



1. Spatenstich am 10. Dezember 2010

**Verkehrsminister Schlotmann
Bildungsminister Tesch
Rektor Schareck**



lecture 3.12.2010

we had so far:

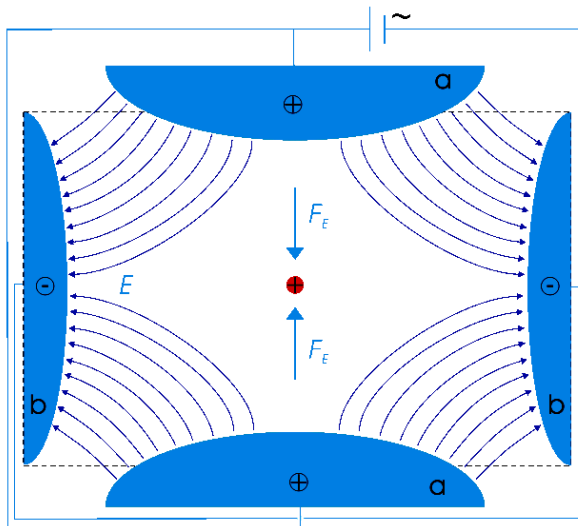
- continuation with trapping and cooling of ions
- ion crystals

now:

- photoionization
- correlated processes, detection

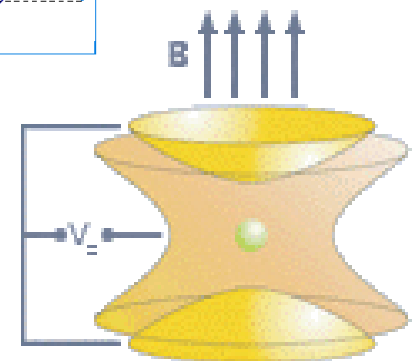
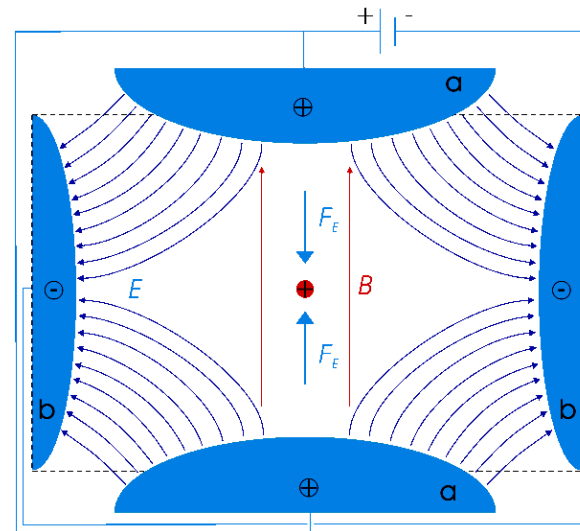
Paul trap

principle: electric
alternating field



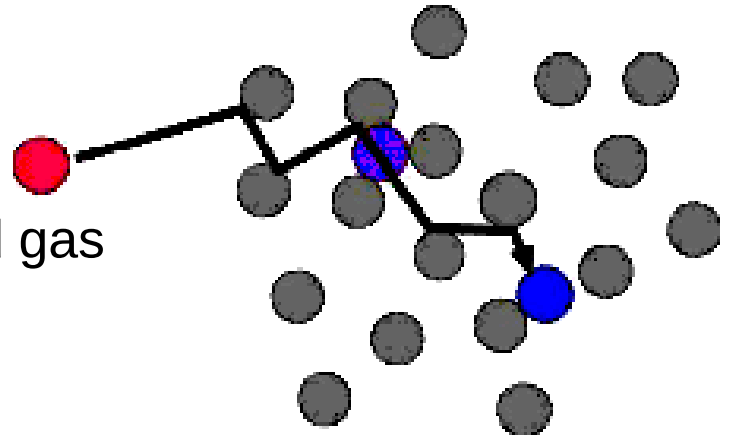
Penning trap

principle:
superposition of
a magnetic field



buffer gas cooling:

- collisions with a cold gas
- final temperature is temp. of the cold gas
- good for all particles

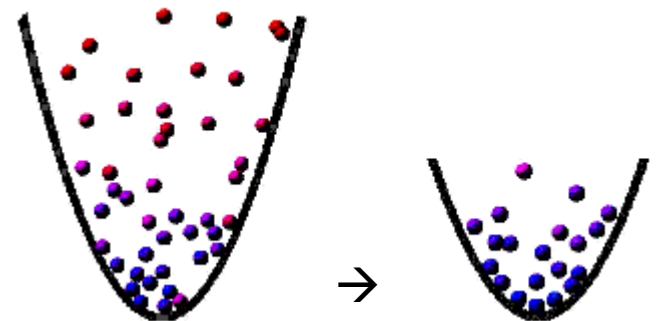


electron collisions cooling:

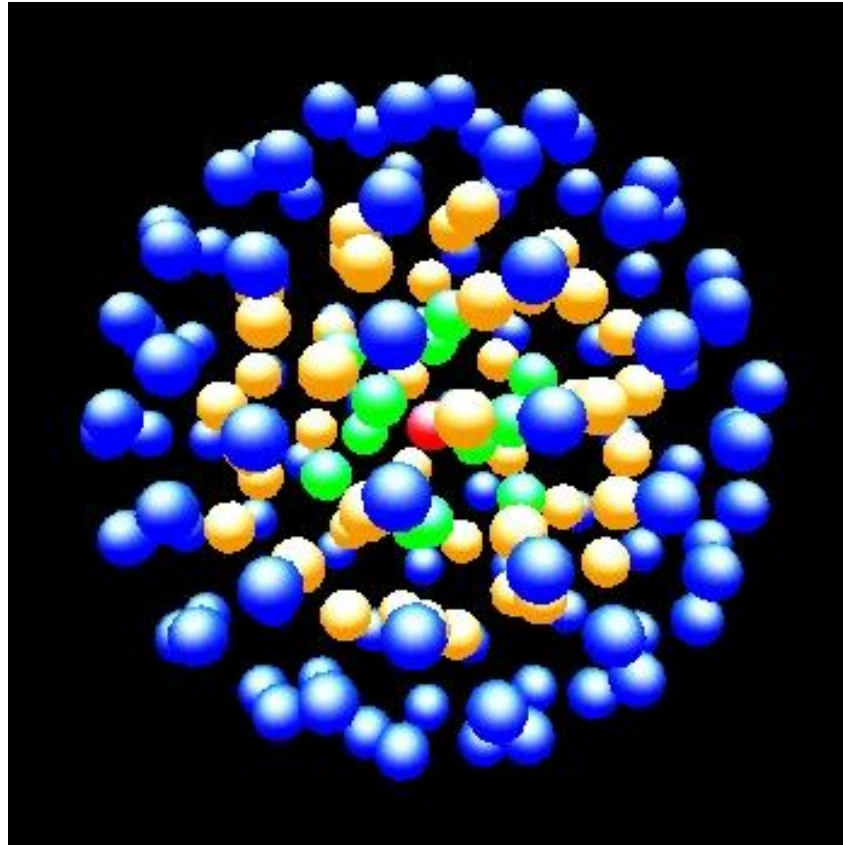
- co-propagating electron beam
 - ion velocity ultimately adapts the electron velocity
- monoenergetic ion beam with low divergence

evaporation cooling:

- hot atoms of the **Maxwell-Boltzmann distribution** will be removed



Wigner crystal



extremely high mass resolution in a FT ion trap

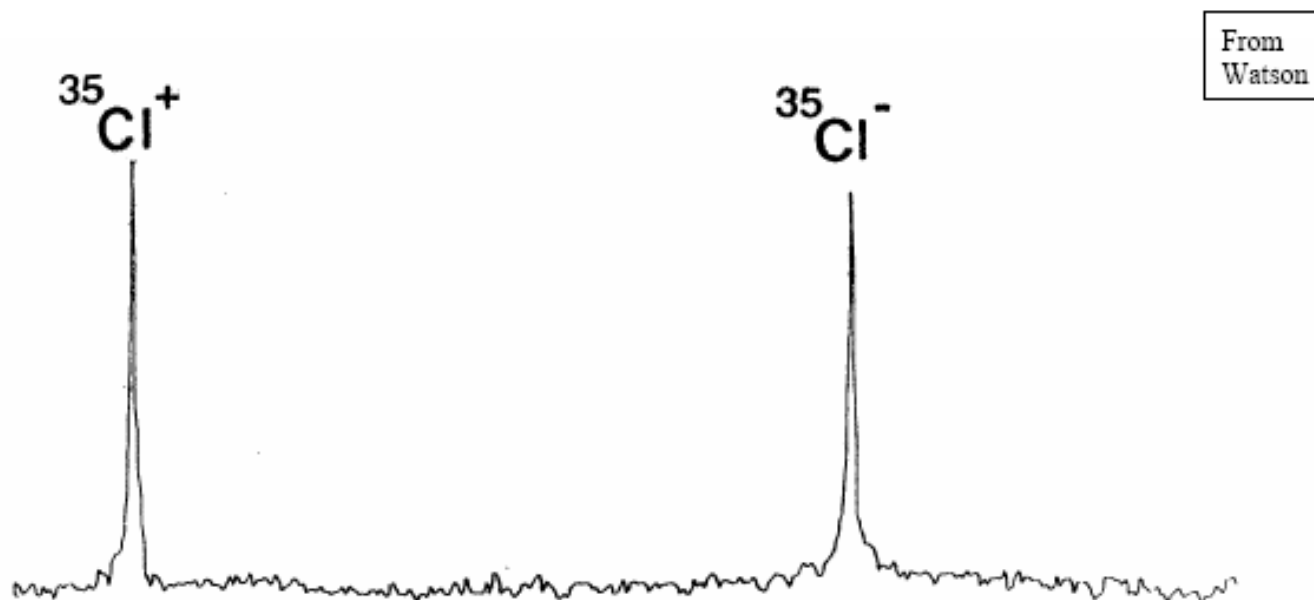
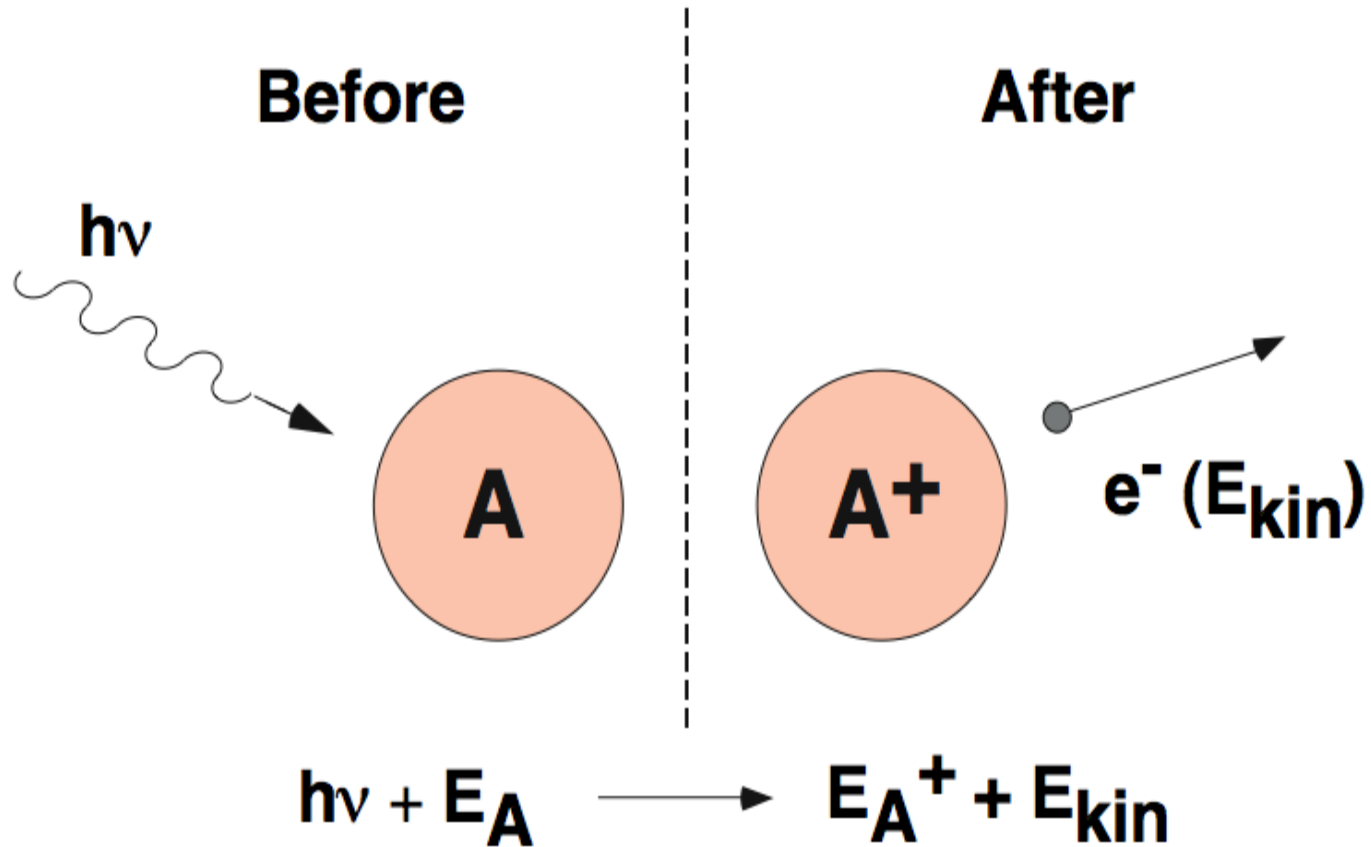


FIG. 4.22. Segment of mass spectrum in region of nominal mass 35 showing a resolution greater than 1,000,000 (FWHM definition) when using FT-MS. The peaks represent the positive and negative ions of ^{35}Cl that have a difference in mass equivalent to the mass of two electrons. The spectrum was obtained using a FT-ICR mass spectrometer with a superconducting magnet (4.7 tesla); the instrument was switched from the positive-ion-detection mode to the negative-ion-detection mode during the scan between the two peaks (Courtesy of Spectrospin AG.)

Photoionisation

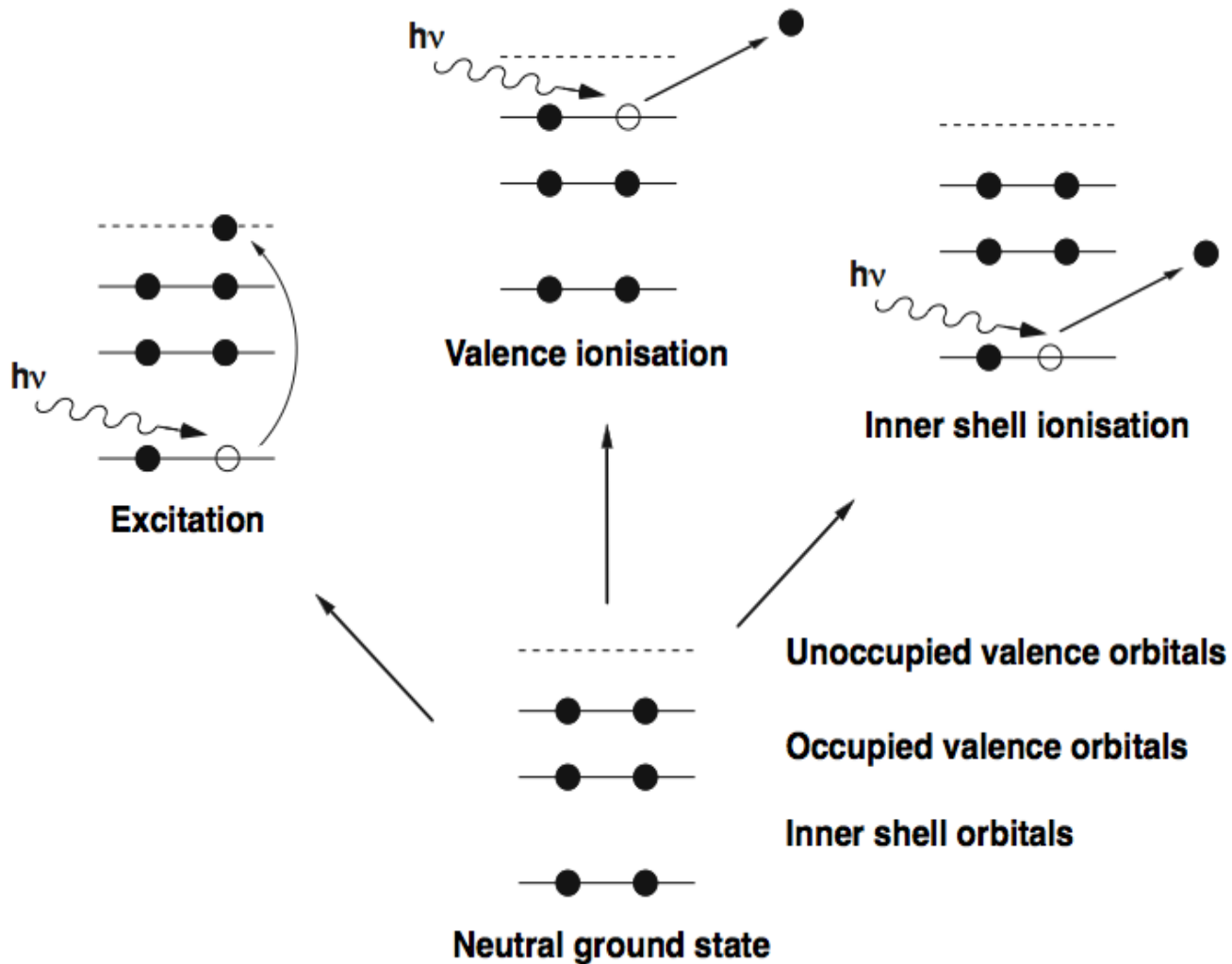


Photoelectric law, A. Einstein 1905:

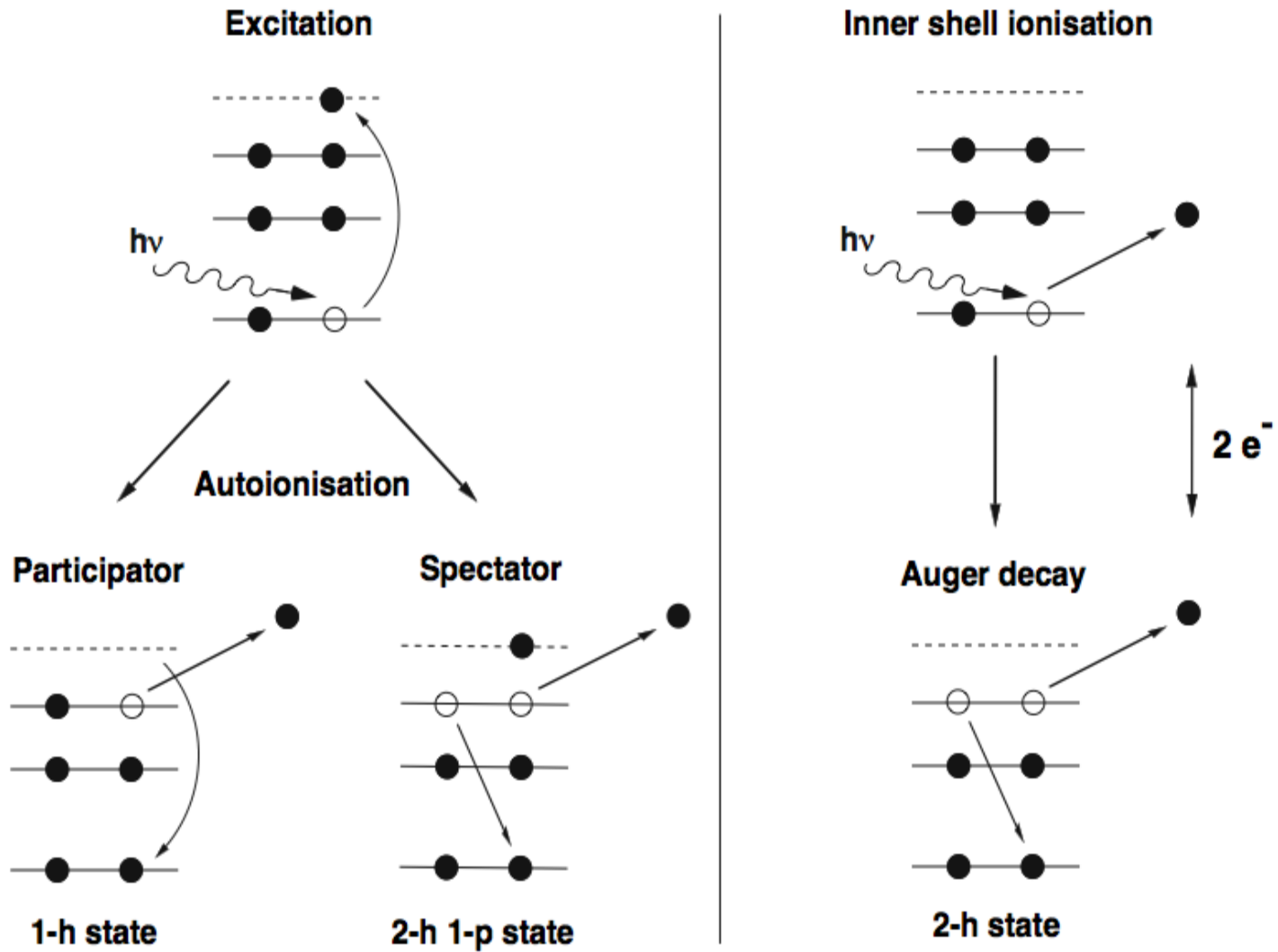
$$h\nu = E_{kin} + E_B$$

IP

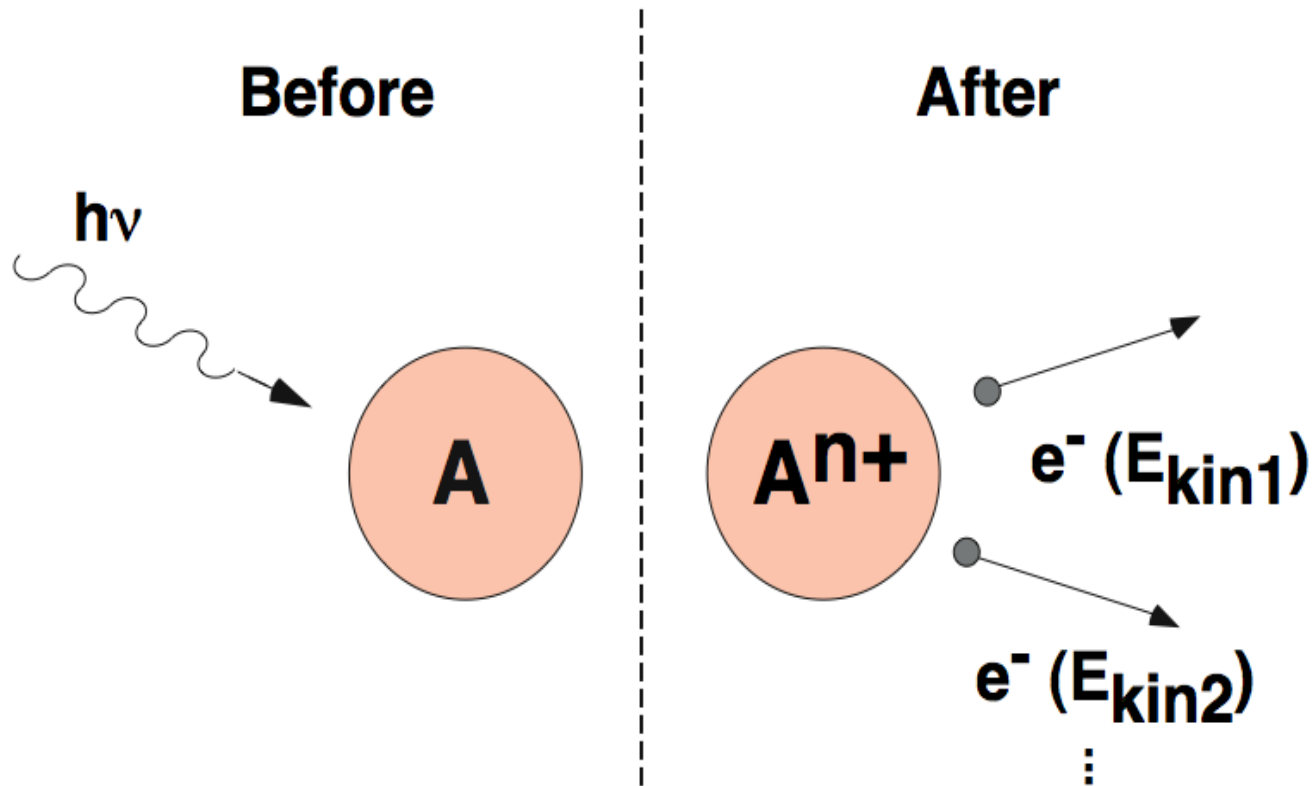
photoexcitation and ionisation processes



deexcitation processes



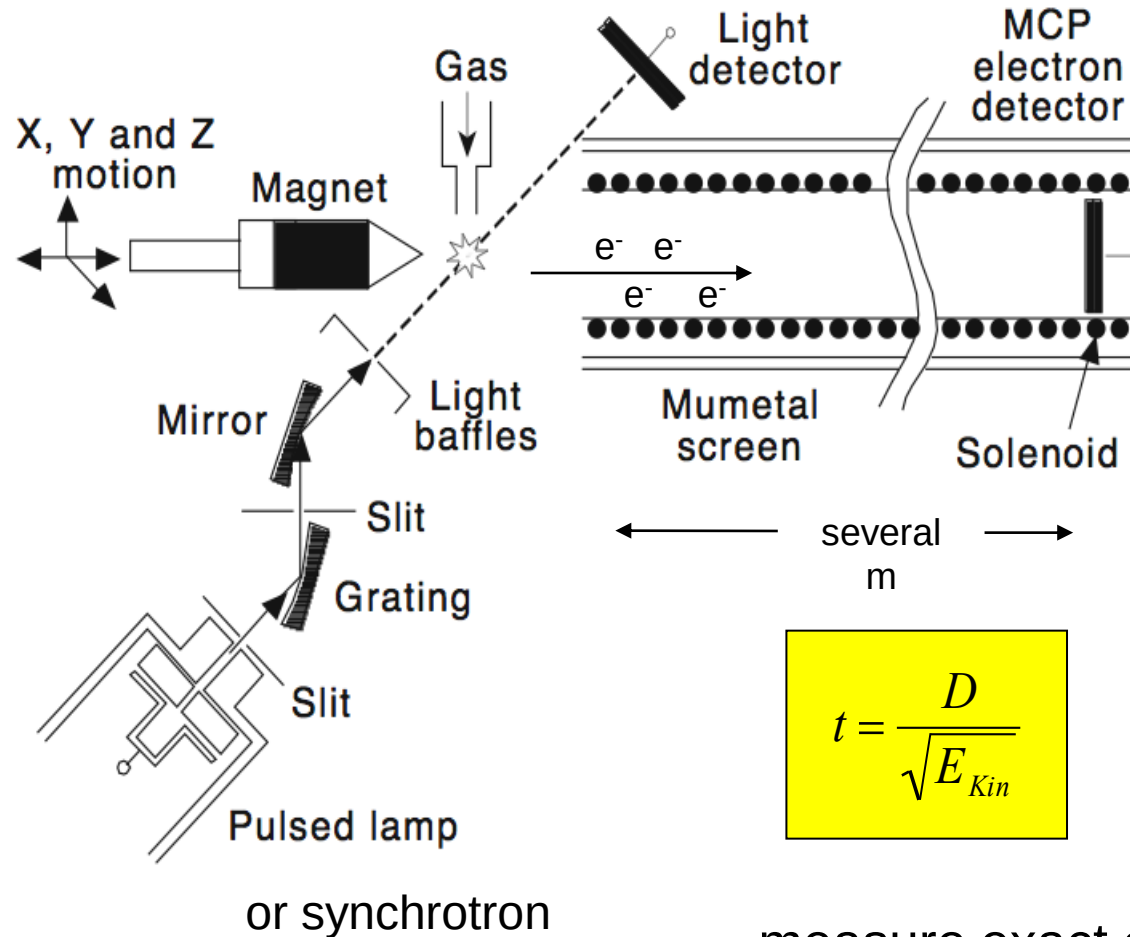
single photon - multiple ionisation



$$E_{B1} + E_{B2} (+ \dots) = h\nu - E_{kin1} - E_{kin2} (- \dots)$$

how to measure correlated electron emission?

time of flight (TOF) electron spectroscopy



$$t = \frac{D}{\sqrt{E_{Kin}}}$$

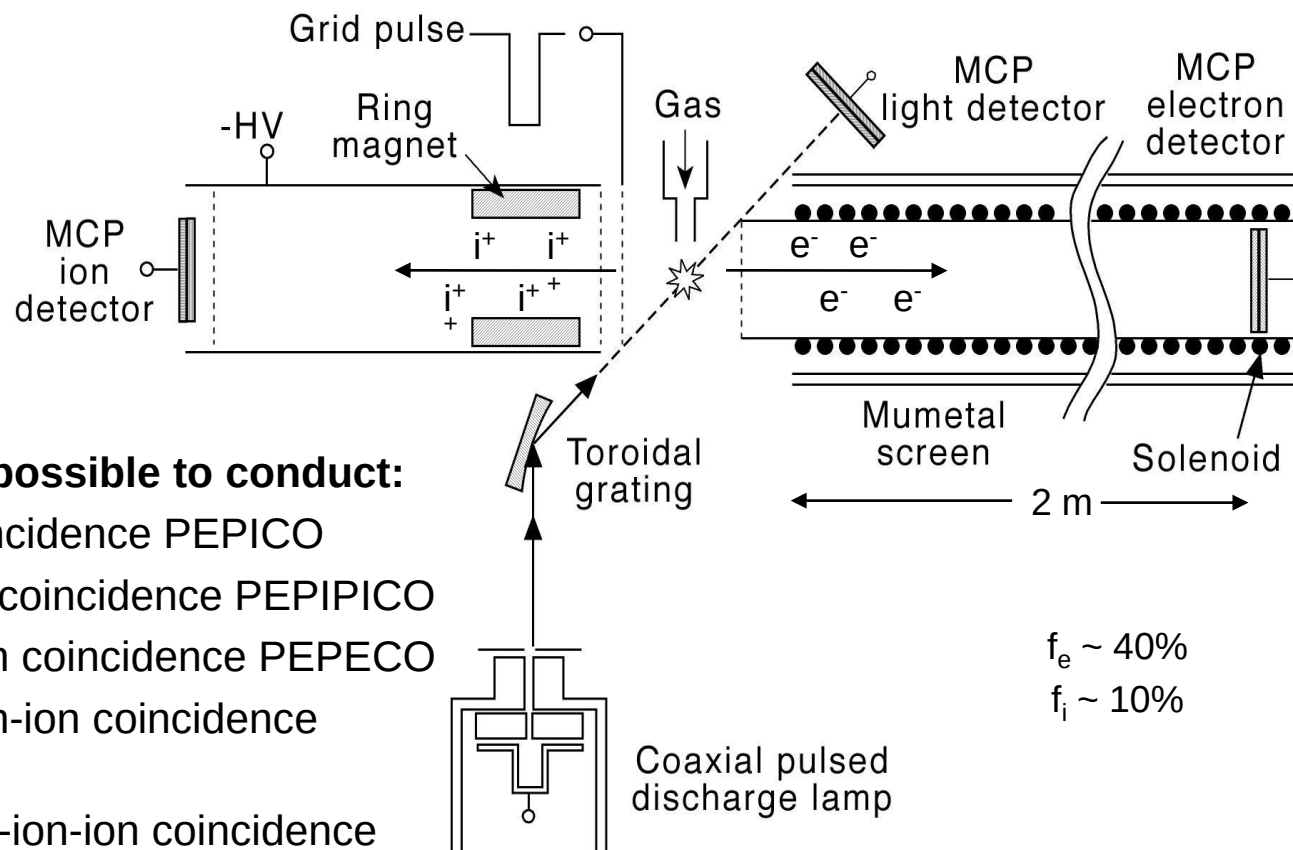
TOF spectrometer instrument...



a long electron drift tube yields high resolution
World's longest electron time-of-flight electron spectrometer

TOF photoelectron-photoion spectroscopy

TOF - PEPEIPICO



Simultaneously possible to conduct:

- Electron-ion coincidence PEPICO
- Electron-ion-ion coincidence PEPIPICO
- Electron-electron coincidence PEPECO
- Electron-electron-ion coincidence (PEPEPICO)
- Electron-electron-ion-ion coincidence (PEPEPIPICO)

$$f_e \sim 40\%$$

$$f_i \sim 10\%$$

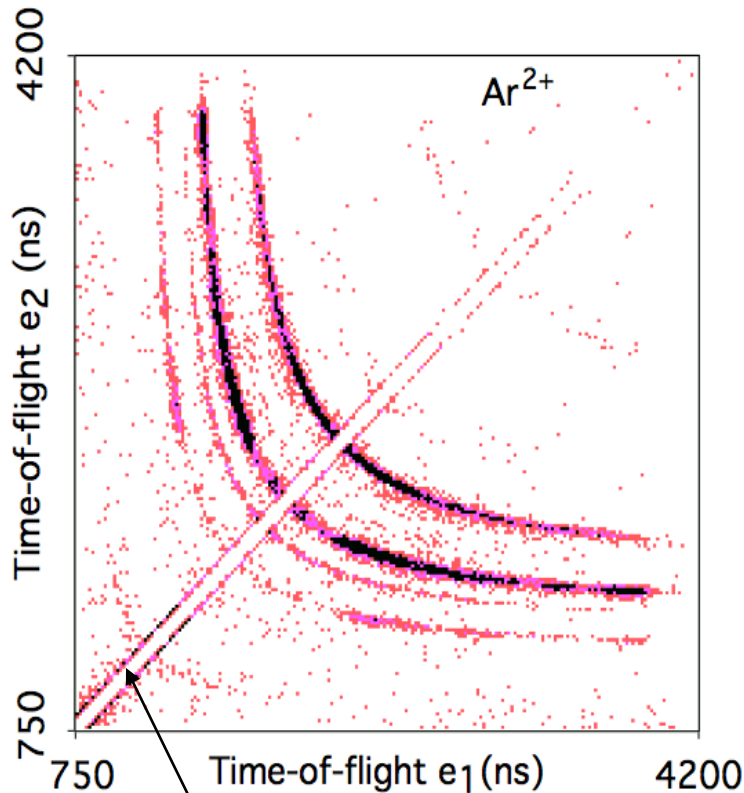
J.H.D Eland and R. Feifel Chem. Phys. 327 85 (2006)

R. Feifel *et al.*, J. Chem. Phys. 125, 194318 (2006)

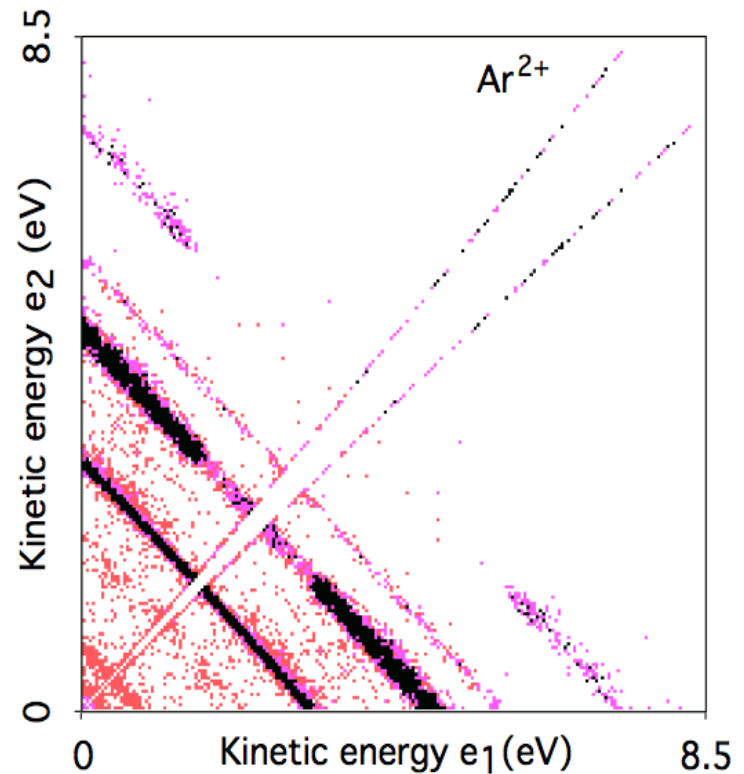
Single photon - double ionisation of Argon ($h\nu = 48.372$ eV)

measure the electrons in coincidence with Ar^{2+}

time spectra



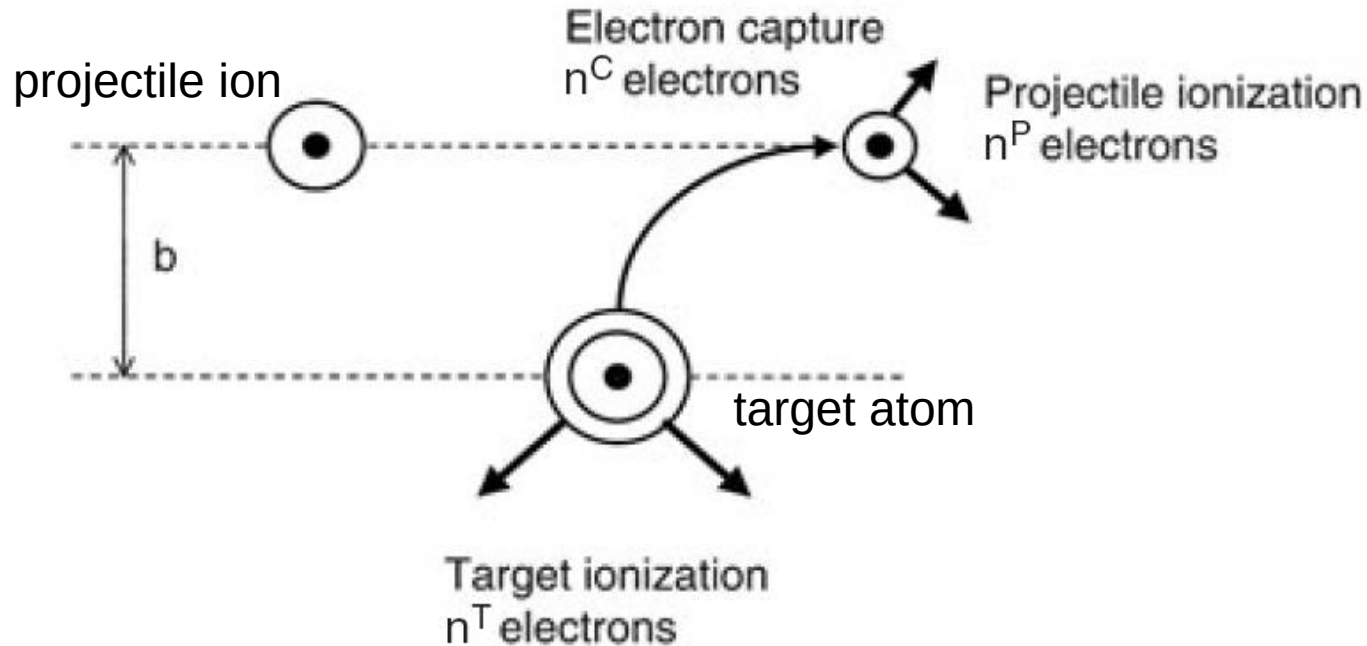
converted into energy space



from the diagonal lines we learn: all energies for e1 and e2 are possible, but their sum is constant, depending on the atomic level

recoil-ion and electron momentum spectroscopy

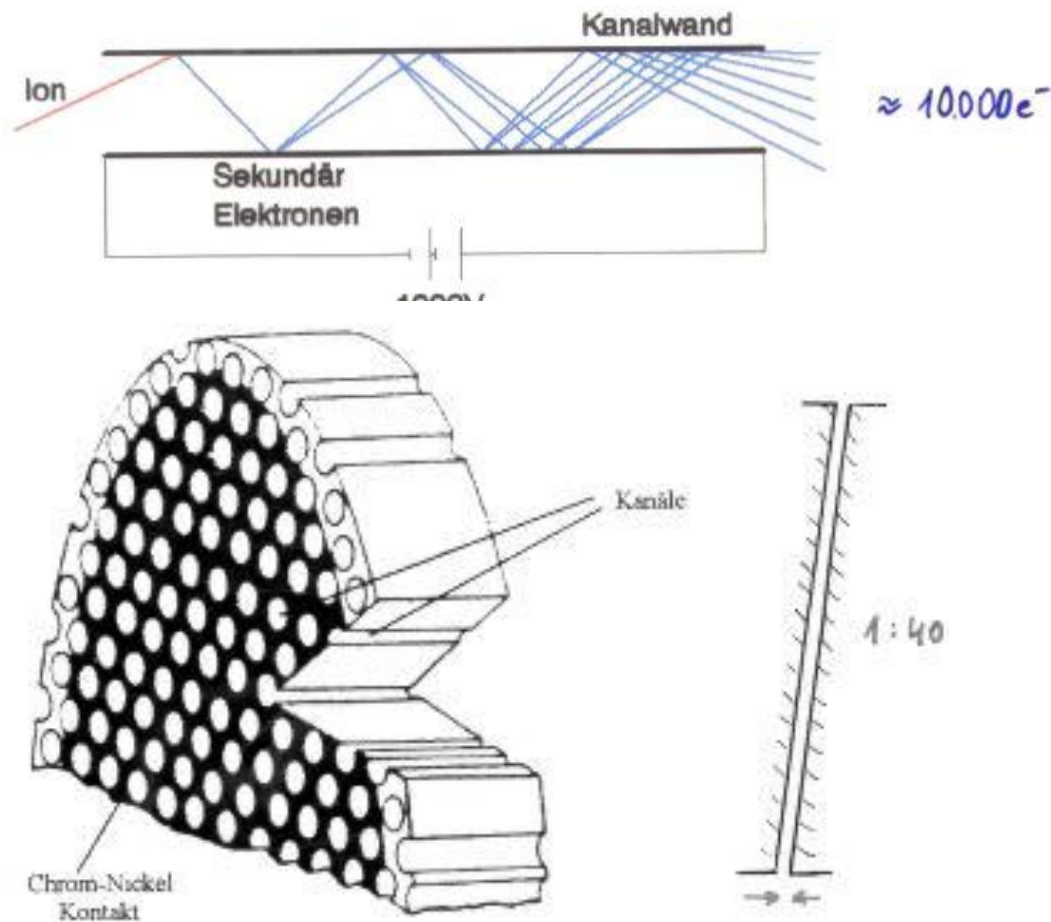
e.g., ion-atom collision: need to measure ion momenta and several electrons



many different reaction channels

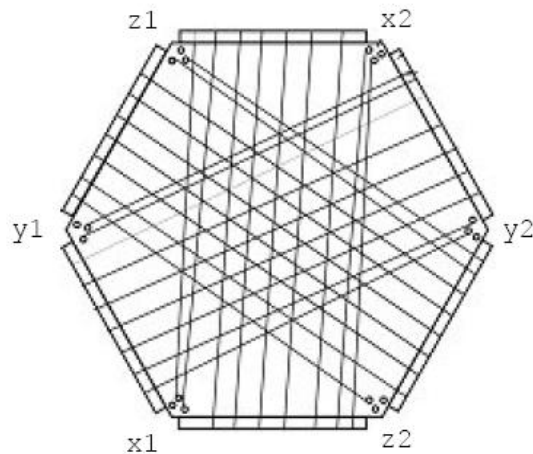
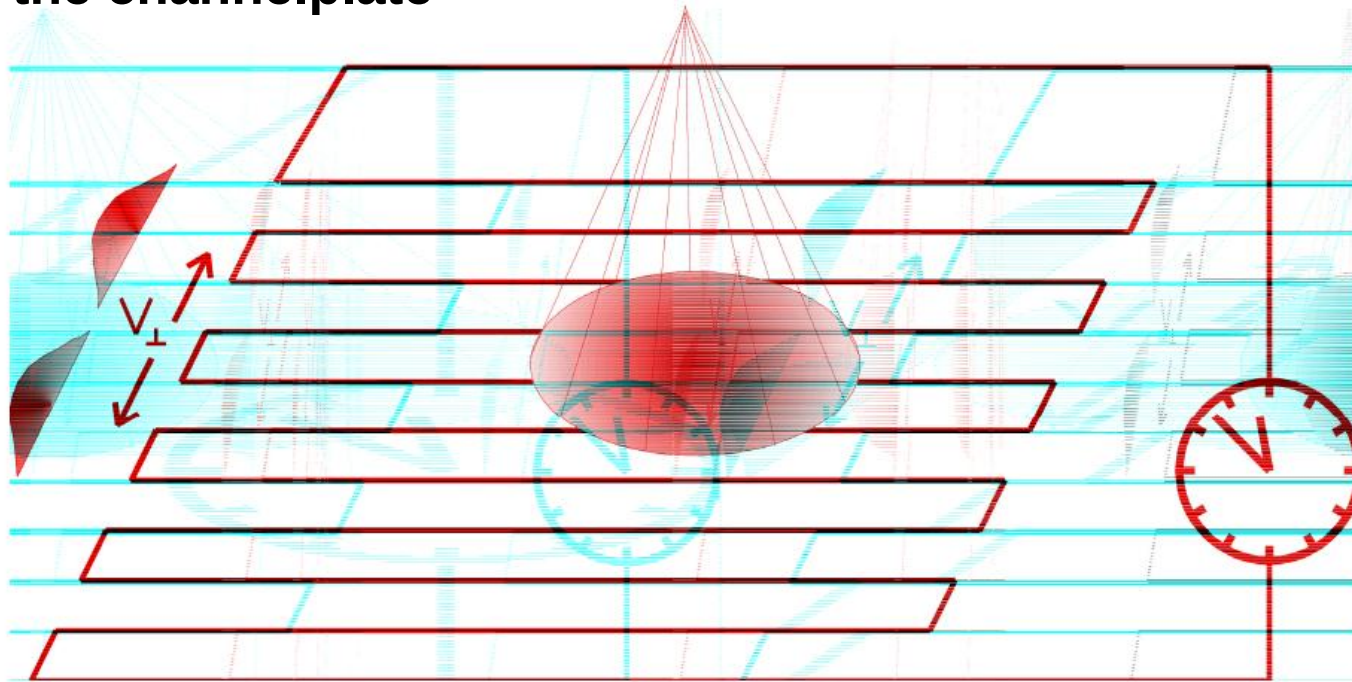
how to build a momentum spectrometer:
need time and spacial resolving detector

important element: multichannel plate detector

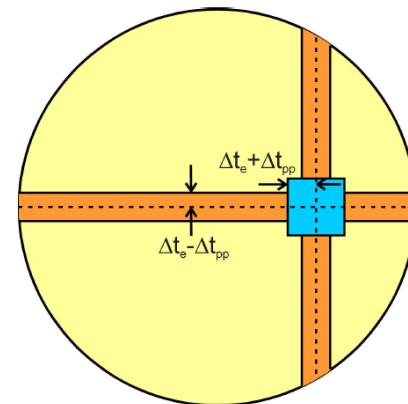


spatial resolution

with position-sensitive detection with the delay-line detector
behind the channelplate



high resolution
with the
Hexanode
detector

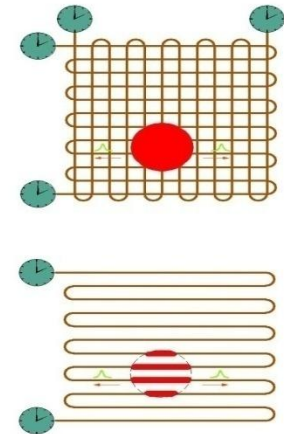
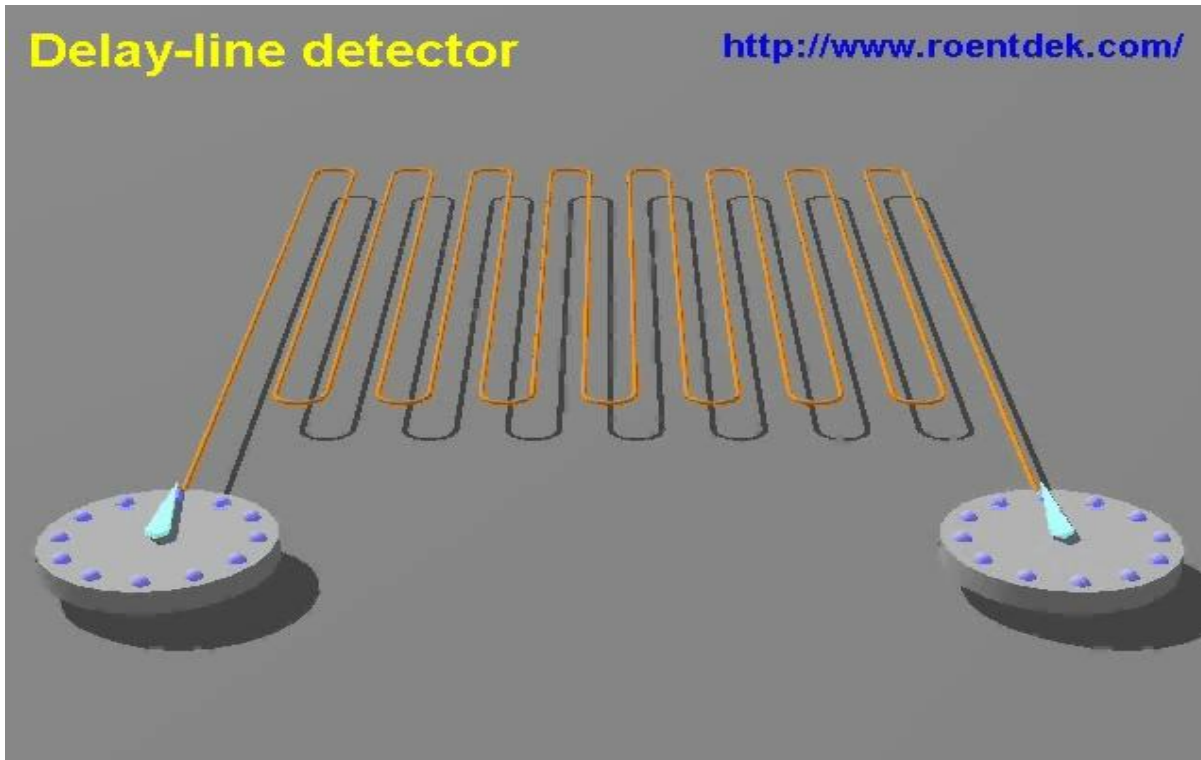


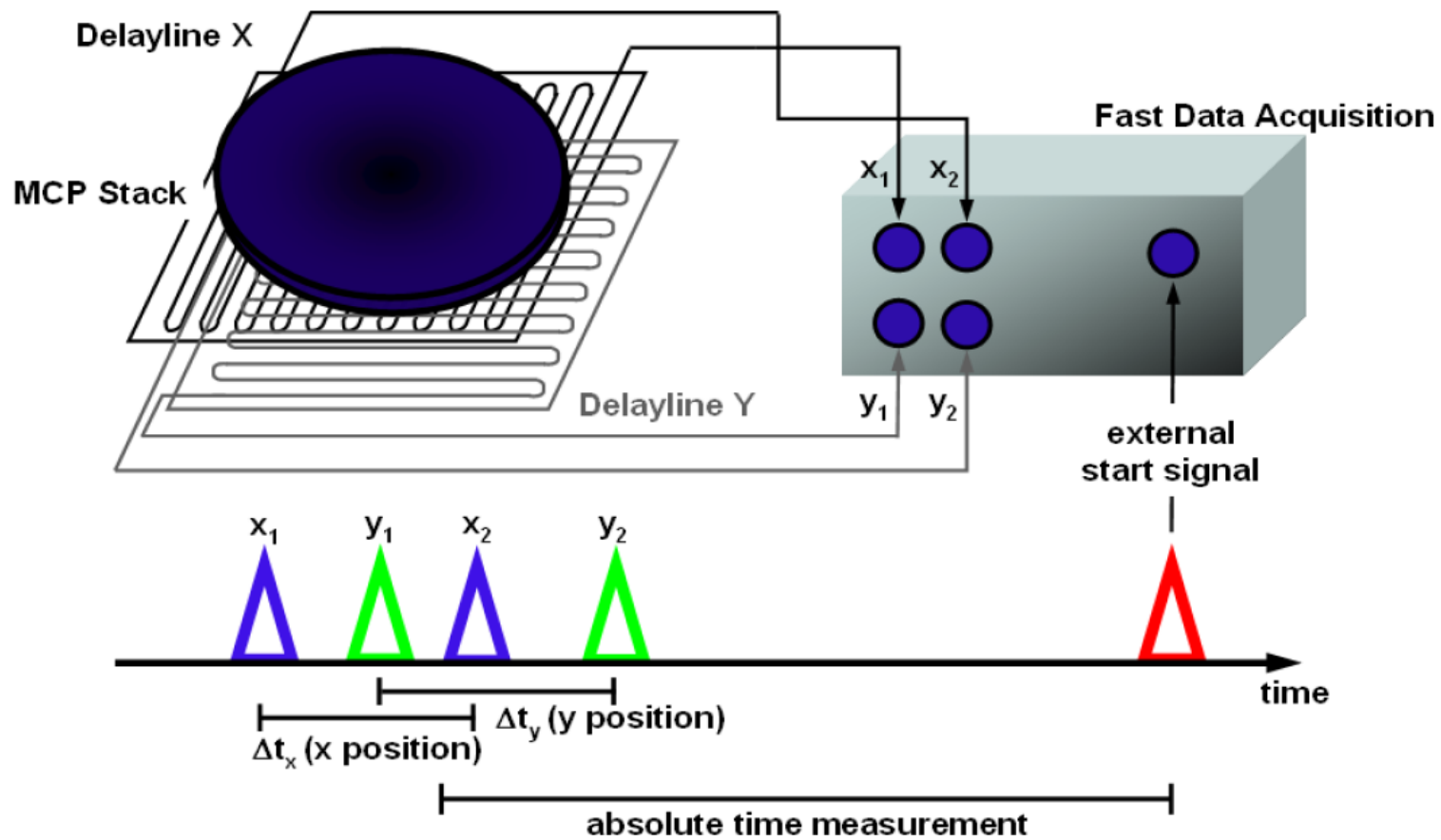
delay-line timing signals

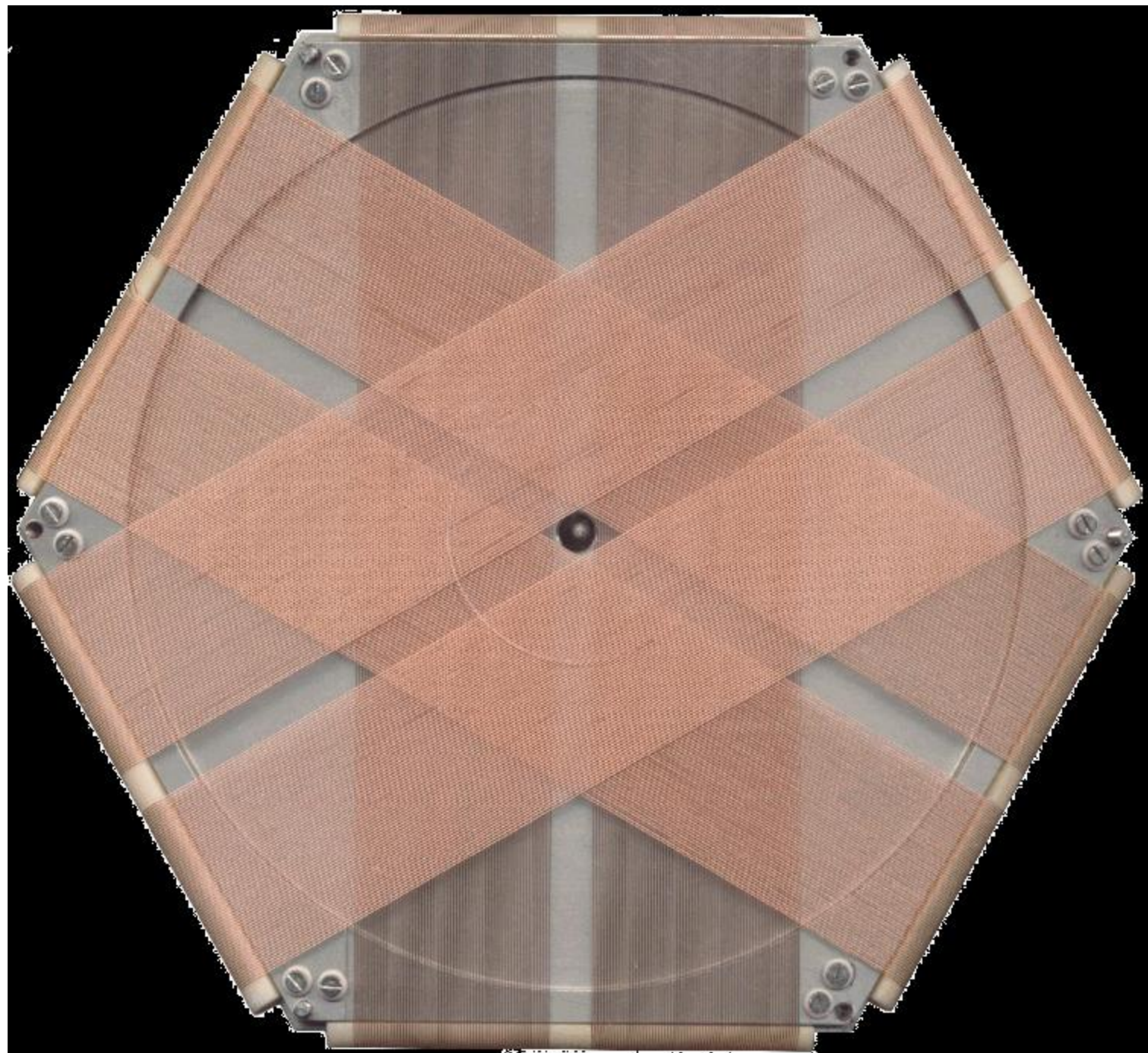
All times recorded in a time-to-digital converter on an event-by-event basis by computer

Delay-line detector

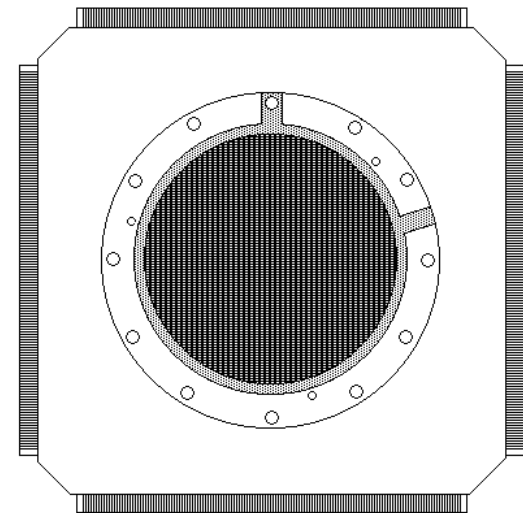
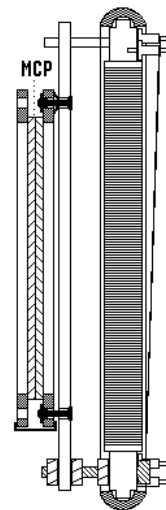
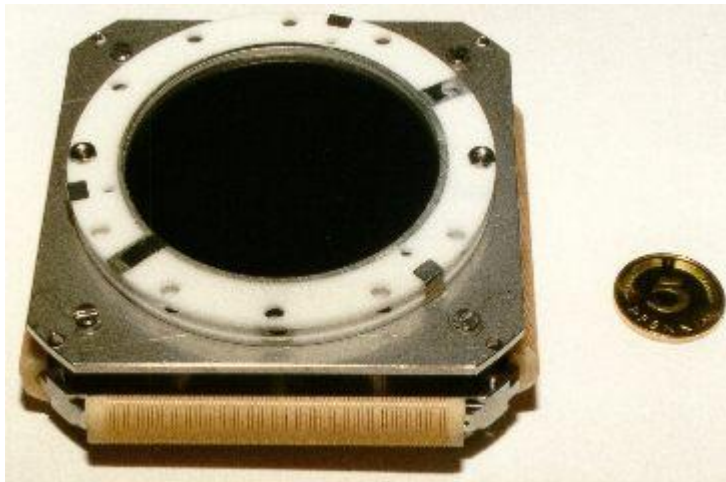
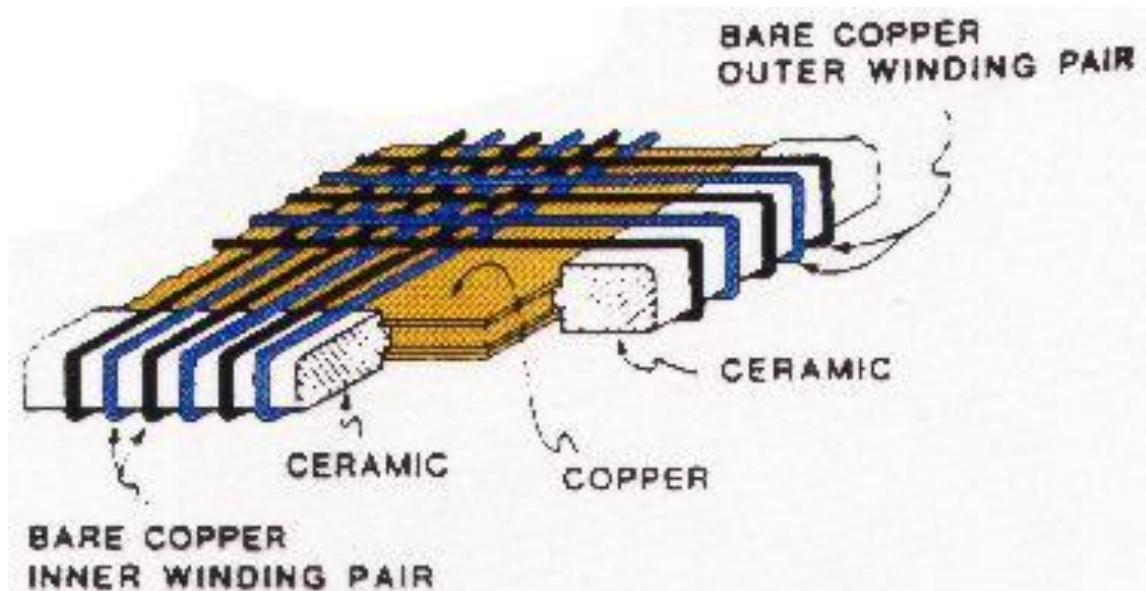
<http://www.roentdek.com/>







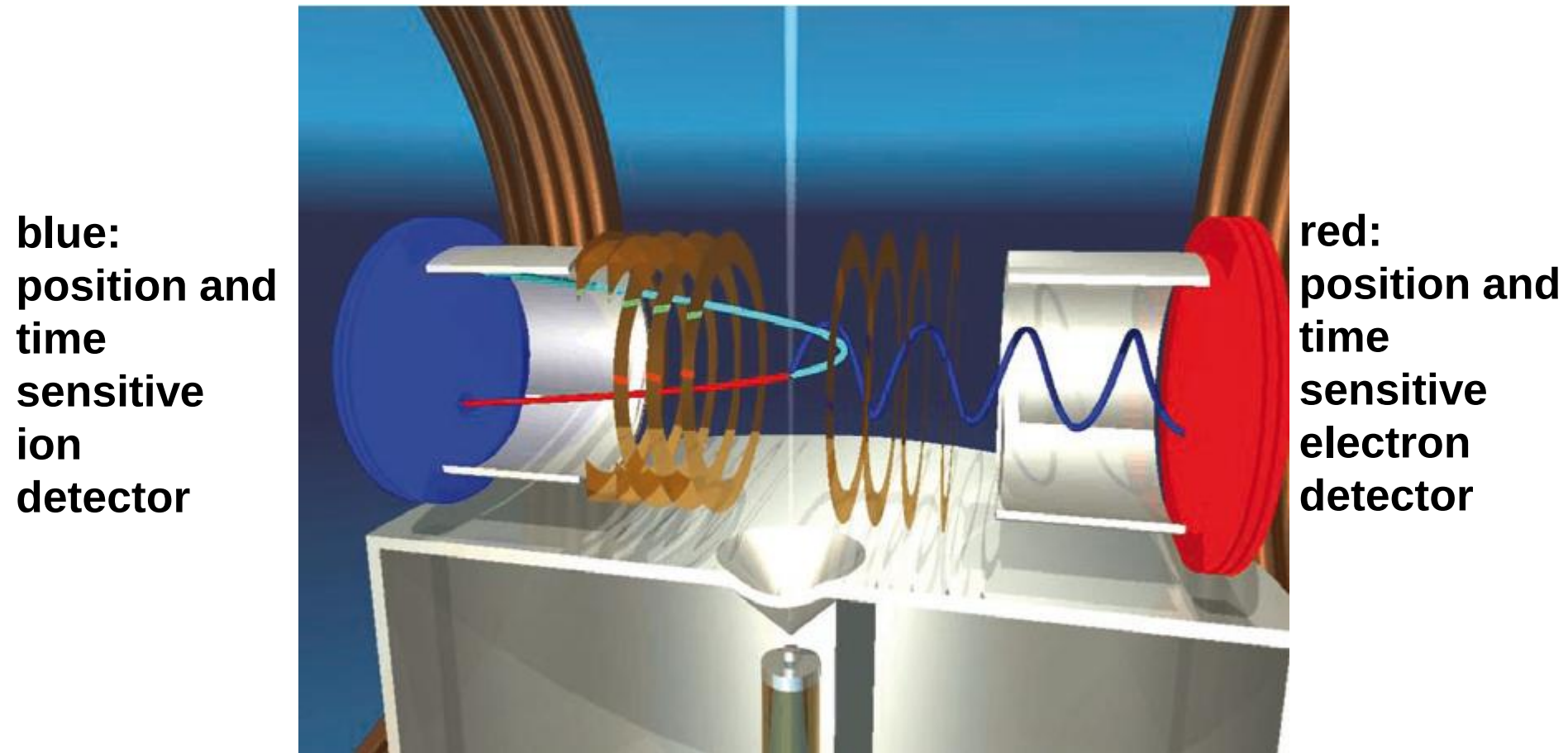
delay line detector



delay line detector with MCP

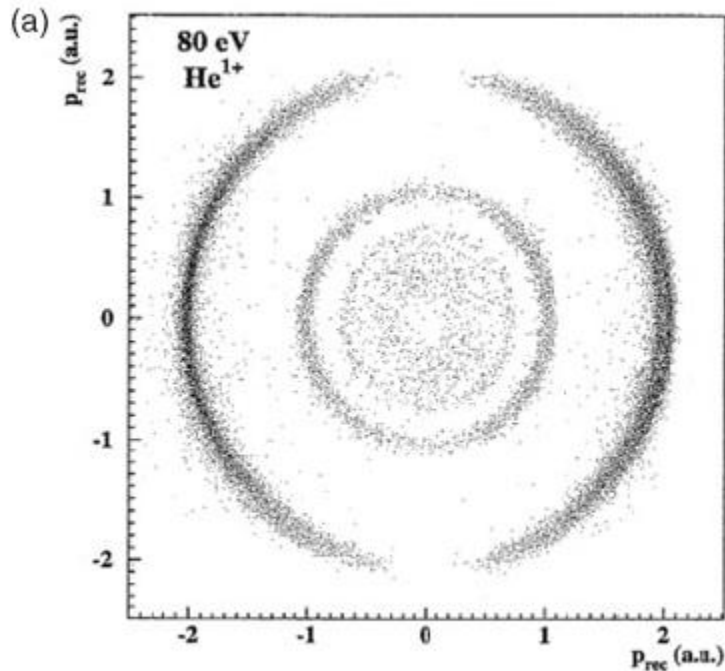
ion and electron momentum spectrometer COLTRIMS

the 'bubble chamber' of atomic physics

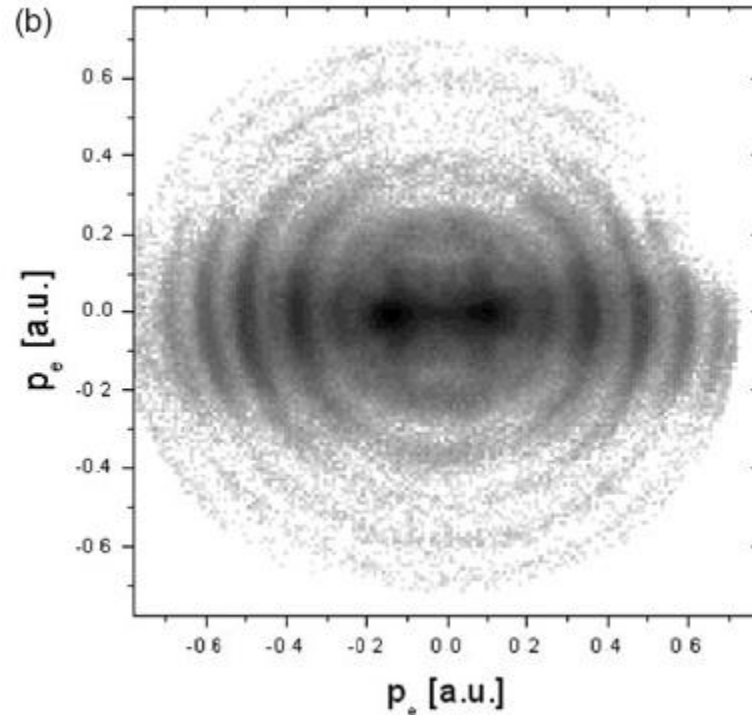


Horst Schmidt-Böcking, Stern-Gerlach medal 2010
of the German Physical Society (DPG)

momentum distributions from He ionization

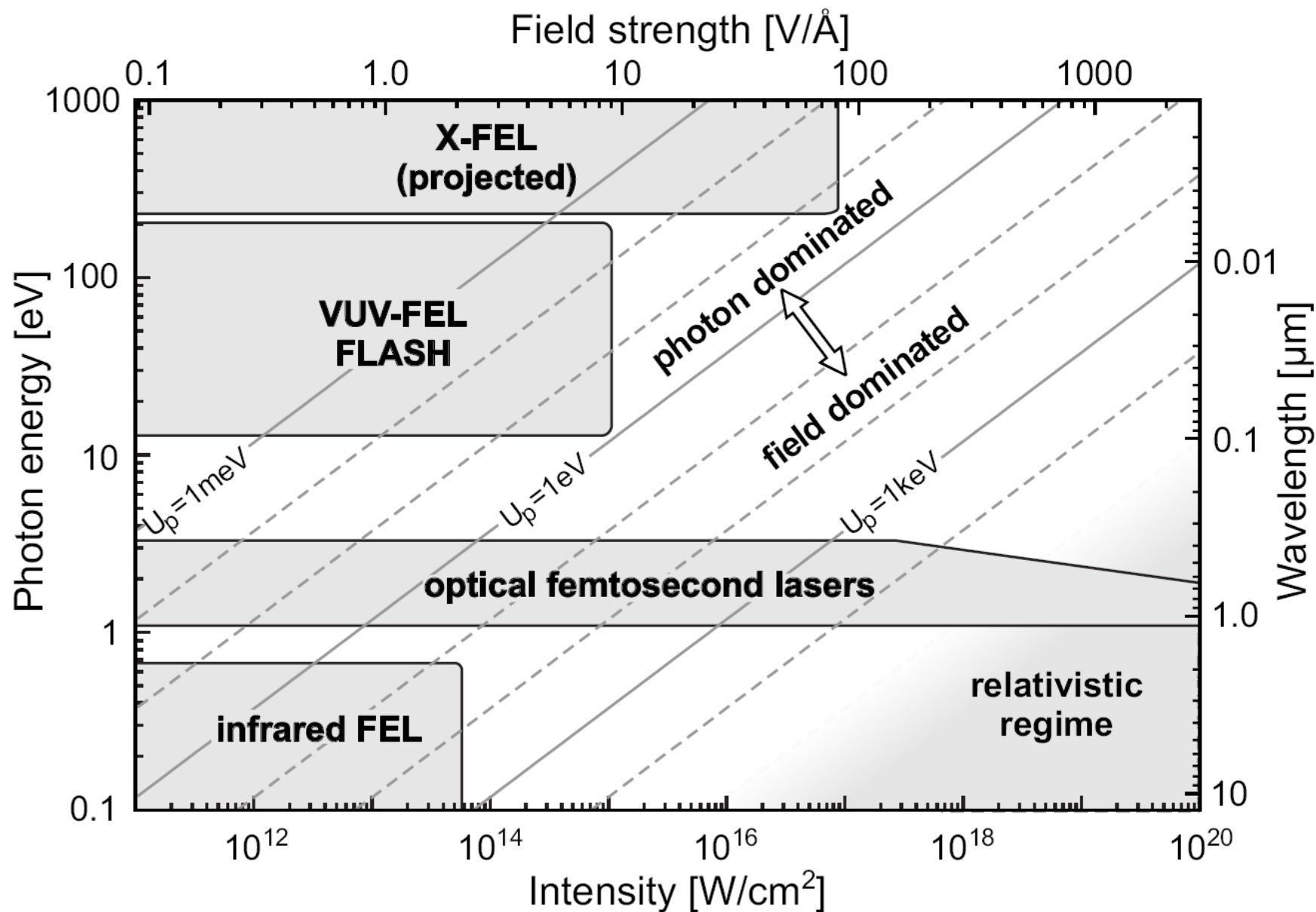


single ionization with 80 eV

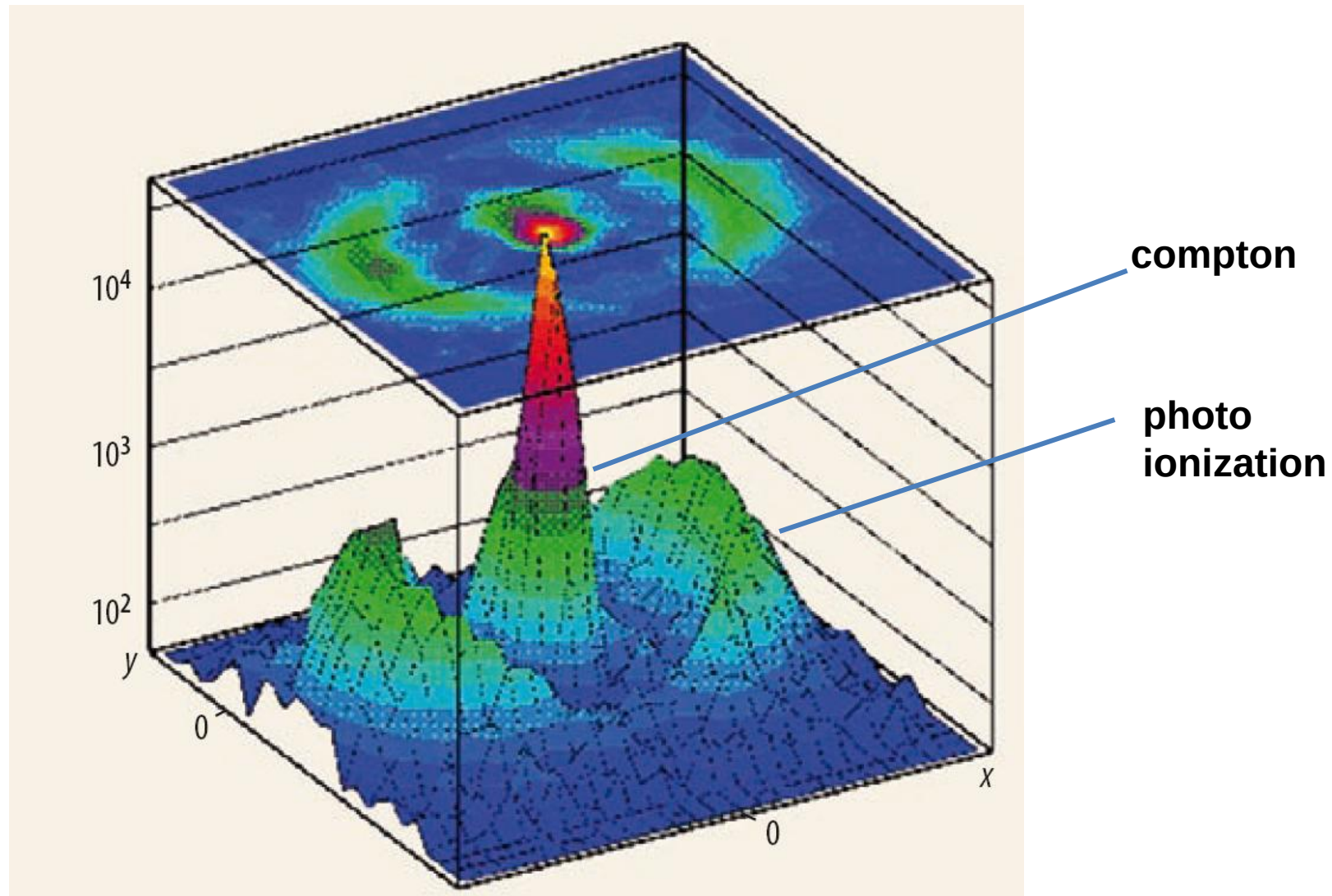


multiphoton single ionization
with 25 fs at 800 nm
10exp15 W/cm²

Laser intensity regimes



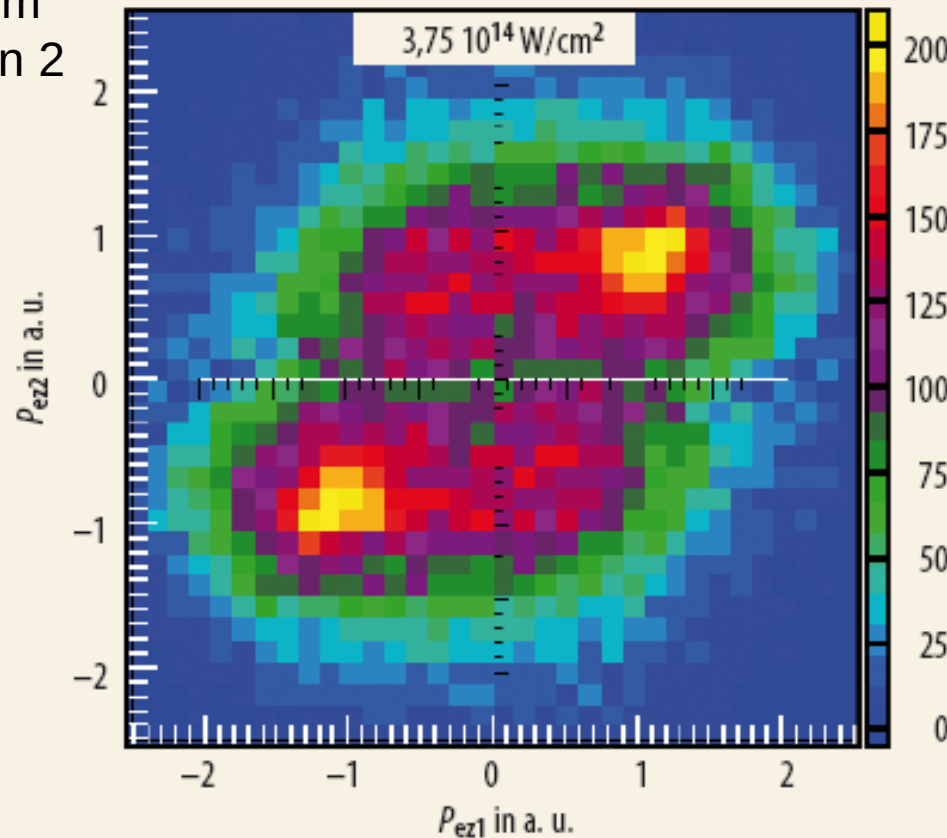
He + momentum distribution for photoabsorption at 8.8 keV



from momentum distributions PI and Compton scattering can be disentangled

2-electron momentum correlation for double ionization in Ar

momentum
of electron 2



momentum of electron 1

**electron correlation in
strong laser field ionization**

**both electrons are
simultaneously emitted (non-
sequential)**

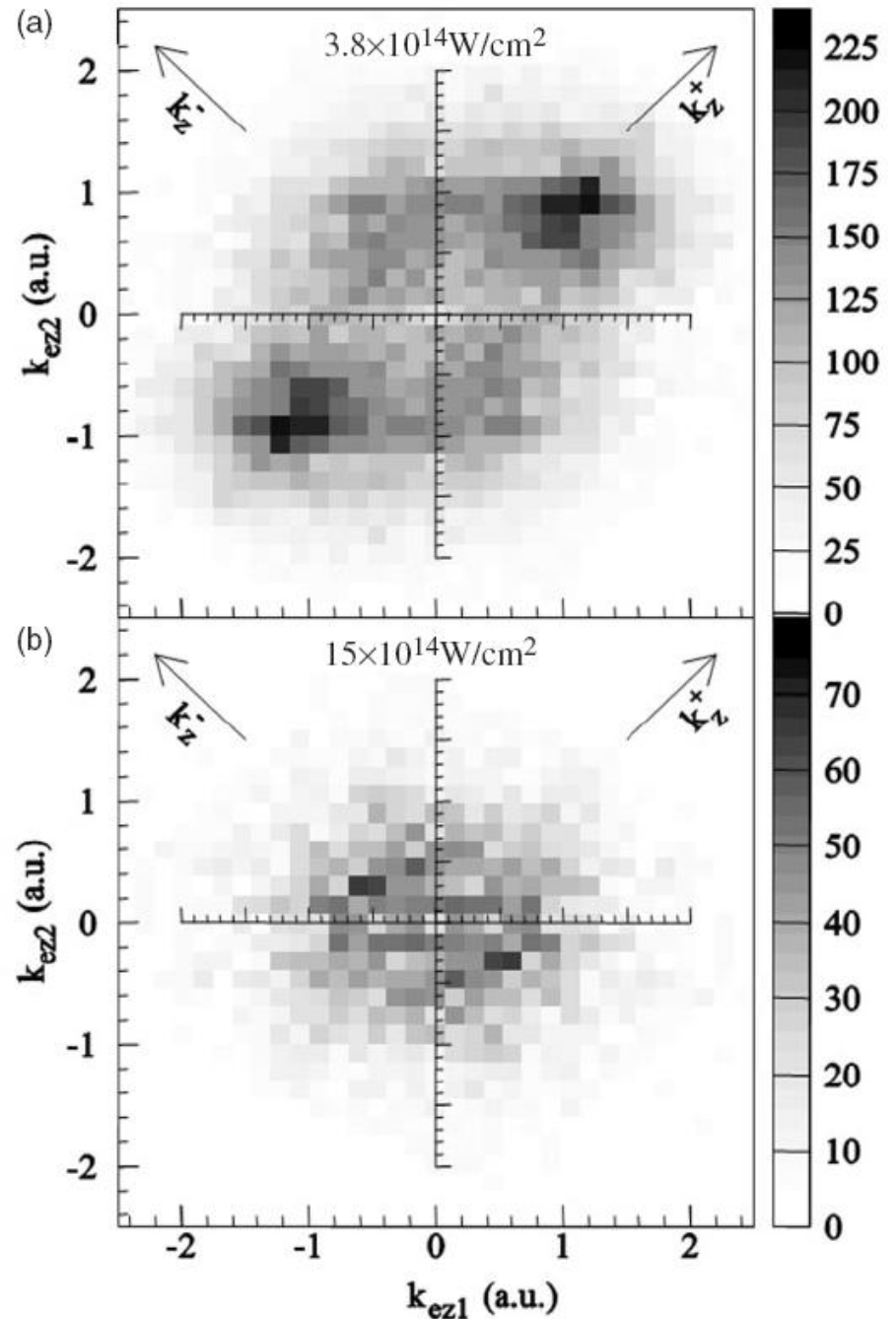
**proof of electron rescattering
process**

2-electron momentum correlation for double ionization in Ar

as before:
non-sequential
regime

sequential regime

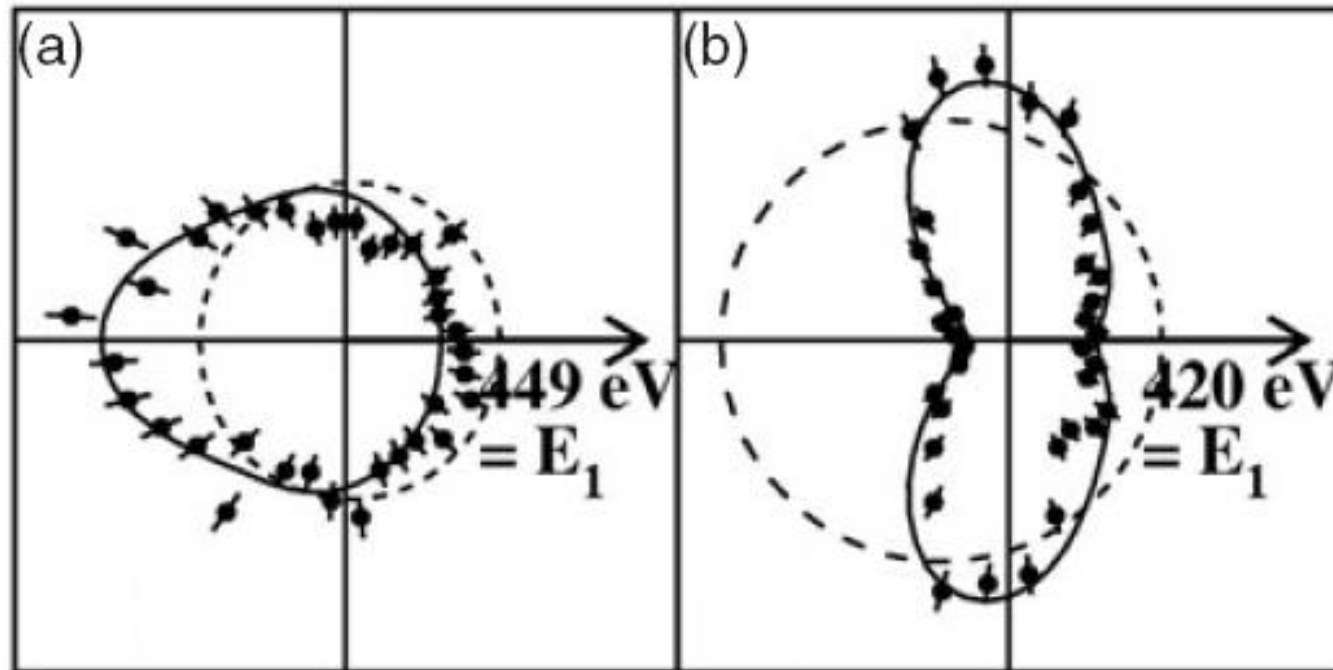
depending on the
laser power!



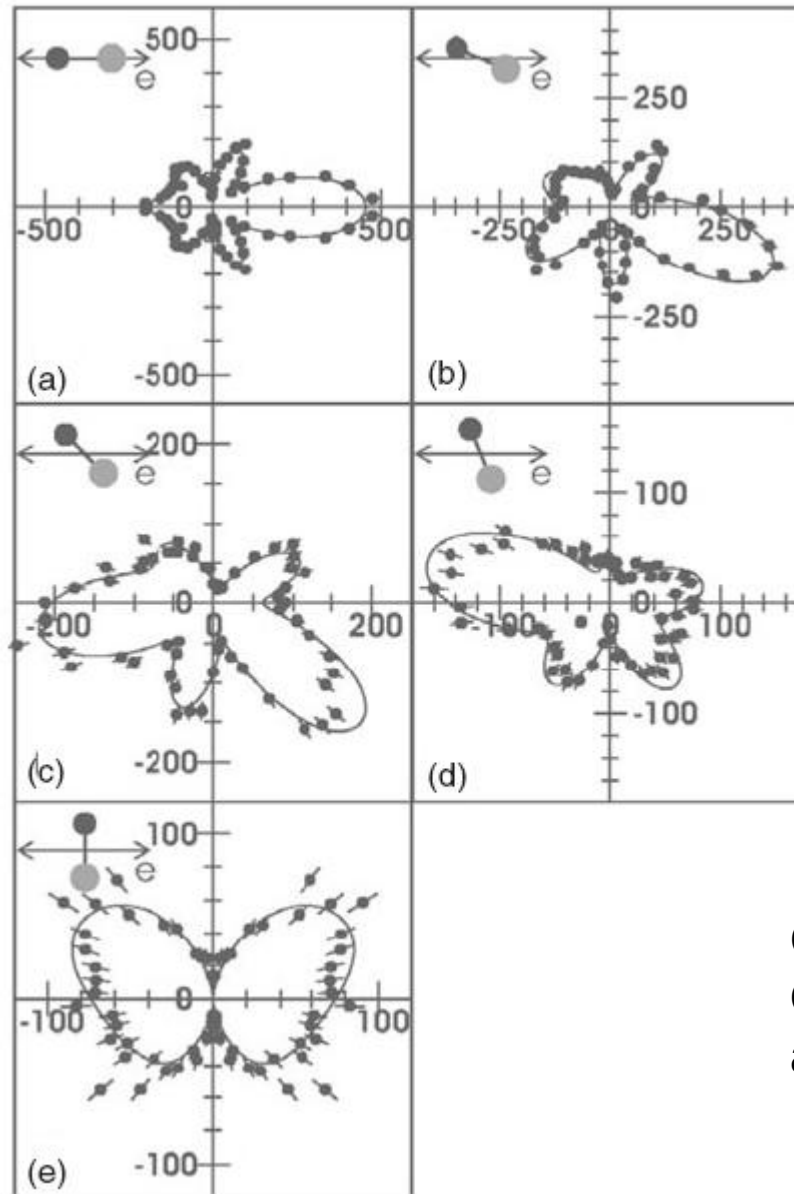
He photo double ionization at 529 eV photon energy

Arrow: direction of electron 1 (with given energy)

symbols: emission of electron 2 (at 2 eV, left, and 30 eV)



Carbon k-shell photoelectrons from CO at 10 eV energy



C : black
O: grey
arrow: light polarization