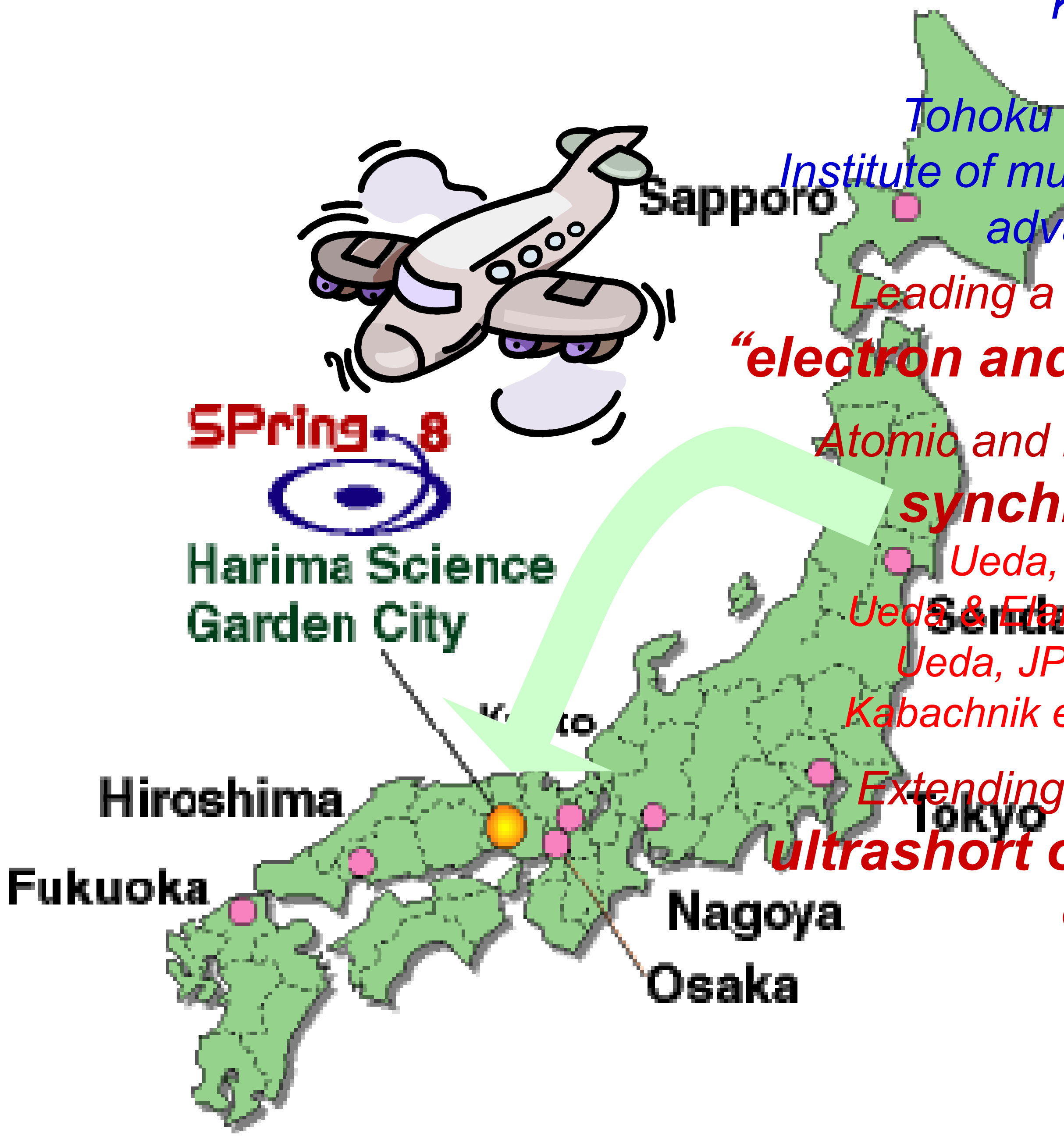
FEL Experiments in Japan: EUV to X

Kiyoshi Ueda
Tohoku University, Sendai, Japan

Introduction….



Kiyoshi Ueda
Professor
Tohoku University（Sendai）
Institute of multidisciplinary research for advanced materials

Leading a group for investigating
"electron and molecular dynamics"

Atomic and molecular science using
synchrotron radiation

Ueda, JPB 36, R1 (2003);
Ueda & Eland, JPB 38, S839 (2005);
Ueda, JPSJ 75, 032001 (2006);
Kabachnik et al. PR 451, 155 (2007).

Extending our research areas to
ultrashort optical laser and FEL
experiments

With SCSS EUVFEL at SPring-8, FLASH and LCLS

- *We have been investigating multiple ionization of atoms, molecules and clusters*
- *We are trying to establish time-resolved spectroscopy*

For SACLA XFEL at SPring-8

- *We are preparing to make molecular movies*

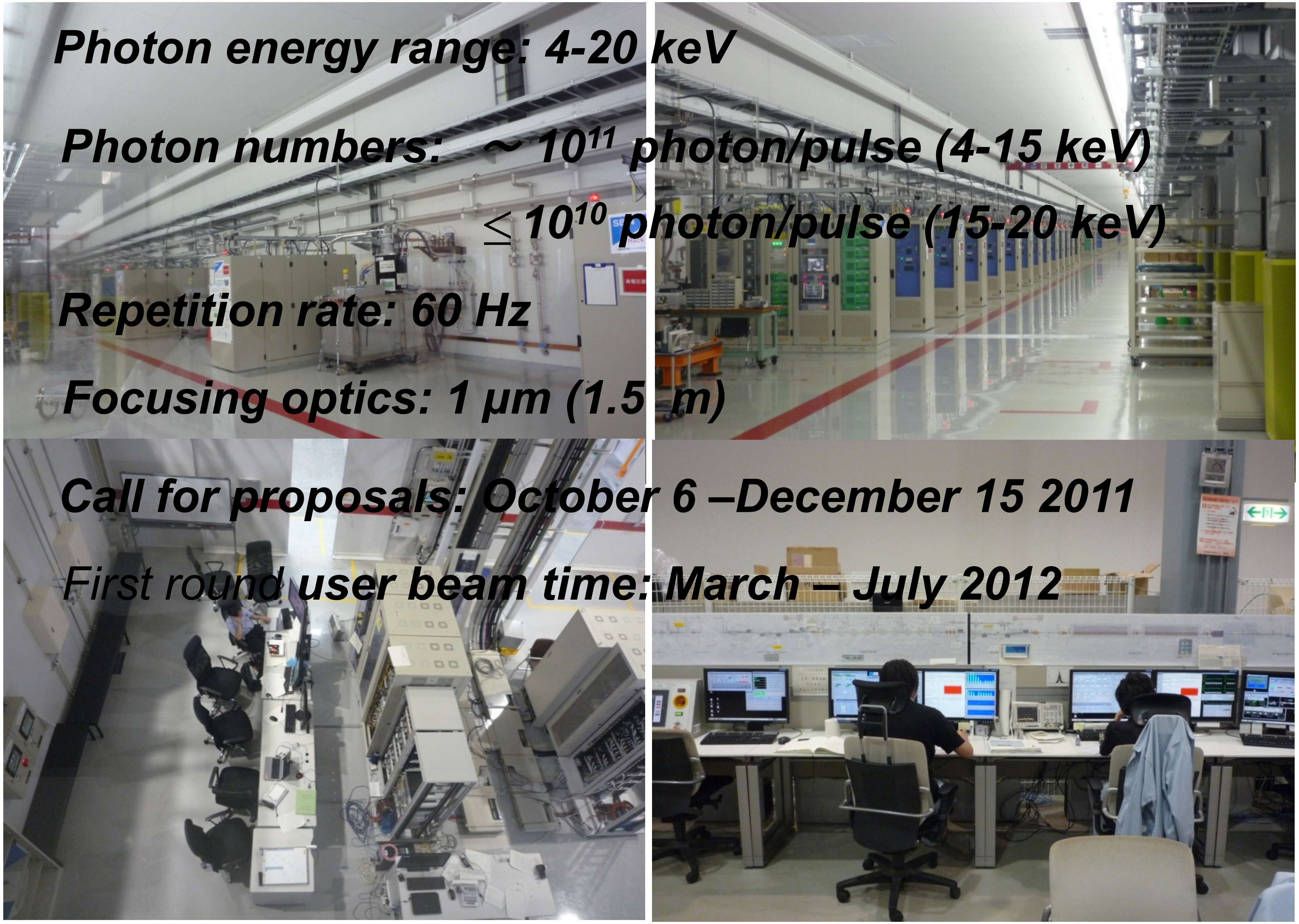
Targets: biomolecule undergoing structural change
nano-crystal undergoing phase change

SACLA XFEL (lased on 7 June!)

Tetsuya Ishikawa
RIKEN

Tsumoru Shintake
RIKEN

SACLA XFEL



Photon energy range: 4-20 keV

Photon numbers: $\sim 10^{11}$ photon/pulse (4-15 keV)

$\leq 10^{10}$ photon/pulse (15-20 keV)

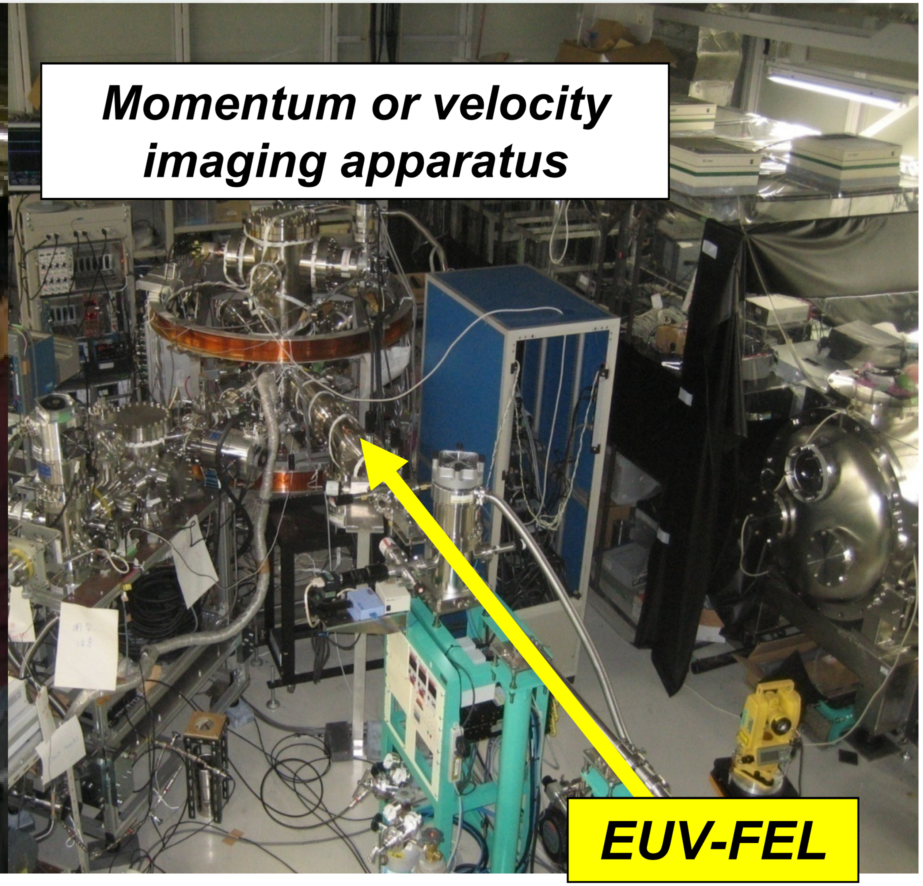
Repetition rate: 60 Hz

Focusing optics: 1 μm (1.5 m)

Call for proposals: October 6 –December 15 2011

First round user beam time: March – July 2012

SCSS test accelerator : EUV-FEL (20-24 eV)



Multiple ionization of rare gas clusters: with M. Yao's group
EUV-pump EUV-probe: with J. Ullrich's group
Electron spectroscopy with VMI: with M. Vrakking's group

Outline and summary

1. Introduction
   Towards the molecular movie with XFEL

2. Two photon single ionization of He atom
   Autocorrelation measurements
   TDSE study and PAD measurements

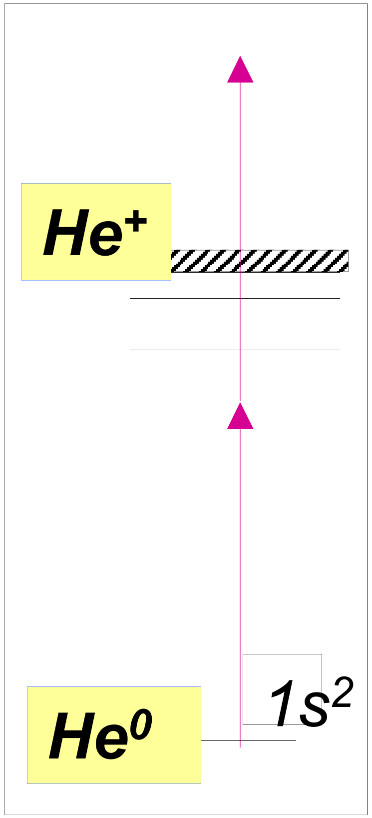
3. Multiple ionization of rare gas clusters
   Frustration of cluster ionization
   Electronic decay of multiply excited clusters
   Charge transfer
   Time dependent Mie plasmon in clusters

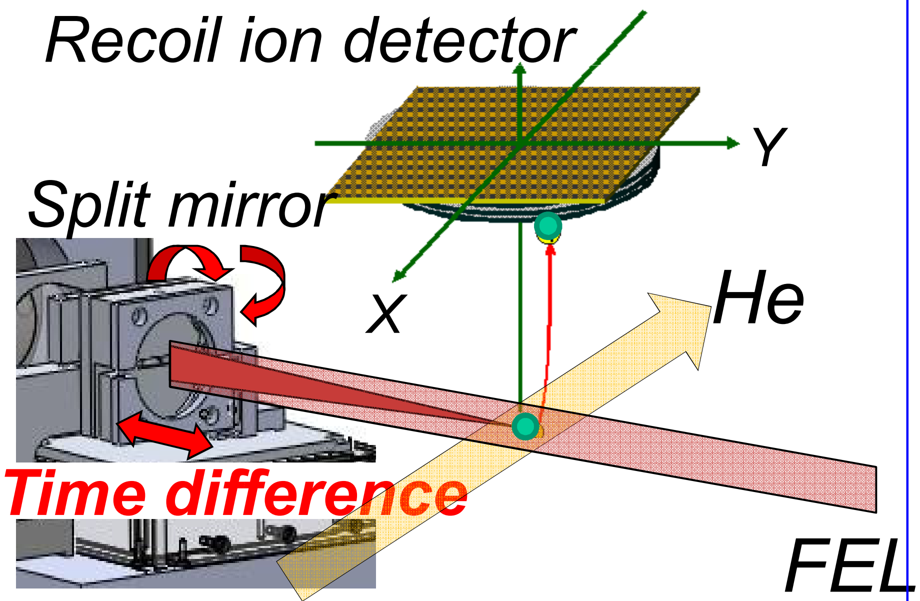
4. Double core hole spectroscopy
   Ab initio study and measurements at LCLS

5. Planned commissioning experiments at SACLA

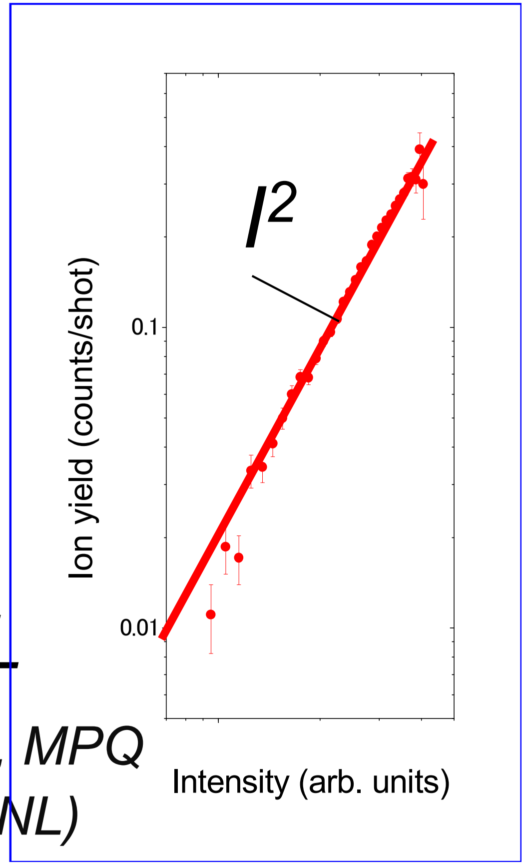
Second-order autocorrelation of EUV FEL pulses via time resolved two-photon single ionization of He

R. Moshammer, Th. Pfeifer, A. Rudenko, Y.H. Jiang, L. Foucar, M. Kurka, K.U. Kuhnel, C.D. Schroter, J. Ullrich, O. Herrwerth, M.F. Kling, X.-J. Liu, K. Motomura, H. Fukuzawa, A. Yamada, K. Ueda, K. L. Ishikawa, K. Nagaya, H. Iwayama, A. Sugishima, Y. Mizoguchi, S. Yase, Yao, N. Saito, A. Belkacem, M. Nagasono, A. Higashiya, M. Yabashi, T. Ishikawa, H. Ohashi, H. Kimura, and T. Togashi

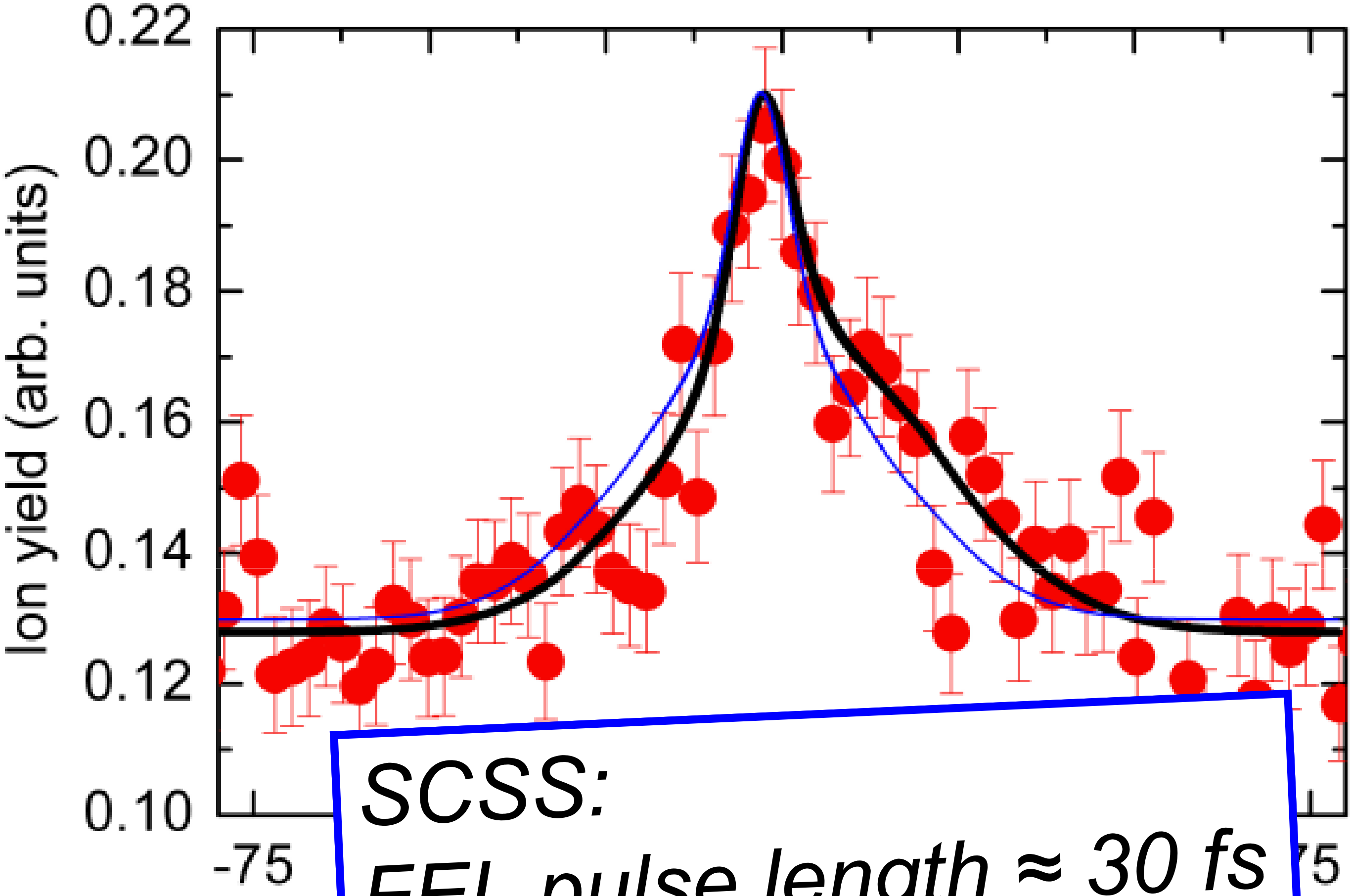




Split mirror assembly:MPI-K, ASG-CFEL, MPQ
Mirror: Mg/Si multilayer (f=600 mm, LBNL)



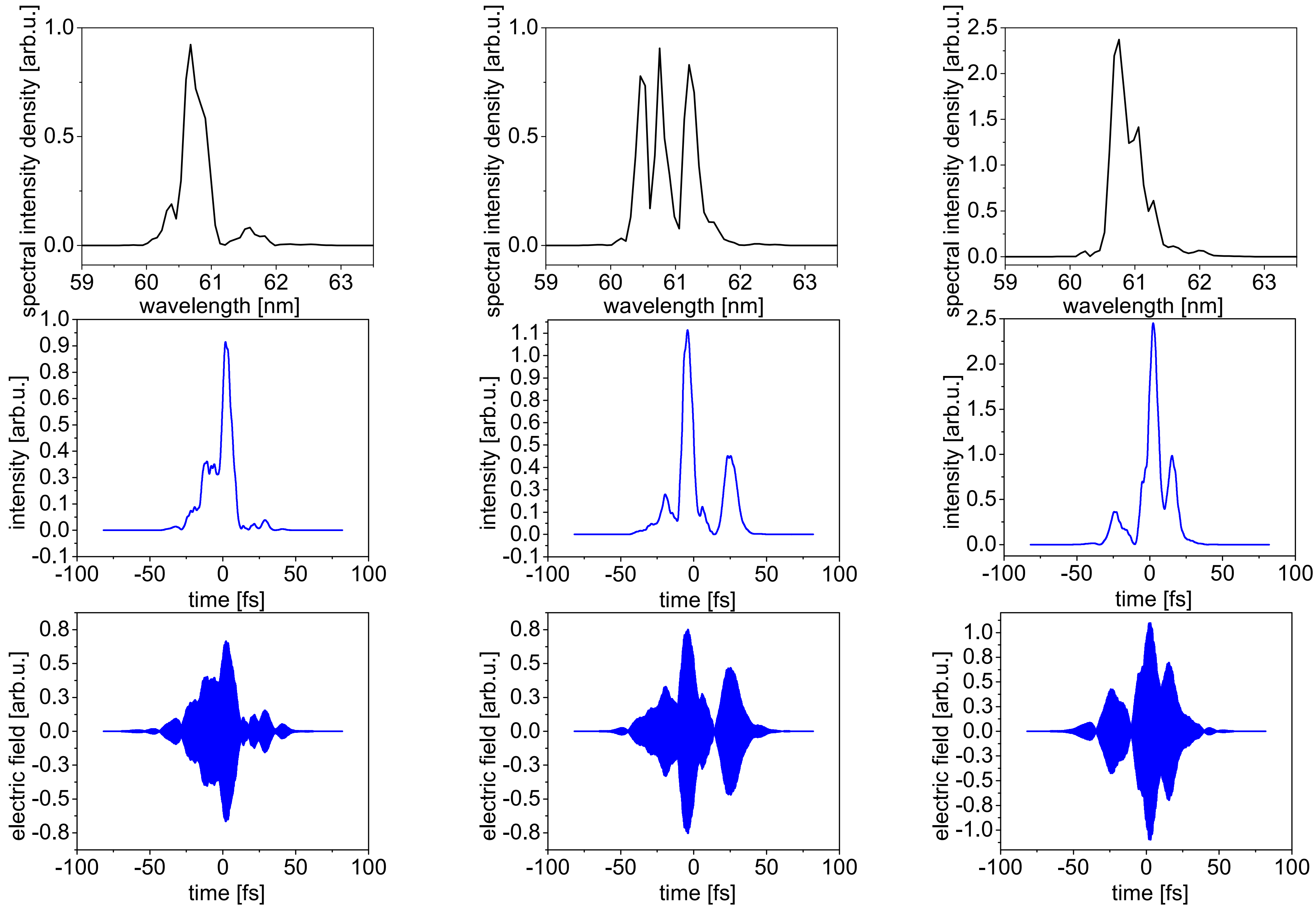
Autocorrelation measurement with He two photon ionization



SCSS:
FEL pulse length ≈ 30 fs
coherence length ≈ 7 fs
Pulse-front tilt ≈ 5 fs

accepted for publication in Optics Express.

SCSS Sample Pulse Shapes



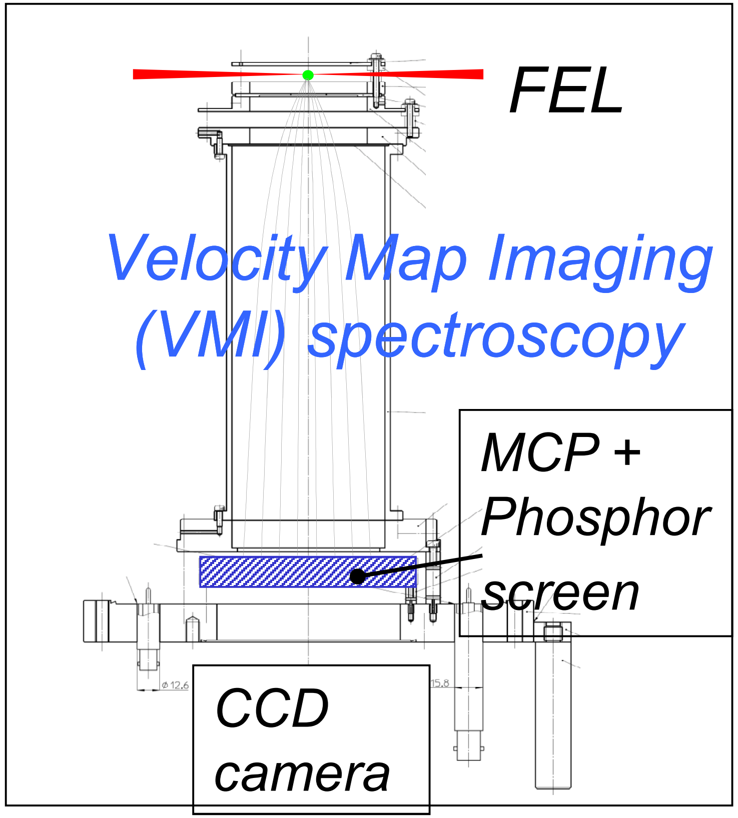
Experimental Evidence for Interference Between the Resonant and Non-resonant Two-Photon Ionization

*R. Ma, **K.L. Ishikawa**, K. Motomura, H. Fukuzawa, A. Yamada, **K. Ueda**, K. Nagaya, S. Yase, Y. Mizoguchi, **M. Yao**, A. Rouzee, A. Hundermark, **M. Vrakking, P. Johnsson**, M. Nagasono, K. Tono, T. Togashi, Y. Senba, H. Ohashi, M. Yabashi, and **T. Ishikawa***

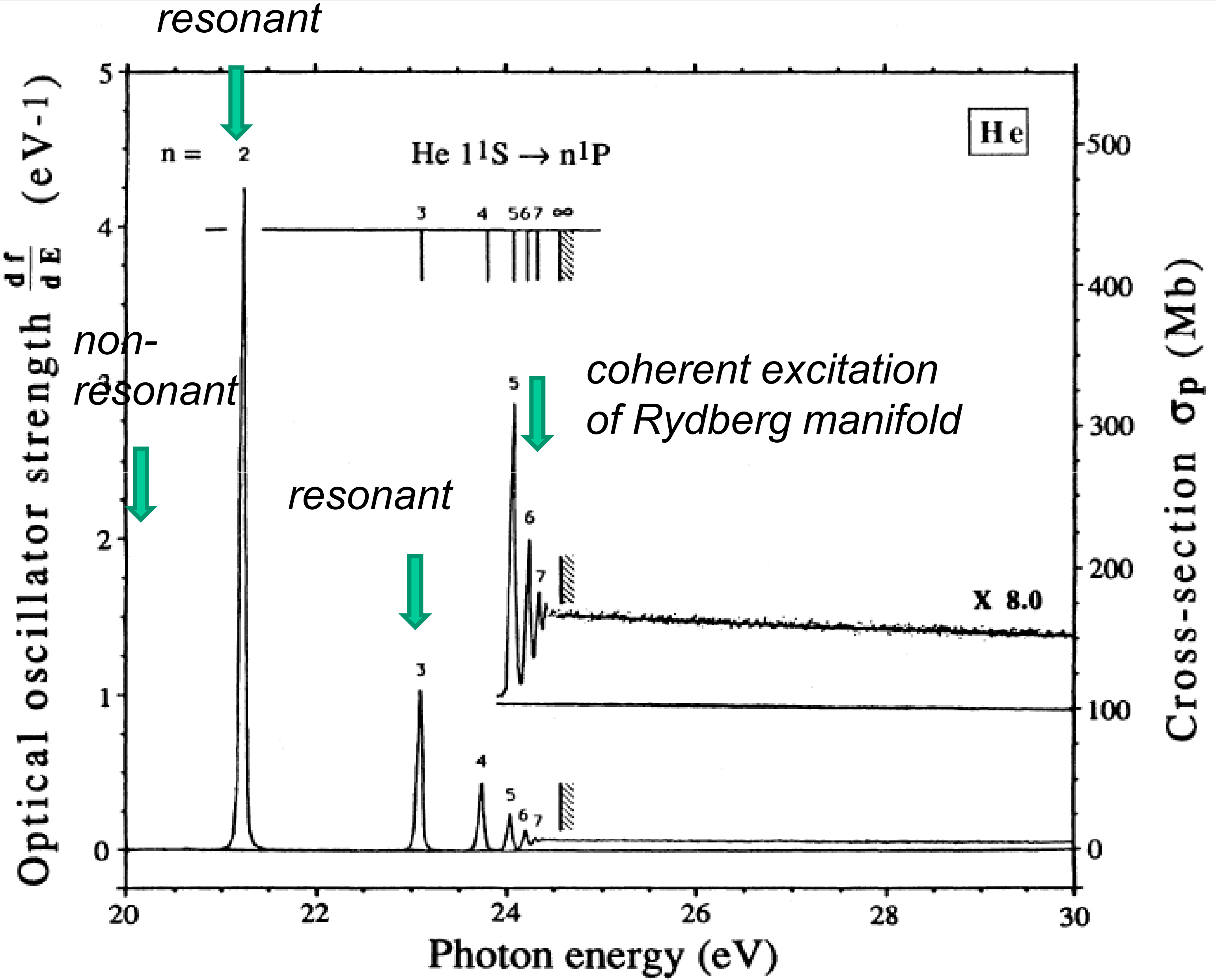
Photoelectron angular distribution for two-photon single ionization of He

Direct numerical simulation of the two-electron time-dependent Schrödinger equation (TDSE)

vs

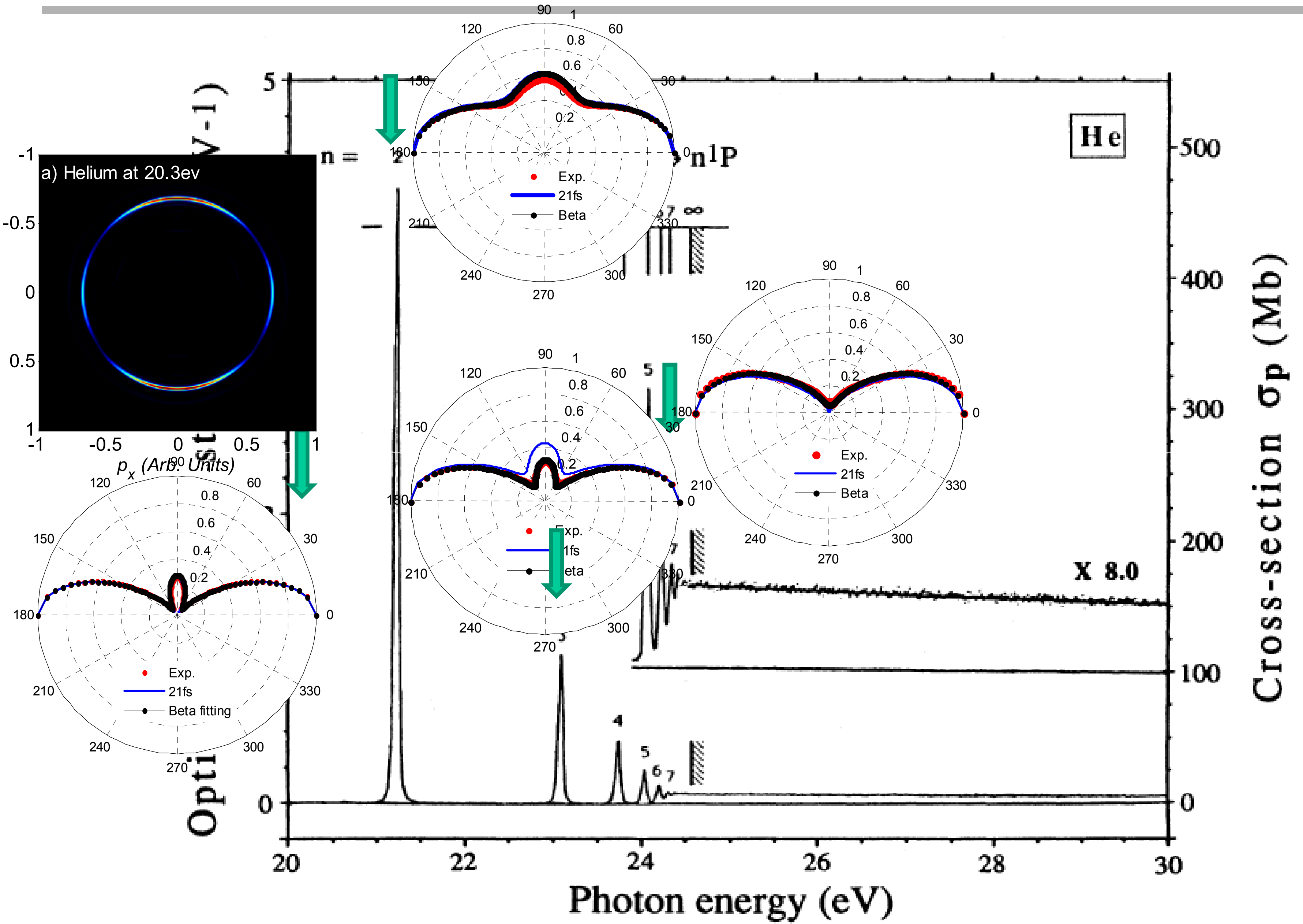


Excitation energies for two-photon ionization of He



W. F. Chan et al., Phys. Rev. A ***44****, 186 (1991)*

Photoelectron angular distribution for two-photon ionization of He



Ma et al. to be submitted.

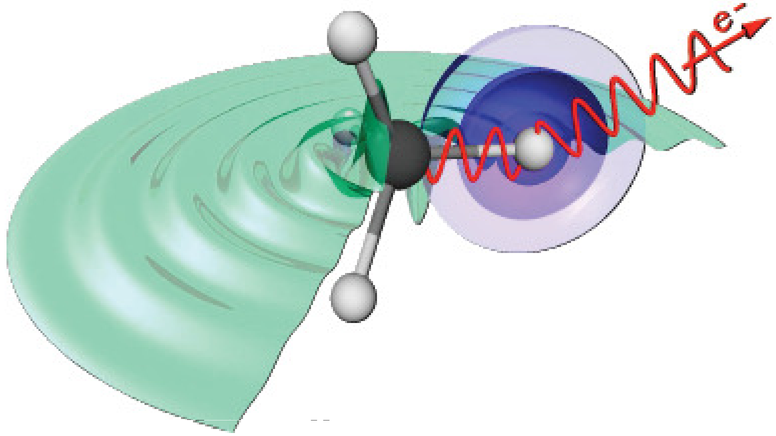
Photoelectron angular distribution (PAD)

$$I(\theta) = \frac{\sigma}{4\pi}\left[1 + \beta_2 P_2(\cos\theta) + \beta_4 P_4(\cos\theta)\right]$$

Anisotropy parameters

$$\beta_2 = \frac{2/7 - X\cos\delta}{X^2/4 + 1/5}$$

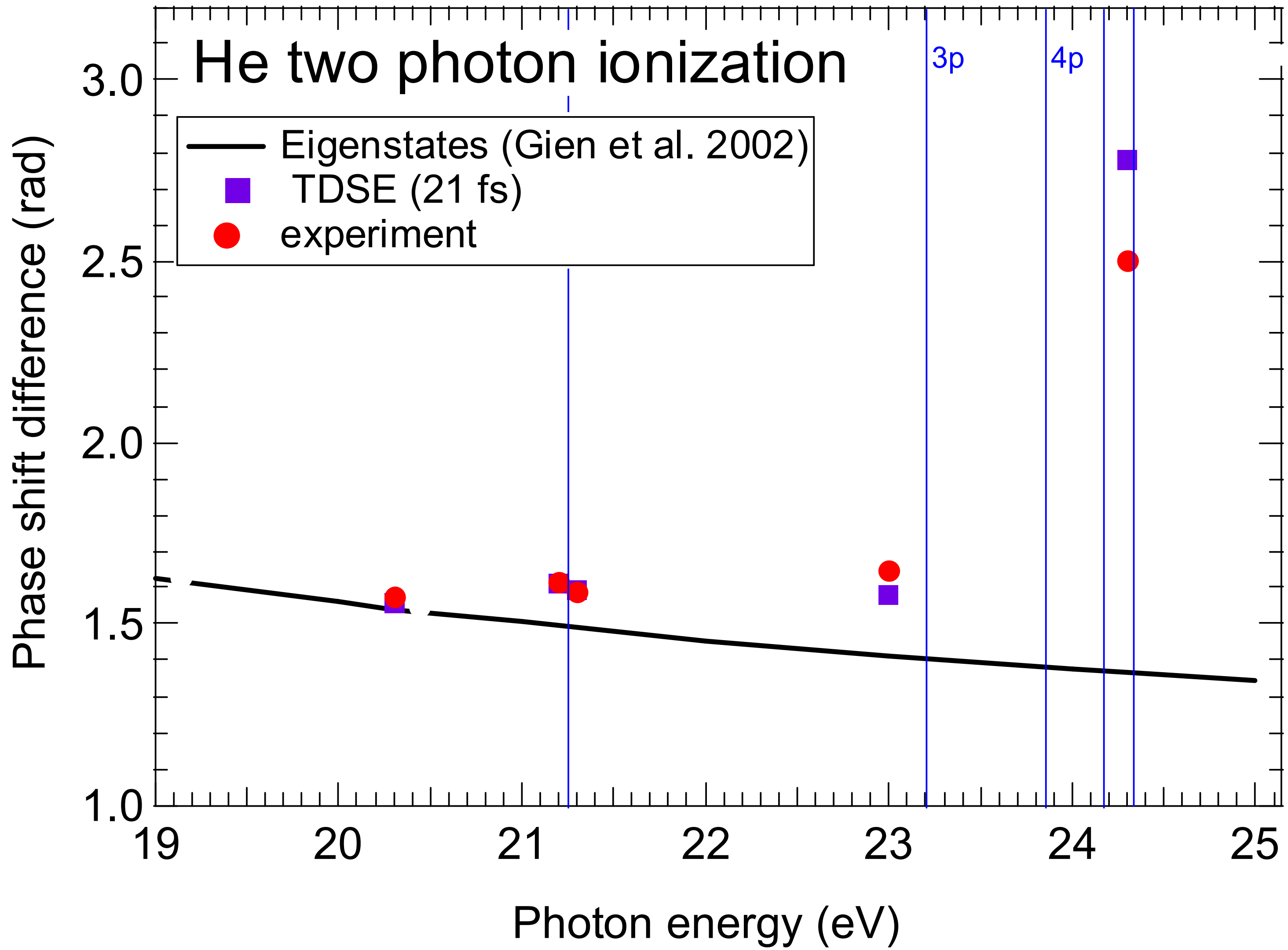
$$X = |c_s/c_d|$$



Cf. L.H. Haber, *et al.*, *Phys. Rev. A* **79**, 031401(R) (2009).

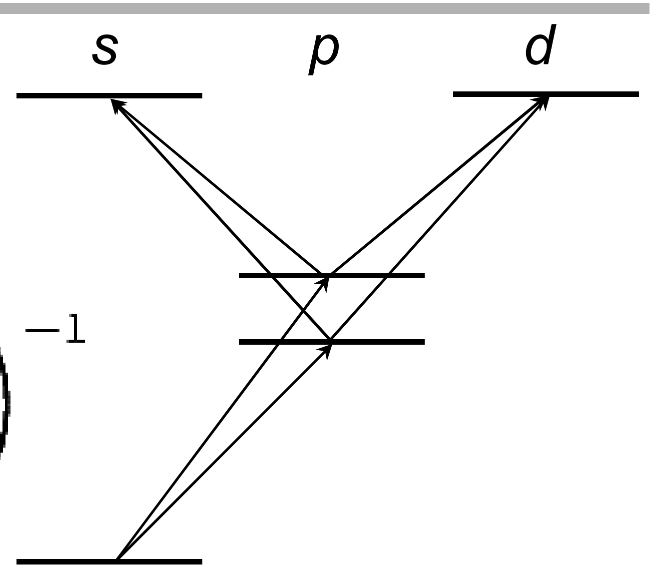
hv	X (exper)	X (TDSE)	δ (exper)	δ (TDSE)
20.3	0.5	0.3	1.6	1.6
21.3	2.0	2.0	1.7	1.7
23.0	0.8	1.2	1.7	1.6
24.3	1.3	0.6	2.5	2.8

Deviation of wavepacket phase difference from eigen phase shift difference



Photoelectron angular distribution (PAD)

$$I(\theta) = \frac{\sigma}{4\pi}\left[1 + \beta_2 P_2(\cos\theta) + \beta_4 P_4(\cos\theta)\right]$$



Anisotropy parameters

$$\beta_2 = \frac{2/7 - X\cos\delta}{X^2/4 + 1/5} \qquad \beta_4 = \frac{72}{35}\left(X^2 + \frac{4}{5}\right)^{-1}$$

Cf. L.H. Haber, et al., Phys. Rev. A ***79****, 031401(R) (2009).*

$$X = |c_s/c_d| \qquad \delta = \delta_{\text{int}} + \operatorname{Arg} c_s/c_d$$

Additional phase shift that depends on the pulse width

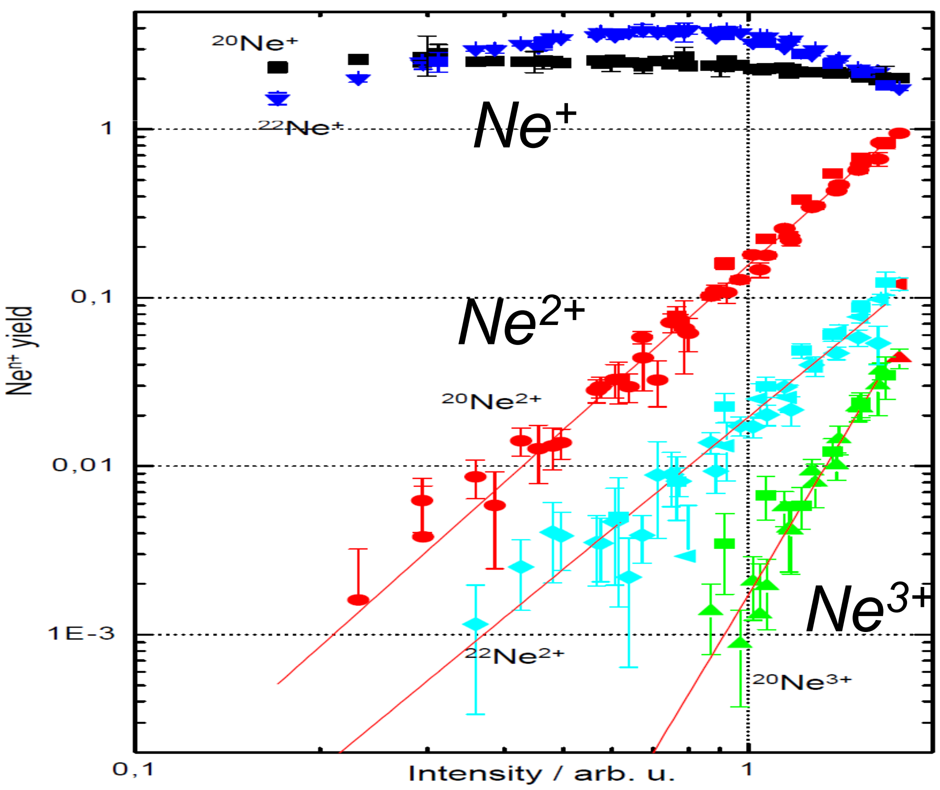
$$c_s = \frac{\pi T^2}{2}\sum_m \mu_{sm}\mu_{mi}e^{-\Delta_m^2 T^2/2}\left[1 - i\,\mathrm{erfi}\left(\frac{\Delta_m T}{\sqrt{2}}\right)\right] \qquad \text{(S wave)}$$

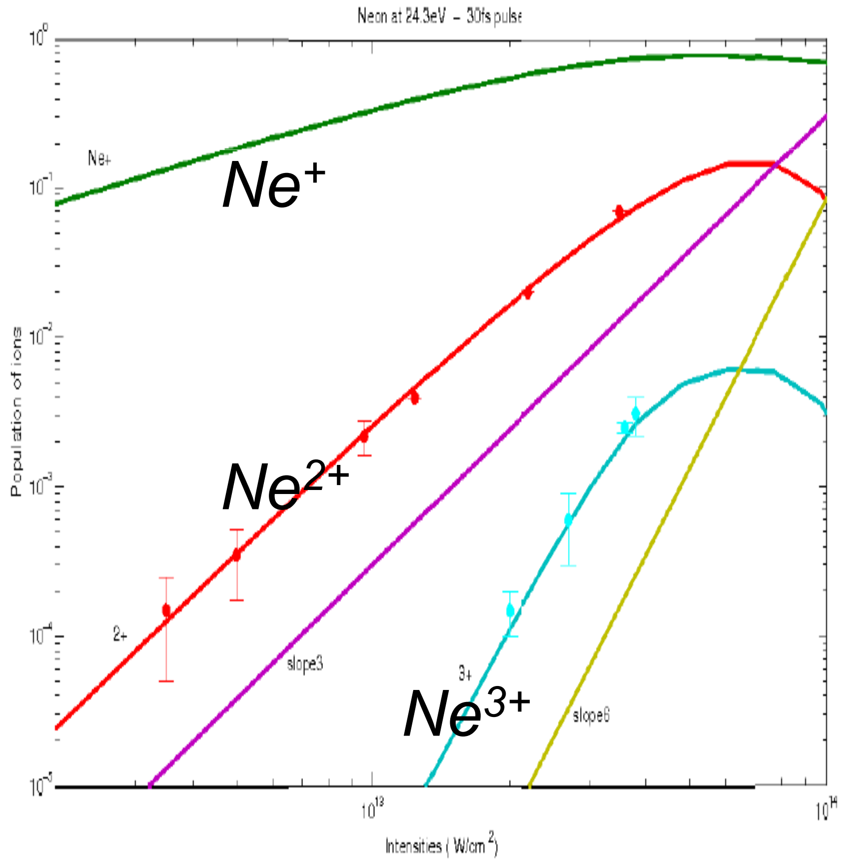
$$c_d = \frac{\pi T^2}{2}\sum_m \mu_{dm}\mu_{mi}e^{-\Delta_m^2 T^2/2}\left[1 - i\,\mathrm{erfi}\left(\frac{\Delta_m T}{\sqrt{2}}\right)\right] \qquad \text{(D wave)}$$

depends on competition between non-resonant and resonant paths, then on pulse width (T)

Multiple ionization of rare gas atoms irradiated by EUV free-electron laser pulses at 51 nm

*M. .Kurka, K. Motomura, K. Papamihail, A. Rudenko, H. Fukuzawa, L. Foucar, H. Iwayama, K. Nagaya, X.-J. Liu, H.-U. Kühnel, G. Prümper, **P. Labropoulos**, **J. Ullrich, K. Ueda,** N. Saito, H. Murakami, **M. Yao**, A. Belkacem, R. Feifel, M. Nagasono, A. Higashiya, T. Togashi, H. Ohashi, and H. Kimura, M. Yabashi, and **T. Ishikawa***





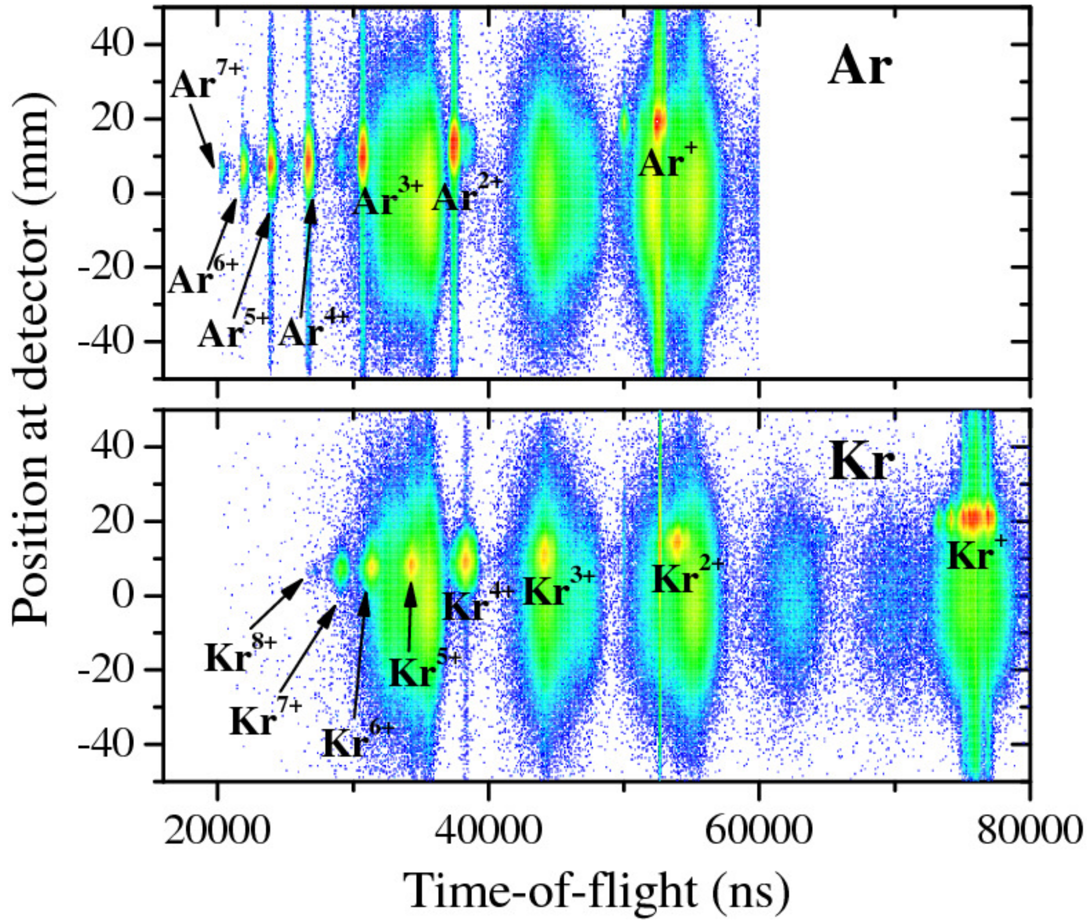
Multiple ionization of rare gas atoms irradiated by EUV free-electron laser pulses at 51 nm

M. .Kurka, K. Motomura, K. Papamihail,A. Rudenko, H. Fukuzawa, L. Foucar, H. Iwayama, K. Nagaya, X.-J. Liu, H.-U. Kühnel, G. Prümper, ***P. Labropoulos, J. Ullrich, K. Ueda,*** *N. Saito, H. Murakami,* ***M. Yao****, A. Belkacem, R. Feifel, M. Nagasono, A. Higashiya, T. Togashi, H. Ohashi, and H. Kimura, M. Yabashi, and* ***T. Ishikawa***

Ar^{7+} > 434 eV
> 18 photons

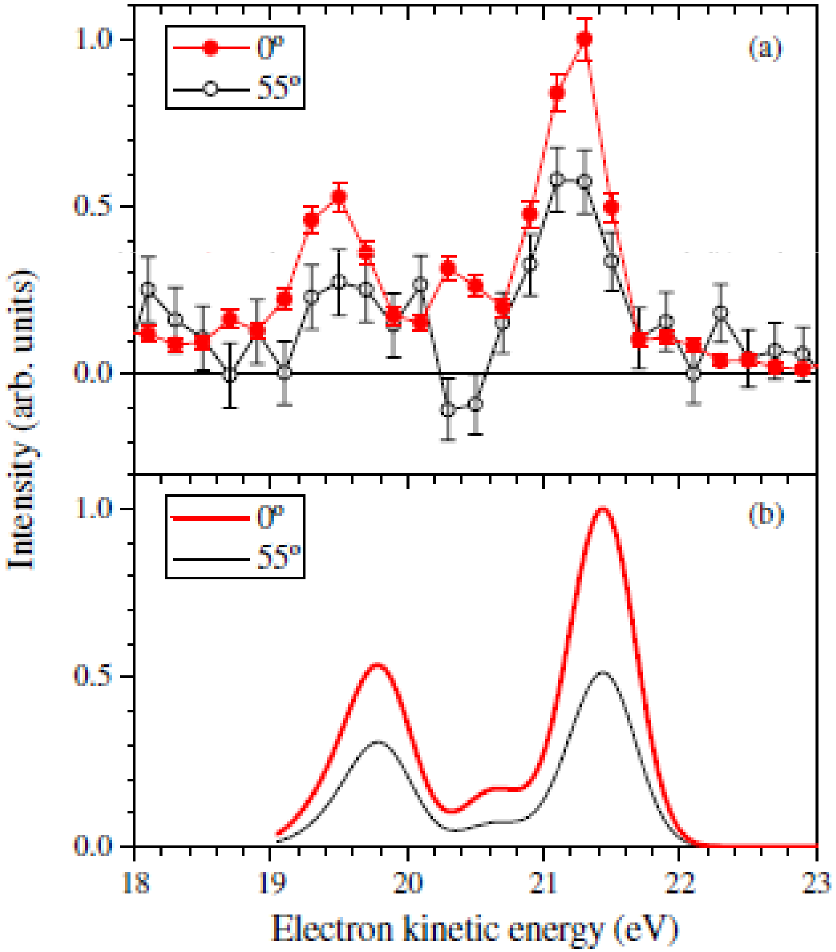
Kr^{8+} > 508 eV
> 21 photons

Mirror:
Mg/Si multilayer
f=250 mm,
made by LBNL



Photoelectron spectroscopy of sequential three-photon double ionization of Ar irradiated by EUV free-electron laser pulses

*H Fukuzawa, E V Gryzlova, K Motomura, A Yamada, **K Ueda**, **A N Grum-Grzhimailo**, S I Strakhova, K Nagaya, A Sugishima, Y Mizoguchi, H Iwayama, **M Yao**, N Saito, P Piseri, T Mazza, M Devetta, M Coreno, M Nagasono, K Tono, M Yabashi, **T Ishikawa**, H Ohashi, H Kimura, T Togashi, and Y Senba*



Ar^{2+} production by resonant two-photon ionization of Ar^{+}

$Ar^{+}(3p^4(^3P)6s\ ^2P_{3/2,1/2}) + h\nu \rightarrow$
$Ar^{2+}(3p^4\ ^3P_{2,1,0}) + e^- \ (21.2\ eV)$

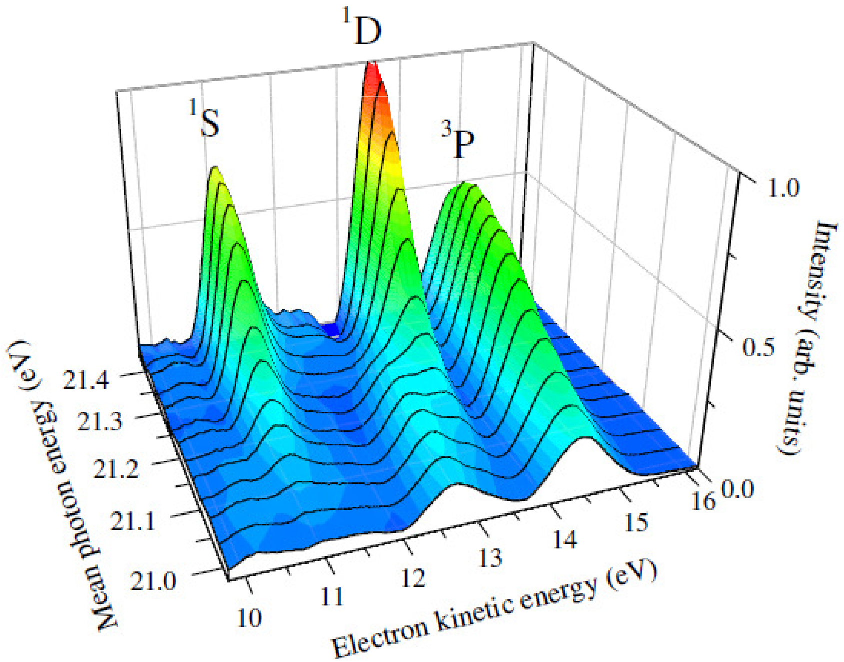
$Ar^{+}(3p^4(^1D)4d\ ^2P_{3/2,1/2}) + h\nu \rightarrow$
$Ar^{2+}(3p^4\ ^1D_2) + e^- \ (19.5\ eV)$

$$I(\theta) \sim 1 + \beta_2 P_2(\cos\theta) + \beta_4 P_4(\cos\theta) + \beta_6 P_6(\cos\theta)$$

*JPB **42**, 111001 (2009).*

Multiphoton double ionization of Ar in intense extreme ultraviolet laser fields studied by shot-by-shot photoelectron spectroscopy

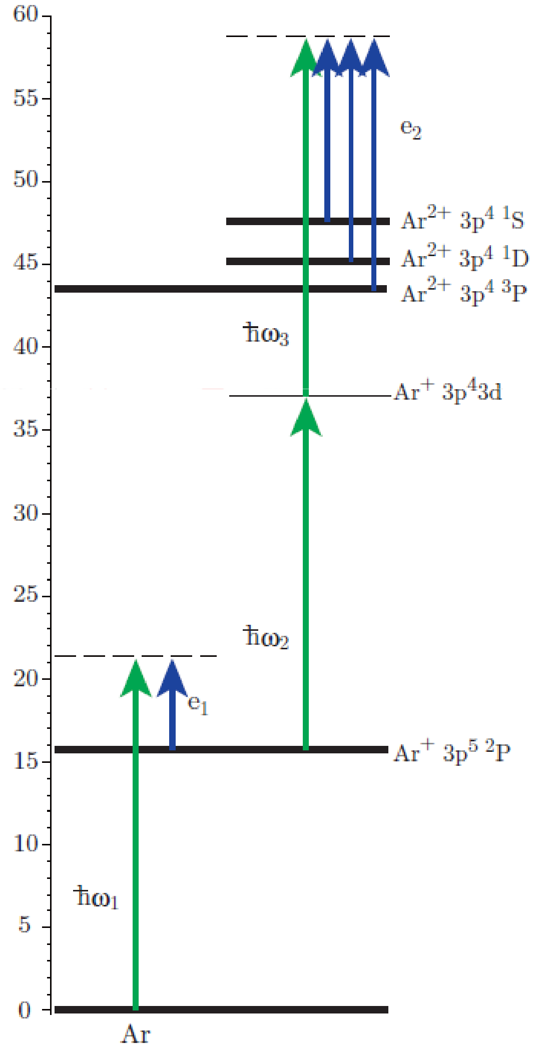
Y. Hikosaka, *M. Fushitani, A. Matsuda, C.-M. Tseng,* ***A. Hishikawa****, E. Shigemasa, M. Nagasono, K. Tono, T. Togashi, H. Ohashi, H. Kimura, Y. Senba, M. Yabashi, T. Ishikawa*



Phys. Rev. Lett. ***105****, 133001 (2010)*

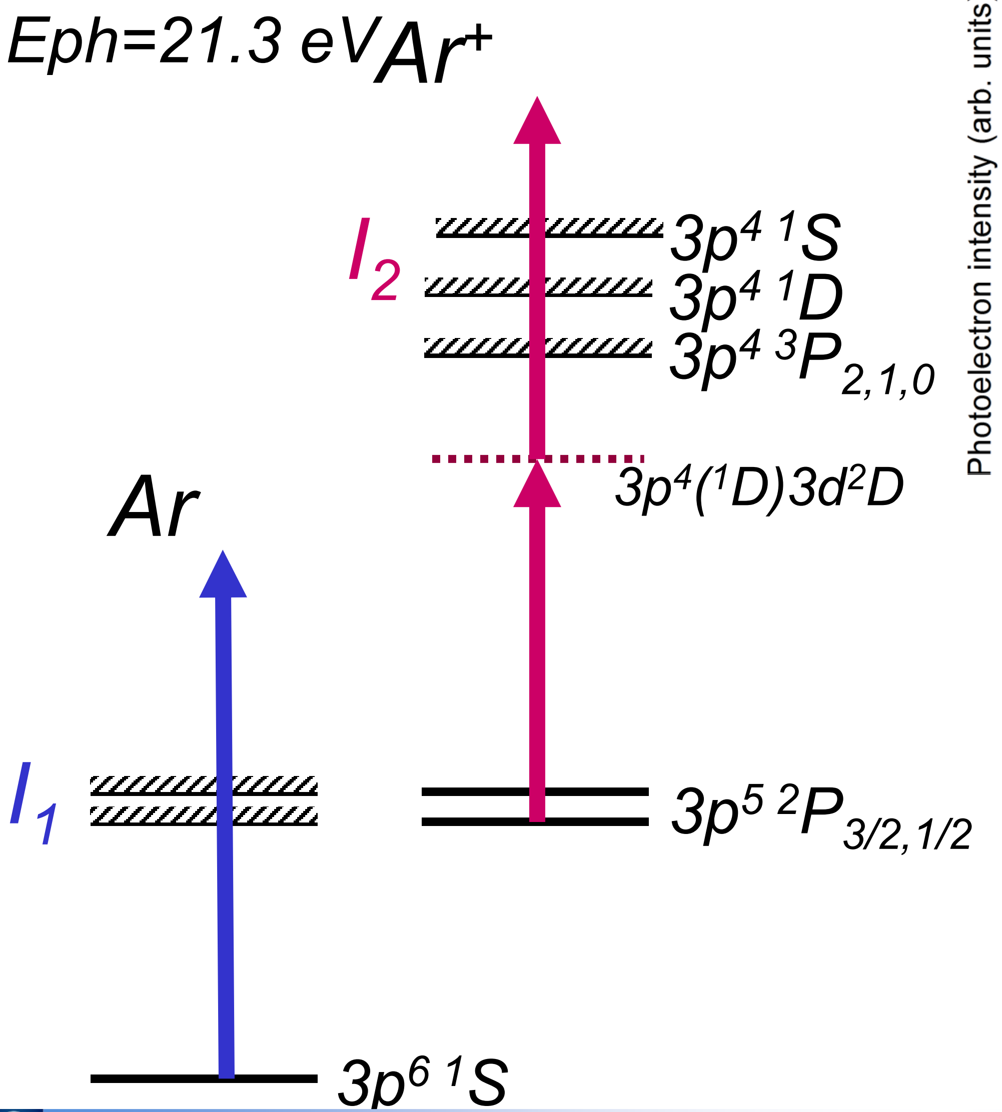
Three-photon double ionization of Ar studied by photoelectron spectroscopy using an extreme ultraviolet free-electron laser: manifestation of resonance states of an intermediate Ar^+ ion

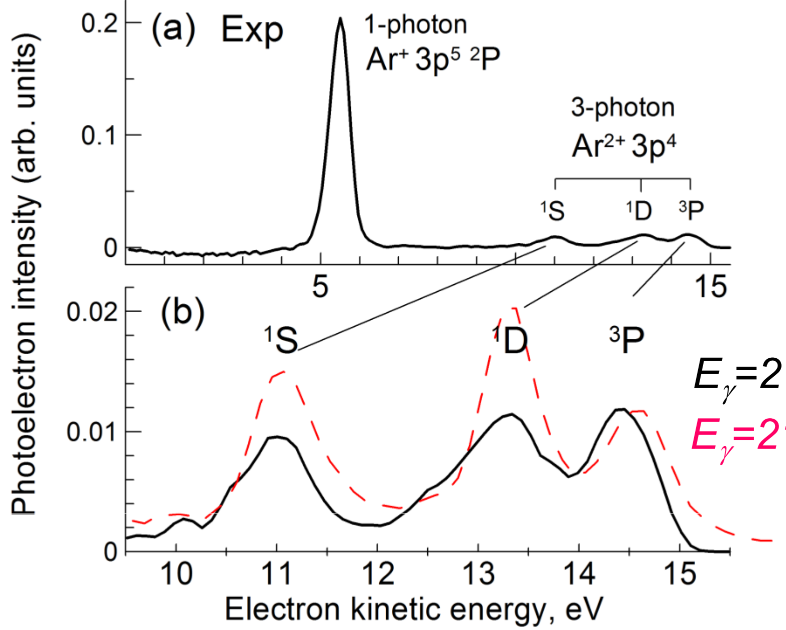
N Miyauchi, J Adachi, ***A Yagishita****, T Sako, F Koike, T Sato, A Iwasaki, T Okino,* ***K Yamanouchi****, K Midorikawa, K Yamakawa, F Kannari, H Nakano, M Nagasono, K Tono, M Yabashi, T Ishikawa, T Togashi, H Ohashi, H Kimura, Y Senba*



J. Phys. B: At. Mol. Opt. Phys. ***44*** *071001 (2011)*

Mechanism of two-photon ionization

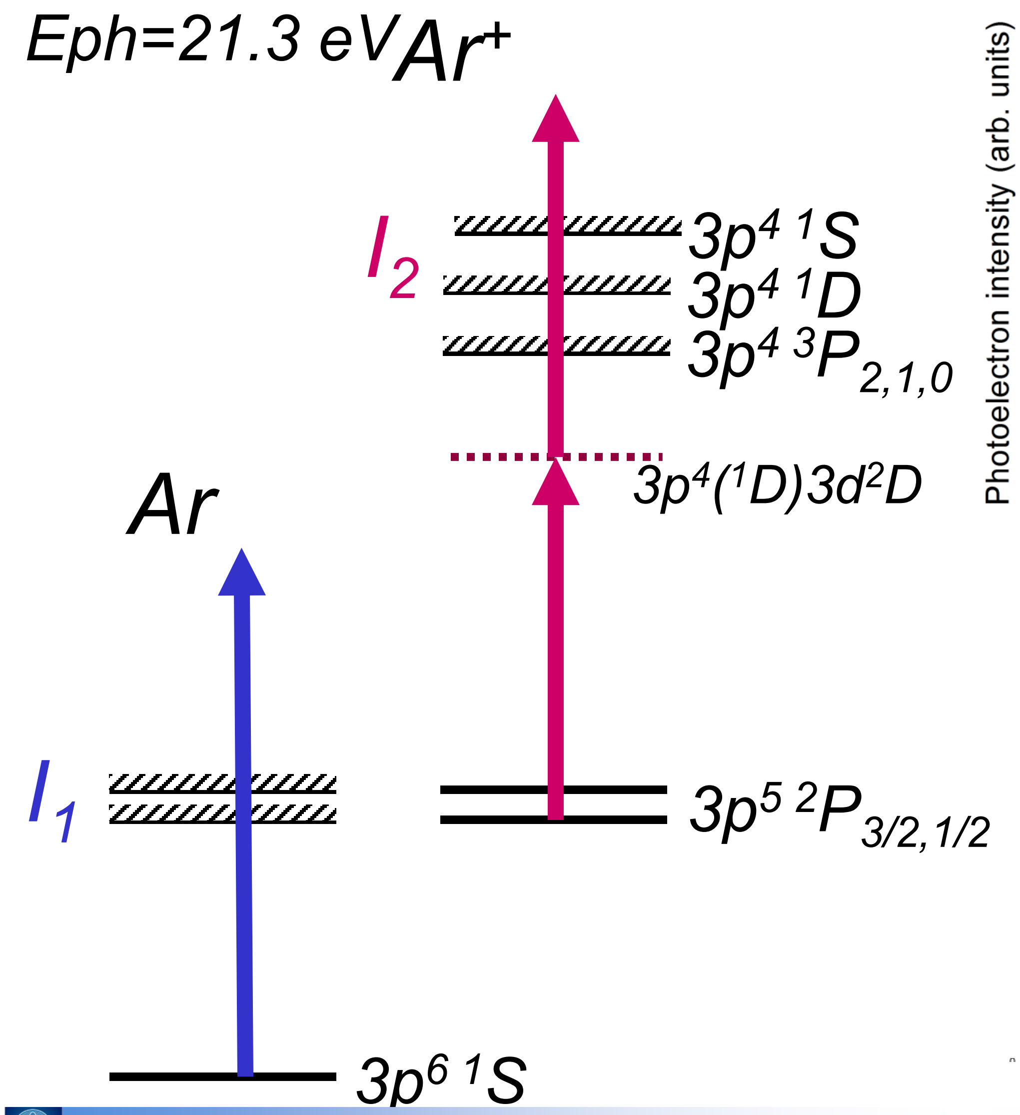


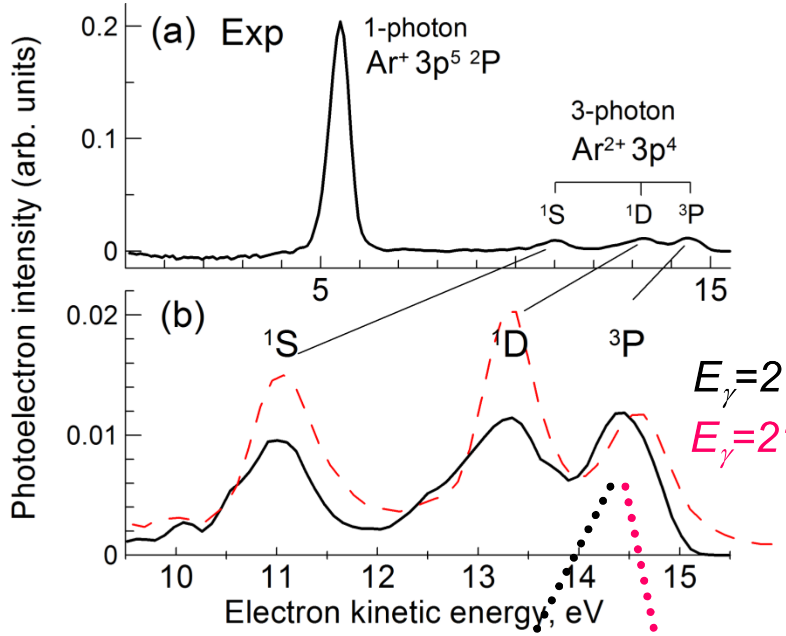


! Strong ionization to ^1S ion

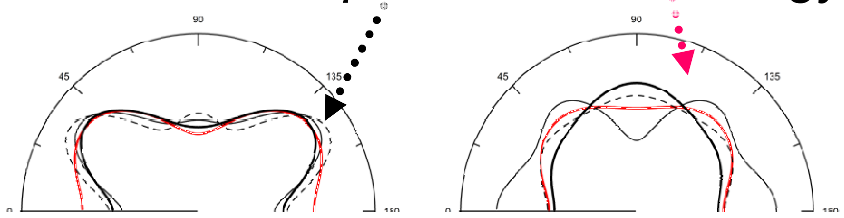
! Increasing relative strength of ^1S and ^1D with increasing of the photon energy

Mechanism of two-photon ionization

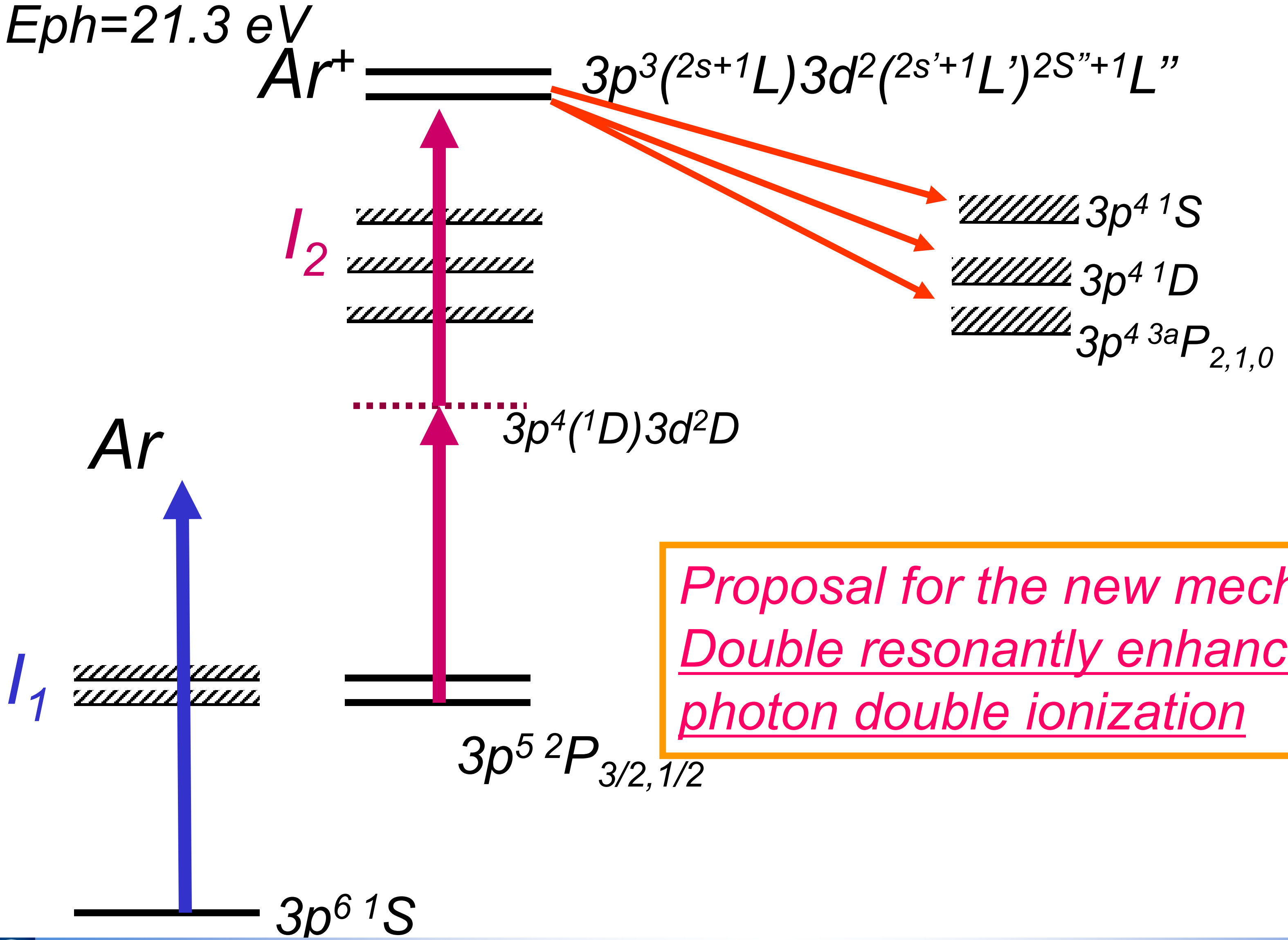




! *Sharp modulation of the angular distributions of photoelectrons as functions of photoelectron energy*



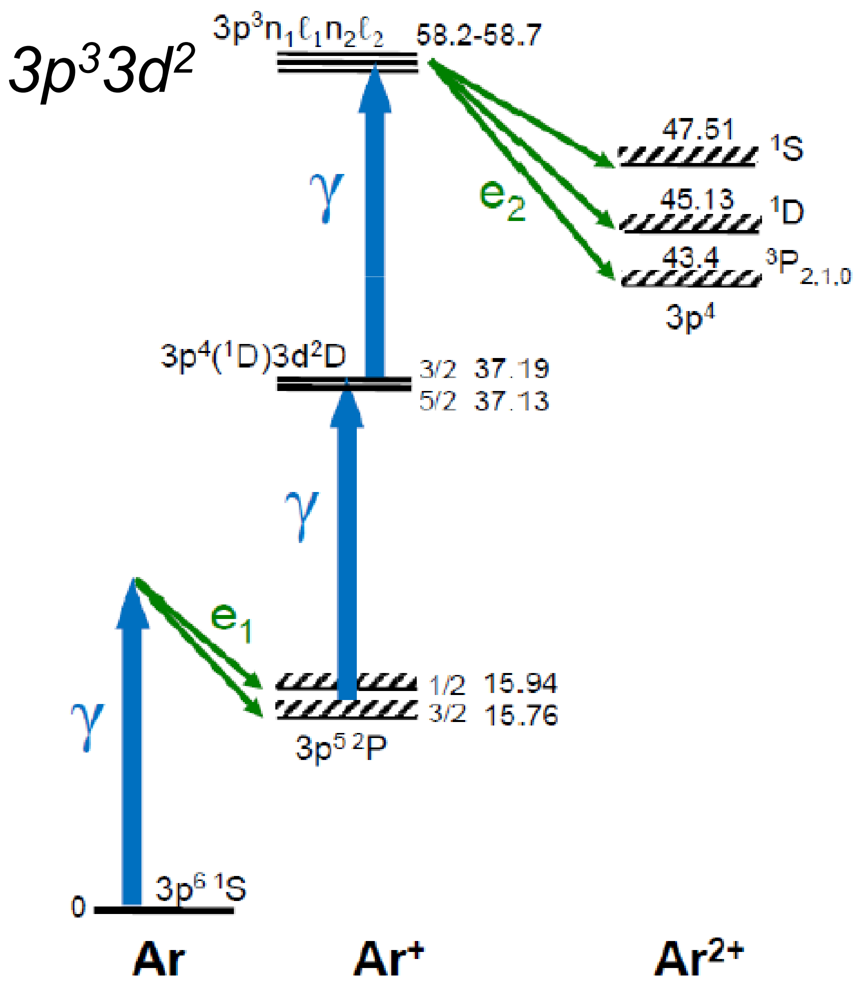
Proposed new mechanism

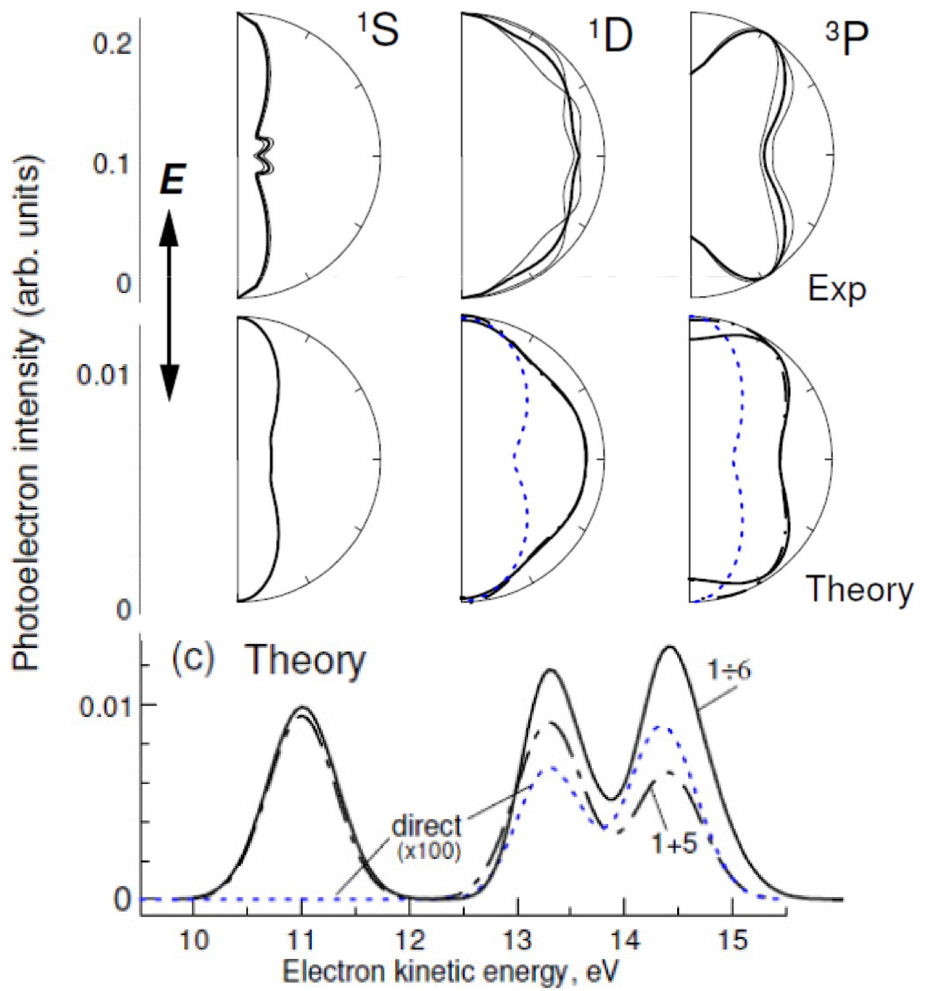


Proposal for the new mechanism:
<u>Double resonantly enhanced three-photon double ionization</u>

Double-resonant three-photon double ionization of Ar atoms induced by EUV free electron laser

E.V. Gryzlova, Ri Ma, H. Fukuzawa, K. Motomura, A. Yamada, K. Ueda, A.N. Grum-Grzhimailo, N.M. Kabachnik, S.I. Strakhova, A. Rouzee, A. Hundermark, M.J.J. Vrakking, P. Johnsson, K. Nagaya, S. Yase, Y. Mizoguchi, M. Yao, M. Nagasono, K. Tono, T. Togashi, Y. Senba, H. Ohashi, M. Yabashi, and T. Ishikawa





Sendai City

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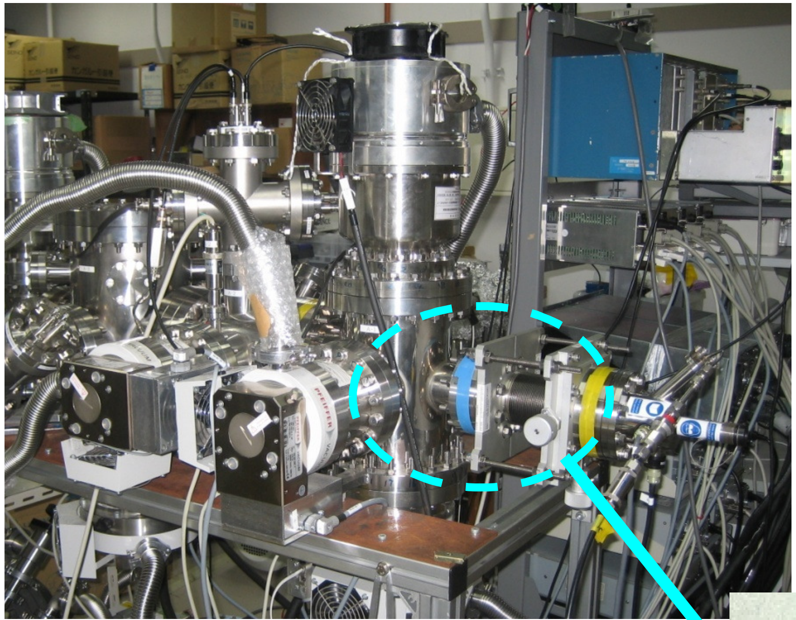
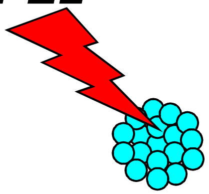
Cold pulsed cluster source



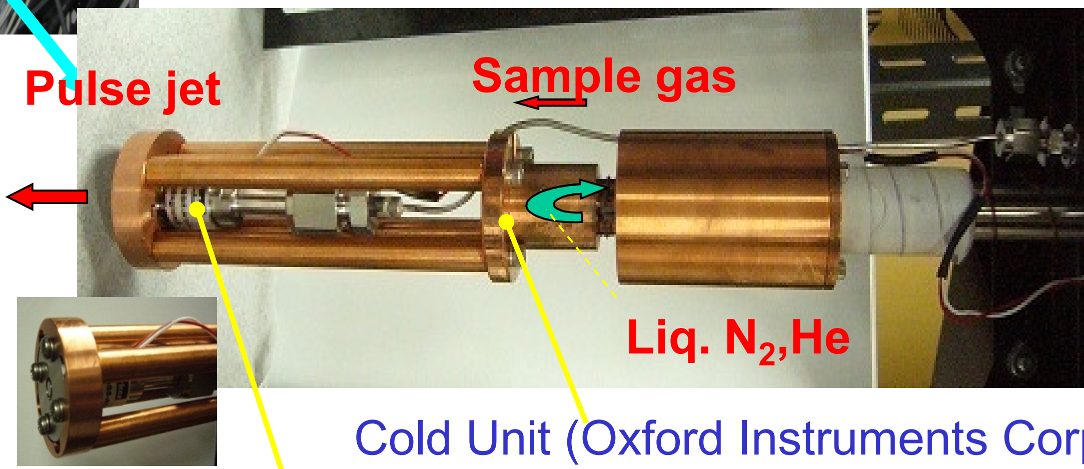
Pulse valve is equipped with liquid He cooling unit. Temperature of cluster source is controlled in the range of 10-300K.

Pulsed cluster beam is coincided with FEL pulses.

*K. Nagaya, H. Iwayama, H. Murakami, **M. Yao**, H. Fukuzawa, K. Motomura, **K. Ueda** et al, J. Electr. Spectrosc. Relat. Phenom. 181, 125-128 (2010).*



Size-controlled cluster beam are exposed to FEL pulses



Cold Unit (Oxford Instruments Corp.)

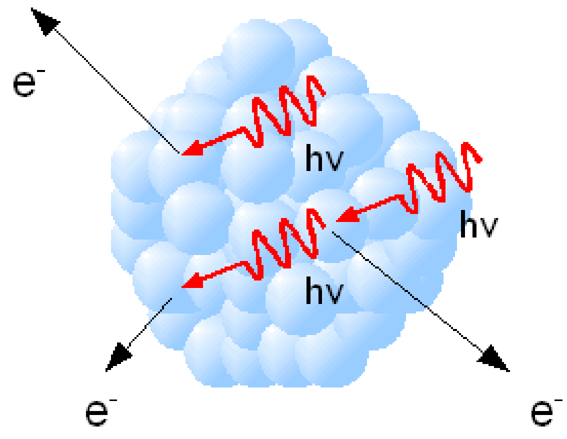
・cooled by liq.N_2 or liq.He.

Pulse Valve Series99 (Parker Instrumentation Corp.)

・fast electro-magnetic valve（min. pulse width : 0.2ms）

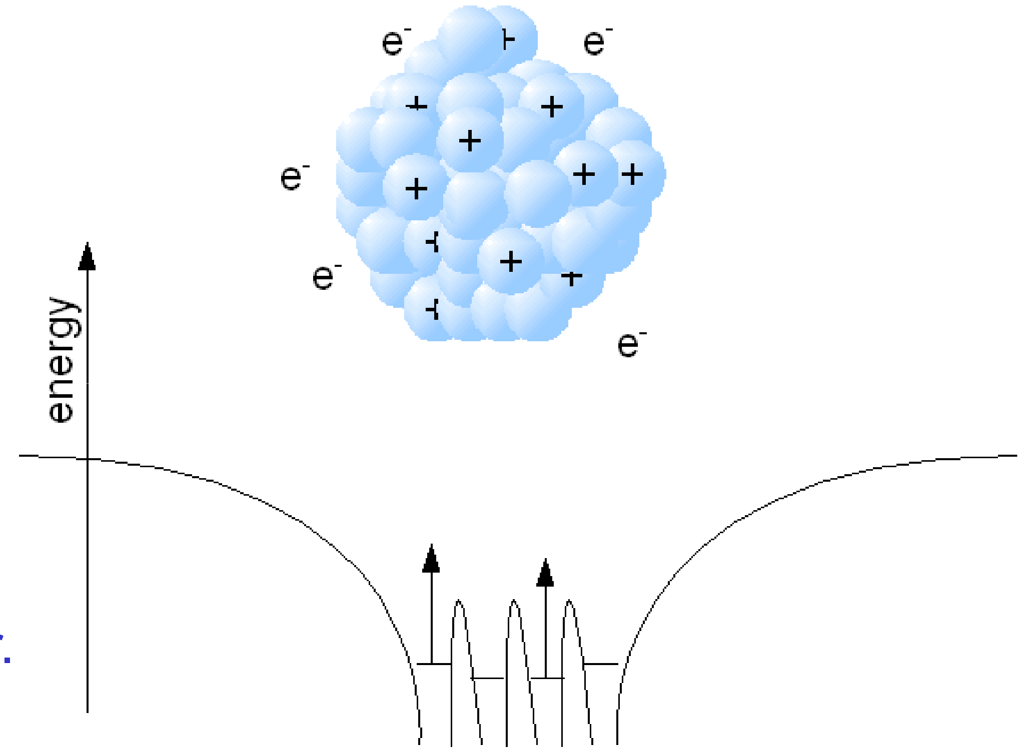
Frustration of the cluster ionization

Ionization energy of atomic Xe (12.13 eV) < 20 eV



Each individual atom will be ionized

Coulomb attractive potential increases with the increase in the charge of the parent cluster.



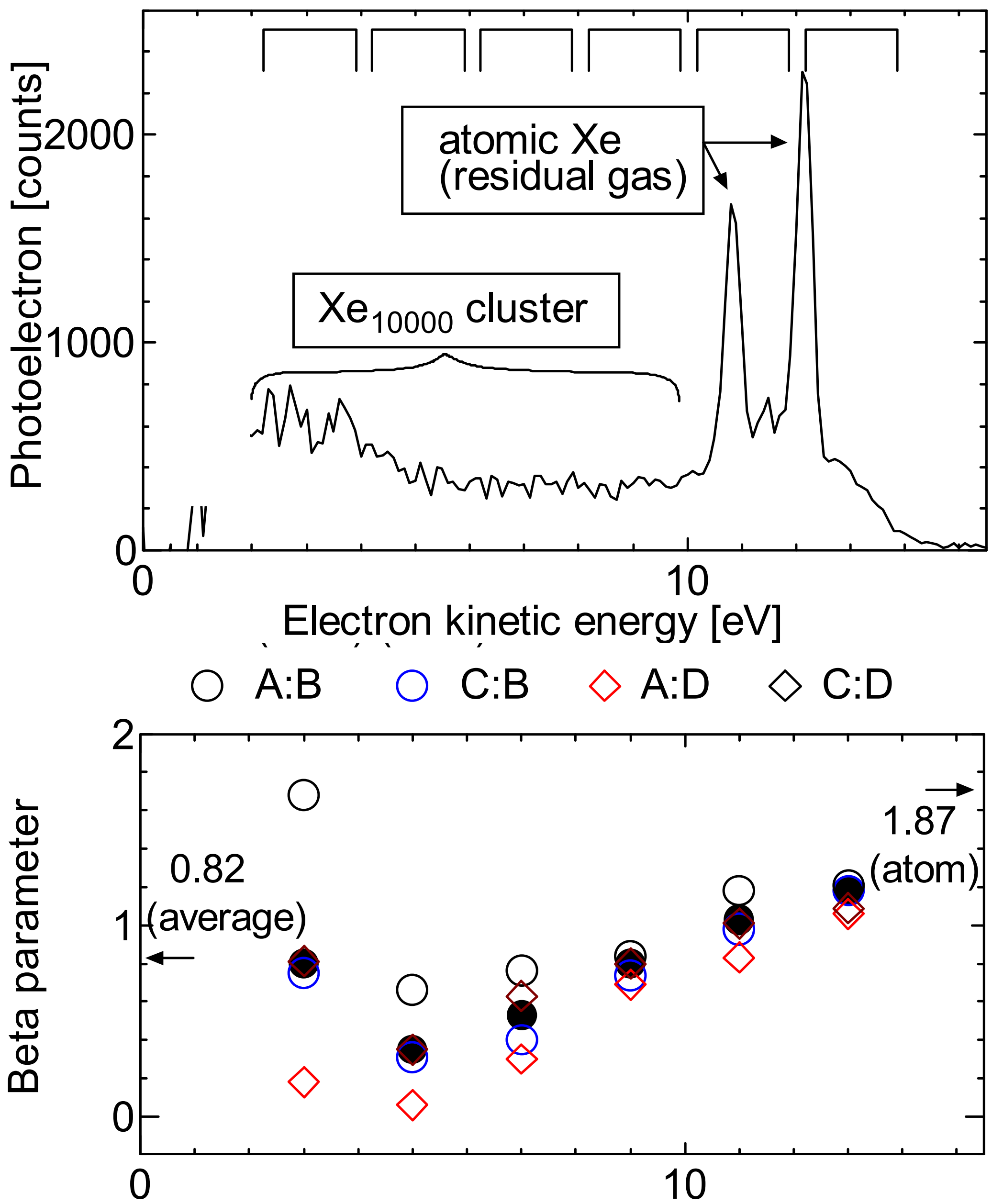
The photoelectron cannot be escaped from the cluster.
Inner ionization occurs but outer ionization is prohibited.

Frustration of the cluster ionization

cf: Bostedt et al., PRL 100, 133401 (2008).

*Fukuzawa et al., PR A 79, 031201 (R) (2009); Iwayama et al., JPB **42**, 134019 (2009).*

Electron emission from the Xe_{10000} cluster



Continuous electron emission is observed as evidence of frustration of cluster ionization!

cf: Bostedt et al., PRL 100, 133401 (2008).

Detection efficiencies of electron detectors are calibrated using data of atomic xenon.

We evaluated the energy dependence of beta parameter.

Beta values decrease with decrease in kinetic energy!

__K Nagaya__, A Sugishima, Y Mizoguchi, H Iwayama, __M Yao__, H Fukuzawa, K Motomura, A Yamada, __K Ueda__, N Saito, P Piseri, T Mazza, M Devetta, M Coreno, M Nagasono, K Tono, M Yabashi, __T Ishikawa__, H Ohashi, H Kimura,T Togashi, and Y Senba

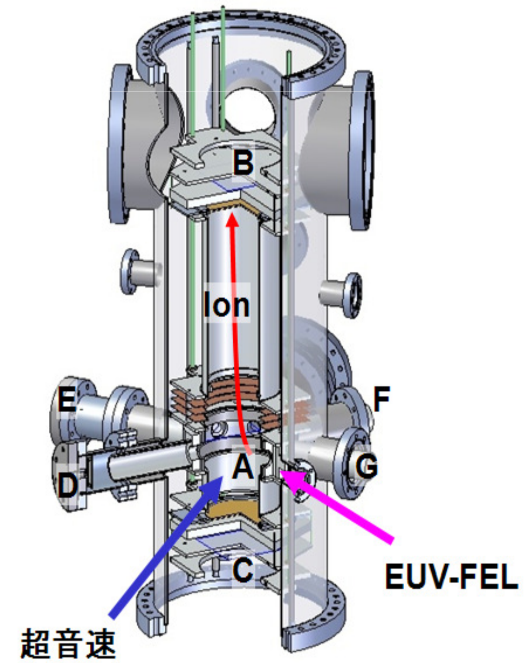
To be submitted.

Electronic decay following multiple excitation in neon clusters exposed to an intense extreme ultraviolet free electron laser

K. Nagaya, *A. Sugishima, H. Iwayama, H. Murakami,* ***M. Yao****, H. Fukuzawa, X.-J. Liu, K. Motomura,* ***K. Ueda****, N. Saito, L. Foucar, A. Rudenko, M. Kurka, K.-U. Kuhnel,* ***J. Ullrich****, A. Czasch, R. Dorner, R. Feifel, M. Nagasono, A. Higashiya, M. Yabashi,* ***T. Ishikawa****, T. Togashi, H. Kimura, and H. Ohashi*

(To be submitted)

Analyzer



Cluster beam

Target: Ne clusters (<N>=1000)

We have measured FEL power depenc ...on yields

Detection of ions

3D momentum imaging:

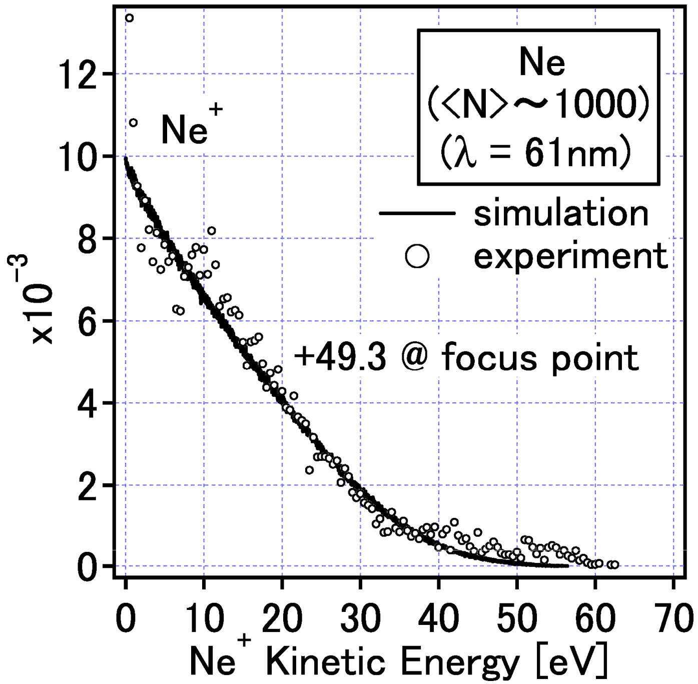
Time-of-Flight T , 2D detection position (X,Y)

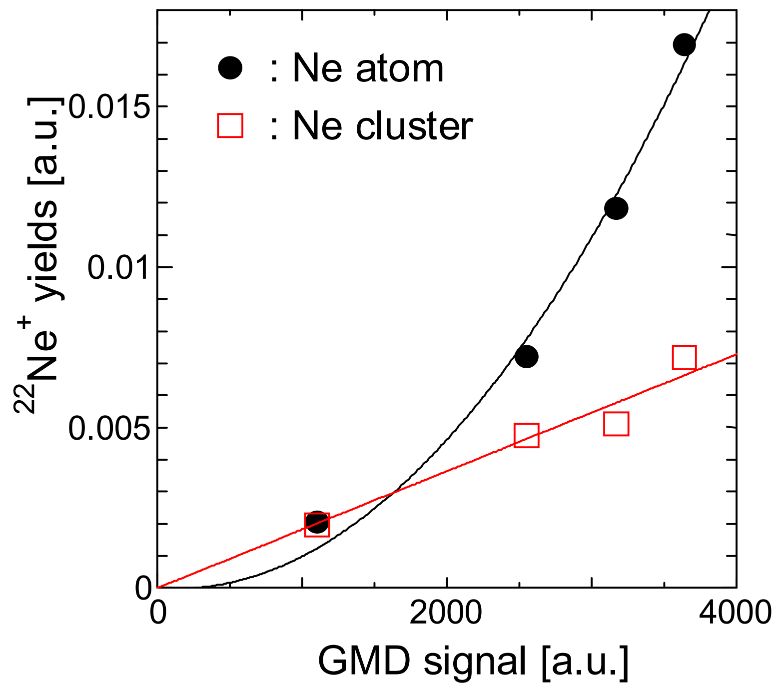
$$T \propto \sqrt{m/q},\quad p_X = m\frac{X}{T},\quad p_Y = m\frac{Y}{T},\quad p_z = -qE\Delta T$$

"Dead time free" detection with wide acceptance angle

Linear FEL power dependence of energetic Ne^+ yields

62 nm (Ne 2p->3d excitation)





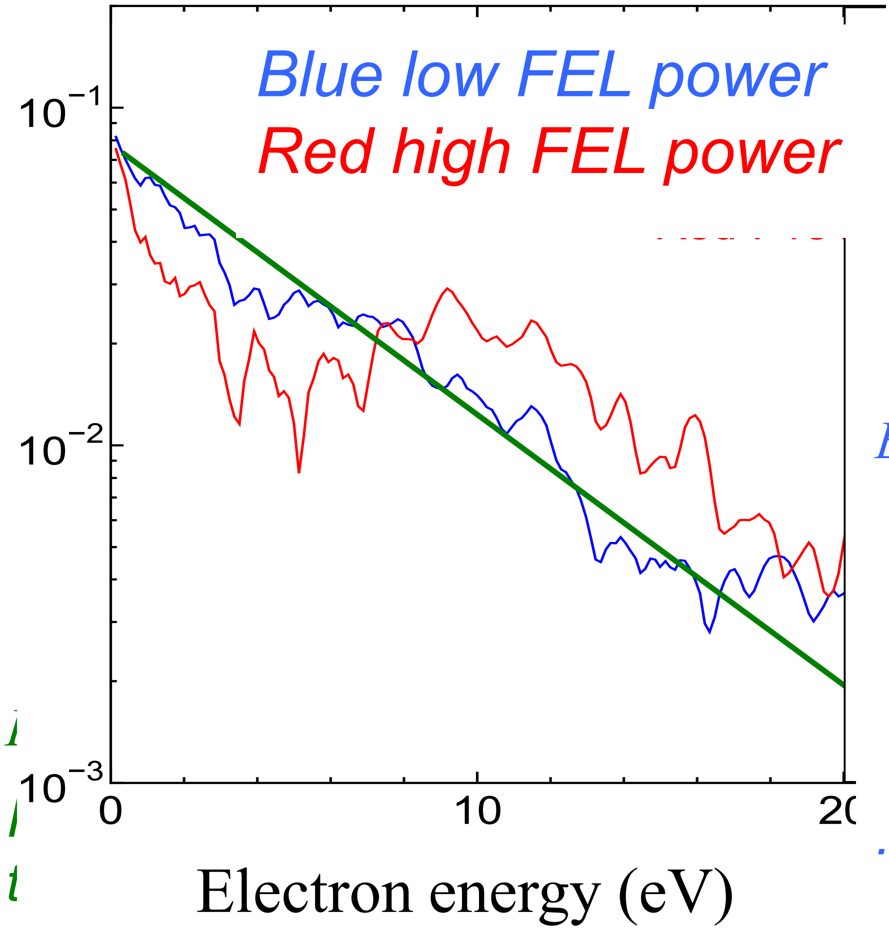
We analyzed kinetic energy distributions of energetic atomic ions using spherical uniform cluster analytical model (Islam et al PRA 73, 041201(R) 2006).

We found ~ 100 photons are absorbed and ~ 50 electrons are emitted.

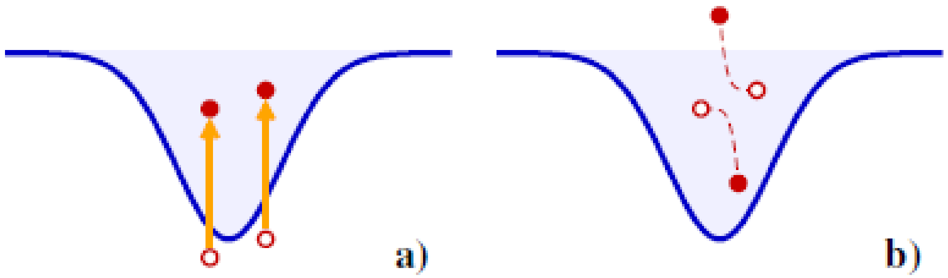
We found linear FEL-power dependence of energetic Ne^+ yields ejected from clusters (<N>=1000), in sharp contract with quadratic FEL-power dependence of Ne^+ yields from the atomic beam.

WHY? *Electronic decay !*

Electronic decay of multiply excited Ne clusters (<N>=1000)



Energy exchange through e-e collisions



Bostedt et al. NJP ***12****, 083004 (2010).*

Plasma picture: collisions between free electrons

At low FEL power: excitation of the individual atoms produces nanoplasma and collisional ionization follows.

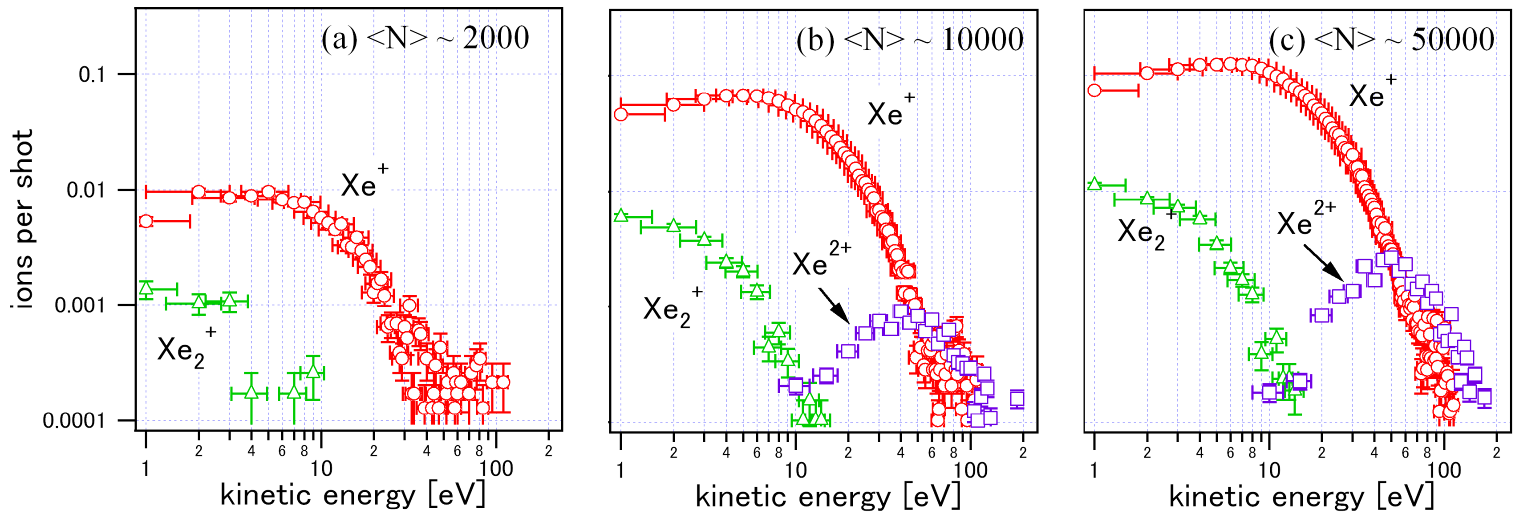
Inhomogeneous charge redistribution in Xe clusters exposed to an intense extreme ultraviolet free electron laser

H. Iwayama, A. Sugishima, K. Nagaya, M. Yao, H. Fukuzawa, K. Motomura, X.-J. Liu, A. Yamada, C. Wang, K. Ueda, N. Saito, M. Nagasono, K. Tono, M. Yabashi, T. Ishikawa, H. Ohashi, H. Kimura, and T. Togashi

J. Phys. B: At. Mol. Opt. Phys. **43**, 161001 (2010).

Target: Xe clusters (<N>=2000, 10000, 50000)

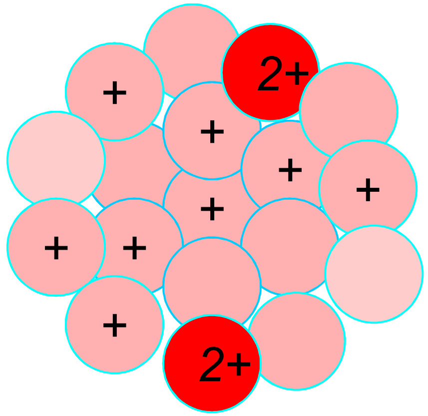
We have measured kinetic energy distribution of the daughter ions ejected after irradiation of the FEL pulse at 52nm.



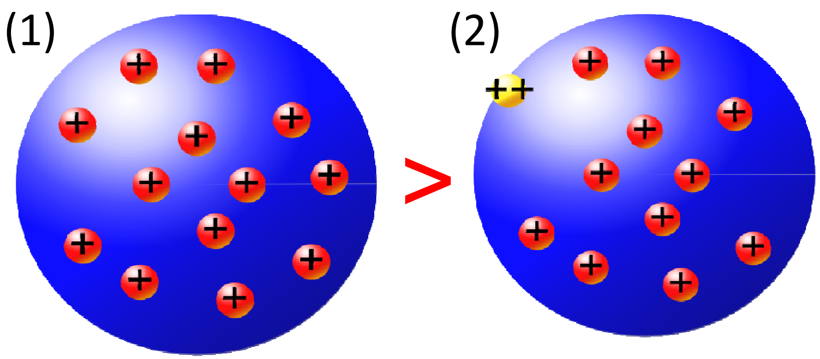
Kinetic Energy Distribution of Xe^{2+} has a hollow distribution.

Kinetic Energy Distribution (KER) of the daughter ions

Xe_2^+ : KER ~ 1 eV (center of the cluster),
Xe^+ : KER~ 10 eV
Xe^{2+} : KER ~ 50 eV (surface of the cluster)



The FEL power is sufficiently high to ionize the Xe atom up to +4, but for the clusters, just doubly charged ions emerge, only from giant clusters.



Doubly charged ions emerge, only when the energy (2) is lower than the energy (1), i.e, only from giant clusters.

charge redistribution?

Iwayama *et al., JPB **43**, 161001 (2010).*

Charge and Energy Transfers in Ar core-Ne shell clusters irradiated by Free Electron Laser Pulses at 62 nm

A. Sugishima, H. Iwayama, S. Yase, H. Murakami, K. Nagaya,, ***M. Yao****, H. Fukuzawa, X.-J. Liu, K. Motomura,* ***K. Ueda****, N. Saito, L. Foucar, A. Rudenko, M. Kurka, K.-U. Kuhnel,* ***J. Ullrich****, A. Czasch, R. Dorner, R. Feifel, M. Nagasono, A. Higashiya, M. Yabashi,* ***T. Ishikawa****, T. Togashi, H. Kimura, and H. Ohashi*

(submitted)

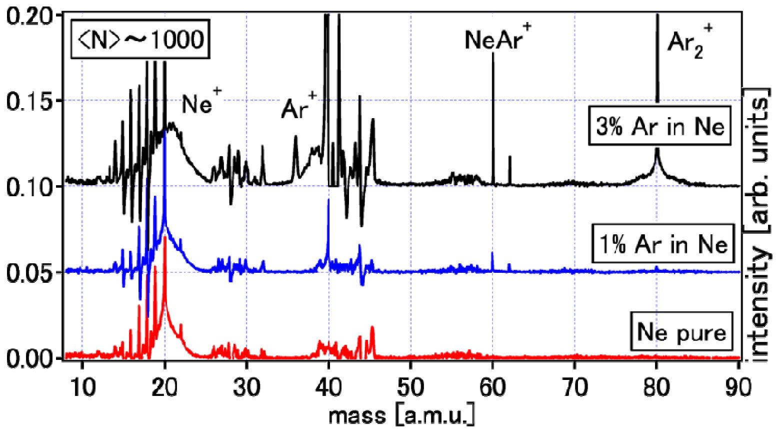
Target:

Ar core- Ne shell clusters (<N>=1000)

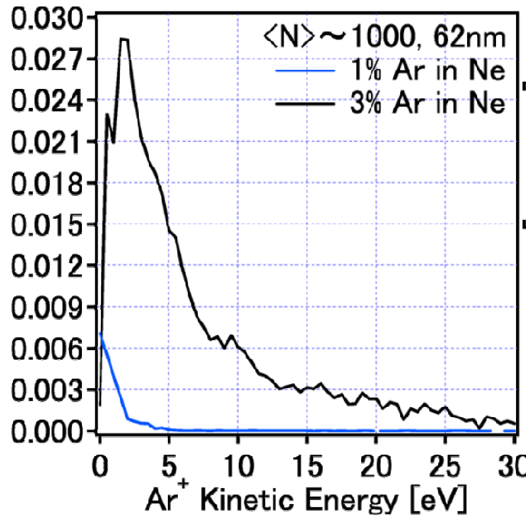
We have measured kinetic energy distributions of Ne^+ and Ar^+ ions ejected from Ar core- Ne shell clusters irradiated by the FEL pulse at 62 nm, i.e., below the Ne ionization threshold and found charge and energy transfer from Ar core to Ne shell.

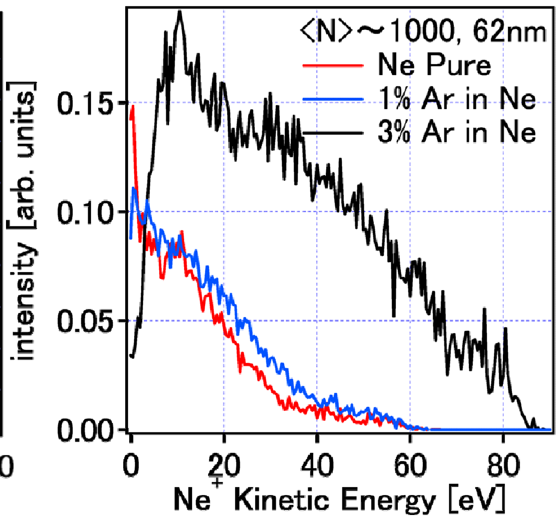
Ar core/Ne shell clusters (<N>=1000) at 62nm

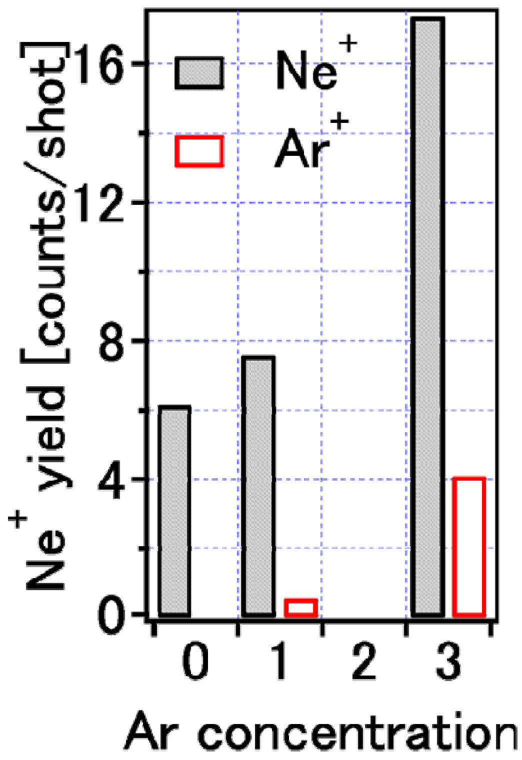
Ion TOF spectra



Ion kinetic energy distributions







The kinetic energy of Ar^+ is much smaller than Ne^+.

→ *The Ar core-Ne shell structure of Ne-Ar cluster is confirmed.*

With increasing Ar mixing ratio, the average kinetic energy and the yield of Ne^+ become large.

→ *Evidence that charges produced at the Ar core migrate to the Ne shell.*

***Sugishima** et al., submitted.*


Sendai
in summer


クリスロード
歓迎 七夕まつり
8月 6日・7日・8日
NTT DoCoMo ドコモショップ
仙台クリスロード店


Tanabata festival

Outline and summary

1. Introduction

Towards the molecular movie with XFEL

2. Two photon single ionization of He atom

Autocorrelation measurements

TDSE study and PAD measurements

3. Multiple ionization of rare gas clusters

Frustration of cluster ionization

Electronic decay of multiply excited clusters

Charge transfer

Time dependent Mie plasmon in clusters

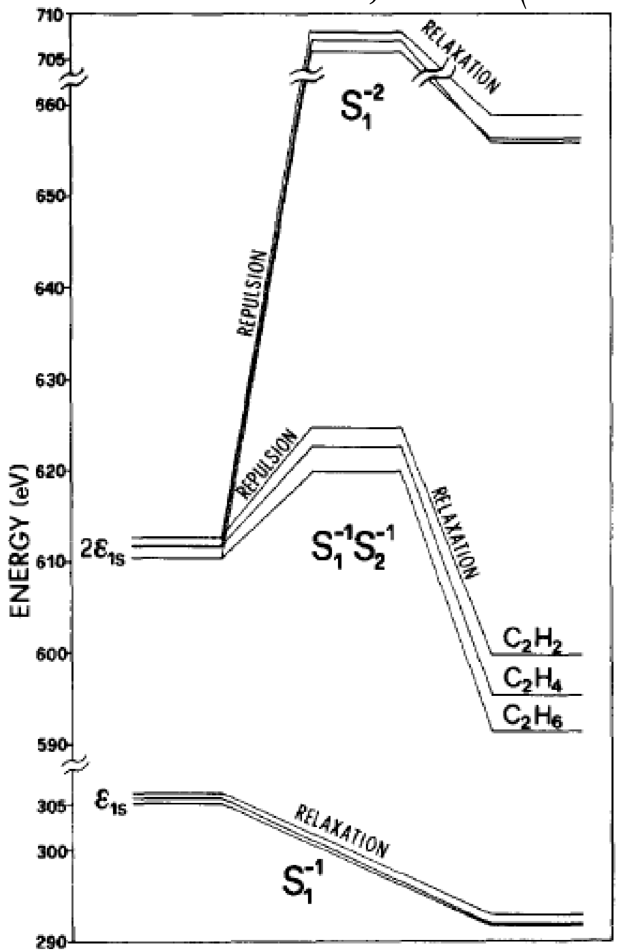
4. Double core hole spectroscopy

Ab initio study and measurements at LCLS

5. Planned commissioning experiments at SACLA

Molecular double core hole spectroscopy

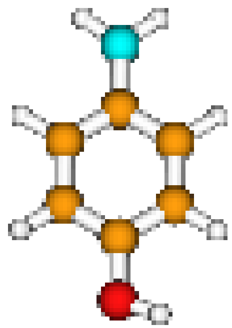
Cederbaum et al. JCP **85**, 6513 (1986).

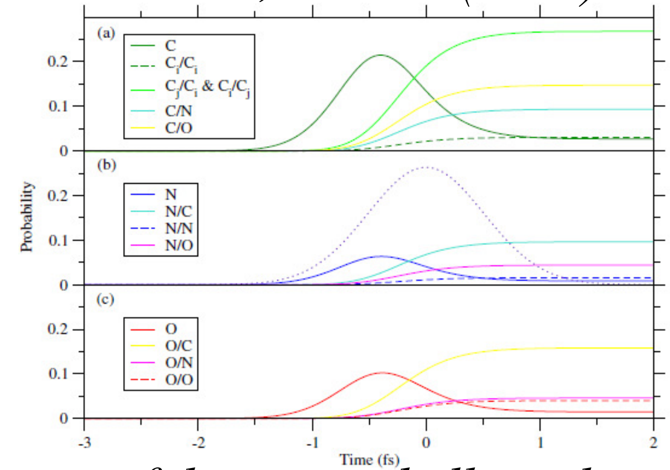


Various contributions of to the energies of single and double core hole states.

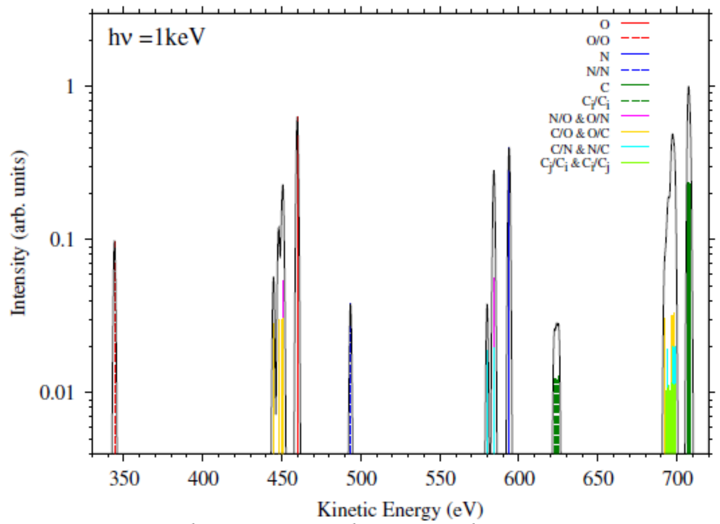
Double core hole energy is very sensitive to the environment of the holes!

Santra et al. PRL **103**, 013002 (2009).





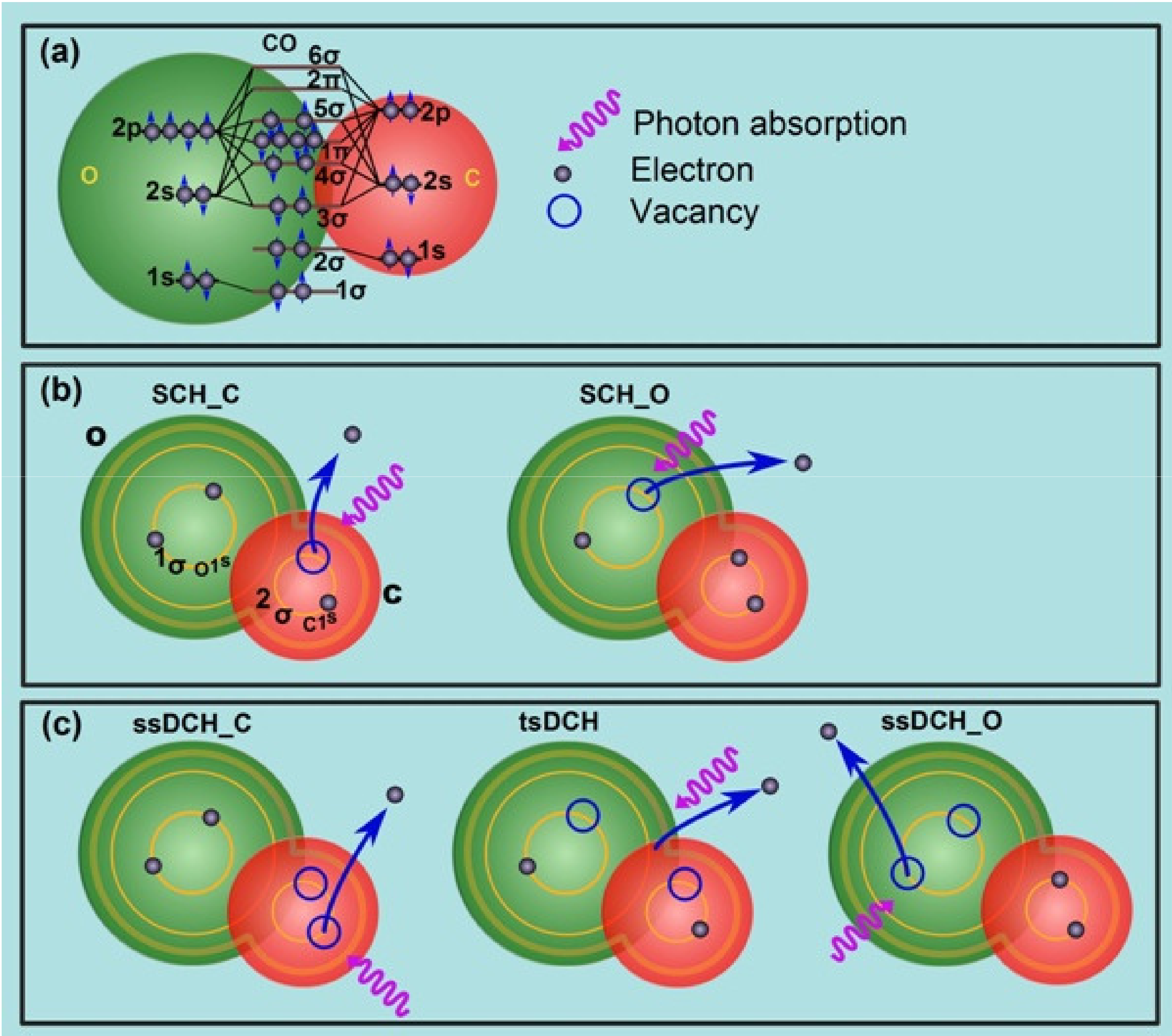
Time evolution of the inner-shell single and double ionization channels



X-ray two-photon photoelectron spectrum

Double core hole spectroscopy is feasible!

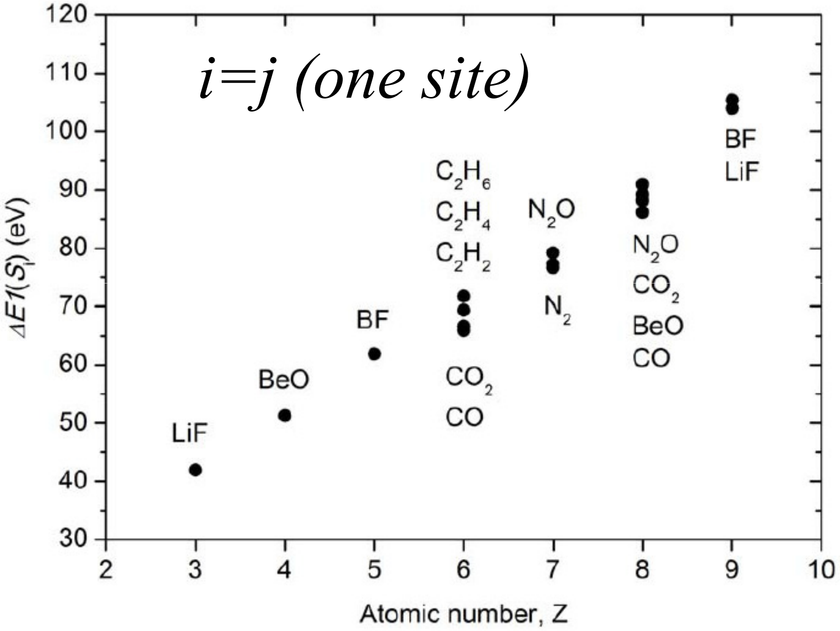
X-ray two photon photoelectron spectroscopy

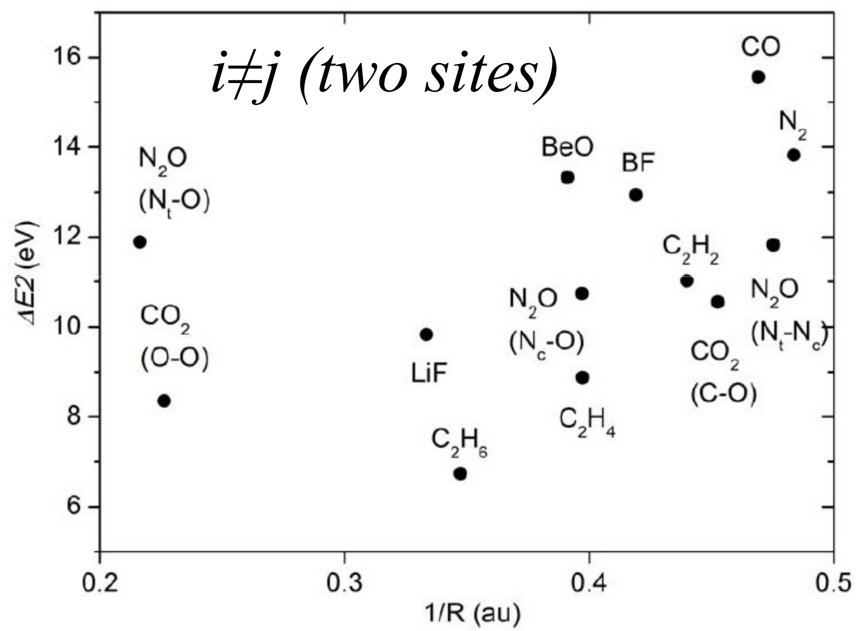


Molecular double core hole electron spectroscopy for chemical analysis

*M. Tashiro, M. Ehara, H. Fukuzawa, **K. Ueda**, C. Buth, N. V. Kryzhevoi, and **L. S. Cederbaum***

J. Chem. Phys. ***132,*** *184302 (2010).*





X-ray two-photon photoelectron spectroscopy

$$\Delta E = KE(1^{st}\ step) - KE(2^{nd}\ step) = DIP(i,j) - [IP(i) + IP(j)]$$

Probing change of electron density that is sensitive of chemical environments

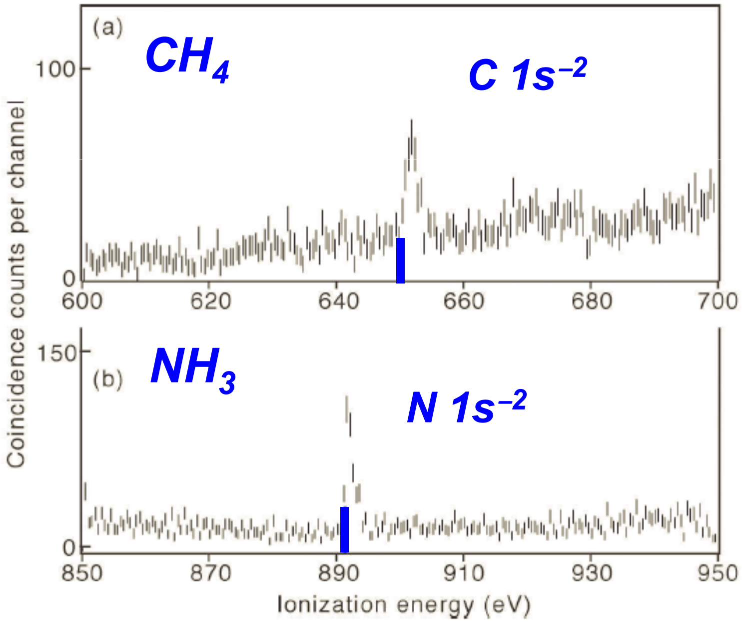
Based on this theoretical prediction, we made the LCLS beam time proposal and got the first beam time (Larsson, Prince, Berrah et al. 21-26 Oct. 2010).

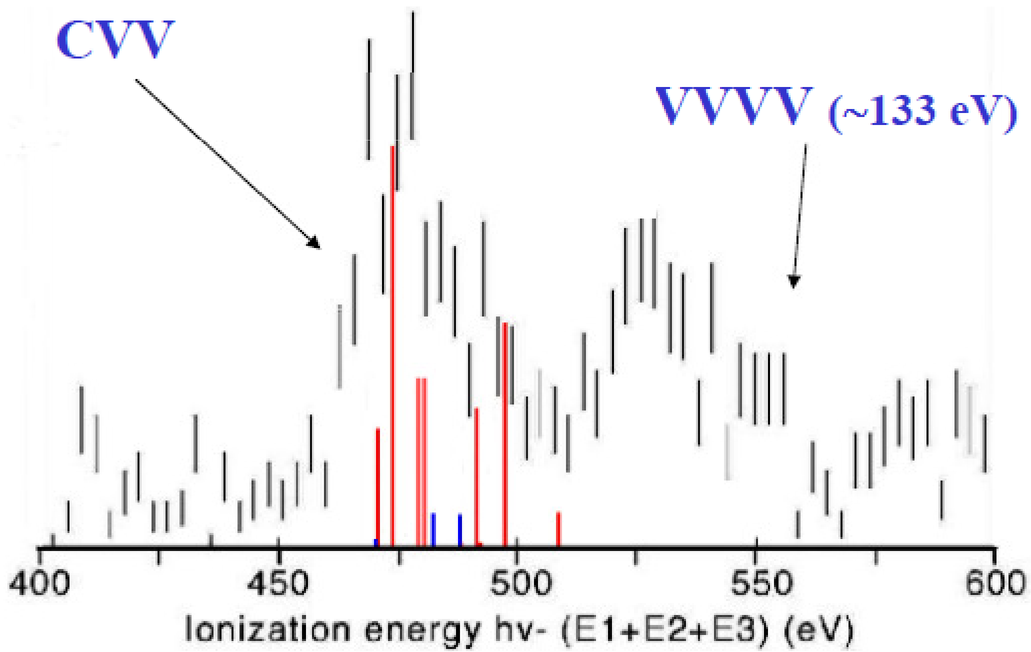
Double core hole creation and subsequent Auger decay in NH_3 and CH_4 molecules

J. H. D. Eland, M. Tashiro, P. Linusson, M. Ehara, K. Ueda, and R. Feifel

Phys. Rev. Lett. ***132,*** *184302 (2010).*

The measured energies of double core hole states in NH_3 and CH_4 have been reproduced accurately by the CASSCF calculations.





The measured Auger spectrum in NH_3 has been reproduced well by the calculations in which Auger rates are evaluated by the overlap integral.

M. Tashiro, K. Ueda, and M. Ehara, submitted

Molecular double core hole spectroscopy at LCLS

__M. Larsson__, P. van der Meulen, P. Salen, H. T. Schmidt, R.D. Thomas, R. Feifel, M.N. Piancastelli (Sweden)

__K.C. Prince,__ R. Richter, F. Tarantelli (Italy)

__K. Ueda,__ M. Tashiro, M. Ehara (Japan)

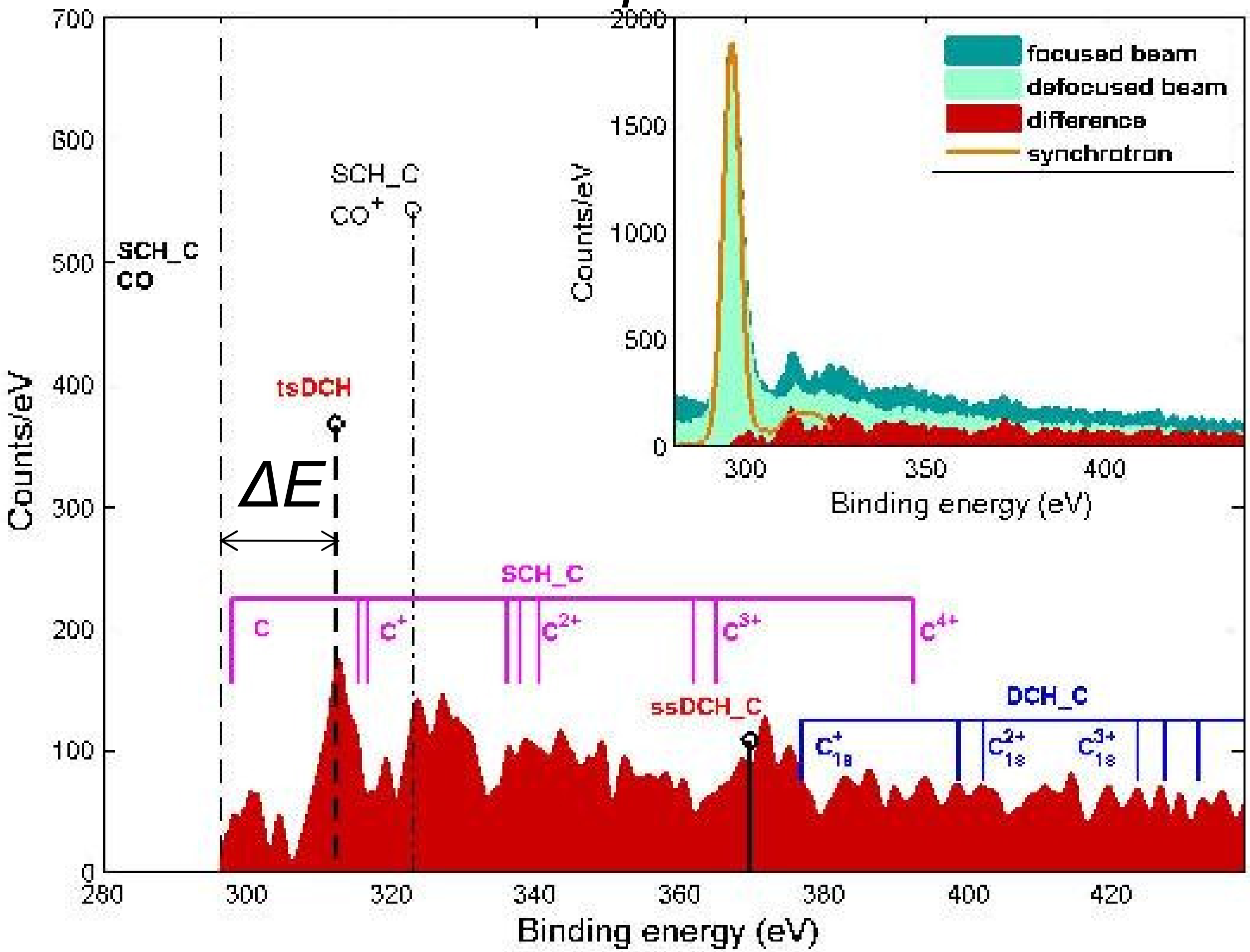
__N. Berrah__, Li Fang, T. Osipov, B. Murphy, P. Juranic, E. Kukk (USA)

J. D. Bozek, C. Bostedt, S. Wada (LCLS)

We have measured double core hole photo-electron spectra and Auger electron spectra of N_2, CO, N_2O, and CO_2.
We have calculated Auger spectra of these molecules as well.
The first paper on CO (Berrah et al) PNAS printed on line.
The second paper on all other molecules submitted to PRL.

X-ray two photon photoelectron spectroscopy on CO

Electron spectra were recorded at focusing and defocusing conditions and the difference spectrum was obtained.



Both one-site and two-site double core hole states are identified at energies closed to predictions by ab initio calculations.

Ionization energies of two-site DCH states

Inter-atomic relaxation energy (IR)

Ionization energy of single core-hole state

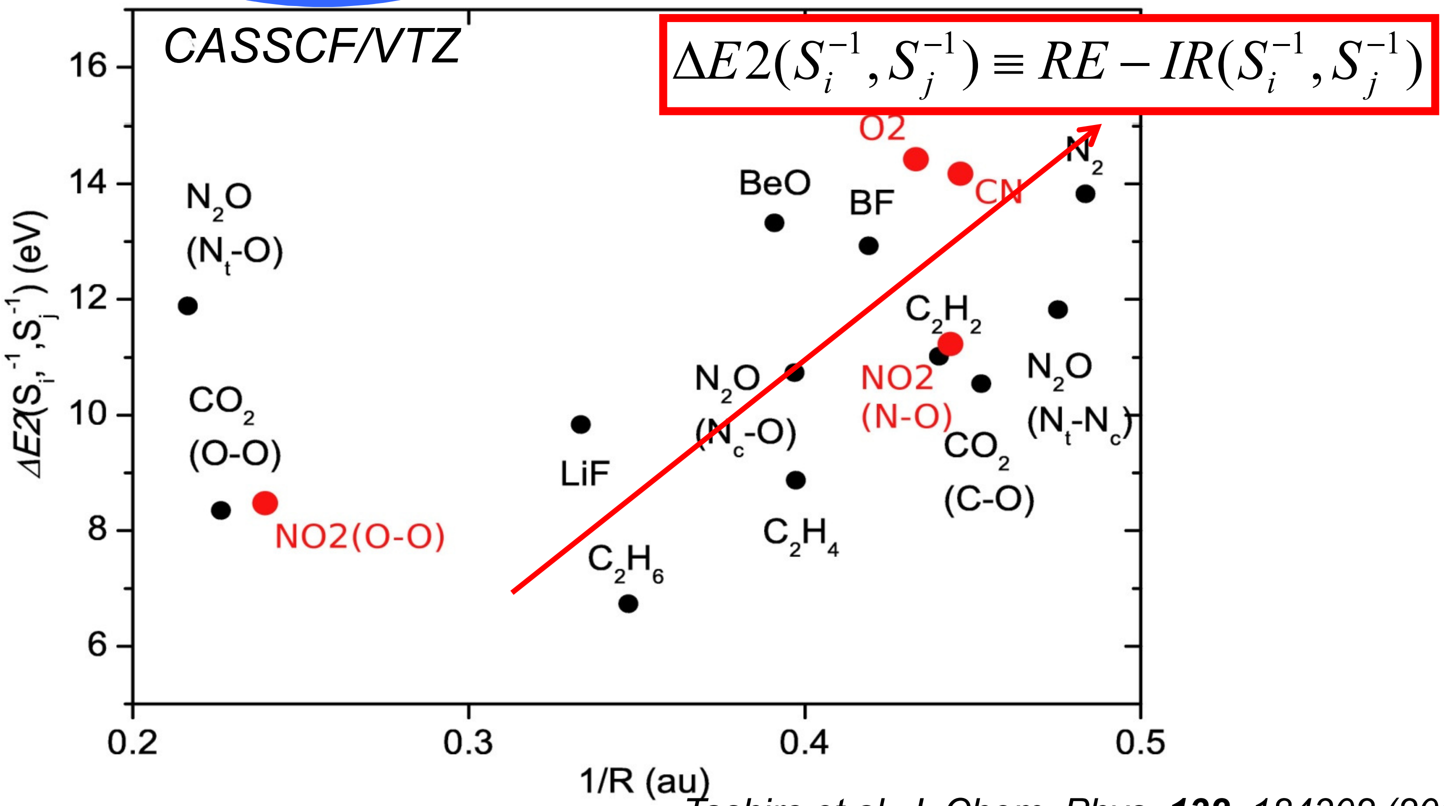
$$\boxed{R(S_i^{-1},S_j^{-1}) = R(S_i^{-1}) + R(S_j^{-1}) + IR(S_i^{-1},S_i^{-1})}$$

Double ionization energy of ts-DCH state

$$DIP(S_i^{-1},S_j^{-1}) = -\varepsilon_{S_i} - \varepsilon_{S_j} + RE - R(S_i^{-1},S_j^{-1})$$

$$RE \cong 1/r_{ij}$$

$$\boxed{\begin{aligned}\Delta E2(S_i^{-1},S_j^{-1}) &\equiv DIP(S_i^{-1},S_j^{-1}) - IP(S_i^{-1}) - IP(S_j^{-1}) \\ &= RE - R(S_i^{-1},S_j^{-1}) + R(S_i^{-1}) + R(S_j^{-1})\end{aligned}}$$



Black :closed shell mol.   Red: open shell

Tashiro et al. J. Chem. Phys. **132**, 184302 (2010)

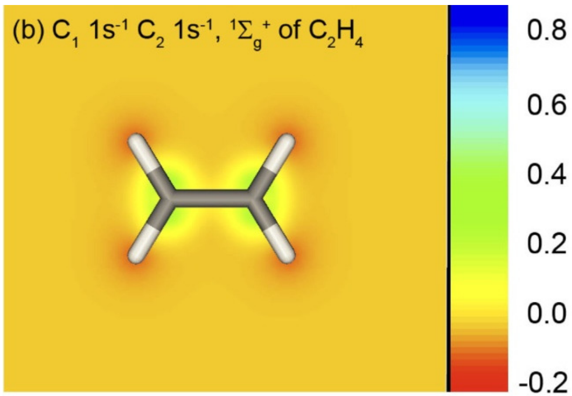
Inter-atomic relaxation energy of ts-DCH states

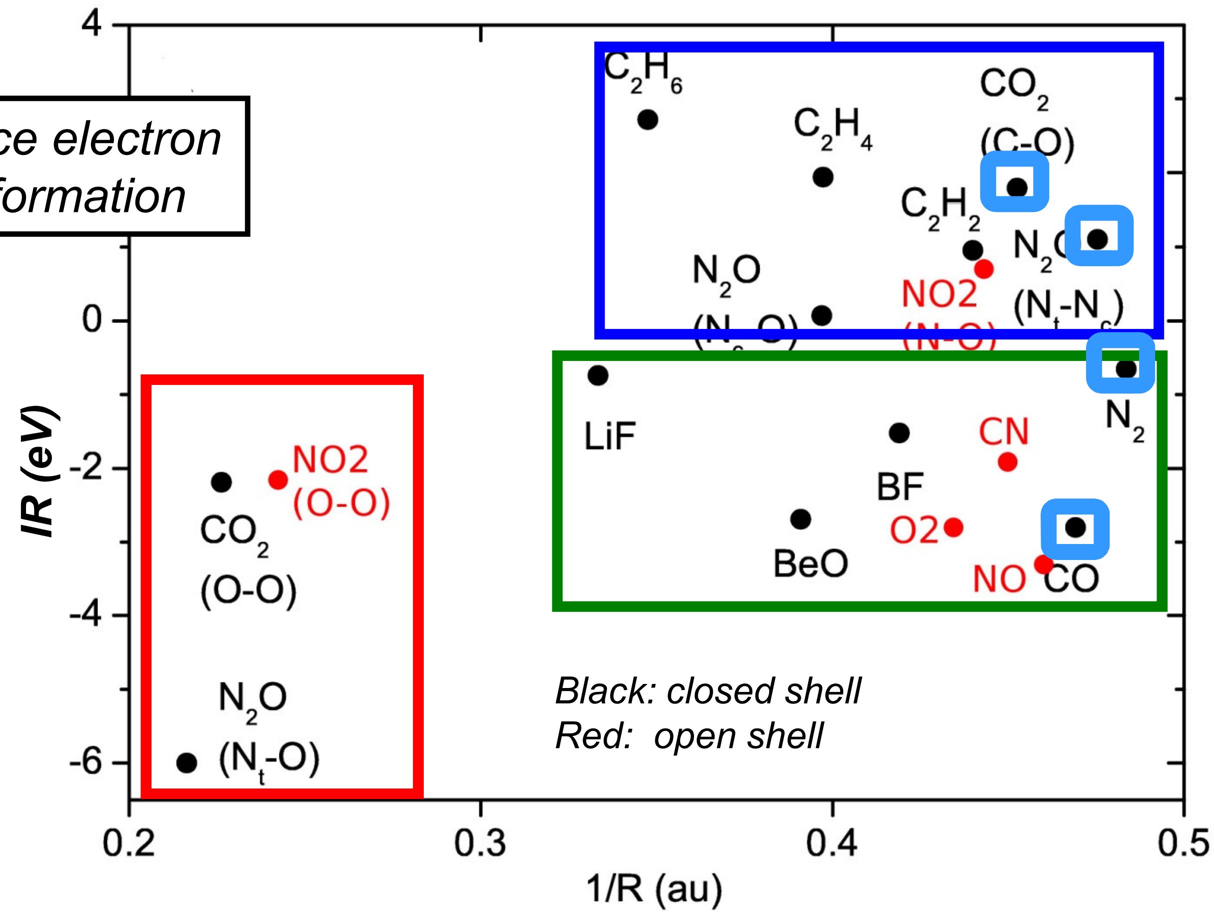
- ***Diatomic mol.***
  IR < 0
- ***Neighboring atoms of polyatomic mol.***
  IR > 0
- ***Atoms at both ends of triatomic mol.***
  IR < 0

Related to the change of valence electron density, resulting from ts-DCH formation

Essence of double core hole spectroscopy for chemical analysis

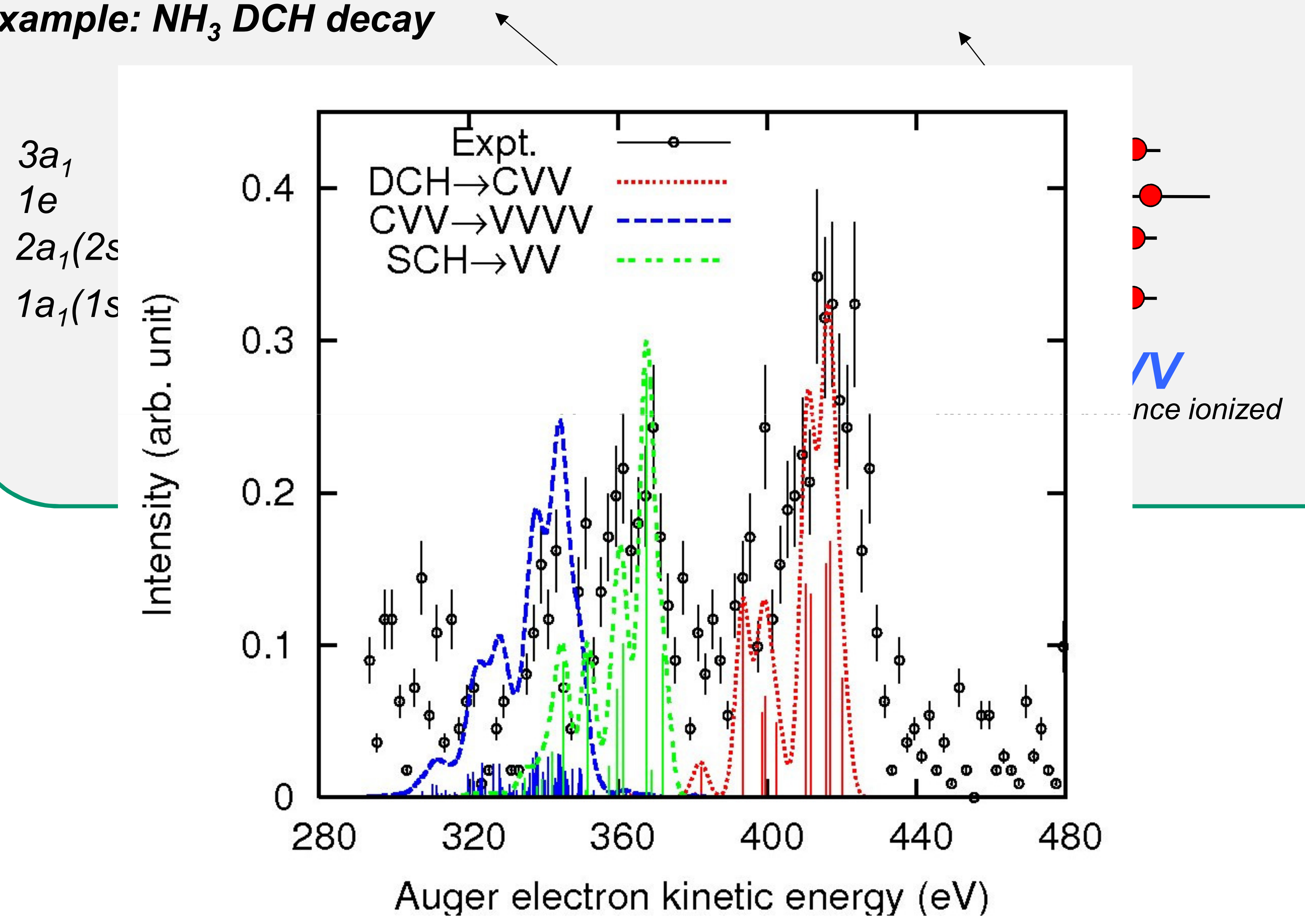
Example: ts-DCH of C_2H_4





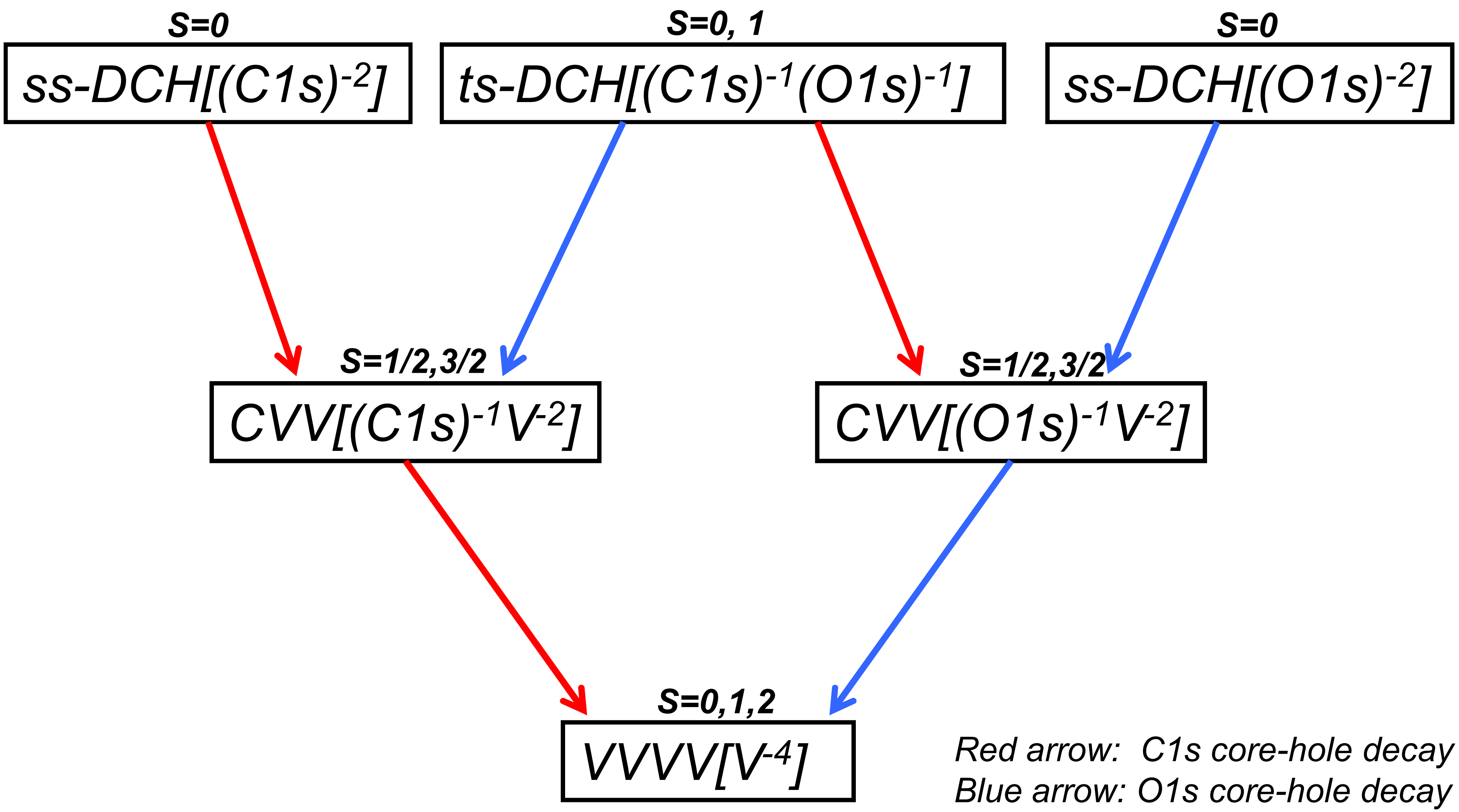
Double core hole Auger spectroscopy

Example: NH_3 DCH decay



M. Tashiro, K. ueda, and M. Ehara, JCP accepted

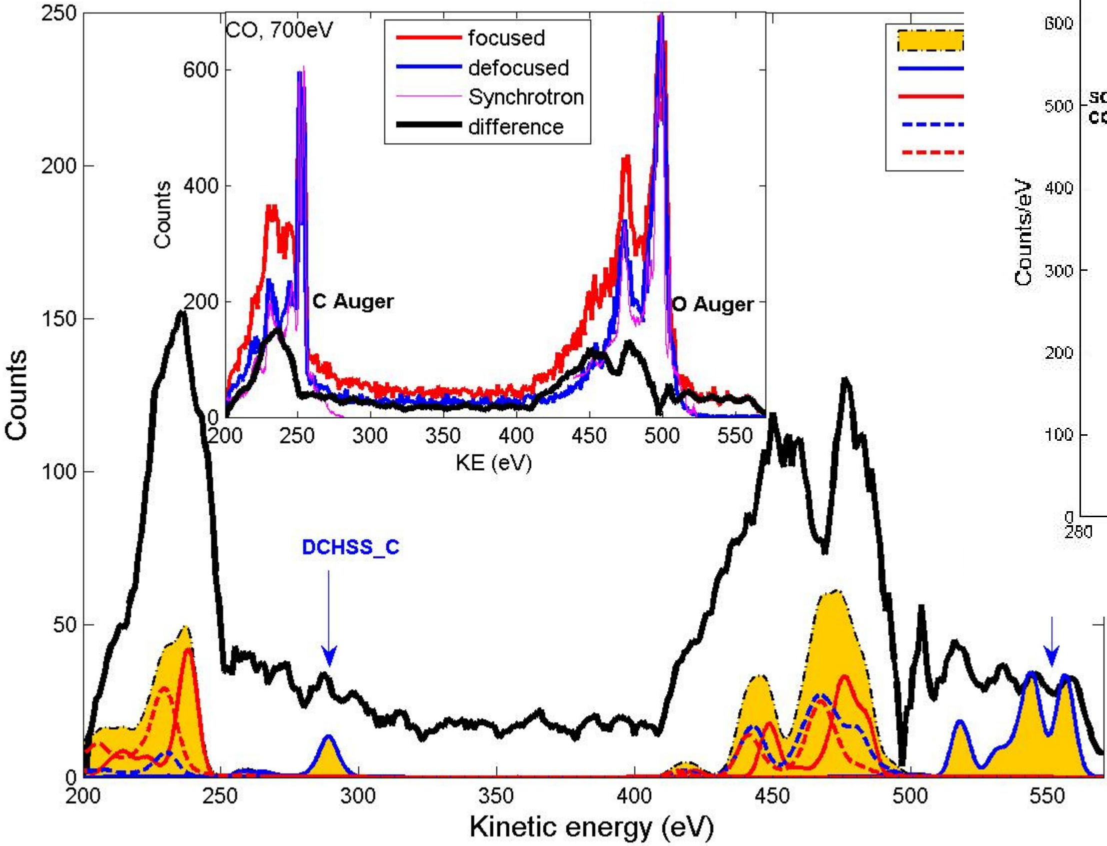
Auger spectra of CO DCH decays

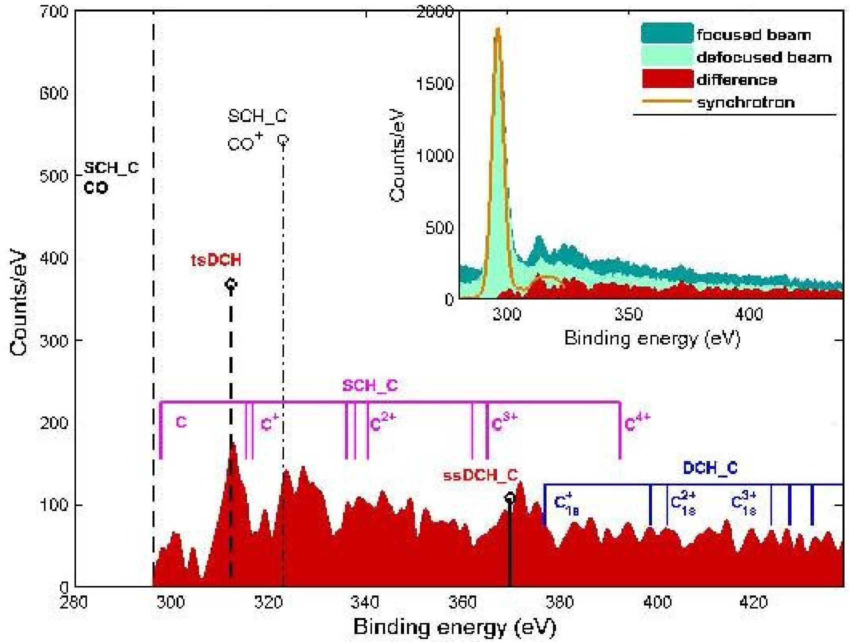


Red arrow: C1s core-hole decay
Blue arrow: O1s core-hole decay

M. Tashiro, K. ueda, and M. Ehara, JCP accepted

Auger spectra of CO DCH decays





Experimental (black) vs theoretical (yellow) Auger spectra

N. Berrah, L. Fang, T. Osipov, B. Murphy, K. Ueda, E. Kukk, R. Feifel, P. van der Meulen, P. Salen, H. Schmidt, R. Thomas, M. Larsson, R. Richter, K. C. Prince, J. D. Bozek, C. Bostedt, S. Wada, M. Piancastelli, M. Tashiro, M. Ehara,PNAS . 108, 16912 (2011).

M. Tashiro, K. ueda, and M. Ehara, JCP accepted

Disentangling formation and decay of molecular two-site double-core-hole states

*Feifel et al: Proposal for use of a new **magnetic bottle** electron spectrometer and a **covariance** technique*

Two-core-hole spectroscopy of biomolecules

*Prince et al: Proposal for applying the above DCH electron spectroscopy to **biomolecules** (formamide and uracil)*

Aug. 25- Sep. 6, 2011

R. Feifel *et al.(Sweden),* ***J.H.D. Eland*** *and* ***L. Frasinski*** *(UK)*

K.C. Prince, L. Avaldi, F. Tarantelli *et al(Italy)*

K. Ueda, S. Wada, O. Takahashi, M. Tashiro, M. Ehara *et al (Japan)*

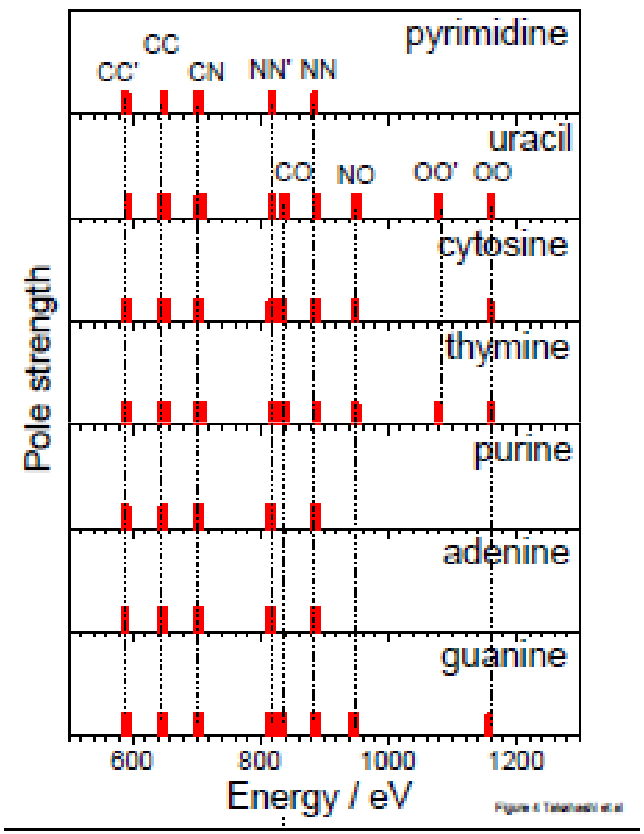
J. Ullrich, L. Faucar *et al (Germany)*

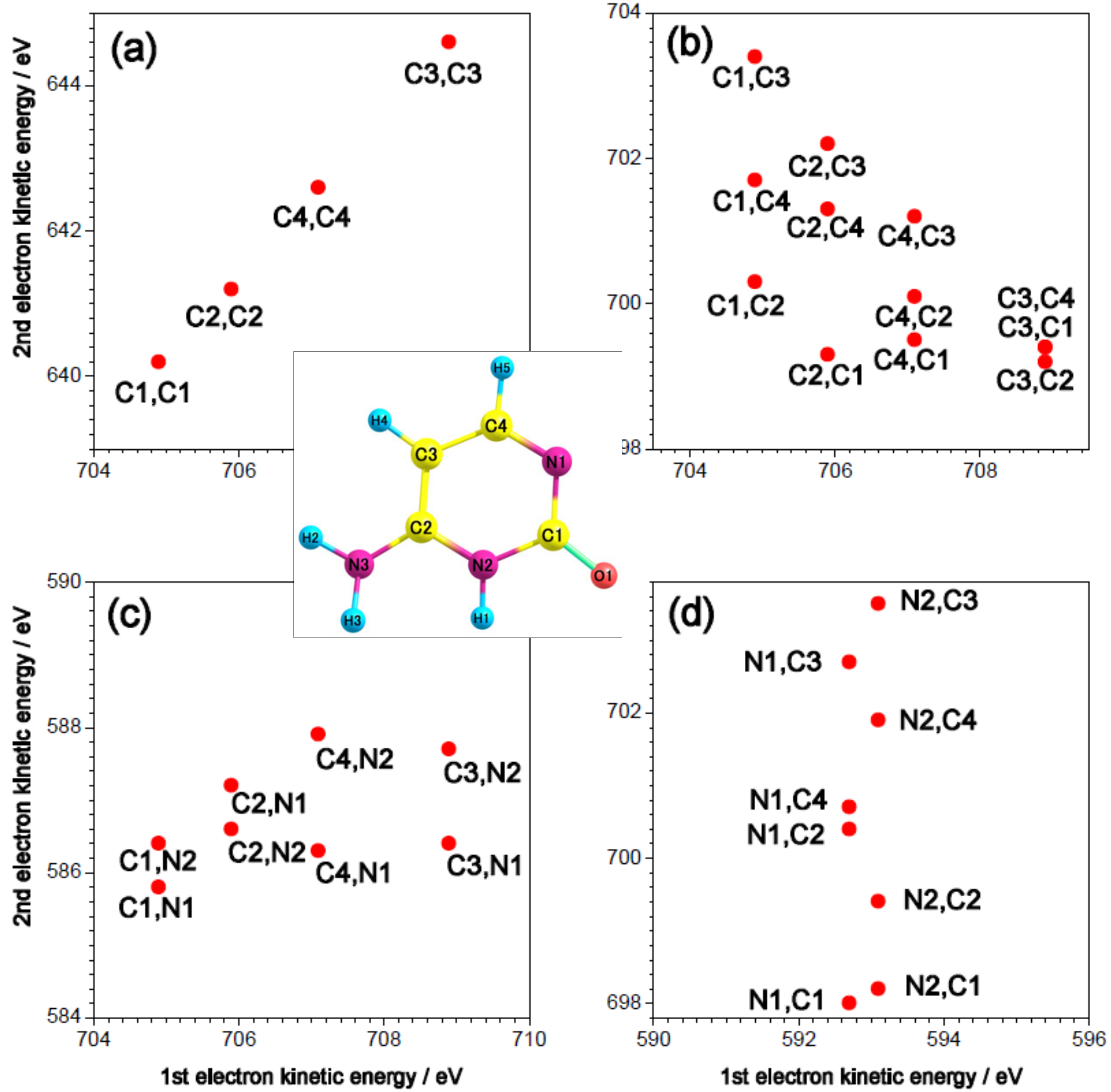
N. Berrah *et al (USA)*

J.D. Bozek, C. Bostedt *et al (LCLS) , and more*

Theoretical double core hole spectroscopy on DNA base

O. Takahashi, *M. Tashiro, M. Ehara, K. Yamasaki, K. Ueda, JPC in press*





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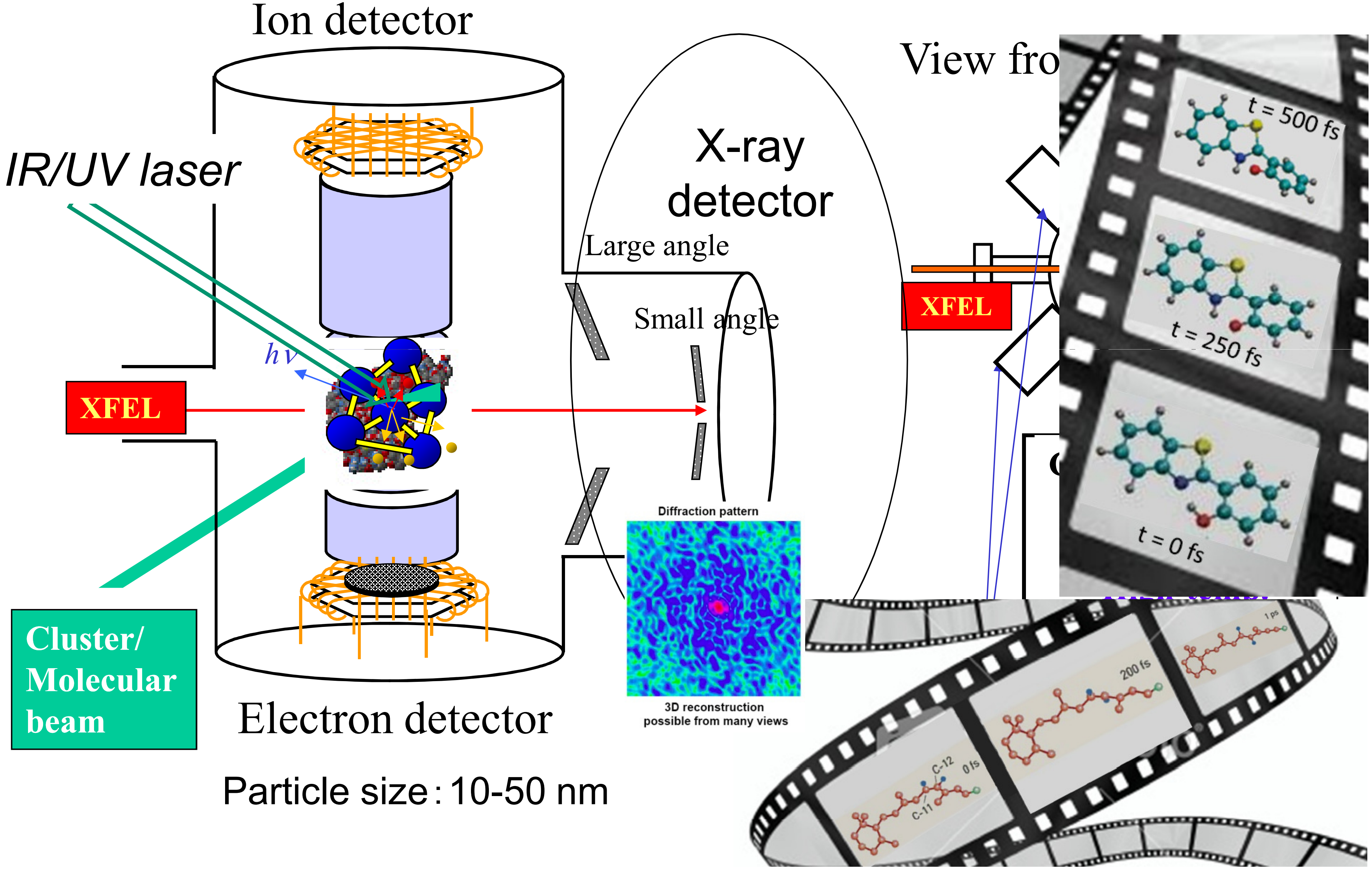
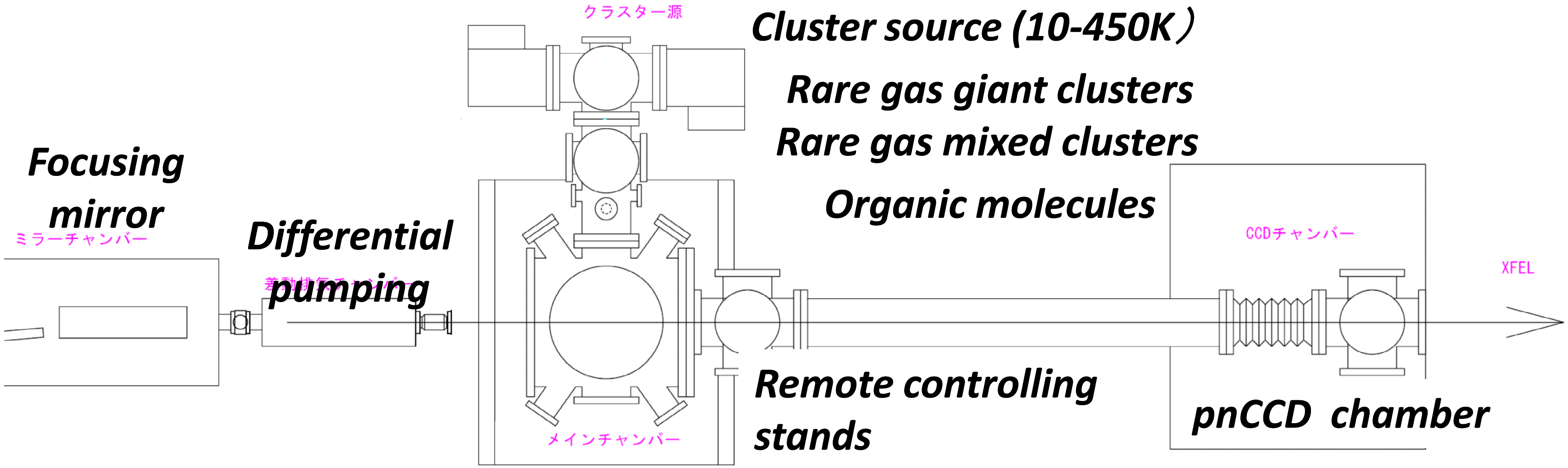
Molecular Movie:

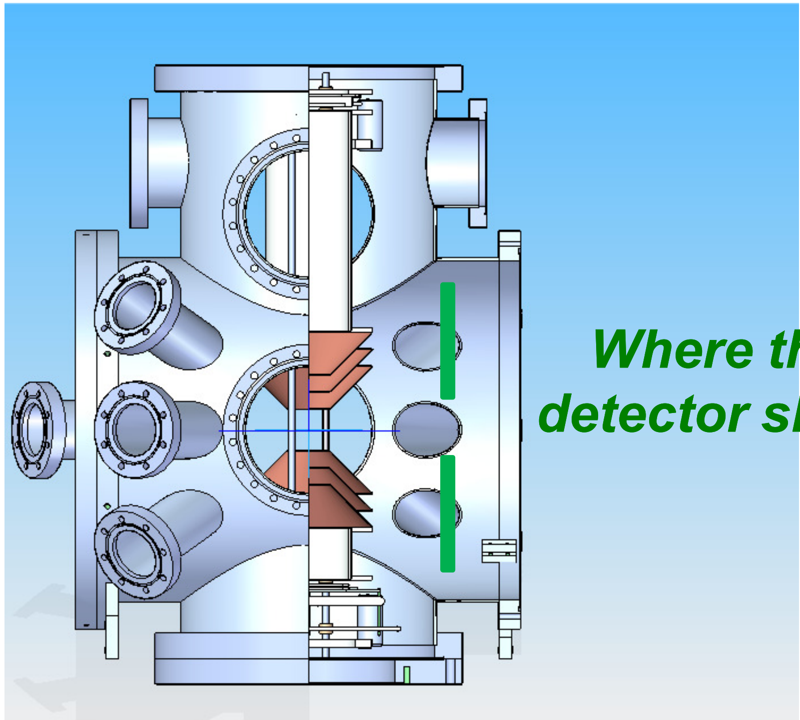
Coherent diffractive imaging of a single particle combined with coulomb explosion imaging and electron diffraction imaging



Particle size : 10-50 nm

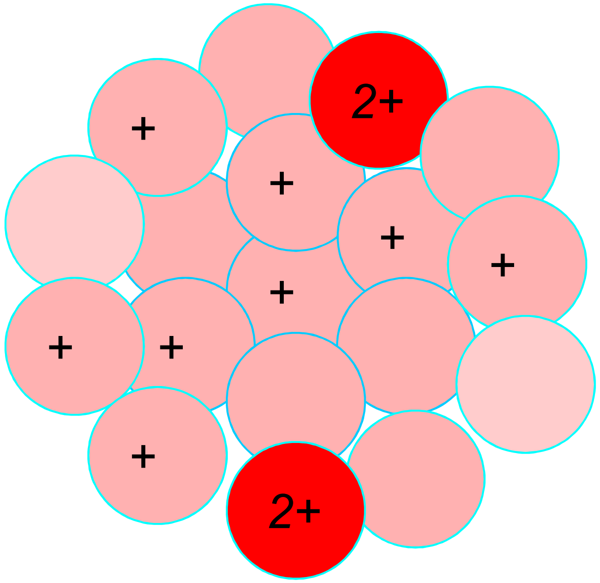
Setup for SACLA experiments



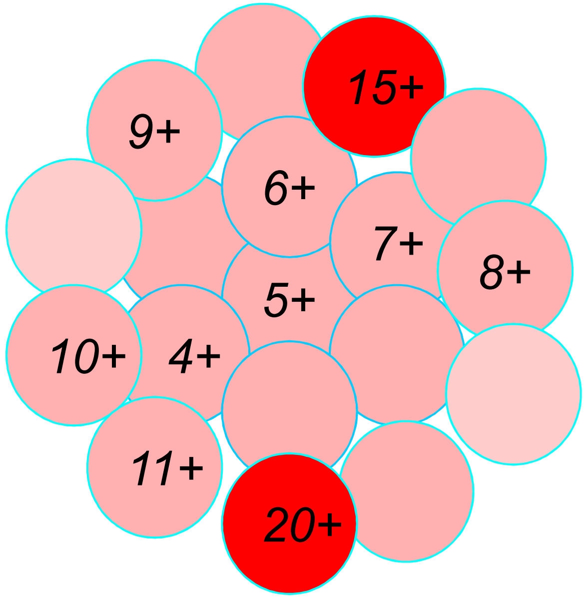


Where the X ray
detector should be?

Rare gas clusters will meet the intense x-ray pulses for the first time!



We found it for EUVFEL pulses



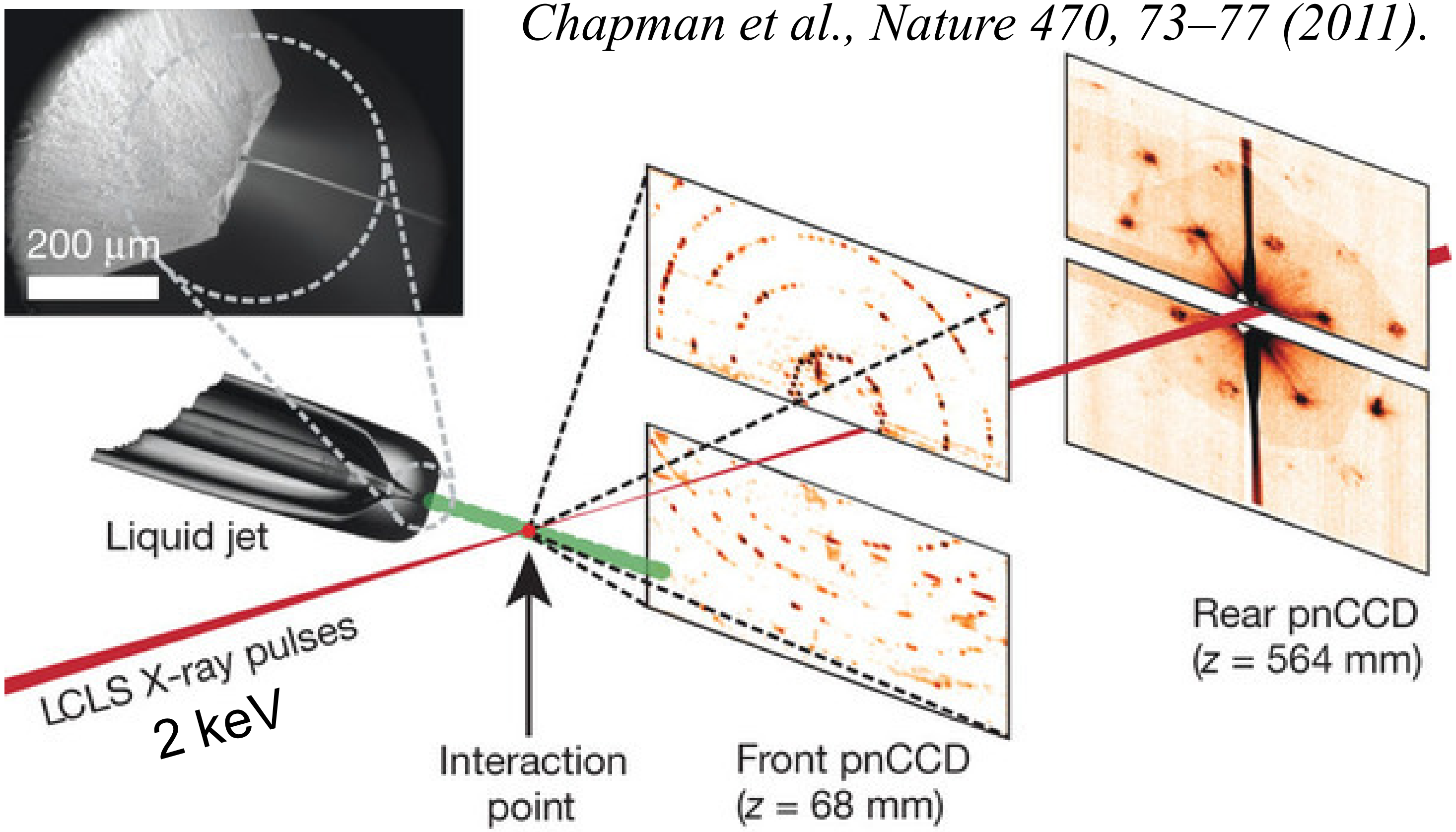
What will happen for XFEL pulses?

Single shot imaging of micro-clusters….

SACLA commissioning experiments in February 2012

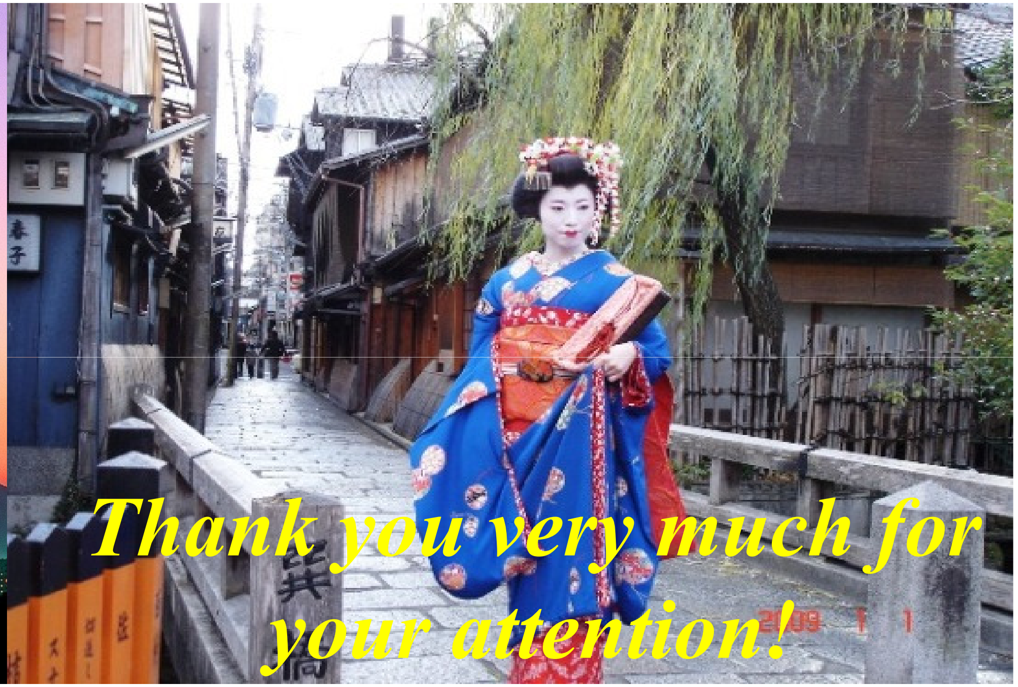
Single shot imaging of protein nano-crystals

Chapman et al., Nature 470, 73–77 (2011).



Radiation damage for hard x-rays


The end


Thank you very much for
your attention!