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FERMI: an overview with insights on Optical Timing System & Longitudinal Diagnostics

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Mario Ferianis

on behalf of Diagnostics and Timing group

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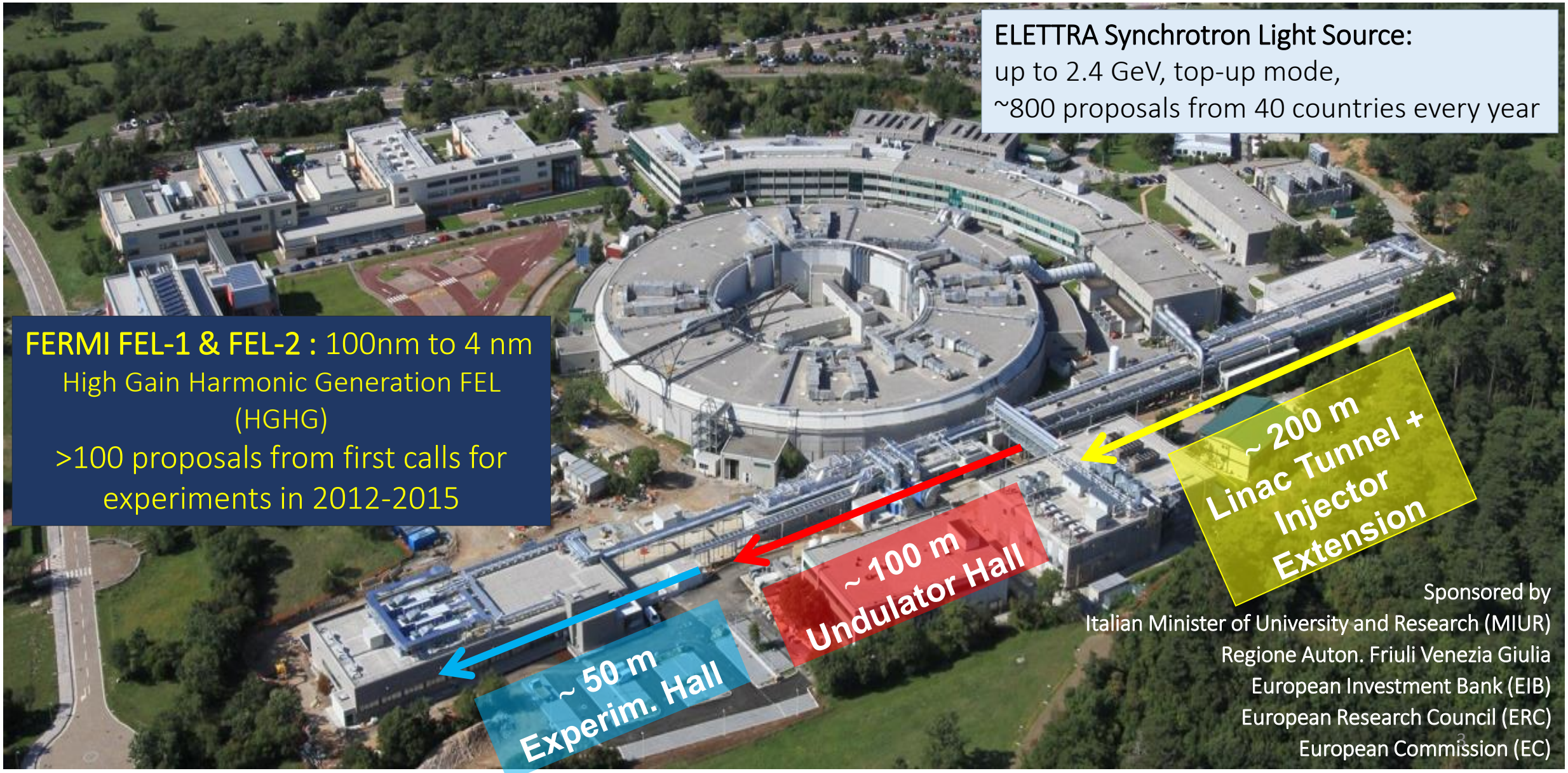
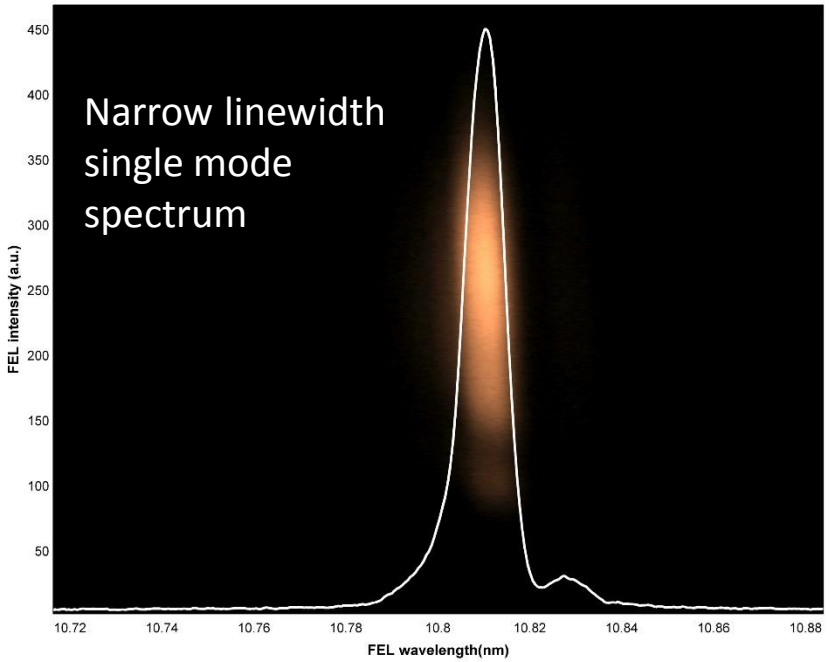
ELETTRA and FERMI



FERMI: seeded FEL



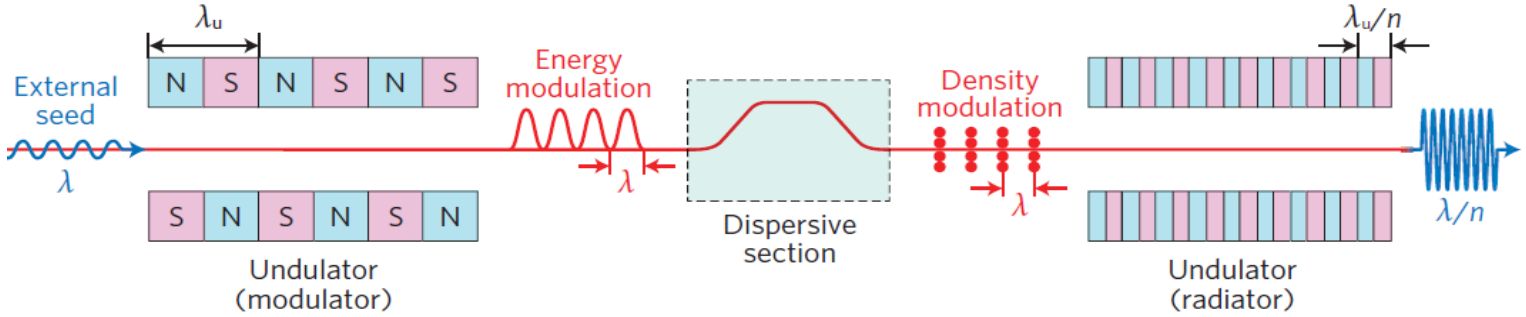


Figure 1 | Scheme for a single-stage HGHG. In a two-stage cascade, harmonic radiation from the first stage is used as an external seed for the second stage. λ, seed wavelength; λ_u, modulator period; n, harmonic number.

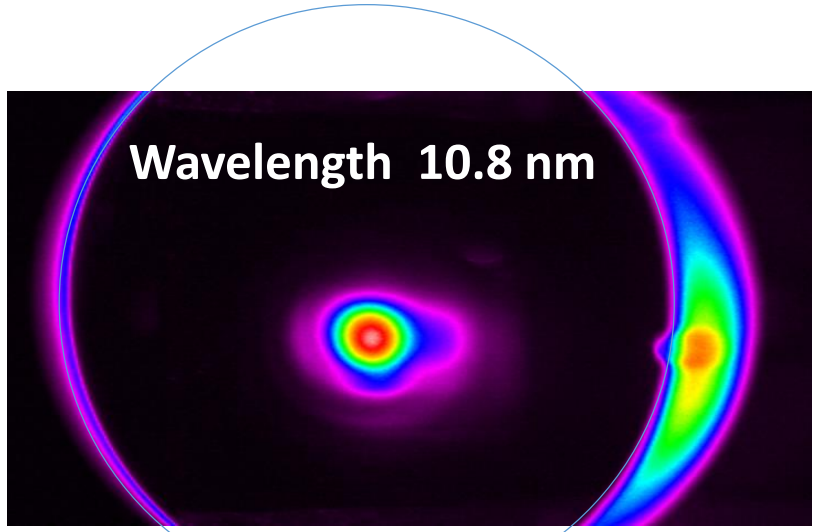
NATURE PHOTONICS | VOL 7 | NOVEMBER 2013 | www.nature.com/naturephotonics

FREE-ELECTRON LASERS

Fully coherent soft X-rays at FERMI

The Italian free-electron laser, FERMI, now generates coherent soft X-rays in the water window (2.3–4.4 nm) by two-stage frequency upconversion of ultraviolet seed laser pulses using the 'fresh bunch' technique.

Toru Hara



FERMI layout

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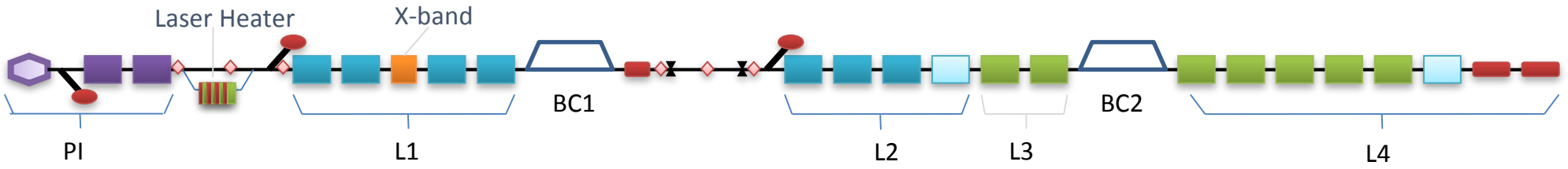
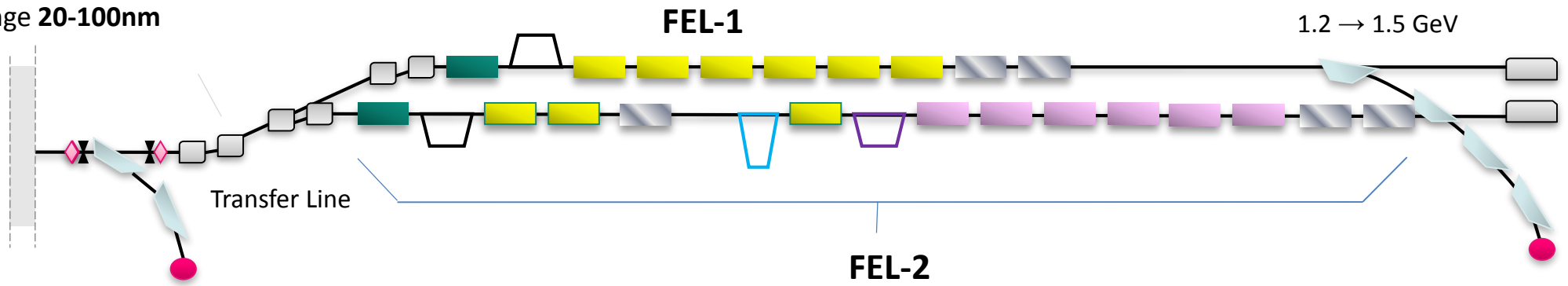
Electron linear accelerator tunnel



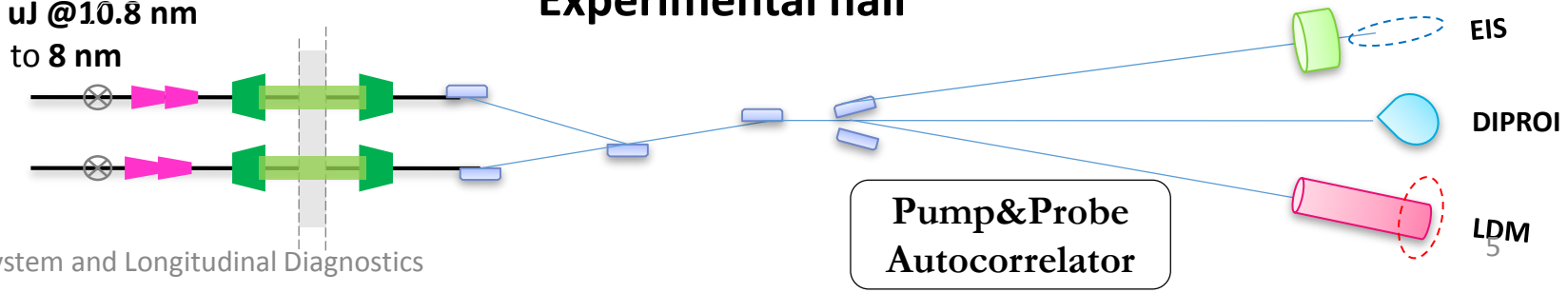
FEL -1: Single stage cascaded FEL
full specs achieved in **2012**, dedicated to user experiments
Continuously tunable in the range **20-100nm**
Bandwidth **5x10^{-4}@ 32 nm**
Energy per pulse **30-100 uJ**
(depending on wavelength – up to a factor 3 more relaxing spectral purity requirements)

Undulator hall

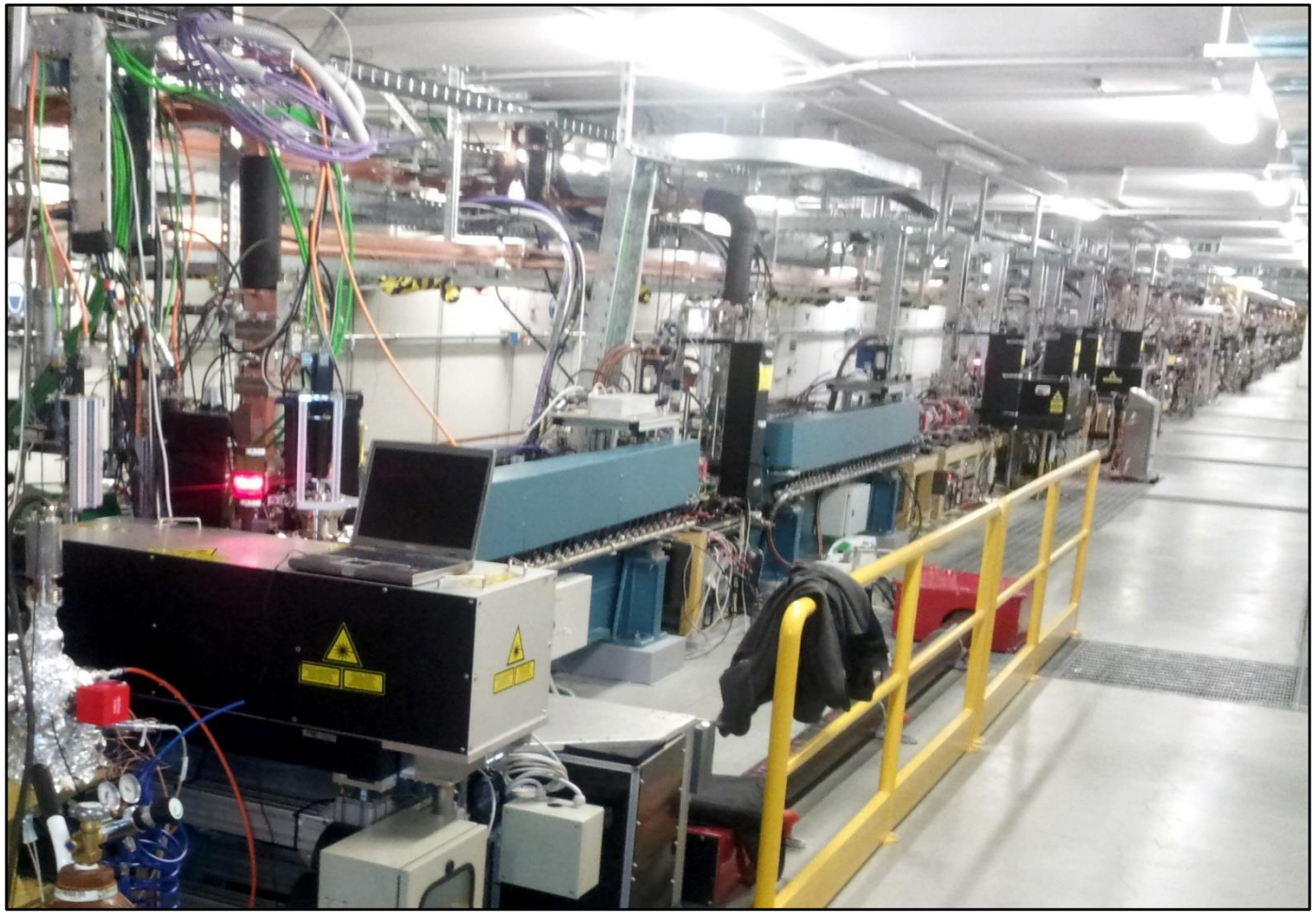


FEL-2: Double stage, fresh bunch, cascade FEL
October 2012 @1.0 GeV: **14.4 nm** & **10.8 nm** ≈**50 uJ @10.8 nm**
March 2013 @1.23 GeV: wavelength range down to **8 nm**
June 2013 @1.4 GeV: down to **5 nm**

Experimental hall



FERMI: LINAC and Undulator Hall



Linear Accelerator LINAC
E = 1,5GeV
Q = 1nC
Frep = 50Hz

Undulator Hall

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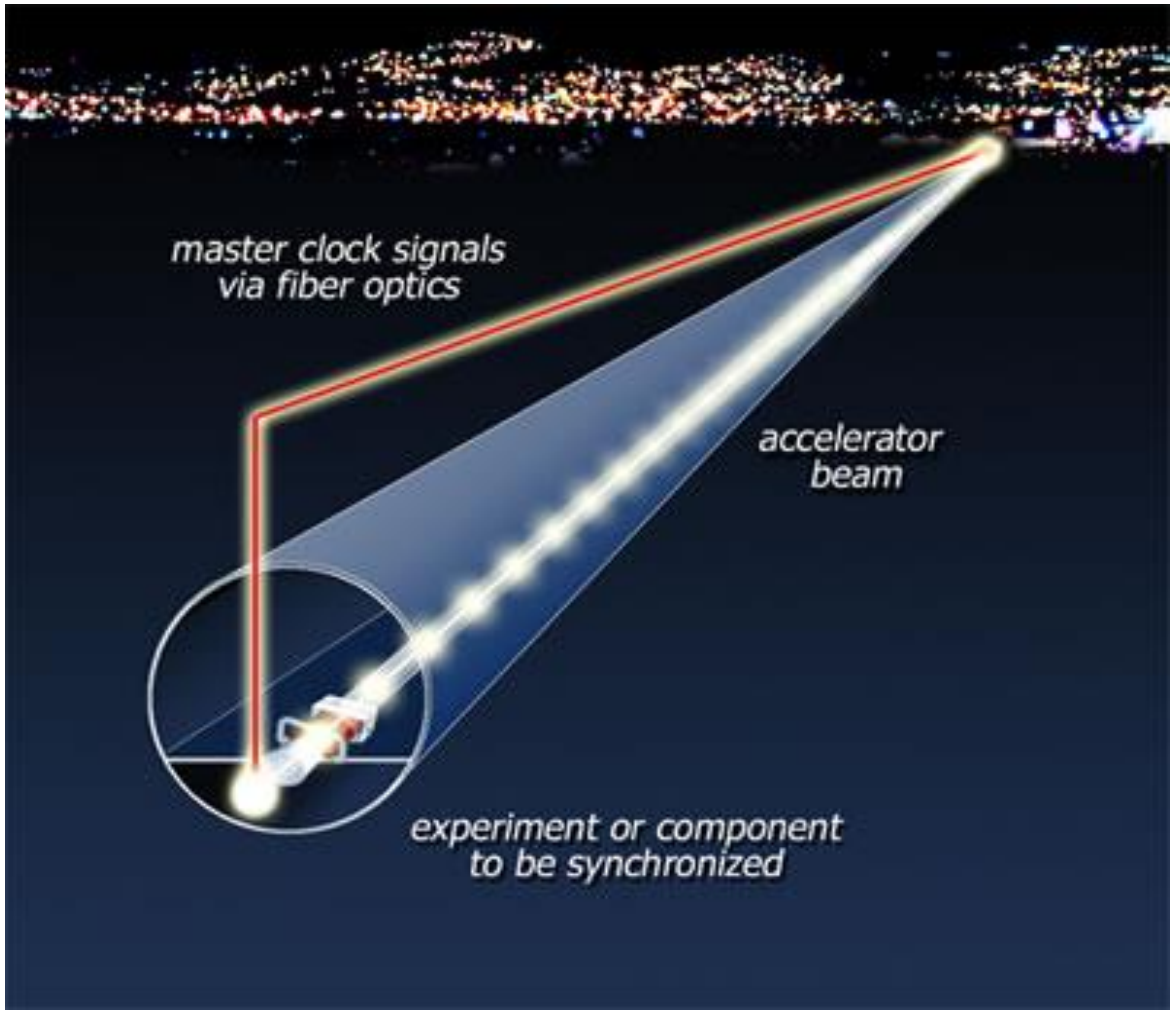
FERMI Optical Timing System



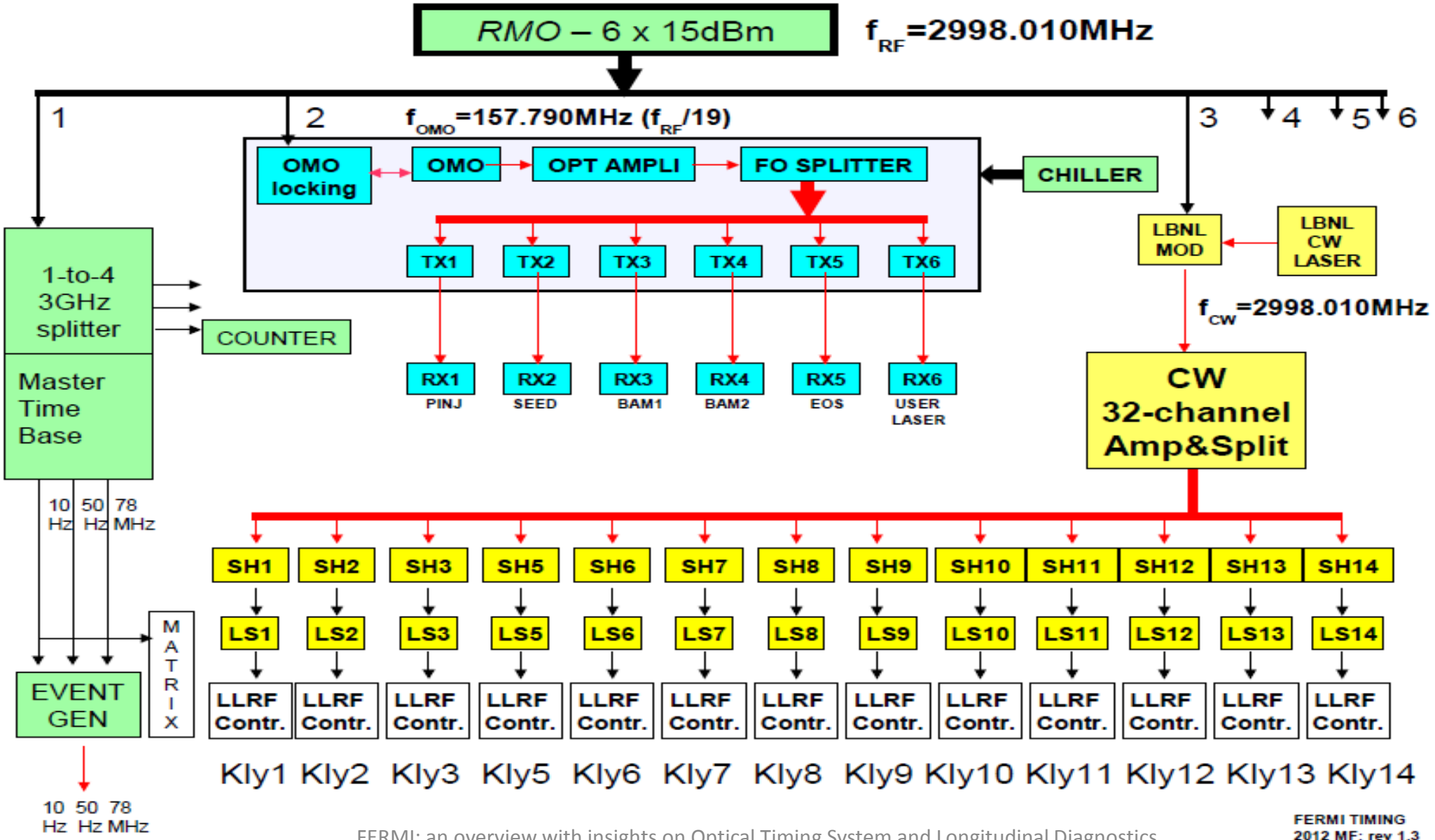
Why Optical ?

- e^- bunch length <500fs_{FWHM}
- to synchronize 100fs lasers
  - > photo-injector
  - > seeding
  - > pump-probe experiments
- facility extension (100s mt.)

Required **jitter & drift** on the distributed **Phase Reference: ≈ 10fs**

First **User Facility** synchronized using exclusively fiber optics timing system

FERMI Optical Timing System



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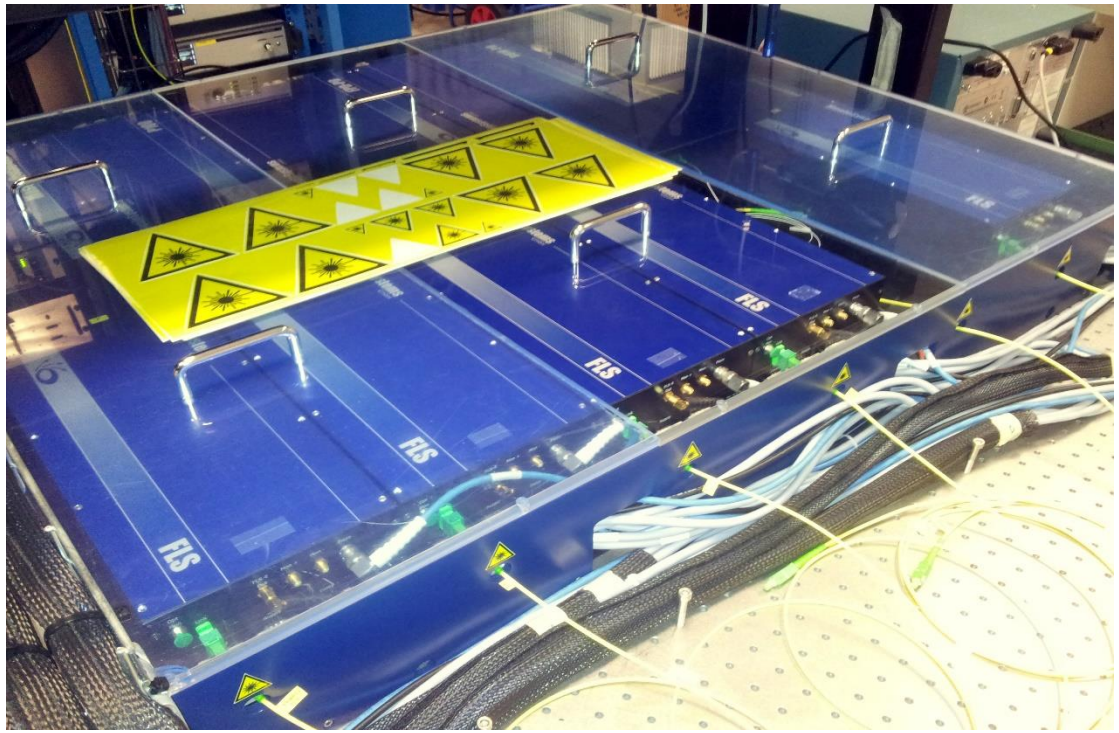
FERMI Optical Timing System

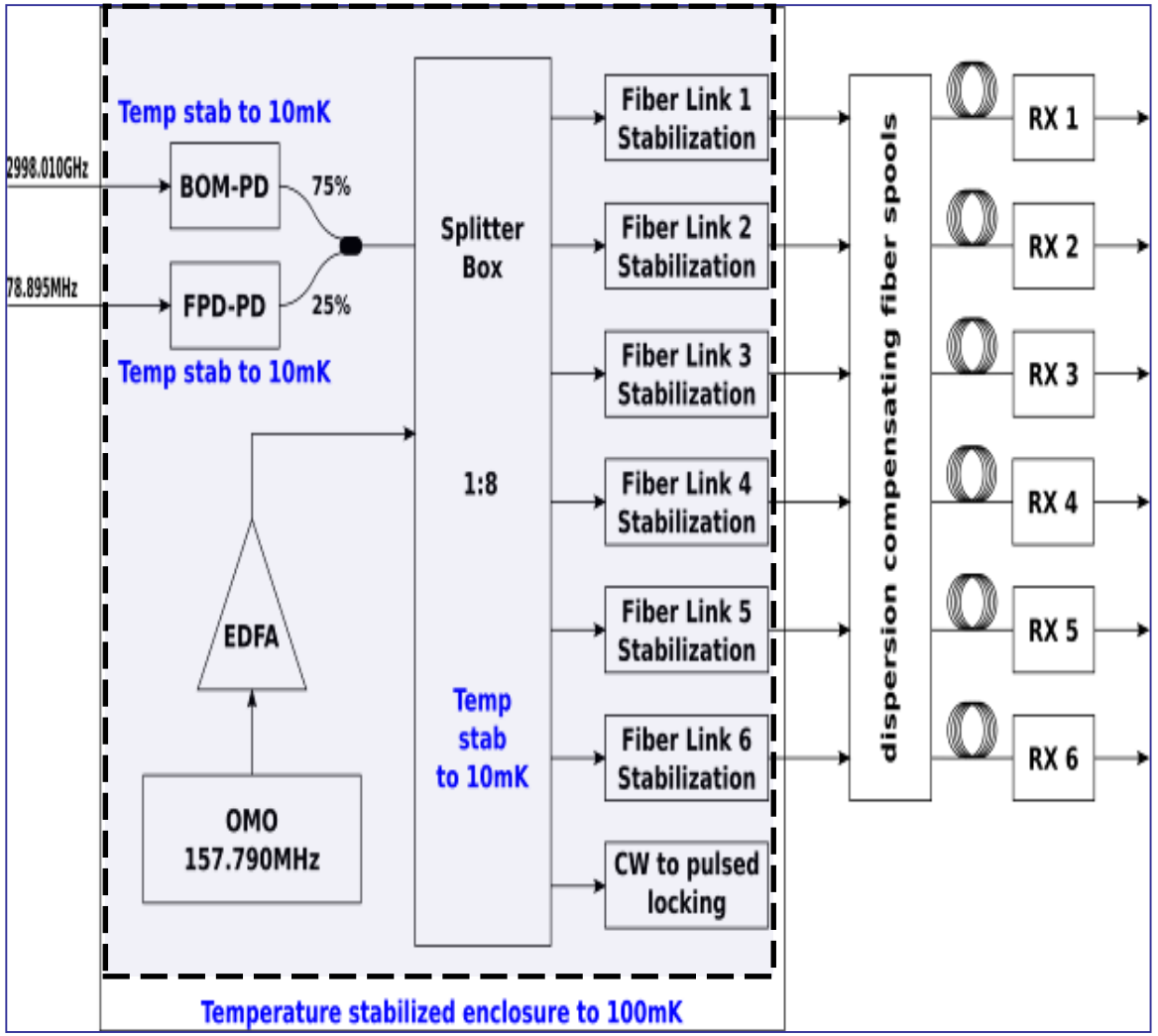
PULSED OPTICAL SYSTEM

Engineered and built by *MENLO Systems, GmbH*

A 2 year project, with on-site installation and testing.

In operation **since Aug '09:** only 2 faults on power supplies





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FERMI Optical Timing System

Out-of-loop,

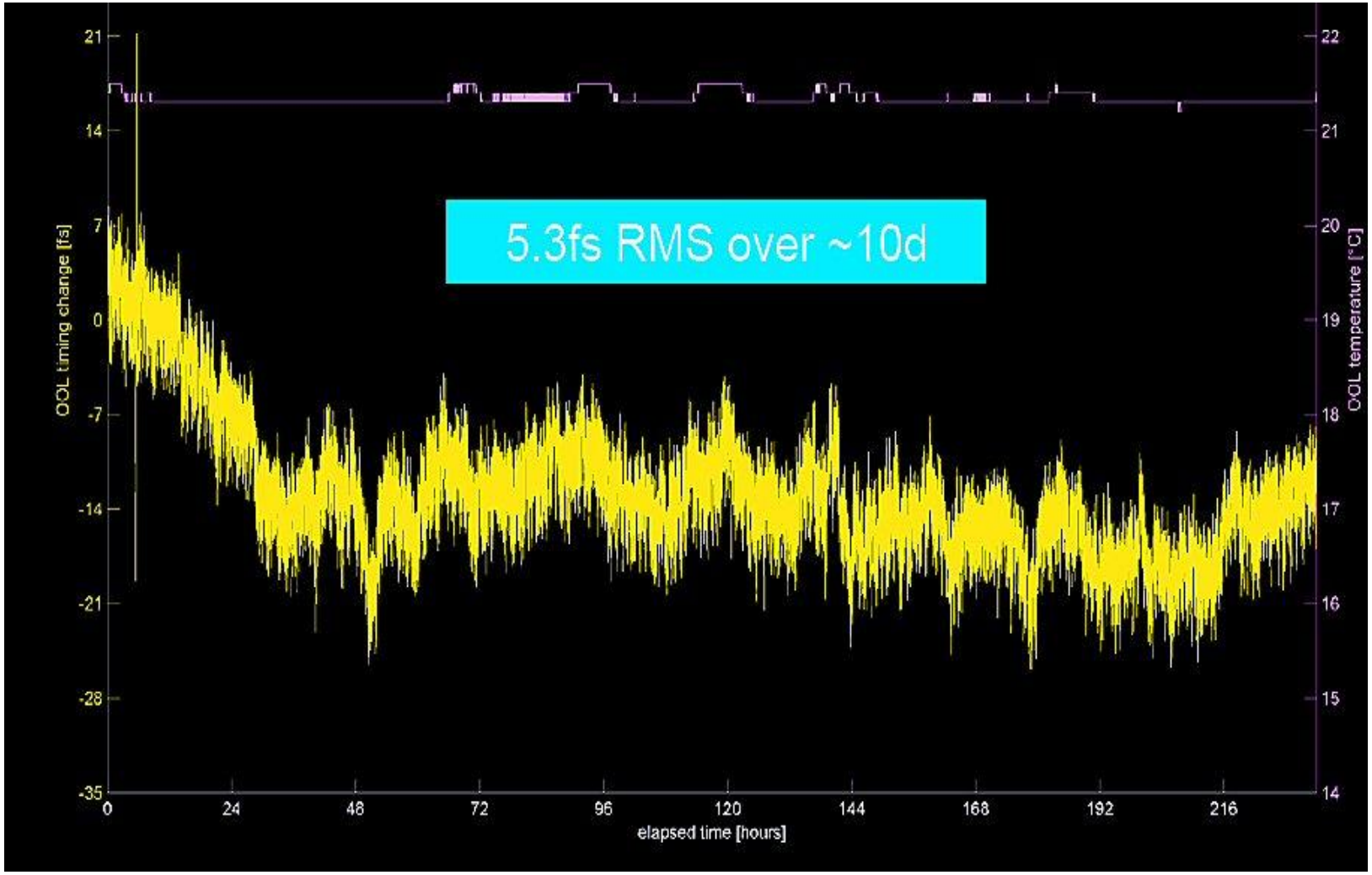
long term (10 days)

drift measurement;

Local optical reference

vs.

150m loop-back stabilized link



FERMI Optical Timing System

First **accelerator Facility** using entirely fiber optics timing system

- 36 delivery points

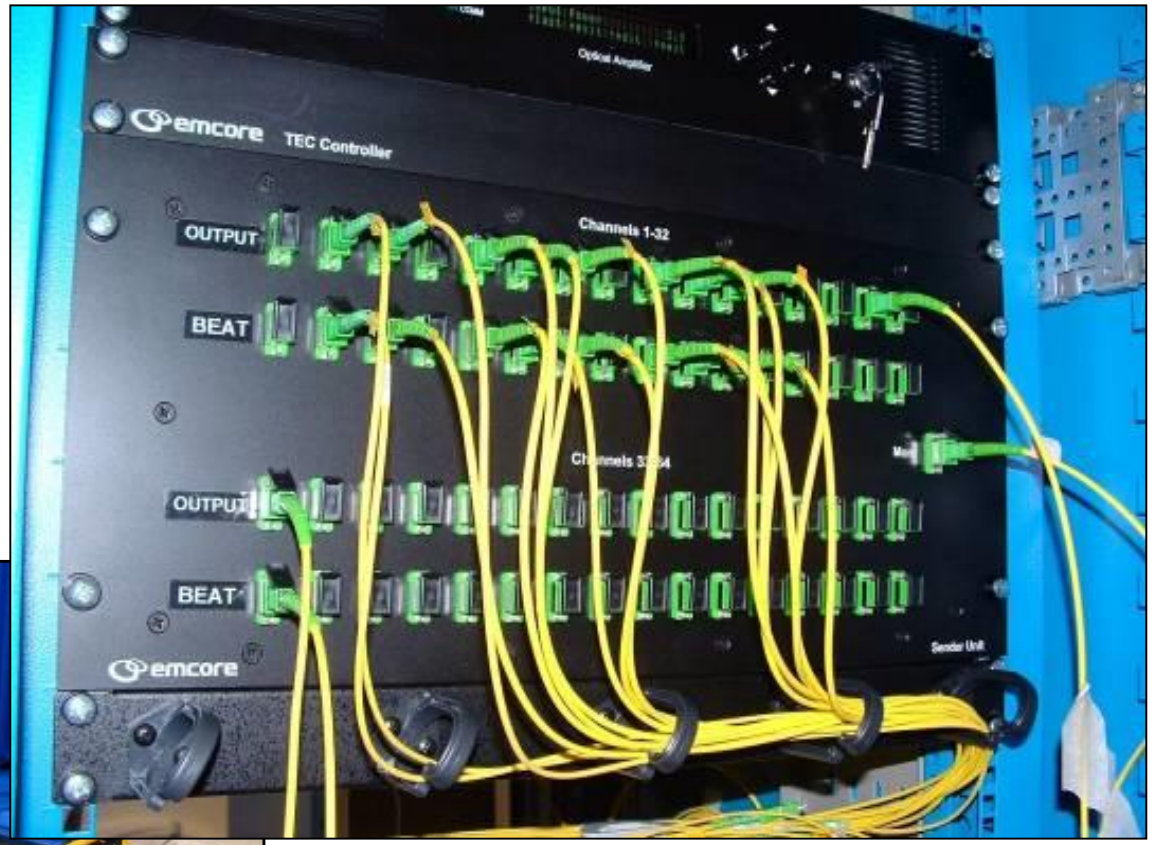
- 68 fiber bundles blown as

~4.5km of 8 S-M fiber bundles

~1.5km of 4 S-M fiber bundles

42km of S-M fibers

6km of M-M fibers



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FERMI Longitudinal Diagnostics

To characterize the *longitudinal phase space* of the electron bunch:

with fs resolution - in single shot (shot to shot, at 50Hz) - non destructively

- **longitudinal profile** (t_{FWHM} < 100s fs)
- **arrival time** and its variations (i.e. jitter) w. r. t. the phase reference
- relative **bunch length** variations
- electron **energy distribution along the bunch**

The **RF deflector** (@3GHz) allows 10s fs resolution, but it's **destructive**

The relative **Bunch Length Monitor** (BLM), it's non destructive

Two **NON DESTRUCTIVE *electro-optical techniques*** have been implemented:

- **Bunch Arrival Monitor**
- **Electro-optical Sampling**

FERMI Longitudinal Diagnostics

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Bunch Length Monitor (BLM)

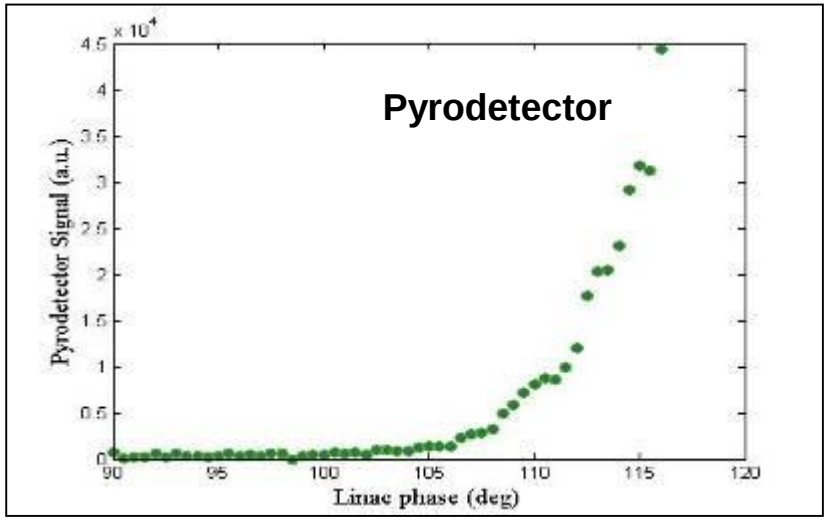
Signal inverse proportional to the bunch length

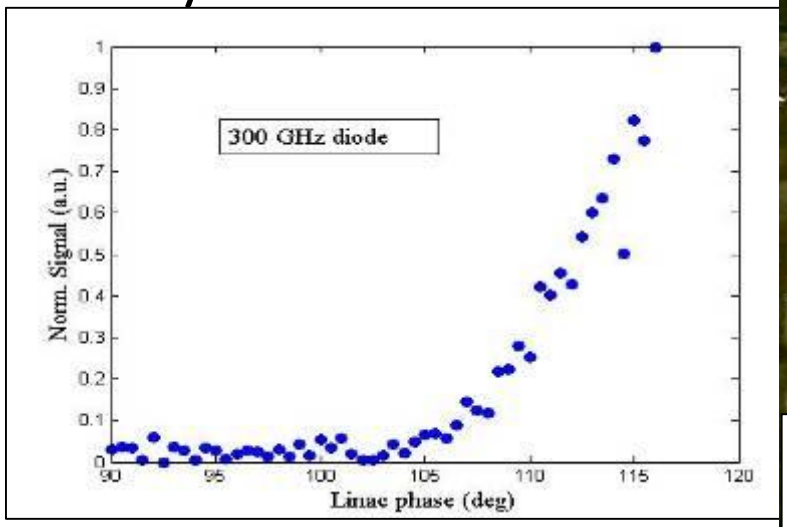
Non destructive diagnostic (installed on BC1 and BC2)

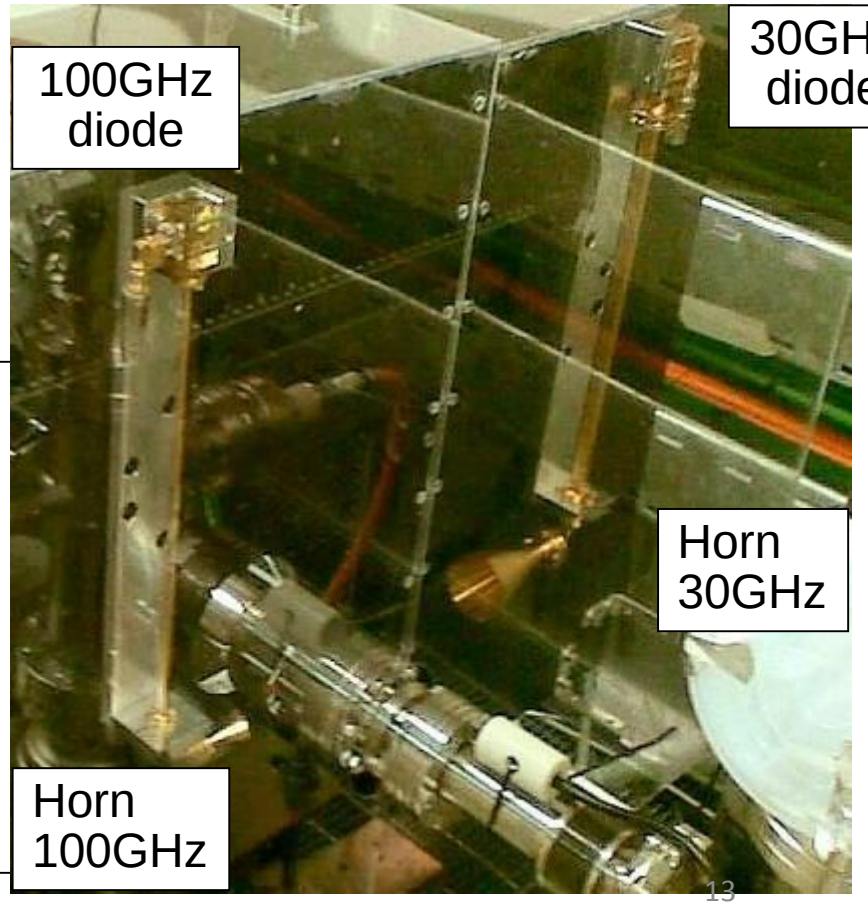
Currently used in compression factor feedback

Based on two different detectors:

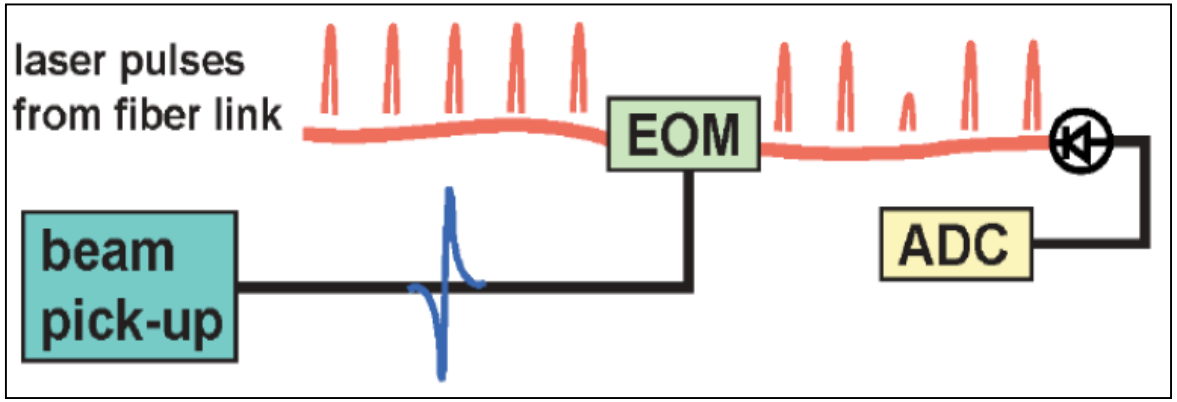
- Coherent SR from 4th BC1 bend + PYRO
- Field from Ceramic Gap + Schottky Diodes







FERMI Longitudinal Diagnostics



Bunch Arrival Monitor (BAM)

Non destructive diagnostic

Based on concept developed at DESY (D)

Resolution=7fs

Installed on:

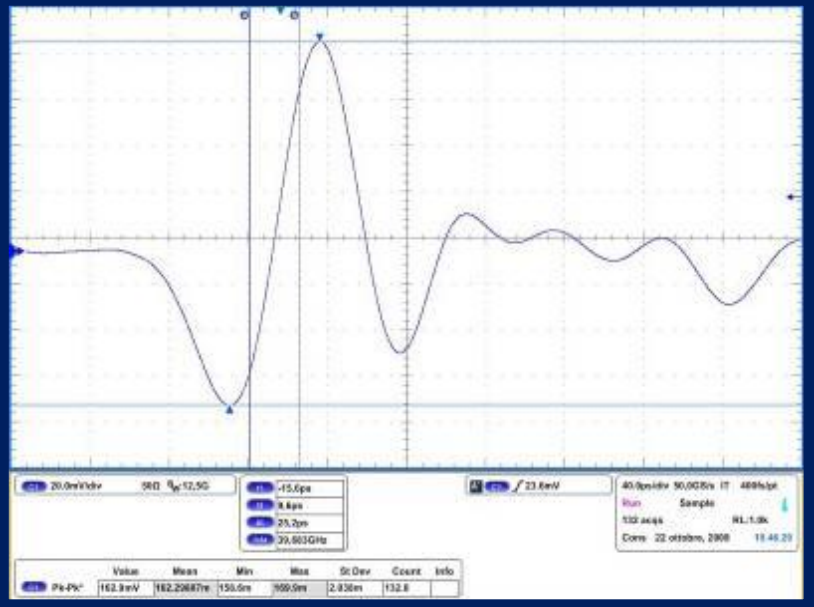
BC1

BC2

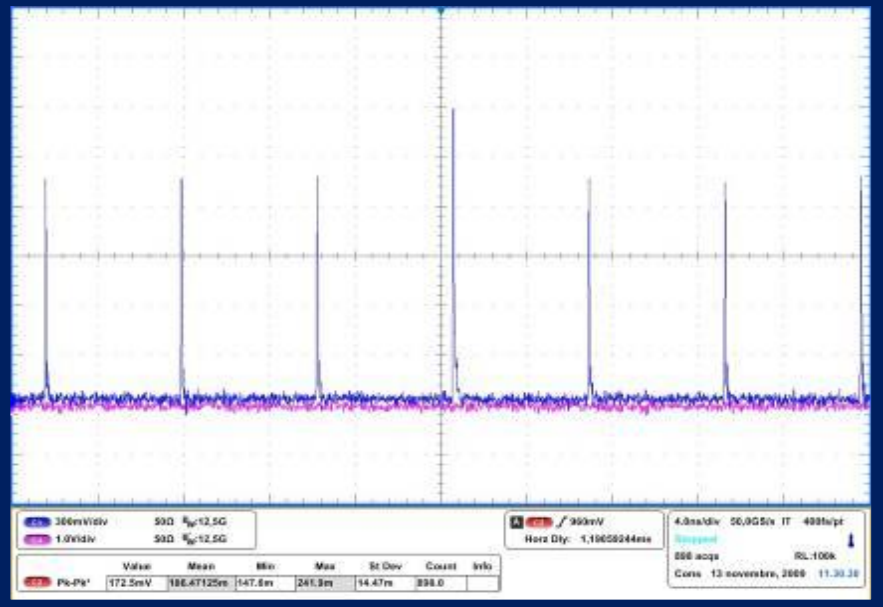
FEL1 modulator

FEL2 modulator

BAM pick-up pulse



OMO amplitude modulated pulse



FERMI Longitudinal Diagnostics

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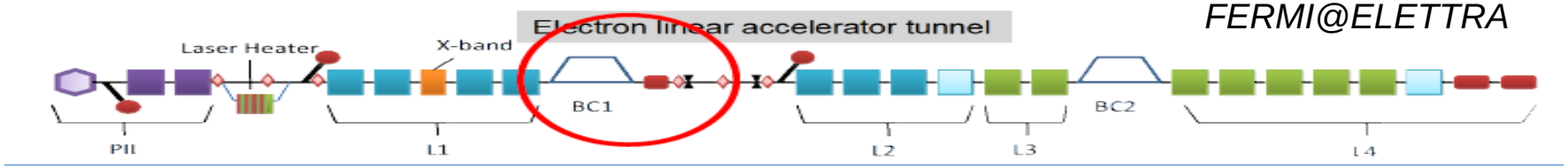
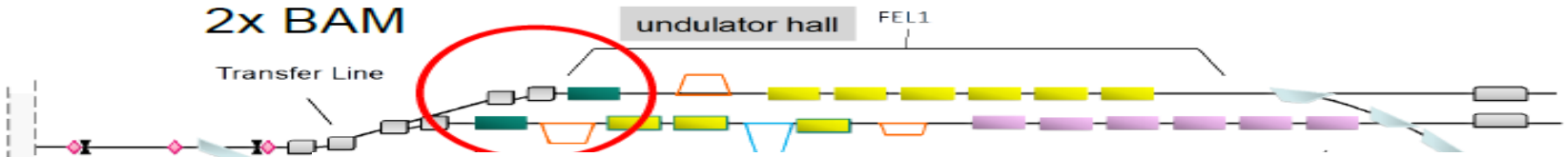
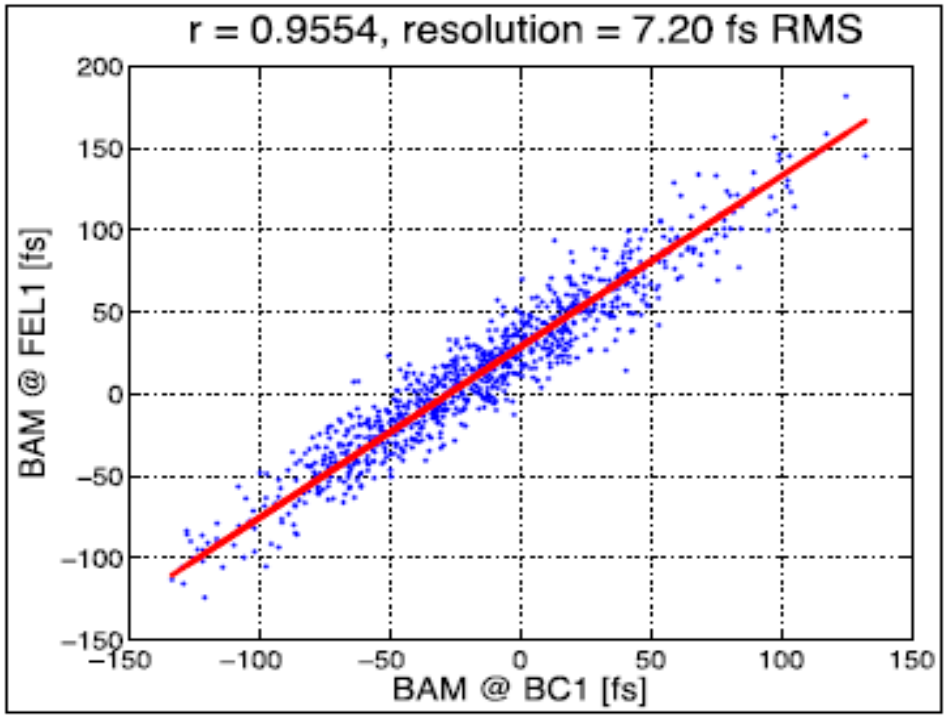
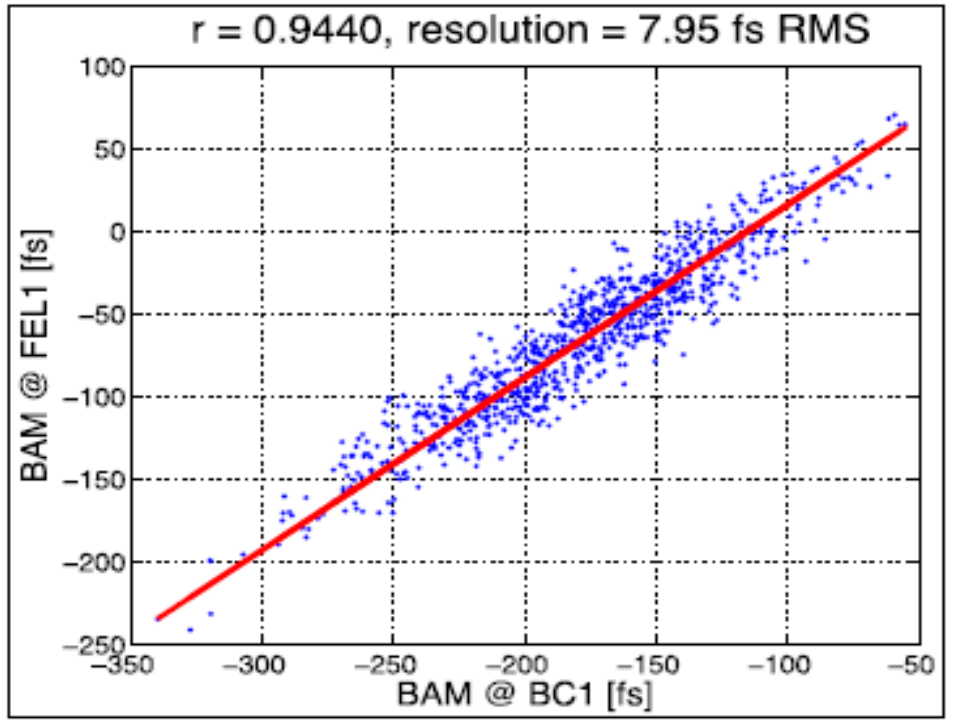


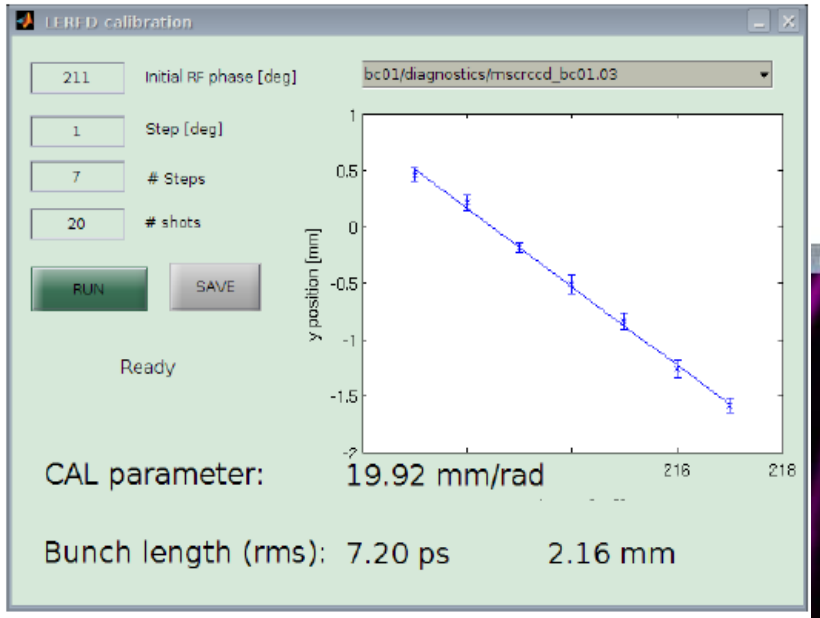


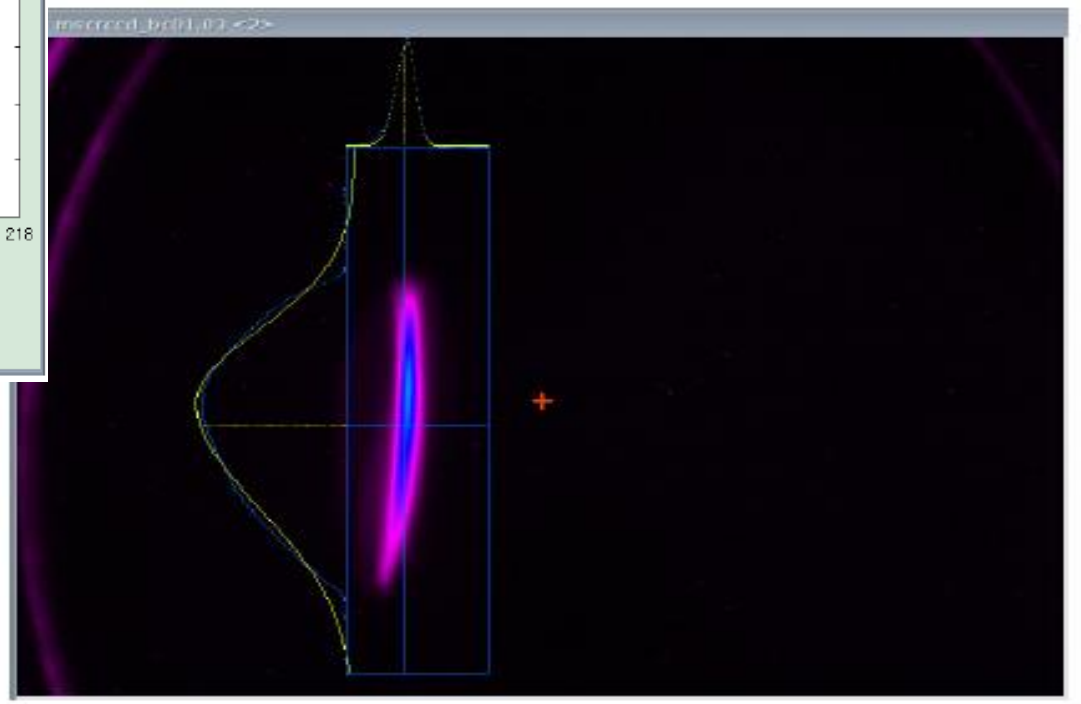


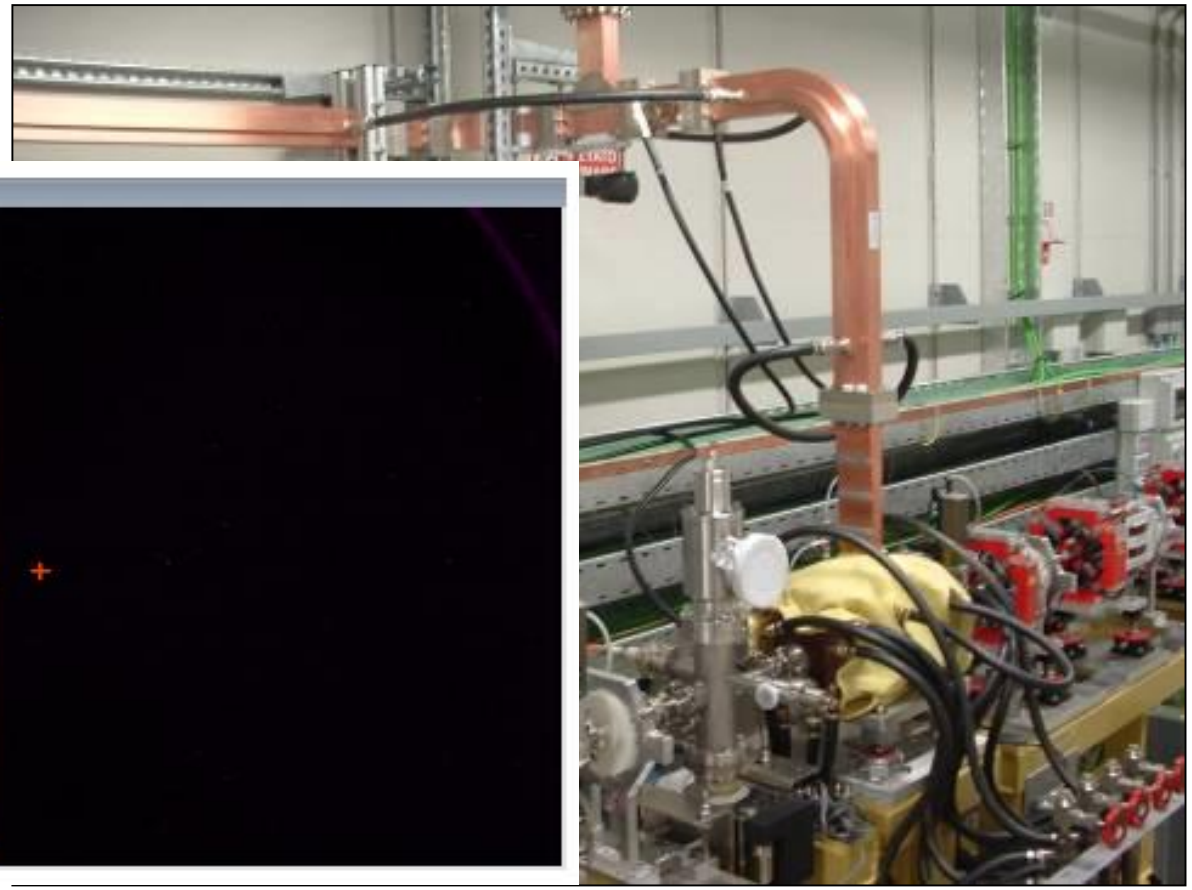


FERMI Longitudinal Diagnostics

Low Energy RF Deflector (BPM) Single-shot longitudinal profile and arrival time







FERMI Longitudinal Diagnostics

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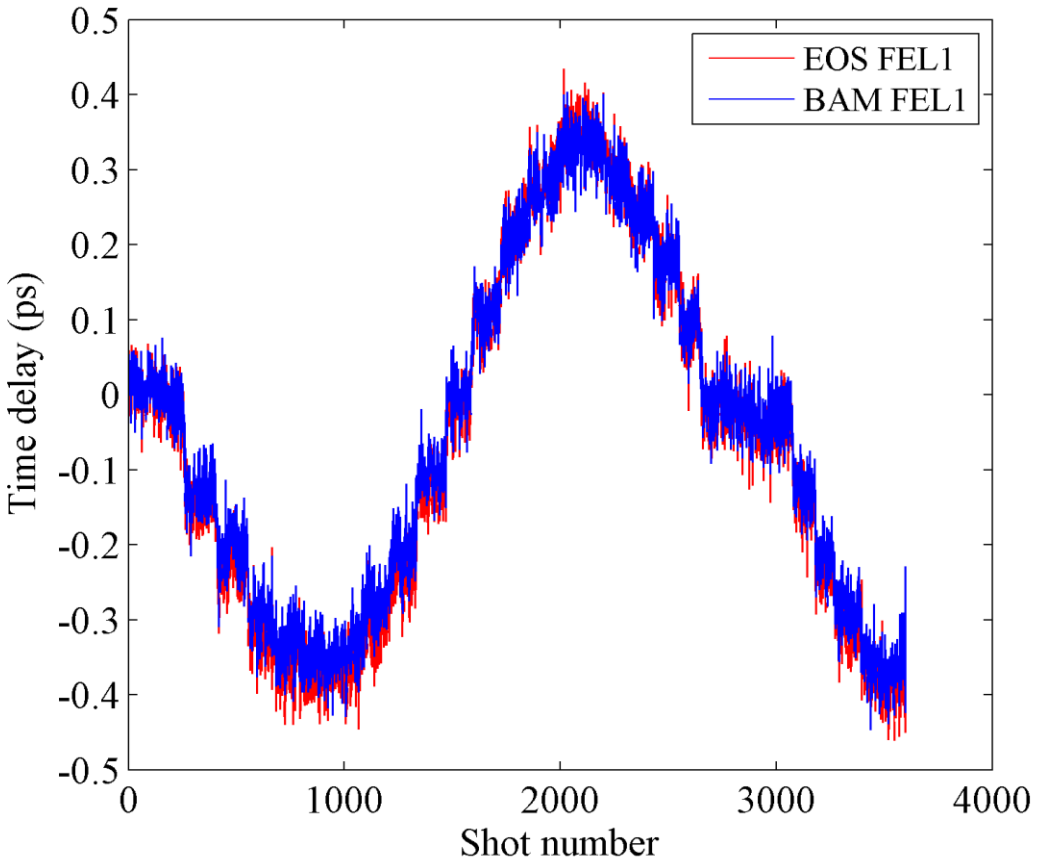
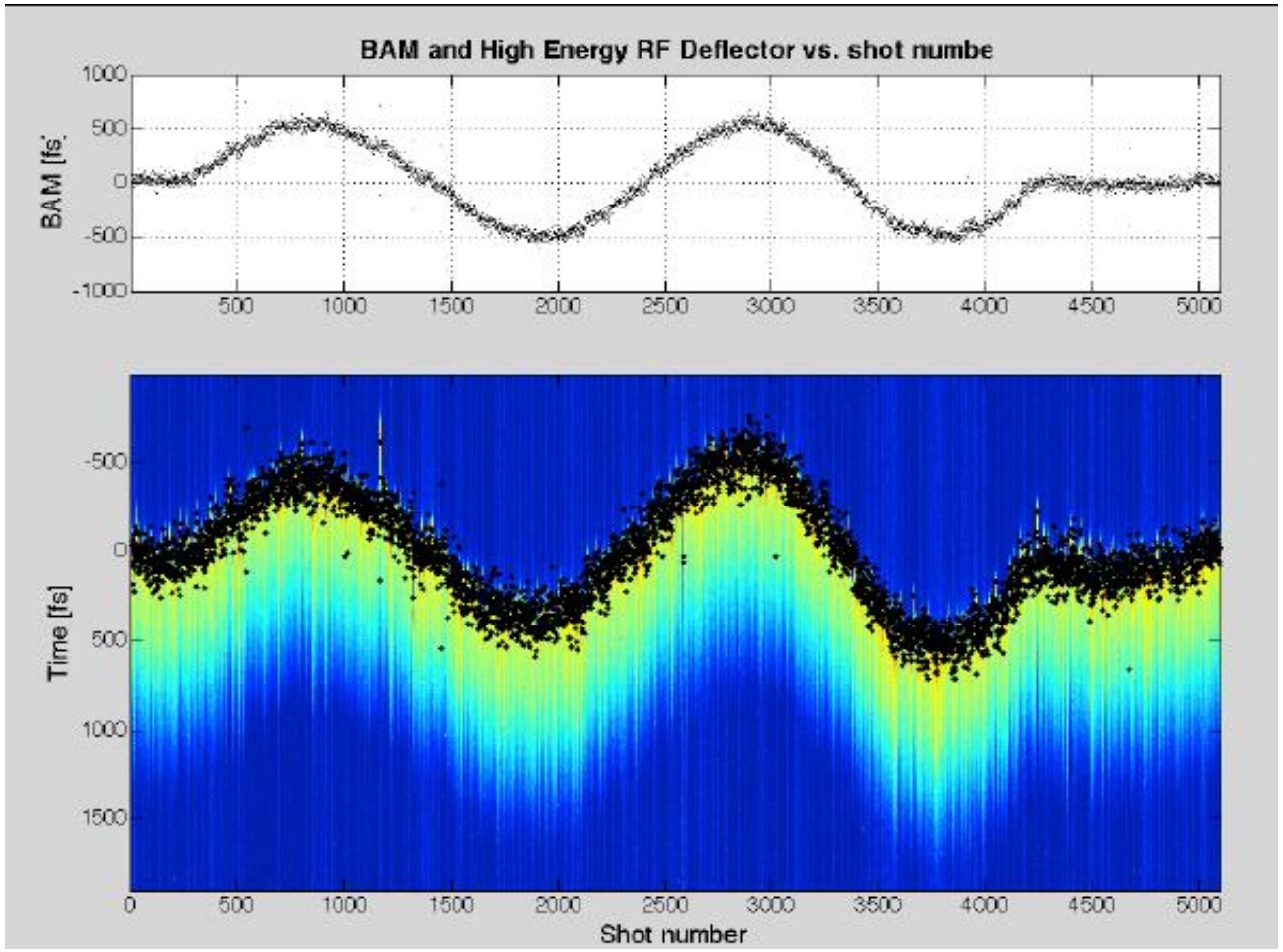
Arrival time comparison as measured With *EOS and BAM*





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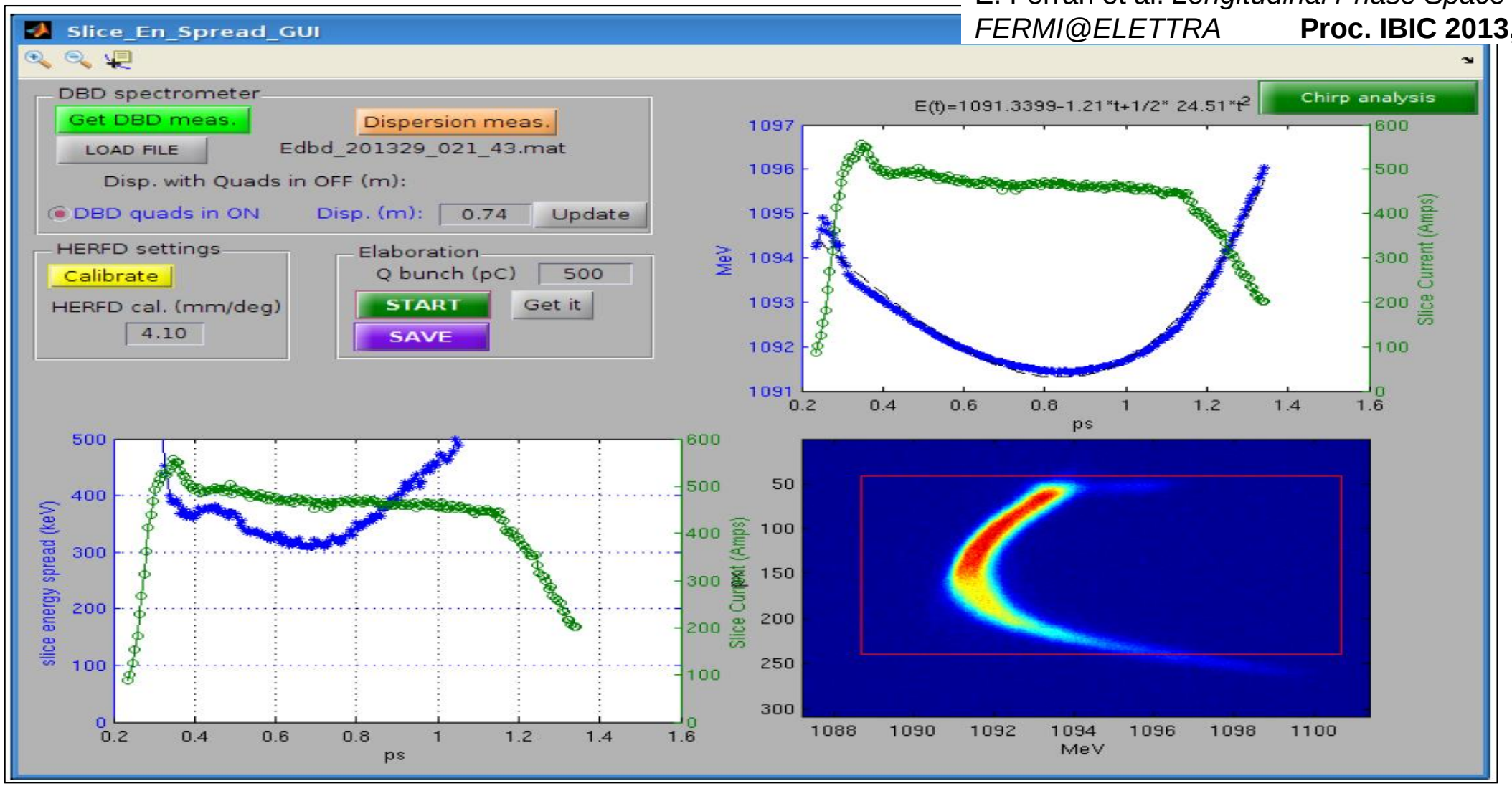


FERMI Longitudinal Diagnostics

Electro Optical Sampling (EOS)

Bunch length, profile and arrival time measurement system

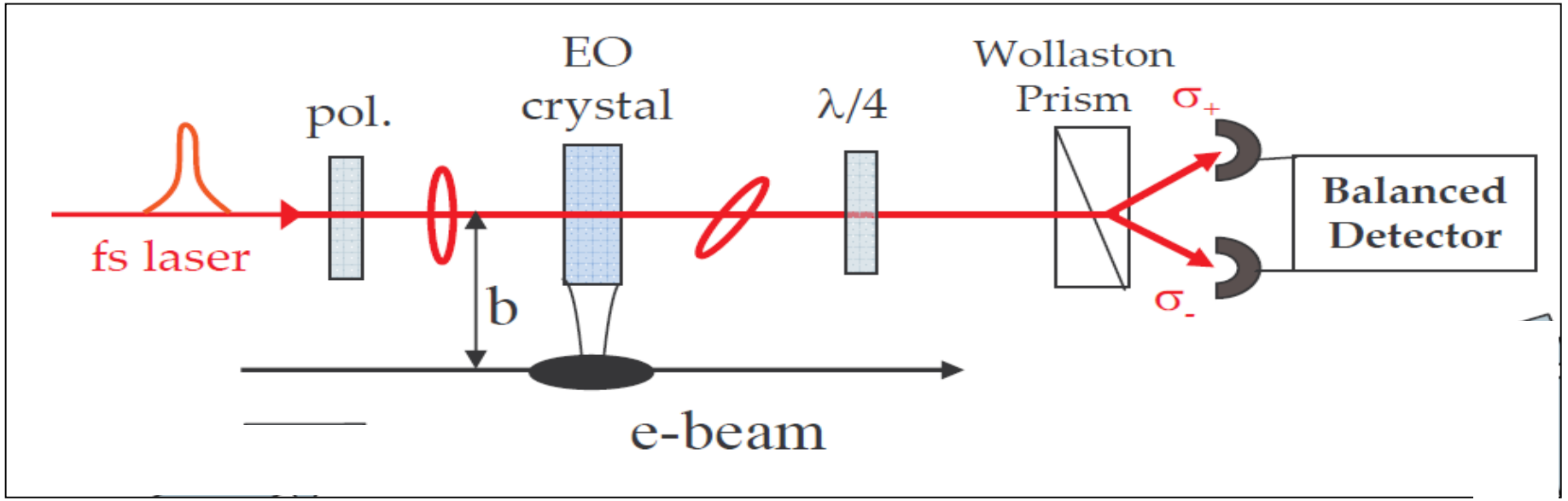
Non destructive diagnostic

Resolution: 20fs

Used also for coarse alignment of seed laser pulse vs. electron bunch

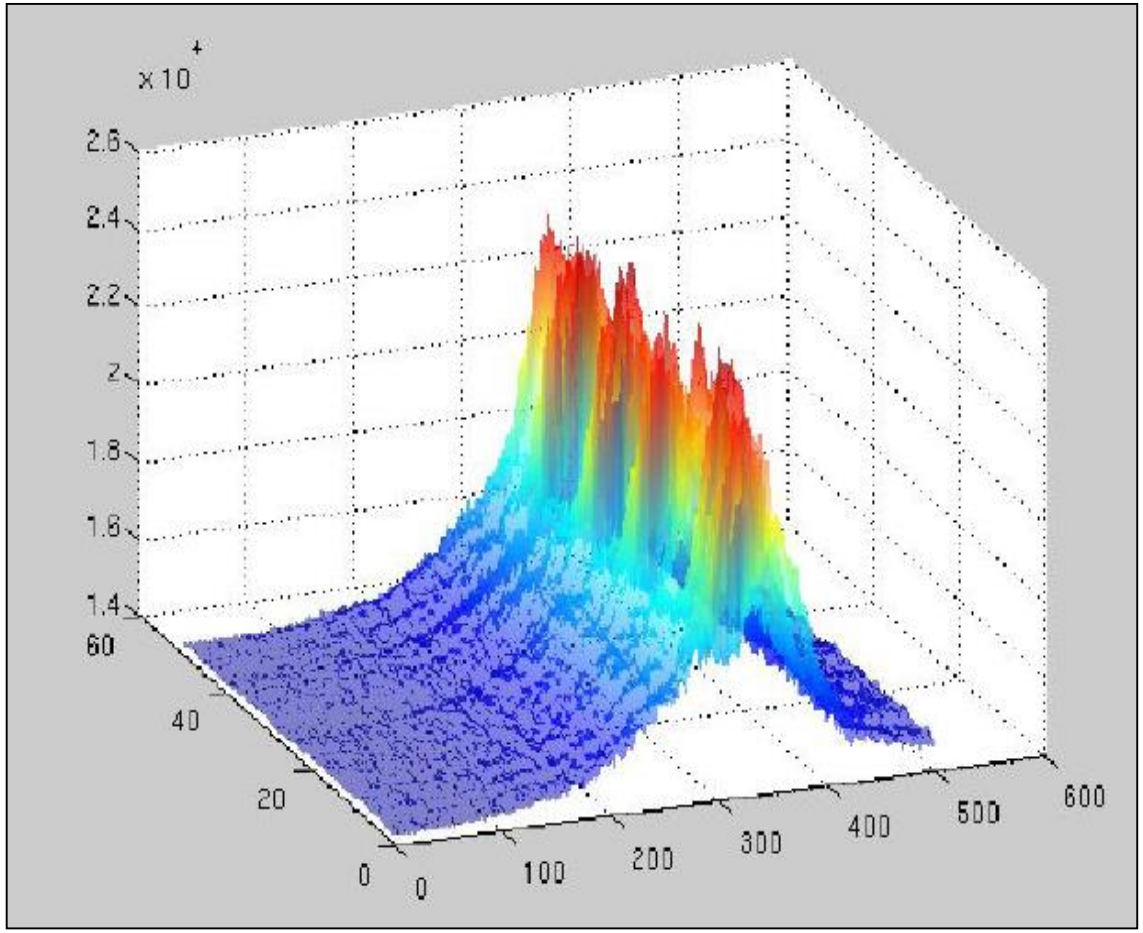
Installed on FEL1

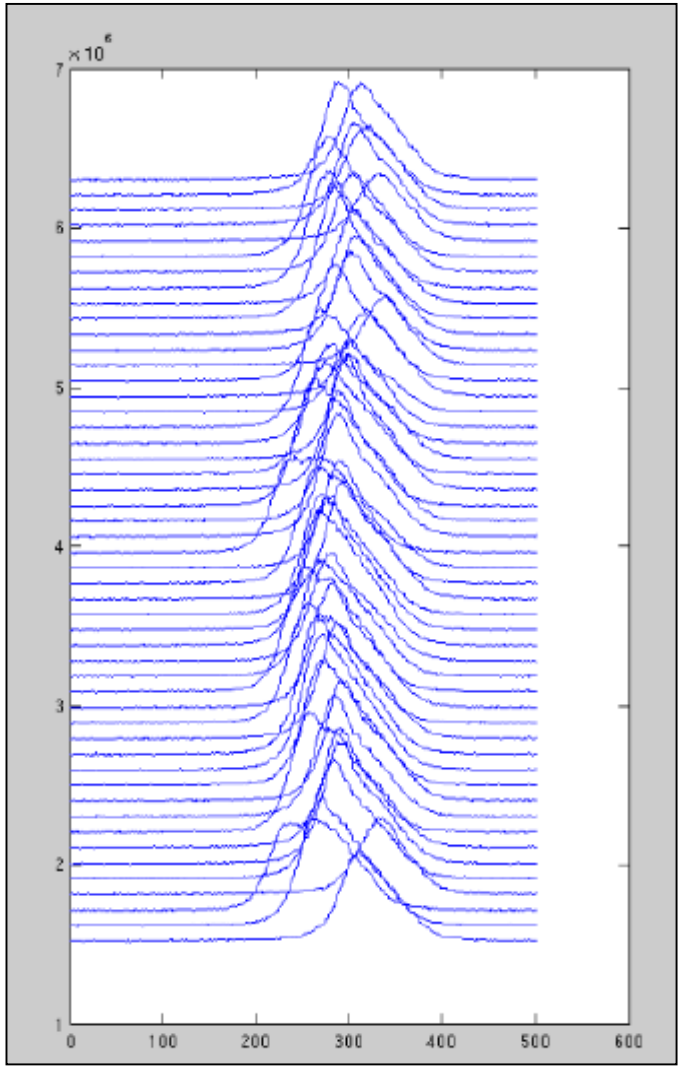
on FEL 2, in progress



FERMI Longitudinal Diagnostics

Electro Optical Sampling (EOS) measurements on FEL1





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FERMI: an overview with insights on Diagnostics & Timing

Thank you
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