# First Experimental Experience at FLASH


**User Operation since August 2005**

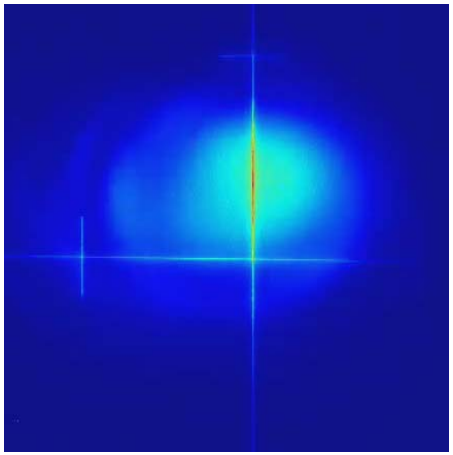
Photon energy 30-200 eV
$10^{13}$ Photons/Pulse
$10^{5}$ Pulses (< 100 fs)
Peak power 1 GW

- **FLASH performance**
- **User operation**
- **Some experimental results**

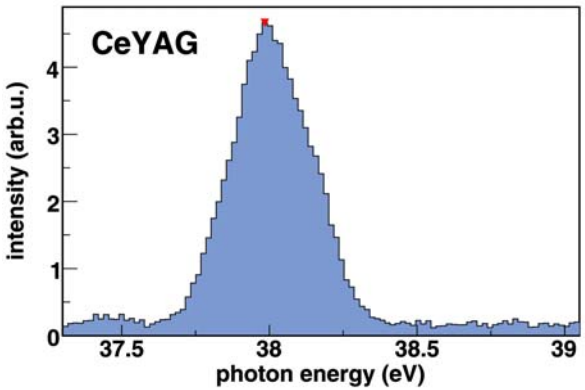
*W. Wurth*
*Institut für Experimentalphysik*
*Universität Hamburg*

# FLASH performance at 32 nm

## Spatial profile



## Spectral distribution



# FLASH performance at 32 nm

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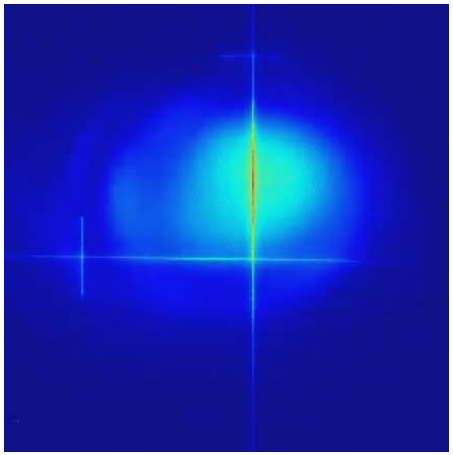

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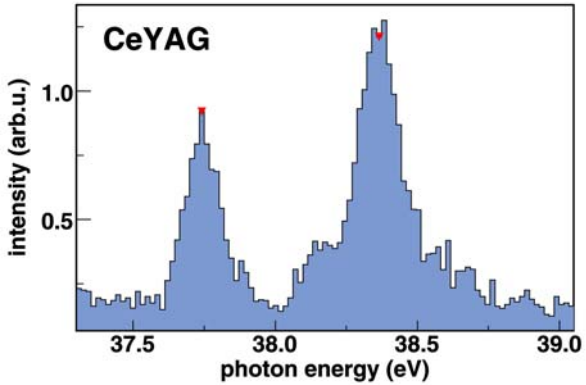
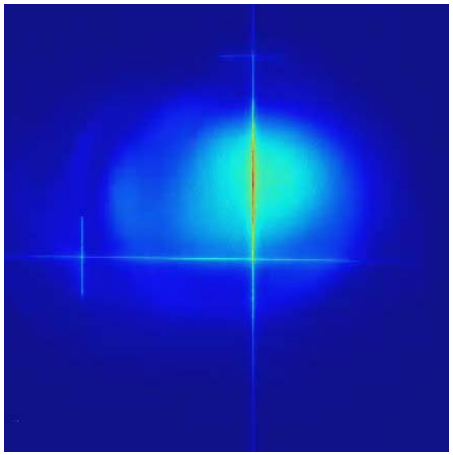


# FLASH performance at 32 nm

## Spatial profile



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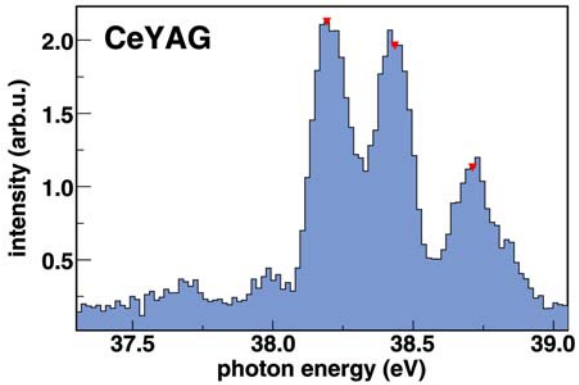

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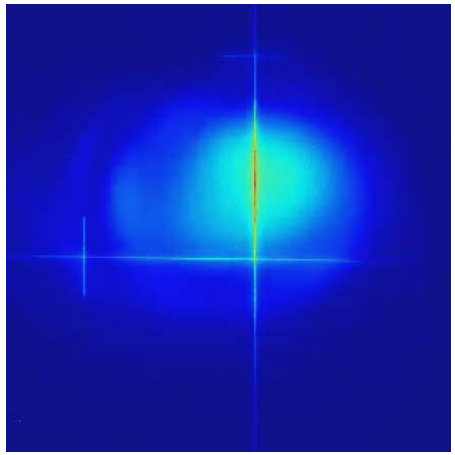
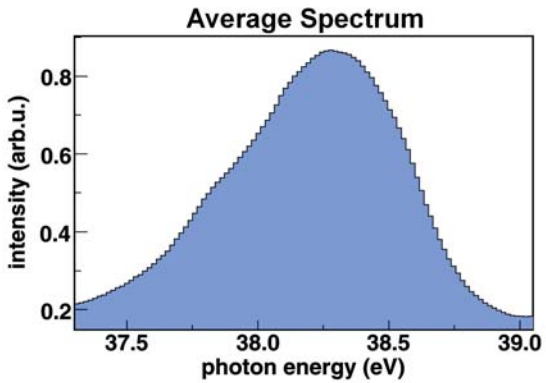
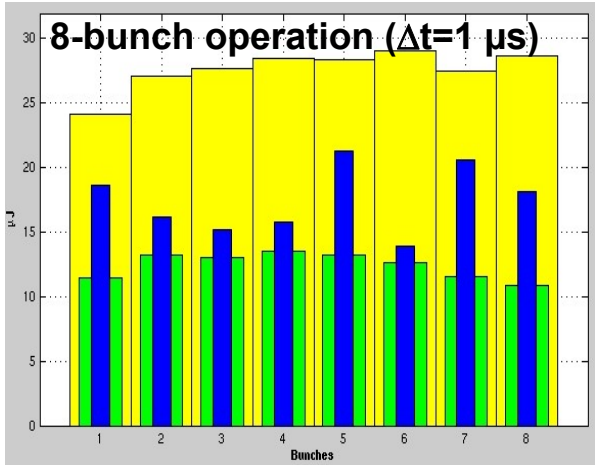
## Spatial profile



## Spectral distribution

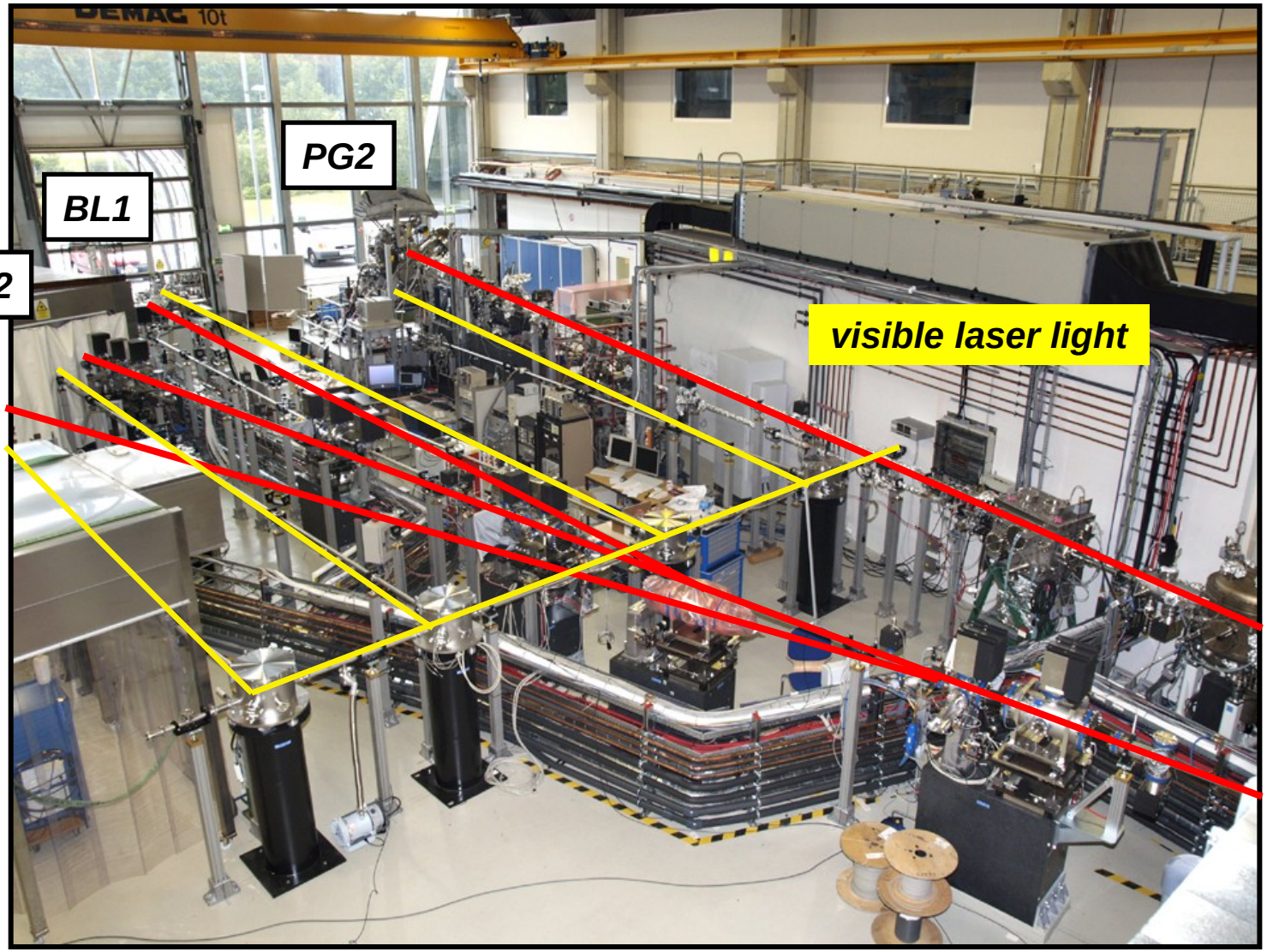



## 2Hz/multi-bunch (≤ 30)




| Parameter | Expected (08.04) | Measured |
|---|---|---|
| Wavelength | 30 nm | 32 nm |
| Pulse duration | 15-50 fs | 20-40 fs |
| Pulse energy | 50-150 μJ | up to 130 μJ (mostly 5-10 μJ) |
| | at saturation | onset of nonlinear regime |
| Bandwidth | 0.8% | 0.5-1.0% |
| Divergence | 70-80 μrad | < 150 μrad |

# FLASH: the VUV-FEL User Facility at DESY



# First Round of User Experiments

30 proposals submitted in 2002
29 proposals approved in Sept. 2002
200 scientists involved from
60 institutes and
11 countries

- *11 proposals were combined in a joint project (peak brightness collaboration)*
- *2 proposals were combined into one project on biological samples (Hajdu, Chapman)*

→ *18 projects,*
*16 are ready and have been scheduled for beamtime*

# User operation Aug. 2005-Feb. 2006

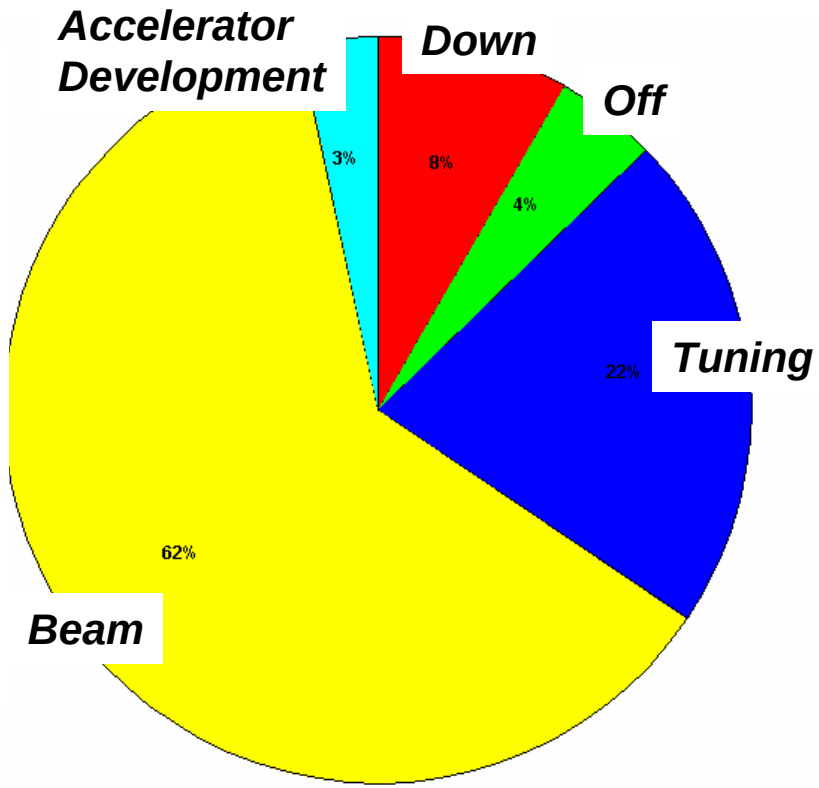
total available beamtime:
16 weeks with 13 user shifts
+ 1 maintenance shift per week

» *208 user shifts total (12 hour shifts)*

14 out of 16 projects had beamtime
2 are scheduled in May' 06

roughly 10-14 shifts/project

**User operation**
**15.08. – 04.09.2005**



# Research Areas

- **Femtosecond time-resolved experiments**
  - Synchronization FEL - optical laser (*Drescher, Meyer*)
  - Pump-probe expts. on atoms and molecules (*Meyer, Drescher*)
  - Sum-frequency generation (*Starke*)

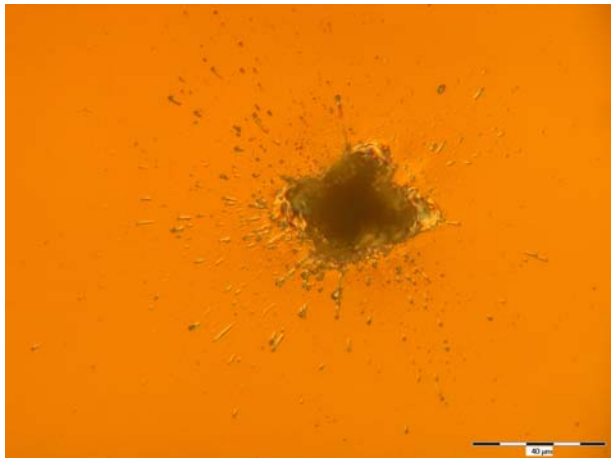
- **Interaction of ultra-intense XUV pulses with matter**
  - Multi-photon excitation of atoms, molecules, clusters… (*Richter, Becker, Moshammer, Möller*)
  - Creation and characterization of dense plasmas (*Lee et al.*)
  - Imaging of biological samples (*Hajdu/Chapman*)

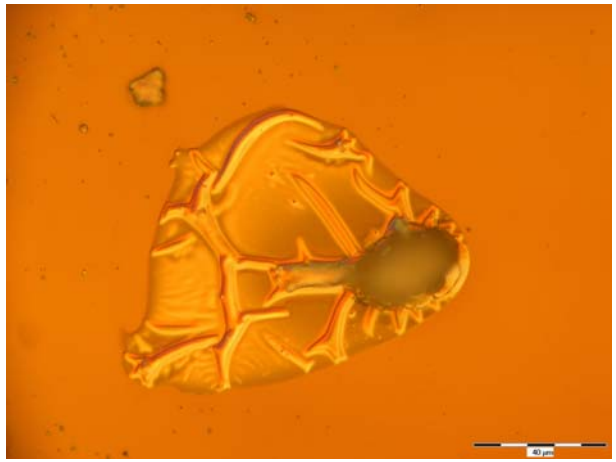
- **Investigation of extremely dilute samples**
  - Photo-dissociation of molecular ions (*Wolf*)
  - Highly charged ions (*Crespo*)
  - Mass selected clusters (*Meiwes-Broer*)

- **Investigation of surfaces and solids**
  - Laser desorption *(Zacharias)*
  - Non-linear effects and surface dynamics (*Föhlisch*)
  - Luminescence (*Kirm*)
  - Nano-spectroscopy of surfaces and solids (*Kipp*)

# High energy density experiments

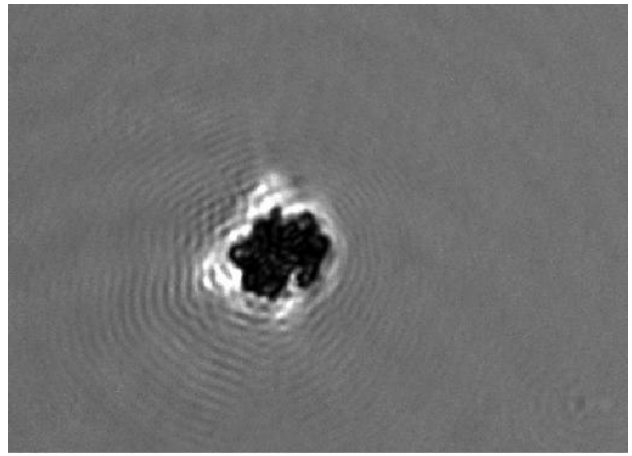
"Peak brightness collaboration" R.W. Lee et al.





Ablation of carbon coating on Si

R. Sobierajski et al.

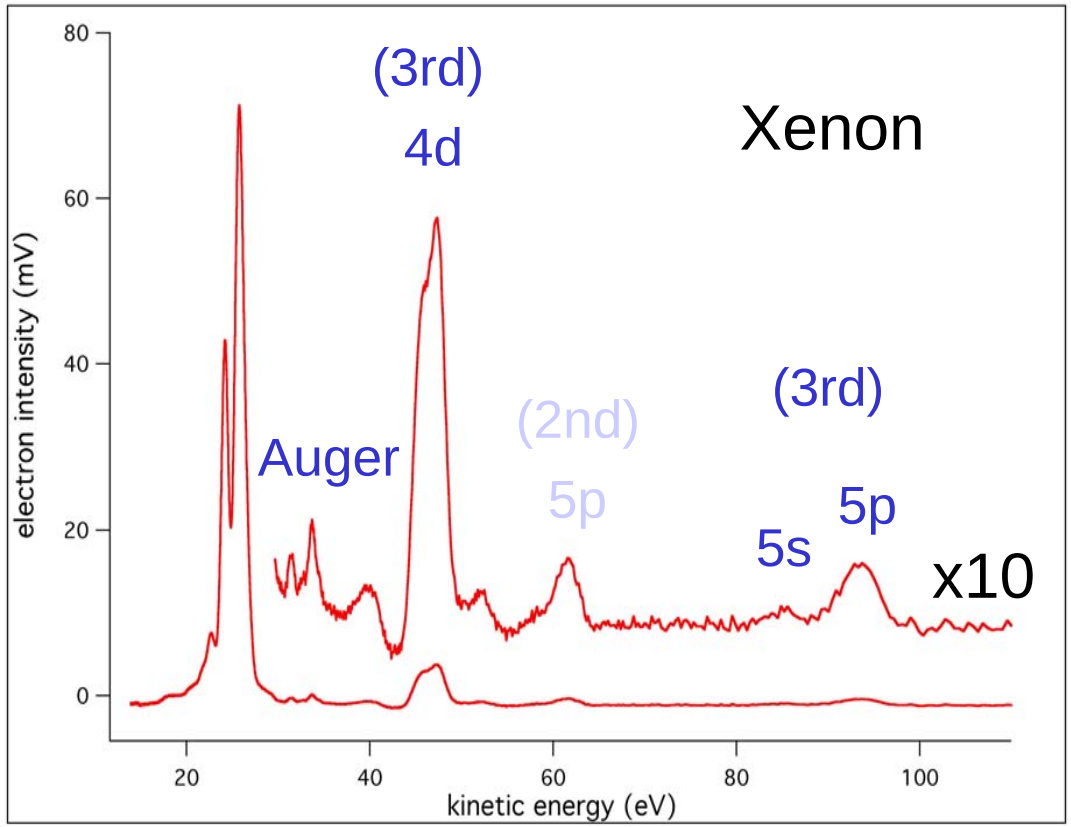


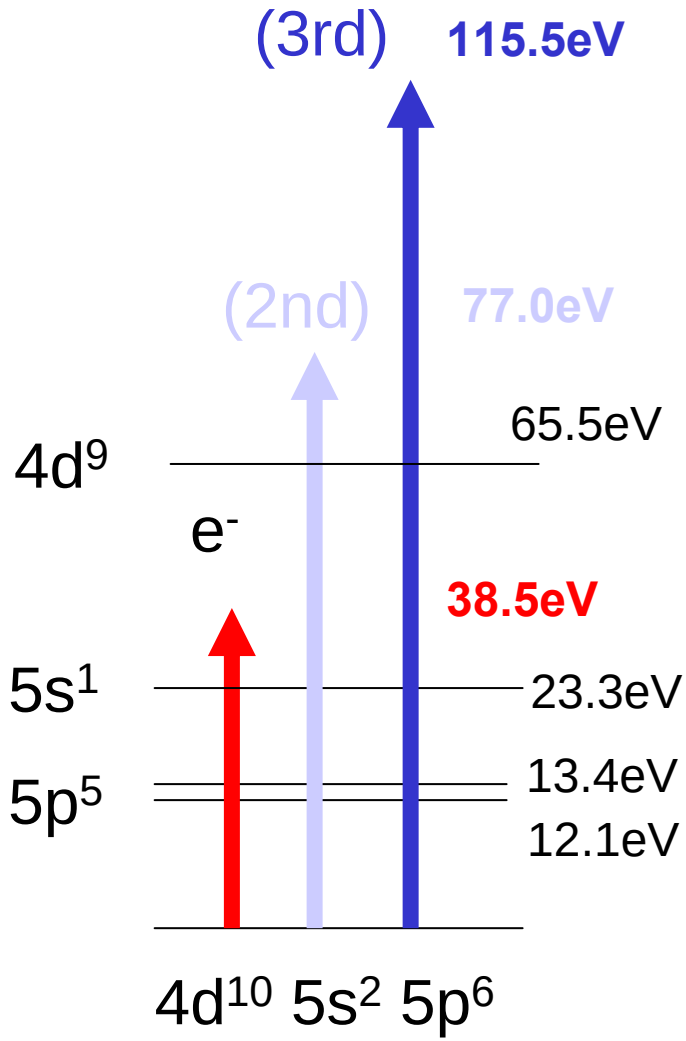
Ablation studies of Si,
time-resolved through illumination
by optical laser pulse

K. Sokolowski-Tinten et al.

# Xe photoionization (M. Meyer et al.)

U(ret) = -15V  **hν (FEL) = 38.5 eV**



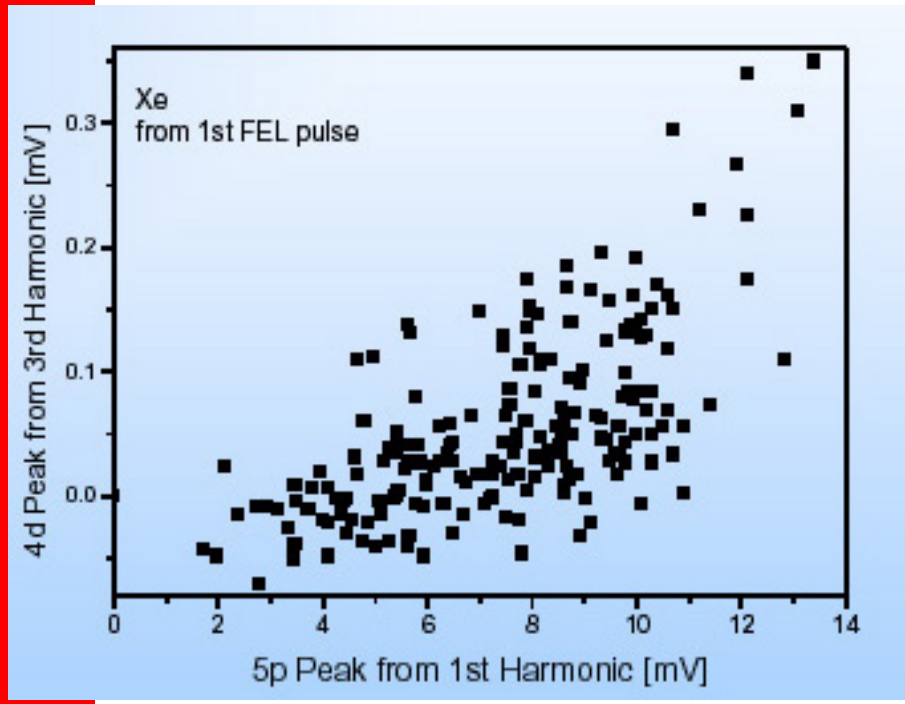



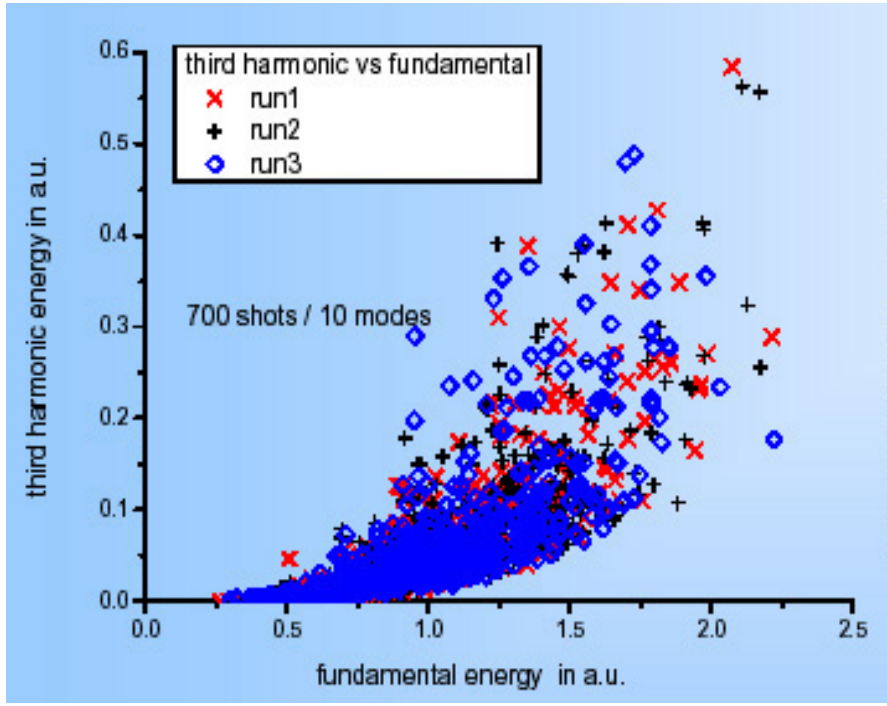

**single shot spectra !!!**

# Higher harmonics

## *Single shot correlation fundamental - third harmonic*

Düsterer et al. Opt.Lett. 2006, accepted




Experiment average 3 μJ
max. 10 μJ

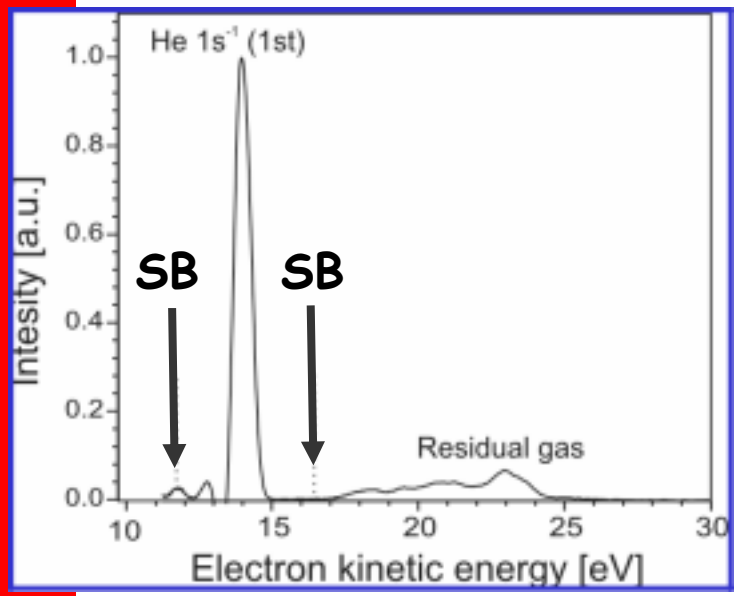
Simulations (G. Geloni, E. Saldin)
10 modes

# Two-photon ionization: towards two colour pump-probe

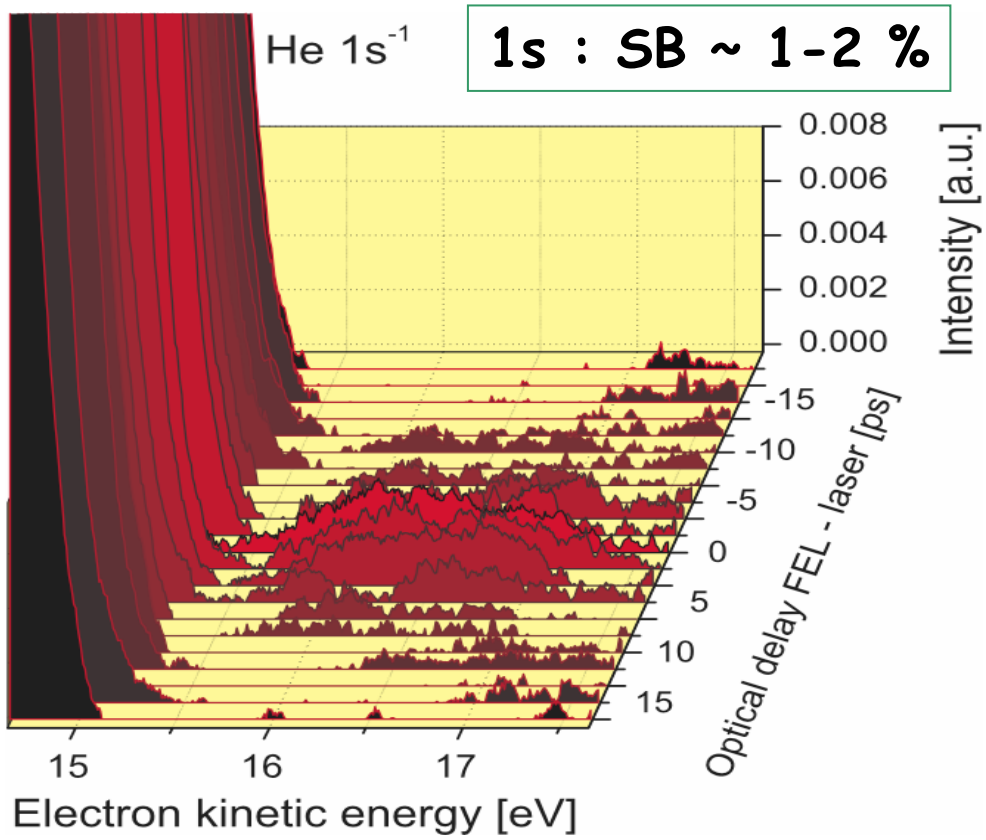
FEL: 32 nm, 1 - 3 μJ, 50 μm focus, 50 fs, ~ $10^{12}$ W/cm$^2$

Laser : 523 nm, 250 μJ, 50 μm focus, 12 ps, ~ $10^{11}$ W/cm$^2$

One-photon ionization

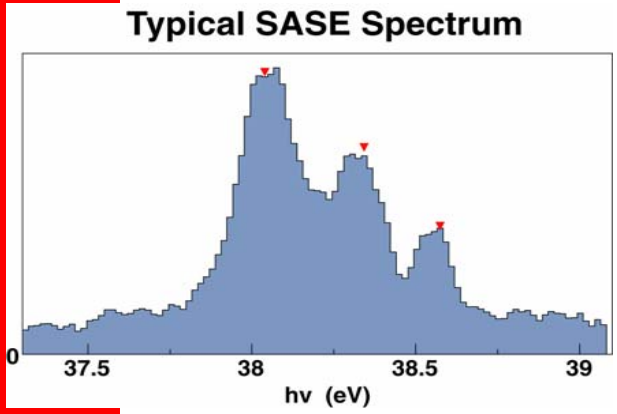



Expected position of sidebands

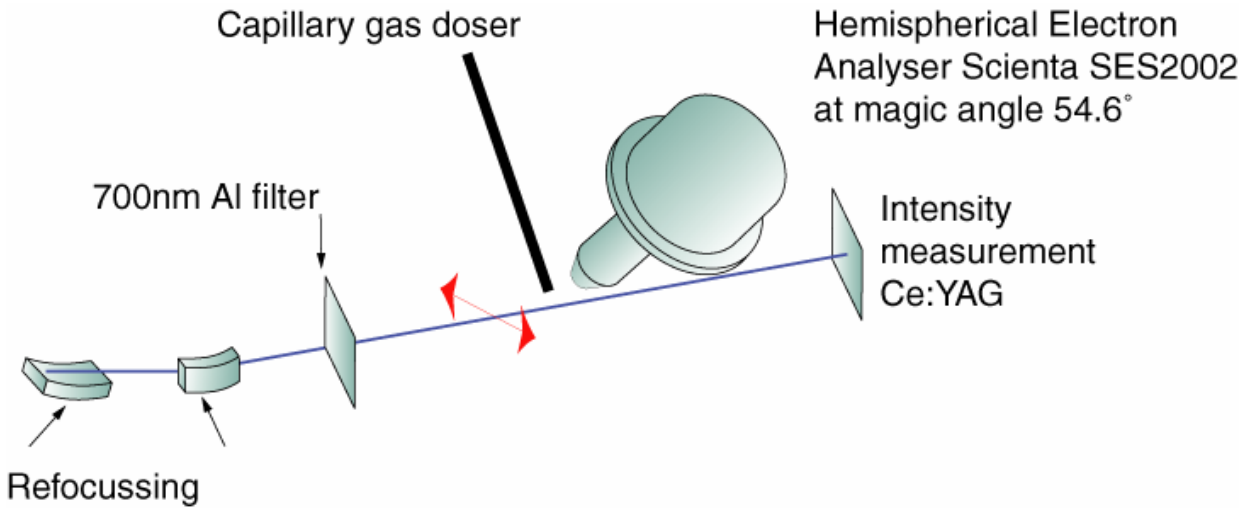



M. Meyer et al.

# Photoelectron spectroscopy as function of pulse energy

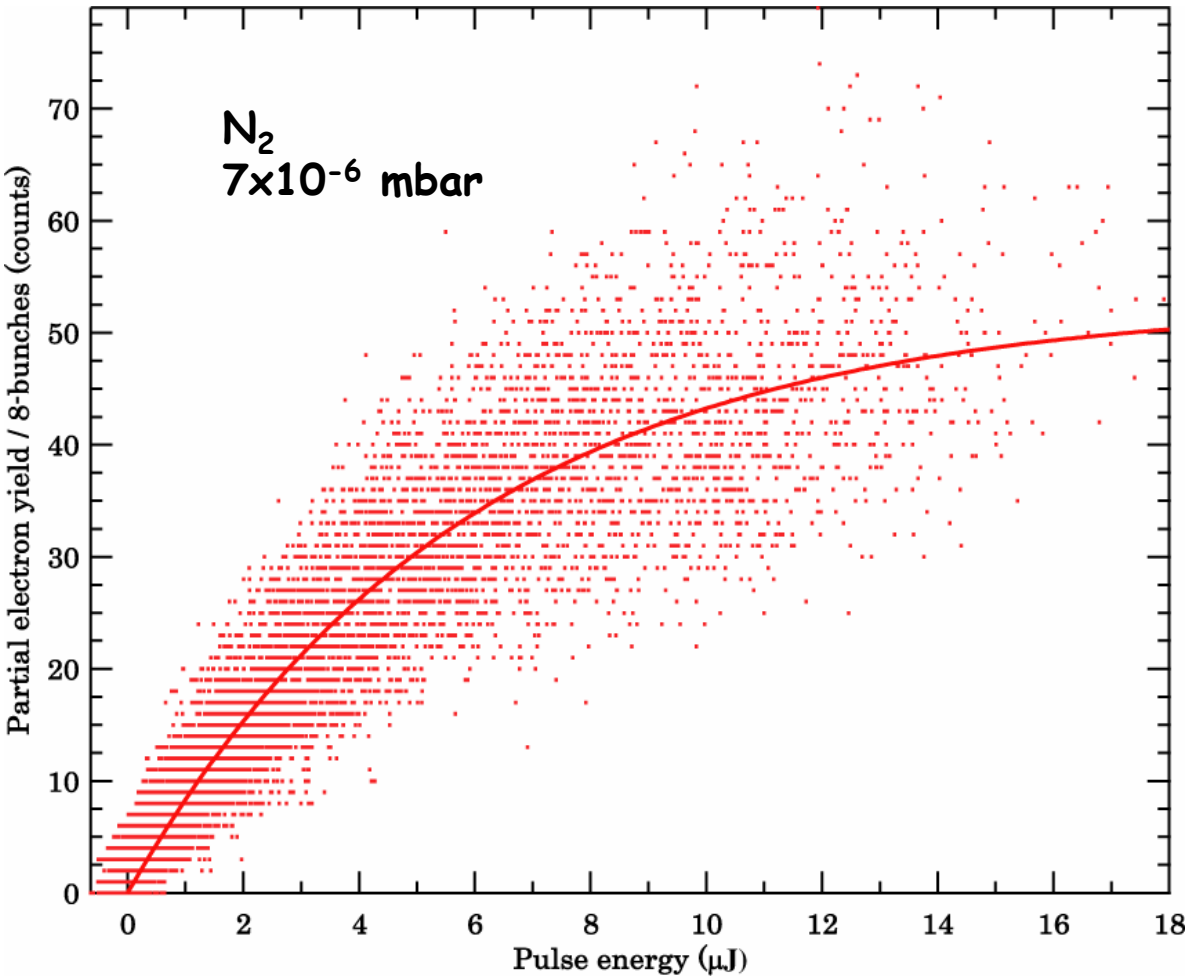



PGM Monochromator
M. Martins, M. Wellhöfer
10 000 < E/ΔE < 50 000.
2nd and 3rd harmonic ~1%
4th harmonic ~1‰
or 0th order




Goal: Time-resolved and element specific spectroscopy of dynamics of excited states

# $N_2$ Photoemission as a function of pulse energy




$A = 66x66\mu m^2$

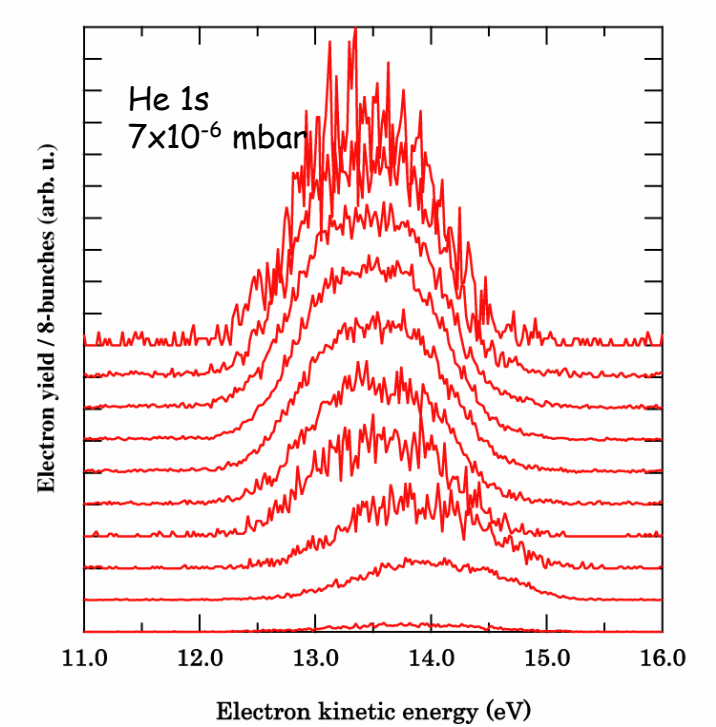
$N_0 = 6.7\ 10^5$

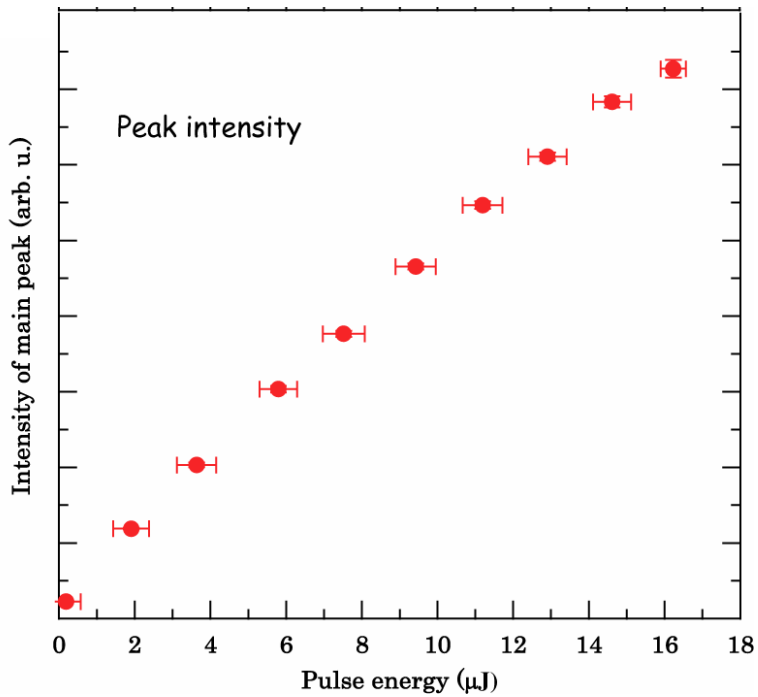
Saturation of Sample Volume
Photoionisation cross section at 38eV
σ = 6.6Mb

$$I(N_p) = N_o\left(1 - e^{-\frac{\sigma}{A}N_p}\right)$$

See also M. Richter et al.

# He 1s Photoemission



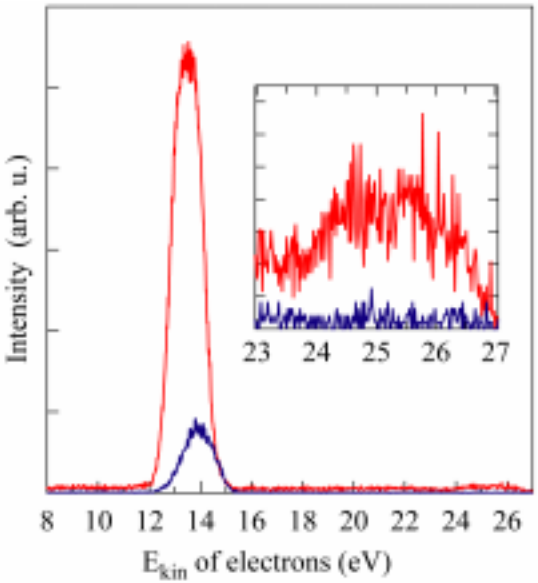



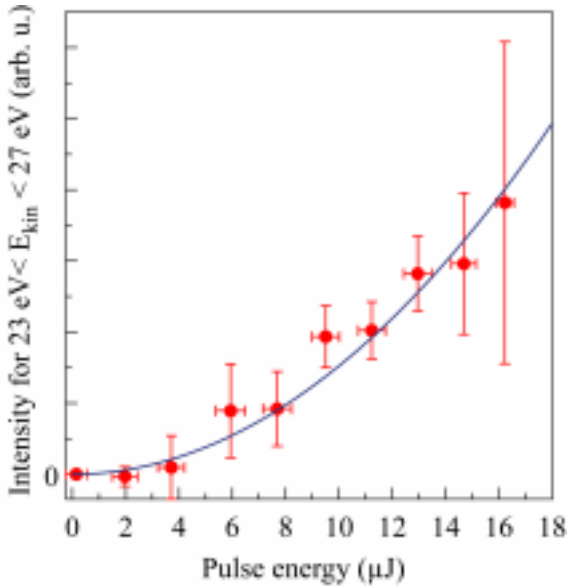

He 1s: 2.77 Mb/atom, BE He 1s: 24.587 eV

J.-J. Yeh and I. Lindau, "Atomic Subshell Photoionization Cross Sections and Asymmetry Parameters: $1 < Z < 103$," *At. Data Nucl. Data Tables* **32**, 1 (1985).

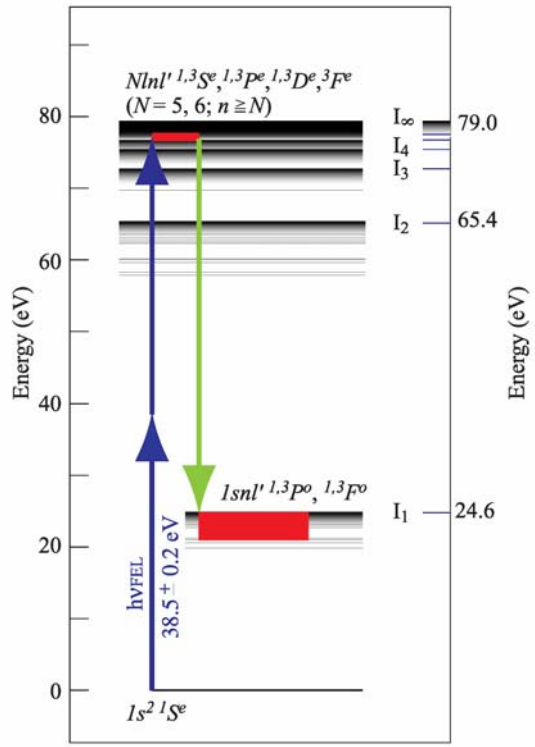
J.-J. Yeh, *Atomic Calculations of Photoionization Cross Sections and Asymmetry Parameters* (Gordon and Breach, Langhorne, PA, 1993).

# Resonant two-photon absorption




Quadratic dependence on pulse energy



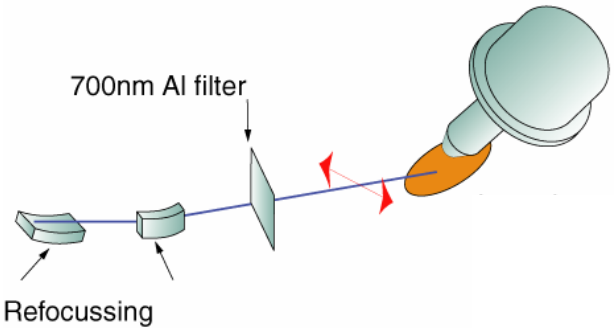

$He^+$: 24.587 eV

$He^{2+}$: 54.416 eV (sequential)

**Evidence for non-sequential resonant two-photon absorption**

Energy levels from: Zhen-sheng Yuan et al., Physical Review A **70**, 062706 (2004)

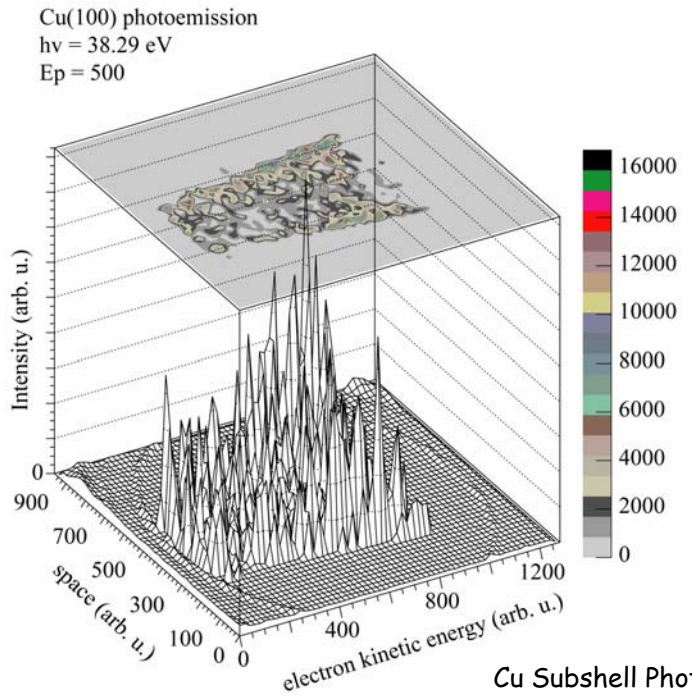
# Single shot photoemission on solids

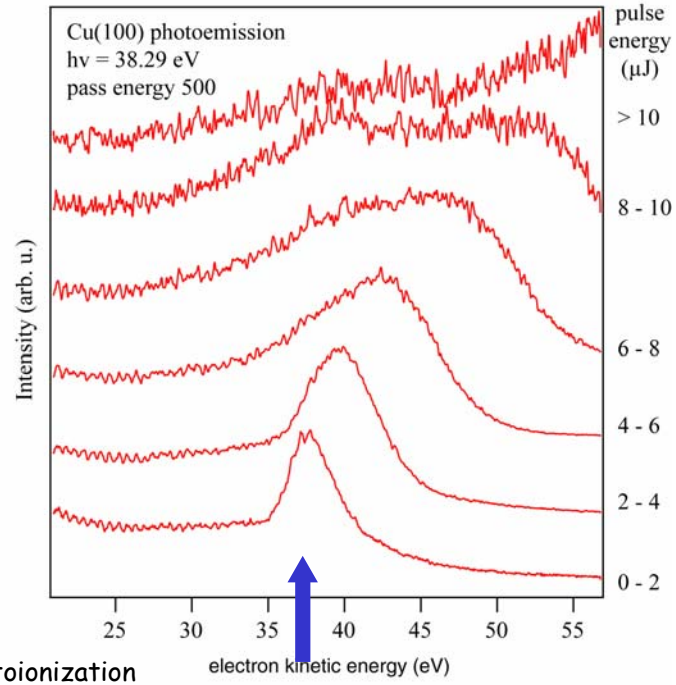



Towards time resolved spectroscopy

single shot photoemission spectra feasible even with higher harmonics

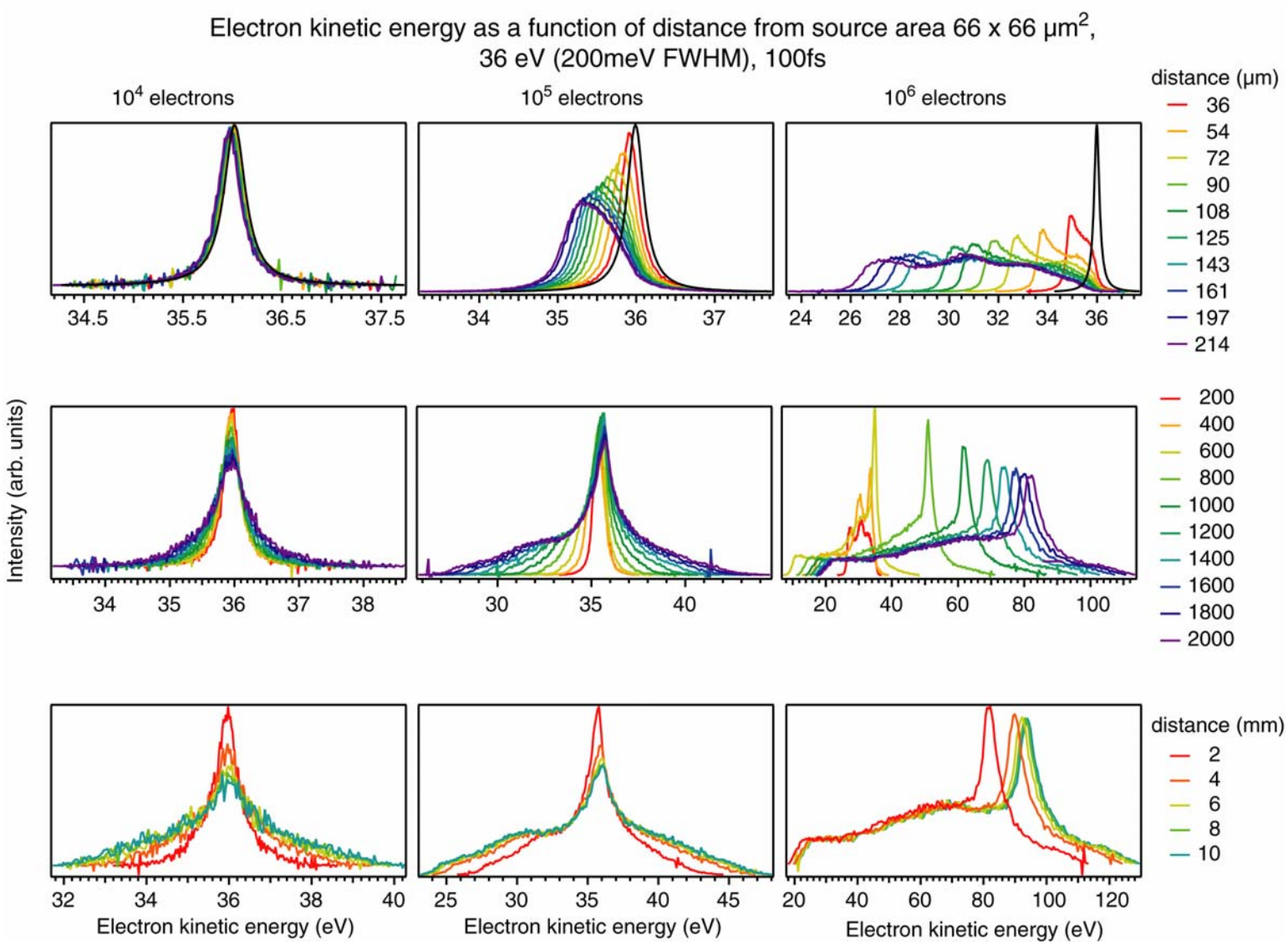
At high peak brillance space charge limitations.



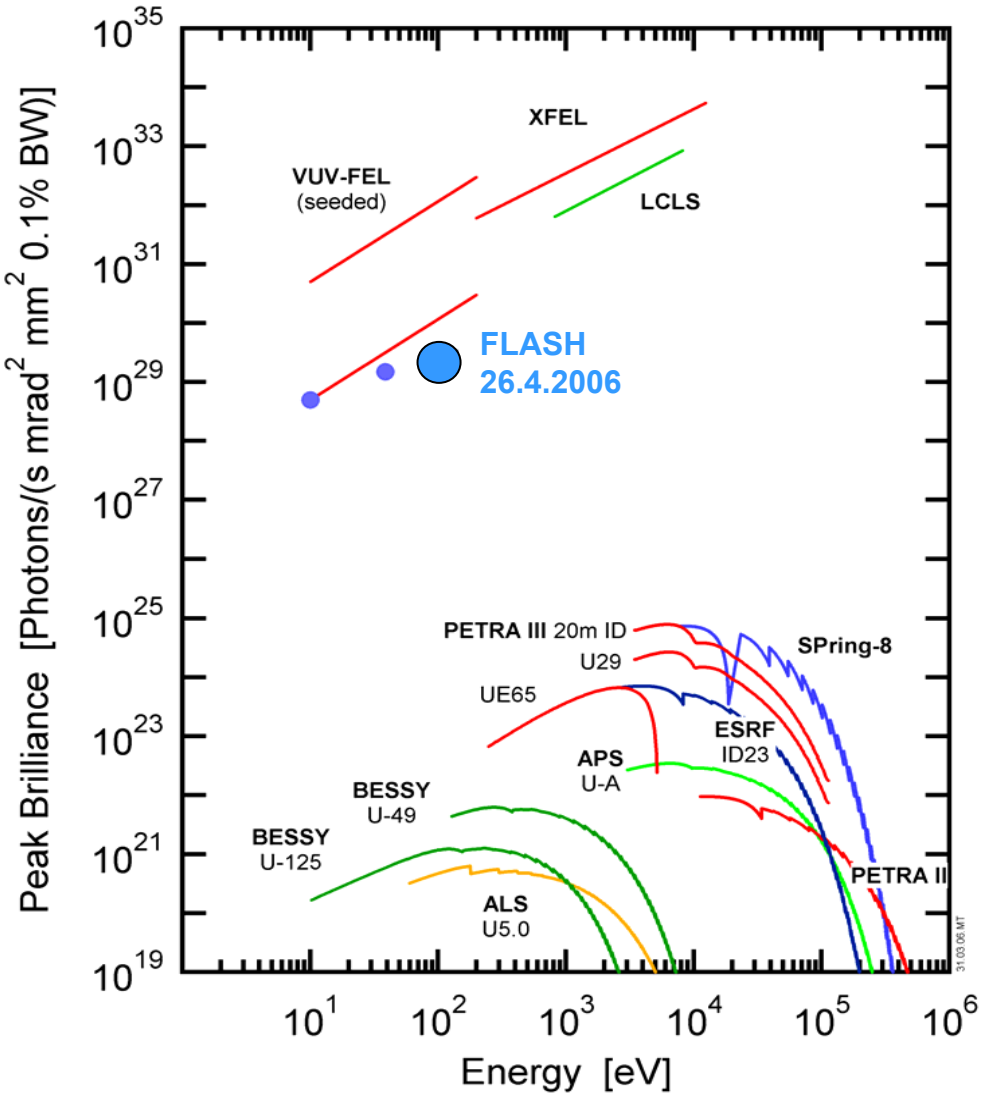

Cu Subshell Photoionization
Cross section at 38 eV:
3d: 9.934 Mb/atom
4s: 0.041 Mb/atom

# Simulation of coulomb explosion




Program courtesy Klaus Flöttman, DESY Astra

# The future is bright !




J. Rossbach

and exciting !

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