Small Quantum Systems (SQS)

M. Meyer
SQS scientific instrument

Townhall meeting, November 10, 2022

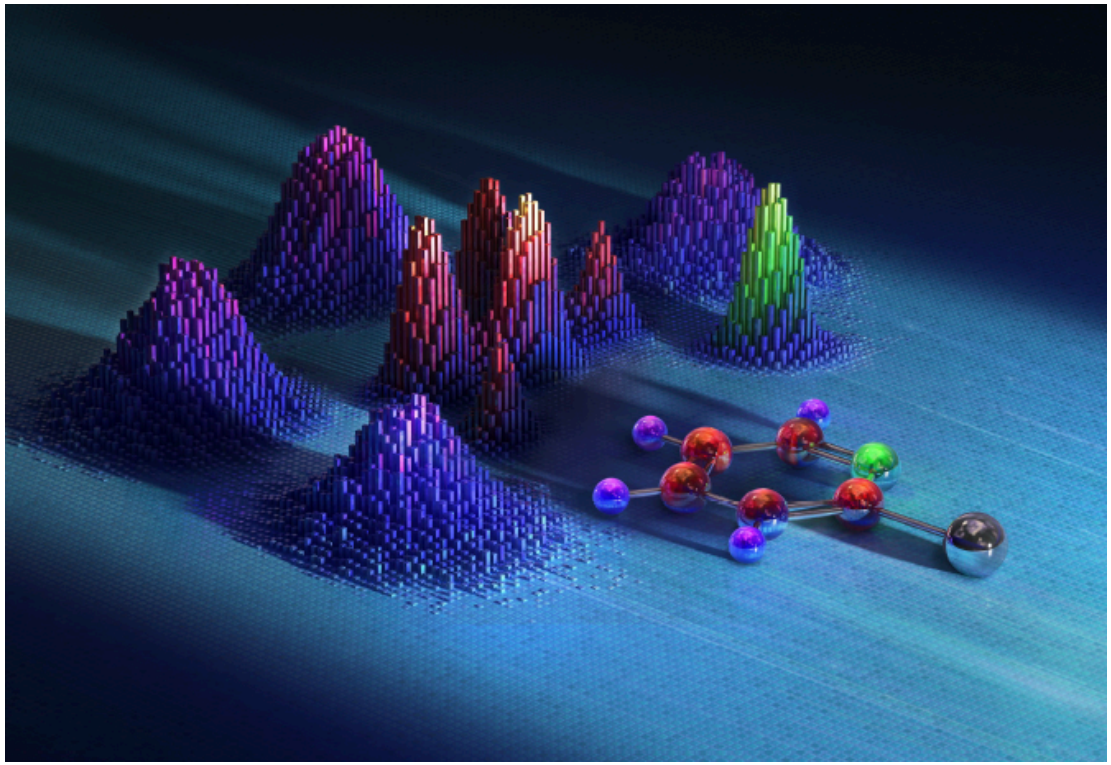
Gas Phase Samples

Soft X-Rays (250 – 3000 eV)

- Study of non-linear phenomena

- Time-resolved investigations

- Coherent Diffraction Imaging



SASE3 Soft X-Ray radiation parameters

Photon Beam Parameter	Unit	Operation 2023 RUN 10	Final Operation
Electron energy	GeV	8.0, **11.5, 14, 16.3**	8.0, 11.5, 16.5, 17
Photon energy	eV	250 – 1000 (@ 8.0 GeV) **500 – 1500 (@ 11.5 GeV)** **660 – 2500 (@ 14 GeV)** **920 – 3000 (@ 16.5 GeV)** **fully tunable !!**	0.25 – 3
Spectral Bandwidth	%	**~1% in SASE mode or monochromatized (resolution: 3000 @ 870 eV)**	0.5 (SASE mode) 0.01 (monochromator)
Pulse duration (calc.)	fs	10 - 25 (FWHM)	2 - 100
Pulse energy	mJ	**up to 10 (depending on photon energy)**	Up to 10
Number of pulses		**up to 400 per train (@ 1.1 MHZ)**	2700 per train (@4.5 MHz)
Polarization		**linear**	Linear & circular
Focus size	µm	**1 – 2 (@ F1 / F1')** **2 – 3 (@ F2)**	0.5 – 2

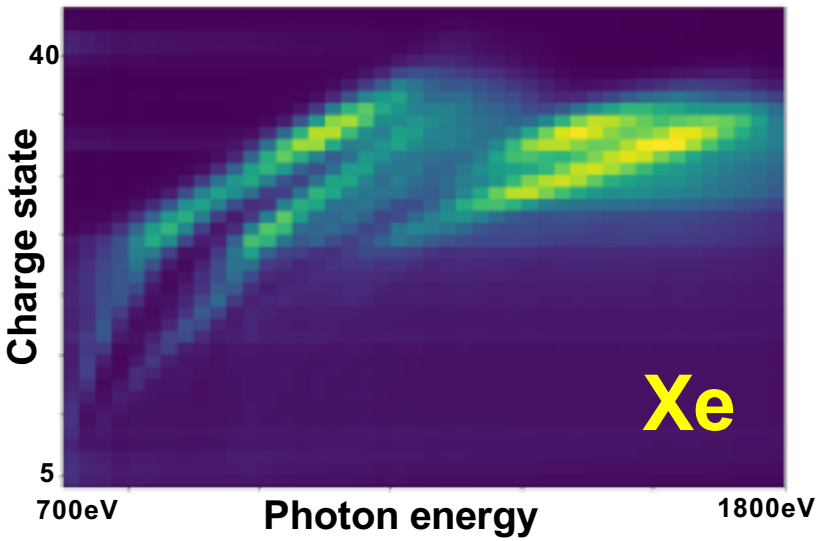
Scientific scope of SQS

Investigations of atoms, ions, molecules and clusters in intense fields and of non-linear phenomena

AQS
Atomic-like Quantum Systems

10^{18} W/cm^2

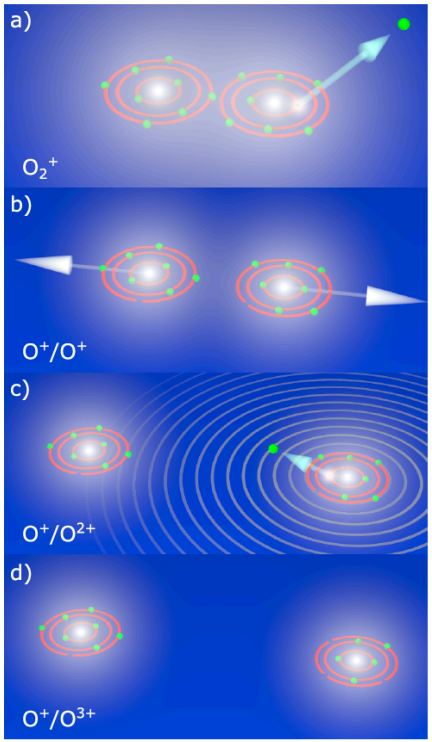
Non-linear spectroscopy



REMI
REaction MIcroscope

10-25 fs

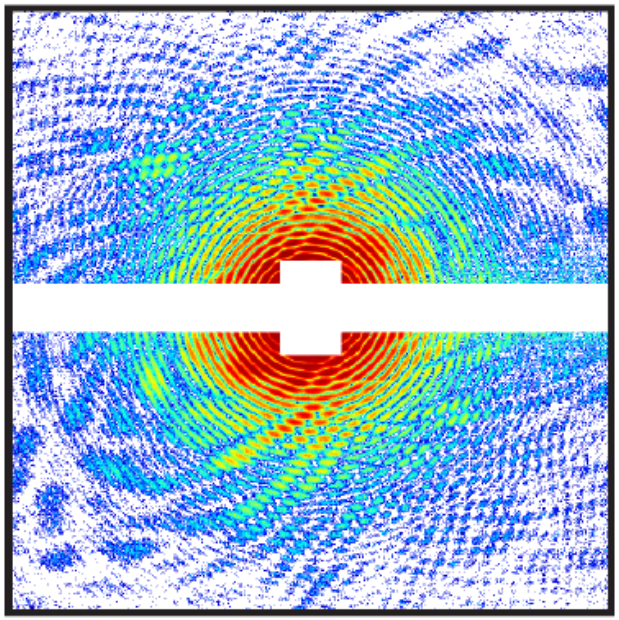
Time-resolved studies



NQS
Nano-size Quantum Systems

coherence

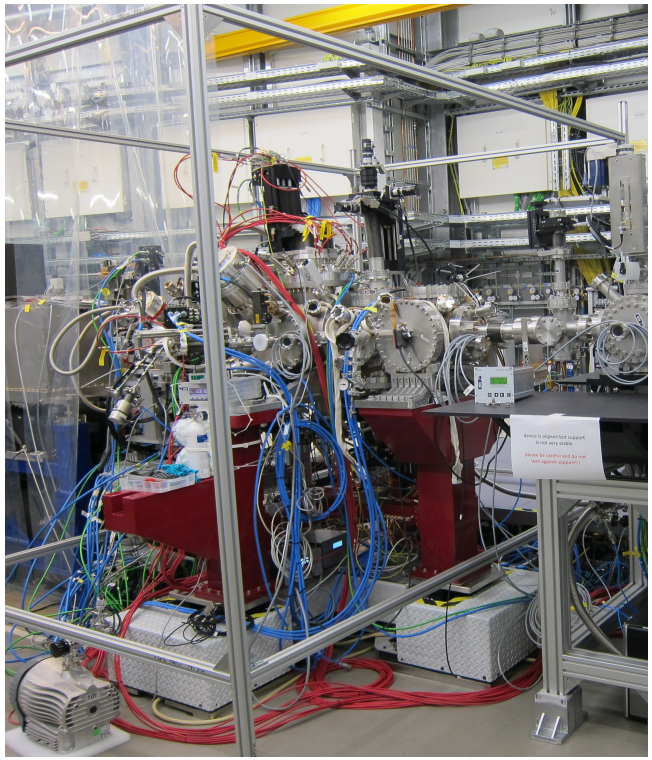
Imaging experiments



Doped He droplet

AQS experimental chamber

Targets: atoms & molecules
Detection: electrons, ions, photons



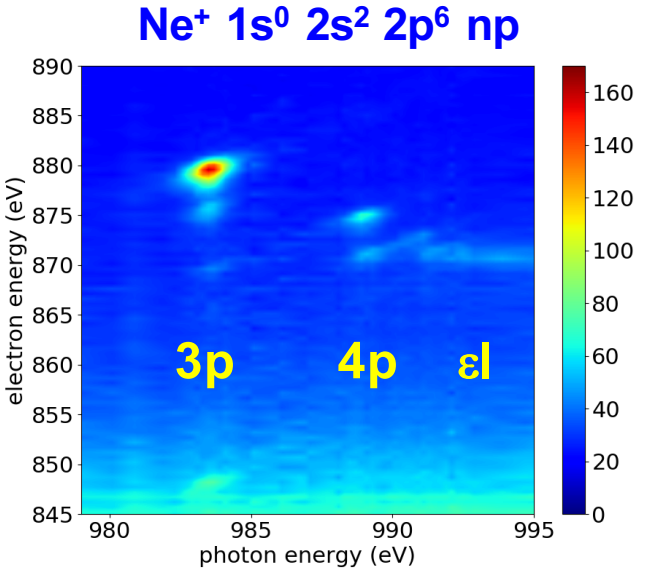
Sample delivery:

- **Supersonic molecular beam**
- **Effusive gas jet (capillary)**

AQS: Atomic-like Quantum Systems

- **6 eTOFs** — **High energy resolution**, **Non-dipole studies**
- **ionTOF** — **High mass resolution**
- **VMI** — **Angular distribution**, **e / ion – coincidences**
- **MBES** — **High electron acceptance**, **e-e, e-ion coincidences**

Example: Non-linear Spectroscopy
Double Core Hole Resonances in Neon



T. Mazza et al.
PRX **10**, 041056
(2020)

SASE: ΔE = 8.5 eV

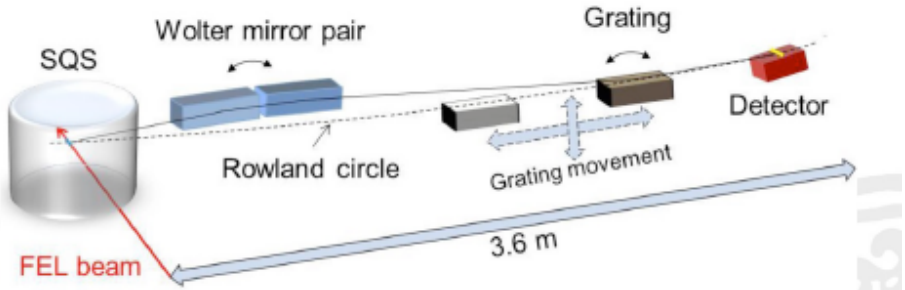
Mono: ΔE = 0.5 eV

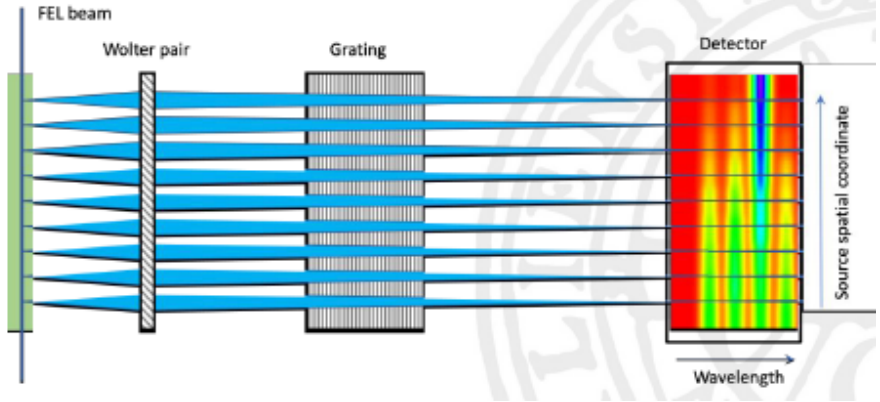
AQS experimental chamber

1D-Imaging XUV Spectrometer

In-kind contribution:

J. Nordgren, J.E. Rubensson (U Uppsala)

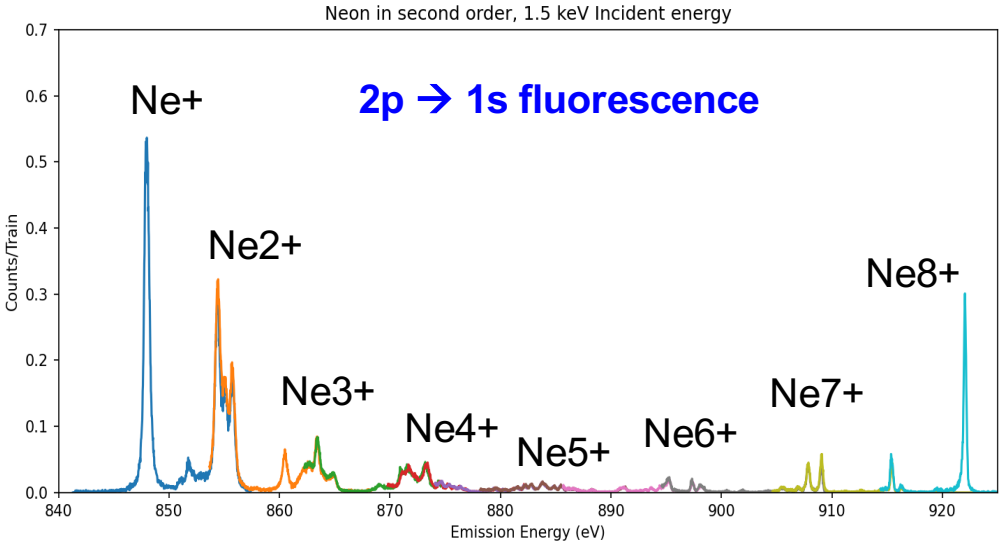


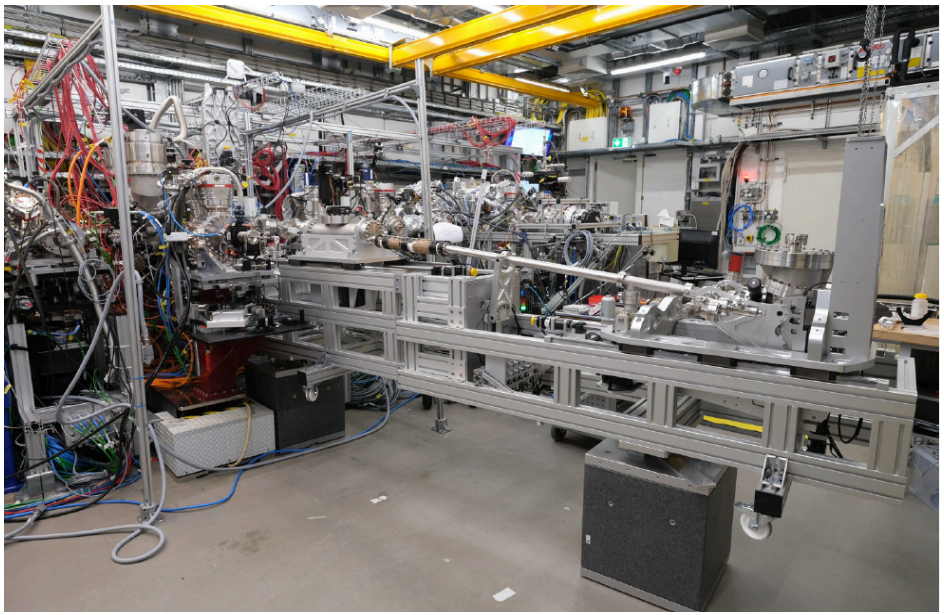


Energy range: 140 – 1150 eV, res. 100meV @ 540 eV

Source size : 2 mm, resolution: 15 μm

First user experiment in Nov. 2022

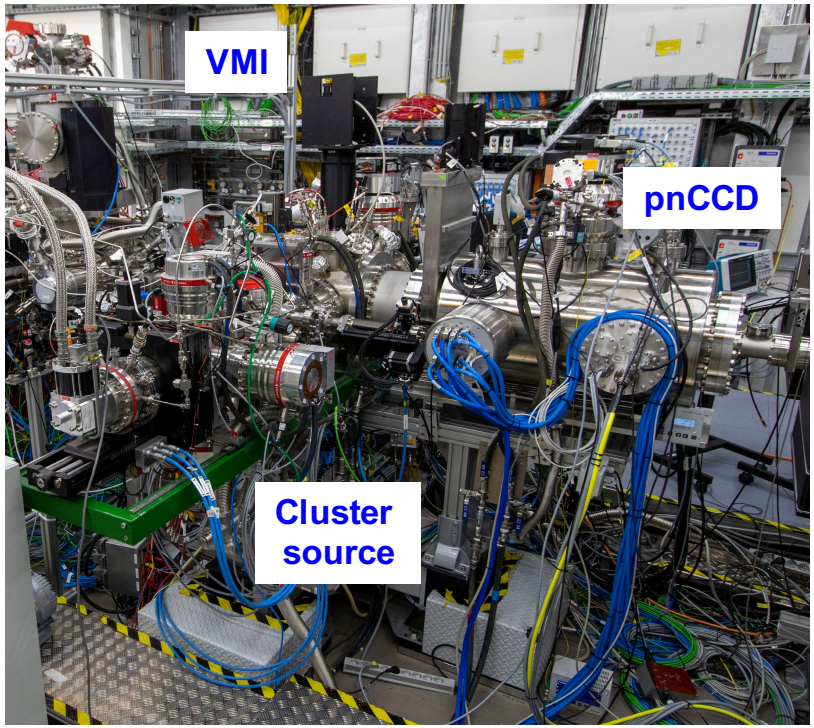




NQS experimental chamber

Targets: Cluster, Nano-particles, bio-molecules

Detection: electrons, ions, photons

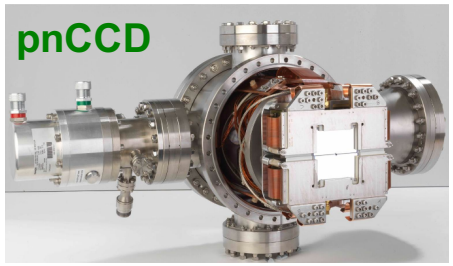


Sample delivery:

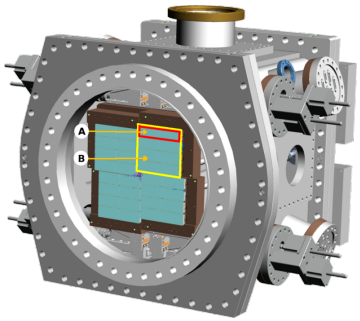
- **Rare gas cluster / He-droplet source**
- **Aerosol source**
- **COMO set-up (J. Küpper / CFEL)**

NQS: Nano-sized Quantum Systems

- **ionTOF** — **Fragmentation products**
- **VMI** — **Angular distribution**
- **Large area pixel detectors** — **Coherent diffraction imaging**



DSSC

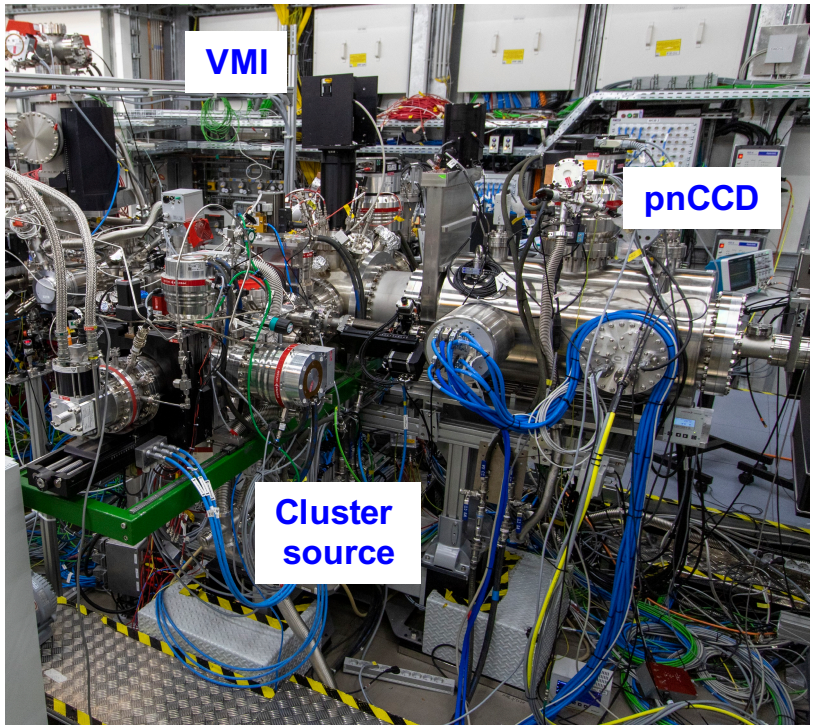


Parameter	pnCCD	Mini-SDD
Energy range	0.03 – 25 keV	0.5 – 6 keV
Detector size	78 x 78 mm^2	210 x 210 mm^2
Number of pixels	1024 x 1024	1024 x 1024
Sensor pixel size	~ 75 x 75 μm^2	~ 236 x 236 μm^2
Dynamic range	>6000 ph @ 1 keV	256 ph @ 1 keV
Frame rate	**Up to 150 Hz**	**0.9 – 4.5 MHz**
Read-out of frames	**1 @ 10Hz**	**800 @ 10Hz**
Vacuum conditions	< 10^{-8} mbar	10^{-7} mbar

NQS experimental chamber

Targets: Cluster, Nano-particles, bio-molecules

Detection: electrons, ions, photons



Sample delivery:

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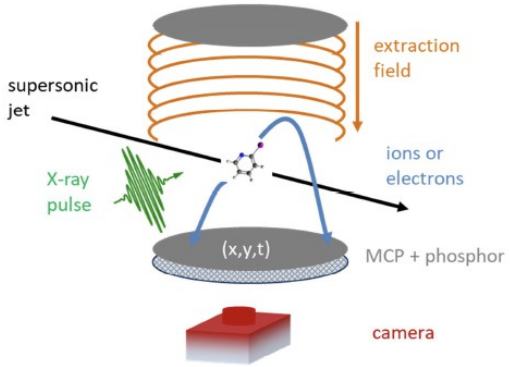
NQS: Nano-size Quantum Systems

- **VMI** **Angular distribution**

Timepix3 camera



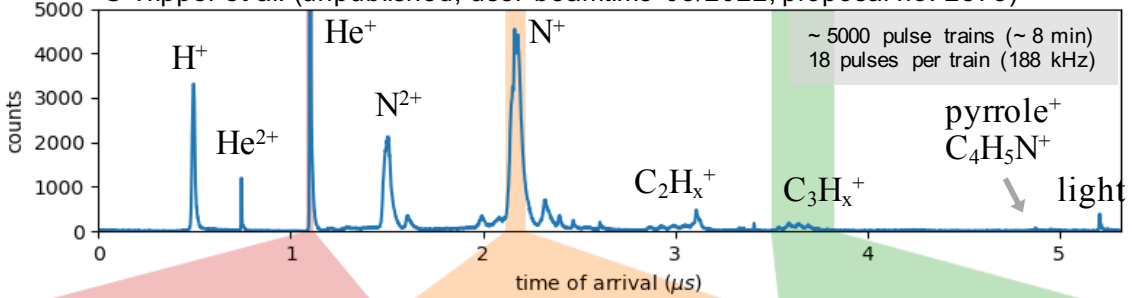
Pulse-resolved VMI images

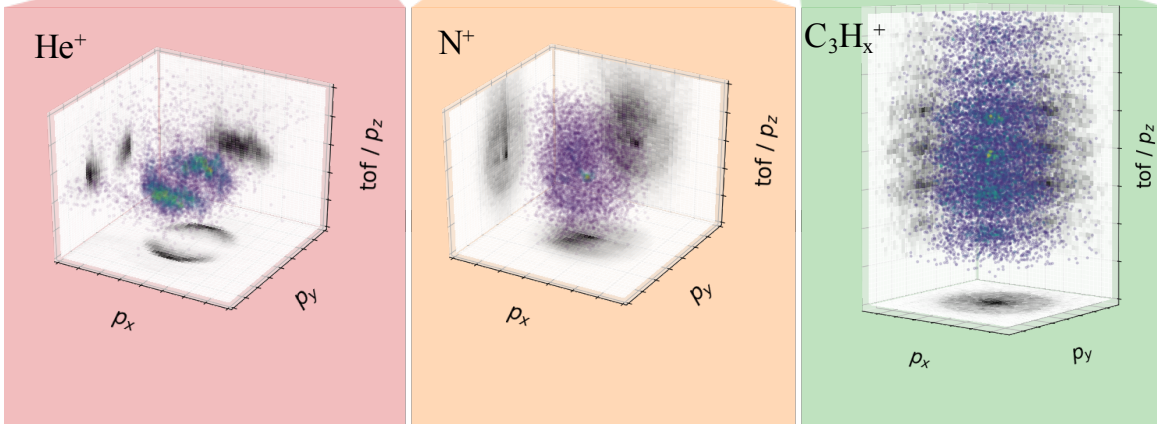
electrons and ions

256 x 256 pixel

200 kHz for ions
2 MHz for electrons

S Trippel et al. (unpublished, user beamtime 03/2022, proposal no. 2873)

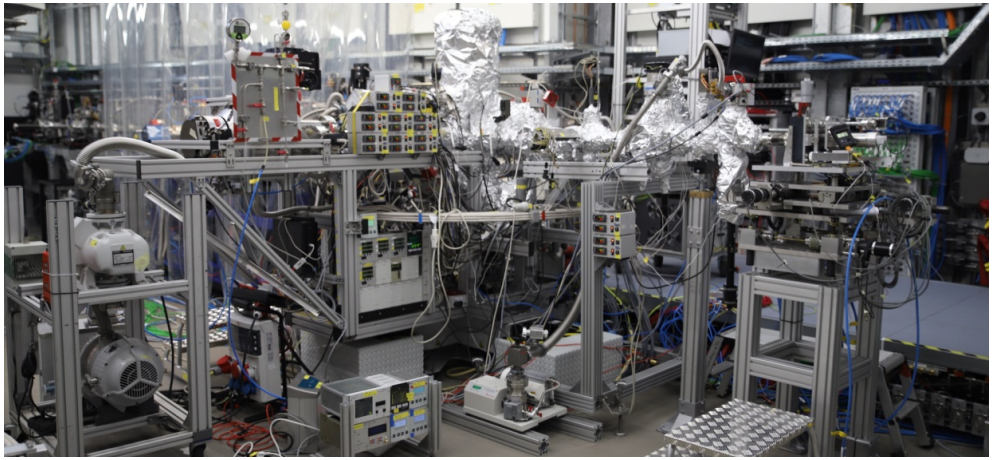


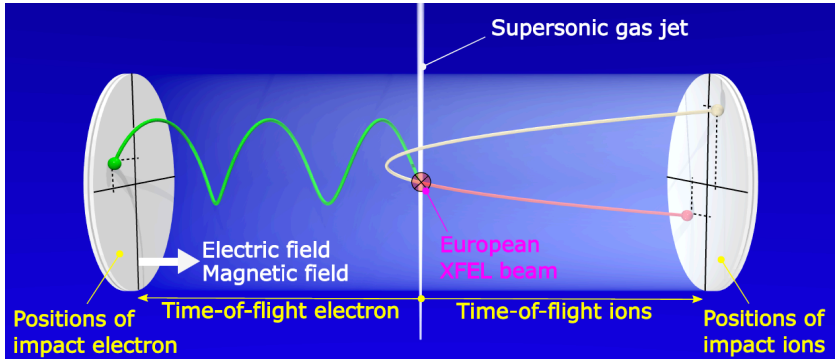


SQS-REMI experimental chamber

Targets: molecules
Detection: electrons, ions

User contribution
U. Frankfurt (R. Dörner et al.)





European XFEL

SQS-REMI Reaction Microscope

COLTRIMS set-up
(Cold Target Recoil Ion Momentum Spectroscopy)

Electron & Ion Momentum Imaging

Coincidence Spectroscopy

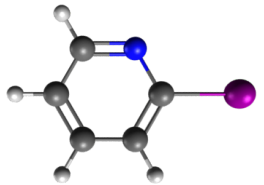
Coulomb Explosion Imaging

Coulomb explosion imaging (CEI)

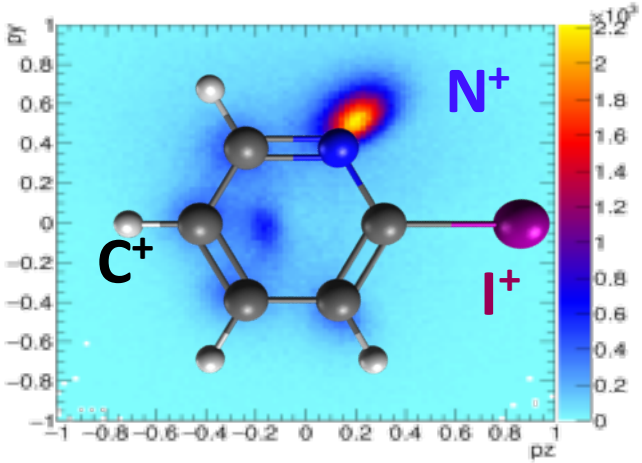
Time-resolved experiments

R. Boll et al., Nat. Phys. 18, 423 (2022)

Iodopyridine



Coincidences I+ / N+ / C+



Time-resolved experiments

X-Ray - Optical Pump-Probe

Pump-Probe Laser (M. Lederer et al.)

< 20 fs, 800 nm, 0.2 mJ at 1.1MHz

< 20 fs, 800 nm, 1 mJ at 188 kHz

SQS extension (T. Mullins et al.)

SHG: 400 nm, ~0.1 mJ, (30 fs)

THG: 266 nm, <10 μJ, 30 fs

Other wavelength (UV and IR) in preparation.
Contact SQS for further Information!!!

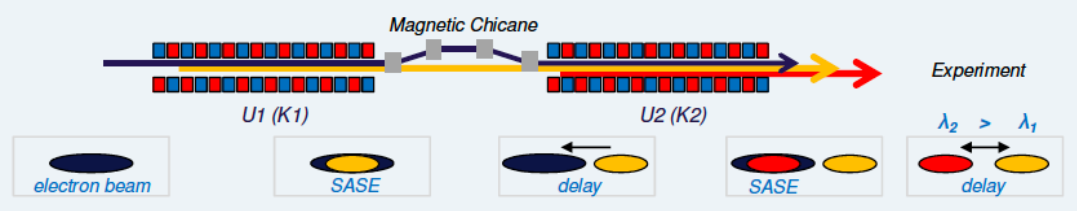
Pulse Arrival Time Monitor

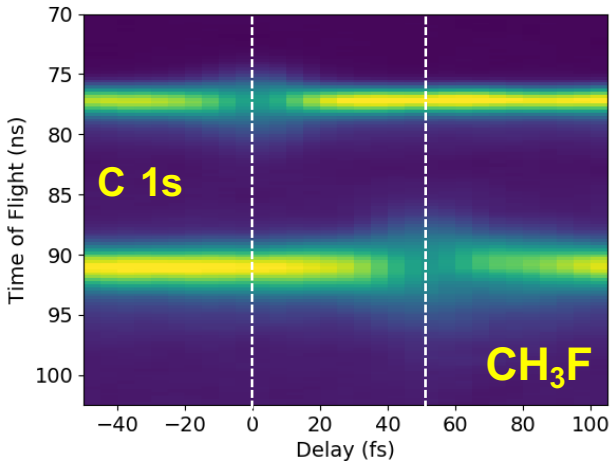
Synchronization < 20 fs

2-Color Pump Probe (2CPP)

X-ray – X-ray Pump-Probe

Magnetic chicane in SASE3 undulator





Electron spectra

C1s photolines

660eV and 698 eV

Delay 50 fs

(D. Rivas et al.)

Photon energy range: 500 – 1500 eV (→ 3000 eV)

Pulse energy: up to 1 mJ

Pulse duration: < 30 fs

Temporal delay: up to 1 ps

Operation in close collaboration with S. Serkez & G. Geloni

RUN 10: August – November 2023

https://www.xfel.eu/facility/instruments/sqs

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AQS: Alberto.DeFanis@xfel.eu

NQS: Yevheniy.Ovcharenko@xfel.eu

REMI: Rebecca.Boll@xfel.eu

Laser: Terry.Mullins@xfel.eu

X-ray beam transport: Tommaso.Mazza@xfel.eu

or simply sqs@xfel.eu

RUN 10: August – November 2023

https://www.xfel.eu/facility/instruments/sqs