APS Insertion Devices

15 February 2002

Liz Moog

IDs installed as of Nov 2001

Type	Number	Length (periods)	K_{eff}
33-mm undulator	23	72	2.75
55-mm undulator	1	43	6.57
27-mm undulator	1	88	1.70\ 2.18¥
27-mm undulator	1	72.5	1.36\ 1.80¥
18-mm undulator	1	198	0.455
85-mm wiggler	1	28	9.47*
Elliptical wiggler (16 cm)	1	18	K_y=14.7† K_xŠ1.4
Circularly polarized undulator (12.8 cm)	1	16**	K_yŠ2.86 K_xŠ2.75

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 and horizontal elliptical wiggler field are electromagnetic, with different fixed gaps.)

* at 15.5 mm gap . Output power would be too high at smaller gap.

† at 24 mm gap (the device minimum). Values are for peak K, not K_{eff}

¥ at 8.5 mm gap .

** In addition to this, there are separate correctors at both ends.

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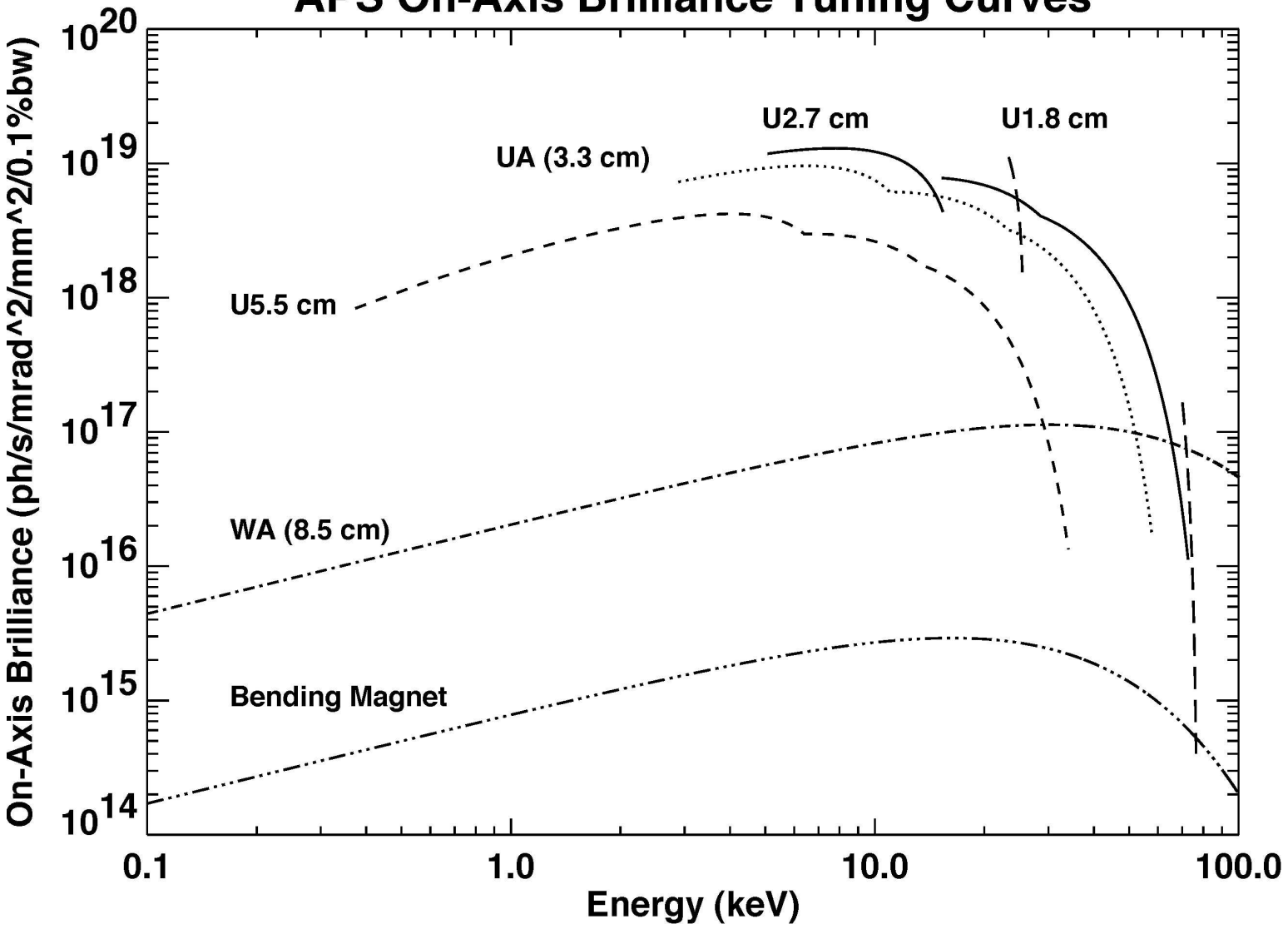
APS On-Axis Brilliance Tuning Curves



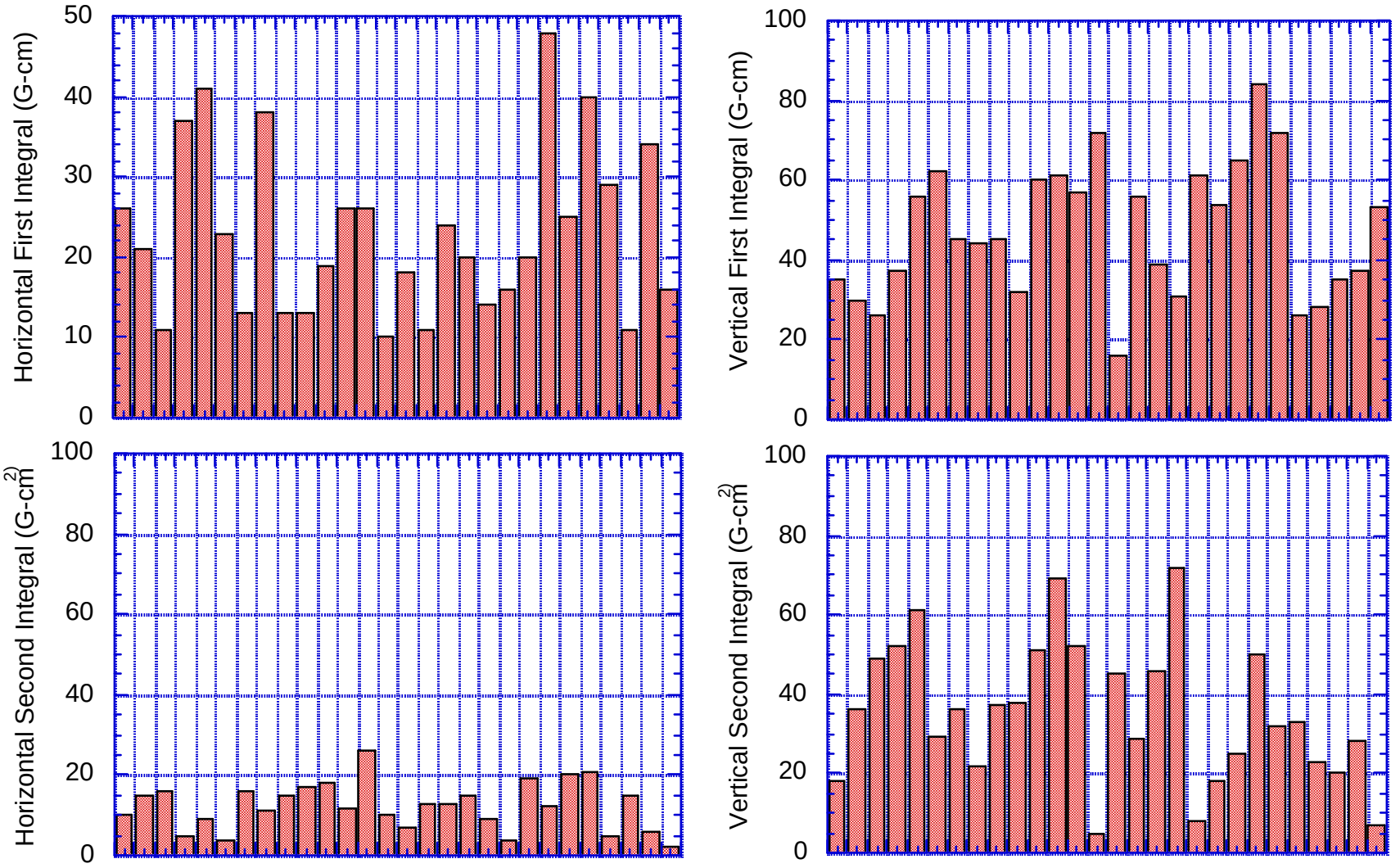
Magnetic tuning:

All IDs are measured at APS before installation.

Initial devices had been tuned by the manufacturer so we just tweaked.

Now devices are assembled by vendor and shipped, unmeasured. We do all tuning.

Tuning of planar devices has become routine.



Max. variation in first & second integrals over gap range.
(full scale on the graph is the original specification)

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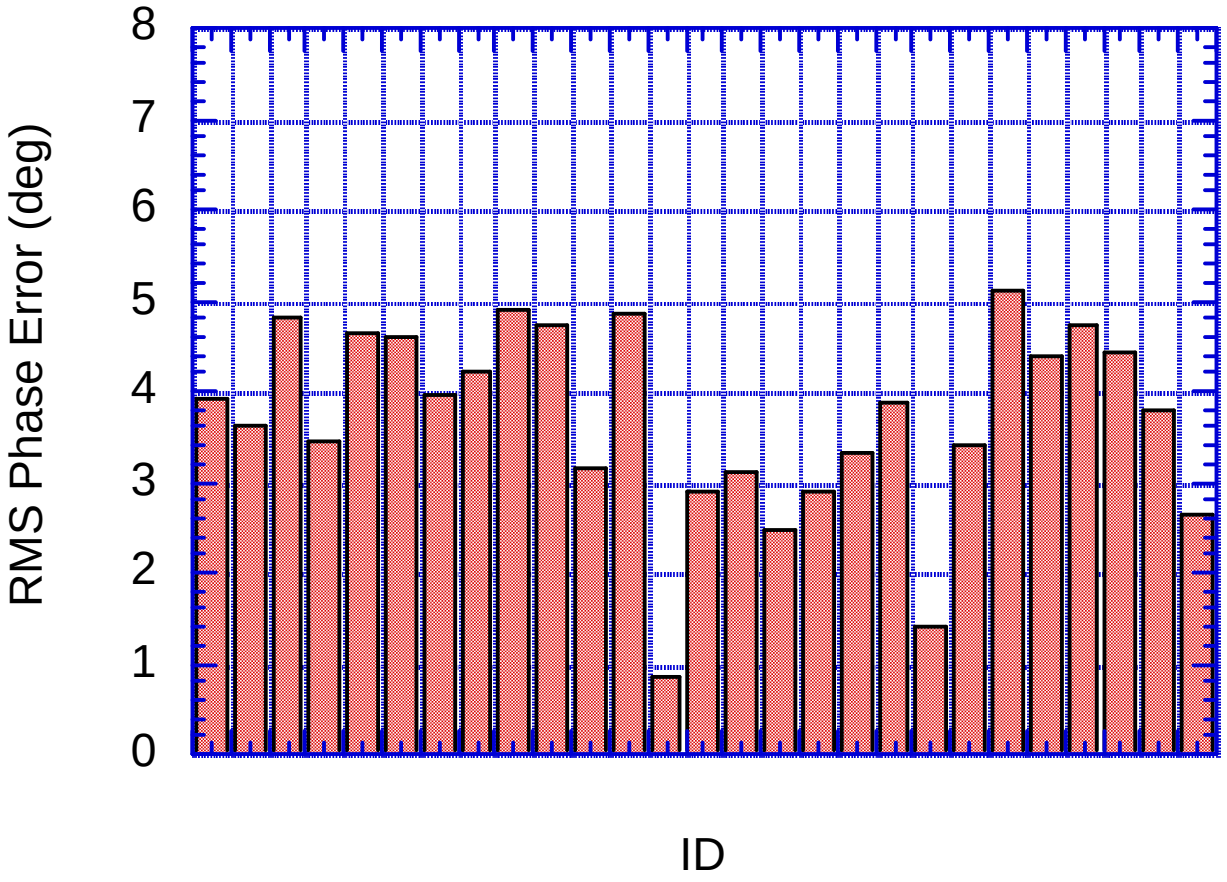
RMS phase errors at 11.5 mm gap



(Requirement is 8 deg.)

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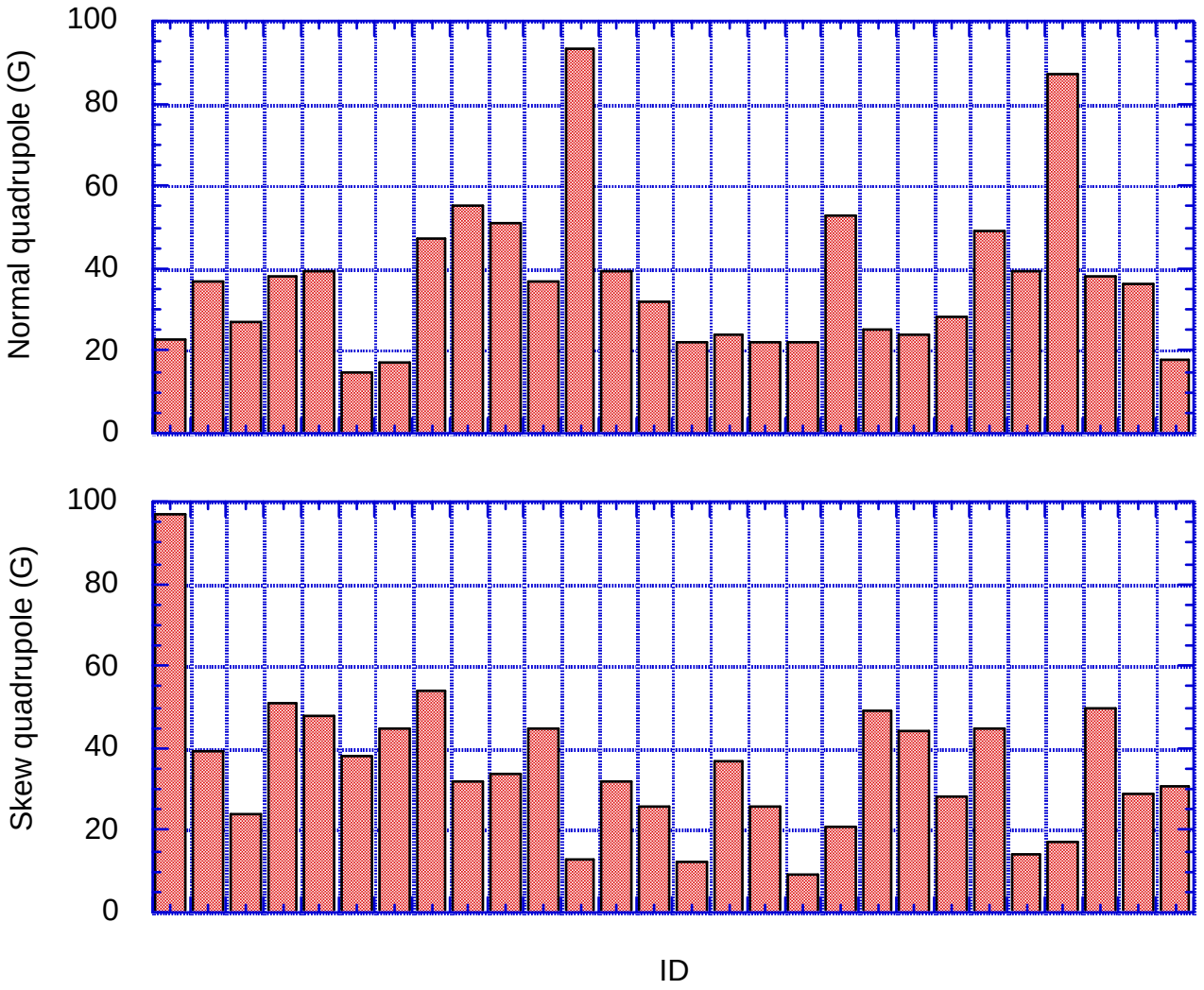
Integrated quadrupole moments



Goal:

50 G

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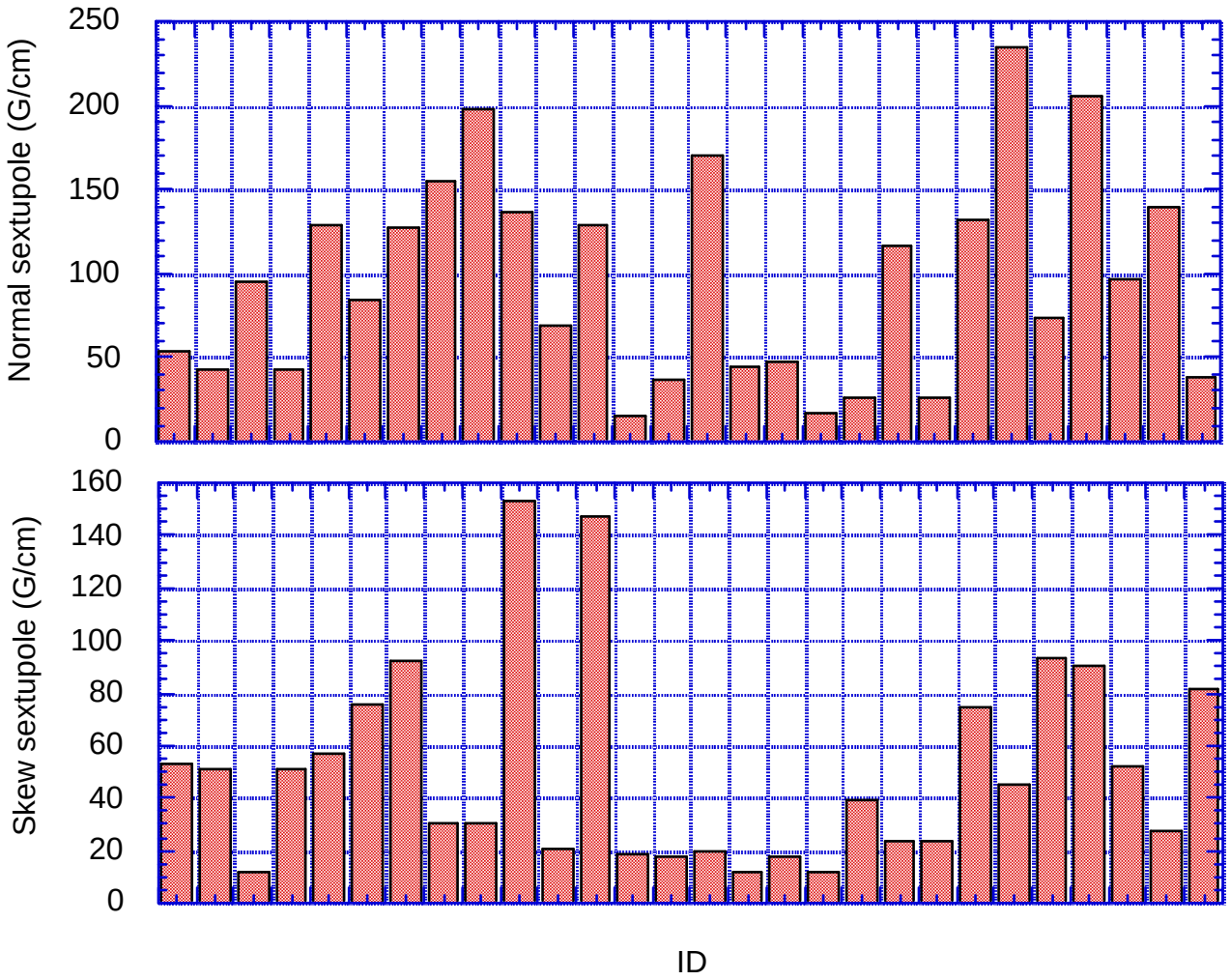
Integrated sextupole moments



Goal:

200 G/cm

100 G/cm

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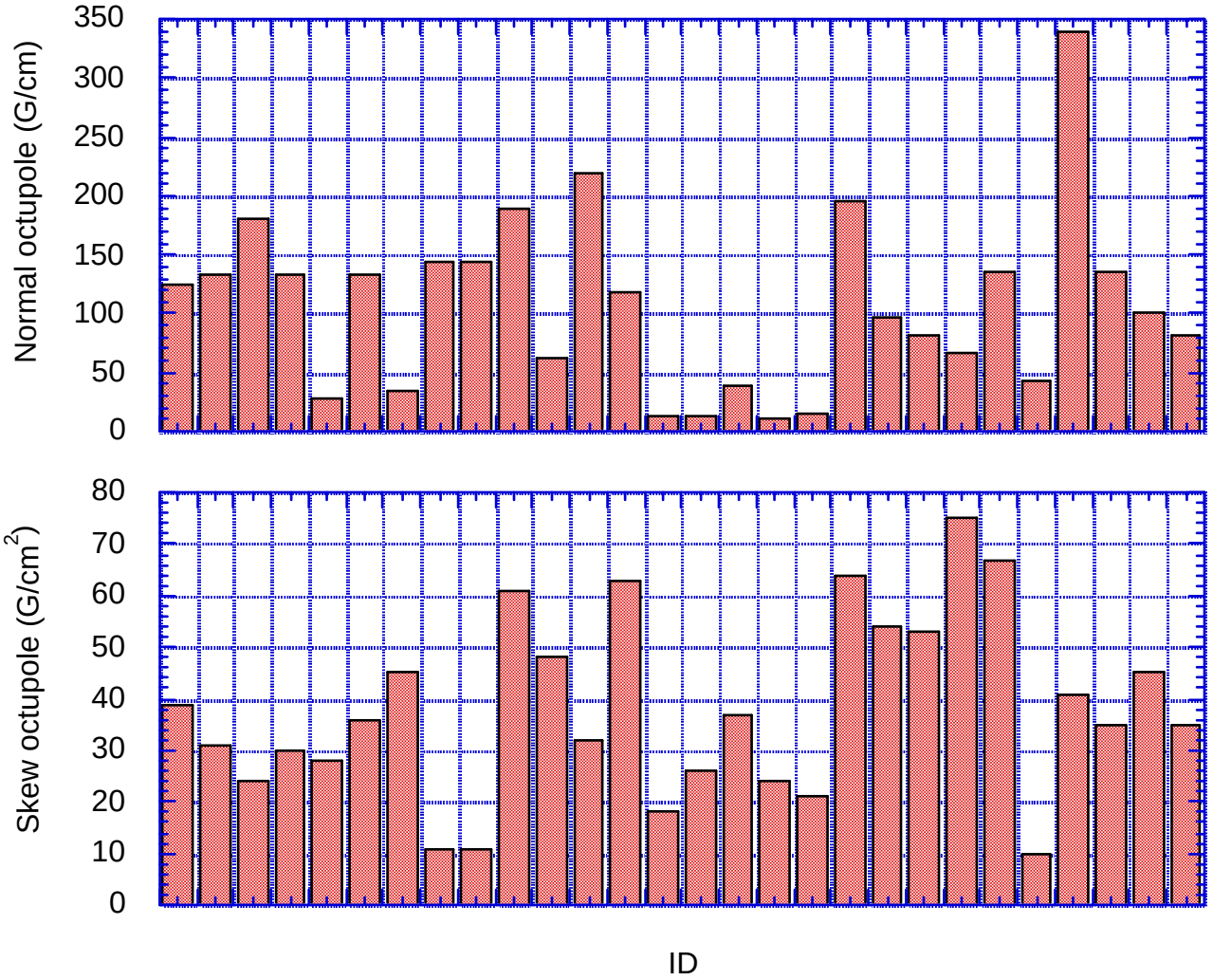
Integrated octupole moments



Goal:

300 G/cm^2

50 G/cm^2

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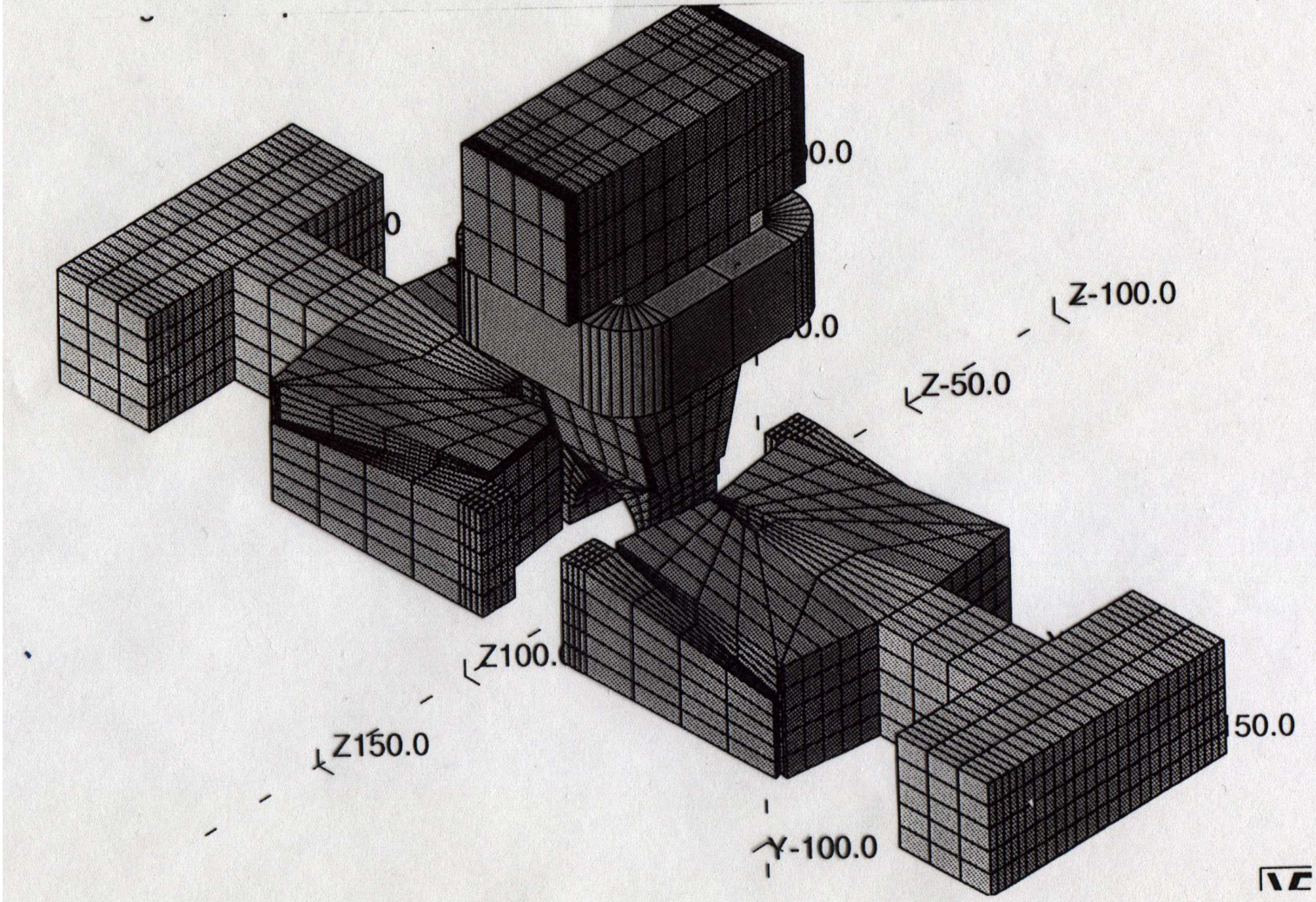
Half period of Elliptical Motion Wiggler

(upper half plane)



APS Elliptical Wiggler for BESSRC-CAT

Period is 16 cm

Horizontal field component is from Electromagnet

- 36 poles, of which 32 are full-field
- 2 end poles (at each end) are nominally1/4 and 3/4 of full strength
- peak field of 0.0947 Tesla (Kx=1.41) at a current of 1.015 A
- up to 10 Hz

Vertical field component is from hybrid permanent magnet structure

- 37 poles, of which 32 are full-field
- 2 poles at the upstream end and one pole at the downstream end have no adjacent magnet to power them
- the third pole at the upstream end and the next-to-last at the downstream end are nominally 1/2 of full strength
- peak field of 0.9826 T (Ky=14.6)
- minimum gap 24 mm

There are electromagnetic correction coils at both ends of the device for vertical and horizontal field correction.


CAUTION
CAUTION
CAUTION
HIGH MAGNETIC FIELD IN AREA
PERMANENT MAGNET
FIELD ALWAYS ON

Circularly Polarized Undulator

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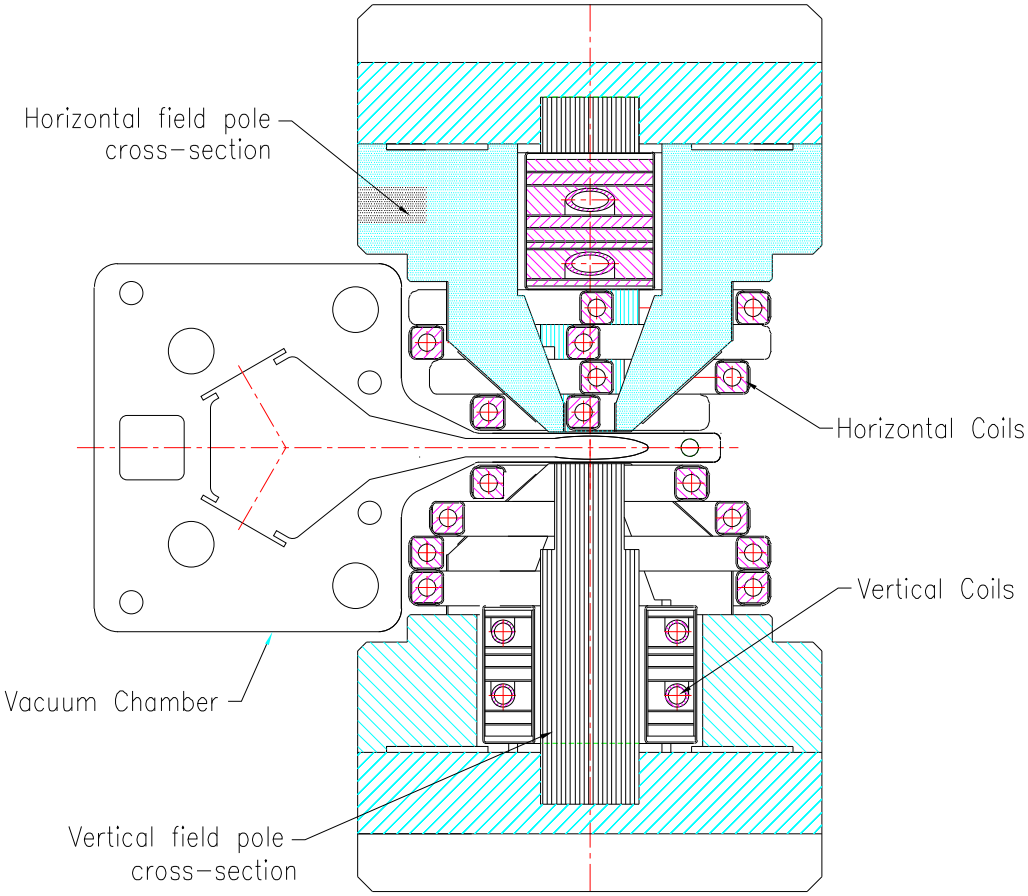
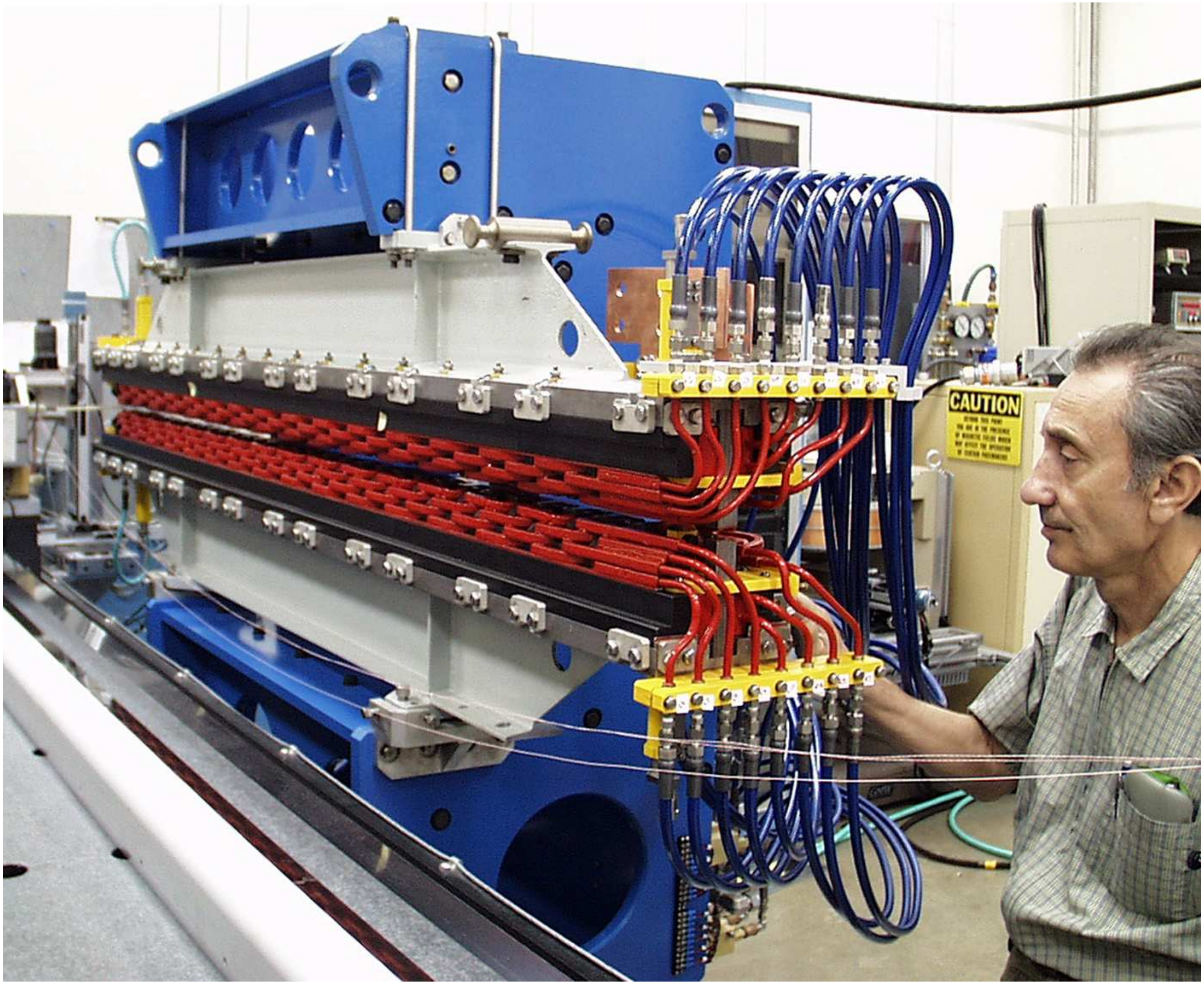
Shown in cross-section.

- 500-3000 eV output
- circular polarization, both left and right
- linear polarization, both vertical and horizontal
- switchable polarization
- compatible with standard ID vacuum chamber, so it can share a straight section
- open along one side for access by magnetic measurement probes




CAUTION

Magnetic tuning of the CPU has been a real challenge, because:

- a change in the specifications (the user changed) added the requirement for linear polarization down to 0.5 keV.
- poor manufacturing tolerances

Many correction coils were added to meet ring requirements

CPU is now being commissioned with beam

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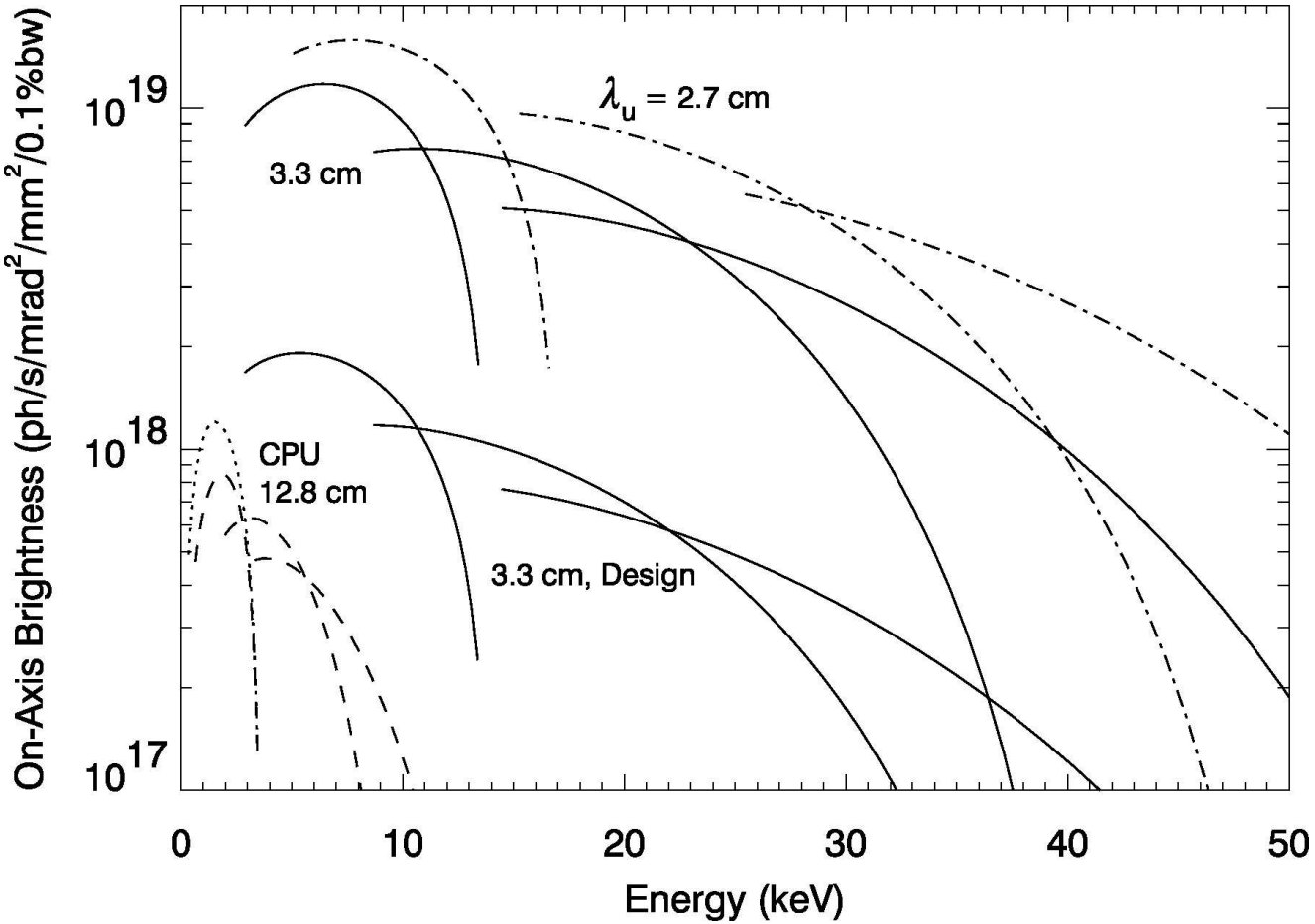
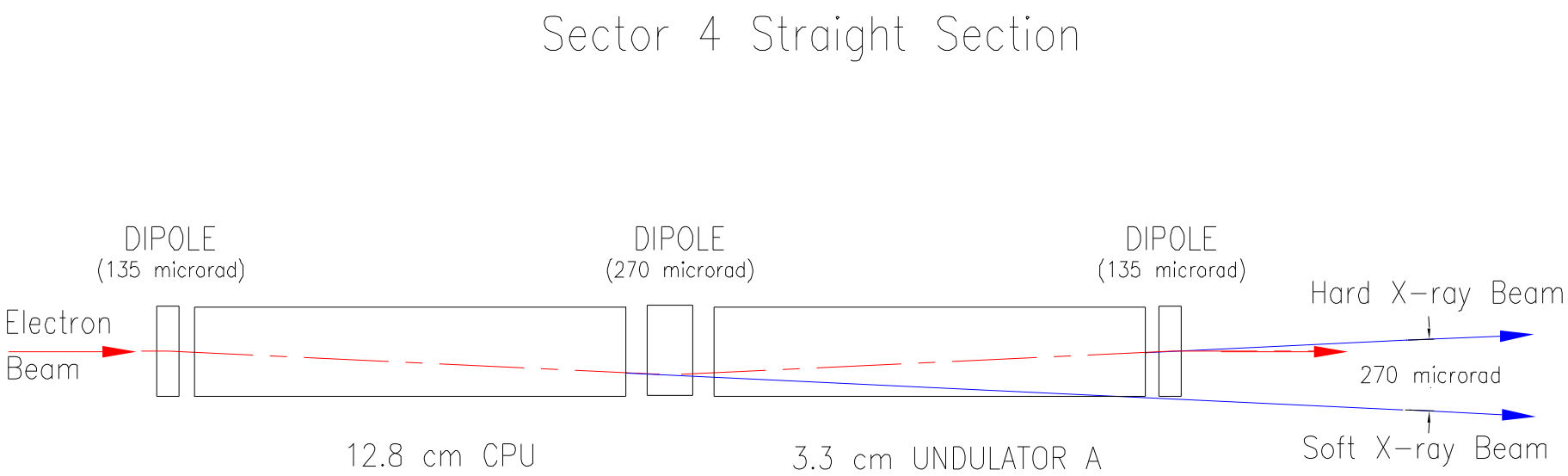


Present APS parameters (ε_x=7.7 nm-rad, $\varepsilon_y/\varepsilon_x$=1.0%), undulators with 3.3 and 2.7 cm periods. Original design of APS with larger vertical emittance ($\varepsilon_y/\varepsilon_x$=10%) is included for comparison. The circularly polarizing undulator (CPU) can produce both circular (dots) and linear (dashes) polarization.

Sector 4 Dogleg

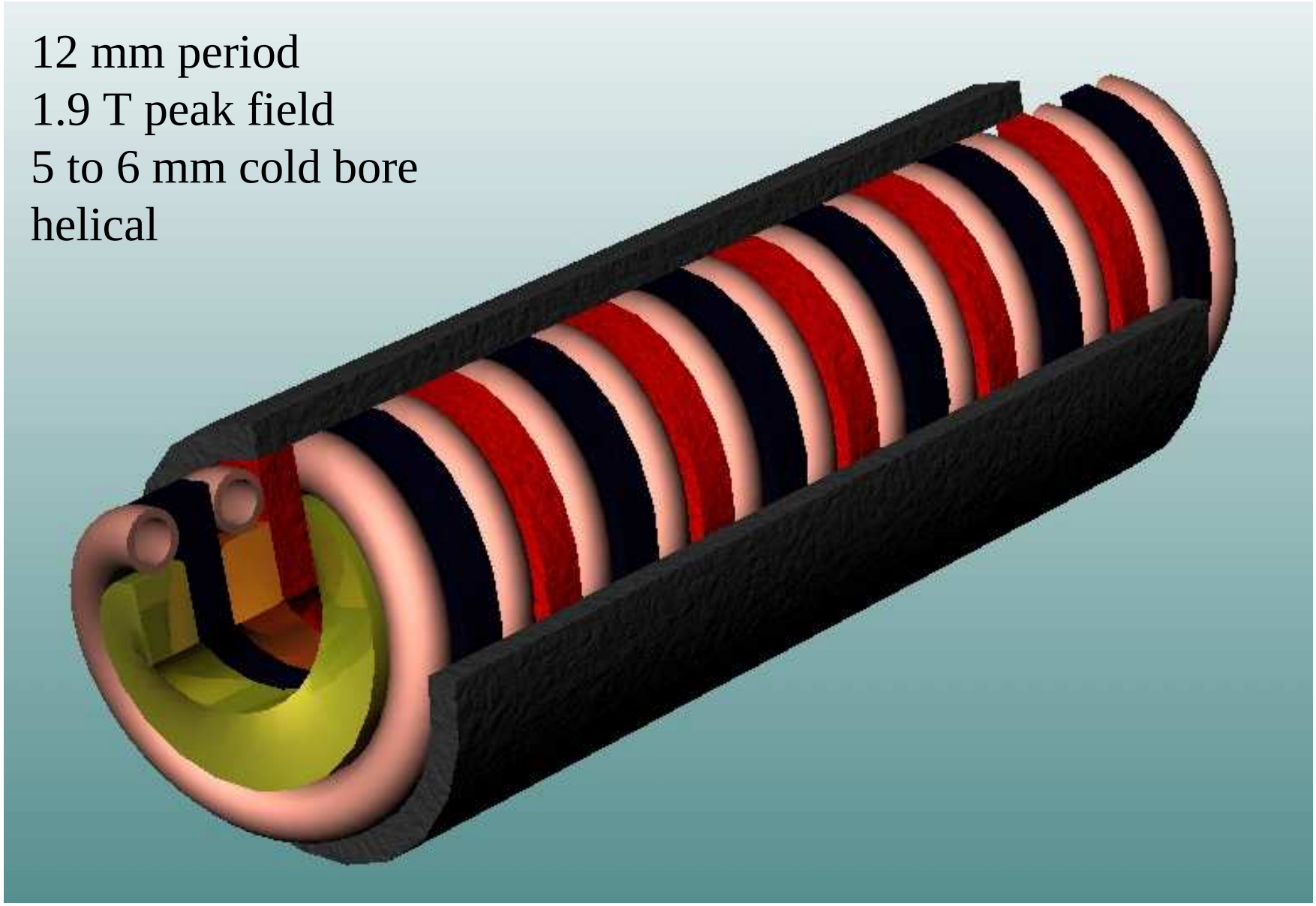


New types of IDs planned

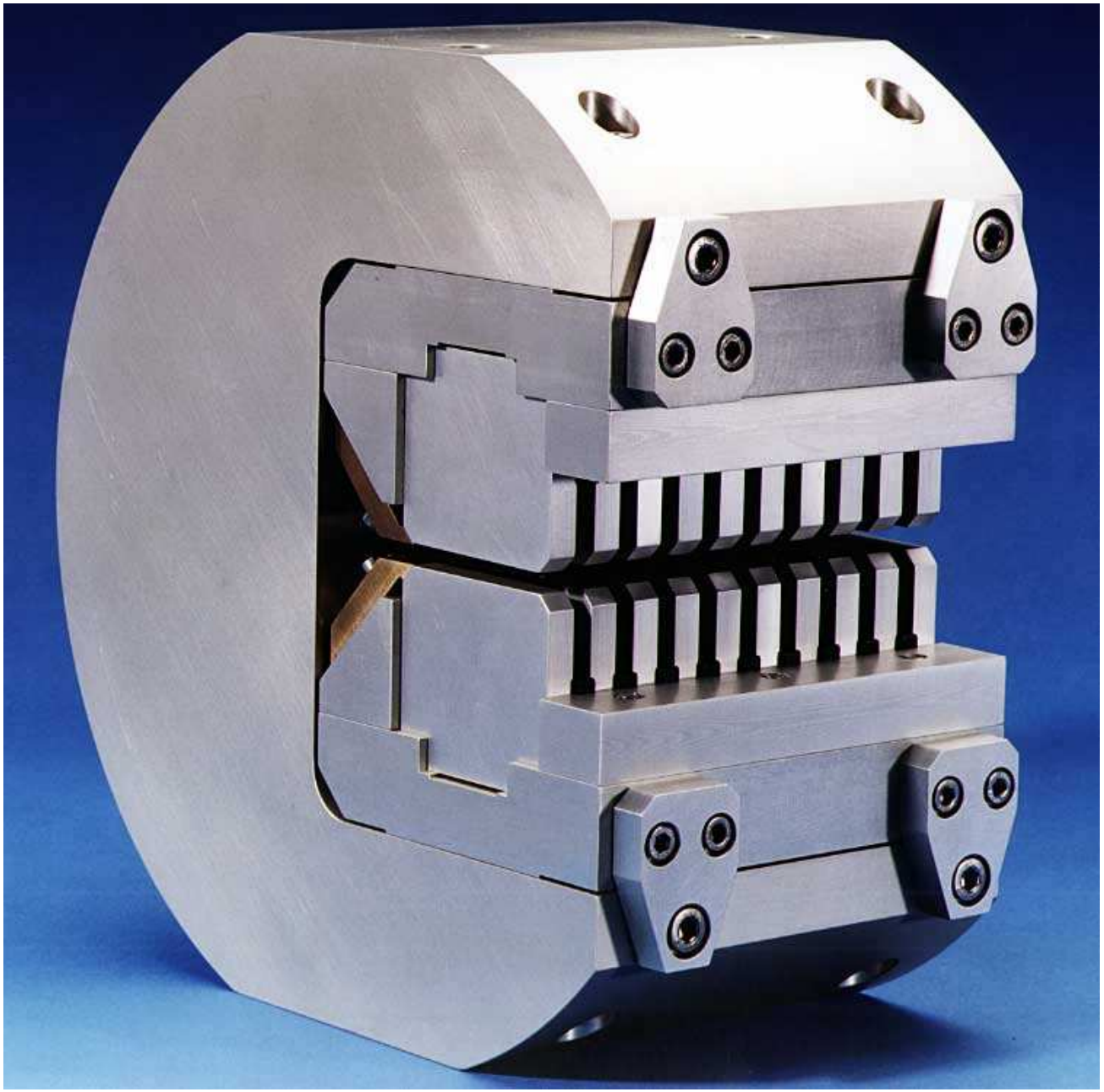
- Superconducting undulator
- Undulators for LCLS
- Undulators for canted beamlines

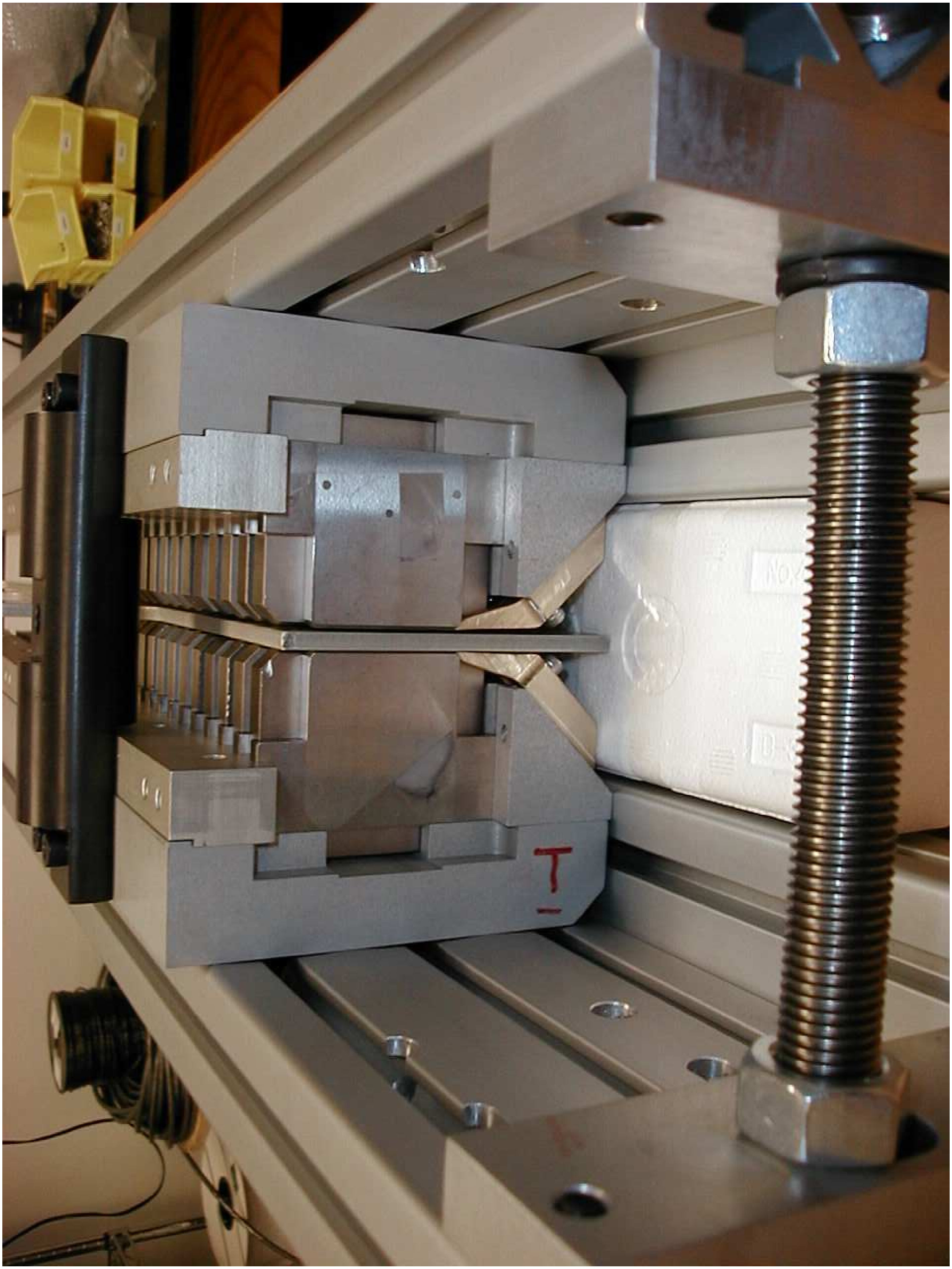
Superconducting undulator concept

12 mm period
1.9 T peak field
5 to 6 mm cold bore
helical



Mockup of LCLS undulator prototype




T

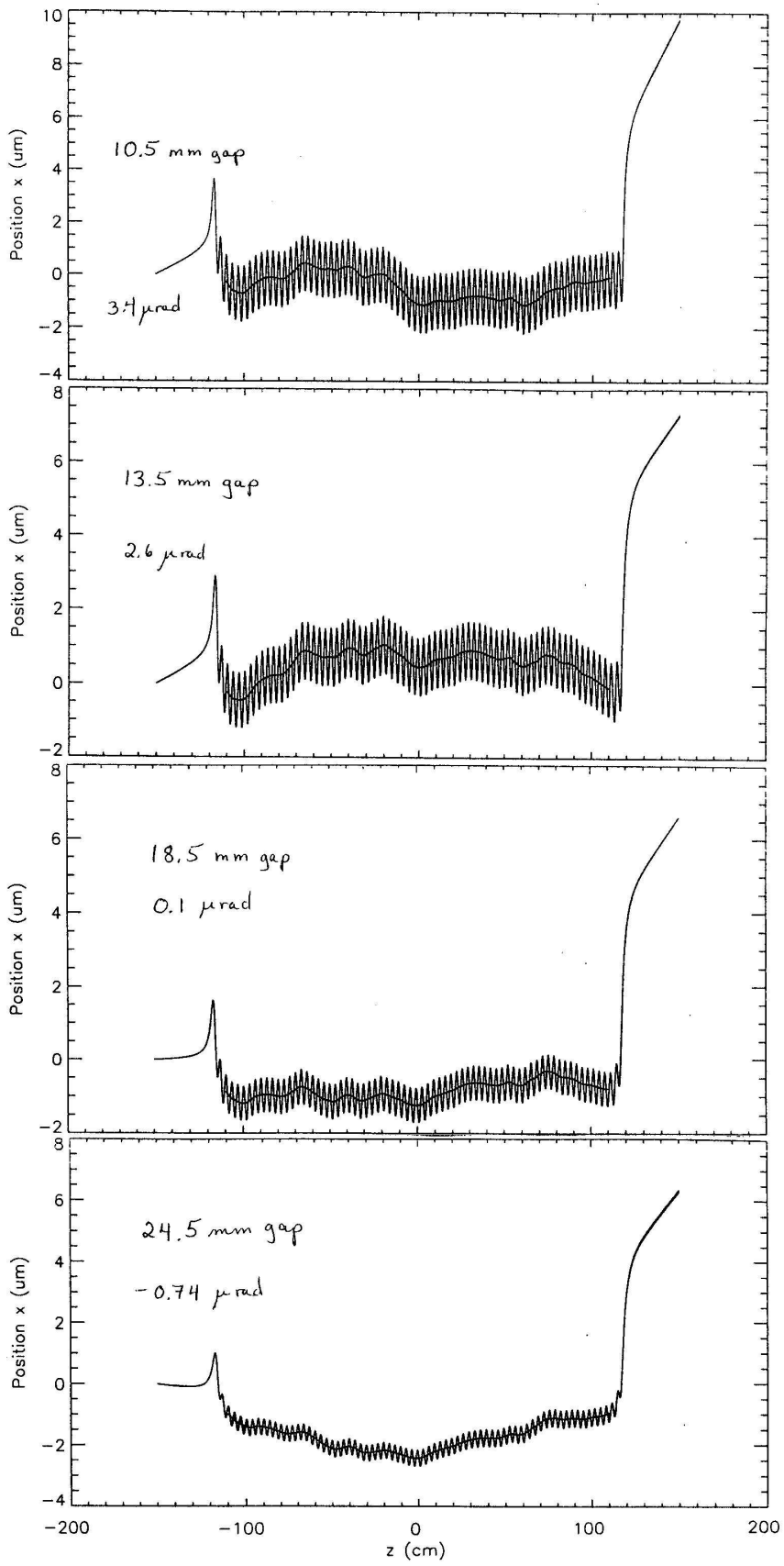
Future ID upgrades

IDs are removed from the ring each shutdown for magnetic checking and some retweaking.

Glenn Decker wants 10x smaller effect on stored beam. All we can achieve with passive correction is ~2x, so we may begin installing correction coils on all IDs

Goal is to allow the beam to be steered through the ID as a function of gap, so that the emitted light beam doesn't move for the users.

Addition of coils may happen in conjunction with periodic checks of ID magnetic fields.


10.5 mm gap
3.4 μrad
13.5 mm gap
2.6 μrad
18.5 mm gap
0.1 μrad
24.5 mm gap
-0.74 μrad
Position x (um)
z (cm)
-200
-100
0
100
200

Radiation Monitoring

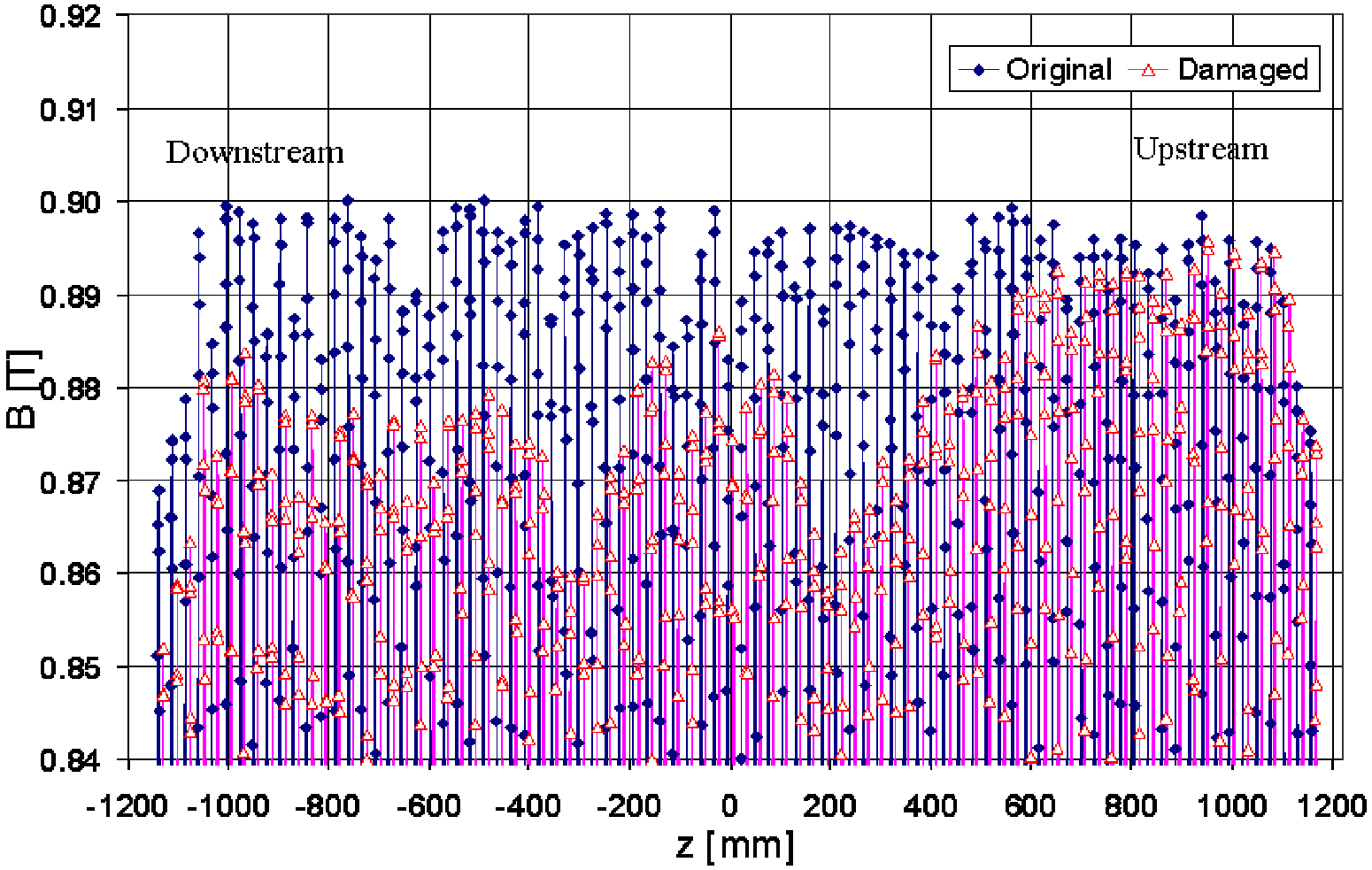
Doses to IDs are measured using TLDs and radiachromic films.

There have been discrepancies between these two techniques that are not completely understood. Both techniques have shortcomings.

We now have a reader for alanine dosimeters and will begin using alanine dosimeters too.

The radiation exposure level turned a TLD in Sector 3 dark brown during the Aug/Sept 2001 run. In December, both undulators in Sector 3 were removed and checked. Both showed a loss in field strength. These were the first devices to show radiation damage.

U27#12 Radiation damage



Plots normalized at upstream end. Actual decrease 2% in 2001 as compared to 1997 original

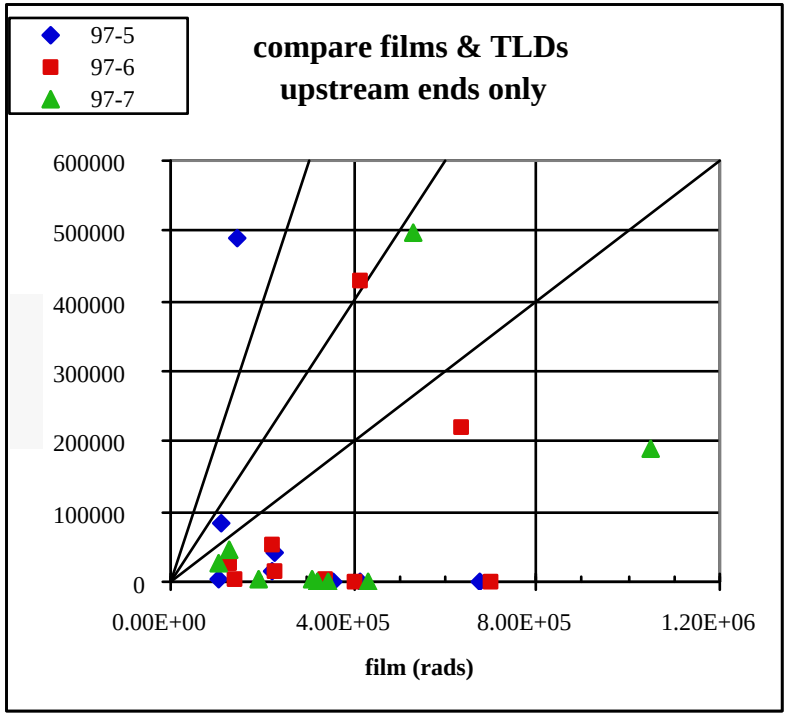
Now that we have damaged devices, how do we repair them?

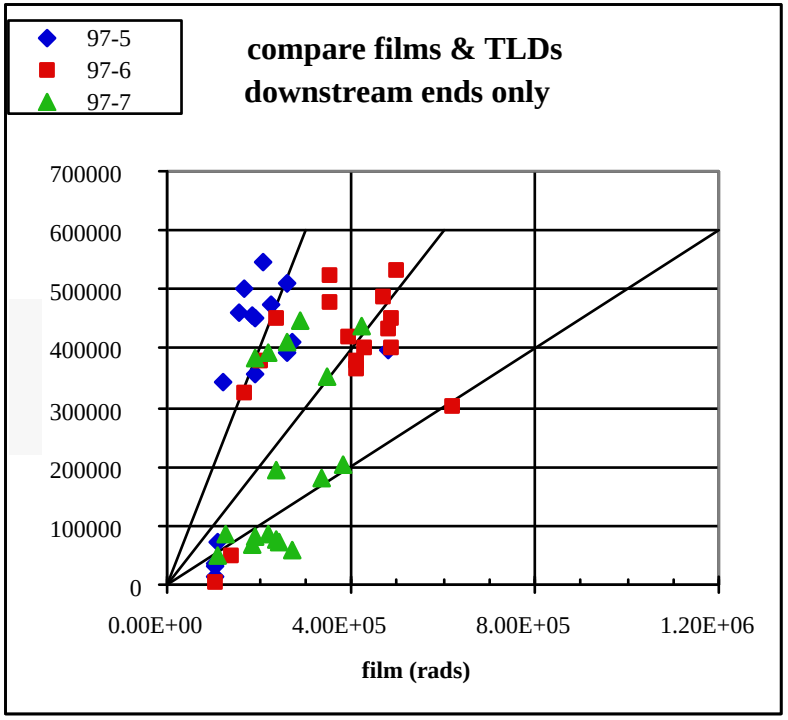
Although U27#12 was retuned partly and reinstalled, it needs to be fixed properly.

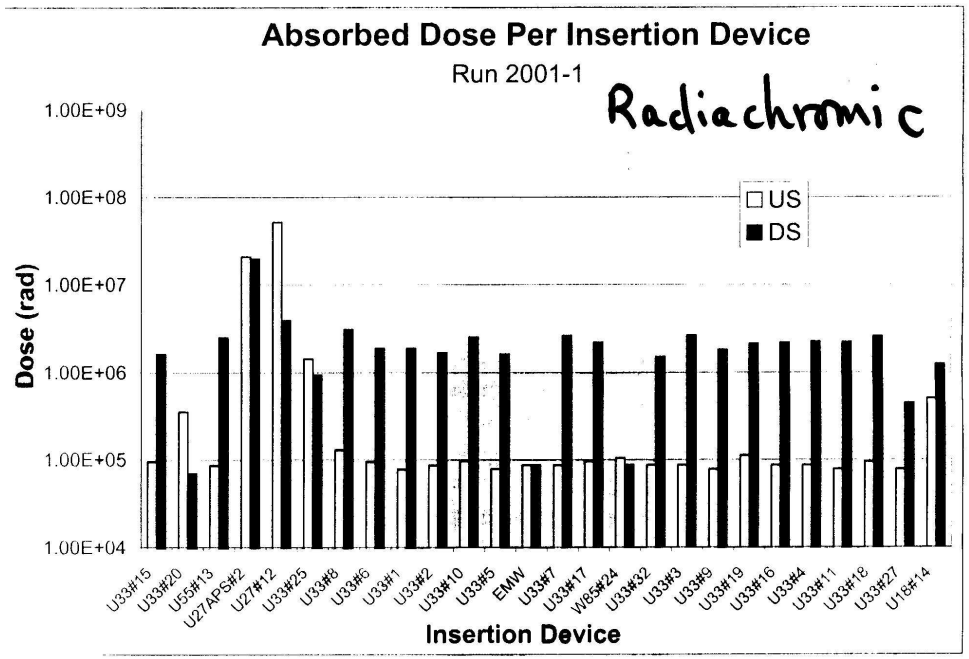
A spare is needed to fill in for it during repairs.

From others' radiation damage studies, we anticipate that the magnets can be remagnetized. That would require a high-field, pulsed magnet.

We may change the grade of magnet material.


97-5
97-6
97-7
compare films & TLDs
upstream ends only
600000
500000
400000
300000
200000
100000
0
0.00E+00
4.00E+05
8.00E+05
1.20E+06
film (rads)


97-5
97-6
97-7
compare films & TLDs
downstream ends only
700000
600000
500000
400000
300000
200000
100000
0
0.00E+00
4.00E+05
8.00E+05
1.20E+06
film (rads)


Absorbed Dose Per Insertion Device
Run 2001-1
Radiachromic
1.00E+09
1.00E+08
1.00E+07
1.00E+06
1.00E+05
1.00E+04
Dose (rad)
US
DS
U33#15
U33#20
U55#13
U27APS#2
U27#12
U33#25
U33#8
U33#6
U33#1
U33#2
U33#10
U33#5
EMW
U33#7
U33#17
W65#24
U33#32
U33#3
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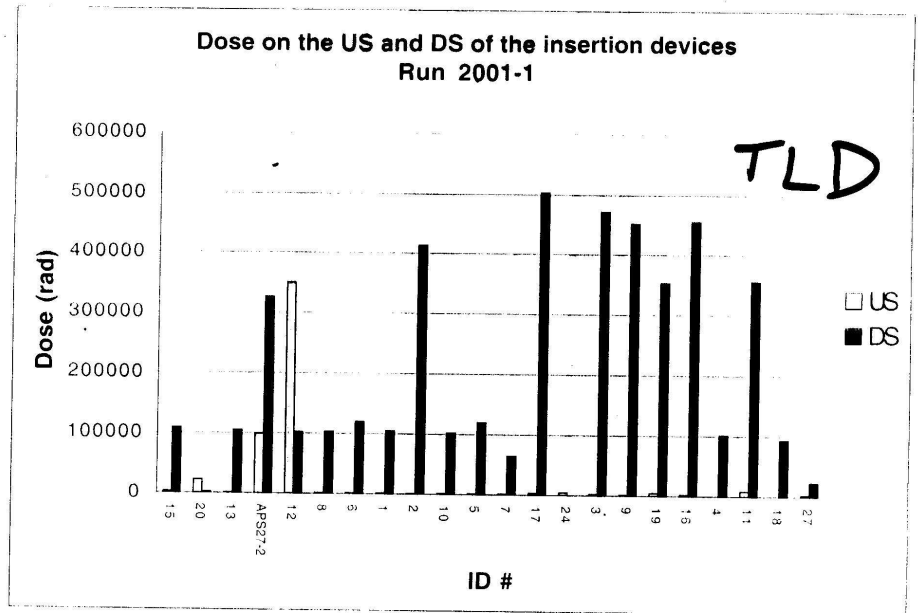
U33#4
U33#11
U33#18
U33#27
U16#14
Insertion Device


Dose on the US and DS of the insertion devices
Run 2001-1
TLD
600000
500000
400000
300000
200000
100000
0
Dose (rad)
US
DS
15
20
13
APS27-2
12
8
6
1
2
10
5
7
17
24
3
9
19
15
4
11
18
27
ID #

Magnet irradiation

In addition to understanding what our dosimeters are telling us, we need to know more about what aspects of radiation the magnets are most sensitive to.

Irradiation experiments have found that NdFeB magnets are unaffected by bending magnet irradiation or by 1-MeV photons (Co^{60} radiation). Neutrons cause damage, however.

Others have found that higher-energy (>17MeV) electrons cause damage.

Other projects, such as ESRF, SPring-8, LCLS, and NLC, are also very interested in determinations of radiation sensitivity.

Future irradiation testing

We are investigating the possibility of setting up an irradiation facility using the booster that would allow us to investigate the energy dependence of the radiation sensitivity.

There is space in the tunnel where a spur line could be built.