

# Pas de médecine sans physiciens

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Cliniques Universitaires Saint Luc  
UCL



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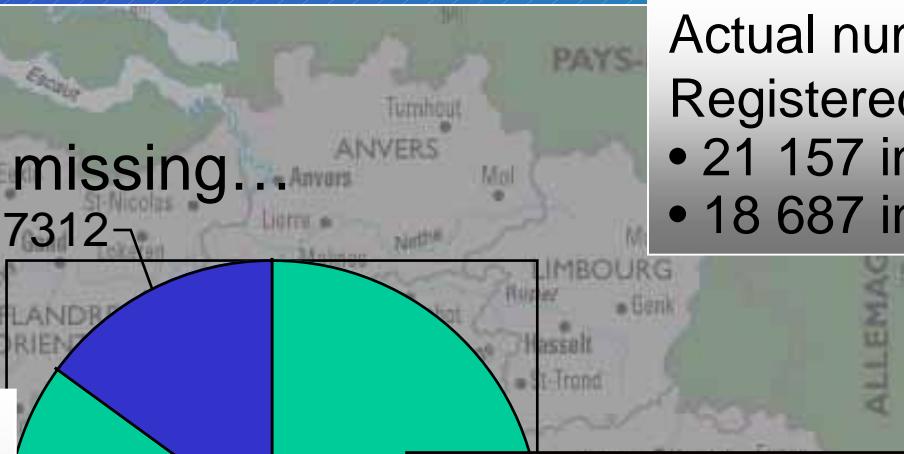
# Depuis 40 ans: l'accélérateur linéaire (linac)



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# Size of the question: Federal cancer registry

According to Dutch registry, about **48 309** case were expected in 1998 and about **55.000** in 2005 (+ 2%/year)



Actual numbers  
Registered in 1998  
• 21 157 in men  
• 18 687 in women

Country	year	% irradiated new cancer patients
<b>Belgium</b>	2003	53
<b>Australia</b>	1995	39
<b>Canada</b>	1987	54
<b>The Netherlands</b>	2000	40-50
<b>United Kingdom</b>	1979	53
<b>Sweden</b>	1992	30-33
<b>United States</b>	1990	57

28.000 patients irradiated in 2003

# Quel est l'effet biologique des radiations ionisantes?



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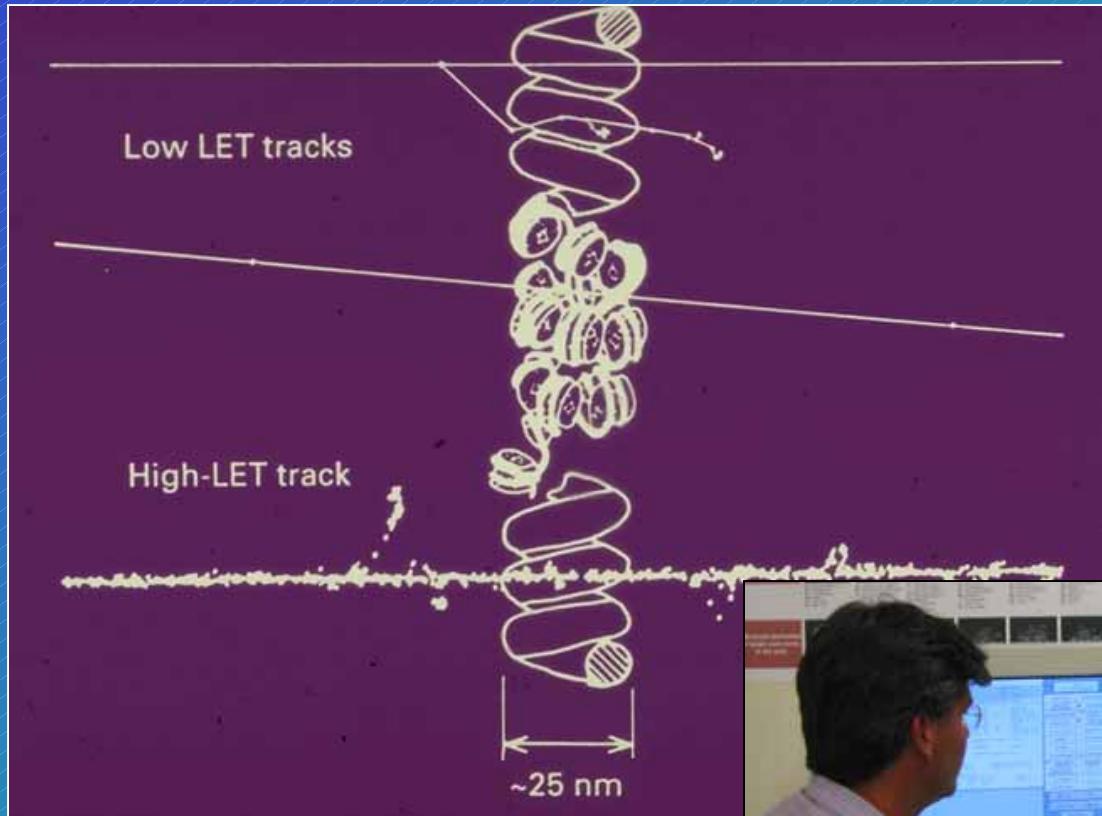
De nombreux arguments indiquent que l'effet principal est au niveau de l'ADN, au sein des chromosomes

QuickTime™ et un décompresseur Photo - JPEG sont requis pour visualiser cette image.

Mort différée

Mort immédiate

# Différentes “sortes” de radiations ionisantes sont utilisées.



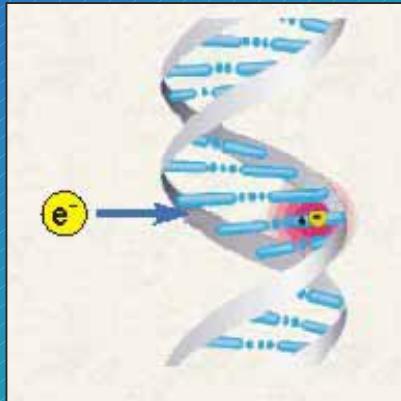
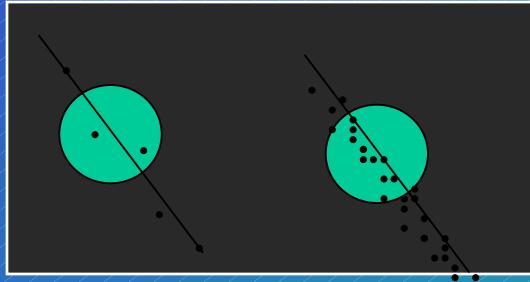
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Interface  
physique/biologie

The important mechanism for biological systems:

Simple and double strand breaks at the DNA level

## Microdosimetry



The absorbed dose alone, as a mean value, will not be able to predict the radiobiological response

The mechanism has to be studied at the appropriate scale: the knowledge of the ionisation density along the track and the concentration of energy deposited by the charged particles traversing matter is essential for the determination of the irreparable damage to the cell.



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## Microdosimetric spectra for external radiotherapy beams

Measurement of microdosimetric spectra for different external radiation beams:

- Neutrons,
- Protons,
- Photons ( $^{60}\text{Co}$ )

Comparison with radiobiological data (RBE)

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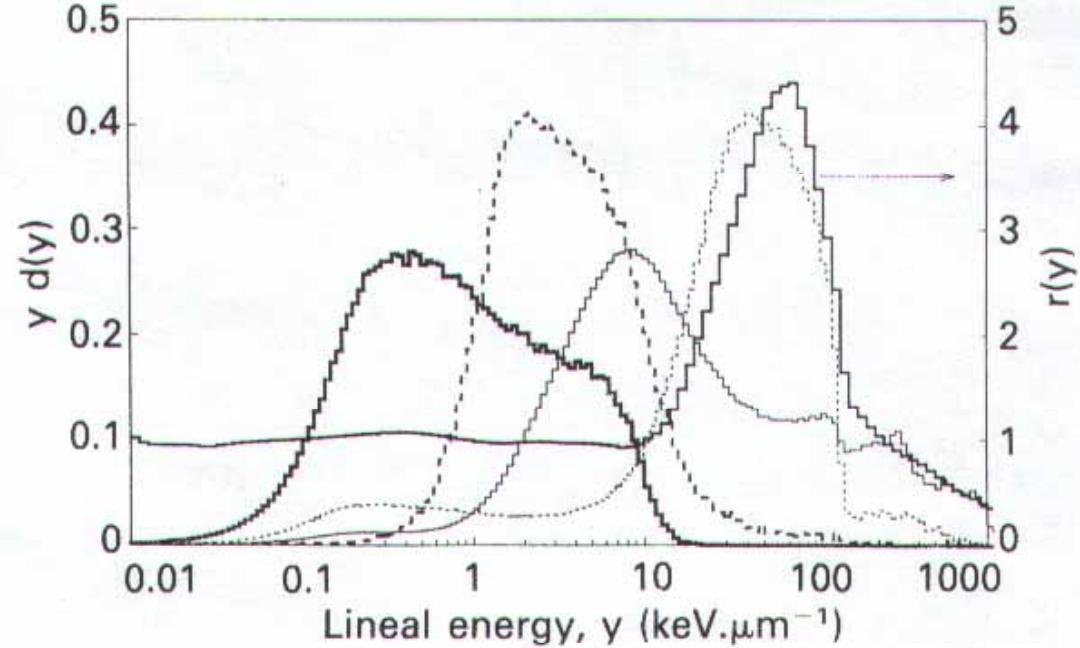
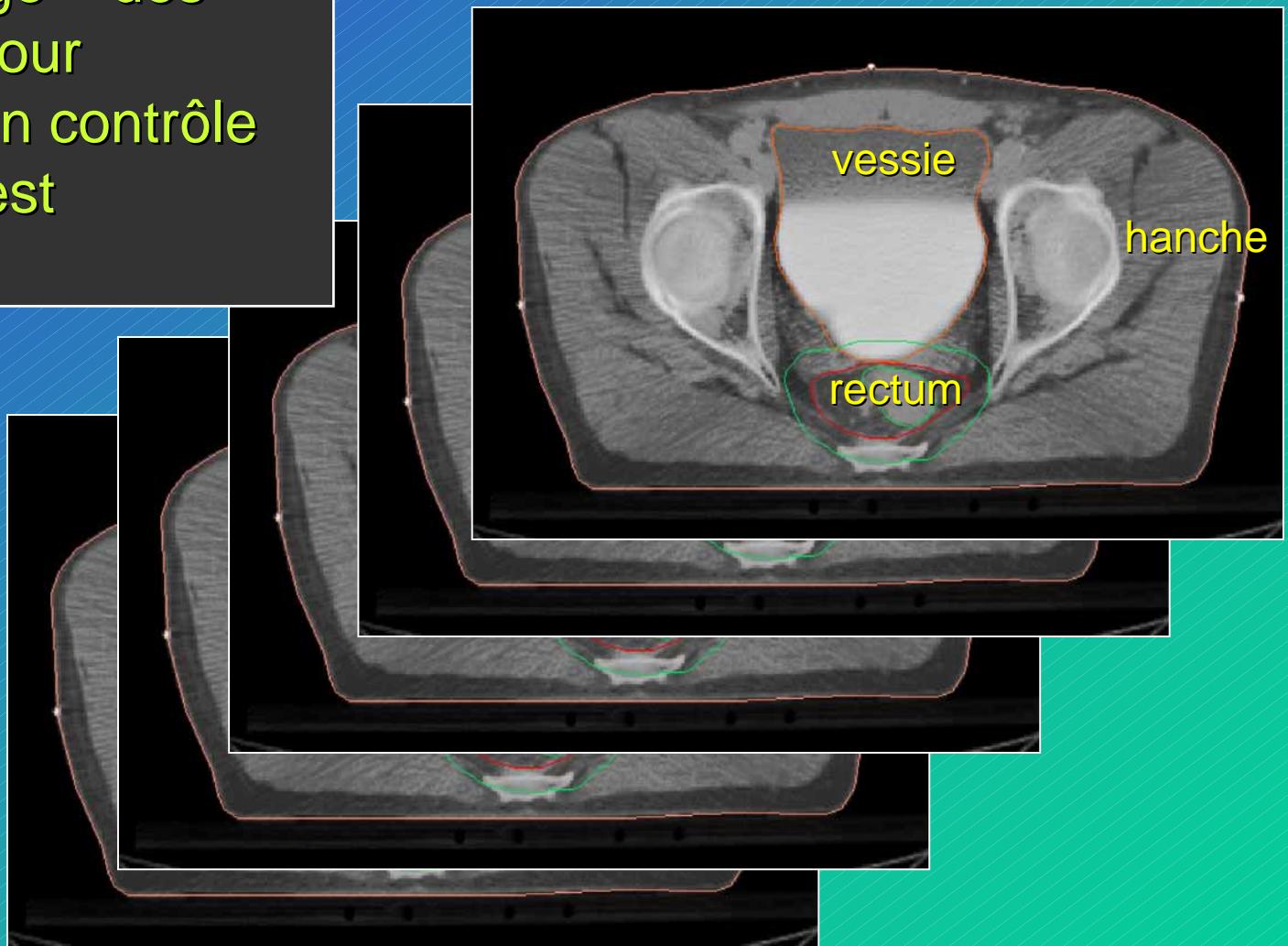


Figure 4. Range of dose distributions in  $y$  measured for the different types of radiation used for the unfolding calculations of  $r(y)$ : (—)  $^{60}\text{Co}$ ; (--) 85 MeV protons; (—) p(65) + Be neutrons<sup>(2)</sup>; (...) d[14] + Be neutrons<sup>(2)</sup>, left scale compared with the weighting function  $r(y)$  (thick solid line, right scale).

# Qu'est-ce que la radiothérapie de conformation?

« Contourage » des structures pour lesquelles un contrôle de la dose est nécessaire



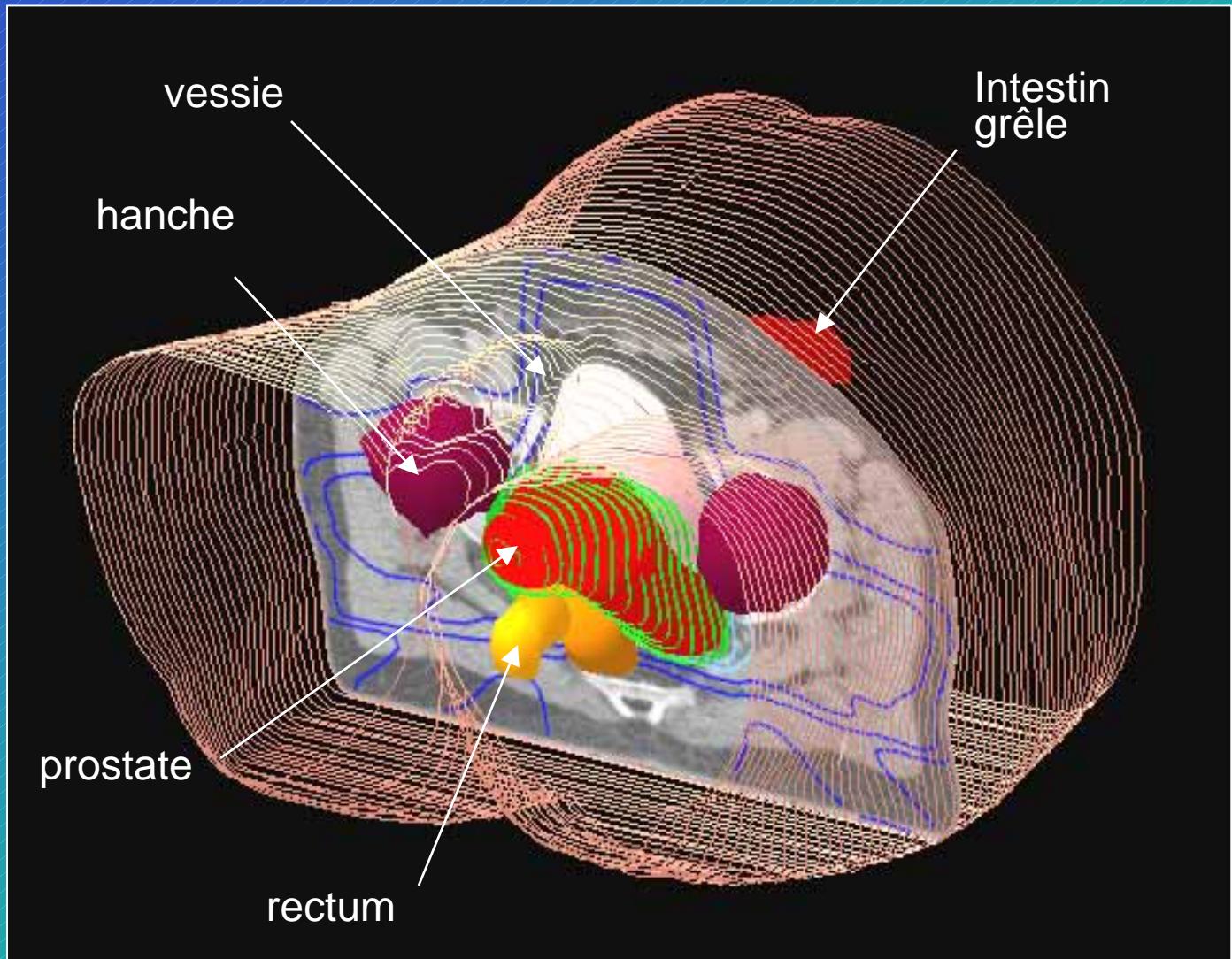
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# Reconstruction 3D

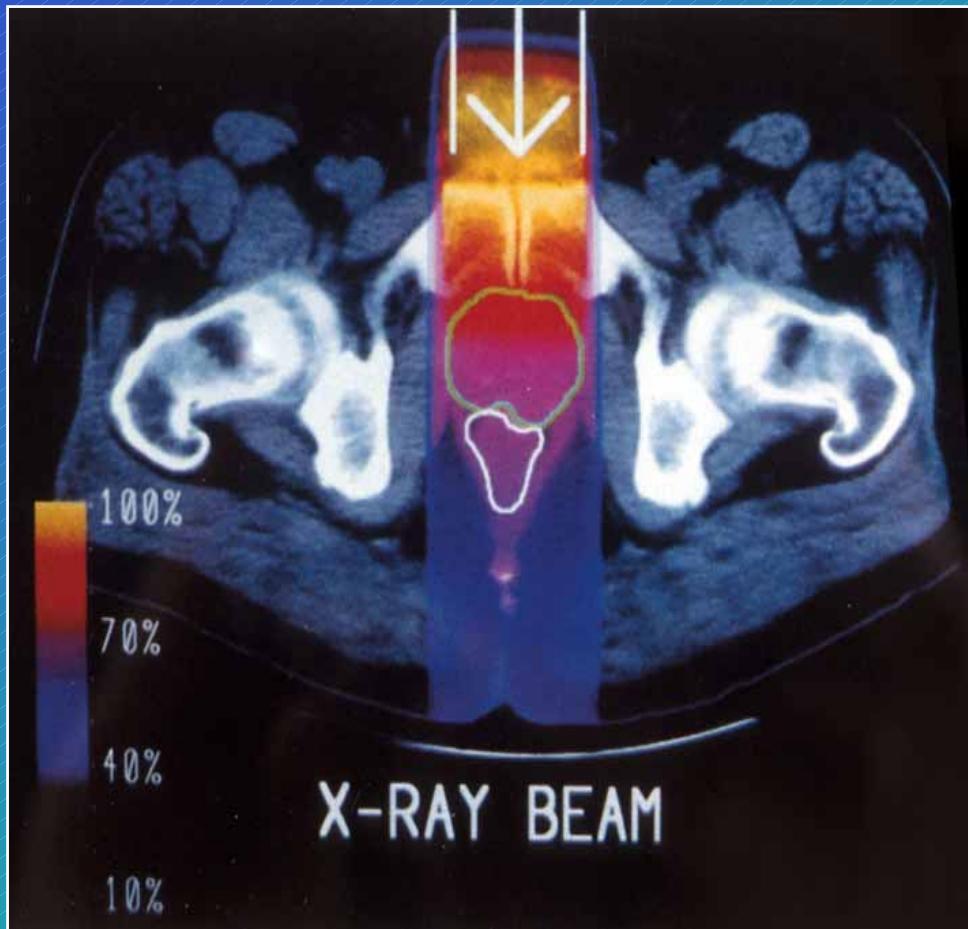
Le  
patient  
virtuel



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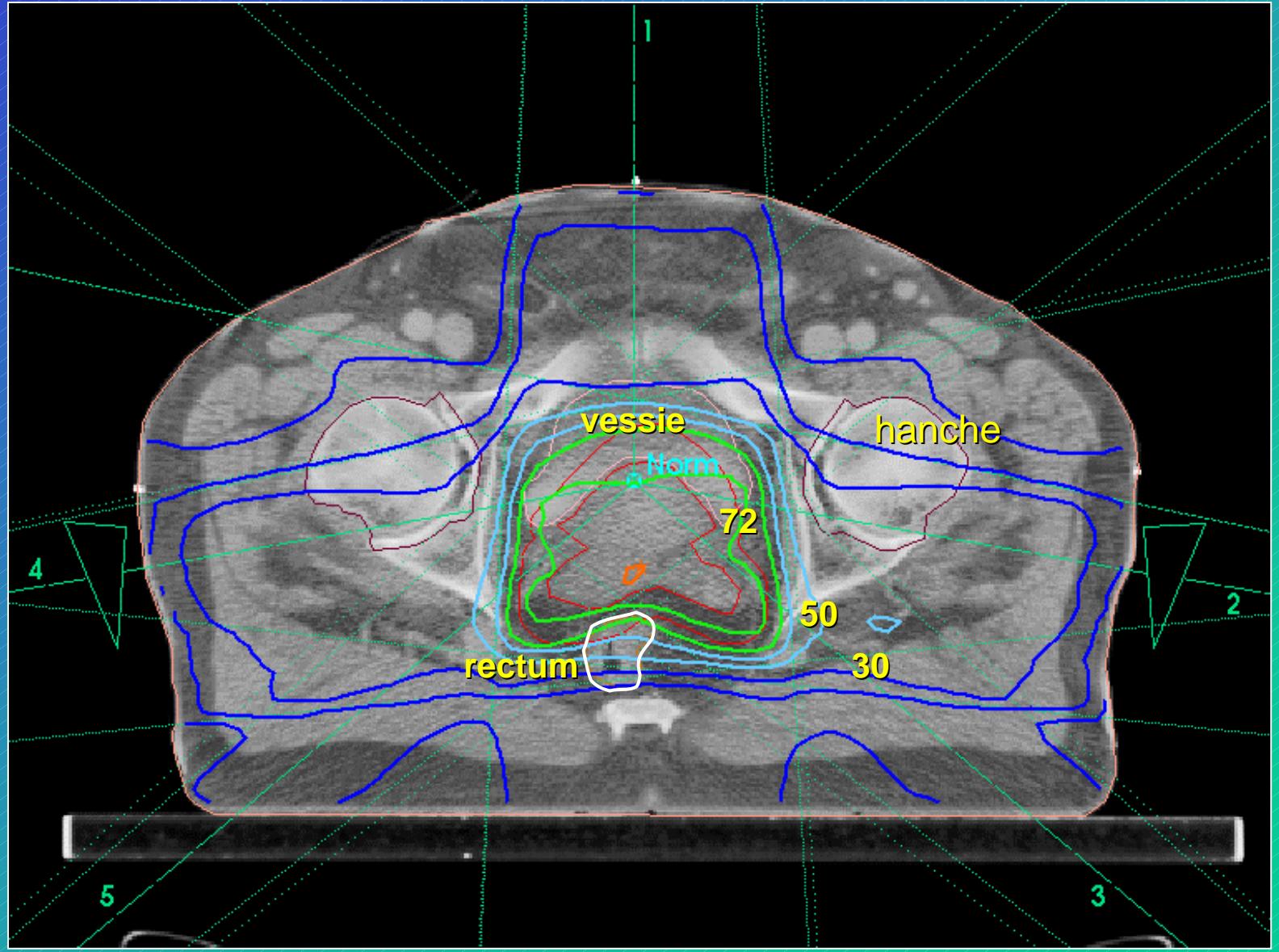


# Calcul de la dose absorbée (en gray)



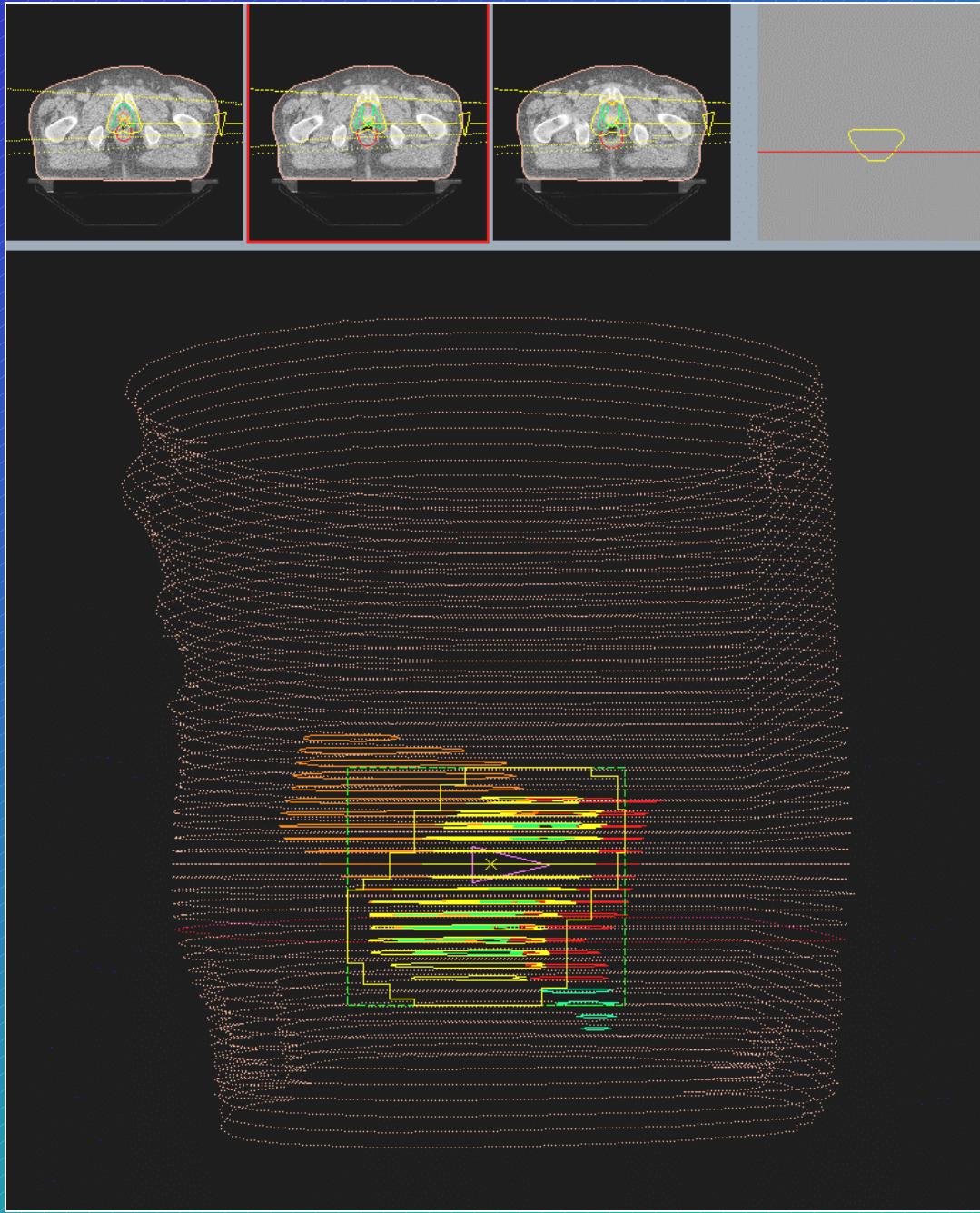
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# Distribution de dose : isodoses



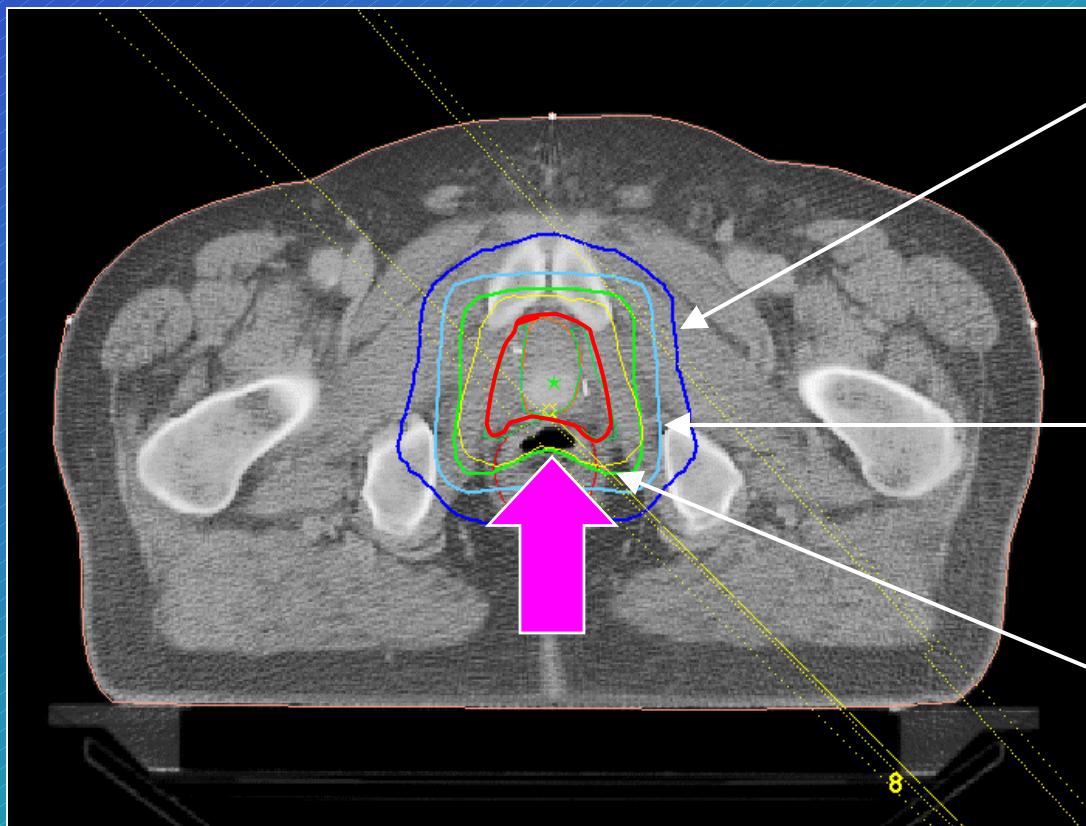
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Faisceau  
latéral  
“conformé”  
à la  
prostate

# Radiothérapie conventionnelle ou technique 3D de conformation : la dose à la tumeur croît de 25 %



Irradiation  
conventionnelle  
(→ 1995)  
60 Gy

3D CRT  
(1995 - 1999)  
70 Gy

Segmentation  
(2000 → )  
74 Gy

# Protection du rectum

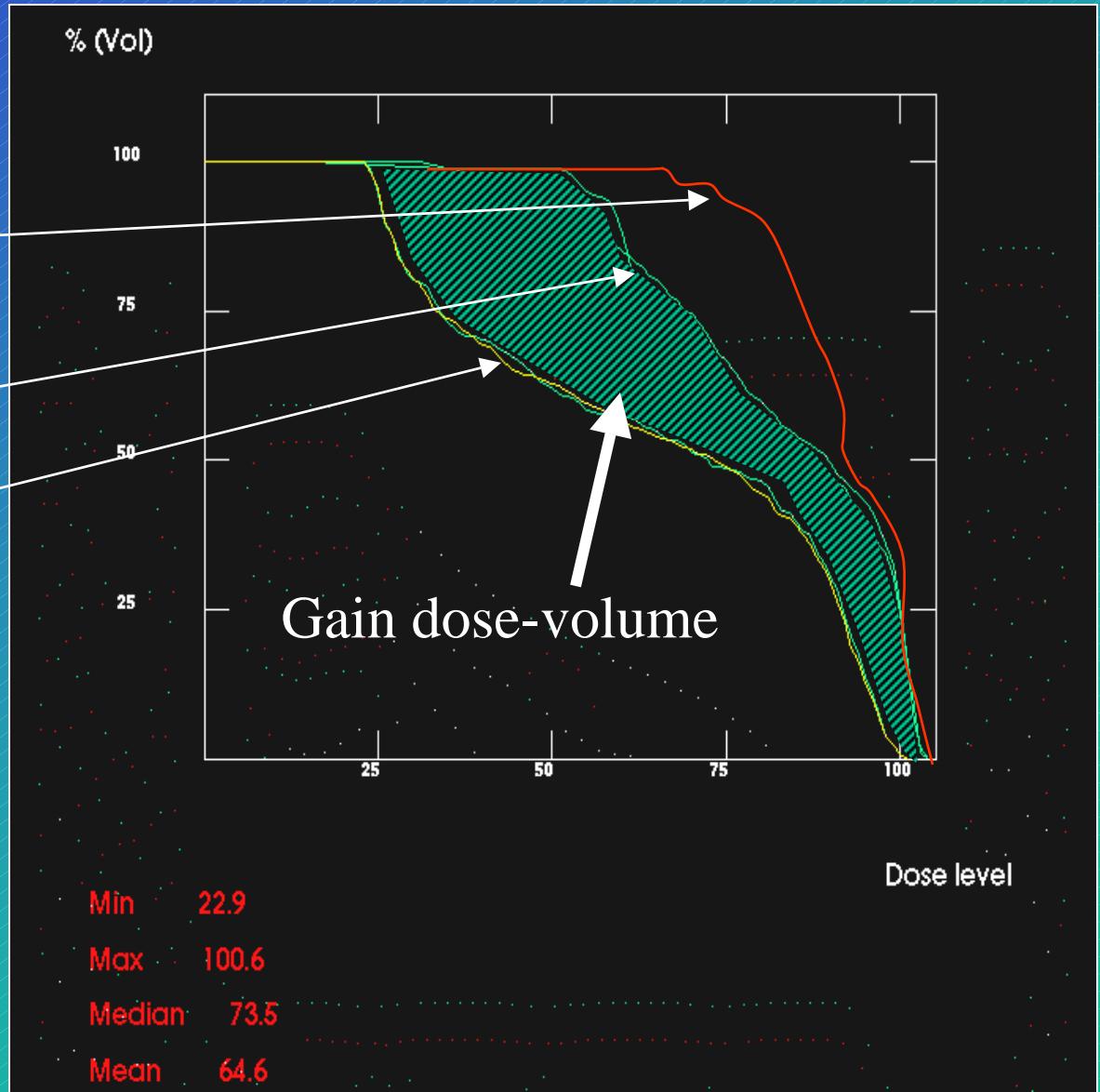
Technique conventionnelle (2D)

Technique 3D simple

Technique 3D segmentée

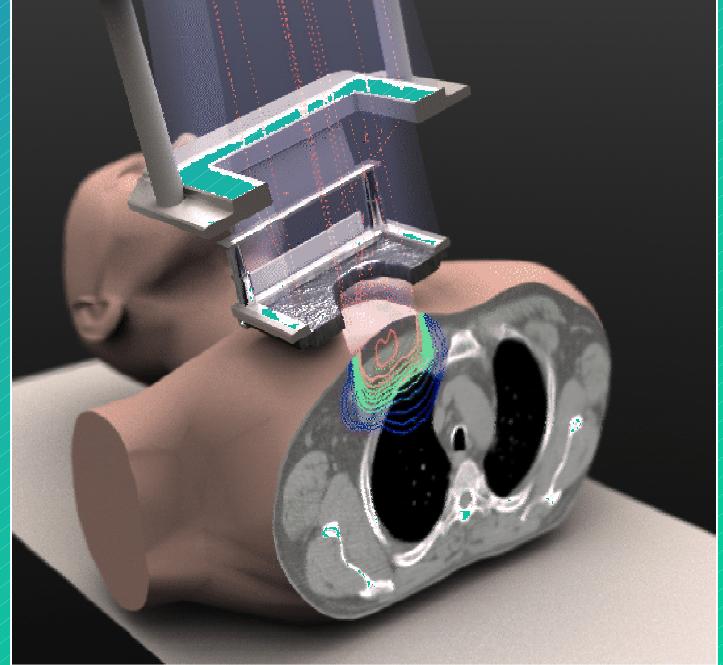
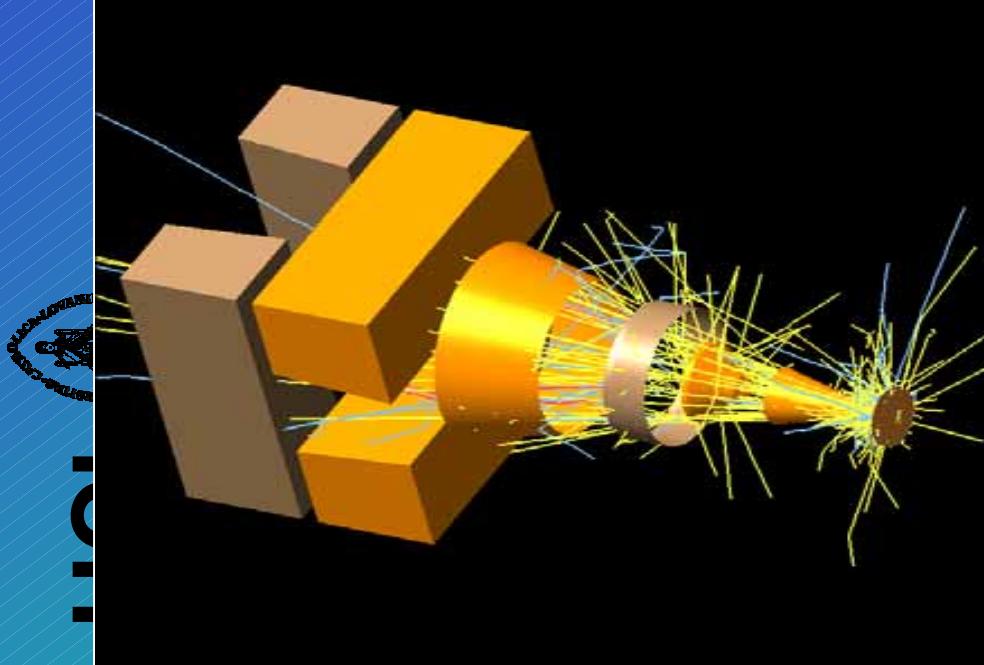


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# La radiothérapie tridimensionnelle ... conformatrice

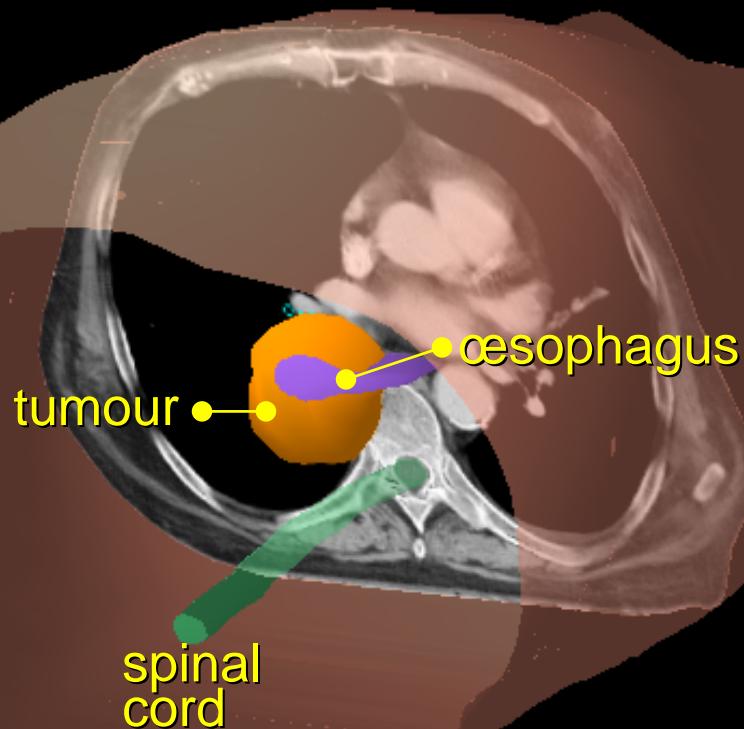
- Une dimension en plus (hauteur) ...
  - Améliorations (grande précision, temps ?) avec calculs Monte Carlo



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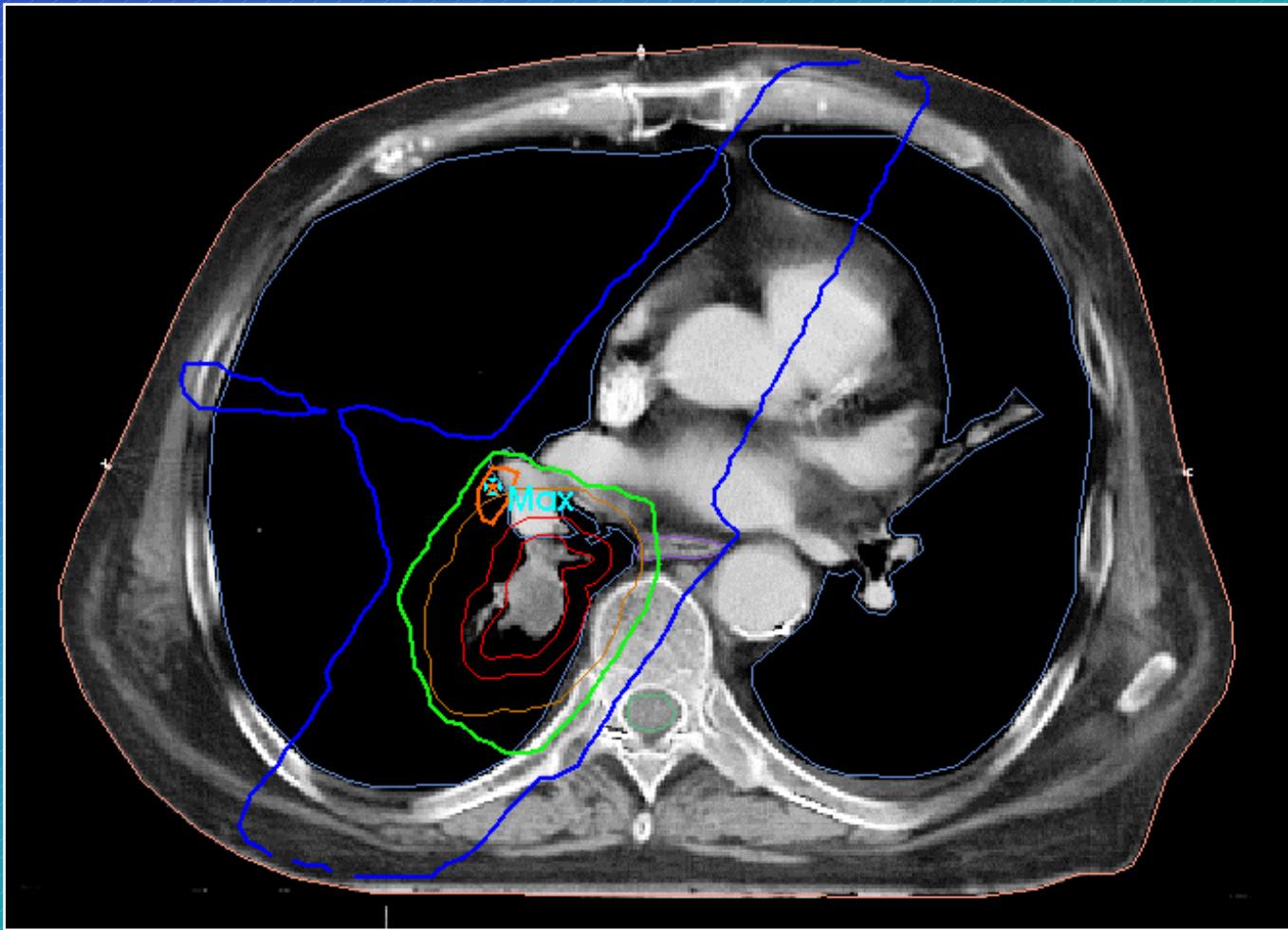
# The 90's : generalisation of 3D conformal radiotherapy

Virtual patient.  
Reconstruction from  
an 80 slices CT with  
5 mm spacing



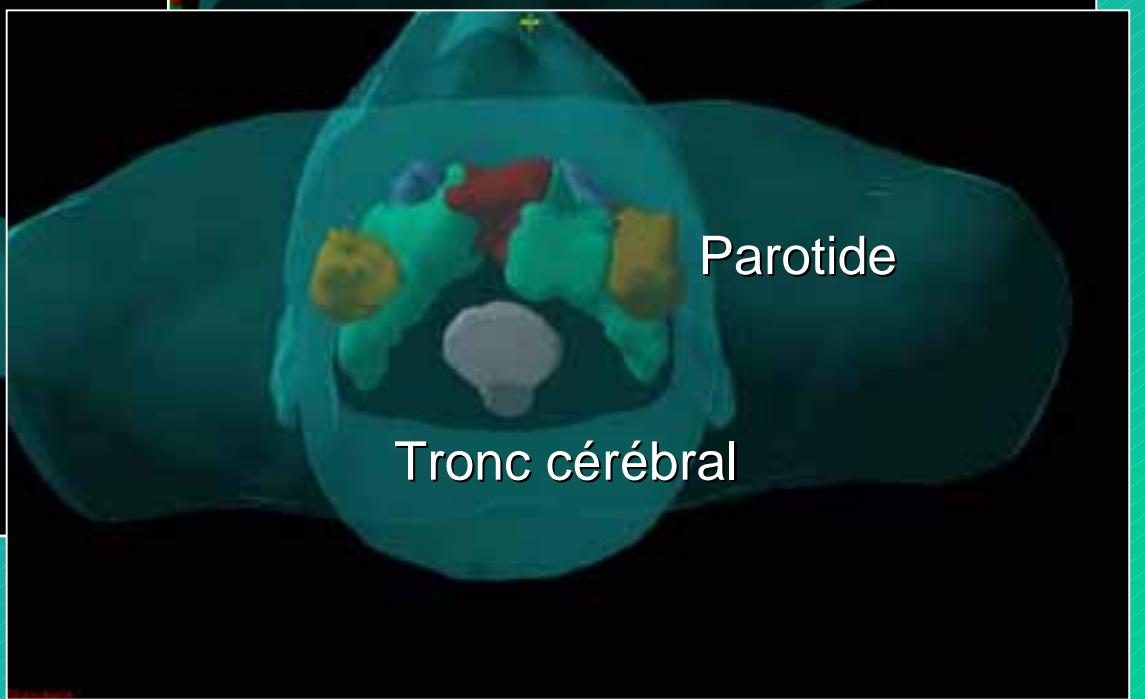
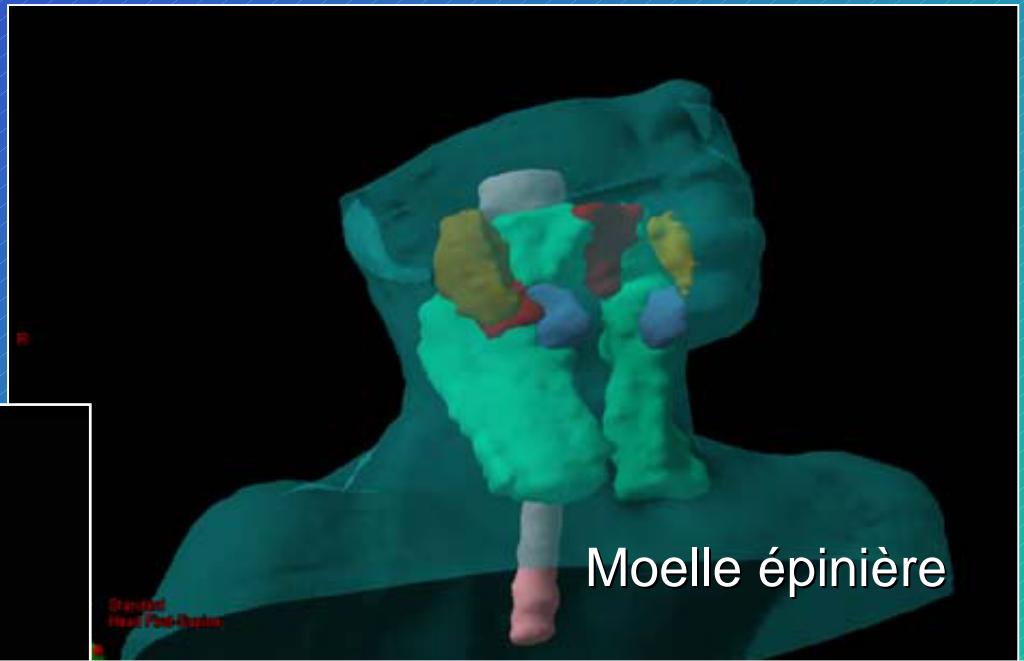
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# Dose distribution : isodoses



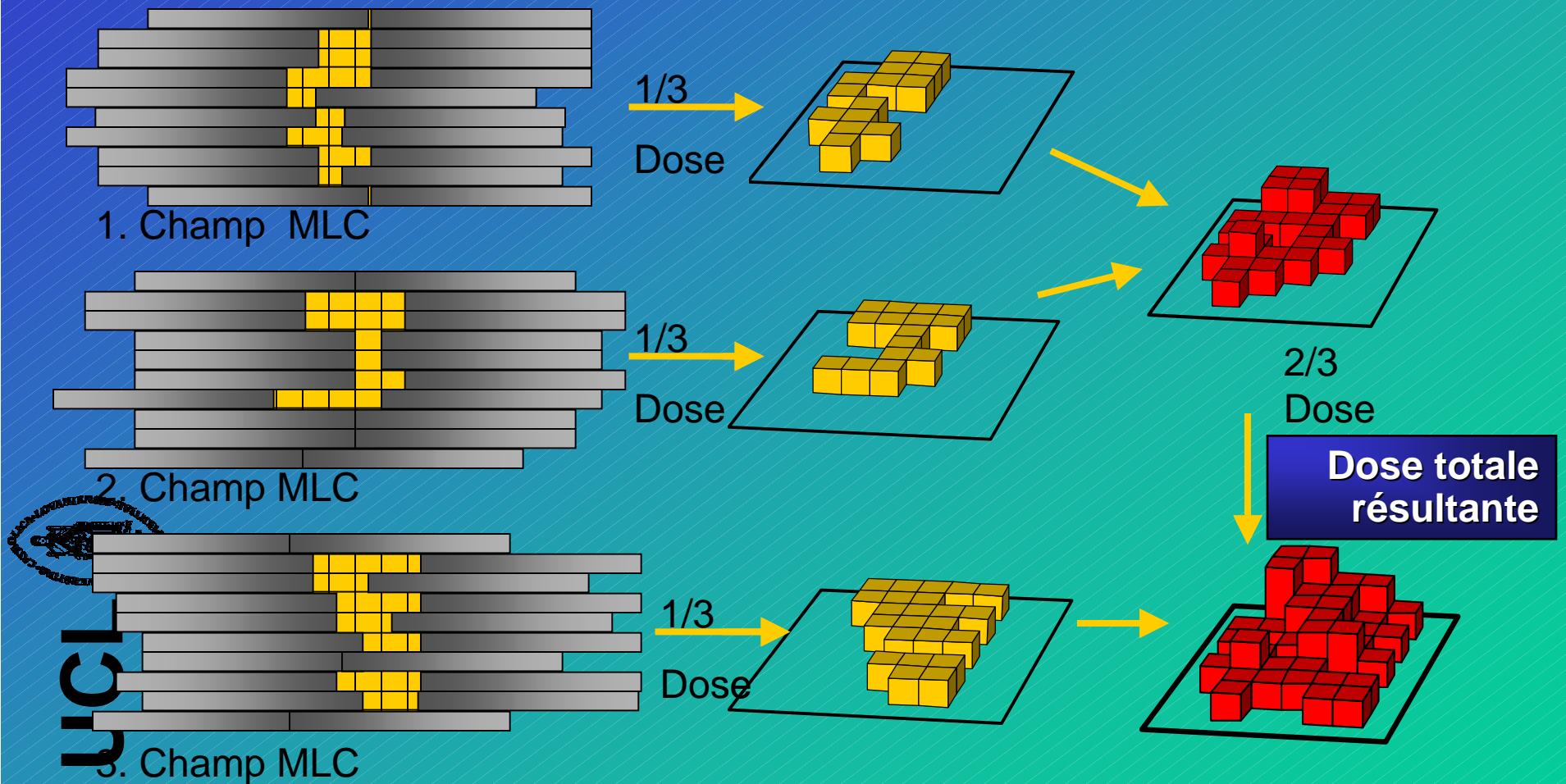
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# Formes et volumes complexes



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# IMRT mode step&shoot (style ELEKTA)



# La radiothérapie tridimensionnelle ... conformationnelle par modulation d'intensité- COMMENT ?

Parotides

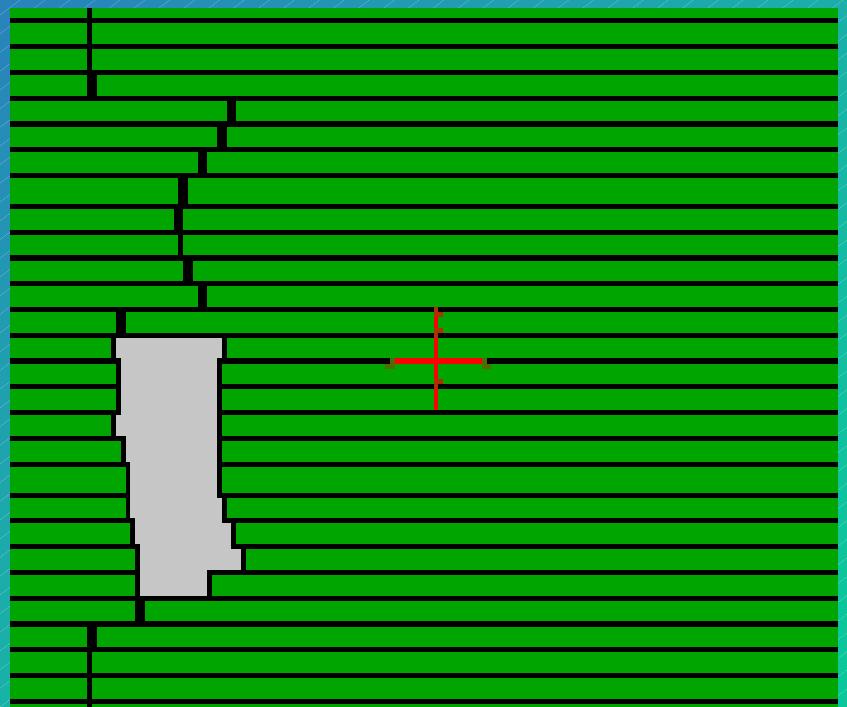
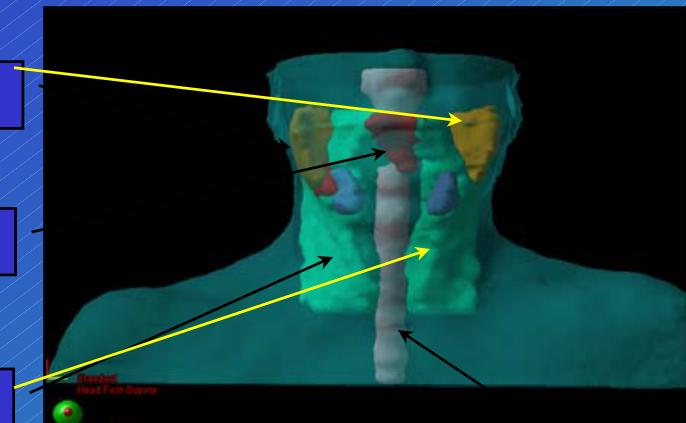
PTV T

CTV N

Moelle +  
Tronc cér.



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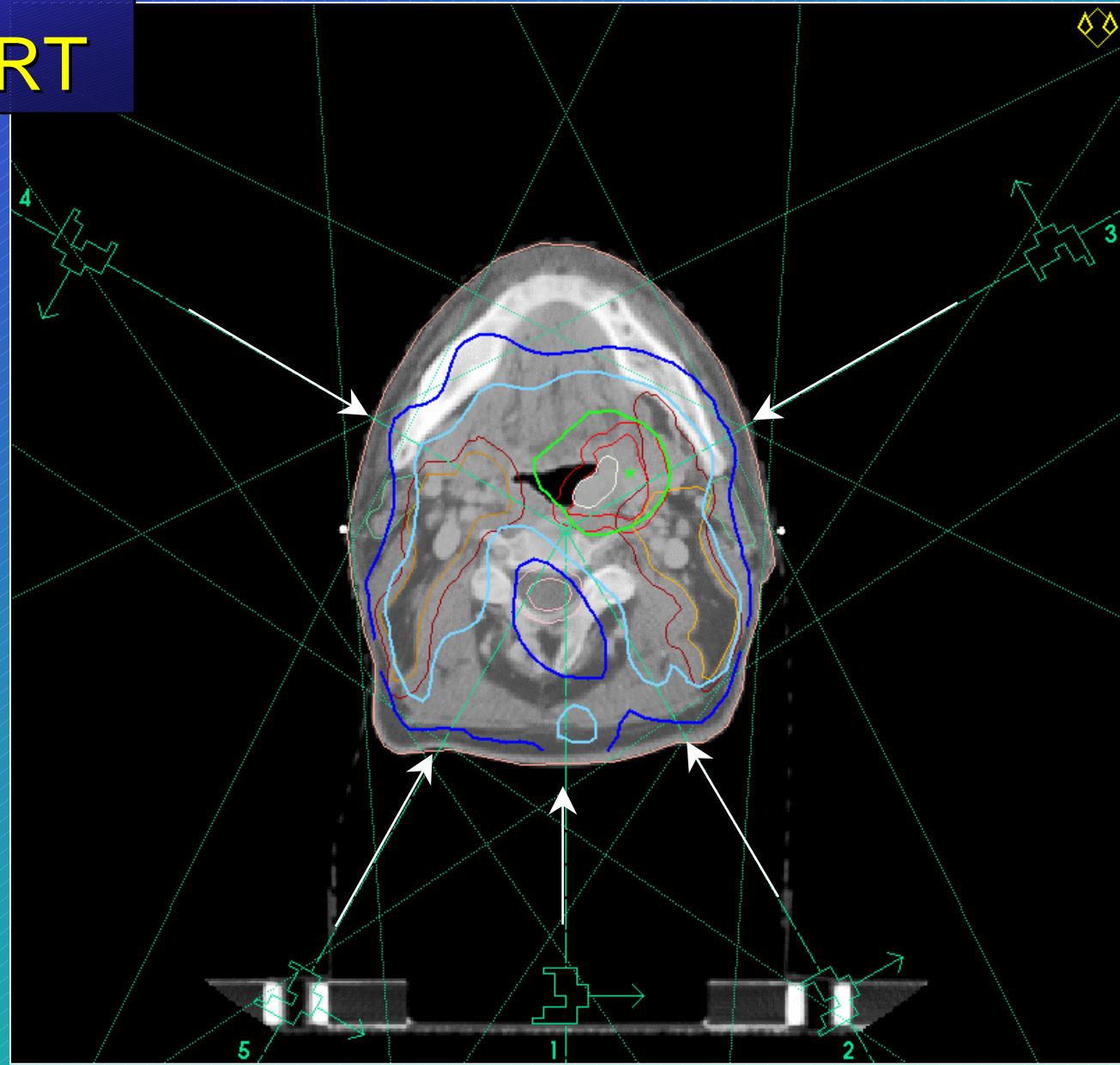


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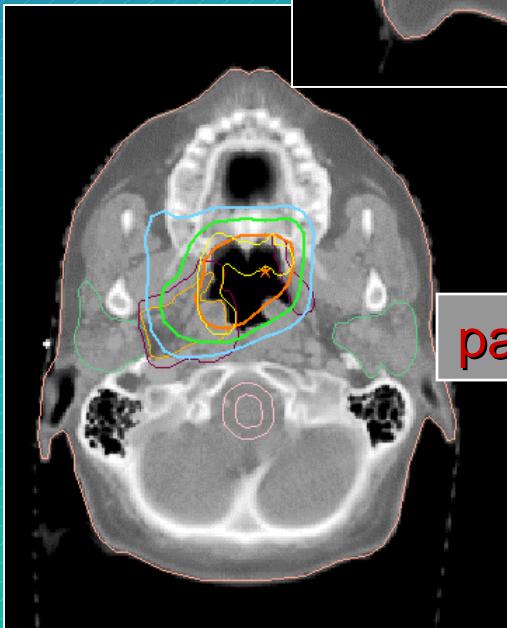
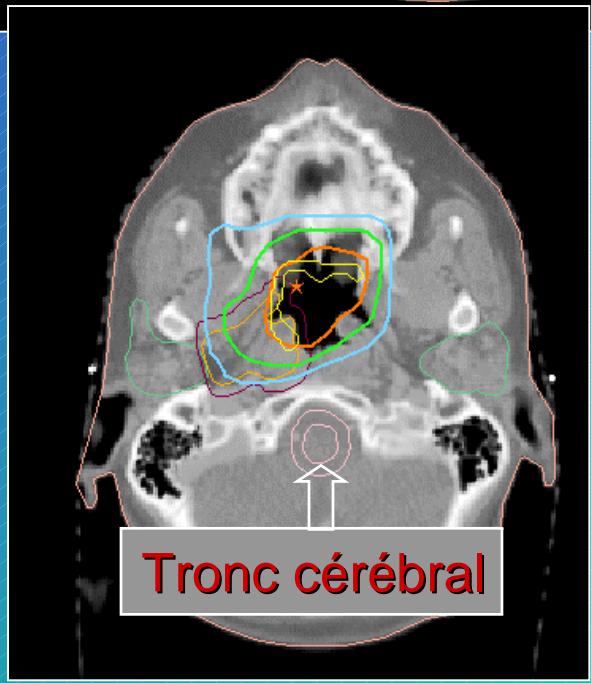
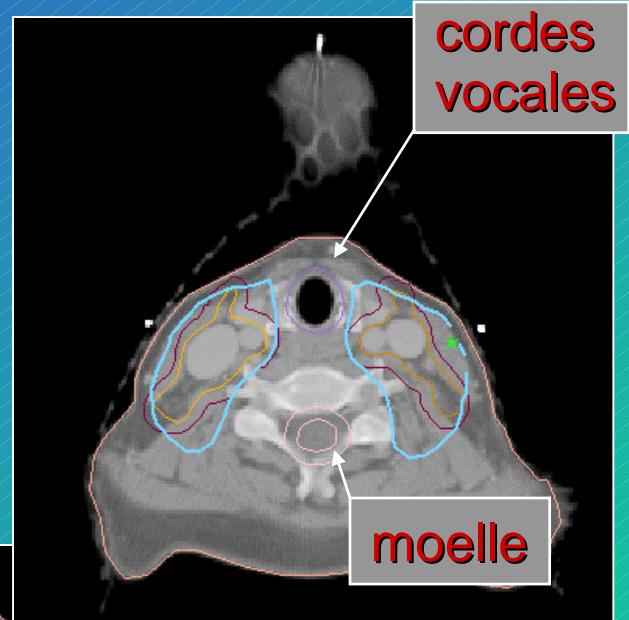
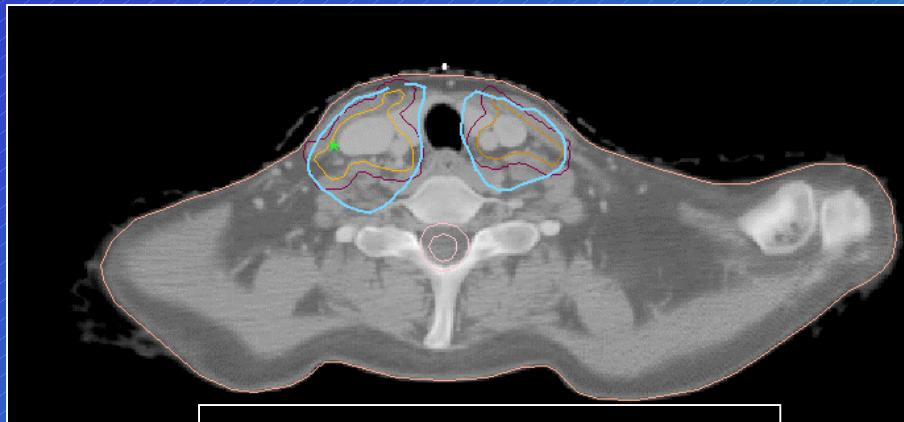
# Solution IMRT



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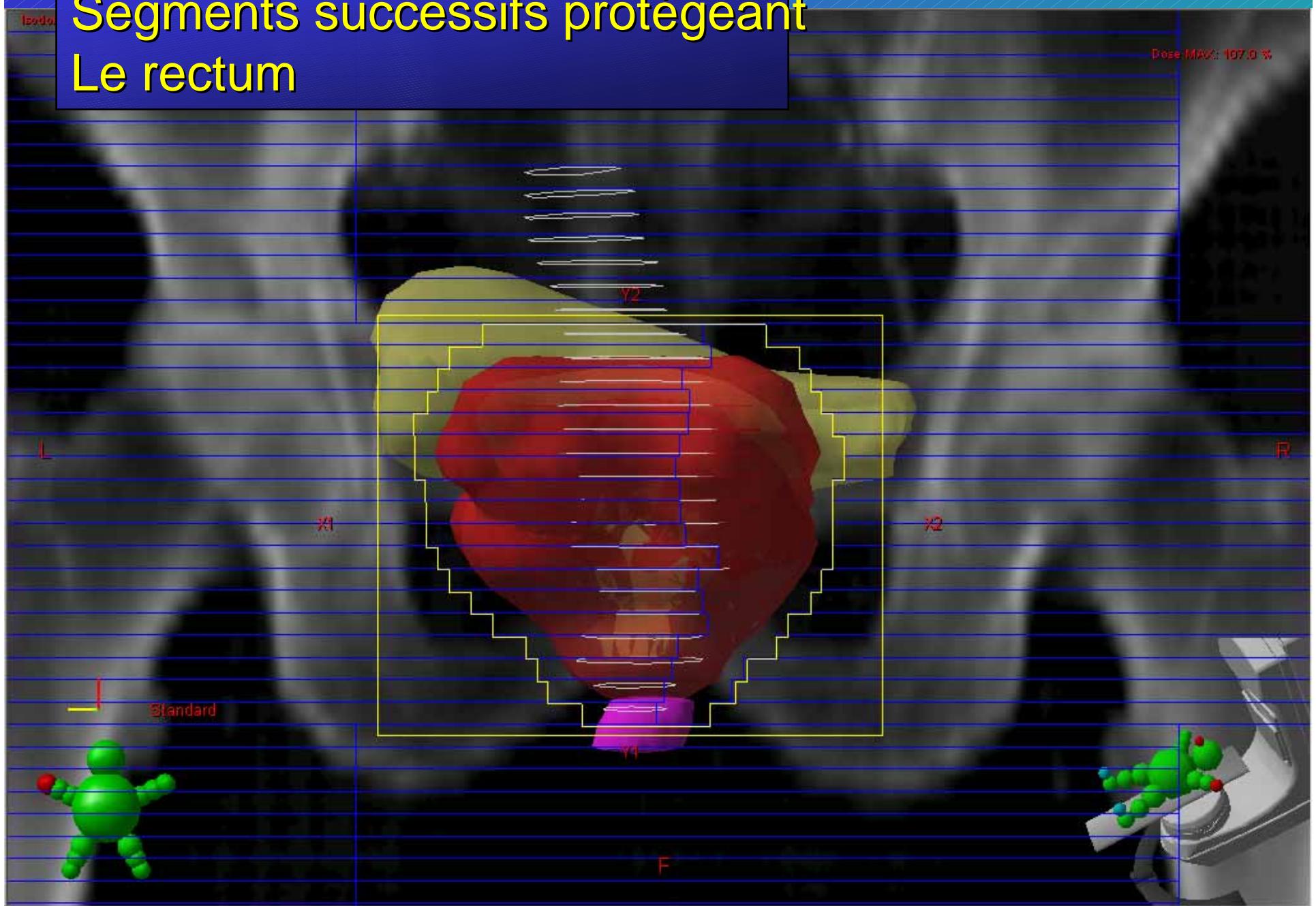


# IMRT en tête et cou : traitement réel

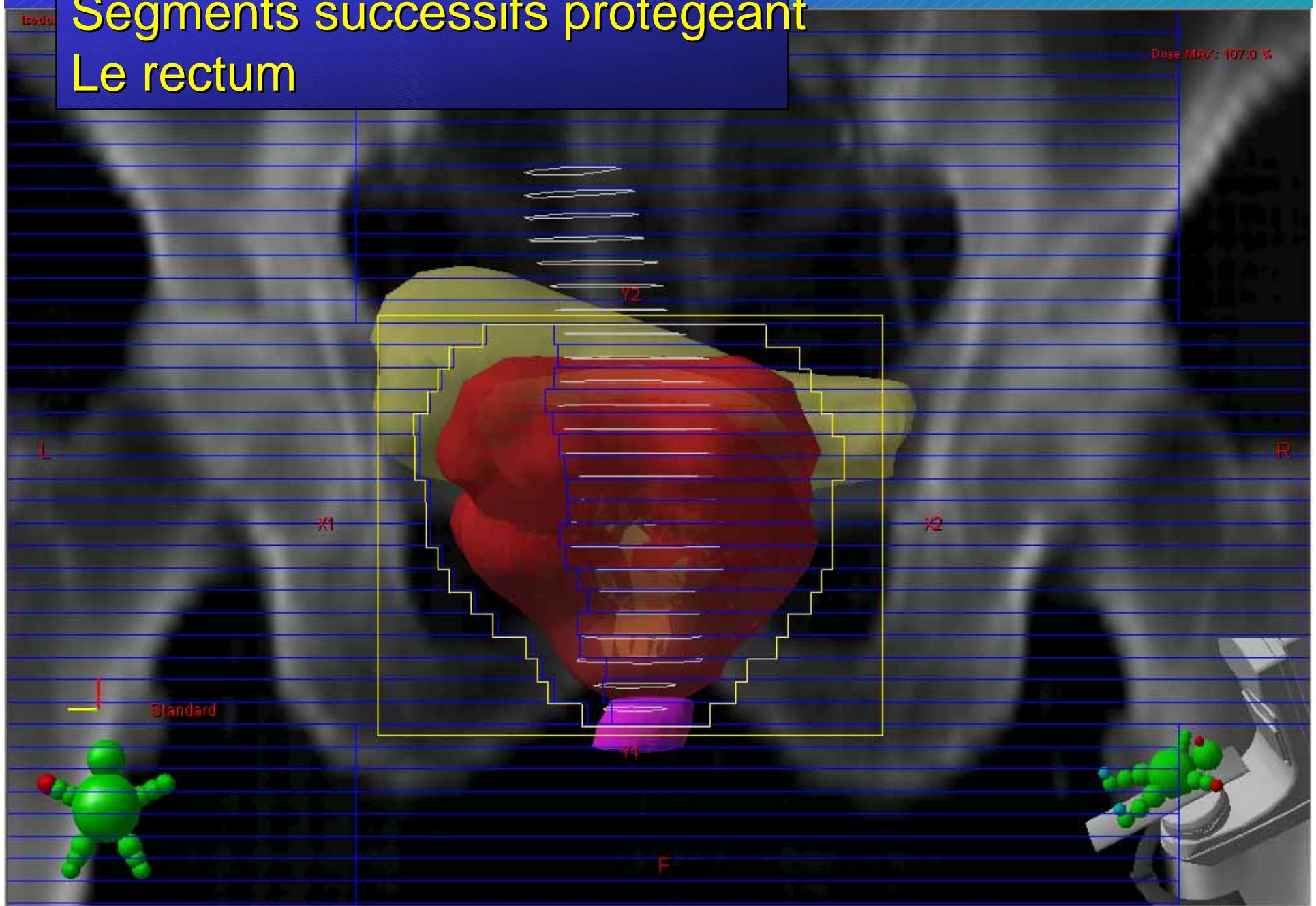


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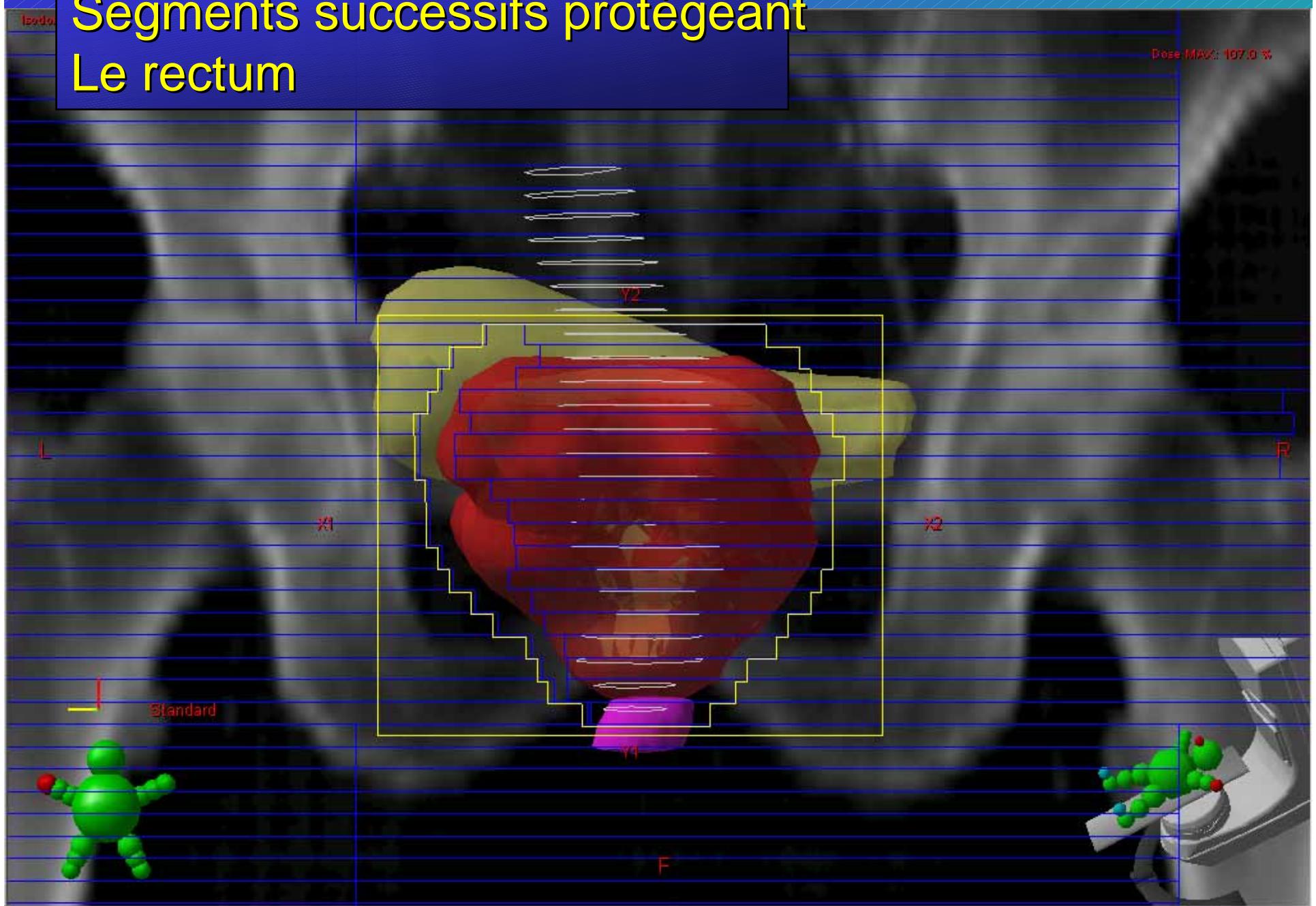
# Segments successifs protégeant Le rectum



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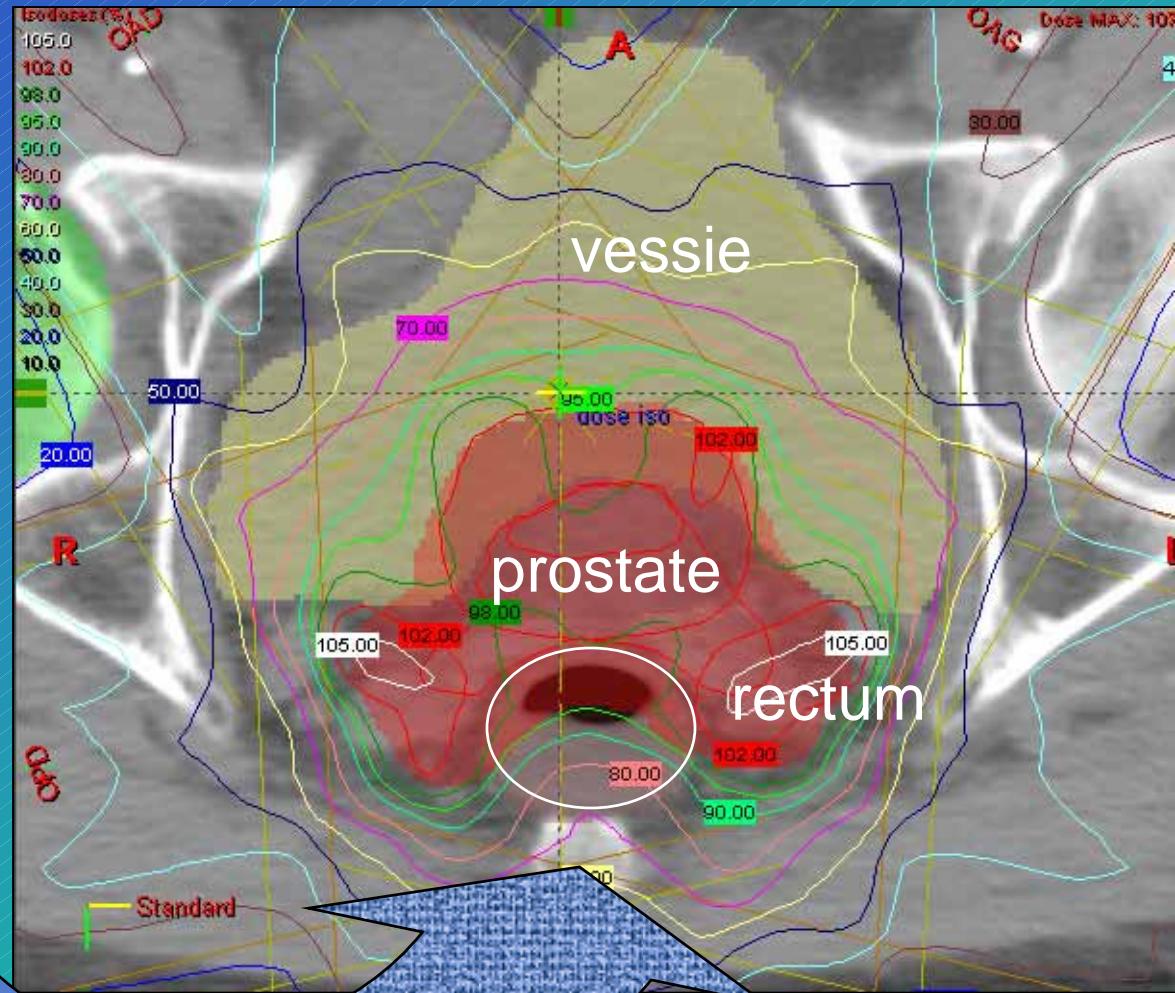


# Segments successifs protégeant Le rectum



# Cancer de la prostate (Namur)

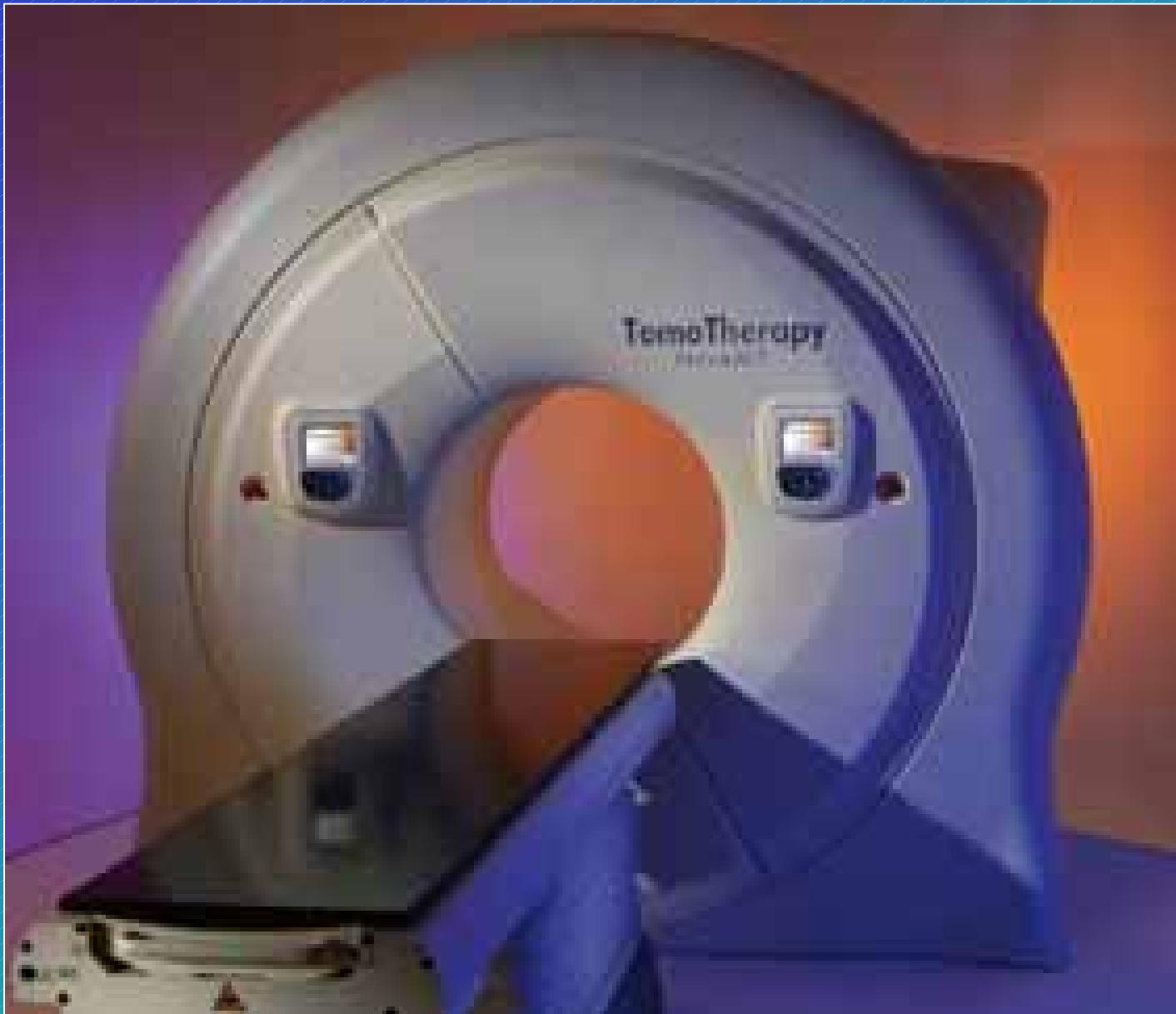
La face postérieure de la prostate est concave, enroulée autour de la face antérieure du rectum.



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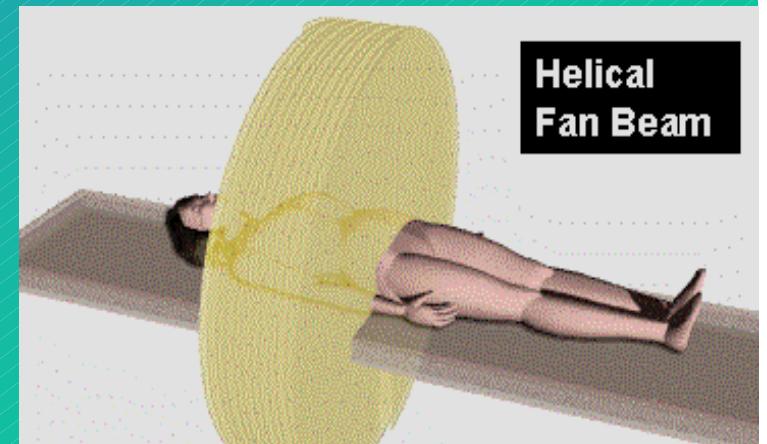


UCL



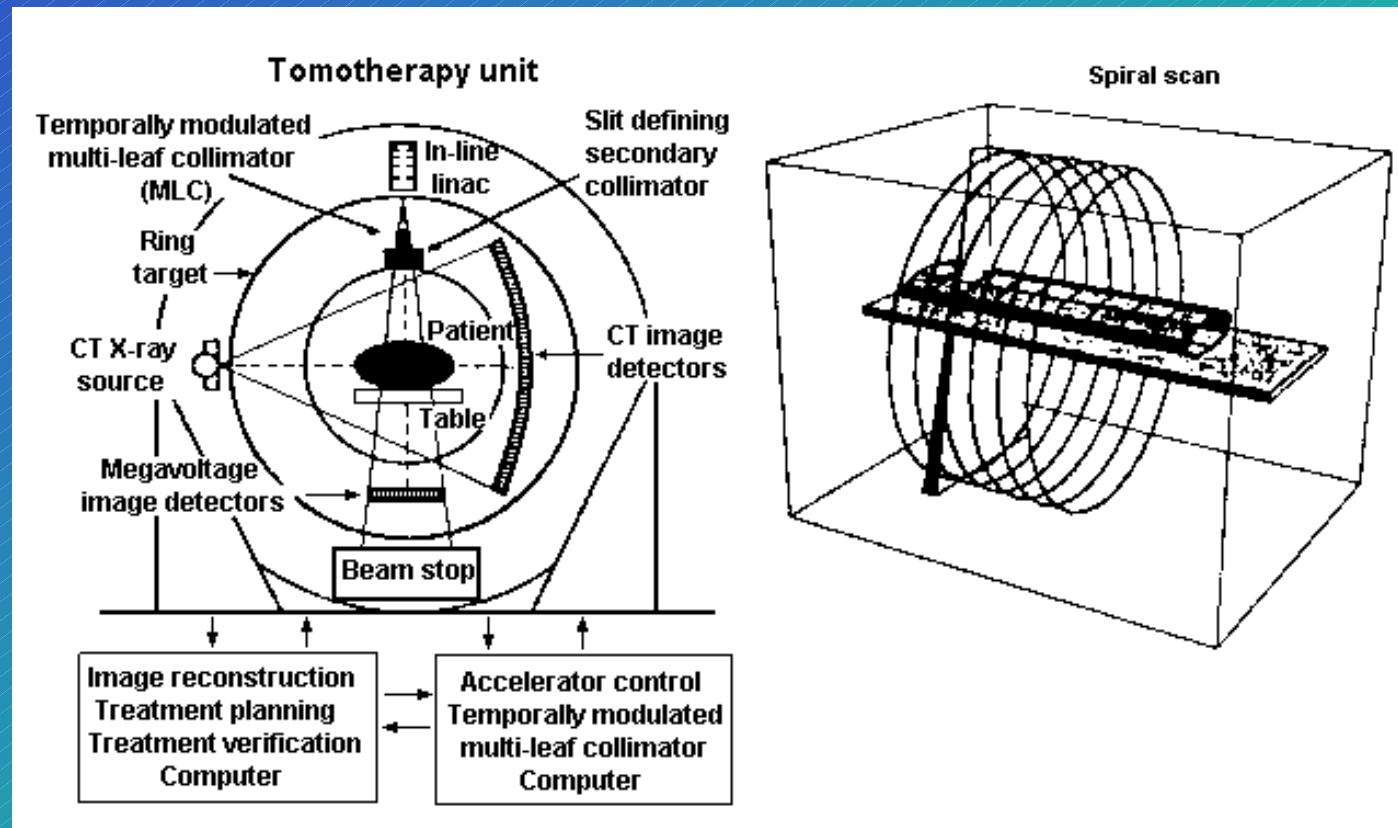
# La tomothérapie

- Système Hélicoidal
- L'anneau est un scanner modifié  
Tunnel → 85 cm
- “fan beam “ de 6MV
- Faisceau modulé par 64 lames  
CML
- Vérification de la position du patient en temps réel par système



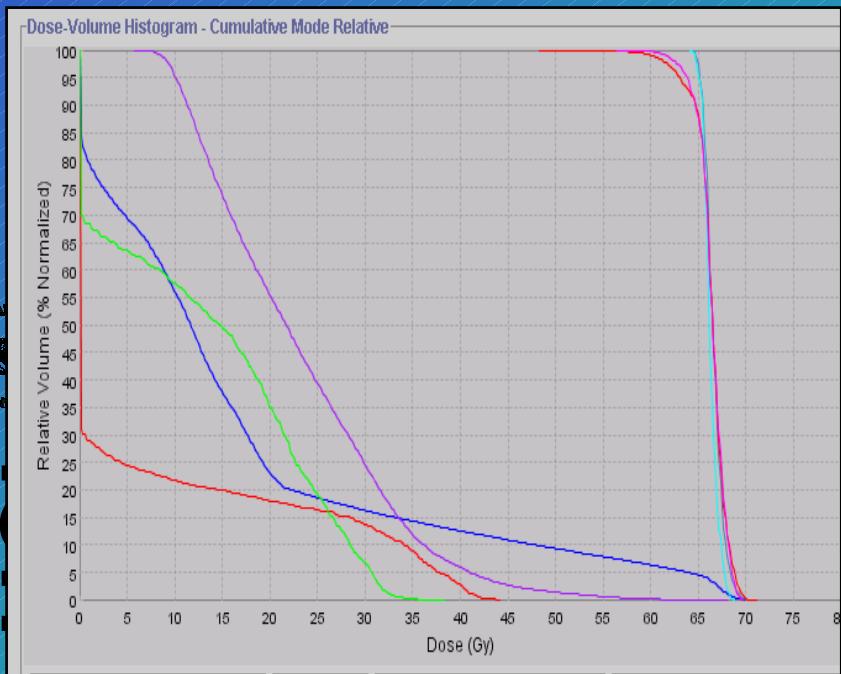
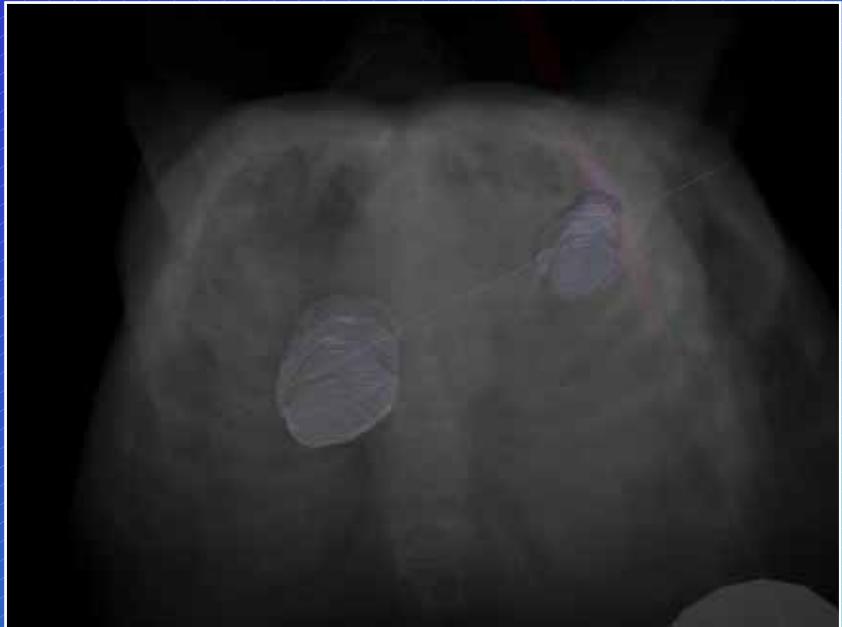
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# Principe (video clip)

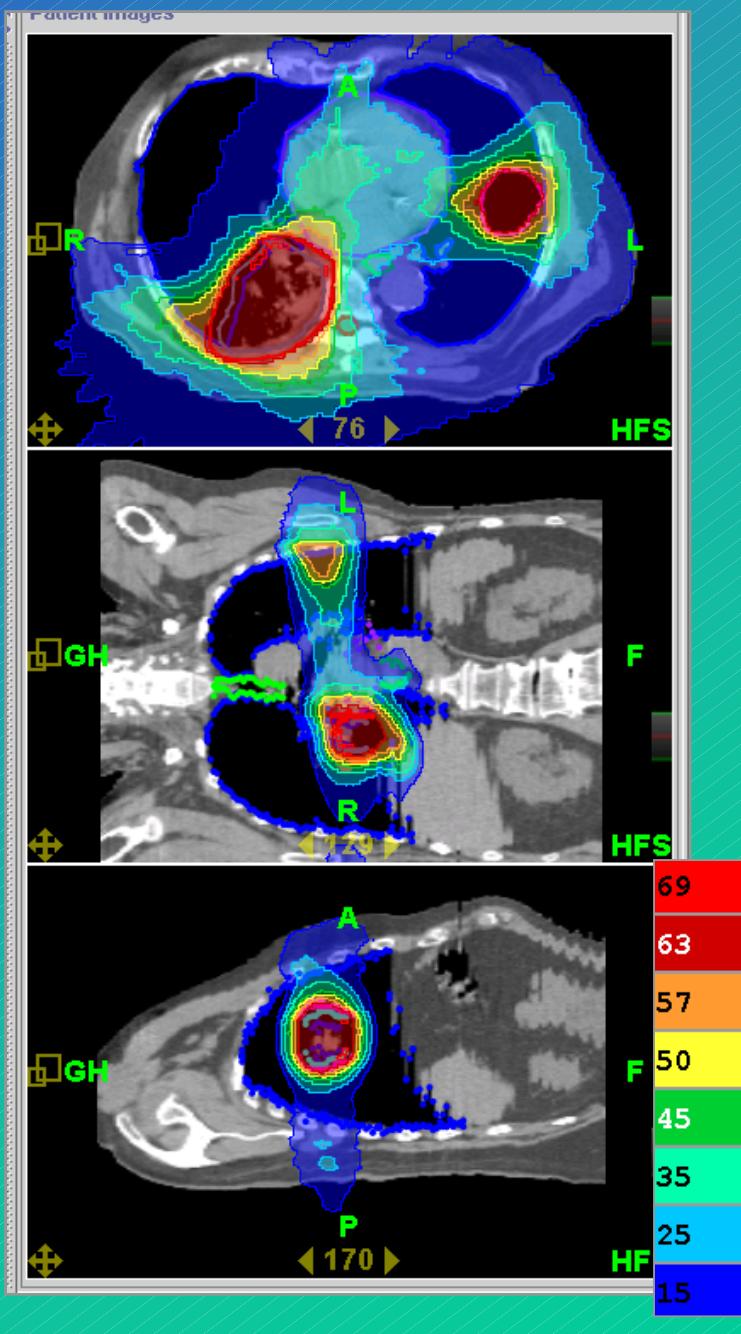


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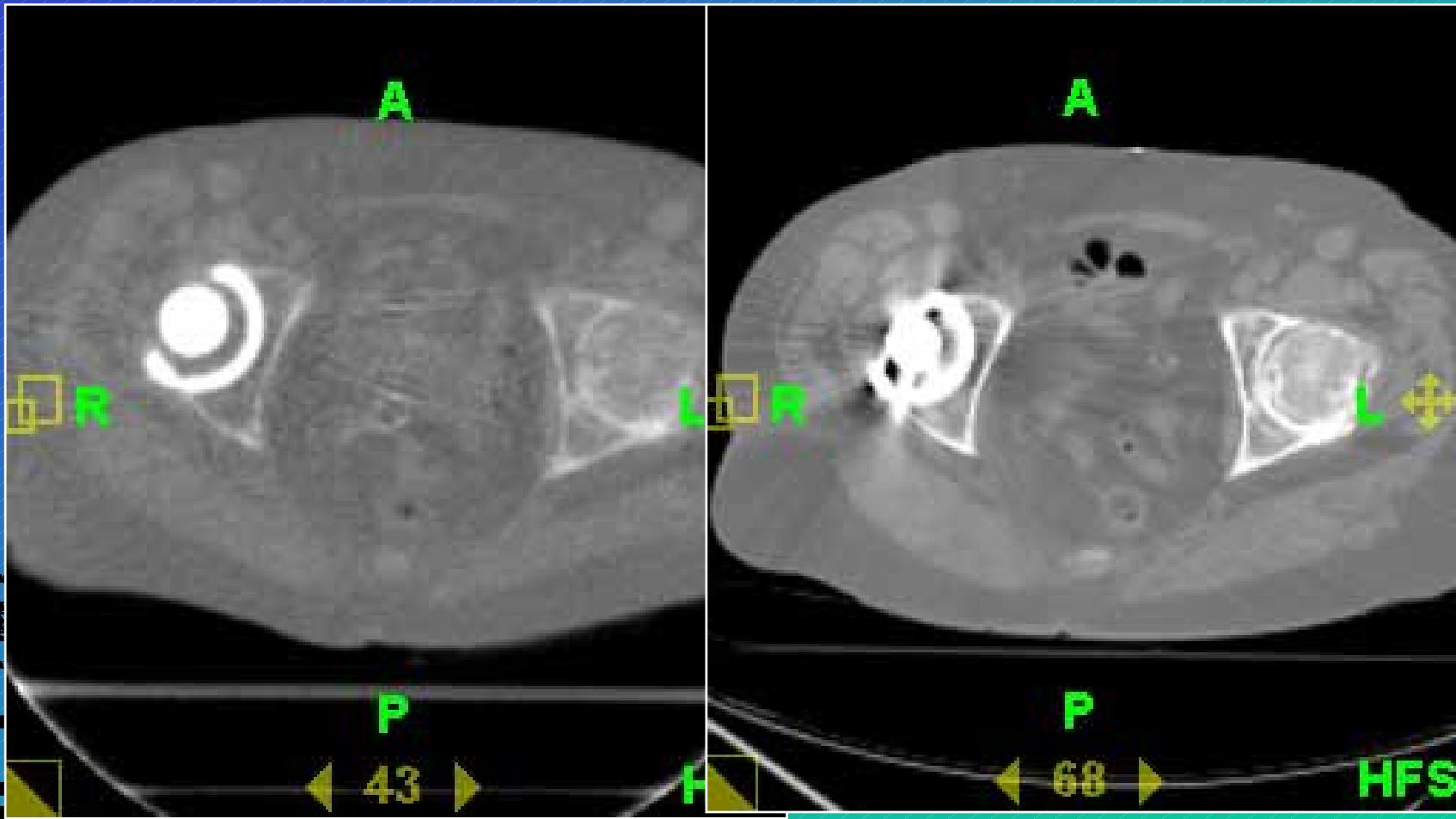
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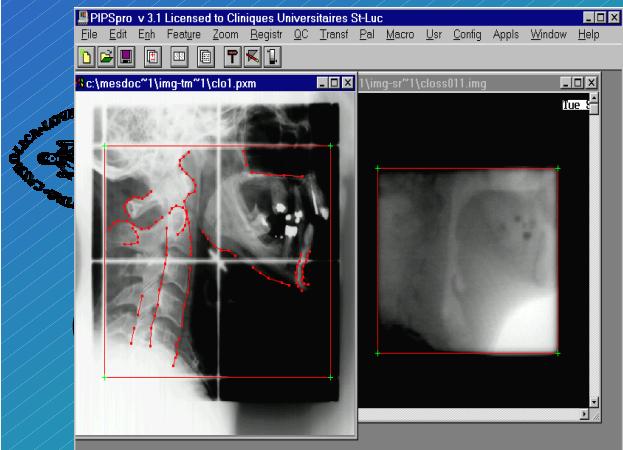
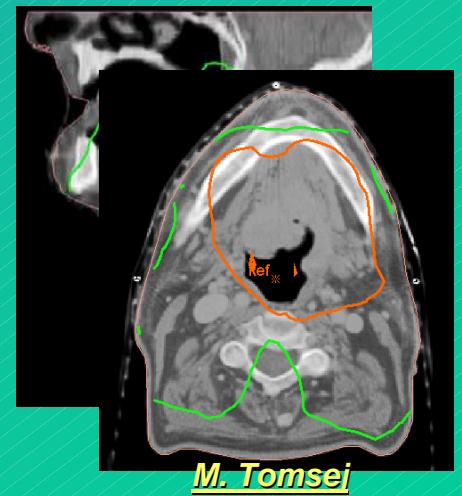
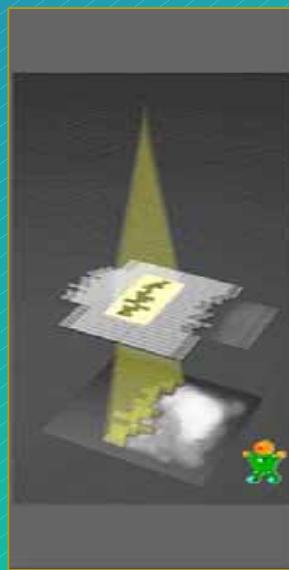
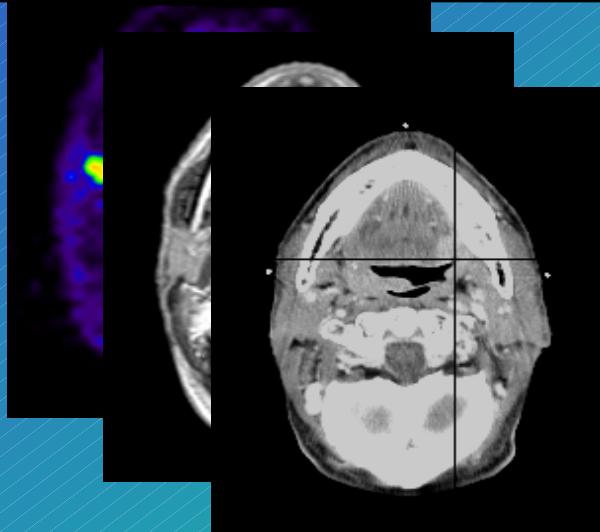
M. Tomsej



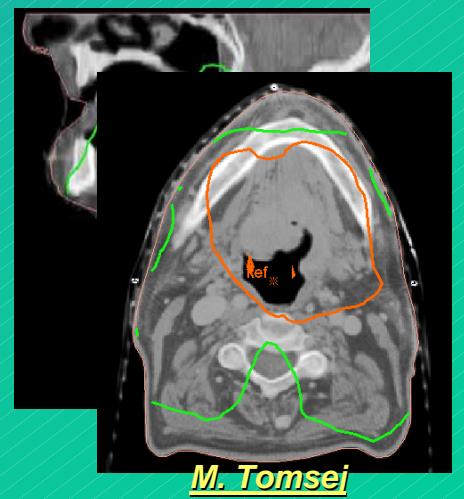
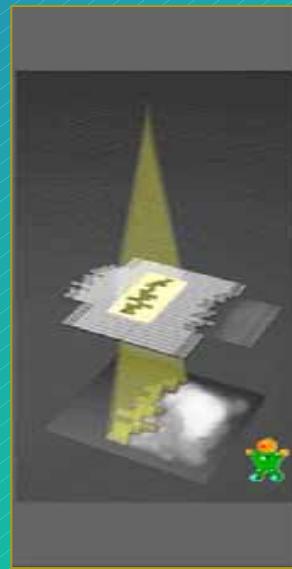
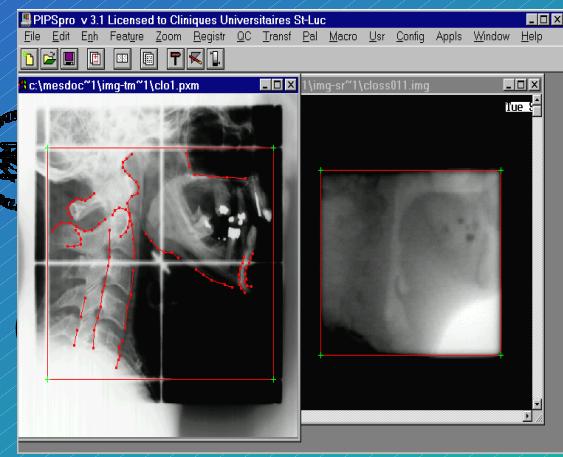
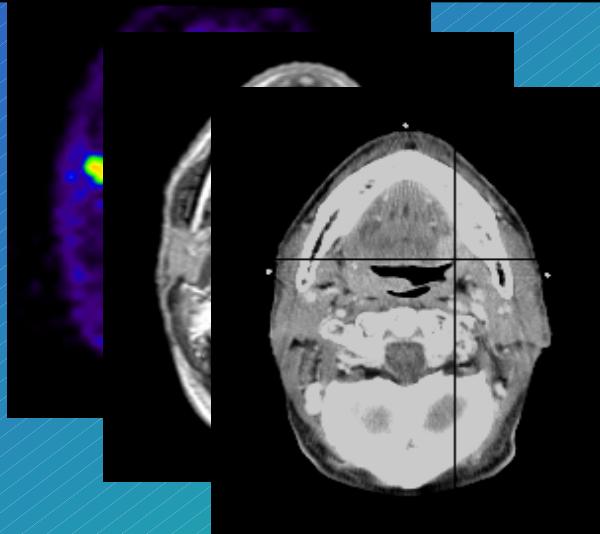
# Imagerie en temps réel



# Assurance de qualité en radiothérapie



# Assurance de qualité en radiothérapie

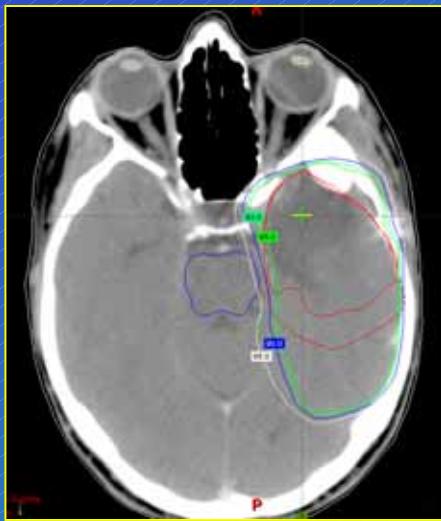


# Nouvelles frontières?

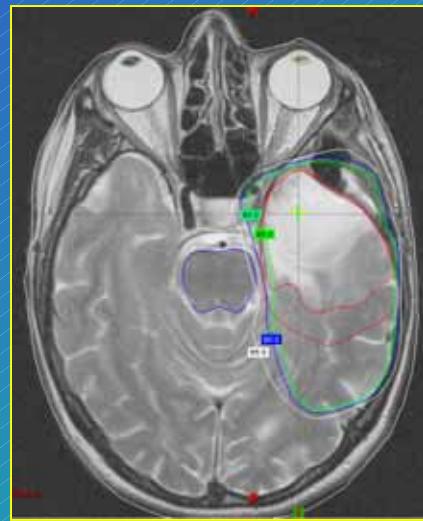


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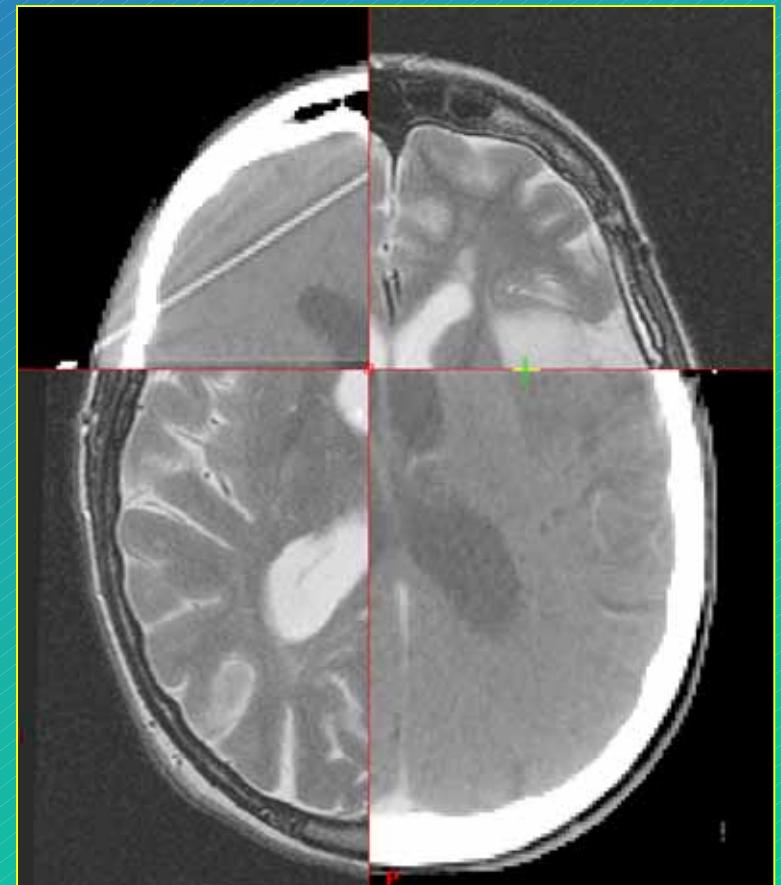
# Fusion RMN-CT-scanner



+



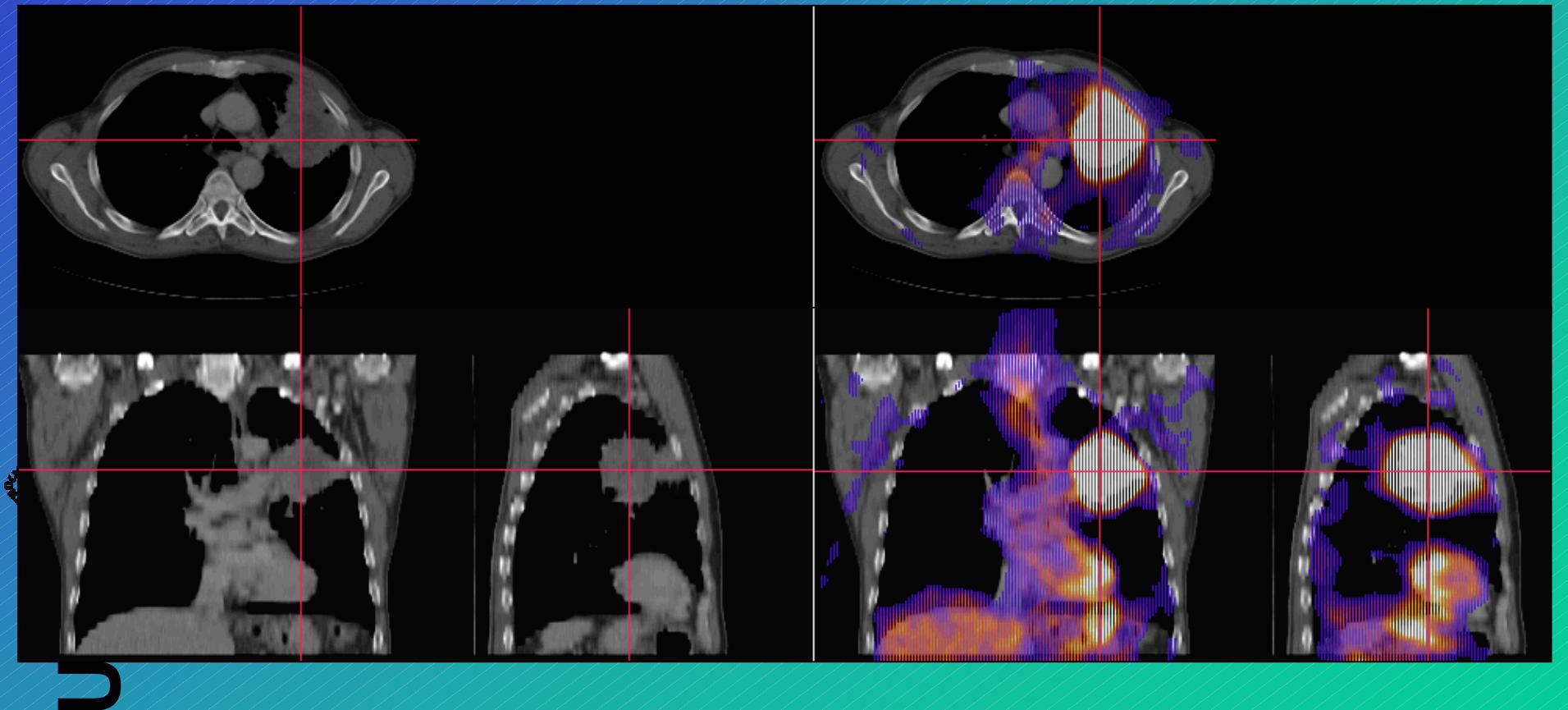
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# Meilleure visualisation ?, meilleure sélection des structures cibles ? Fusion PET-CT: nouvelle imagerie



# What is Particle Therapy (1)

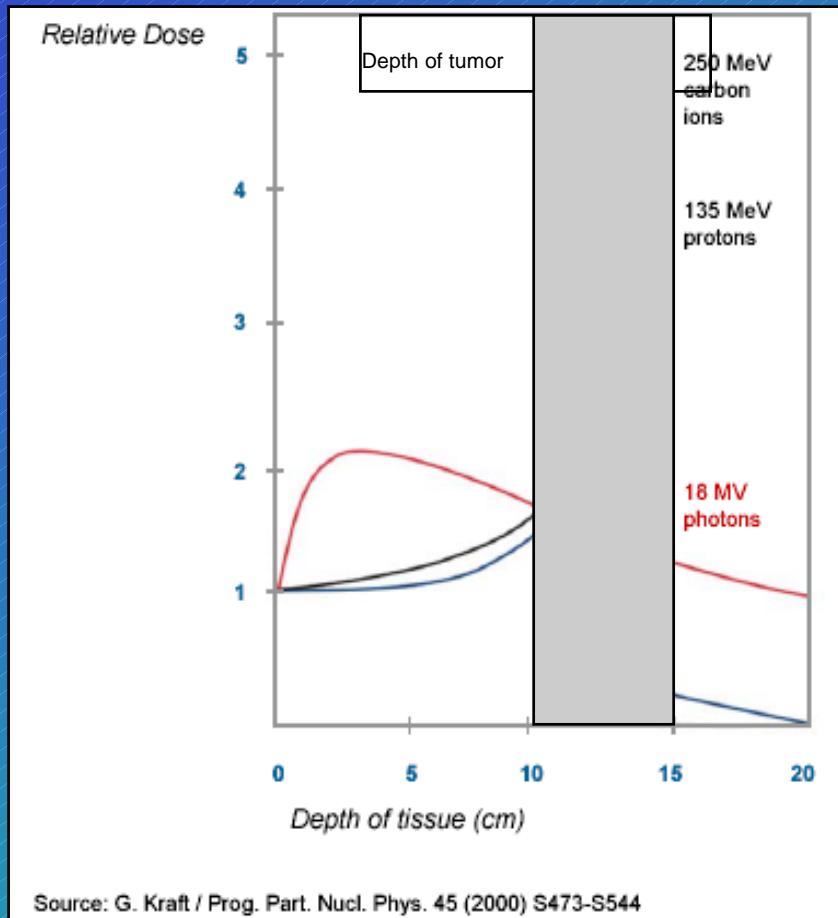
## Bragg Peak

Conventional radiation therapy (RT, IMRT) uses high-energy X-rays (Photons) to destroy tumor cells

- significant tissue interaction in front and behind the tumor

Particle Therapy (PT) uses accelerated atomic particles (carbon ions and protons) to destroy tumor cells

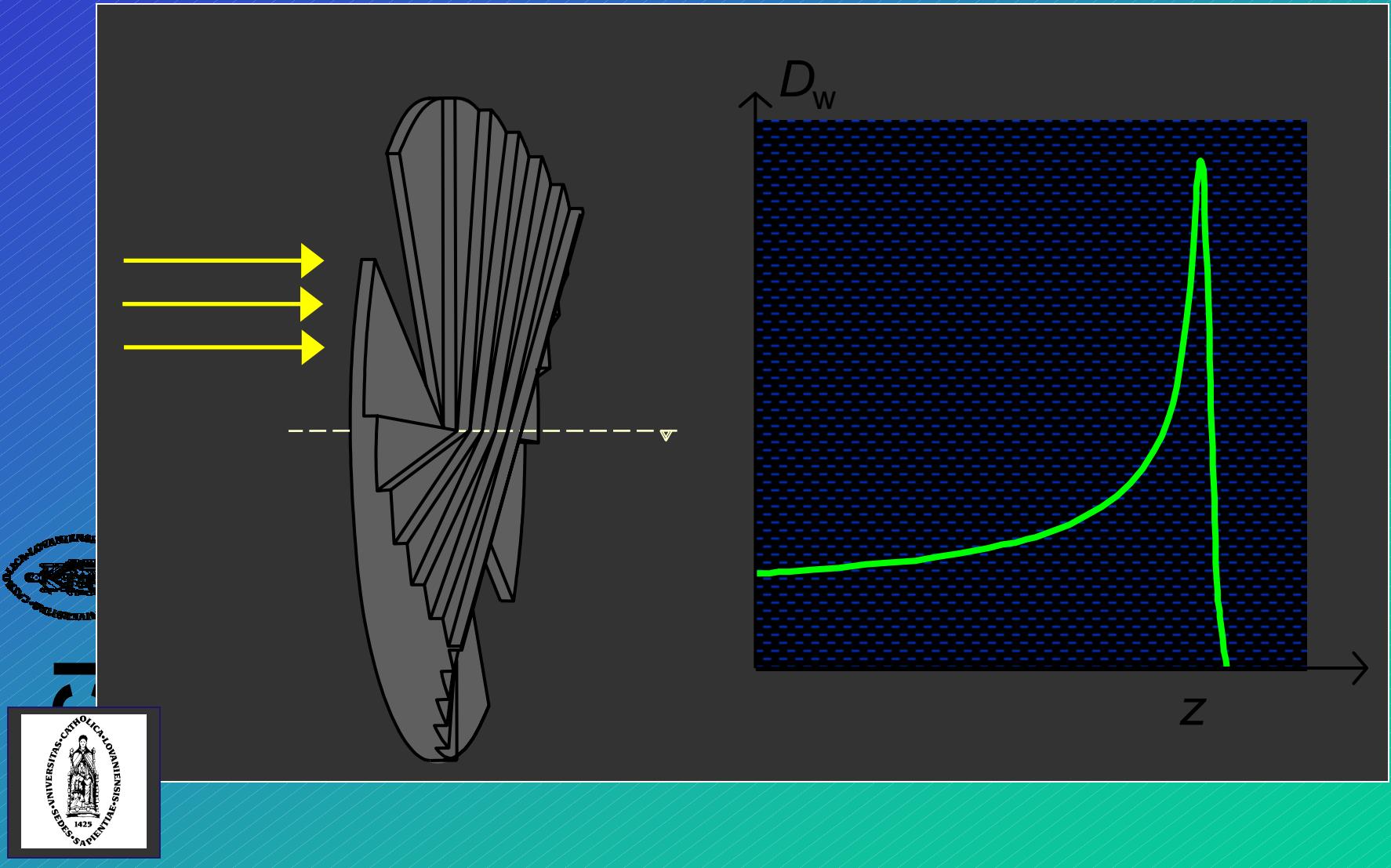
- low tissue interaction in front of the tumor, none / slight tissue interaction behind the tumor



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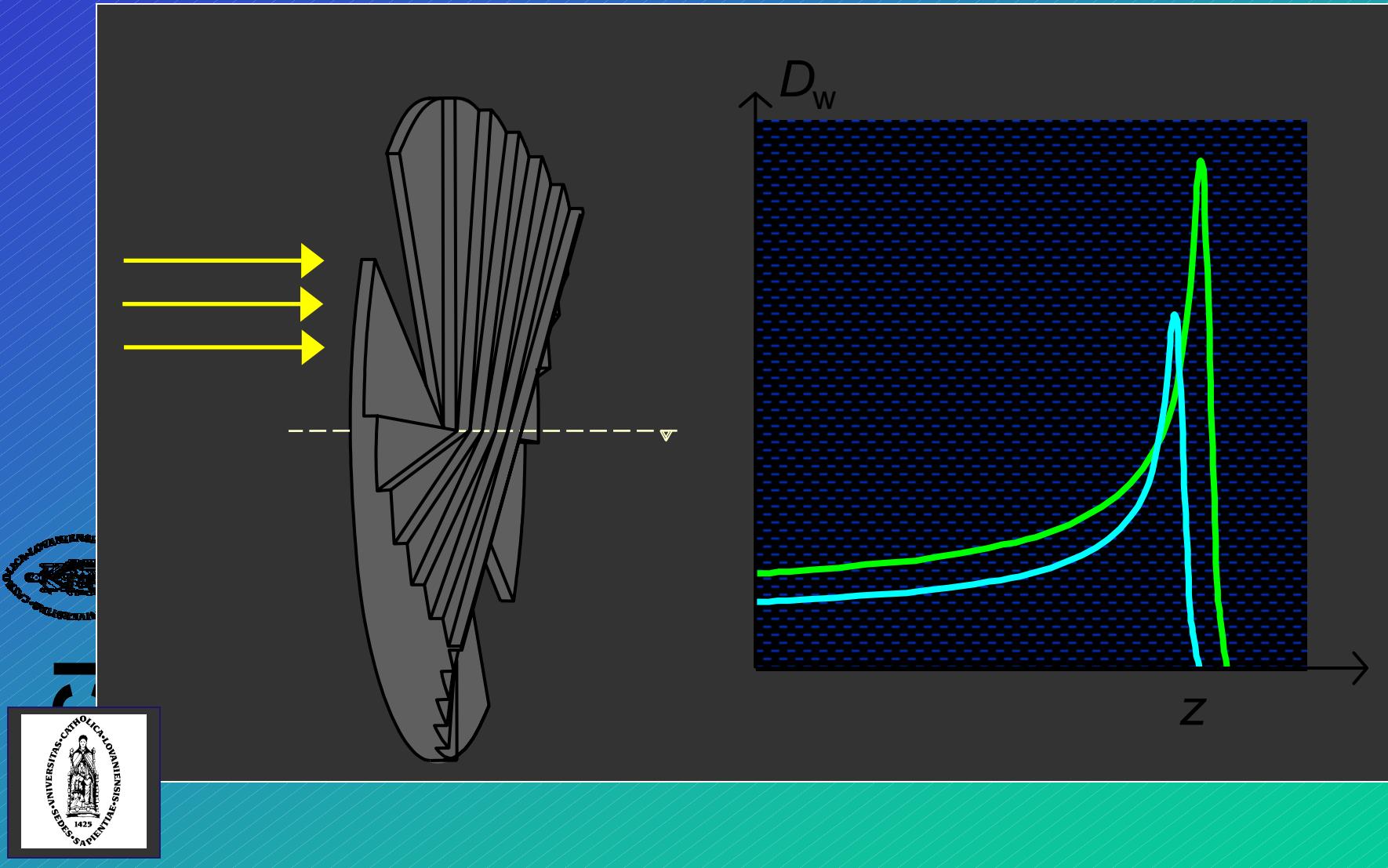
protons

## Range modulation of a clinical proton beam



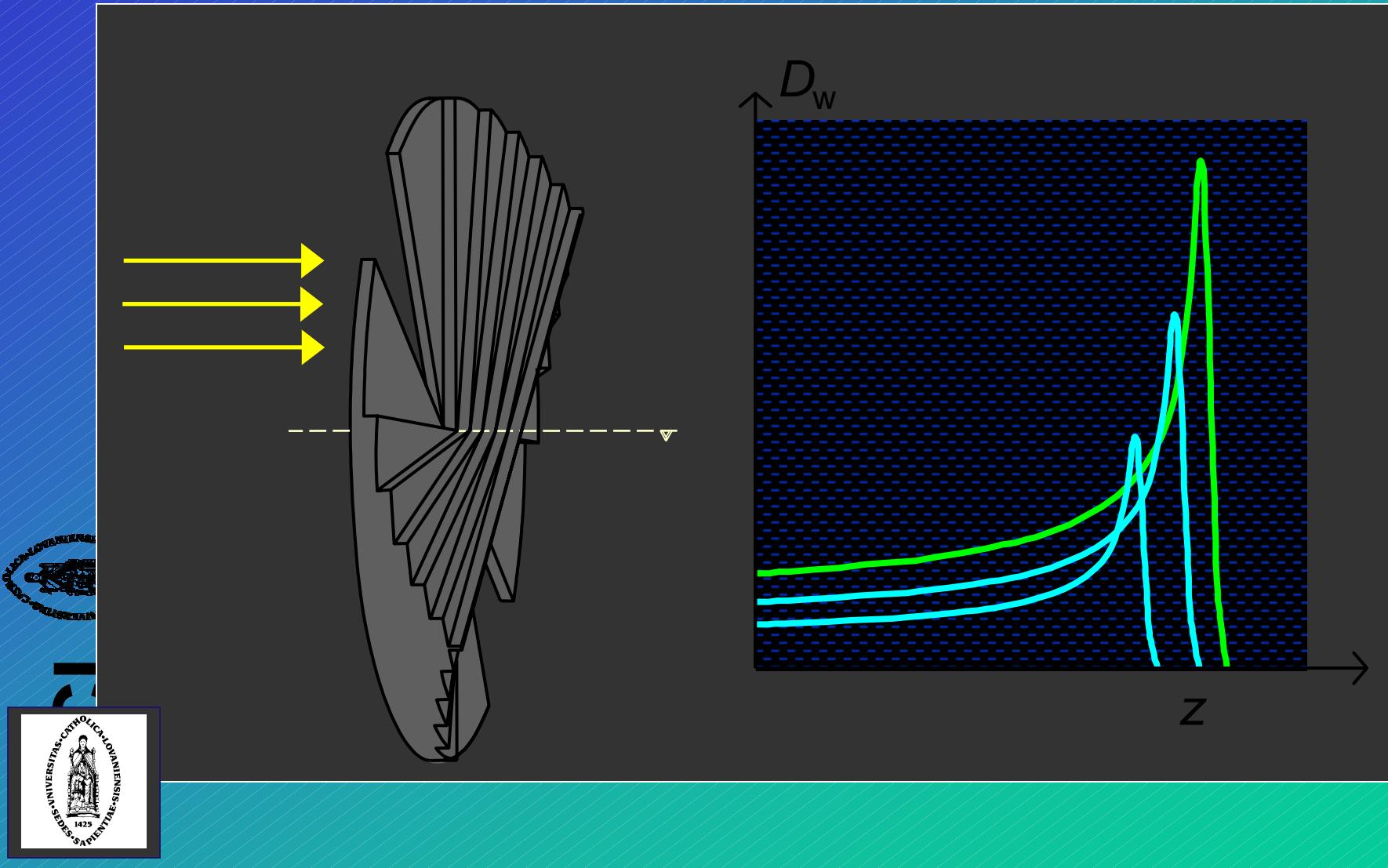
protons

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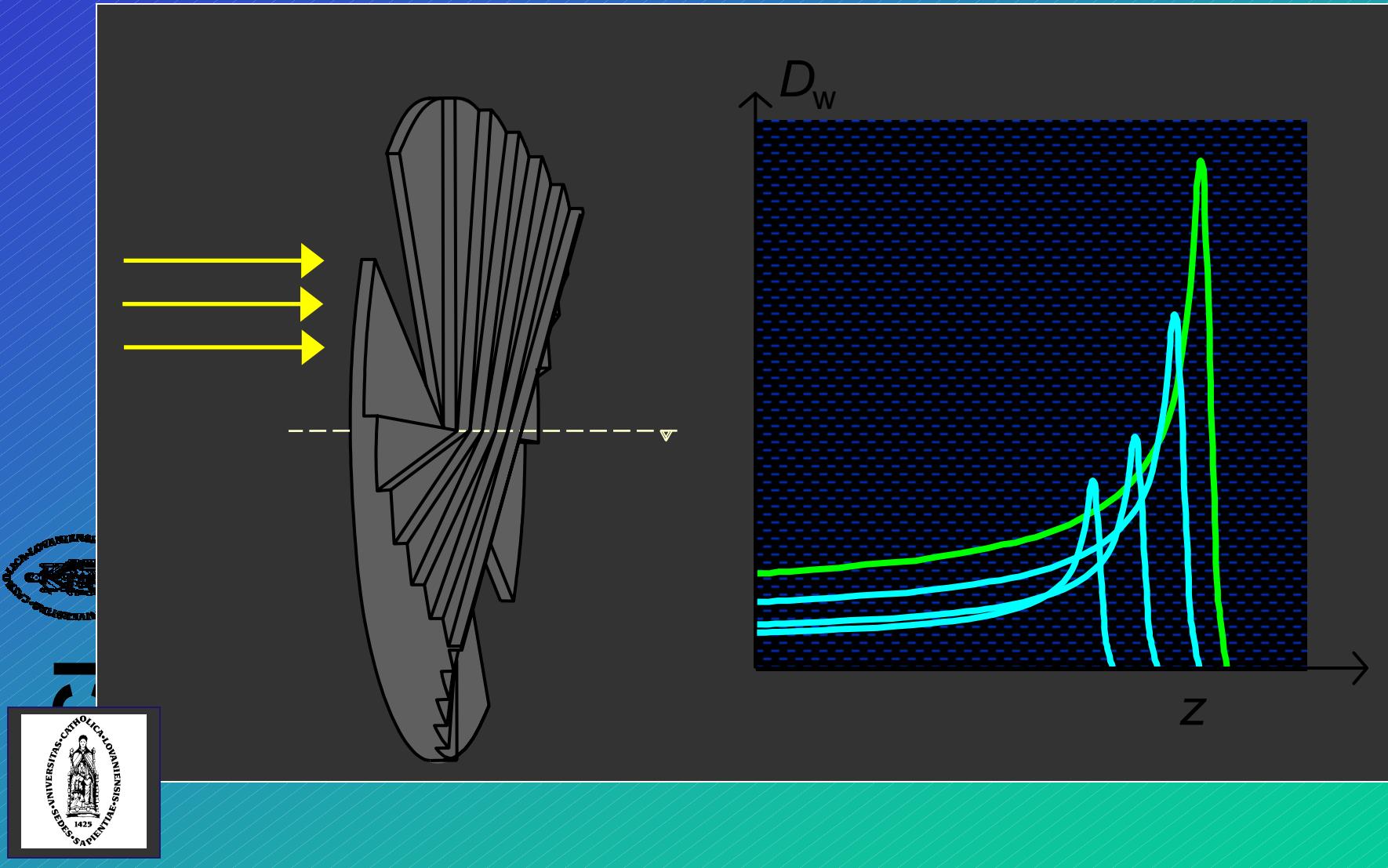
protons

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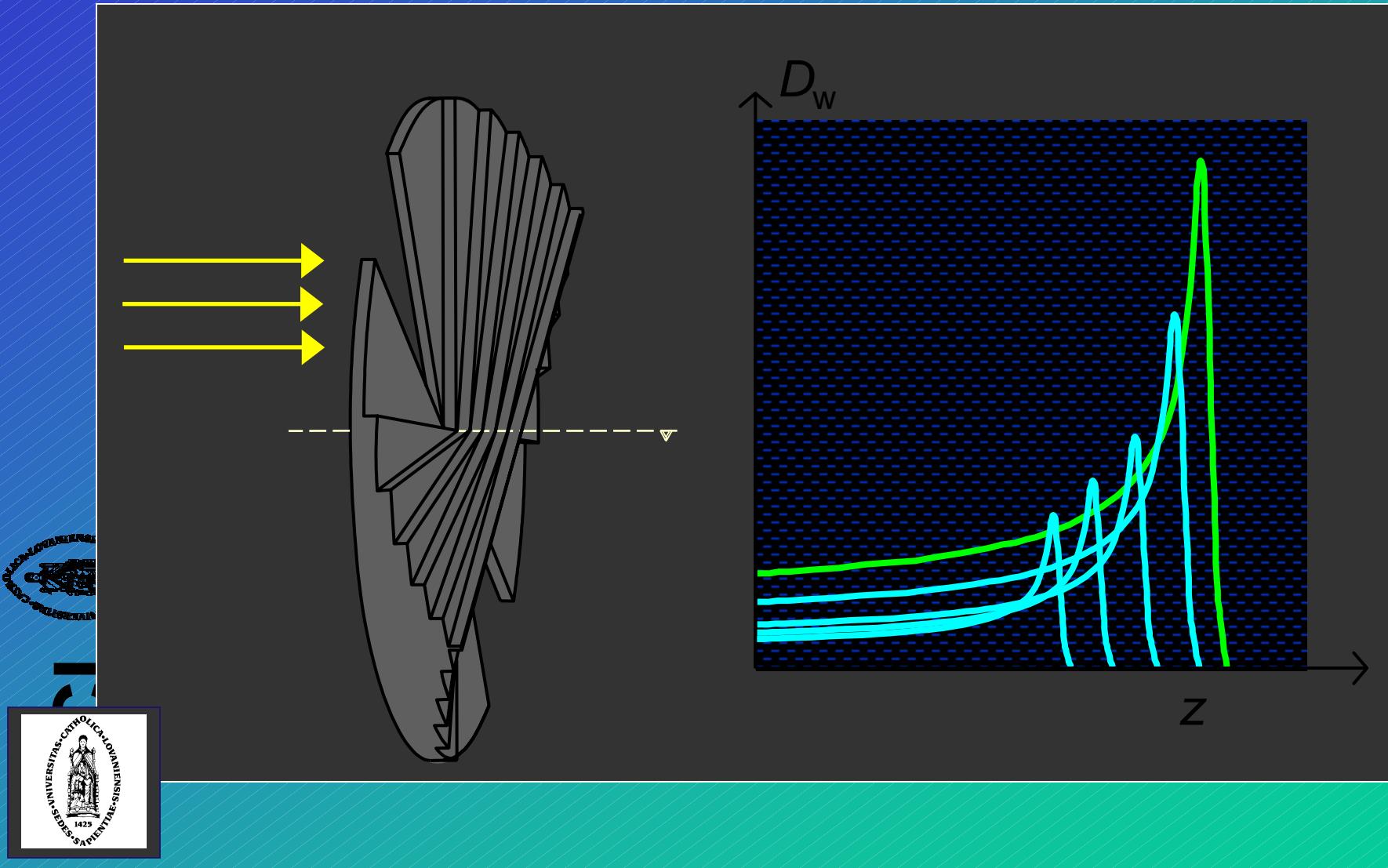
protons

## Range modulation of a clinical proton beam



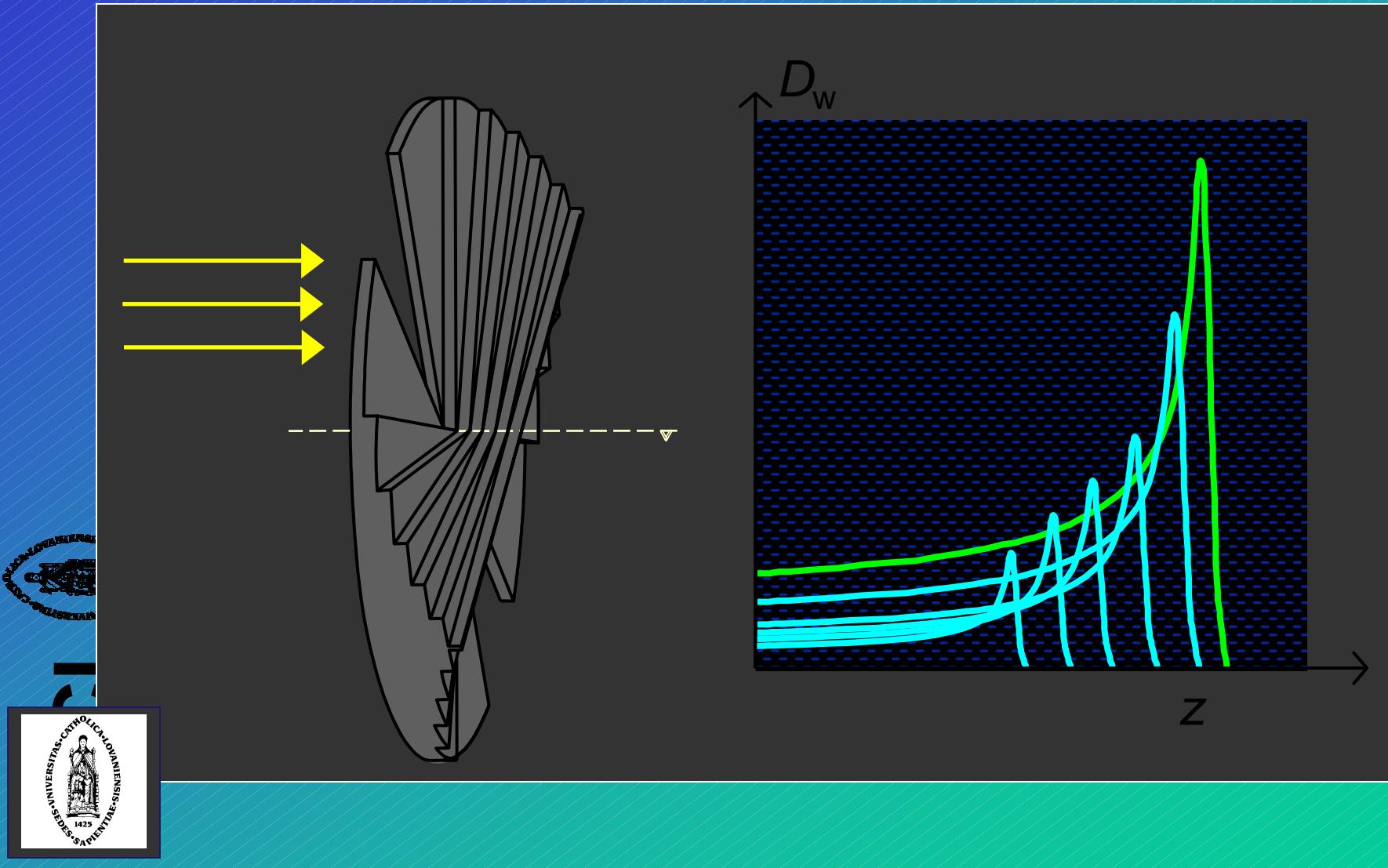
protons

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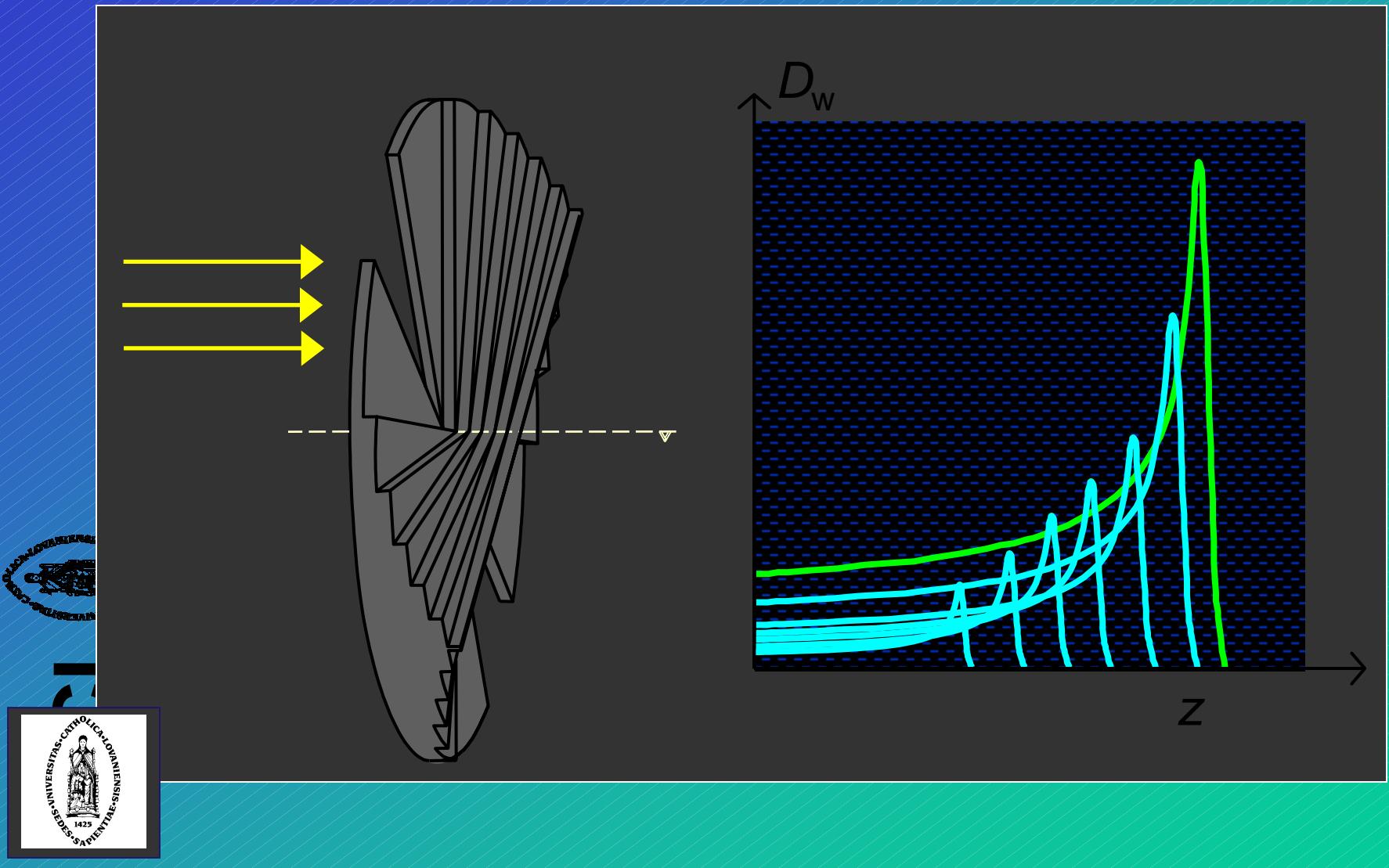
protons

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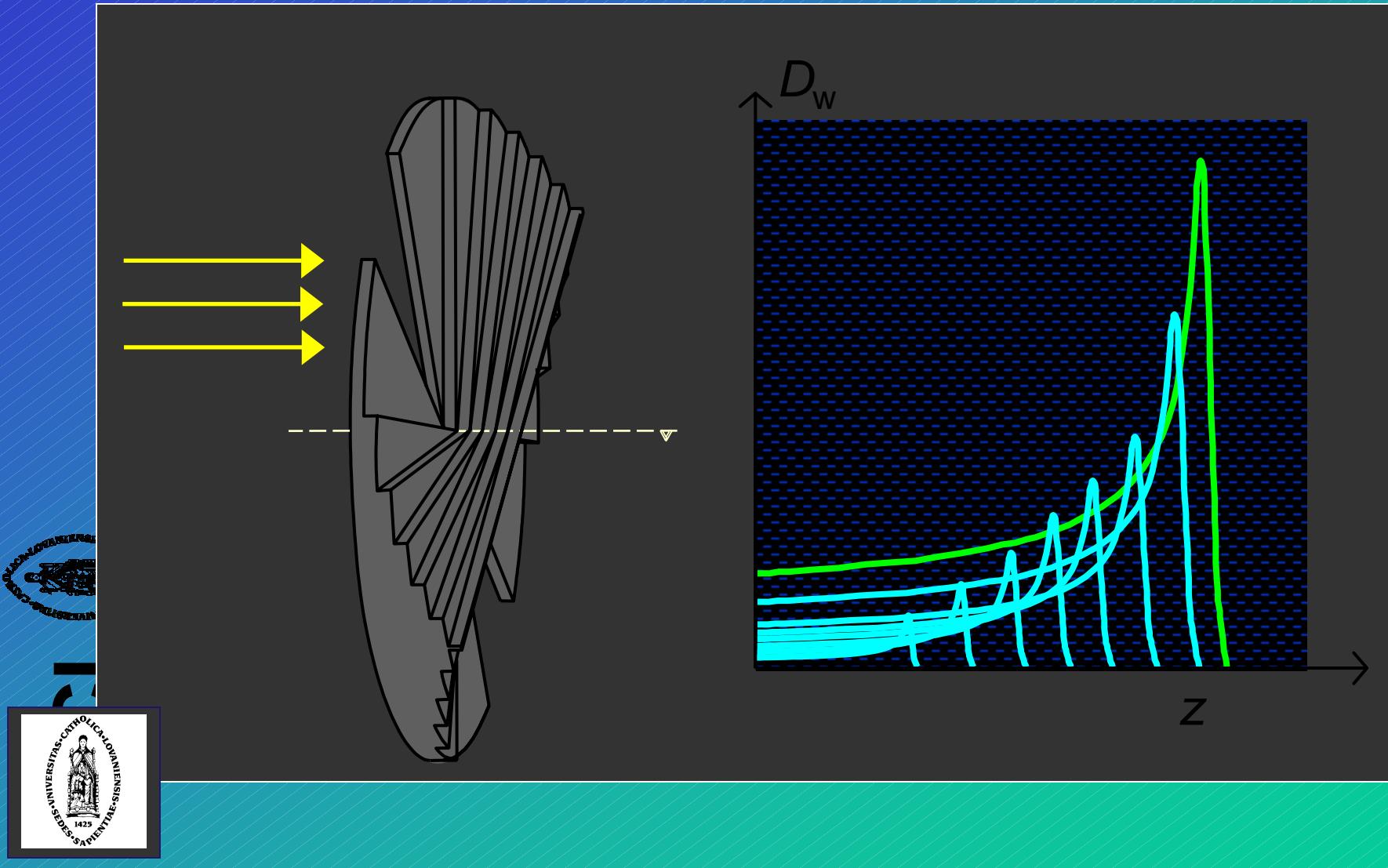
protons

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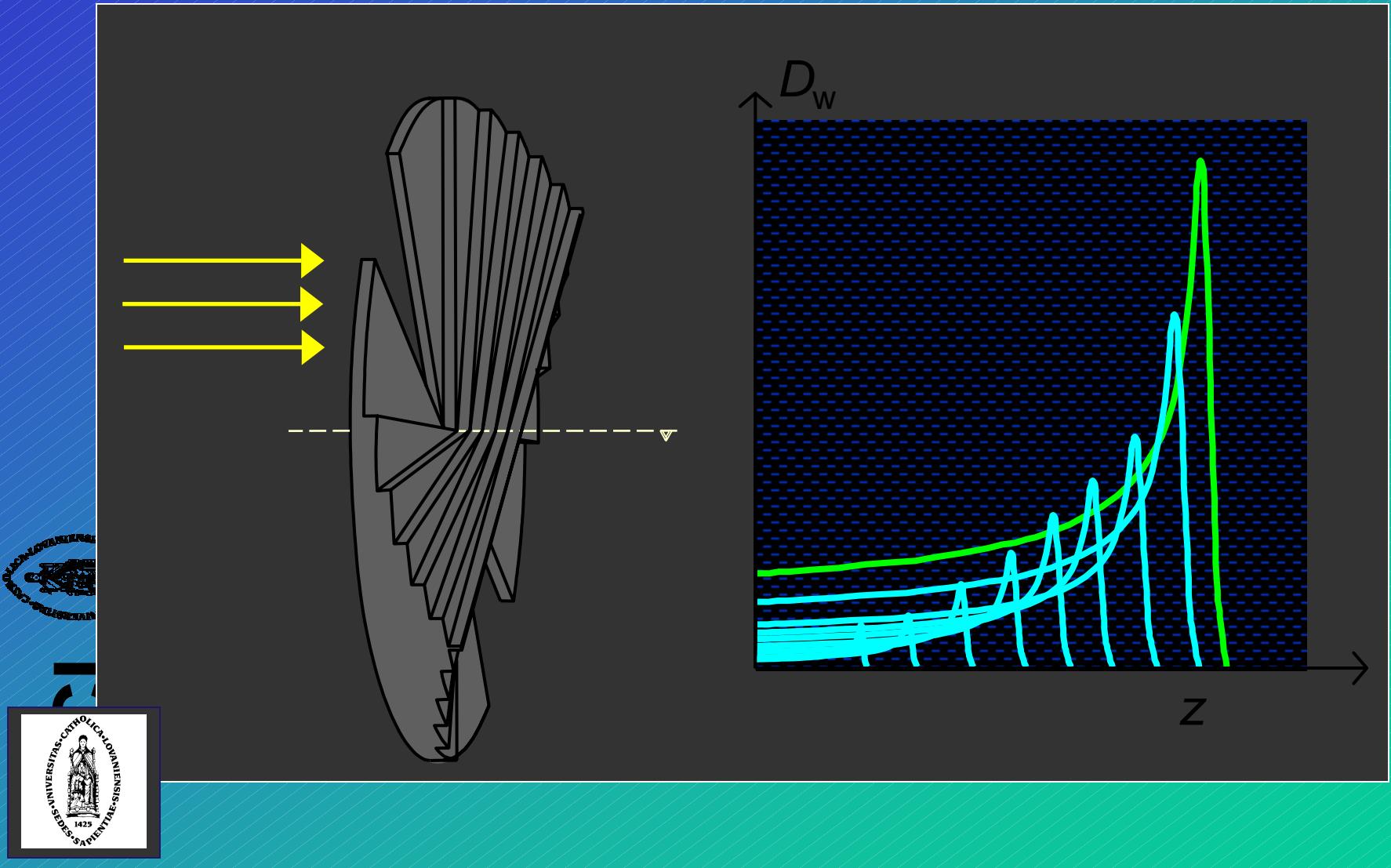
protons

## Range modulation of a clinical proton beam



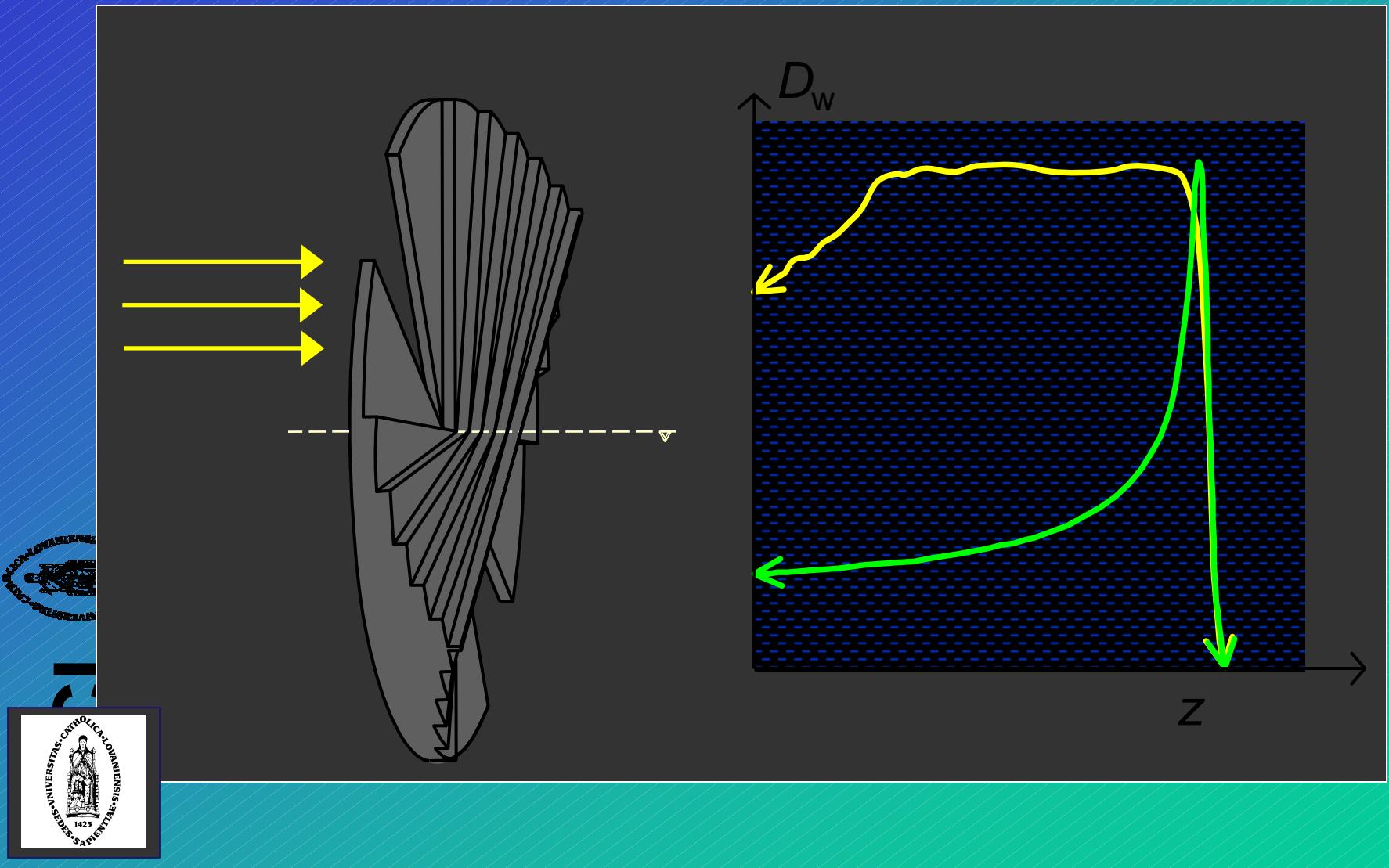
protons

## Range modulation of a clinical proton beam



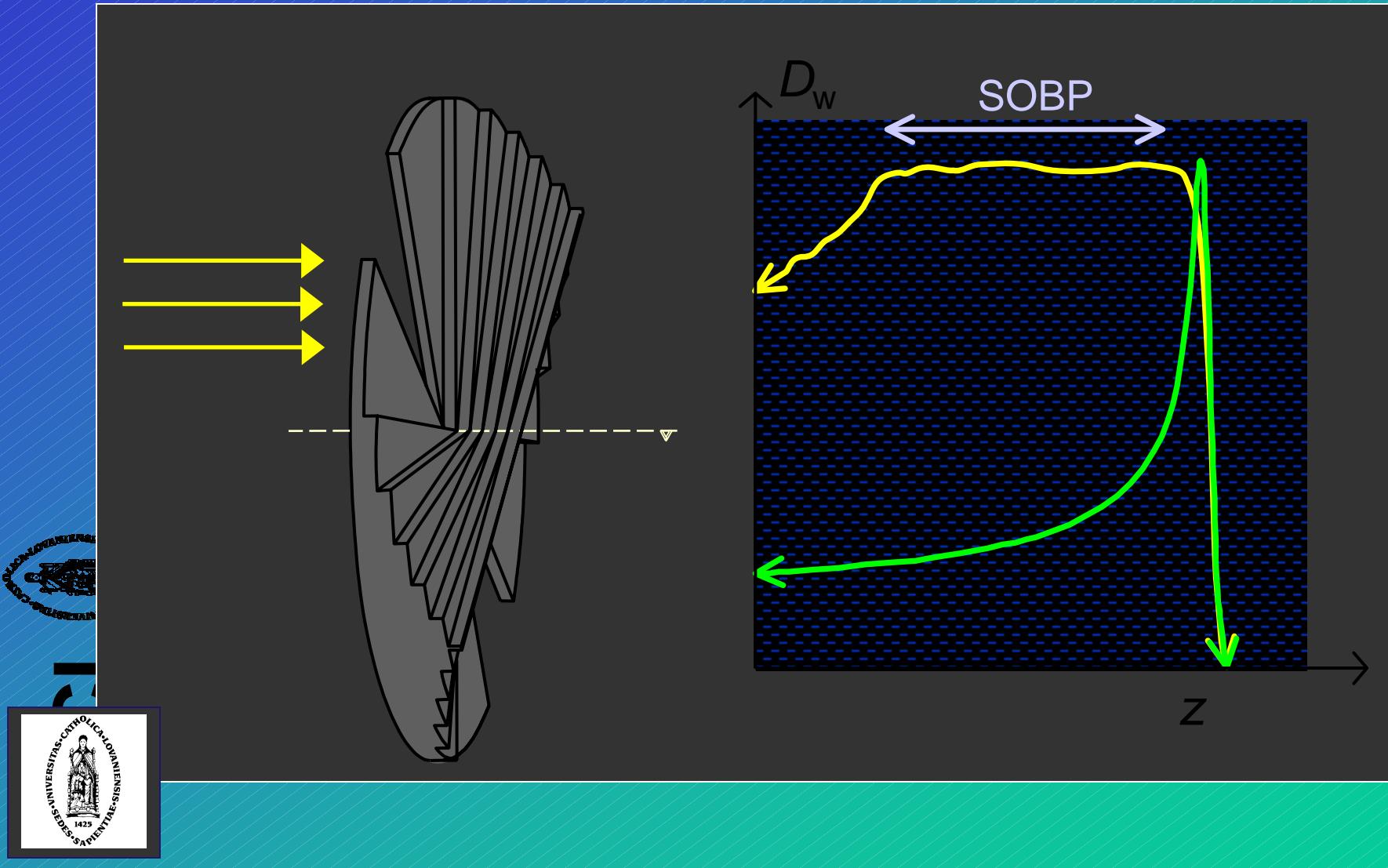
protons

## Range modulation of a clinical proton beam



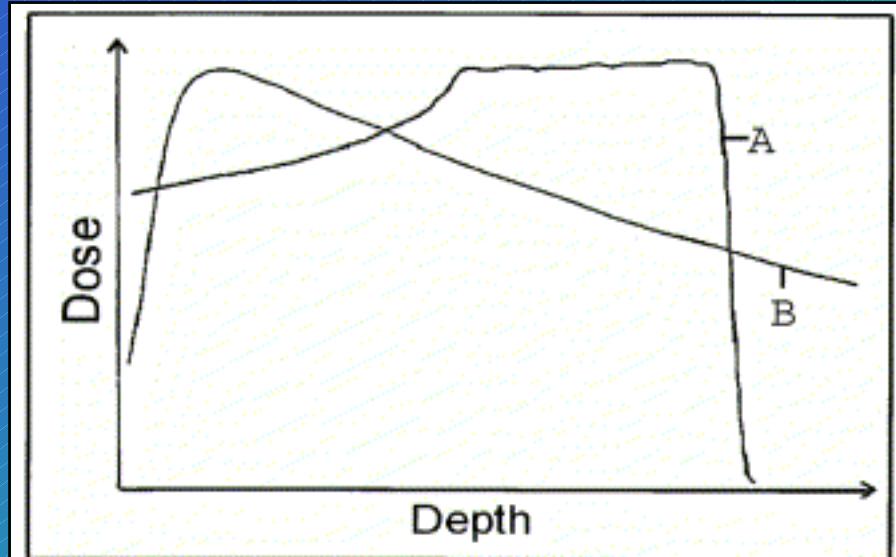
protons

## Range modulation of a clinical proton beam

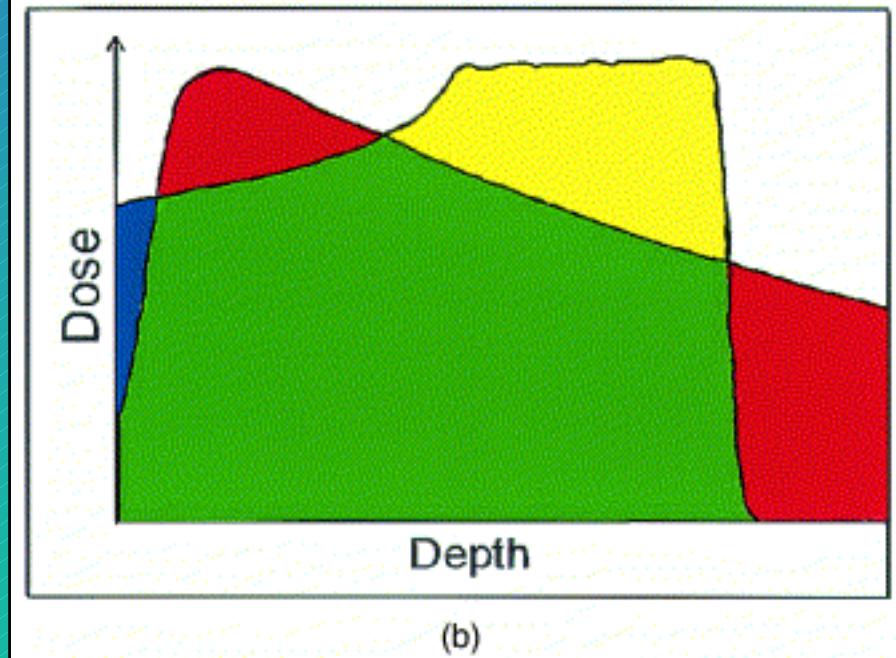




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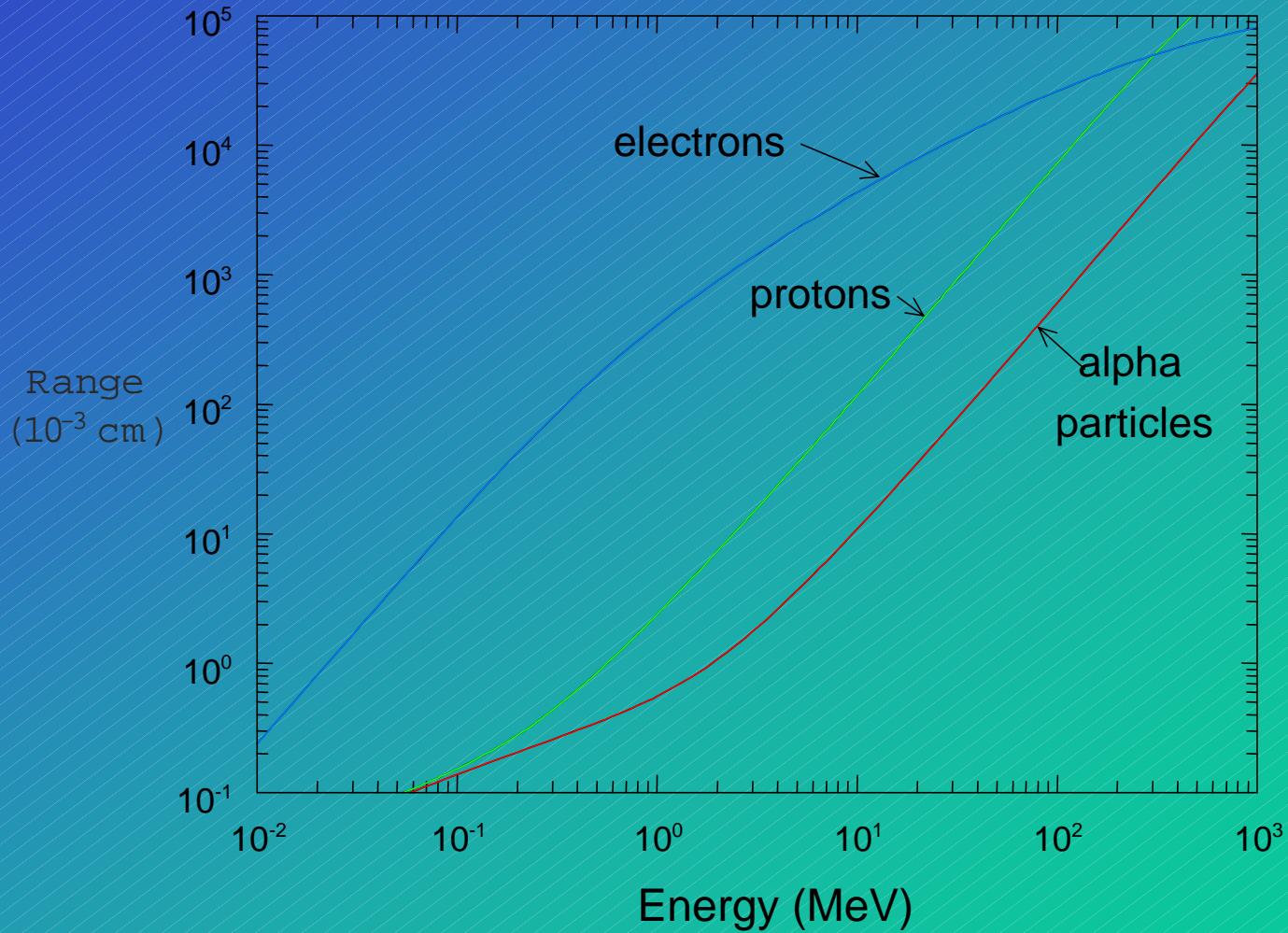
(a)



(b)

protons

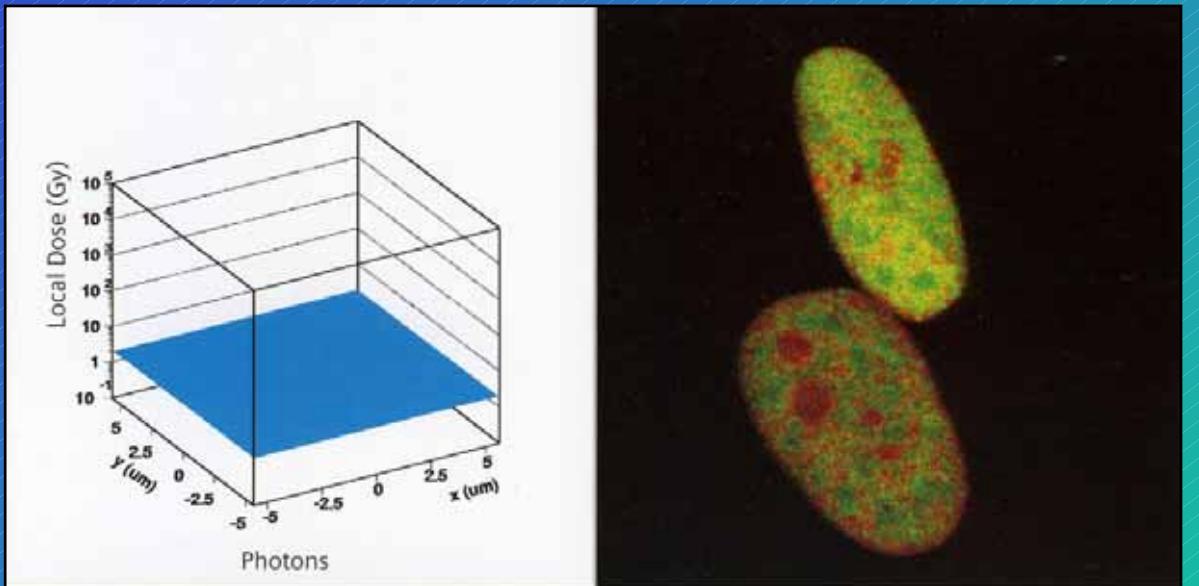
## Range of electrons, protons and a-particles



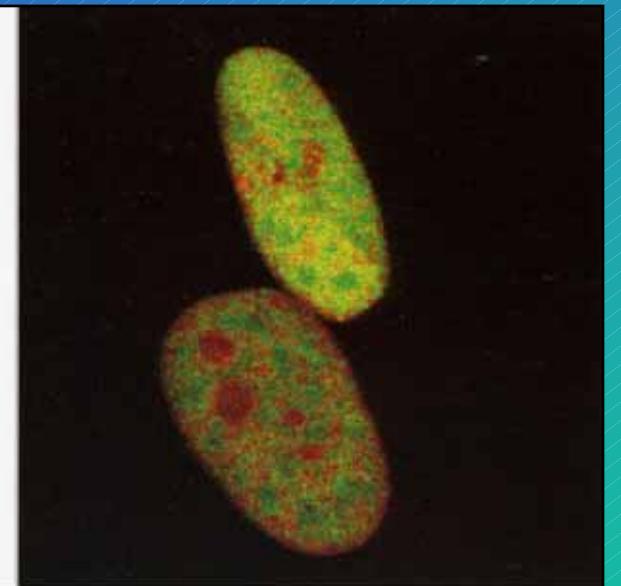
**UCL**



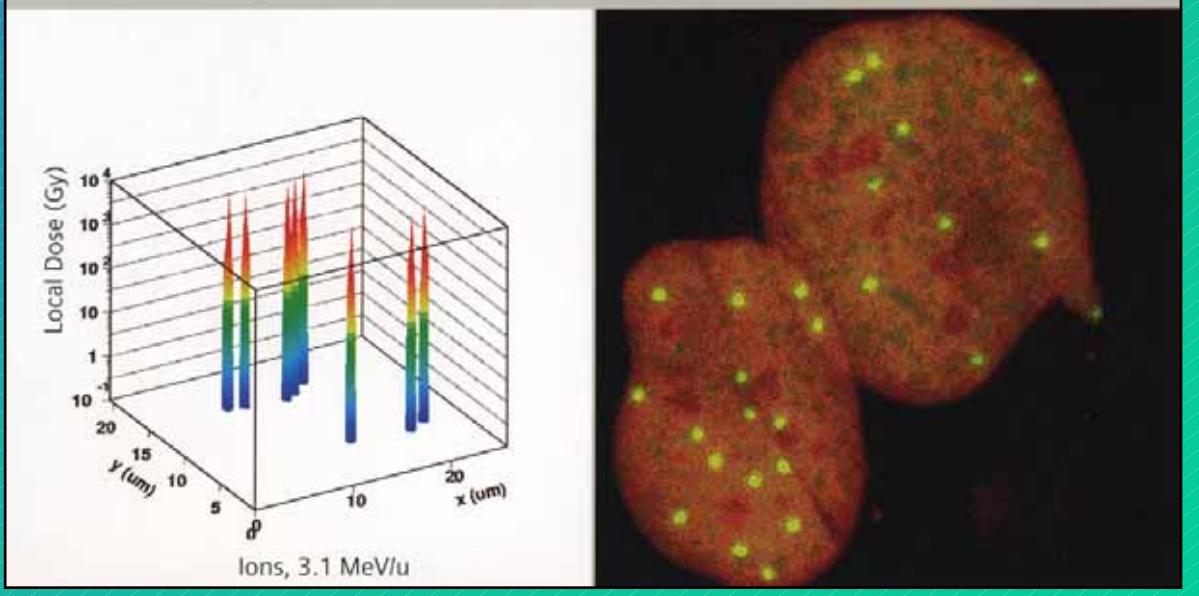
# Induction of repair enzymes with X-rays and carbon ions



The microscopic dose is evenly distributed over the cell nuclei for photons.



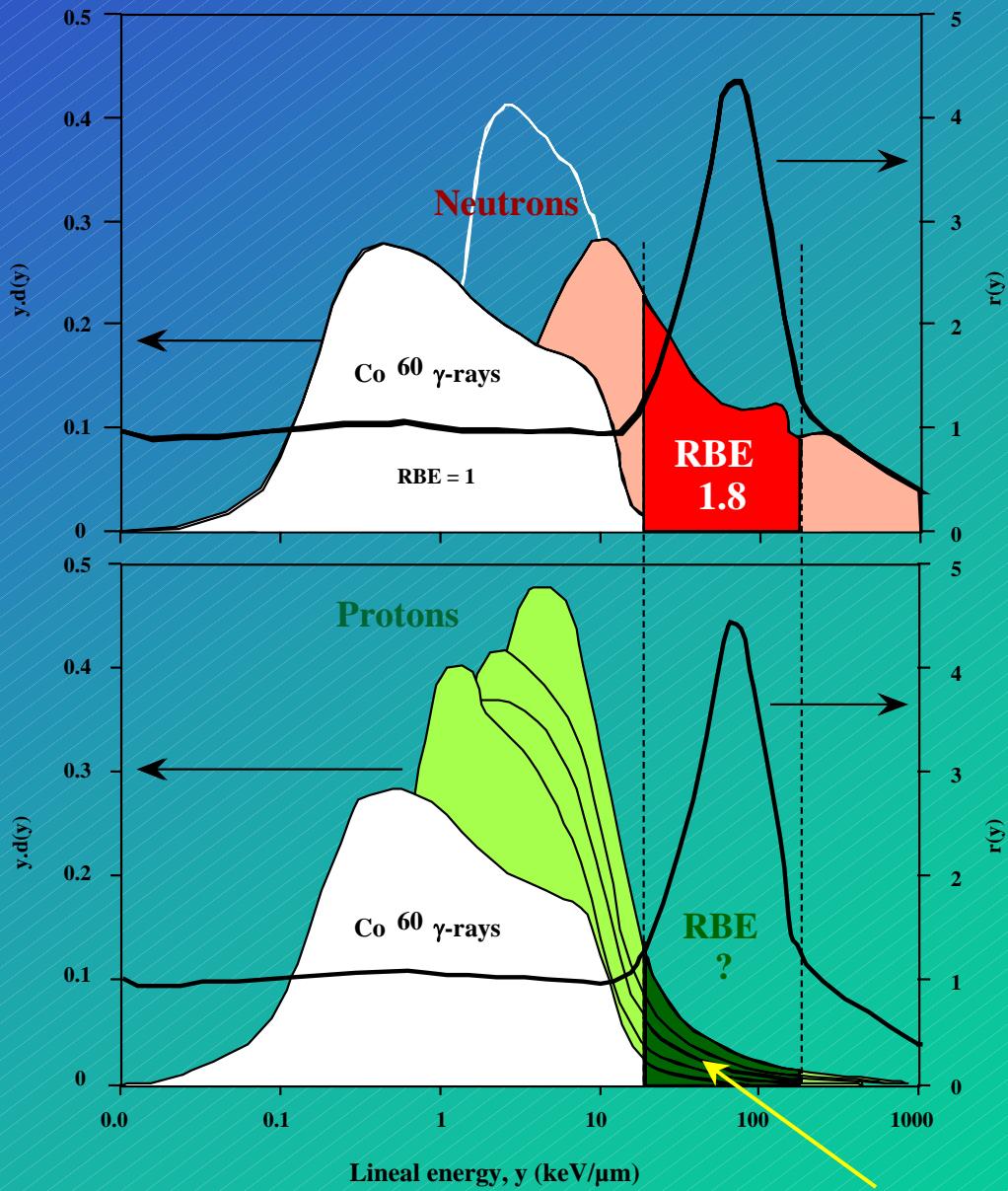
The image shows cell nuclei after X-irradiation. Repair related proteins (yellow color) show up all over the cell nucleus in an immune fluorescent image. Cell repair is normally achieved after half an hour.



Proton beams belong to low-LET radiation, i.e. their biological effectiveness is close to unity, except in the peak where most energy is deposited.



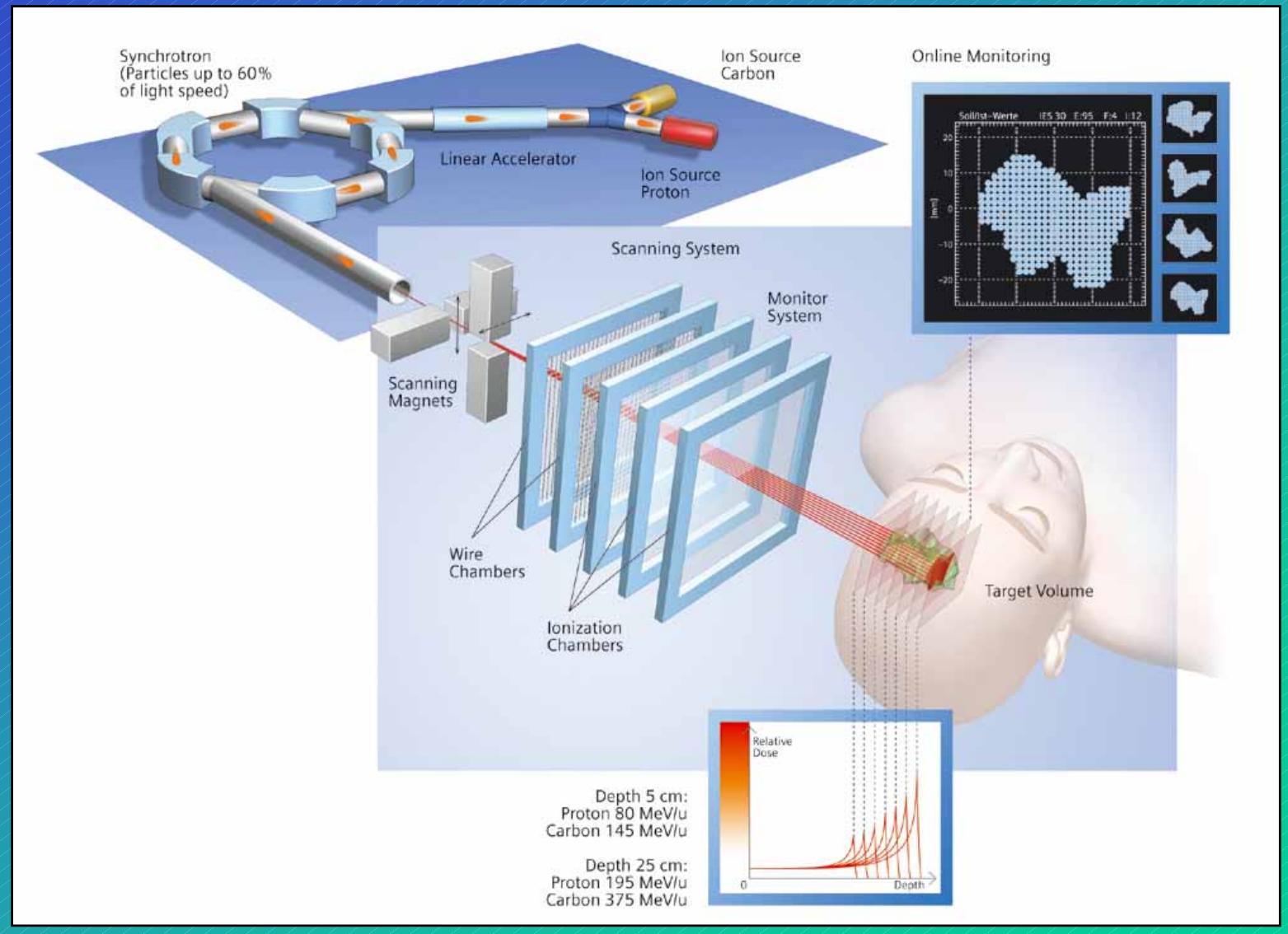
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"heavy" energy deposits in the peak



# What is carbon ion therapy



## Clinical Applications Carbon treatment of para-aorta Lymphnode (Morbus Hodgkin phase IIB)

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### Organ dose

**40 Gy**

**39 Gy**

**41 Gy**

**Bone marrow**

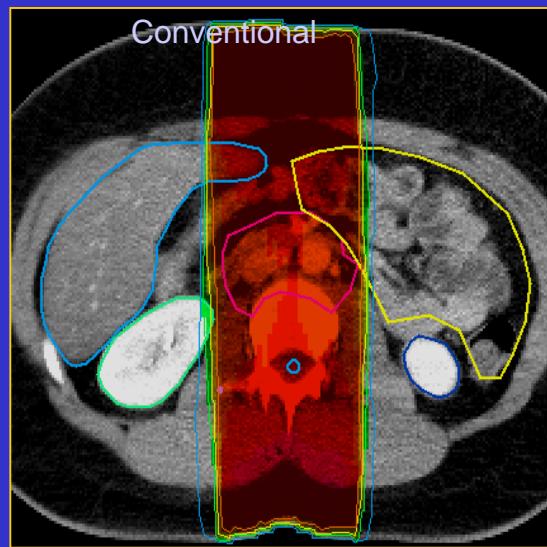
**< 1 Gy**

**Intestinal**

**26 Gy**

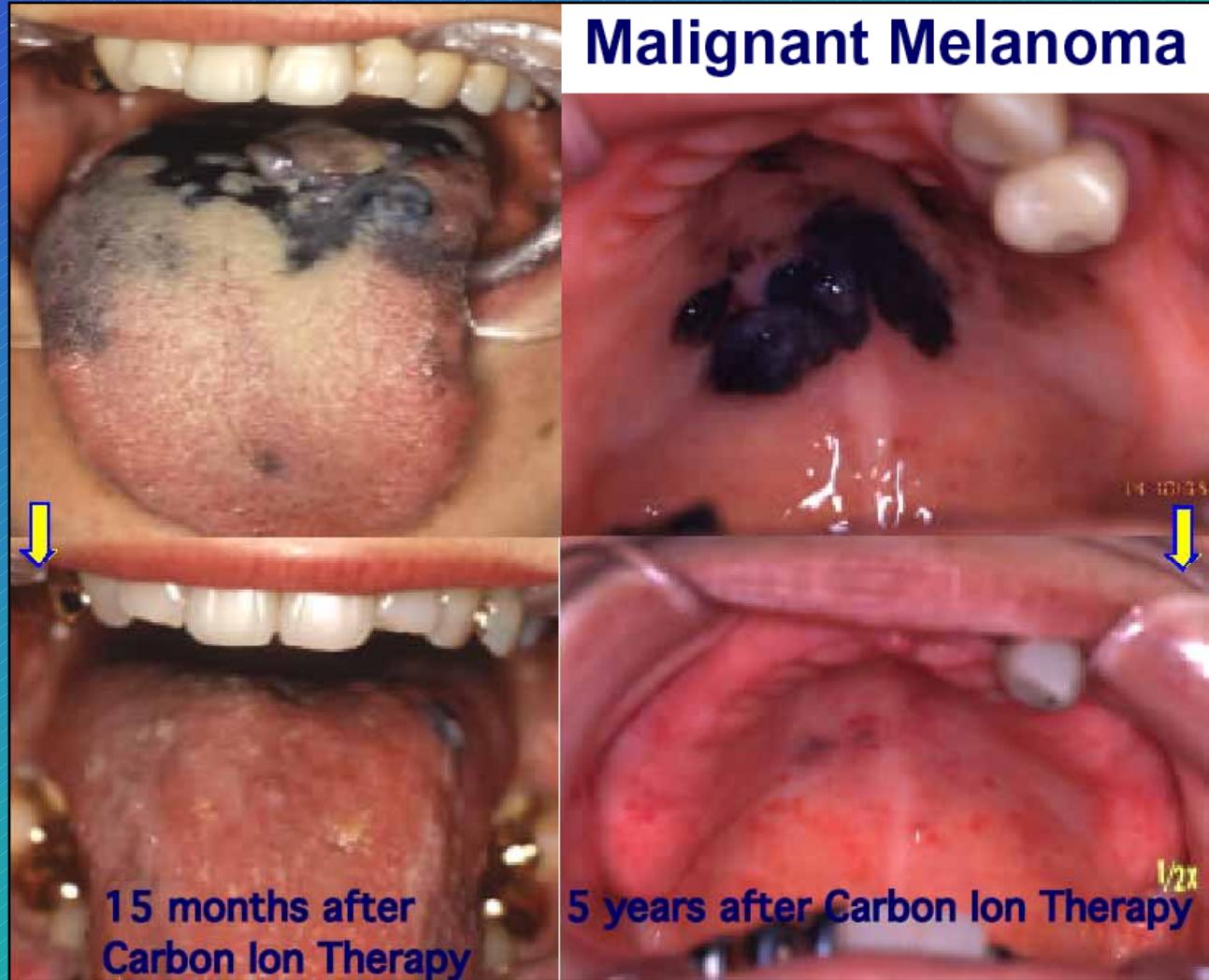
**Spine**

**< 1 Gy**



*Courtesy of Prof. Debus, University Clinic of Heidelberg*

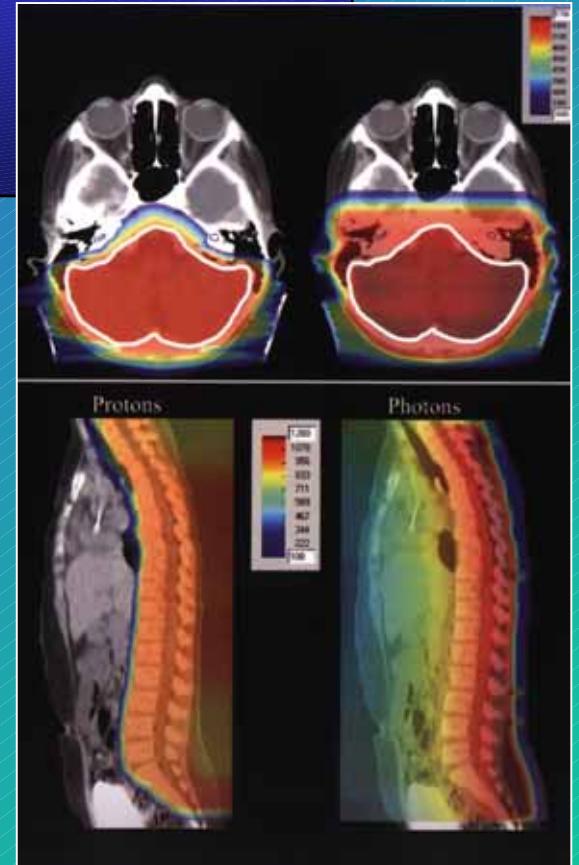
# Treatment with carbon ions in Chiba



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# Main indication: pediatric oncology

	2000	2001	2003
leukemia	85	108	90
lymphoma	39	43	34
Embryonal tumours	52	54	63
CNS	94	68	65
Bone	15	18	24
STS	35	34	35
<b>total</b>	<b>320</b>	<b>325</b>	<b>313</b>



Medulloblastoma in a  
5-year old child  
4 MV photons vs. protons

Potential recruitment in Belgium around  
100 case/year according to current  
practice



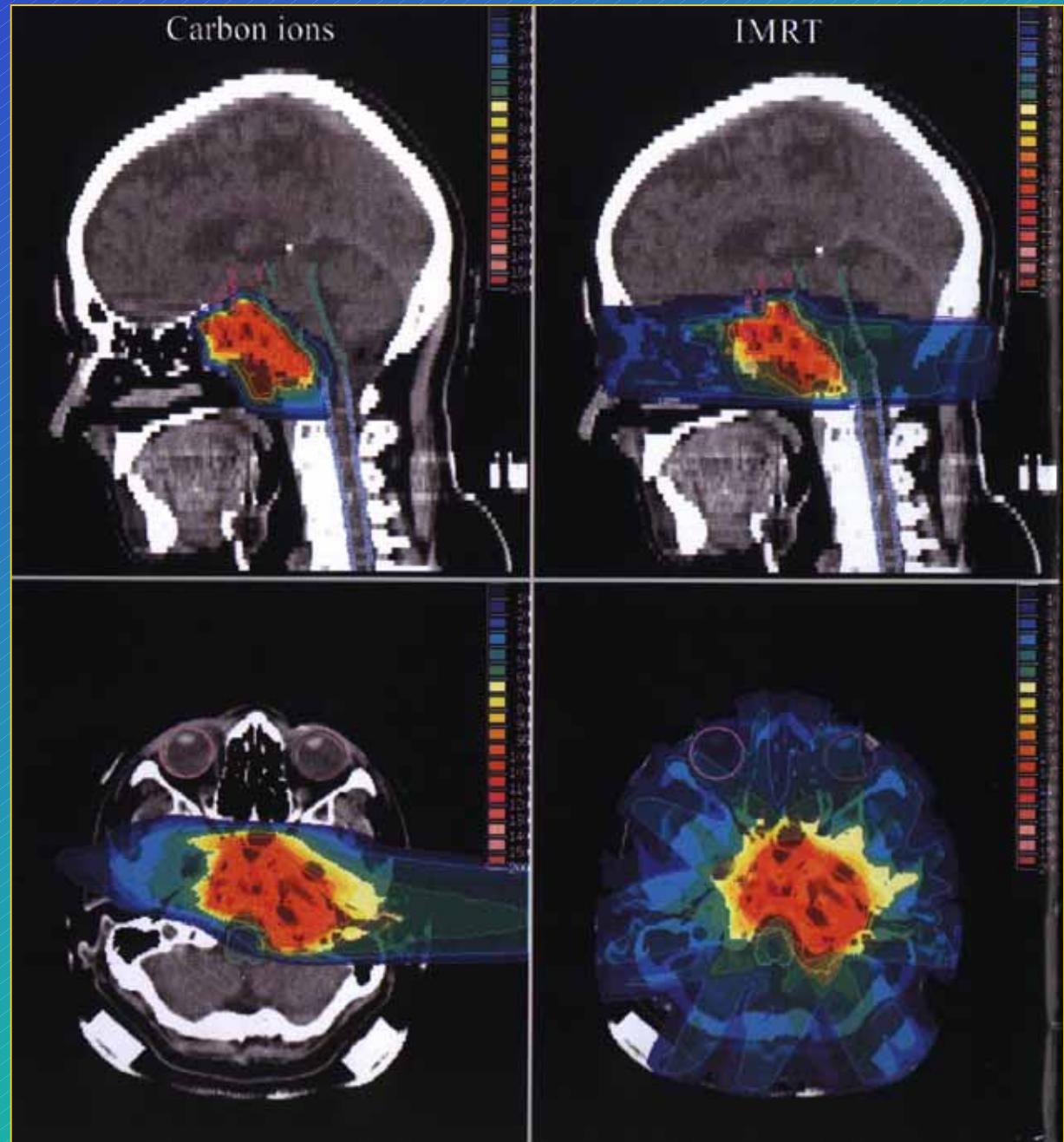
**UCL**

Carbon ions :  
improved  
penumbra

Chondrosarcoma  
of the left petrous  
bone



UCL

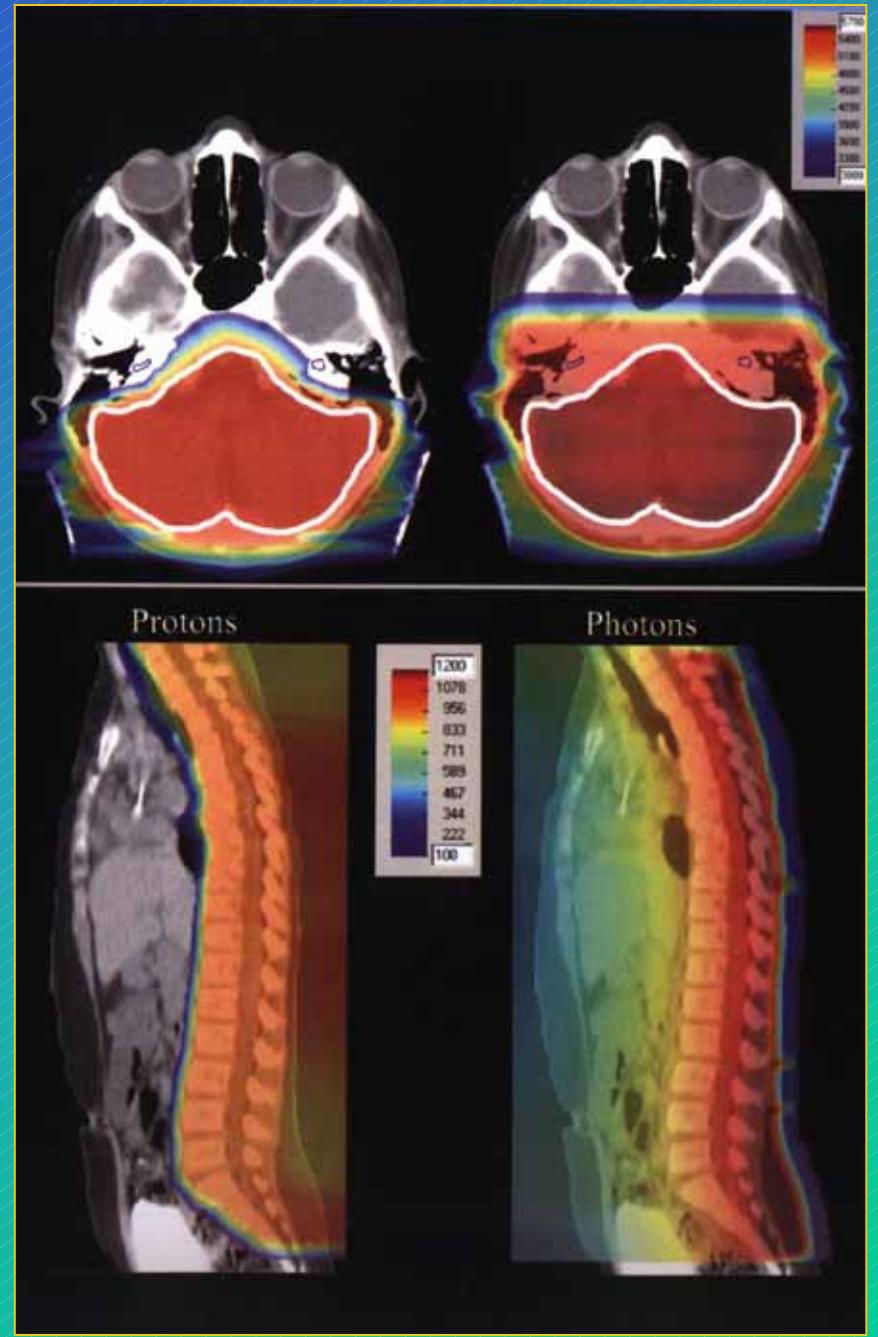


# Main indication: pediatric oncology

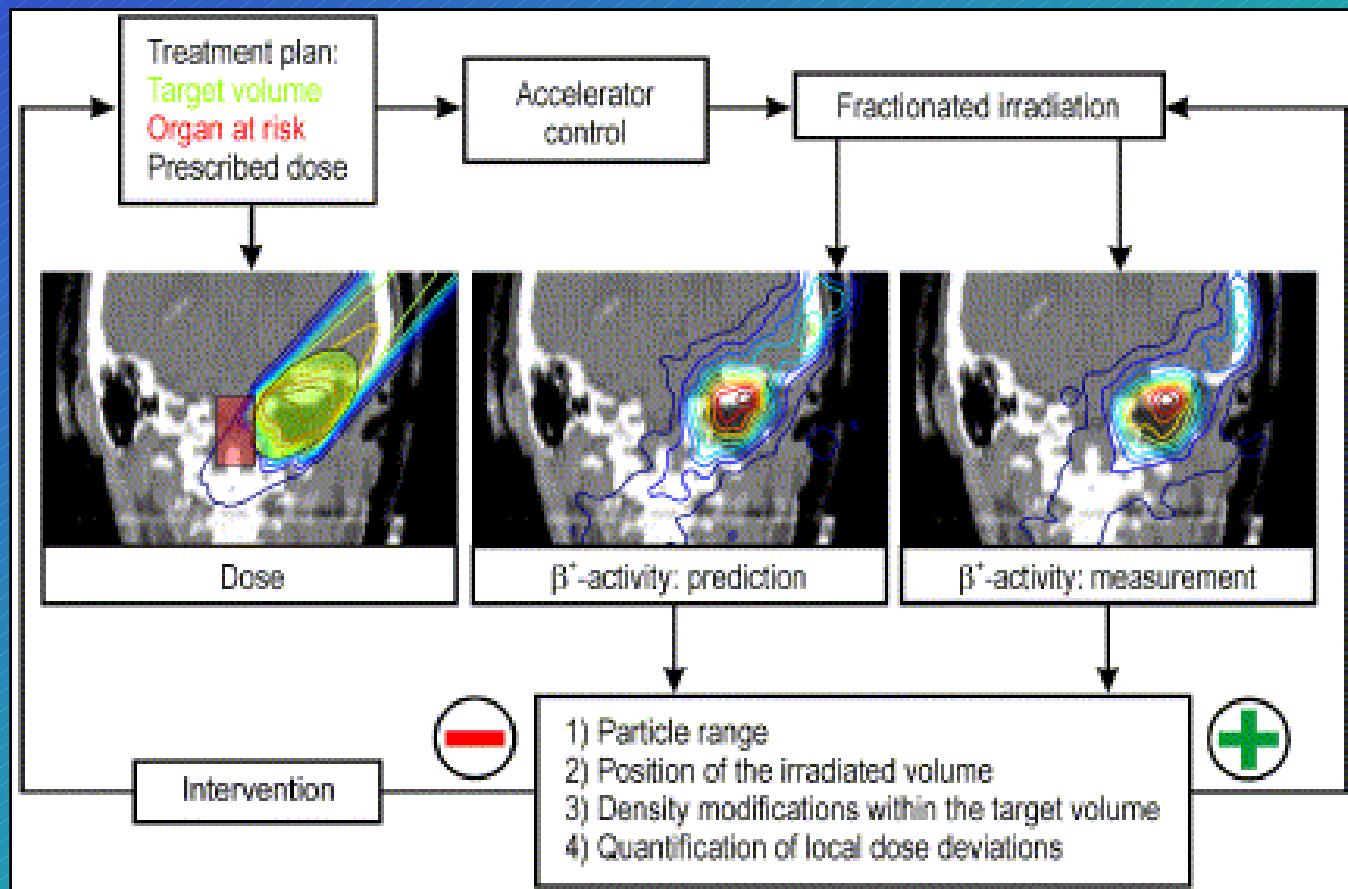
Medulloblastoma in  
a 5-year old child  
4 MV photons vs.  
protons



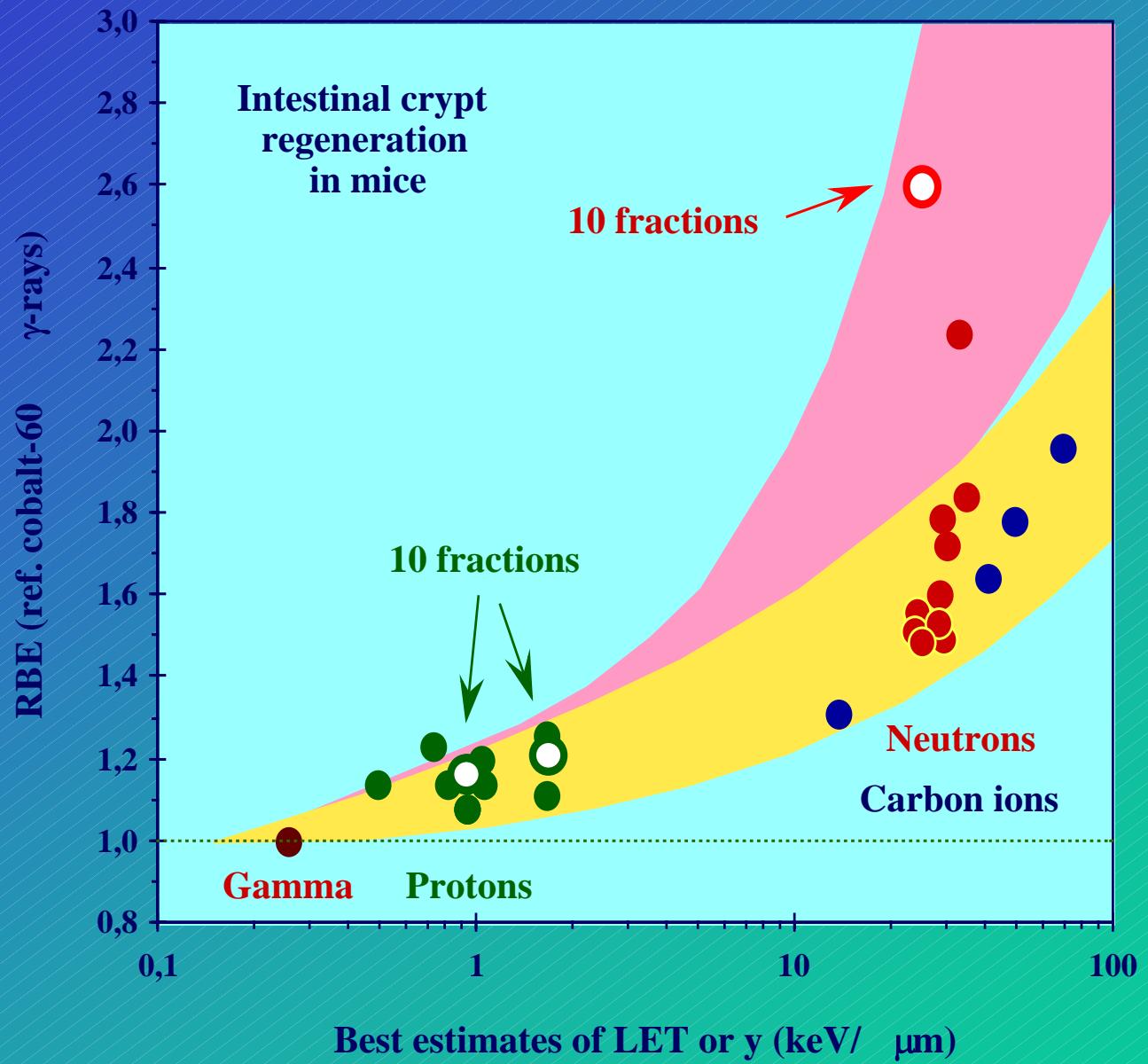
UCL



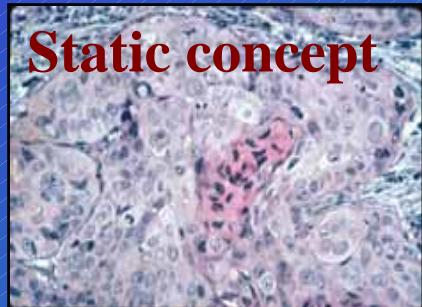
# Carbon ion treatment validation with *in vivo* PET imaging



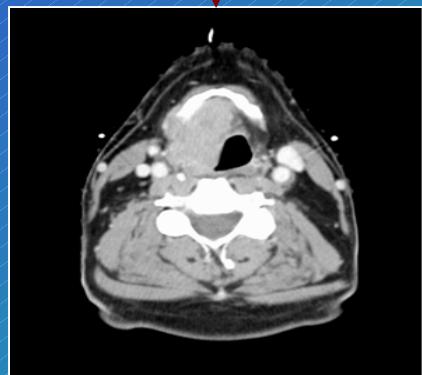
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# From static RT to dynamic RT...



QuickTime™ et un décompresseur Cinepak sont requis pour visionner cette image.

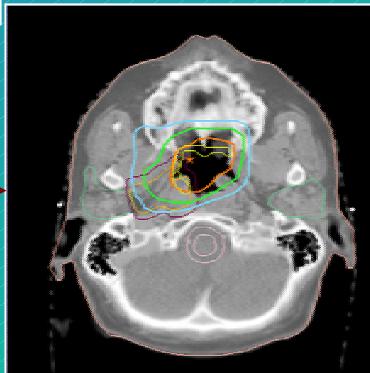


Dynamic concept

QuickTime™ et un décompresseur Cinepak sont requis pour visionner cette image.

Static R/

Adaptive R/



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# Radiothérapie adaptative

- ... quid pendant le traitement ?

[M. Tomsei](#)

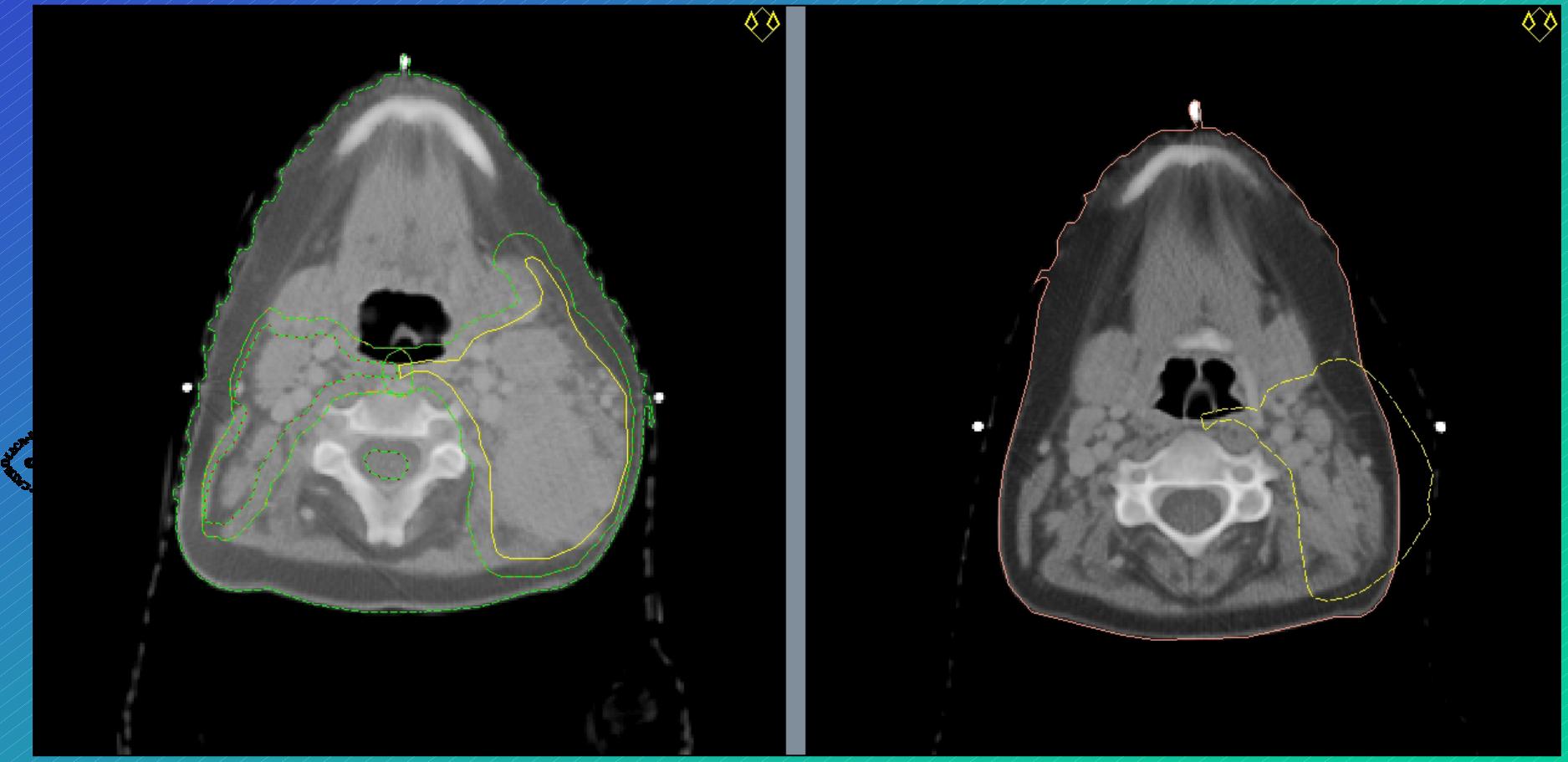


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# Radiothérapie adaptative

- ... quid pendant le traitement ?

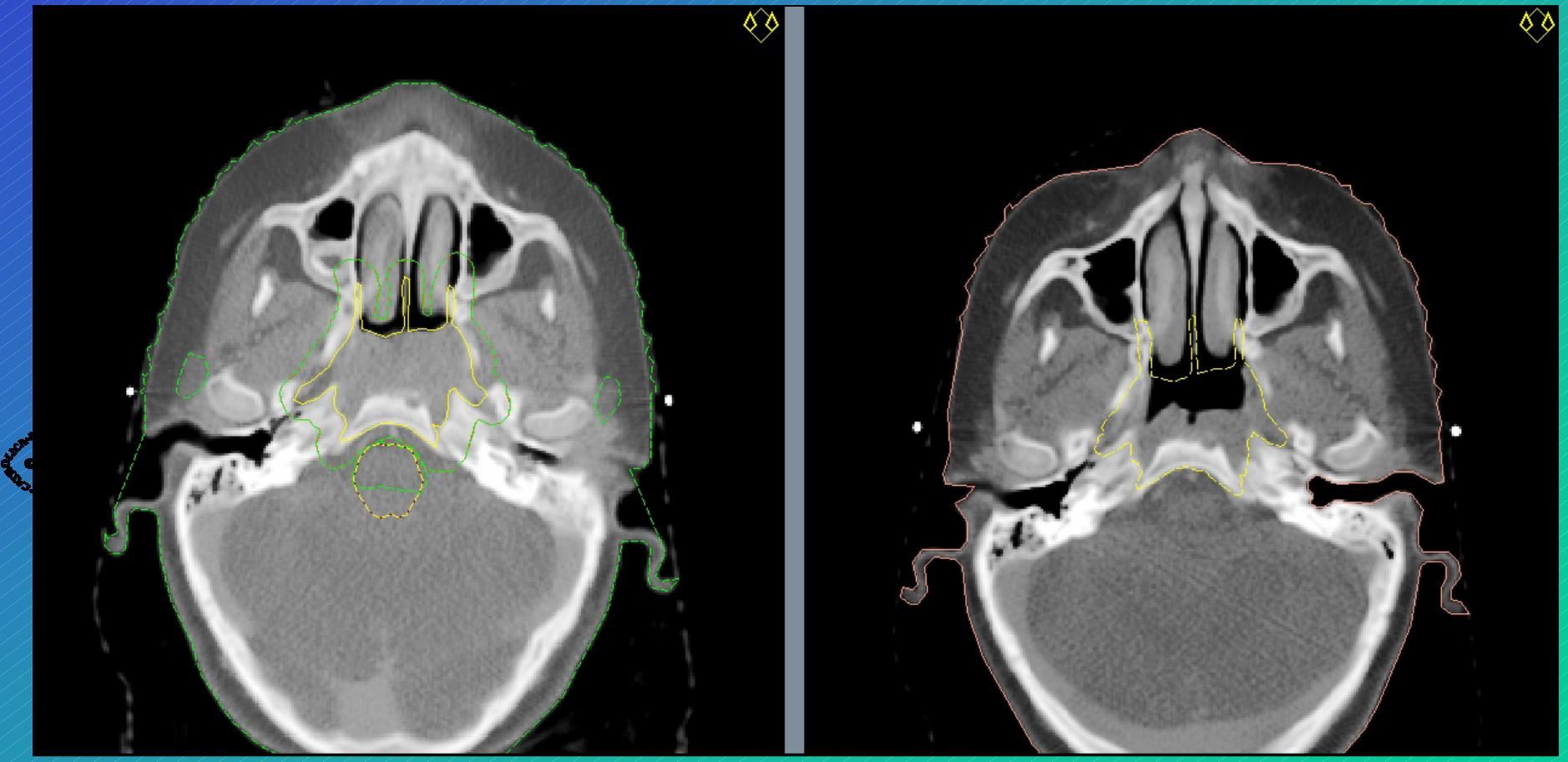
M. Tomsei



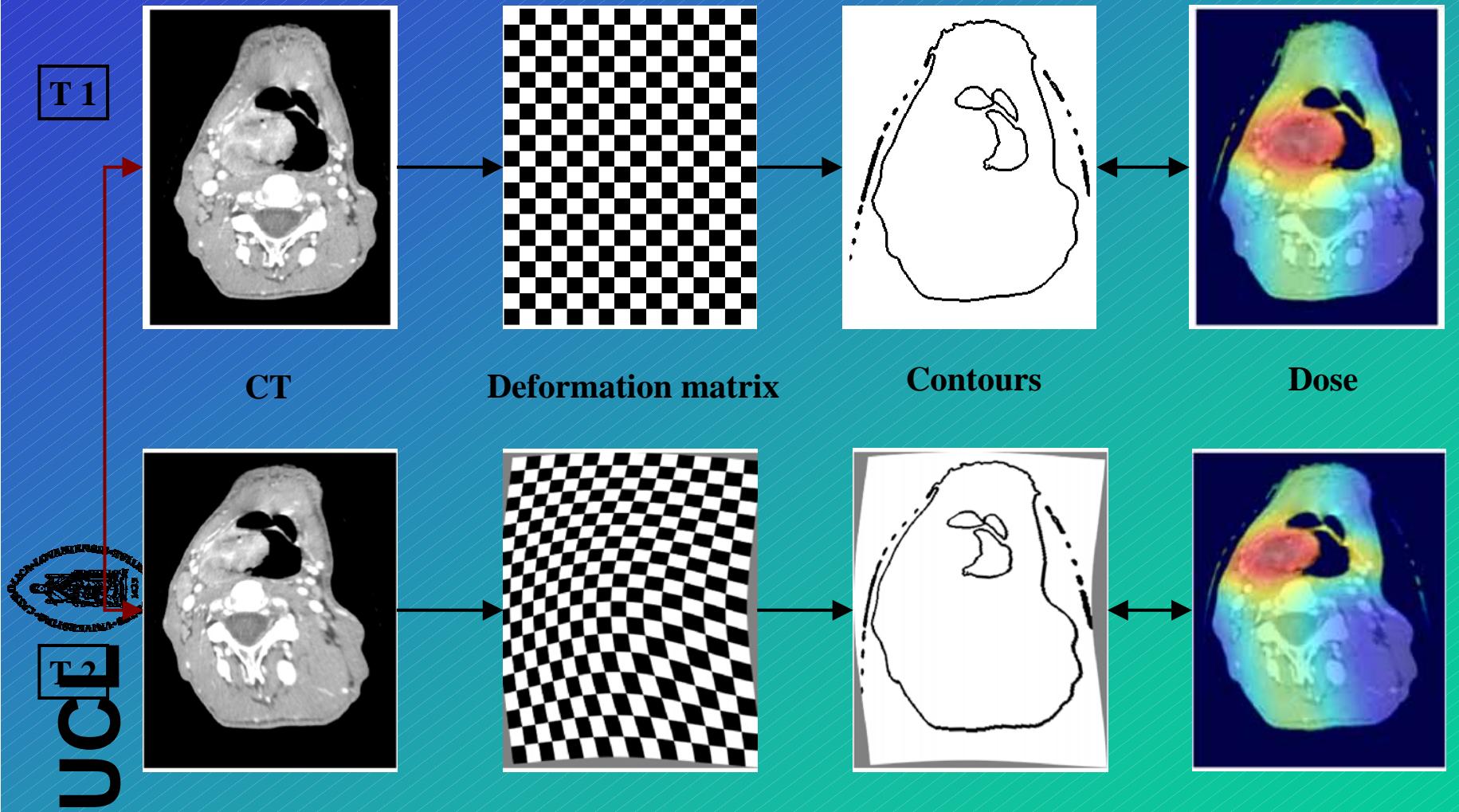
# Radiothérapie adaptative

- ... quid pendant le traitement ?

M. Tomsei



# Non-rigid dose distribution



## VI. Control of the quality system



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# In vivo dosimetry : effect of uncertainty on patient thickness

- Entrance dose on beam axis with TLD dosimeters



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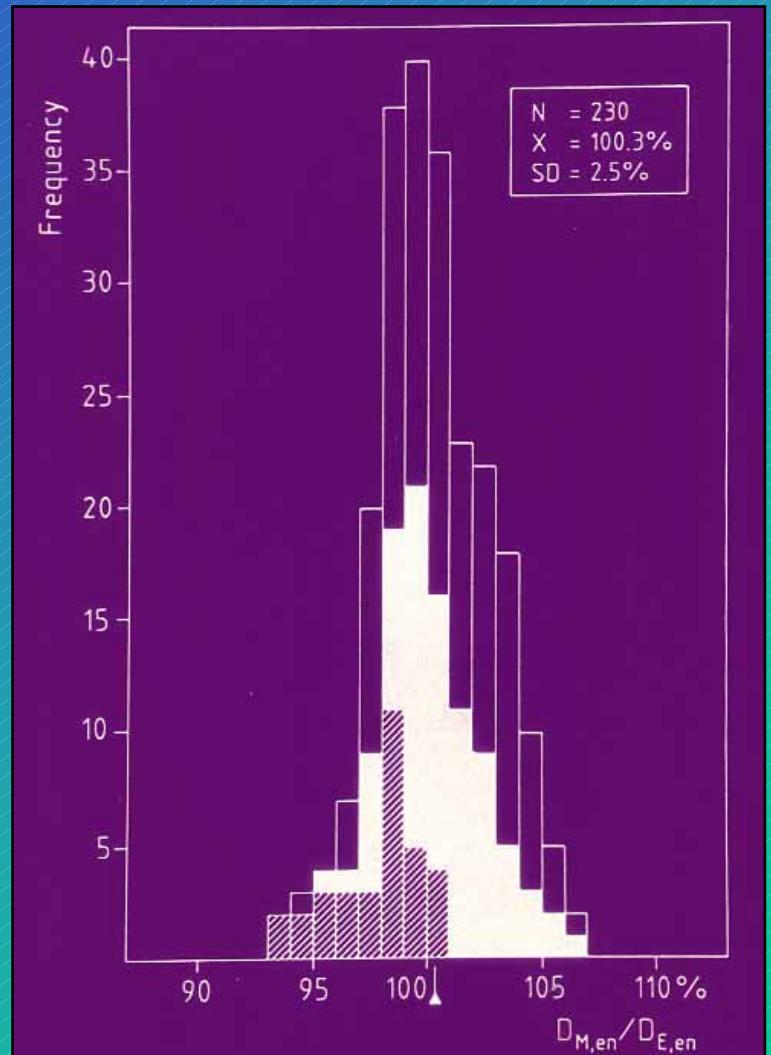


Fig. 4. Results of entrance dose measurements. The histogram shows the frequency distribution of  $D_{M,en}/D_{E,en}$  ( $N = 230$ ) with a mean value ( $X$ ) of 100.3% and one relative standard deviation of 2.5%. The three subgroups (black, white and grey) correspond to different inaccuracies in contours: *black values* are used for patient diameter underestimations ( $\geq 1$  cm):  $N = 75$ ; *white values* for correct contours:  $N = 132$ ; *grey values* for patient diameter overestimations ( $\geq 1$  cm):  $N = 33$ .

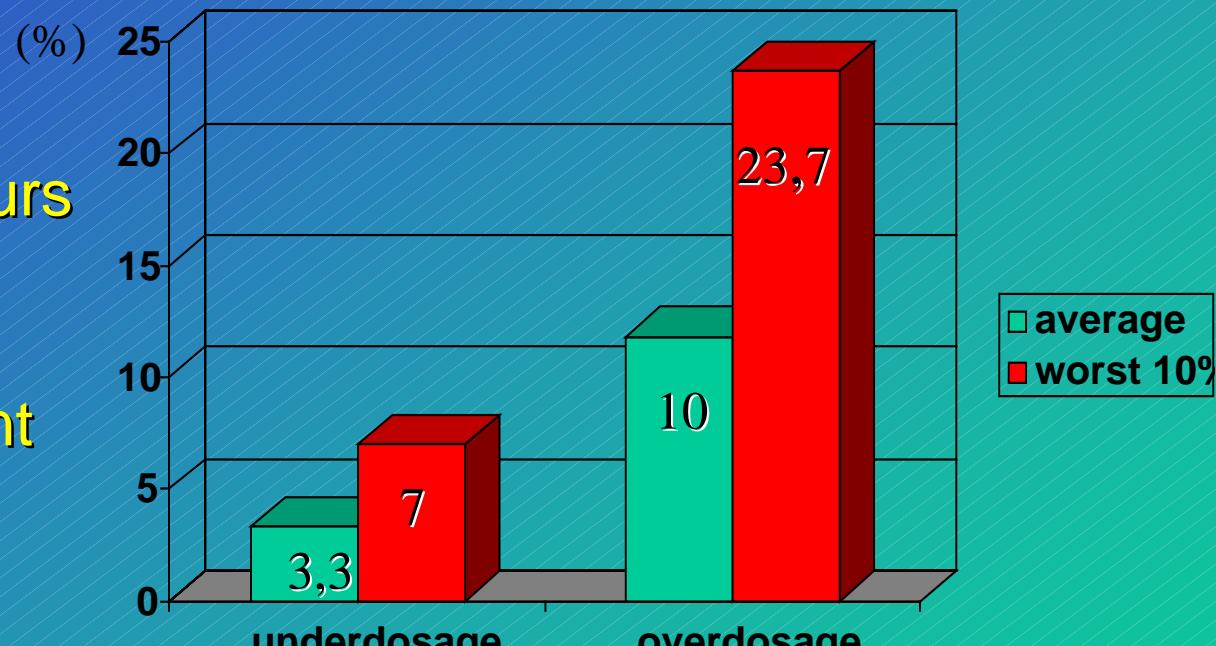
# Impact clinique d 'une imprécision de dosimétrie EORTC

(R & O, 48 (S1): 728, 1998)

65 accélérateurs  
ont été  
surveillés:  
22 sous dosent  
41 sur dosent



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Baisse du  
contrôle local

Effets tardifs  
modérés

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JAN-WILLEM H. LEER  
ALAN MCKENZIE  
PIERRE SCALLIET  
DAVID I. THWAITES

## PRACTICAL GUIDELINES FOR THE IMPLEMENTATION OF A QUALITY SYSTEM IN RADIOTHERAPY

A PROJECT OF THE ESTRO QUALITY ASSURANCE COMMITTEE

SPONSORED BY

"EUROPE AGAINST CANCER"



PHYSICS FOR CLINICAL RADIOTHERAPY  
BOOKLET No. 4

**Total  
Quality  
Management**

# Vers une radiothérapie de conformation fonctionnelle?

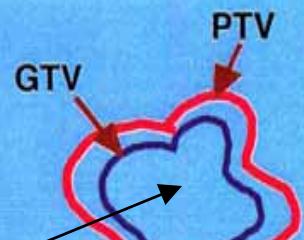
Conformation anatomique

CT  
IRM



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## Biological Target Volume?



- PET
- IUDR
- Tumor growth

- PET
- F-miso
- Hypoxia



Biological Eye View

- MRI/MRS
- choline/citrate
- Tumor burden



Biol. Tgt.  
Volume

PTV

Conformation  
« fonctionnelle »

# La physique médicale

- Radiothérapie
  - Imagerie médicale
  - Médecine nucléaire
  - Industrie
  - Organismes régulateurs
  - RECHERCHE
- La radiothérapie était sur une voie de garage en 1980.
  - AR avril 1991
  - AR avril 1994
  - Recertification (jury médical).



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Mots clés : multidisciplinarité, physique appliquée, service à la société, programation, variété, radiobiologie, profession humaine... ET LES MEDECINS?



**UCL**

on  
ualiser cette image.