Planificación de IMRT

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Créditos;
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Curso Nacional Introducción IMRT.
HHA Cuba 2008

Maestría en Física Médica
Dosimetría Clínica en Radioterapia
Curso 2011-2012

Contenidos

- Planificación de IMRT
- Planificación con optimización directa, Field-in-Field
- Planificación con optimización inversa, Múltiples campos estáticos y VMAT
- Inteligencia artificial

Indicaciones más frecuentes de la IMRT

- **Evitar estructuras sensibles**
- **Blancos intracraneales grandes**
- **Lesiones muy irregulares**
- **Re-irradiación**
- **Irradiar blancos múltiples**
- **Escalar dosis**

Justificación...

In addition to satisfying at least one of the four selection criteria noted above, the radiation oncologist's decision to employ IMRT requires an informed assessment of benefits and risks including:

- Determination of patient suitability for IMRT allowing for reproducible treatment delivery.
- Adequate definition of the target volumes and organs at risk.
- Equipment capability, including ability to account for organ motion when a relevant factor.
- Physician and staff training.
- Adequate quality assurance procedures.

https://www.astro.org/uploadedFiles/Main_Site/Practice_Management/Reimbursement/IMRT MP.pdf

¿Qué diferencia la IMRT de la 3D-CRT?

- **Definición de la prescripción**
- **Optimización**
- **Método de administración**
- **Garantía de Calidad**
- **Administración del tratamiento y verificación**

IAEA TECDOC 1588, 2008. Transition from 2-D Radiotherapy to 3-D Conformal and Intensity Modulated Radiotherapy

Planificación de IMRT

- **Flujo de Trabajo**

1 Delimitación y márgenes

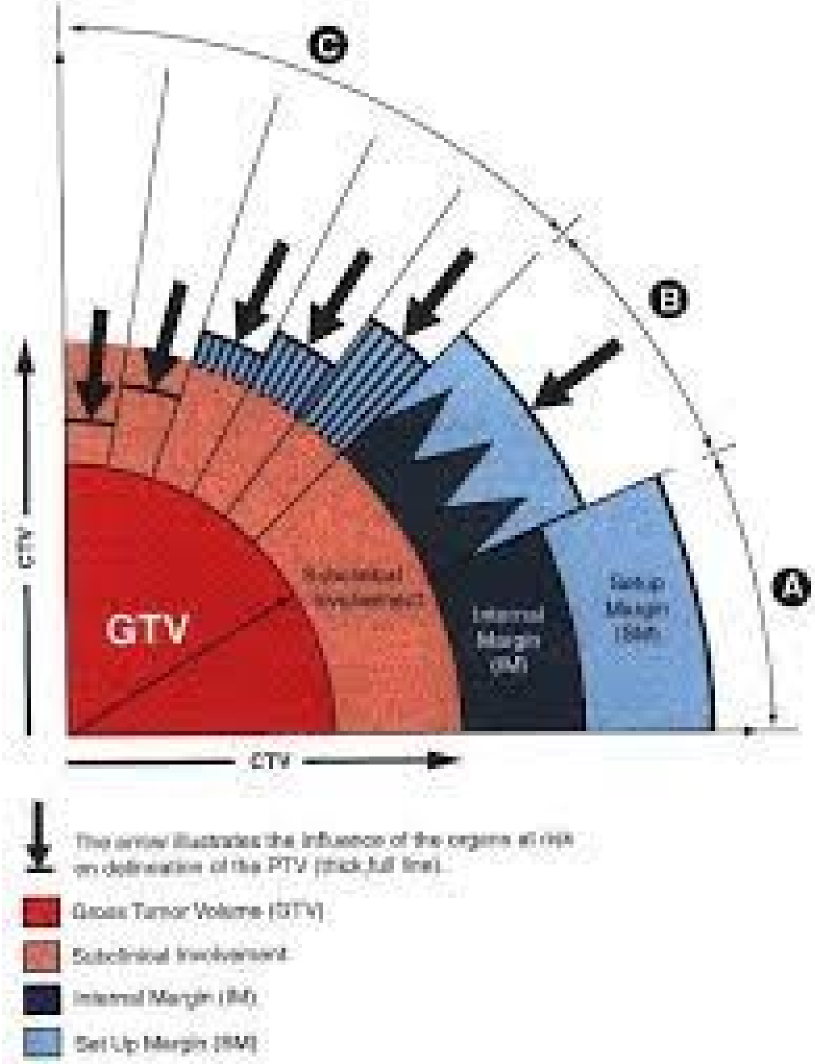
2 Colocación de haces, decisión de la configuración de tratamiento

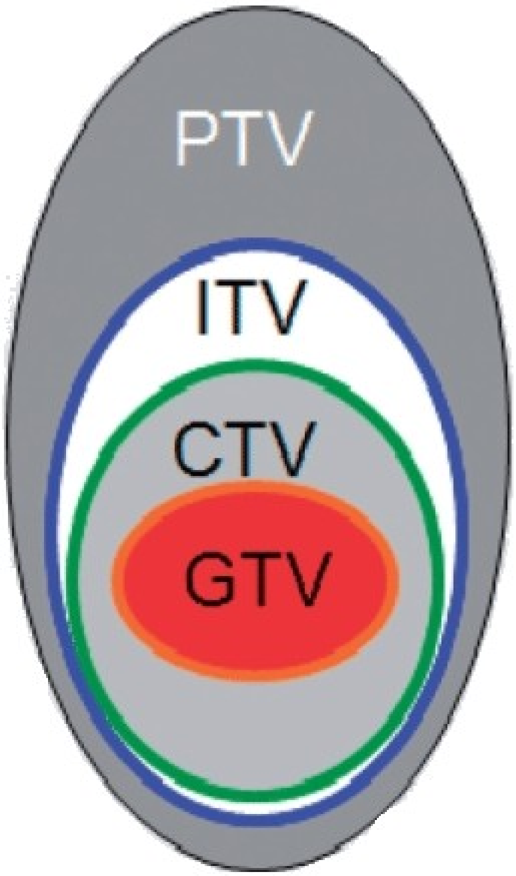
3 Optimización directa/inversa

5 Revisión del plan

Planificación IMRT.

Definición de Volúmenes. ICRU 62





Planificación IMRT.
Definición de Volúmenes. ICRU 62

- **Identificación del GTV/CTV**

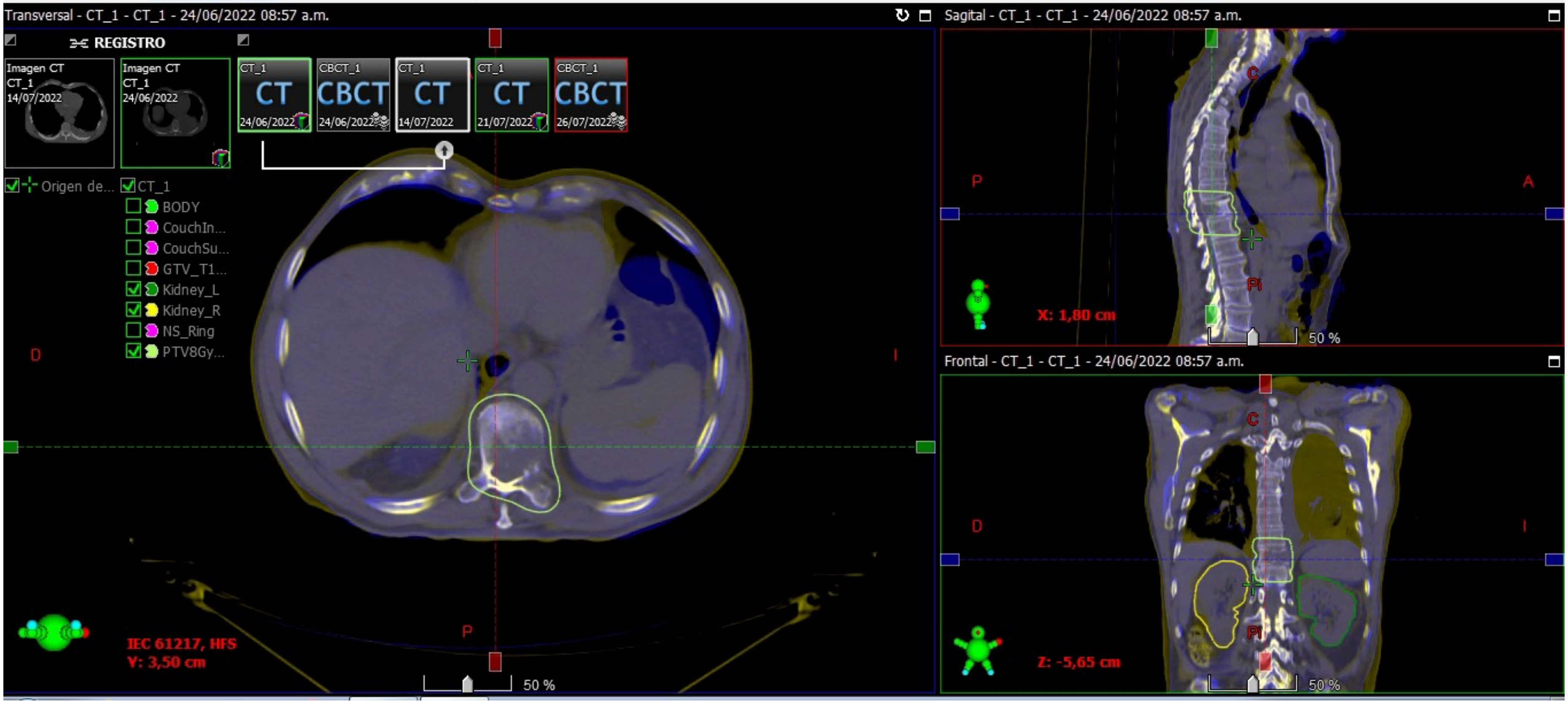
Registro CT-PET/SPECT

Registro CT-MRI

Planificación IMRT.

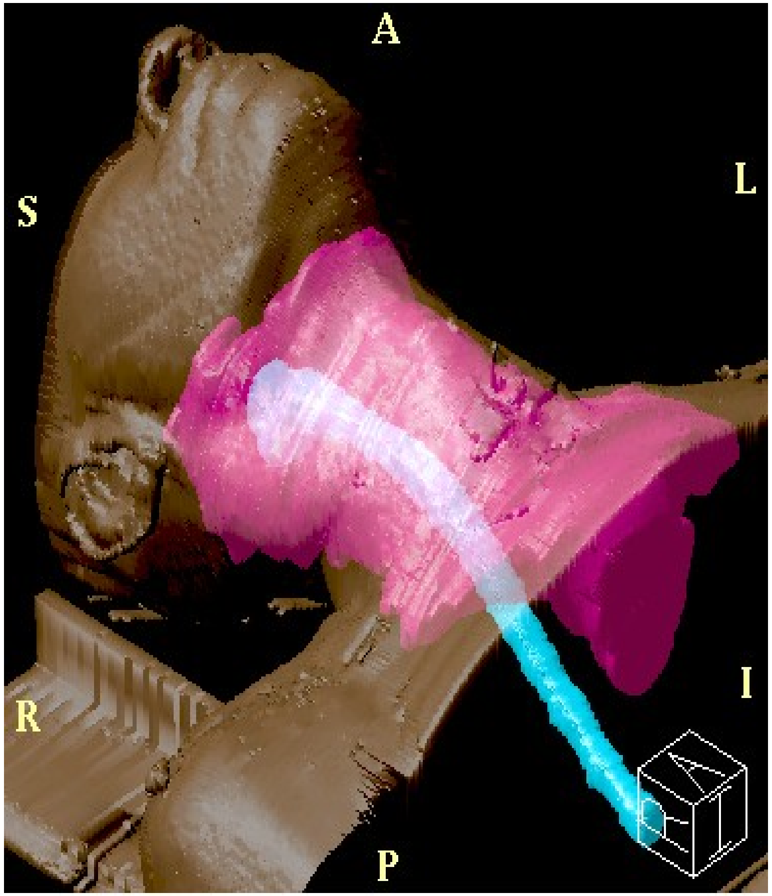
Definición de Volúmenes. ICRU 62

- **Identificación del GTV/CTV**

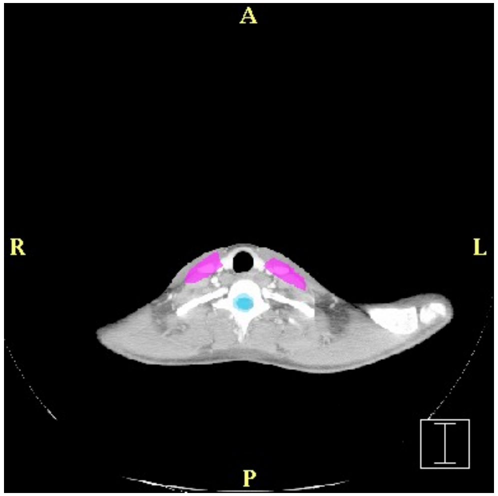


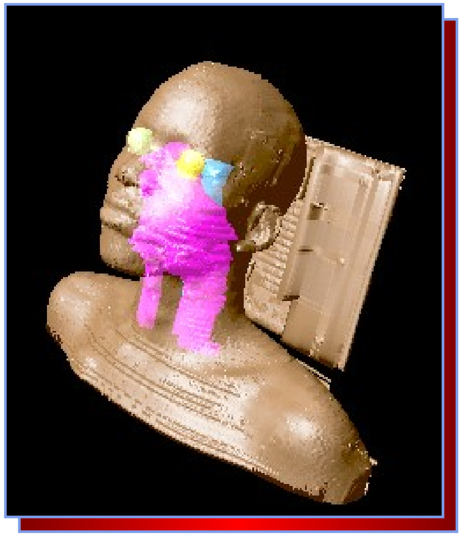
Planificación IMRT.
Definición de Volúmenes

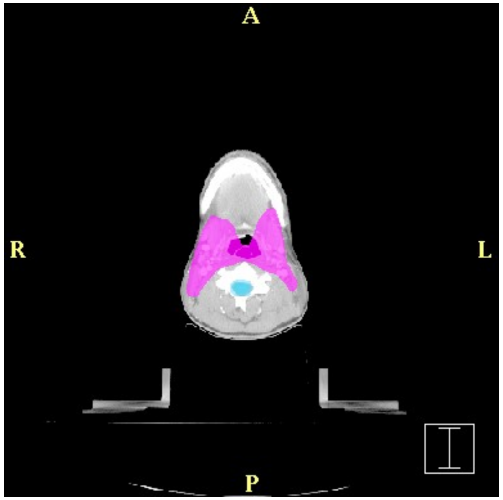
- **Identificación del GTV / CTV y OARs**



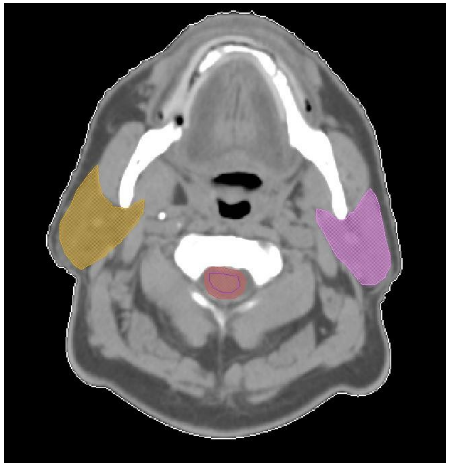
Planificación IMRT.
Definición de Volúmenes

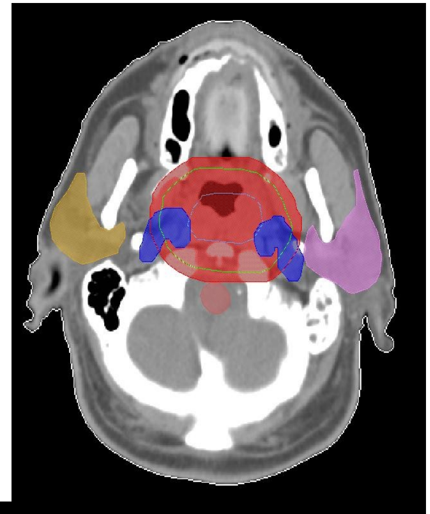


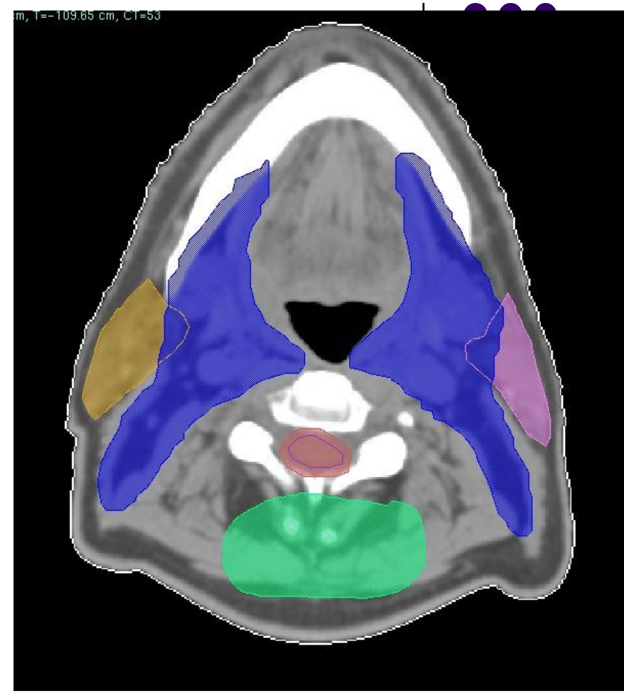


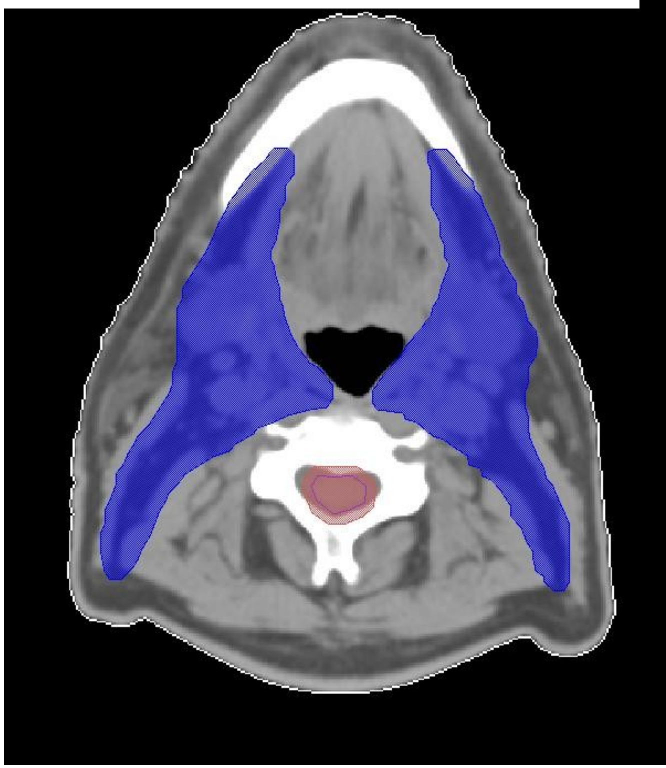


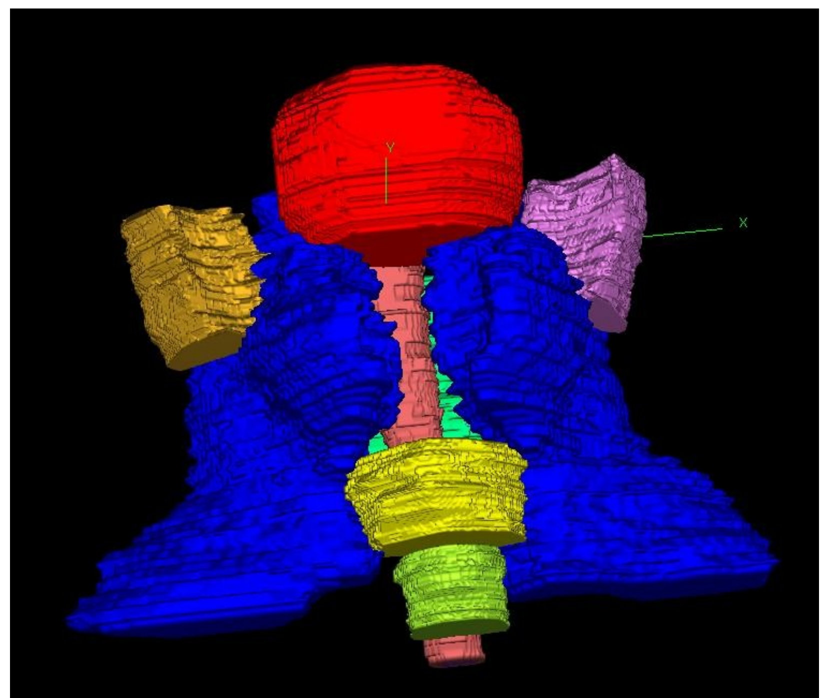
Vista generadas en 3D del GTV/CTV y OARs






T=-109.65 cm, CT=53

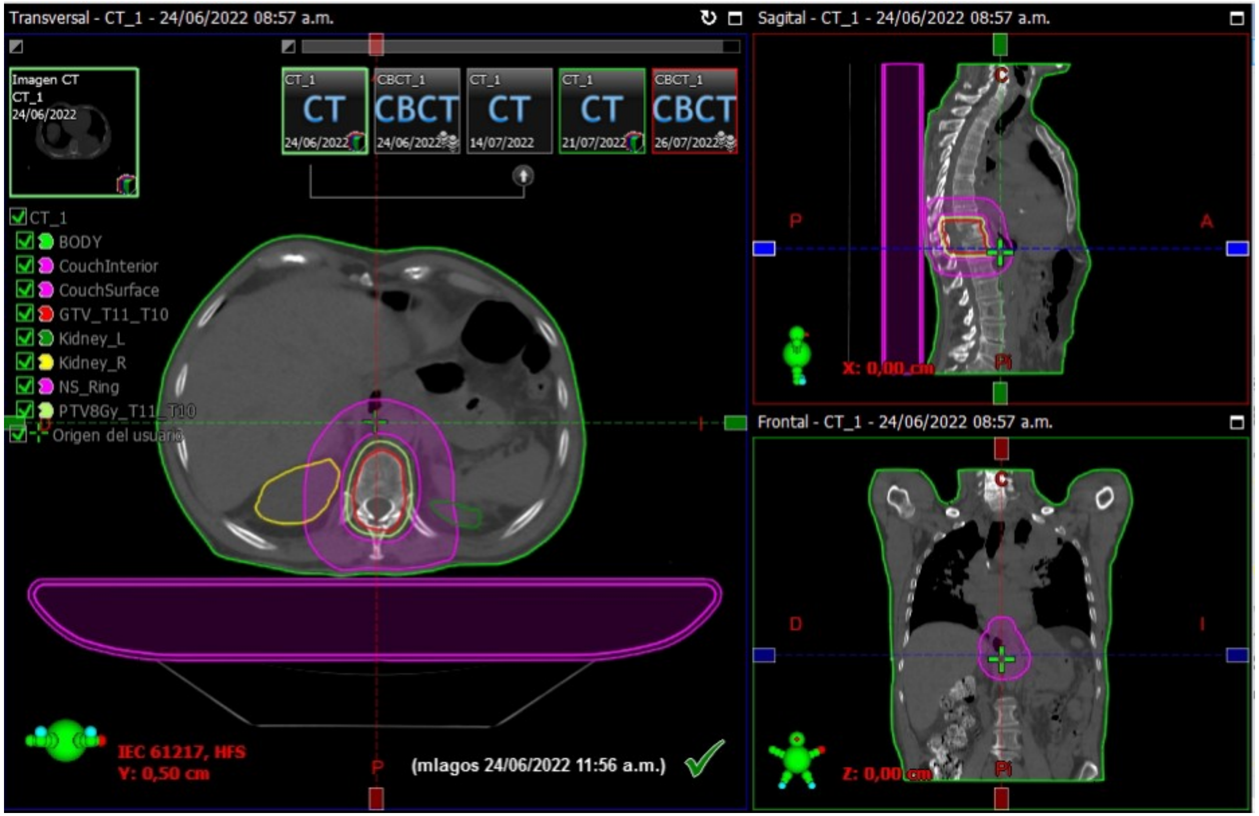



Y
X

Planificación IMRT.

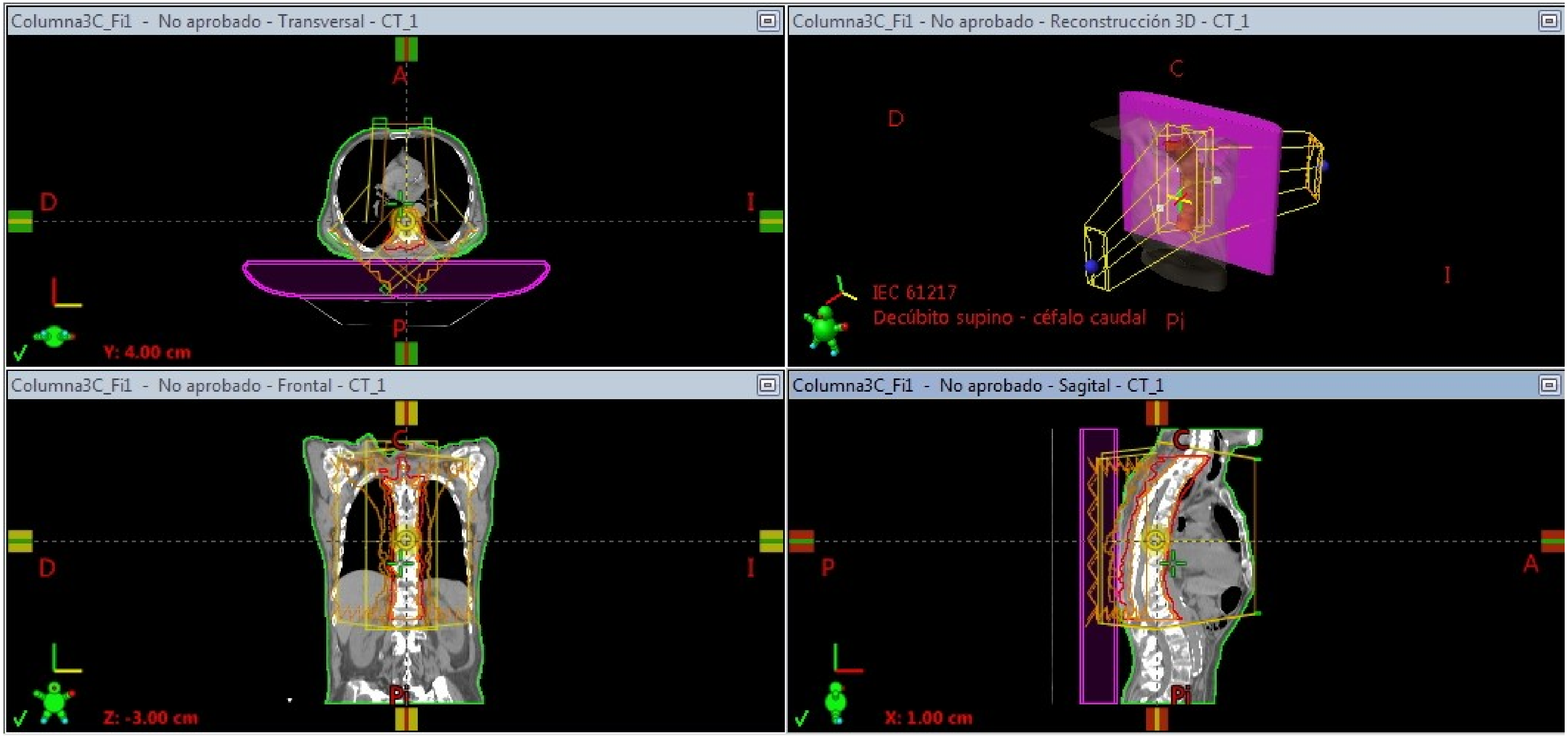
Definición de Volúmenes, estructuras adicionales

- **Estructuras de soporte/camillas**
- **Compensadores/Bolus**
- **Estructuras de ayuda a la optimización**



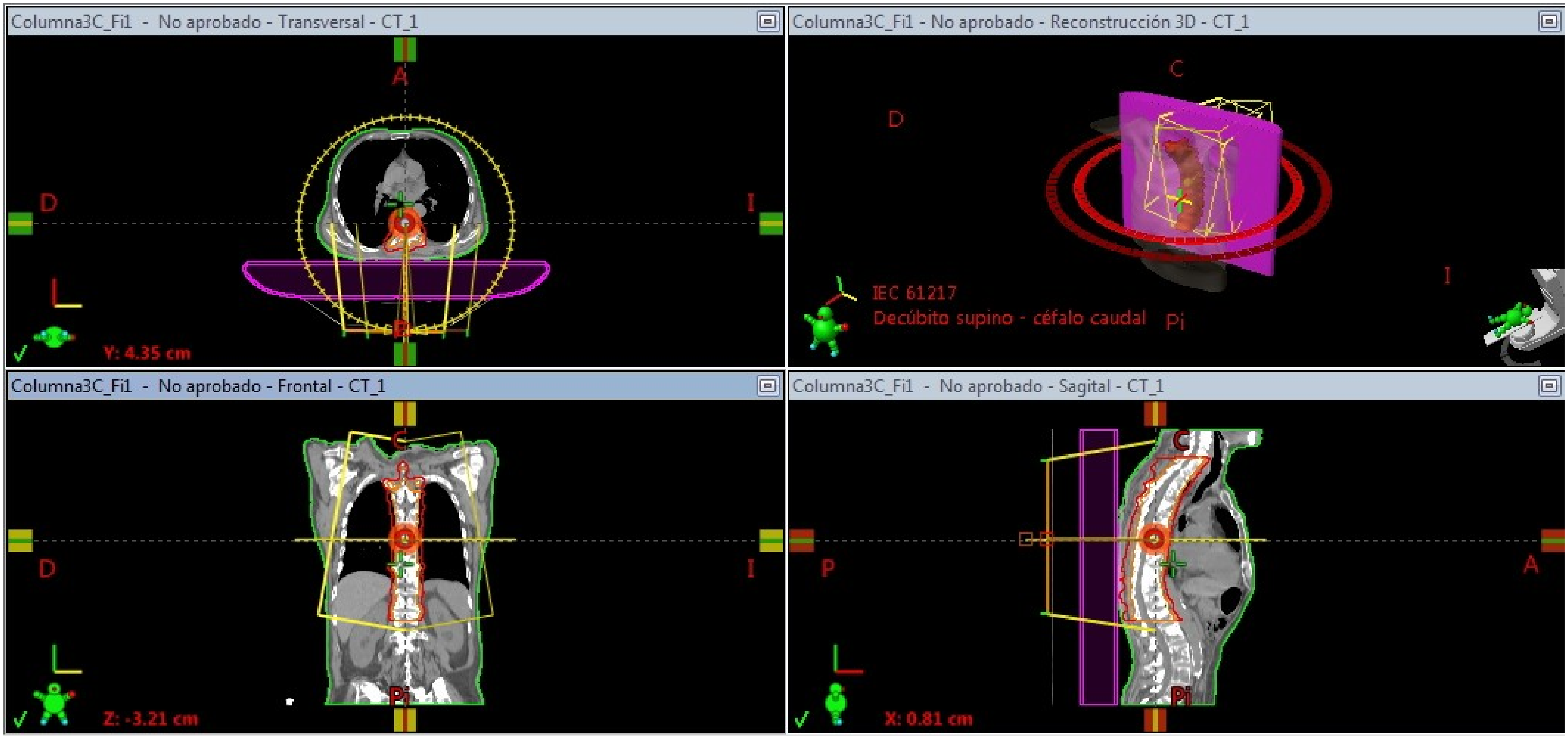
Planificación IMRT.
Configuración de tratamiento

- **Administración estática**



Planificación IMRT.
Configuración de tratamiento

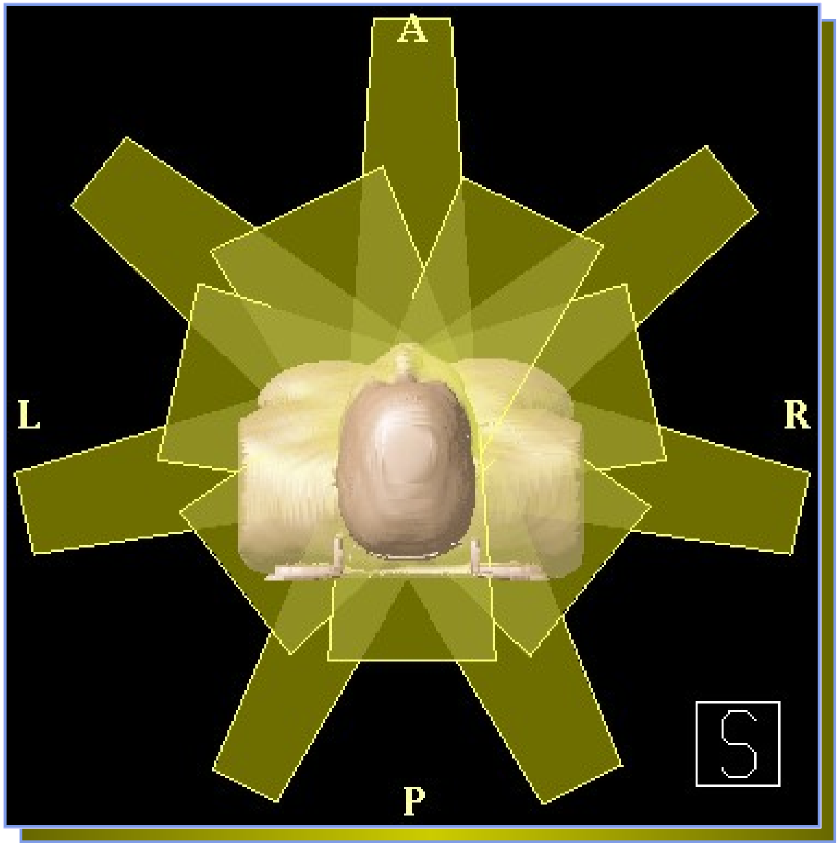
- **Administración dinámica**



Planificación IMRT.

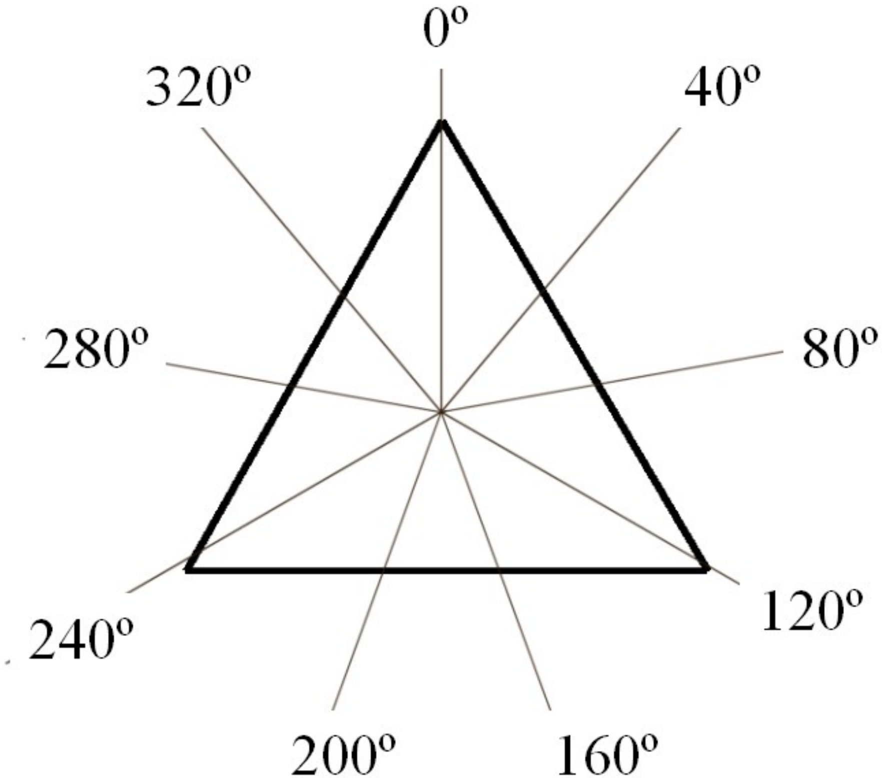
Configuración de tratamiento. Administración estática

- **Se emplean números impares de haces (5, 7 ó 9).**
- **No se usan haces contrapuestos paralelos**



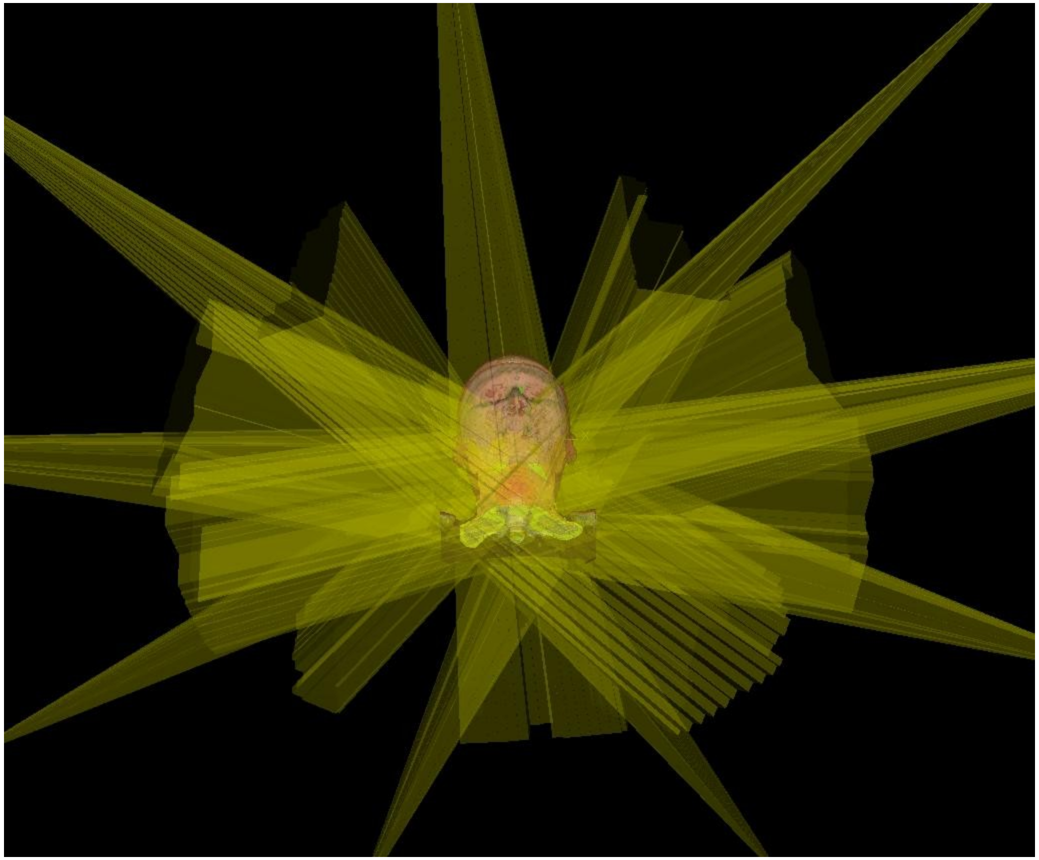
Planificación IMRT.

Configuración de tratamiento. Administración estática



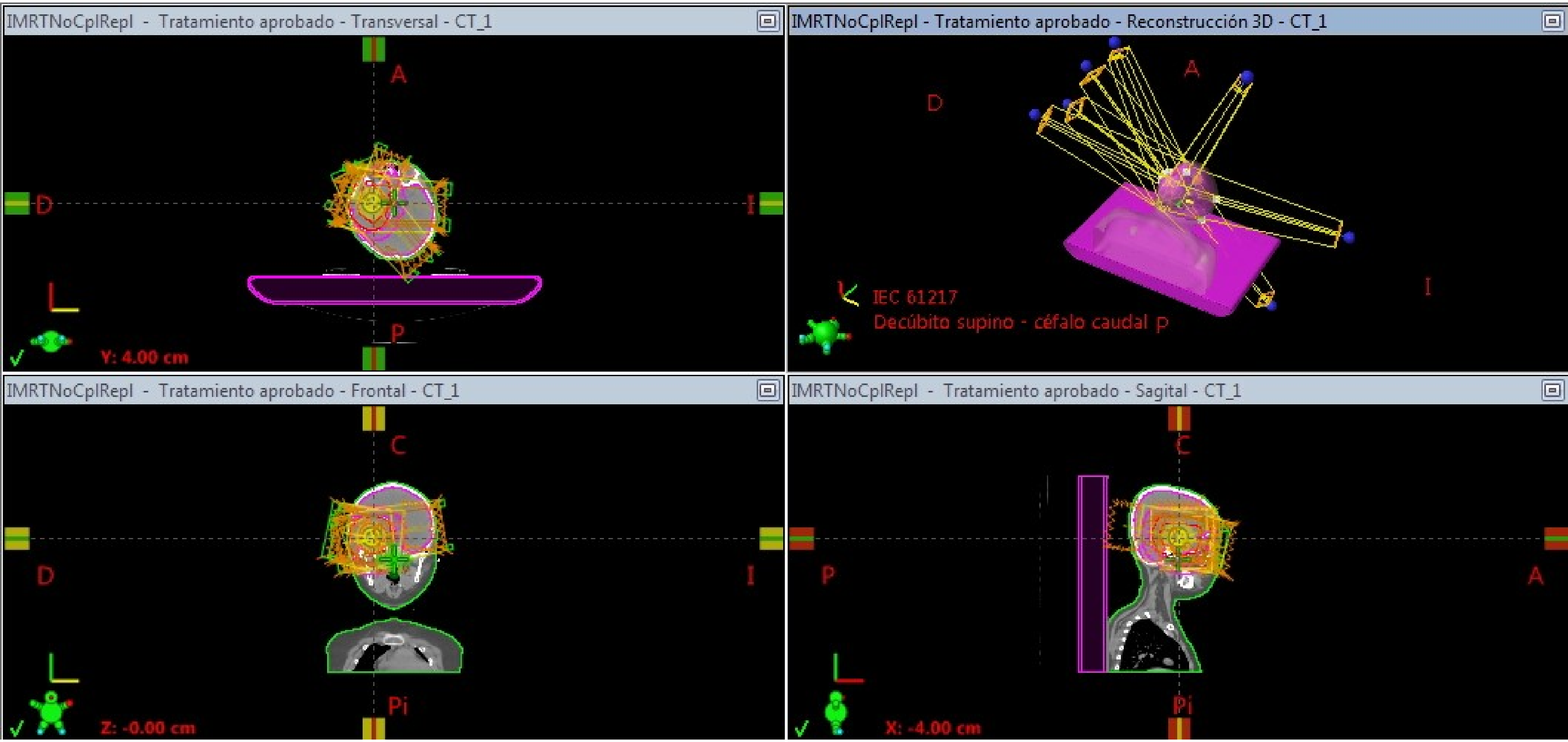
Planificación IMRT.

Configuración de tratamiento. Administración estática



Planificación IMRT.
Configuración de tratamiento. Administración estática

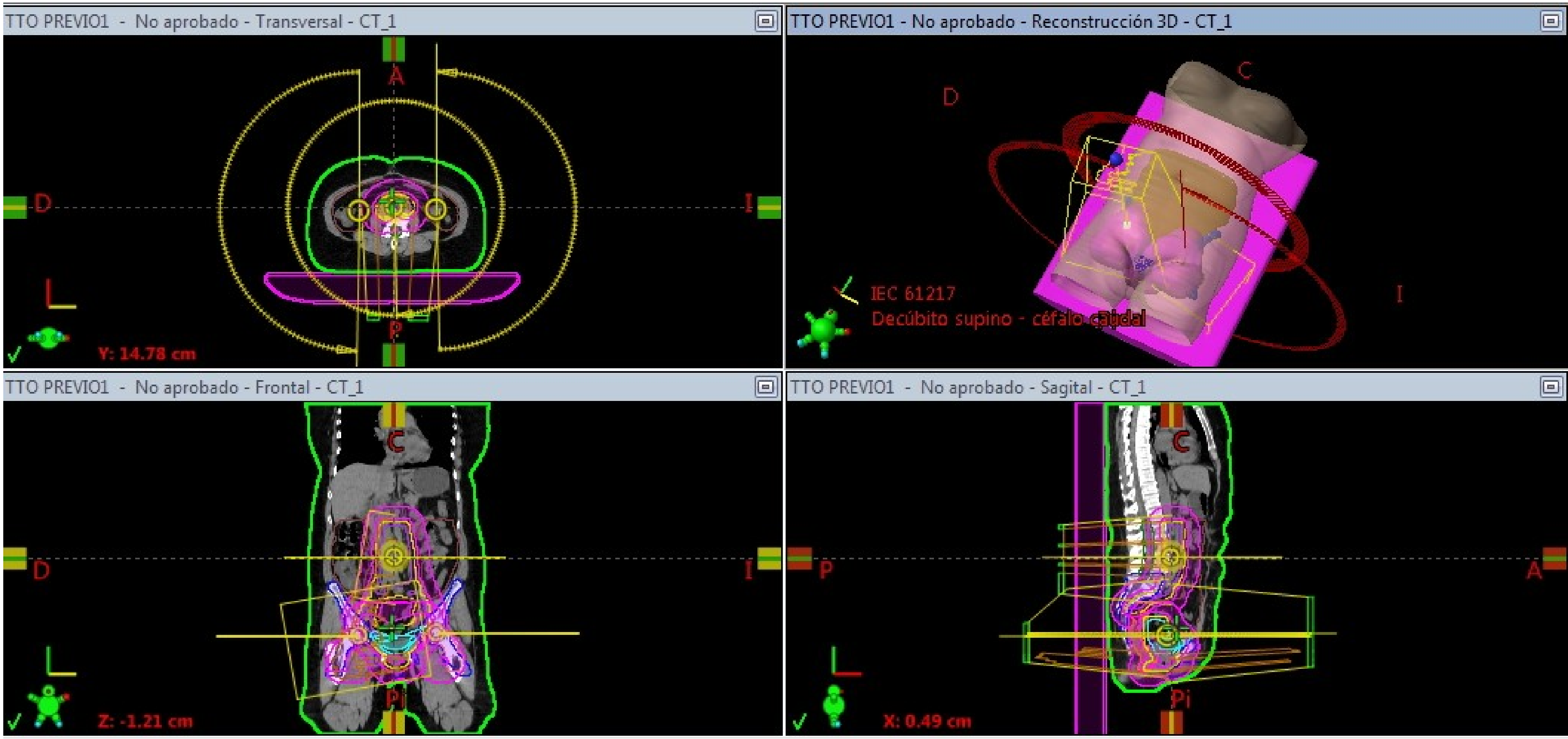
- **Campos no coplanares**



Planificación IMRT.

Configuración de tratamiento. Administración dinámica

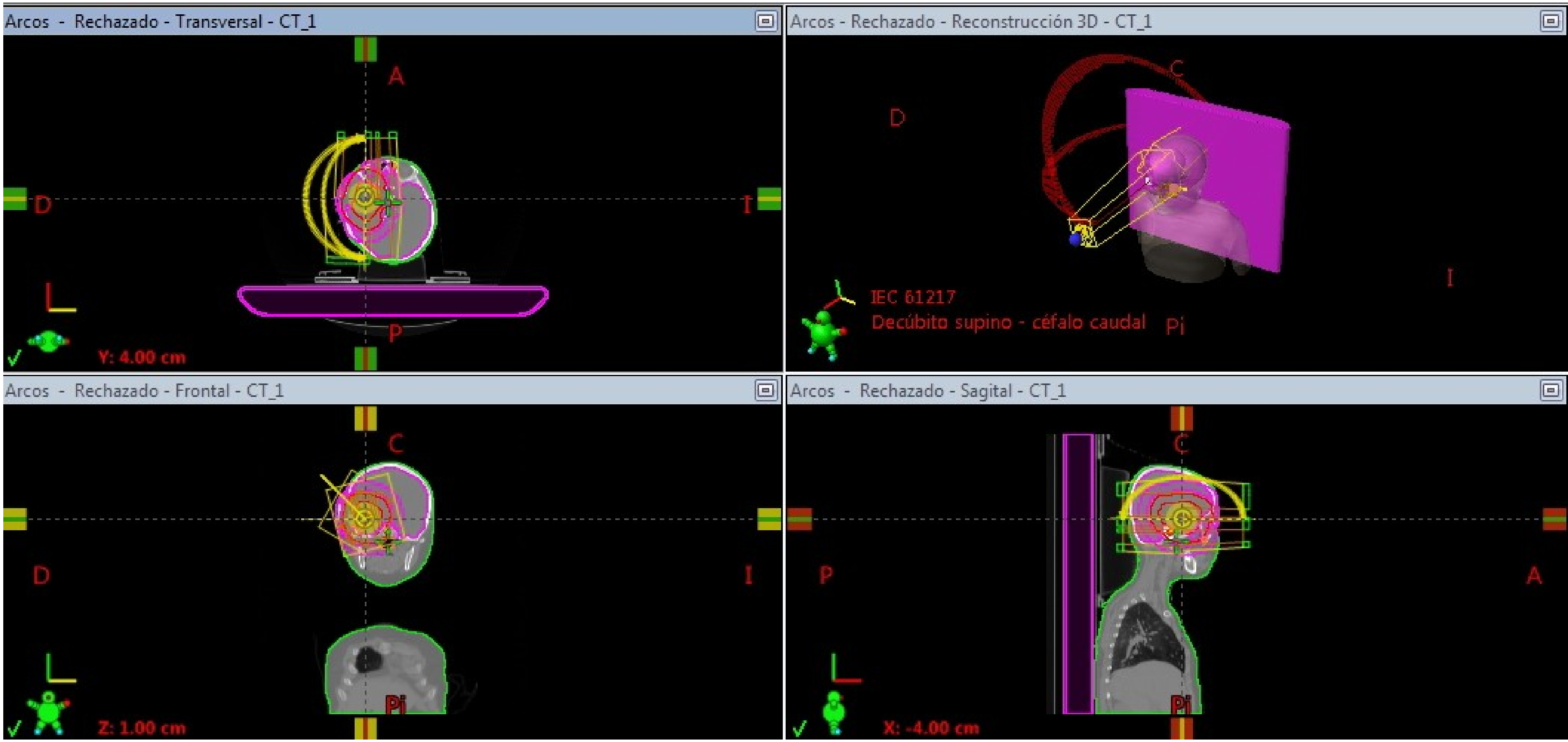
Uno o más arcos de diferentes amplitudes y centrados en uno o más isocentros dependiendo de la localización/extensión del CTV



Planificación IMRT.

Configuración de tratamiento. Administración dinámica

- **Arcos no coplanares**



Planificación IMRT.
Optimización

- **Uno de los pre-requisitos para la aplicación clínica de la IMRT fue el desarrollo de estrategias de PLANIFICACION INVERSA.**

- **Simplemente porque las estrategias disponibles de planificación directa (“Forward”) no eran factibles de aplicar a la optimización del enorme número de parámetros de tratamiento que se presentaron de pronto para lograr una administración eficiente de los campos con IM**

Planificación IMRT.

Optimización. Planificación Inversa vs Directa

- **RT Convencional (*Planificación directa*)**
  - **El usuario sugiere posible solución**
  - **El TPS muestra los resultados para implementar el plan**
  - **Se realiza iteración intuitiva (basada en experticia) hasta lograr un plan aceptable.**

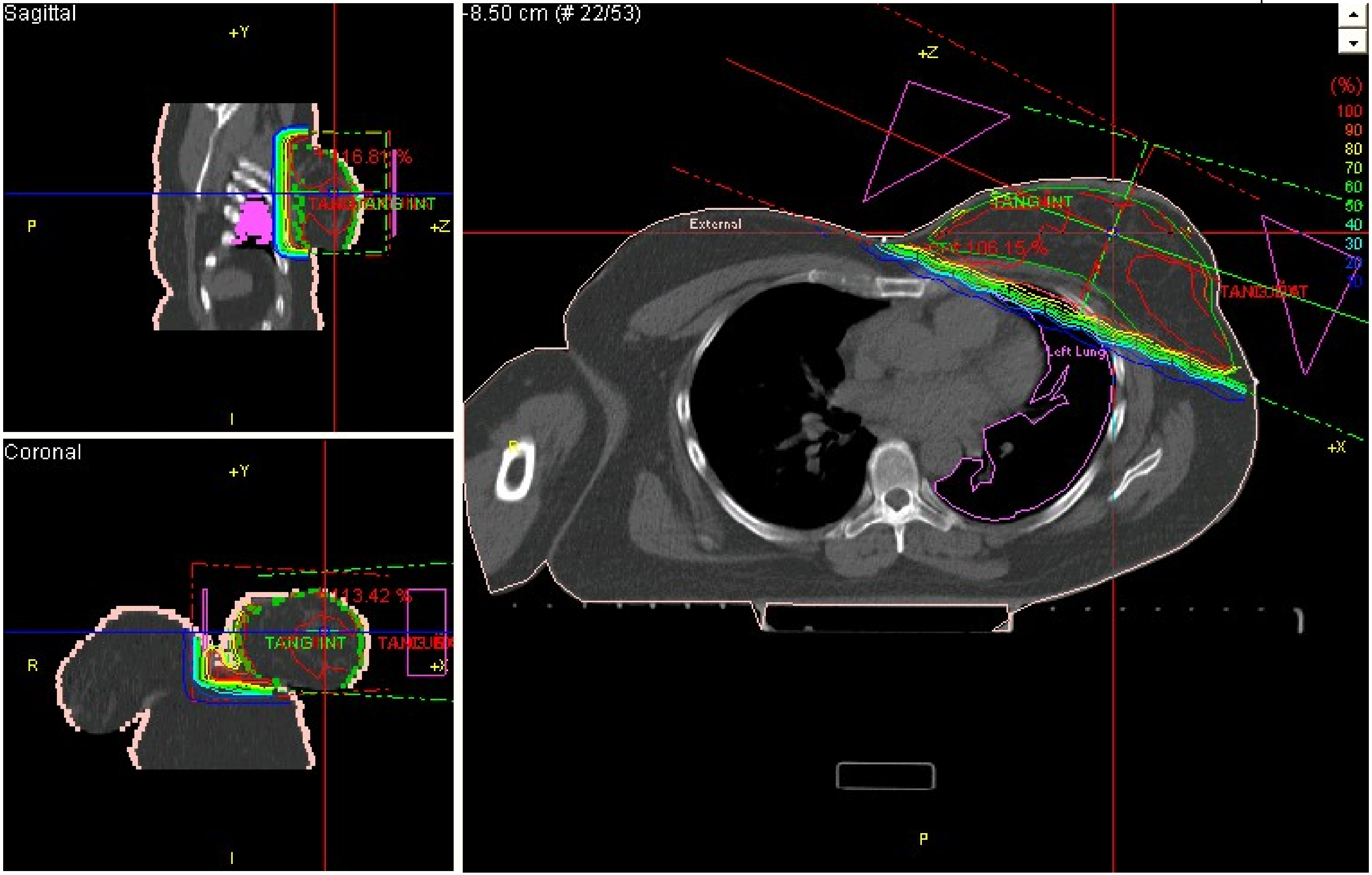
- **IMRT (*Planificación inversa*)**
  - **El usuario establece objetivos (“*goals*”) deseados en términos de dosis y volúmenes**
  - **El TPS sugiere una “solución óptima” por iteraciones sucesivas**
  - **El usuario evalúa el plan sugerido por el TPS y eventualmente restablece los goals hasta que el plan sea satisfactorio**

Planificación IMRT.

Optimización. Planificación Directa (field-in-field)

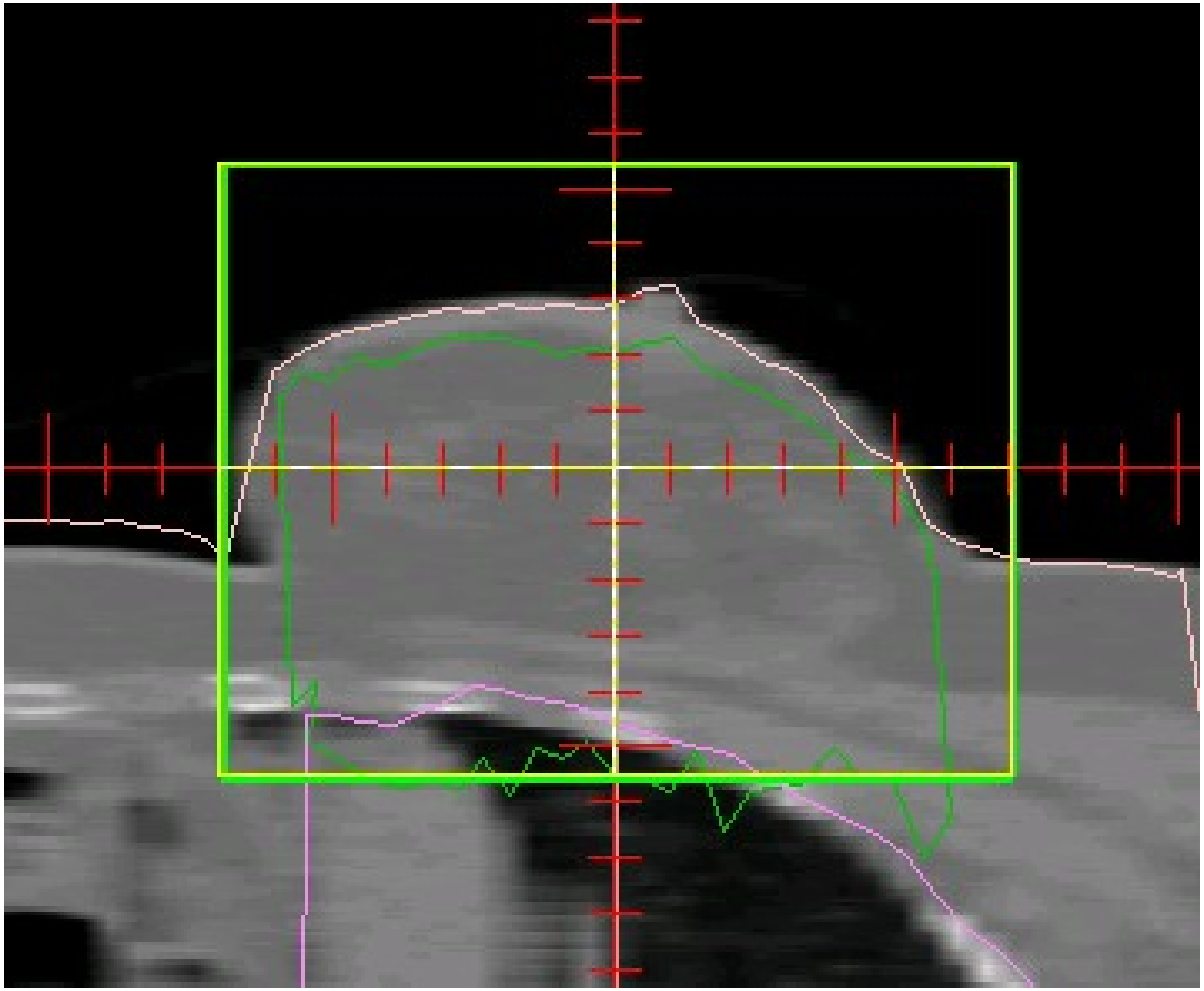
- **Utiliza las herramientas de planificación existentes para 3DCRT**
- **Definición de segmentos estáticos de campos superpuestos**
- **pesos intuitivos o asignados mediante optimización asistida**
- **distribuciones de dosis resultantes en el volumen blanco y órganos críticos reajustadas iterativamente (prueba-error)**

Planificación IMRT.
Optimización. Planificación Directa (field-in-field)



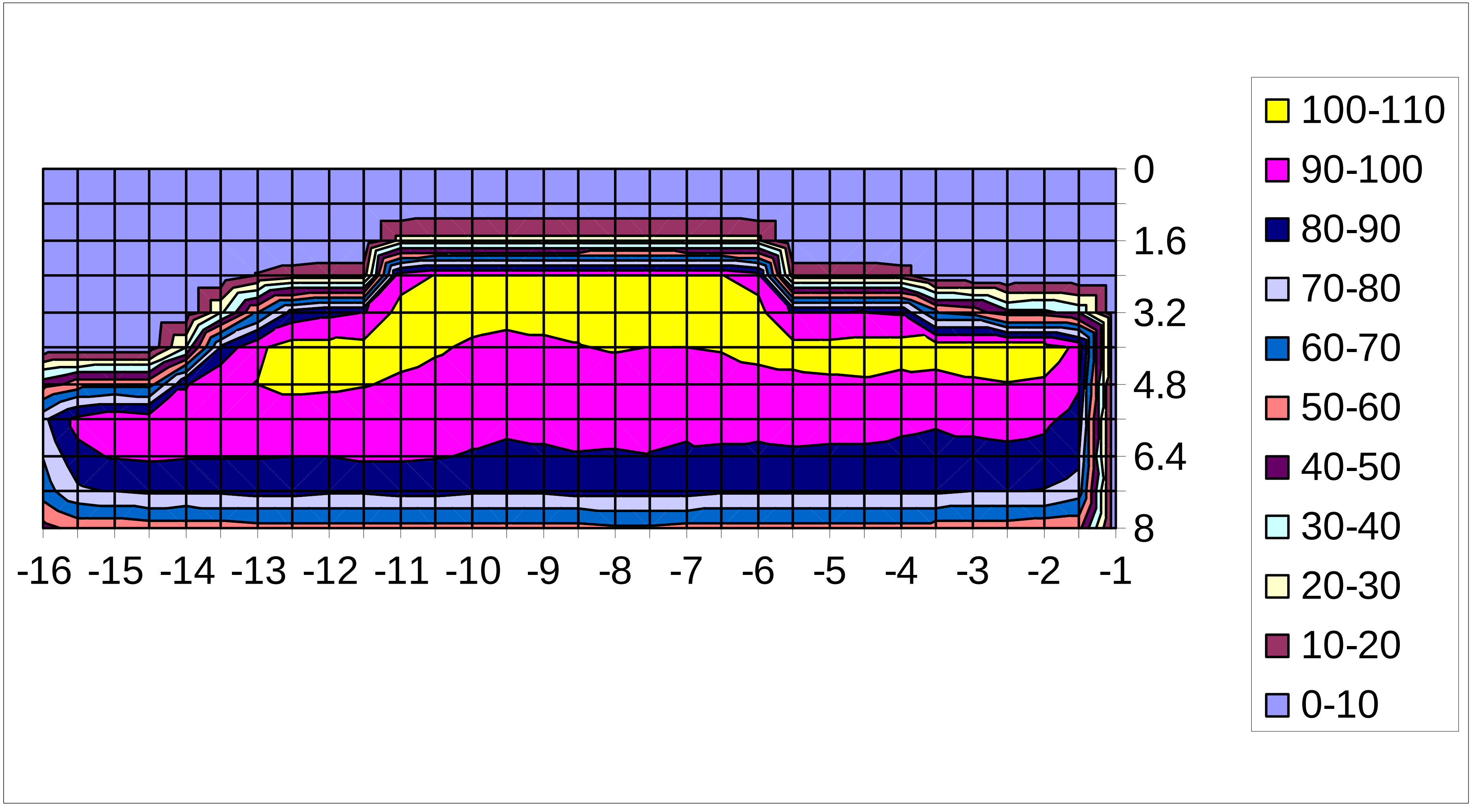
Planificación IMRT.

Optimización. Planificación Directa (field-in-field)



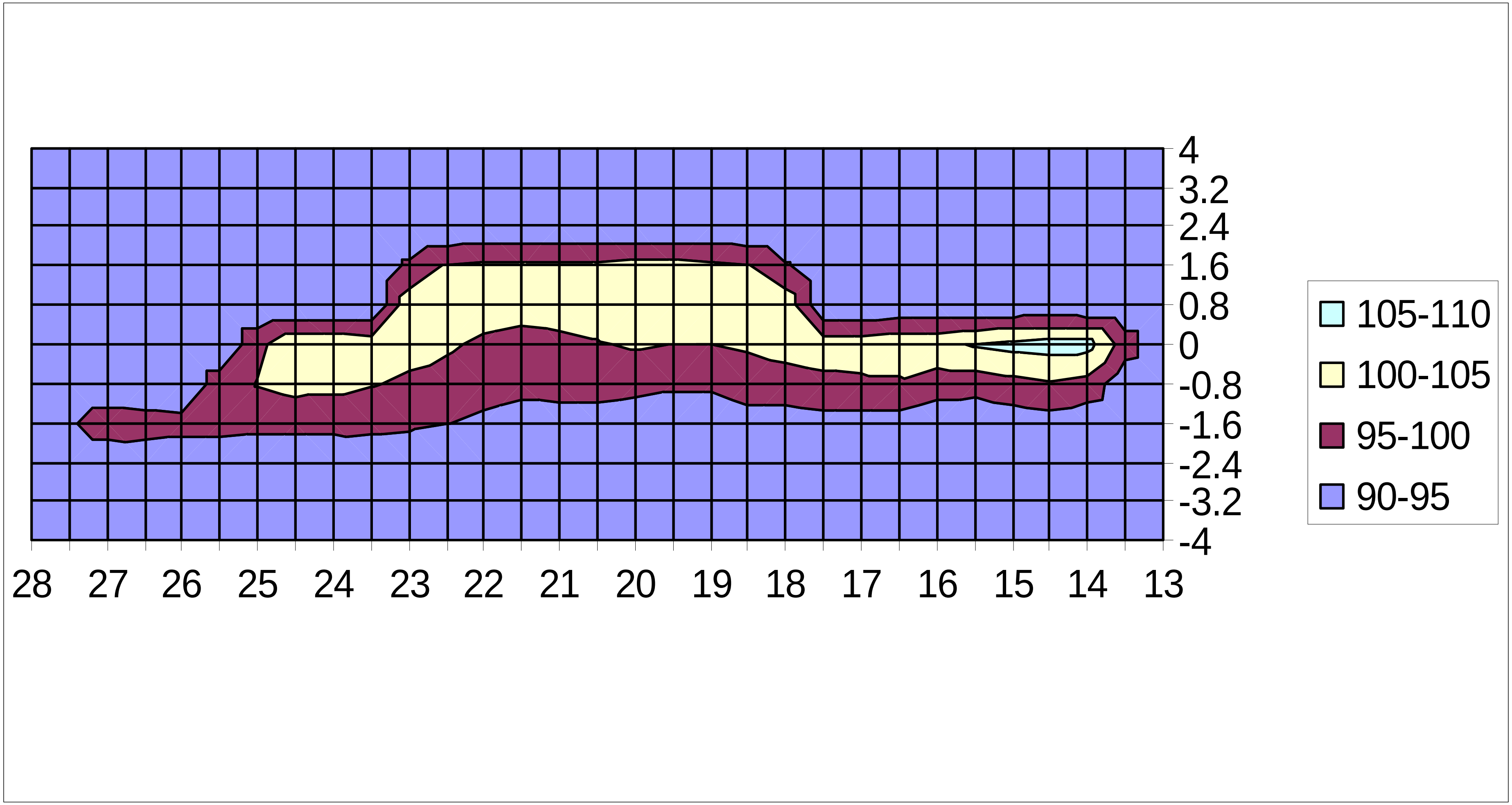
Planificación IMRT.

Optimización. Planificación Directa (field-in-field)



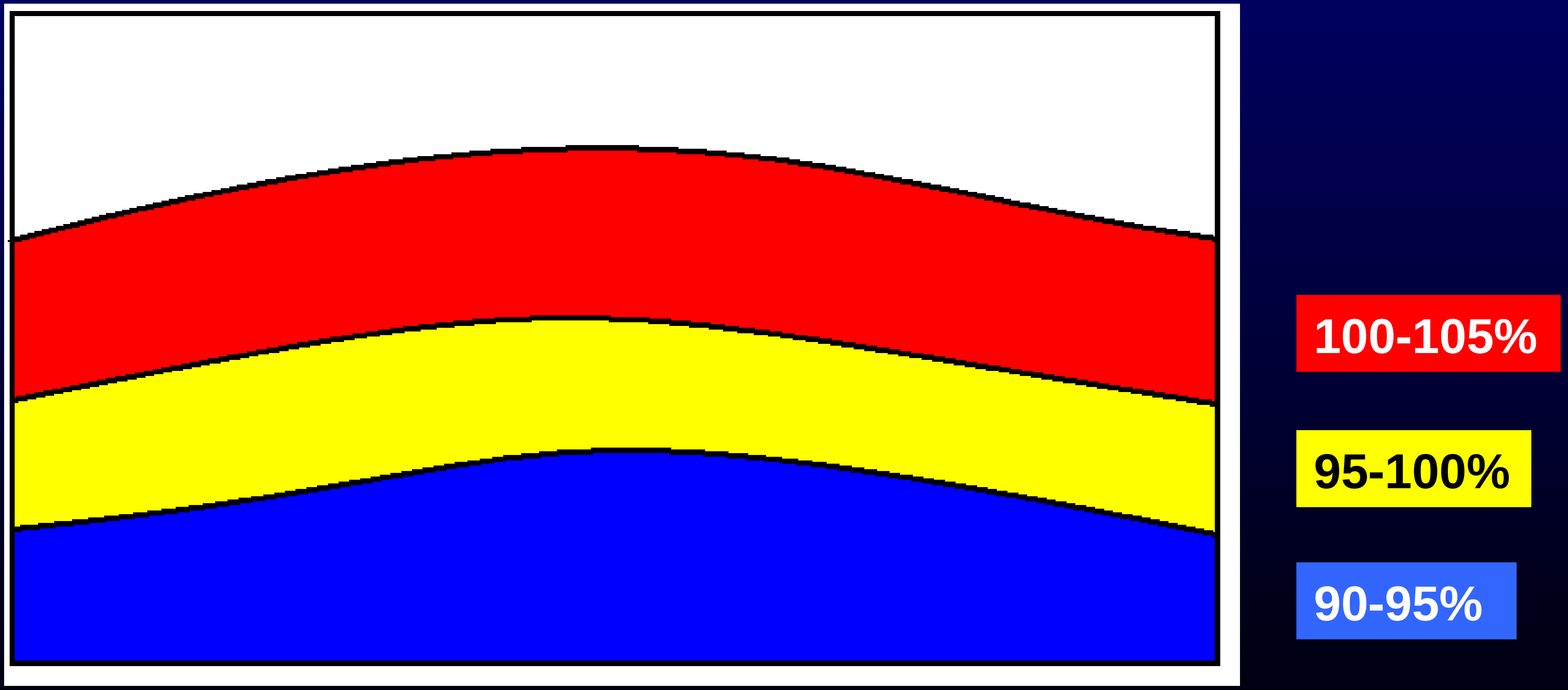
Planificación IMRT.

Optimización. Planificación Directa (field-in-field)



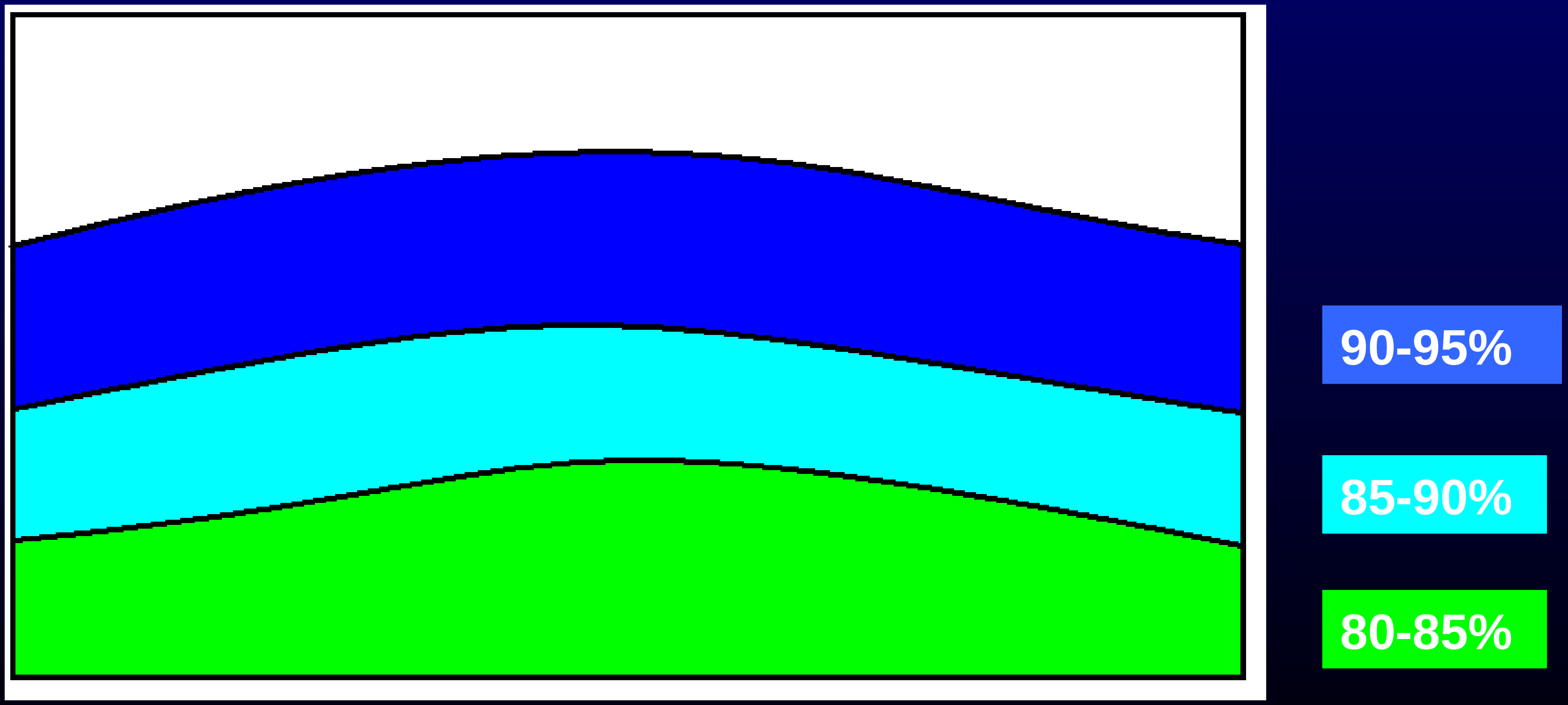
Desarrollo de la Solución Tipo.
Asignación de pesos

Segmento Tipo A. Peso 100% Condición Inicial



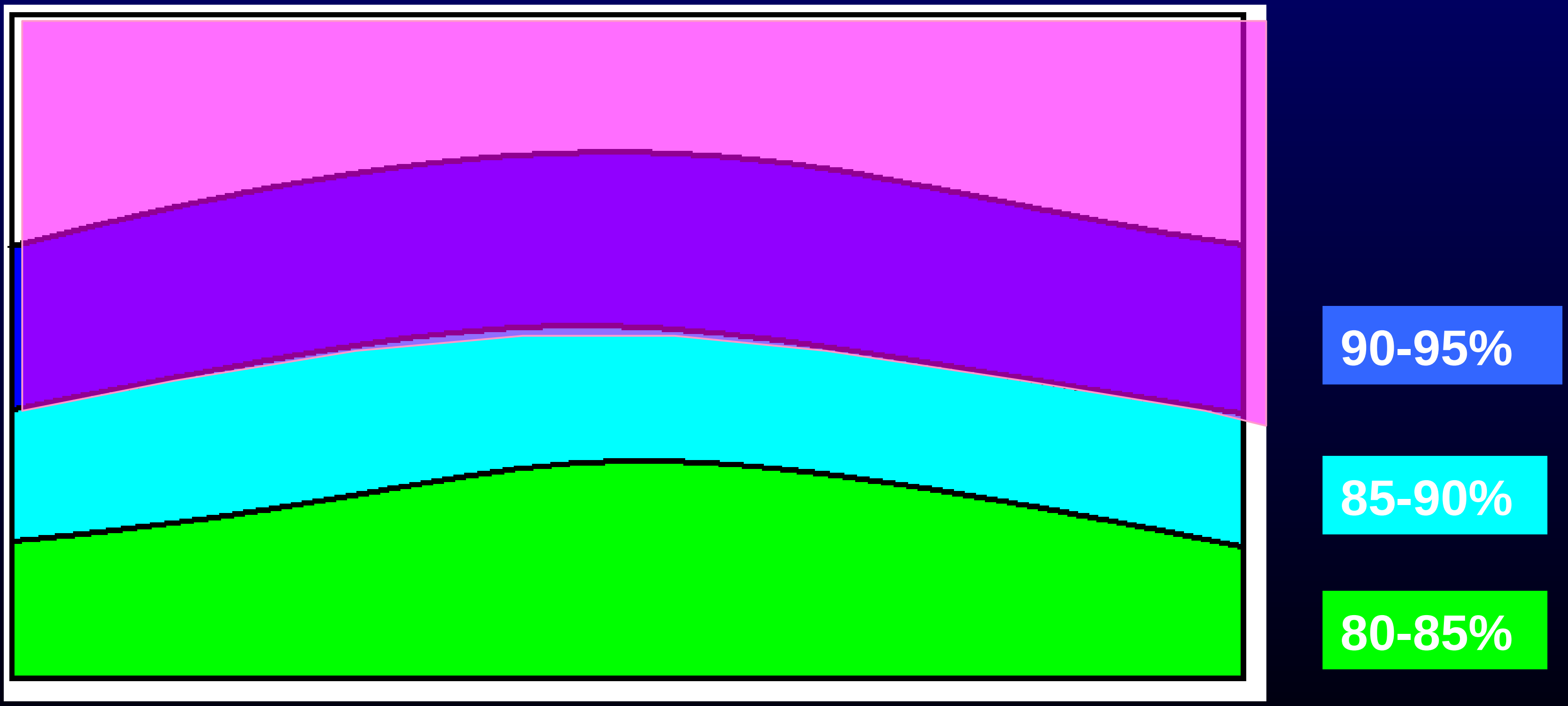
Desarrollo de la Solución Tipo. Asignación de pesos

Segmento Tipo A. Peso 90%

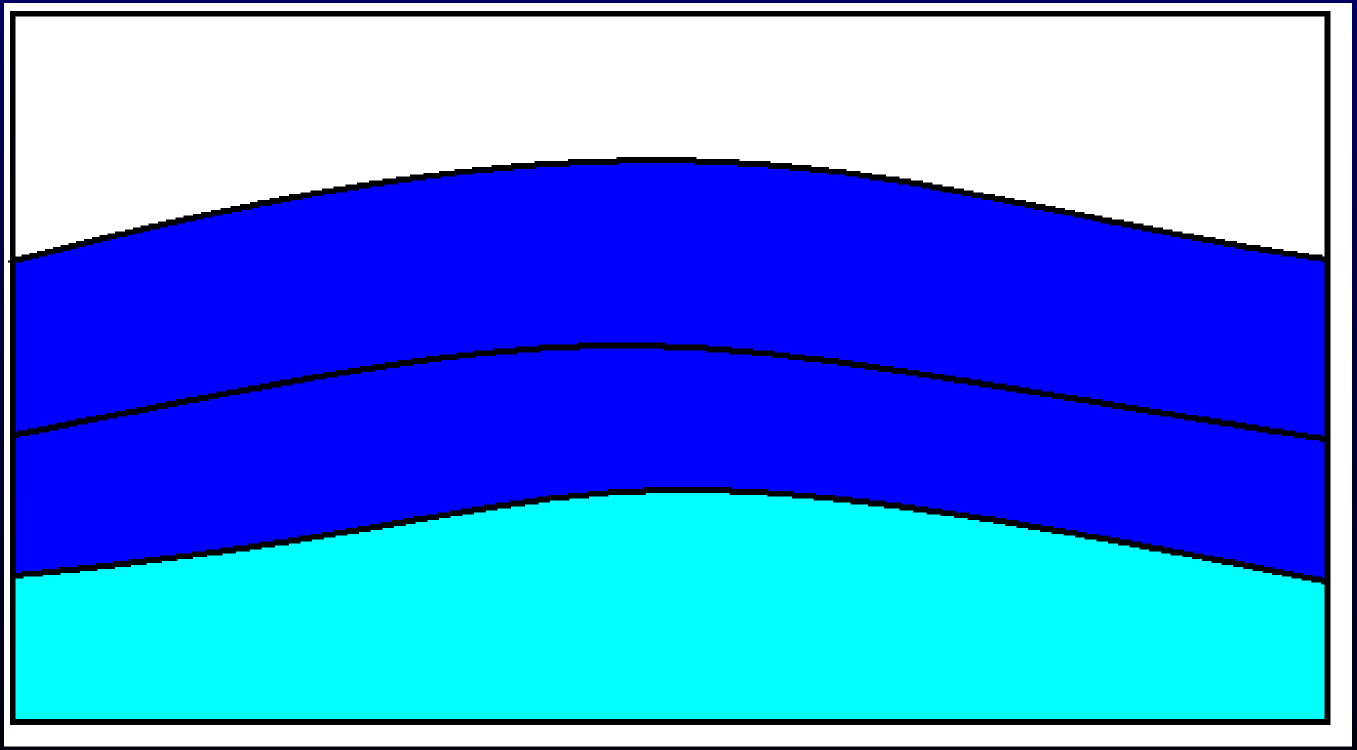


Desarrollo de la Solución Tipo. Asignación de pesos

Segmento Tipo B. Peso 5%



Desarrollo de la Solución Tipo.
Asignación de pesos
1er Segmento Tipo B. Peso 5%

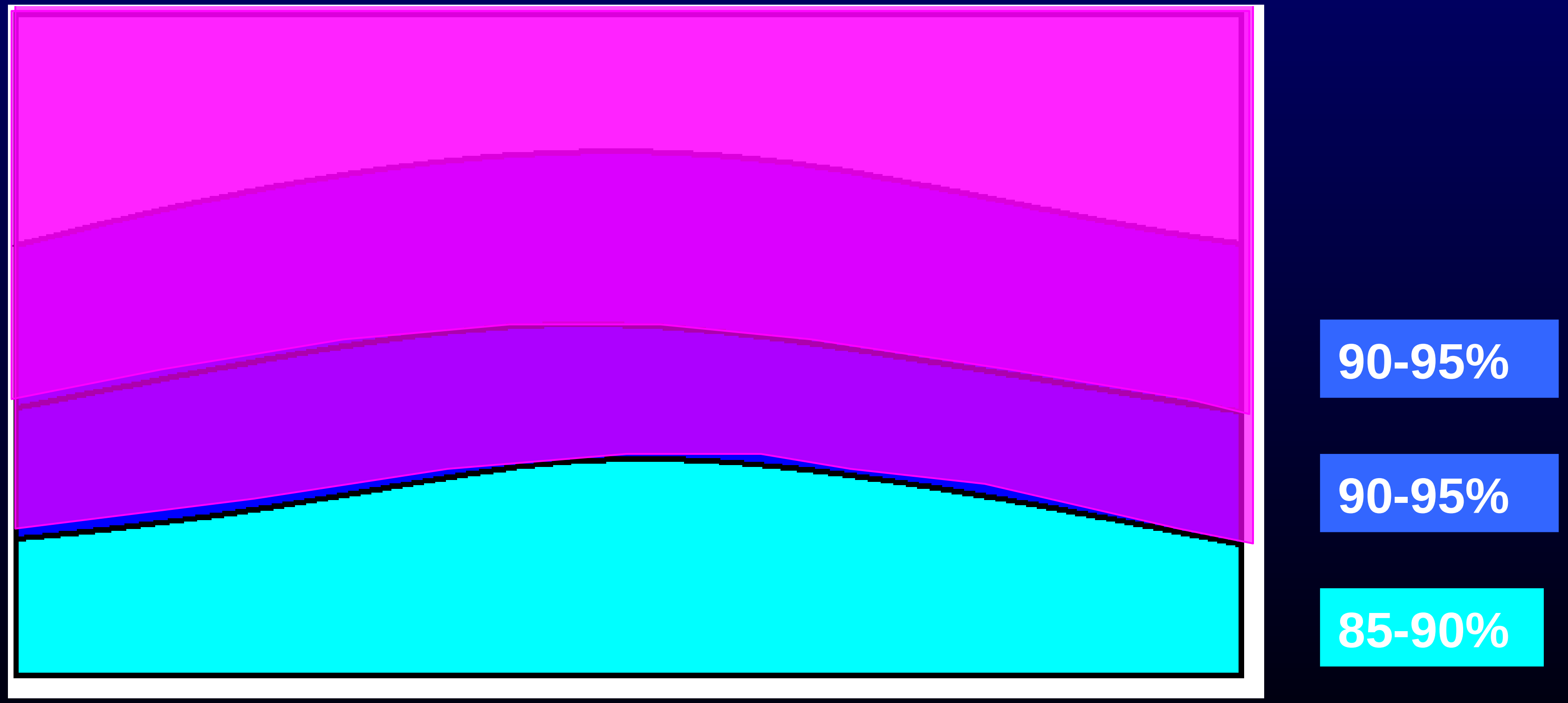


90-95%

90-95%

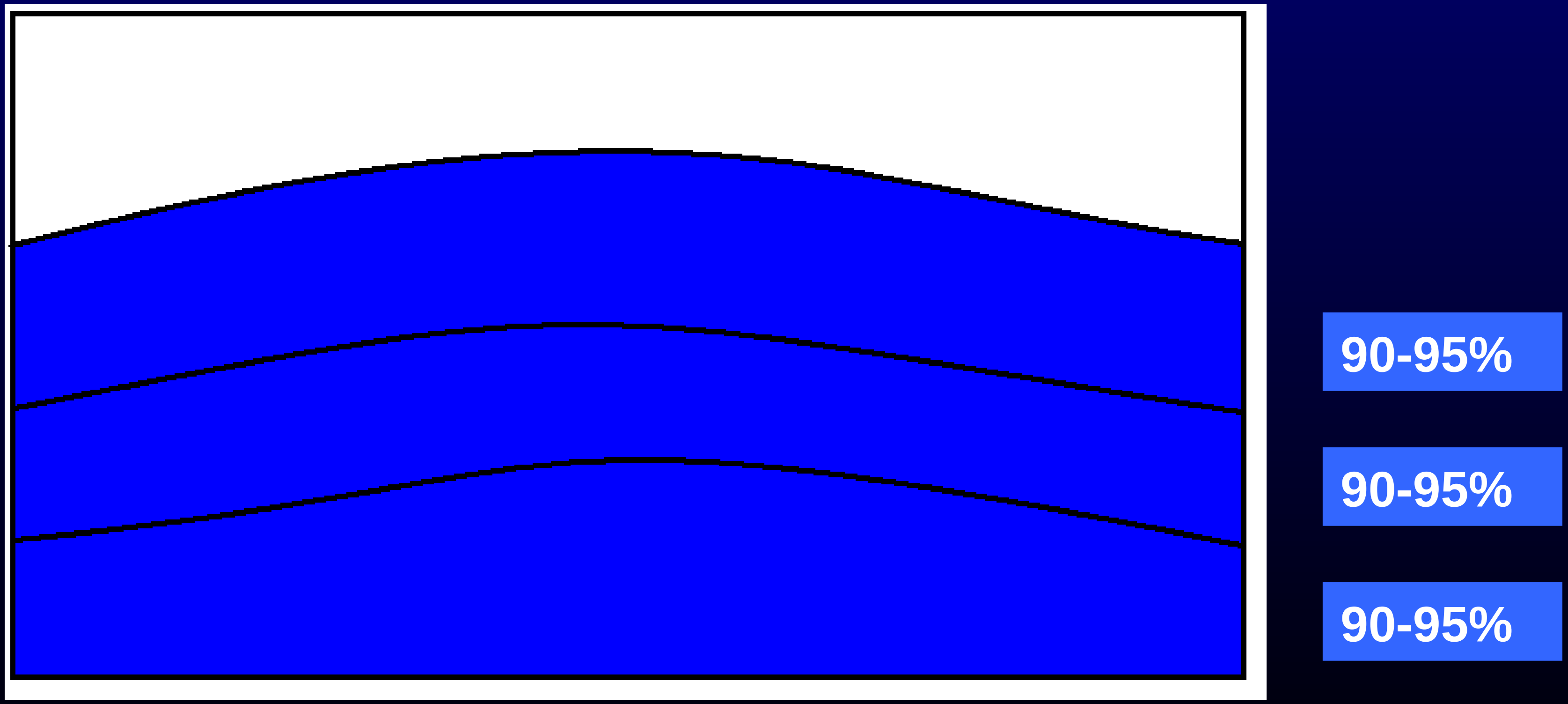
85-90%

Desarrollo de la Solución Tipo.
Asignación de pesos
1er Segmento Tipo B. Peso 5%



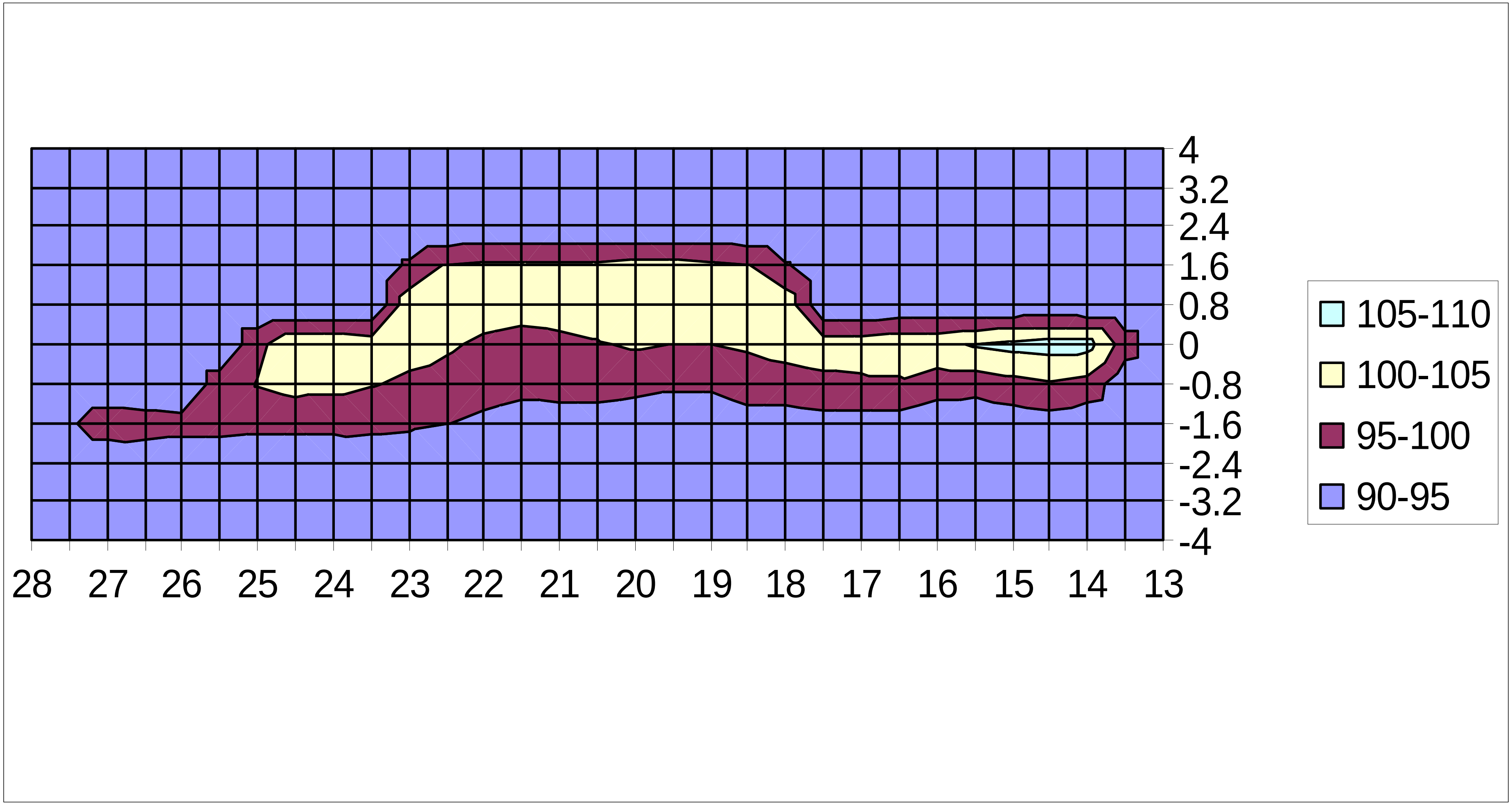
Desarrollo de la Solución Tipo. Asignación de pesos

Resultado Final



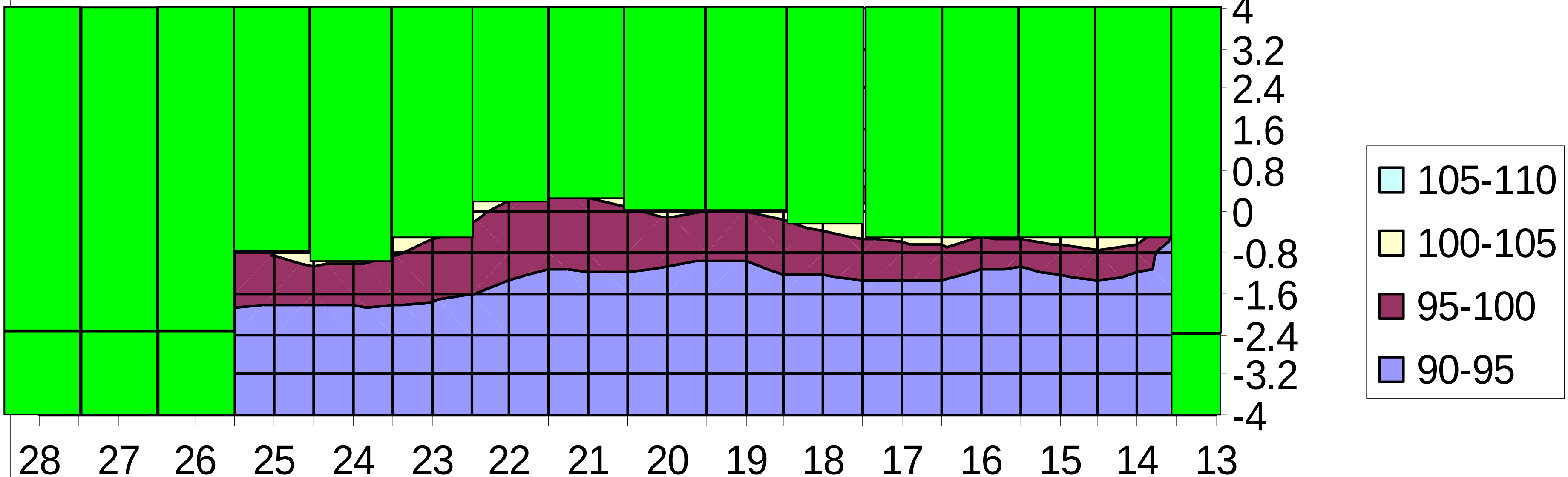
Planificación IMRT.

Optimización. Planificación Directa (field-in-field)



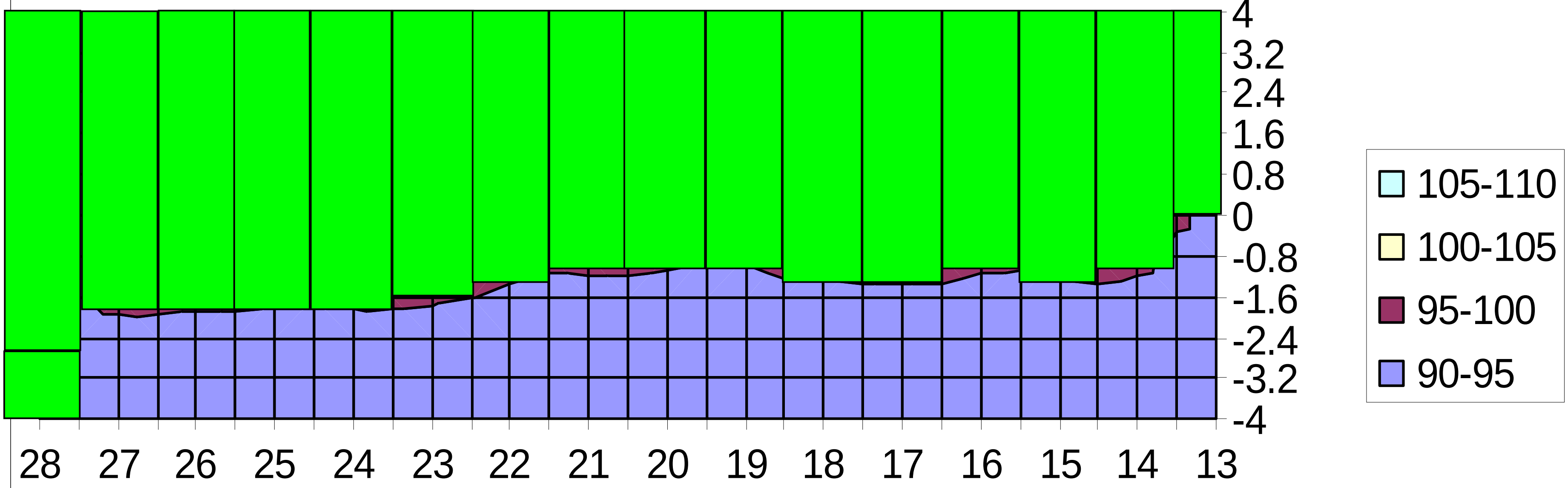
Planificación IMRT.

Optimización. Planificación Directa (field-in-field)



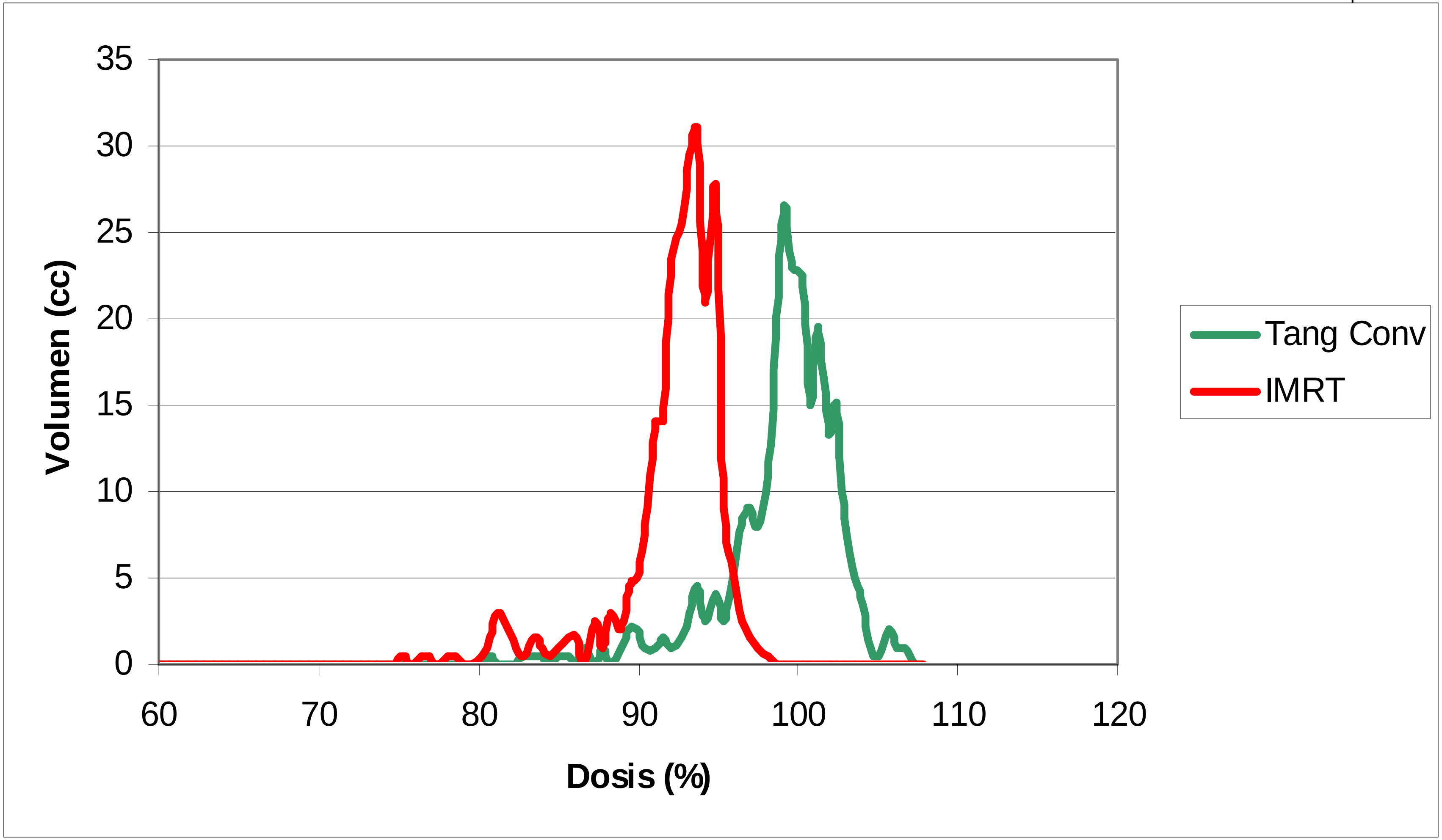
Planificación IMRT.

Optimización. Planificación Directa (field-in-field)



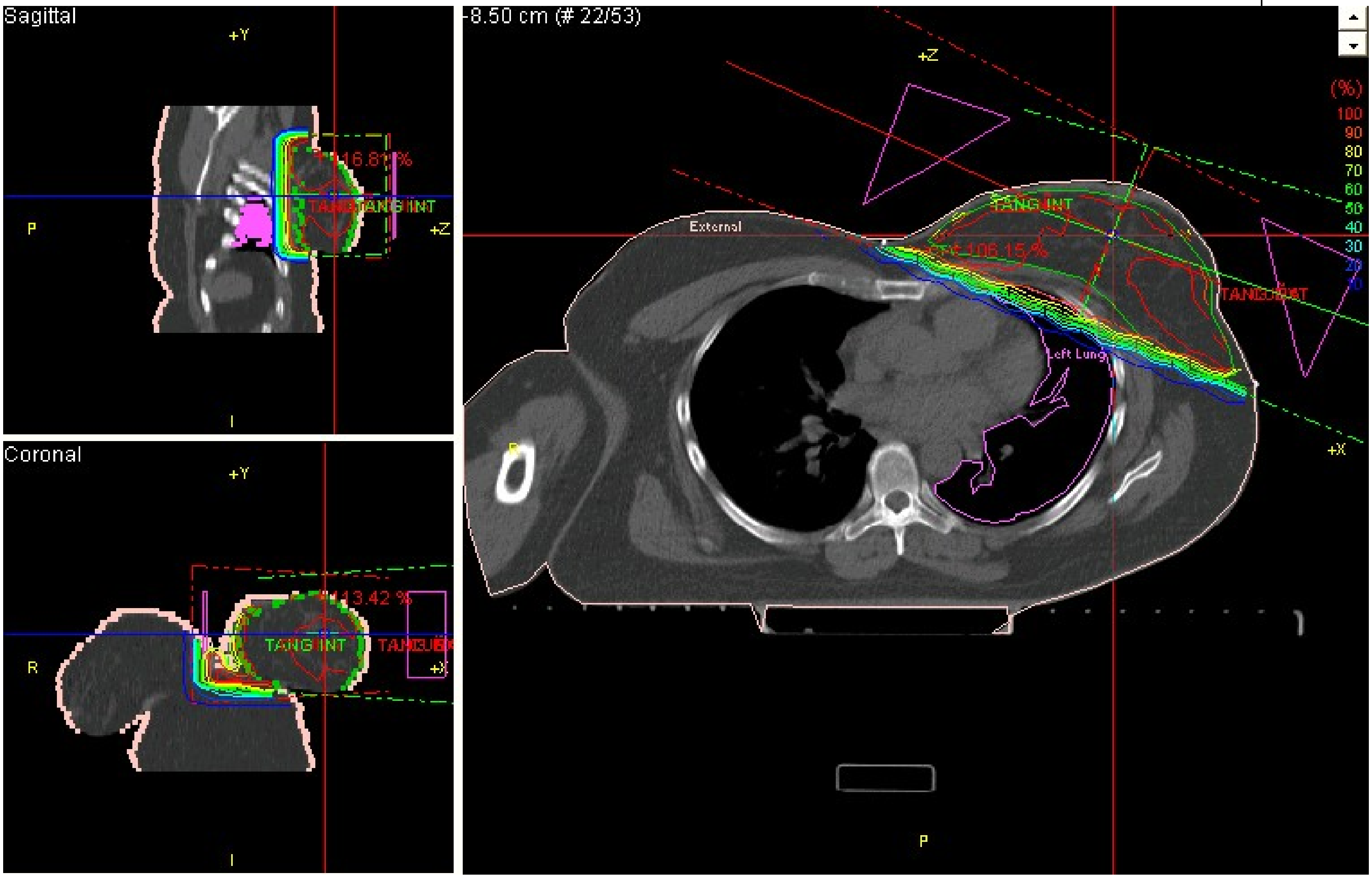
Planificación IMRT.

Optimización. Planificación Directa (field-in-field)



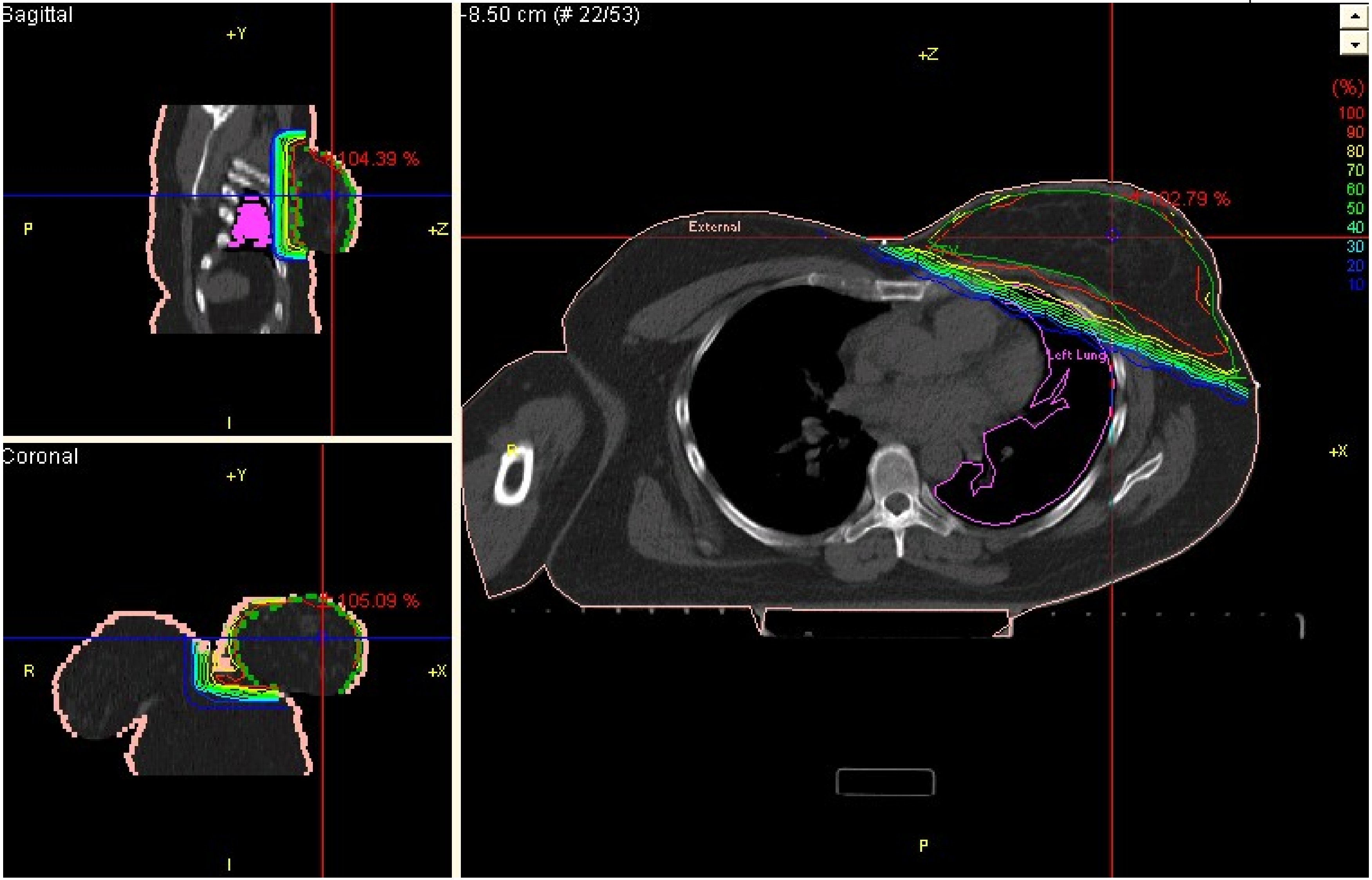
Planificación IMRT.

Optimización. Planificación Directa (field-in-field)



Planificación IMRT.

Optimización. Planificación Directa (field-in-field)



Planificación IMRT.

Optimización Planificación Inversa. Prescripción

- Objetivos de dosis (goals)
- Restricciones de dosis (constraints)
- Restricciones de volumen
  - Prescripción no en un punto
- Pérdida de información geométrica
  - Todas las partes del OAR son iguales
  - Todas las partes del PTV son iguales

Planificación IMRT.

Definición de la Prescripción

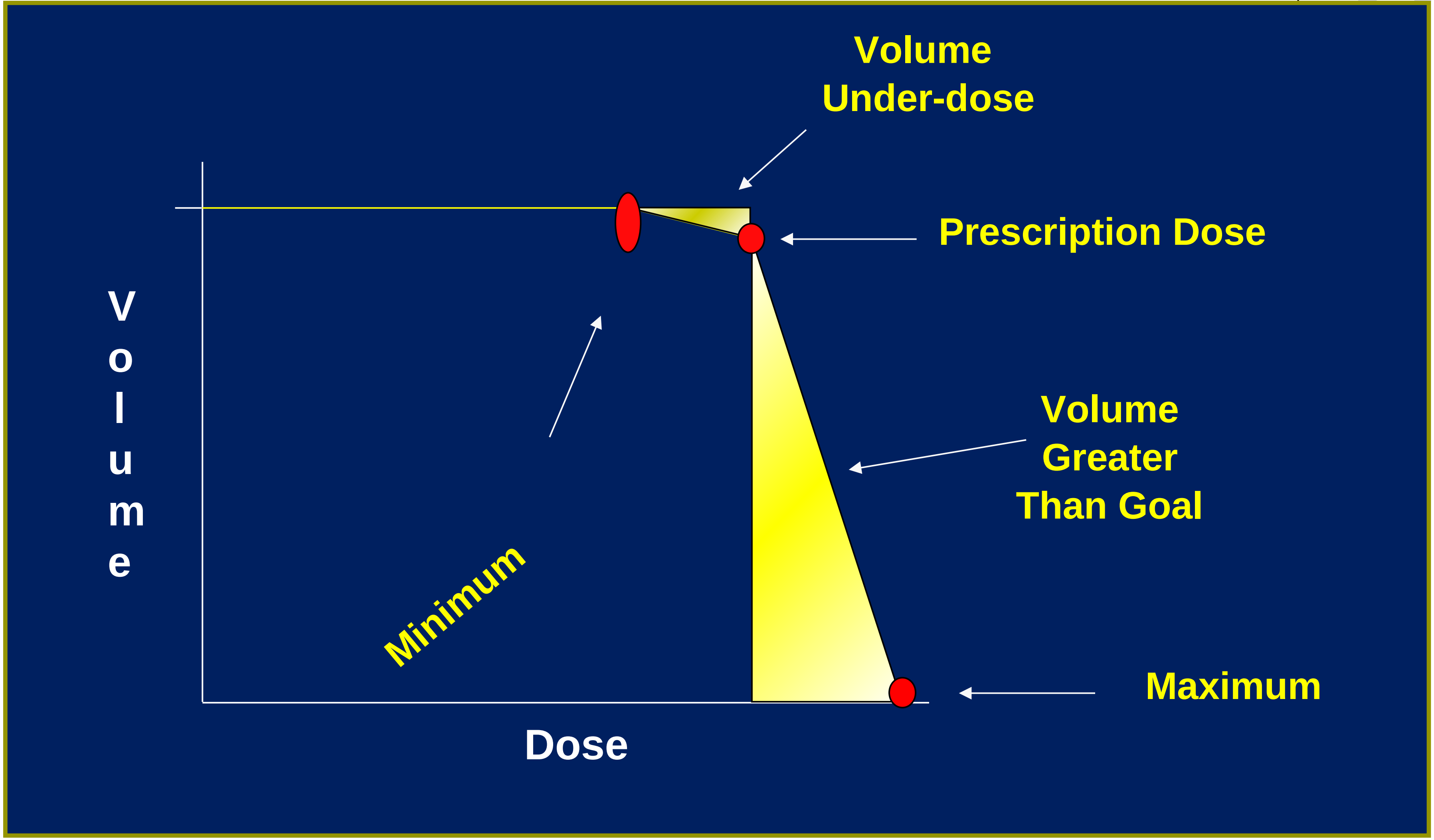
- **Pre-establecer DVH de PTVs y OARs**

Target Name		Type	Goal (Gy)	Vol Below Goal (%)	Min (Gy)	Max (Gy)
Pros+SemVes_LIJ - target		ICRU 50	25.2	5	24.8	26.2

Sensitive Structure Name		Type	Limit (Gy)	Vol Above Limit (%)	Min (Gy)	Max (Gy)
Tissue		ICRU 50 Tissue	18.6	20	0.0	26.4
Rectum_I		ICRU Structure	16.0	24	7.6	26.4
Rectal_Wall		ICRU Structure	16.0	24	7.2	26.4
Bladder_I		ICRU Structure	16.0	25	8.1	26.4
Bladder_Wall		ICRU Structure	16.0	24	7.8	26.1
Femur_L		Reference	15.2	16	7.0	19.1
Femur_R		Reference	14.8	16	7.0	19.2

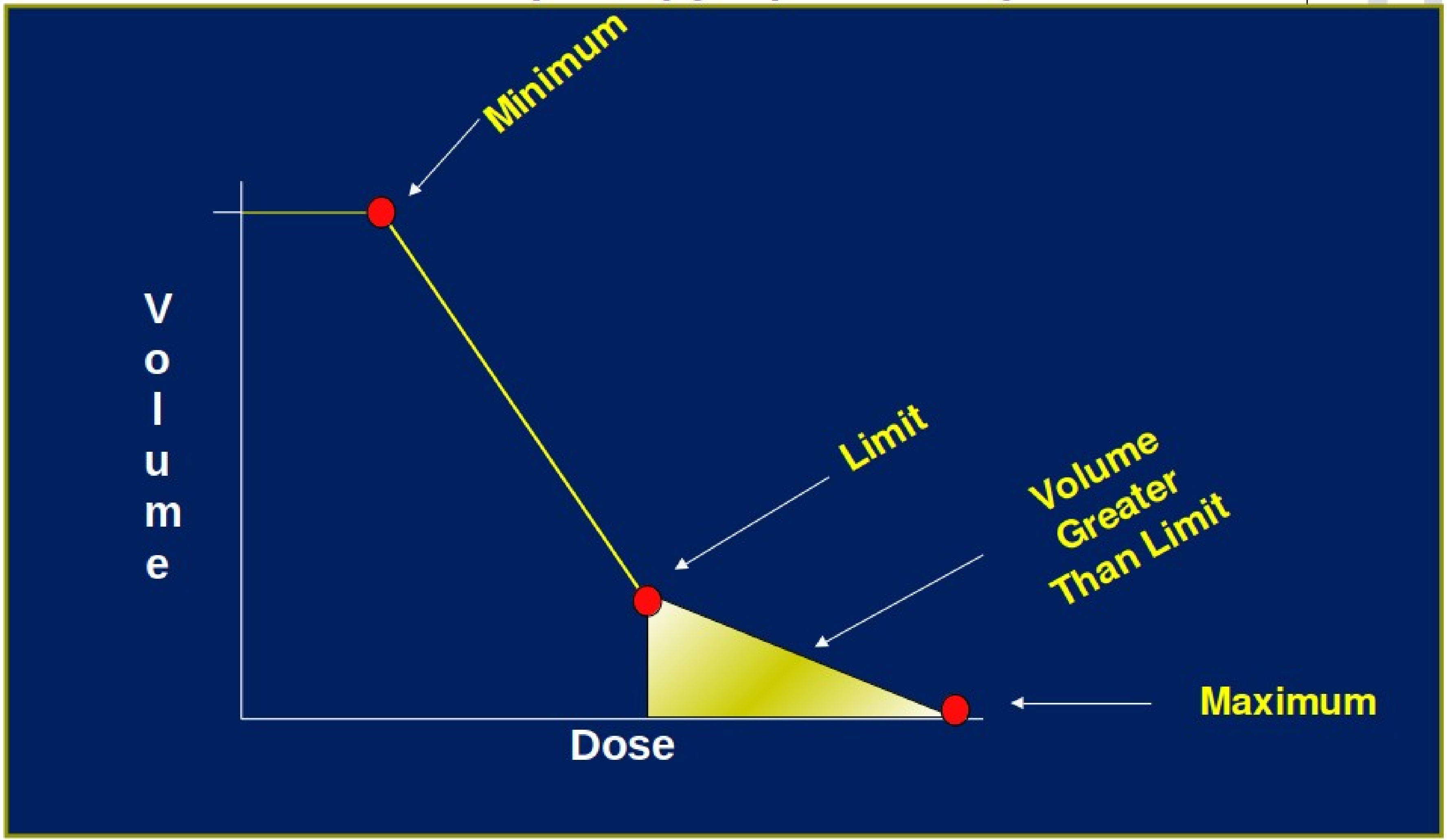
Planificación IMRT.

Definición de la Prescripción (ejemplo de PTV)



Planificación IMRT.

Definición de la Prescripción (ejemplo de OAR)



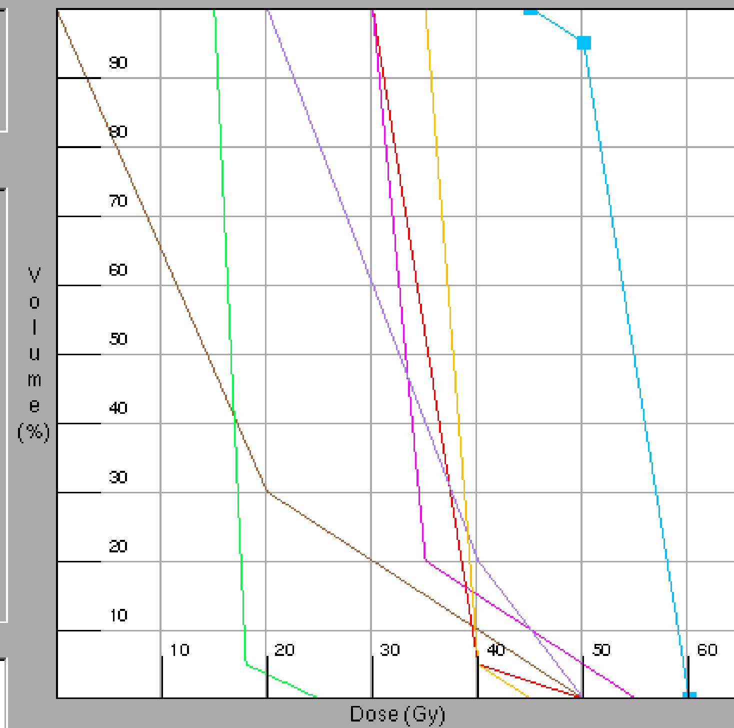
Planificación IMRT.

Definición de la Prescripción (Prescripción Corvus)

Tissue Heterogeneity Correction during Dose Calculation

Target Name	Type	Goal (Gy)	Vol Below Goal (%)	Min (Gy)	Max (Gy)	I	U
CTV-1 - target	ICRU 50	50.0	5	45.0	60.0		✓

Sensitive Structure Name	Type	Limit (Gy)	Vol Above Limit (%)	Min (Gy)	Max (Gy)	I	U
Tissue	ICRU 50 Tissue	20.0	30	0.0	50.0		✓
Heart	Critical Structure	40.0	5	30.0	50.0	✓	✓
Liver	Critical Structure	35.0	20	30.0	55.0		✓
Lung (R)	ICRU Structure	18.0	5	15.0	25.0		✓
OAR-1	Critical Structure	40.0	20	20.0	50.0		✓
Spinal cord	Critical Structure	40.0	5	35.0	45.0		✓



Prescription Instructions

ICRU 50 Target

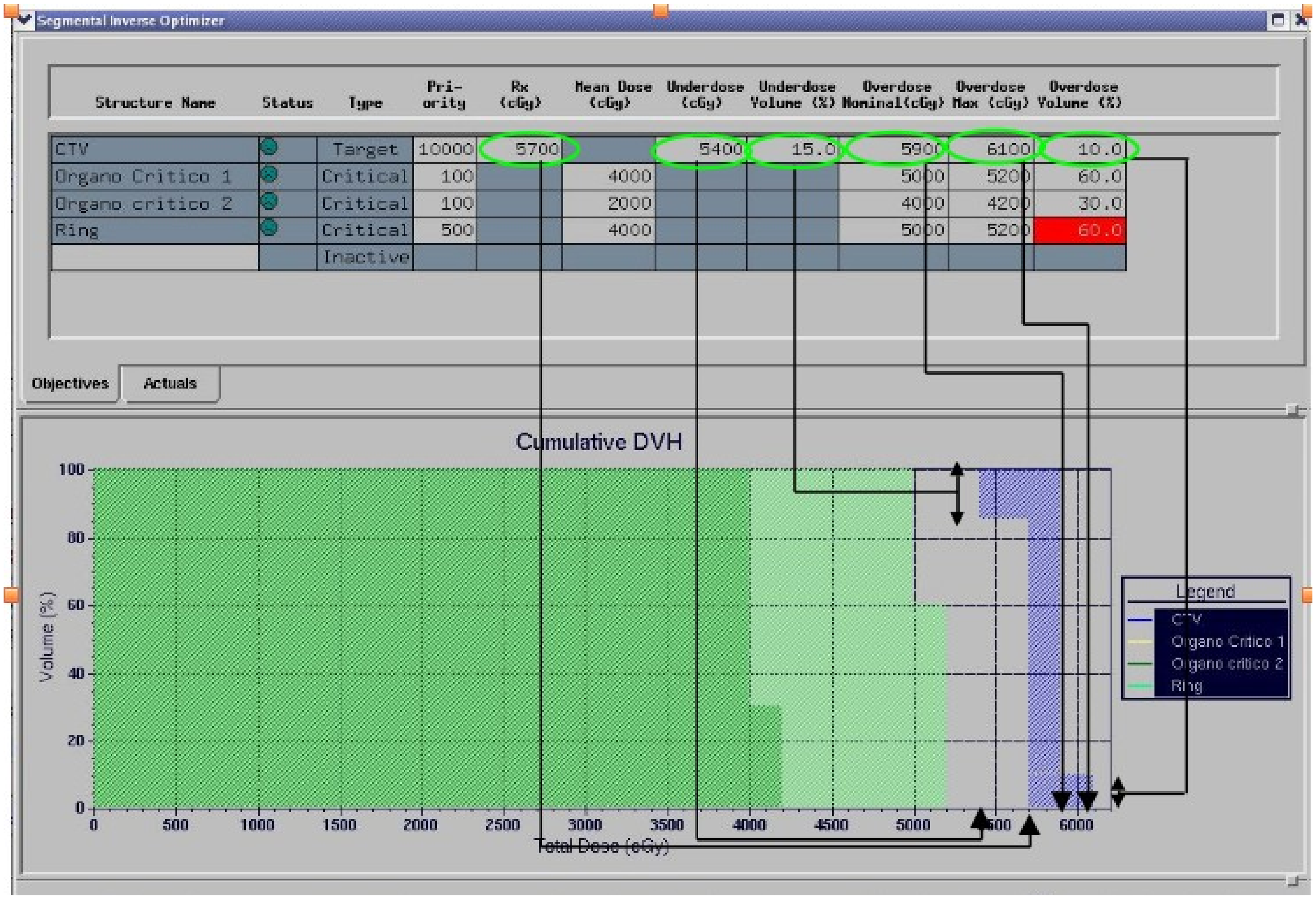
PURPOSE: Targets where the Maximum dose should not be more than 107% of prescribed dose and where the Minimum should not be less than 95% of prescribed dose.

SETTINGS: Goal = Desired dose to 95% of target volume
Minimum = 95% of Goal
% under = 3 - 5%
Maximum = 107% of Goal
"I" = Improve homogeneity at expense of conformality and coverage

NOTES: Use only ICRU Tissue as Tissue Type

Planificación IMRT.

Definición de la Prescripción (Prescripción PrecisePlan)



Structure Name	Status	Type	Pri-ority	Rx (cGy)	Mean Dose (cGy)	Underdose (cGy)	Underdose Volume (%)	Overdose Nominal(cGy)	Overdose Max (cGy)	Overdose Volume (%)
CTV		Target	10000	5700		5400	15.0	5900	6100	10.0
Organo Critico 1		Critical	100		4000			5000	5200	60.0
Organo critico 2		Critical	100		2000			4000	4200	30.0
Ring		Critical	500		4000			5000	5200	60.0
		Inactive								

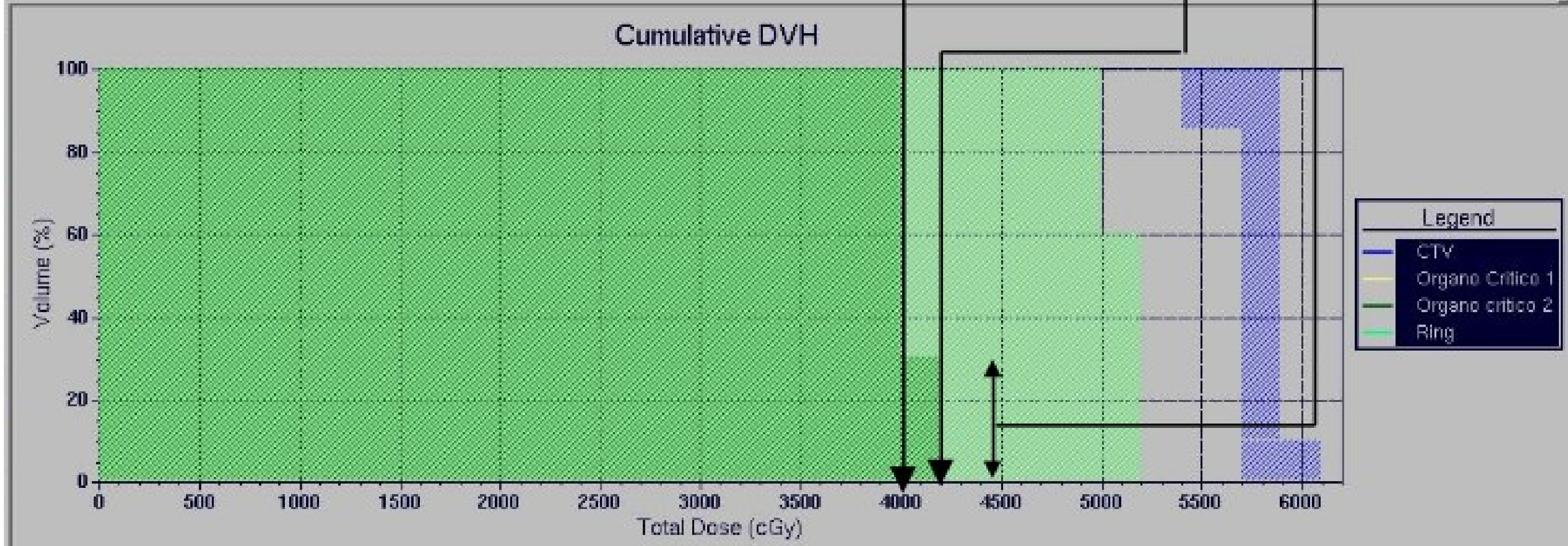
Planificación IMRT.

Definición de la Prescripción (Prescripción PrecisePlan)

Segmental Inverse Optimizer

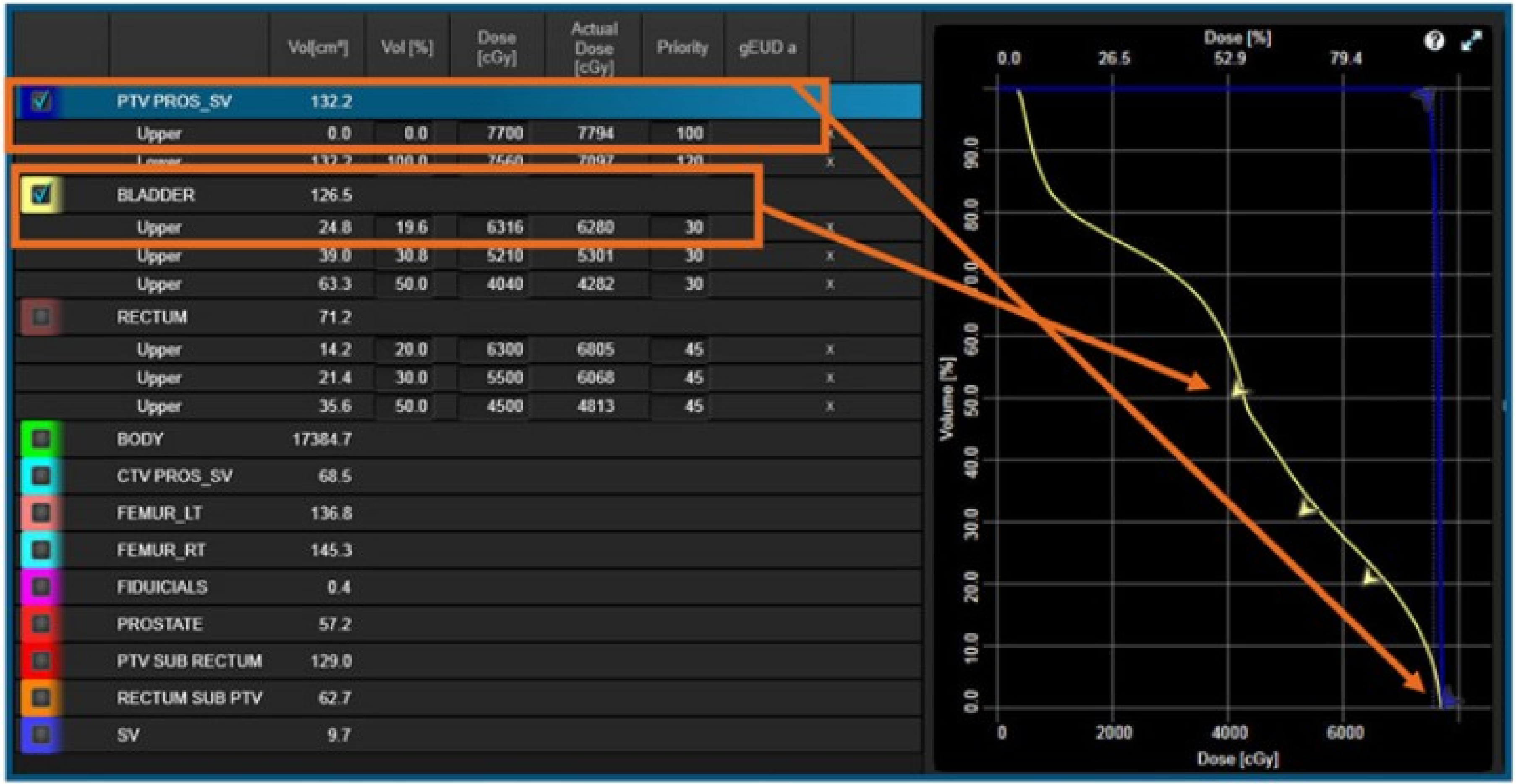
Structure Name	Status	Type	Pri-ority	Rx (cGy)	Mean Dose (cGy)	Underdose (cGy)	Underdose Volume (%)	Overdose Nominal(cGy)	Overdose Max (cGy)	Overdose Volume (%)
CTV		Target	10000	5700		5400	15.0	5900	6100	10.0
Organo Critico 1		Critical	100		4000			5000	5200	60.0
Organo critico 2		Critical	100		2000			4000	4200	30.0
Ring		Critical	500		4000			5000	5200	60.0
		Inactive								

Objectives | Actuals



Planificación IMRT.

Definición de la Prescripción (Prescripción Eclipse)

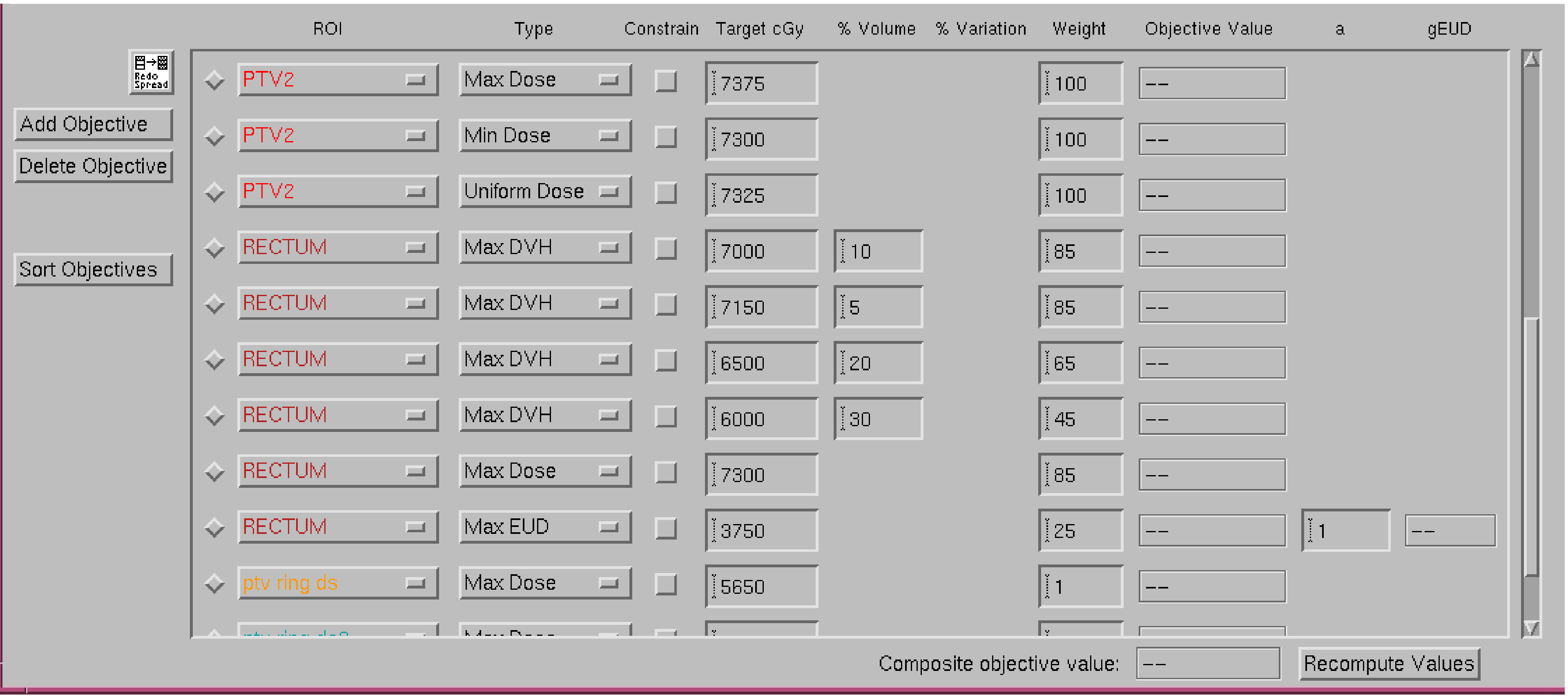


	Vol[cm³]	Vol [%]	Dose [cGy]	Actual Dose [cGy]	Priority	gEUD a	
PTV PROS_SV	132.2						
Upper	0.0	0.0	7700	7794	100		
Lower	132.2	100.0	7560	7097	120		x
BLADDER	126.5						
Upper	24.8	19.6	6316	6280	30		x
Upper	39.0	30.8	5210	5301	30		x
Upper	63.3	50.0	4040	4282	30		x
RECTUM	71.2						
Upper	14.2	20.0	6300	6805	45		x
Upper	21.4	30.0	5500	6068	45		x
Upper	35.6	50.0	4500	4813	45		x
BODY	17384.7						
CTV PROS_SV	68.5						
FEMUR_LT	136.8						
FEMUR_RT	145.3						
FIDUCIALS	0.4						
PROSTATE	57.2						
PTV SUB RECTUM	129.0						
RECTUM SUB PTV	62.7						
SV	9.7						

Eclipse 13 Inverse Planning Operations. EC102. VMS, 2014

Planificación IMRT.

Definición de la Prescripción (Prescripción Pinnacle)



Quantitative Analysis of Normal Tissue Effects in the Clinic (QUANTEC).

Int. J. Radiation Oncology Biol. Phys., Vol. 76, No. 3, Supplement, pp. S1–S2, 2010

Organ-Specific Papers

1. **Brain**
2. **Optic Nerve/Chiasm**
3. **Brain Stem**
4. **Spinal Cord**
5. **Ear**
6. **Parotid**
7. **Larynx/Pharynx**
8. **Lung**
9. **Heart**
10. **Esophagus**
11. **Liver**
12. **Stomach/Small Bowel**
13. **Kidney**
14. **Bladder**
15. **Rectum**
16. **Penile Bulb**

Vision Papers

True Dose
Imaging
Biomarkers
Data Sharing
Lessons of QUANTEC

Each with 10 sections

1. **Clinical Significance**- Describes the clinical situations where the organ is irradiated, and the incidence/significance of organ injury.
2. **Endpoints**- Describes the different endpoints often considered when assessing injury, the impact of endpoint-selection on the reported injury rates, the challenges/utilities of different endpoints, and the time course of organ injury.
3. **Challenges Defining Volumes**- Describes how the organ is typically defined (or segmented) on treatment planning images. Includes a discussion of uncertainties/challenges in organ definition (e.g. changes in organ volume/shape during therapy), and the associated impact on DVH's and dose/volume/outcome analyses.
4. **Review of Dose/Volume Data**- A comprehensive summary of reported 3D dose/volume data for clinically-relevant outcomes.
5. **Factors Affecting Risk**- Other clinical factors affecting the risk of injury are noted (e.g. age, combined modality therapy, dose fractionation).
6. **Mathematical/Biological Models**- Models that have been used to relate 3D dose/volume data to clinical outcomes are summarized, along with associated model parameters, limitations and uncertainties.
7. **Special Situations**- Most of the data discussed relates to conventional fractionation. This section describes situations were the presented data/models may not apply (e.g. hypo-fractionation).
8. **Recommended Dose/Volume Limits**- The available information is condensed into meaningful dose/volume limits, with associated risk rates, to apply clinically.
9. **Future Toxicity Studies**- Describes areas in need of future study.
10. **Toxicity Scoring**- Recommendations on how to score organ injury.

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A Story of Hypofractionation and the Table on the Wall

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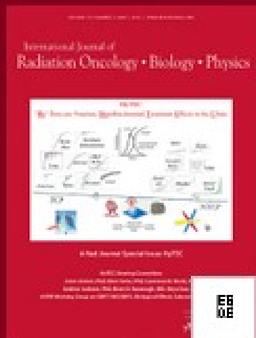
Received Jul 29, 2021; Revised Sep 7, 2021; Accepted for publication Sep 14, 2021

I was recently informed that I won a contest that I did not actually enter. A Twitter poll was organized through @Radiation Nation inspired by Sue Yom, the new editor of the journal, asking, "What do people consider the gold standard for treatment planning for hypofractionated RT?" Response options were "HyTEC; AAPM TG-101; Timmerman Sheet; and NRG/RTOG protocols." With just over 100 total votes in 24 hours, "Timmerman Sheet," which at University of Texas Southwestern we call our "constraint tables," won with 37.5% of votes. Not to rub it in, but 2 of the other options, "AAPM TG-101" and most "NRG/RTOG protocols," were taken directly from older versions of our tables. of their conception and evolution has been part of the overall story of SABR and the postmodern use of hypofractionation. For this editorial, I would like to tell my version of the 2, interwoven stories.

SABR, my preferred name over the duller, less descriptive, stereotactic body radiation therapy (or SBRT), is now a commonplace treatment such that centers not performing it are arguably out of touch by missing essential modern capabilities.[1-3] Indeed, with the approach of the dreaded Alternative Payment Model from the Centers for Medicaid and Medicare Services, I think conventionally fractionated radiation therapy will quickly become untenable, spelling doom

International Journal of
Radiation Oncology • Biology • Physics ASTRO



Volume 110, Issue 1, p1-256

A Red Journal Special Issue: HyTEC

Edited by Jimm Grimm, Ellen Yorke, Lawrence Marks, Andrew Jackson, Brian Kavanagh, Jinyu Xue

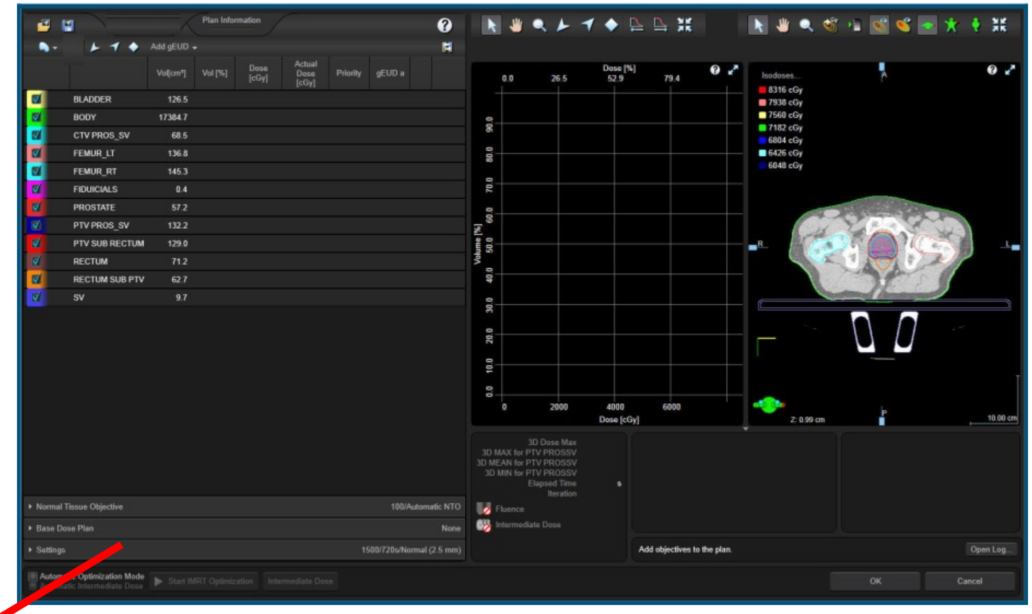
Current Issue   Articles in Press   Archive

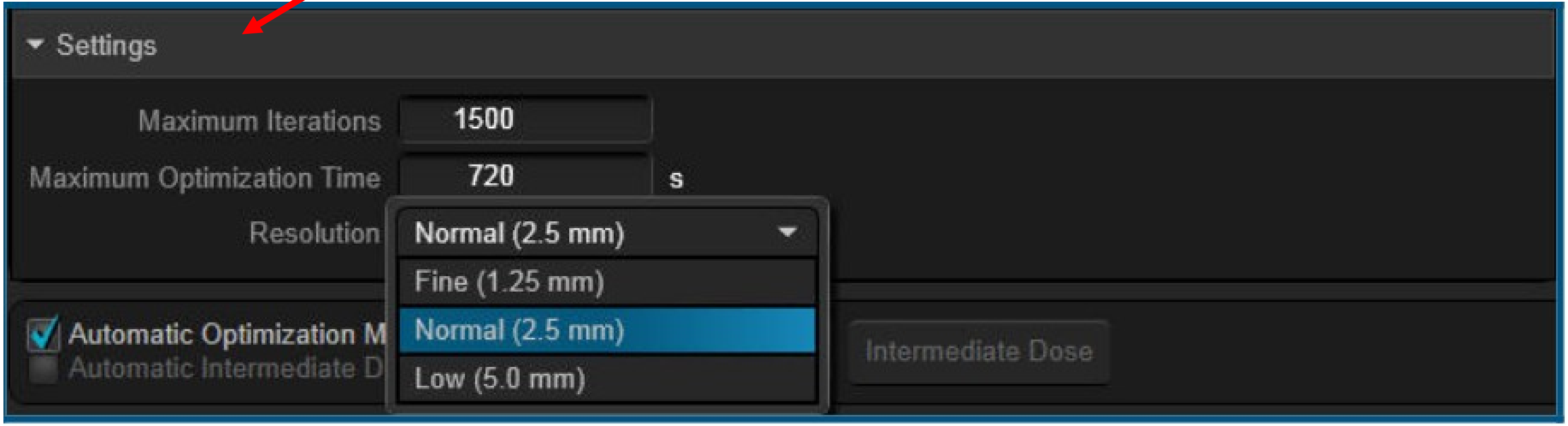
The Editor's podcast for this edition
HyTEC Special Issue
Click here

HyTEC Introduction

Planificación IMRT.

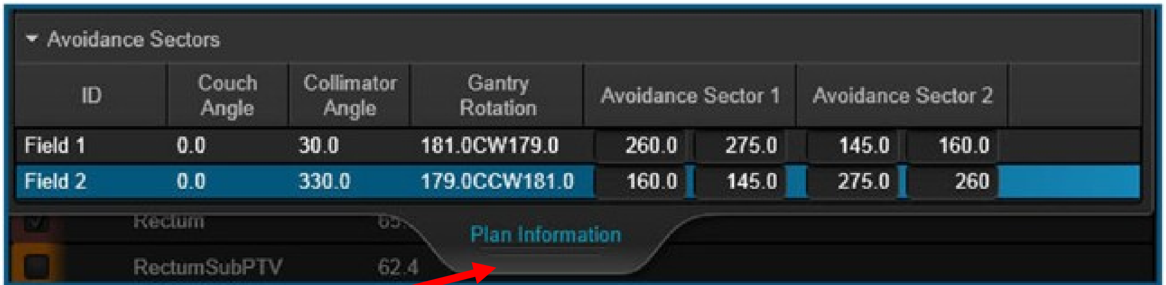
Optimización Planificación Inversa. Herramientas

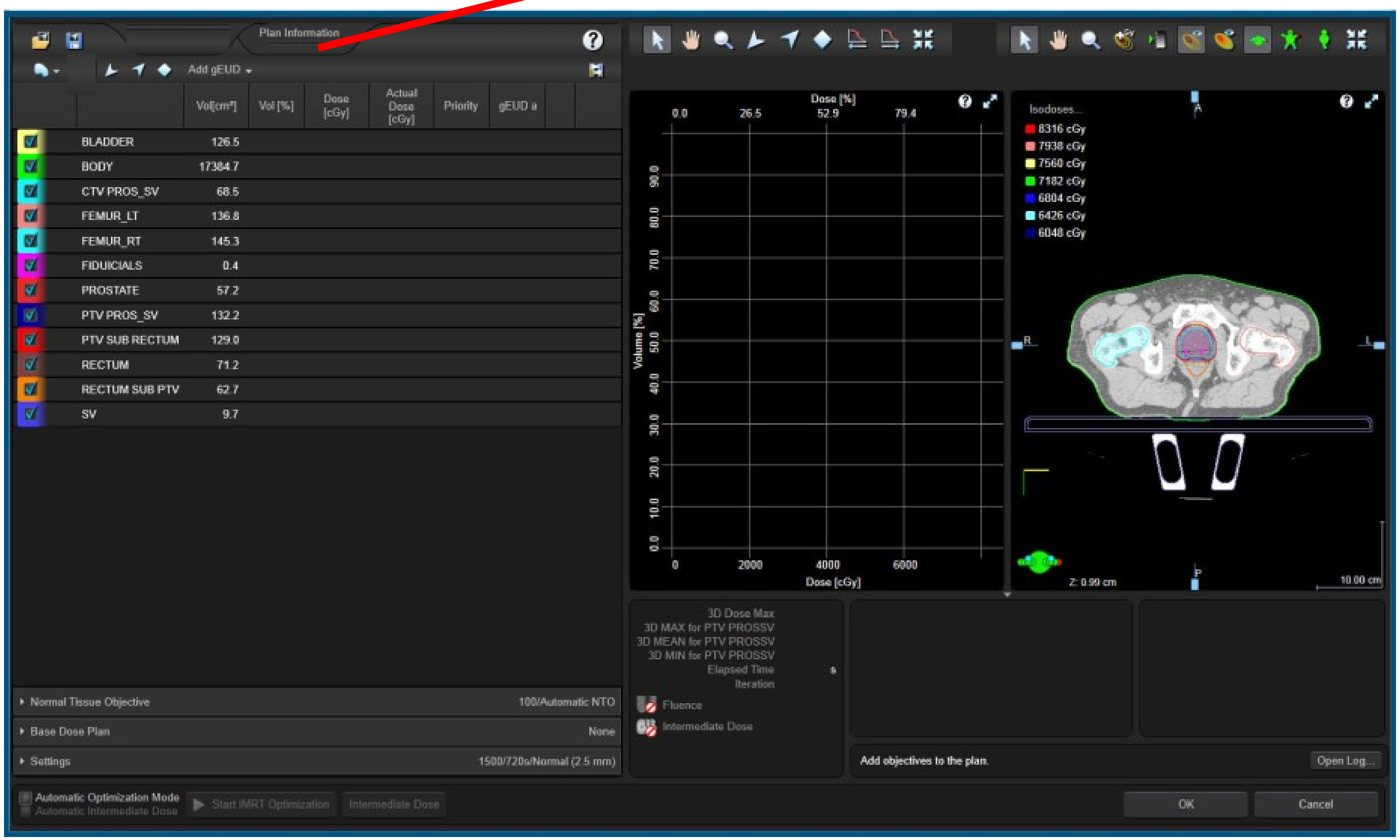




Planificación IMRT.

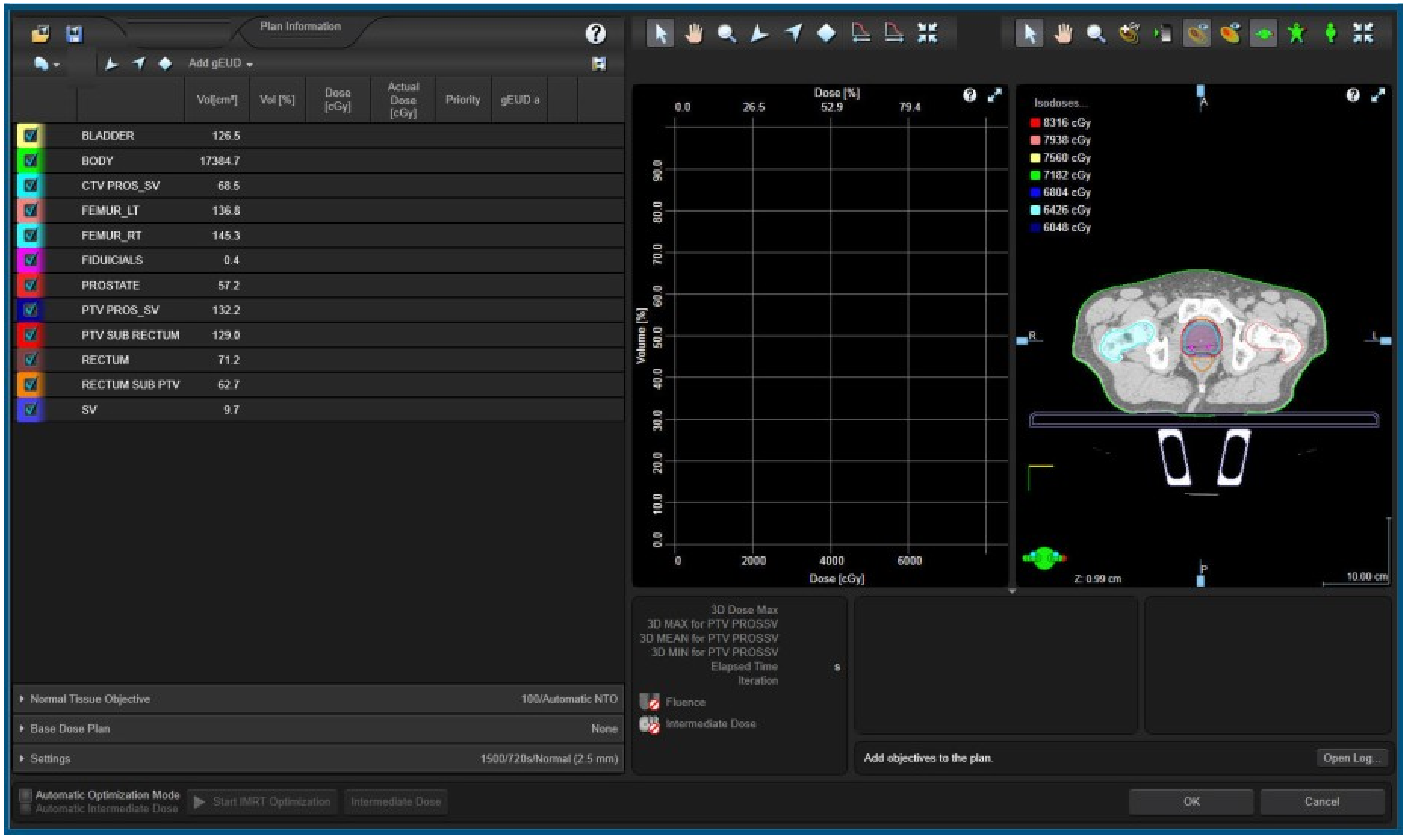
Optimización Planificación Inversa. Herramientas

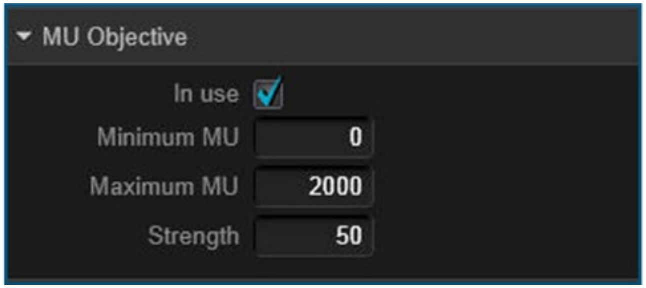




Planificación IMRT.

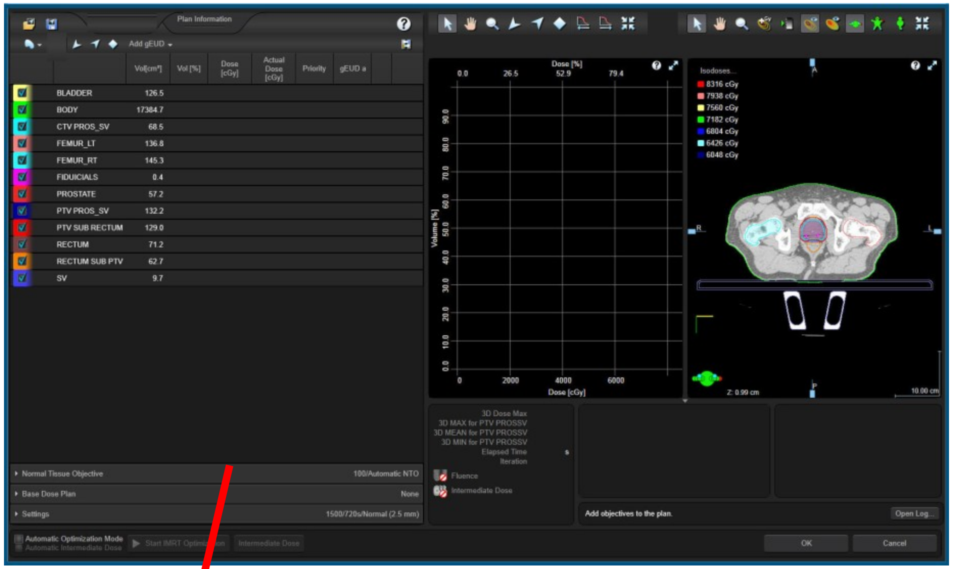
Optimización Planificación Inversa. Herramientas





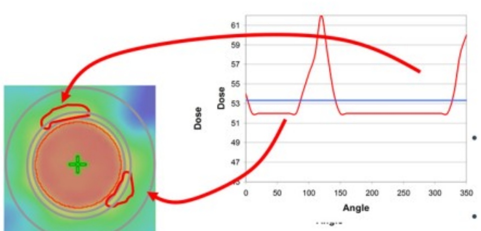
Planificación IMRT.

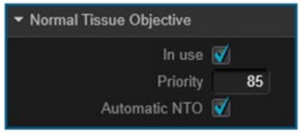
Optimización Planificación Inversa. Herramientas



Automatic Normal Tissue Objective

- Automatic - penalty issued for points having higher than mean dose at given distance



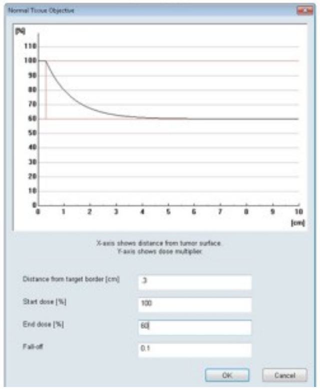


- Interactive
  - NTO may be turned on/off during Optimization
- Automatic
  - Penalty issued for points having higher than mean dose at given distance

Skills Circle

Manual NTO

- Defines desired dose gradient **outside** the target(s)
  - Minimizes hotspots around the target
- Priority
- Parameters
  - Distance from target border
  - Start and end dose
  - Fall-off



Eclipse 13 Inverse Planning Operations. EC102. VMS, 2014

Planificación IMRT.

Optimización Planificación Inversa. Herramientas

Generalized Equivalent Uniform Dose (gEUD)

Skills Circ

- gEUD is the uniform dose distribution that gives the same biological effect (clinical effect) equivalent to that of a given heterogeneous dose distribution
  - The concept of equivalent uniform dose (EUD) assumes that any two dose distributions are equivalent if they cause the same radiobiological effect.

- Examples of cord DVHs to one max dose point that result in the same radiobiological effect

$$\mathrm{gEUD} = \left(\sum_i v_i D_i^a \right)^{1/a}$$

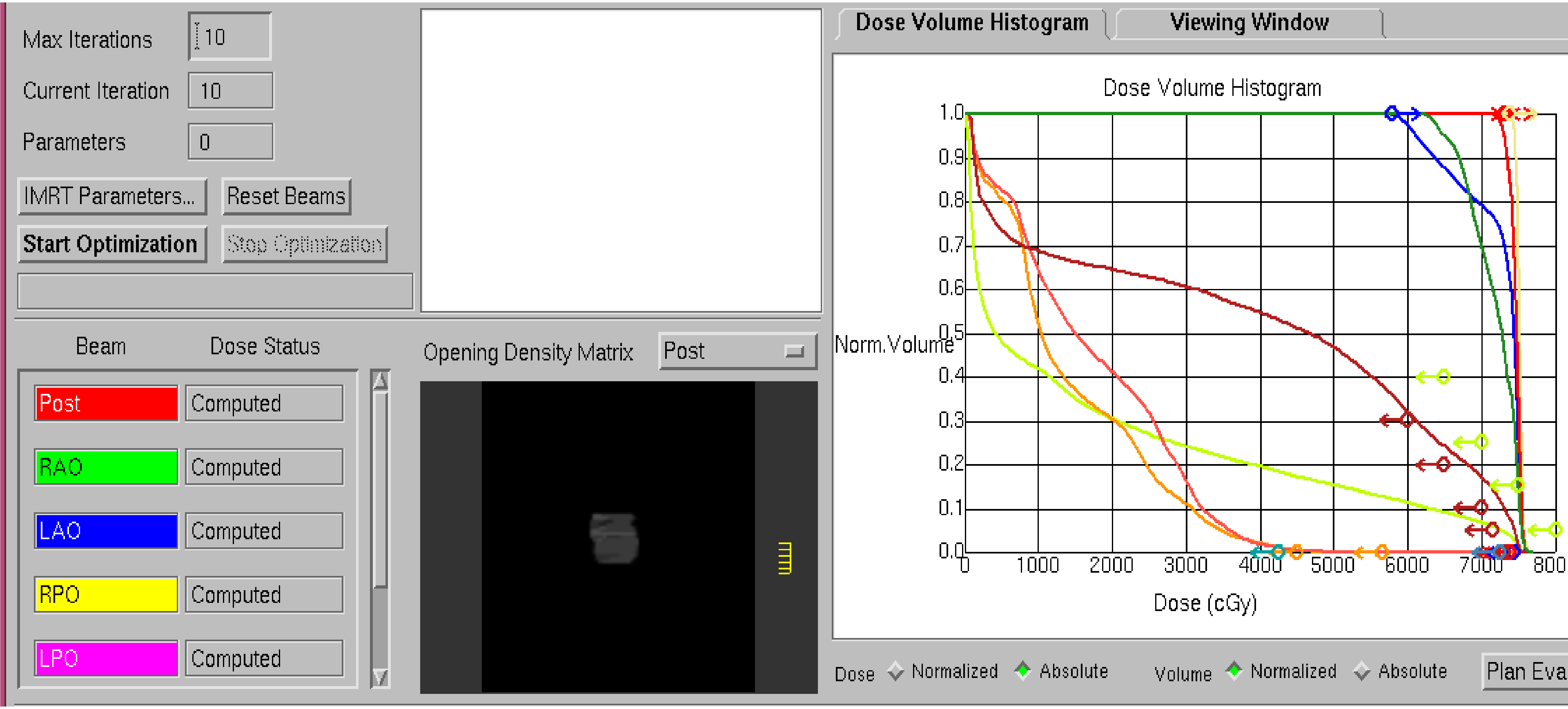
- The parameter ‘a’ is negative for all tumors (targets).
- The parameter ‘a’ is positive for all normal structures.
- For target structures, ‘a=1’: acts as a mean dose objective. Cold and hot spots are given equal weight

Eclipse 13 Inverse Planning Operations. EC102. VMS, 2014

The Use and QA of Biologically Related Models for Treatment Planning. AAPM TG 166. 2012

Planificación IMRT.

Evaluación de la optimización (Prescripción Pinnacle)



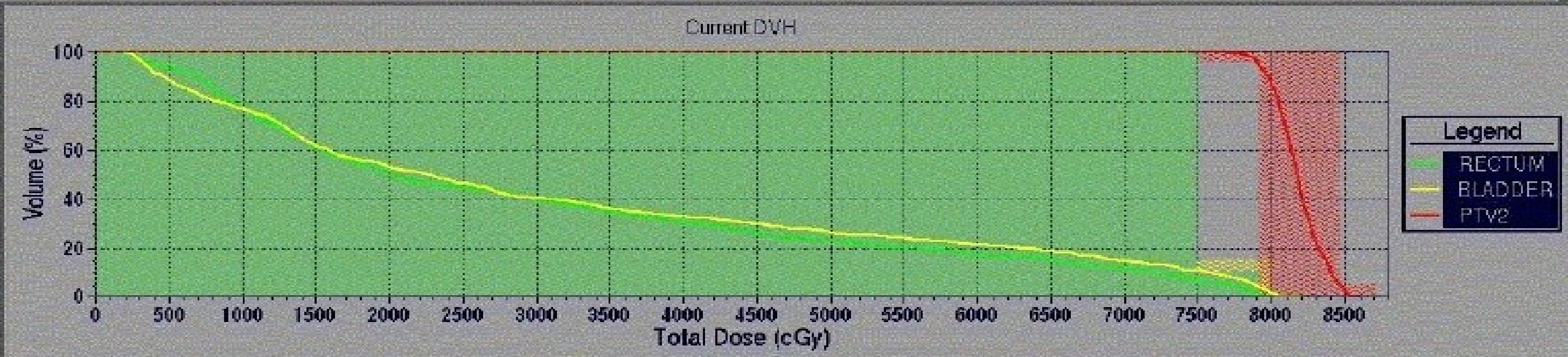
Planificación IMRT.

Evaluación de la optimización (Prescripción PrecisePlan)

Segmental Inverse Optimizer

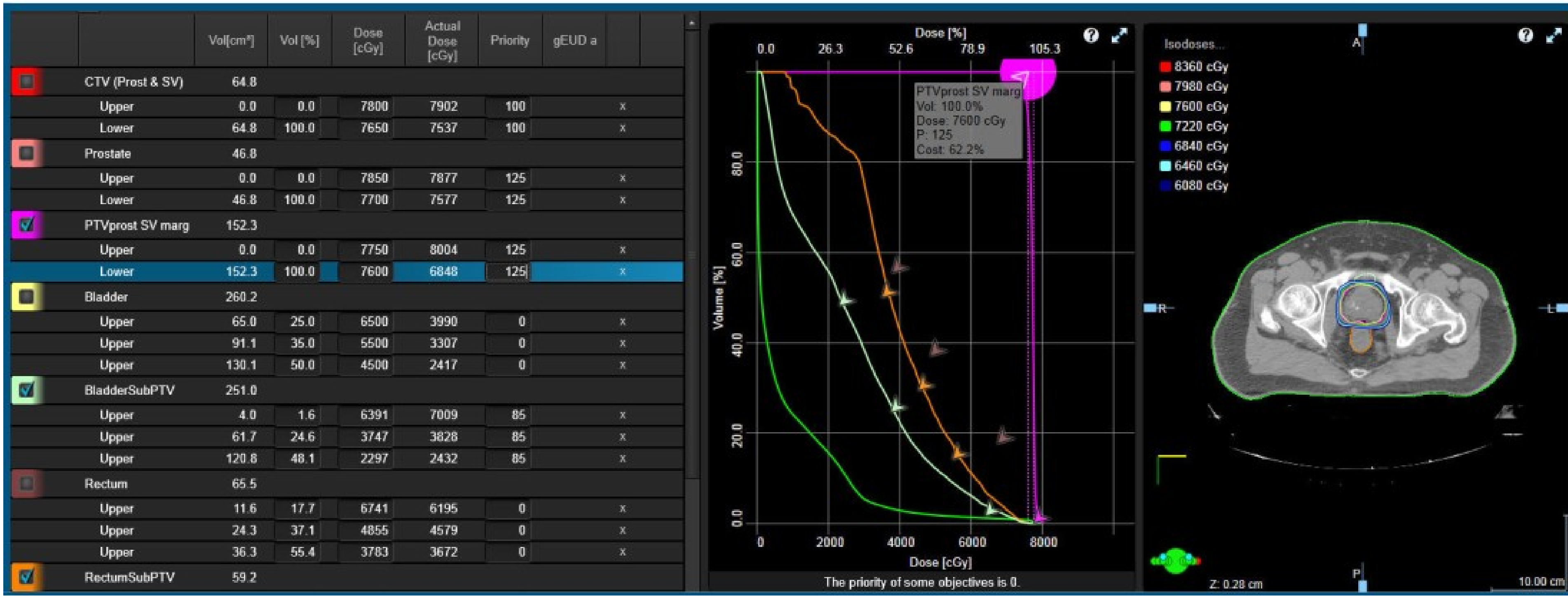
Structure Name	Status	Type	Priority	Rx (cGy)	Mean Dose (cGy)	Under Dose (cGy)	Under Dose Volume (%)	Over Dose Nominal(cGy)	Over Dose Max (cGy)	Over Dose Volume (%)
RECTUM		Critical	10		6000			7500	7920	10.0
BLADDER		Critical	10		6500			7500	8000	15.0
PTV2		Target	100	7920		7524	5.0	8474	8712	5.0
		Inactive								

Objectives Actuals



Planificación IMRT.

Evaluación de la optimización (Prescripción Eclipse)



	Vol[cm³]	Vol [%]	Dose [cGy]	Actual Dose [cGy]	Priority	gEUD a	
CTV (Prost & SV)	64.8						
Upper	0.0	0.0	7800	7902	100		x
Lower	64.8	100.0	7650	7537	100		x
Prostate	46.8						
Upper	0.0	0.0	7850	7877	125		x
Lower	46.8	100.0	7700	7577	125		x
PTVprost SV marg	152.3						
Upper	0.0	0.0	7750	8004	125		x
Lower	152.3	100.0	7600	6848	125		x
Bladder	260.2						
Upper	65.0	25.0	6500	3990	0		x
Upper	91.1	35.0	5500	3307	0		x
Upper	130.1	50.0	4500	2417	0		x
BladderSubPTV	251.0						
Upper	4.0	1.6	6391	7009	85		x
Upper	61.7	24.6	3747	3828	85		x
Upper	120.8	48.1	2297	2432	85		x
Rectum	65.5						
Upper	11.6	17.7	6741	6195	0		x
Upper	24.3	37.1	4855	4579	0		x
Upper	36.3	55.4	3783	3672	0		x
RectumSubPTV	59.2						

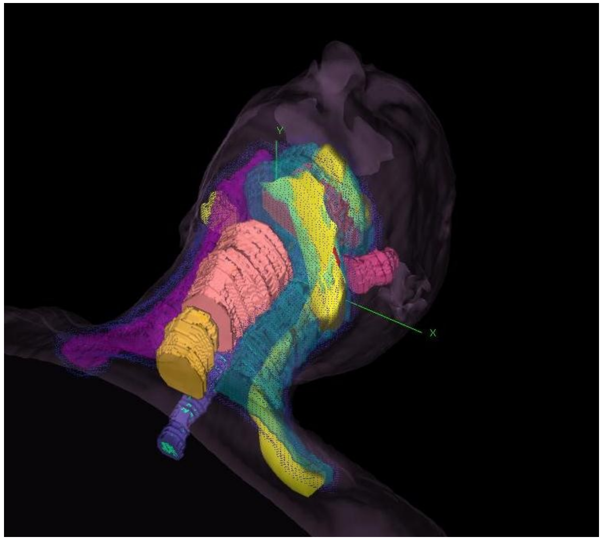
Eclipse 13 RapidArc/VMAT Operations. EC112. VMS, 2014.

Planificación IMRT.

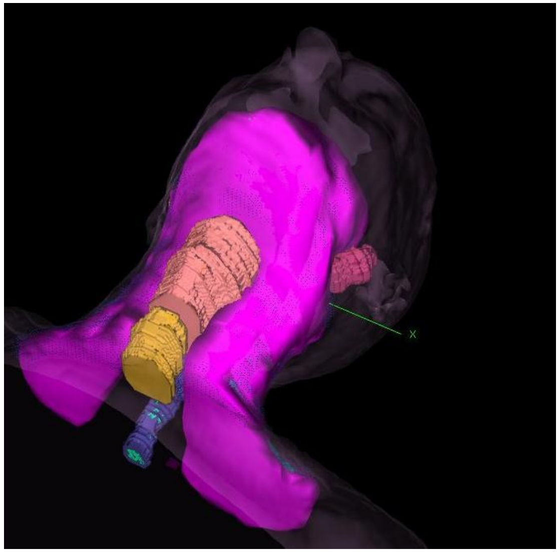
Evaluación de la optimización (Isodosis Pinnacle)

Planificación IMRT.

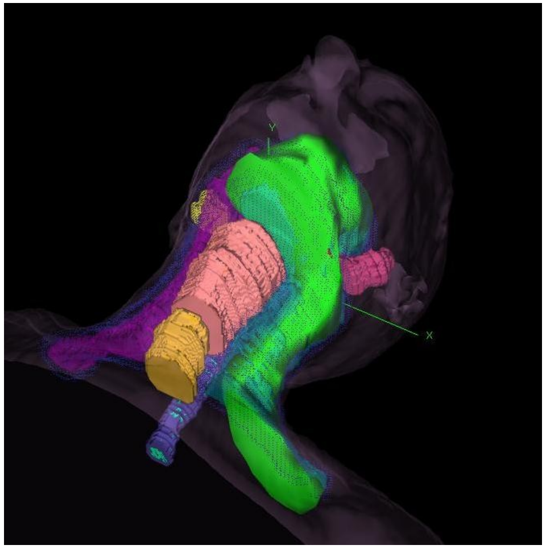
Evaluación de la optimización (Isodosis PrecisePlan)



72 Gy (GTV72)



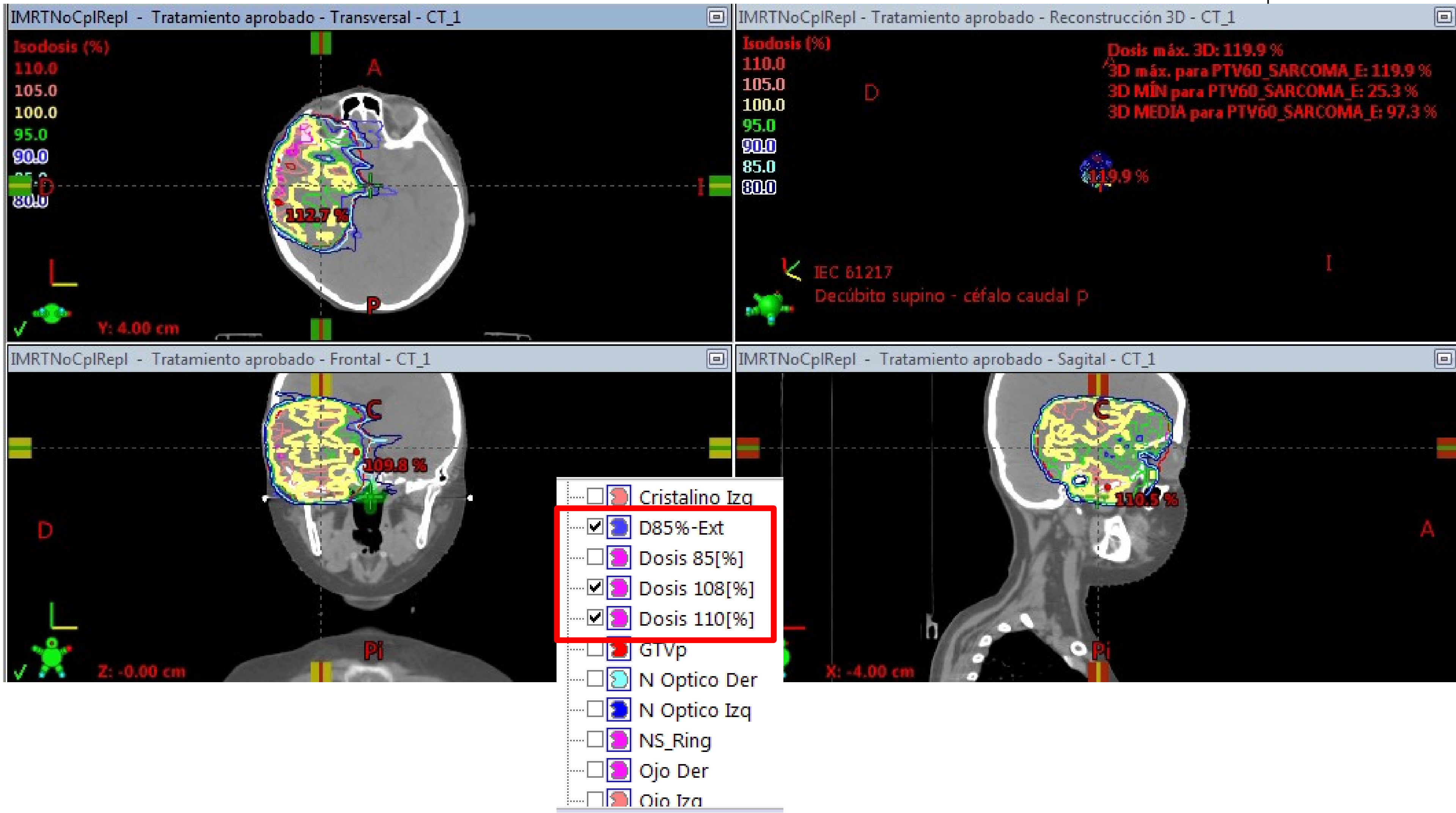
50 Gy (PTV50)



66 Gy (CTV66)

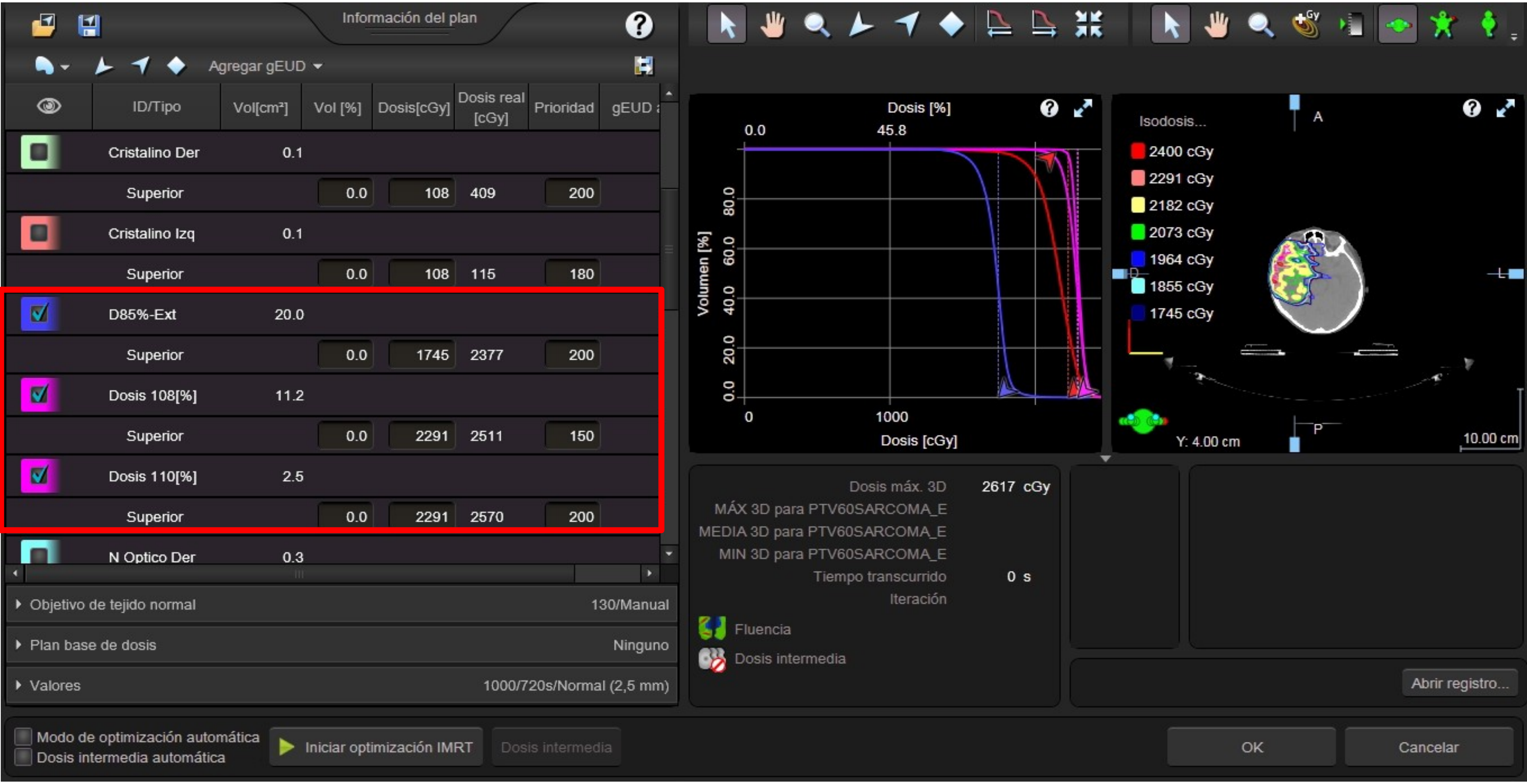
Planificación IMRT.

Evaluación de la optimización (Isodosis Eclipse)



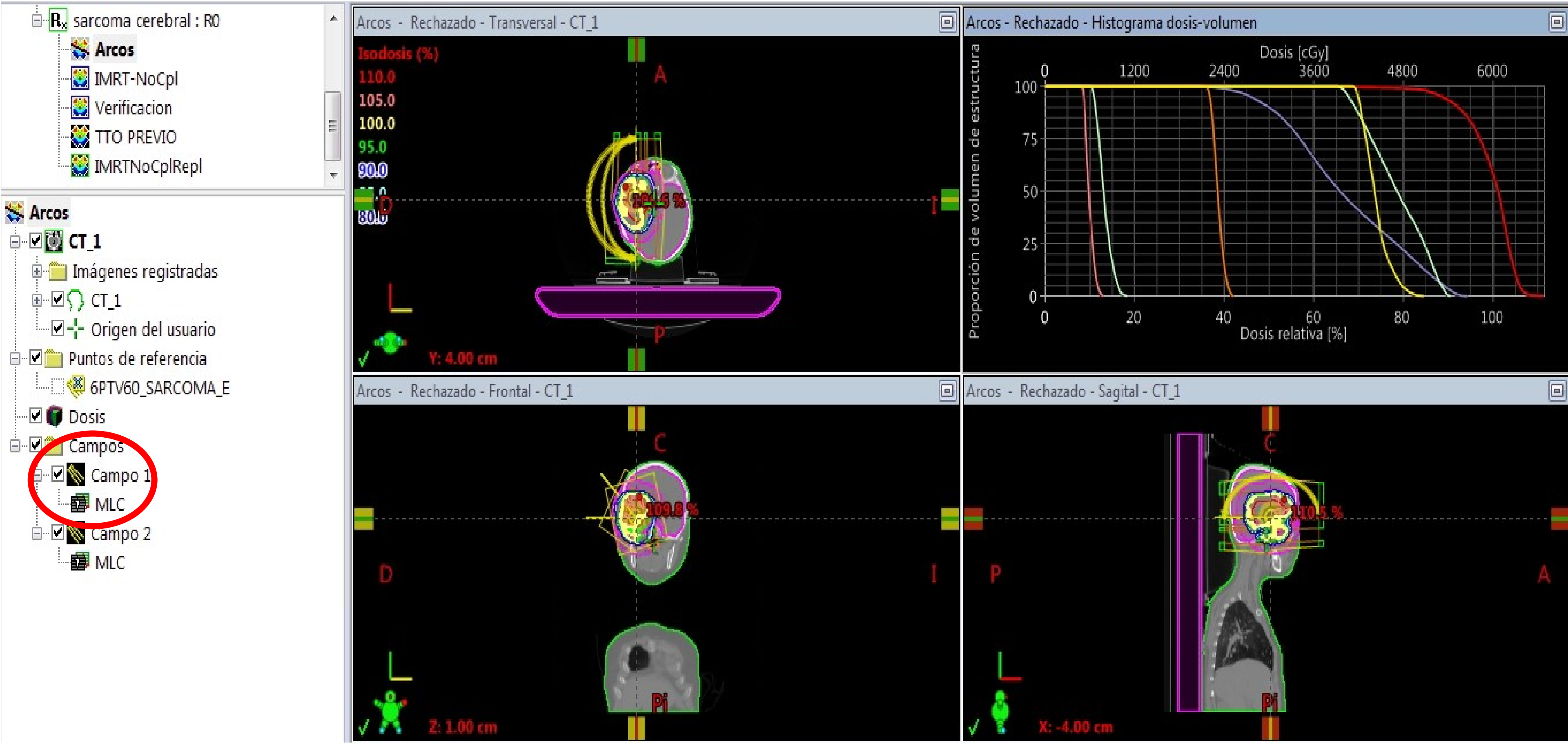
Planificación IMRT.

Nueva optimización (Eclipse)



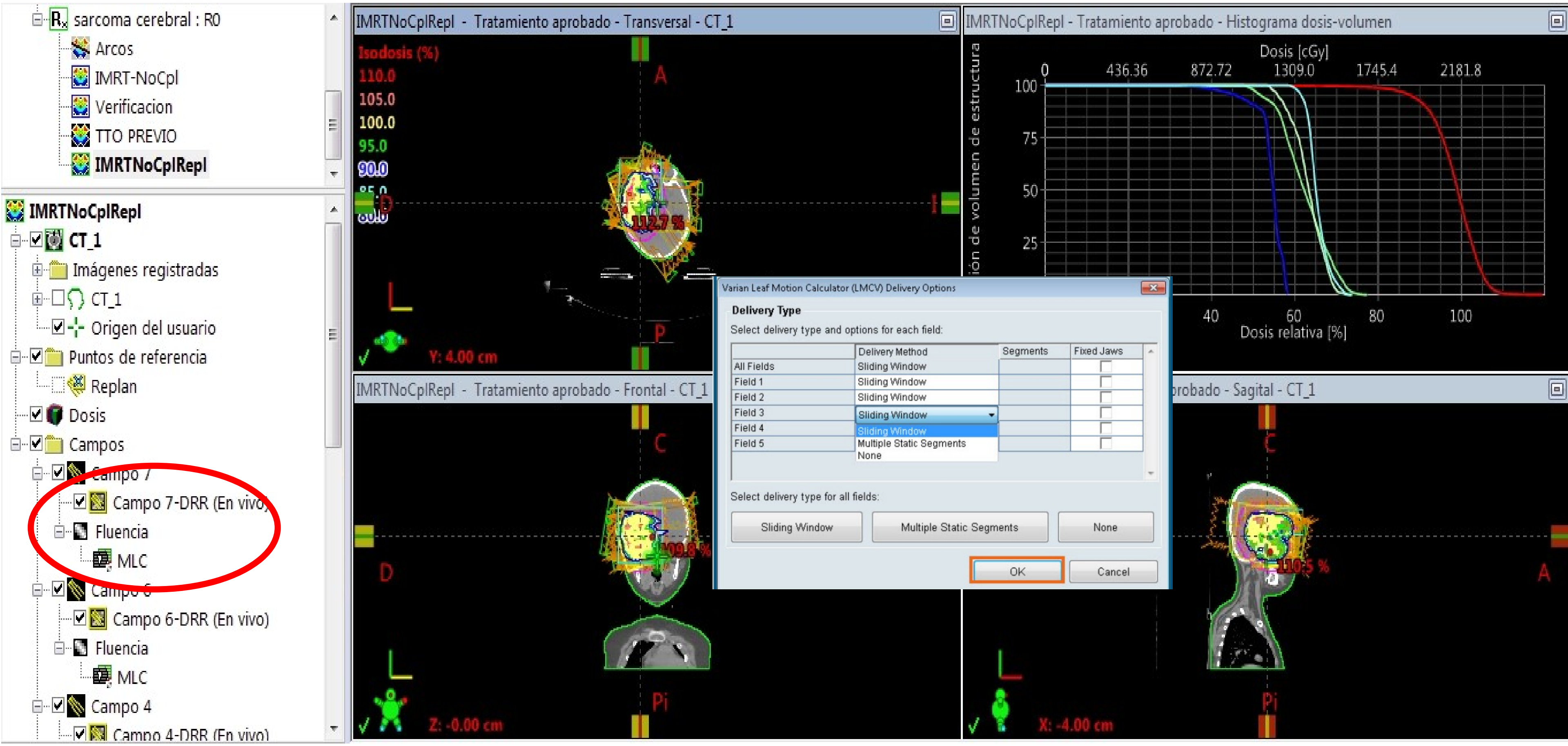
Planificación IMRT.

Evaluación del plan (Eclipse)



Planificación IMRT.

Evaluación del plan (Eclipse)

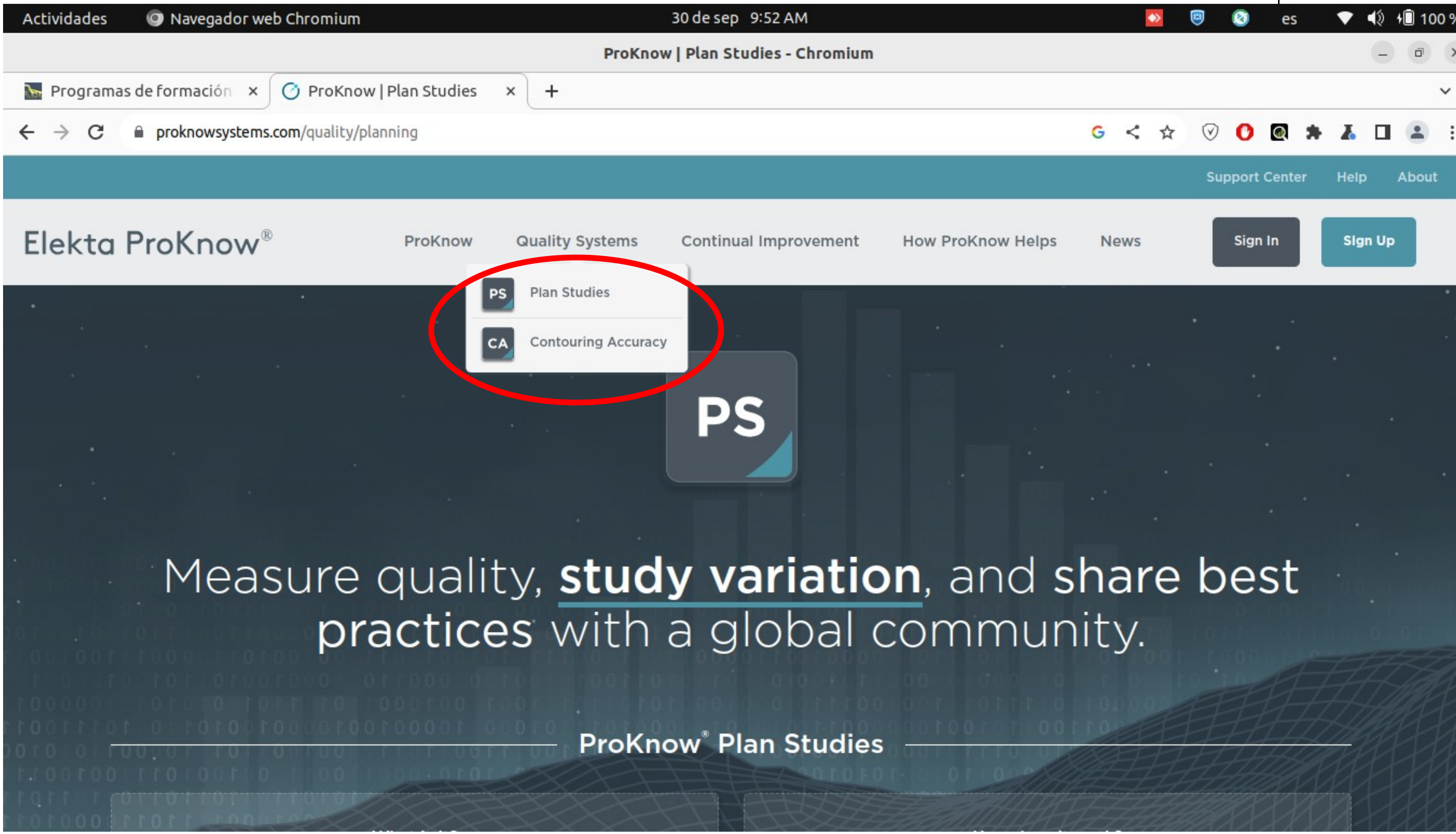


Planificación IMRT.

Consejos

Planificación IMRT.

Consejos



Planificación IMRT.

Consejos

2016 AAMD / RSS Plan Study

SBRT Prostate

Ben Nelms, Ph.D.

&

Keitt Mobile, M.S., C.M.D.

Planificación IMRT.

Consejos

Monaco

- Try to get you best results you can on the first stage
  - Only little tweaks on second stage
- Set calculation grid to 2mm
- Understand how the cost functions work
- Use Quadratic Overdose in Body to create rings

Planificación IMRT.

Consejos

MONACO

- Make sure your constraints are set in the correct order
- Consider manually weighting your Target
- Watch your Iso-constraints and Relative Impacts
  - Compare
    - Will you really gain by your adjustment

Planificación IMRT.
Consejos

ECLIPSE

- Need to understand how to use the NTO (Normal Tissue Optimizer) properly
- Otherwise need to utilize rings
- About 50% seem to use both rings and NTO
    - .1 to .5cm around PTV
    - 1 to 1.5cm around PTV
    - .1 to .3cm around urethra and NVB

Planificación IMRT.

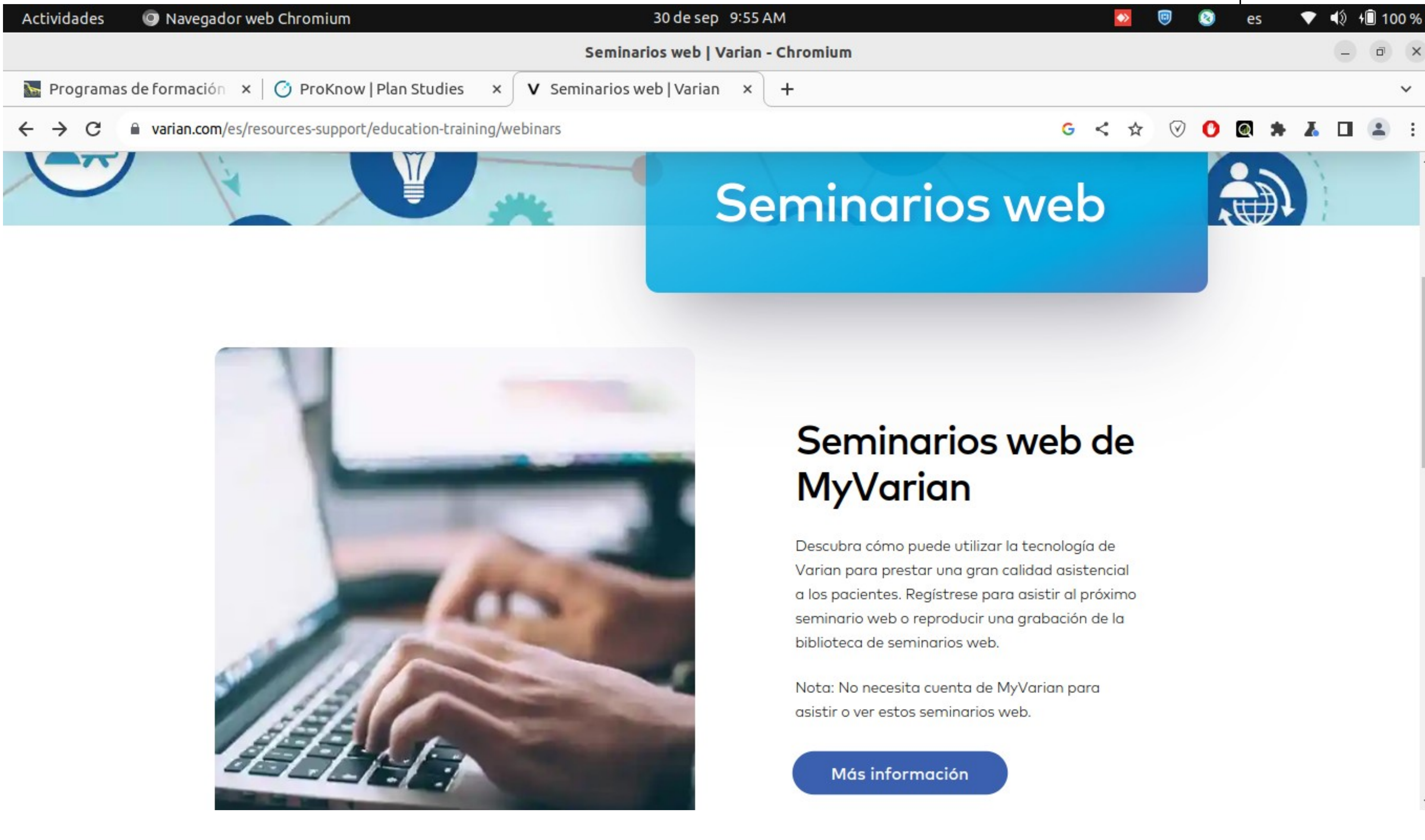
Consejos

ECLIPSE

- Pay attention to priorities
- Pause the optimizer often
  - Make tweaks if needed
  - Especially in level one and two
- Collimator angles 10-90 degrees use

Planificación IMRT.

Consejos



Inteligencia Artificial en Radioterapia
planeación de tratamientos automatizada

- **Implementación de reglas automatizadas y razonamiento (ARIR)**

- Varian ESAPI, (Eclipse scripting application programming interface)

- Pinnacle AutoPlanning

- RaySearch Laboratories, RayStation AutoPlanning

Artificial Intelligence in Radiotherapy Treatment Planning: Present and Future. Wang C, 2019

Inteligencia Artificial en Radioterapia

planeación de tratamientos automatizada

- **Modelación de conocimiento previo en la práctica clínica (KB)**

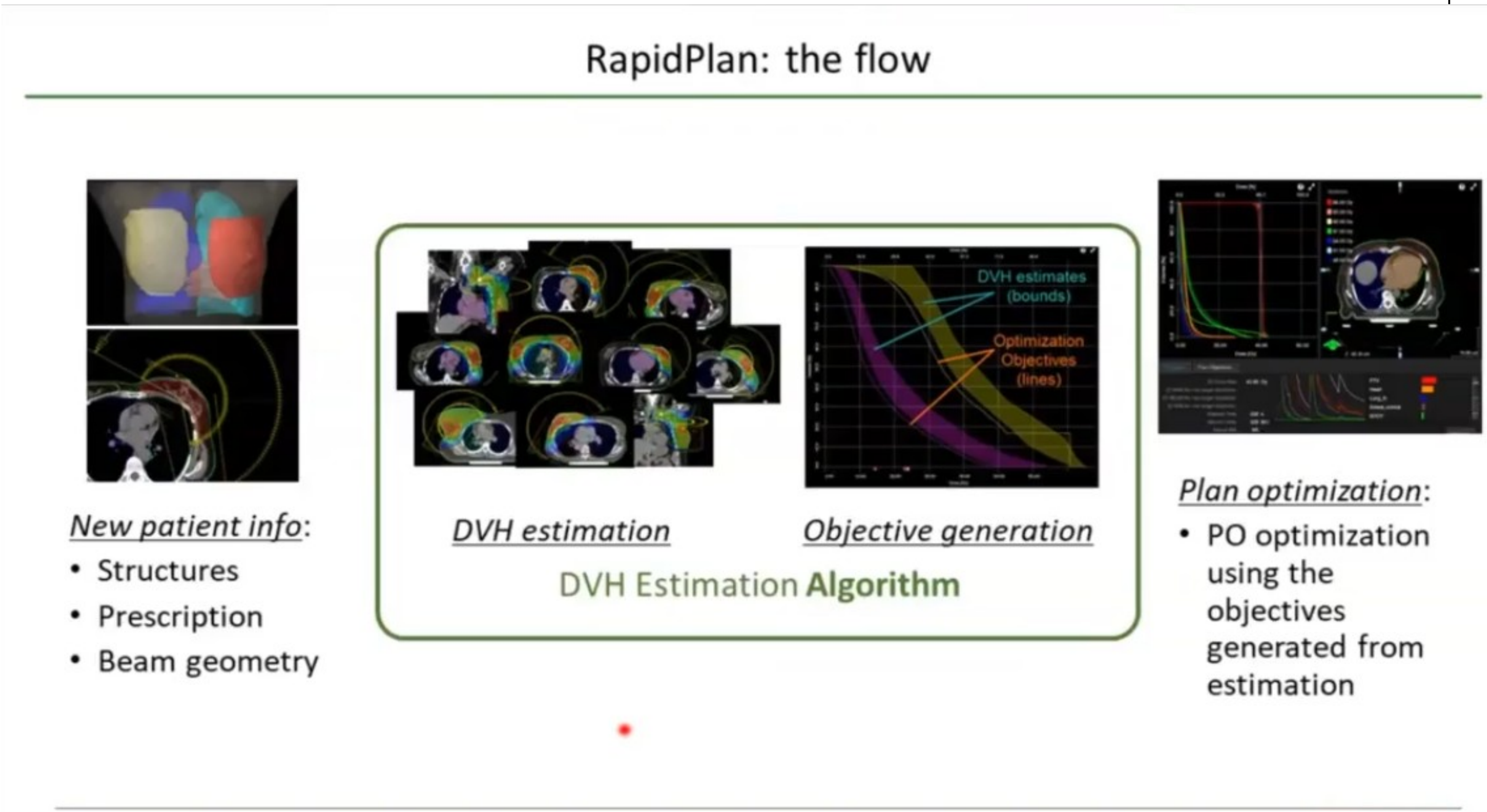
- Varian RapidPlan VMAT

Quantitative analysis of the factors which affect the interpatient organ-at-risk dose sparing variation in IMRT plans. Yuan L, MP 2012.

Artificial Intelligence in Radiotherapy Treatment Planning: Present and Future. Wang C, 2019

Inteligencia Artificial en Radioterapia

- **Varian RapidPlan VMAT**

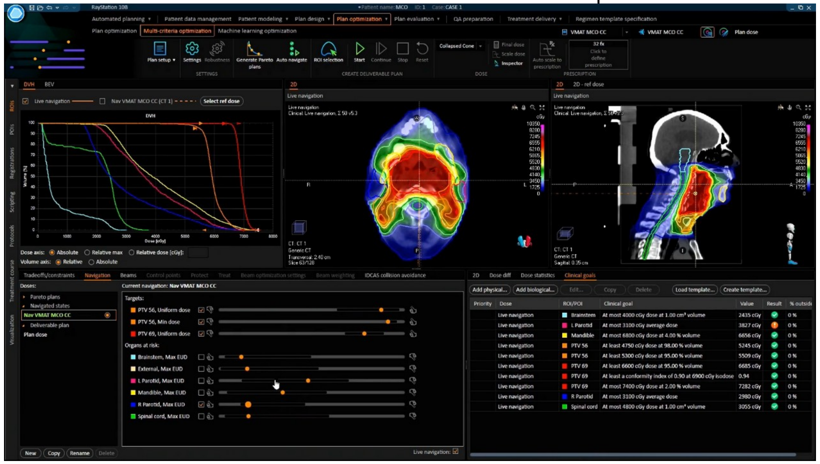


https://www.myvarian.com/s/mvwebsummary?Id=a0O0h00000ZVTIIEA5&lang=undefined

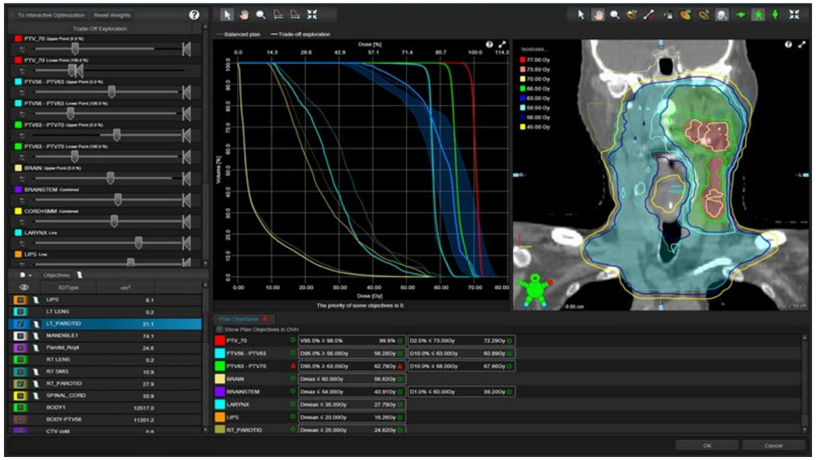
Inteligencia Artificial en Radioterapia
planeación de tratamientos automatizada

- **Optimización multicriterio (MCO)**

- RaySearch Laboratories, RayStation



- Varian Eclipse



Artificial Intelligence in Radiotherapy Treatment Planning: Present and Future. Wang C, 2019