Operation and Upgrades of the LCLS

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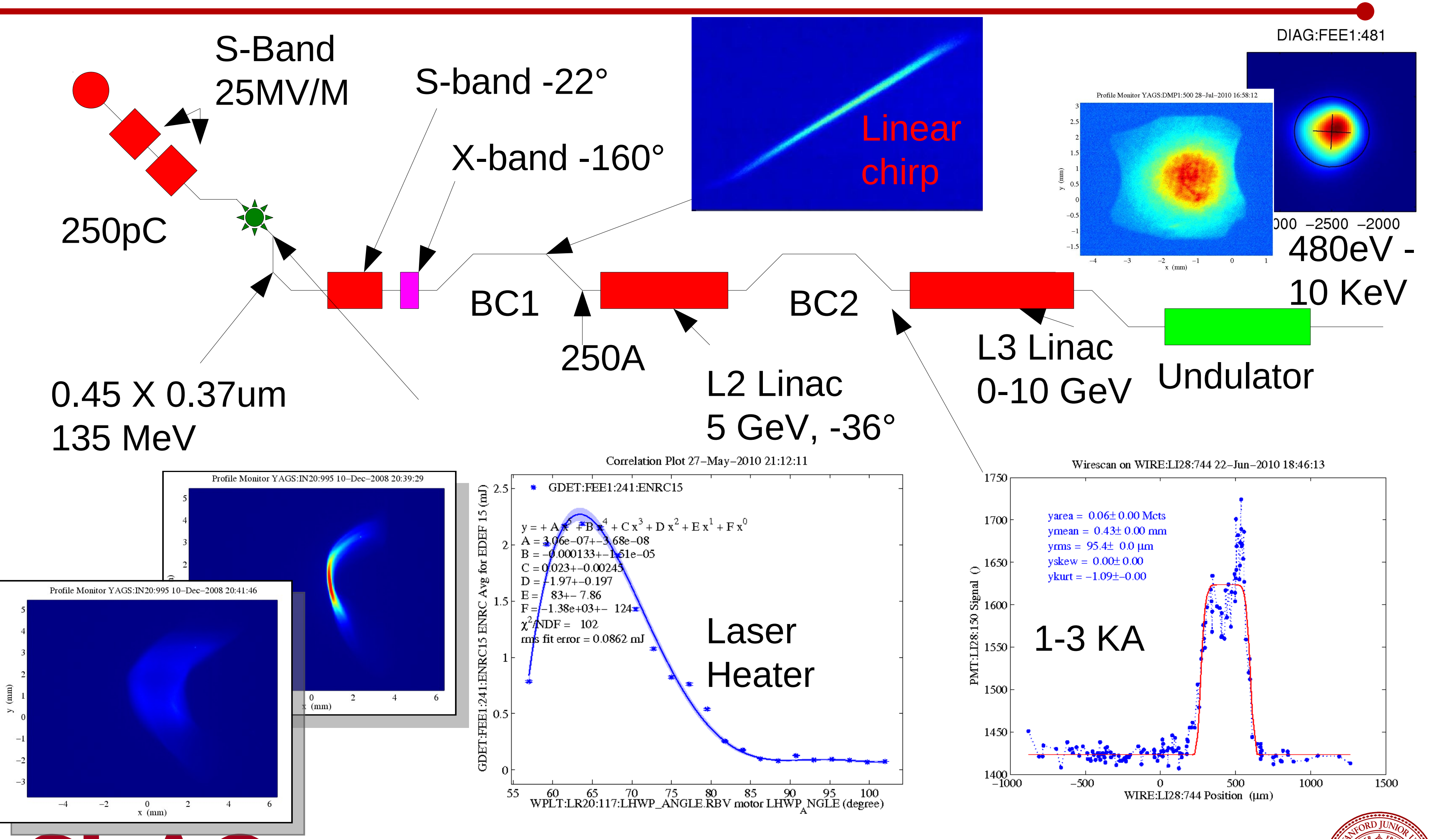
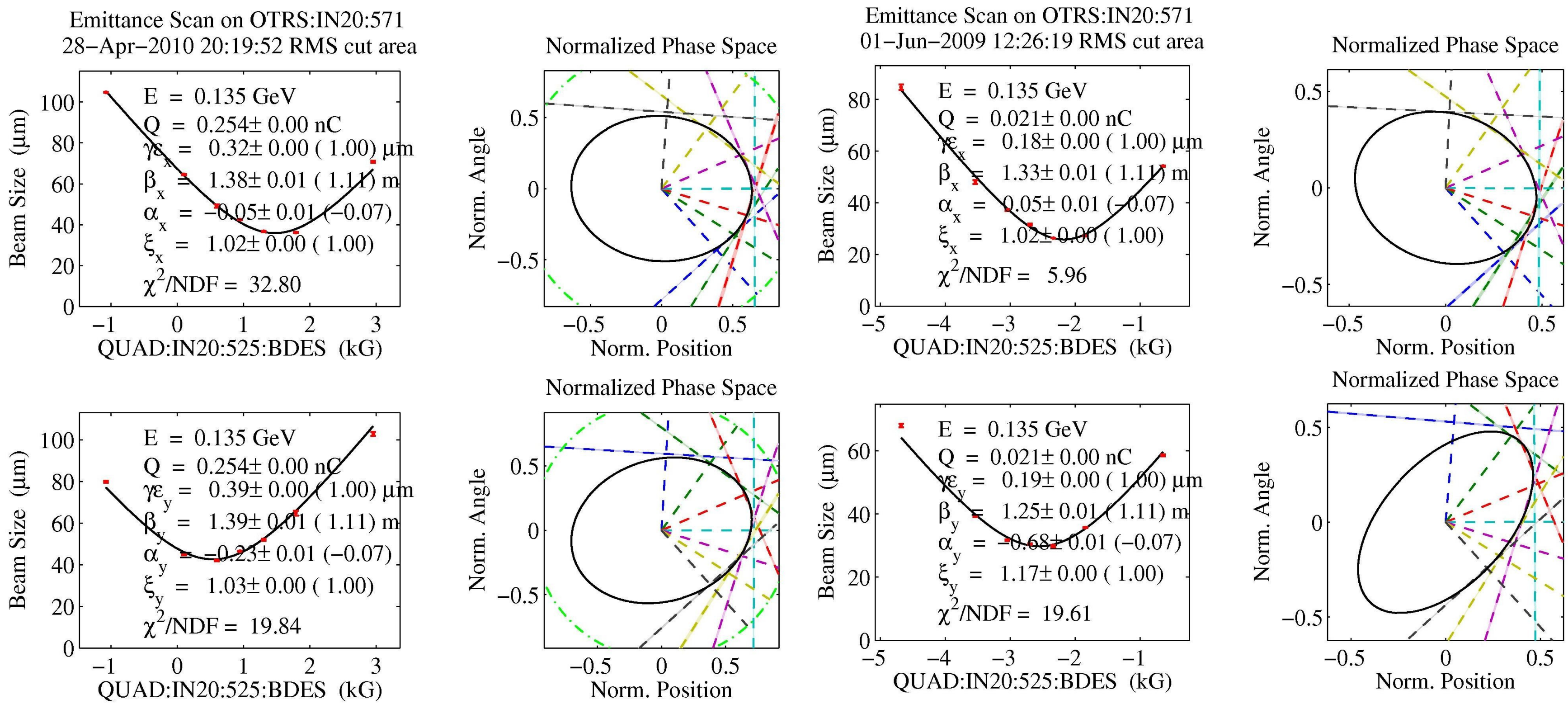
LCLS Accelerator



Injector Emittances

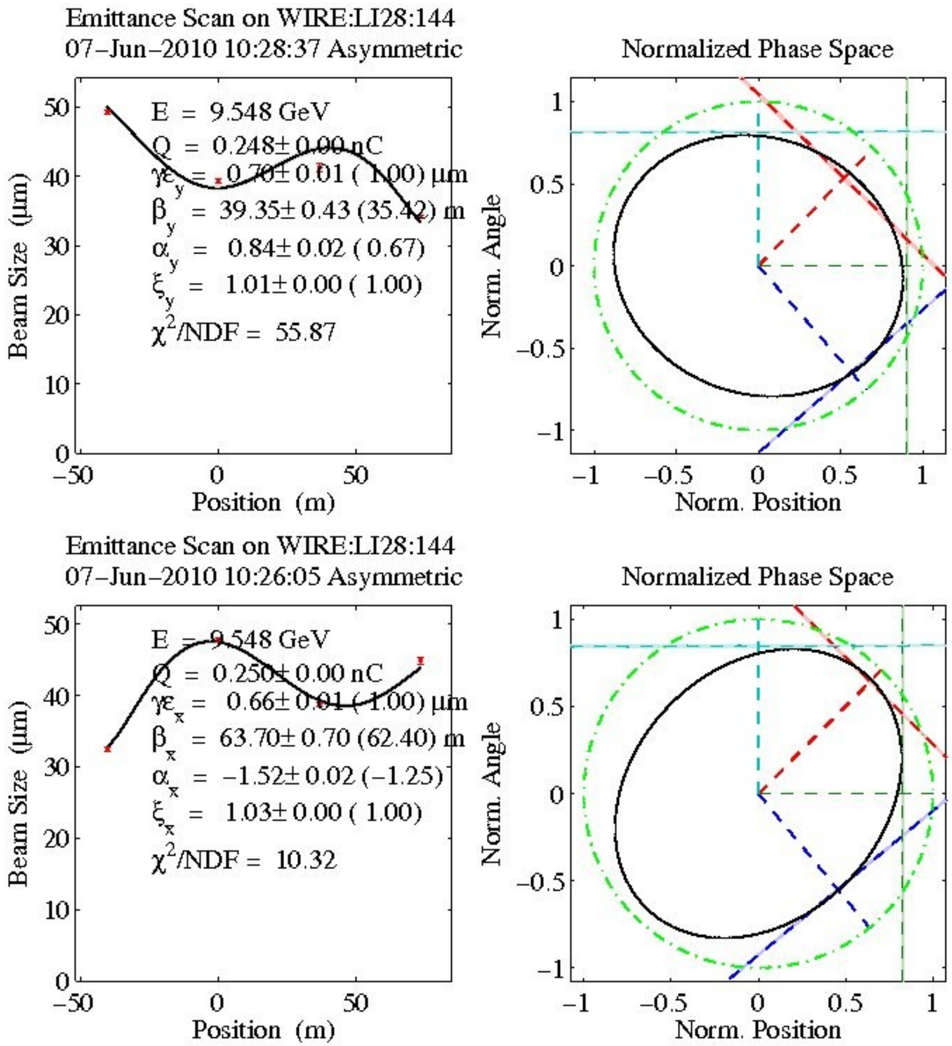


Emittance < 0.4 um both planes at 250pc.

Emittance <0.2um both planes at 20pc (low charge mode)

Note: Emittance 95% cut

Emittance at end of LINAC



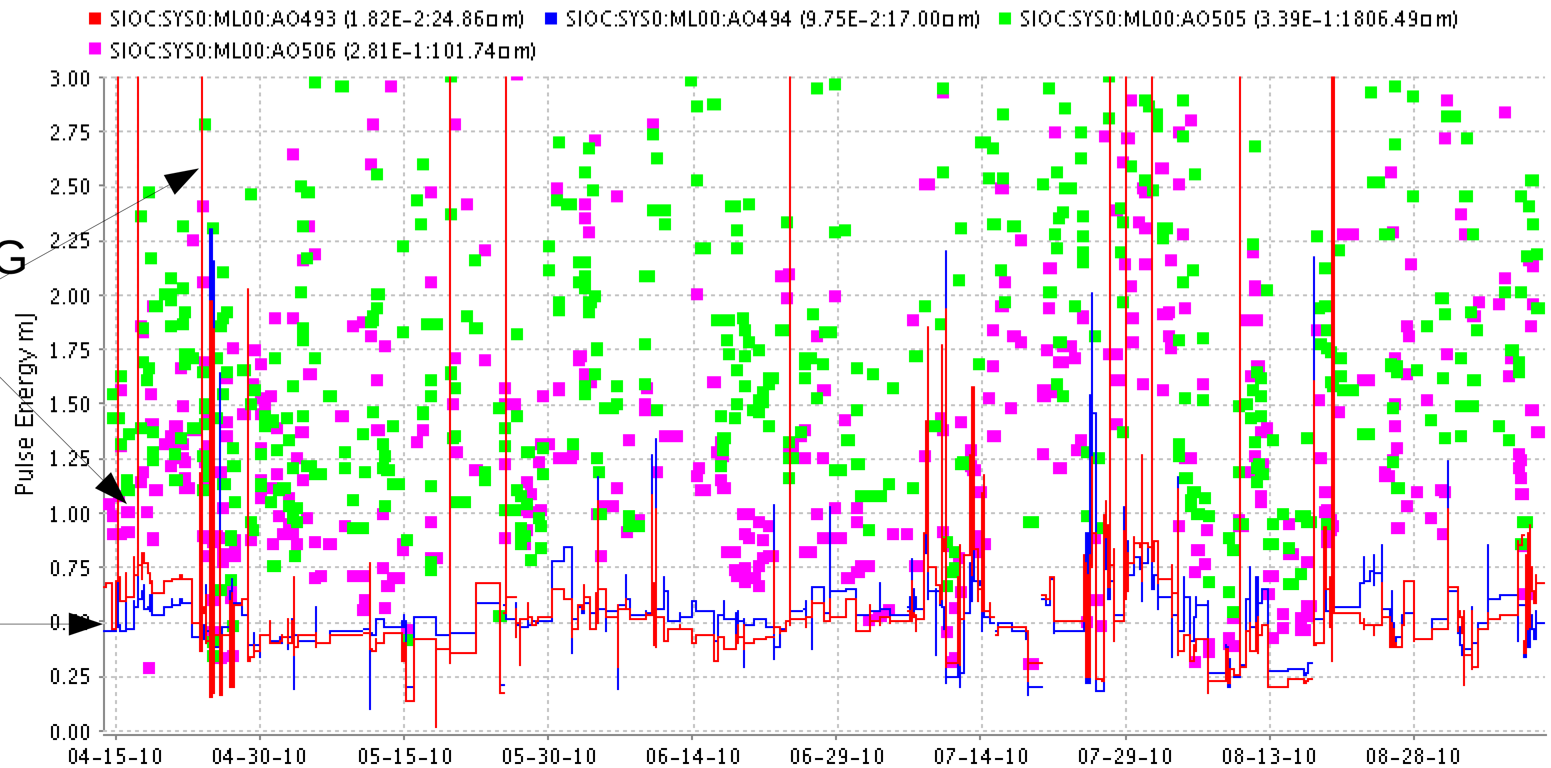
0.7 X 0.7 um Emittance at 14 GeV compressed beam(3KA)

Result of extensive experience tuning the SLAC LINAC: LCLS had > 1 year to tune the injector and LINAC!

Orbit bumps used to cancel wakefield tails

Emittance History

emit X BMAG
Before
Undulator



Injector
135 MeV

Emittance typically 0.5um at 135 MeV
Emittance X BMAG at undulator entrance 0.7-3um depending on energy and peak current.

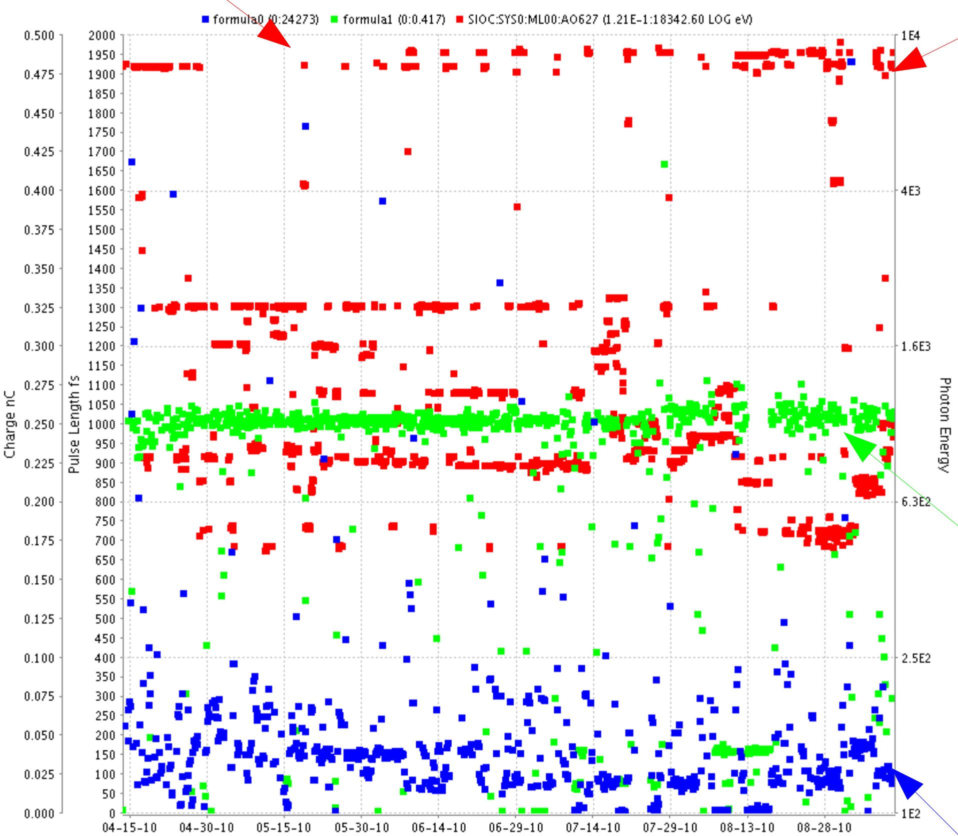
User Operation

- Adjust to match user requirements
  - FEL wavelength
  - Pulse length
  - Trade-off between power and spectral bandwidth (adjust undulator taper)
- Schedule
  - 12 hour experiment shifts
  - 1 day / week for maintenance / upgrades
  - 1 day/week for machine development

LCLS User Run 2

9 KeV

Photon Energy



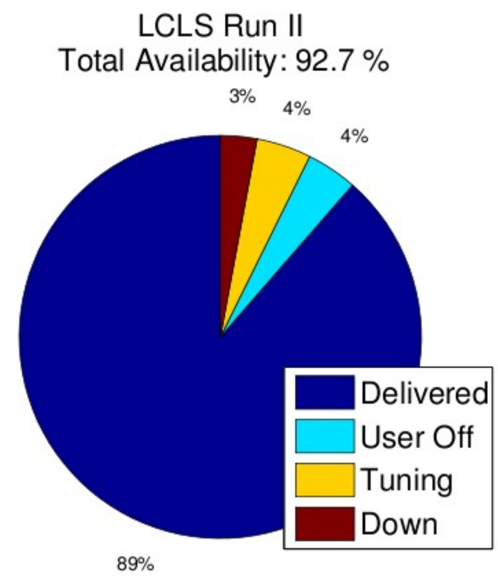
250pC

Bunch Charge

500fs

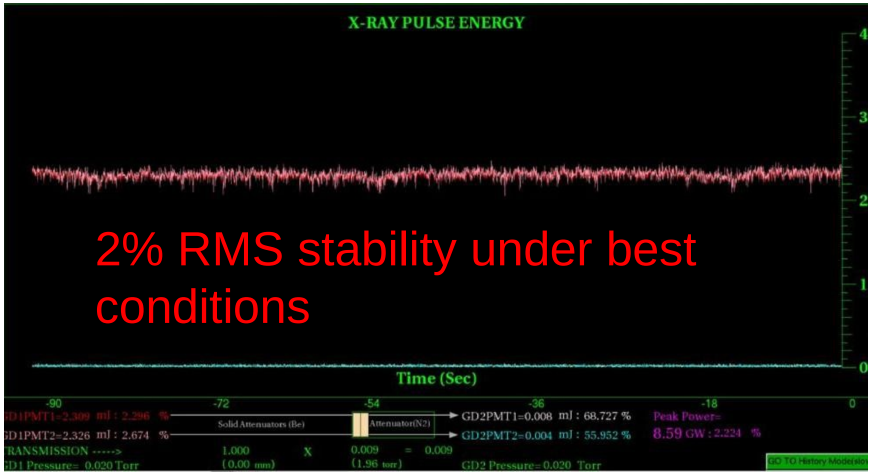
Bunch Length

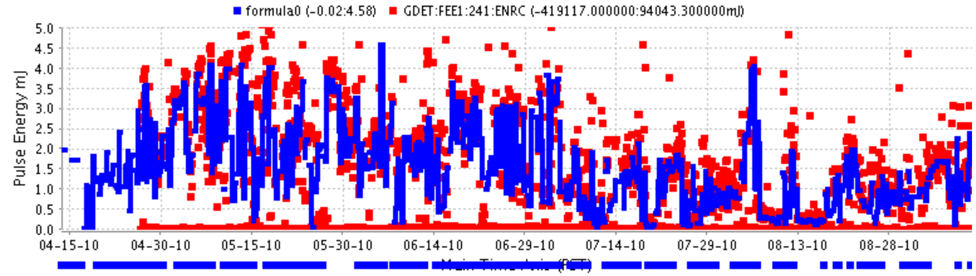
4 month user run



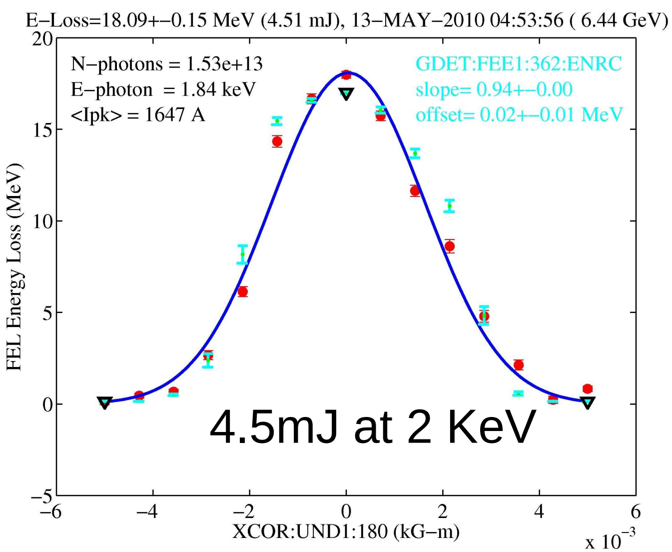
Operation at user requested wavelength and pulse length

FEL Power





FEL pulse energy vs time during user run (5 mJ full scale)



Highest operating power is at 2KeV, 150fs pulse
Generally > 1mJ from 500eV to 9 KeV

Shorter bunches (down to 50fs) result in lower output pulse energy.

Best stability 2% RMS, more typically 5-10% RMS

Low Charge Operation

Several users requested low charge (20pC) operating mode for very short pulses

No direct pulse length measurement available, but believed to be < 5fs FWHM

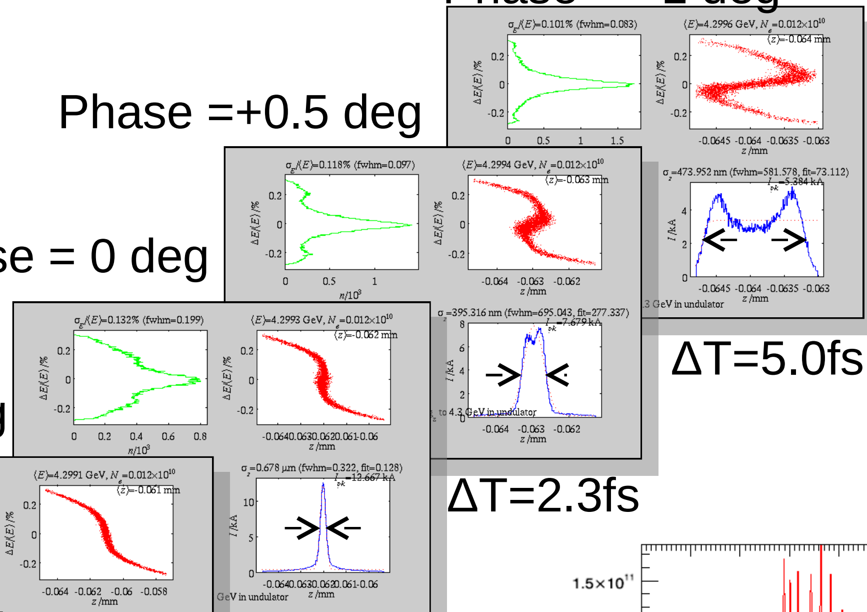
Phase = +1 deg

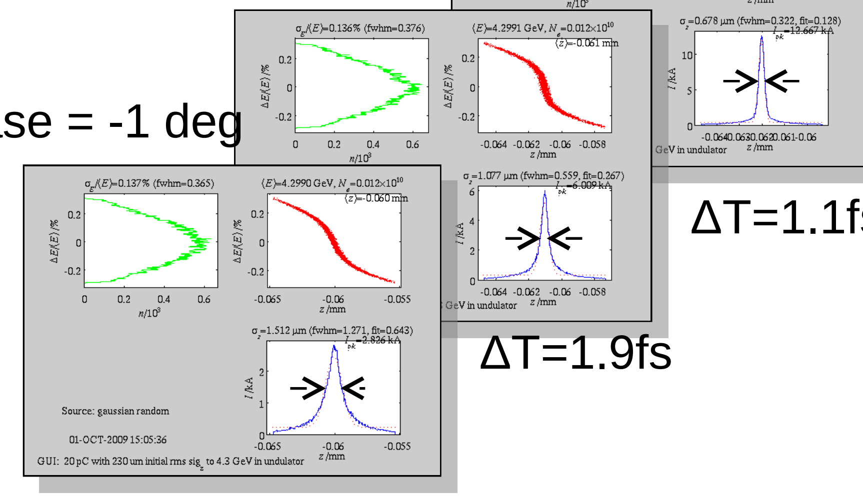
Phase =+0.5 deg

Phase = 0 deg

Phase = -0.5 deg

Phase = -1 deg



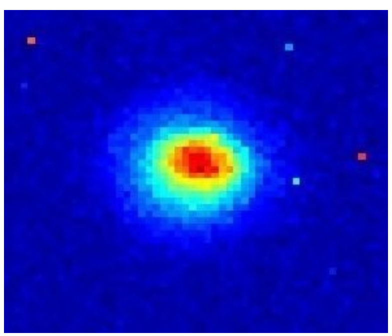


ΔT=5.0fs

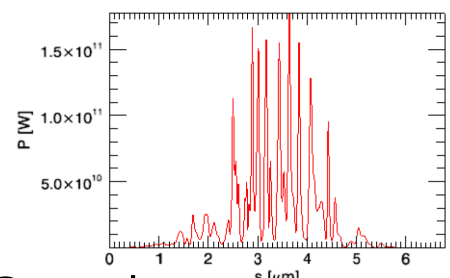
ΔT=2.3fs

ΔT=1.1fs

ΔT=1.9fs

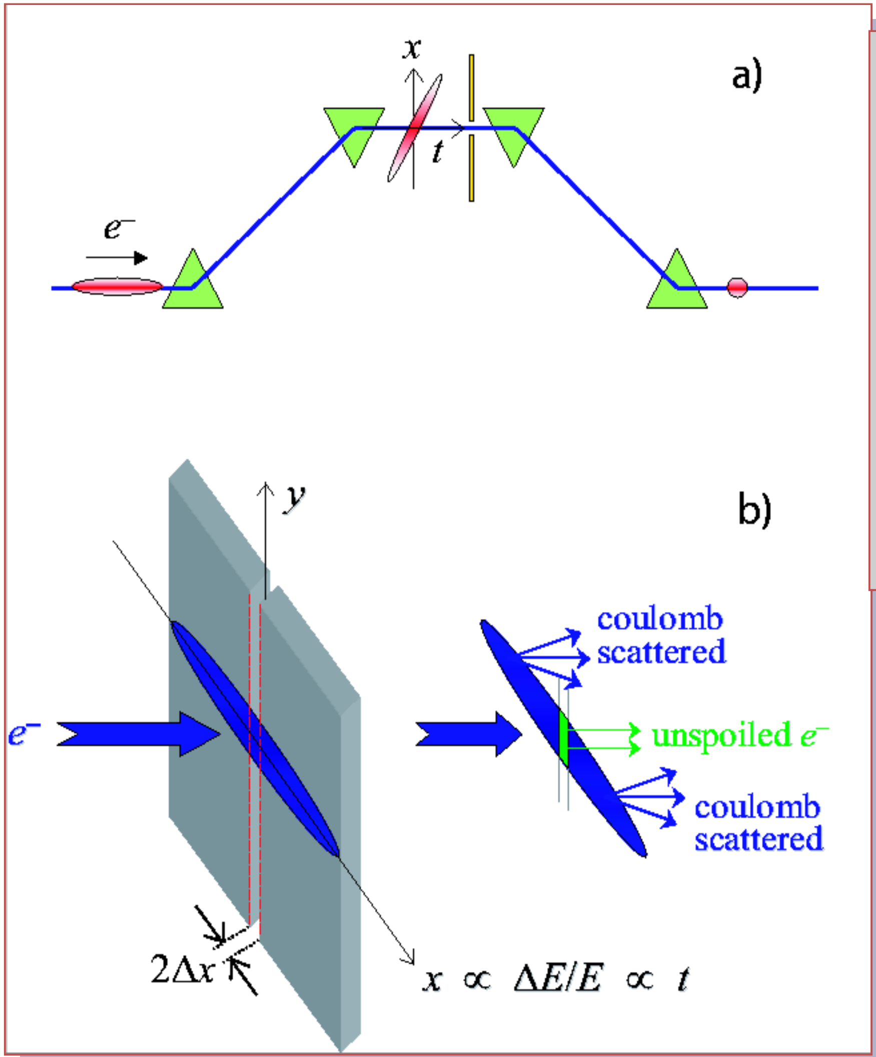


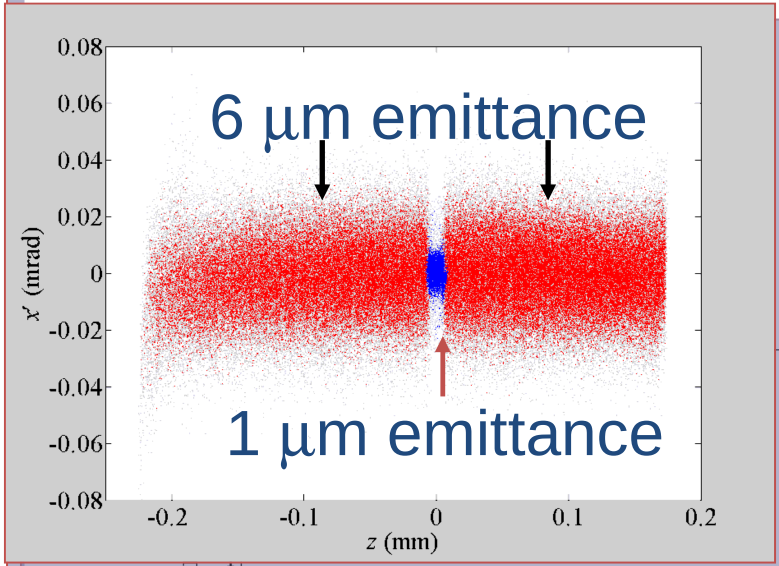
ΔT=4.2fs we typically operate here

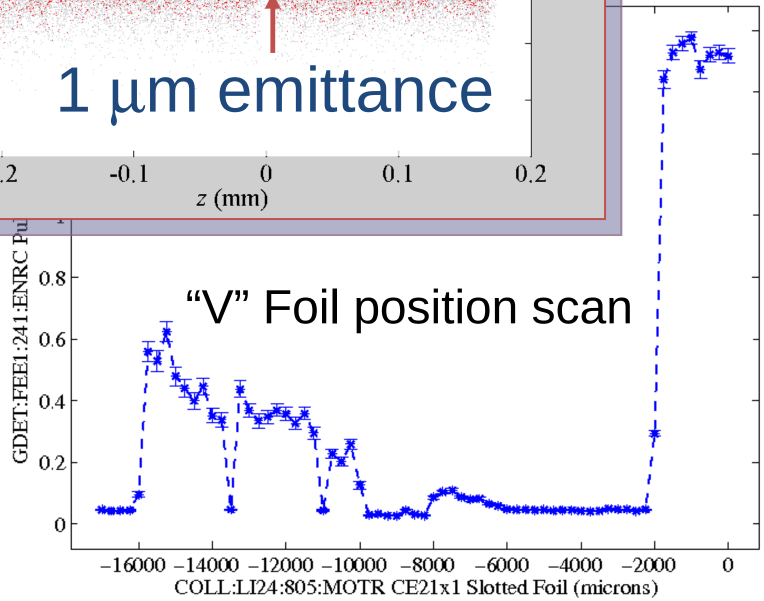


Genesis Simulation for over compression 5fs FWHM

"Slotted Foil" short bunches





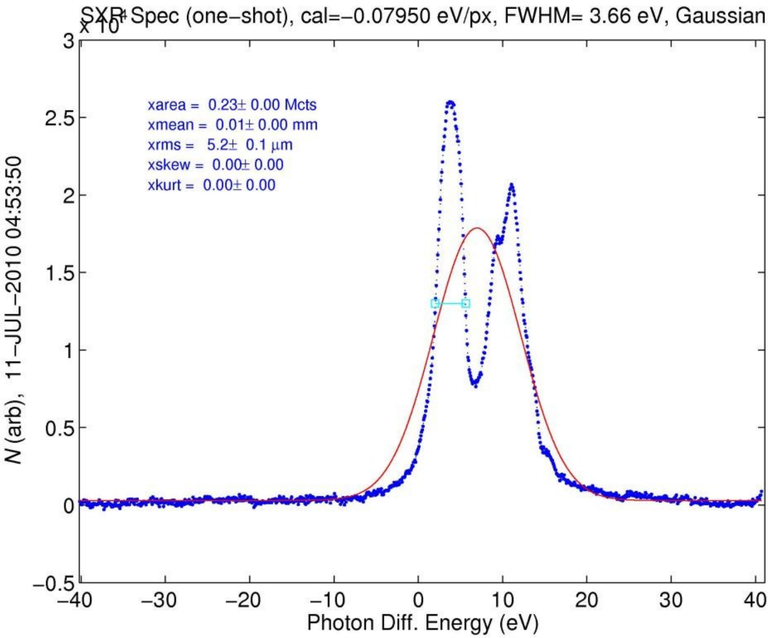


No direct pulse length measurement

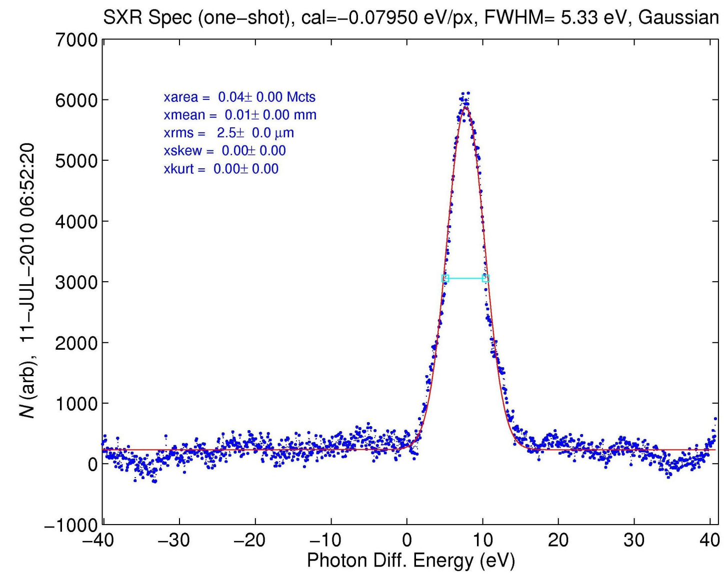
Short Pulse User Operation

- Low Charge Mode (20-40pC)
  - Low emittance → high peak power
  - Couple hours to switch from normal to low charge
  - Recently developed 100pC mode to fill the gap between 40 and 250pC
- Slotted foil mode (at 250pC)
  - Fast pulse length tuning (just move foil)
  - Rapid switching from normal operation
- Both modes used for experiments

Low Charge **AND** Slotted Foil



X-ray spectrum with 20pc operation – few spikes suggest ~5 fs pulses



With 20pc and slotted foil see single spike spectrum suggests very short pulses

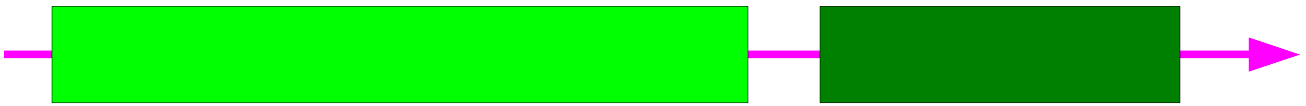
No direct measurement but may be producing ~1fs X-ray pulses

Short Pulse Timing

- FEL can probably produce sub femtosecond pulses
- Most useful for pump / probe experiments to study ultra-fast phenomena
- Existing optical lasers can produce few-femtosecond pulses (100as in the UV)
- Need precision timing control / measurement: State of the art is still~50fs.

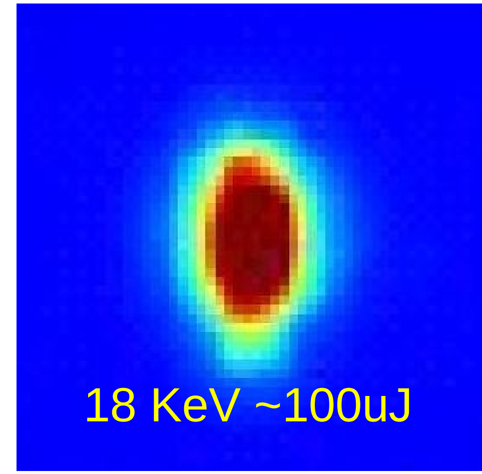
Near Term Upgrades

Harmonic Afterburner:

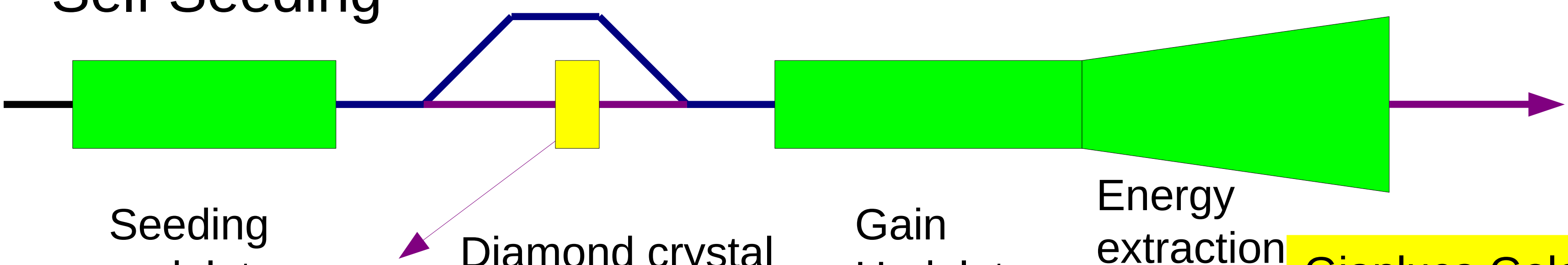


Existing undulator - enough sections to saturate

Undulator with reduced K to tune for ½ wavelength. Bunched beam radiates at 2nd harmonic wavelength



Self Seeding



Seeding undulator

Diamond crystal band-stop filter

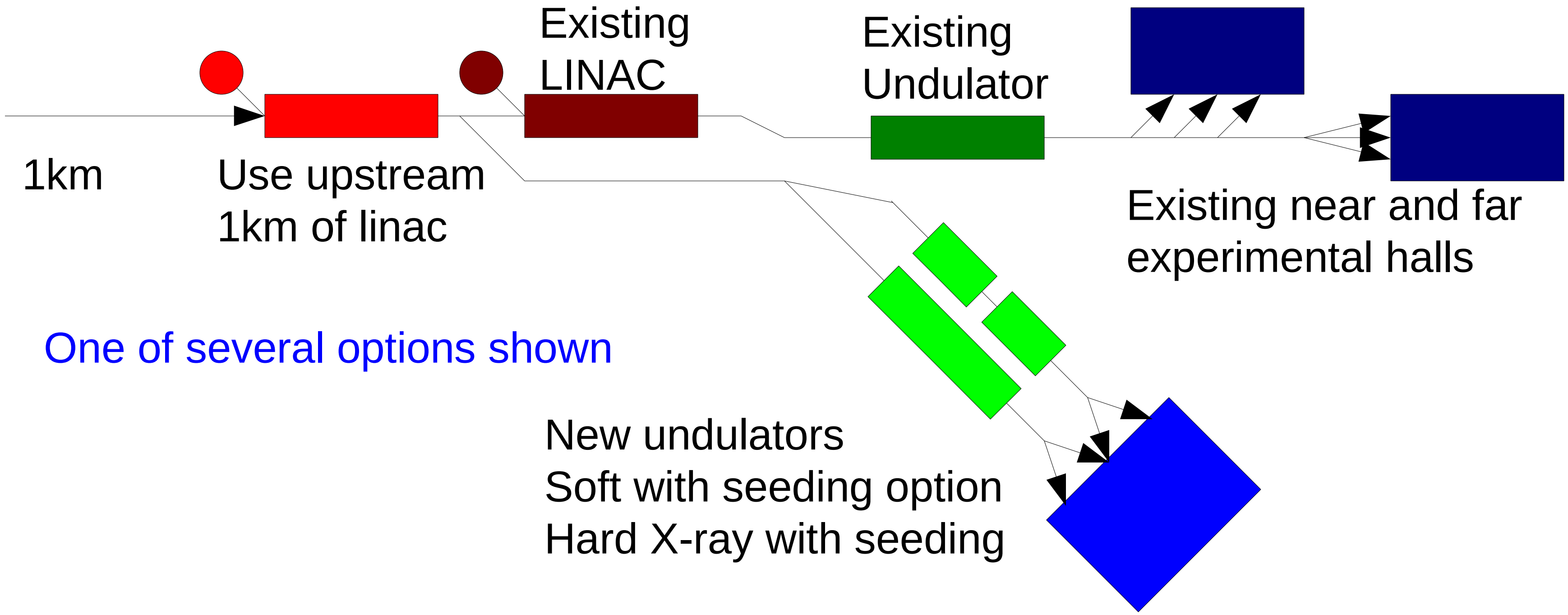
Gain Undulator

Energy extraction taper

Gianluca Geloni
Vitali Kocharyan
Evgeni. Saldin

Produce high power narrow band hard X-rays

Long Term - LCLS_II

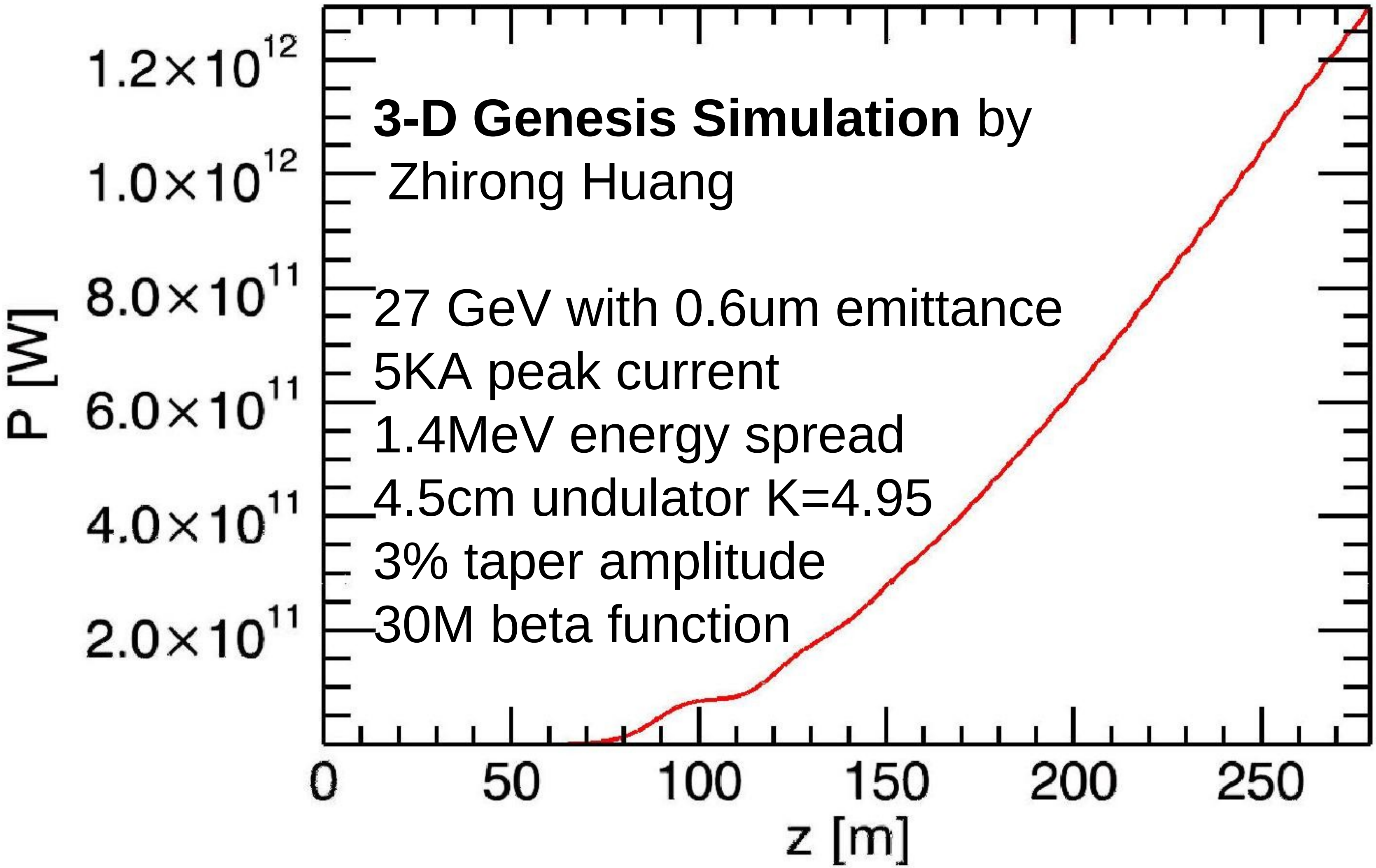


LCLS_II will modify1km of the existing SLAC linac as a second 14 GeV accelerator

Can drive a new set of undulators in a new tunnel and experimental hall

Can be used in conjunction with existhing LCLS linac for up to 28 GeV for ultra-hard X-rays or a high peak power FEL

TW 1Å FEL


3-D Genesis Simulation by
Zhirong Huang
27 GeV with 0.6um emittance
5KA peak current
1.4MeV energy spread
4.5cm undulator K=4.95
3% taper amplitude
30M beta function
P [W]
1.2×10^12
1.0×10^12
8.0×10^11
6.0×10^11
4.0×10^11
2.0×10^11
0
50
100
150
200
250
z [m]

LCLS Future Possibilities

- Existing beam brightness sufficient for 30-50 KeV FEL
- Use of 28 GeV LINAC (2 km) with self-seeding could produce > 1TW at 1Å
- 2 bunch (8.4 ns separation) lasing demonstrated. RF pulse can support 10 bunch operation
- Operation at 360 Hz at reduced energy being studied