

Curso de Radioterapia Intraoperatoria

Utilaje de radioterapia intraoperatoria II-ELIOT

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ÍNDICE

- Opciones de IOeRT clásicas y actuales
- Radioprotección
- Características técnicas del acelerador lineal de electrones LIAC 10 MeV
- Breve repaso a las series de IOeRT y criterios del Hospital Clínic
- Diferentes pasos del procedimiento RIO con electrones
- Caracterización dosimétrica LIAC para el cálculo de UM

Opciones IOeRT clásicas

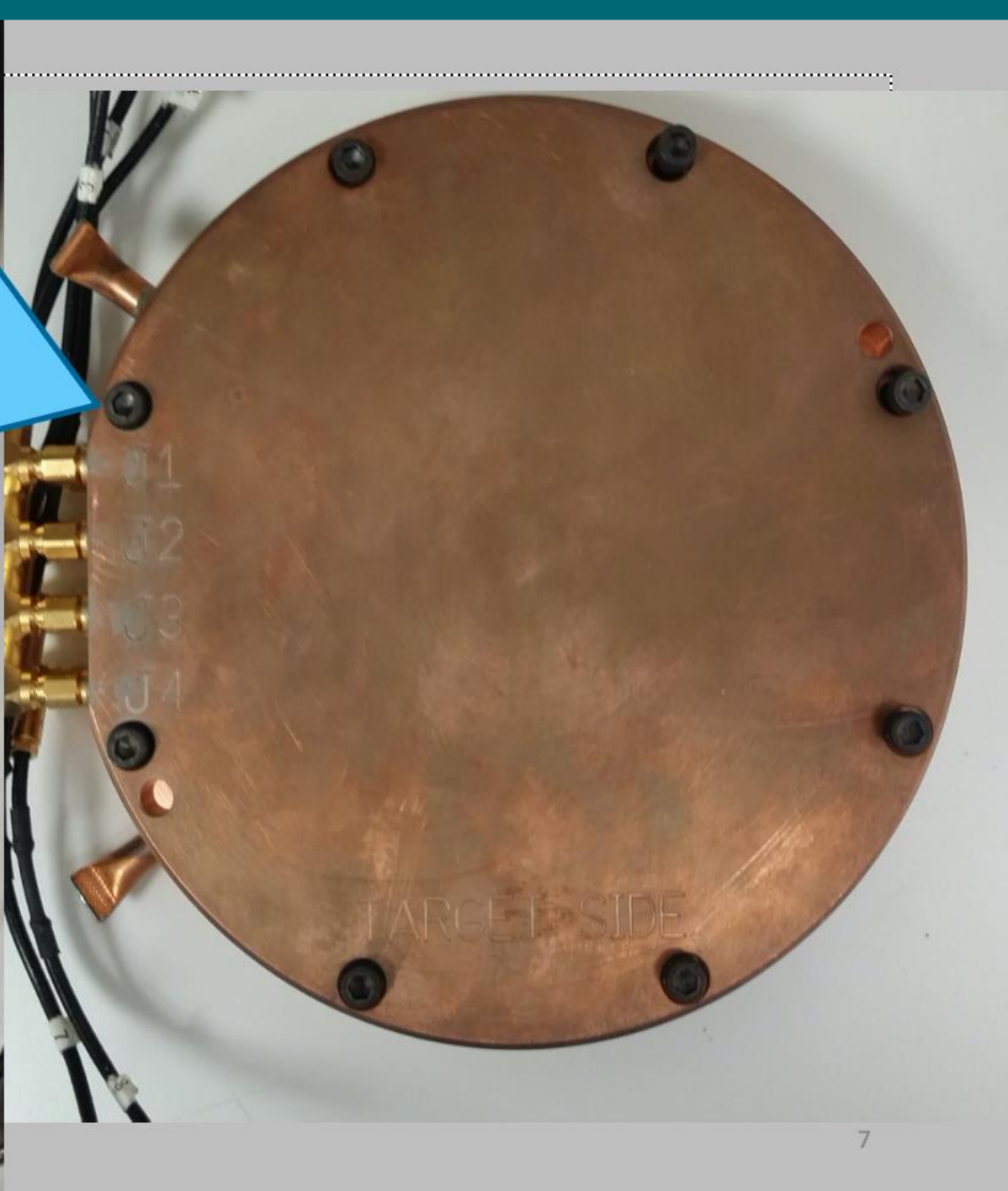
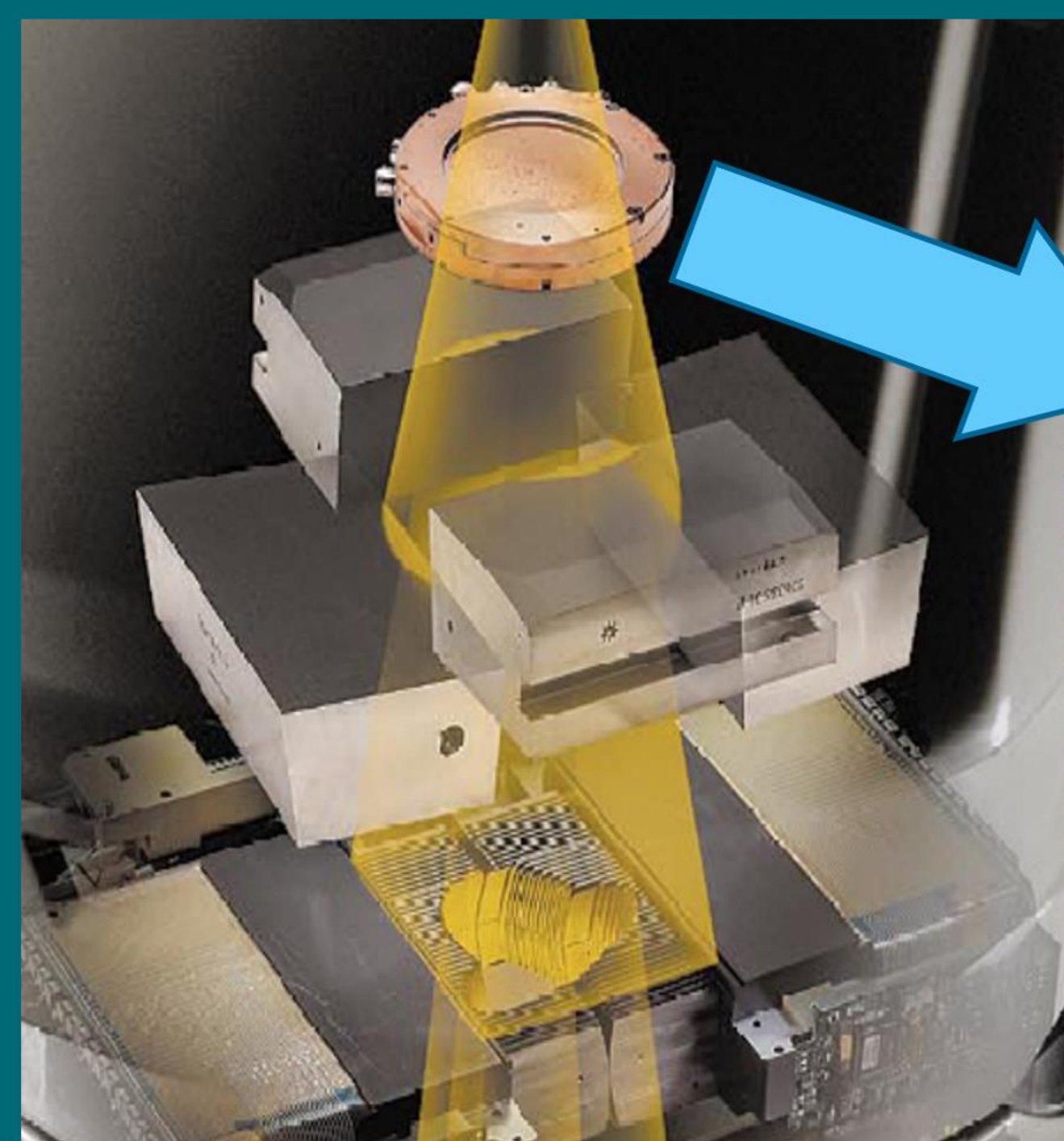
- desarrollos *in-house* con la colaboración de fabricantes
- esterilización bunker
- transporte del paciente abierto

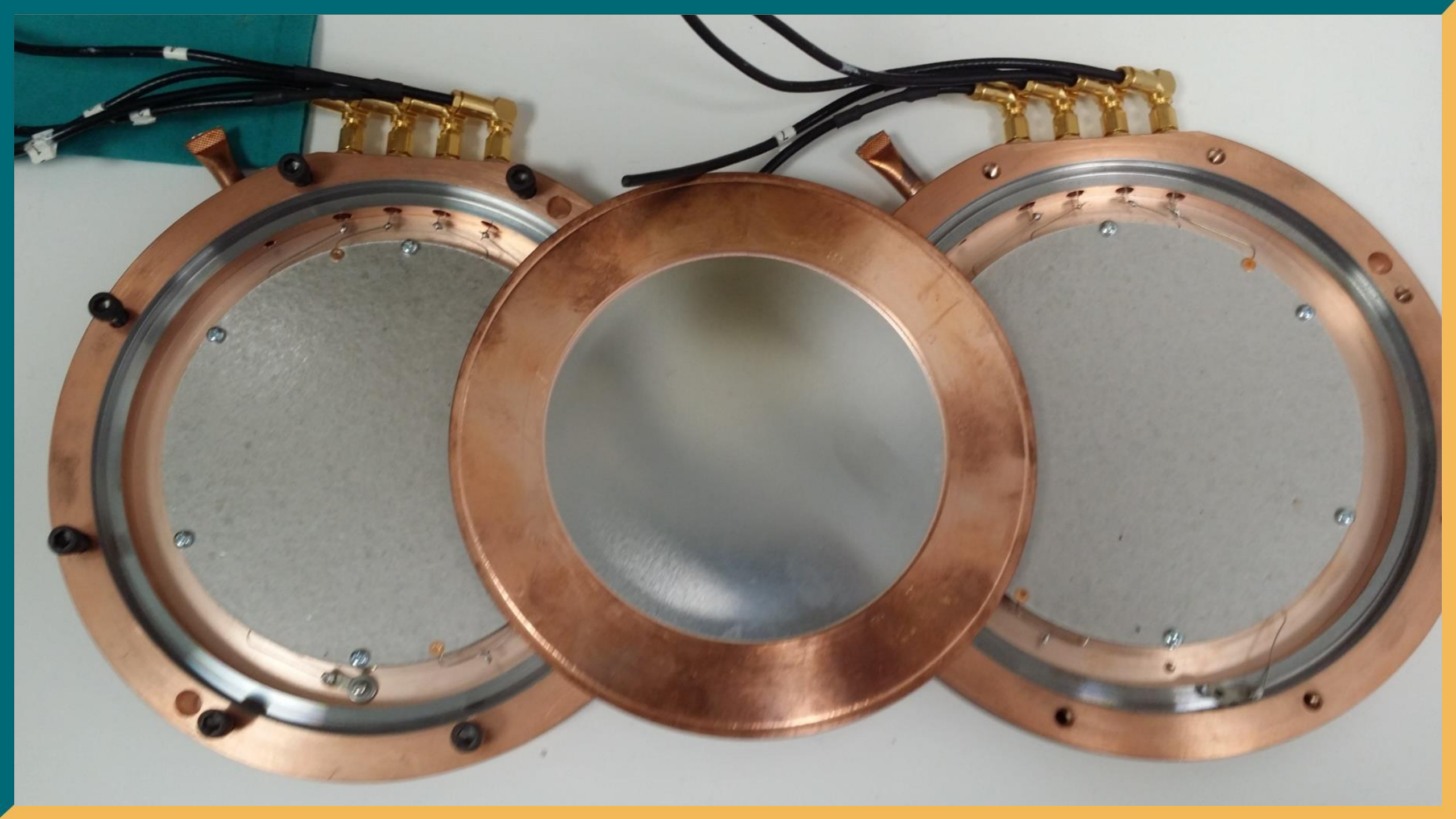


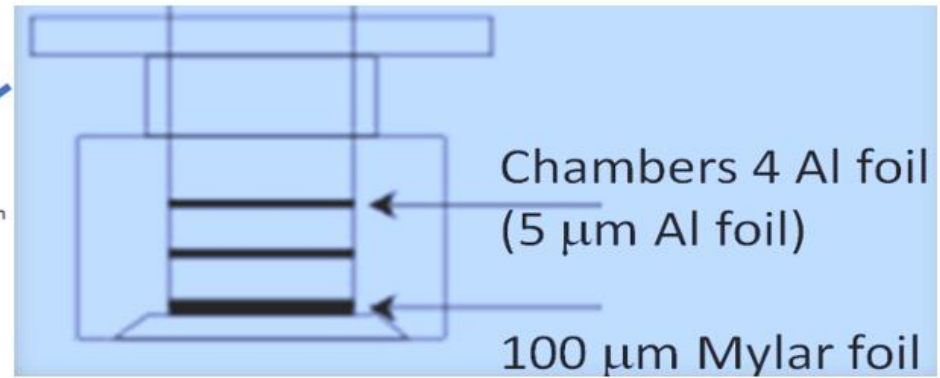
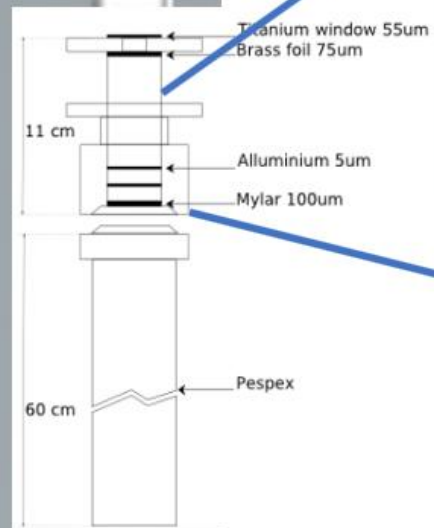
En quirófano es preferible una óptica diferente

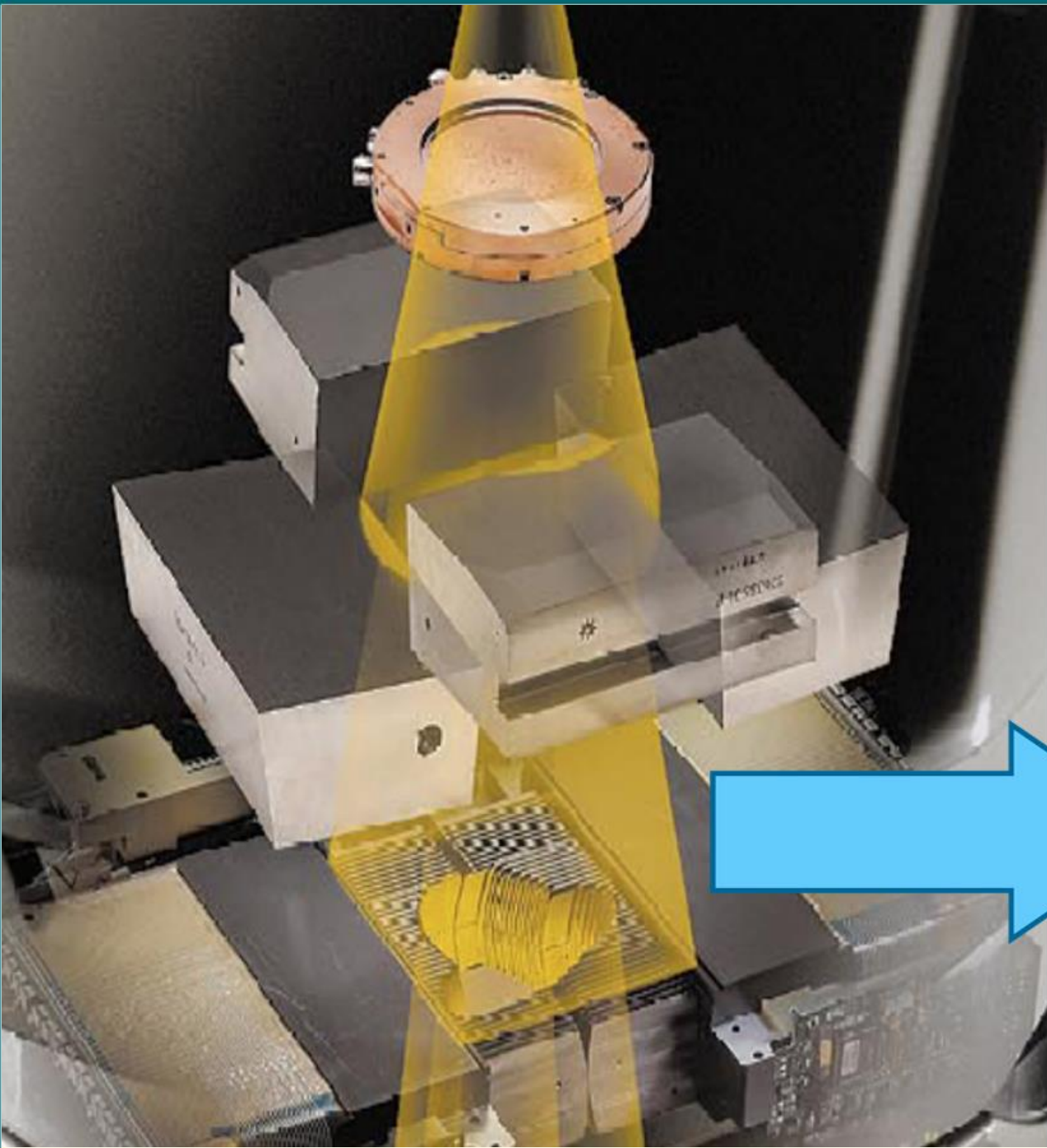




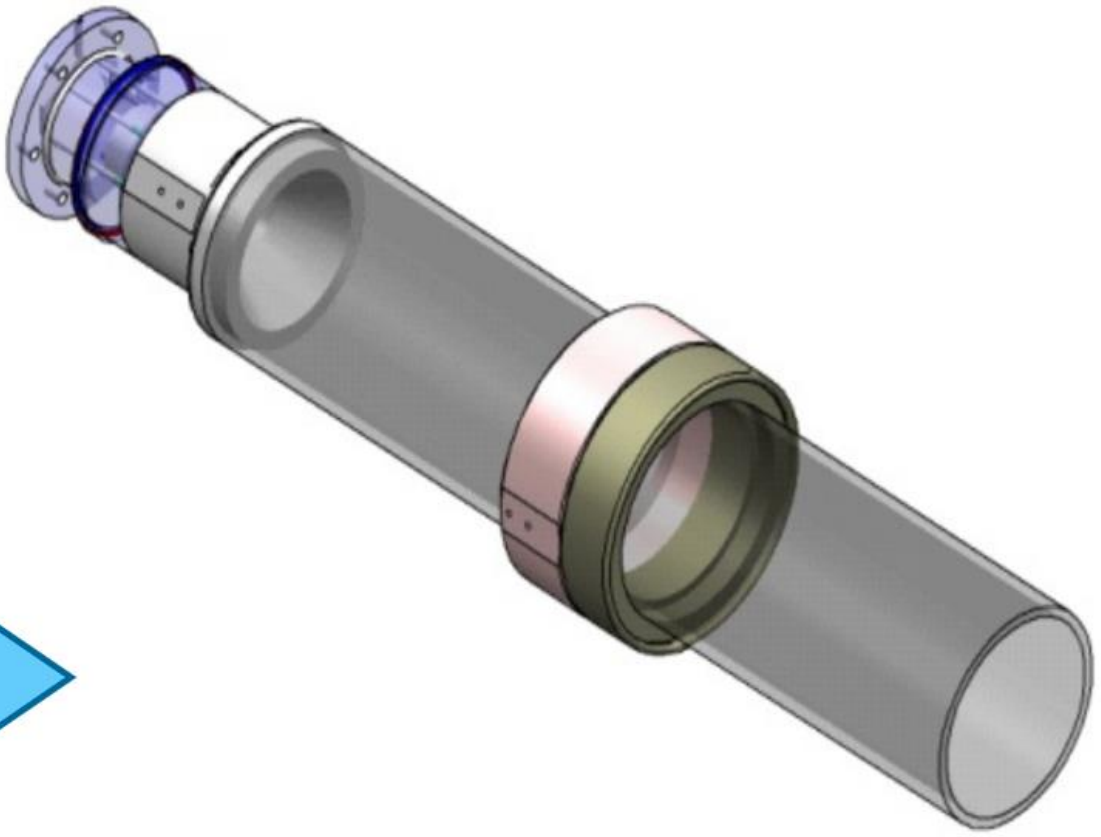








Aplicador de PMMA transparente



Opciones IOeRT



Las ópticas con elementos de bajo número atómico reducen bremsstrahlung

Aceleradores de intraoperatoria en España

- 2012 Hospital Clínic (Barcelona)
- 2013 Hospital General Universitario Gregorio Marañón (Madrid)
- 2018 Hospital Universitario Marqués de Valdecilla (Santander)
- 2018 Clínica Universitaria de Navarra (Pamplona)
- 2019 Hospital Universitari i Politècnic La Fe (Valencia)
- 2019 Hospital Universitario Ramón y Cajal (Madrid)

Radioprotección





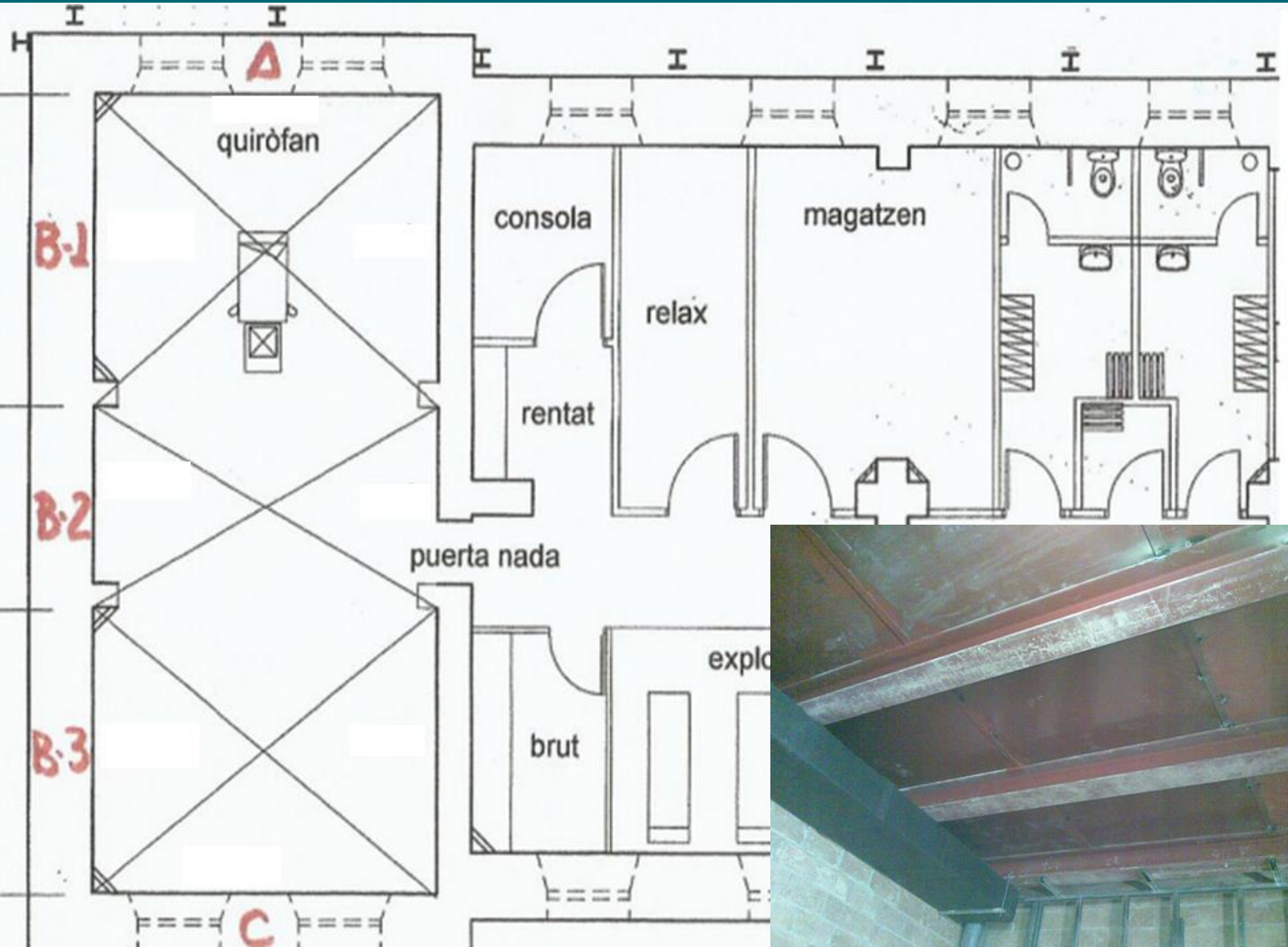


FORJADO = 25 cm

ZONA A
TECHO 6 MM. HIERRO
+ 8 CM HORMIGON
BARITADO

ZONA B
TECHO 6 MM. DE HIERRO
+ 7 CM HORMIGON
BARITADO

ZONA C
TECHO 6 MM. DE HIERRO
+ 4 CM HORMIGON
BARITADO



MURO HOSPITAL
95 CM

MURO HOSPITAL 80 CM
+ 14 CM HORMIGON BARITADO

+ 12 CM HORMIGON
BARITADO

+ 10 CM HORMIGON
BARITADO

+ 6 CM HORMIGON
BARITADO

B-1

B-2

B-3

2'2 cm
quiròfan

consola

magatzen

relax

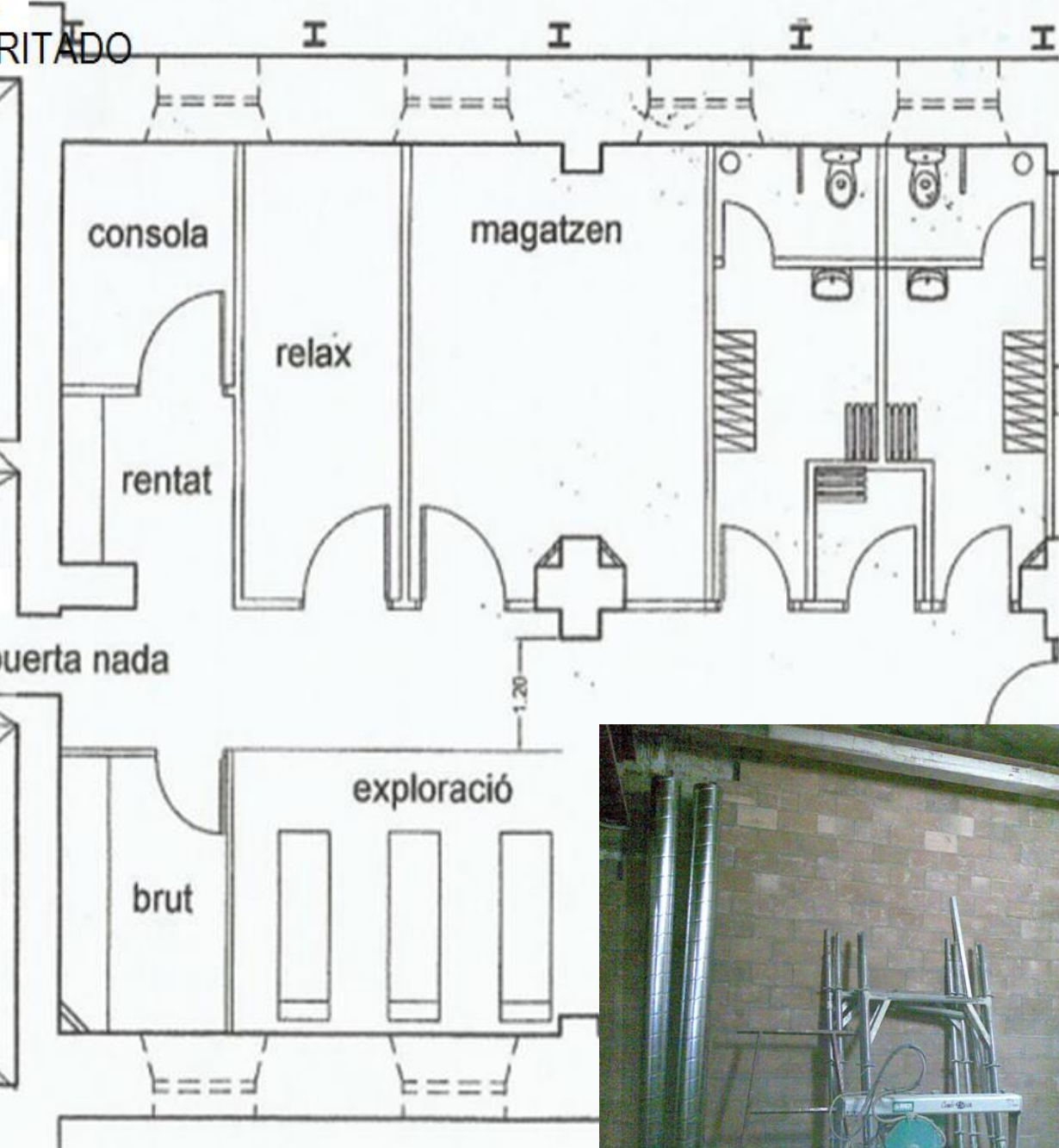
rentat

puerta nada

exploració

brut

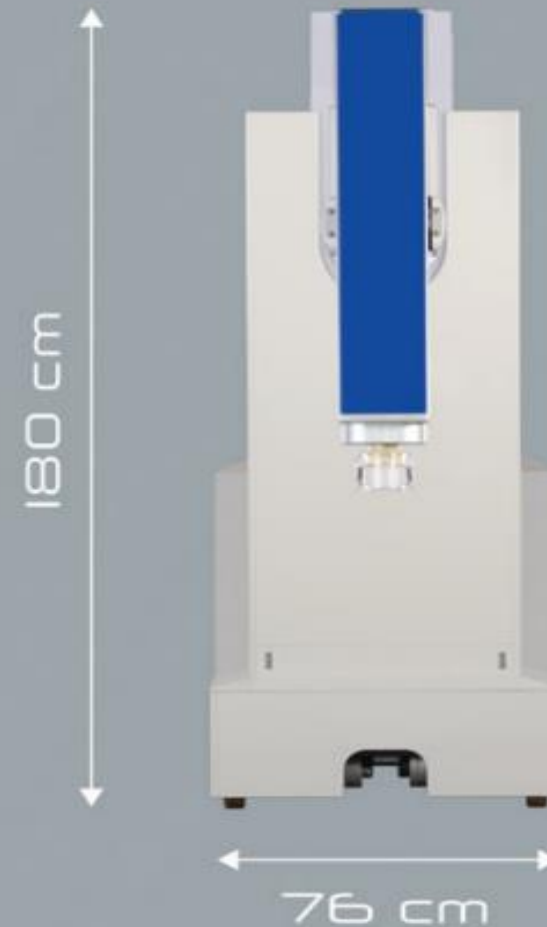
C







FEATURE	VALUE
Nominal Energies (model 12 MeV)	6, 8, 10, 12 [MeV]
Nominal Energies (model 10 MeV)	4, 6, 8, 10 [MeV]
Surface Dose	$\geq 85\%$ model 10 MeV $\geq 87\%$ model 12 MeV
Beam Current	≤ 1.5 [mA]
Field Dimensions	\emptyset : 3, 4, 5, 6, 7, 8, 10 [cm] Angles: $0^\circ, 15^\circ, 30^\circ, 45^\circ$
Flatness (maximum energy value)	$\leq 3\%$ \emptyset 10, 8, 7, 6 [cm] $\leq 9\%$ \emptyset 4, 5 [cm] $\leq 12\%$ \emptyset 3 [cm]
Symmetry (maximum energy value)	$\leq 3\%$
Applicator length	60 [cm]
Source Surface Distance (SSD)	71.3 [cm]
Dose rate (applicator \emptyset 10 cm)	3 ÷ 20 [Gy/min]
E-gun pulse duration	≤ 4 [μ s]
Long term stability	$\leq 3\%$
Short term stability	$\leq 1\%$
Linearity	$\leq 1\%$
Stray X-radiation (PDD Bremsstrahlung tail)	$\leq 0.7\%$



MOBILE UNIT

Length	210 [cm] 82.68 [inch]
Width	76 [cm] 29.92 [inch]
Height	180 [cm] 70.87 [inch]
Weight	400 [kg] 882 [lb]

CONTROL UNIT

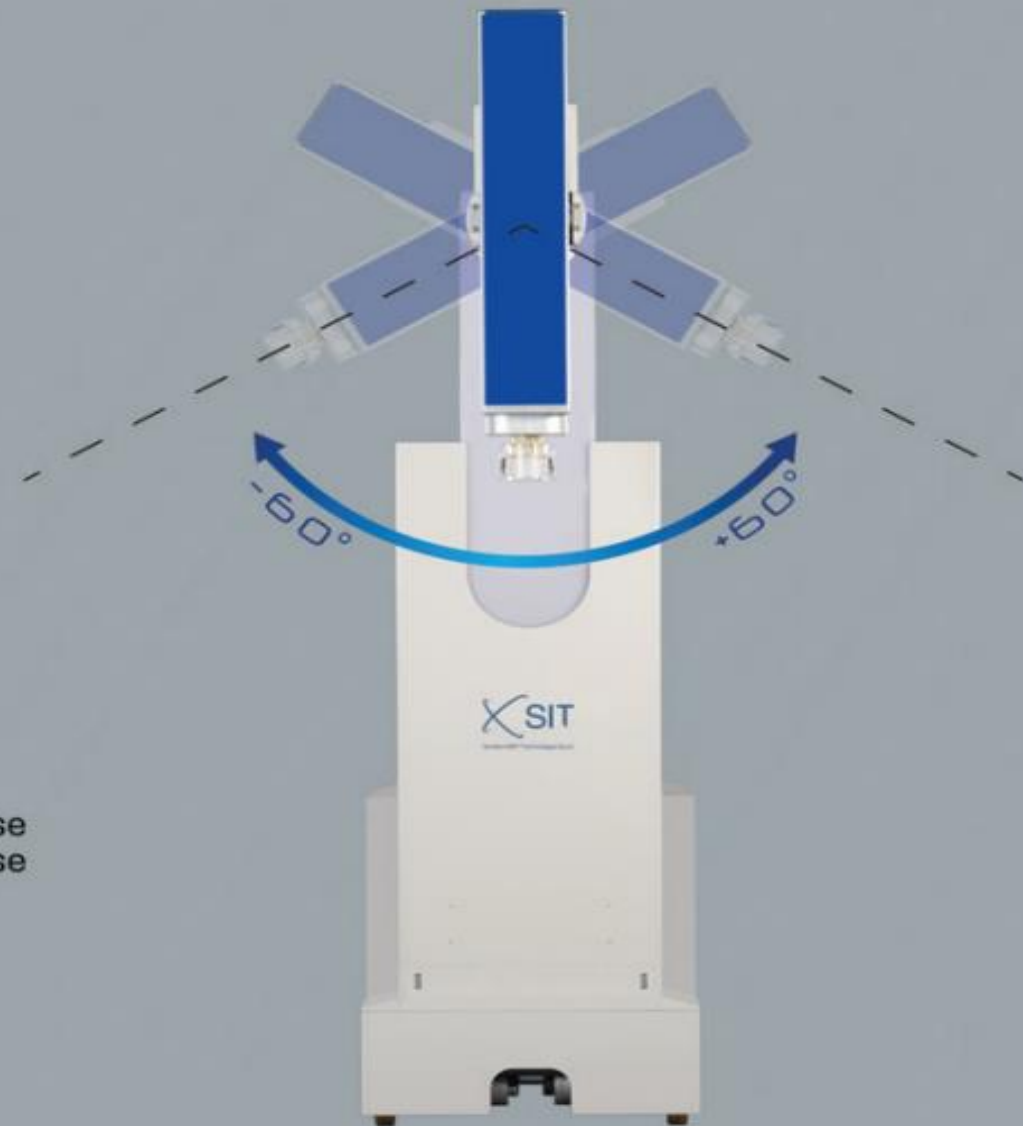
Length	80 [cm] 31.50 [inch]
Width	60 [cm] 23.62 [inch]
Height	120 [cm] 47.24 [inch]
Weight	120 [kg] 265 [lb]

ELECTRICAL SPECIFICATIONS

Maximum environmental temperature	25 [°C] 77 [°F]
Power dissipated (heating load)	≤ 2.5 [kW]
Power supply	3 [kVA] 230 [Vac] 50 [Hz] 1 phase 3 [kVA] 110 [Vac] 60 [Hz] 1 phase

ACCESSORIES

Mobile radioprotection barrier	HVL,TVL (lateral) beam absorber (horizontal)
Patient Radioprotection Disc PATENTED	Ø: 4, 5, 6, 7, 8, 9 [cm]





Elevation 90 cm



Pitch angle $+30^\circ - 15^\circ$



Applicators are available in diameters from 30 to 100 mm (120 mm upon request), and bevel angles of 0°, 15°, 30° and 45°.



0°



15°

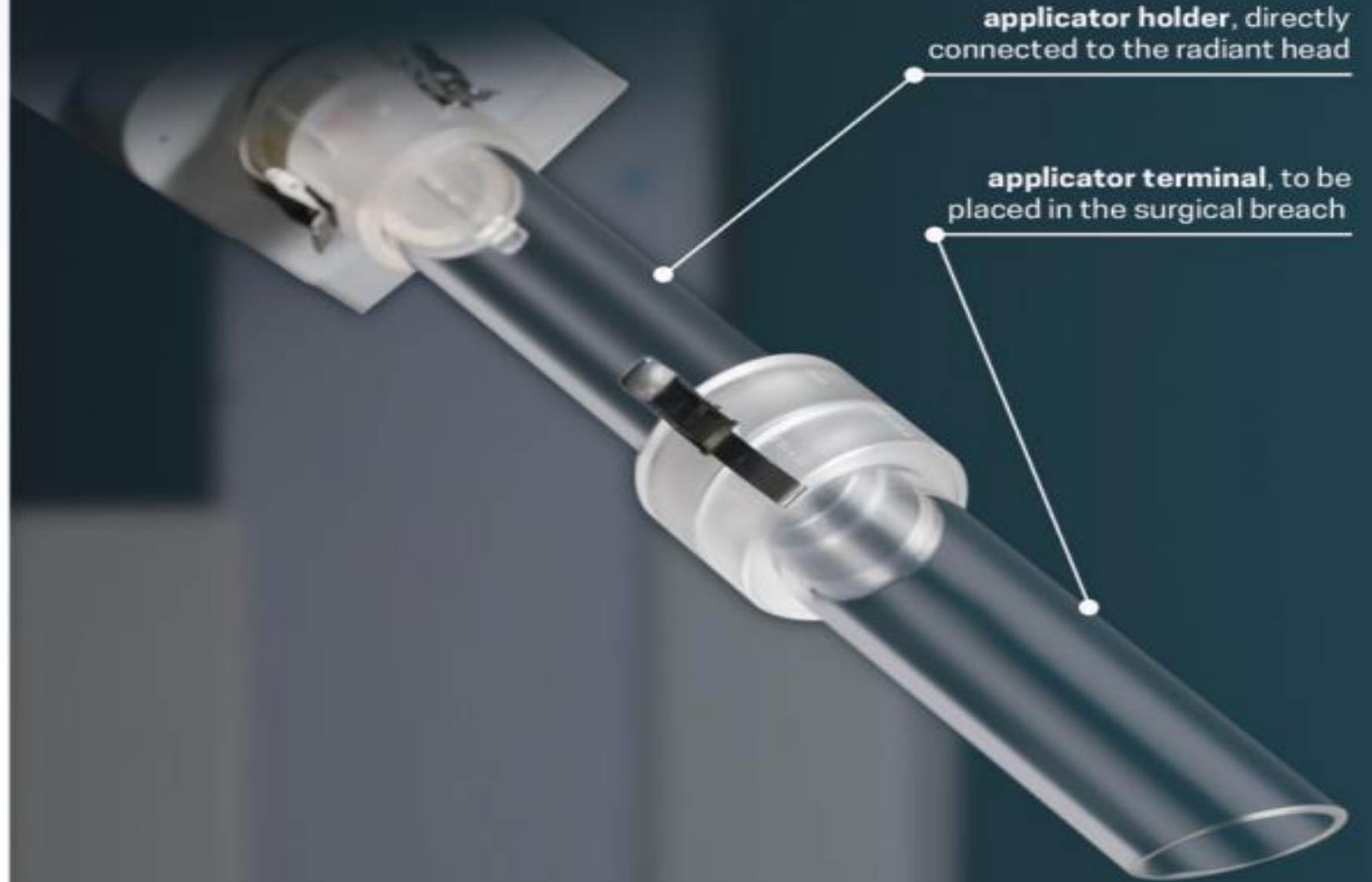


30°



45°

The applicator is made of two parts that are connected during the hard-docking phase:





Series IOeRT y criterios de inclusión Clínic

IOeRT as BOOST

STUDY	TREATMENT	NUMBER OF PATIENTS TREATED	LOCAL CONTROL
Sequential Intervention Study	IOeRT BOOST (9 Gy at 90% isodose) + external standard RT of 51-56.1 Gy (1.7 Gy per fraction)	190	100% (1) 4.3 years follow up
	external standard RT of 51-56.1 Gy (1.7 Gy per fraction) + external BOOST of 12 Gy	188	95.7% (1) 6.9 years follow up
First IOeRT Boost Experience	IOeRT BOOST (12 Gy at 90% isodose) + hypofractionated external RT 37.05 Gy (13 fractions of 2.85 Gy per fraction)	211	100% (2) 1 year follow up
ISiORT Pooled Analysis	IOeRT BOOST (10 Gy at 90% isodose) + external standard RT of 50-54 Gy (1.7-2 Gy per fraction)	1109	99.2% (3) 6 years follow up
HIOB Protocol: First Results	IOeRT BOOST (10 Gy at 90% isodose) + hypofractionated external RT 40.5 Gy (15 fractions, 2.7 Gy per fraction)	645	100% (4) 1 year follow up
Case Series Results of a Locally Advanced Breast Cancer (LABC) Post Induction Chemotherapy	IOeRT BOOST (9 Gy at 90% isodose) + external standard RT of 51-57 Gy (1.7-1.8 Gy per fraction)	83	98.5% (5) 5 years follow up
	external standard RT of 51-57 Gy (1.7-1.8 Gy per fraction) + external BOOST (12 Gy, 2 Gy per fraction)	26	88.1% (5) 5.7 years follow up
Triple-negative Breast Cancer Experience *	IOeRT BOOST (9.6 Gy median Dmax) + external standard RT (median total dose of 54 Gy)	71	93% (6) 8.1 years of follow up

IOeRT as SINGLE DOSE

TREATMENT	PATIENTS SELECTION CRITERIA	NUMBER OF PATIENTS TREATED	LOCAL CONTROL
21 Gy prescribed at 90% of isodose	SUITABLE PATIENTS ASTRO guidelines	294	98.5% (8) 5.8 years follow up
21 Gy prescribed at Dmax (18.9 Gy at 90% of isodose)	SUITABLE PATIENTS ASTRO guidelines	226	99.6% (9) 46 months follow up
21 Gy prescribed at 90% of isodose	SUITABLE PATIENTS ASTRO guidelines	758	98.8% (10) 5.2 years follow up

ASTRO GUIDELINES UPDATE: broader selection criteria

In September 2016, ASTRO published the Update of the Accelerated Partial breast Irradiation (APBI) Consensus Statement in order to provide a guidance on use of IORT for Partial Breast Irradiation (PBI) in early stage breast cancer [7]. On the basis of the published evidence and the mature results obtained thanks to the 5.8 years follow-up of the ELIOT trial, it has been recognized the efficacy of performing the IORT with electrons. In details, the ASTRO society stated the following recommendations:

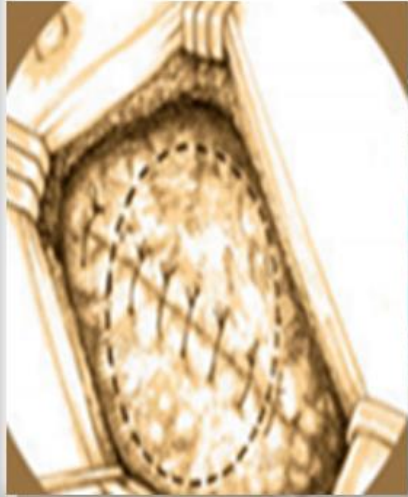
- IORT with electrons (IOeRT) can be used in the clinical practice outside of a clinical trial for the suitable group of patient;
- IORT with low energy x-rays can never be used outside of a clinical trial.

4. Hypofractionated WBI plus IOERT-boost in early stage breast cancer (HIOB): Updated results of a prospective trial, Fastner G, Reitsamer R, et al., Radiother Oncol. Vol.115 (Supplement 1):S233-4, 2015.

5. IOERT as anticipated tumor bed boost during breast-conserving surgery after neoadjuvant chemotherapy in locally advanced breast cancer-Results of a case series after 5-year follow-up, Fastner G. et al., Int. J. Cancer, Vol. 136, pp. 1193-1201, 2015. DOI: 10.1002/ijc.29064

Criterios de inclusión facilitados por Dra.Oses	RIO Boost	RIO Exclusiva
Carcinoma	Ductal o lobulillar infiltrante de mama	ductal infiltrante de mama (o tubular, coloide, mucinoso, medular)
Cirugía	cirugía conservadora (tumorectomía o segmentectomía)	cirugía conservadora de mama
Edad	cualquier edad	≥ 60 años
tamaño tumoral	< 35 mm	20 – 25 mm
márgenes	Libres > 2 mm	libres > 2 mm
multicentricidad/multifocalidad	unicéntrico, puede ser multifocal pero que no contraindique la cirugía conservadora	unicéntrico y unifocal
grado histológico	cualquiera	I o II
receptores hormonales	positivos o negativos	Positivos
her2	positivo o negativo	negativo
Ki67	cualquiera	< 10 %
ganglios	pueden tener positivos	negativos

Diferentes pasos del procedimiento



Preparación lecho +
colocación disco 6 min



4

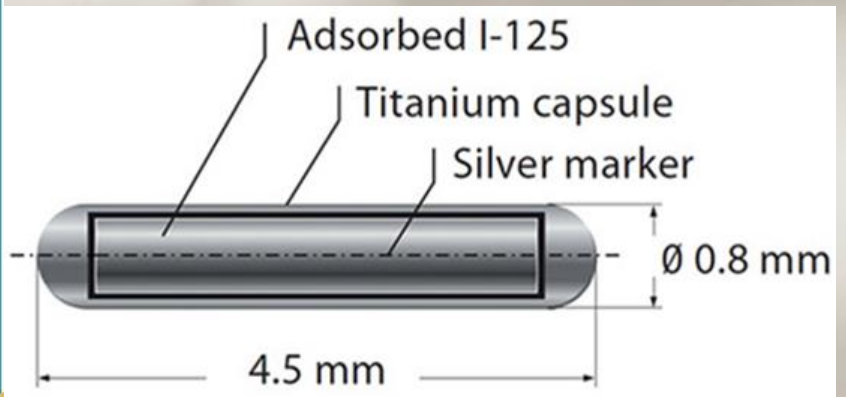
Docking 5 min



5

Programación e irradiación 2 min





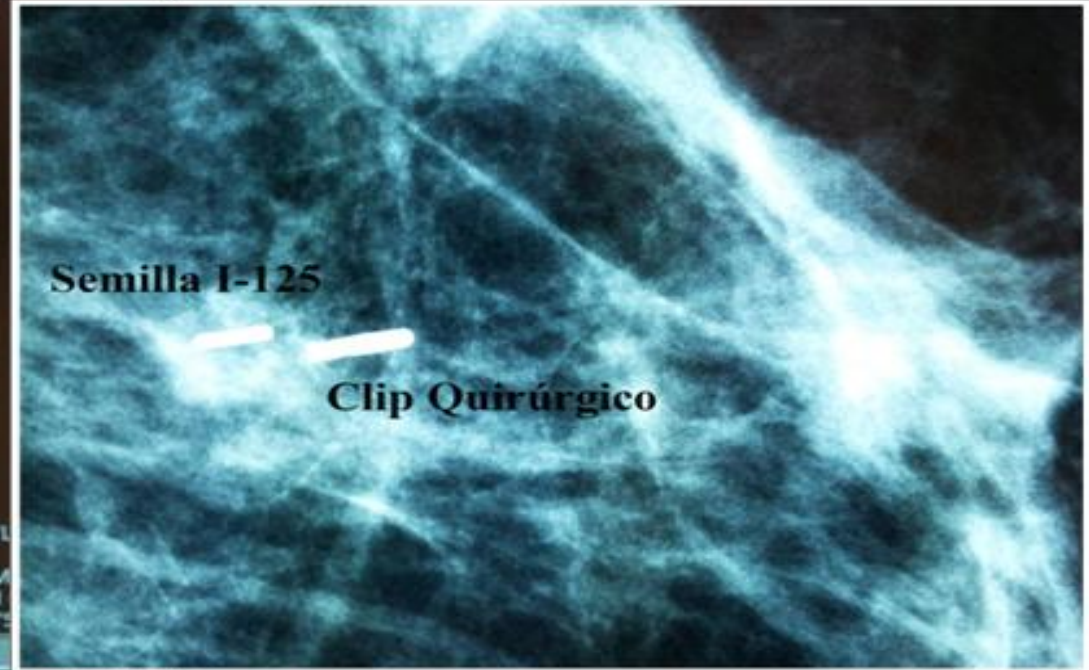
H. Clinic

Op: LI

DOB: Jun 04 1946 Age: 072Y F
Id: 5021746

Exam: Nov 27 2018, 10:42:46

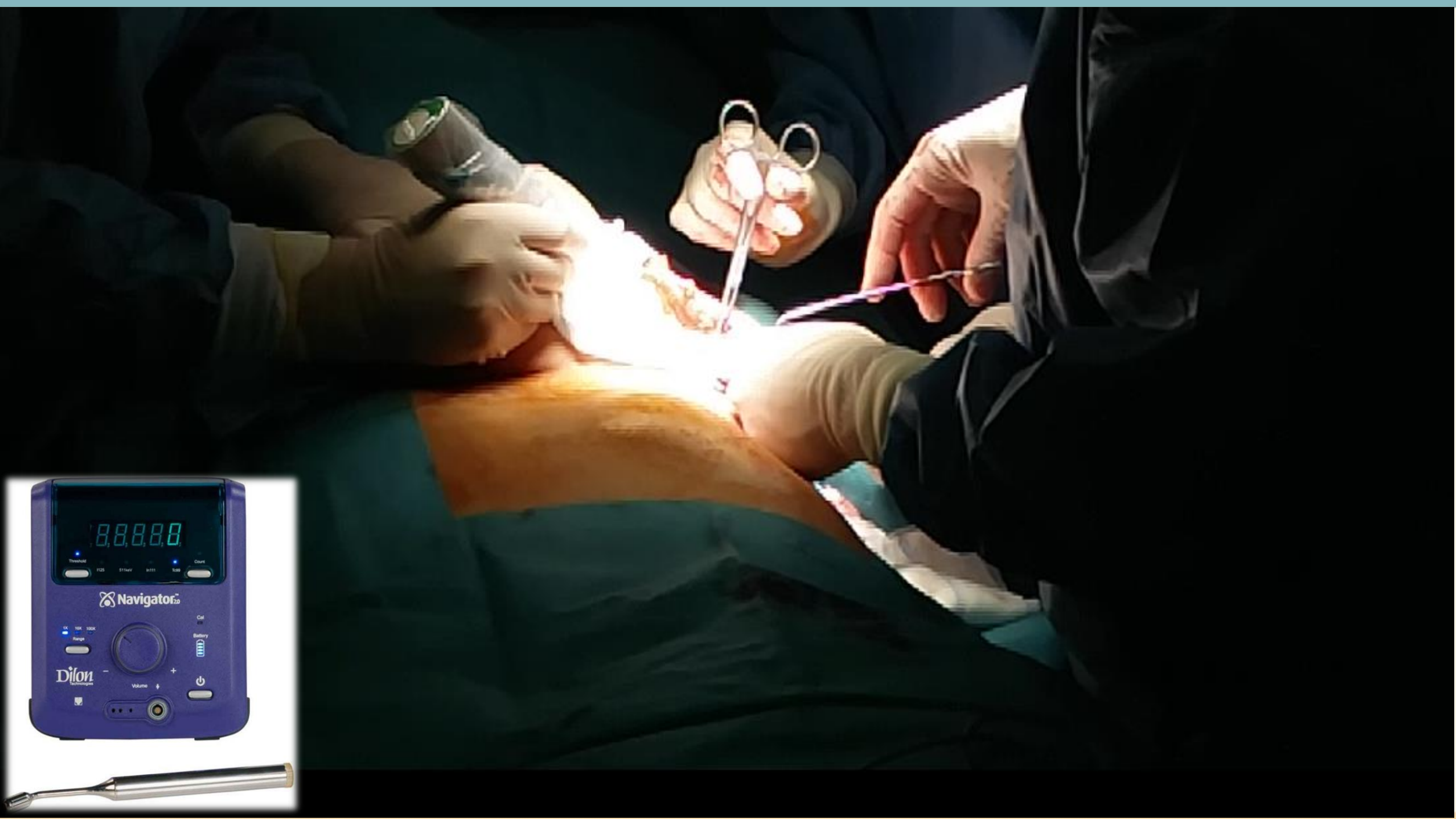
L
LM

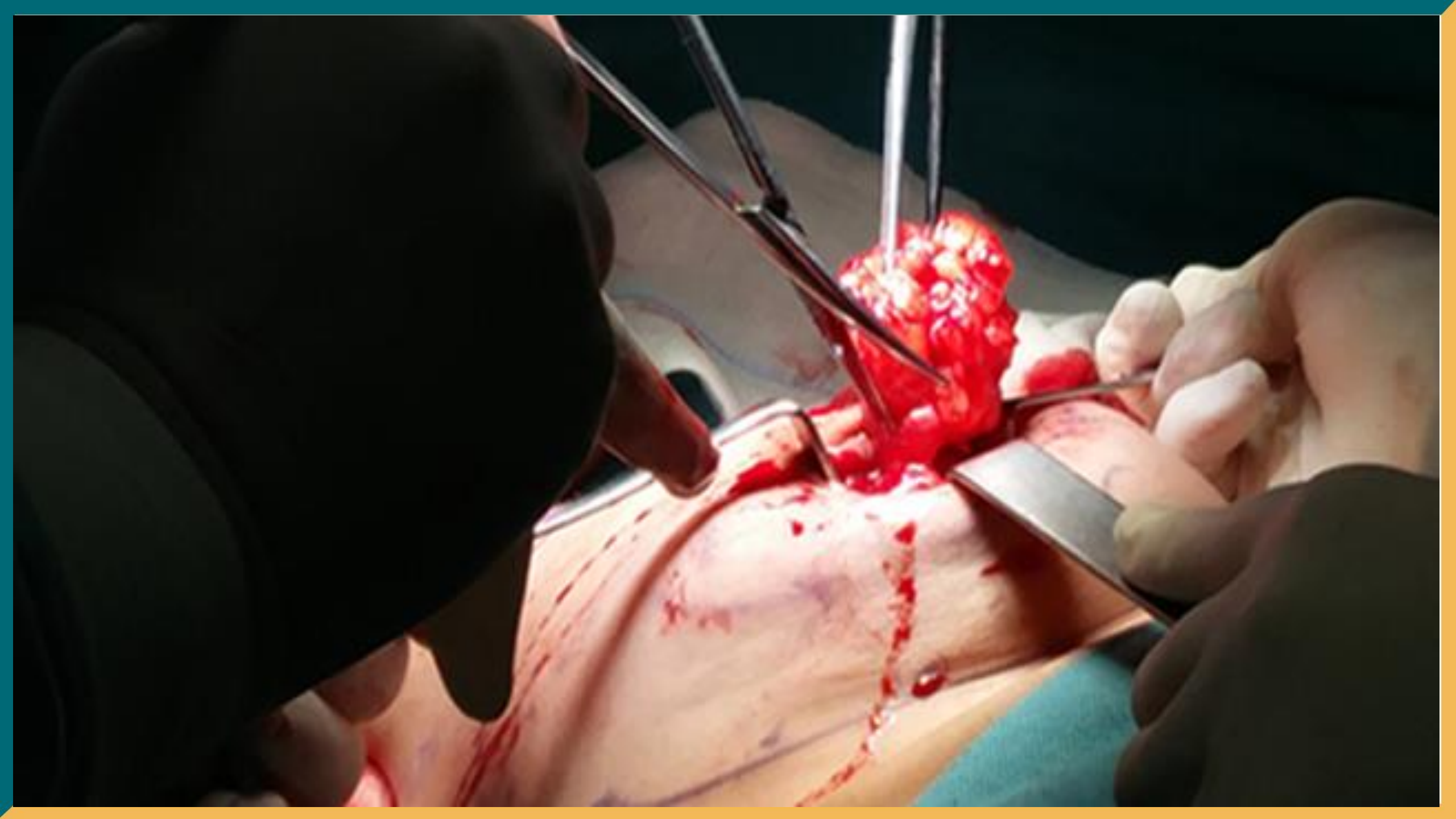


Semilla I-125

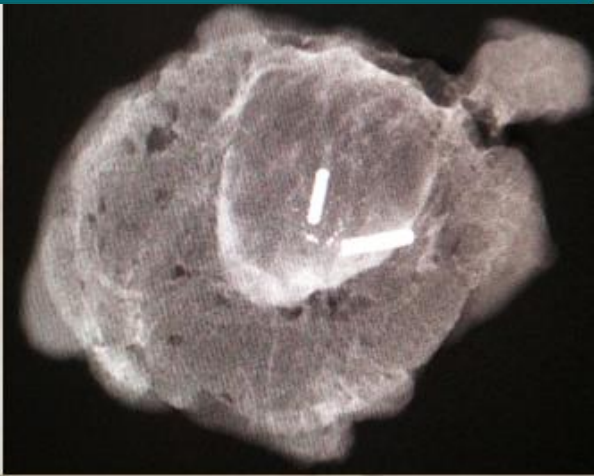
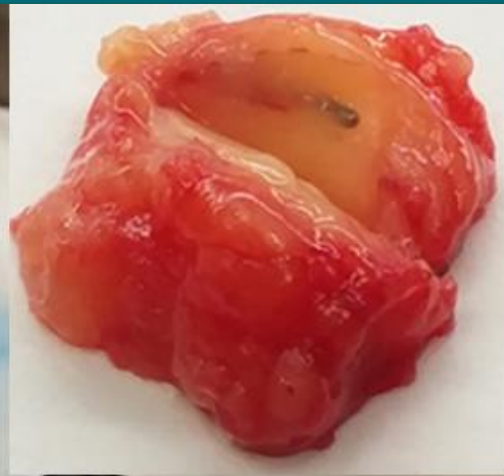
Clip Quirúrgico

WW: 900 WL
Zoom = 1.00 ROT:
Inc: 90 AGD: 1.64 mGy ESE: 8.27 mGy 0.3 Processed PREMIUM
29 kV 84 mAs Rh/Rh Grid AOP/STD 9 daN
GE MEDICAL SYS









CLÍNICA
BARCELONA
Hospital Universitari

Incisión quirúrgica

Separación de la piel

Resección del tumor

Desprendiendo la glándula

Extracción ganglio + medida ex-vivo

Extracción ganglio + medida ex-vivo

separación de la piel

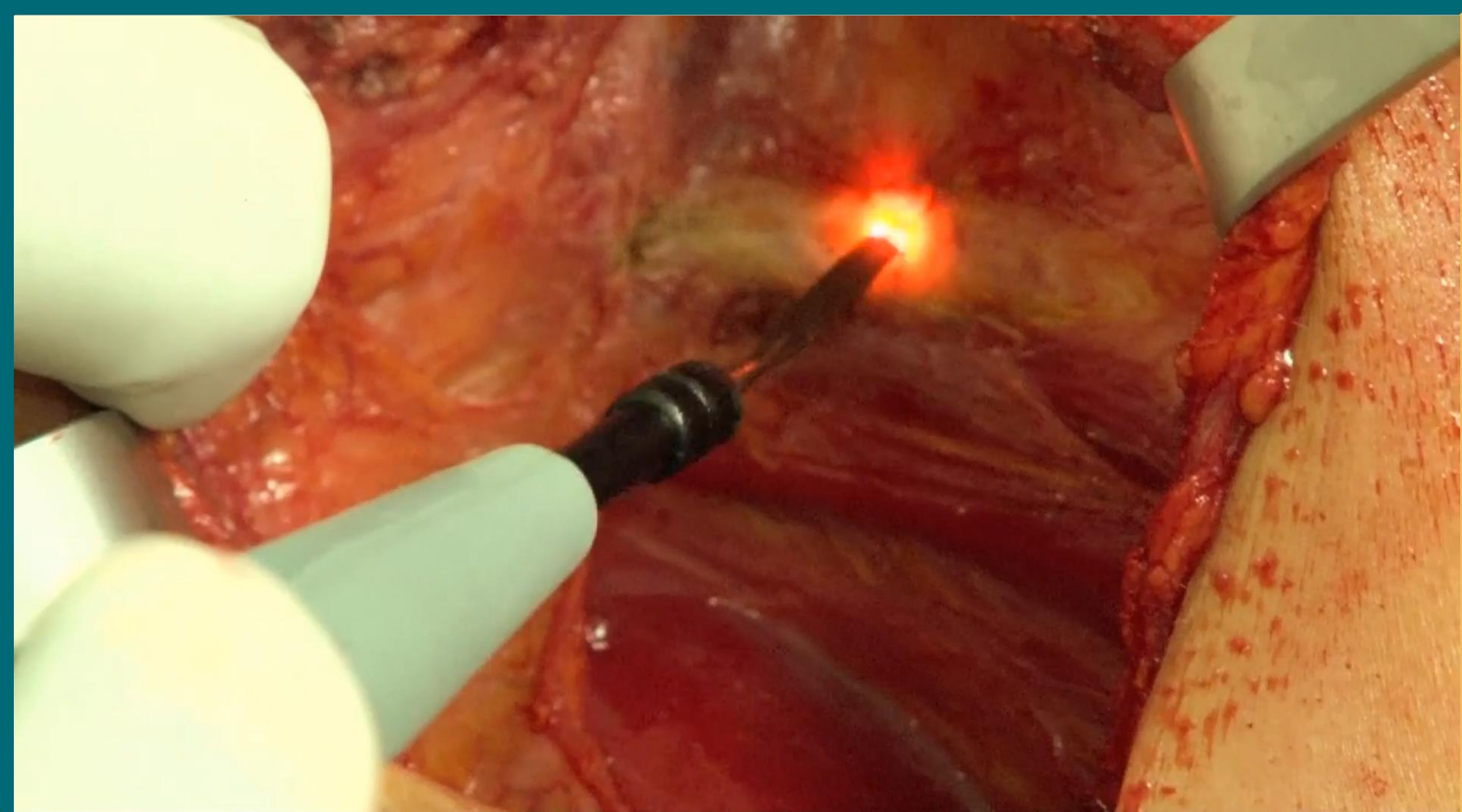
Introducción del disco de protección

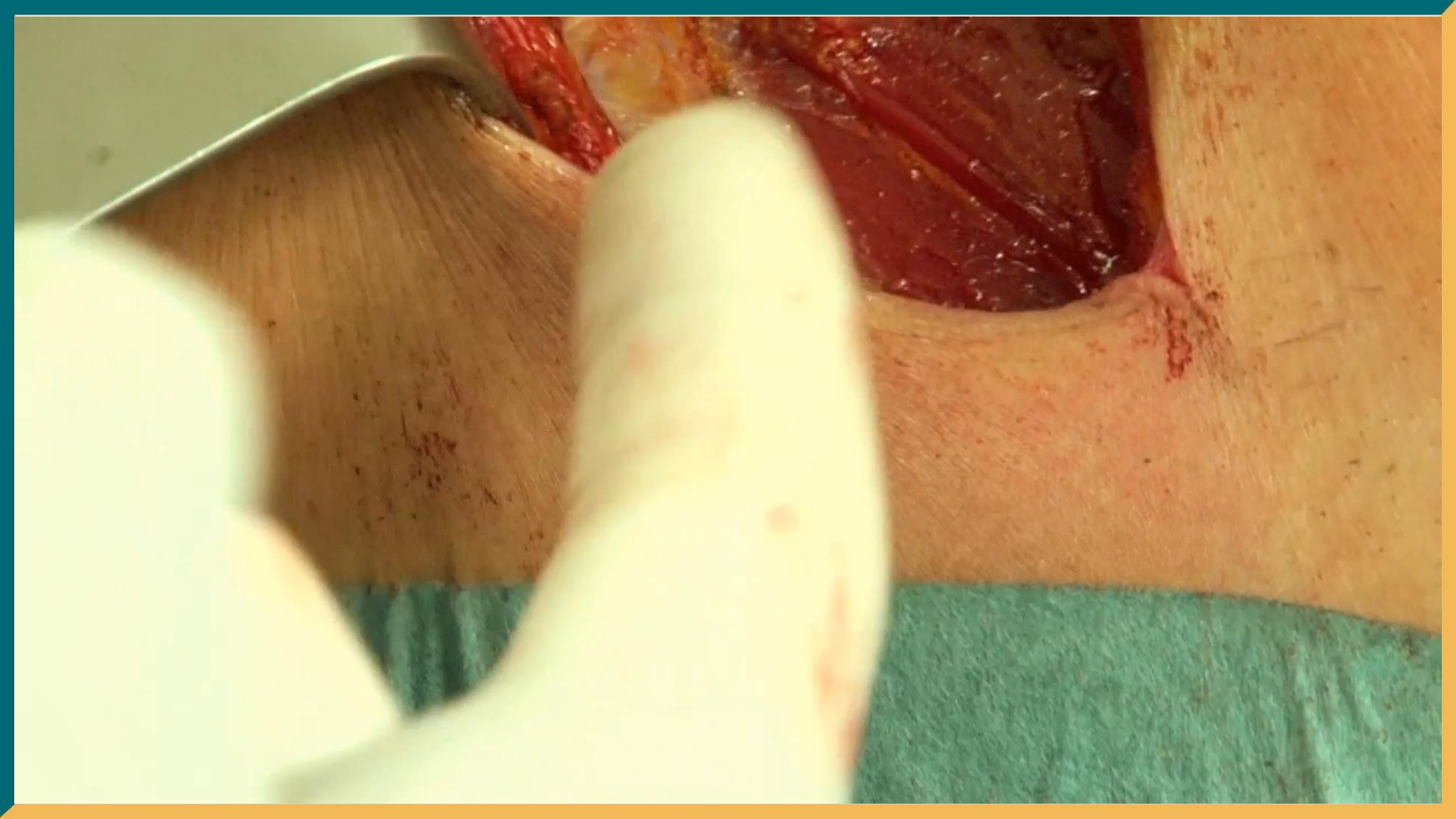
sutura













Discos suturables de radioprotección

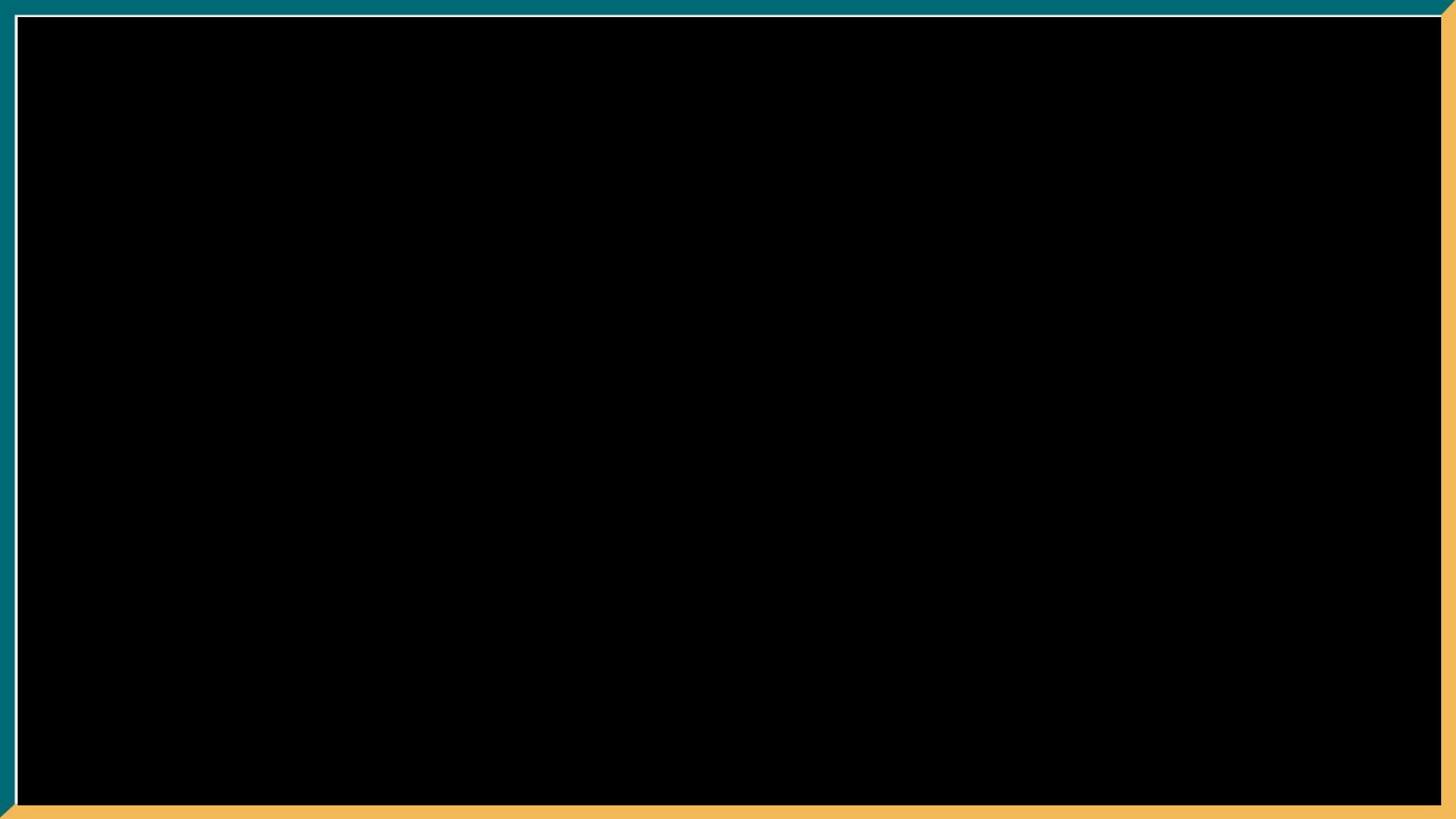


- Los cuatro agujeros del anillo plástico permiten suturar el disco para evitar desplazamiento durante la irradiación
- Un disco de acero AISI 316 L
- Un disco de politetrafluoroetileno (PTFE) más conocido como Teflón[®]

Materials	Density (g/cm ³)	Thickness
AISI 316L steel	8	3 mm
PTFE	2,2	3 mm

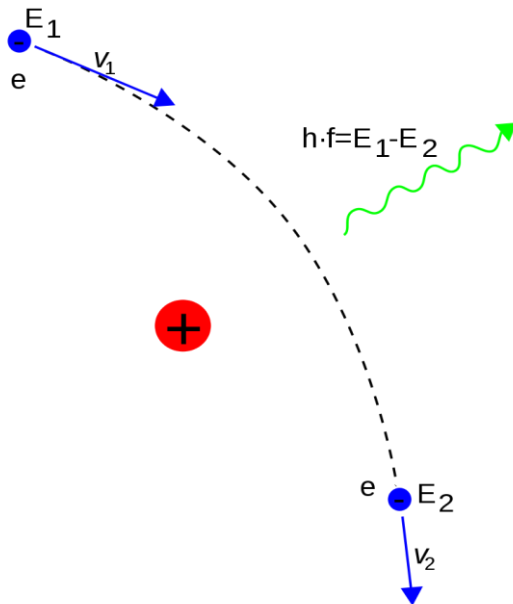
- una vez introducido permite medir el espesor de tejido



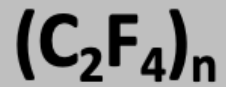


Uso clínico

- La parte plástica se coloca en la parte superior hacia el haz de electrones para reducir el backscatter



Teflón



12.0107 1082,6 2,55 C Carbono 1s ² 2s ² 2p ²	6	18.998403 1681,0 2,99 F Fluor 1s ² 2s ² 2p ⁵	9
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acero AISI 316L

S - 0,03

P - 0,045

C - 0,08

N - 0,1

Si - 0,75

Mn - 2,0

Mo - 2,5

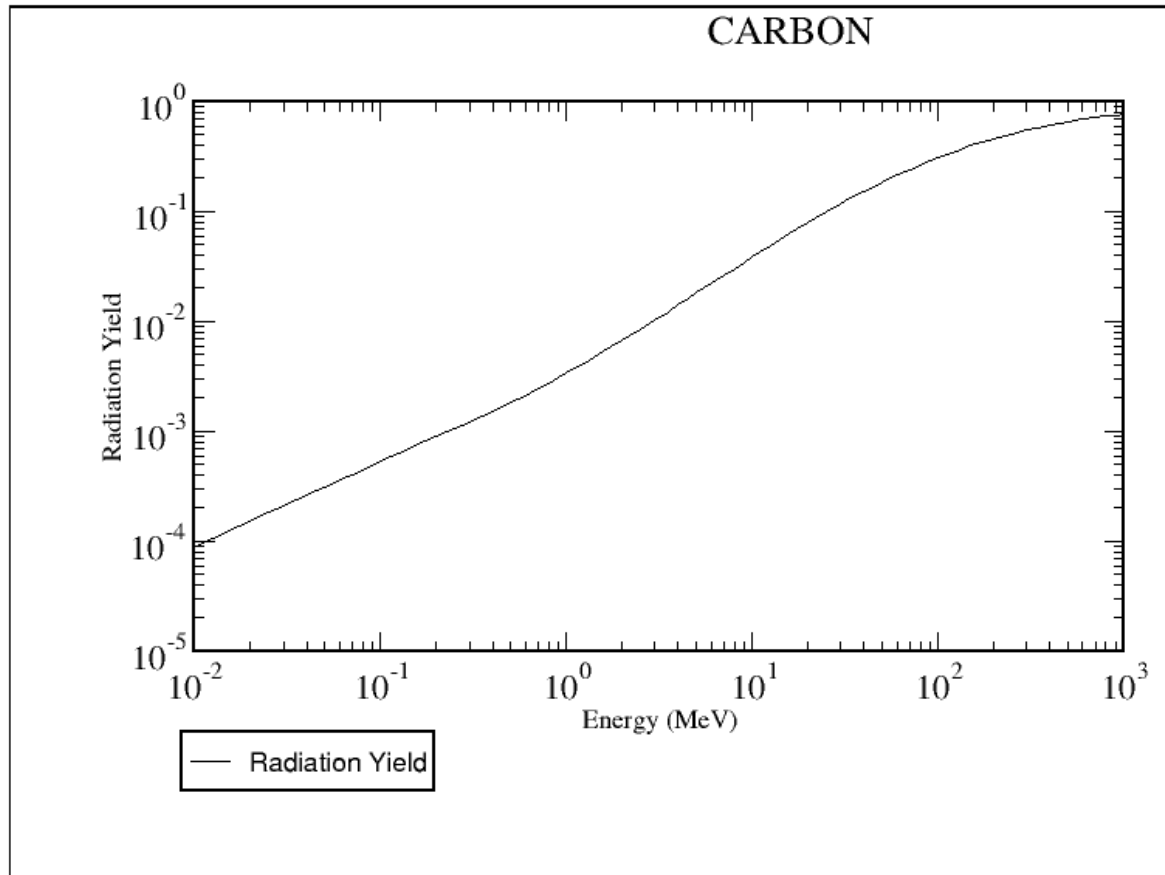
Ni - 12,0

Cr - 17,0

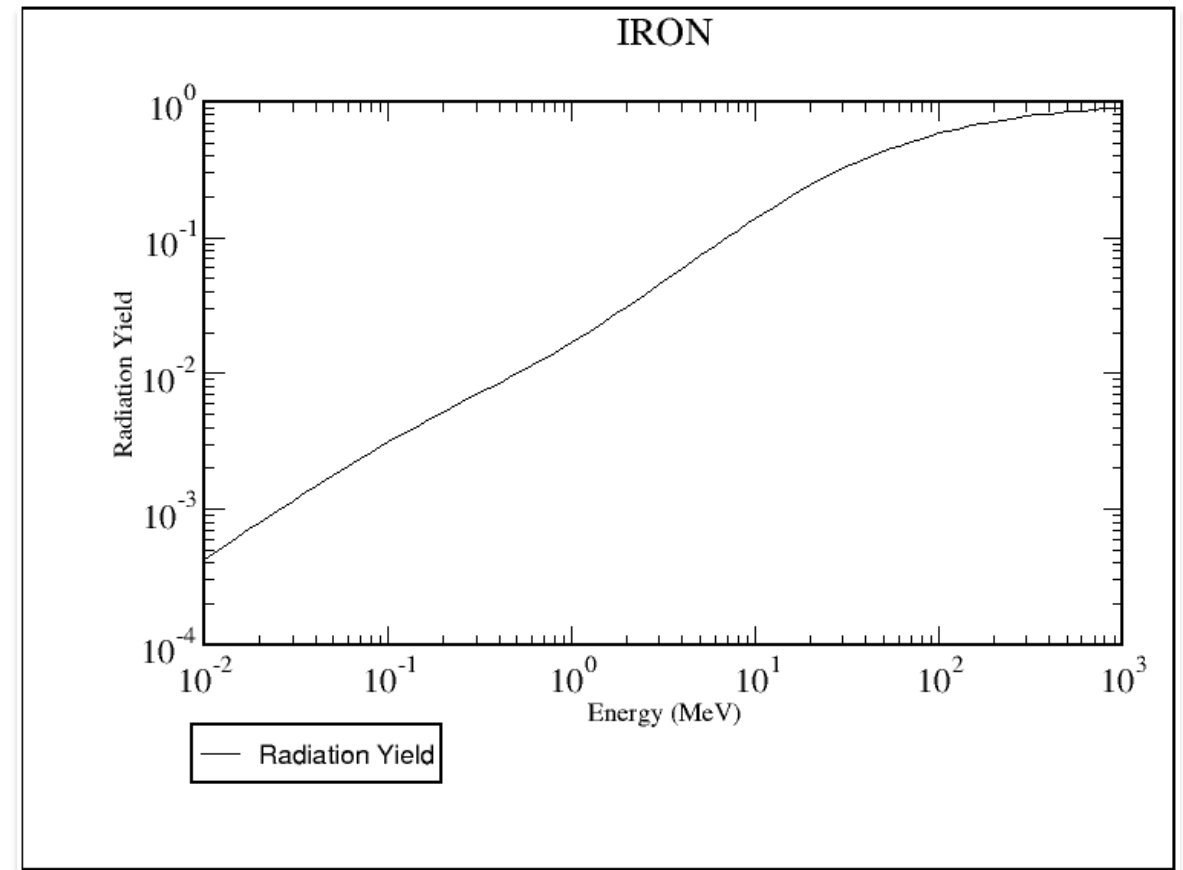
Fe - 65,495

51.9962 24 652,9 1,66 Cr Cromo [Ar] 3d ⁵ 4s ¹	26	55.845 26 762,5 1,83 Fe Hierro [Ar] 3d ⁶ 4s ²	28	58.6934 28 737,1 1,88 Ni Níquel [Ar] 3d ⁸ 4s ²
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Teflón

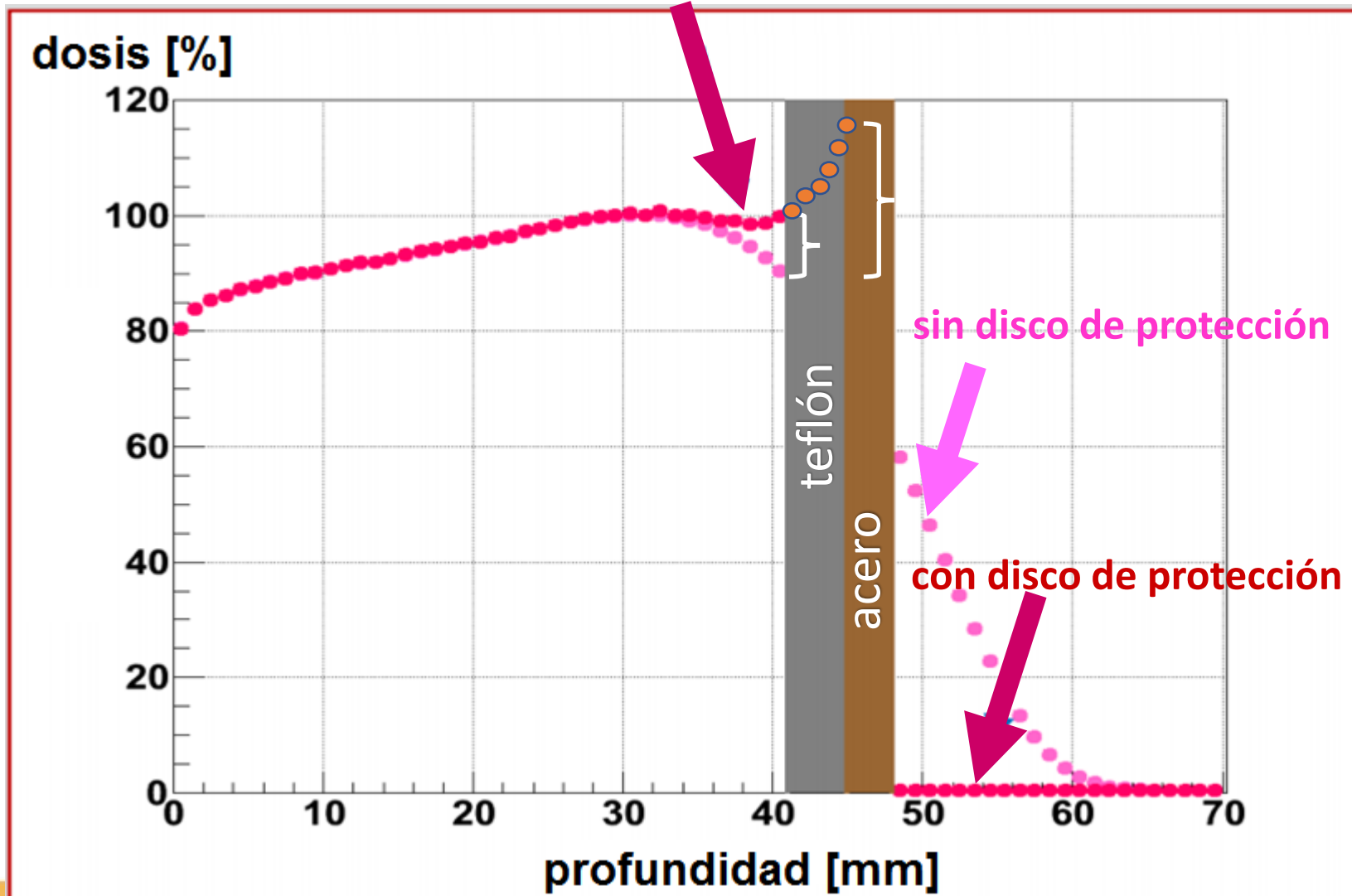


acero AISI 316L



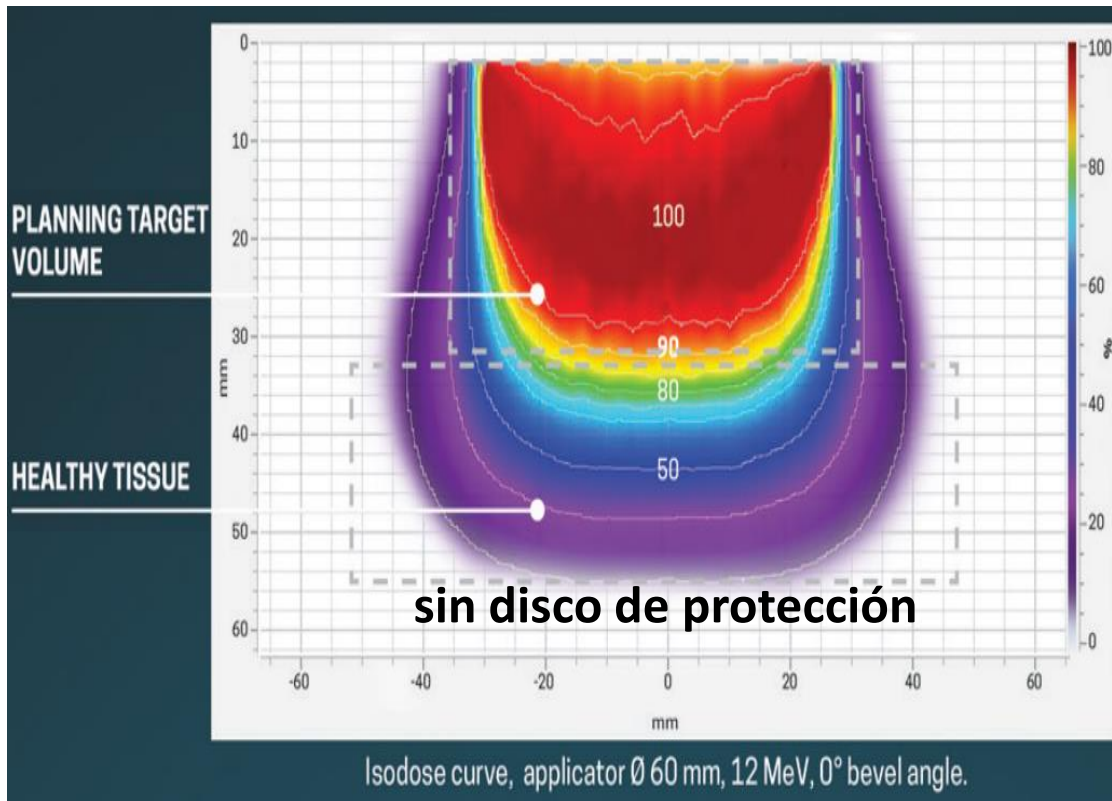
Disminución del backscatter del acero

backscatter



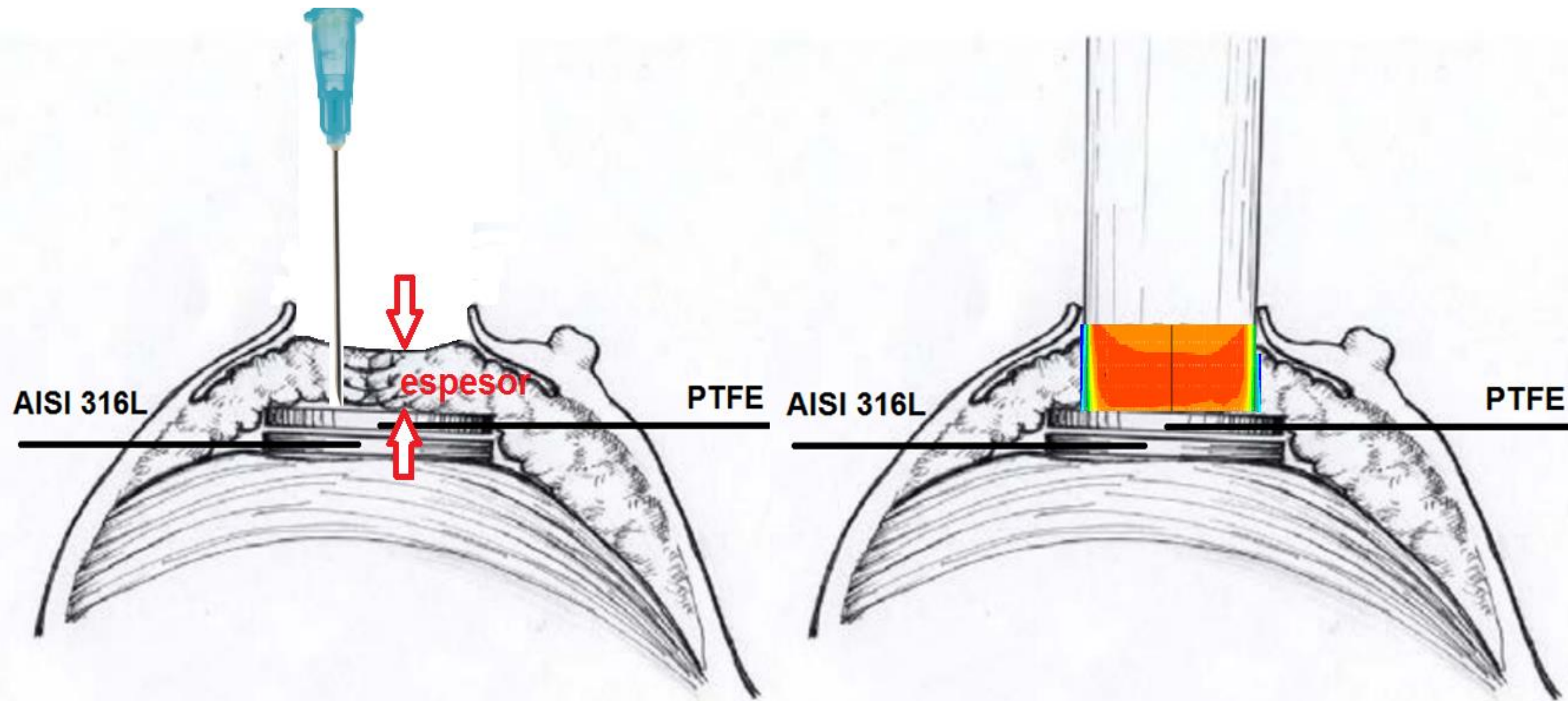
Atenuación de la dosis

- > 95% para 10 MeV
- > 99% para el resto de energías (4 MeV, 6 MeV, 8 MeV)

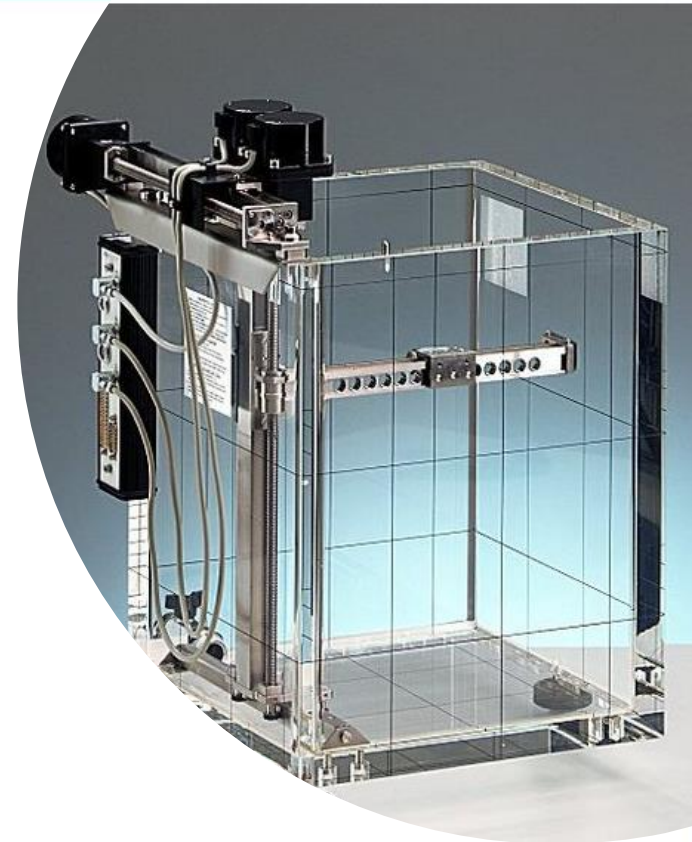
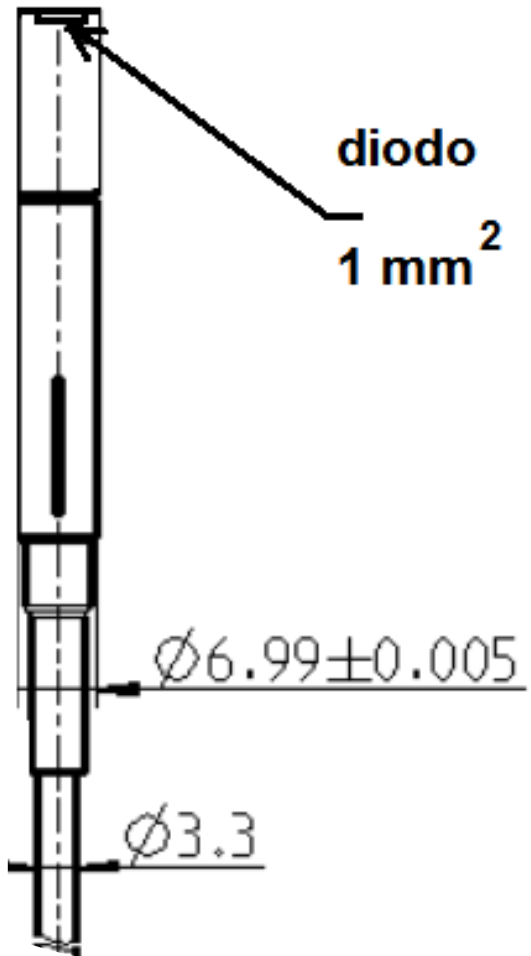


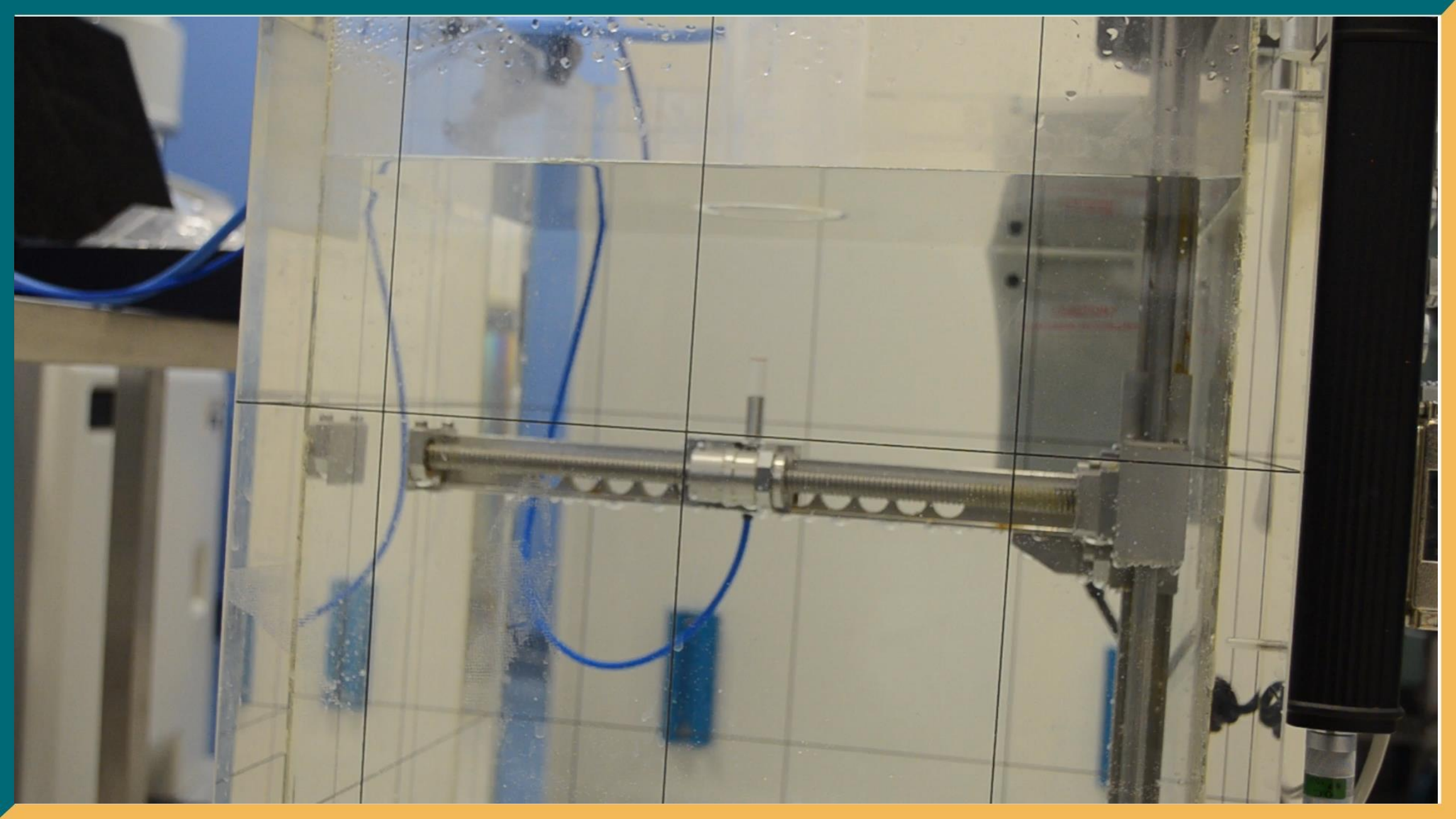


Espesor medido



Rendimiento en profundidad







Linac **Measurement**

Current[A] Range Med/Low Time [s]
10.80E-12 142.6E-12 Meas. Time [s] 3.00
 with Reference

PTW 60017 Diode E
Reference:
PTW 34001 Roos

PDD and Profiles Defaults

Change View

PDD

Profiles

Inplane Profiles
Angle [°] 0.0
Offaxis [mm] 0.0

Crossplane Profile.
Angle [°] 0.0
Offaxis [mm] 0.0

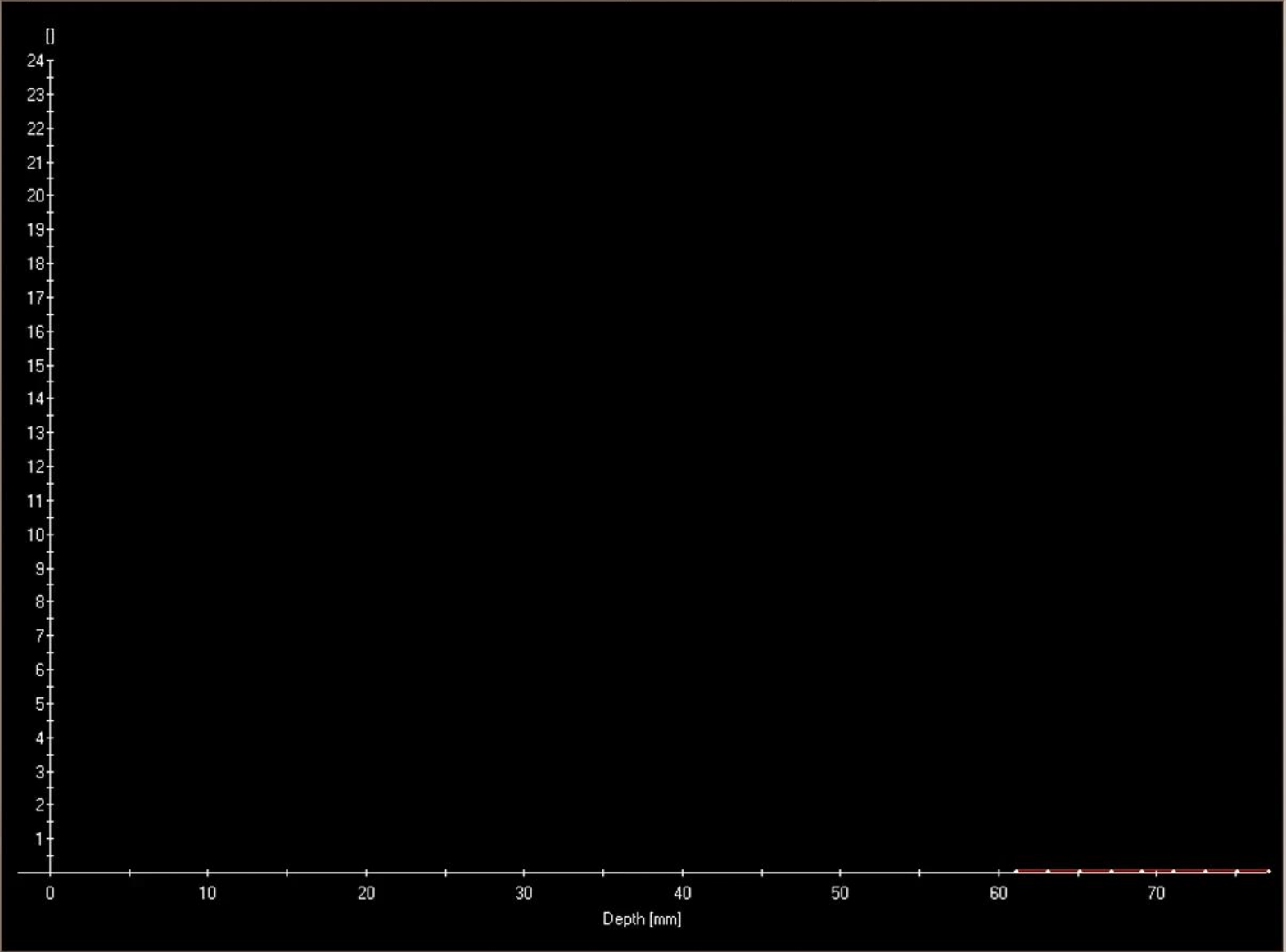
halfsided Profiles

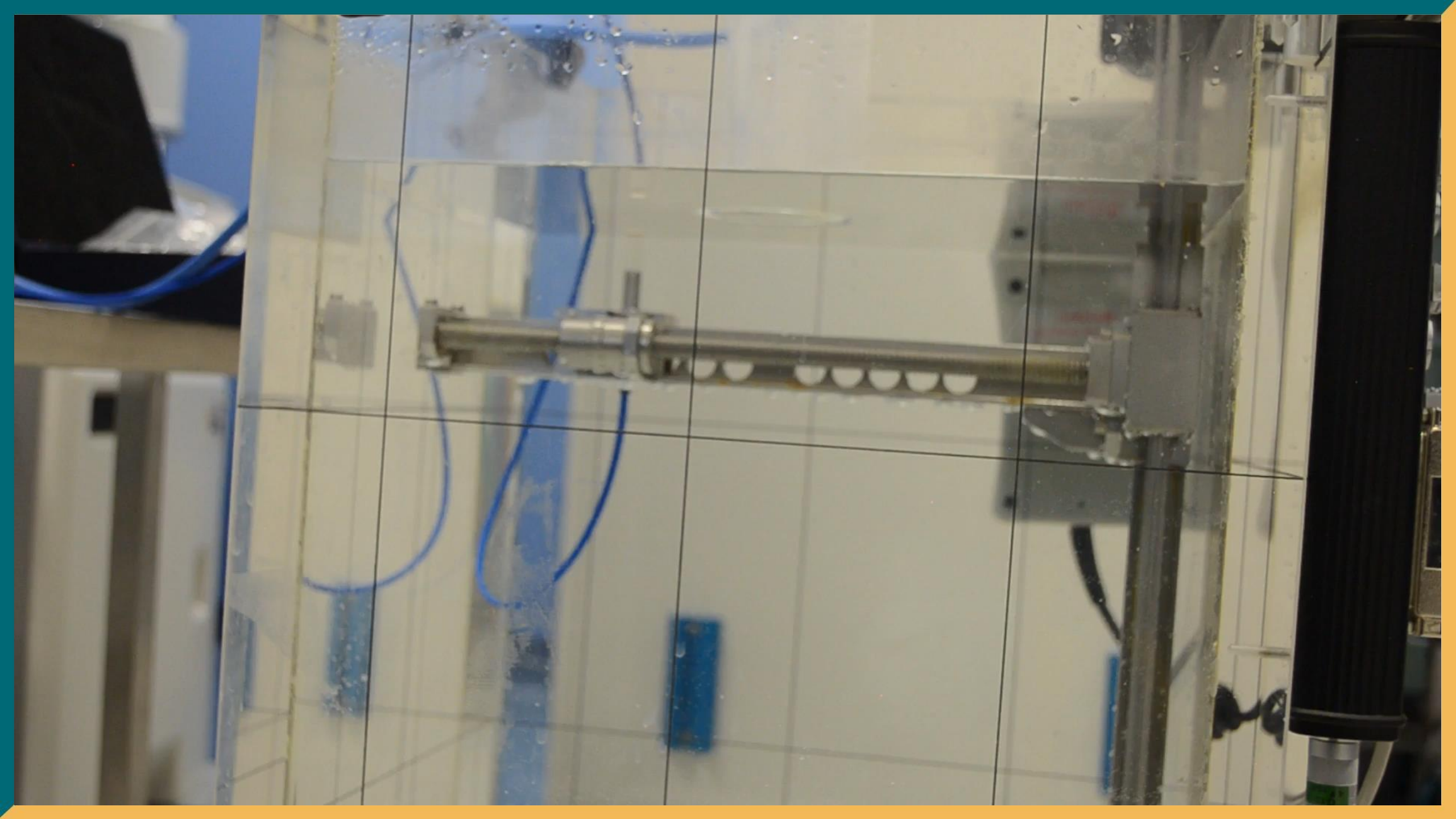
Depths [mm]
15.0

Medium Water

A: 0,0 B: 59,0 C: 0,0

Comment: calibracion0_bevel0_aplicador10_fdd







Linac **Measurement**

Current[A] Range Med/Low Time [s]
51.10E-12 142.9E-12 Meas. Time [s] 3.00
 with Reference

PTW 60017 Diode E
Reference:
PTW 34001 Roos

PDD and Profiles Defaults

Change View

PDD

Profiles

Inplane Profiles
Angle [°] 0.0
Offaxis [mm] 0.0

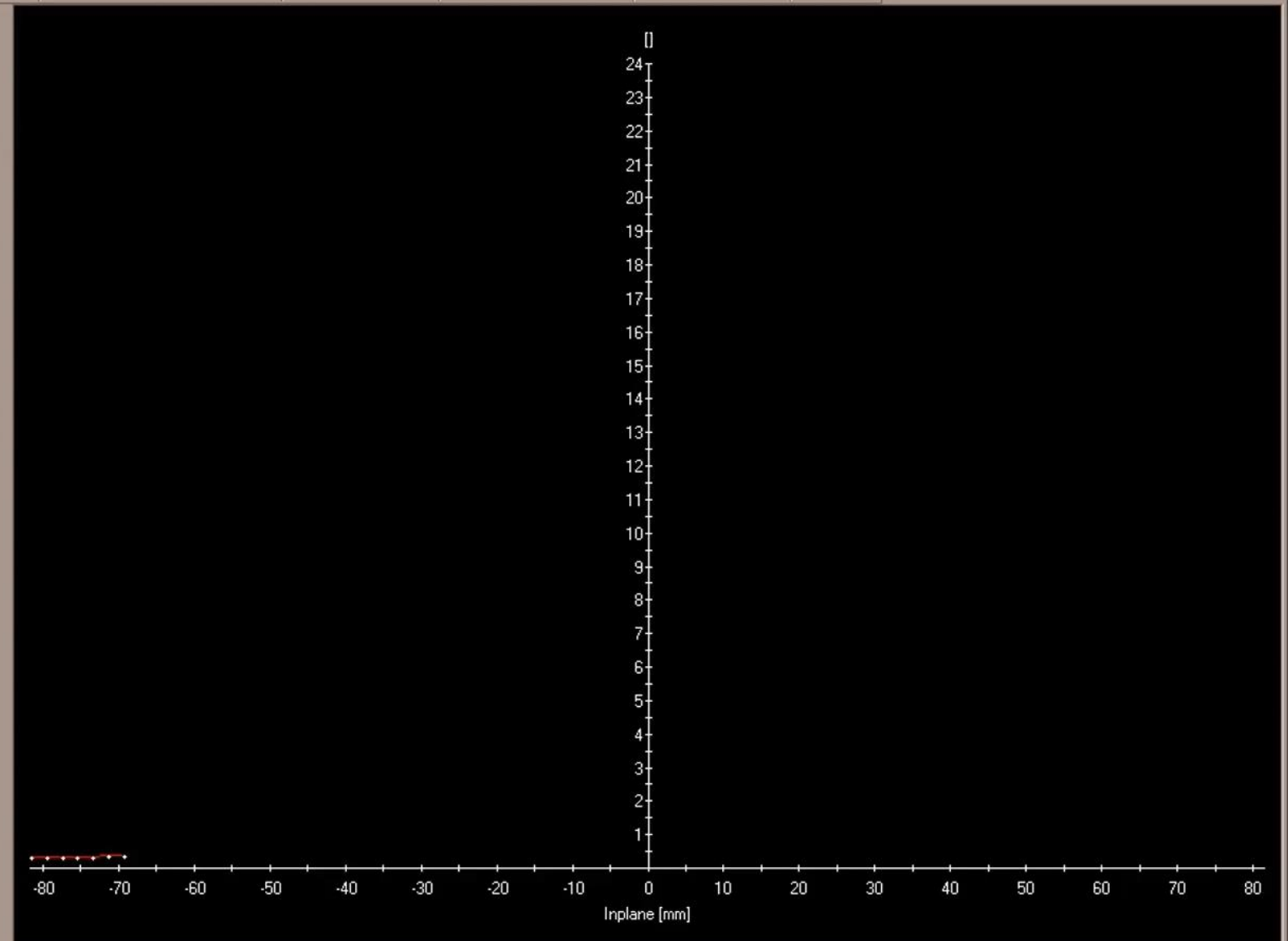
Crossplane Profile.
Angle [°] 0.0
Offaxis [mm] 0.0

halvesided Profiles

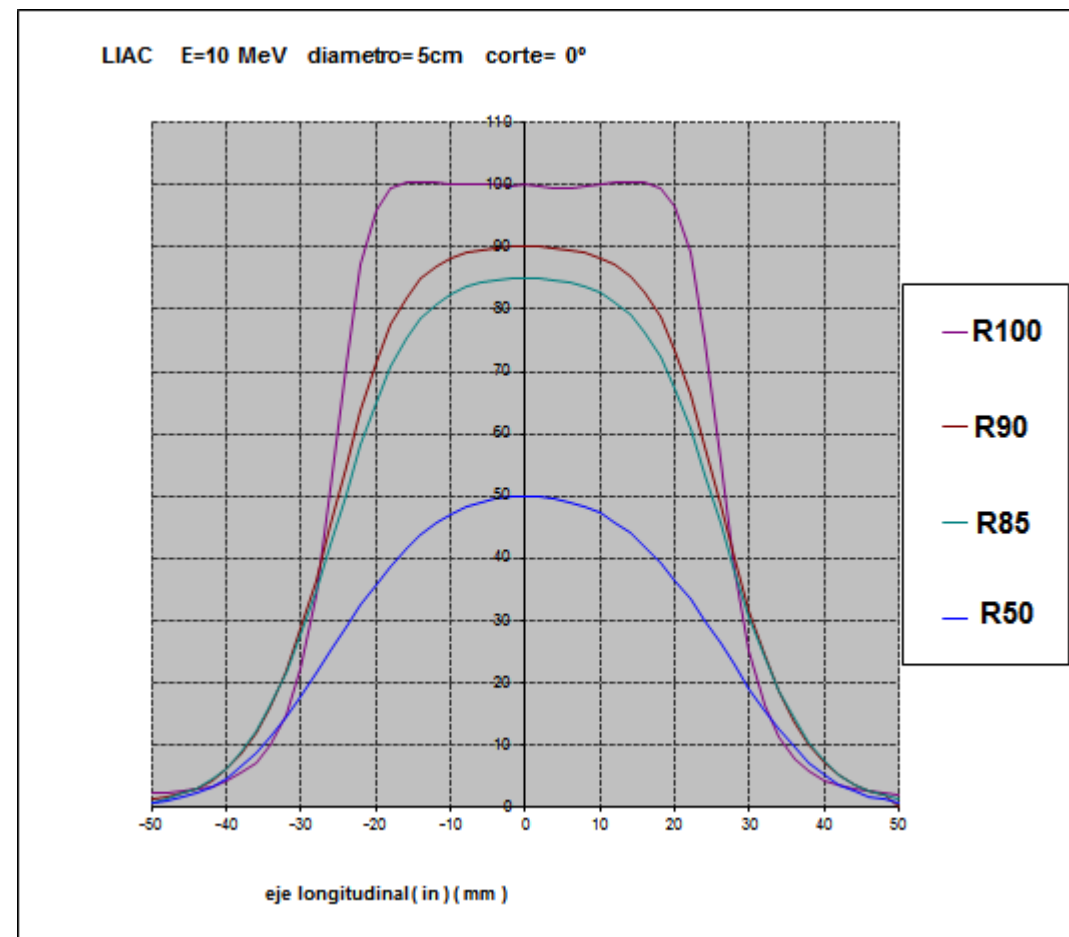
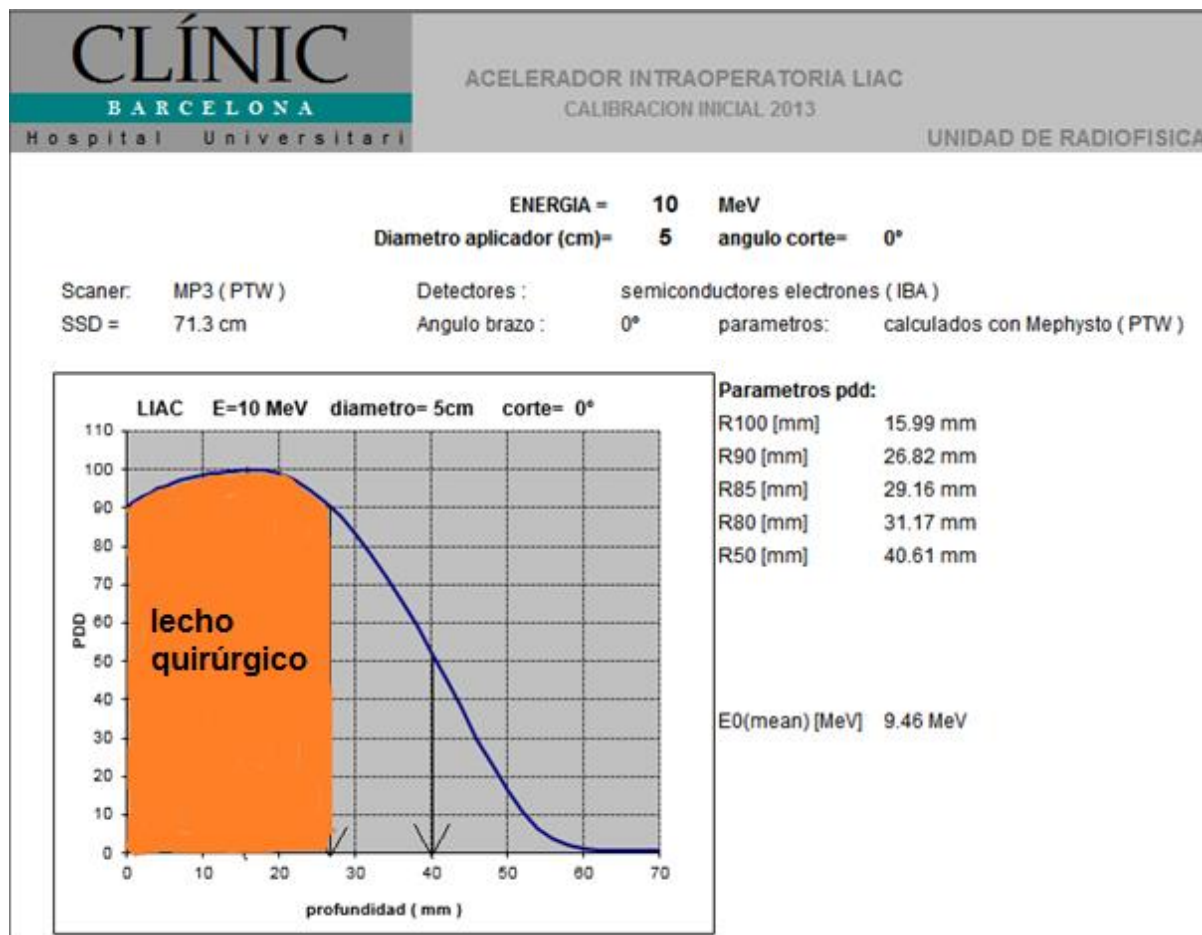
Depths [mm]
15.0

A: -67.4 B: 15.0 C: 0.0 Medium Water

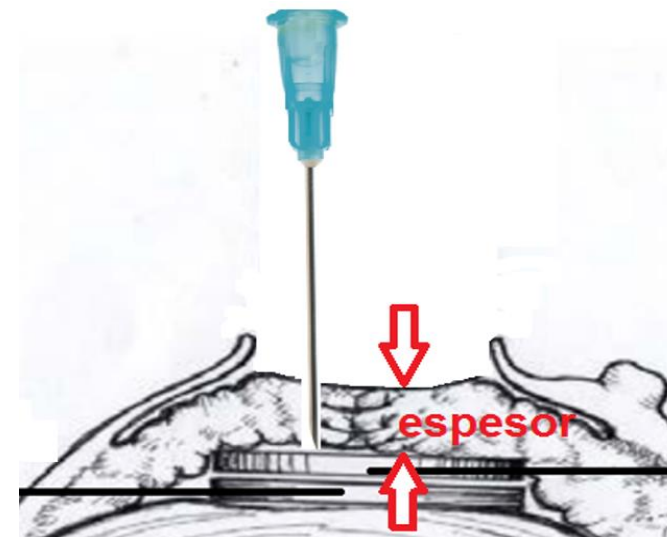
Comment: calibracion0_bevel0_aplicador10_fdd



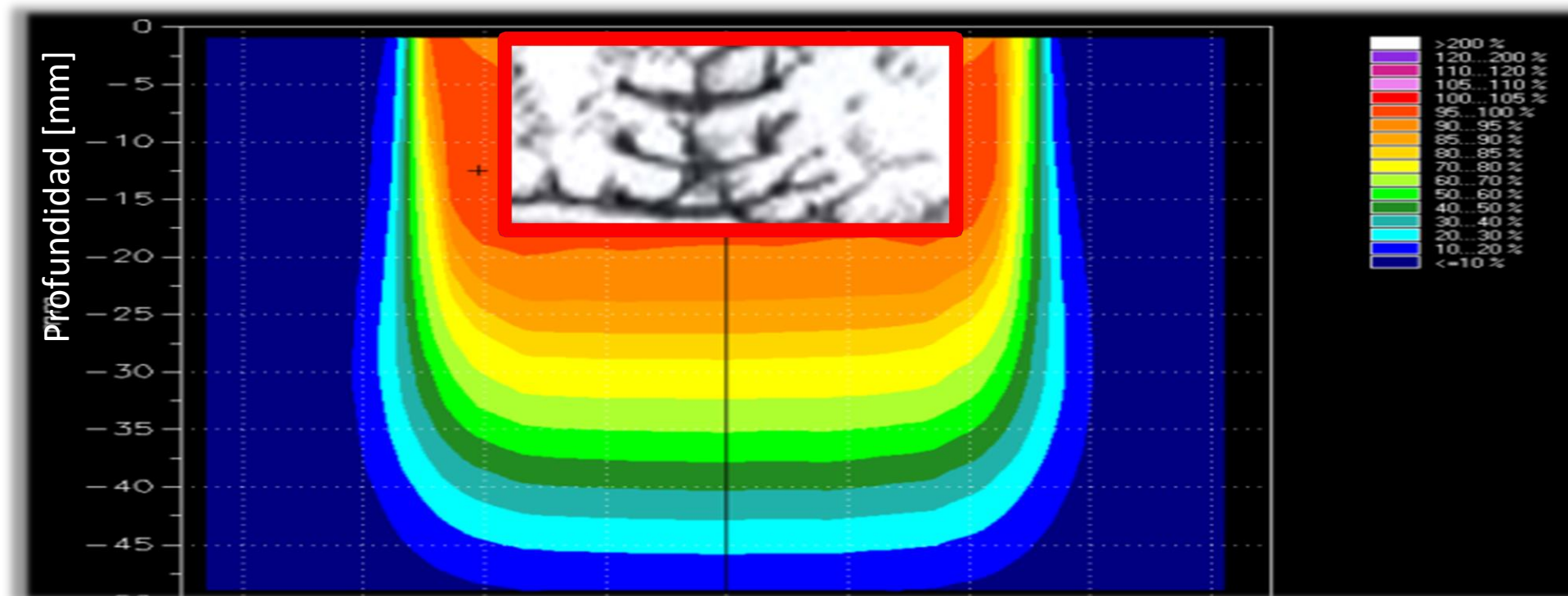
Perfiles a diferentes profundidades

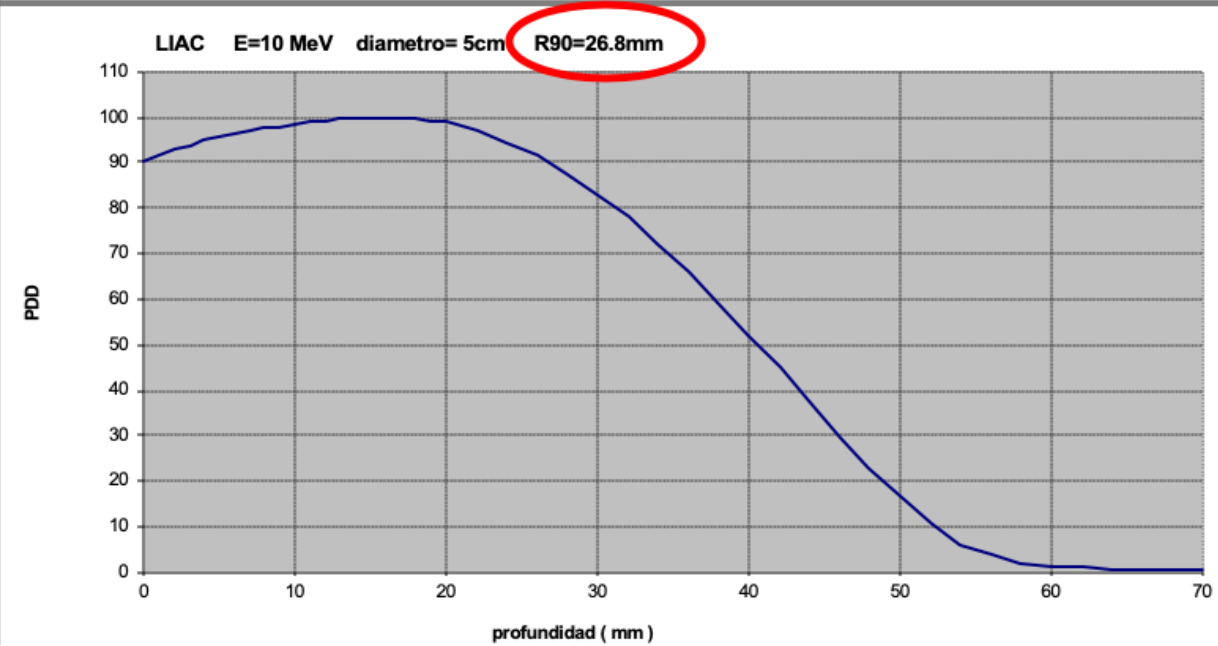
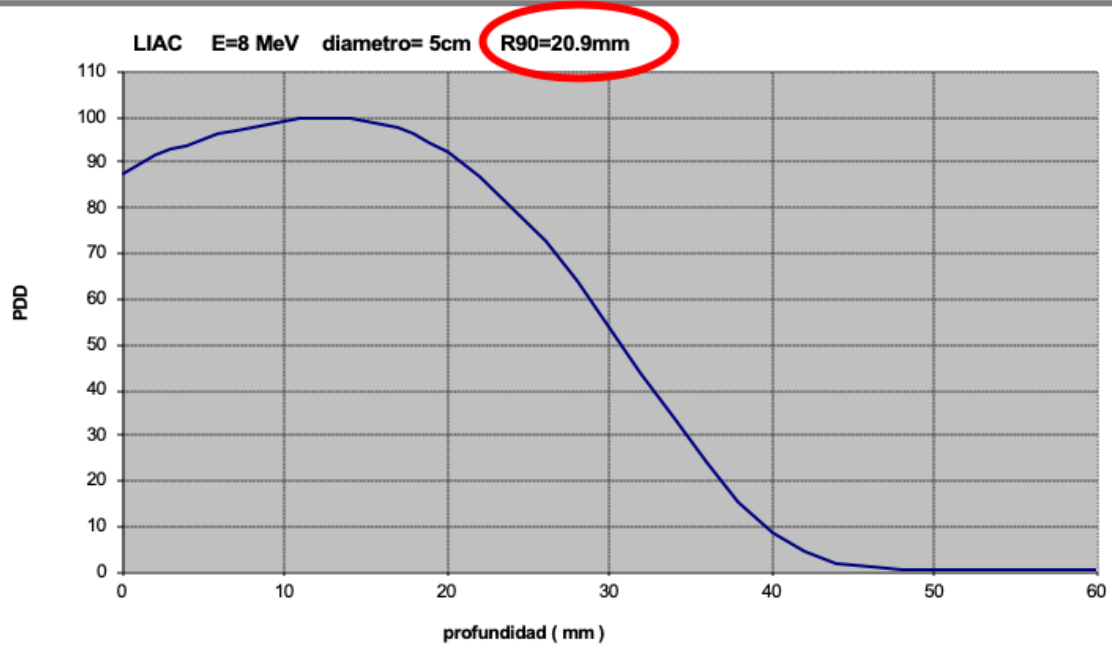
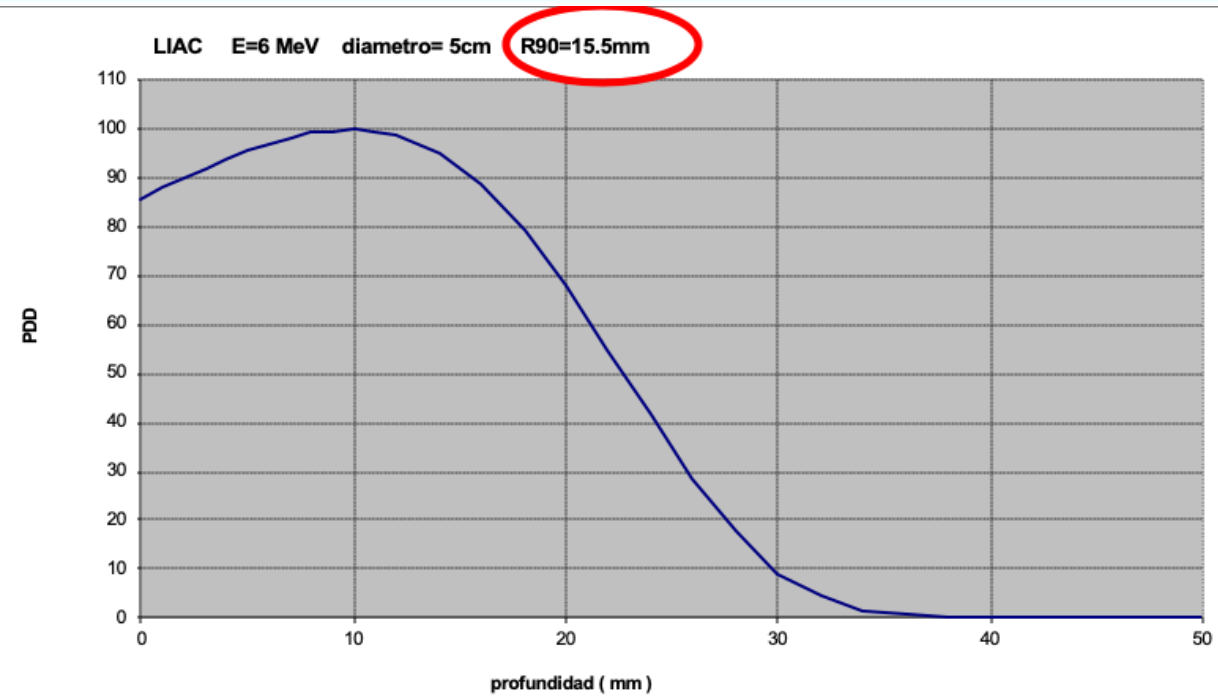
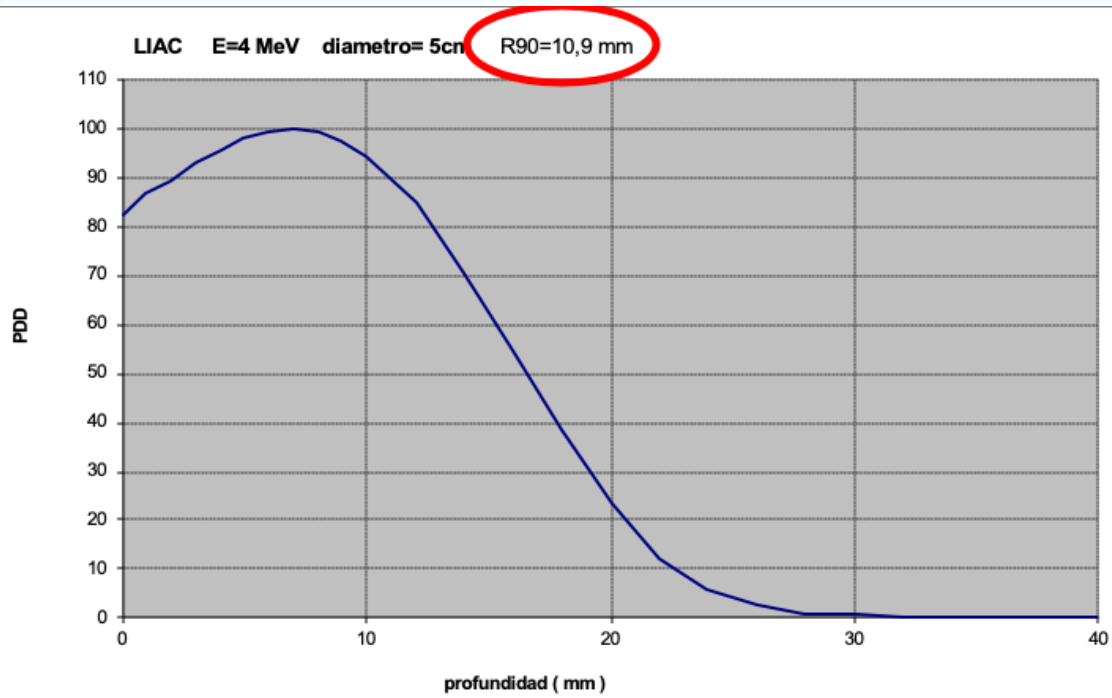


Curvas de isodosis



Distancia al eje [mm]





Selección de la energía en función del espesor medido con la aguja

E/4 ~ R90

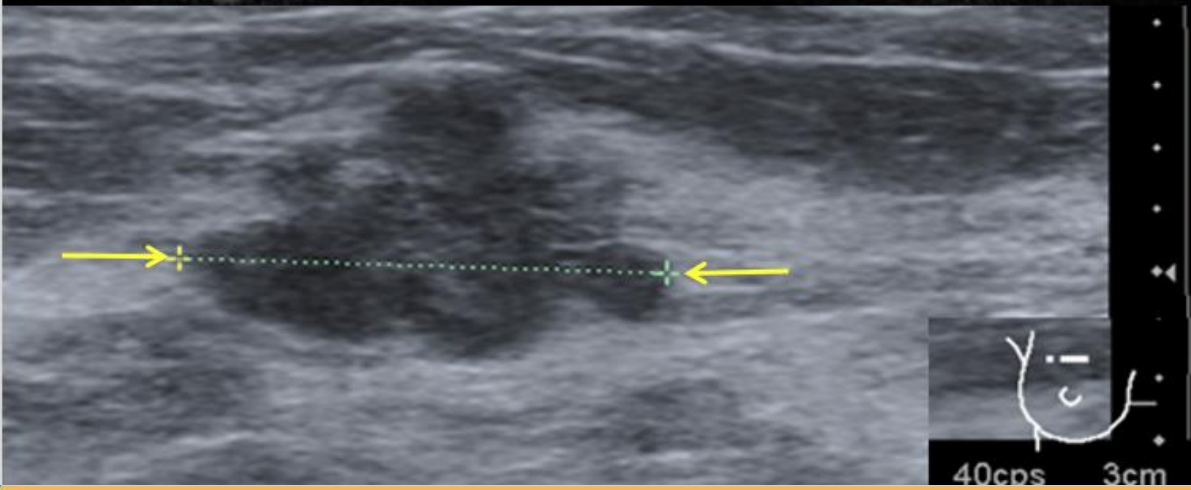
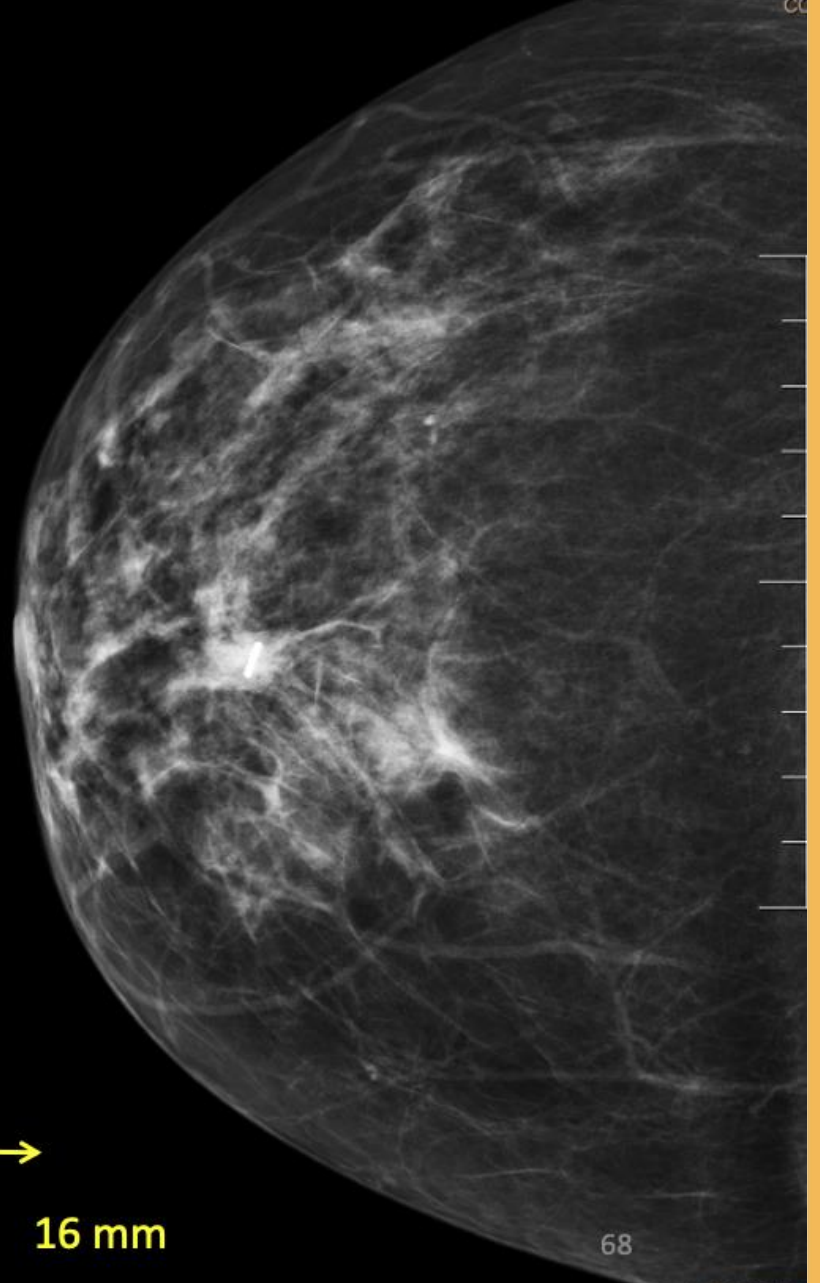
		Aplicador (diámetro) ángulo de corte: 0°					
		3 cm	4 cm	5 cm	6 cm	7 cm	8 cm
~ 1 cm	4 MeV	1.09 cm	1.12 cm	1.09 cm	1.13 cm	1.08 cm	1.08 cm
~ 1.5 cm	6 MeV	1.53 cm	1.58 cm	1.55 cm	1.52 cm	1.52 cm	1.49 cm
~ 2 cm	8 MeV	1.94 cm	2.06 cm	2.09 cm	2.08 cm	2.07 cm	2.08 cm
~ 2.5 cm	10 MeV	2.45 cm	2.68 cm	2.68 cm	2.74 cm	2.72 cm	2.75 cm

Tabla de R90 en función de la energía y del aplicador.

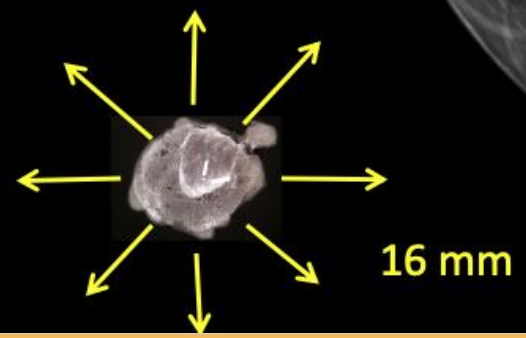
Selección del aplicador en función del tamaño del tumor



¿Qué tamaño de aplicador?

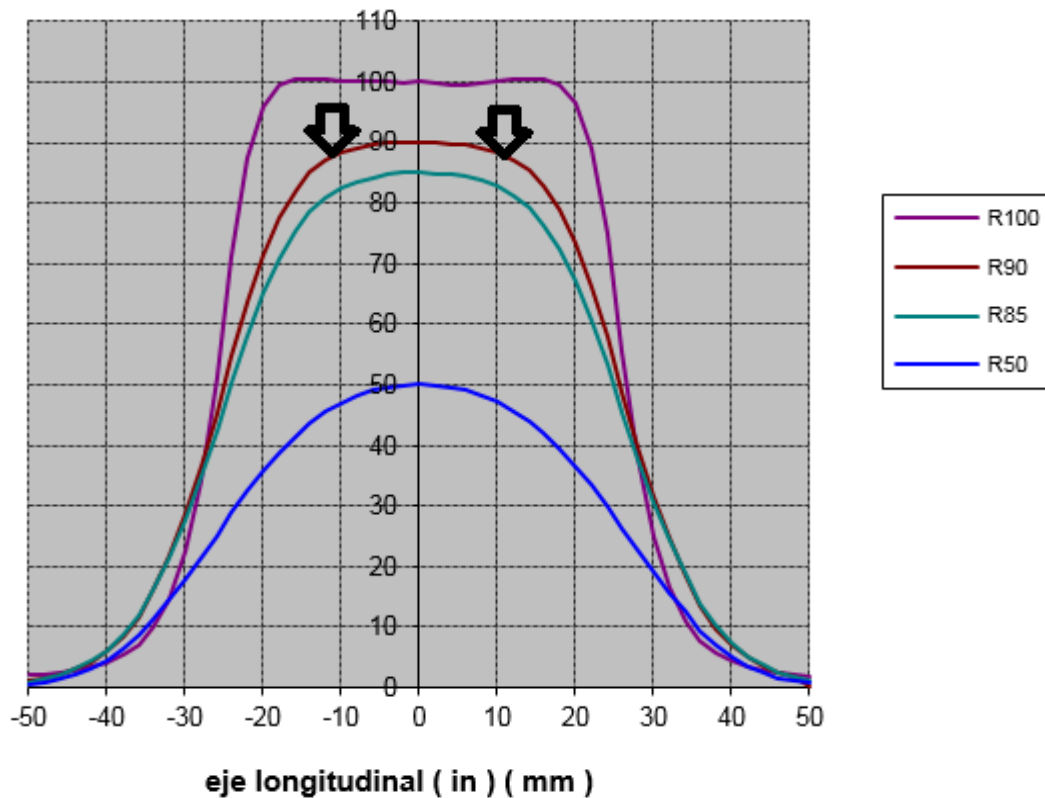


D=14,8 mm



Diámetro efectivo

LIAC E=10 MeV diametro= 5cm corte= 0°



DIAMETRO EFECTIVO PARA TRATAMIENTOS DE LOS APLICADORES DEL LIAC

ANGULO DE CORTE = 0° DFS=71.3 cm

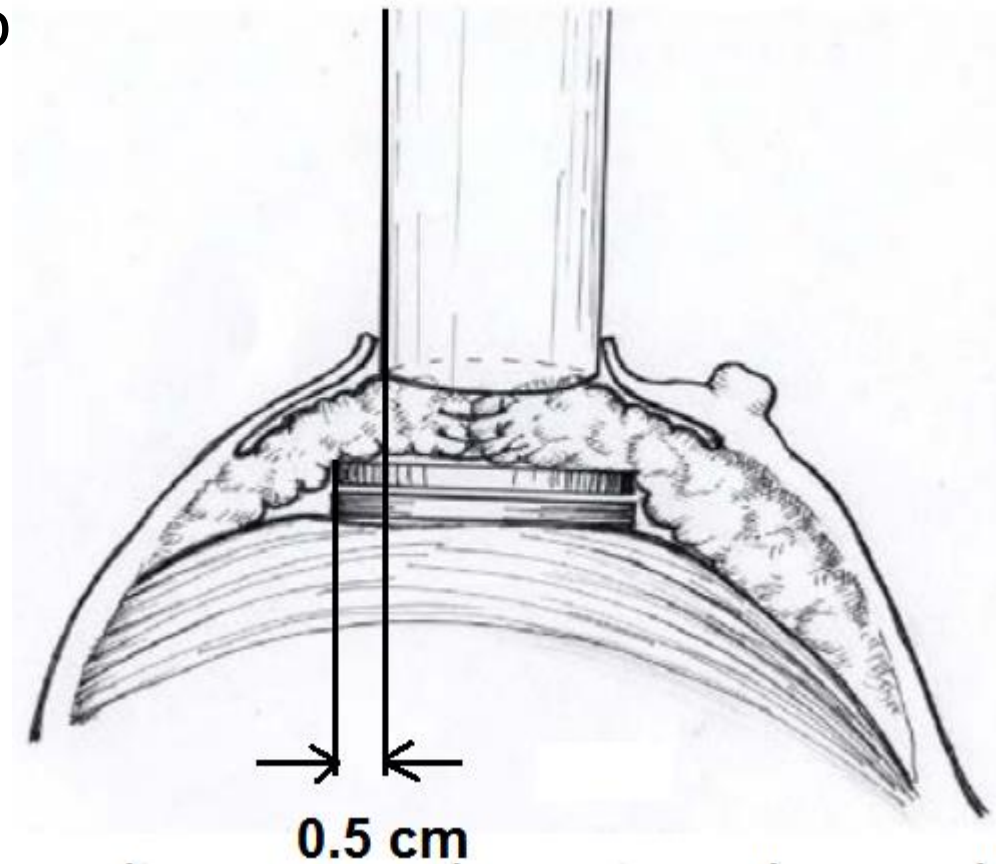
DIAMETRO APLICADOR (cm)

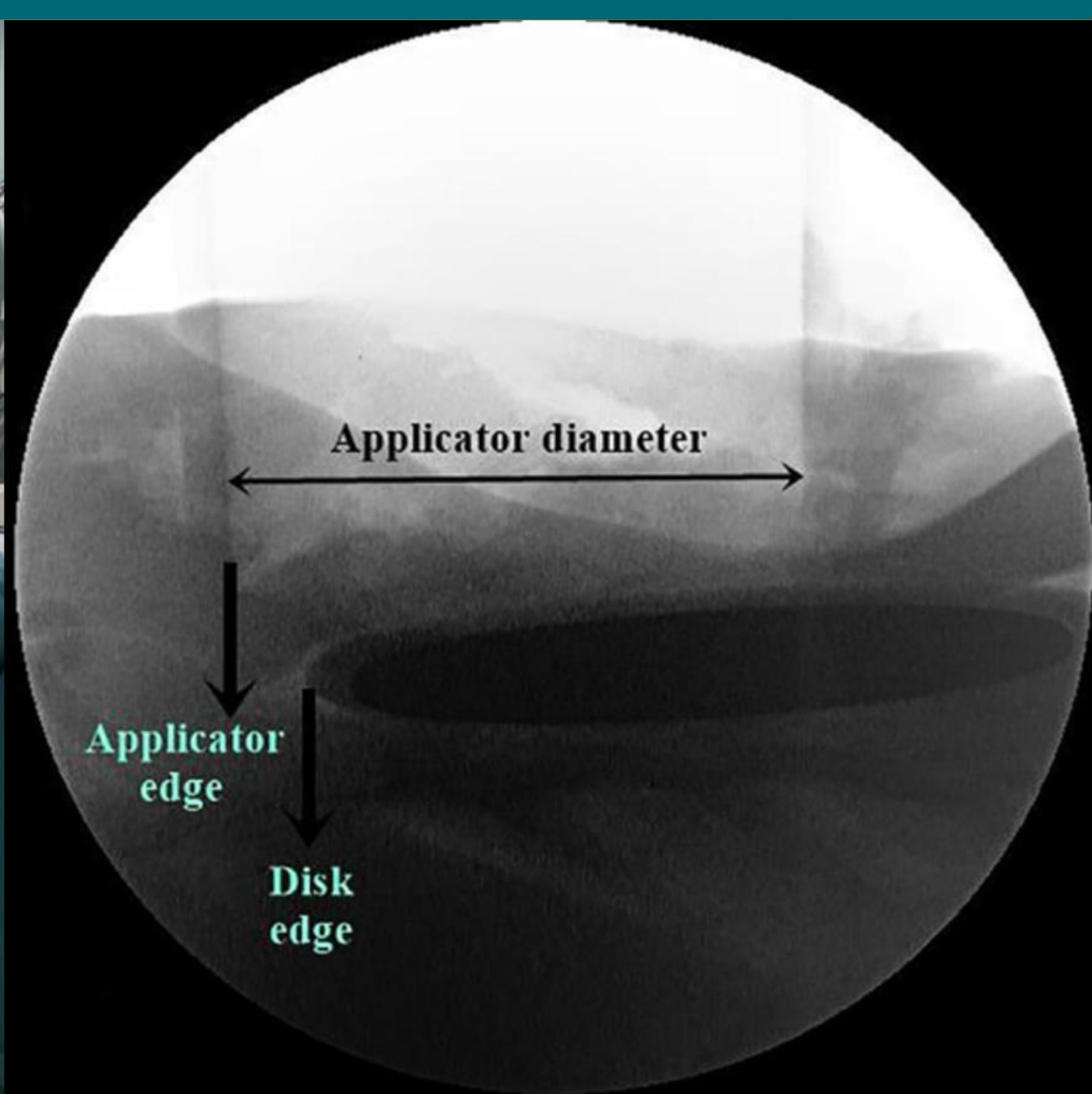
ENERGIA	3 cm	4 cm	5 cm	6 cm	7 cm	8 cm
4 MeV	1.4	2.3	3.5	4.5	5.8	6.8
6 MeV	1.3	2.2	3.3	4.4	5.6	6.7
8 MeV	1.2	1.9	3.0	4.1	5.3	6.3
10 MeV	1.2	1.8	2.7	3.5	4.8	5.6

El diámetro efectivo se ha calculado como el diámetro del 95% en los perfiles (inline, crossline) a R90.
Se han utilizado los perfiles medidos en Calibración_U_2 del 05/02/2013 a 20/03/2013

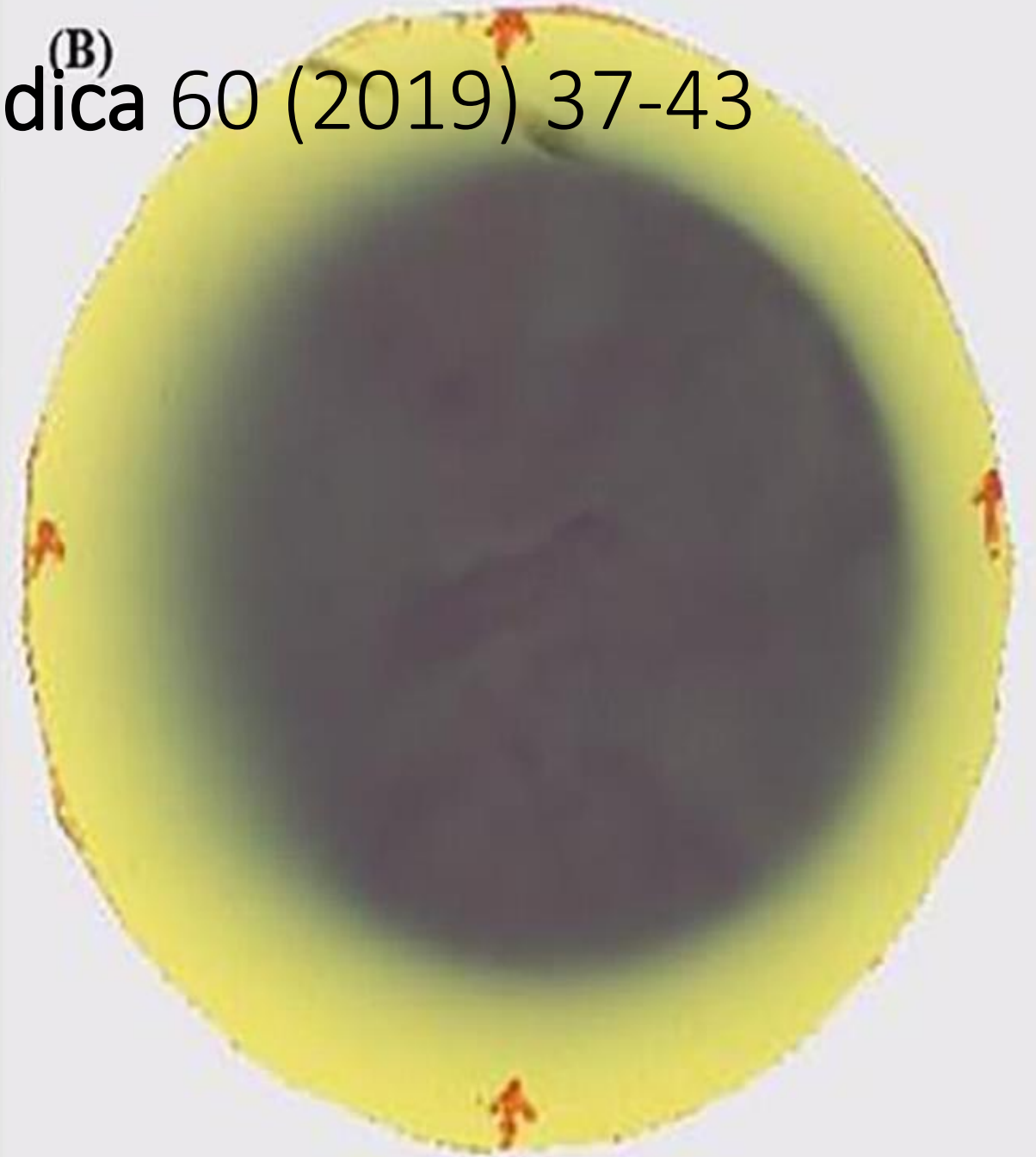
¿Qué tamaño de disco?

- El diámetro del disco tiene que ser mínimo 1cm superior al diámetro del aplicador

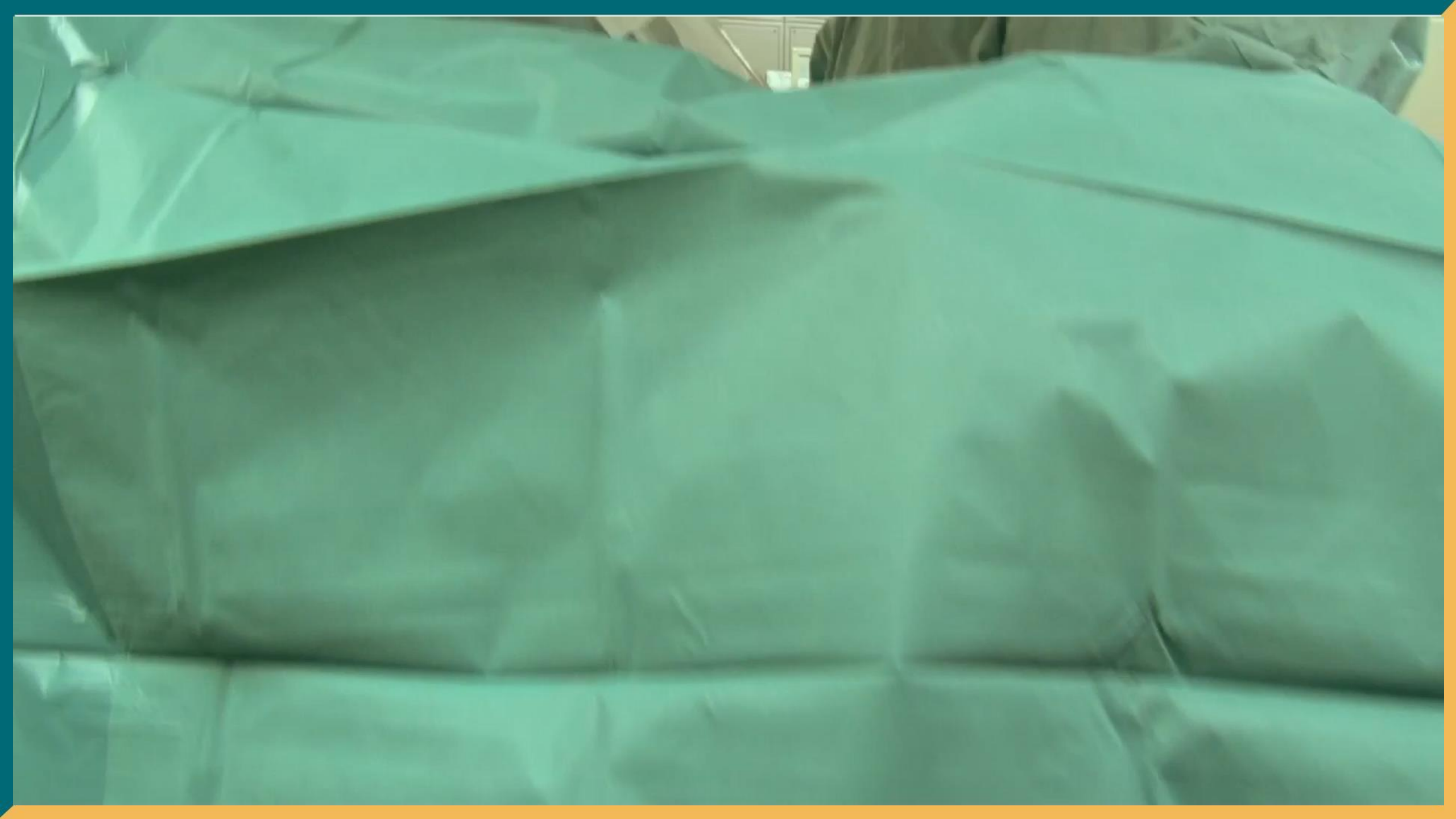




(A) Baghani et al., *Physica Medica* 60 (2019) 37-43



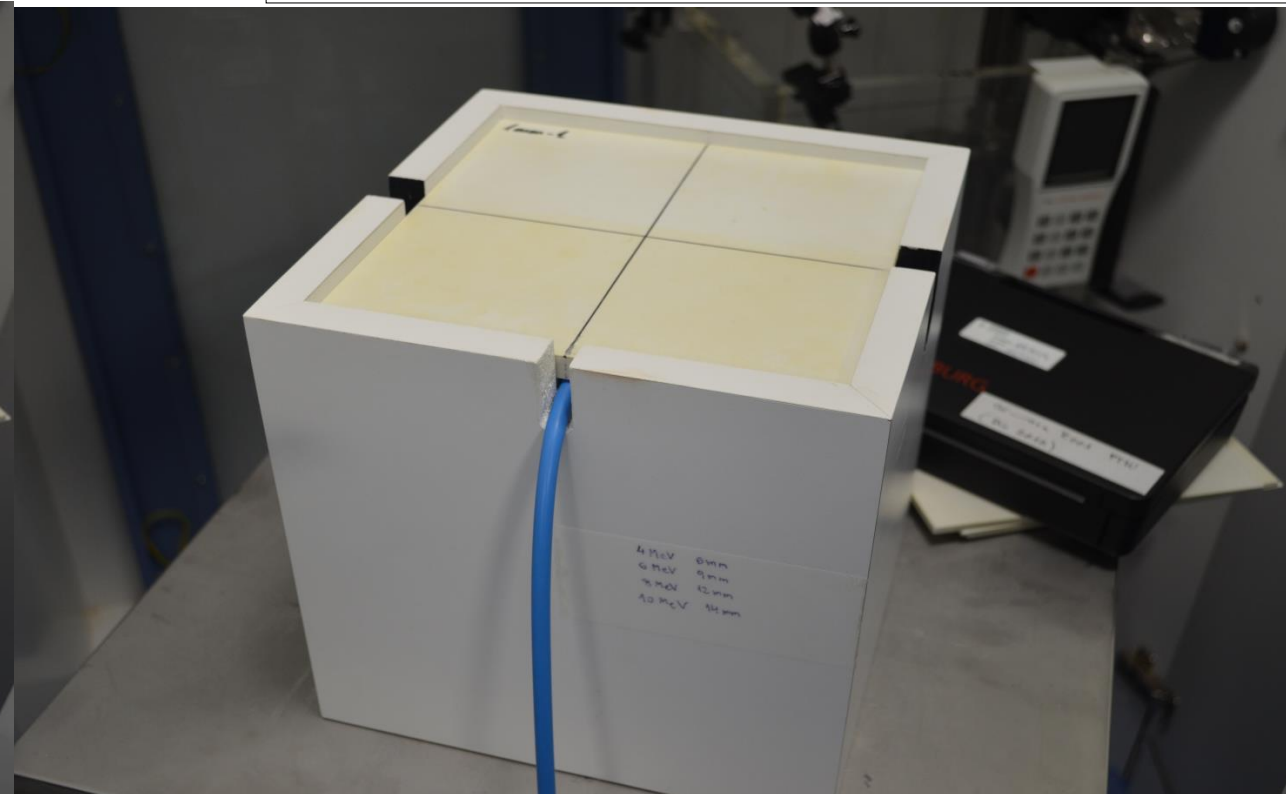
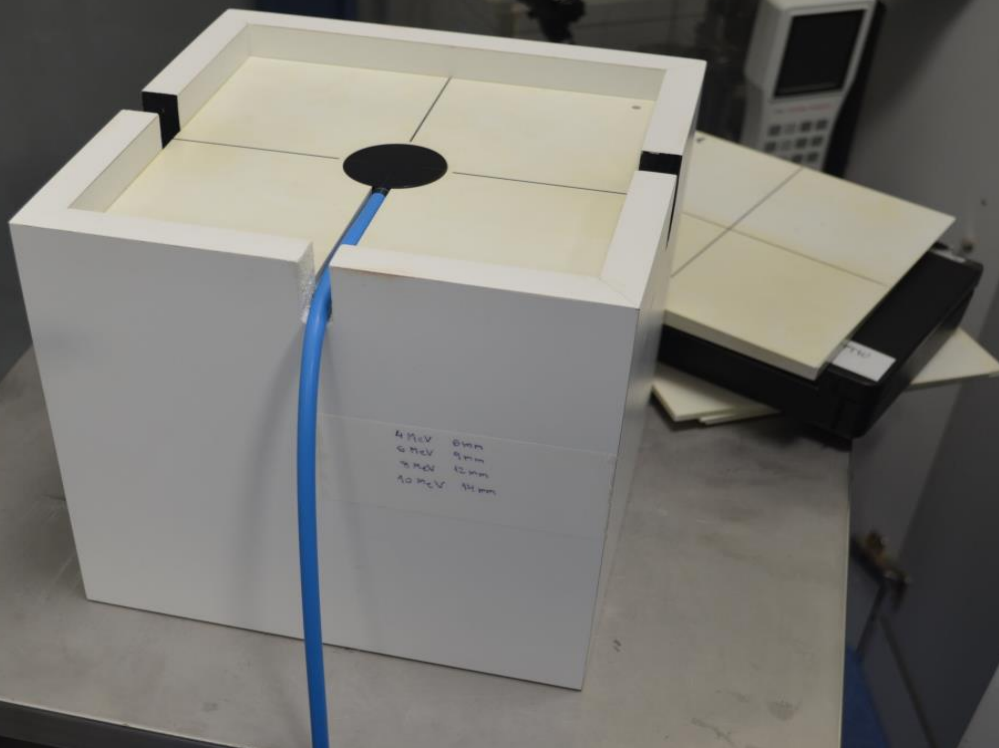
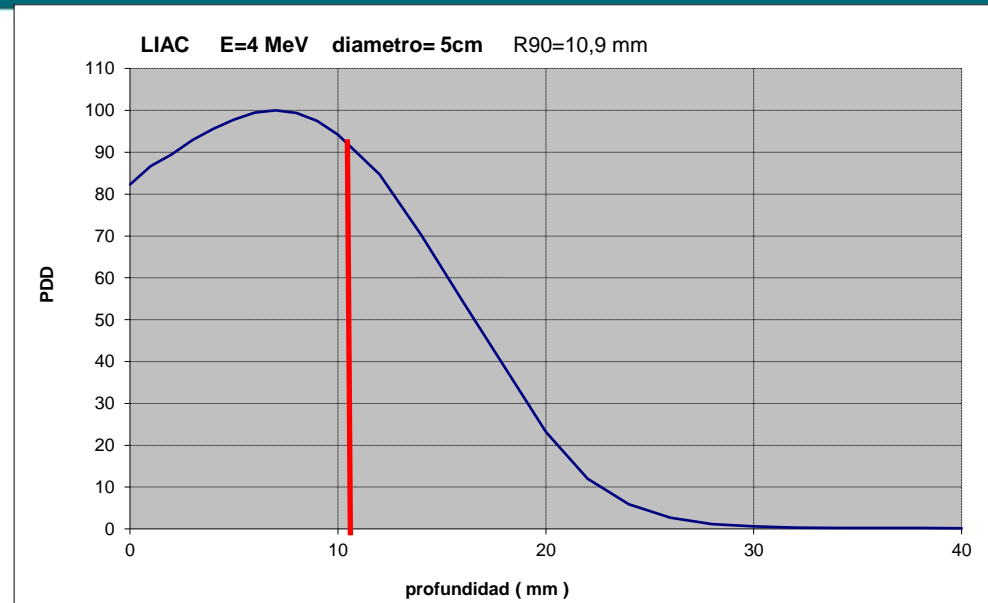






Cálculo UM

- $UM = D / \text{tasa de dosis}@90\%$



Oncólogo Radioterapeuta

- Es responsable de la definición del volumen a irradiar.
- En colaboración con el cirujano tiene en cuenta las áreas sospechosas de infiltración, evaluación de los márgenes de resección.
- Es responsable de la prescripción de la dosis, de la elección de los aplicadores a emplear y de la energía de los haces de electrones.
- Es responsable del posicionamiento del aplicador y del acoplamiento.

En esta última fase colabora con el personal técnico de radioterapia.

Muchas gracias por su atención

