

# Small Quantum Systems (SQS)

M. Meyer  
SQS scientific instrument

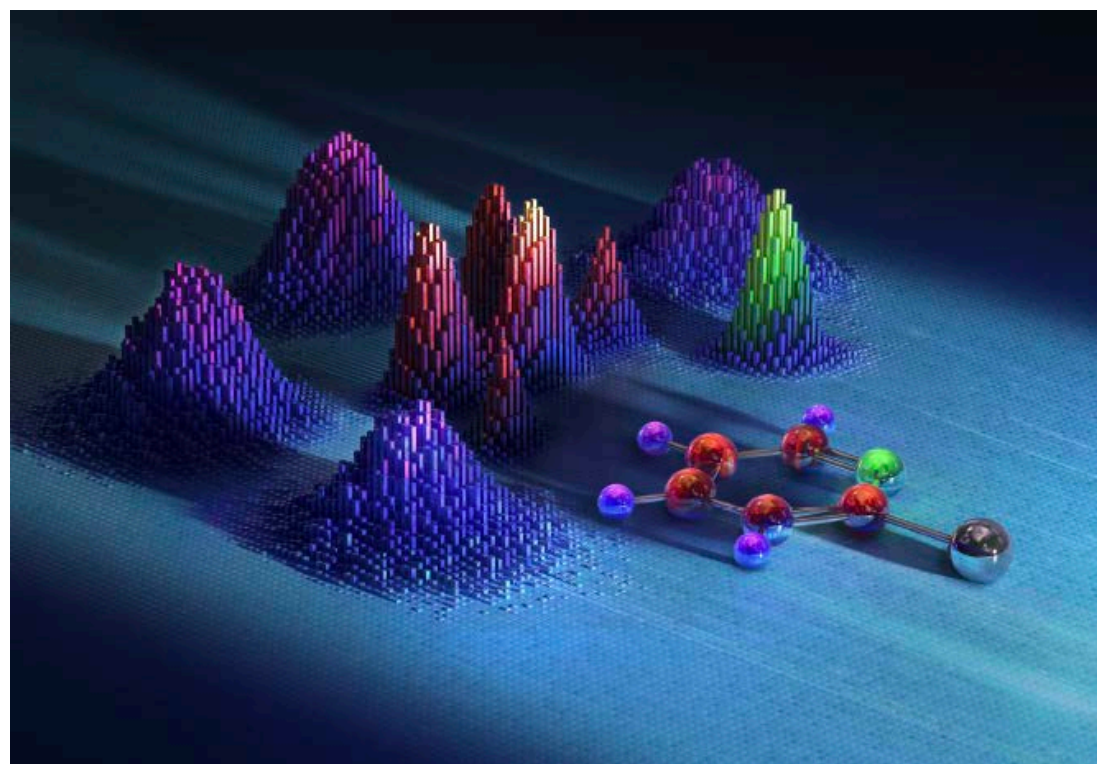
Townhall meeting, May 12, 2022



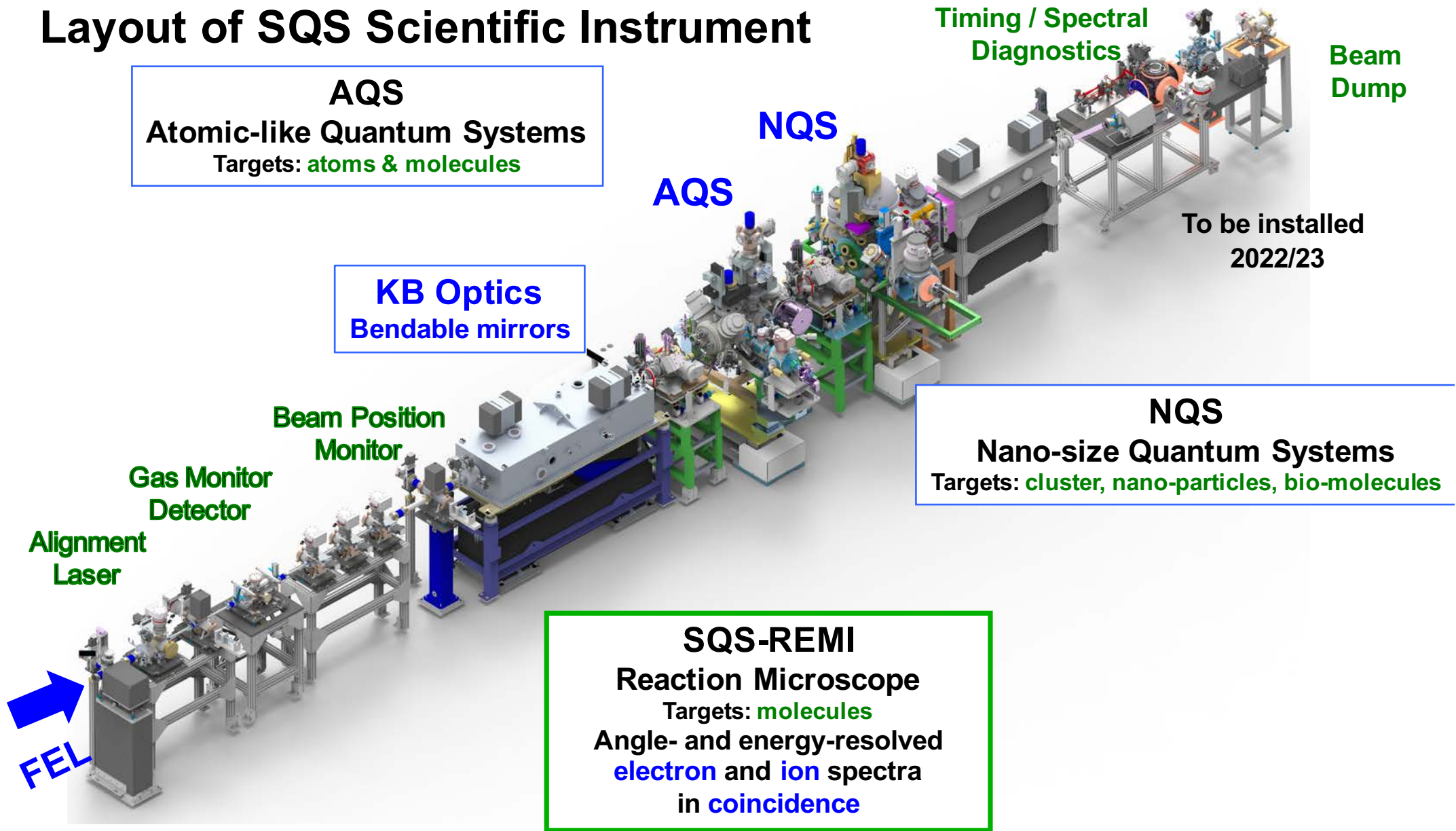
## Gas Phase Samples

Soft X-Rays (260 – 3000 eV)

- Study of non-linear phenomena
- Time-resolved investigations
- Coherent Diffraction Imaging



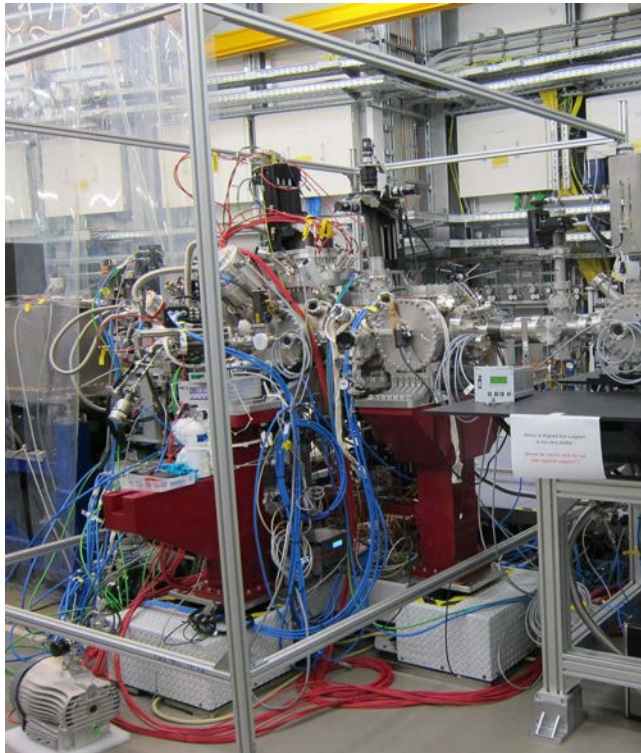
# Layout of SQS Scientific Instrument



# AQS experimental chamber

Targets: atoms & molecules

Detection: electrons, ions



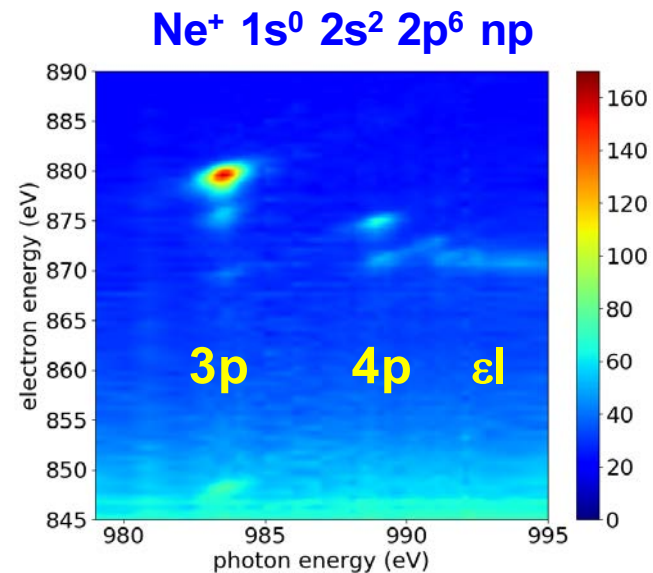
Sample delivery:

- 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:  $\Delta E = 8.5$  eV

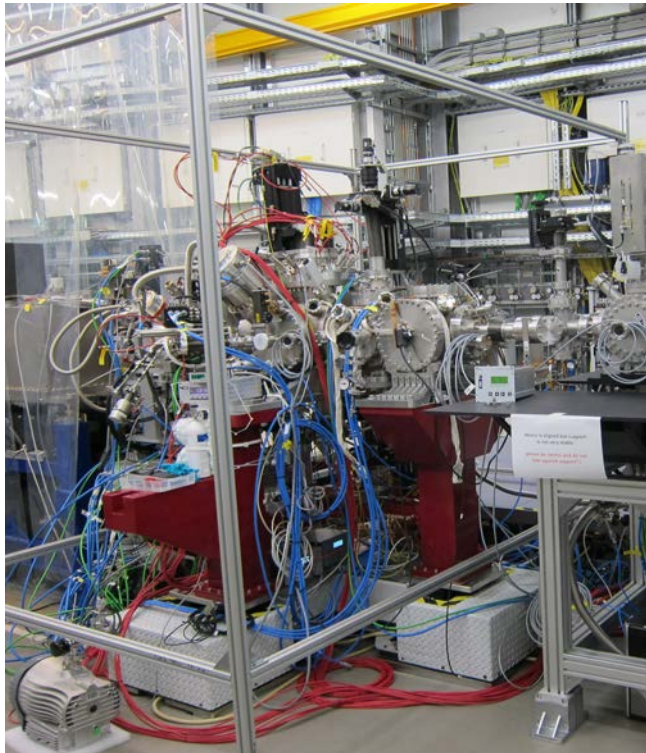


Mono:  $\Delta E = 0.5$  eV

# AQS experimental chamber

Targets: atoms & molecules

Detection: electrons, ions



Sample delivery:

- Supersonic molecular beam
- Effusive gas jet (capillary)
- Gas cell

European XFEL

## AQS: Atomic-like Quantum Systems

- 6 eTOFs High energy resolution  
Non-dipole studies
- ionTOF High mass resolution
- VMI Angular distribution  
e / ion – coincidences

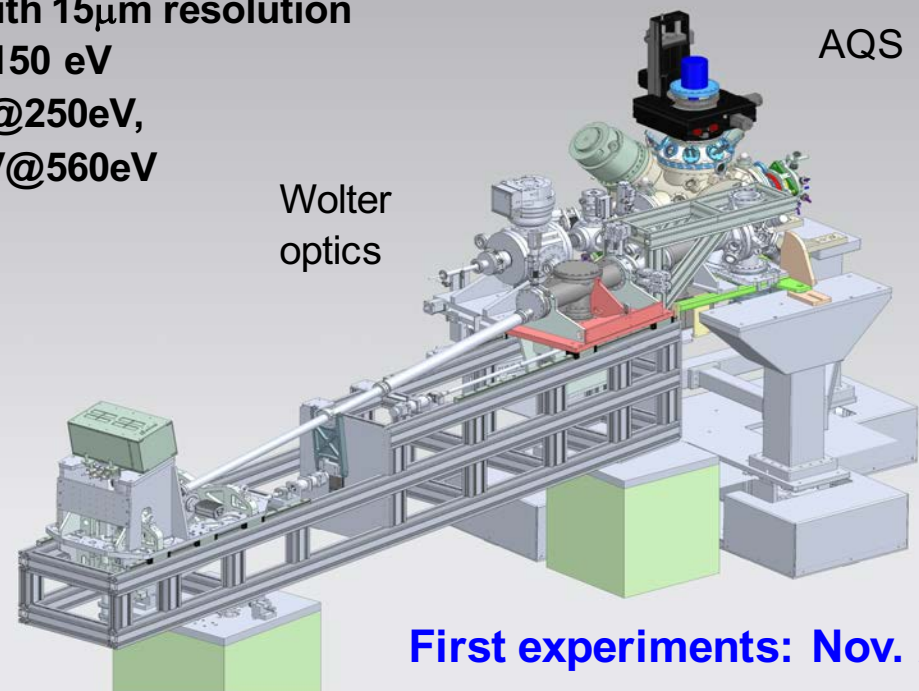
### 1D Imaging Soft X-ray Spectrometer

(In-kind U. Uppsala)  
Nordgren/Rubensson

2mm with 15 $\mu$ m resolution  
140 – 1150 eV  
70meV@250eV,  
100meV@560eV

Wolter  
optics

AQS

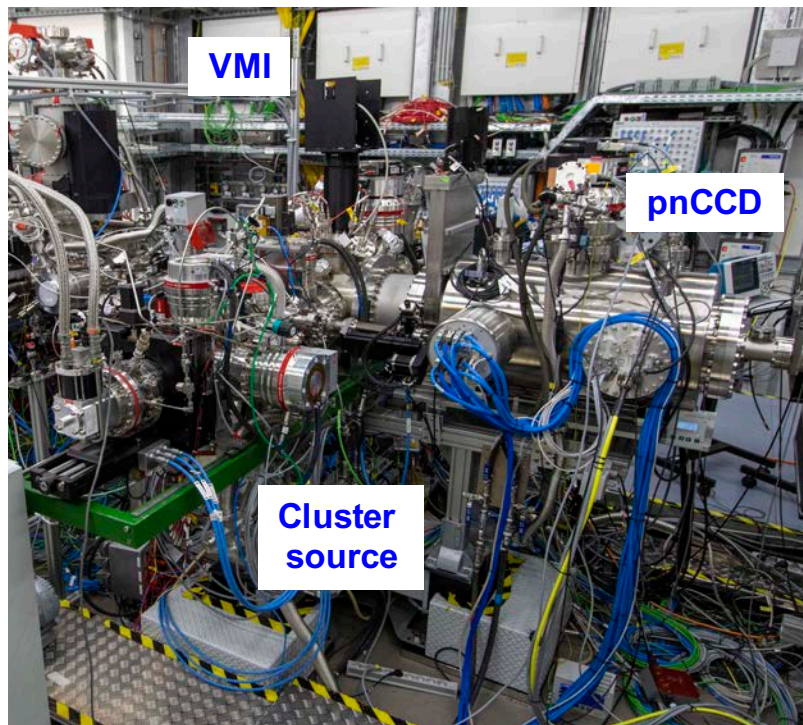


First experiments: Nov. 2022

# NQS experimental chamber

Targets: Cluster, Nano-particles, bio-molecules

Detection: electrons, ions, photons



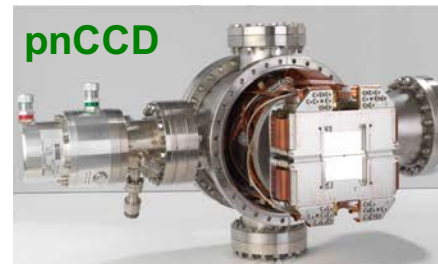
Sample delivery:

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

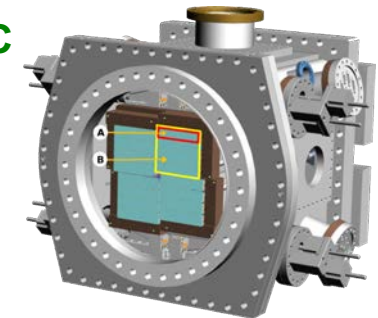
European XFEL

## NQS: Nano-size Quantum Systems

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



DSSC

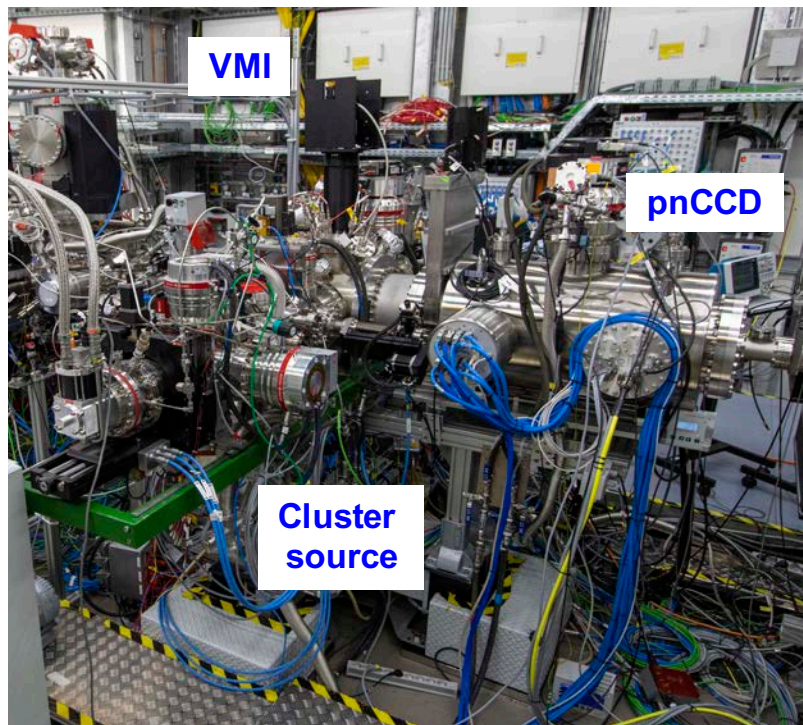


Parameter	pnCCD	Mini-SDD
Energy range	0.03 – 25 keV	0.5 – 6 keV
Detector size	78 x 78 mm <sup>2</sup>	210 x 210 mm <sup>2</sup>
Number of pixels	1024 x 1024	1024 x 1024
Sensor pixel size	~ 75 x 75 μm <sup>2</sup>	~ 236 x 236 μm <sup>2</sup>
Dynamic range	>6000 ph @ 1 keV	256 ph @ 1 keV
Frame rate	Up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

# NQS experimental chamber

Targets: Cluster, Nano-particles, bio-molecules

Detection: electrons, ions, photons



Sample delivery:

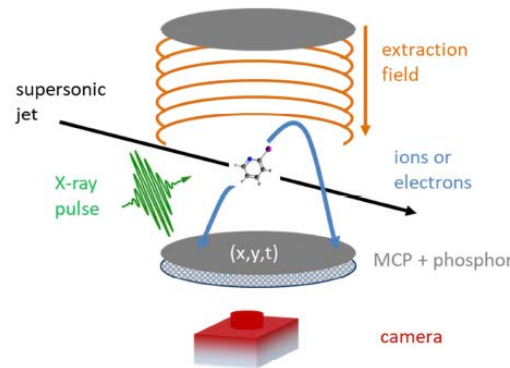
- Rare gas cluster / He-droplet source
- Aerosol source
- COMO set-up (J. Küpper / CFEL)

European XFEL

## NQS: Nano-size Quantum Systems

- VMI

Angular distribution



## Timepix3 camera

First exp.: March 2022

Pulse-resolved VMI images

electrons and ions

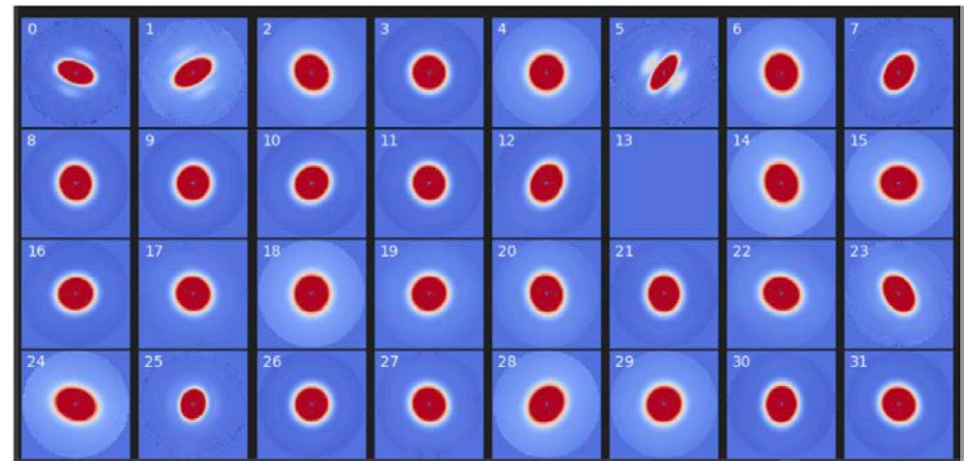
256 x 256 pixel

200 kHz for ions

2 MHz for electrons

First experiments:  
DSSC August 2021

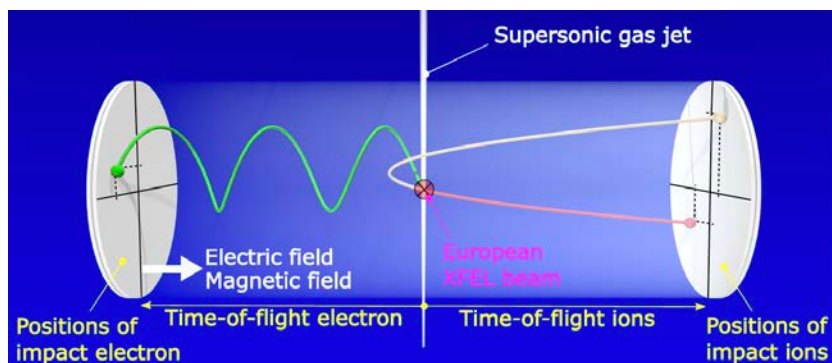
F. Maia et al.  
E. coli 70S Ribosome



# 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)

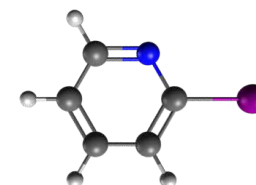
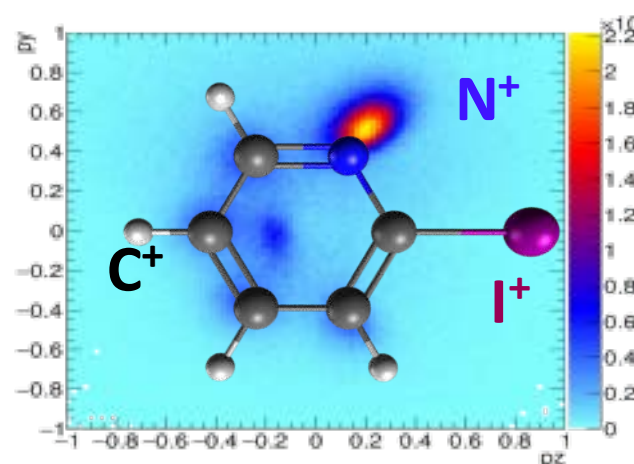


Time-resolved experiments

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

Iodopyridine

Coincidences I<sup>+</sup> / N<sup>+</sup> / C<sup>+</sup>



# 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 (D. Rivas / T. Mullins)

SHG: 400 nm, ~0.1 mJ, <30 fs

THG: 266 nm, <10  $\mu$ J, <30 fs

Other wavelength (UV and IR) in preparation.

Contact SQS for further Information!!!

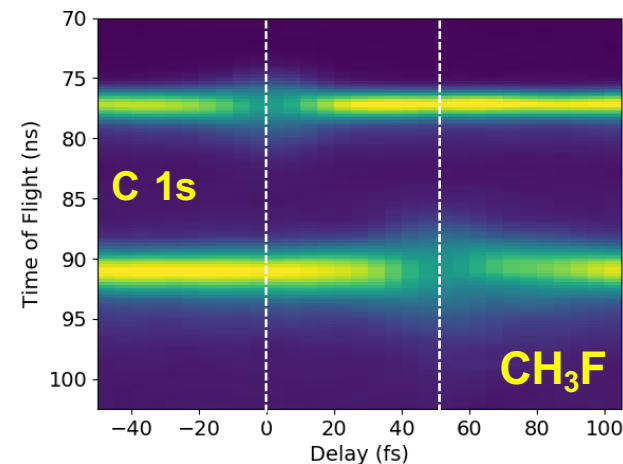
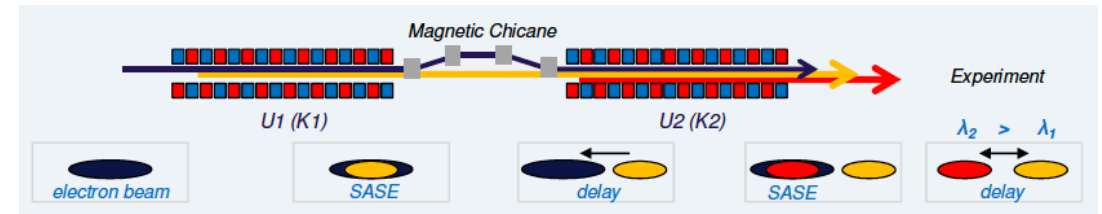
Pulse Arrival Time Monitor

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 ( $\rightarrow$  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



## SASE3 Soft X-Ray radiation parameters

Photon Beam Parameter	Unit	Operation 2022	Final Operation
		RUN 9	
Electron energy	GeV	8.5, 11.5, 14, 16.5	8.5, 11.5, 16.5, 17
Photon energy	eV	260 – 1100 (@ 8.5 GeV) 500 – 1500 (@ 11.5 GeV) 660 – 2500 (@ 14 GeV) 920 – 3000 (@ 16.5 GeV) fully tunable !!	0.26 – 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 circular (basic functionalities)	Linear & circular
Focus size	μm	1 – 2 (@ F1 / F1') 2 – 3 (@ F2)	0.5 – 2

## RUN 9: February – June 2023

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

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<b>X-ray beam transport:</b>	<u><a href="mailto:Tommaso.Mazza@xfel.eu">Tommaso.Mazza@xfel.eu</a></u>

or simply [sqs@xfel.eu](mailto:sqs@xfel.eu)