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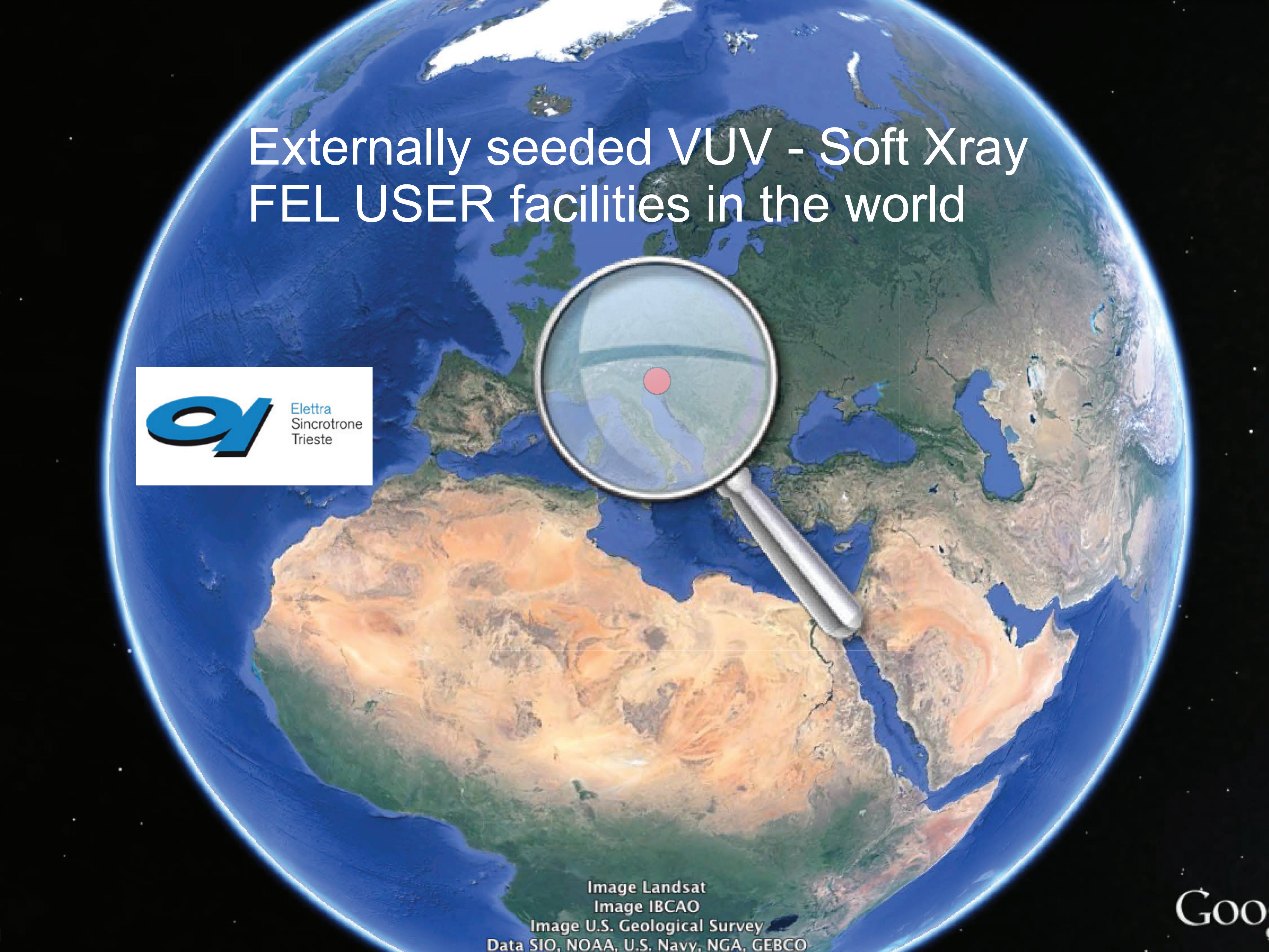
FERMI FEL-2 First lasing

L. Giannessi,

on behalf of the FERMI Commissioning Team

Externally seeded VUV - Soft Xray FEL USER facilities in the world



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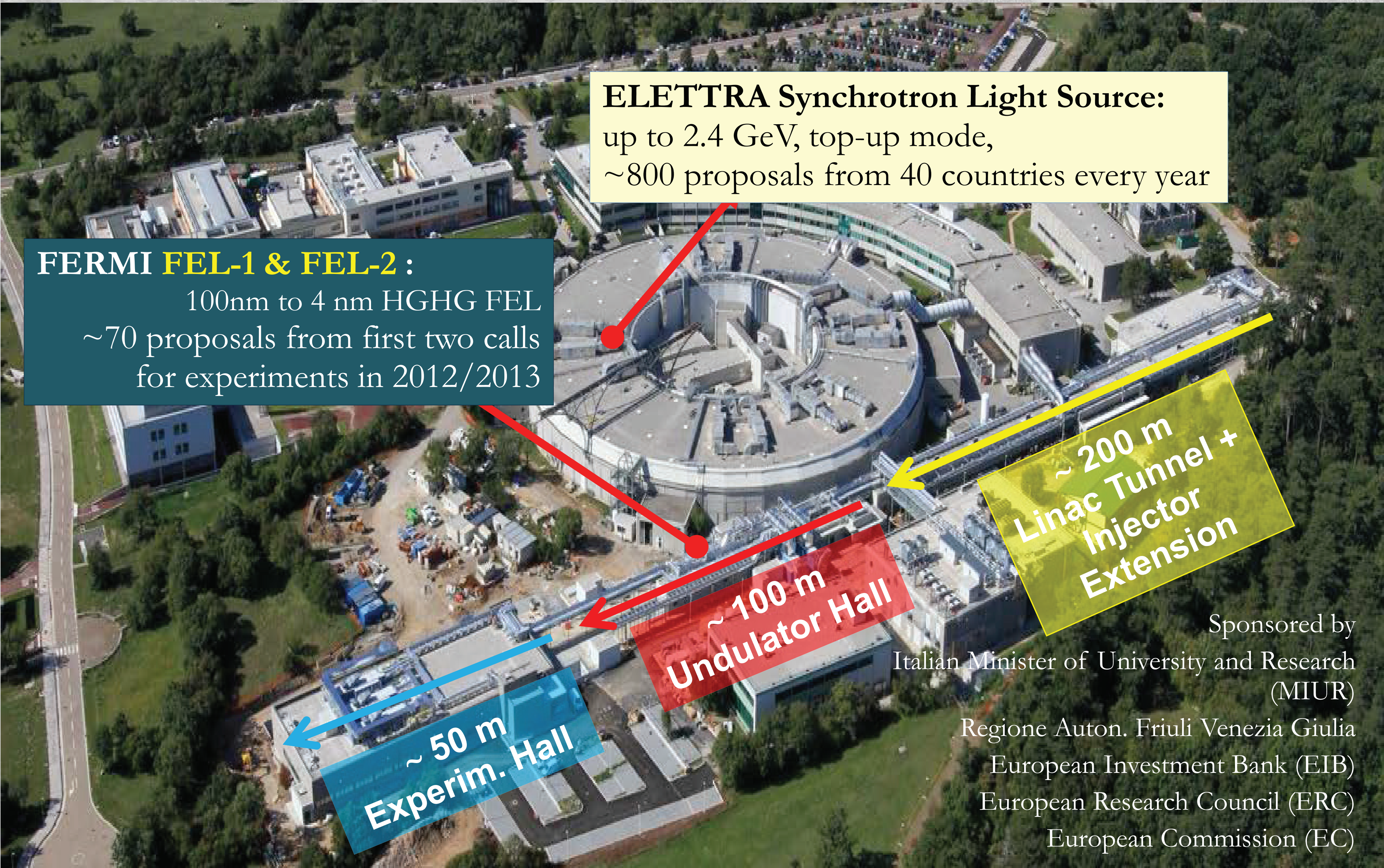
FERMI and Elettra



ELETTRA Synchrotron Light Source:
up to 2.4 GeV, top-up mode,
~800 proposals from 40 countries every year

FERMI FEL-1 & FEL-2 :
100nm to 4 nm HGHG FEL
~70 proposals from first two calls
for experiments in 2012/2013

Sponsored by
Italian Minister of University and Research (MIUR)
Regione Auton. Friuli Venezia Giulia
European Investment Bank (EIB)
European Research Council (ERC)
European Commission (EC)

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FERMI FEL-1 & FEL-2 STATUS

- **FEL -1:** **Single stage cascaded FEL, full specifications achieved in 2012, now dedicated to user experiments**
  - Continuously tuneable in the wavelength range 20-65 nm (up to 100nm possible with specific machine setup)
  - Bandwidth (best) 5×10^{-4} @ 32 nm
  - Energy per pulse 30-100 uJ (depending on wavelength setting – up to a factor 2-3 more relaxing the spectral purity requirements)

- **FEL-2:** **Double stage, fresh bunch, cascade FEL, in commissioning**
  - October 2012 commissioning @ 1.0 GeV, 14.4 nm & 10.8 nm ≈50 uJ @10.8 nm
  - Extended wavelength range down to 8 nm in March 2013 (@1.23 GeV) commissioning
  - Down to 5 nm and below in June 2013 (@1.4 GeV)

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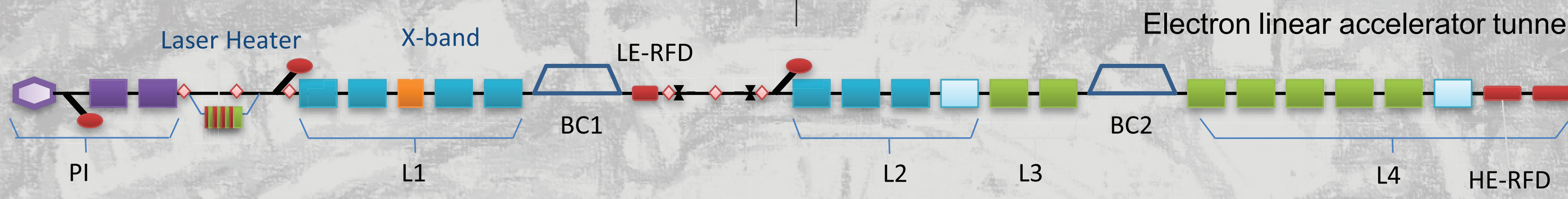
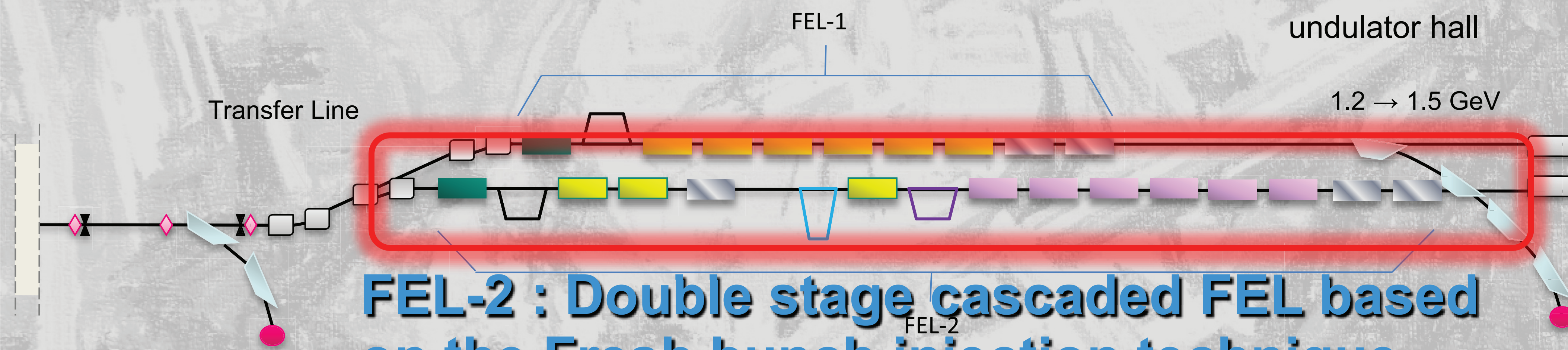
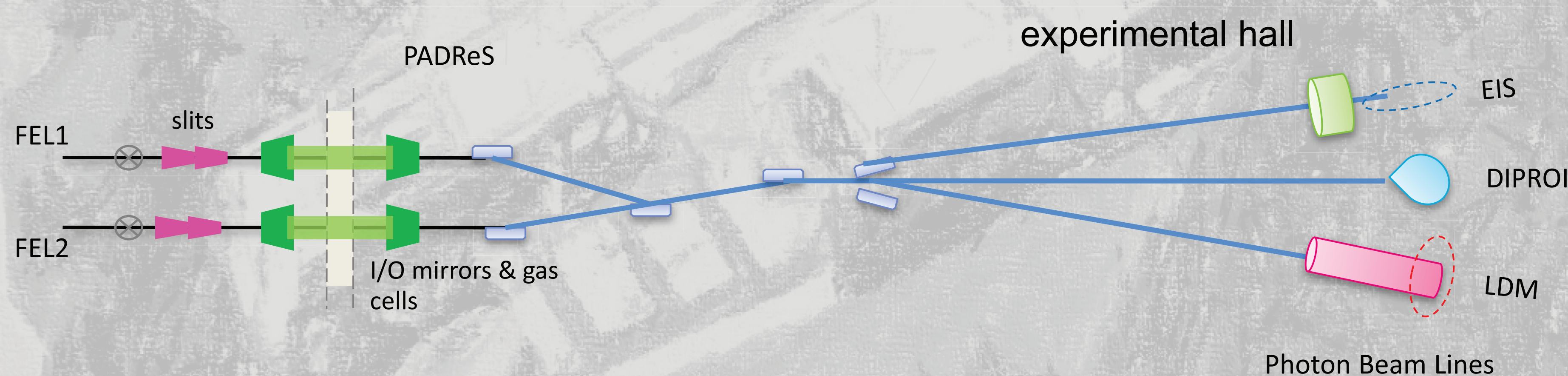
FERMI LAYOUT

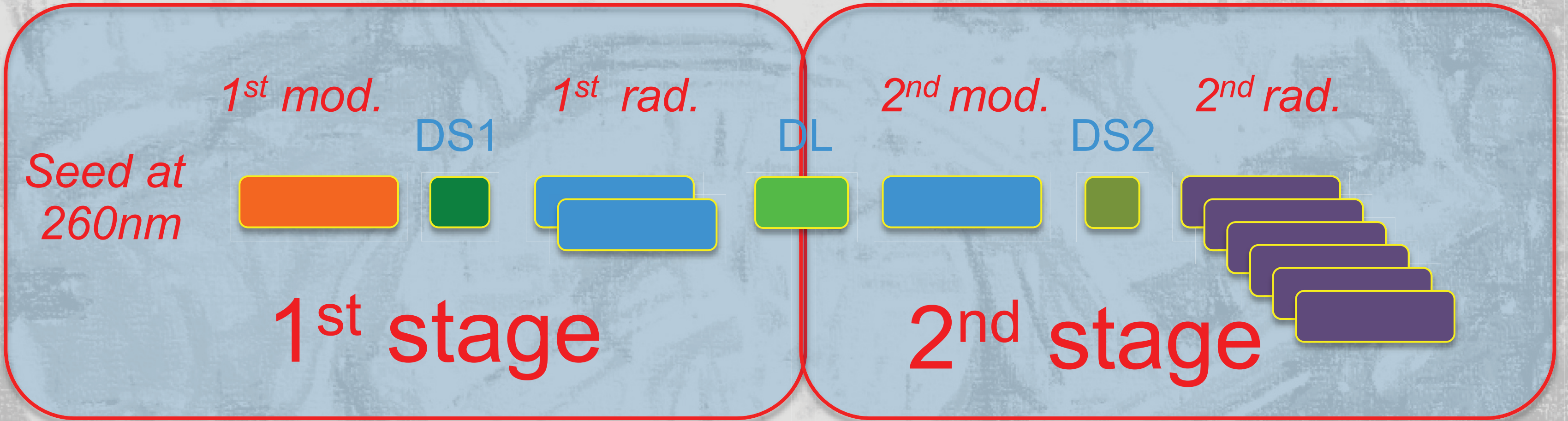




FEL-2 : Double stage cascaded FEL based on the Fresh bunch injection technique



The Fresh Bunch Injection Technique*



Two HGHG FELs stages

- The first stage is seeded by the Ti:Sa 3rd harmonic
- The second stage is seeded by the first stage FEL
- The two FELs operate with the same e-beam

*L. H. Yu, I. Ben-Zvi, Nim 1993

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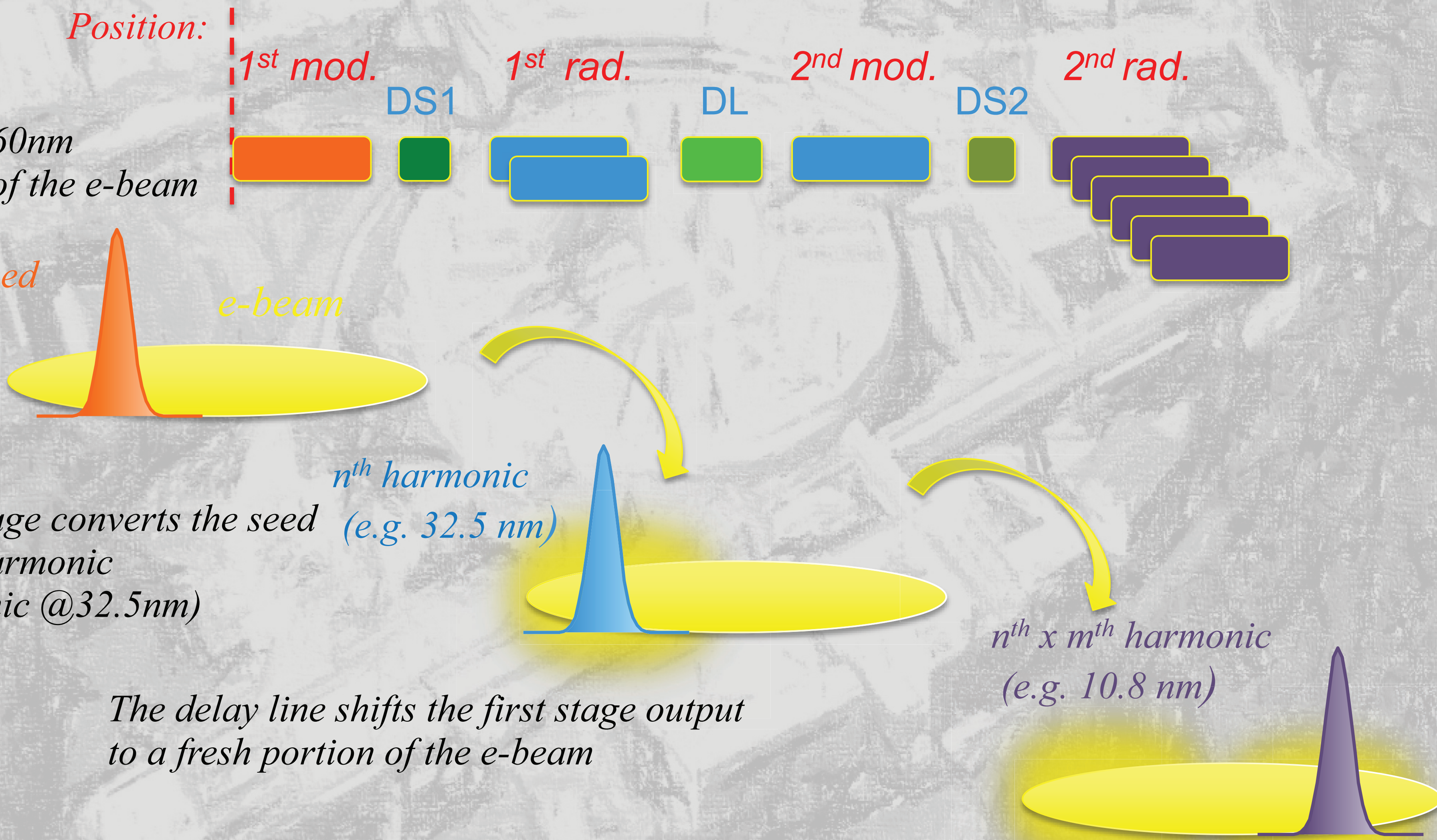
The Fresh bunch injection technique



The seed @260nm is on the tail of the e-beam

The first stage converts the seed to the n^{th} harmonic (8^{th} harmonic @32.5nm)

The delay line shifts the first stage output to a fresh portion of the e-beam

The second stage converts the first stage to the n^{th} x m^{th} harmonic of the seed

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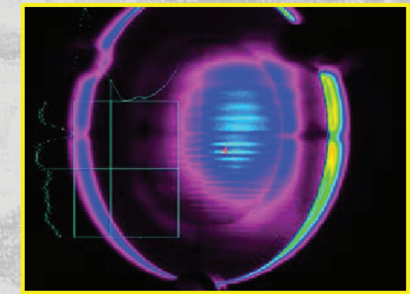
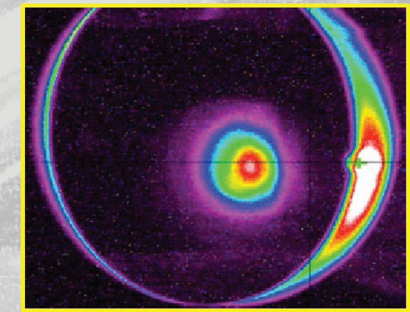
First lasing of FEL-2

STEPS

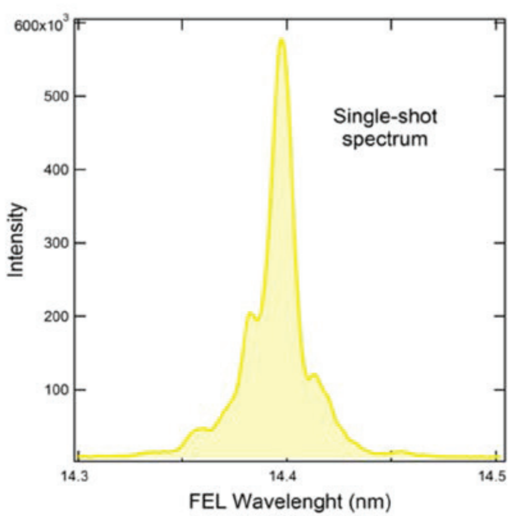
1. Lase with first stage at 43nm, 6th harmonic of the seed
2. Align the first part of the electron orbit with the output of the first stage, and ensure the superposition of “seed” and electrons in the second modulation stage
3. Use filters (Pd, Zr) to cut light at “long” wavelengths and distinguish emission from first and second stage
4. With the delay line off, lase in whole bunch mode, i.e. coherent electron modulation (and induced energy spread) transported from the first to second stage. Optimize orbit and matching to the undulator beamline, also with all the undulators in the second stage tuned at 14.4nm (6th x 3rd harmonic of 260nm)
5. Turn on the delay line verifying the stability of the orbit and optimize output vs. seed intensity and vs. the first and second dispersive sections strength





First light with delay line on (in fresh bunch mode) on October 11th 2012

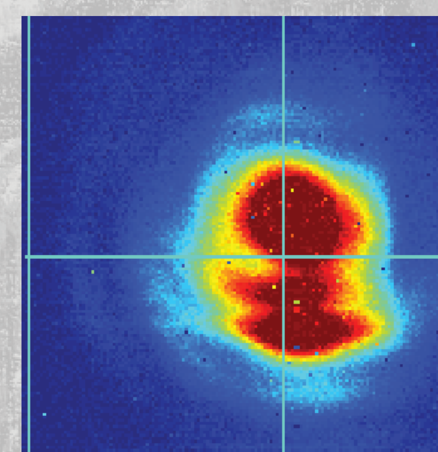
Spectrum



6th x 3rd harmonic of the seed (260nm)

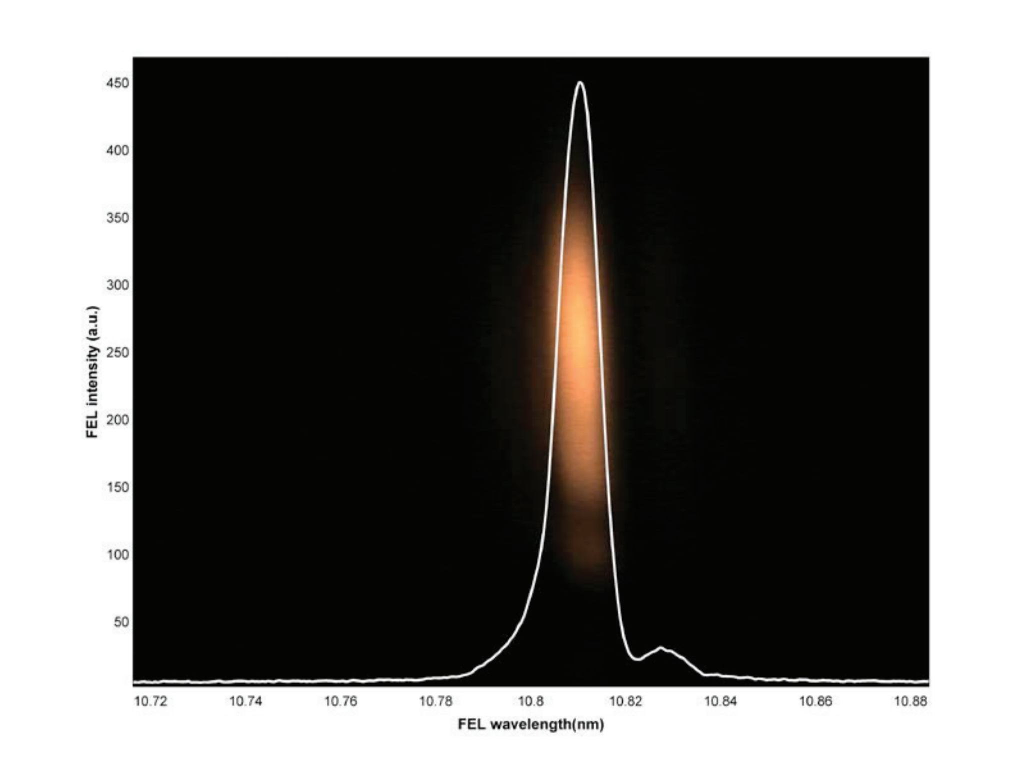
14.4nm

October 12th 2012

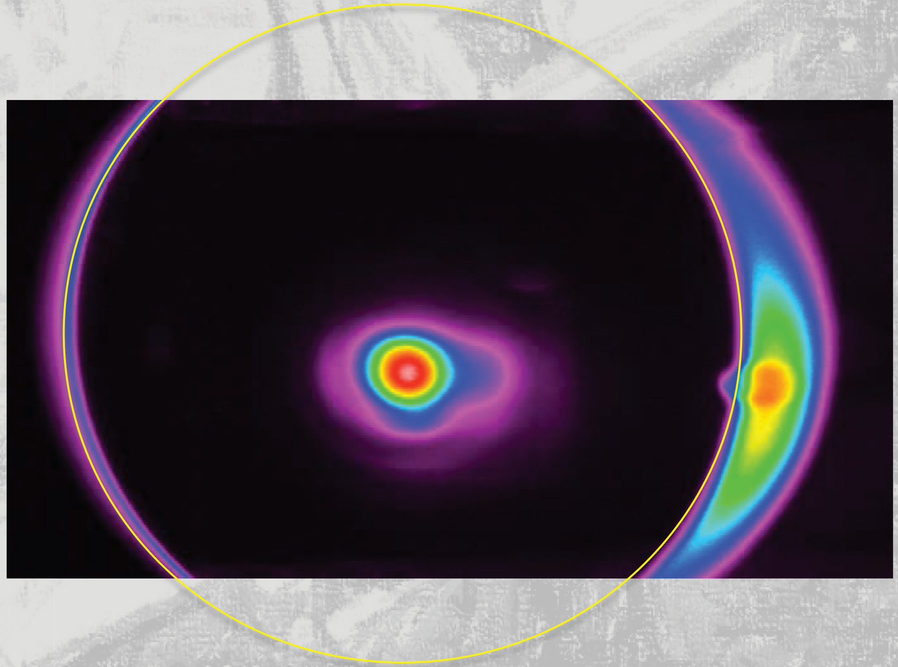


FEL-2 First commissioning shifts*

Narrow linewidth, single mode spectrum @ 10.8nm



Gaussian like transverse mode



During the October run the FEL was optimized at 10.8nm (24h)

* *E. Allaria et al. "Two Stage, Seeded Soft X-Ray Free-Electron Laser", submitted to Nature Photonics*

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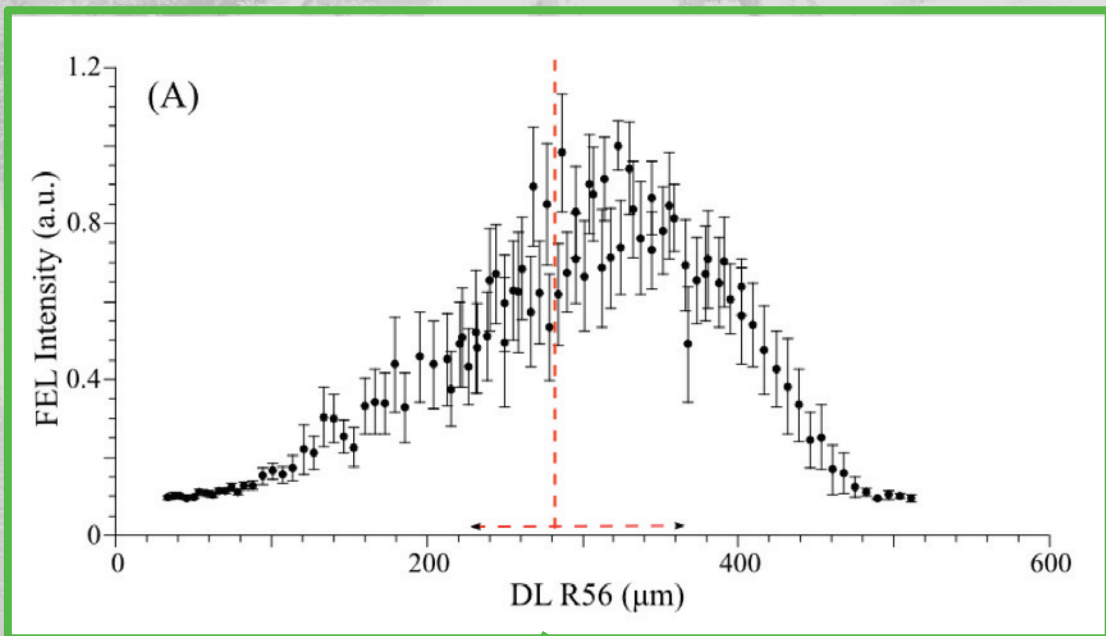
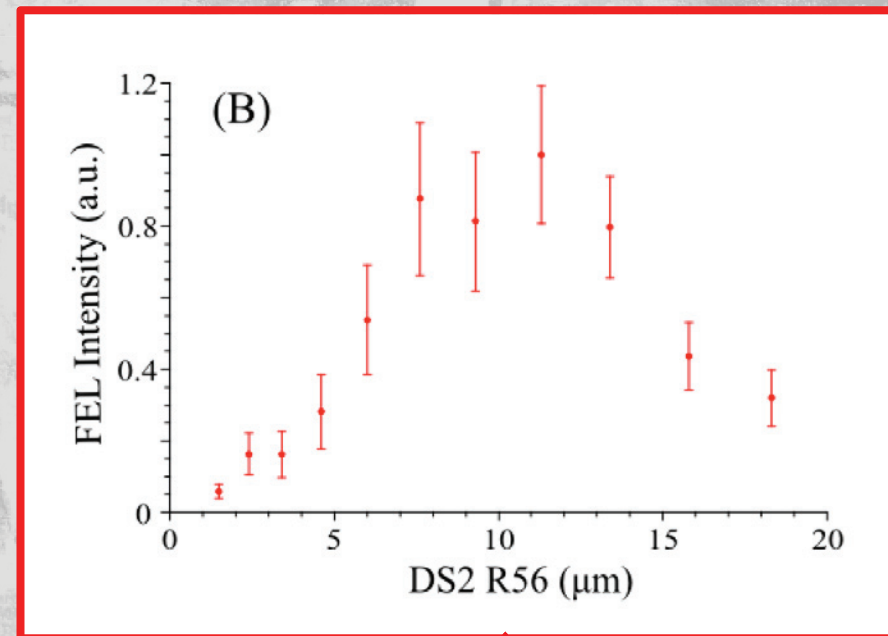
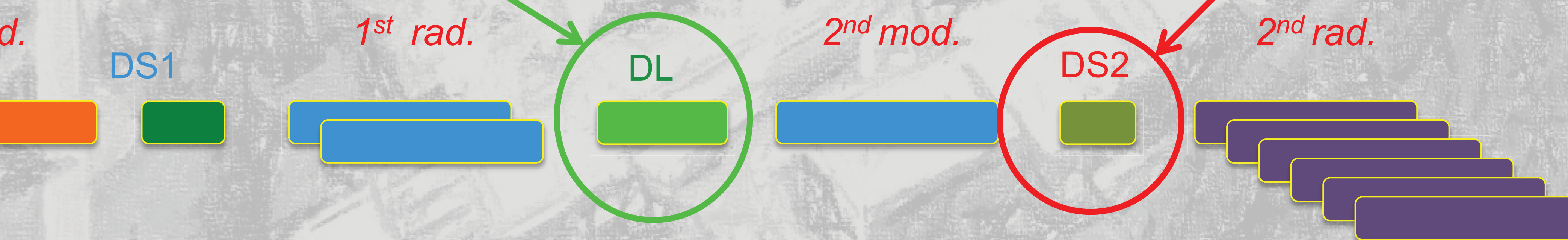
A proof of "fresh bunch" effect







The sensitivity of the output intensity to dispersion BEFORE and AFTER the second modulator is very different

➔ Energy modulation is occurring on fresh electrons at the 2nd modulator

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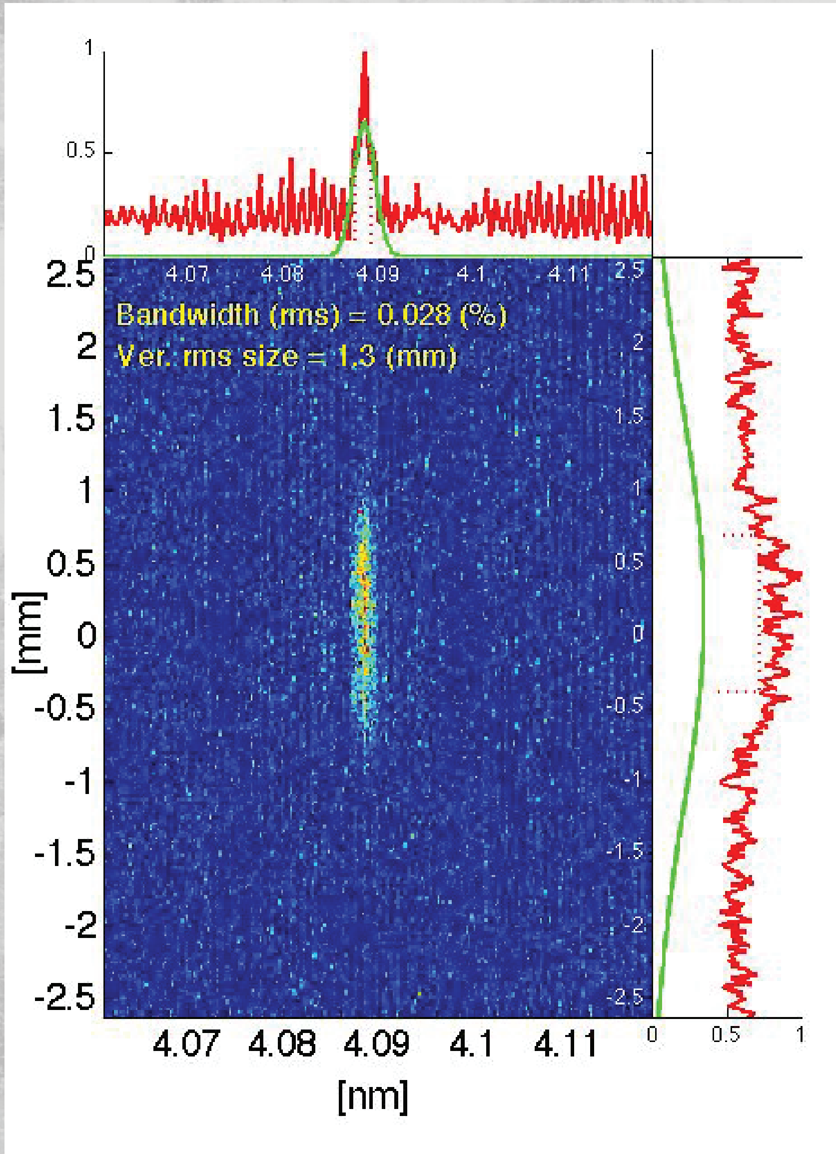
Increasing the electron beam energy - 4.09 nm

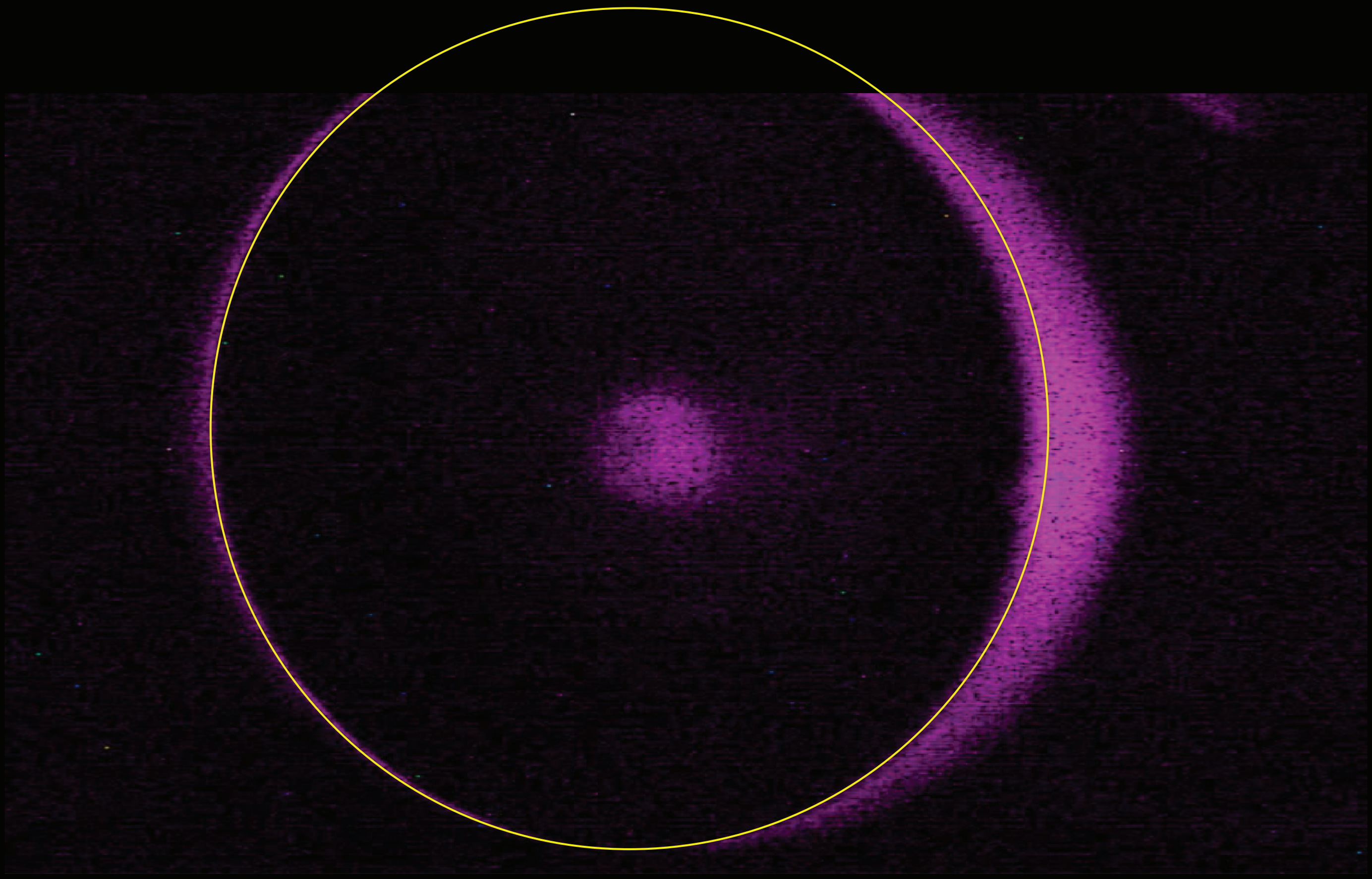


Spectrum measured with e-beam 1.4 GeV

Spectrometer efficiency much lower than at 10.8nm.

Energy per pulse >1uJ

FERMI FEL-2



78 harmonic of the seed laser (261.3 nm,
first stage @6th harmonic & 2 stage @13th harmonic)
Coherent emission at **3.35 nm** (about 25nJ)

Looking forward

Courtesy of F. Capotondi

… more on FERMI during the conference

- THIANO01 Double Stage Seeded FEL With Fresh Bunch Injection Technique, E. Allaria
- TUIANO01 Seed Laser Configurations for Advanced Pump-probe Schemes With FELs, M. Danailov
- MOOCNO01 Emittance Control in the Presence of Collective Effects in the FERMI@Elettra Free Electron Laser Linac Driver, S. Di Mitri
- TUOCNO01 Electron Beam Longitudinal Phase Space Manipulation by Means of an AD-HOC Photoinjector Laser Pulse Shaping, G. Penco
- TUOBNO02 Optical-EUV Pump and Probe Experiments With Variable Polarization on the Newly Open LDM Beamline of FERMI@Elettra, P. Finetti
- THOANO03 Experimental Characterization of the Laser Heater Effects on a Seeded FEL, E. Ferrari
- THOCNO04 Jitter-free Time Resolved Resonant CDI Experiments Using Two-color FEL Pulses Generated by the Same Electron Bunch, M. Zangrando

And the posters …

- MOPSO02 Measurement of Electron-Beam and Seed Laser Properties Using an Energy Chirped Electron Beam, E. Allaria et al.
- **TUPSO93** Photon Beam Spectral Distribution Determination and Advanced Focusing Systems: Two Key Technologies for the First Successful Experiments at FERMI@Elettra FEL, M. Zangrando et al.
- WEPSO67 Progress with the FERMI Laser Heater Commissioning, S. Di Mitri et al.,
- WEPSO22 FERMI@Elettra Status Report, LG et al.

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The success of the FERMI@Elettra project depends on the work of the entire FERMI team and of the staff of Elettra-Sincrotrone Trieste

Team organization at http://www.elettra.trieste.it/lightsources/fermi/fermi-management-page.html

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Thank you