

Status and Perspectives of Elettra and FERMI



A. Franciosi

Elettra-Sincrotrone Trieste S.C.p.A. and University of Trieste

Elettra 2.0-2.4 GeV 3rd generation Synchrotron Radiation Facility



FERMI 1.5 GeV seeded Free Electron Laser Facility



Elettra-Sincrotrone Trieste S.C.p.A.

- A nonprofit shareholder company of national interest:

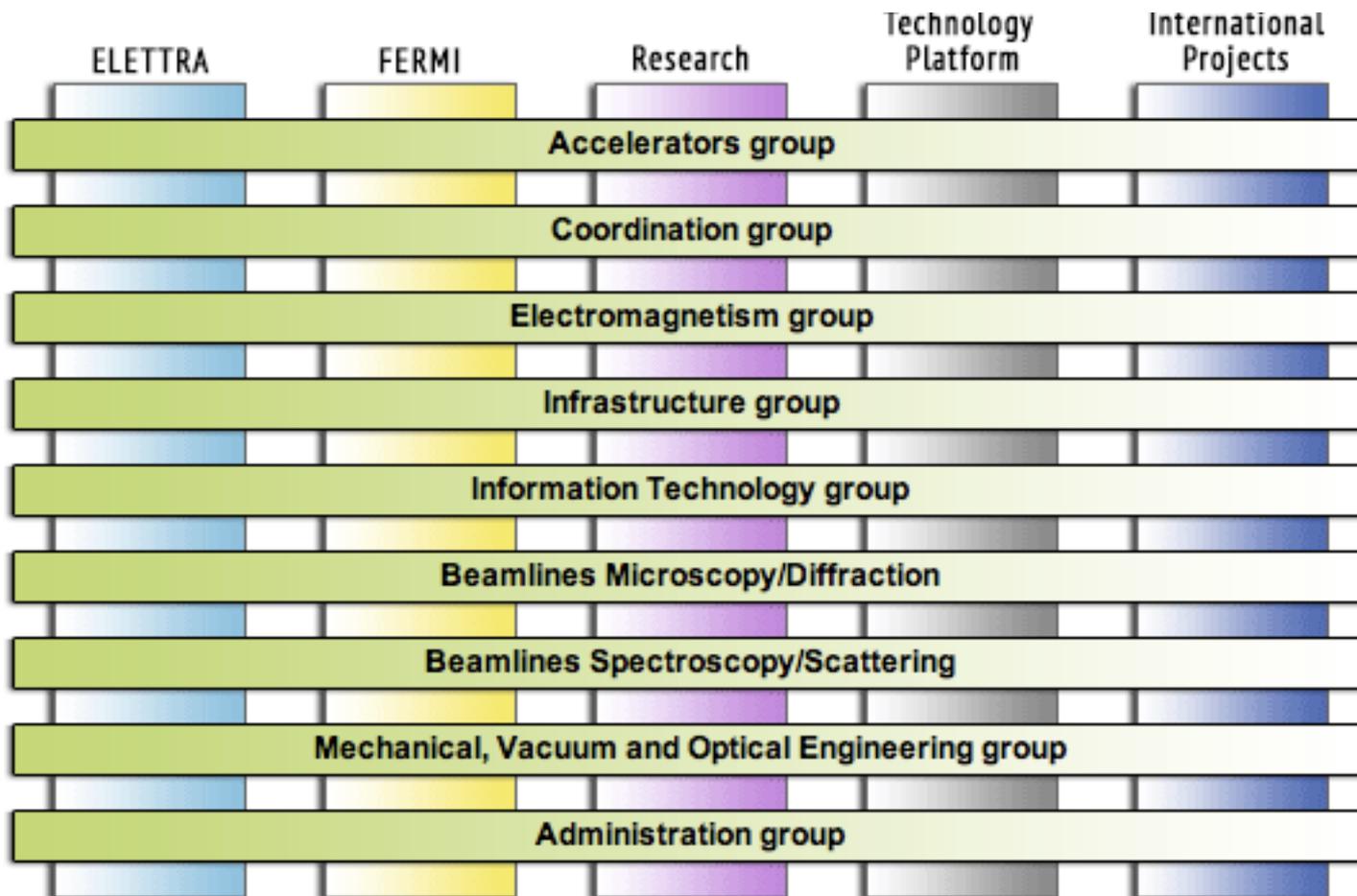
AREA Science Park	53.7%
FVG Regional Government	37.6%
CNR	4.9%
Invitalia Partecipazioni S.p.A.	3.8%
- Established in 1987 to construct and manage synchrotron light sources – international facility
 - > Promote cultural and socioeconomic growth at the regional, national and international level
 - > State-of-the art research facilities, technical leadership, skill development and transfer

Elettra-Sincrotrone Trieste in a nutshell:

2015 projected budget:	59.5 M€
Recurrent government funding:	26.9 M€
National and International projects:	28.4 M€
Friuli Venezia Giulia regional grants:	2.1 M€
Direct industrial income:	2.1 M€

Total payroll:	460
Permanent employees:	267
Term employees:	22
Collaborators/consultants:	73
Fellows:	57
Research associates:	11
Trainees:	16
Temporary staff:	14





Elettra 2.0-2.4 GeV 3rd generation Synchrotron Radiation Facility



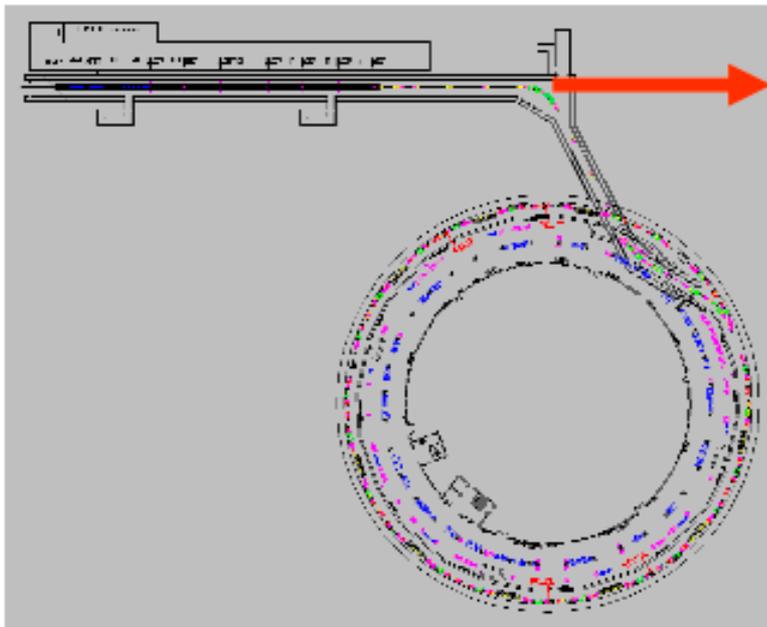
FERMI 1.5 GeV seeded Free Electron Laser Facility



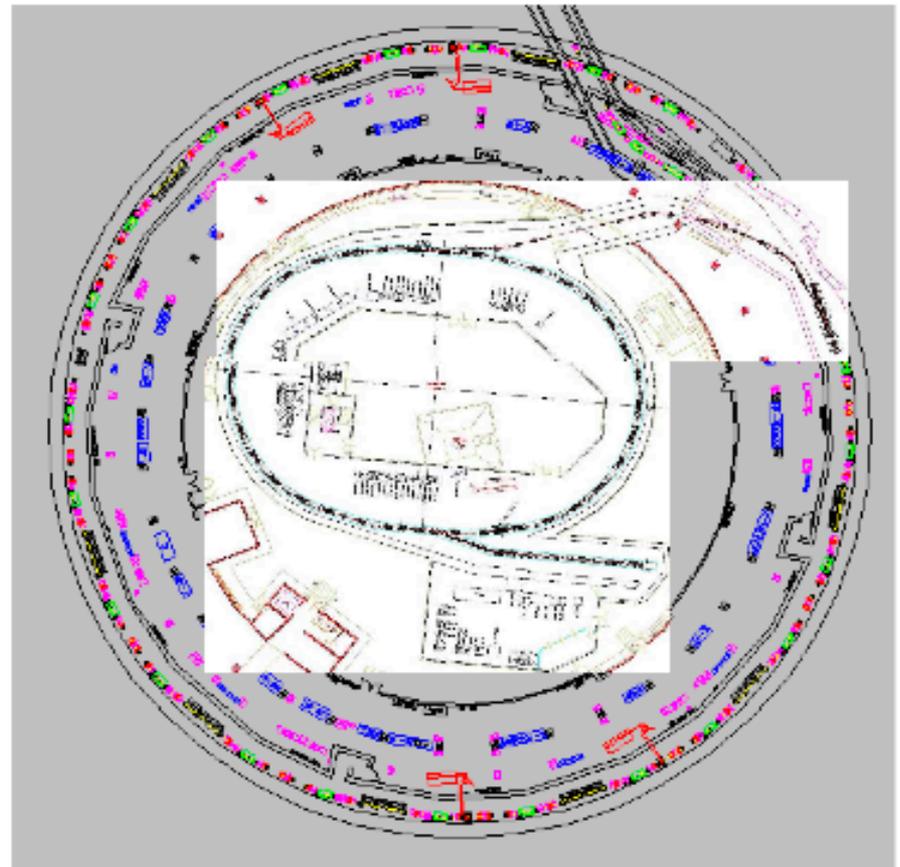
Booster full-energy injector:

Past and Present Configurations

till 2007



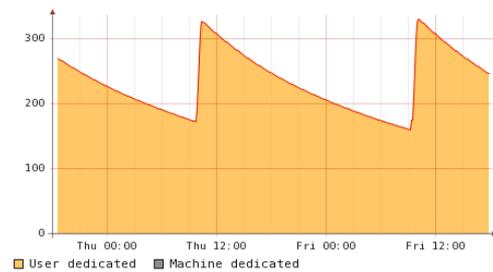
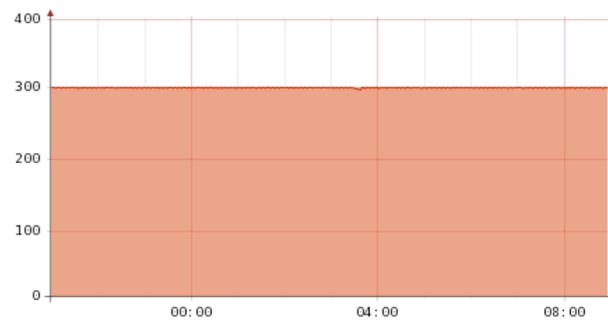
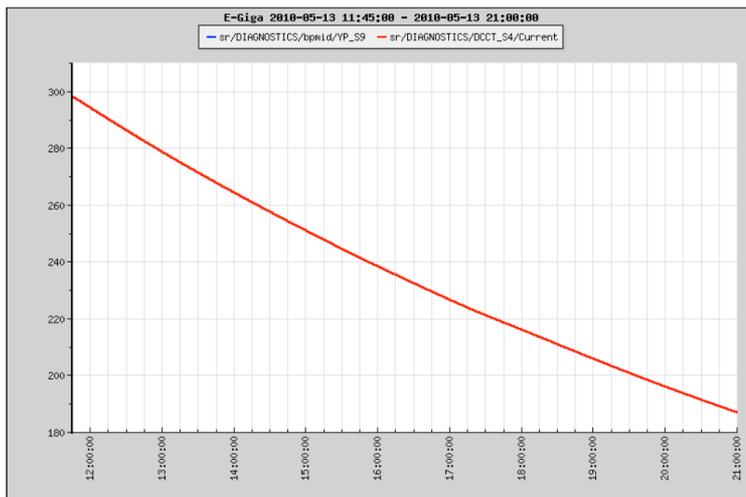
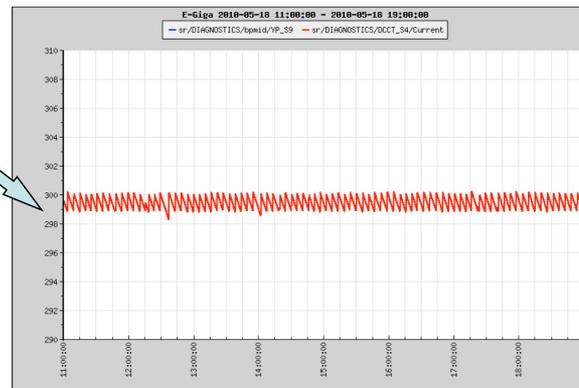
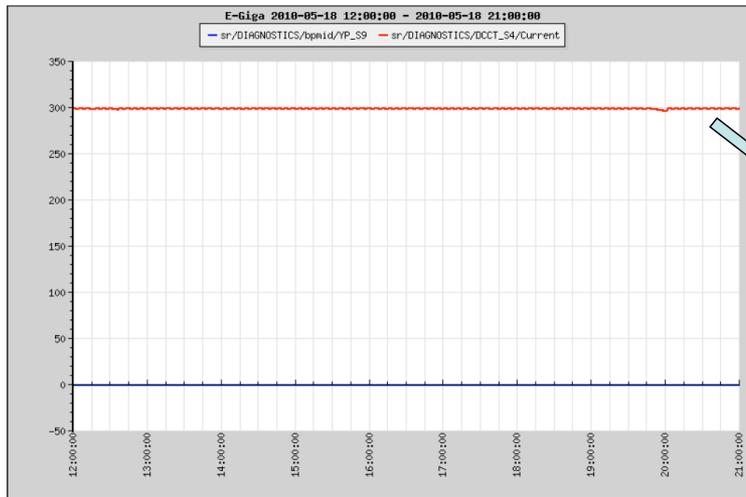
From 2008



Project Leader: M. Svandrlik

top-up since 2010

*In 2014: uptime was 97% of the scheduled user beamtime
the highest ever recorded at Elettra, MTBF 60 hours*



■ User dedicated ■ Machine dedicated

Elettra

26 beamlines
in operation

major upgrades:

XRD1
SuperESCA
Nanospectroscopy

under construction:

XRD2
XPRESS

**November-
December
2015**





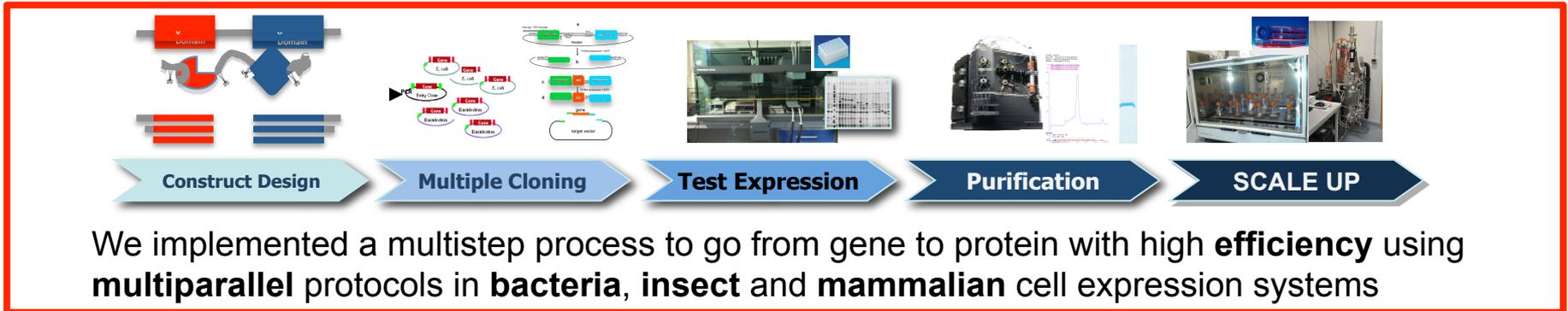
Elettra Sincrotrone Trieste

Biotechnology at Elettra

The *PROTEO Protein Production Facility*

A biotechnological platform that provides a specialized support to express and purify recombinant proteins for **functional and structural studies**.

Recombinant proteins are fundamental “**reagents**” for basic and applied bio research
Availability of suitable proteins is a usual **bottleneck** in biological studies



The PROTEO Lab is funded under the Cross-Border Cooperation Programme Italy - Slovenia 2007-2013





Elettra Sincrotrone Trieste

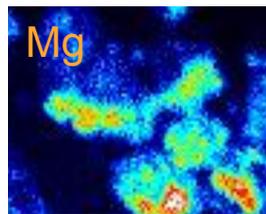
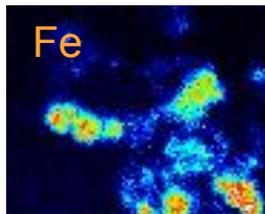
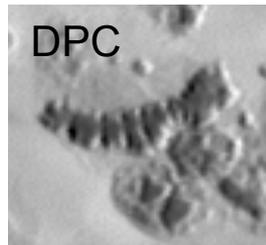
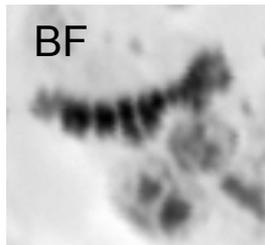
Biotechnology at Elettra

Nanotoxicology

Complementary methodologies (FTIR Microscopy and Low energy X-ray Fluorescence Microscopy @ SISSI & TwinMic beamlines) for the evaluation of **toxic effects of nanoparticles and nanomaterials at cell and tissue level**

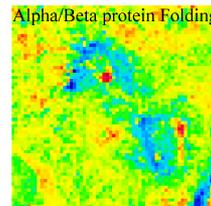
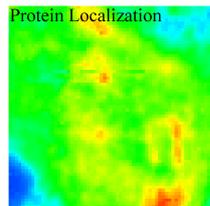
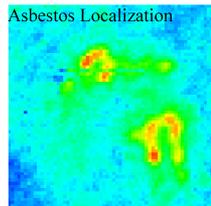
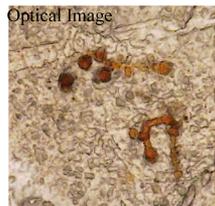
Asbestos in lung tissue

New insights on asbestos toxicity mechanism (TwinMic and SISSI beamlines)



X-ray Fluorescence Microscopy

25um

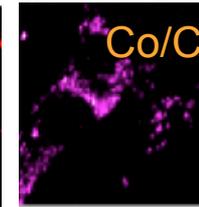
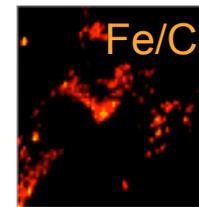
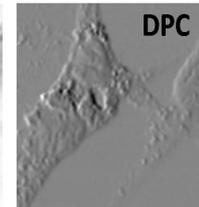
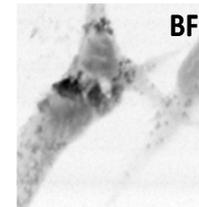


Max
Min

FTIR Microscopy

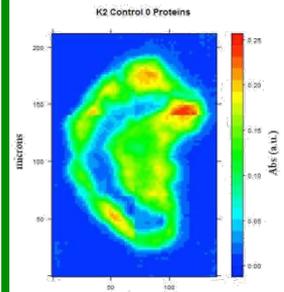
Effect and distribution of NPs in cells

P. Marmorato, G. Ceccone, A. Gianoncelli, L. Pascolo, J. Ponti, F. Rossi, M. Salomé, B. Kaulich, and M. Kiskinova, Toxicology Letters, 2011, 207 - 2, 128.



CoFe₂O₄ NPs distribution in fibroblast cells (TwinMic beamline) 40 um

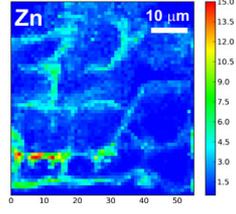
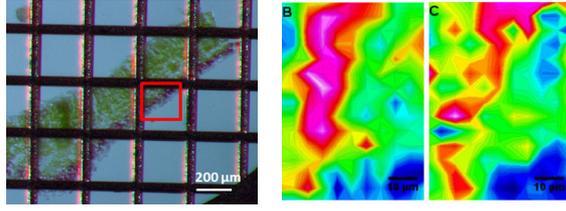
X-ray Fluorescence Microscopy



Effects of ingested NPs on the biochemical profile of hepatopancreatic cells of *P. Scaber* model organism, complemented with metal distribution patterns at tissue level (SISSI beamline, FTIRM)

Cd/Zn accumulation in *Noccaea praecox*

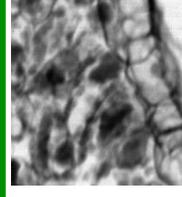
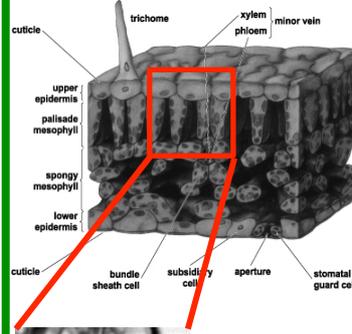
FTIR Microscopy analysis



Spatially resolved characterization of leaves of Cd/Zn hyperaccumulating *Noccaea praecox* (SISSI beamline)

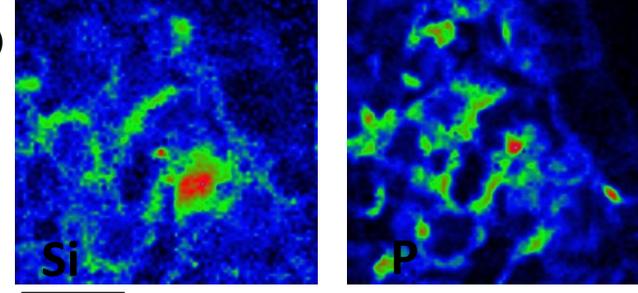
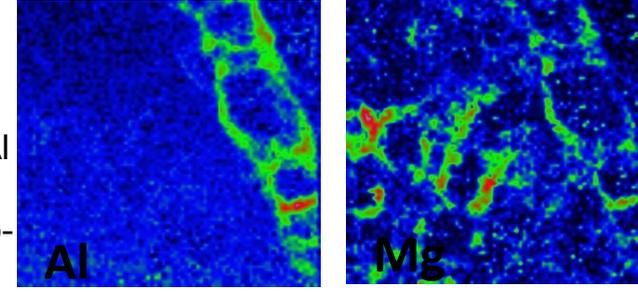
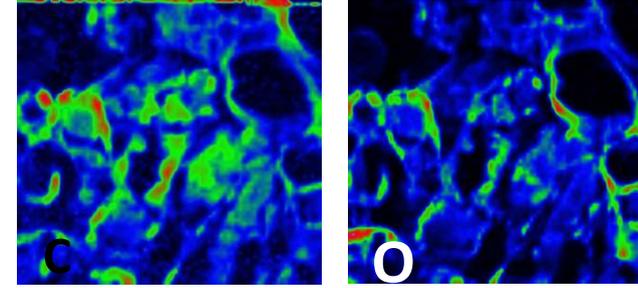
Aluminum localization in tea leaves

Cross-section of a leaf



Functionality and toxicity of Al in tea leaves analysed at sub-cellular level (TwinMic Beamline, XRF)

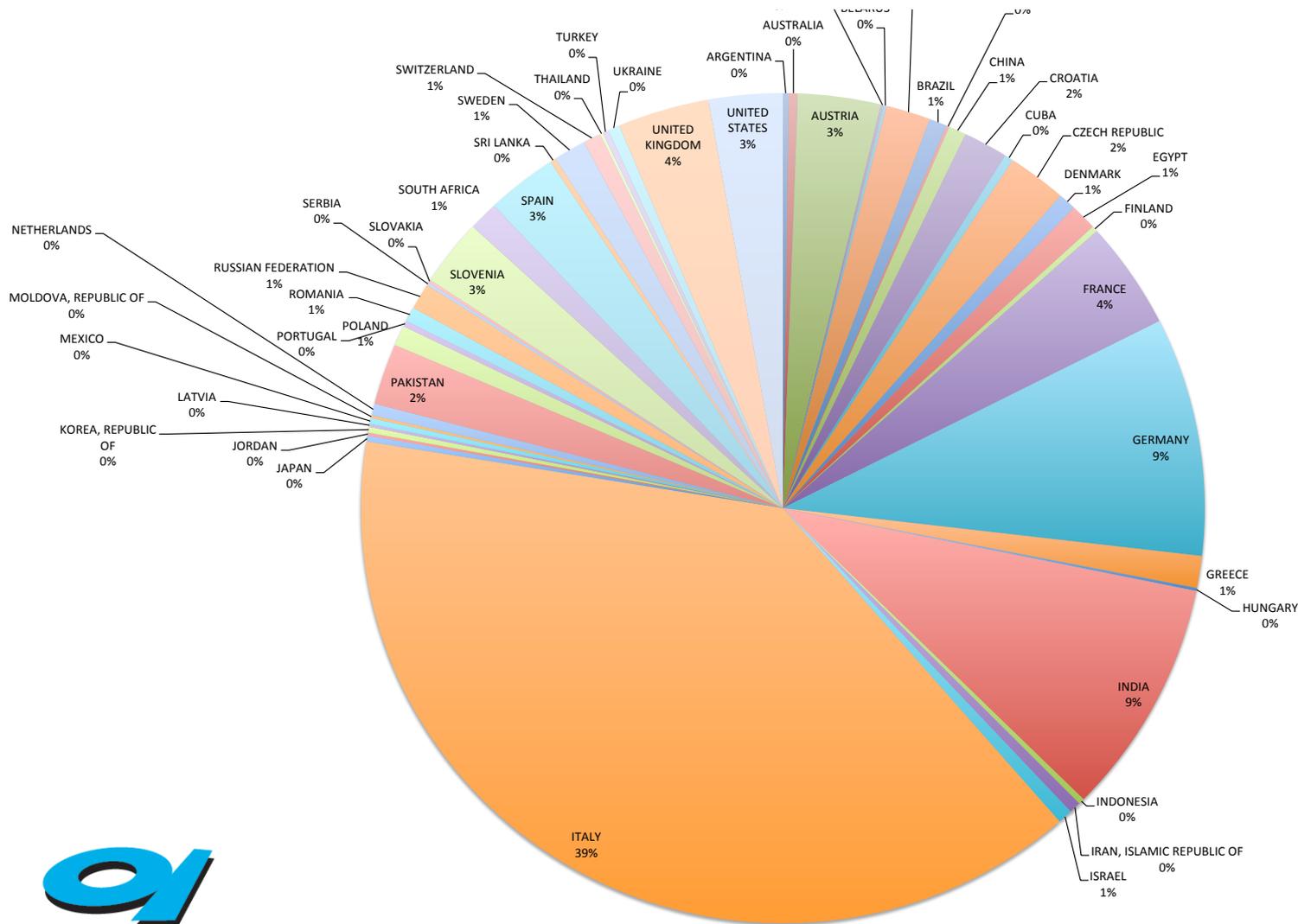
In young tea leaves the preferential accumulation of Al occurs at the end of the transpiration stream, in the epidermal cell walls



15 µm

947 Proposals received in 2014 (+10.1%)

64 from CERIC-ERIC



ERIC: European Research Infrastructure Consortium

- A new legal framework, at EU level, to facilitate the joint establishment and operation of Research Infrastructures of European interest among several countries
- A legal body recognised in all EU Member States

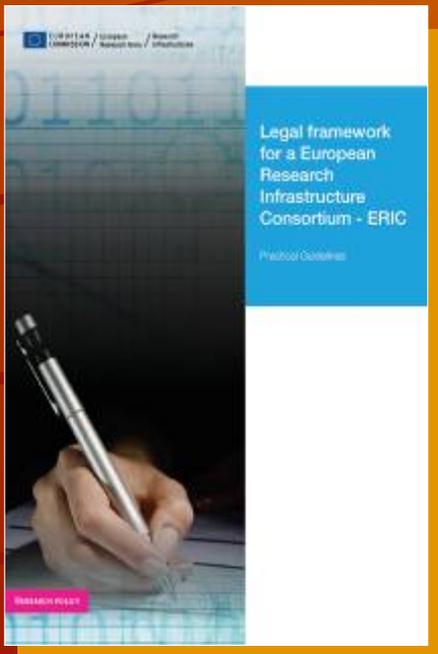
- Current status:

Awarded ERICs:

- **SHARE** (17/03/2011, hosted by the Netherlands)
- **CLARIN** (29/02/2012, hosted by the Netherlands)
- **EATRIS** (11/11/2013, hosted by the Netherlands)
- **BBMRI** (22/11/2013, hosted by Austria)
- **European Social Survey** (22/11/13, hosted by the U.K.)
- **ECRIN** (29/11/2013, hosted by France)
- **CERIC-ERIC** (28/06/2014, hosted by Italy)
- **DARIAH** (15/08/2014, hosted by France)

- Current applications:

ESS, EURO-ARGO, ICOS, JIV, LIFEWATCH



CENTRAL EUROPEAN RESEARCH INFRASTRUCTURE CONSORTIUM:



Italy (Elettra), Austria (SAXS and TU Graz Laboratory),
Czech Republic (Materials Science and Prague Laboratory),
Hungary (Budapest Neutron Center), Romania (Magurele
Laboratory), Slovenia (NMR center).

- common entry point and integrated services for users
- single proposal evaluation system
- free and open access by quality selection only
- support and logistic services as required
- joint IPR and industrial policy
- joint educational and outreach activities

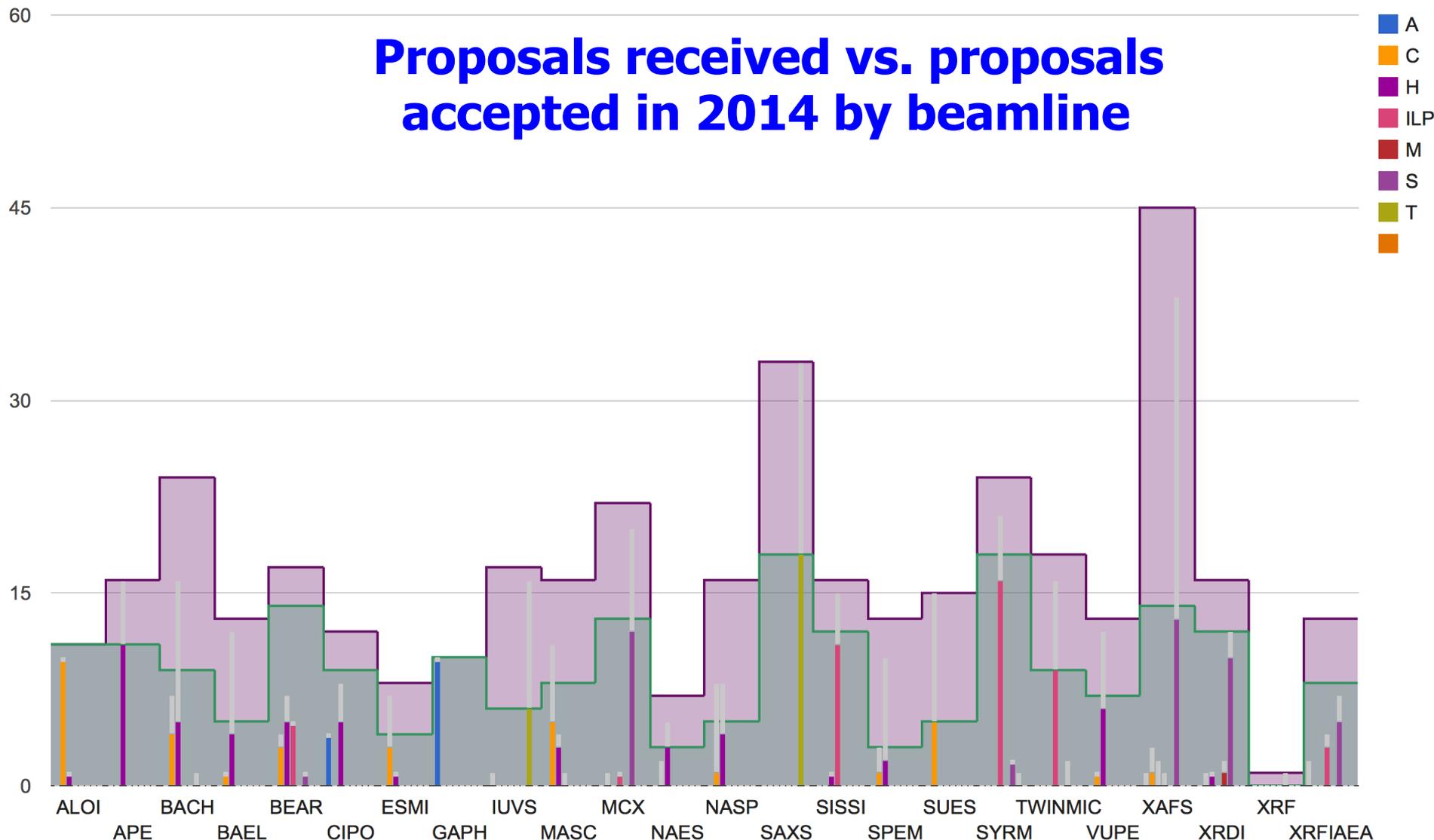
CERIC "call zero" received 30 proposals (1/3 accepted)

CERIC "call one" received 44 proposals (1/3 accepted)

CERIC "call two" received 55 proposals (1/3 accepted)



Proposals received vs. proposals accepted in 2014 by beamline



S=structures **ILP**=inst.&life sci.&polym. **T**=scattering **H**=E&M
A=atom.&mol.sci. **C**=catalysis&surf.sci. **M**=protein¯om.



Main tendency: Brighter, Diffraction limited

i.e.

Low Emittance Rings

Elettra 2.0

Increased brilliance

Reduced beam size

Increased intensity

Same circumference

Elettra 2.0

N-bends	Emittance (nmrad)	σ_x (μm) ID	σ_y (μm) ID	σ_y (μm) @1% coupl ID
2	7	240		14
4	0.82	70	43	4.3
5	0.65	40	30	3
6	0.25	32	32	3.2
7	0.19	29	29	2.9
8	0.12	25	22	2.2
9	0.087	18	17	1.7

As the number of dipoles increases free space is generally reduced

To save space one should combine the elements as much as possible:

Defocusing in dipoles

Skew quads + correctors

Sextupoles + correctors

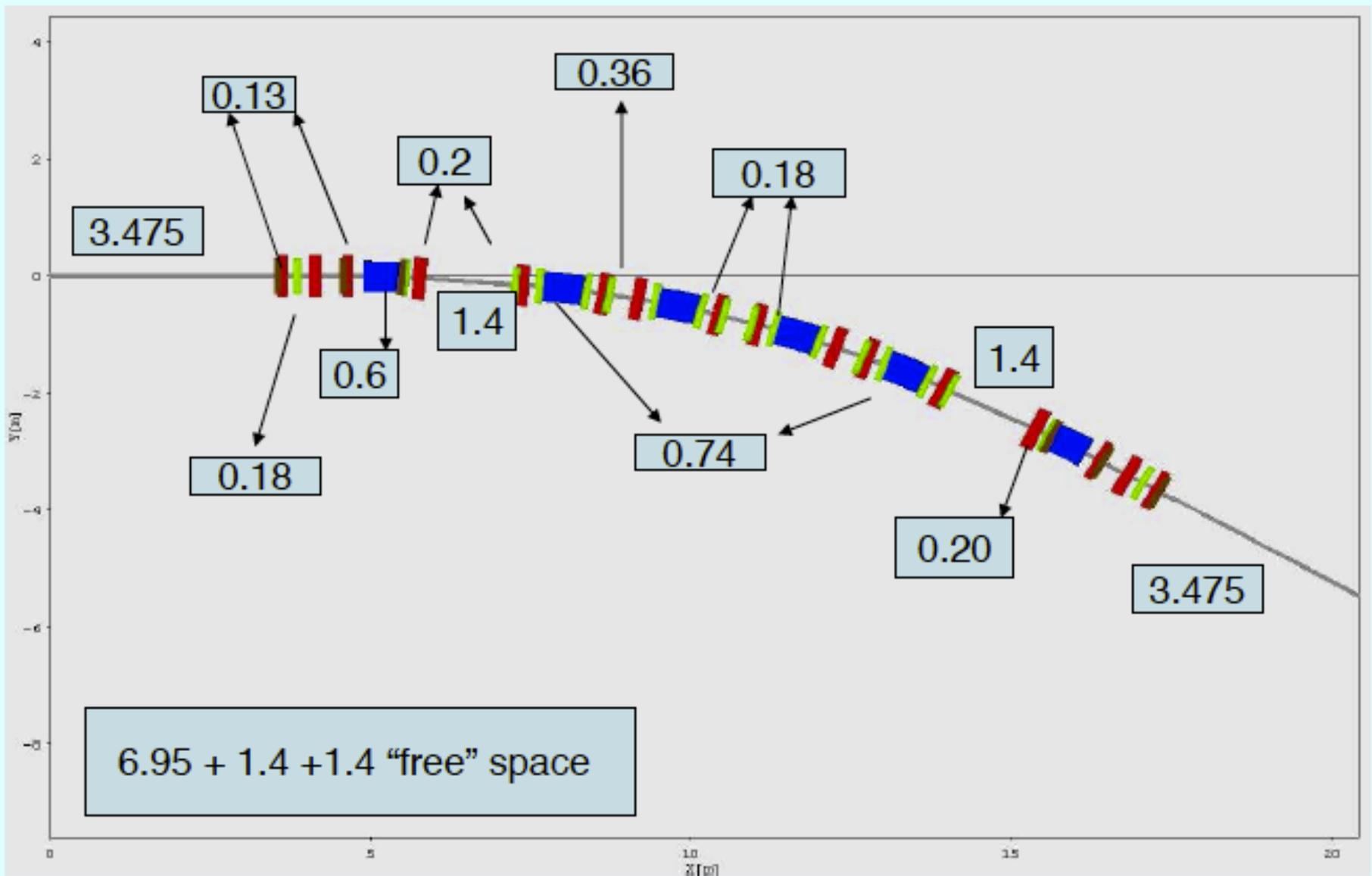
BPM inside the quadrupoles

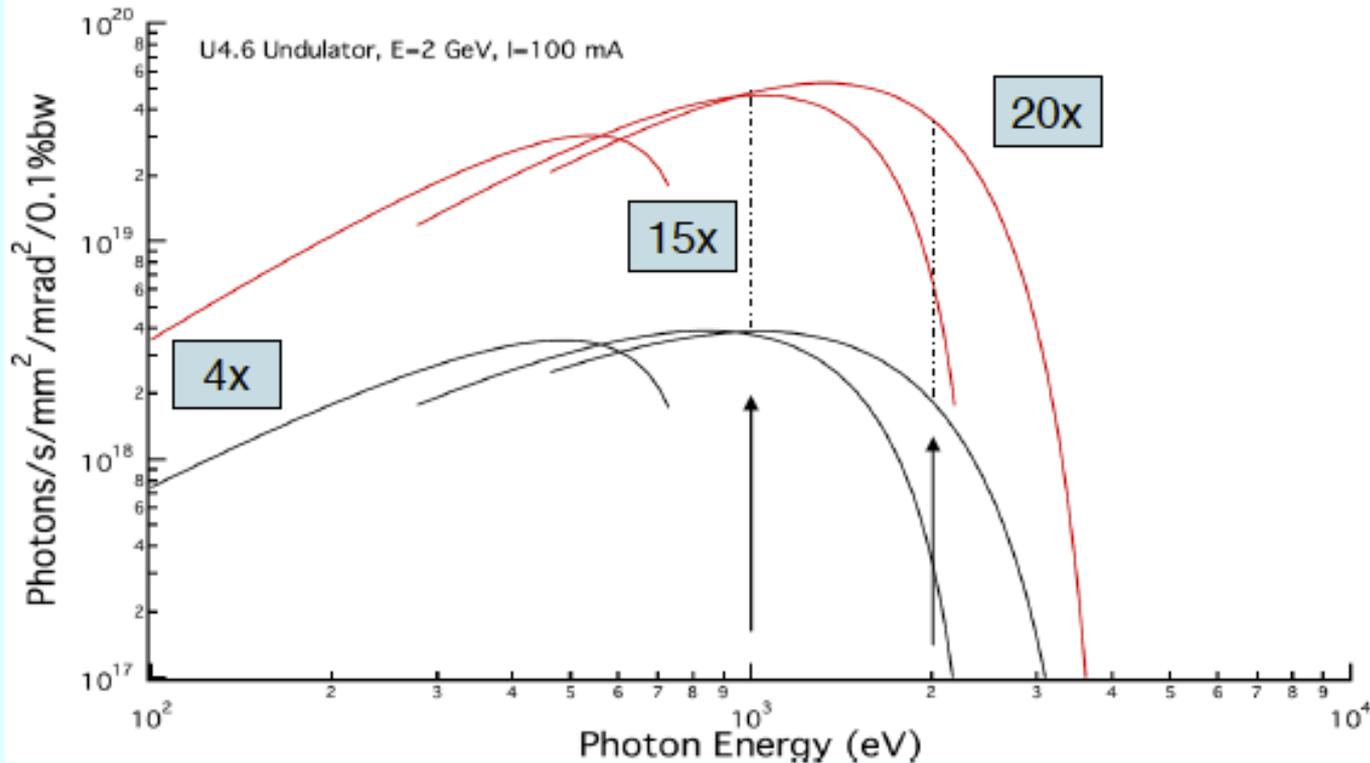
Lateral pumping

Dynamic aperture is reduced but still quite acceptable as we will see.



Elettra 2.0





Super ESCA @ 2 GeV 100 mA

Graph by B. Diviacco

Brilliance increasing as expected
Spot size/div decreased by a factor of 5

Elettra : 7 nrad
 Beam dimensions:
 x,y (245,14) μm
 x',y' (28, 6) μrad

Long straights - 0.25
 nm-rad
 Beam dimensions:
 x,y (43,3.0) μm
 x',y' (5.7, 0.8) μrad

0.25 nm-rad – short
 straights
 Beam dimensions:
 x,y (45,3.1) μm
 x',y' (8, 0.9) μrad

x 28 reduction in emittance, x 5 reduction in beam size and divergence

Elettra 2.0-2.4 GeV 3rd generation Synchrotron Radiation Facility



FERMI 1.5 GeV seeded Free Electron Laser Facility

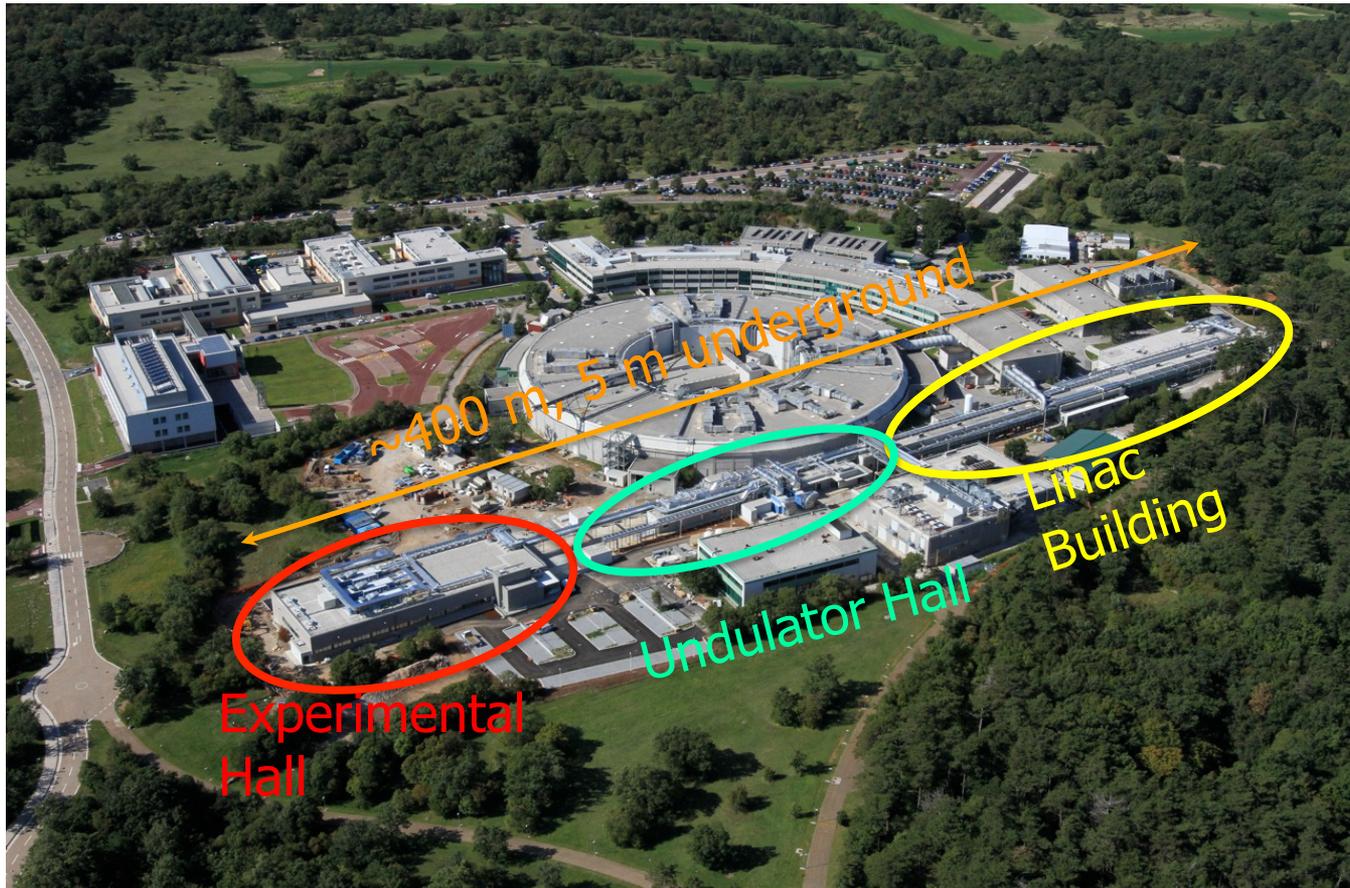




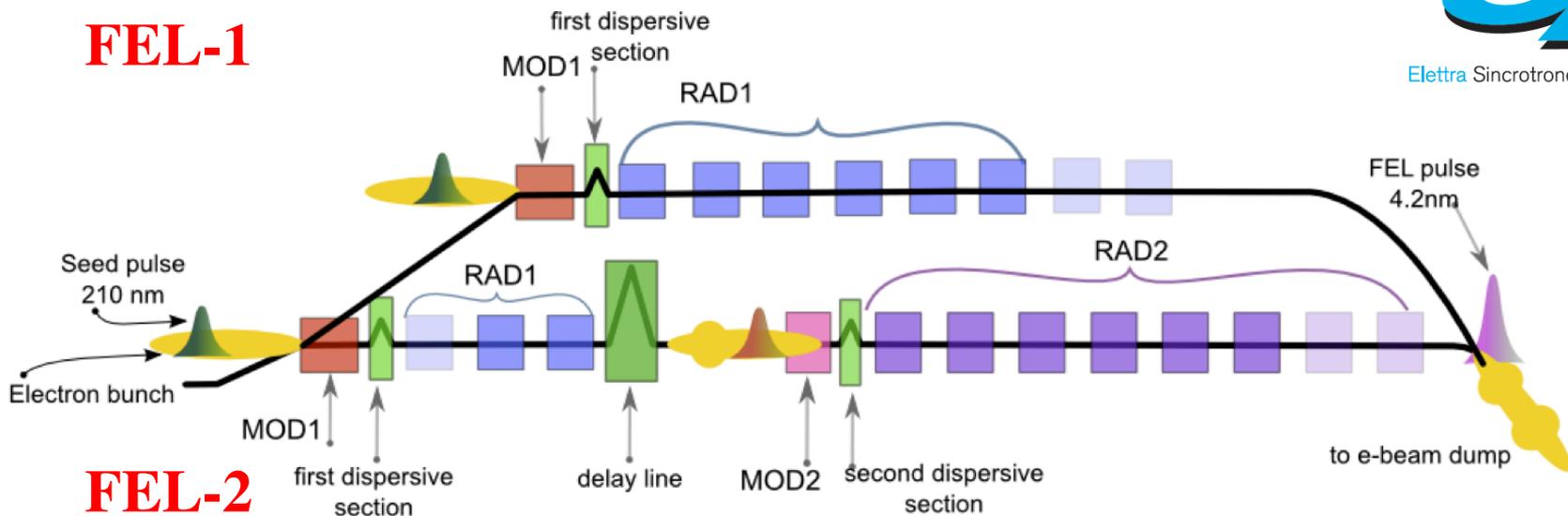
Elettra Sincrotrone Trieste

FERMI@Elettra

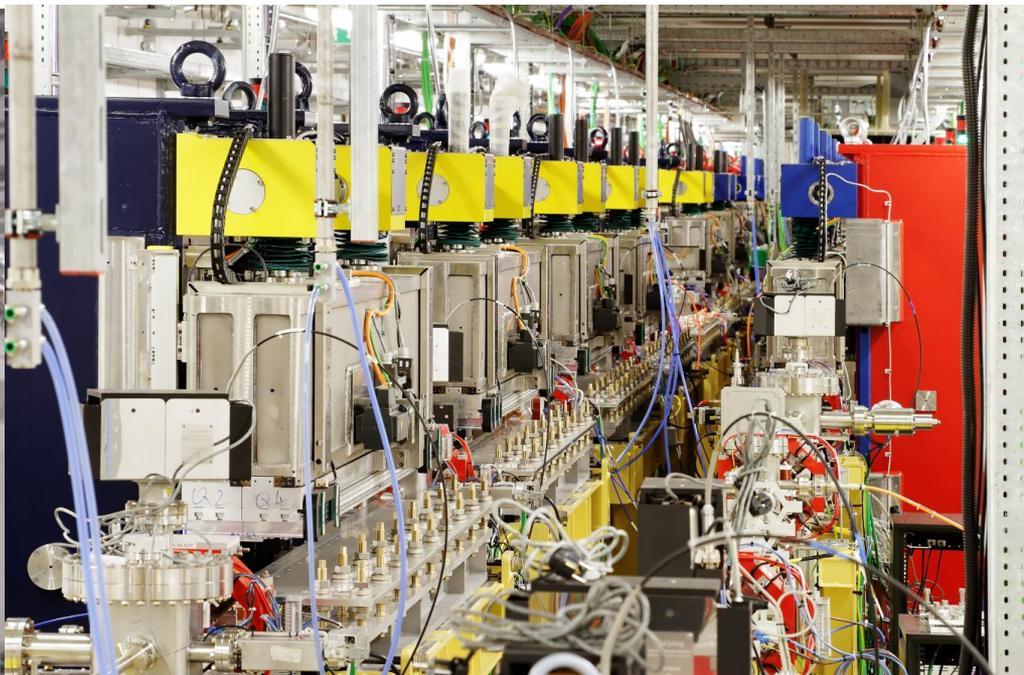
Overall length of underground part (5 m below ground): ~ 400 m
Three main parts: Linac & Klystron Hall; Undulator Hall; Experimental Hall



FEL-1



FEL-2



KYMA born in 2007 as Sincrotrone Trieste spin off to produce undulators for Synchrotron and FEL light sources

10 employees

4 million Revenues

More than 50 Undulators already supplied in worldwide Synchrotrons/FEL:

- Elettra for Fermi (Italy)
- Brookhaven National Laboratory for NLSL-II (USA)
- Pohang Accelerator Laboratory for PLS2 (Korea)
- Max Plank Postech for PLS2 (Korea)
- Uppsala University for XFEL (Germany)
- ENEA for SPARC-FEL (Italy)
- Huazhang University for THz-FEL (China)



FERMI@Elettra: Experimental Hall



Elettra Sincrotrone Trieste



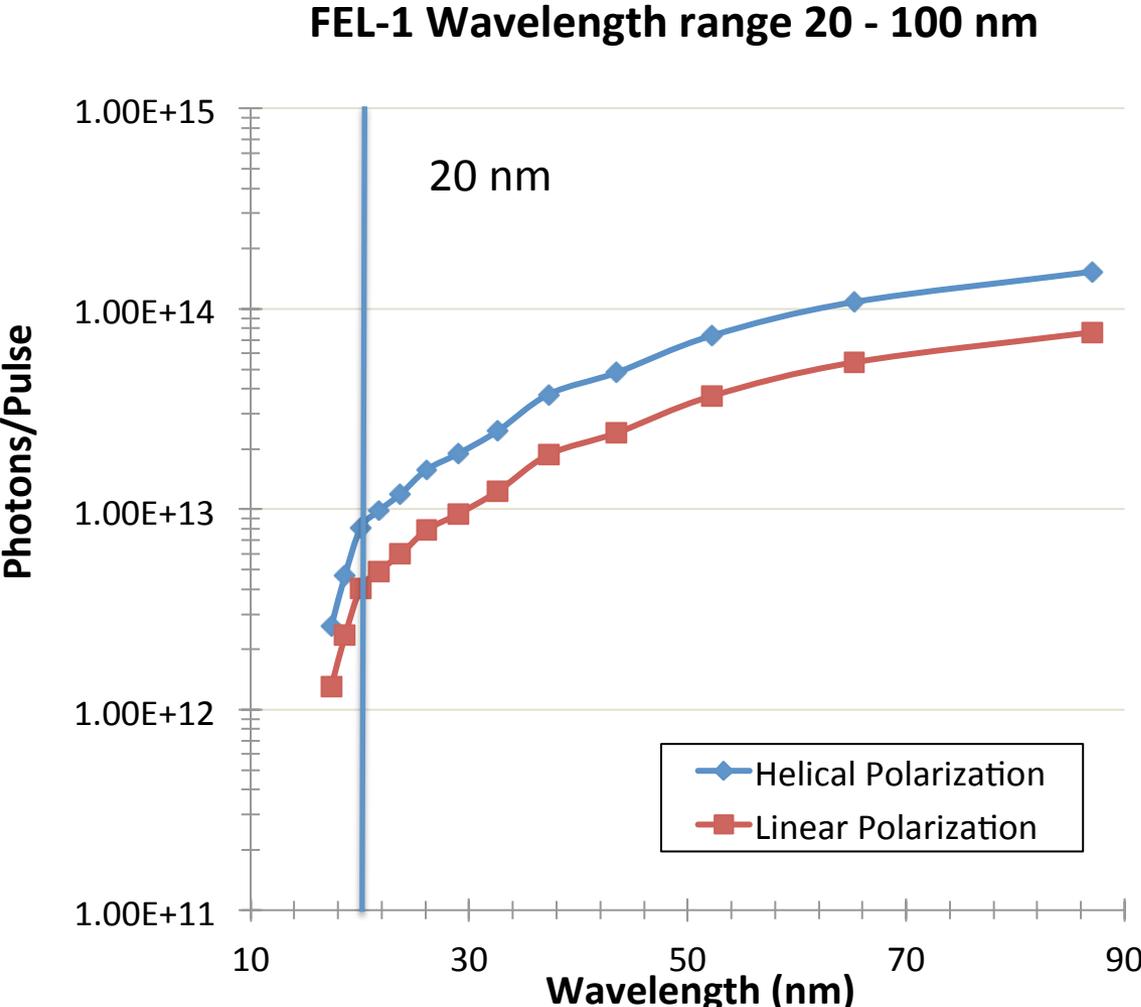
Beamlines and Experimental Chamber

Highly coherent and stable pulses from the FERMI seeded free-electron laser in the extreme ultraviolet

Two-stage seeded soft-X-ray free-electron laser

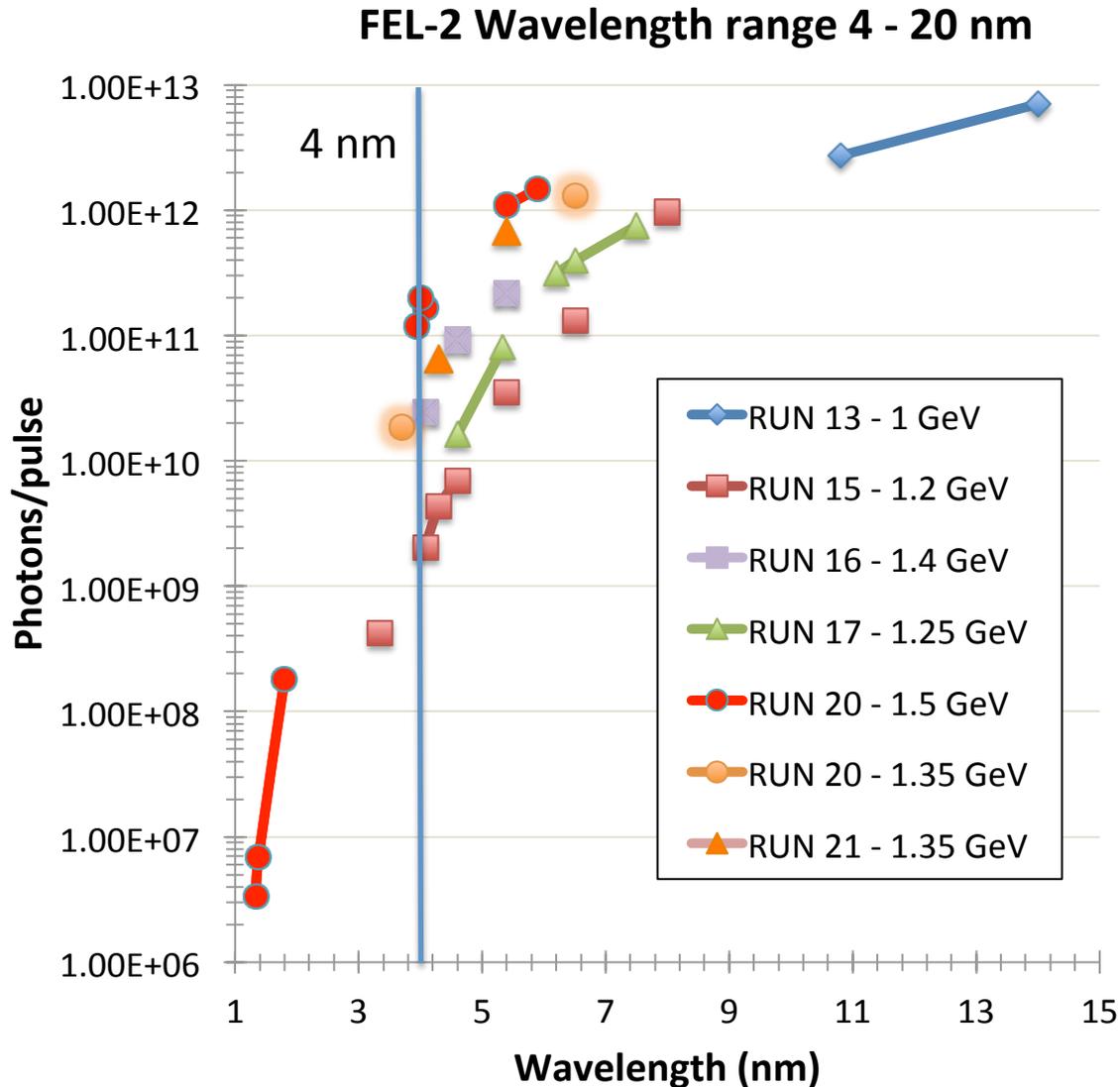
E. Allaria¹, D. Castronovo¹, P. Cinquegrana¹, P. Craievich^{1†}, M. Dal Forno^{1,2}, M. B. Danailov¹, G. D'Auria¹, A. Demidovich¹, G. De Ninno^{1,3}, S. Di Mitri¹, B. Diviacco¹, W. M. Fawley^{1*}, M. Ferianis¹, E. Ferrari¹, L. Froehlich¹, G. Gaio¹, D. Gauthier^{1,3}, L. Giannessi^{1,4*}, R. Ivanov¹, B. Mahieu^{1,5}, N. Mahne¹, I. Nikolov¹, F. Parmigiani^{1,2}, G. Penco¹, L. Raimondi¹, C. Scafuri¹, C. Serpico¹, P. Sigalotti¹, S. Spampinati^{1,3}, C. Spezzani¹, M. Svandrlik¹, C. Svetina^{1,2}, M. Trovo¹, M. Veronese¹, D. Zangrando¹ and M. Zangrando^{1,6}

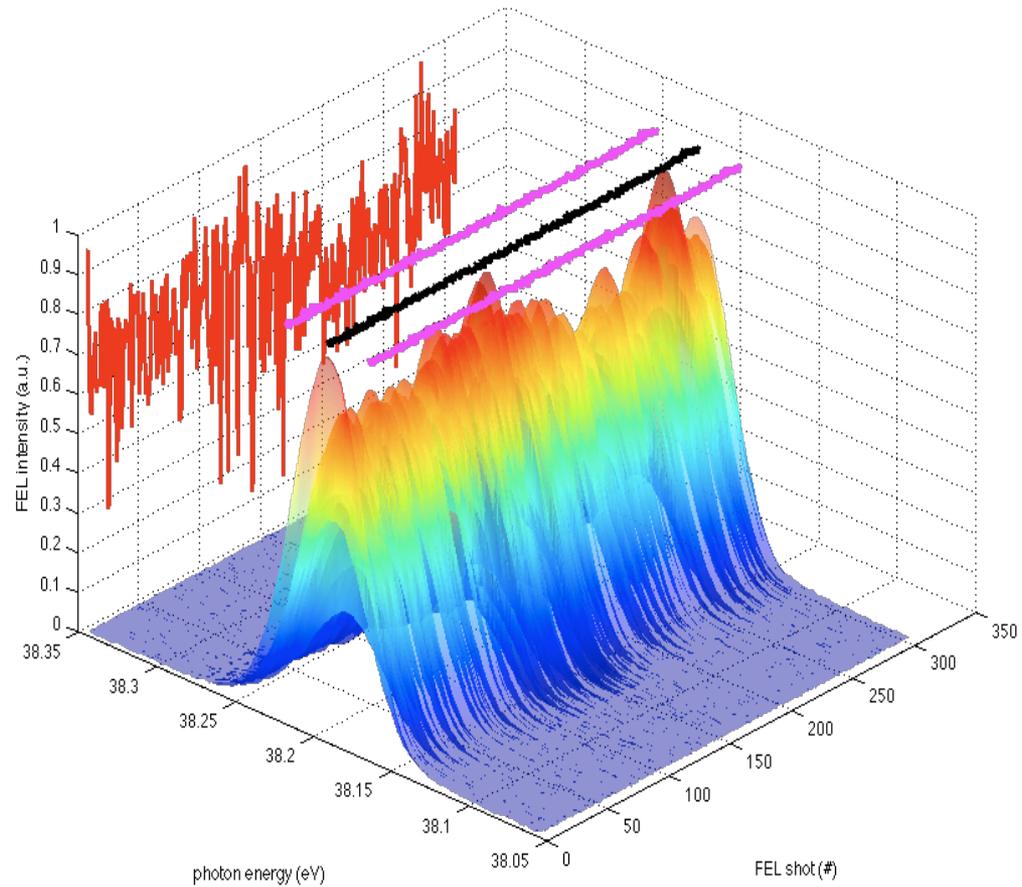
FEL 1 – Photons/Pulse (achieved - average)



FEL 2 – Photons/Pulse achieved (average)

Helical Polarization - *Data analysis from RUN 23 still in progress*

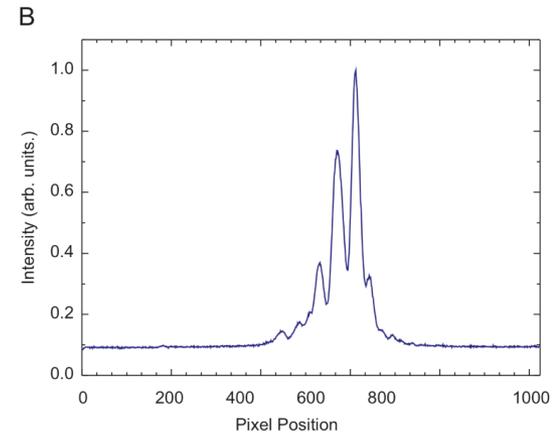
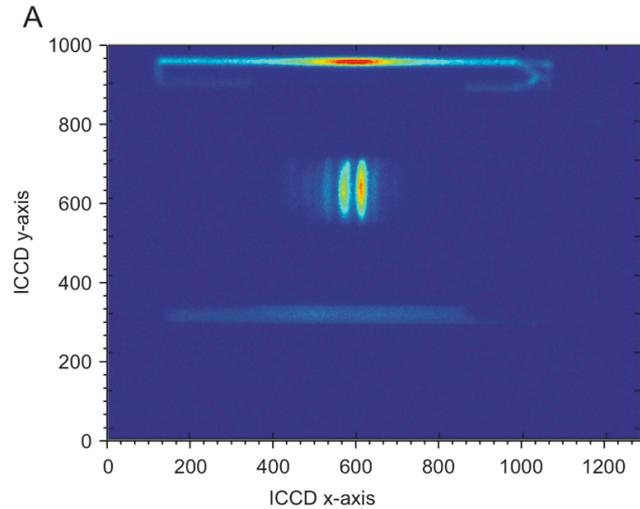
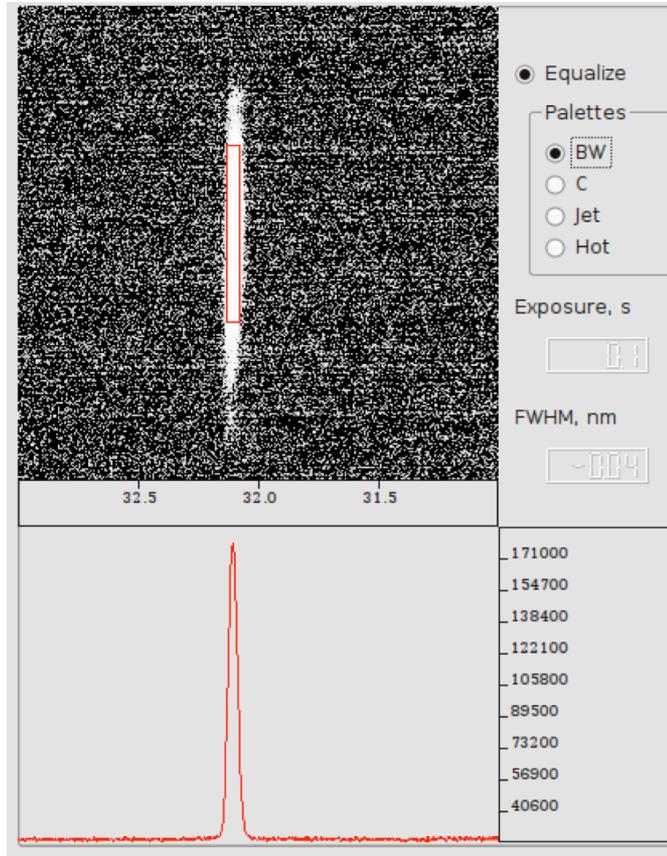




FEL photon energy	$\sim 38.19\text{eV}$
Photon energy fluctuations	$= 1.1\text{meV (RMS)}$
FEL bandwidth	$= 22.5\text{meV (RMS)}$
	$= 5.9\text{e}^{-4} \text{ (RMS)}$
FEL bandwidth fluctuations	$= 3\% \text{ (RMS)}$

Multi-shots spectral emission recorded from FERMI FEL-1.

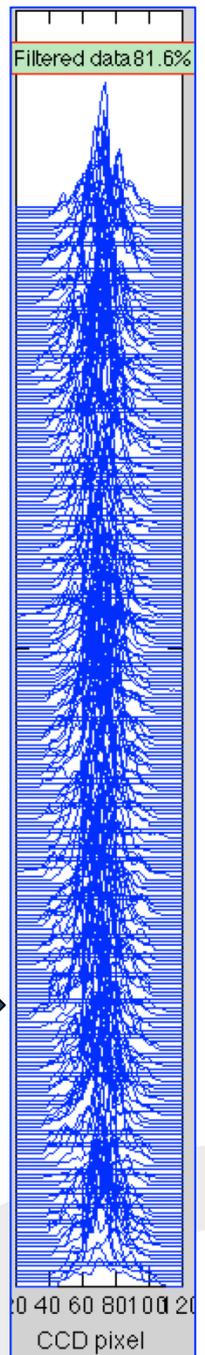
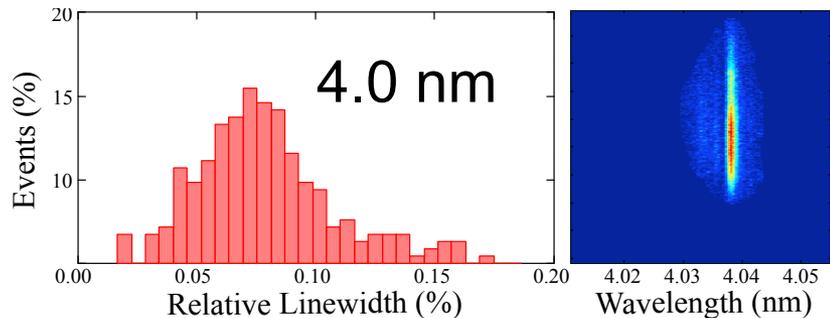
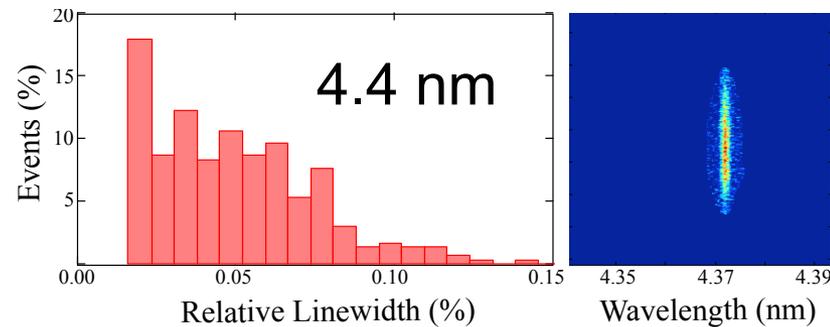
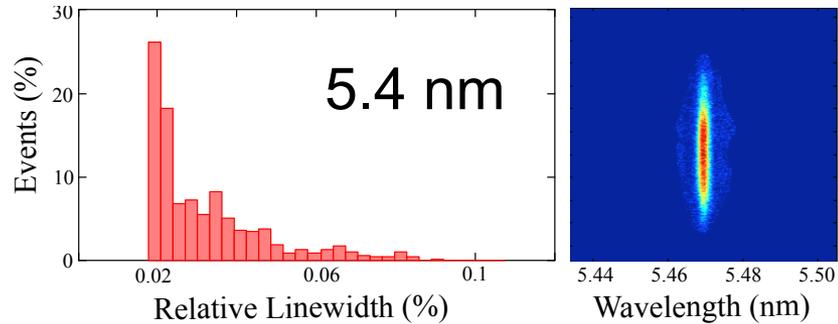
26.4 nm



Spectral lines as measured at FERMI@Elettra (left panel) and at the FLASH SASE facility in Hamburg, Germany (right panel).

FEL-2 spectra vs. wavelength

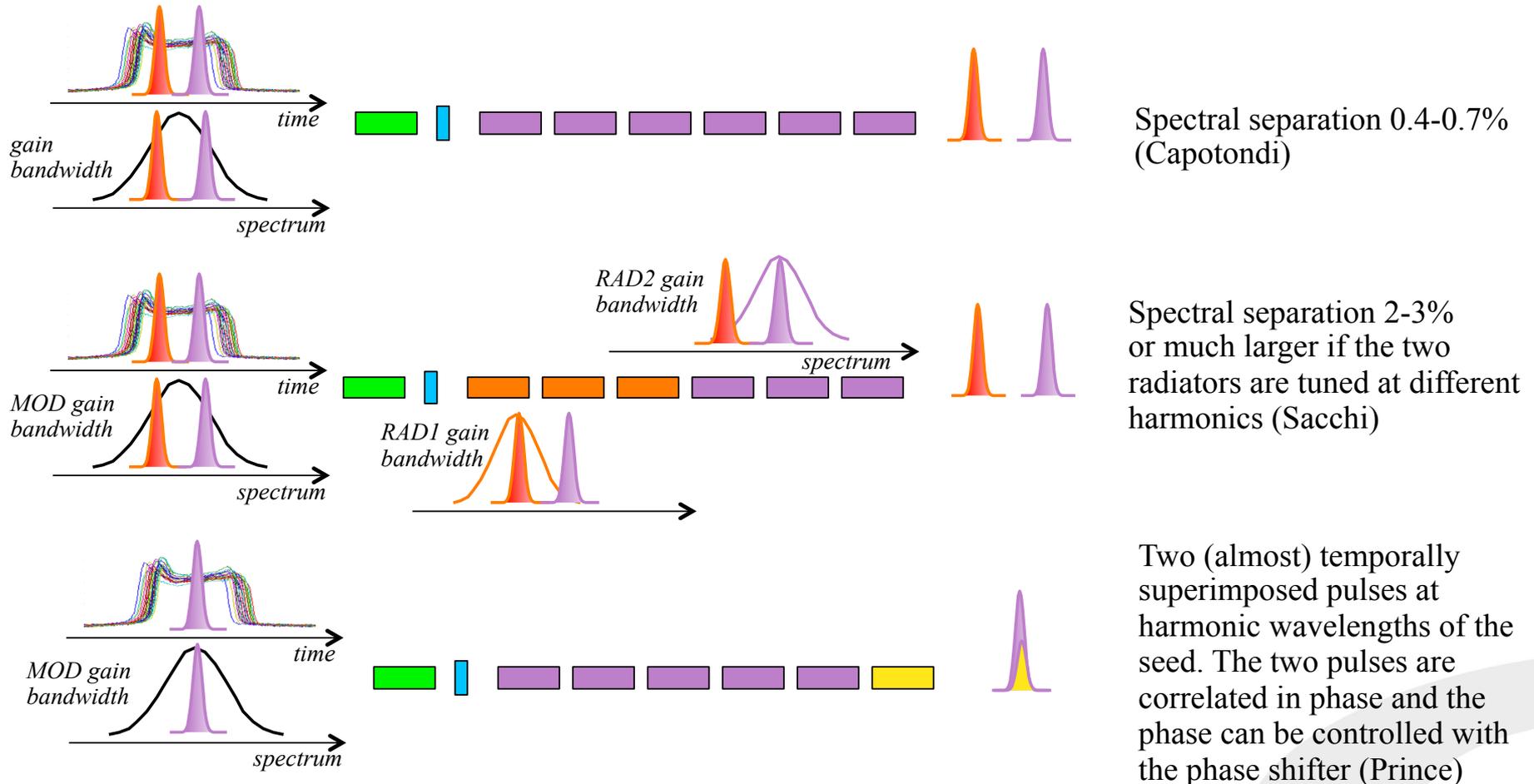
- Lower wakes/
microbunching instability
with the lower charge/
current
- Improved orbit in the last
undulator == more
effective
- Improved matching
- **Spectral quality still
critical, especially at
4.0nm (up to 10 μ J/pulse)**

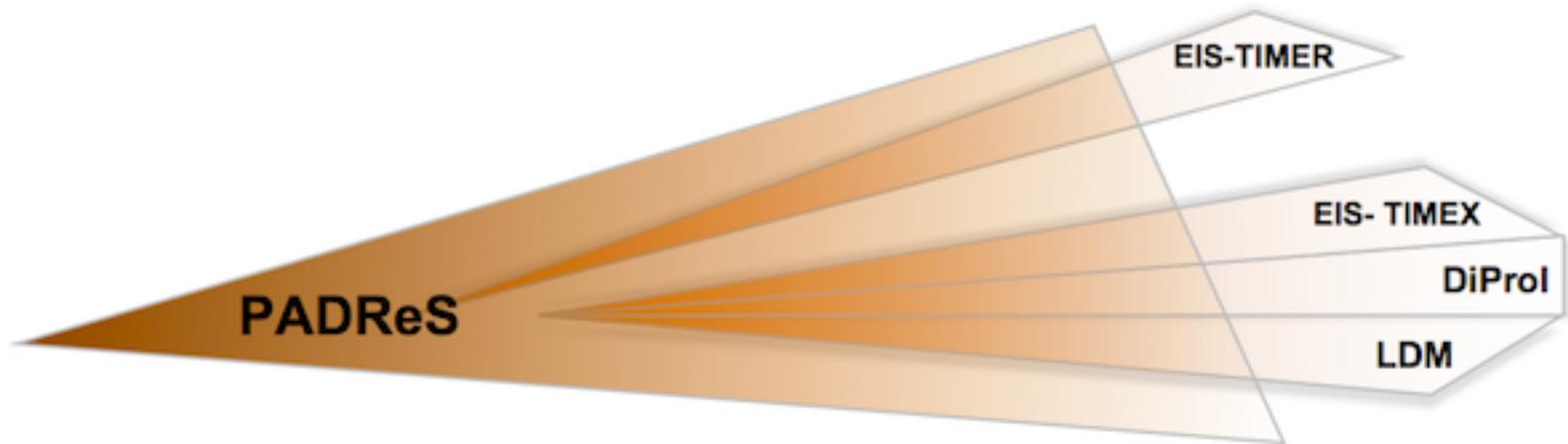


Sequence of spectra @4nm. 20% of data discarded

Multiple pulse configurations

Multiple pulses can be generated by **double pulse seeding** in different ways, depending on the requirements on the output radiation. Temporal **separation between 25-300 and 700-800 fs**. Shorter separations are accessible via FEL pulse splitting*. Larger separations require the split & delay line.





DIFFRACTION AND PROJECTION IMAGING M. Kiskinova

- *Ultrafast Coherent Imaging*
- *Full-field x-ray Microscopy and Lensless Imaging*

ELASTIC AND INELASTIC SCATTERING PROGRAM C. Masciovecchio

- *t-Resolved Spectroscopy of Mesoscopic Dynamics* **TIMER**
- *Elastic Scattering from Matter under Extreme Conditions* **TIMEX**

LOW DENSITY MATTER PROGRAM C. Callegari

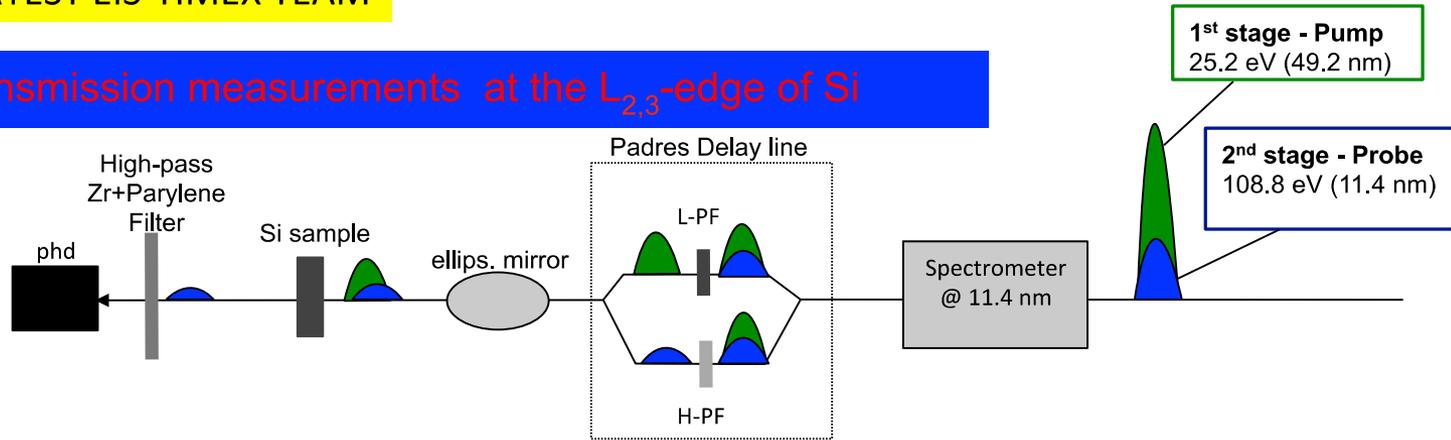
- *Atomic, Molecular and Optical Science*
- *Spectroscopic Studies of Reaction Intermediates*
- *Clusters and Nanoparticle Spectroscopies*
- *Ultrafast Proc. & Imaging of Gas Phase Clusters and Nanoparticles*

Under construction: MAGNEDYN, TERA FERMI, TIMER

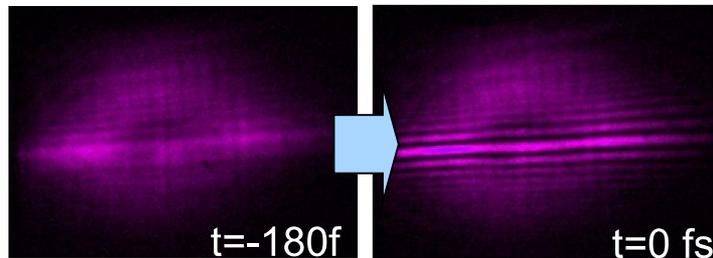
EIS-TIMEX FEL/pump-FEL/probe

COURTESY EIS-TIMEX TEAM

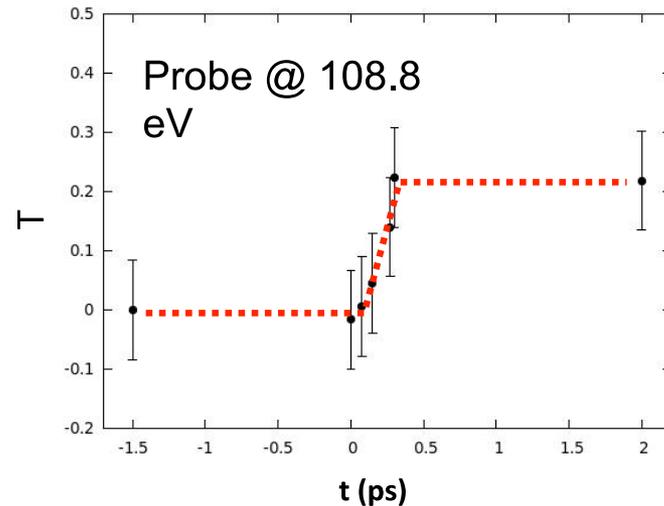
Transmission measurements at the $L_{2,3}$ -edge of Si



Interference fringes on a yag screen close to the sample are used to find the longitudinal superposition of the pump-probe beams



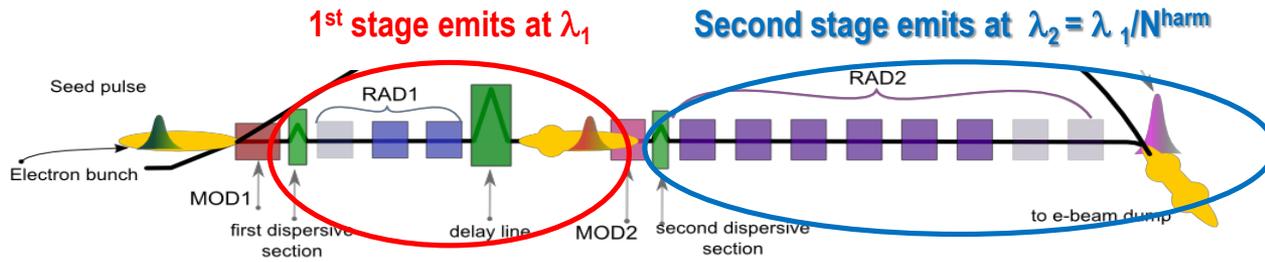
Ultrafast laser-driven transmission change associated with metalization of the Si



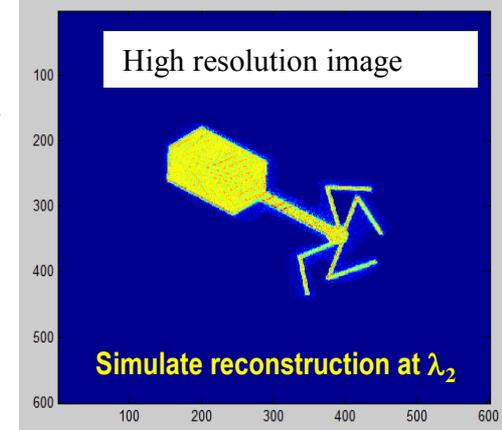
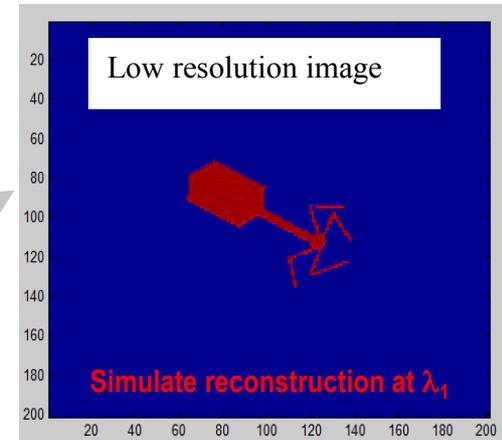
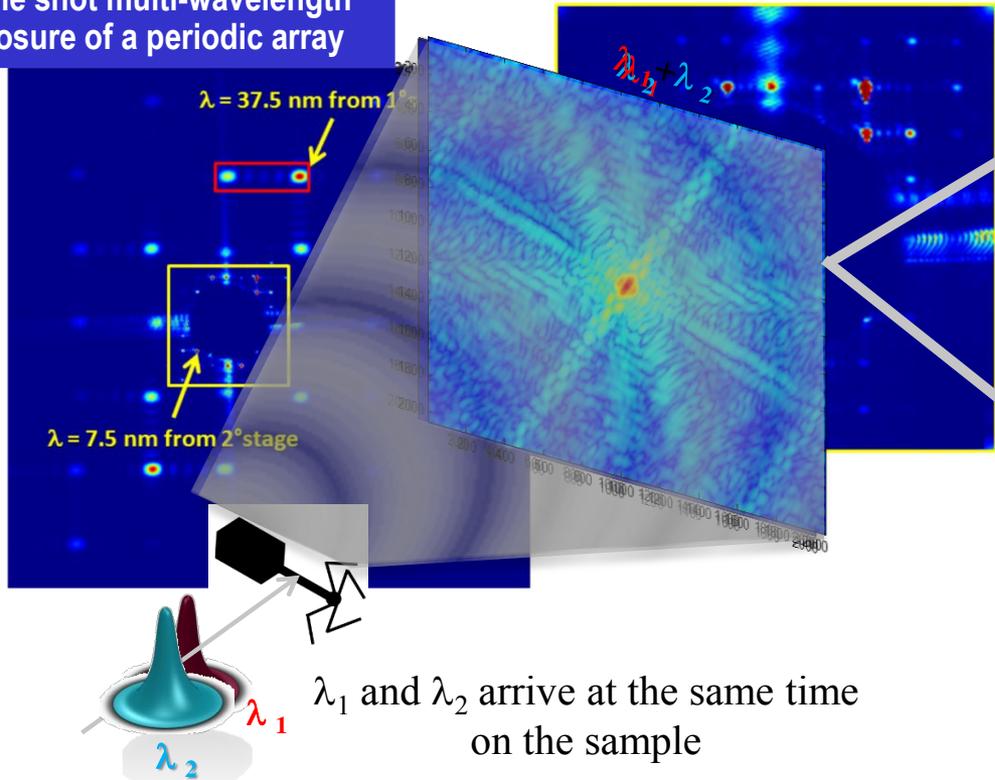
Multi-wavelengths imaging with FERMI-FEL 2



Elettra
Sincrotrone
Trieste



Single shot multi-wavelength exposure of a periodic array



Four-wave mixing experiments with extreme ultraviolet transient gratings

F. Bencivenga¹, R. Cucini¹, F. Capotondi¹, A. Battistoni^{1,2}, R. Mincigrucci^{1,3}, E. Giangrisostomi^{1,2}, A. Gessini¹, M. Manfreda¹, I. P. Nikolov¹, E. Pedersoli¹, E. Principi¹, C. Svetina^{1,2}, P. Parisse¹, F. Casolari¹, M. B. Danailov¹, M. Kiskinova¹ & C. Masciovecchio¹

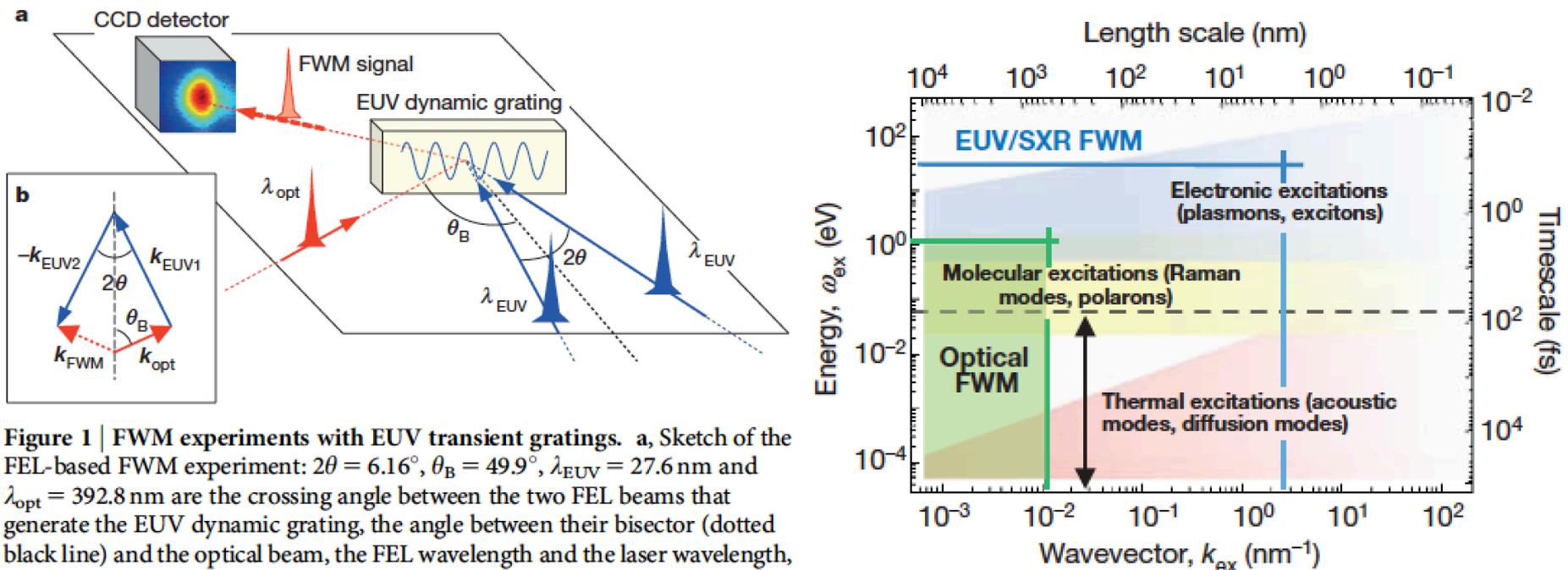
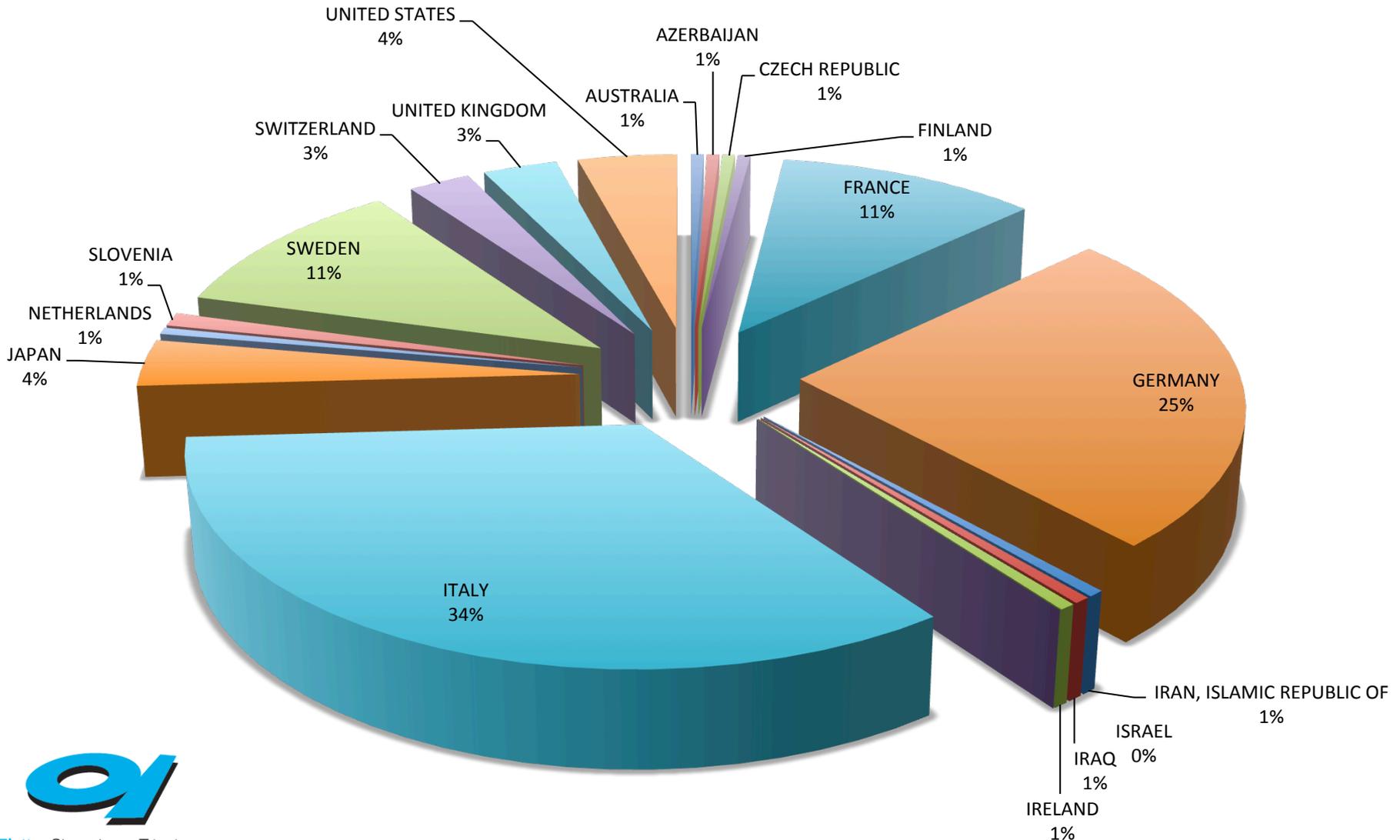


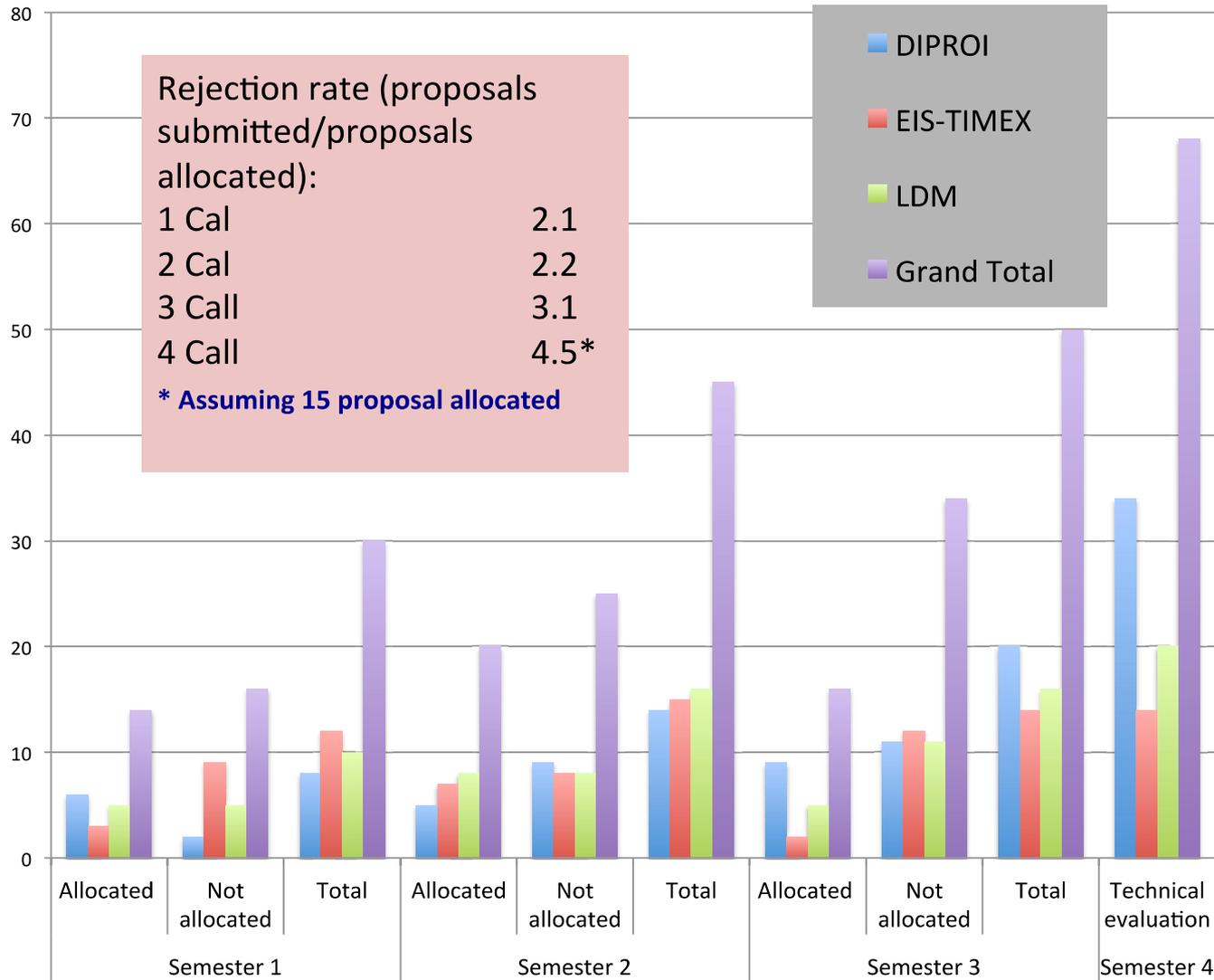
Figure 1 | FWM experiments with EUV transient gratings. **a**, Sketch of the FEL-based FWM experiment: $2\theta = 6.16^\circ$, $\theta_B = 49.9^\circ$, $\lambda_{\text{EUV}} = 27.6 \text{ nm}$ and $\lambda_{\text{opt}} = 392.8 \text{ nm}$ are the crossing angle between the two FEL beams that generate the EUV dynamic grating, the angle between their bisector (dotted black line) and the optical beam, the FEL wavelength and the laser wavelength, respectively. A CCD sensor is placed in the expected propagation direction of the FWM signal beam (k_{FWM}), which is determined by the ‘phase matching’ (shown in **b**; here k_{opt} , $k_{\text{EUV}1}$ and $k_{\text{EUV}2}$ are the wavevectors of the optical and of the two FEL pulses, respectively).

30+45+50+68=193 proposals submitted to FERMI

FERMI submitted proposals - Semester 1 to 4



FERMI USERS STATISTICS AND FUTURE STRATEGY



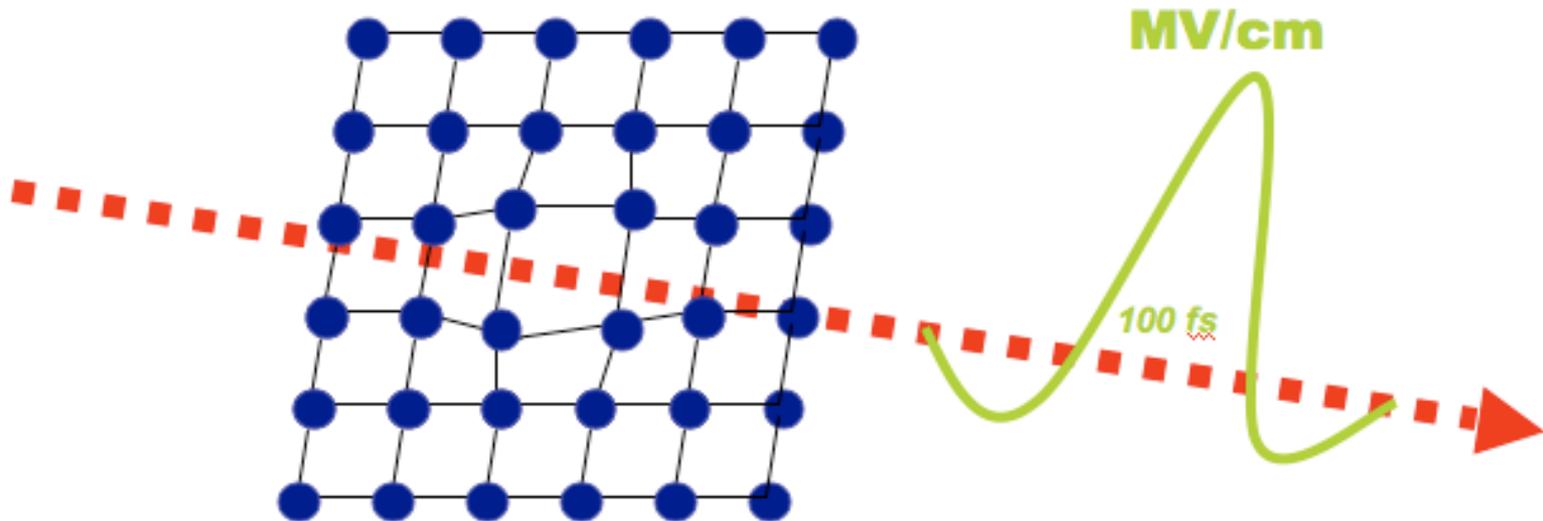
TeraFERMI

Non-linear THz optics at MV/cm fields

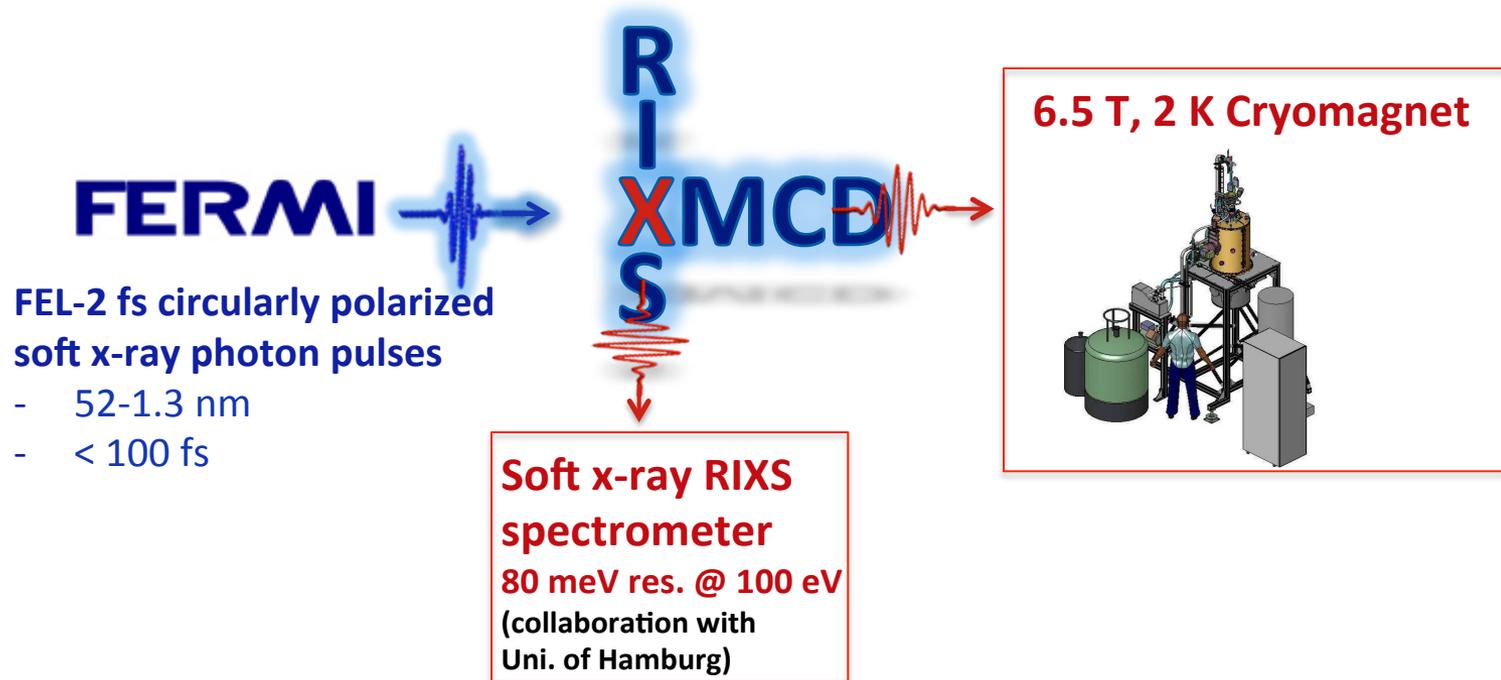
Ultra-short, high-power THz pulses between 1 mm - 20 μm (0.3 -15 THz)

Access to the Reststrahlen-band gap

Pumping on electronic, vibrational, magnetic excitations
-> *Superconductivity, Heterostructures, Magnetism, etc.*



Ultrafast magnetodynamical studies in the light of FERMI@Elettra: the **MagneDyn** beamline



complementary observables

Combine femtosecond pumps

- FEL x-ray pulses:
 - single pulse (pump),
 - double pulses (pump-probe)
- fs laser pulses: IR, visible, THz

Combine femtosecond probes

- FEL soft x-ray pulses: single pulse, double pulses
 - XAS/XMCD
 - RIXS
- optical reflectivity: IR, visible
 - MOKE

Accelerator Parts

Elettra, over the years, has acquired great experience in developing and realizing accelerators components, i.e. undulators, resonant cavities etc. For the production of Insertion Devices, a specific spin-off company (Kyma S.r.l.) has been set-up, while other components will be provided directly by Elettra.

Product list

- Low Level RF Electronic Units
- Electromagnetic RF devices
- Elettra Type RF Cavities and Accessories
- 3D magnetic structures
- Chicane Bunch Length Compressors

Lab Instruments

Several instruments necessary for typical or extreme applications are available: fast picoammeters, multi-point strain gauge, charge pulse amplifiers, ion chambers, pulse generators, RF filters etc. Every tool is intelligent and in some cases "Epics/Tango interface" is already provided.

Product list

- AH401 / AH401B Picoammeter
- PIT-RFLN-Wide Bandwidth Pulse Amplifier
- AH501 Picoammeter
- RUD-RFLN-XLS Pulse Amplifier
- AH501B Picoammeter
- XPi Data Acquisition System
- L01 DOSFET Reader

Power Supply Equipment

New families of intelligent (DSP or PC embedded) power supplies, that cover many typologies (high voltage/current, four-quadrant etc.) and configurations are forthcoming. Epics or Tango interface are often already present and custom-built solutions are possible.

Product list

- MAS-TER HV Bipolar Power Supply System
- HiSTAR Series Power Supply

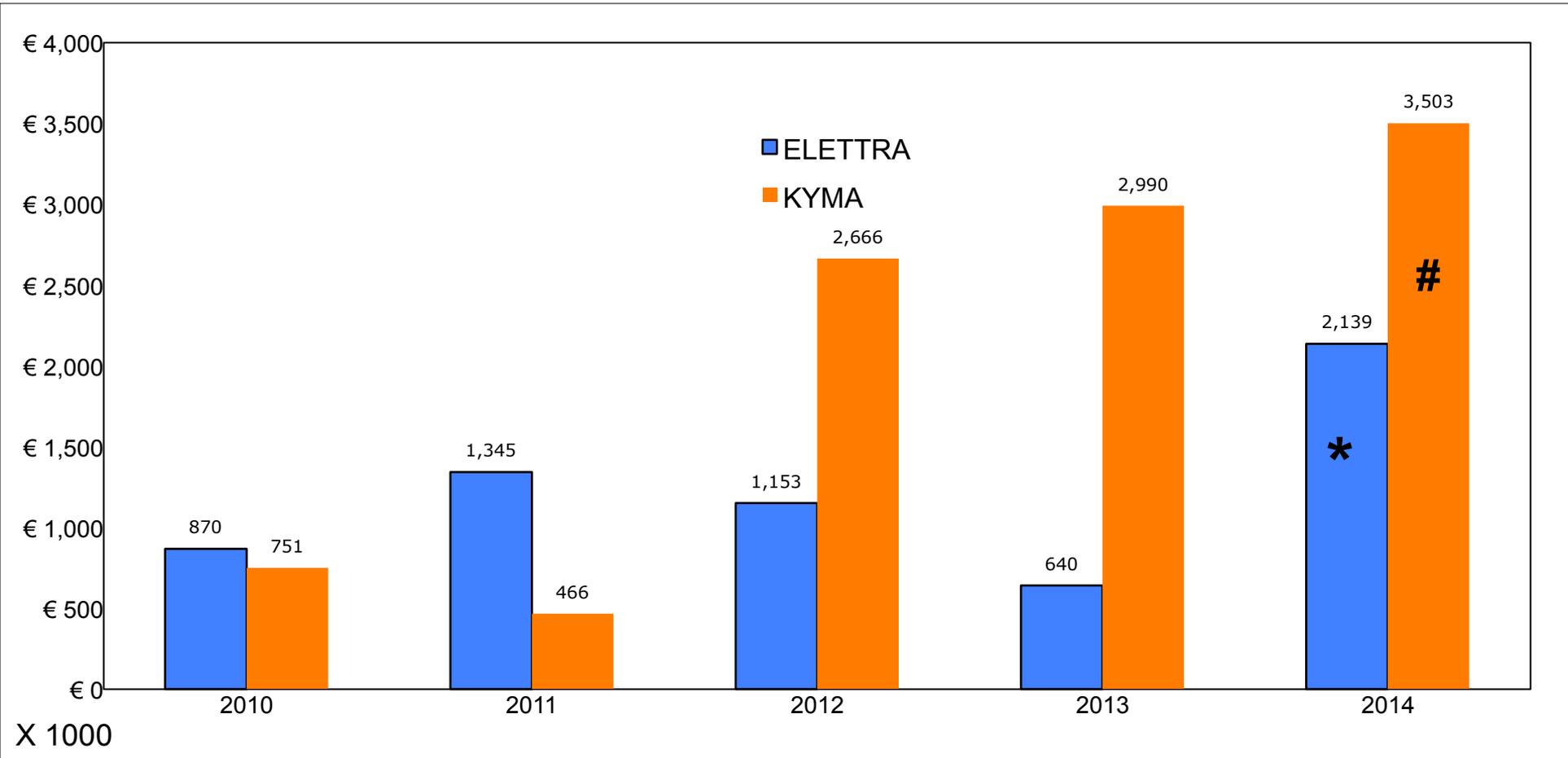
Detectors

Photons and charged particles detectors, based on cross delay anodes, multi anodes and centroid finding techniques are steadily developed. 3D information (x, y, time) with spatial and time resolutions in the order of tens of microns and picoseconds are available through many custom-built solutions.

Product list

- Photons and charged particles 3D (x,y,t) detectors
- XBPM-DR1 X-ray Beam Position Monitor
- BLM - IC02 Ionization Chamber Beam Loss Monitor
- FCB-001 Cavity Beam Position Monitor

EVOLUTION OF INDUSTRIAL INCOME



Based on orders already confirmed (*) and without including the FERMI-related sales (#)

ELETTRA INDUSTRIAL LIAISON OFFICE



THANK YOU

A. Franciosi

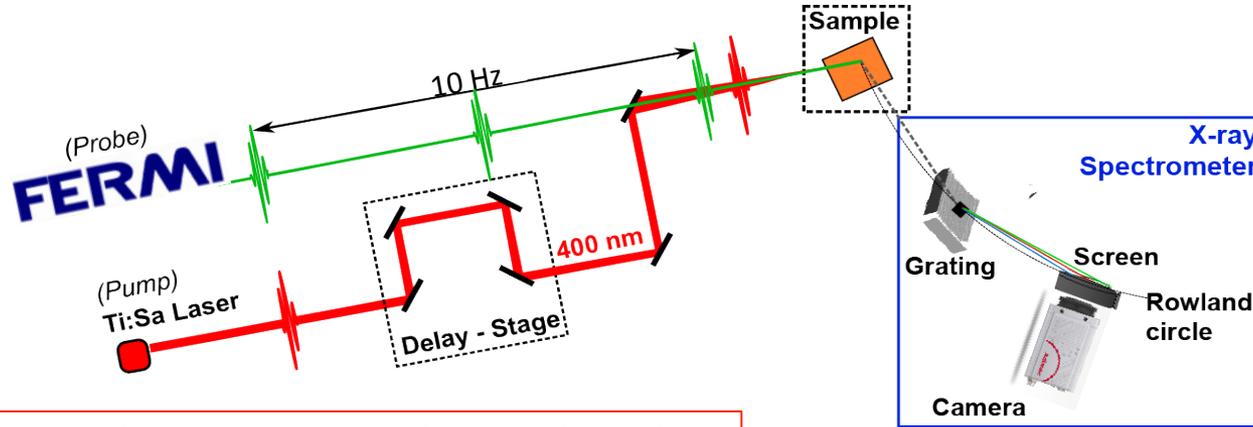
Elettra-Sincrotrone Trieste S.C.p.A. and University of Trieste

ELETTRA Parameters

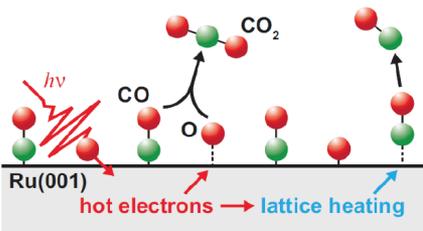
Beam energy [GeV]		2	2.4
Storage ring circumference [m]	259.2		
Beam height in experimental area [m]	1.3		
Number of achromats	12		
Length of Insertion Device (ID) straight sections [m]	6(4.8 utilizabile per ID's)		
Number of straight sections of use for ID's	11		
Number of bending magnet source points	12		
Beam revolution frequency [MHz]	1.157		
Number of circulating electron bunches	1 - 432		
Time between bunches [ns]	864 - 2		
Tunes: horizontal/vertical	14.3/8.2		
Natural emittance [nm-rad]		7	9.7
Energy lost per turn without ID's [keV]		255.7	533
Maximum energy lost per turn with ID's [keV] (all)		315	618.5
Critical energy [keV]		3.2	5.5
Bending magnet field [T]		1.2	1.45

Geometrical emittance coupling %	£ 1%		
Spurious dispersion (at the centre of IDs): horizontal (rms max/min) [cm]	6/2.		
Spurious dispersion (at the centre of IDs): vertical (rms max/min) [cm]	2/0.5		
Injected current [mA]		320	150
Machine dominated by the Touschek effect			
Energy spread (rms) %		0.08	0.12
Lifetime [h] (natural)		8.5	32
Lifetime [h] (with 3 rd harmonic cavity)		27	32
Bunch length (1 σ) [mm]*		5.4	7
Beam dimensions (1 σ)*			
ID source point - horizontal/vertical [μm]		241/15	283/16
Bending magnet source point - horizontal/vertical [μm]		139/28	197/30
Beam divergence (1 σ)*			
ID source point - horizontal/vertical [μrad]		29/6.	35/8.
Bending magnet source point - horizontal/vertical [μrad]		263/9	370/13

XES and RIXS probe the valence electronic structure in an atom specific and chemical state selective manner.

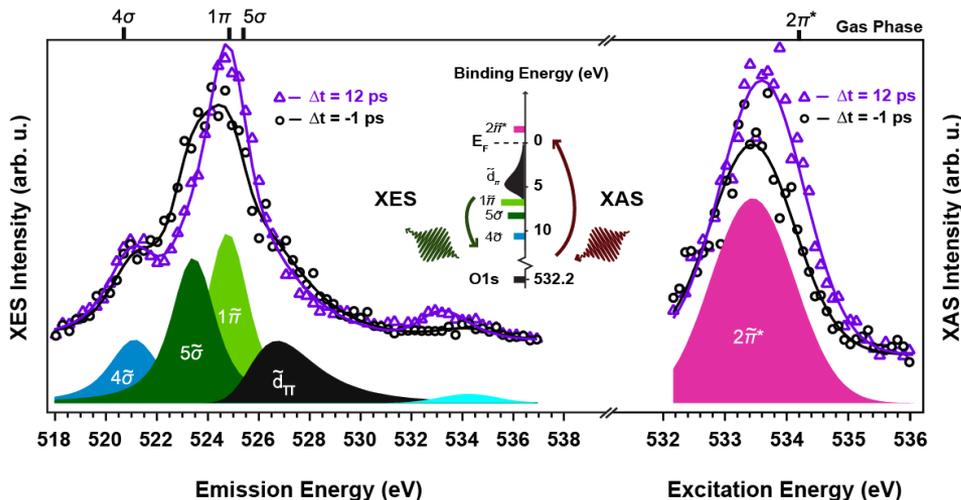


Example (@LCLS): CO desorption from Ru(0001)



Time Resolved RIXS employed to follow the bond-breaking between CO and Ru surface after optical laser irradiation by looking at changes in the electronic structure (filled XES and empty XAS states).

© Martin Wolf



W. Wurth, Hamburg

RIXS at FERMI

- Soft x-ray, 52- 950 eV
- THz to Mid-IR pumping.
- Seeded x-ray FEL:
 - Tunable transform limited x-ray FEL.
 - Less jitter, especially in intensity
 - No need for monochromator -> more flux
- Tight focus (<10 μm) -> high resolution for the RIXS spectrometer.
- Higher Repetition rate for more flux (50 Hz)

M. Dell'Angela et al., Science 339, 1302 (2013)

Four-wave mixing experiments with extreme ultraviolet transient gratings

F. Bencivenga¹, R. Cucini¹, F. Capotondi¹, A. Battistoni^{1,2}, R. Mincigrucci^{1,3}, E. Giangrisostomi^{1,2}, A. Gessini¹, M. Manfredda¹, I. P. Nikolov¹, E. Pedersoli¹, E. Principi¹, C. Svetina^{1,2}, P. Parisse¹, F. Casolari¹, M. B. Danailov¹, M. Kiskinova¹ & C. Masciovecchio¹

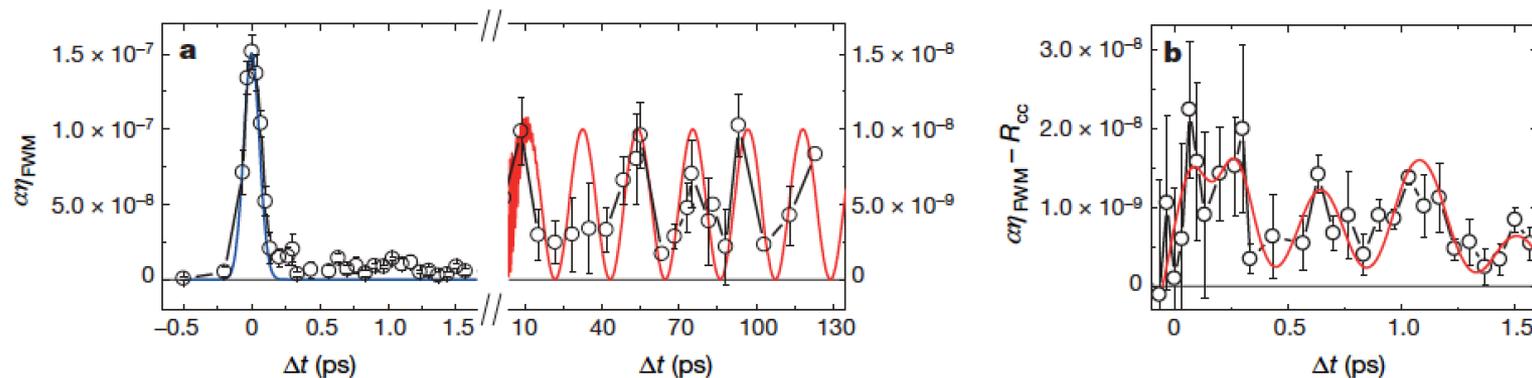


Figure 3 | Time evolution of the FWM signal. **a**, Black circles (connected by lines where there is enough distance between adjacent points) show the time dependence of the FWM signal, scaled to the intensity of the input beams (error bars are estimated as one standard deviation of the set of CCD images corresponding to the same Δt value); the blue and red lines are R_{cc} and the

expected signal modulation due to acoustic modes, respectively (right-hand y axis plots same quantity as left-hand axis, but on an expanded scale). **b**, Black circles connected by lines are the FWM signal after R_{cc} is subtracted. The red line is the modulation due to oscillations at frequencies $\nu_1 = 1.15$ THz and $\nu_2 = 4.1$ THz. Error bars, as a.



Elettra 2.0

Energy 2 GeV

Emittance 0.251 nmrad -> 28 times reduction

Beam dim 32/22 μm (round beam) or 40/2.2 μm at 1% coupling

$\alpha = 3 \times 10^{-4}$ -> shorter bunches by a factor of 2

Tune 33.32, 8.38, chrom -60

Espread $7 \cdot 10^{-4}$

DE/turn 178.5 keV,

Damping times (msec)

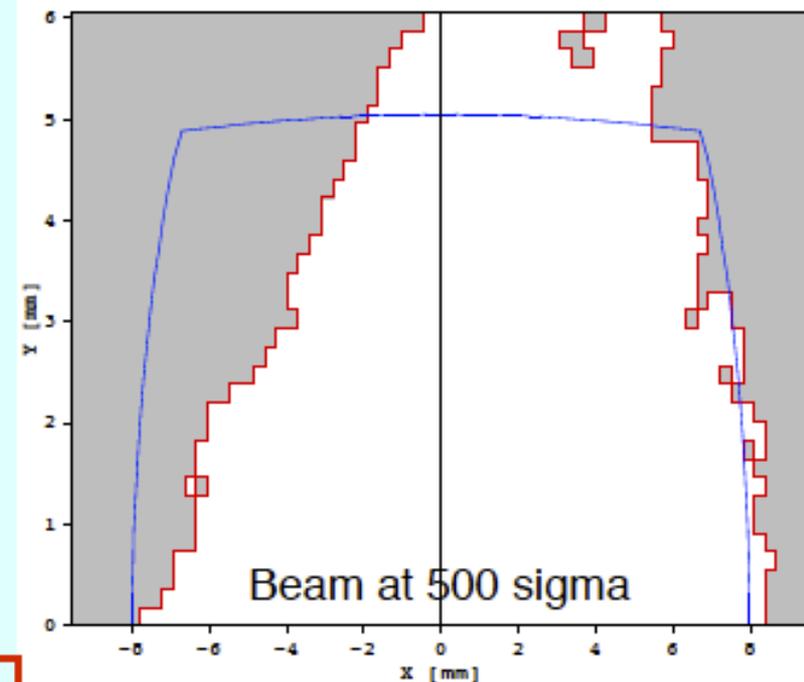
X 12.4, Y 19.3 E 13.5

Dipoles: field 0.8 T and 19 T/m

Quads: K max 9.5 -> 64 T/m -> 12.8 T ($l=0.2\text{m}$)
(max integrated field 15 T using vacoflux reached 19 T)

Sext: max $K_2=100$ (700 T/m^2)

Chamber 22x7 mm and 22x22



Elettra nominal:

Dipoles: field 1.2 T and gradient 2.86 T/m

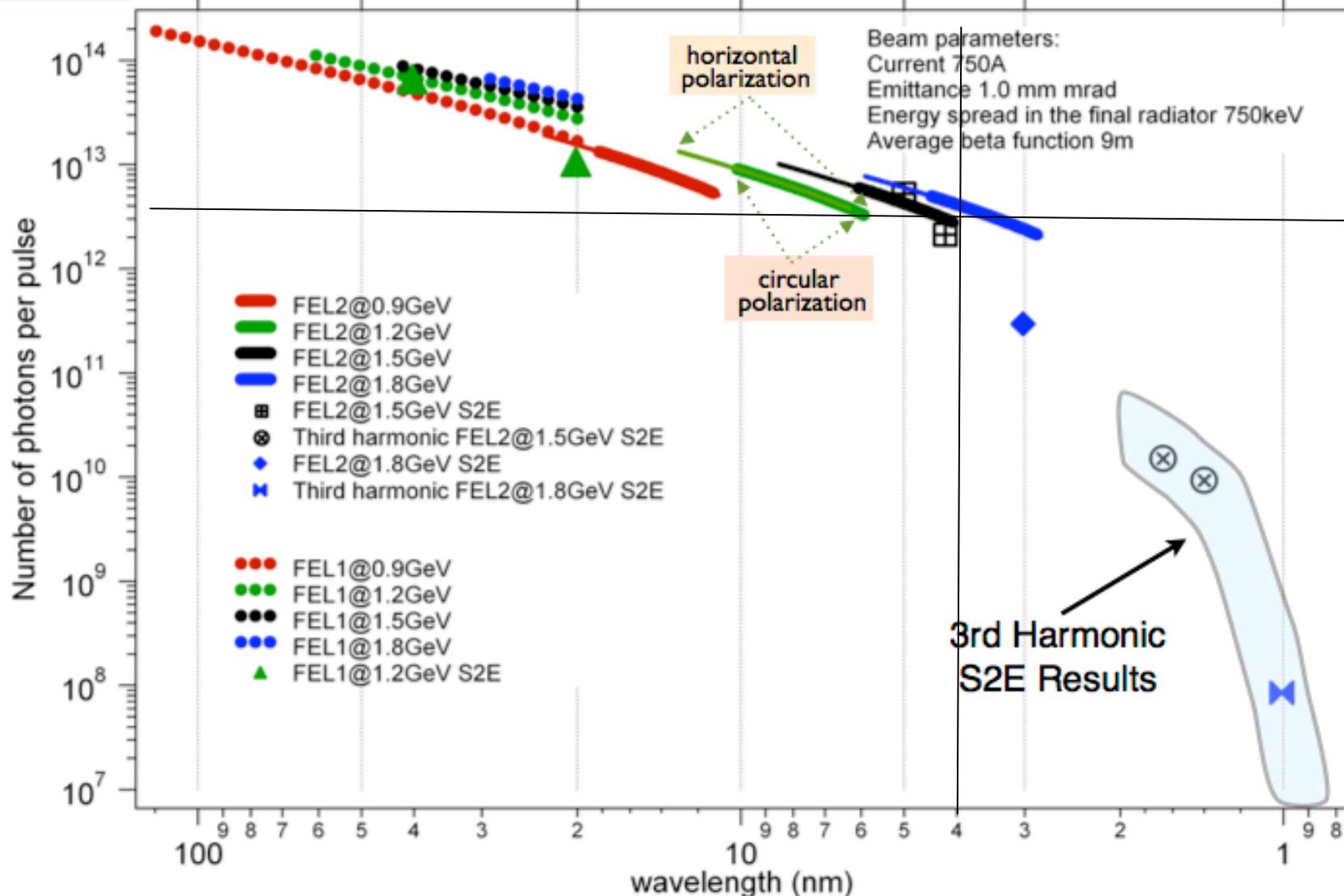
Quads: max gradient 15 T/m

Sext: max gradient 70 T/m^2

FEL-1 and FEL-2 Output Characteristics vs. λ

photon energy:

12.40 eV 24.80 eV 61.99 eV 123.98 eV 247.97 eV 413.28 eV 1239.84 eV



International Award FEL 2013 to Luca Giannessi



Luca Giannessi, Senior Scientist at ENEA and Head of Machine Physics at FERMI, is the winner of the prestigious international award FEL 2013.

The prize is annually awarded "to a person who has Contributed significantly to the advancement of the field of Free-Electron Laser (...). It gives the international community the FEL Recognize opportunity to one of its members for His or her outstanding achievements. "

The prize was awarded to Dr. Giannessi during the [35th International Free-Electron Laser Conference](#), which took place in **New York** (August 26 - 30).

(Invited talks from Allaria, Danailov, Di Mitri, Ferrari, Finetti, Giannessi, Penco, Zangrando)

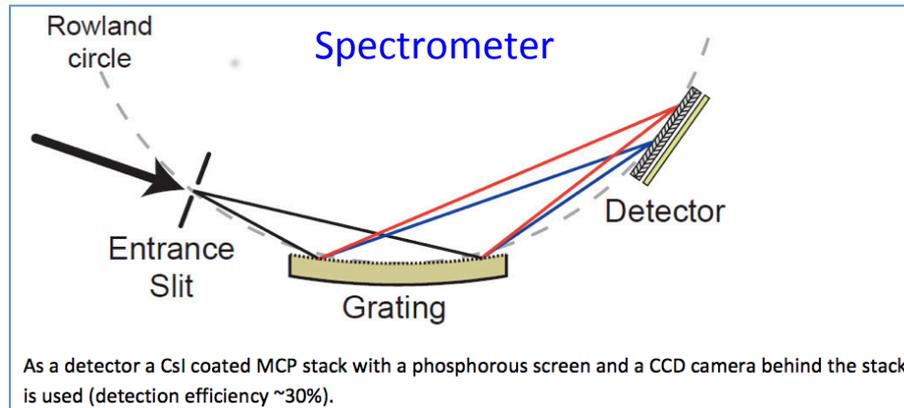
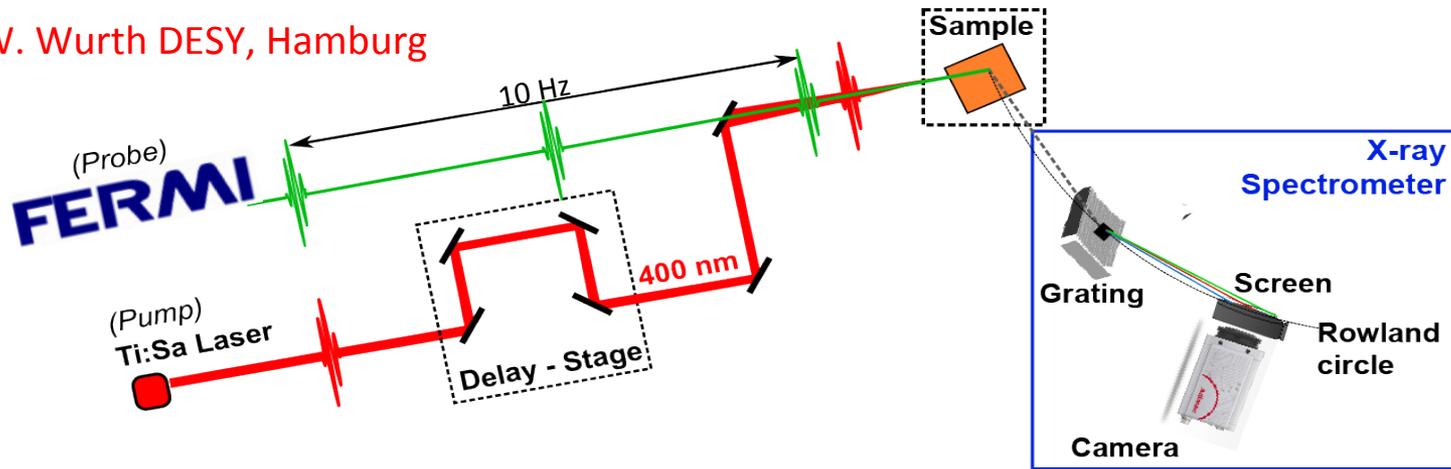
First Lasing of FERMI FEL-2

L. Giannessi (Elettra-Sincrotrone Trieste S.C.p.A.)

During the month of October 2012 the commissioning of the light source FEL-2 at FERMI was successfully concluded. Fermi FEL-2 is the first seeded FEL operating with a double stage cascade in the "fresh bunch injection" mode. The two stages are two high gain harmonic generation FELs where the first stage is seeded by the 3rd harmonic of a Ti:Sa laser system, which is up converted to the 4th-6th harmonic. The output of the first stage is then used to seed the second stage. A final wavelengths of 10.8 nm was obtained as the 24th harmonic of the seed wavelength at the end of the two frequency conversion processes, demonstrating that the FEL is capable of producing single mode narrow bandwidth pulses with an energy of several tens of microjoules.

RIXS spectrometer: available

Prof. W. Wurth DESY, Hamburg

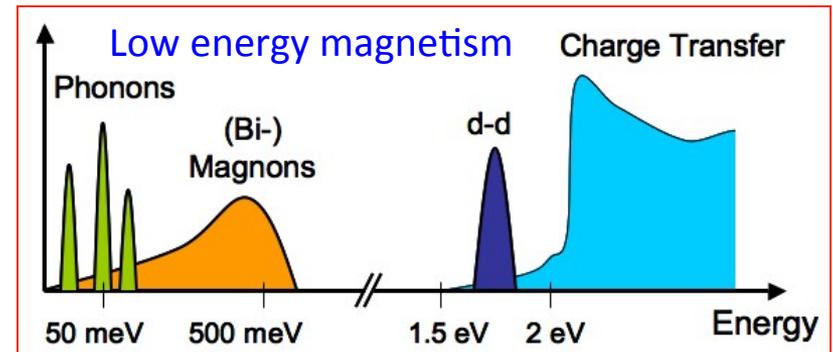


Grating configuration (can be changed):

	Grating 1	Grating 2	Grating 3
Ruling	1200l/mm	400l/mm	300l/mm
Radius	5m	5m	3m
Angle of incidence	88.1°	87.4°	84.6°
Energy range	300-1500eV	100-450eV	50 [*] -200eV

*Energies between 20-50 eV are also possible

The resolution with a 10 μ m slit is roughly 80meV at 100eV photon energy.



A NEW CHALLENGE: E-ST to implement the in-kind Italian participation in international large scale projects

CERIC-ERIC

EuroFEL/IRUVX

European XFEL

European Spallation Source

Extreme Light Infrastructure

NanoFoundry and Fine Analysis

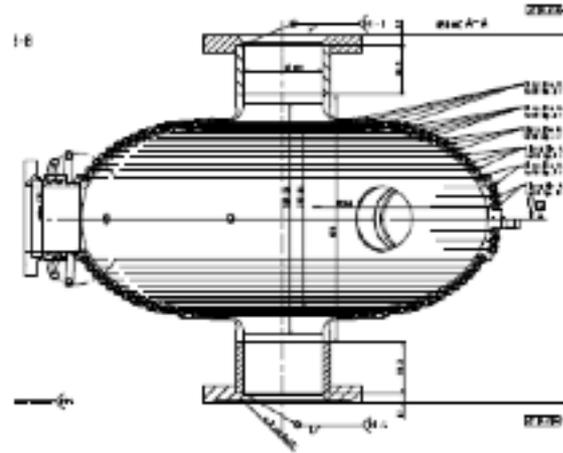
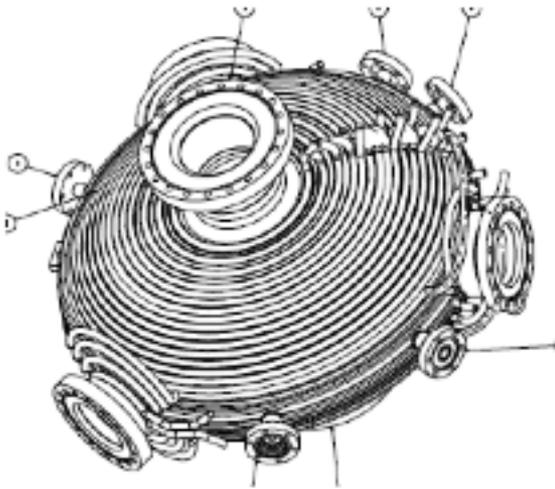
SESAME

Difficulties include timeline of MIUR funding vs. construction schedule (ESS), VAT recovery, in-kind national goals vs. open tender policy, etc.

*€1.250.000 contract
signed on May 12, 2014*



Elettra Sincrotrone Trieste



The main characteristics of the RF cavity accelerating will be:

f_0	499.654 MHz \pm 1 MHz
V_{acc} maximum	650 kV
Power losses	\leq 66 kW
R_{shunt}	\geq 3.2 M Ω

Elettra role:

- ✓ Produce 4 improved RF cavities
- ✓ Train SESAME personnel in RF

SOLARIS Project

- ✓ Construction of a 1.5 GeV synchrotron in Krakow (PL)
- ✓ Technologically identical to the MAX IV 1.5 GeV ring (Lund, S)
- ✓ Linac injector operated at 550-600 MeV
- ✓ Ring operated in a ramped-decay mode (550 MeV → 1.5 GeV)



Elettra's role:

- ✓ Provide expertise in many design, installation, test and commissioning tasks
- ✓ Construct beamline

€ 3.520.000

Scientific Advisory Council

- **I. Lindau (chair)**, K. Horn, S. Larsen, K. Nugent, B. Patterson, M.N. Piancastelli, J.-P. Samama, C. Shank, R. Schoenlein, W. Würth

Machine Advisory Committee

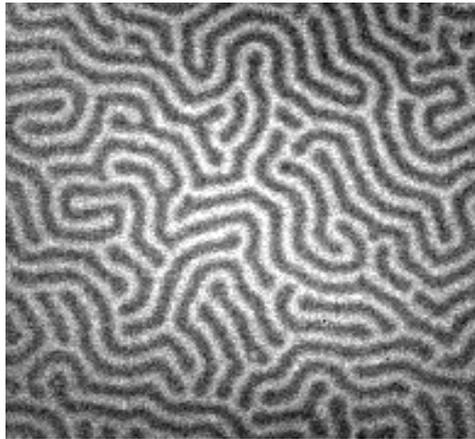
- **R. Walker (chair)**, H. Braun, P. Emma, M. Eriksson, P. Kuske, A. Nadji, C. Pellegrini, F. Willeke, S. Zholents

**About 100 synchrotron radiation laboratories all over the world,
but only fifteen third-generation, ultrabright facilities in operation:**

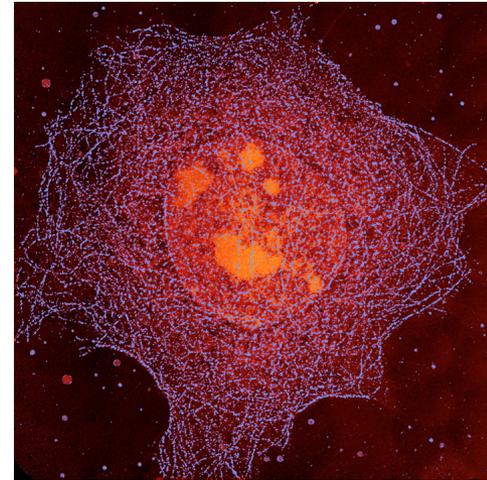
ESRF	6 GeV	France
ALS	1.6 GeV	USA
APS	7 GeV	USA
BESSY II	1.7 GeV	Germany
Elettra	2.4 GeV	Italy
Spring-8	8 GeV	Japan
MAX II	1.5 GeV	Sweden
SLS	2.4 GeV	Switzerland
PETRA III	6.0 GeV	Germany
PLS-II	3 GeV	Korea
SRRC	1.4 GeV	Taiwan
SSRL	3 GeV	USA
CLS	2.9 GeV	Canada
Soleil	2.5 GeV	France
Diamond	3 GeV	United Kingdom
Australian Synchrotron	3 GeV	Australia

*<- tra le prime, ma
aggiornata nel 2008*

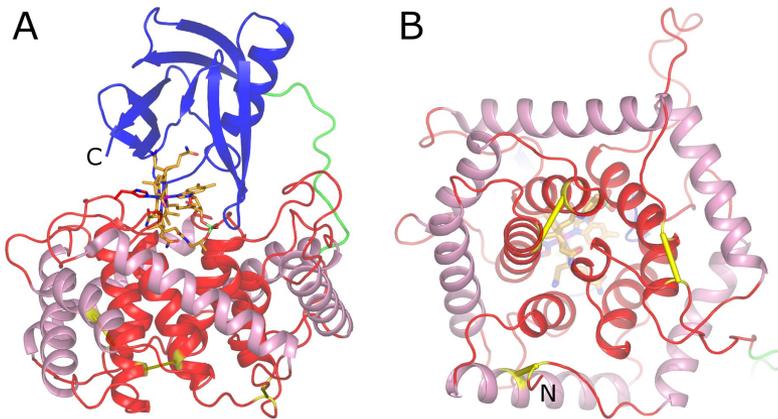
FeGd Multilayer



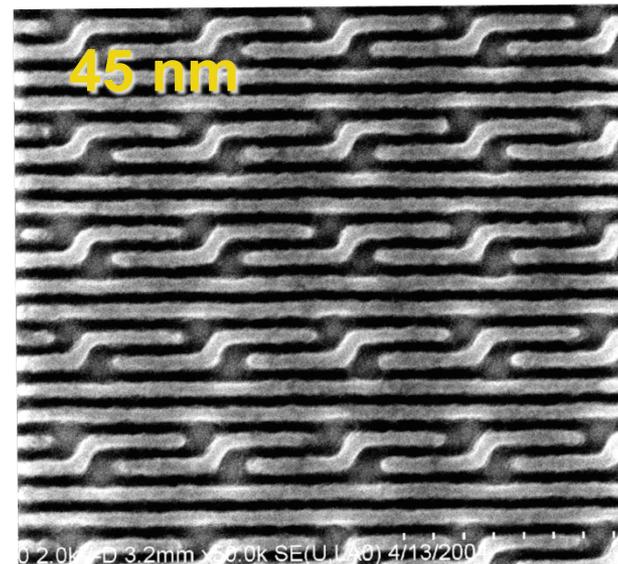
$\hbar\omega = 707.5 \text{ eV}$
Fe L₃-edge



Microtubules in a mouse epithelial cell



Overall structure of transcobalamin



Prof. Ingolf Lindau (chair, synchrotron radiation)

Dr. Lucia Aballe (magnetism, microscopy), beamline scientist at ALBA-CELLS

Prof. Paolo Scardi (X-ray diffraction), University of Trento.

Dr. Bruce Ravel (XAS), NIST

Dr. Francesco de Carlo (x-ray imaging, SYRMEP)

Dr. Annalisa Pastore (NMR expert, bio).

Prof. Jan Sykora, ASCR, Department of Analytical and Material Chemistry, Česká Republika (NMR, materials science)

Dr. Elvio Carlino (TEM)

Dr. Cécile Hébert, Head of CIME (Interdisciplinary Center for Electron Microscopy), EPFL. (EvCo member).

Prof. Henk Vrielinck (EPR), Department of Solid state sciences, University Gent

Prof. Francesco Sacchetti (neutron diffraction)

Dr. Zsolt Révay (FRM-II Garching, PGAA expert)

Dr. Noémi Székely, Jülich Centre for Neutron Science, (SANS/soft matter)

Dr. Gergely Nagy, PSI, (TOF-techniques/biology)

Dr. NEMŠÁK Slavomír, HZB (surface science expert, materials science BL e SPL)



Elettra
Sincrotrone
Trieste

Elettra at a glance



- 400 employees
- 100000 m²
- 5000 hours /year
- 32 beamlines
- more than 1000 Users
- from more than 50 countries

- ✓ Multi-disciplinary environment
- ✓ Leading edge technologies
- ✓ Open knowledge
- ✓ Several application fields
- ✓ Cross-fertilization



Know how



Only 4 EUV-X-ray FEL operating worldwide:

LCLS-I	SLAC, Stanford, USA	SASE	X-rays
FLASH	DESY, Hamburg, Germany	SASE	EUV/soft-X-rays
SACLA	SPring-8, Harima, Japan	SASE	X-rays
FERMI	Elettra-Sincrotrone Trieste	seeded	EUV/soft-X-rays

Under construction:

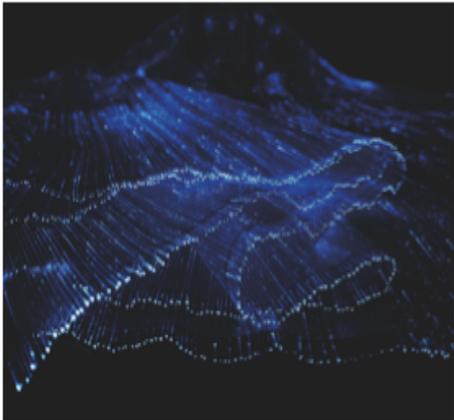
EU XFEL	DESY, Hamburg, Germany	self-seeded	soft/hard-X-rays
SwissFEL	PSI, Villigen, Switzerland	self-seeded	soft/hard-X-rays
LCLS-II	SLAC, Stanford, USA	self-seeded	X-rays
PAL-XFEL	Pohang, Korea	SASE	soft/hard-X-rays

Industrial Liaison Office is active since 2004

Manage the industrial relationships and the technology transfer activities of Elettra Sincrotrone Trieste

Team of 5 people with scientific and economic background

Elettra Industrial Liaison Office



Services

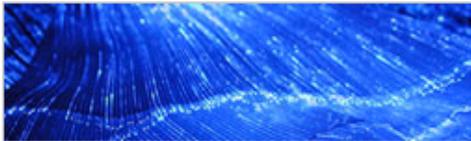
» Agrofoodstuff



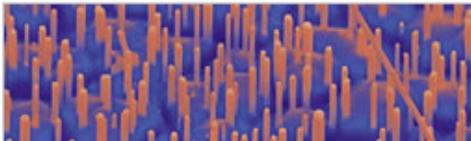
» Conservation of the Cultural heritage



» High-Tech Materials



» Micro and nanotechnologies



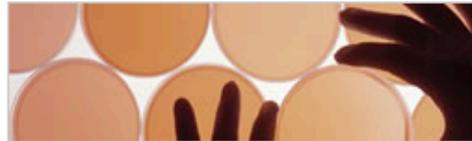
» Chemistry and Catalysis



» Energy and the environment



» Medicine and Diagnostics



» Optics, Electronics and ICT



» search inside services

» Advanced search

The Technological Offering

Synchrotron light has unique characteristics of intensity and coherence that can reveal otherwise inaccessible details of materials, simplify their manipulation and provide information in multiple fields of study including electronics, environmental sciences, materials engineering, medicine, and micro and nanotechnologies. The light is generated by electron accelerators, carried through micrometrically collimated beams selected according to their wavelengths, and transmitted through a beamline to the utilisation and measurement stations.

In this section a number of studies and developments undertaken at the Elettra in recent years are described. You'll find many examples of the wide range of the services. The Industrial Liaison Office of Elettra-Sincrotrone Trieste S.C.p.A. promotes technology transfer and offers assistance to all who wish to take advantage of its sophisticated skills and equipment.

Our guidelines

1. Direct access to an extensive range of facilities and techniques
2. Discuss your needs
3. Scouting our expertise
4. Feasibility Study to start
5. Commercial offer



Our guidelines

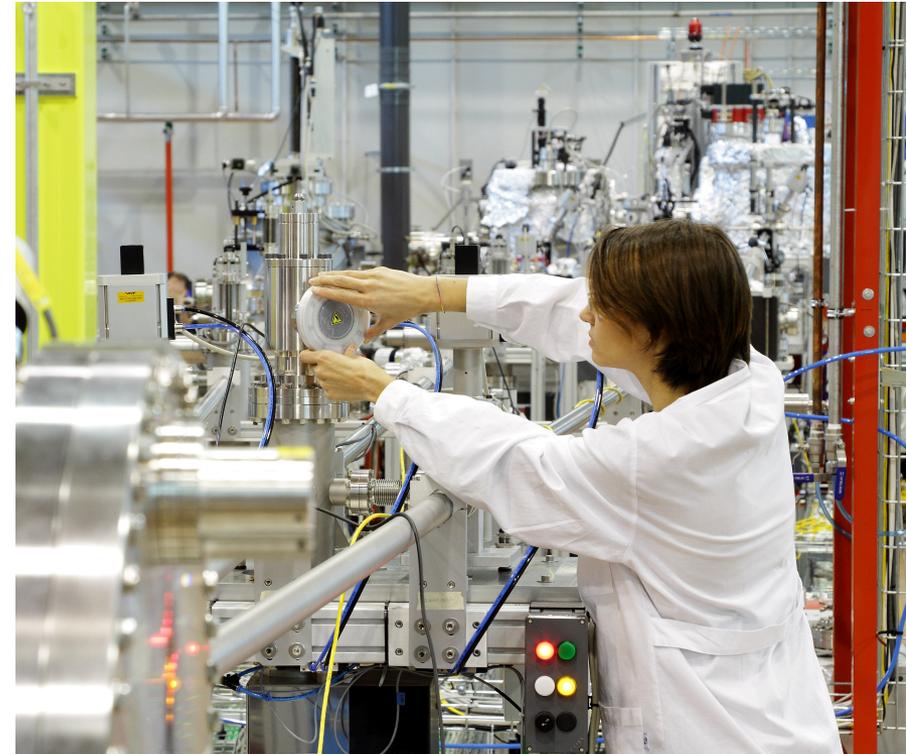
Feasibility Study is “free of charge”

Quotations based on time, cost
and performance

Activities structured as a Project

Continuous collaboration, sharing
of results, knowledge transfer

Confidentiality is a must!



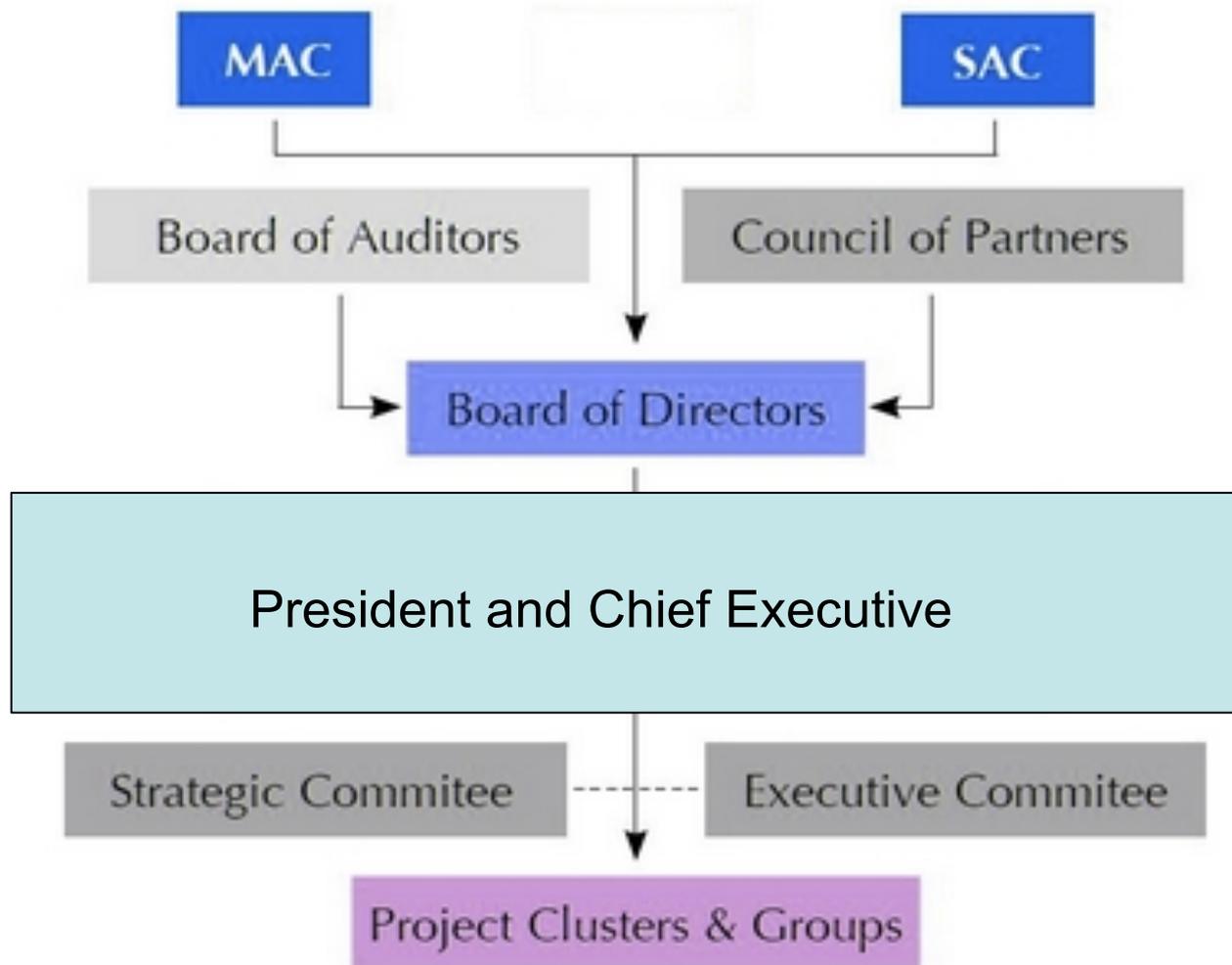


Elettra
Sincrotrone
Trieste

Contact us and ask for a meeting!



ilo@elettra.eu

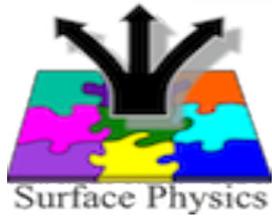




Central European
Research Infrastructure
Consortium



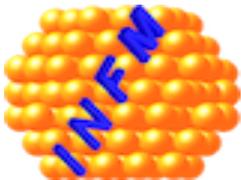
Elettra Sincrotrone Trieste



CERIC-ERIC

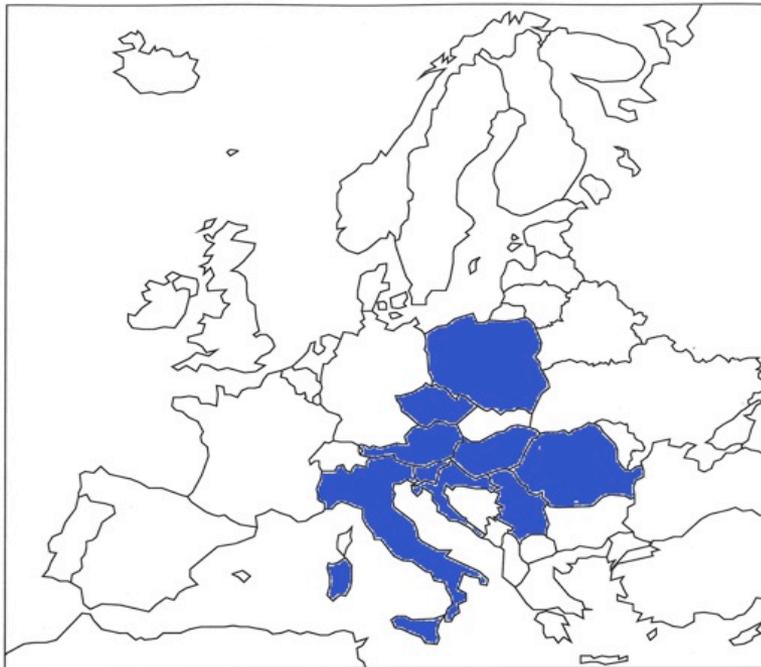


*The Central European Research
Infrastructure Consortium*





CERIC-ERIC is a **distributed research facility**, set up as an ERIC by nine Countries (*Austria, Croatia, Czech Republic, Hungary, Italy, Poland, Romania, Serbia, Slovenia*), open to other interested countries.



The scopes of CERIC are:

- to support excellent research in the field of nano-level analysis and synthesis of materials
- speed-up the alignment East-West EU

as a distributed facility, will have:

- One integrated Partner Facility per Country
- a common entry point offering the available services, for incoming users proposals;
- a single evaluation system to select them and give the access to the integrated services;
- free and open access by quality selection only;
- support and logistic services as required;
- a single and effective governance, based on a common legal form, and a single management in charge of its integrated operation.
- Joint IPR, industrial, educational, communication and development activities

- Synchrotron Radiation beamlines in Trieste

Esca Microscopy

BaDElPh

IUVS

Materials Science

MCX

DXRL

Nanospectroscopy

SAXS

SISSI

Spectromicroscopy

SYRMEP

XRD1

XAFS

SuperESCA

TwinMic

- XPD and FESEM facilities in Prague

- Tandem Accelerator facility in Zagreb *

Nuclear microprobe

TOF-ERDA

RBS channeling

Irradiation

PIXE/RBS/PIGE

- Light Scattering Laboratory and SAXS facility in Graz
- HRTEM and EPR facilities in Bucharest
- Neutron Research beamlines in Budapest:
BIO GINA MTEST PSD SANS
TAST RAD RNAA PGAA TOF
- Nuclear Magnetic Resonance in Ljubljana:
David (800 MHz) Magic (600 MHz)
Lara (600 MHz) Odie and Ajax (300 MHz)

CERIC "call zero" received 30 proposals (1/3 accepted)

CERIC "call one" received 44 proposals (1/3 accepted)

Ingolf Lindau (Chair), Stanford University and University of Lund

Lucia Aballe, ALBA-CELLS, Spain

Paolo Scardi, University of Trento, Italy

Bruce Ravel, NIST, USA

Francesco de Carlo, Argonne National Lab, USA

Annalisa Pastore, NIMR, London, U.K.

Jan Sykora, ASCR, Česká Republika

Elvio Carlino, IOM-CNR, Trieste, Italy

Cécile Hébert, EPFL, Switzerland

Henk Vrielinck, University Gent, Belgium

Francesco Sacchetti, University of Perugia, Italy

Zsolt Révay, FRM-II Garching, Germany

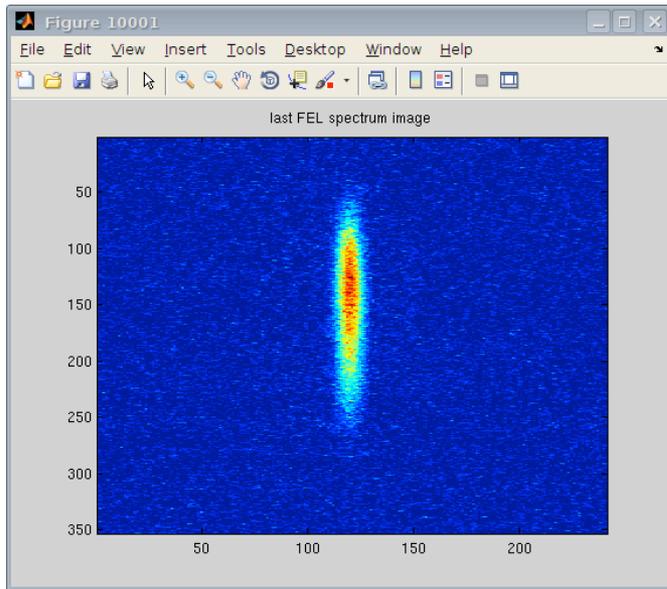
Noémi Székely, Jülich Centre for Neutron Science, Germany

Gergely Nagy, Paul Scherrer Institut, Switzerland

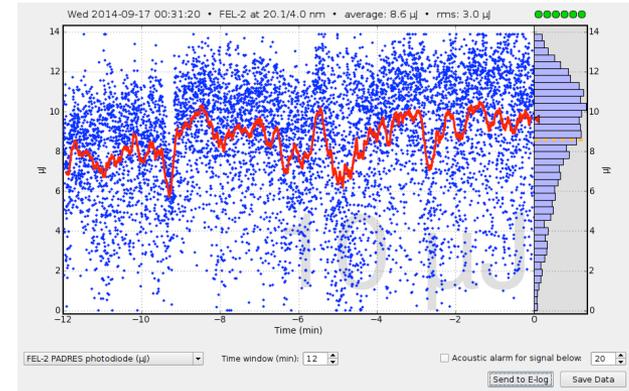
Nemsak Slavomír, Helmholtz Zentrum Berlin, Germany

5.4 nm - Single mode spectrum

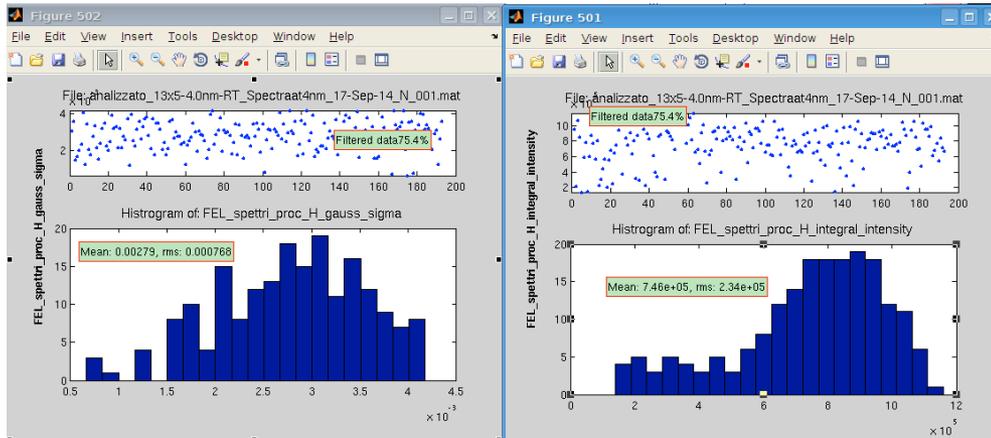
Spectral linewidth 3×10^{-4} (rel. rms – 90%shots)



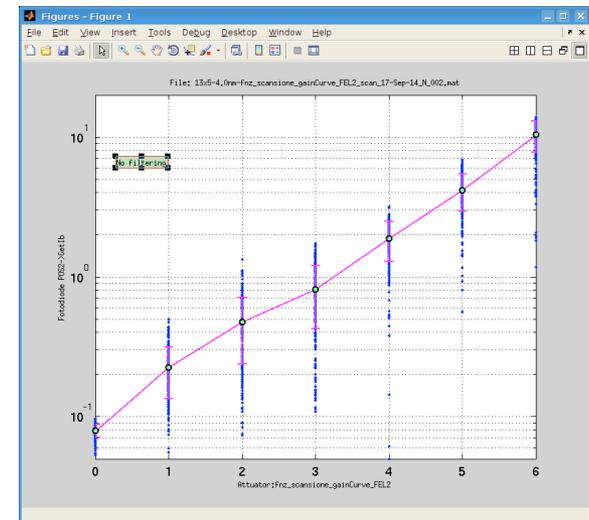
4 nm – 10 μ J “average” energy per pulse



4 nm - spectral linewidth 7×10^{-4} (rel. rms 75%shots)
energy stability 30% rms fluctuations in energy

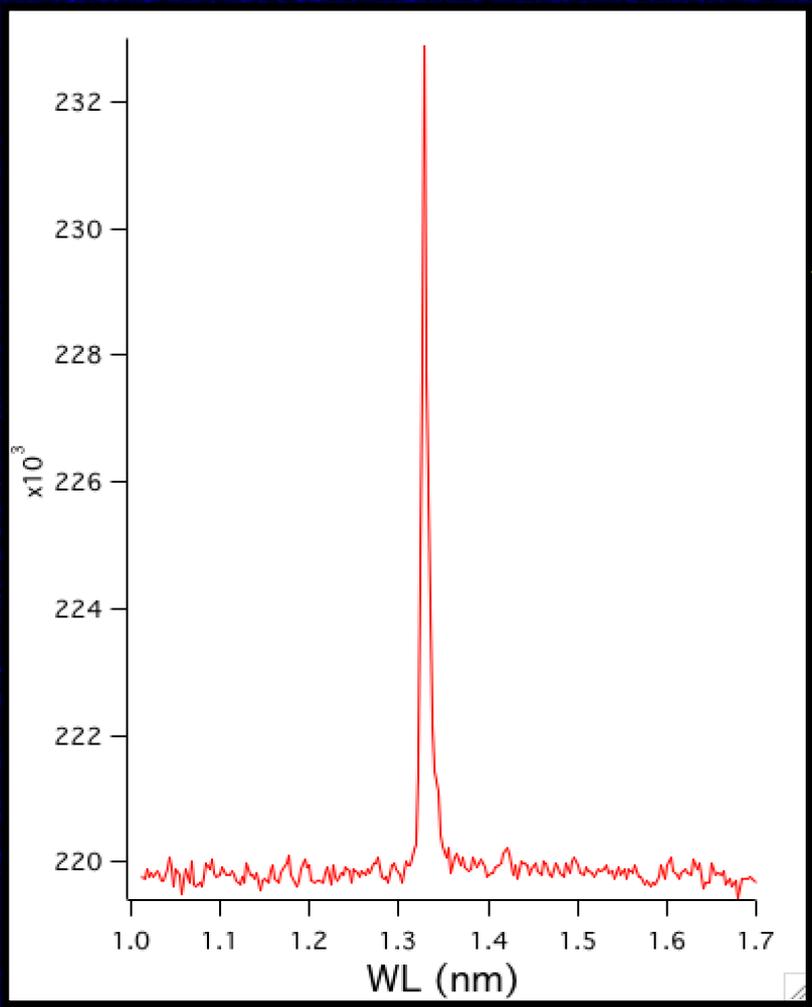


4 nm - exponential gain



2nd
harmonic of
5.4nm

4th
harmonic of
5.4nm



Winspec raw image

h 192

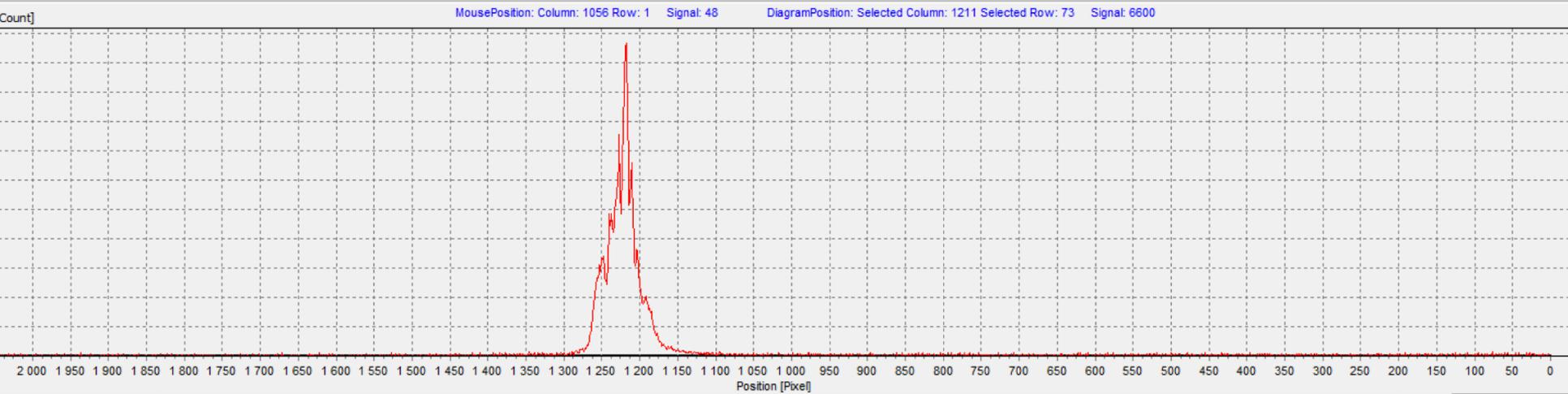
800

1000

1200

4rd harmonic of 5.4 nm, i.e., 1.35 nm, 1nJ/pulse

FEL 3h spectrum @ 1.67 nm (2015)



Scientific Advisory Council

- **I. Lindau (chair)**, K. Horn, S. Larsen, K. Nugent, B. Patterson, M.N. Piancastelli, J.-P. Samama, C. Shank, R. Schoenlein, W. Würth

Machine Advisory Committee

- **R. Walker (chair)**, H. Braun, P. Emma, M. Eriksson, P. Kuske, A. Nadji, C. Pellegrini, F. Willeke, S. Zholents

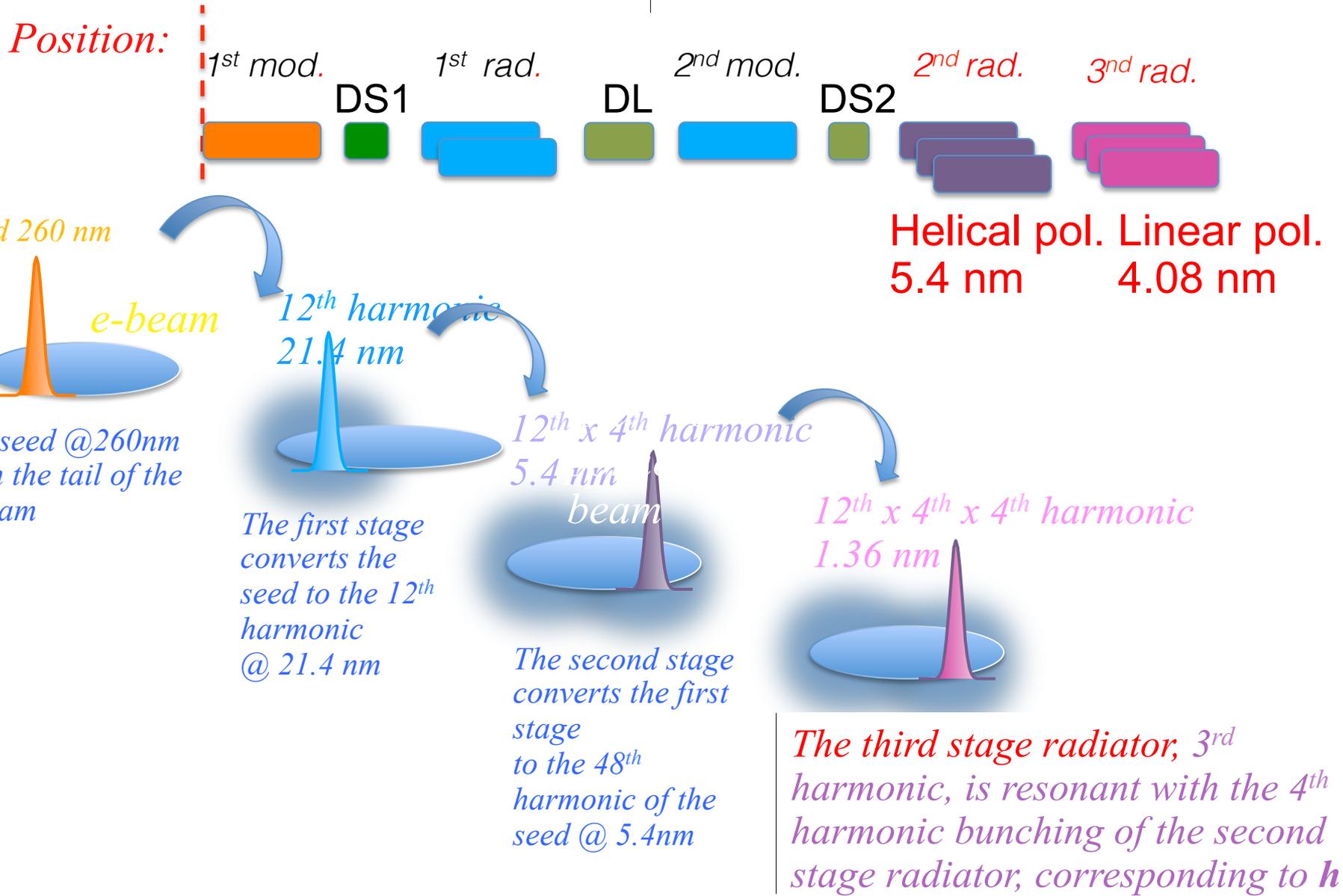
Elettra 2.0-2.4 GeV 3rd generation Synchrotron Radiation Facility



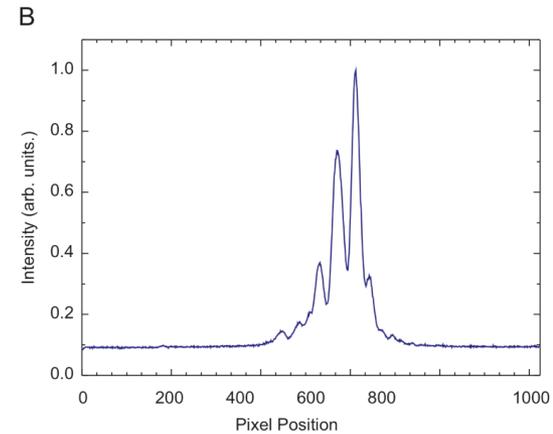
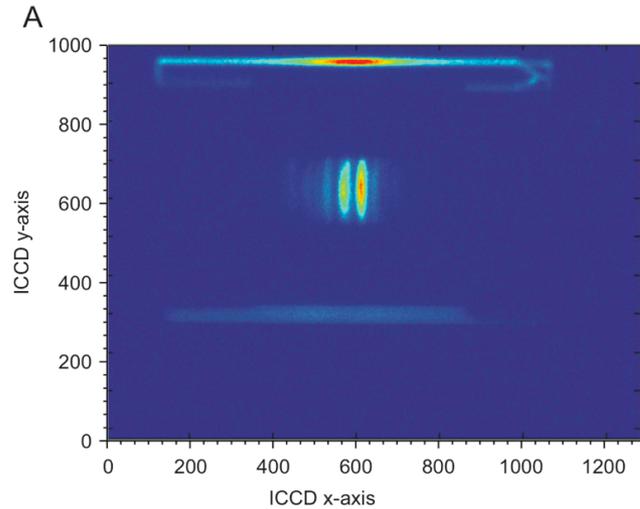
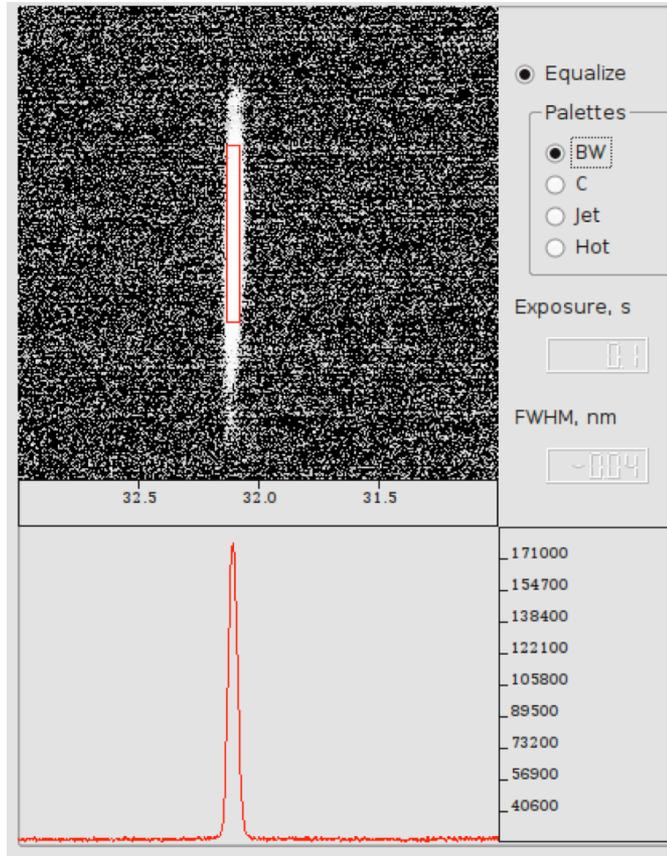
FERMI 1.5 GeV seeded Free Electron Laser Facility



FERMI FEL-2: harmonics

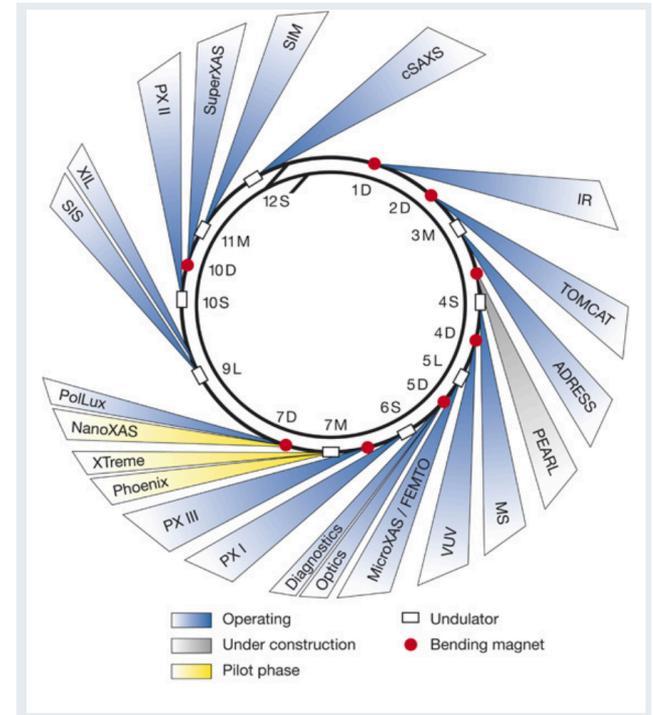


26.4 nm

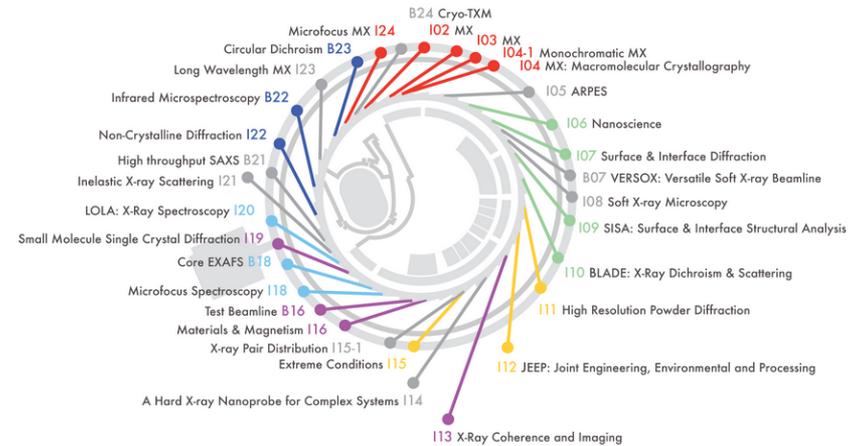


Spectral lines as measured at FERMI@Elettra (left panel) and at the FLASH SASE facility in Hamburg, Germany (right panel).

SLS, Svizzera



DIAMOND, Gran Bretagna



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14 “Flagship Projects” – Approved by CIPE on March 23, 2011

QUADRO FINANZIARIO PROGETTI BANDIERA - PNR 2011-2013						
PROGETTI	2010	2011	2012	2013	Annualità successive	TOTALE MIUR/ENTI
						A
1 Epigenomica	3,00	8,00	9,00	10,00		30,00
2 Ritmare - ricerca italiana per il mare	20,00	70,00	90,00	90,00	180,00	450,00
3 L'ambito nucleare	3,00	10,00	13,00	13,00		39,00
4 ASTRI – astrofisica con specchi a tecnologia replicante italiana	3,00	2,00	2,00	1,00		8,00
5 La fabbrica del futuro	2,00	2,00	4,00	4,00		12,00
6 NanoMax	0,00	6,00	8,00	9,00		23,00
7 InterOmics	0,00	8,00	9,00	8,00		25,00
8 Elettra-Fermi – EUROFEL	5,00	11,00	13,00	16,00		45,00
9 Super B factory	34,00	22,00	34,00	45,00	115,00	250,00
10 SIGMA	80,00					80,00
11 Satellite ottico per telerilevamento	100,00					100,00
12 Ricerca e Innovazione tecnologica nei processi di conoscenza, tutela, valorizzazione e sicurezza dei Beni Culturali	2,00	8,00	10,00	10,00	0,00	30,00
13 Cosmo - Skymed II generation		100,00	100,00	100,00	300,00	600,00
14 IGNITOR		25,00	25,00	30,00		80,00
	252,00	925,00				
totale 2010/2013		1177,00			595,00	1772,00

leftover €12.8 will be released in 2014 and 2015

SOLARIS Project: contracts

2 years contract for the delivery of expert consultancy services in the range of adaptation, construction, integration and launch of a new type of synchrotron radiation source based on technology developed

€ 450.000

(to be completed by March 2015)

design, manufacturing, and delivery with installation and site acceptance test of the complete UARPES beamline

€ 3.070.000

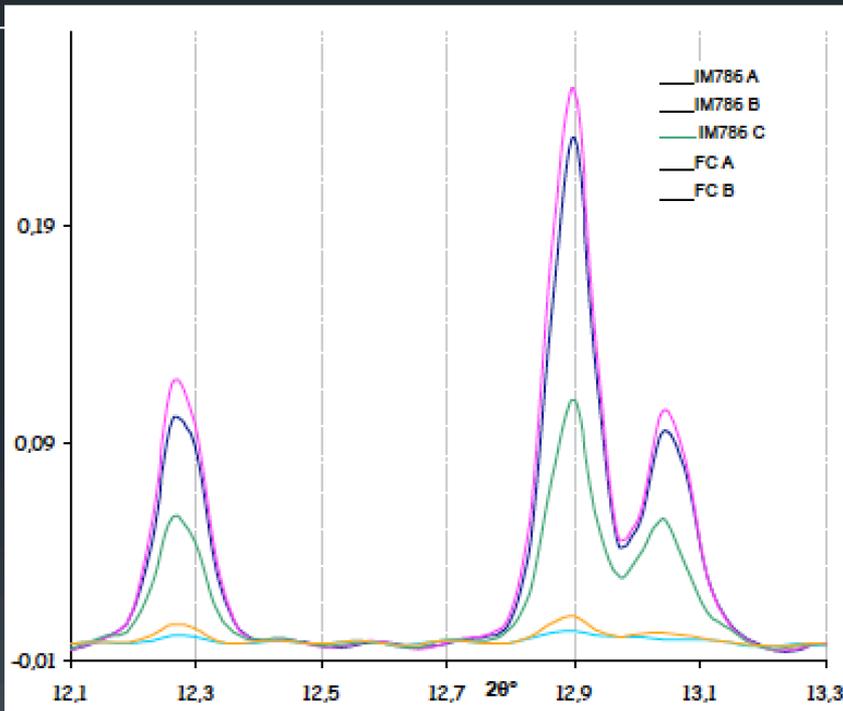
(to be completed by April 2015)

SYNCHRO BEAM PHARMACEUTICALS START-UP

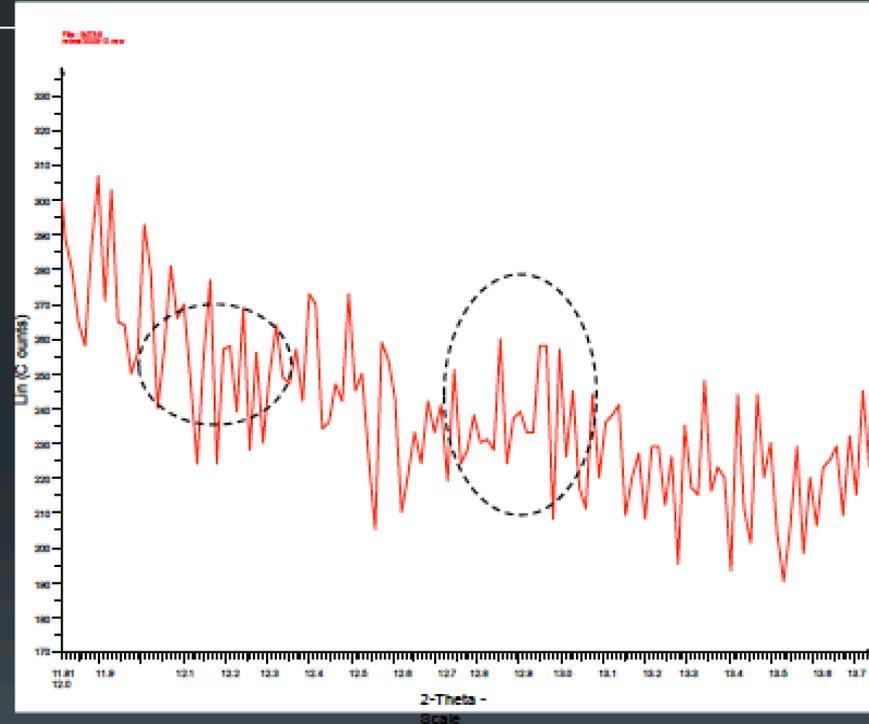
SYB Pharma Technology

A "4K Ultra HD" Picture of APIs Crystal Form Structure

Synchrotron Light XRPD



Conventional XRPD



POLYMORPHISM PURITY PATTERNS OF API'S FOR QUALITY CONTROL AND INTELLECTUAL PROPERTY RIGHTS PROTECTION

Construction of a 2.5 GeV third-generation source in Jordan



**SESAME | SYNCHROTRON-LIGHT FOR EXPERIMENTAL SCIENCE
AND APPLICATIONS IN THE MIDDLE EAST**



- **Attosecond Laser Science** (*ELI-ALPS*, Szeged, HU):
Attosecond, high-flux XUV pulse generation to monitor the electronic-structural dynamics in complex molecular systems for applications in a variety of research areas.
- **High-Energy Beam Facility** (*ELI-Beamlines*, Prague, CZ):
Ultrashort, high-flux X-ray pulse generation and laser-plasma acceleration of electrons and ions for studies in the (bio)medical and materials science fields.
- **Nuclear Physics Facility** (*ELI-NP*, Magurele, RO):
Development of an ultraintense laser source by coherent combination of two 10 PW lasers;
development of a high-brightness γ -ray source through inverse Compton for nuclear physics studies.



DIFFRACTION AND PROJECTION IMAGING PROGRAM M. Kiskinova

- *Ultrafast Coherent Imaging*
- *Full-field x-ray Microscopy and Lensless Imaging*

STATUS AND OPPORTUNITIES

ELASTIC AND INELASTIC SCATTERING PROGRAM C. Masciovecchio

- *t-Resolved Spectroscopy of Mesoscopic Dynamics* **TIMER**
- *Elastic Scattering from Matter under Extreme Conditions* **TIMEX**

TIMEX STATUS AND OPPORTUNITIES

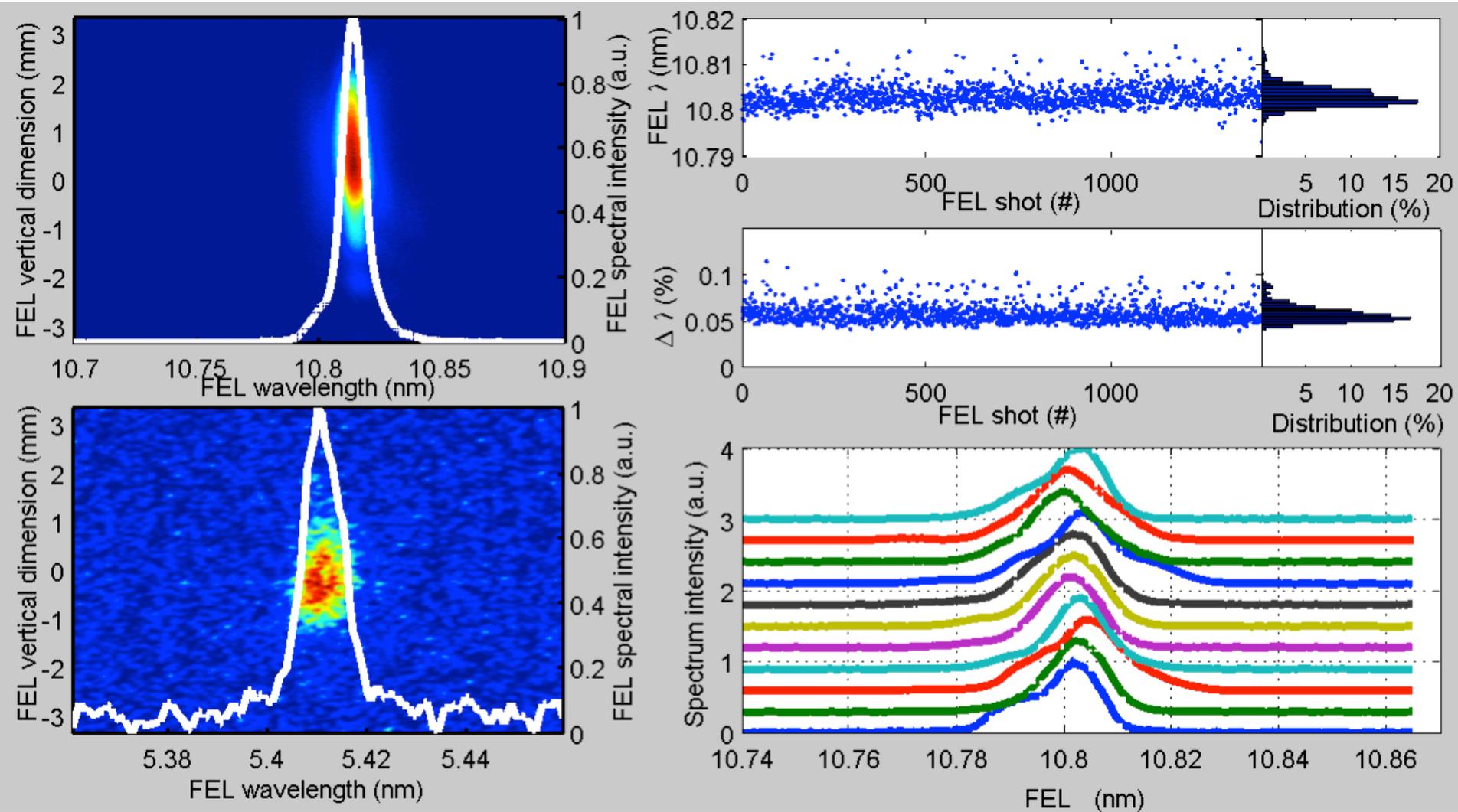
LOW DENSITY MATTER PROGRAM C. Callegari

- *Atomic, Molecular and Optical Science*
- *Spectroscopic Studies of Reaction Intermediates*
- *Clusters and Nanoparticle Spectroscopies*
- *Ultrafast Proc. & Imaging of Gas Phase Clusters and Nanoparticles*

LDM STATUS AND OPPORTUNITIES

Next time:

MAGNEDYN, TERA FERMI, TIMER



Single-shot FEL-2 spectra at 10.8 and 5.4 nm. Bottom right plot: sequence of 11 pulses at 10.8 nm. The top and center right: (also at 10.8 nm) Gaussian fits to the wavelength centroid and spectral FWHM for 1400 pulses, together with the corresponding histogram.

Biotechnology at Elettra

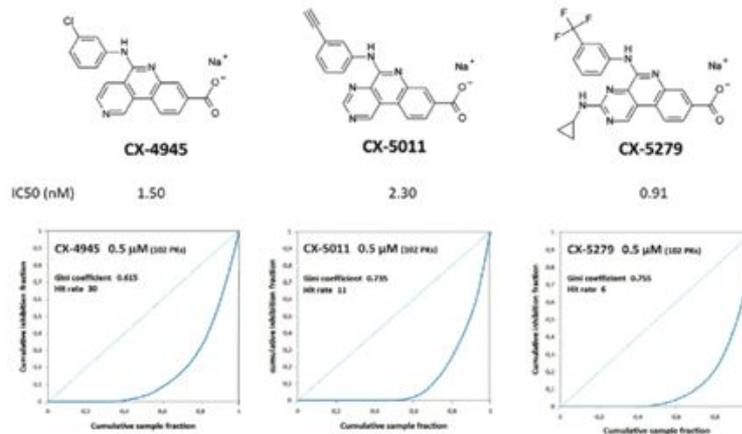
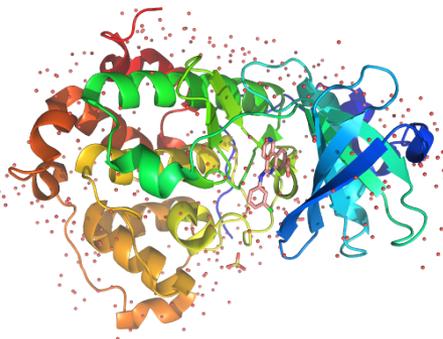
Structure-based functional macromolecules engineering

The detailed 3D structure of proteins and enzymes is determined at the X-ray diffraction beamline and correlated to their function and properties (e.g., active site attributes, charge distribution, substrate binding features) for the **rational design of novel compounds** for biotech applications

Structure Based Drug Design

Rational design of new compounds, acting as potential drugs or pesticides

XRD1 **Unprecedented Selectivity and Structural Determinants of a New Class of Protein Kinase CK2 Inhibitors in Clinical Trials for the Treatment of Cancer**



Other applications

- **Macromolecule engineering for optimized industrial processes**, to tune activity in xenobiotic conditions or for immobilization (e.g., enzyme catalyzed synthesis or remediation of polluted environment)
- **Creation of Synthetic biological organisms**, i.e., designing and constructing biological devices and novel biological systems acting as biosensors, reactors, etc.

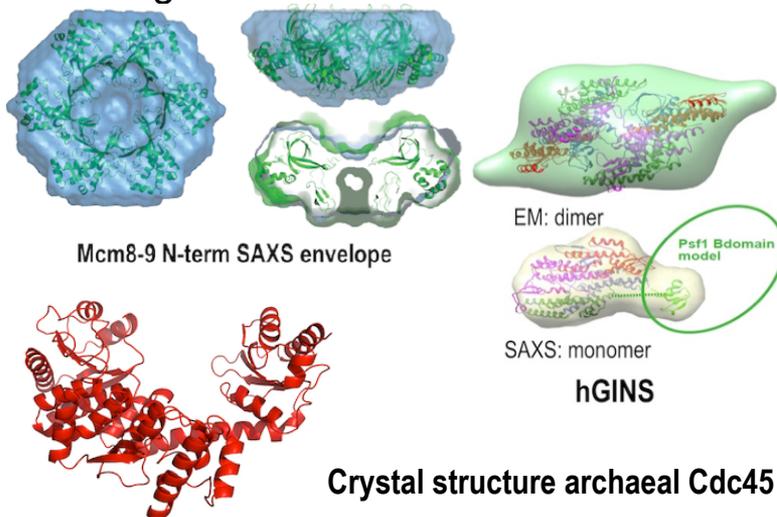
Biotechnology at Elettra

Proteins involved in DNA replication and repair

The **Structural Biology Lab** combines the use of biochemical, biophysical and various structural biology methods to understand the function and architecture of a number of key factors in **DNA replication and repair**. Due to their involvement in proliferation and genome stability they are good **tumor markers** and **potential drug target for cancer therapy**.

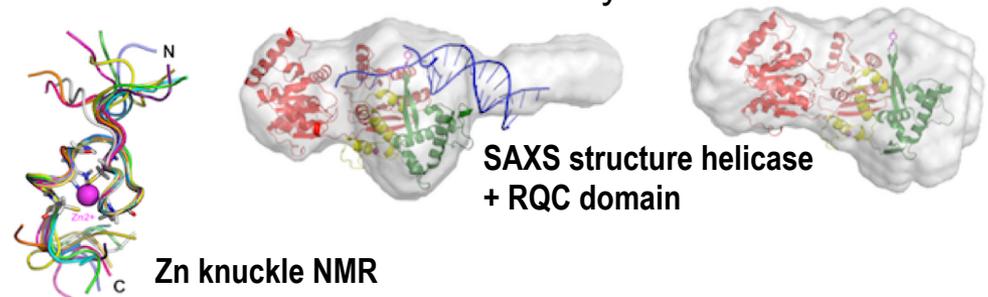
The CMG complex

The CMG complex acts as the replicative helicase and is composed of **Cdc45**, **Mcm** and **GINS**. We can express the human components as well as the archaeal homologues.



RecQ helicases

RecQ helicases act at the interface between replication, recombination and repair and many are involved in genetic diseases. We are focusing on human **RecQ4**, involved in Rothmund-Thomson syndrome.

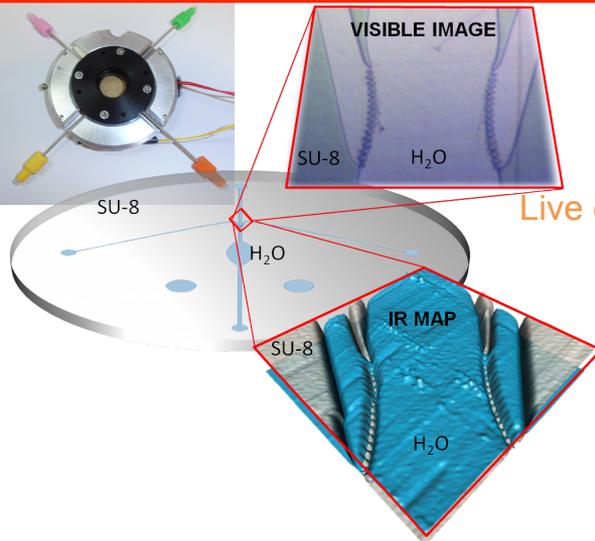


Projects funded by the Associazione Italiana per la Ricerca sul Cancro.

Biotechnology at Elettra

Live cell sorting and real-time monitoring of cell response

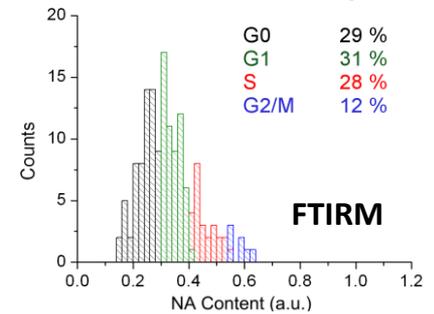
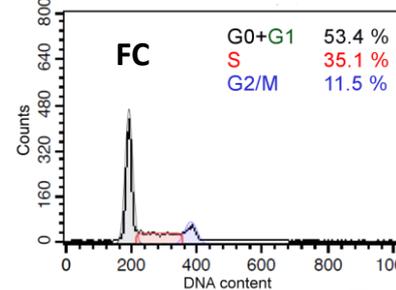
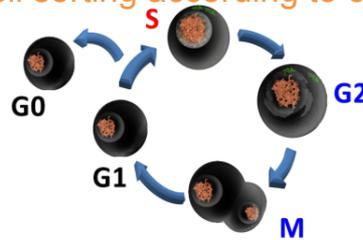
Synchrotron Radiation FTIR Microscopy available at the **SISSI beamline** provides **biochemical information on bio-samples**, with a lateral resolution of few microns in the Mid-IR



In-situ sorting of live cells according to their status

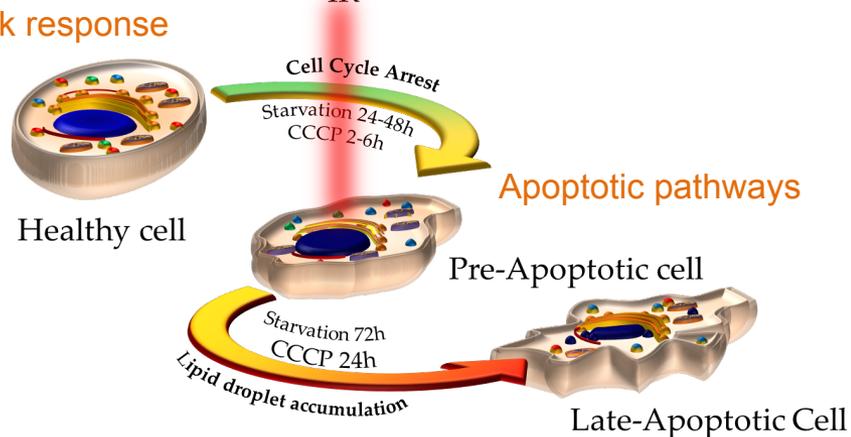
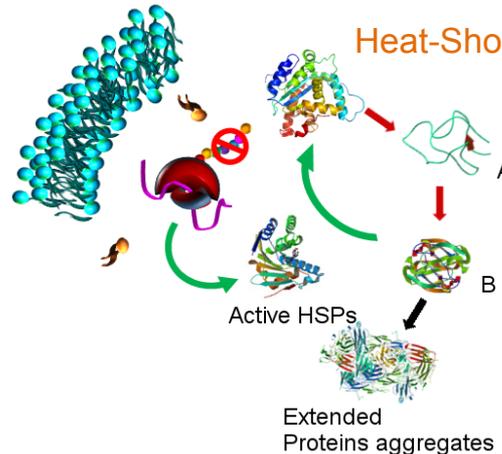
Specifically designed microfabricated Vis-IR transparent devices for real time monitoring of live cells

Live cell sorting according to cell-cycle stage with accuracy comparable to Flow Cytometry



Live cell dynamics

FTIR Microscopy as a label free analytical methodology for real-time monitoring of the response of individual live cell to stressors

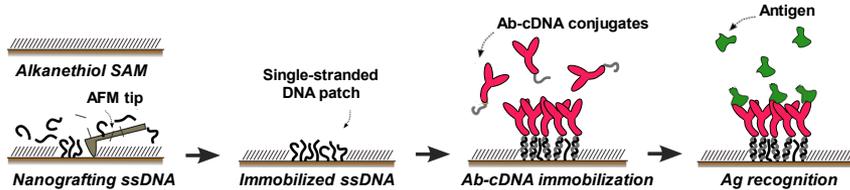


Biotechnology at Elettra

Micro and nano-devices for medical diagnostics

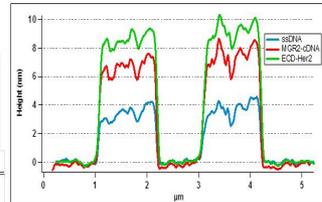
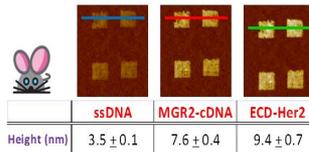
The **NanoInnovation Lab** exploits advanced surface functionalization and optical/electrical read-out techniques to develop devices for the **sensitive, label-free and real-time detection of circulating disease biomarkers** and for the kinetics of enzymatic reactions

Nanodevices for Her2 detection in serum

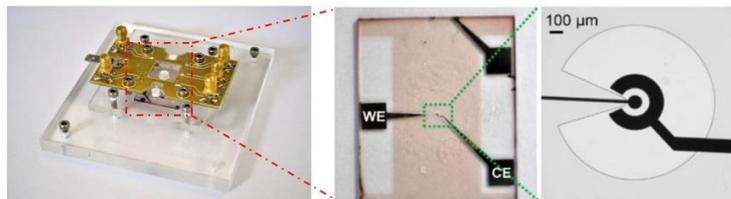


Atomic Force Microscopy-based protein nanoarrays for **ECD-Her2** tumor target detection in small biosample volumes

Antibody: MGR2-cDNA conjugate

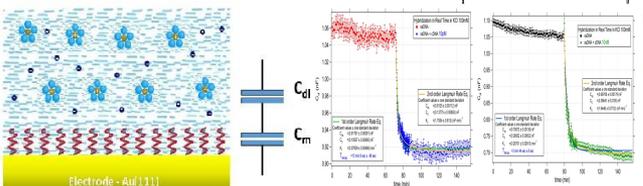


Electrochemical microdevices for fast miRNA and biomarkers detection in serum and cell extract

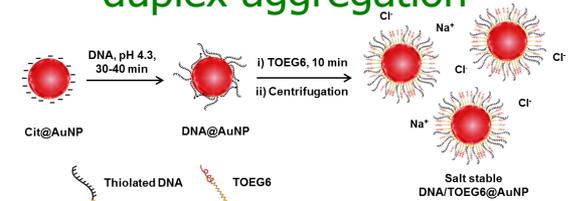


Based on the detection of double-layer capacitance change at the gold electrode upon biorecognition, are:

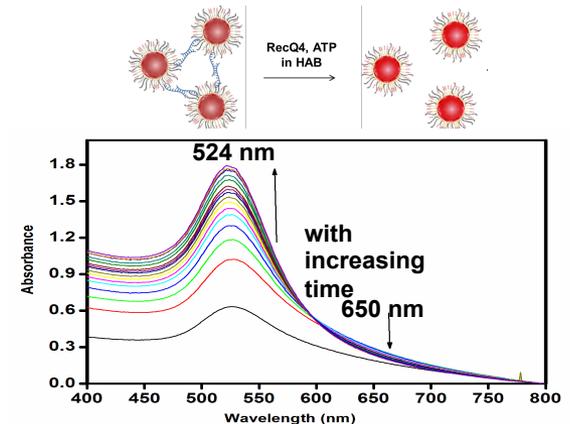
- cheap, label-free
- real-time
- highly sensitive (low detection limit 1 pM)
- broad dynamic range

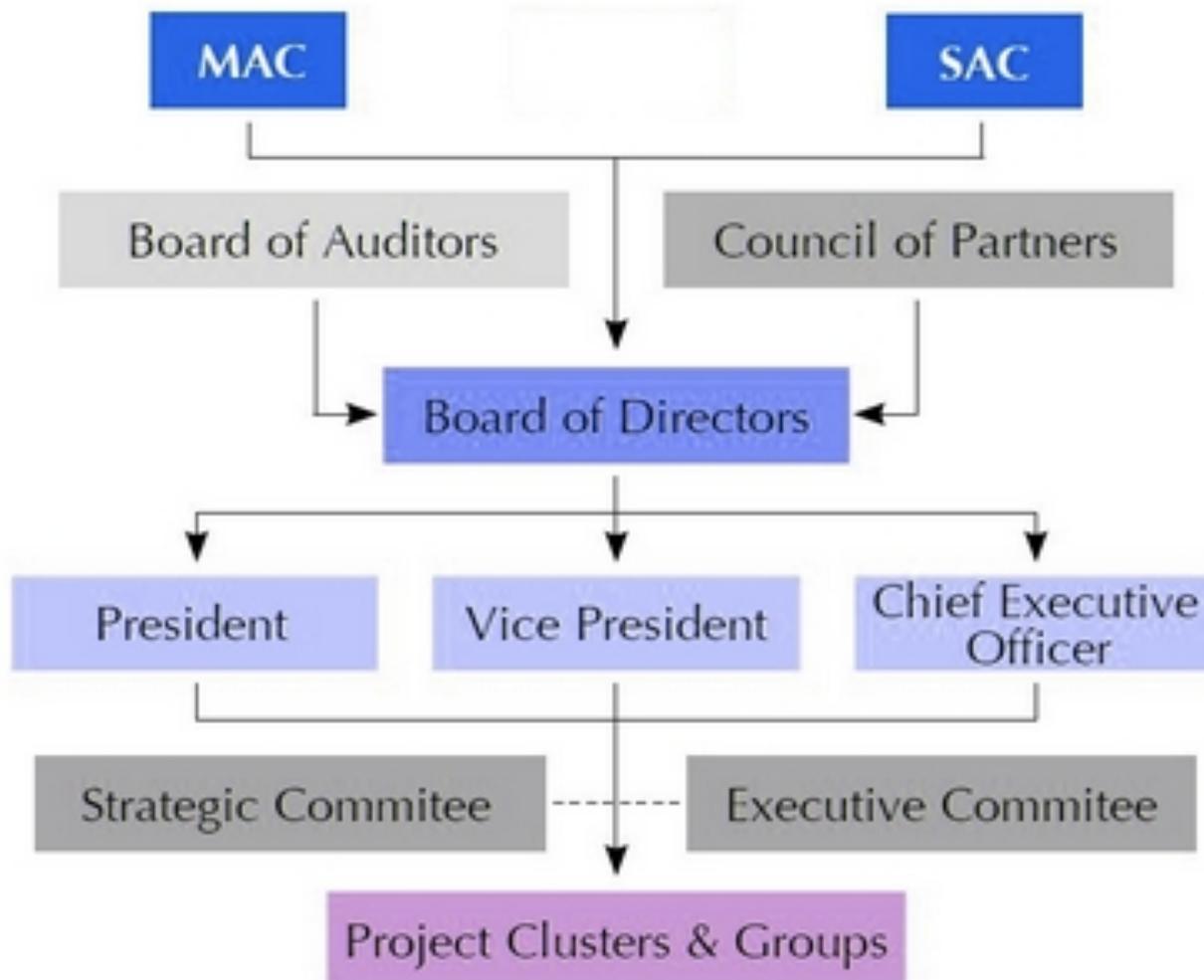


Synthesis of novel DNA-coated Au nanoparticles for monitoring enzymatic reactions through duplex-aggregation

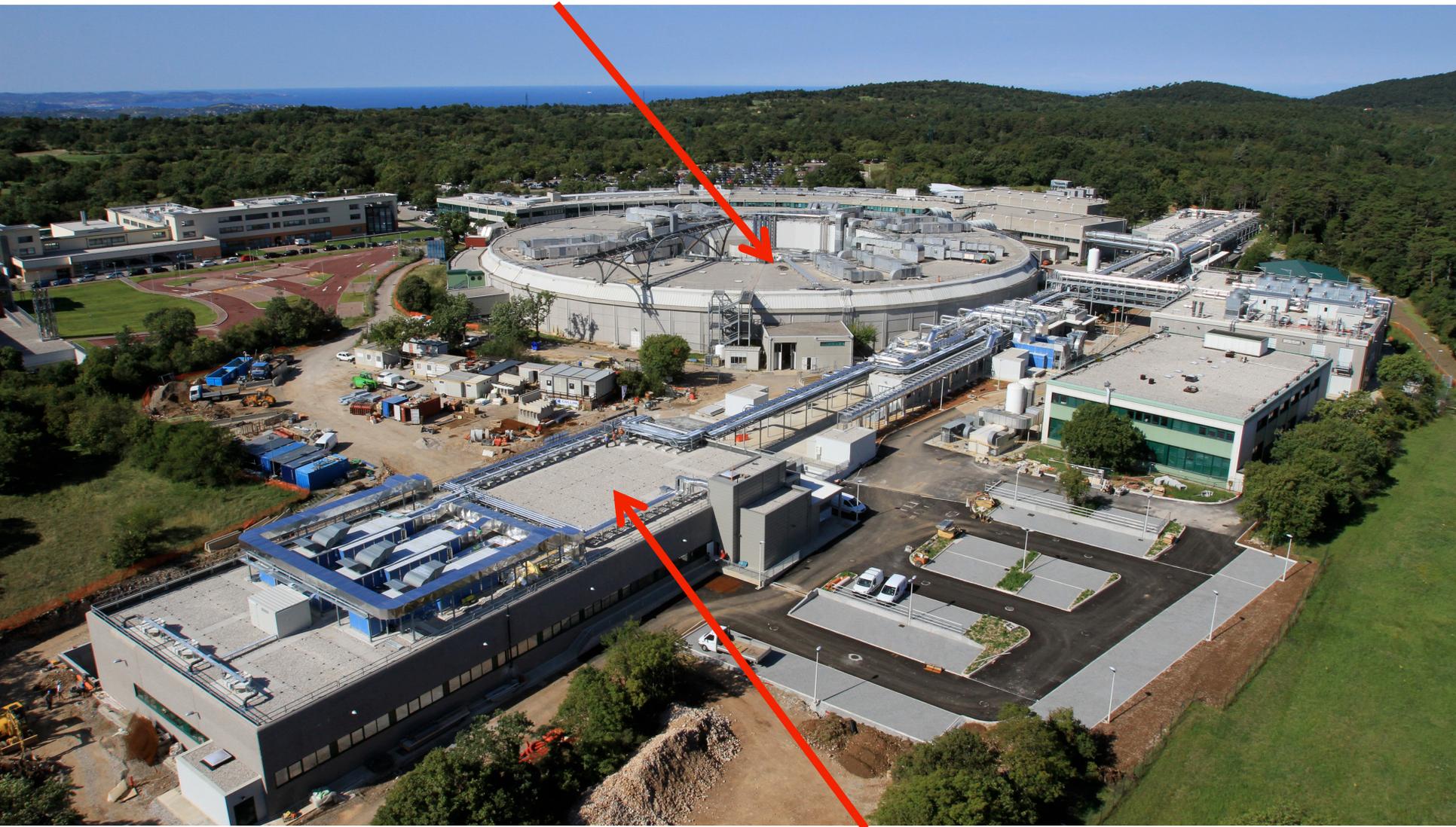


Label-free assay based on UV-Vis adsorption. Comparable with fluorescence monitoring in terms of resolution, but cheaper and faster





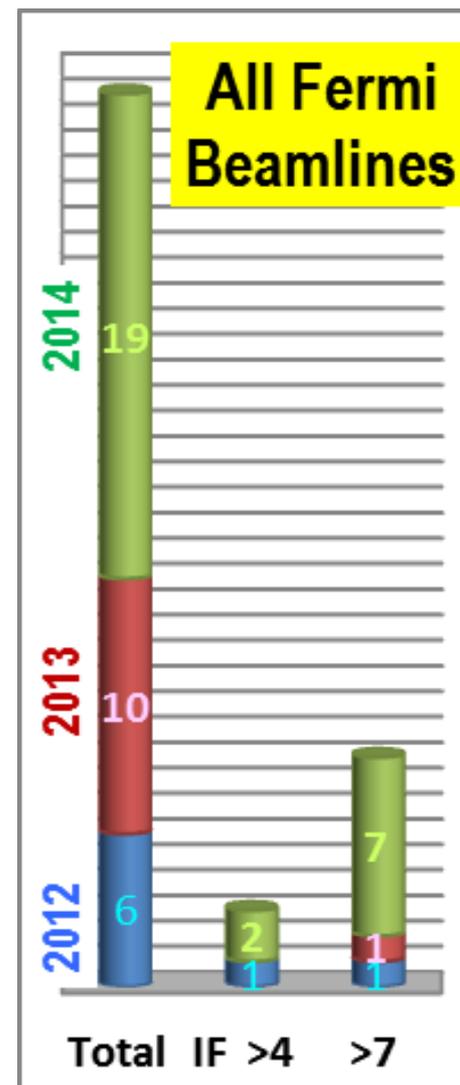
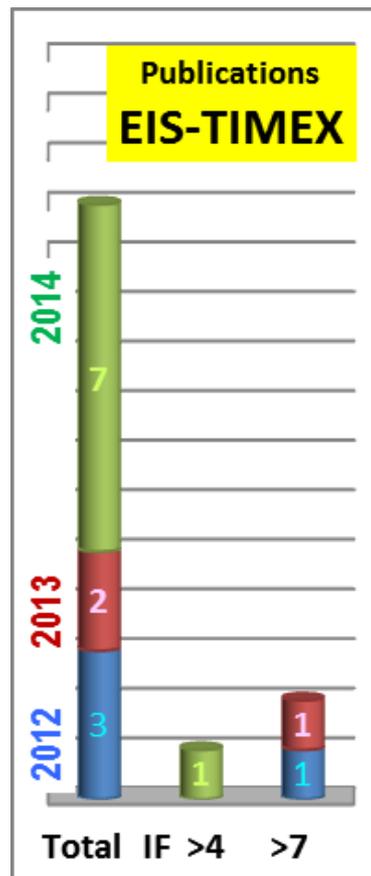
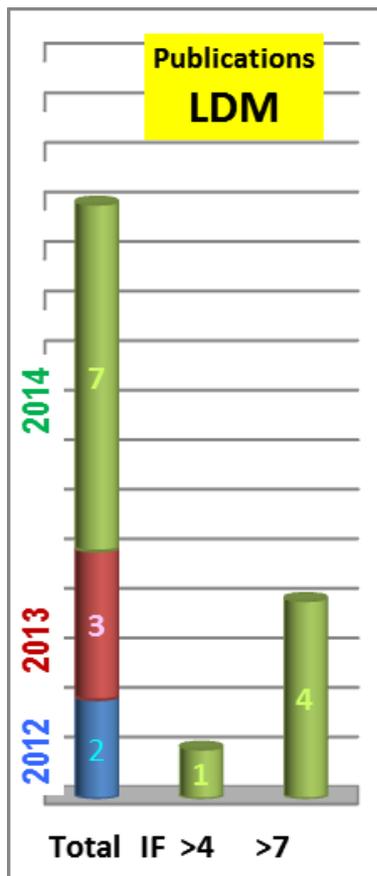
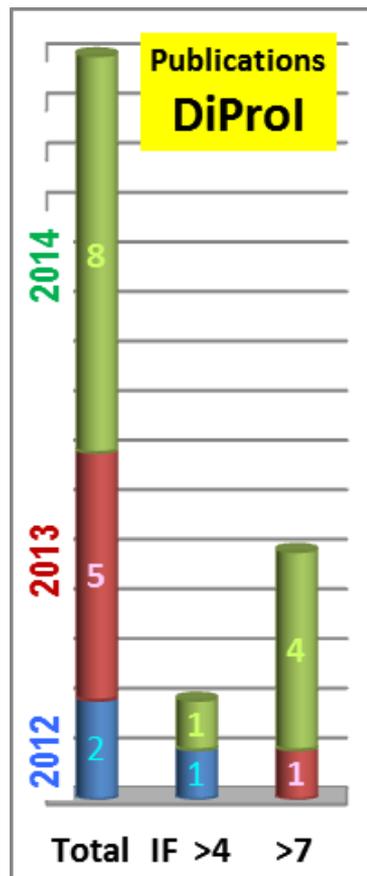
Elettra 2.0-2.4 GeV 3rd generation Synchrotron Radiation Facility



FERMI 1.5 GeV seeded Free Electron Laser Facility



Publications

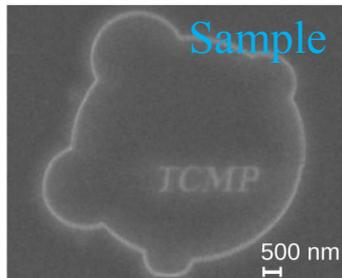
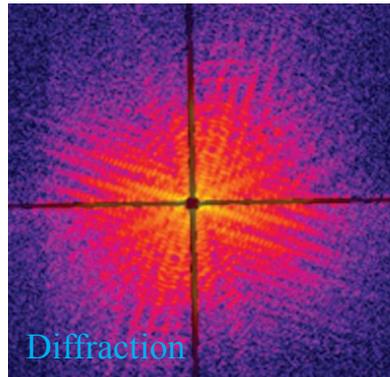
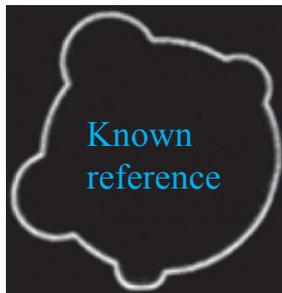


X-ray **holography** with **customizable reference**

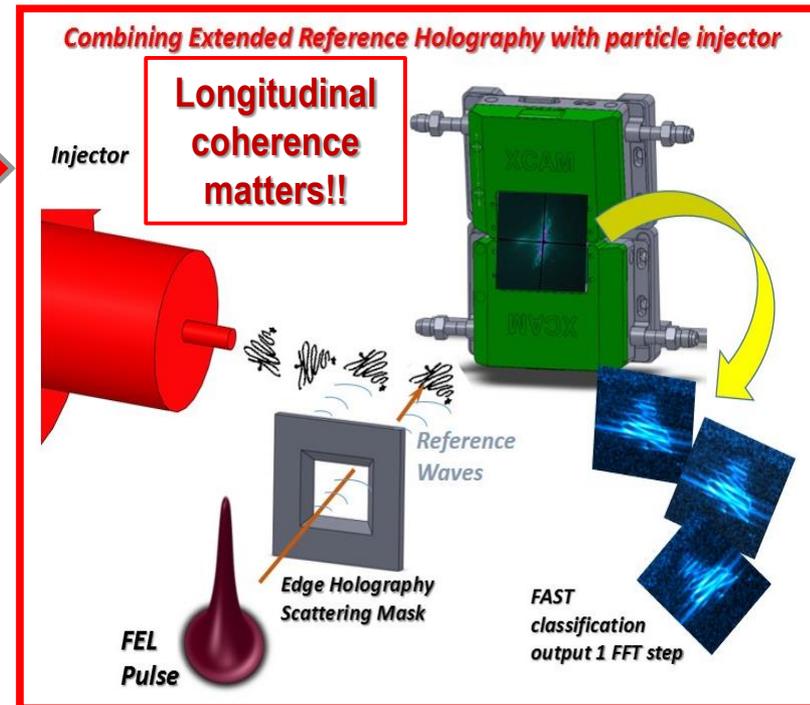
Ideal FTH → overcoming restriction due to the reference wave → single-shot imaging

Conjugate-gradient algorithm to recover the image

FTH with an almost **unrestricted choice for the reference**



Hologram refined with RAAR phase retrieval



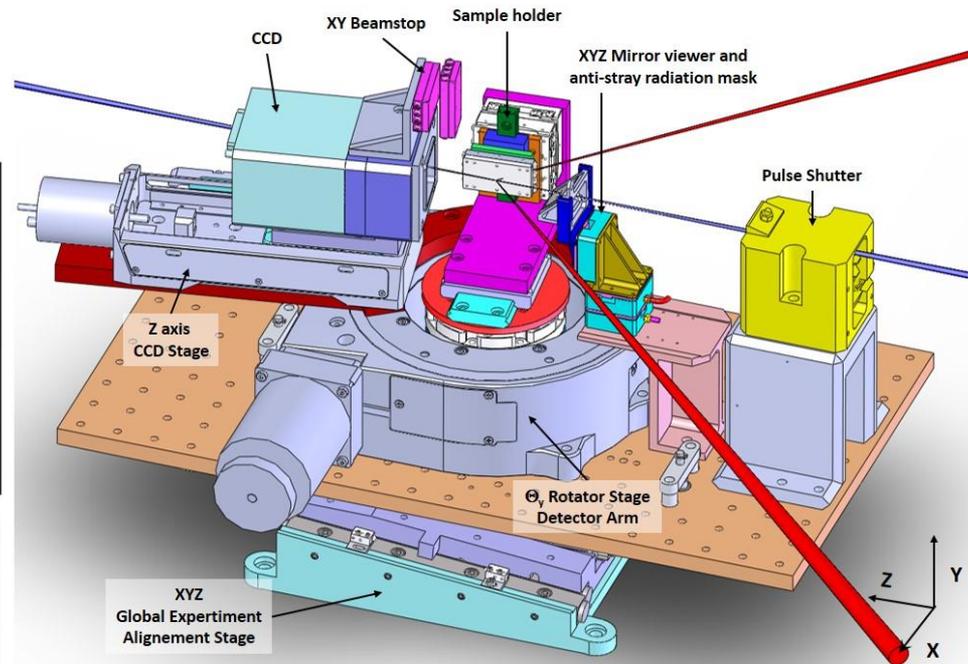
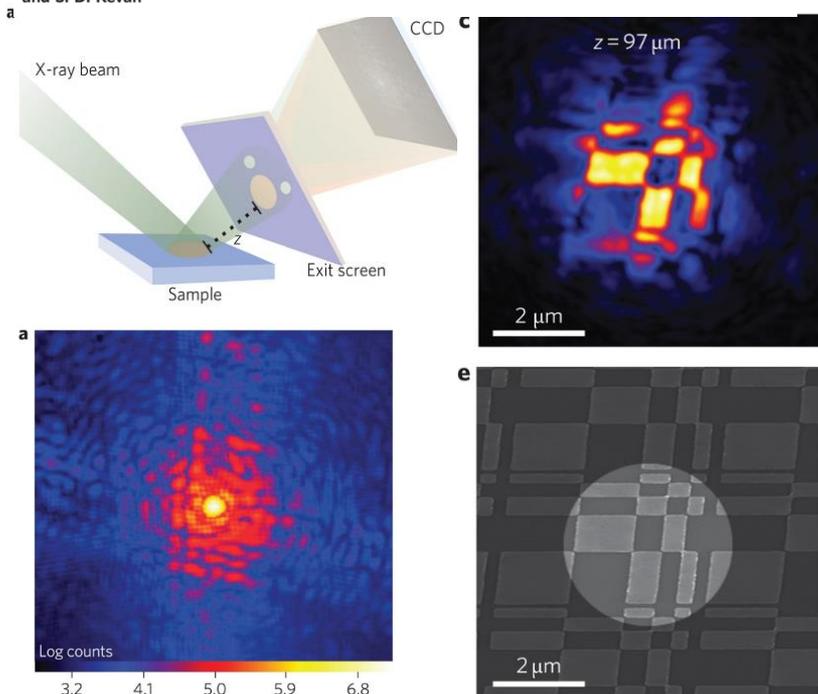
Lenseless imaging in reflection geometry

Soft X-ray reflection configuration is the choice for **thick samples** and when the sample properties of the **top layers** are of interest



Lenseless X-ray imaging in reflection geometry

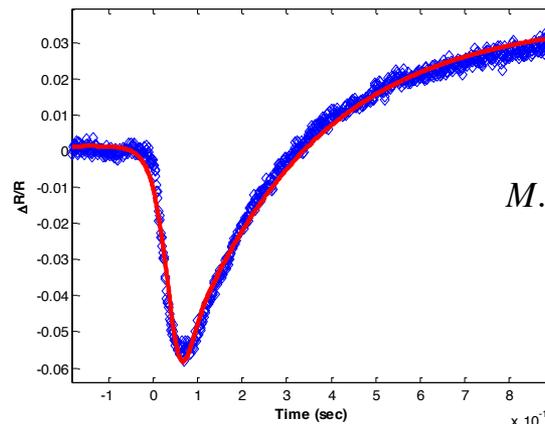
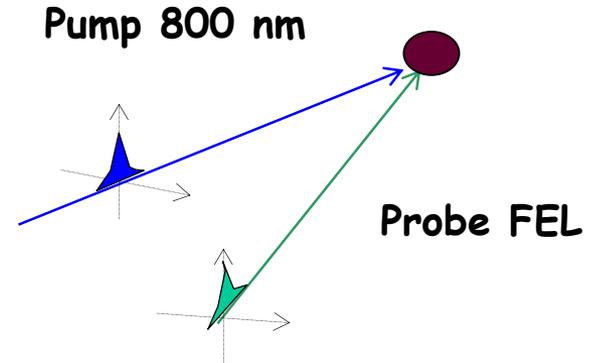
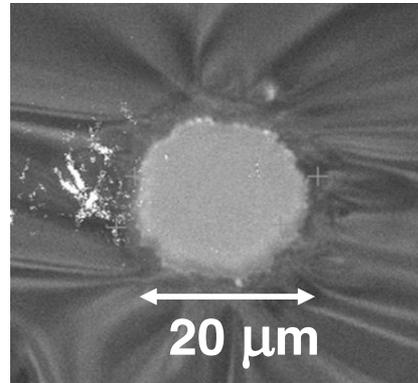
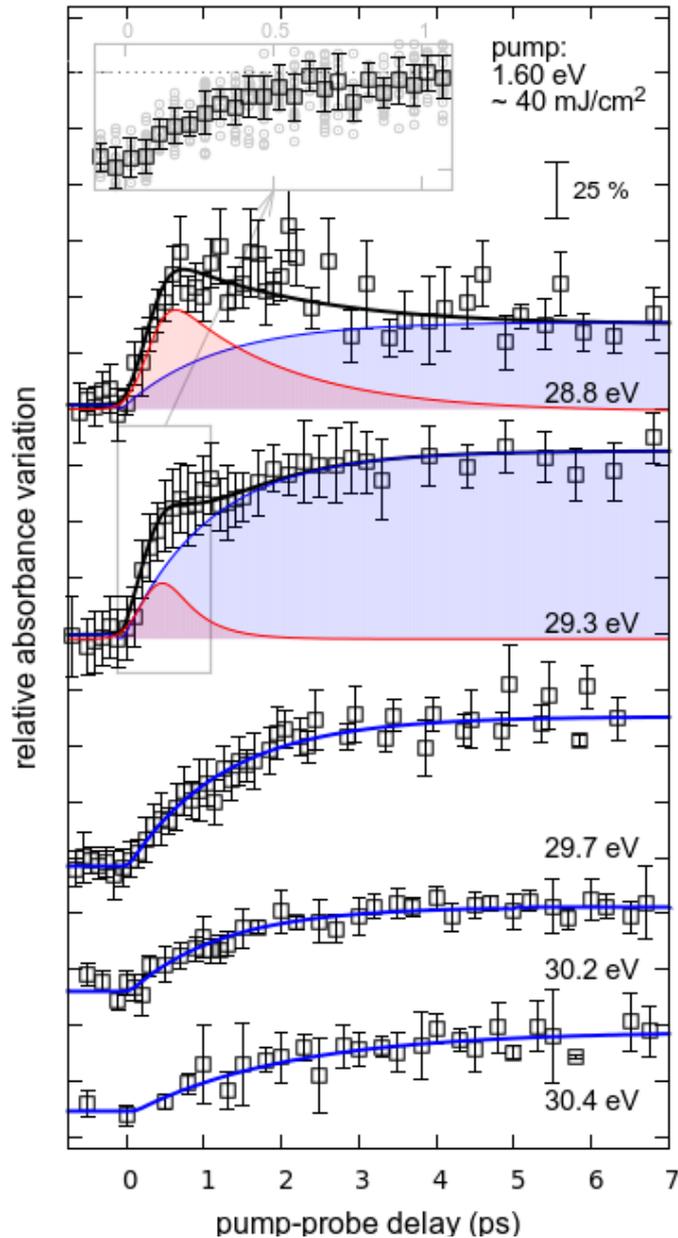
S. Roy^{1*}, D. Parks^{1,2}, K. A. Seu^{1,2}, R. Su^{1,2}, J. J. Turner³, W. Chao⁴, E. H. Anderson⁴, S. Cabrini⁵ and S. D. Kevan²



Under implementation
(collaboration with C. Gutt)

Variation of off-specular (x, y) scattering density reflects inhomogeneity of various origin (chemical, magnetic, structural), and allows exploiting ultrafast spatial evolution following the relevant correlation lengths.

Pump & Probe on Germanium

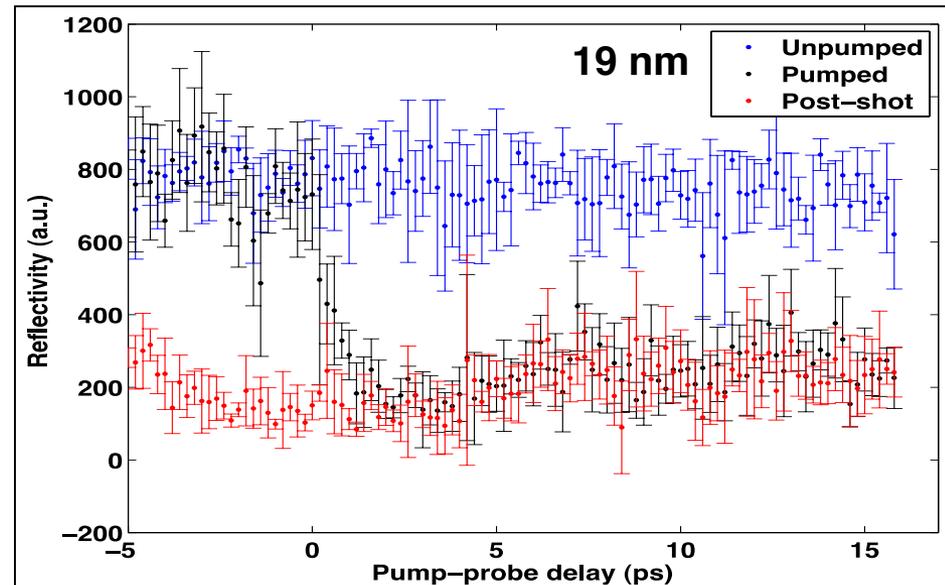
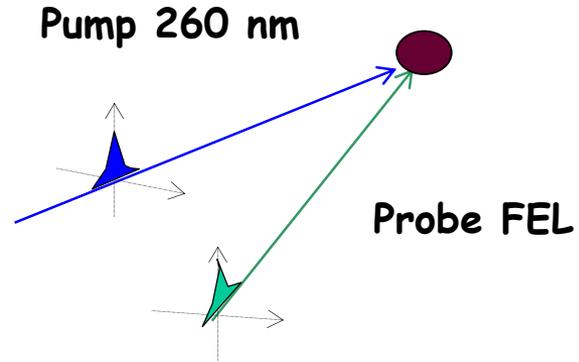
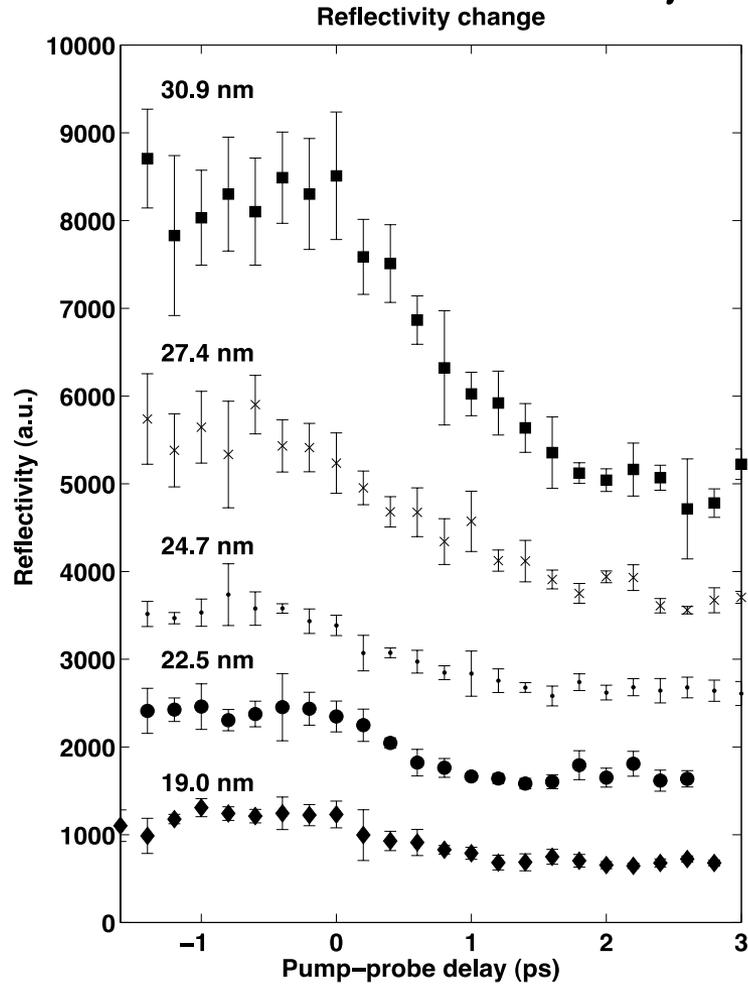


M. Danailov et al. Opt. Express (2014)

Upon the absorption edge (Fermi level) the spectroscopy is sensitive both to the **Fermi function smearing** (red curve) and to the shift of the edge due to the **metalization** of the sample (blue curve)

E. Giangrisostomi et al., submitted

Pump & Probe on Carbon



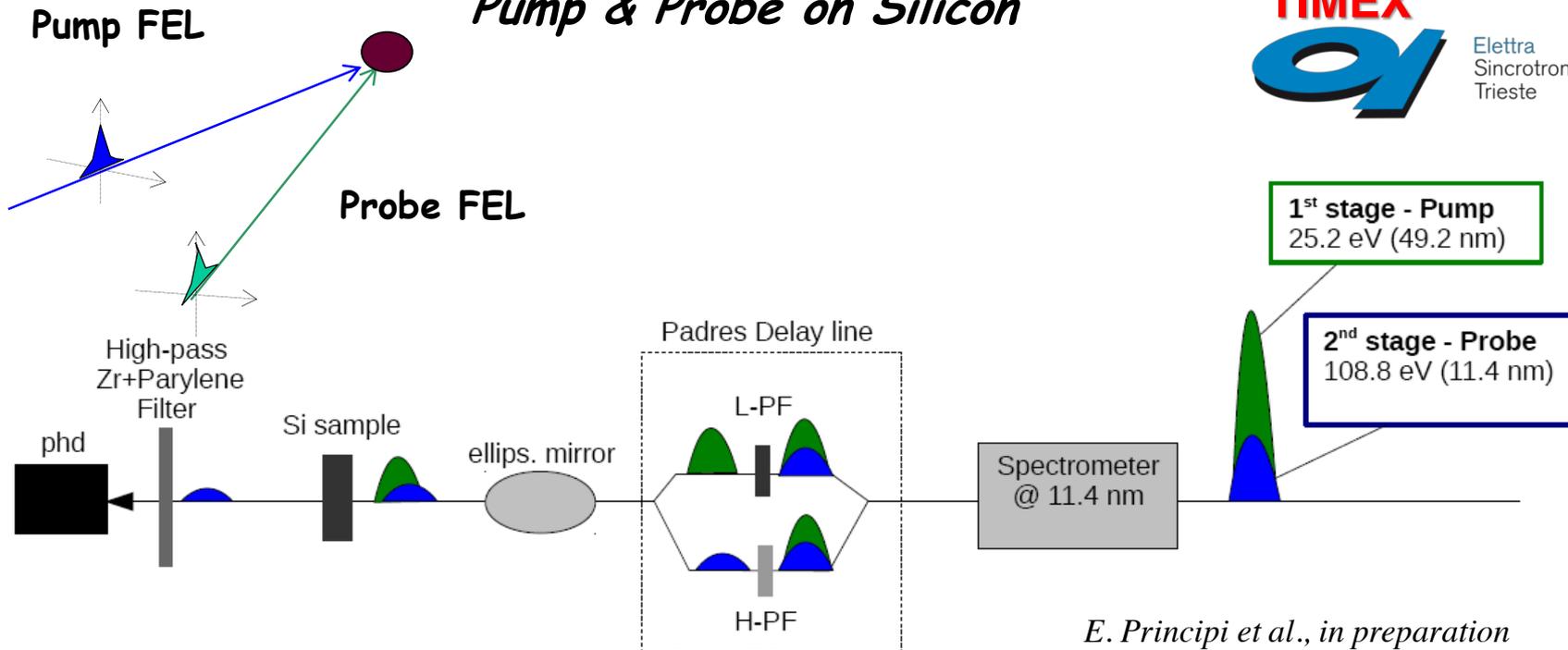
- Measurements **above plasma** frequency
- **Decrease** of reflectivity
- Relaxation time 1/10 of Infrared

N. Bloembergen, Nature (1992)

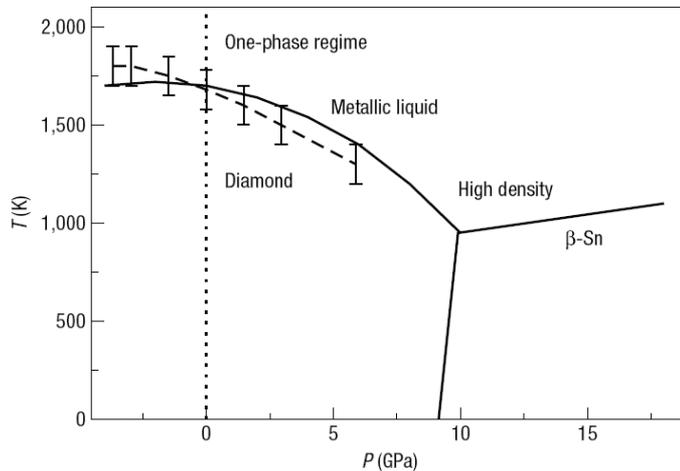
R. Mincigrucci et al., Photonics (2015)

R Mincigrucci et al., in preparation

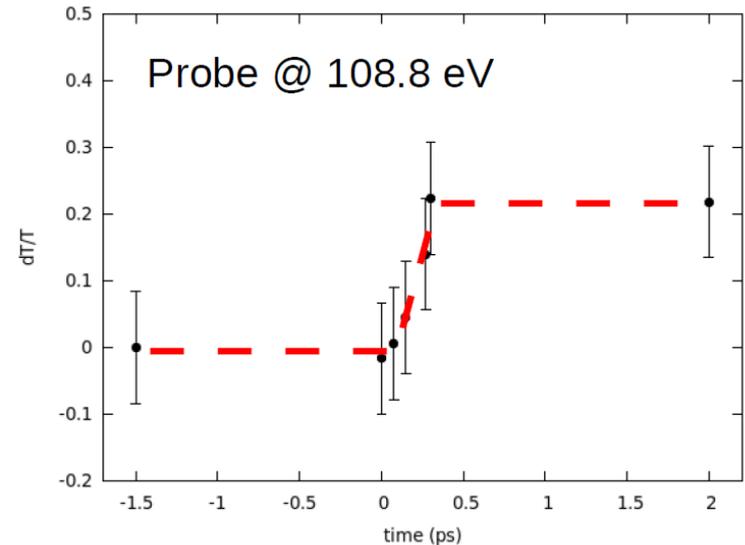
Pump & Probe on Silicon



E. Principi et al., in preparation



P. F. McMillan et al., Nature (2005)



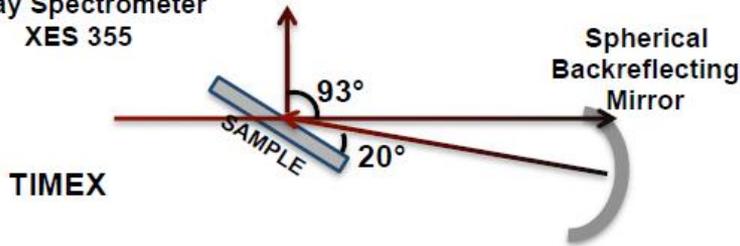
Co Medge RIXS at TIMEX

W. Wurth (UNI HH/CFEL) and S. Bajit (CFEL/DESY)
TIMEX, MagneDyn and T-ReX teams

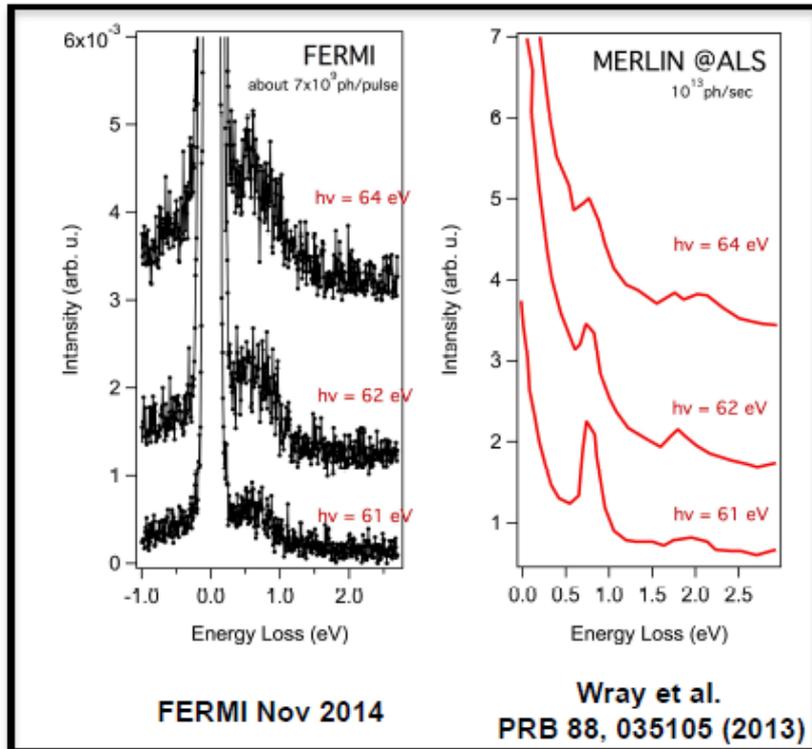


Elettra
Sincrotrone
Trieste

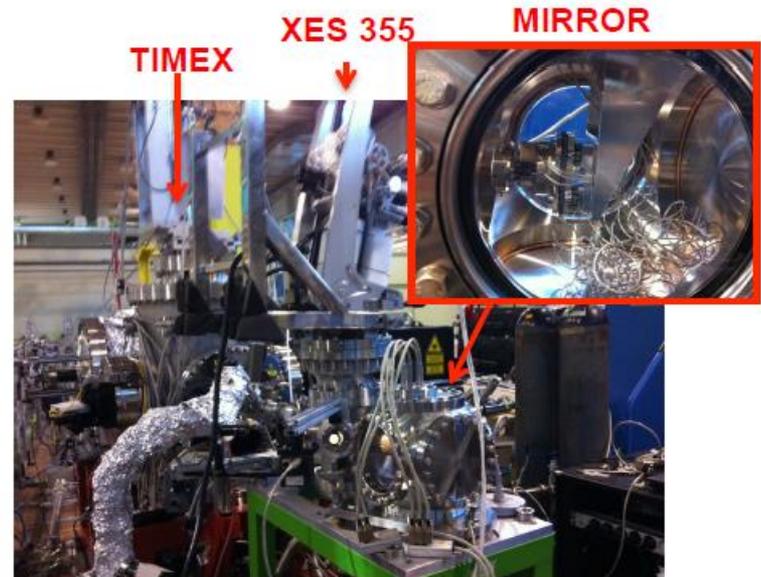
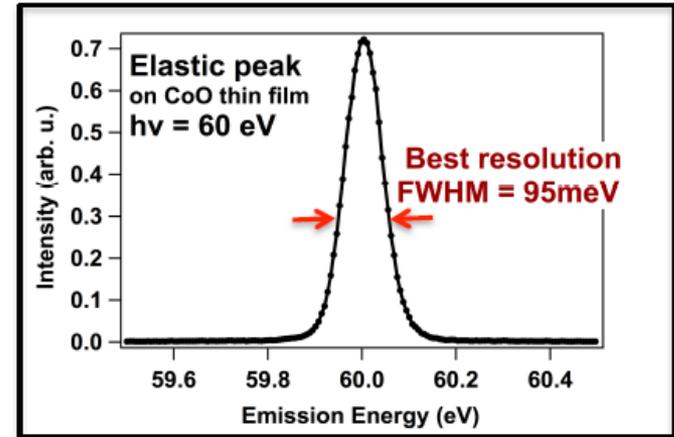
X-ray Spectrometer
XES 355



dd- excitations in CoO
(sample from Z. Q. Qiu (UC Berkeley))



Resolution

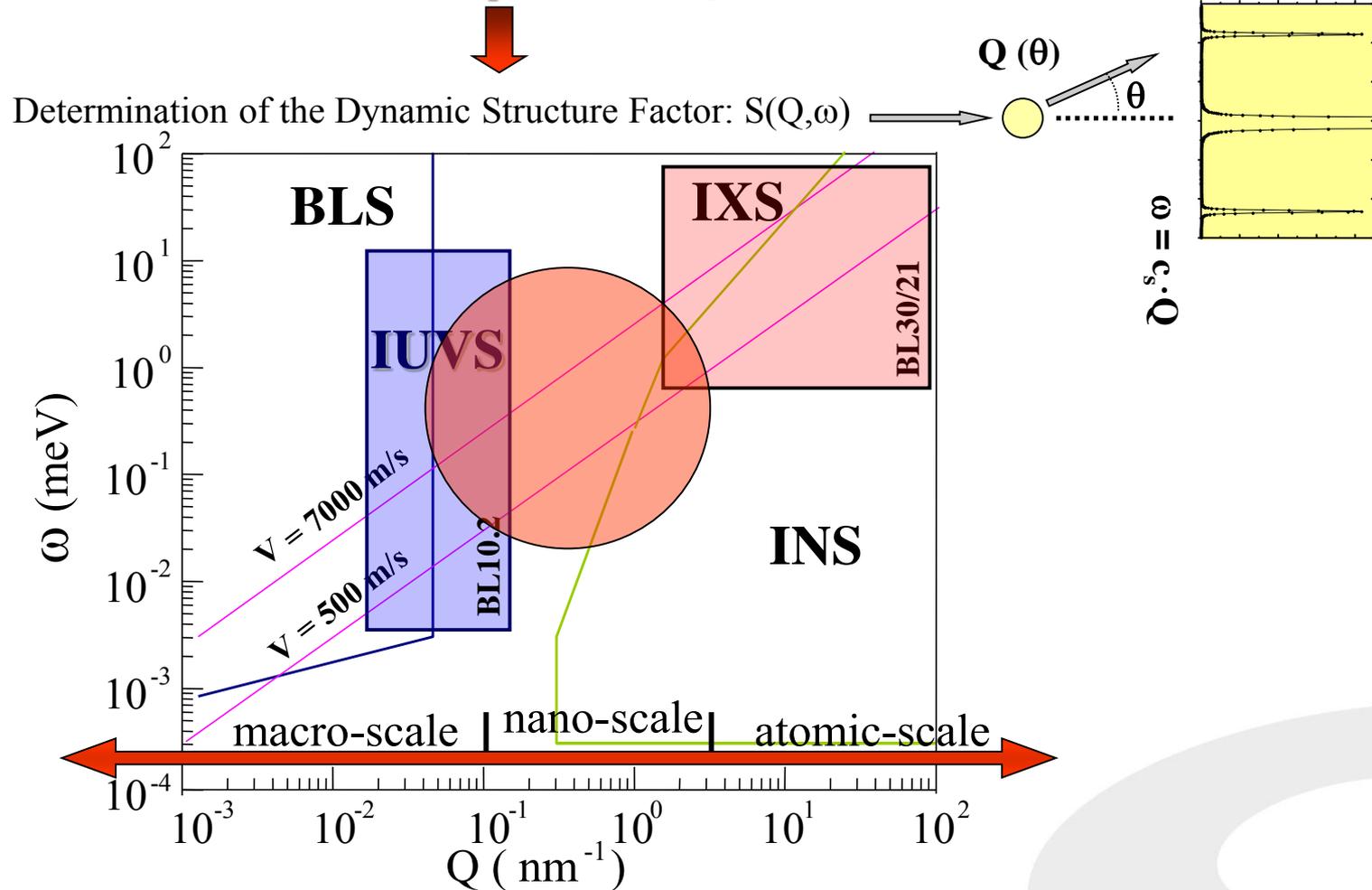


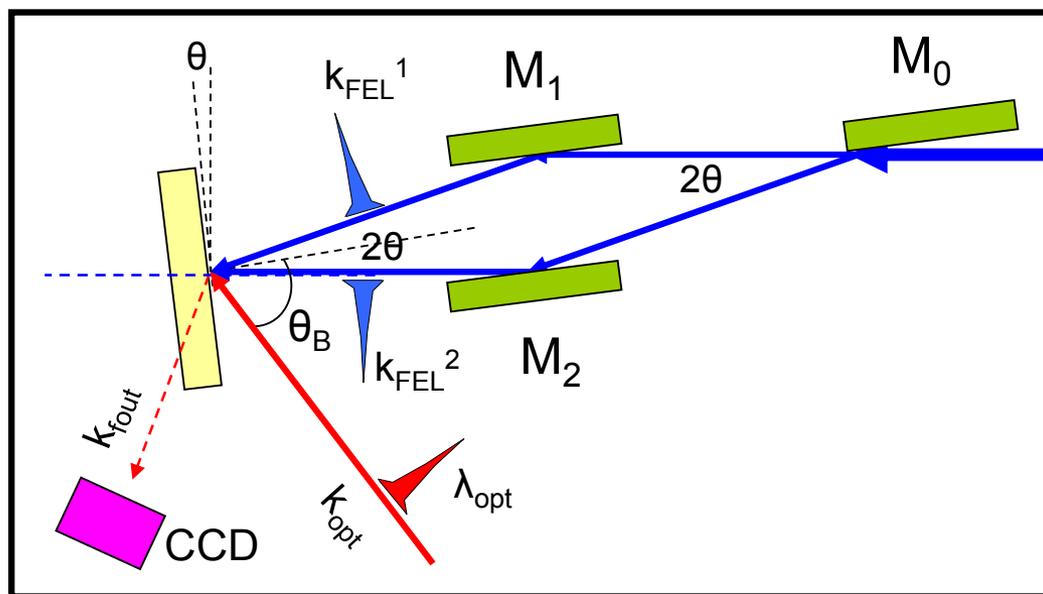
EIS - TIMER

TIMER

TIME-Resolved spectroscopy of mesoscopic dynamics in condensed matter

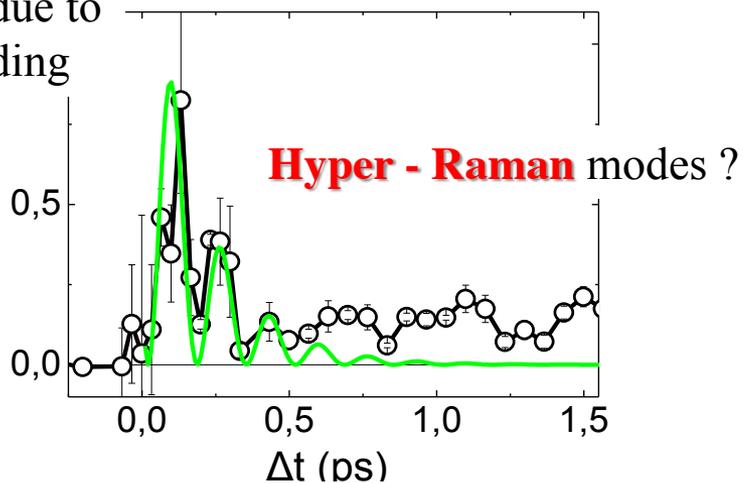
Challenge: Study Collective Excitations in **Disordered Systems**
in the **Unexplored** ω - Q region





$\lambda_{FEL} = 27.6 \text{ nm}$

Raman modes due to tetrahedral bending



Acoustic-like excitations

