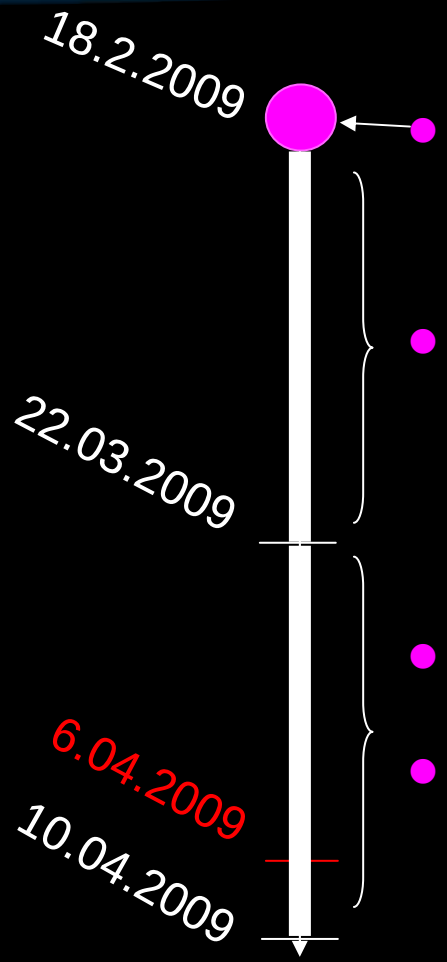
SPARC FEL – Status & perspectives

L. Giannessi
ENEA – C.R. Frascati
On behalf of the SPARC collaboration

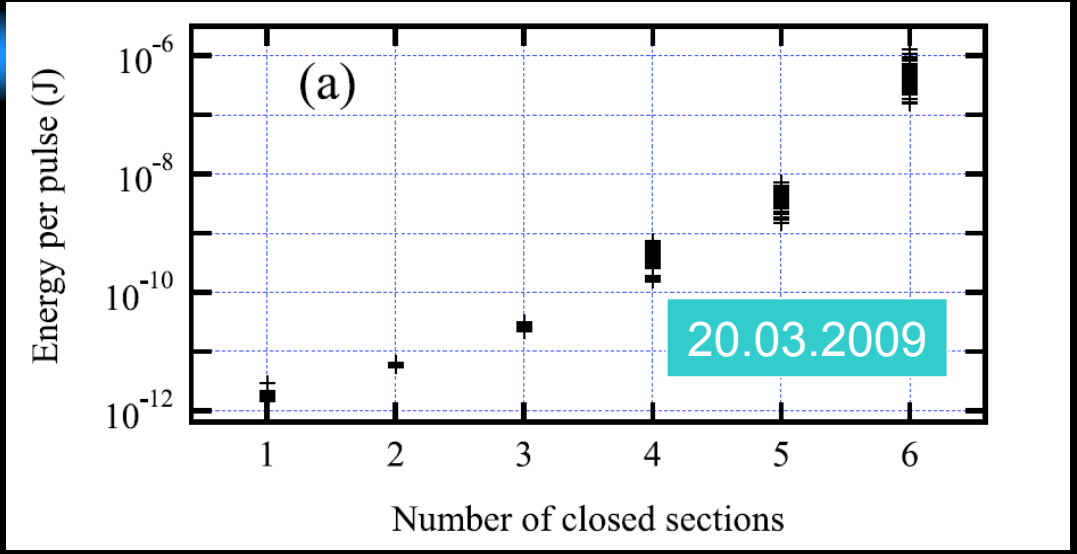
Frascati, 8/6/2009

SPARC

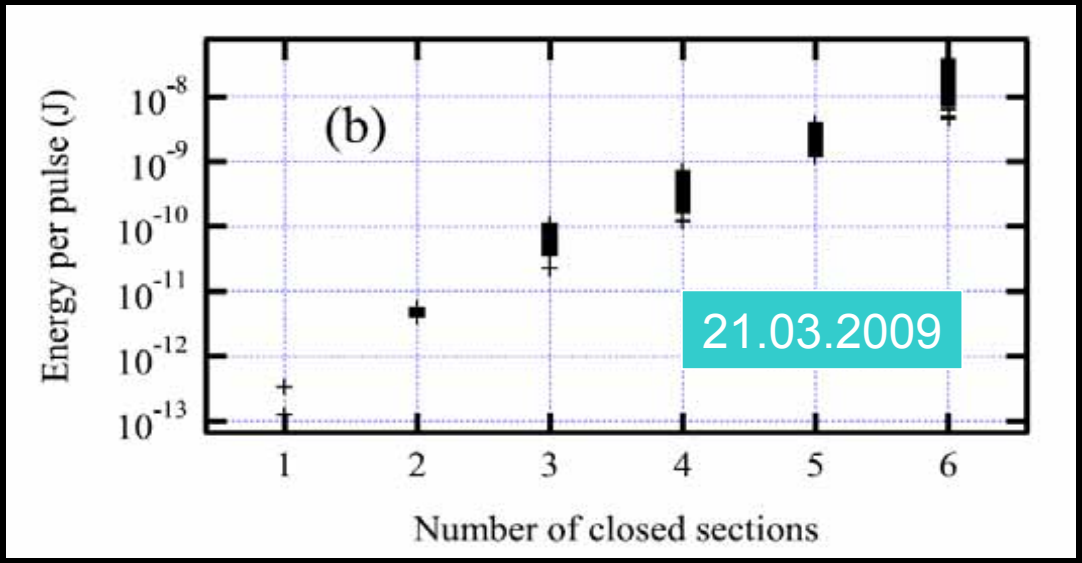


- LIFE meeting :
  - SPARC commissioned
  - First lasing @500 nm achieved
- Shifts until 22.03.2009
  - Beam based quadrupoles alignment
  - Absolute measure of FEL pulse energy vs z
  - Attempts to detect FEL harmonics
  - First tests of phase shifters
- Velocity bunching
- Earthquake
  - Orbit modifications
  - Undulators beam based alignment required

SASE results

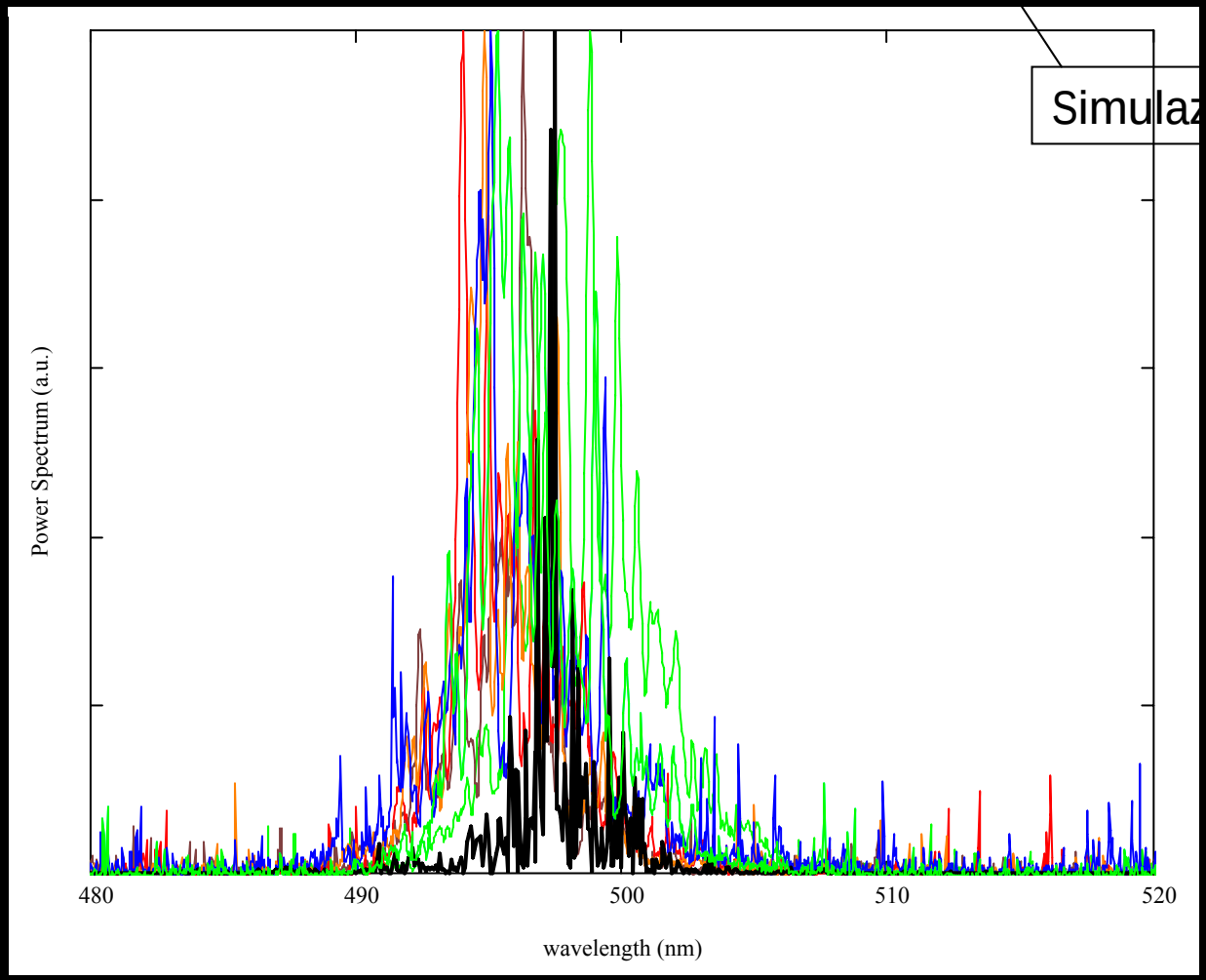


Q=0.25 nC



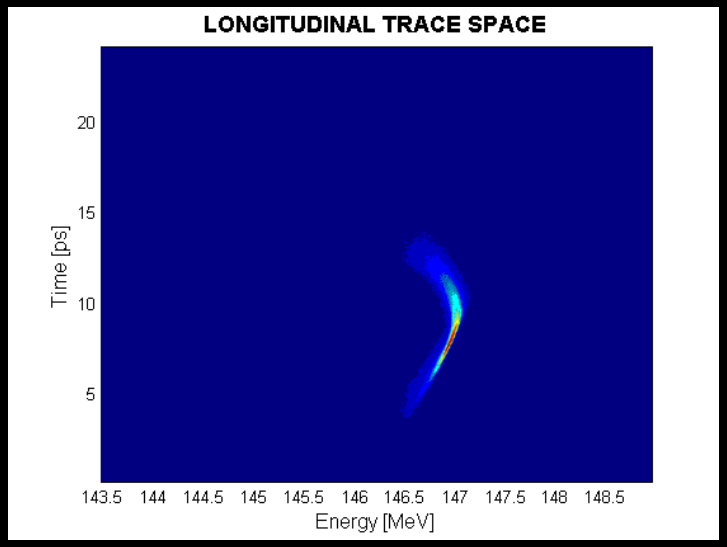
Q=0.2 nC

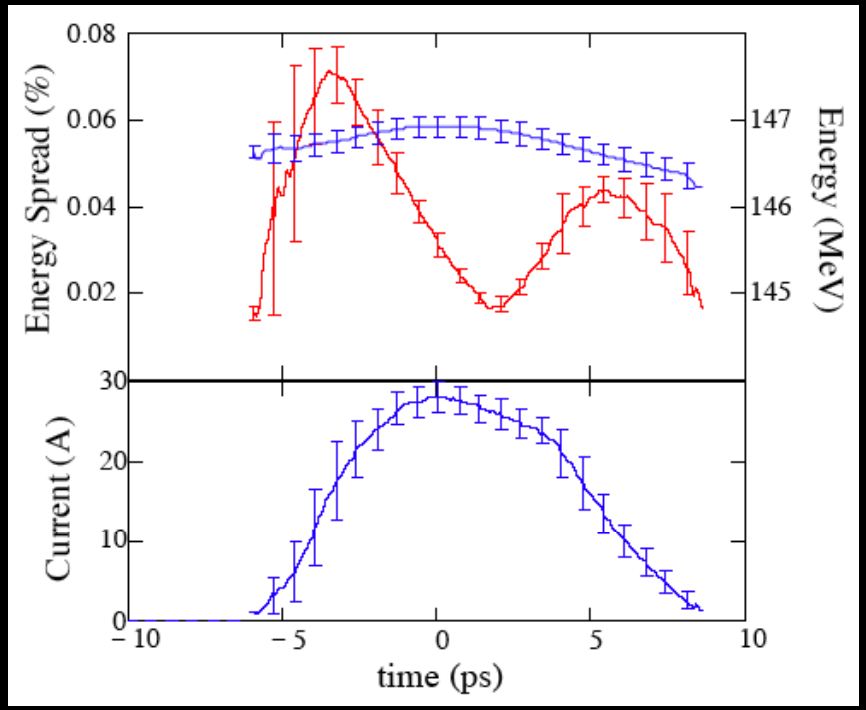
Spectra



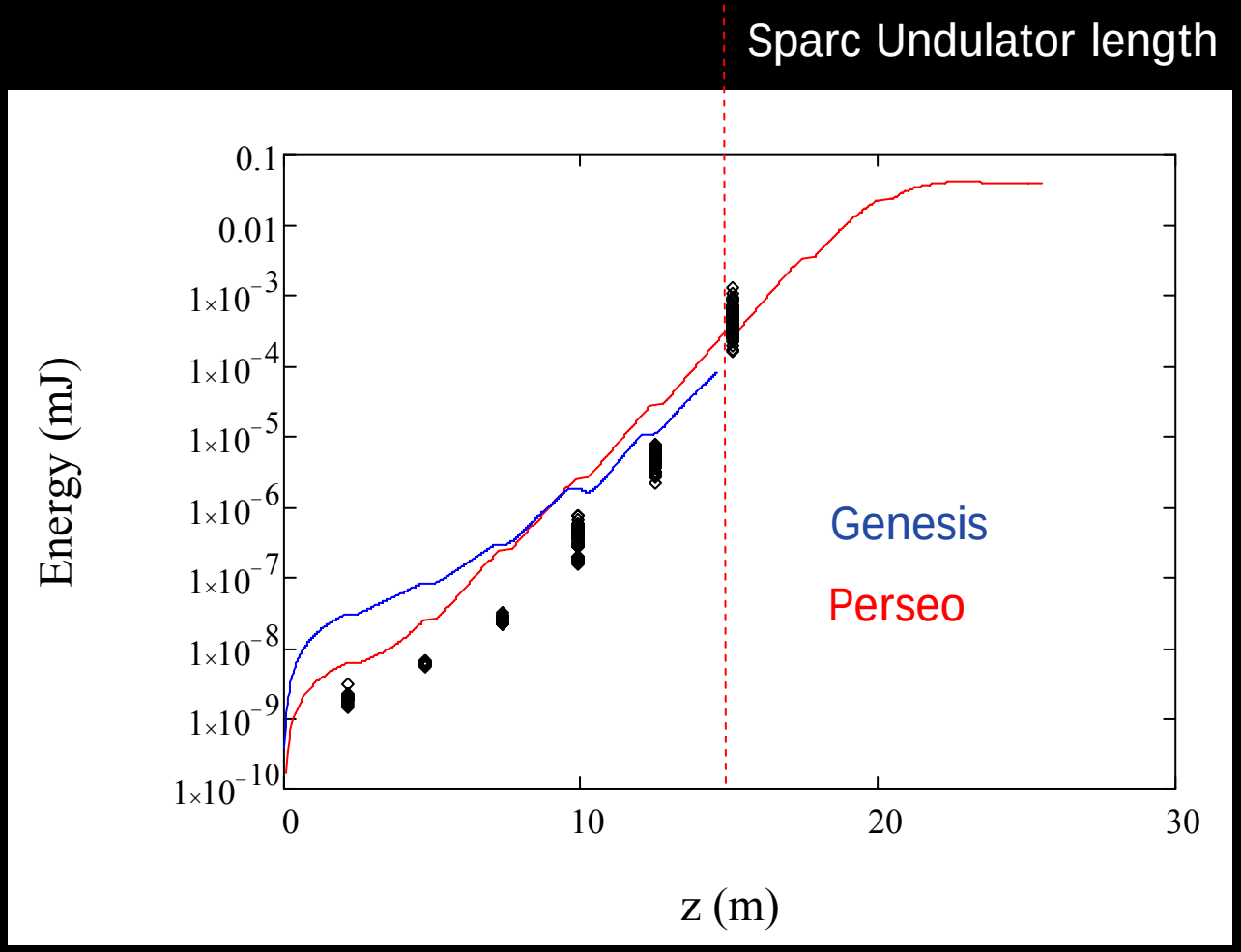
Spazio fasi rielaborato da D. Filippetto,
calibrazione deflettore del 18.03.2009 …

Q=250 pC
Ex=2 mm.mrad Ey=2.7 mm.mrad





Luca Giannessi,
LIFE Meeting
Frascati 8.06.2009


Sparc Undulator length
Energy (mJ)
0.1
0.01
1×10^-3
1×10^-4
1×10^-5
1×10^-6
1×10^-7
1×10^-8
1×10^-9
1×10^-10
0
10
20
30
z (m)
Genesis
Perseo

Next steps

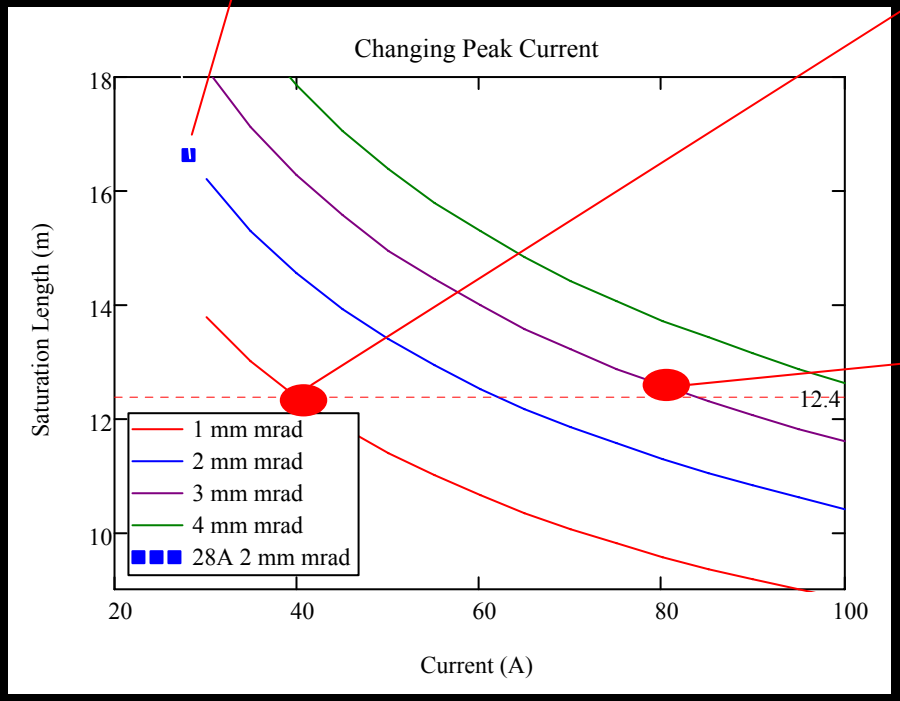
- SASE
  - SATURATION
  - HARMONICS
    - In vacuum filter wheel
    - In vacuum diagnostics (spectrometer)

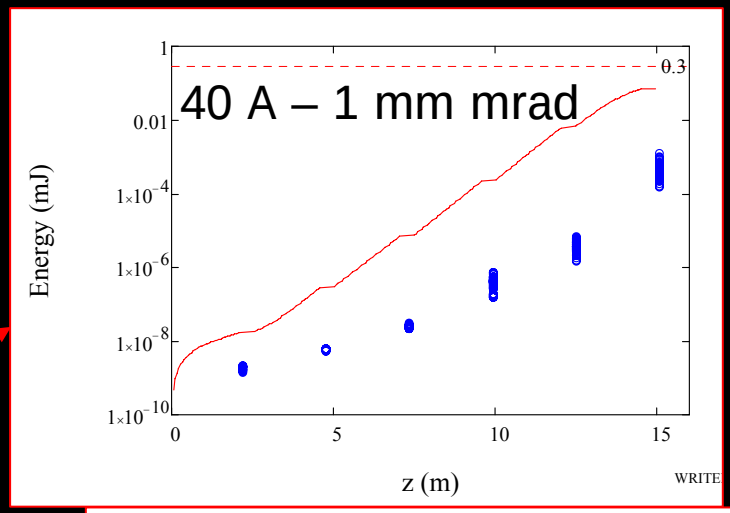
- SEEDING EXPERIMENTS
  - Synchronization
    - First synchronization tests with two lasers
    - Optical transfer line to the intermediate level
    - Streak camera set-up
  - Seeding with 400nm
  - Seeding with harmonics in gas
  - Cascaded FEL configurations

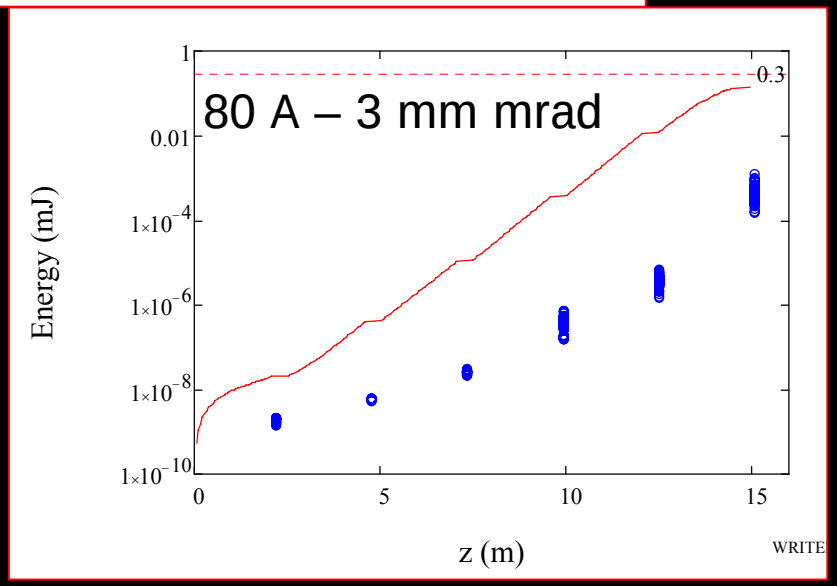
Luca Giannessi,
LIFE Meeting
Frascati 8.06.2009

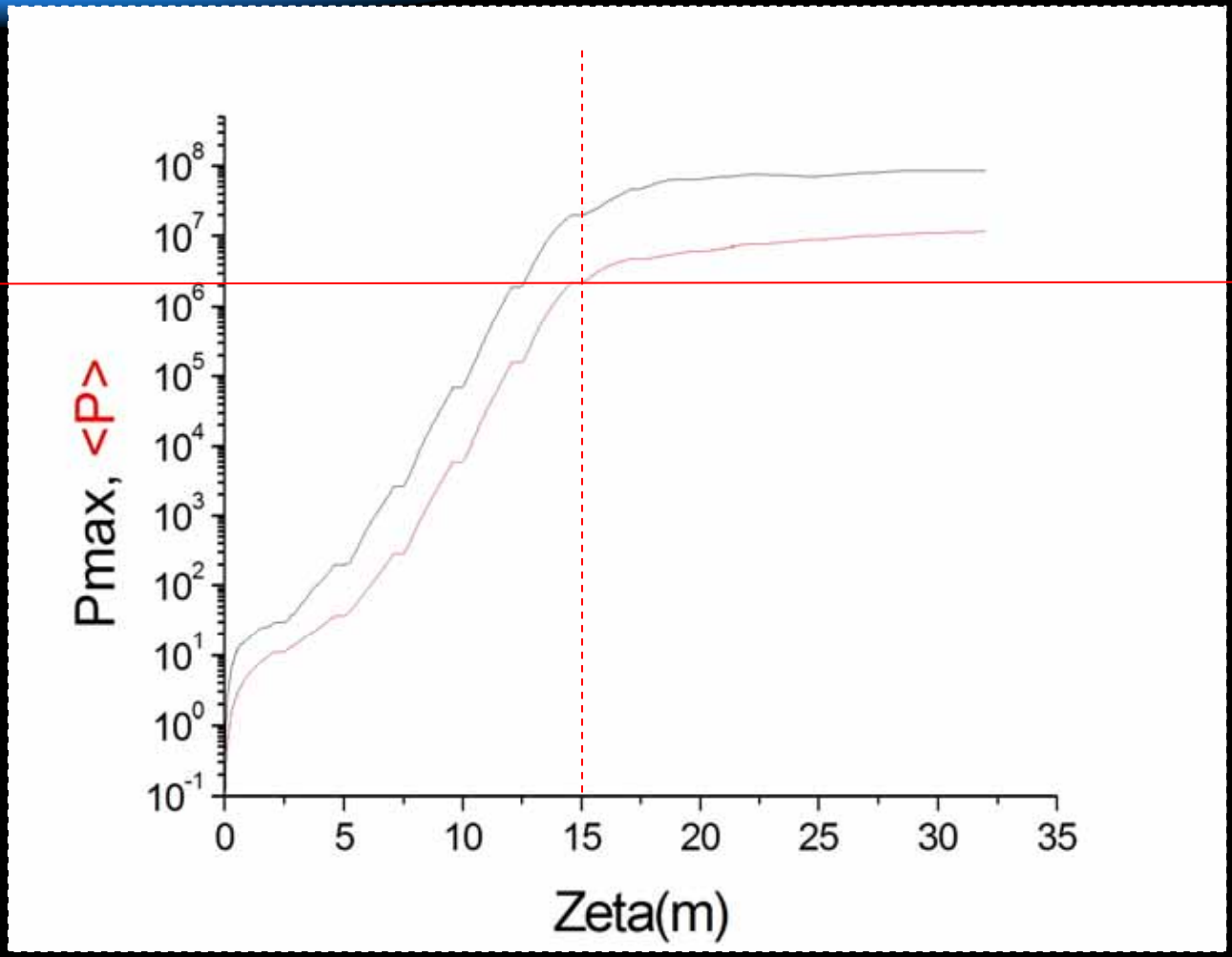
SASE

Shift in March








Pmax, <P>
10^{8}
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
0
5
10
15
20
25
30
35
Zeta(m)

Optimized working point (C. Ronsivalle)

BEAM PARAMETERS AT CATHODE

Q=500 pC

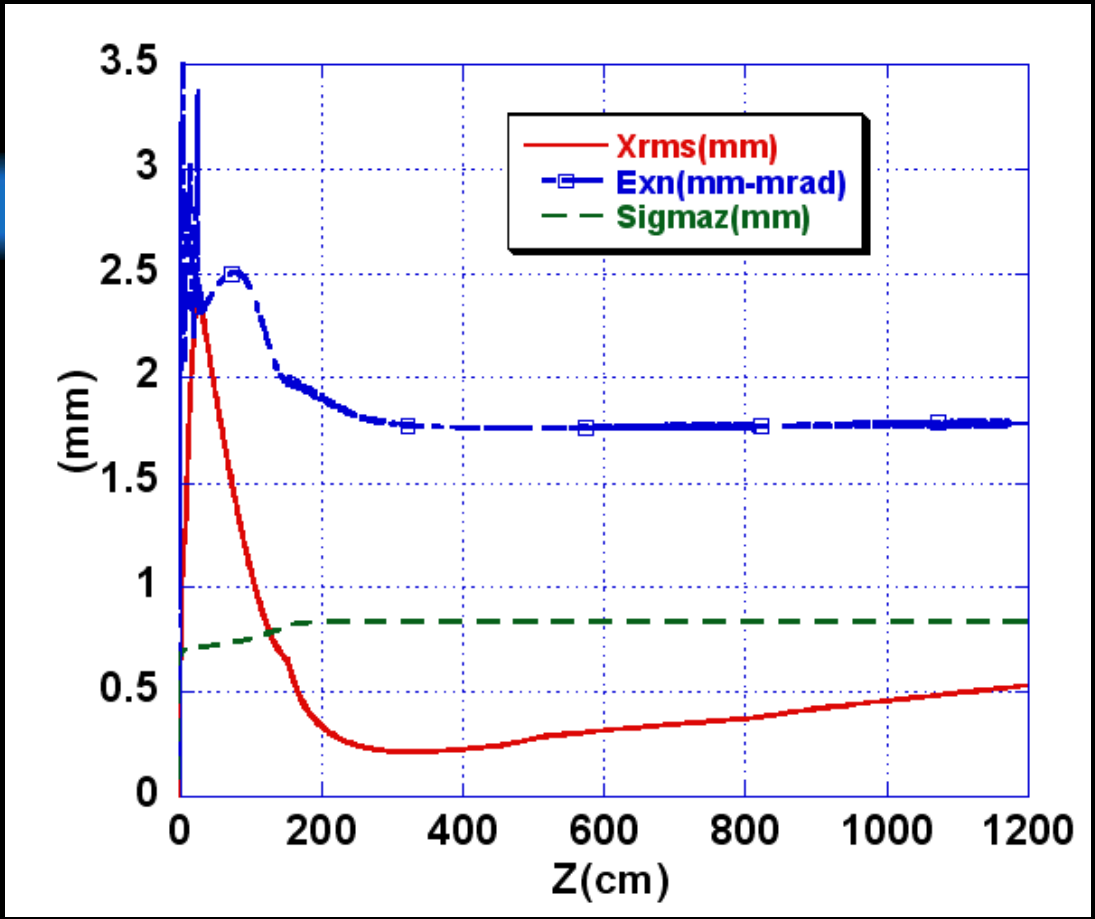
$\sigma x = \sigma y = 420$ um

Laser pulse: flat top FWHM=7.3 psec (measured on 18 June 2009)

Launching phase at the cathode: 22° (instead of the usual 30°) in order to achieve a partial compensation of the space charge bunch lengthening by RF compression

Note: this means that on the phase scan curve the working point phase has to be moved toward phases with lower charge. Q=500 pC is the charge at the new working phase!

Transverse and longitudinal envelopes



Isol=158 A*

1.8 mm-mrad**

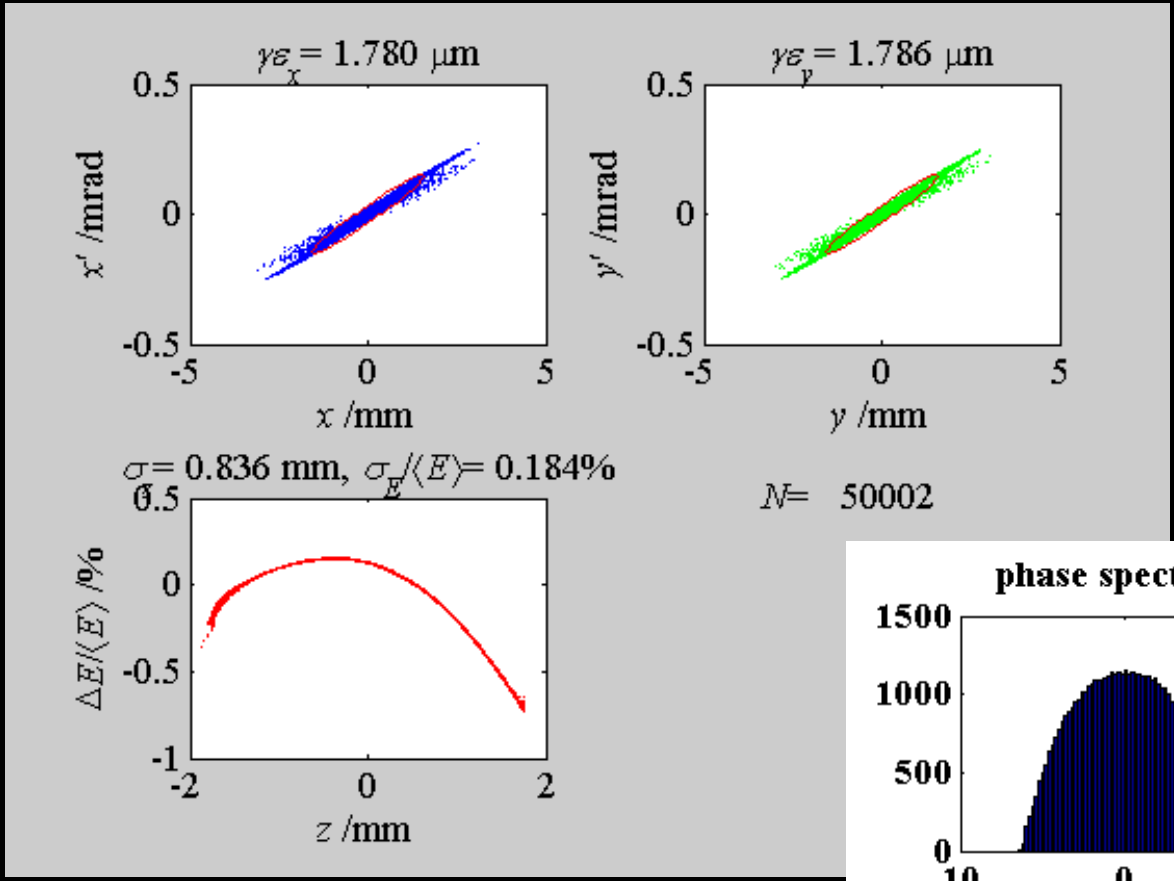
***This value can be taken as a reference point around which to perform the optimization**

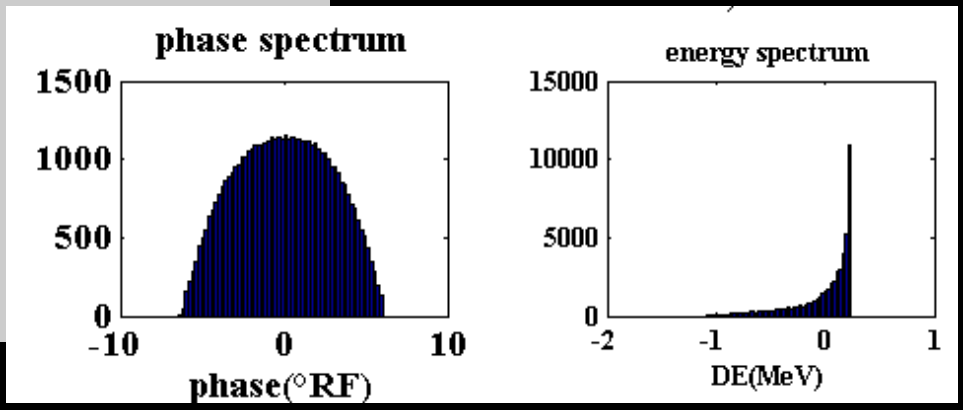
****In order to simulate more realistic conditions a worst value for the estimated thermal emittance has been used and not particular care to projected emittence optimization for the gun-solenoid have been taken**

Parmela Simulation 50k particles

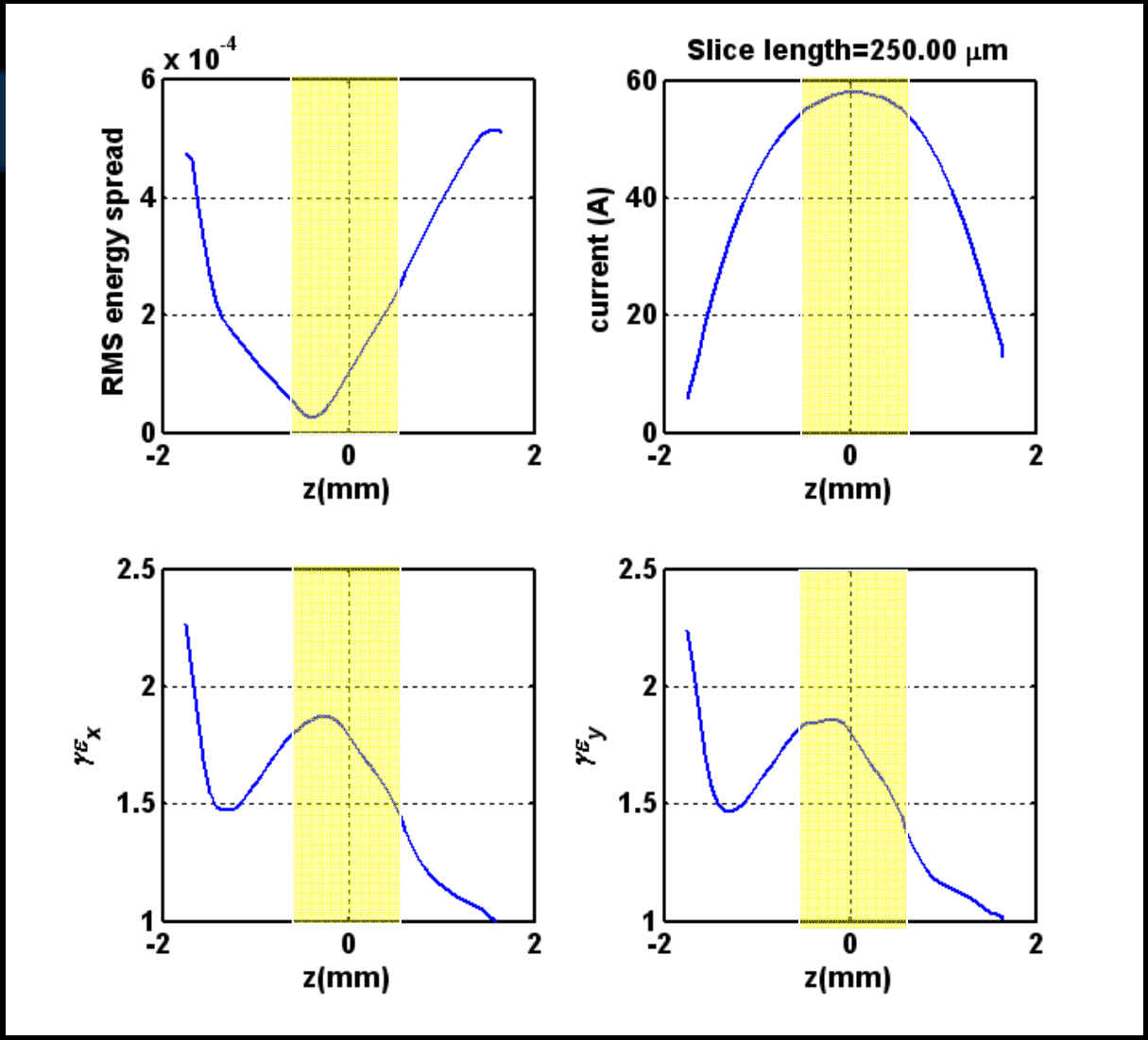
(Ronsivalle)

BEAM AT LINAC OUTPUT



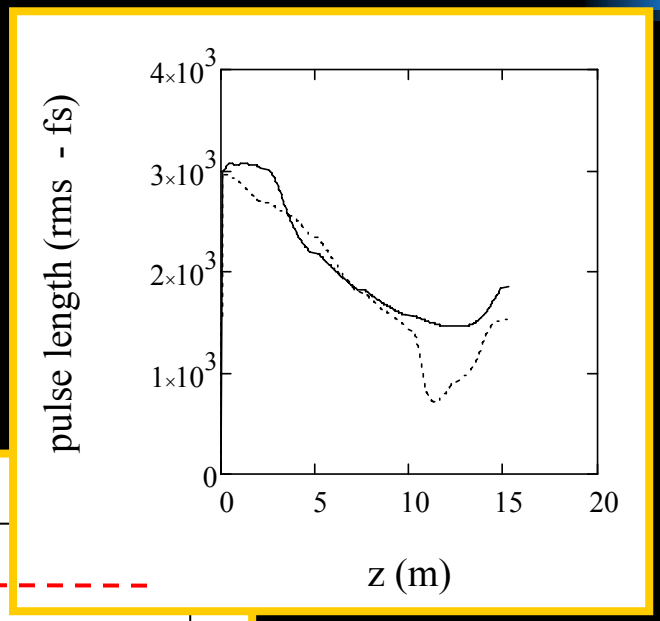


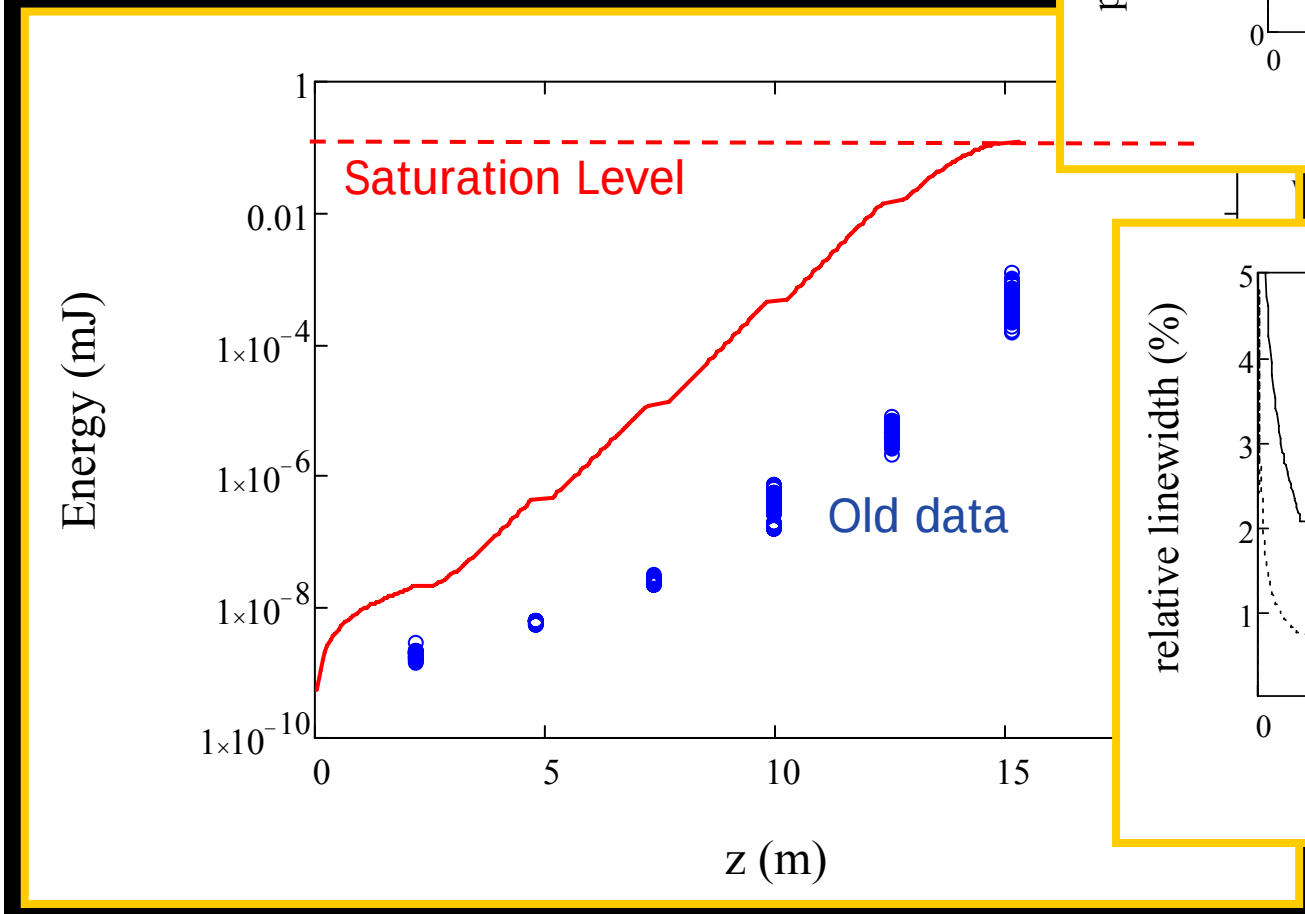
Slice analysis (Ronsivalle)

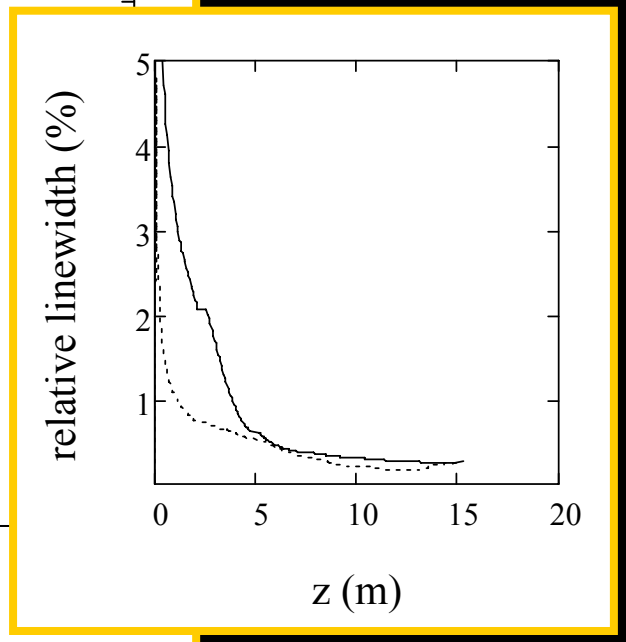


- **Max slice current=58 A**
- **Emittance of slice with max. current= 1.75 mm-mrad**
- **Average current 51.8 A**

FEL Simulation

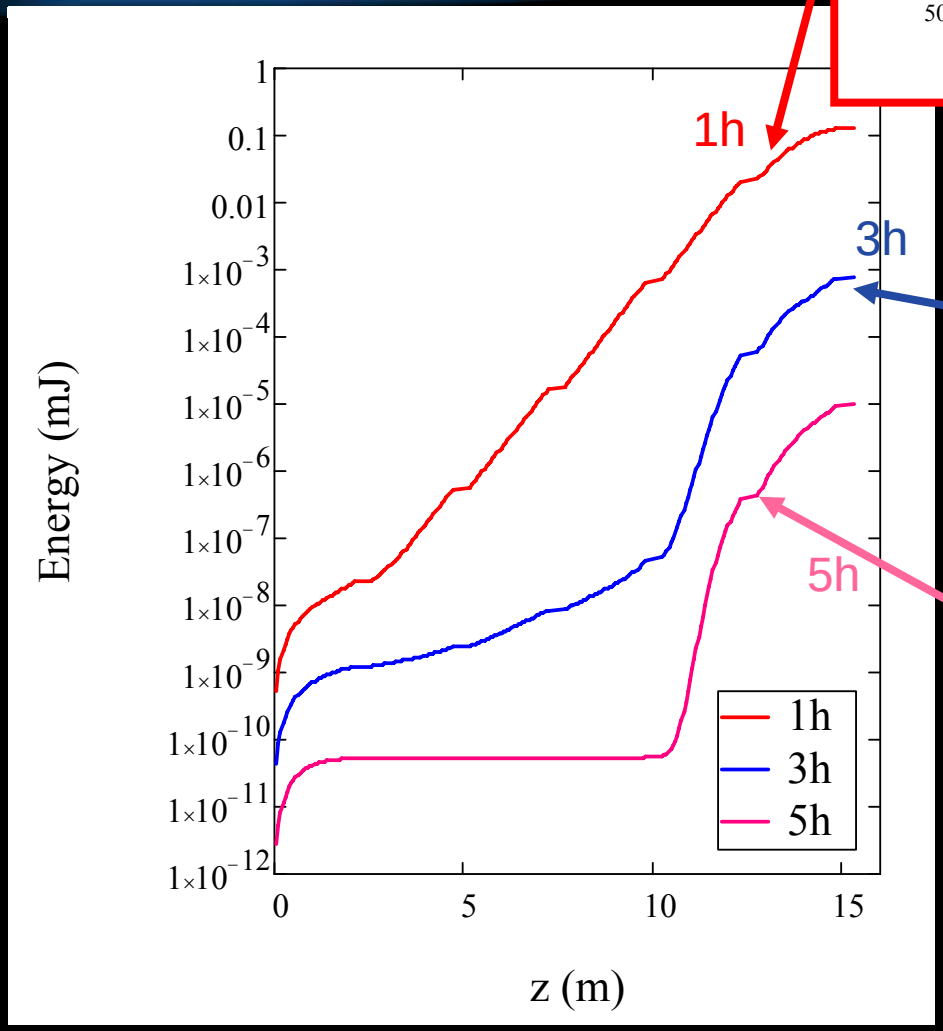


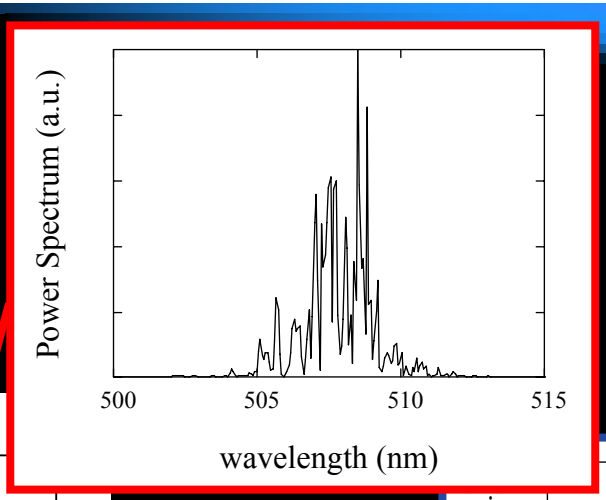


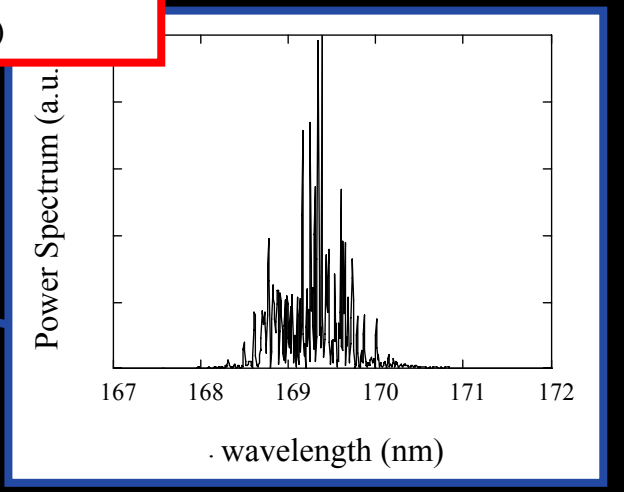


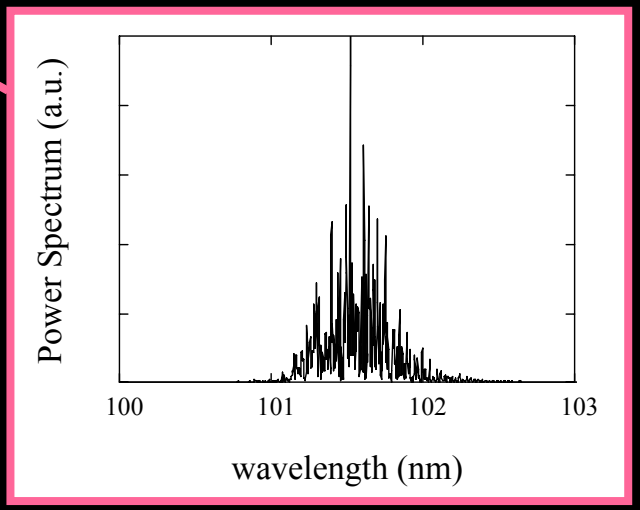
Perseo simulation

Higher harmonics



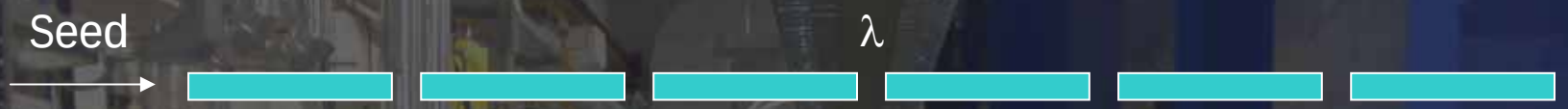






Seeded configurations

FEL Amplifier



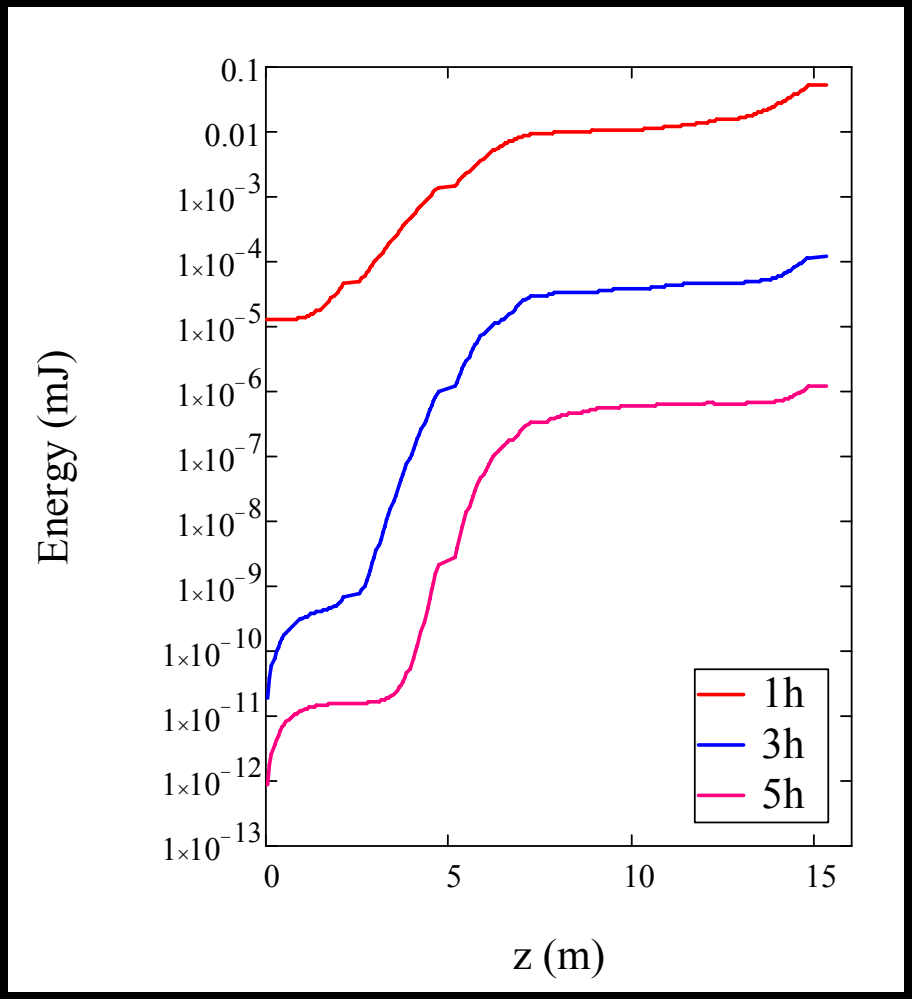
FEL Harmonic Generation

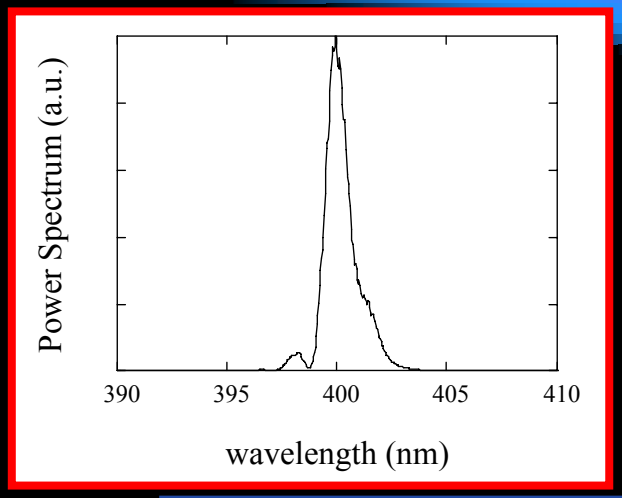
FEL Harmonic Cascade

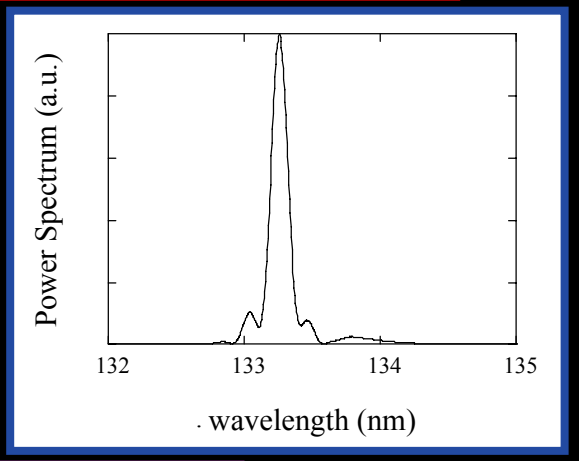
Fresh Bunch injection technique

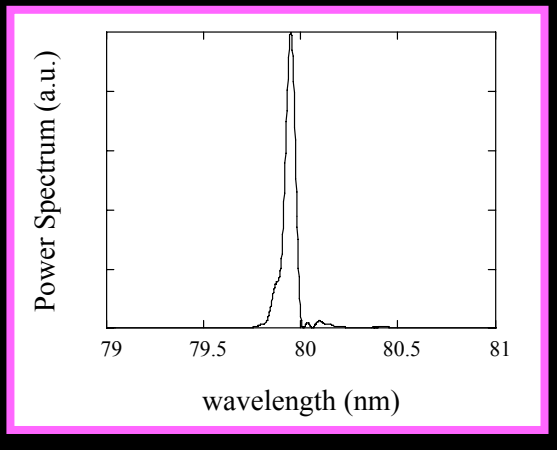
Seeded amplifier @400 nm

100kW seed peak power

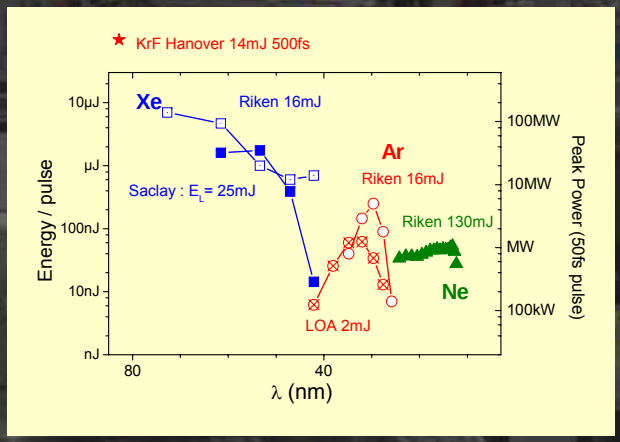


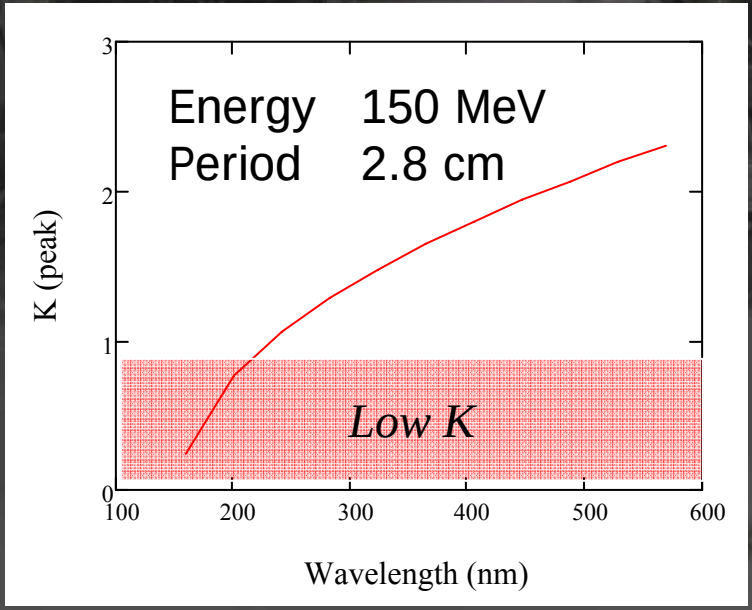






Seeding with high order harmonics generated in gas

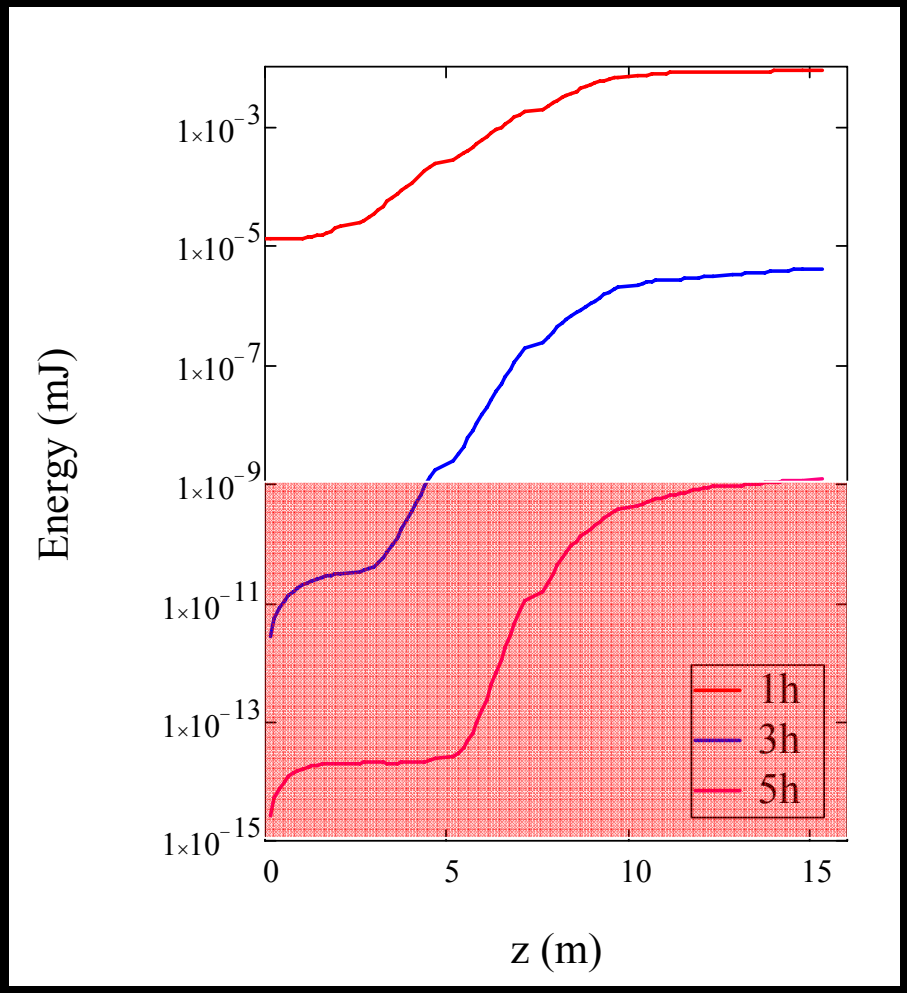


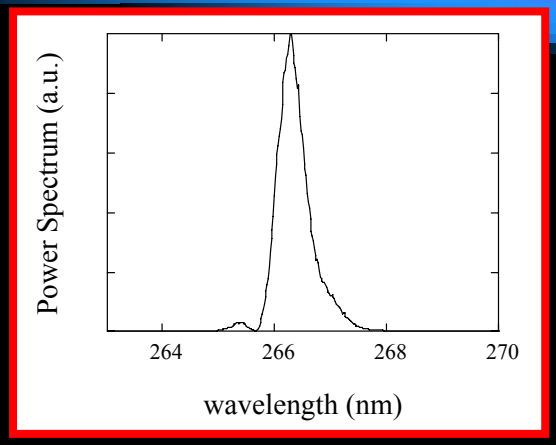


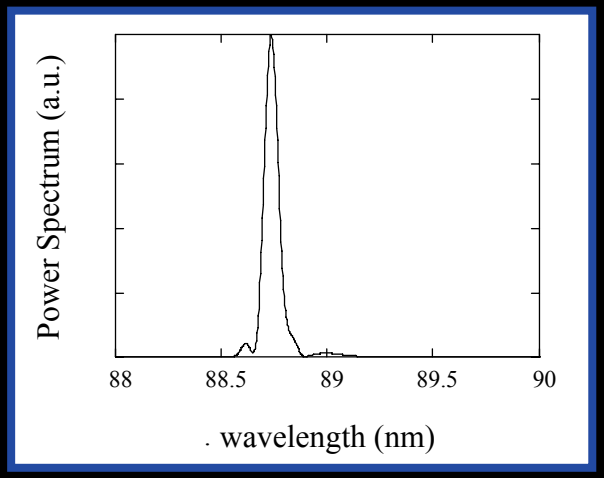
Increase beam energy is mandatory for wavelengths shorter than 266 nm

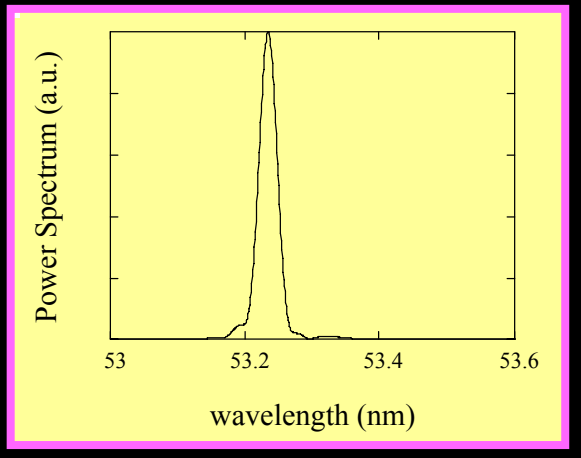
Seeded amplifier @266 nm

100kW seed peak power









Harmonic Cascaded FEL

Resonant at λ_1

Resonant at $\lambda_2 = \frac{m}{n}\lambda_1, \quad m \neq n$

UM1 → UM2

Emitted wavelength: $\lambda_m = \frac{\lambda_2}{m} = \lambda_n$

Bunching at $\lambda_n = \frac{\lambda_1}{n}$

Harmonics Spectra of the two undulators

1° Undulator 2° Undulator

\+

Superradiamt regime

a) Anticipate SASE saturation

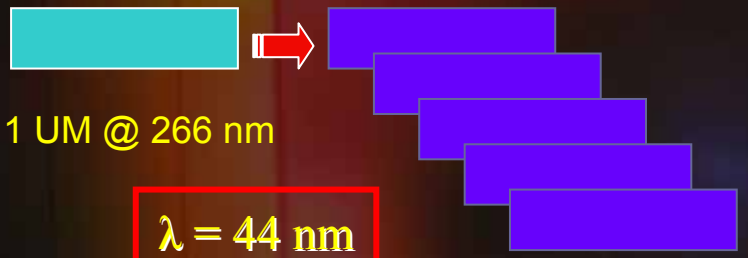
b) Increase efficiency
(eff. proportional to slippage)

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

Critical parameters

$n = 6$ and $m = 5$

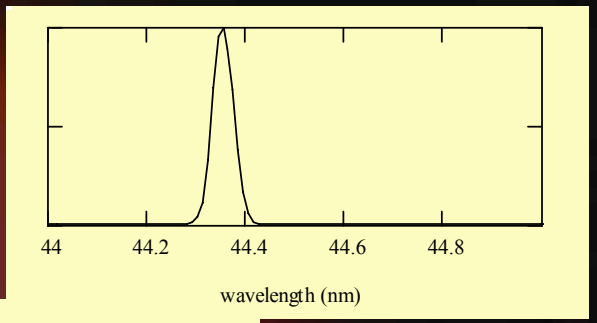
$n = 6$ $\quad$ $m = 5$

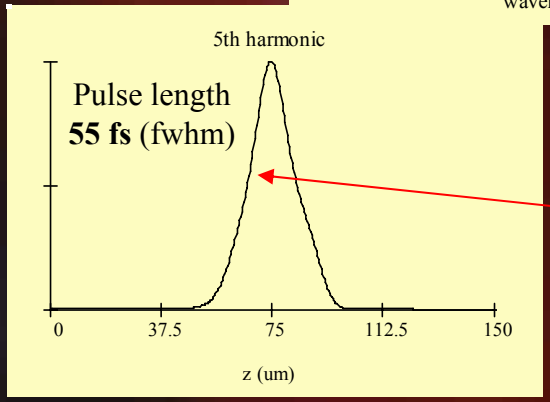


1 UM @ 266 nm

$\lambda = 44$ nm

5 UM @ 222 nm

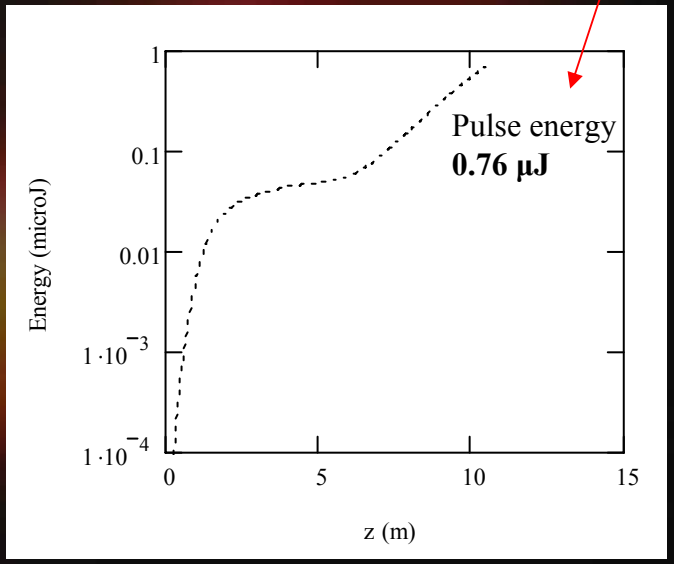




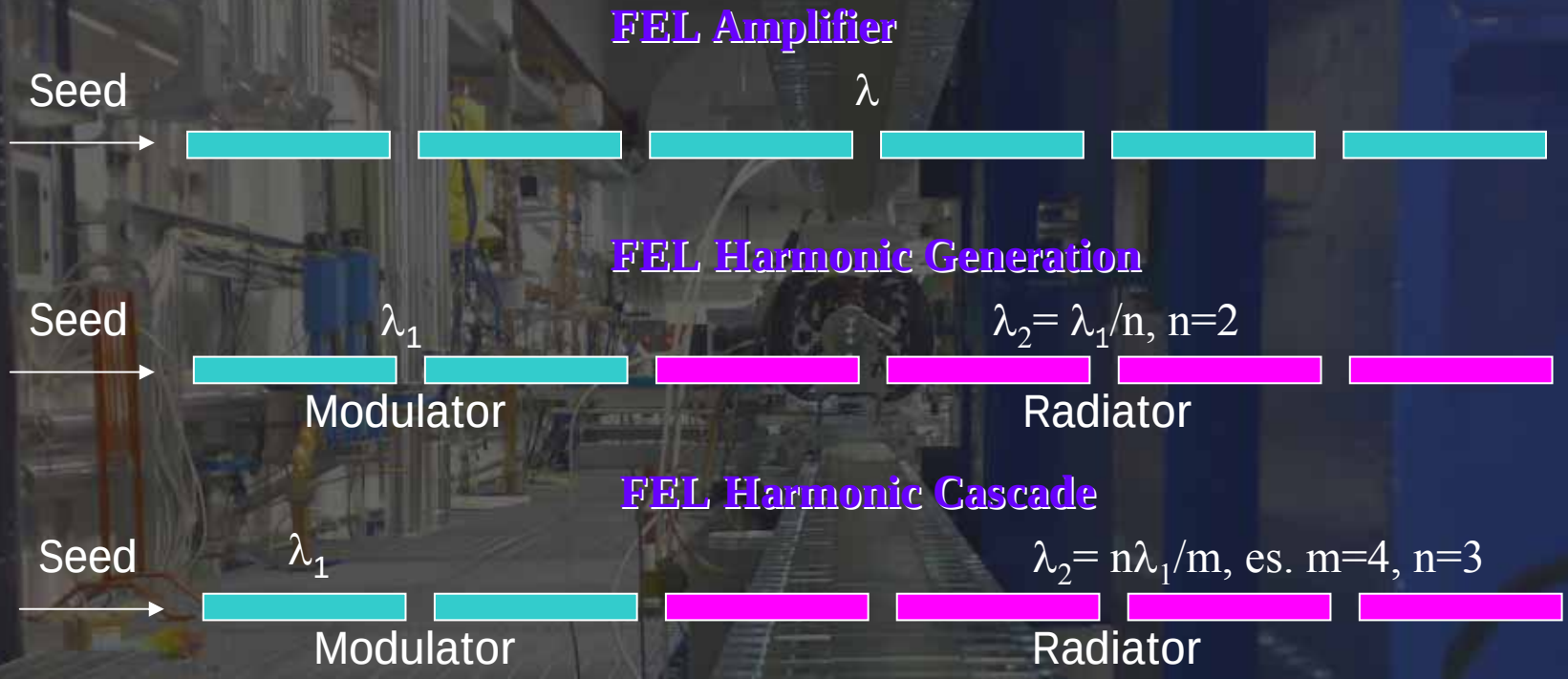
Peak power ≈ 12 MW

Main parameters

Undulator period	2.8 cm
Undulator K (UM1/UM2)	1.95 / 1.69
Number of periods	77 / 77*5
Beam energy	200 MeV
Res. wavelength (nm)	266 / 222
E-beam current	110 Amp
Energy spread	10^{-4}
Emittance	1 mm-mrad
Input pulse length (fwhm)	100 fs

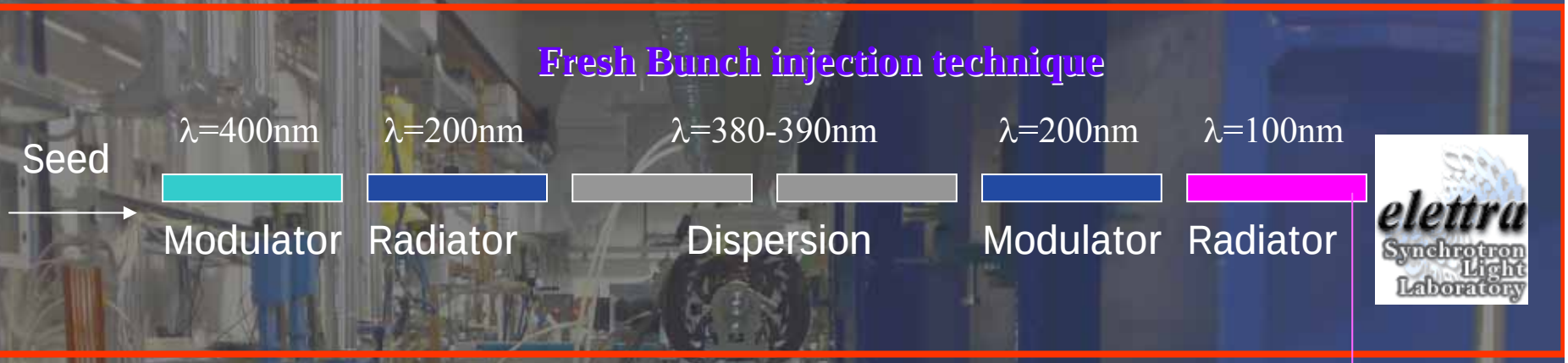


Seeded configurations



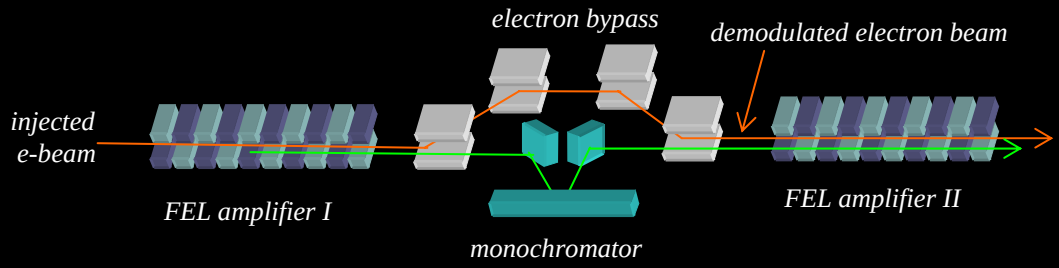
- SCSS – HHG experiments → OK – limited wavelength range
- (Brookhaven like) HGHG experiments → OK
- FEL CASCADE with HGHG → OK (NEW experiment)
- HARMONIC CASCADE → verify working point (NEW experiment)

Fresh bunch injection technique

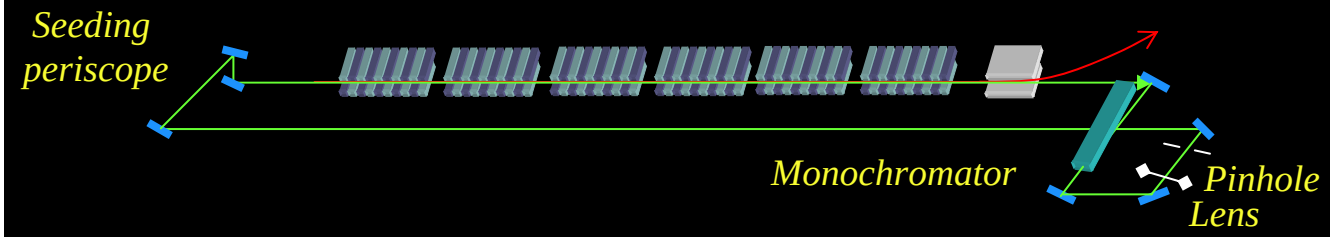


Self seeded: Regenerative amplifier

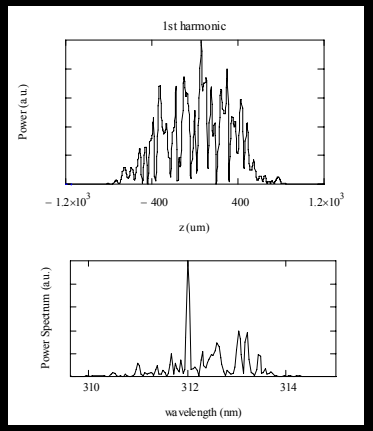
DESY



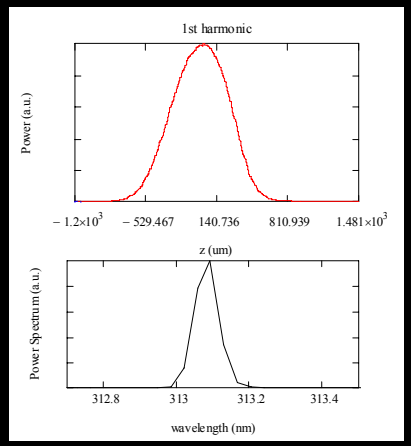
SPARC



First PASS



Second PASS



FEL experiments

- SASE full saturation
  - Higher order harmonics
- Seeding
  - SEED synchronization
  - SEEDED operation @400 nm
  - SEEDED operation with HHG
  - CASCADED FEL operation
- To do:
  - Increase current & energy
  - Increase reliability
  - Set up for short wavelengths