The Elettra Laboratory of Sincrotrone Trieste

A. Franciosi

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

Third Generation Synchrotron Radiation Facilities:

ESRF	6 GeV	France	
ALS	1.6 GeV	USA	
APS	7 GeV	USA	
BESSI II	1.7 GeV	Germany	
Elettra	2.4 GeV	Italy	*<- one of the oldest*
Spring-8	8 GeV	Japan	
MAX II	1.5 GeV	Sweden	
SLS	2.4 GeV	Switzerland	
PLS	2 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	

Adapted from H. Winnick, SSRL, Stanford

Maintaining our competitive edge:

- Full energy injection and top-up operation
- New ultrabright, ultrafast source development
- Major infrastructure upgrades needed

Enter the FERMI @ Elettra Project and the EIB:

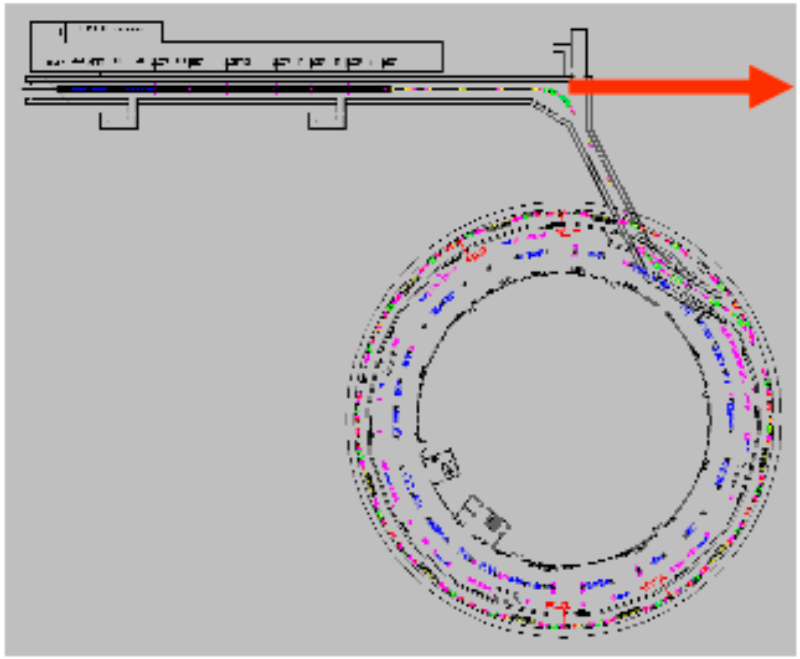
6-year project for the construction of:

- Full-energy injector for Elettra
- Fourth generation free-electron laser source
- New trigeneration UPS power plants
- Site infrastructure improvements

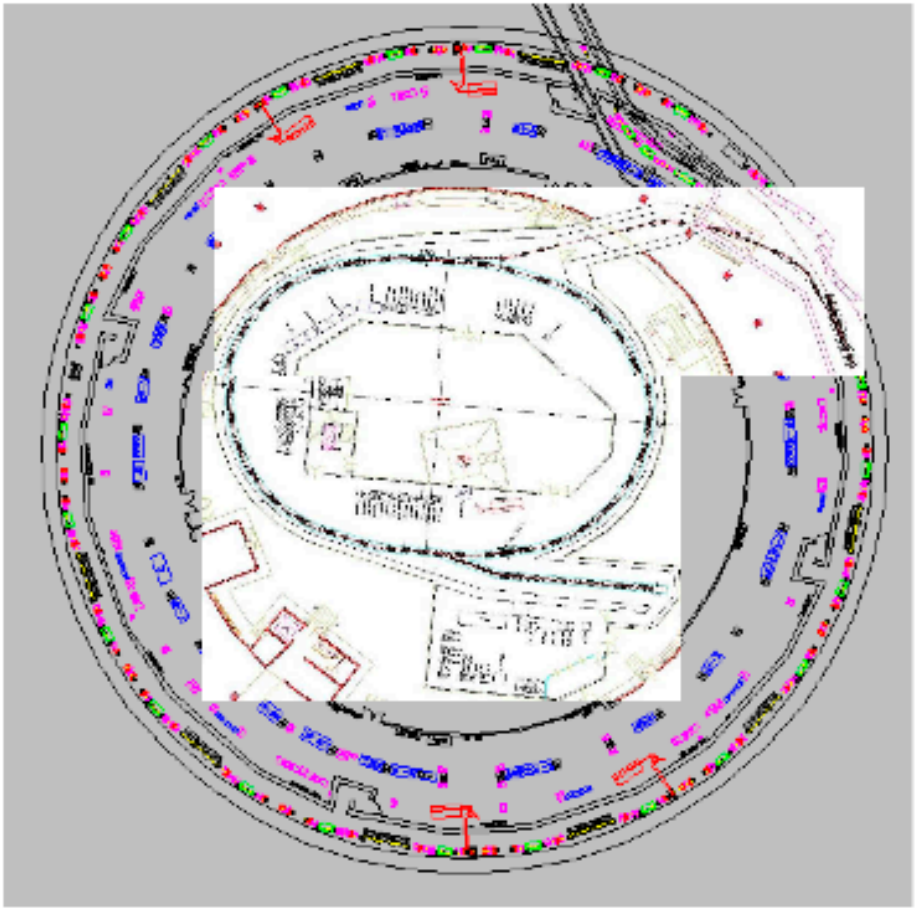
Booster full-energy injector:

Past and Present Configurations

till 2007



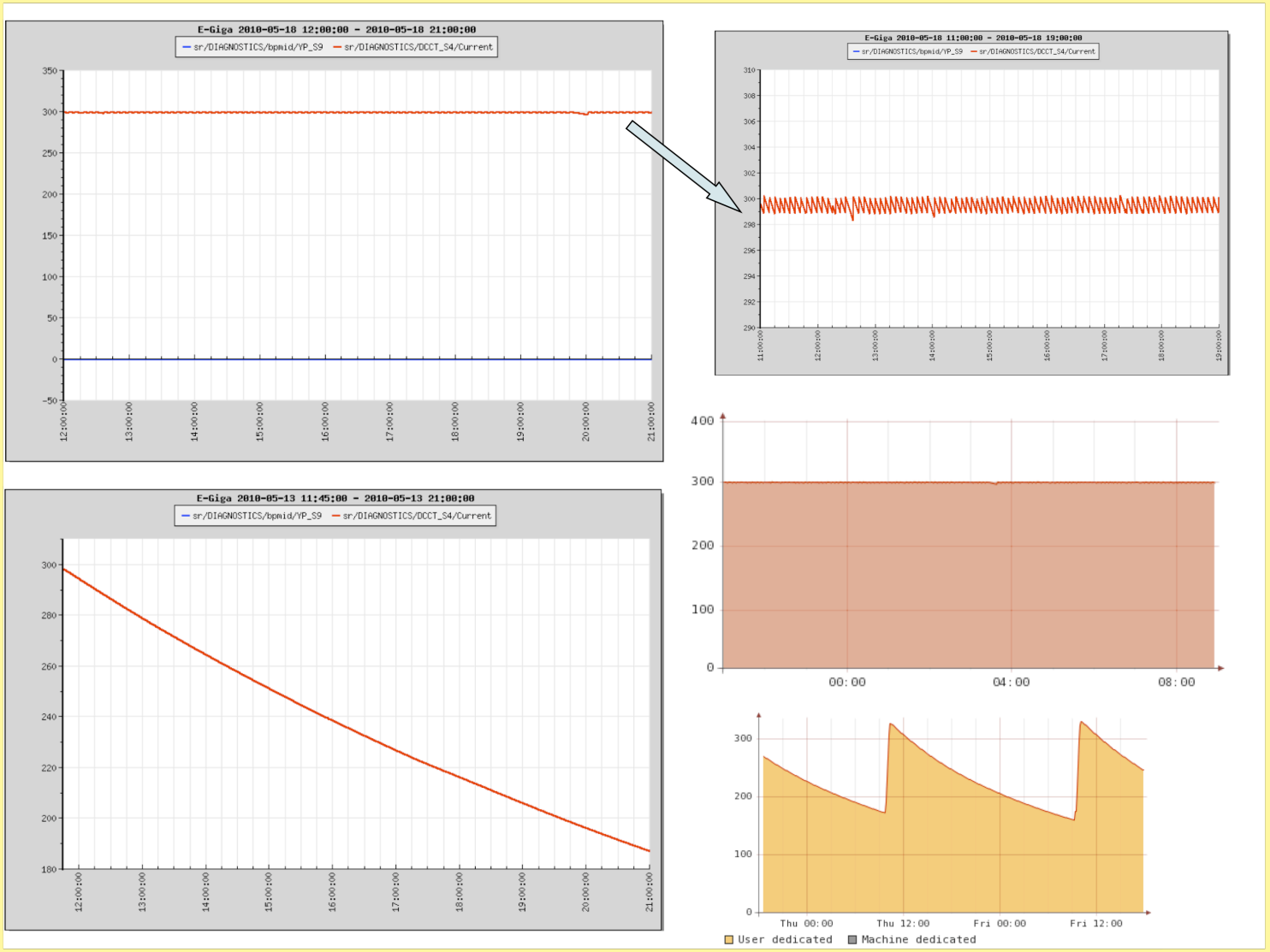
From 2008



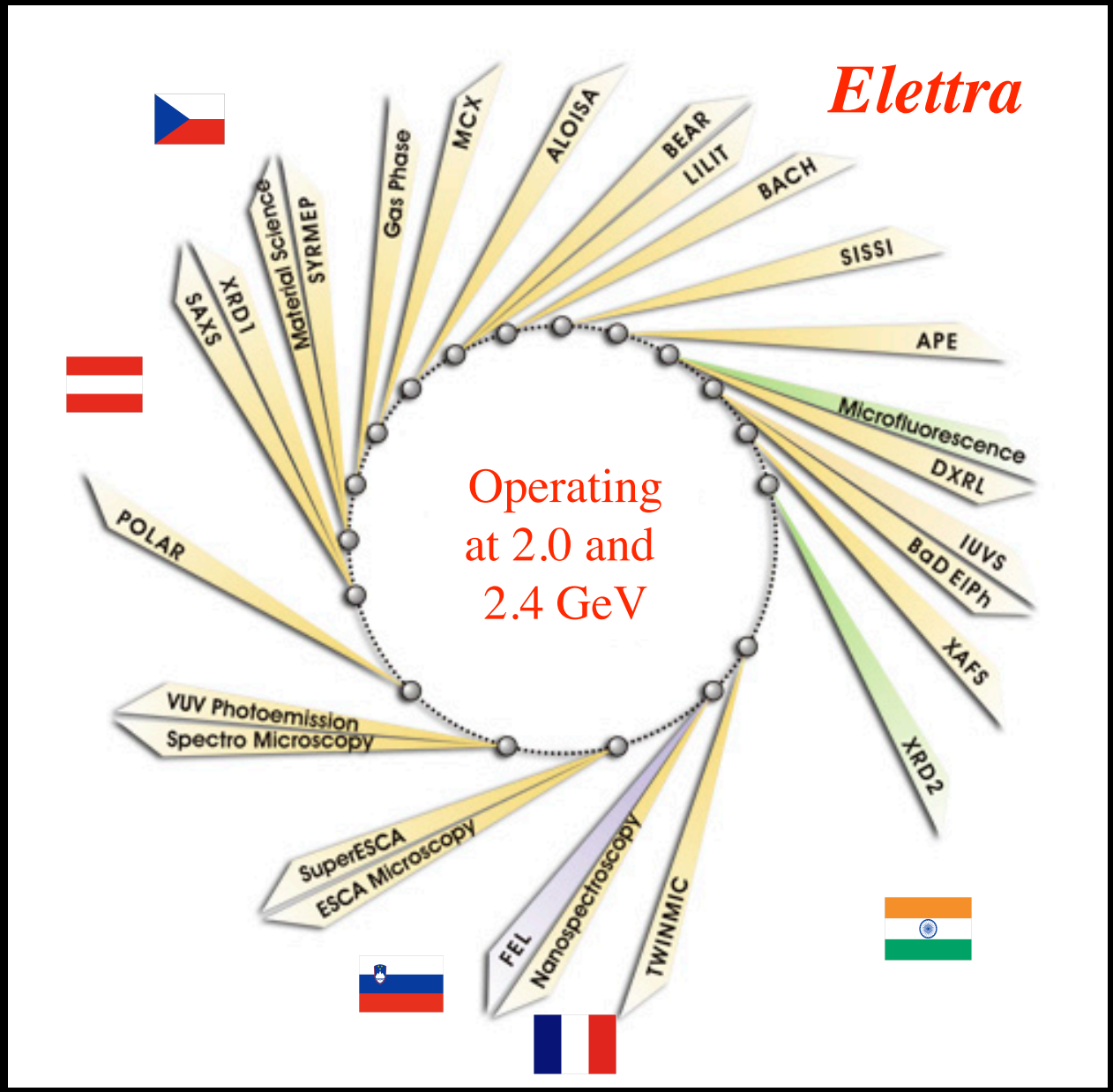
Project Leader: M. Svandrlik

Booster arc west

Top-up sanctioned by the ST Board on May 21, 2010



Project Leader: E. Karantzoulis



26 beamlines

in operation

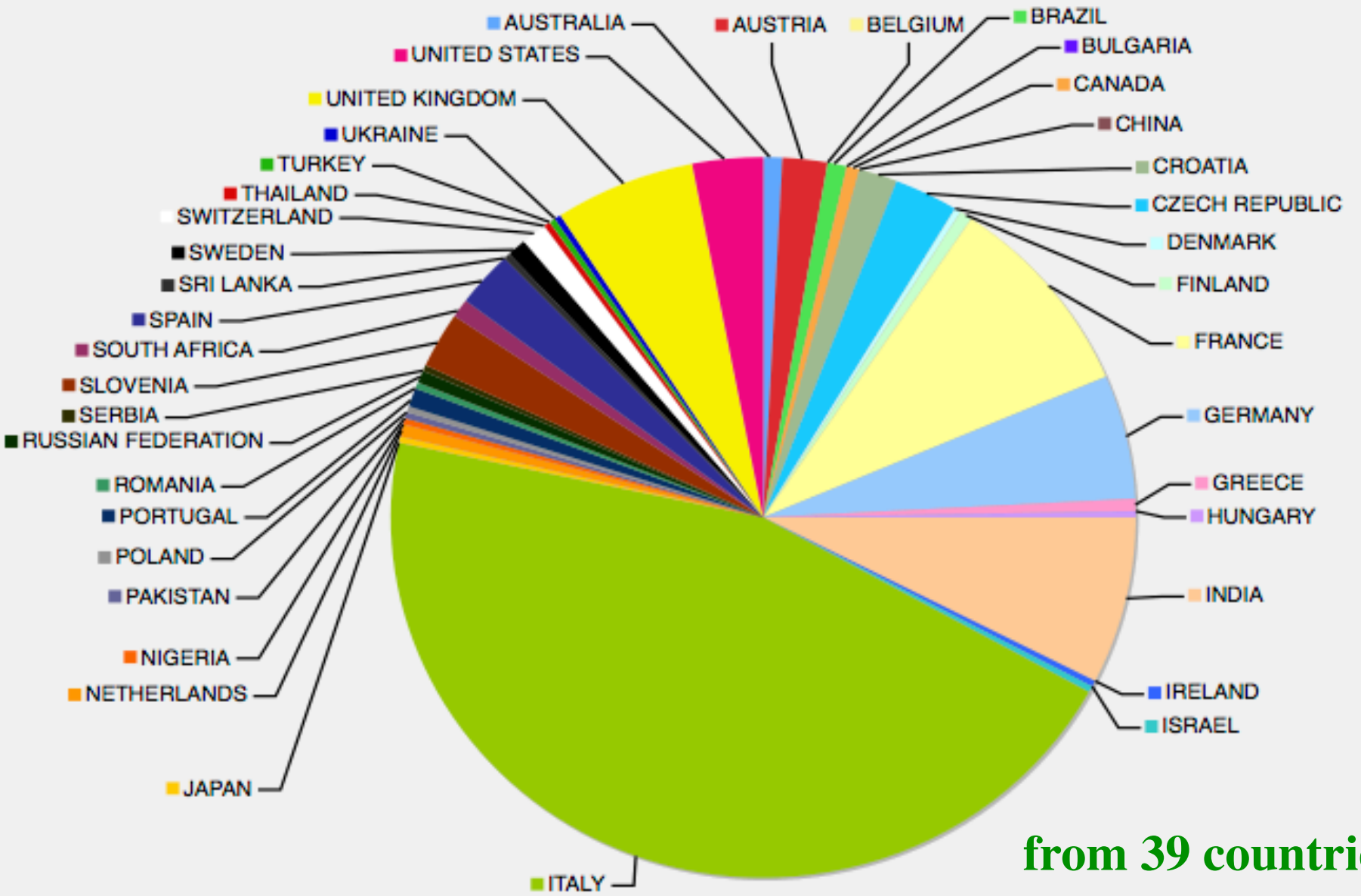
major upgrades:

XRD1
SuperESCA
FEL

under construction:

Microflurescence
XRD2

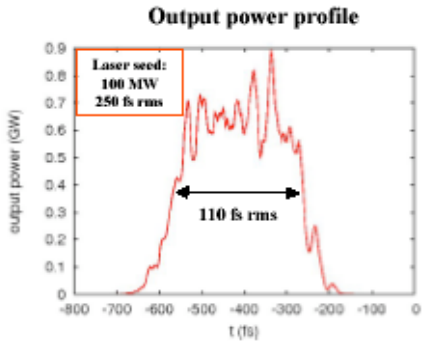
795 proposals total received in the two calls of 2009

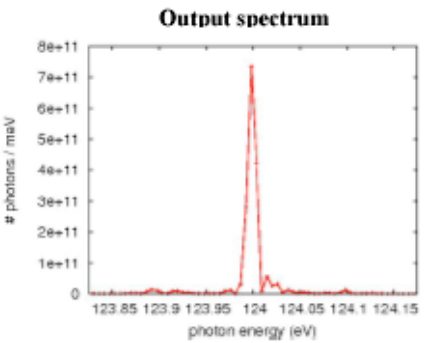


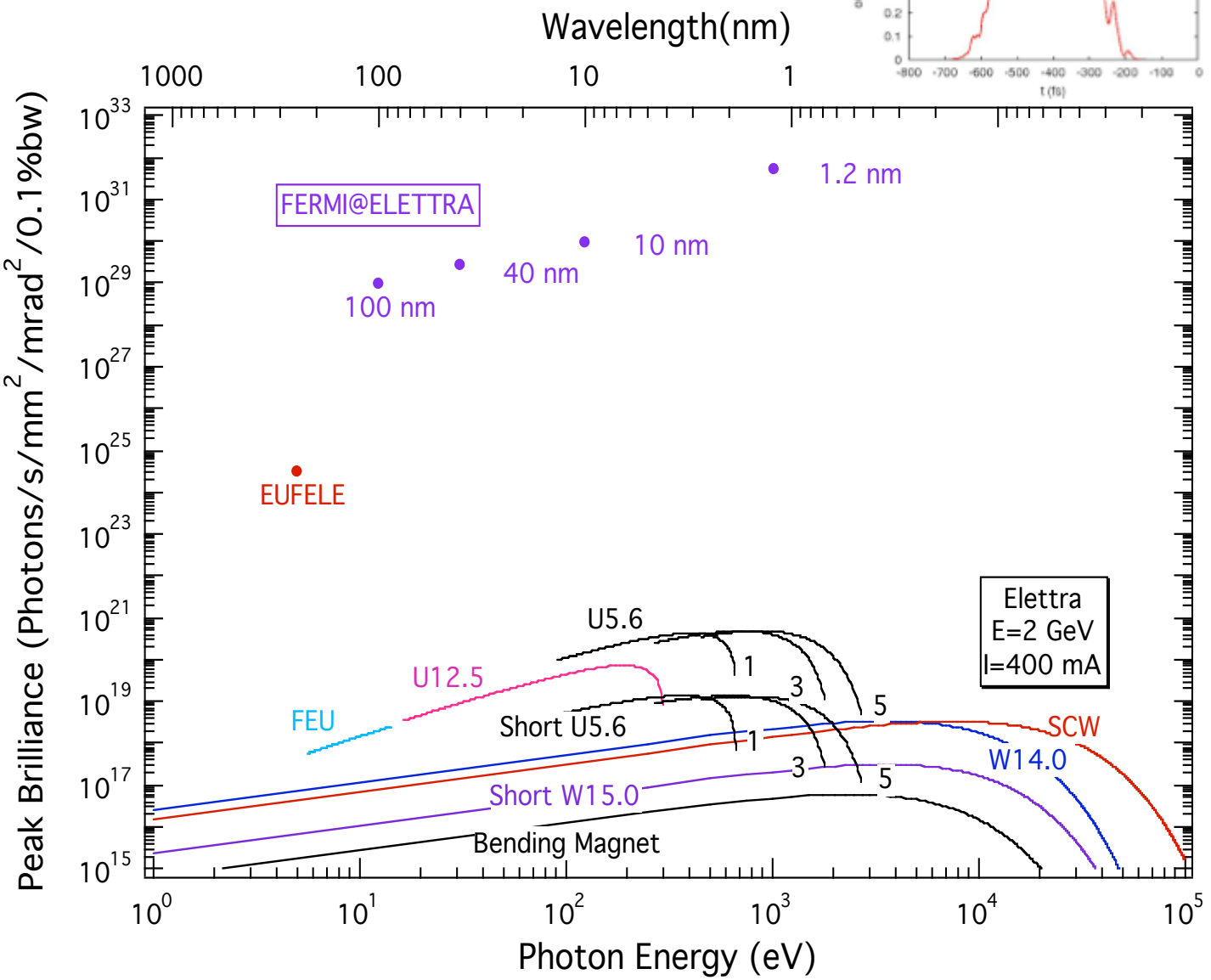
from 39 countries

FEL-2: Results at 10 nm (fresh bunch)

FERMI@Elettra



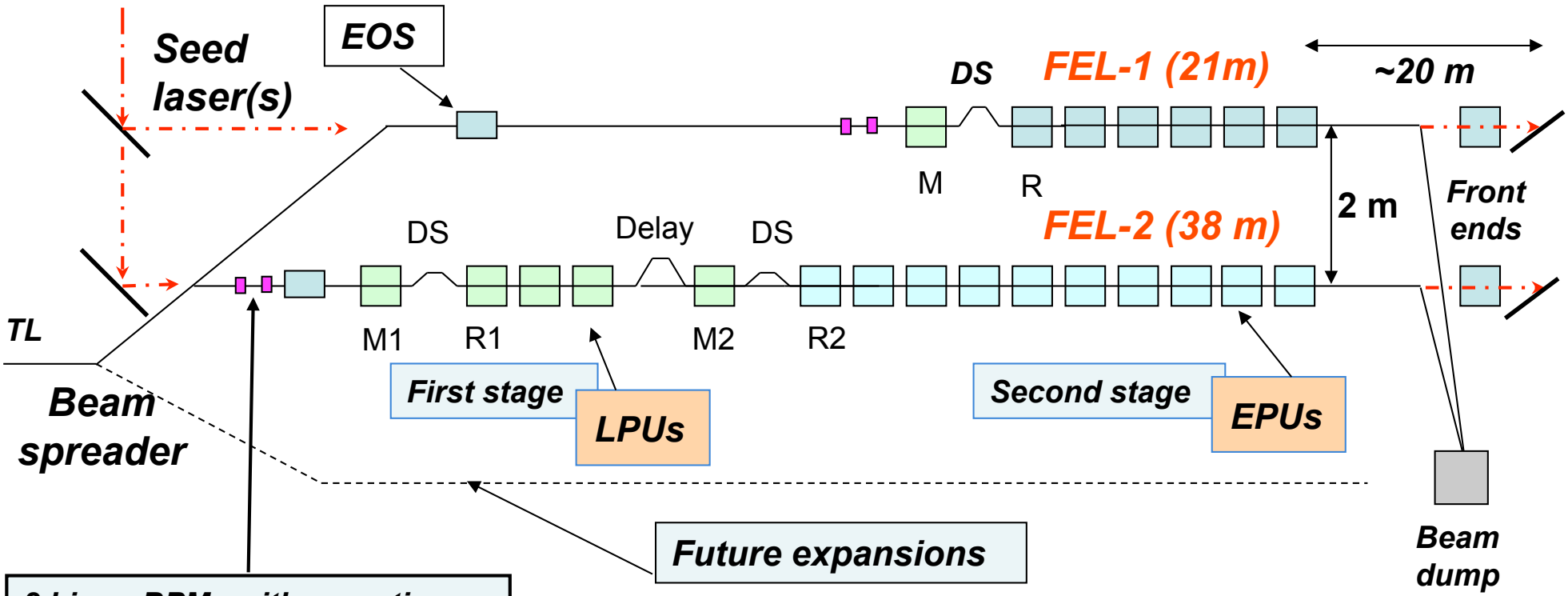




FEL power:
1 GW
100 fs
at 10 nm

Undulators and FEL layout

Conceptual layout of the FELs, transport line, spreader and beam dump



2 hi-res BPMs with no optics inside for BBA (min. sep = 5 m)

FEL-2 Configurations
- **Fresh bunch**
- **Whole bunch**
- **HHG seeding**

Description:

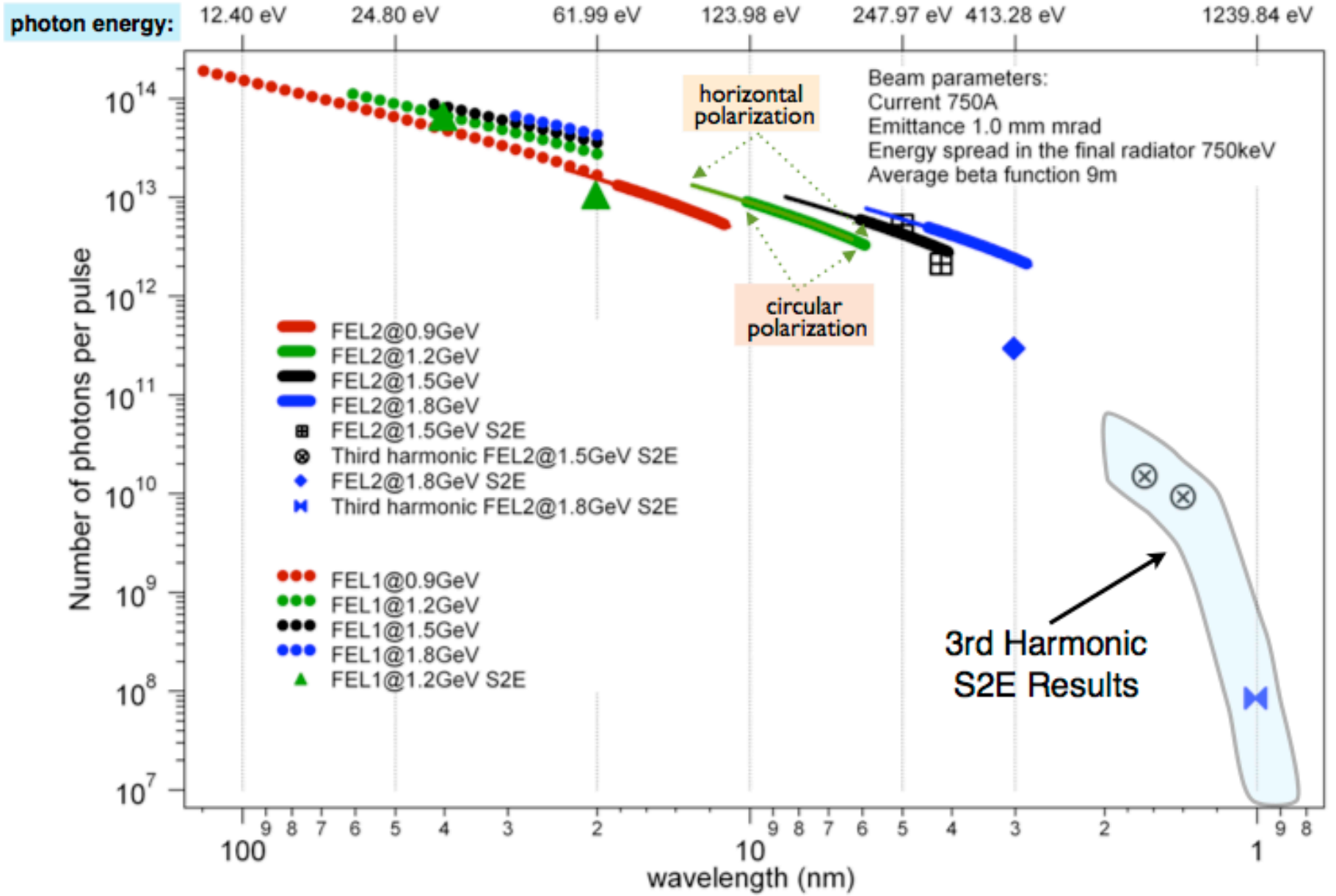
- undulator axis separated by 2 m

- transverse/energy collimation incorporated

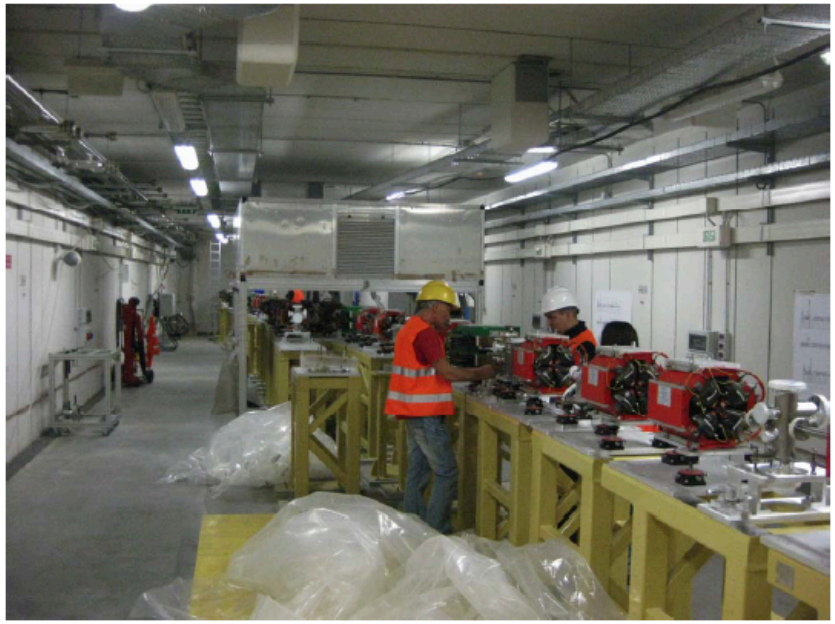
- space for matching optics, BPMs, EOS, other diag.

- small angles to CSR effects: ~ 6 deg total

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



7 months ago

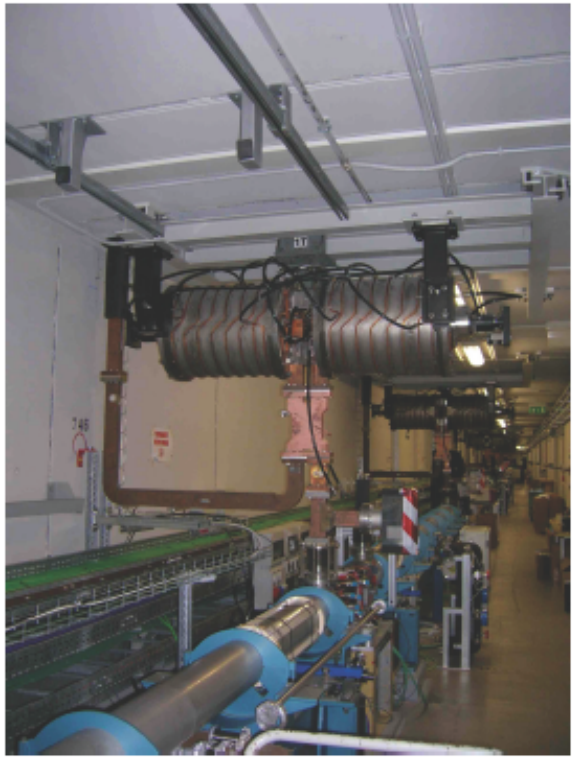


FERMI experimental hall 7 months ago

FERMI experimental hall 7 months ago

FERMI experimental hall yesterday


Slide provided by M. Svandrlik
Courtesy of
D. La Civita
End of May:
BC1 chicane installed
and ready for
commissioning



DIFFRACTION AND PROJECTION IMAGING PROGRAM

Lawrence Livermore National Laboratory, University of Uppsala, KTH Stockholm, King's College London, CFEL, DESY, SLAC, TASC-INFM-CNR, Sincrotrone Trieste - ***M. Kiskinova***

ELASTIC AND INELASTIC SCATTERING PROGRAM

Universities of Roma I, Camerino, l'Aquila, California Berkeley, ESRF, LENS Florence, MIT Boston, Lawrence Livermore National Laboratory, Sincrotrone Trieste - ***C. Masciovecchio***

LOW DENSITY MATTER PROGRAM

Universities of Freiburg, Göttingen, Würzburg, Milano, Roma I, Uppsala, Perth, California San Diego, Southampton, Perugia, Trieste, Technical University of Berlin, EPFL Lausanne, IMIP-CNR, ISM-CNR, LIXAM-CNRS Orsay, LAC-CNRS Orsay, Sincrotrone Trieste - ***C. Callegari***

EUROPEAN RESEARCH INFRASTRUCTURE CONSORTIA (ERIC) in 2013

EuroFEL (formerly IRUVX) consortium, which now includes PSI and SPARC; EUV and soft x-ray lasers

Elettra & FERMI-centered regional ERIC, with Austria, Slovenia, Croatia, etc. FVG Regional government seems to support this enthusiastically.

Sincrotrone Trieste S.C.p.A.

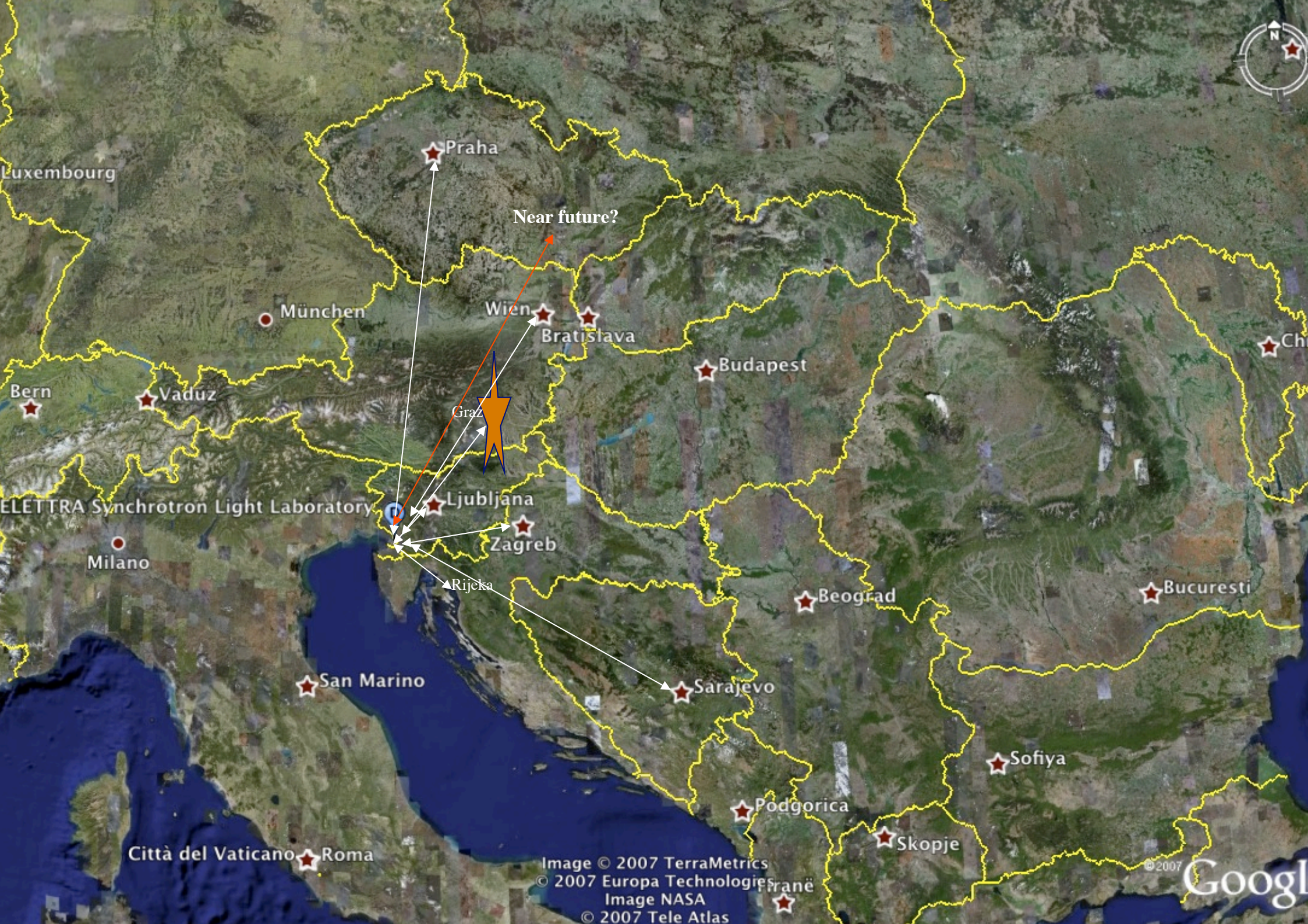
- A nonprofit shareholder company of national interest:

AREA Science Park	51.1%
FVG Regional Government	39.8%,
CNR-INFM	5.1%
Sviluppo Italia FVG S.p.A.	4.0%

- Established in 1987 to construct and manage synchrotron light sources – international facility

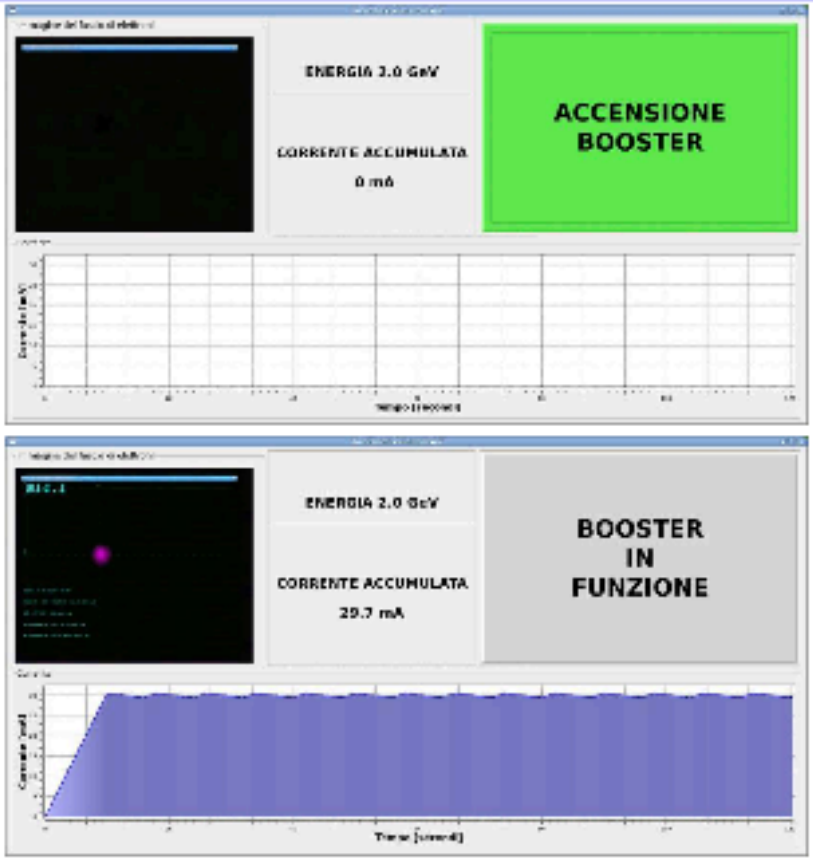
-> Promote cultural and socioeconomic growth at the regional, national and international level

-> State-of-the art research facilities, technical leadership, skill development and transfer


Praha
Luxembourg
Near future?
München
Wien
Bratislava
Budapest
Bern
Vaduz
Graz
ELETTRA Synchrotron Light Laboratory
Ljubljana
Zagreb
Milano
Rijeka
Beograd
Bucuresti
San Marino
Sarajevo
Sofiya
Podgorica
Città del Vaticano
Roma
Skopje
Tiranë
Image © 2007 TerraMetrics
© 2007 Europa Technologies
Image NASA
© 2007 Tele Atlas
©2007
Google

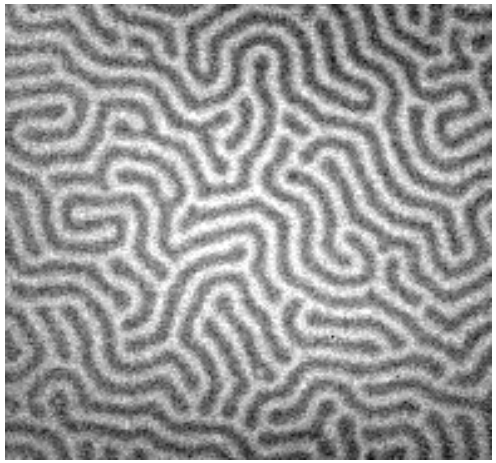
Booster full-energy injector:

Inauguration on March 28th, 2008

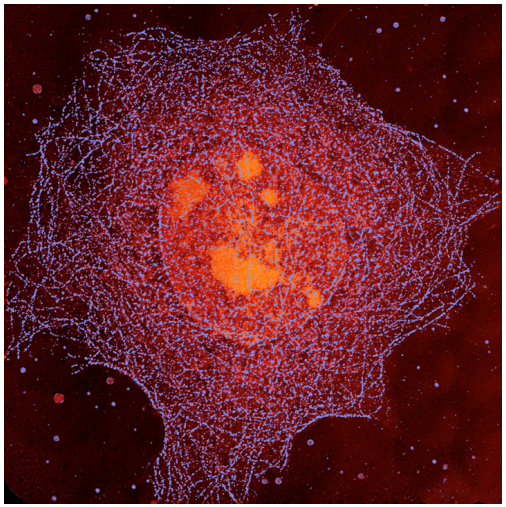


On March 28th the President of the Italian Republic, Giorgio Napolitano, inaugurated the Booster!

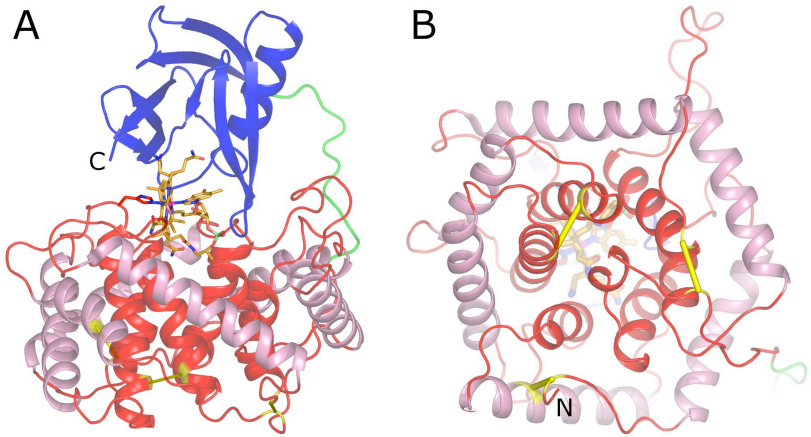
FeGd Multilayer



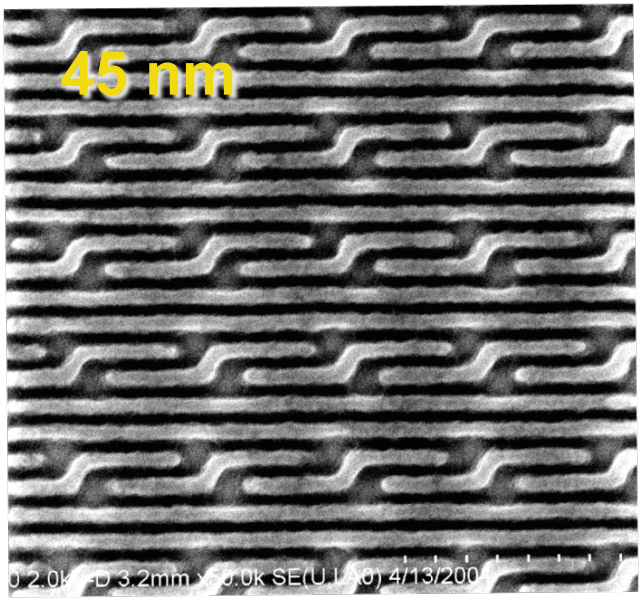
$\hbar\omega$ = 707.5 eV
Fe L_3-edge



Microtubules in a mouse epithelial cell



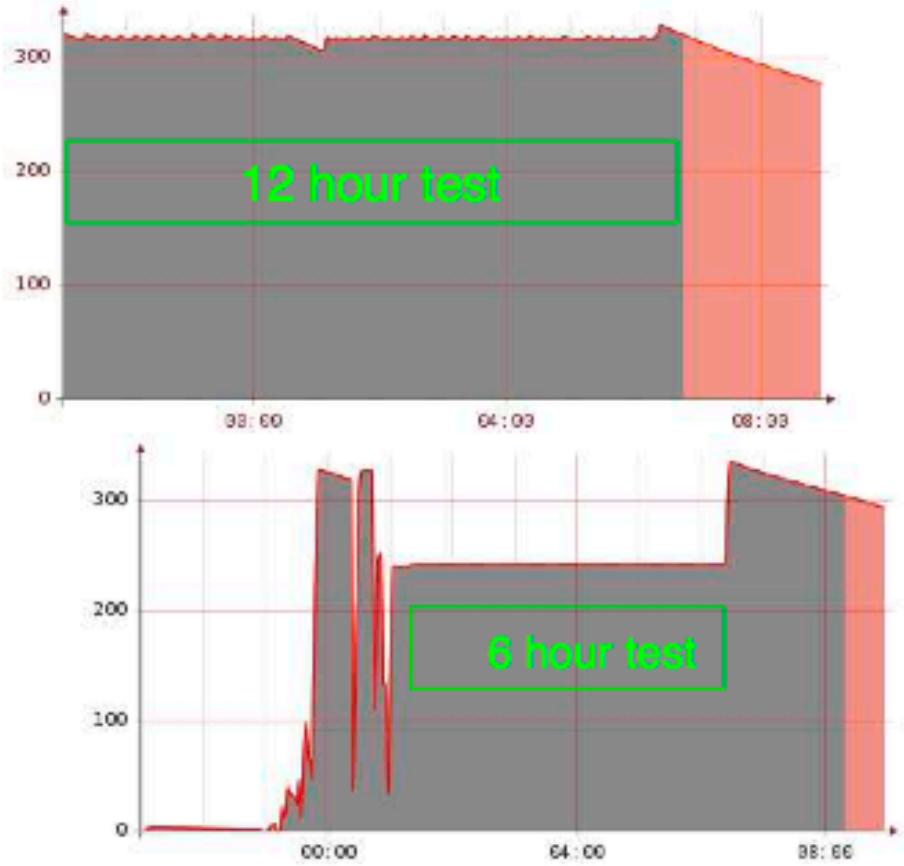
Overall structure of transcobalamin

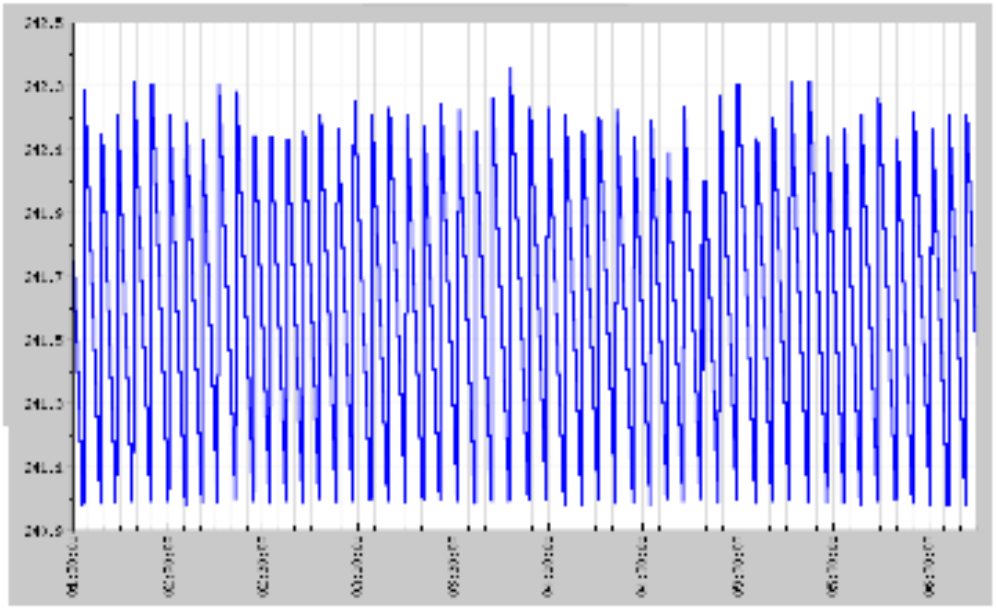


Top-up tests

Confirmed that top up is possible at both energies, more critical at 2 GeV. Series of tests also for the stability of the injector.

Still not available the special top-up instrumentation (June 09)

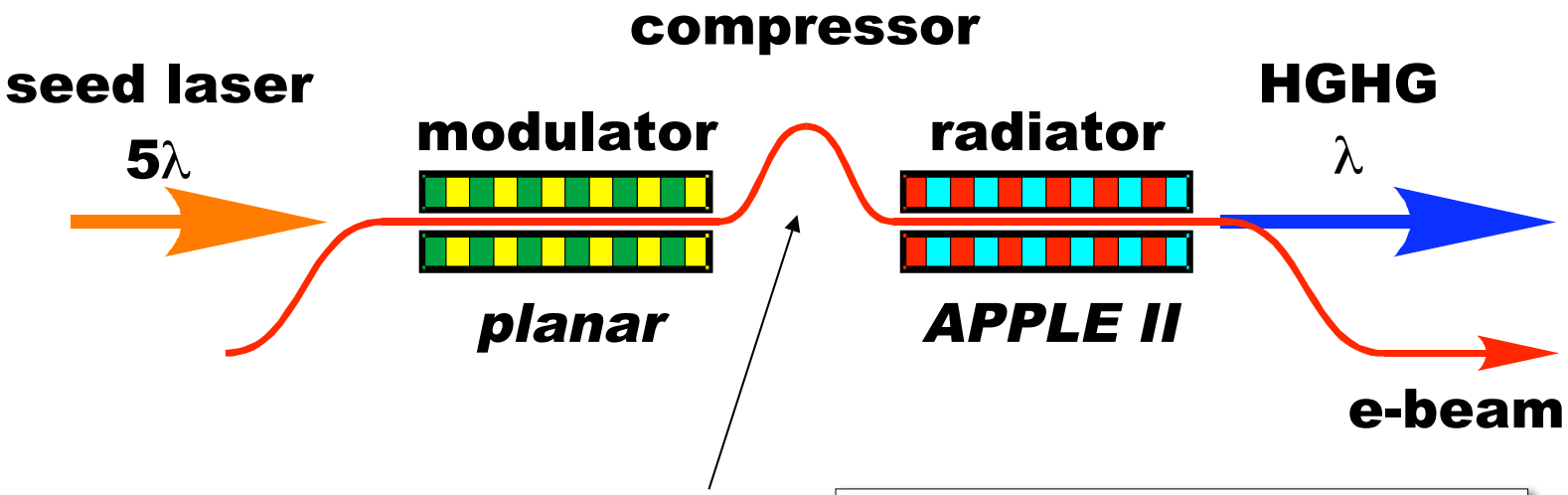




Every 5 minutes / ~ 0.1 mA/sec ~10 sec

Stability 1 ± 0.15 mA

High Gain Harmonic Generation - HGHG



More compact and fully temporally coherent source, control of pulse length and control of spectral parameters.

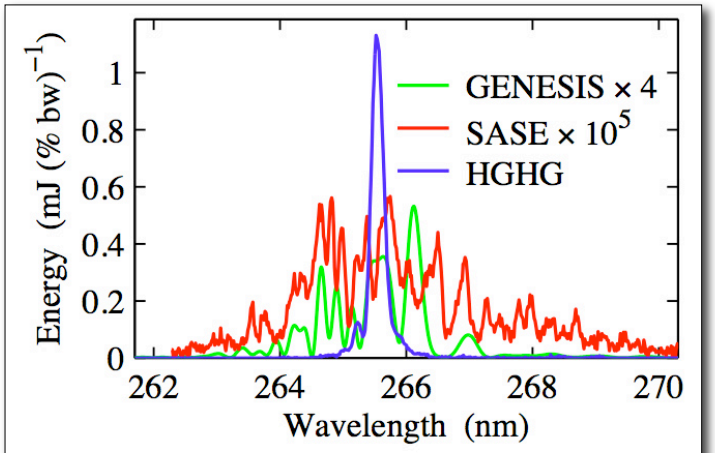


FIG. 4: Single shot HGHG spectrum for 30 MW seed (blue), single shot SASE spectrum measured by blocking the seed laser (red) and simulation the SASE spectrum after 20 m of NISUS structure (green). The average spacing between spikes in the SASE spectrum is used to estimate the pulse length.

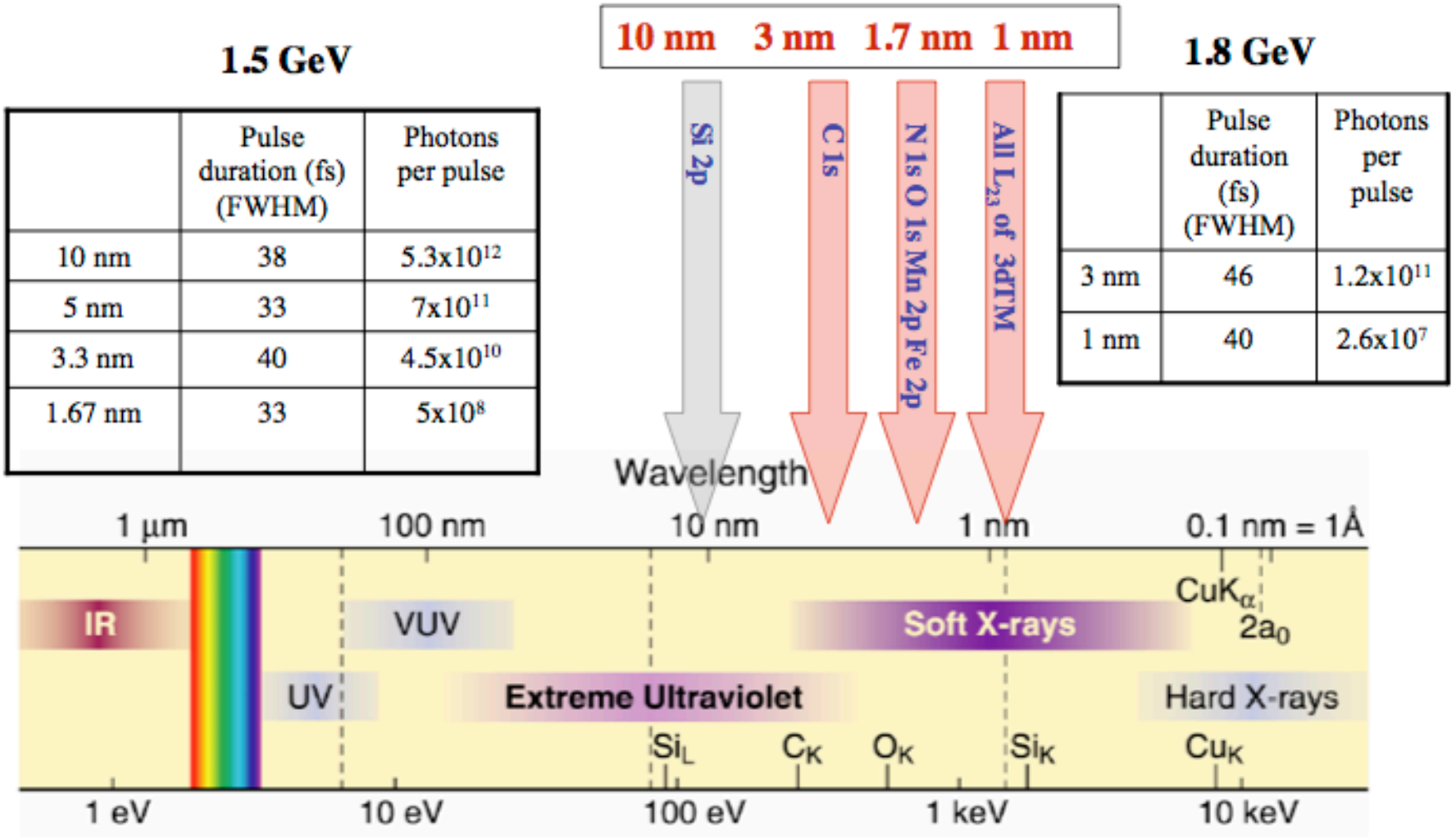
Li-Hua Yu
DUV-FEL

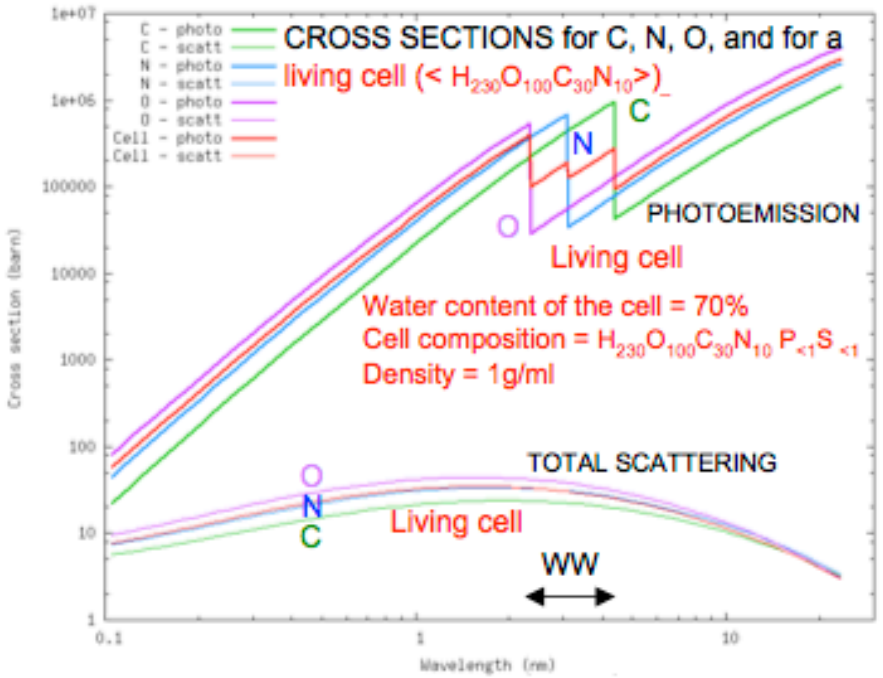
1.5 GeV

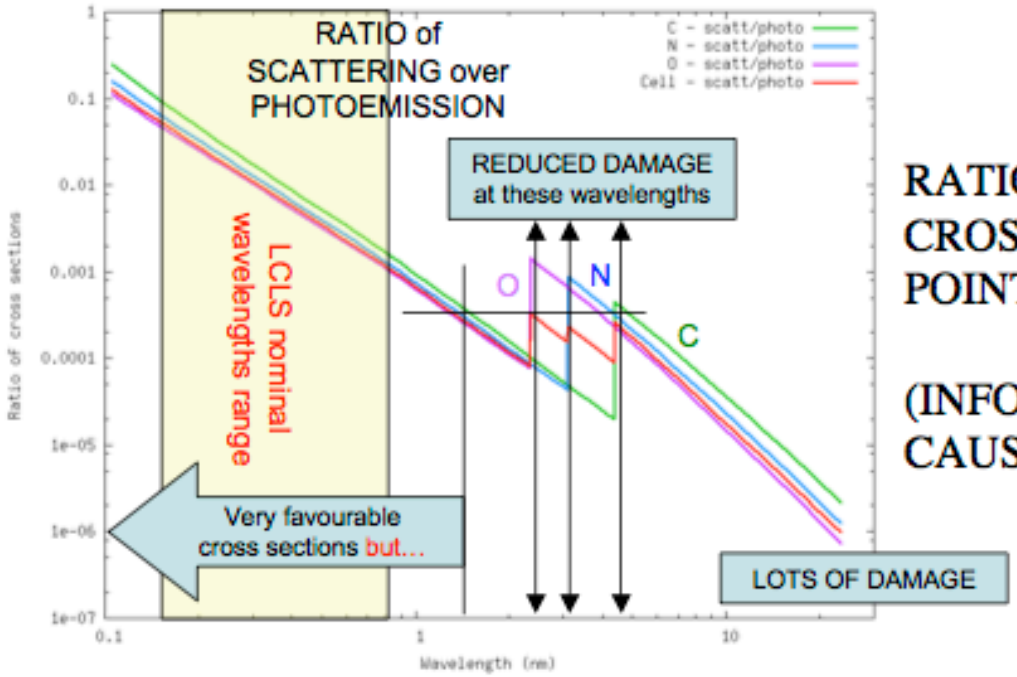
	Pulse duration (fs) (FWHM)	Photons per pulse
10 nm	38	5.3×10^{12}
5 nm	33	7×10^{11}
3.3 nm	40	4.5×10^{10}
1.67 nm	33	5×10^{8}

1.8 GeV

	Pulse duration (fs) (FWHM)	Photons per pulse
3 nm	46	1.2×10^{11}
1 nm	40	2.6×10^{7}







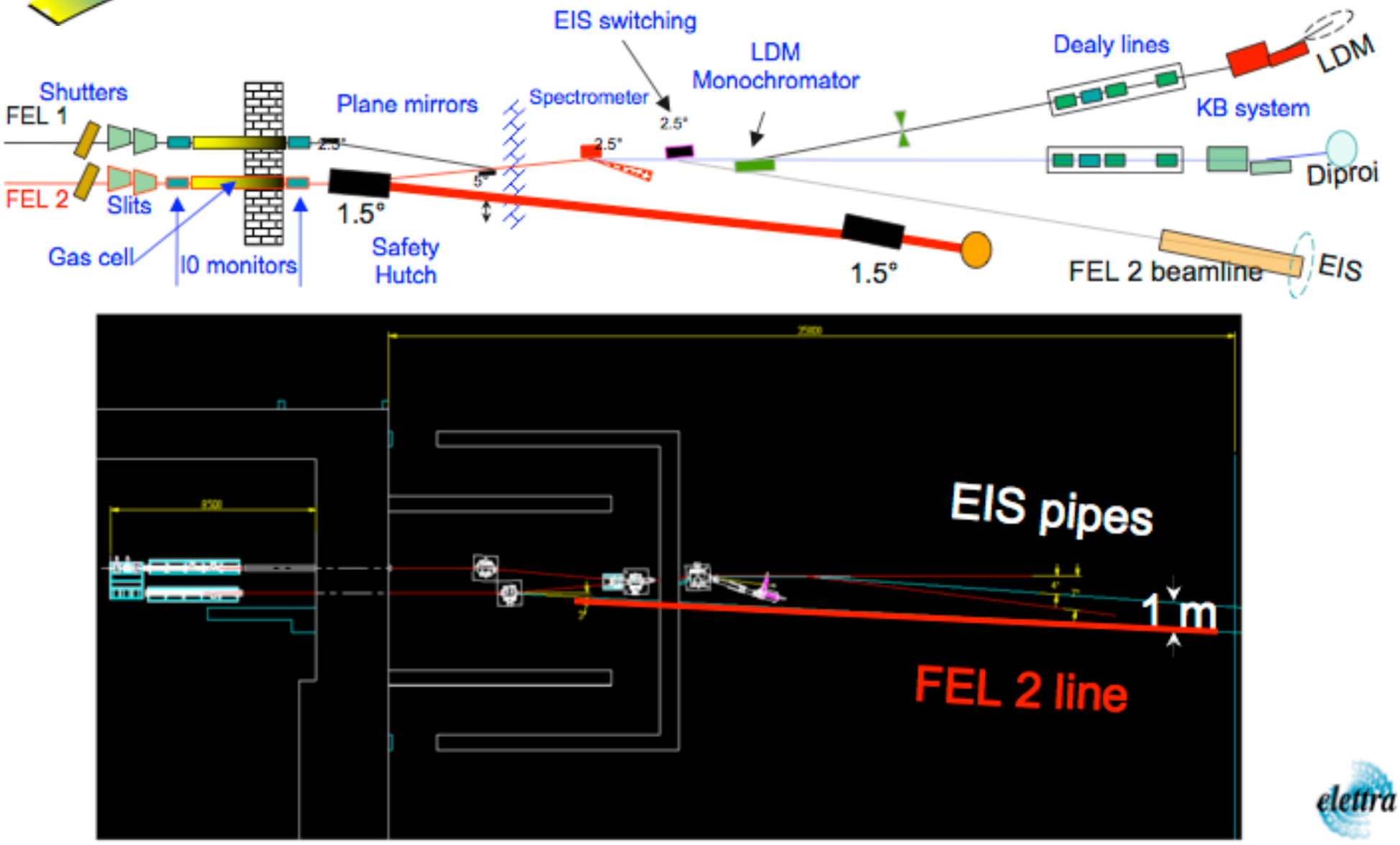
IMAGING LIVING CELLS

WHICH WAVELENGTH IS THE BEST?

It is not necessarily the shortest..

RATIO of SCATTERING / PHOTOELECTRIC CROSS SECTIONS GIVES a STARTING POINT

(INFORMATION GAINED OVER DAMAGE CAUSED)


EIS switching
LDM
Monochromator
Dealy lines
LDM
Shutters
FEL 1
Plane mirrors
Spectrometer
KB system
2.5°
2.5°
2.5°
FEL 2
Slits
5°
Diproi
1.5°
Safety
Hutch
Gas cell
I0 monitors
1.5°
FEL 2 beamline
EIS
EIS pipes
1 m
FEL 2 line

FERMI @elettra

DIFFRACTION AND PROJECTION IMAGING PROGRAM *M. Kiskinova*

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

Lawrence Livermore National Lab and 8 other major international institutions

ELASTIC AND INELASTIC SCATTERING PROGRAM *C. Masciovecchio*

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

Universities of Rome and Camerino and other 7 major international institutions

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*

University of Freiburg, TUB, and 16 other major international institutions

FIRST ELECTRON BEAM AT FERMI@Elettra

18:44 on August 19, 2009

As announced the other day via company wide e-mail and also printed in the ElettraNews, the first electron beam has been generated in the linac tunnel of FERMI@Elettra. This is a step of capital importance in the commissioning of this new fourth-generation light source.

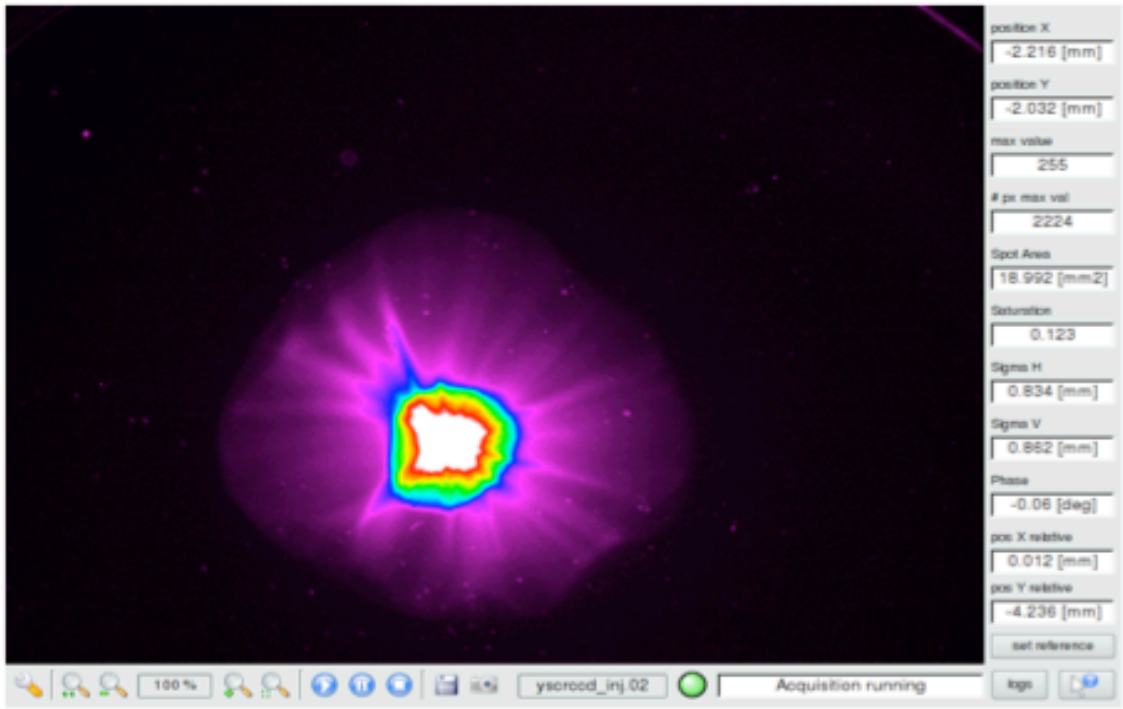


Figure caption: Image of the FERMI@Elettra electron beam following extraction from the surface of the copper photocathode and subsequent acceleration to roughly 5 MeV.

Also: HHG source for seeding at FERMI funded by the Dutch National Science Foundation (University of Twente and Coherent Europe B.V.)

Project budget

Total estimated project cost: 164.0 M€

- Italian MUR 36.0 M€
- Friuli-Venezia-Giulia Region 10.0 M€
- EU and other public funds: 28.0 M€

Partial total: 84.0 M€

- EIB loan - State guarantee 60.0 M€

EIB loan - RSFF – ERCF 20.0 M€*

Total: 164.0 M€

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

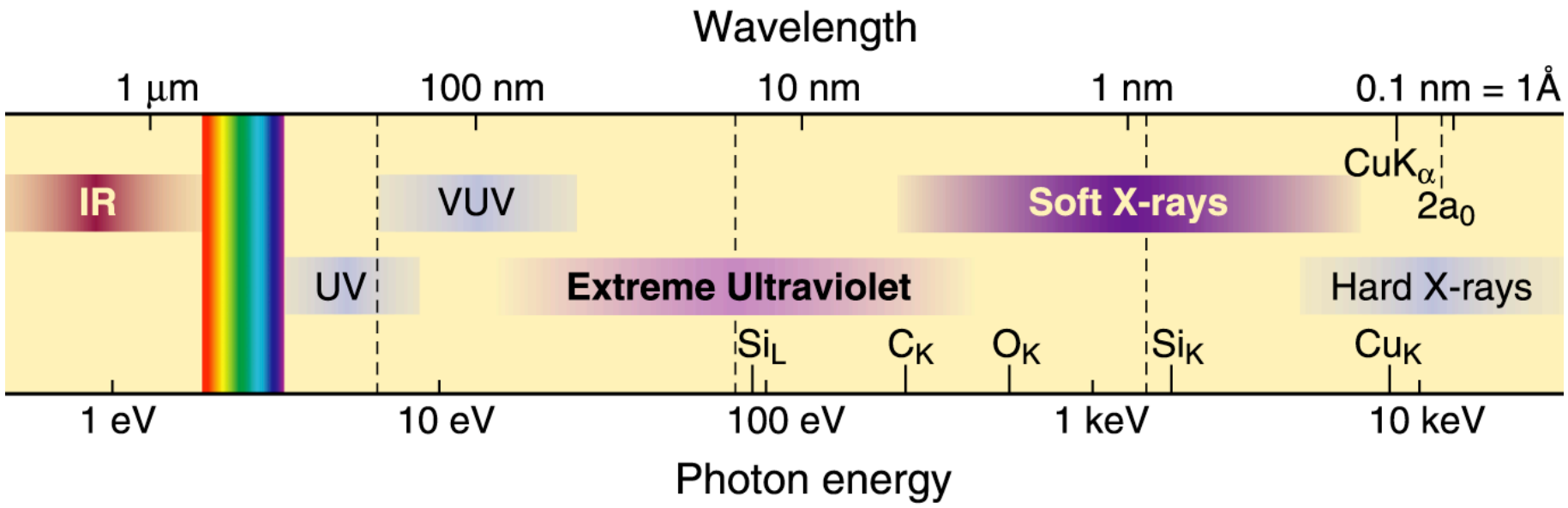
Geometrical emittance coupling %	£ 1%		
Spurious dispersion (at the centre of IDs): horizontal (rms max/min) [cm]	6/2.		
Spurious dispersion (at the centre of IDs): vertical (rms max/min) [cm]	2/0.5		
Injected current [mA]		320	150
Machine dominated by the Touschek effect			
Energy spread (rms) %		0.08	0.12
Lifetime [h] (natural) Lifetime [h] (with 3rd harmonic cavity)		8.5 27	32 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

Decision making and evolution

- **1975-80** ESF proposal for two complementary synchrotron laboratories (hard X-ray/ EUV-X range)
- **1983-87** Italy decides to participate in ESRF and build the complementary laboratory in Trieste, as a "bridge to the East", alongside other international institutions, and to foster growth of a Research Area (set up at the same time)
- **1994** Elettra inaugurated by the President of Italy
- **1994-today** "in kind" participations by Austria, Check Republic, Slovenia, and India, associate to IAEA and CEI
- **2008- ??** EUROFEL Consortium (formerly IRUVX)

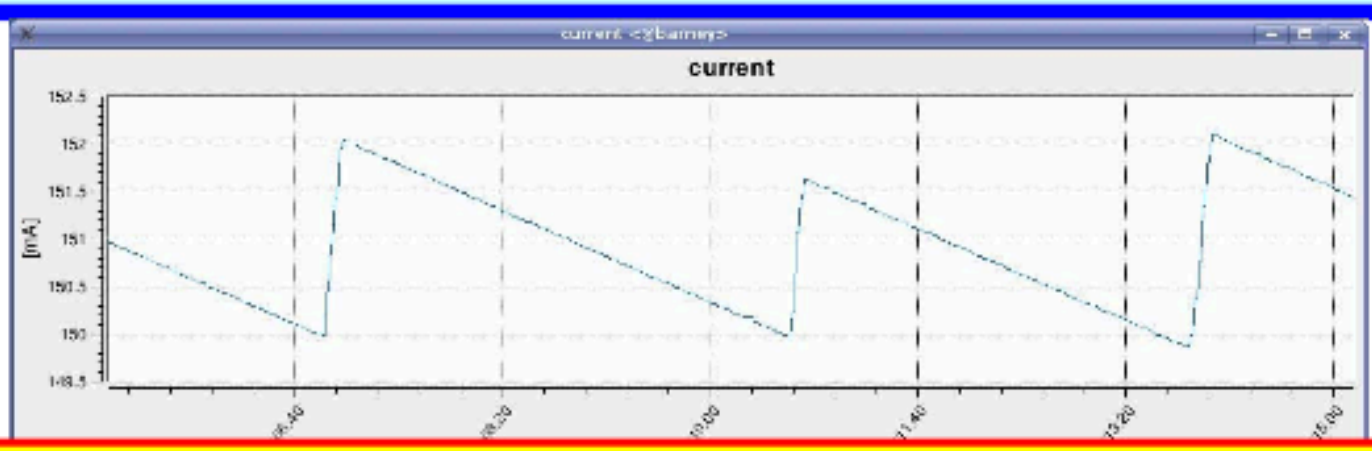
and the Area di Ricerca di Trieste is now the largest in Italy

The Short Wavelength Region of the Electromagnetic Spectrum

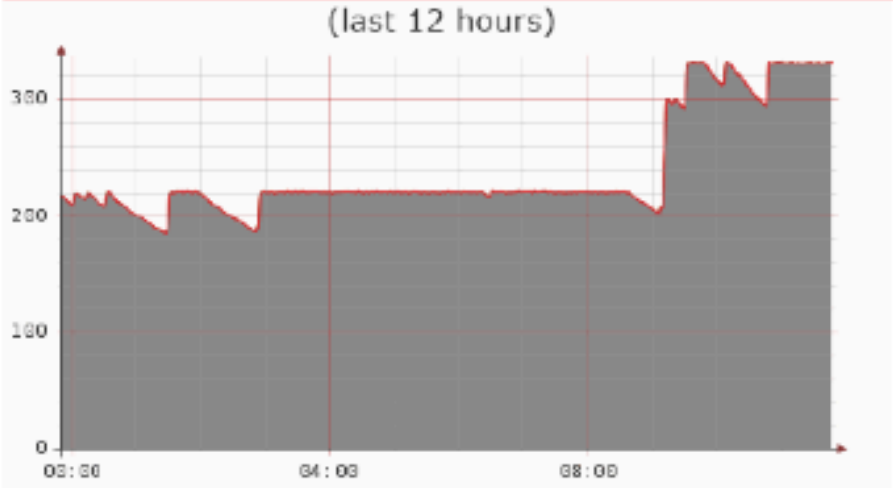


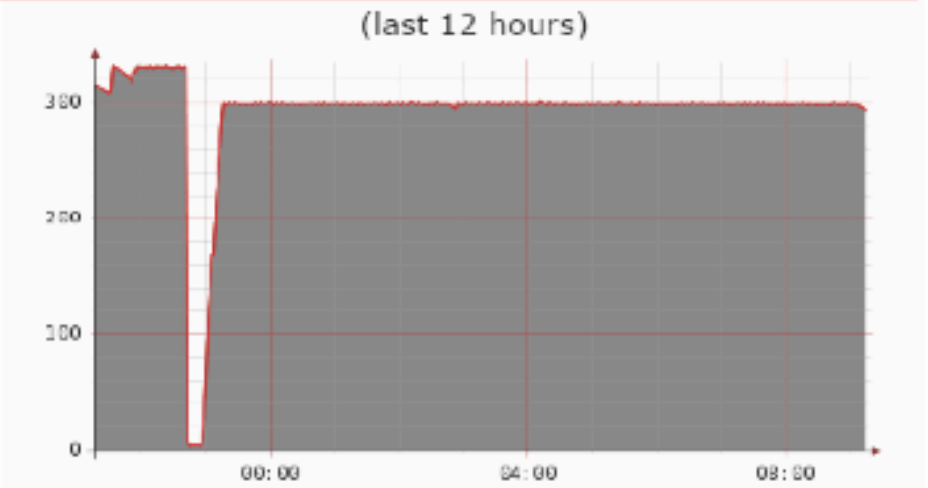
- **See smaller features**
- **Write smaller patterns**
- **Elemental and chemical sensitivity**

Anticipating Elettra's future?

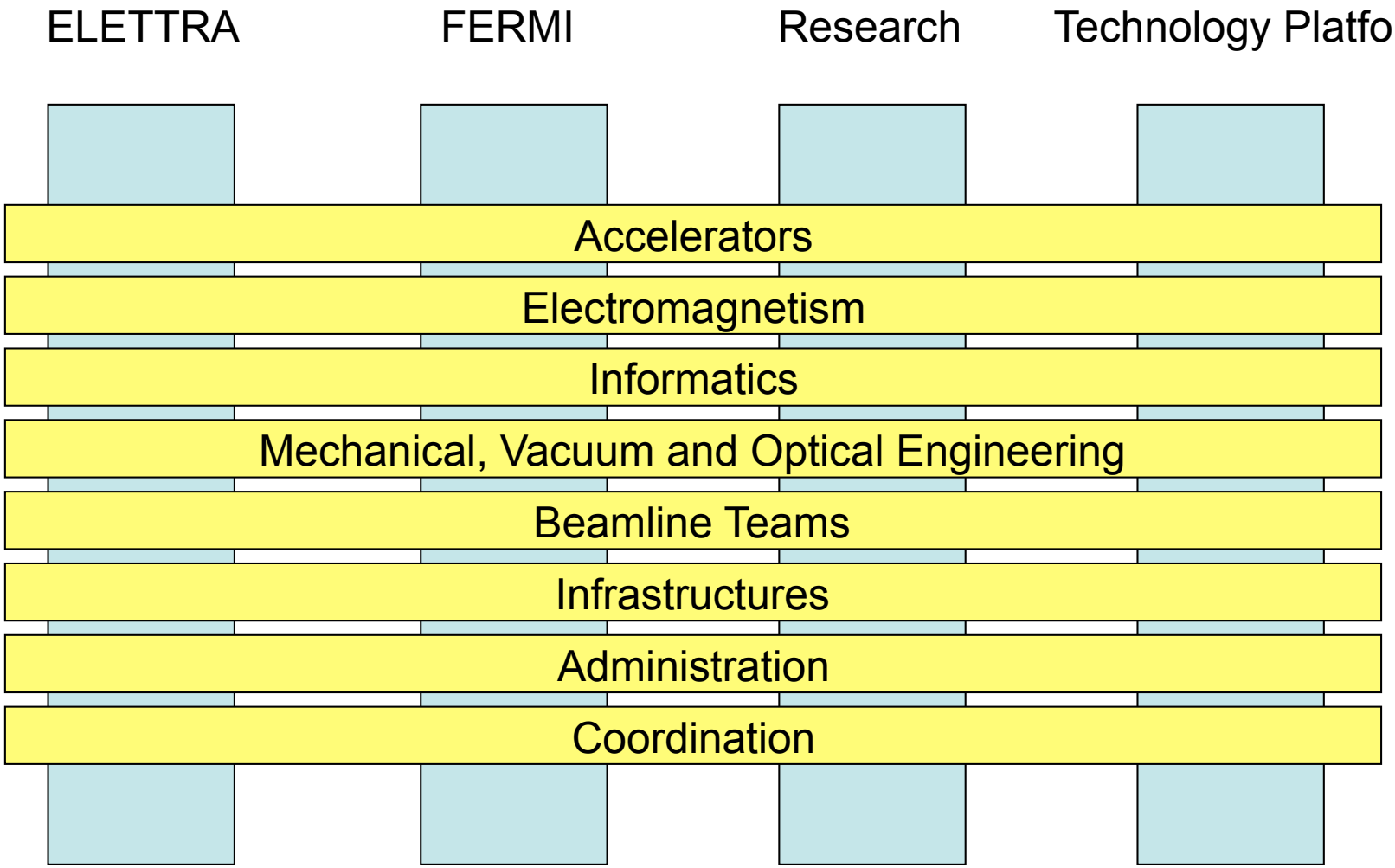


Frequent injection mode tests; just used for vacuum conditioning (IDs open, shutter closed)! And a bit of advertising...





Project Clusters & Groups



Structural biology - tools & people

XRD1 beamline M. Polentarutti, D. Lamba, S. Onesti et al.

- completely refurbished (at ST)

XRD2 beamline M. Polentarutti, S. Onesti et al.

- to be installed on the sc wiggler (at ST)

new ST structural biology lab P. Storici, G. Legname, S. Onesti et al.

- for protein expression and crystallization (at ST)

EXTERNAL RELATED FACILITIES

prion biology laboratory G. Legname et al.

- HPLC, TOF mass spectrometer (at SISSA and CBM)

bio-TEM facility E. Carlino, Diane Latawiec, G. Legname et al.

- JEOL JEM-2010F UHR FEG TEM (at TASC)

new NMR facility A. Pastore (?) et al.

- 800 MHz instrument (in Ljubljana)

Scientific Advisory Council

- D. Attwood, G. Brown, G. Chiari, C. Fadley, R. Huber, S. Larsen, **I. Lindau,** D. Menzel, C. Shank, F. Van der Veen

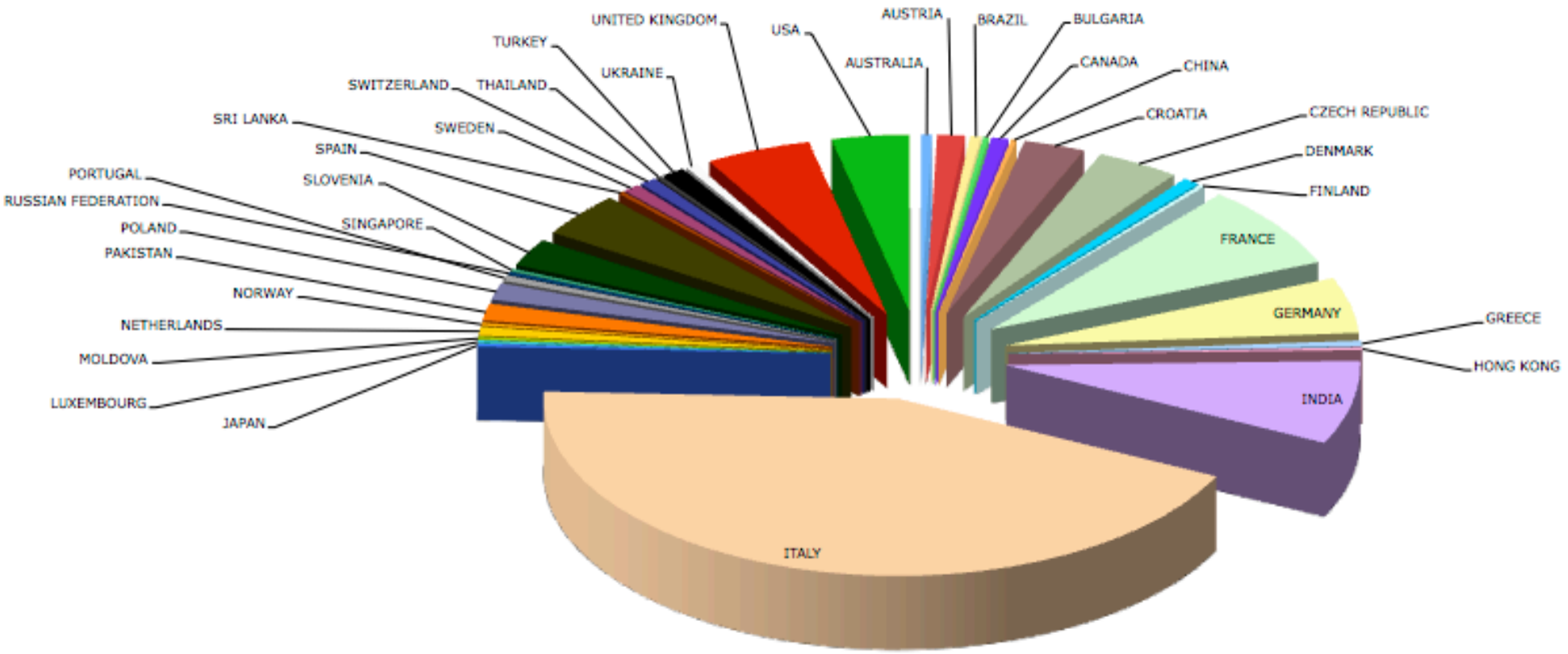
Machine Advisory Committee

- P. Emma, M. Eriksson, J. Hastings, C. Pagani, C. Pellegrini, M. Pool, R. Schoenlein, H. Weise, **R. Walker**

Industrial Advisory Panel

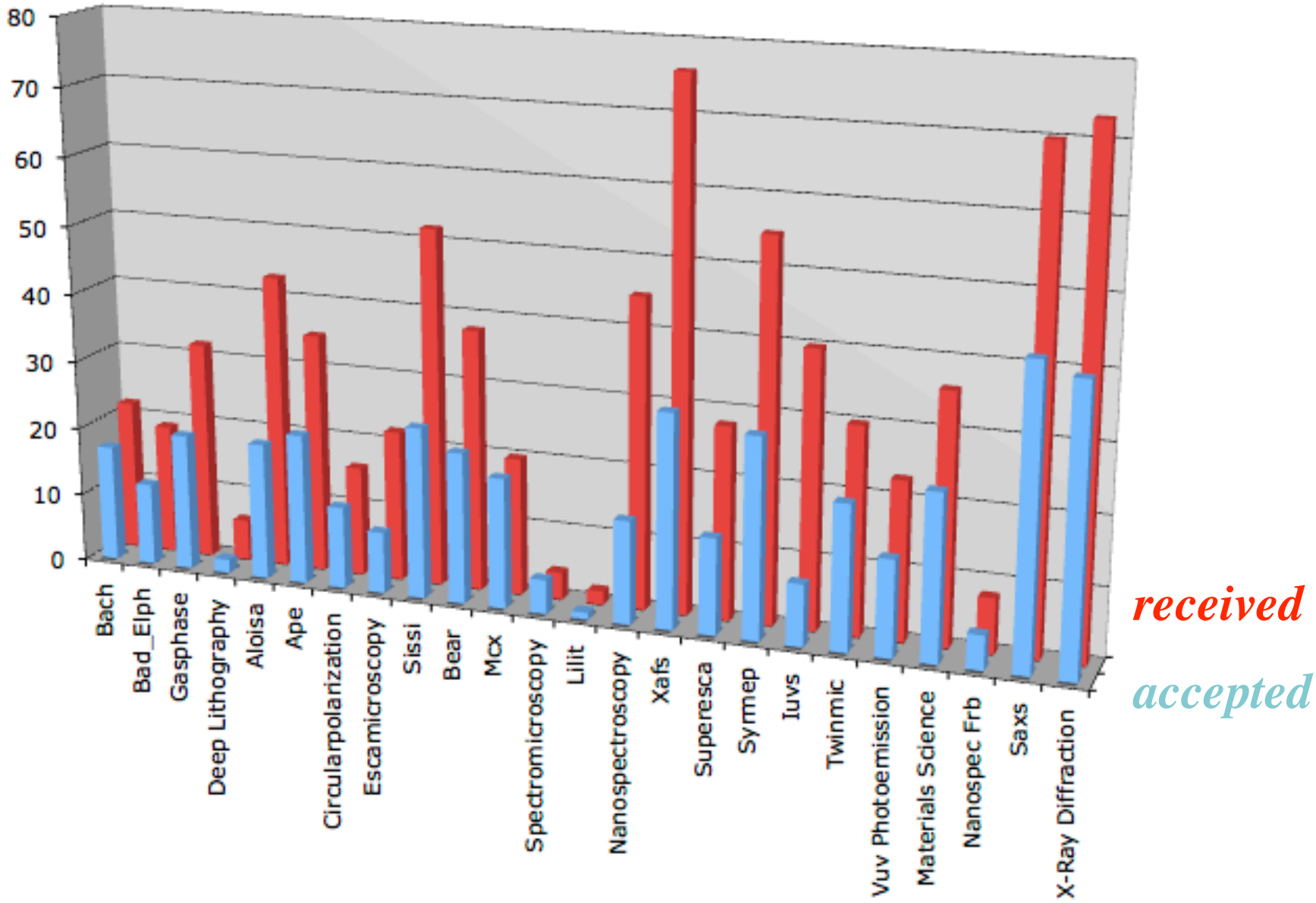
- **A. Sangiovanni-Vincentelli, E. Albizzati, M. Arienzo, C. Castellano, M. Ferrari**

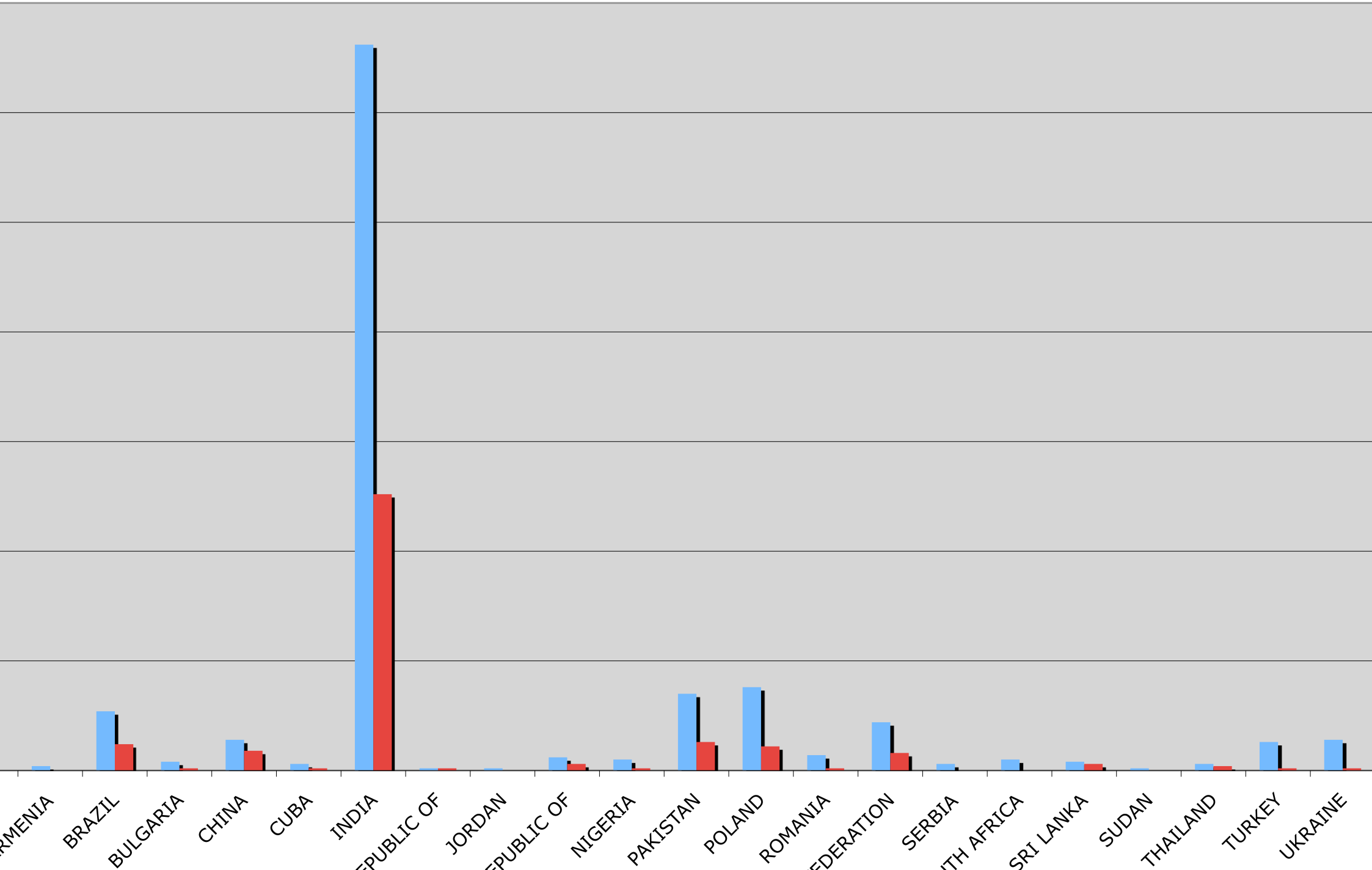
394 proposal received in the *first semester* 2010



from 36 different countries

Proposals received - first call 2010




RMENIA
BRAZIL
BULGARIA
CHINA
CUBA
INDIA
AMIC REPUBLIC OF
JORDAN
OVA, REPUBLIC OF
NIGERIA
PAKISTAN
POLAND
ROMANIA
SIAN FEDERATION
SERBIA
SOUTH AFRICA
SRI LANKA
SUDAN
THAILAND
TURKEY
UKRAINE

FIRST ELECTRON BEAM AT FERMI@Elettra

18:44 on August 19, 2009

As announced the other day via company wide e-mail and also printed in the ElettraNews, the first electron beam has been generated in the linac tunnel of FERMI@Elettra. This is a step of capital importance in the commissioning of this new fourth-generation light source.

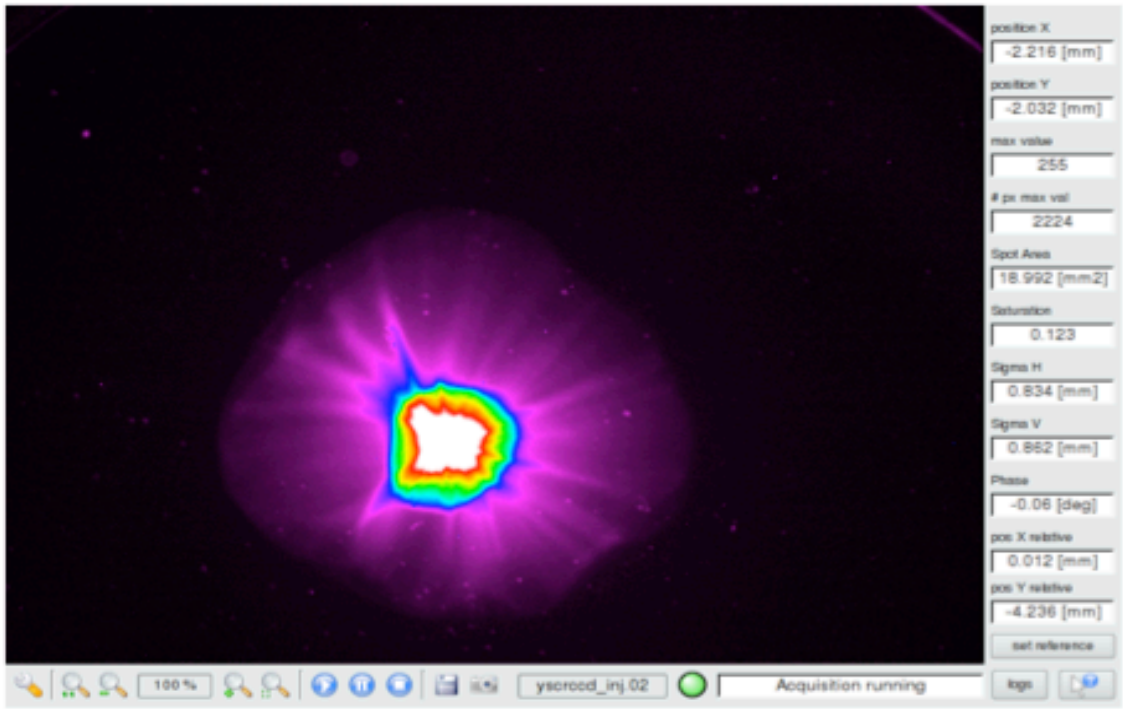


Figure caption: Image of the FERMI@Elettra electron beam following extraction from the surface of the copper photocathode and subsequent acceleration to roughly 5 MeV.

Officially inaugurated by Ms. Gelmini on November 30, 2009

FERMI @elettra

Head of Scientific Programs: F. Parmigiani

DIFFRACTION AND PROJECTION IMAGING PROGRAM

Lawrence Livermore National Laboratory, University of Uppsala, KTH Stockholm, King's College London, CFEL, DESY, SLAC, TASC-INFM-CNR, Sincrotrone Trieste - ***M. Kiskinova***

ELASTIC AND INELASTIC SCATTERING PROGRAM

Universities of Roma I, Camerino, l'Aquila, California Berkeley, ESRF, LENS Florence, MIT Boston, Lawrence Livermore National Laboratory, Sincrotrone Trieste - ***C. Masciovecchio***

LOW DENSITY MATTER PROGRAM

Universities of Freiburg, Göttingen, Würzburg, Milano, Roma I, Uppsala, Perth, California San Diego, Southampton, Perugia, Trieste, Technical University of Berlin, EPFL Lausanne, IMIP-CNR, ISM-CNR, LIXAM-CNRS Orsay, LAC-CNRS Orsay, Sincrotrone Trieste - ***C. Callegari***

Third world proposals 2005-2010