“Small Quantum Systems”
Scientific Instrument

WP-85

A. De Fanis, T. Mazza, H. Zhang, M. Meyer

European XFEL GmbH

TDR_2012: http://www.xfel.eu/documents/technical_documents

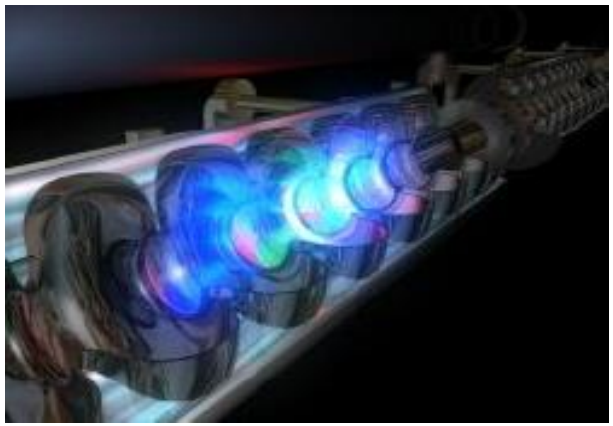
XFEL Users Meeting 2014, January 29th, 2014

SQS Scientific Instrument

“Investigation of atoms, ions, molecules and clusters in intense fields and non-linear phenomena”

SASE 3: 250 – 3000 eV

European XFEL



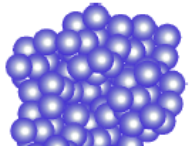
N x hν

2 - 100fs

“Small Quantum Systems”

Atoms

Molecules



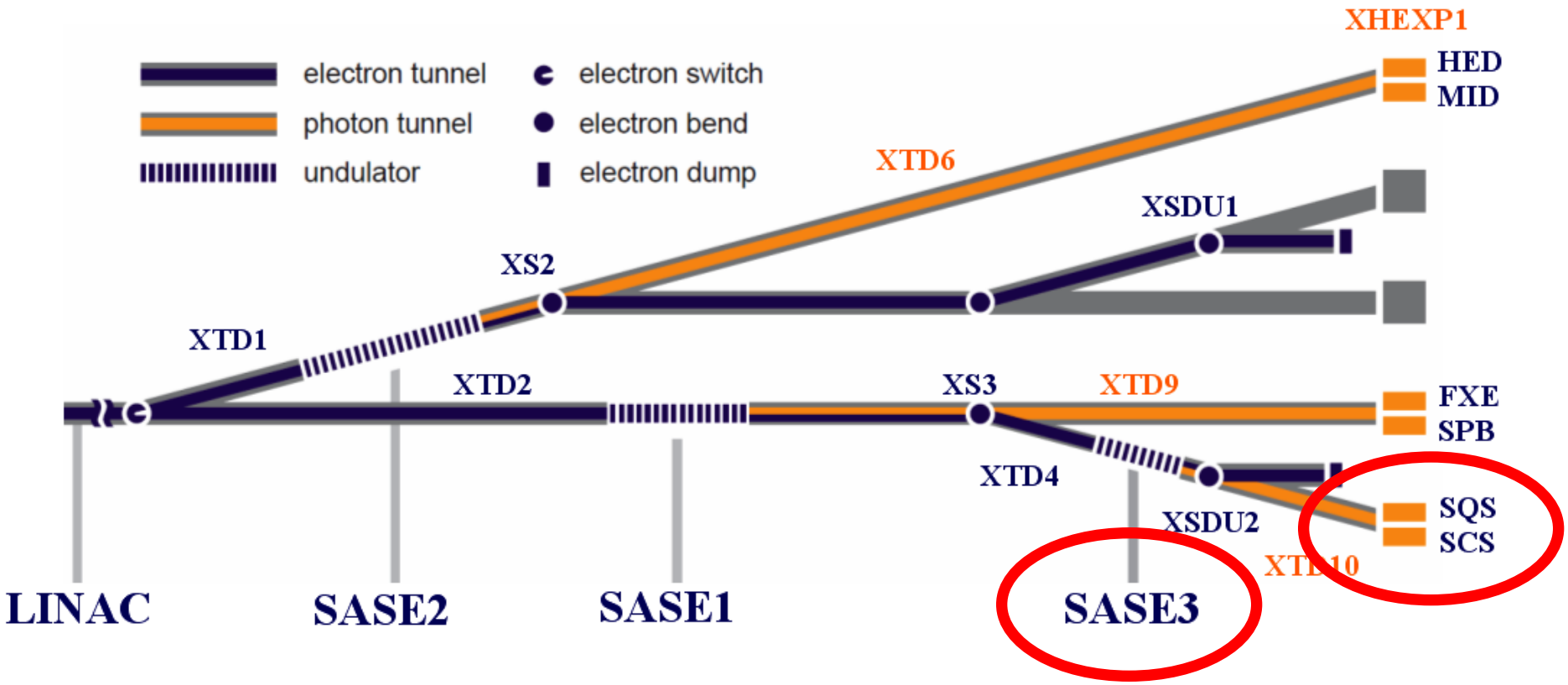
Clusters

Multi-photon processes, Ultra-fast dynamics, Extremely dilute targets

Multiple-Coincidences (e^-, ion, γ) , Pump-Probe, Coherent Diffraction Imaging

Photon beam transport systems

European XFEL



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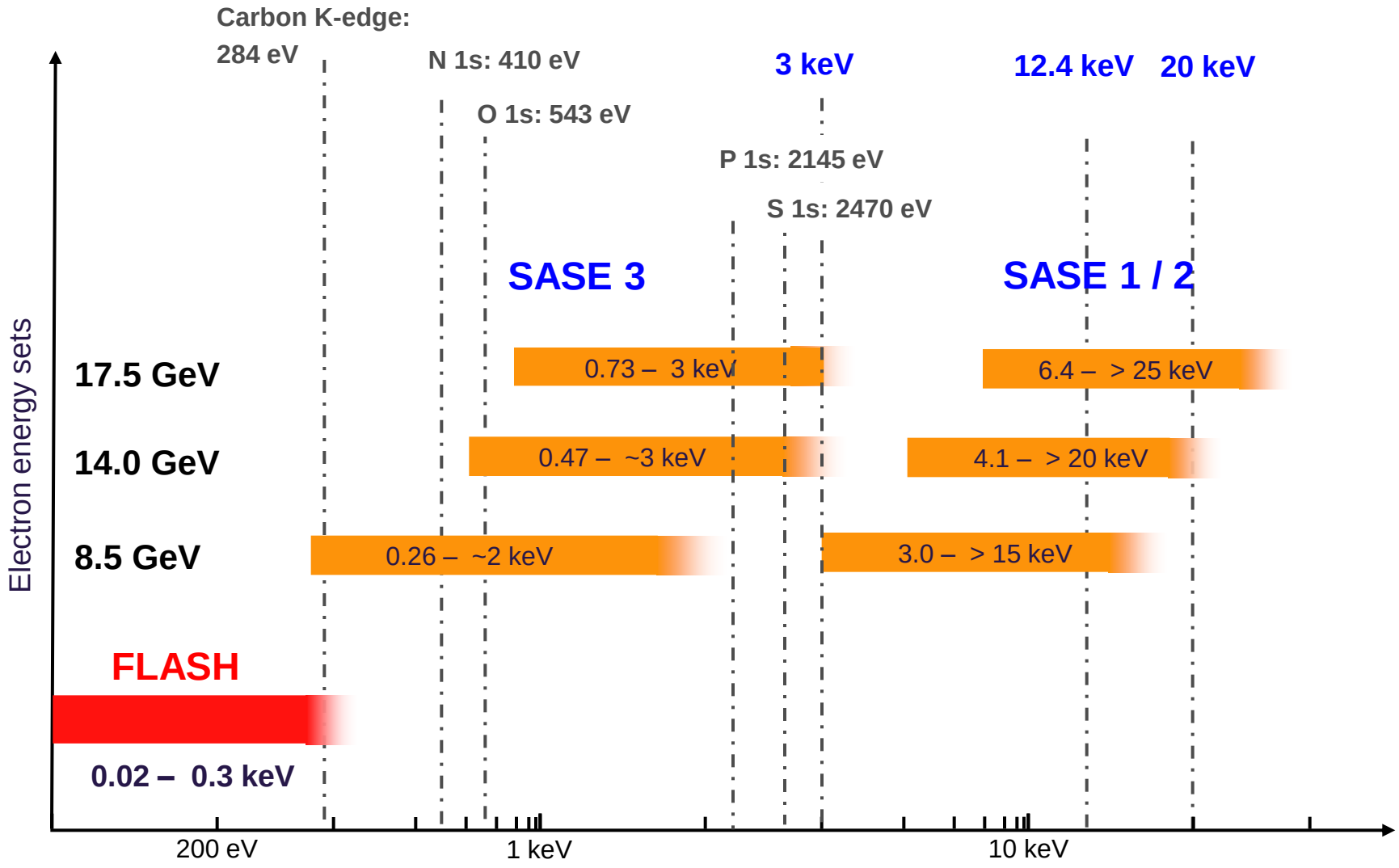
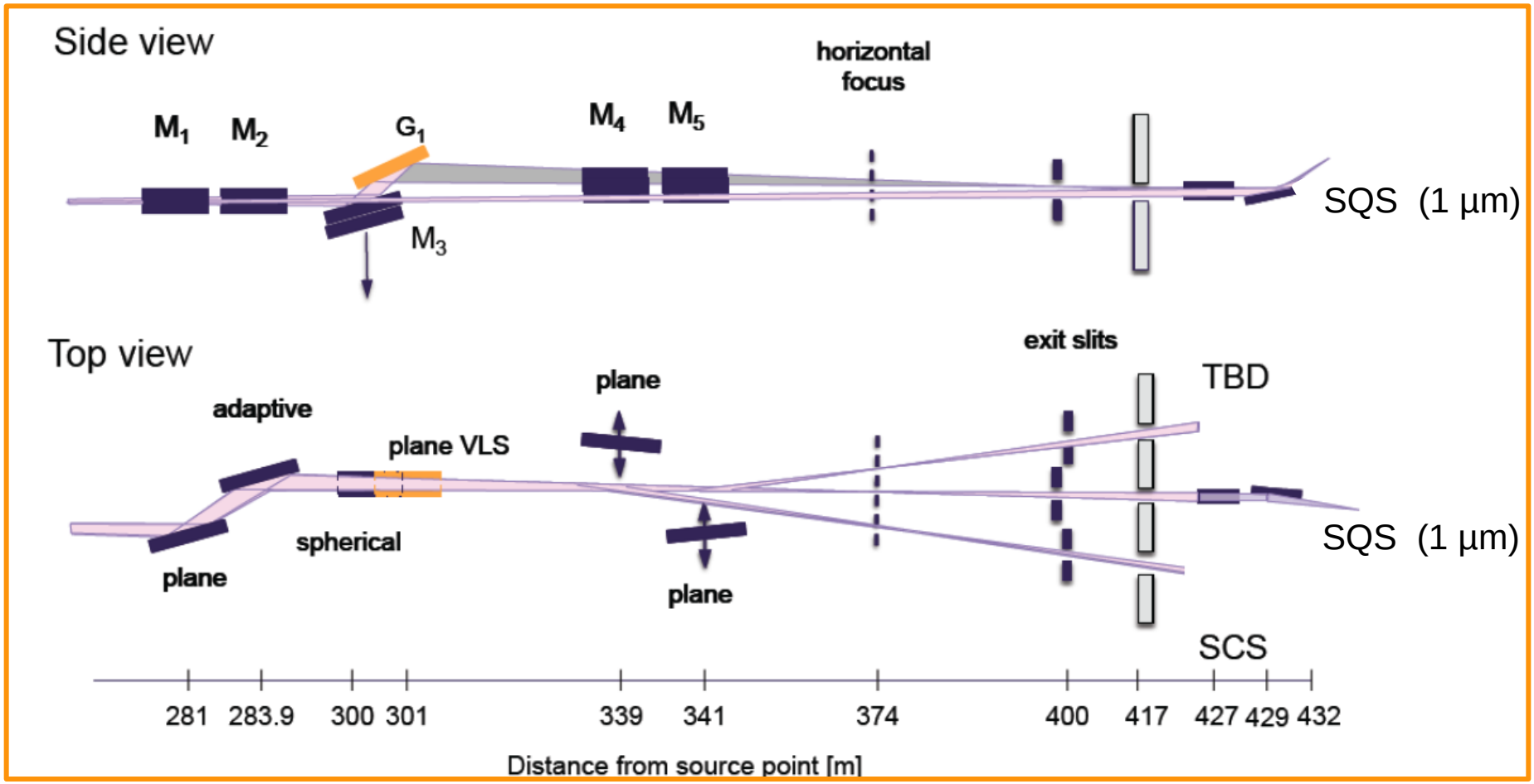
Photon energy ranges



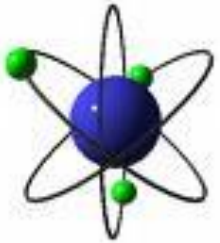
Photon beam transport systems

- direct beam → **Small Quantum System (SQS)**
- monochromatized → Spectroscopy @ Coherent Scattering **(SCS)**

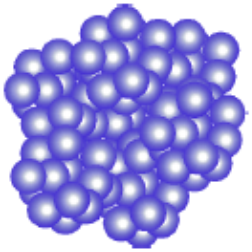


SASE3 & SQS Performances

SASE3	$h\nu$ = 260 – 3000 eV	P = 0.2 – 11.0 mJ	Lin./Circ. Pol.
	ΔT = 2 – 100 fs	Coherence: 0.96	Split & Delay

Atoms 

Molecules 

Clusters 

Non-linear phenomena
10^{17} – 10^{18} W / cm^2

Time-resolved studies
low jitter (<10 fs)

Imaging experiments
Spatial coherence

Chemical sensitivity C (1s), N (1s), O (1s), Rare Earths (3d)

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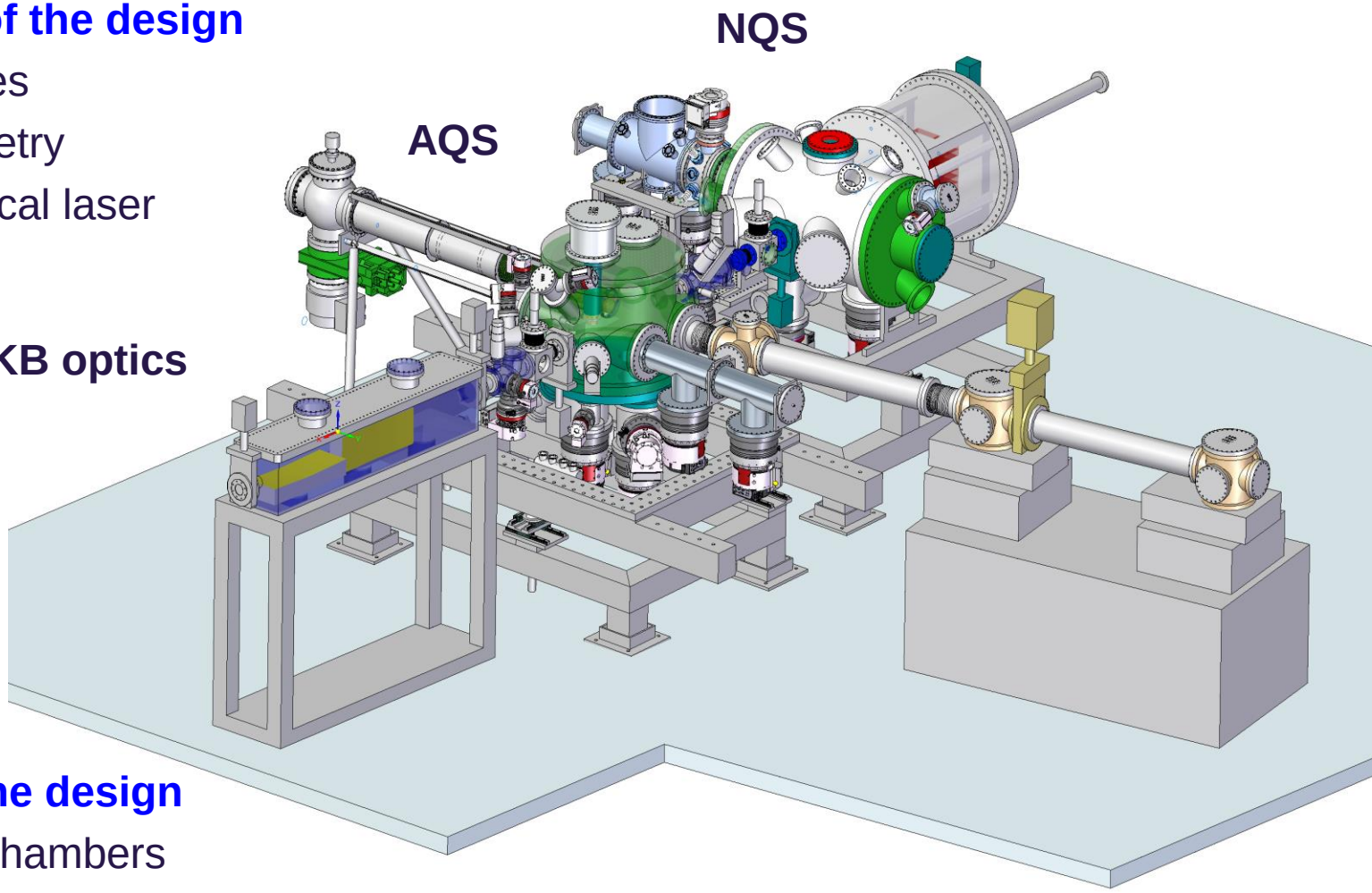
High repetition rate:
< 27000 pulses/ sec

➡ **High data collection rate**
Multi-particle coincidences

General Layout of SQS

Optimization of the design

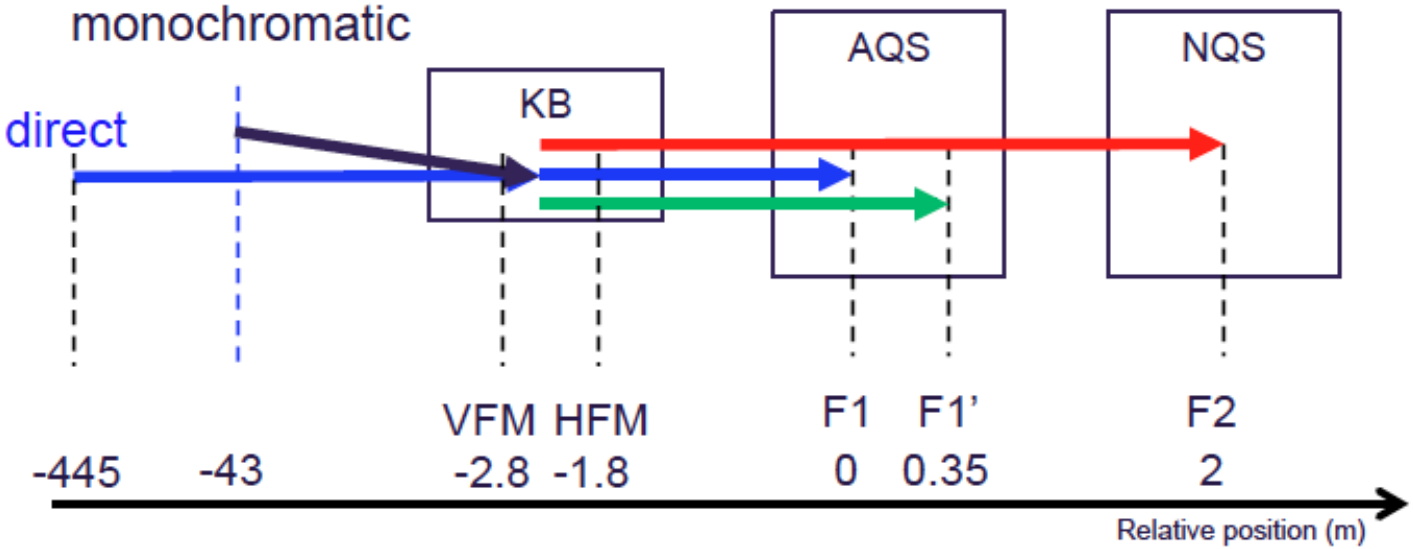
- Focal distances
- Internal geometry
- Access of optical laser



Versatility of the design

- Exchange of chambers
- Exchange of standard components

KB focusing optics (in coll. with WP-73)

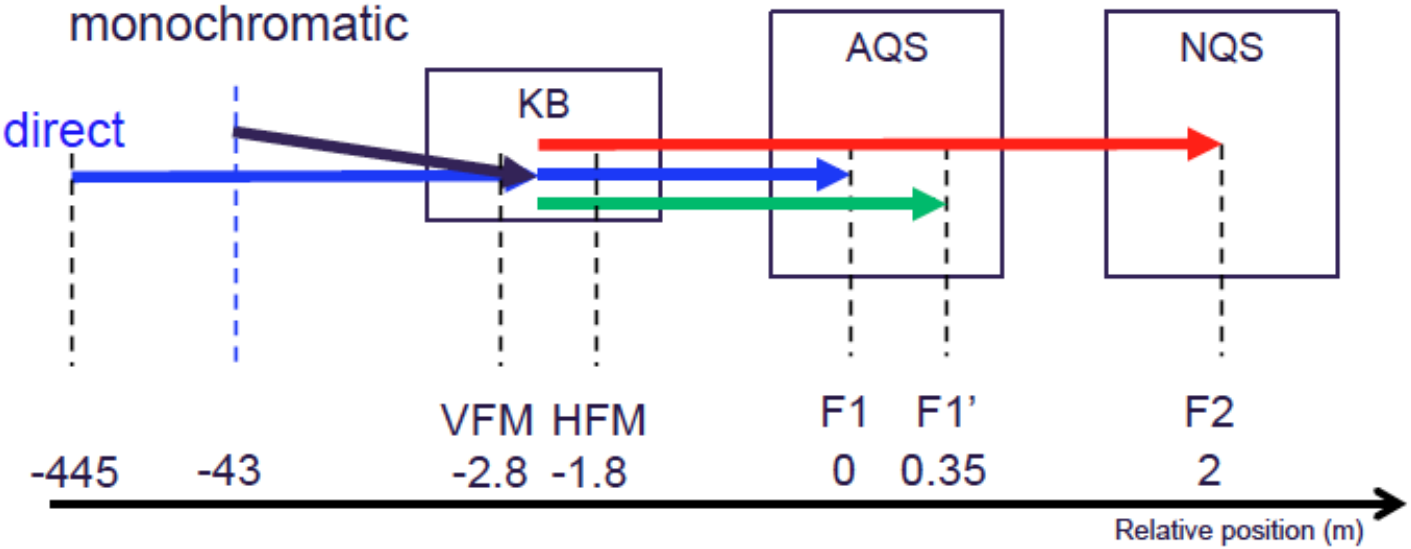


T. Mazza
WP85

KB mirrors

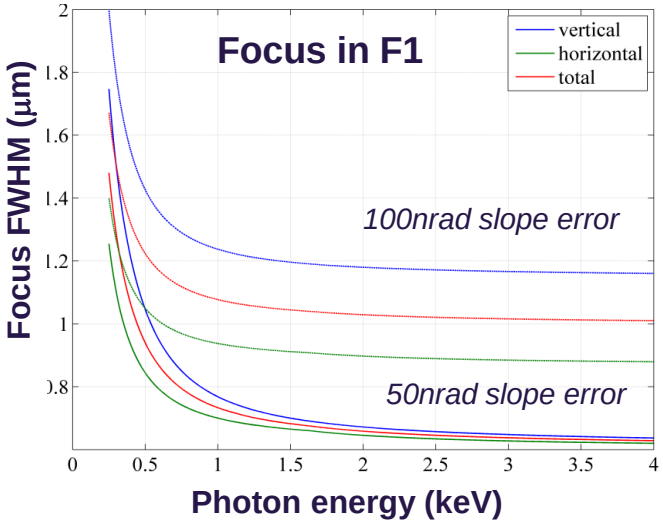
- Piezo-benders
- Length: 850 mm
- B4C coated
- 9 mrad incidence
- Slope error 50 nrad
- Water cooled

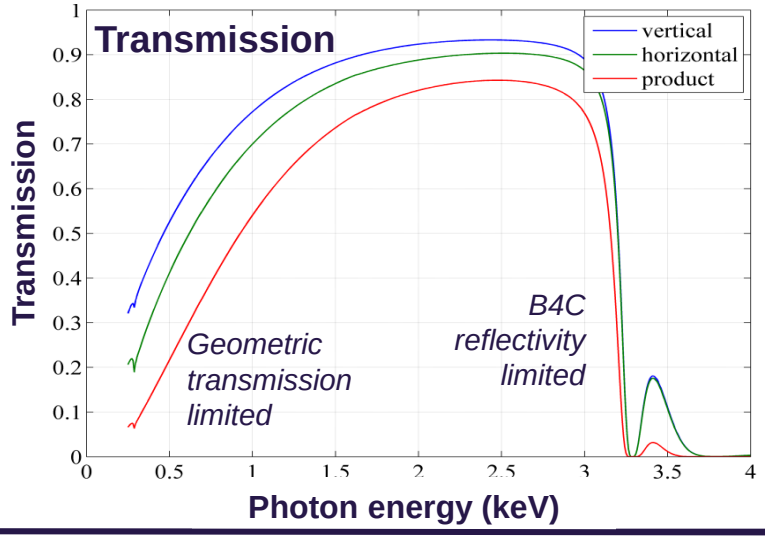
KB focusing optics (in coll. with WP-73)



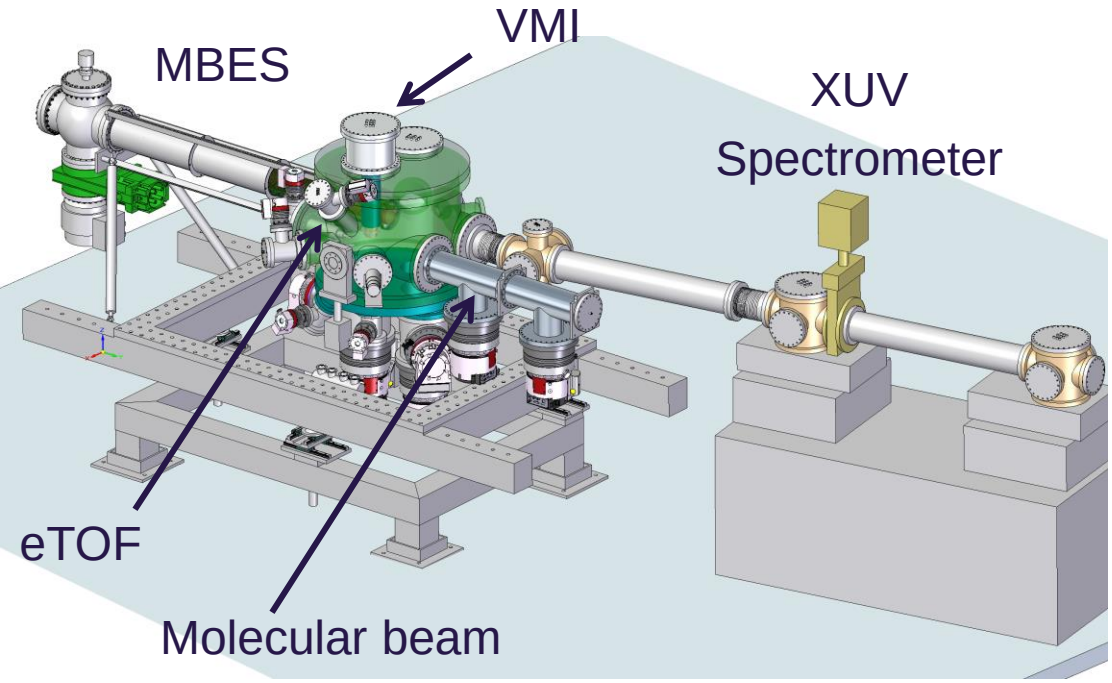
T. Mazza

WP85





AQS experimental chamber



Analyser	Focus	Acceptance	Resolution
HReTOF	F1	< 0.5% of 4π	$E / \Delta E > 10^4$
MBES	F1'	> 50% of 4π	$E / \Delta E \approx 10^2$
VMI	F1	4π	$E / \Delta E \approx 10^2$
XUV spectrometer	F1'	< 1% of 4π	$E / \Delta E > 10^4$

AQS

Atomic-like Quantum Systems

Targets: atoms & small molecules

Molecular beam

Vacuum: 10^{-11} mbar

Focus: ≤ 1 mu → 50 mu

electrons, ions, photons

- HR electron spectroscopy

- Angle-resolved spectroscopy

- Non-dipole studies

- HR fluorescence spectroscopy

- e / e – coincidences

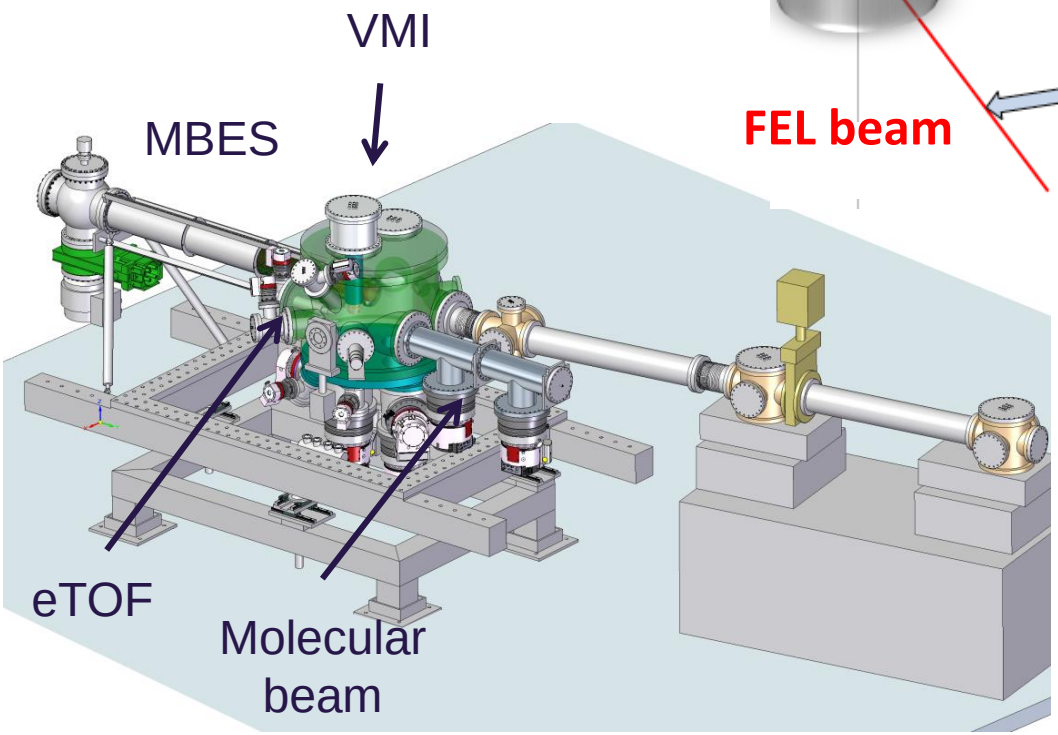
- e / ion - coincidences

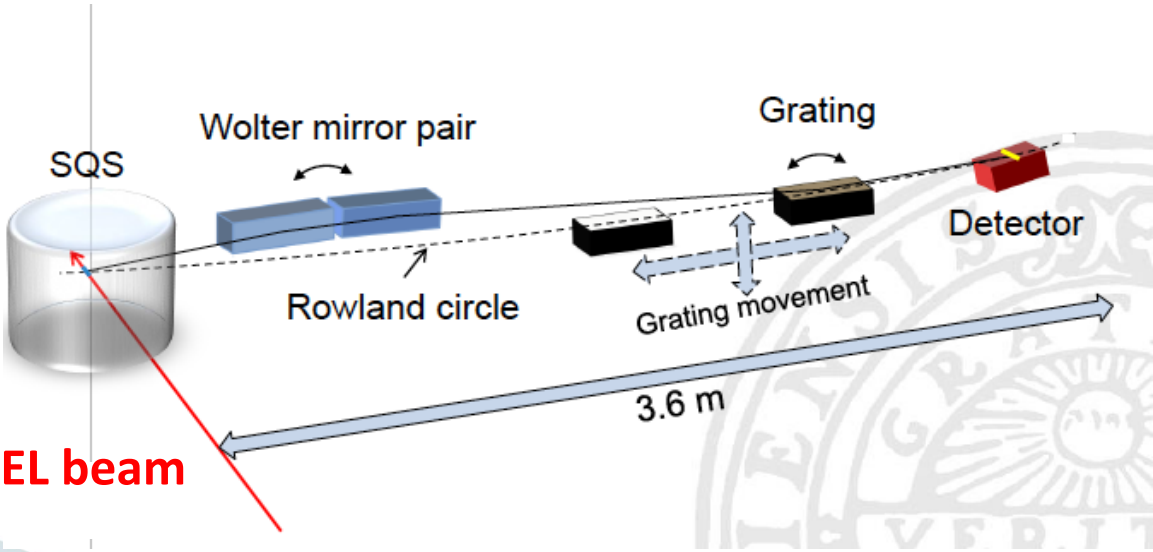
AQS: XUV 1D Imaging spectrometer

In-Kind Contribution:

J. Nordgren, J-E. Rubensson,

Uppsala University, Sweden





Optimized Design

Spectral resolution: 10 - 50 meV

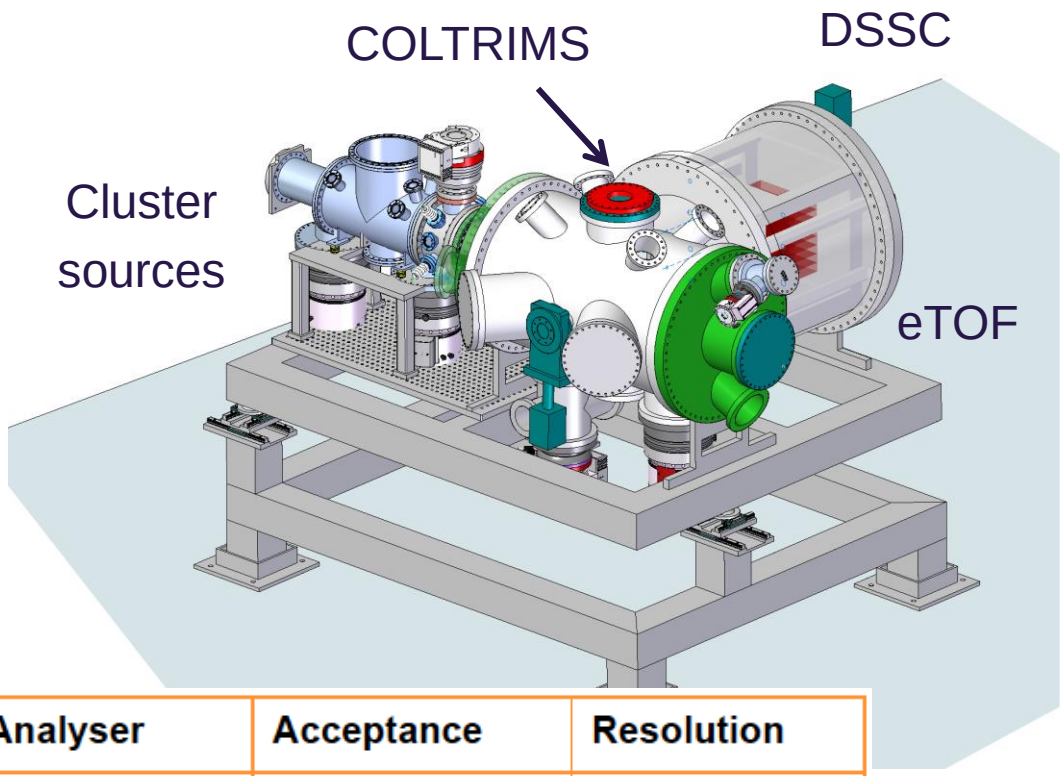
Spatial resolutions: 2 μm

Single pulse sensitivity

New detector development

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

NQS Experimental Chamber



Analyser	Acceptance	Resolution
COLTRIMS	4π	$E/\Delta E \approx 10^2$
2D pixel detector	variable	< 5 nm
Ion TOF	4π	$E/\Delta E > 10^3$
eTOF	5 % of 4π	$E/\Delta E > 10^3$

NQS
Nano-size Quantum Systems

Targets:
cluster, nano-particles, bio-molecules
Cluster source, liquid jet, aerosols
Vacuum: 10^{-9} - 10^{-10} mbar
Focus: ≤ 1 mu → 50 mu

electrons, ions, photons

- Diffraction Imaging
- Ion/electron spectroscopy
- hν / ion – coincidences
- e / ion – coincidences
- hν / e / ion – coincidences

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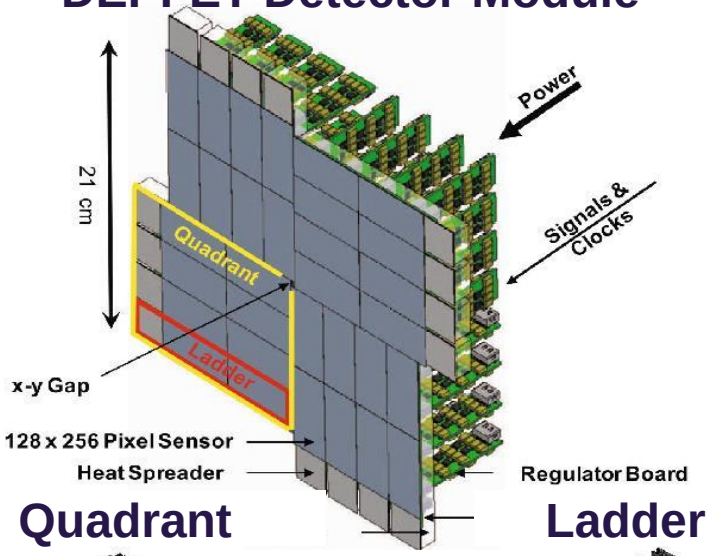
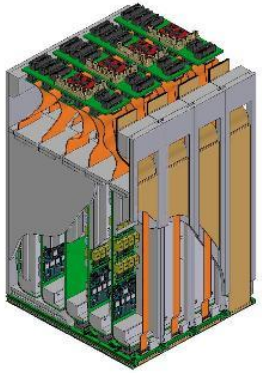
DSSC 1 M Pixel Detector Module (M. Kuster)

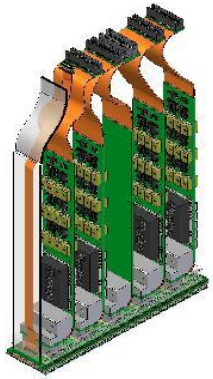
DEPFET Detector Module



Quadrant



Ladder



Key Detector Parameters

- Goal: Single photon sensitivity
  5 σ @1 keV and 4.5 MHz
- Energy range
  0.5 – 6 (25) keV
- Dynamic range
  > 6000 photons/pixel/pulse @1 keV
- Single photon sensitivity
  5 σ @ 1 keV (5 MHz)
  5 σ @ 0.5 keV (≤ 2.5 MHz)
- Number of storage cells 576
- Smallest detector unit “ladder
  128 x 512 pixels
- 4 ladders built on quadrant
- 4 quadrants = 1k x 1k detector

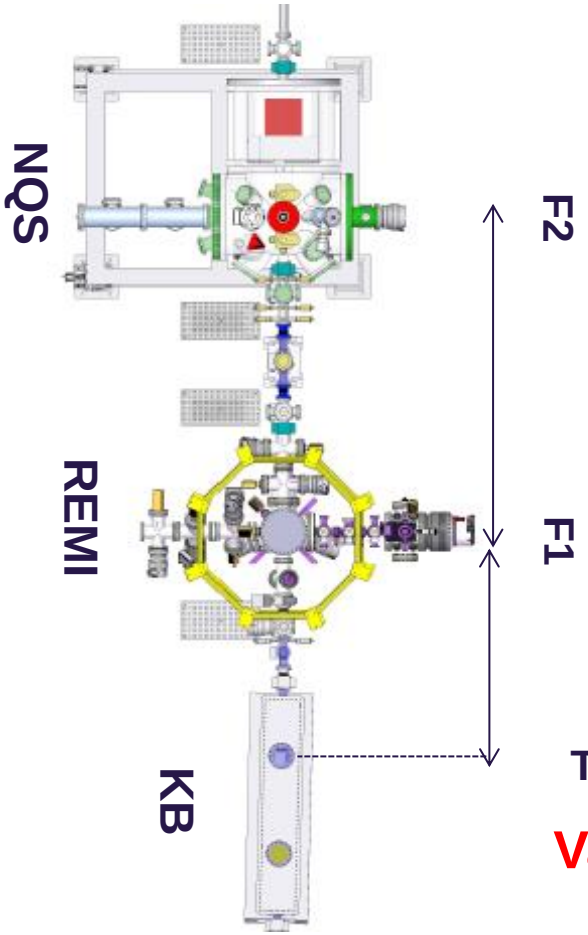
Porro et al. NIM A (2010) vol. 624 pp. 509

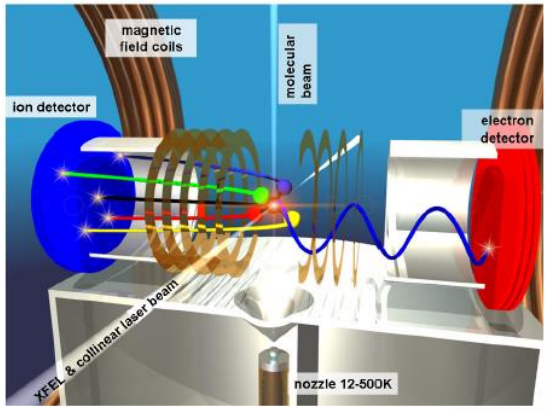
Data transfer rate: 1 GB / train (10 GB / s)

3rd chamber: Reaction Microscope

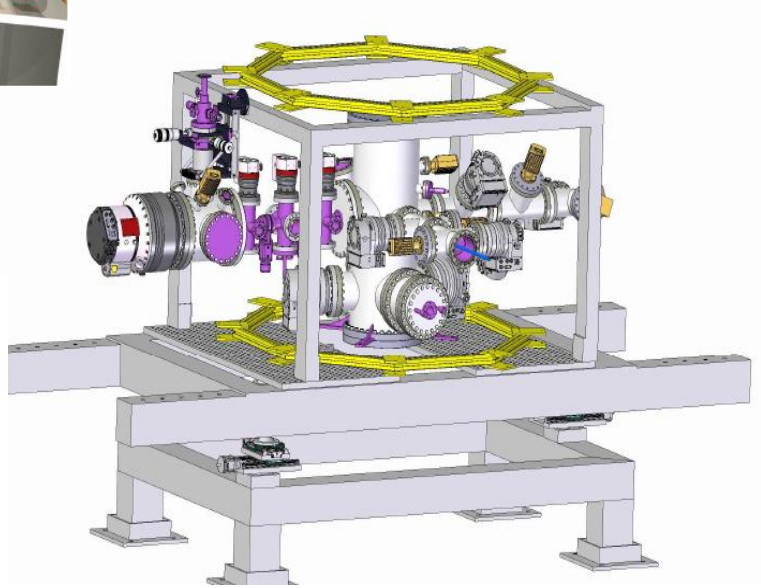
User Consortium (BMBF financed): **R. Dörner, R. Moshammer, et al.**

U. Frankfurt, MPI Heidelberg





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



SQS REMI

Targets: Molecular beam

Vacuum: < 10^{-10} mbar

Focus: 1 μm

In-kind contribution and Add-on equipment

In-Kind Contributions

- **1D Imaging XUV spectrometer**
  University of Uppsala
  J-E. Rubensson, J. Nordgren

- **Magnetic Bottle Electron Spectrometer**
  University of Uppsala
  R. Feifel

User Consortia / Add-on

- **SQS-REMI: Reaction Microscope**
  U. Frankfurt, MPI Heidelberg
  R. Dörner, R. Moshammer

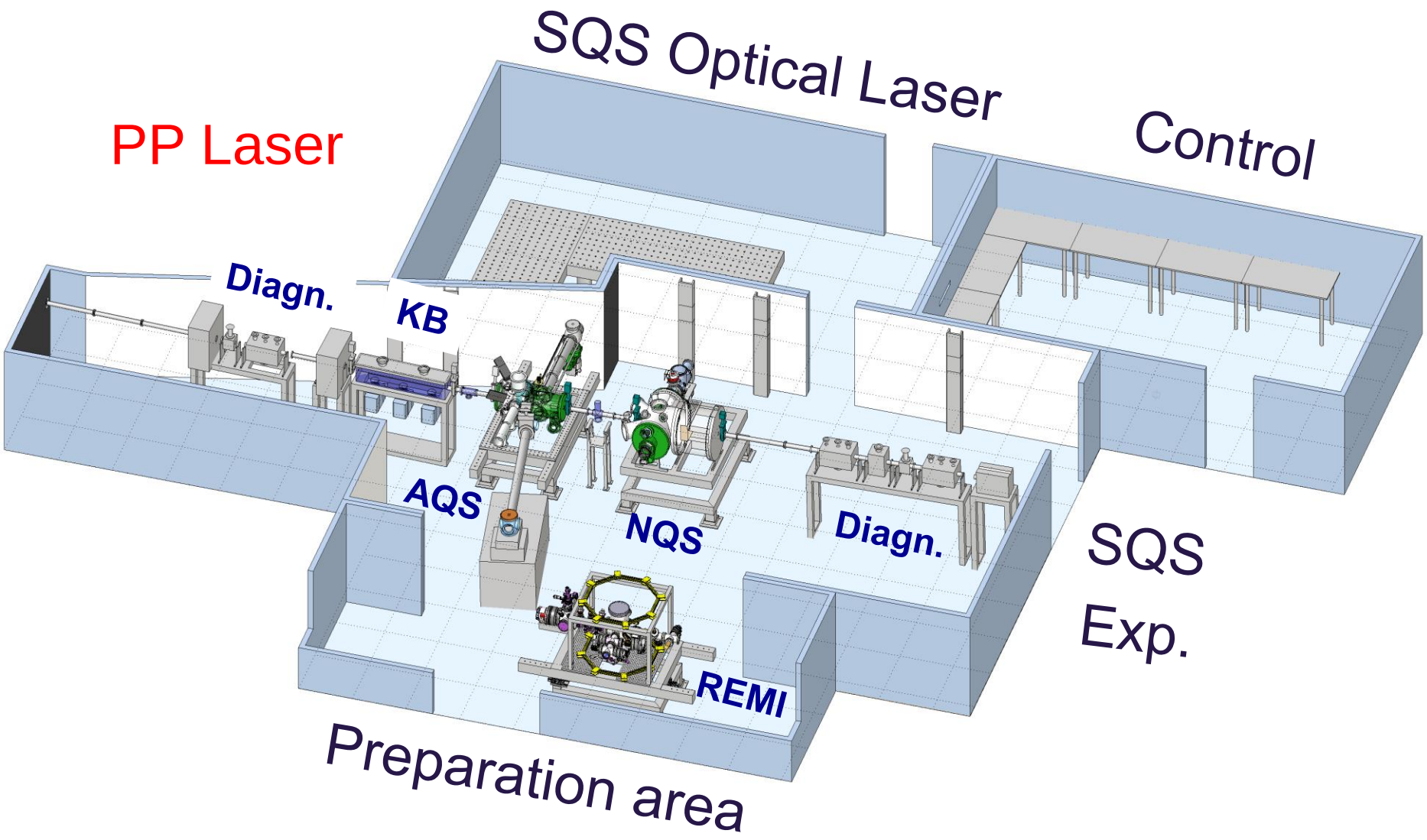
- **COMO**
  State-, size-, and isomer-selected samples of polar molecules and clusters
  CFEL Hamburg, J. Küpper

- **HR-VUV spectrometer**
  U Kassel, A. Ehresmann

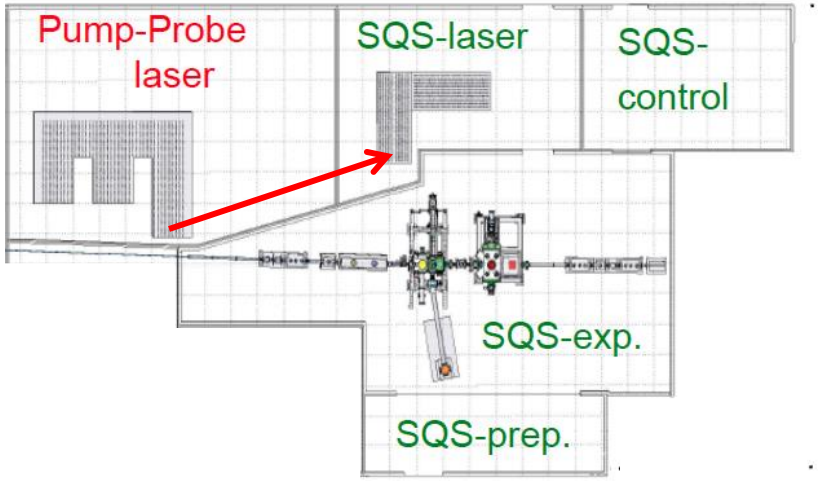
- **Pulsed Microplasma Cluster Sourc**
  U Milano, P. Piseri

- **Cristal Spectrometer**
  FU Berlin, E. Rühl

General Layout of SQS Scientific Instrument



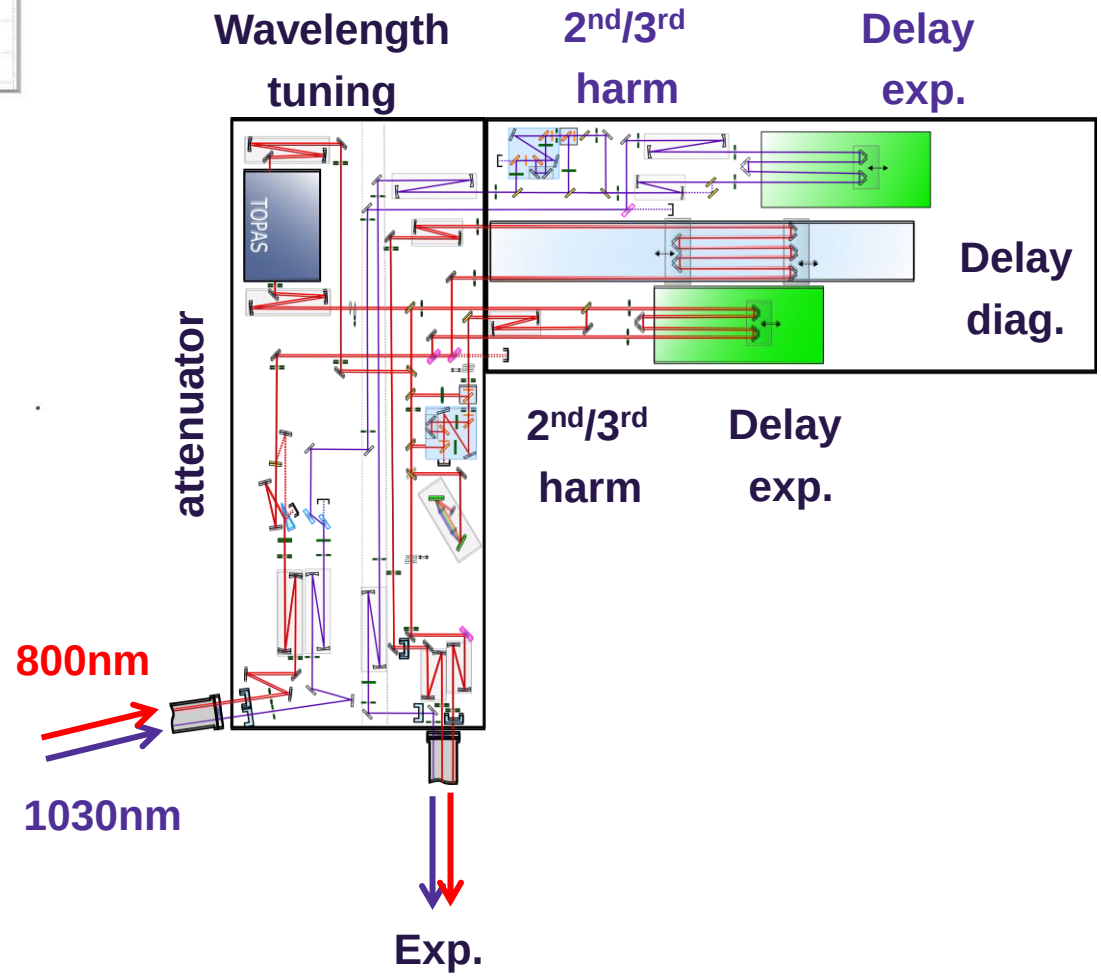
Layout of SQS Optical Laser (in coll. with WP-78)



Pump-Probe Laser

	Pump-Probe	Alignment
rep.rate	1 - 4.5 MHz	100 kHz
energy	0.2 – 1 mJ	1 – 250 mJ
duration	10 - 100 fs	30 fs / 1 ns
synchro.	< 10 fs	< 10 fs

SQS Laser



Time line

	2014				2015				2016				2017	
	1.	2.	3.	4.	1.	2.	3.	4.	1.	2.	3.	4.	1.	2.
KB mirrors	Final design Call for tender		Delivery								Installation		Commissioning	
AQS chamber	Optimization, User feedback		Final design		Purchase and reception		Assembly and test HERA South lab.				Installation		Commissioning	
NQS chamber	Optimization, User feedback			Final design		Purchase and reception		Assembly and test HERA South			Installation		Comm.	
SQS REMI	Final design, assembly and test at the University of Frankfurt								Shipping to Hamburg		Installation		Comm.	
Diagnostics	Optimization, final design						Purchase, assembly, test				Installation		Commissioning	
SQS Optical Laser	Optimization, final design				Purchase			Assembly and test, PETRA III Laser lab					Installation	

Start installation: early/mid 2016

First FEL beam: Feb 2017

PP laser available: > mid 2017

SQS @SASE3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Thank you for your attention!

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Experimental area