Status report and some perspectives for the Centre de Protonthérapie d'Orsay of Institut Curie

French Ukrainian Workshop @ Orsay 19-23 October 2020

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Summary

1. Histories
2. Principles of Protontherapy
3. Today’s treatment and activities at CPO
4. Some of the perspectives

5. Questions & Discussions

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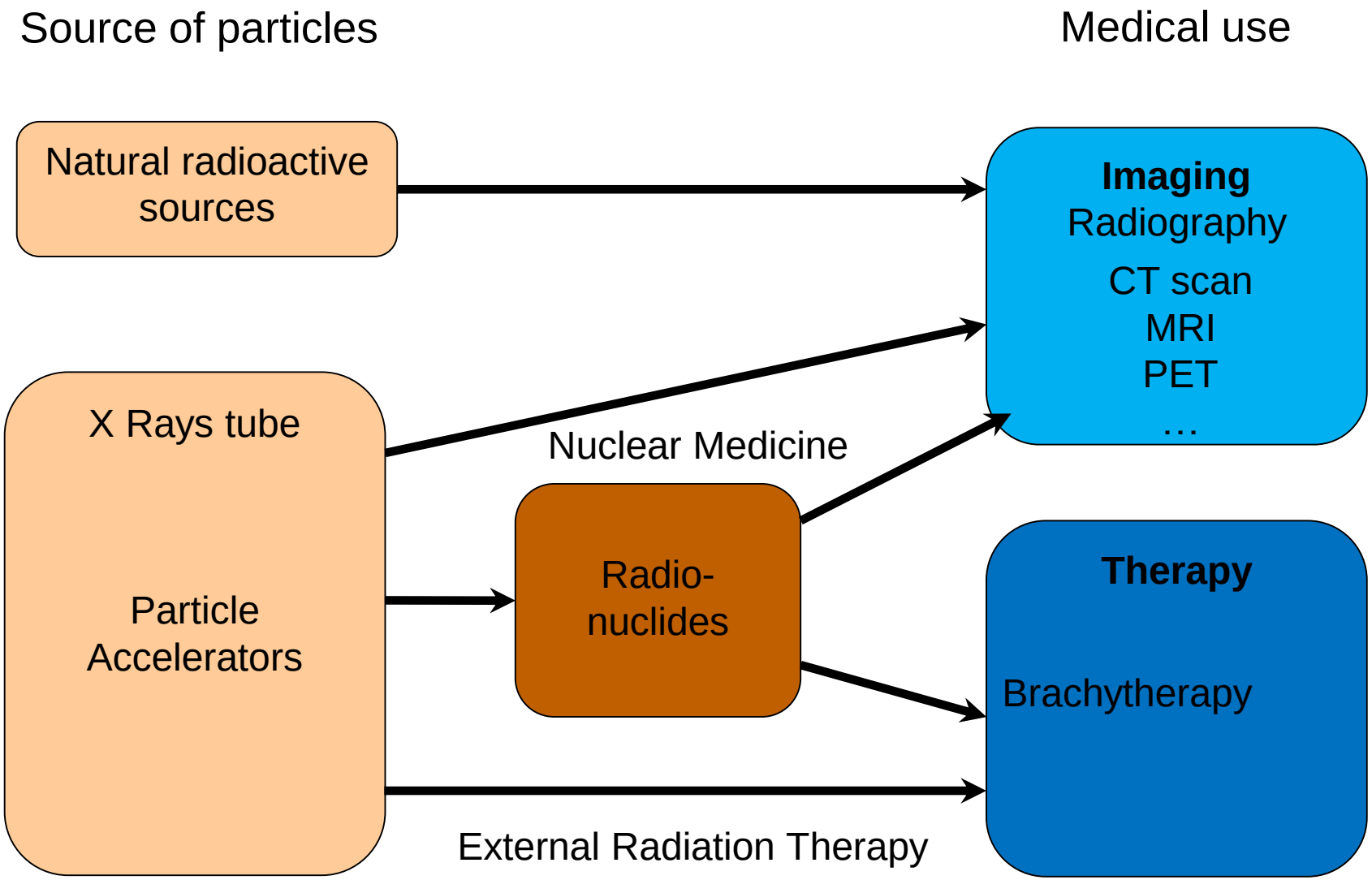
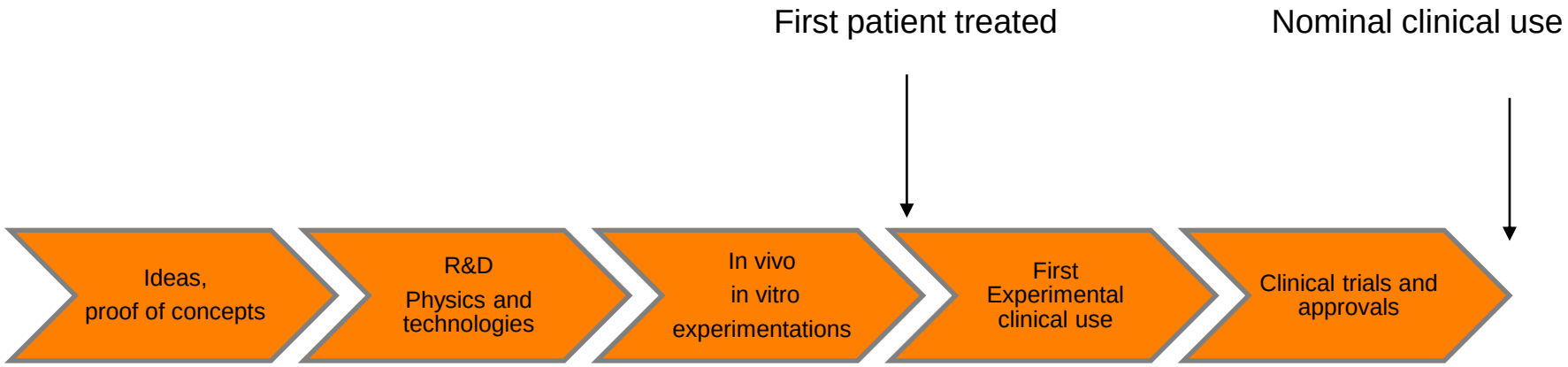

Source of particles
Medical use
Natural radioactive sources
X Rays tube
Particle Accelerators
Radio-nuclides
Nuclear Medicine
External Radiation Therapy
Imaging
Radiography
CT scan
MRI
PET
…
Therapy
Brachytherapy

Life-cycle of a new treatment modality



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Histories

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université
PARIS-SACLAY
IJCLab
Irène Joliot-Curie
institutCurie
(building 101)
institutCurie
Centre de Recherche
Centre de Protonthérapie

Marie Curie

I+F Joliot Curie

1957

Orsay Campus

1900 — 1950 — 2000 — 2020

Cyclotron
Collège de France
Paris

Building
101

Synchro-
cyclotron
156 MeV
Philips

Synchro-
cyclotron
200 MeV
IPNO

Cyclotron
230 MeV
IBA

IJCLab
Irène Joliot-Curie

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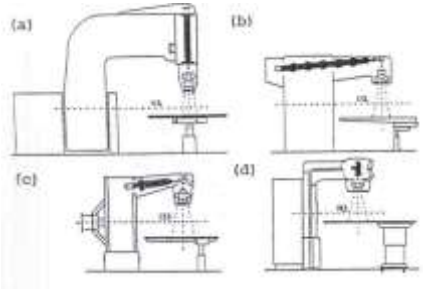
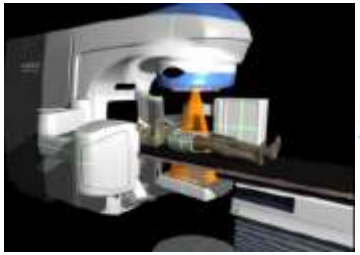
Radiation Therapy

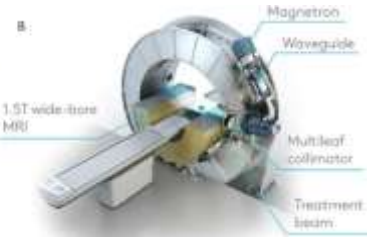
Chicotot



First « Linacs » machine



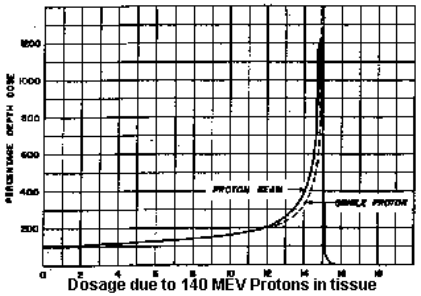
Modulation intensity



IRM-Linac

1900 — 1950 — 2000 — 2020

H. Bragg



Bragg Peak

R. Wilson

Berkeley Team

1st industrial PT facilities

Proton Therapy

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Principles of Proton Therapy

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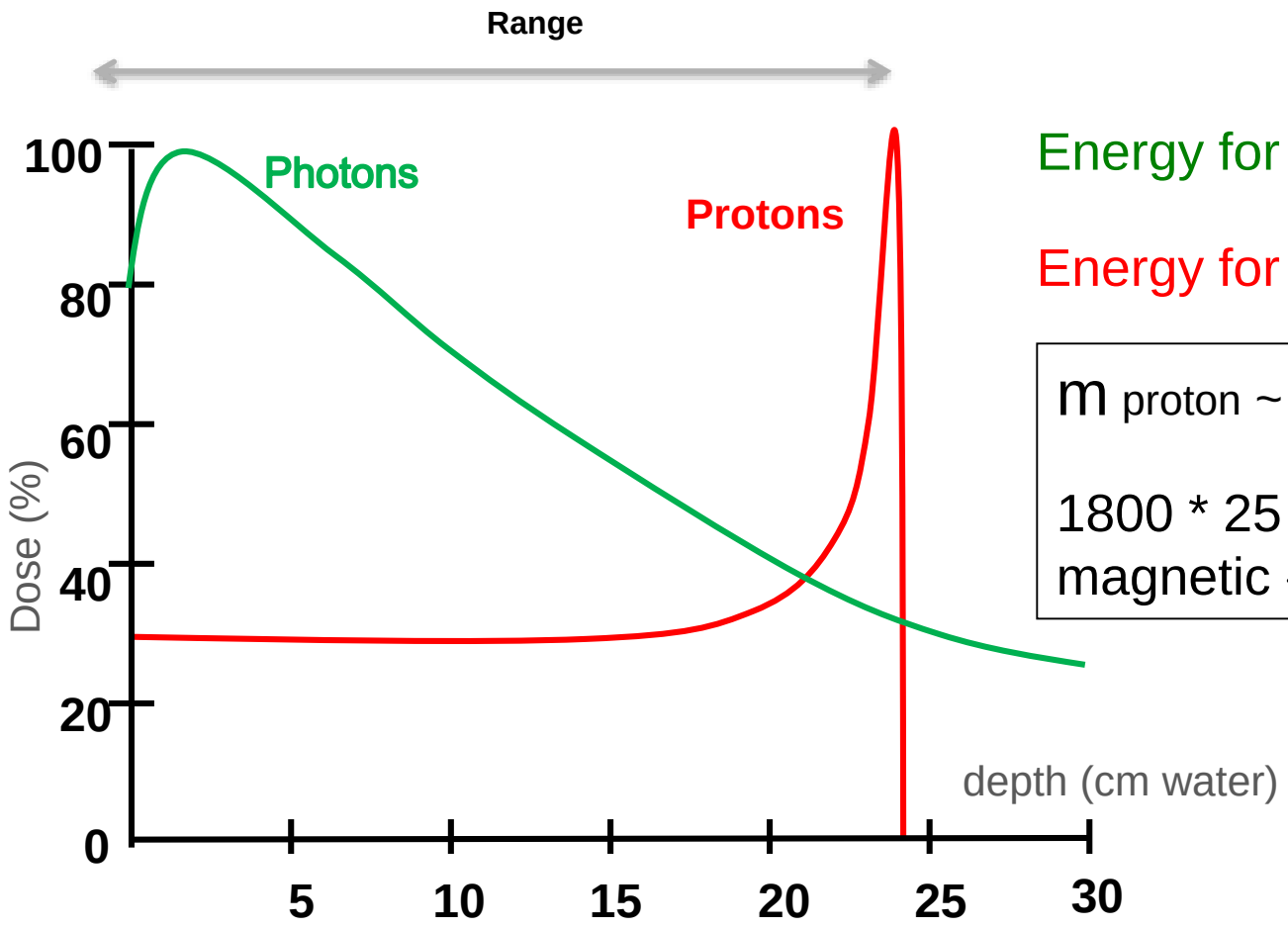
Main rationale for protontherapy: the distal curve, Bragg peak



Energy for photons ~ 10 MeV

Energy for protons ~ 250 MeV

m proton ~ 1800 m electron

1800 * 25 = **45 000 times** of magnetic « power » required !

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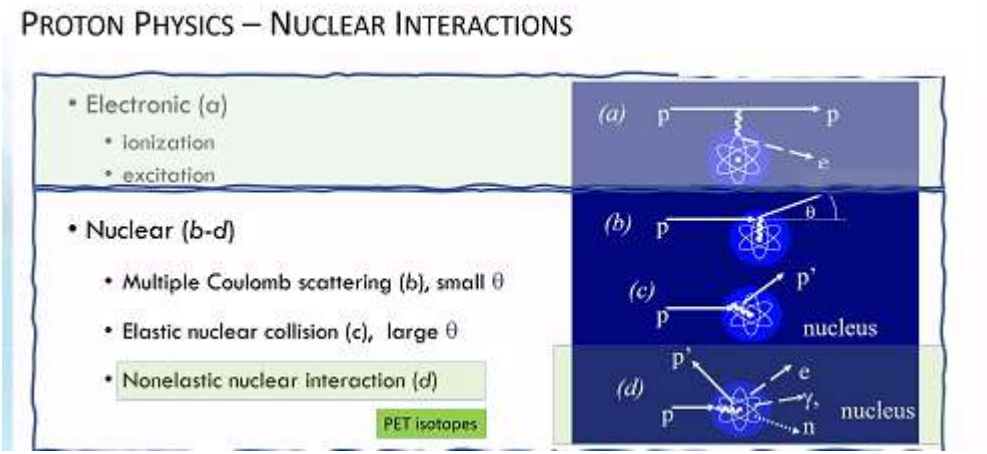
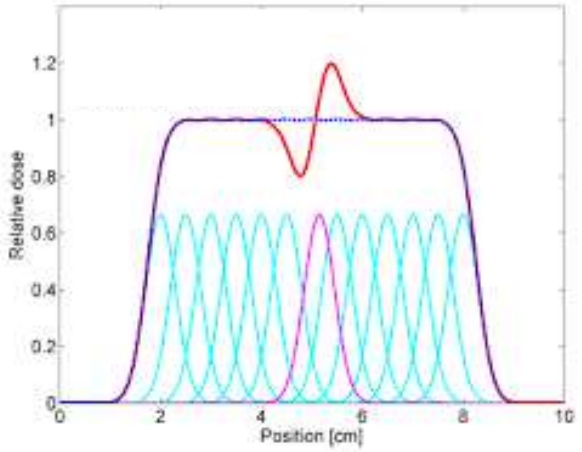
Principles of protontherapy (distal and lateral penumbraes)





Potential effect of motion

Beth –bloch formulae

$$(dE/dx) = \frac{4\pi z_{eff}^2 e^4 (N_A Z)\{\ln(2mv^2/I(1-\beta^2)) - \beta^2 - \Sigma(Ci/Z)\}}{A m_e v^2}$$

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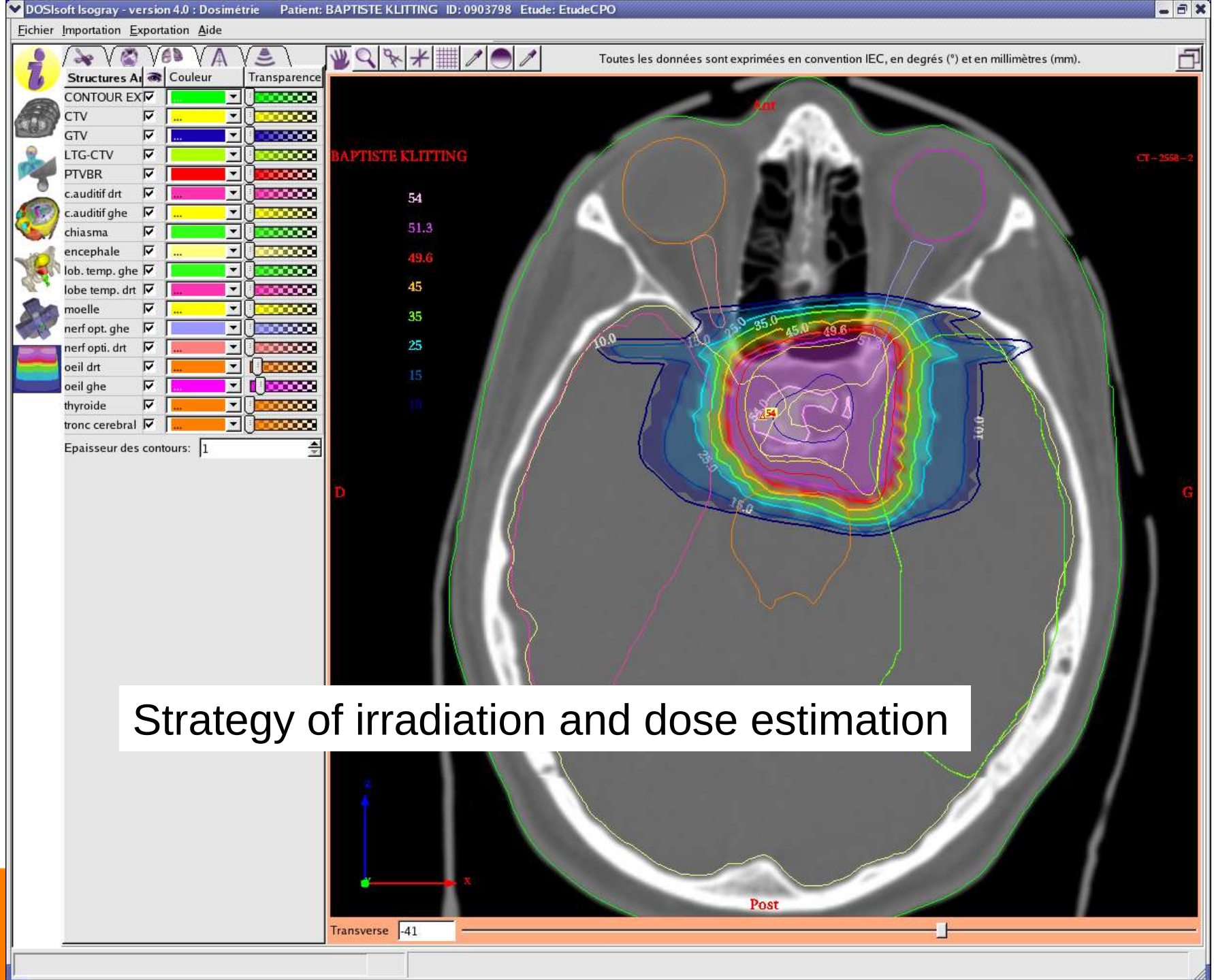
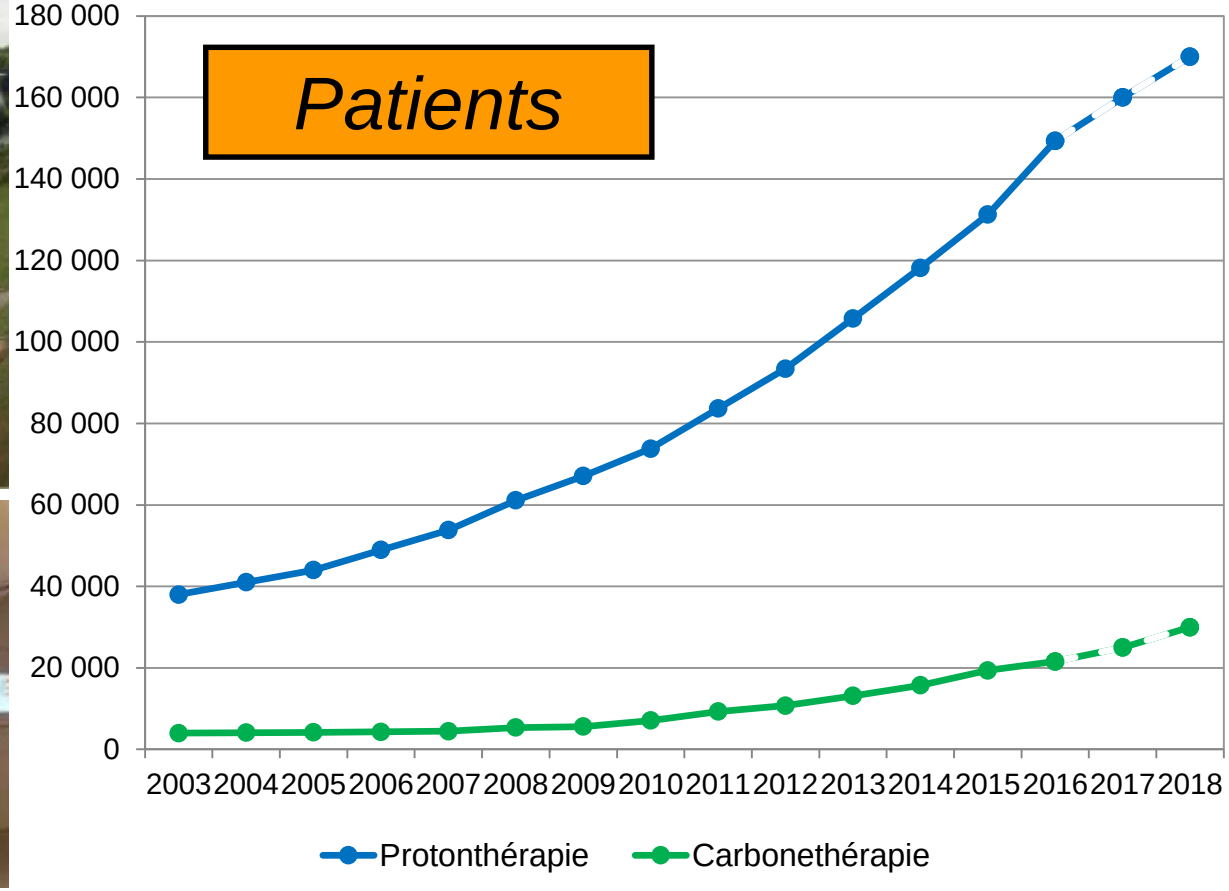


Strategy of irradiation and dose estimation

Present statistics

in 2018
105 facilities

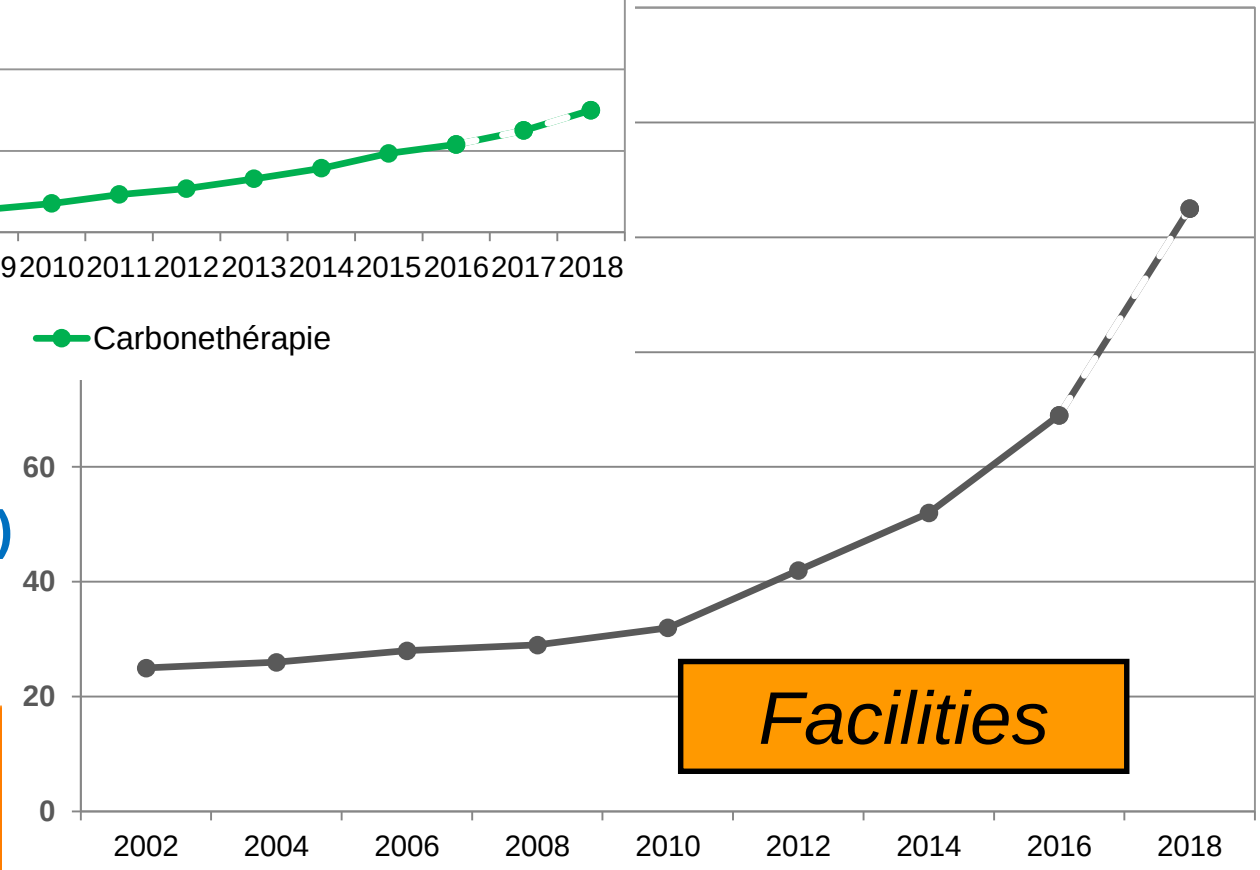
Patients

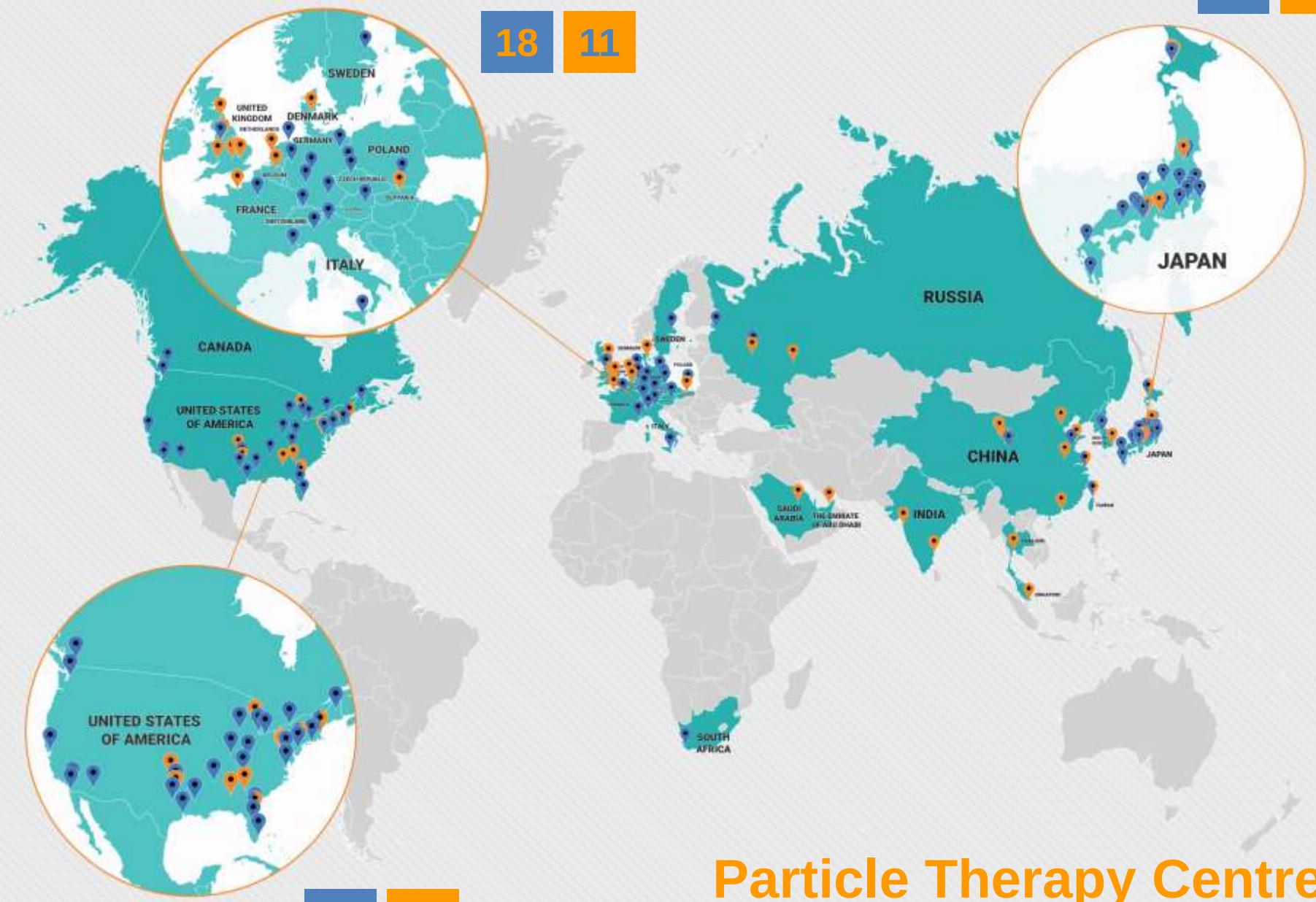


Protontherapy
170.000 pts (~0, 5 % RT)

Carbon-therapy
30.000 pts

Facilities





Particle Therapy Centres

FUNCTIONAL CENTERS UNDER CONSTRUCTION

Today’s treatments at CPO

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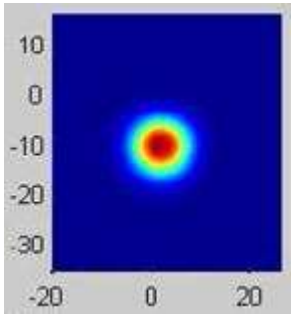
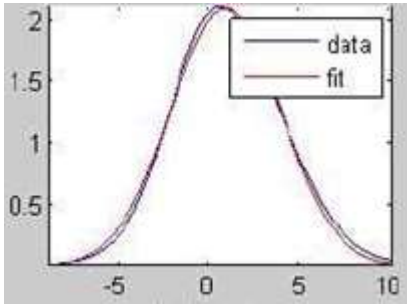
Pencil Beam

Spot size from 3 to 8 mm (sigma)





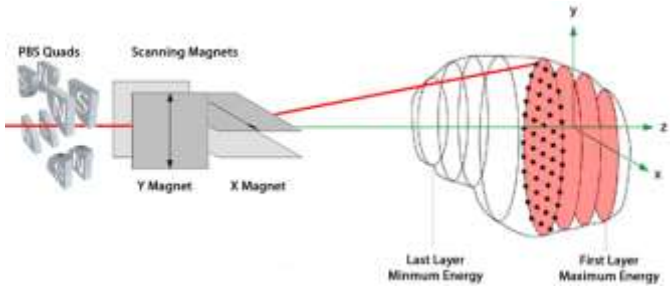
Scanning

Scan in both direction to cover the tumor

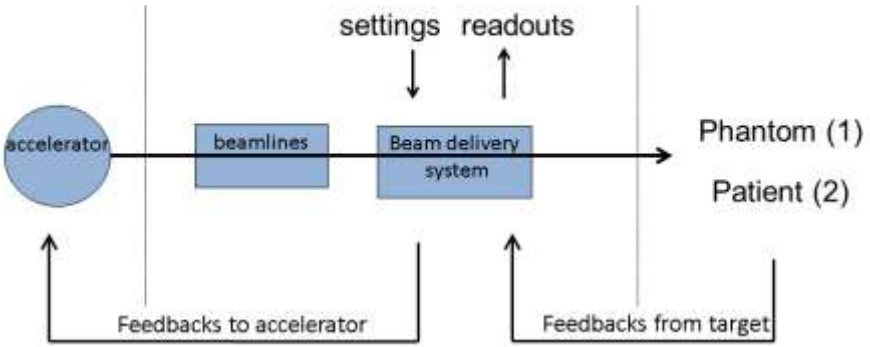
1 spot : 2,5 ms min

Transition beetween 2 spots : 2 ms

1 liter in less than 1 minute



Beam delivery systems



1 session of treatment: ~20 min/patient, 1 min of beam, 2 Gy delivered (~ 35 sessions / patient)

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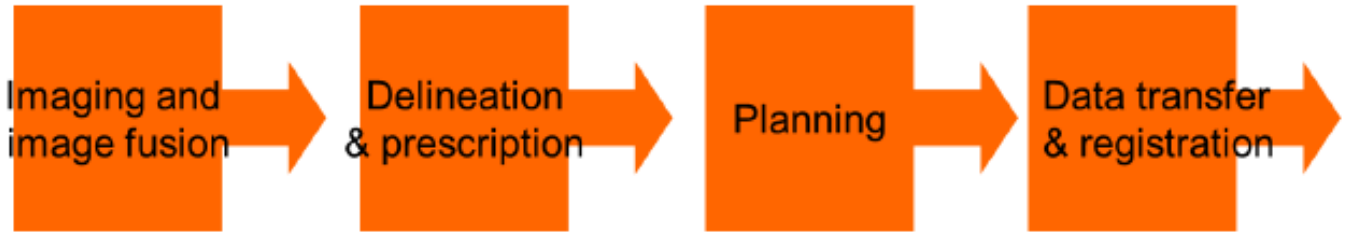
Treatment planning

-General process

- Acquisition of imaging data (CT, MRI, PET), registration
- Conversion of CT values into relative stopping power or mass densities
- Delineation of regions of interest
- Physical basis, proton beam orientations and calculation
- Design of each beam
- Optimization of the plan and validation
- Quality assurance, fabrication of patient specific apertures or boluses



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Features of activities at CPO

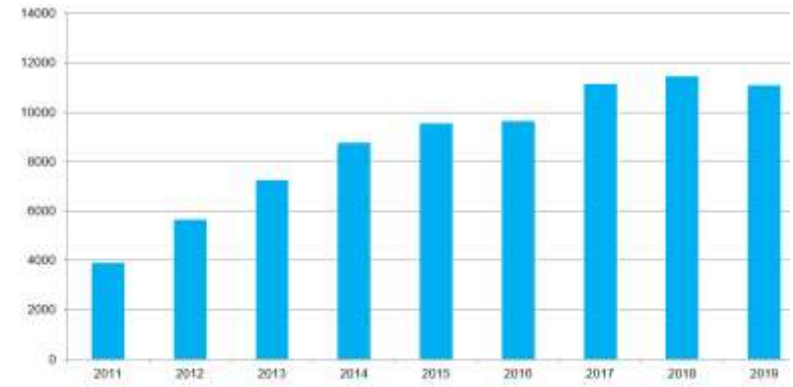
- 3 treatment rooms
- Technical hours 6:30 - 19h30
- Patients: 8h00- 18h30
- 40-50 patients / day

Staff: 50 people

- Medical doctors, medical physicist
- Therapists, medical Secretaries, Admin
- Technicians and Engineers

- Maintenances: Monday-Thursday early morning + some saturdays,
- 4 Fridays OFF /year (no long shutdown)

nb of sessions / year



années	2011	2012	2013	2014	2015	2016	2017	2018	2019
nb séances	3904	5658	7253	8757	9567	9837	11141	11444	11090
report 3 salles	2.8%	3.4%	1.4%	0.9%	2.2%	3.6%	1.6%	1.0%	2.2%
séances jour J	97.2%	96.6%	98.6%	99.1%	97.8%	96.4%	98.4%	99.0%	97.8%

~ 98% of patients treated the day scheduled

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Top 4 of today's issues

- **Preventive maintenance – « skilled » Monitoring**
- **Escalation process**
- **Range uncertainties**
- **Imaging – quality and adaptative approach**

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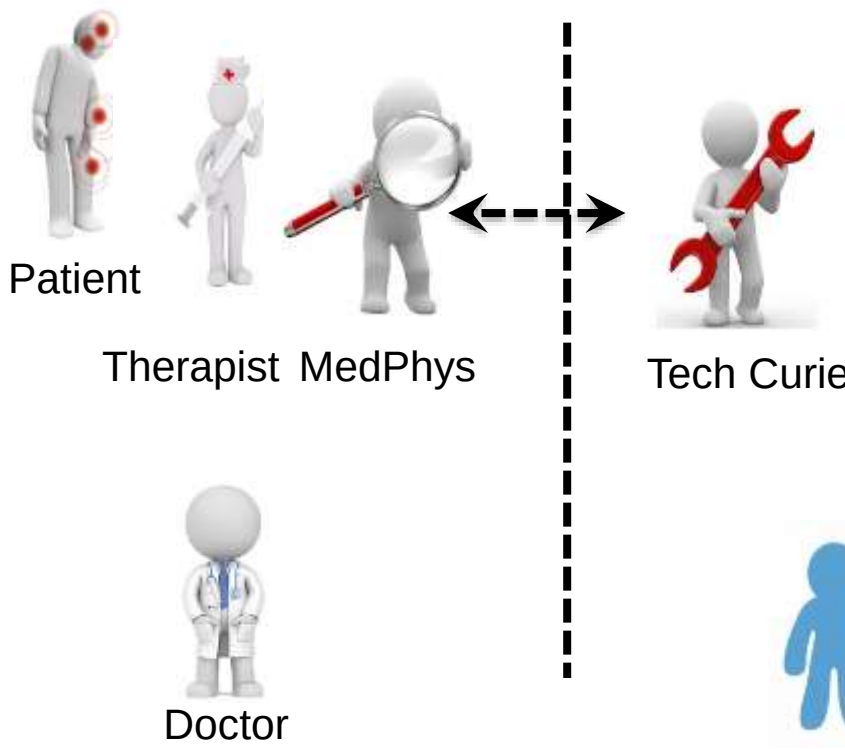
Example of short–term issues: interaction&escalation

Medical Technical



- Timing and protocols for escalation
(2 min - 10 min – 30 min- 1h- 2hour-1day)

- Protocol of interface **1-1** (simple, no affect)
Level of trust in the diagnosis and duration

-

- Define who is the **owner** of the affair
- Critical Components **Identified**
- Documentation- Safeties

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Perspectives

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Masse (tonnes)

300

200

100

C isochrone
IBA C230
220 t
Ø 4,3 m

B_{max} = 2,2 T

B_{max} = 5,6 T

B_{max} = 10 T

B_{max} = 3 T

C iso. S-C
VARIAN 250
90 t
Ø 3,1 m

Syn-C S-C
IBA S2C2 230
50 t
Ø 2,5 m

Syn-C S-C
MEVION S250
20 t
Ø 1,8 m

The challenge
to shrink the dimension
of the accelerators.

And to decrease the
cost of treatment

Perspectives for Centre de Protonthérapie

- **Clinical** activities – more patients –more publications – more localizations

- Smooth **operations** and reliability – Management of **obsolescences**

- Intensification of **Experimentations** (evening and shifts)

- Investigation for **innovations** modalities

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Experimental Irradiation conditions at ICPO

What and when

✓Physics and radiobiology experiments
✓Afternoon, evenings or saturdays depending on the research project
✓Availability: 200h/year (at least)

How

✓Engineers and medical physicists support in the design and preparation of the experiment
✓ Possibility to store physics equipments in a specific room
✓ Radiobiology experiments can be performed with the support of RadExp plateform (IC – Research Center, see next slide)
✓ Availability of cells and animal models (Research Ministry dedicated authorizations),
✓ Radioprotection follow up
✓ Beam time and preparation are available under payment

Contact: comex.cpo@curie.fr

(A. Patriarca , L. De Marzi)

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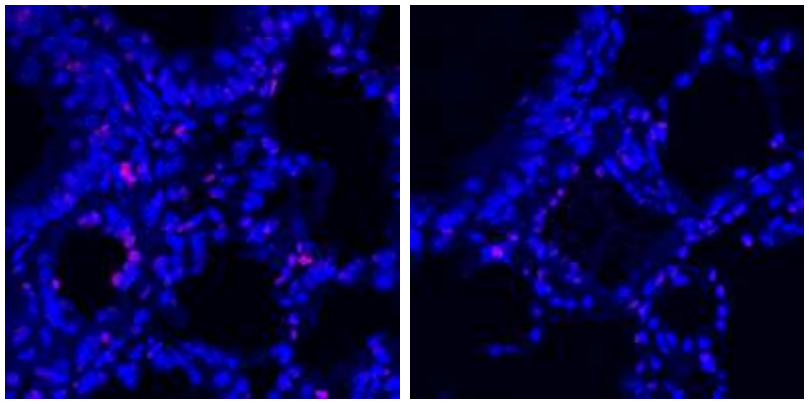
FLASH radiotherapy

dose delivery time << 500 ms and dose rate >> 40 Gy/s



IC Inserm U1021/UMR 3347CNRS

RESEARCH ARTICLE

RADIATION TOXICITY

Ultrahigh dose-rate FLASH irradiation increases the differential response between normal and tumor tissue in mice

Vincent Favaudon,[1,2*] Laura Caplier,[3†] Virginie Monceau,[4,5‡] Frédéric Pouzoulet,[1,2§] Mano Sayarath,[1,2¶] Charles Fouillade,[1,2] Marie-France Poupon,[1,2‖] Isabel Brito,[6,7] Philippe Hupé,[6,7,8,9] Jean Bourhis,[4,5,10] Janet Hall,[1,2] Jean-Jacques Fontaine,[3] Marie-Catherine Vozenin[4,5,10,11]

(V. Favaudon, C. Fouillade, S. Heinrich, L. De Marzi, A. Patriarca, P. Verrelle, et al…)

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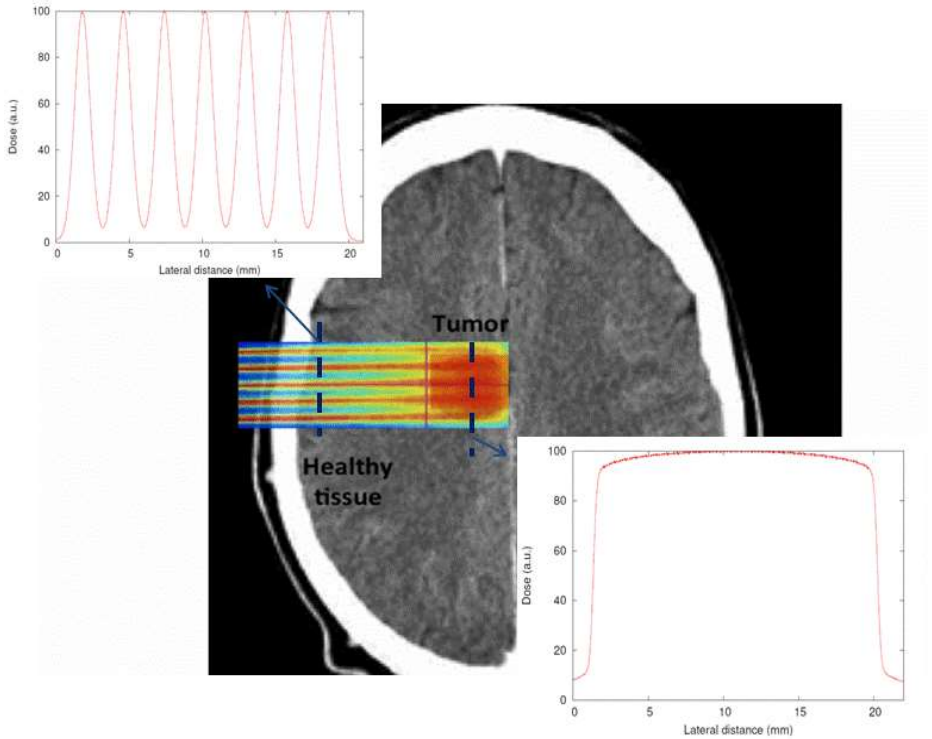
Mini beam Radiation Therapy



The healthy tissues would profit from the spatial fractionation of the dose: a lateral dose profile (peak and valleys pattern) at 3 cm depth is show on the left. A homogenous dose distribution is obtained in the tumor.

(Y. Prezado, A. Patriarca, L. De Marzi, et al)

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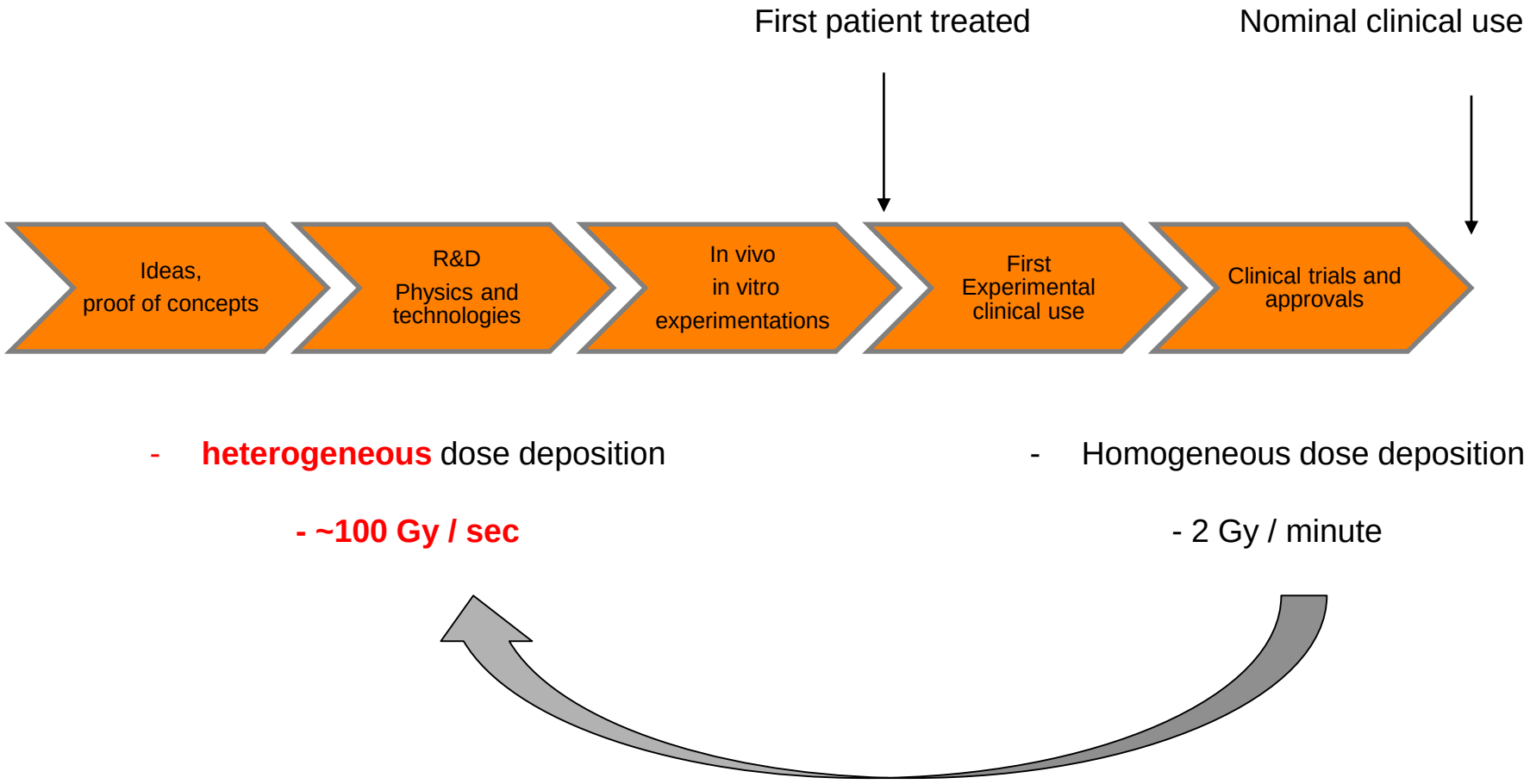
Life-cycle of a new treatment modality



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People and Teams Associated to this presentation

BTI service:

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CPO: Dr R. Dendale, F.Goudjil, S. Lucas, C. Rochas, C. Davet, J. Verdonck

And all the teams

Radiation Onoclogy Dept: Pr G. Créhange, Dr V. Calugaru, Dr P. Verrelle

IC Research Centre:

M. Amor Guéret, M. Dutreix, V. Favaudon, S. Heinrich, C. Fourcade

Y. Prezado, F. Pouzoulet.

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Summary

Thank you !

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