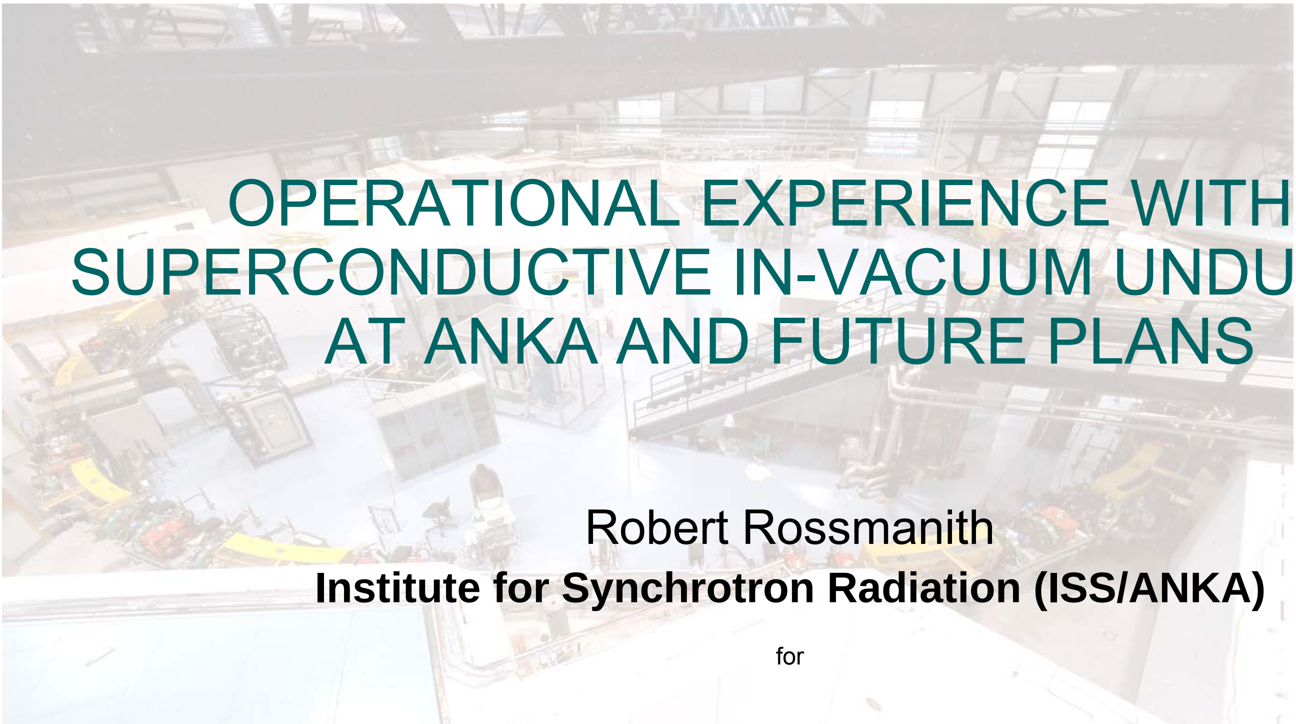

OPERATIONAL EXPERIENCE WITH A SUPERCONDUCTIVE IN-VACUUM UNDULATOR AT ANKA AND FUTURE PLANS

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Institute for Synchrotron Radiation (ISS/ANKA)

for

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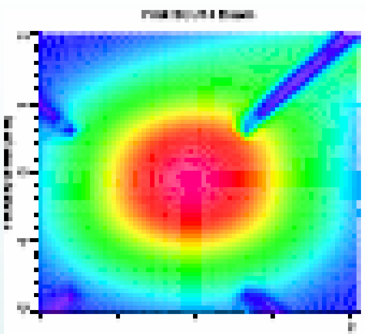
NbTi SCU **Demonstrator**

Period length 14 mm, 100 periods, gap 8, 12, 16 mm

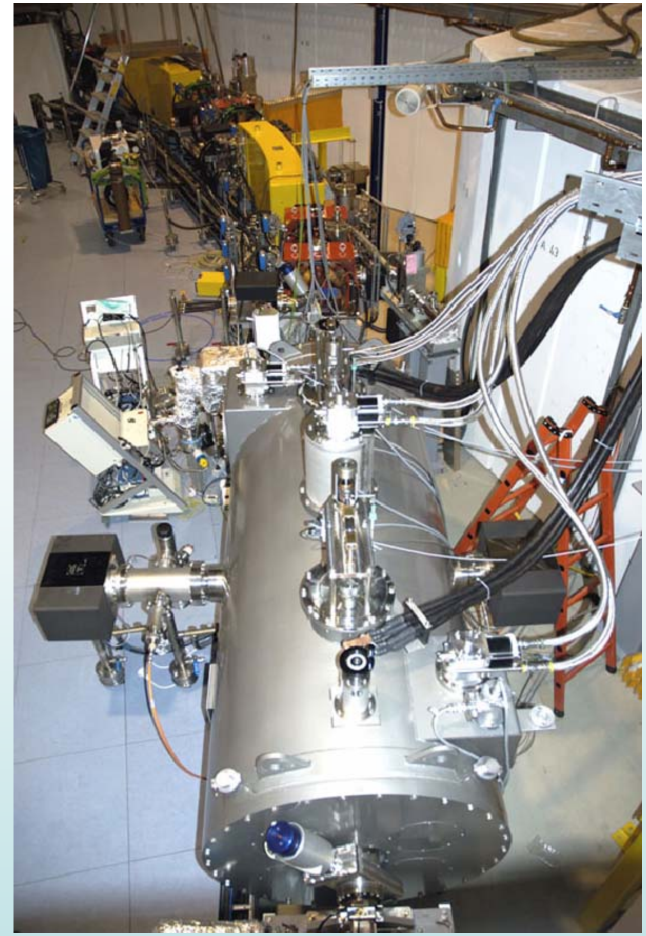


First beam
March 29
2005

Since March 2005 cold in ANKA

(only routine maintenance of cryo-coolers)

Compatible with normal user operation



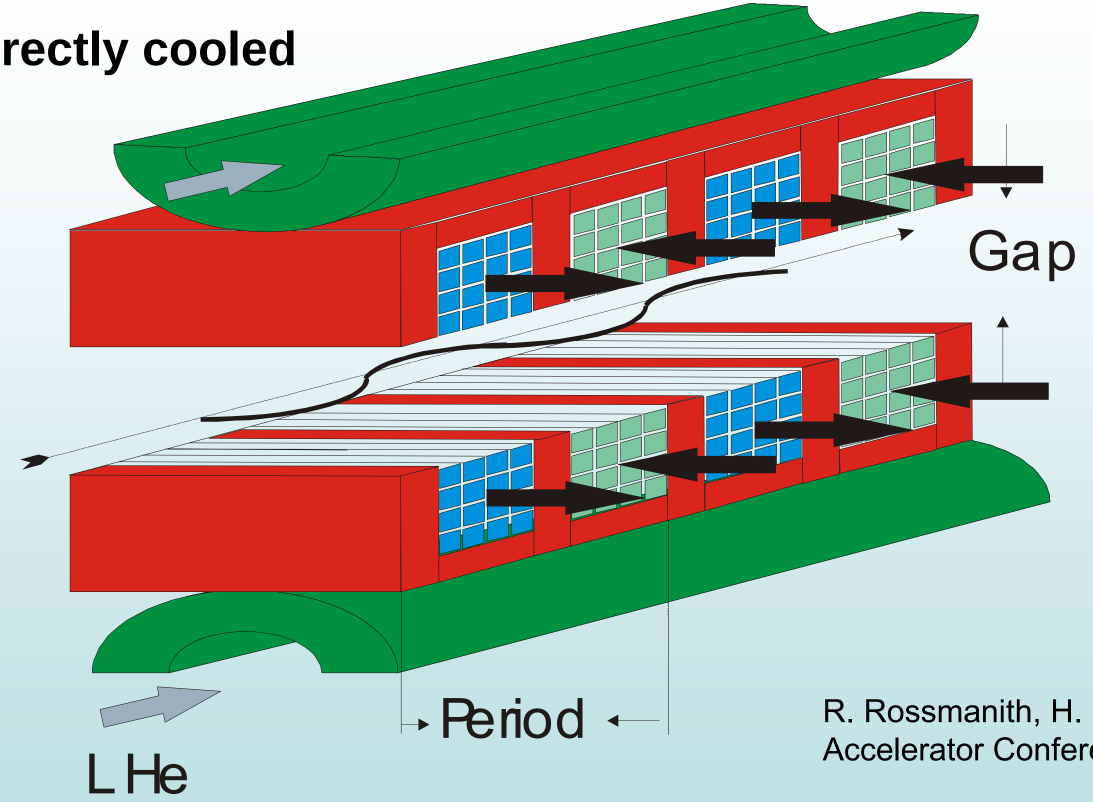
Built by ACCEL Instr. GmbH, Germany

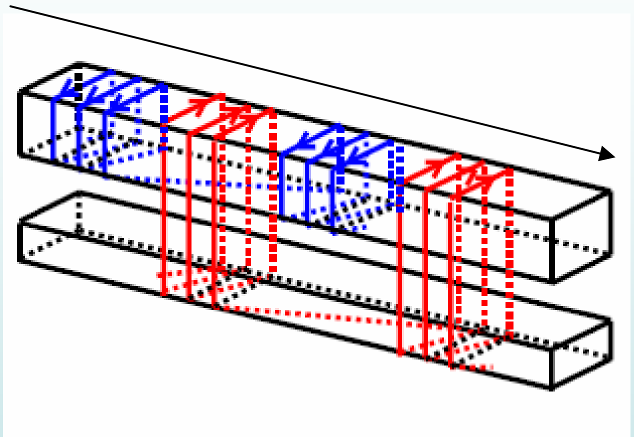
Basic idea of a superconductive undulator

Wires as close as possible to the beam:

indirectly cooled

One wire, without any interruption





R. Rossmanith, H. O. Moser, Proc. European Particle Accelerator Conference 2000, Vienna, Austria

Nowadays established technology: ANKA, Argonne, Berkeley, MAXLAB, ACCEL Instr., Taiwan… (everybody slightly different)

Cryostat for the ANKA undulator

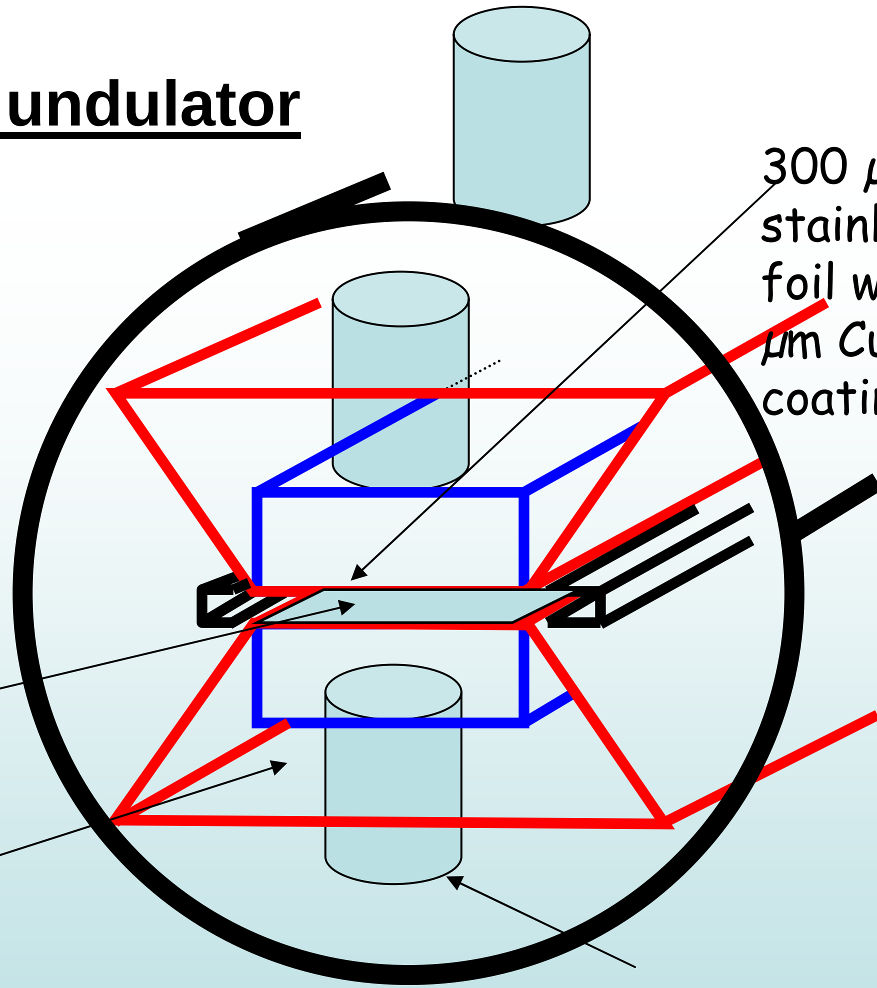
14 mm period length, 100 periods

8, 12 16 mm gap and open (29 mm)

Double vacuum system

Beam vacuum

Thermal insulation vacuum



300 µm stainless foil with 30 µm Cu coating

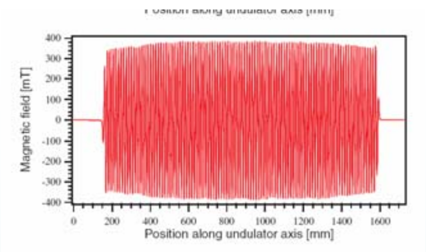
Three 1 W cryo-coolers

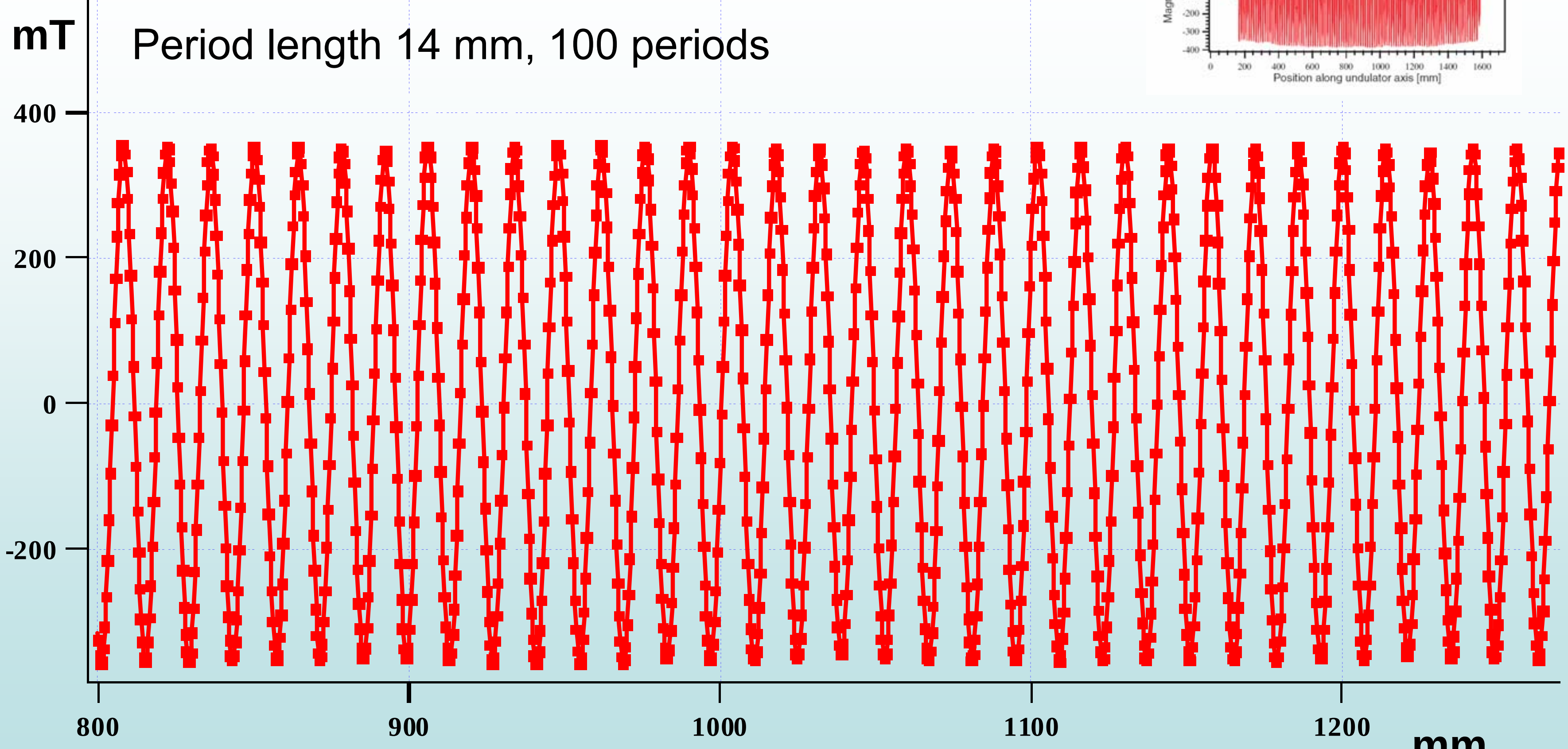
A. Bernhard et al., Proc. European Particle Acc. Conf. 2004, Lucerne, Switzerland

Field measurements without beam

Example: ANKA undulator 8 mm gap, 500 A

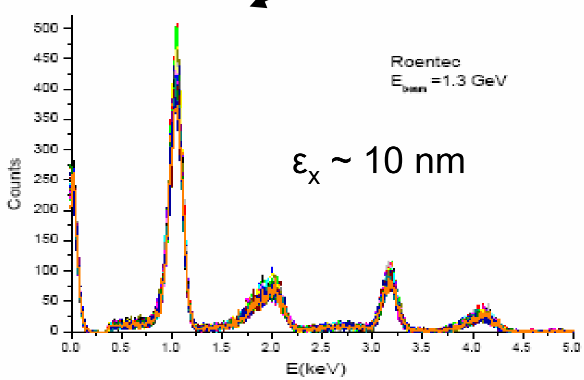
Period length 14 mm, 100 periods





Measured spectra

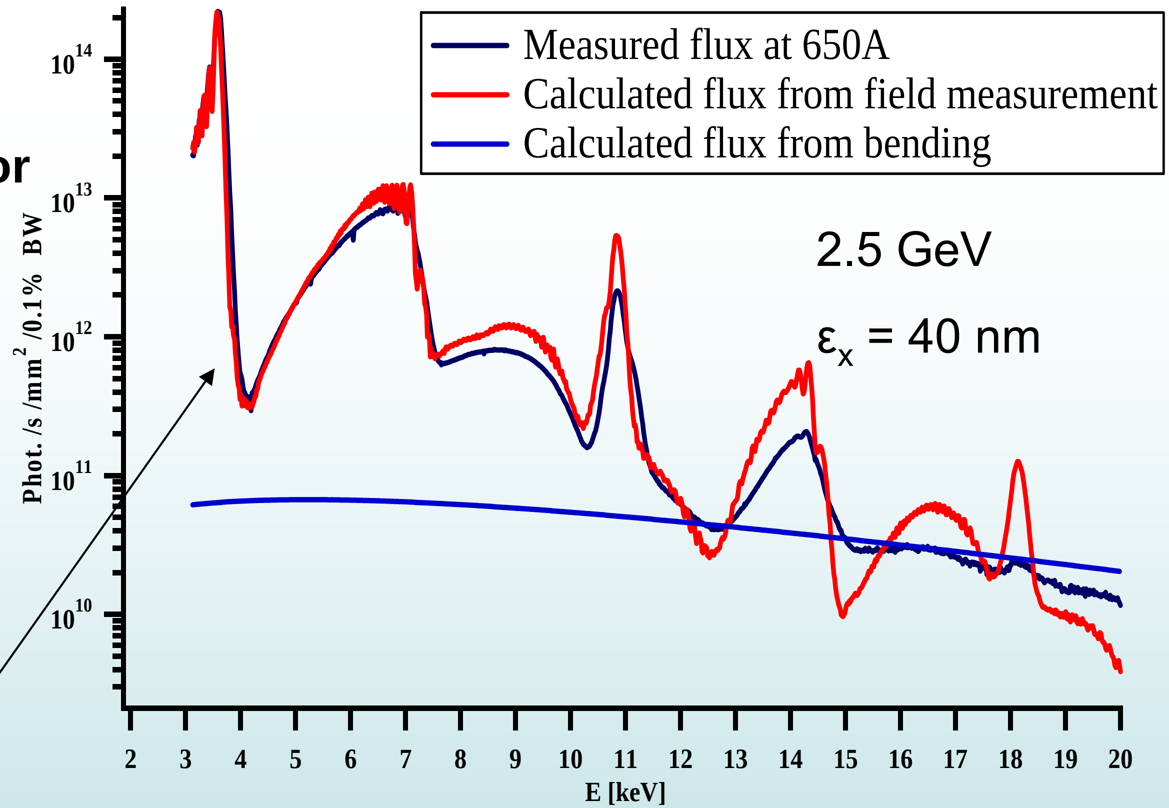
without monochromator



$\varepsilon_x \sim 10$ nm

with monochromator of

Univ. Wuppertal (Si111)



2.5 GeV

$\varepsilon_x = 40$ nm

K=0.56, gap = 8 mm

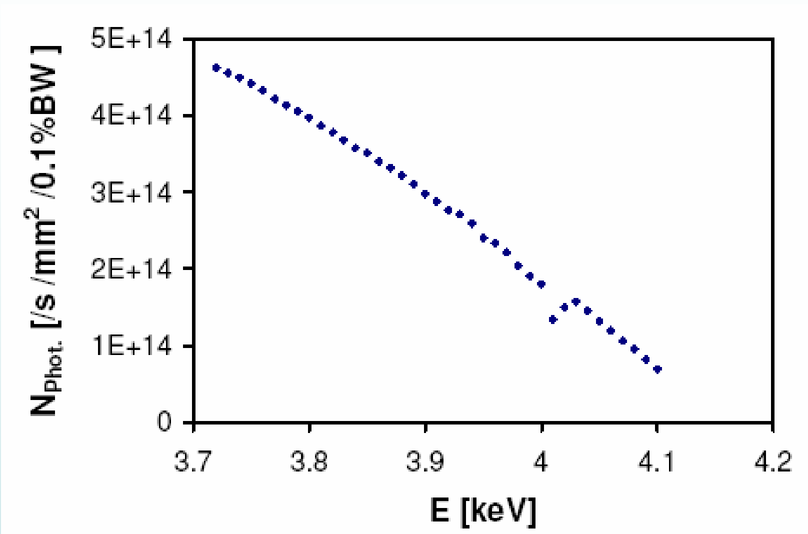
Absolute beam energy calibrated by resonance spin depolarization

(A.S. Mueller et al, Energy Calibration of the ANKA storage ring, Proc. PAC 2003, Lucerne, Switzerland)

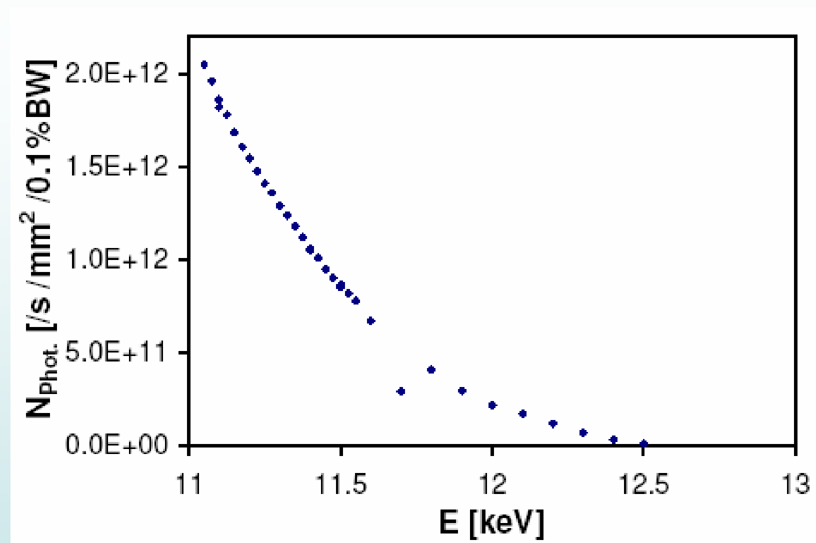
A. Bernhard et al. IEEE Transactions of Applied Superconductivity, in print

Simultaneous tuning of undulator and monochromator (tests for QuickEXAFS)

(B. Griesebock, U. Haake D. Lutzenkirchen-Hecht and R. Frahm, University of Wuppertal, private communication)



1st harmonics



3rd harmonics

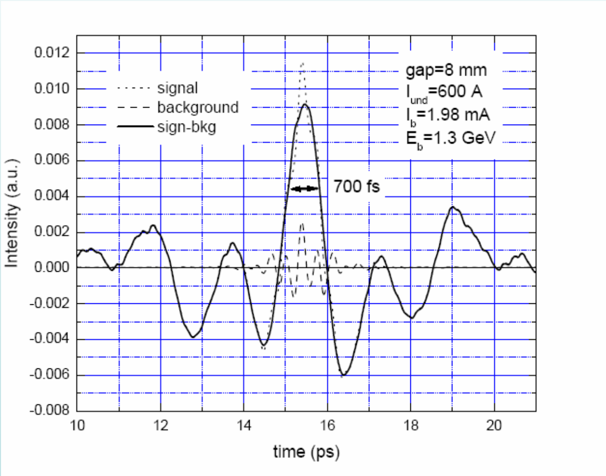
Max. tuning speed: 10 A/sec limited by power supply; this experiment 1A/sec

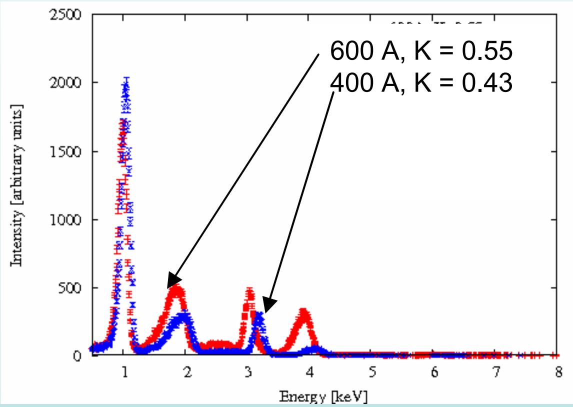
Subpicosecond X-ray pulses

ANKA can operate in a low momentum compaction factor optics at 1.3 GeV

Generating 500 to 700 fsec long pulses

Measurement of bunch length: coherent IR radiation is measured by an IR Michelson interferometer (Hung-Chi Lihn et al., Physical Review E, 1996, W. Barry 1991, workshop Japan)





Spectrum of 500 to 700 fsec pulses

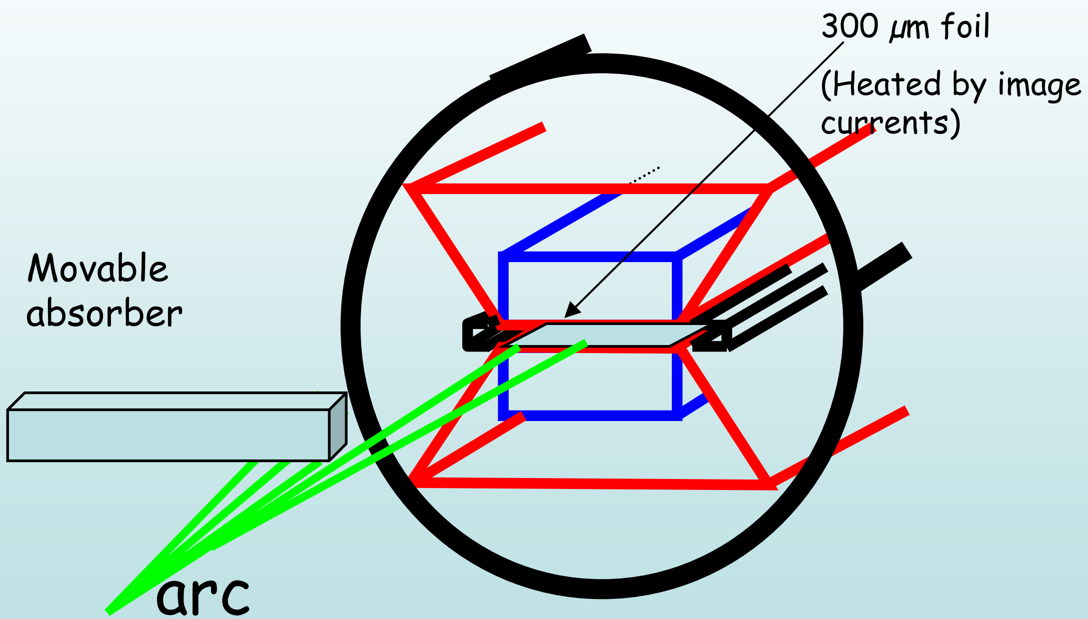
Temperature effects at ANKA undulator

S. Casalbuoni et al., Phys. Rev. STAB 9, 010702 (2006)

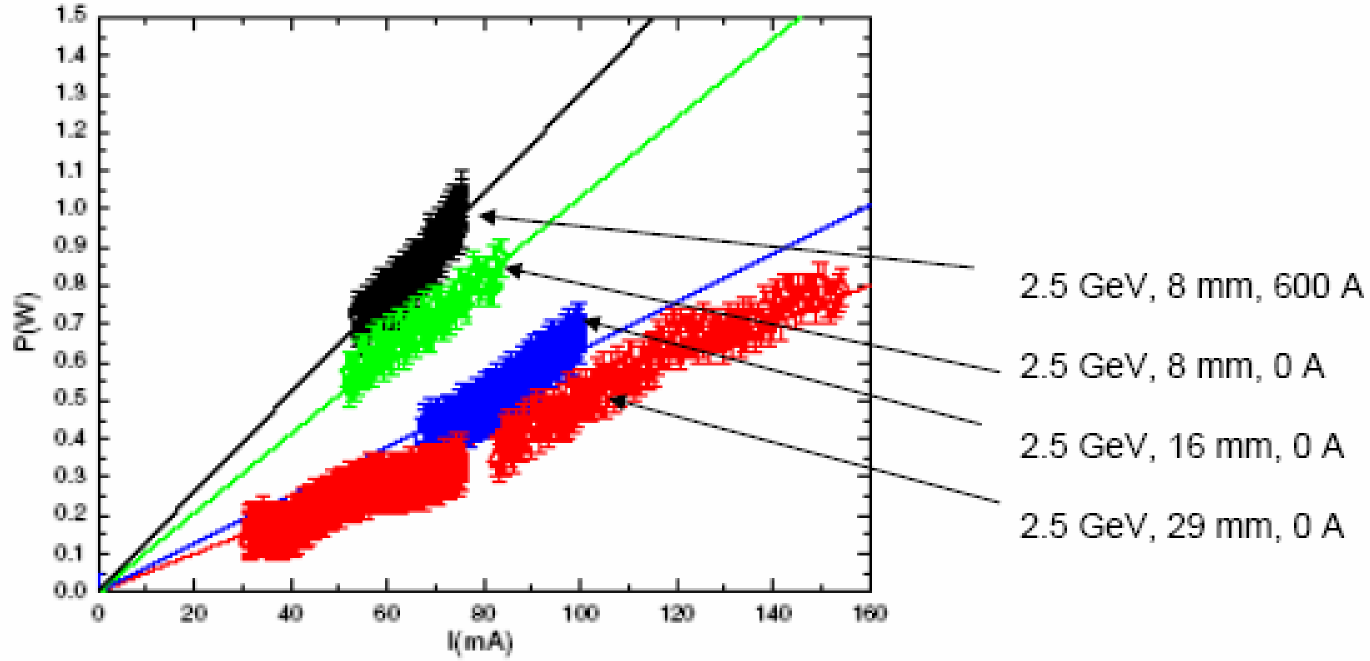
Conventional Theory: two effects (talk by B. Podobedov at ESRF workshop 2003, www.esrf.fr)

a.) Heating by image currents ~ I^2, bunch length, gap

b.) Heating by Syn. Rad. ~ I, beam energy



Comparison of measured values with theory

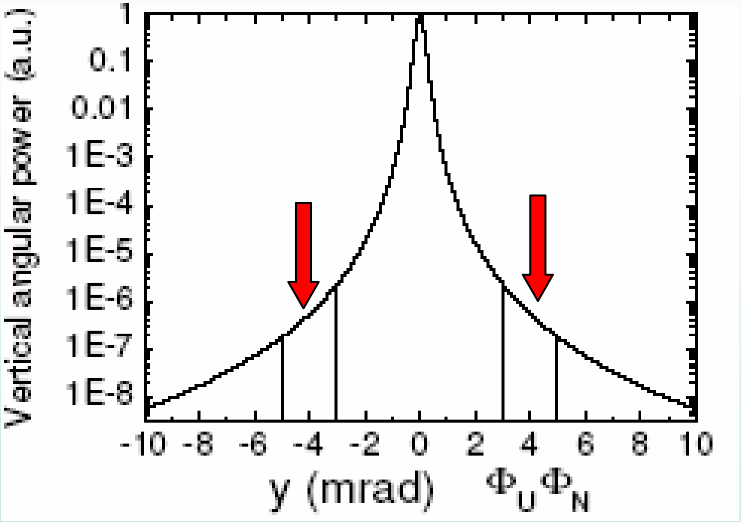


First simple idea: proportional to I, heating by synchrotron radiation

Checking the numbers (following E. Wallen and G. LeBlanc in Cryogenics, 2004)

A.) Resistive wall heating: For ANKA (bunchlength of 10 mm, gap 8 mm and 100 mA current) the deposited power by this effect is **22 mW** taking into account the anomalous skin effect.

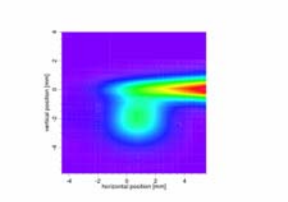
B.) Synchrotron heating

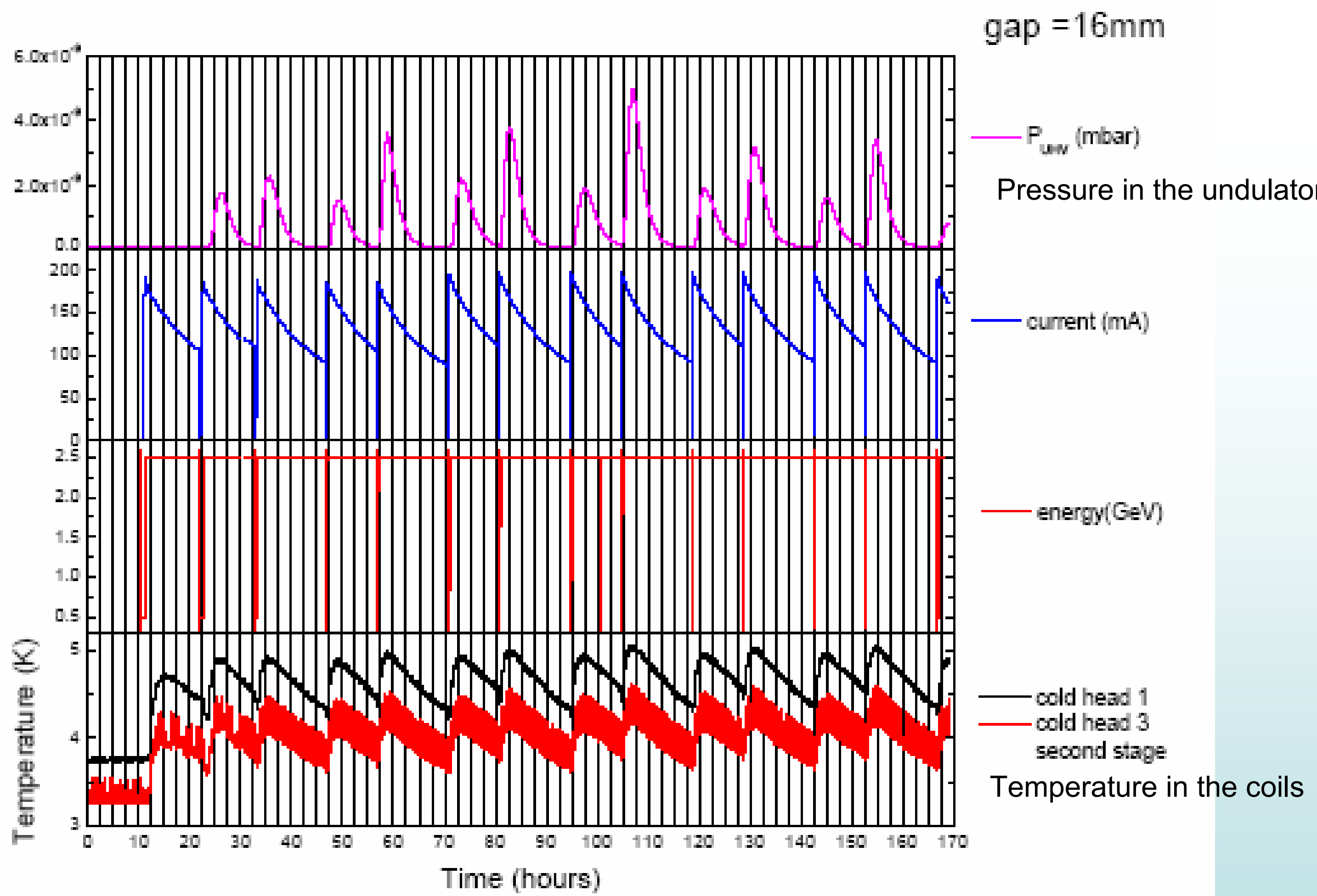


0.063 W per 100 mA

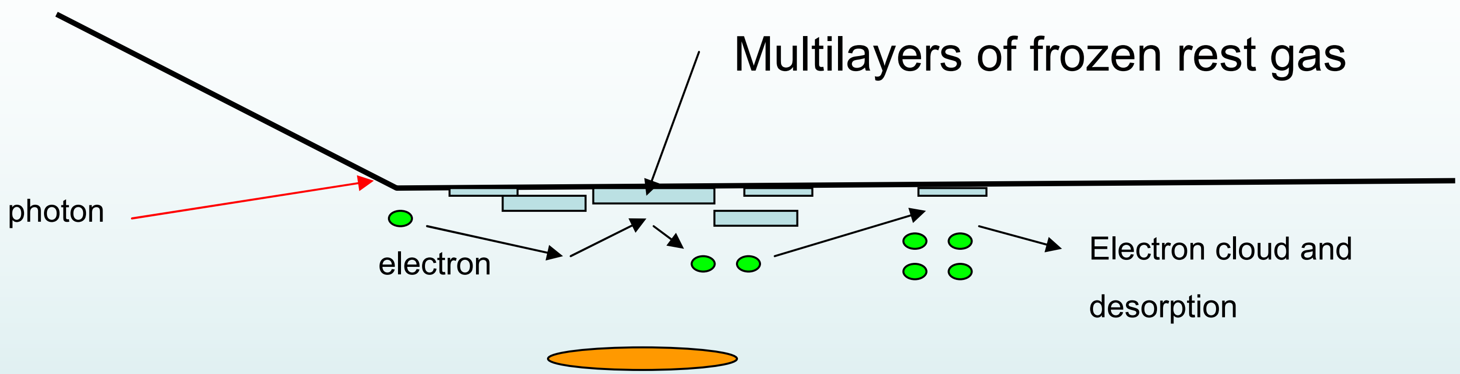
Absorbed power by a factor 10 to 20 too high

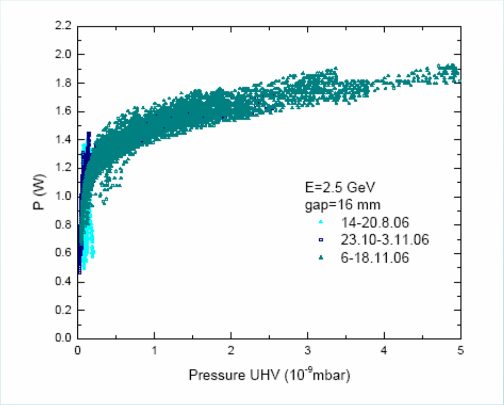
Misalignments???



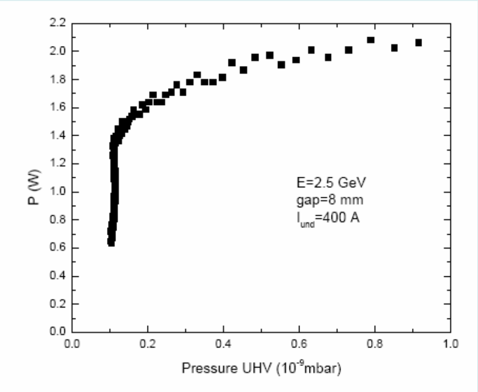

gap =16mm
P_uhv (mbar)
Pressure in the undulator
current (mA)
energy(GeV)
cold head 1
cold head 3
second stage
Temperature in the coils
Temperature (K)
Time (hours)

Basic idea on the physical process: (F. Zimmermann, CERN and S. Casalbuoni, ANKA)

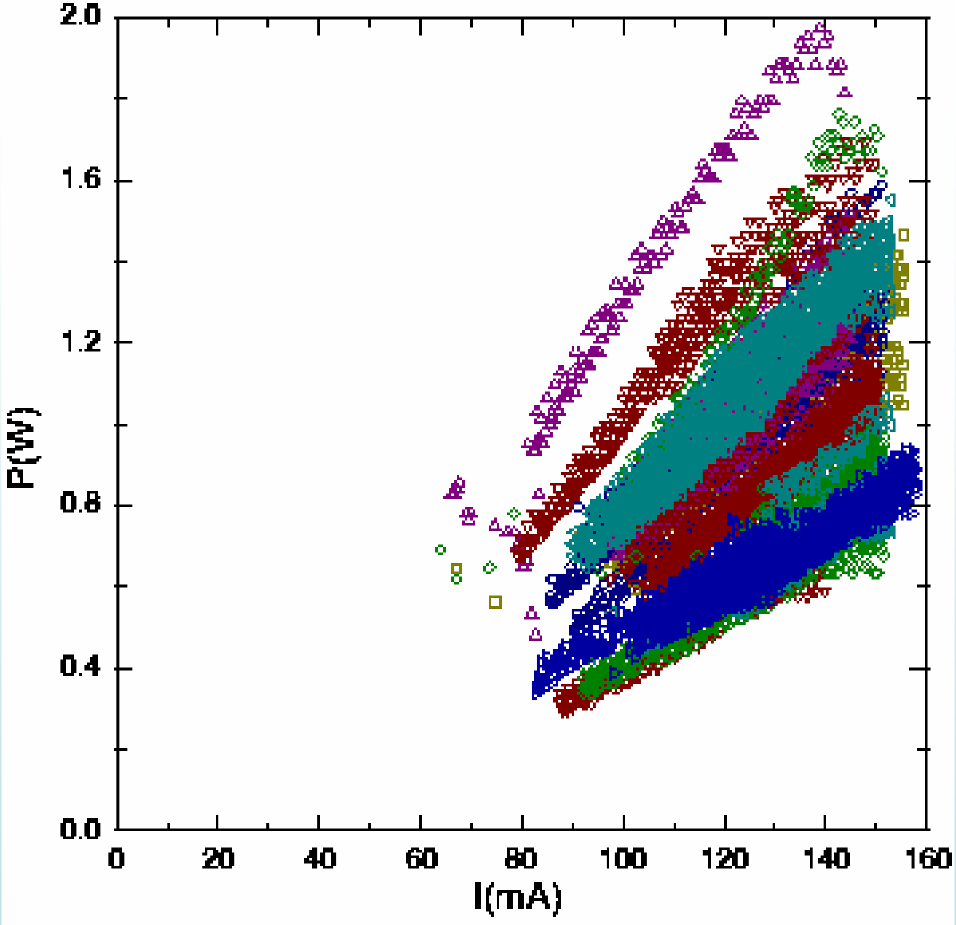




electron clouds



Investigations under way if the temperature effect is dominated by an electron cloud effect



Statistics over one year

Orbit is identical

Maybe rest gas is the explanation

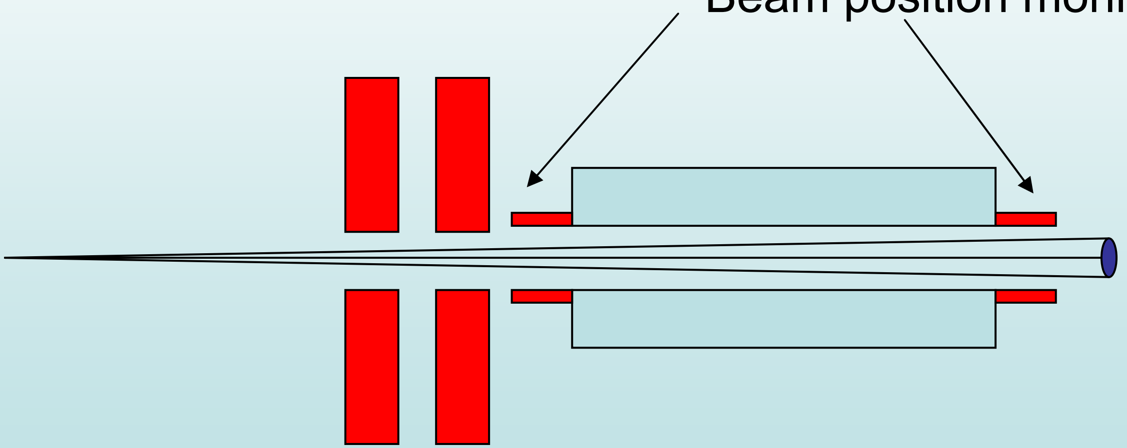
If yes: remedy is a differential pumping section in front and after the undulator

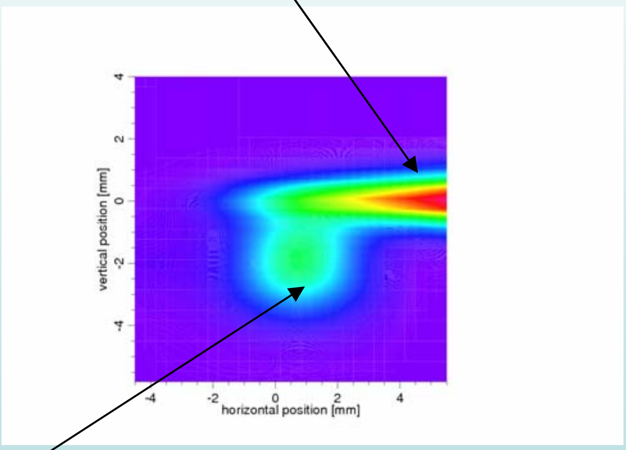
(Y. Cho et al., IEEE Trans. NS, 1977 for cold bore proton rings)

Summary:

Heating by beam in ANKA < 1 W / 100 mA (in general)

Improvement by differential pumping section in front and after the (small gap) undulator and better local orbit correction



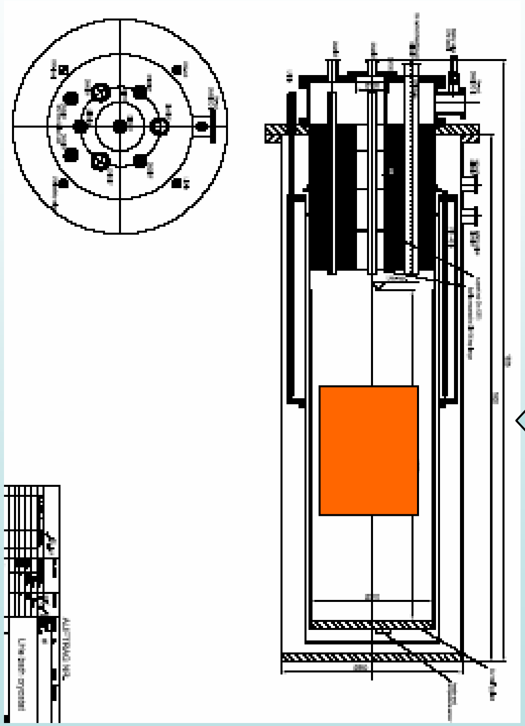


● Demonstrator has shown, that a superconductive small gap undulator is a viable device for ANKA

● We are in the process of building a new SCU14 device (hopefully without all the teething problems of the last one)

● Plan is to install it in about two years from now

<u>EU Project JRA4 :</u> **ANKA (coordinating institute)**
MAXLAB
ELETTRA
ESRF



<u>Questions to be Investigated</u>

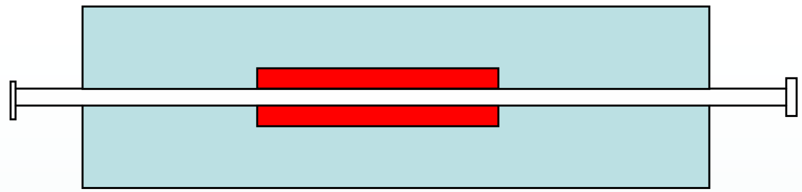
MAXLAB: Cooling System for higher beam heat load

ANKA: Vertical test and field measuring stand for

small devices (similar to BNL D. Harder et al., Proc. PAC 2005) and test device for full undulators

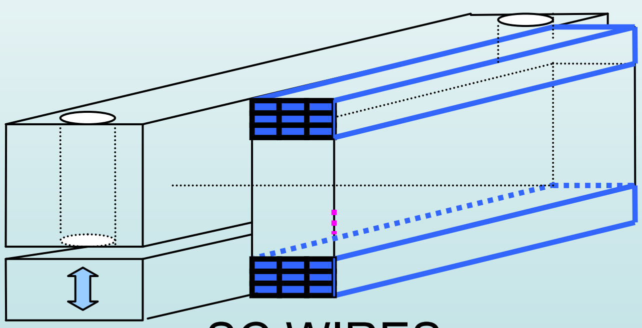
Full system: horizontal cryostat

Integral measurements:



Phase error compensation:

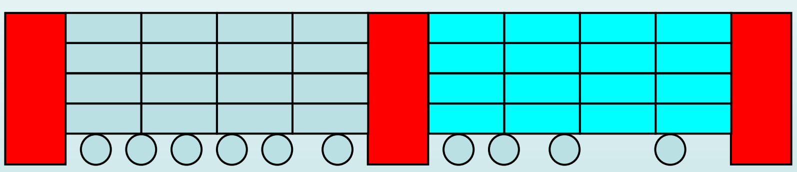
Mechanical shimming



SC WIRES

POLE

Electrical shimming



Or any other more innovative technique

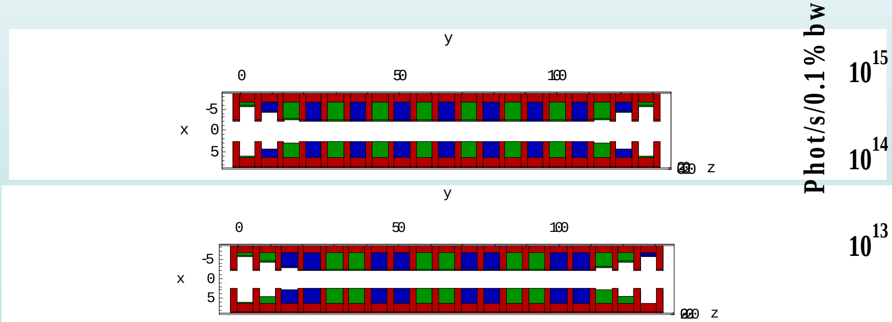
Longterm solution:

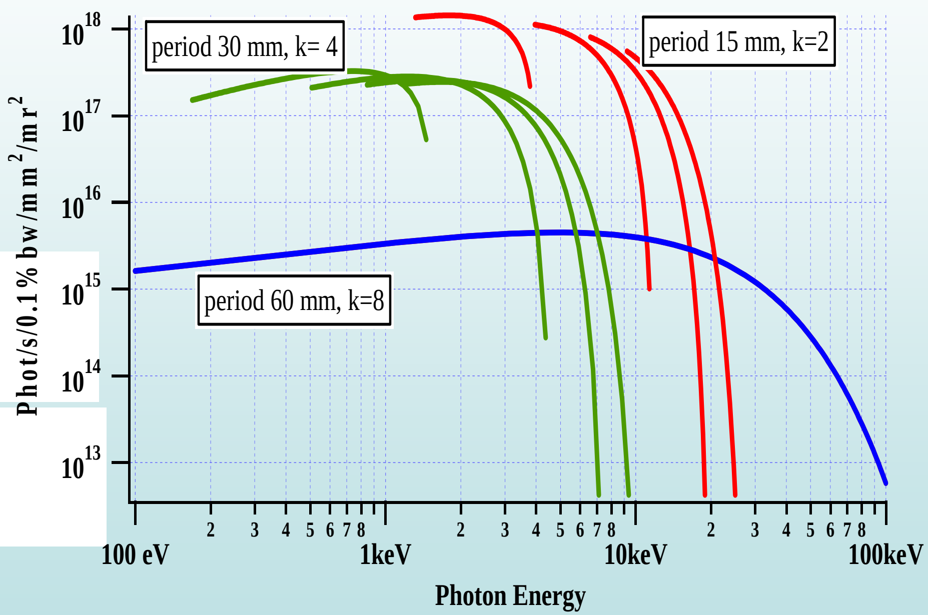
● Nb_3Sn instead of NbTi wires allow higher operating temperatures but not so easy to handle (similar to Brookhaven and Berkeley).

SCUW

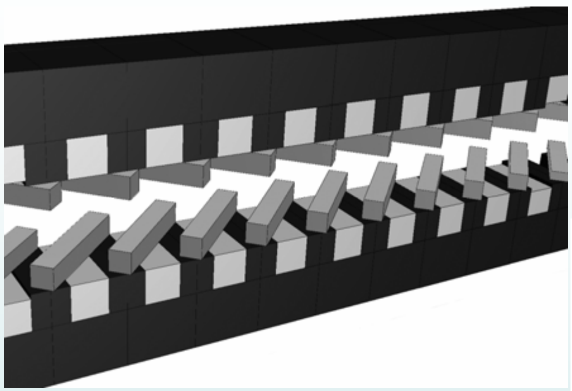
Undulator with variable

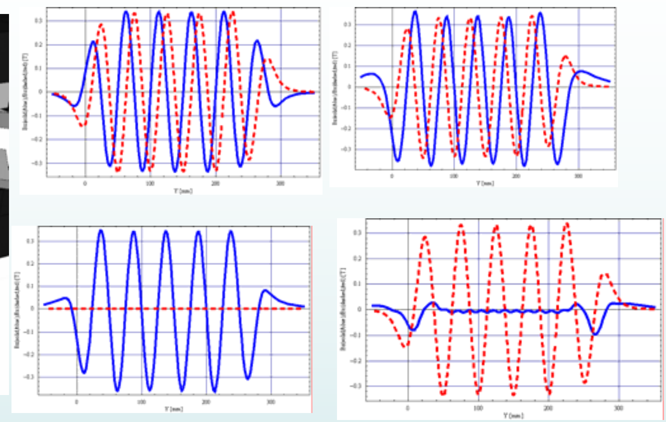
period length

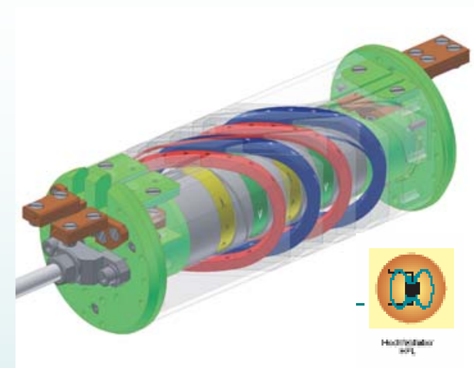




Helical undulator

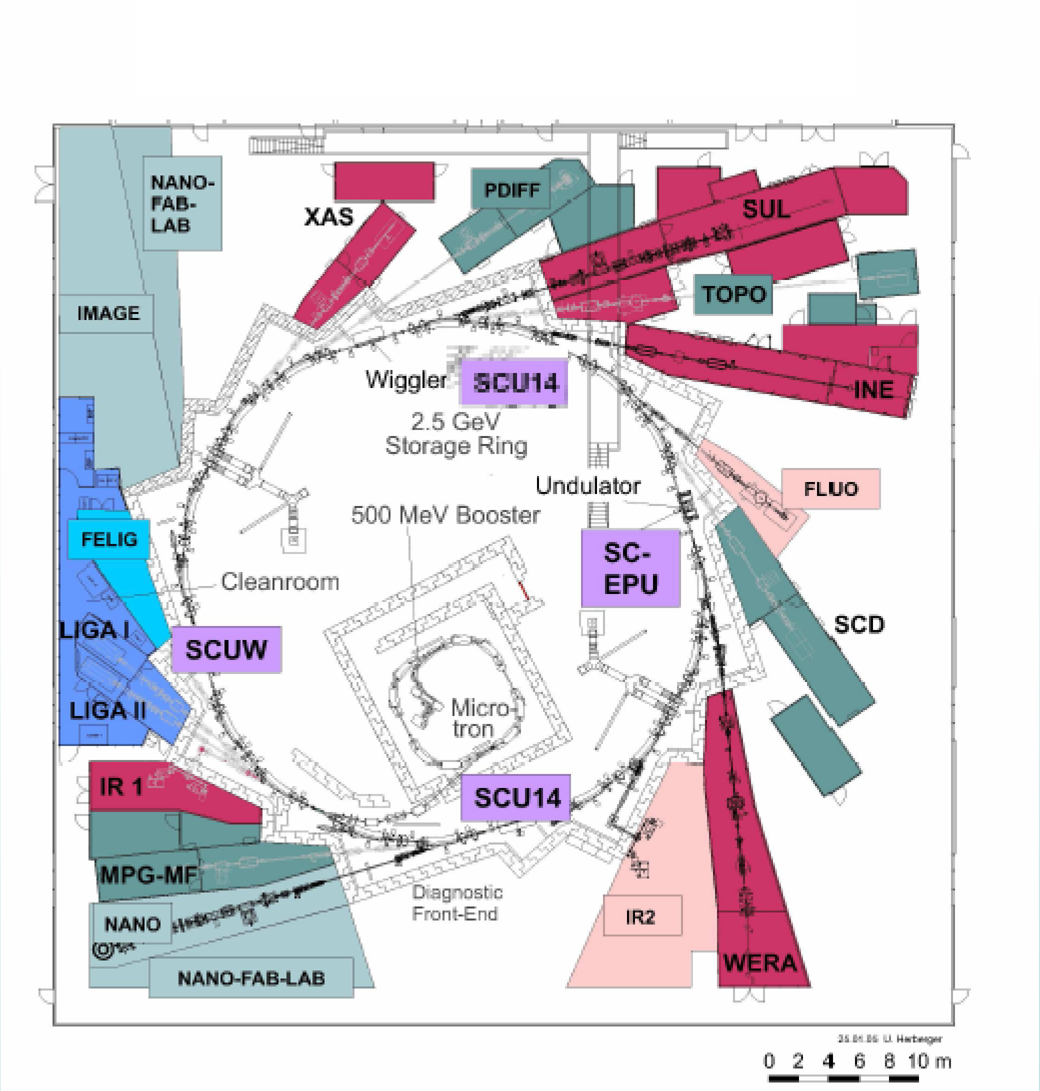




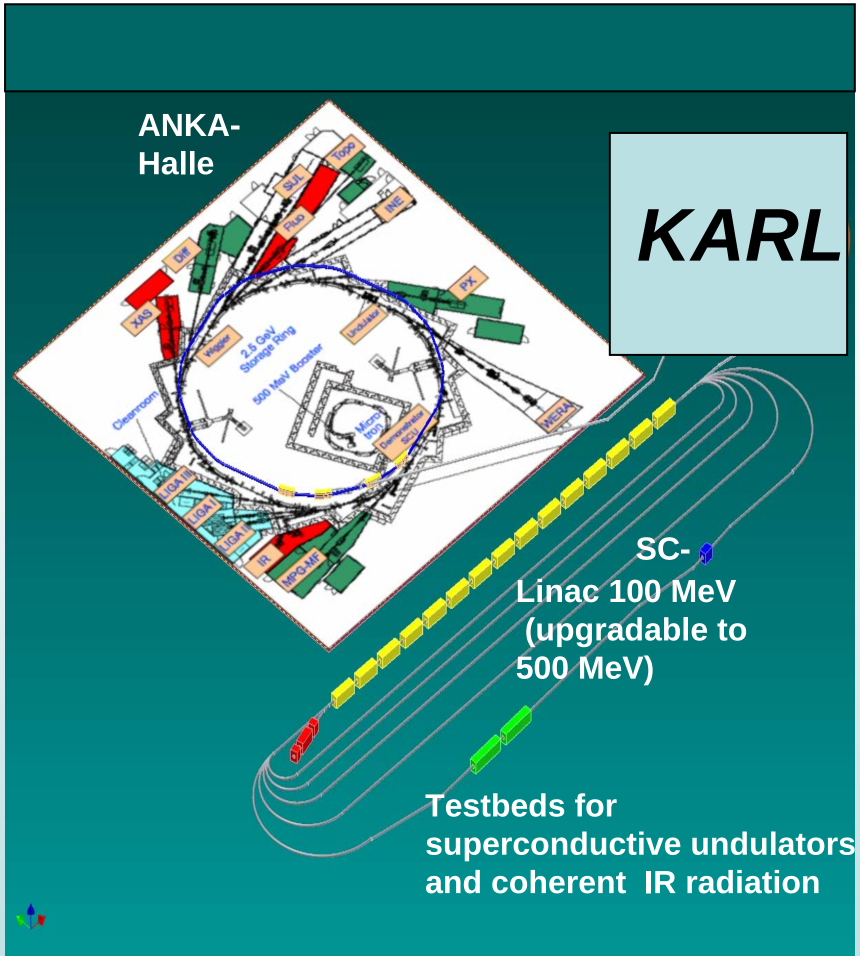


Prototype built, works as expected

ANKA will host 4 sc undulators

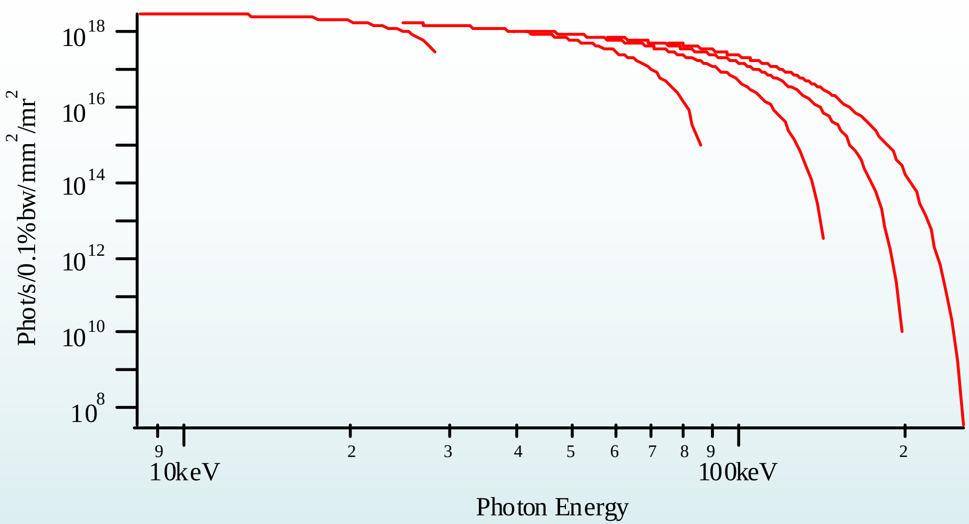


Study: **KARL** (Karlsruhe energy recovery linac)



End Energy	2.5 GeV
LINAC Energy	500 MeV
Cw Current	10 mA
Accelerating gradient	20 MeV/m
Rf frequency	1.3 GHz
Normalized beam emittance	2 µm
Minimum bunch length	200 fs

KARL will be a highly brilliant light source



Gap 1 to 2 mm

(similar to MAMI experiment)

K=2.26 for a period length of 2 mm