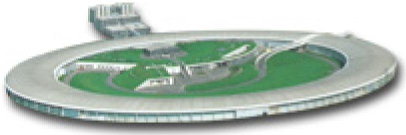


ESRF Insertion Devices

1 Status
- Installed IDs
- standard IDs
- R&D

2 Circular polarisation
- undulators
- wigglers

3 In vacuum IDs
- status
- technology
- R&D

J.Chavanne, C. Penel ,B. Plan, F.Revol

Installed IDs

Segments	Type	Length [m]	Min Gap [mm]	Material
6	In-vacuum Undulators	~ 2	5-6	Sm_2Co_{17}
13	Undulators & 3T Wiggler	~ 1.6	11	NdFeB
38	Undulators	~ 1.6	16	NdFeB
8	Wigglers	~ 1.6	20-25	NdFeB
65	Total			

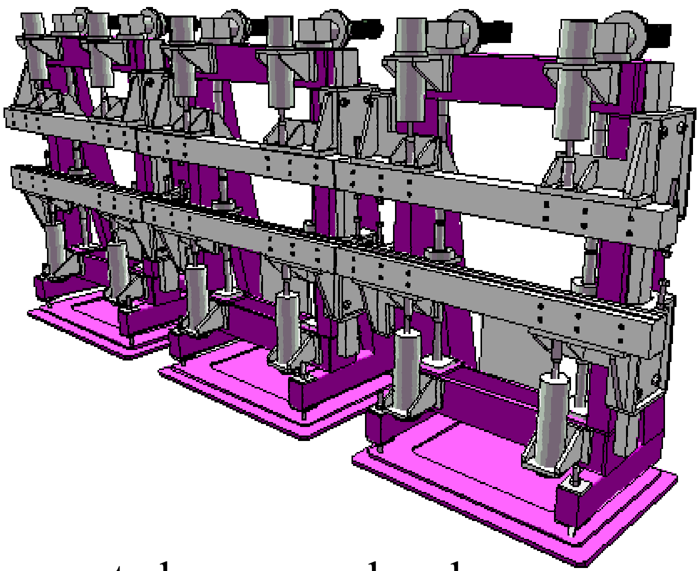
A Number of Exotic Ids : Helical, Aplle II, Quasiperiodic,….
More Details @ : http://www.esrf.fr/machine/groups/insertion_devices/Ids/installed_IDs.html

ID Segmentation

3 independent segments/ straight section (5 m)

Advantage=beamline flexibility

- can be 3 different magnetic structures
- optimum cumulated length vs. heat load
- limits failure impact on beamline operation



End of December 2002

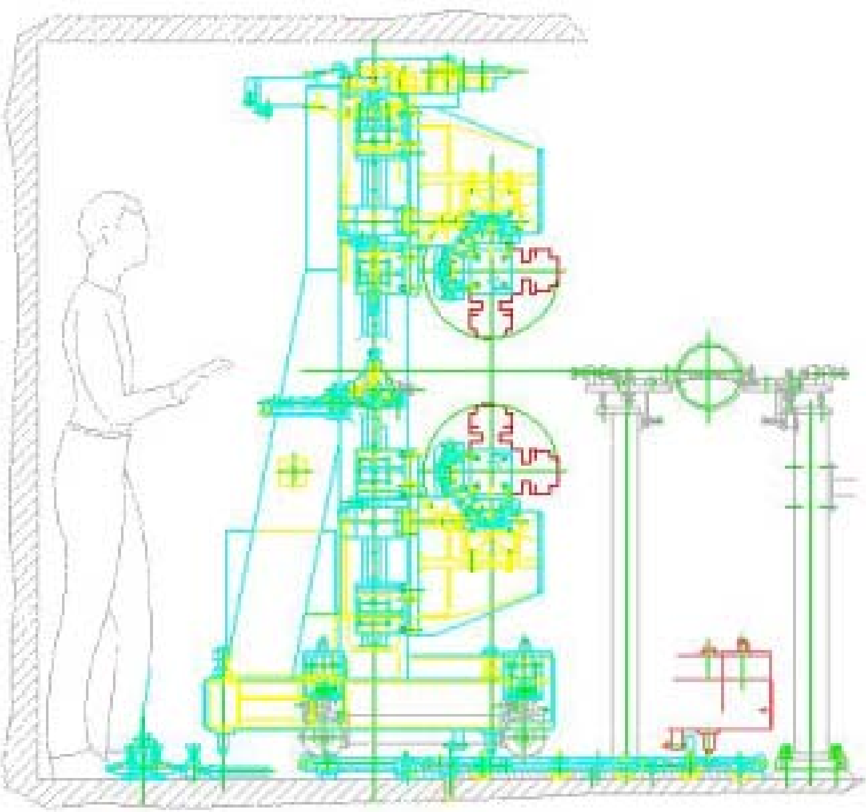
Fully equipped straights: 21
Straights with one free position: 6
Straights with two free positions: 1

2003/2004:
Start upgrade of a number of straights:
15 mm stainless steel ----> 10 mm aluminium neg coated vacuum chambers

≈ 12 new magnet assemblies; U32,U35 & shorter period U2x

Revolving Undulators

Additional degrees of freedom for beamlines:



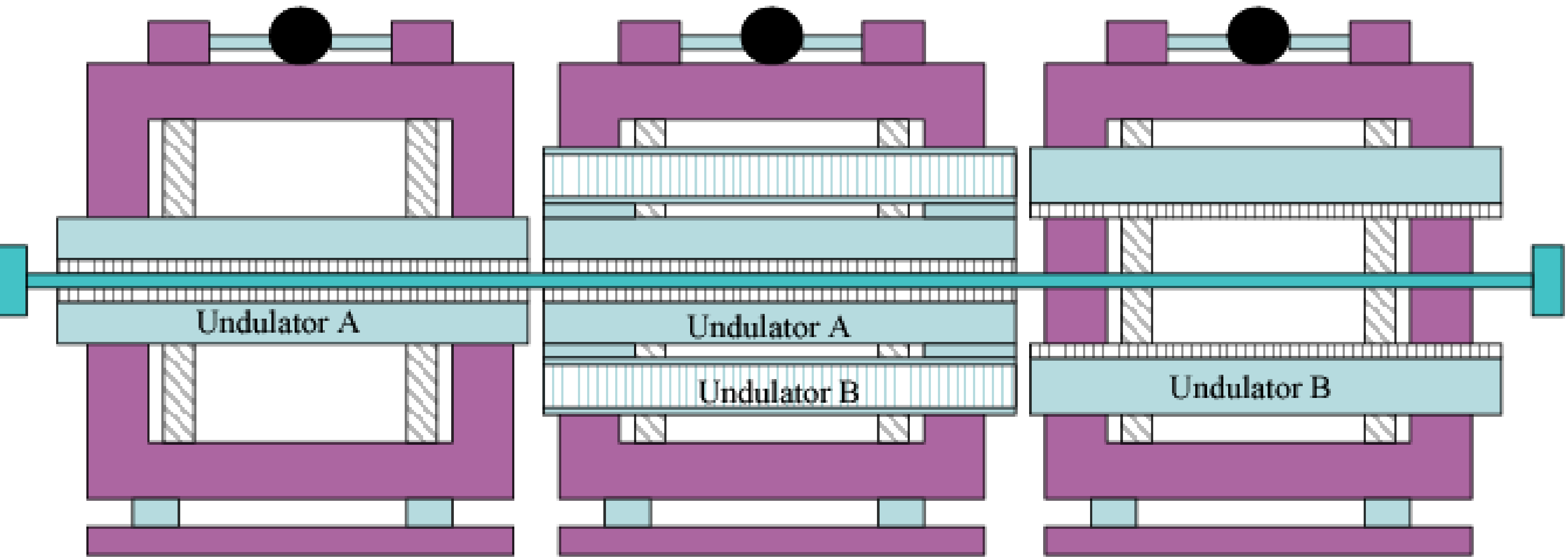
2 different undulators on the same support:

Features:
-Length: 1.6 m
-Interchangeable with standard IDs
-Compatible with all vacuum chambers

Status
-first prototype end of December 2002
-Construction of three devices in 2003

Revolving Undulators

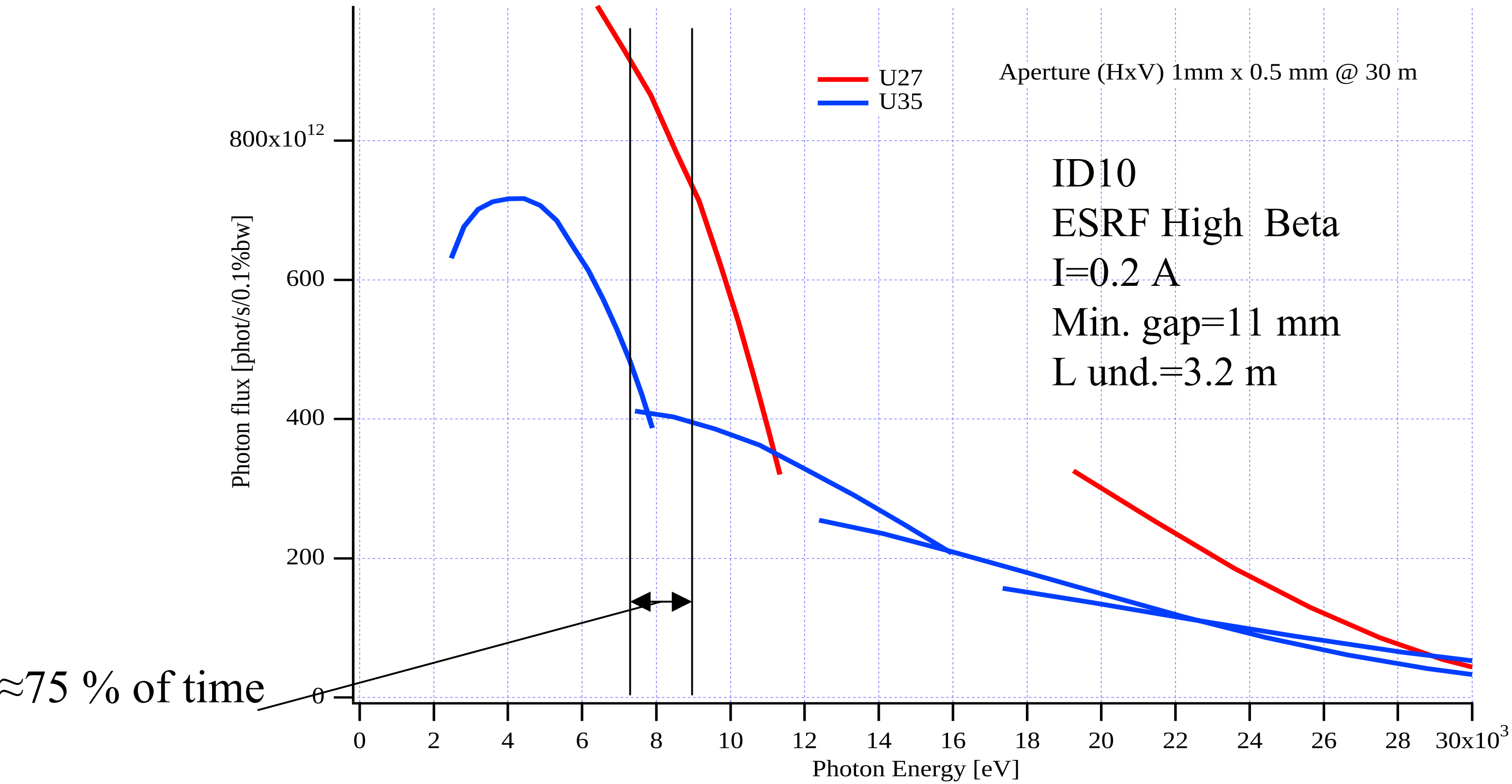
A simple example:



Standard undulator | Revolver undulator | Standard undulator

Result: two 3.2 m long undulators in a 5 m straight section

Revolving Undulators



Typical Revolver Undulator :

- K=2.2, Continuously Tunable
  Period ~ 35 mm @ 11 mm

\+

K=1-1.5 High Brilliance but limited tunability :
Period ~ 18-27 mm @ 11 mm

Circular polarization

Photon energy: 0.4 to ≈ 15 keV

Helical undulators

6 devices installed:

"HELIOS" type :

2 devices

$\lambda_0 = 52$ mm

APPLE II type:

3 devices

$\lambda_0 = 38$ & 88 mm

1 Electromagnet/permanent magnet device: $\lambda_0 = 80$ mm

Photon energy:> 20 keV

Asymmetric wigglers

3 devices installed:

1- B_0=1.1 T, $\lambda_0 = 210$ mm, 7 periods

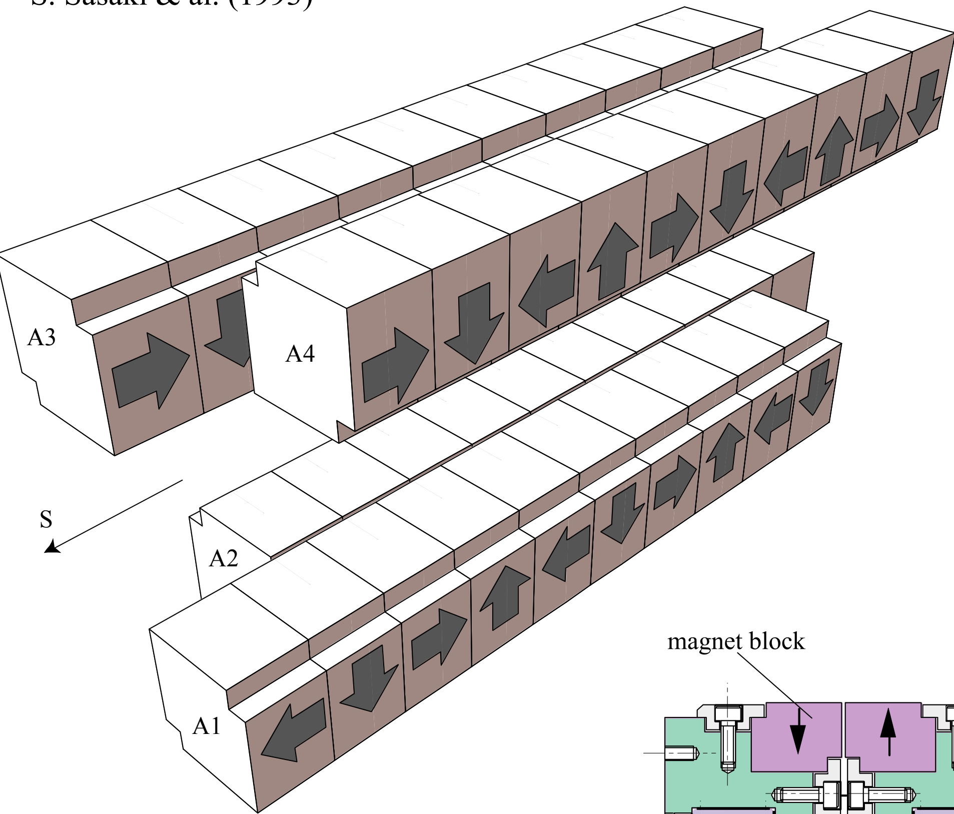
2- B_0=1.9 T, $\lambda_0 = 230$ mm, 7 periods

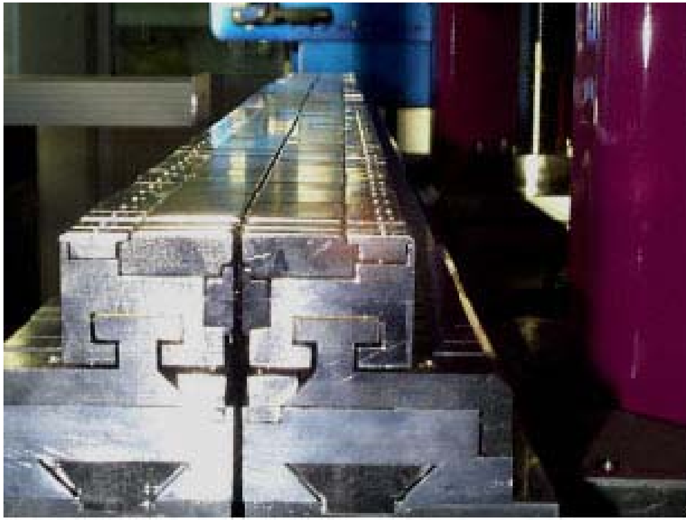
3- B_0=3.1 T, $\lambda_0 = 375$ mm, 2 periods

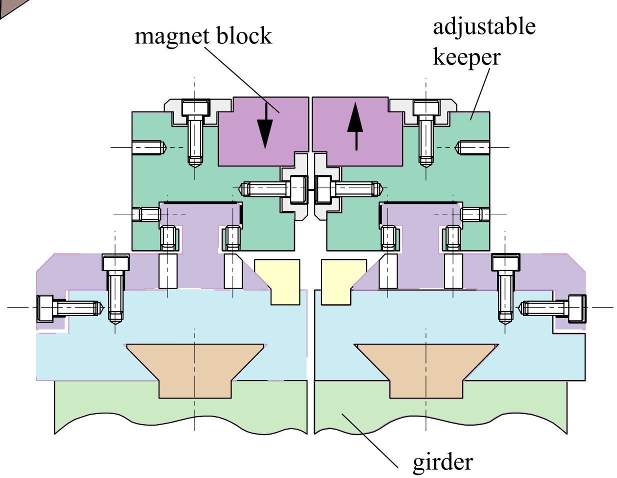
Fast flipping of circular polarization is important (circular dichroism)

APPLE II undulators

S. Sasaki & al. (1993)







λ_0=88 mm

- L= 1.6 m
- E_f :0.3 - 2.5 keV

λ_0=38 mm

- L= 1.6 m
- E_f : 3.5 - 8 keV

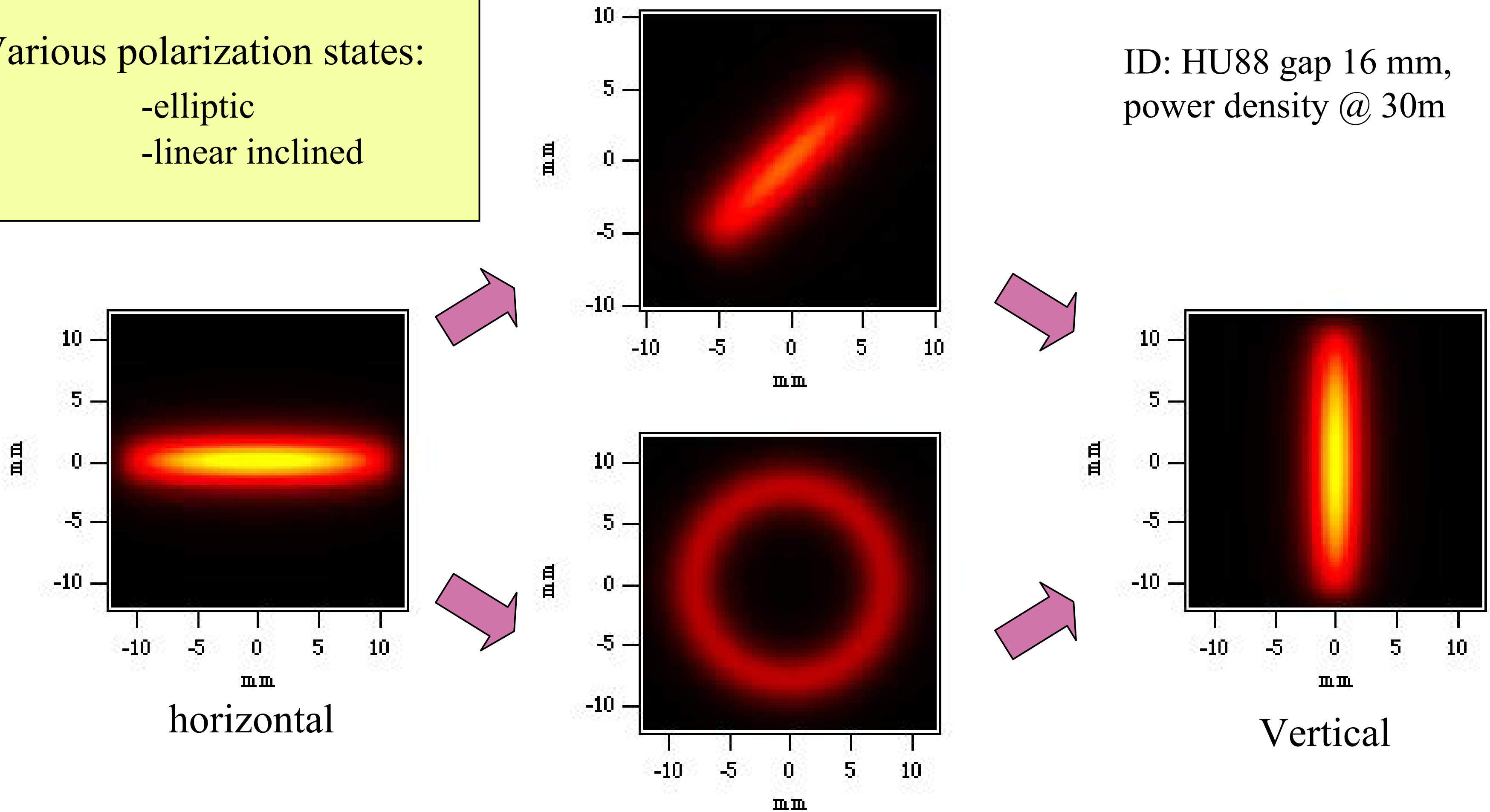
APPLE II undulators

Advantage: High flexibility

Various polarization states:

- -elliptic
- -linear inclined

ID: HU88 gap 16 mm,
power density @ 30m



APPLE II undulators

- Drawback :

-> Complicated technology

-mechanically (forces)

-field error correction

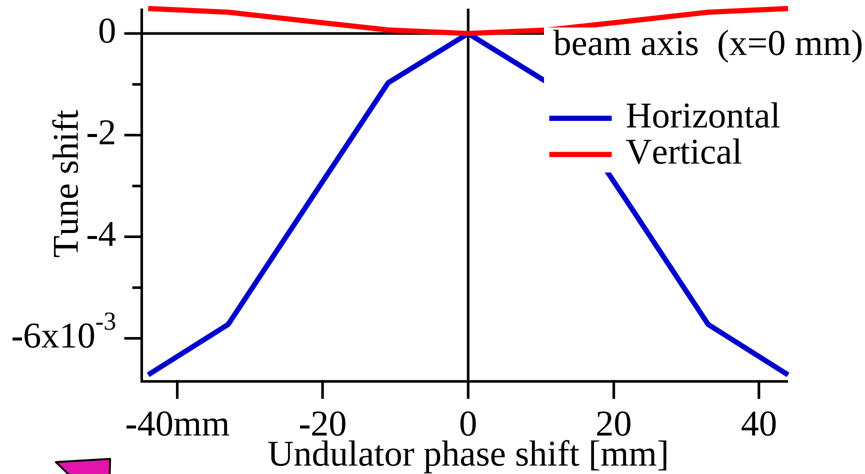
-> Interaction with stored beam

-usual COD (~ 1/E)

+

-significant systematic focusing (~ $1/E^2$)

- non linear effect (predictable)
- can be (partially) corrected



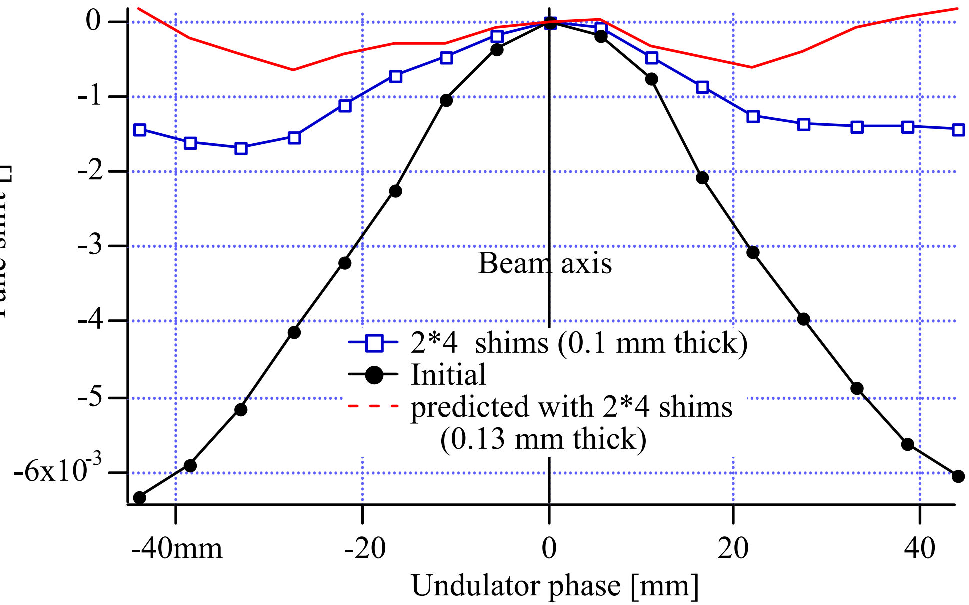
ID: ESRF HU88 gap 16 mm

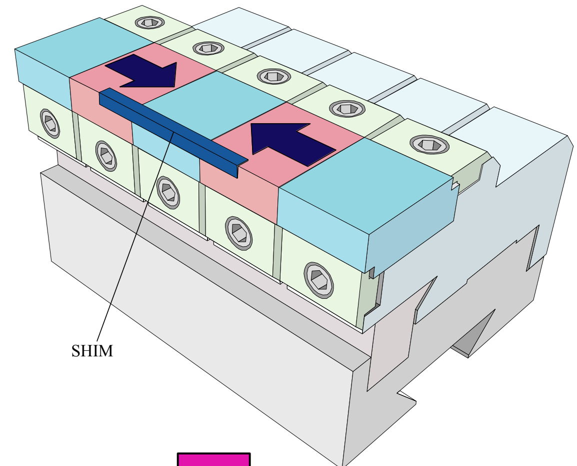
$$d\nu_{x,z} = \frac{-5.7\ 10^{-4}}{4\pi}\,\bar{\beta}_{x,z}\left(\frac{\lambda_0}{E}\right)^2 L\,\frac{\partial^2}{\partial x^2, z^2}\left(B_{0x}^2 + B_{0z}^2\right)$$

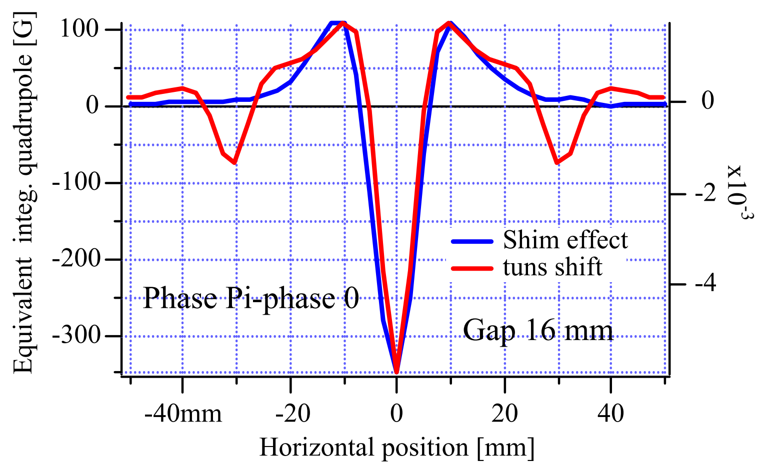
$$B_x(x,z,s) = B_{0x}(x,z)\sin(k_s s)$$

$$B_z(x,z,s) = B_{0z}(x,z)\sin(k_s s + \phi)$$

Horizontal tune shift correction on APPLE II







Method optimized for elliptic mode

- correction partial in linear inclined mode

Works well on both HU88 devices

ID8 APPLE II
Layout

2 identical segments

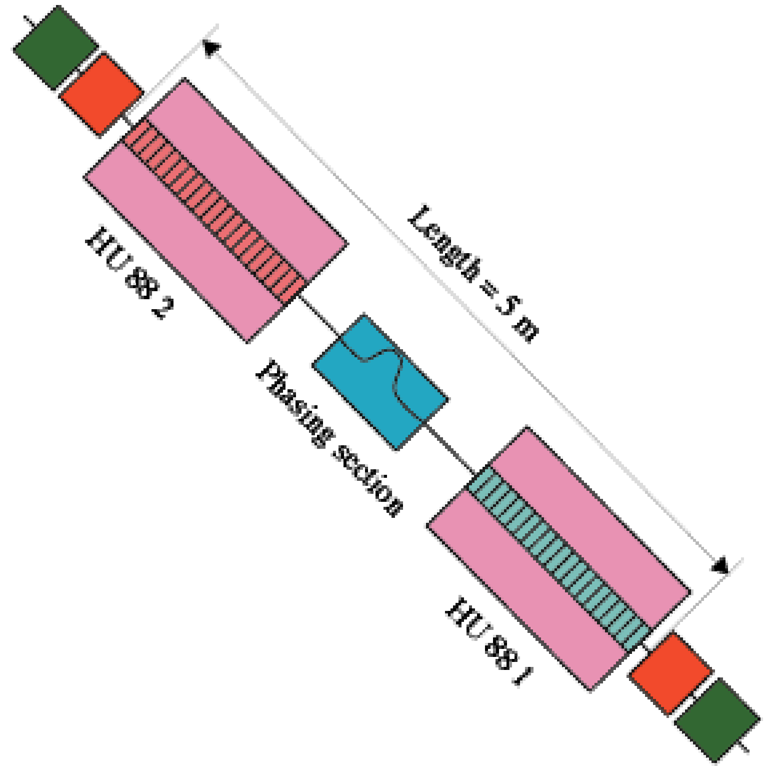
- period 88 mm
- L=1.6 m
- Bxmax=0.55 T
- Bzmax = 0.6 T

+

Phasing section (DC electromagnet)

- Bmax=0.1 T @ 10 A
- Phase shift =2 π @ 350 eV

Current directly controlled and calibrated by beamline



Operation of APPLE II undulators

At ESRF: Users can freely change gap and phase on all helical undulators

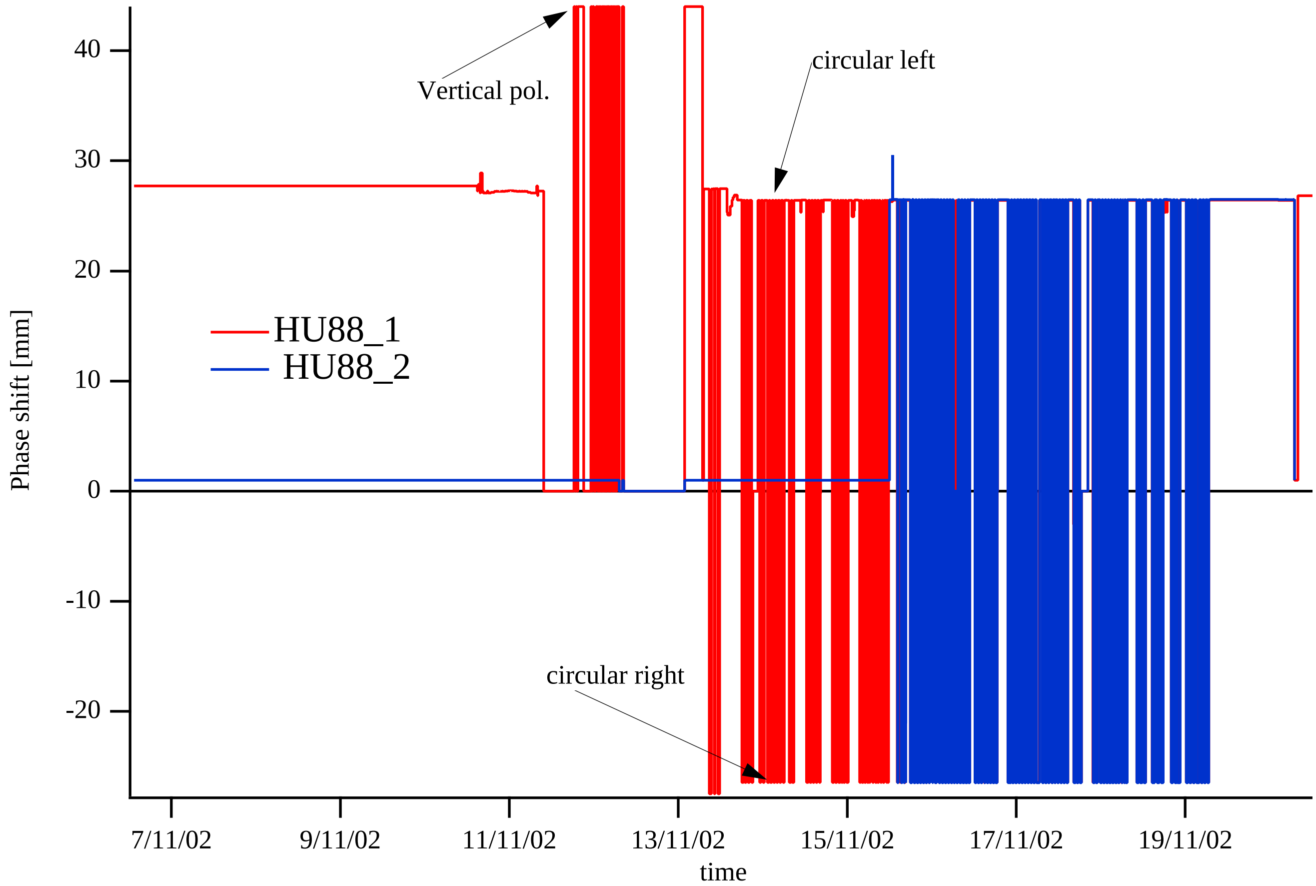
Typical frequency of phase change:

ID8 (HU88):

~ 15-20/ hour

ID12 (HU38):

~ up to 200/hour



Electromagnet/permanent magnet helical undulator

ESRF

Vertical field

Coil -6 layers
-water cooled
-I max=250 A- -

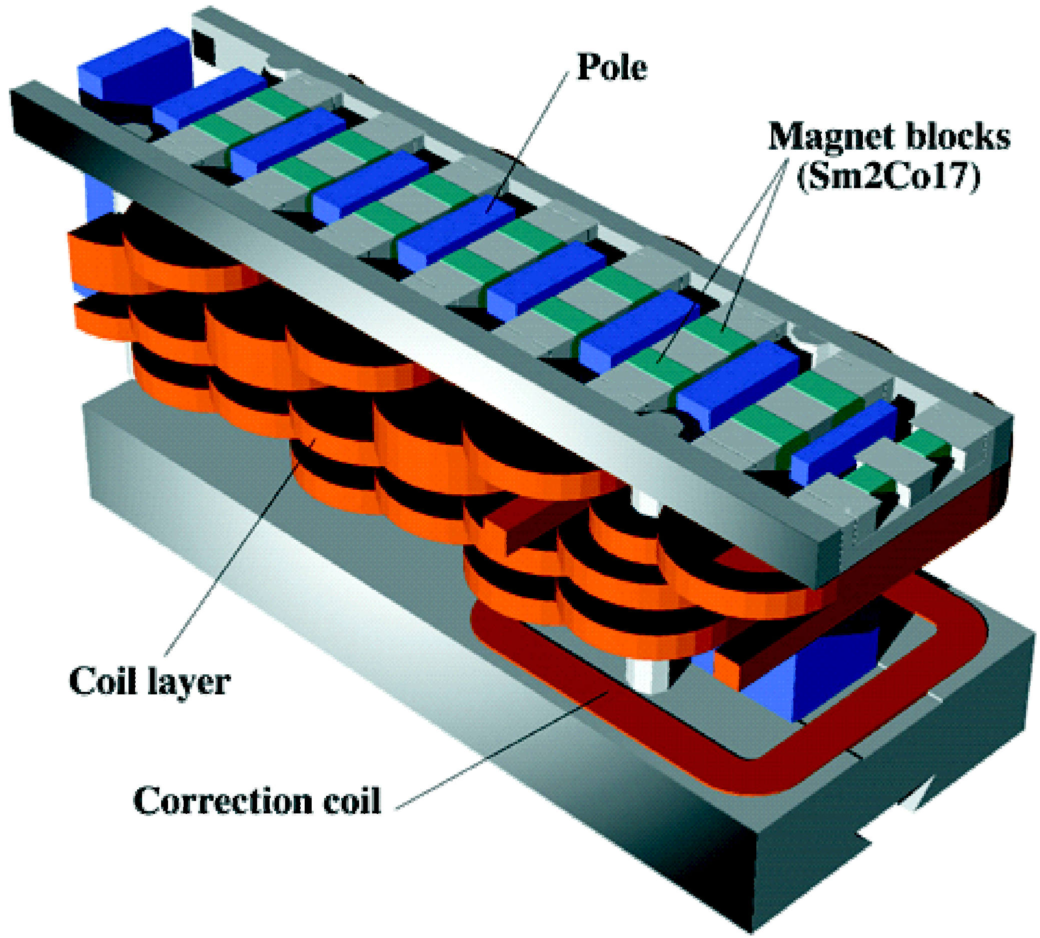
+

Magnetic circuit

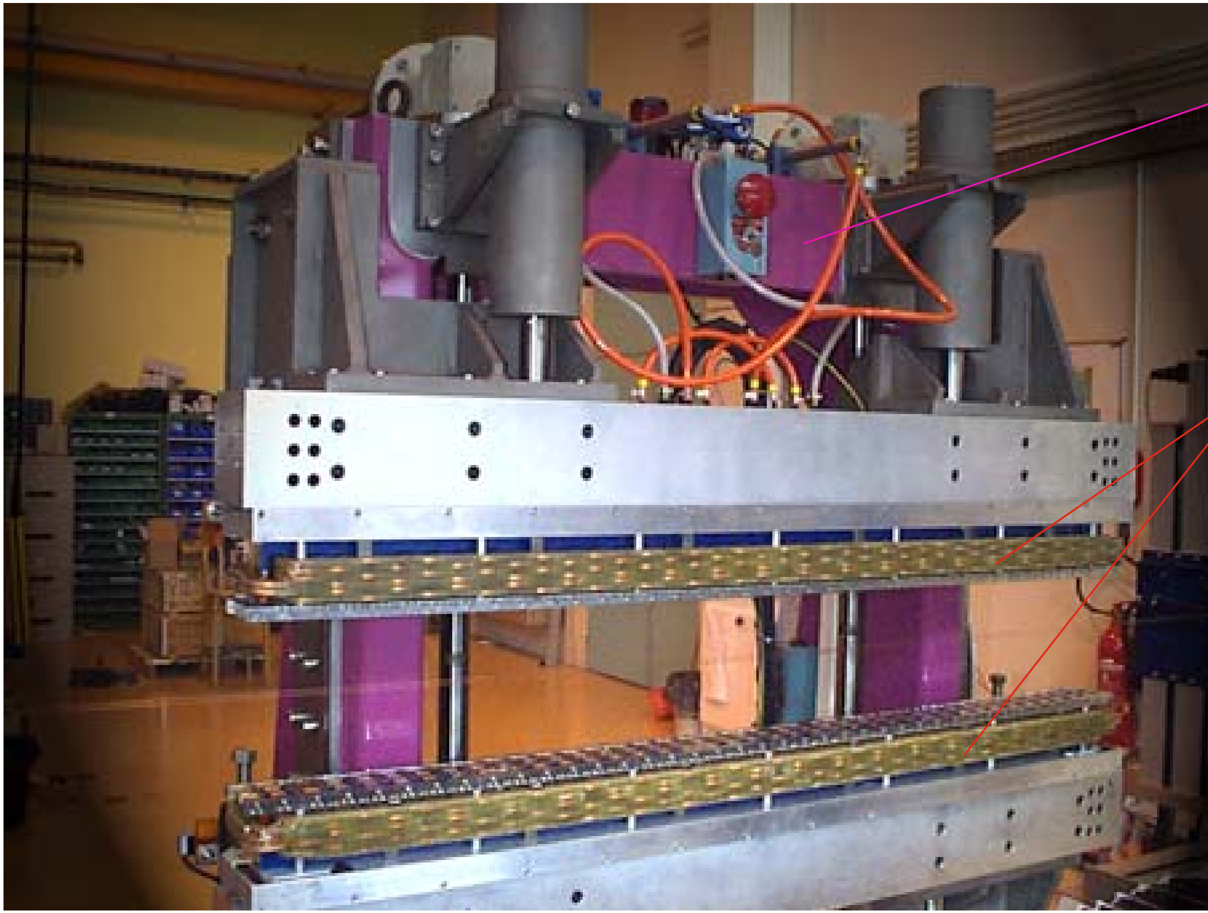
-Fe-Si material
-laminated

Horizontal field

- p.m blocks
- Sm2Co17



EMPHU structure



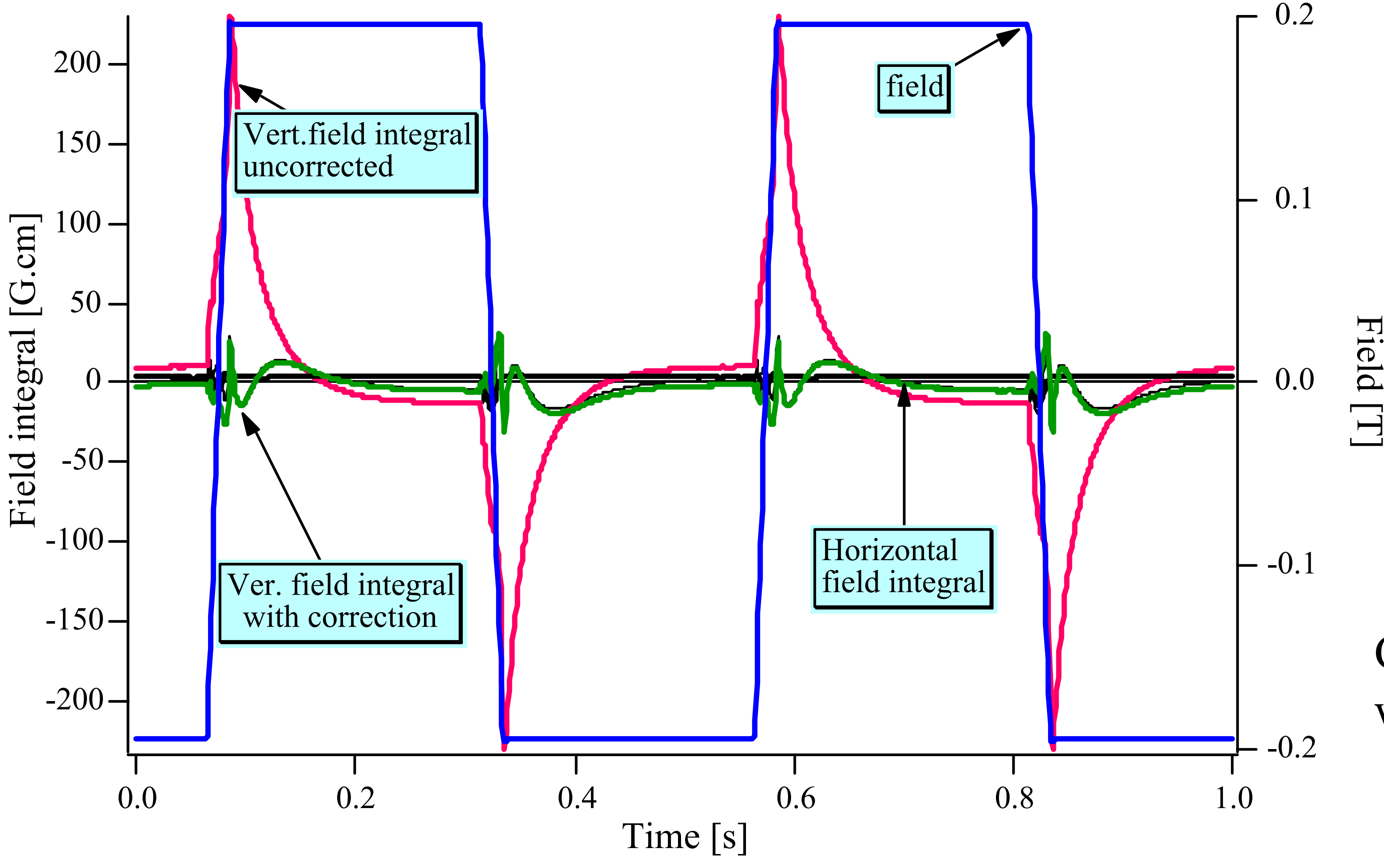
Standard support

Undulator

Min. gap 16 mm
λ_0= 80 mm
L=1.6 m (41 poles)
B_z max=0.2 T
B_z max=0.2 T
R_{dc}=0.05 Ohm
L=2mH
E_f=1.6 Kev @ 16 mm

Device optimised for circular polarization

EMPHU AC correction



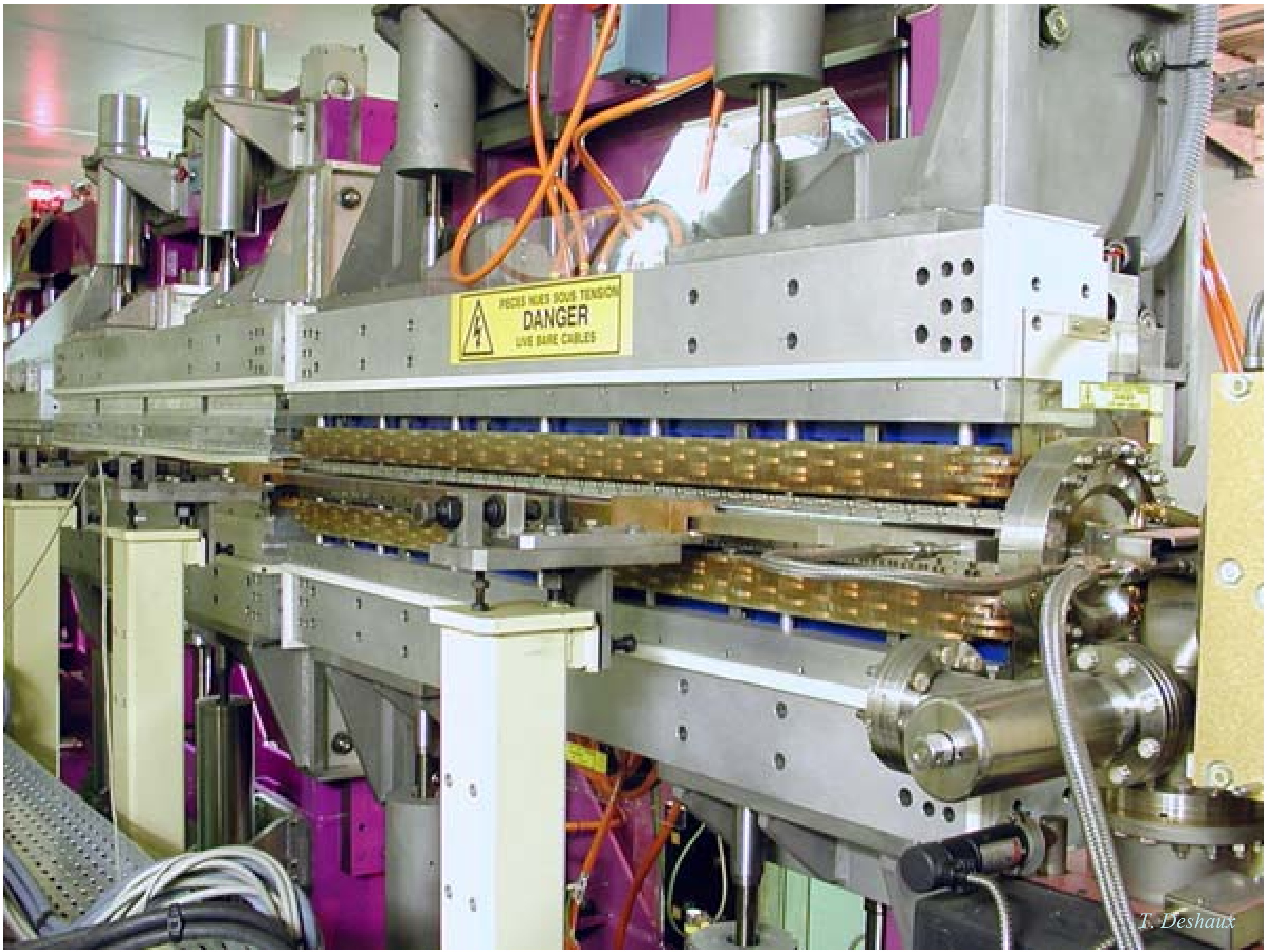
F=2Hz
Gap 16 mm

Correction controlled with DSP

$i_C = f(I_{DC}, Gap) + g(dI/dt, Gap)$

I:main current
ic: current in correction coil

EMPHU in ESRF ring



Installed in ID12

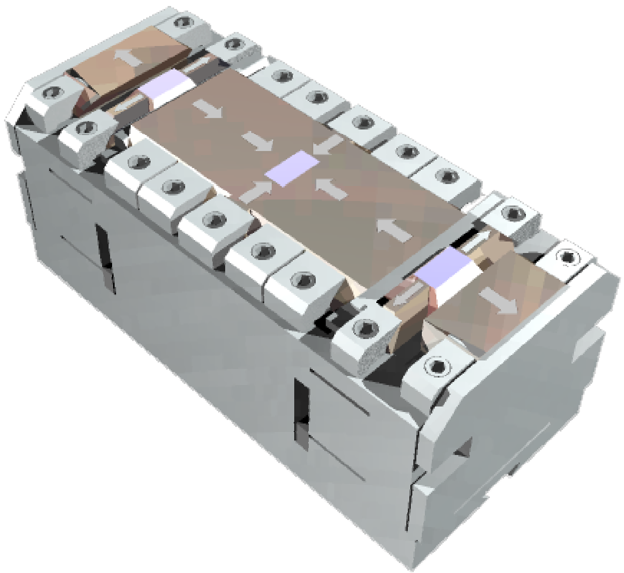
Since summer 1998

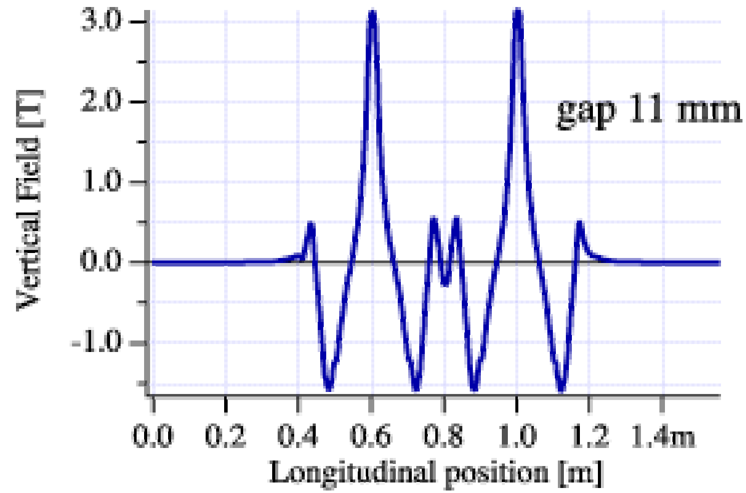
Operation modes

-DC

-AC @ 2Hz max

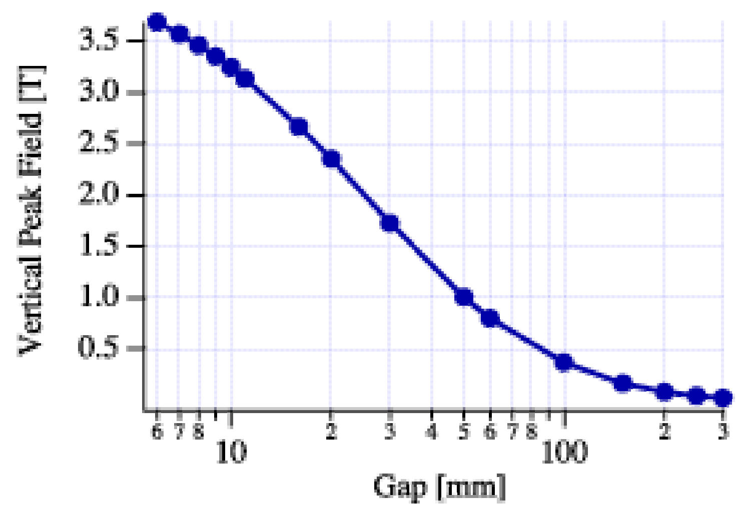
3 Tesla permanent magnet wiggler



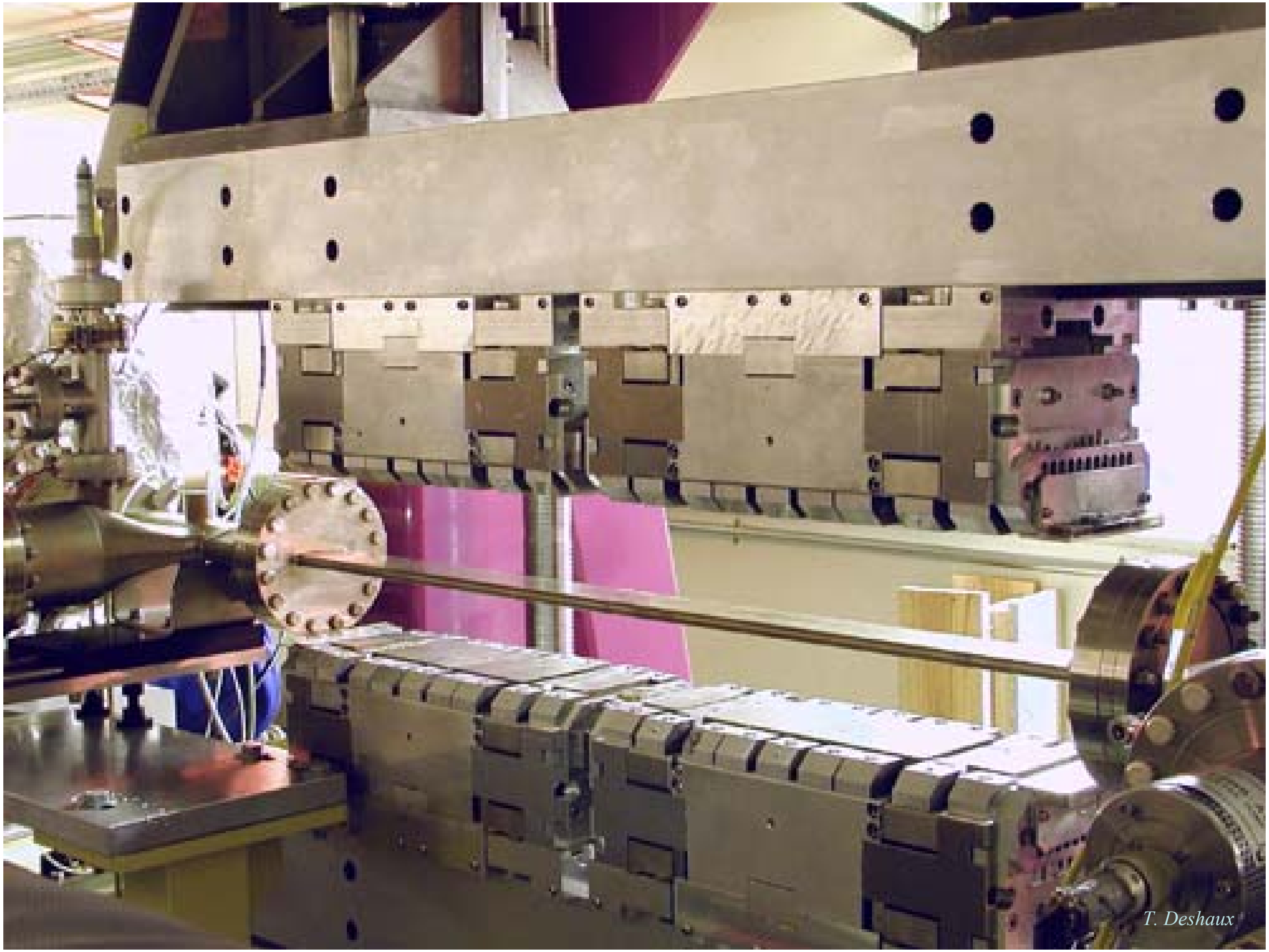


Measured peak field:

3.13 T @ gap 11 mm
3.57 T @ gap 6 mm



3 Tesla permanent magnet wiggler



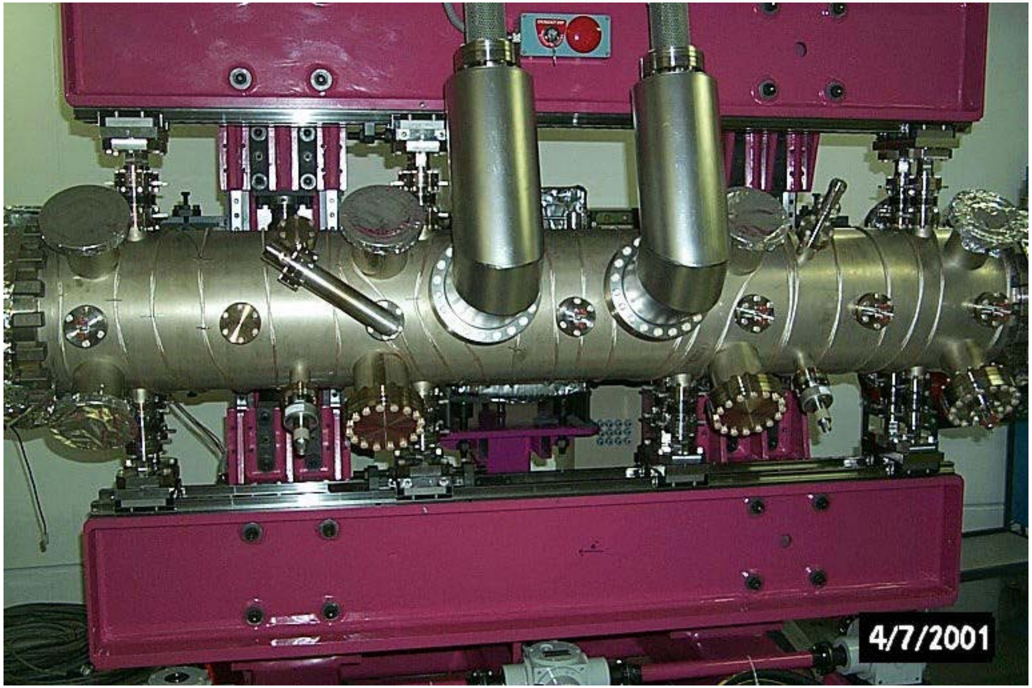
Installed on ID15 October 2001

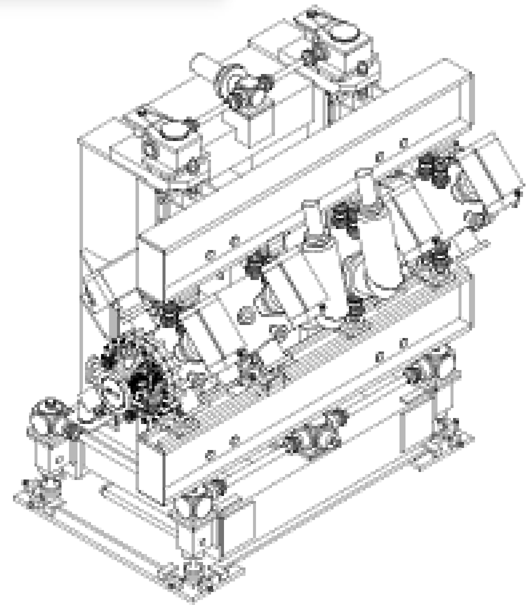
In replacement of the 4 T SCW

Field integral has hysteresis vs gap (asymmetry)

Operates as a binary device with hysteresis correction

In-vacuum Undulators





R&D started in 1997

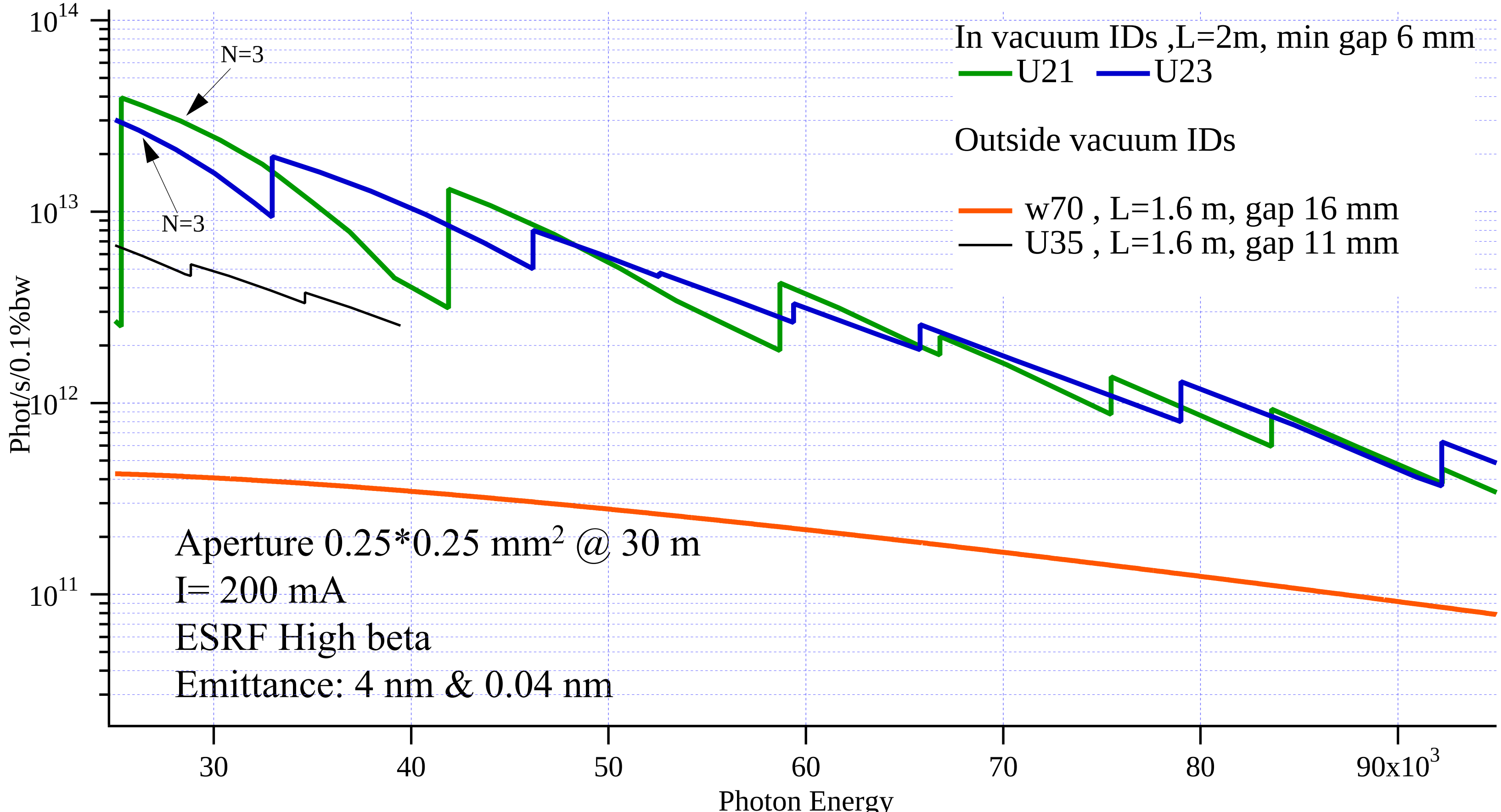
First prototype installed in January 1999

In vacuum IDs

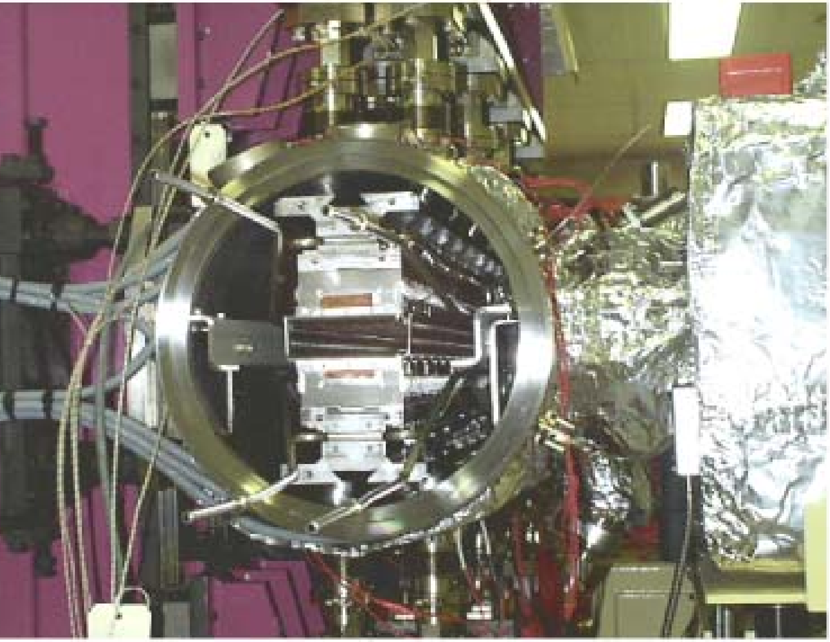
Main purpose

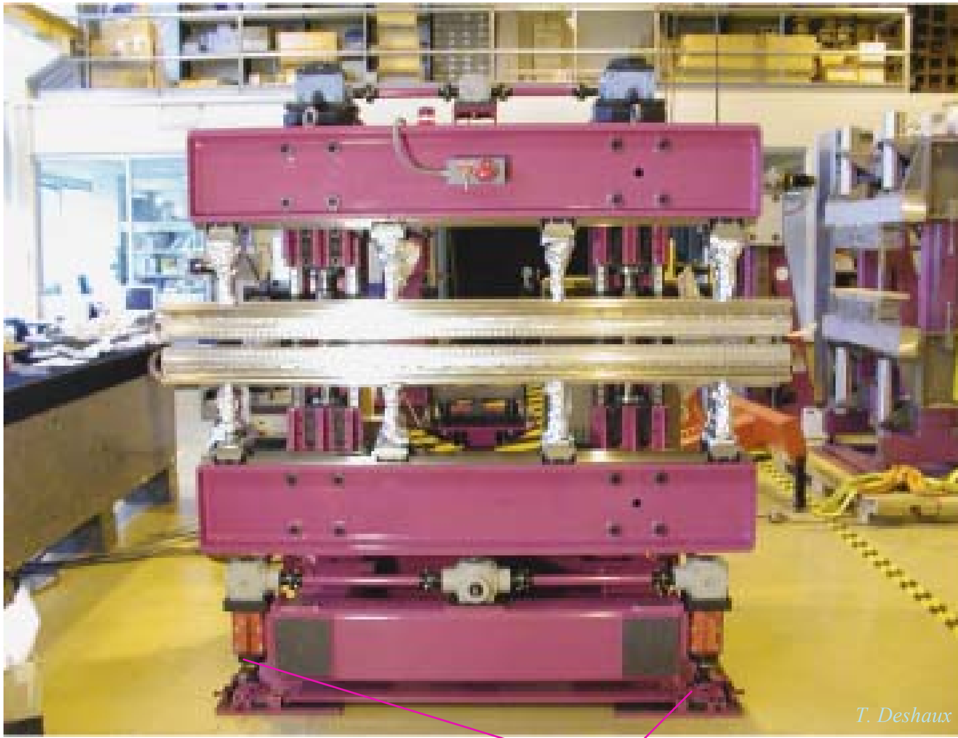
-higher flux in 50-100 keV region

- undulators :K≈1.5 to 1.8 (λ_0=21-23 mm)



Technology of in vacuum IDs





Vertical motion (motorised)

Magnetic assembly

- p.p.m. & hybrid type
- material Sm2Co17

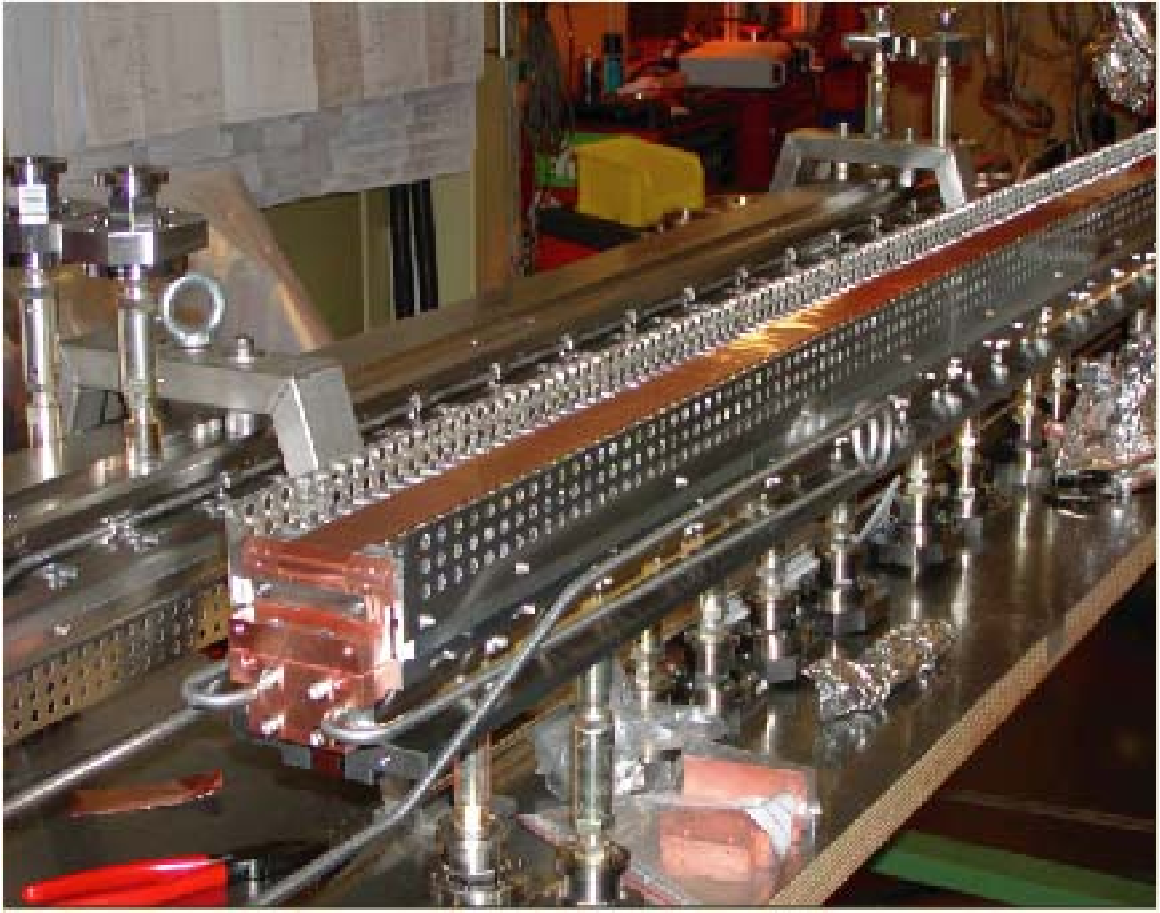
Baking ≈ 120-140 deg +
Potential radiation damages

Gap control	- 1 mm/sec - 0 to 30 mm - encoder resol.: 0.625 µm

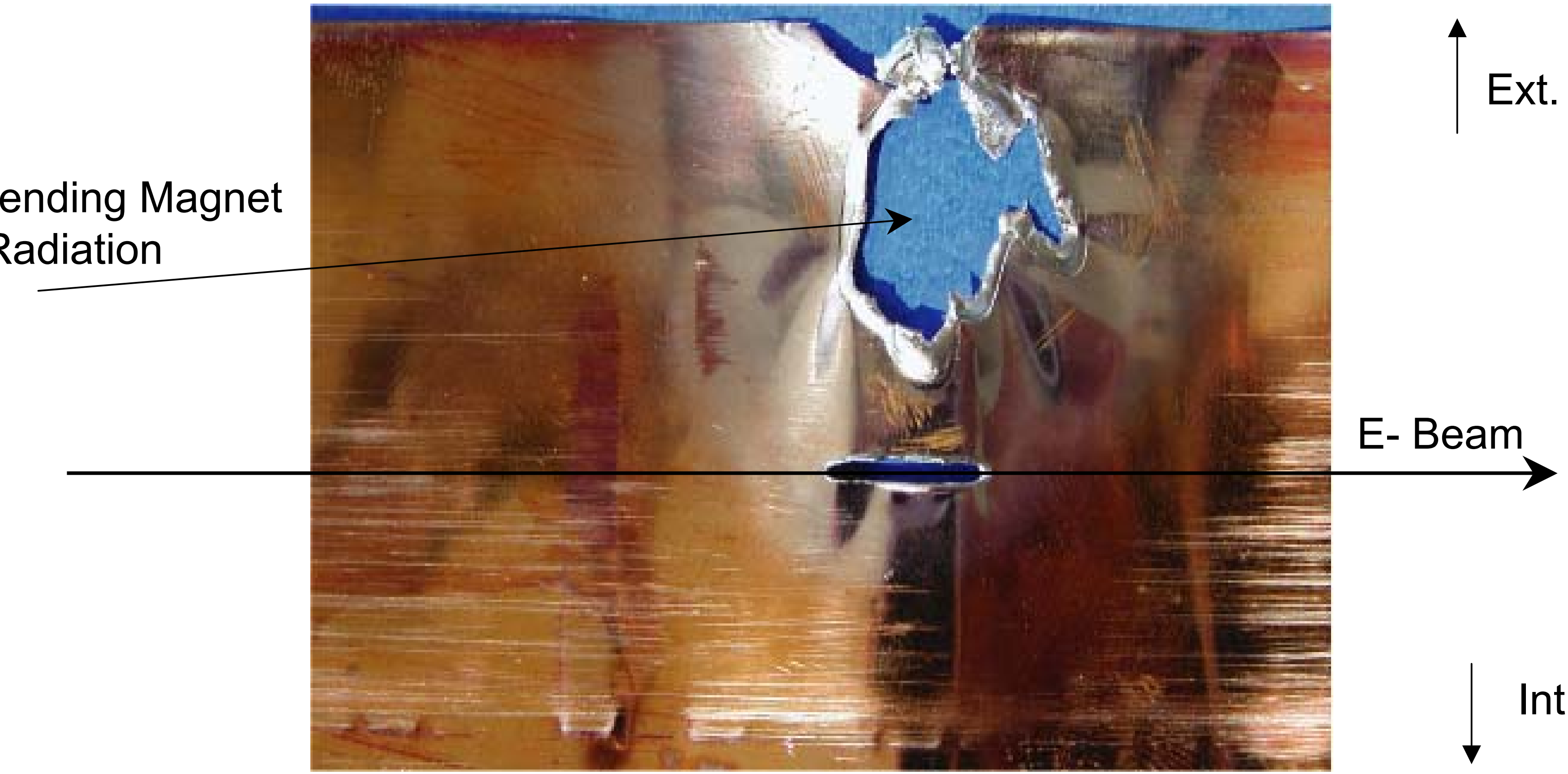
Copper Nickel Sheet

Copper :
Cure Resistive Wall
Instability

Nickel :
To insure flatness by
Magnetic force



Cu/Ni Sheet Damaged of ID9 In-vacuum Undulator

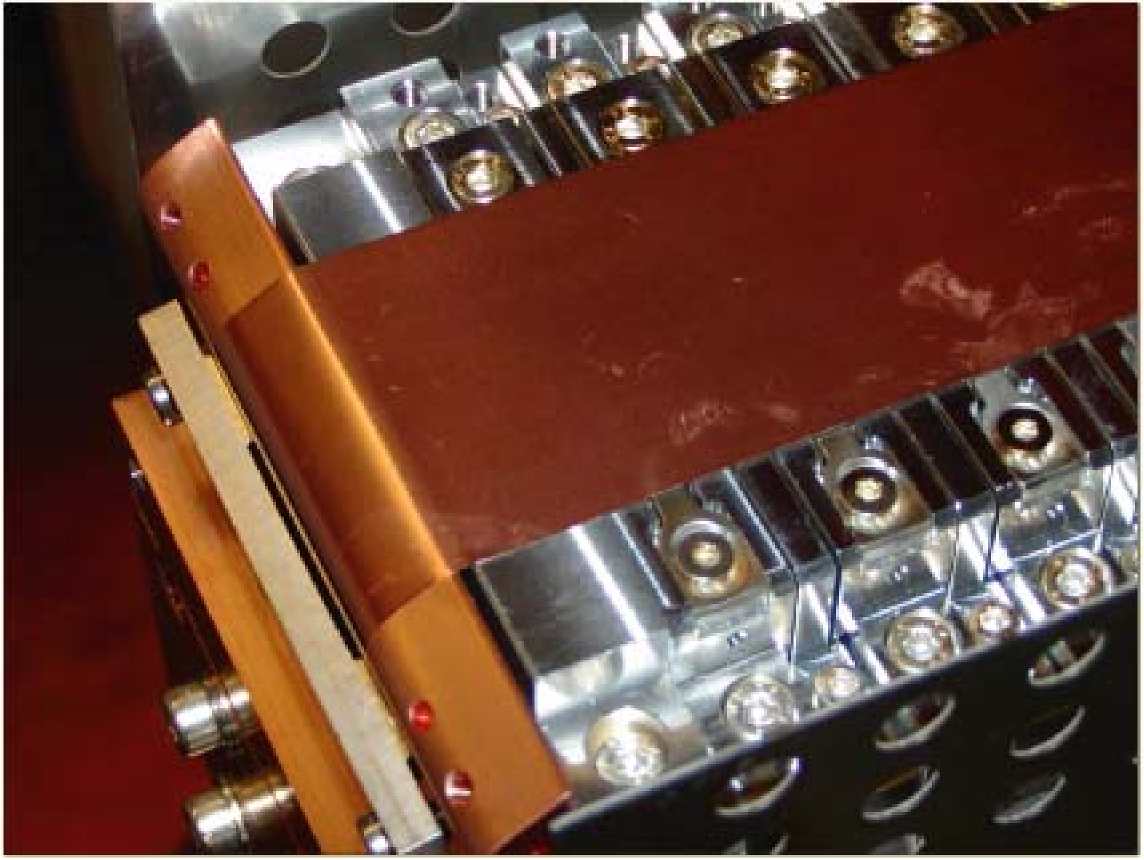


Remedies

Cu+Ni thickness increased :
60+25 -> 60+50 micr.

Improve
longitudinal Stretching

No problem since then



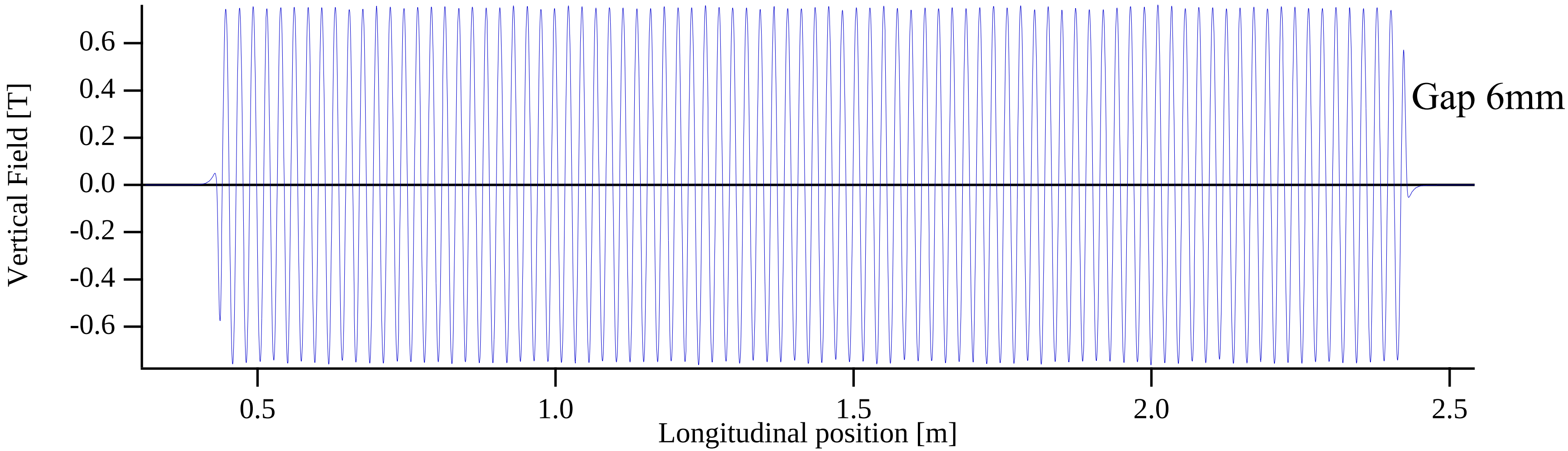
Magnetic measurement of in vacuum IDs

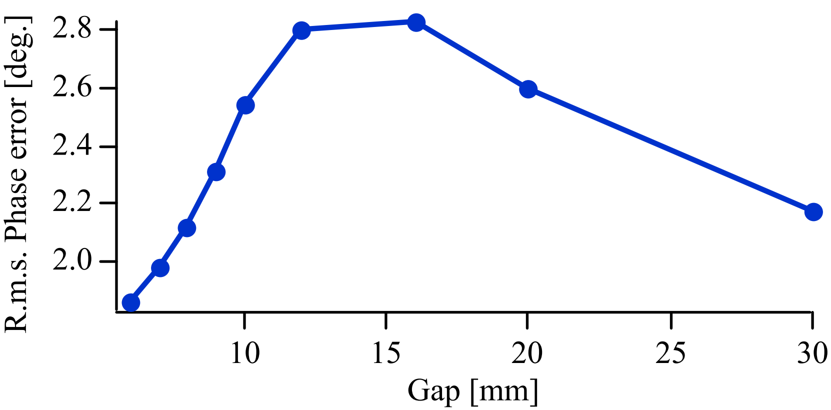
Field measurements:

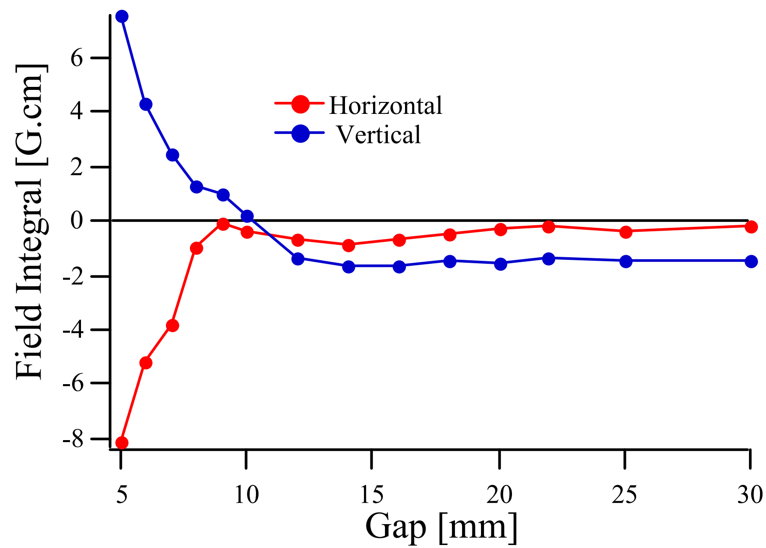
Methods used for measurement & correction of conventional IDs are usable

But take more time (~ nb of periods)

Magnetic measurement of in vacuum IDs



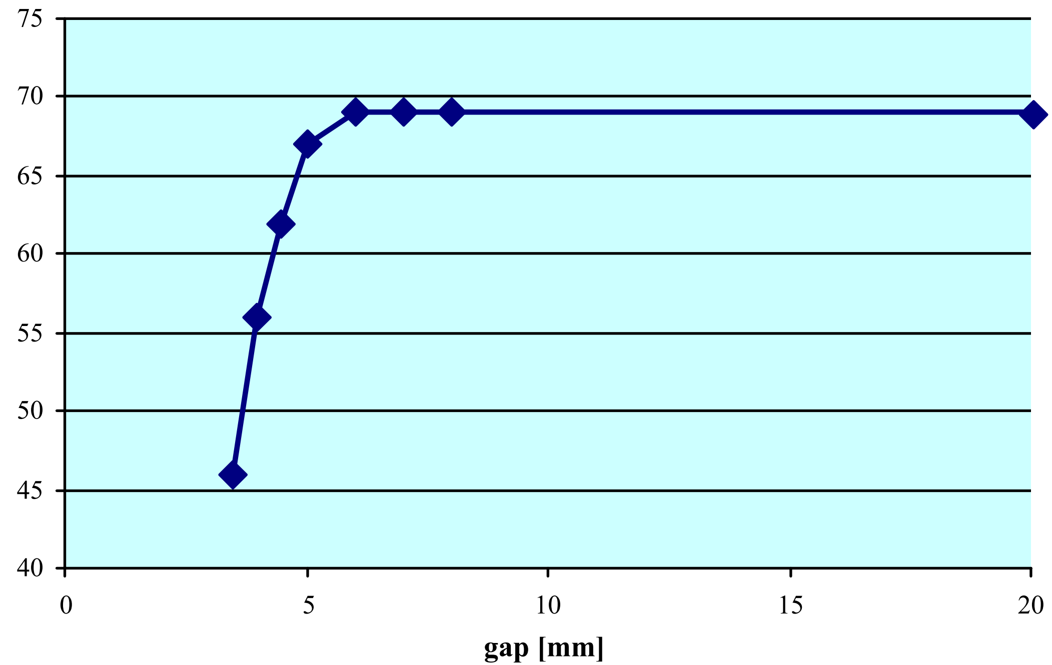




U23, L= 2m

In vacuum IDs: lifetime vs gap

MDT ID 23 Apr 2001	
mode	uniform
I [mA]	195
scrapper	opened



ID11 in vacuum U23

L=1.6 m

=

Other in vacuum IDs

L=2 m

<=10 % lifetime reduction @ gap 5 mm (uniform & 2/3 filling mode)

Effect on the beam of ID9,ID13,ID22,ID29

- Field Integrals < 20 Gcm for all gap settings => No correction coils.
- No measurable perturbation in multibunch, 16bunch, Hybrid user operation (lifetime, orbit,..)
- Some small impedance or tune shift effects observed with all in-vacuum undulator closed in high current single bunch (preliminary).

Status of In-vacuum Undulators

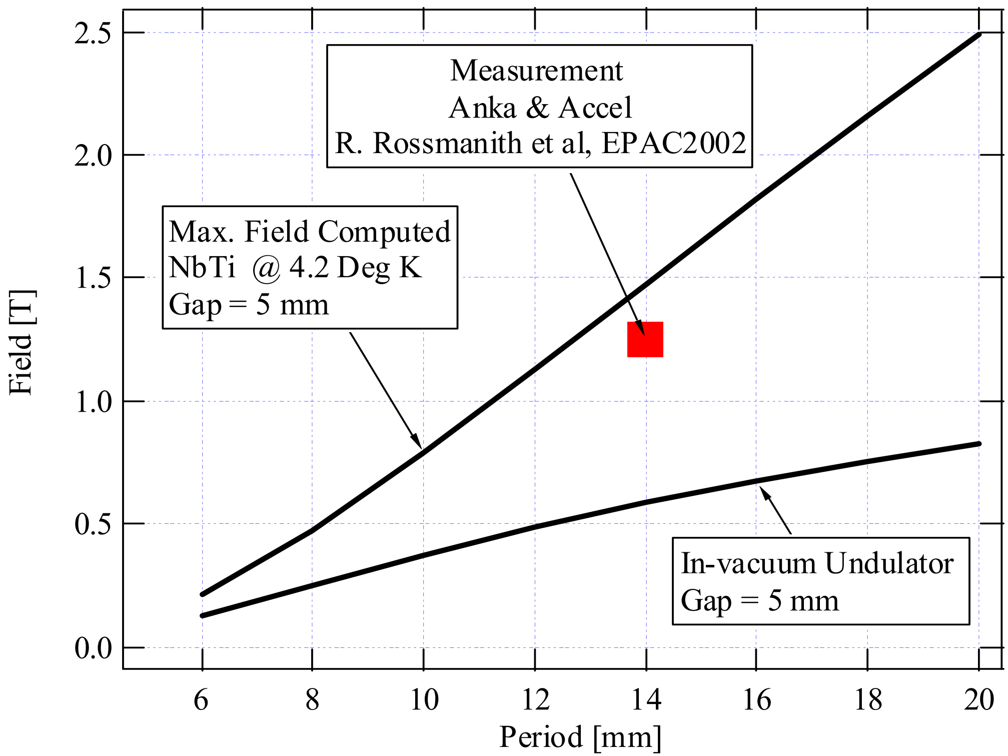
ESRF

SS	Period [mm]	L [m]	Type	Min. Gap [mm]	Rms Phase Error [deg] @ 6 mm	Field Int. vs Gap [Gcm]	Status
ID11	23	1.6	Hybrid	5	?	70	Jan 99
ID22	23	2	PPM	6	1.9	26	July 01
ID9	17	2	PPM	6	< 5	<15	July 01
ID29	21	2	PPM	6	2.3	<15	Dec 02
ID13	18	2	PPM	6	<5	<15	July 02
ID11	22	2	Hybrid	6	< 2	<15	Dec 2003
ID30	23	2	PPM	6	< 2	<15	July 2003
ID30	23	2	PPM	6	< 2	<15	July 2003

Magnet Material : Sm_2Co_{17}

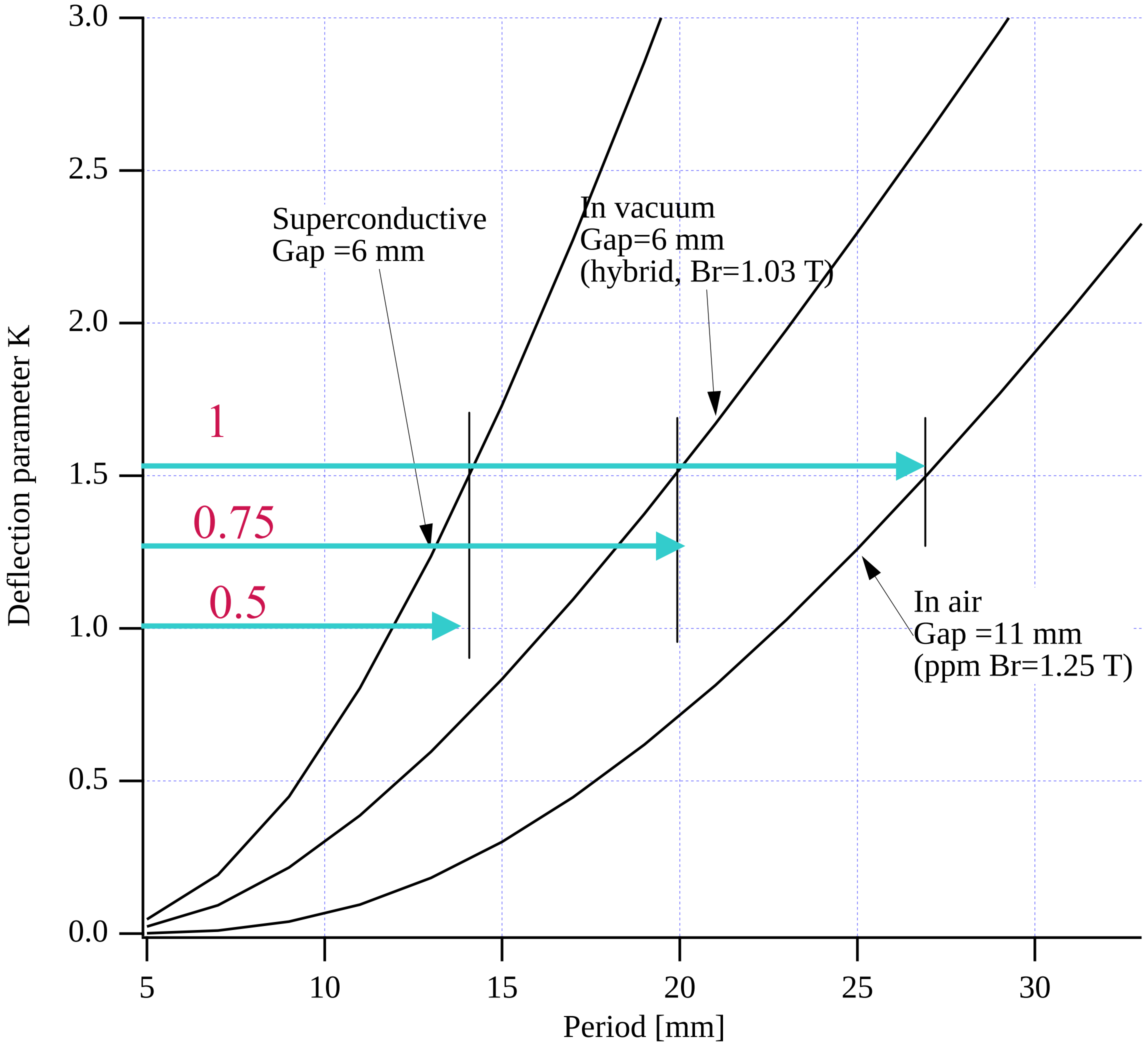
- Baked at 120 deg C
- No demagnetization so far (~ 4 years @ 5< g <7 mm on ID11)

Recent Achievement of Superconducting Undulators



Superconducting Undulators

Motivation



Technological Issues

- Magnetism
  - Accurate magnetic field & field integral calculation
  - Magnetic measurement
  - Multipole and Phase shimming
  - Closed orbit distortion due to the hysteresis like persistent currents

- Cryogenic
  - Use cryocoolers integrated in Cryostat (Sumitomo, Cryomech,..)
  - Controlling heatload budget at 60 and 4 K :
    - conduction
    - Sheet resistivity
    - Synchrotron radiation,
    - Geometrical Wake fields.

- Low vessel pressure when both cold and warm
  - Baking, NEG ?…

- Electron Beam Dynamics

Announcing :
Workshop on
Superconducting Insertion Devices

ESRF, 30th June-1st July, 2003

- Review the recent development in superconducting technology :
  - Wigglers
  - Undulators
  - Mechanical & Cryogenic Engineering
  - Magnetic Field Measurement
  - Beam Dynamics Issues

- Stimulate world wide exchange and cooperation