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LCLS Prototype Undulator

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represents

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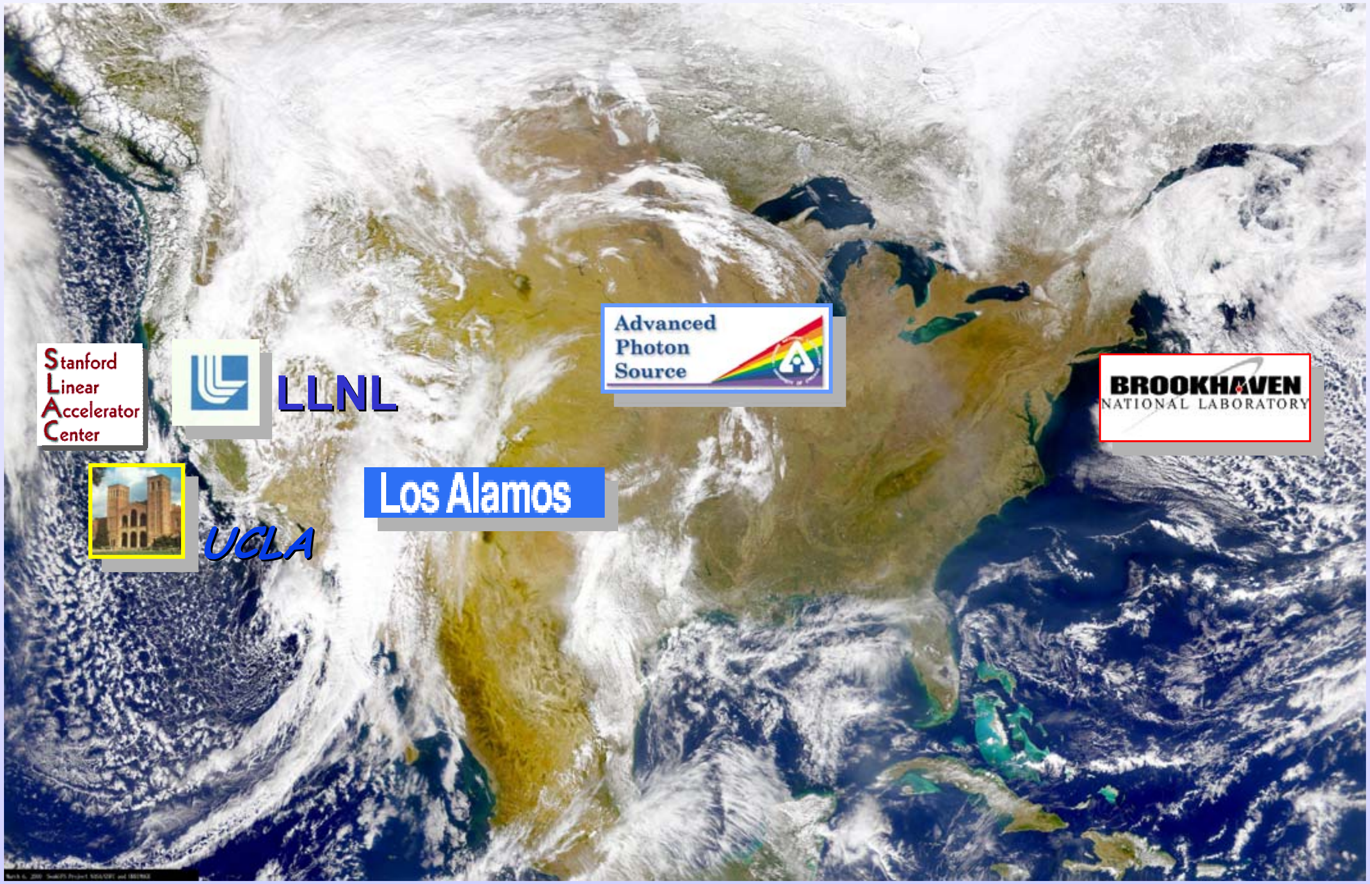
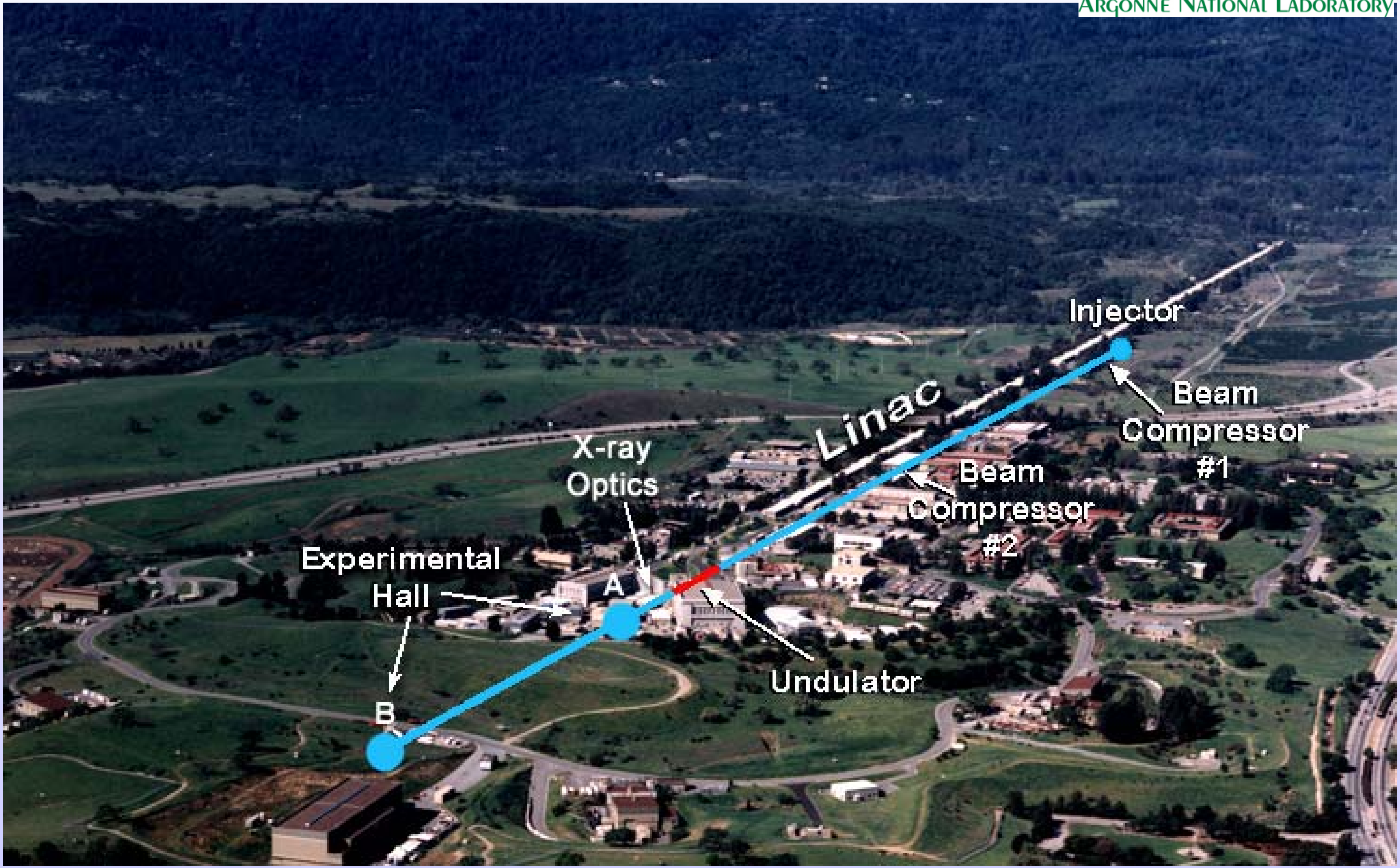
LCLS R&D Collaboration




Injector
Beam Compressor #1
Linac
Beam Compressor #2
X-ray Optics
Experimental Hall
A
B
Undulator

Basic Undulator Parameters

Undulator Type	*planar hybrid*	
Magnet Material	*NdFeB*	
Gap	*6*	*mm*
Period Length	*3*	*cm*
Peak On-Axis Field	*1.32*	*T*
K	*3.71*	
Segment Length	*3.42*	*m*
Number of Segments	*33*	
Segment Break Lengths	*0.187-0.421*	*m*
Undulator Magnet Length	*112.8*	*m*
Undulator Device Length (incl. Breaks)	*121.1*	*m*
Undulator Filling Factor	*93*	*%*

Tolerances for an undulator section (Undulator and quadrupole)

<x>, y	2μm
$\lvert Re(A/A_0) - 1 \rvert$	2%
$\phi - 2\pi n$	10 deg
Δy	50μm

These tolerances correspond to 3% growth of gain length

$$A = \int_0^L I_{1y}(z) e^{-ik/2\gamma^2 [z + \int_0^z I_{ix}^2(z')dz' + \int_0^z I_{iy}^2(z')dz']} dz$$

Phase slippage over the length of one section

$$\varphi = \frac{k}{2\gamma^2}\left[L + \int_0^L I_{1x}^2(z)dz + \int_0^L I_{1y}^2(z)dz \right]$$

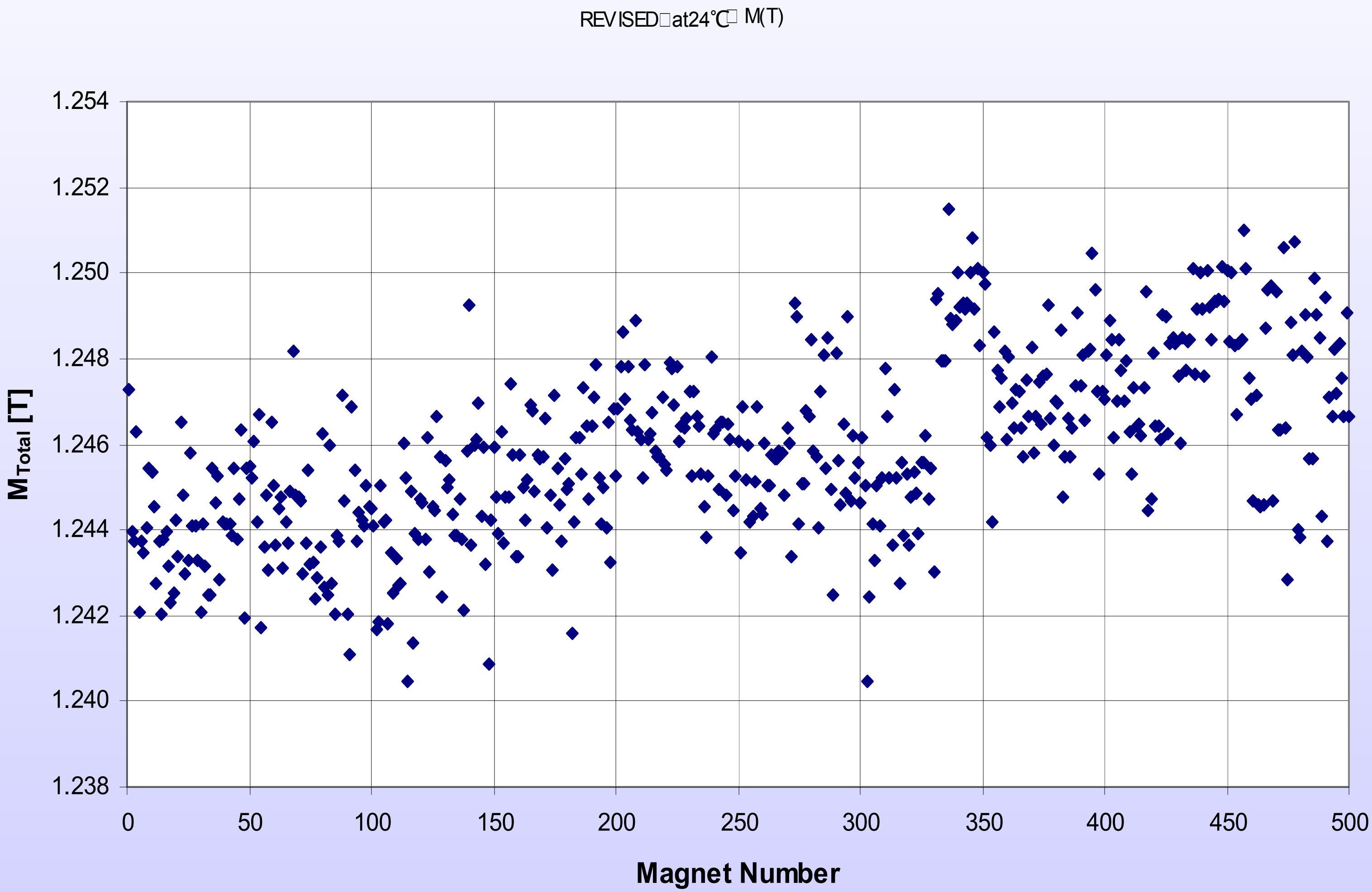
Method of Tuning

Sorting

Shimming

Sorting

- Main component of magnetic moment
- Field integrals
- Pole height and cant


REVISED at24℃ M(T)
1.254
1.252
1.250
1.248
1.246
1.244
1.242
1.240
1.238
M_{Total} [T]
0
50
100
150
200
250
300
350
400
450
500
Magnet Number

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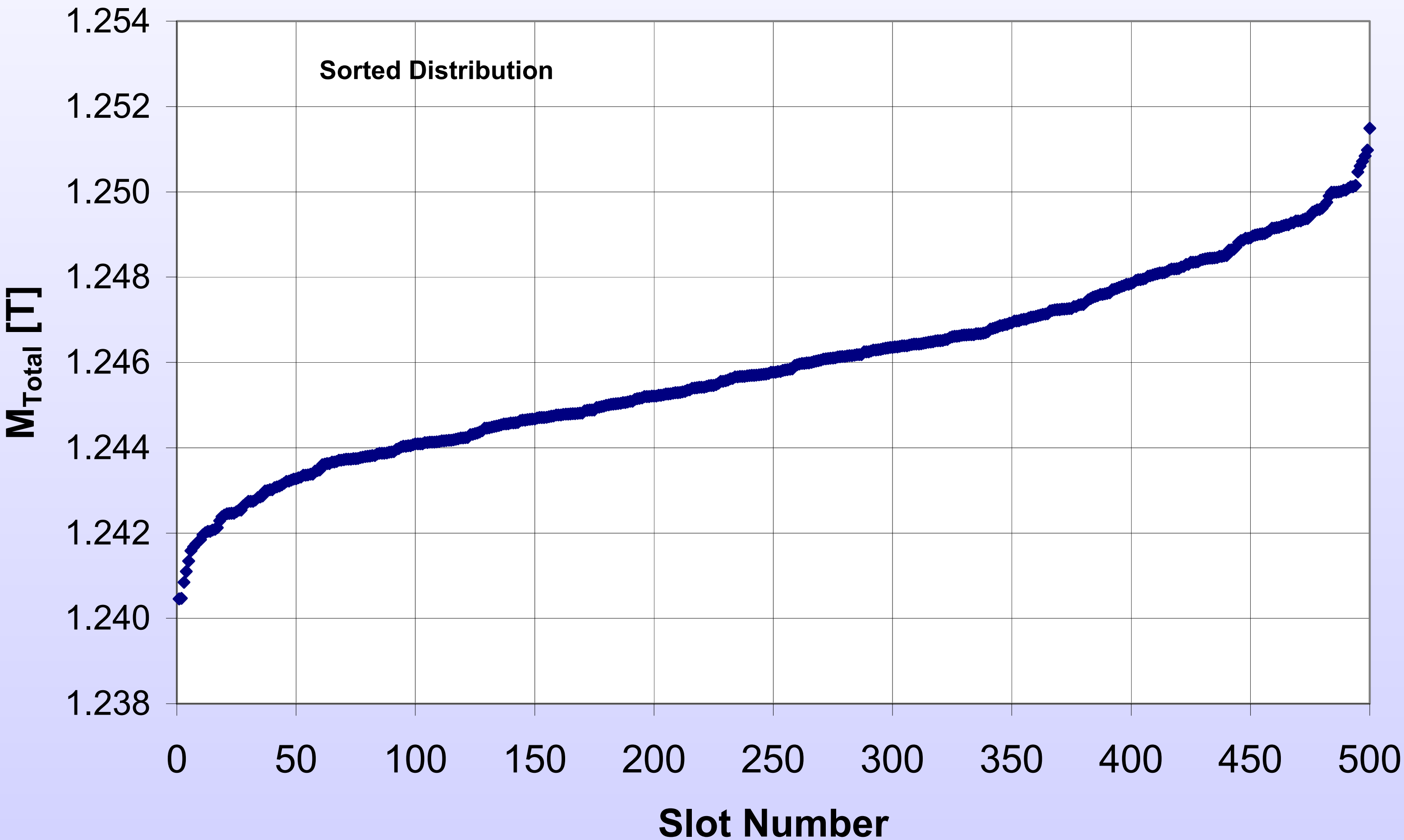
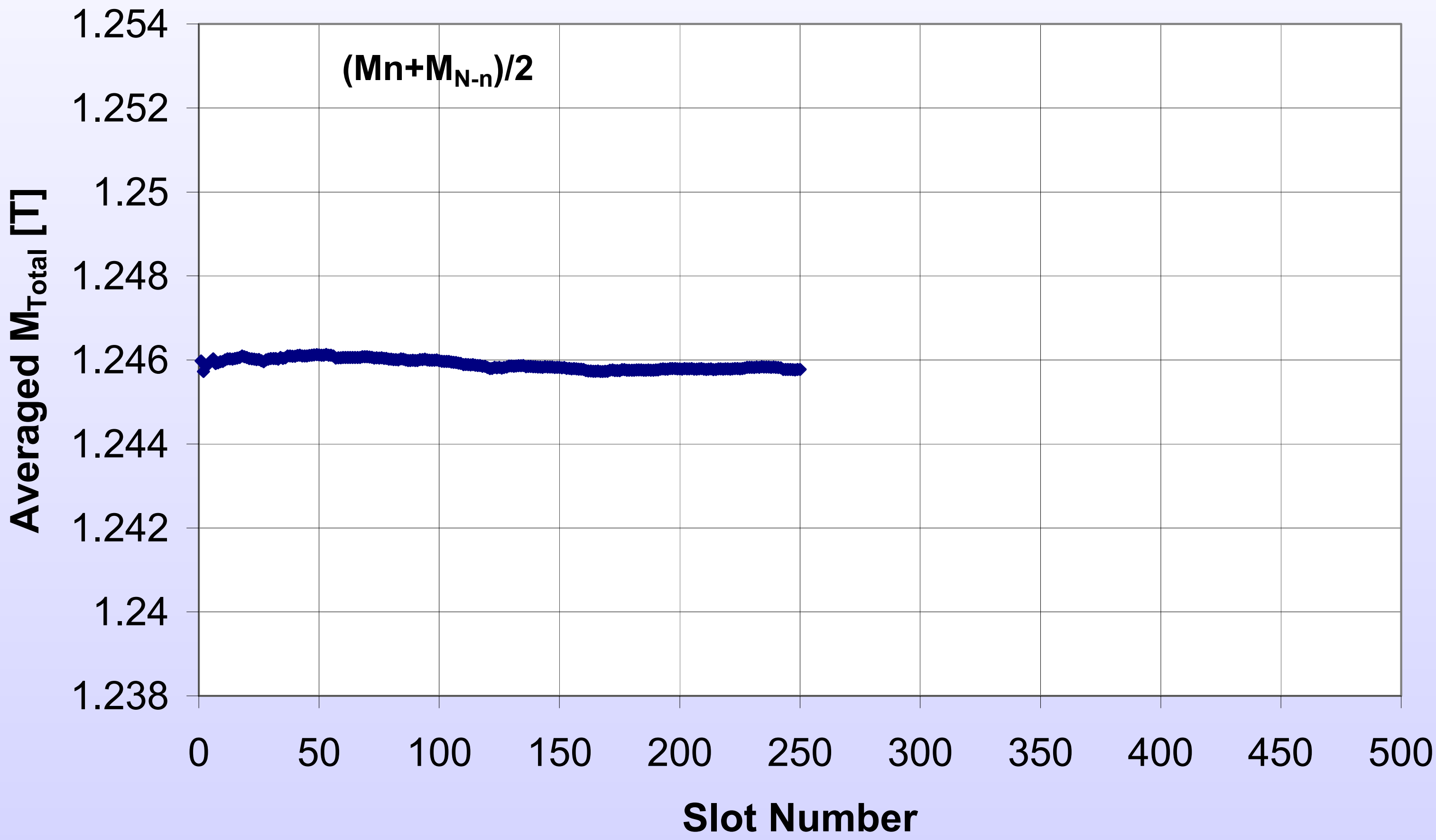
Sorted in ascending order



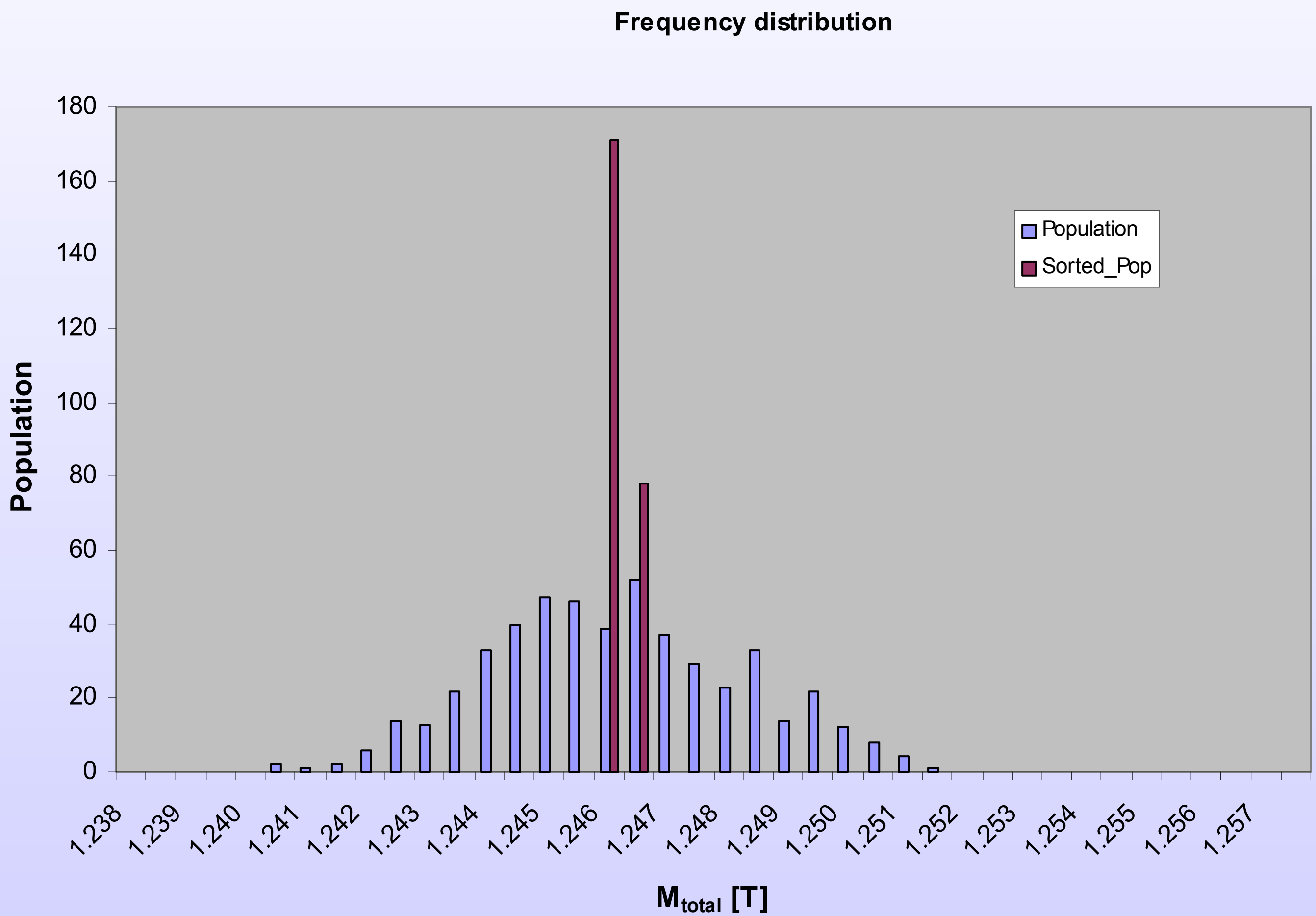
After pairing



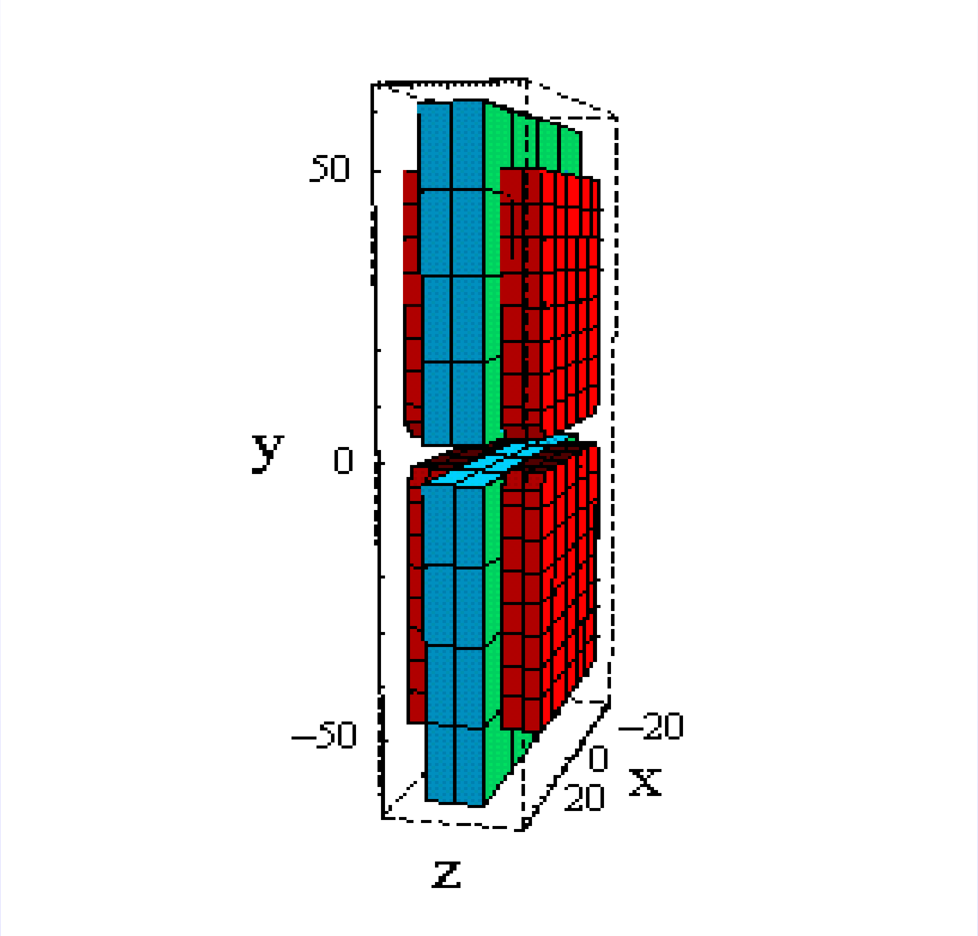
X-axis: Slot Number

Y-axis: Total magnetic moment

Histogram of population before and after pairing



Sandwich Fixture for Field Measurements



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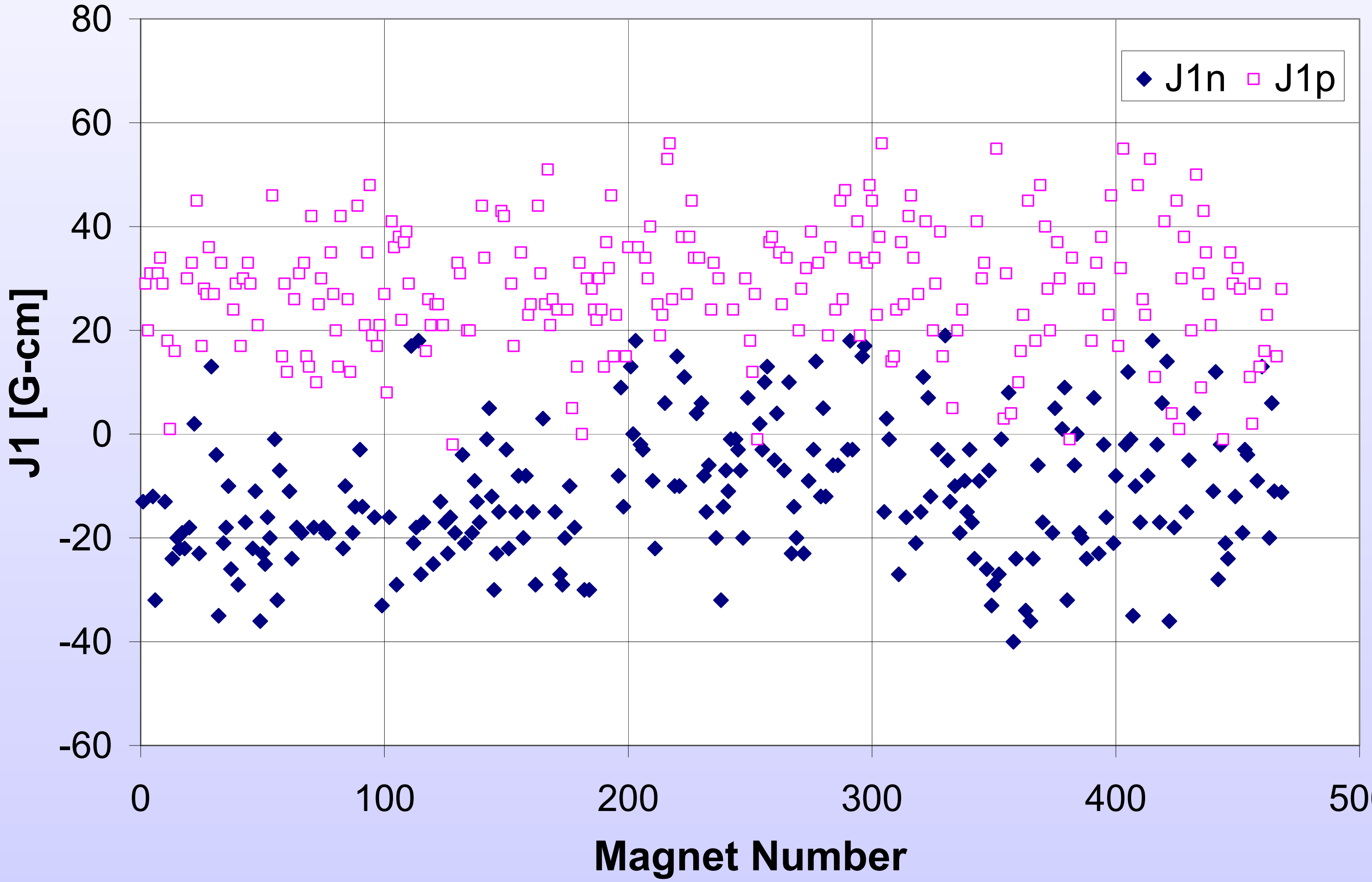
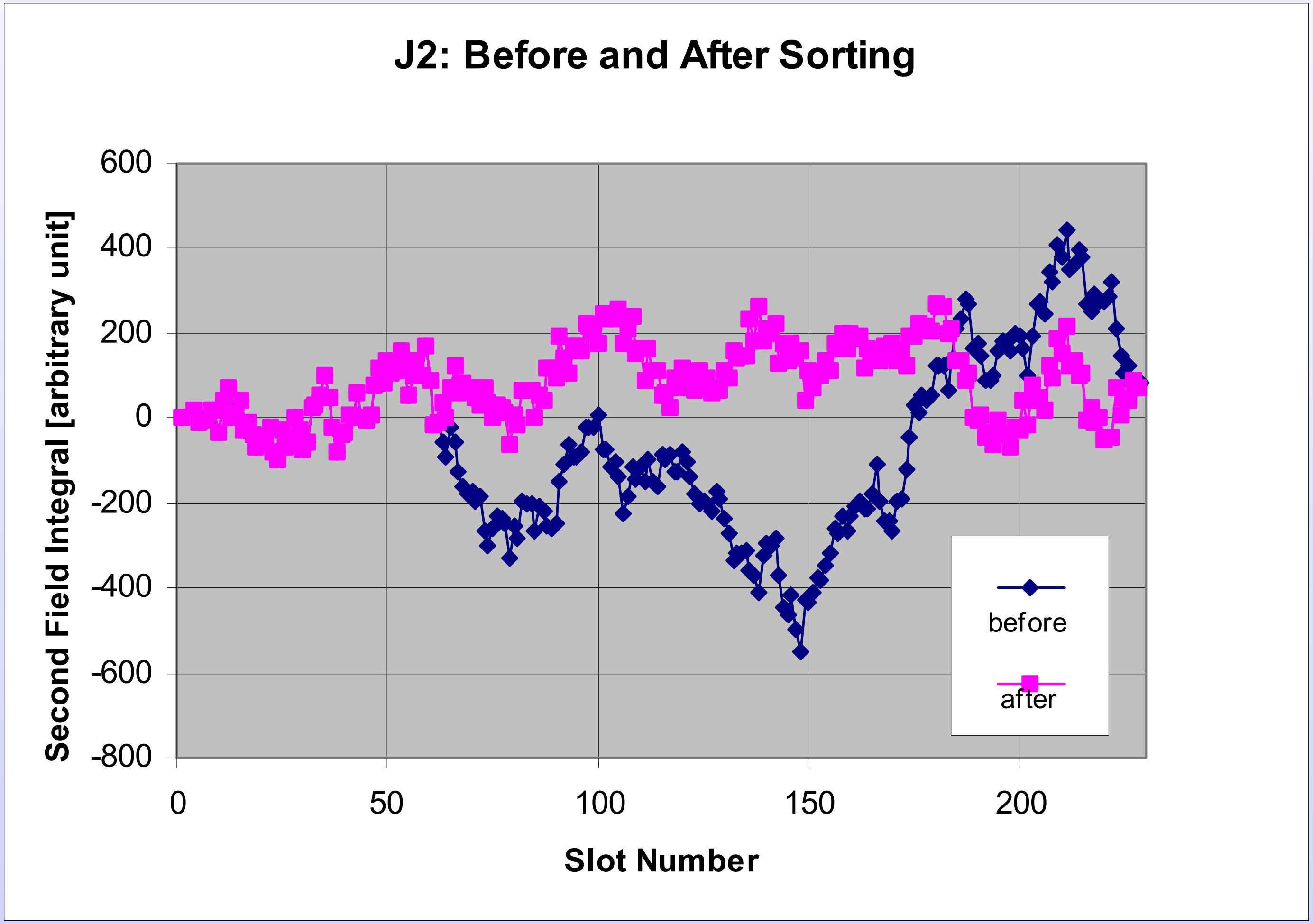
Measured with the Sandwich Fixture



Sum of measured J1 with the Sandwich Fixture



Before assembling the device, we also did….

- Sorting of pole heights was done to achieve the best possible gap uniformity along the device.

- Cants were sorted in such a way as to provide easy access for mechanical measurements of the gap using ceramic gauge blocks.

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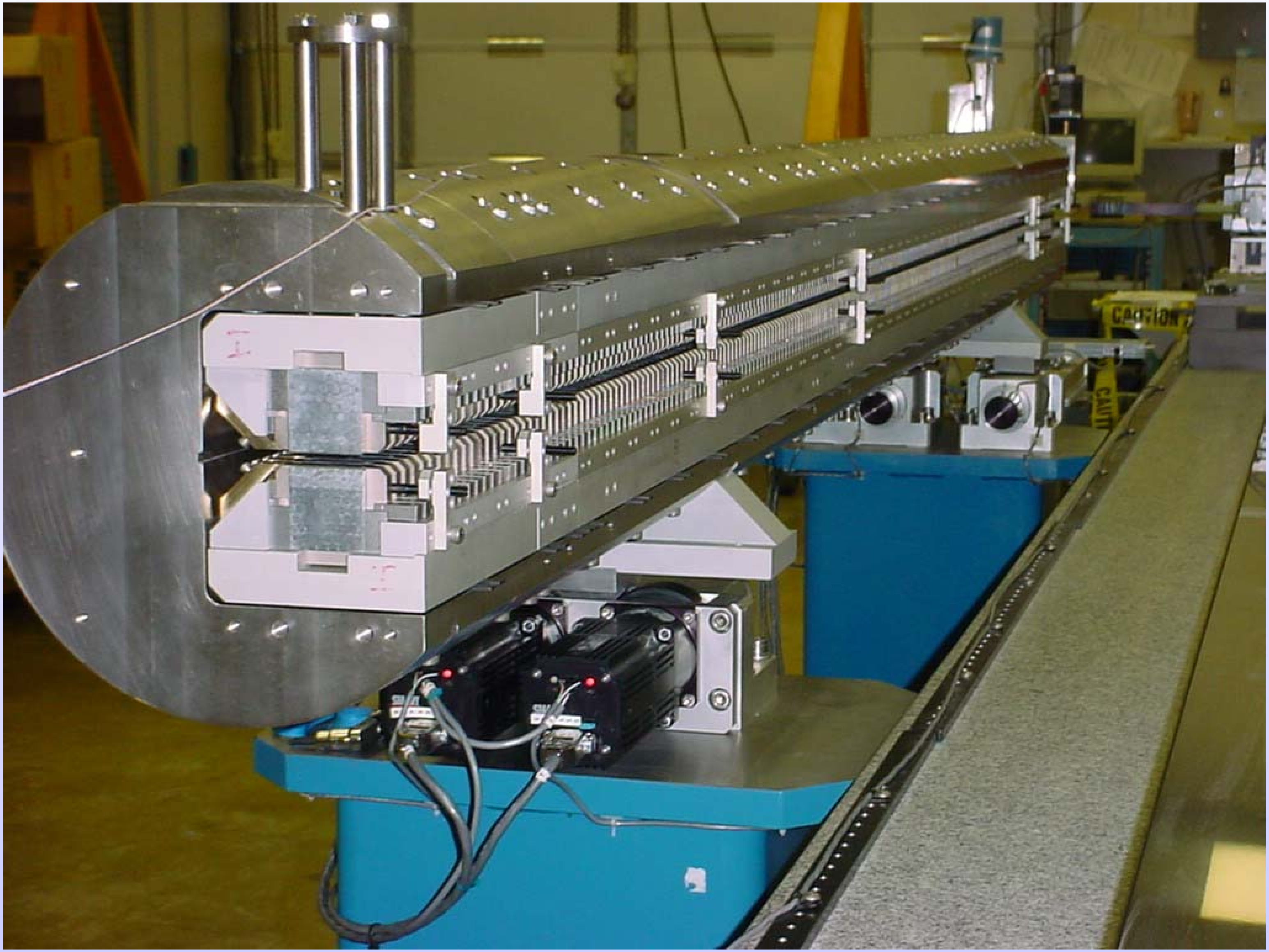

Shimming

- Trajectory shim
- Phase shim
- Mechanical shim

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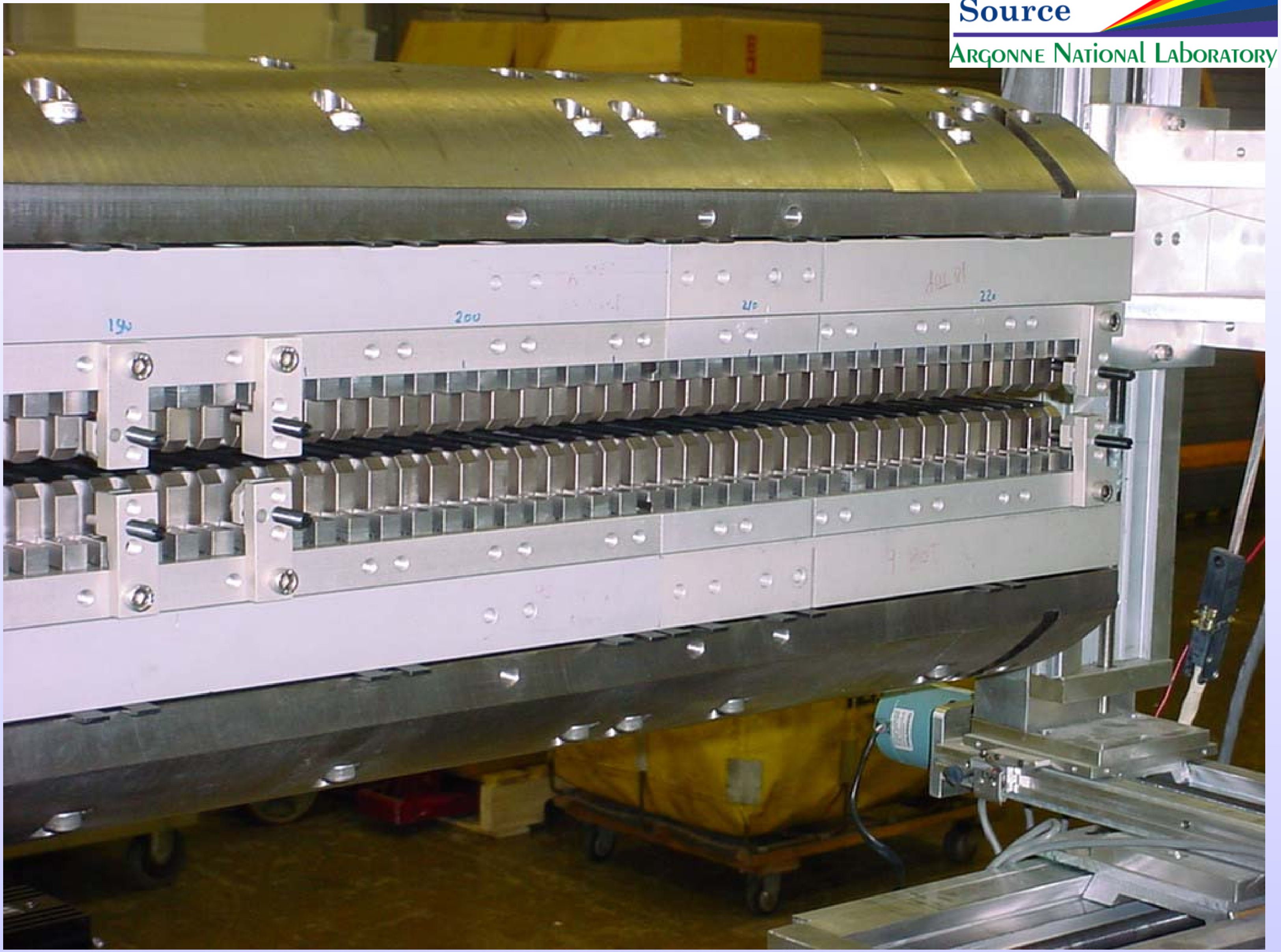
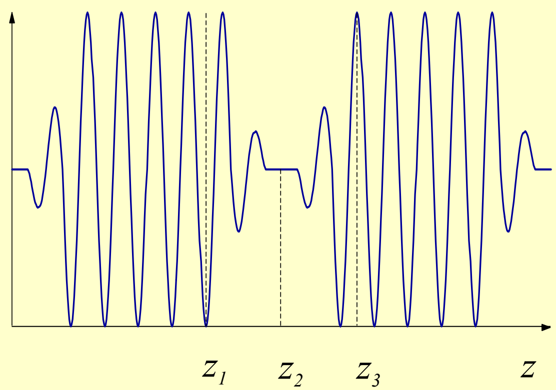


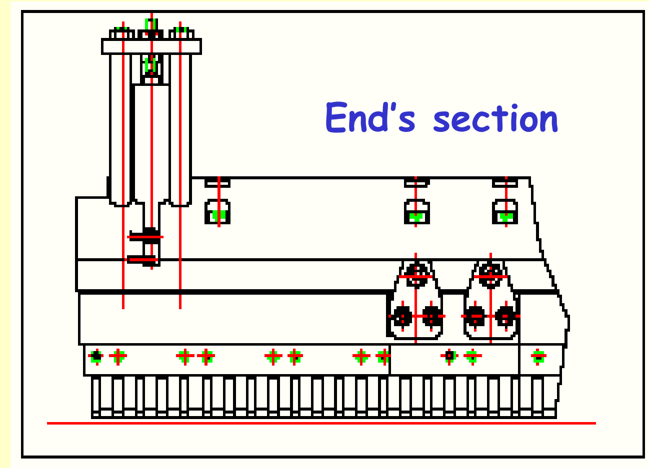
Phasing of the Undulator Sections

$$\Delta t = \int_{z_1}^{z_3} \left(\frac{1}{v_z} - \frac{1}{c} \right) dz = \frac{\lambda}{c} n$$

for antisymmetric II



$$\frac{v_z}{c} \cong 1 - \frac{1}{2\gamma^2} - \frac{e^2}{2(\gamma m c^2)^2} \left[\int_{z_1}^{z} B_y(z')dz' \right]^2$$



Phase Advance

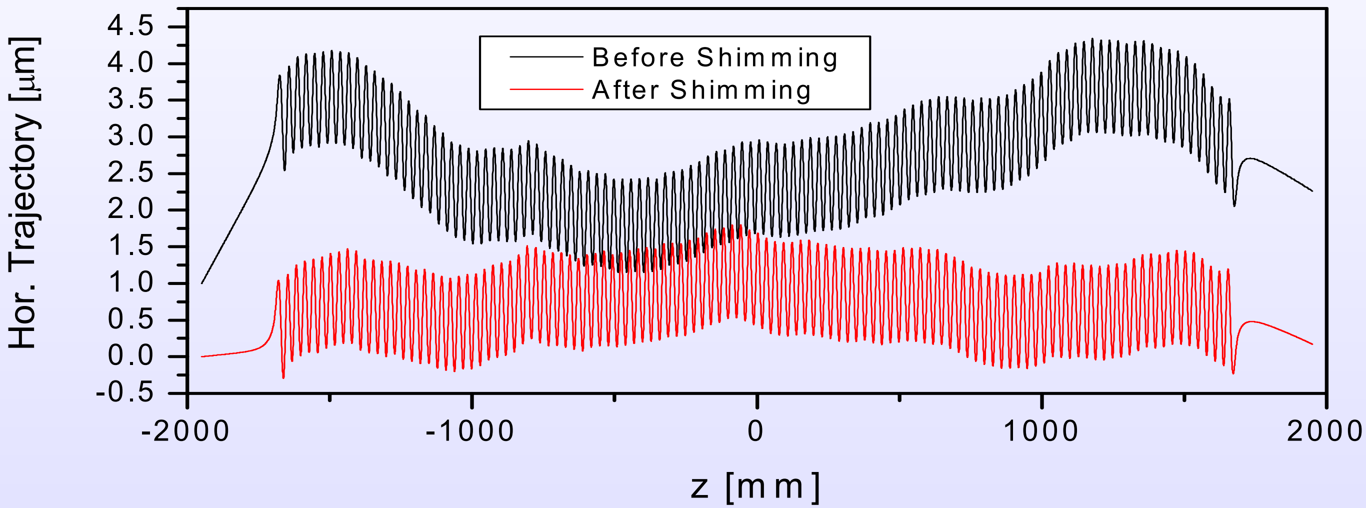
$$\Delta\varphi \cong 4\pi \frac{\Delta K}{K} \cdot N$$

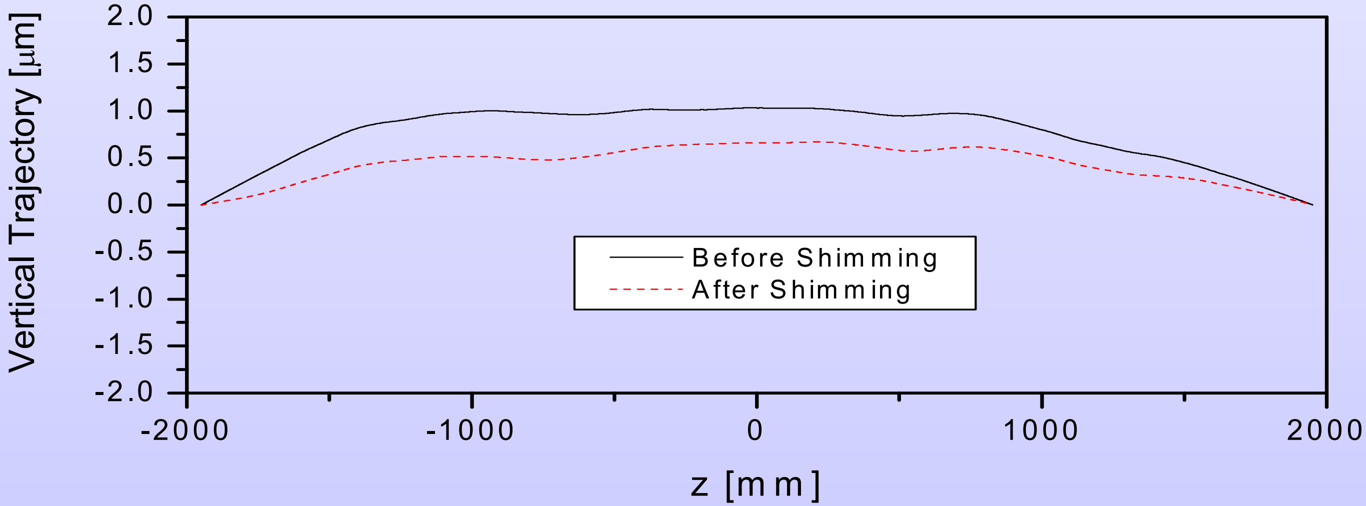
N - number of poles

For one undulator section

$$\Delta\varphi \simeq \pm 50^\circ$$

Electron Energy = 14.35 GeV





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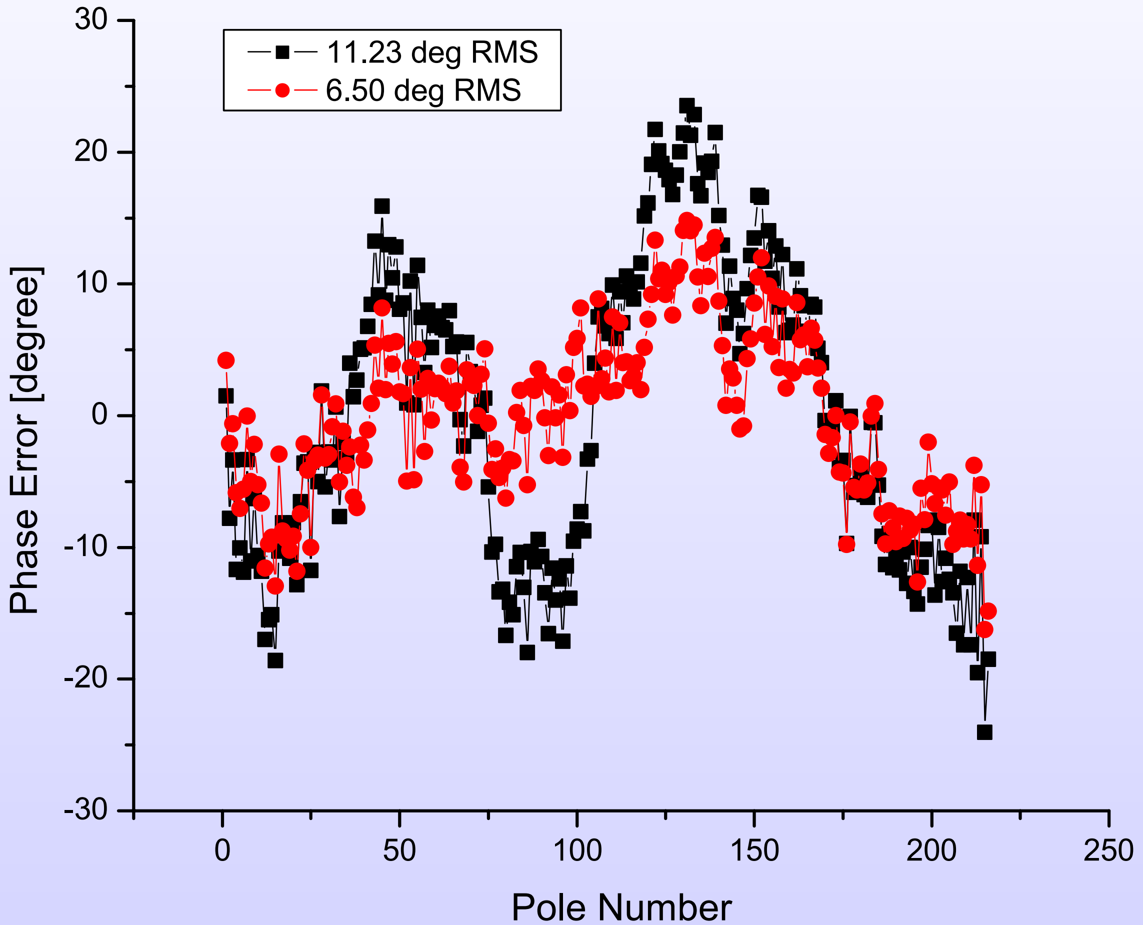

Phase error vs. pole number before tuning (black) and after (red) for the whole section.

Conclusions

- Sortings of magnets and poles were done.
- A prototype undulator was assembled.
- Gap increased from design value (6 mm) to 6.35 mm to achieve designed K_{eff} (3.71).
- Simple shimming techniques were established.
- Performance after tuning was well below tolerances.

  $\langle x \rangle$, y $< 2\ \mu m$, $Re(A/A_0)$: 7% → 0.2%, ϕ=6.5 deg

Conclusions (continued)

- K_{eff} temperature dependence was measured. ΔK/K is 0.0005 per 1C°.
- Challenging part is adjusting K_{eff} to the same value for all (33) undulators.

$$\Delta K/K < 1.5 \times 10^{-4}$$

- Device ends will have a possibility of remote gap tuning.

Other related presentations by our group

TU-P-20:

Positioning System for the LCLS Undulators

WE-P-48:

Radiation Effects Studies at the Advanced Photon Source

End of presentation