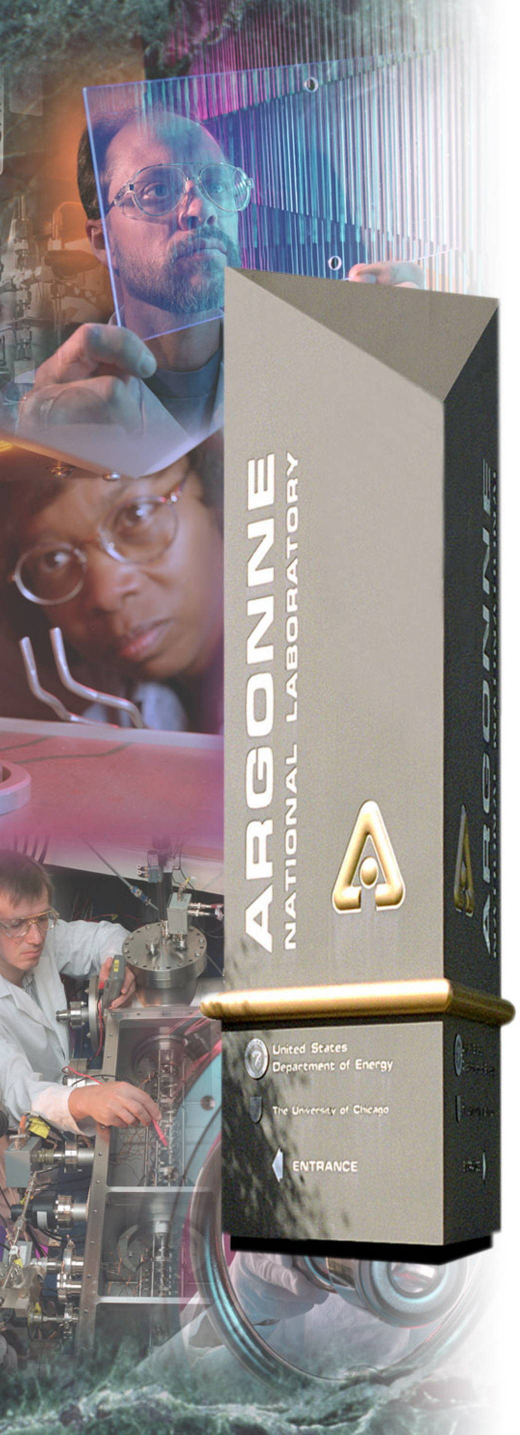

LCLS Undulator Parameter Workshop

Performance Analysis Using RON
(and some notes on the LCLS prototype)

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Argonne National Laboratory

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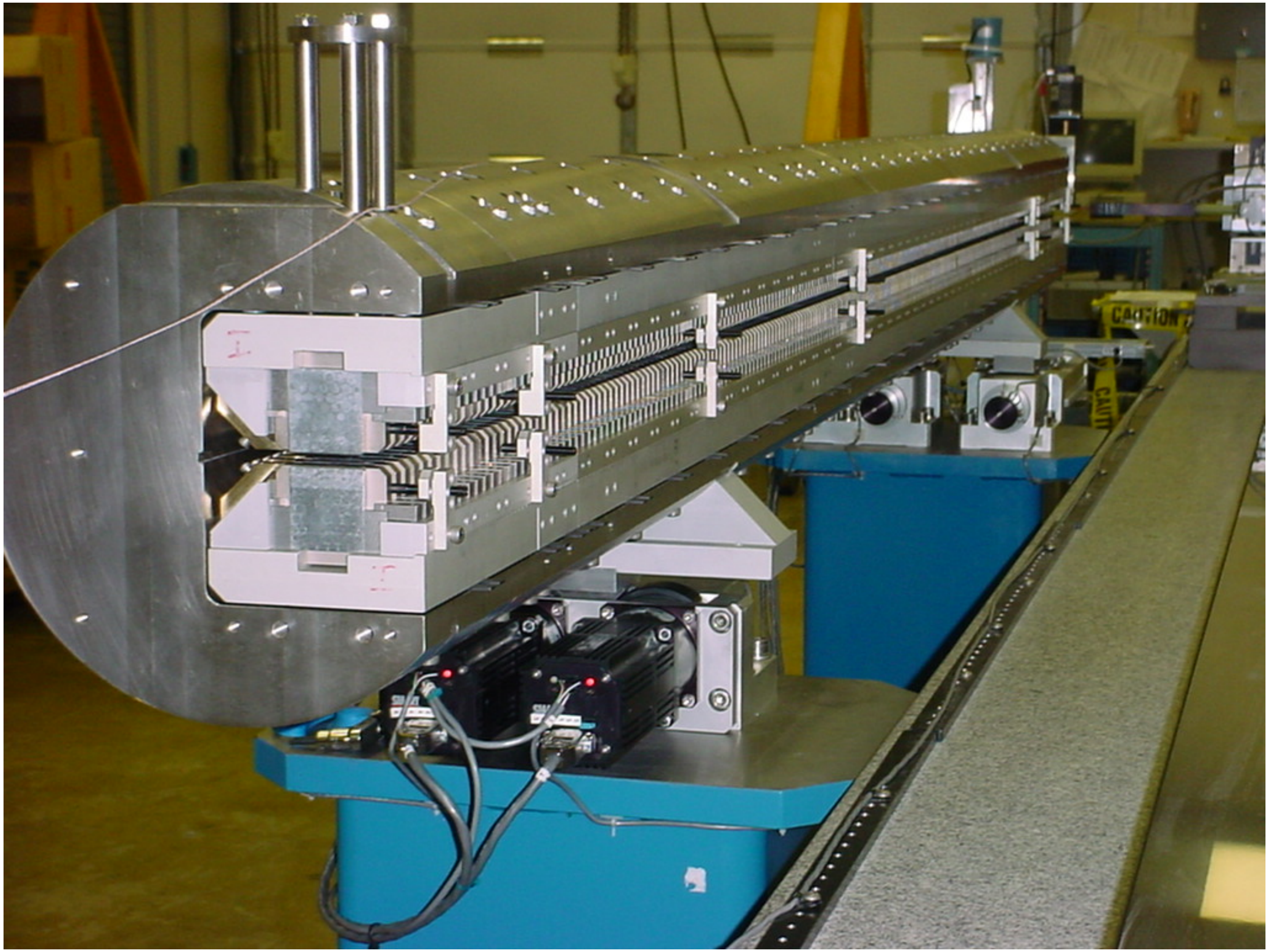
Outline

- Some information on the LCLS prototype
- Modified semi-analytical approach to estimate gain length and saturation length (N. Vinokurov)
- RON simulation results (gain length and sensitivity to variation of average B-field)
- Conclusions

LCLS "New" Parameters

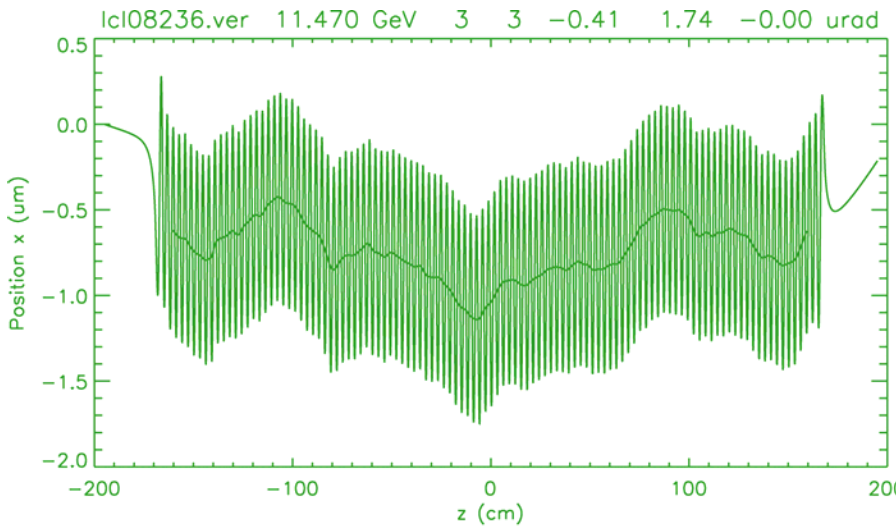
Beam energy, E	3.63, 11.47, 14.04 GeV
Beam peak current, I	3.4 kA
Beam energy spread, $\delta E/E$	3.9×10^{-4}, 1.3×10^{-4}, 1.0×10^{-4}
Normalized beam emittance, ε_n	1.2×10^{-6} m-rad
FODO lattice, quad strength	60 T/m
Average beta function, $\beta_x \sim \beta_y$	10, 25, 30 m
Average beam size, $\sigma_x \sim \sigma_y$	41, 37, 36 μm
Break length pattern	3-3-4
Radiation wavelength, λ_r	15, 1.5, 1.0 Å
Undulator period length, λ_w	3.0 cm
Undulator K value	2.841
Undulator gap	~ 8.2 mm (for NdFeB)
Resonance break length (n=1)	151 mm

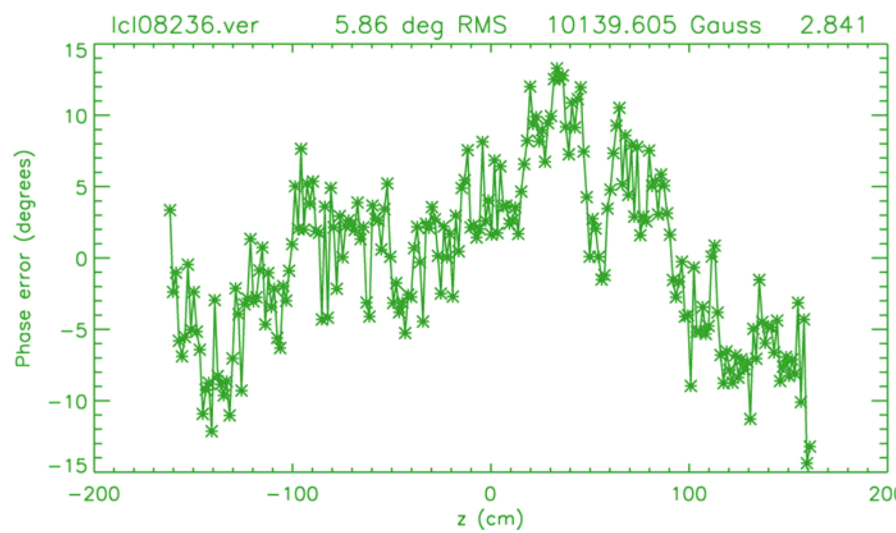
LCLS Prototype Undulator In the Magnetic Measurement Laboratory



Derived Horizontal Trajectory and Phase Errors at 11.47 GeV

- **Measured B-field at 6.35 mm gap scaled from 13312 Gauss to 10140 Gauss**
- **K = 2.84, λ_r = 1.5 Å**
- **Gap ~ 8.2 mm for NdFeB with remanent magnetic field (B_r) of 1.24 Tesla**
- **Phase slippage for 113 periods is 3547 mm (from scaled measured field)**
- **Ti-core is 3400 mm: ~ 150 mm "extra" drift space at each break section (in addition to "3-3-4" breaks)**
- **"Resonance" break length is 151 mm**

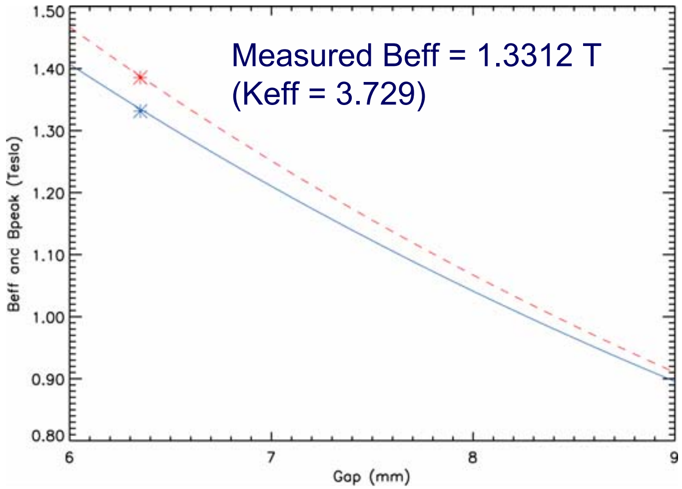


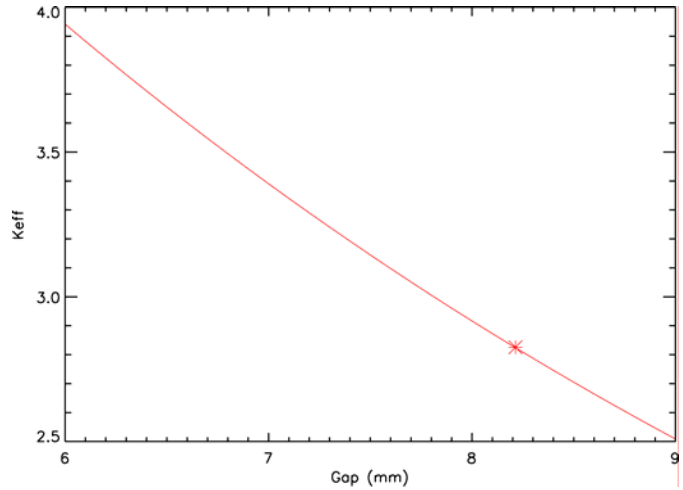


Model Calculated B-fields vs. Measured Values at 6.35 mm Gap

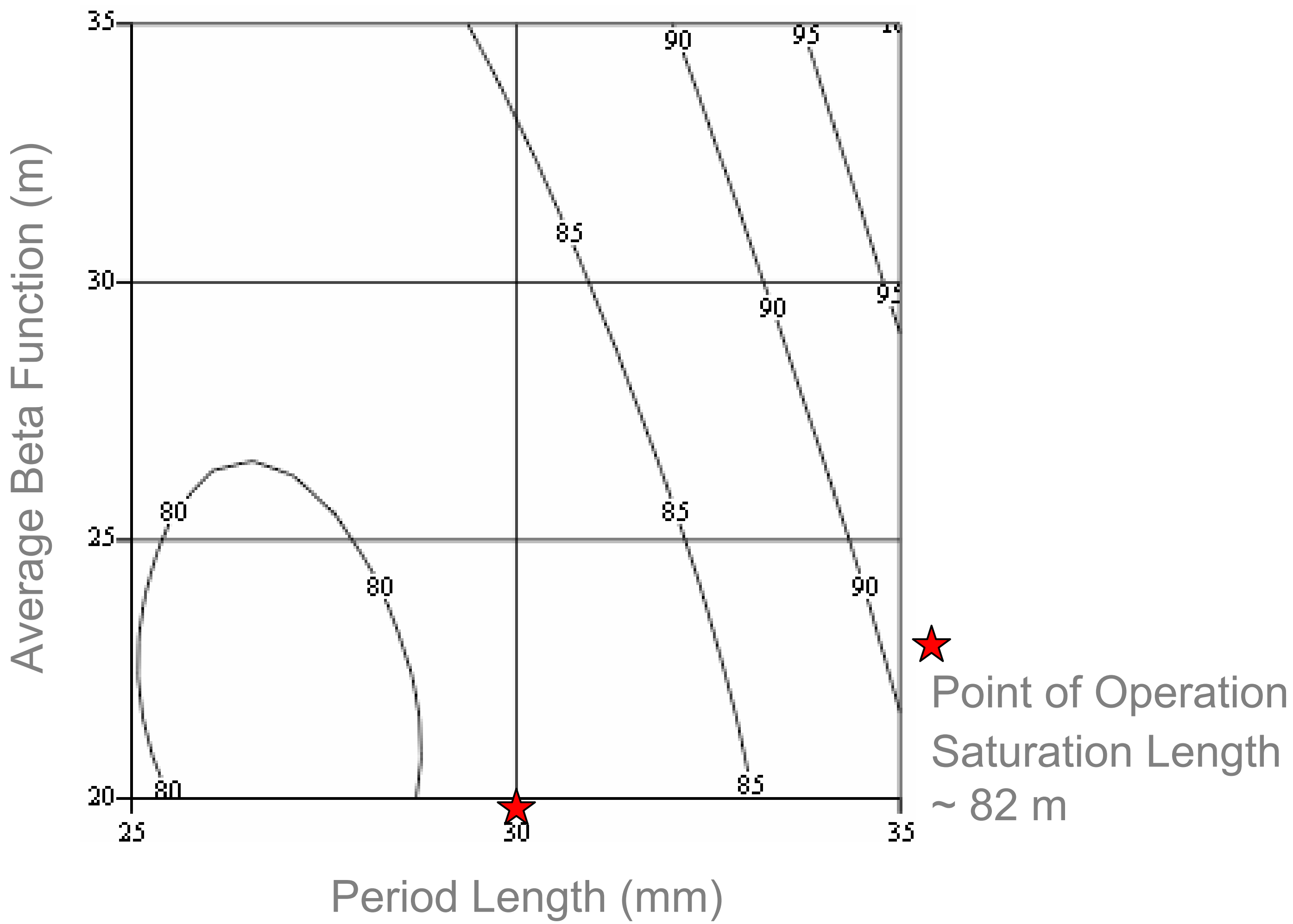
- **NdFeB magnets with remanent magnetic field (B_r) of 1.24 Tesla**
- **B(T) = Bo(T)*exp(-q*gap)**
- **B_{effo} = 3.473 T**
  q_{eff} = 0.1506 mm^{-1}
  B_{peako} = 3.811 T
  q_{peak} = 0.1591 mm^{-1}
- **Gap(mm) B_{eff}(T) B_{peak}(T) K_{eff}**

Gap(mm)	B_{eff}(T)	B_{peak}(T)	K_{eff}
8.00	1.0411	1.0672	2.916
8.10	1.0255	1.0503	2.873
8.20	1.0102	1.0338	2.830
8.30	0.9951	1.0174	2.787

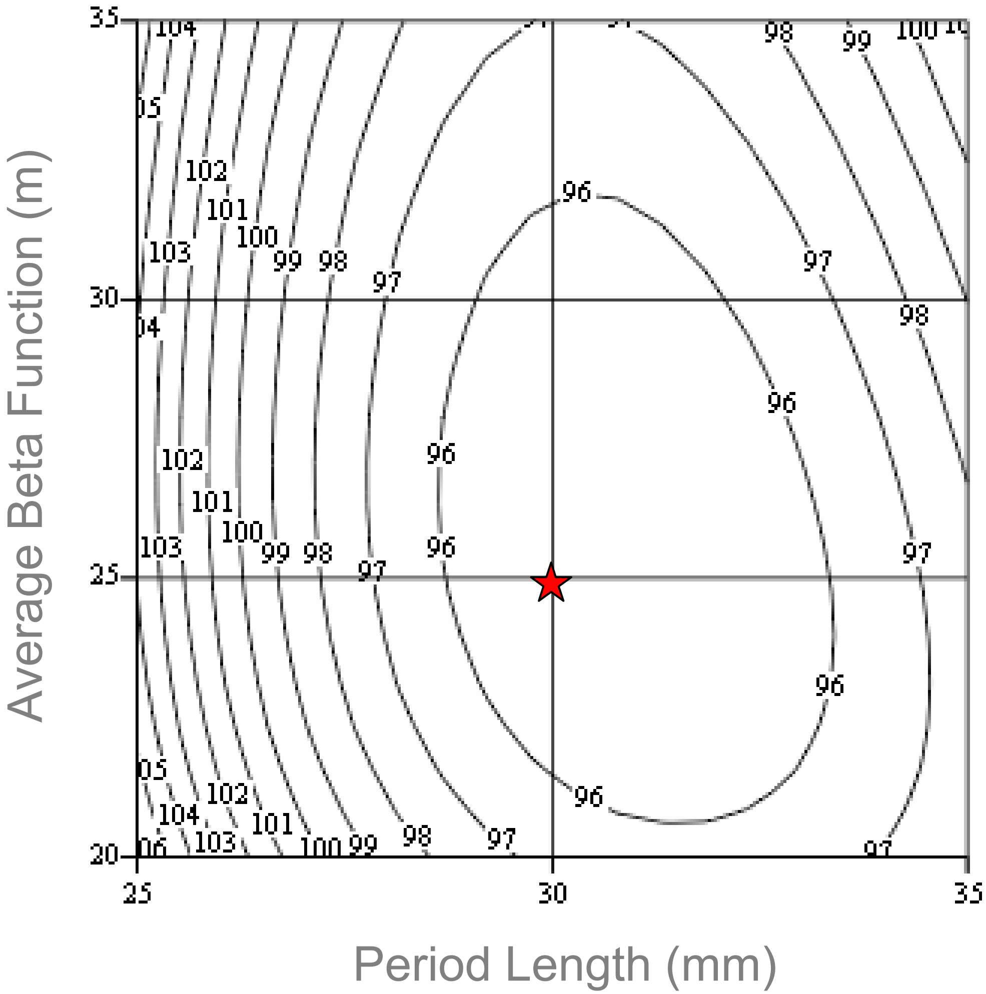




"Old" Parameters (from CDR; 1.2 mm-mrad): Contours of Constant Saturation Length @ 1.5 Á



“New” Parameters (3-3-4 breaks; 1.2 mm-mrad): Contours of Constant Saturation Length @ 1.5 Å

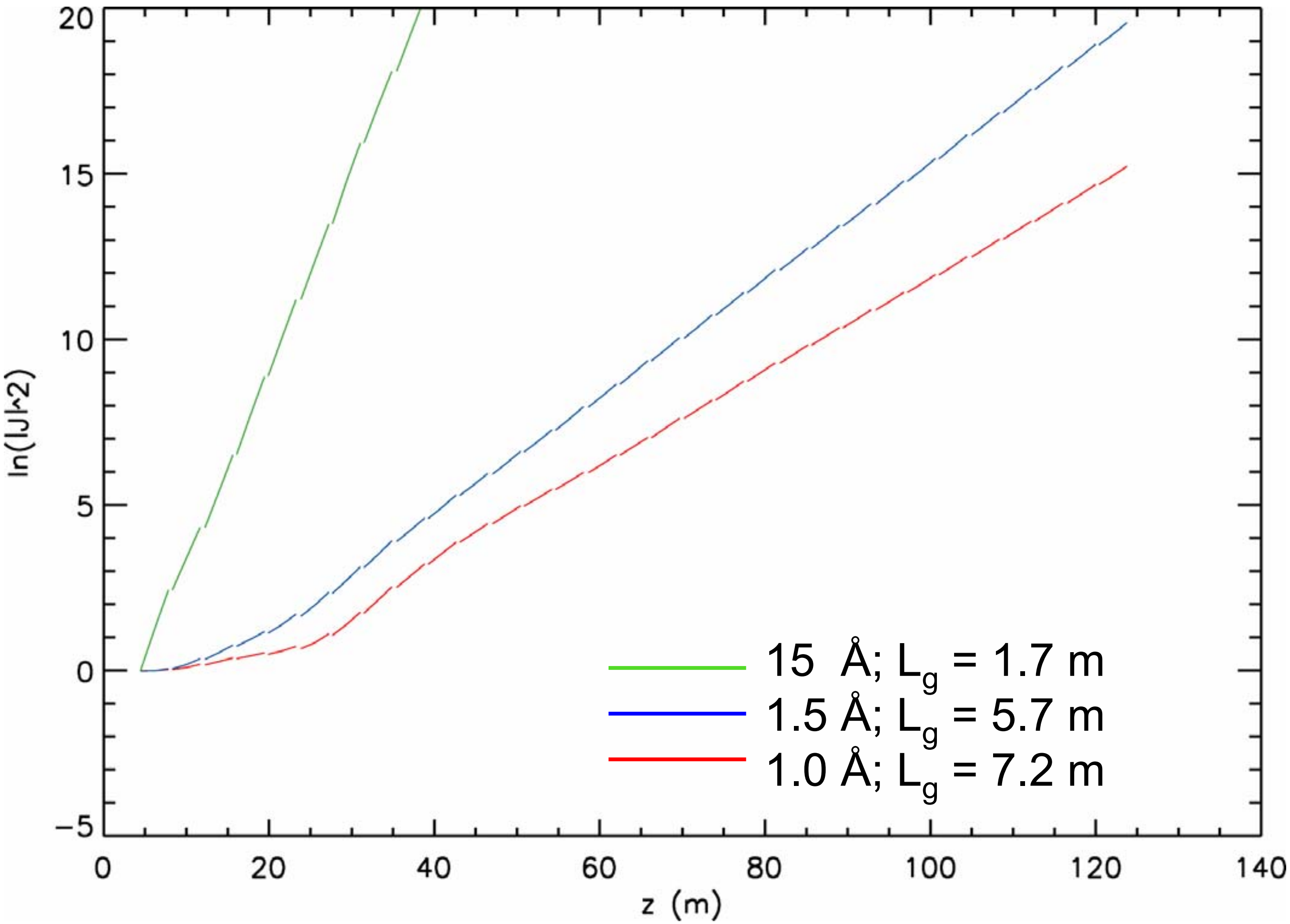


★ Point of Operation

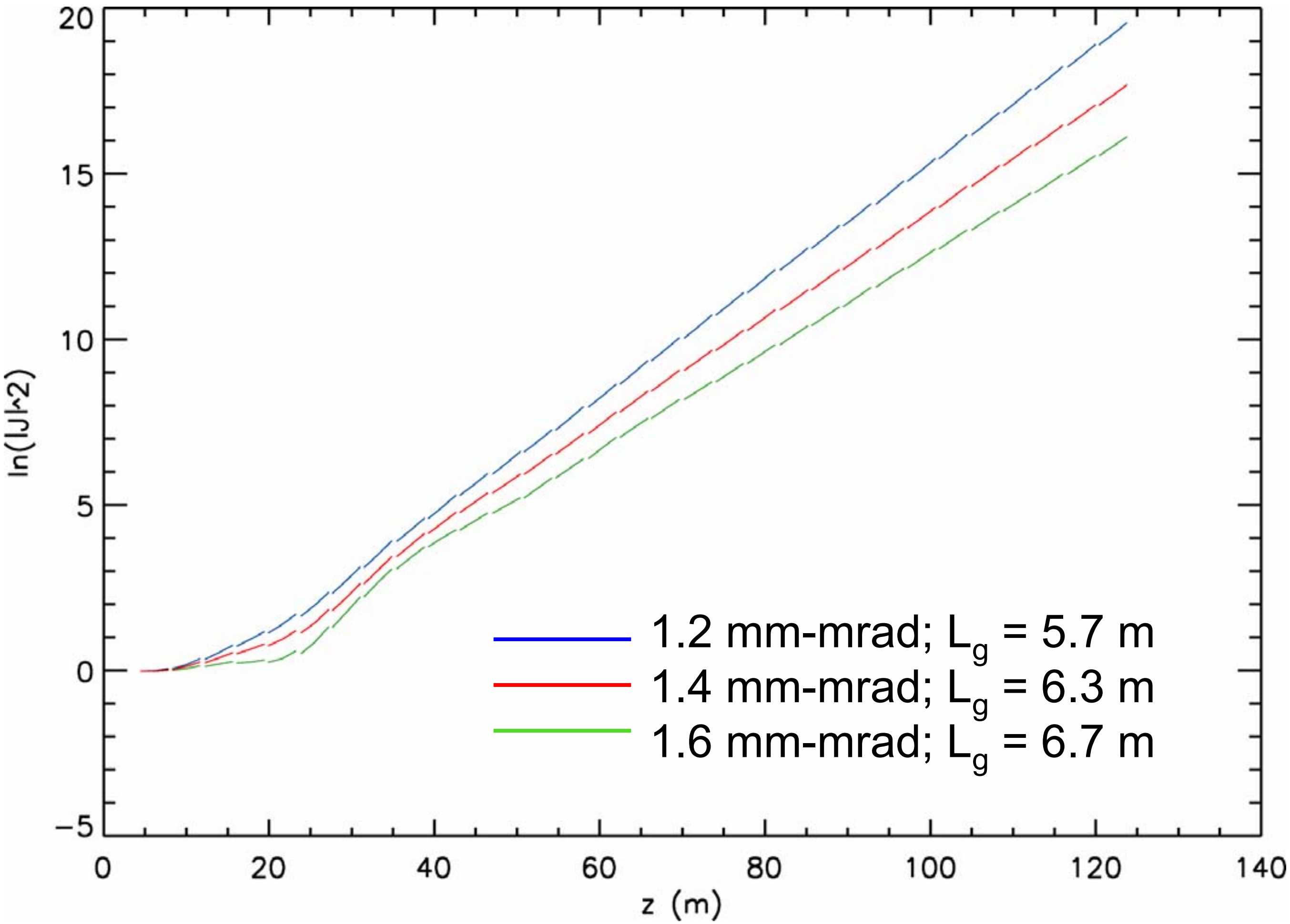
Saturation Length ~ 96 m

Gain Length ~ 5.6 m

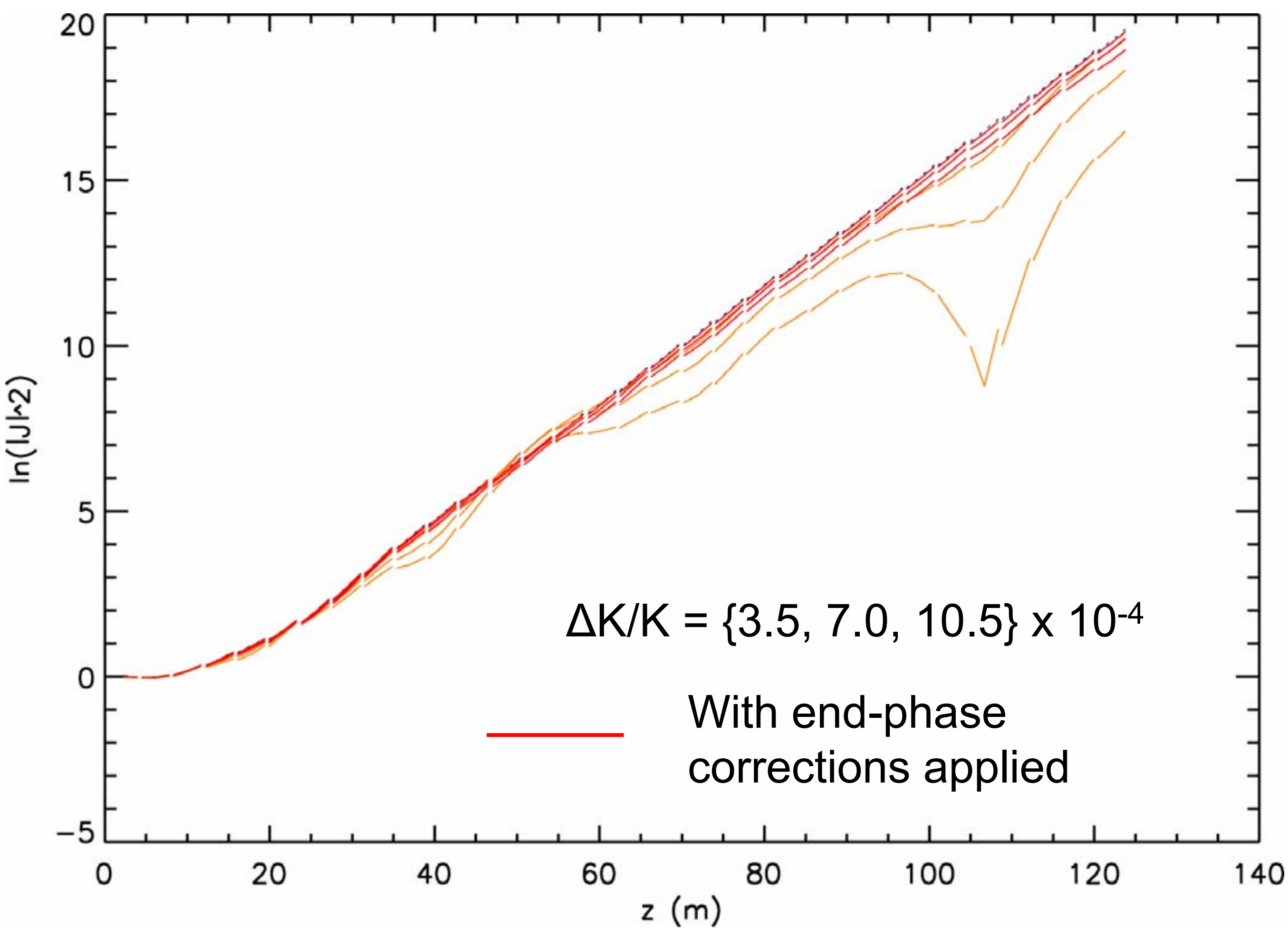
FEL Gain @ 1.2 mm-mrad vs. Radiation Wavelength



FEL Gain @ 1.5 Å vs. Emittance



ΔK/K Variation from Device to Device: w/ and w/o End-Phase Corrections @ 1.2 mm-mrad and 1.5 Å



Conclusions

- **The proposed changes of increased undulator gap (to ~ 8.2 mm and reduced K value to ~ 2.84) and increased break lengths lead to an increase in the saturation length by ~ 14 m (4 undulator segments) at 1.5 Å and 1.2 mm-mrad**
- **At shorter wavelength (< 1.5 Å) and at larger emittance (> 1.2 mm-mrad), the saturation length increases even further**
- **The increase of the average *β*-function (decrease of the quadrupole gradient to ~ 60 T/m) only marginally increases the saturation length (~ 2 m) at 1.5 Å**
- **The undulator end-gap adjustments for end-phase corrections are able to compensate undulator magnetic field amplitude variations of ~ 10^{-3}**