Review of Compton sources

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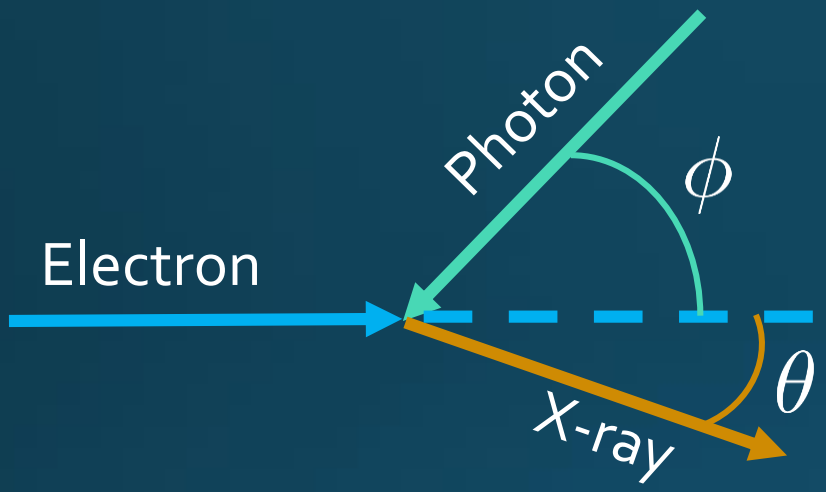
Compton scattering

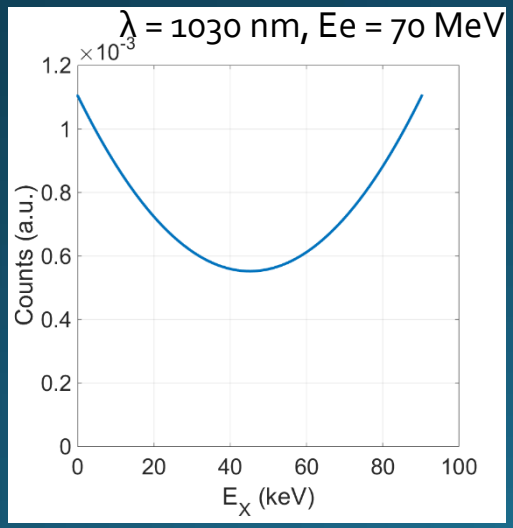


$$E_X^{max} \simeq \underbrace{4\gamma^2 h\nu}$$

40 keV photons with 50 MeV electrons

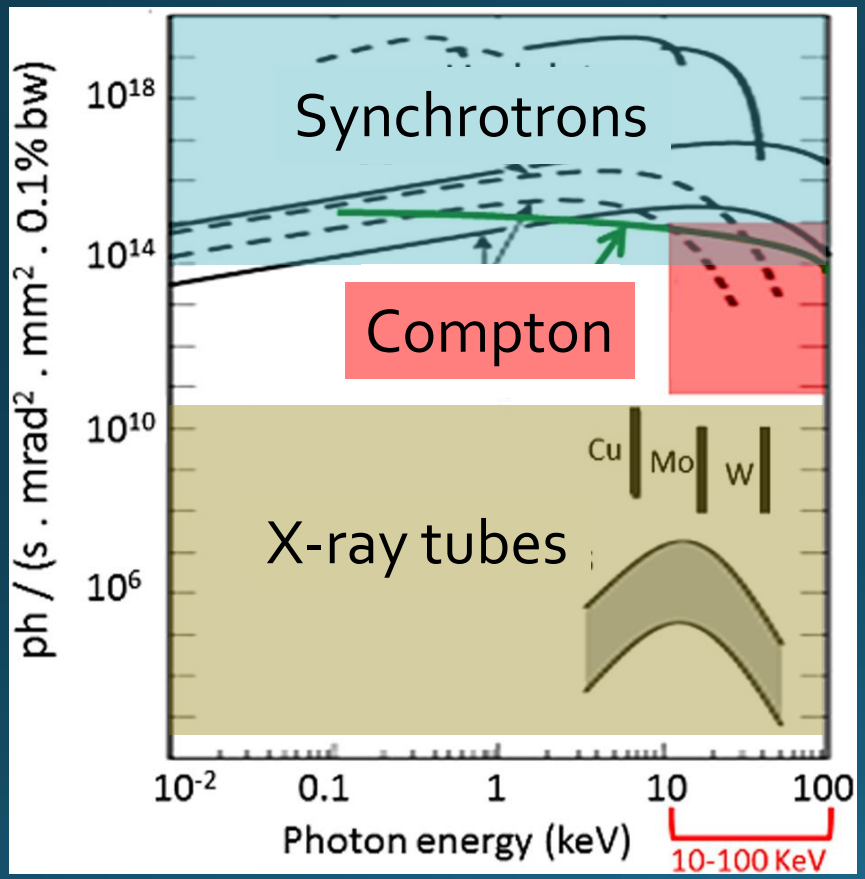
Powerful mechanism to boost photon

Synchrotrons: > GeV electrons



Reduce cost & footprint

Brillance of X-ray sources



Marie Jacquet, Potential of compact Compton sources in the medical field. Physica Medica, 32, 12, (2016)

$$\text{Brillance} = \frac{\Delta N_X}{(2\pi)^{5/2}\Delta t_X \sigma_X^2 \theta_X^2}$$

- Flux
- Given divergence
- Given beam size
- Given energy spread

- Global performance
- To compare sources

Compton sources

Nom	Type	Flux (ph/s)	Energie (keV)	Divergence (mrad)	$\Delta E_{X,\gamma}/E_{X,\gamma}$ (%)	Statut
AIST [62]	L-CP	10^7	12-40	2.5	4	Opération
MEGa-ray [37]	L-CP	1.6 x 10^6	478	60	12	Opération/Développement
TTX [63]	L-CP	10^8	52	4.8-6.7	4	Opération
STAR [64]	L-CP	10^8	40-140	10	1-10	Financé / Développement
CXLS [38]	L-CP	5 x 10^{11}	12.4	4.3	5	Non financé / Développement
SXFEL [39]	L-CP	4.5 x 10^7	3.7-39 x 10^3	0.8	<0.5	Non financé / Développement
ELI-NP-GBS [25]	L-CO	8 x 10^8	0.2-19.5 x 10^3	0.025-0.2	<0.5	Financé / Développement
ELSA [40]	L-CO	2.9 x 10^4	11	10	/	Opération
Smart Light [65]	L-CO	> 10^5	60	1	1	Financé / Développement
cERL [66]	L-FP	3 x 10^7	7	0.14	0.4	Opération
LUCX [67, 68]	L-FP	3 x 10^6	10	/	5	Opération
BRIXS [69]	L-FP	10^{11}	20-90	/	/	Non financé / Développement
FERMILAB [70]	L-FP	8 x 10^9	1.1 x 10^3	/	0.25	Non financé / Développement
NewSUBARU [71, 18]	A-CP	5 x 10^6	1.7-4 x 10^3	/	/	Opération
LEPS2 [72]	A-CP	7 x 10^6	0-2.4 x 10^6	/	/	Opération
GRAAL [73]	A-CP	3 x 10^6	0.4-1.5 x 10^6	/	1.1	Opération
SLEGS [74]	A-CP	10^{9-11}	22 x 10^3	/	/	Non financé / Développement
HIgS [75]	A-FEL	3 x 10^{7-9}	1-100 x 10^3	/	/	Opération
UVSOR [76]	A-FEL	1.6 x 10^8	15-25 x 10^3	/	3	Opération
MuCLS/CLS [46, 47]	A-FP	3 x 10^{10}	15-35	4	3	Opération / Commercialisé
MightyLaser [48]	A-FP	4 x 10^8	24 x 10^3	/	/	Démonté (2014)
ThomX [26]	A-FP	10^{11-13}	45-90	10	1-10	Financé / Développement

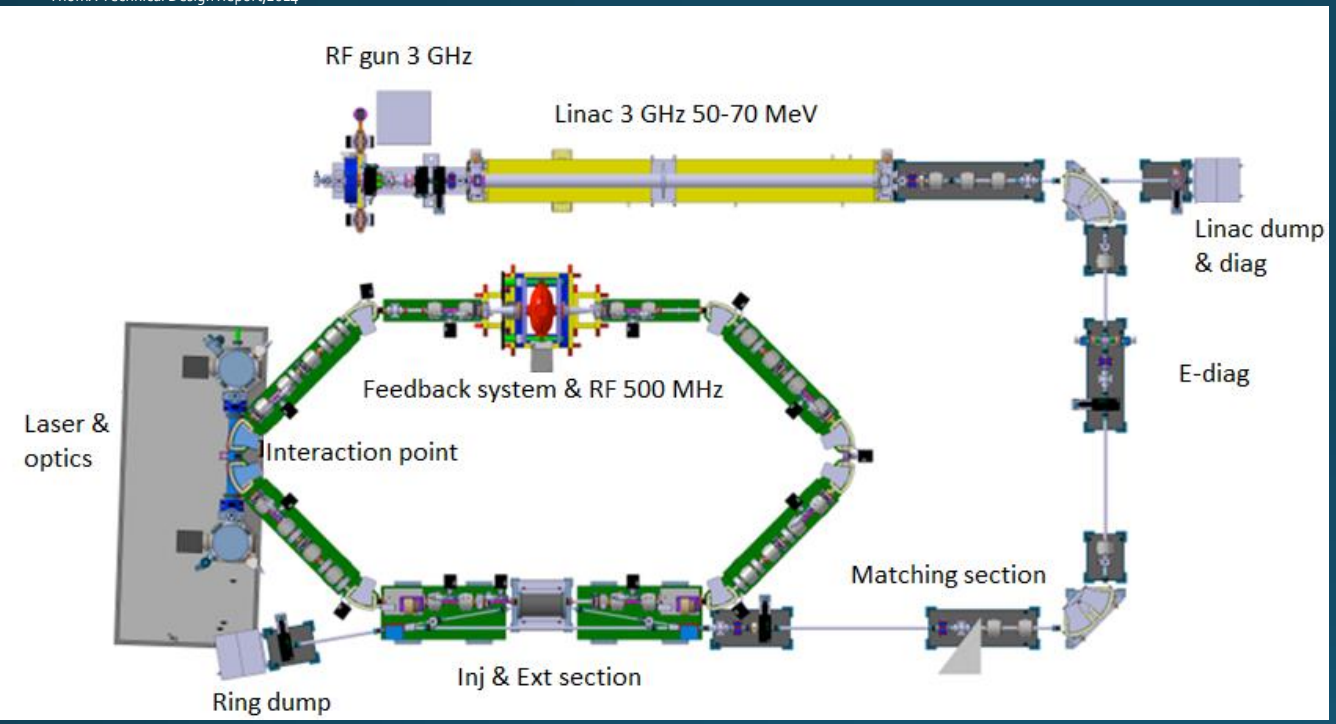
Storage ring + Fabry-Perot cavity

- High repetition rate
- High laser <power>
- High flux

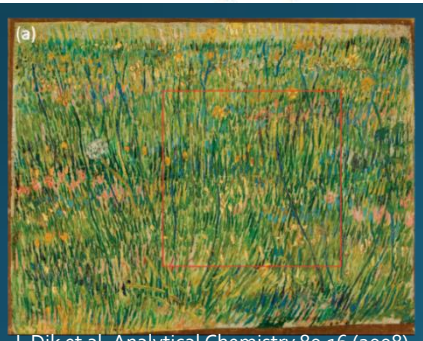
- Large energy spread

ThomX - LAL, France

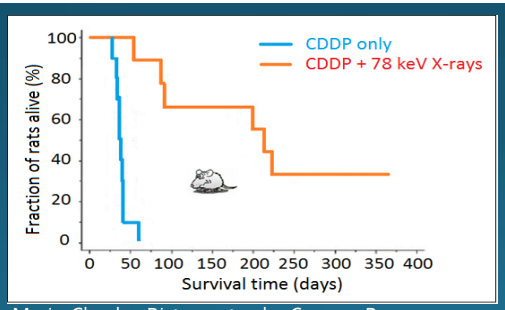
ThomX Technical Design Report,2014



- 16,7 MHz
- 50-70 MeV electrons
- 1 nC
- 1030 nm photons
- 600 kW stored



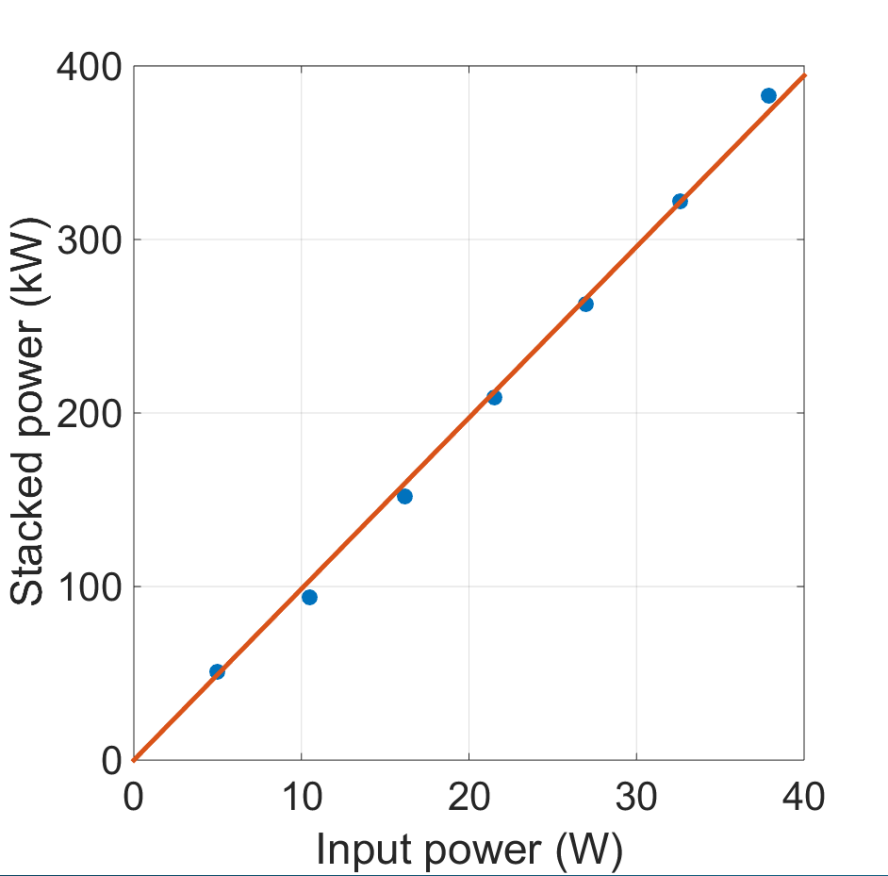
J. Dik et al. Analytical Chemistry 80.16 (2008).



Marie-Claude Biston et al. *Cancer Res* 2004;64:2317-2323

$$\text{Flux} = 10^{11-13}\ \text{X/s}$$
$$\Delta E/E = 1\text{-}10\%$$
$$E_X^{max} = 45\text{-}90\ \text{keV}$$
$$\text{Divergence} = 10\ \text{mrad}$$

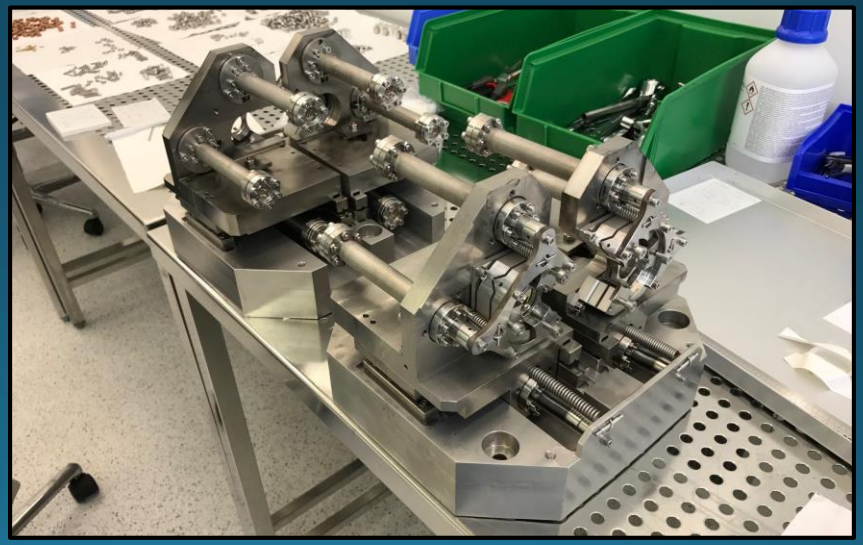
Fabry-Perot cavity stacked power



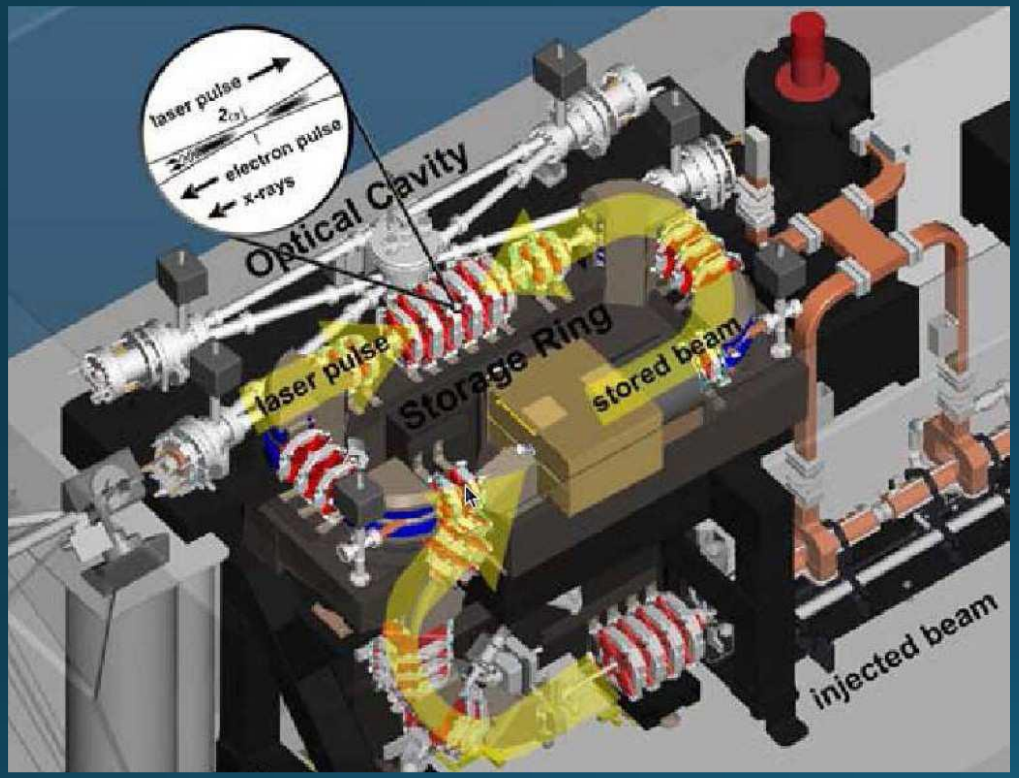
- Max stable stacked power ~ ***390 kW***

- Finesse ~ ***24 000***
- Effective enhancement factor ~ ***10 000***
- Spatial coupling ~ ***90 %***

Pictures



Lyncean Compact Light Source



- Commercially available
- Installed in Munich

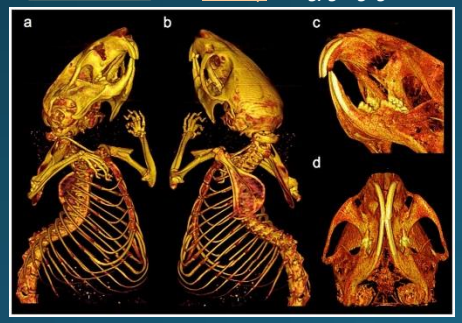
- 65 MHz

- 45 MeV electrons
- 250 pC

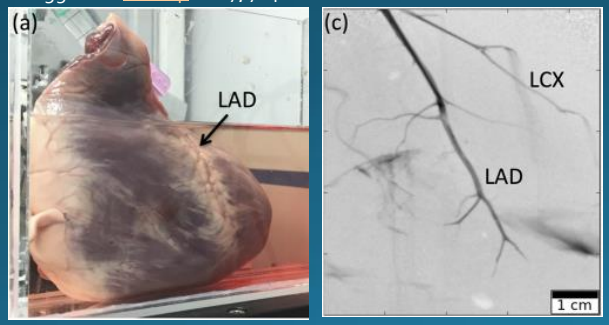
- 1030 nm photons
- 300 kW stored

$$\text{Flux} = 3 \text{ x } 10^{10} \text{ X/s}$$
$$\Delta E/E = 3\%$$
$$E_X^{max} = 15\text{-}35 \text{ keV}$$
$$\text{Divergence} = 4 \text{ mrad}$$

K. Achterhold et al. Sci Rep. 2013; 3: 1313



E. Eggl et al. Sci Rep. 2017; 7: 42211

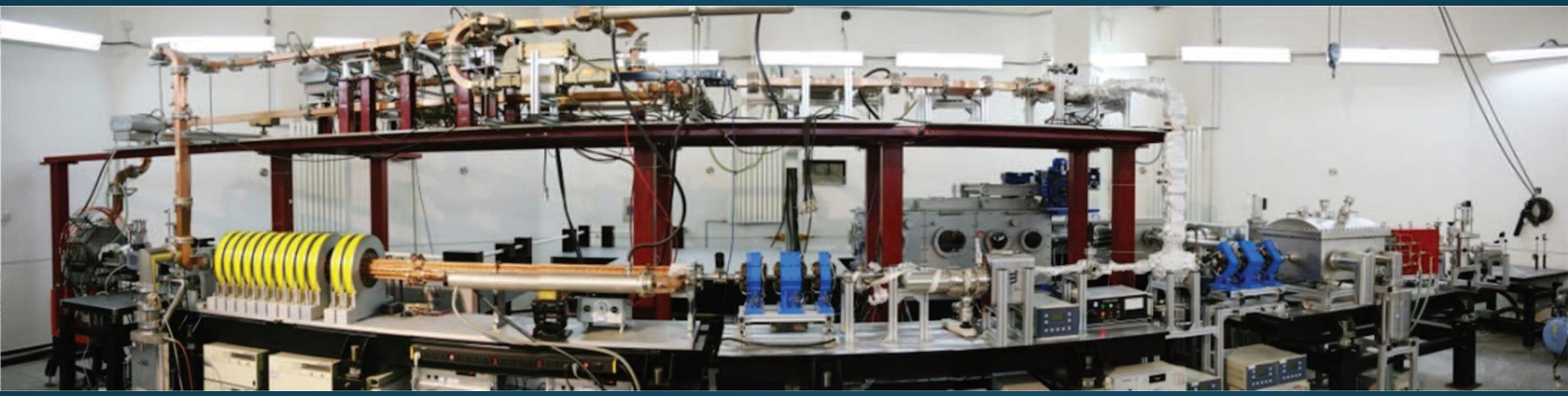


NC Linac + direct laser beam

- Low energy spread
- High tunability
- High brillance

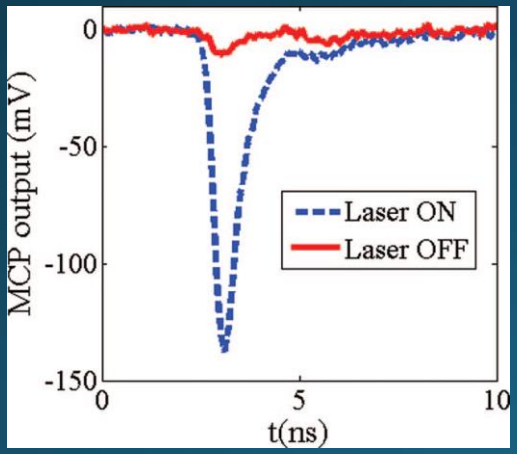
- Low repetition rate
- Low flux

TTX - Tsinghua University, China

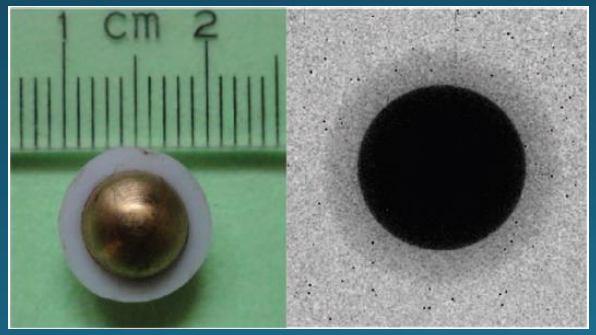


Y. Du et al. Rev. Sci. Instrum. 84, 053301 (2013)

- 46,7 MeV electrons
- 200 pC



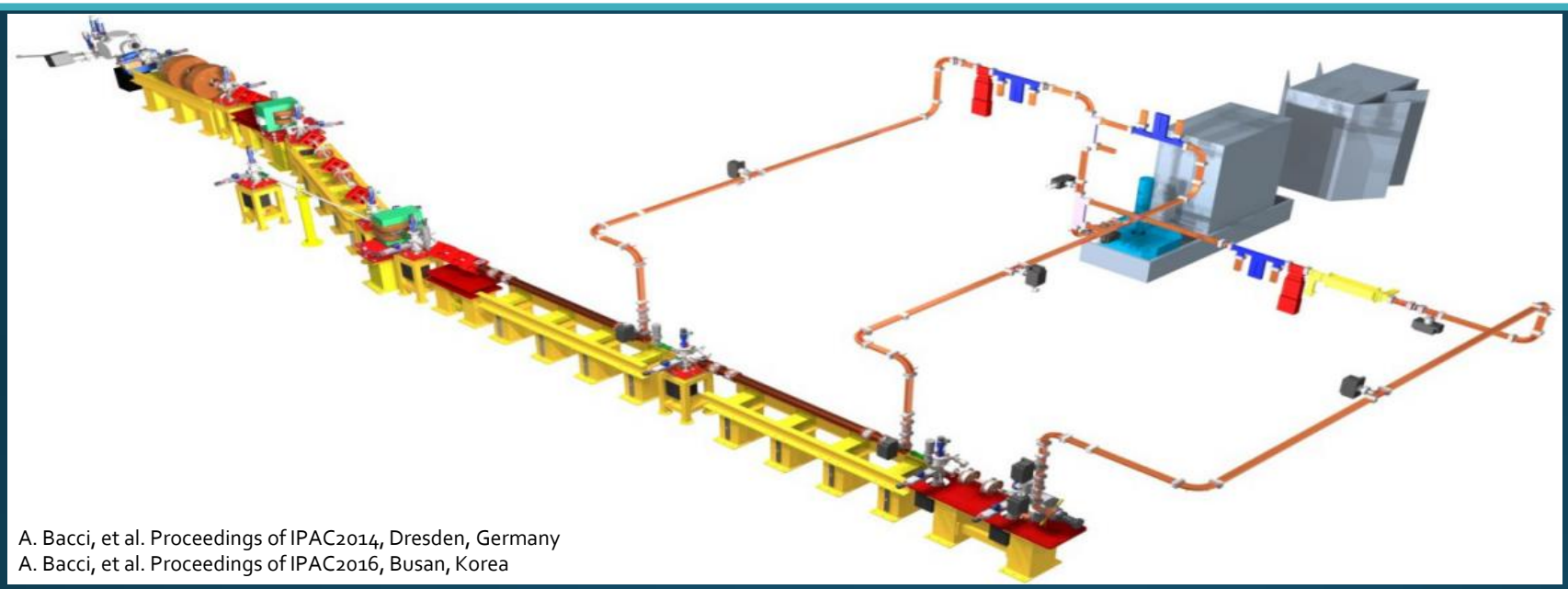
20 s, 100 shots



- 800 nm photons
- 300 mJ
- 70 fs

$$\text{Flux} = 10^6 \text{ X/pulse}$$
$$\Delta E/E = 4\%$$
$$E_X^{max} = 51.7 \text{ keV}$$
$$\text{Divergence} = 5 \text{ mrad}$$

STAR - Calabria, Italy



A. Bacci, et al. Proceedings of IPAC2014, Dresden, Germany
A. Bacci, et al. Proceedings of IPAC2016, Busan, Korea

- Matter science
- Cultural heritage
- Radiological imaging
- Microtomography

- 100 Hz

- 50-100 MeV electrons
- 200 pC

- 1030 nm photons
- 400-500 mJ
- 5 ps

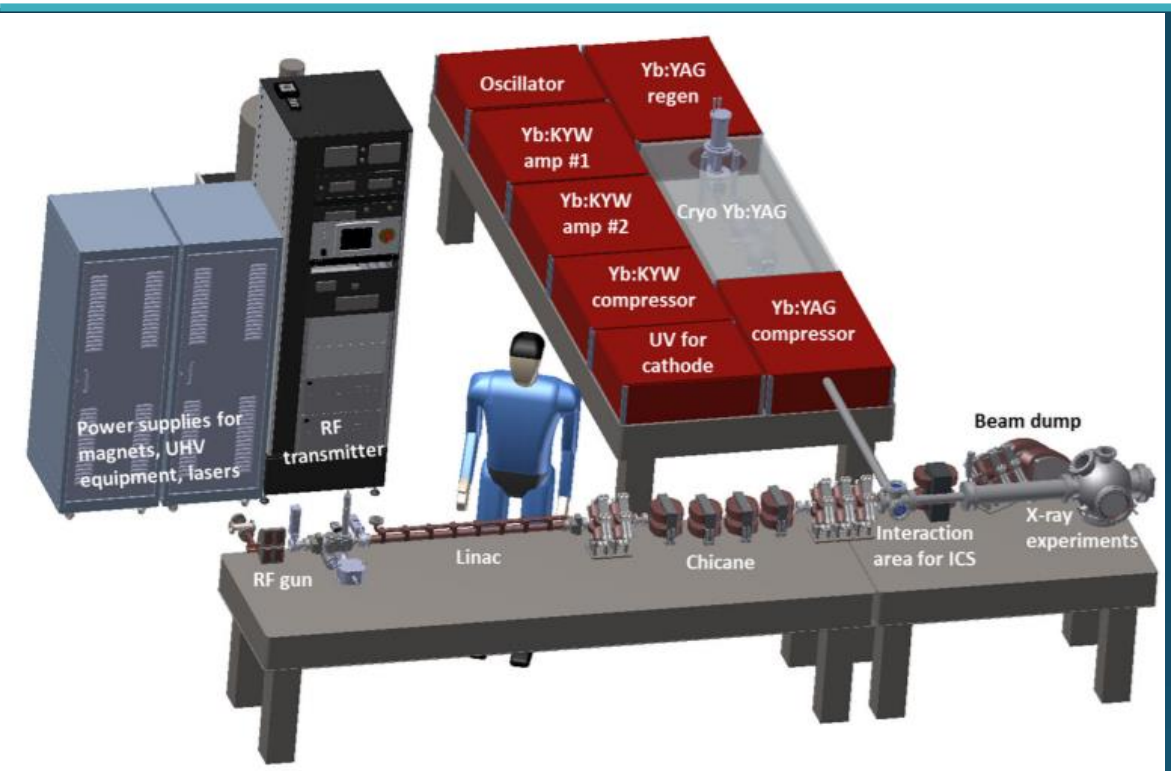
$$\text{Flux} = 10^8 \text{ X/s}$$
$$\Delta E/E = 1\%$$
$$E_X^{max} = 40\text{-}140 \text{ keV}$$
$$\text{Divergence} = 5 \text{ mrad}$$

NC Linac + laser circulator

- Low energy spread
- High tunability
- High brillance

- Low repetition rate
- Low flux

CXLS - MIT, USA

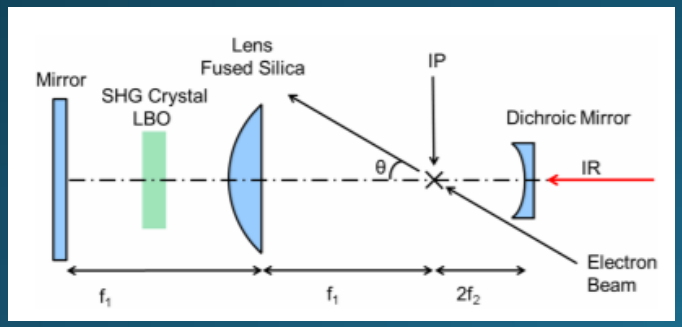


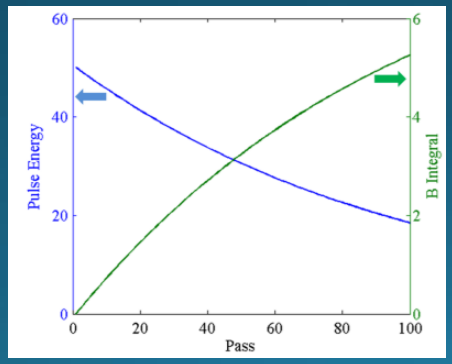
- 1 kHz
- 100 pulses @ 200 MHz

- 18 MeV electrons
- 100 pC
- X-band

- 515 nm photons
- 100 mJ
- 1 ps

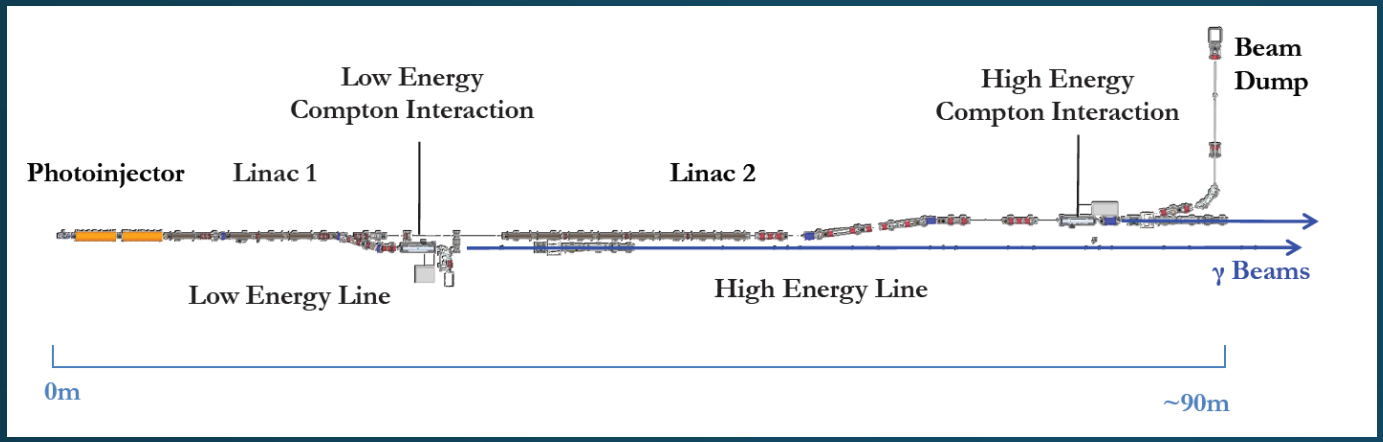
W. S. Graves et al. Phys. Rev. ST Accel. Beams 17, 120701 (2014)



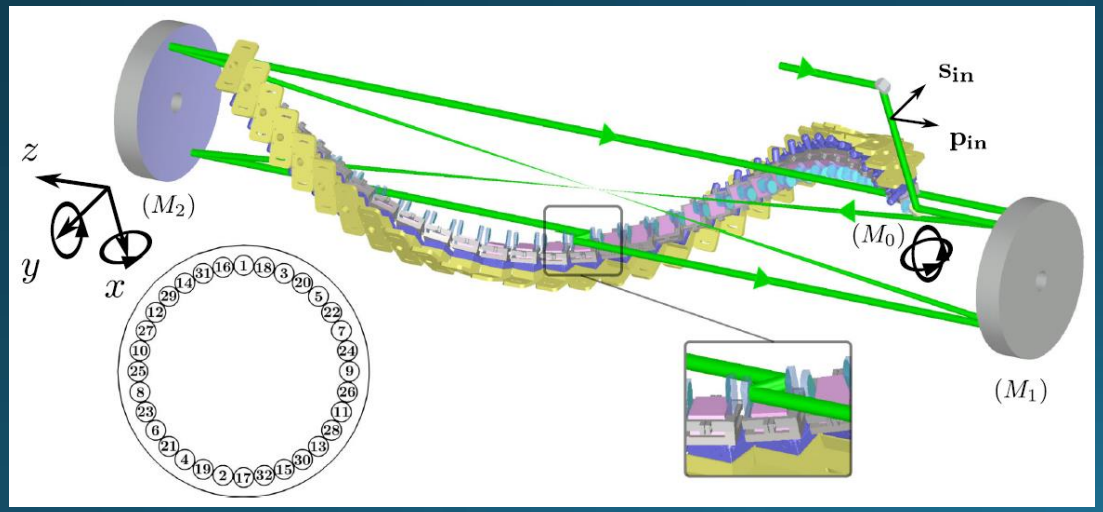


$$\text{Flux} = 5 \text{ x } 10^{11} \text{ X/s}$$
$$\Delta E/E = 5\%$$
$$E_X^{max} = 12.4 \text{ keV}$$
$$\text{Divergence} = 5 \text{ mrad}$$

ELI-NP-GBS - Magurele, Romania



L. Serafini et al. ELI-NP Gamma Beam System Technical Design Report. 2014
K. Dupraz. PhD thesis. 2015



- 100 Hz
- 32 bunches @ 62 MHz

- 100-720 MeV electrons
- 250 pC
- Hybrid S and C-band

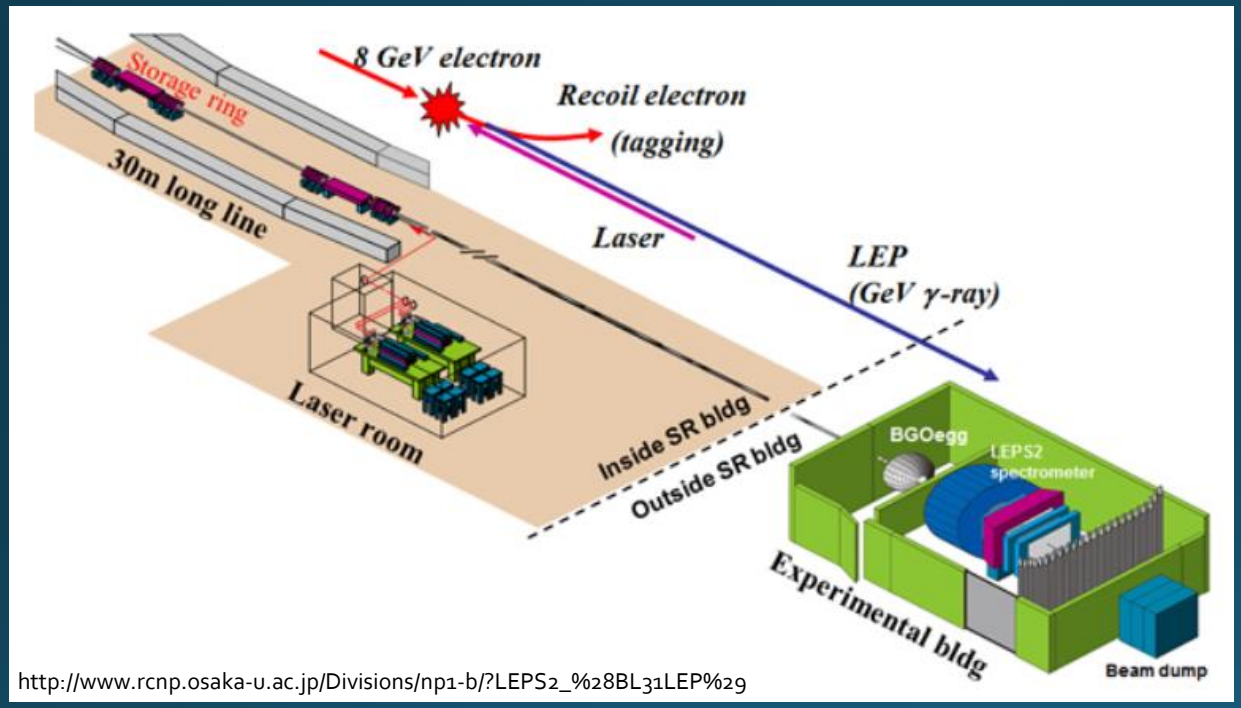
- 515 nm photons
- 200/400 mJ
- 1 ps

$$\text{Flux} = 8 \text{ x } 10^8 \text{ X/s}$$
$$\Delta E/E < 0.5\%$$
$$E_X^{max} = 0.2\text{-}19.5 \text{ MeV}$$
$$\text{Divergence} < 0.03\text{-}0.2 \text{ mrad}$$

Other configurations

LEPS – Spring-8, Japan

Storage ring + direct laser beam



http://www.rcnp.osaka-u.ac.jp/Divisions/np1-b/?LEPS2_%28BL31LEP%29

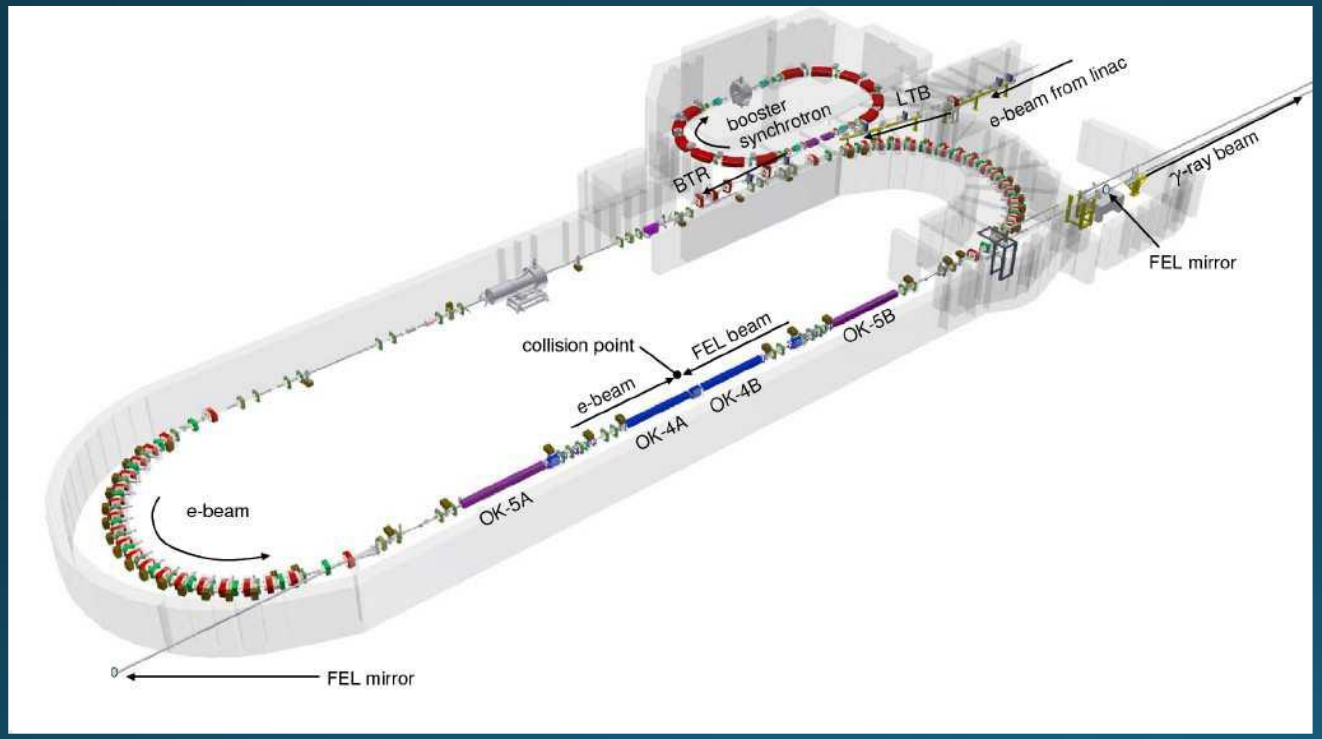
- 7,975 GeV electrons
- 100 mA
- 355 nm photons

- Particle physics
- Photon-proton collider

$$\text{Flux} = 10^7 \text{ X/s}$$
$$\Delta E/E < 1\%$$
$$E_X^{max} = 1.3\text{-}2.4 \text{ GeV}$$

HIGS– Duke University, USA

Storage ring + free-electron laser



Y.K. Wu. Proceedings of IPAC2015, Richmond, VA, USA

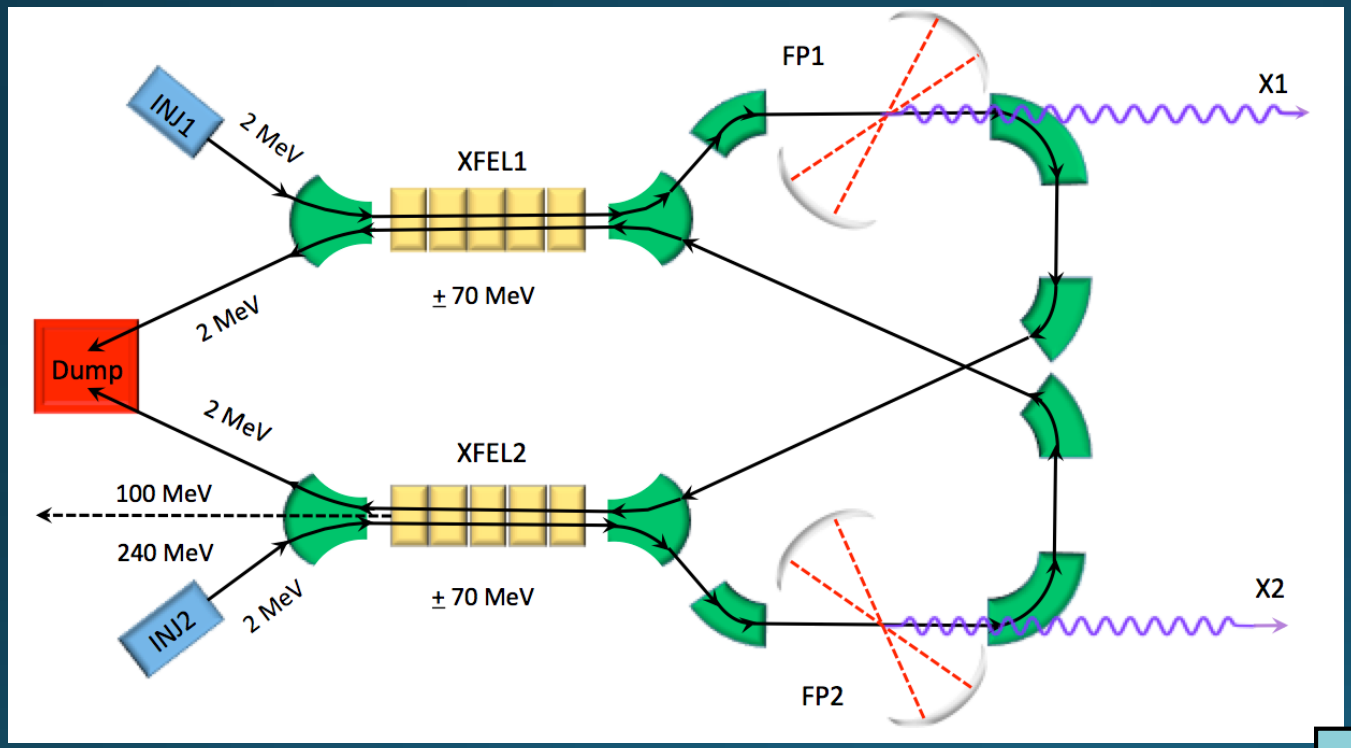
- 2,8 MHz
- 0,24-1,2 GeV electrons
- 60-80 mA
- 193-1064 nm photons

- Nuclear physics

$$\text{Flux} = 1\text{-}24 \text{ x } 10^7 \text{ X/s}$$
$$\Delta E/E = 5\%$$
$$E_X^{max} = 1\text{-}95 \text{ MeV}$$

BriXS – Milano, Italy

CW ERL + Fabry-Perot cavity



L. Serafini. BriXS Expression of Interest. 2015

- 100 MeV electrons
- 100 mA

- 193-1064 nm photons
- 1 MW stored (!)

- Imaging
- Radiotherapy
- X-ray fluorescence

$$\mathrm{Flux} = 10^{15}\ \mathrm{X/s}$$
$$\Delta \mathrm{E/E} = 10\%$$
$$\mathrm{E}_{X}^{max} = 20\text{-}200\ \mathrm{keV}$$

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