Undulator demagnetization due to radiation losses at FLASH

Jochen Skupin / Joachim Pflüger

FSUS

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Outline

1. The FLASH sacrificial undulator ("Opferundulator")
2. Radiation dose measurements
3. Demagnetization of sacrificial undulator
4. Review of TTF1 results
5. FEL simulations with adjusted K-parameter (by B. Faatz)
6. Conclusions

The FLASH sacrificial undulator ("Opferundulator")

Purpose

- installed to test radiation damage to magnetic structures

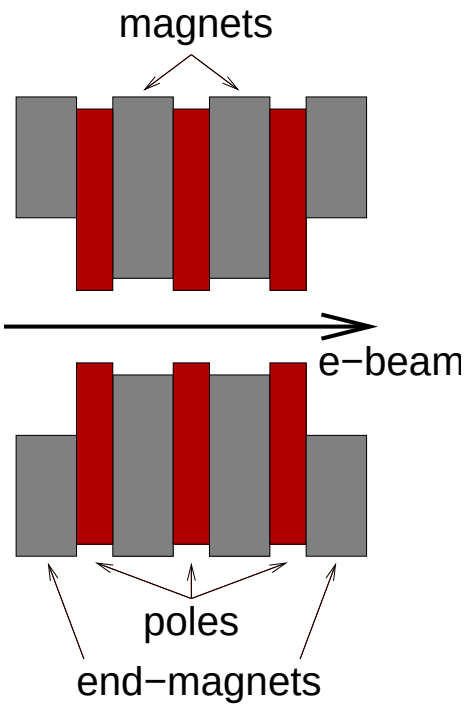
⇒ installed at a position where high radiation doses are to be expected

⇒ should have no impact on machine performance

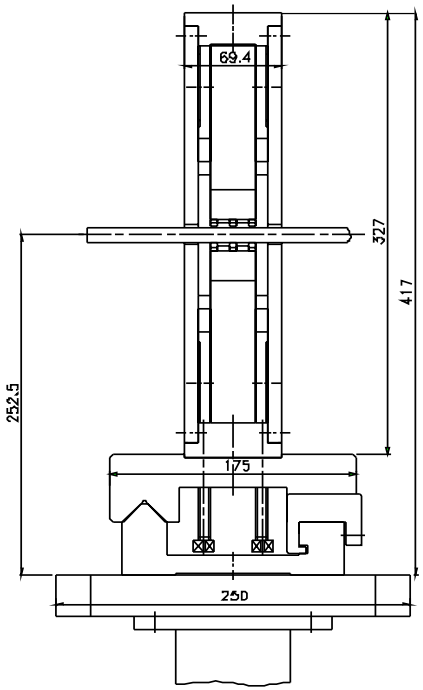
Design of the sacrificial undulator

- short piece of standard undulator structure with 3 poles, 2 normal magnets and 2 end-magnets on either side of the e-beam

schematic drawing



technical drawing



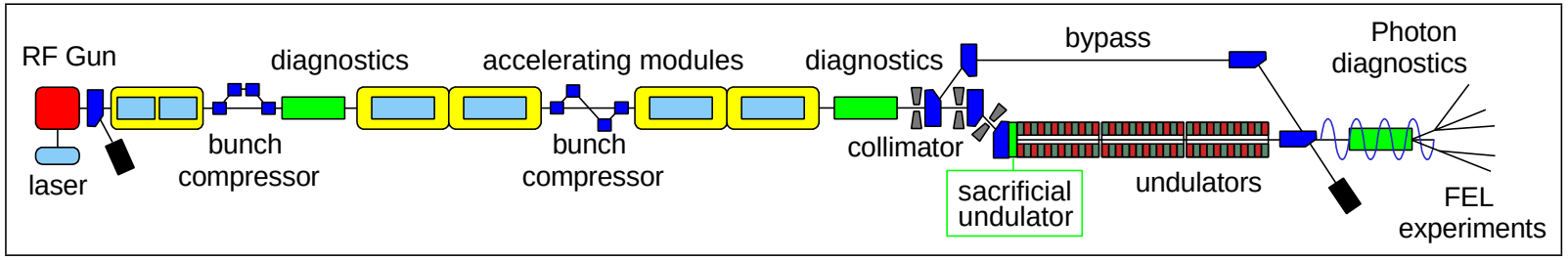
photo

- Parameters:

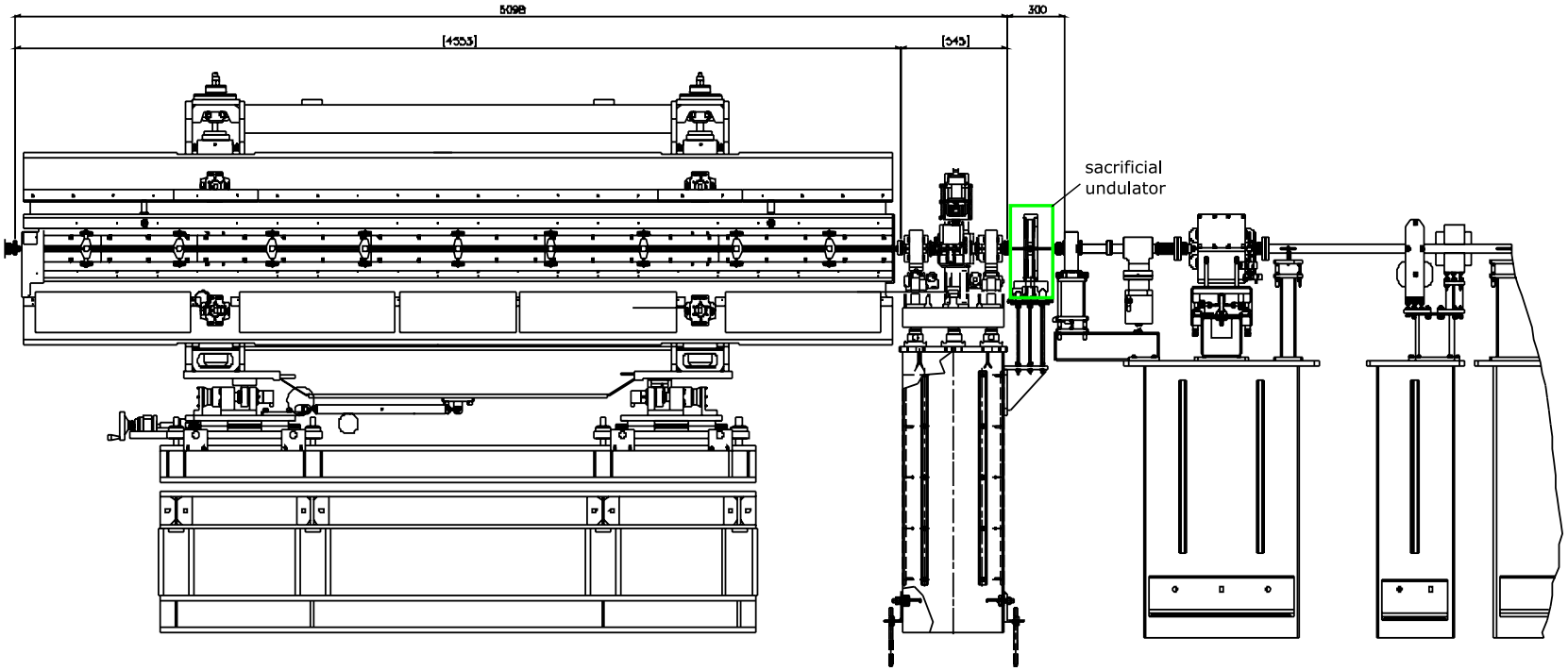
Period	Gap	Peak magnetic field	K
27.3 mm	12 mm	0.486 T	1.23

Installation location

- position in FLASH layout before first undulator module:

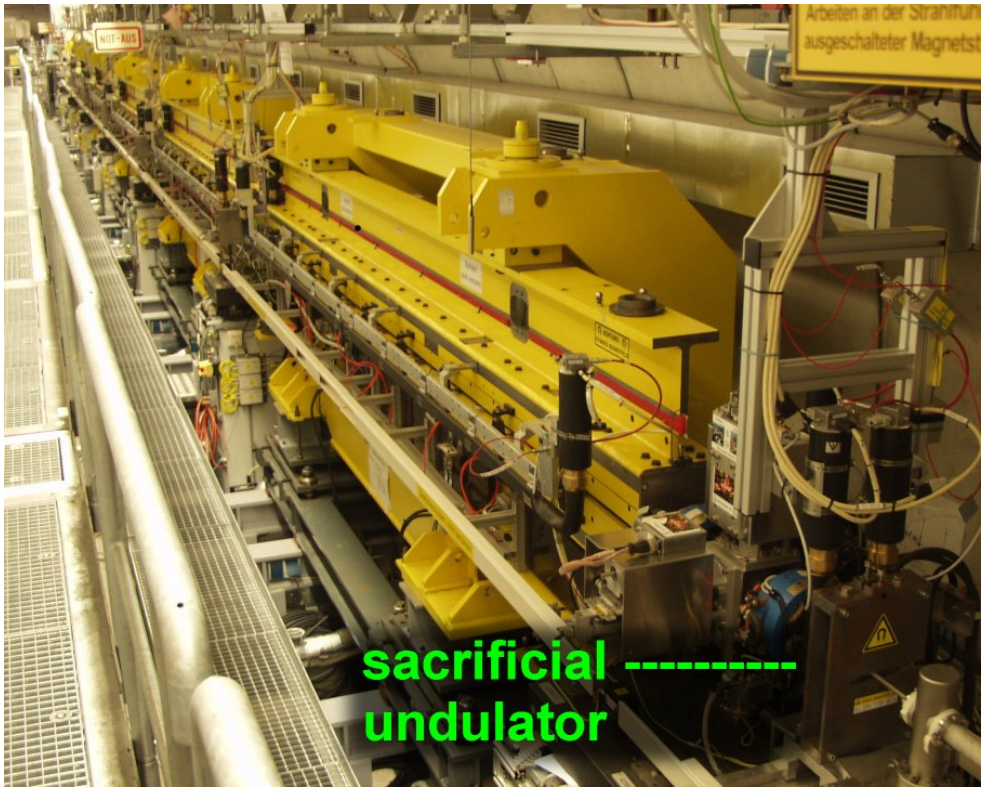


- technical drawing:



Installation location

- photos from FLASH tunnel:

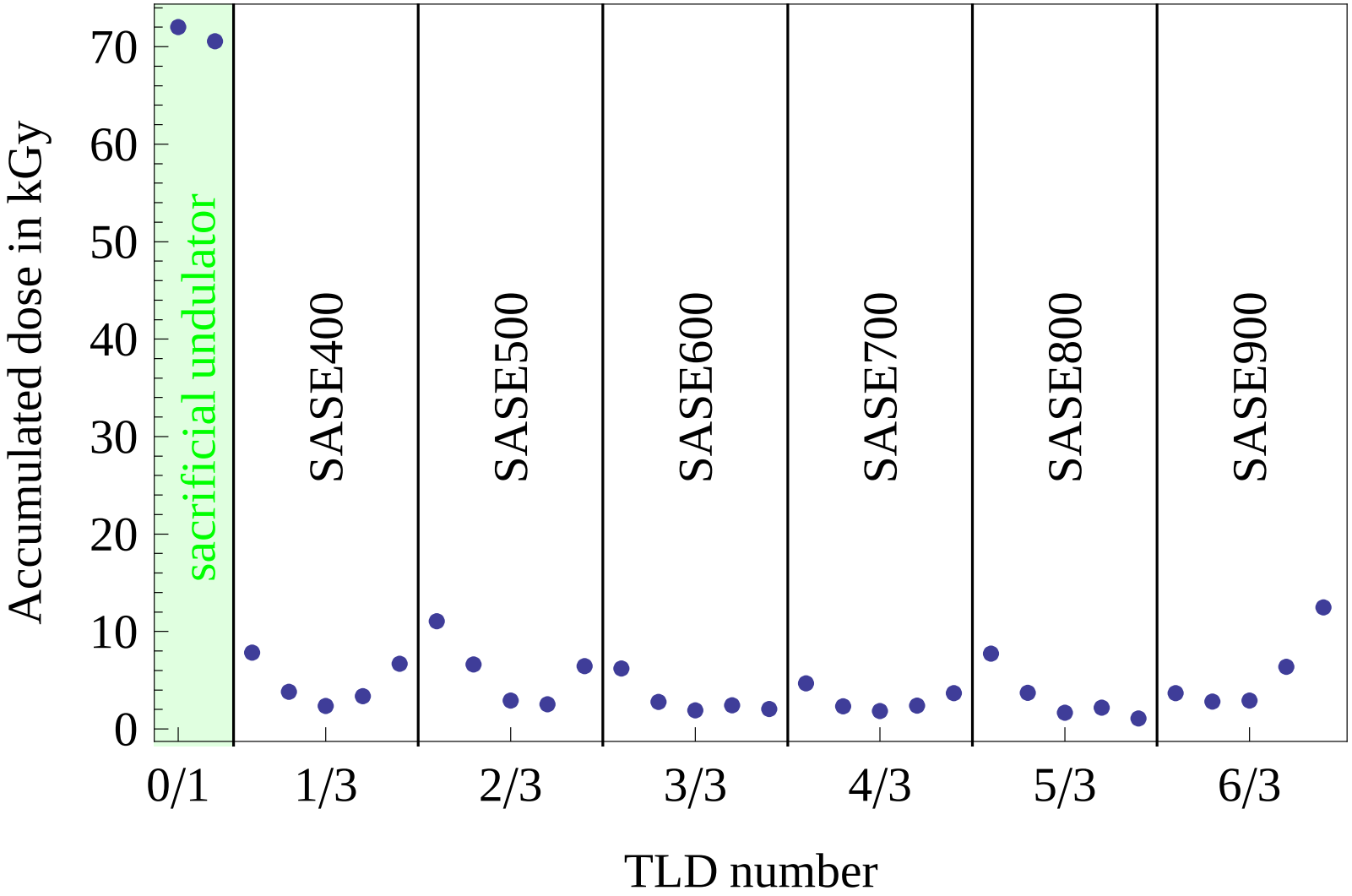


Radiation dose measurements

Dosimeters (TLDs)

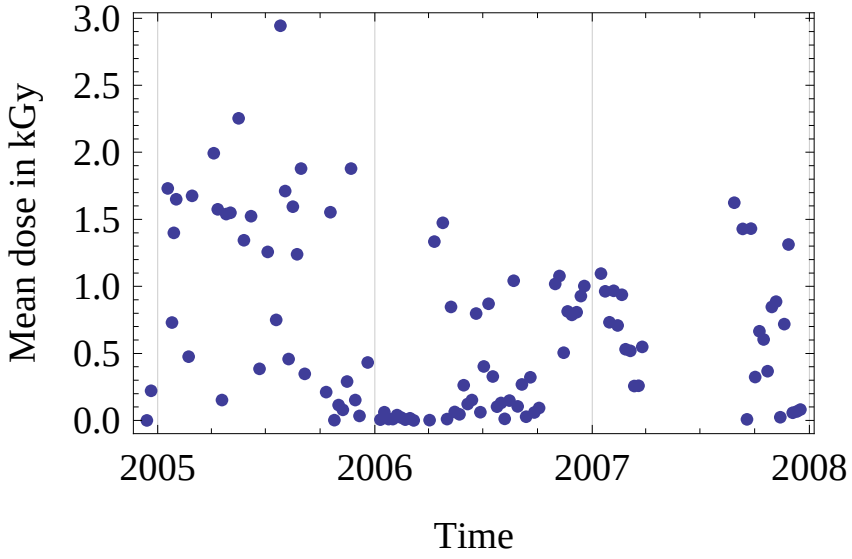
- 32 thermoluminescense dosimeters (TLDs)
- 5 at every SASE undulator
- 2 at the sacrificial undulator
- weekly dose measurements

Current accumulated doses

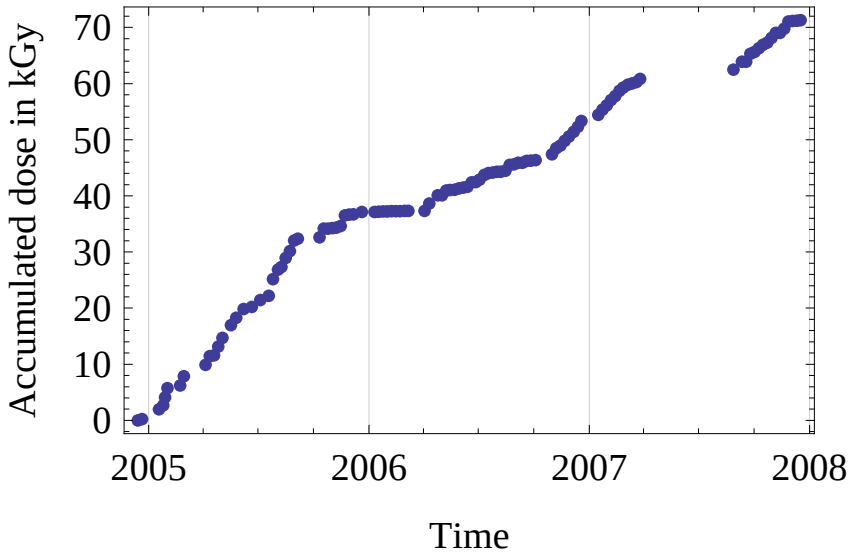


Mean dose at sacrificial undulator

- mean doses of positions 0/1 & 0/2



single measurements



accumulated doses

Demagnetization of sacrificial undulator

Magnetic measurements

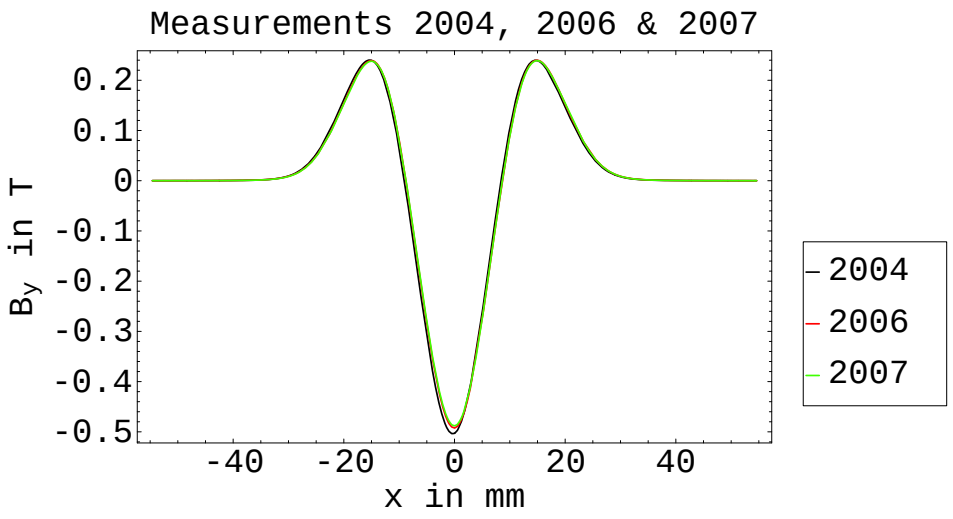
- the magnetic field of the sacrificial undulator was measured in years 2004, 2006 and 2007:

Date	Dose in kGy	Filename
2004-08-13	0. (before first installation)	POLETN6.AVG
2006-03-21	37.	POLETN19.AVG
2007-09-29	61.	POLETN01.AVY

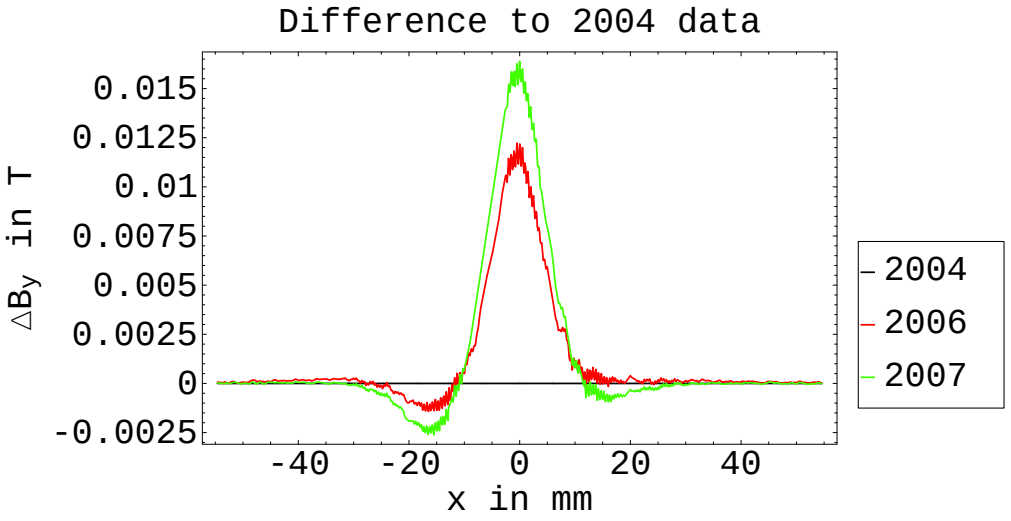
- the following results are based on the comparison of the vertical field along the magnetic centre of the structure

Measured magnetic fields

- magnetic fields:

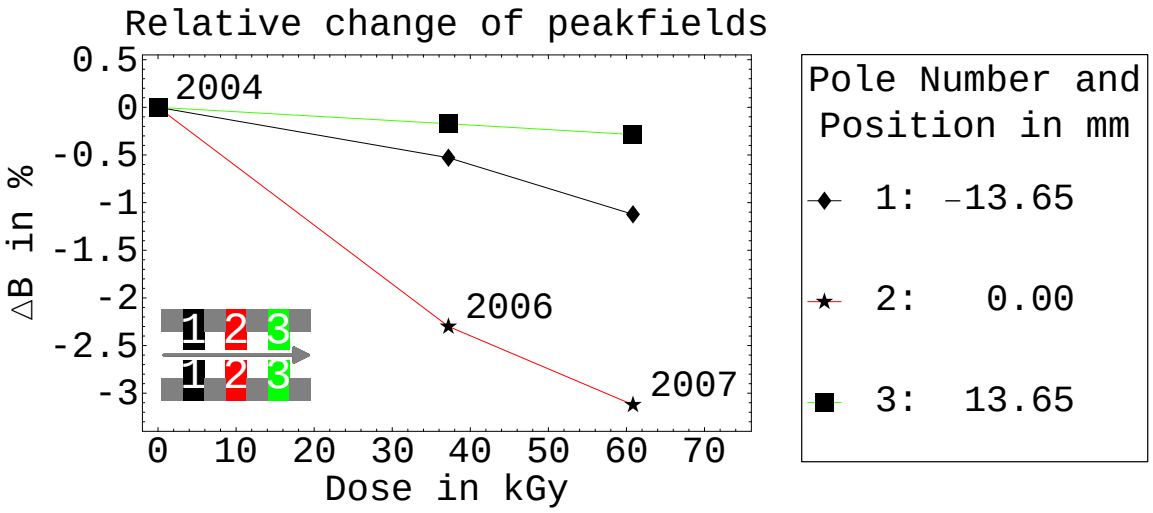


- field differences:



Trend analysis

- percentual change of peakfield on poles:



Date	Dose in kGy	Fieldchange in % on Pole 1	Pole 2	Pole 3
2004-08-13	0.	0.0	0.0	0.0
2006-03-21	37.	-0.5	-2.3	-0.2
2007-09-29	61.	-1.1	-3.1	-0.3

- maximal demagnetization on mid-pole of about:

$$5 \cdot 10^{-4}/\mathrm{kGy}$$

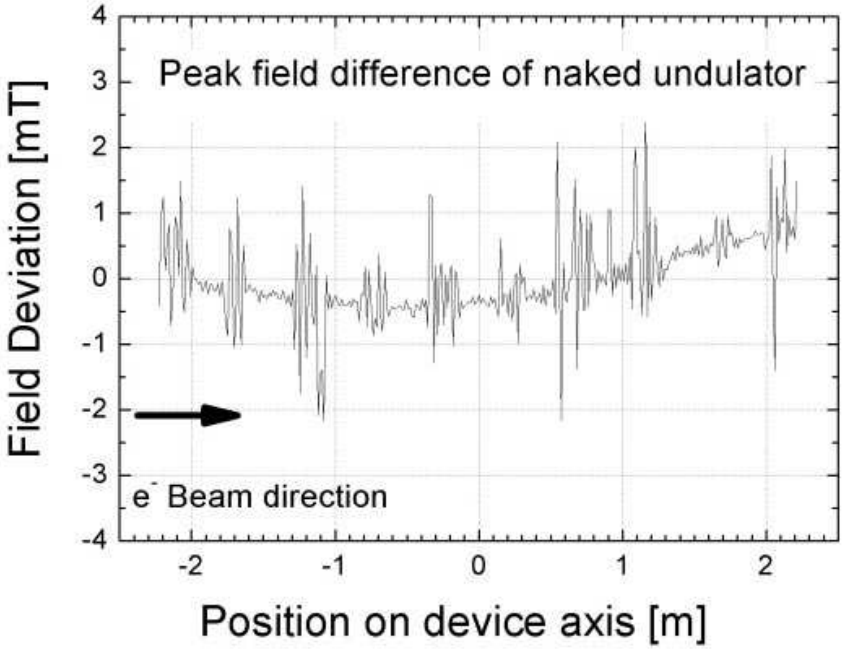
Review of TTF1 results

NIM paper

- NIM paper *"Radiation exposure and magnetic performance of the undulator system for the VUV FEL at the TESLA Test Facility Phase-1 after 3 years of operation"* by J. Pflüger et al. states:

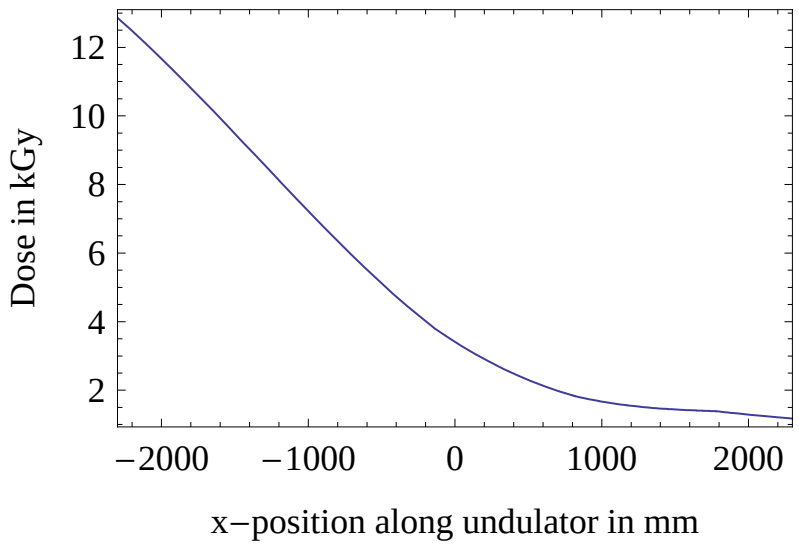
  We could not detect radiation induced demagnetization ... at dose levels up to 12000 Gy.

- analysed were differences between the absolute peak field values of the data taken after deinstallation in May 2002 and those taken before installation in 1999

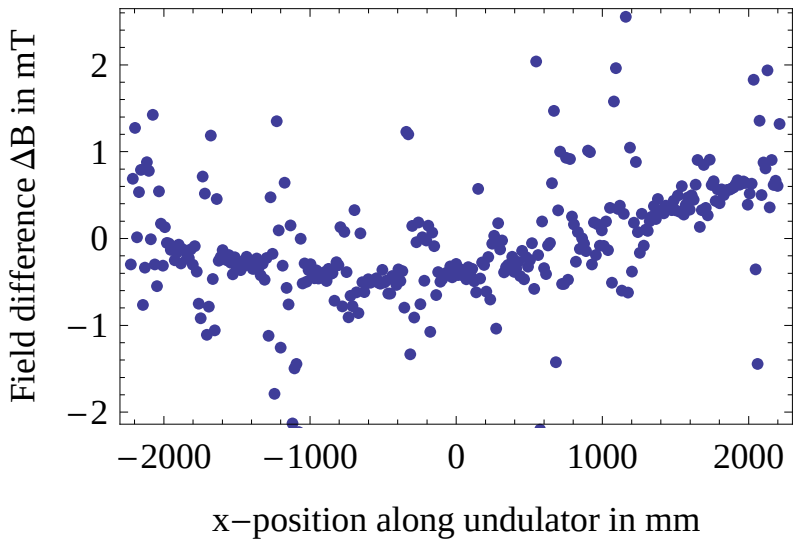


Data used for review

- measured doses at SASE300:

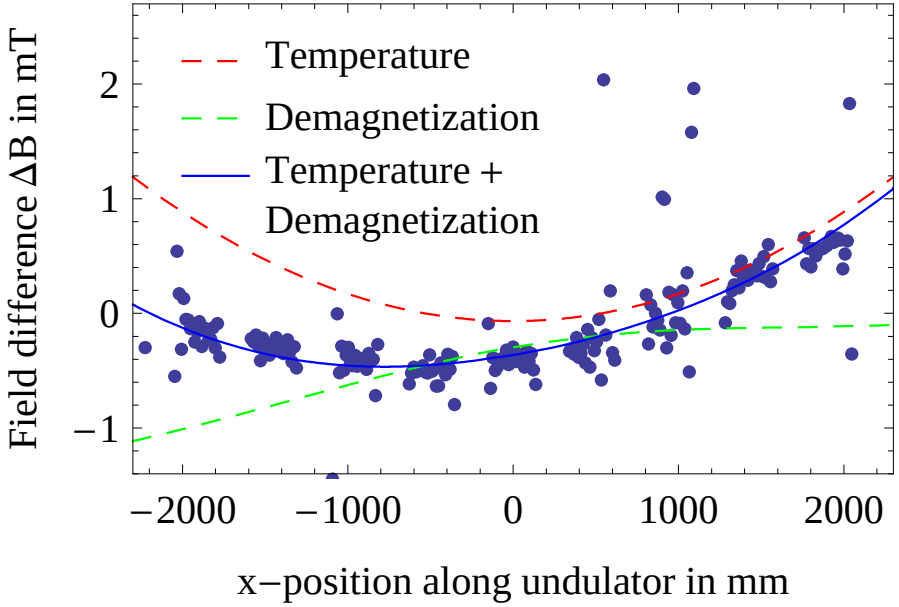


- difference between absolute peak field values from NIM paper:



New analysis of measurements

- omit values from 10 regions with focusing magnets
- pronounced parabolic field difference by temperature induced girder deformation, should be symmetrical to center of undulater
- fitting a centered parabola and a function proportional to measured dose
- sum of these functions approximates field difference well



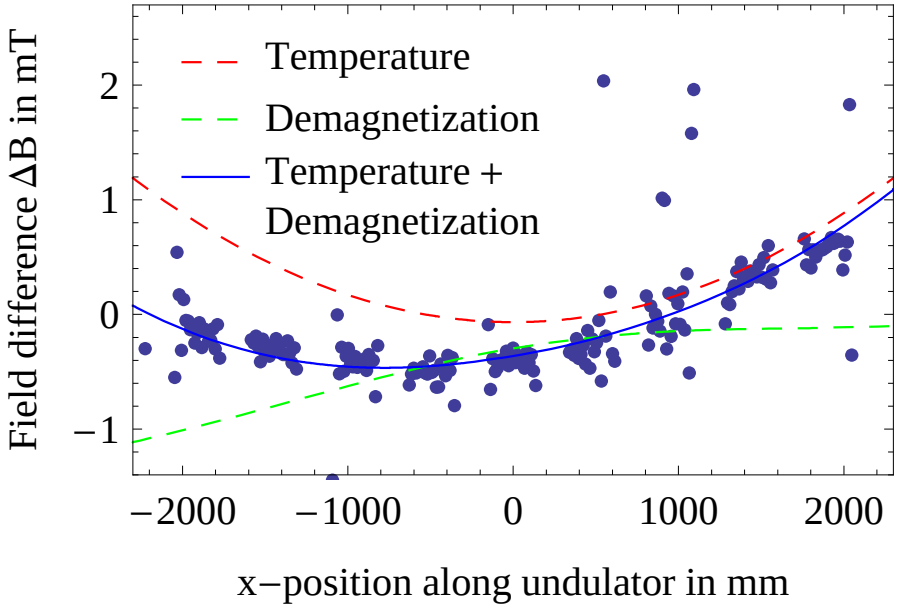
Result

- fit parameter for dose dependence yields a rel. demagnetization of about:

$$2 \cdot 10^{-4}/\mathrm{kGy}$$

- this is lower but in the same range as the result for the sacrificial undulator:

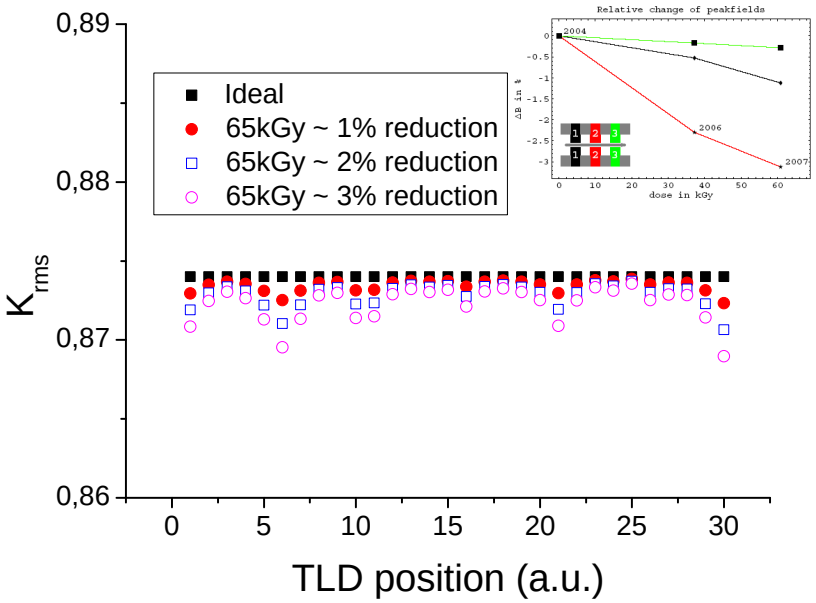
$$5 \cdot 10^{-4}/\mathrm{kGy}$$

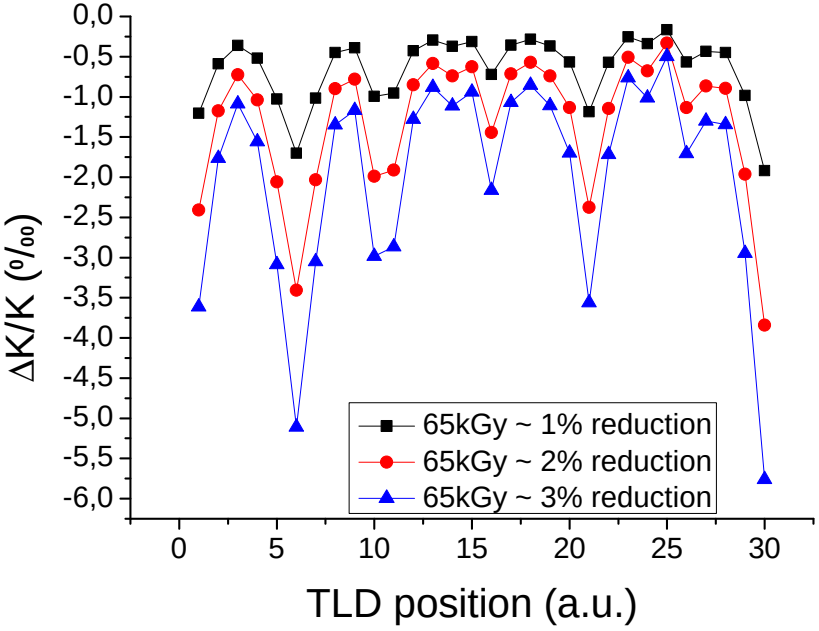


FEL simulations with adjusted K-parameter (by B. Faatz)

Change of K-parameter

- change of K-parameter derived from dose measurements, assuming demagnetization rates between $1.66 \cdot 10^{-4}$/kGy, and $5 \cdot 10^{-4}$/kGy

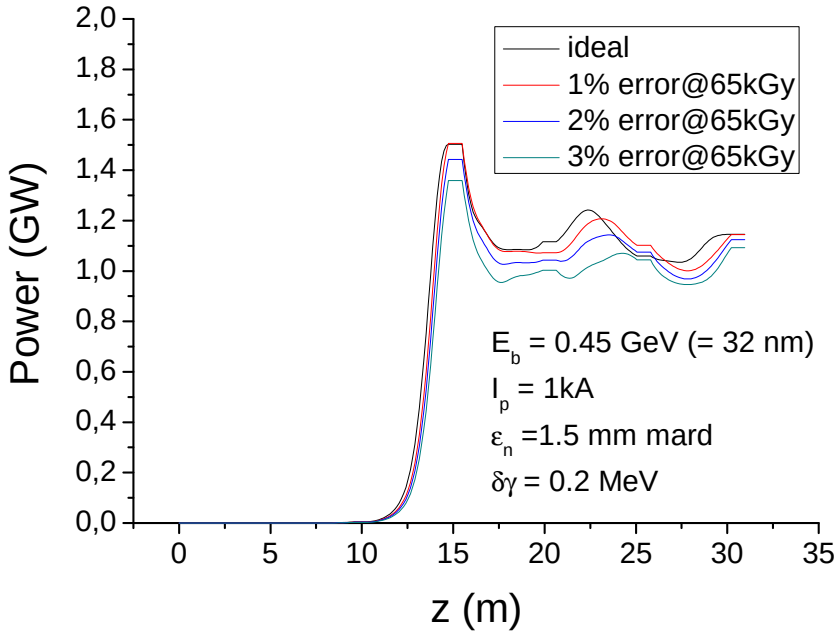




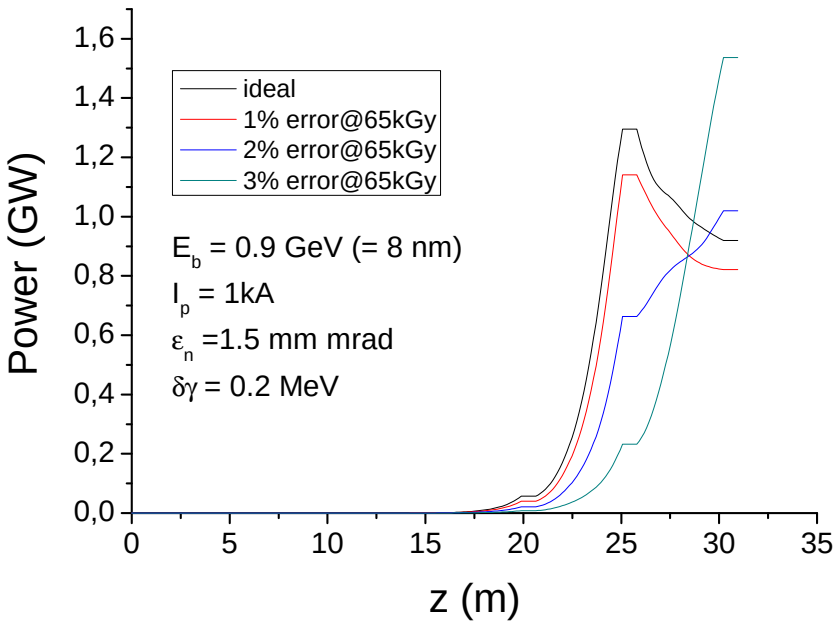
SASE power dependence

- *preliminary* steady state simulation of SASE power:

30 nm



8 nm



⇒ for lower wavelength saturation length increases with increasing demagnetization

Conclusions

Conclusions

- analysis of sacrificial undulator shows demagnetization due to radiation losses
- also visible in review of TTF1 measurements
- estimated demagnetization rate between $2 \cdot 10^{-4}$/kGy and $5 \cdot 10^{-4}$/kGy
- FEL simulations show that SASE process may be influenced by demagnetization

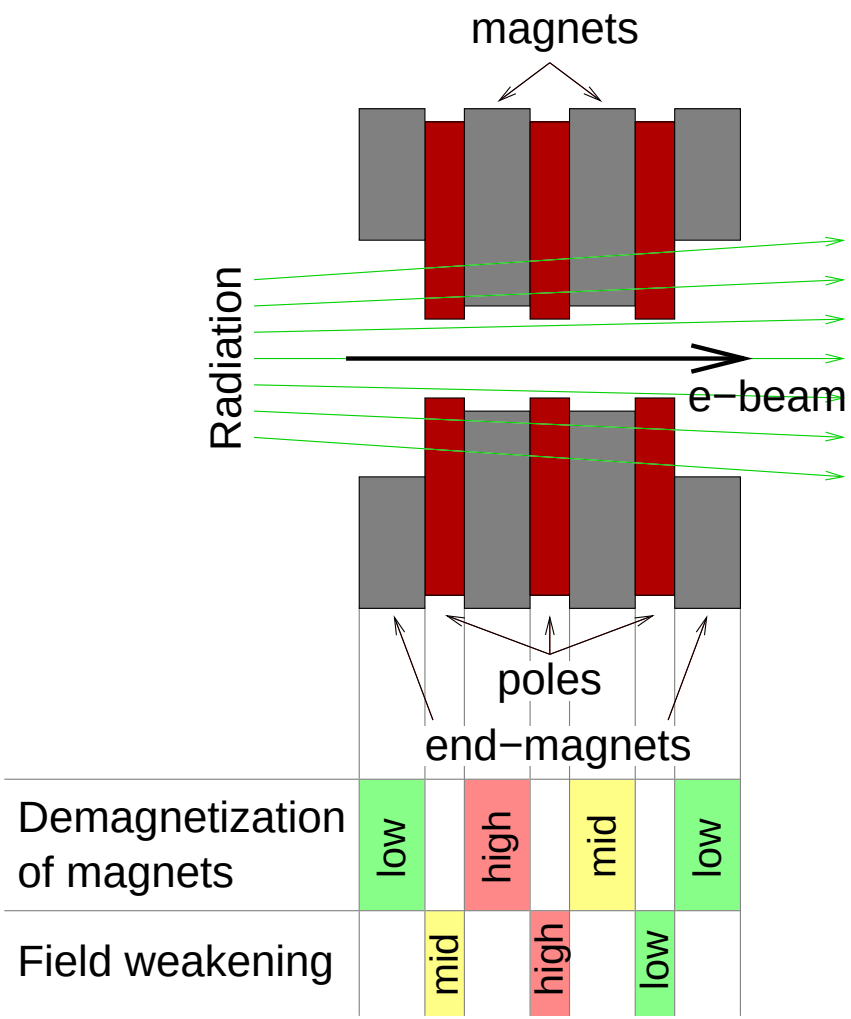
Additional slides for discussions

Different pole demagnetization

- all 3 poles of the sacrificial undulator show different demagnetization

⇒ it is known that radiation hardness of magnetic materials correlates to coercive field, according to J. Pflüger it might be possible that the ratio of magnetic field to coercive field has an influence too

⇒ it might be a simple geometrical explanation



⇒ to be sure, the sacrificial undulator would have to be disassembled to measure single magnets

TTF1 vs. FLASH results

- TTF1 demagnetization with $2 \cdot 10^{-4}$/kGy considerable lower than the $5 \cdot 10^{-4}$/kGy for the sacrificial undulator, possible reasons:

⇒ machine changes from TTF1 to FLASH

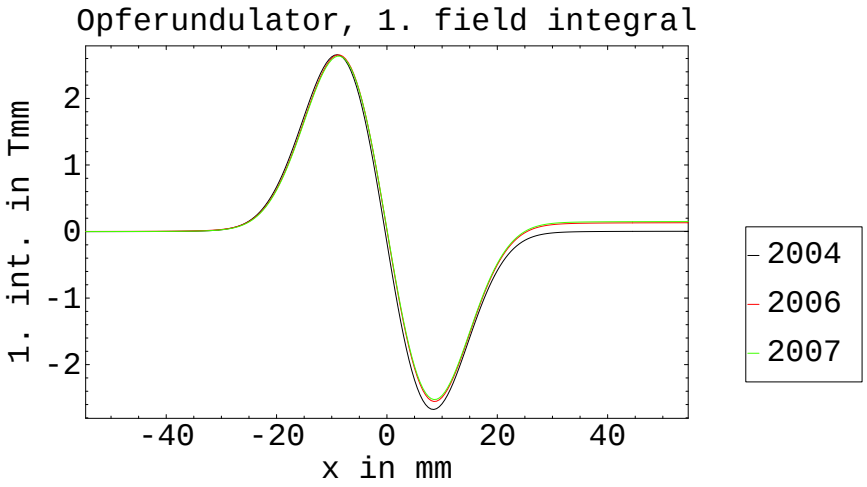
⇒ position of sacrificial undulator may not be representative for undulator system

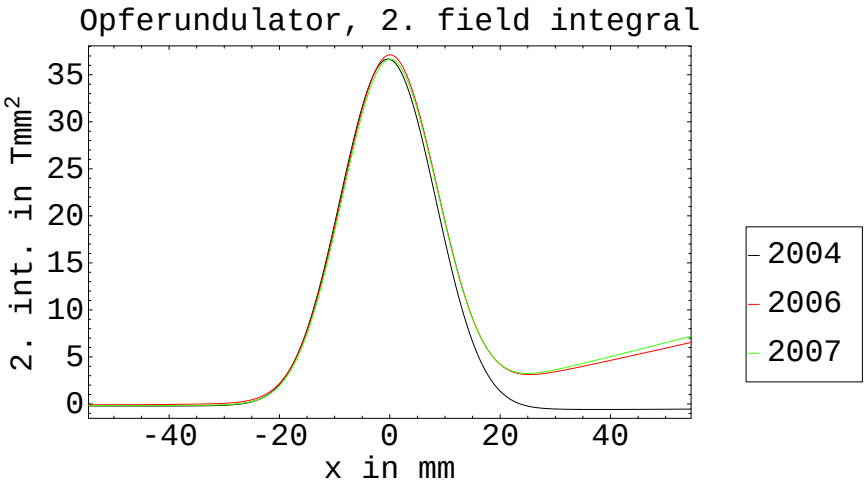
⇒ magnet gap in TTF1 larger than in FLASH

⇒ position of TLDs changed

Field integral of sacrificial undulator

- 1. and 2. field integrals for the measurements from 2004, 2006 and 2007





⇒ the 1. field integral at the end of the undulator increased from 0.00 Tmm in 2004 to 0.13 Tmm in 2006 and 0.15 Tmm in 2007