Argonne NATIONAL LABORATORY

... for a brighter future

APS IDs

For NSLS-II visit 21 May 2009

U.S. Department of Energy

UChicago Argonne LLC

Office of Science
U.S. DEPARTMENT OF ENERGY

A U.S. Department of Energy laboratory managed by UChicago Argonne, LLC

APS IDs installed as of May 2009

Period length	Number	Length (periods)	K_{eff}
33-mm (Undulator A)	25	72	2.74
33-mm	5	62	2.74
18-mm	1	198	0.46
23-mm	3	103	1.17 [a)]
27-mm	3	88	1.78
30-mm	2	79	2.20
30-mm	3	69	2.20
35-mm (SmCo)	1	67.5	3.08 [b)]
55-mm	1	43	6.57
128-mm (Circularly Polarized Und.)	1	16	$K_{x,y}<2.8$

Device length includes the ends - approx. one period at each end is less than full field strength.
K value is at 10.5 mm gap unless stated otherwise. CPU is all-electromagnetic.
[a)] at 10.6 mm gap.
[b)] at 9.5 mm gap.

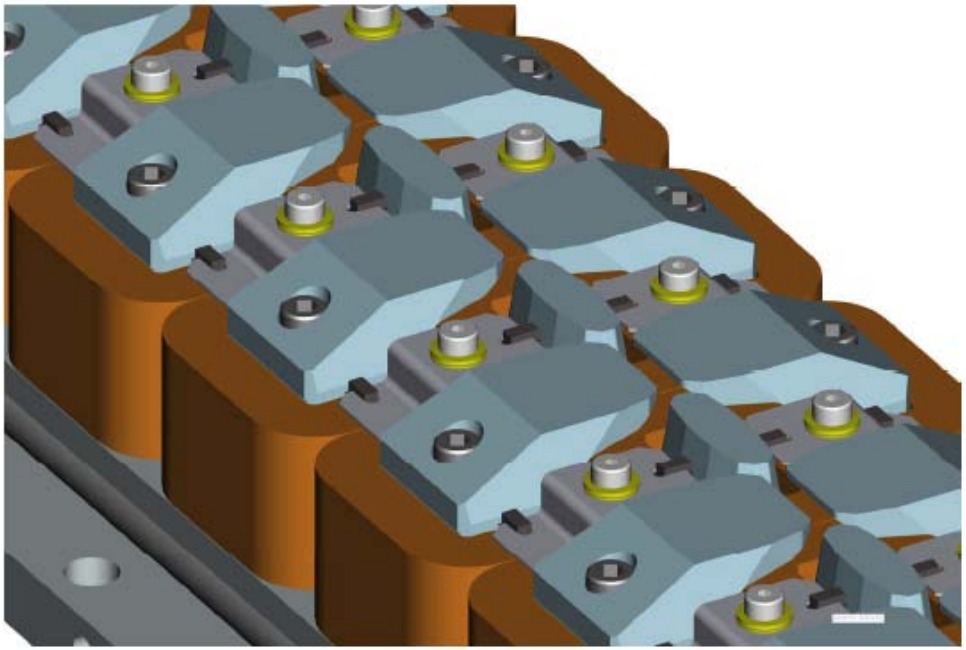
Total: 45 IDs

Where IDs came from

Period length	Number	Origin
33-mm (Undulator A)	25	STI Optronics
33-mm	5	STI Optronics, APS mod.
18-mm	1	STI Optronics
23-mm	3	APS
27-mm	3	Magn designs APS; One STI-built, others APS
30-mm	2	APS
30-mm	3	APS
35-mm (SmCo)	1	APS
55-mm	1	APS magn design, STI-built
85-mm (Wiggler A) (removed)	2 built	STI Optronics
128-mm (Circ. Polarized Und)	1	Budker / APS
Elliptical wiggler (removed)	1	Budker / APS

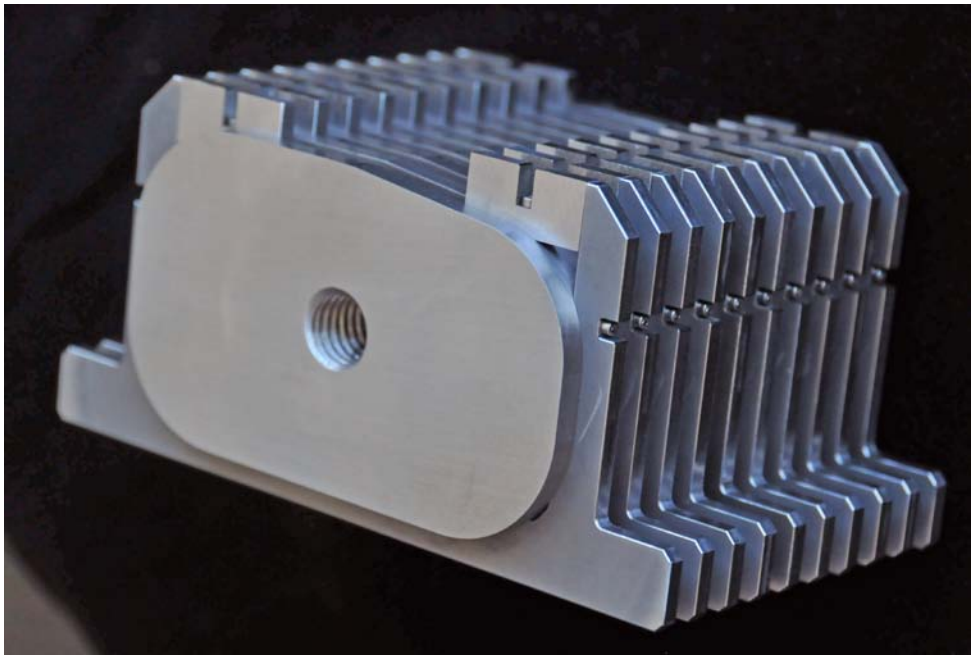
An electromagnetic, quasiperiodic, variably polarizing undulator for IEX

- *12-cm period; 4.8-m long; all electromagnetic.*
- *A few (quasiperiodic) poles are powered separately and can deliver weaker field.*
- *Quasiperiodicity shifts higher harmonics in energy so they don't pass through monochromator; the improved S/N compensates for the reduced first harmonic.*
- *Polarization can be left or right circular, or horizontal or vertical linear.*
- *Photon energy as low as 200 eV in horiz. linear mode; as low as 400 eV in other modes. Up to 2.5 keV.*
- *Will fit standard APS ID vacuum chamber.*
- *An 0.4-m-long prototype is under construction at APS.*



Superconducting undulator for high photon energy

- *An R&D project is making good progress towards building a superconducting undulator for APS.*
- *Goal is tunability from 20 to 25 keV in the 1st harmonic.*
- *Undulator period of 16 mm; beam stay-clear of 7 mm.*
- *42-pole magnetic structures have been successfully produced and tested, reaching the expected critical current and showing good magnetic field quality.*



Other undulators

APS FEL undulators were standard undulators A, but with different magnetic tuning requirements (fixed gap, more demanding trajectory straightness, less of phase errors)

The LCLS undulators were designed at APS.

- Outside machine shops made the parts and assembled the 40 production undulators.
- APS provided training in handling magnets and assembly of magnetic structures.
- APS advised SLAC on measurement system construction, and trained the measurers

Magnetic Measurement Techniques

- Rotating Coil
  - Measurements of the first and second field integrals are best if
    - The field integrals are close to zero.
    - The period lengths of magnetic structure are much less than period of the wire-vibration period length.
    - The errors increase with the strength of the magnetic field and the undulator/wiggler period and the length of the device. Very good reproducibility (see Table I).
  - Measurements of integrated multipole components are reliable and not dependent on the quality of the coil.
  - Translation mode allows to decrease the required time and is prefered for such measurements.
  - Different types of coil design are used in different laboratories (one wire, flat coil etc.)

- Search Moving Coil
  - Results are reliable and especially helpful for horizontal field measurements. Recommended as a reference for other measurement techniques.
- Stretched Wire
  - Preferable technique for first and second field integral measurements, especially of the vertical field at very small magnetic gaps.

Magnetic Measurement Techniques (cont'd)

- Hall Probe
  - Main tool to measure detailed field distribution. The so-called vertical Hall probe type is preferable to avoid the planar Hall probe effect (PHE). It also has an advantage of using a very small sensor, located in the same area as for the two-axis probe.
  - It requires good calibration with small steps for precise measurement of field integrals.
  - Recently new possibilities were examined and new Hall probes were designed to compensate or even cancel PHE.

Table I. Magnetic Measurement Parameters Achieved (Coils)

- Rotating Coil
  - For 0.1° step and 2 sec/revolution, 0.15 G-cm reproducibility.
  - Main source of errors is the width of the coil.
- Moving Coil
  - For 0.2 mm step and speed 200 mm/sec, 5 G-cm reproducibility.
- Stretched Single Wire
  - For 20 µm step and speed 10 mm/sec, 5 G-cm reproducibility.

- Coil Lengths
  - Rotating coil and stretched single wire ~4 m.
  - Short moving coils: 70 – 90 mm.

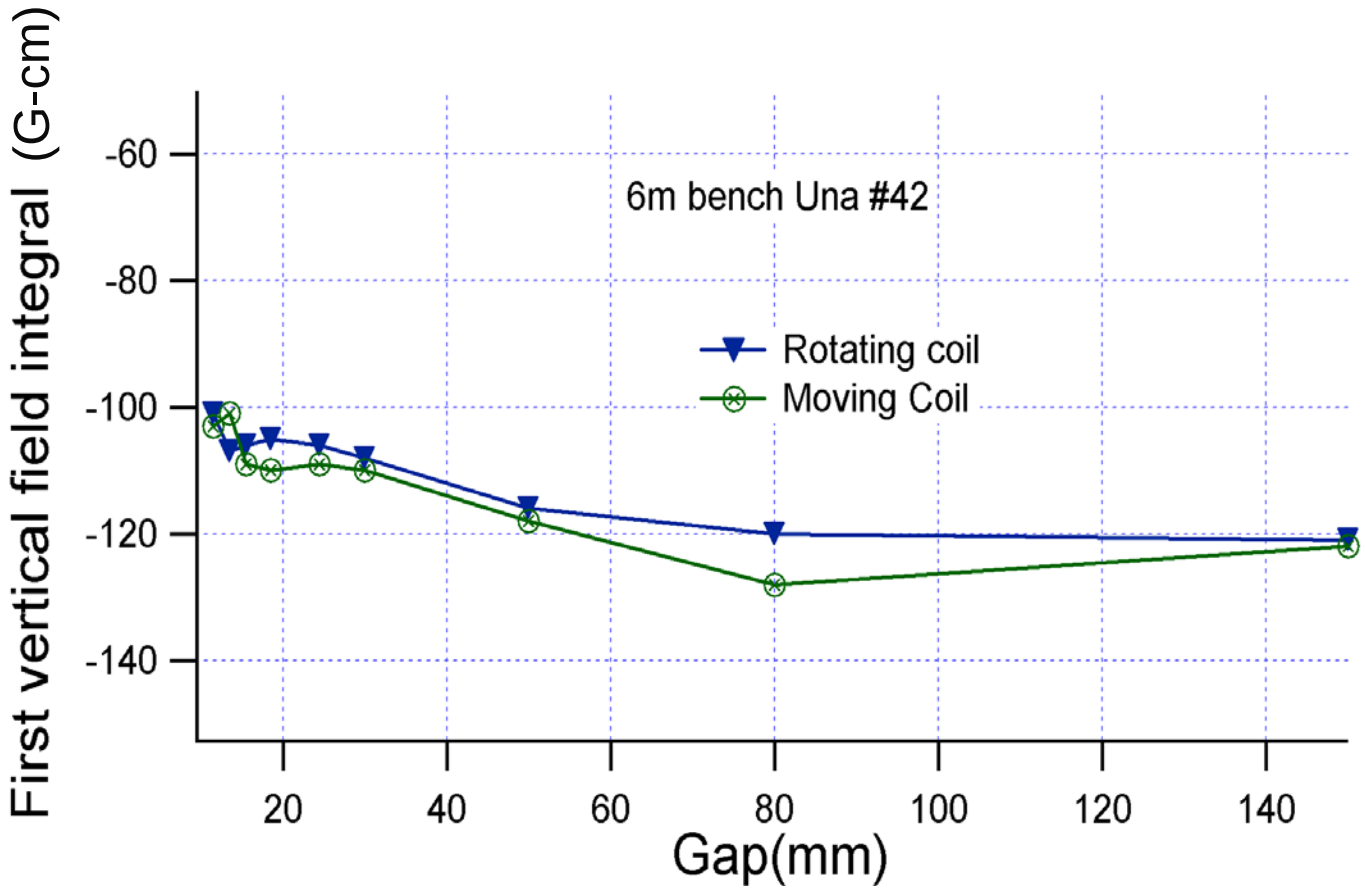
Table II. Magnetic Measurement Parameters Achieved (Hall Probes)

- Absolute Hall Probe Calibration Accuracy
  - ±0.5 Gauss
- Reproducibility of Hall Probe Measurements
  - First field integral ± 2.5 G-cm
  - Second field integral ± 3400 G-cm
  - B_{eff} measurements 0.15 Gauss (rms)
  - Phase error 0.02° (rms)
- Accuracy (first field integral)
  - 30 G-cm taking into account zero drift ~0.1 Gauss
- Speed
  - 100 mm/sec

Magnetic Measurement Absolute Accuracy

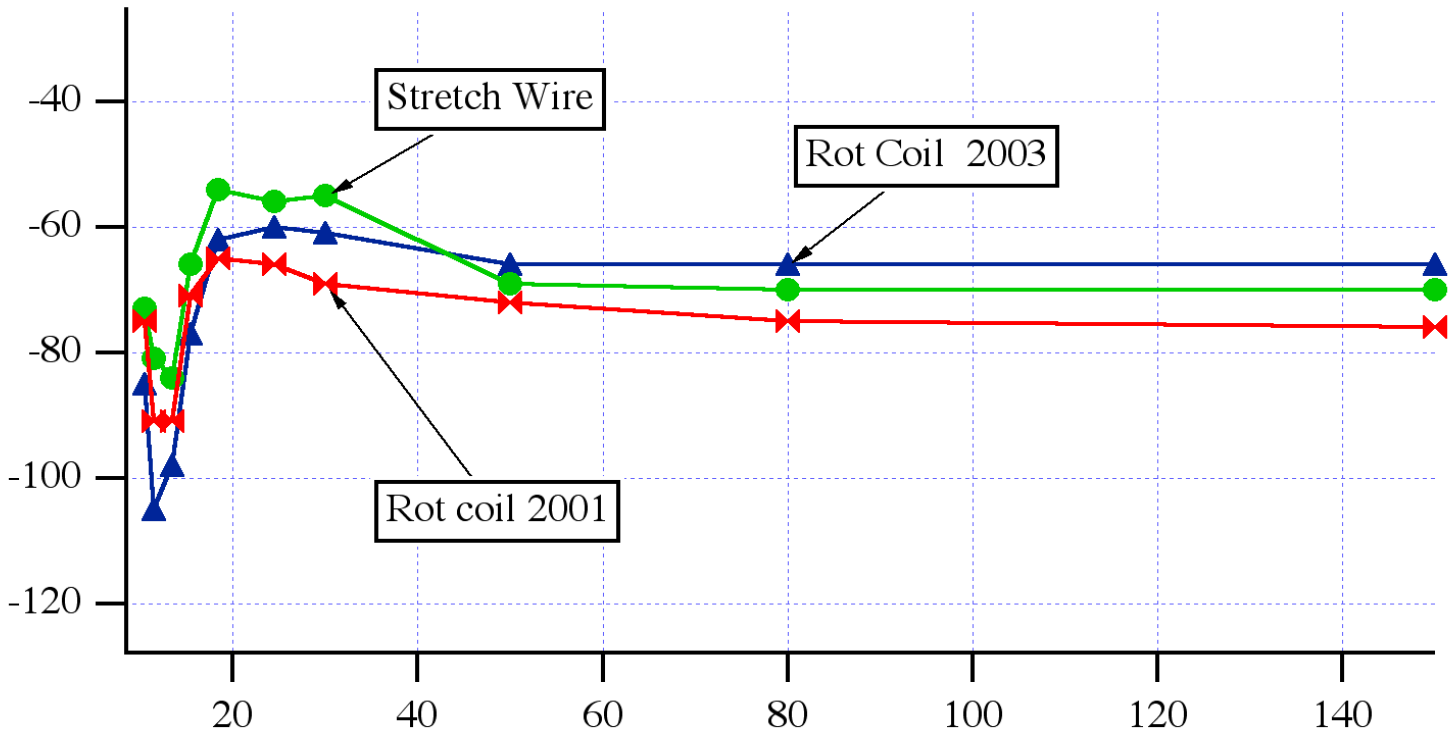
- Absolute accuracy of measurements are defined by systematic errors and calibration errors, first field integral accuracies are estimated to be
  - 30 G-cm for Hall probes and rotating coil (at small gaps)
  - 10 G-cm for stretched wire and short moving coil.
- Other errors include the difference in environmental conditions between MMF and the operational facility (earth field, magnetic material close to the ends of the undulators).

Results from Rotating Coil and Moving Coil



- First vertical field integrals (G-cm) vs. gap (mm)

Reproducibility of Stretched Wire and Rotating Coil (2001 and 2003)

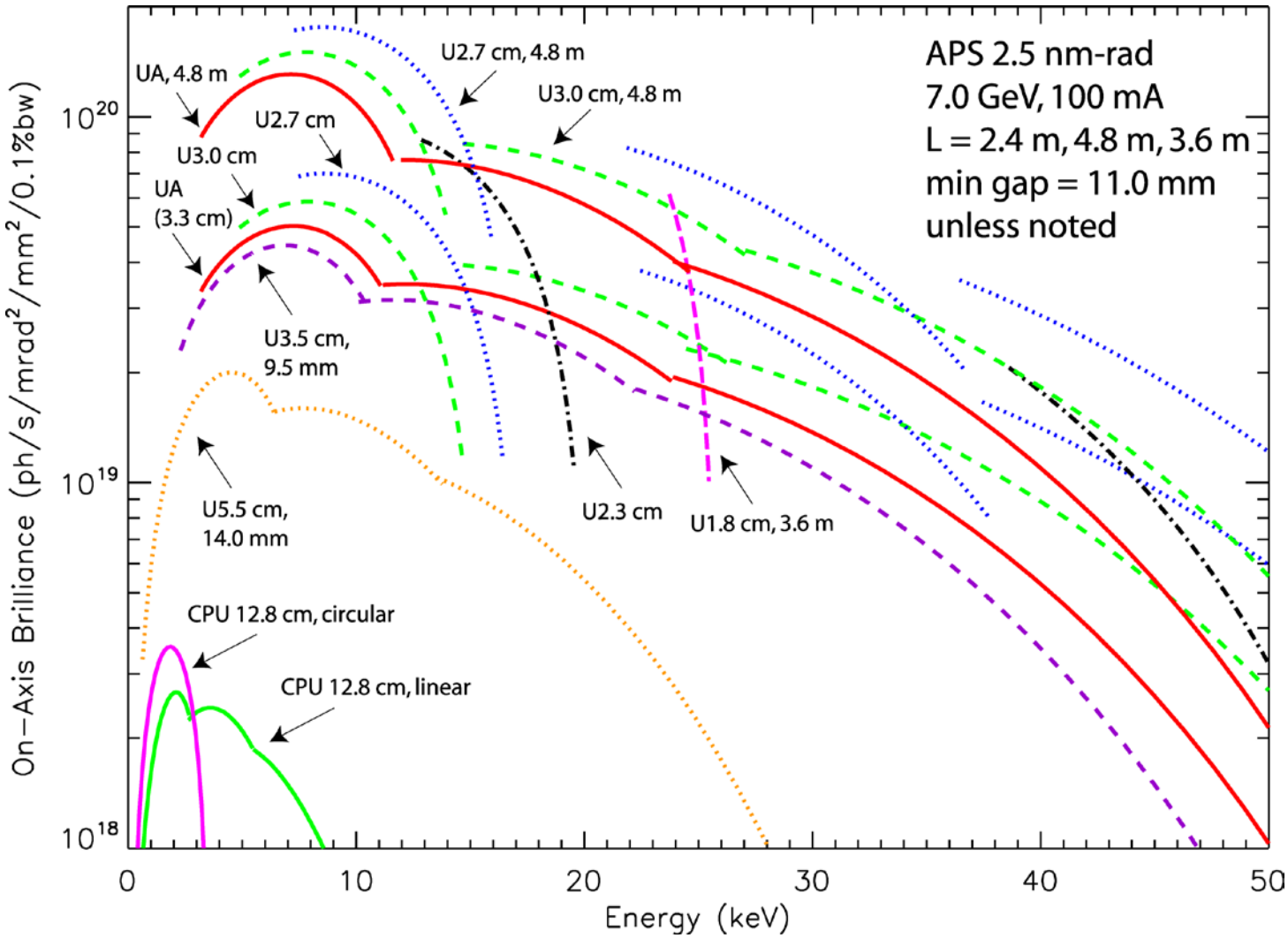


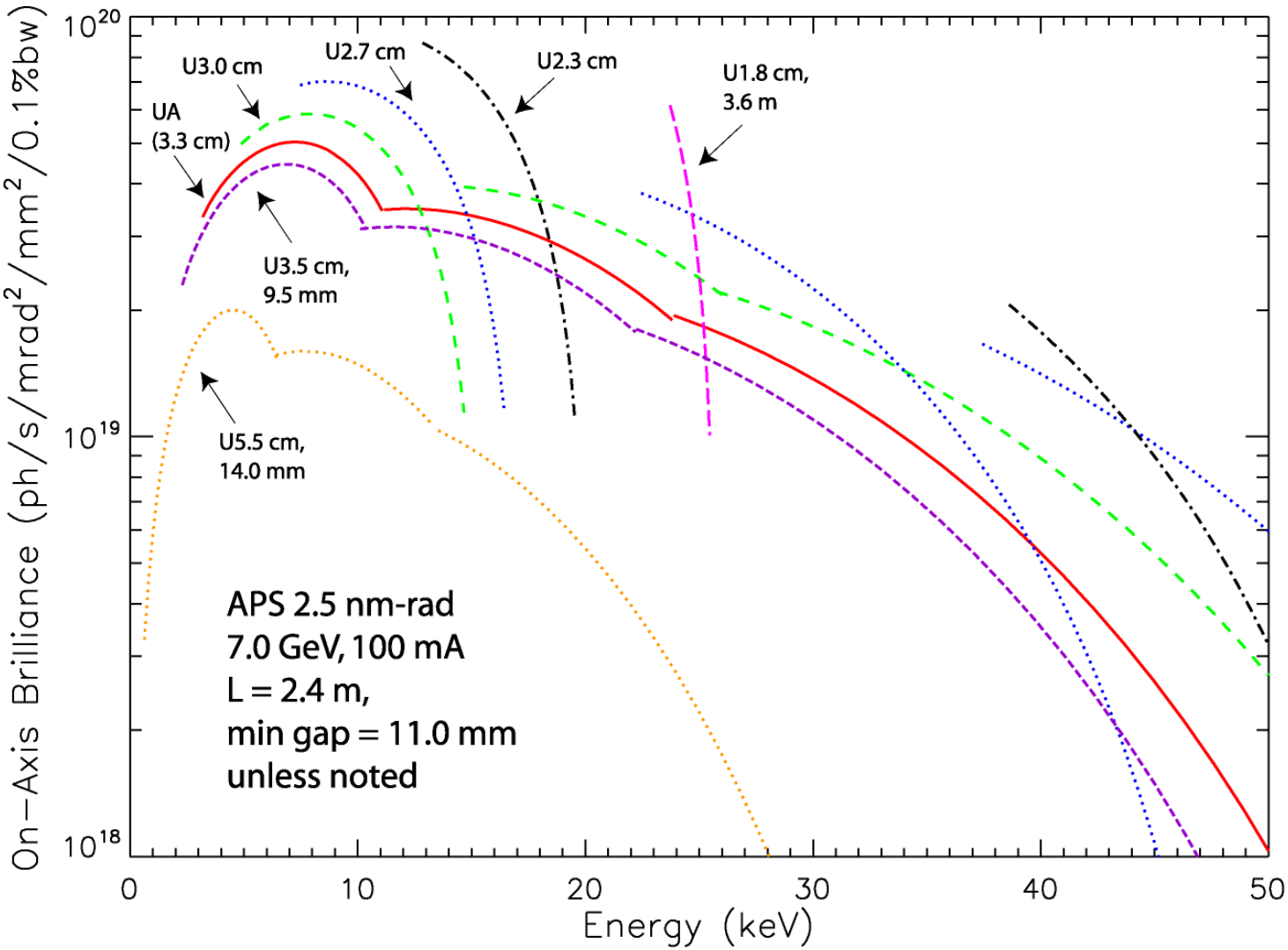
- First vertical field integrals (G-cm) vs. gap (mm)

Additional slides

Tuning curves for selected existing APS IDs, as background info

On-Axis Brilliance Tuning Curves for Existing Undulators



- Beam energy 7.0 GeV, beam current 100 mA, emittance 2.5 nm-rad, and coupling 1%.

On-axis brilliance: Undulators of various period lengths