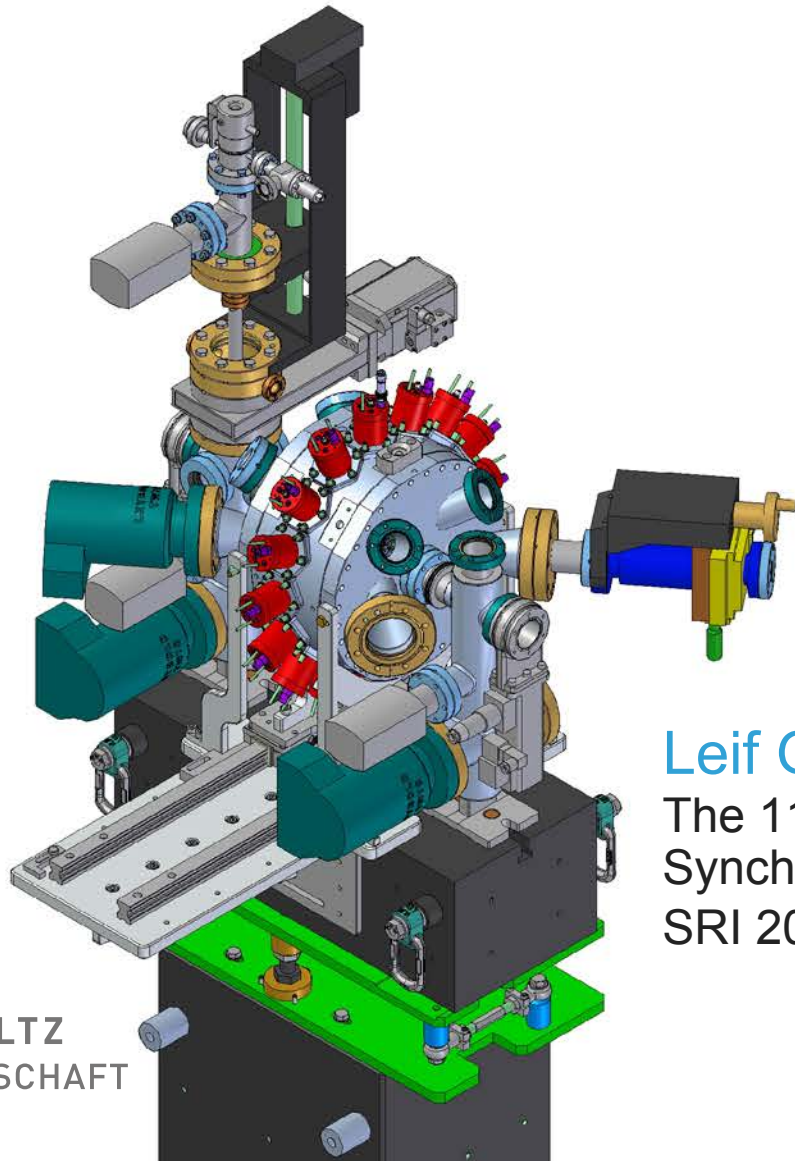


An online diagnostic unit monitoring the relevant photon properties.



Leif Glaser, DESY, FS-PE, Hamburg, Germany
The 11th International Conference on
Synchrotron Radiation Instrumentation
SRI 2012, Lyon, France, July 9-13, 2012

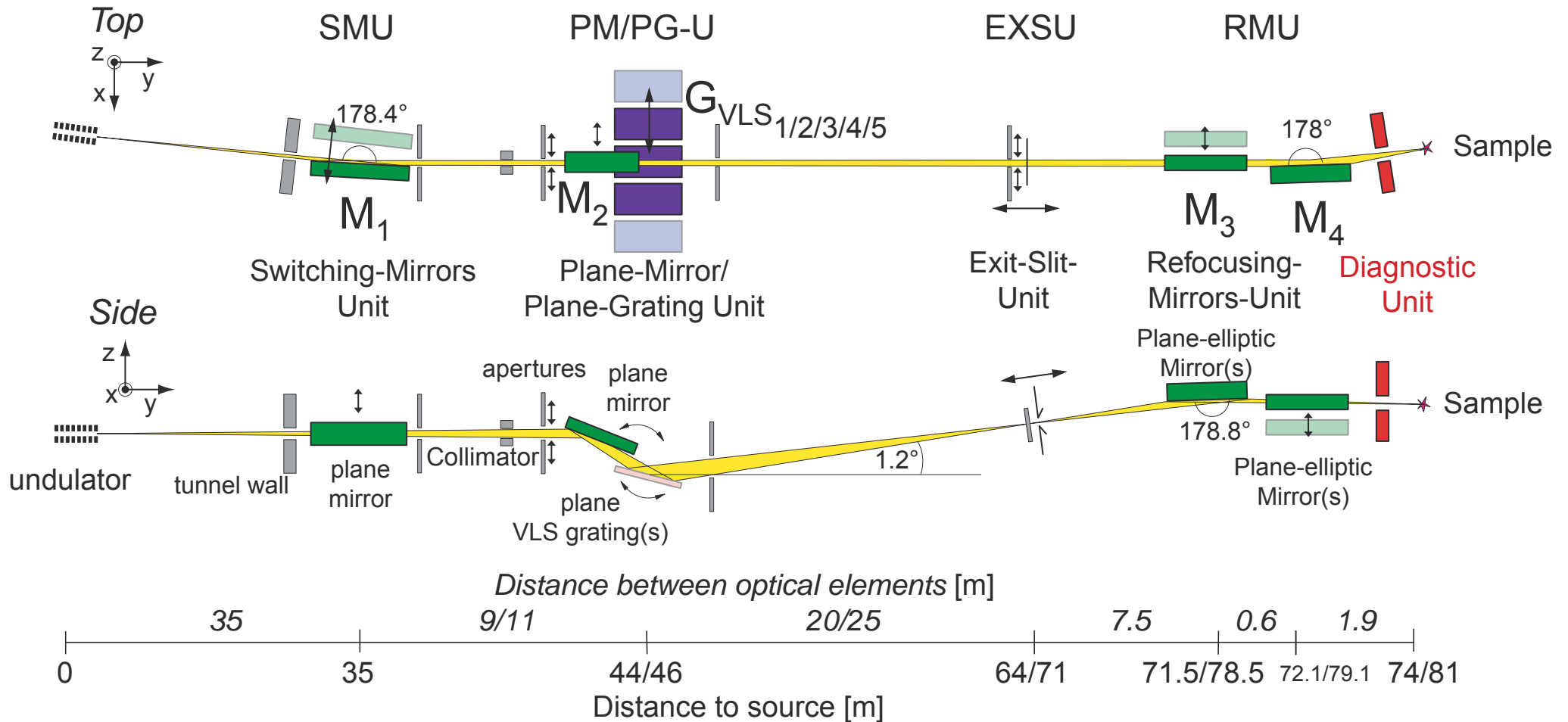
Acknowledgements

- > **Markus Braune, Uwe Becker** (*Fritz-Haber-Institut der MPG, Berlin*)
- > **Burkhard Langer** (*FU Berlin*)
- > **Lorenz Jahn, Michael Martins** (*U Hamburg*)
- > **Kai Tiedtke** (*FLASH, DESY*)
- > **Jörg Stempfer, Sonia Francoual, Dinesh Kumar Shukla** (*P09@PETRA III*)
- > **Jens Buck** (*European XFEL*)
- > **Jens Viefhaus, Sascha Deinert, Markus Ilchen, Frank Scholz, Jörn Seltmann, Beata Terka, Ivan Shevchuk** (*P04@PETRA III, DESY*)
Olof Gutowski, Michael Wellhöfer, Peter Walter
- > DESY workshops **ZM, ZE**
- > HASYLAB groups **FS-BT, FS-EC, FS-PE**



Variable Polarization XUV Beamline P04 at PETRA III - Layout

> Plane grating monochromator with Varied Line Space grating



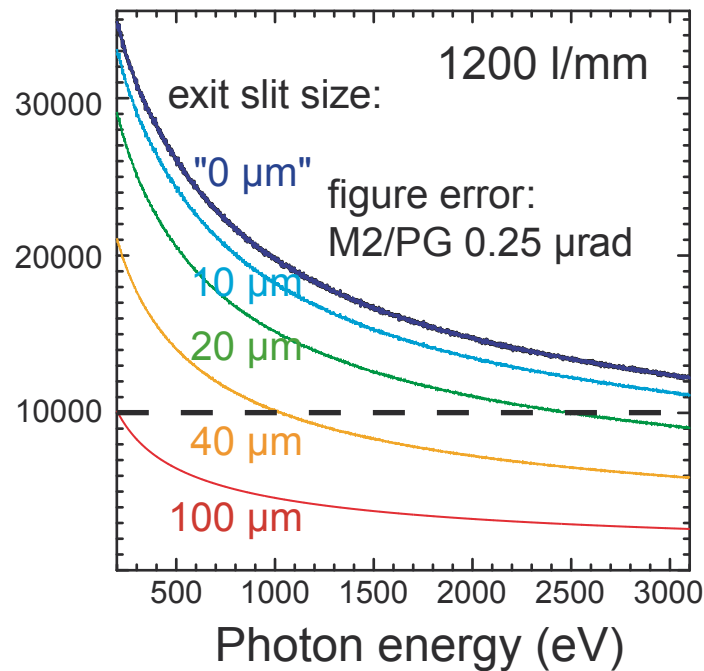
- Very wide photon energy range: 250-3000 eV with 1st harmonic of undulator
- As few as possible, only plane(-elliptical) optical elements \Rightarrow high transmission



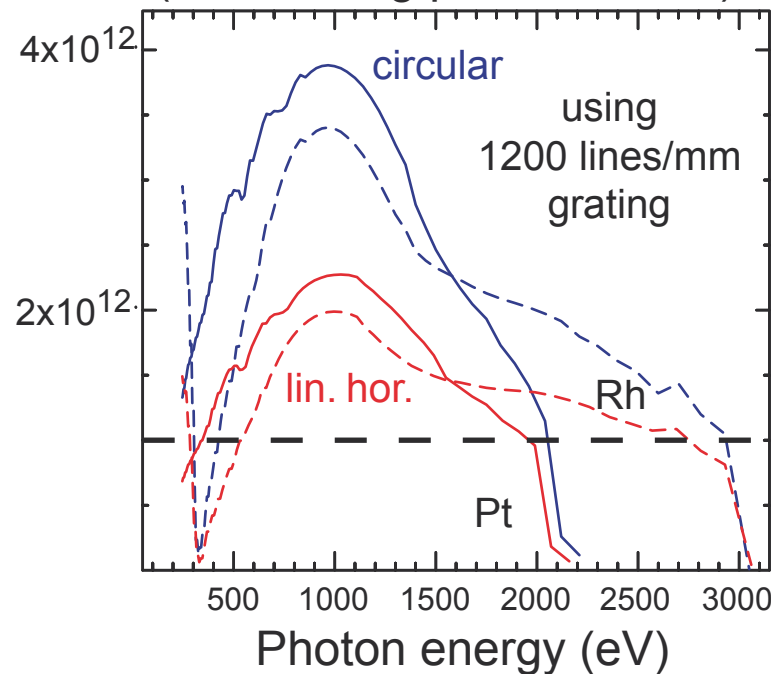
P04 - Beamline Performance

- > Photon energy range: (<100) 250 - 3000 eV
- > Resolving power: $>10^4$ (up to $>3 \times 10^4$ @1 keV)
- > Photon flux: $>10^{12}$ photons/s (up to 5×10^{12})
- > Spot size at sample: $10 \times 10 \mu\text{m}^2 / 50 \times 50 \mu\text{m}^2$
- > Polarization (switching rate): circular, linear hor./vert. (<0.1 Hz)

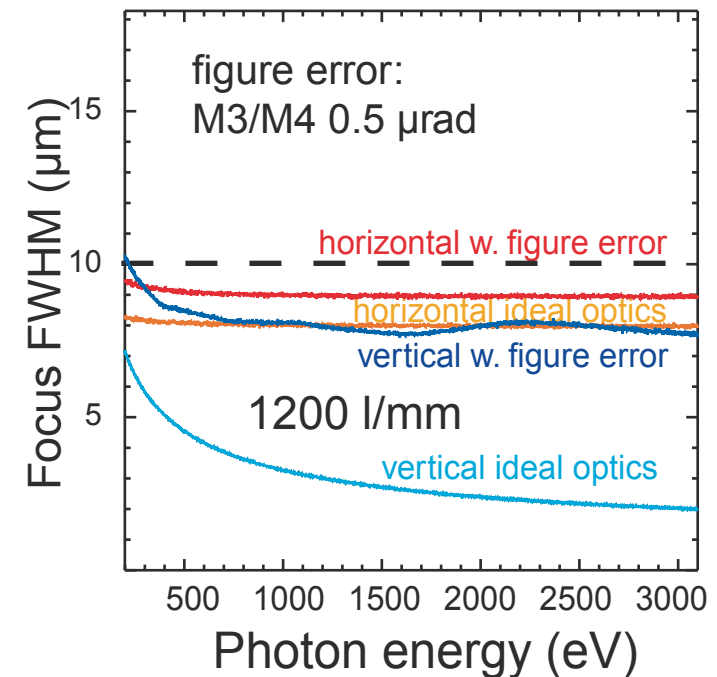
Resolving power



Photon flux on the sample (at resolving power 10,000)



Spot size at sample



Online Diagnostic Unit for Beamline Quality Control

- > (Offline) characterization tool for:
 - Focus size ("automatic algorithm" for alignment)

Online Diagnostic Unit for Beamline Quality Control

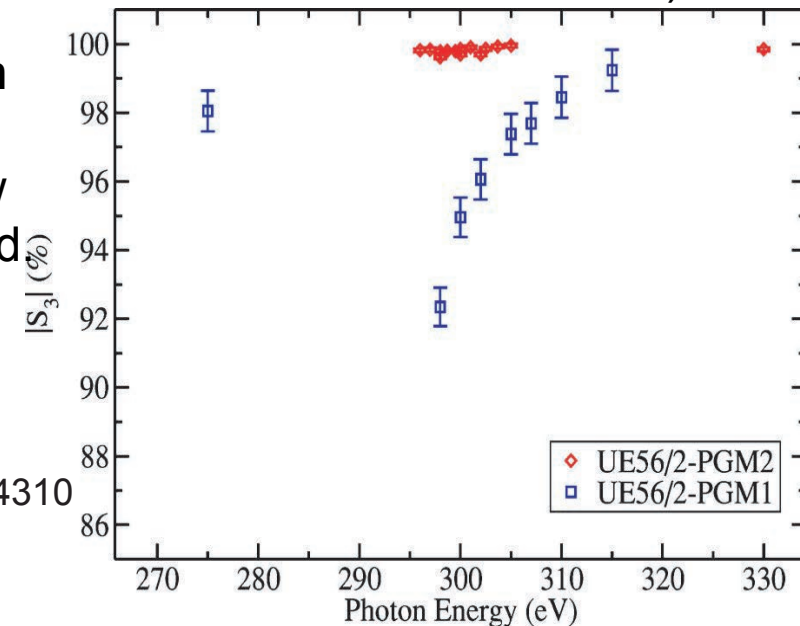
- > (Offline) characterization tool for:
 - Focus size ("automatic algorithm" for alignment)
- > (Online) beamline monitors for:
 - **Photon flux** (accuracy $\leq 1\%$ absolute, $\leq 0.1\%$ relative)
 - **Beam position** (accuracy $\leq 1 \mu\text{m}$)
calibration possible with "destructive" BPMs
 - **Photon energy** (calibration should be $\leq \Delta E$, $\leq 1/10,000$)
 - **Degree of polarization**
(accuracy $\leq 1\%$)
user warning if S_i below
a user-defined threshold.



Online Diagnostic Unit for Beamline Quality Control

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C. J. Harding *et al.*,
J. Chem. Phys. **123** (2005) 234310



Online Diagnostic Unit for Beamline Quality Control

Photoionization cell
(online insert-/removable)

Angular resolving
TOF-spectrometers

Differential
pumping sections
(on both sides)

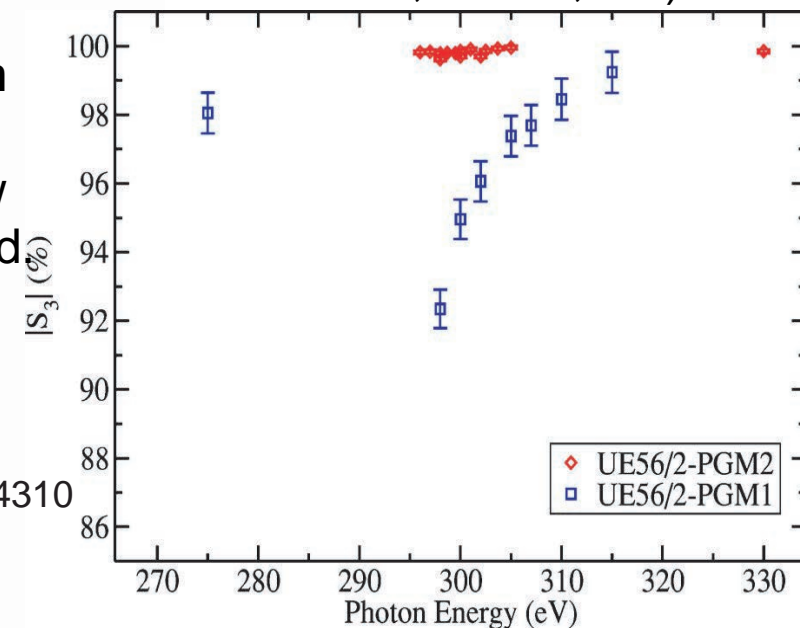
Connection to
user experiment

> (Offline) characterization tool for:

- Focus size ("automatic algorithm" for alignment)

> (Online) beamline monitors for:

- **Photon flux** (accuracy $\leq 1\%$ absolute, $\leq 0.1\%$ relative)
- **Beam position** (accuracy $\leq 1 \mu\text{m}$)
calibration possible with "destructive" BPMs
- **Photon energy** (calibration should be $\leq \Delta E$, $\leq 1/10,000$)
- **Degree of polarization** (accuracy $\leq 1\%$)
user warning if S_i below a user-defined threshold

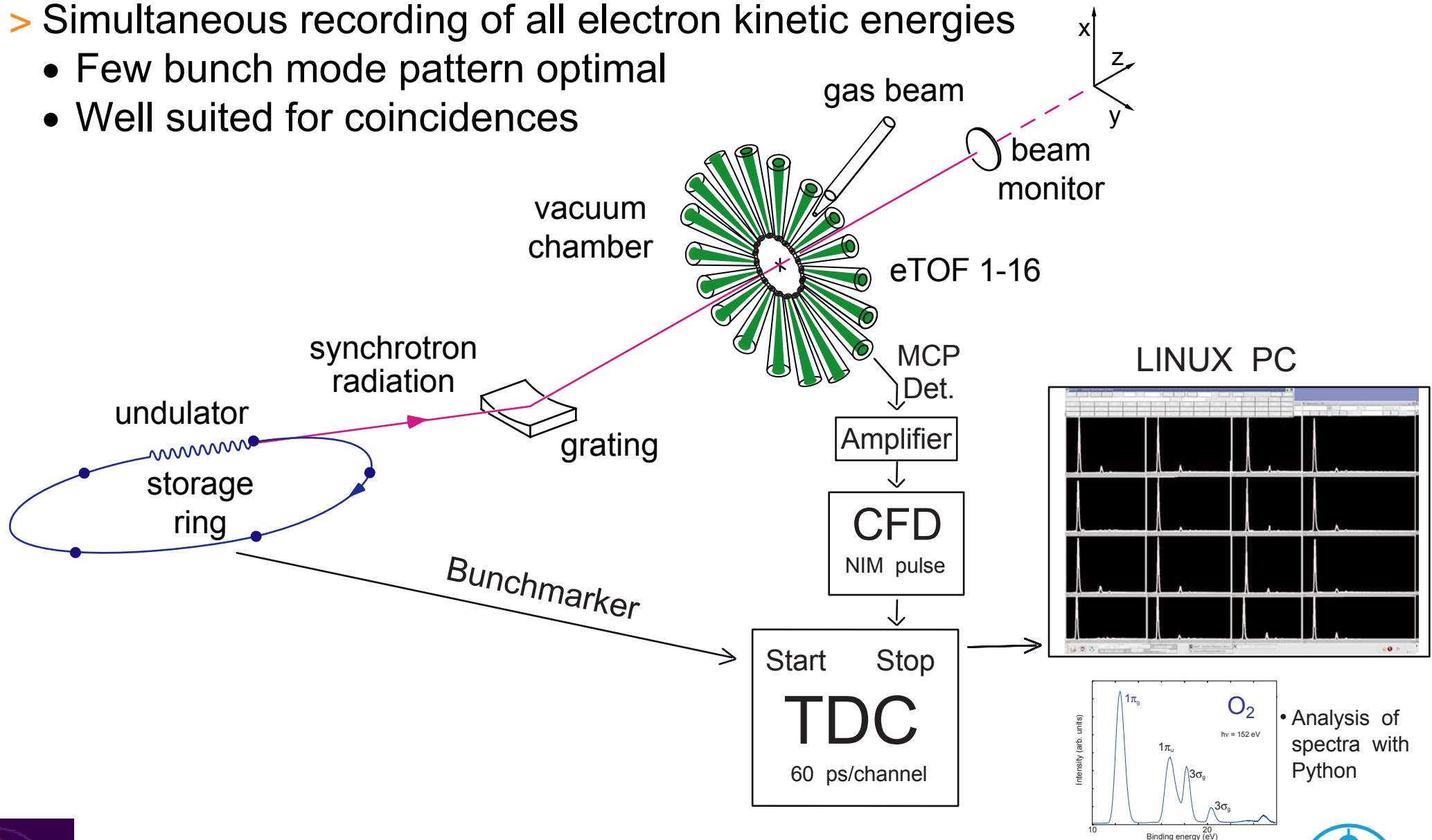


C. J. Harding *et al.*,
J. Chem. Phys. **123** (2005) 234310

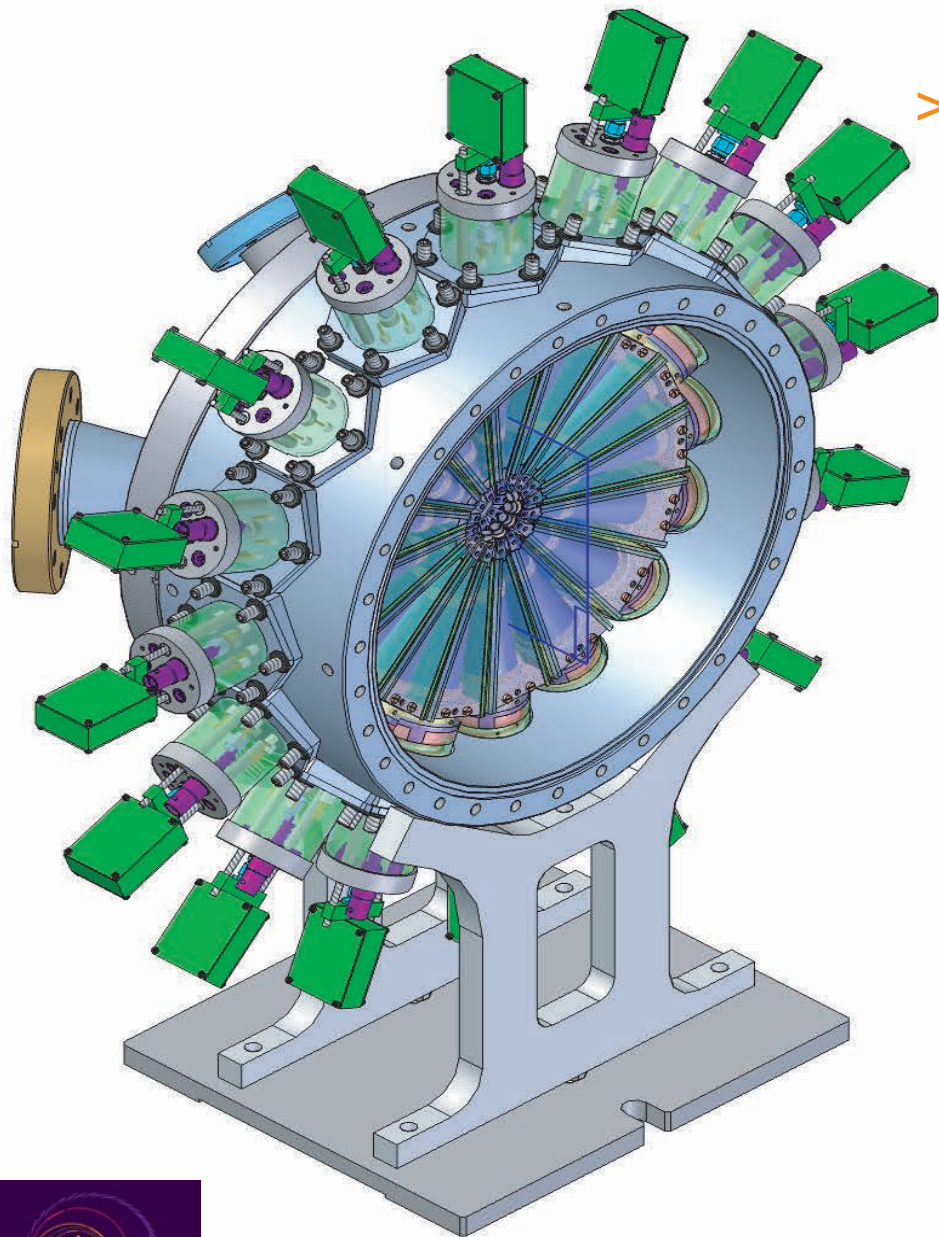


Time-of-flight Electron Spectroscopy Setup - Data Acquisition

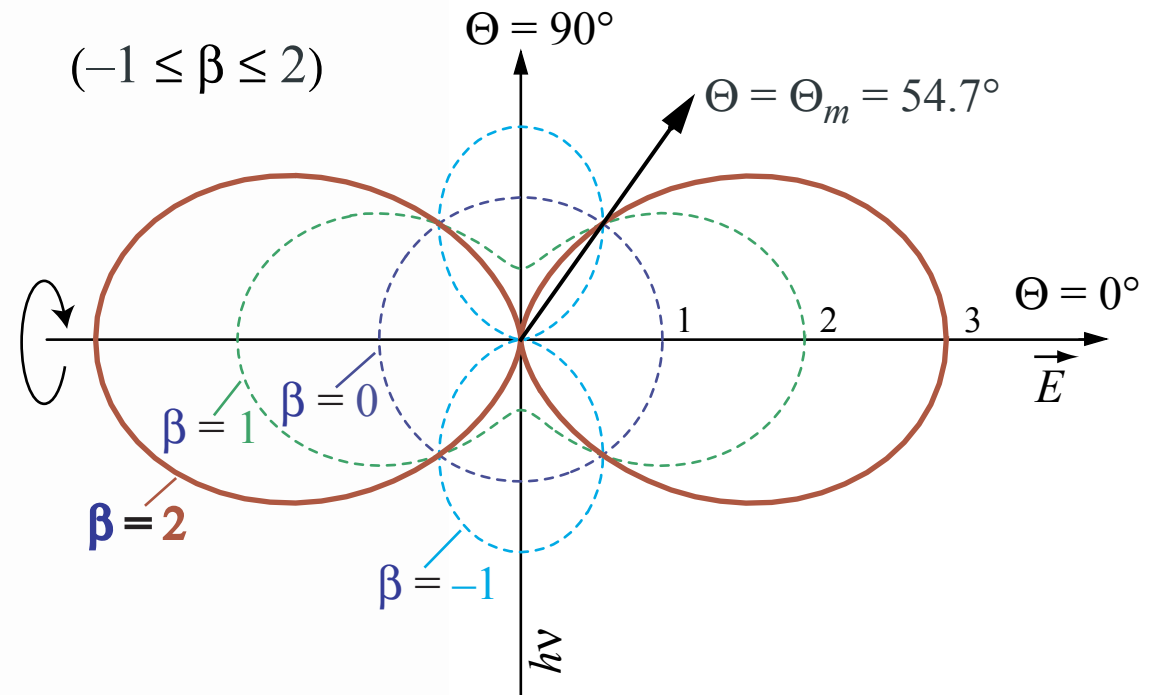
- > Simultaneous recording of all electron kinetic energies
 - Few bunch mode pattern optimal
 - Well suited for coincidences



Diagnostics via Angle-Resolved Electron Spectroscopy

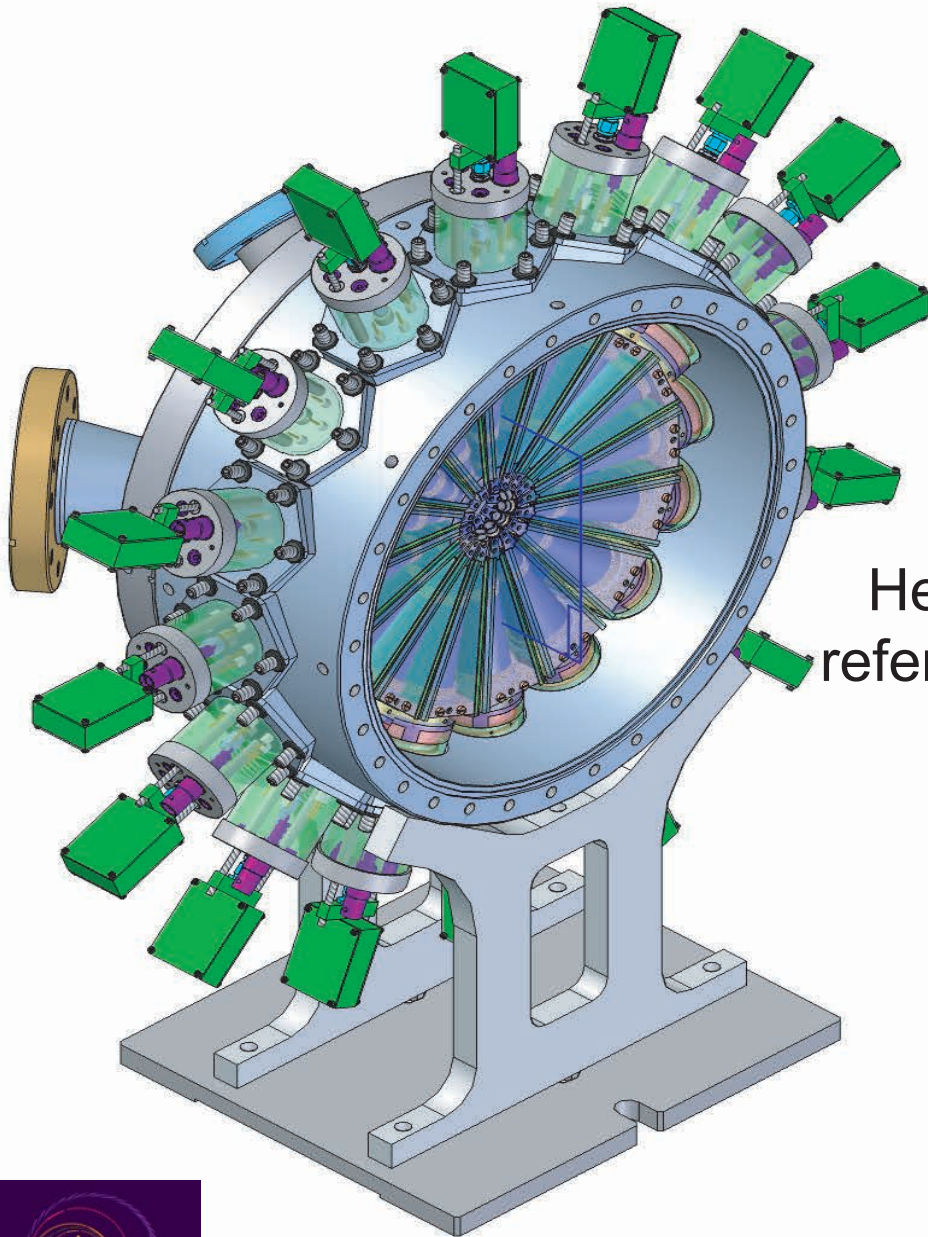


> Online monitoring of flux, $h\nu$, $\Delta h\nu$, polarization via photo-ionization / angle-resolved PES



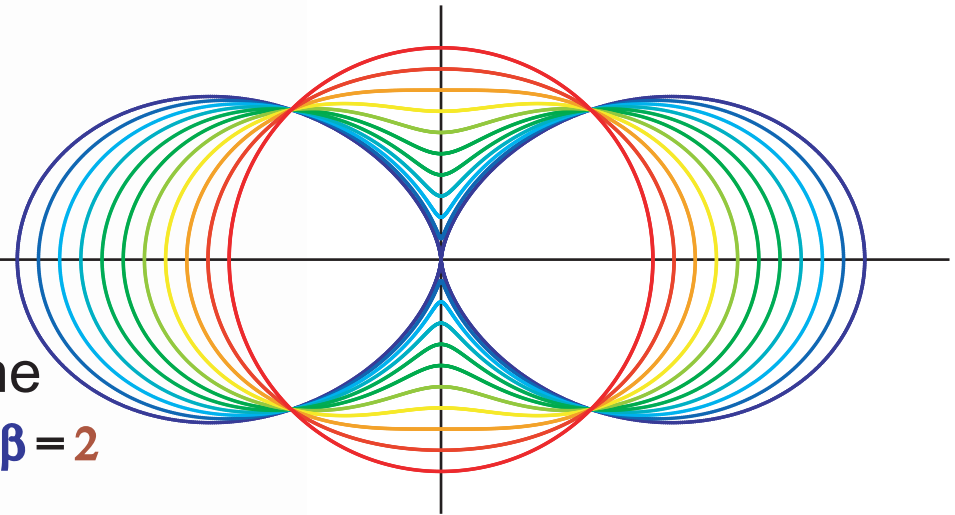
• Take e.g. Helium 1s as reference line

Determination of the Degree of Polarization



> E.g. horizontally linear polarized light:
 $S_1 = 1.0/0.9/0.8/0.7/0.6/0.5/0.4/0.3/0.2/0.1/0.0$

Helium 1s
reference line
has: $\beta = 2$

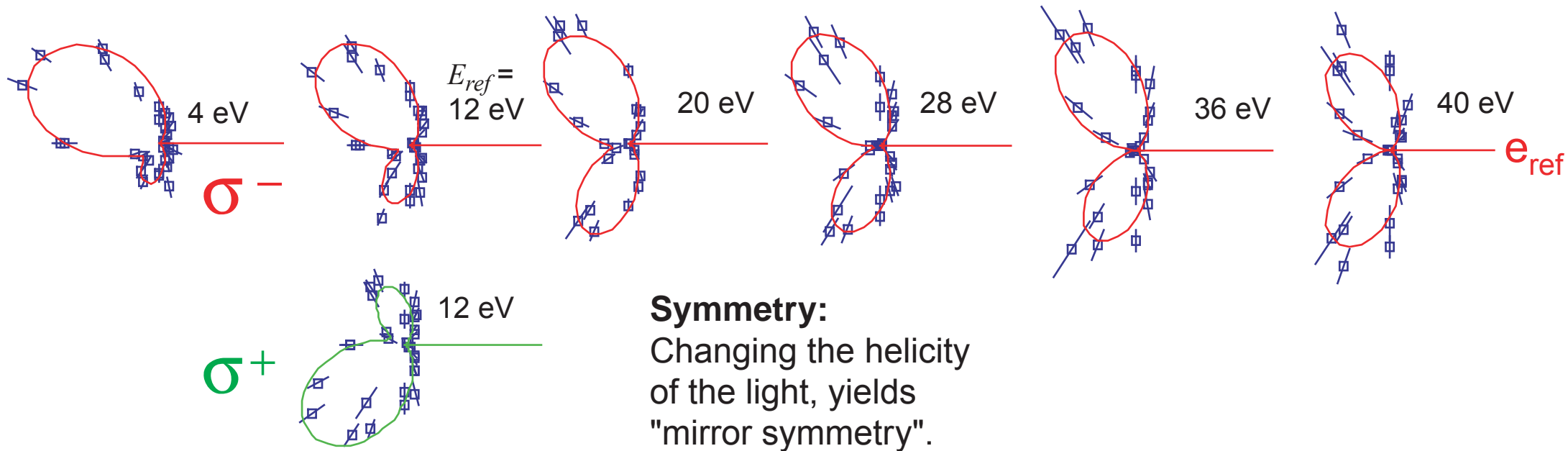


- > Precise reference lines necessary for all hv:
- Generation of a reference-data base in progress
 - Develop procedures for "beamline metrology"
 - Direct determination of S_3 requires coincident detection

Determination of the Degree of Circular Polarization

- > Circular Dichroism of the Helium photo double ionization TDCS:

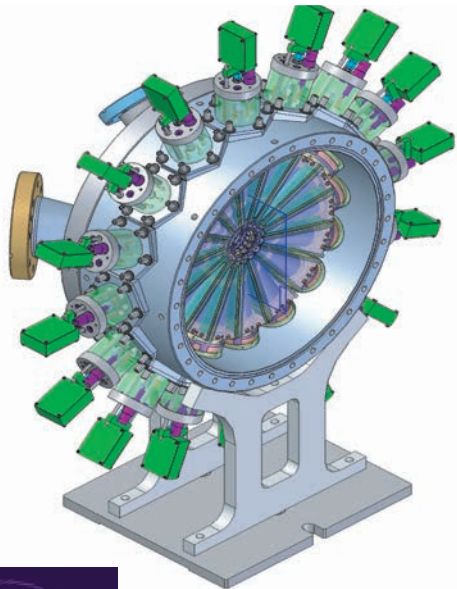
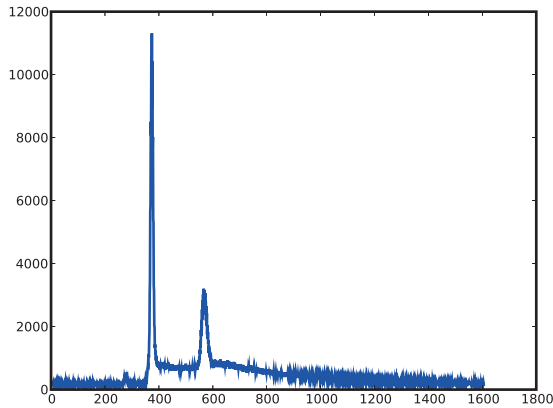
$$h\nu = 159 \text{ eV} \quad (E_{exc} = 80 \text{ eV})$$



- > Determination of all Stokes parameters possible:
Lörch *et al.* JPB **32** (1999) L371

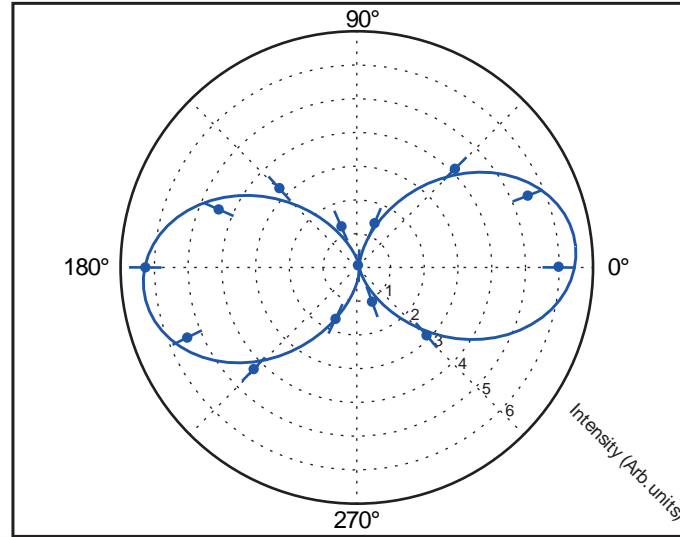
Test of Online Diagnostic Unit at PETRA III (Beamline P04)

> First successful tests at P04 beamline with N₂ 1s line

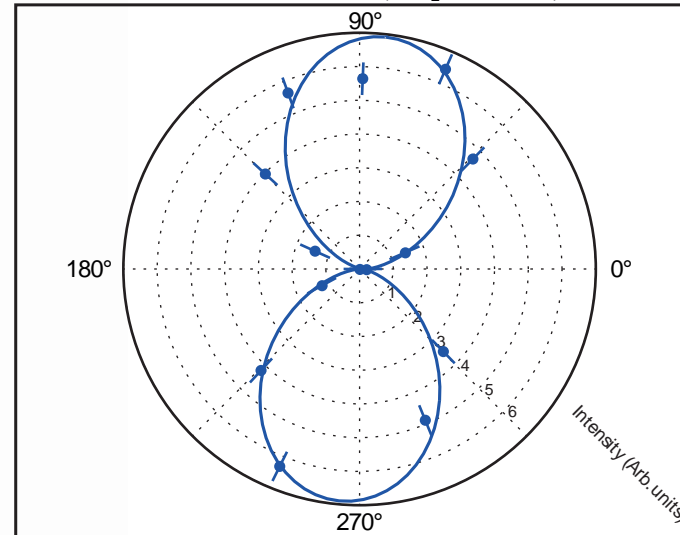


> linear polarization

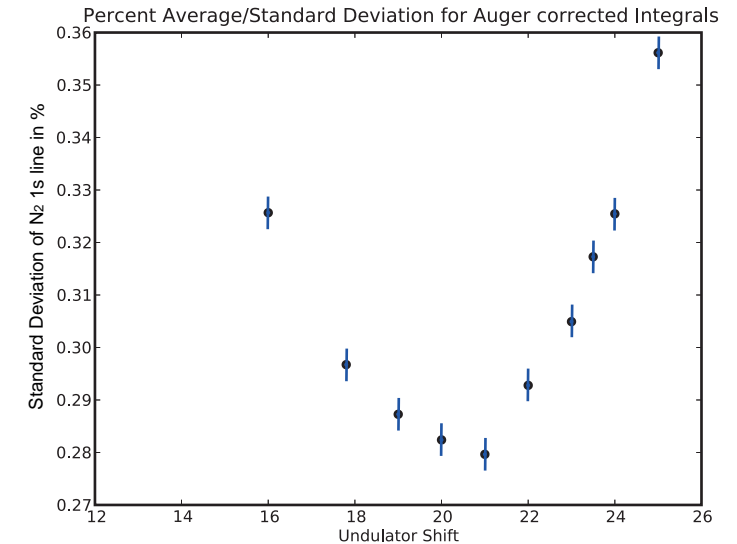
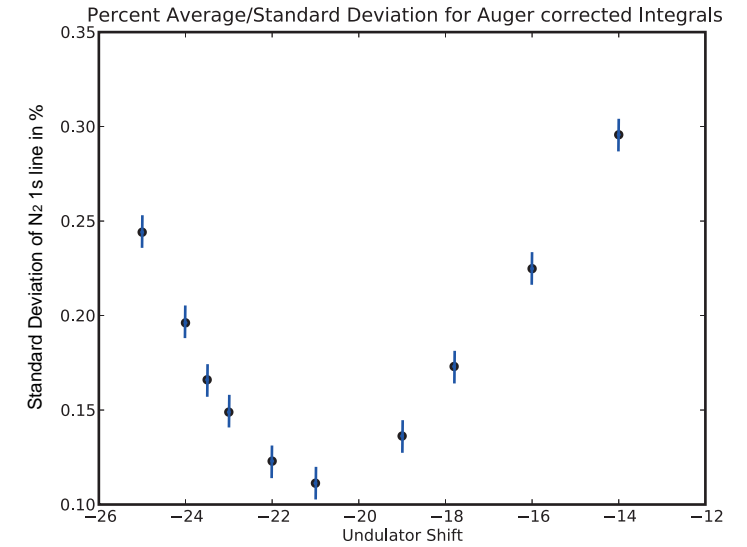
Horizontal Polarization @P04 (N₂ 1s @470 eV)



Vertical Polarization @P04 (N₂ 1s @470 eV)

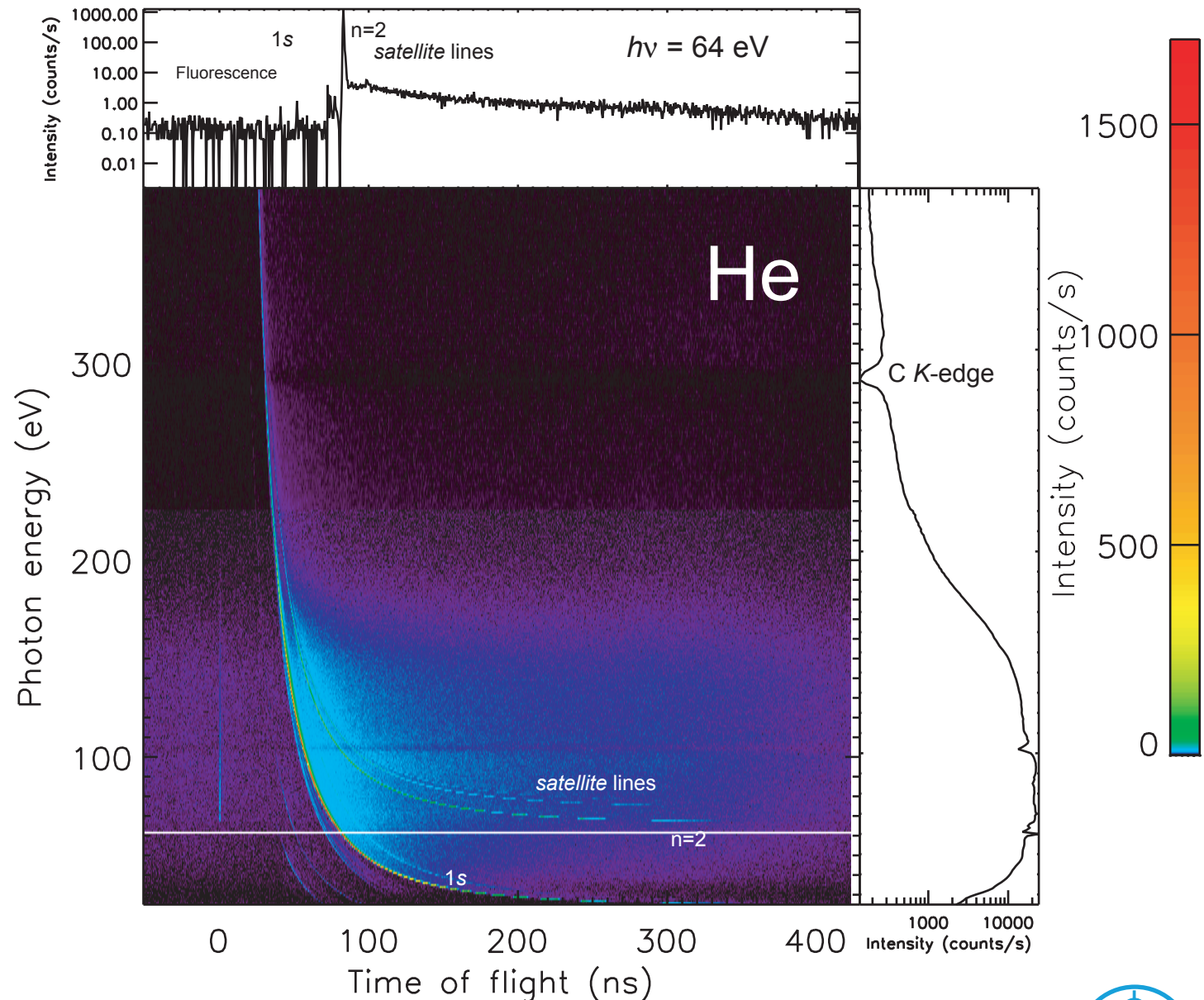


> circular polarization



Determination of Photon Flux

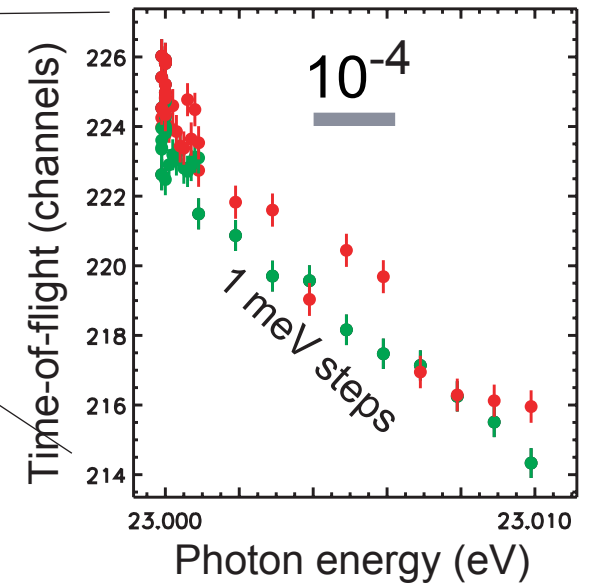
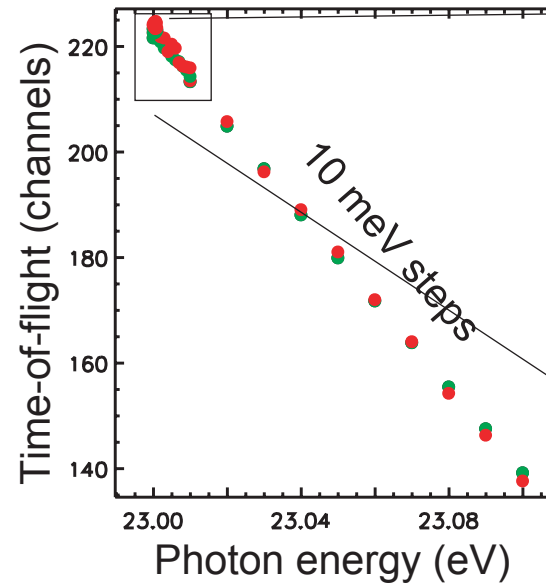
- > By evaluation of the photoelectron yield taking into account the partial cross sections
- > Determination of higher orders is possible
- > Absolute calibration via photoionization cell(s)



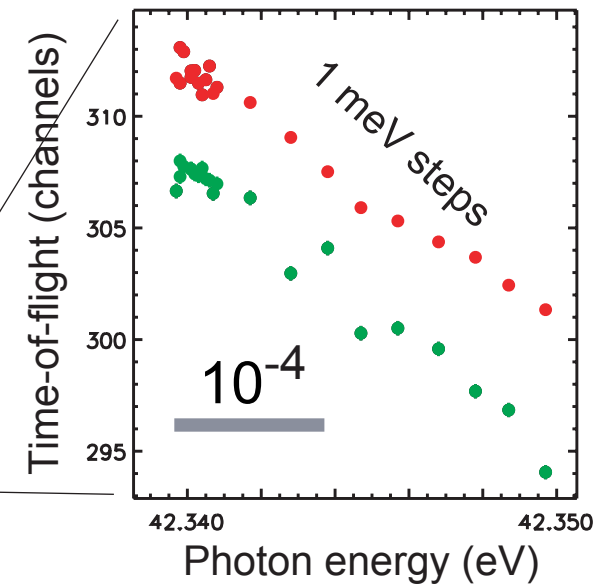
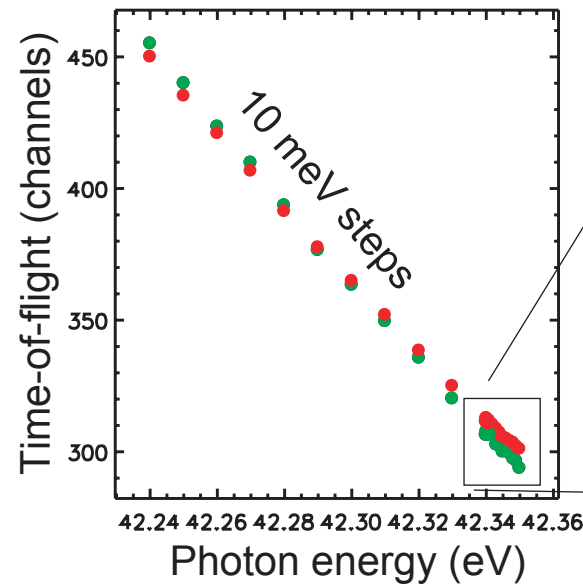
Determination of Photon Energy

$$U_{\text{ret}} = 0 \text{ V}$$

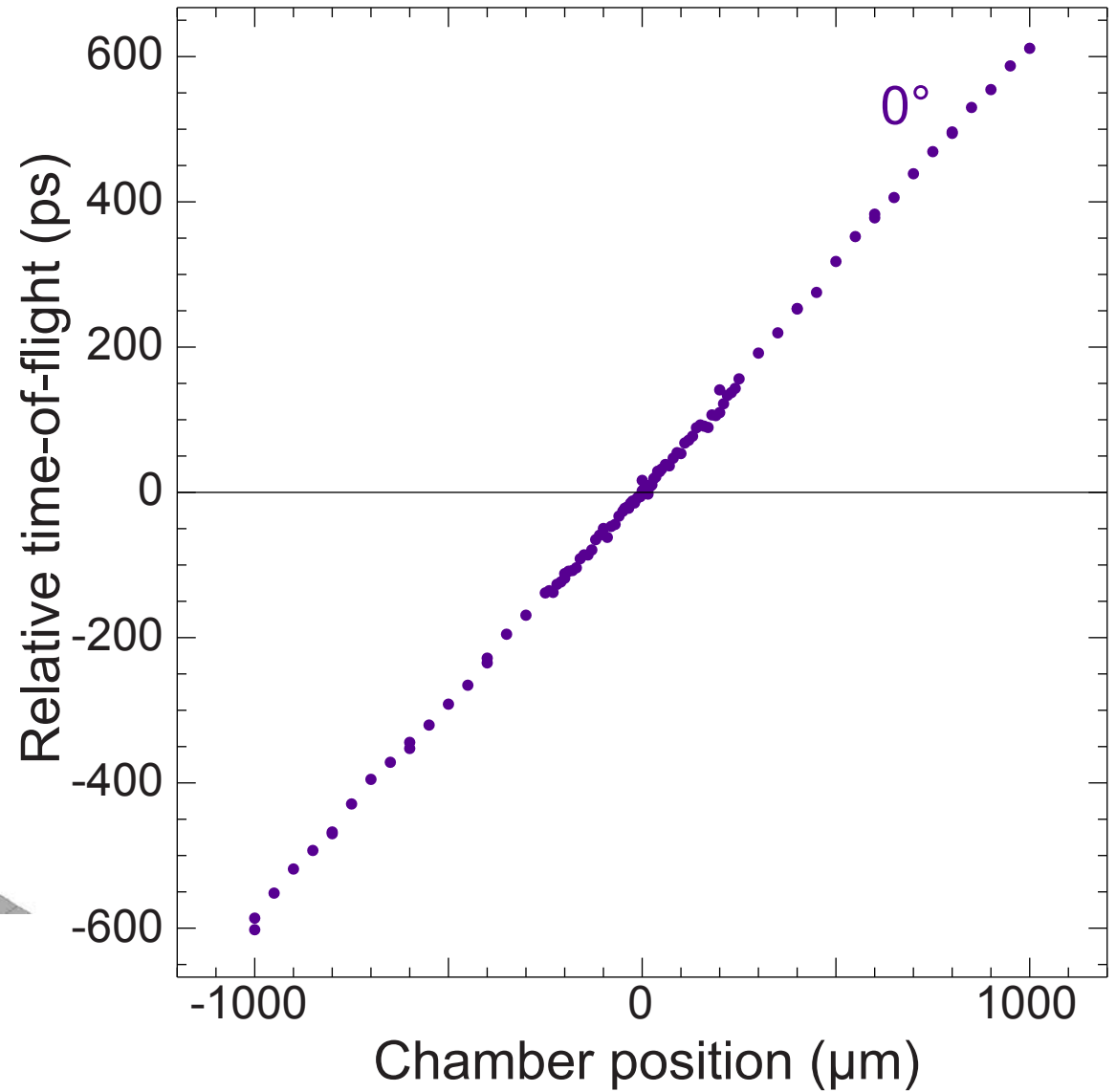
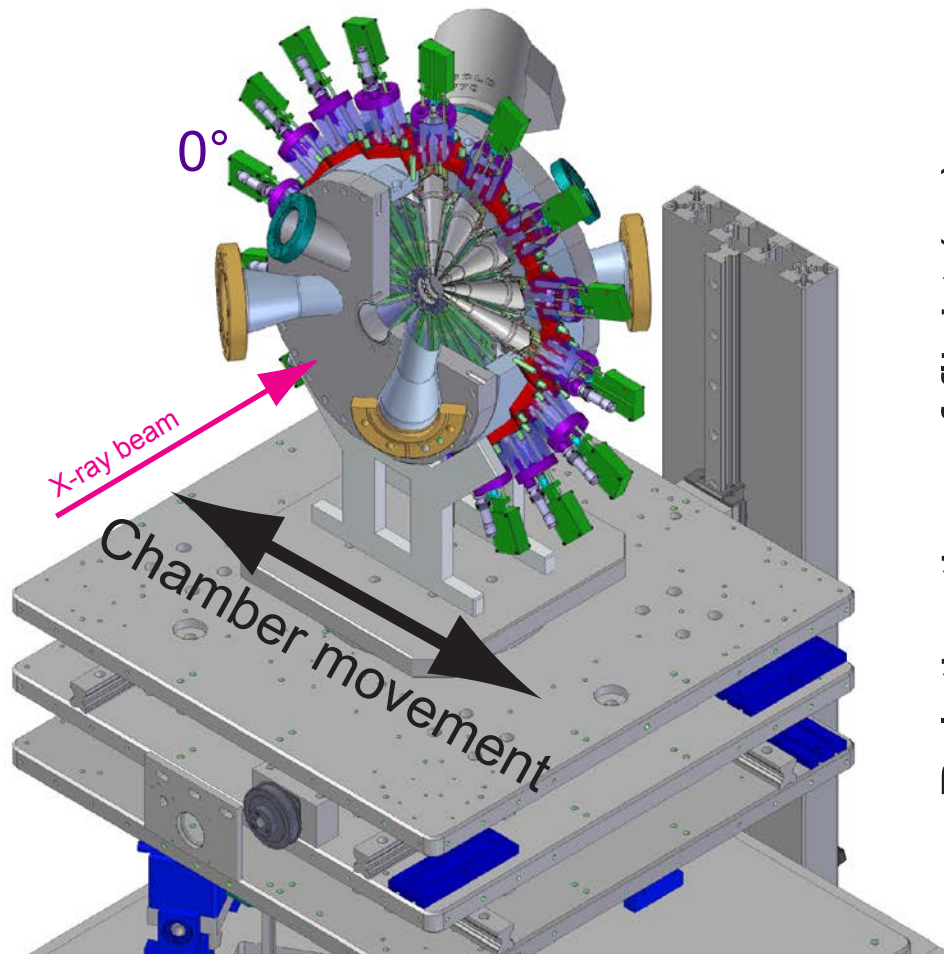
- > accuracy better than 10^{-4}
- > improved via retardation (successfully tested at higher energies)



$$U_{\text{ret}} = -20 \text{ V}$$

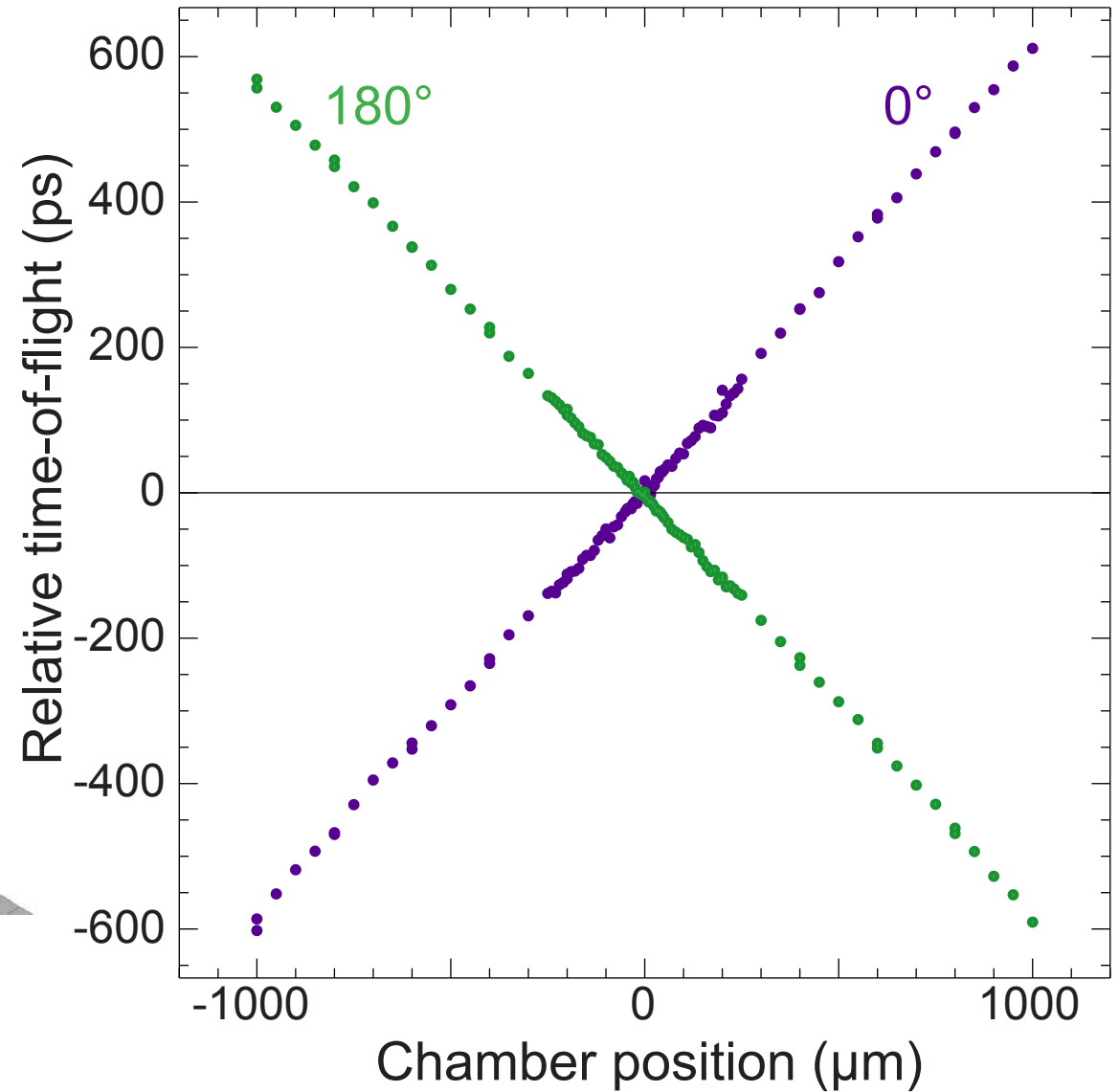
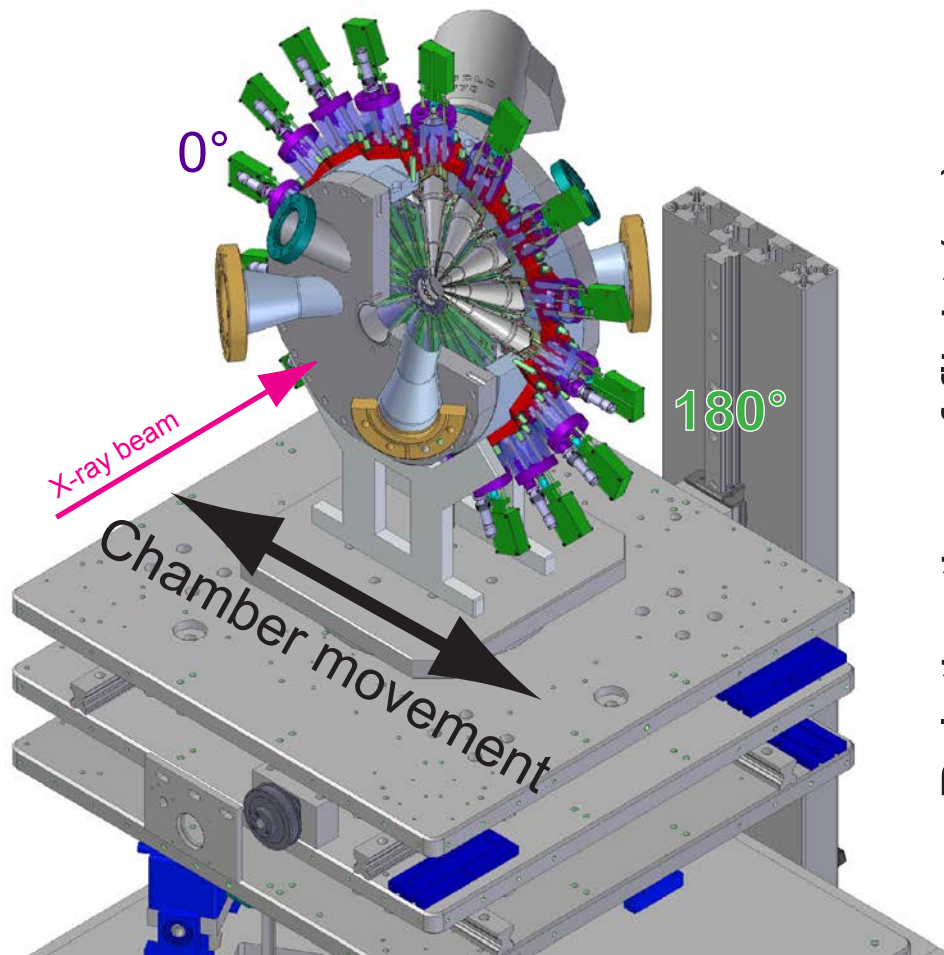


Determination of Beam Position



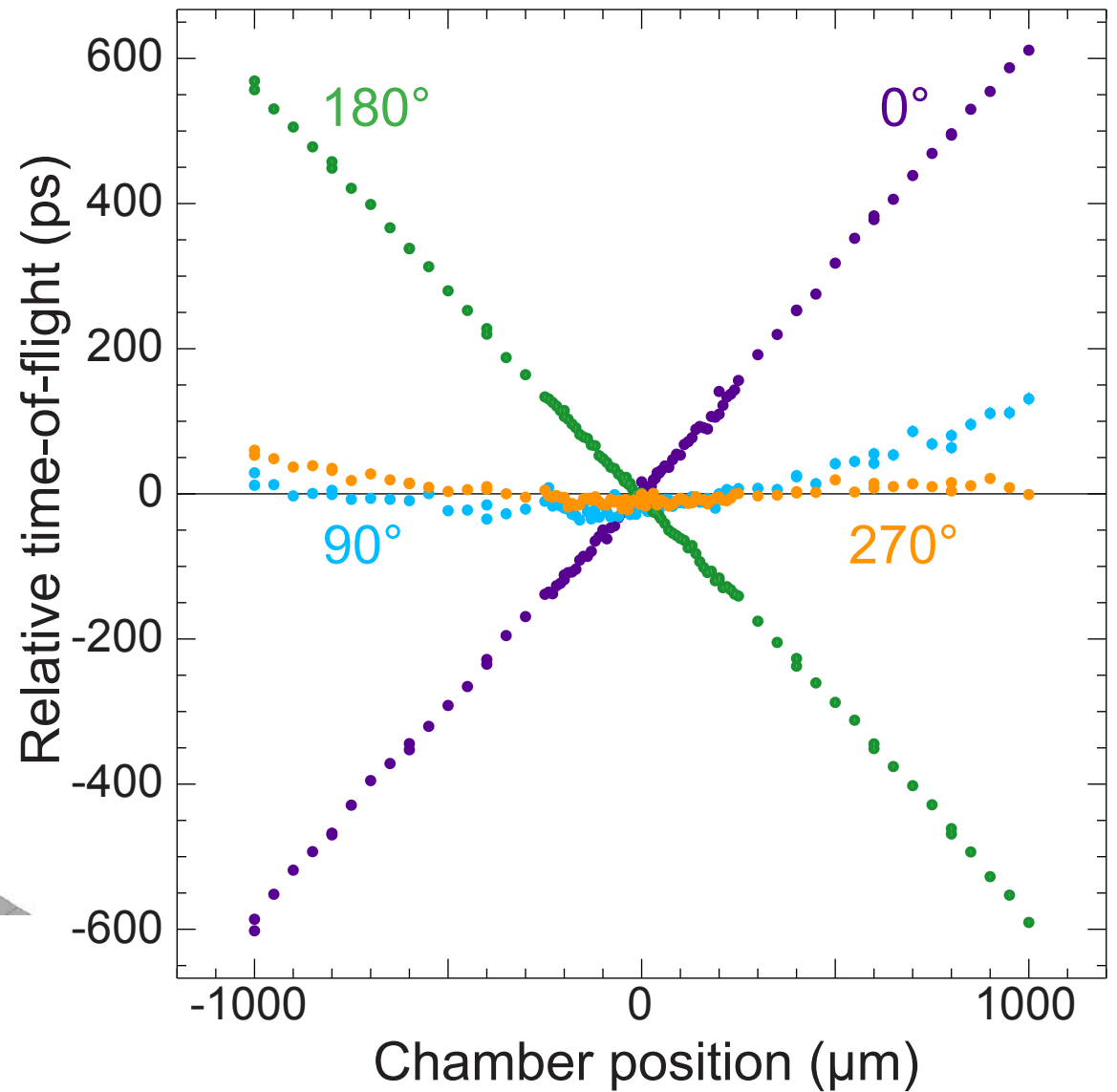
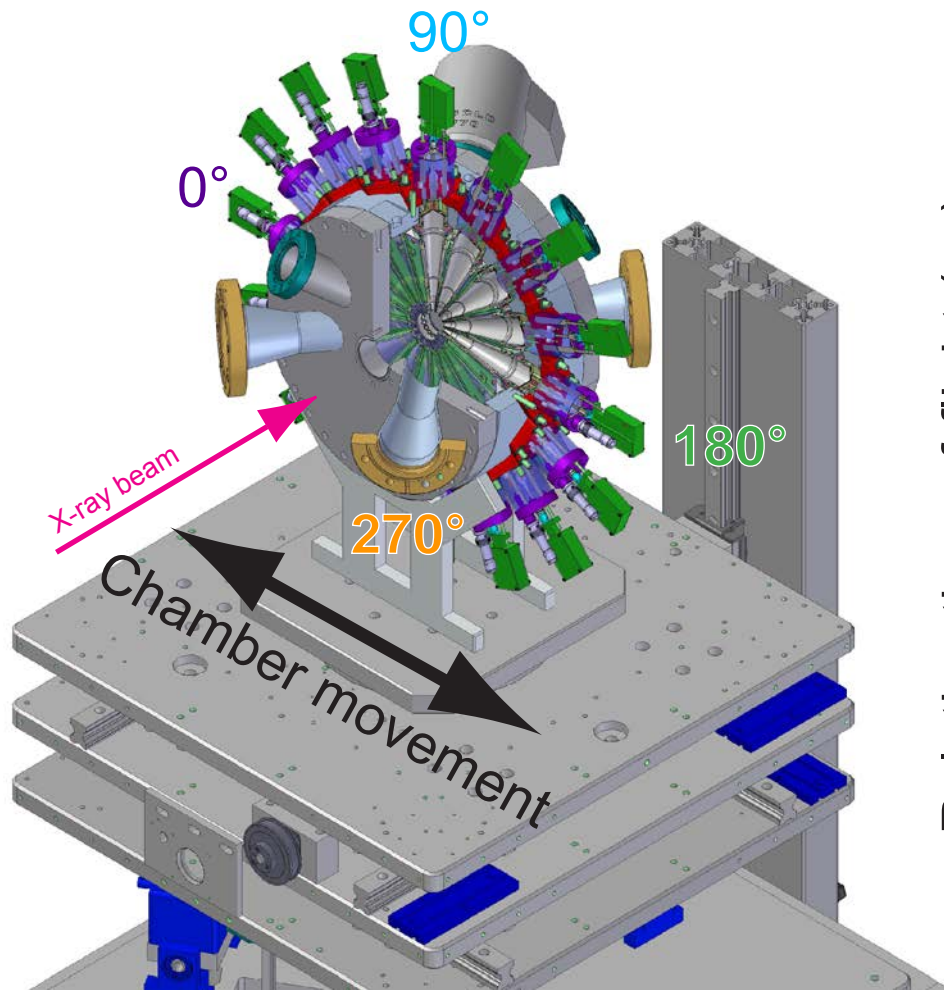
- > accuracy in the μm -range
- > improved via retardation

Determination of Beam Position



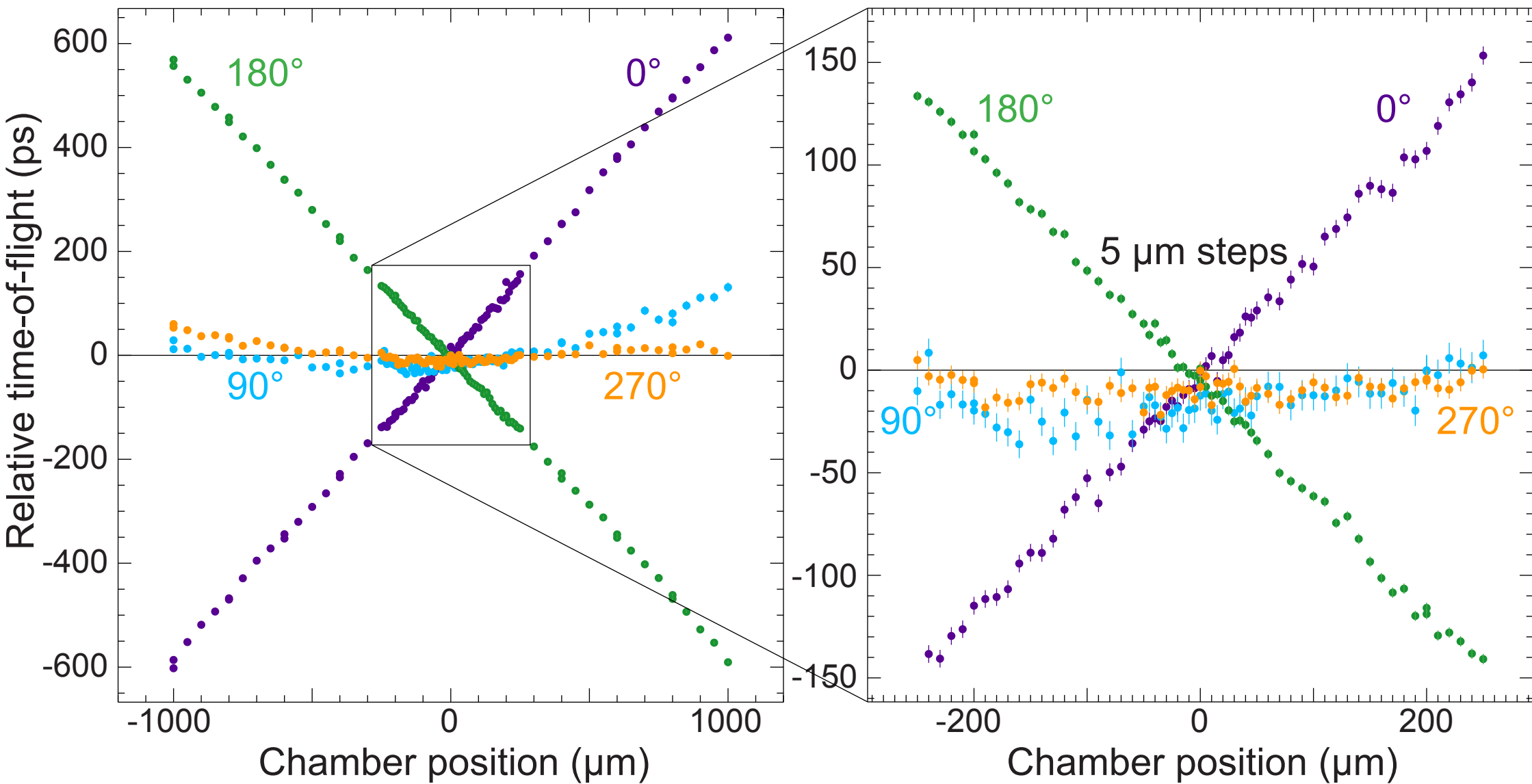
- > accuracy in the μm -range
- > improved via retardation

Determination of Beam Position



- > accuracy in the μm -range
- > improved via retardation

Determination of Beam Position



accuracy in the μm -range, ~ 1 ps per μm



Test of Online Diagnostic Unit at FLASH (PG-0)

Single shot spectra!

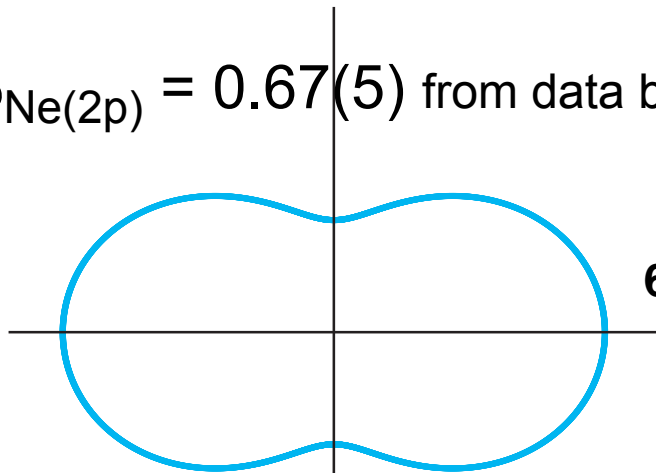
$$h\nu = 47 \text{ eV}$$

$$(\lambda = 26 \text{ nm})$$

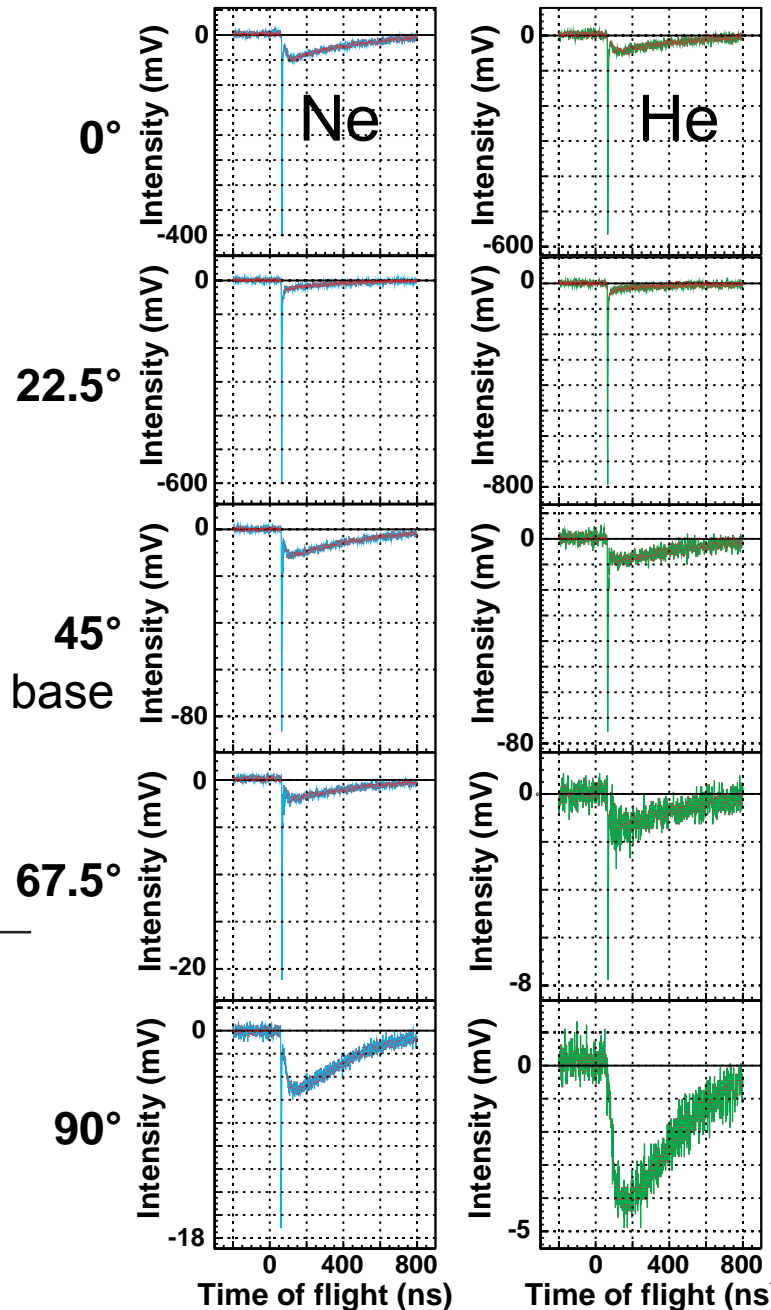
Ne

$$P_{\text{ch}} = 2 \times 10^{-6} \text{ hPa}$$

$$\beta_{\text{Ne}(2p)} = 0.67(5) \text{ from data base}$$



⇒ Detector efficiency



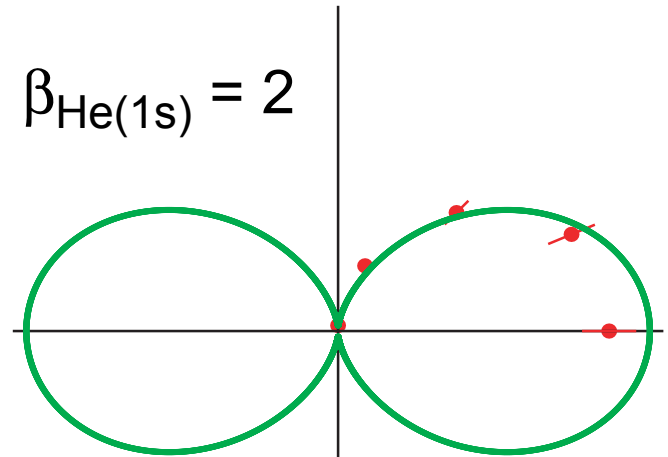
Using PES to monitor
SASE-FEL spectra

M. Wellhöfer *et al.*, *JINST* 3 (2008) P02003

He

$$P_{\text{ch}} = 3 \times 10^{-6} \text{ hPa}$$

$$\beta_{\text{He}(1s)} = 2$$

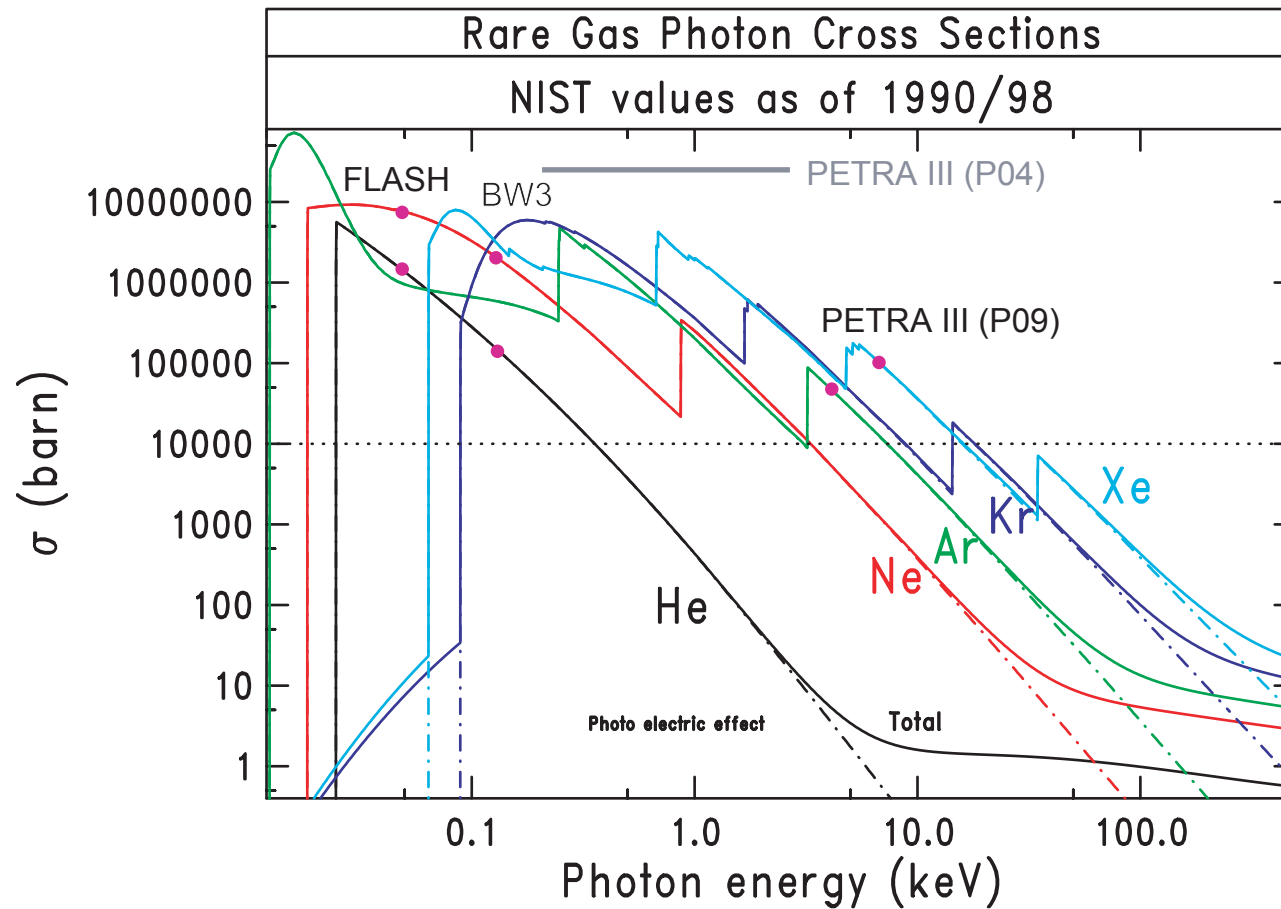


⇒ $P_{\text{lin}} \geq 0.96(4)$



Towards Higher Photon Energies

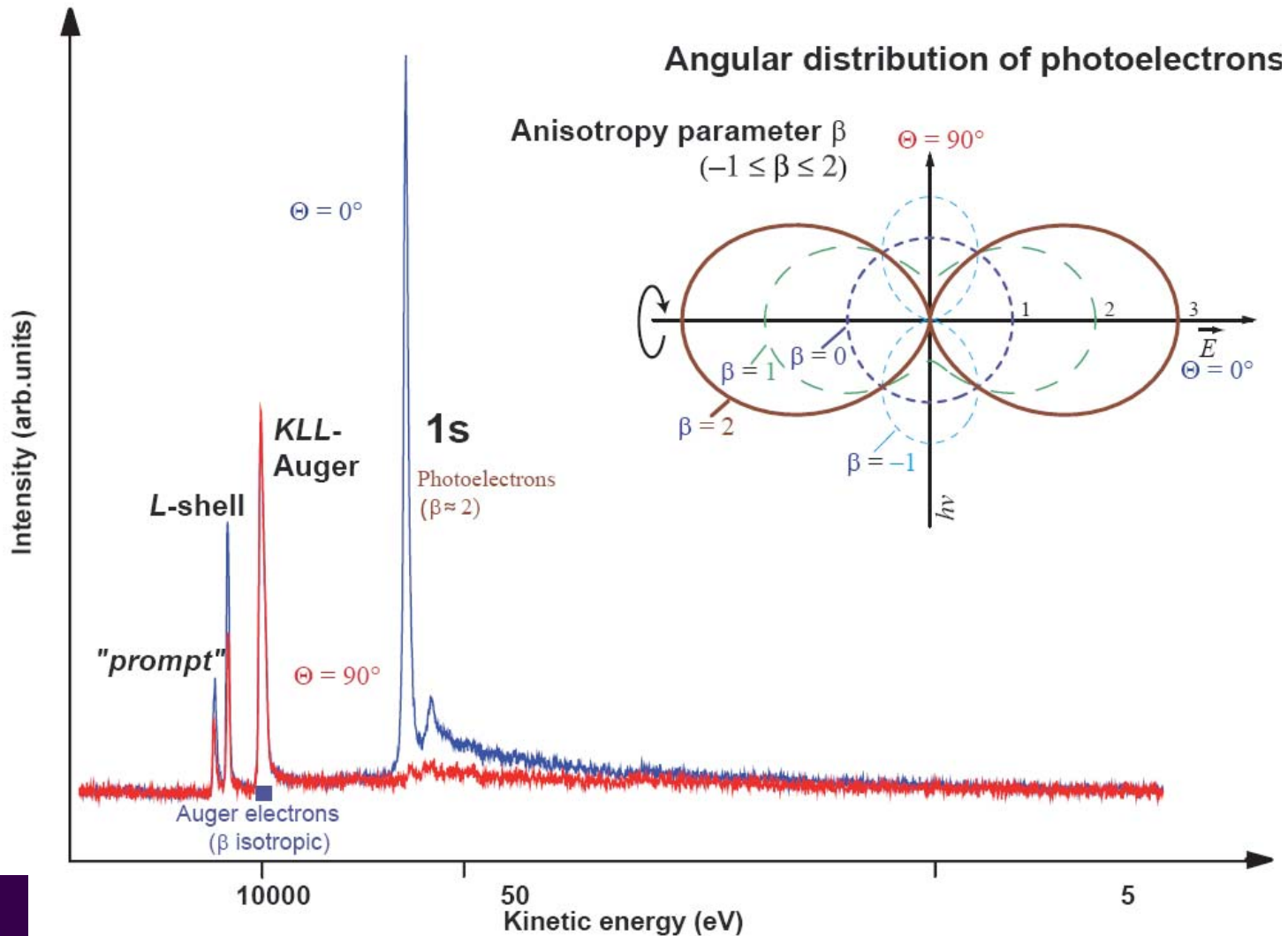
- > Demand for keV-range: PETRA III, European XFEL,...



- > Photoionization cross section seems to be large enough up to about 10 keV (increase gas pressure accordingly)

First Hard X-ray data (P09 Beamline @ PETRA III)

Photoelectron Spectra of Krypton at 14.4 keV



Challenges

- > **Engineering:**

 - Enhance reliability, go for simplicity

- > **Data acquisition:**

 - Migration/adaption from TDC-based to FADC-based system

- > **Data analysis:**

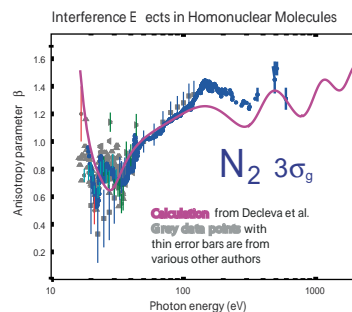
 - Improve data base,
extension towards automated algorithms

- > **Functionality:**

 - Higher energies,
better resolution/accuracy,
better efficiency

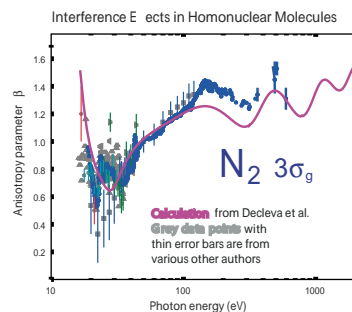
Summary and Outlook

- > Online diagnostic unit for P04 successfully tested:
Main goals achieved, speed/accuracy has to be improved
- > Extension of the method to higher photon energies (up to 15 keV)
has been demonstrated
- > First results of the early prototype show that single shot diagnostics is
also feasible at free electron laser based (soft) x-ray sources
- > Mobile online diagnostic unit is available for other sources:
adaption to other facilities/beamline needs is possible
- > Mobile online diagnostic unit
also serves as a research tool:



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Posters with further information:

improved Gas inlet

TH-L-P-06 (Jörn Seltmann)

P04-Beamline

TH-G-P-15 (Leif Glaser, Jens Viefhaus)

