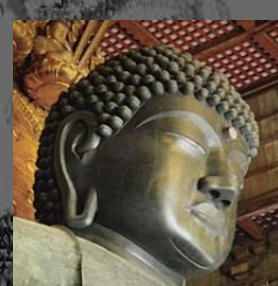
First Lasing of FERMI FEL-2 (1° stage) and FERMI FEL-1 recent results update

Luca Giannessi

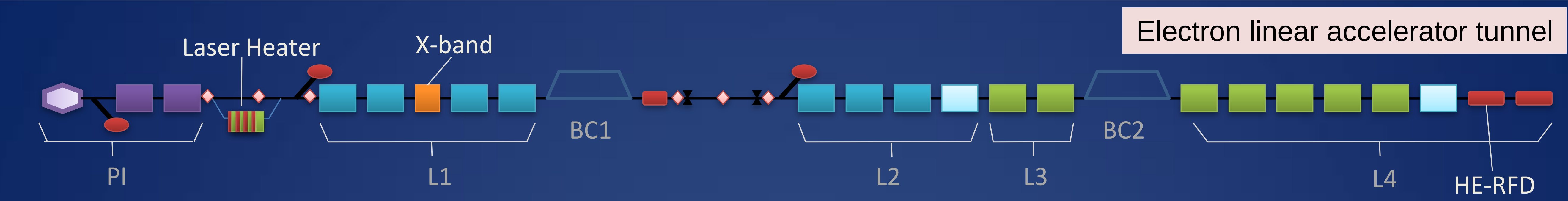
Sincrotrone Trieste and ENEA

on behalf of the FERMI commissioning team

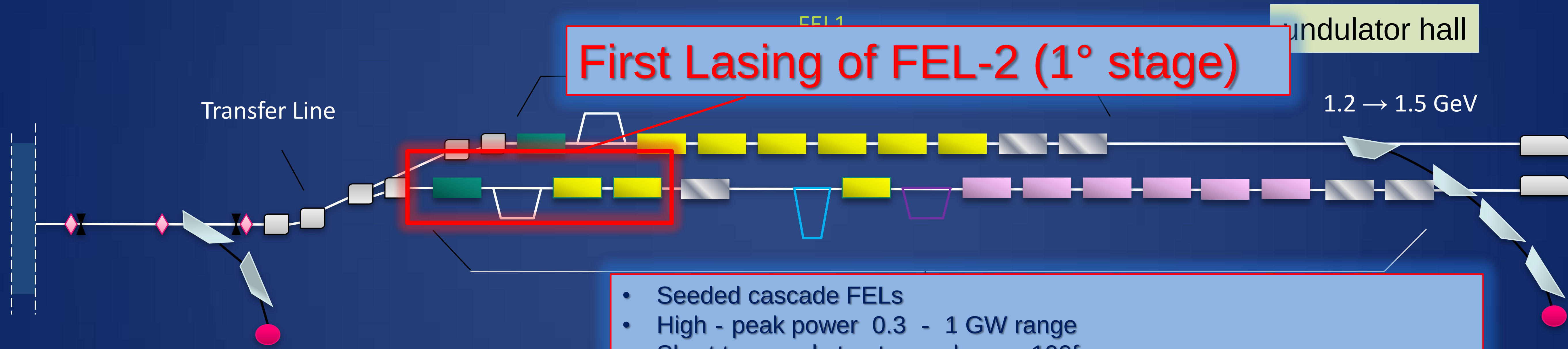


34th International
Free Electron Laser Conference
26-31 August 2012
Nara Prefectural New Public Hall, Nara, Japan

FERMI LAYOUT



First Lasing of FEL-2 (1° stage)

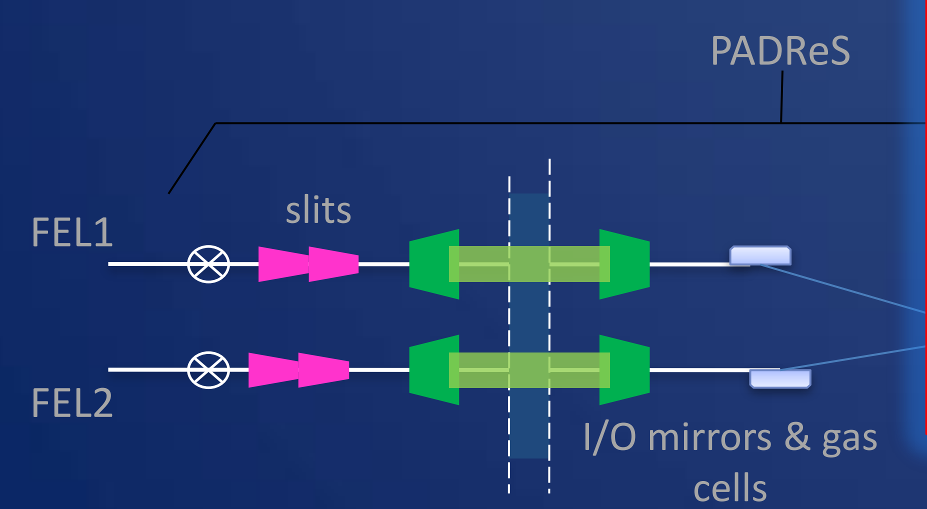


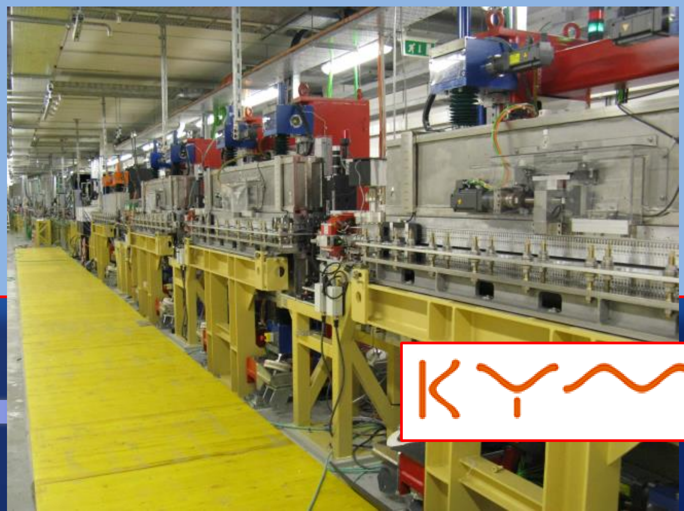
- Seeded cascade FELs
- High - peak power 0.3 - 1 GW range
- Short temporal structure sub ps →100fs
- Longit. and transv. Coherence
- Tunable wavelength APPLE II - type Undulators variable polarization horizontal/circular/vertcal from KYMA
  1 mod + 6 rad in FEL 1 &
  2 mod + 8 rad in FEL-2

Spectral Ranges

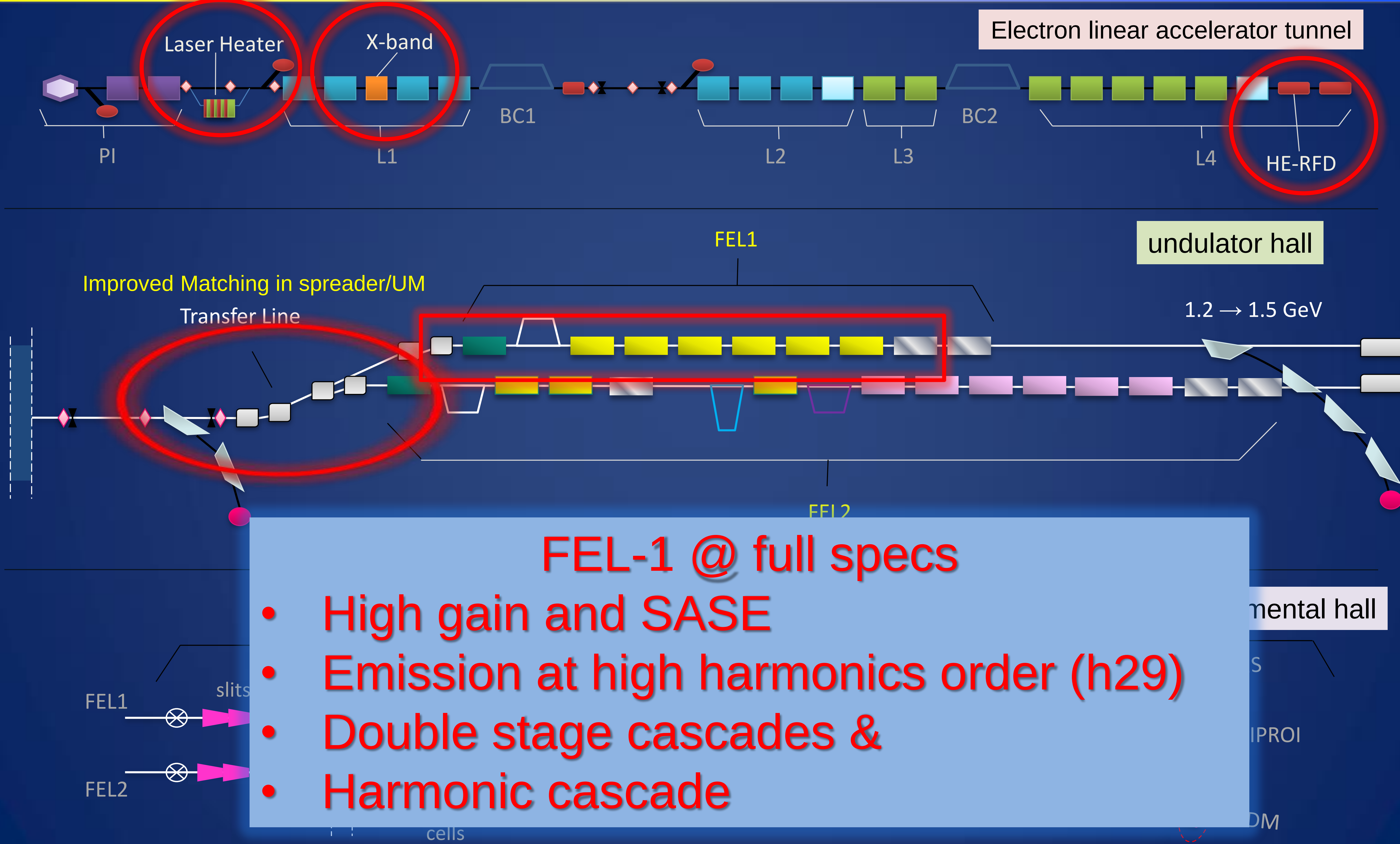
FEL-1: 80 - 20 nm

FEL-2: 20 - 4 nm





FERMI LAYOUT



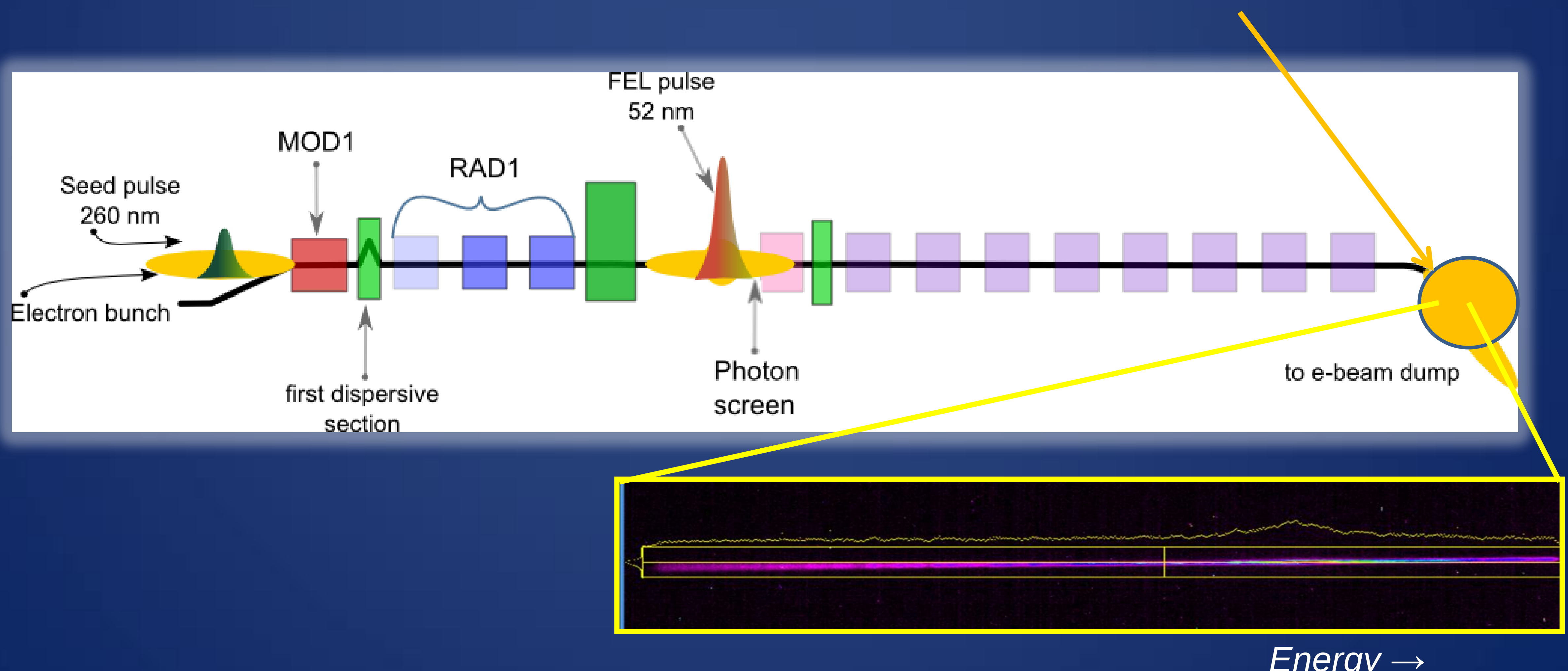
FEL-1 @ full specs

- High gain and SASE
- Emission at high harmonics order (h29)
- Double stage cascades &
- Harmonic cascade

FERMI FEL-2 First lasing

- Main goal was to achieve evidence of coherent emission from FIRST STAGE (one modulator – two radiators) to
  - Test Alignments of various components
  - demonstrate that installed systems were properly working

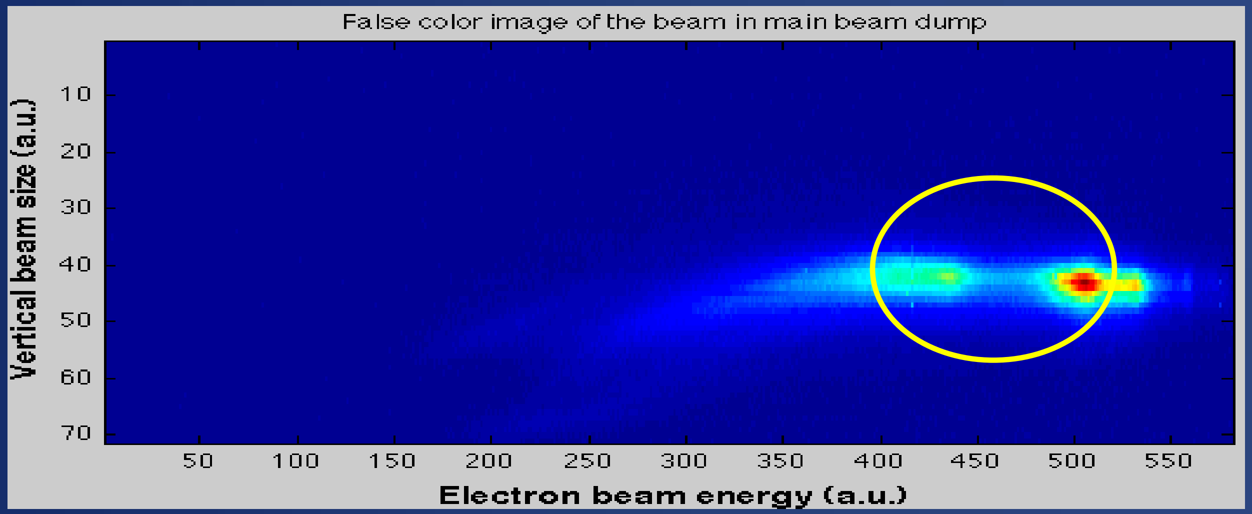
- Available diagnostic only consists of IUFEL screens and a YAG screen in PADReS and electron energy spectrometer after the undulator

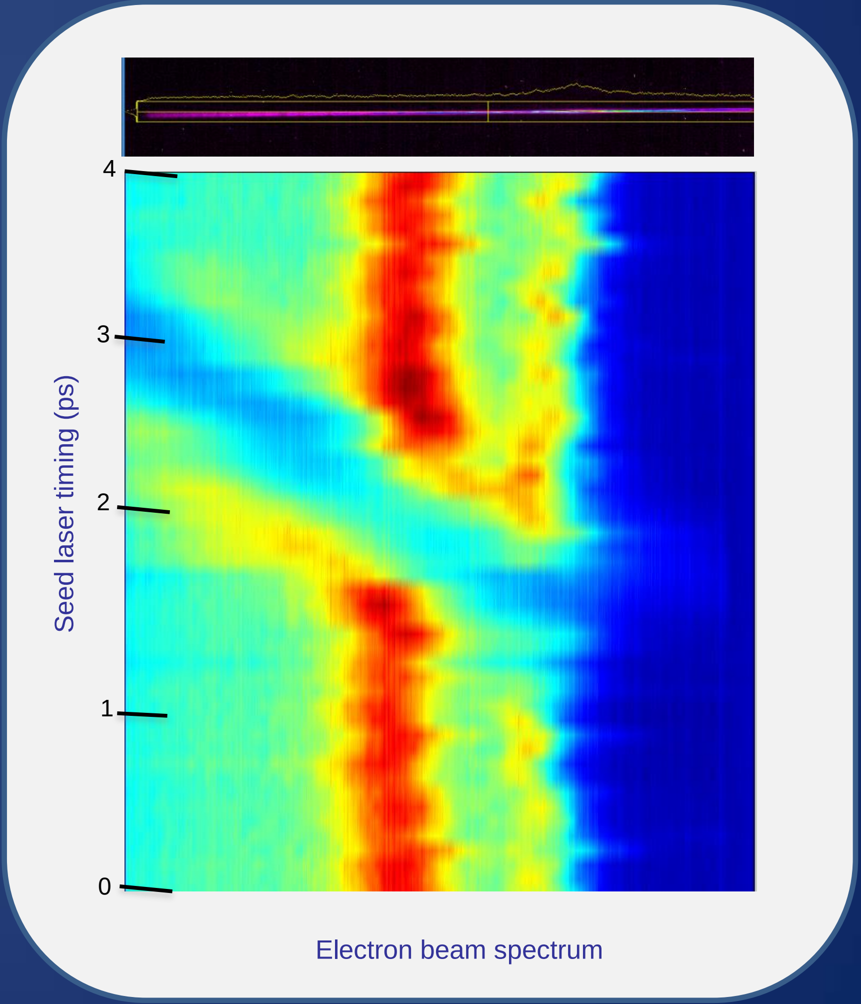


FERMI FEL-2 First lasing

- To detect a non optimized FEL we first look for the interaction between the electron beam and the seed laser looking at the e-beam spectrum.
- The laser induced energy spread on the beam is clearly visible on an energy/phase chirped beam and allow to optimize the seed synchronization

Delay line scan

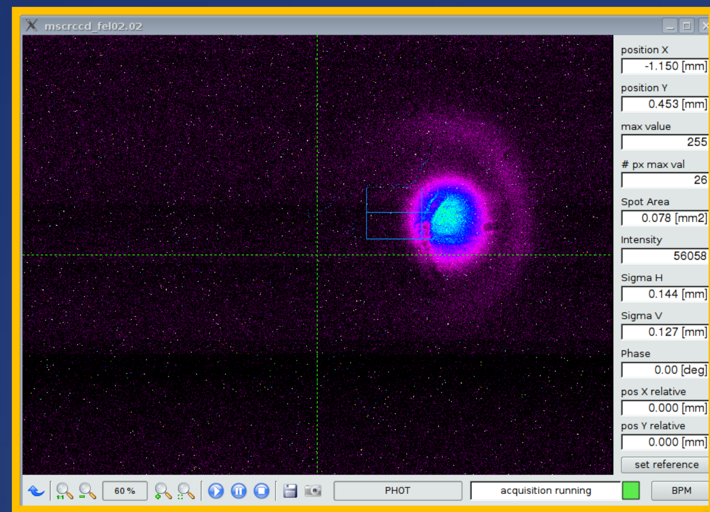


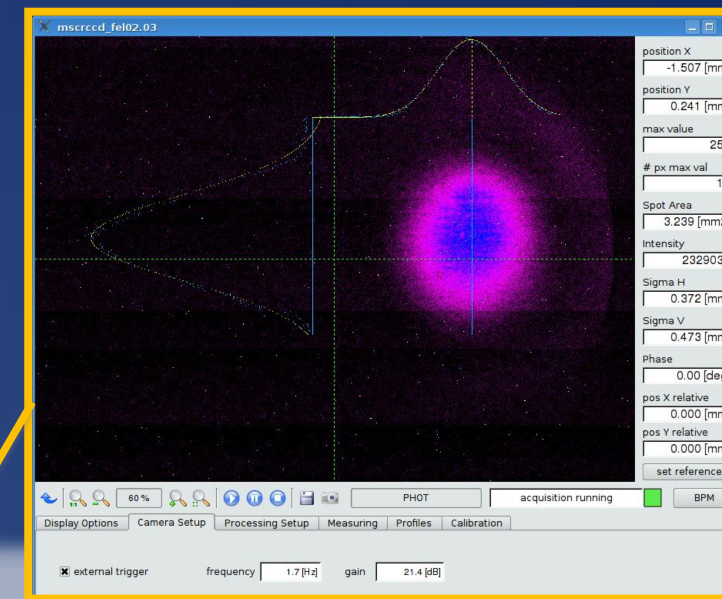


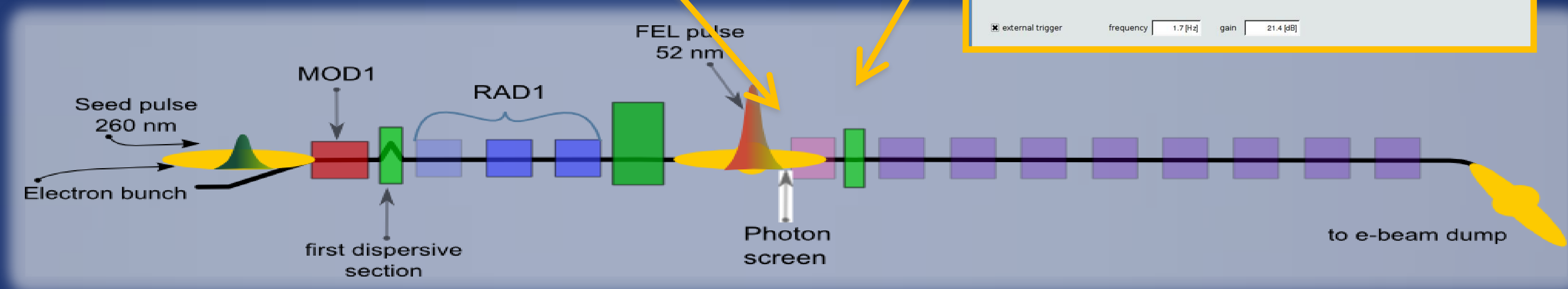
Heated electrons show up as a «hole» in the energy distribution (example from FEL-1 commissioning)

FERMI FEL-2 First lasing (cont…)

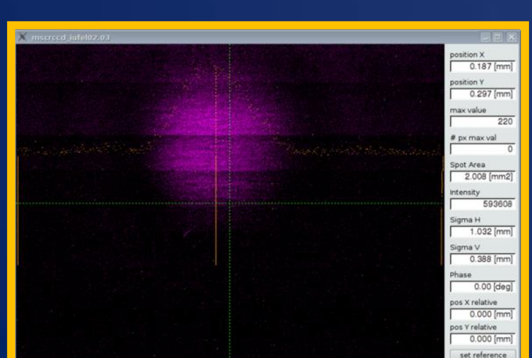
After a quick optimization of parameters we detected photons at 52 nm in the two screens after the radiator.

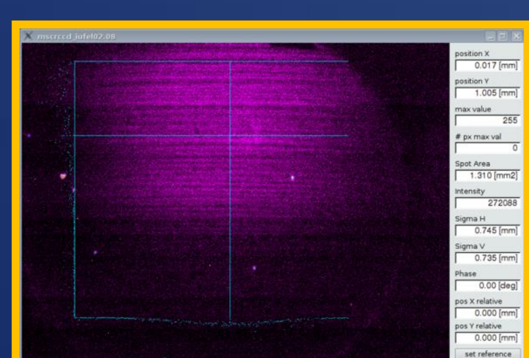


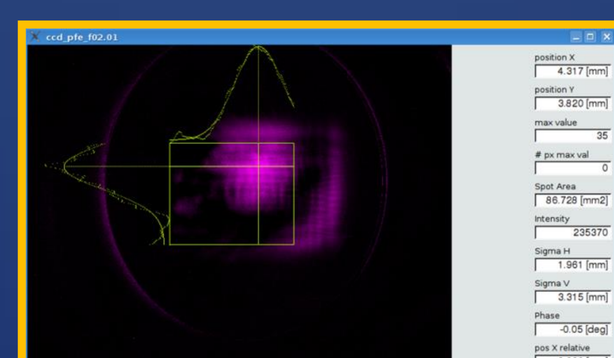


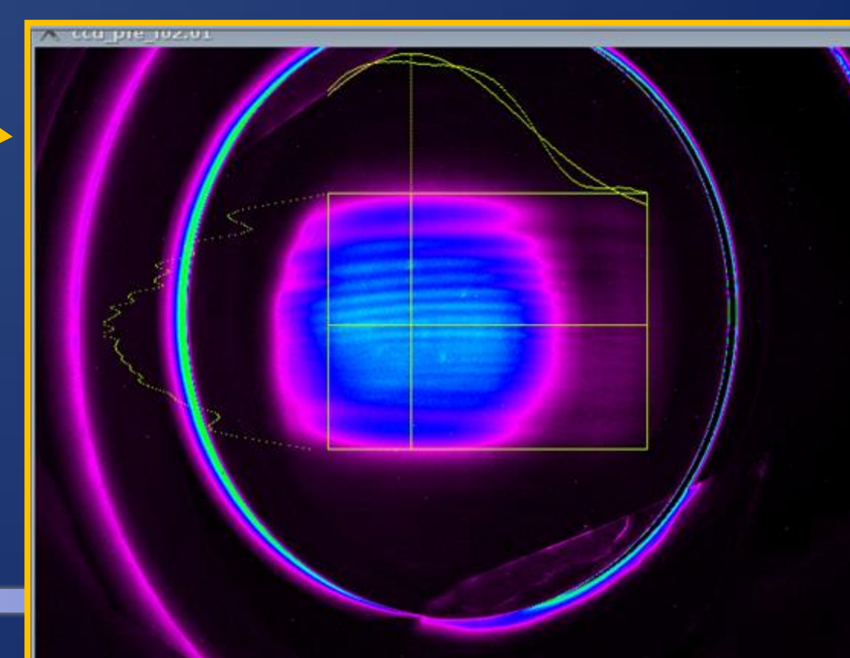


The (few) available screens and irises in between radiators allowed to transport the beam to diagnostics at the end. The FEL spot has been clearly seen on the YAG installed in PADReS, 55 m far from the emitting radiator.







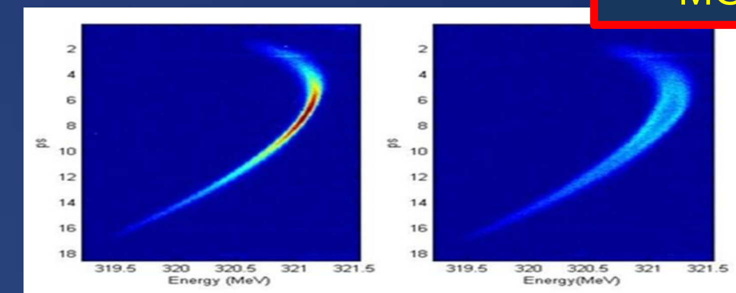


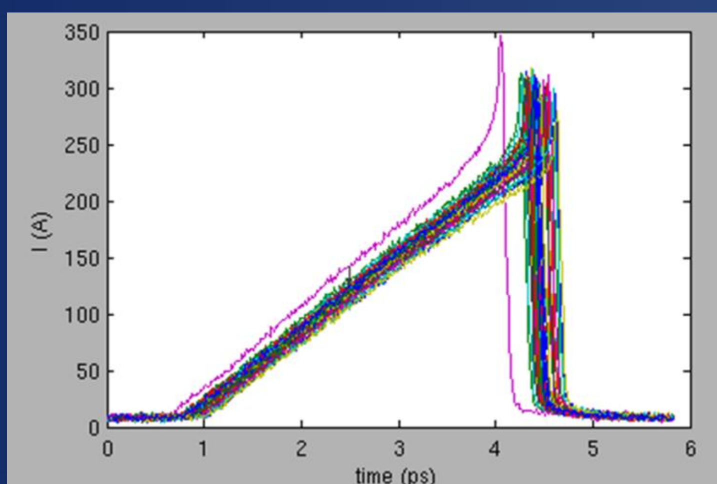
FERMI FEL-1 increase of performances

New «Tools» available to control of longitudinal phase space

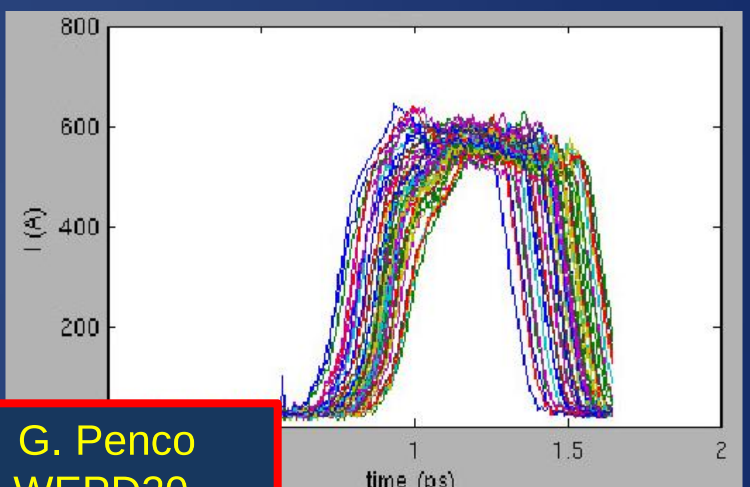
S. Spampinati
MOPD58

- High Energy RF Deflector
- Laser Heater
- X-Band cavity for phase space linearization



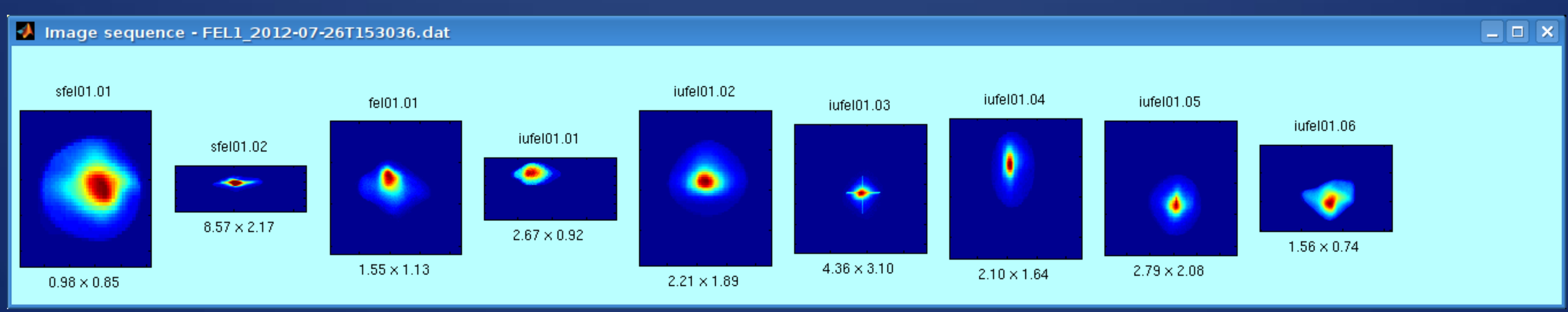


- Higher peak current (500-600A)
- Lower energy spread (dep. on laser heater)
- Uniform beam parameters over a longer time interval (400-500 fs)



G. Penco
WEPD20

Beam based alignment of magnetic components and better control of beam optics and orbit through spreader/injection line and undulator

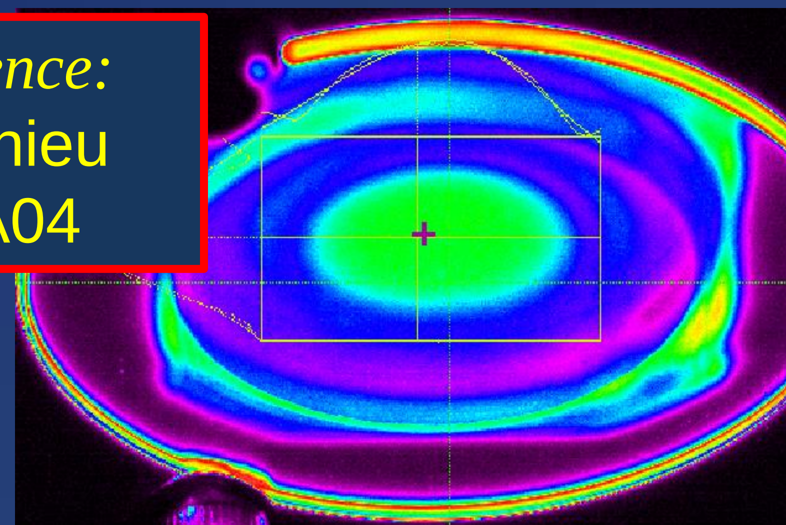


FERMI FEL-1 recent results

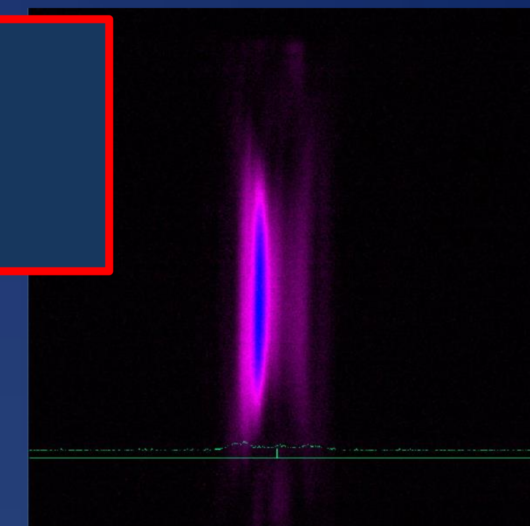
@ 52 nm

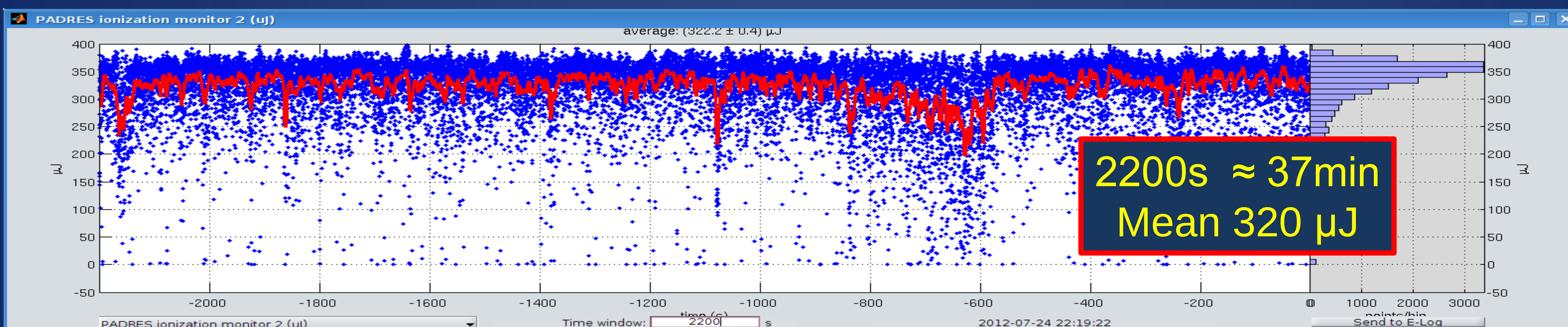
(h5)

Coherence:
B. Mahieu
TUOA04

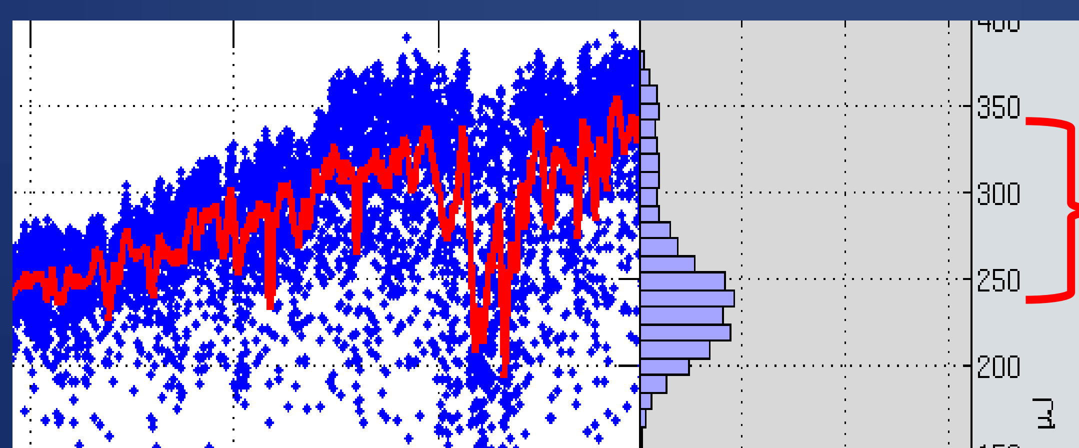


Spectrum:
E. Allaria
TUOB02

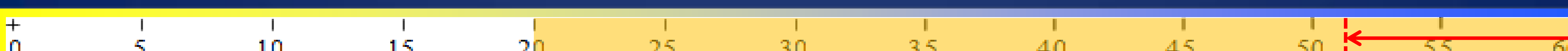




2200s ≈ 37min
Mean 320 μJ



Optimization via taper of last three UM (up to $\Delta\lambda/\lambda \approx 1.8\%$)



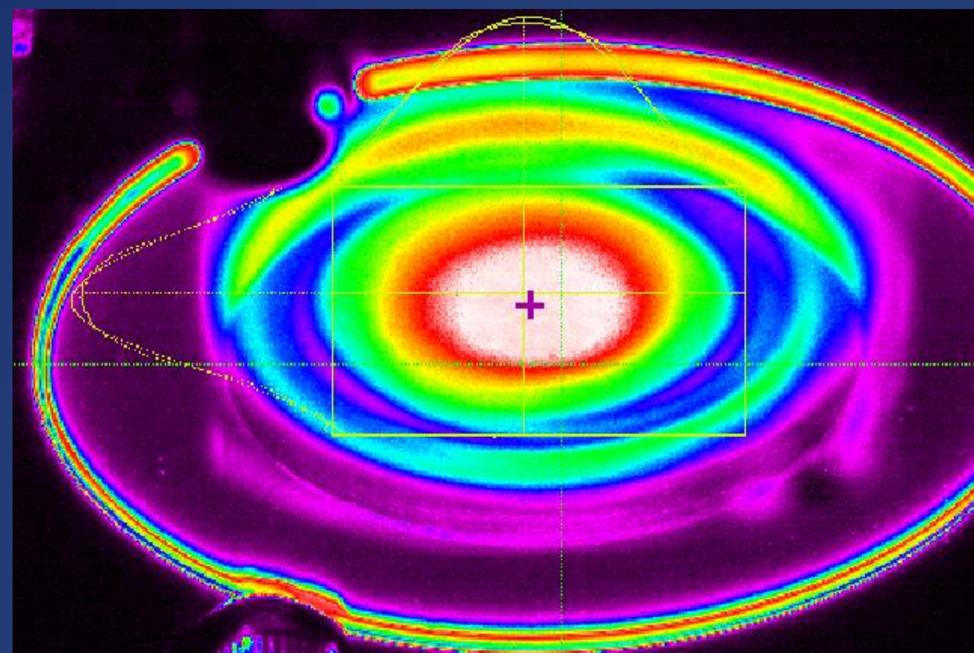
Wavelength (nm)

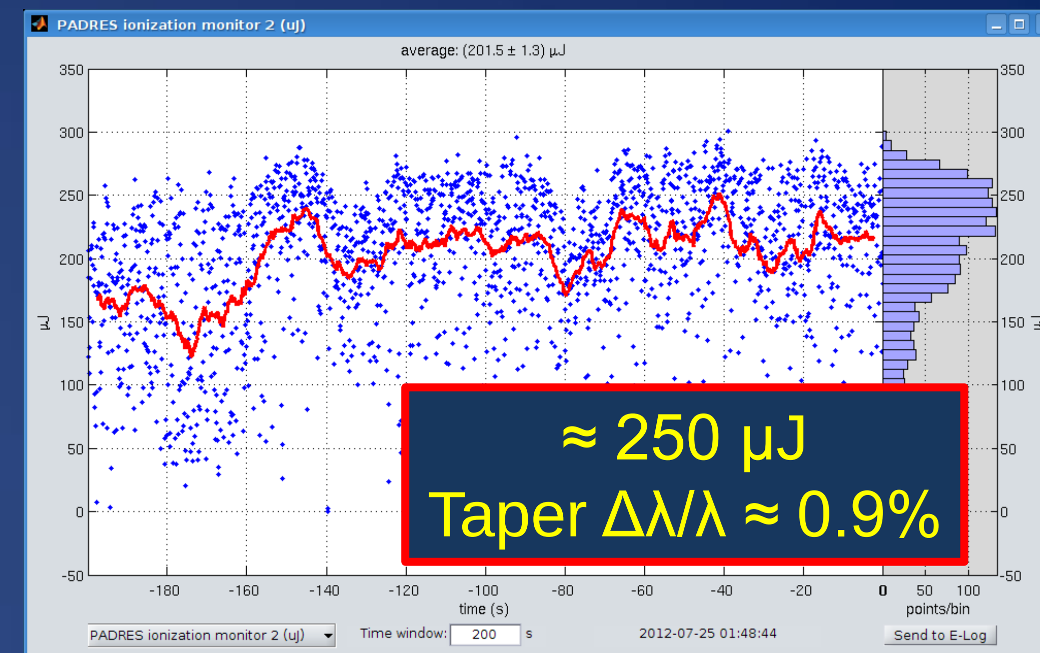
FEL-1 wavelength range

FERMI FEL-1 recent results

@ 26 nm

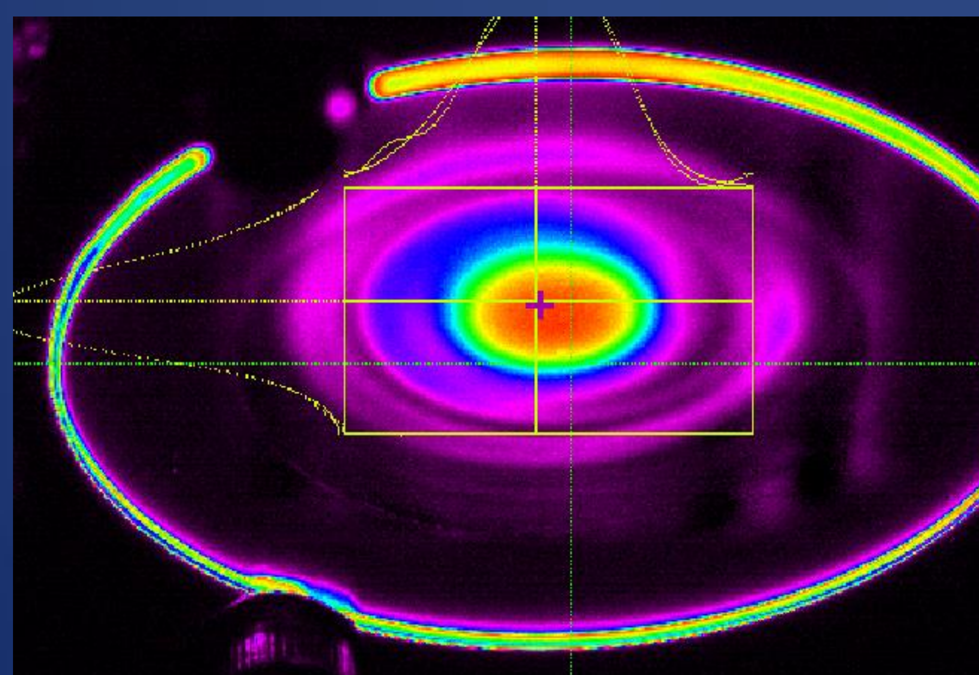
(h10)

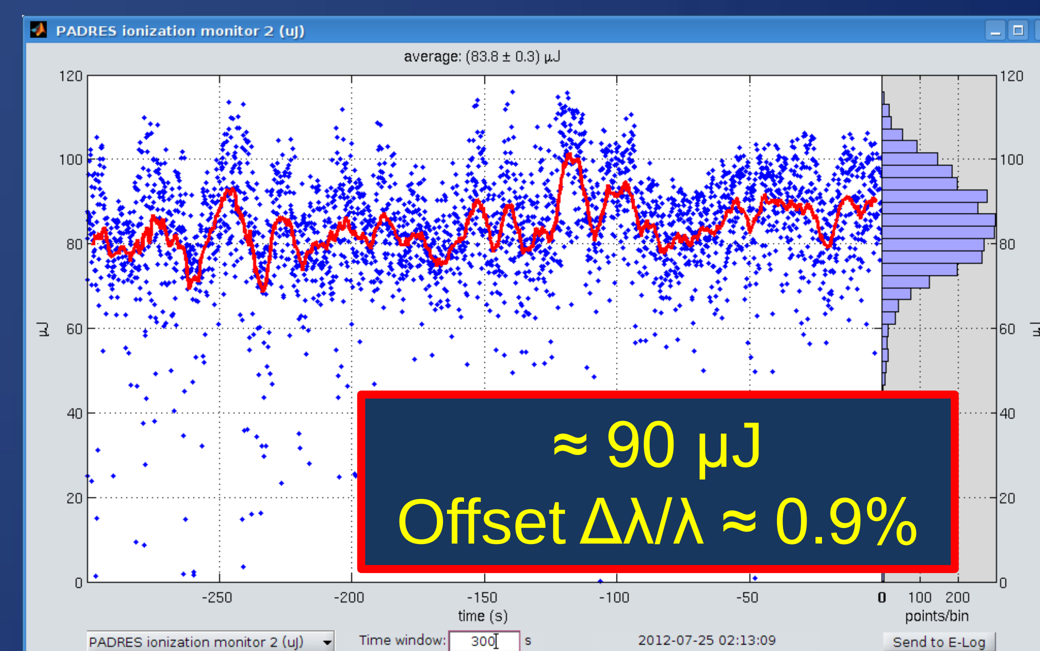




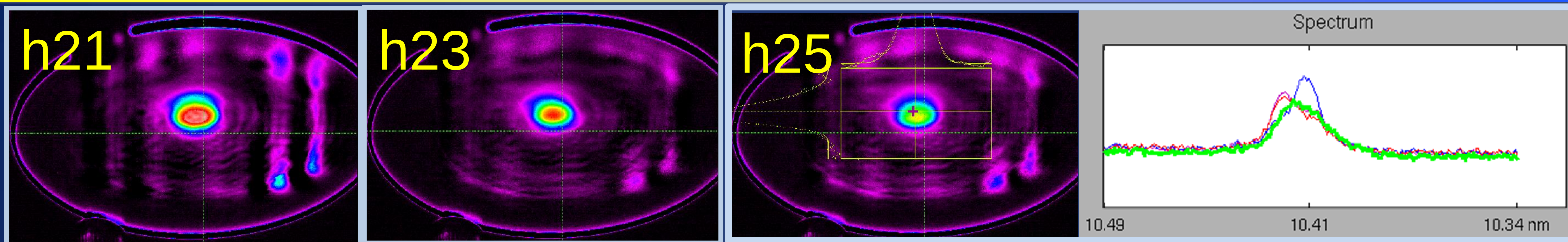
@ 20 nm

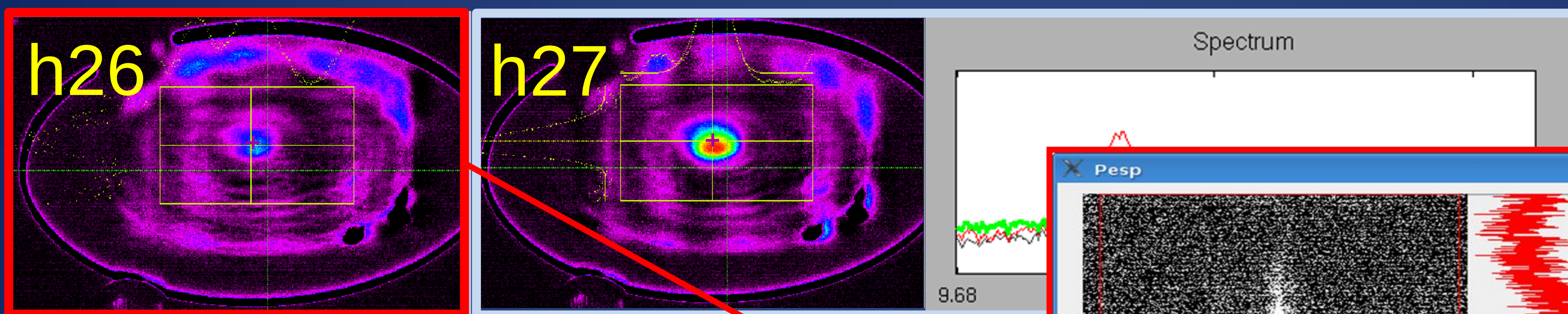
(h13)

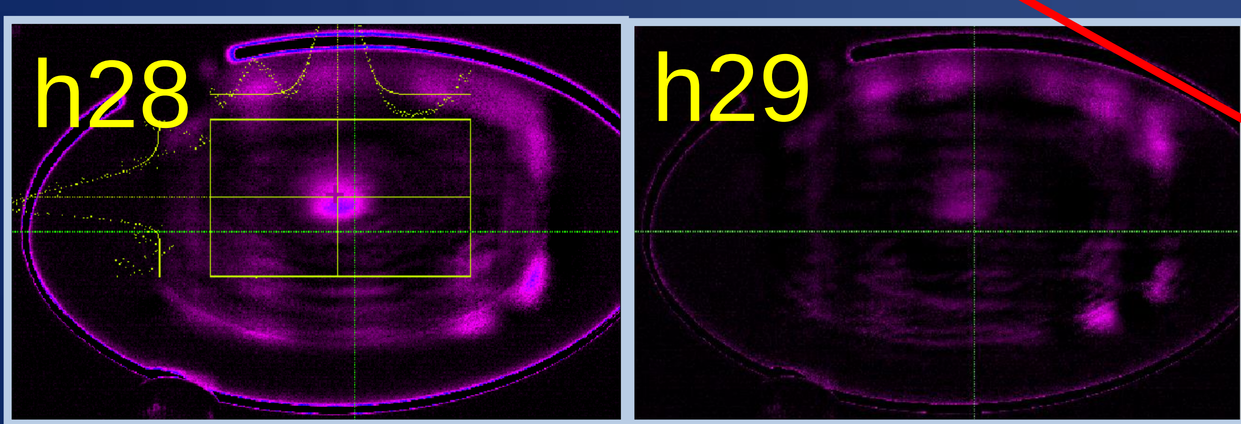


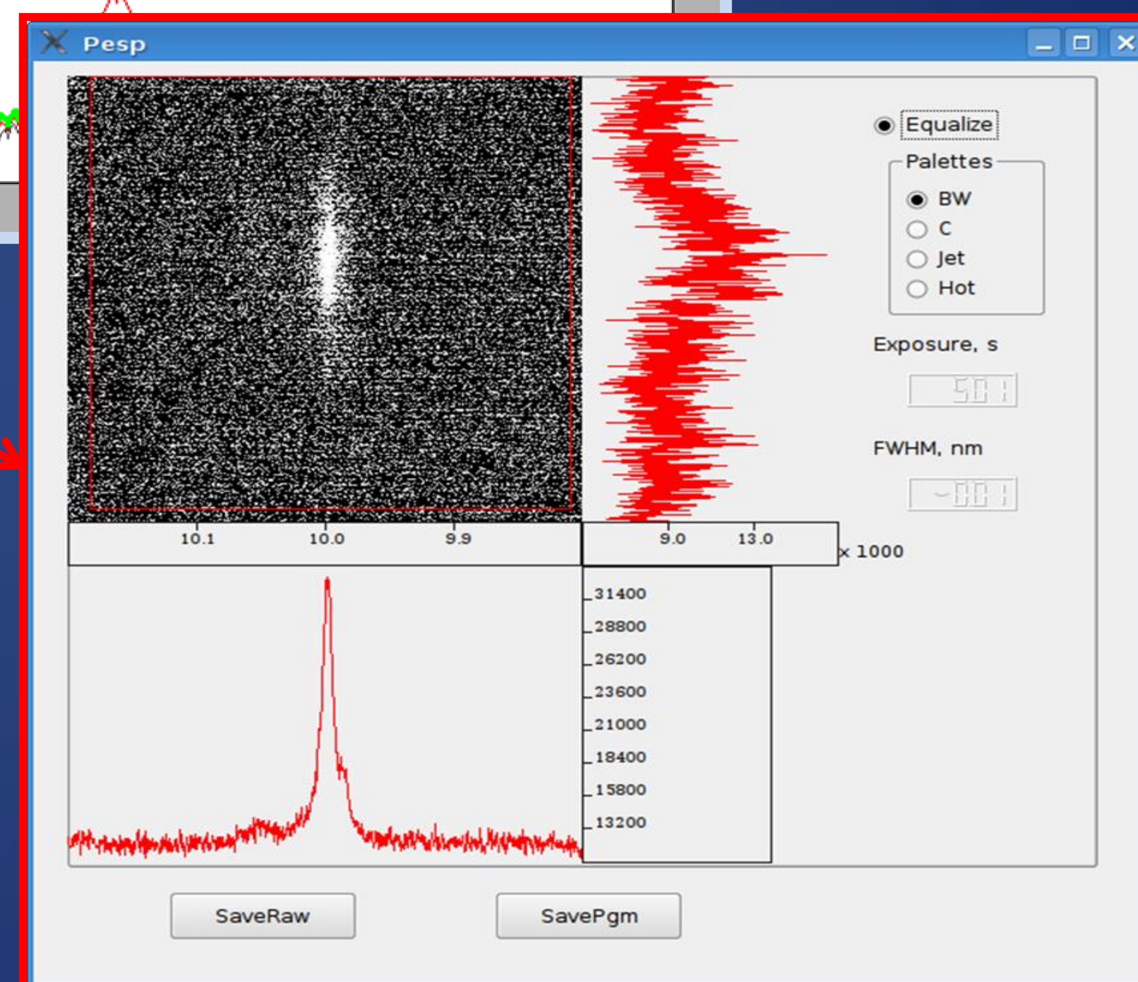


FERMI FEL-1 high harmonic conversion







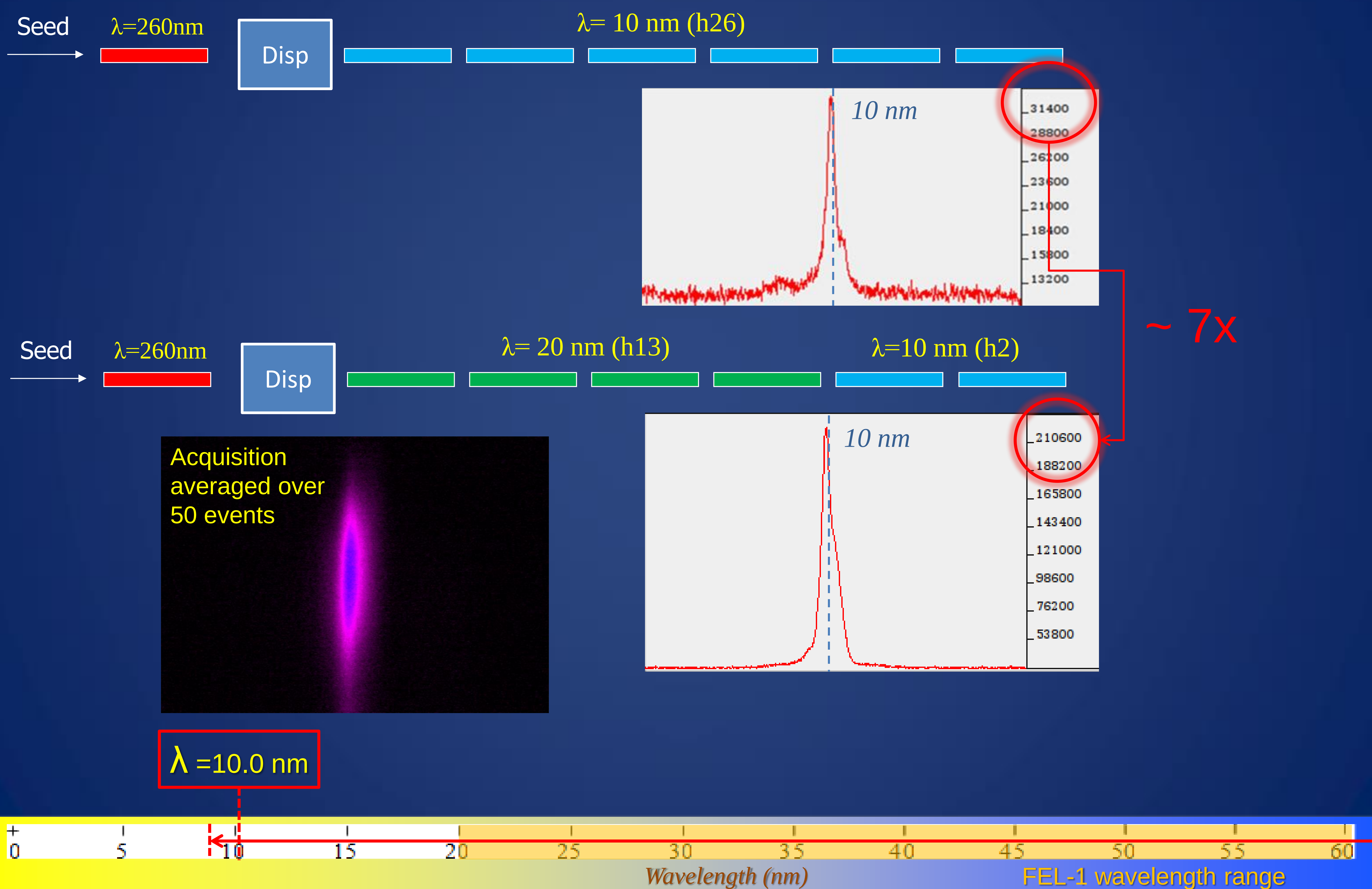


We could not measure intensities because of the interference of longer wavelength radiation mainly emitted off axis

λ = 8.96 nm

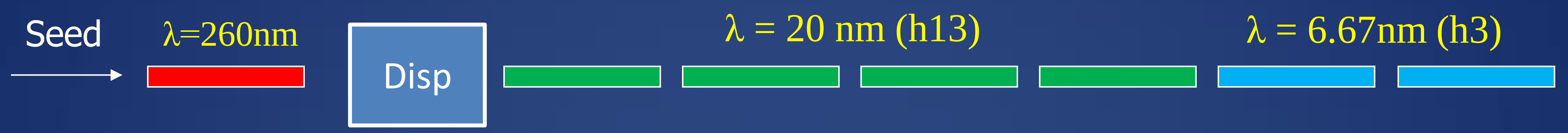
λ = 12.38 nm

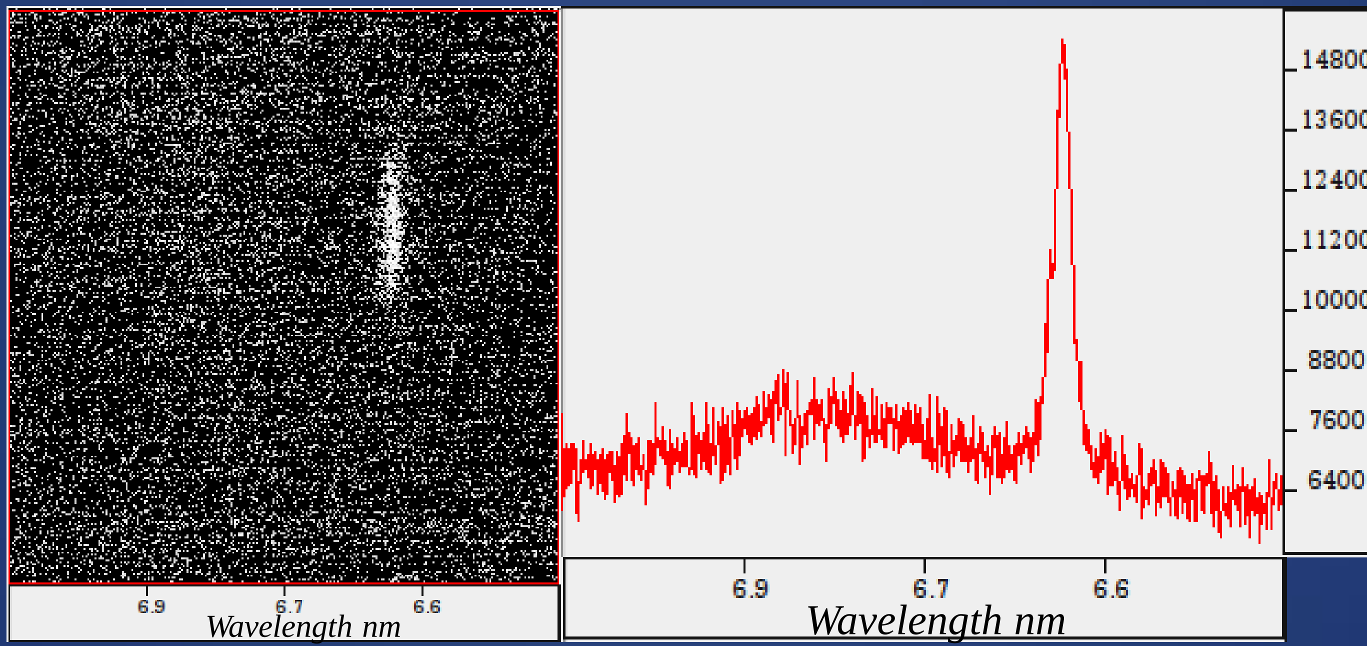
FERMI FEL-1 double stage cascade



FERMI FEL-1 double stage cascade

The last two undulators tuned to h3 of the previous ones

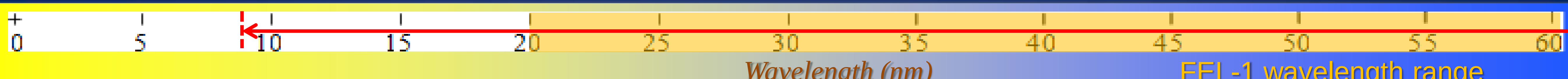




K (peak) ≈ 0.61

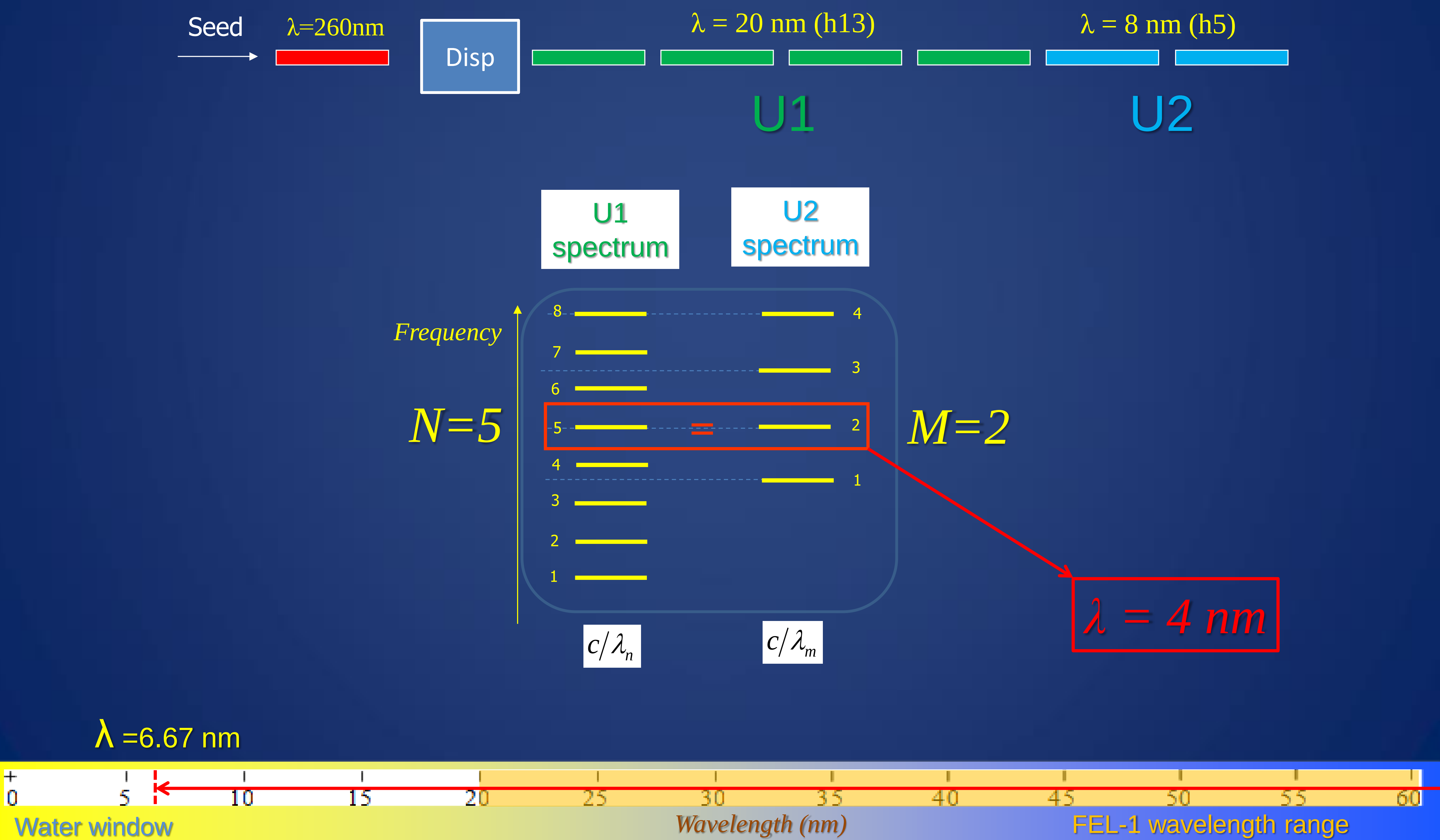
λ = 6.67 nm

λ =8.97 nm



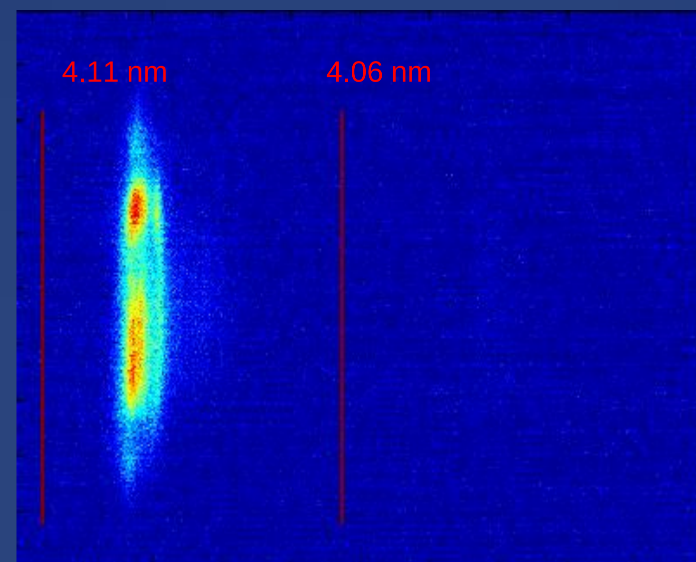
FERMI FEL-1 harmonic cascade*

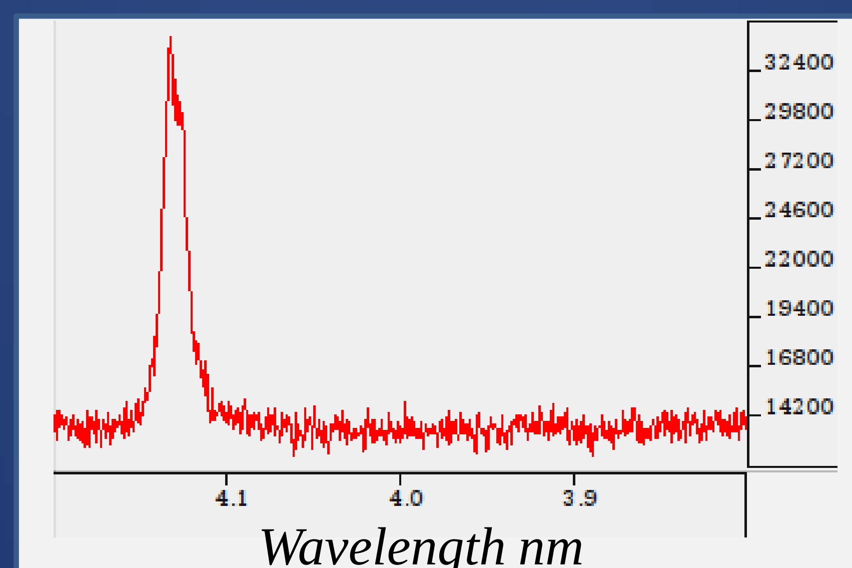
* L. Giannessi, P. Musumeci, New Journal of Physics 8 (2006) 294



FERMI FEL-1 harmonic cascade

First evidence of coherent emission in the water window from a seeded FEL





h65

λ = 4.16 nm
λ = 16.67 nm

Summary

- First lasing of the first stage of FEL-2
- FEL-1 in user operation at specifications in the range 20nm → 52nm
- High harmonic order multiplication factor observed from FEL-1
- First demonstration of
  - a double stage cascade seeded FEL
  - Harmonic cascaded FEL with coherent emission in the water window

… and the first lasing of FEL-2 first and second stage, in October (hopefully).

Users' Meeting Thematic Workshops for 2012

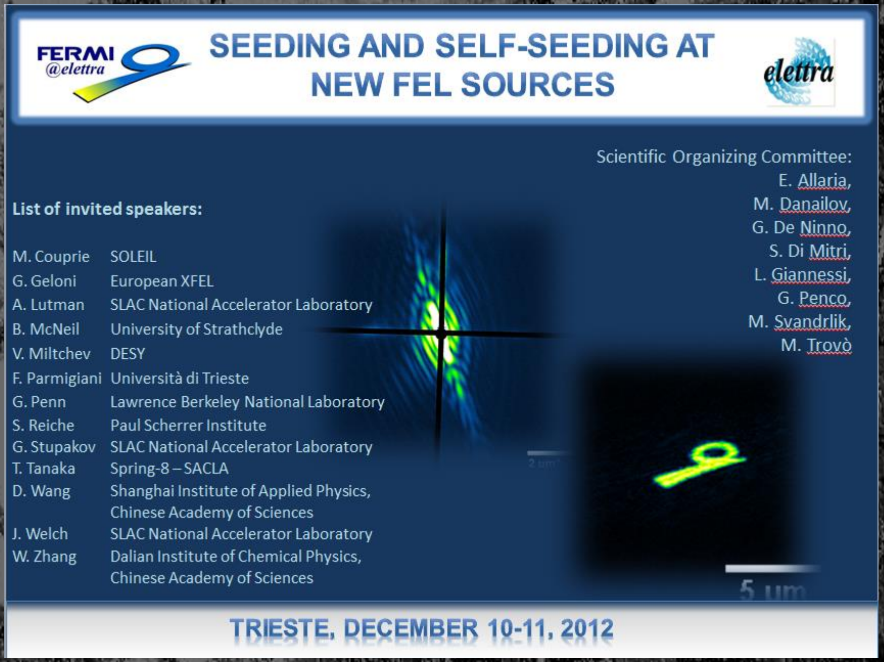
December, 10-11

Seeding and Self-seeding at New FEL Sources

Scientific Organizing Committee

E. Allaria, M. Danailov, G. De Ninno, S. Di Mitri, L. Giannessi, G. Penco, M. Svanderlik, M. Trovò

- **List of invited speakers:**
- M. Couprie SOLEIL
- G. Geloni European XFEL
- A. Lutman SLAC National Accelerator Laboratory
- B. McNeil University of Strathclyde
- F. Parmigiani Universita' di Trieste
- G. Penn Lawrence Berkeley National Laboratory
- S. Reiche Paul Scherrer Institute
- G. Stupakov SLAC National Accelerator Laboratory
- T. Tanaka Spring-8 – SACLA
- D. Wang Shanghai Institute of Applied Physics, Chinese Academy of Sciences
- J. Welch SLAC National Accelerator Laboratory
- W. Zhang Dalian Institute of Chemical Physics, Chinese Academy of Sciences



http://www.elettra.trieste.it/SSSFEL12/

FERMI Commissioning Team

E. Allaria, L. Badano, D. Castronovo, M. Danailov, G. D'Auria, G. De Ninno, S. Di Mitri, B. Diviacco, W. Fawley, E. Ferrari, L. Fröhlich, G. Gaio, E. Karantzoulis, B. Mahieu, G. Penco, C. Serpico, S. Spampinati, C. Spezzani, C. Svetina, M. Trovò, M. Veronese, M. Zangrando and myself.

… and we acknowledge the contribution of all the FERMI project office and collaborators: M. Svandrlik, D. Zangrando, F. Parmigiani, M. Cornacchia, W. Fawley, S. Tazzari

and of M. Danailov , A. Demidovitch, R. Ivanov, I. Nikolov, P. Sigalotti, for the maintenance and operation of the laser system,L. Raimondi, N. Mahne and the entire PADRES group for the development of the spectrometer and beamline diagnostic hardware of A. Fabris and the RF group, M. Ferianis and the timing and diagnostics group, M. Lonza and the controls group

Thank You

Summary of FERMI contributions

Coherence Properties of FERMI@Elettra
B.Mahieu TUOA04

Spectral Characterization of the FERMI Pulses in the Presence of Electron-beam Phase-space Modulations
E. Allaria TUOB02

Photon Beam Transport Systems at FERMI@Elettra: Microfocusing FEL Beam with a K-B Active Optics System
L. Raimondi THOA02

FERMI@Elettra Progress Report
Poster TUPD01

Commissioning of the FERMI@ELETTRA Laser Heater
Poster MOPD58

Dependence of FEL Intensity on the Available Number of Undulators for FERMI FEL-1
Poster WEPD11

Linear Polarization Control with Cross-polarized Helical Undulators at FERMI
Poster THPD21

Time-Sliced Emittance and Energy Spread Measurements at FERMI@Elettra
Poster WEPD20

34th International Free Electron Laser Conference
26-31 August 2012
Nara Prefectural New Public Hall, Nara, Japan