FERMI@Elettra FEL 1 Commissioning

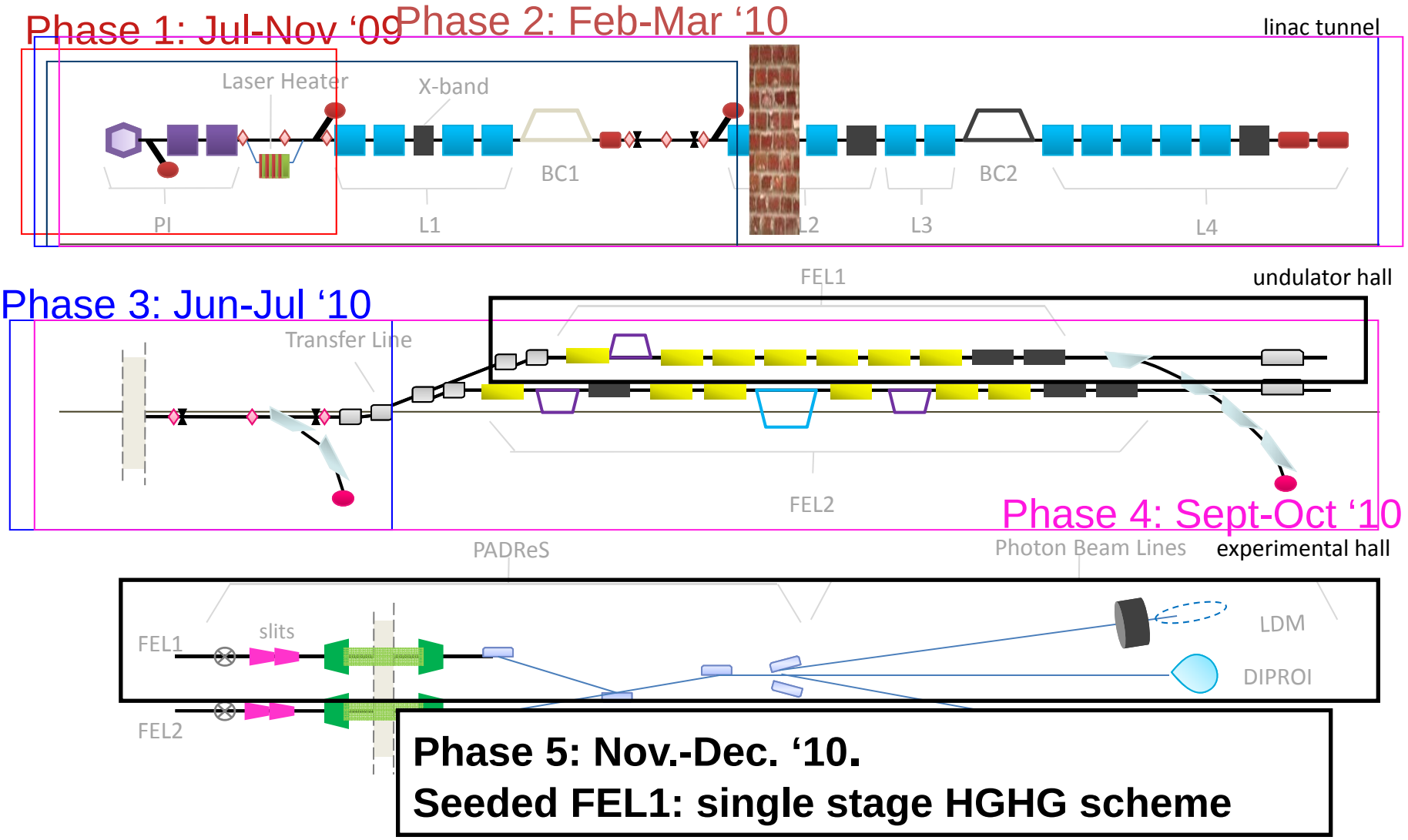
Paolo Craievich

On behalf of the Fermi Commissioning Team

OUTLINE

- *Commissioning overview*
- *Electron beam characterization*
- *Seeded FEL 1 first light*

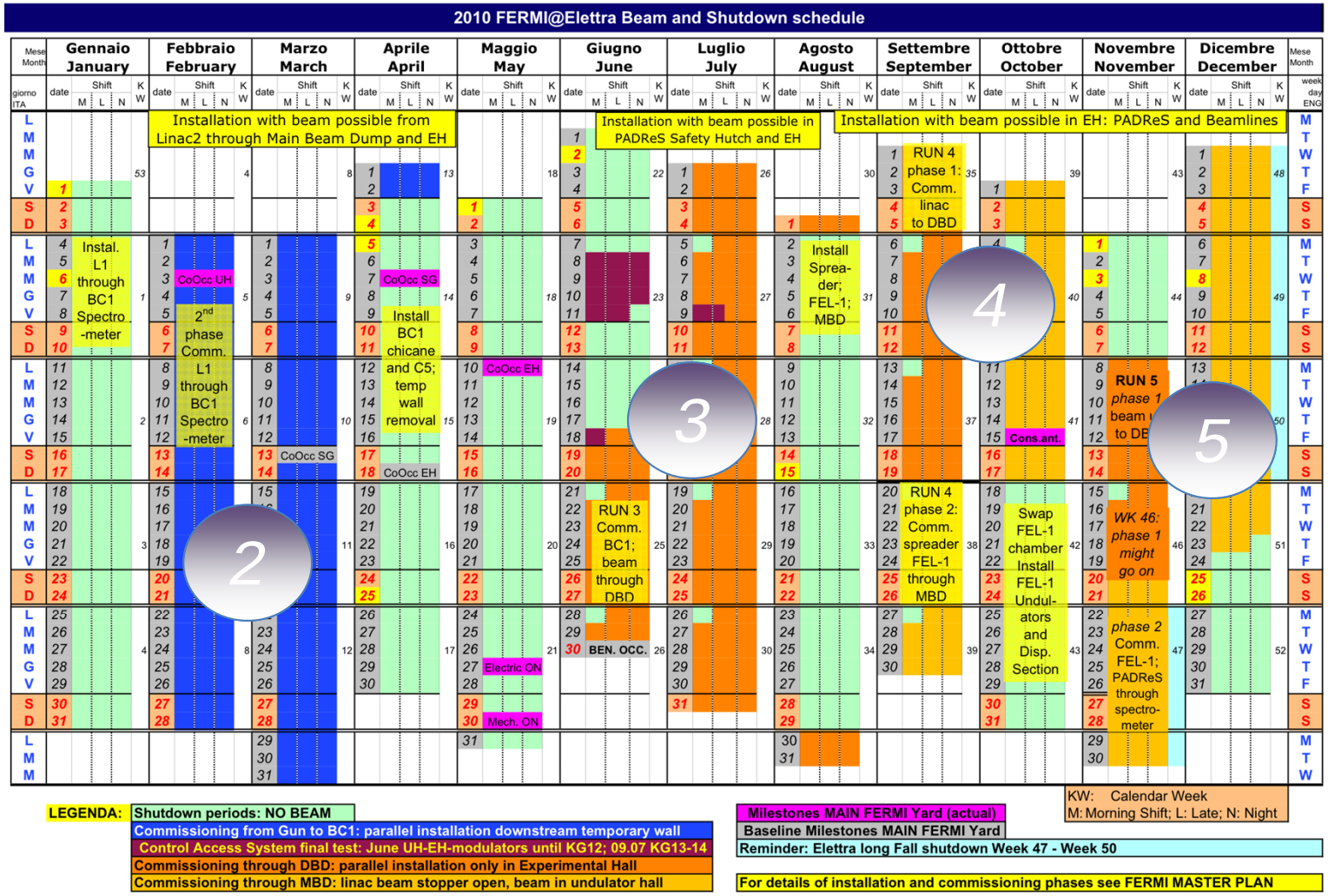
FERMI FEL1 commissioning



Phase 5: Nov.-Dec. '10.
Seeded FEL1: single stage HGHG scheme

Commissioning Operations in 2010

Commissioning activities were based on 2 shifts (6h-16h, 16h-2h) per 6 days/week



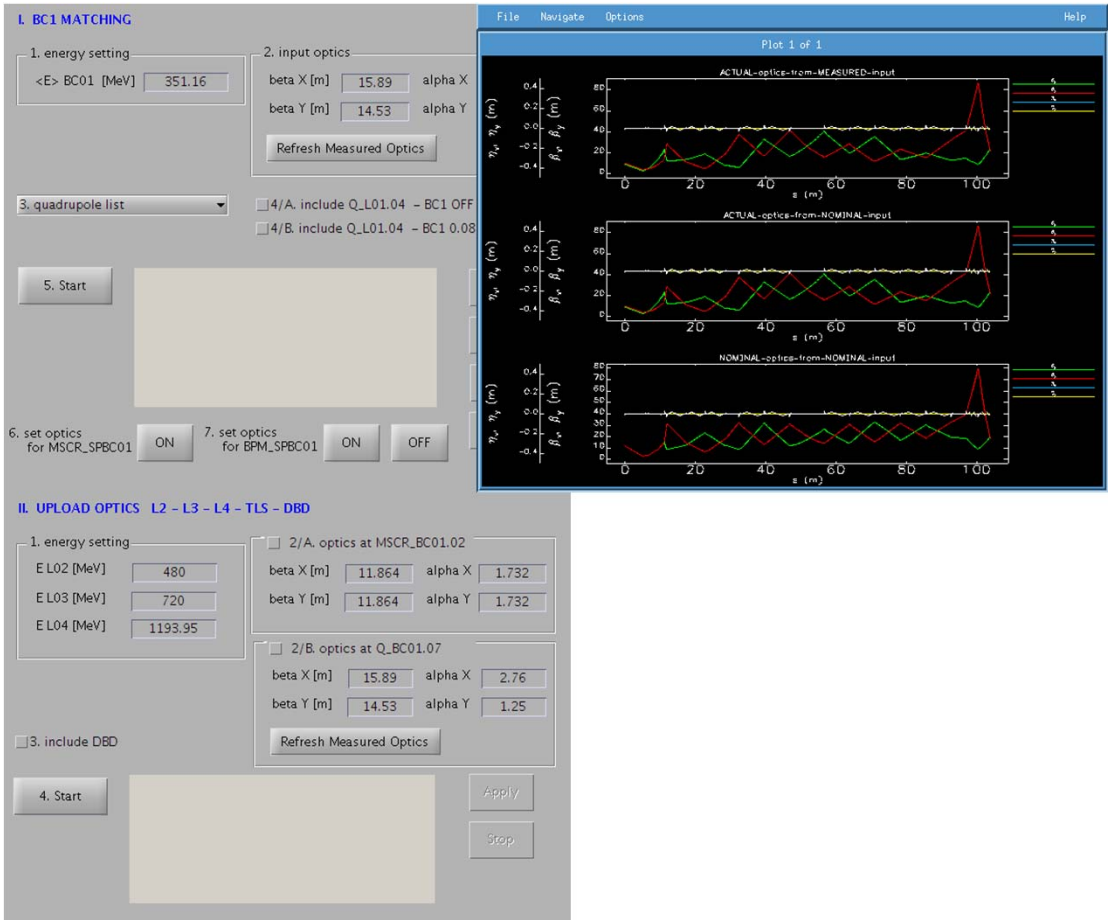
Low charge option

After verifying the feasibility of nominal charge operation at 800pC with ramped profile, we set the machine in low charge operation in order to have by Dec. 2010 the first Seeded-FEL radiation at 50-60nm (without BC2 and X-band system):

- Q=350pC
- Laser: 5ps (full width), Flat-top (diam=1.3mm)
- Bunch compressed a factor ~5, (full width~1ps) at 1.2GeV

Some useful tools

Beam matching and transport (LH-BC1, BC1-linac, TLS-SFEL, FEL-MDB)



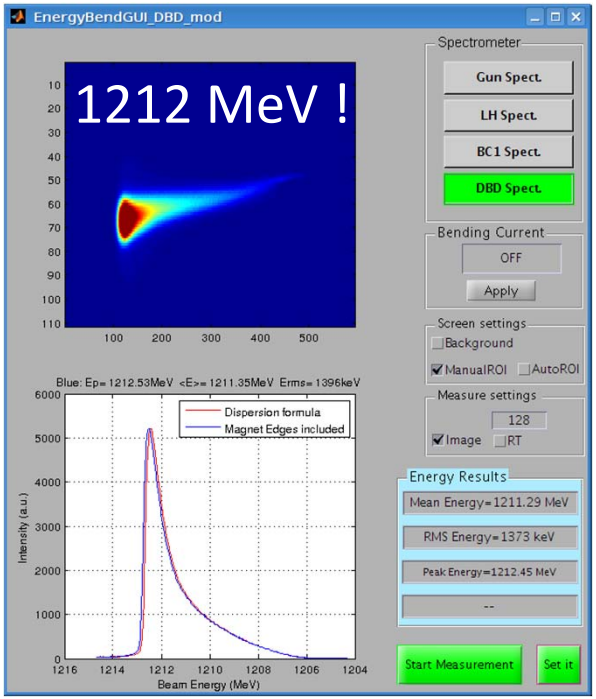
Ref. Di Mitri, Scafuri, Penco

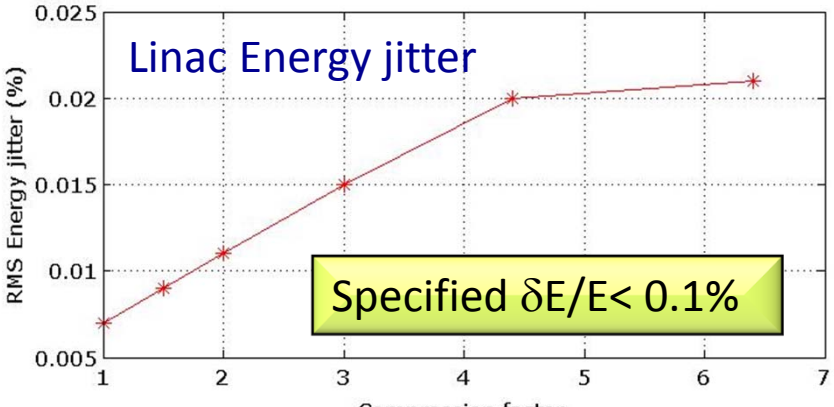
Beam trajectory feedback (rep. rate 1.3 Hz, merging of response matrix)

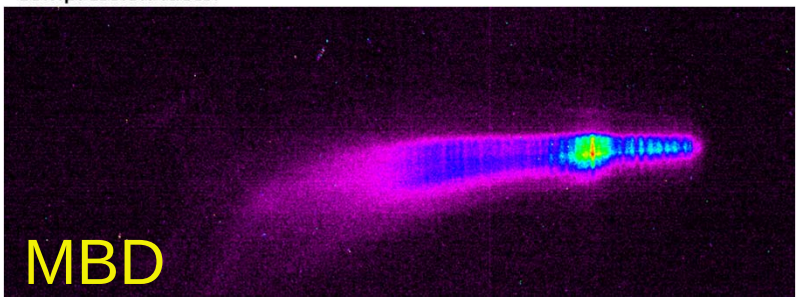
Ref.: Gaio, Di Mitri, Sjöström

Beam transport in DBD&MDB

- In RUN 3 the beam was transported in DBD at 700 MeV and functionality of all the diagnostics and RF structures were verified
- In RUN 4 we increased the linac energy by completing RF conditioning
- In RUN 4 before installing undulators we had to define a reliable trajectory in the FEL beamline, losses ≤ 1%@350pC

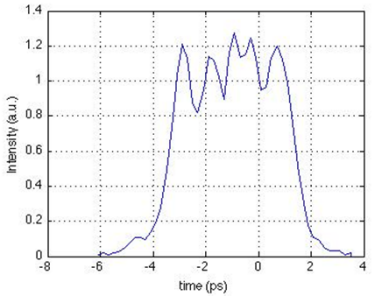


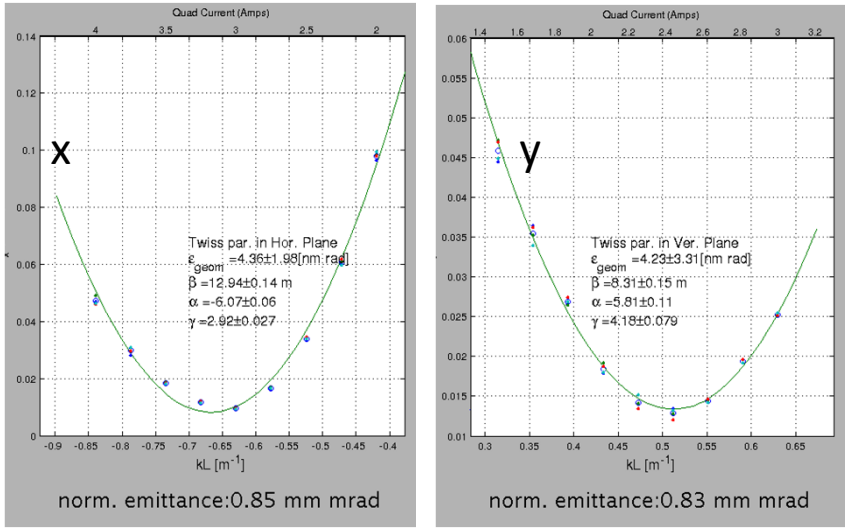




Emittance Studies@350pC (Run 3-4-5)

Laser: FWHM=5ps,
ϕ= 1.3mm





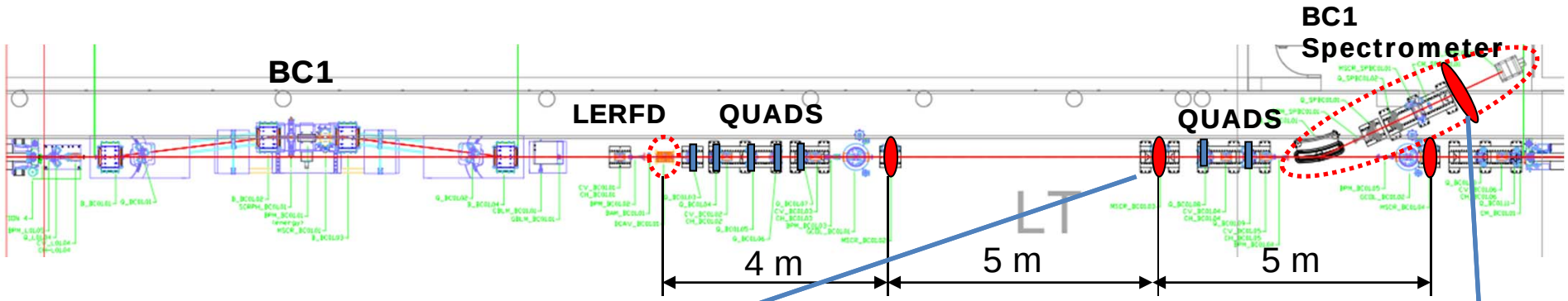
Best performance in LH:
0.85 mm mrad

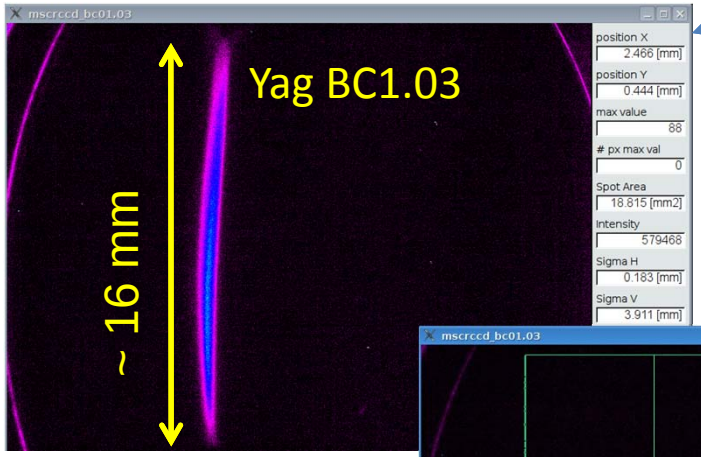
Centering the beam on the BPMs in L01 -> $\varepsilon_{x,y}$=1.3 mm mrad with BC1 in off and when compress x6.5 -> ε_x>3 mm mrad.
Steering the beam in L01:

	ε_x	ε_y
BC1 Off	1.1	1.0
BC1 Off, with L01 at +25deg	1.7	1.3
BC1 On, CF=1	1.3-1.6	1.3-1.5
BC1 On, CF=6.5 (L01 at +25deg)	1.9	1.4

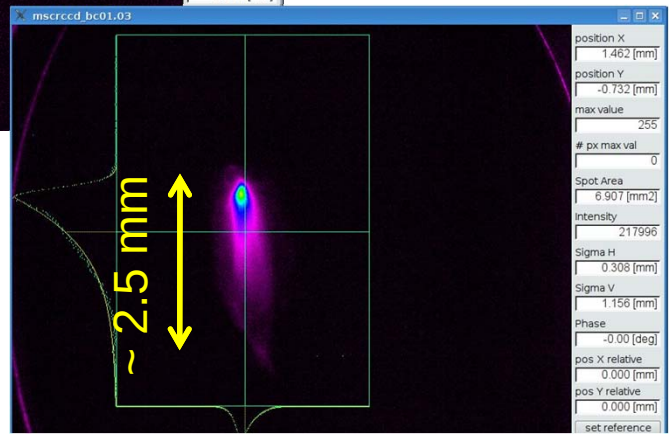
Ref. Di Mitri, Penco

LERFD commissioning in RUN 4

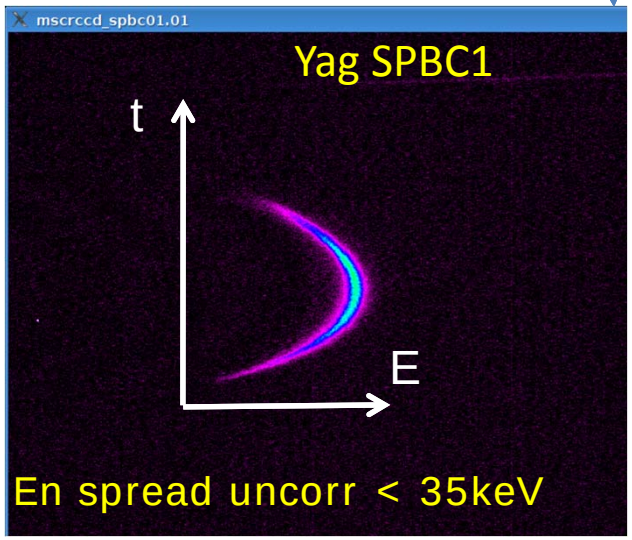




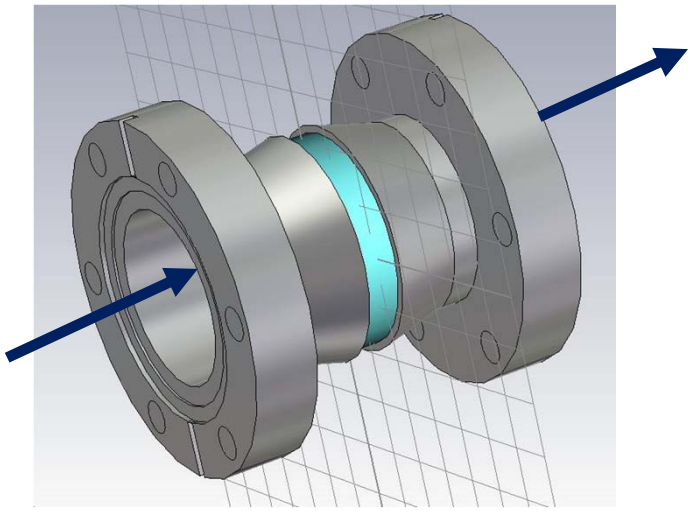
Uncompressed beam
~ 6ps (FWHM)
σ_Y~200 mm



CF=6;
beam ~ 1ps (FWHM)



BLM- CERAMIC GAP in RUN3

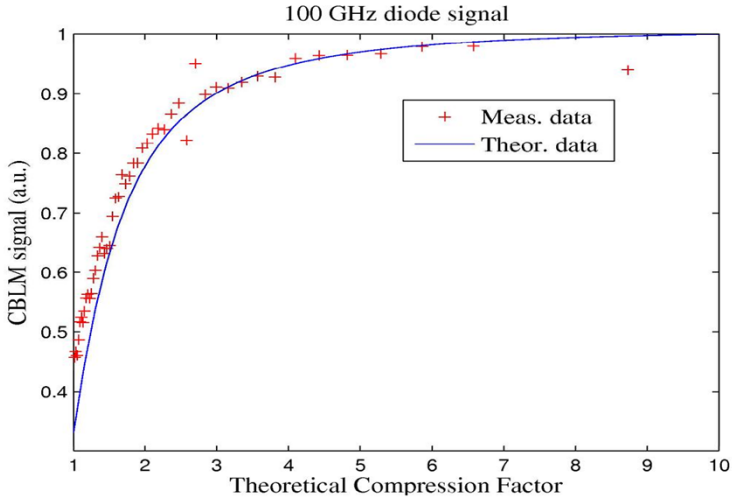


Spectrum-angular density of the radiated energy (Appio, Veronese et al. FEL10)

$$\frac{d^2W(\theta)}{d\omega d\Omega} = \beta q^2 \frac{\sin^2\theta J_0^2(ka\sin\theta)}{4\pi^2 c(1-\beta\cos\theta)^2 I_0^2(\frac{ka}{\beta\gamma})}$$

$$\left|\sqrt{\frac{1-\beta}{1-\cos\theta}}e^{jk\ell(1-\beta\cos\theta)/\beta} + j\sqrt{\frac{1+\beta}{1+\cos\theta}}e^{-jk\ell(1-\beta\cos\theta)/\beta}\right|^2$$

L.Palumbo CERN LEP TH/84-4 1984



Comparison of exp signal from 100GHz diode and theory vs theoretical compression factor.

Assumptions:

- Initial bunch length 6ps;
- Bunch profile rectangular for calculation of long. form factor used in coherent emission

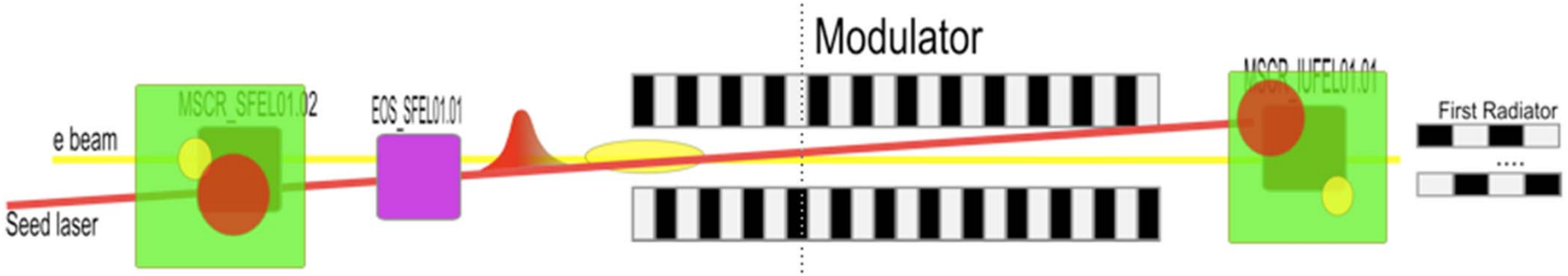
Data manipulation:

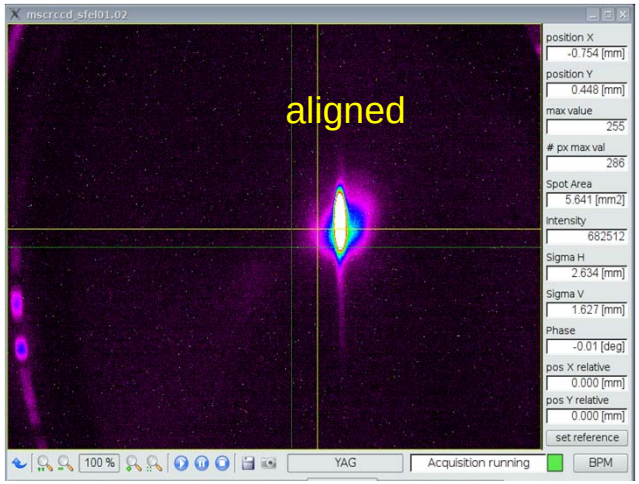
Nomalization to maximum value

Veronese, Appio et al.

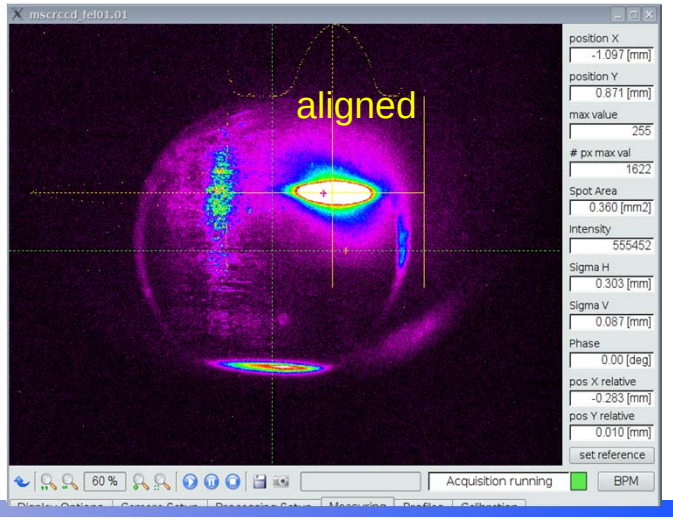
RUN 5 results (9th Nov. – 23rd Dec.)

- Beam has been transported to the MBD (compressed and uncompressed) and the trajectory was under control
- In order to superpose seed laser and e-beam we used the seed laser steering mirrors and after some interations we can obtain the alignement between seed and e-beam



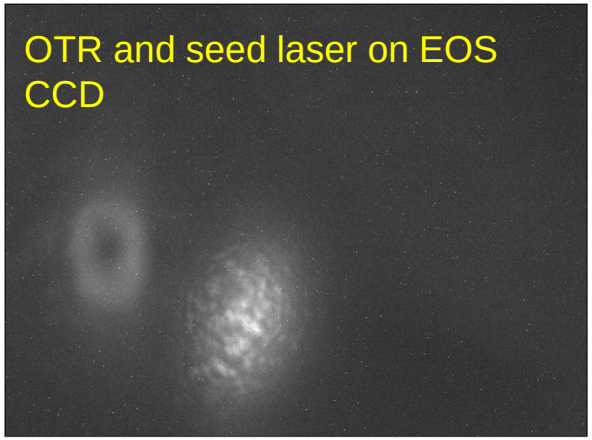


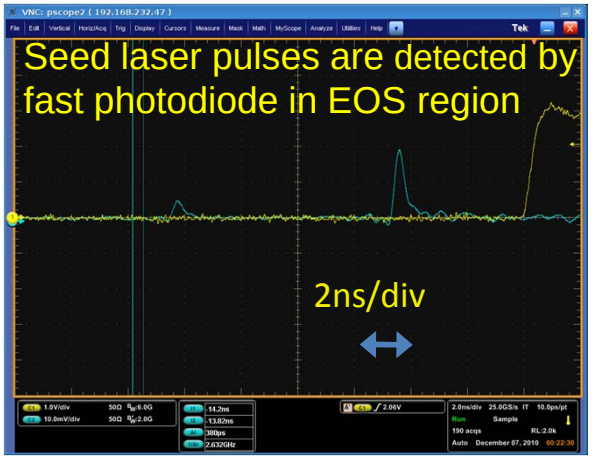
Spezzani, Veronese Sigalotti
Demidovichet al.

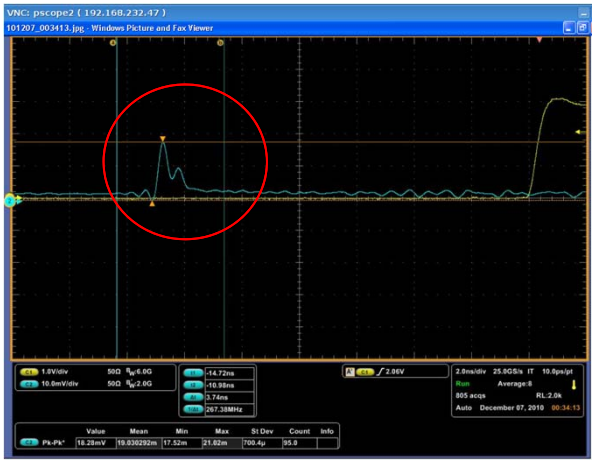


RUN 5 results (9th Nov. – 23rd Dec.)

- Seed-electron timing alignment:
  - The seed laser and the electron beam have been detected on the photodiode installed in the EOS chamber





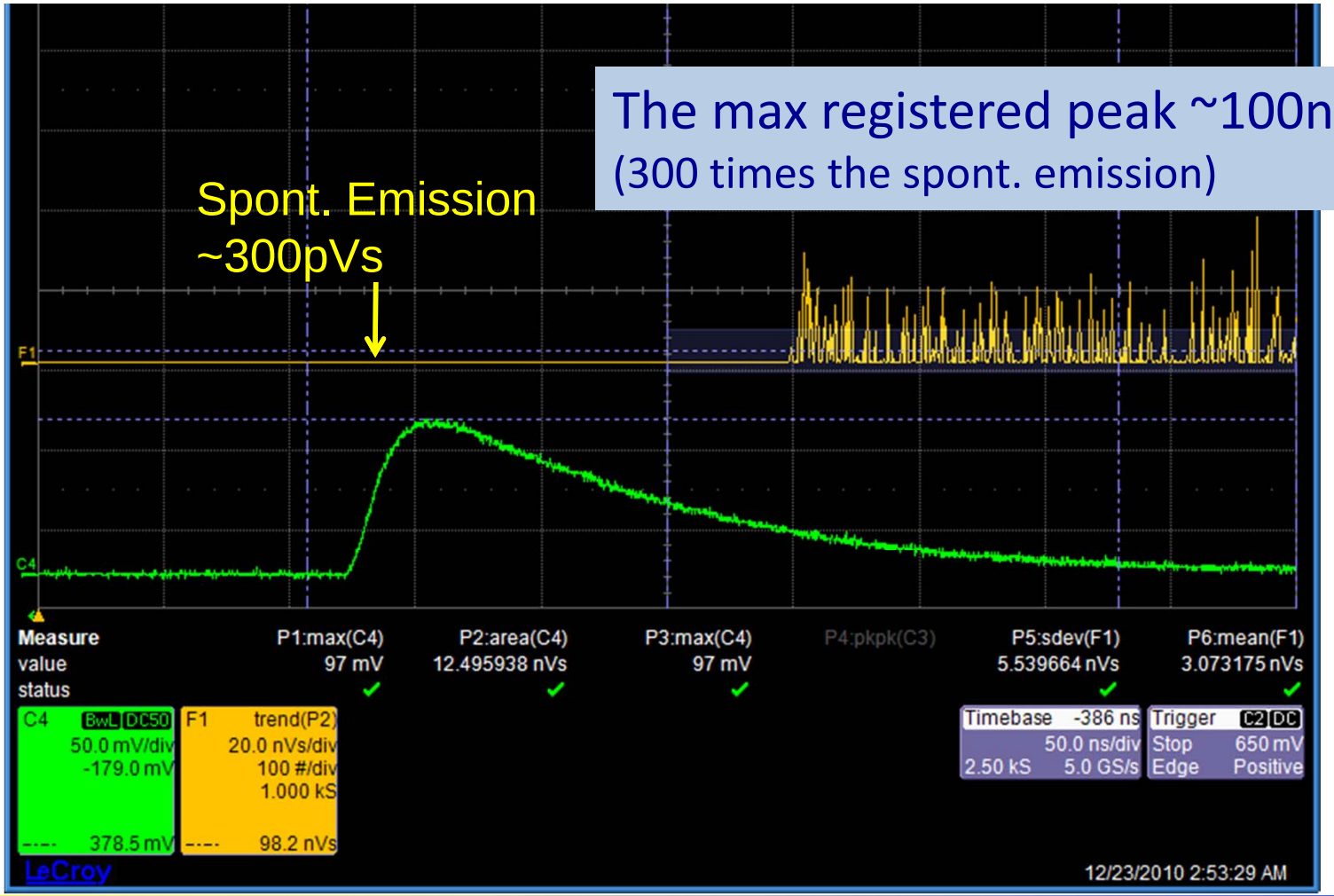


After the signal optimization using a CCD it has been possible to obtain the timing parameters that allow to overlap in time e-beam and seed laser within +-50 ps

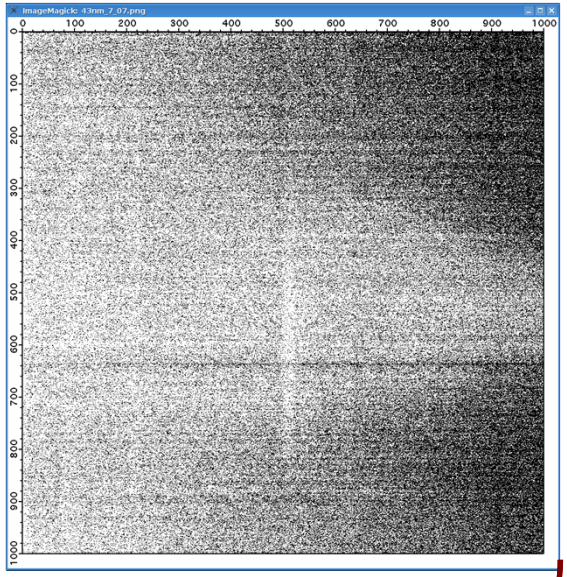
M.Veronese, C.Spezzani, P. Sigalotti, R.Ivanov et al.

RUN 5 results: Seeded FEL

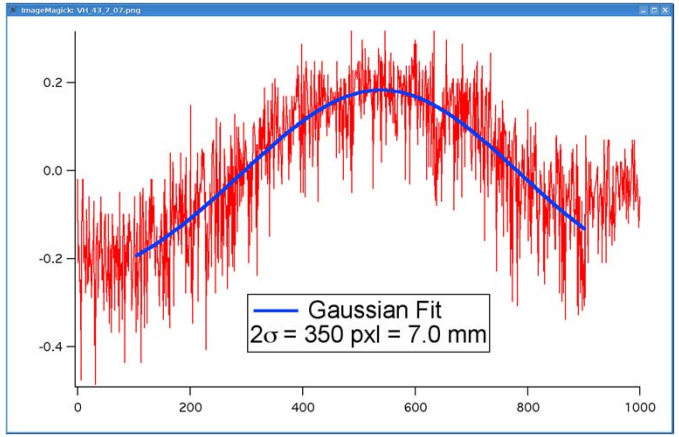
Using the delay line of the seed laser to do the fine tuning between seed and e-beam and radiators tuned at 43nm:



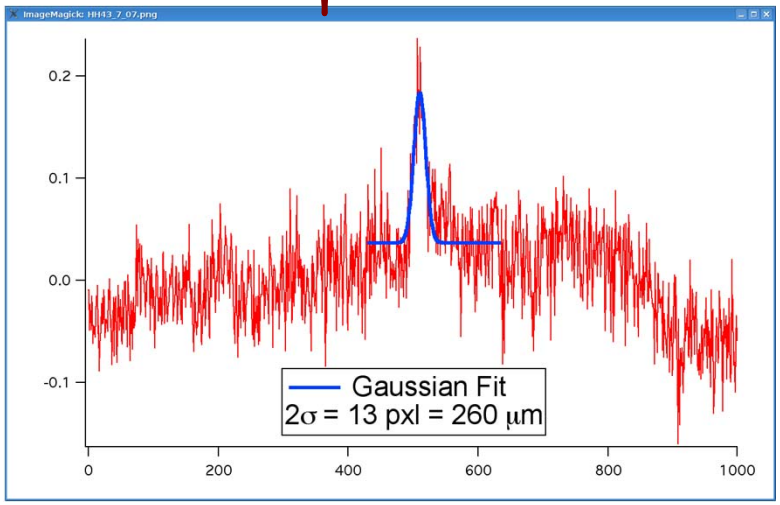
Seeded FEL: energy spectrum at 43nm



Measured with the PADReS photon energy spectrometer (no background subtraction has been done)



The vertical beam size (unfocused) has been estimated to be around **9mm FWHM**



The fit with a Gaussian function gives a FWHM of 330μm with an energy bandwidth of 33meV
Temporal pulse duration of the seed laser was 250fs.

Ref. D. Cocco, M. Zangrando

FEL higher harmonics

Preliminary

Number of harmonic	Wavelength (nm)	CHG signal (a.u.)
6	43.3	2.2
8	32.5	1.8
10	26	1.5
12	21.7	2
13	20	1.2/1.8
14	18.6	1.2
15	17.3	1.2

We acquired CHG signal up to the **15th harmonics (17.3nm)** by using the PADReS photodiode

…more other useful systems

- High resolution cavity BPM in the FELs beamlines
- Bunch arrival monitors in LH, after BC1 and Linac end
- Electro-optical sampling: in front the modulator
- Machine protection system & RadFET Dosimeters
- LLRF in the RF plants
- Timing & synchronization
- Bunch number and real time acquisition (correlations)
- Photon BPMs
- I0 monitor
- Photon beam spectrometer
- Stripline BPMs and Multiscreen stations
- Control system well integrated
- …

Acknowledgements

FERMI Commissioning Team, Engineers, Laser group,

Diagnostic group, Control group, ELETTRA Operators,

Linac Group, FERMI Commissioning Guests

Thank you for your attention