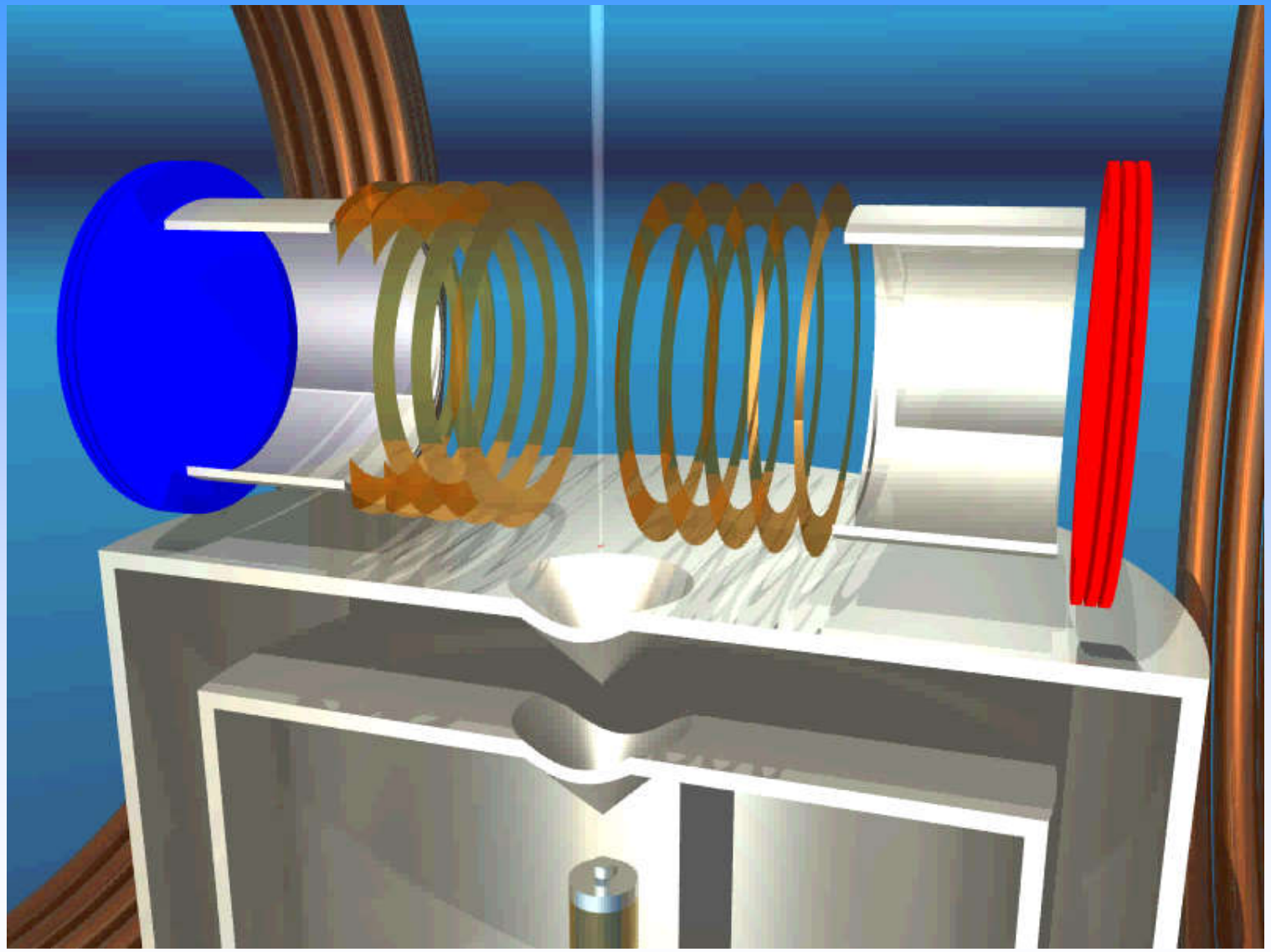
The XFEL-**Reaction Microscope**

- design, status and parameters

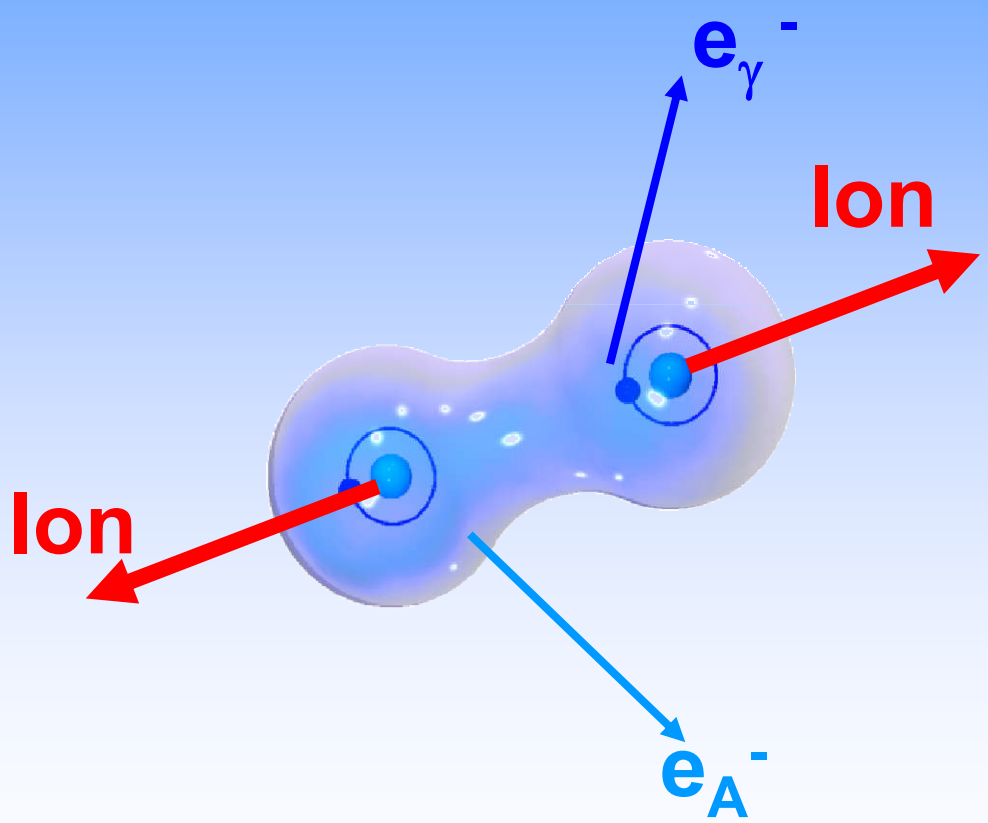
Markus S. Schöffler

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

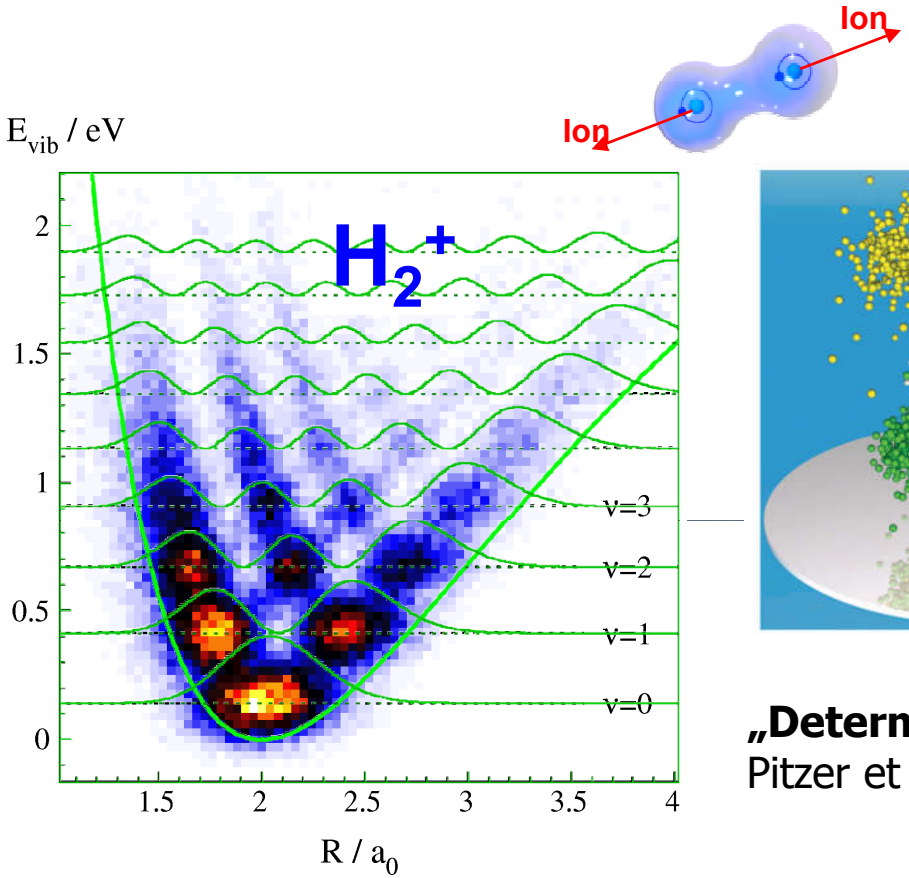
The COLTRIMS-Reaction Microscope



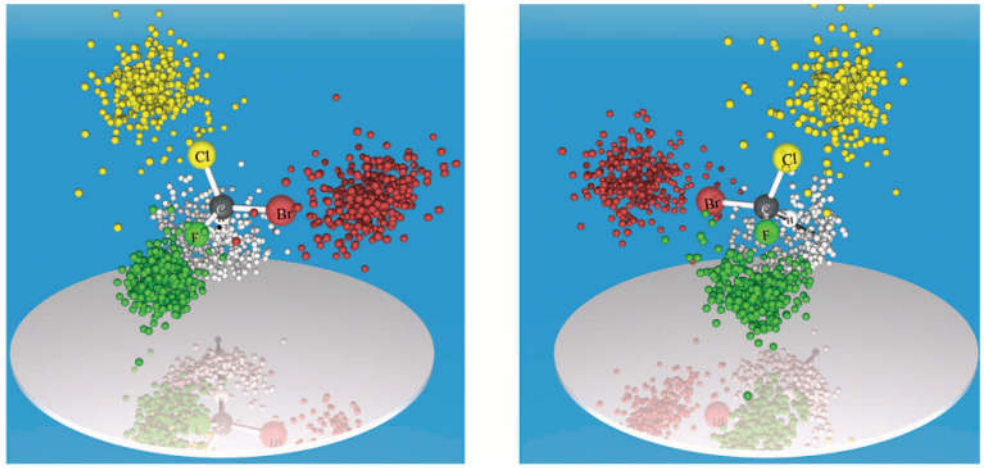
Introduction



Ion detection

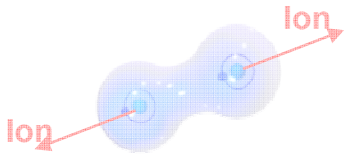


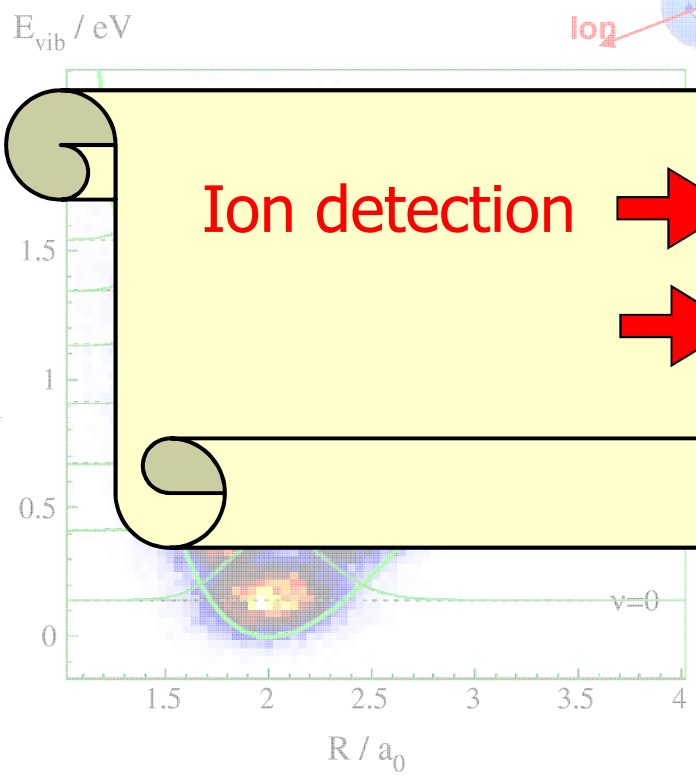
„Spatial Imaging at the quantum limit"
L. Schmidt et al PRL **108**, 73202 (2012)



„Determination of the absolute Configuration"
Pitzer et al., Science **341**, 1096 (2013)

Ion detection





Ion detection → internuclear wave function

→ molecular geometry

„Determination of the absolute Configuration"
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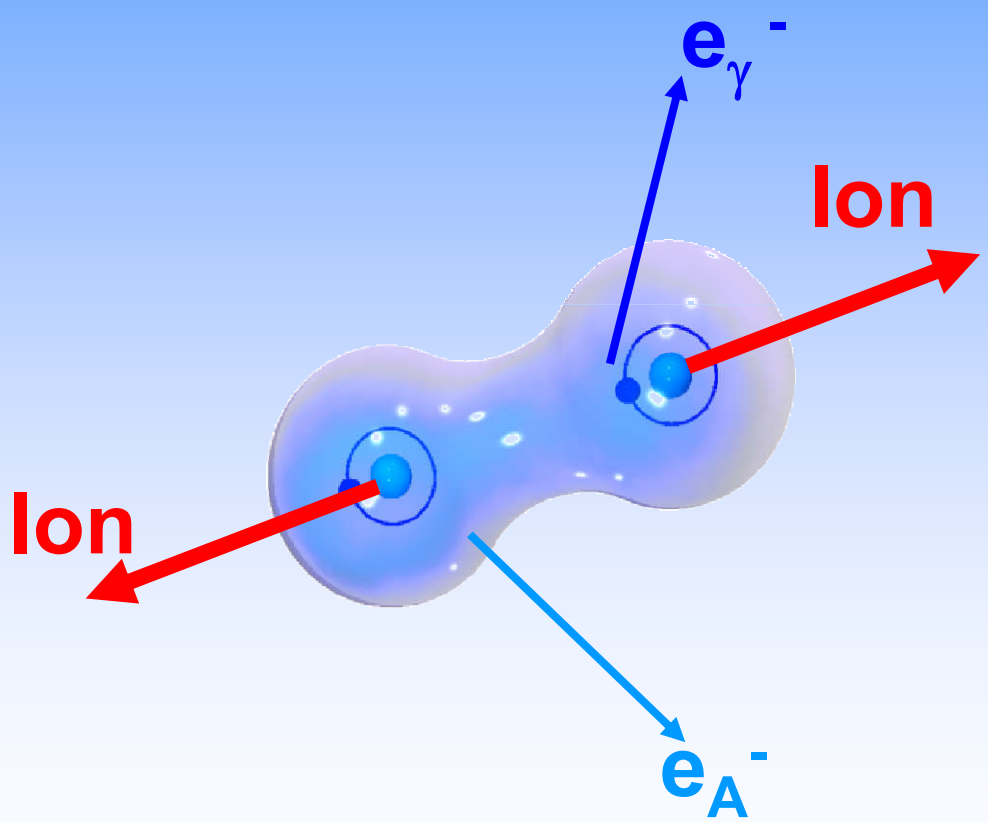
Photoelectron



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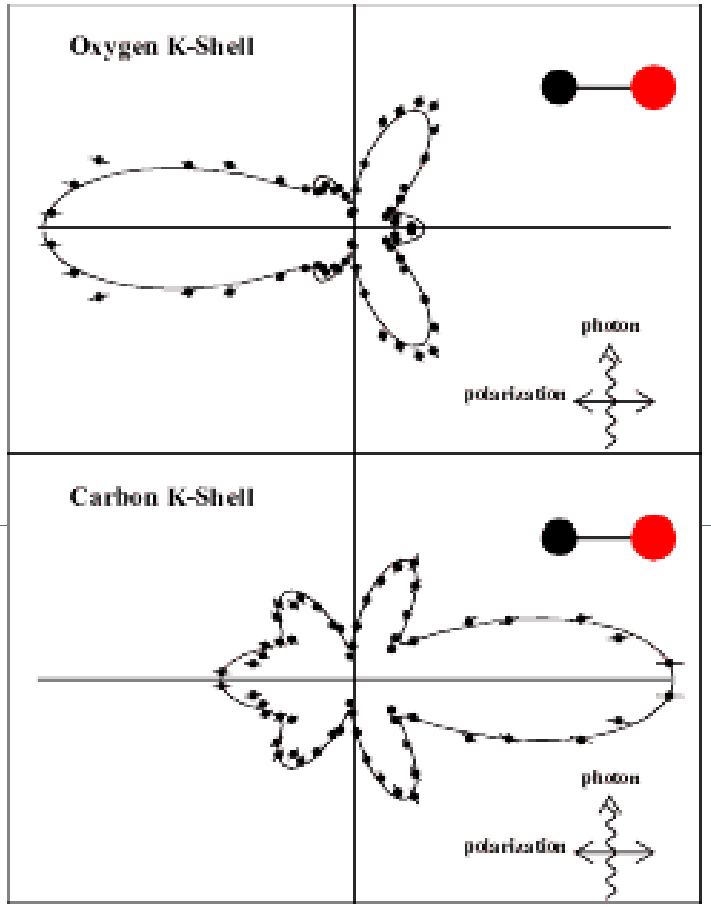
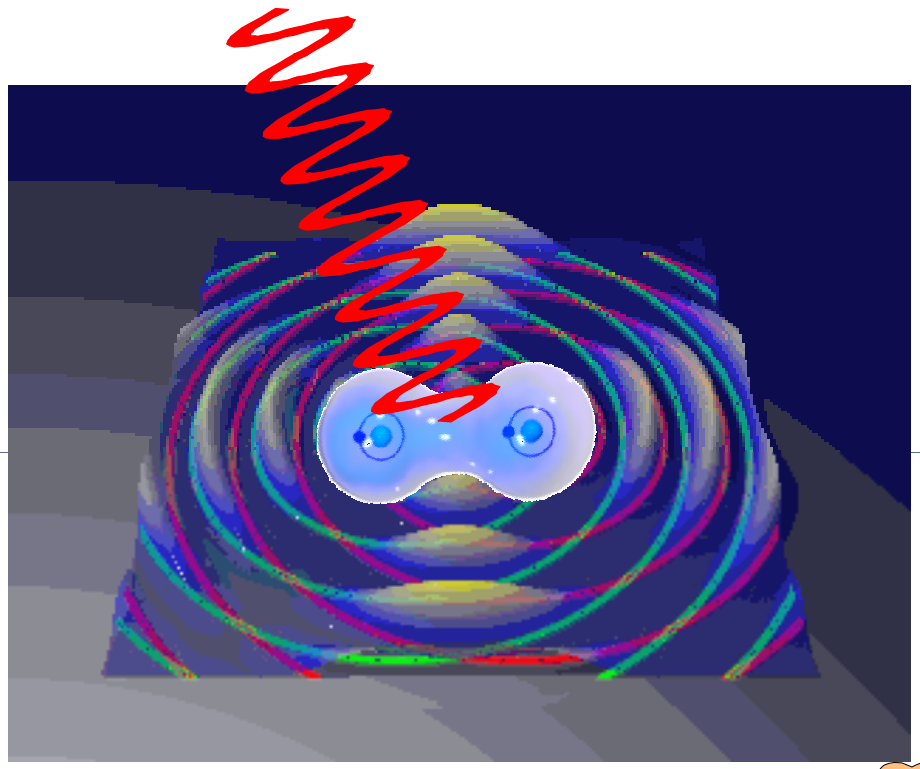
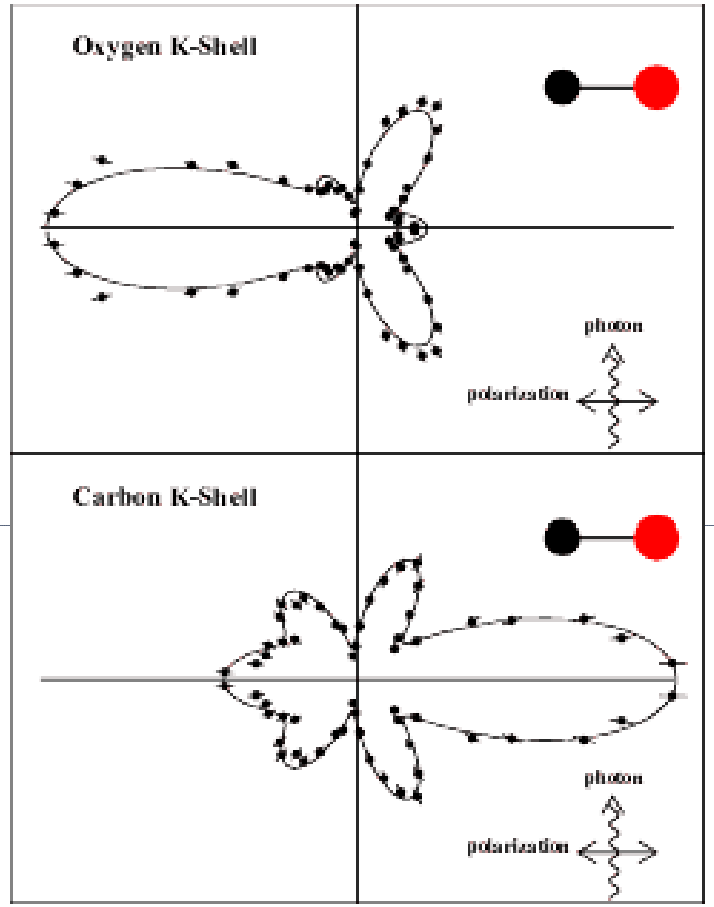




„Molecules illuminated from within"
Landers et al., PRL **87**, 013002 (2001)

Photoelectron



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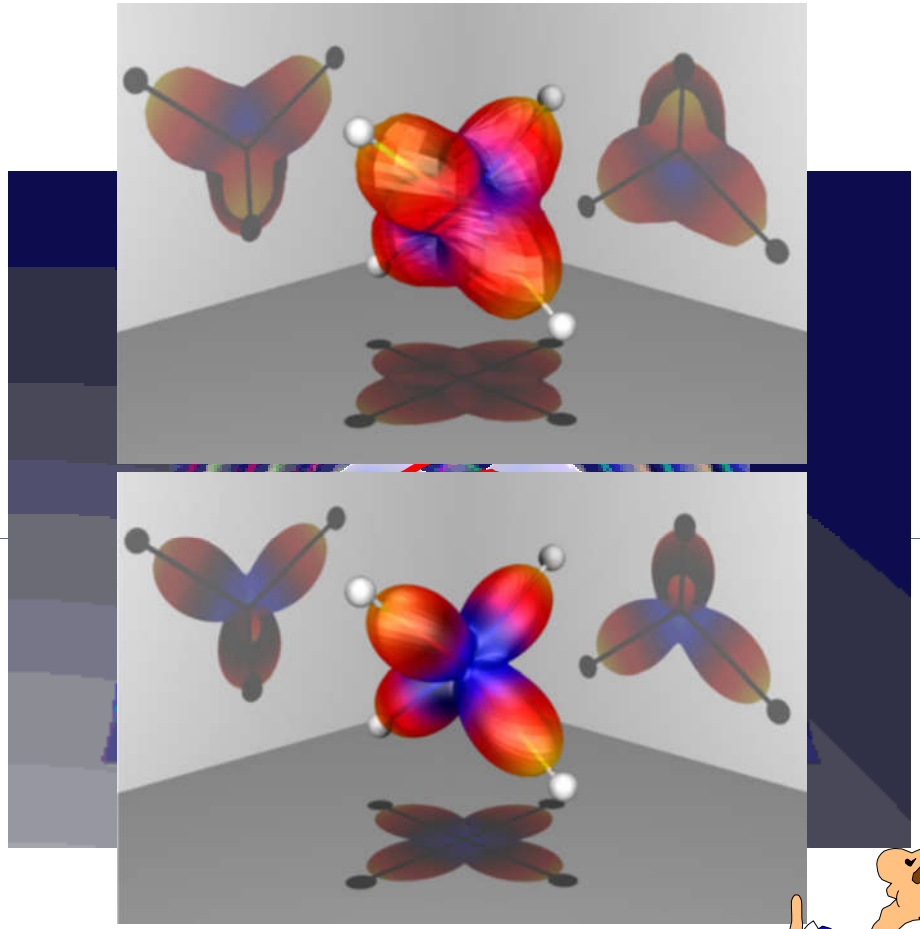
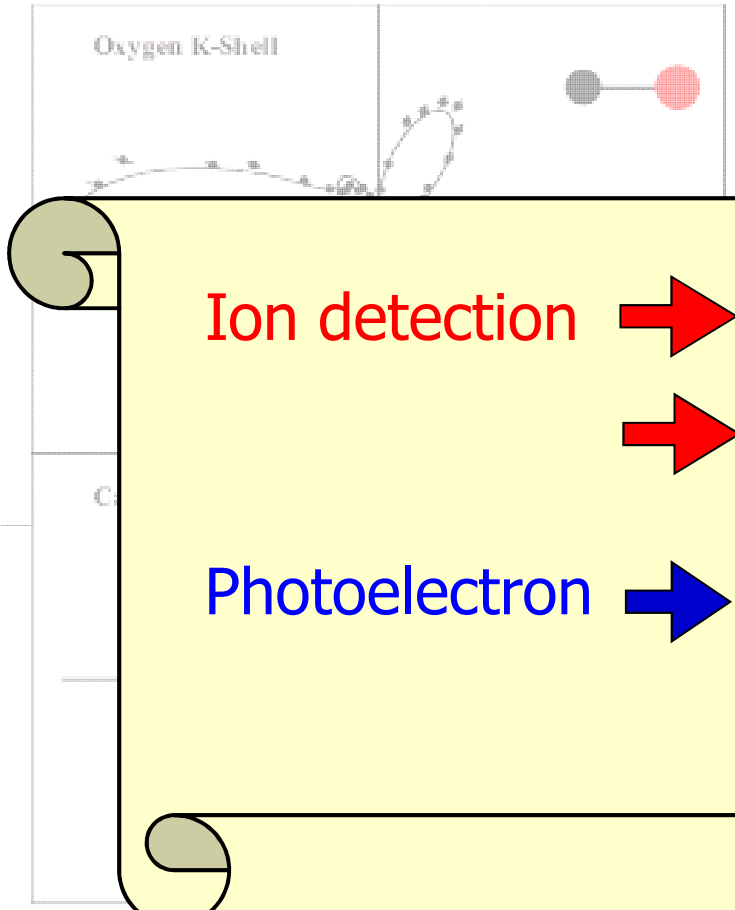
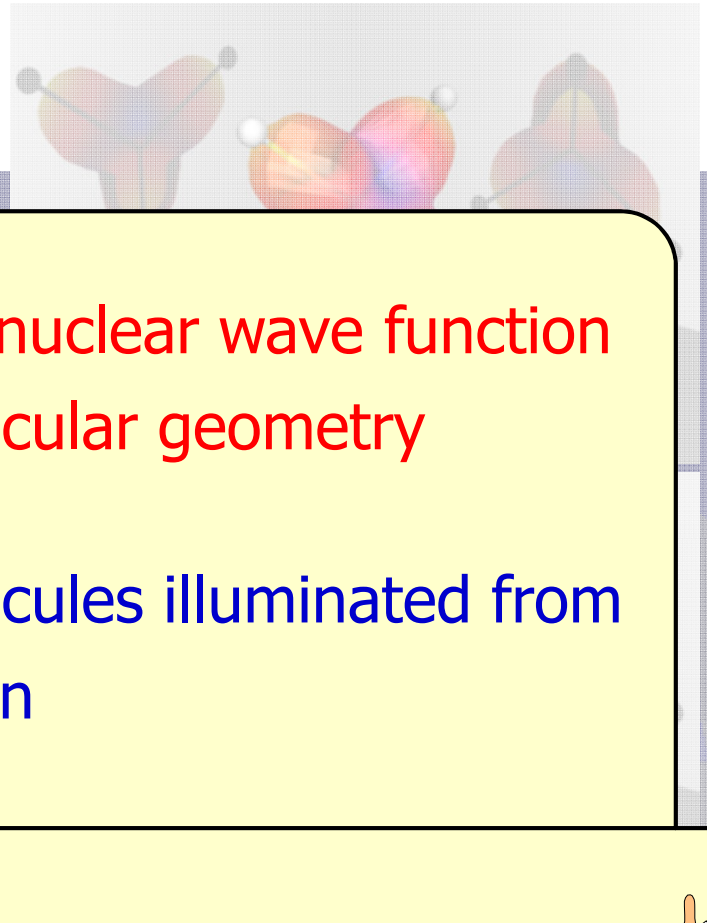


„Molecules illuminated from within"
Williams et al., PRL **108**, 233002 (2012)

Photoelectron





Ion detection → internuclear wave function

→ molecular geometry

Photoelectron → molecules illuminated from within

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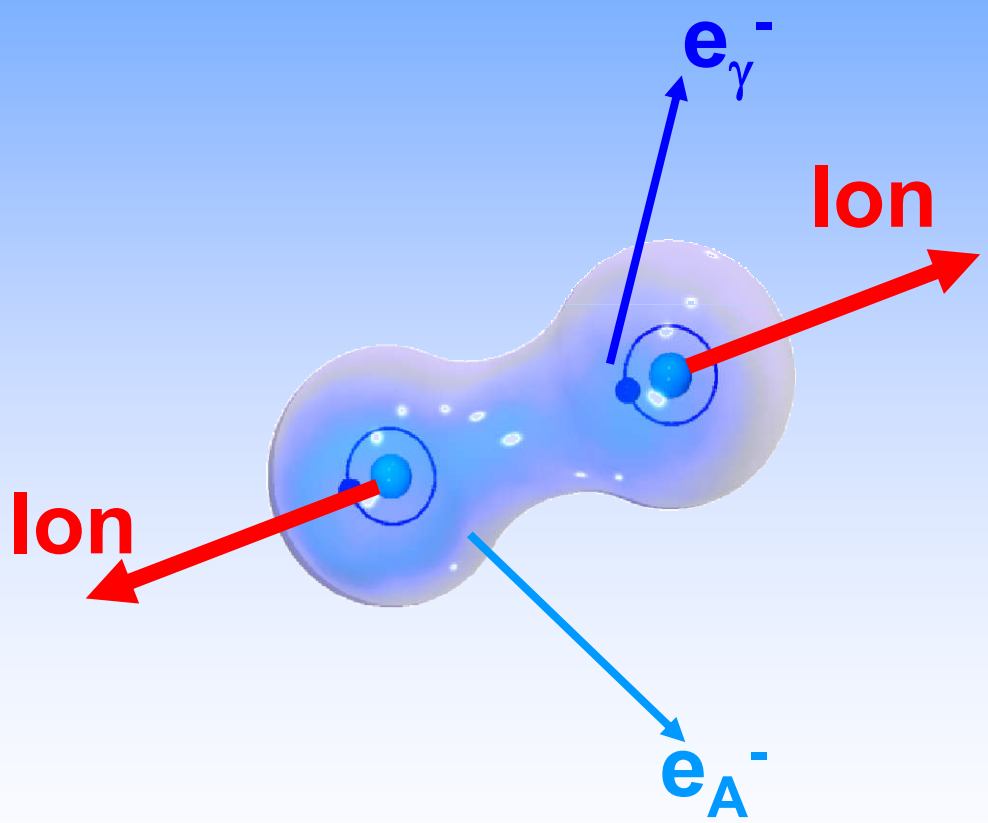
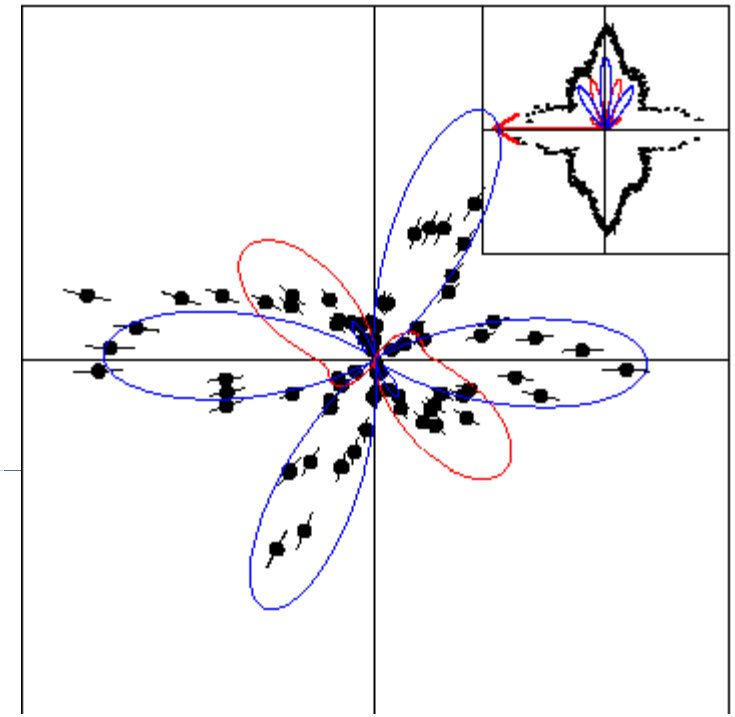
Landers et al., PRL **87**, 013002 (2001)

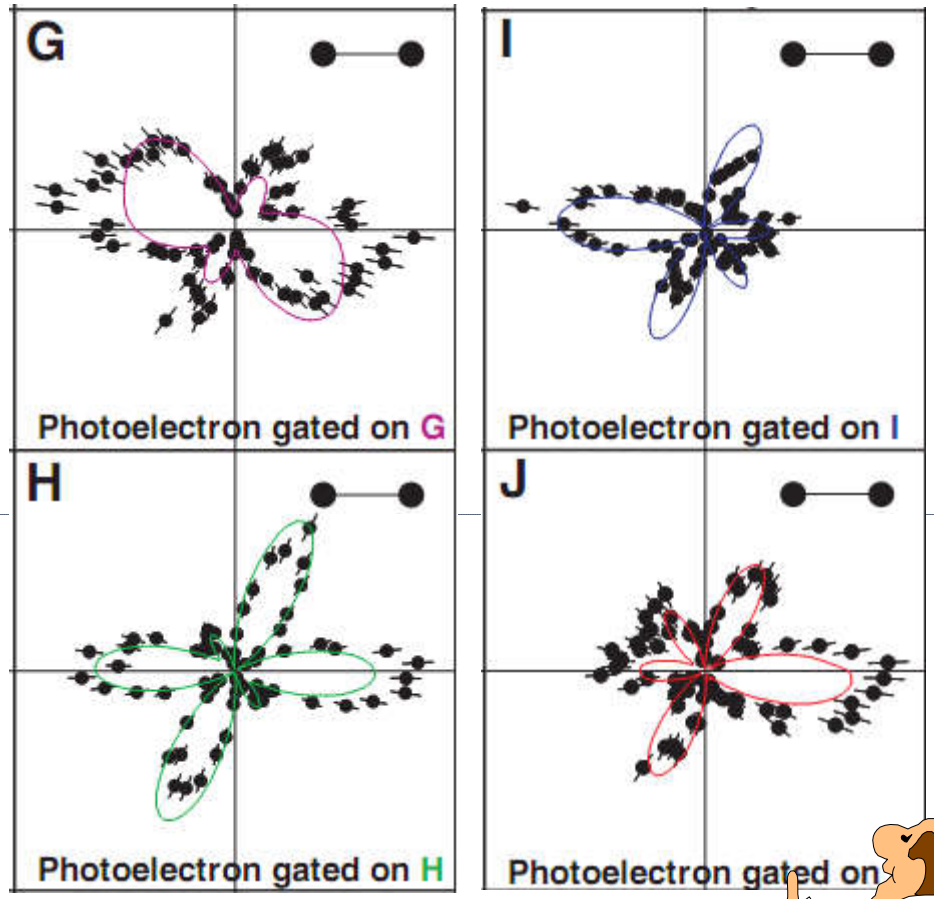
„Molecules illuminated from within"
Williams et al., PRL **108**, 233002 (2012)

Secondary electrons



Electron-Electron-coincidences





„Corehole localization & electron entanglement in N_2"
Schöffler et al., Science **320**, 920 (2008)

Electron-Electron-coincidences

Ion detection → internuclear wave function

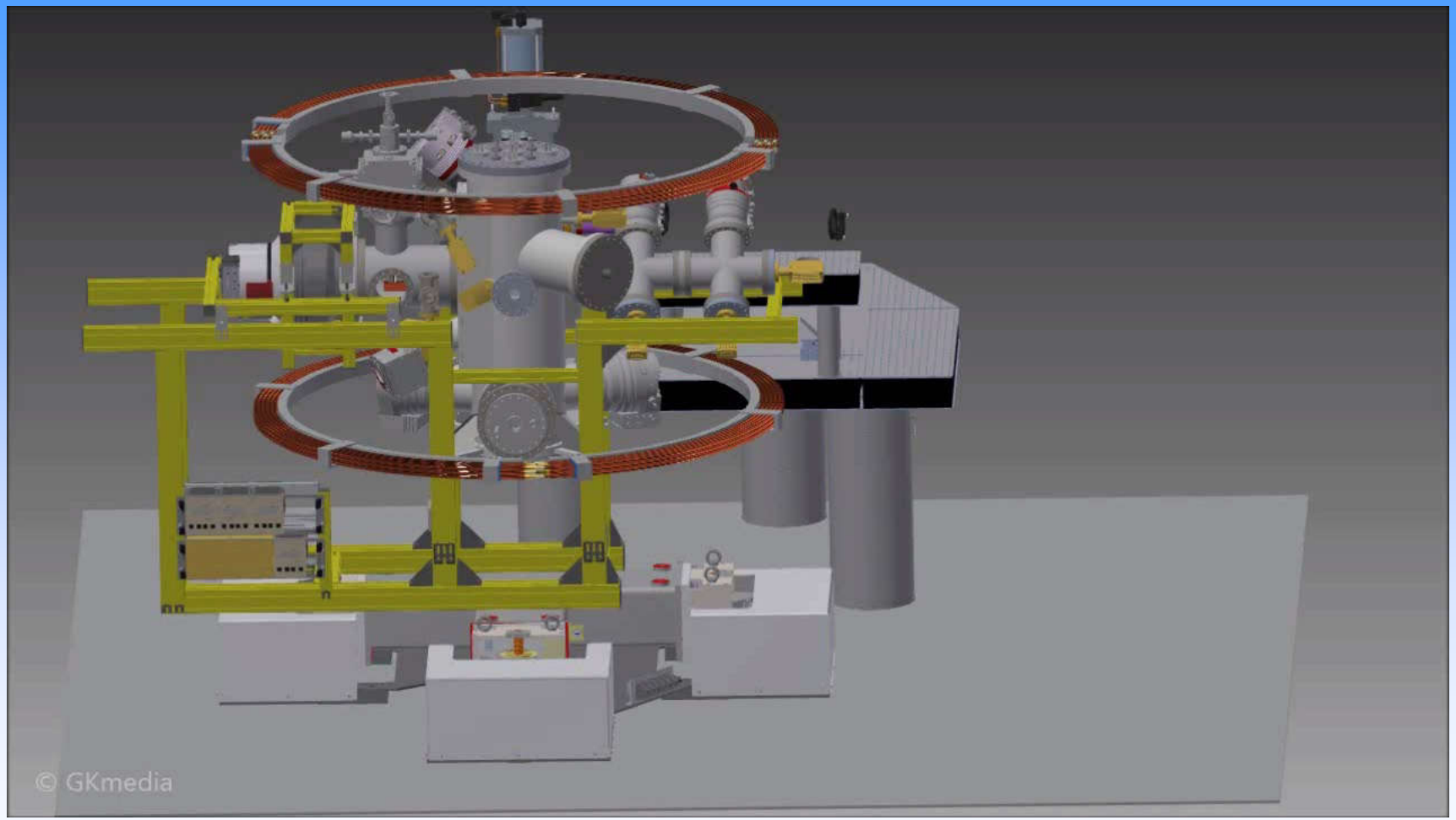
→ molecular geometry

Photoelectron → molecules illuminated from within

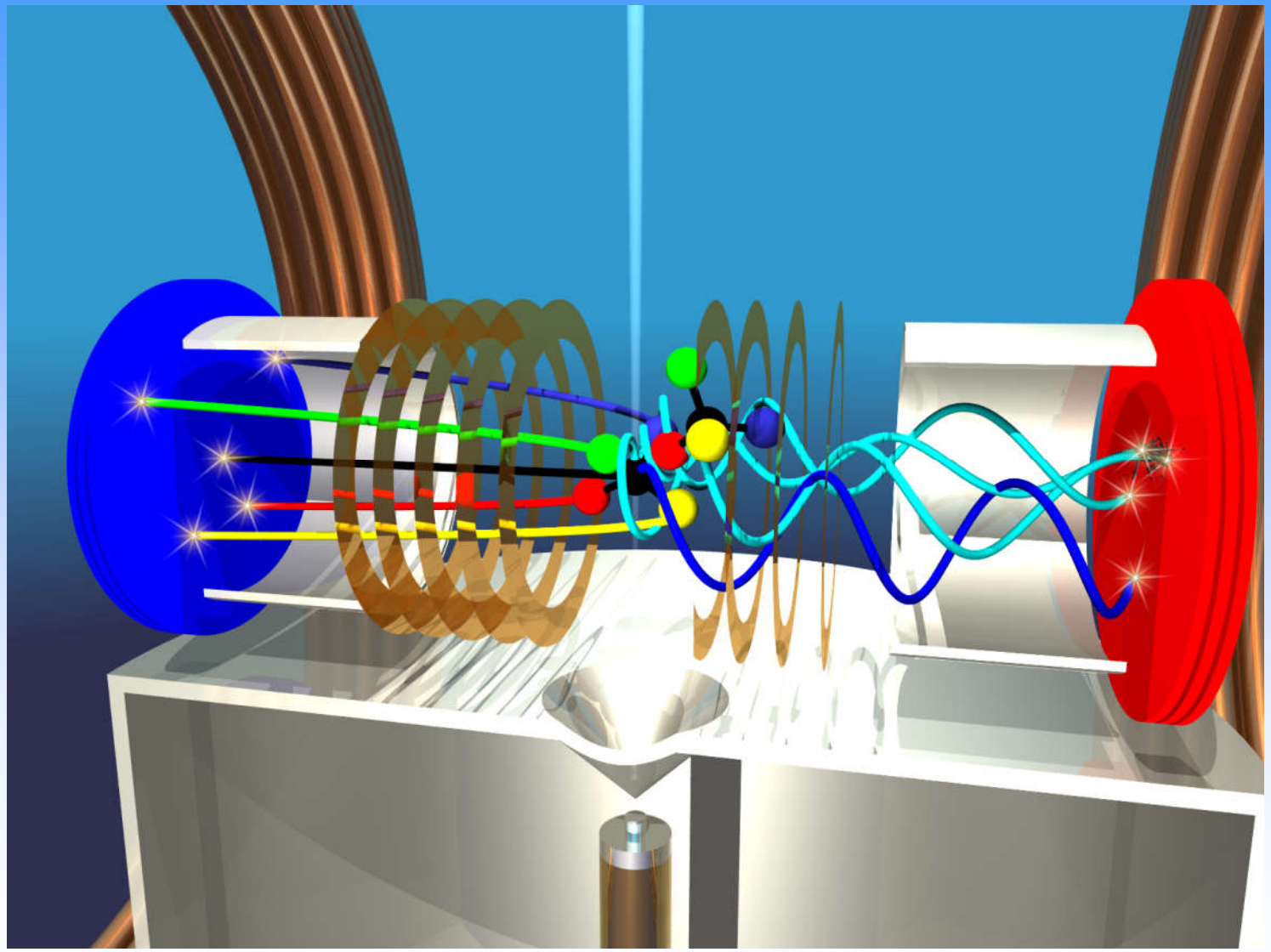
2nd electron → entanglement

„Coreshole localization & electron entanglement"
Schöffler et al., Science **320**, 920 (2008)

Movie



The main challenge



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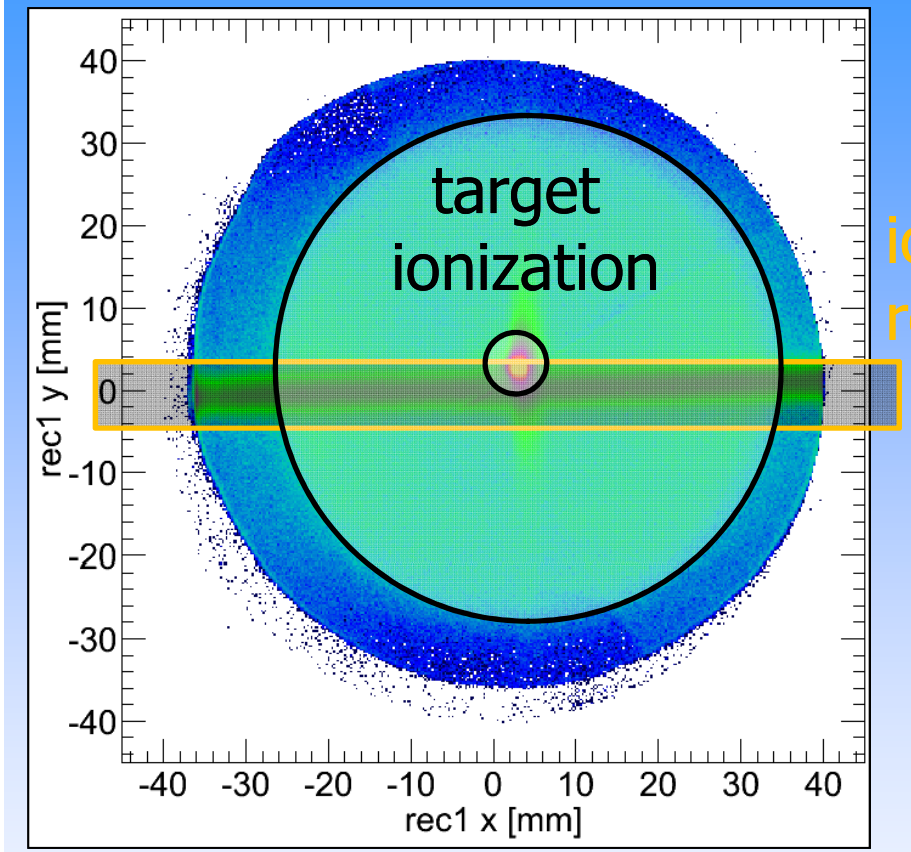
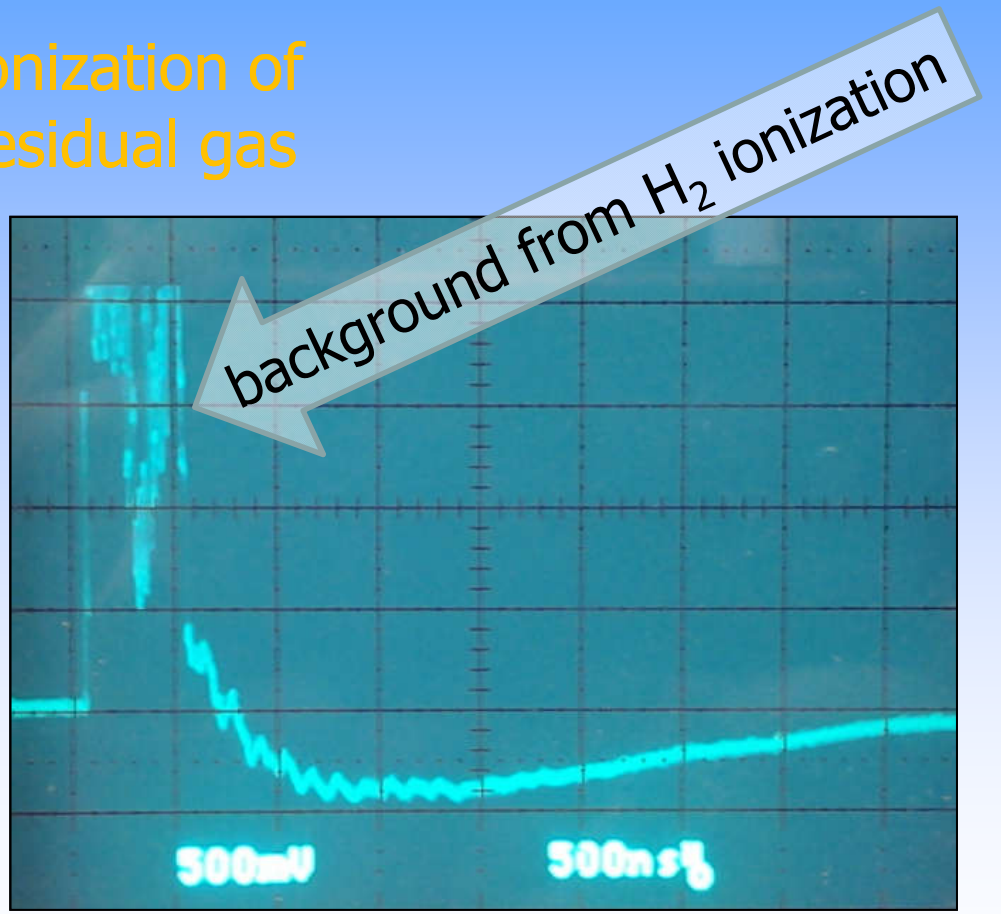


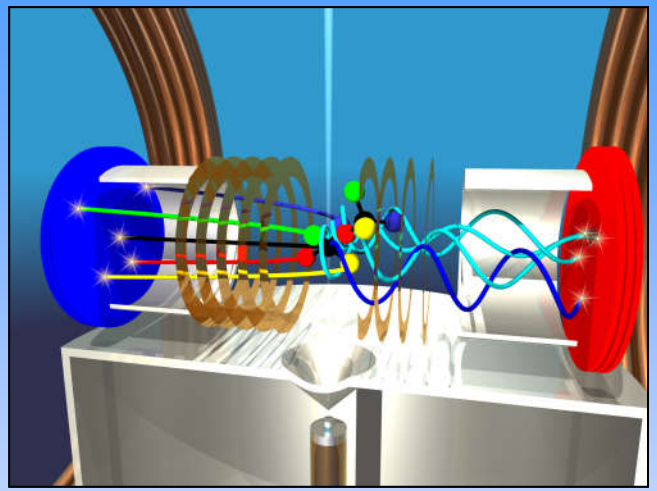
ionization of residual gas

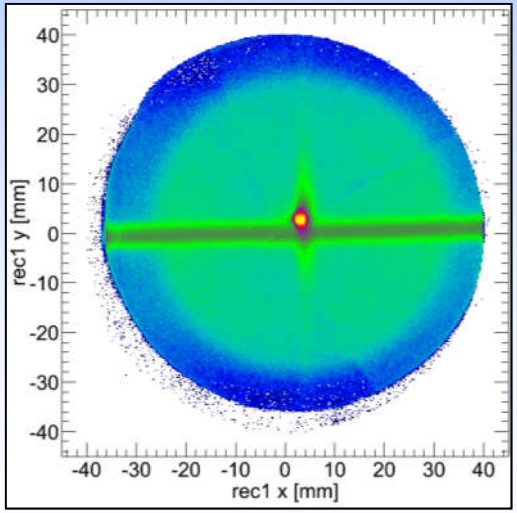
light propagation direction



saturated detector signal (FLASH)

The main challenge: countrates

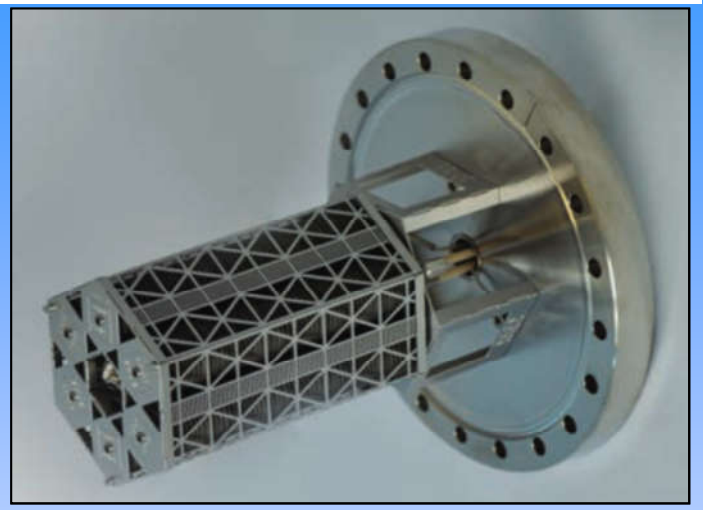




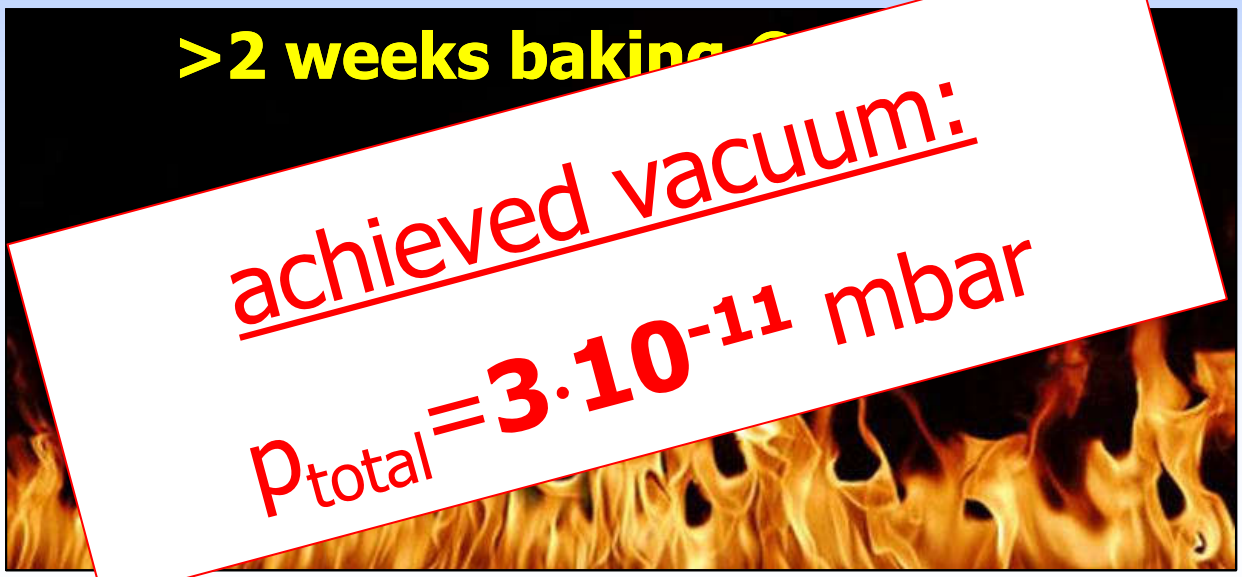
target density < low
(<1 ionization/pulse)

residual gas << low
(<<1 ionization/pulse)

Vacuum (interaction chamber)



- turbo molecular pump (2 x 700 l/s), doubly backed with turbo pumps
- NEG pump (3500 l/s H_2, 2700 l/s H_2O)
- optional LN_2 cold trap + TSP (>2000 l/s H_2 & H_2O)

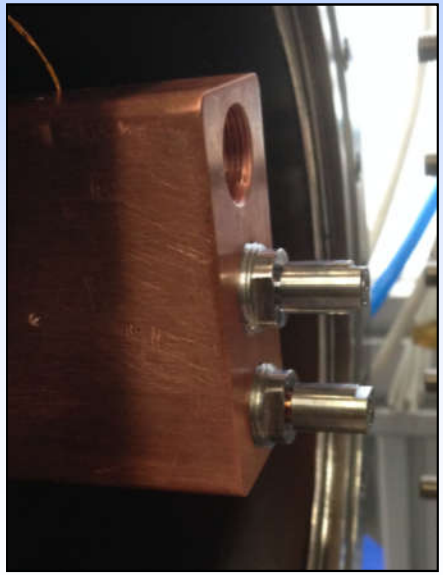


achieved vacuum:

p_{total}=**3·10^{-11}** mbar

Target

- Cryostatat (10 – 500 K) for precooling/heating
- 3 different nozzles (5 – 200 µm)
- nano-positioner for variable target geometry (10 µm … 1 mm)
- long dilute 4-stage jet (length ≈1.5 m)
- short dense 3-stage jet (small cross section; XFEL=Synchrotron)



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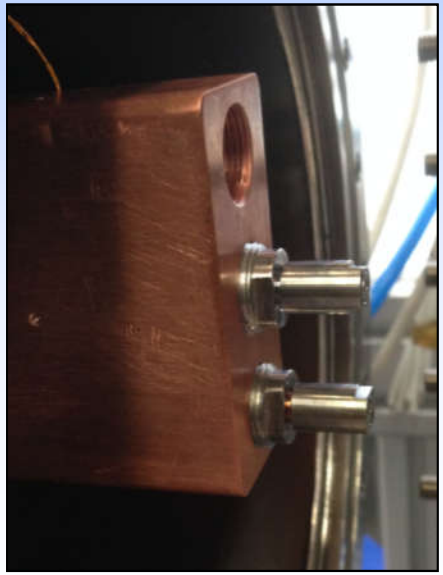

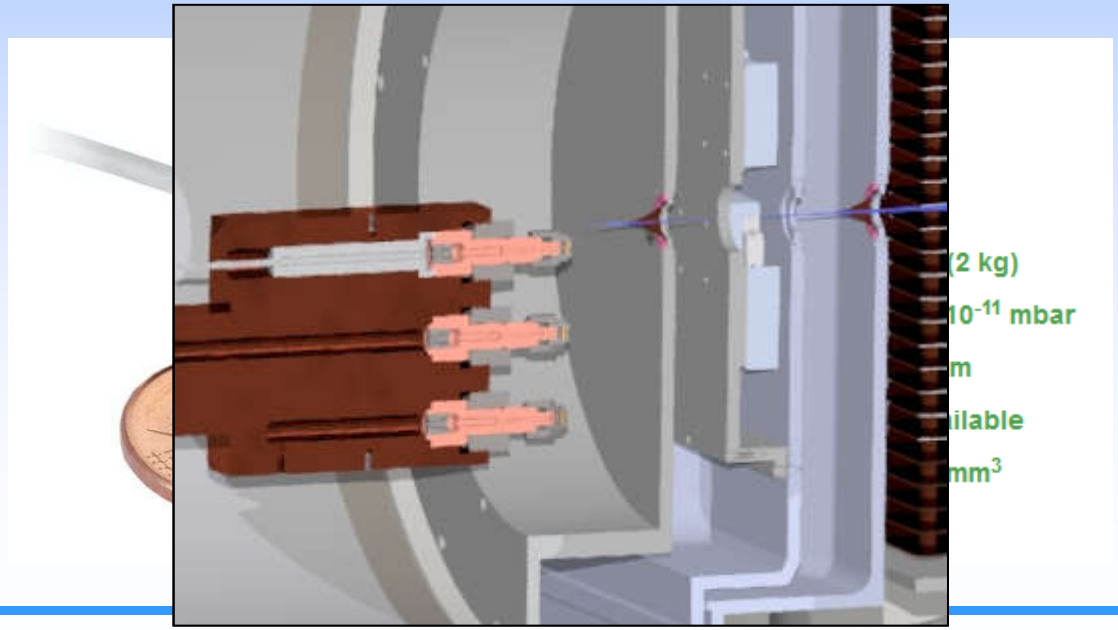

densities & rates

Residual gas ionization within XFEL beam (d=2 μm):

- 0.05 H_2 molecules along beam
- 0.008 N_2 molecules along beam
- σ_γ suppression: H_2/N_2 @ 420 eV 1:3000

Target area density:

- short & dense: up to $2 \cdot 10^{11}$ particles/cm^2 (Helium)
- long & dilute: <0.1 molecule/focus

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- 0.008 N_2 molecules along be
- σ_γ suppression: H_2/N_2 @ 420

Target area density:

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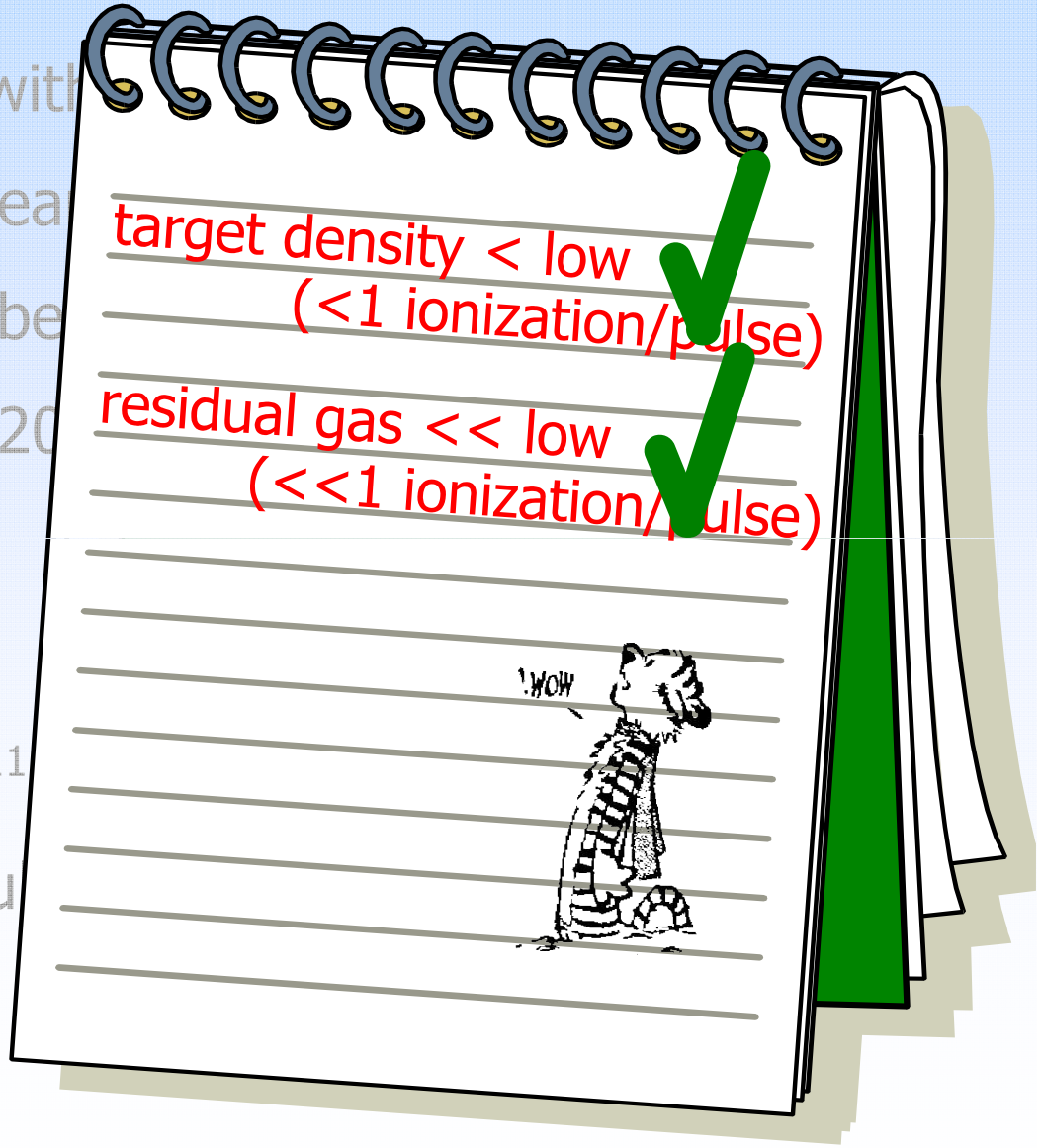
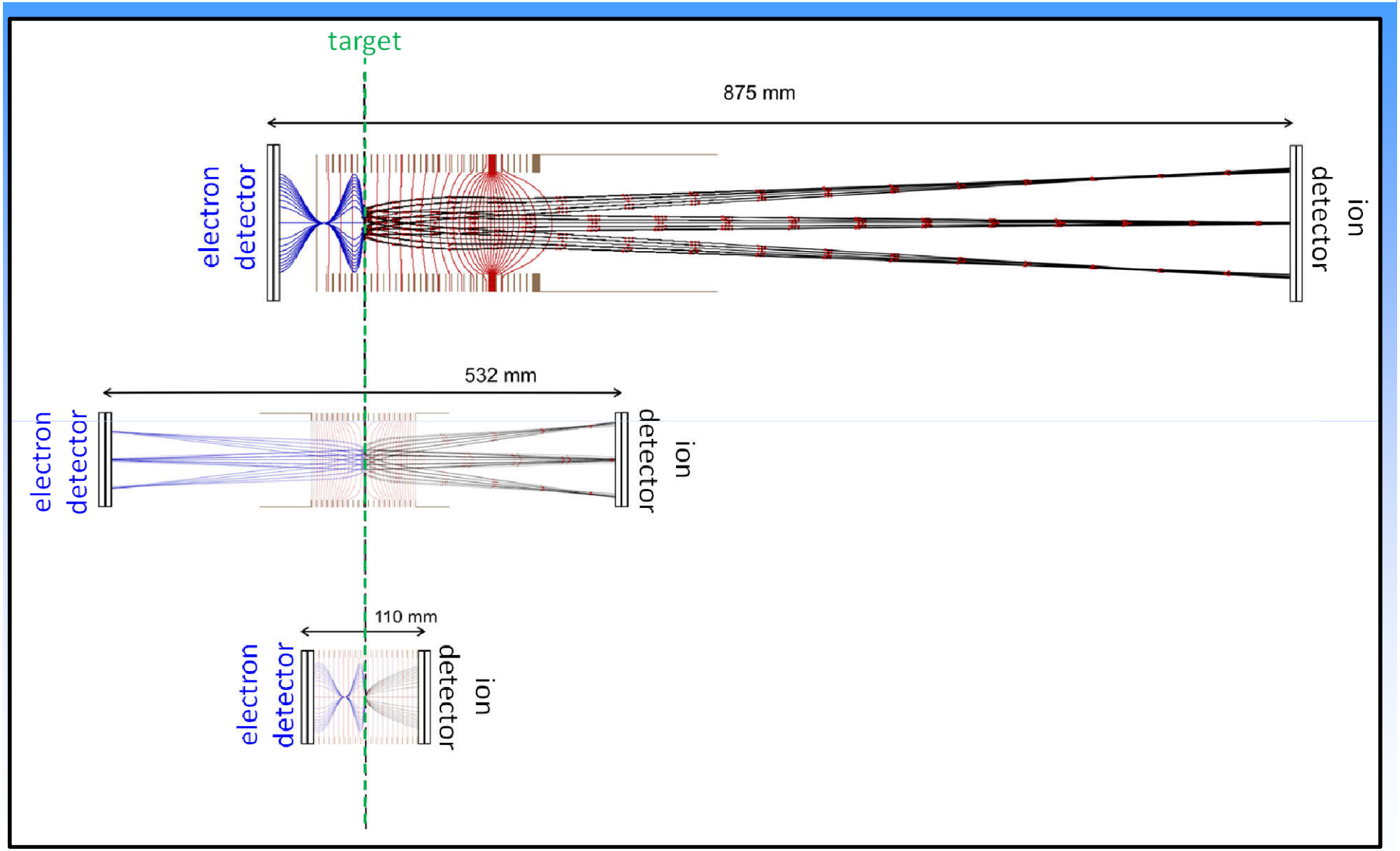
- long & dilute: <0.1 molecu

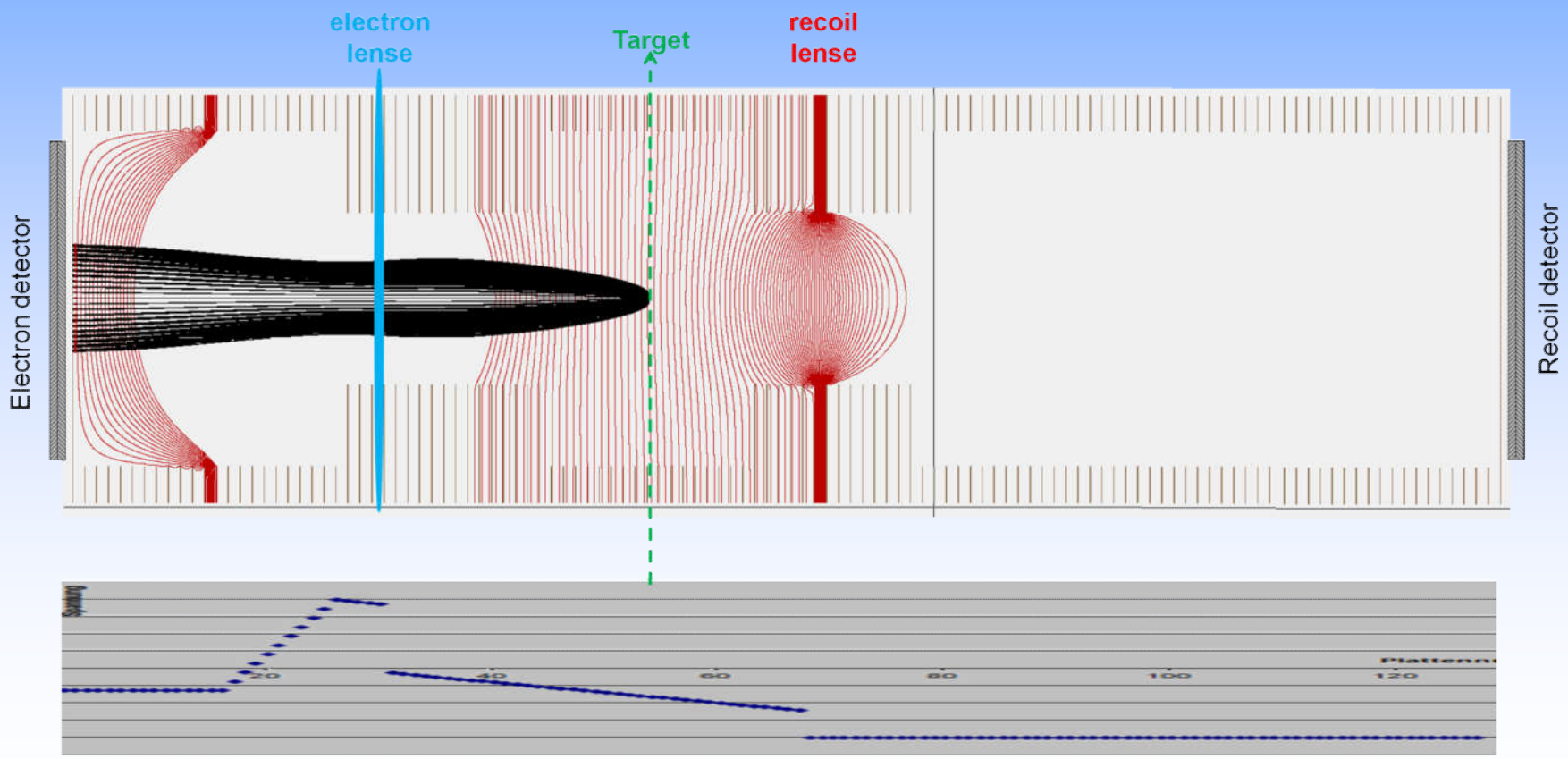


Spectrometer



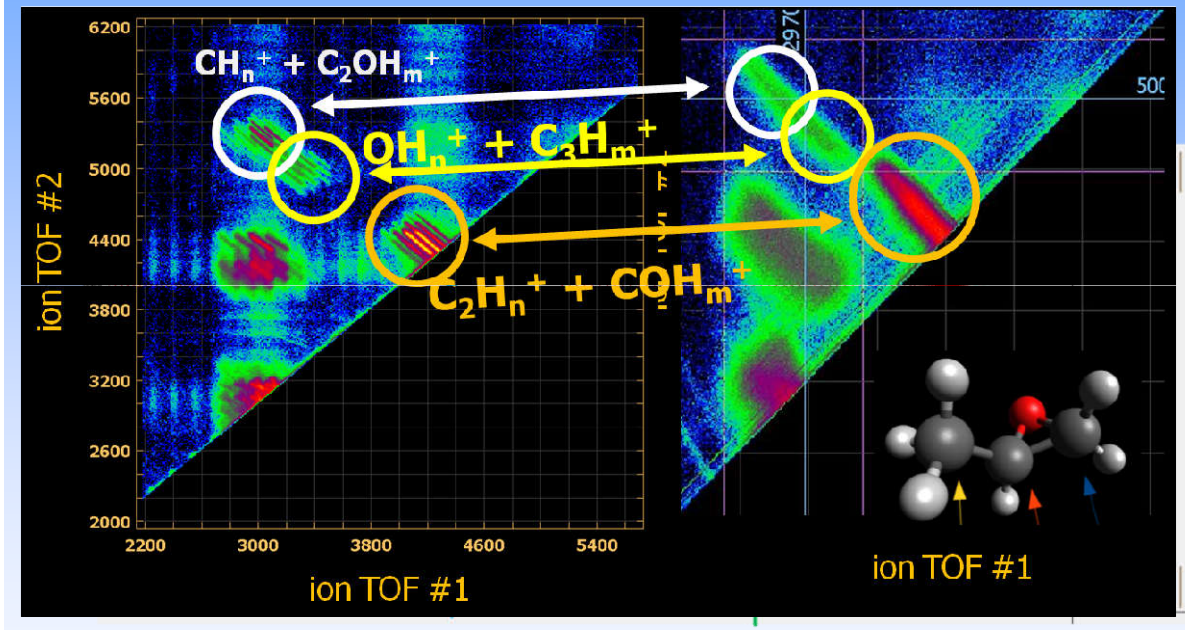
Spectrometer

- variable in length/geometry (5 – 75 cm) for optimal resolution

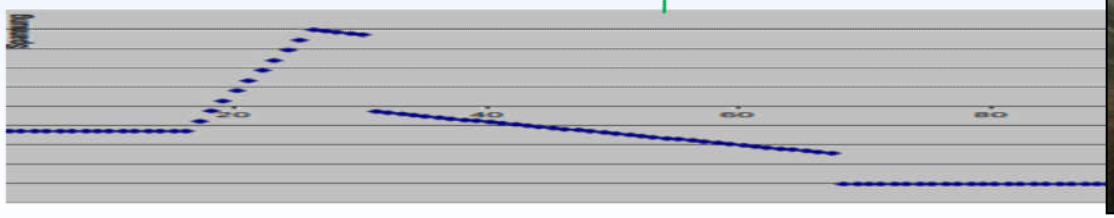


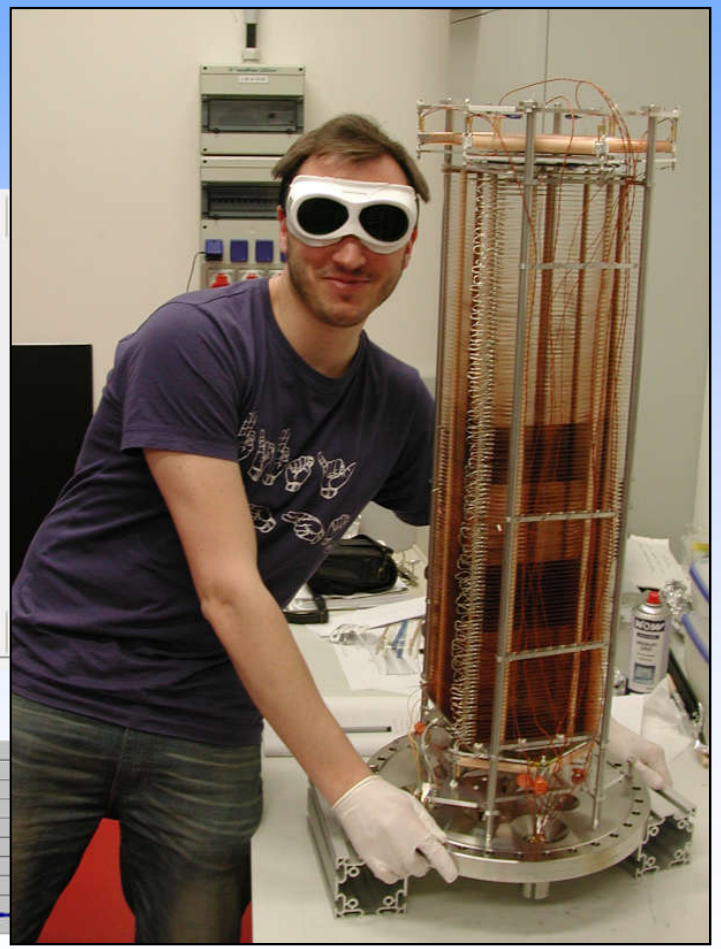
Spectrometer

- variable in length/geometry (5 – 75 cm) for optimal resolution
- magnetic fields up to 50 Gauss (0.1 eV - 2 keV elec. with 4π)



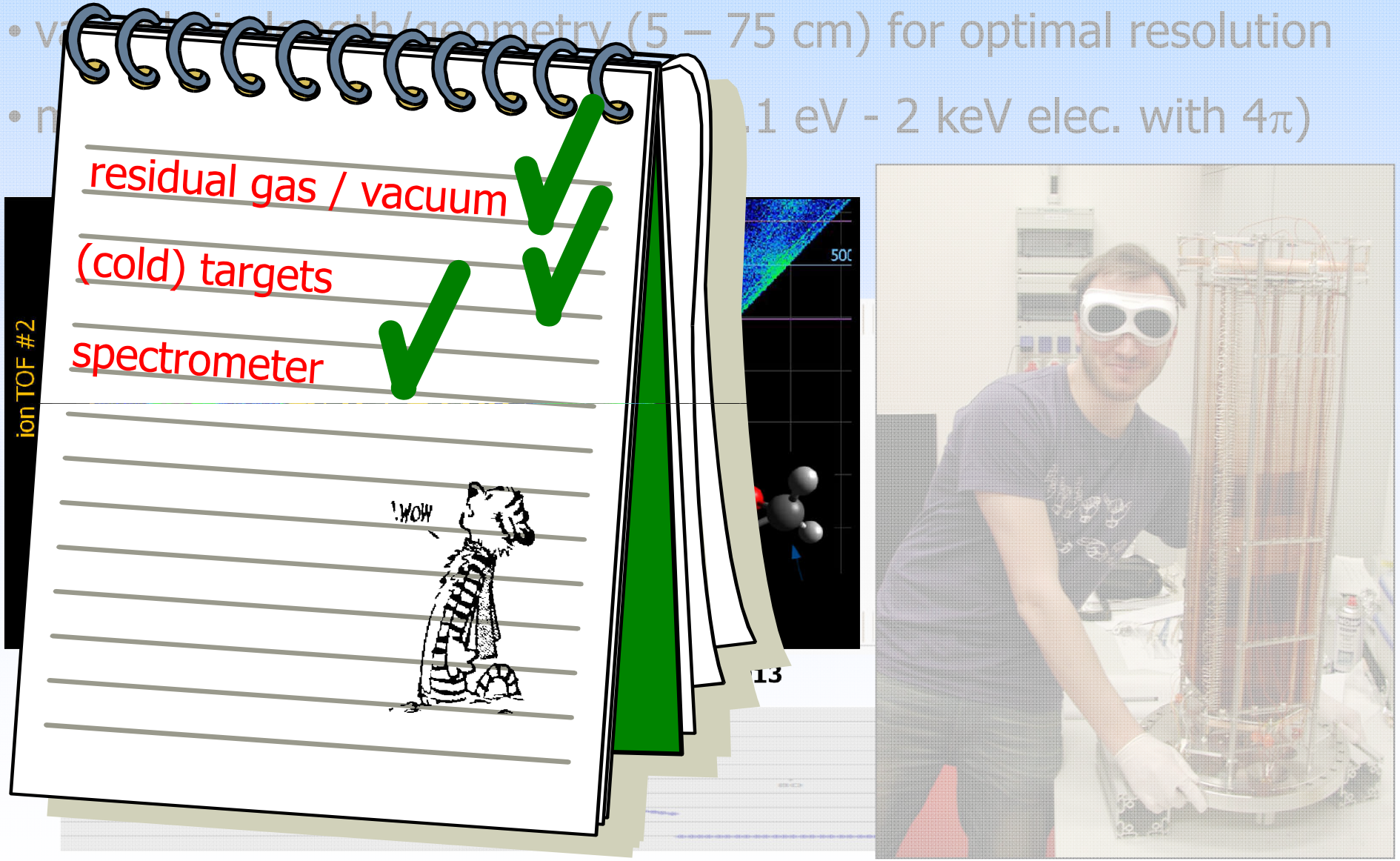
spectrometer 2015 **spectrometer 2013**





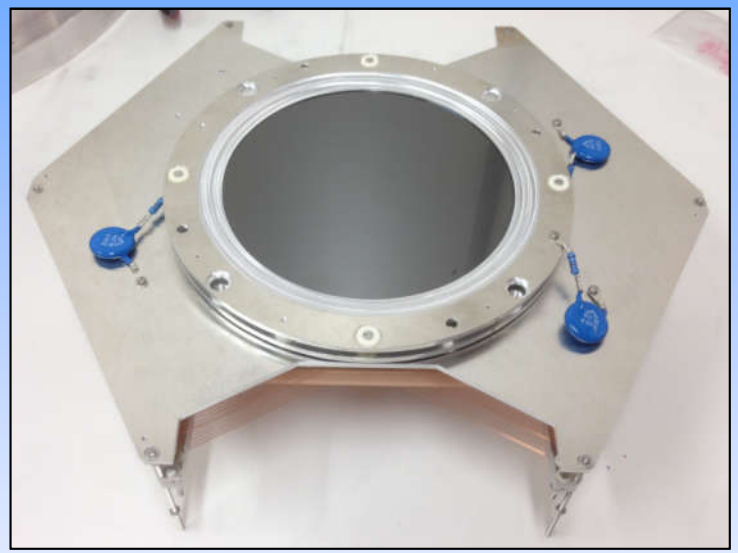
Spectrometer

- v[illegible] length/geometry (5 – 75 cm) for optimal resolution
- n[illegible] 1 eV - 2 keV elec. with 4π)

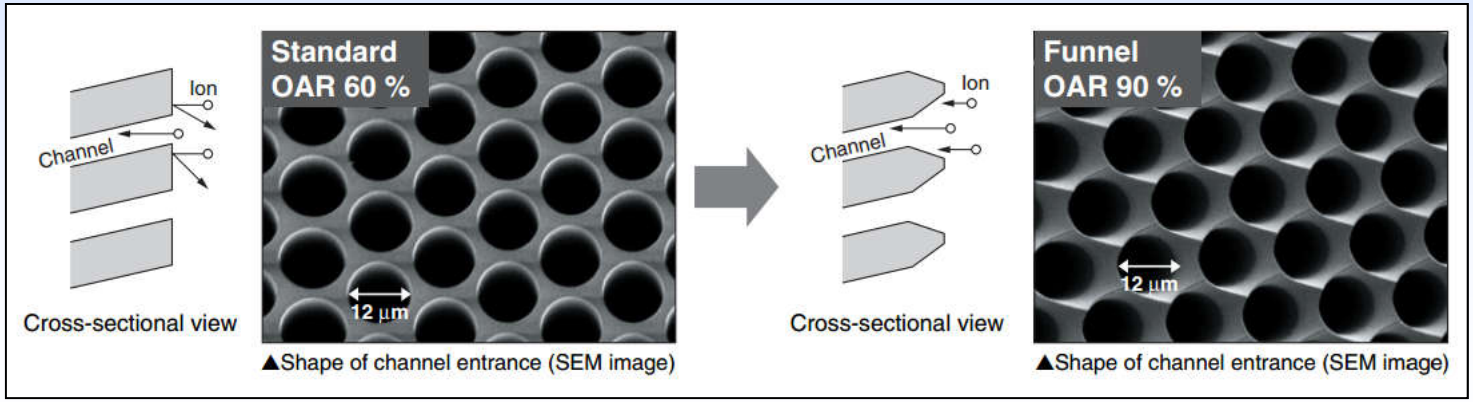


Detectors

- MCP detectors with hexagonale delayline anode (∅ 120 mm)
- or high efficiency funnel MCP (∅ 75 mm)

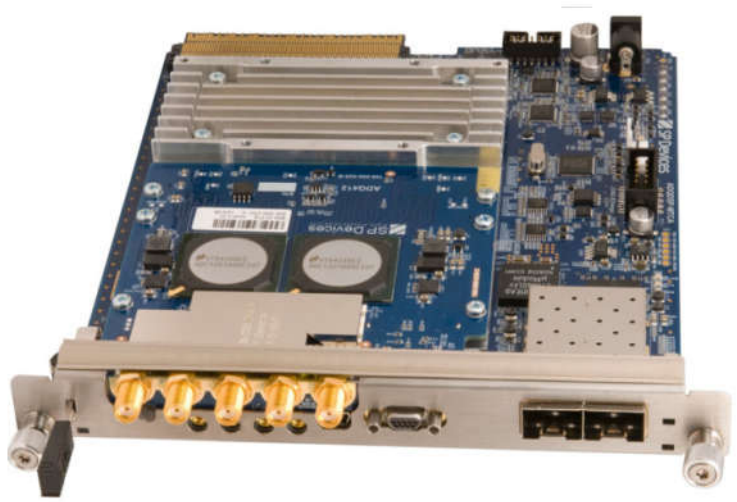


# particles	normal	funnel	gain
1	60%	90%	1,5
2	36%	81%	2,3
3	22%	73%	3,4
4	13%	66%	5,1
5	8%	59%	7,6
6	5%	53%	11,4

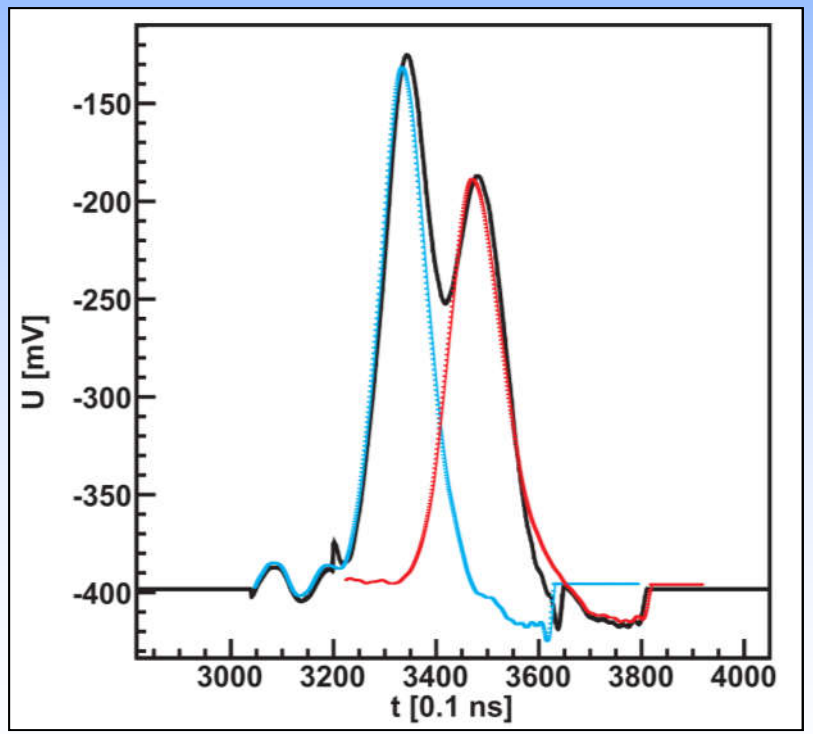


Detectors

- MCP detectors with hexagonale delayline anode (∅ 120 mm)
- or high efficiency funnel MCP (∅ 75 mm)
- pulse tracking via fast ADC (SP Devices 4 x ADQ412)



- Up to 4 analog channels
- Up to 4 GSPS sampling rate
- 12 bits resolution
- Up to 2 GHz analog bandwidth



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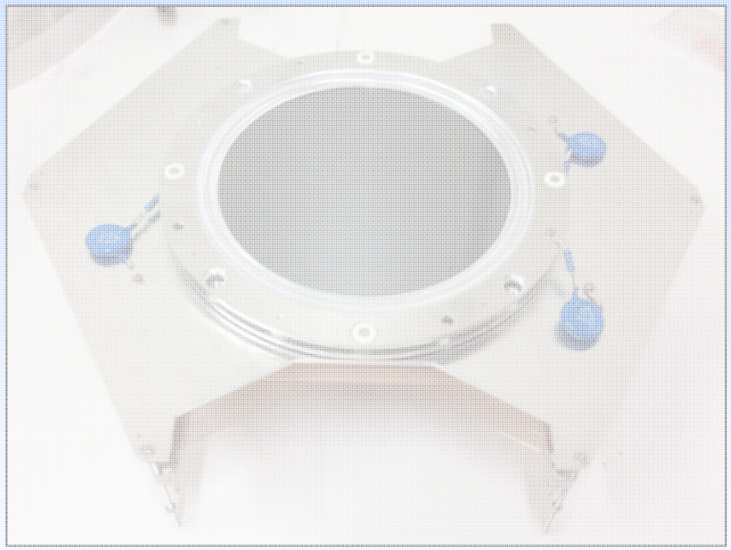
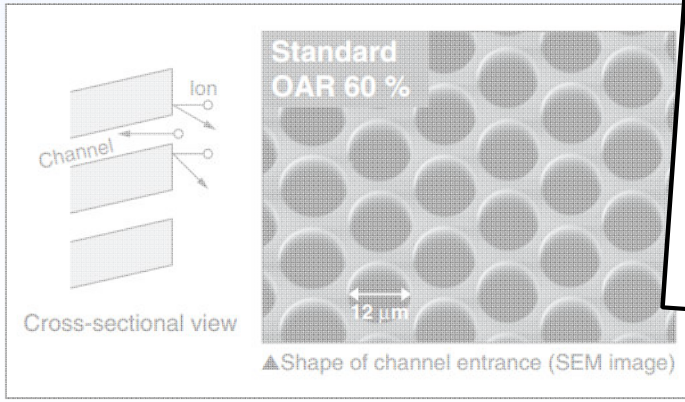
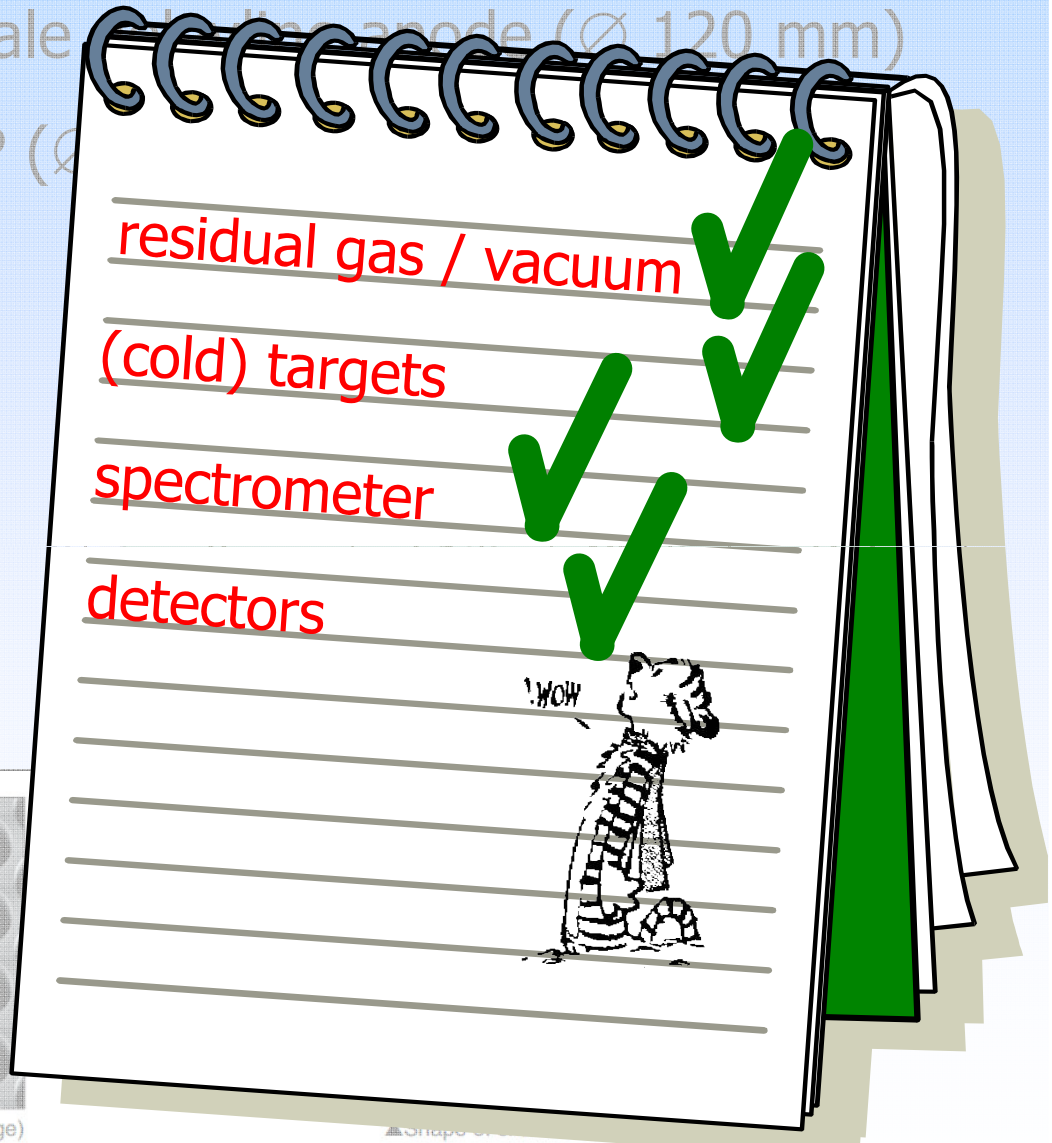






The XFEL-REMI

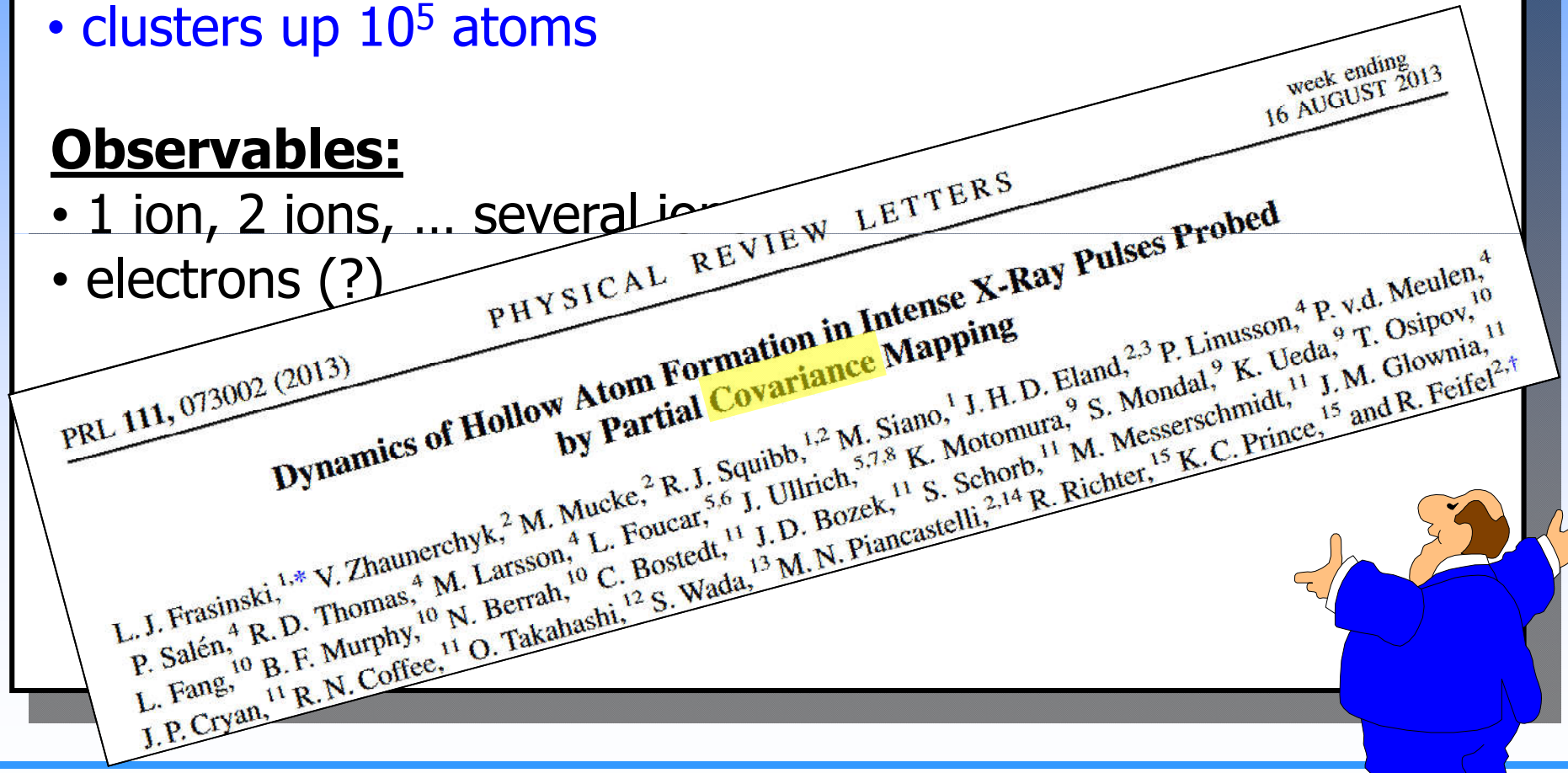
Summary – The First Experiment(s)

Targets:

- anything out of gas bottle
- any liquid with some vapor pressure
- clusters up 10^5 atoms

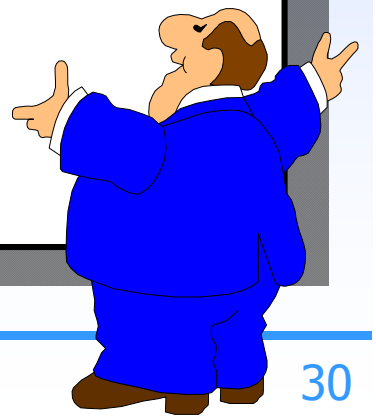
Observables:

- 1 ion, 2 ions, … several ion
- electrons (?)


PRL 111, 073002 (2013) PHYSICAL REVIEW LETTERS week ending 16 AUGUST 2013

Dynamics of Hollow Atom Formation in Intense X-Ray Pulses Probed by Partial Covariance Mapping

L. J. Frasinski,[1,*] V. Zhaunerchyk,[2] M. Mucke,[2] R. J. Squibb,[1,2] M. Siano,[1] J. H. D. Eland,[2,3] P. Linusson,[4] P. v.d. Meulen,[4] P. Salén,[4] R. D. Thomas,[4] M. Larsson,[4] L. Foucar,[5,6] J. Ullrich,[5,7,8] K. Motomura,[9] S. Mondal,[9] K. Ueda,[9] T. Osipov,[10] L. Fang,[10] B. F. Murphy,[10] N. Berrah,[10] C. Bostedt,[11] J. D. Bozek,[11] S. Schorb,[11] M. Messerschmidt,[11] J. M. Glownia,[11] J. P. Cryan,[11] R. N. Coffee,[11] O. Takahashi,[12] S. Wada,[13] M. N. Piancastelli,[2,14] R. Richter,[15] K. C. Prince,[15] and R. Feifel[2,†]



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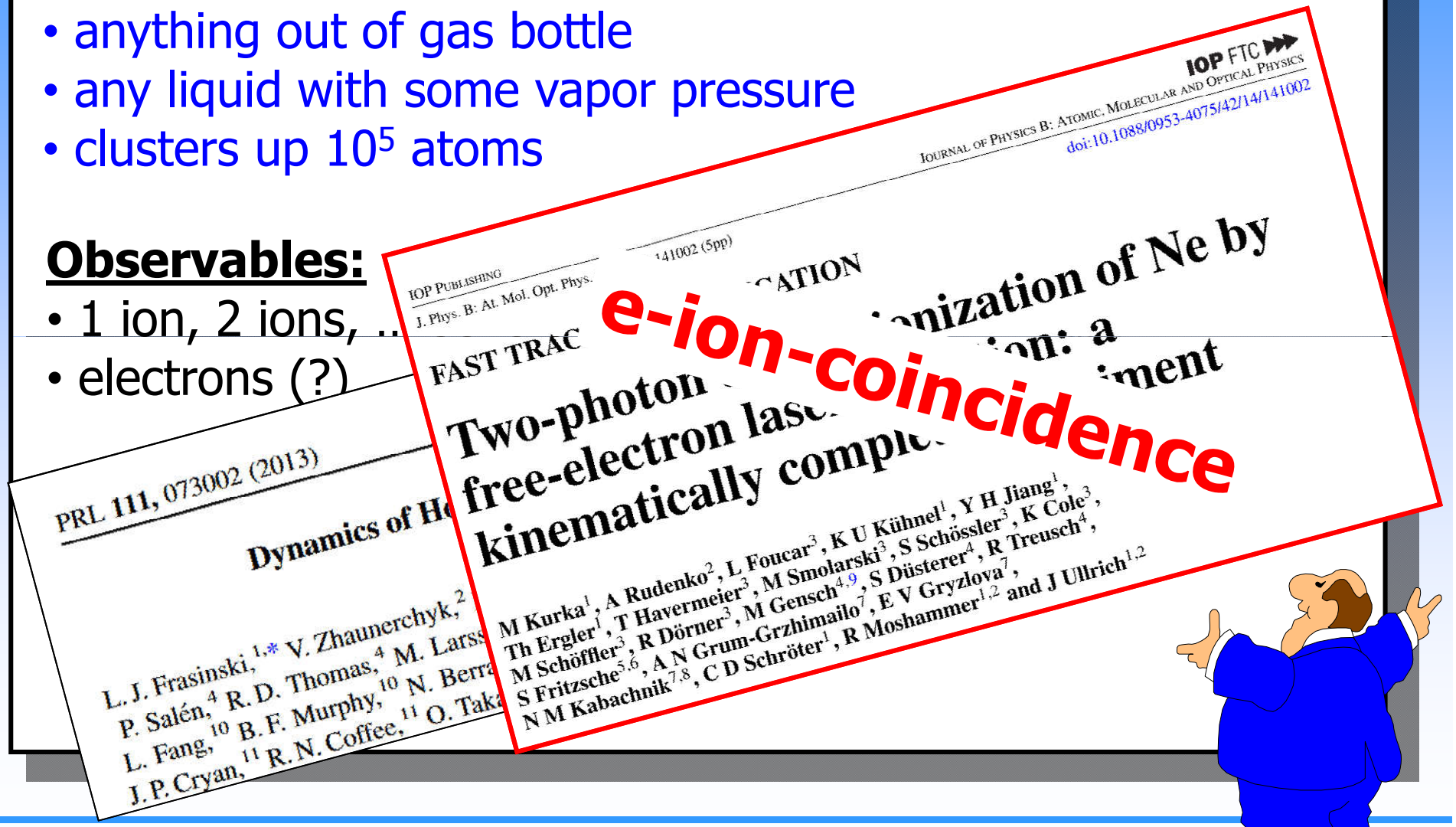

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- clusters up 10^5 atoms

Observables:

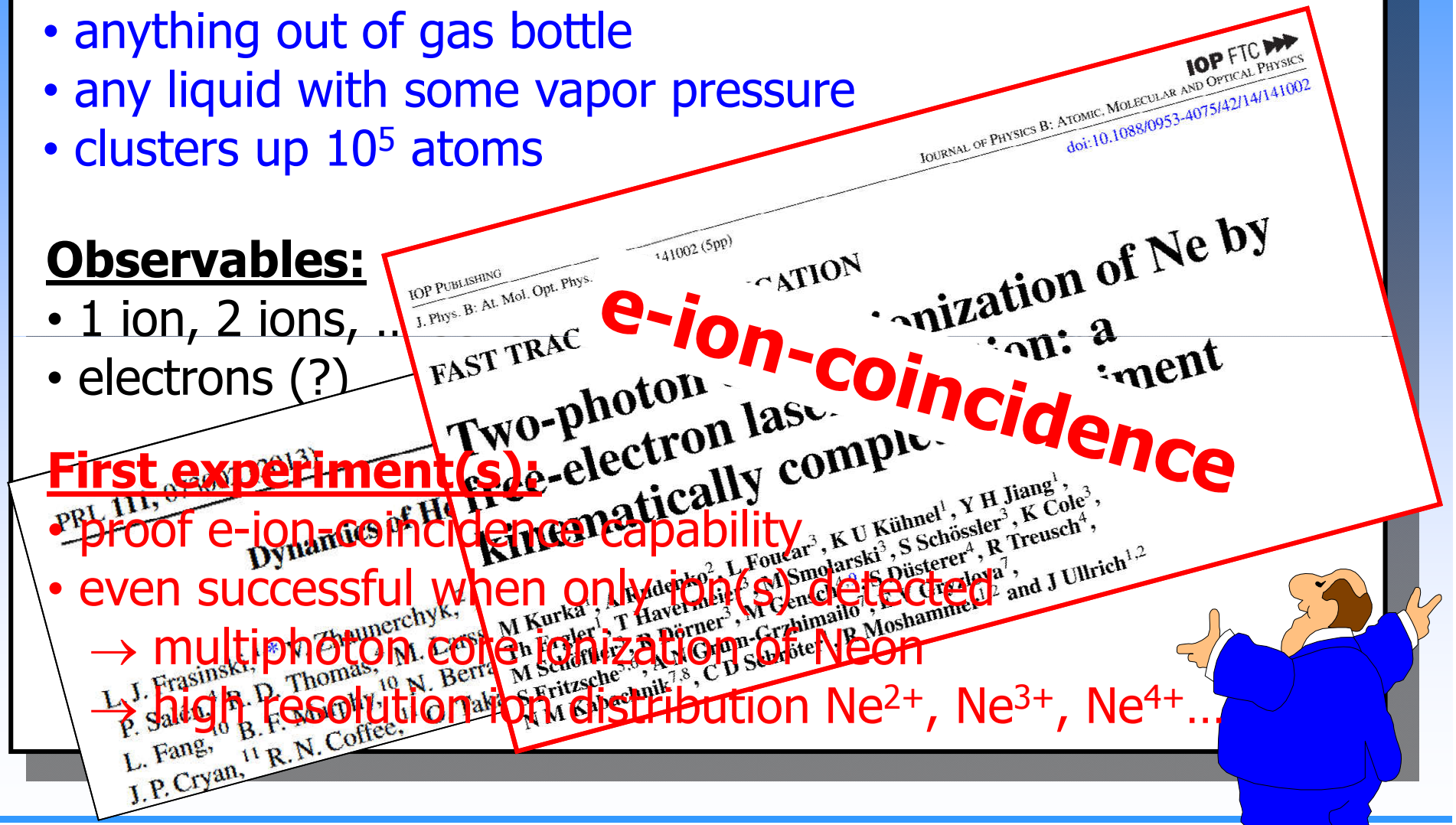
- 1 ion, 2 ions, ..
- electrons (?)

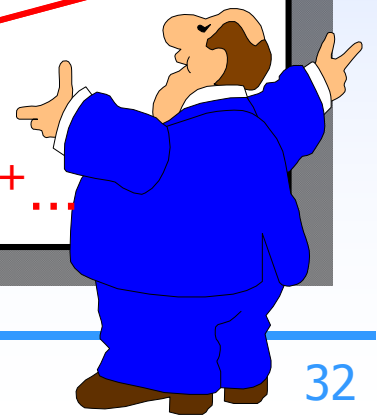
First experiment(s):

- proof e-ion-coincidence capability
- even successful when only ion(s) detected

→ multiphoton core ionization of Neon

→ high resolution ion distribution Ne^{2+}, Ne^{3+}, Ne^{4+}...





Acknowledgement

thanks for your attention

2016)

Ministry of Education and Research

FSP-302