Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin
Nationales Metrologieinstitut

ACCURATE MEASUREMENT OF THE MLS ELECTRON STORAGE RING PARAMETERS

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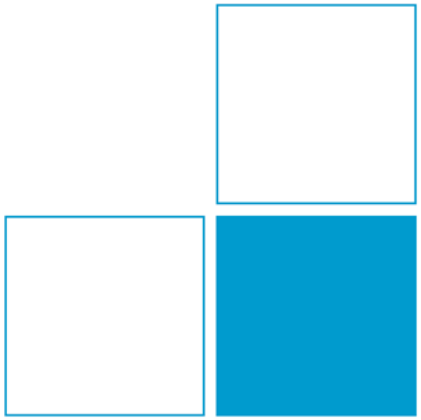


Outline

Introduction
- Physikalisch-Technische Bundesanstalt (PTB)
- Metrology Light Source (MLS)
- Source-based radiometry

Measurement of the storage ring parameters

Summary

Physikalisch-Technische Bundesanstalt

- PTB: German national metrology institute, located in Braunschweig and Berlin
- departments located in Berlin-Adlershof use synchrotron radiation from the electron storage rings BESSY II and MLS
- **tasks**: - Realization and dissemination of radiometric units the in UV, VUV, X-ray spectral range by
  using the SR sources as primary sources (Based Radiometry)
  and detector based Radiometry
  - Characterization of optical components, in particular for EUV lithography
  - Other applications of quantitative radiation measurements, spectrometry, metrology

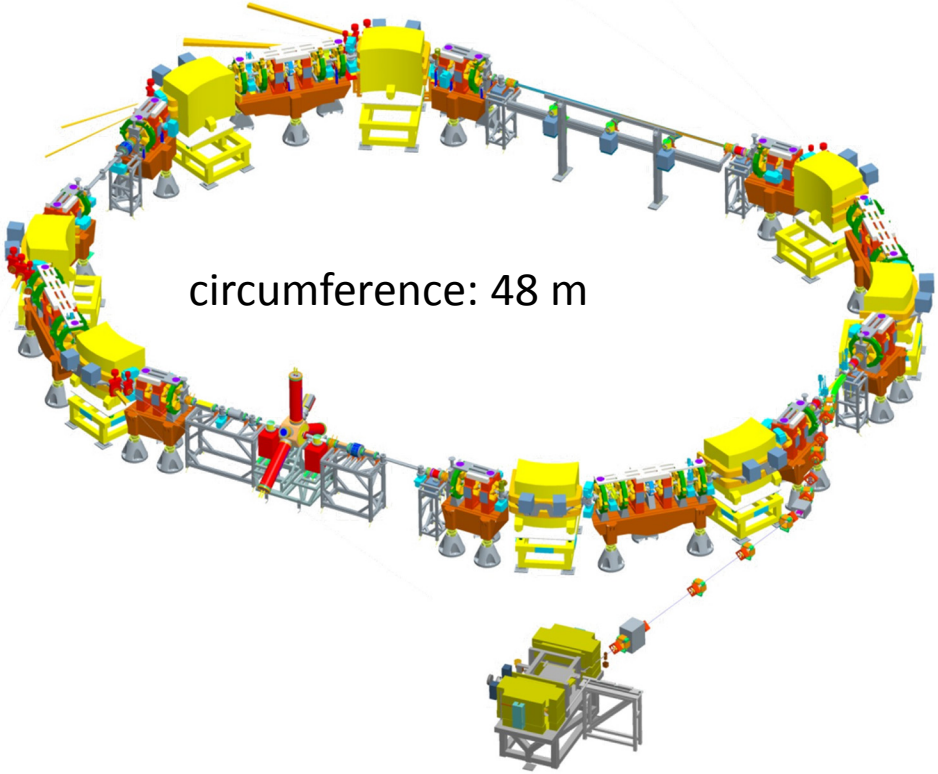
PTB in Berlin-Adlershof

PTB laboratory for X-ray radiometry at BESSY II

Metrology Light Source of PTB for UV und VUV radiometry

PTB staff in Berlin–Adlershof: 60

Metrology Light Source (MLS) electron storage ring



In user operation since 2008

Optimized for UV/VUV and IR /FIR spectral range

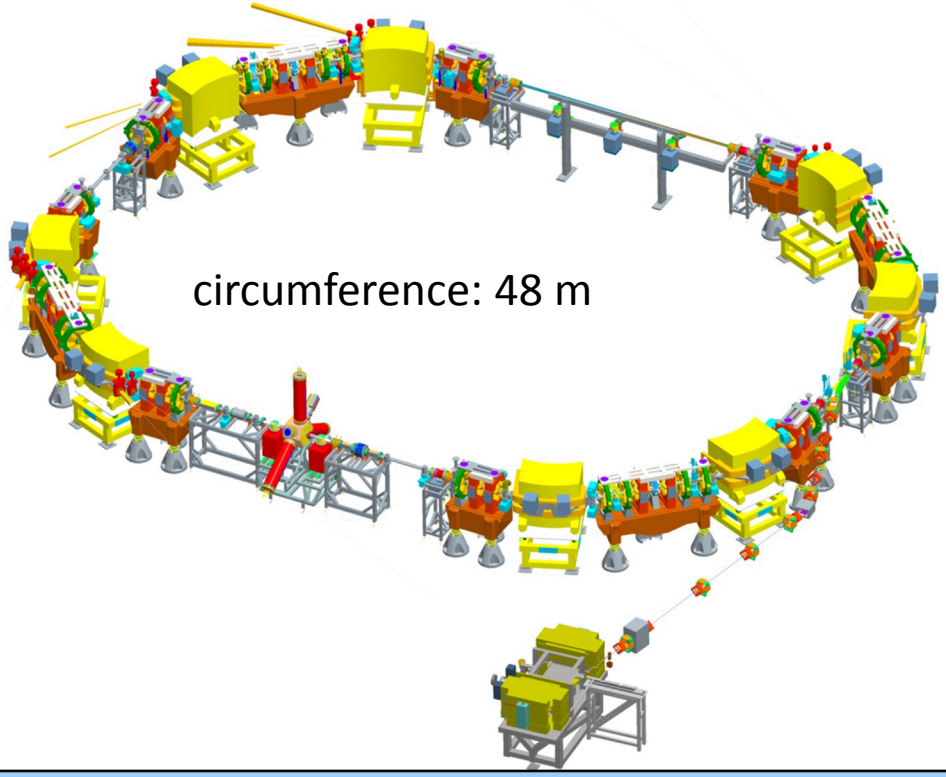
Owned by PTB

Operated by HZB

Complements PTB measurement capabilities at BESSY II

Large flexibility in operation

Metrology Light Source (MLS) electron storage ring



In user operation since 2008

Optimized for UV/VUV and IR /FIR spectral range

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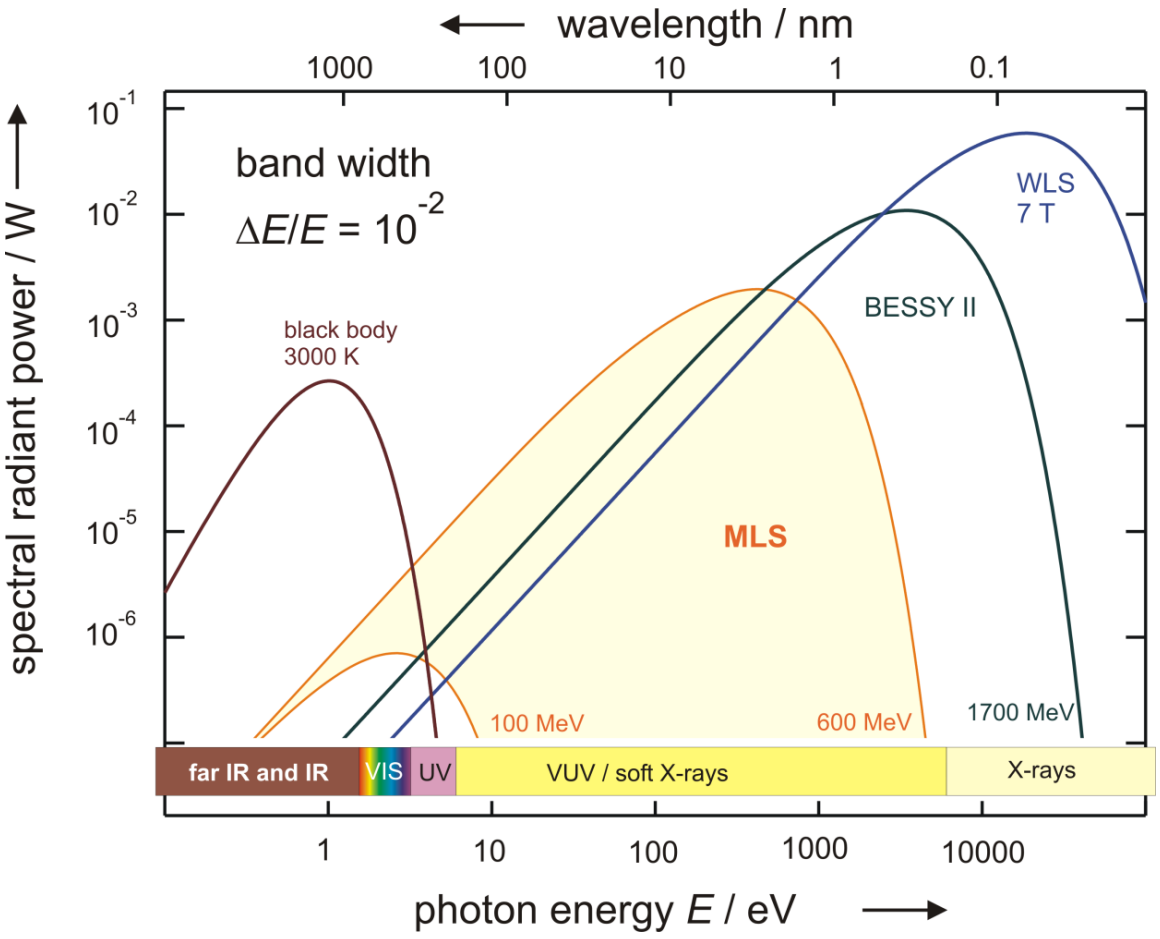
Complements PTB measurement capabilities at BESSY II

Large flexibility in operation

Parameter	Value
lattice structure	double bend achromate
circumference	48 m
electron energy	105 MeV to 630 MeV
magnetic induction of bending magnets	0.23 T to 1.38 T
characteristic wavelength	3.4 nm to 735 nm
characteristic photon energy	1.7 eV to 364 eV
electron beam current	1 pA to 200 mA
natural emittance (600 MeV)	100 nm rad (standard)/ 25 nm rad (low emmitance)
injection energy	105 MeV
revolution time	160 ns
beam life time (630 MeV)	6 h @ 150 mA / 30 h @ 1 pA
momentum compaction factor	- 5 x 10^{-2} to 5 x 10^{-2}

MLS synchrotron radiation spectral range



electron energy:
105 MeV to 630 MeV

characteristic wavelength:
3.4 nm to 735 nm

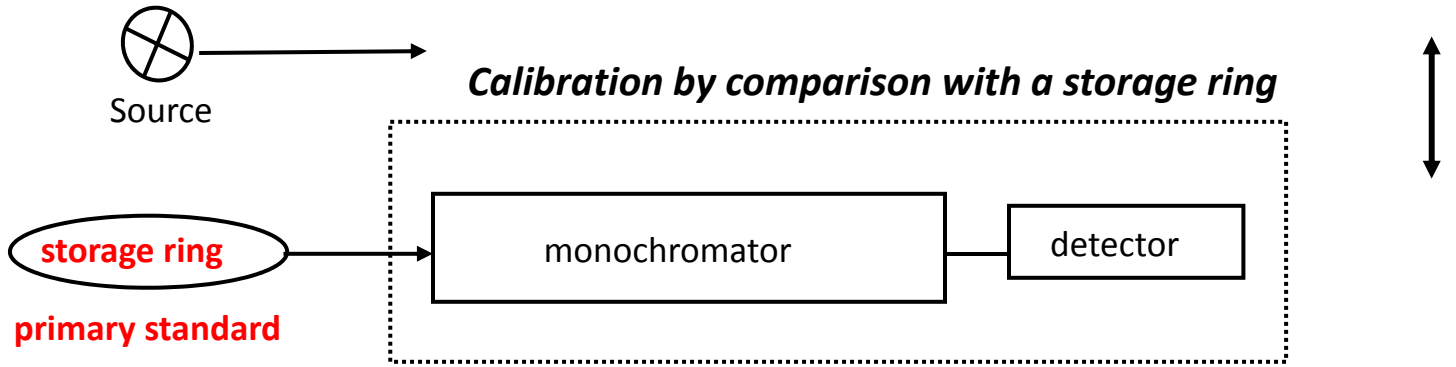
electron beam current:
1 pA (1 e^-) to 200 mA

photon flux can be adjusted to experiment by more than 11 decades!

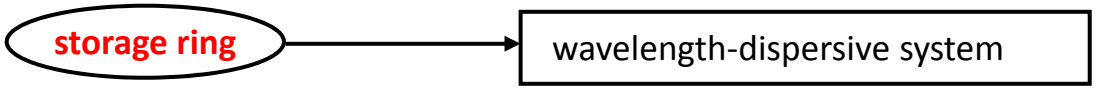
Source-based calibration schemes

Basis: Primary source standard electron storage ring

- **Task 1:** Calibration of sources



- **Task 2:** Calibration of - energy-dispersive detectors (e. g. Si(Li), HPGe, CCD)
  - wavelength-dispersive systems



Important property: MLS has a dynamic range of more than 11 orders of magnitude in photon flux! (BESSY II even 12 orders)

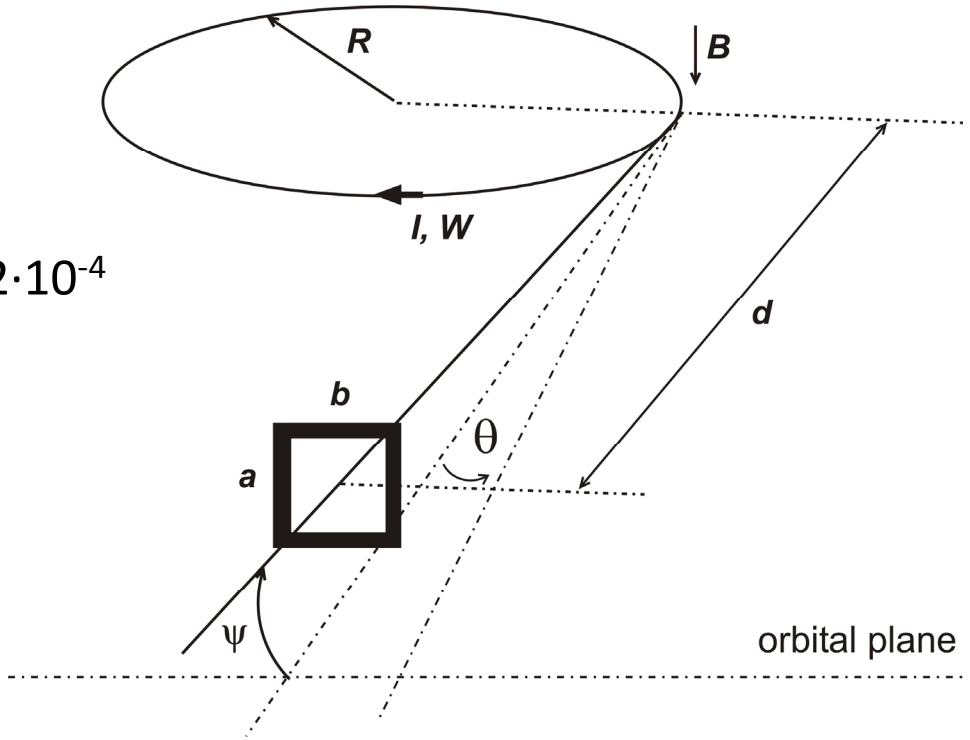
Requirement for calibration: Special operation parameters of the storage ring

Accurate measurement of MLS parameters

Parameters needed for the calculation (Schwinger):

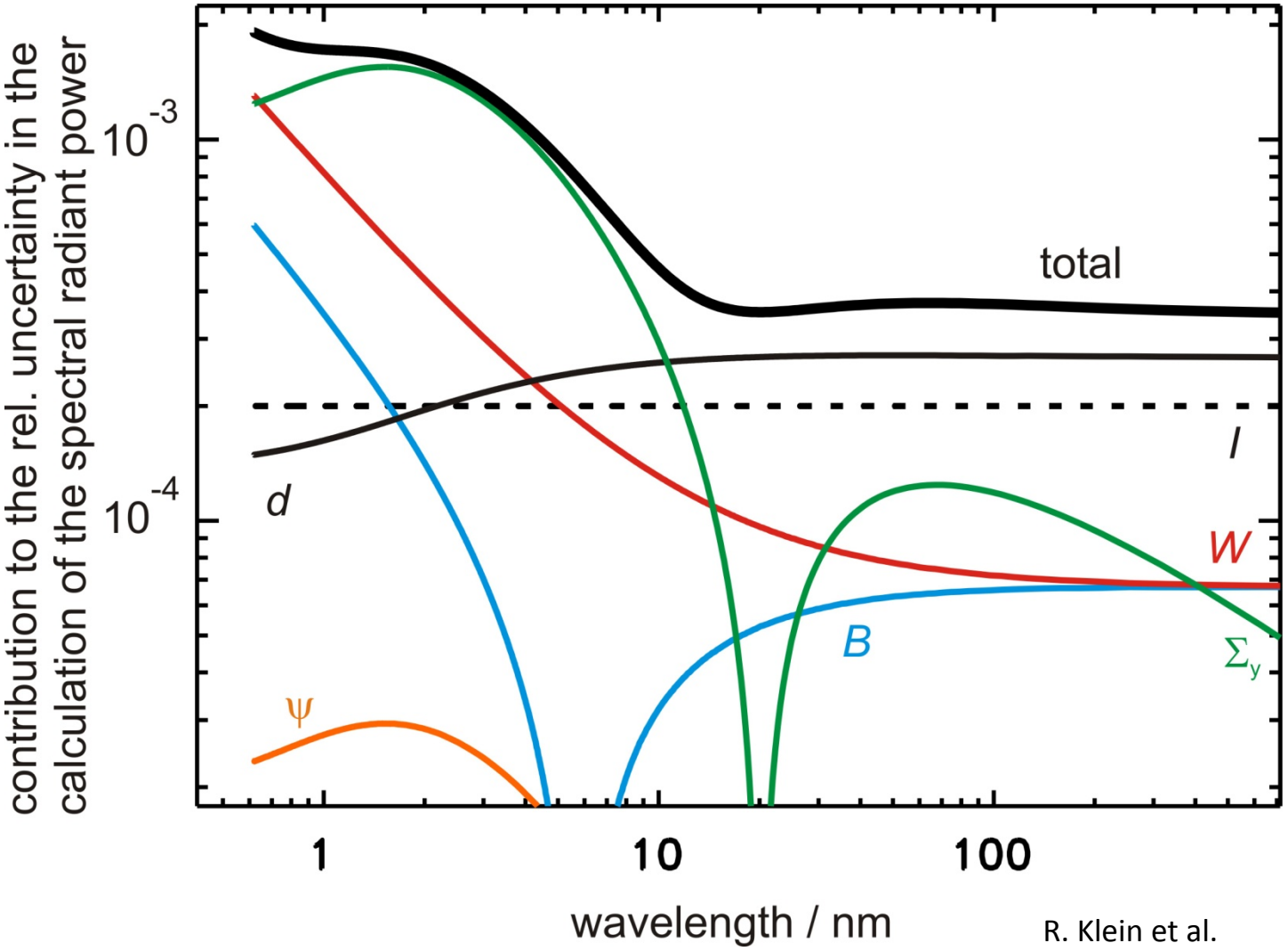
- electron energy W: $u_{rel} < 5 \cdot 10^{-4}$
- electron beam current I: $u_{rel} < 2 \cdot 10^{-4}$
- magnetic induction at the source point B: $u_{rel} < 1 \cdot 10^{-4}$
- electron beam size and divergence Σ_γ: $u_{rel} < 10$ %
- distance d: $u = 2$ mm

have to be measured with small relative uncertainty



Accurate measurement of MLS parameters

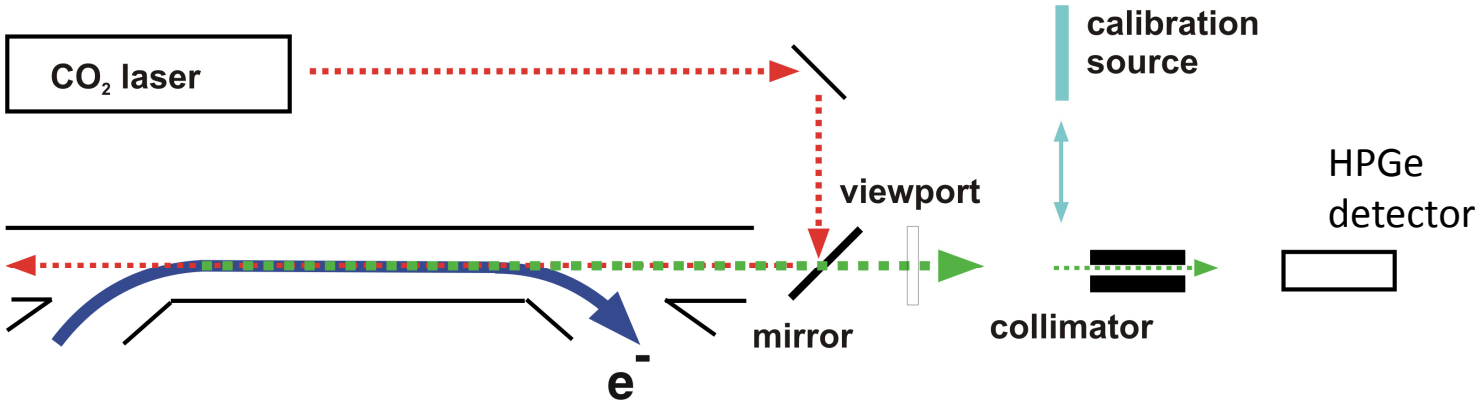
Relative uncertainty in the calculation of the spectral radiant intensity /spectral power

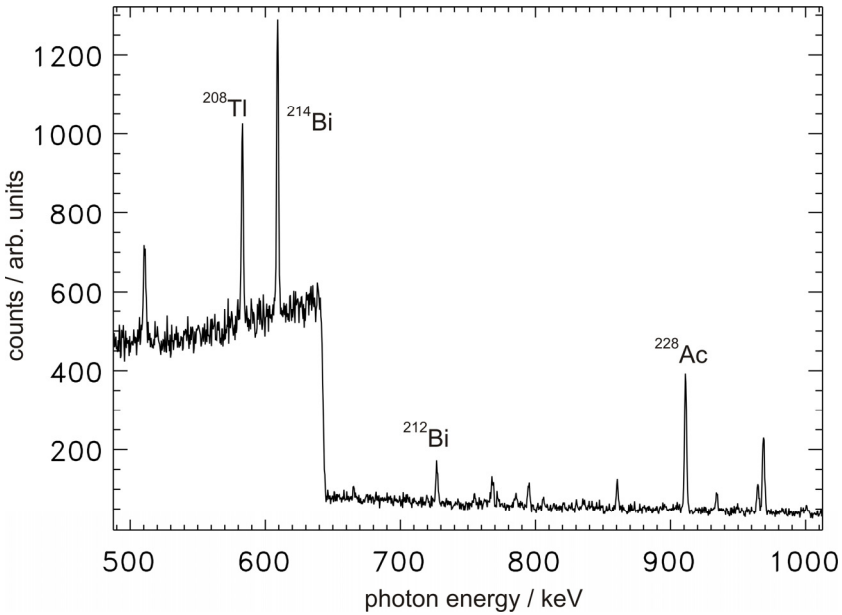


R. Klein et al.
Phys. Rev. STAB 11 (2008) 110701

Accurate measurement of MLS parameters

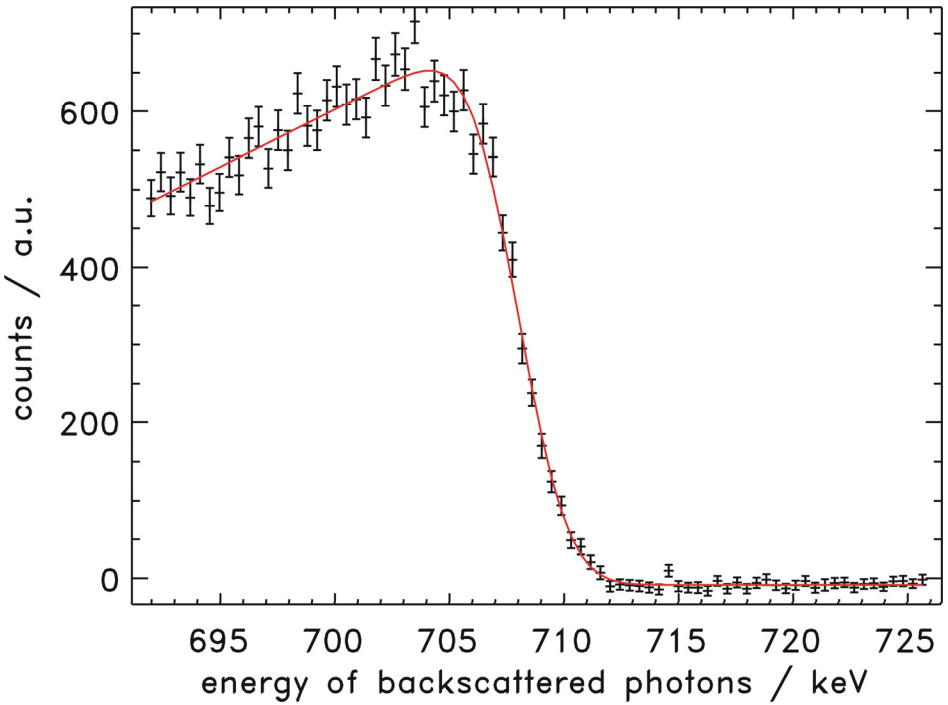
Electron energy measurement ($u < 5 \cdot 10^{-4}$)

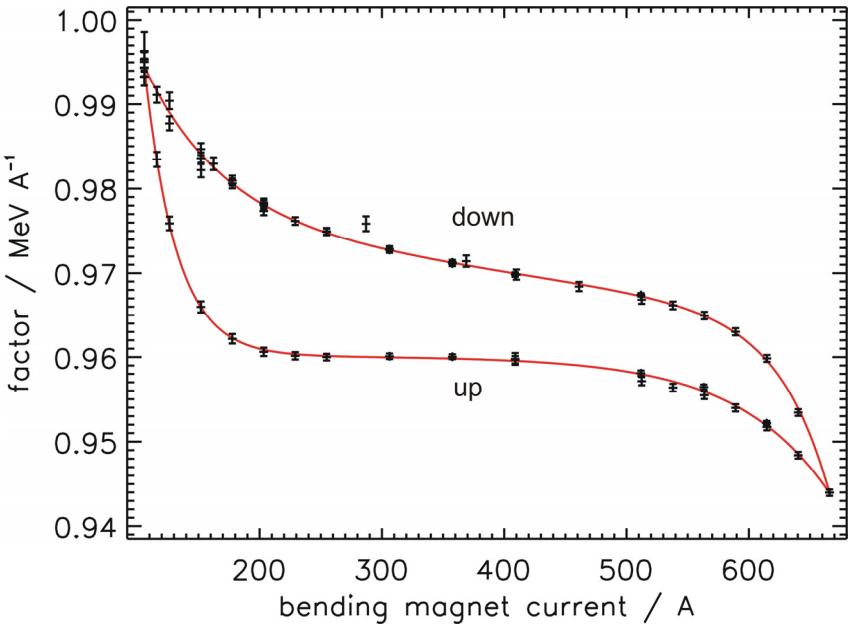




Accurate measurement of MLS parameters

Electron energy measurement



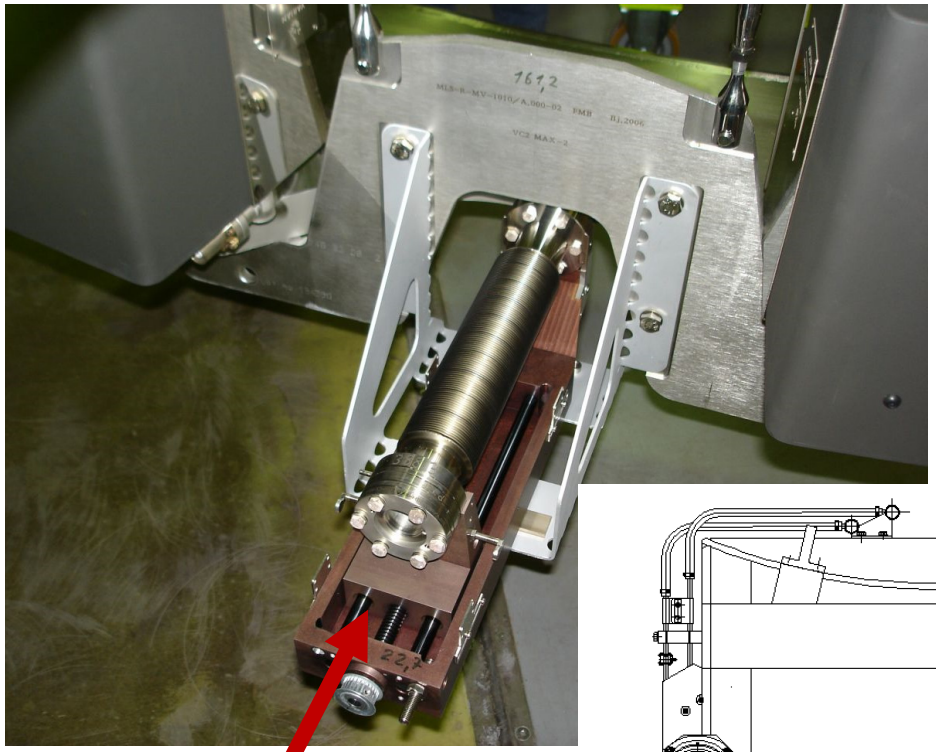


$$E_{\text{scatter}} \sim W^2 E_{\text{laser}}$$

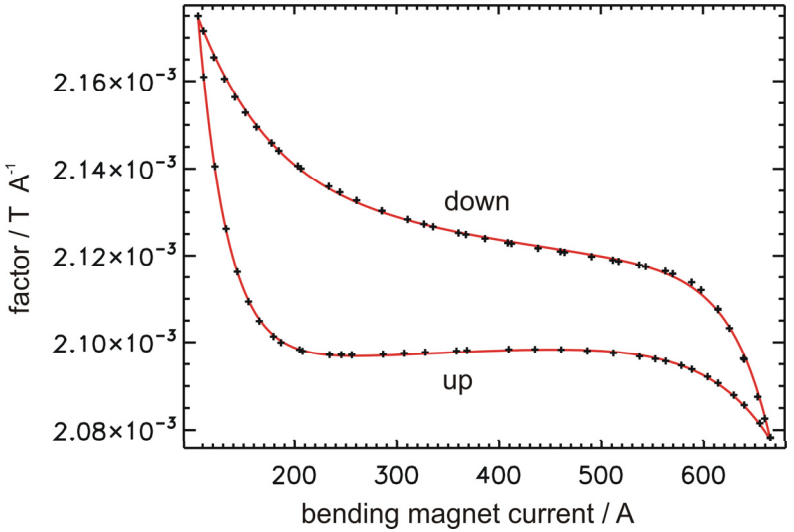
electron energy *W* has been measured in the full operational range from 105 MeV to 630 MeV

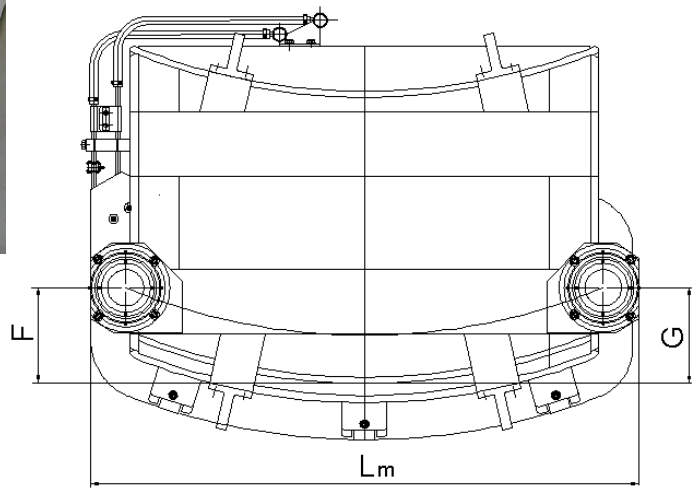
Accurate measurement of MLS parameters

Magnet induction at source point ($u < 1 \cdot 10^{-4}$)



NMR probe

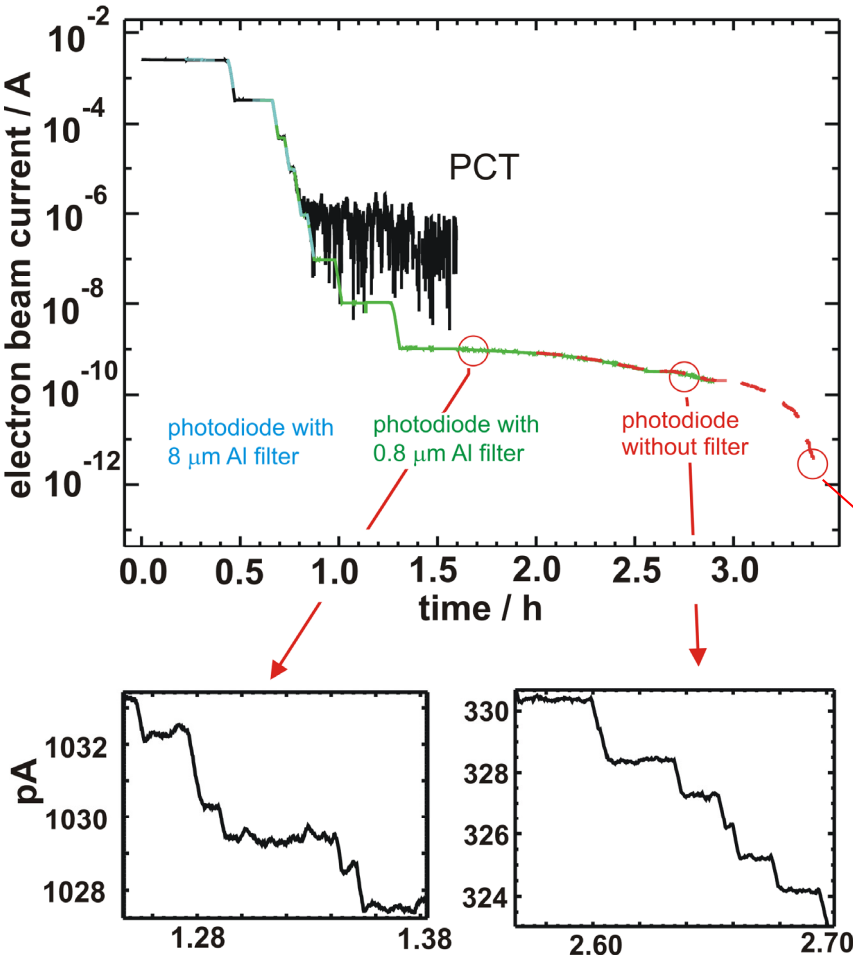


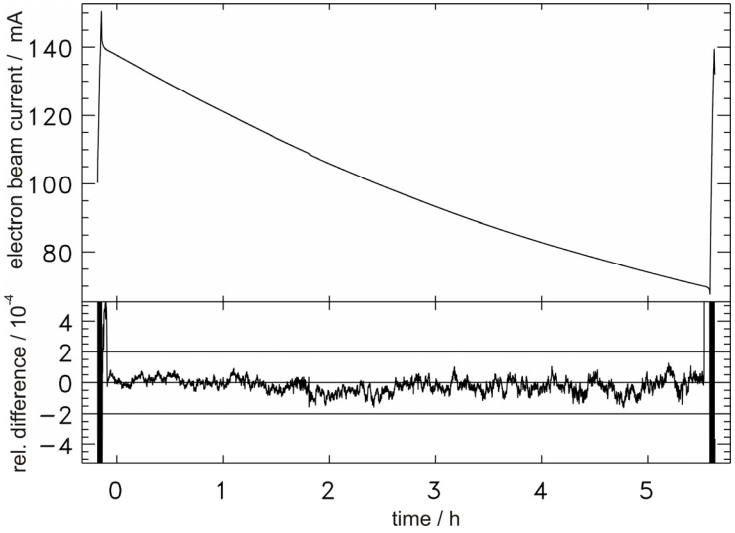


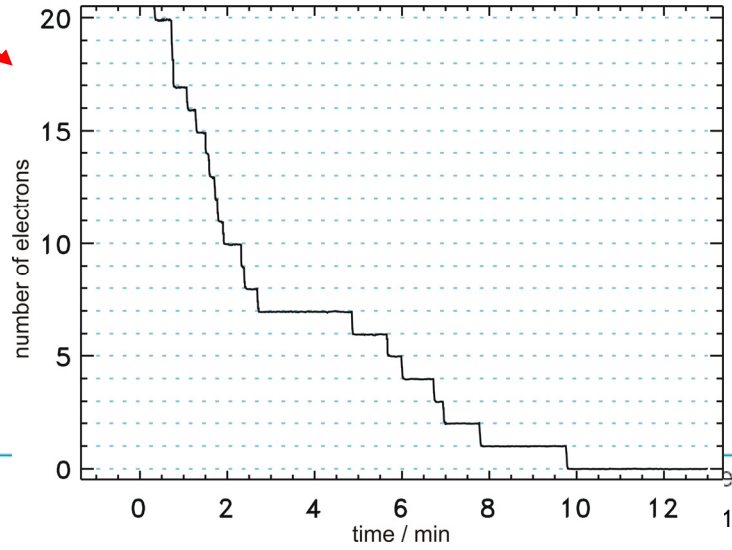
Accurate measurement of MLS parameters

Electron beam current measurement ($u < 2 \cdot 10^{-4}$ in upper and lower range)

electron beam current can be varied over more than 11 decades



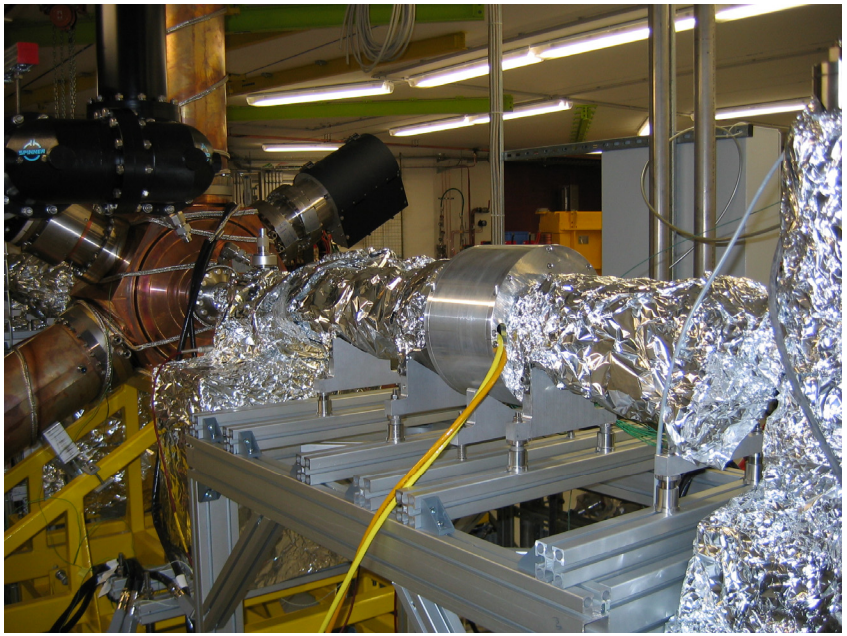




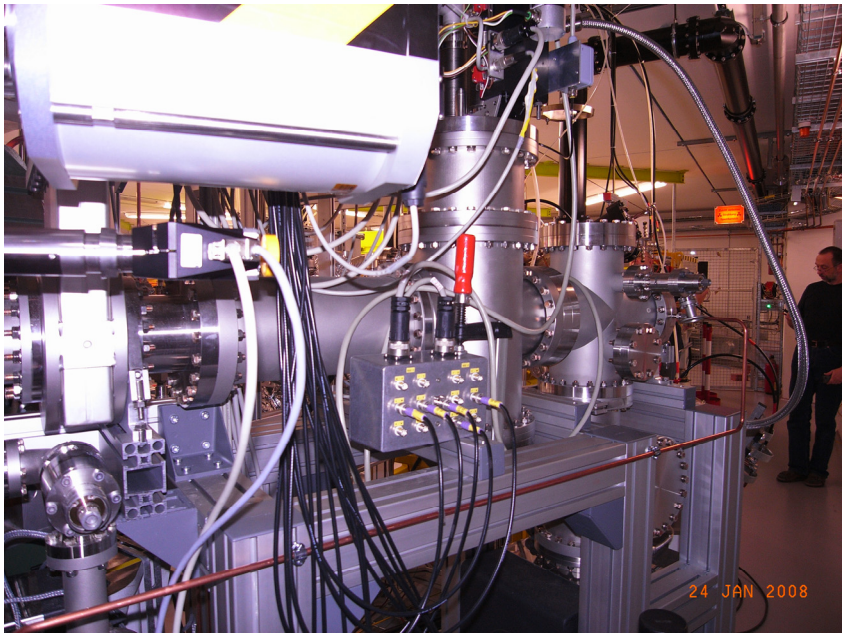
Accurate measurement of MLS parameters

Electron beam current measurement

PCT

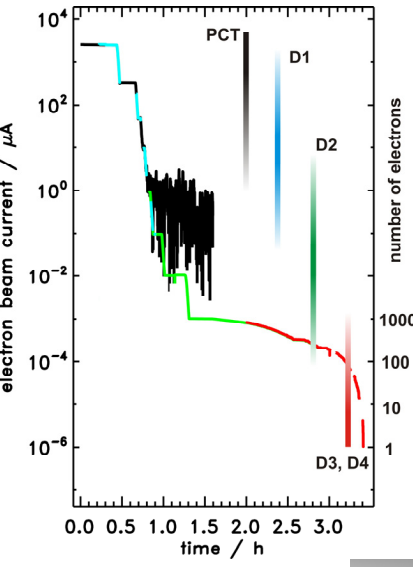


Photodiodes

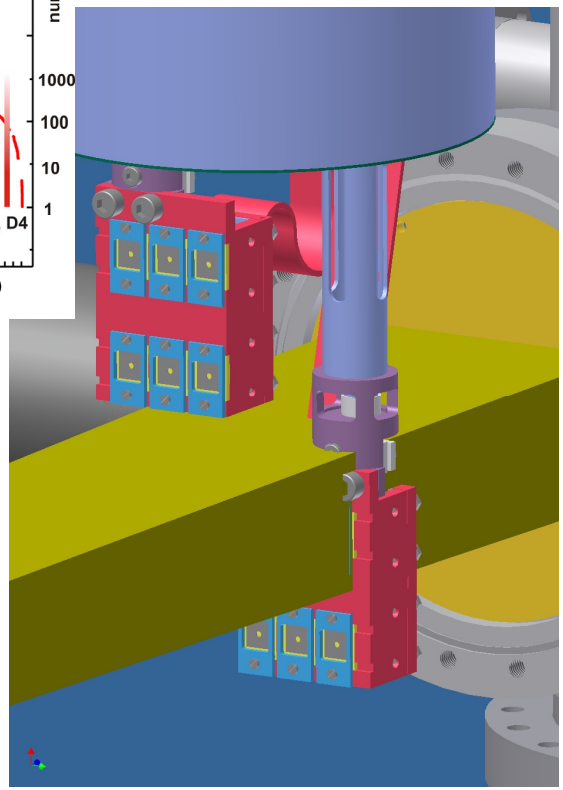


Accurate measurement of MLS parameters

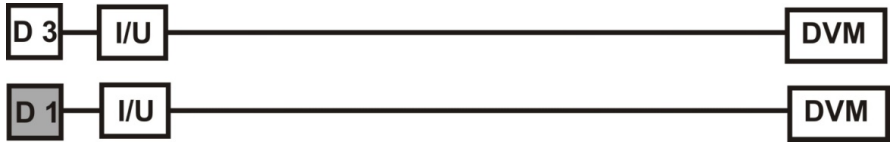
Electron beam current measurement

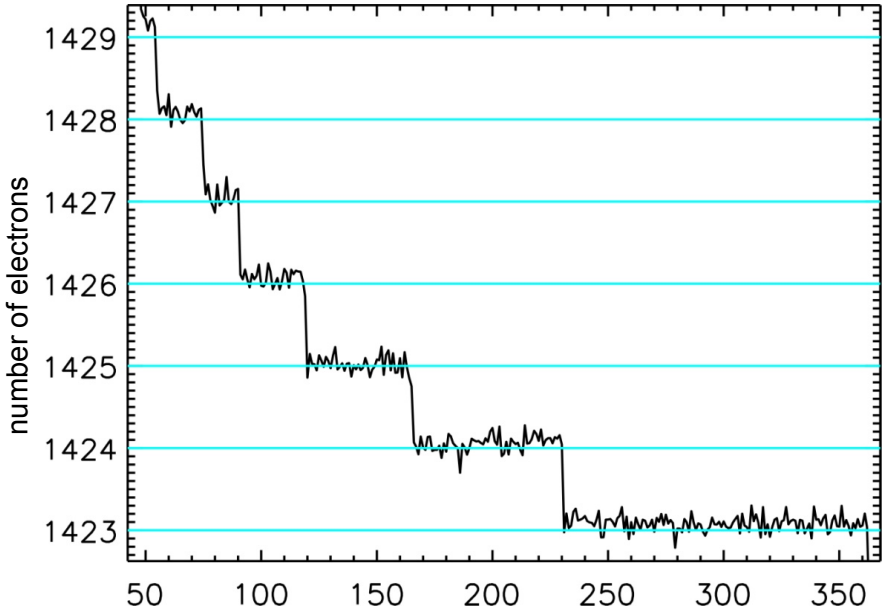


$I = N_e \, e \, \nu_{rev}$



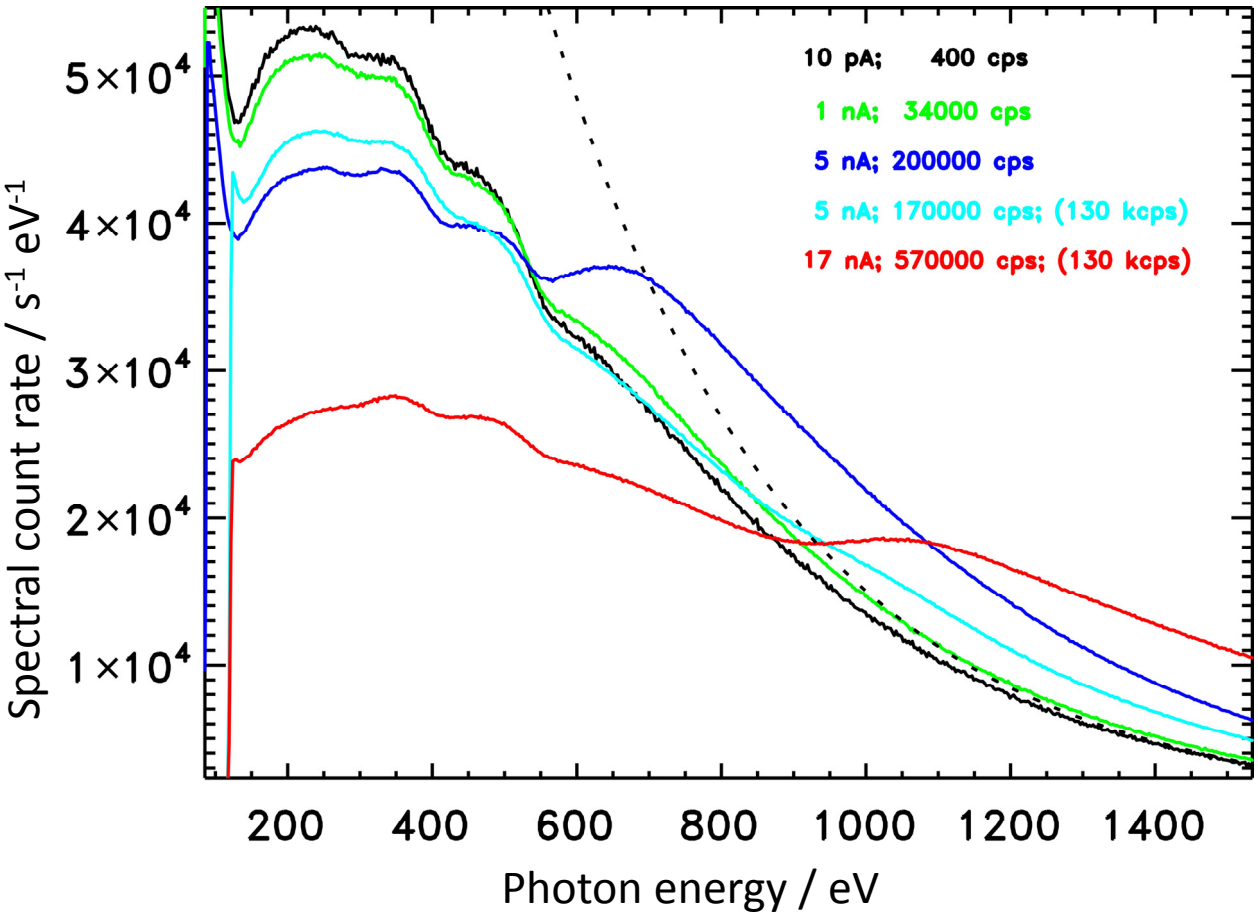
I/U-converters inside storage ring





Accurate measurement of MLS parameters

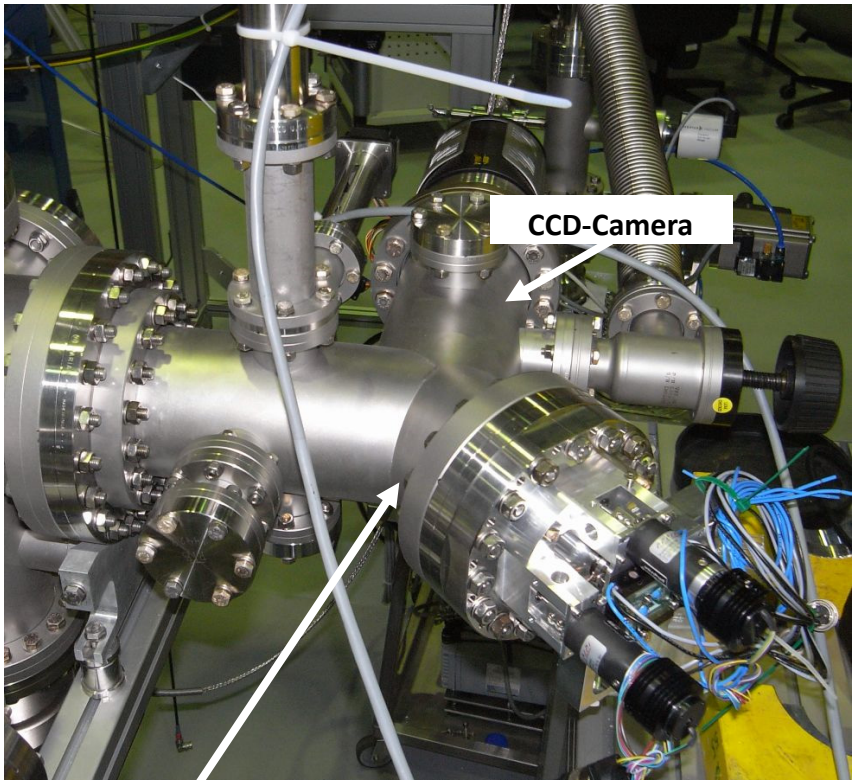
Example: calibration of a SDD with calculable synchrotron radiation



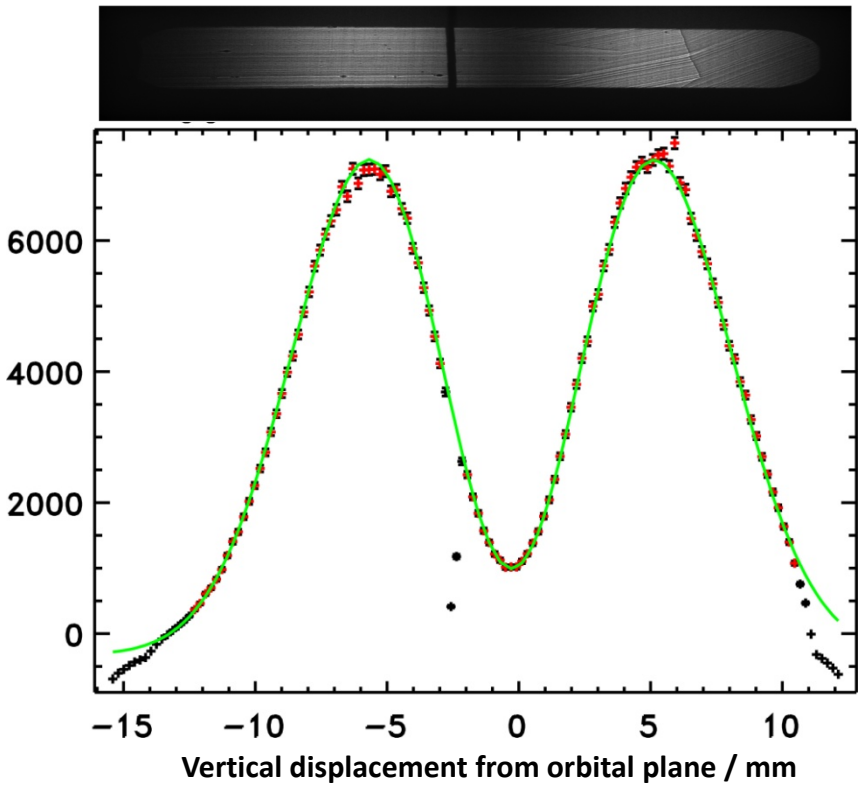
Accurate measurement of MLS parameters

Bragg polarimeter for the measurement of the

effective vertical source size $\Sigma_y = (\sigma_y^2 + d^2 \sigma_{y'}^2)^{1/2}$

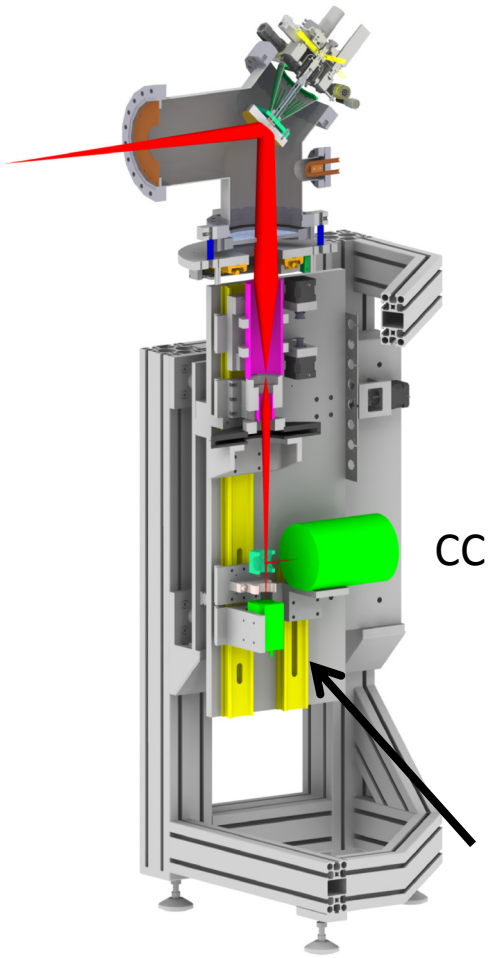


Bragg reflection: 1103 eV photons
Brewster angle: σ polarisation component



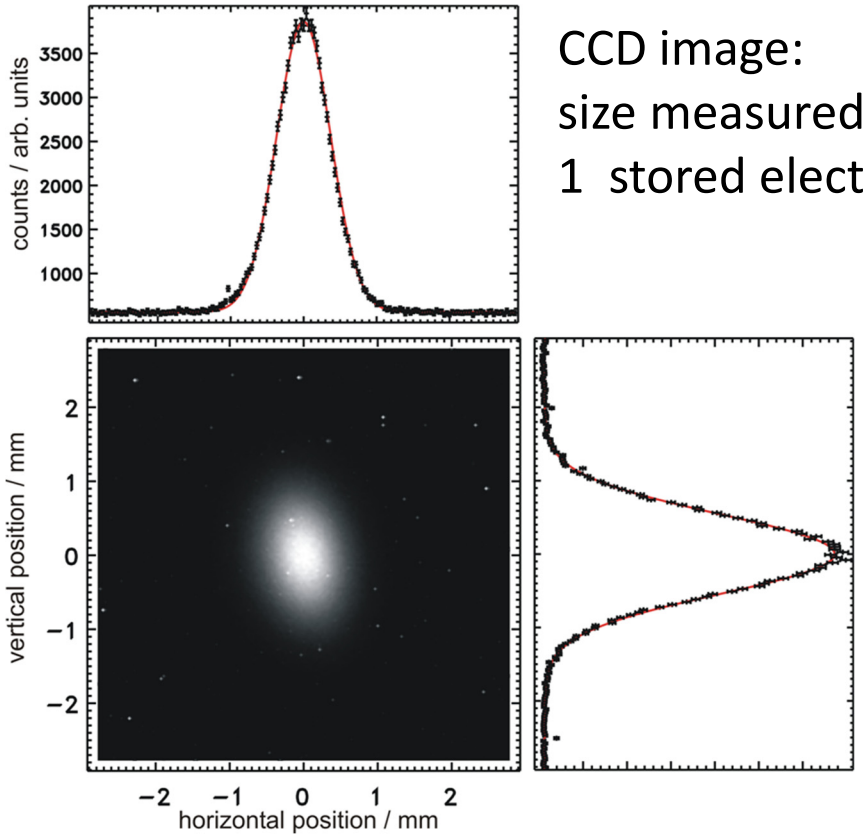
Accurate measurement of MLS parameters

2 Systems for beam size measurements



CCD image

life image camera

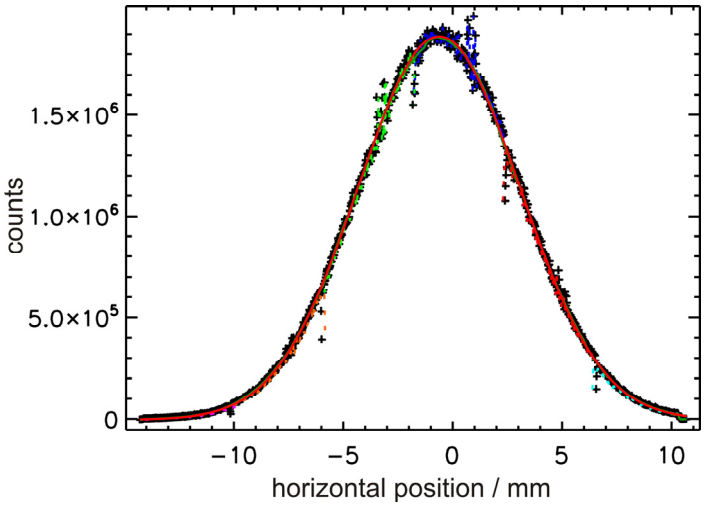


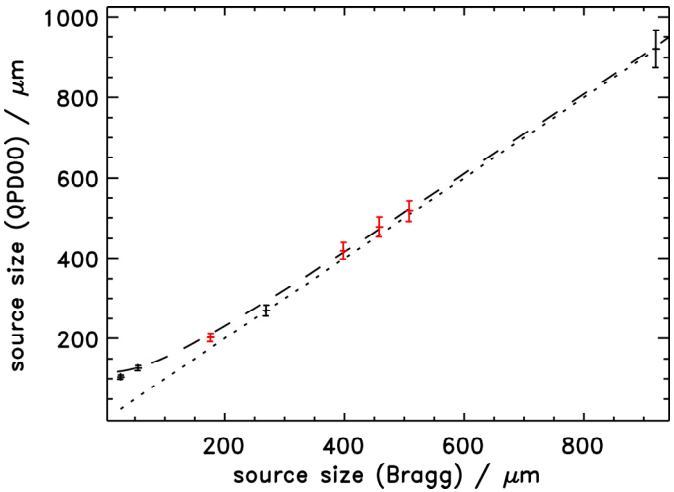
CCD image:
size measured with
1 stored electron

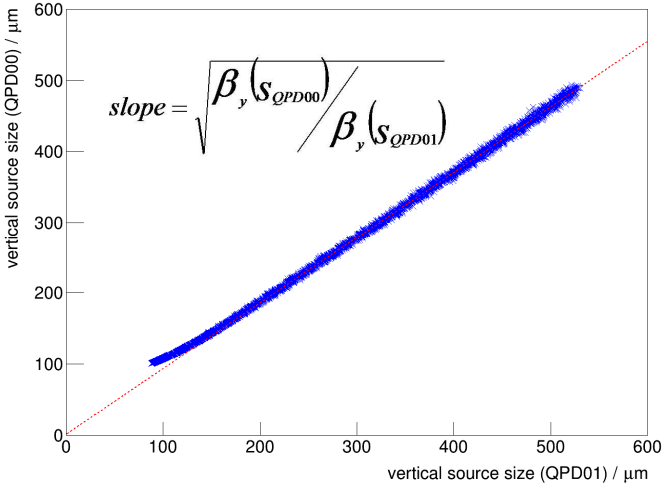
Accurate measurement of MLS parameters

Verification of beam size measurements

Using the Bragg-Polarimeter as a
X-ray camera (extra pinhole in beam path)
Allows direct measurement of beam size an comparison with values measured by the Optical system:
- good agreement better than 5 %
- 120 µm resolution of optical system







Summary

PTB operates the Metrology Light Source as primary source standard.

Equipment for the accurate measurement of all parameters relevant for this is installed.

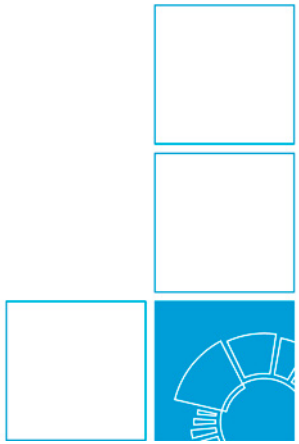
The spectral radiant power up to the VUV spectral region can thus be calculated to better than 0.2 %.

Not covered in talk:
BESSY II is used by PTB as a primary source standard up to the soft X-ray spectral region in a similar fashion.

More diagnostics at MLS, e.g. streak camera for bunch length measurements (low-α operation).

Thank you!

and thanks to my co-authors and
the MLS operation team of HZB



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7.14 Synchrotron Radiation Sources

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