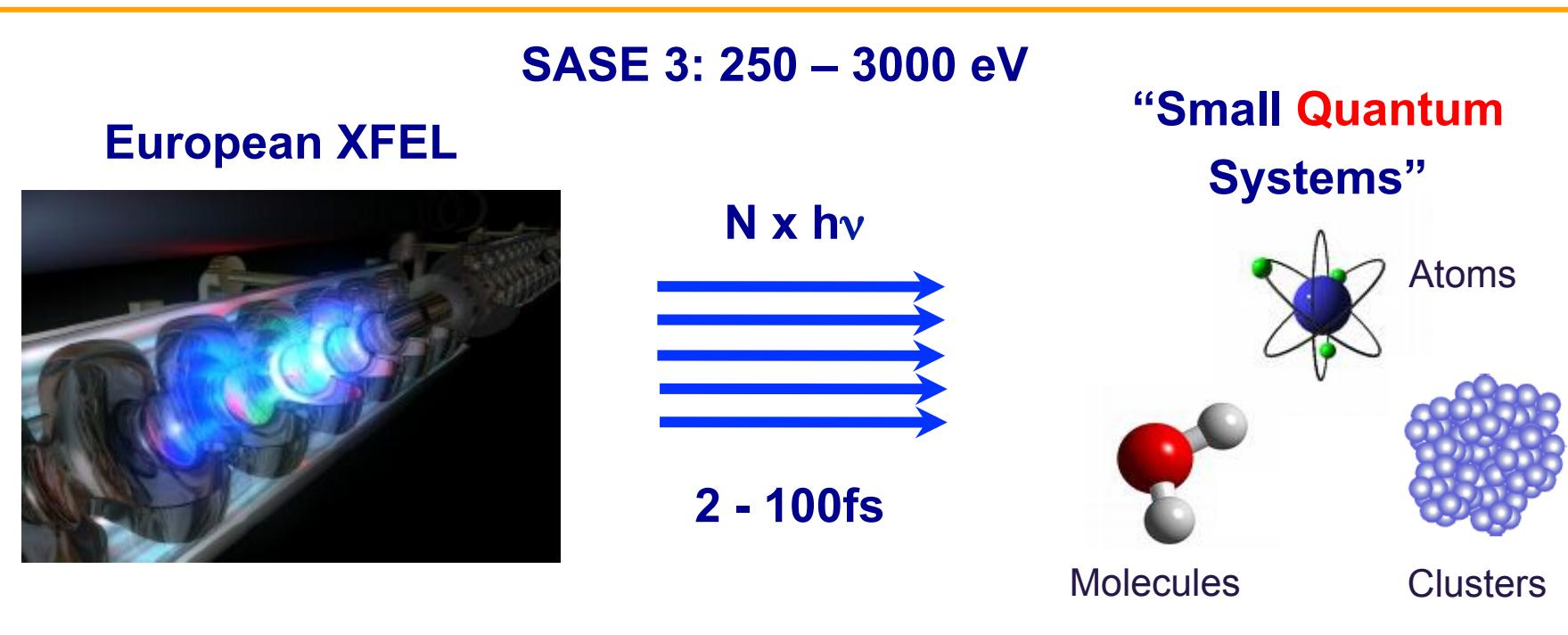




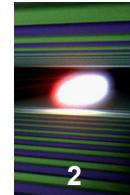
# SQS “Small Quantum Systems” Scientific Instrument

M. Meyer, European XFEL GmbH



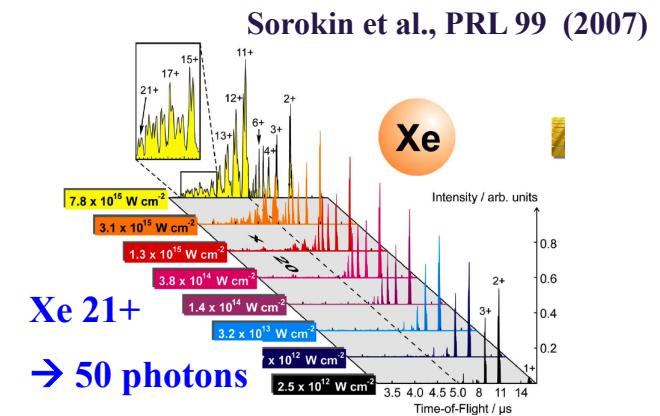
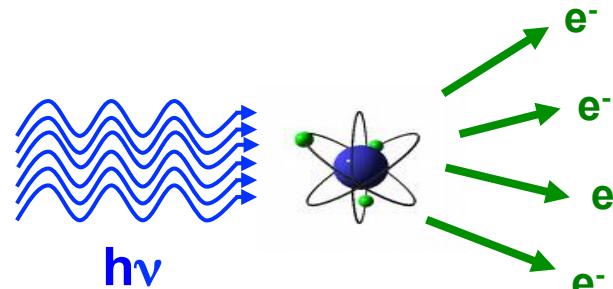
# Science applications @ SQS

Cluste  
rs



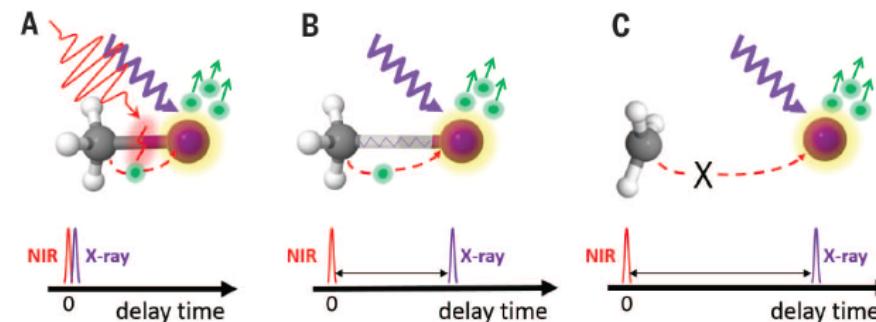
## Non-linear phenomena

$10^{17} - 10^{18} \text{ W / cm}^2$



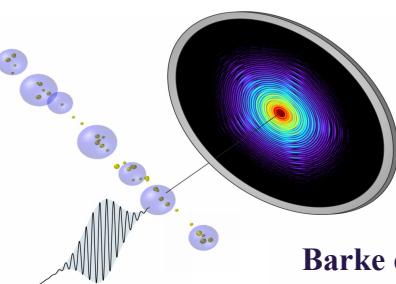
## Time-resolved studies

low jitter ( $< 10 \text{ fs}$ )

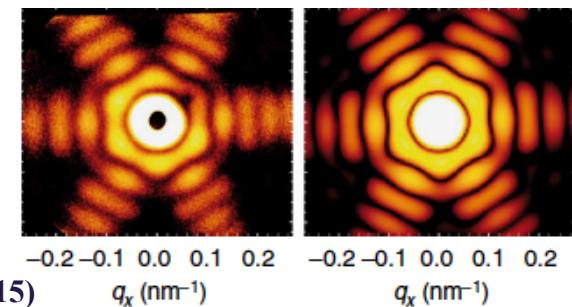


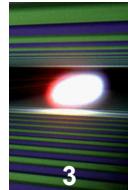
Erk et al., Science 345 (6194), 288 (2014)

## Imaging experiments Spatial coherence



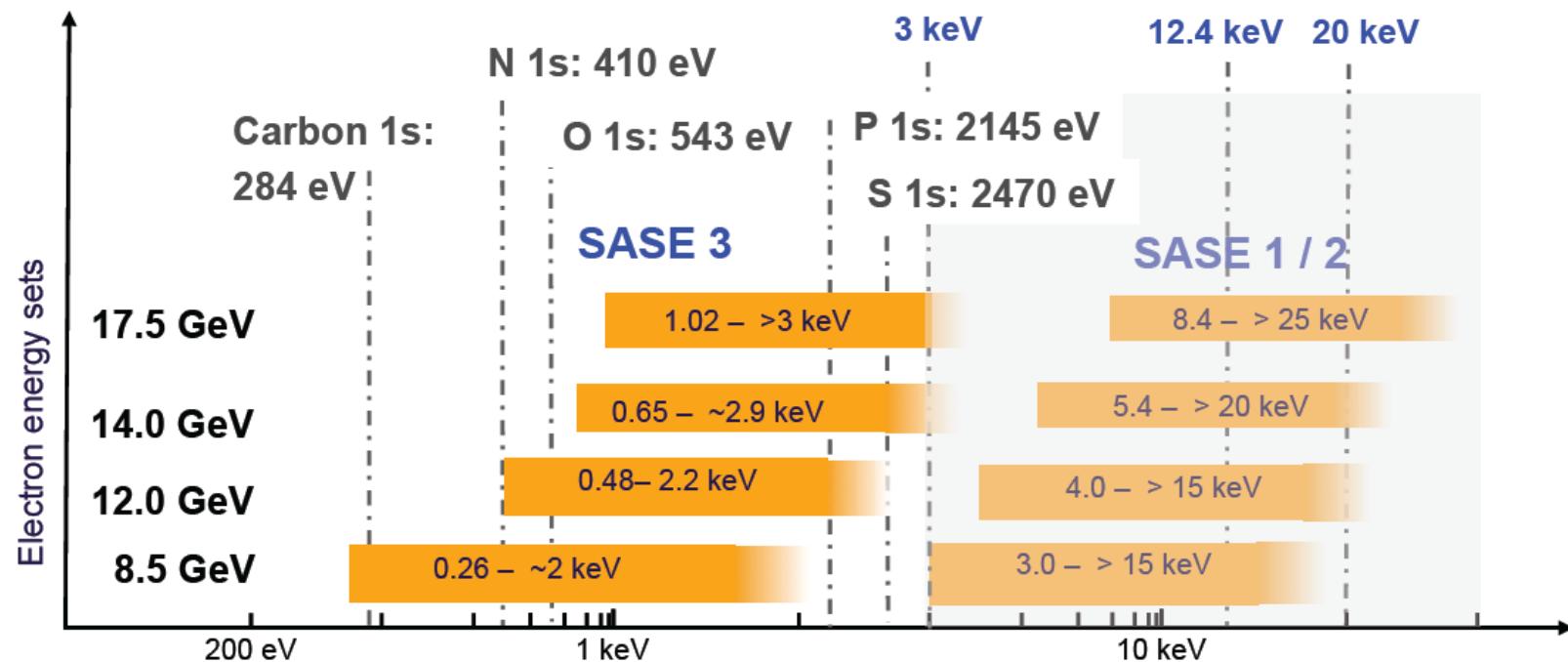
Barke et al.,  
Nat.Comm.6, 6187 (2015)





## SASE3 Parameters

<b>SASE3</b>	$h\nu = 260 - 3000 \text{ eV}$	$P = 0.2 - 11.0 \text{ mJ}$	Lin./Circ. Pol.
	$\Delta T = 2 - 100 \text{ fs}$	Coherence: 0.96	Split & Delay



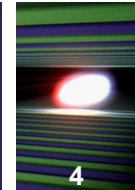
High repetition rate:

< 27000 pulses/ sec



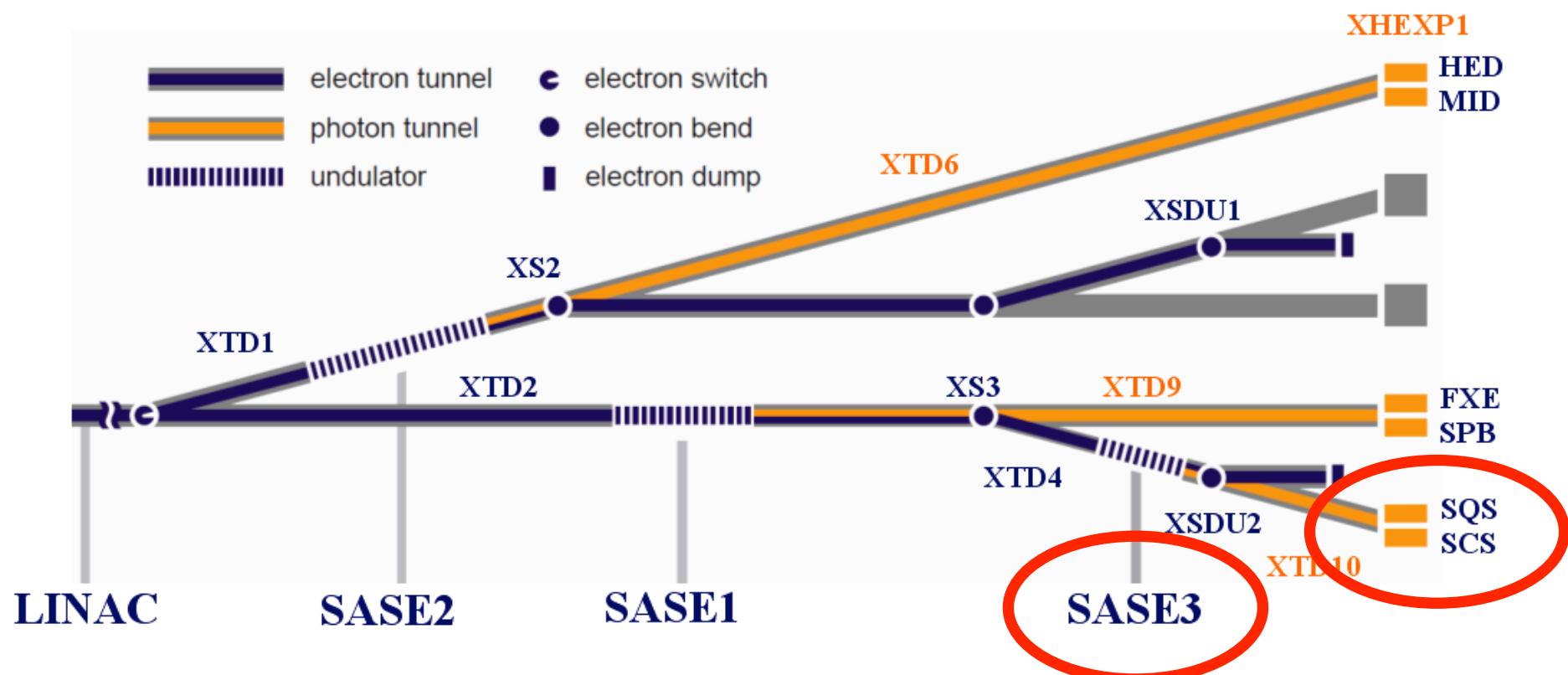
High data collection rate

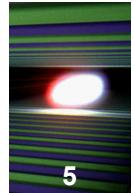
Multi-particle **coincidences**



# Photon beam transport systems

## European XFEL

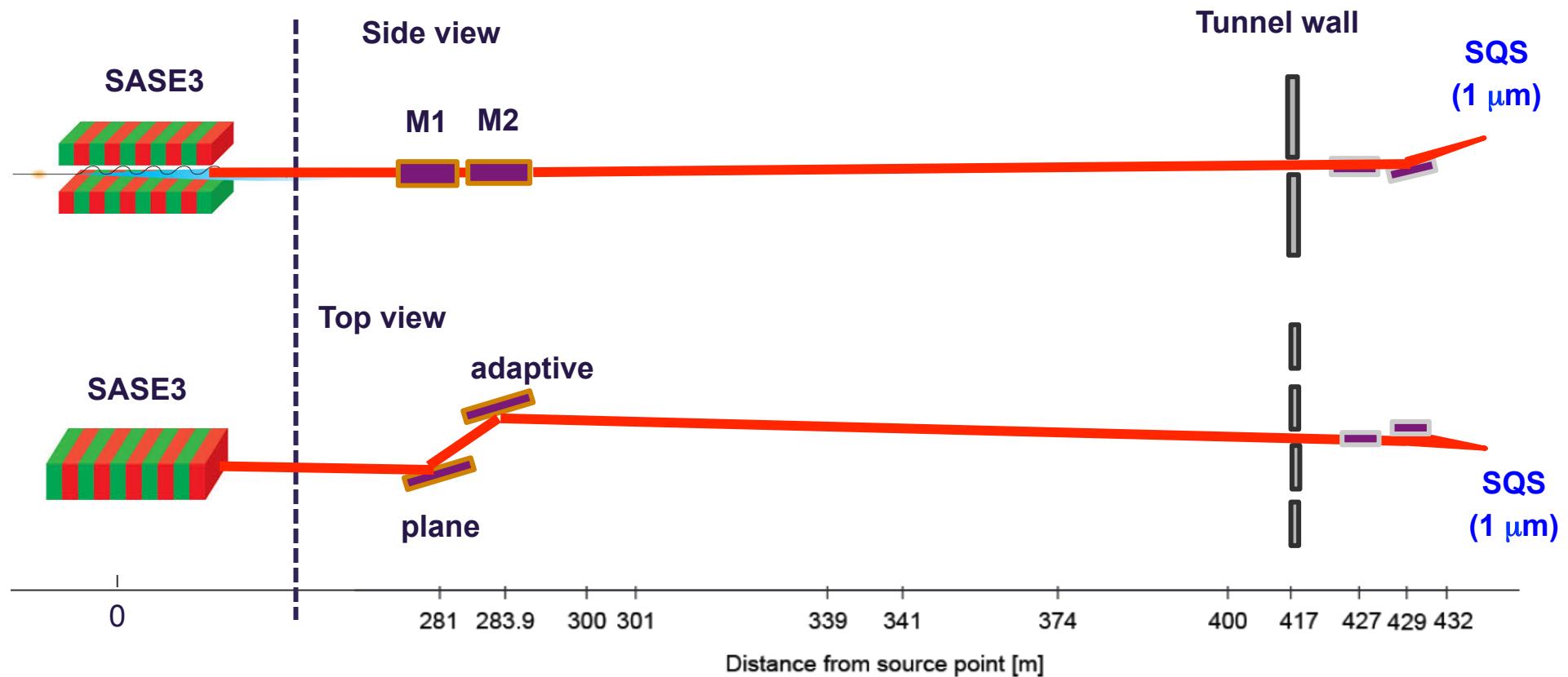


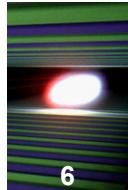


# Photon beam transport systems

- direct beam

→ Small Quantum System (SQS)

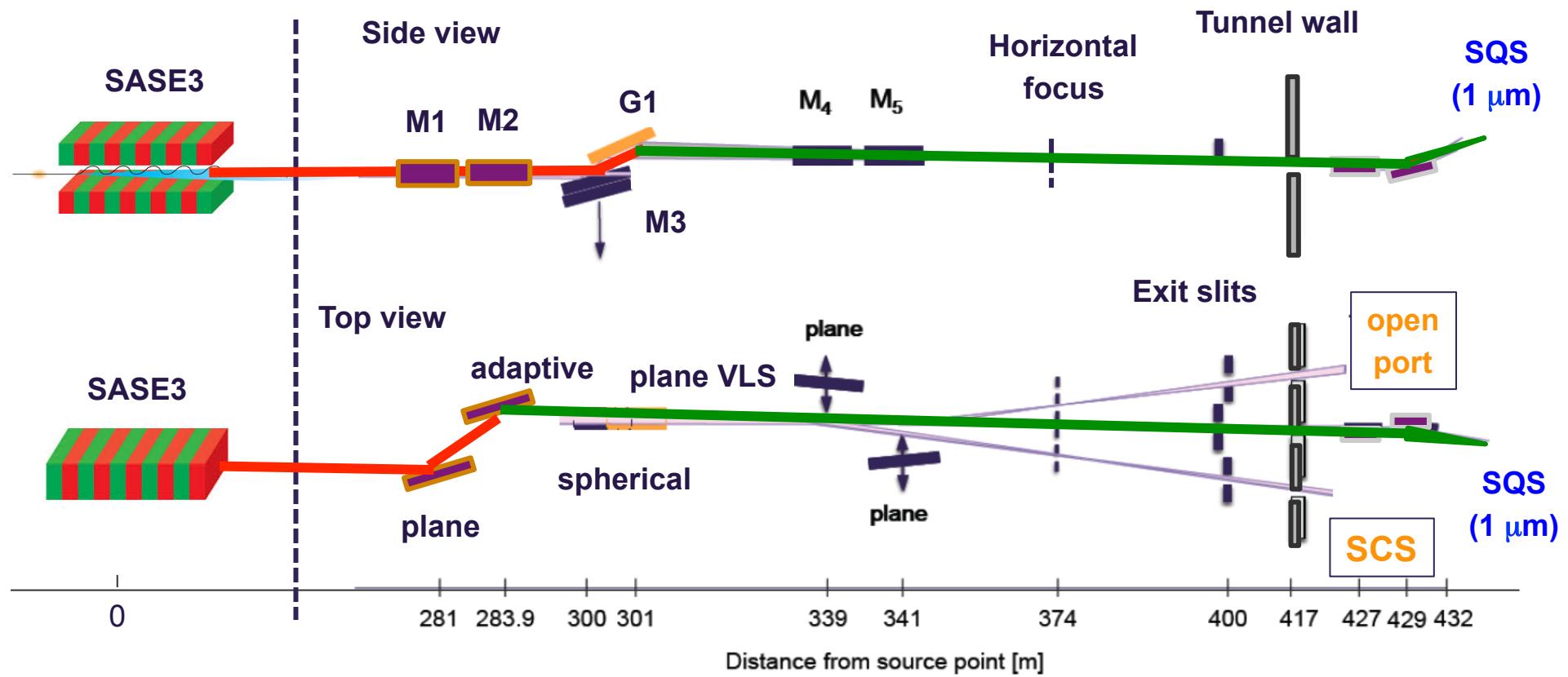




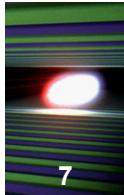
# Photon beam transport systems

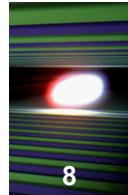
- **direct beam** → **Small Quantum System (SQS)**

**Option: monochromatic beam**

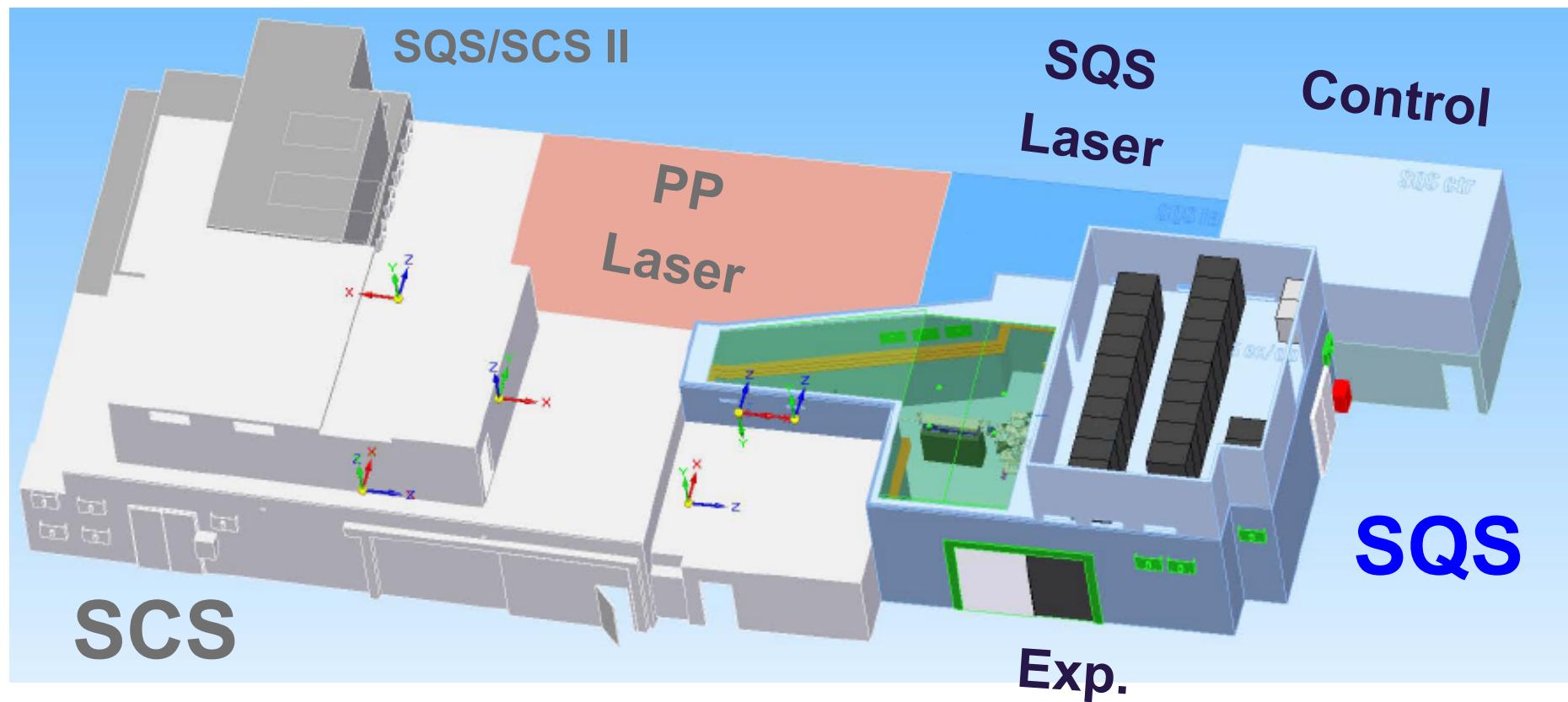


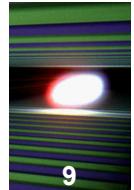
## View to the SASE3 experimental area



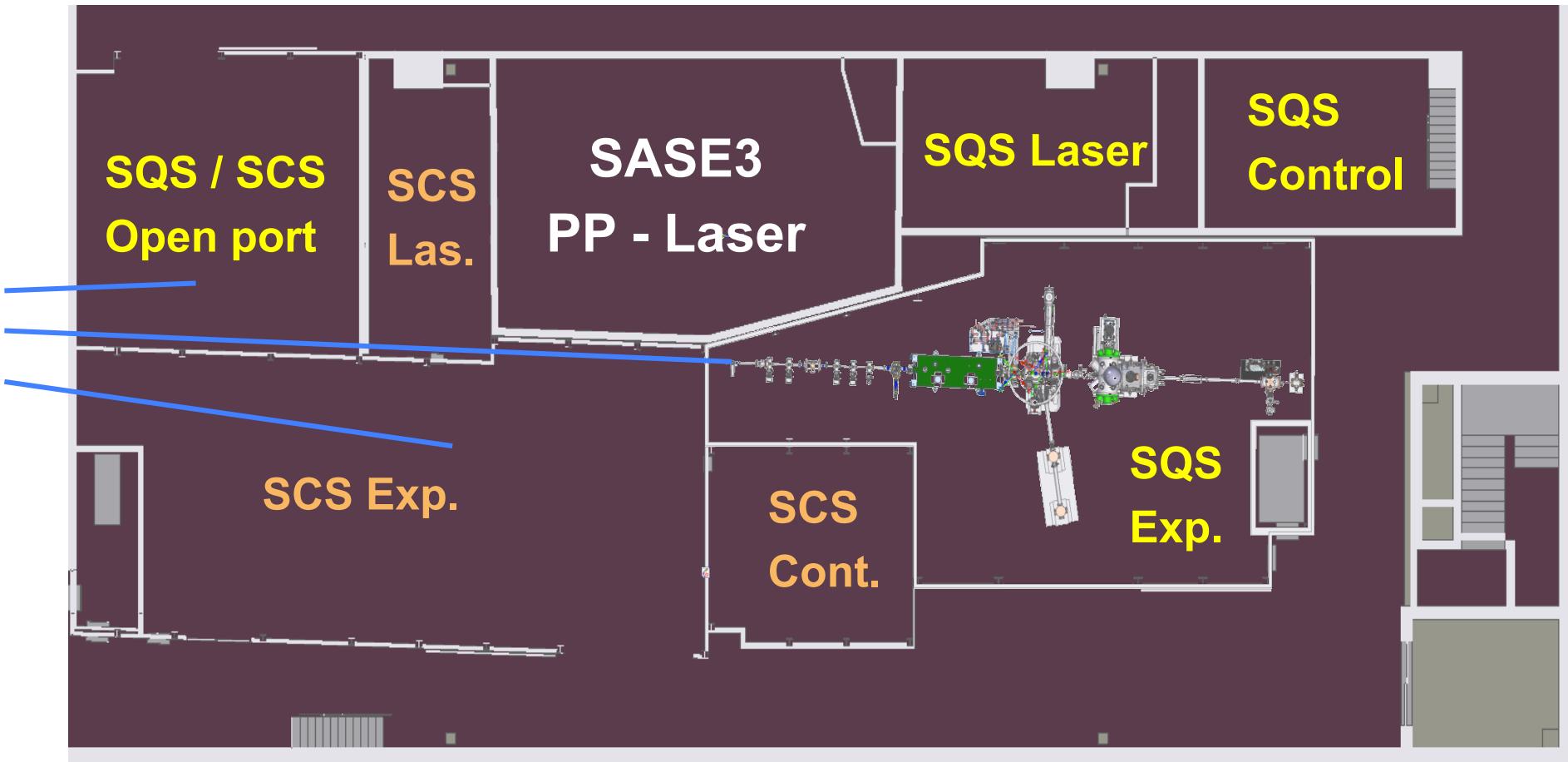


# SASE3

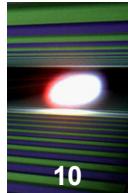




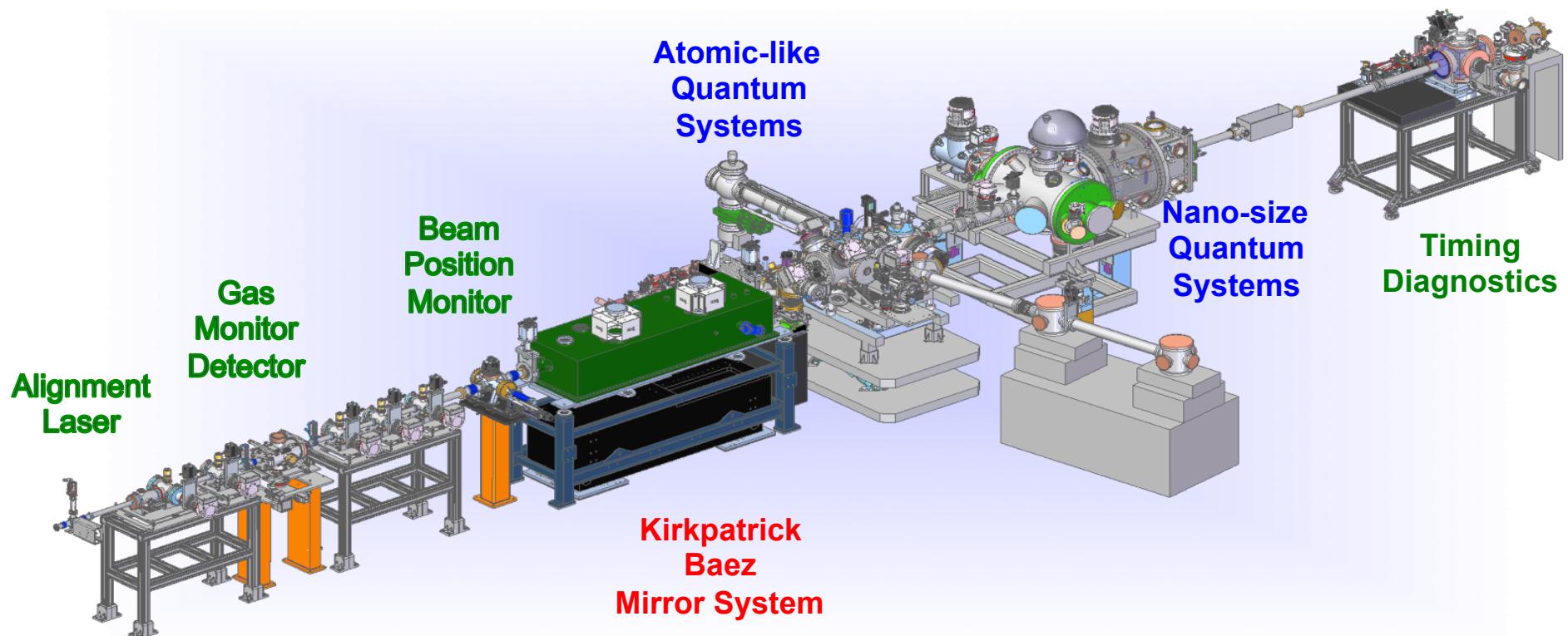
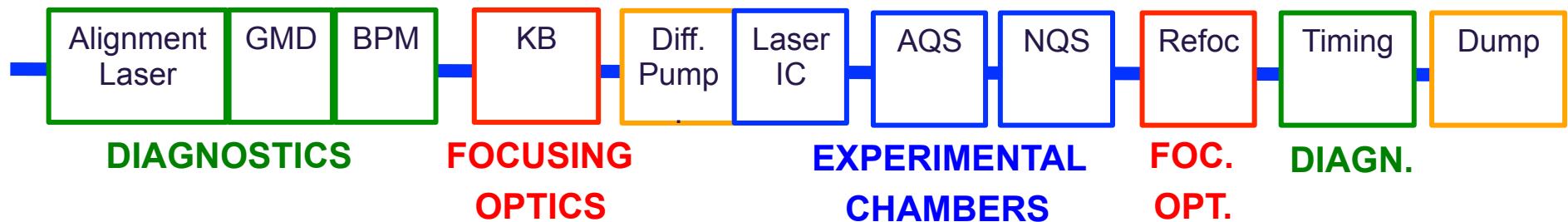
## General Layout of SASE3 Area



## SASE3 Experimental area

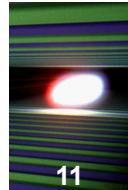


## General Layout of SQS Scientific Instrument



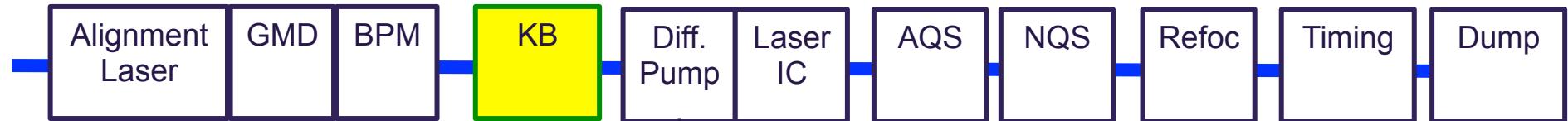


SQS Scientific Instrument

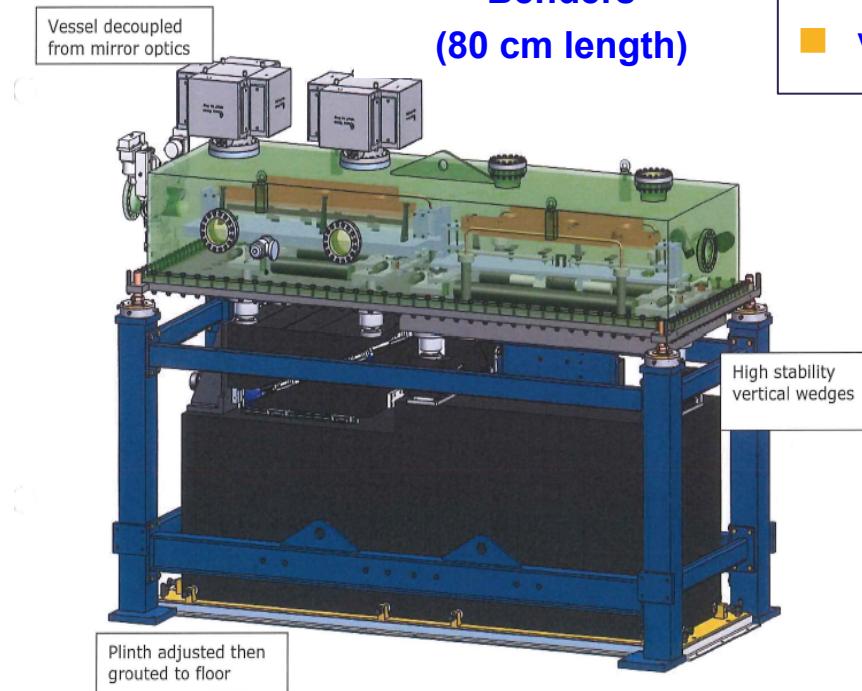


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## Focusing optics for SQS



**Cooled Mechanical  
Benders  
(80 cm length)**



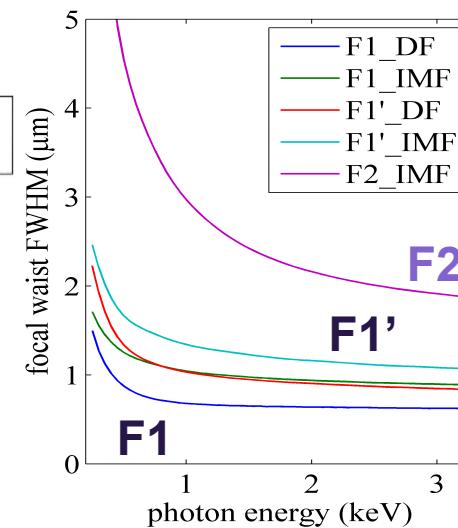
**FMB Oxford**

- 3 interaction points
- $\leq 1$  micron focus
- variable focus size

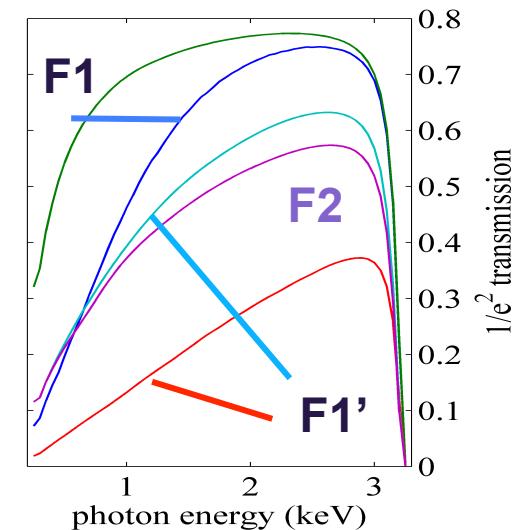
### High Quality Mirrors

Pre-polished for F1  
Shape optimized for F1'  
Best effort for F2

### Focus size

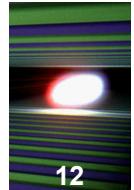


### Transmission





SQS Scientific Instrument

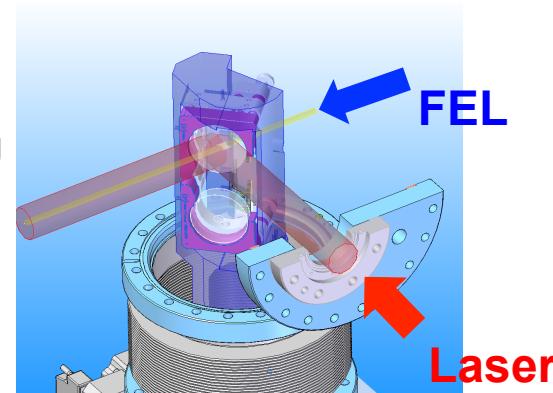
European  
**XFEL**

## Laser In-coupling Unit

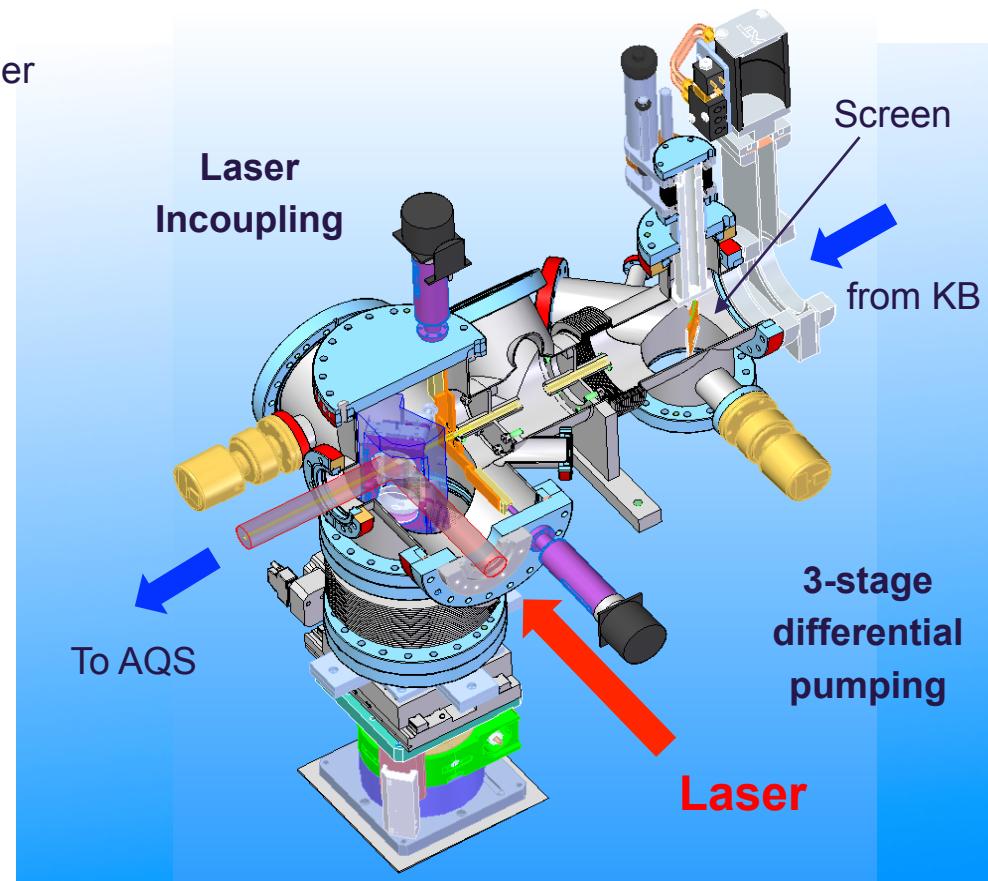


- Motorized laser in-coupling mirrors
- Mirror mount vibrationally decoupled from chamber
- YAG screens to monitor FEL beam

Laser  
Incoupling



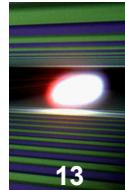
Laser  
Incoupling



	Pump-Probe	Molecular Alignment
wavelength	800 nm	800 nm / 1030 nm
rep. rate	1 – 4.5 MHz	100 kHz
energy	0.2 – 1 mJ	3 mJ / 100 mJ
duration	10 – 100 fs	20 fs / 1 ns

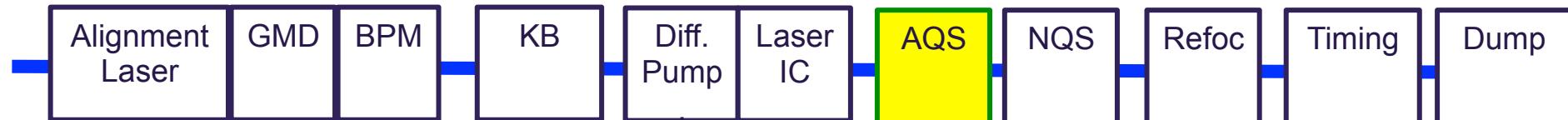


SQS Scientific Instrument

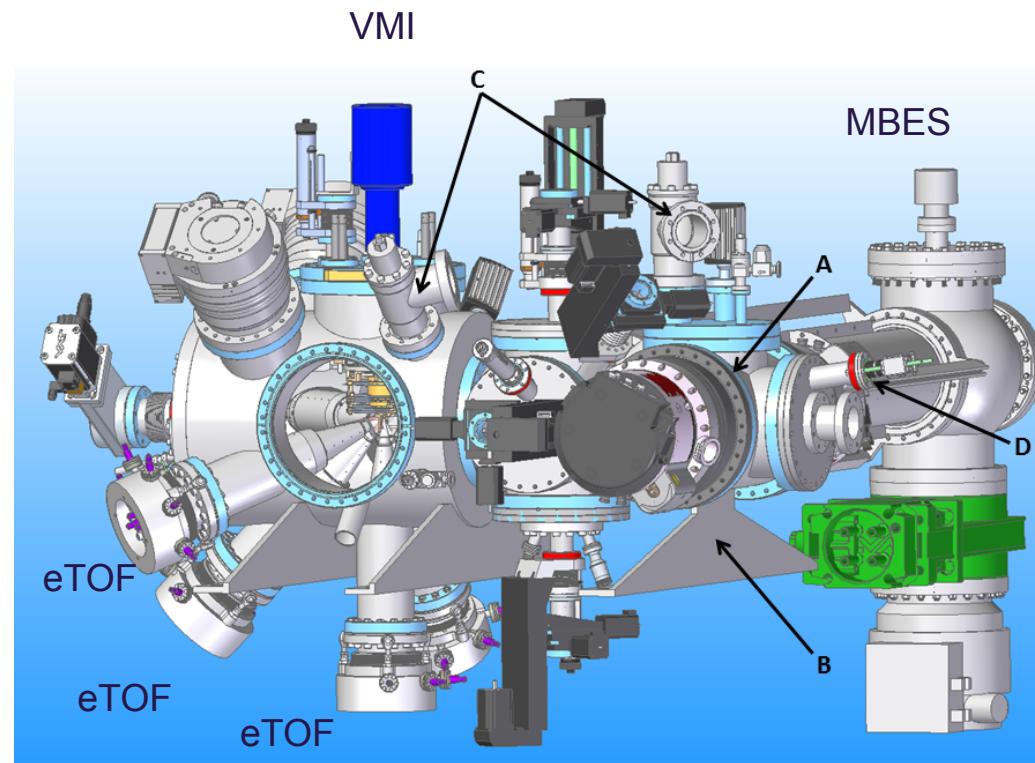


European  
**XFEL**

## AQS experimental chamber



### [AQS: Atomic-like Quantum Systems](#)



Targets: atoms & small molecules

Molecular beam

Vacuum:  $10^{-11}$  mbar

Focus:  $\leq 1 \mu\text{m} \rightarrow 50 \mu\text{m}$

electrons, ions, photons

- eTOFs

High energy resolution  
Non-dipole studies

- VMI Spectrometer

Angular distribution  
e / ion - coincidences

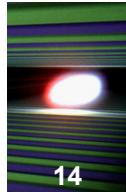
- Magnetic Bottle Electron Spectrometer

e / e - coincidences

- 1D imaging XUV fluorescence spectroscopy

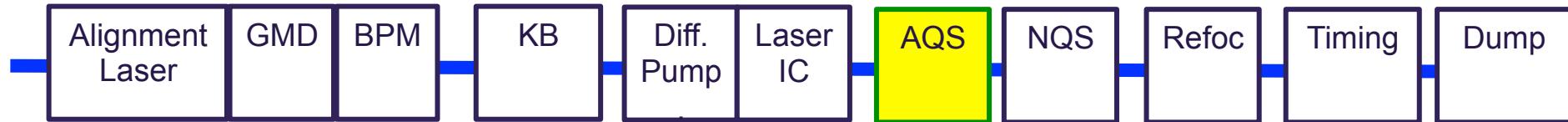


SQS Scientific Instrument

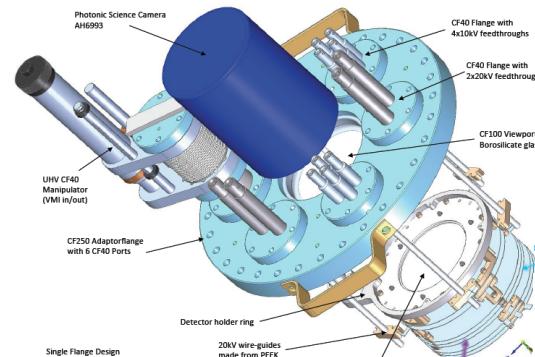
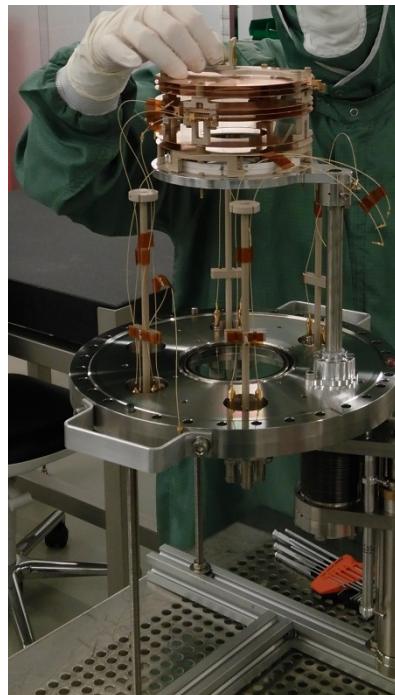


European  
**XFEL**

## VMI spectrometer @ AQS



## Velocity-Map-Imaging (VMI) Spectrometer



### New Design

(in coll. with S. Deinert, DESY)

Segmented Parabolic Repeller

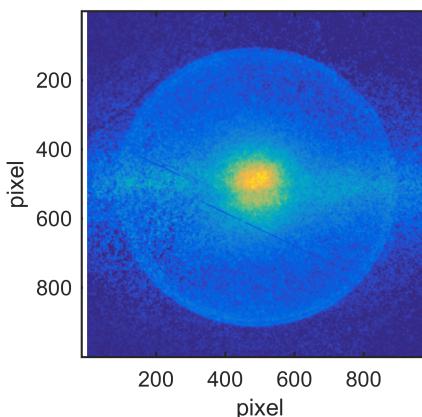
Nominal resolution:  $E / \Delta E = 10^2$

Energy range: 1 - 500eV

Delay Line Detector or Phosphor screen

Enabling TOF – Coincidence Measurements

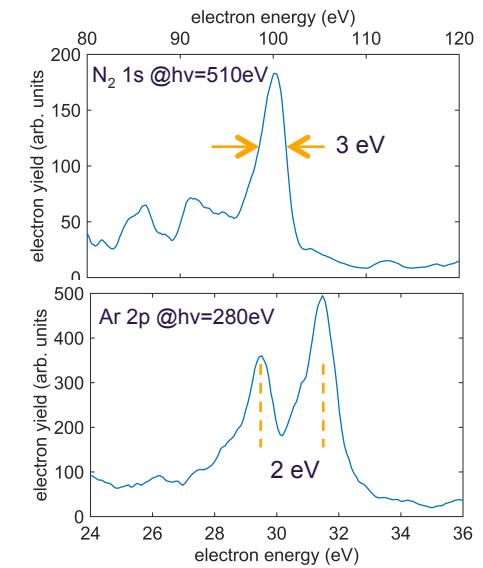
Ion TOF mode – resolution  $m / \Delta m > 100$



### Test beamtime at P04@PETRAIII

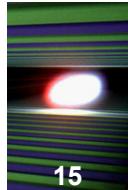
- Ar KLL Auger (~220eV) with angular resolution
- Achieved resolution (prior to any optimization)  
~ 3% over the measurement range

### Electron energy spectra after image inversion



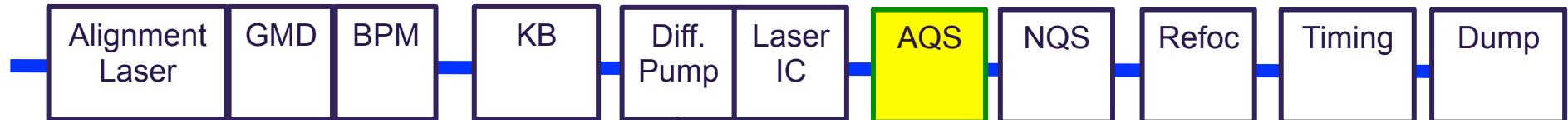


SQS Scientific Instrument

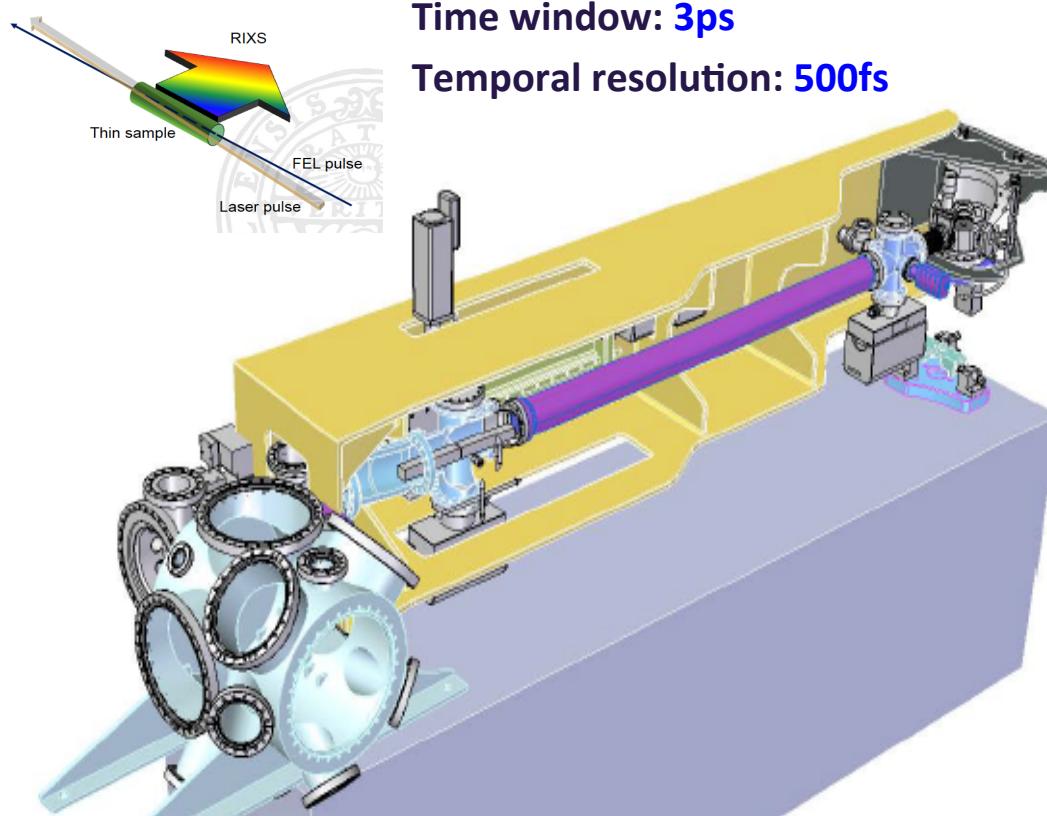


European  
**XFEL**

## XUV spectrometer @ AQS



### 1D-Imaging XUV Spectrometer



Time window: **3ps**

Temporal resolution: **500fs**

### Optimized Design

Pair of Wolter mirrors

VLS grating

Photon energy range: **250 – 1000 eV**

Spectral resolution: **10 - 50 meV**

Spatial resolutions: **20 μm**

Single pulse sensitivity

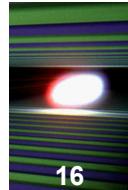
### New detector development

MCP with multi-parallel delay-line readout  
(in coll. WP-75)

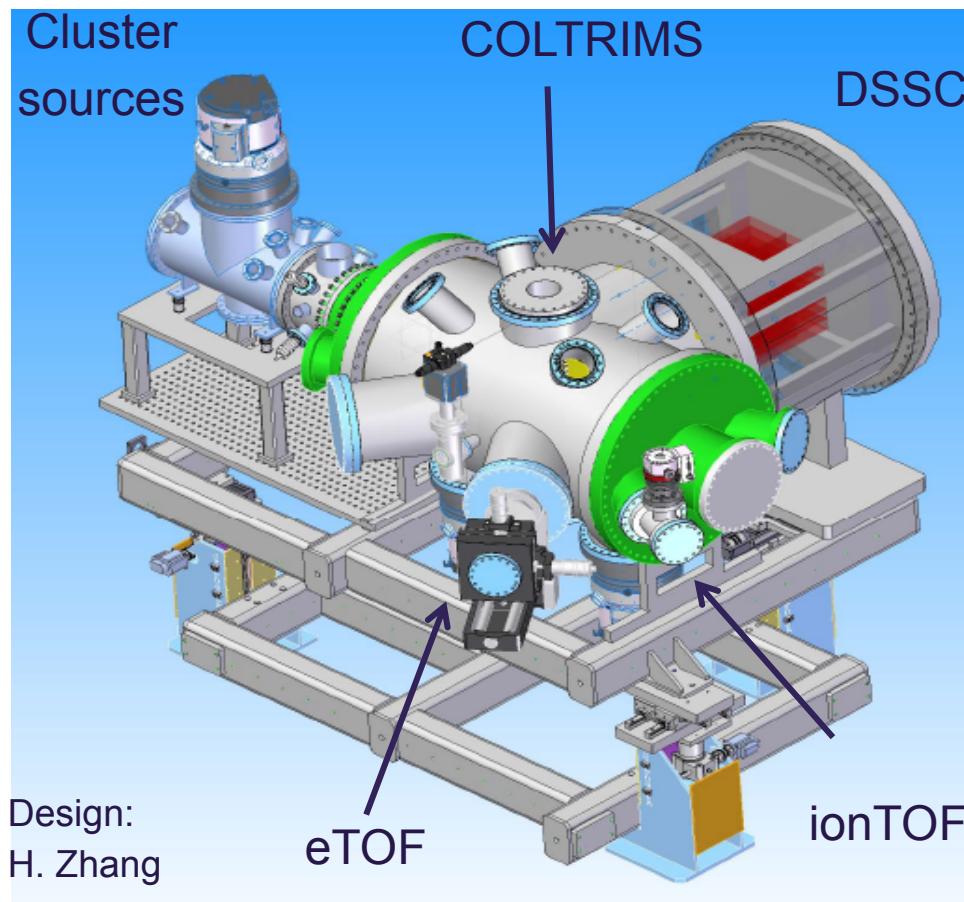
**J. Nordgren, J-E. Rubensson**  
**Uppsala University, Sweden**



SQS Scientific Instrument

European  
**XFEL**

## NQS experimental chamber



[NQS: Nano-size Quantum Systems](#)  
Cluster, Nano-particles, Bio-molecules  
Cluster source, liquid jet, aerosols

Vacuum:  $10^{-9} - 10^{-10}$  mbar

Focus:  $\leq 1 \mu\text{m} \rightarrow 50 \mu\text{m}$

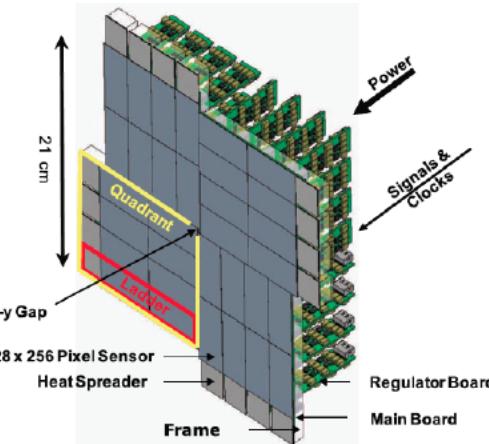
Spectrometer	Acceptance	Resolution
2D detector DSSC	variable	$< 5 \text{ nm}$
COLTRIMS	$4\pi$	$E/\Delta E = 10^2$
Electron TOF	$< 5\% \text{ of } 4\pi$	$E/\Delta E > 10^3$
Ion TOF	$4\pi$	$E/\Delta E > 10^2$

## Detectors and Sample delivery @ NQS



**DSSC (1 M Pixel Detector Module)  
DEPFET Sensor with Signal Compression  
(DSSC Consortium, WP-75)**

Porro et al.  
NIMA624,  
509 (2010)



- Energy range: 0.5 – 6 (25) keV
- Dynamic range  
    > 6000 photons/pixel/pulse @ 1 keV
- Single photon sensitivity
- Number of storage cells: 576

### Sample delivery systems

#### ■ COMO

State-, size-, and isomer-selected samples  
of polar molecules and clusters  
CFEL Hamburg, J. Küpper et al.

#### ■ Pulsed Microplasma Cluster Source

U Milano, P. Piseri et al

#### ■ Pulsed Cluster and Nano-particle Source

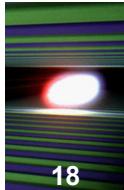
U Berlin, T. Möller/D. Rupp & U Rostock, T. Fennel

#### ■ Mass-selected Cluster Source

U Rostock, K.-H. Meiwes-Broer et al.

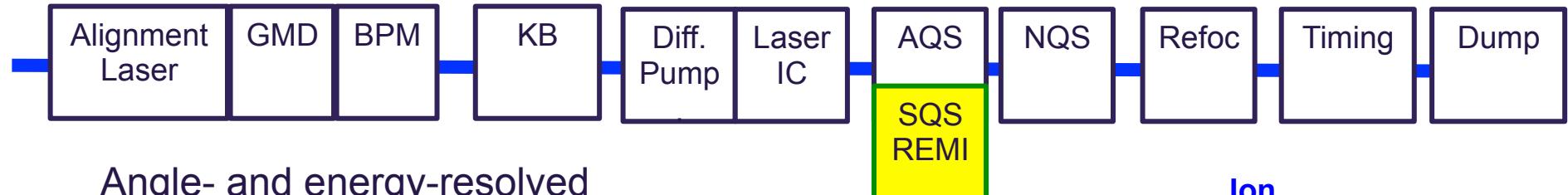


SQS Scientific Instrument

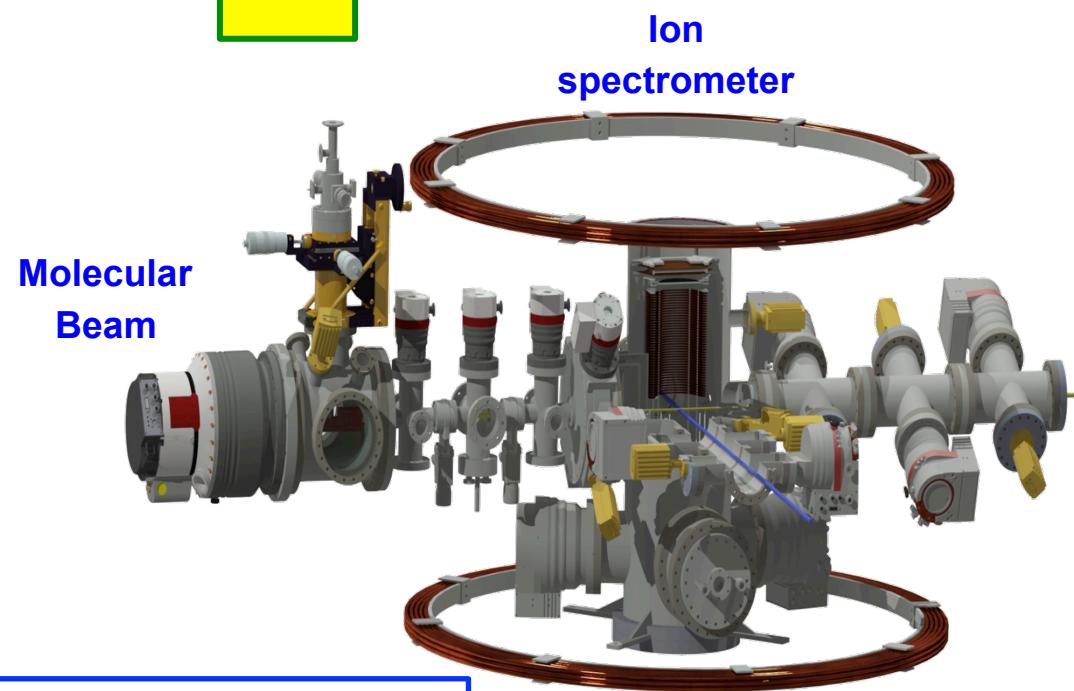
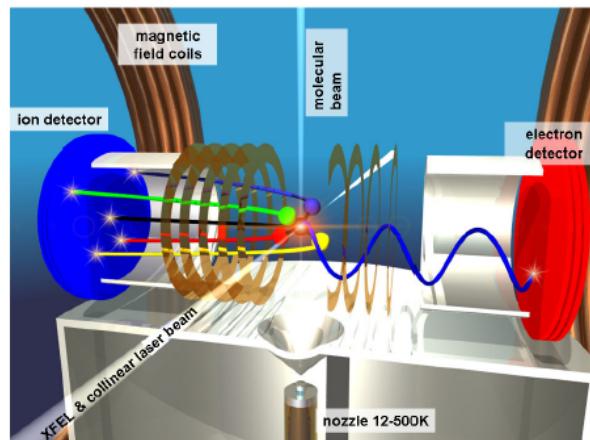


European  
**XFEL**

## Reaction Microscope(REMI) @ SQS



Angle- and energy-resolved  
**electron** and **ion** spectra  
in **coincidence**

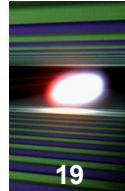


### User Collaboration:

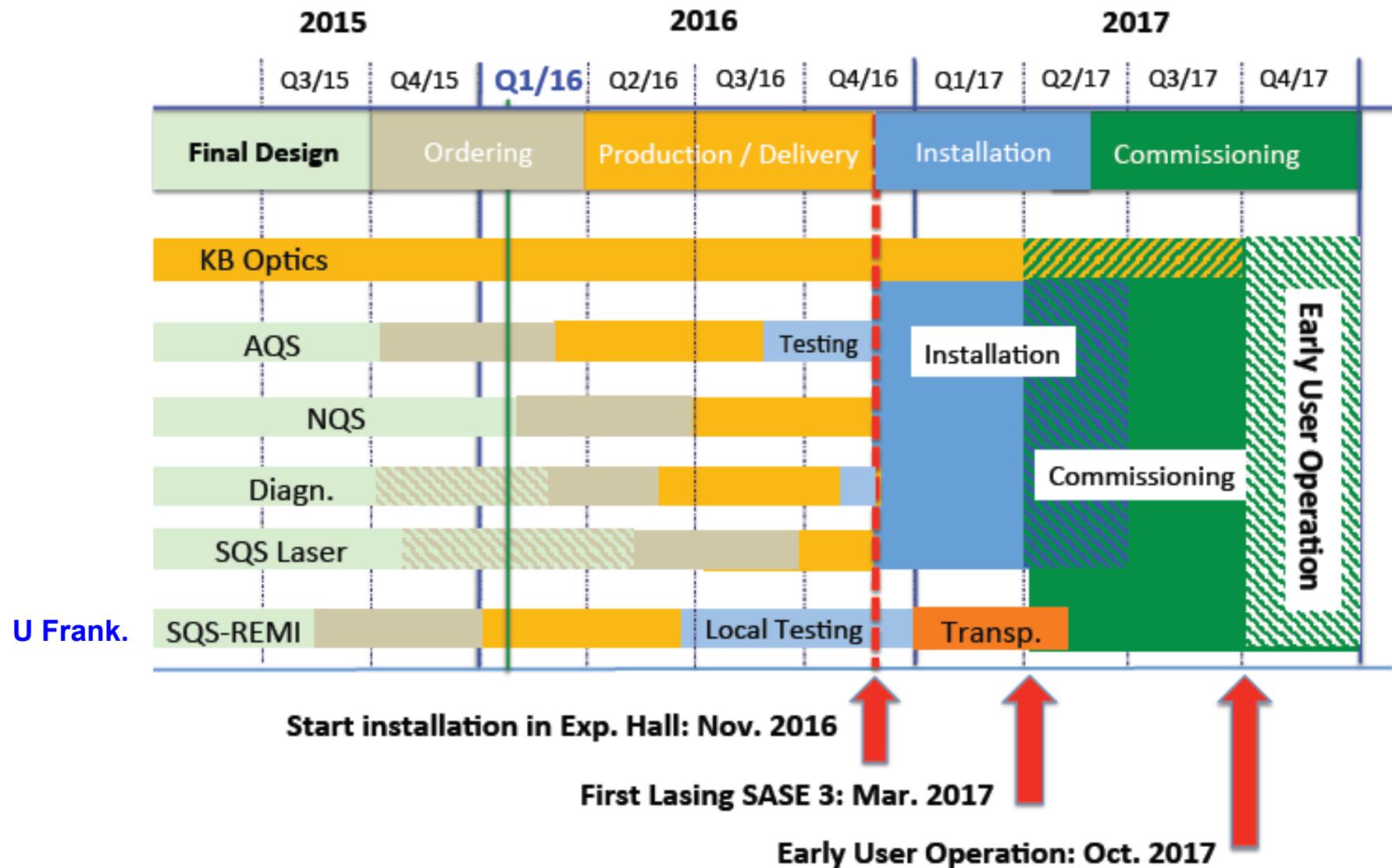
R. Dörner, R. Moshammer, et al.

U. Frankfurt, MPI Heidelberg

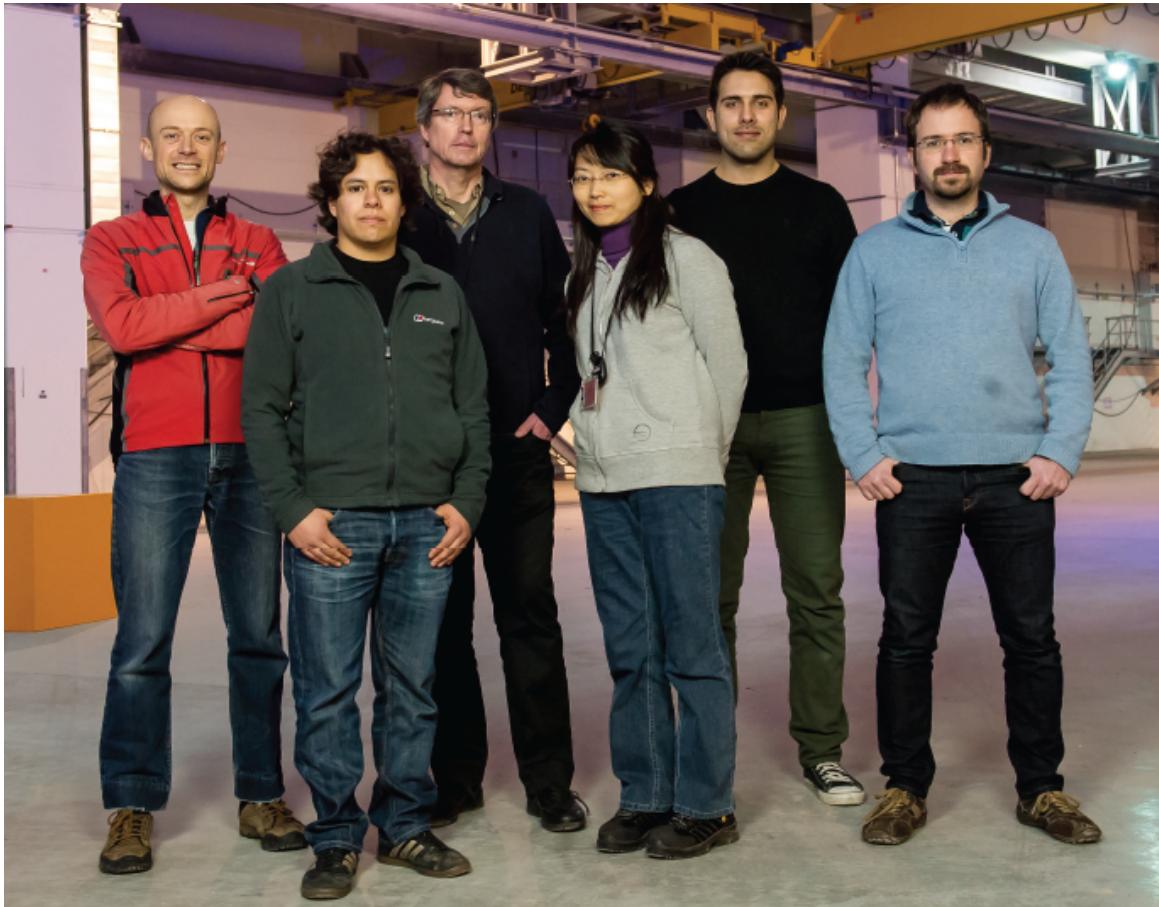
Targets: Molecular beam  
**Vacuum:  $< 10^{-11}$  mbar**  
Focus: 1  $\mu\text{m}$



## Schedule for SQS Scientific Instrument



## Acknowledgement SQS – team



**A. de Fanis      M. Meyer      J. Rafipoor**

A. Achner

H. Zhang

T. Mazza



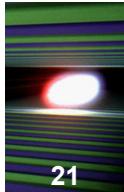
**T. Baumann**



**Y. Ovcharenko**



**I. Shevchuk**



# European XFEL

