Medical applications of Compton generation

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Warnings :

- This is a laser physicist point of view… not from a MD!
- All applications presented are really from synchrotron radiation research…

Outline

- Applications of monochromatic Xray sources to medical imaging

  Oncology, Angiography
- RadioTherapy
- Why go from synchrotron to Compton Xrays?
- What MDs are waiting for…

Medical Xray imaging : medical state of the art

- Standard tool : Xray tubes, very polychromatic

Standard range : up to 250 kV

- Low energy → dose deposition;

  high energy → scatter
- No spatial or longitudinal coherence

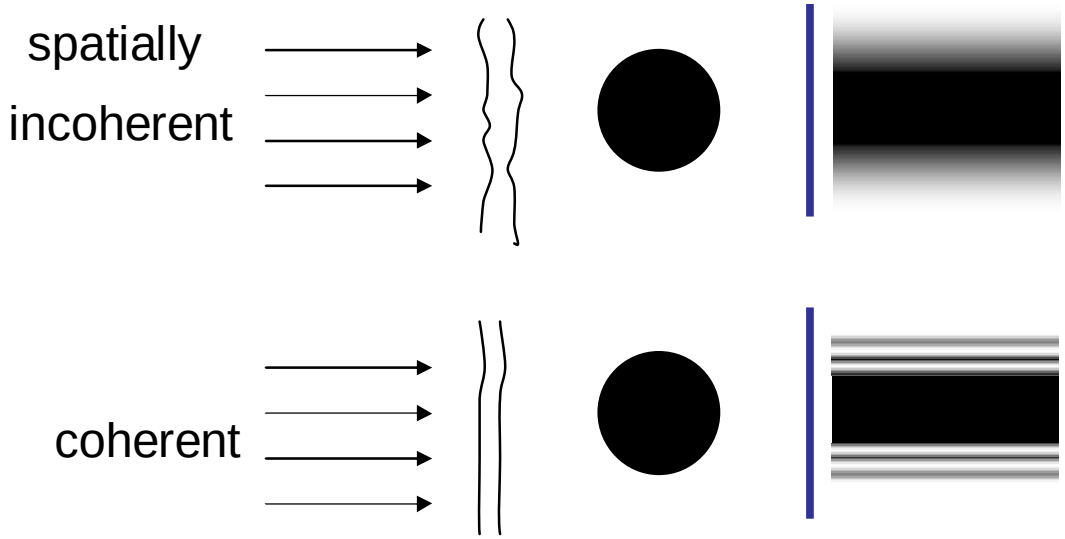
  → low resolution; absorption only
- Possibility to add sensitizers (contrast agents)

Medical imaging : how can monochromatic Xray beams help?

- Get rid of low hν absorption / high hν scatter

  → *very clear images*
- Monochromaticity allows propagation to create spatial coherence
- Possibility to use resonant interaction with sensitizers

Phase contrast Imaging

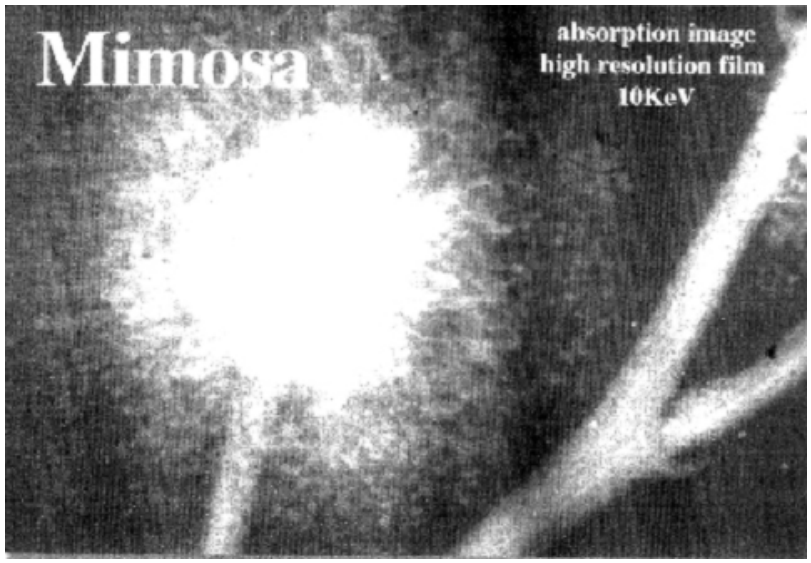


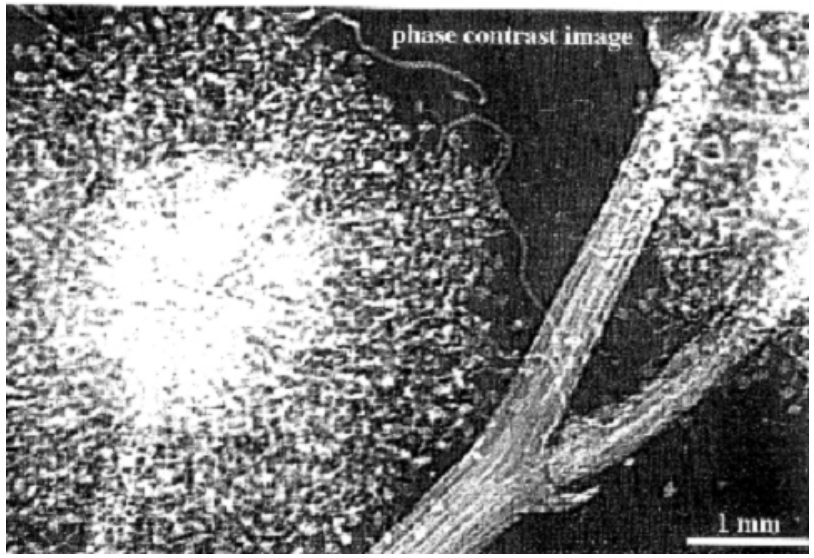
Smooth shadow
→ Low resolution

Random spatial phase
Pure absorption image

Fresnel diffraction fringes
→ Higher visual resolution

Locally fixed spatial phase
« Phase » image



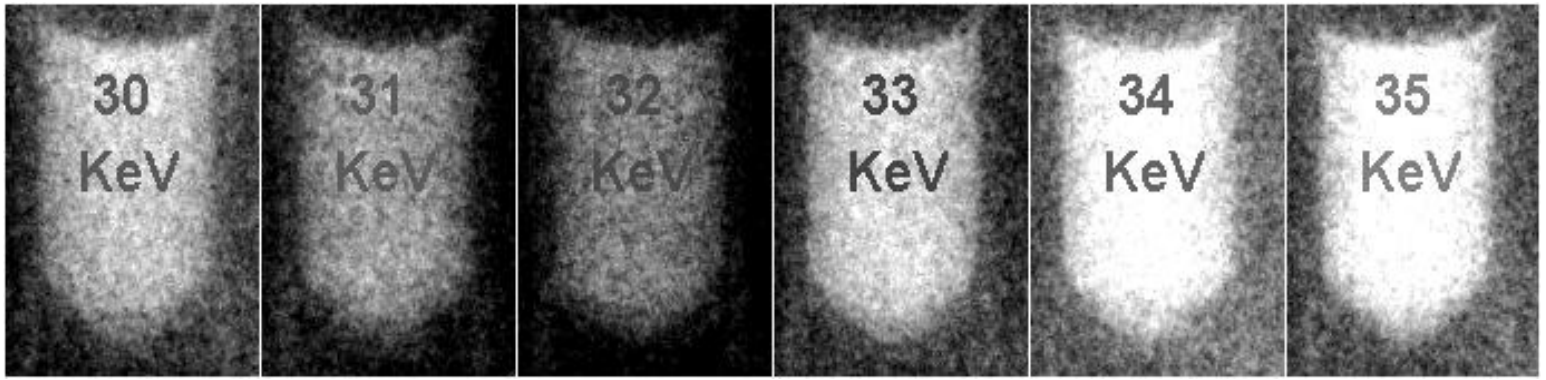


Courtesy G. Margaritondo

Kα differential imaging

- Introduce contrast agent with high Z element : I

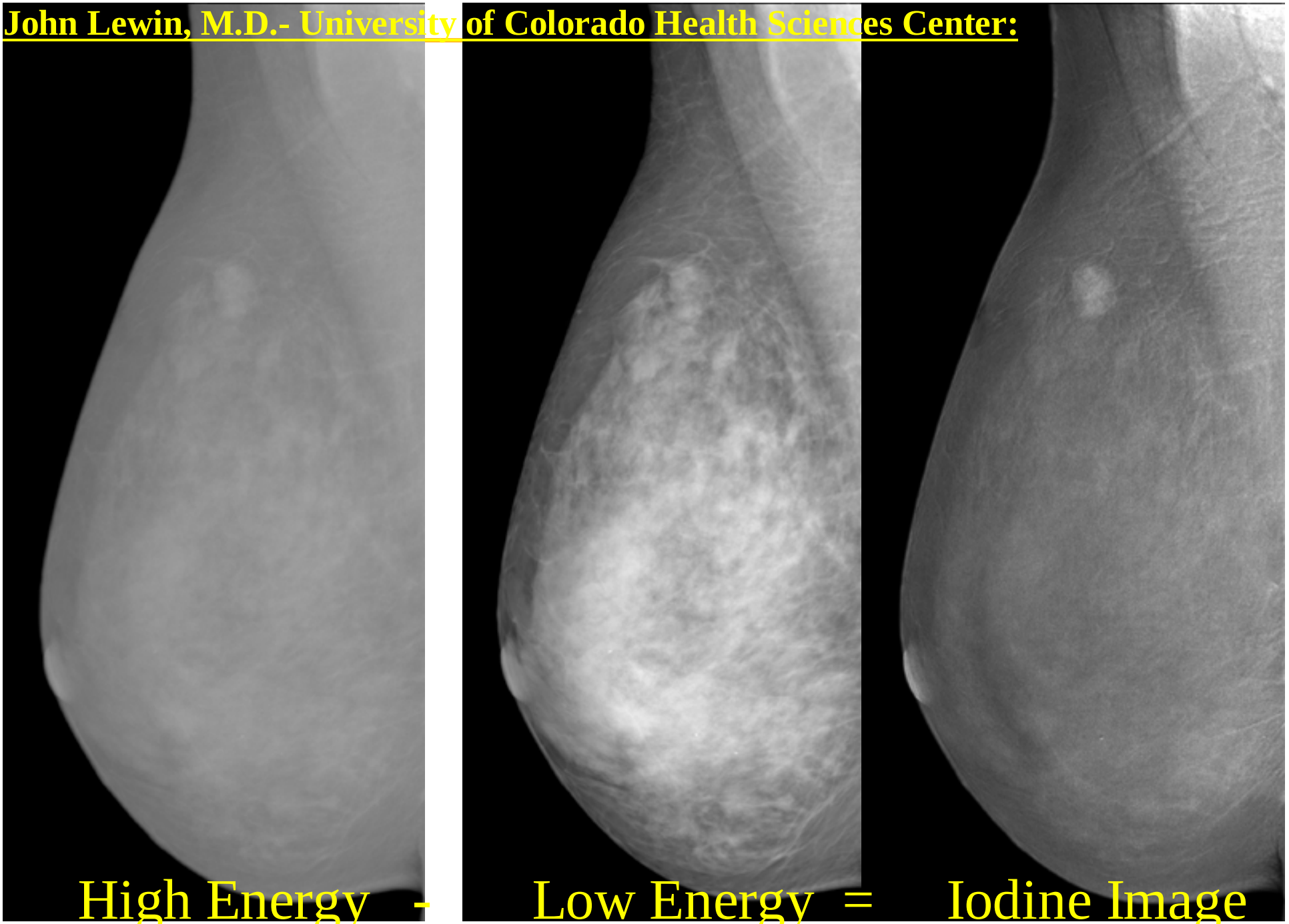
Iodine k-edge is at 33.2 keV



Courtesy F. Carroll, MXIsystems

- Substract two images taken at hν(Kα) + ε and hν(Kα) - ε

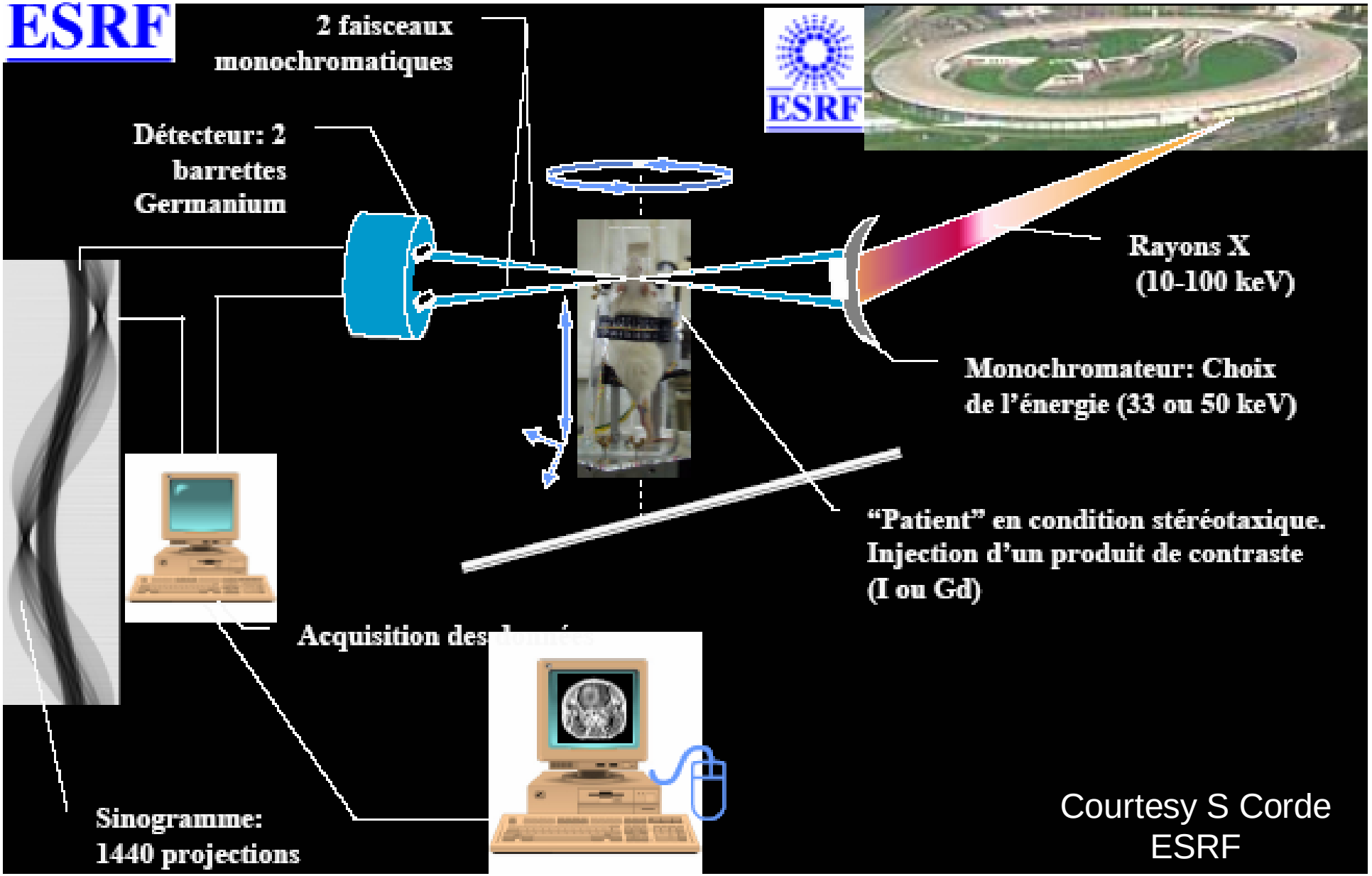
John Lewin, M.D.- University of Colorado Health Sciences Center:



Computer Tomography with contrast agents

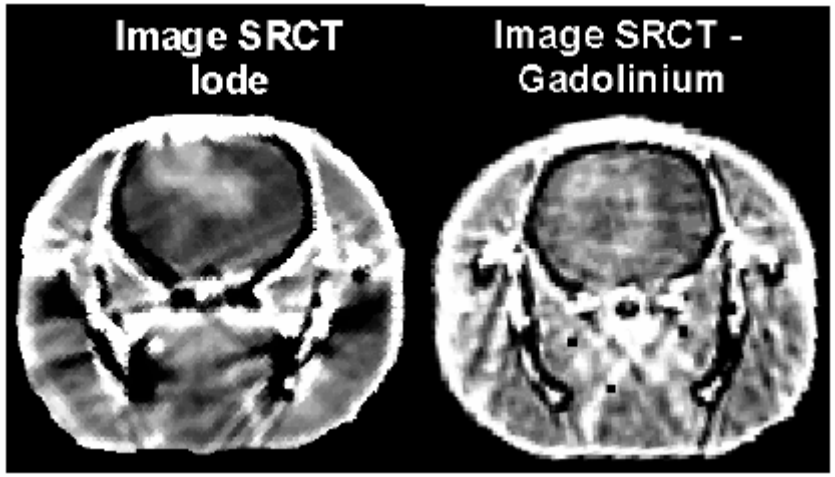
- Main contrast agents : compounds based on Iodine, Gadolinium ; Platinum
- Also : Barium in gastro-oesophaegical system, Xenon in lungs
- Many of these compounds have intrinsic toxicity, even with no-zero morbidity

Reminder : principle of CT



Courtesy S Corde
ESRF

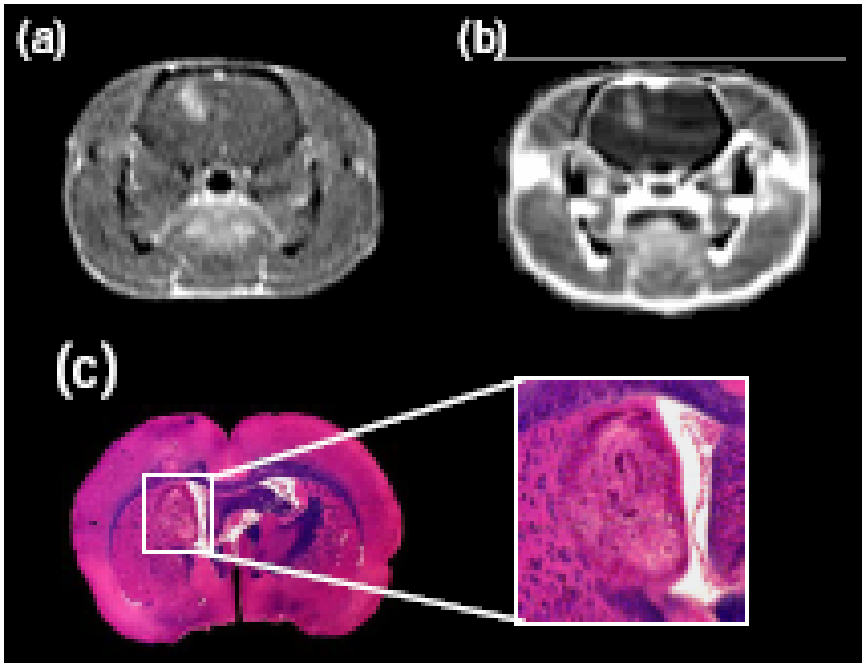
Application of CT with I and Gd :



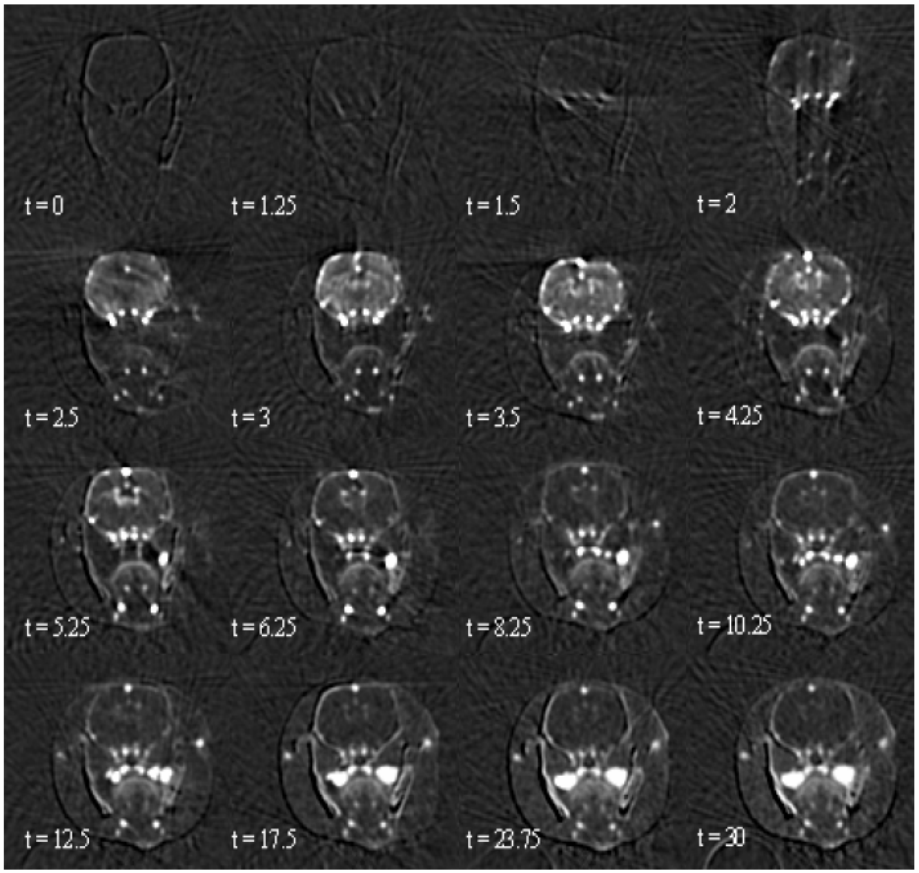
Courtesy S Corde
ESRF

Comparison with other imaging techniques :

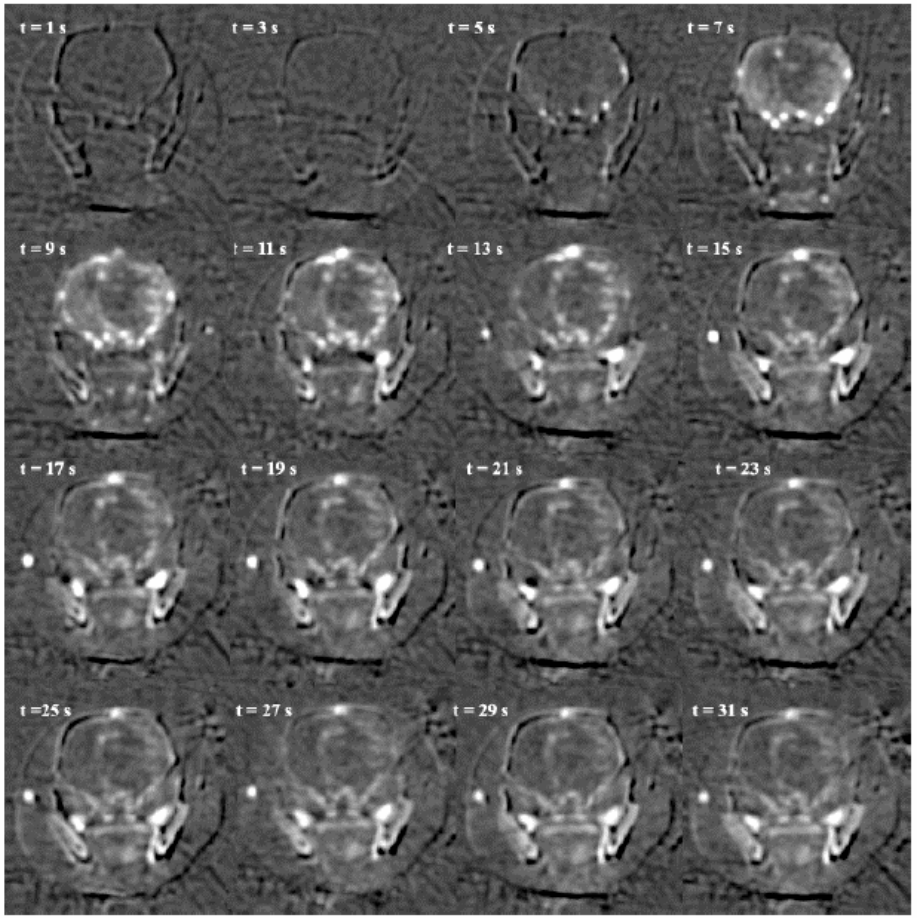
(a) : Synch. Rad. differential CT
(b) : NMR imaging
(c) : post-mortem histology



Angiography : dynamic investigation of blood perfusion in rat brain



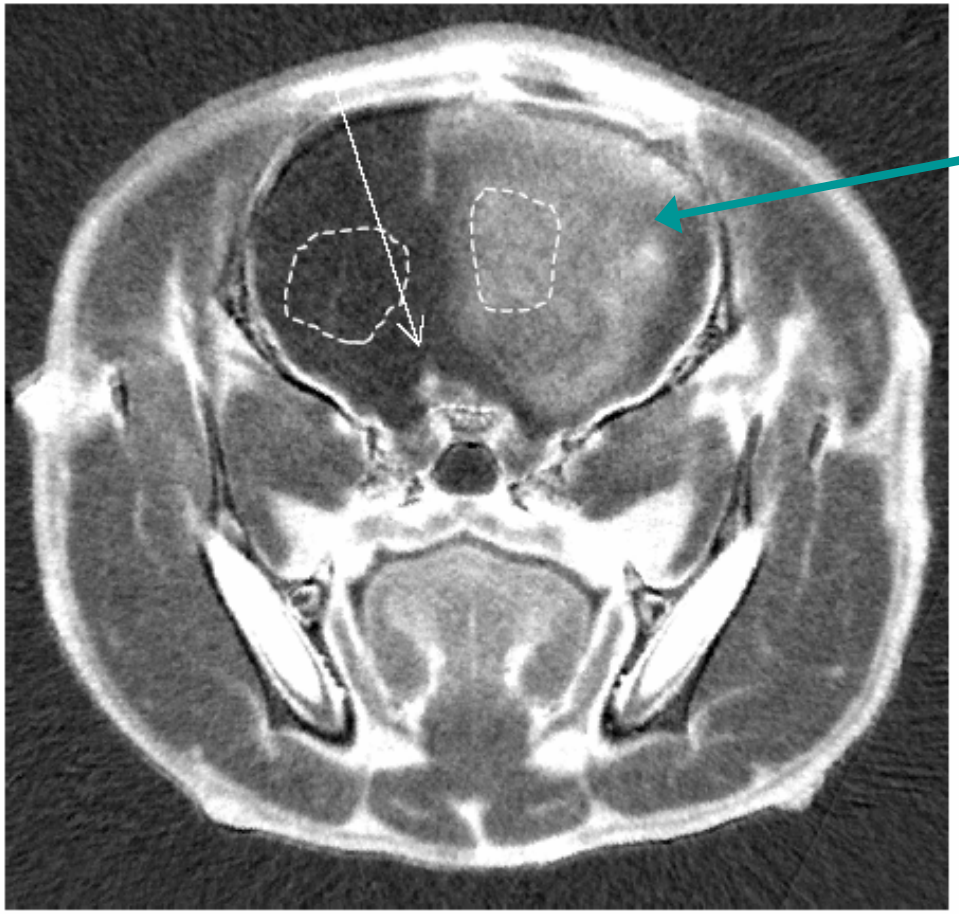
Healthy cerebral tissue



Large brain tumor on right hand side

These techniques can be combined :

Study of blood perfusion of rat glioma by I differential imaging



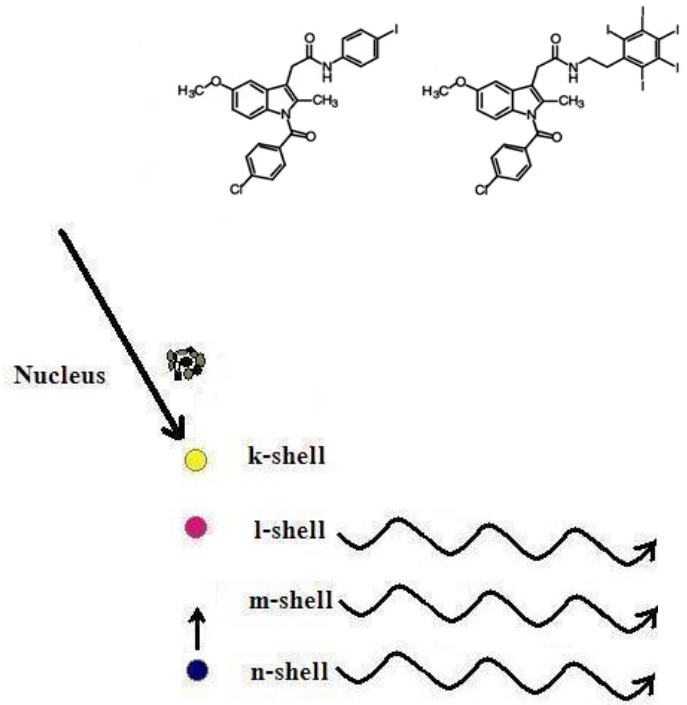
« Map » of increased permeability of Hemato-encephalic Barrier

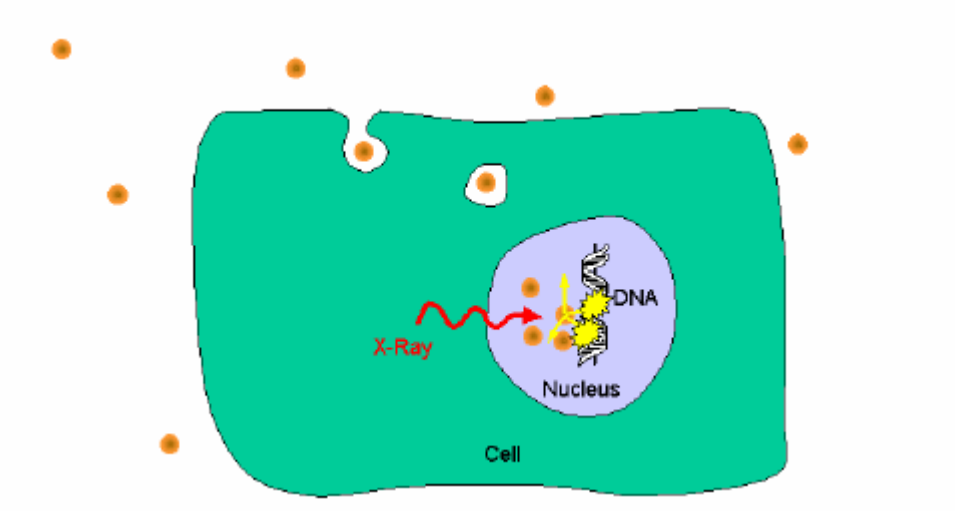
Xray RadioTherapy : medical state of the art

- RX therapy is one of 3 big tools against cancer
  (often used together with Chemitherapy and surgery)
- Very high photon Xrays : up to 6 MVp
- Very high doses : up to 60 Gy in tumor
- Low differential absorption of tumor : < 10%
- Strong irradiation of sane tissues → major side effects (functional damage, Xray induced tumors)
- New technique : Intensity Modulation RT
- Brain glioma still not curable → almost no RT

Photon activation therapy

- Excite selectively around High Z sensitizer





High probability of double-strand breaks

Why is single ν Xray useful?

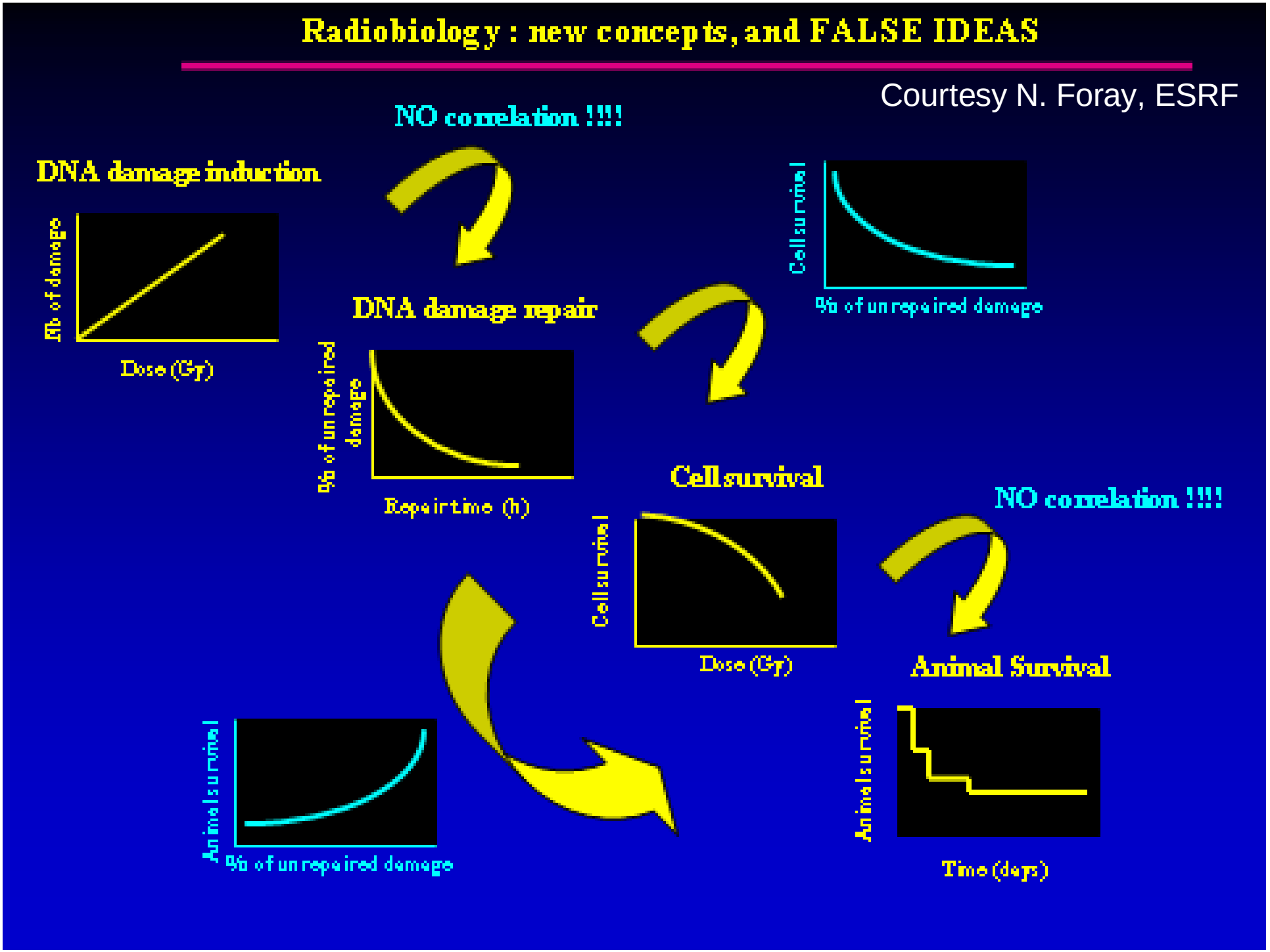
- Sensitizer → Dose Enhancement Ratio > 1
- No beam hardening → homogeneous dose
- Pencil like beams → sharp boundaries

But!

Extremely complex physical – chemical – biological – medical behaviour!

Radiobiology : new concepts, and FALSE IDEAS

Courtesy N. Foray, ESRF



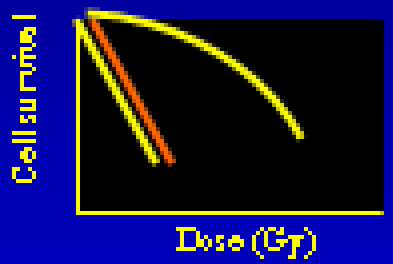
Photoactivation of iodinated contrast agents and cis-platinum: A comparison ...

DNA damage induction

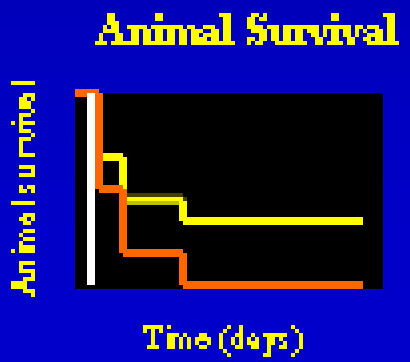
Courtesy N. Foray, ESRF

DNA damage repair

Cell survival



Animal Survival



In a nutshell : might work for therapy,
but no certainty yet

Applicability of Compton sources :

Main aim → not have to use that :

Technical requirements

- Flux : looks feasible , even for therapy
- Photon energy : the higher the better
- Divergence : often too small
- Monochromaticity : adjustable (→ fine)
- Compacity : marvelous
- Radioprotection : a nightmare
- Coupling to IMRT : very difficult
- Cost : much too expensive for medics

Conclusion :

The coupling between laser and electron acceleration – storage technologies

might be extremely useful for medical imaging and radio-therapy, especially for brain glioma

(but no certainty yet for RT)

Many thanks to…

- Dr J. Bourhis, MD, and Dr A. Bridier (IGR)
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