Operations Analysis Group
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Update on LCLS Start-to-End Simulations

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Advanced Photon Source
Argonne National Laboratory

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Start-to-End Simulations

- Studied jitter sensitivity using start-to-end simulations.
- Used the “Dec00” LCLS lattice of P. Emma and M. Woodley.
- Performed 150 randomized simulations using PARMELA, **elegant**, and GENESIS:
  - One PARMELA run produced particle distribution at 150 MeV (C. Limborg)
  - 150 **elegant** runs tracked randomized linac configurations (M. Borland).
  - GENESIS used to simulate FEL output. (Y-C Chae)

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Effects Included in elegant Simulations

- 6-D tracking using 2nd-order matrices.
- Rf elements with exact time and energy dependence, and end-focusing.
- Transverse and longitudinal wakefields of accelerating structures.
- Resistive wall wakefields.
- Incoherent synchrotron radiation.
- CSR is included in all dipoles, as well as in drift spaces following dipoles.
- Residual dispersion correction from tracking unperturbed case.

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Simulation Error Levels (P. Emma)

Quantity	RMS Jitter Level
initial x, y centroid	2.1 μm (1% of size)
initial x', y' centroid	0.19 μr (1% of divergence)
initial t centroid	0.9 ps
initial energy	0.1% + timing/phase contrib. (0.1 deg on L0)
charge	2%
L1 phase	0.1 deg
L1 voltage	0.1 %
L2 phase, L3 phase	0.07 deg
L2 voltage	0.07 %
L3 voltage	0.05 %
x-band phase	0.3 deg
x-band voltage	0.25%
BC1 dipoles	0.02% (ganged)
BC2 dipoles	0.05% (ganged)
other dipoles	0.01% (ganged)

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GENESIS Simulations

- Performed by Y.-C. Chae (APS).
- Beams from **elegant** cut into 20 slices of fixed time length.
- Slices analyzed to provide centroids and rms values to GENESIS.
- FEL output for each slice is computed independently, simulating effects of:
  - variation in charge and bunch length
  - variation in energy and energy spread
  - variation in beta functions
  - variation in centroid positions

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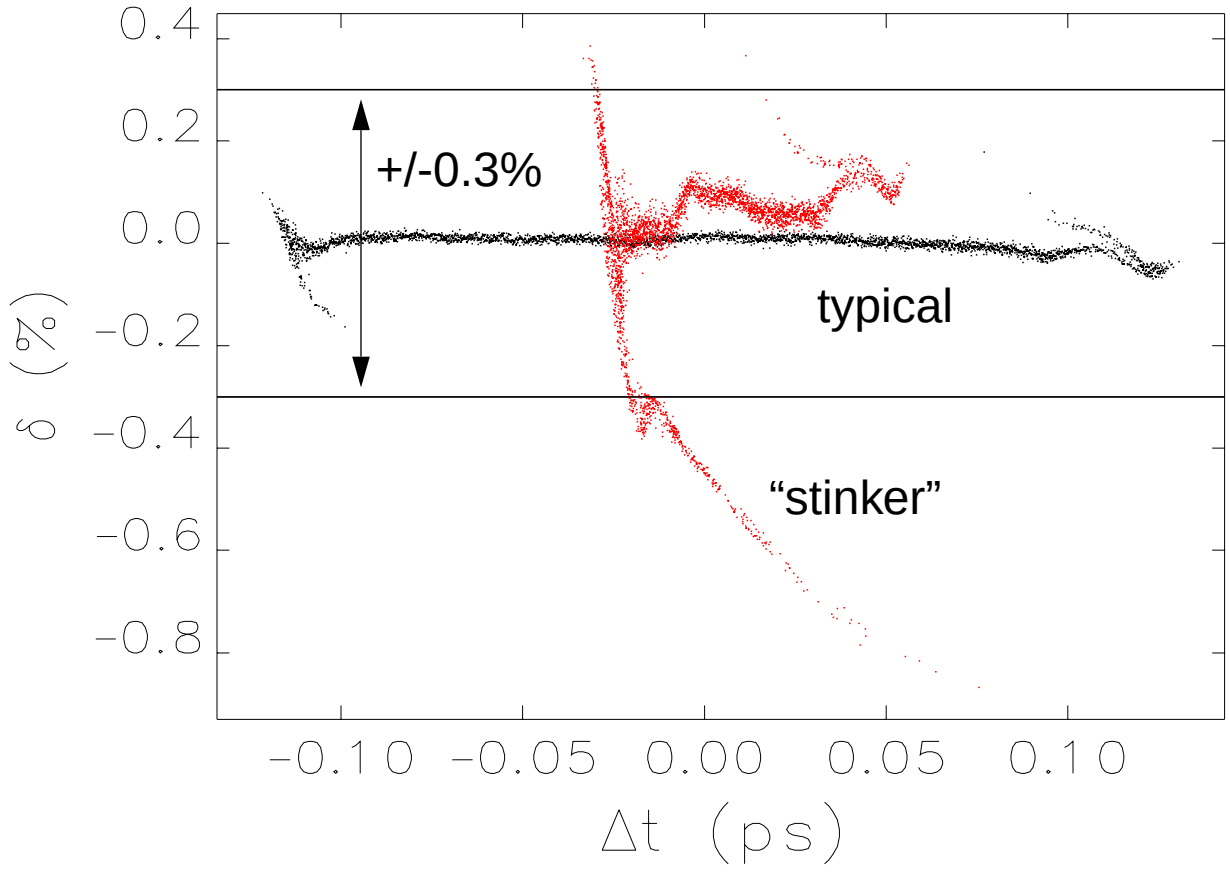
Use “Calculational Cut” to Remove Tails



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Jitter Results from elegant Using Calculational Cut

Quantity	Unit	Median	RMS Variation			"Clipped" RMS Variation		
Case		1	1	2	3	1	2	3
Beam Energy	%	0	0.15	0.14	0.11	0.14	0.11	0.10
C-S Current	kA	3.9	2.9	2.9	1.2	1.0	1.1	0.7
C-S En. Spread	10^{-4}	0.9	1.3	1.2	0.7	0.6	0.5	0.4
C-S x Emittance	μm	0.72	0.63	0.02	0.15	0.05	0.01	0.03
C-S y Emittance	μm	0.65	0.01	0.01	0.01	0.01	0.01	0.01
C-S Gain Len.	m	2.7	0.9	0.1	0.3	0.1	0.06	0.06

- Case 1: nominal, w/CSR.
  Case 2: nominal, w/o CSR.
  Case 3: 0.5ps injected beam timing jitter, w/CSR.
- C-S, or "Core-Slices", are the central 80% of the 20 beam analysis slices.
- "Clipped" RMS variation involves removing the worst 10% before computation.
- M. Xie's formulae are used to compute gain length.

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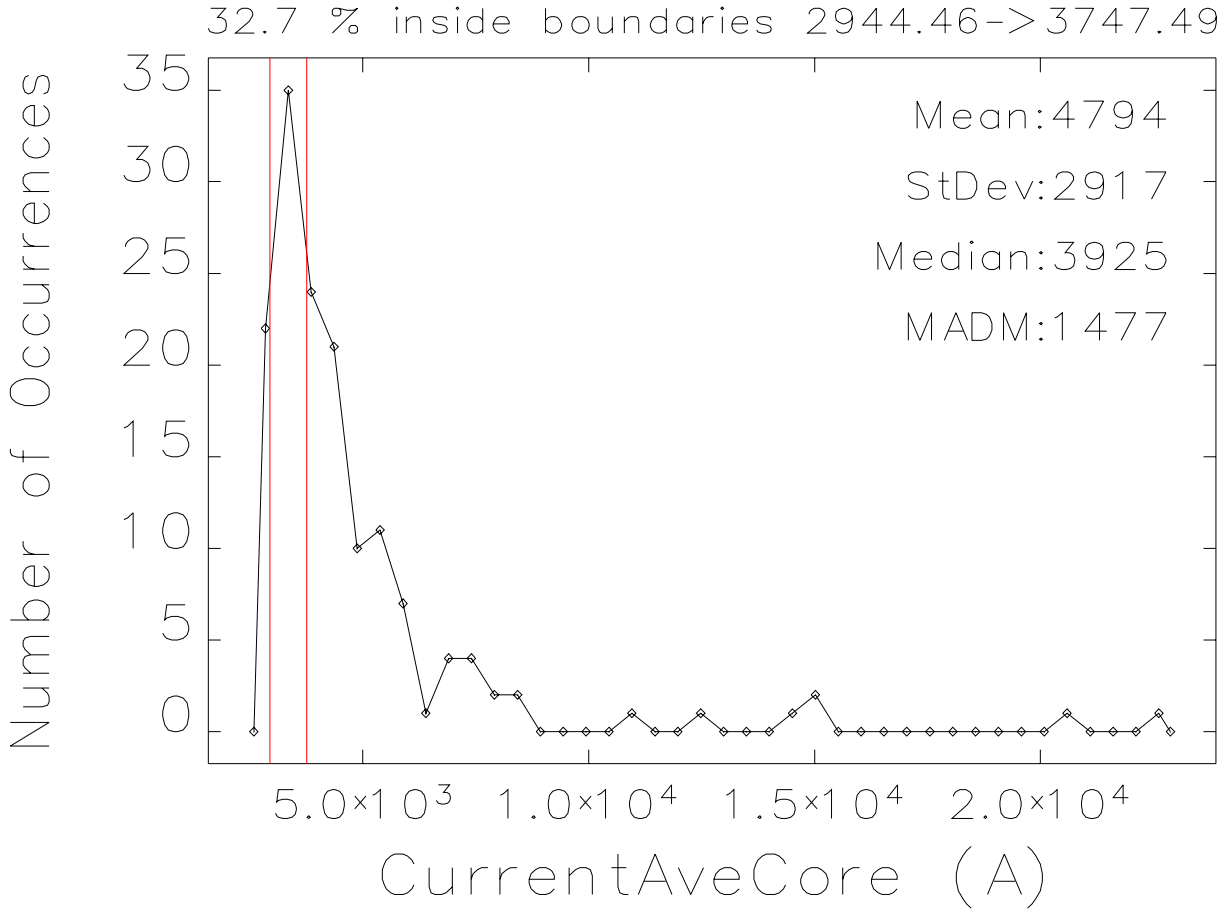
Core-Slice Current Jitter



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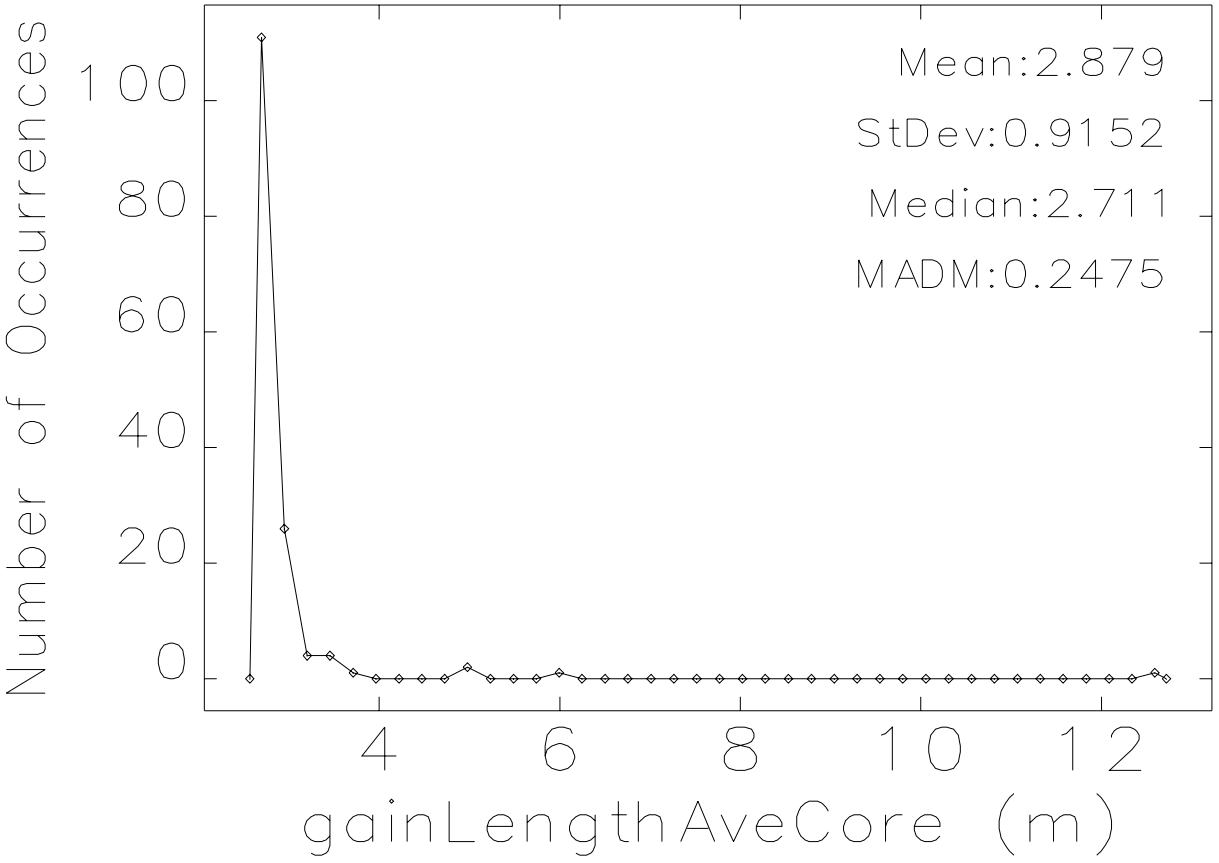
Core-Slice Gain Length Jitter



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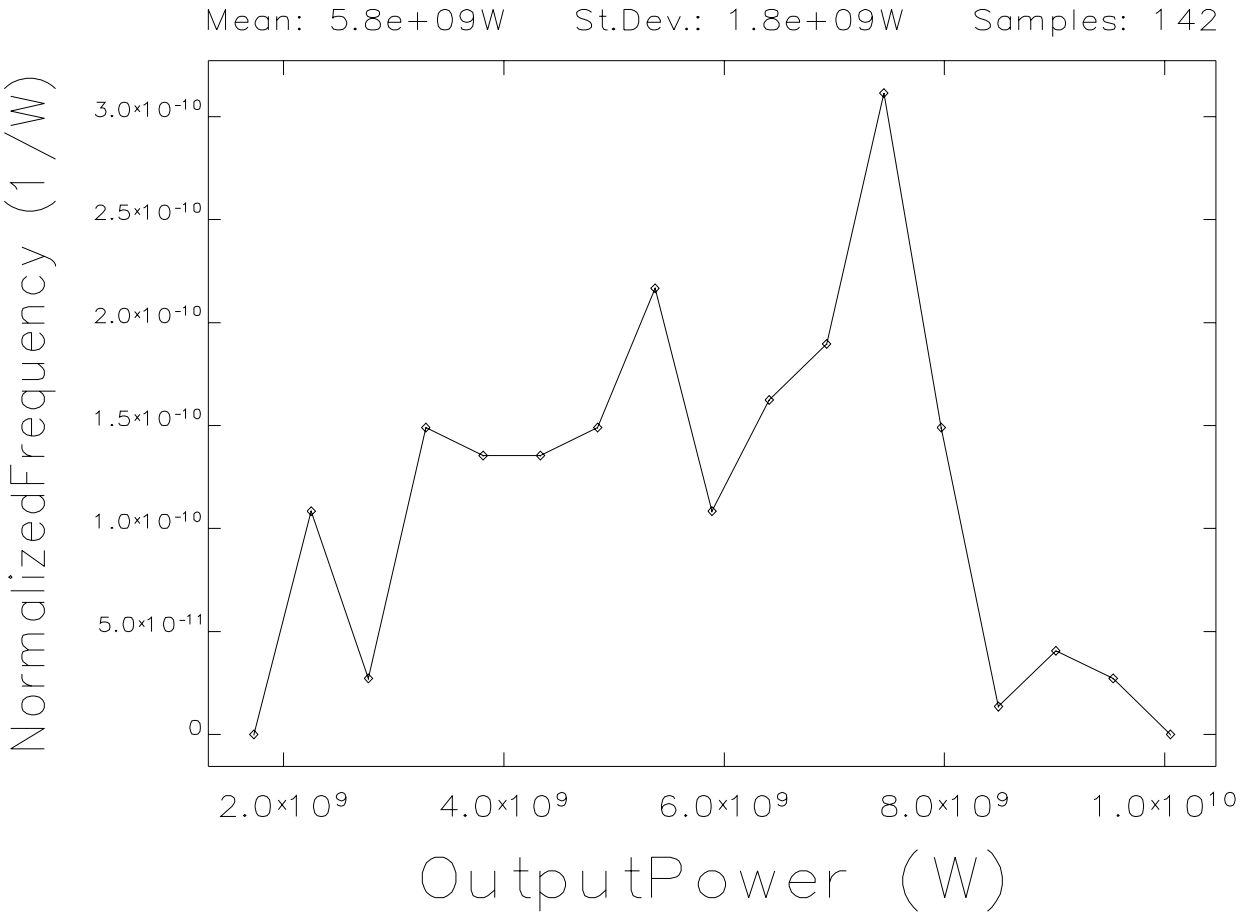
Jitter Results from GENESIS



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Jitter Results from GENESIS