Terapia Hadrónica (→ Protonterapia)
Bases y últimas novedades

A.Mazal and A.Fourquet
F.Goudjil, L.deMarzi,
S.Meyroneinc, A.Patriarca,
R.Dendale

En nombre del equipo del
Centre de Protonthérapie d'Orsay (CPO)

Institut Curie, France

Valencia
10 Marzo 2016

Acknowledgments:
Canceropôle, France Hadron,
PhysiCancer, J.Bernabeu

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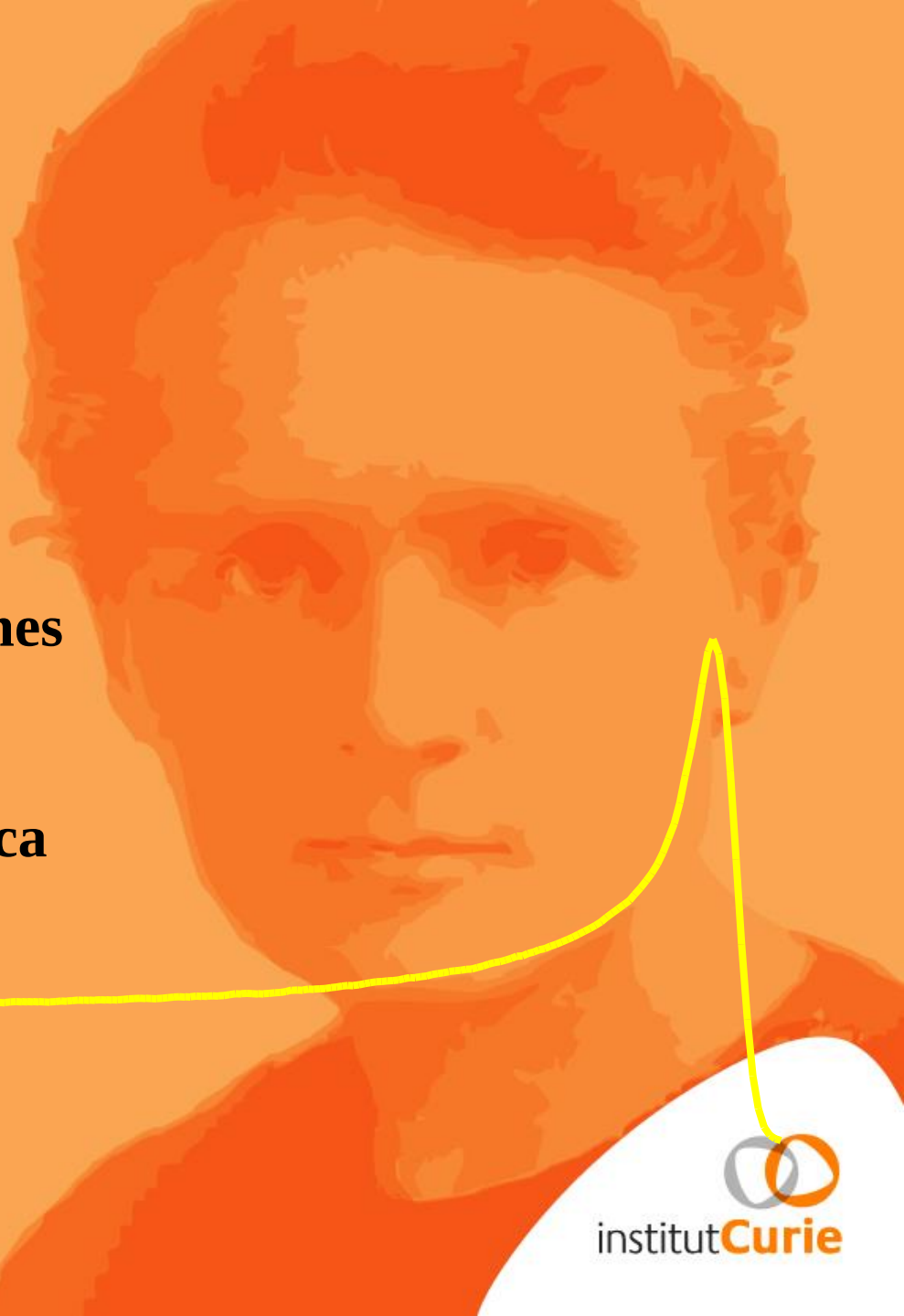
MENU

1. **Bases físicas e interés clínico**
2. **El centro de Orsay :**

   de sistemas pasivos

   hacia sistemas dinámicos
3. **Los límites actuales y soluciones**
4. **Investigación y desarrollo :**

   física, tecno, biología → clínica
5. **Conclusiones**



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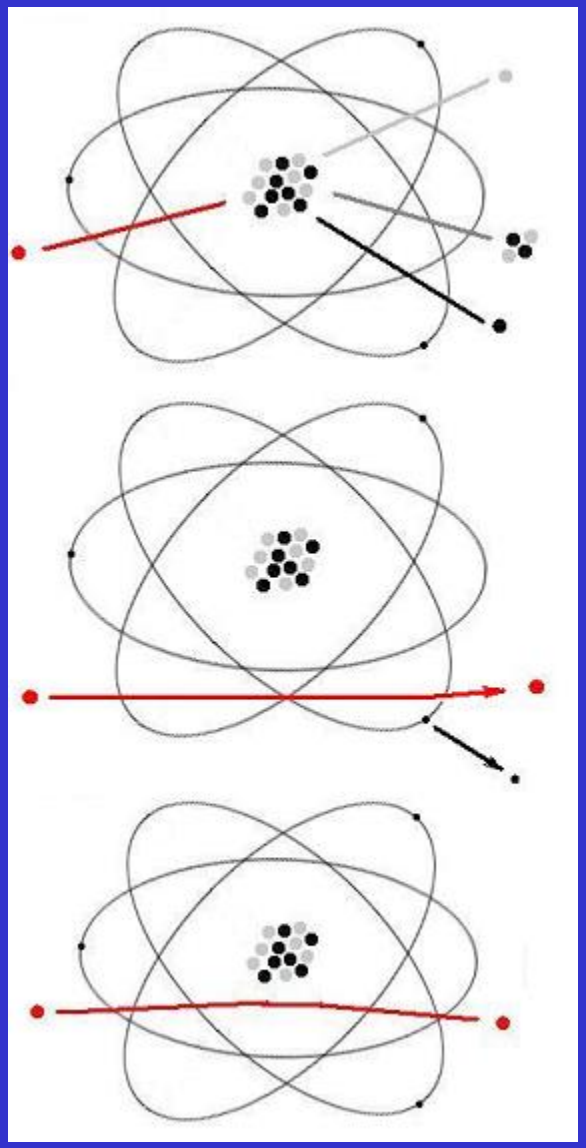
Un poco de Física :
interacciones haz particulas cargadas con la materia.
Las principales son :



Con el núcleo :
→ producción de neutrones

Con los electrones :
→ ionización y dosis

Difusión múltiple con el núcleo :
→ penumbra

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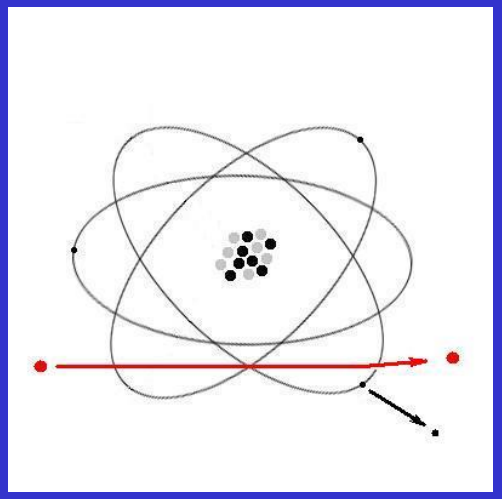
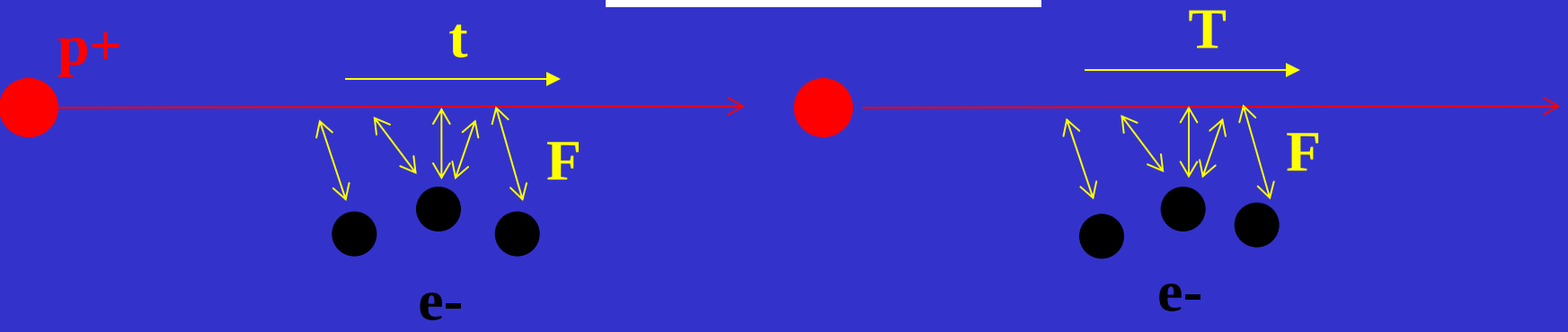
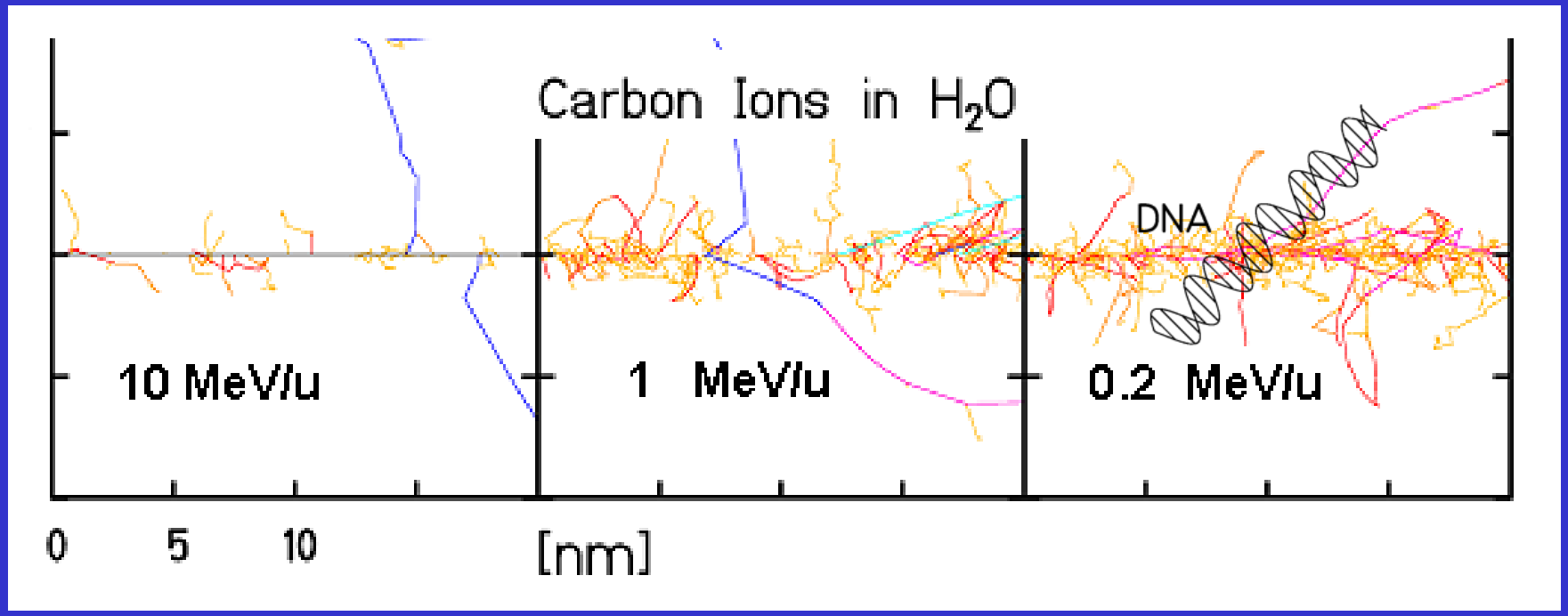
Interacción de un protón con un átomo





Dose distribution in nanometer scale (carbon beam)



M. Kraemer, M. Scholz

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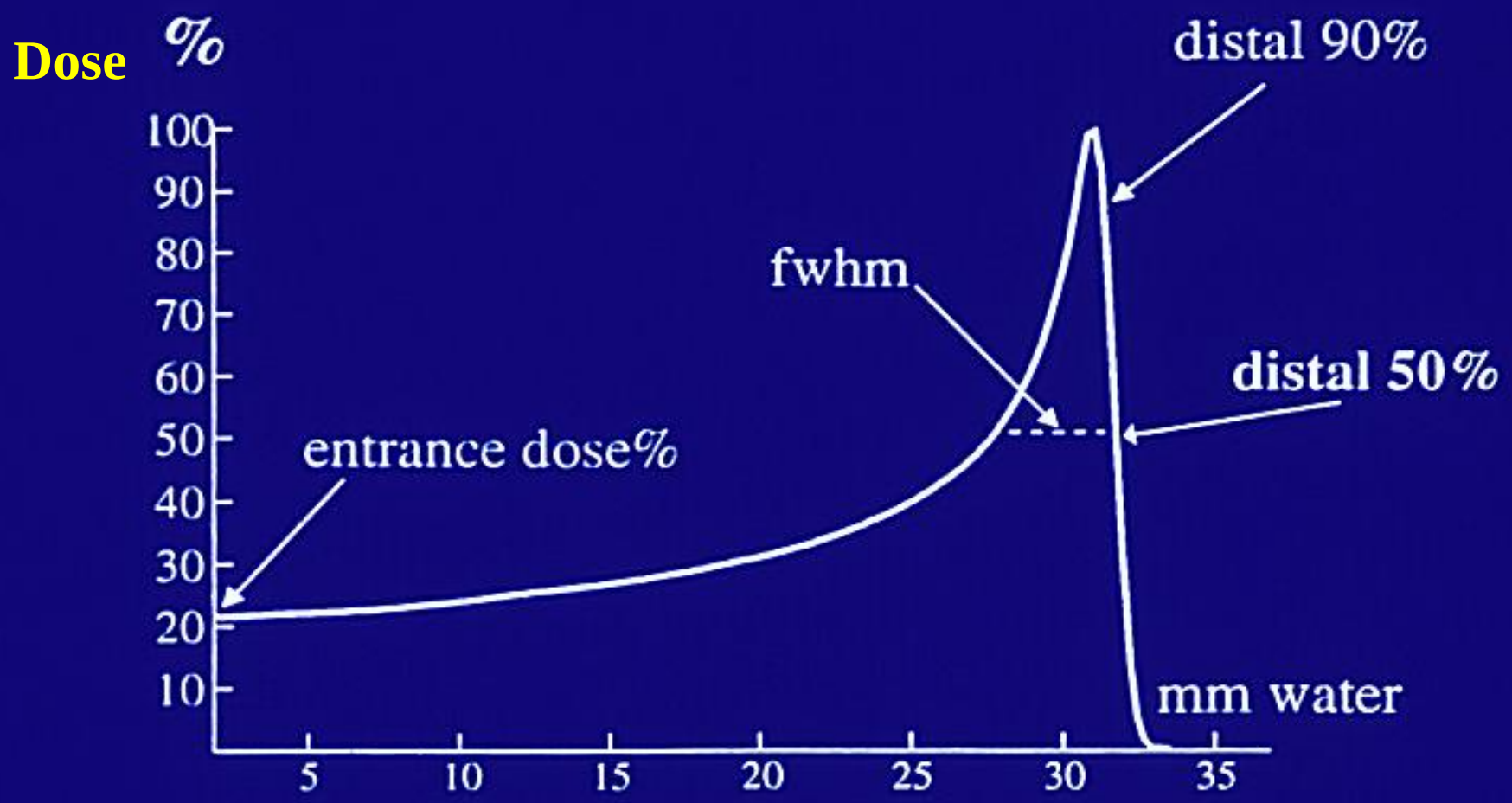
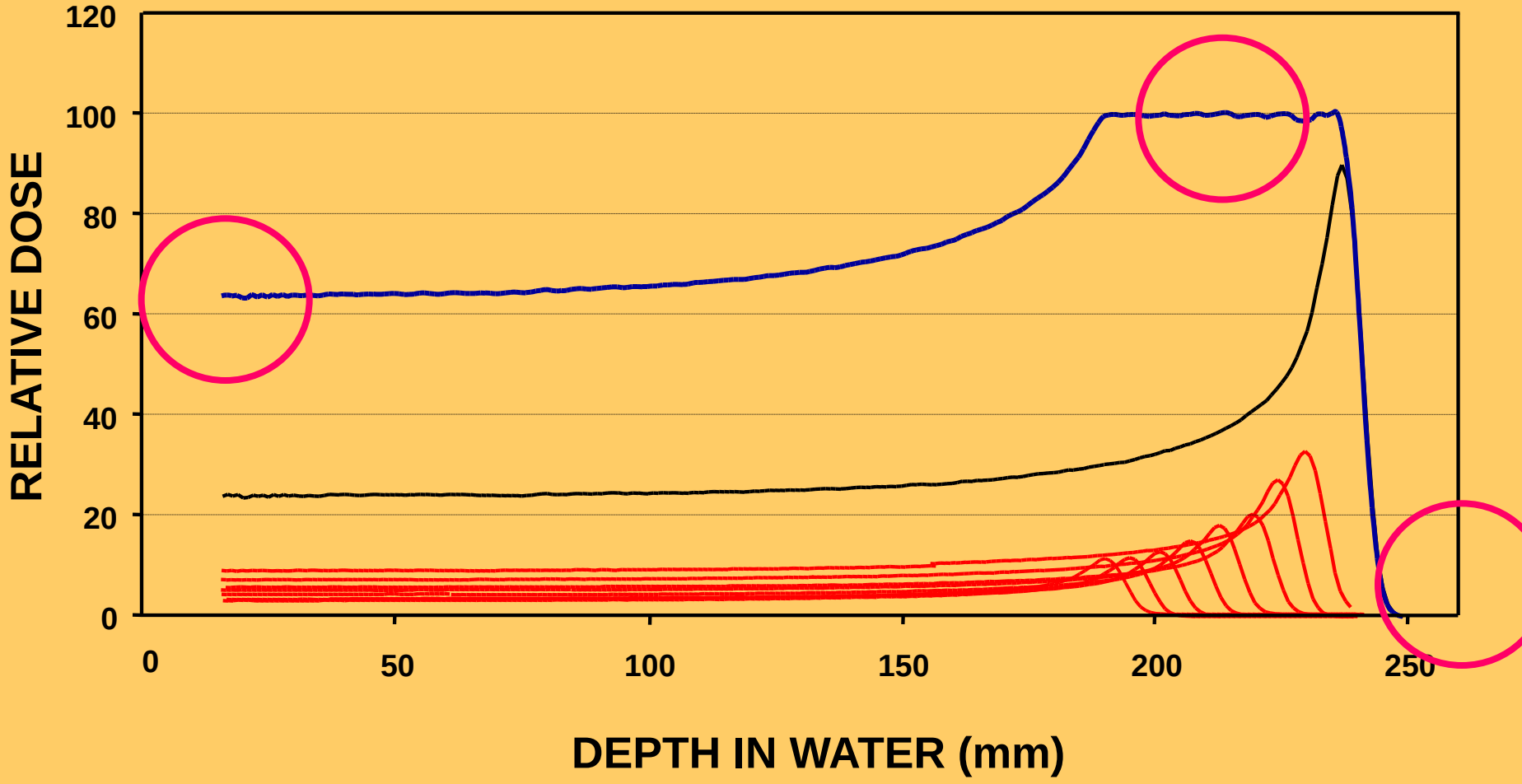
Characteristics of Bragg Peak



Pure Bragg peak depth of 60.4 MeV protons

Spread-out Bragg Peak (SOBP)



(Andy Kohler // graph : Niek Schreuder)

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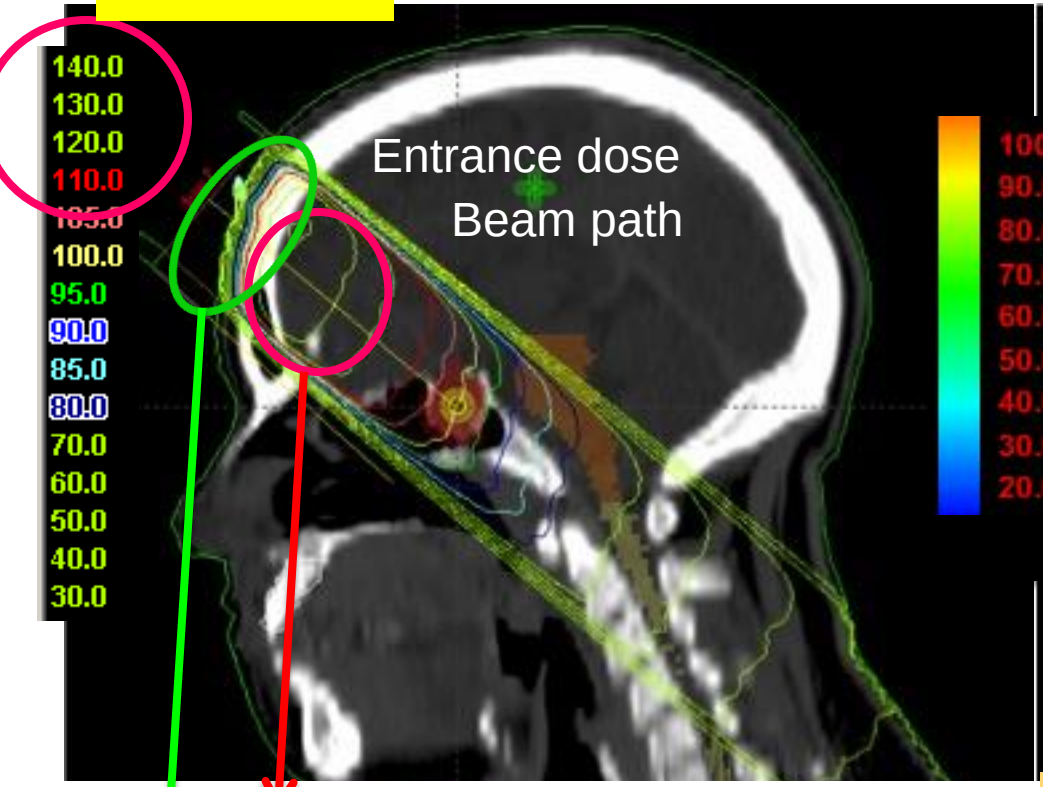
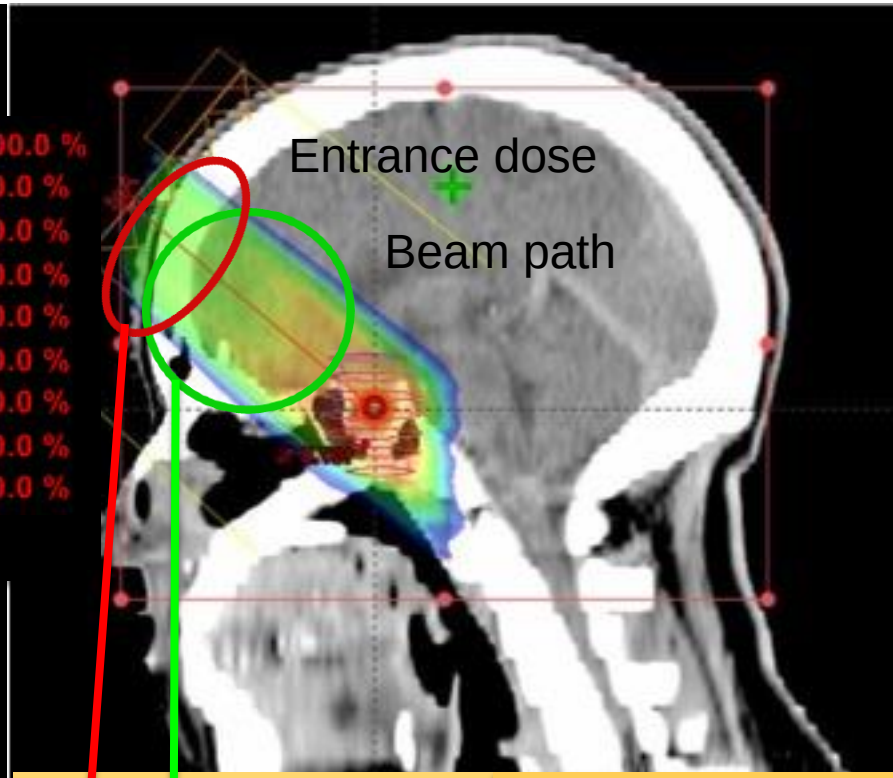
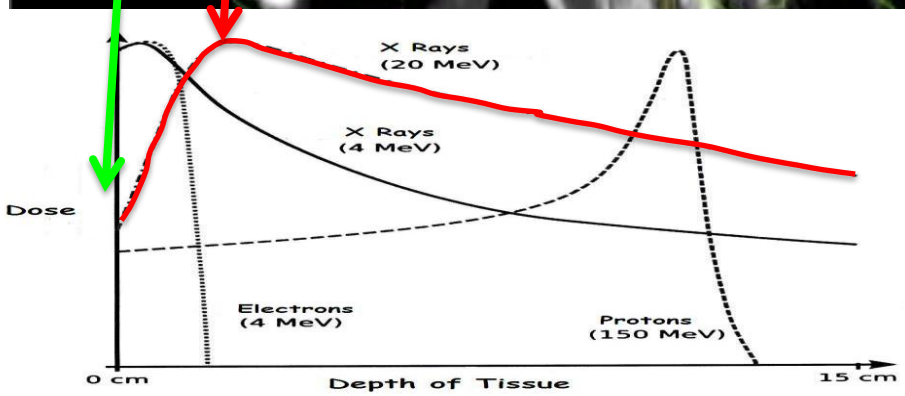
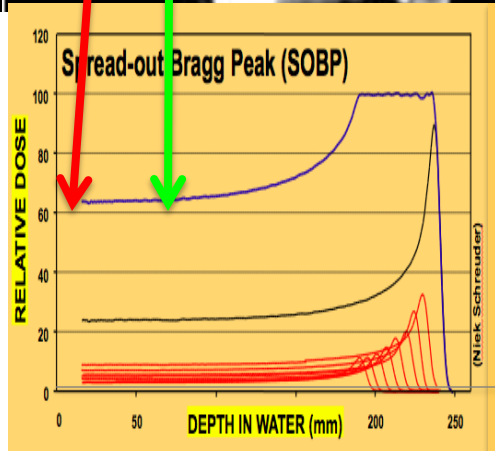
Moving from planning with photons to protons? (Isodoses)
(concepts for 1 beam ~ valid for passive and active techniques…)

Entrance

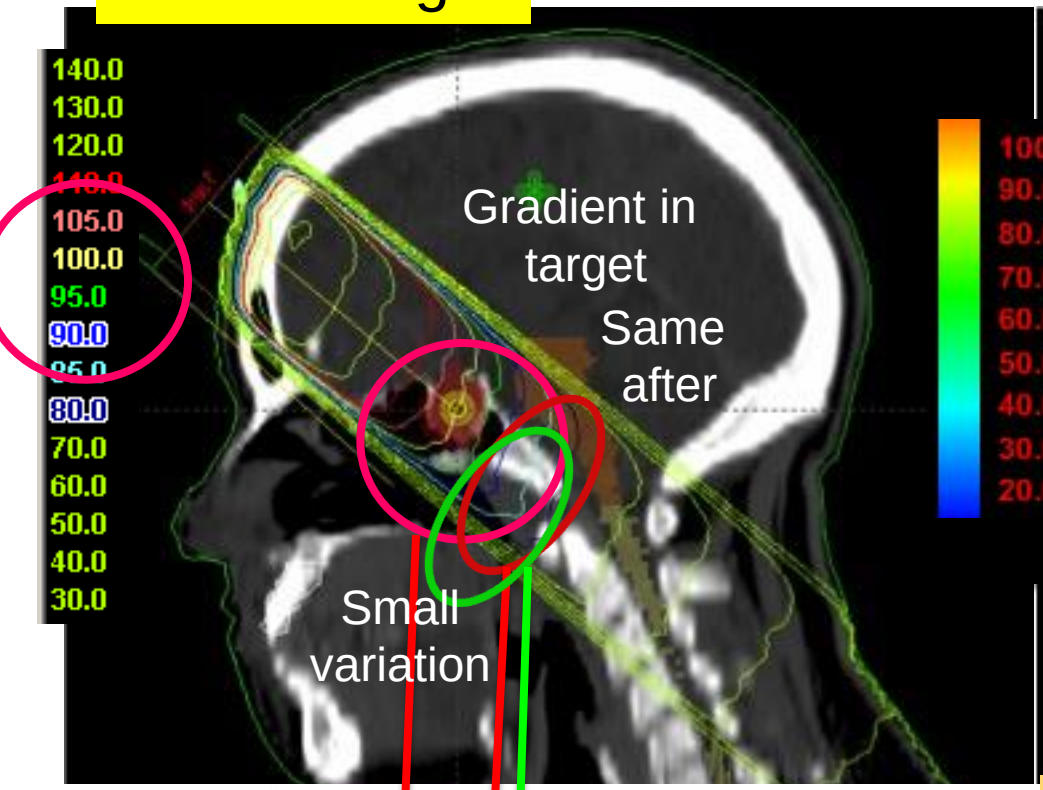


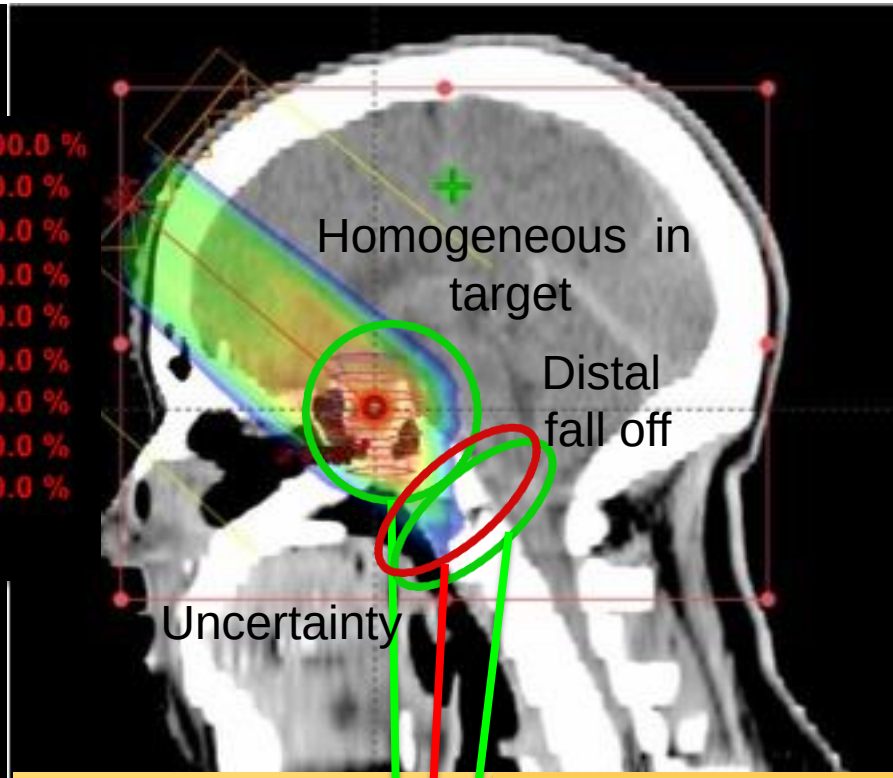


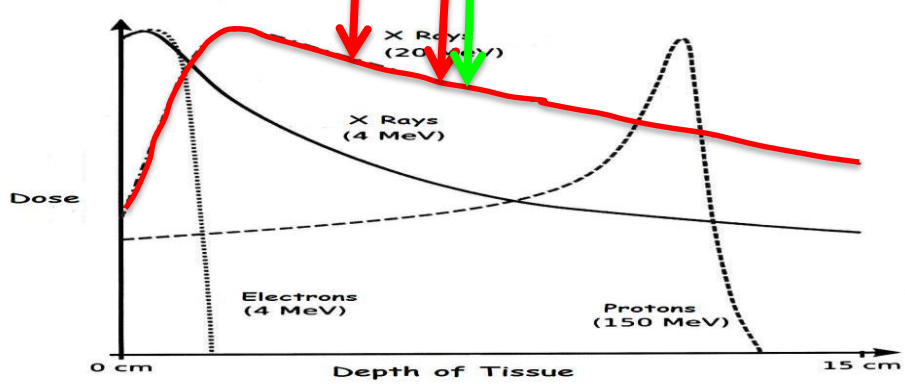


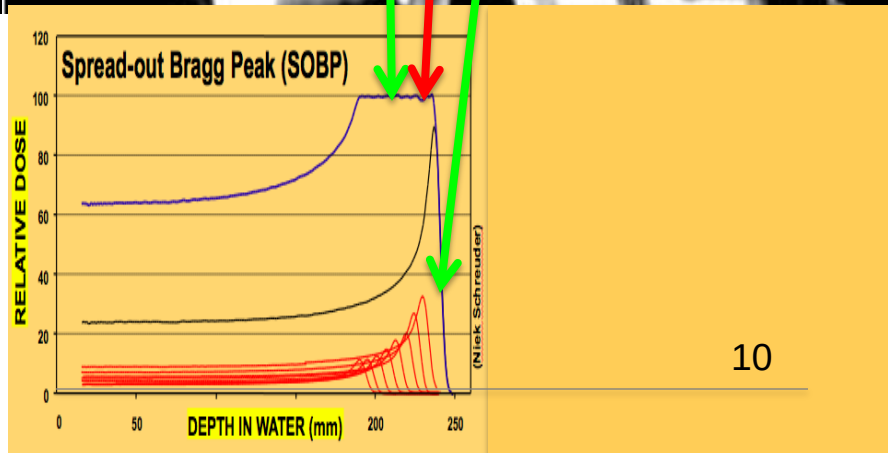


Around target

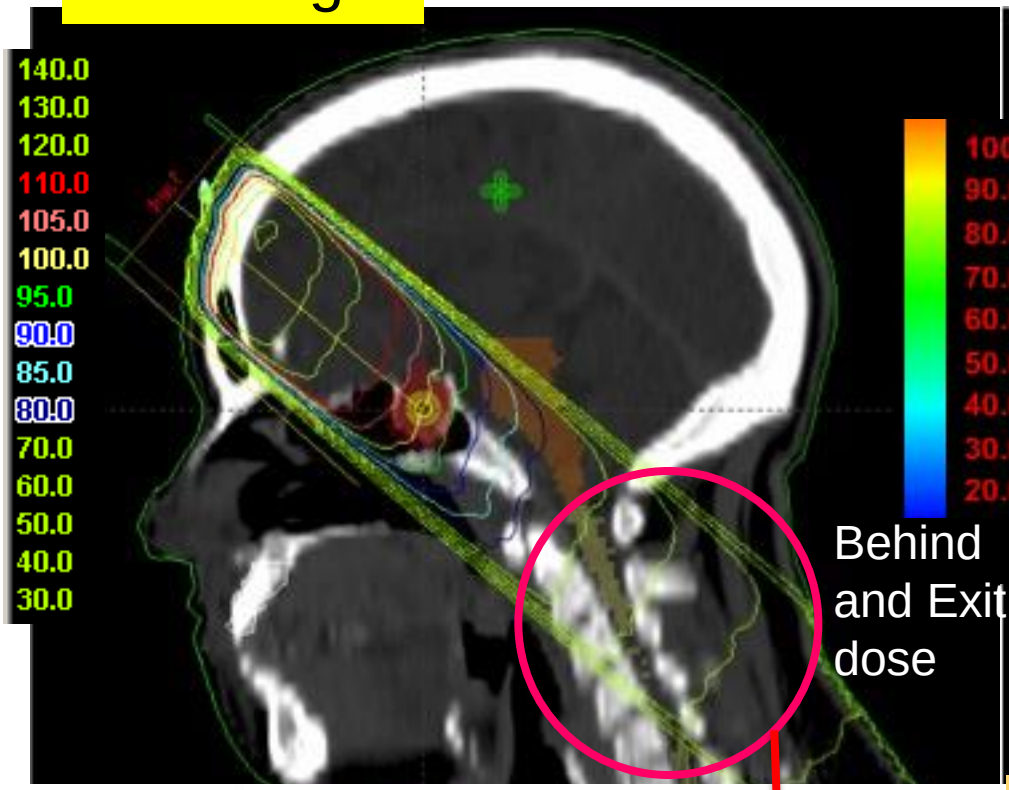




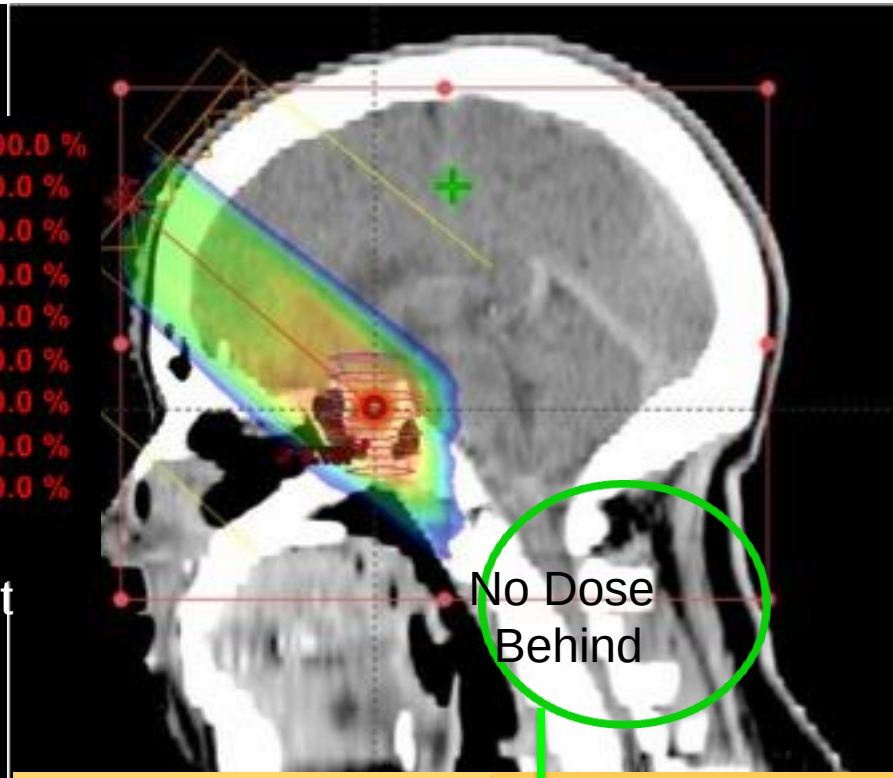




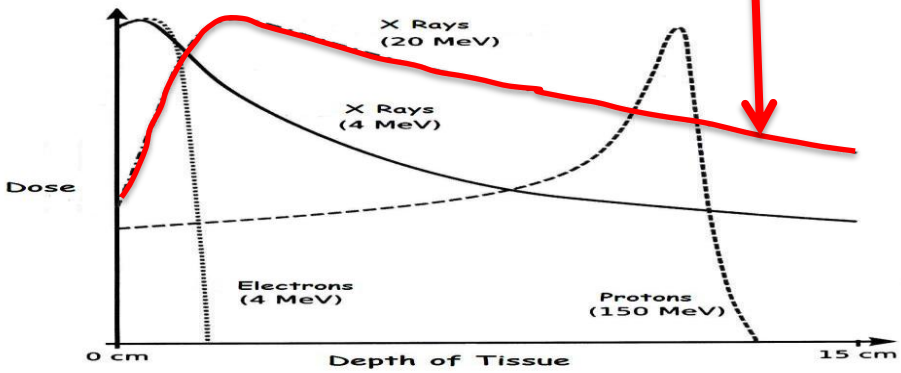
After target

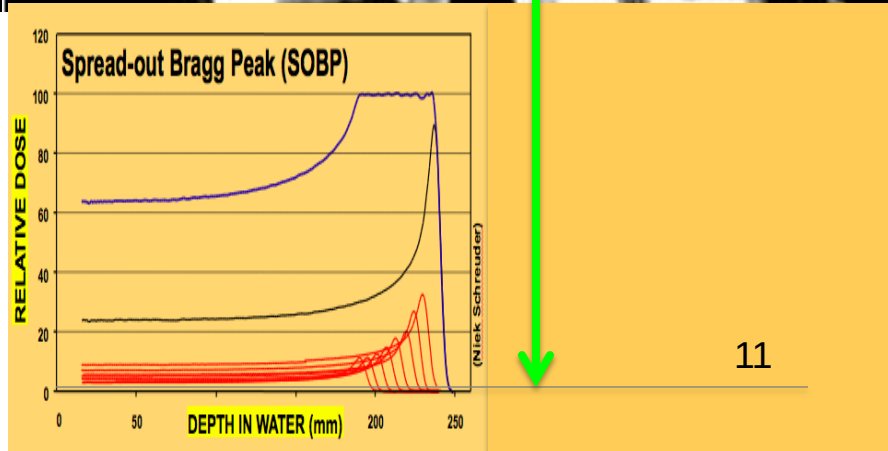


Behind and Exit dose

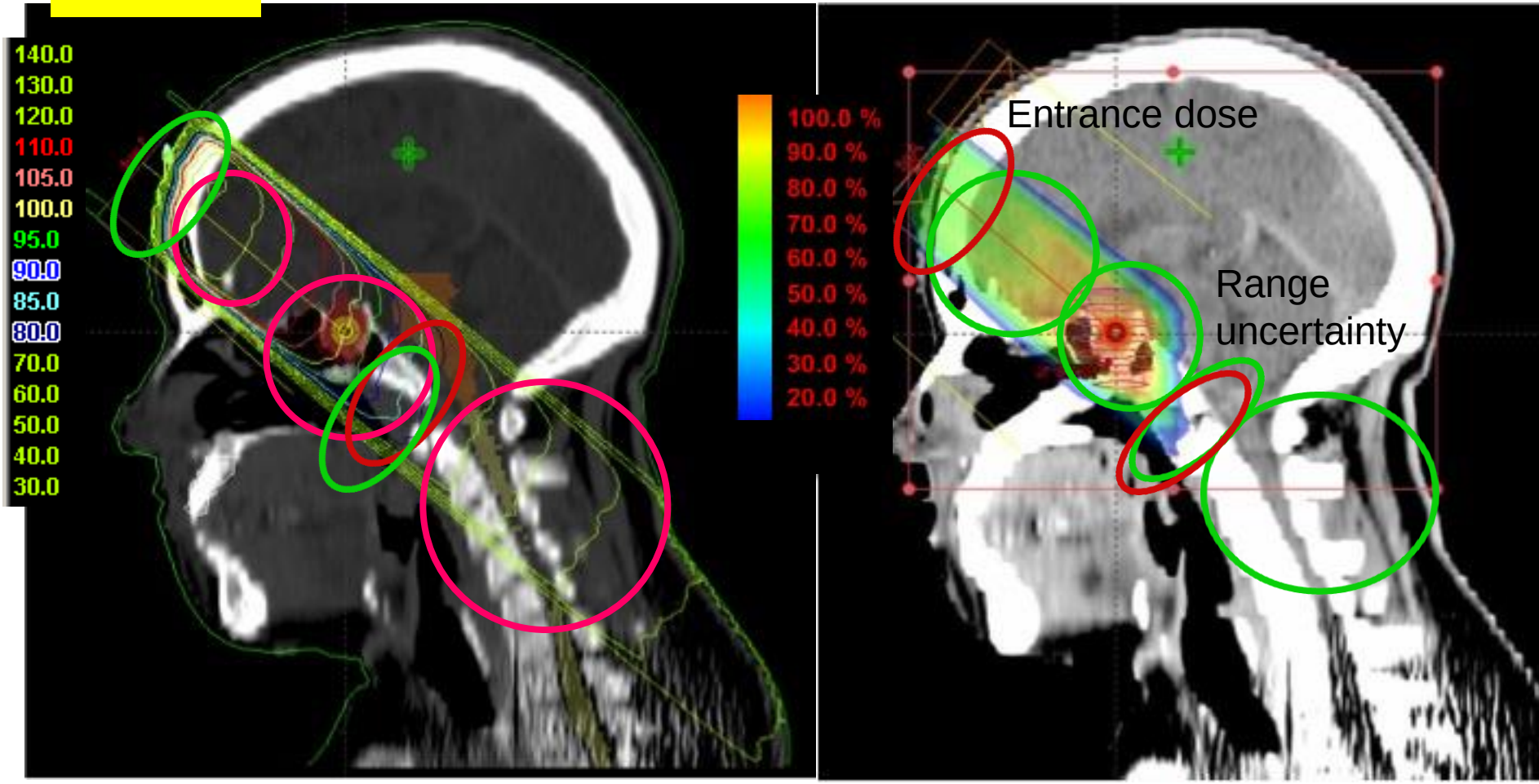


No Dose Behind

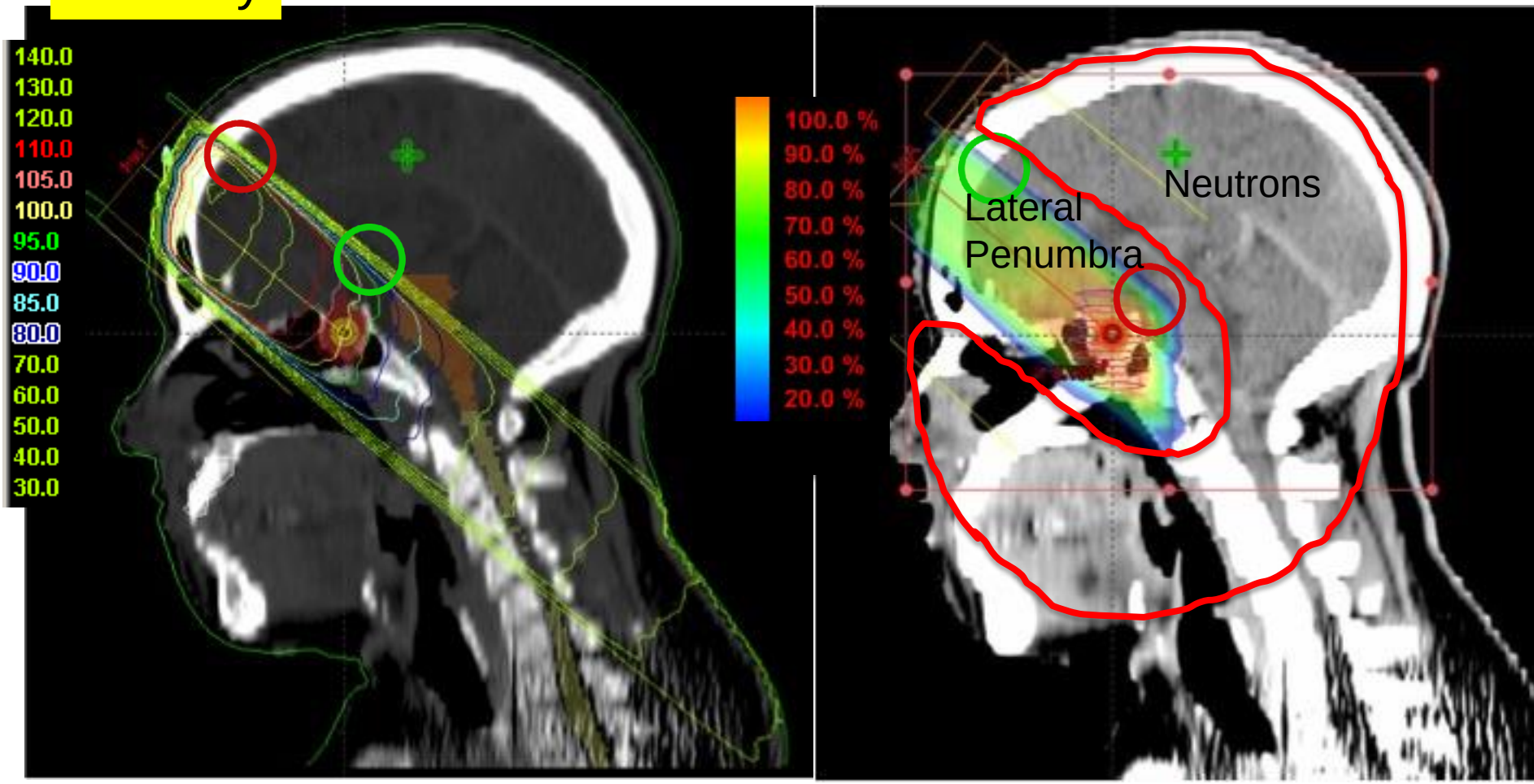


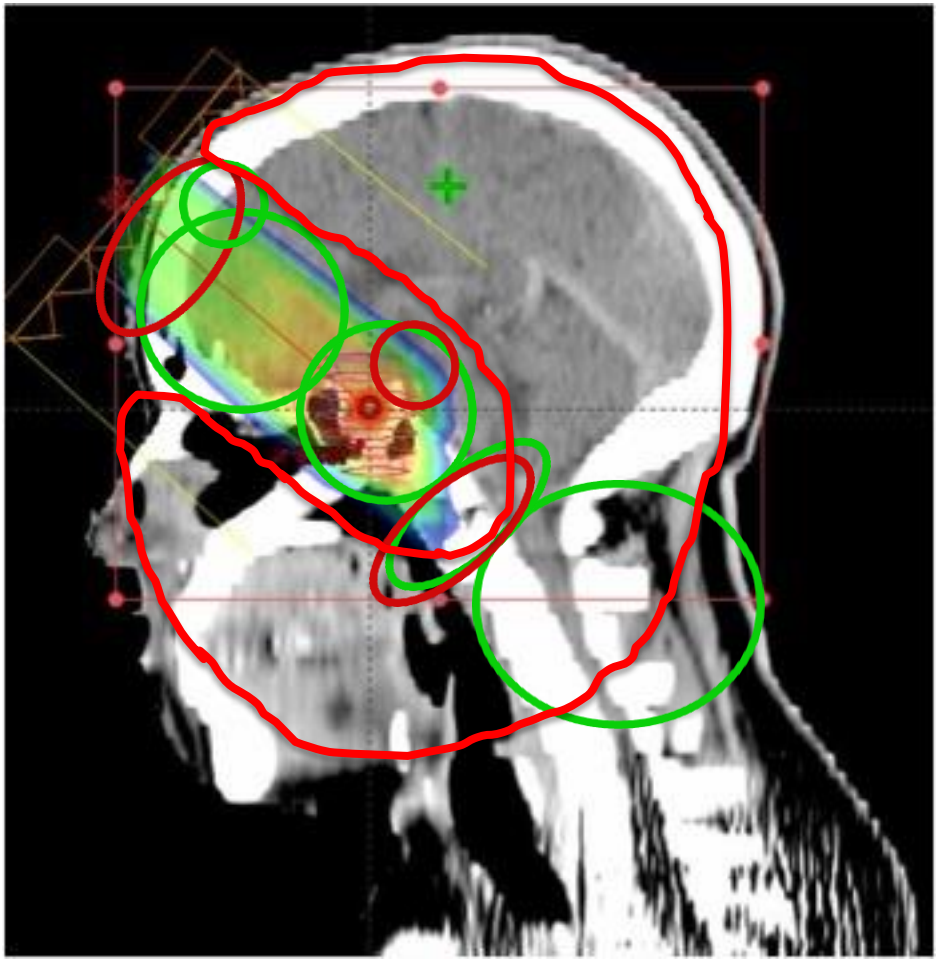


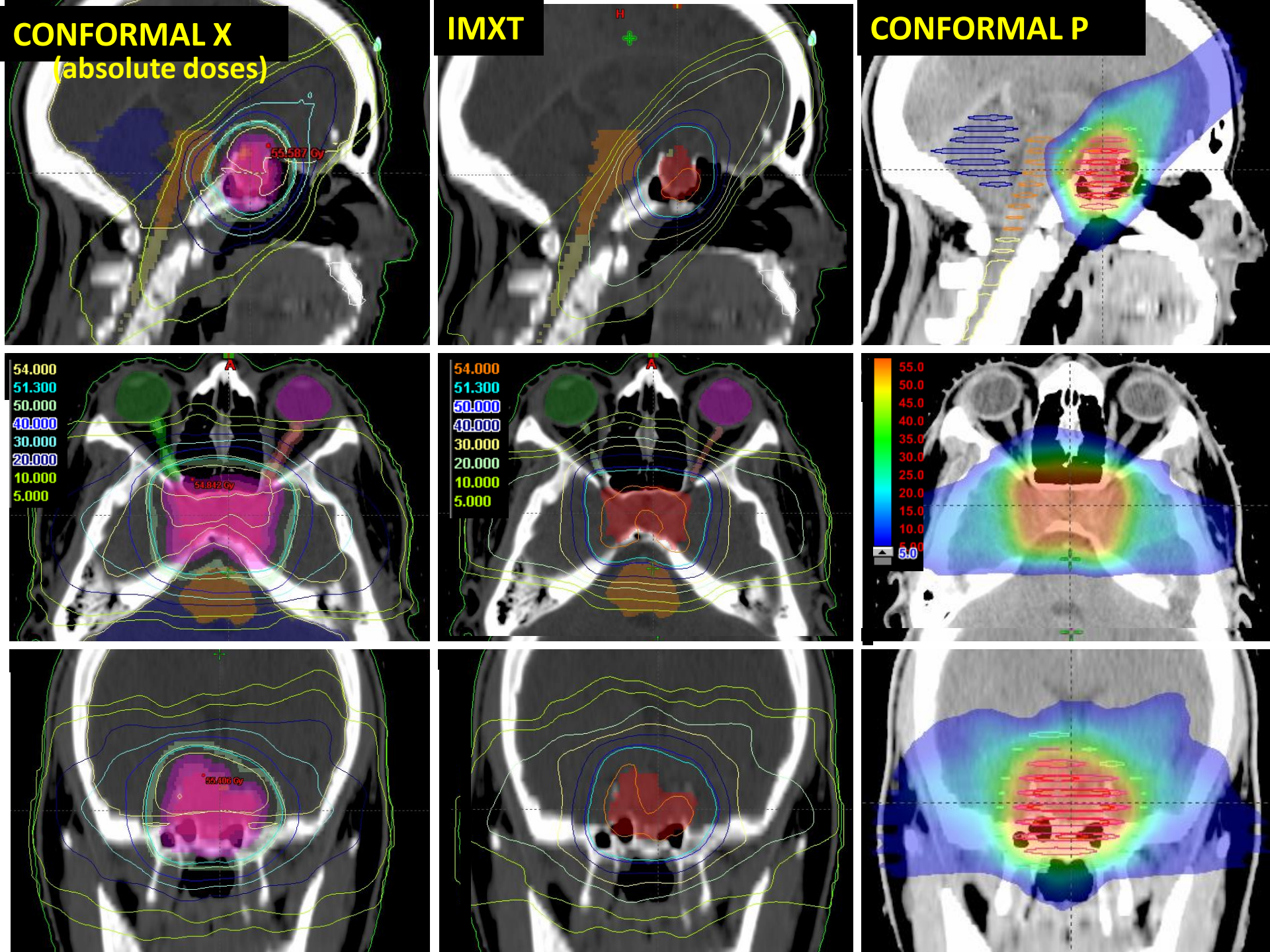
On axis


140.0
130.0
120.0
110.0
105.0
100.0
95.0
90.0
85.0
80.0
70.0
60.0
50.0
40.0
30.0
100.0 %
90.0 %
80.0 %
70.0 %
60.0 %
50.0 %
40.0 %
30.0 %
20.0 %
Entrance dose
Range uncertainty

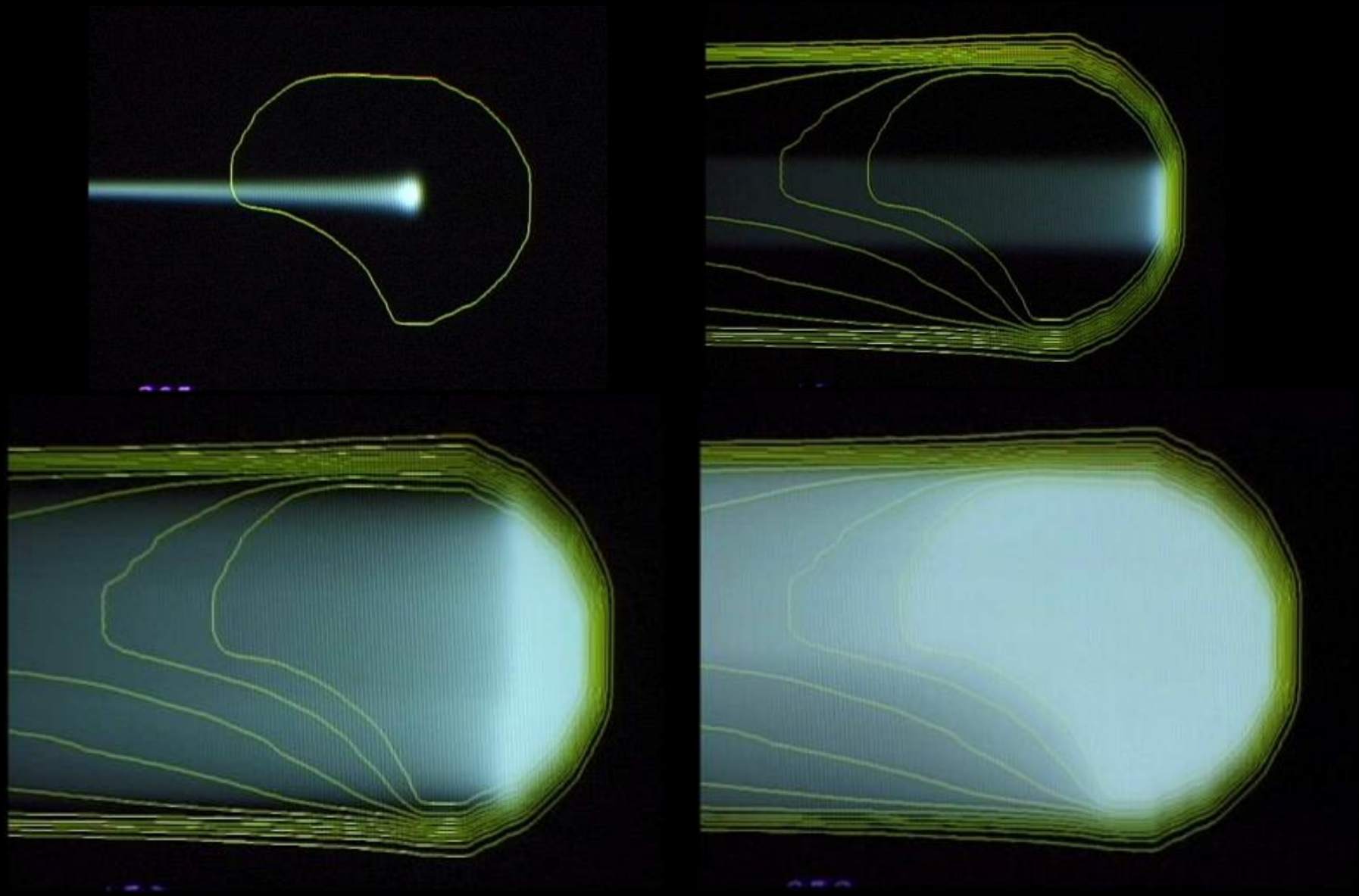
Laterally


140.0
130.0
120.0
110.0
105.0
100.0
95.0
90.0
85.0
80.0
70.0
60.0
50.0
40.0
30.0
100.0 %
90.0 %
80.0 %
70.0 %
60.0 %
50.0 %
40.0 %
30.0 %
20.0 %
Lateral
Penumbra
Neutrons



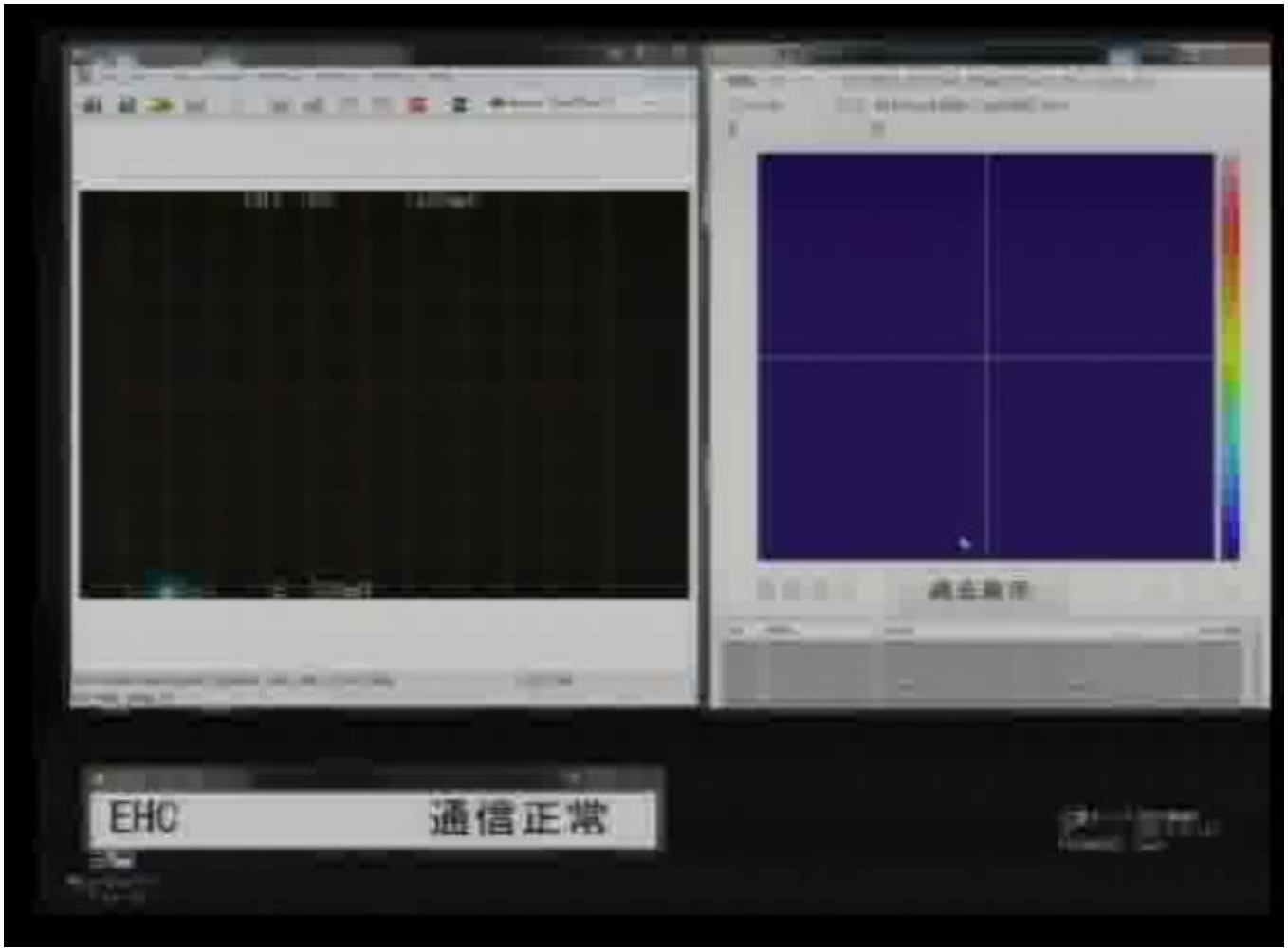

CONFORMAL X
(absolute doses)
IMXT
CONFORMAL P
55.587 Gy
54.842 Gy
55.406 Gy
54.000
51.300
50.000
40.000
30.000
20.000
10.000
5.000
55.0
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0

Pencil Beam Scanning



(Pedroni et al, 1995 / PSI)

Pencil Beam Scanning (PBS)

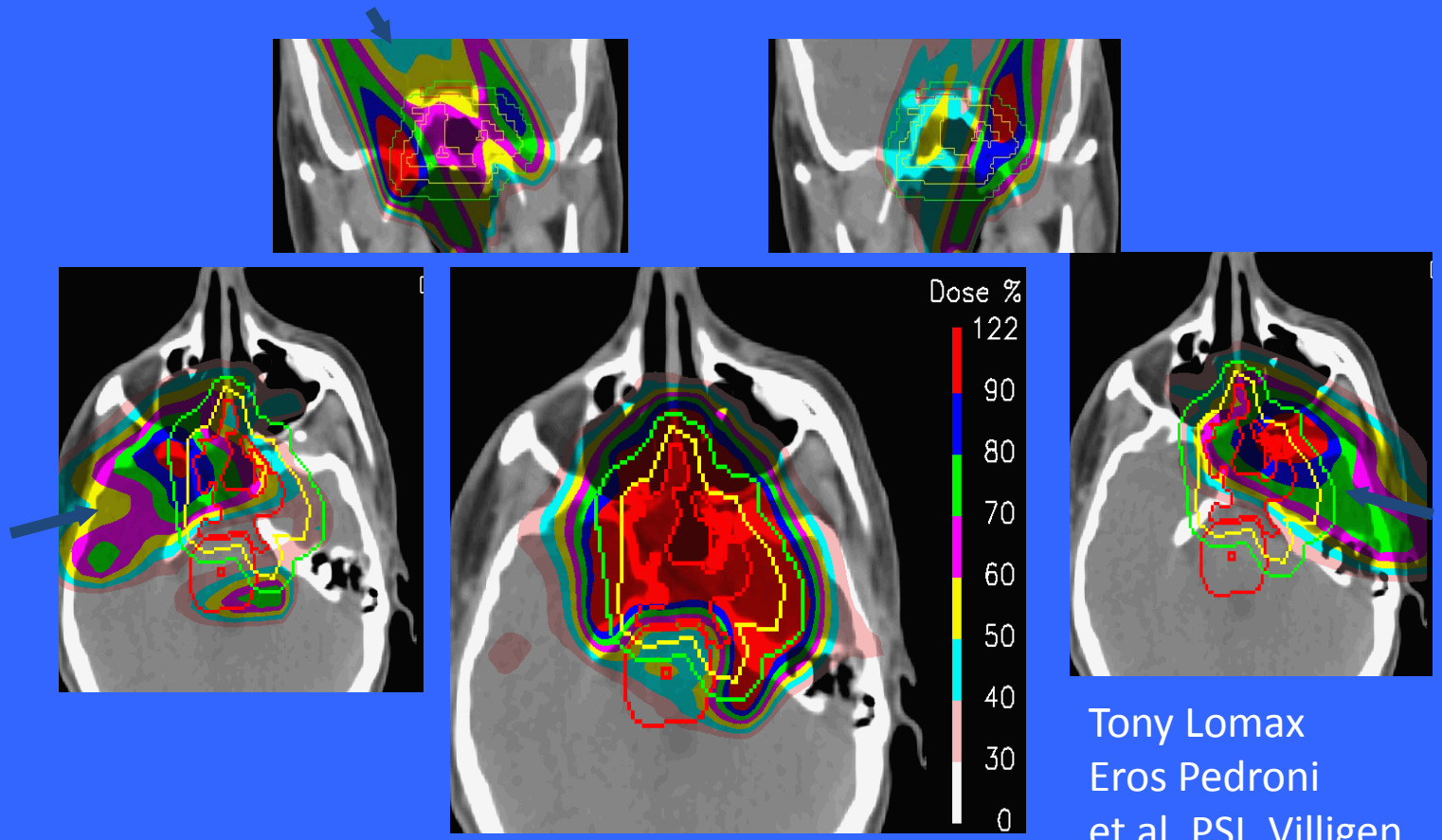


Kamada, PTCOG 2014

Pencil Beam Scanning (PBS)

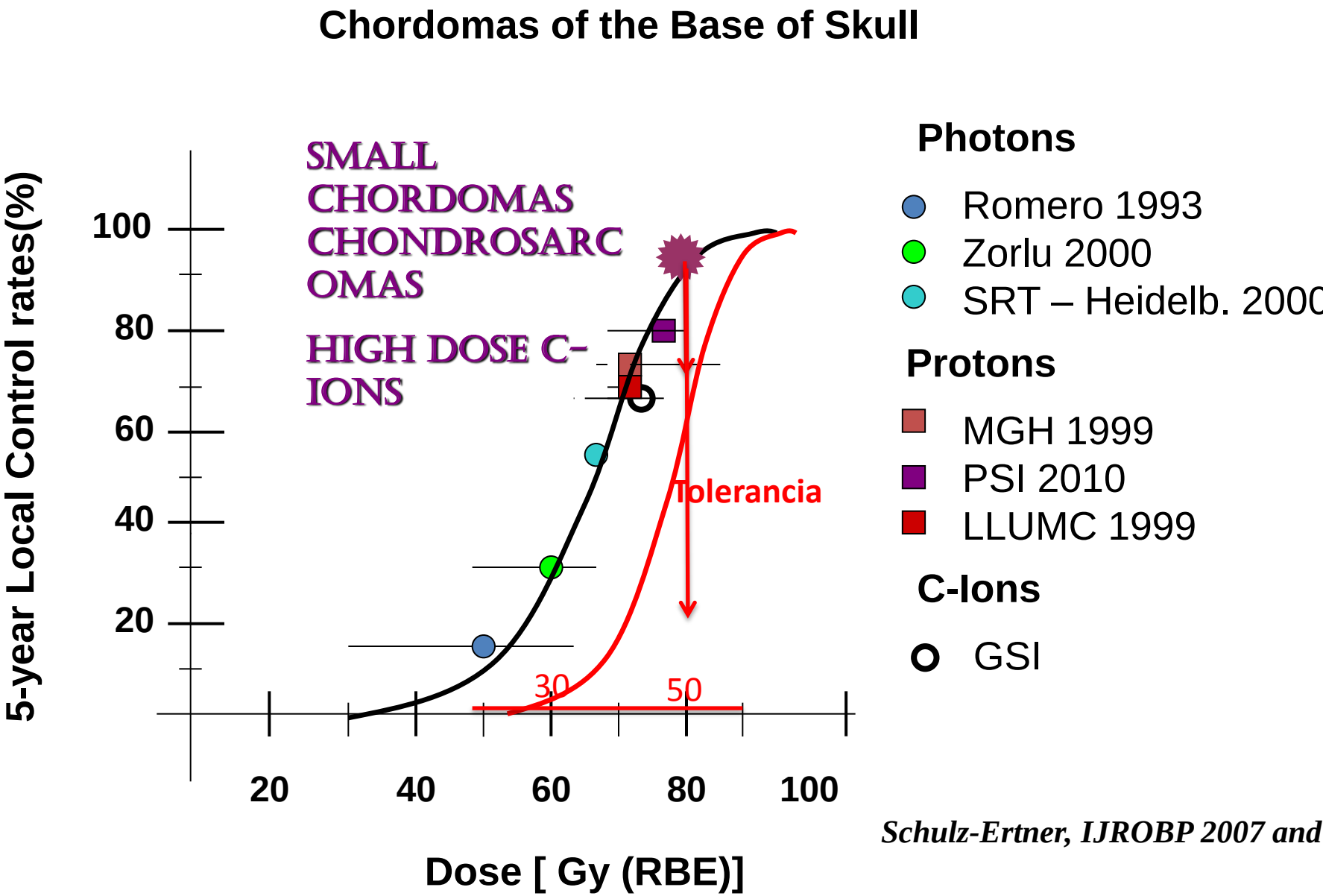
Intensity Modulated Proton Therapy

(IMPT)



Tony Lomax
Eros Pedroni
et al, PSI, Villigen
& other pioneers

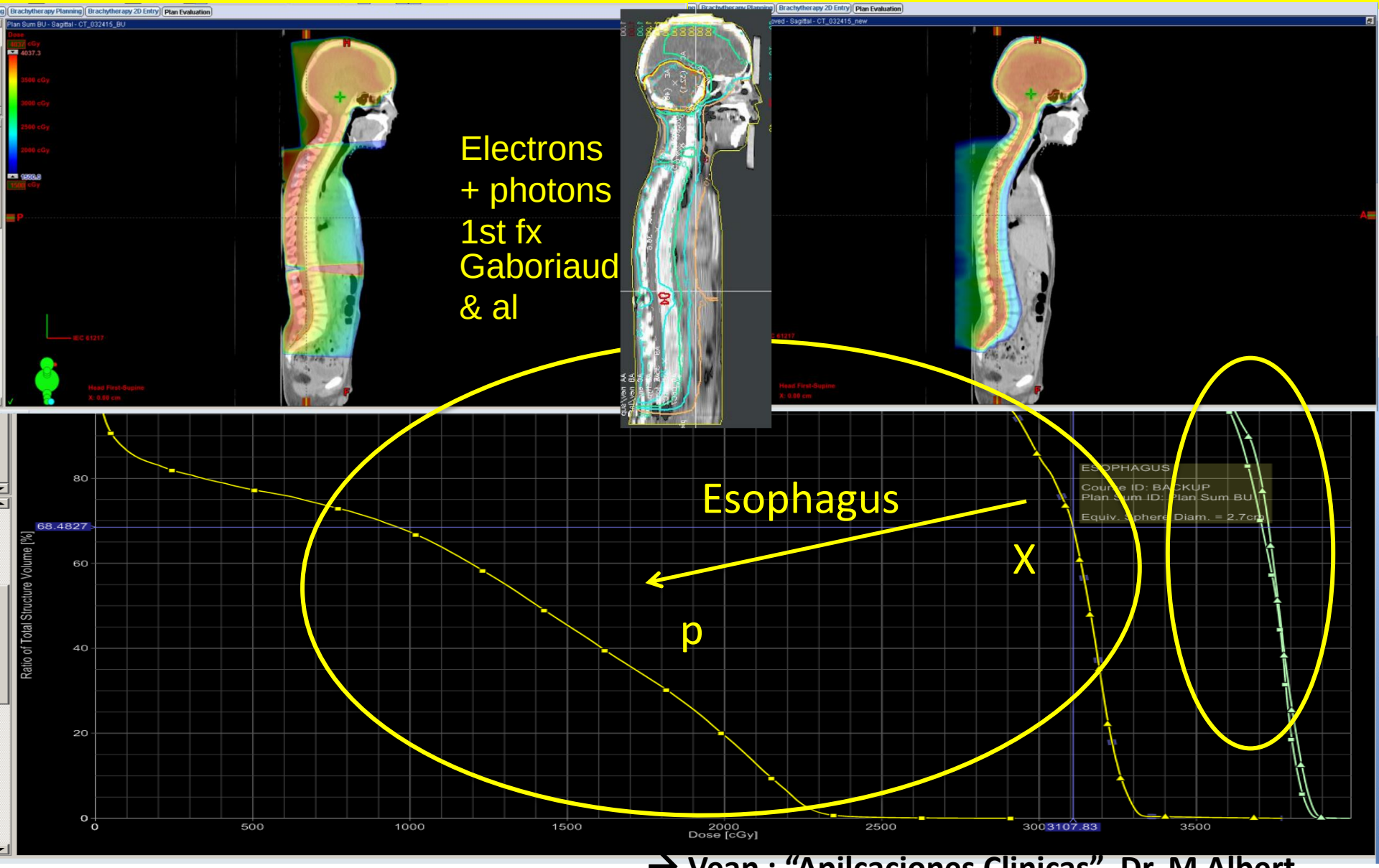
Local control
(photons, protons, carbon…)



Schulz-Ertner, IJROBP 2007 and

CSI: Photons (left & triangles), PBS (right & squares)

Jim McDonough, U. Penn



→ Vean : "Apilcaciones Clinicas" Dr. M Albert

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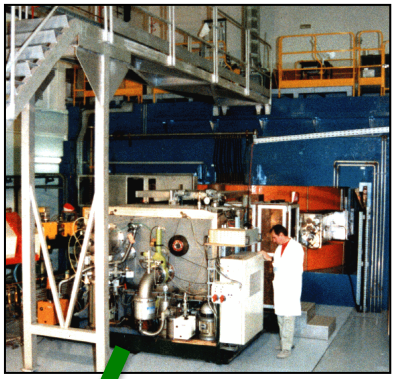
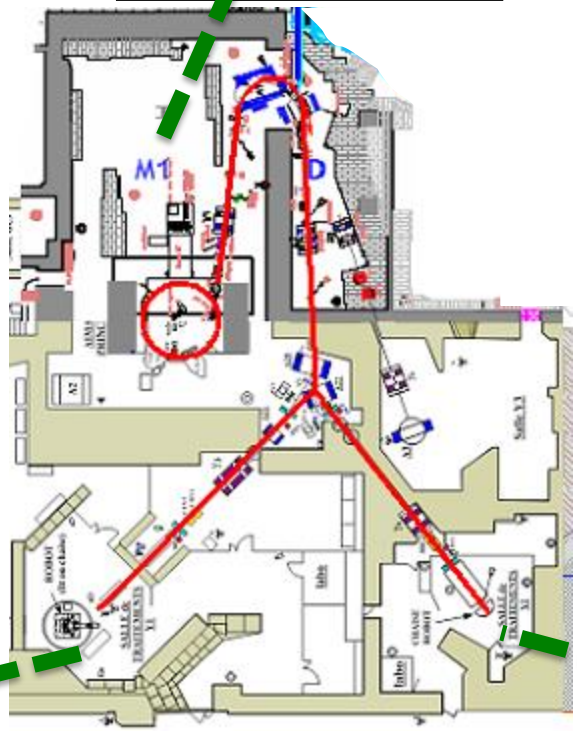
Institut Curie : Centre de Protonthérapie d'Orsay - CPO

(From existing facility, Nuclear Physics Institut)

1958:
Research

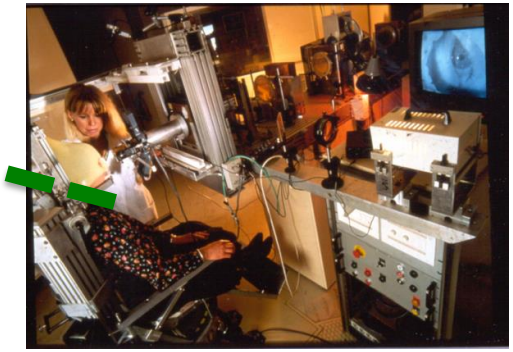


1991-2010 :
clinical



(2) Large fields

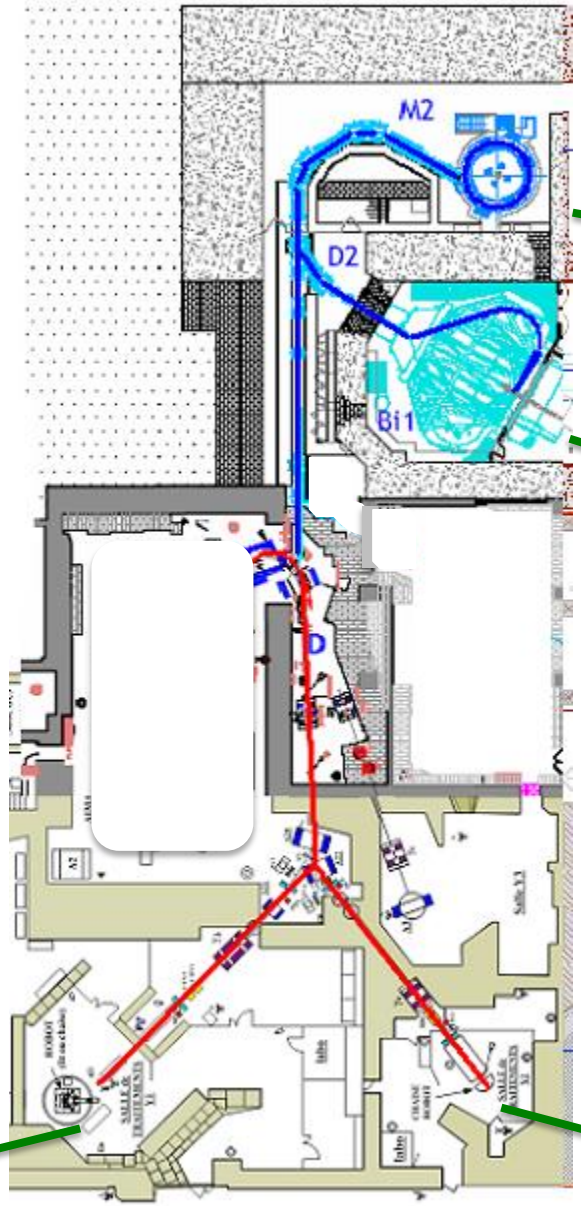
(1) Small fields



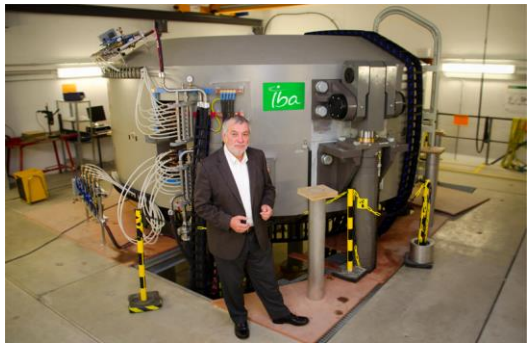
Institut Curie : Centre de Protonthérapie d'Orsay - CPO

2006 -2010 :
New Industrial equipment (IBA)

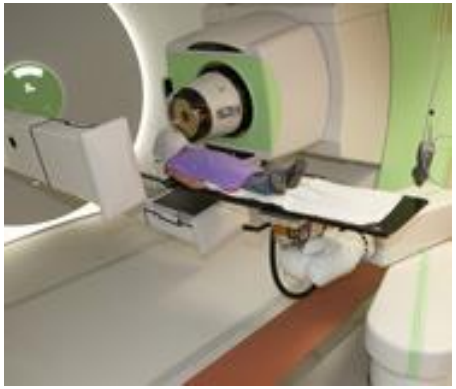
1991-2010 :
clinical



Accelerator

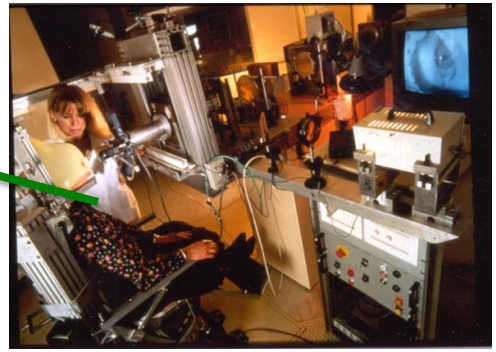


(3) Universal Gantry



(2) Large fields

(1) Small fields



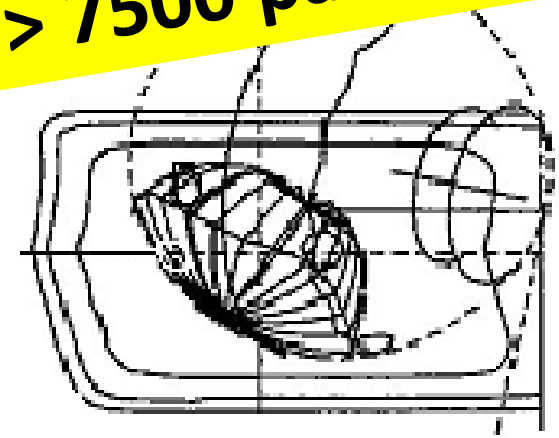
Radiation Therapy Department (Dr. A. Fourquet)

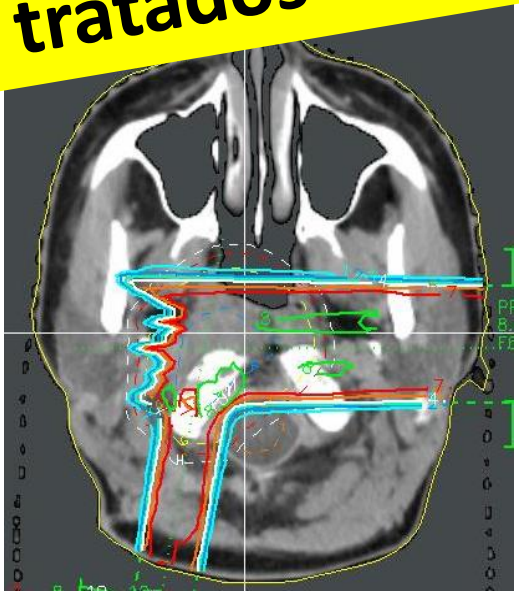
9 linacs , 2 Tomotherapies, 1 Rx150kV,
1 proton cyclotron (1 Gantry & 2 fixed rooms)
Brachytherapy I125, PDR, HDR

5000 patients/year in RT
(**550 pats/year with protons = 11 %**) → 9000 fr

> 7500 pacientes tratados con protones en el Curie,

Eyes





Pediatrics

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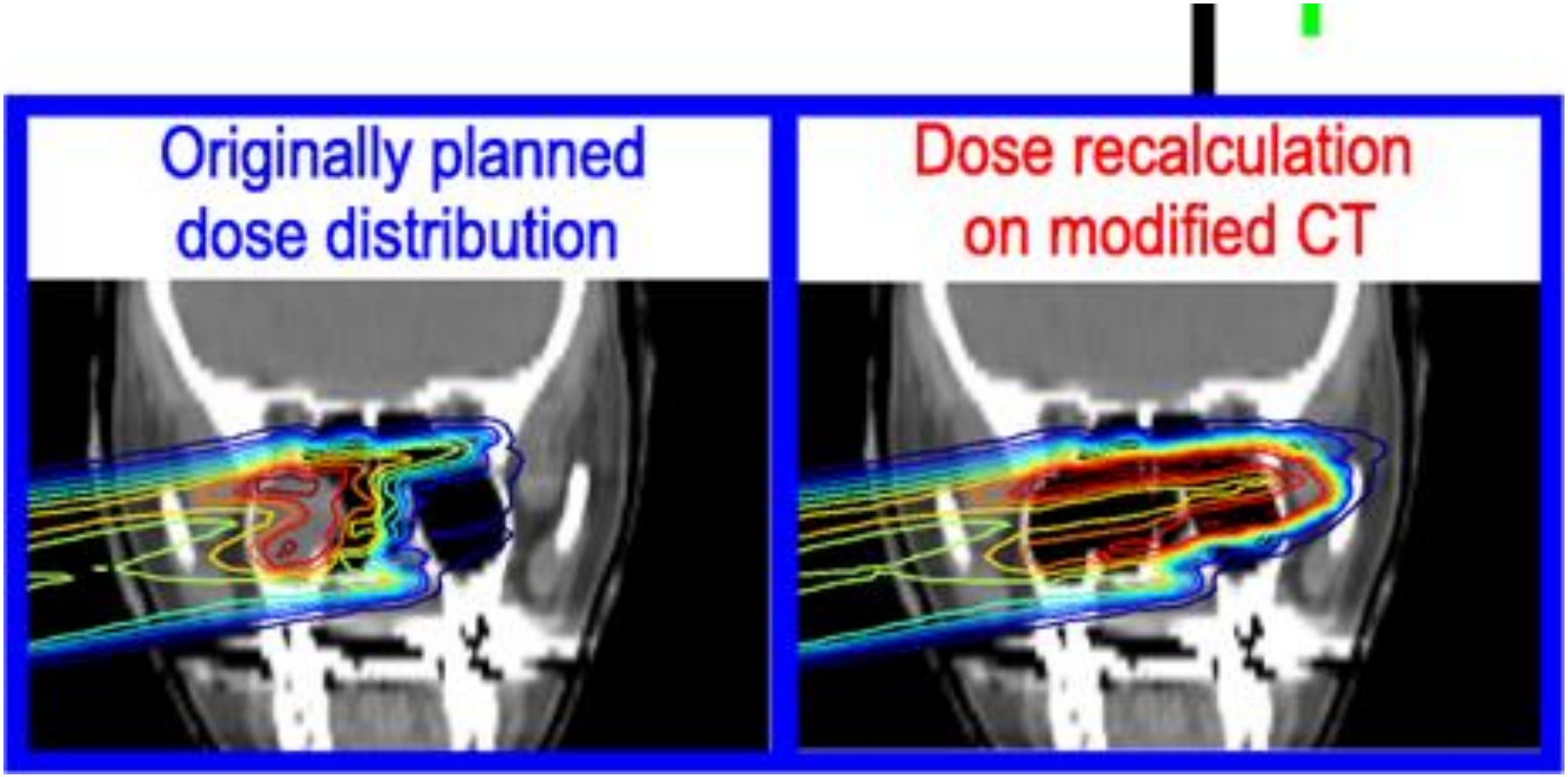
UNCERTAINTIES IN THE RANGE

ex : Effect of density changes (eg : in the target volume or in the beam path)

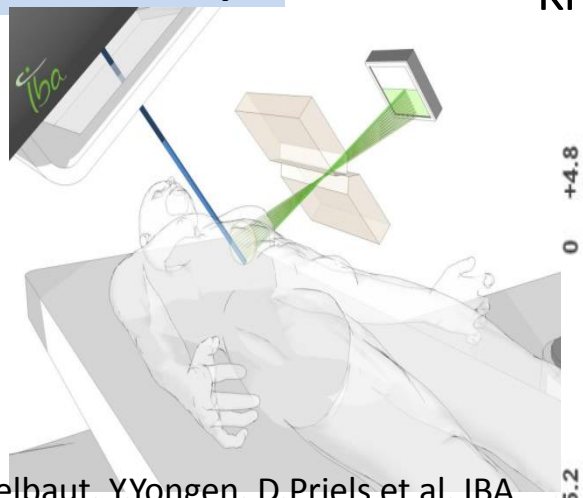


W. Enghardt et al.

Uncertainties in the range : solutions ?

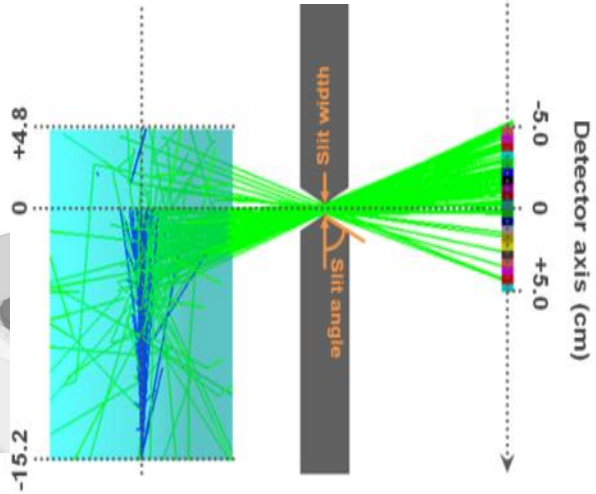
Verification of range

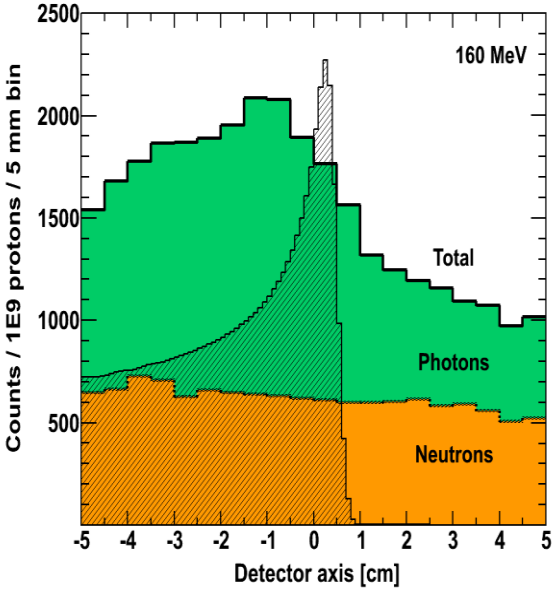
Gamma Prompt



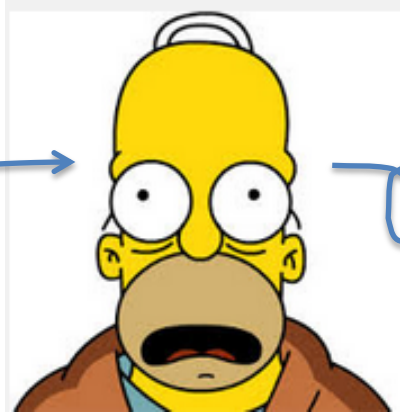
F.Stickelbaut, Y.Yongen, D.Priels et al, IBA

Knife-edge slit camera

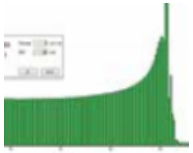




Residual range



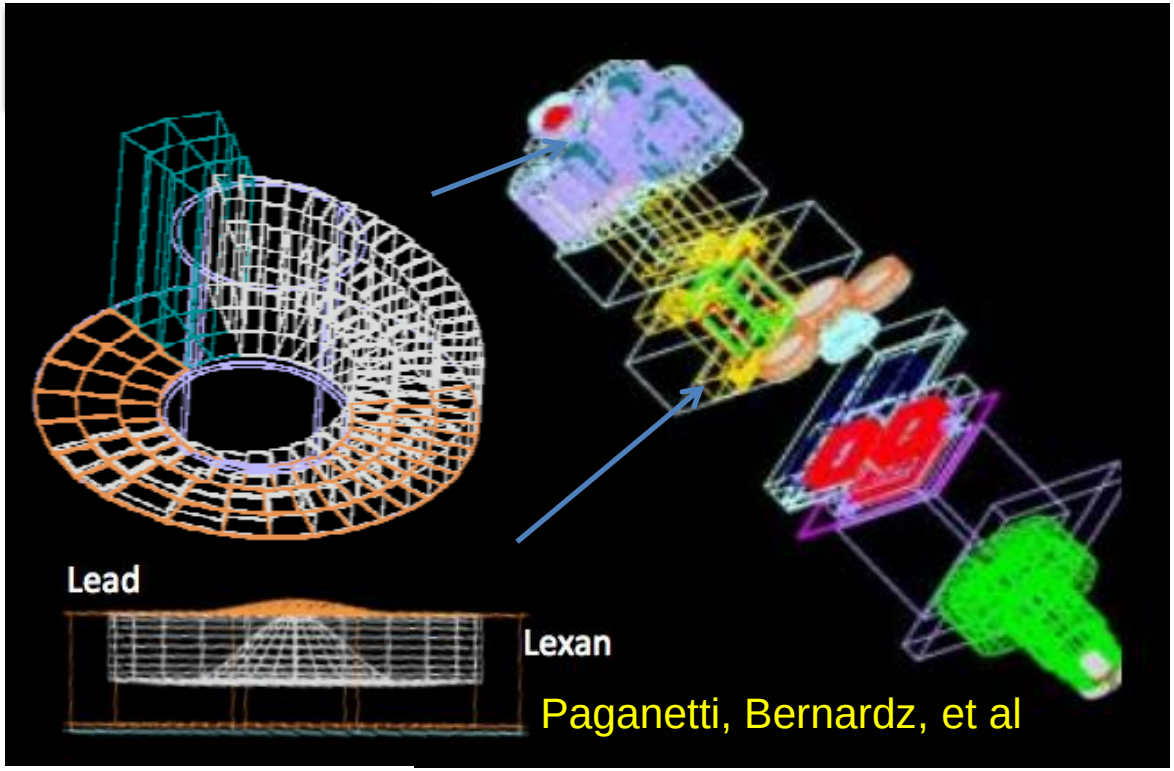
H. Simpson et al, 1987

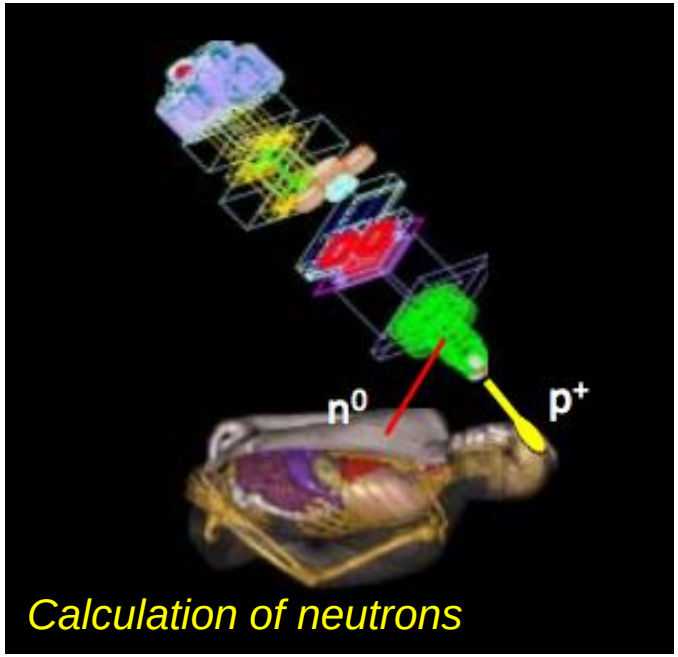


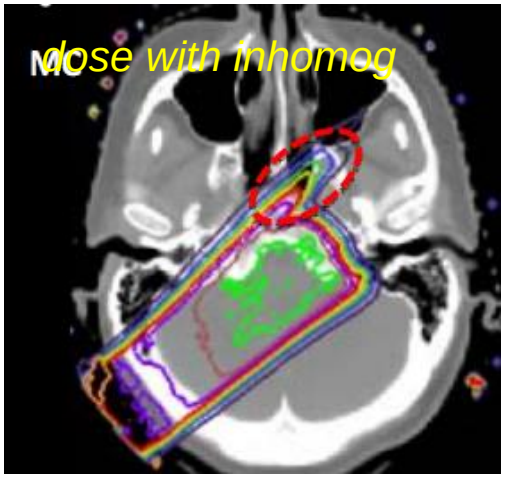
MLIC

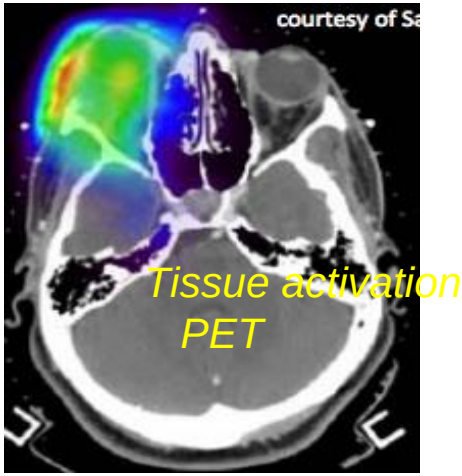
→ Vean presentacion Gabriela LLosa

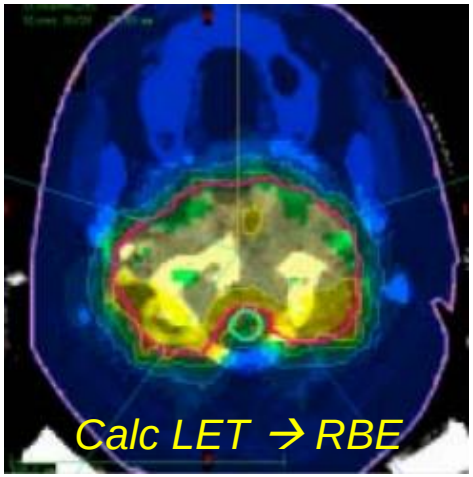
Limits in Beam models : towards Monte Carlo











Vean presentaciones de Daniel Sanchez Parcerisa y Miguel Antonio Cortes Giraldo

M.D.Anderson, Houston// Komiki et al//PTCOG

LUNG

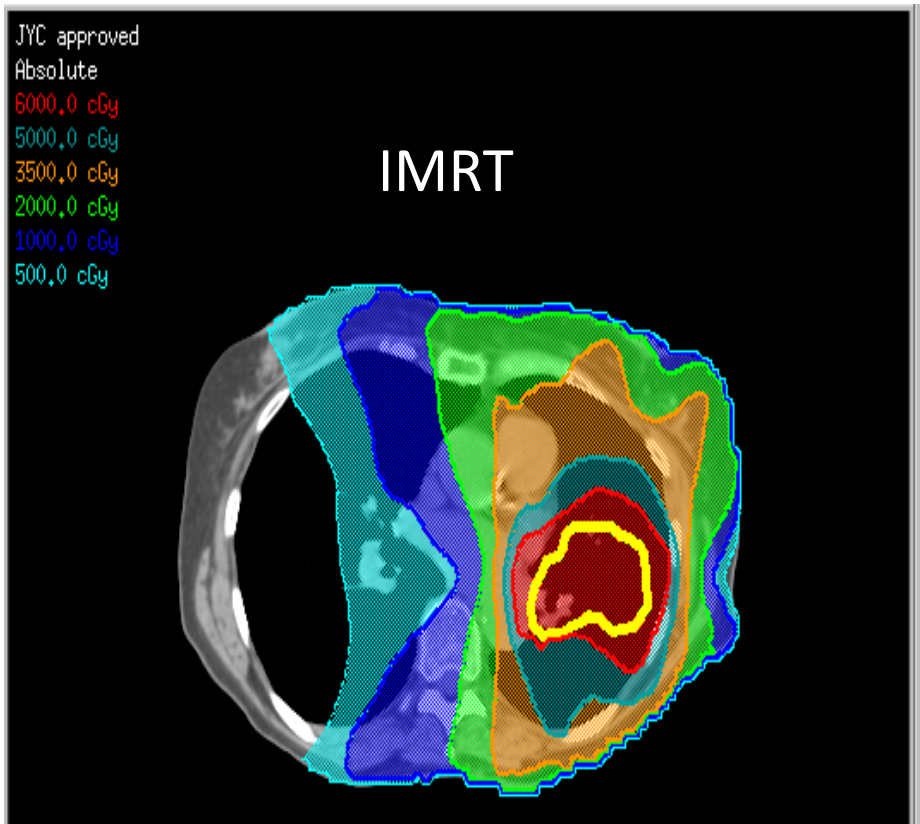
Proton dose escalation still spares more normal tissues

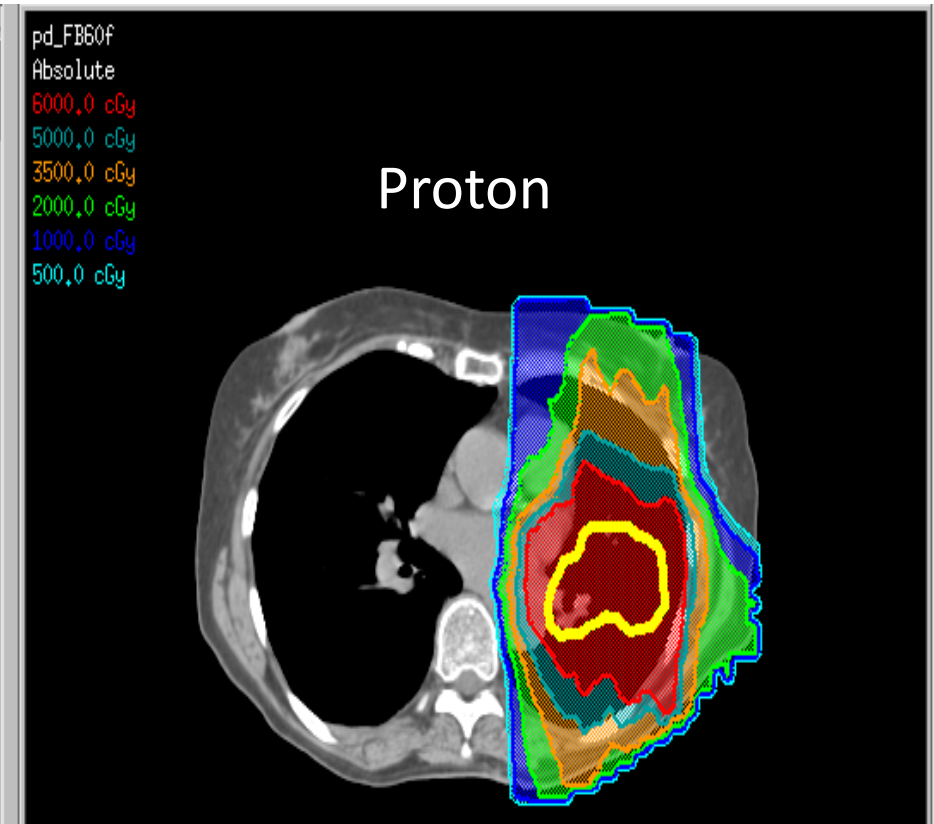
Proton 87.5 GY vs photon 60 GY in stage I

Proton 74 GY vs photon 60 Gy in stage III

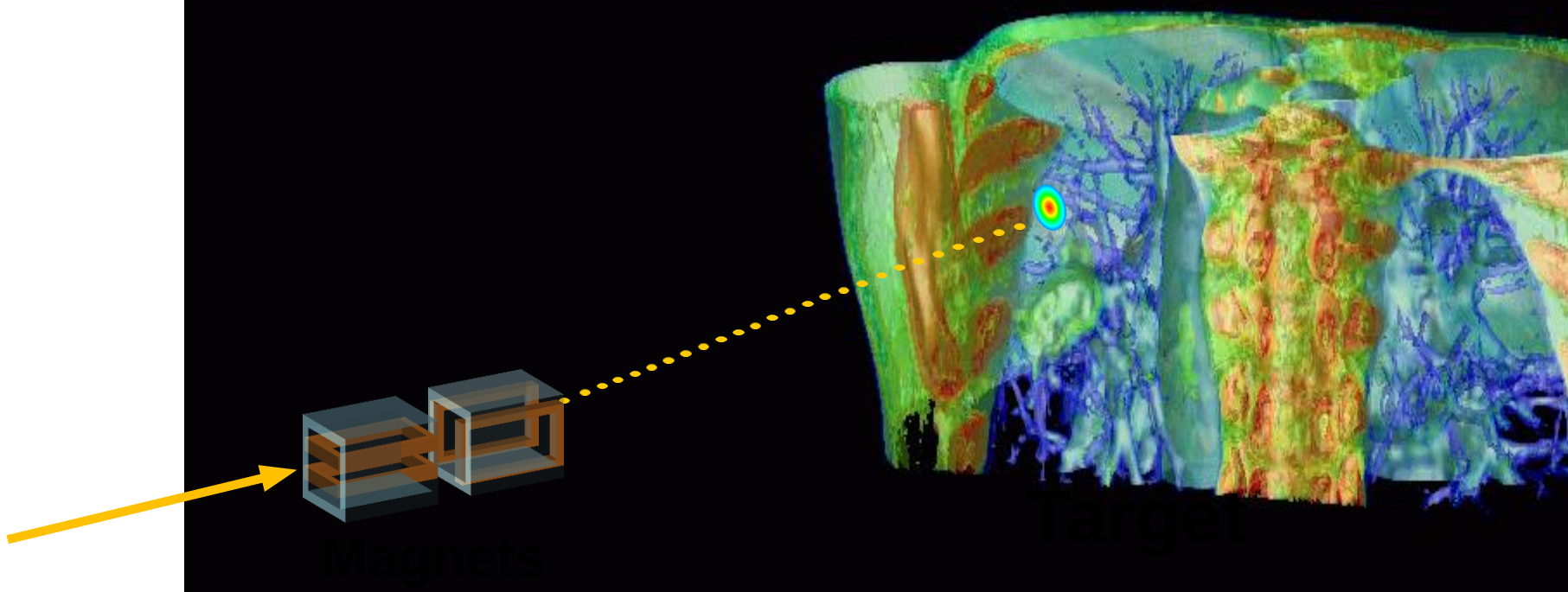
(Chang et al: Int J Rad Onc Bio Phys 65:1087-96, 2006)

Stage III





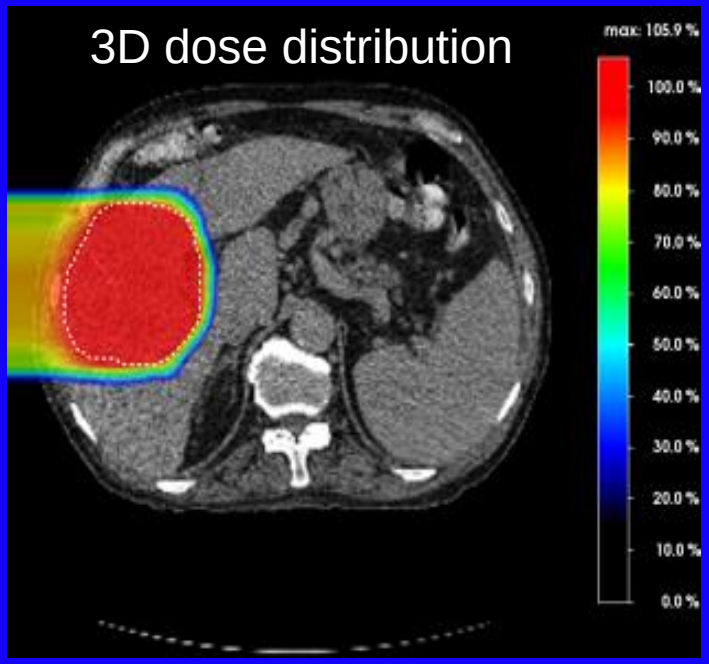
Beam Delivery : 3D Pencil Beam Scanning



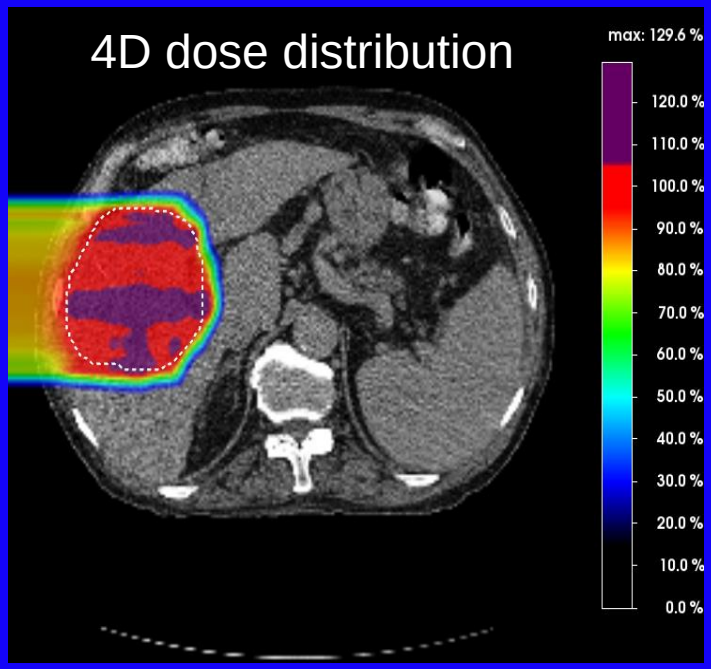
4D by Rietzel, Beam by Kamada

The interplay effect – A clinical example

Static case



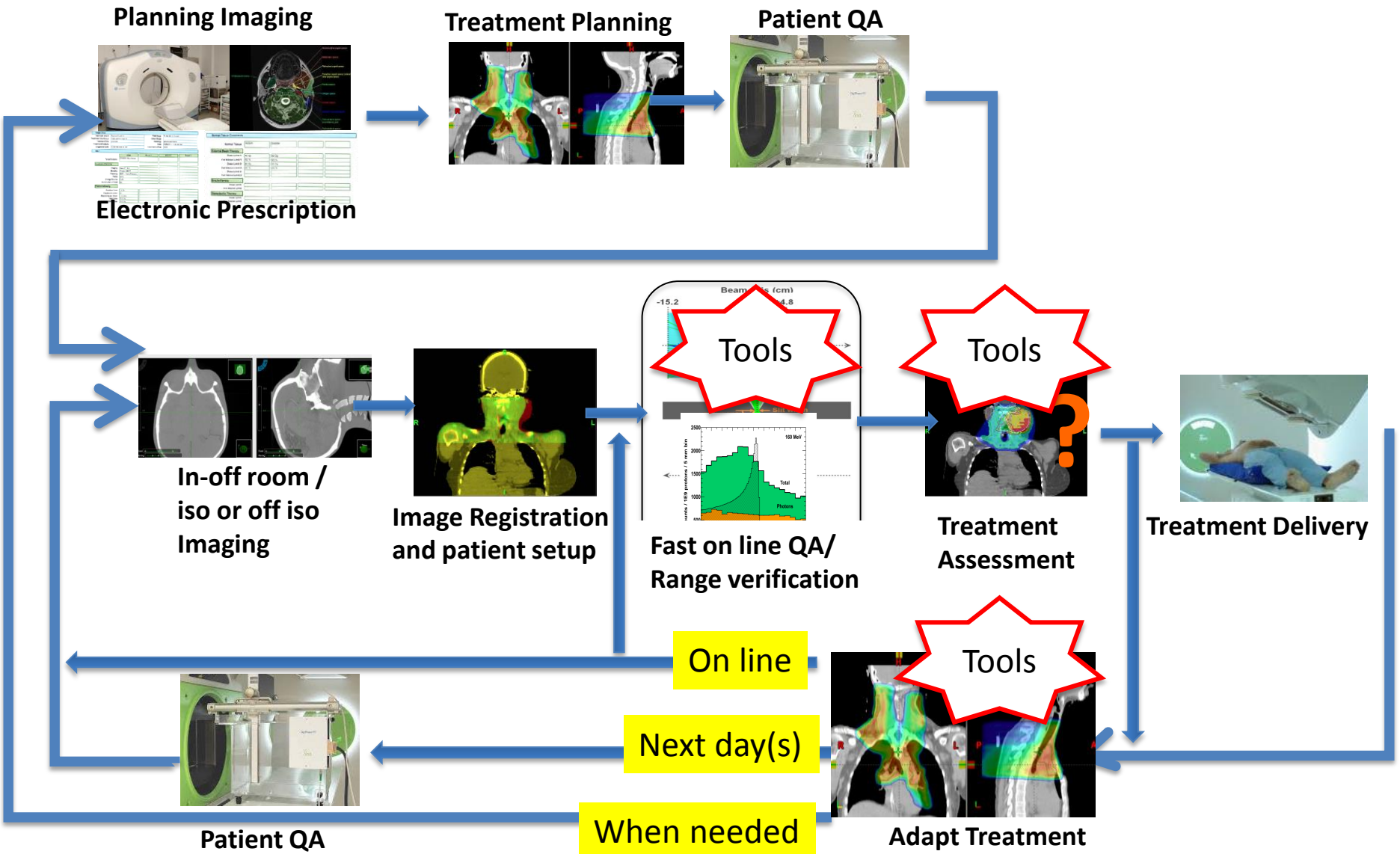
~6mm S-I motion



Boye et al, Med. Phys. 40, 0617021:11, 2013

T. Furukawa?, NIRS

adaptive workflow with pencil beam scanning



(G. Olivera, A.Mazal)

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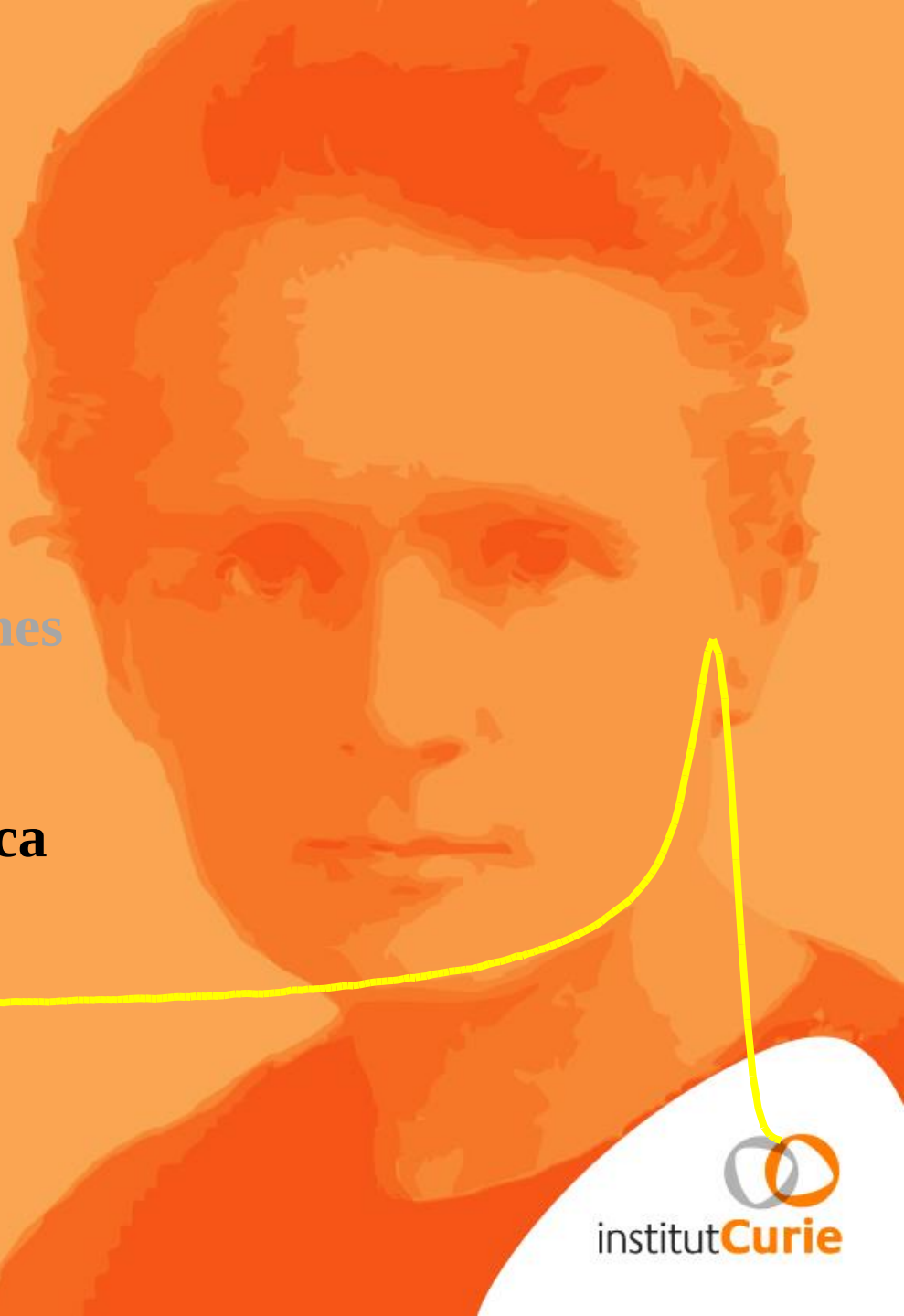

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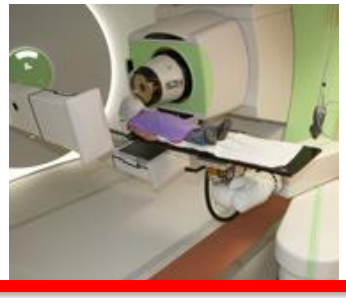
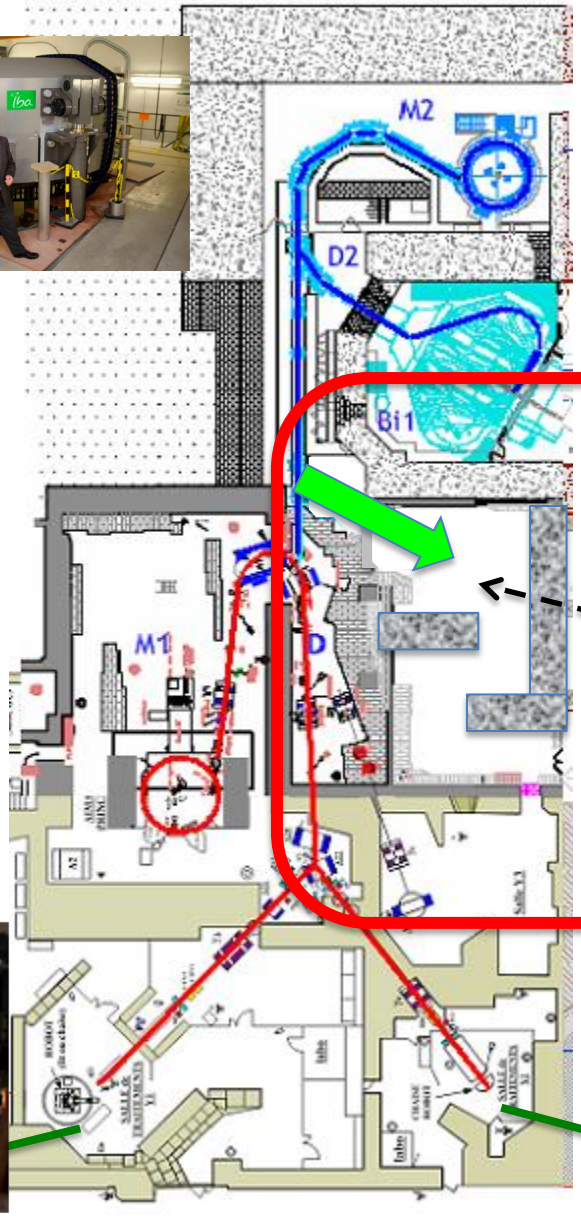
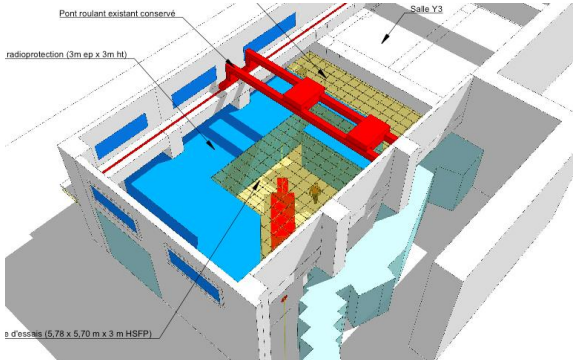
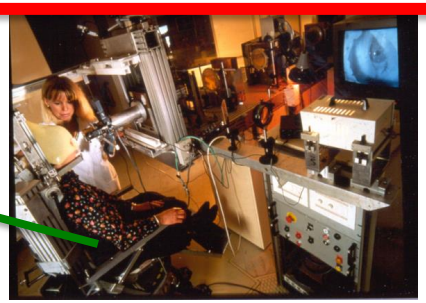
Institut Curie : Centre de Protonthérapie d'Orsay - CPO







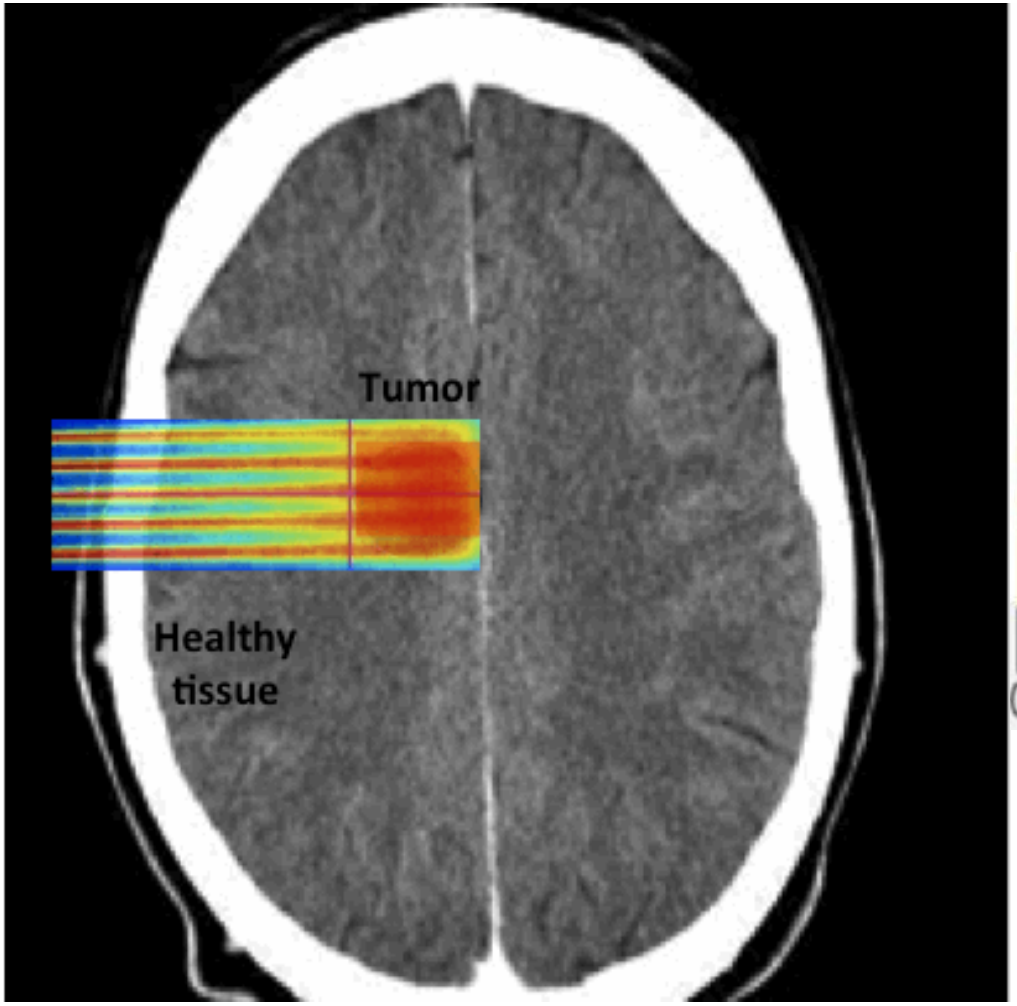
New experimental line:
France-Hadron funding



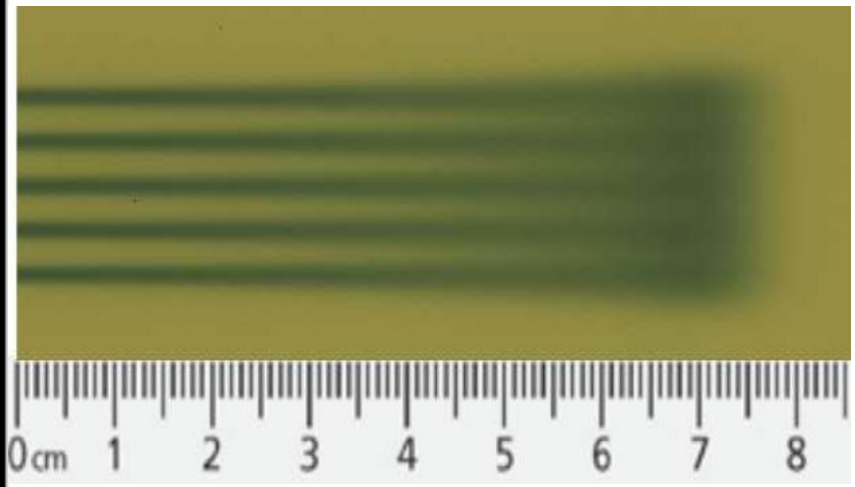
Proton MiniBeam Radiation Therapy (pMBRT)

Theoretical concept :
Y. Prezado et al., Med. Phys. 2013

Experimental beam :
CPO Mai-Juin 2014



Spatial distribution



PBS : without collimators,
High peak-valley ratio, no neutrons
Possibility to modulate intensity…

From synchrotron irradiation

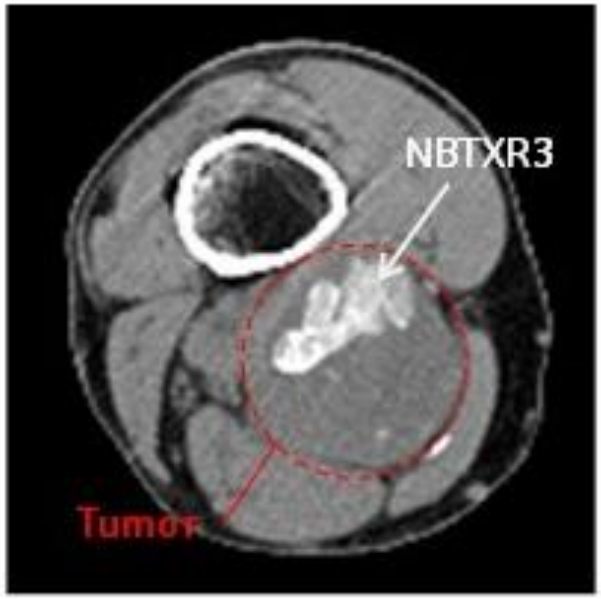
(France Hadron)

Painting target volumes injected with nanoparticles ?

Phase I : NBTXR3 + 50 Gy Rx

CT scan - 24h post IT injection- Day 2

Myxoid liposarcoma
Tumor volume: 1814.4 cc
NBTXR3 volume: 45 mL (2.5%)



ASCO, 2014
http://www.nanobiotix.com/news/release/

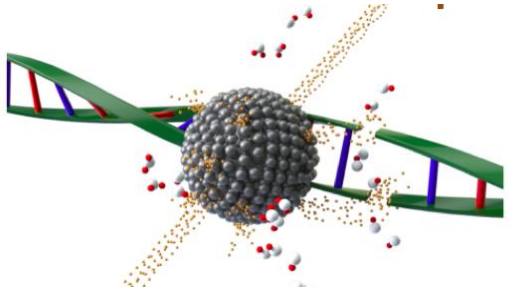
From irradiations with photons

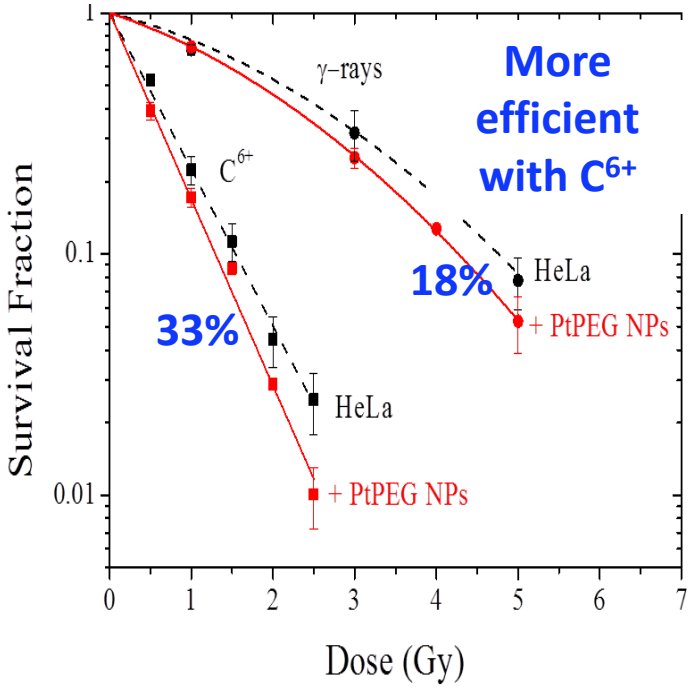
ISMO

Sandrine LACOMBE

Erika PORCEL

UNIVERSITÉ PARIS SUD



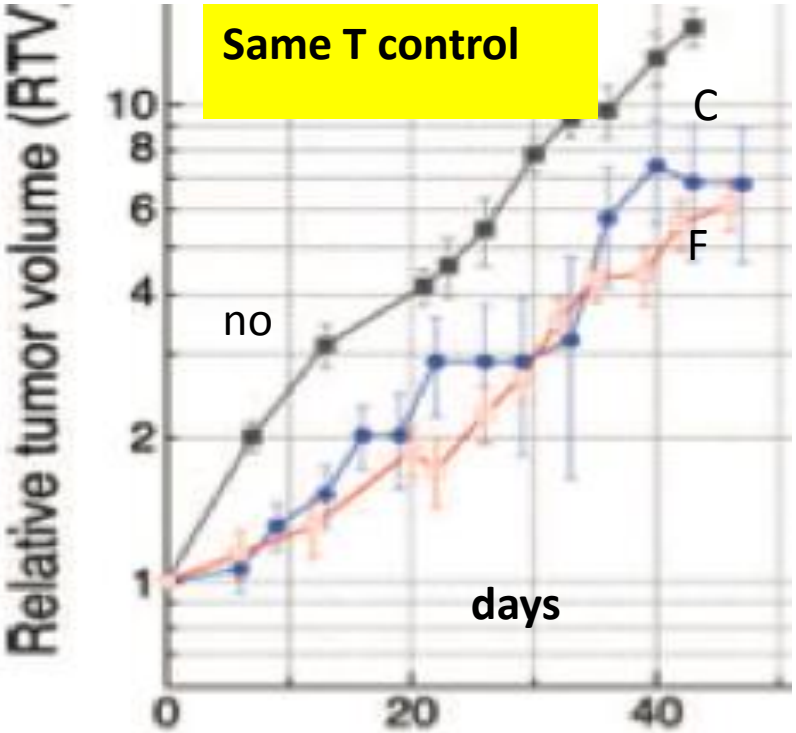


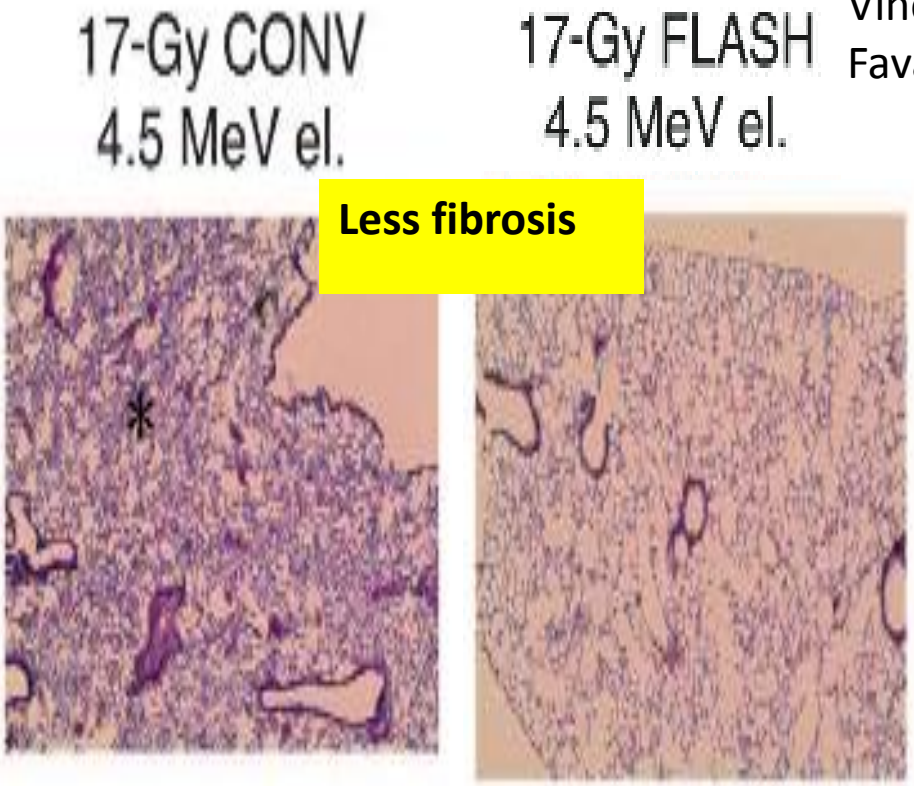
Porcel et al, 2010, 2014
Jong-Ki Kim et al // for protons 2012

"FLASH –Effect" Ultrahigh dose-rate FLASH irradiation

Sci Transl Med 16 July 2014

Vincent Favaudon





From electrons irradiations

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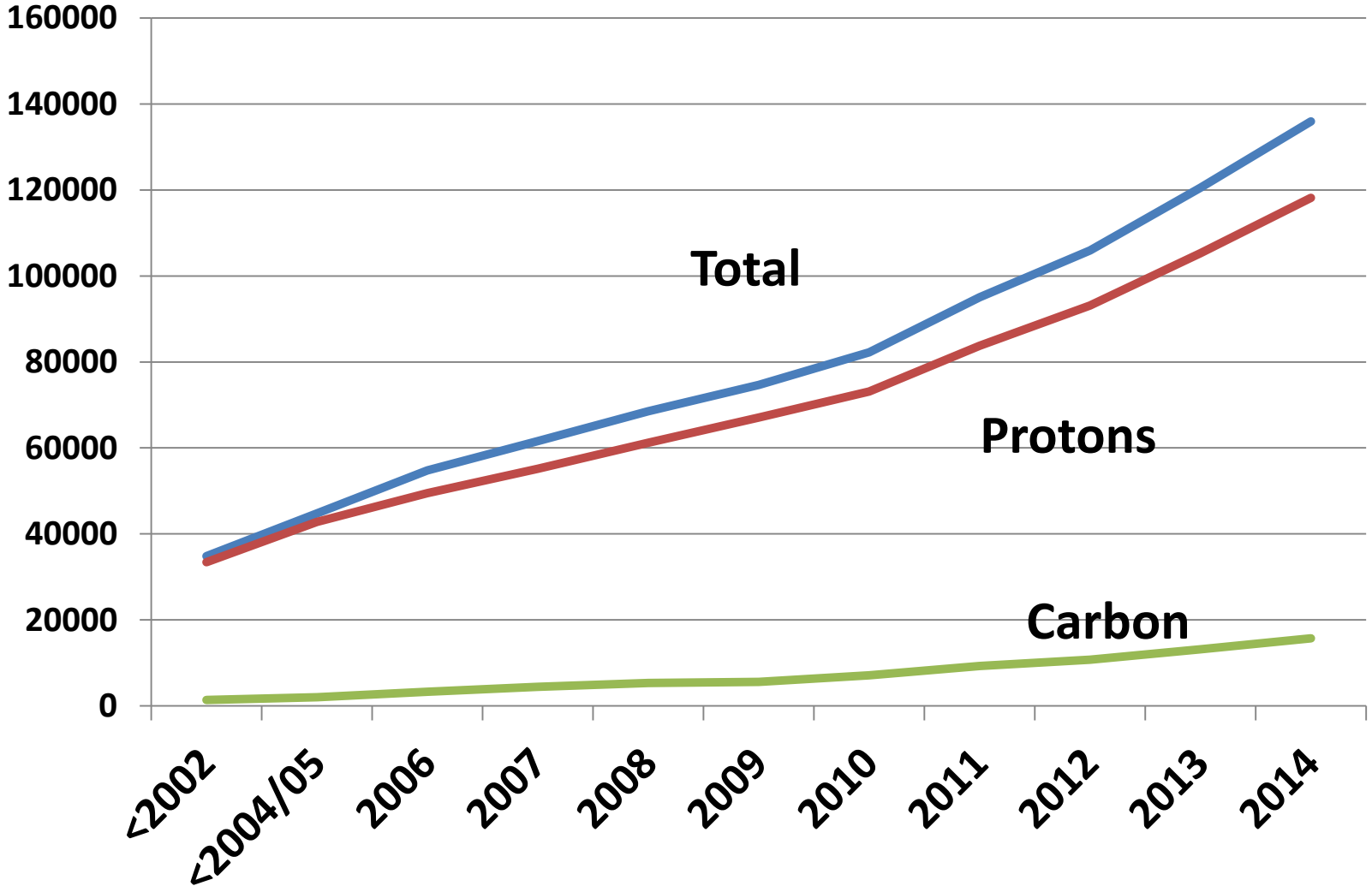
PTCOG/ M.Jermann, 2015

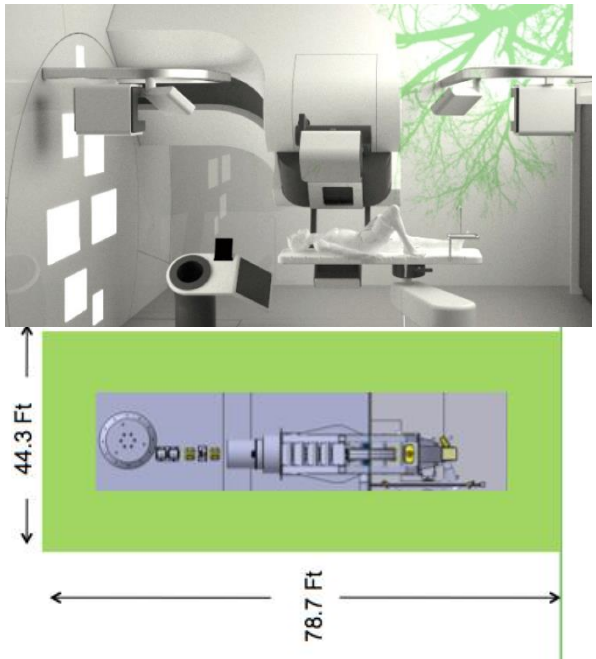
Cumulated number of Patients treated in the world



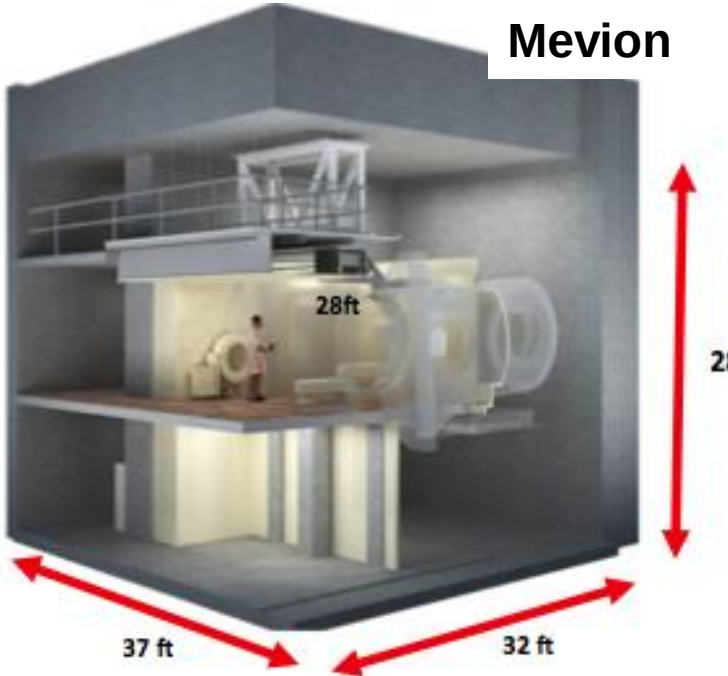
De multisalas a monosalas

100 → 50 → 20-30 M$ → ??

IBA

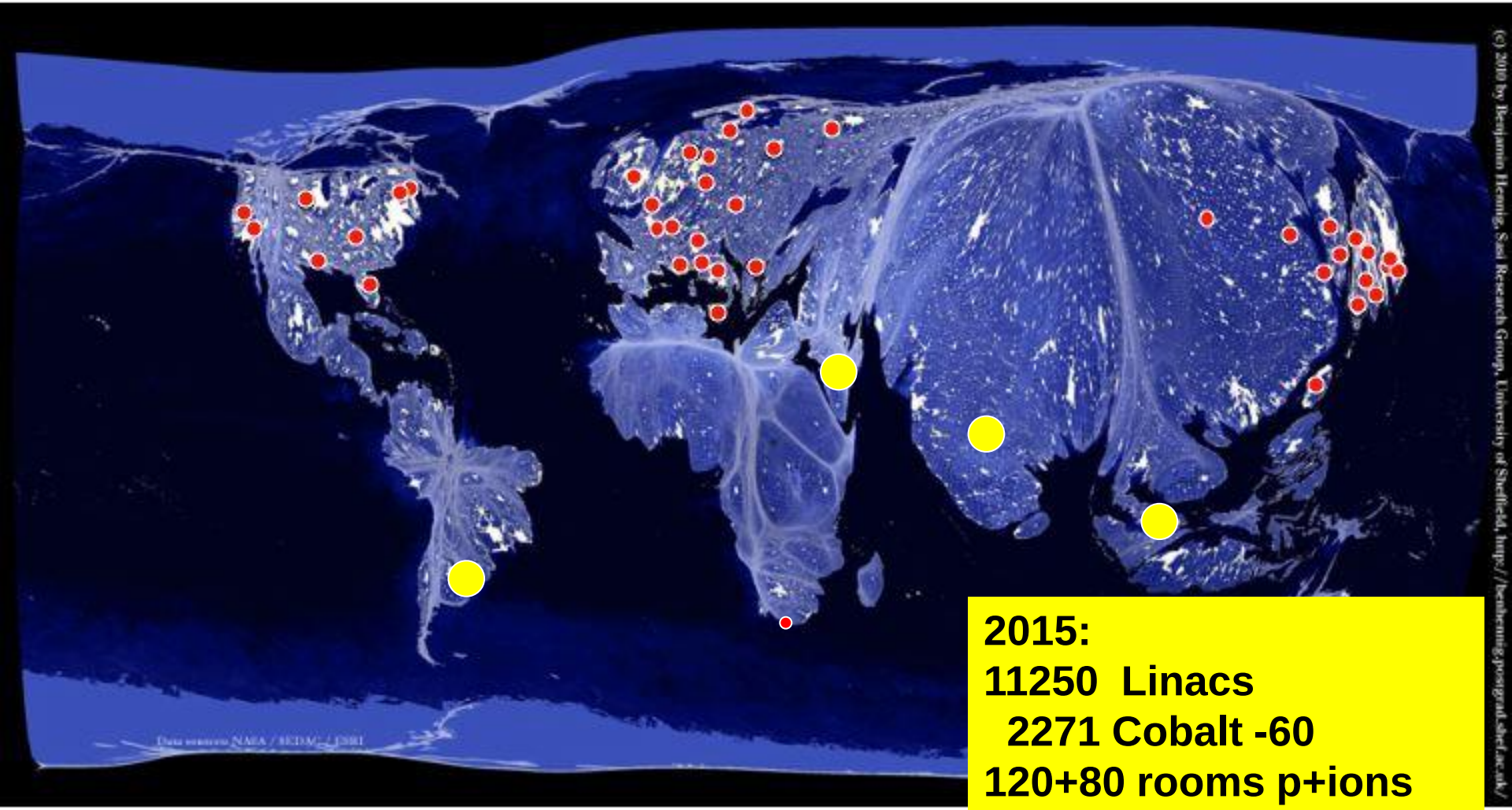


Mevion



Proton and Carbon-Ion Therapy Facilities Around the World

Area resized according to the nation's **population** (2010)



From Bill Chu, PTCOG 50, USA

Conclusiones

1. La protonterapia llegó a un estado de madurez, en sinergía con las técnicas convencionales. Los costos disminuyen, el numero de centros y de protocolos clínicos aumenta exponencialmente.
2. Hay un gran numero de temas de investigación, fundamental y aplicada (física, biología, preclínica, clínica, socioeconómica,…)
3. Dos preguntas :
    1. Cual será el rol en el futuro de los iones mas pesados?
    2. Para cuando un centro en España ?

PROTONTERAPIA
Bases y ultimas novedades

Gracias !

Preguntas ?

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