A Multi-Purpose Reaction Microscope for Gas-Phase Experiments at FLASH II

Proposal for a permanently installed REMI at FLASH II

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MPIK Heidelberg and Max-Planck ASG Hamburg

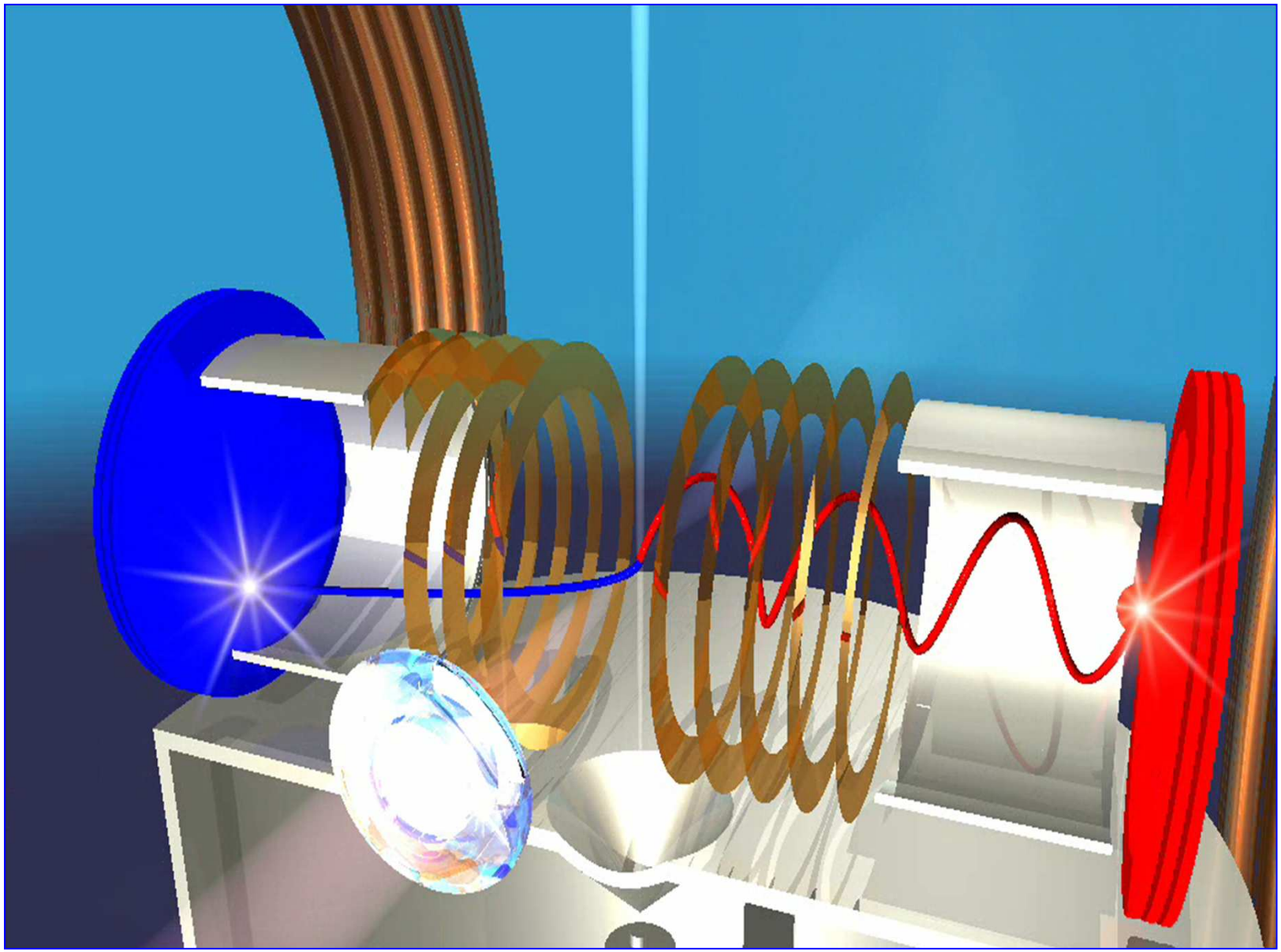
G. Brenner, K. Tiedtke

HASYLAB at DESY

Outline

- ***Reaction Microscope at FLASH***
- Coincidences: Why & How
- A Few Results
  - Multi-Photon Processes
  - XUV-XUV Pump-Probe
  - XUV-IR Pump-Probe
- Present Status and Realization

Reaction Microscope (REMI) at FLASH



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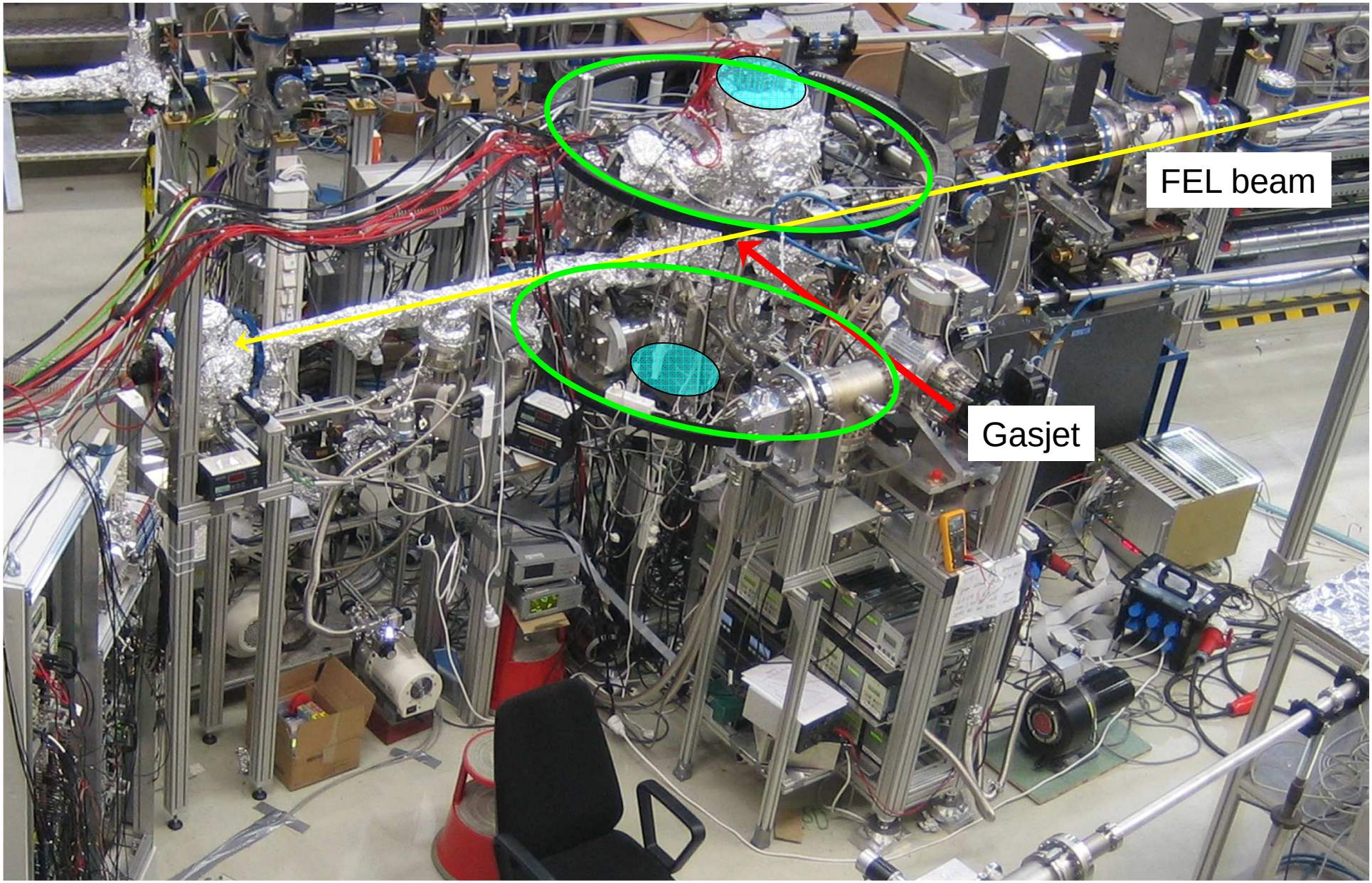


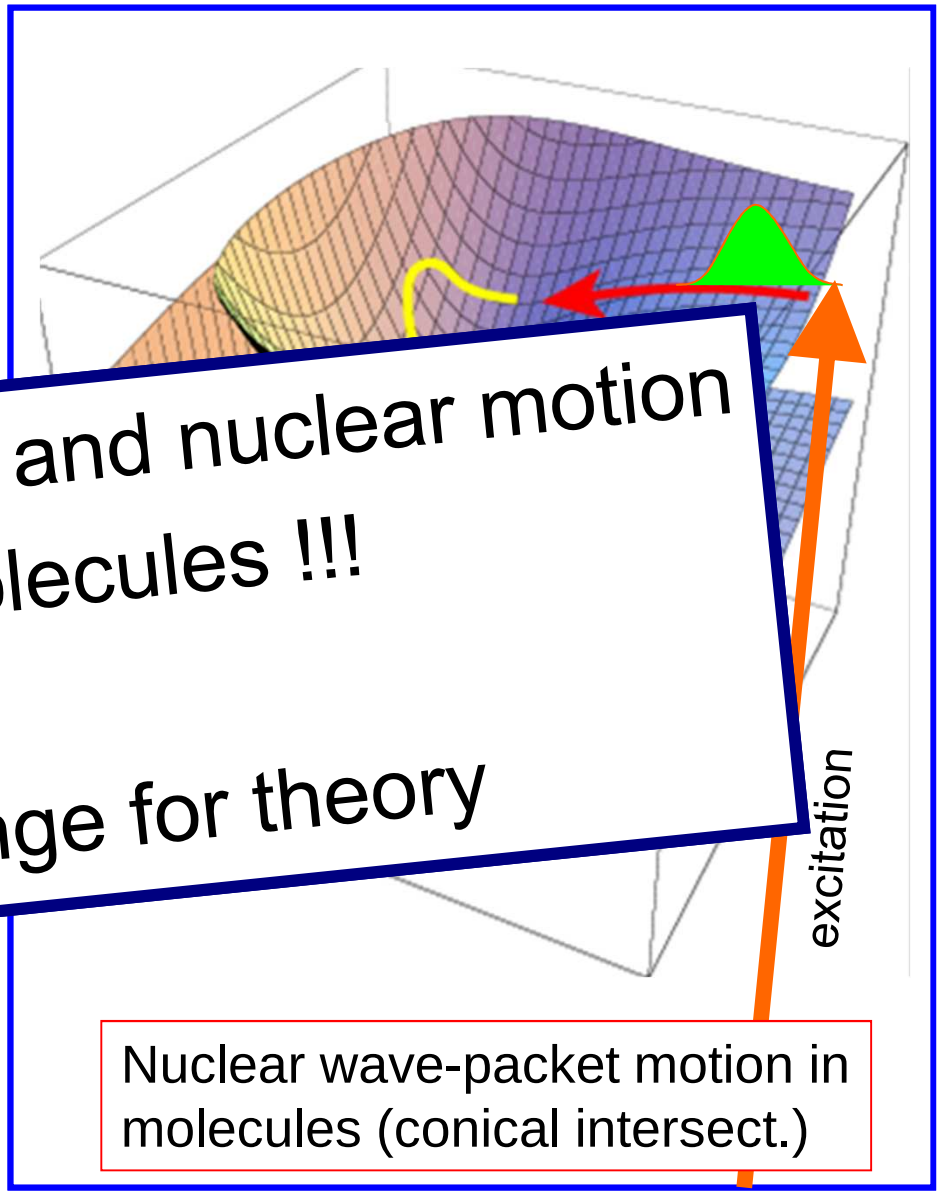
The Physics Goal

Observation of molecular relaxation processes

- time-resolved

Interplay of electronic and nuclear motion in small molecules !!!

A real challenge for theory



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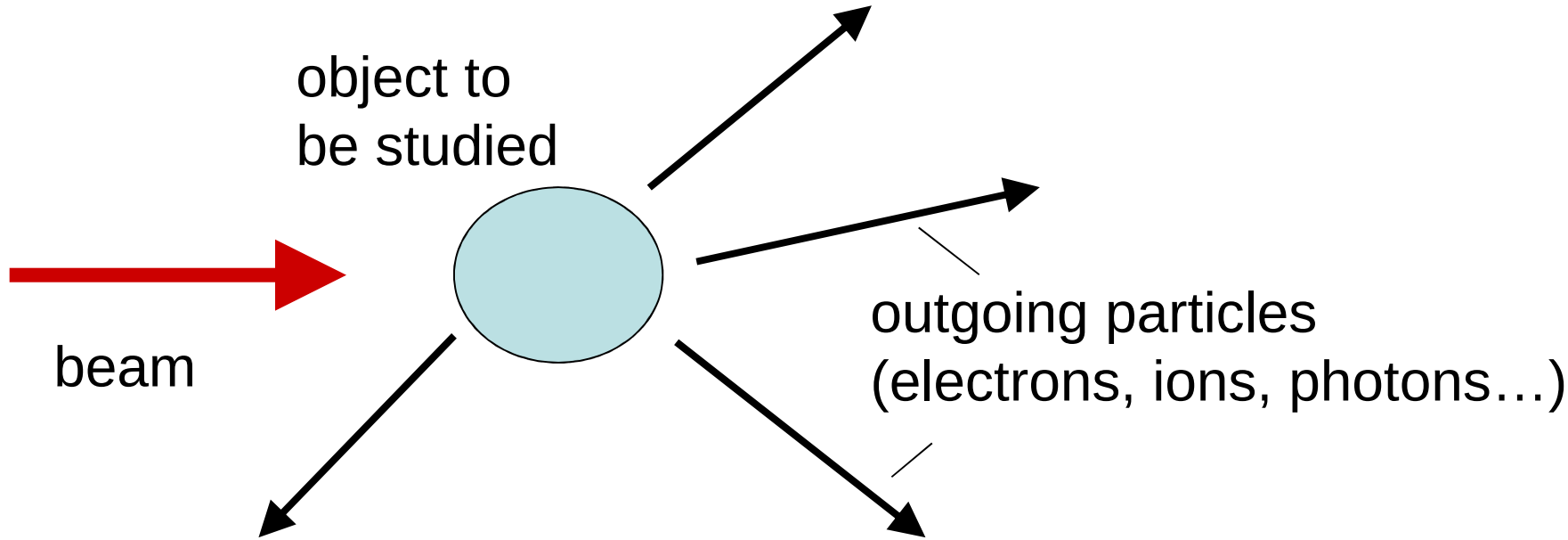
Coincidence Spectroscopy



Particle Physics Approach:

Measure the masses, momenta and charges of all fragments that are emitted in a single events !!!!

Coincidence Experiments at FELs

The 1st requirement:

Coincidence Experiments at FELs

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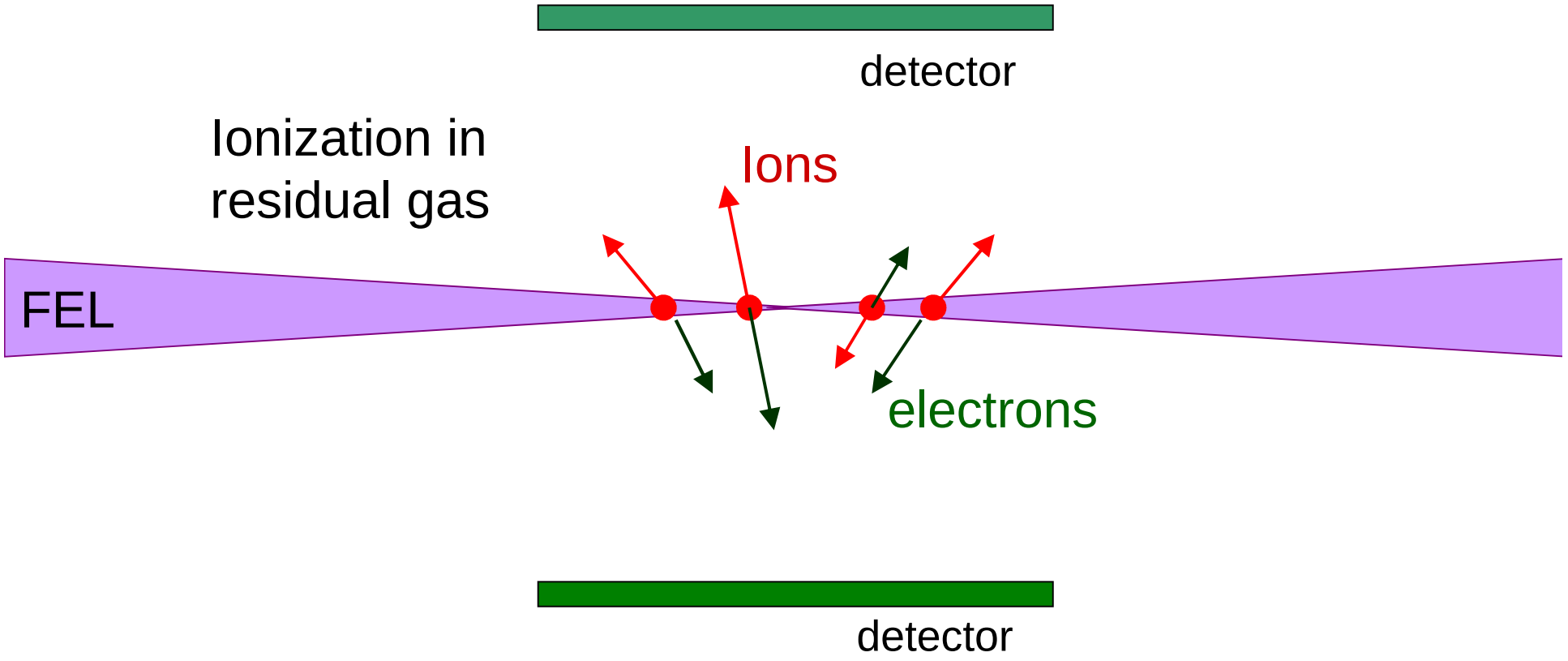
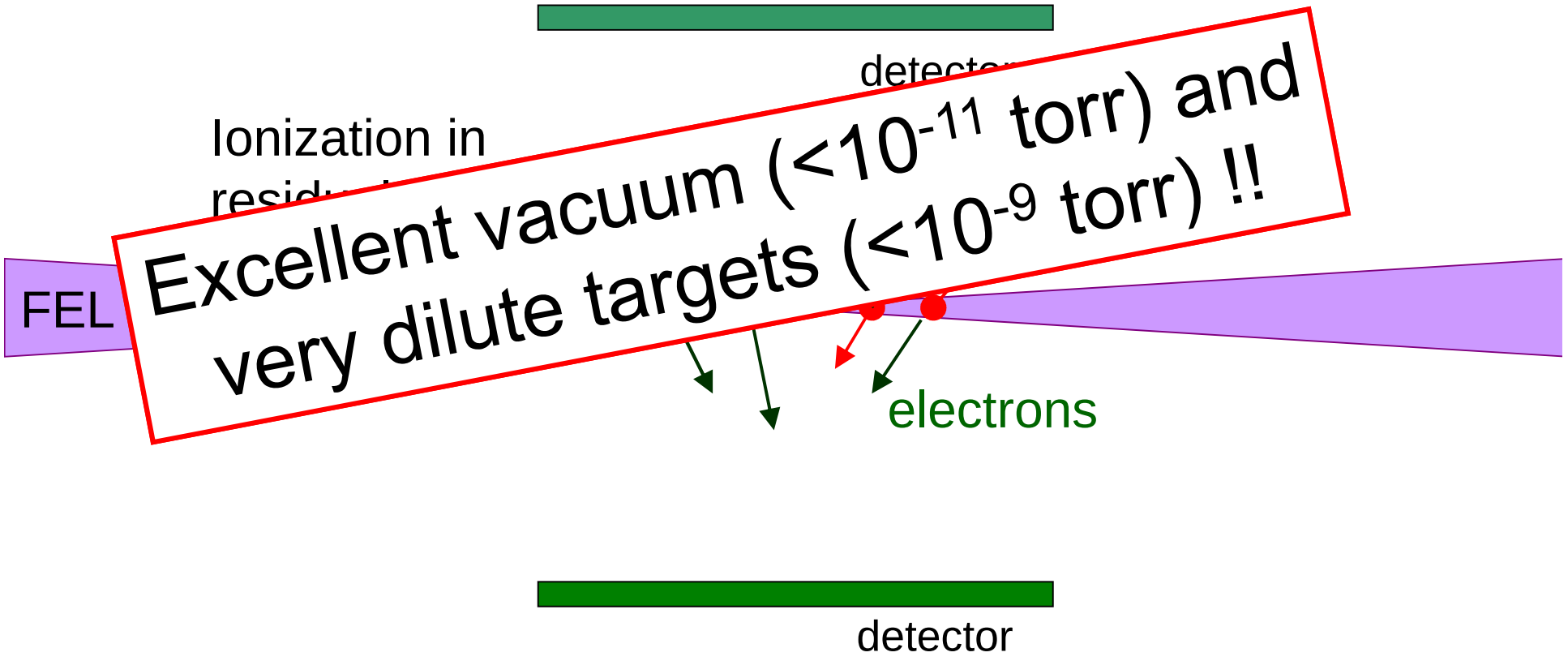


Coincidence Experiments at FELs

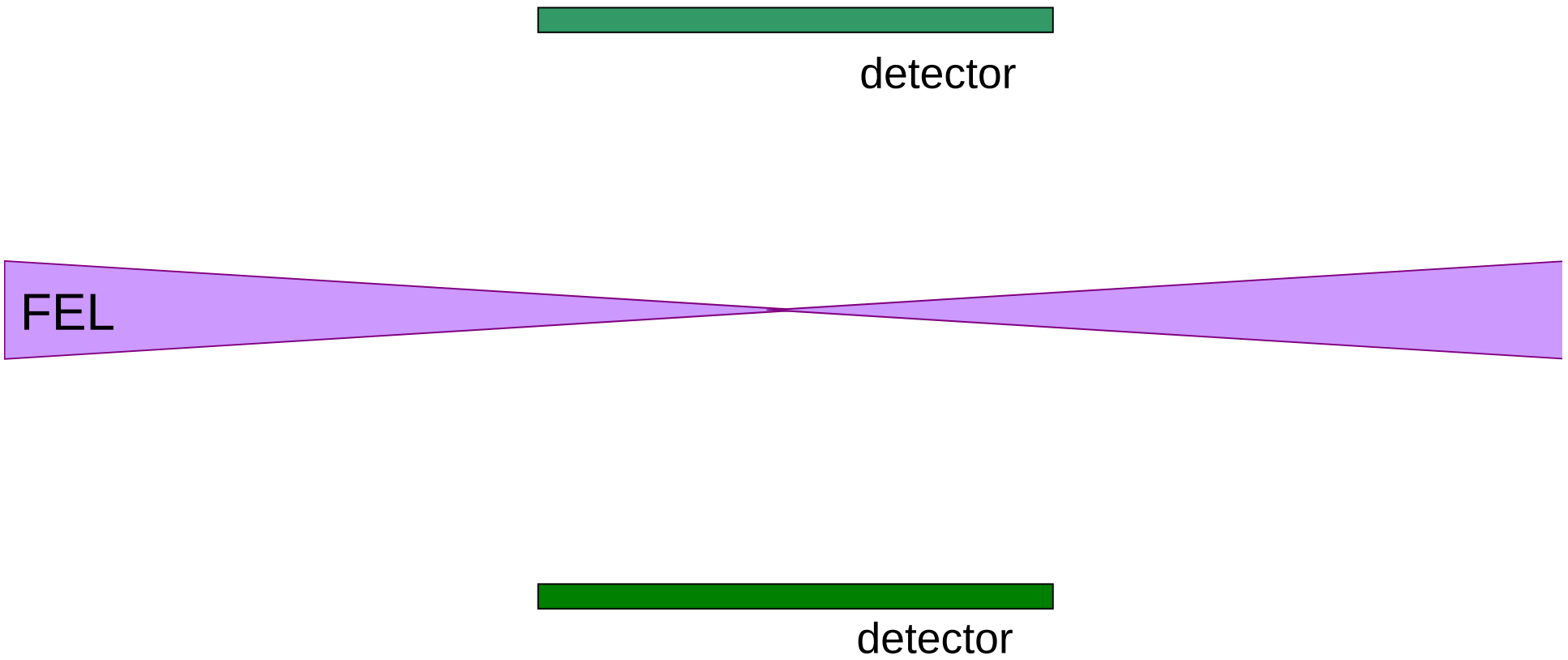
The 1st requirement:

- Detectors get “flooded”
- Space charge effects
- Which electron belongs to which ion?



Coincidence Experiments at FELs

The 2nd requirement:



Coincidence Experiments at FELs

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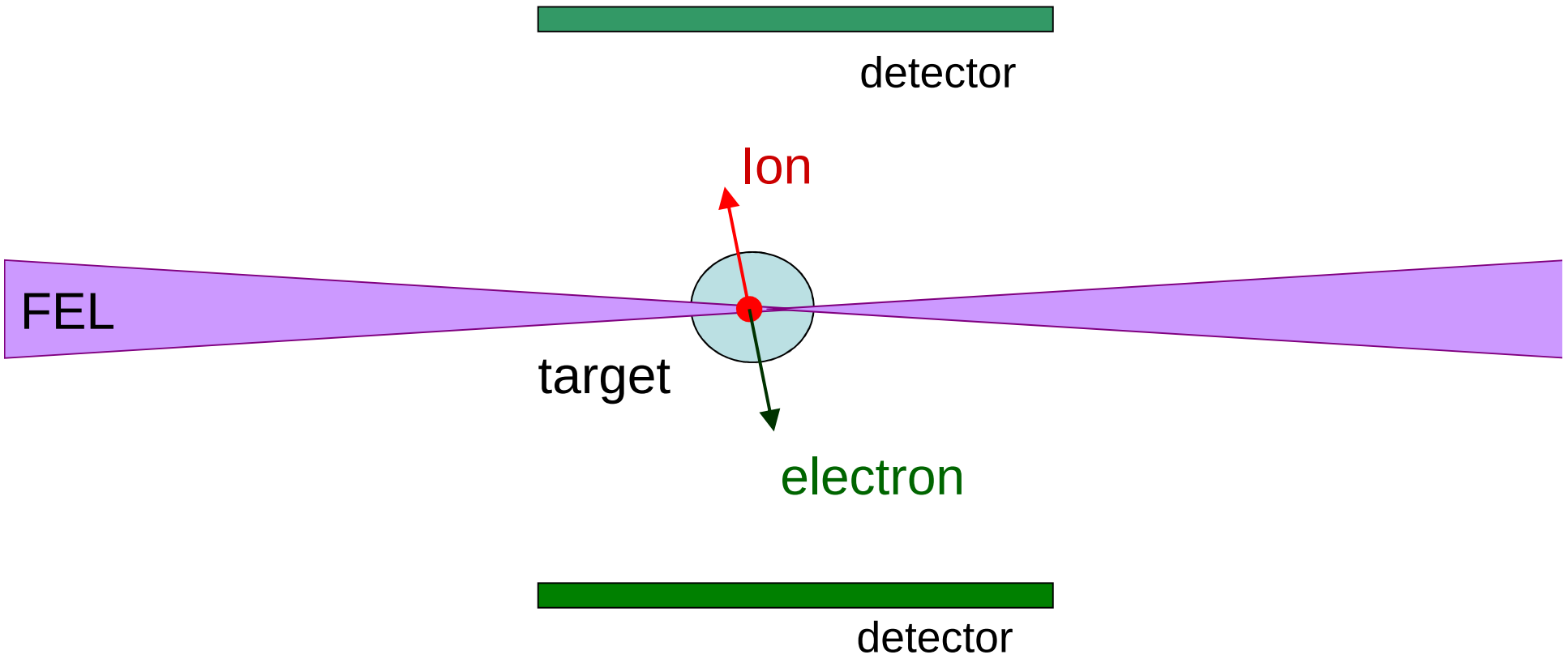


Coincidence Experiments at FELs

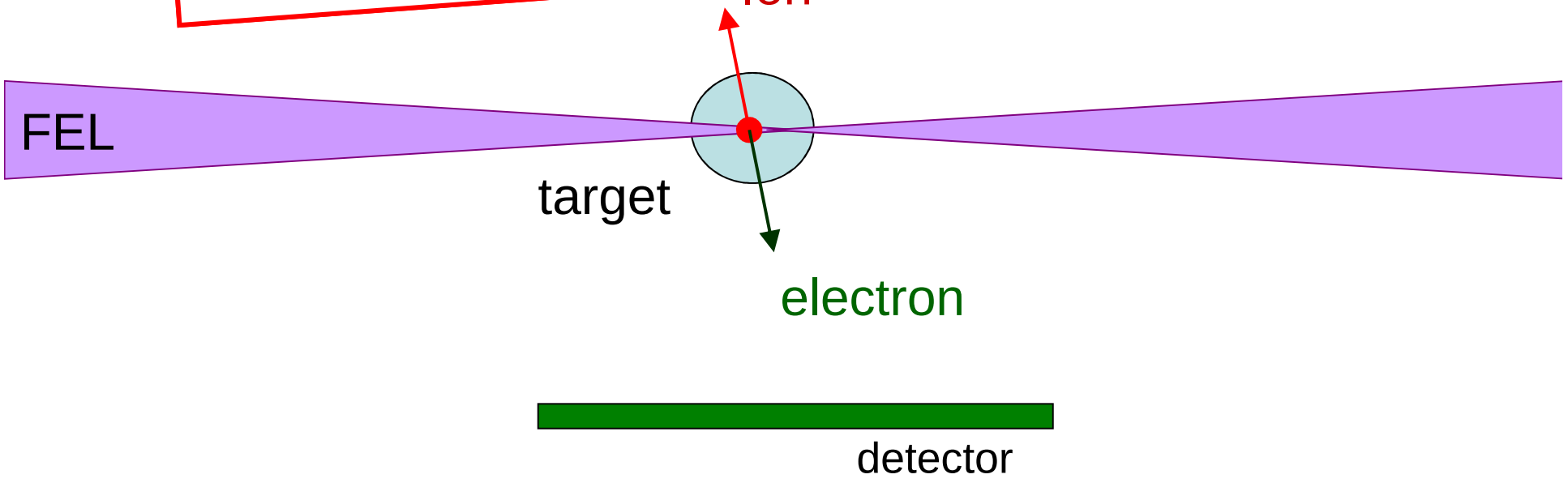
The 2nd requirement:

- No more than one event per laser shot !!

ectron
?

A high repetition rate is needed !!

- FLASH now: 300 Hz
- FLASH future: up to 10 kHz !



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Multi-Photon Ionization of N_2

Fragmentation and Coulomb-Explosion of N_2 ($N^+ + N^+$ channel)

- Ion momentum distributions
- Angular emission pattern

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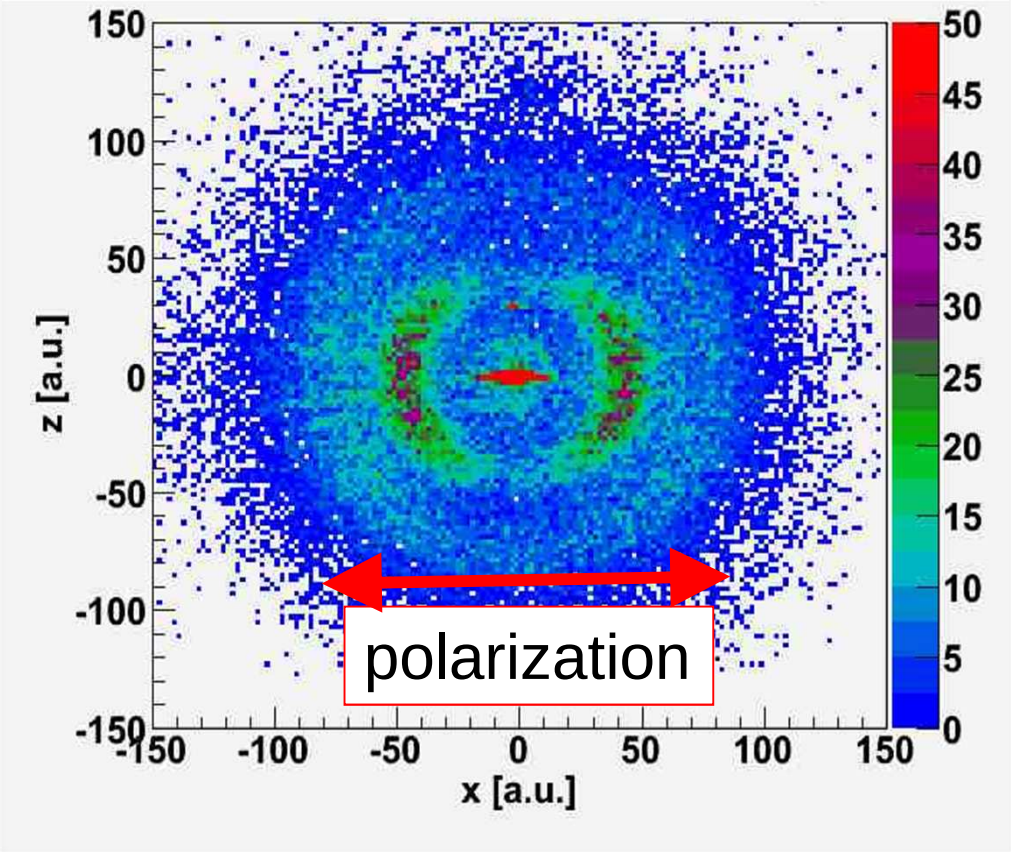
momentum of N^+ (singles)



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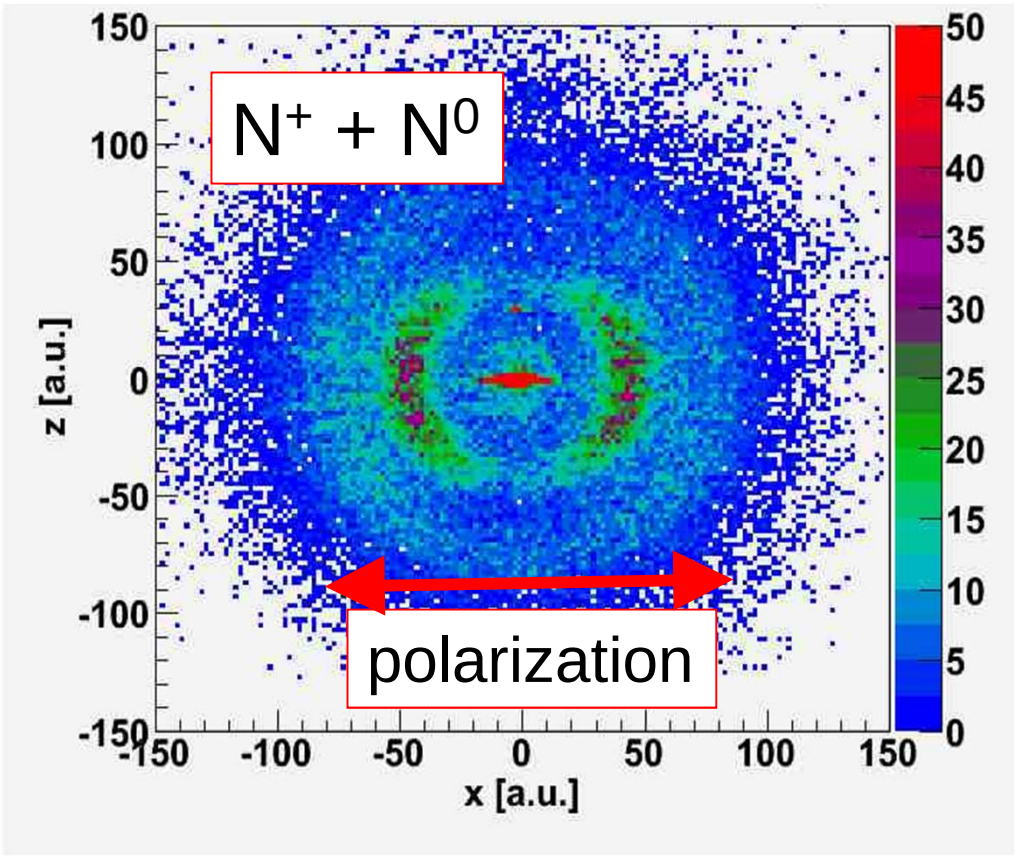
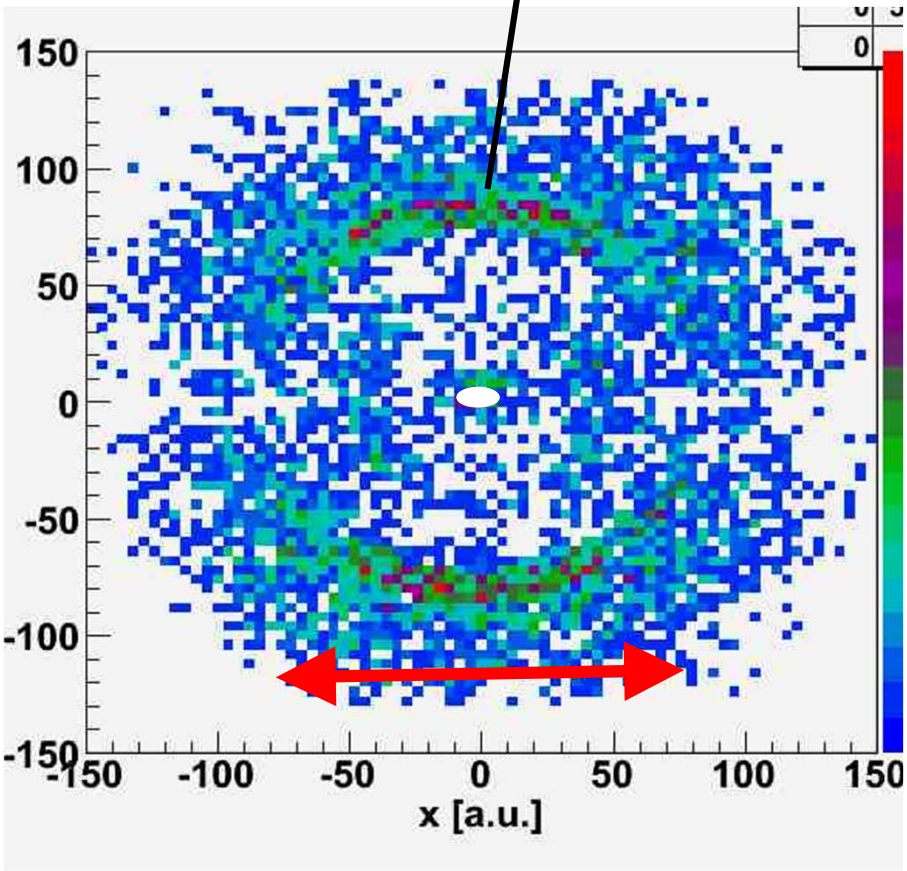
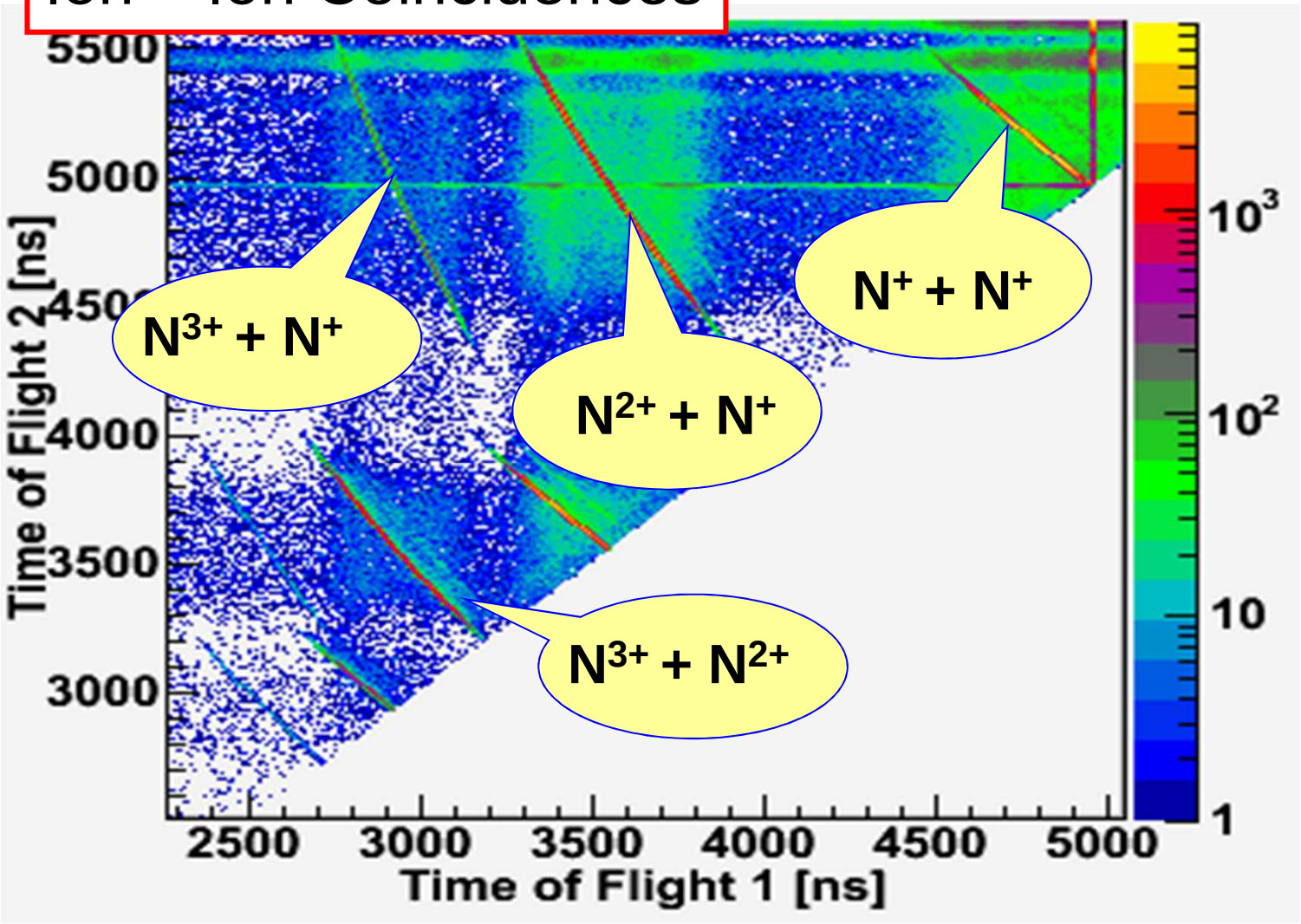


$N^+ + N^+$ (coincident)



Multi-Photon Ionization of N_2

Ion – Ion Coincidences



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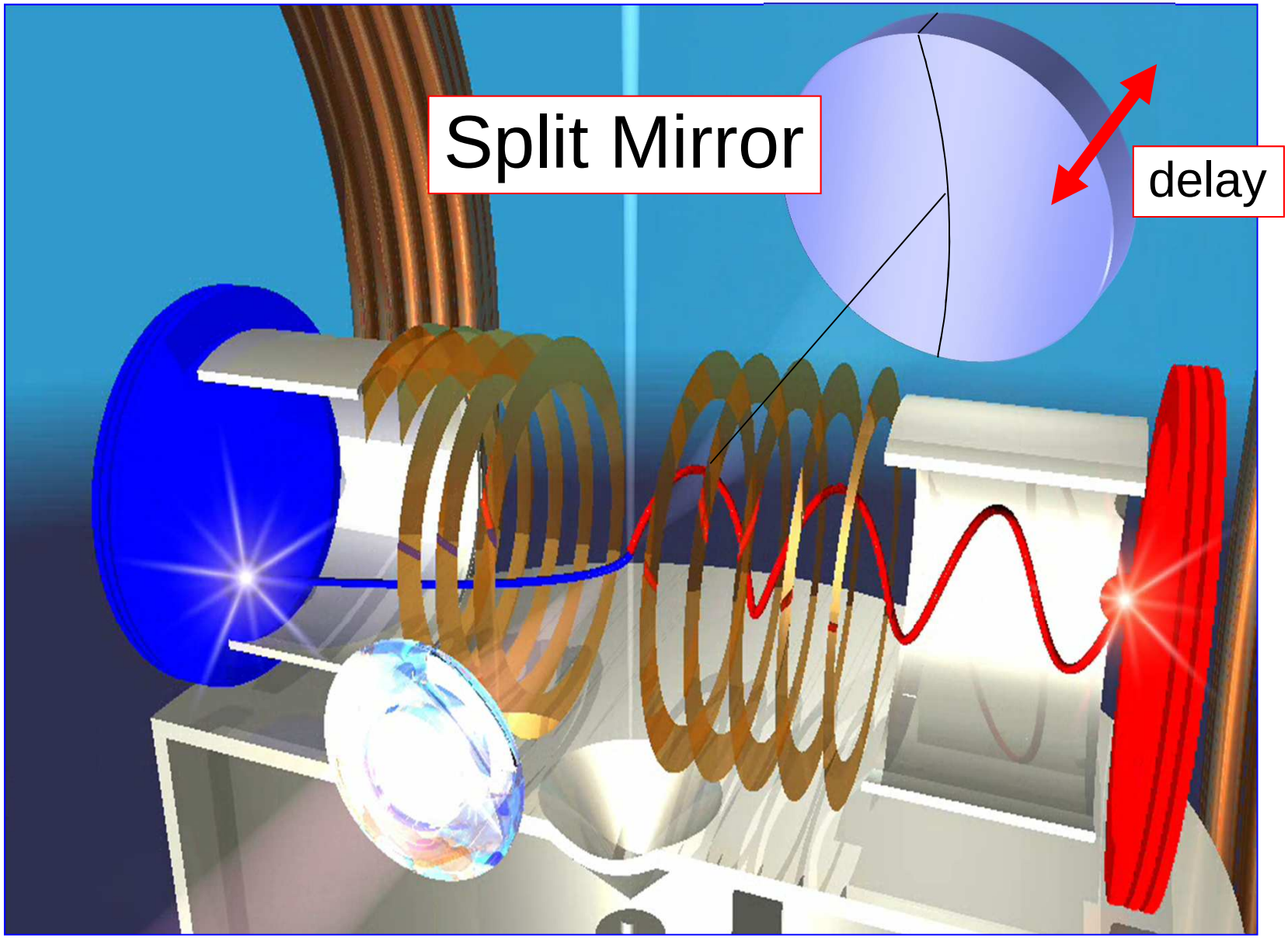
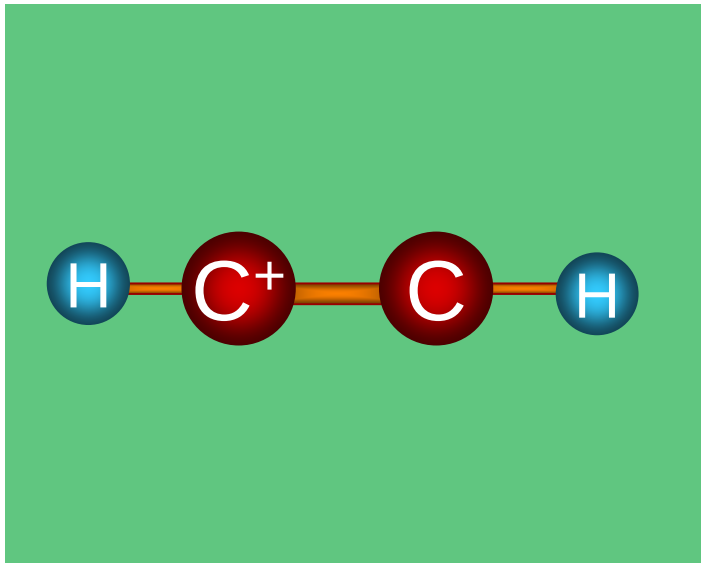
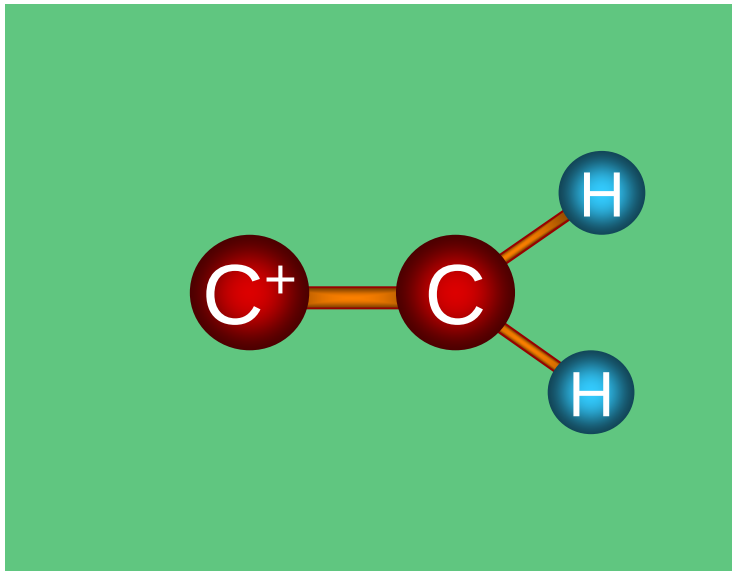
XUV-Pump – XUV-Probe setup



Conformational change of excited C_2H_2

Acetylene + photon (38 eV) => Vinylidene





Wikipedia:

" Isomerization.....transforming light into other forms of energy."

"Photoisomerizable molecules are already put to practical use, for instance, in pigments for rewritable CDs, DVDs, and 3D optical data storage solutions."

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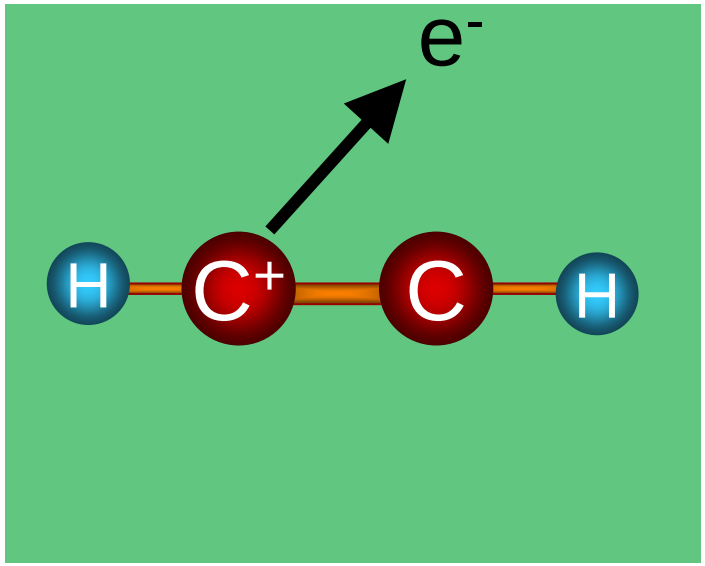

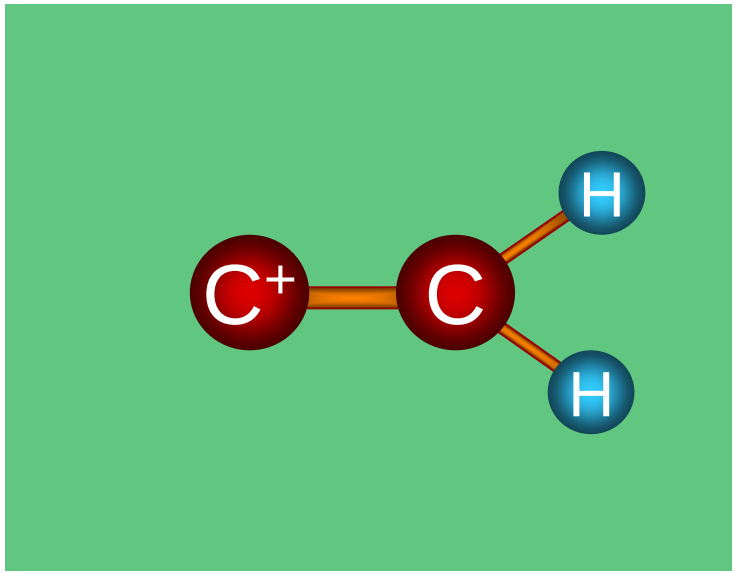

1. step:
Ionization with pump pulse

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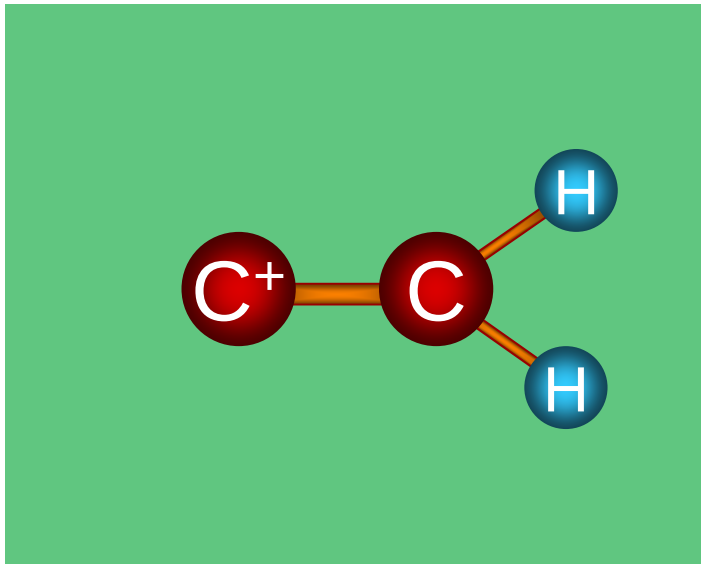

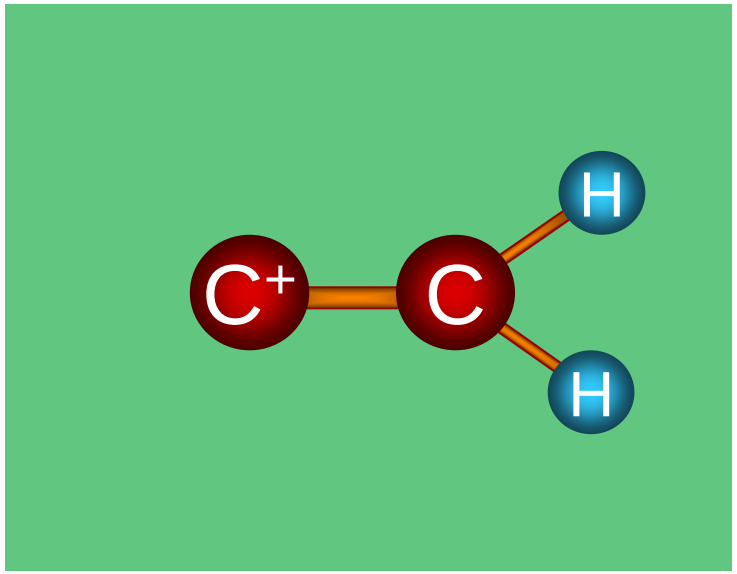

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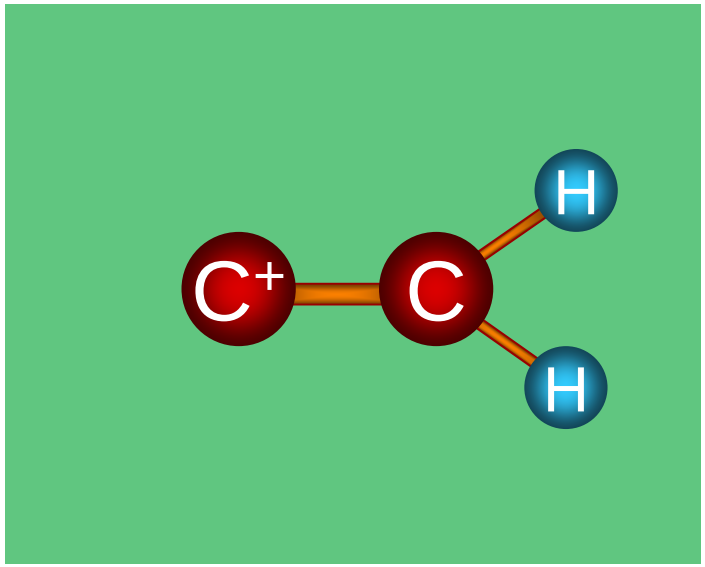

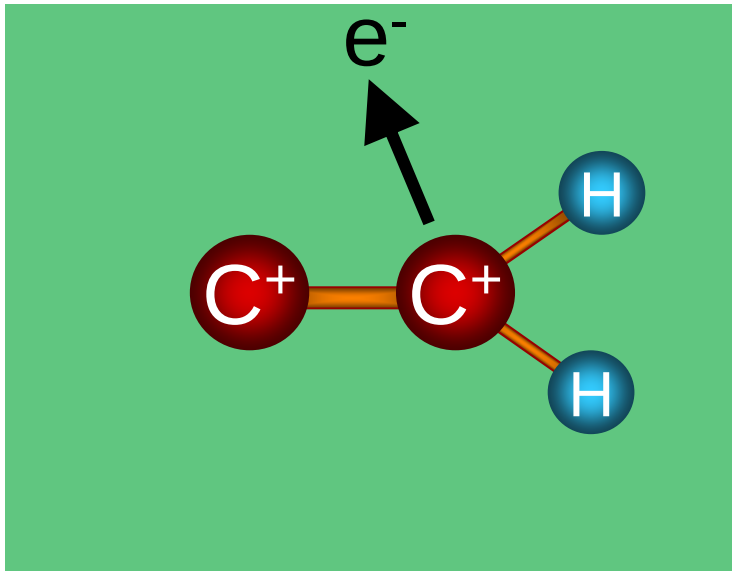

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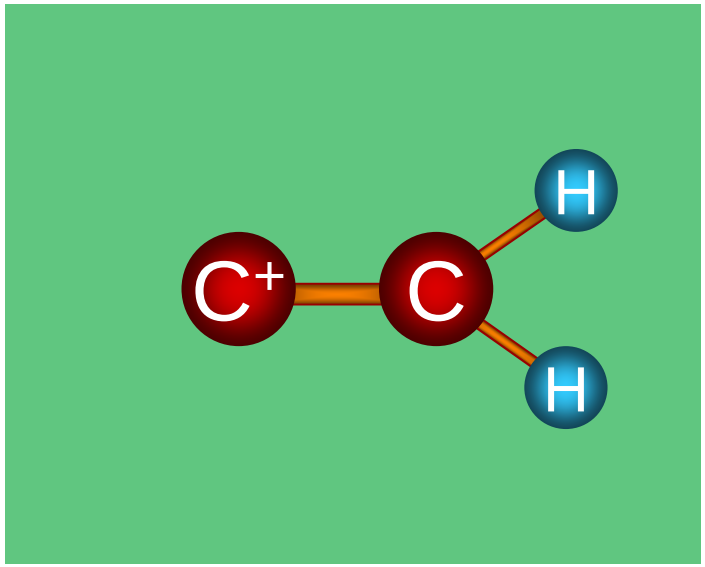

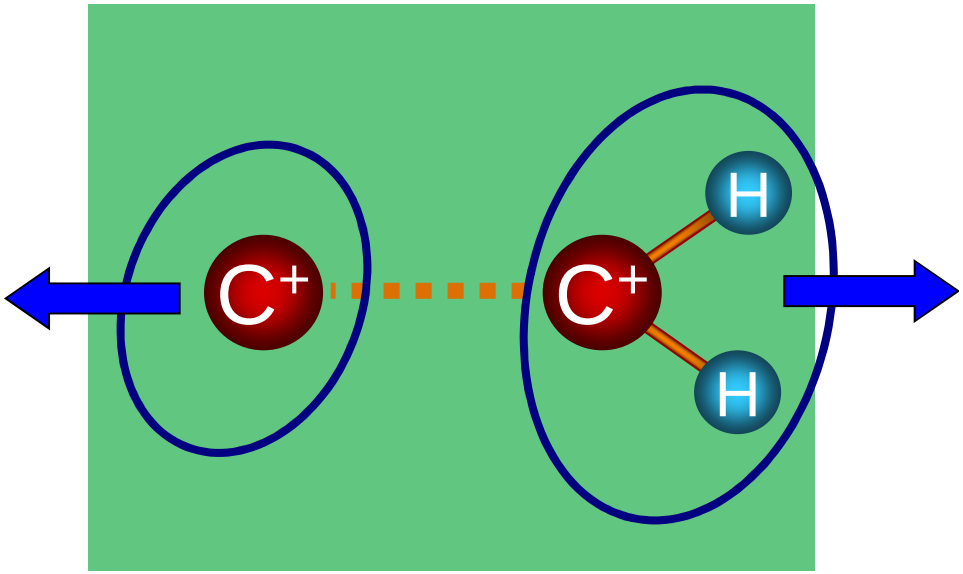

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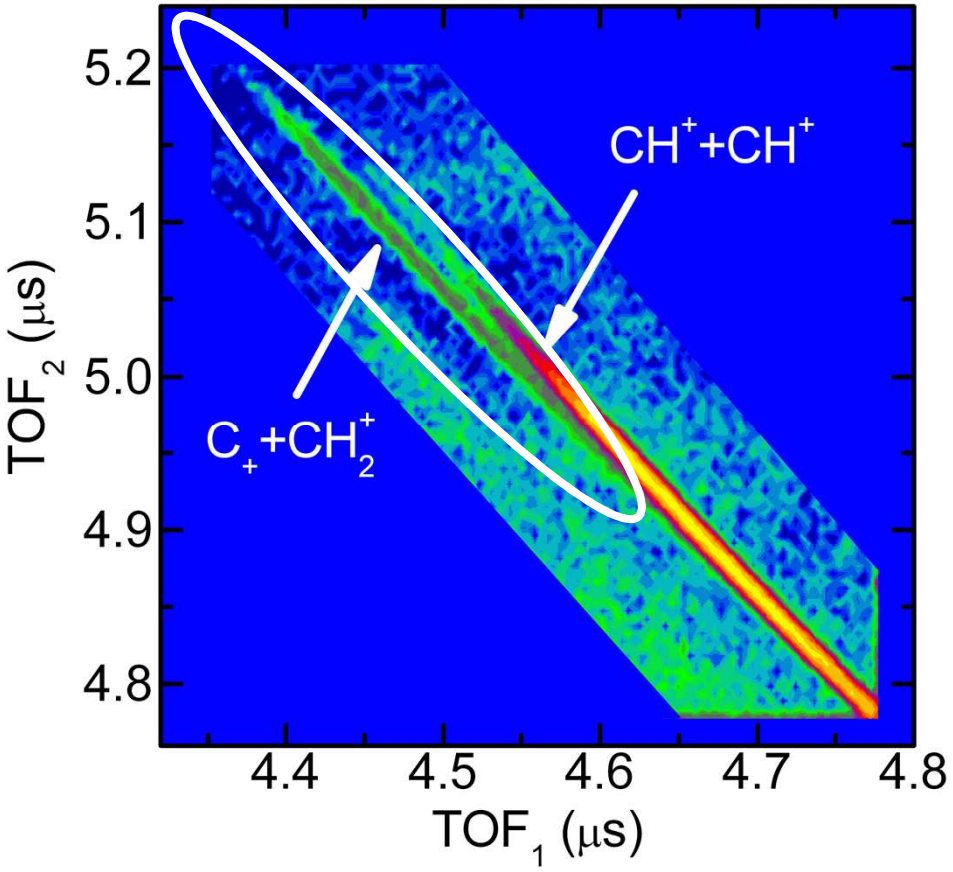

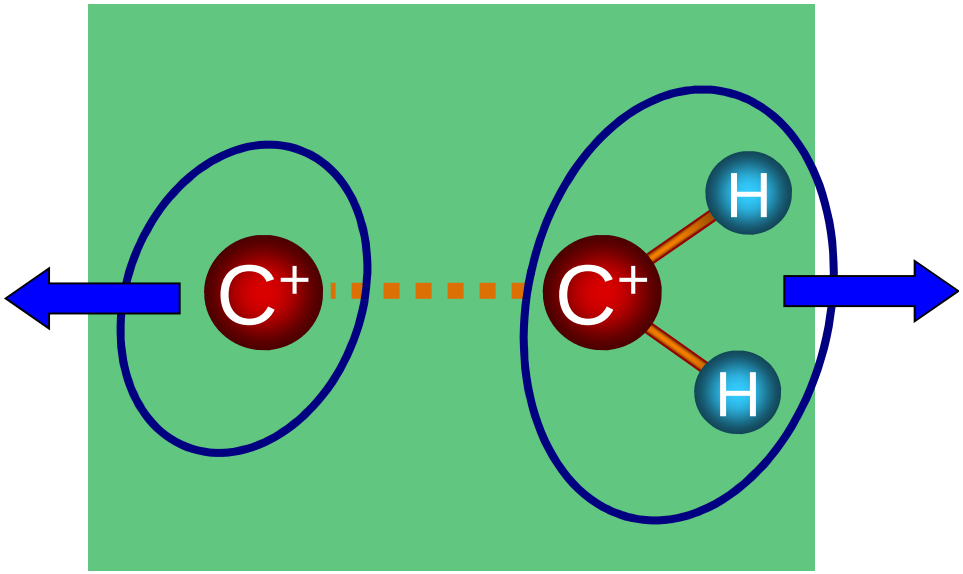

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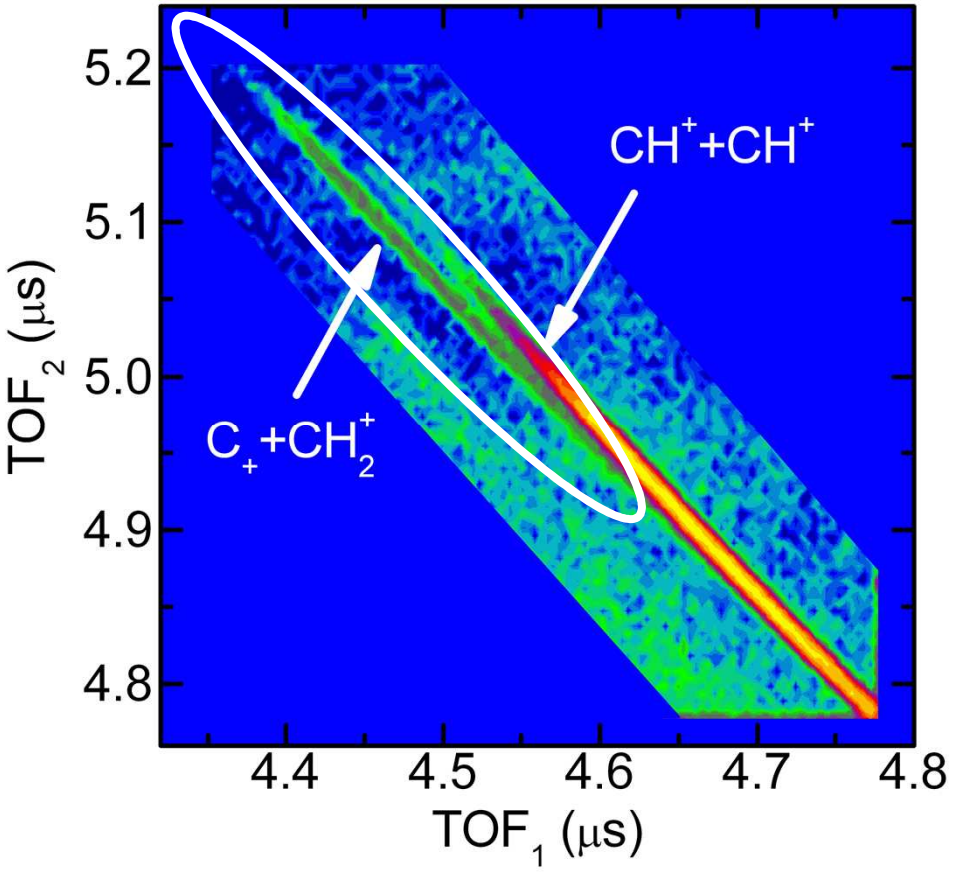

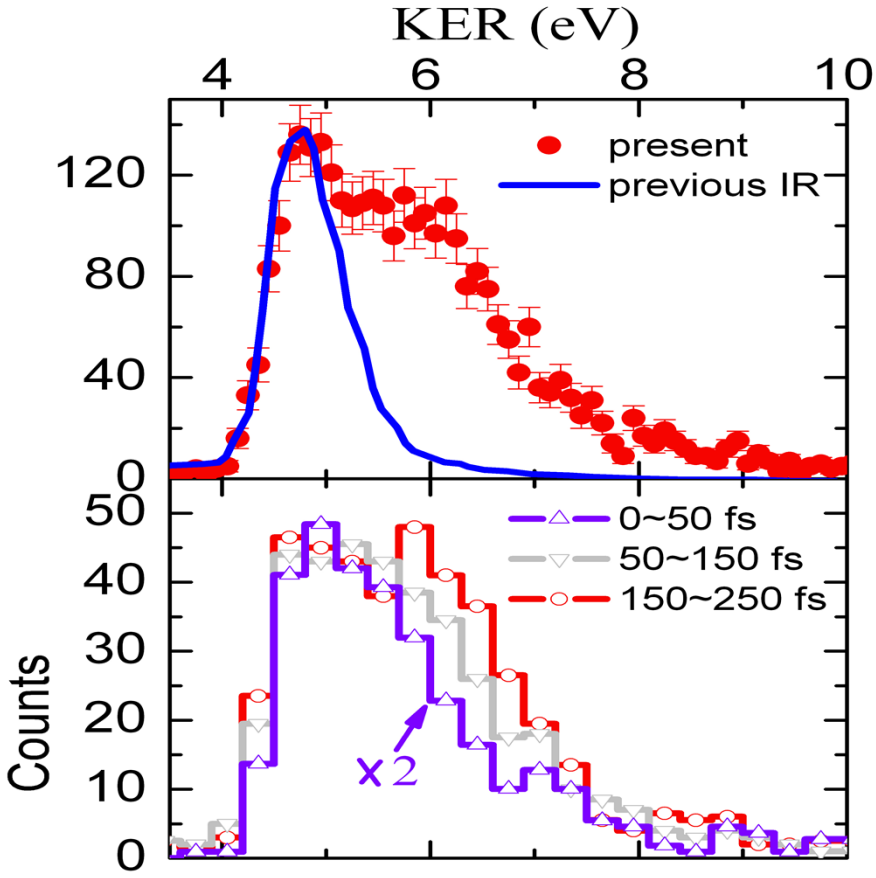

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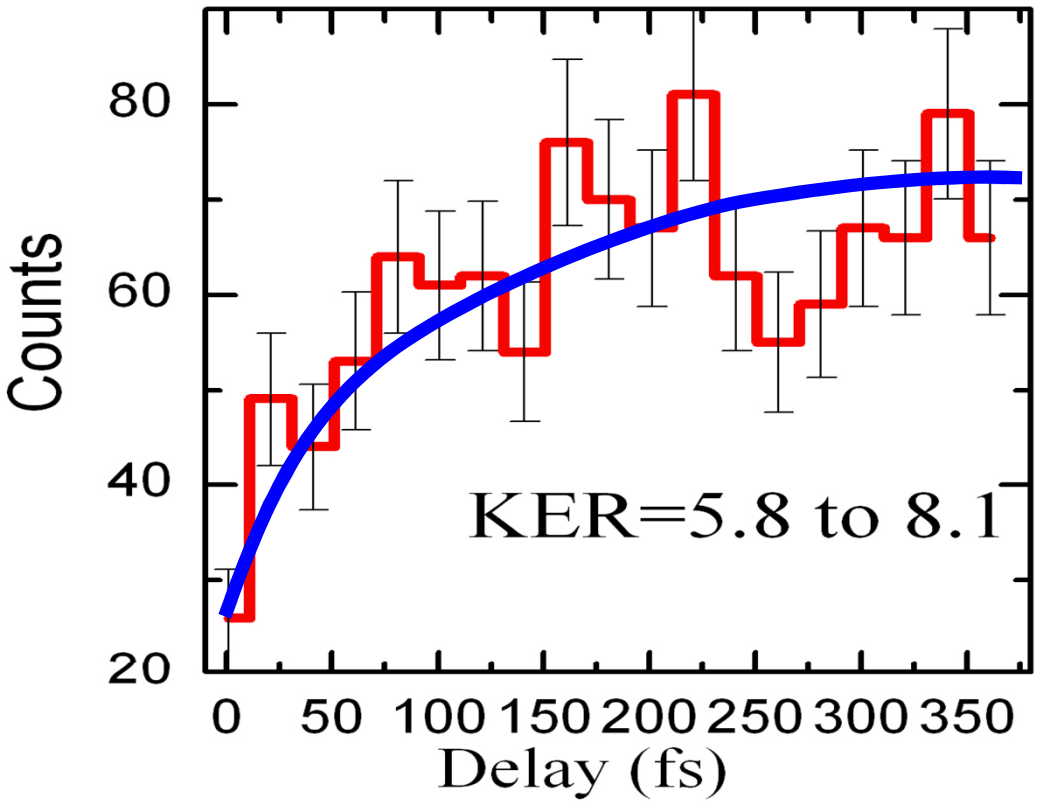

proton migration or isomerization time

$T \approx 52 \pm 15$ fs

Y. Jiang et al., PRL 105 (2010)

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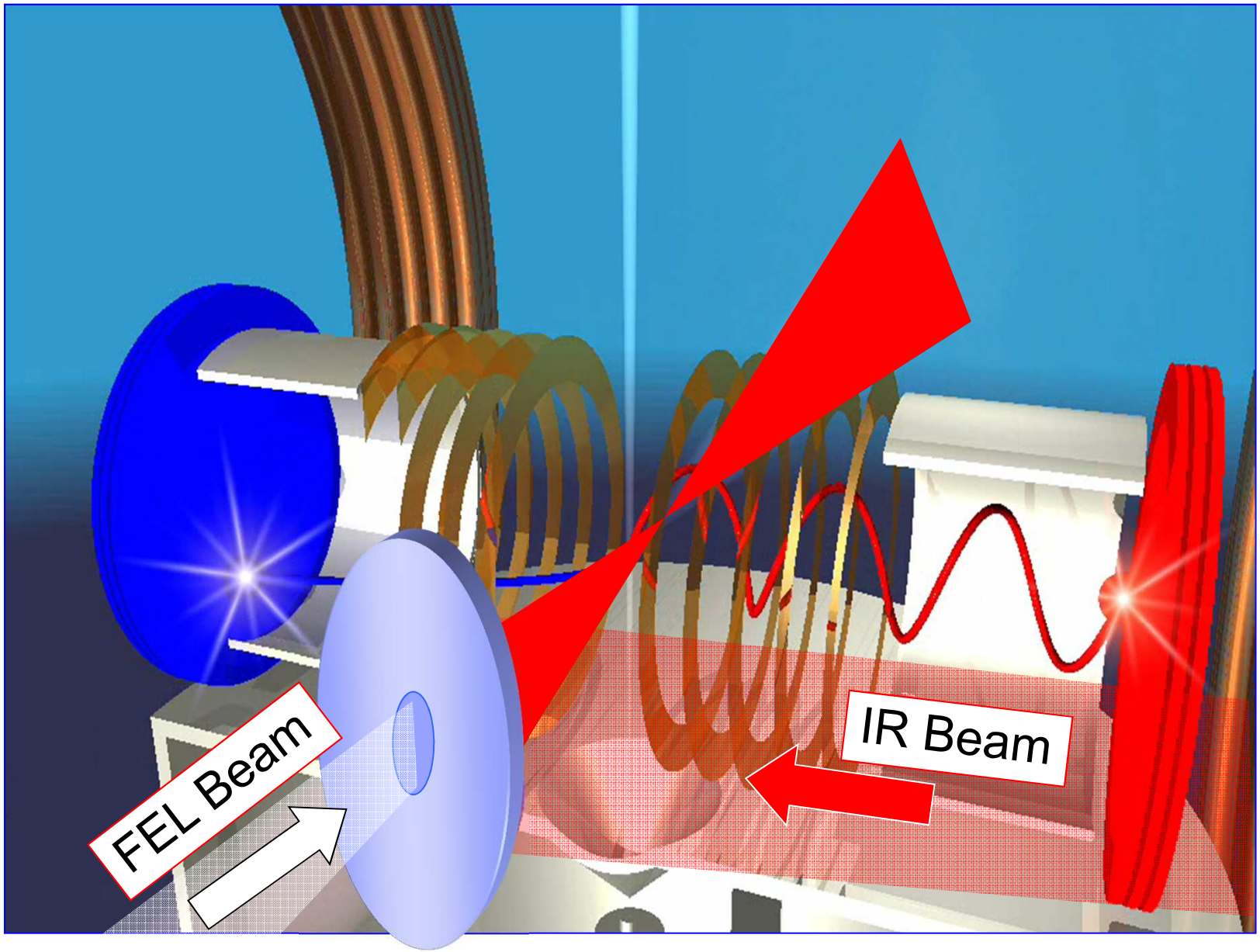
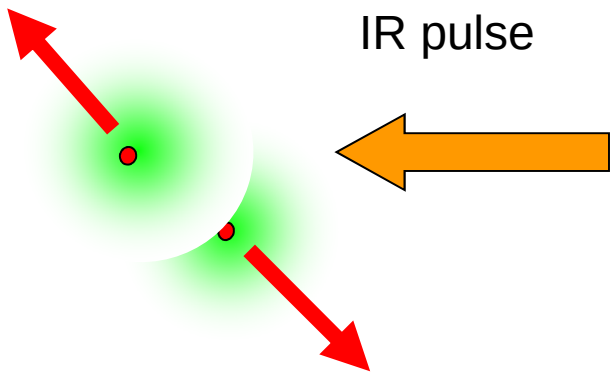
IR-Pump – XUV-Probe setup



IR – XUV Pump-Probe:
Multiple Ionization of Dissociating I_2 Molecules

The Idea:

1. step



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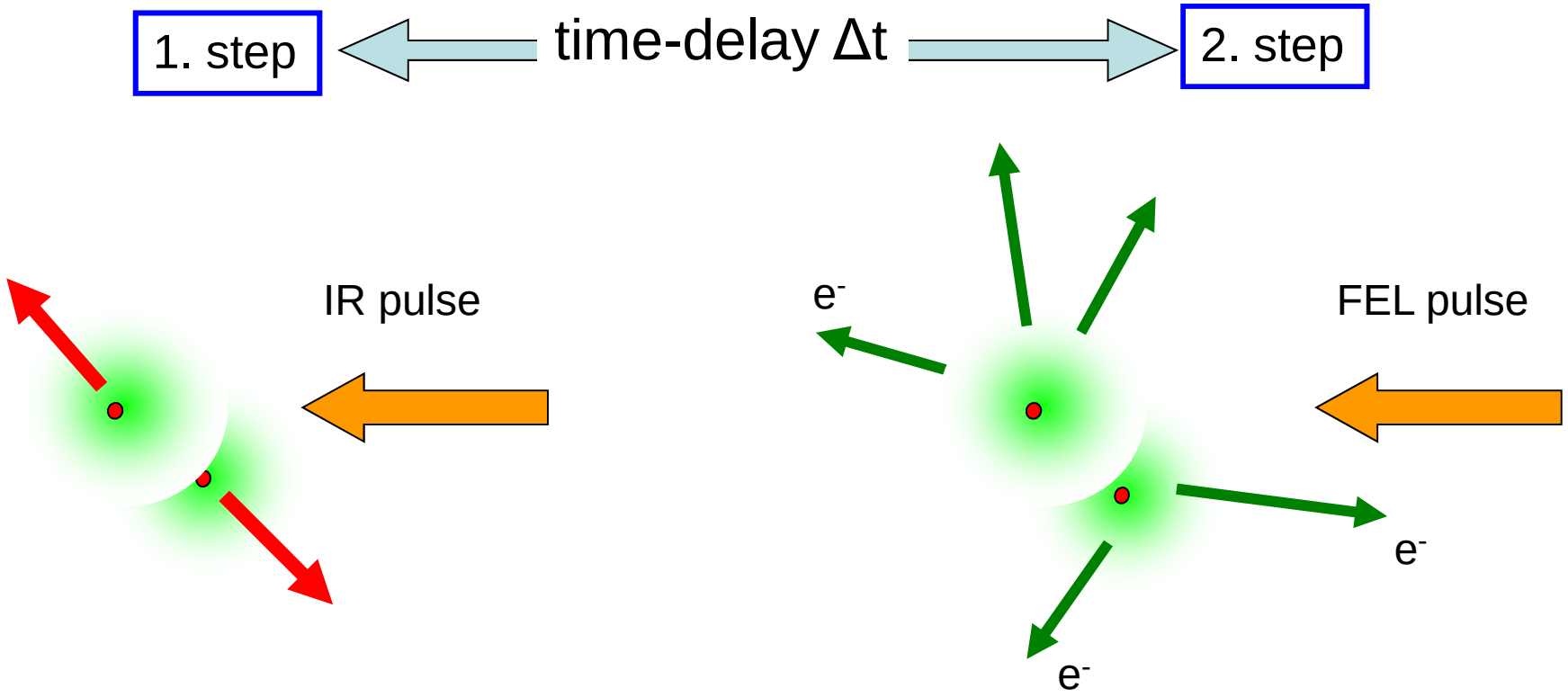

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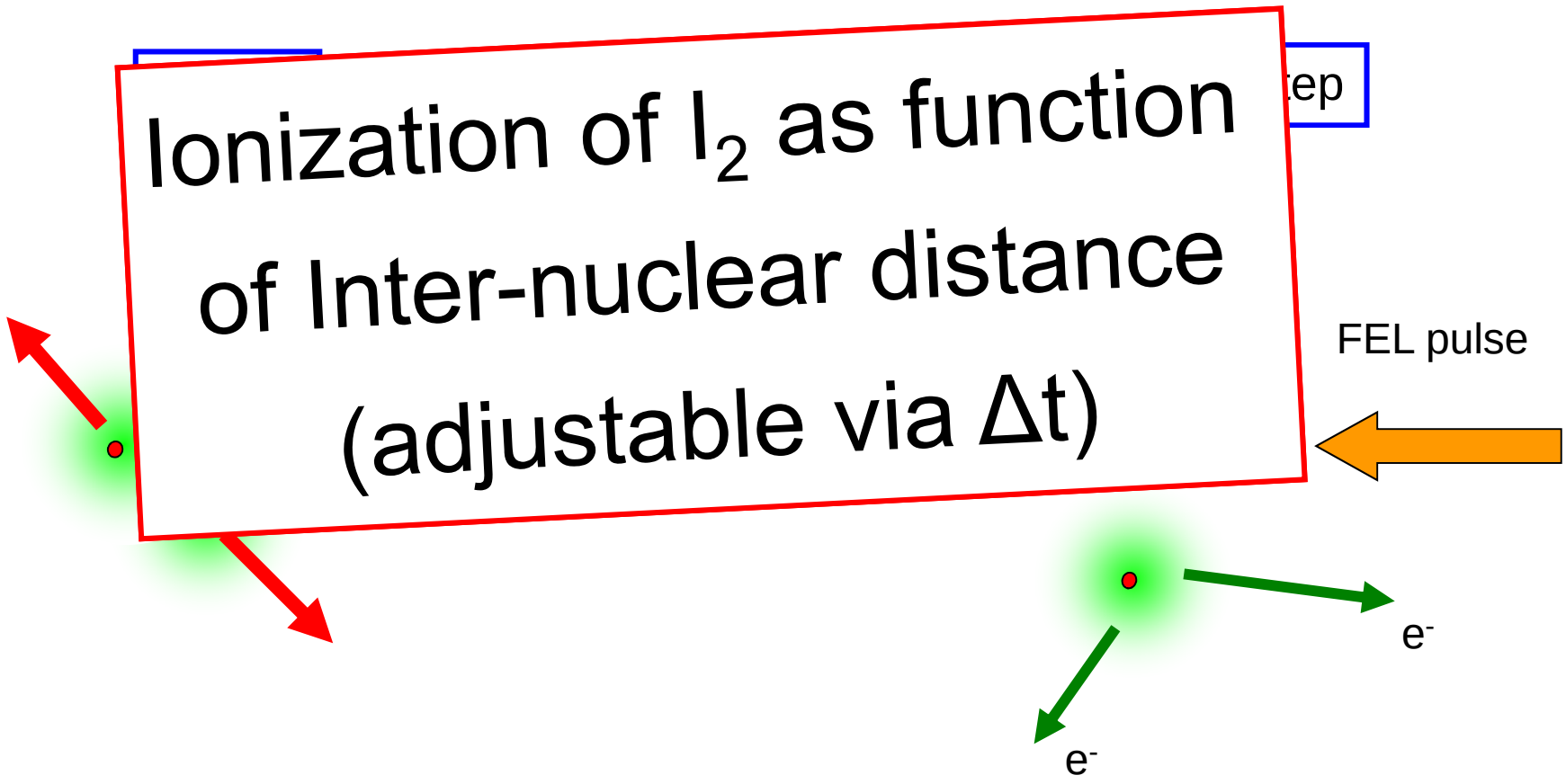


Why is this of interest ?

M. Richter et al., PRL 2009

Ionization of Xe with 92 eV Photons

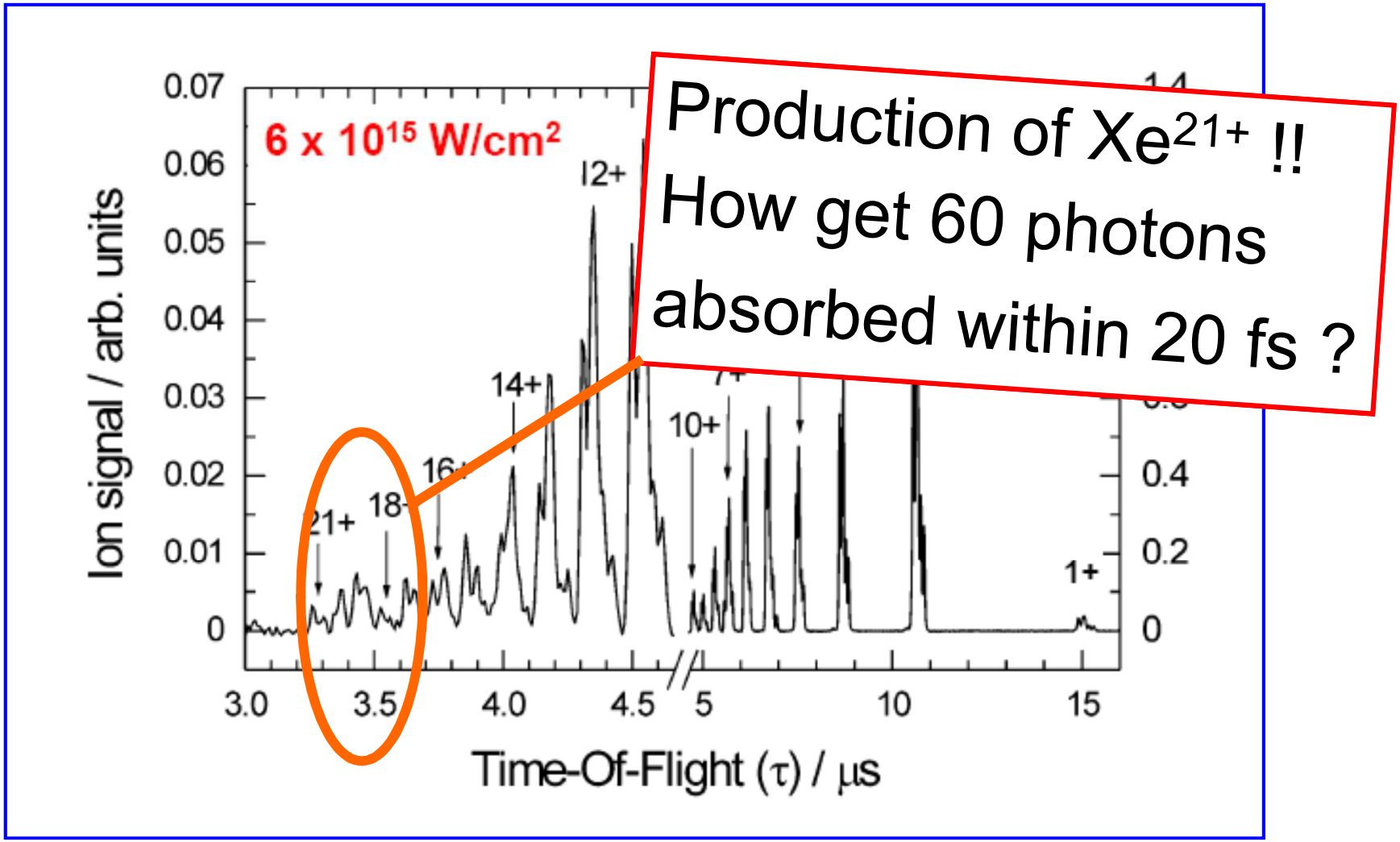


Photo-absorption cross section for Xe

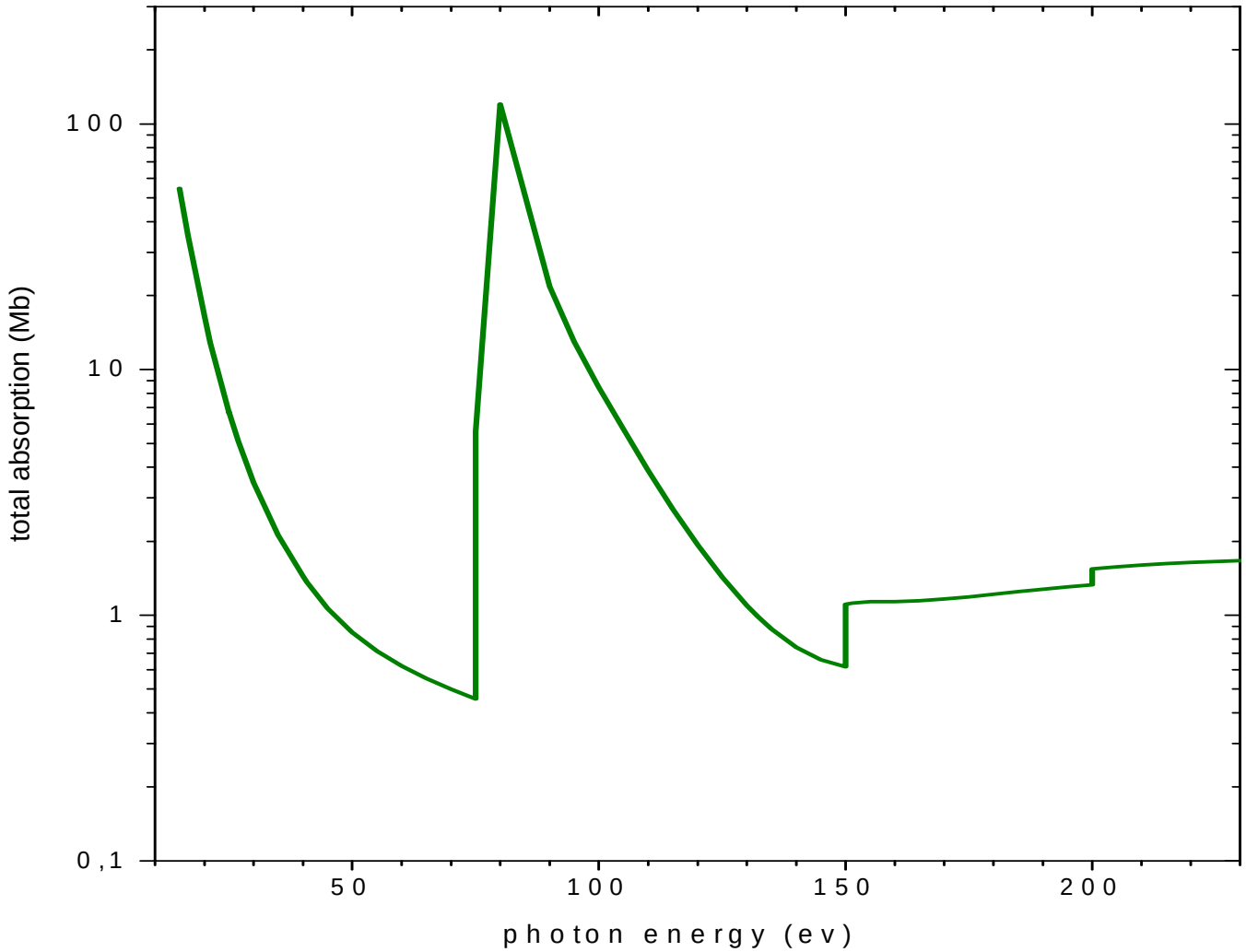
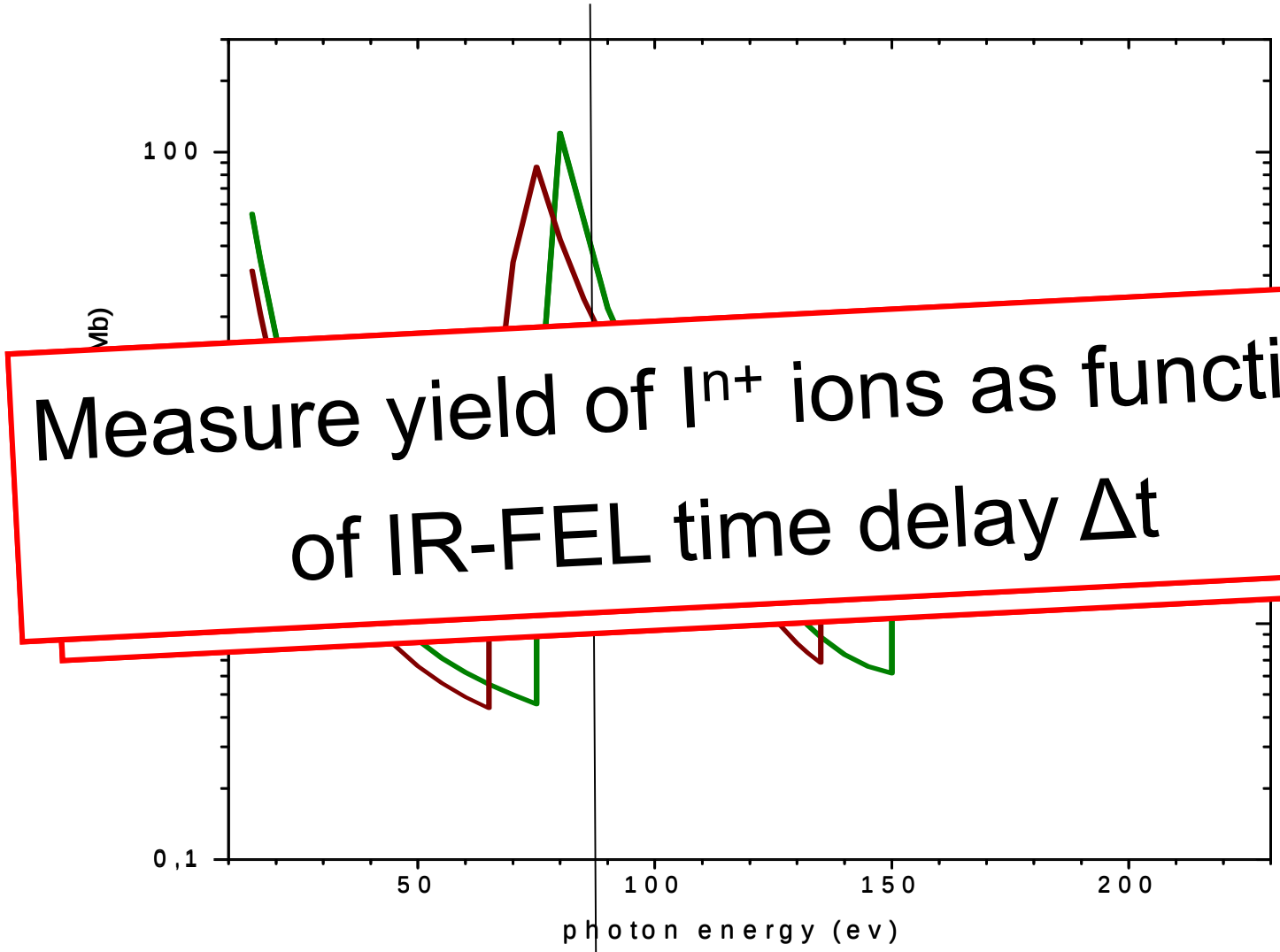


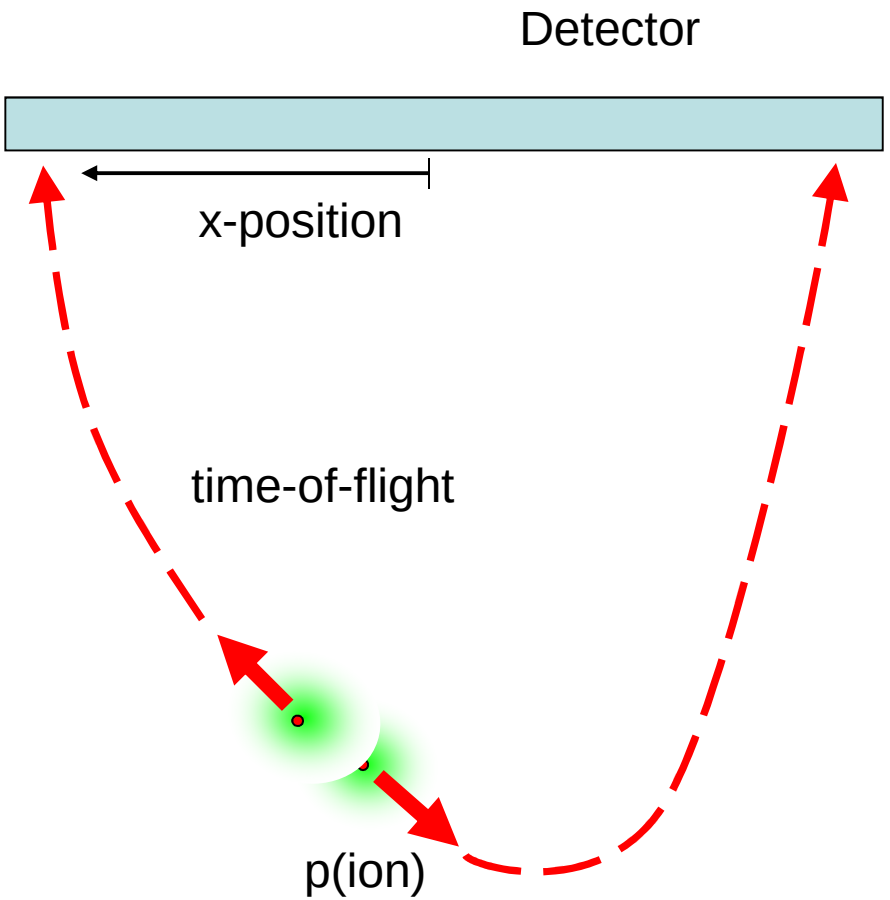
Photo-absorption cross section for Xe **and I**



Measure yield of I^{n+} ions as function of IR-FEL time delay Δt

~ 85 eV, 14 nm

Multiple Ionization of Dissociating I_2 Molecules



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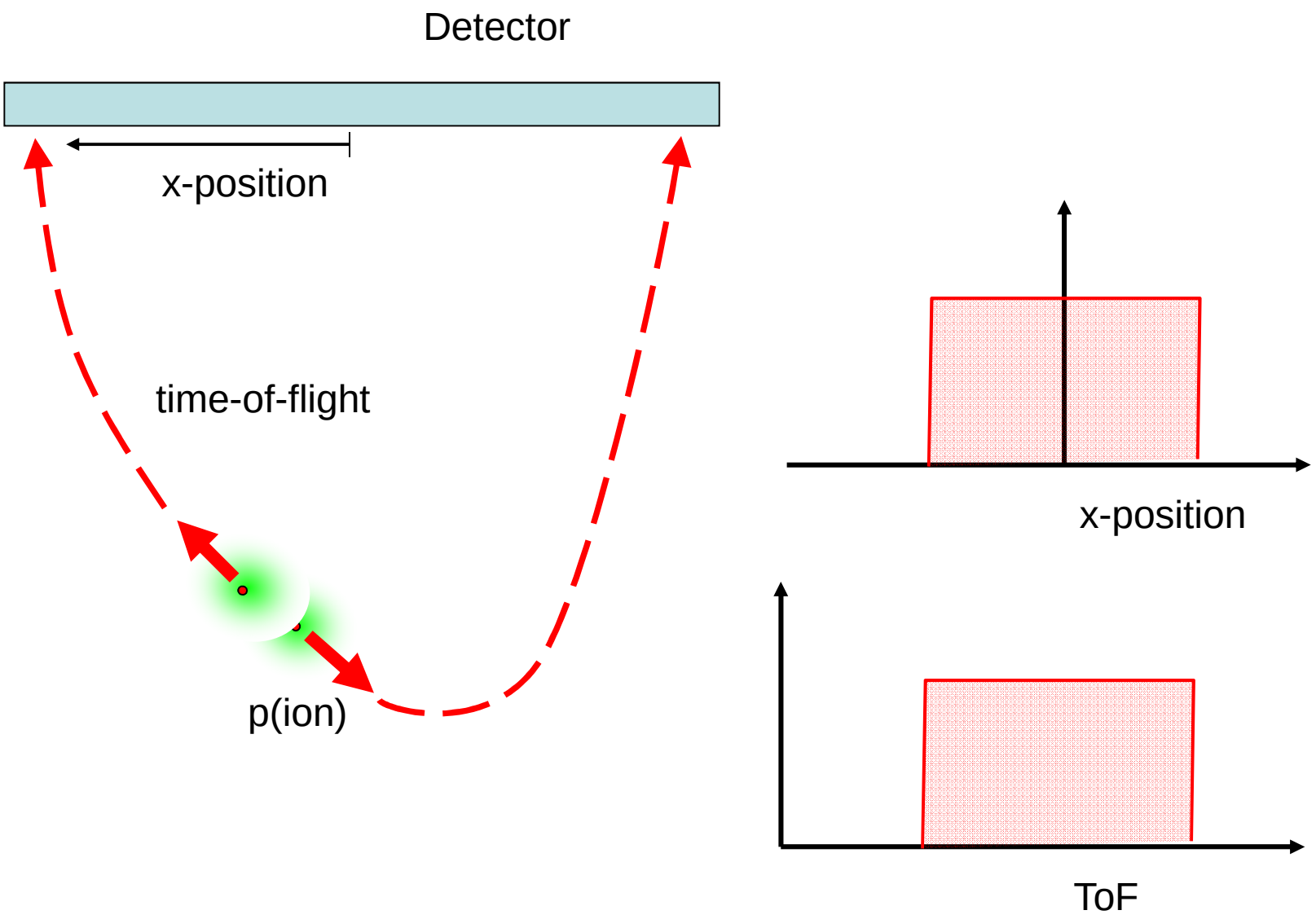

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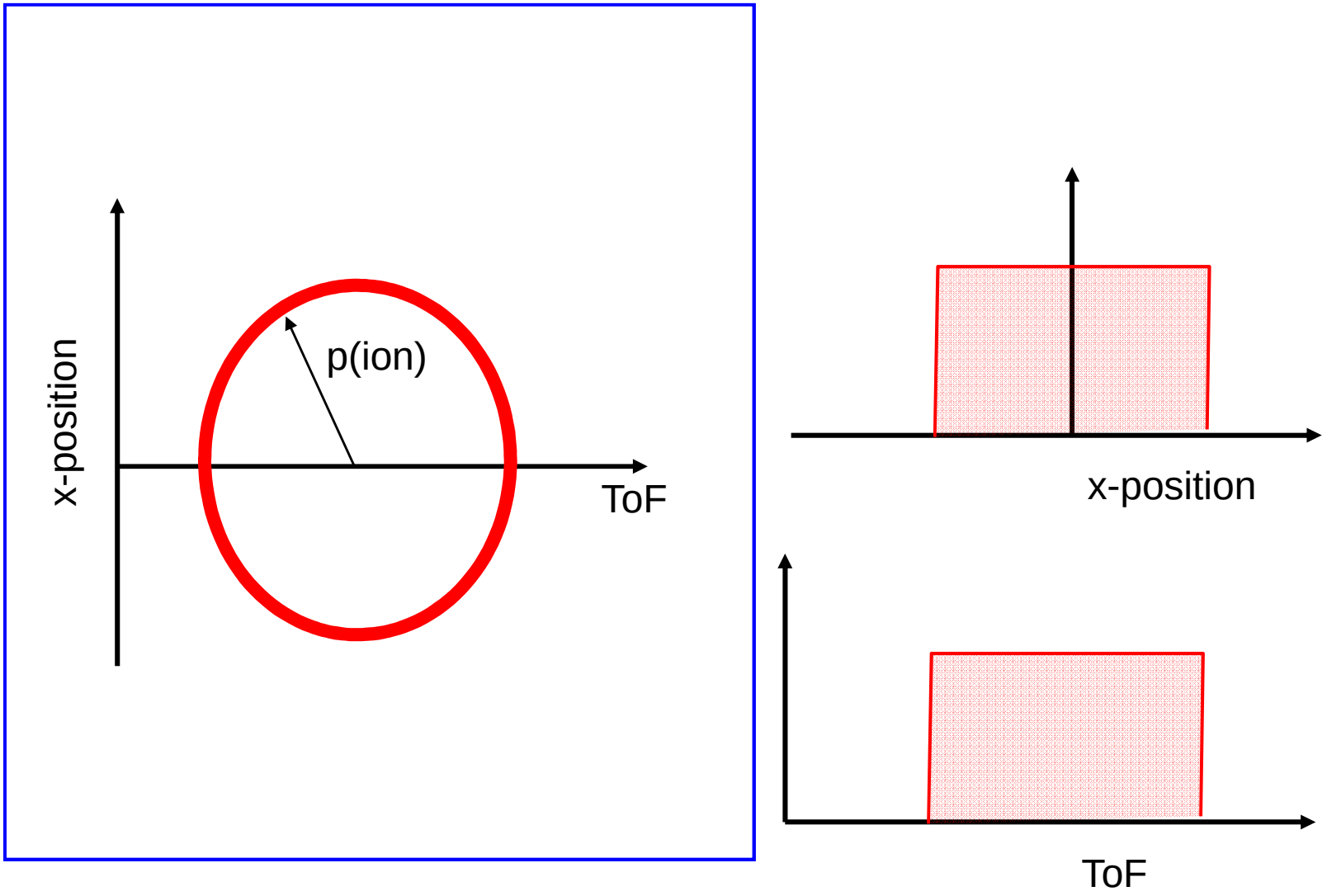
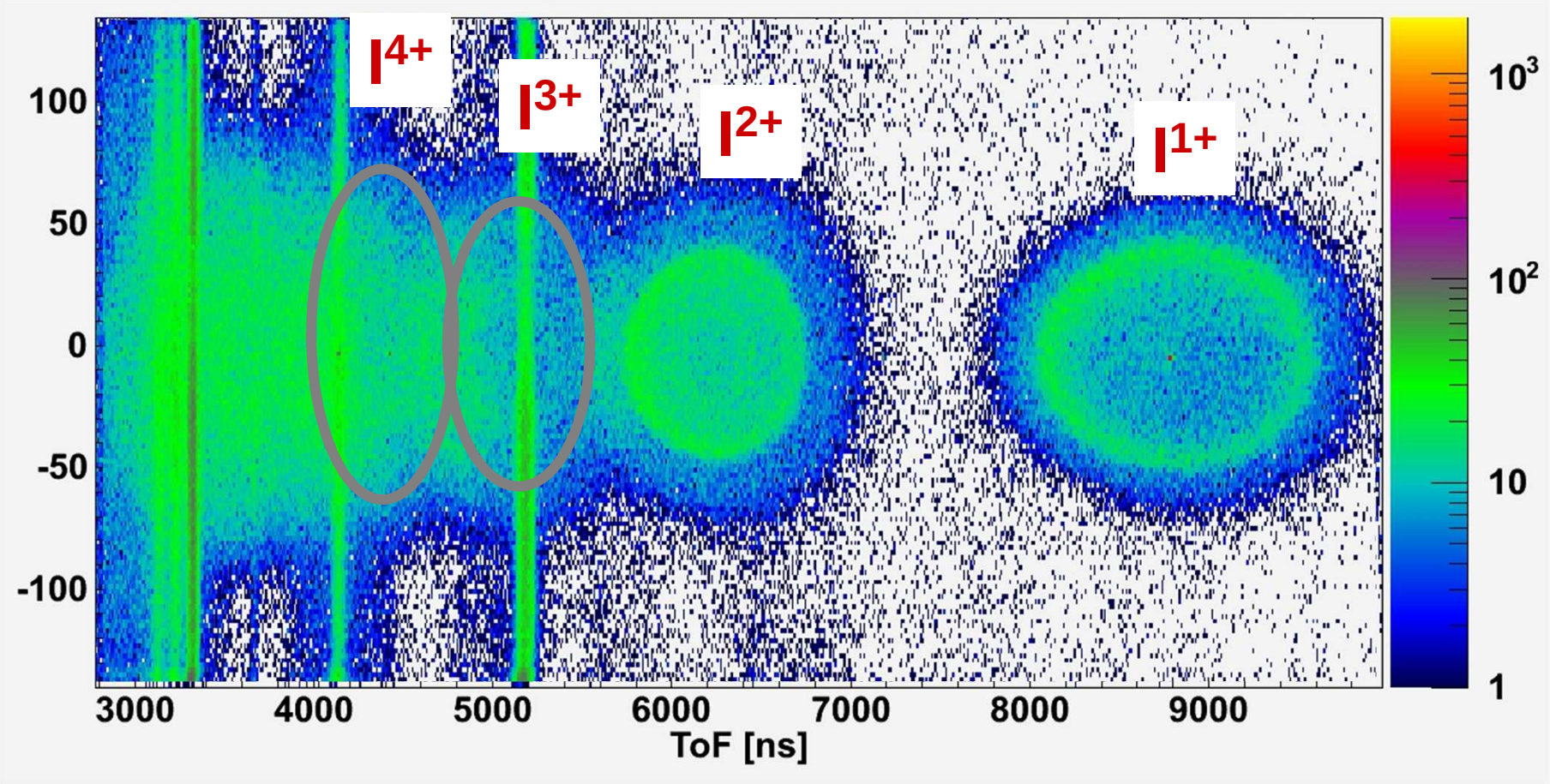


Multiple Ionization of Dissociating I_2 Molecules

FEL pulse only (no IR) (hv = 85 eV, I ≈ 10^{14} W/cm^2)



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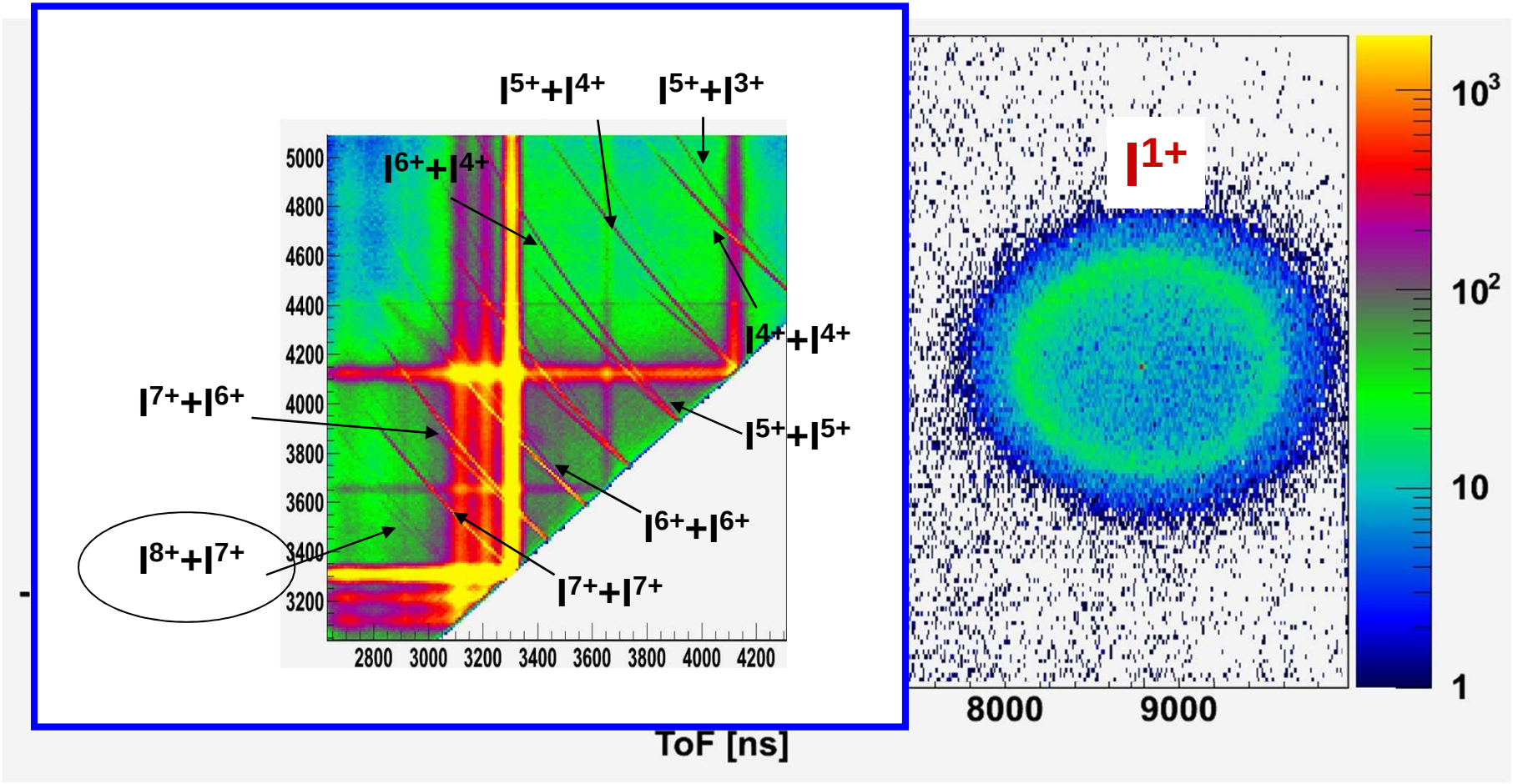

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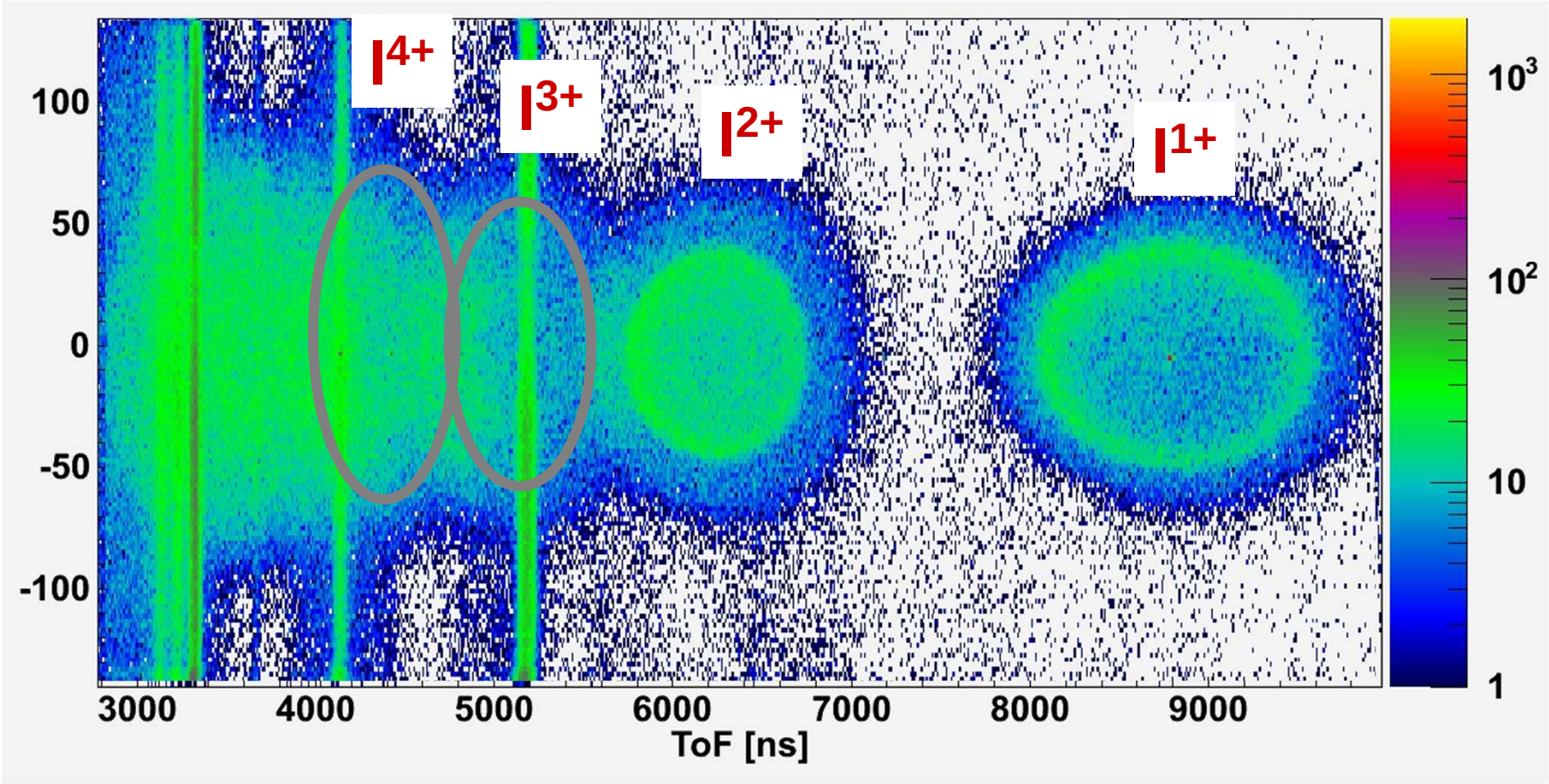

Multiple Ionization of Dissociating I_2 Molecules

FEL and IR

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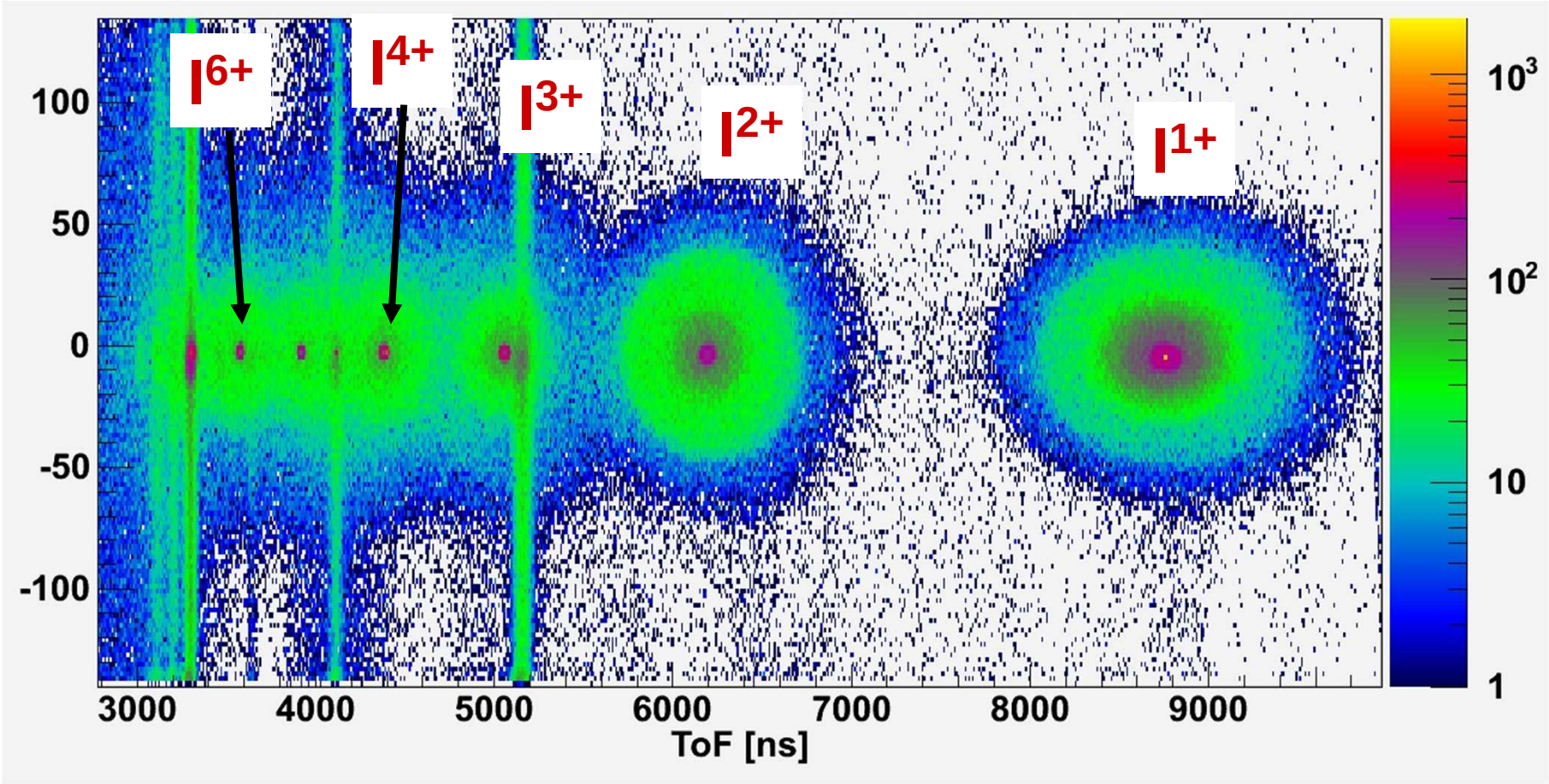

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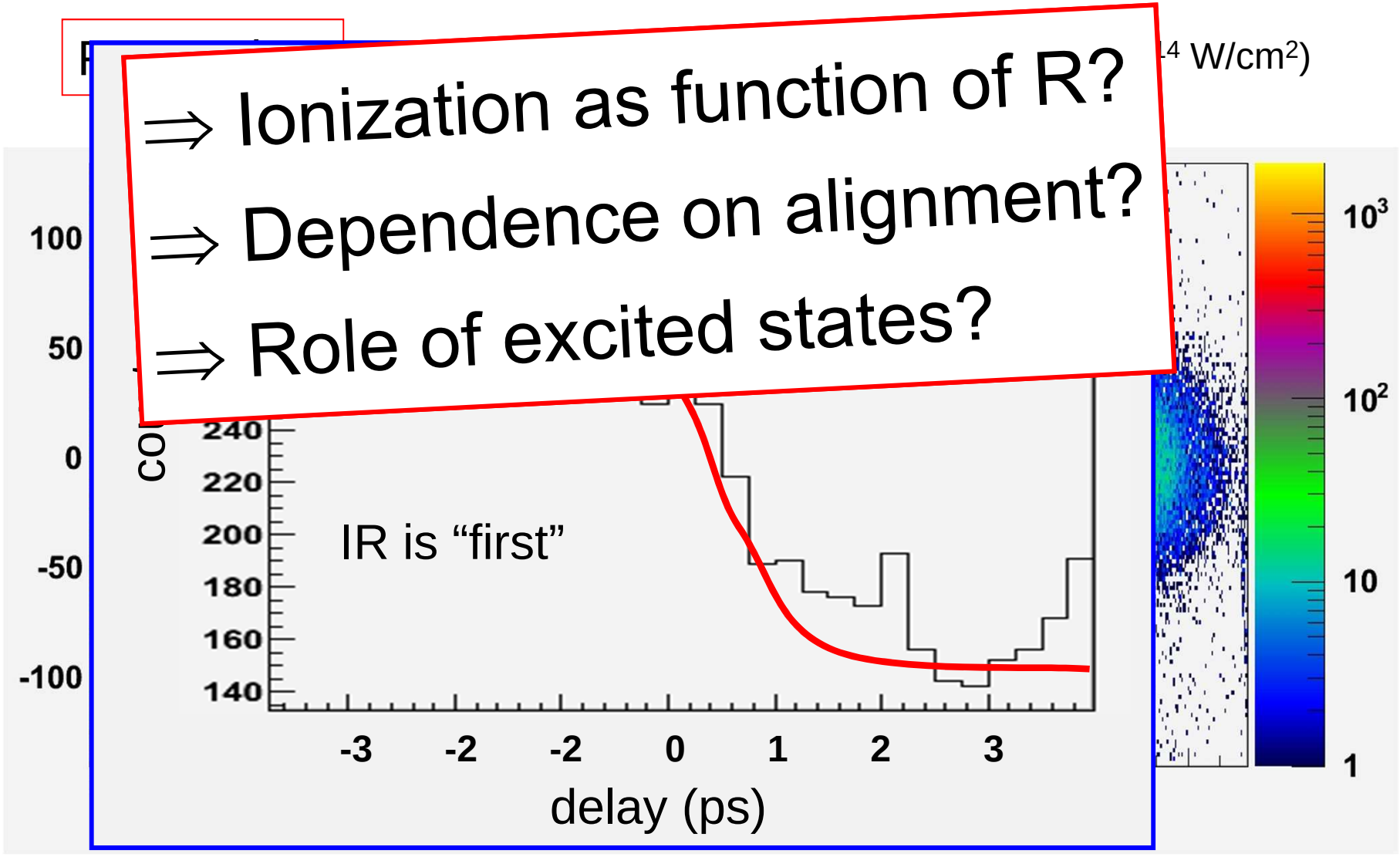

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Present Status (the advertising part)

In average 4 – 5 accepted experiments per proposal round
(in total between 40 – 50 shifts per round)

This is not very efficient !!

No room for continuous improvements !!

Hardly affordable on a longer term !!

- and **3 weeks** to collect date at the beam-line.
- everything is disassembled and brought back to HD.

Output during the last 2 years

Y. Jiang, A. Rudenko, M. Kurka, K. Kühnel, T. Ergler, L. Foucar, M. Schöffler,
S. Schössler, T. Havermeier, M. Smolarski, K. Cole, R. Dörner, S. Düsterer,
R. Treusch, M. Gensch, C.D. Schröter, R. Moshammer, J. Ullrich:
Few-photon multiple ionization of N2 by extreme ultraviolet free-electron laser radiation.
Phys. Rev. Lett. 102 (2009) 123002

M. Kurka, A. Rudenko, L. Foucar, K. Kühnel, Y. Ji
M. Smolarski, S. Sch usch, S. Fritzsche, A.
Grum-Grzhimailo, E.
C.D. Schröter, R. Mos
Two-photon double io experiment.
J. Phys. B. 42 (2009)

Y. Jiang, A. Rudenko,
K. Zrost, T. Ferger, D.
S. Schössler, T. Haver
S. Düsterer, R. Treusc
EUV-photon-induced n s.
J. Phys. B. 42 (2009) 1

Last 2 years:

14 in refereed journals

3 of them in PRL

C. Bostedt, H. Chapman, J. Costello, J.R.C. Lopez-Urrutia, D. Düsterer, S. Epp,
J. Feldhaus, A. Föhlisch, M. Meyer, T. Möller, R. Moshammer, M. Richter,
K. Sokolowski-Tinten, A. Sorokin, K. Tiedtke, J. Ullrich, W. Wurth:
Experiments at FLASH
Nucl. Instr. and Methods A 601 (2009) 108

Y. Jiang, A. Rudenko, E. Plesiat, L. Foucar, M. Kurka, K.U. Kühnel, T. Ergler,
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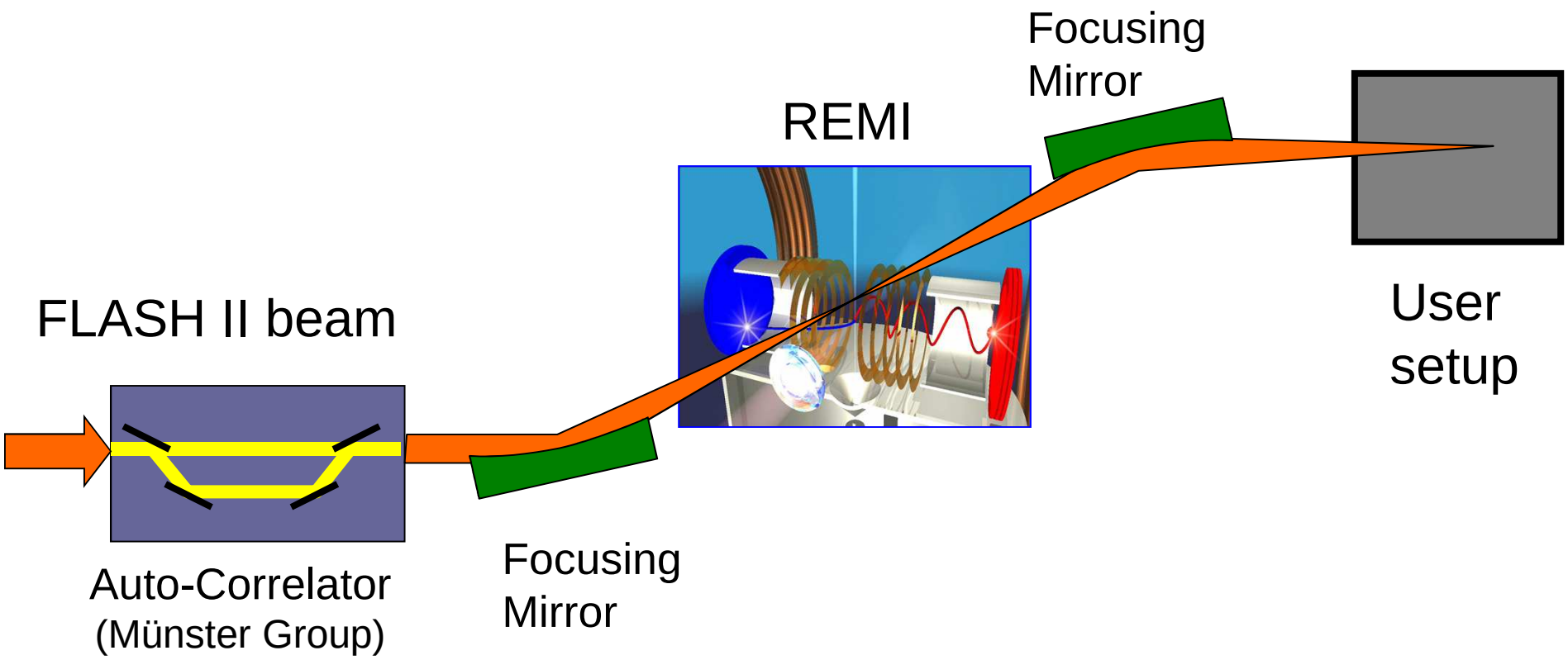
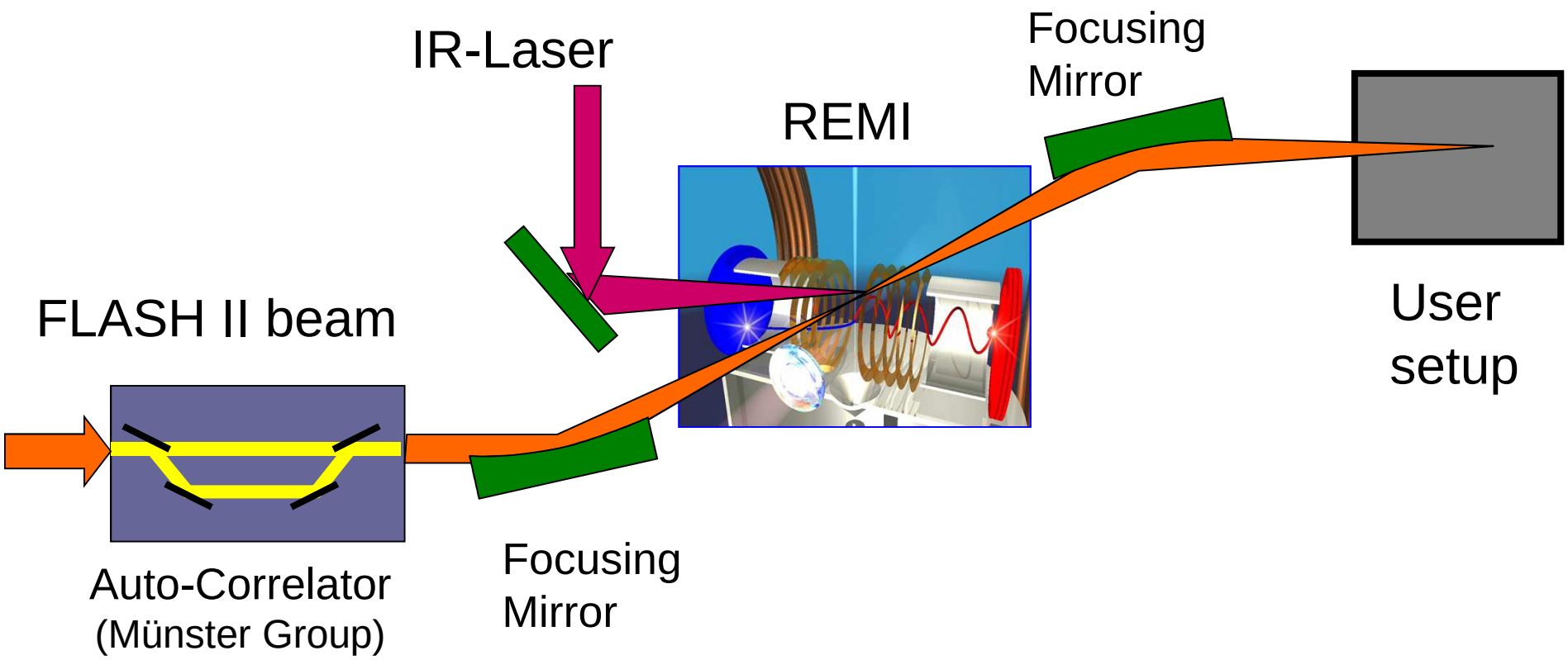
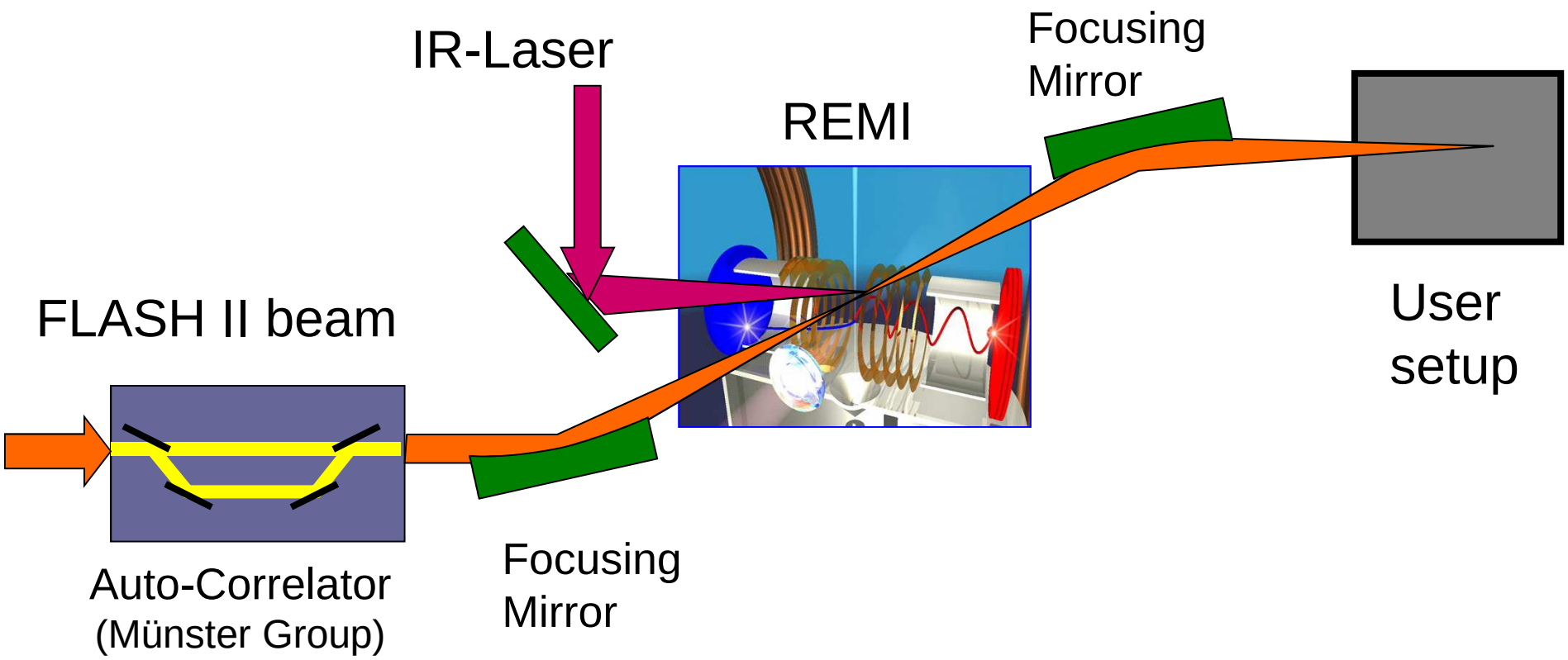
Realization of permanent installation



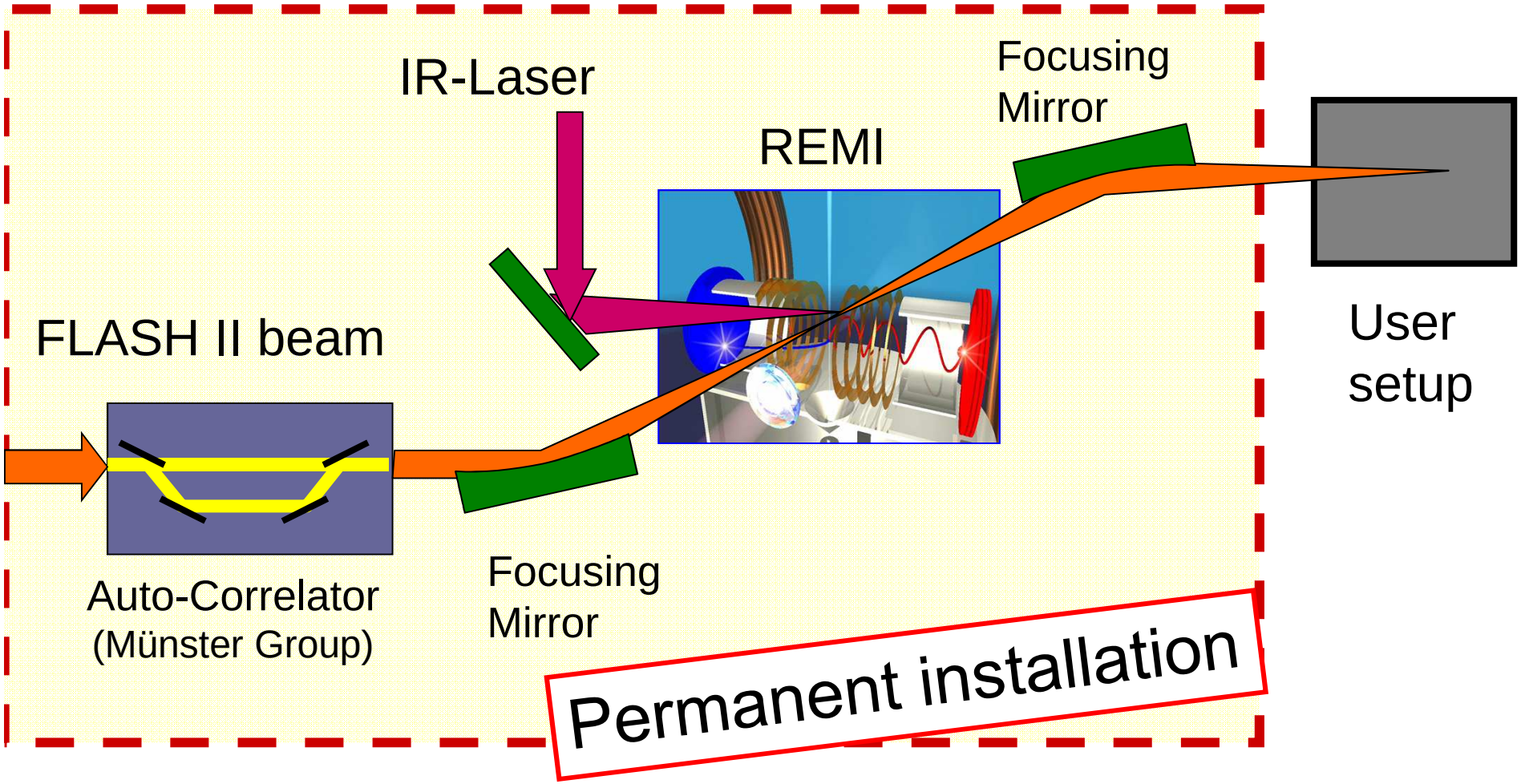
Realization of permanent installation



The “Dream Beamline”



The “Dream Beamline”



The “Dream Beam” (parameters)

Wavelength:	5 nm …. 50 nm (emphasis on long)
Pulse-Length:	10 fs (ideally 1 fs)
Repetition rate:	10 kHz (with 2 μs spacing)
Intensity:	10 μJ … 100 μJ

AND

Fully synchronized IR-Laser (on a level of < 10 fs) !!!

LIST (Incomplete) of **USERS / COLLABORATORS** that expressed interest in **REMI** experiments:

Prof. Ali Belkacem . . .	LBNL Berkeley
Prof. Itzik Ben-Itzhak . .	Kansas State Univ.
Prof. Nora Berrah	Western Michigan Univ.
Prof. John Costello	Dublin City Univ.
Prof. Reinhard Dörner	Univ. Frankfurt
Dr. Uwe Hergenhahn	MPI für Plasmaphysik
Prof. Ronnie Hoekstra	Univ. Groningen
Prof. Matthias Kling . . .	MPI für Quantenoptik
Prof. Edwin Kukk	Turku Univ.
Dr. Michael Meyer . .	XFEL Desy
Prof. Henrik Stapelfeldt	Aarhus Univ.
Prof. Kjyoshi Ueda	Tohoku Univ.

End