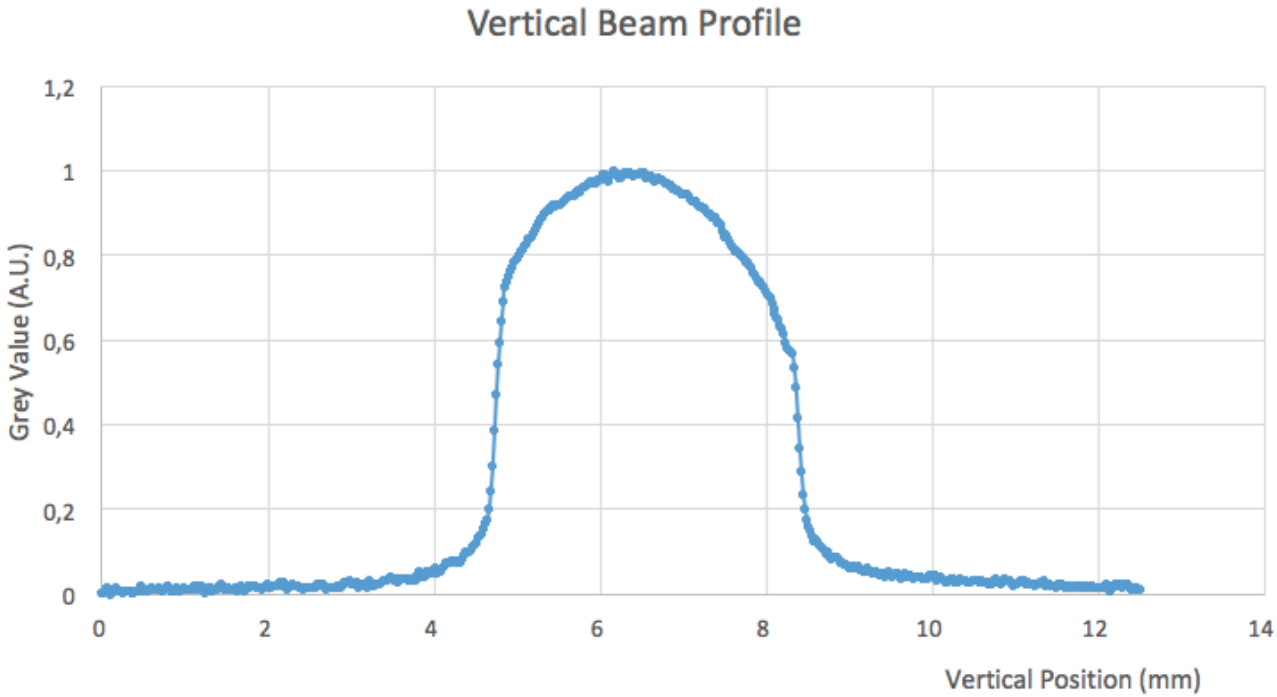
(m)



(n)

VERTICAL BEAM PROFILE

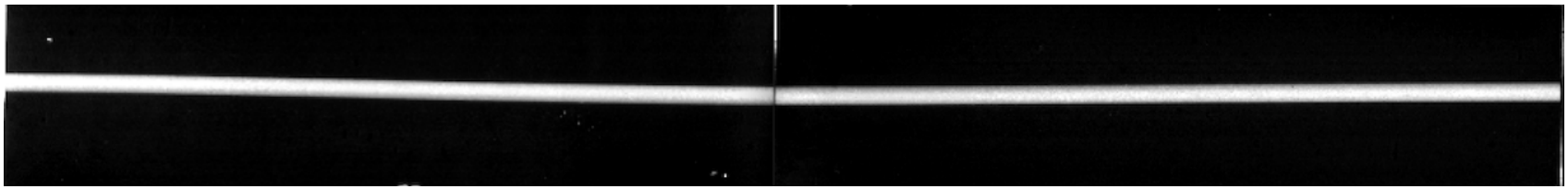
Profile of vertical dose distribution:



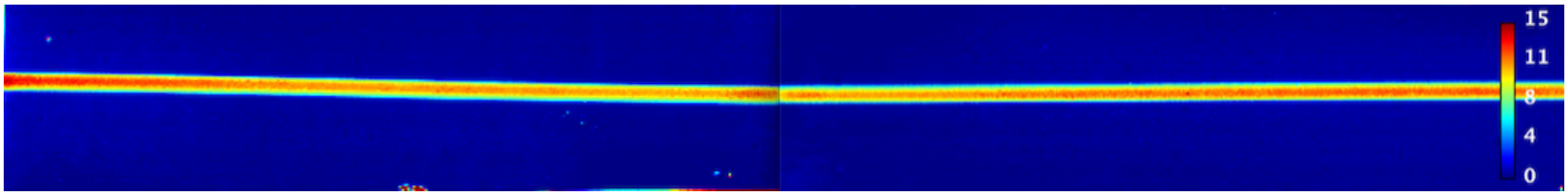
- 1200 dpi scan: 1 pixel=2 μm;
- FWHM=3,61 mm;
- Magnification: 20%.

360°

Radiochromic film scan:



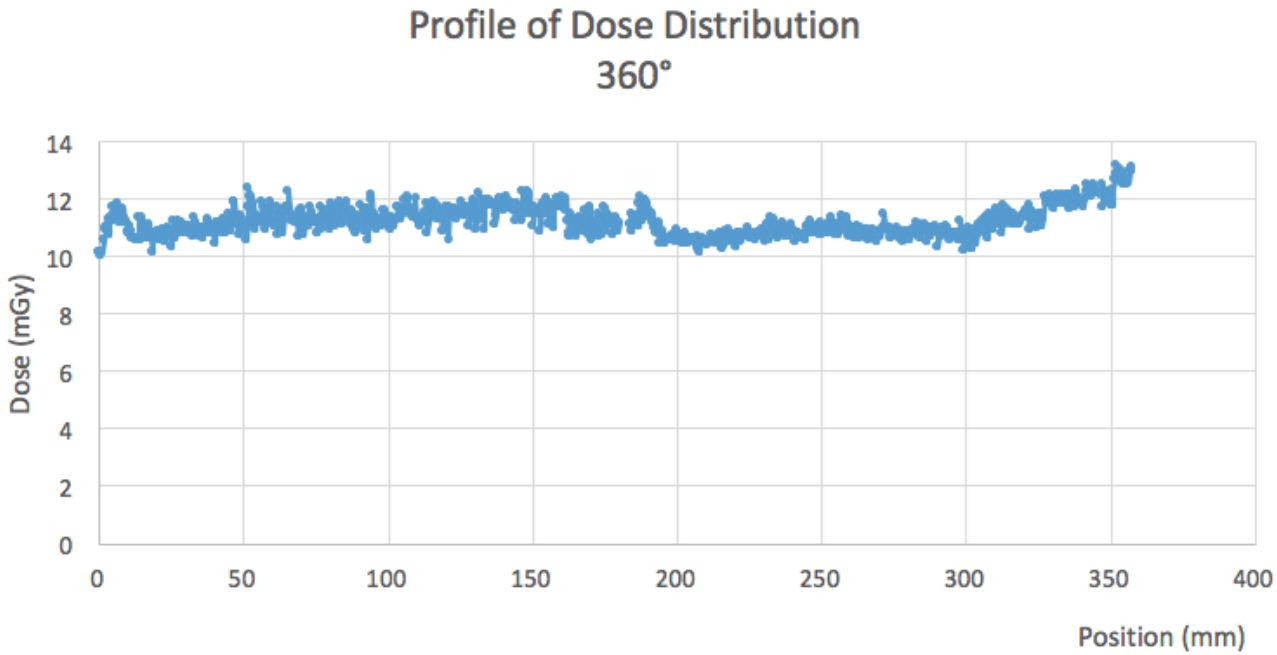
(o)



(p)

360°

Profile of horizontal dose distribution:



- Maximum variation: 24% of the maximum dose;
- $MGD_v = 7.8$ mGy $\rightarrow$ Dose 175% - 130% of MGD_v.

DOSE EVALUATION

The dose is proportional to the change in reflectance of the film:

- Films have to be scanned both before and after irradiation;
- PV (pixel value) change is evaluated as:

$$\Delta R = R_{before} - R_{after} = \frac{PV_{before}}{2^{16}} - \frac{PV_{after}}{2^{16}}$$

- A piece of control film is never irradiated:

$$\Delta R^{control} = R^{control}_{before} - R^{control}_{after} = \frac{PV^{control}_{before}}{2^{16}} - \frac{PV^{control}_{after}}{2^{16}}$$

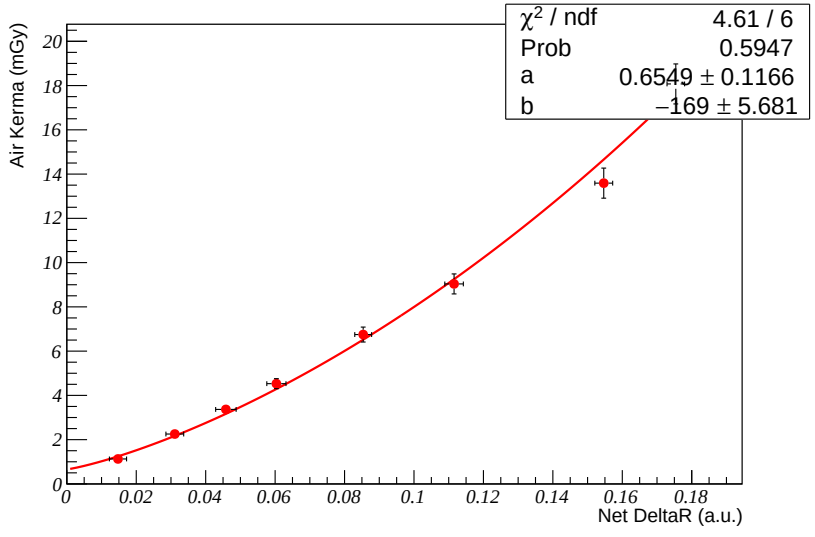
- The net change in reflectance is:

$$net\Delta R = \Delta R - \Delta R^{control}$$

CALIBRATION PROCEDURE

We want a dose-response curve for the specific energy (38 keV):

- Obtained plotting the air Kerma K^{film} as a function of the corresponding film response netΔR;
- 3 4×4 cm film pieces exposed at the same time;
- Different values if air-Kerma (1-20 mGy);
- Best fitting funtion logarithm one: $K^{film} = a + \frac{b\ net\Delta R}{\ln(net\Delta R)}$



Other QC Protocol Measurements

Ideas for other measurements:

- Air Slits and Vacuum Slits control;
- μ curve to verify energy;
- Phantom to verify bed movement;
- CTDI to check dose.