Detectors and what we use them for at ELISA

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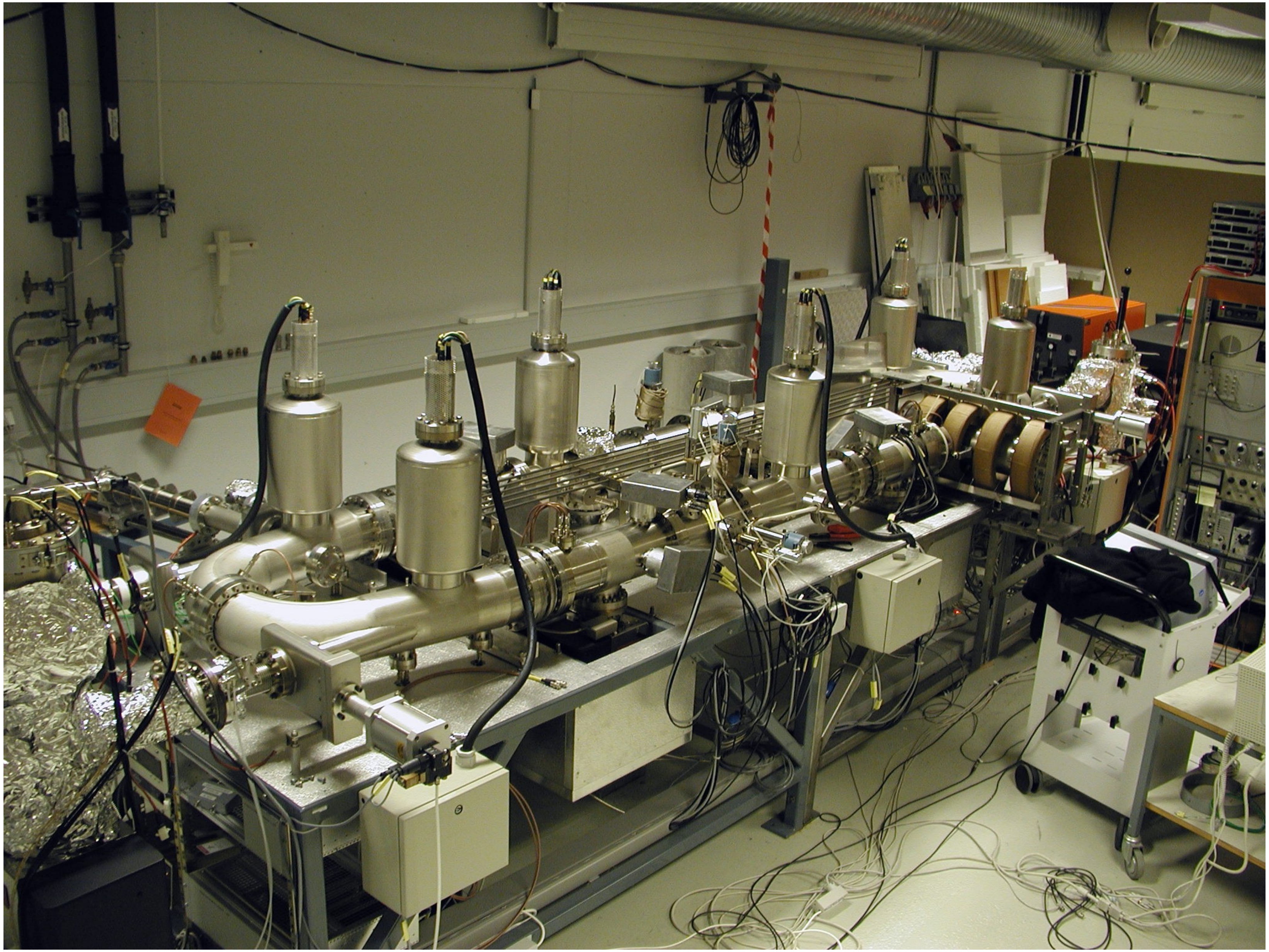
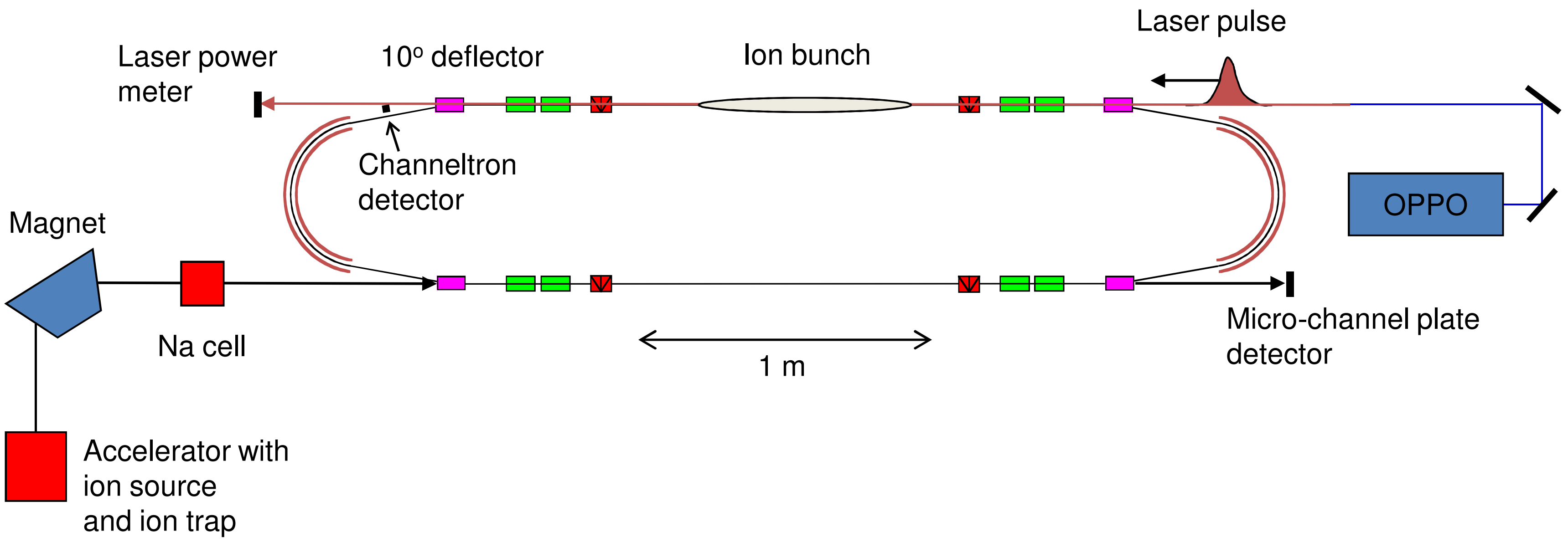
Low Current, Low Energy Beam Diagnostics, November 25, 2009

ELectrostatic Ion Storage ring in Aarhus (ELISA)



Elisa data



Ring design:

8.3 m in circumference

160º deflectors

10º deflectors

Stores ions with energies up to 22 keV per charge

Beam diagnostics:

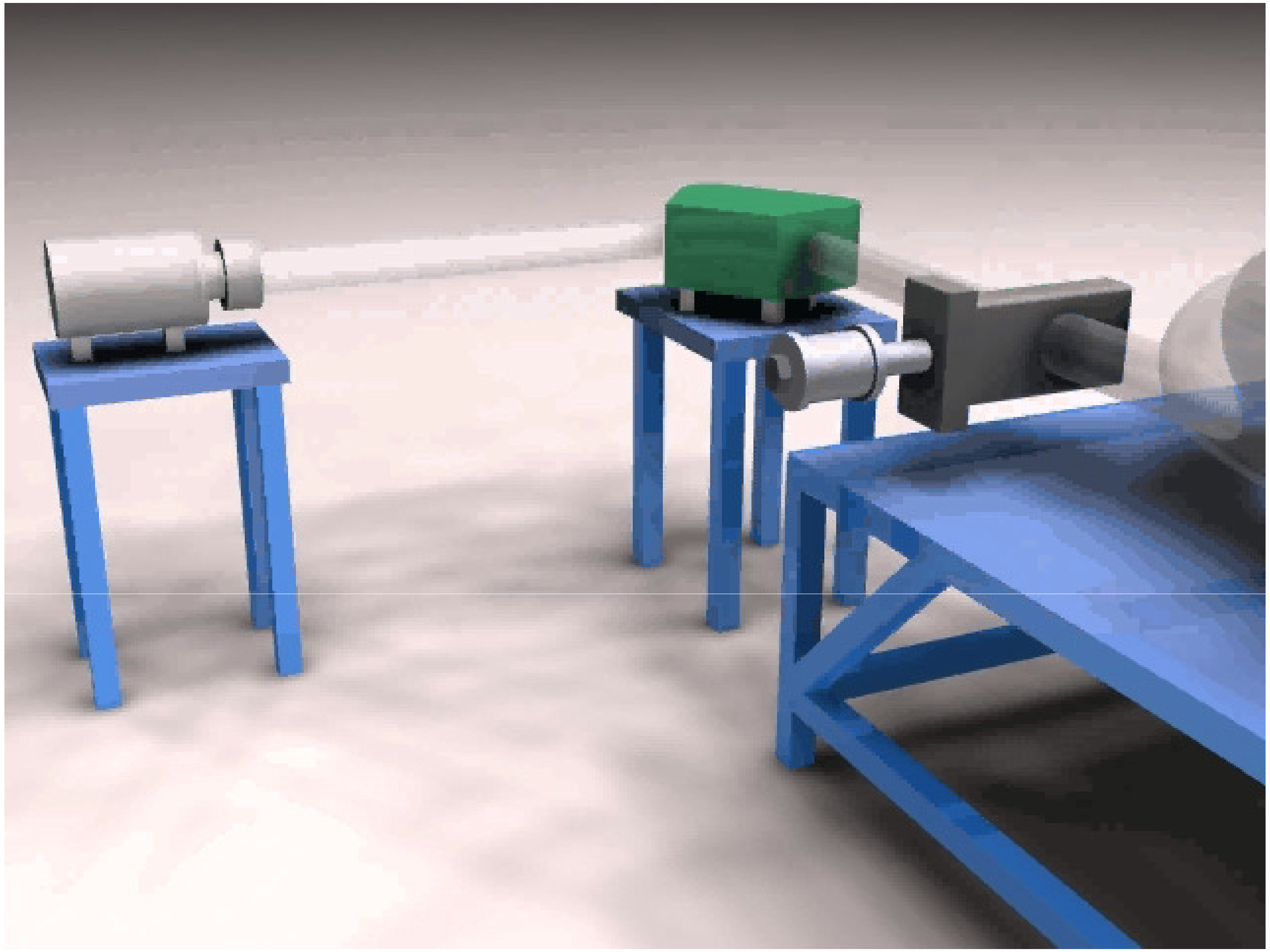
4 horizontal pickups

4 vertical pickups

Scrapers

MCP detectors

ELectrostatic Ion Storage Ring Aarhus (ELISA)



S.P. Møller, *NIM A* **394**, 281 (1997).

J.U. Andersen, J.S. Forster, P. Hvelplund, T.J.D. Jørgensen, S.P Møller, S. Brøndsted Nielsen, U.V. Pedersen, S. Tomita, H. Wahlgreen, *Rev. Sci. Instrum.* **73**, 1284 (2002).

ELISA = ELectrostatic Ion Storage ring Aarhus

Commisioned in 1999

ENTIRELY ELECTROSTATIC

Advantages:

Store ions of fixed charge and energy with arbitrary mass

Useful for study of heavy ions: fullerenes, biomolecules and other macromolecules

Combined with an electrospray ion source and a multipole ion trap to accumulate the ions for injection into ELISA.

Two others are operating in Japan, rings in Stockholm, Frankfurt and Heidelberg are under construction.

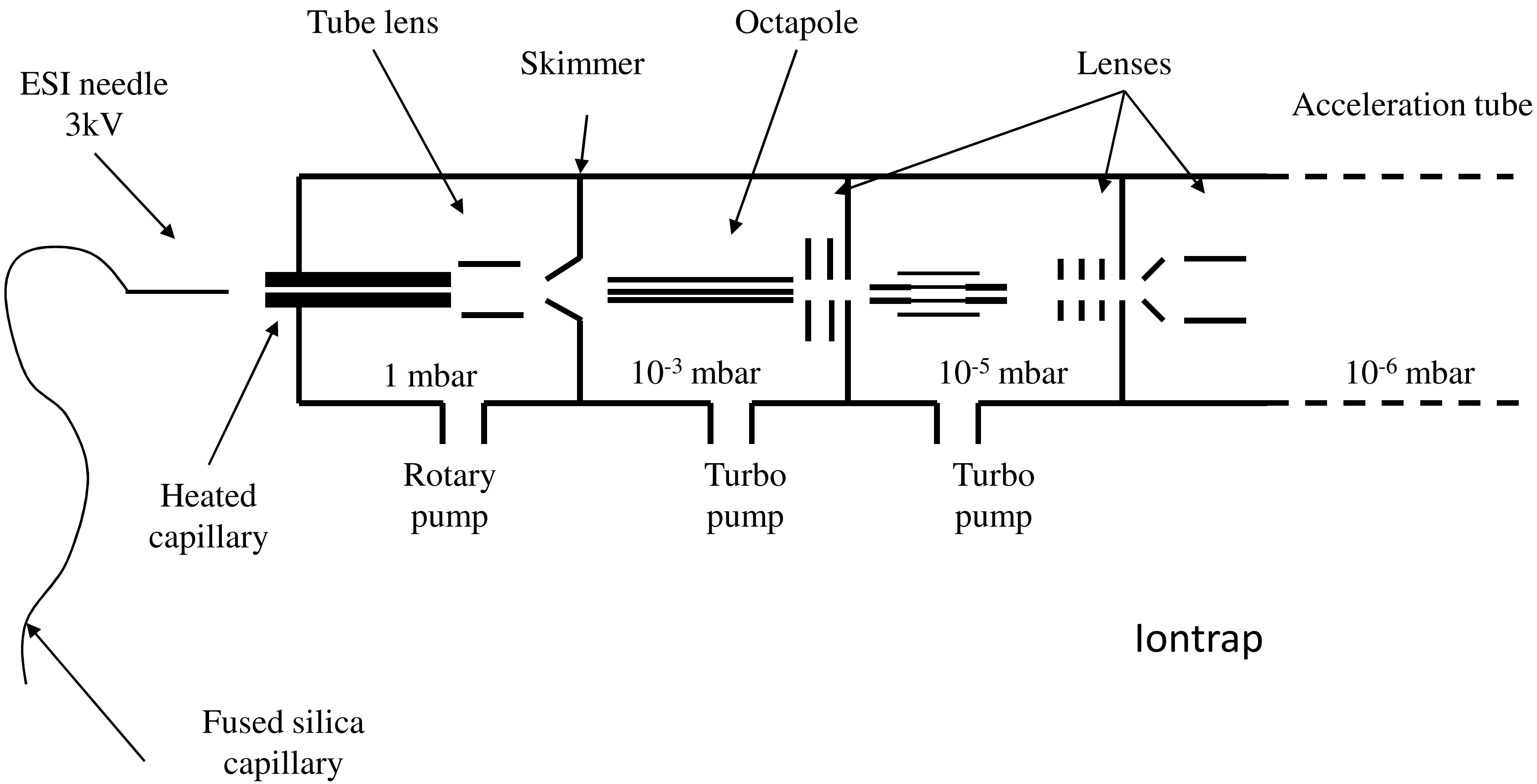
Three pieces of information

Lifetimes with respect to dissociation

At what wavelengths ions absorb light

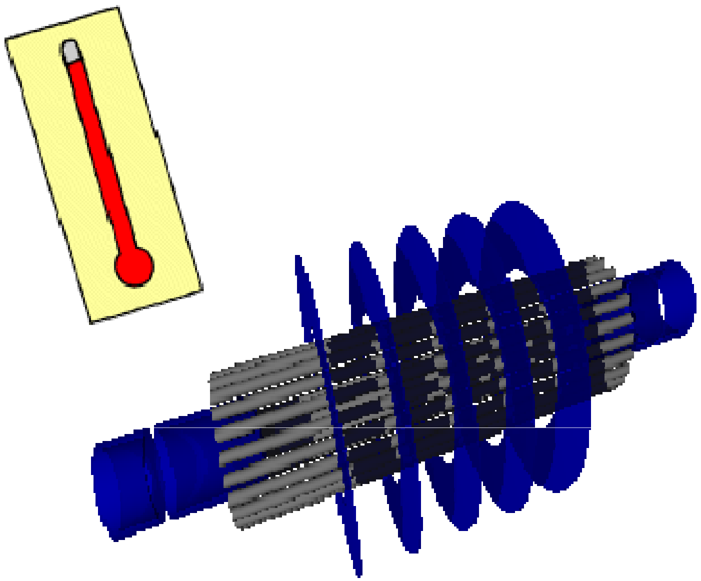
Daughter ion masses

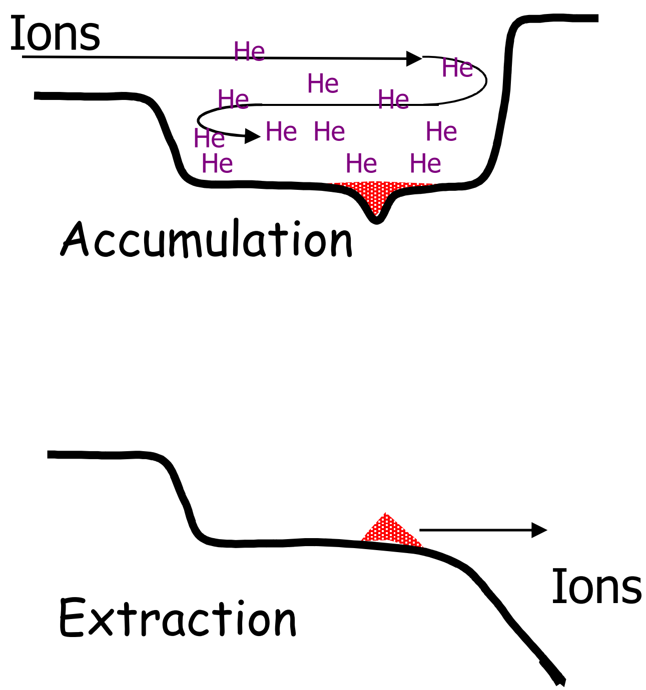
Electrospray ion source

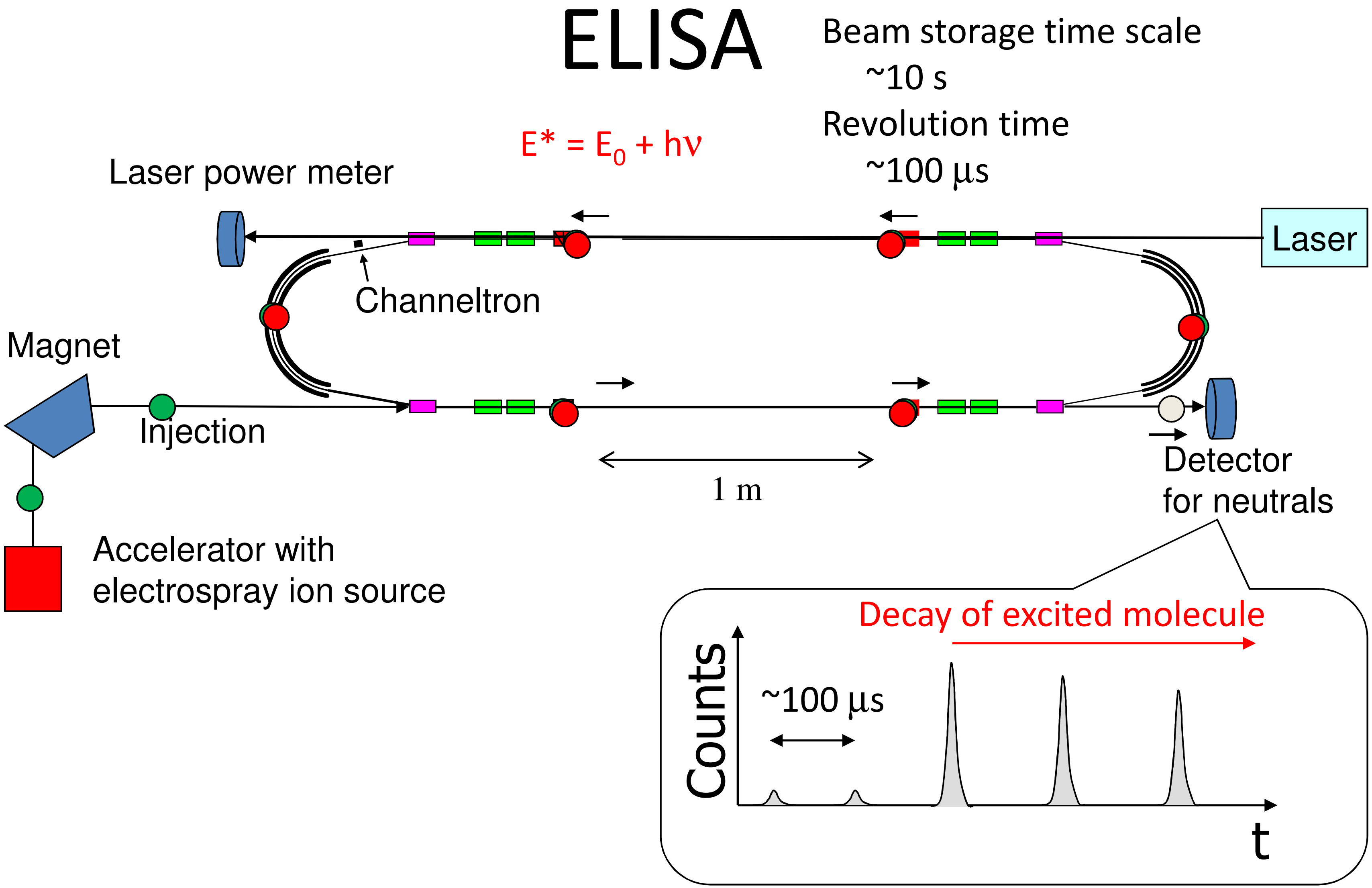


Iontrap

22-pole ion trap

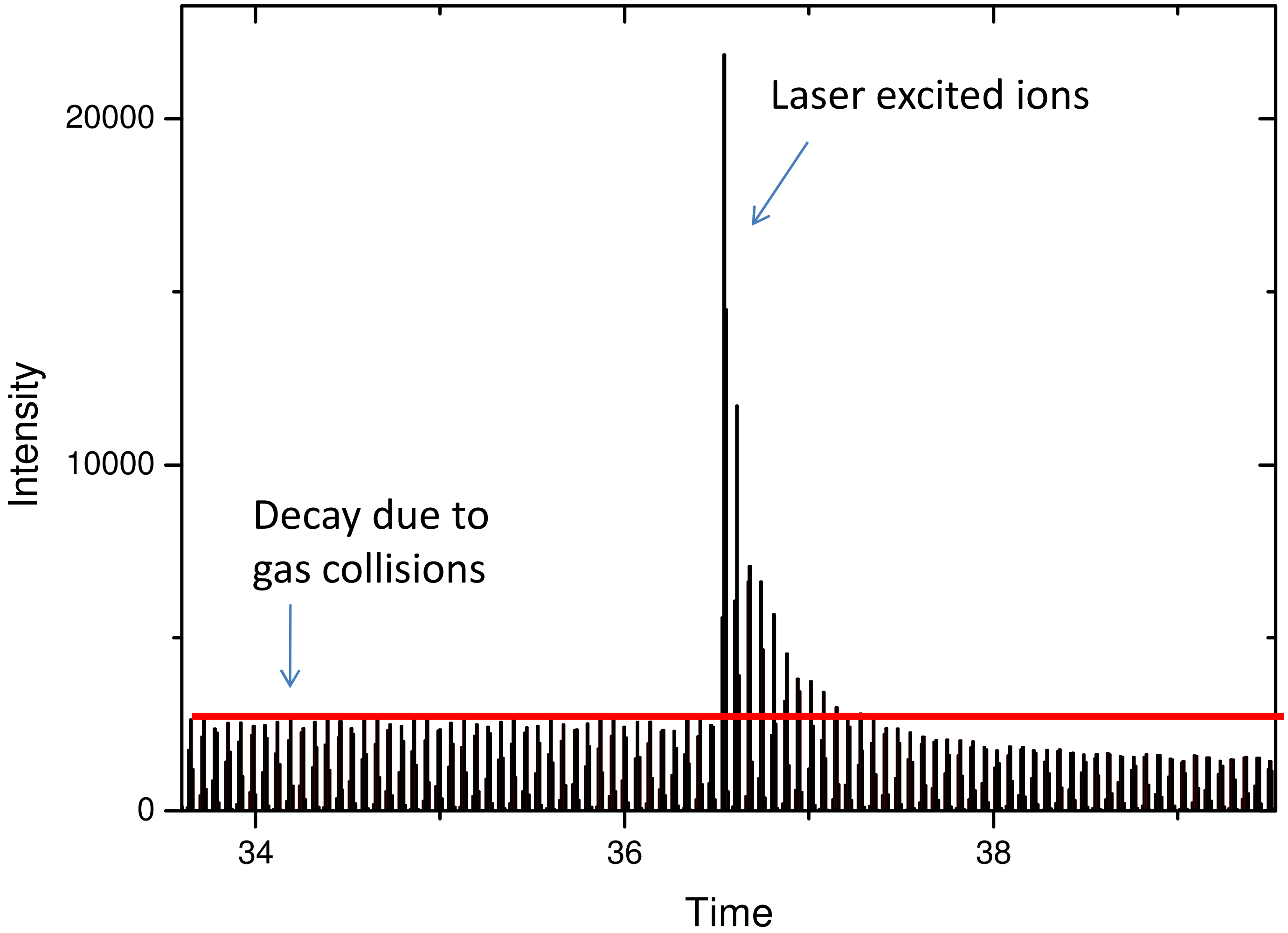




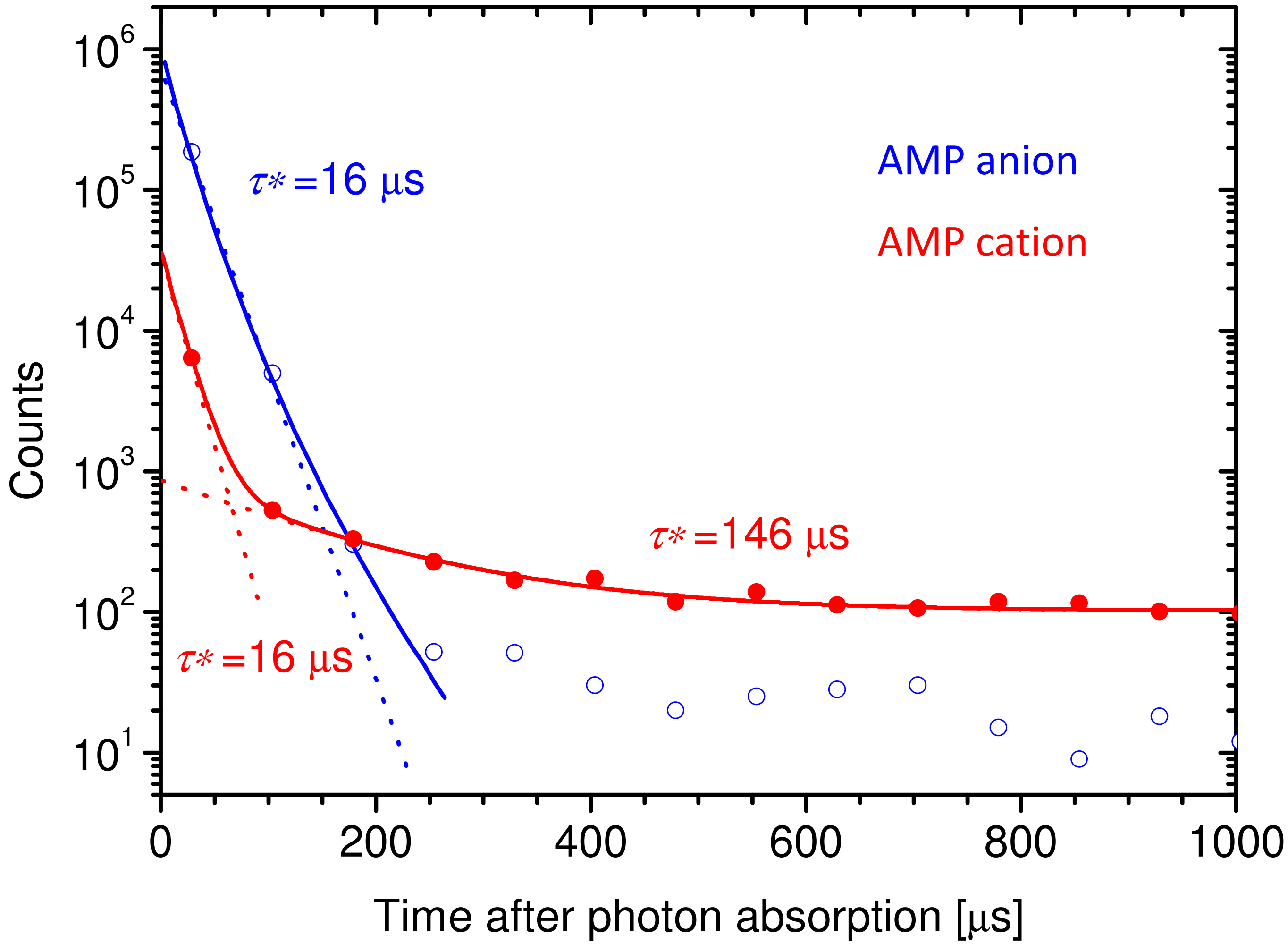


ELISA
Beam storage time scale
~10 s
Revolution time
~100 μs
E* = E0 + hν
Laser power meter
Laser
Channeltron
Magnet
Injection
1 m
Detector
for neutrals
Accelerator with
electrospray ion source
Decay of excited molecule
Counts
~100 μs
t

LASER EXCITED IONS

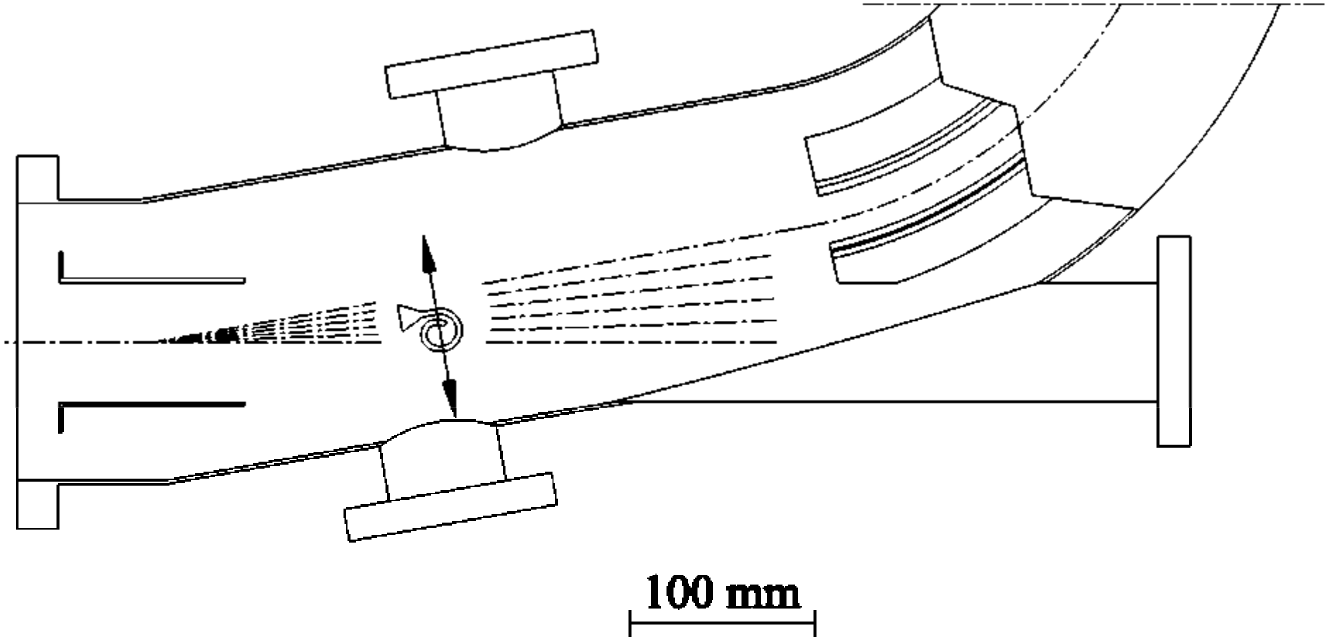


Lifetimes for statistical dissociation of photoexcited ions

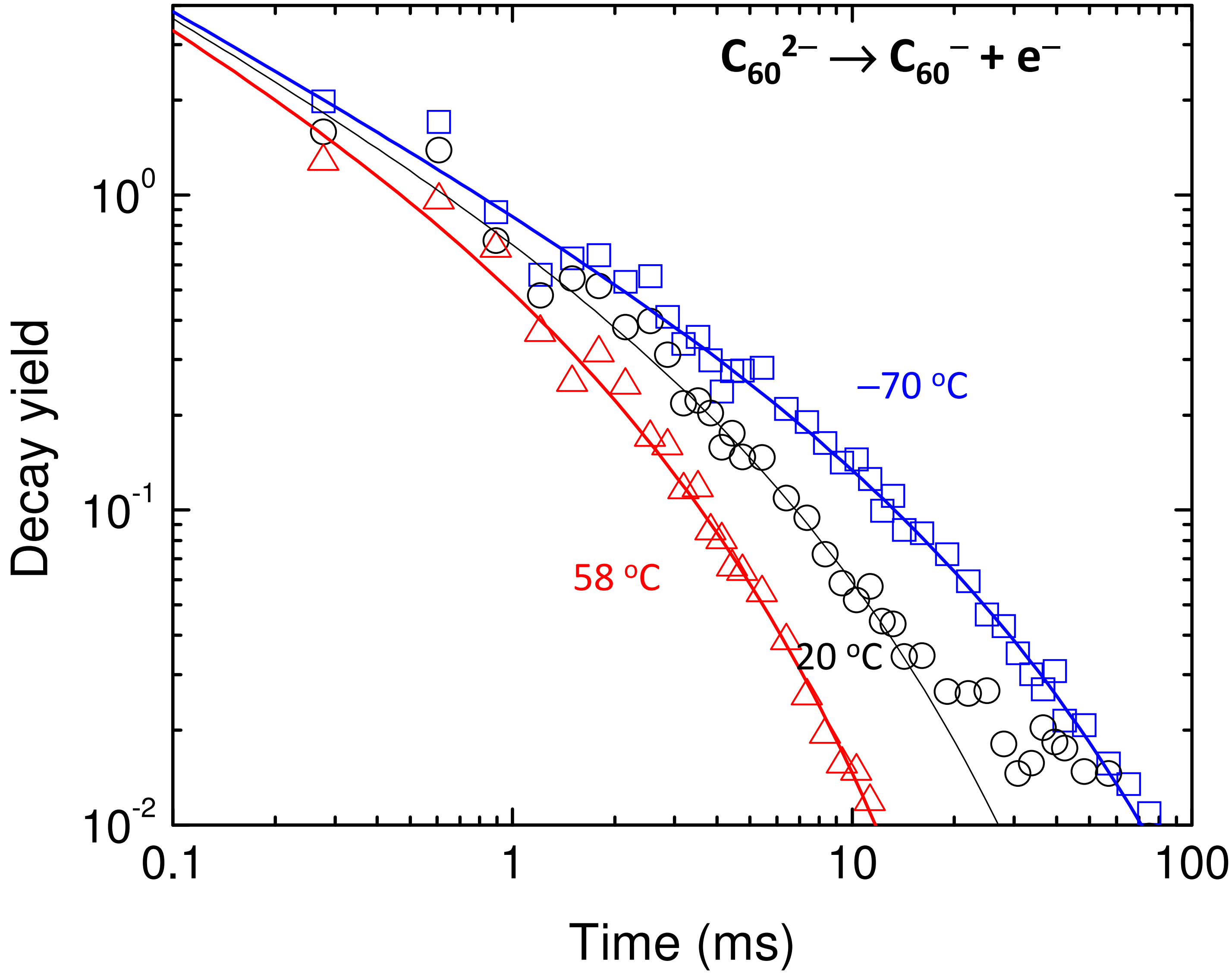


S. Brøndsted Nielsen, J.U. Andersen, J.S. Forster, P. Hvelplund, B. Liu, U.V. Pedersen, and S. Tomita, *Phys. Rev. Lett.* **91**, 048302 (2003)

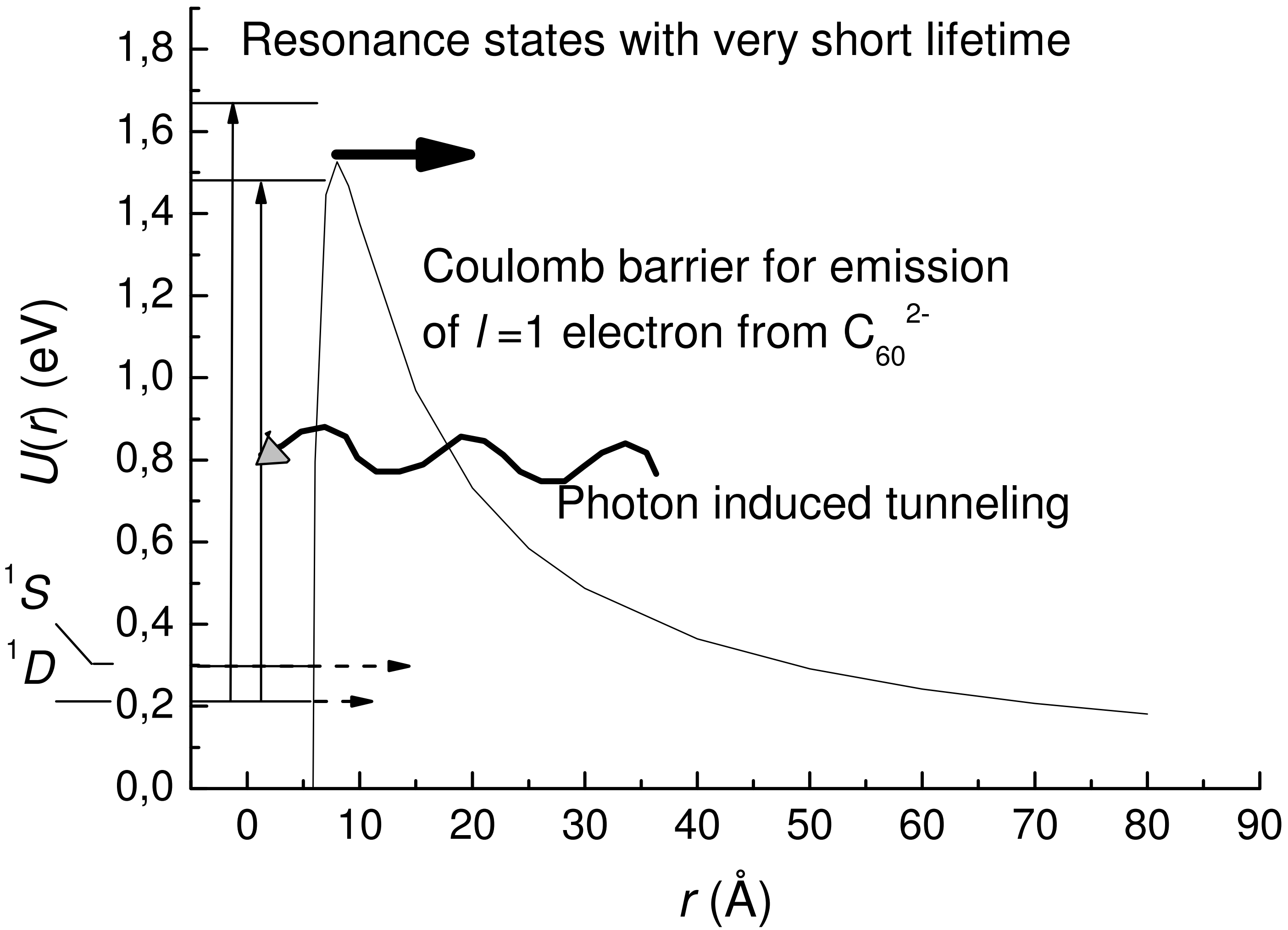
Channeltron detector



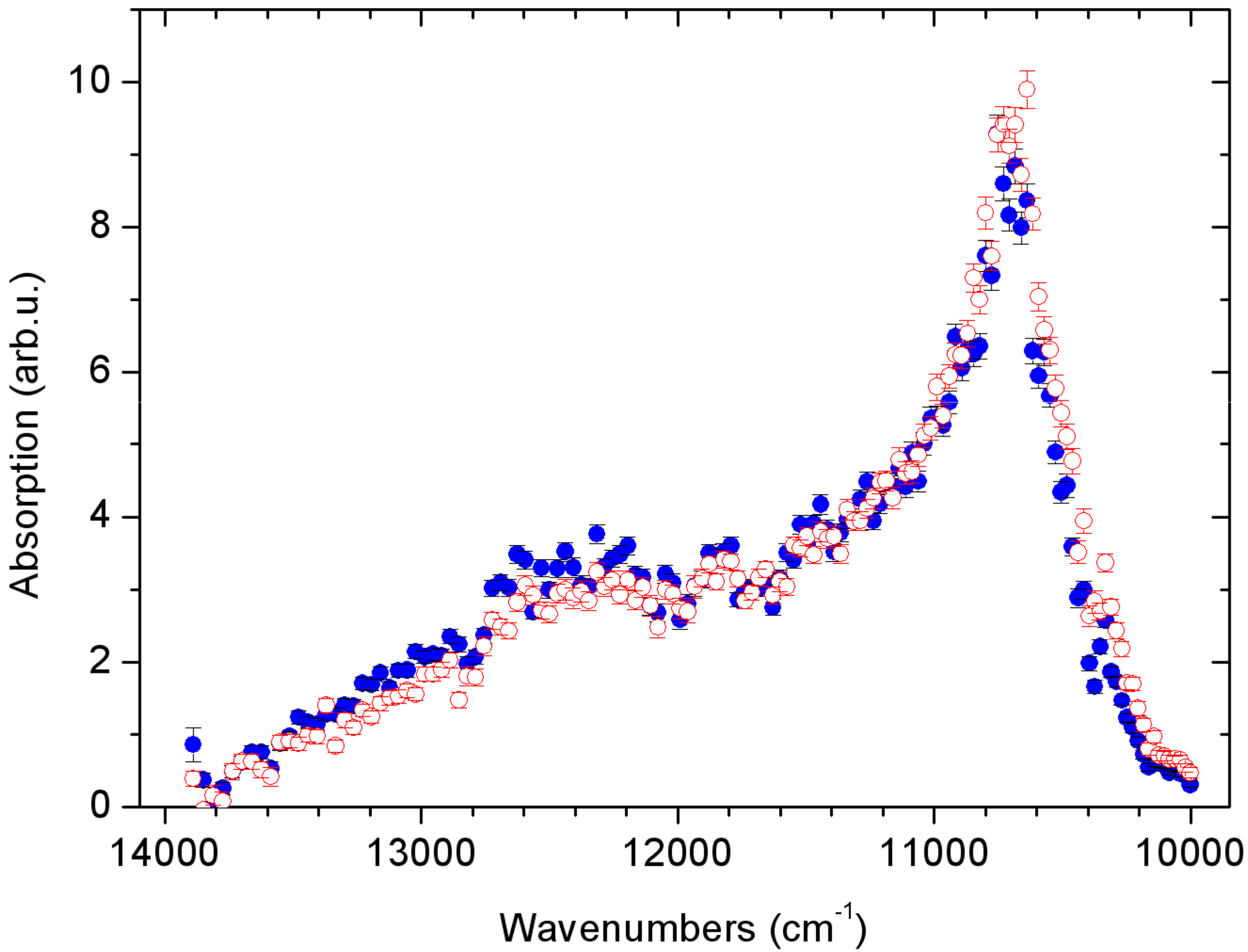
LIFETIME SPECTRA OF C_{60}^{2-} WITH RESPECT TO ELECTRON LOSS



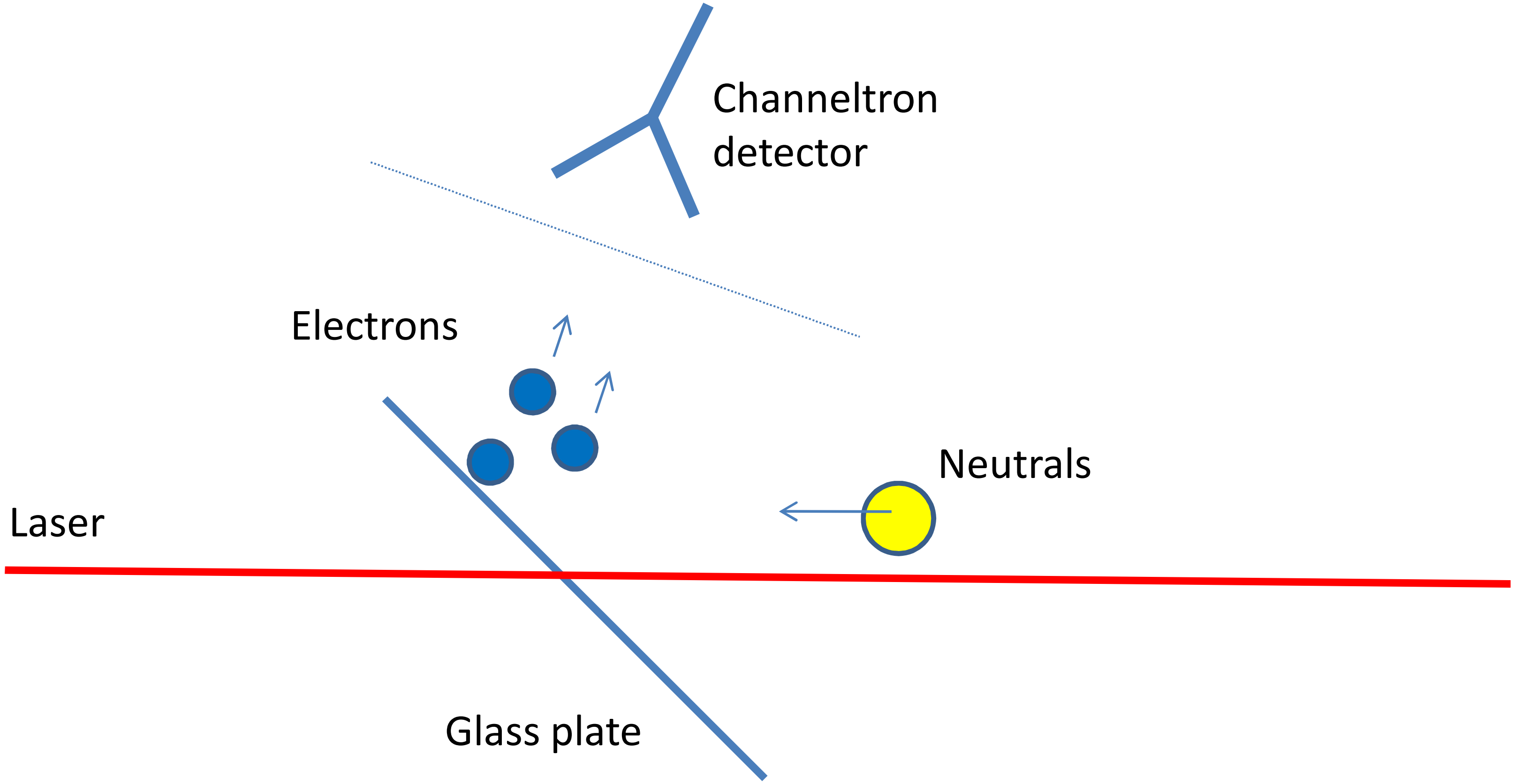
SPECTROSCOPY OF C_{60}^{2-} STATES



ABSORPTION SPECTRA OF C_{60}^{2-} AFTER DIFFERENT STORAGE TIMES



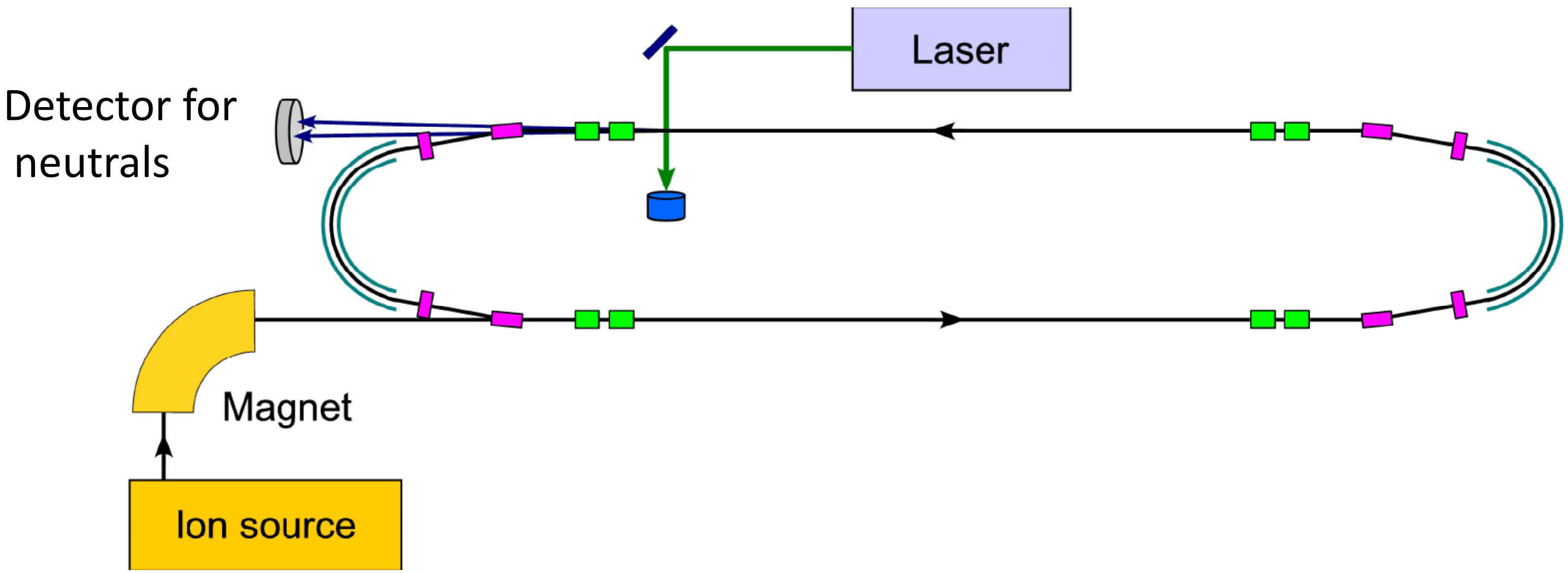
Glass plate detector / secondary electron detector.

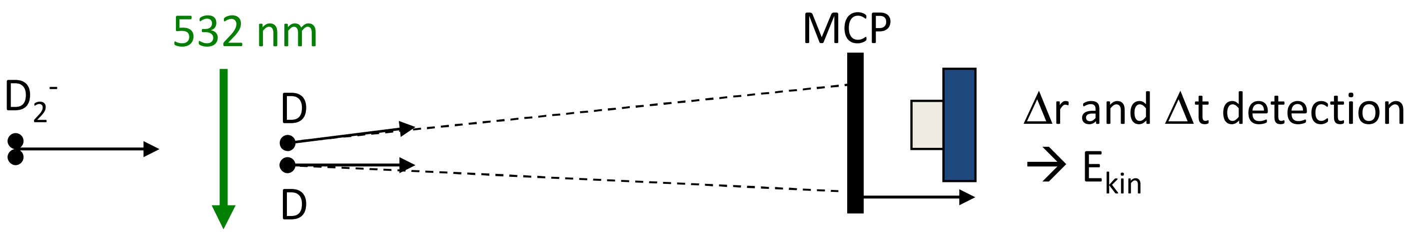


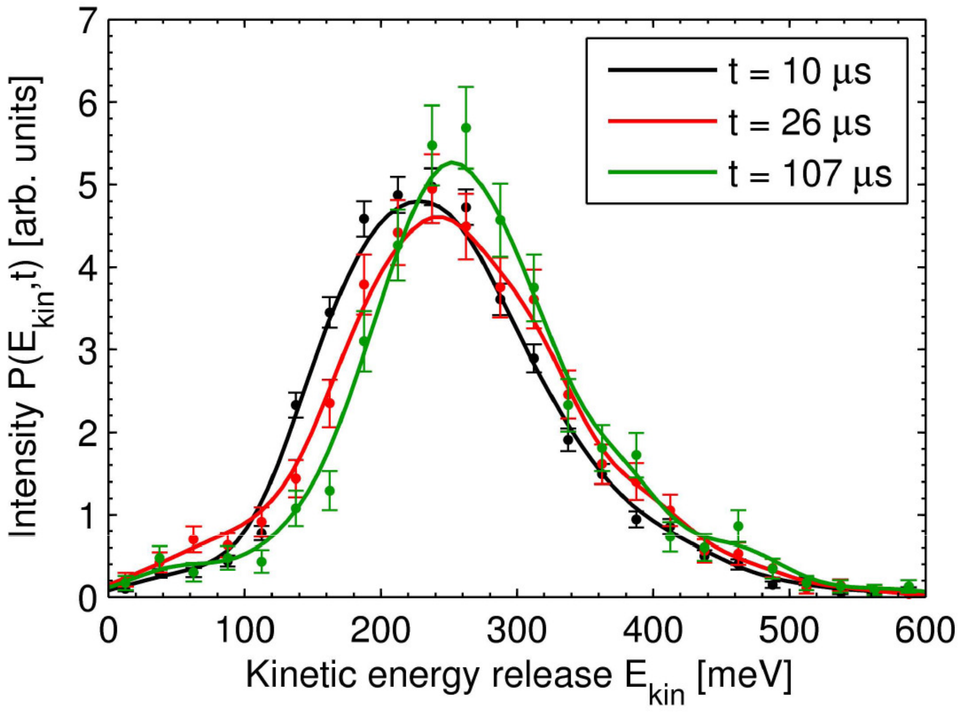
Neutrals make secondary electrons when they hit the glass plate while most of the laser light is transmitted.
Works down to the UV-range

Momentum imaging of ions stored in ELISA

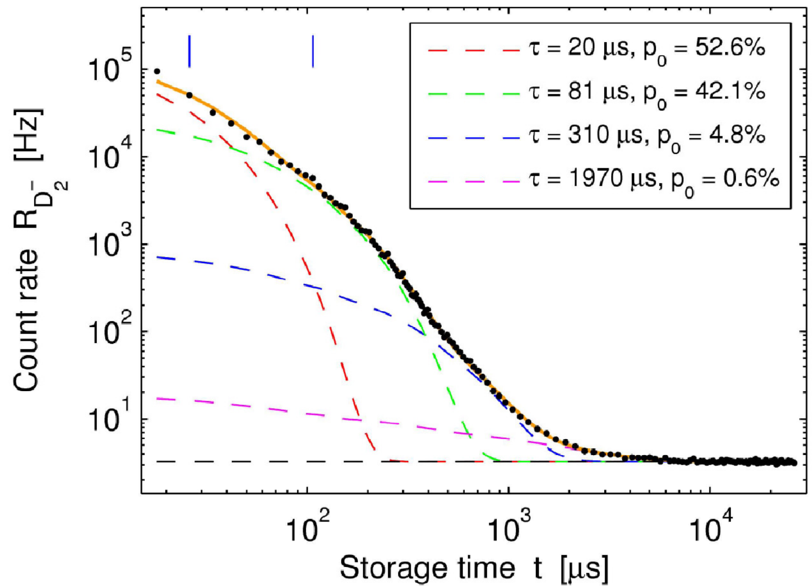
Momentum imaging of ions stored in ELISA







$$E_{\mathrm{kin}} = \frac{1}{2}\mu[(\Delta r)^2 + (\Delta t\, v_{\mathrm{b}})^2]\left(\frac{v_{\mathrm{b}}}{L}\right)^2,$$



ELISA: A new scheme for daughter ion mass spectrometry

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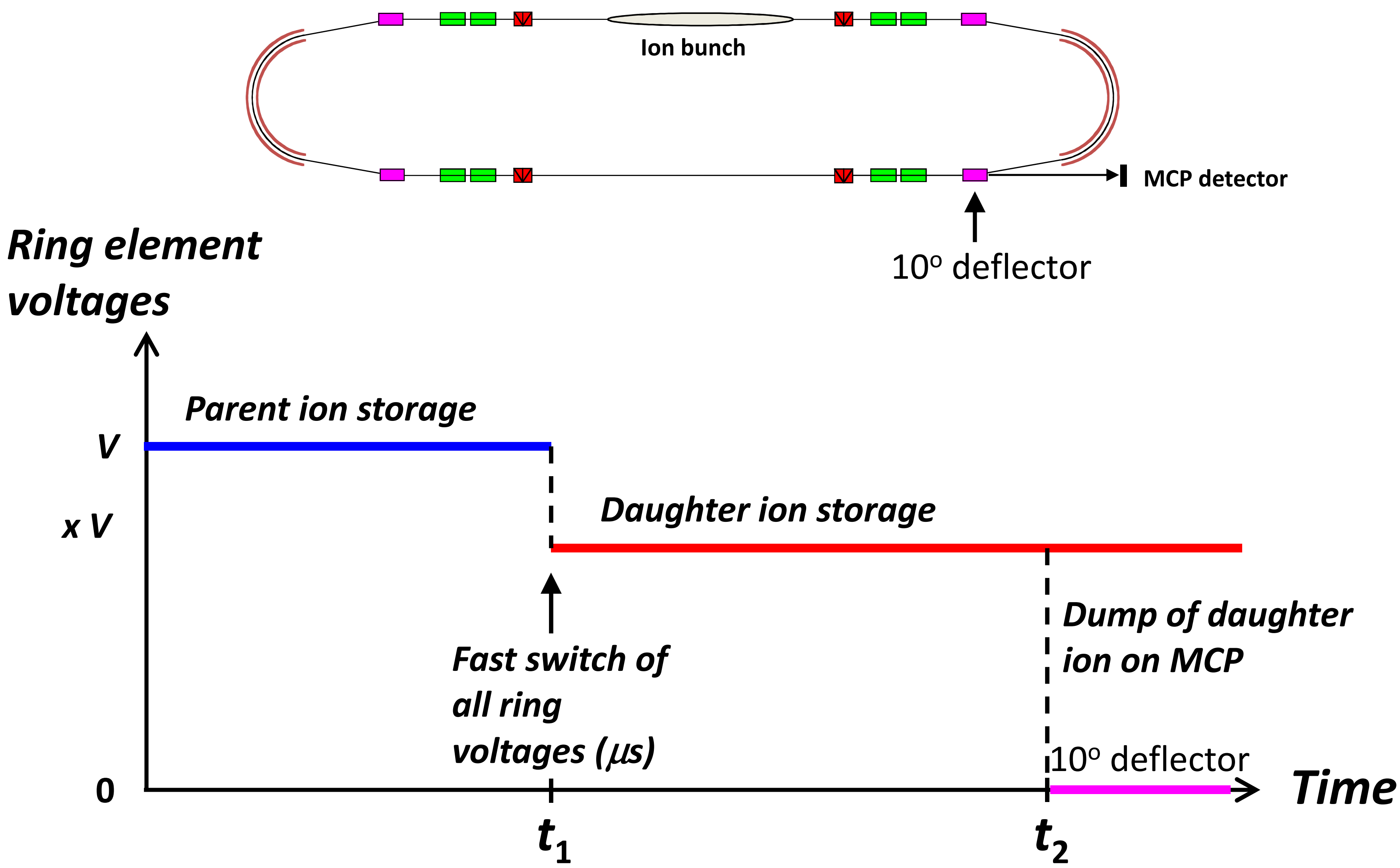
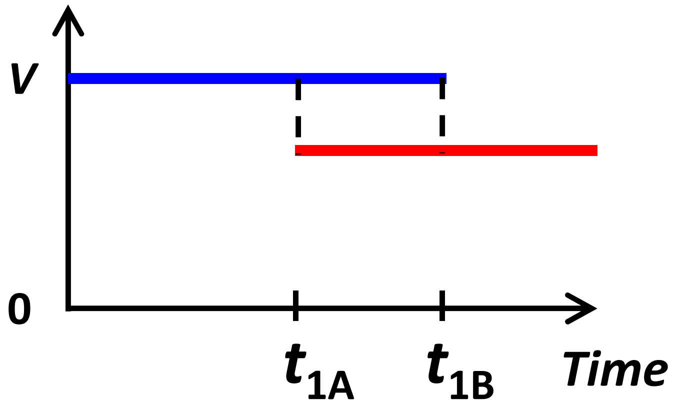
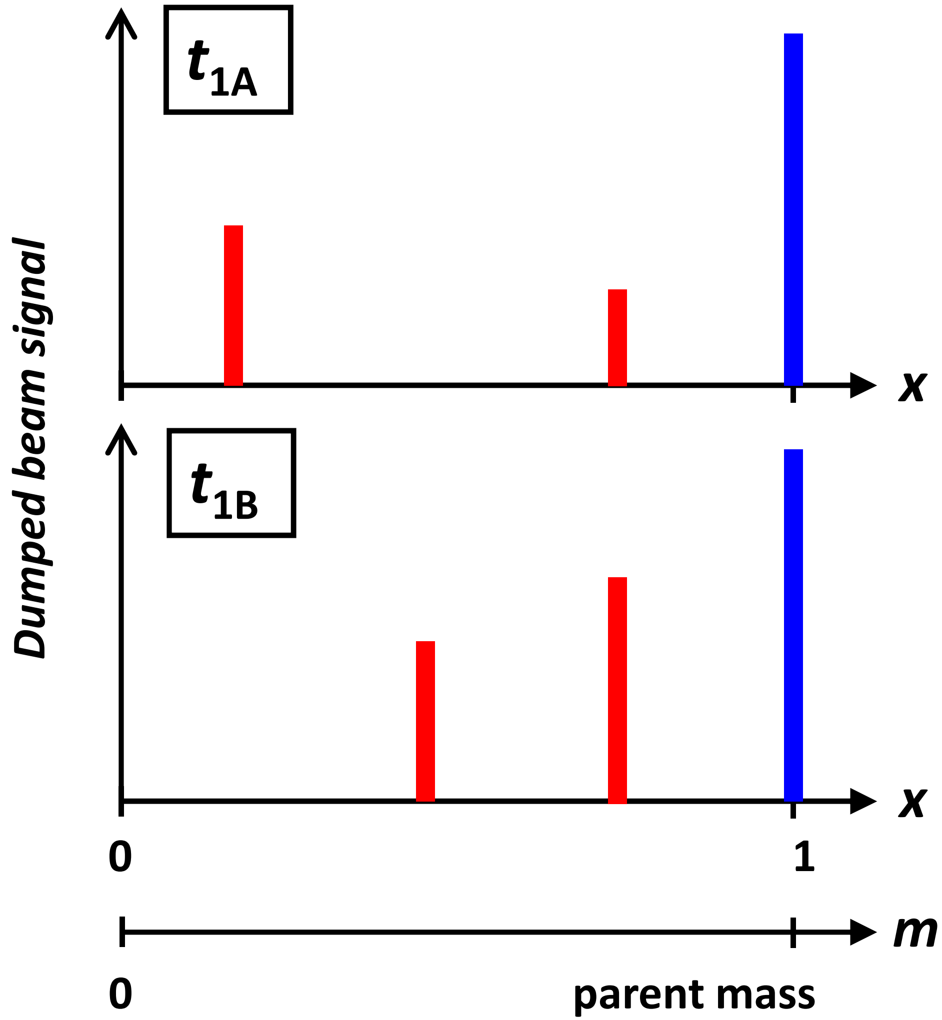


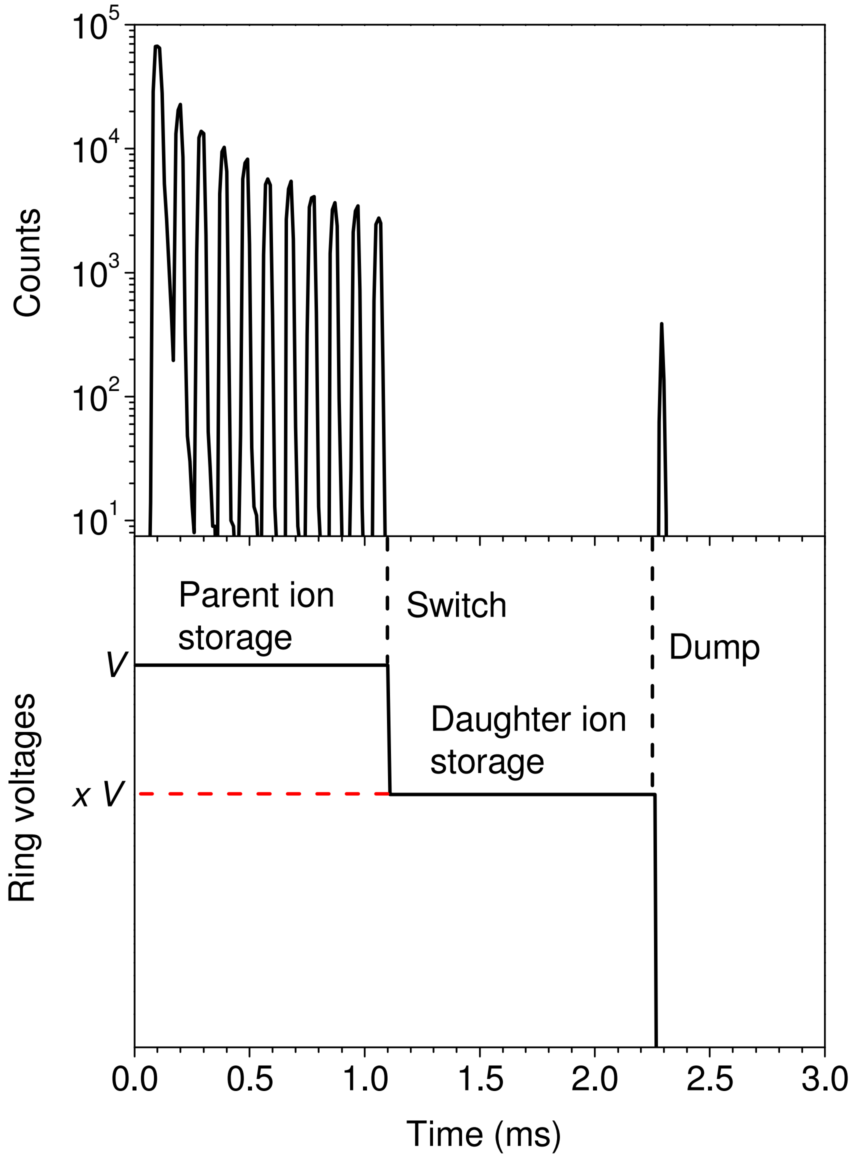
Signal in MCP detector as a function of scaling parameter *x* and storage time t_1





Time-resolved fragmentation mass spectrometry on the μs to ms time scale

Dissociation of a molecule in the ring



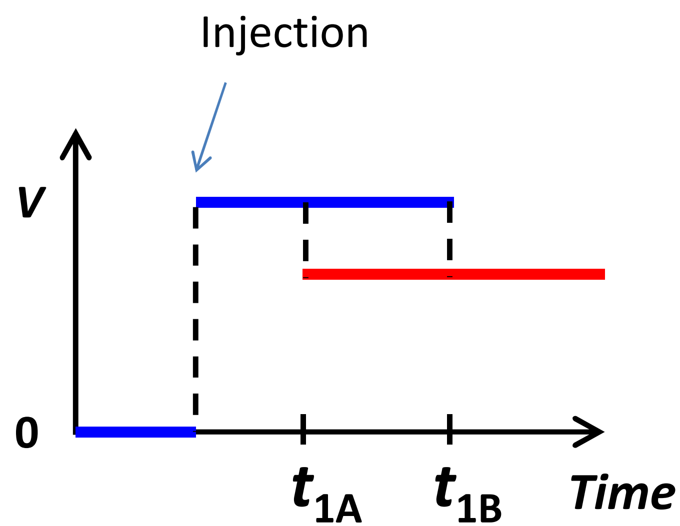
1) Molecule was stored in the ring

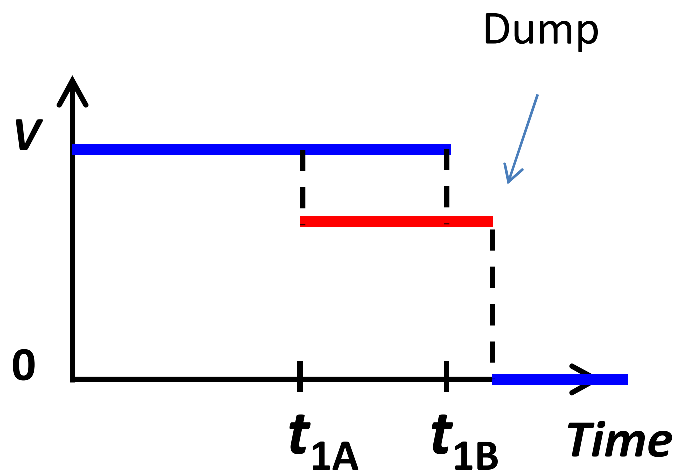
2) After 1.1 ms, ring voltages were switched to store daughter ion

3) After 1.15 ms of storage, the daughter ion was dumped in the MCP detector

Consideration for switching times, type of switches ..

Switch times faster than 1 μs
Voltages up to 3 kV
Vertical needs to be bipolar
Injection and dump switch – 3 levels.

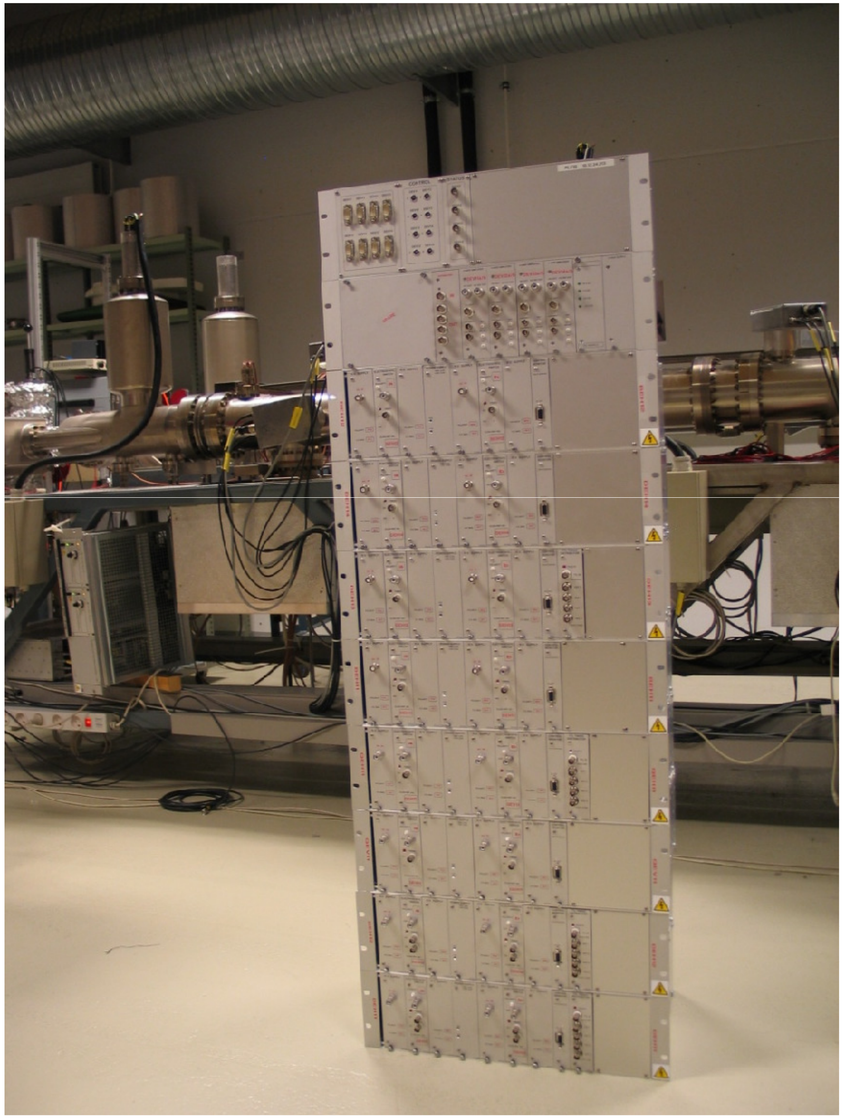




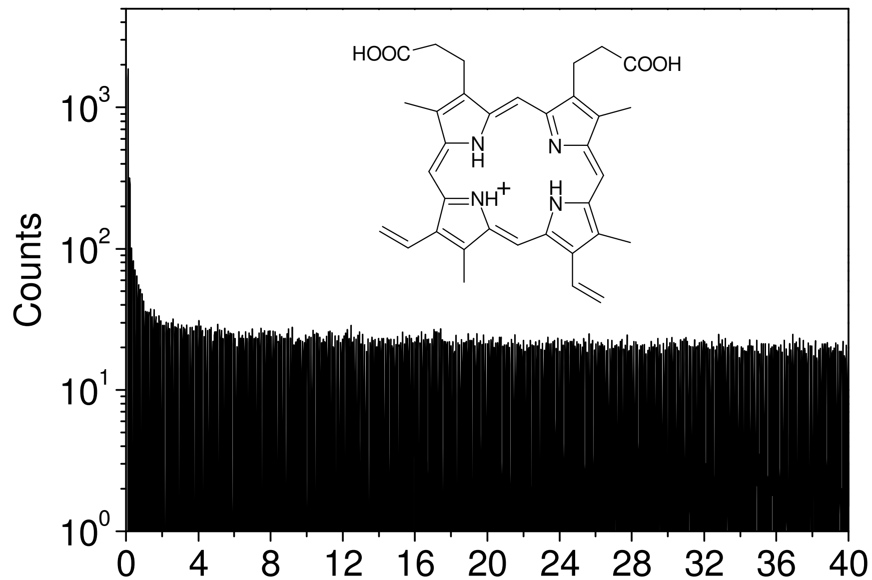
Horizontal deflectors:
16 new solid state switches with power supllies

Vertical deflectors:
Replaced by fast amplifiers (bipolar).

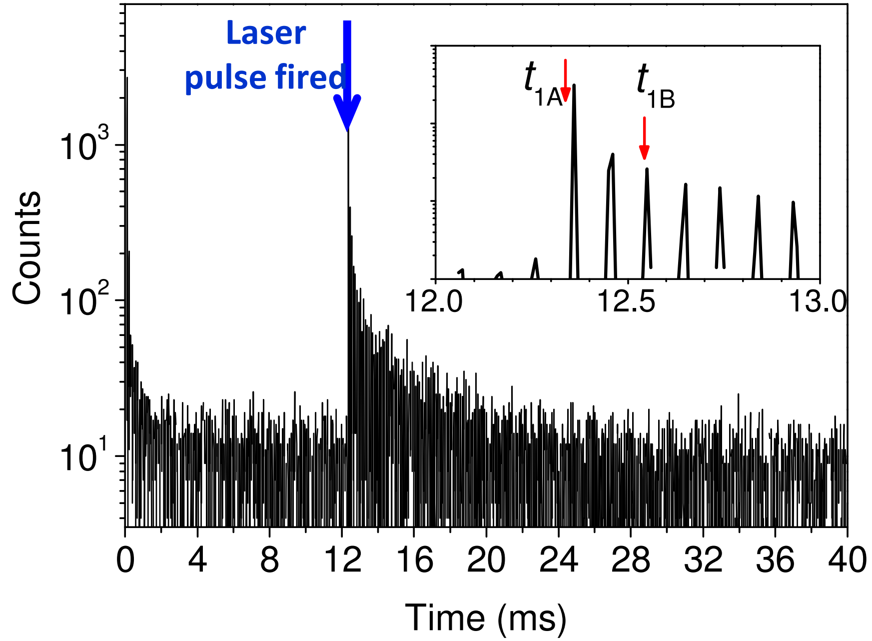
All is integrated into the control system.



Photodissociation of protoporphyrin ions in ELISA with 390-nm light



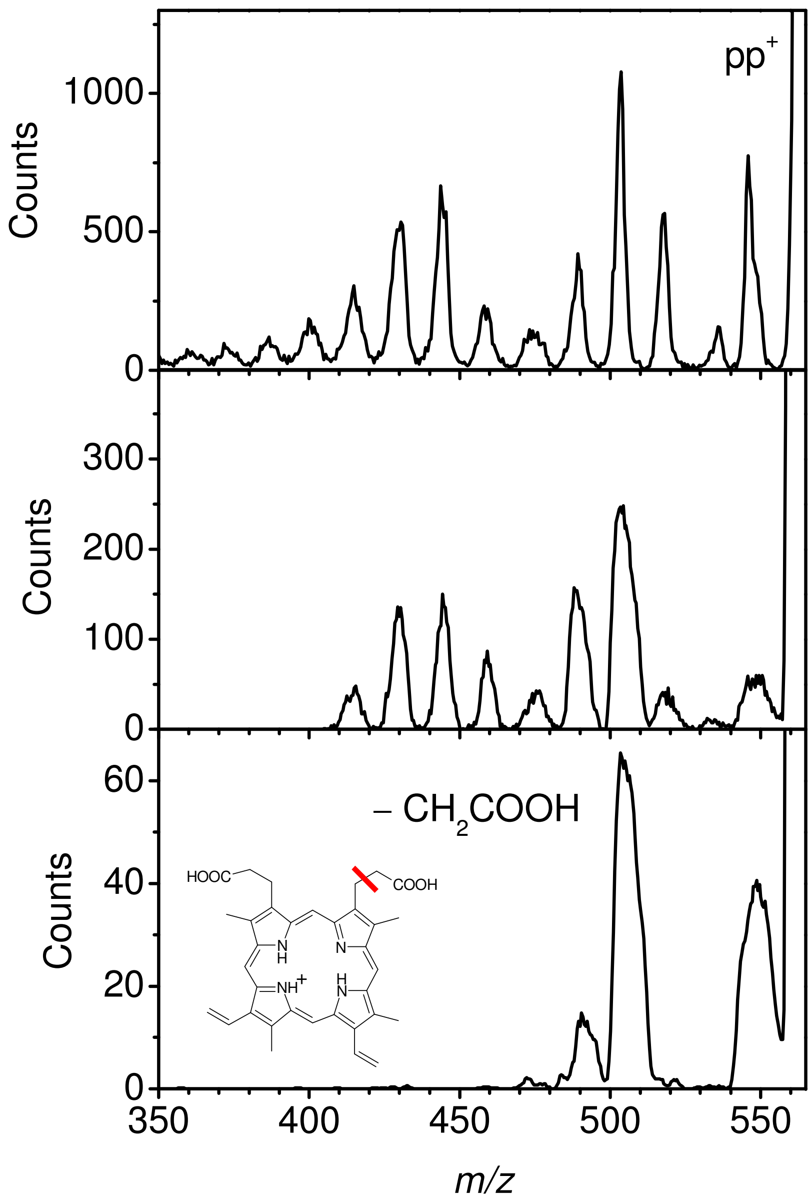
Neutrals from collisions with residual gas



Laser pulse fired after 12.4 ms.

Daughter ion mass spectra were recorded right after (t_{1A}) and after 190 μs (t_{1B}) of storage.

Daughter ion mass spectra



High-energy CID spectrum (50-keV collisions) recorded at another instrument

ELISA switch at t_{1A}:
Fragmentation due to both one-photon and two-photon absorption

ELISA switch at t_{1B}:
Fragmentation due to one-photon absorption since all ions that have absorbed two photons have decayed.

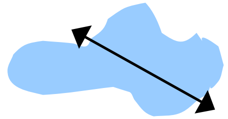
K. Støchkel, U. Kadhane, J.U. Andersen, A.I.S. Holm, P. Hvelplund, M.-B. S. Kirketerp, M.K. Larsen, M.K. Lykkegaard, S. Brøndsted Nielsen, S. Panja, and H. Zettergren,

"**A new technique for time-resolved daughter ion mass spectrometry on the microsecond to millisecond time scale using an electrostatic ion storage ring**,"

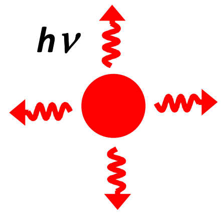
Rev. Sci. Instrum. **79**, 023107 (2008).

ELISA experiments

- Collisional cross sections (geometrical size of molecule)



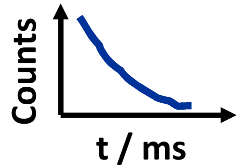
- Radiative cooling (emission from infrared active vibrations)



- Lifetimes after photon absorption:

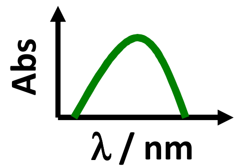
  statistical decay processes

  excited state lifetimes, *e.g.,* triplet states



- Electron autodetachment lifetimes

- Absorption spectroscopy



THE GROUP

Principal investigators:

Preben Hvelplund   Jens Ulrik Andersen   Steen Brøndsted Nielsen

Post docs:

Jean Wyer   Kristian Støchkel

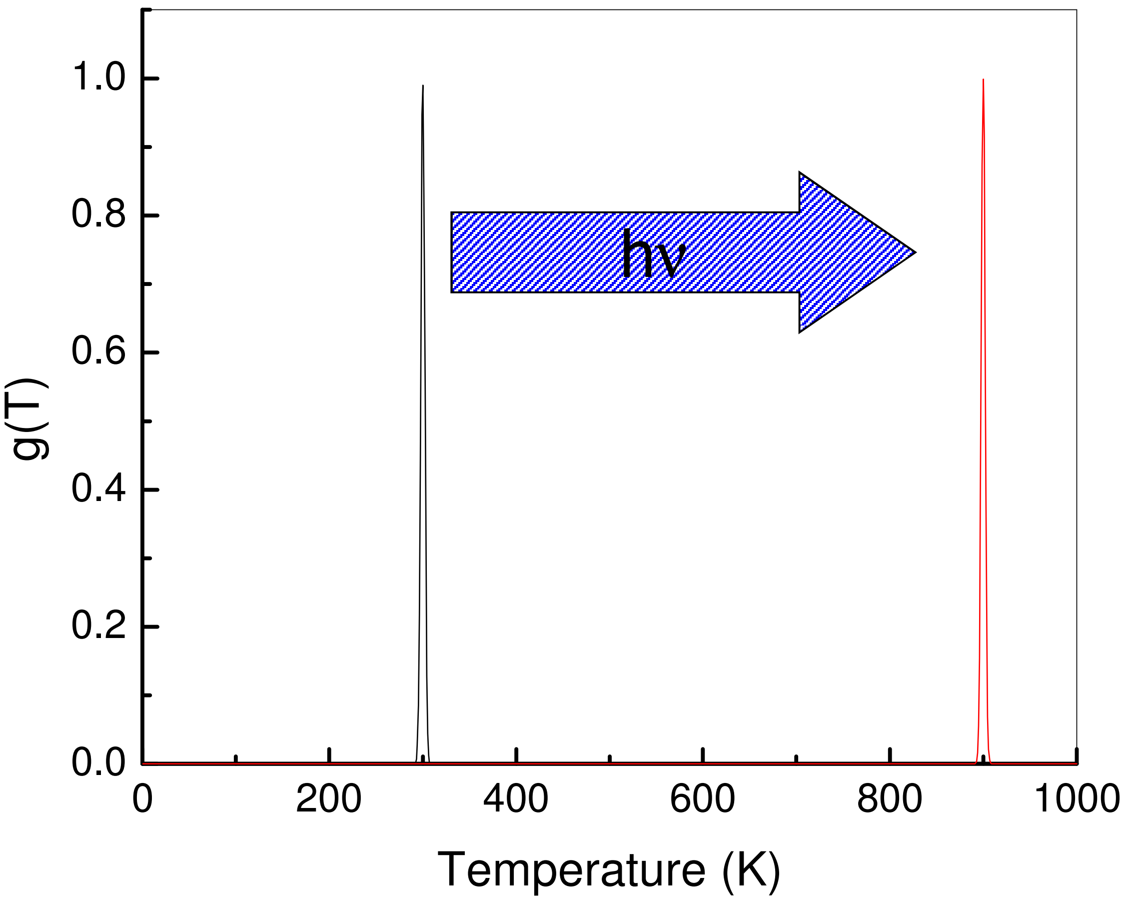
Students:

Maj-Britt S. Kirketerp   Lisbeth M. Nielsen   Camilla S. Jensen

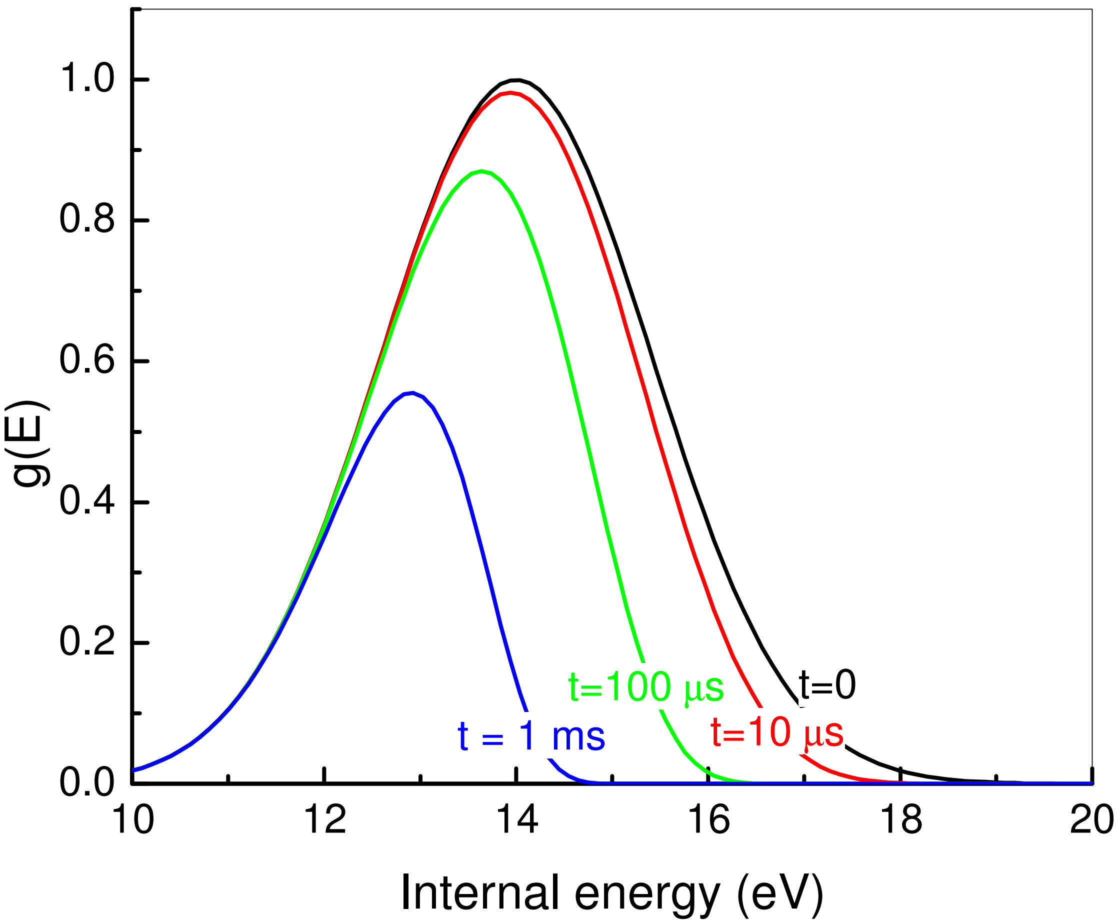
Klaus Eriksen

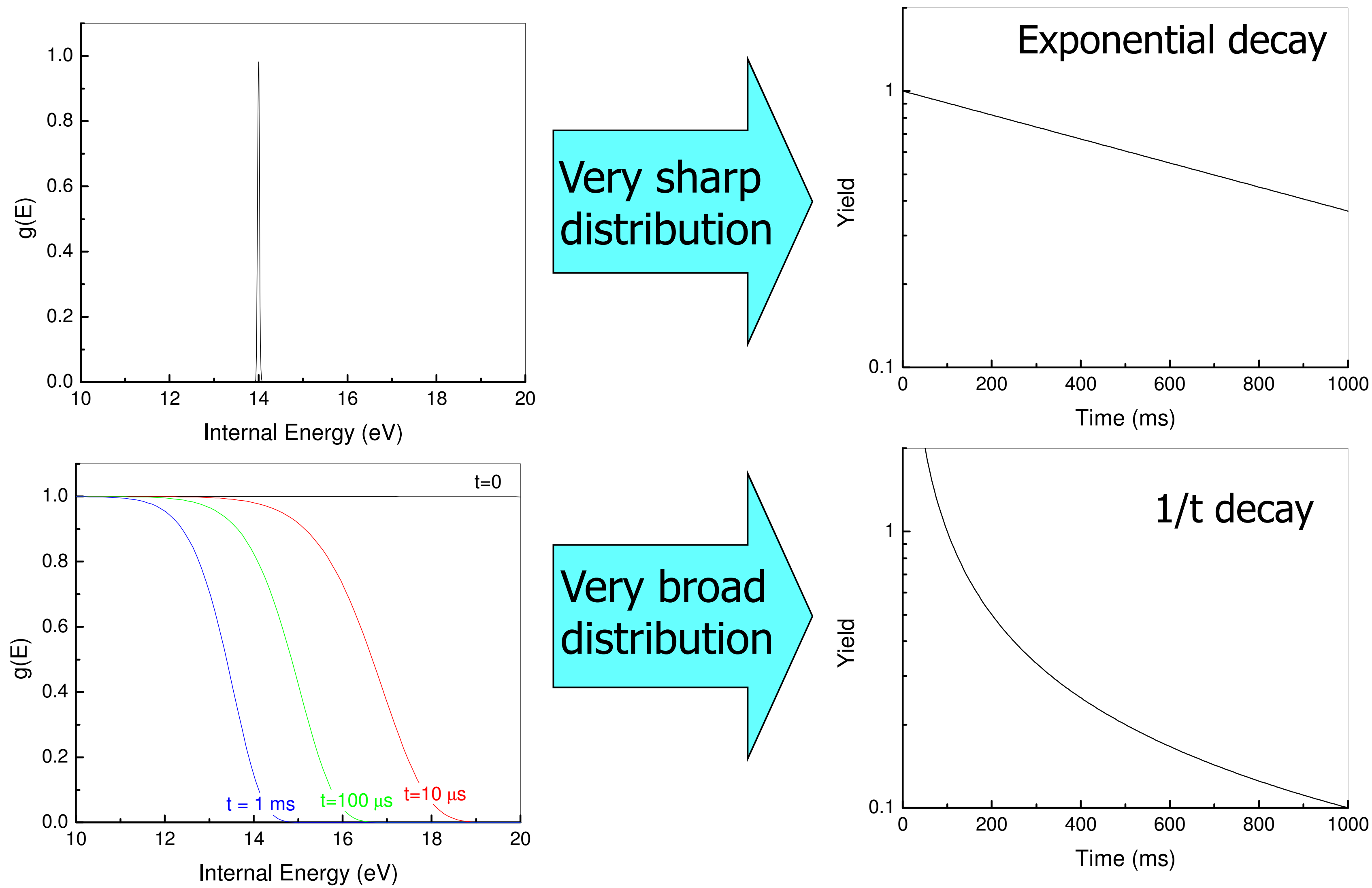
FNU   Lundbeckfonden   Carlsbergfondet   Villum Kann Rasmussen

Heating by photon absorption



Energy distribution changes in time

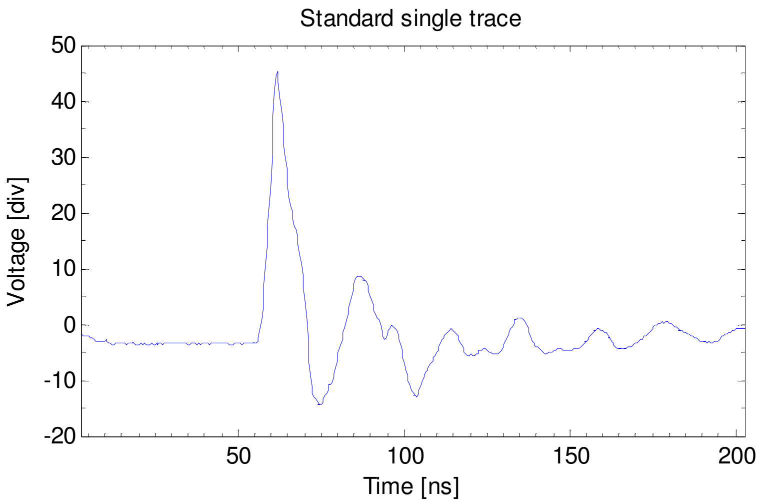


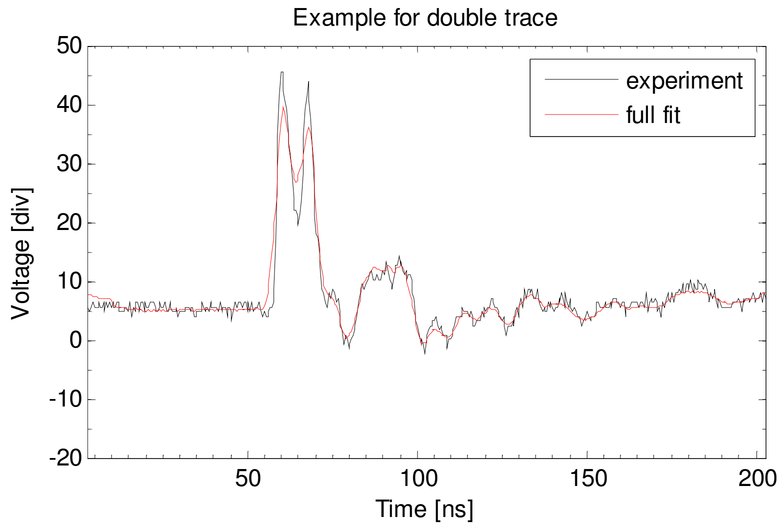


g(E)
1.0
0.8
0.6
0.4
0.2
0.0
10
12
14
16
18
20
Internal Energy (eV)
Very sharp distribution
Exponential decay
Yield
1
0.1
0
200
400
600
800
1000
Time (ms)
t=0
t = 1 ms
t=100 μs
t=10 μs
g(E)
Internal Energy (eV)
Very broad distribution
1/t decay
Yield
Time (ms)

Table 1
Design parameters for ELISA

General parameters	
Injection energy	25 keV
Circumference	6.28 m
Revolution time	2.9 μs (p), 77 μs (C_{60})
Betatron tunes (Q_H, Q_V)	1.206, 1.439
Chromaticities (ζ_H, ζ_V)	-1.7, -1.3
Momentum compaction (α_p)	0.50
160° spherical deflectors	
Electrode radii	235 and 265 mm
Nominal voltages	±4.0 kV
10° deflectors	
Plate distance	50 mm
Plate length	100 mm
Nominal voltages	±2.2 kV
Electrostatic quadrupoles	
Inscribed radius	26.2 mm
Electrode length	50 mm
Nominal voltages	±0.43 kV
Chopper and inflector	
Rise/fall time	< 200 ns.


Standard single trace
Voltage [div]
Time [ns]
50
40
30
20
10
0
-10
-20
50
100
150
200


Example for double trace
experiment
full fit
Voltage [div]
Time [ns]
50
40
30
20
10
0
-10
-20
50
100
150
200