Plans for small gap operation at SLS

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Swiss Light Source

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PSI

ICFA 17th Advanced Beam Dynamics Workshop on

FUTURE LIGHT SOURCES

Argonne National Laboratory

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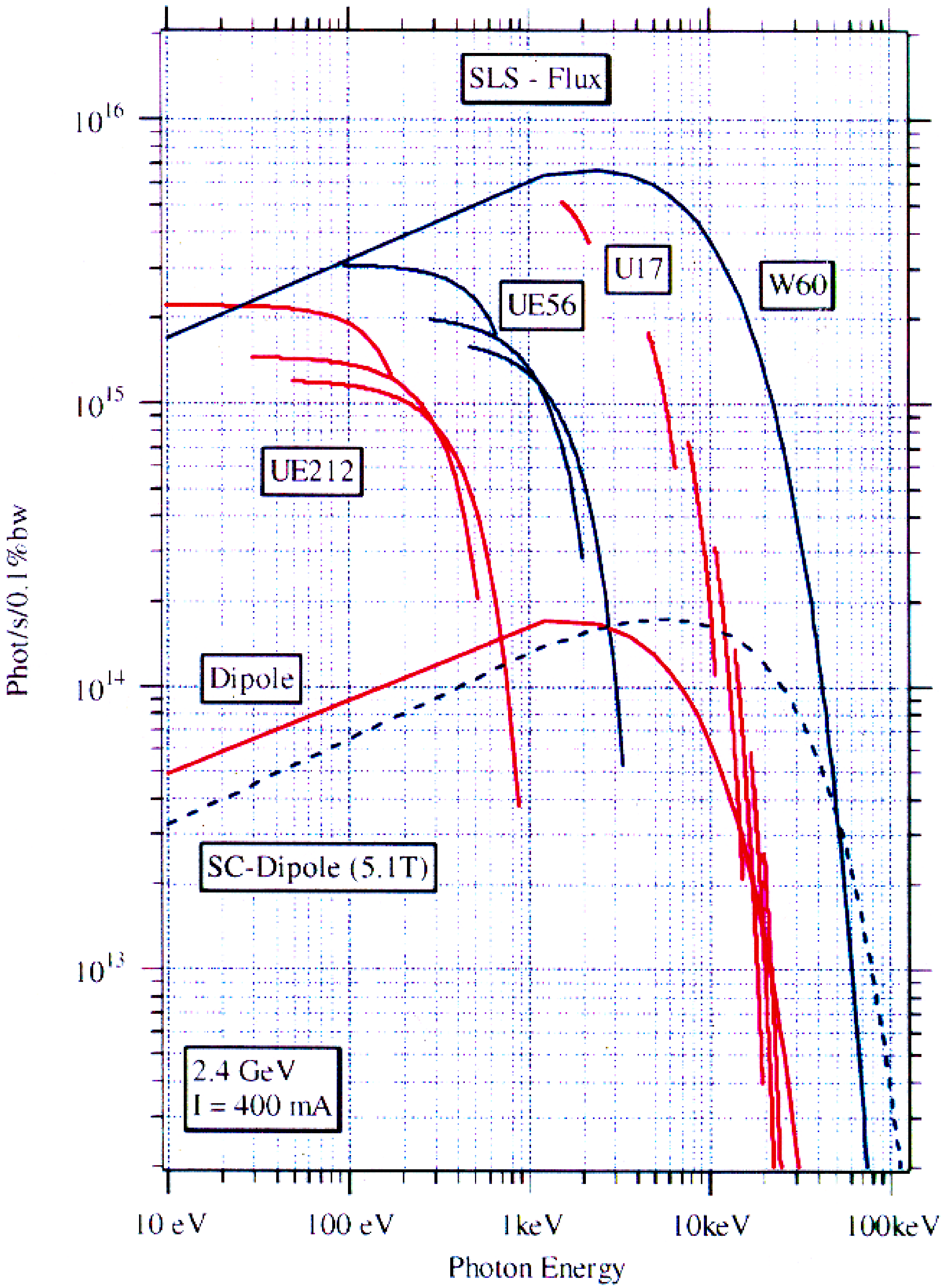
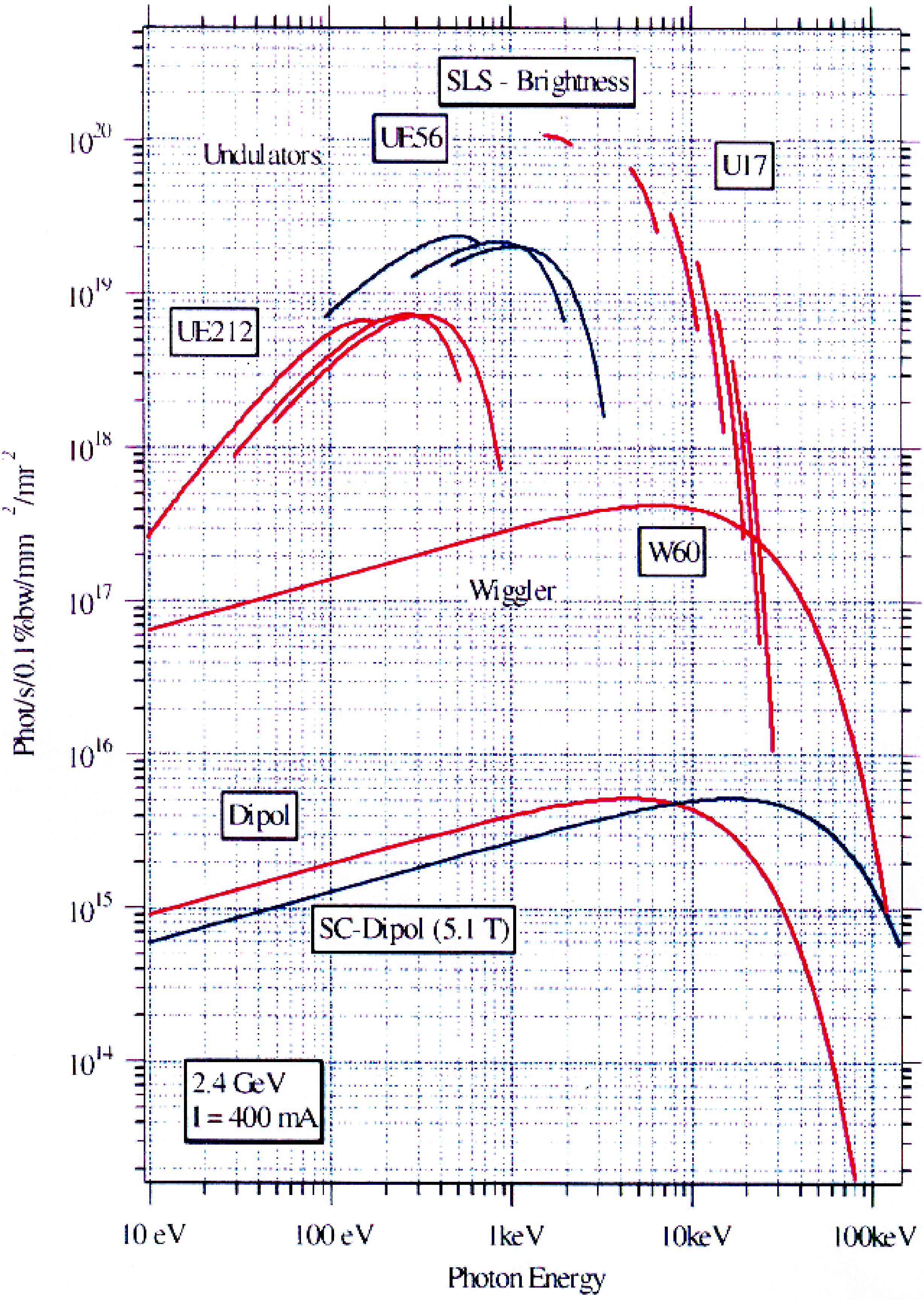
Machine parameters

Energy	[GeV]	2.4
Circumference	[m]	288
RF frequency	[MHz]	500
Harmonic number		(2 5 x3x5 =) 480
Peak RF voltage	[MV]	2.6
Current	[mA]	400
Single bunch current	[mA]	10
Tunes		20.8 / 7.1
Natural chromaticity		-70/-20
Momentum compaction		0.0007
Critical photon energy	[keV]	5.4
Natural emittance	[nm·rad]	4.8
Radiation loss per turn	[keV]	512
Energy spread		$0.9*10^{-3}$
Damping times (h/v/l)	[ms]	9 / 9 / 4.5
Bunch length	[mm]	3.5


SLS - Flux
U17
W60
UE56
UE212
Dipole
SC-Dipole (5.1T)
2.4 GeV
I = 400 mA
10^{16}
10^{15}
10^{14}
10^{13}
Phot/s/0.1%bw
10 eV
100 eV
1 keV
10keV
100keV
Photon Energy


SLS - Brightness
Undulators
UE56
U17
UE212
W60
Wiggler
Dipol
SC-Dipol (5.1 T)
2.4 GeV
I = 400 mA
Phot/s/0.1%bw/mm²/mr²
Photon Energy
10 eV
100 eV
1keV
10keV
100keV
10^{20}
10^{19}
10^{18}
10^{17}
10^{16}
10^{15}
10^{14}

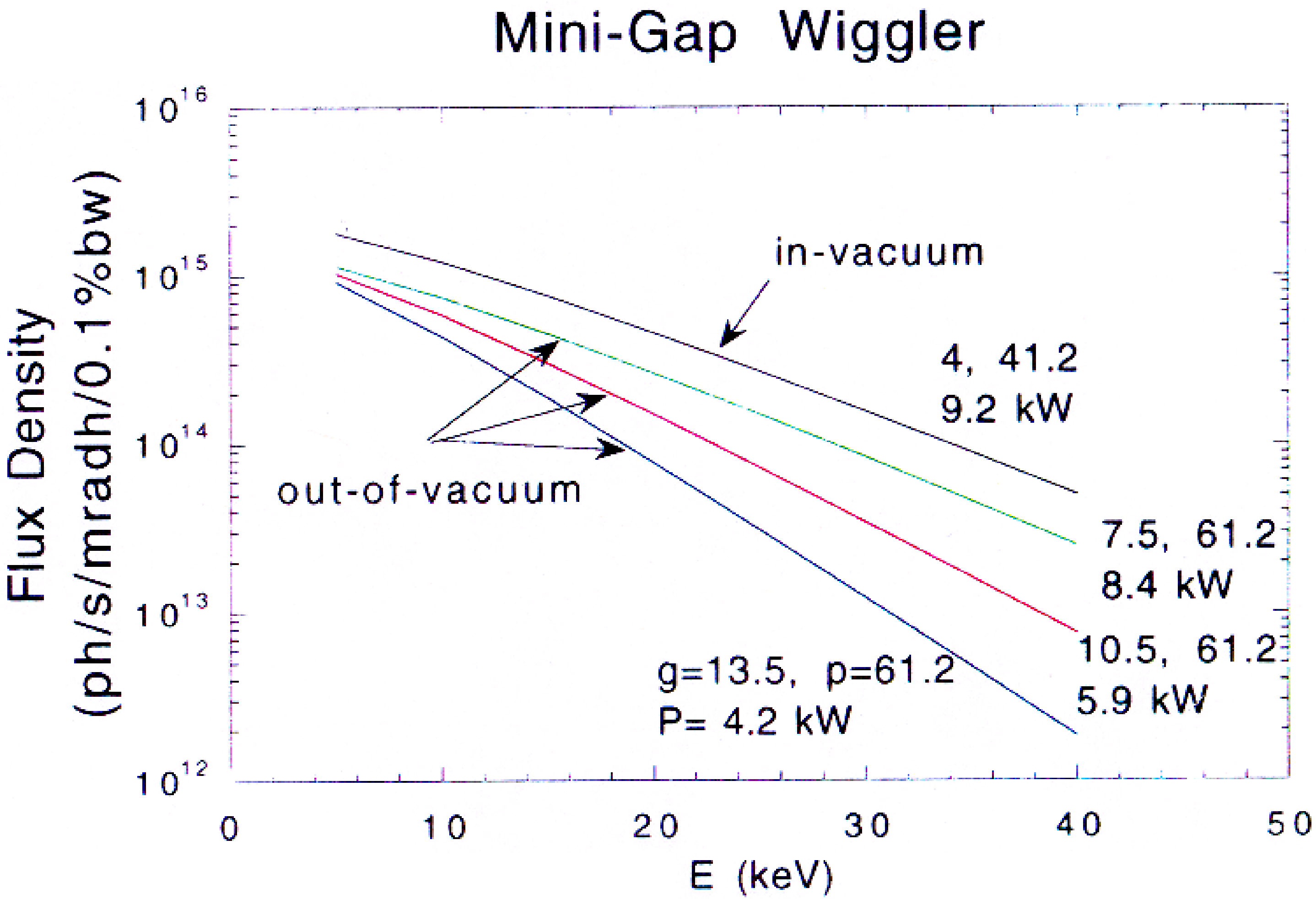
SLS Material Science beamline : MS-wiggler W60

wiggler outside the vacuum
fixed gap ID-chambers (APS chambers, extruded Alu.)

ID-chamber (initial)	: g_{vac} = 8.0mm or 11.0mm	2 chamb[ers]
" (final)	: g_{vac} = 5.0mm	used
energy range	: 5 - 40 keV (E_c = 7.5 keV)	
figure of merit	: max. horiz. flux density min. total radiated power	
current	: 400 mA	
energy	: 2.4 GeV	
spectral flux	: 2.0×10^{15} photons/s/0.1% bw (10 ke[V]) 3.8×10^{13} photons/s/0.1% bw (40 ke[V])	
total power	: 8.4 kWatt	

wedge pole design
⊕ side magnets

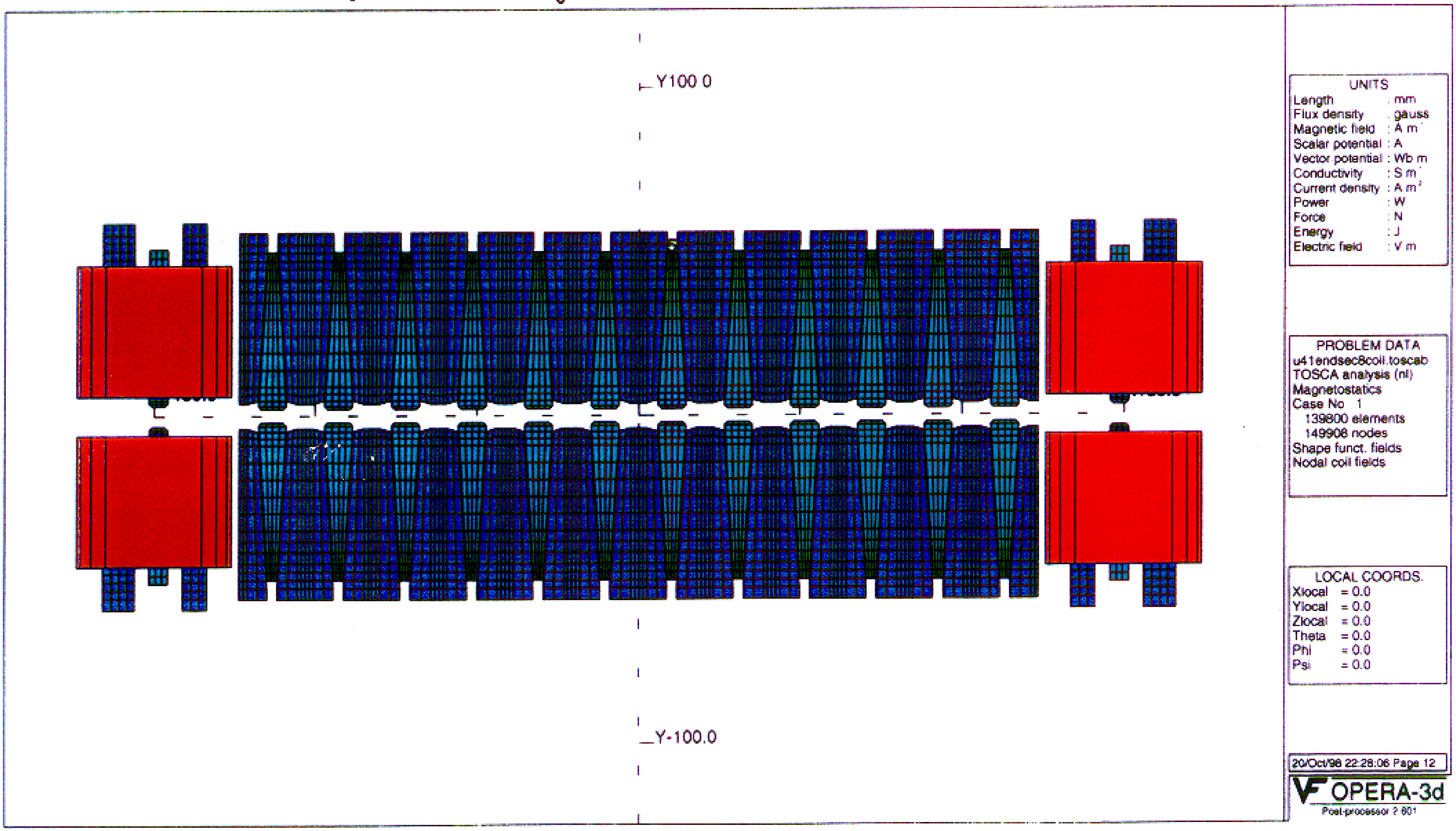
period length	: 61.2 mm
# periods	: 33
ID straight length	: 3.2 m
magnetic gap (initial)	: g_{mag} = 10.5 - 11.0 mm or 13.5 - 14.0 m[m]
" " (final)	: g_{mag} = 7.5 mm
B_{max} (B_{eff})	: 1.97 T (1.69 T) (Tosca calc.)
K_{max} (K_{eff})	: 11.2 (9.7)
magnet material	: Neomax - 48BH (B_r = 1.36 T, H_{cJ} = 14 kOe)

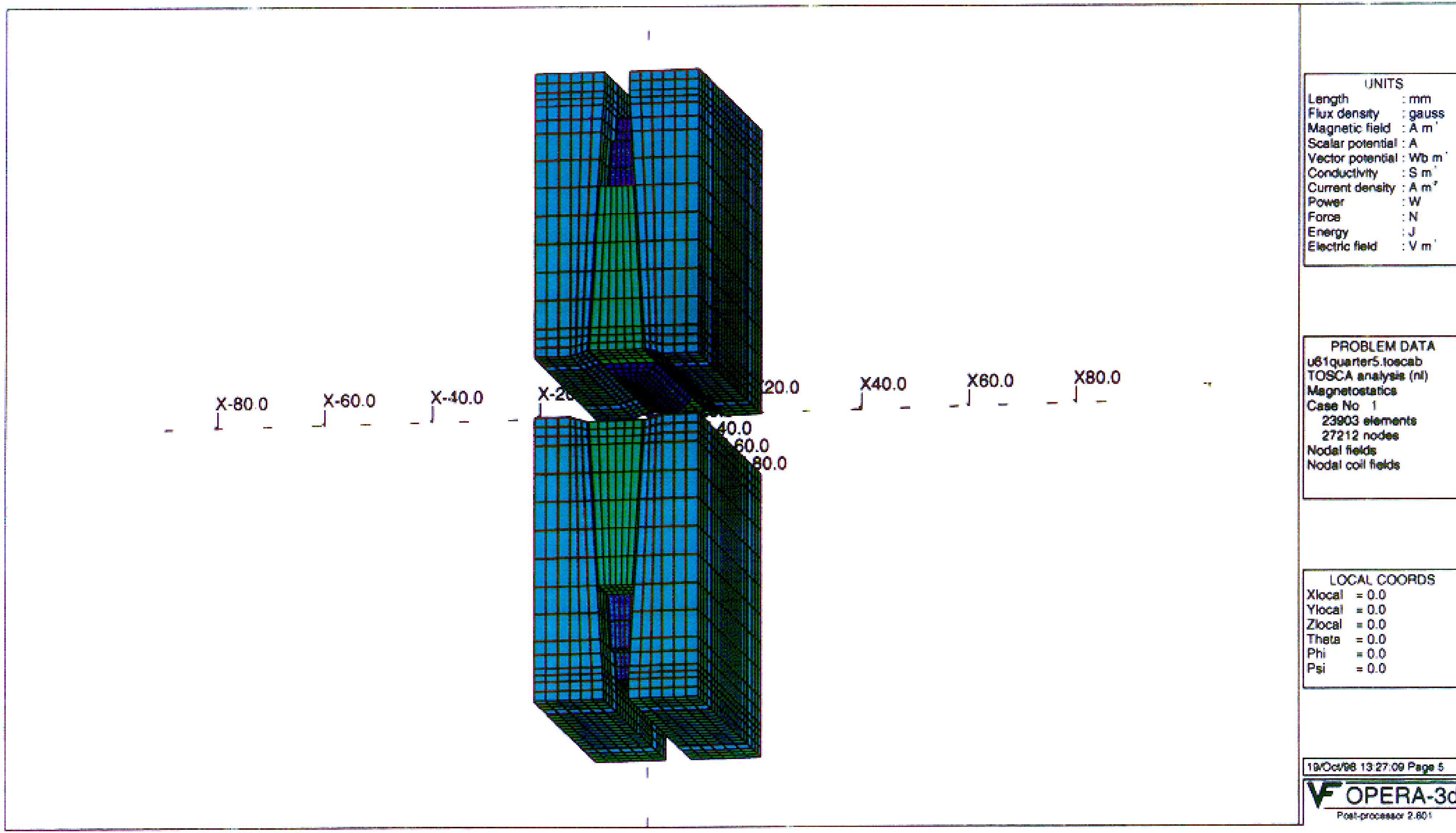


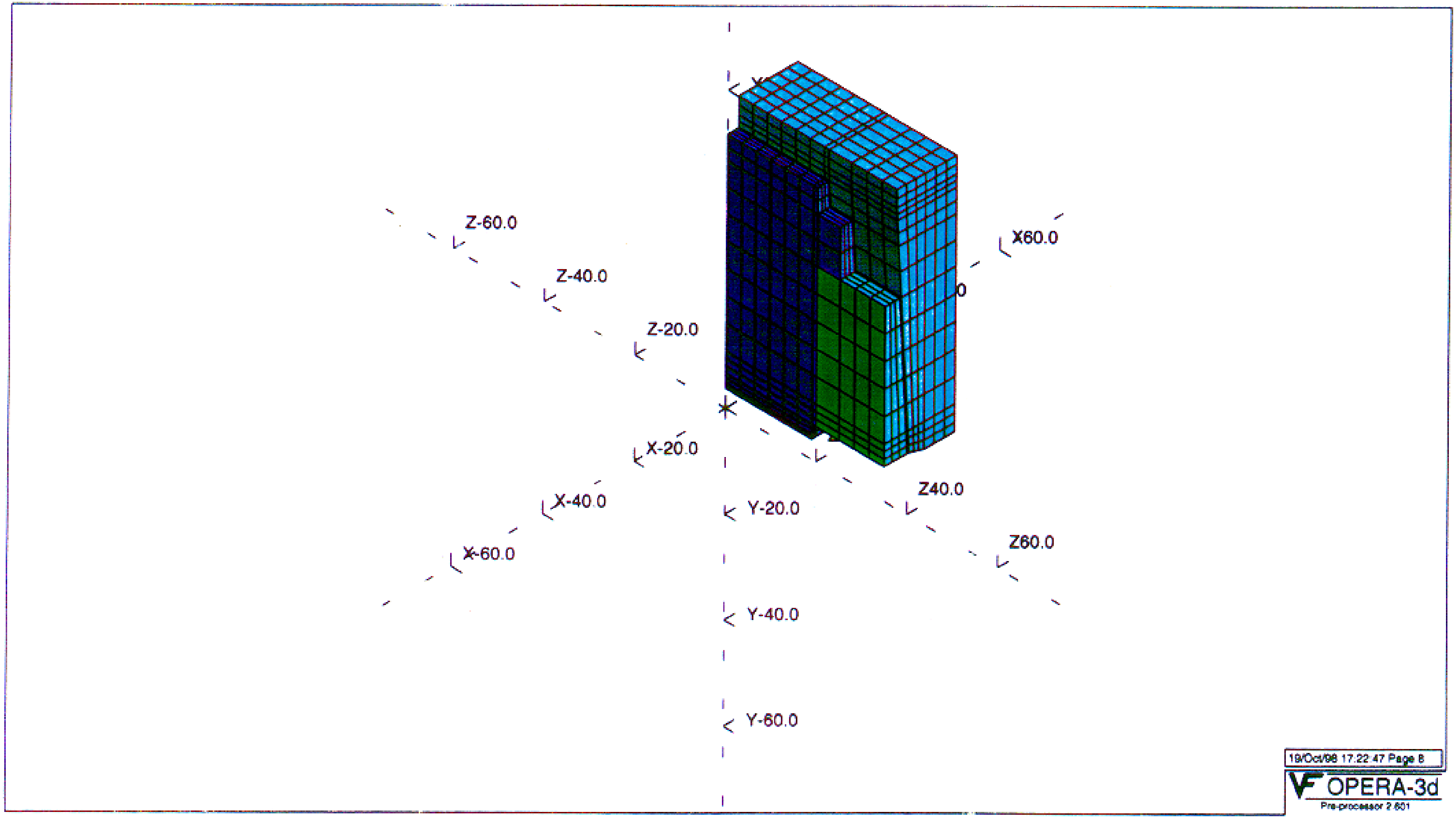
Mini-Gap Wiggler
Flux Density (ph/s/mradh/0.1%bw)
E (keV)
10^16
10^15
10^14
10^13
10^12
0
10
20
30
40
50
in-vacuum
out-of-vacuum
4, 41.2
9.2 kW
7.5, 61.2
8.4 kW
10.5, 61.2
5.9 kW
g=13.5, p=61.2
P= 4.2 kW

SLS MS-wiggler W60

magnet design ⊕ endpole design : similar to Bessy II hybrid undulators
U49, U41, W/U125
↳ wedge pole design ⊕ side magnets

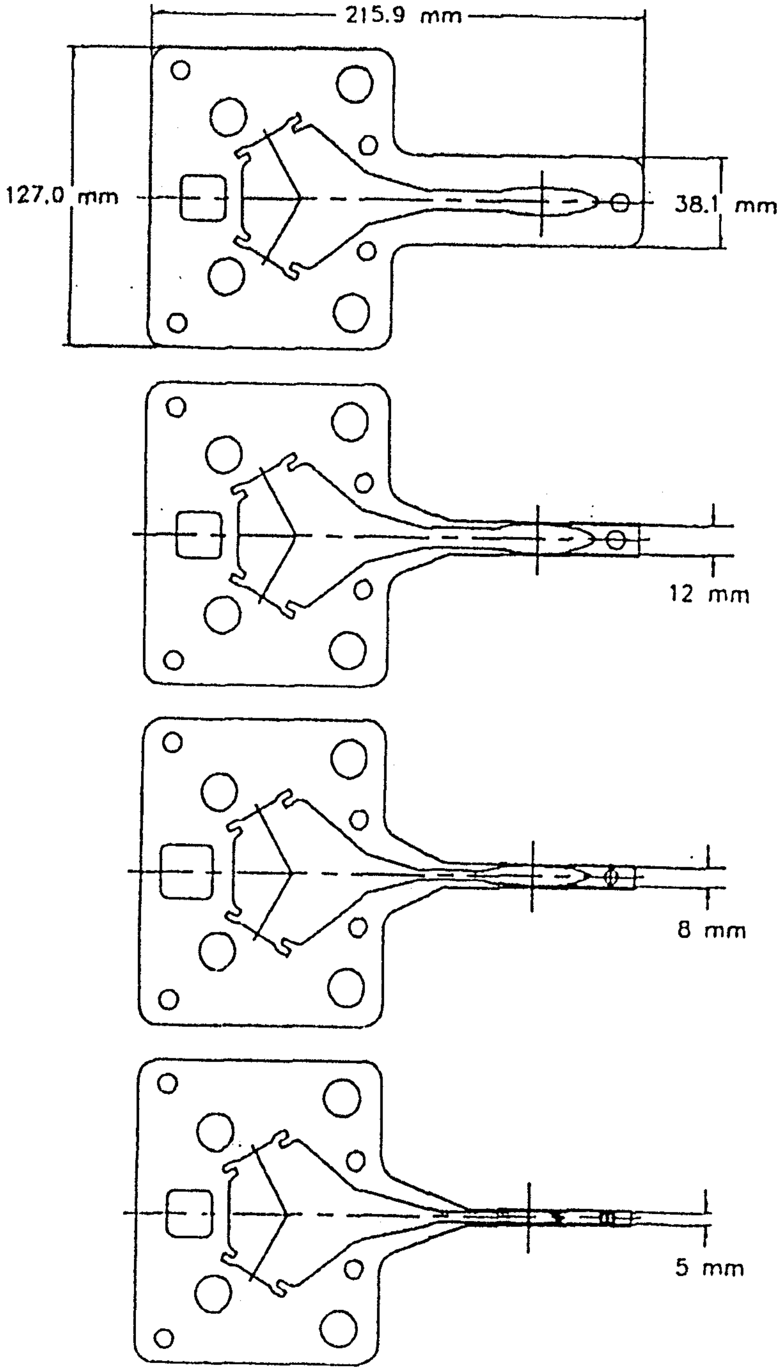


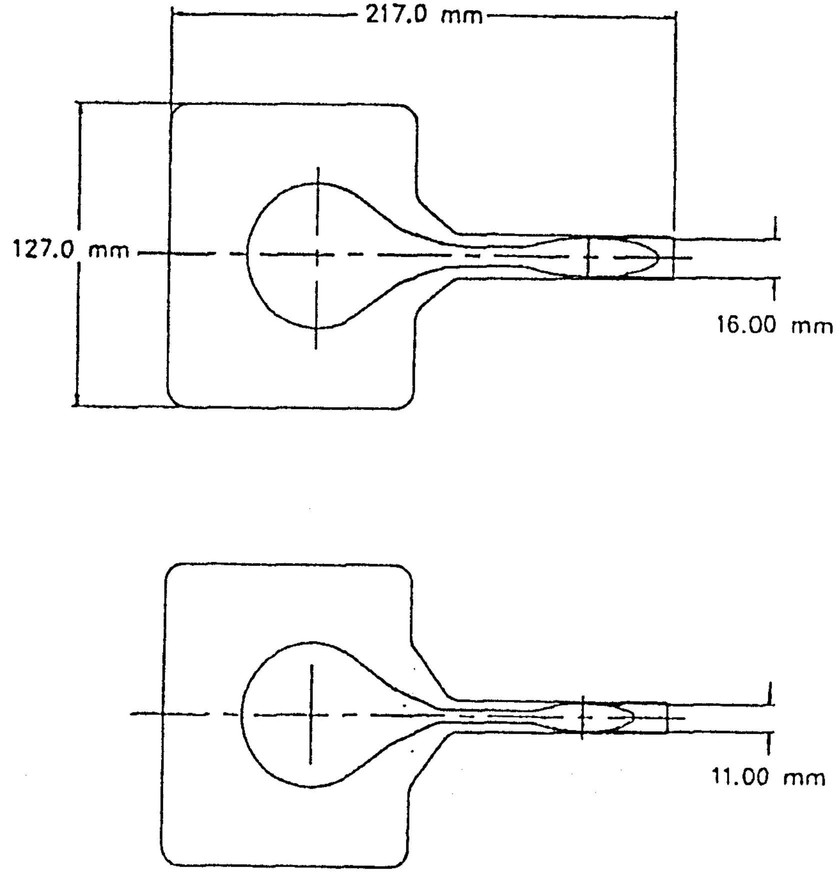

X-80.0
X-60.0
X-40.0
X40.0
X60.0
X80.0
UNITS
Length : mm
Flux density : gauss
Magnetic field : $A\ m^{-1}$
Scalar potential : A
Vector potential : $Wb\ m^{-1}$
Conductivity : $S\ m^{-1}$
Current density : $A\ m^{-2}$
Power : W
Force : N
Energy : J
Electric field : $V\ m^{-1}$
PROBLEM DATA
u61quarter5.toscab
TOSCA analysis (nl)
Magnetostatics
Case No 1
23903 elements
27212 nodes
Nodal fields
Nodal coil fields
LOCAL COORDS
Xlocal = 0.0
Ylocal = 0.0
Zlocal = 0.0
Theta = 0.0
Phi = 0.0
Psi = 0.0
19/Oct/98 13:27:09 Page 5
OPERA-3d
Post-processor 2.801


Z-60.0
Z-40.0
Z-20.0
X60.0
0
X-20.0
X-40.0
X-60.0
Y-20.0
Z40.0
Z60.0
Y-40.0
Y-60.0
19/Oct/98 17:22:47 Page 8
OPERA-3d
Pre-processor 2.601

APS ID VACUUM CHAMBER FAMILY

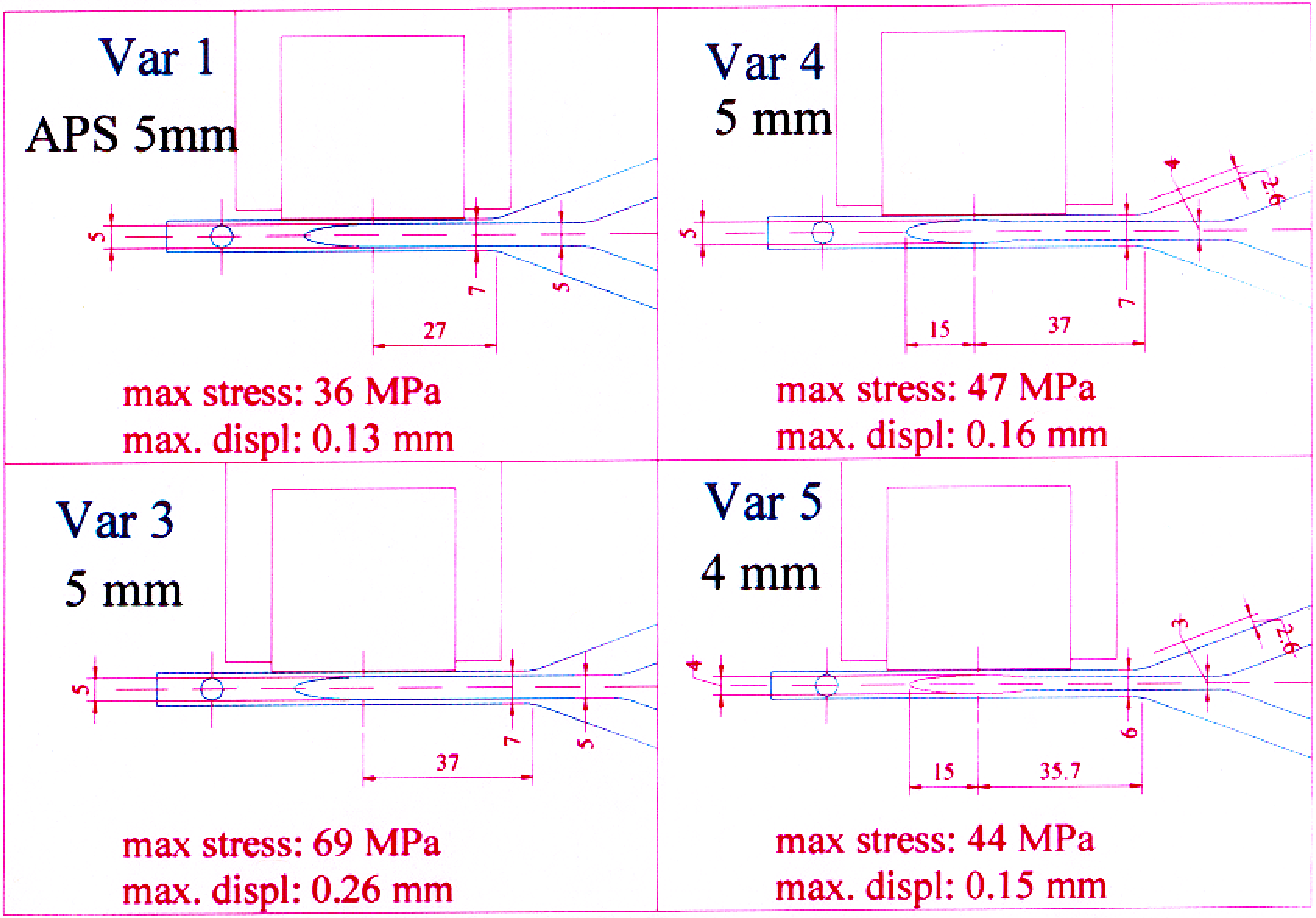
(E.M. Trakhtenberg, E. Gluskin, S. Xu, Rev. Sci. Instr. 66 1995, 1809-1811)



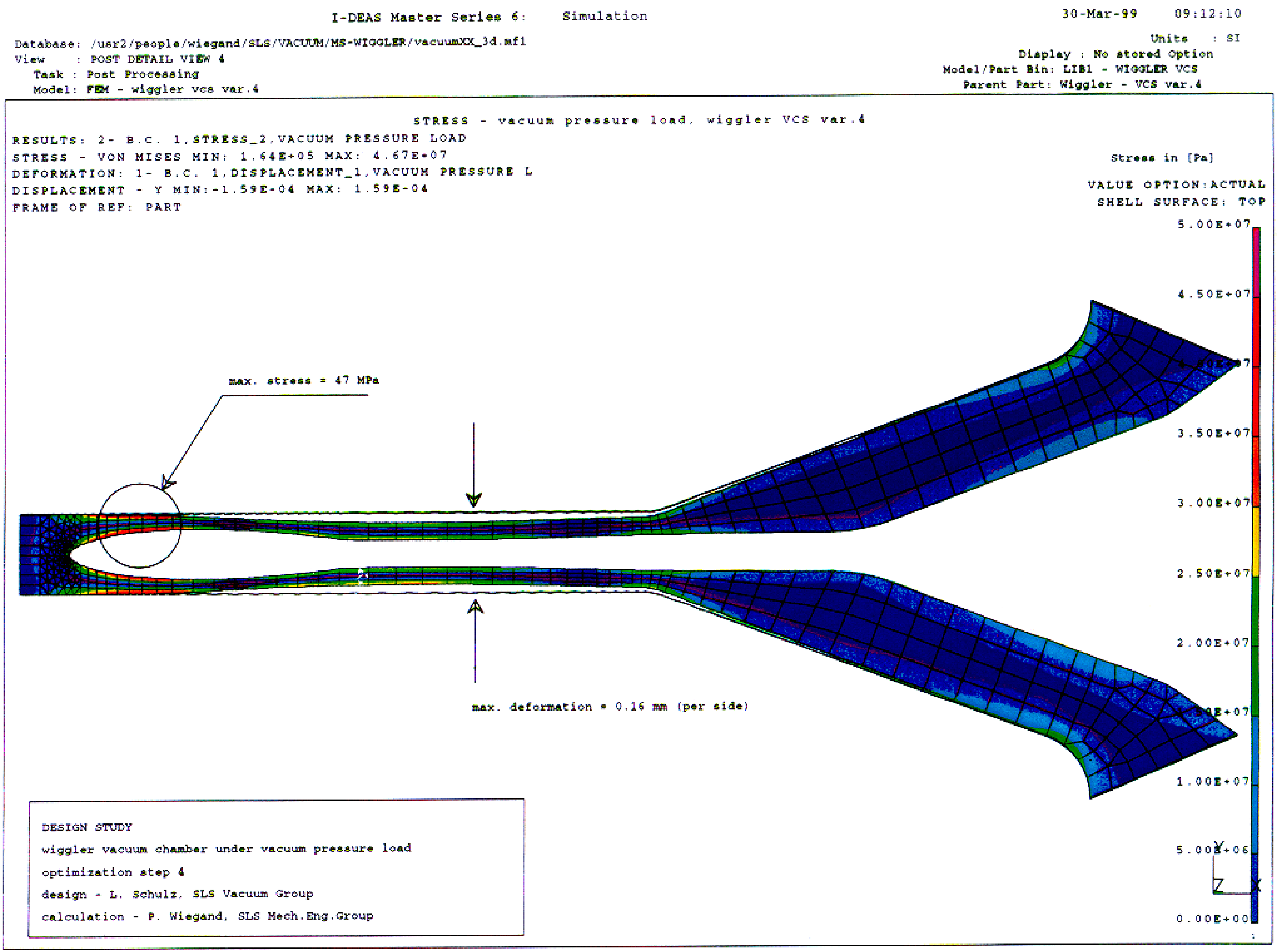


SLS ID Vacuum

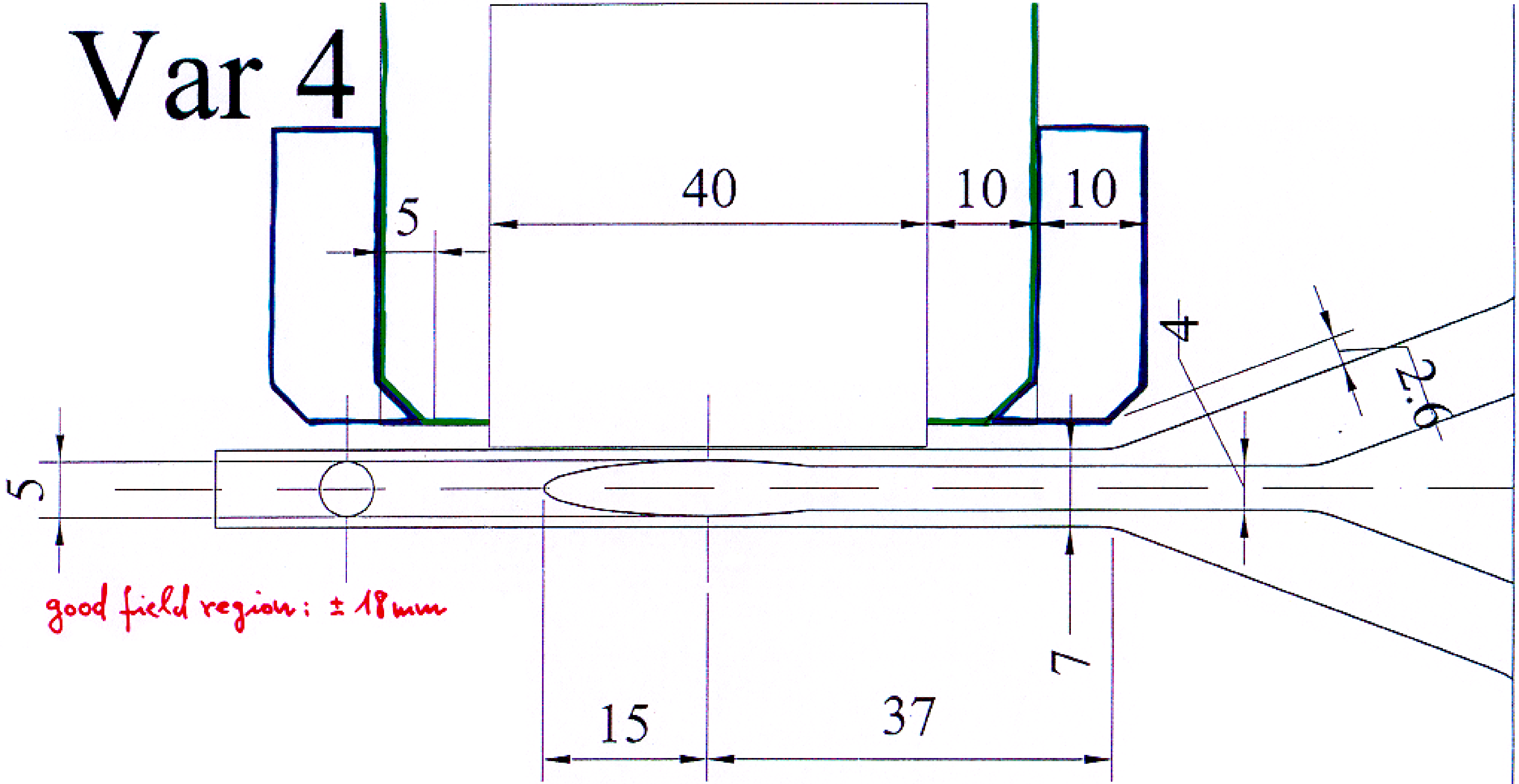
Variations of the APS Small Gap Chamber



preliminary studies


I-DEAS Master Series 6: Simulation
30-Mar-99 09:12:10
Database: /usr2/people/wiegand/SLS/VACUUM/MS-WIGGLER/vacuumXX_3d.mf1
View : POST DETAIL VIEW 4
Task : Post Processing
Model: FEM - wiggler vcs var.4
Units : SI
Display : No stored Option
Model/Part Bin: LIB1 - WIGGLER VCS
Parent Part: Wiggler - VCS var.4
STRESS - vacuum pressure load, wiggler VCS var.4
RESULTS: 2- B.C. 1,STRESS_2,VACUUM PRESSURE LOAD
STRESS - VON MISES MIN: 1.64E+05 MAX: 4.67E+07
DEFORMATION: 1- B.C. 1,DISPLACEMENT_1,VACUUM PRESSURE L
DISPLACEMENT - Y MIN:-1.59E-04 MAX: 1.59E-04
FRAME OF REF: PART
Stress in [Pa]
VALUE OPTION:ACTUAL
SHELL SURFACE: TOP
5.00E+07
4.50E+07
3.50E+07
3.00E+07
2.50E+07
2.00E+07
1.00E+07
5.00E+06
0.00E+00
max. stress = 47 MPa
max. deformation = 0.16 mm (per side)
DESIGN STUDY
wiggler vacuum chamber under vacuum pressure load
optimization step 4
design - L. Schulz, SLS Vacuum Group
calculation - P. Wiegand, SLS Mech.Eng.Group

Var 4

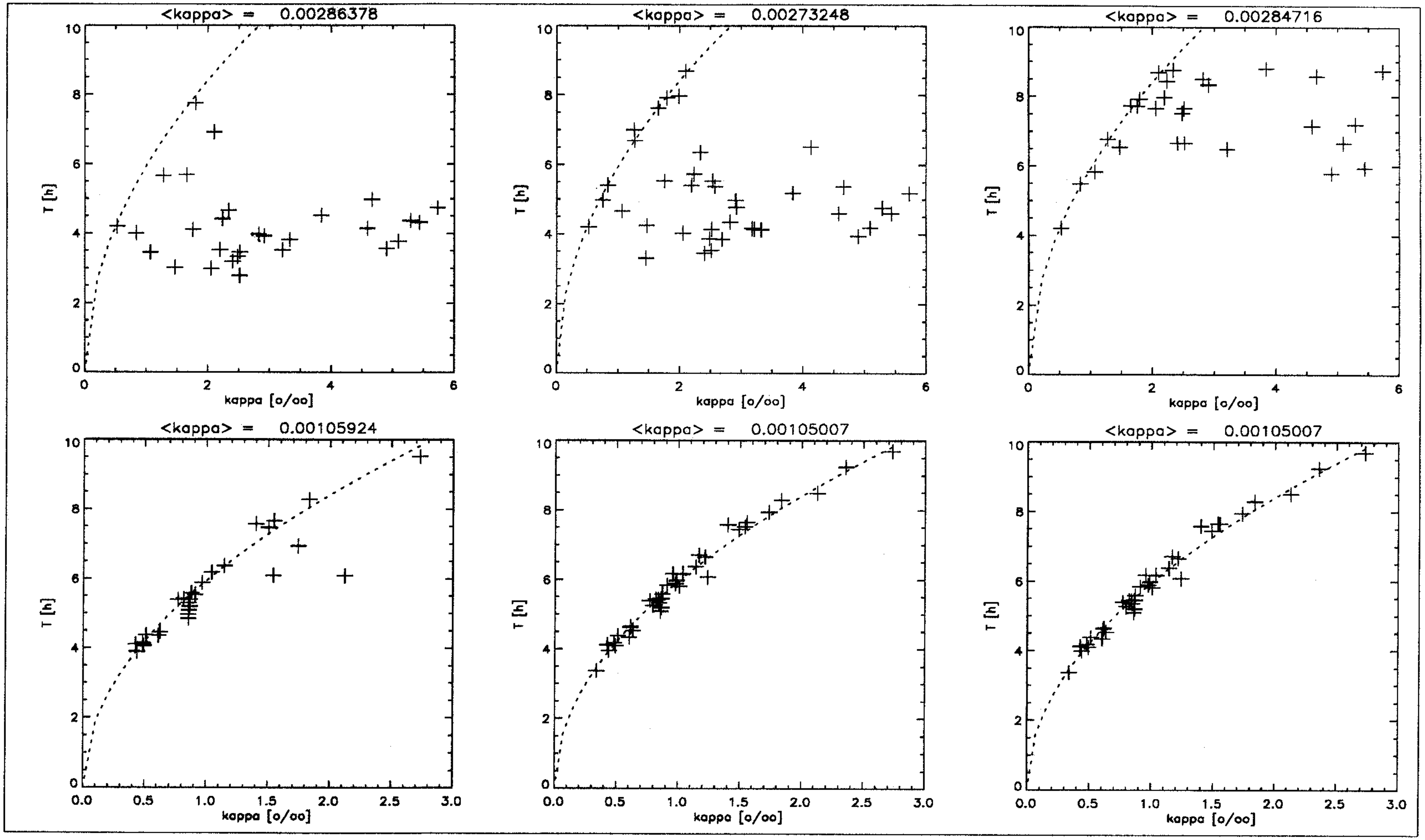


max stress: 47 MPa

max. displ: 0.16 mm

BEAM LIFETIME STUDIES FOR THE SLS STORAGE RING

M. Böge, A. Streun, Paul Scherrrer Institut, 5232 Villigen, Switzerland



3 mm **4 mm** **32 mm**

Touschek lifetime vs. coupling for different full gap heights
Upper row without, lower row with coupling correction.
Dotted curve: T~sqrt(kappa) for the error free lattice : points not lying on this curve indicate beam losses

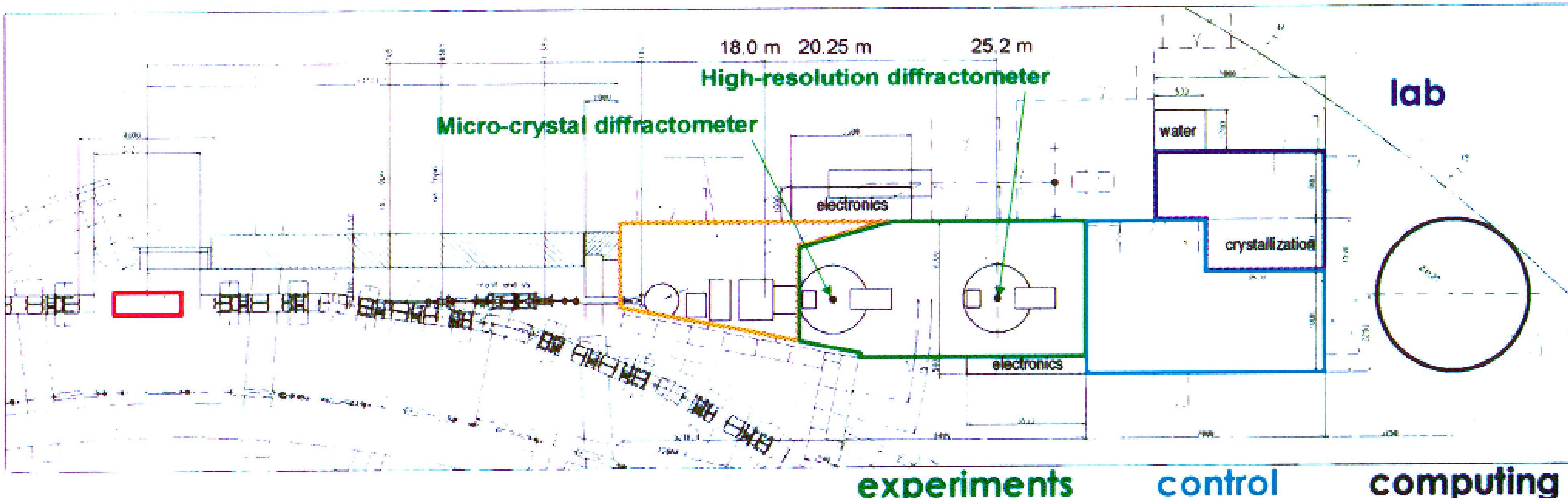
$\kappa = \varepsilon_y / \varepsilon_x$

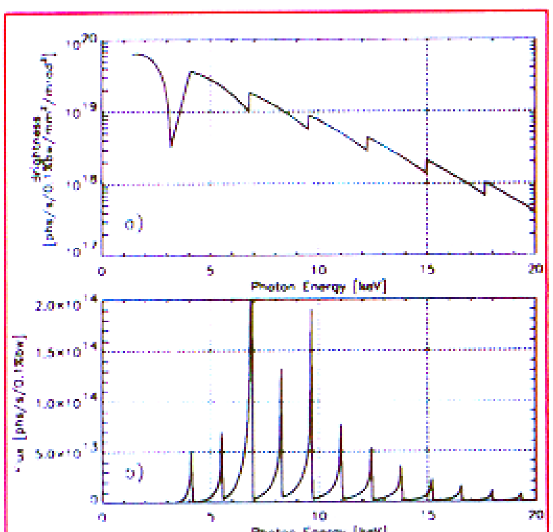
SLS Protein Crystallography Beamline 6S

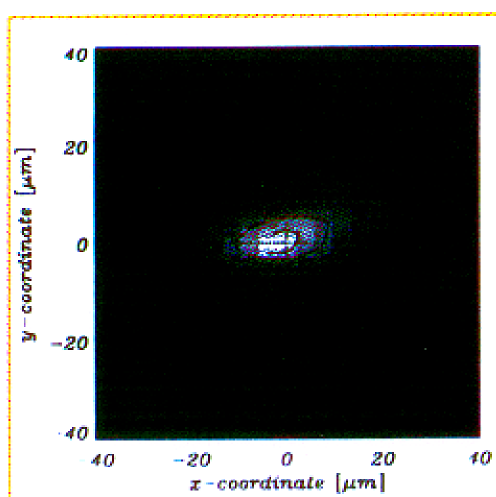
High Brighness In-Vacuum Undulator Radiation

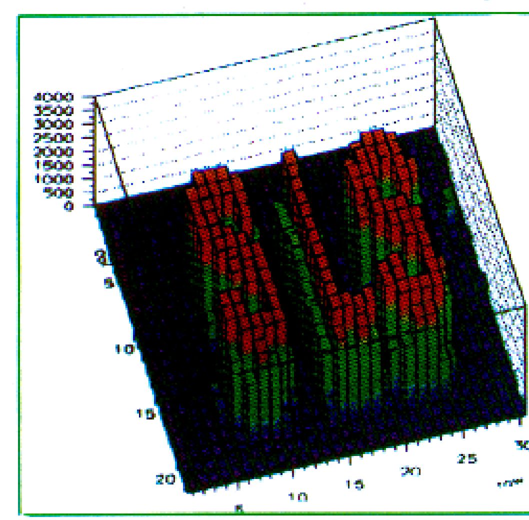
Decoupled, dynamically focussing optics

Fast read-out, large area Pixel Detector









Clemens Schulze. bl_layout_180999

Scientific Motivation

- micro-crystals
- large unit cell structures

but

$$I_{hkl} \approx \frac{V_x}{V_c} \times I_0$$

V_x: crystal volume ↘
V_c: unit cell volume ↗ → I_0: primary beam intensity ↑

high flux
/ (small area
x low divergence) → **HIGH BRIGHTNESS**

- Multi-wavelength Anomalous Diffraction

SLS Advantages

- high brightness undulator radiation
- small source point (low β-section)
- short distance between source and optics
- tunability

Detector Requirements

Suitable detector for the SLS PX-beamline must be adapted to:

Main Beamline Properties

- Static protein crystallography of crystals with small physical dimensions as well as large unit cell structures
- Energy range: 5-17.5 keV
- Beam intensity: max 10^{13} X-rays/s on probe

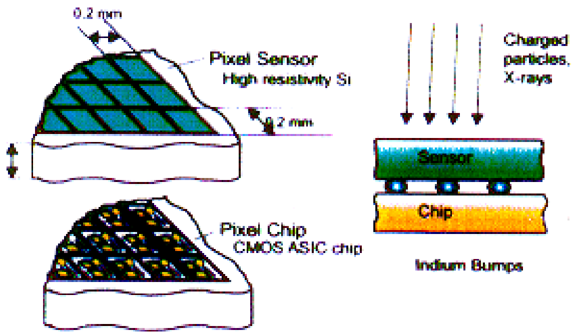
Needs of PX experiments

- Large area
- Fast read-out
- Low noise -> single photon counting detector

Pixel Detector Development

F1: CMS Collaboration: R. Horisberger et al, SLS: Christian Brönnimann

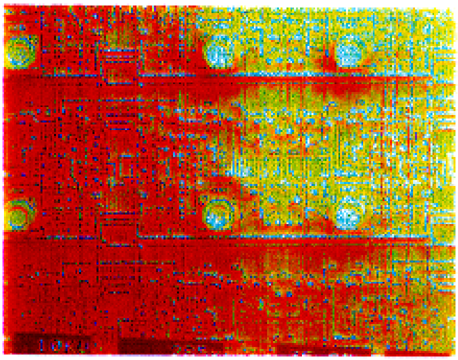
Principle



- Single photon counters
- Fast read-out, good energy and position resolution
- Architecture of pixel chip is dependent on application
- Choice of sensor material: (e.g. Si, GaAs)

Status

- Development of ASIC chips in CMOS technology
- Development of in-house bump bonding facility
- Goal: Assembly of large pixel detectors (>10^6 pixels)



REM-scan of 22x30 prototype pixel chip

Applications

- Tracking detectors for charged particles with excellent position resolution (~20µm) and very fast readout (particle physics).
- Imaging detectors for X-rays (Protein crystallography, powder diffraction, medical applications at SLS)

Typical measurement at SLS / PX - beamline

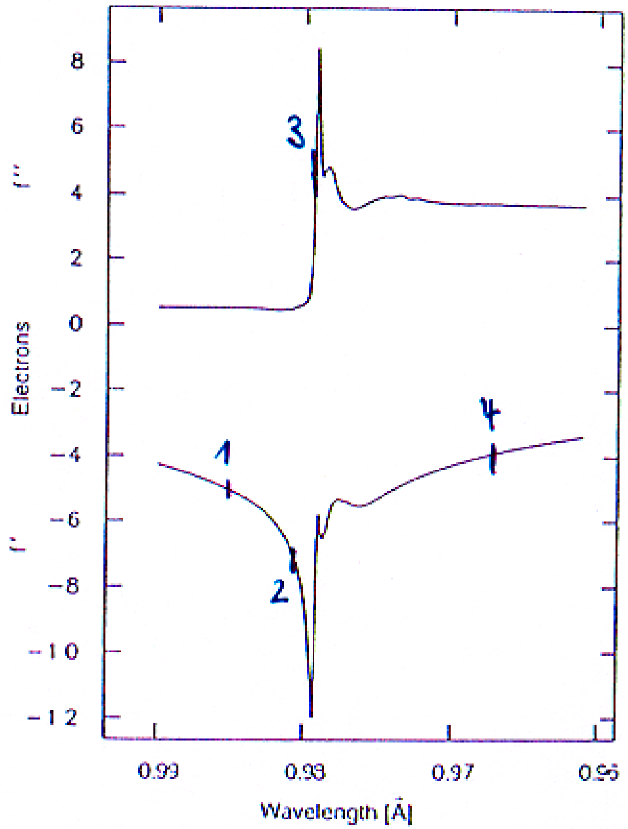


FIG. 2. Anomalous scattering factors near the absorption edge of selenium from a crystal of *E. coli* selenomethionyl thioredoxin. This spectrum was measured at SSRL beam line 1-5 at high resolution. (Reproduced from Ref. 18, by permission of Oxford University Press.)

Se edge : 12.6 keV
Br edge : 13.5 keV } 90% of all measurements in this region

→ measurements at photon energies 1, 2, 3, 4
energies 1-3 within linewidth (0.5% FWHM) : scan monochrometer only
ΔE (1-3) = 25 eV

energy 4 : undulator gap change, $\Delta g = 50\,\mu m \mathrel{\hat{=}} \Delta E \approx 150$ e
ΔE (1-4) = 150 eV

measurement cycle: energy 1 2 3 4 — θ (rotate crystal)

1	2	3	4	θ
· →	· →	· →	· ↓	0°
· ←	· ←	· ←	·	5°
↓ · →	·	. . . .		10°
				⋮

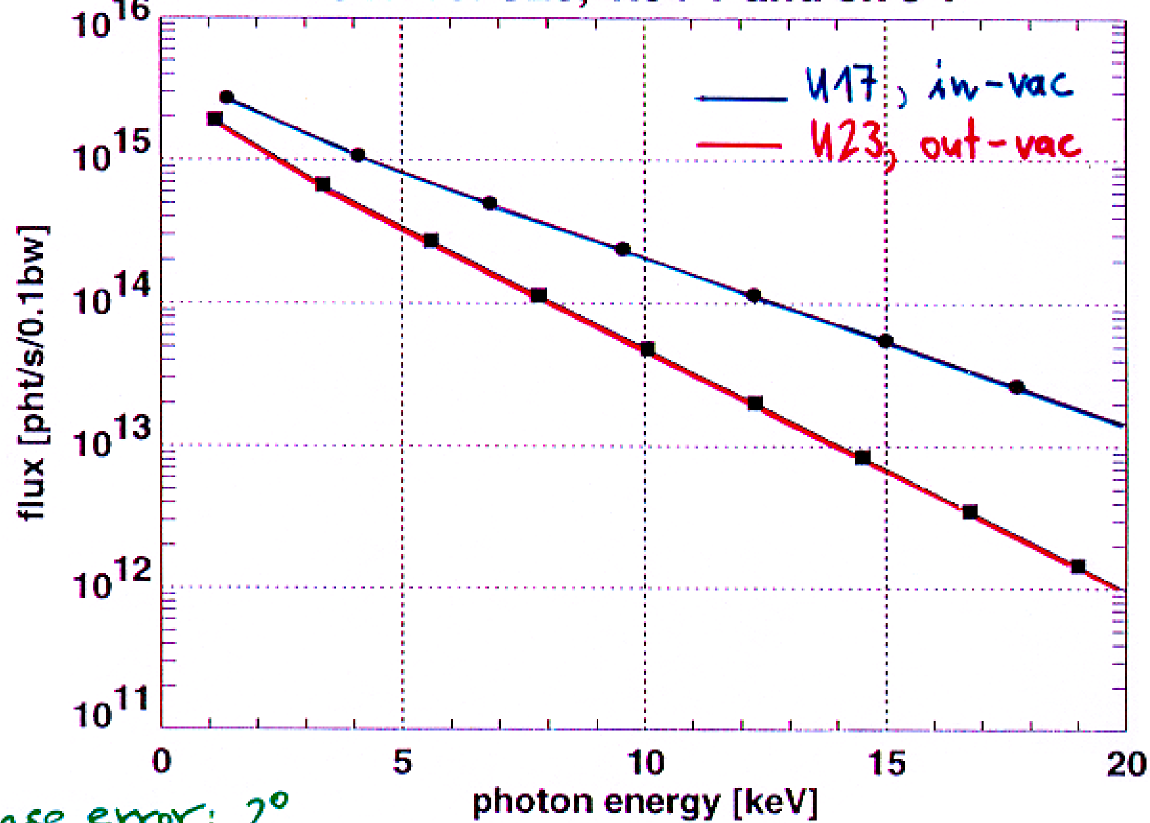
50 measurements / setpoint

1 measurements takes ~ 1 sec with Pixel-Detector

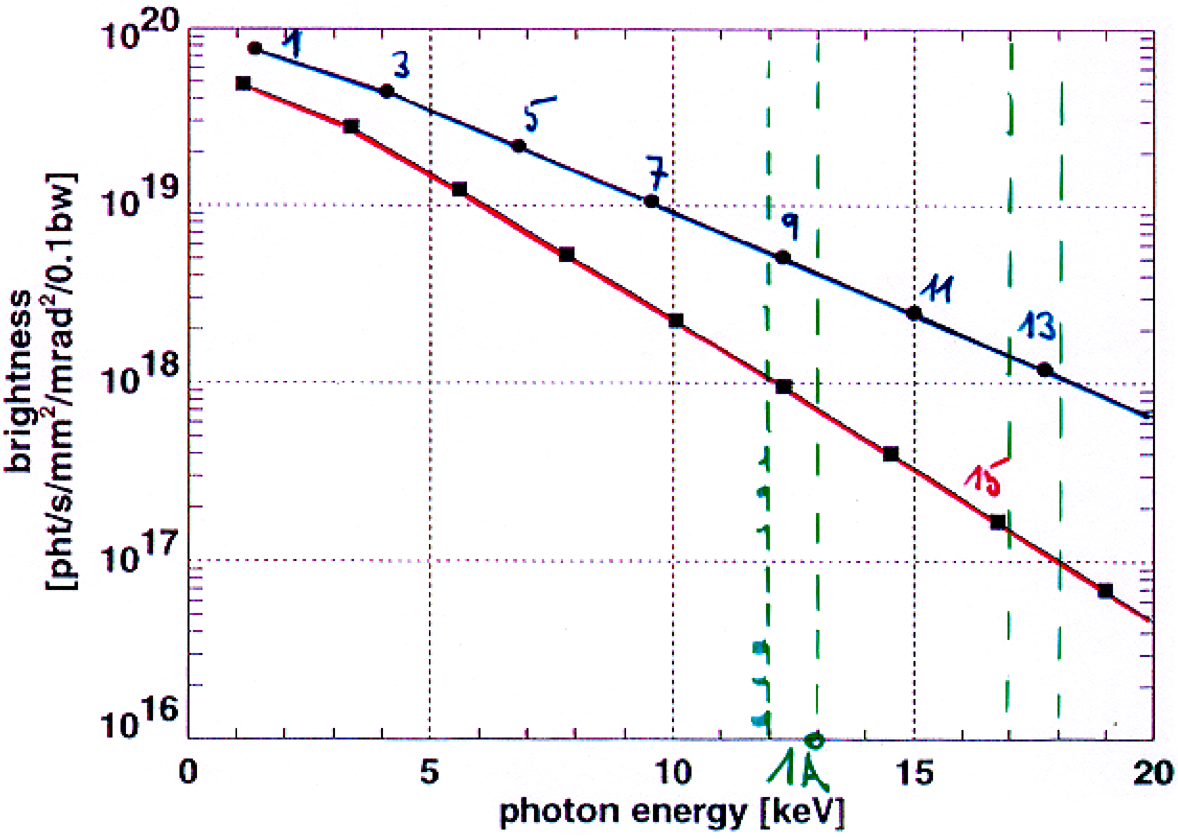
⇕ no backlash for the drive system;

tuning range 12-14 keV $\mathrel{\hat{=}} \Delta g = 4-5$ mm

U17 vs. U23, 1.04 T and 0.70 T



phase error: 2°



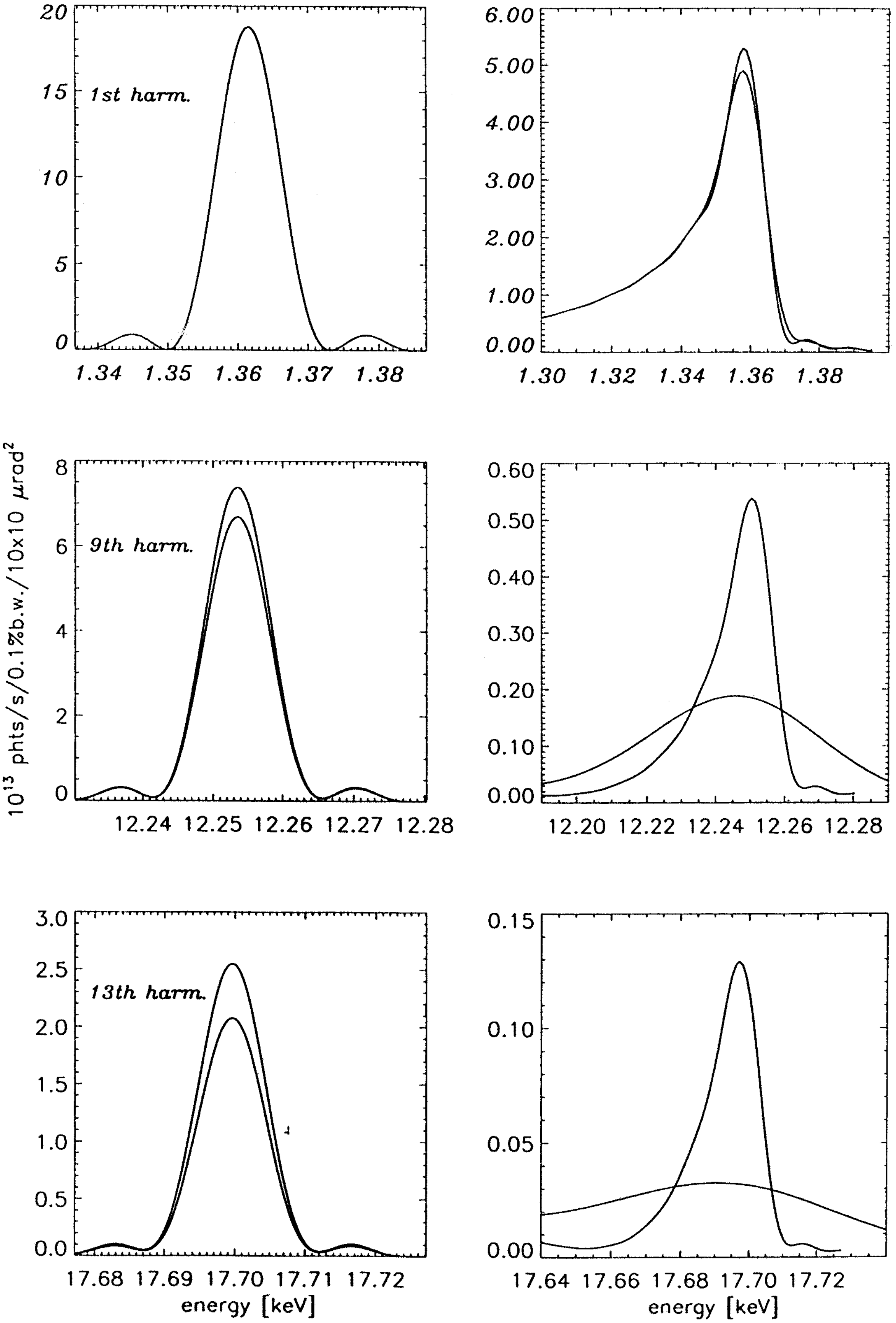
C. Schulze, outin.ps, Fri Oct 30 07:53:00 1998

PX - undulator

real beam

single electron spectra

spectra including emittance and energy spead



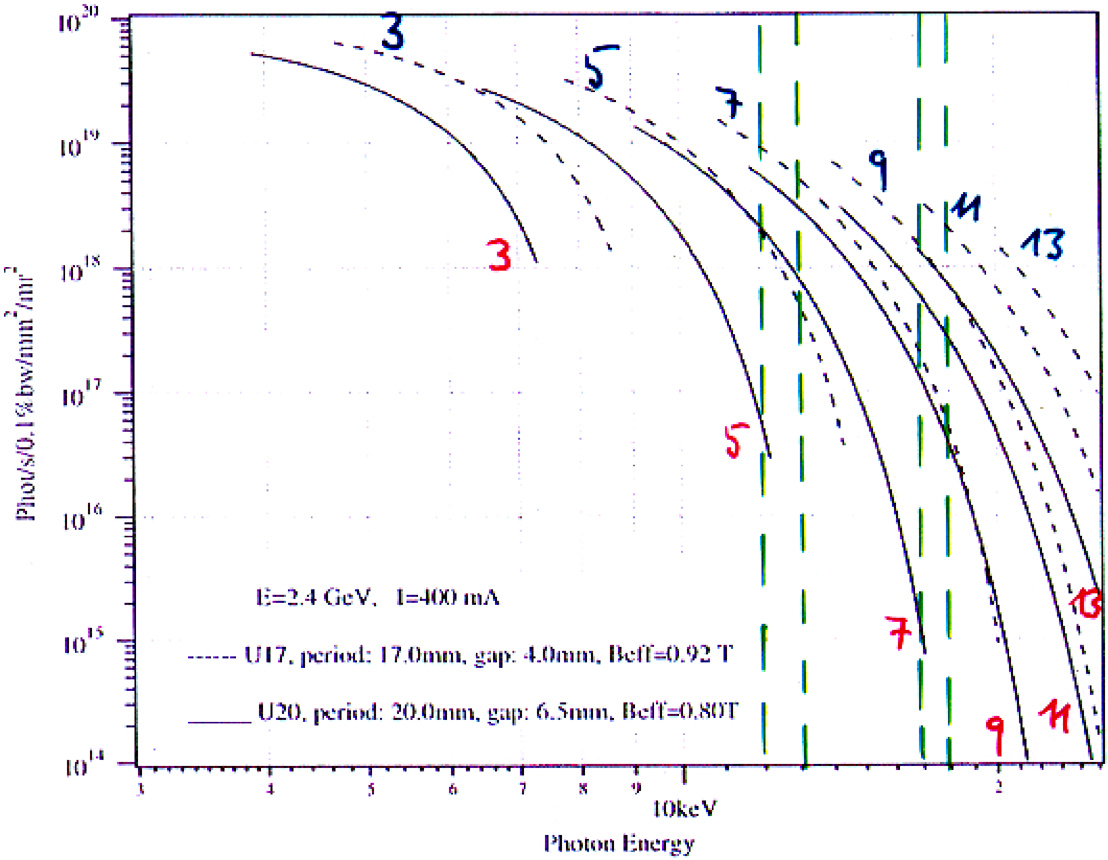
Distance: 10 m, I = 400 mA, pinhole 0.1 x 0.1 mm²

C. Schulze, sac1198.ps, Fri Oct 23 16:07:54 199

Magnet Materials

(A)	Sm_2Co_{17}	$B_r = 1.05T$ $H_{cJ} \simeq 1850\,kA/m$	Vacomax 225 HR
(B)	$Nd_2Fe_{14}B$	$B_r = 1.15T$ $H_{cJ} \simeq 2300\,kA/m$ $H_{cJ} \simeq 1980\,kA/m$	Neomax-32 EH, Vacodym 400 HR Neomax-33 UH
(C)	$Nd_2Fe_{14}B$	$B_r = 1.21T$ $H_{cJ} \simeq 1950\,kA/m$	Neomax-35 EH, Vacodym 396 HR
(D)	$Nd_2Fe_{14}B$	$B_r = 1.26T$ $H_{cJ} \simeq 1600\,kA/m$	Neomax-39 SH, Vacodym 383 HR

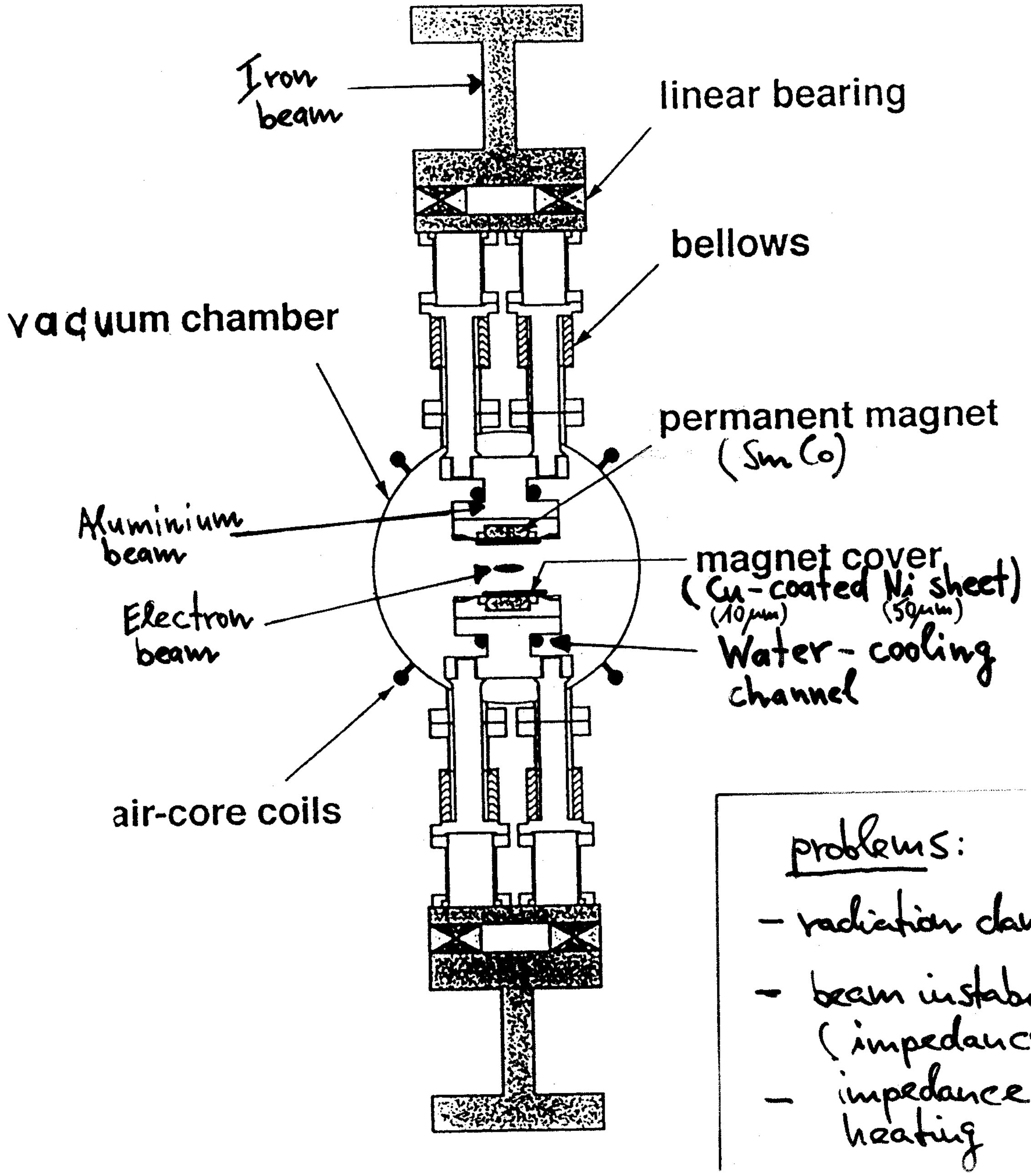
in-vacuum undulator : materials (A), (B)
out-vacuum undulator : materials (A) - (D)



U20 : out-vacuum option, 4mm APS chamber (has to be developed)
NdFeB - magnets, $B_r \approx 1.26$ T

In-Vacuum Undulators (risky technology!)

g = 4.0mm



problems:

- radiation damage
- beam instabiliti (impedance)
- impedance heating

1.) Bessy "in-vacuum" undulator (first in-vac device, medium vacuum)

2.) SPring-8 (ultra-high vacuum)

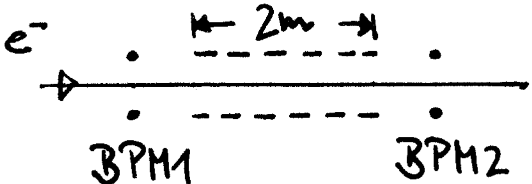
→ SPring-8 / NSLS

→ SPring-8 / ESRF

→ ESRF - - → ESRF / PSI (collab.)

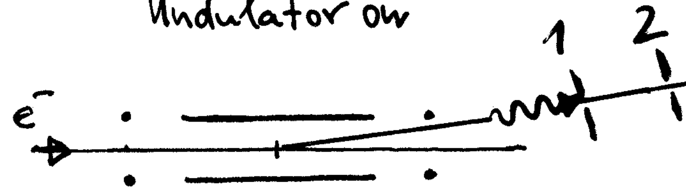
Alignment

"Undulator off"



"straight line" reference: electron beam

"Undulator on"

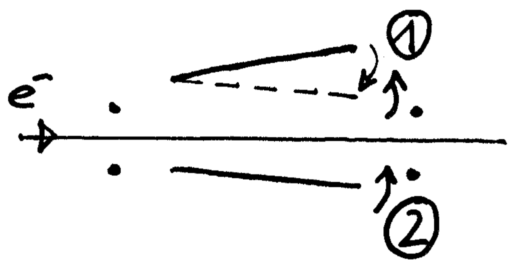


"straight line" reference: photon beam

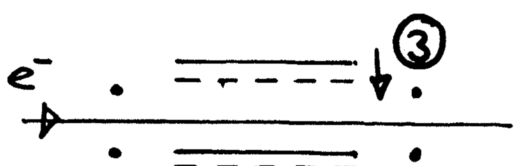
In general there is: (neglect bending | sag)

gap taper
" tilt
" offset

} ⇒ measure ⊕ correct



		monitor:
①	correct: gap taper (≲ 5 μm)	abs. lin. Encoder
②	correct: gap tilt	tilt-sensor?
③	correct: gap offset	lifetime, bremsstrahlung

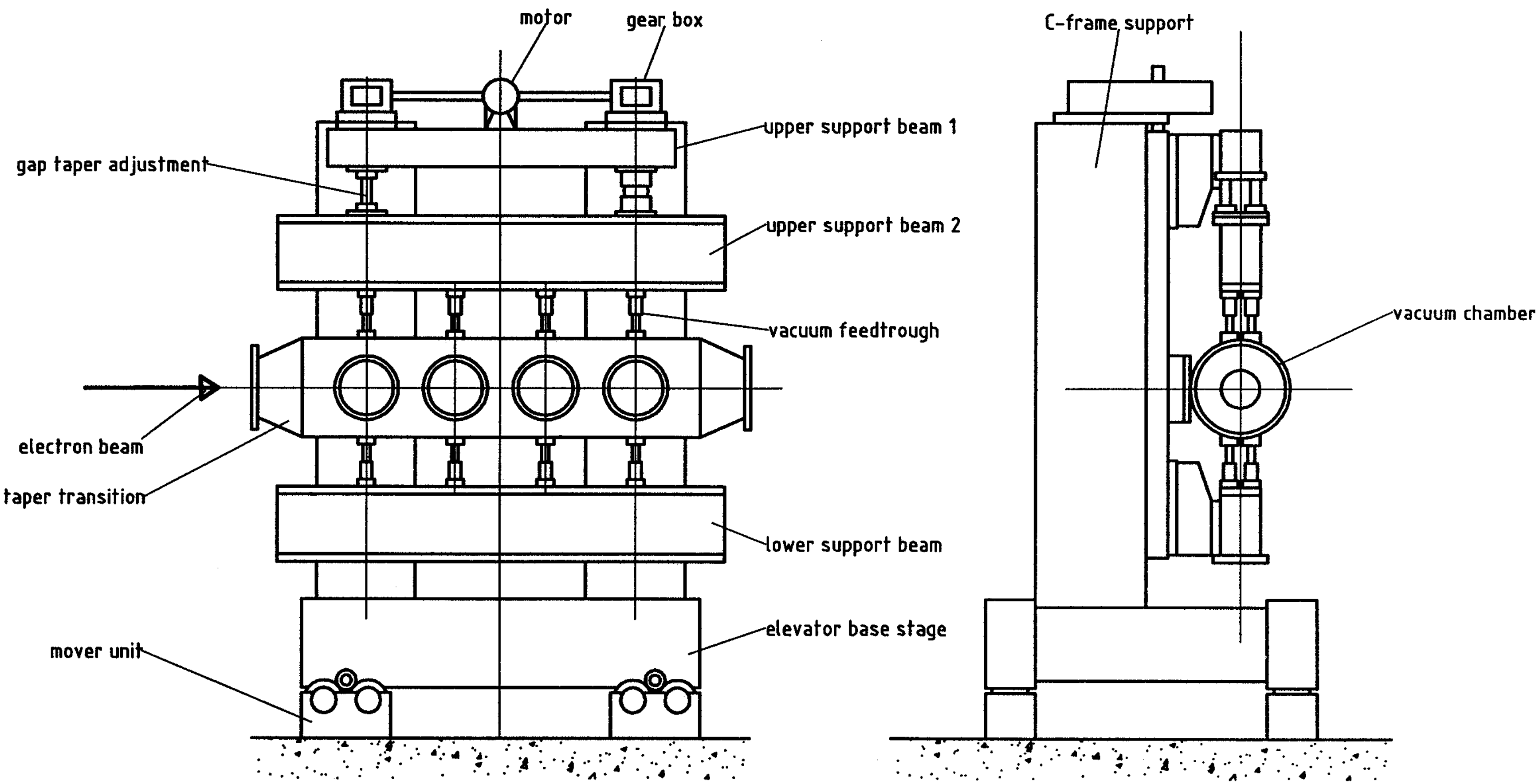


Drive system

coarse gap-adjustment : switch undulator on | off
fine " " : correct gap taper

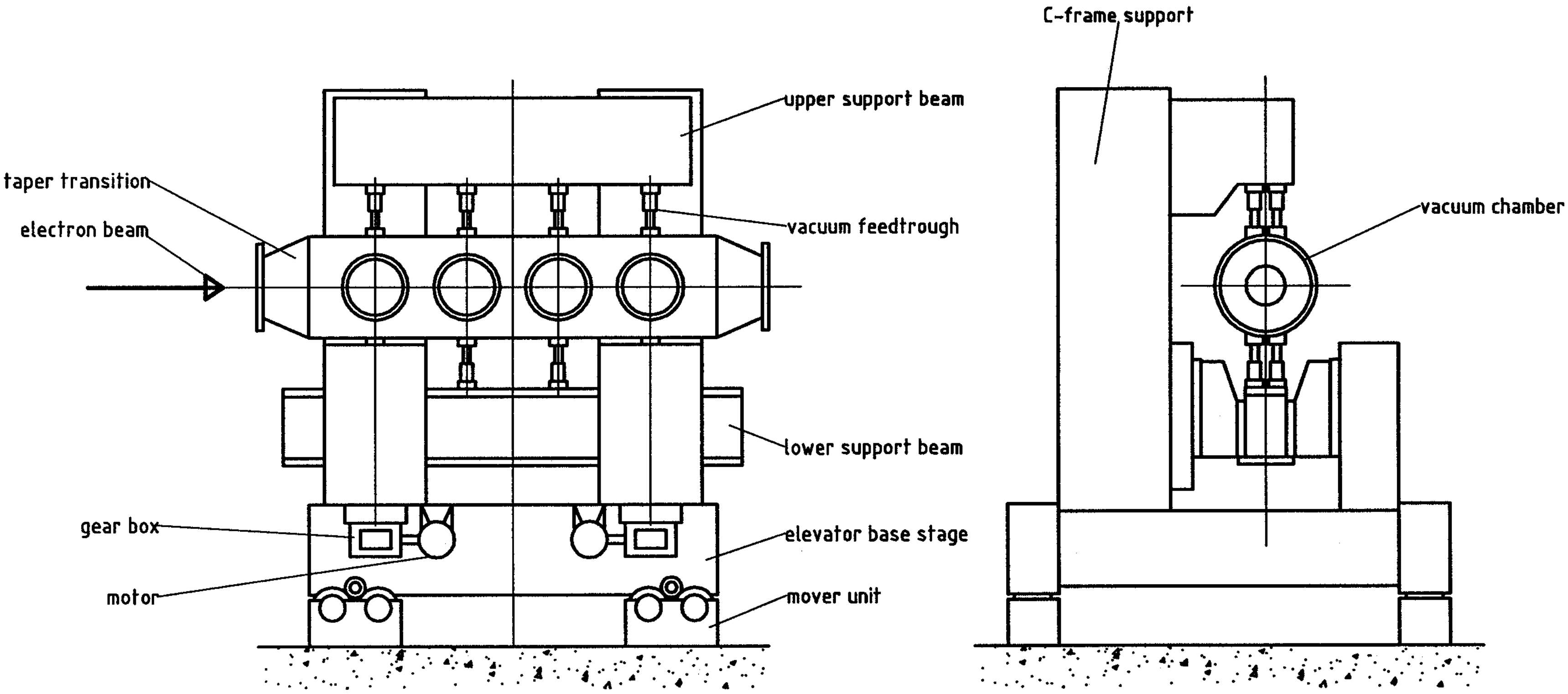
fine adjustment undulator support : correct gap tilt
" " offset

In - Vacuum Undulator
Support and Drive System



SLS	
Vakuum Undulator Var. I	
Uebersichtskizze	2-30040.36.036

In - Vacuum Undulator
Support and Drive System



Anlage SLS

Baugruppe Vakuum Undulator Var. II

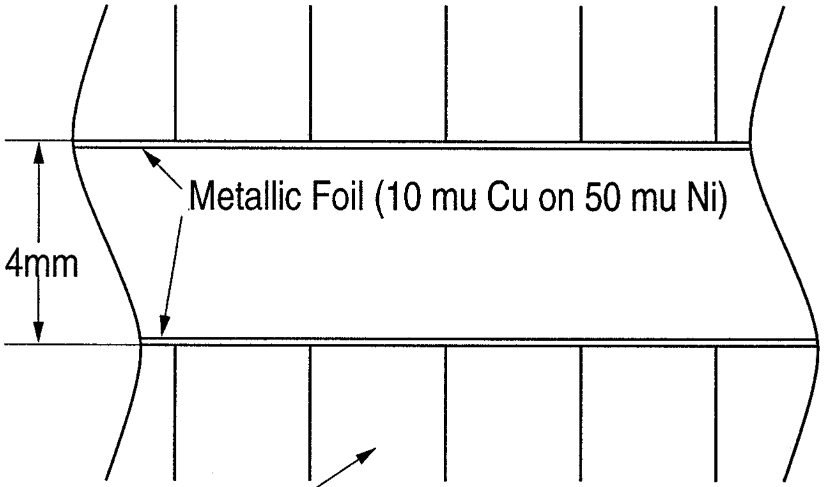
PSI

Uebersichtskizze

2-30040.36.037

Resistive Impedances in the SLS In Vacuum Undulator

Structure Layout:



Total undulator length: 2m

Above 43 MHz resistance dominated by Cu layer, 10-43 MHz by Ni layer

Assuming constant gap height (reality: periodic variation by app. 0.2 mm)

Results

	Undulator	Std. ring chamber
Z/n	1 mOhm	39 mOhm
Max. transverse Impedance (f. tune 0.44)	3.4 MOhm/m	1.3 MOhm/m
Corr. CB instability growth rate	0.55 ms	1.5 ms
Conductive Losses:		
100% fill/0.4A	11 W/m	3.1 W/m
4 nC single bunch	0.5 W/m	0.2 W/m

Missing:

- Behaviour <10 MHz (Global Layout!)
- Gap height variations (Z/n, long range wakes)