Atomic-like Quantum System End-Station

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Scientific Instrument SQS
Instrument Scientist

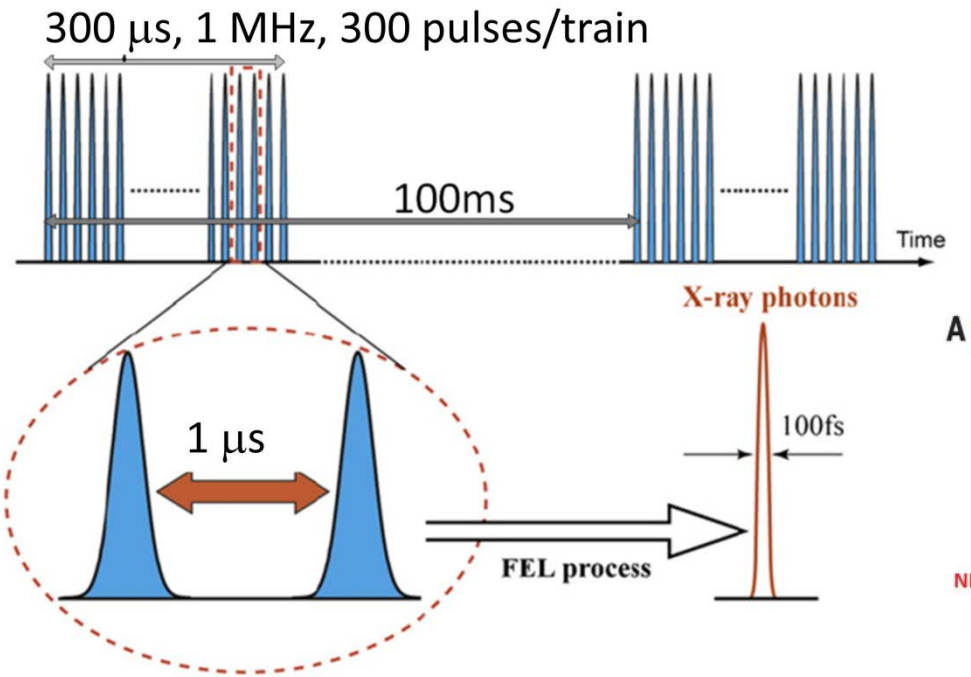
SQS Early User Workshop
Schenefeld, 12th February 2018

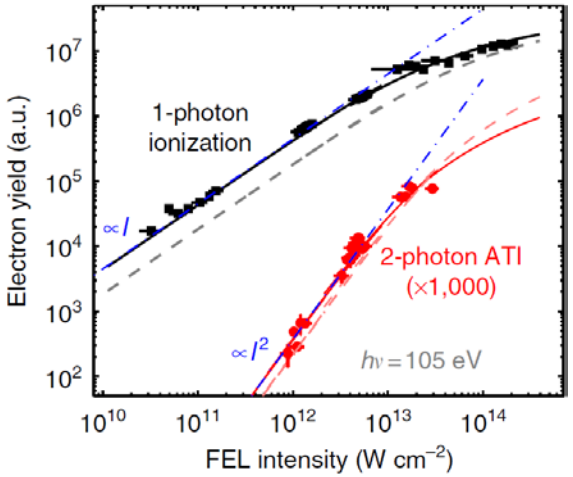
SQS: Small Quantum Systems

SASE3 – SQS beam parameters on the sample, day 1	
hν	1000 eV
Δhν	0.5% (but monochr. is also available)
Pulse duration	50 - 100 fs
Pulse energy	≤ 3 mJ
Beam size	~ 1.5 – 2.5 μm
Rep. rate	1 MHz

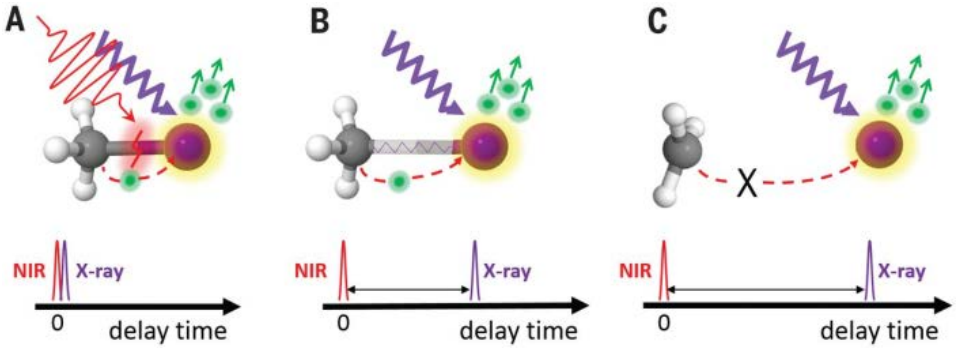
Science:

- Non-linear X-ray physics on small samples
- Time-resolved fs molecular dynamics: isomerization, fragmentation, …





Mazza *et al*. **5** 3648 Nat. Commun. (2015)



Erk *et al* **345** 288 Science (2014)

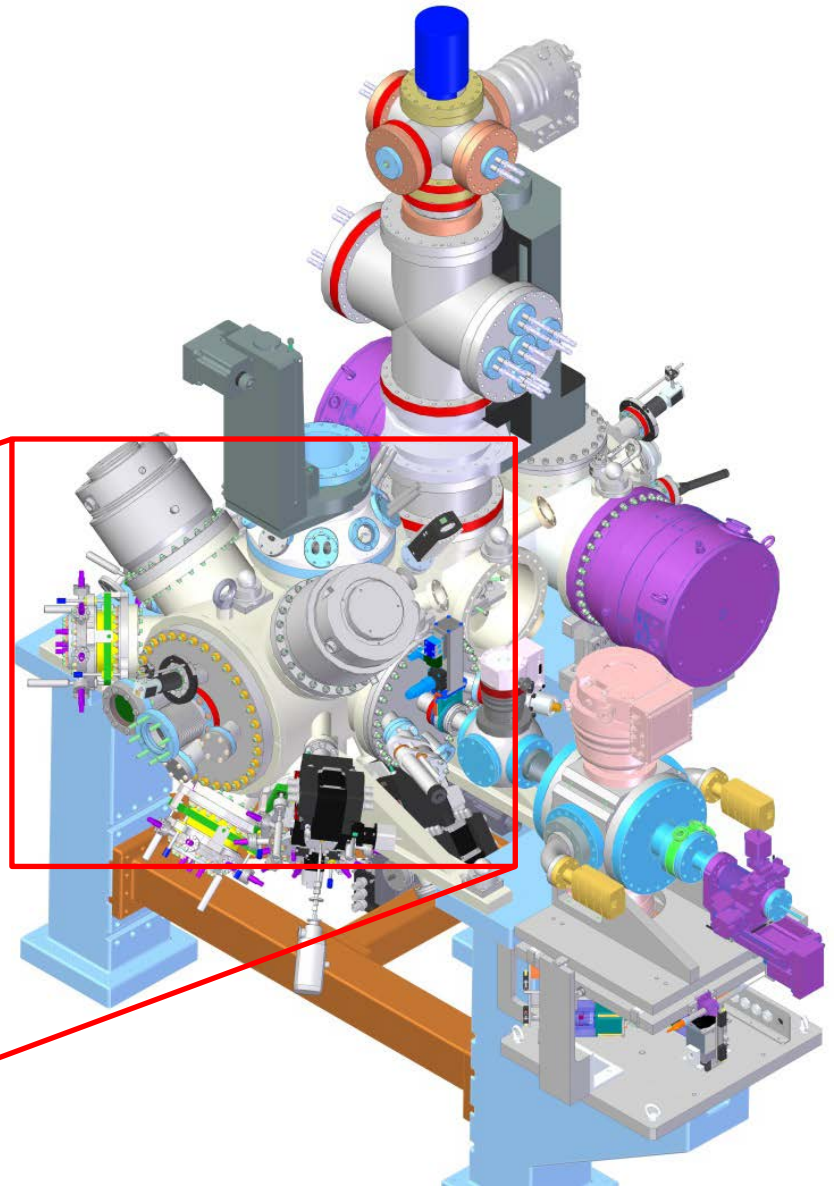
The AQS instrument

Techniques:

- Angle resolved electron spectroscopy
- Ion spectroscopy
- Multi-particle coincidence:
  - UHV, 10^{-10} mbar
- electr.-electr., ions-ions, electr.-ions
- XUV fluorescence

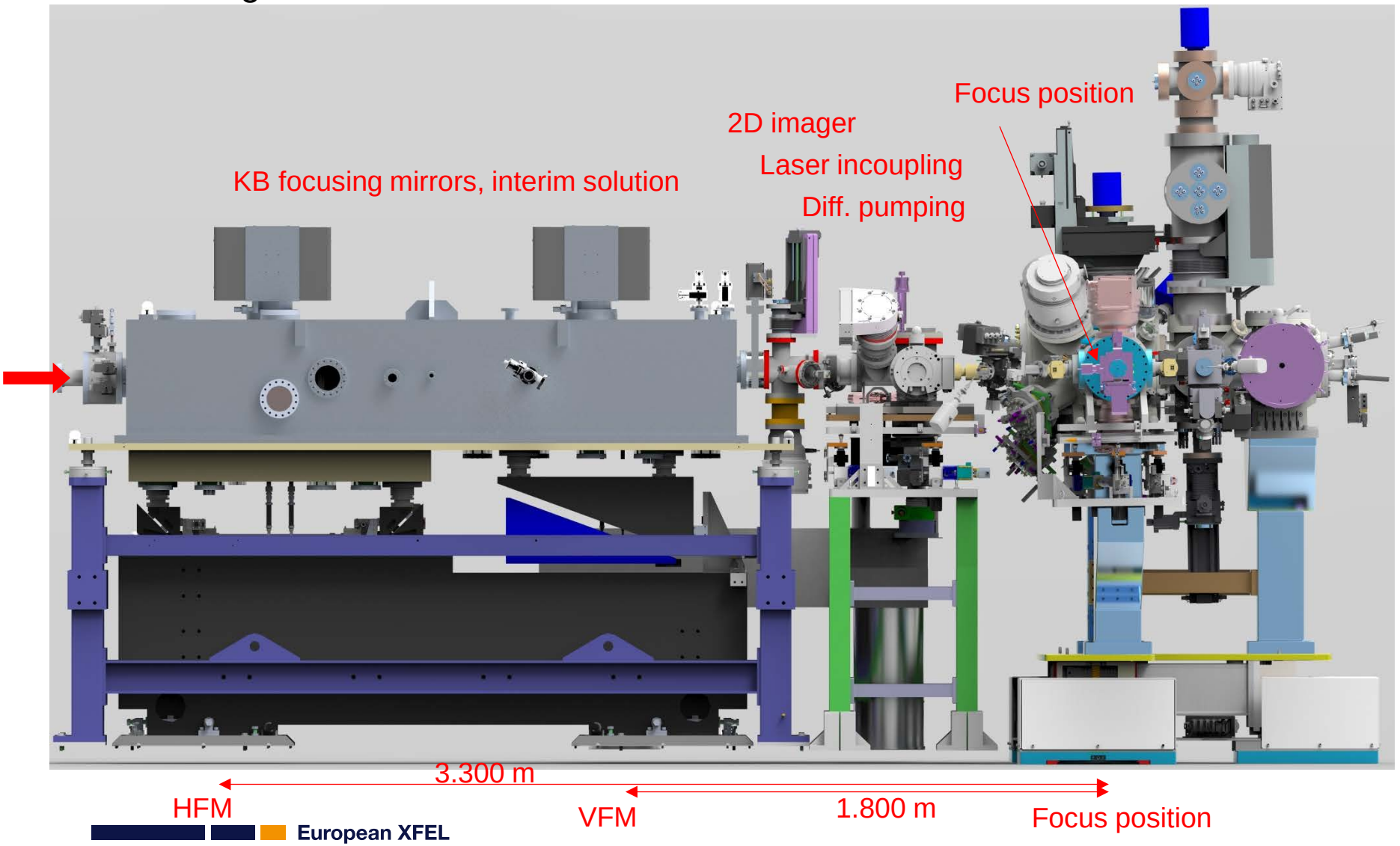
Samples:

- Gas-phase: atoms, molecules



Geometry of the SQS-AQS instrument

during 1st users beam, with interim focus solution



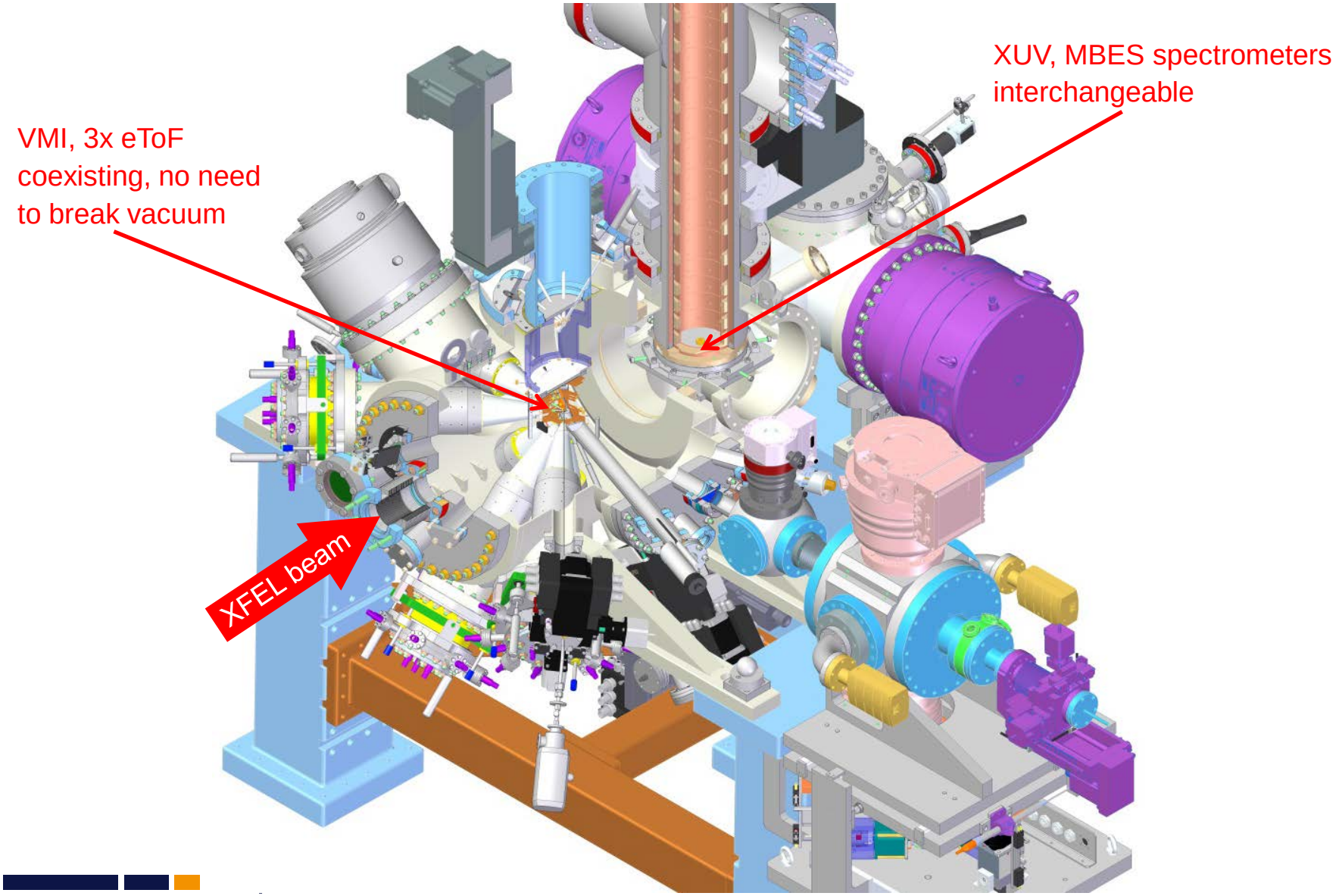
Spectrometers of the SQS-AQS instrument

	Electron Energy Resolution	Angle Acceptance % of 4π	Electrons			Detection
				Kinetic Energy	Rep. rate	
eTOF, x3	10,000	~0.14%	Yes	0-3000 eV	≤4.5 MHz	Electrons, or Ions
VMI	100	100%	Yes	0-1200 eV	MHz or ≤10 Hz	Electrons, or Ions
Magnetic bottle, MBES	100	≥50%	Yes	0-3000 eV	≤4.5 MHz	Electrons **and** Ions
XUV spectrometer	-	-	No	-	≤4.5 MHz	Photons

They can also run together, or even in coincidence

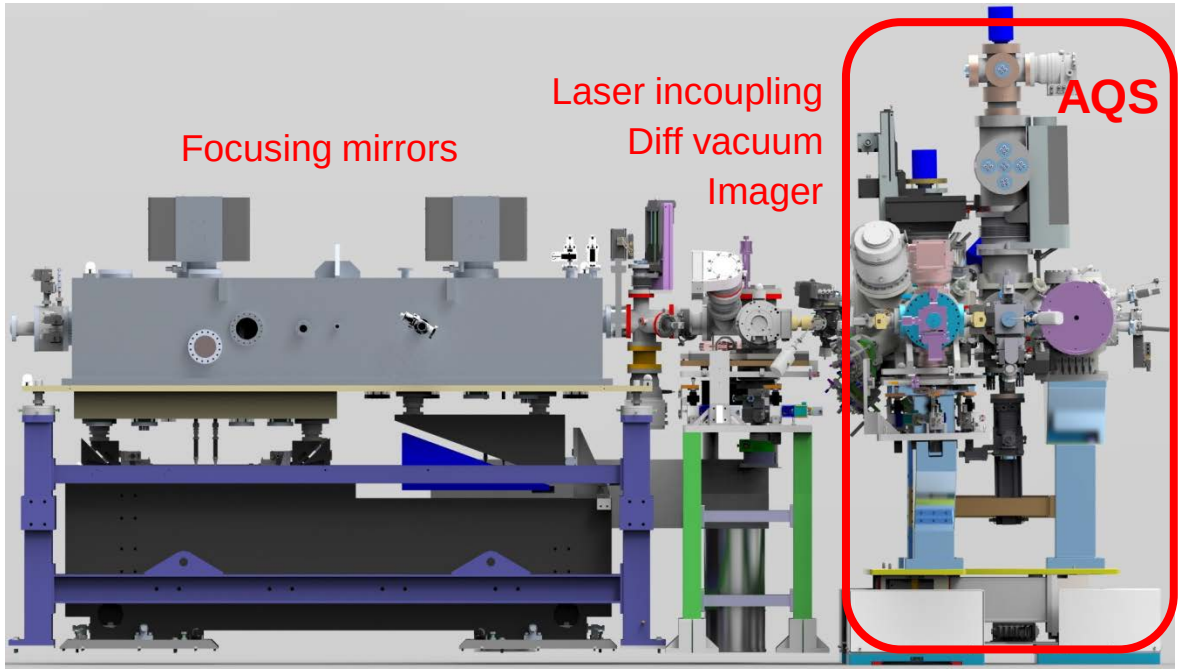
When to use each spectrometer?	
eTOF	Best electron energy resolution ΔE Full energy range 10 – 3000 eV
VMI	100% of 4π Angle resolved
Magnetic bottle, MBES	Full energy range 10 – 3000 eV 100% of 4π Electrons-ions coincidence

Spectrometers of the SQS-AQS instrument

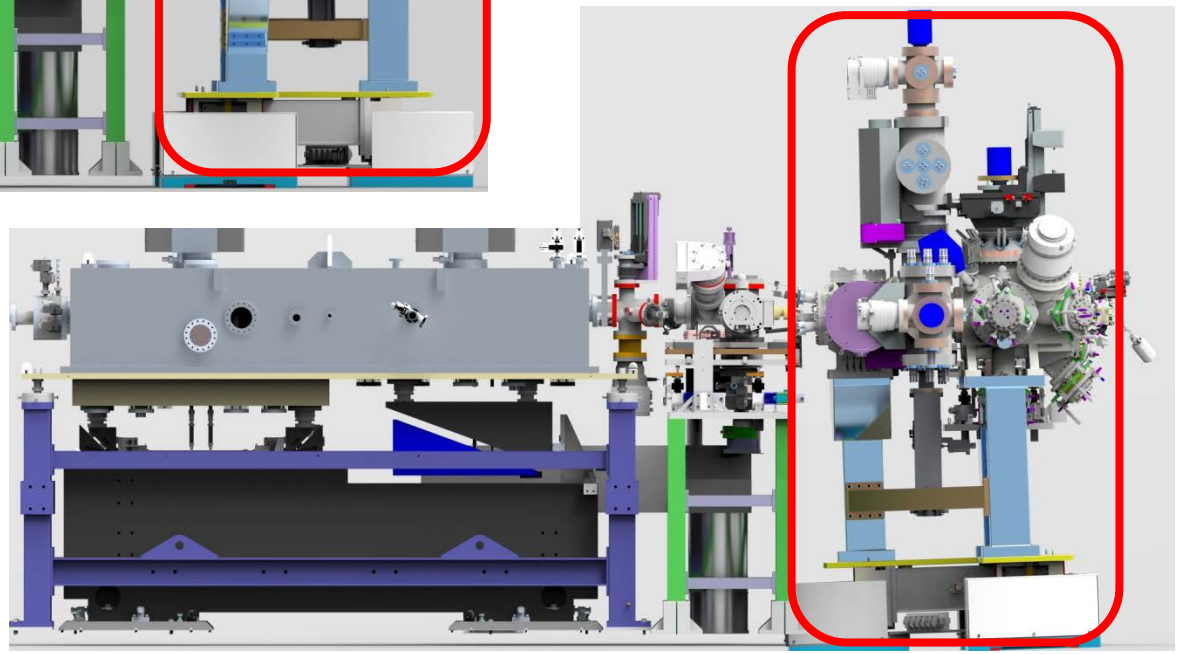


Geometry of the SQS-AQS instrument

Air-pads to exchange/move chambers



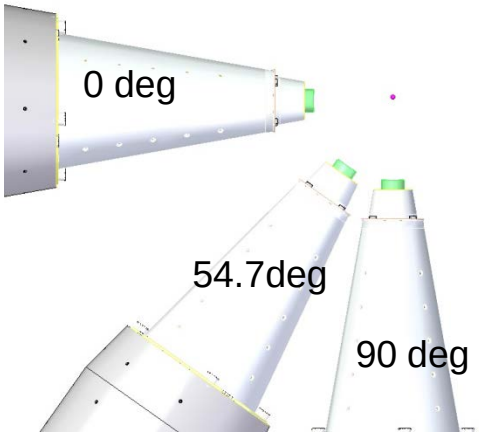
AQS station turned 180deg to switch from VMI/eTOF to MBES



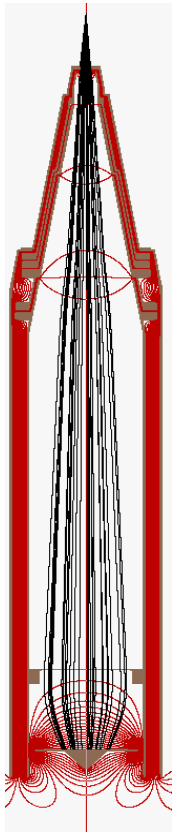
Electron time-of-flight spectrometer(s)

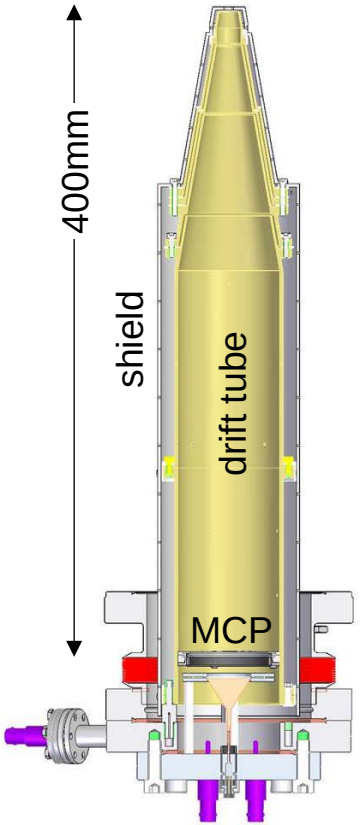
- Commissioned at DESY
- Confirmed world record resolution
  - ► ΔE = 70meV @ 811 eV,
  - ► E/ΔE > 10000
- Full energy range: 0 - 3000 eV
- All 3x tof are installed!

eTOF specifications	
Length	400mm
Detector	Hamamatsu, MCP, diam. 27mm, single anode
Readout	Digitizer 3GHz 10GS/s 14bit
Acceptance	0.14% of 4π



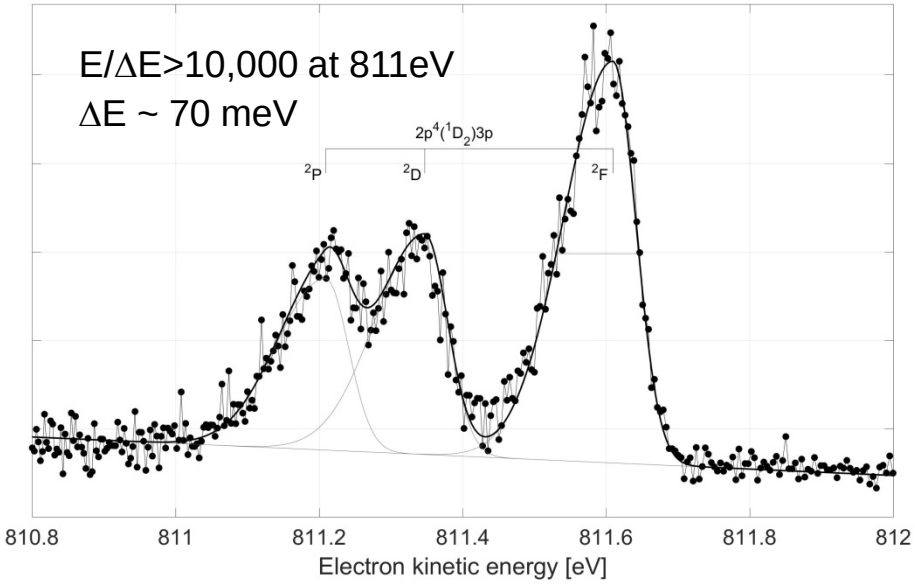
simulation design construction

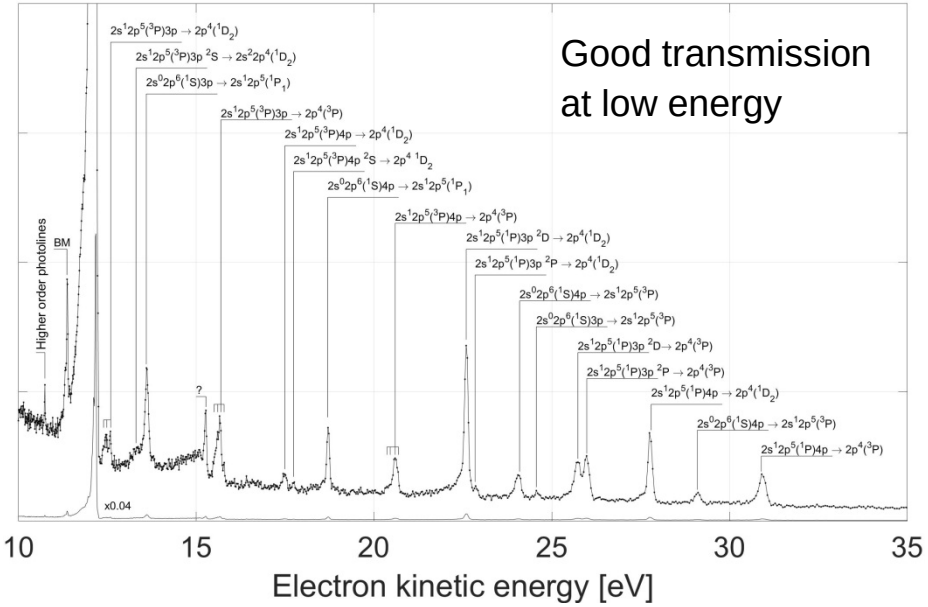




Electron time-of-flight spectrometer(s)

- Keys for resolution and transmission:
  - ► Low magnetic field:
    - 1μT, 10 mG, 2% of Earth
  - ► Particle optics simulations
  - ► Fast detector and electronics:
    - 450 ps FWHM, 120 ps rise
    - 3 GHz, 10 GS/s
    - 14 bit digitizer -> no need for preamp.

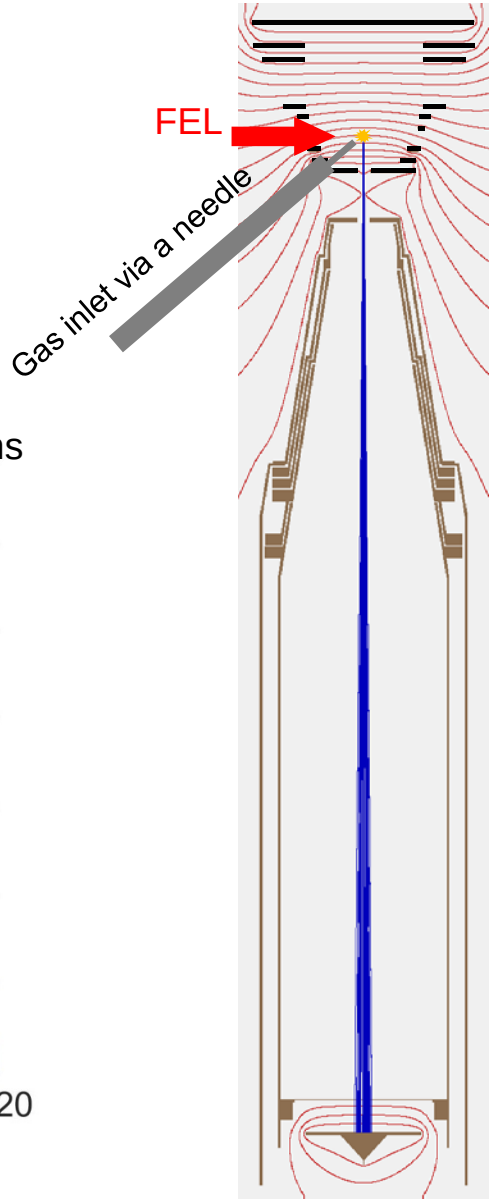




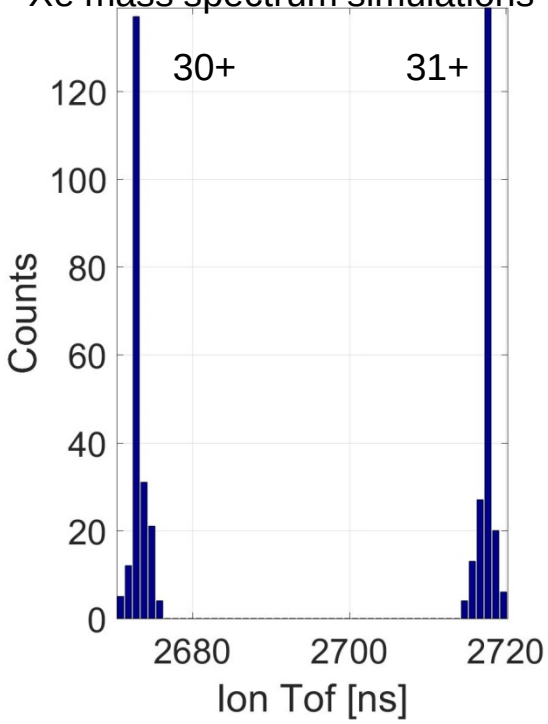
DAQ: see talk of T.Baumann later today

VMI + eTOF for ions spectroscopy

- VMI+eToF spectrometer(s) can work together as an ion spectrometer
  - ► VMI electrodes push/pull ions into the tof tube
    - Simulations indicates good mass resolution
    - Effective diagnostic of beam power density



Xe mass spectrum simulations

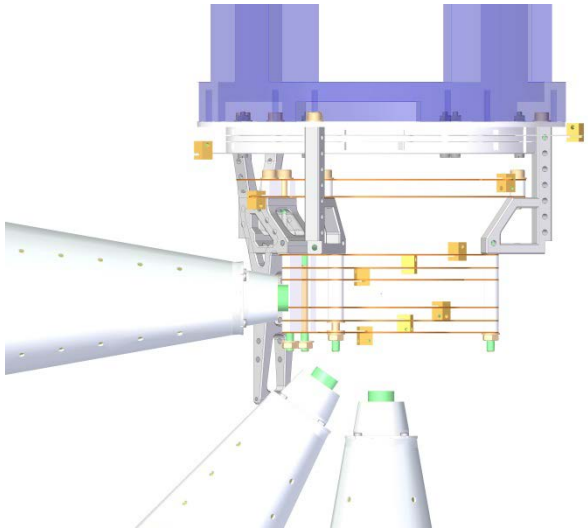


Sorokin *et al.* Phys. Rev. Lett. (2007)

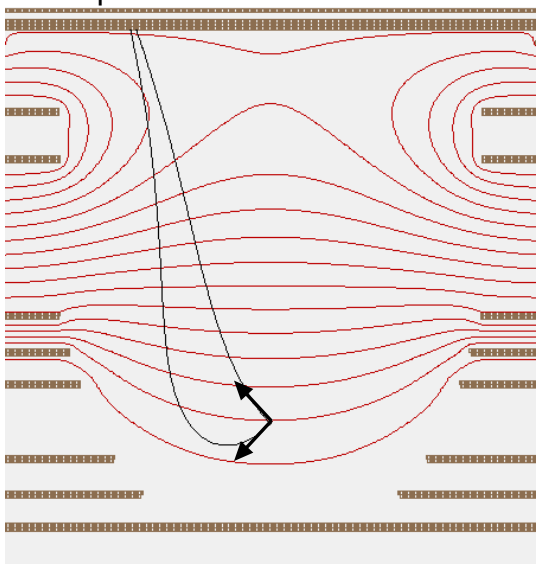
Rudek *et al.* Nat. Phot. (2012)

Velocity Map Imaging, VMI, spectrometer

- Energy ≤500 eV (mode1), ≤1200 eV (mode2)
- Resolution ΔE/E confirmed 2%, aiming for 1%
- Detector:
  - ► 10 Hz: Phosphor-CMOS
  - ► MHz: PImMS, Timepix3 (tentative)
- Spectroscopy or coincidence possible
- Can run in parallel with the ToF
- Can do coincidence with the ToF
- Can run in pulsed-mode, for ions

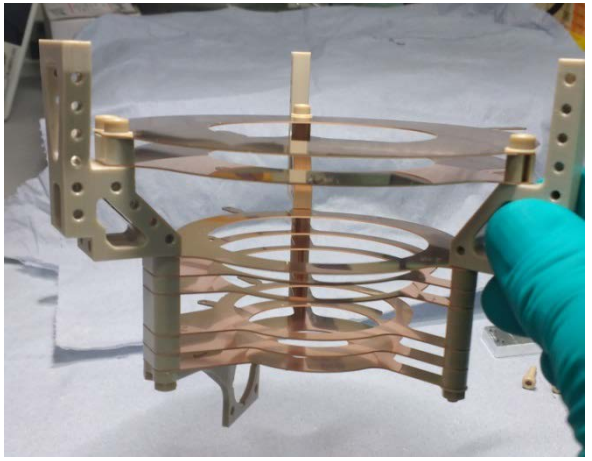


2d position sensitive detector



MHz capability with "tme-stamping" cameras

	PImMS2	TimepixCam
Pixels	324x324	256x256
Hits/pix	≤4	≤1
Dead time	150 ns	1.5 μs
Rep. rate	10 Hz	Continuous
Person	Oxford Univ. Brouard and Vallace group	Brookhaven NL A. Nomerotski

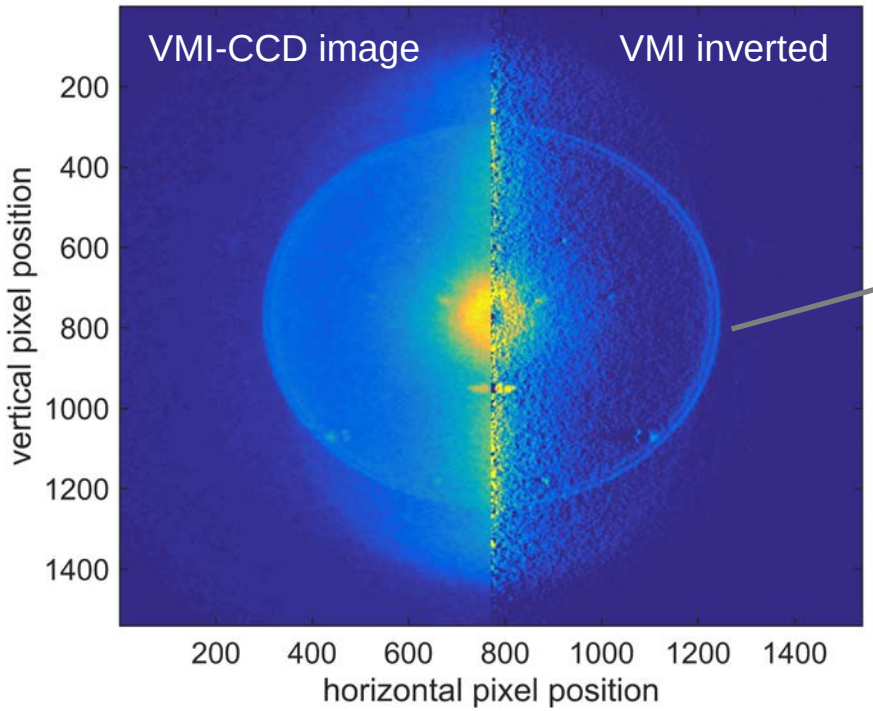


K. Amini *et al.*, Rev. Sci. Inst. 86, 103113 (2015)
M. Fisher-Levine & A. Nomerotski, J. Instrum. 11, C03016 (2016)

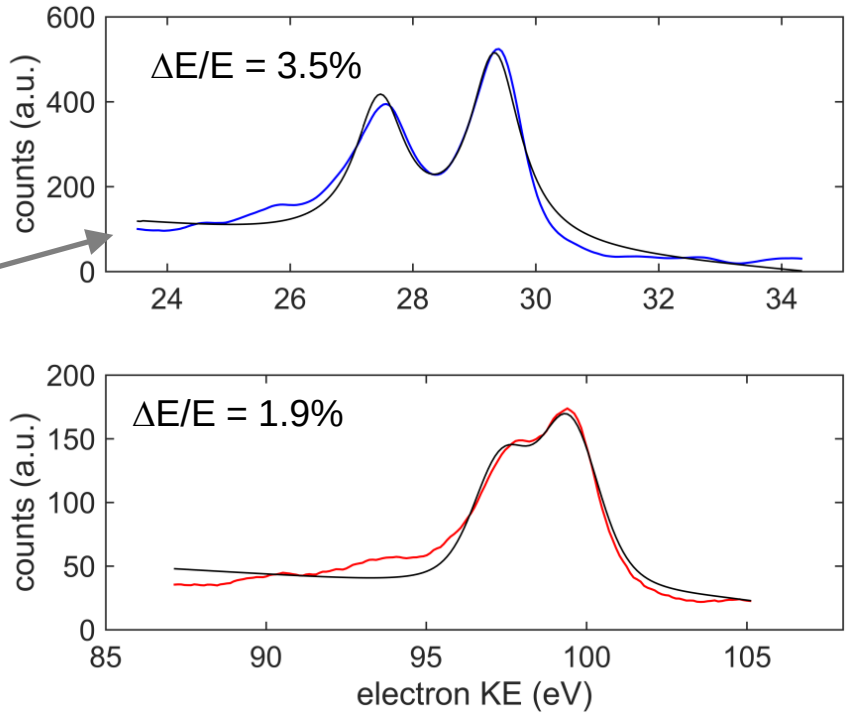
Velocity Map Imaging spectrometer

- Prototype commissioned at DESY, 2016

Ar 2p photoelectrons, ca. 30 eV

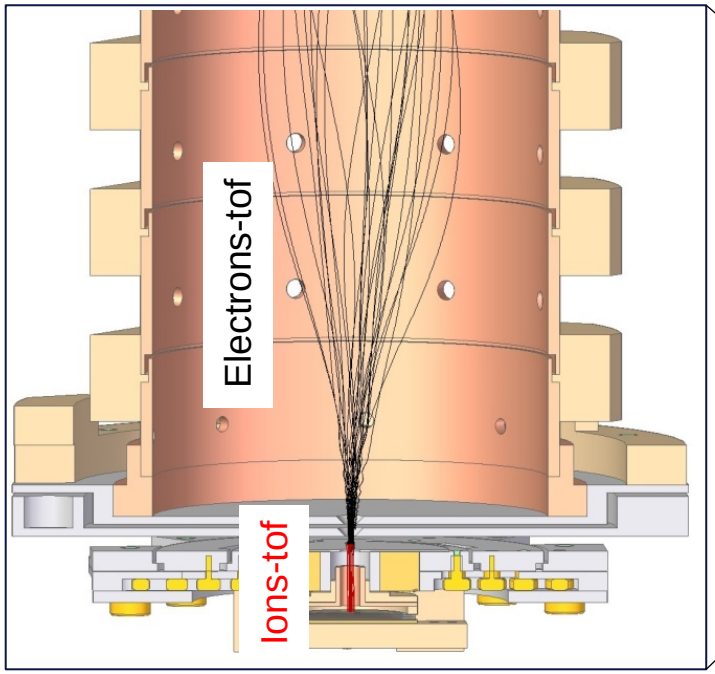


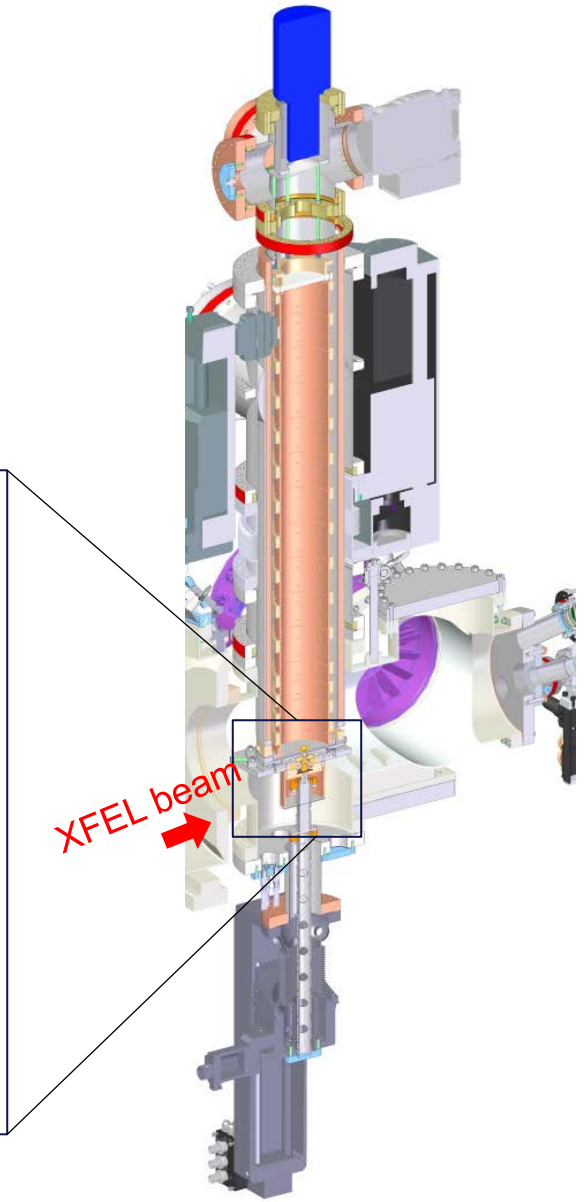
Ar 2p photoelectrons



MBES, magnetic bottle spectrometer

- XFEL.SQS own-design (S.Deinert)
- Early model existing at DESY
- Resolution aimed at $\Delta E \leq 1$ eV
- Electrons-ions or electrons-electrons coincidence possible
- Electron energy ≤ 3000 eV, with ≥ 50% acceptance
- Rep. rate ≤ 4.5 MHz (electrons only)





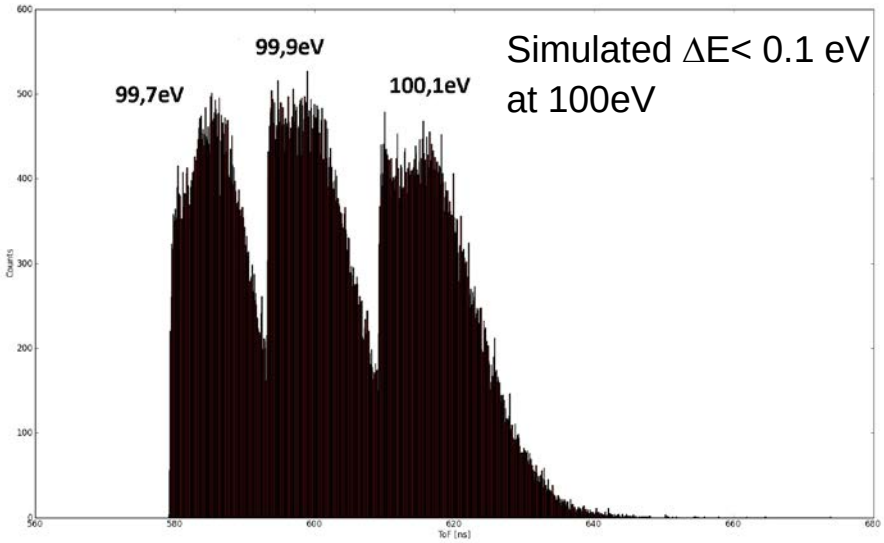
Innovative MCP “funnel” concept to favor coincidence

Kruit and Read *J. Phys. E.* **16** 313 (1993)
Eland and Feifel *Chemical Physics* **327** 85 (2006)

MBES, magnetic bottle spectrometer

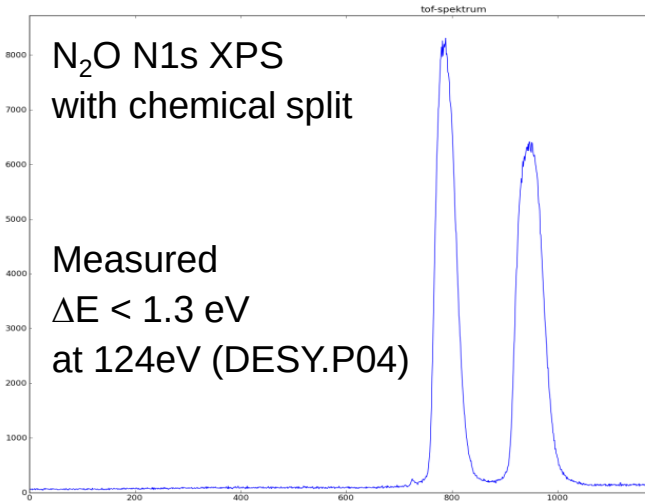
Simulation from present model:

Simulated ΔM< 2amu
at 100amu



Simulated ΔE< 0.1 eV
at 100eV

Measurements from early model:



N_2O N1s XPS
with chemical split

Measured
ΔE < 1.3 eV
at 124eV (DESY.P04)

PLEASE:
Contact us with your specific requests to know what specifications are to be expected (Mass or Energy resolution, transmission, …)

1-D Imaging XUV spectrometer

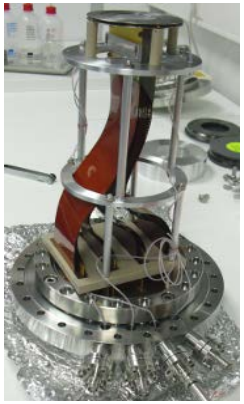
Not compatible with interim optics: not available on day 1

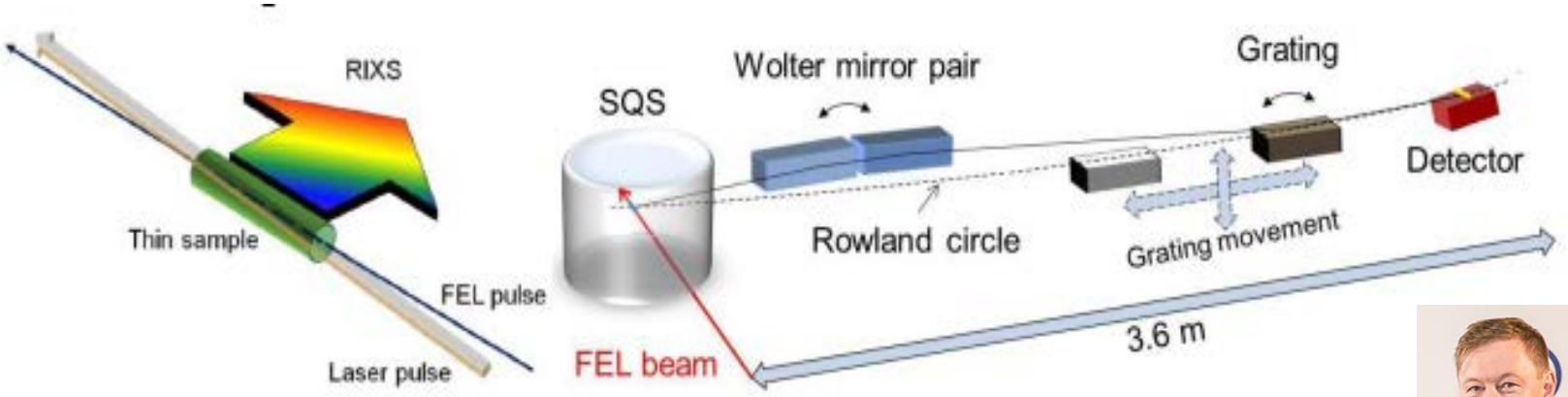
- In-kind contribution from J.E. Rubensson, Uppsala
  - ► Spectroscopy in vertical direction
  - ► Imaging along the beam in horizontal direction
  - ► Gas or liquid samples
  - ► Pulse characterization

Expected performance

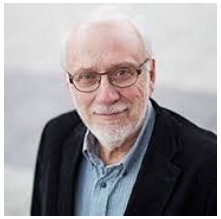
- Photon energy range 250 – 1000 eV
- Energy resolution $\Delta E/E$ ~ 10,000
- Spatial resolution along the beam 10μm = 1fs
- Acceptance 5x10^{-6} of 4π

MCP-stack, 128-fold, DLD multihit detector





J.E. Rubensson



J. Nordgren

They are here, speak with them!

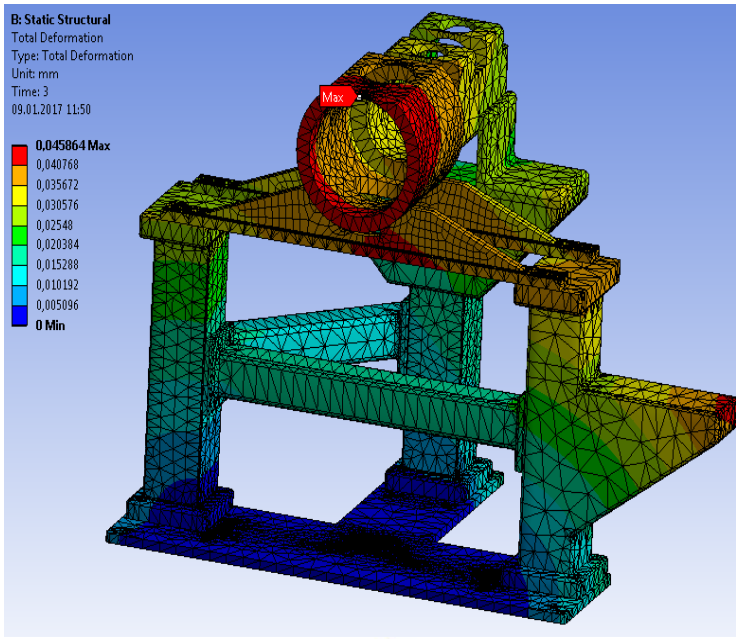
Summary: AQS readiness for 1st users beam

	Status for 1st users on day-1	Maximum shot resolved rep. rate	Sample of day-1	Detector	Contact person
etof, x3	Ready	Any	Gas	MCP assembly + 3GHz 10GS digitizer	Alberto De Fanis
VMI	Ready	10 Hz with CMOS MHz with Timestamp camera	Gas	MCP + Phosphor, with sCMOS or Timestamp camera	Tommaso Mazza Rebecca Boll
MBES	Ready	Any, electrons ~ 100 kHz, ions	Gas	MCP + digitizer + sCMOS imaging	Sascha Deinert

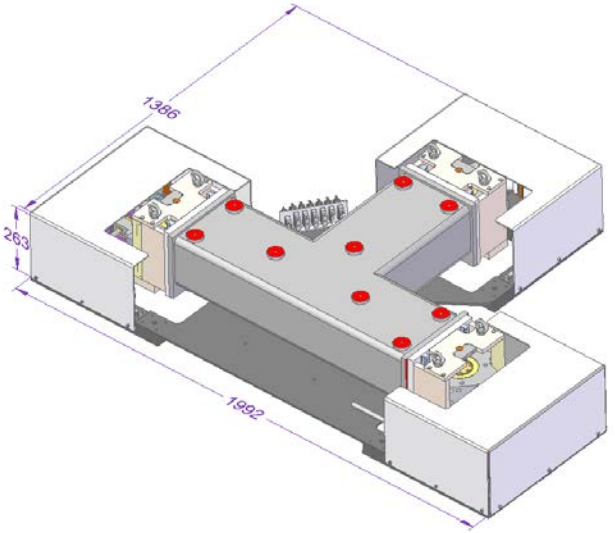
AQS support

- Designed by Y.Ovcharenko with Newport, ready to be installed.
- Stable steel base, Aluminium legs
- Tripod uncoupled system for leveling Z vertical axis motion, a longitudinal X and lateral Y motion, 2 rotation axis Theta (X, Z) and 1 rotation axis Theta Y.

	Range	Resolution	Repeatability	Speed
Travel X, Y	≤100 mm	≤ 1μm	≤ 5 μm	≤ 2 mm/s
Travel Z	≤150 mm	≤ 1μm	≤ 5 μm	≤ 0.2 mm/s
Rx Ry	≤ 2°	≤ 1m°	≤ 5 m°	≤ 0.01 m°/s
Rz	≤ 2°	≤ 1m°	≤ 5 m°	≤ 0.01 m°/s



- ANSYS FEA analysis combined with real hall measurement: extent of vibrations can be tolerated



Support summary:

- Delivered!
- Stable. Simulations shows that vibrations of the floor can be tolerated
- Remotely controlled
- 6-axis adjustable in fine steps and large travel range

Thank you for your attention

The SQS team

- A. Achner
- T.M. Baumann
- R. Boll
- A. De Fanis
- S. Deinert
- P. Grychtol
- M. Ilchen
- T. Mazza
- M. Meyer
- J. Montaño
- Y. Ovcharenko
- N. Rennhack
- R. Wagner
- P. Ziołkowski

- In-kind contribution:
  - XUV spectrometer
    - ► J.E. Rubensson, J. Nordgren (Uppsala)

- Commissioning of spectrometers with synchrotron beam
  - DESY P04
    - ► J.Viefhaus, J.Buck, G.Hartmann, L.Glaser,
  - XFEL Diagnostic group
    - ► J.Liu