Rencontre LAL-Soleil

The Compton activity

Group ILC positron source & ThomX

Alessandro Variola
LAL Orsay. IN2P3 – CNRS

History

- Polarimetry for HERA. Technology associated with high gain Fabry Perot cavity
- EuroTeV => Polarimetry for ILC
- Idea (from LAL) for polarized positron sources. Collaboration Posipol
- Scaling at low energy => Medical (and not…) applications : ThomX
- Implications :
  a) fiber laser development
  b) ANR for ATF experiment => Gamma factory !!!!!!

In all these programs our Compton activity is based, glued and managed by 1 variable : the repetition frequency of the Compton Collision.

I will not talk about technology (see F.Zomer talk).

Alessandro Variola
LAL Orsay. IN2P3 - CNRS
Rencontre LAL-Soleil

LABORATOIRE
DE L'ACCÉLÉRATEUR
LINÉAIRE

- ILC positron source

Generation of Positrons & Compton

- Compton effect is by far the most efficient energy booster
- At relative low electron energy hard gammas can be produced
- Gammas impinge on a target => pairs (and polarization is conserved…)
- Pairs are separated, positron are captured and re-accelerated to the damping rings
- Stacking is necessary

One step back : before Snowmass

- What is the problem of a Compton based polarised positron source?

  Photon/collision = $\sigma\, n_e\, n_g\, f_{overlap}$ where $\sigma = \frac{8\pi r_0^2}{3} = 6.65\ 10^{-29}$m

ILC train = 2820 bunches @ $2\ 10^{10}\ e^{-/+}$ / bunch

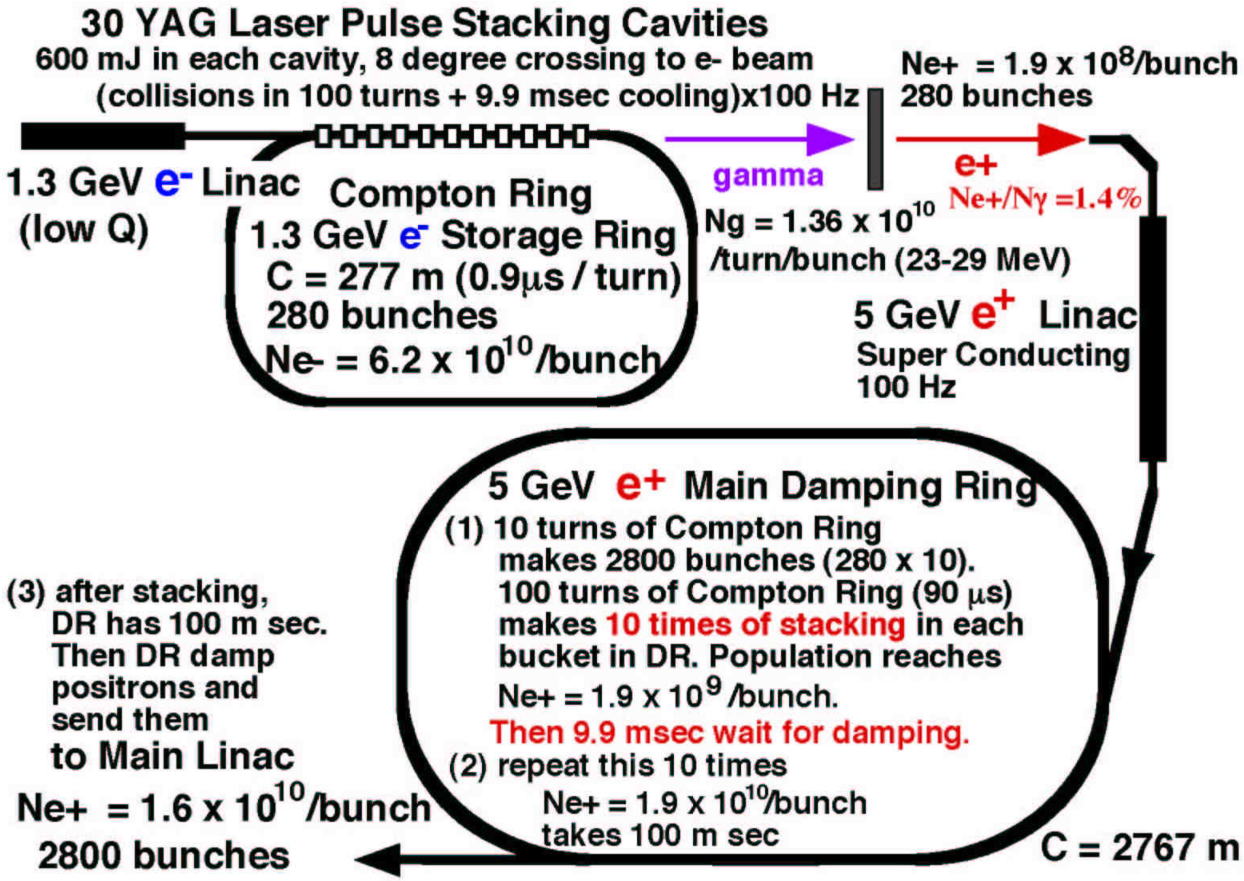
EXTREMELY LOW.

So to compensate, as far as the single collision is concerned, it is evident that we have to increase the densities of the photons and electrons bunches and optimise the collision overlap. => ACCELERATORS TECH, LASER + OPTICAL CAVITIES

ILC beam parameters are really demanding in positron fluxes BUT in 200 msec period (5Hz). So (K.Moenig) it is possible to produce less positrons per collision and to spend 100 msec re-injecting in the same bucket of the positrons damping ring => SNOWMASS PROPOSAL

•SNOWMASS BASIC IDEA => COMPTON
•accumulation ring, high frep, high current.
•Two proposed schemes taking into account respectively
•the Solid State and the CO2 lasers.

More visual……



BUT

- Compton ring dynamics has been analysed (NSC KIPT Kharkov, Ukraine – LNF Frascati Italy)

- Difficulties:
- 1)Touschek lifetime (high charged bunches at low energy)
- 2)Beam dynamics (close to the linear regime, in each collision, the generated energy spread is ~ 30 MeV @ 1.3 GeV and increases for higher energies). Need for an intra-period of cooling
- 3)Current in the ring
- 4)Long bunch ~ 5 mm. (We propose different schemes to compensate for this effect: OPO crab, bunch compression and decompression)
- 5)Low emittance, low momentum compaction.....

Meeting all these requirements is maybe possible, but very difficult.

some thinking :

- Compton ring:

What is the advantage over the linac?

CW frep!!...but using it with low duty cycle (cooling in Compton Ring), we practically lose it.

Ncharges per bunch due to stacking in storage ring

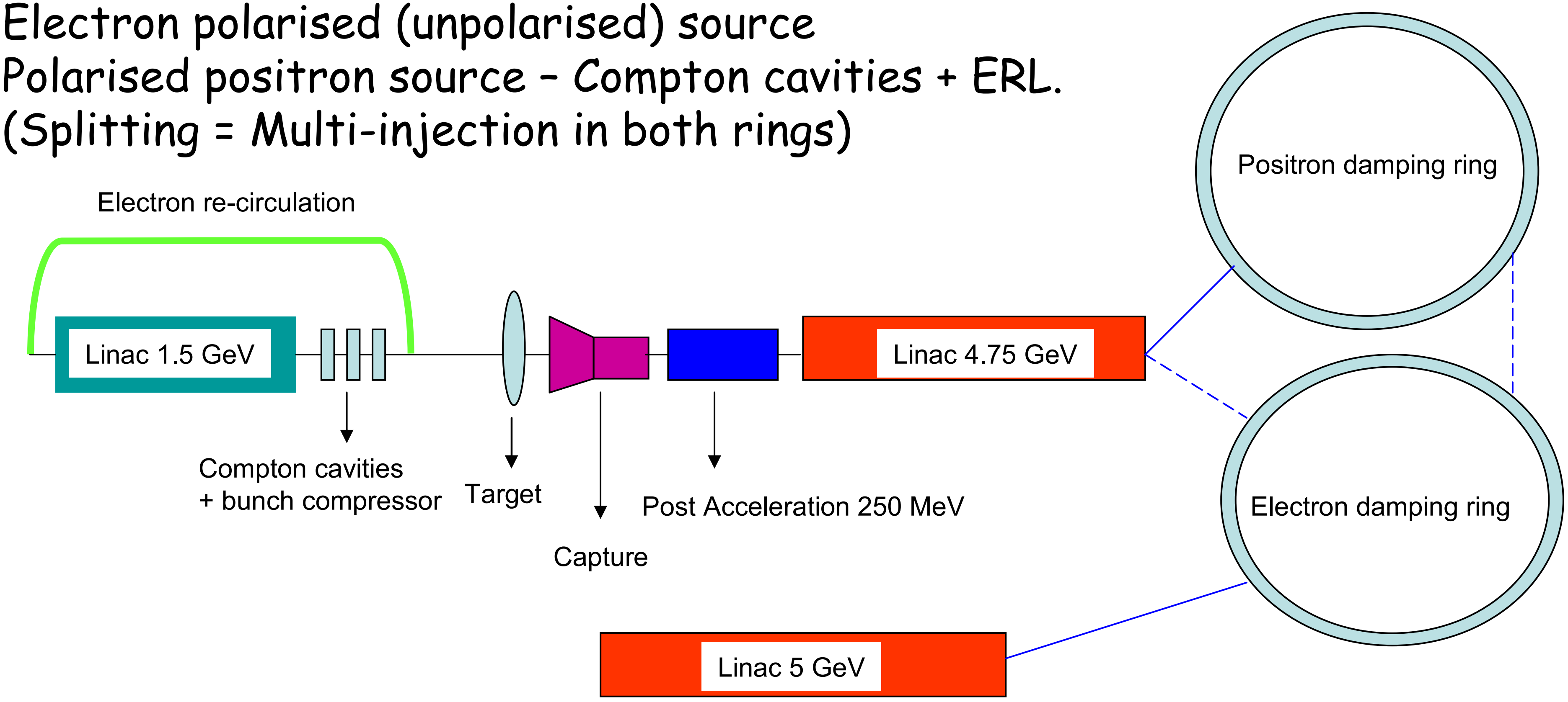
What are the disadvantages?

Machine stability 10 interaction points, Tousheck lifetime, bunch length (Compton cross section and re-injection in the damping ring….)

But if we succeed in compressing the bunch enough, the increase in cross section can compensate for the reduction in single bunch charge……………………………………………=>

Two sources. One source every damping ring
If damping rings at the same location …….new scenarios:

Electron polarised (unpolarised) source
Polarised positron source – Compton cavities + ERL.
(Splitting = Multi-injection in both rings)



The first 1.5 GeV linac can be substituted with a 6 GeV one to have both sources

LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

Looking at this table…ERL is much more than a concrete solution !

JLab	AES JLAB	Cornell	Dares. ERLP	JAERI Th.Ionic	BINP Th.Ionic	Boeing	LANL AES	LUX	AES BNL	4GLS	
DC	DC	DC	DC	DC	Dc	NCRF	NCRF	NCRF	SRF	SRF	
1.5	0.75	1.3	1.3	0.5	0.18	0.433	0.7	1.3	0.7	1.3	RF (GHz)
0.075	0.75	1.3	0.08	0.01 (0.083)	0.011 (0.09)	0.027	0.033 (0.35)	1.3	0.35	1.3	frep
0.133	0.133	0.077	0.08	0.5	1.7	4.75	3.0	1.0	1.4	0.08	Q (nC)
10	100	100	6.5	5 (40)	20 (150)	32	100 (1050	1300	500	100	I (mA)
<7	1.2	<1	1.5	30	32	~7	6		2.1	0.5	ε (μm)
3.2	6.3	2	4		50				15		ERL bl (ps)
44	44	30	20			53	16			10	Laser bl (ps)
527	527	527	527			527	527		527	527	Laser wl (nm)

Alessandro Variola
LAL Orsay. IN2P3 - CNRS
Rencontre LAL-Soleil

Compton scheme:

- We can subdivide the scheme into different phases:

a) Production (rep frequency, FP cavity)
b) Capture (AMD magnetic field, target) + polarisation selection
c) Stacking in the damping ring (3D emittance, rep frequency for cooling)

Point a) requires high cross section (charge per bunch, light pulse. Limit = Non linear regime) and low rep freq (pump laser of the cavity)
Point b) requires low frep (or train of pulses) for pulsed magnet, short bunch length, forward production for the acceptance.
Point c) requires very good 3D emittance and low frep

So talking about Compton collision, we need (at the same current) an ERL machine that increase the charge per bunch (as much as we can) and decreases the frep (from 10 to 75 MHz).

LAL

- At present we are working on the design of the whole system in parallel to our R&D of FP cavity and high power lasers.
- Important need in stacking simulations (determinant for the scheme success => high frep, multiple stack in pre-damping ring or in damping ring)
- ERL……a new Arc en Ciel (for gamma production) ?

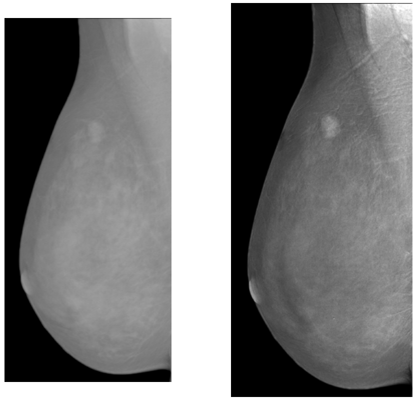
- ThomX

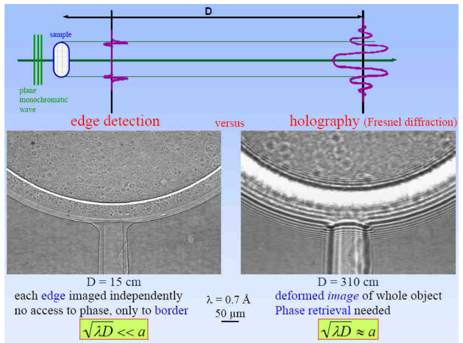
ThomX

- The impact of Synchrotron sources for medical applications is well known.
- This is essentially due to three different parameters: flux, monochromaticity (absorption is f dependent – reduction of diffuse background) and sources 3D sizes (source coherence). This allows real time radiology and tomography on microscopic scale.
- Coherent imaging: different applications in mammography, microangiography (dichromography), coronography, diffraction enhanced imaging, microtomography…….
- In some of these applications a fundamental role is played by the contrast agents (iodine, gadolinium….). They enhance absorption in a peaked f range enhancing the image contrast.
- At present different studies are being carried out to evaluate the use of markers (iodine, gadolinium, platine..) for radiotherapy. Different absorption edges, so different penetration depth.

Markers role
The system must be TUNABLE!

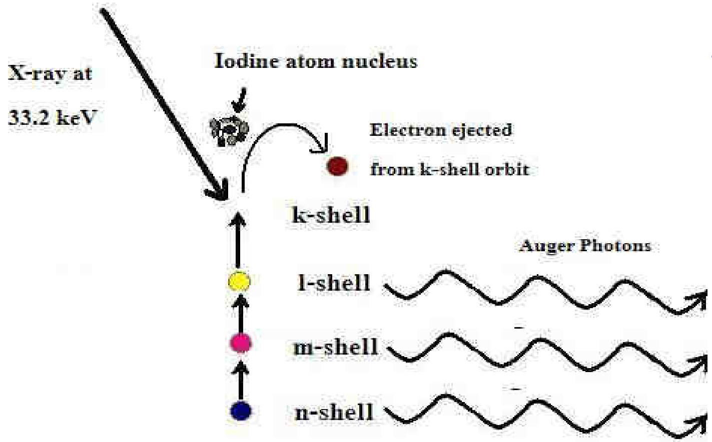
Imaging



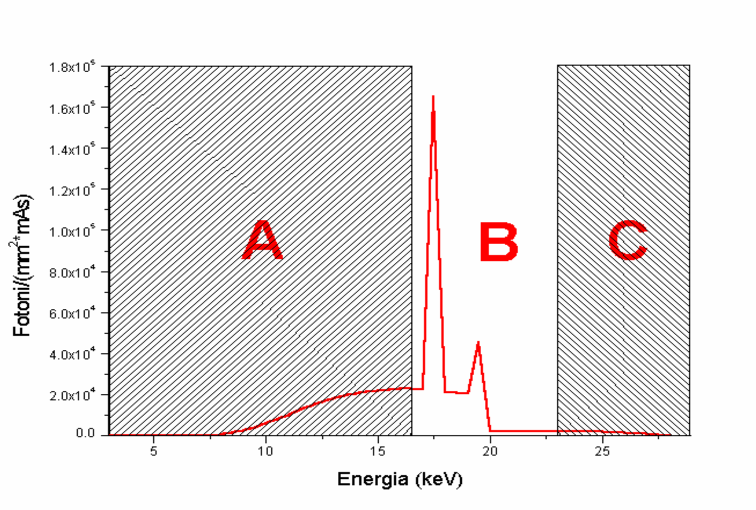


Diffraction Imaging

Therapy



45 keV: Iodine (IUdR)	Tumour à 2-6 cm
55 kev: Gadolinium (GadTex)	Tumour à 6-10 cm
85 keV: Platine (Cis-platine)	Tumour >10 cm



Alessandro Variola
LAL Orsay. IN2P3 – CNRS
Rencontre LAL-Soleil

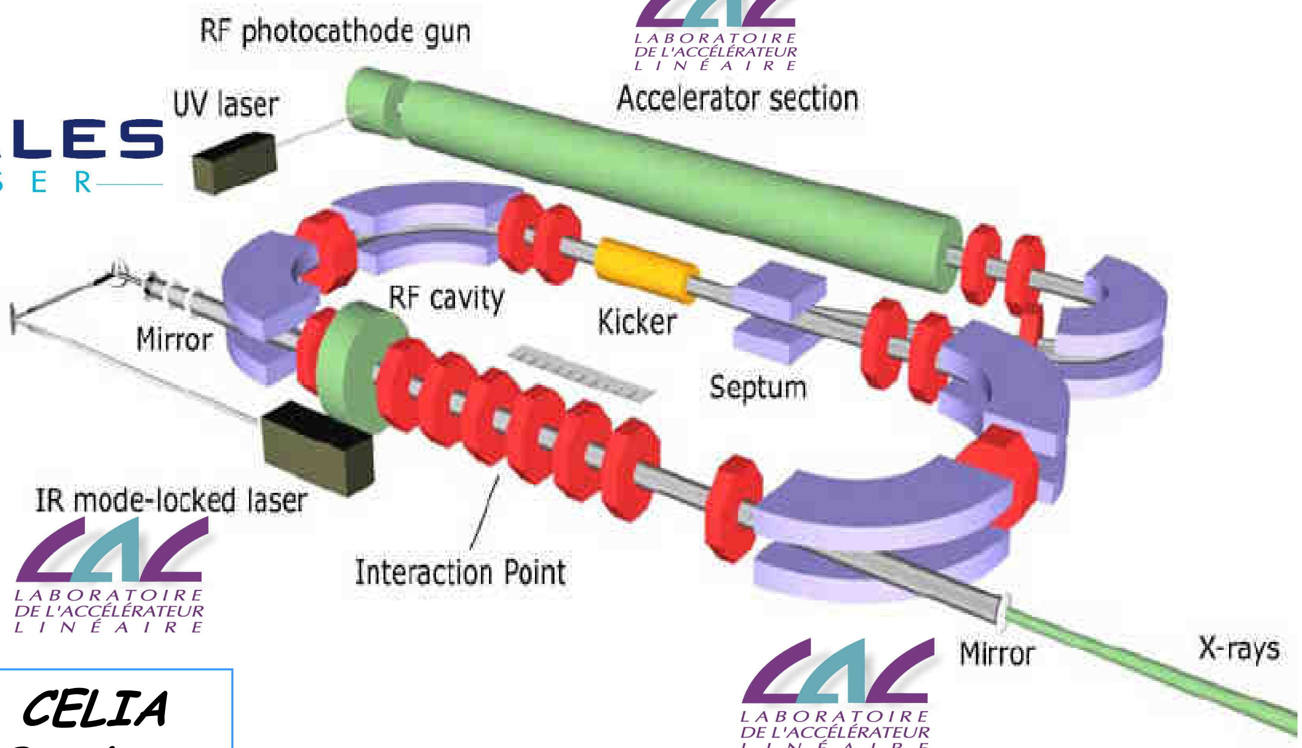
So what are the requirements?

- X-ray source
- Tunable 30-90 keV
- Monochromatic (coherence @ 50%, therapy @ 10%)
- Flux 10^{10}-10^{13} X/sec (but angiography requirements can be less with new generation HARP detectors)
- Sources size of tenths of microns
- Compact (must fit in a hospital)
- Cheap (few MEuros)
- Easy to maintain and use …(let's not exaggerate…)

ANSWER: ThomX => New generation compact X ray source by Compton scattering.

The Compton machine
What it looks like
Example Lyncean-tech

THALES LASER



CELIA
Bordeaux

Alessandro Variola
LAL Orsay. IN2P3 – CNRS
Rencontre LAL-Soleil

LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

Collaboration among LAL Orsay, THALES, CELIA Bordeaux, IGR Villejuif

Radio ThomX demonstrator

- **Compact electron storage ring = high f_{rep} electron bunches**
- **System of high f_{rep} and average power laser coupled with high gain optical resonator.**

Source explored range	
X energy	50-90 keV*
Flux	10^{11} - 10^{13} ph/s
Bandwidth	10 %**
Divergence	< 2 mrad
Price	< 5 M€

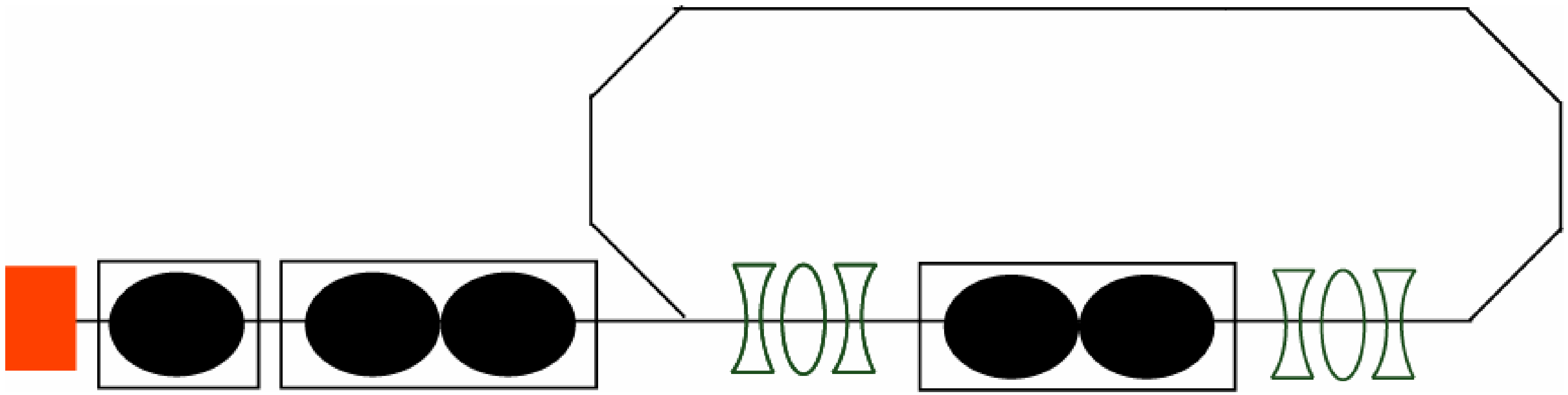
Accelerator and laser	
Ring and injector energies	50 MeV (tunable?)
Charge	1 nC
Emittance (normalised rms,)	< 5 π mm mrad
β*	10 cm =>IP ~ 70 μm
Intracavity average power	> 100 kW
Bunch length, rms	5-10 ps*
Compton f_{rep}	50-200 MHz

But the ERL solution will be examined too

ERL-WHY NOT?

1 arc de recirculation de l'ordre de 7 m de long

Possibilité de mettre plusieurs point d'interaction



Injecteur + booster de 5 à 10 MeV

1 cryomodule simplifié type TESLA avec 2 cavités

C.Bruni

Alessandro Variola
LAL Orsay. IN2P3 – CNRS
Rencontre LAL-Soleil

LAL

- The project is developed in LAL (a lot of affinities with e+ sources)
- Design and R&D
- ERL scheme feasibility
- We need accumulator ring expertise

- # Thank you for your attention
- Thanks to F.Zomer, C.Bruni and J.P Brasile for the slide material

[CANCER RESEARCH 64, 2317–2323, April 1, 2004]

Cure of Fisher Rats Bearing Radioresistant F98 Glioma Treated with *cis*-Platinum and Irradiated with Monochromatic Synchrotron X-Rays

Table 1 *Survival data from rats bearing F98 glioma and treated with the indicated protocols*

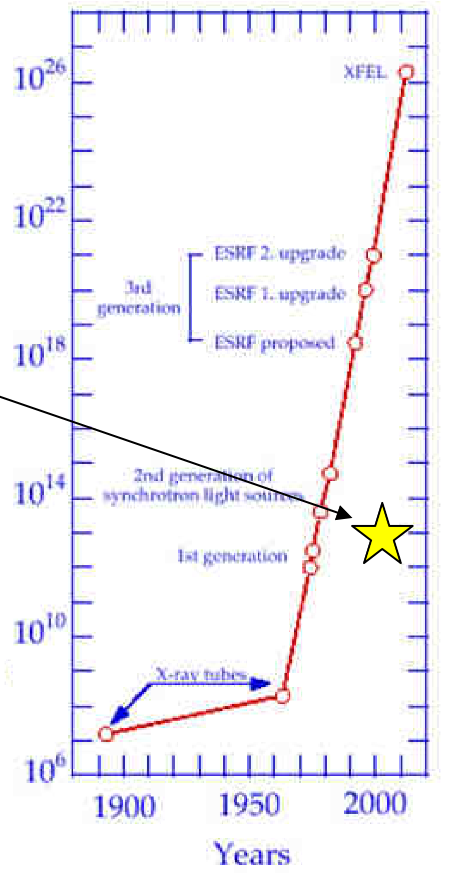
Group	No. of rats	Range of Survival times (days/(median))	% Increased life span
Untreated controls	12	24–37/ (26)	28%
3 g of CDDP	10	28–60/ (37)	39%
Irradiated controls	10	33–70/ (48)	71%
3 g of CDDP 15 Gy	**18**	**42–365/ (206.5)**	**661%**
3 g of CDDP 15 Gy	**11**	**49–365 / (110)**	**557%**

CDDP, *cis*-diammine dichloroplatinum (II);

Six and four rats still alive after 1 year for experiment 1 and 2, respectively.

LABORATOIRE
DE L'ACCÉLÉRATEUR
L I N

Our
Project



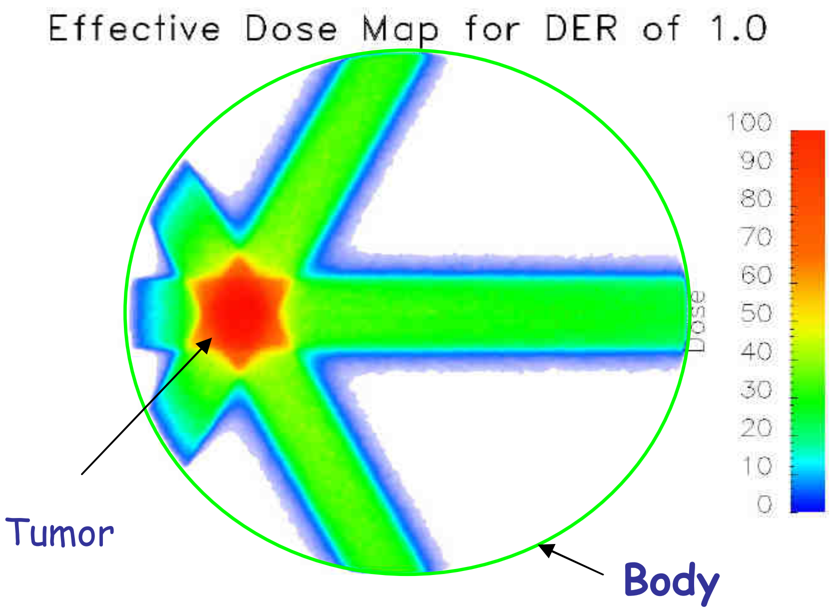
L'ESRF

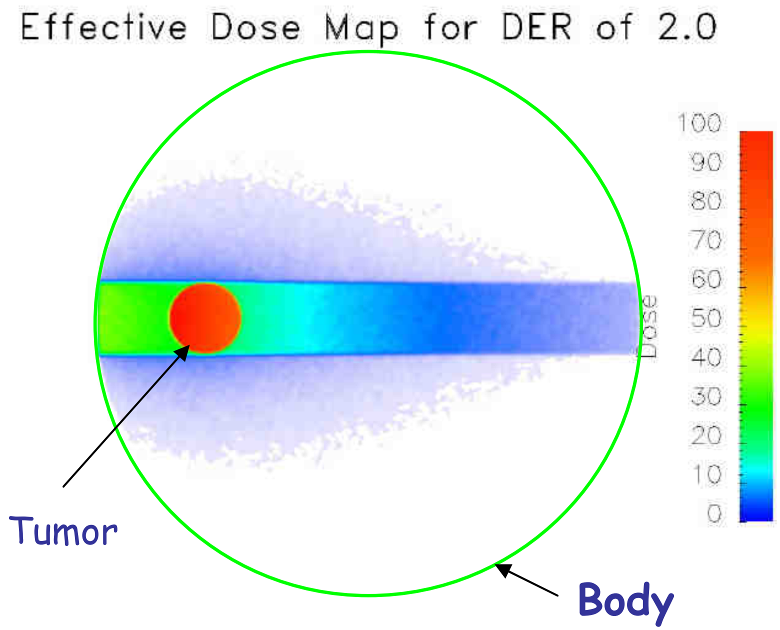
Erice, April 15th, 2004 **Workshop on "*Particle A***

One cm diameter tumor, 2 cm deep to the skin, containing IUdR.

Single 50 keV monochromatic beam

IMRT – 7 Mev beams X3





With DER of 1.0 – dose is 60 Gy

With DER of 2.0 – need to give 30 Gy
With DER of 3.0 – need to give 20 Gy
With DER of 5.0 – need to give 12 Gy

DER = Dose Effective Response

Most DERs now published are 3-5 X

needs: 10^{11} ph/s@10%

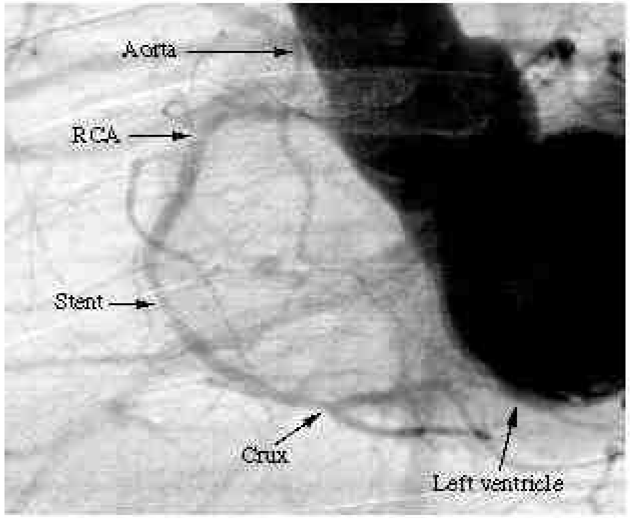
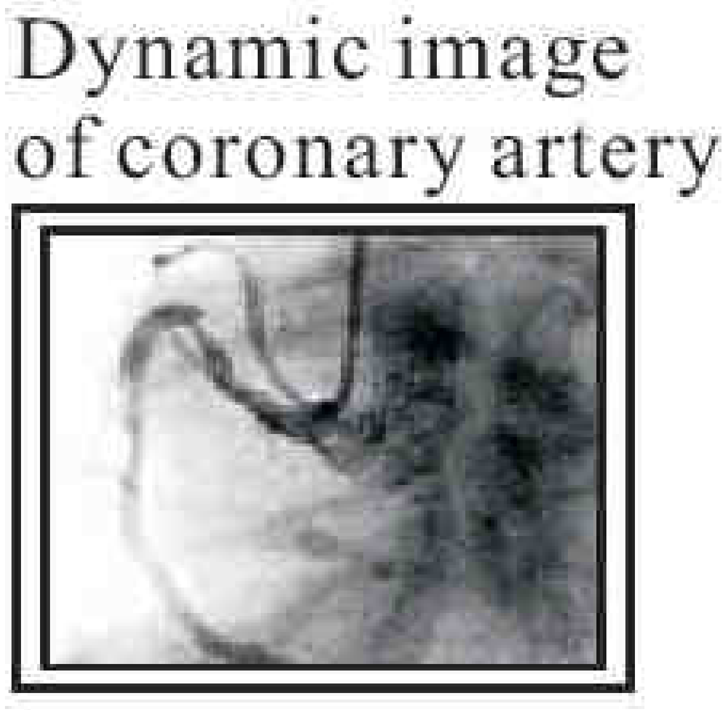


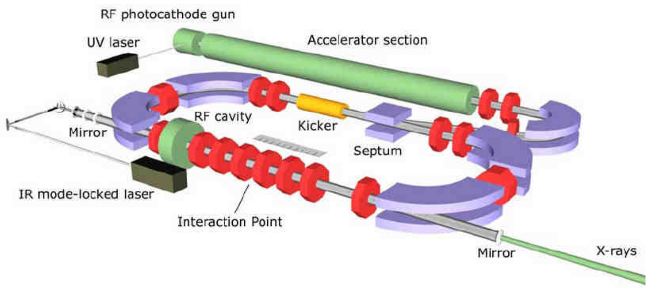
Fig 1 Image of the heart and arteries of the first human patient at ESRF's Medical Beamline: this differential angiogram results from logarithmic subtraction of two images obtained simultaneously on either side of the iodine absorption edge. The right coronary artery (RCA) shows a stent and the crux (courtesy H. Elleaume, ESRF [H. Elleaume et al., Phys. Med. Biol. 45, L39-L43 (2000)]).



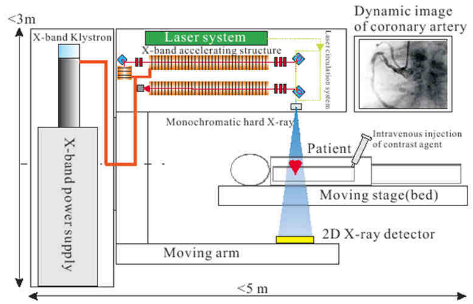
Dynamic images (33 shots/s) of the coronary artery, with **37 keV X-rays** , **10^{11} photons/s**

Ref: KEK-AR
and Tsukuba University,

Alessandro Variola
LAL Orsay. IN2P3 – CNRS
Rencontre LAL-Soleil



Vanderbilt: F. Carroll
Lyncean Technologies: R. Ruth
MIT: D. Moncton



Sumitomo-Festa (S-band, medical)
Univ. of Tokyo - NERL (S-band, medical)
NIRS - Univ. of Tokyo - KEK (X-band, medical)
SLAC (X-band, medical)
Brookhaven ATF (S-band, by-product in laser acceleration)
Livermore (S-band, material studies, nuclear weapons)