Esperimento Marix-Rad: Gruppo V Bologna

Durata 1 anno.

Sezioni partecipanti: BO, FE, NA, MI

Collaborazioni con: Istituti Ortopedici Rizzoli, Technische Universität München

Coordinatore Nazionale: *Paolo Cardarelli.* Coordinatore locale: *Armando Bazzani*

Partecipanti: *Gastone Castellani, Lorenzo Isolan, Carlo Emilio Montanari,*
Sandro Rambaldi, Marco Sumini

Collaboratori esterni: *Giorgio Turchetti (INDAM/GNFM), Massimo Placidi (Berkeley LBNL)*

Obiettivo

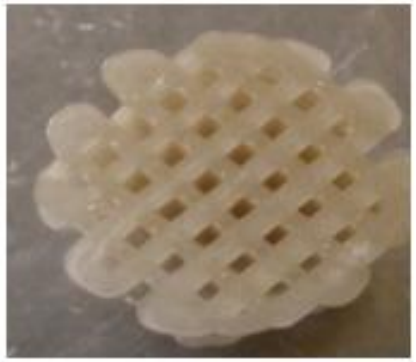
Analisi di campioni biomimetici, realizzati con stampanti 3D, tramite X-ray imaging dual energy e PPCI presso la sorgente Compton MuCLS di Monaco.

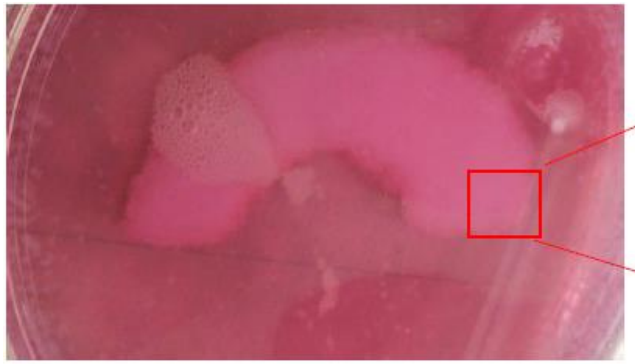
Simulazioni delle immagini ottenute con MuCLS.

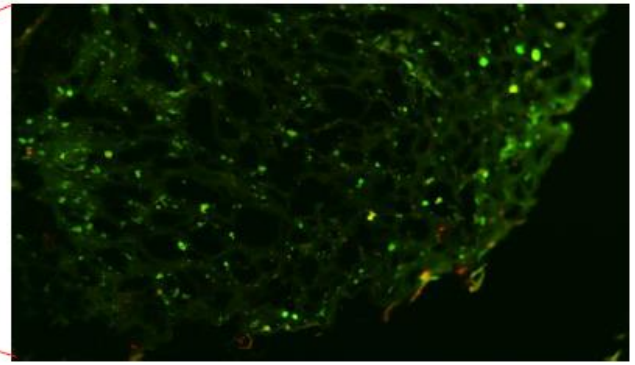
Confronto con immagini da microtomography convenzionale con mezzo di contrasto.

I campioni: realizzati mediante stampante 3D partendo da immagini tomografiche X o NMR. **Dr. Brunella Grigolo**

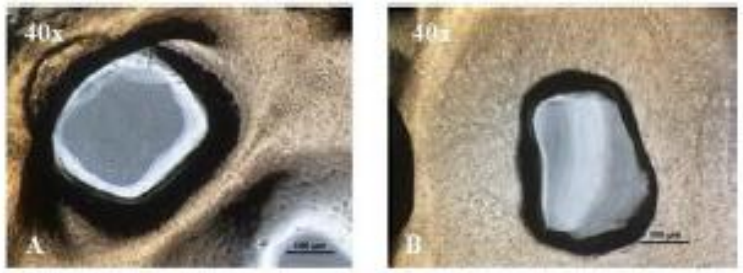
SERVIZIO SANITARIO REGIONALE
EMILIA - ROMAGNA
Istituto Ortopedico Rizzoli di Bologna
Istituto di Ricovero e Cura a Carattere Scientifico



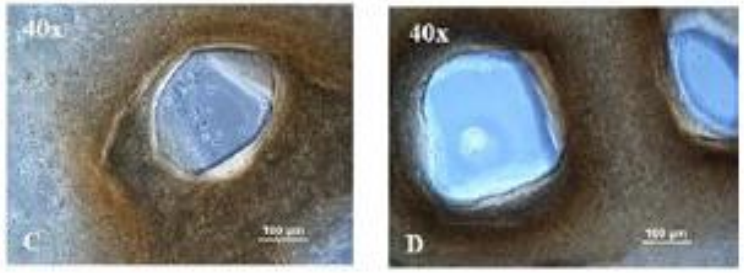




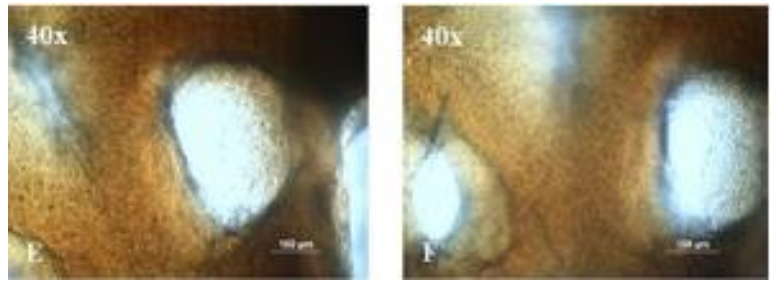
Materiale biocompatibile Menisco in collagene con staminali Sopravviv. cellule a 28 giorni



Dopo la stampa



Giorno 14 dopo impianto



Giorno 28

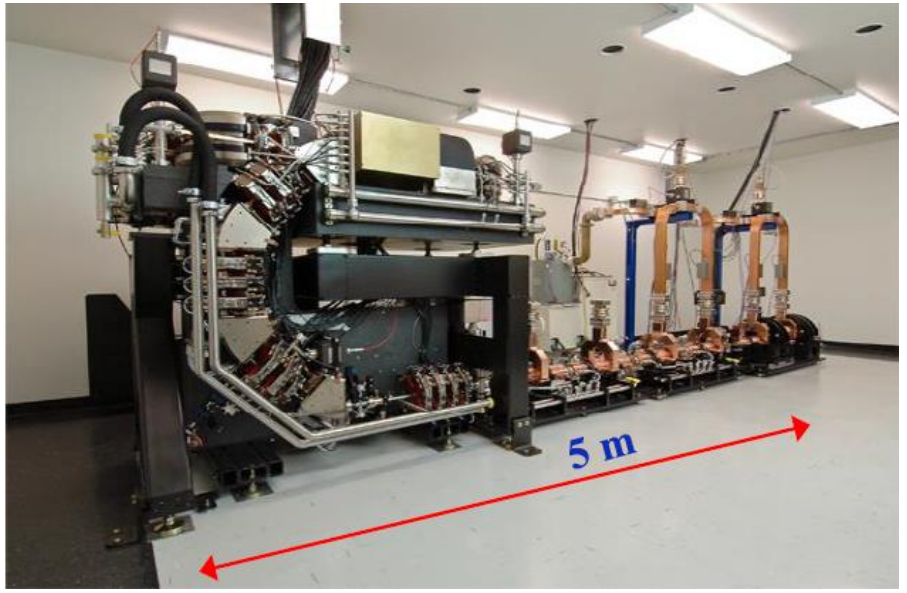
Follow up attuale: mediante istologia con sacrificio del coniglio impiantato.
Impossibile su paziente tranne il caso di un secondo intervento.

Prospettive imaging ICS: follow up anatomico e funzionale non invasivo dell'impianto.

Sorgente ICS di Monaco: anello accumulazione e + ricircolatore luce laser.

Energia $\mathbf{E_e \leq 44\ MeV}$

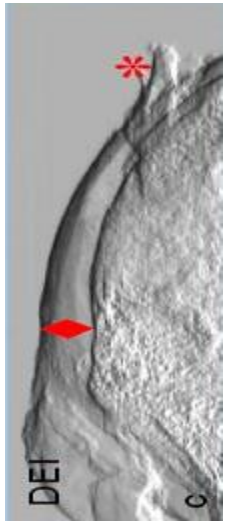
X-ray: $\mathbf{E_X \leq 35\ keV}$, flusso $\mathbf{\sim 10^{11}\ ph/s}$

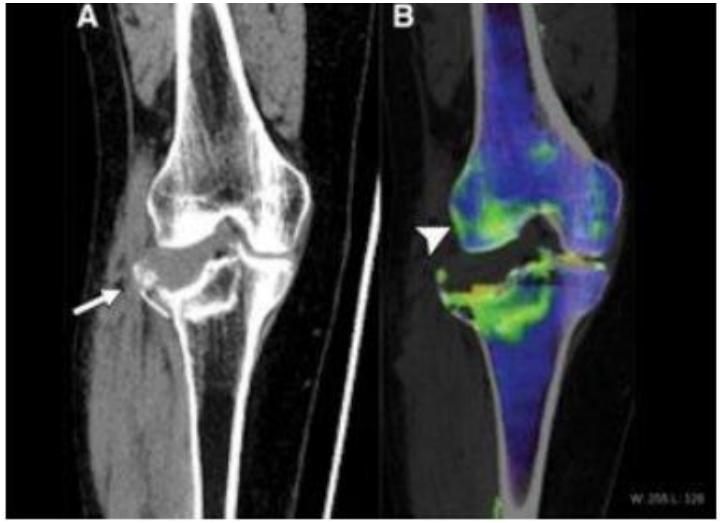


Imaging programmato: contrasto di **fase PPCI** e **dual energy** (X energy shift ~ 2 keV).

Dual energy per tessuti molli ottimale con sorgente monocromatica. Un confronto sugli stessi stesso campioni non è stato ancora mai eseguito. La formalizzazione dell'accordo per l'attività sperimentale è in fase conclusiva.

Imaging possibile: utilizzo di un **mezzo contrasto** come lo iodio per sottrazione K-edge a 33 keV, oppure nanoparticelle d'oro. Gli agenti di contrasto cationici sono indicati per cartilagini e menisco.



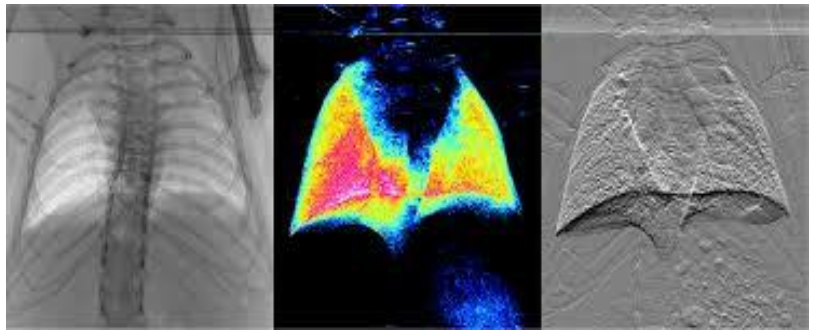


PHASE-CONTRAST IMAGING

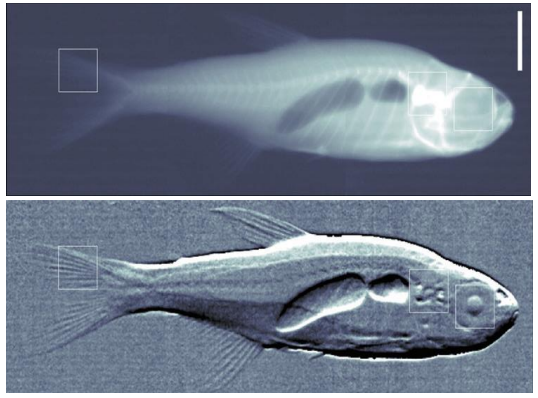
A brilliant **coherent** (or partially coherent) source allows to take advantage of X-ray refraction

X-ray Phase-Contrast Imaging

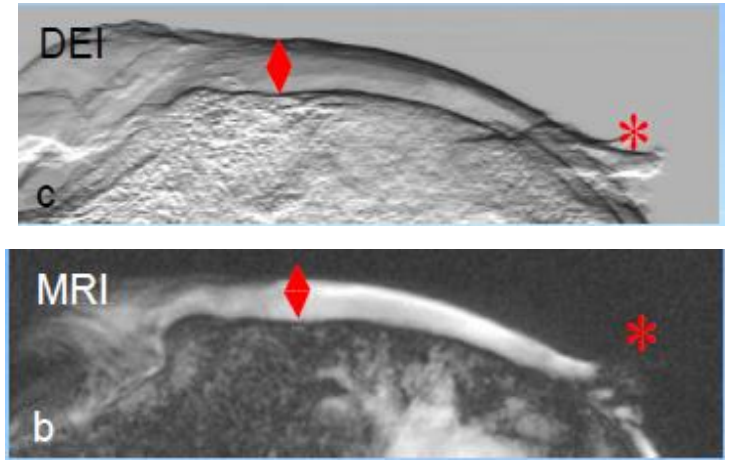
high-resolution images of low contrast details not visible in conventional absorption X-ray imaging



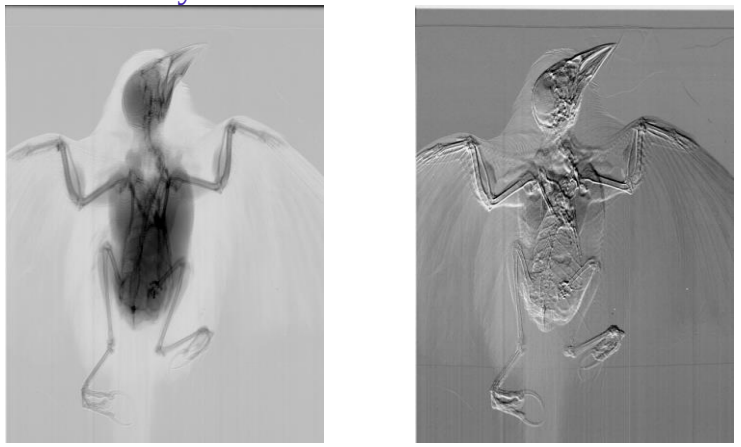
Courtesy: M. Kitchen et al. / Monash University



Courtesy: F. Pfeiffer et al. / TUM



Courtesy: G. Tromba et al. / Elettra TS



Courtesy: G. Tromba et al. / Elettra TS

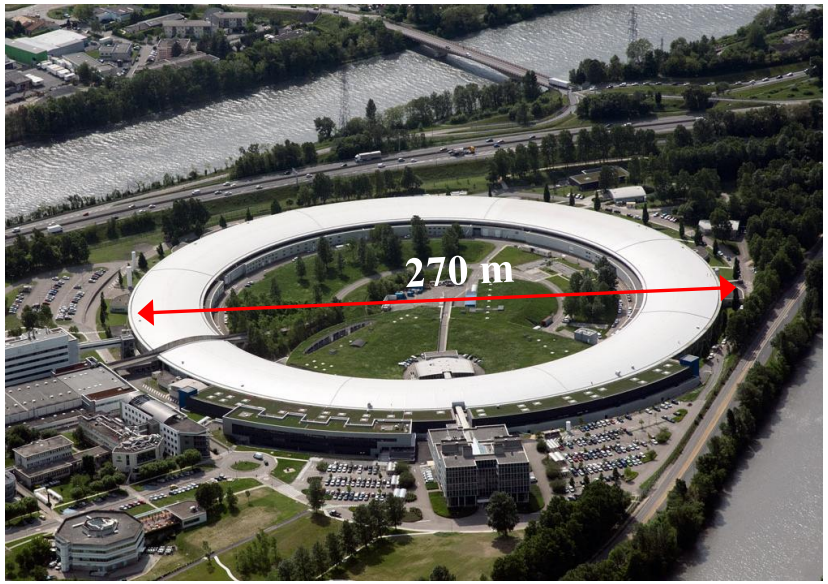
FROM SYNCHROTRON TO ICS X SOURCES

SYNCHROTRONS
UNDULATOR

COMPACT SOURCE
ICS

X-ray energy has similar expressions but…

$$E_X^u \sim hc\left(\frac{E_u^2}{\lambda_u}\right) \qquad \lambda_{ph} \sim 10^{-4}\,\lambda_u \qquad E_X^{ICS} \sim 4hc\left(\frac{E_{ICS}^2}{\lambda_{ph}}\right)$$



ESRF: 6 GeV e- / **844 m** Circumference
10-40 keV X-rays

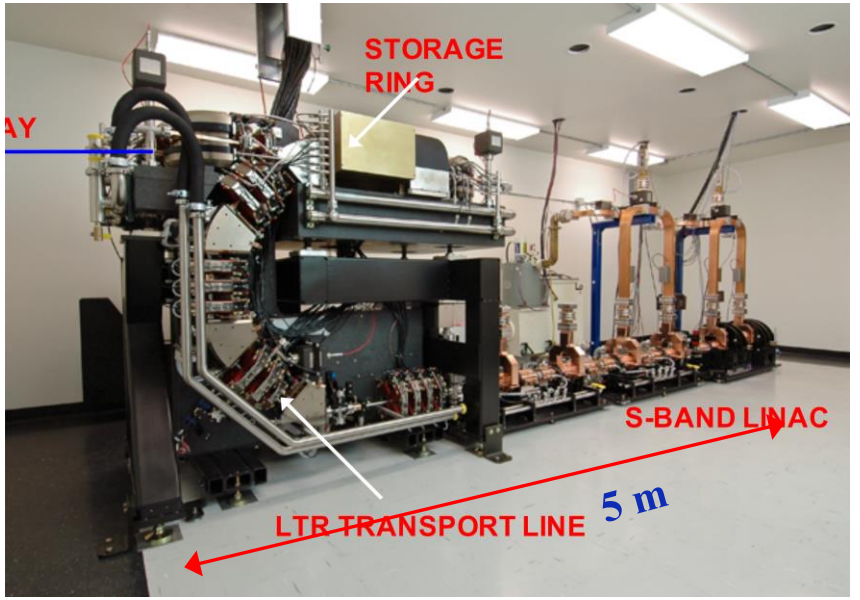
TWO BIG ADVANTAGES

$$E_{ICS} \sim 10^{-2}\,E_u$$

COMPACTNESS, COSTS
HIGHER E_x *@ LOWER* E_u

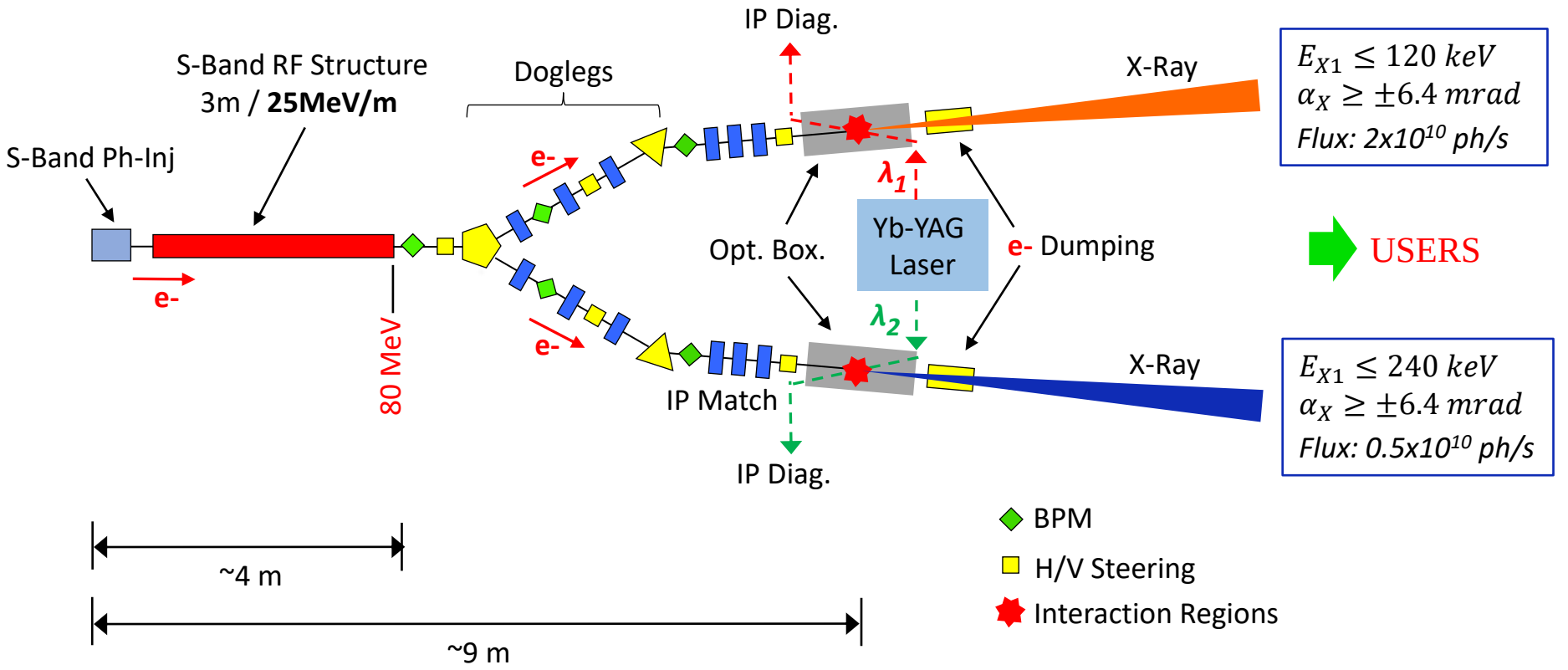
$$\alpha_X^{ICS} \gg \alpha_X^u$$

SHORTER IMAGING DISTANCE



CLS: 40 MeV e- / **5x4 m²** footprint
30-40 keV X-rays

Double Arm S-Band STAR–like Source



$E_{X1} \leq 120\ keV$
$\alpha_X \geq \pm 6.4\ mrad$
Flux: 2x10[10] ph/s

USERS

$E_{X1} \leq 240\ keV$
$\alpha_X \geq \pm 6.4\ mrad$
Flux: 0.5x10[10] ph/s

FOOTPRINT ~ 3 x 9 m²

SHORT PARAMETER LIST

Scattered Photon **Energy** scales with the **square** of the **electron Energy** and the **Laser Harmonic**

$$E_X = 1.9 \times 10^{-2} \frac{E_e^2(MeV)}{\lambda_{ph}^0(mm)} h_L$$

Scattered Photon **Flux** scales with the **Linac current** and the **Inverse square** of the the **Laser Harmonic**

$$N_X = \sigma_T L = \frac{\sigma_T}{A(\beta)} \frac{E_{LP}^0 I_{linac}}{e\,hc} \frac{\lambda_{ph}^0}{h_L^2}$$

Key parameters range

E_e 40 - 80 MeV

h_L =1 **flux 2 10^{10} ph/s**
E_X 30-120 KeV

h_L =2 flux 0.5$10^{10}$ ph/s
E_X 60-240 KeV

SOURCE	PARAMETER		VALUE
LINAC	Energy	*MeV*	80
	Bunch charge	*pC*	500
	Bunch length	*ps*	3.5
	Peak current	*A*	140
	Avg. current	*μA*	0.05
	Rep. Rate	*Hz*	100
Yb-YAG LASER	Pulse Energy	*J*	0.85
	Wavelength	*nm*	1024-512
	Harmonic h_L		1-2
	Pulse duration	*ps*	5
	Rep. Rate	*Hz*	100
X-ray	Energy	*keV*	120- (240)
	Pulse duration	*ps*	<5
	Flux	*ph/s*	2- (0.5))x10^{10}
	Divergence	*mrad*	+/- 6.4