STAR project: The Italian Compton Source and the interaction chamber

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November 28th, 2017, Padova (IT)

Index

- A Brief view of Thomson/Compton European Sources
  - One Big Facility & four smaller one
  - The Sparc-Thomson Interaction Chamber
- The **STAR** project: **S**outhern Europe **T**homoson back scattering source for **A**pplied **R**esearch
  - Location & Funds; Dimension/Cost projects Scaling
  - Beam-line & main characteristics
  - Interaction Chamber
  - Source performances
- Conlcusions

European Thomson/Scattering X-Ray sources

- A Big facility in Romania; Extreme Light Infrastructure-Nuclear Physics (ELI-NP), C-band linac booster and up to 20 MeV high quality γ-ray

- Smaller machines that are opening interesting research lines are:

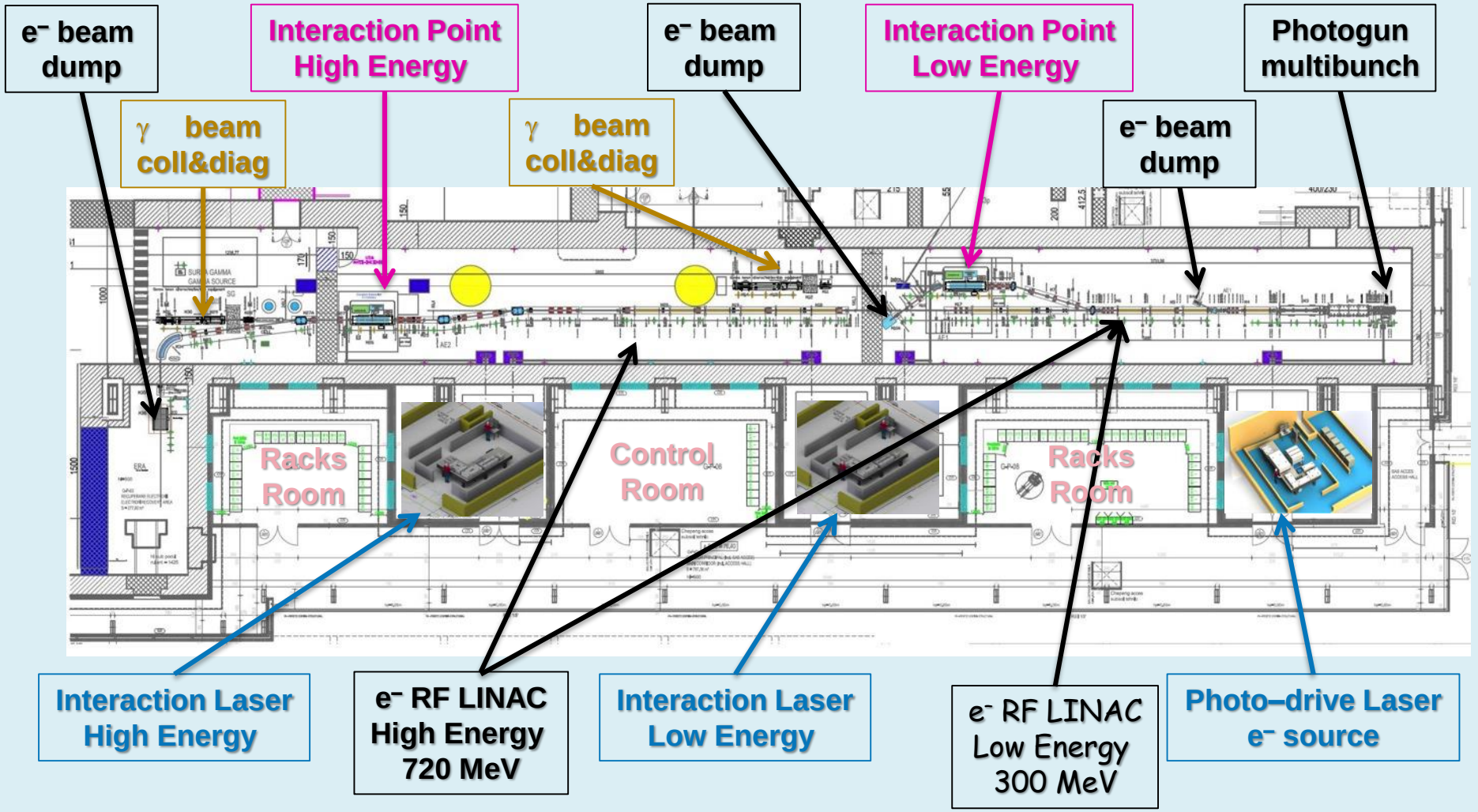
  - ThomX (@LAL, Orsay, France), a small electron ring producing 40-90 KeV, [Yesterday's Talk "Thom-X and Other Laser-Thomson Sources", Pierre Favier].

  - STAR @ University of Calabria (CS, Italy). A Linac driven source of monochromatic, ps-long, polarized 20 to 140 keV X-ray beams.

  - SPARC_lab (@ INFN Frascati Lab) first Italian Thomson scattering.
    C. Vaccarezza et al., NIMB A 829 (2016) 237-342.

  - Sources which start to be commercially available:
    Technische Universität München (TUM, Germany) Compact Light Source, 35keV X-ray. Very interesting but still not commercially attractive to produce high energy X-Ray with very narrow bandwidth, as often requests.

A big machine: ELI-NP Layout



Compact Light Source @ Monaco (Germany): Commercially available

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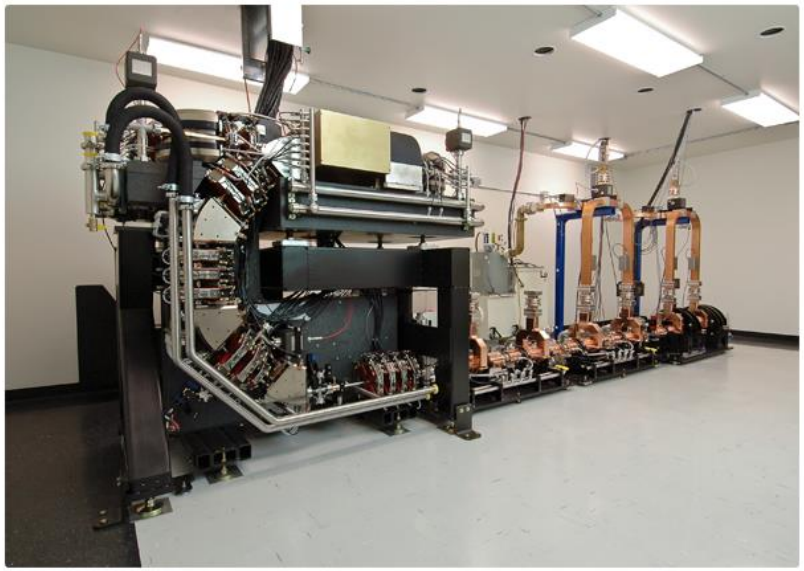
illuminating X-ray science™

- **Compact Light Source**
- Compact X-ray Station

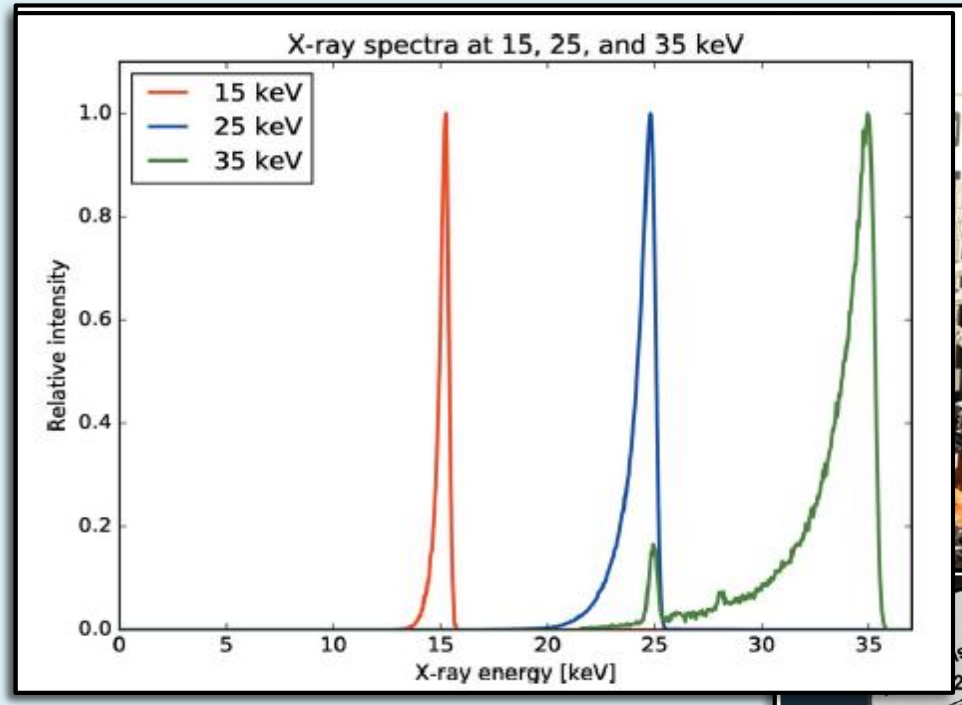
THE LYNCEAN COMPACT LIGHT SOURCE (CLS)

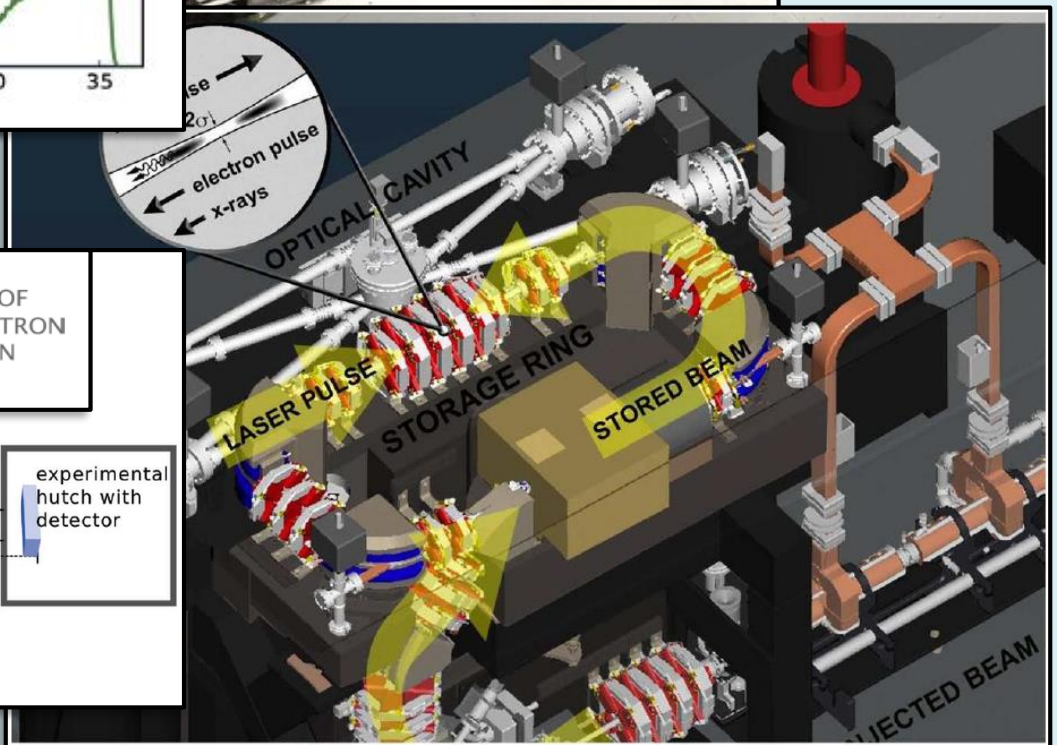
A breakthrough in local, on-demand X-ray synchrotron light

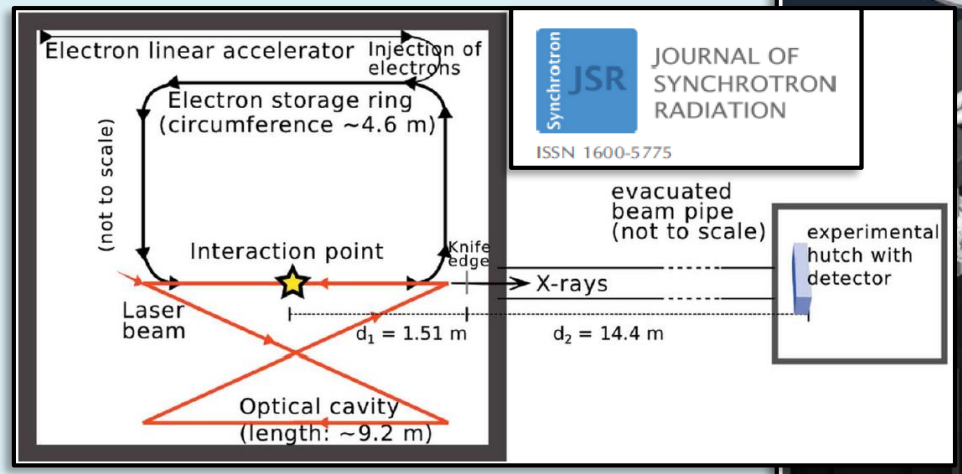


The Lyncean CLS assembled at the headquarters of Lyncean Technologies, Inc. in Palo Alto, CA

Compact Light Source @ Monaco (Germany): Commercially available







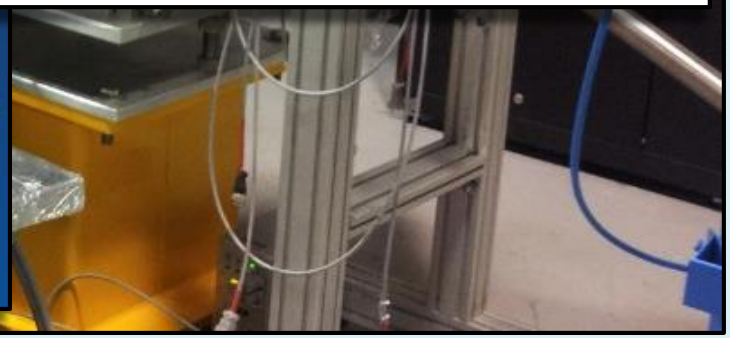
Synchrotron JSR JOURNAL OF SYNCHROTRON RADIATION
ISSN 1600-5775

SPARC_LAB thomson Line

Results in Ref:C. Vaccarezza et al., NIMB A 829 (2016) 237-342.

Table 1: Thomson Source Design Parameters

Electron Beam	Energy	(MeV)	30
	Energy spread	(%)	<0.1
	Charge	(pC)	100-800
	Emittance	(mm mrad)	1÷3
Laser Beam	Wavelength	(nm)	800
	Pulse energy	(J)	1÷5
	Pulse length	(ps)	6
	Spot size	(μm)	10
	Repetition rate	(Hz)	10
X-ray Beam	Photon energy	(keV)	20-500
	Photon number per shot		10^9
	Source rms radius	(μm)	10
	Bandwidth	(%)	10



The STAR Project

STAR brief description:

- A Monochromatic & tunable & ps-long & polarized X-ray beam from 20 to 140 keV.
- Experiments on matter science, cultural heritage analysis and radiological imaging, by using micro-tomography, are planned.
- An Yb:Yag 100 Hz, 150mJ colliding laser (Amplitude).

Actors in the project :

- UNICAL (UNIversità della CALabria)
- CNISM (Consorzio Nazionale Interuniversitario per le Scienze fisiche della Materia)
- Sincrotrone Trieste
- INFN (Istituto Nazionale di Fisica Nucleare)

UNIVERSITÀ DELLA CALABRIA

cnism

Elettra Sincrotrone Trieste

INFN

Location & Funds

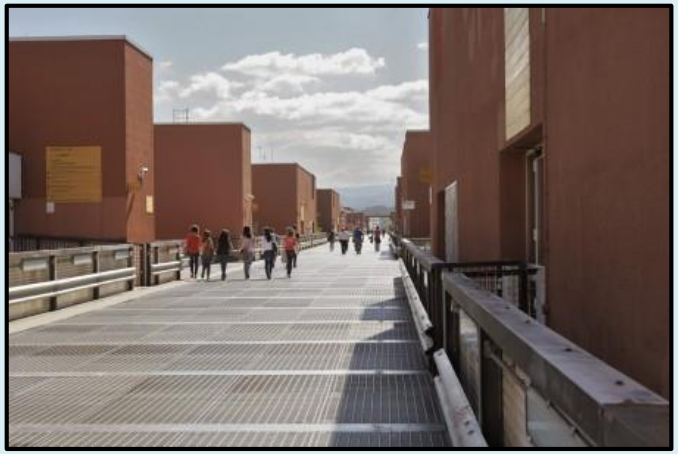
The economical support comes from the EU for Regional Convergence (including Calabria) Development Funds for the community, including research infrastructures

Gross domestic product per capita (US Dollars)	
Italy	35.000
Calabria	23.000

Location

University of Calabria (UNICAL):
International Architect competition in 1974 (won by Gregotti Bureau), built in 1977

- 35.000 Students
- Strong physics department (strong collaborations with CERN)



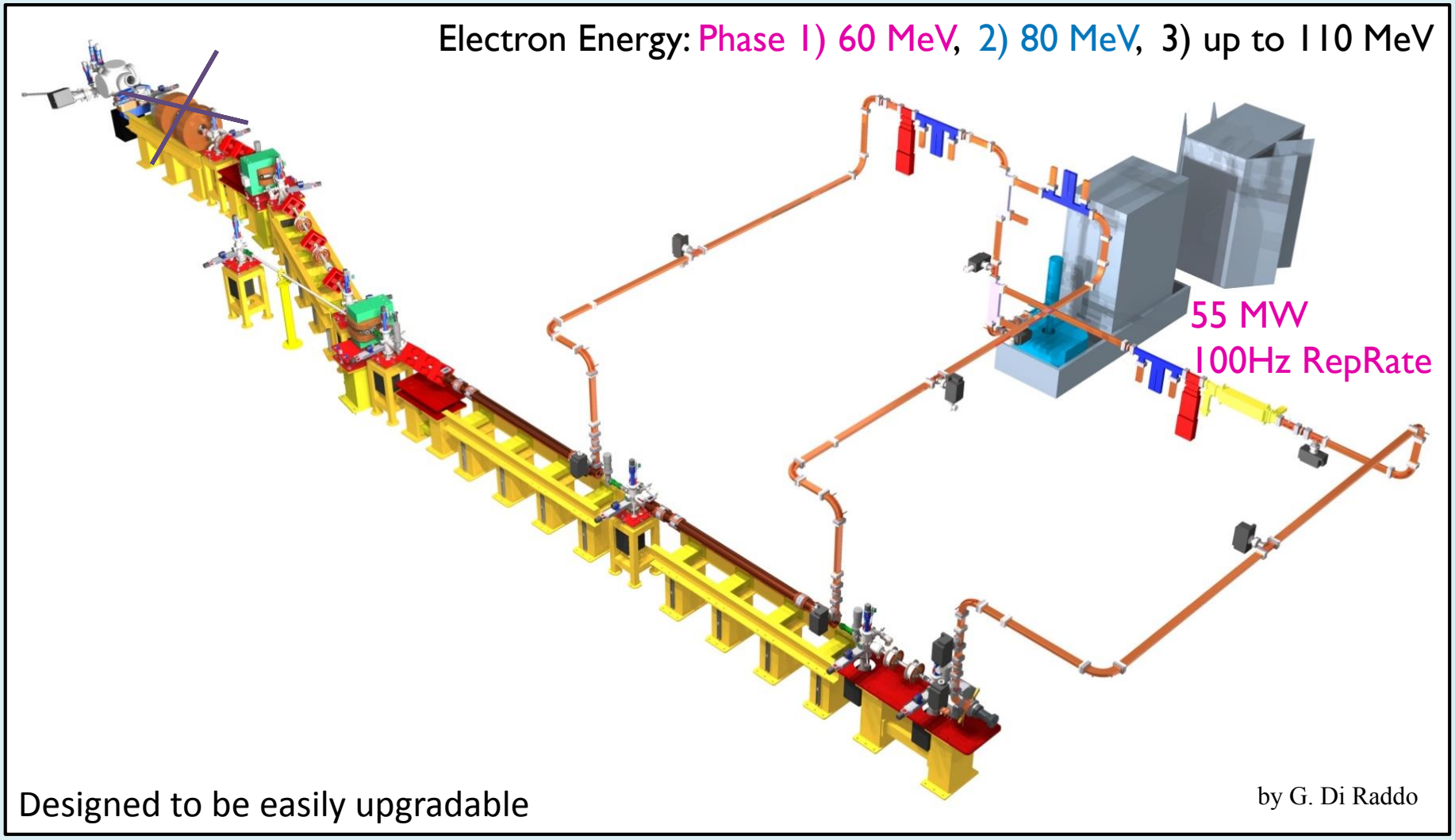
Dimensions & Costs Scaling

Features of available X-ray sources

	Cost (M€)	Size (m)	Energy (keV)	Features
Syncrotrons	500	500	0.1 - 100	General purpose
FEL	1000	1000	0.01 - 10	Peak intensity, time resolution
ELI – NP (TBS for γ)	300	100	20000	Only available γ source
STAR (TBS for X)	15 ~ **10**	30 ~ **10**	7-120 (240)	Cost, portability, tunability

E. Puppin Courtesy

STAR project layout

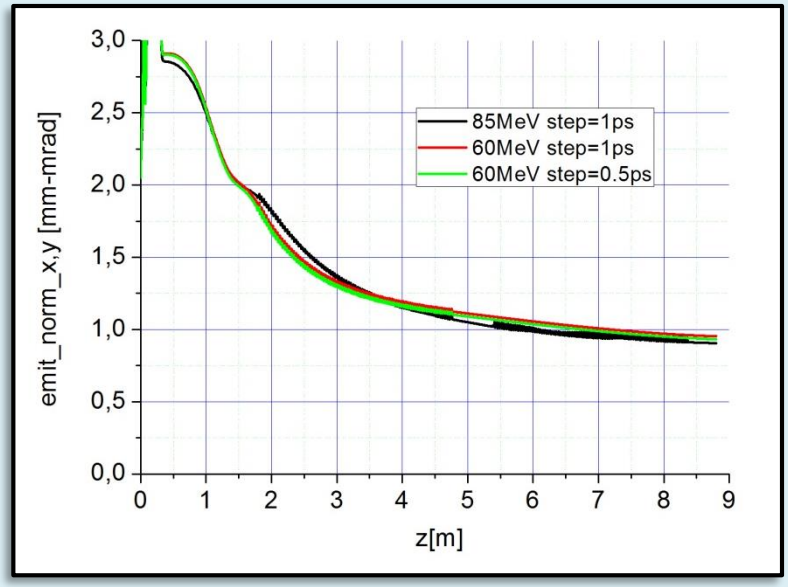


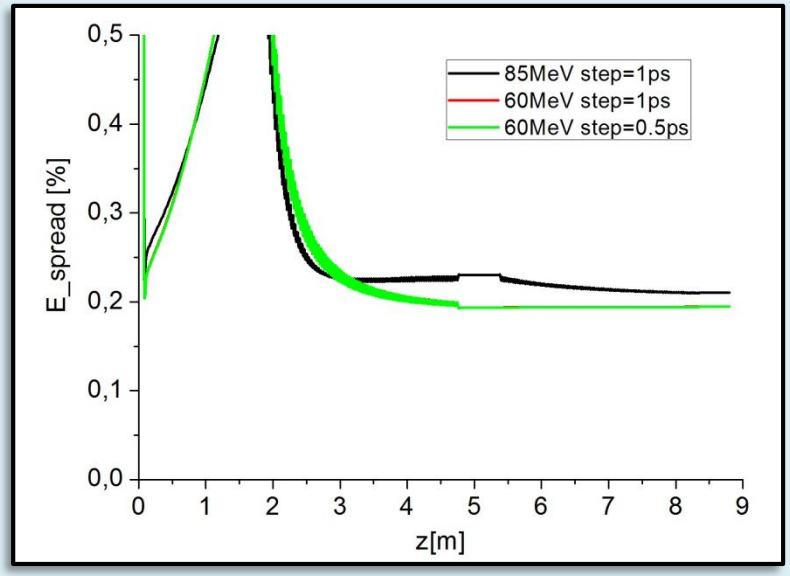
Injector Optimization (1-8.8m) for the two phases: 60 MeV and 85 MeV

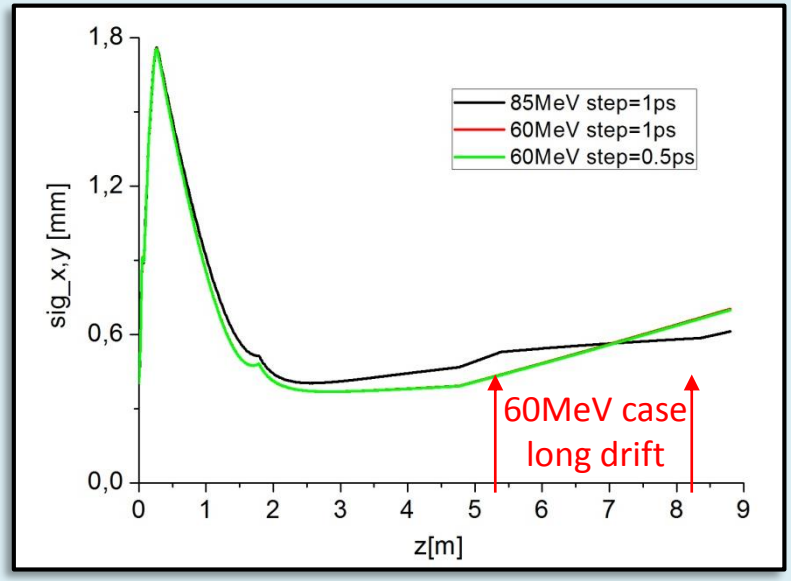
60 MeV – one S-band TW SLAC cavity
Sig_t=3.4ps (Gaussian pulse)
Sig_x=340 micron
Charge=0.5 nC

85 MeV – two S-band TW SLAC cavities
Sig_t=3.7ps (gauss pulse)
Sig_x=320 micron
Charge=0.5 nC

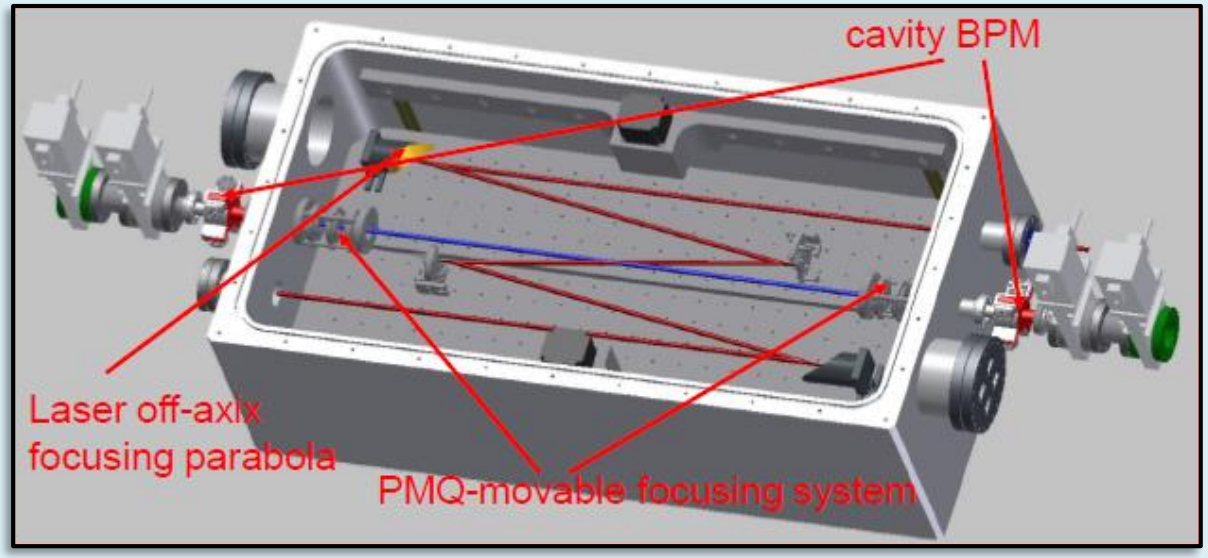
5000mp Astra simulations







A new interaction chamber scheme 1/3

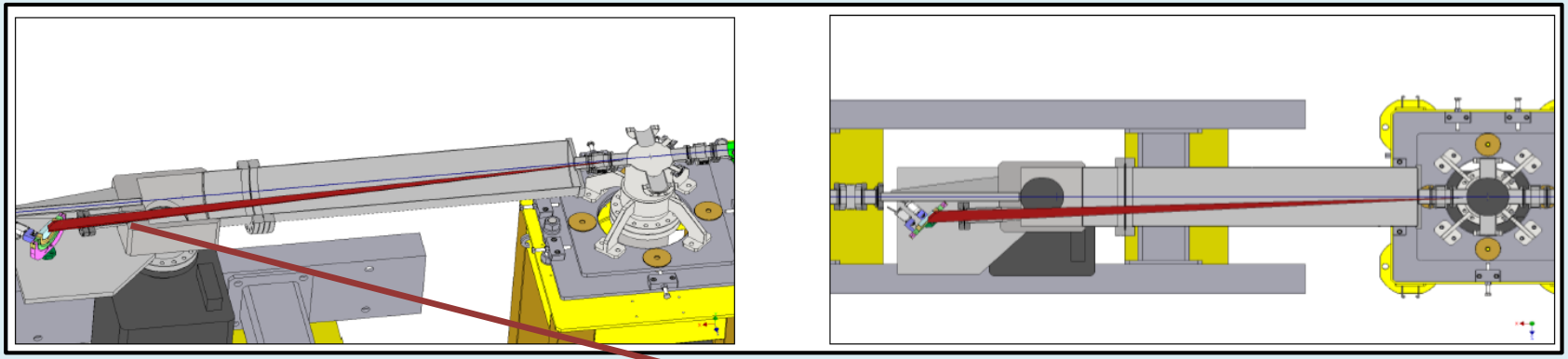


very expensive

250-300k€

- 2 x Cavity BPM
- 2 x Movable permanent Quads fousing channel

New scheme



The Interaction Chamber is a diagnostic chamber, with a laser entrance as tested at Fermi_lab (Trieste) for the cathode laser; (as planned @ Eli-np & STAR)

A new interaction chamber scheme 2/3

At realative low energy (as at STAR, 0.5 nC for 60-100 MeV) the focusing channel have to be as compact as possible

PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS
8, 072401 (2005)

Adjustable, short focal length permanent-magnet quadrupole based electron beam final focus system

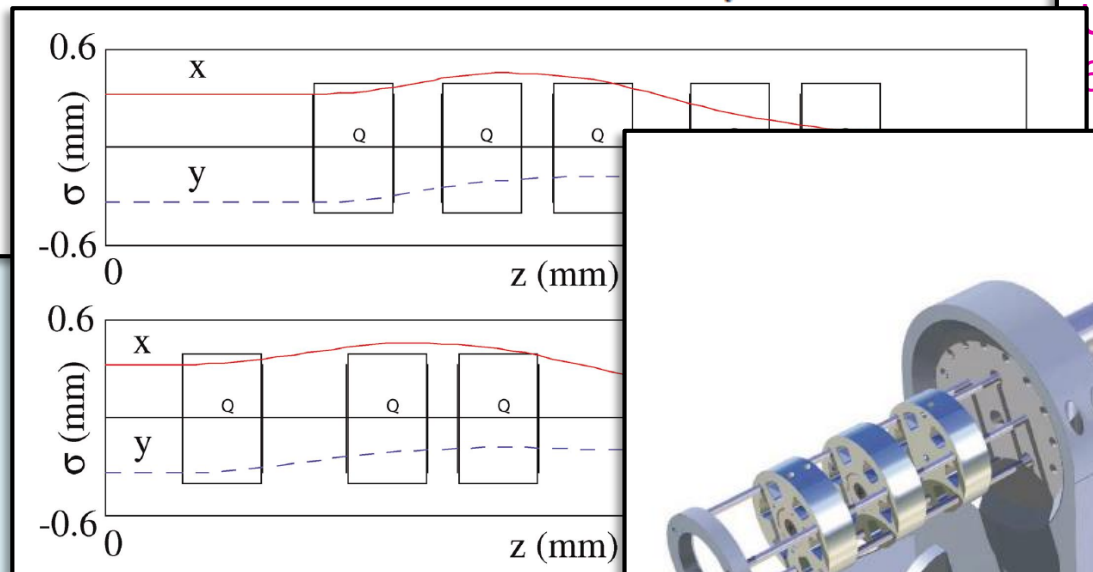
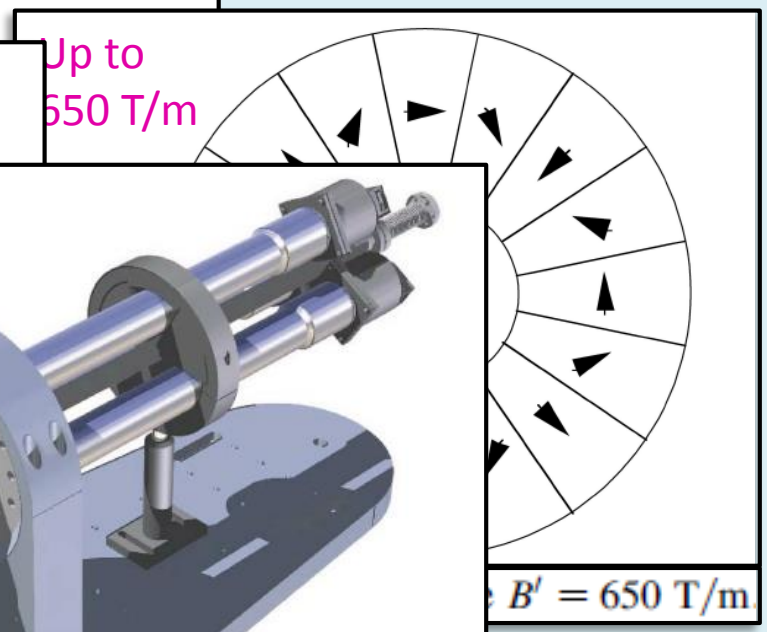


FIG. 8. (Color) Beam energy: 72 MeV (to

Up to
650 T/m



$B' = 650$ T/m

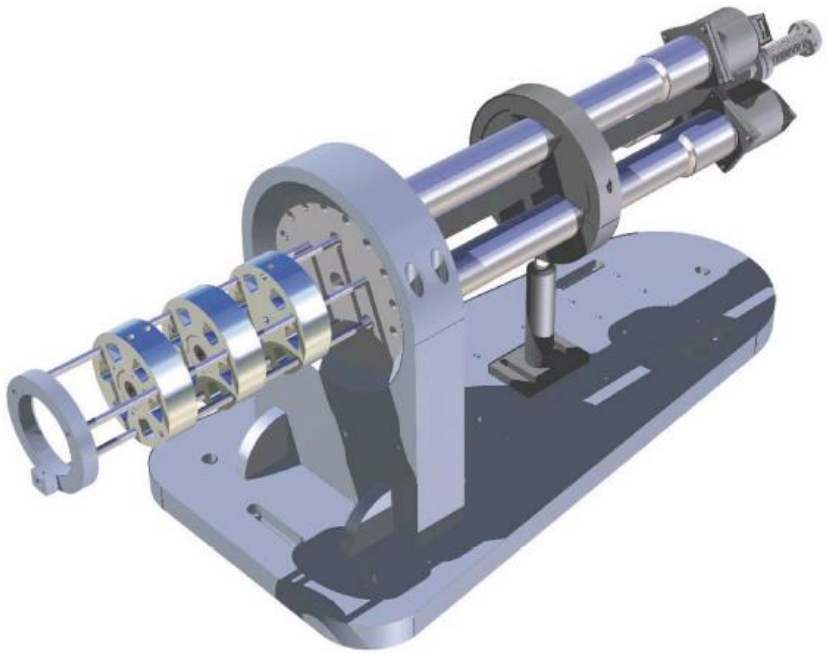
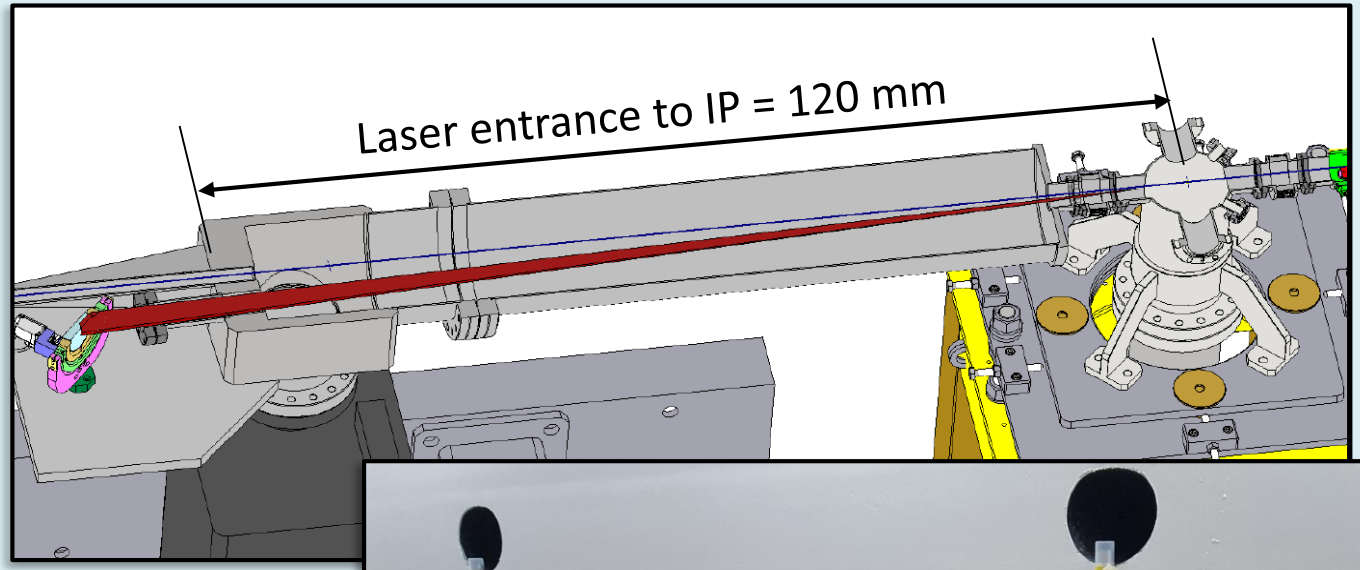


FIG. 14. (Color) Rendered CAD drawing of the final-focus assembly.

A new interaction chamber scheme 3/3

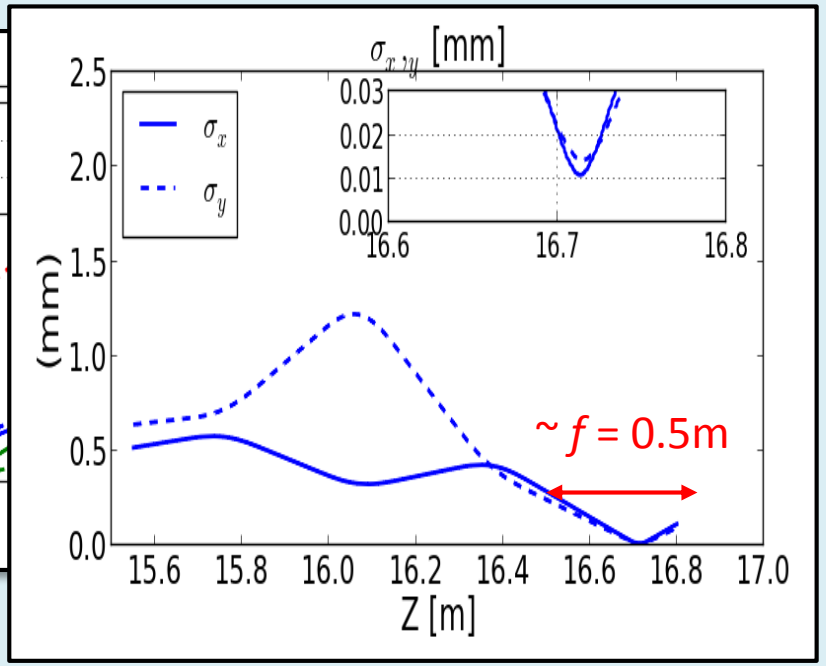


f_laser=1500 mm
IP_angle = 2.3°
(e^- vs laser)

The Focusing channel

We studied more solutions, starting from Permanent Quadrupole and Solenoids

FINAL FUSING CHANNEL

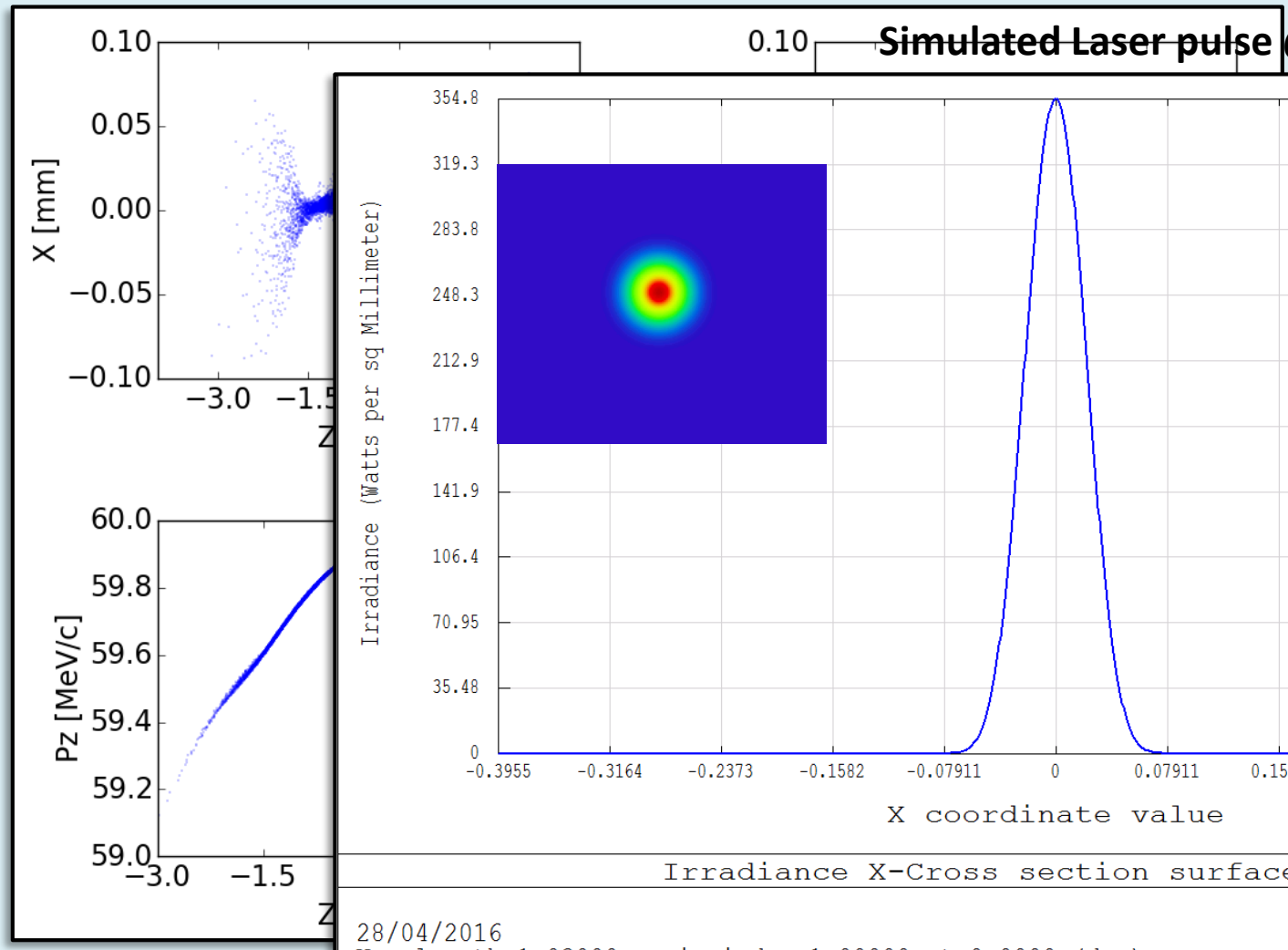


Source performances 1/3

Electron beam Parameters	
Electron Energy [MeV]	59.81
Bunch charge [nC]	0.5
Bunch length rms [mm]	0.93
Normalize Emit. x,y [um]	1.7, 1.8
Energy Spread %	0.2
Spot size rms; x,y@ IP	9.5, 13.2
Interaction Laser Parameters	
Pulse energy [mJ]	150
Pulse Lenght rms [ps]	1.9
Spot size w0, rms [um]	28
Wavelegth [nm]	1029

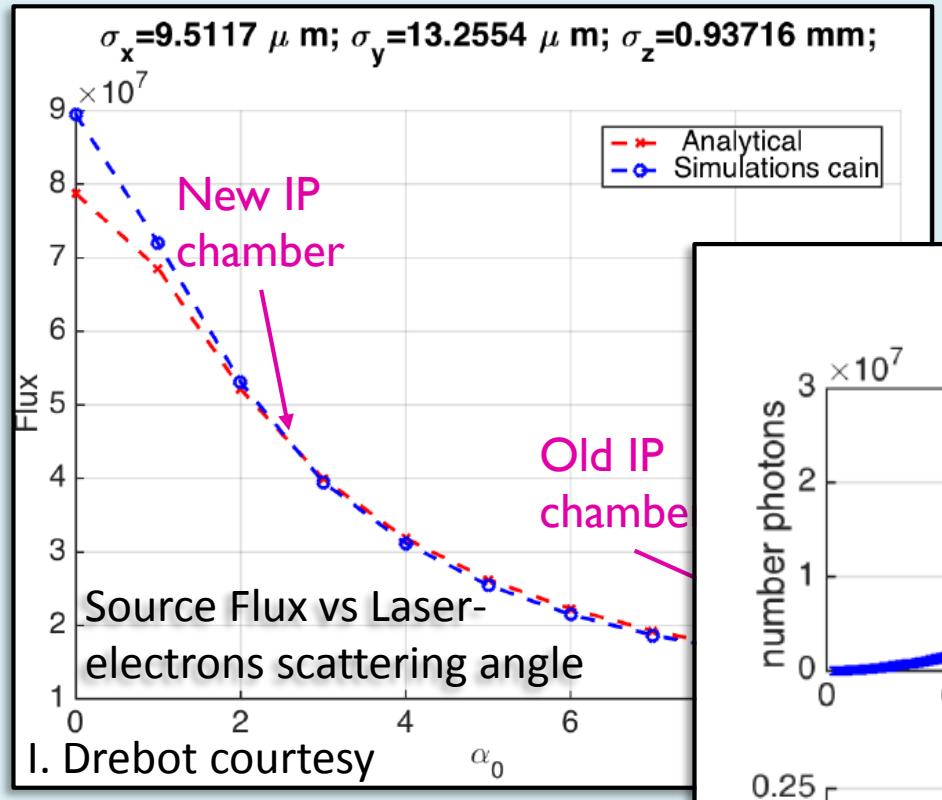
Source performances 2/3

Simulated Electron Bunch @ Interaction Point

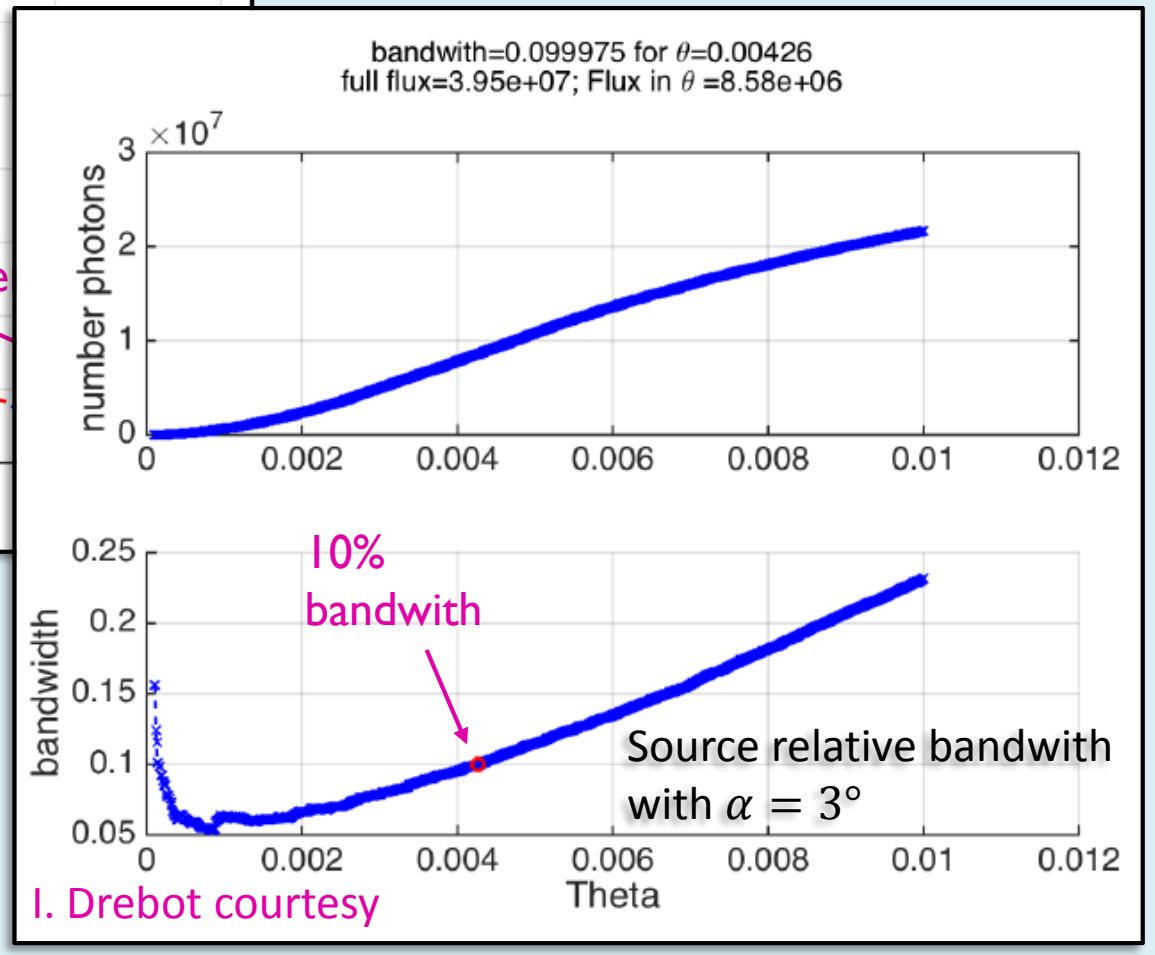


Simulated Laser pulse @ Interaction Point

Source performances 3/3



- Old IP chamber α_{IP} = 10°
- New IP chamber α_{IP} = 2.3° (here α_{IP} = 3° , to be conservative)



In Conclusion

Compton/Thomson X-ray Sources, in the last few years, by simulations & by recent experimental results have shown great advantages in more and more fields: radiological medical imaging, matter science, study of the historical finds (e.g. unroll of burnt papyrus), etc. …

Further the possibility to produce synchrotron radiation by not huge machines easily overcoming 100keV x-ray energy with small (order of 10 meters)

Waiting for to TURN-ON of … e news @ Munich CLS

Thanks for your attention

…tropy imaging with a compact …otron x-ray source", C. Jud* at al. Scientific Reports 7, Article number: 14477; Online: 03 November 2017 *Tecnical University of Munich

Microfractures are often missed in classical radiographs; x-ray vector radiography (XVR) can overcome this limitation: degree of anisotropy and orientation of scattering structures