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ID Developments at APS

Liz Moog

Three-Way Meeting - APS, ESRF and SPring8,
Argonne National Laboratory, June 2-3, 2003

Outline

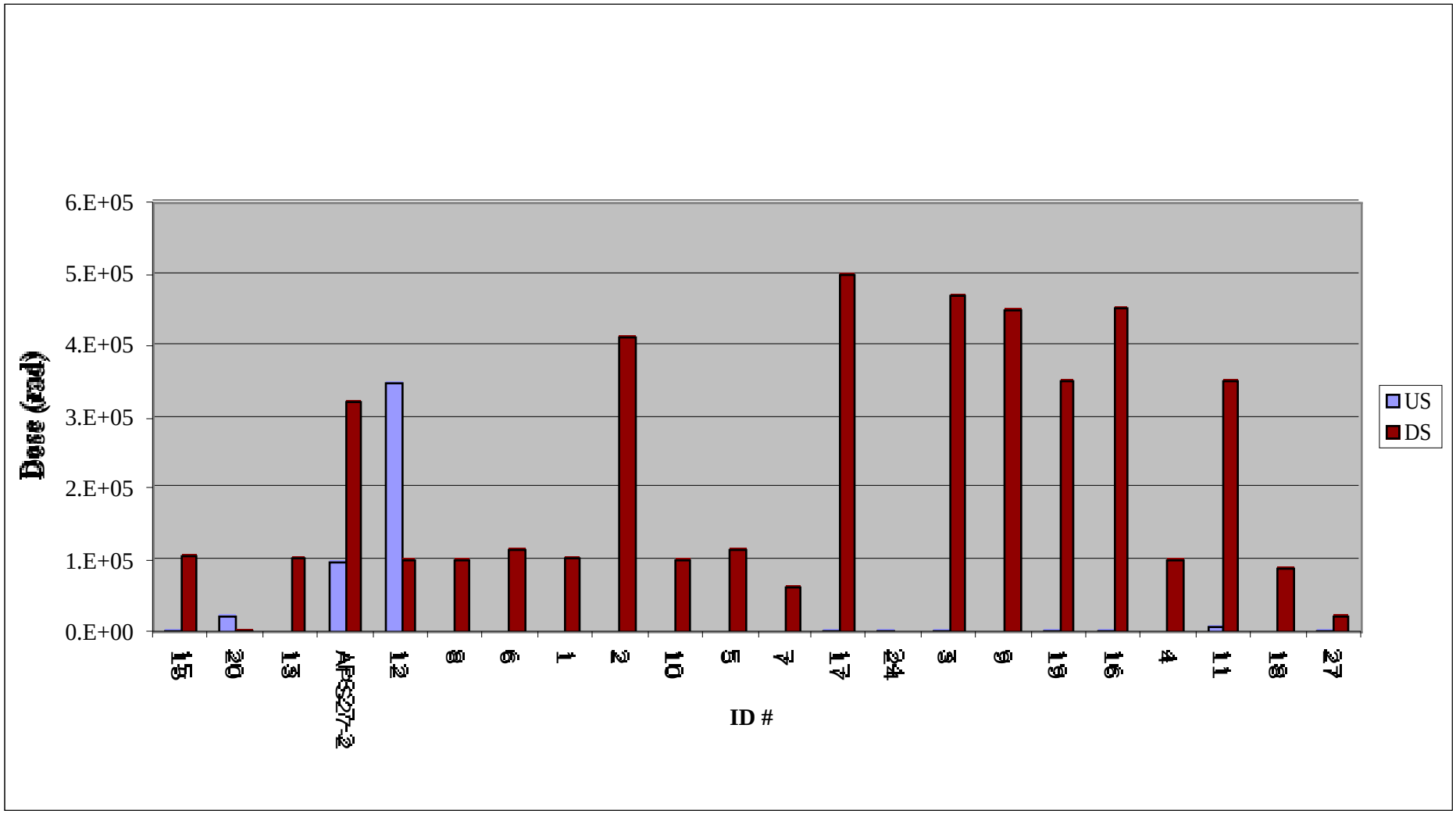
Radiation damage to IDs

- Dose measurements
- Effect on IDs
- What we've done about it

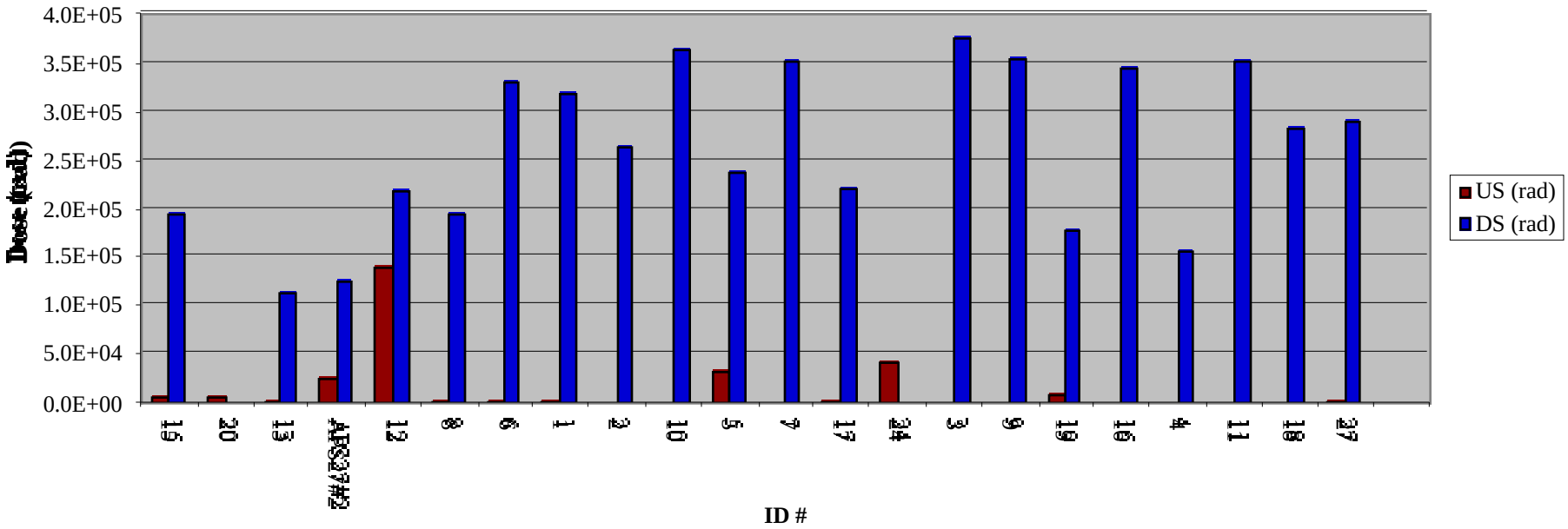
New IDs under investigation

- superconducting undulator
- variable period undulator

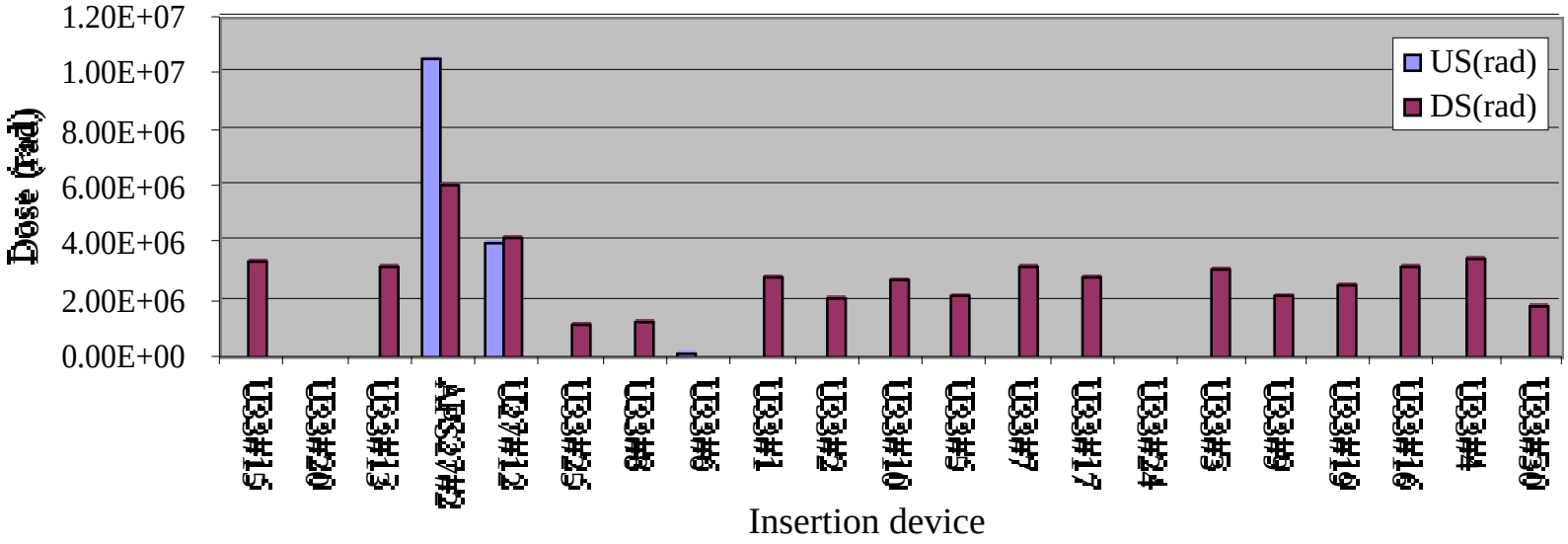
Run 2001-1 ID dose (TLD-700)



Run 2001-2 ID dose (TLD-700)



Run 2001-3 ID dose (TLD-800)



Actual doses may have been higher. TLD-800's fade when readout is delayed, and the readout of these was delayed by the repair of the TLD reader. Useful dose range of TLD-800 is to 10 Mrad.

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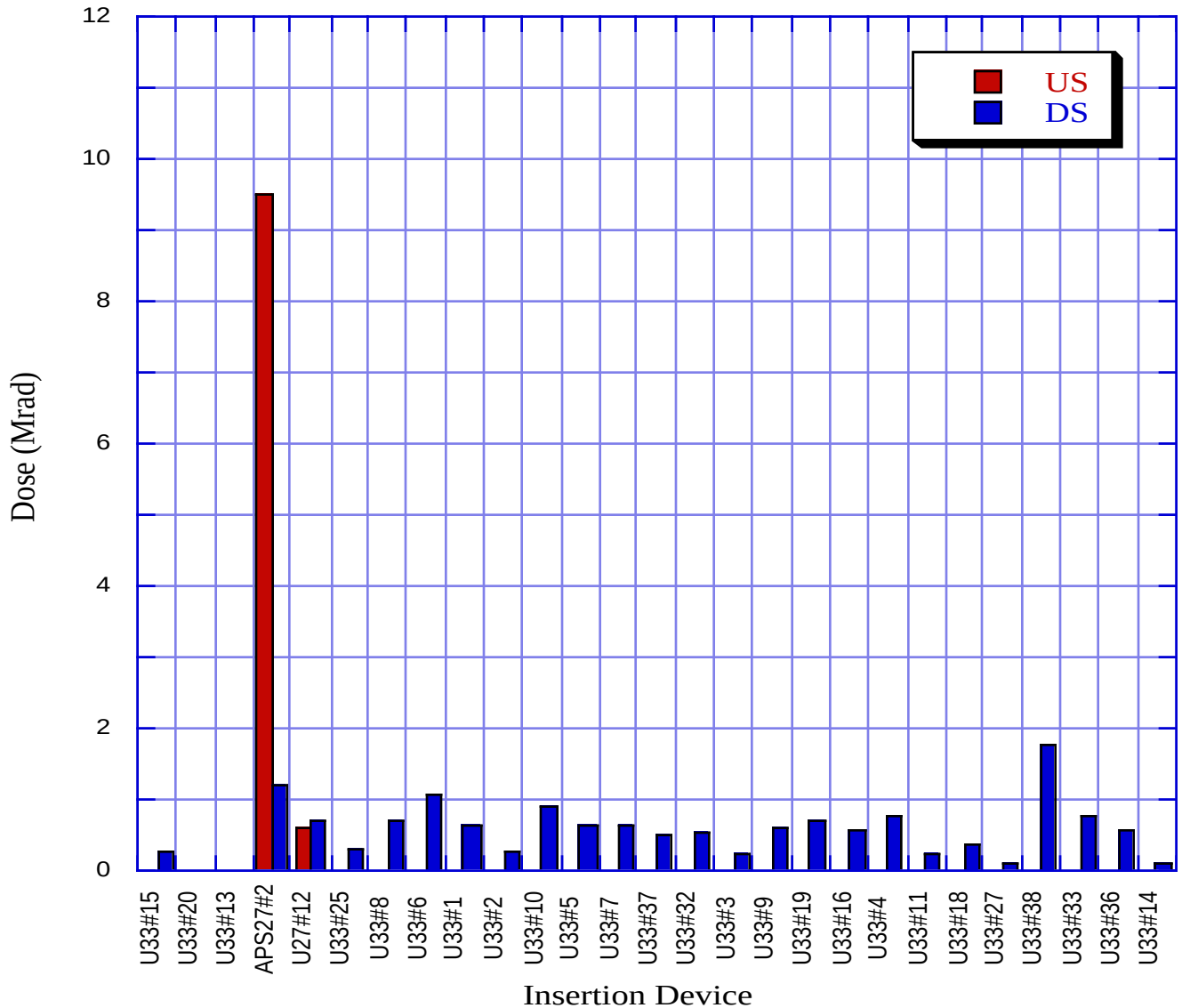
Doses were exceptionally high in Sector 3 because:

- injection efficiency was low in the new lattice
- Sector 3 vacuum chamber has 5-mm vertical aperture
- the user often works at low gap

Measures taken to improve things:

- improvement of the low-emittance lattice & injection efficiency
- W shielding installed before Sector 3 IDs (no room for Pb)
- booster lattice and transfer line improvements

Run 2003-1 ID dose (alanine)



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U33#15 **Gap 11.5mm** **Sector 1 DS**

Date	RMS Phase error	3rd harm., % of ideal	notes
1997 Sept. 9	2.88	89.8	reference
2002 May 2	5.91	82	some damage
2002 May 3	5.14	84	tuned, taper 0.040 mm

U33#3 **Gap 11.5mm** **Sector 15 DS**

1997 Sept.	4.54	91	reference
2002 May	5.14	89	still OK

U33#9 **Gap 11.5mm** **Sector 17 DS**

1997 Sept.3	4.86	86.1	reference
2002 Sept 25	12.99	58.0 (1st 91.2%)	damaged
2002 Sept 25	5.78	82.8	tuned, taper 0.09 mm

U33#4 **Gap 11.5mm** **Sector 20 DS**

1996 Sept	3.44	91.6	reference
2002 Sept	3.37	92.6	still OK

U33#10 **Gap 11.5mm** **Sector 9 DS**

1997 Aug	4.72	84.7 (1st 93.16%)	reference
2003 Jan	7.67	77.8 (1st 92.35%)	some damage
2003 Jan	5.36	84.4 (1st 92.5)	tuned, no taper

U33#5 **Gap 11.5mm** **Sector 10 DS**

1997 Feb	4.62	89.9 (1st 96.2%)	reference
2003 Jan	5.06	89.5 (1st 95.9%)	still OK

U33#17 **Gap 11.5mm** **Sector 13 DS**

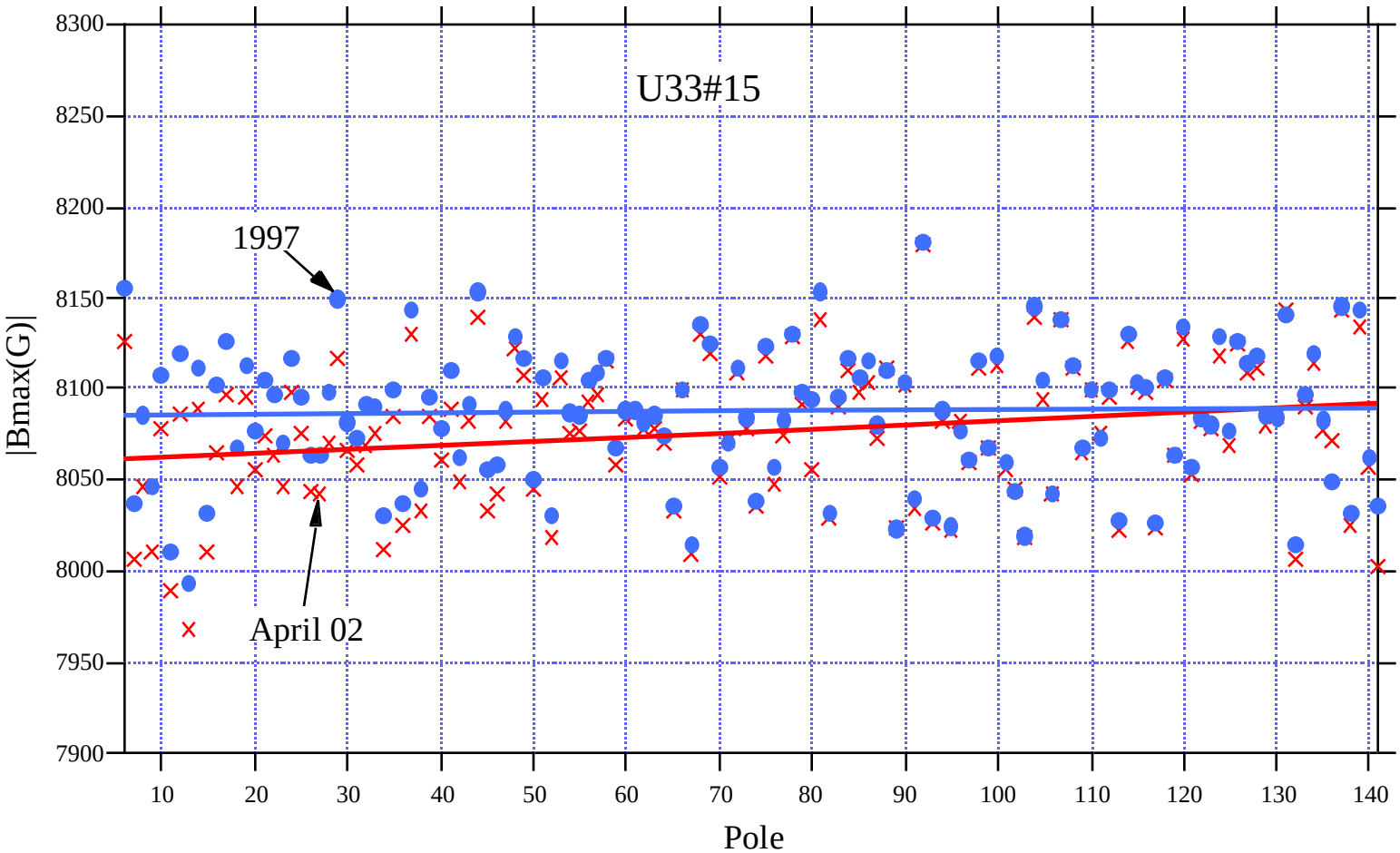
1997 July	2.45	92 (1st 96.2%)	reference
2003 April	2.97	89.3 (1st 95.9%)	still OK

U33#30 **Gap 11.5mm** **Sector 22 DS**

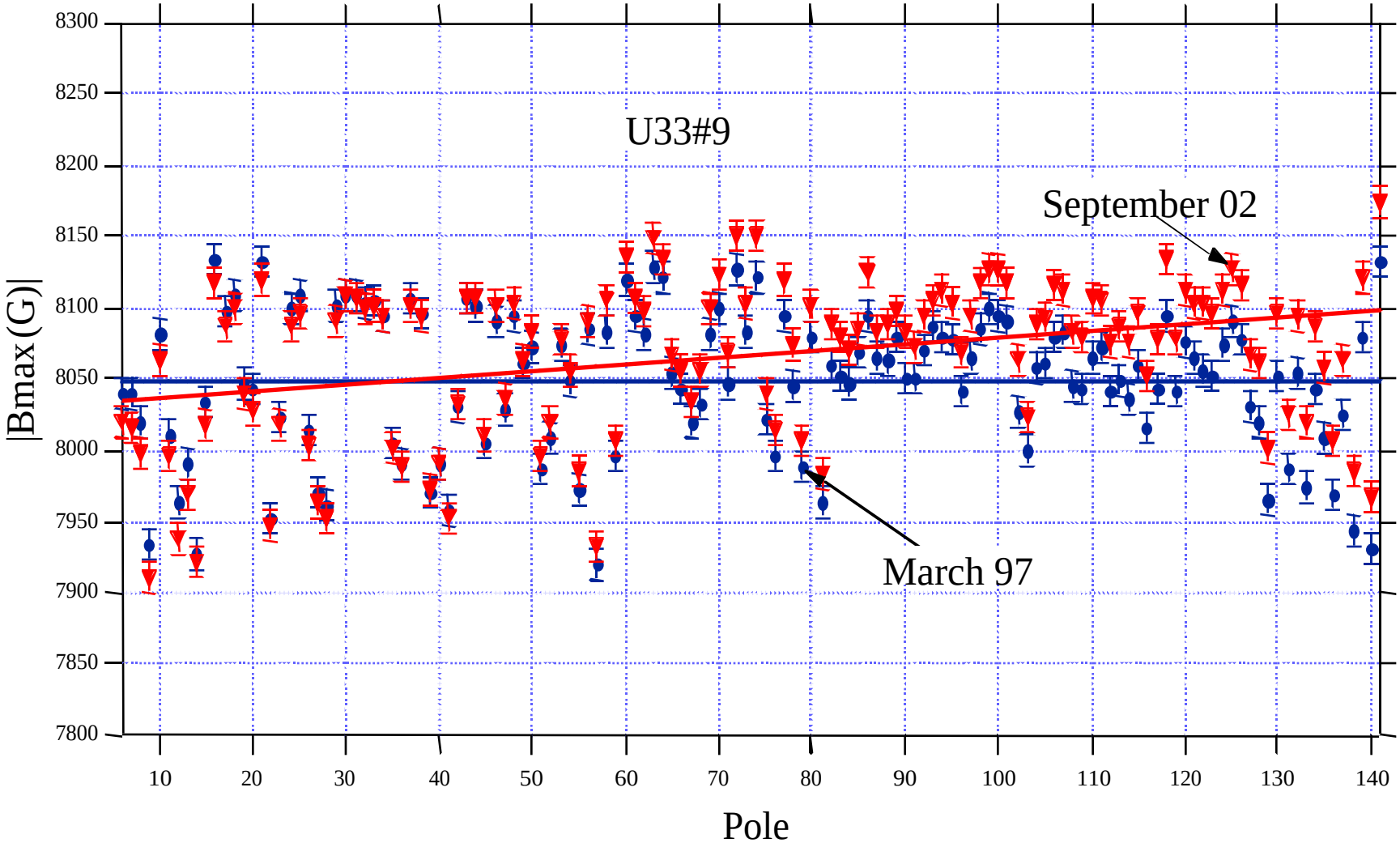
1997 Feb	4.4	89. (1st 100%)	reference
2003 March	4.67	88.6 (1st 100%)	still OK

Sign of taper: + means the upstream end is opened to correct the device

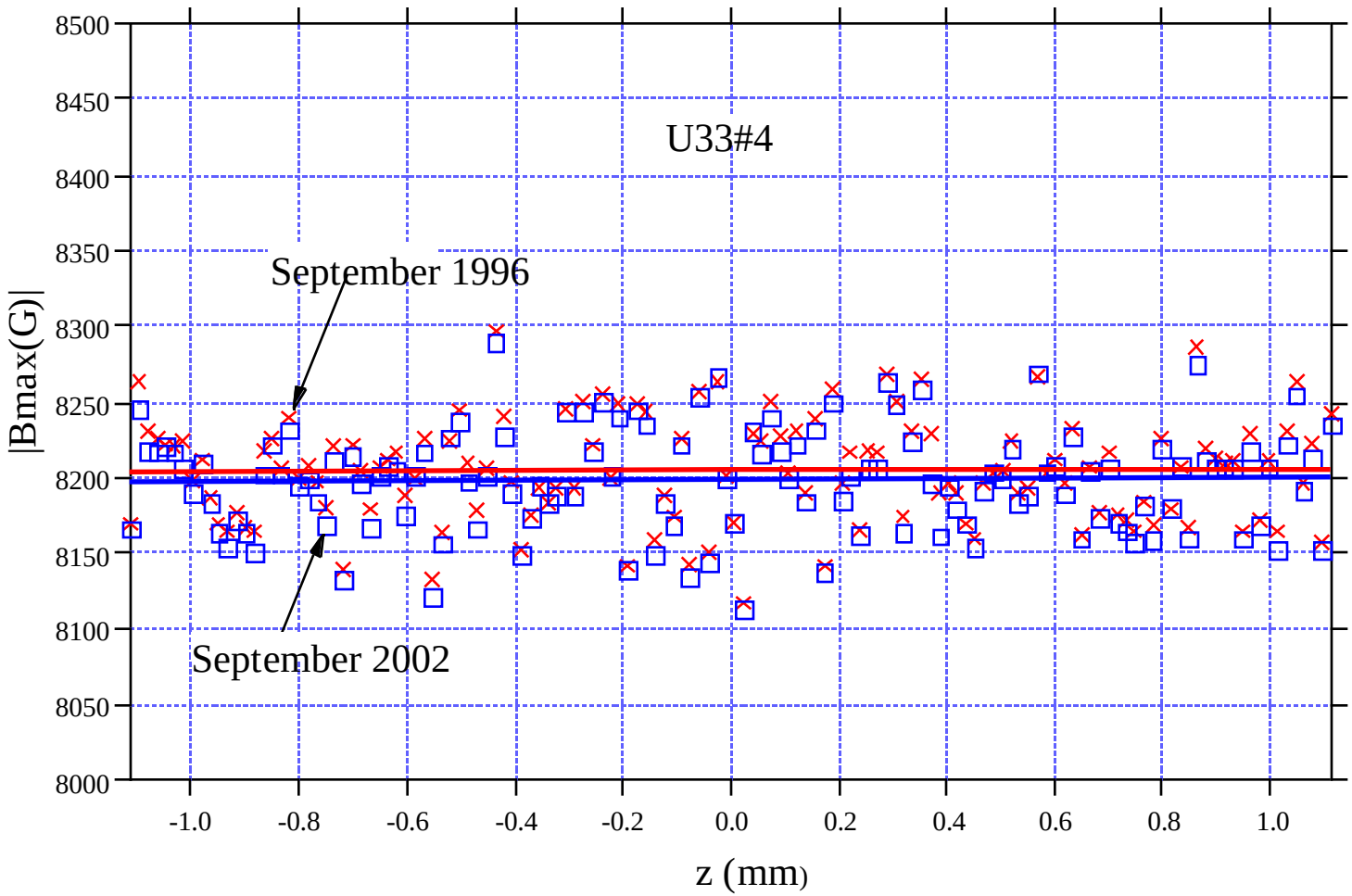
Small changes at the downstream end



Small changes



Measurement comparison between 1996 and 2002 for undamaged undulator



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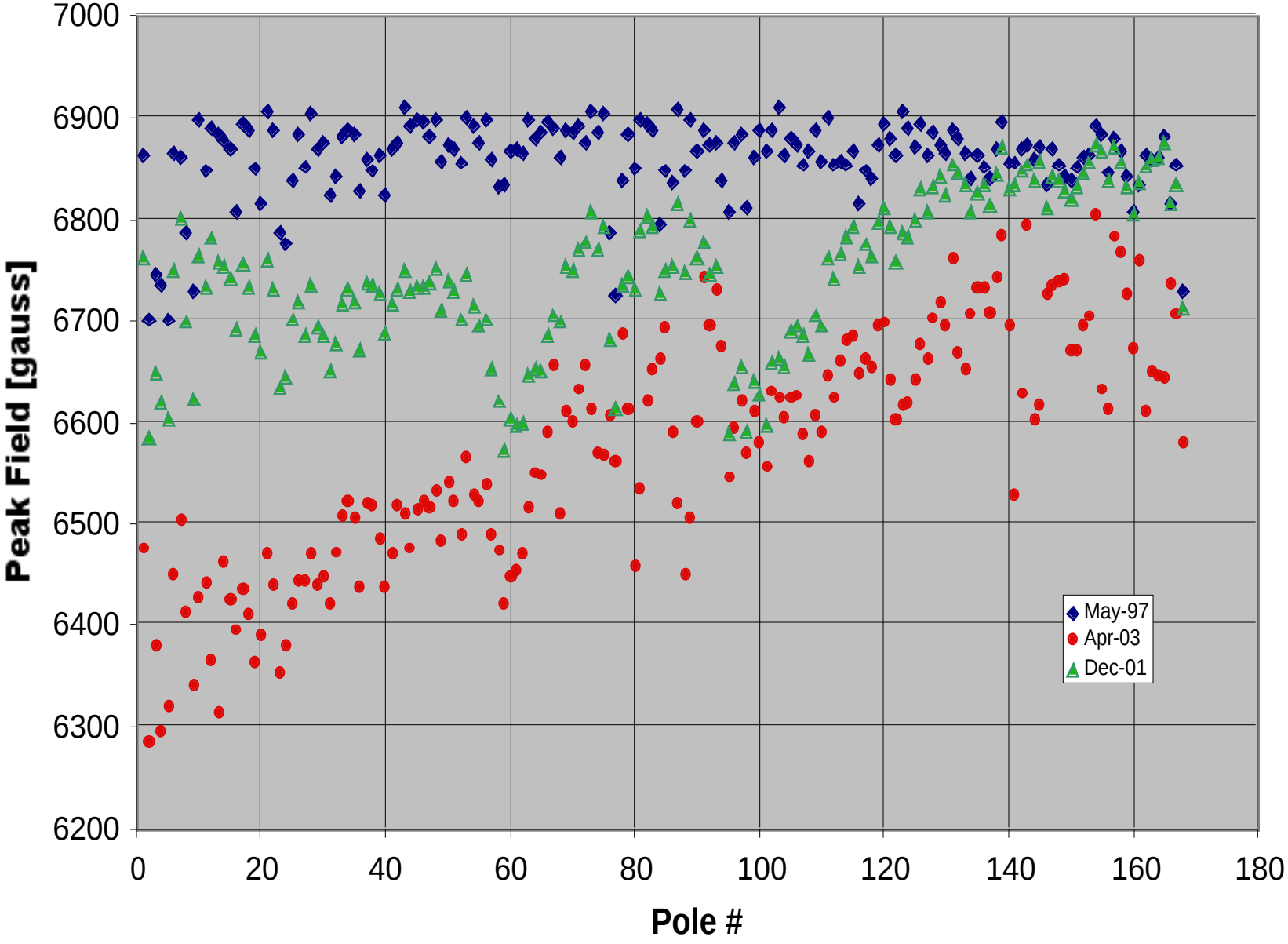
U27#12 **Gap 10.5mm** **Sector 3 DS**

Date	RMS Phase error	3rd harm., % of ideal	notes
1997 June 23	5.45	82.6	reference
2001 Dec. 31	36.5	35.2	damaged
2002 Jan. 3	9.29	69.0	tuned, taper 0.160mm
2002 May 6	14.14	52	more damage
2002 May 7	10.81	62.4	tuned, taper 0.185mm
2002 Sept 12	15.00	49.2	more damage
2002 Sept 13	6.9	75.2	tuned, taper 0.235
2003 Jan 3	13.68	56.6	more damage
2003 Jan 3	6.4	80.4	tuned, taper 0.315 mm
2003 April	6.56	78.1 (1st 95.3%)	tuned, taper 0.47 mm, more shims

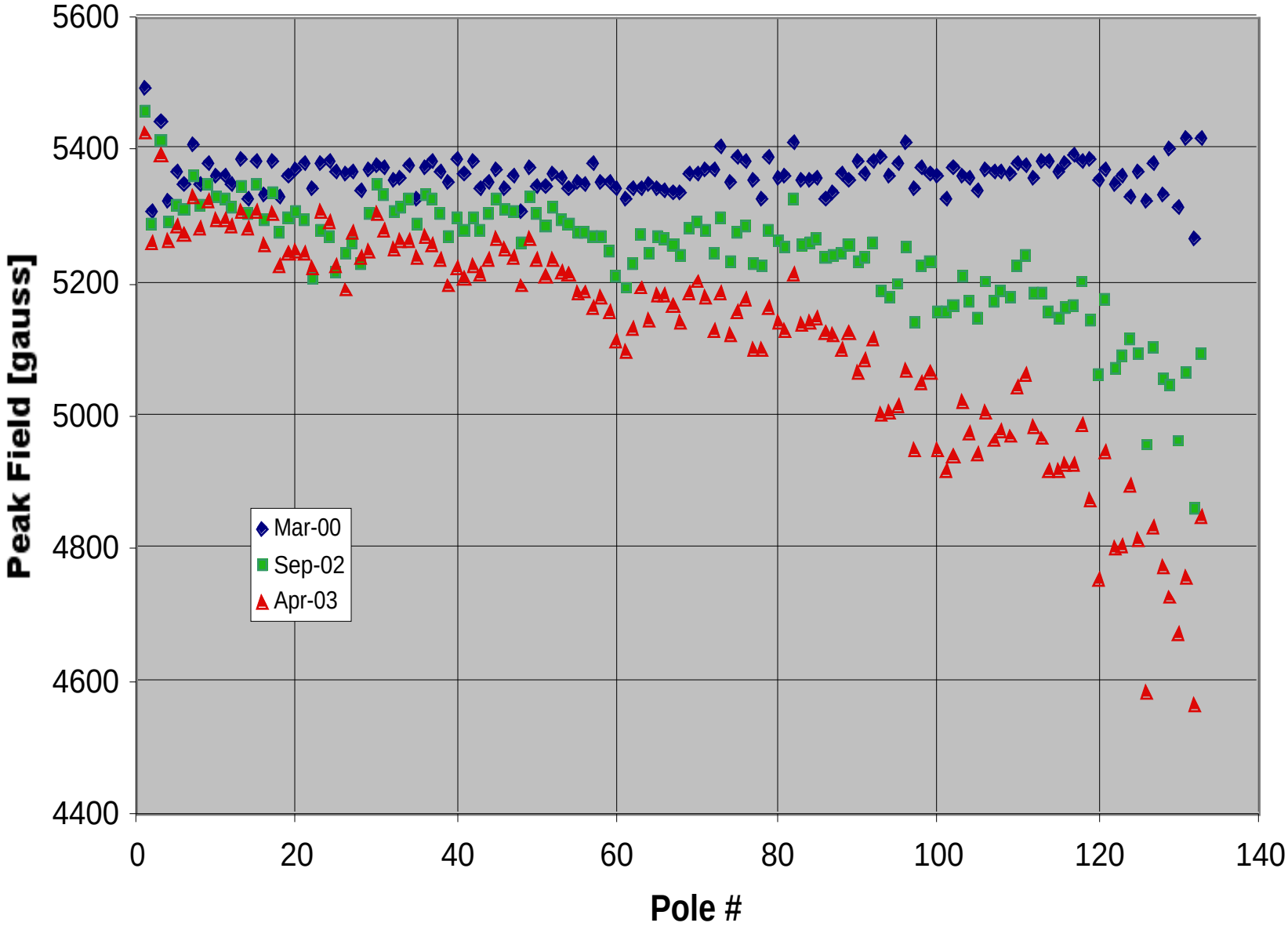
APS27#2 **Gap 11.5mm** **Sector 3 US**

2000 June 23	2.62	91.5	reference
2002 Jan. 8	10.79	64.2	damaged
2002 Jan. 8	3.67	86.1	tuned, taper -0.150 mm
2002 Sept 18	32.9	30.9	more damage
2002 Sept 18	5.90	74.1	tuned, taper -0.4 mm
2003 Jan 3	32.7	28 (1st 69.5%)	more damage
2003 Jan 3	5.62	76.3	tuned, taper –0.9 mm; 3% weaker Beff overall
2003 May 8	3.87	89.7 (1st 100%)	replace 36 magnets with spares; turn rest of magnets in US half; remove taper

U27#12 Damage Sequence



APS27#2 Damage Sequence



The taper needed to compensate for the weakened magnets was large enough that the users couldn't reach the desired field strength.

We had 36 spare magnets.

Overall field strength of ID was down by ~12%.

Individual magnet blocks were only ~6% weak as measured by turning them in the Helmholtz coils.

Damage distribution in magnet block

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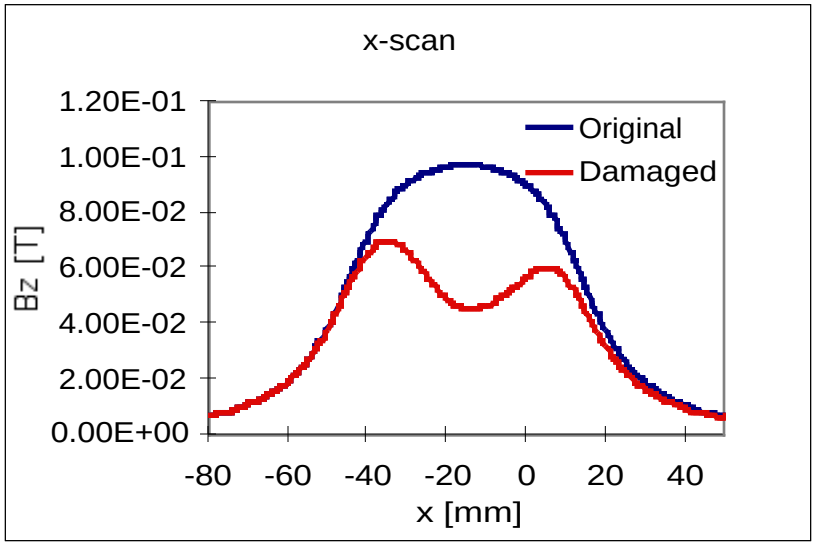
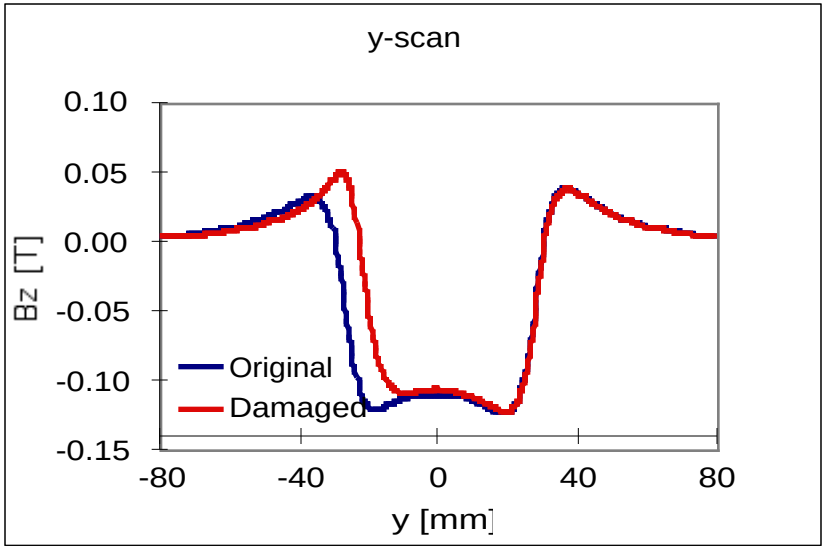
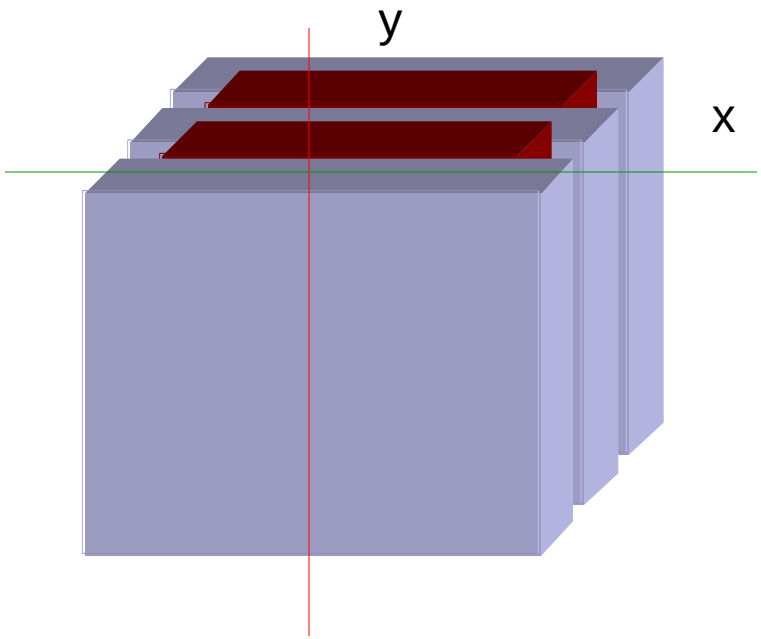
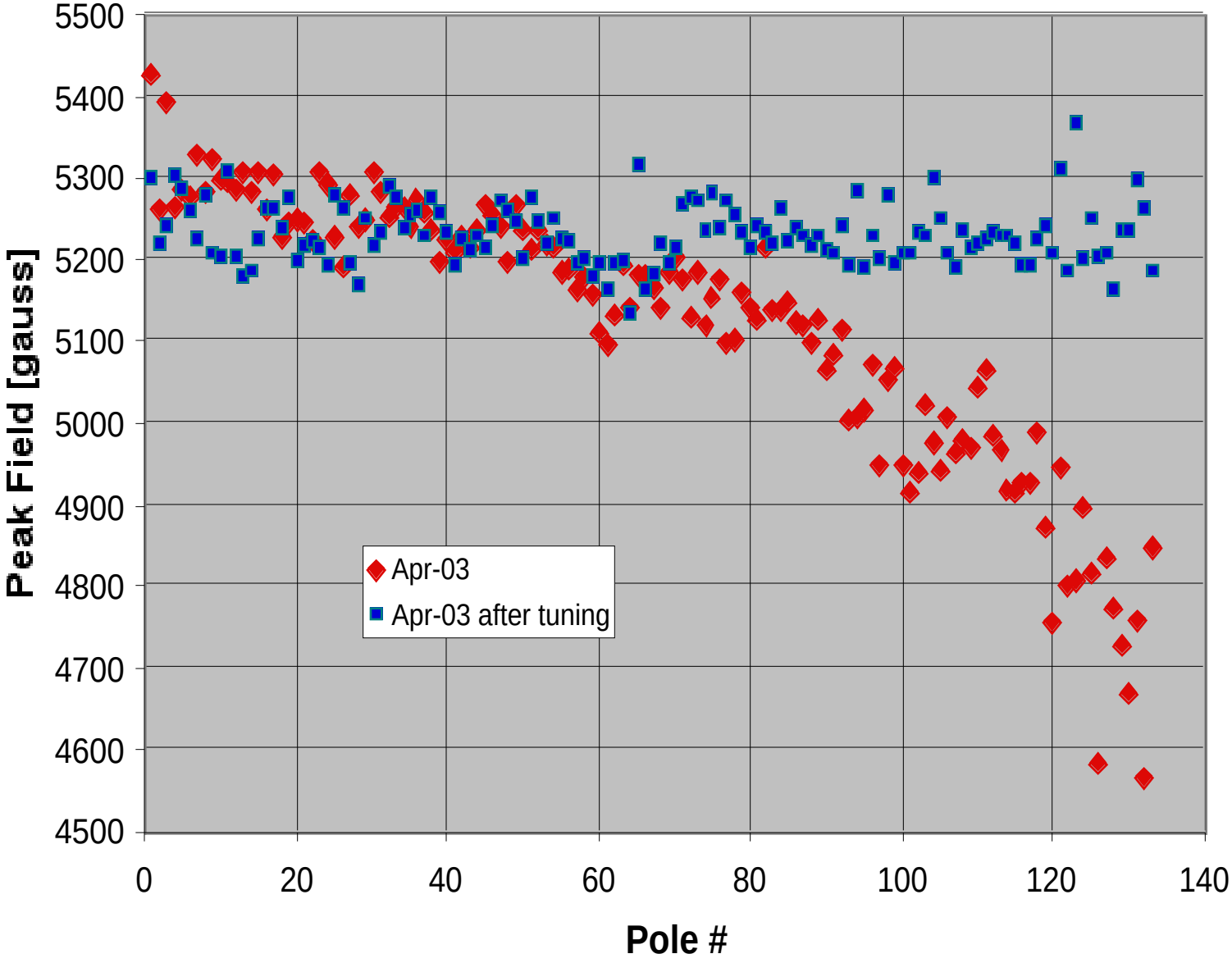
Magnet #6 from U/S end of APS#2 Undulator







APS27#2: Before and After Tuning



Year	U27#12 gap (mm)	APS27#2 gap (mm)	flux (arb.units)
1999	10.81		1.3
2000	10.73	9.173	1.3
2001	10.75	9.164	1.2
2002	10.5	9	1.1
2003 Jan	10.43	8.78	1.0
2003 now	10.37	9.045	1.3

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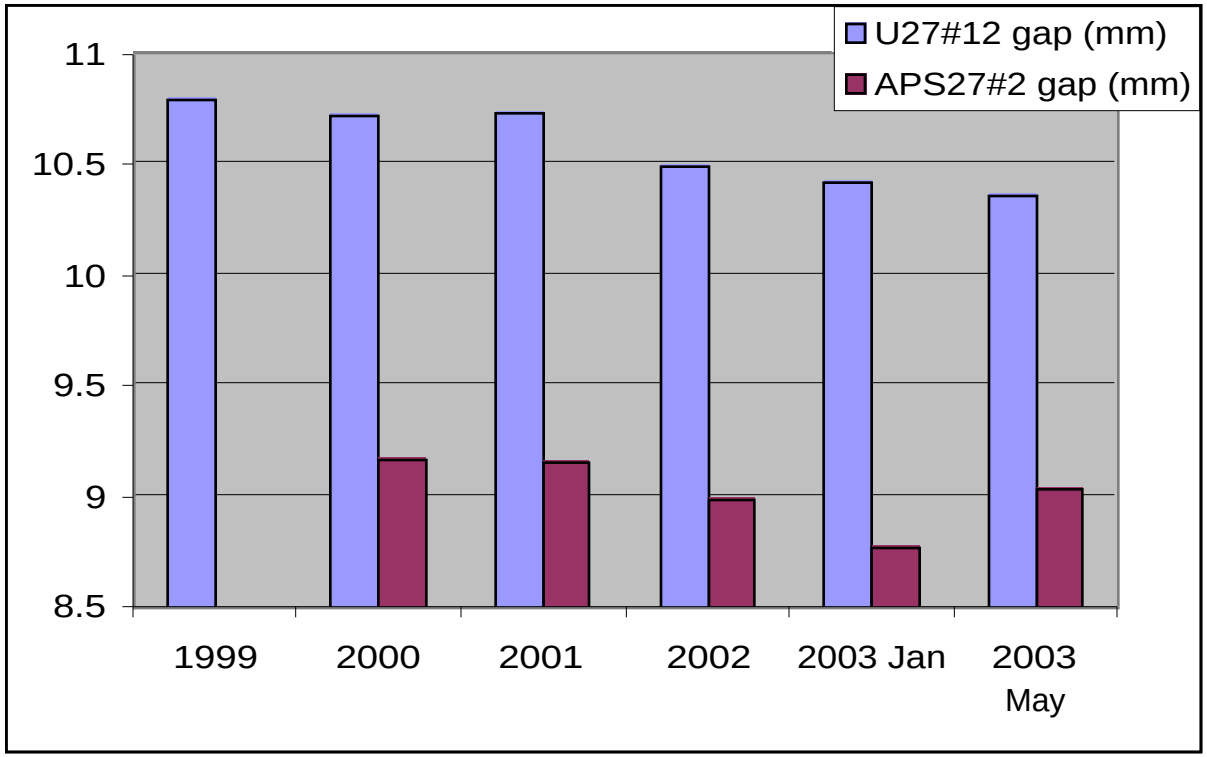
The User's viewpoint, when setting up for 21.657 keV light



Computer-controlled Pulsed Magnetizer

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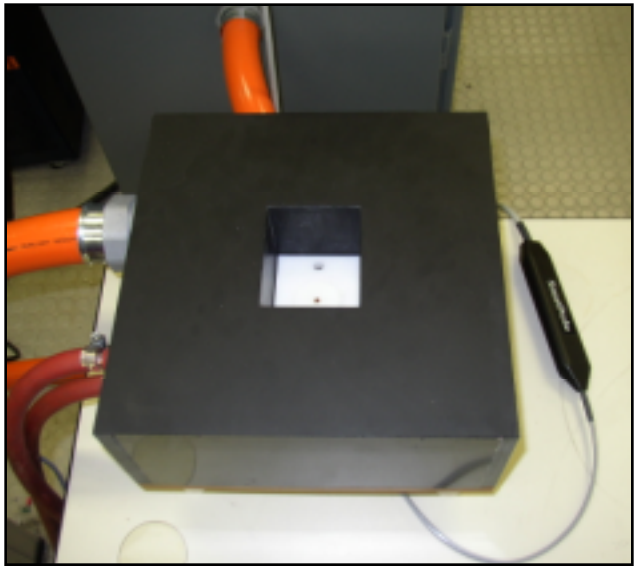
- Automated reverse-field treating, guided by Hall probe
- Nominal maximum field: 35 kOe
- Pulse width: 9.4 ms
- Max magnet size: 90 x 58 x 27 mm
- Capacitor cycle time: <15 s

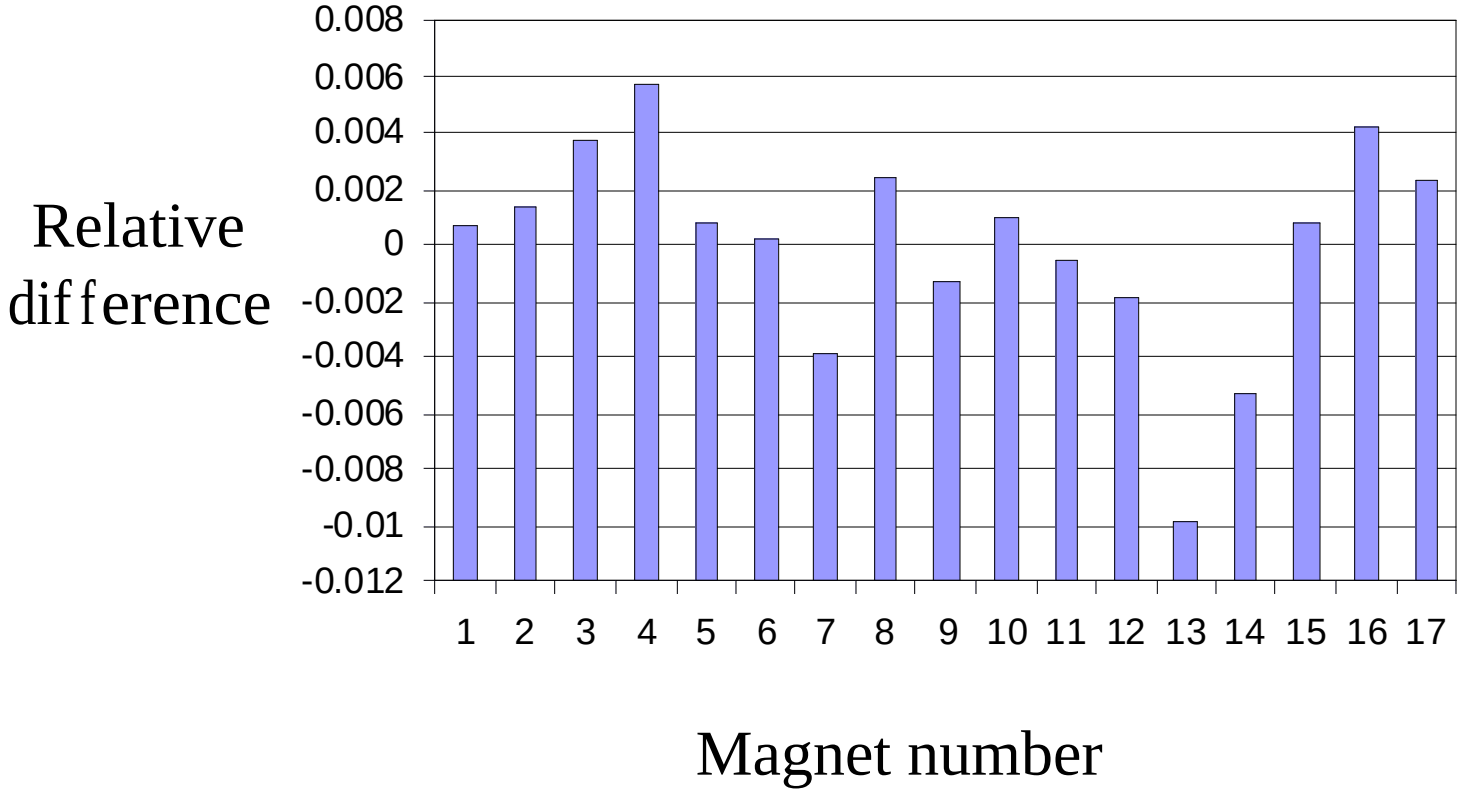


Magnetizing Fixture

Power supply and control system

Helmholtz Coil Measurement Results

Initial results after remagnetizing and stabilizing a few radiation-damaged magnets



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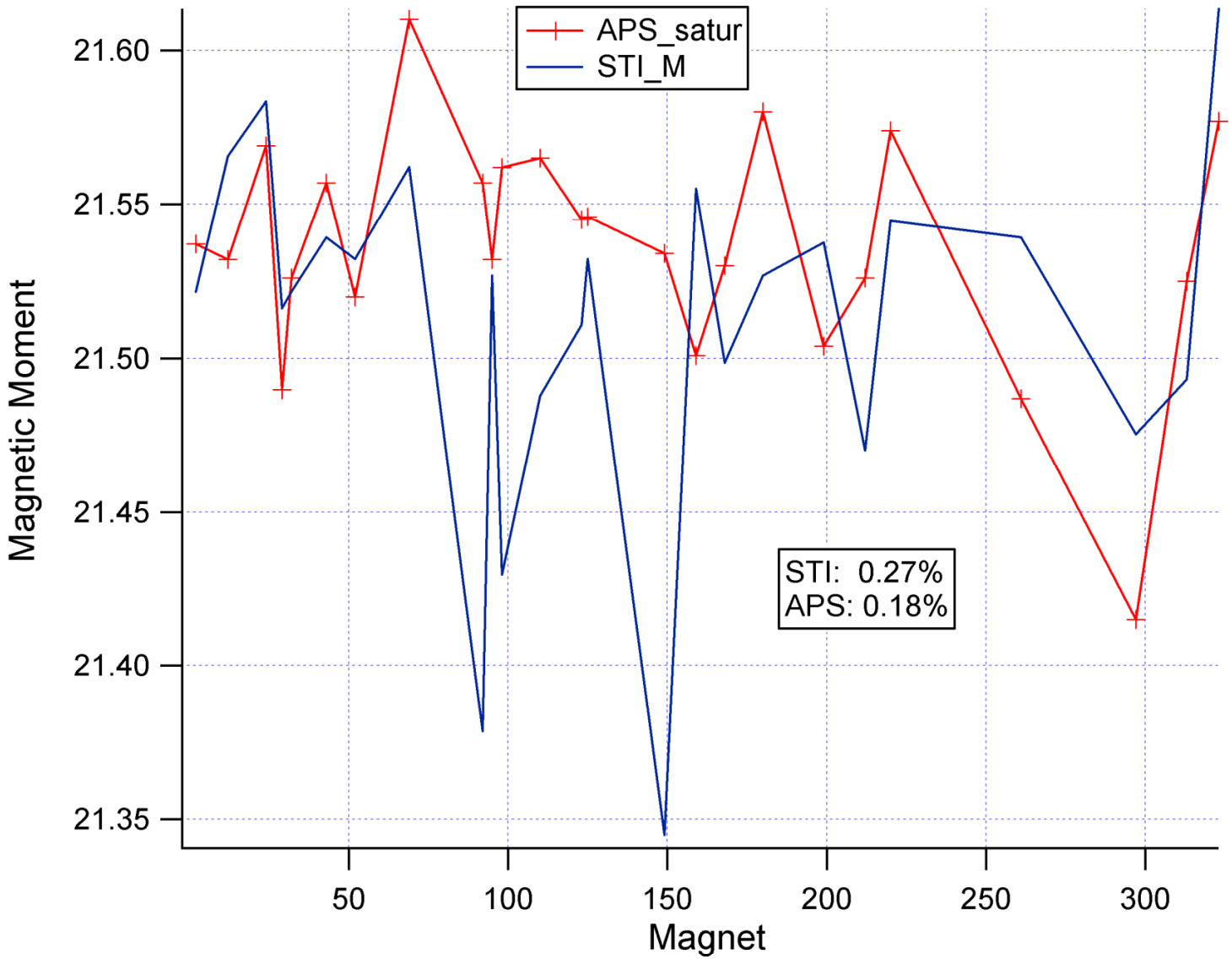

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New Insertion Devices being investigated

- Superconducting undulator
- Variable period undulator

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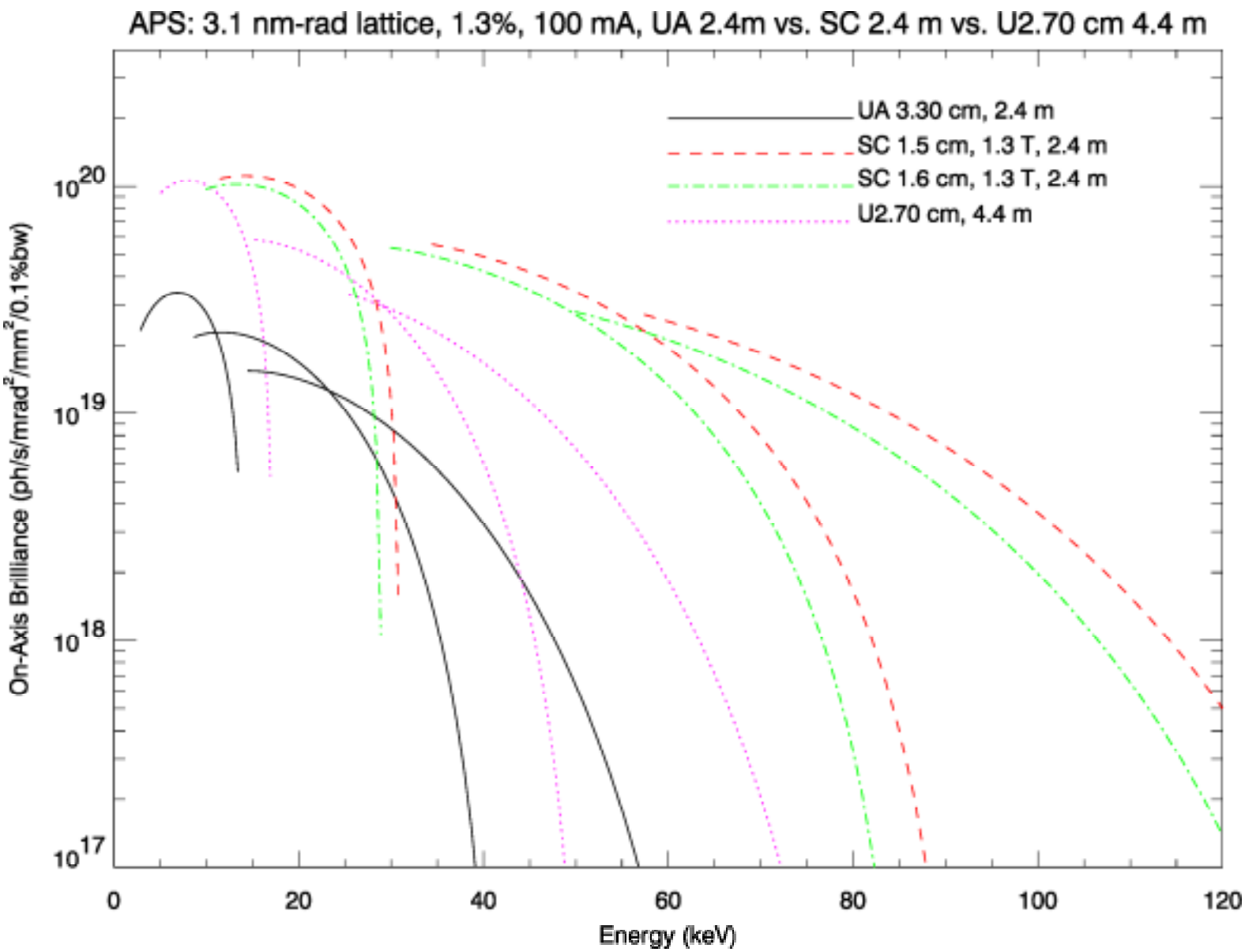
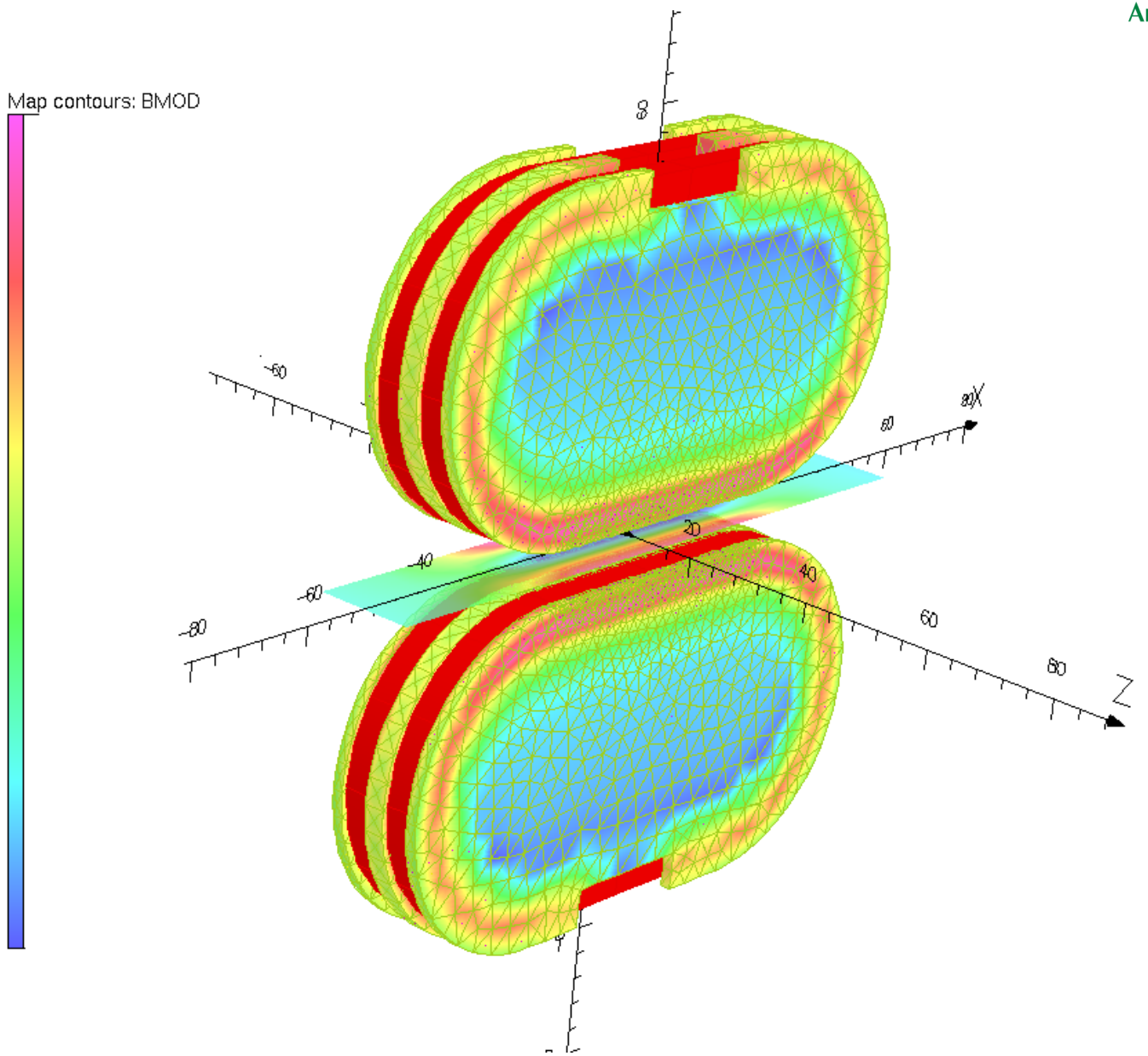


Model for Superconducting Undulator



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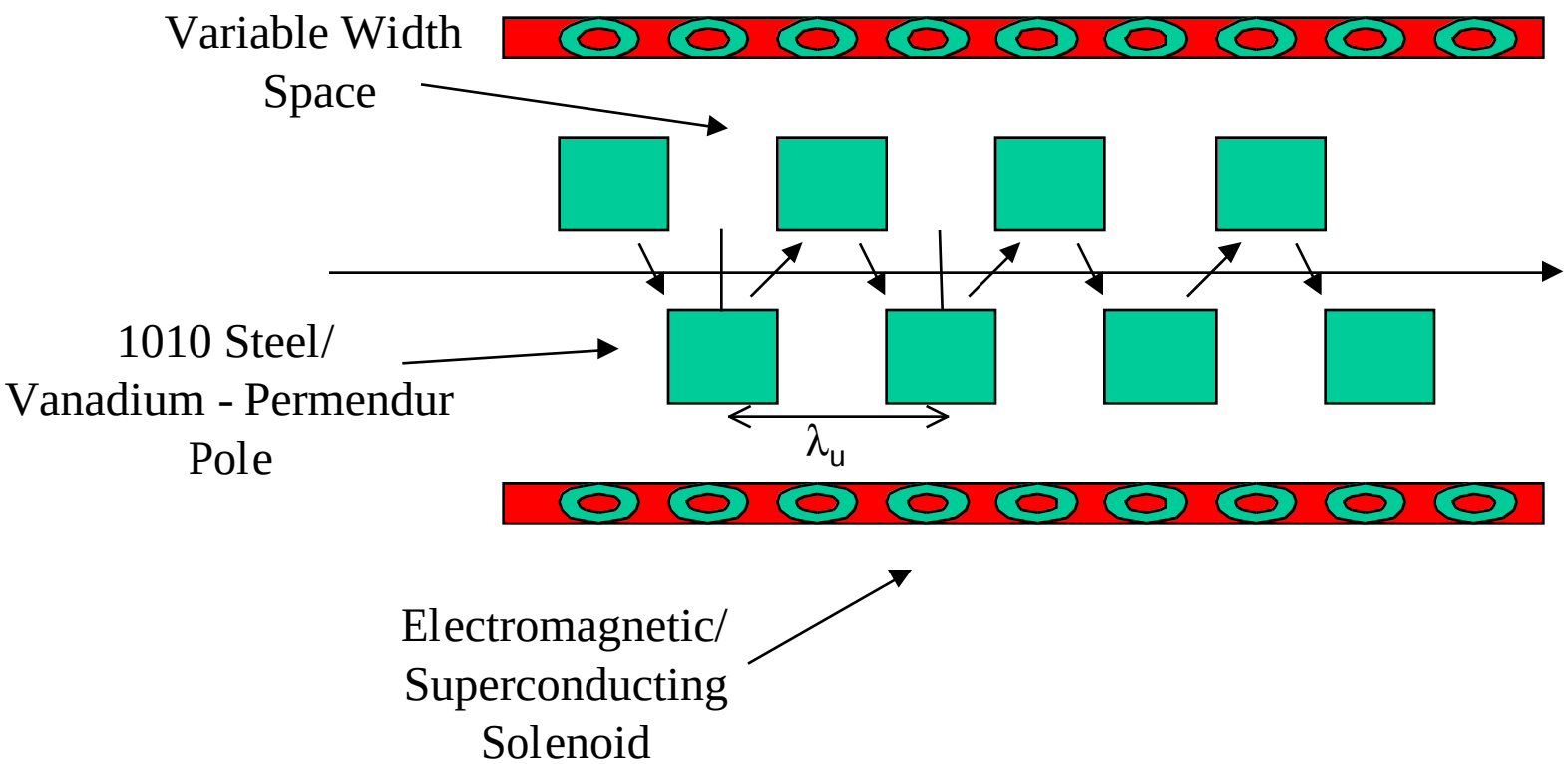
Superconducting undulator challenges:

- Magnet and cryostat design
- Beam heating effects
- Measuring the field
- Field quality

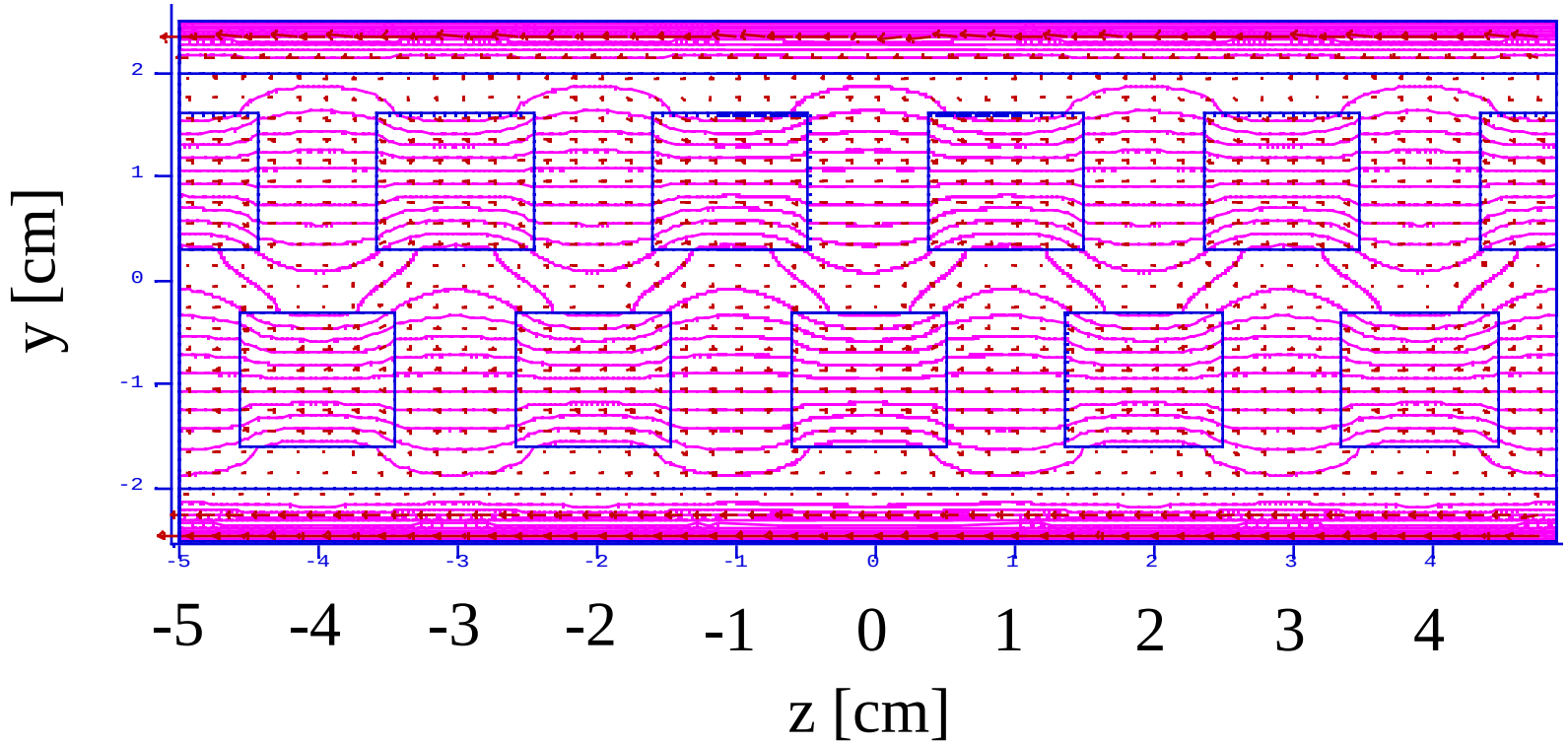
A collaboration is being proposed between the 4 light sources supported by the US-DOE.

Schematic of poles and solenoid for Variable Period Undulator*



*Shenoy, Lewellen, Shu, and Vinokurov

Magnetic field map calculation



period=2cm, pole width=1.13cm, gap=0.6cm

Conceptual view of Variable Period Undulator

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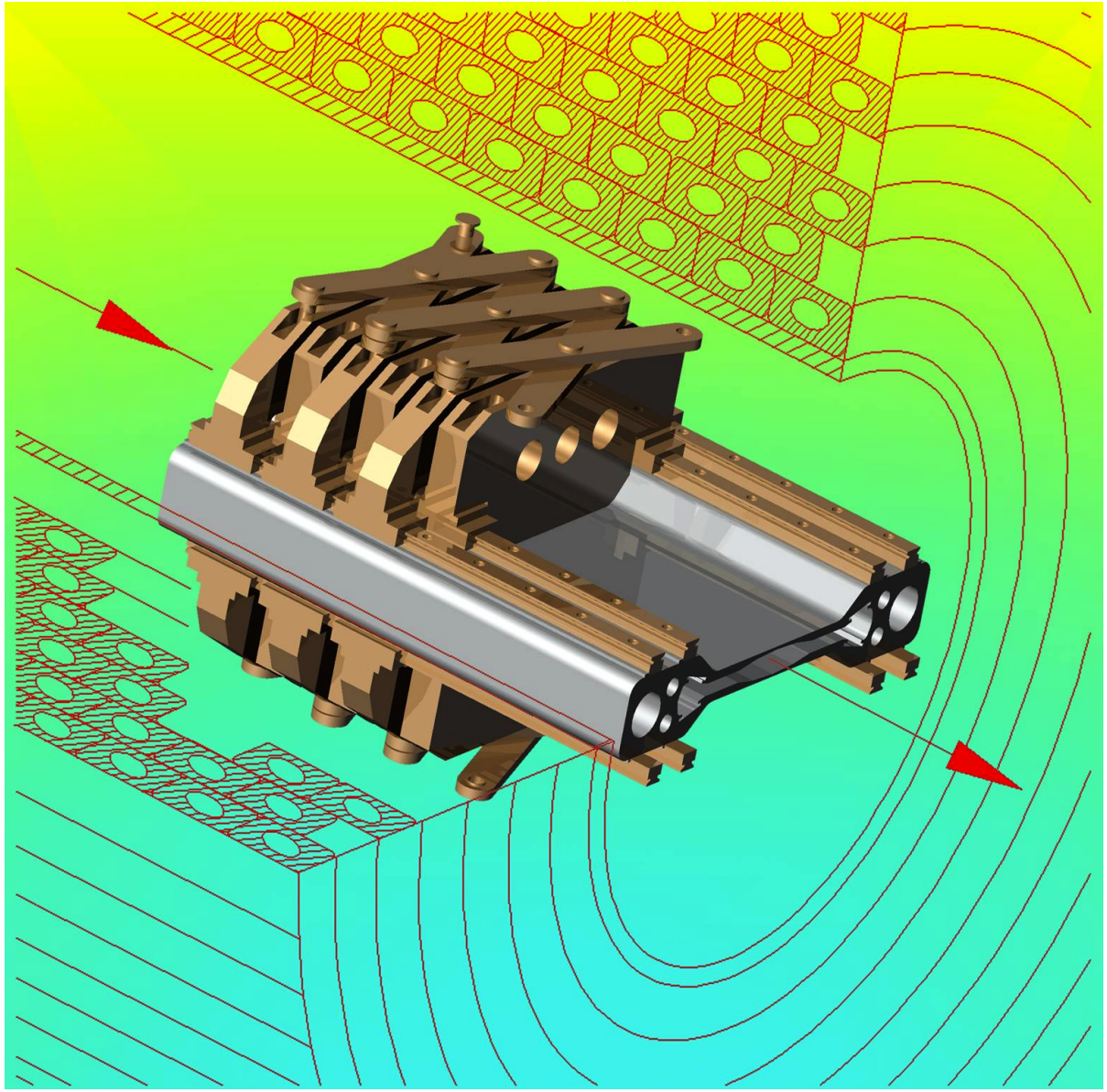

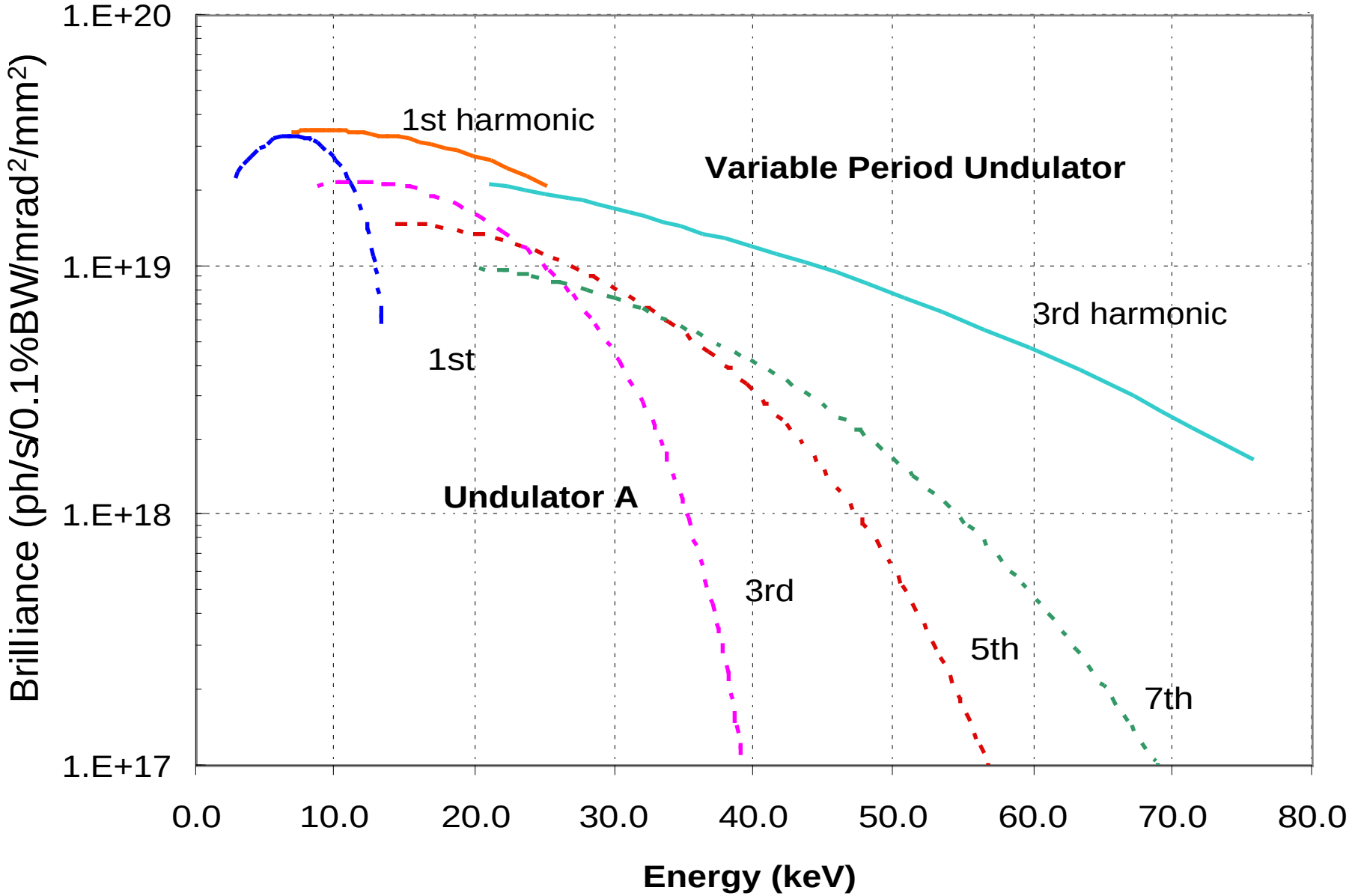
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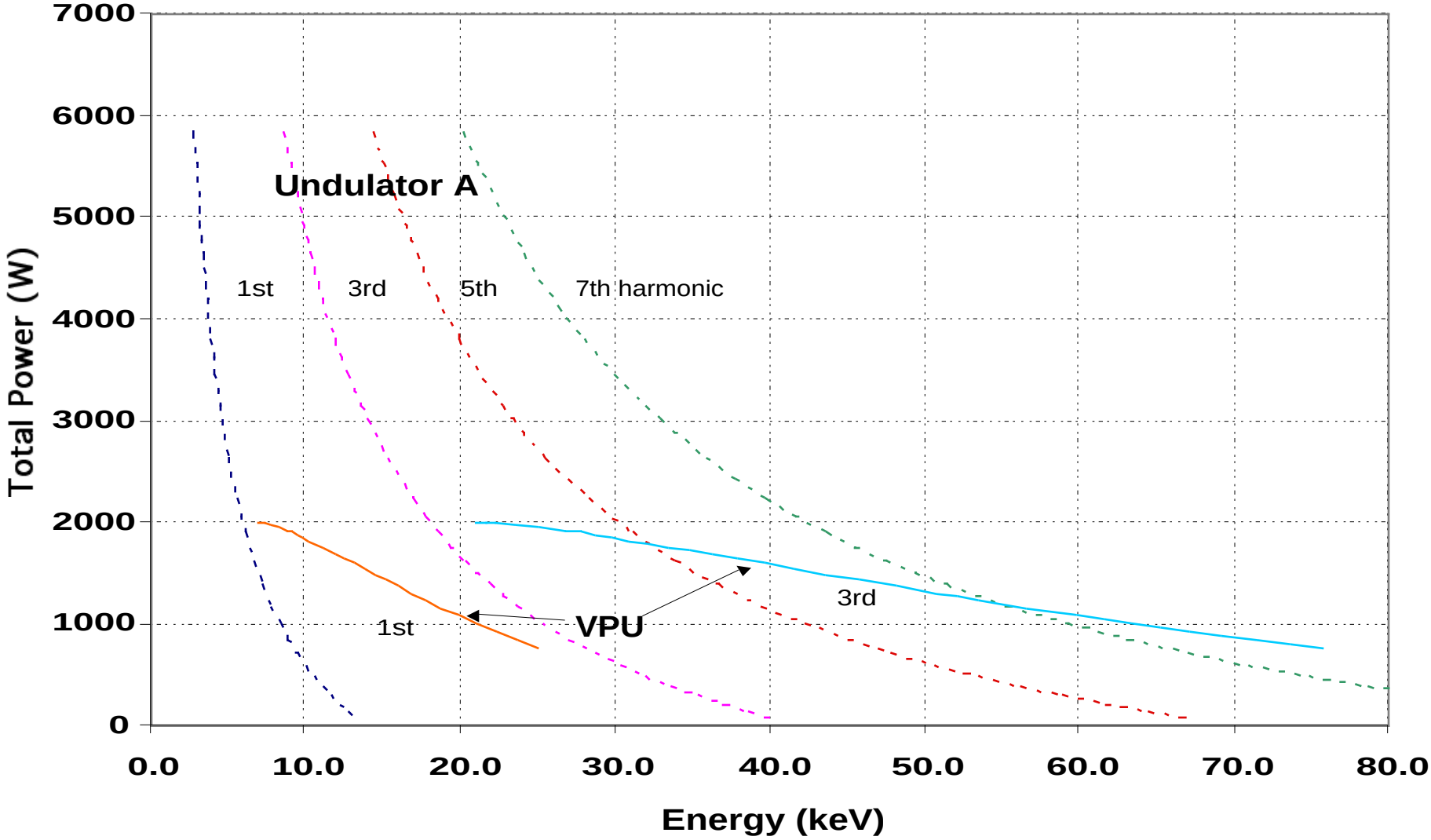
1.E+20
1.E+19
1.E+18
1.E+17
Brilliance (ph/s/0.1%BW/mrad²/mm²)
1st harmonic
Variable Period Undulator
3rd harmonic
1st
Undulator A
3rd
5th
7th
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
Energy (keV)

Variable Period Undulator - Power



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Challenges:

- Field quality
- Field quality during period variation
- The axial solenoid field causes beam rotation, which needs correcting.

Possibilities:

- compensating coil(s) at end(s) of ID
- two undulators, end-to-end with opposite solenoid fields and proper pole phasing*

*suggested by Vadim Sajaev