17TH ADVANCED BEAM DYNAMICS WORKSHOP ON
FUTURE LIGHT SOURCES

Advanced Photon Source Low-Energy Undulator Test Line

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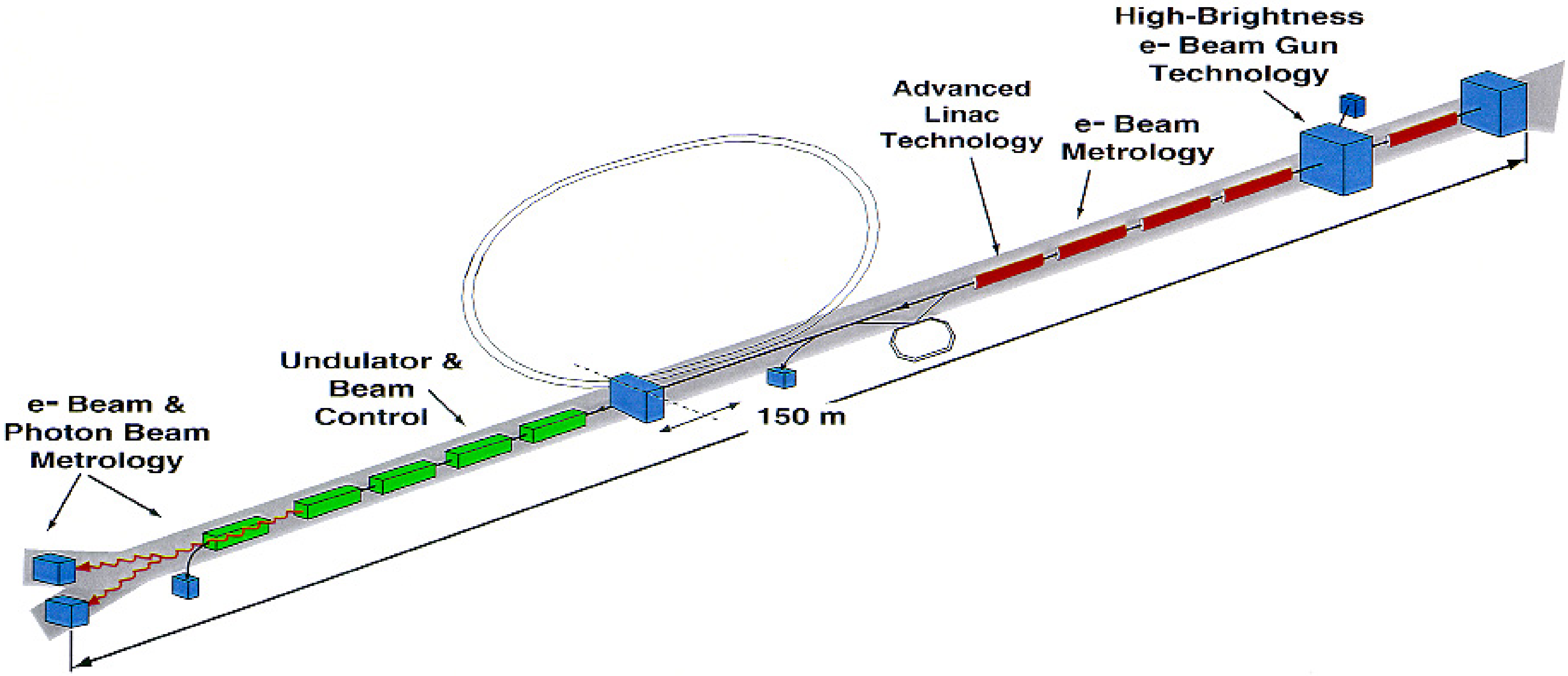
ARGONNE NATIONAL LABORATORY, ARGONNE, IL U.S.A.

ADVANCED PHOTON SOURCE LOW-ENERGY UNDULATOR TEST LINE

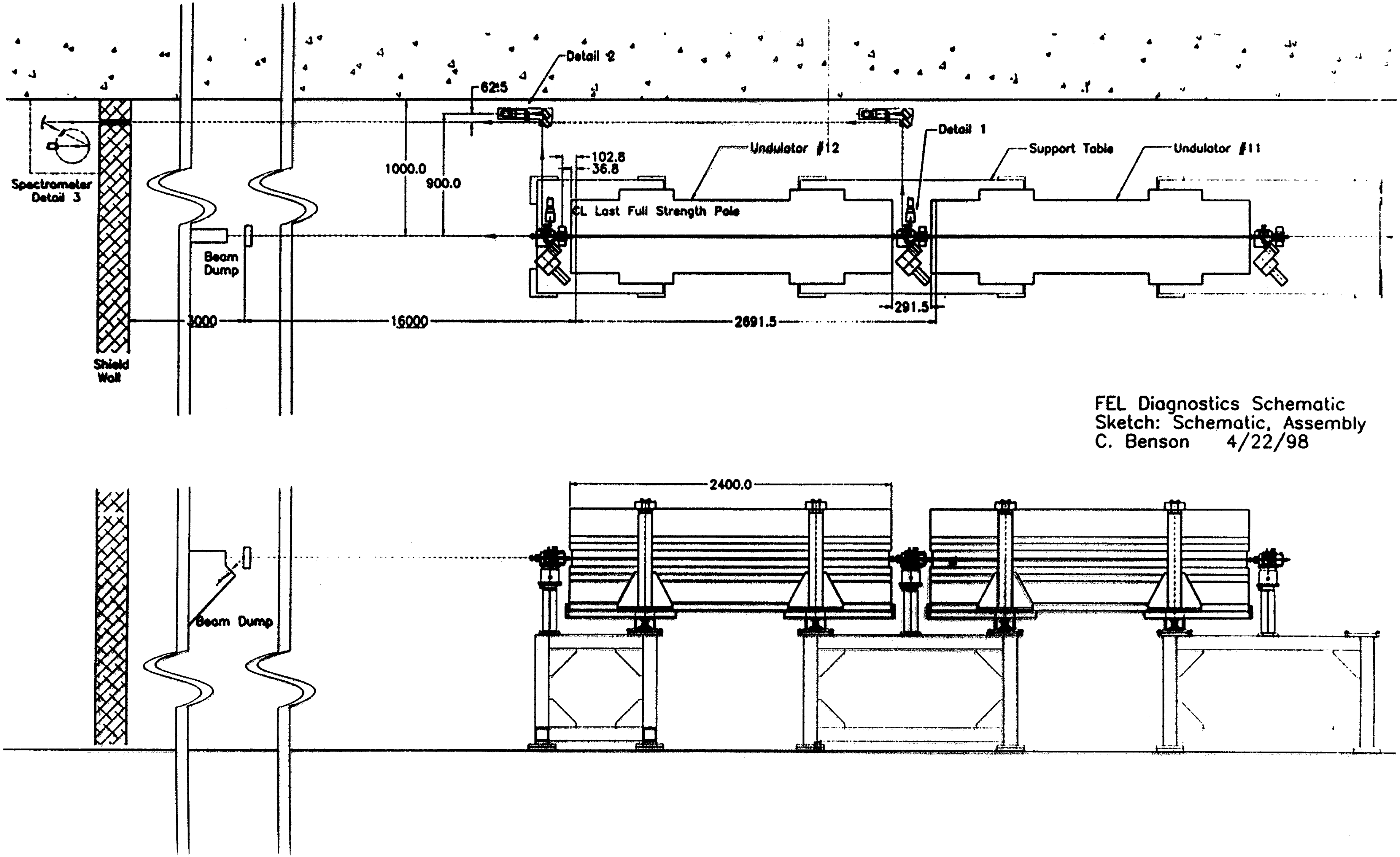


The APS FEL will use separated undulator sections, with horizontally focusing quadrupoles in the drift spaces between undulators.

- Simulations showed no harmful effect on the beam bunching (except for a longer tunnel to make up for the drift length).

- Simpler undulators - identical to standard APS Undulator A.

- Drift spaces can hold diagnostics.



FEL Diagnostics Schematic
Sketch: Schematic, Assembly
C. Benson 4/22/98

FEL Parameters

Wavelength	532 nm
Beam energy	220 MeV
Normalized emittance	5• mm-mrad
Peak current	150 A
Energy spread	0.1 %
Focusing	separate quadrupoles
Undulator period	33 mm
Undulator parameter K	3.1
Undulator effective field	10.061 kG
Nominal magnetic gap	9.3 mm (fixed)
Undulator length	2.4 m
Cell length	2.7265 m
Number of cells	12
Gain length	1.3 m

FEL magnetic field requirements

For SASE, particle beam and photon beam must overlap

- require of vendor that $\iint B\,dz\,dz' < 3300$ G-cm^2 over entire undulator length
- in both x and y directions
- an environmental field of 0.3 G gives $\iint B = 8300$ G-cm^2, so earth's field becomes significant
- corresponds to 45 µm displacement for 220 MeV beam. This is too large for 100 µm beam, so further tuning is done at APS.
- no separate first integral requirement. Problems could be fixed during APS measurement and tuning.

For SASE, emitted light wavelength must be the same for different undulators

- Simulations were run of electron bunch peak current density with errors in K_{eff} between undulators.

- Require B_{eff} of all undulators to lie within 15-G-wide range

- A gap error of 16 µm changes B_{eff} by 15 G.

- Undulator magnetic field will change with temperature due to temp. coefficient of magnets and thermal expansion of support. Temp uniformity within a total range of 1.5°C is necessary.

Phase matching from one undulator to the next places magnetic requirements on the undulator end tuning.

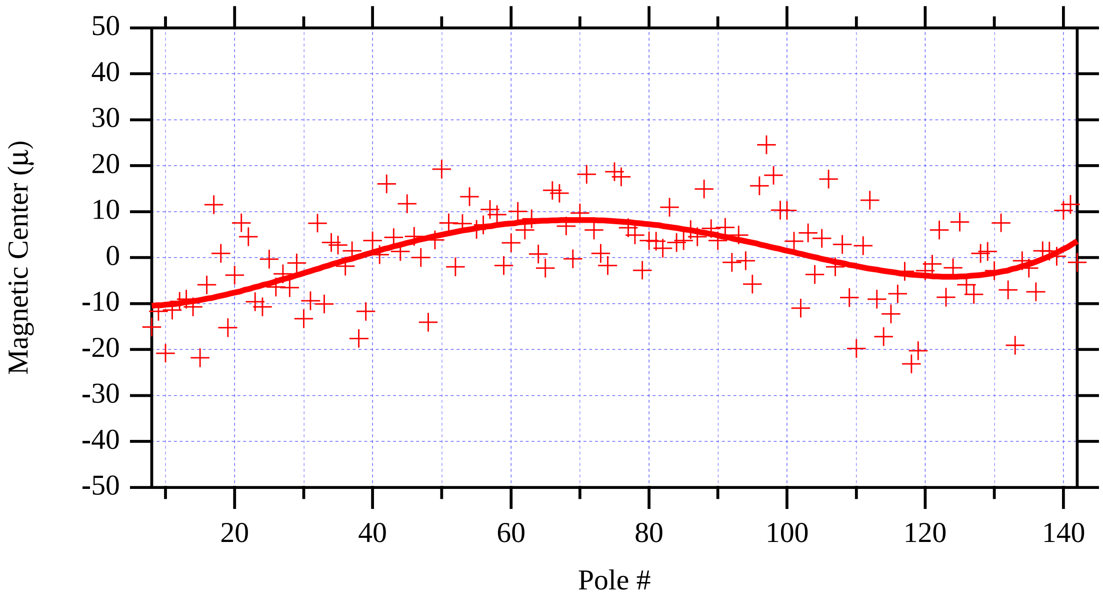
- Simulations of the electron beam bunching lead to a 1 mm tolerance in longitudinal spacing between undulators.

- Undulator ends must be tuned so the undulator spacing required for proper phasing is within the mechanical adjustment range.

- This tuning is done at APS and the necessary break length is determined at APS.

Midplane height variation will affect beam focusing

- Simulation results lead to 50 µm tolerance on overall vertical position
- Pole-to-pole scatter is unimportant because it is on a shorter scale than the β-function of the particle beam



Phase error requirement is less demanding than for an APS undulator

- higher harmonics are most sensitive to phase errors

- FEL only relies on a bright first harmonic

- FEL requirement for <10° rms phase error gives about a 3% brightness decrease in first harmonic

Much of this magnetic tuning is done by STI Optronics, by their choice of and arrangement of magnet blocks, by their careful attention to mechanical details during manufacture and assembly, and by their initial magnetic tuning.

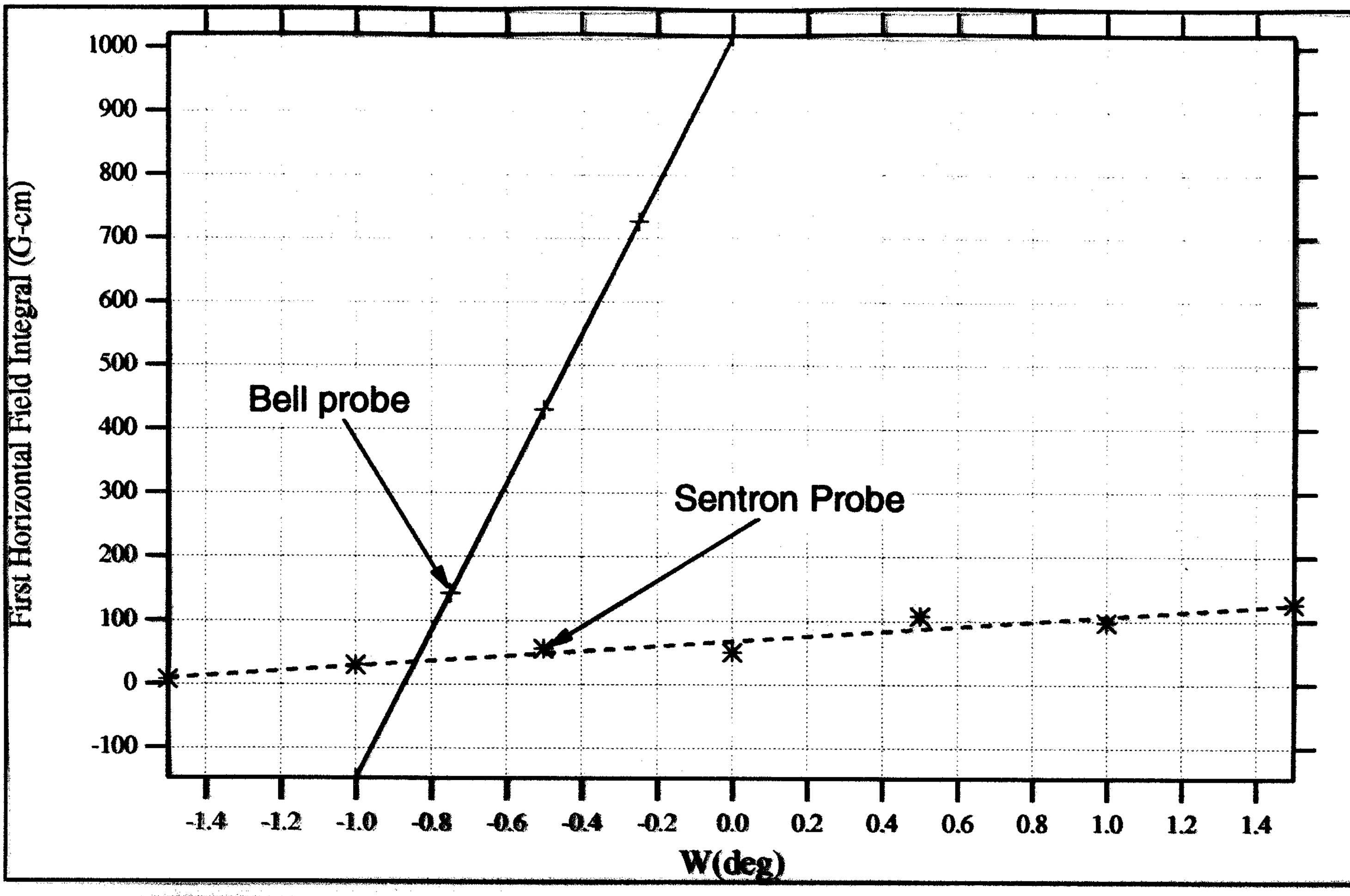
After the magnetic structures arrive at APS, I. Vasserman checks them magnetically and refines the magnetic tuning.

Measurements of a weak horizontal magnetic field when there is a strong vertical magnetic field are challenging, because of the planar Hall effect.

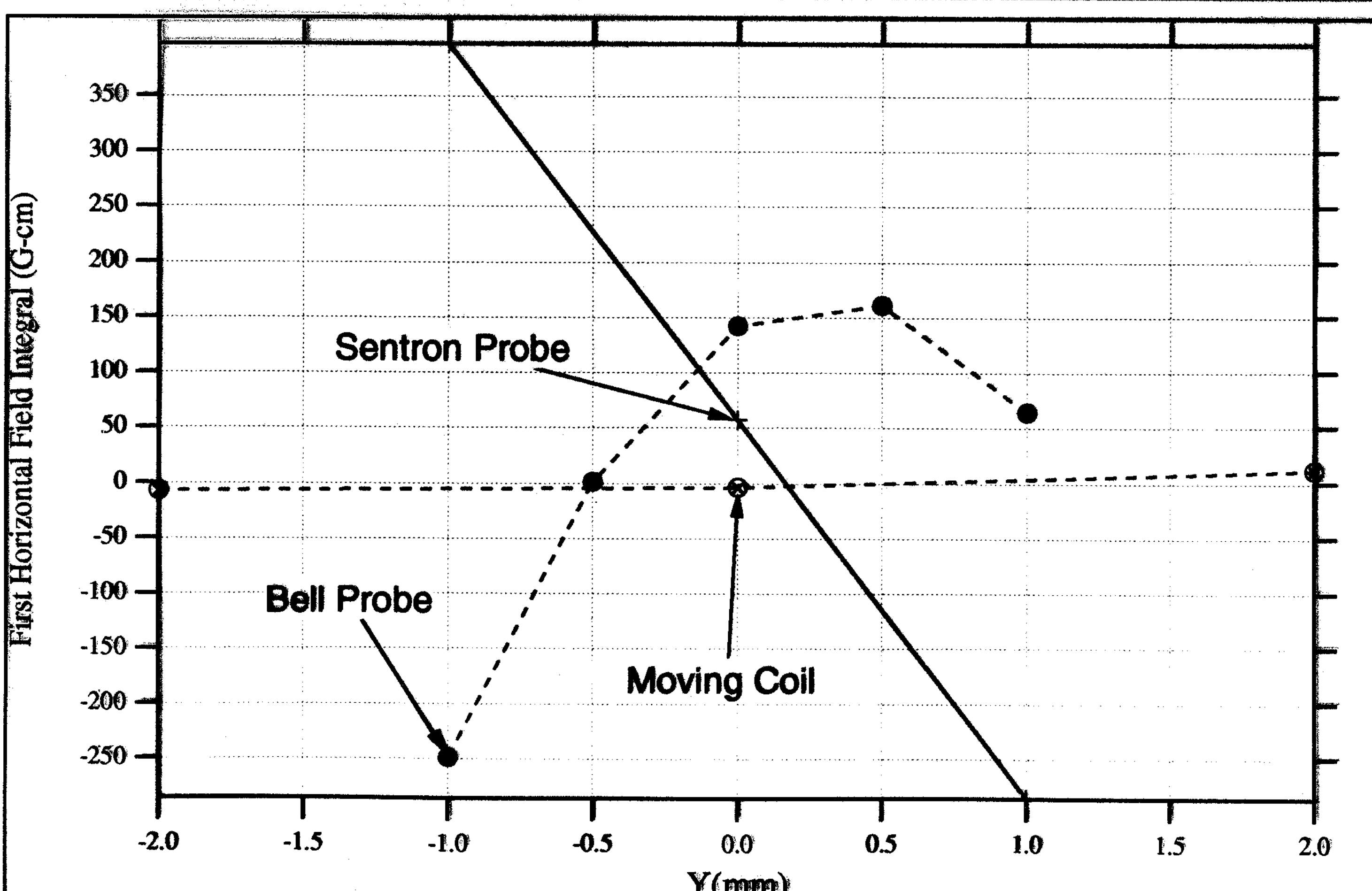
Two probes from different vendors were tried.

Problematic parameters were the angle of the probe and the vertical position of the probe.

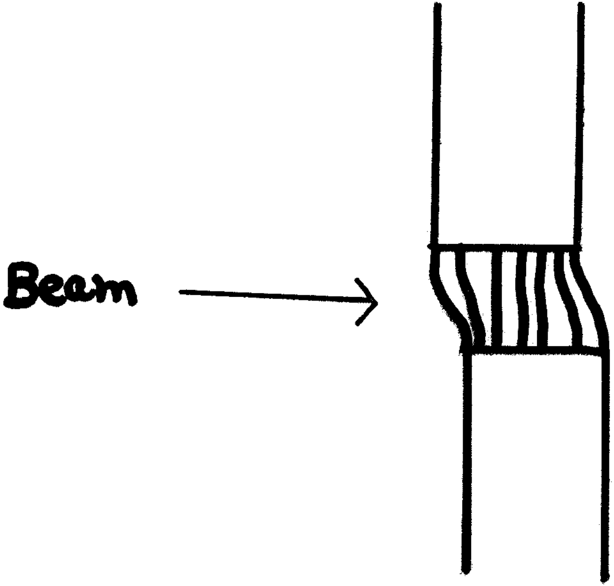
Moving coil measurements provide reference values for first and second field integrals.

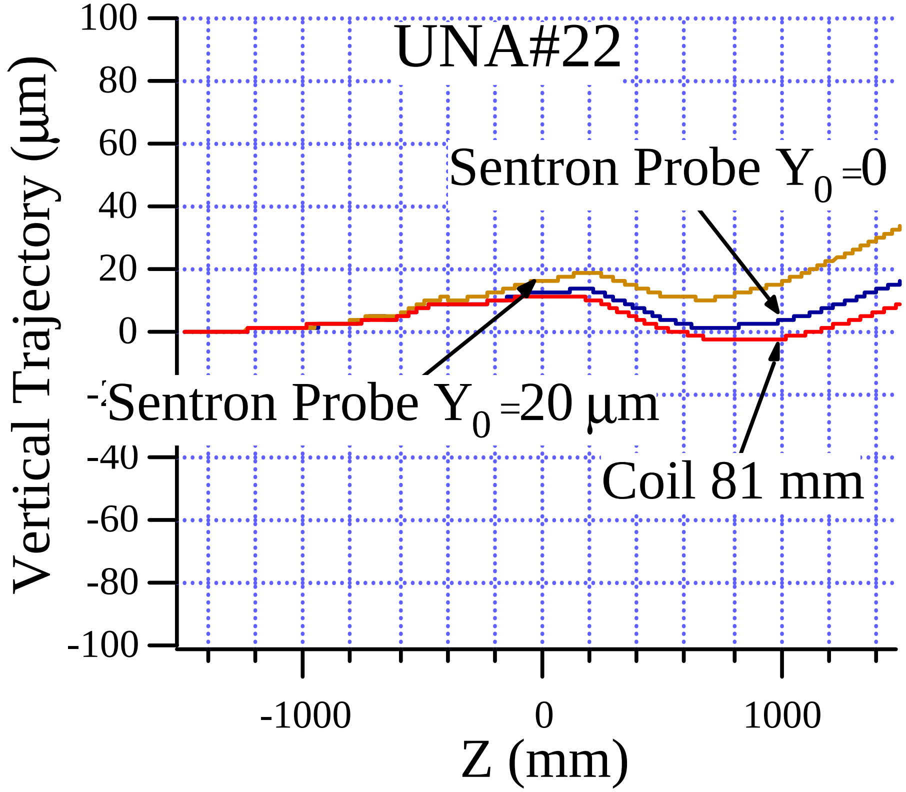


1000
900
800
700
600
500
400
300
200
100
0
-100
First Horizontal Field Integral (G-cm)
Bell probe
Sentron Probe
-1.4
-1.2
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
W(deg)



350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
First Horizontal Field Integral (G-cm)
Sentron Probe
Bell Probe
Moving Coil
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
Y(mm)


Beem



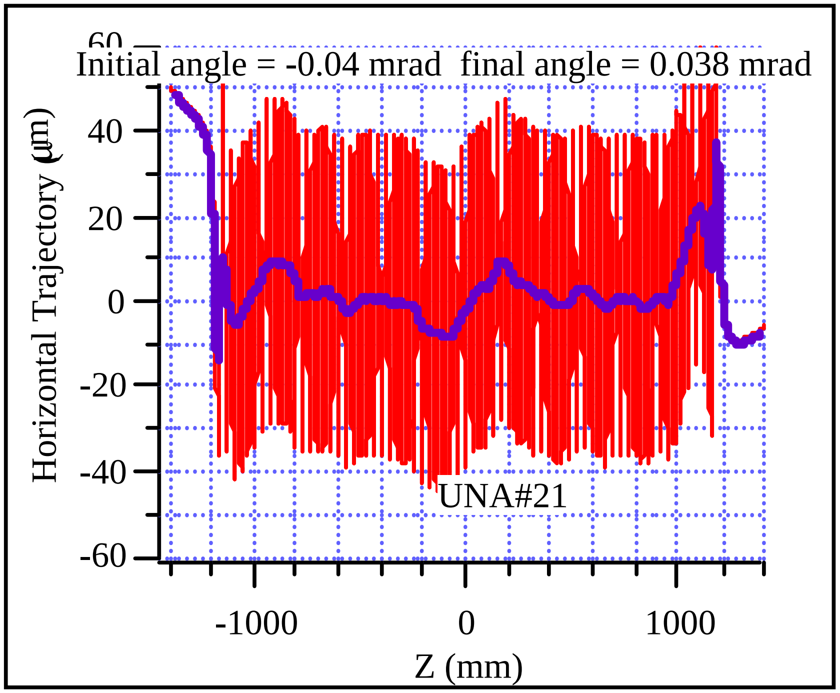
Hall probe measurements with different Y offsets, along with a moving coil reference measurement. The particle energy is 220 MeV.

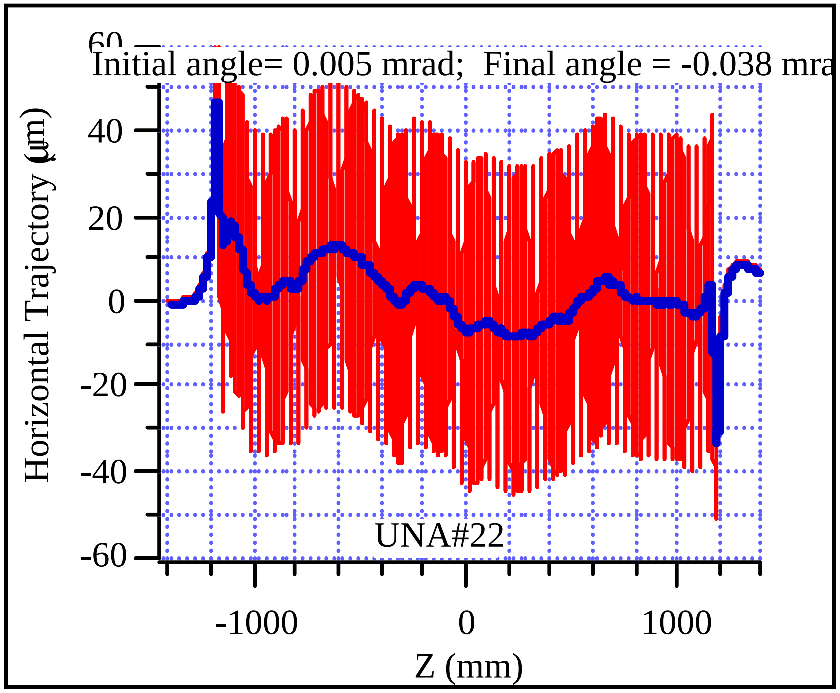
Two magnetic structures have been tuned for the FEL.

Initial magnetic measurements and tuning were performed with the magnetic structures on a standard undulator variable-gap support.

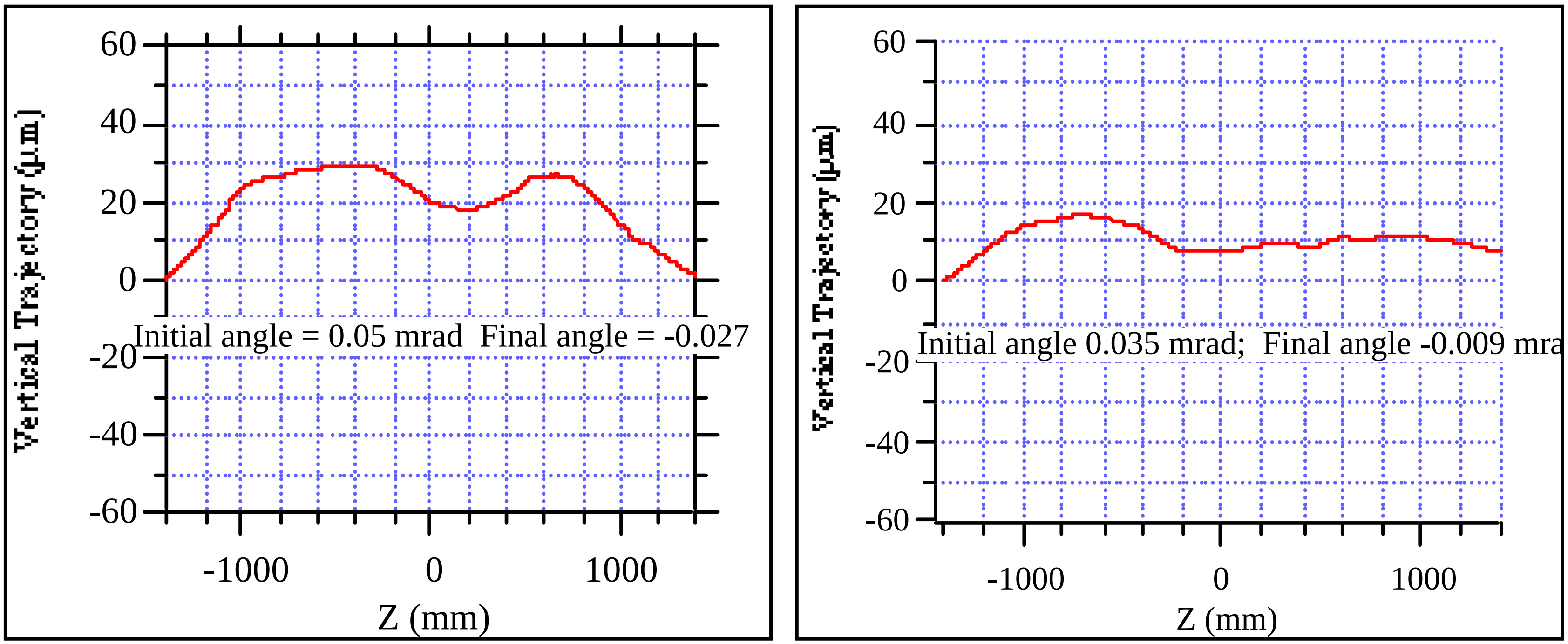
Transfer to the fixed-gap FEL support was not as easy as hoped, however. Although the magnetic structures were supported at the same longitudinal z positions in both supports, they sagged differently.

A few microns makes a big difference!





Horizontal trajectory of the first two FEL undulators. The blue line is the wiggle-averaged trajectory.



Vertical trajectory of the first two FEL undulators.

Necessary break length required for proper phasing between undulators for the first two FEL undulators:

	UNA #21	UNA #22
DS end (cm)	19.68	20.44
US end (cm)	20.02	20.12

The APS FEL Undulator Participants

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and

STI Optronics