AMO endstation at Shanghai FELs and research

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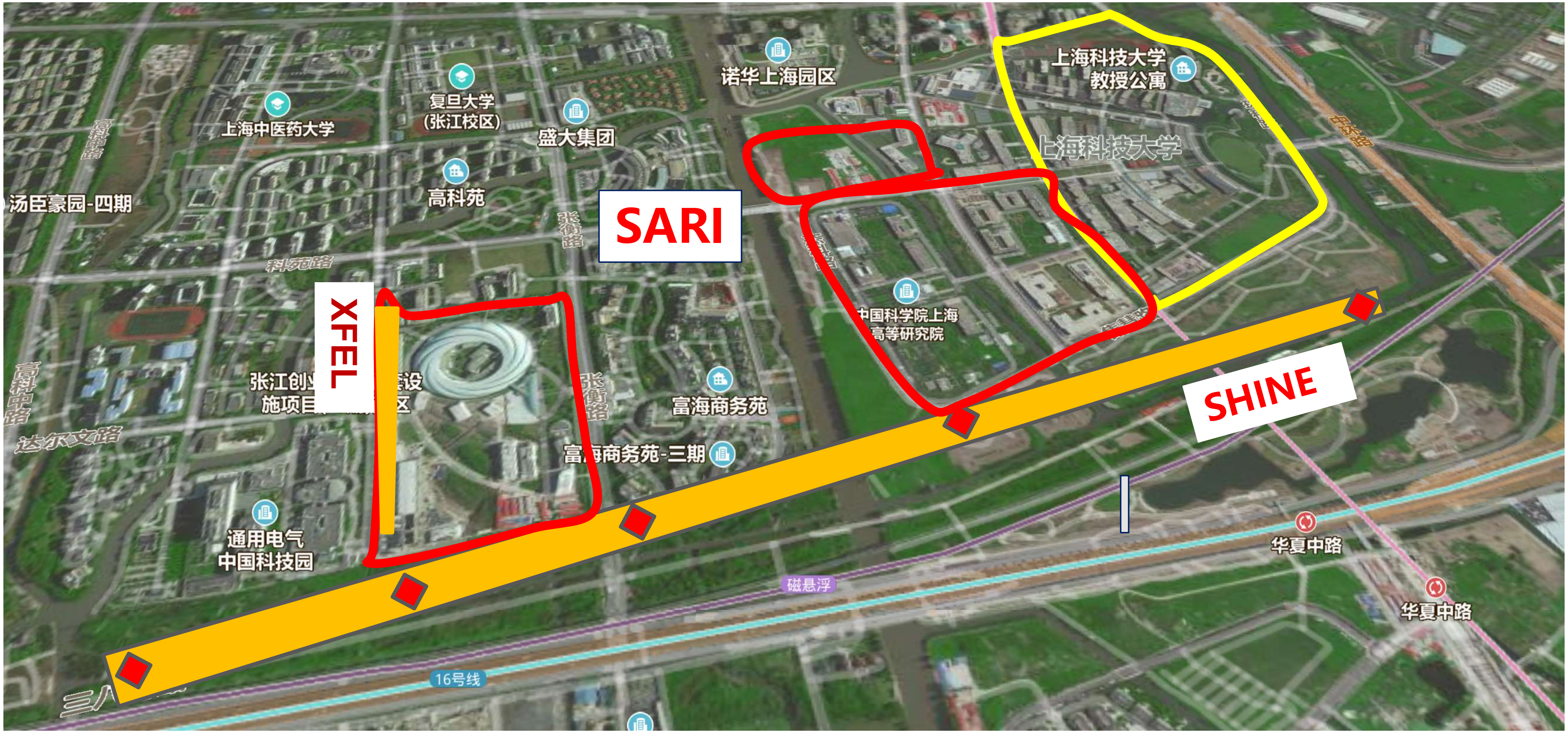
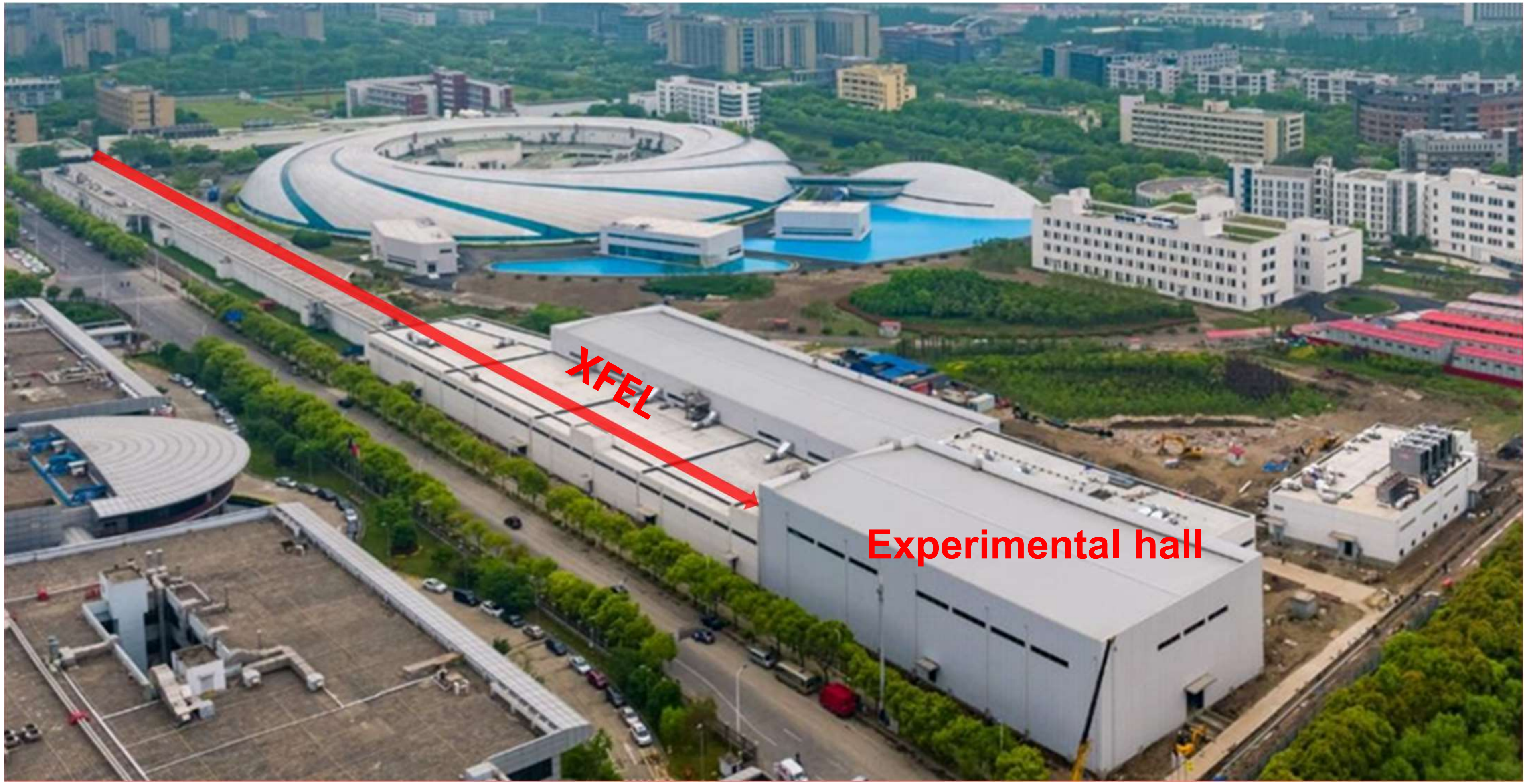
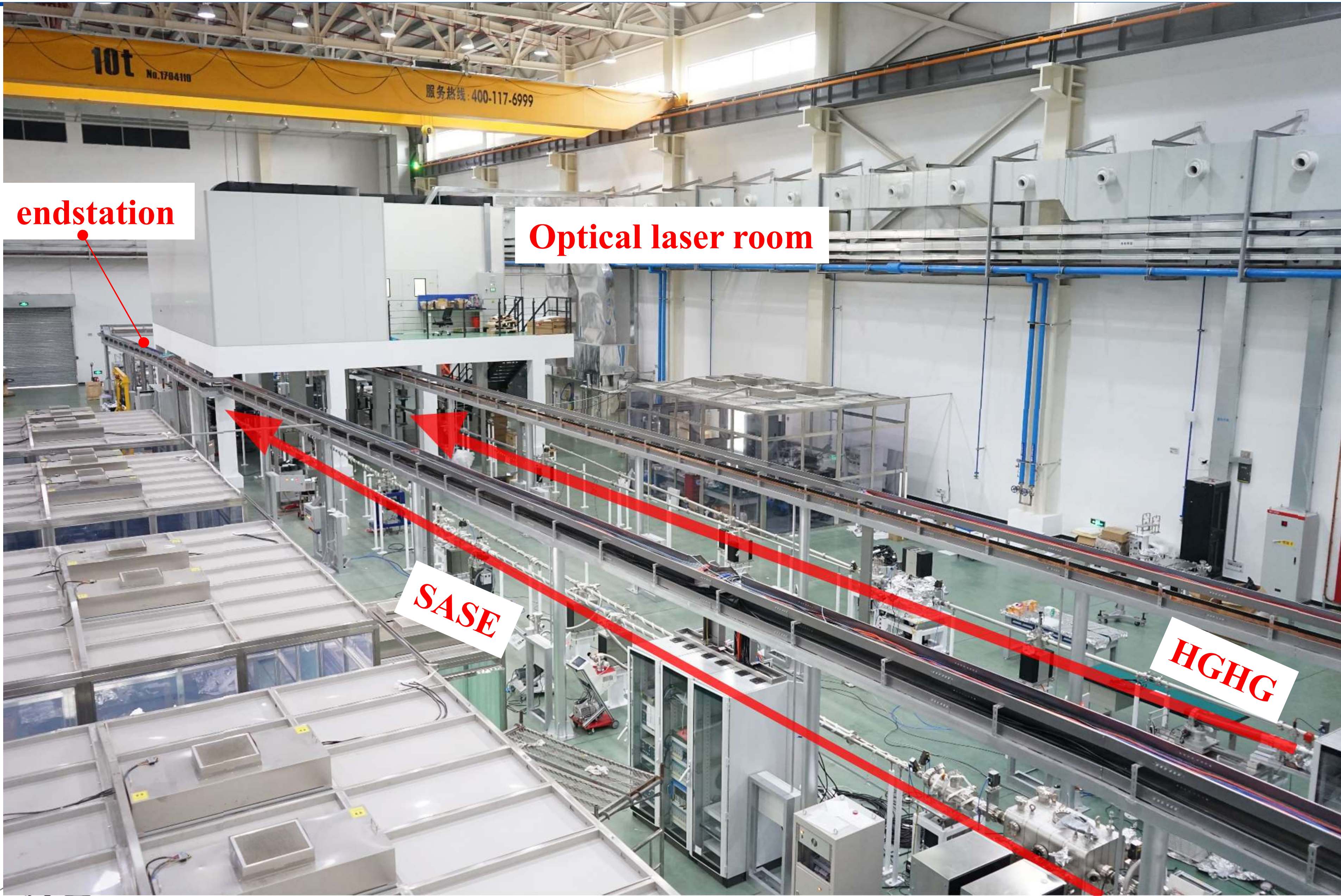
FELs at Shanghai



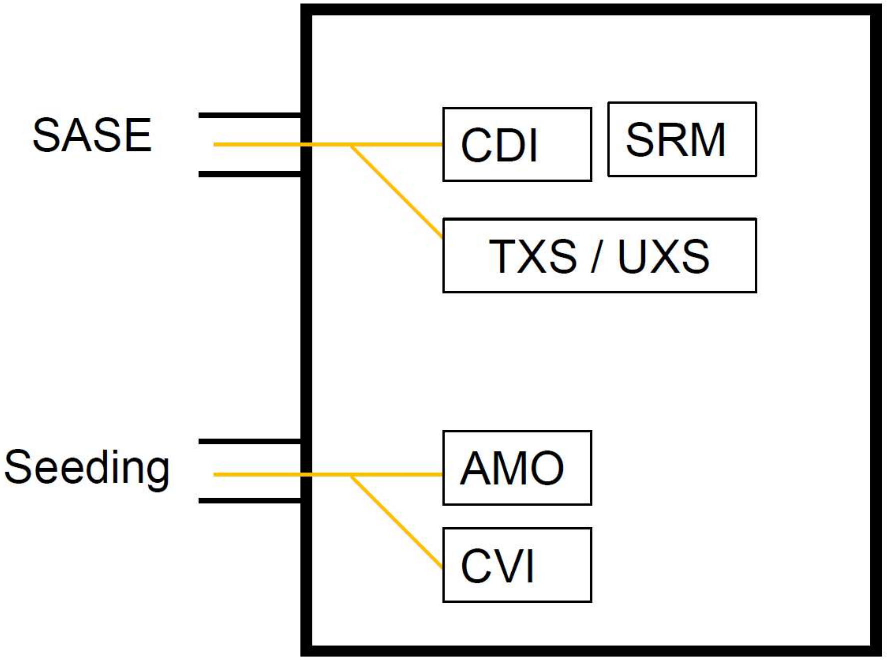
SXFEL



SXFEL：experimental hall



SXFEL：experimental hall



CDI Coherent Diffraction Imaging

SRM Live-cell Fluorescence Super-resolution Microscope

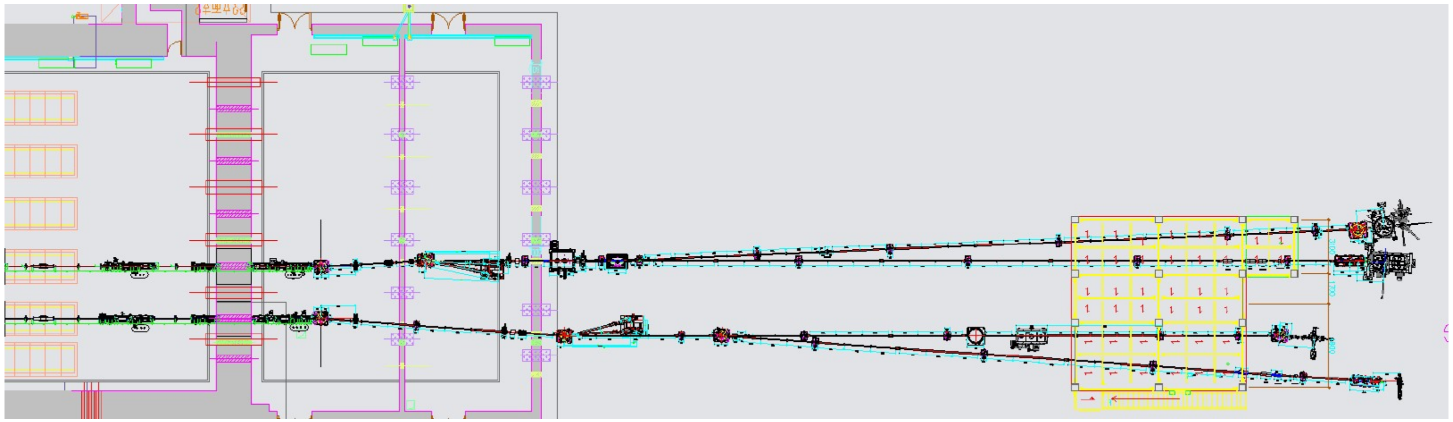
TXS Time-resolved X-ray Scattering

UXS Ultrafast X-ray Spectroscopy for Chemistry

PES Ambient Pressure Photoelectron Spectroscopy

AMO Molecular Dynamic Imaging

CVI Composite Velocity-map Imaging Spectrometer

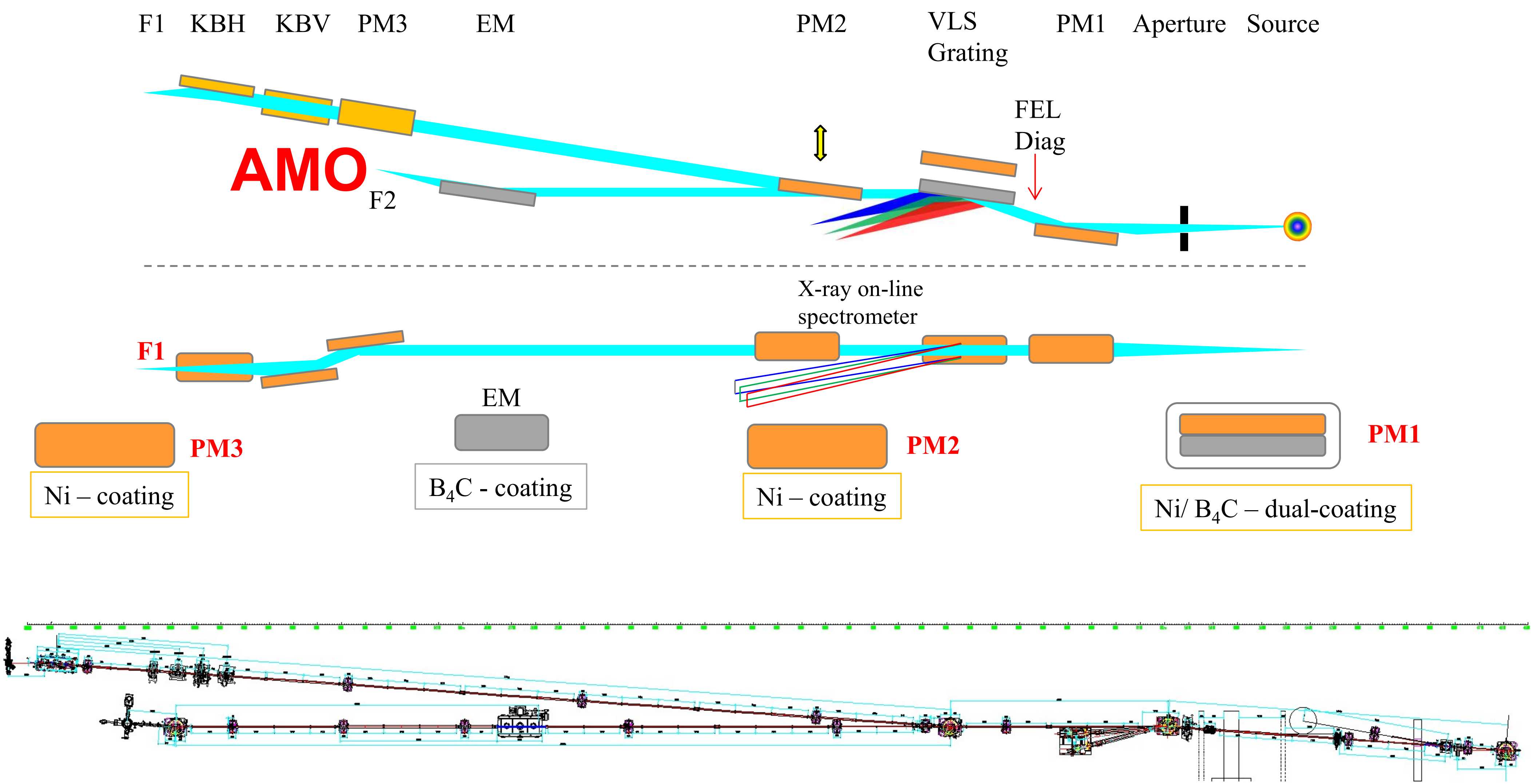


SASE

HGHG

SHINE

Seeding FEL Beam-line Layout (Bin Li)



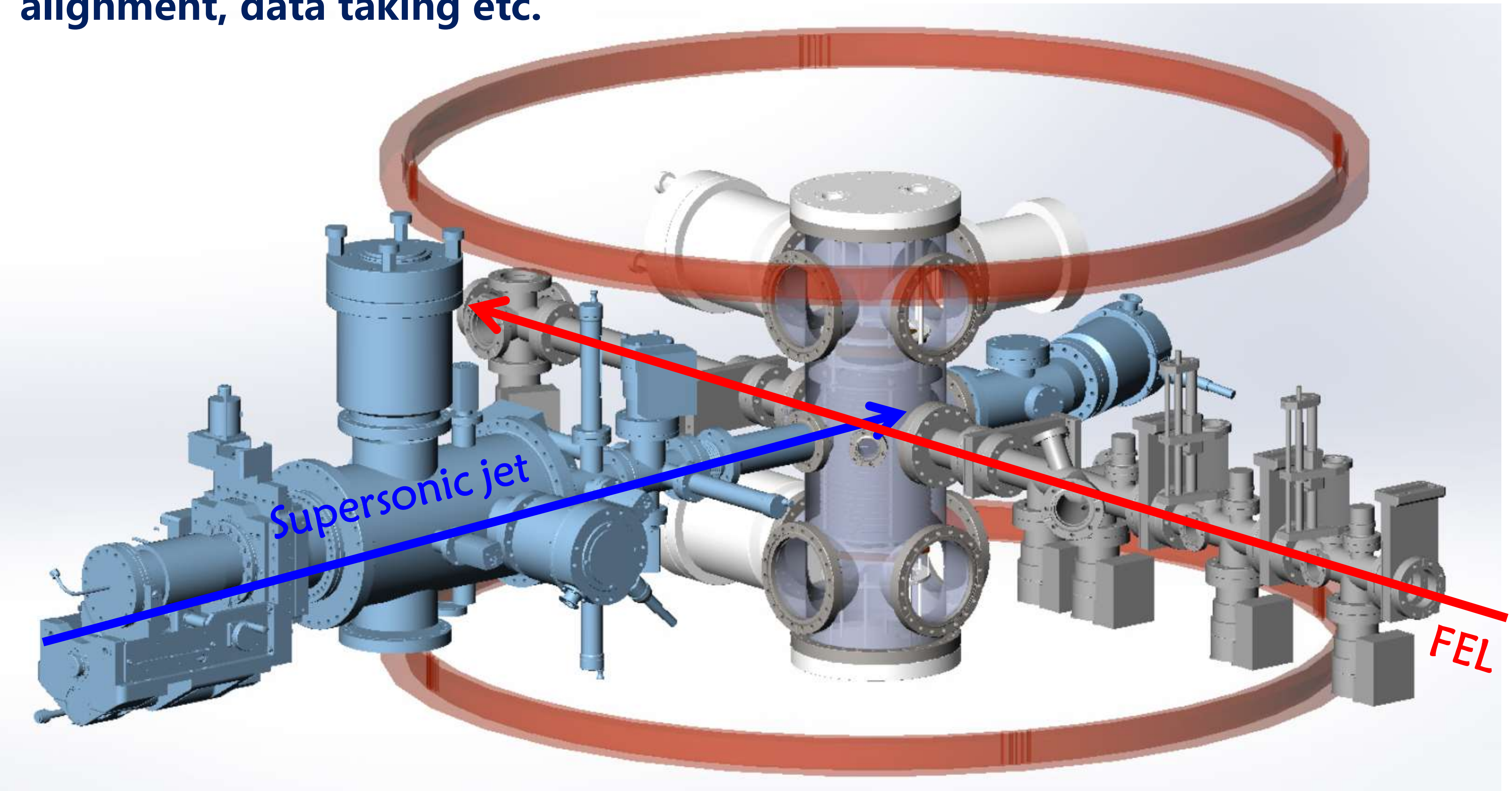
Seeding FEL Parameters (Bin Li)

Parameters	Units	Seeding FEL
Photon energy range	eV	100eV-620eV
Repetition rate	Hz	10Hz(baseline) 50Hz(upgrade)
Pulse Energy	μJ	100eV-300eV(～50uJ) 400eV(～20uJ) 500eV(～5uJ)
Energy Resolution (ΔE/E)		~0.03% (100eV) ~0.01% (200-400eV)
Polarization		Plano or Elliptic
Pulse length (FWHM)	fs	50-200fs
Resolving power of on-line spectrometer		$E/\Delta E > 2x10^4$ (250-620 eV) $E/\Delta E > 3x10^4$ (100-250 eV)
Spot diameter @sample	μm	<6μm (400eV) <20μm (100eV)

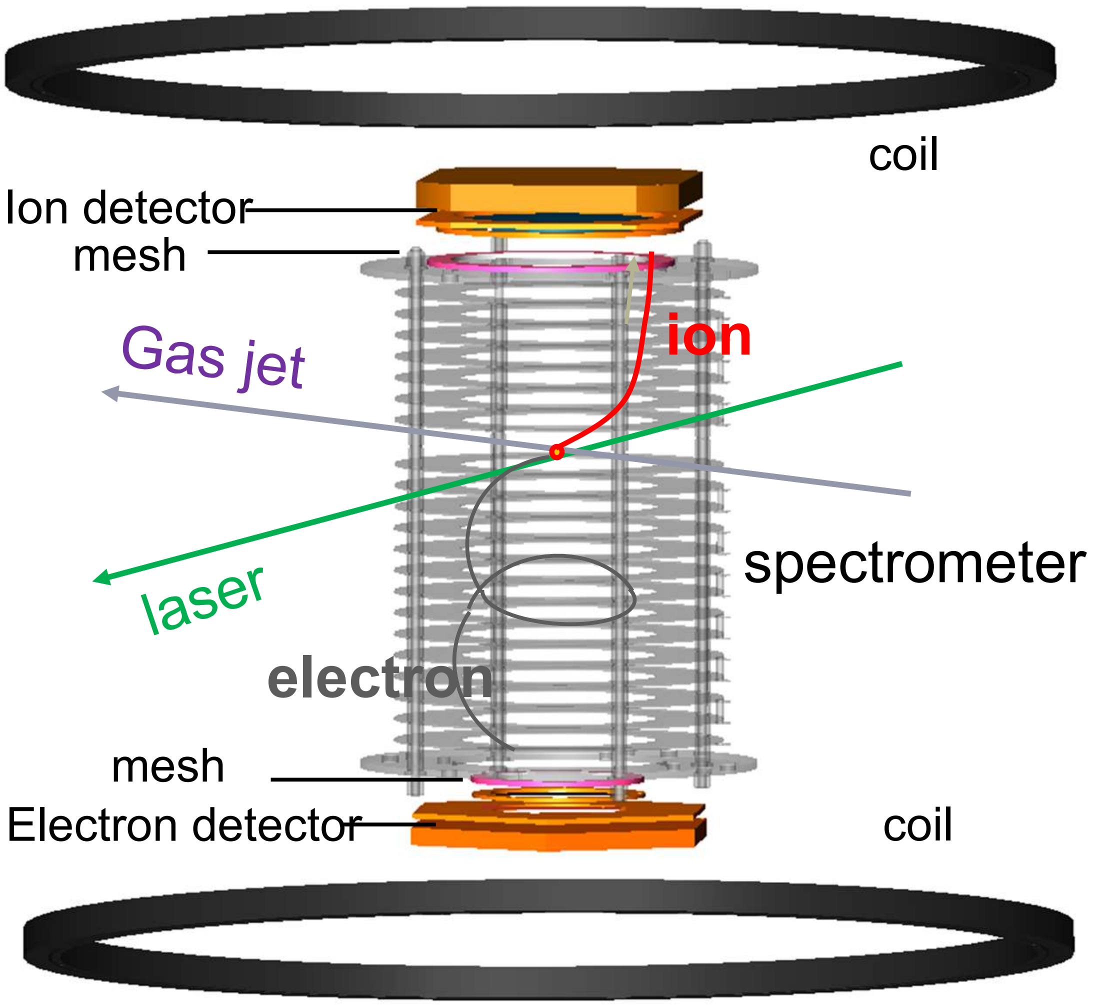
Optical lasers: 35fs, 240 nm-15 μm, HHG (Jiaming Jiang)

AMO endstation: Coltrims/REMI

Supersonic Jet, dump, diff. pump, main chamber, alignment, data taking etc.



Reaction Microscope （REMI/Coltrims）： technical routine



MCP： t_z –> Pz

Delayline: t_x, t_y –> x, y –> Px, Py

Spectrometer:

- μeV resolution for ions
- meV for electrons

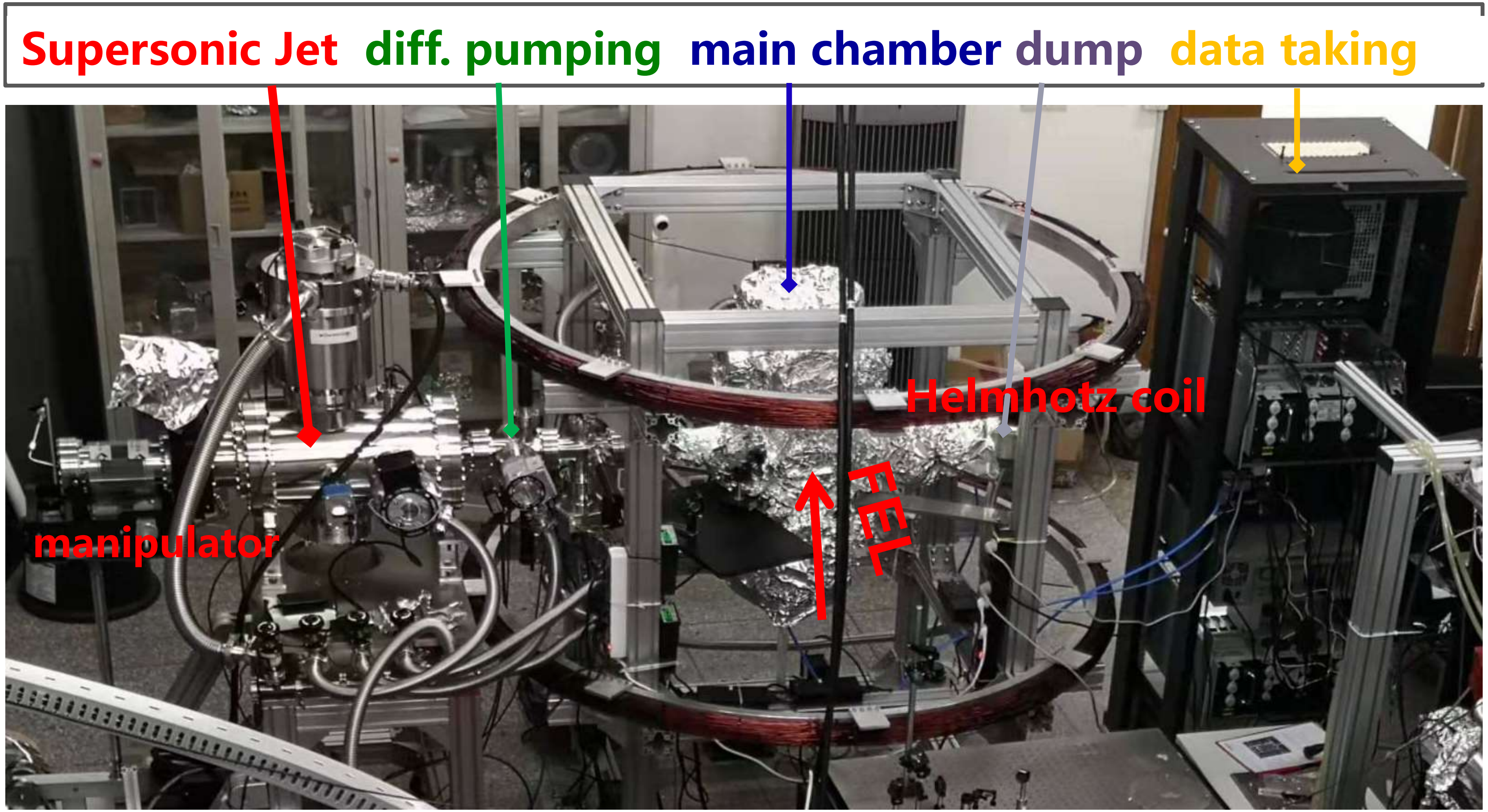
- base pressure 10^{-11} mbar
- fast detector readout (Multi-channels, 1 GHz)

- Target density: 10^{12} cm^{-3}
- Target temper.: 100 mK

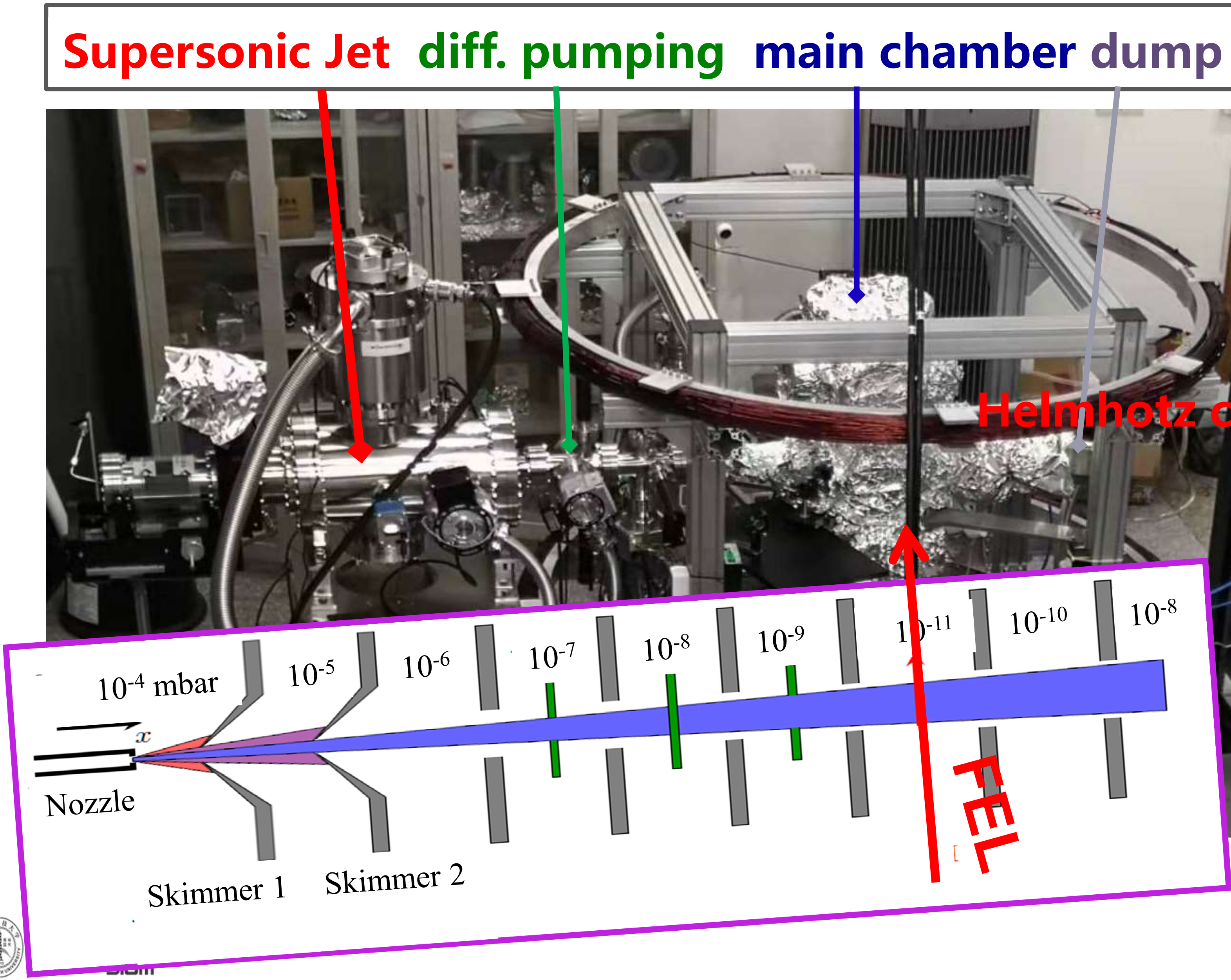
Character:

- Supersonic jet for gas phase and volatile targets
- 4π electron and ion imaging
- Electron and ion in coincidence

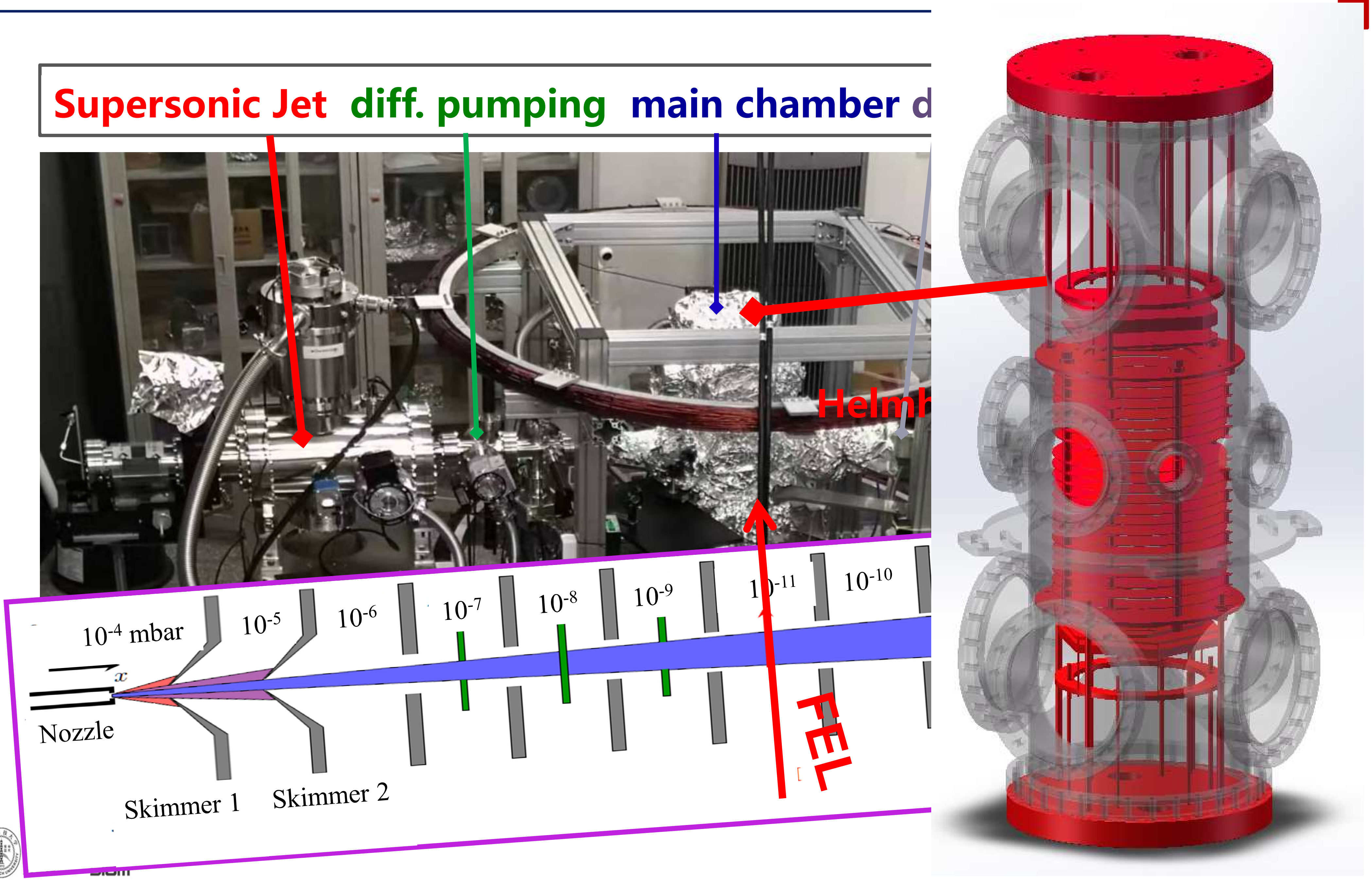
COLTRIMS@SXFEL



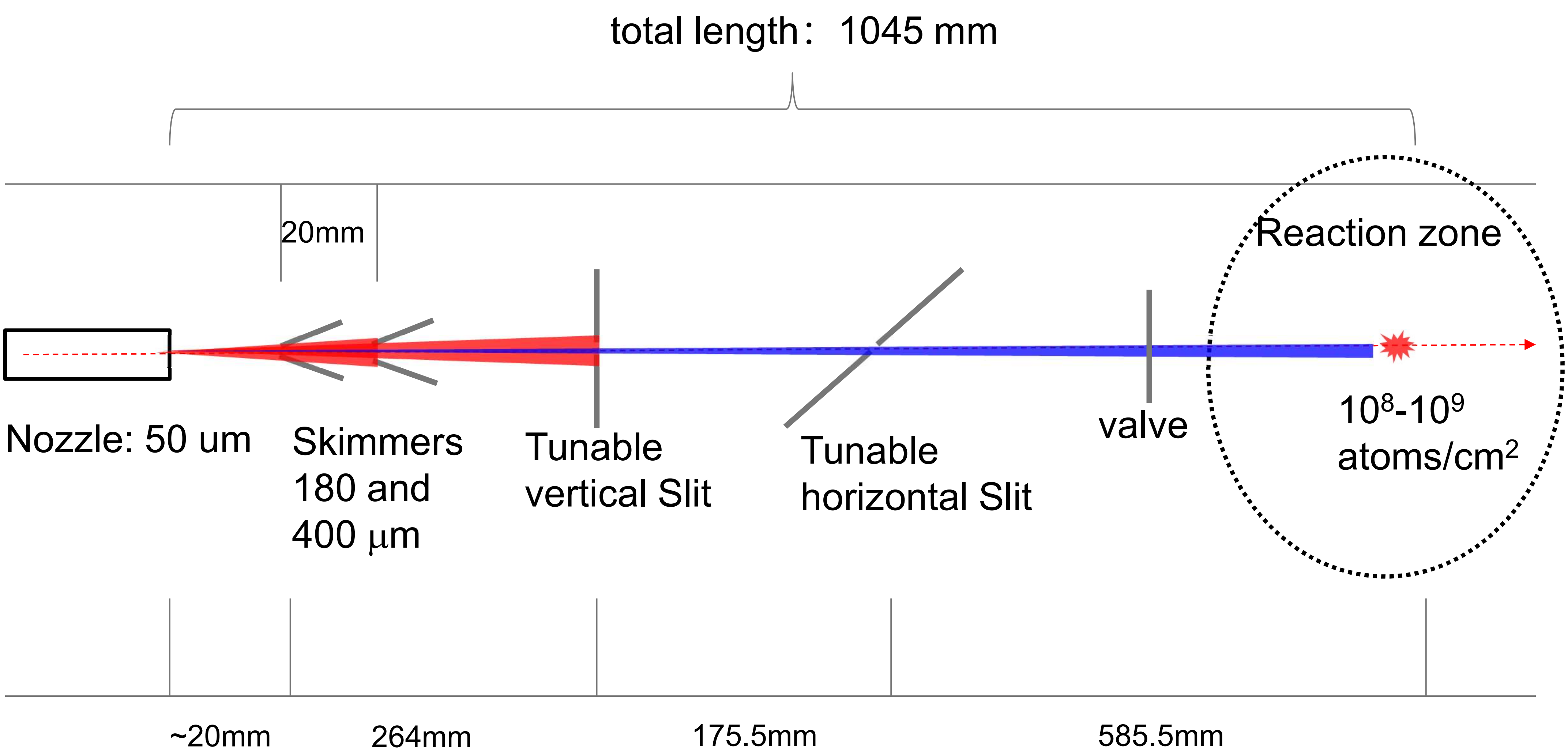
COLTRIMS@SXFEL



COLTRIMS@SXFEL

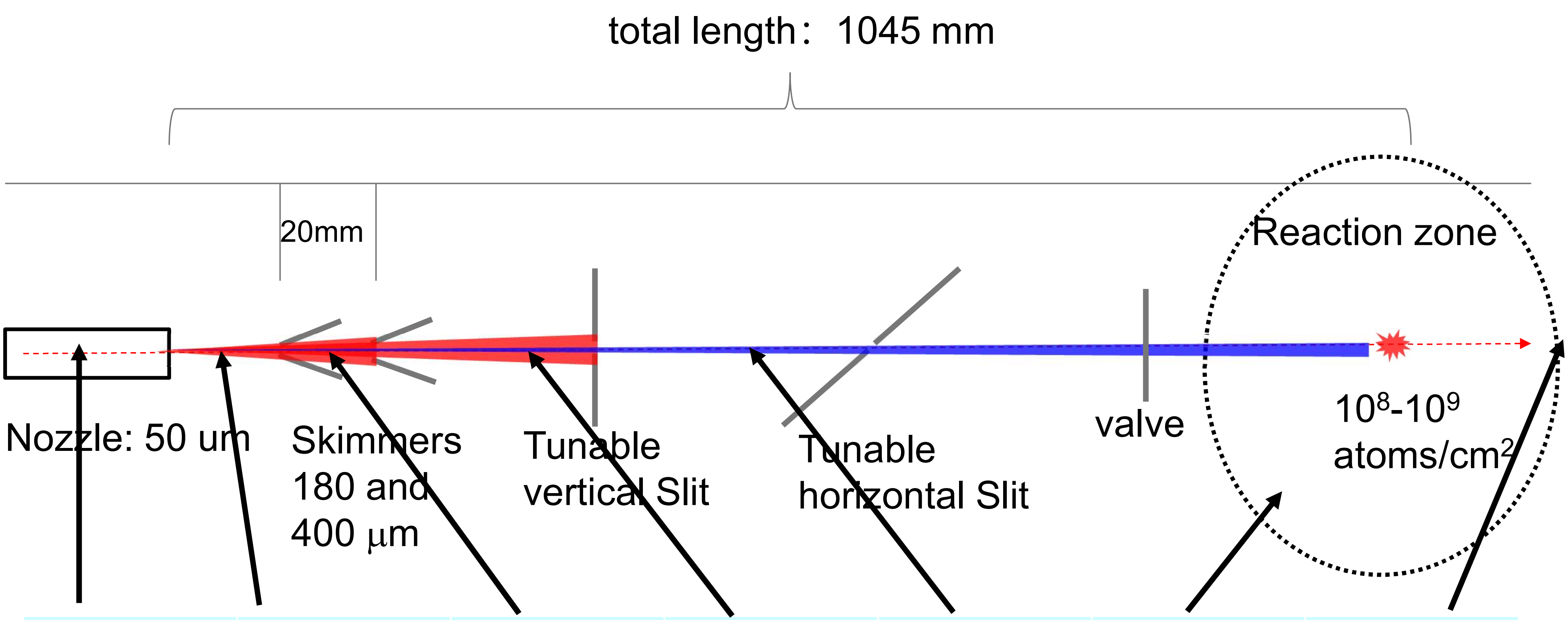


Supersonic gas jet



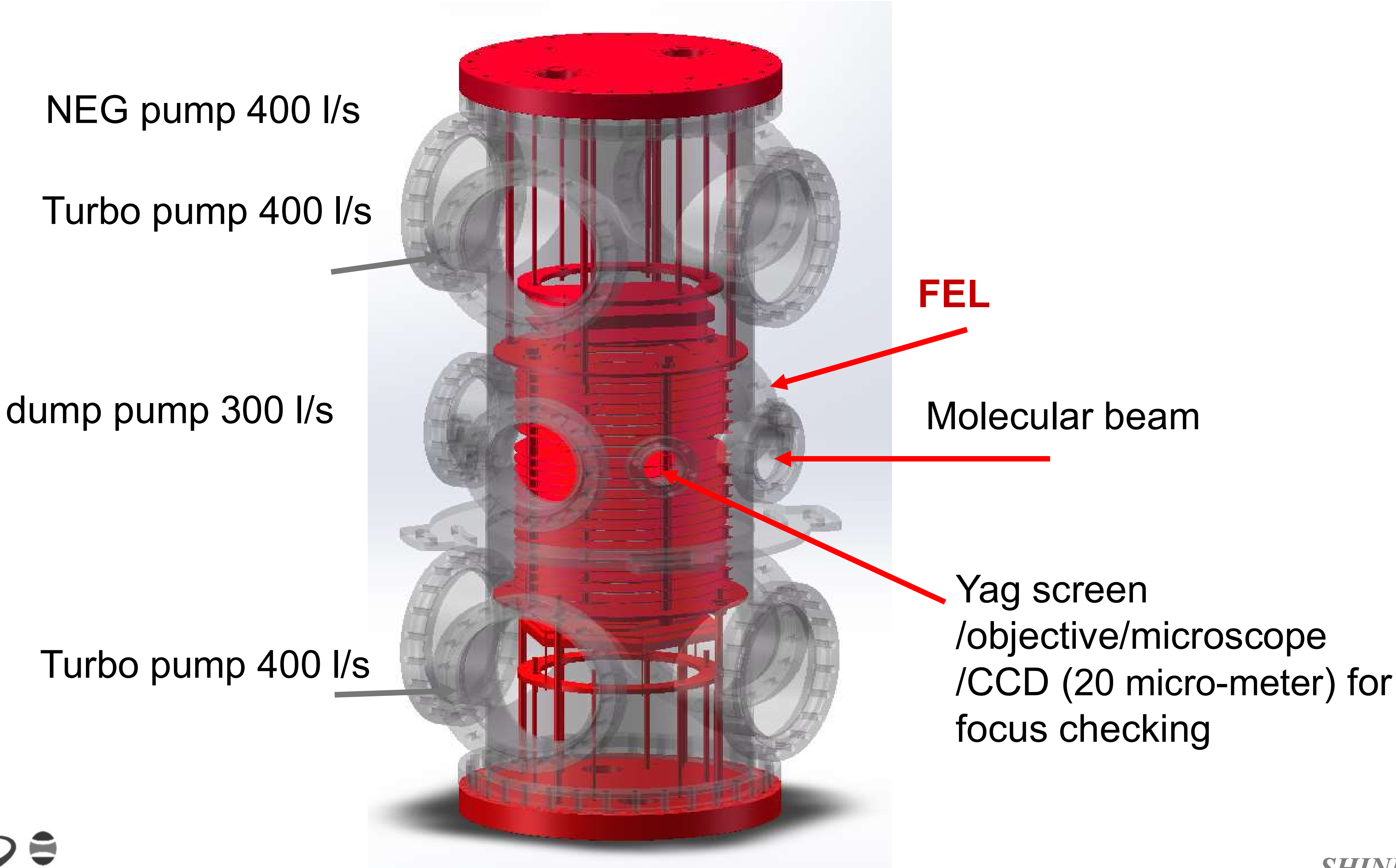
The position of the nozzle can be tuned by a manipulator

Supersonic gas jet



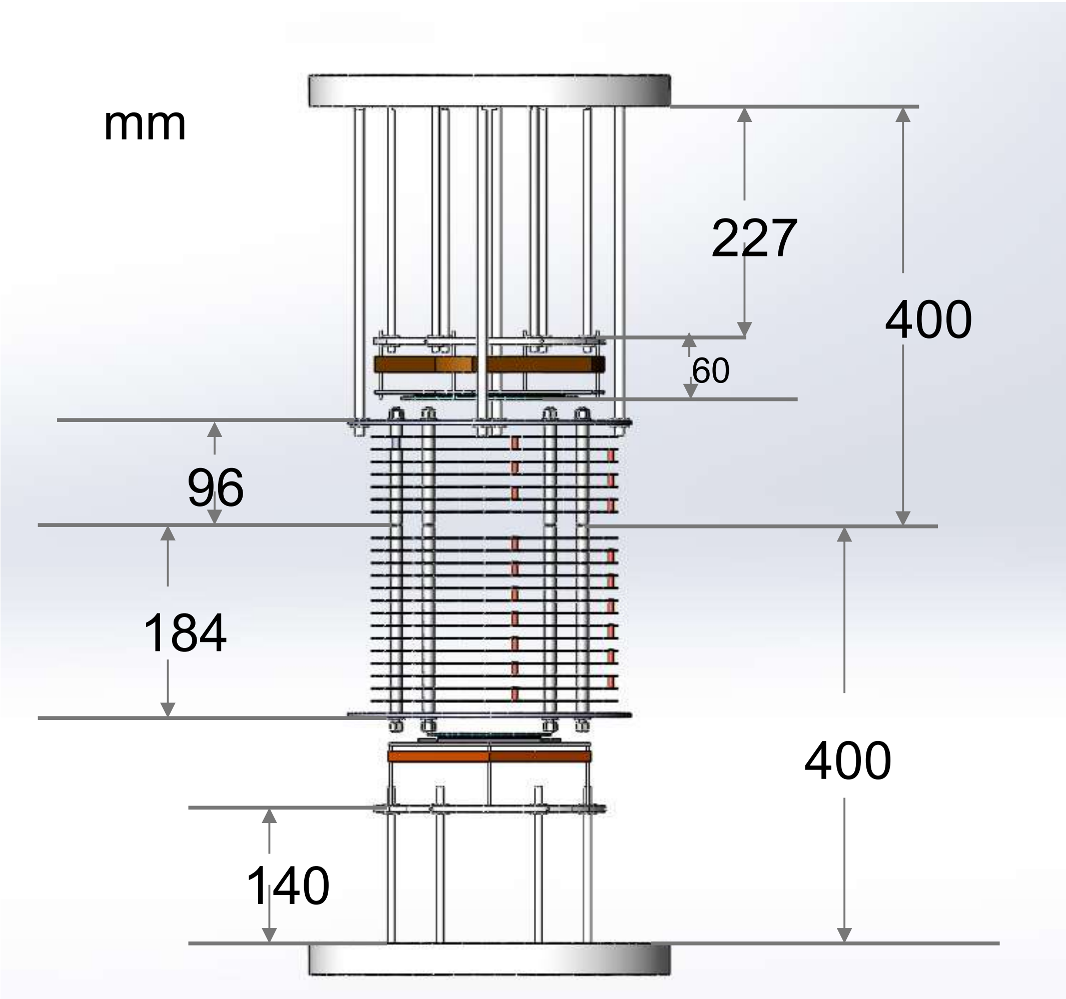
	P1	P2	P3	P4	Main chamber	dumping
Before injection	4.2E-9 torr	2.9E-9 torr	1.4E-9 torr	1.2E-9 torr	2.1E-10 torr	9.5E-11 torr
2.5 bar	3.2E-3 torr	2.1E-8 torr	6.4E-9 torr	2.1E-9 torr	2.2E-10 torr	1.2E-10 torr

Main chamber overview



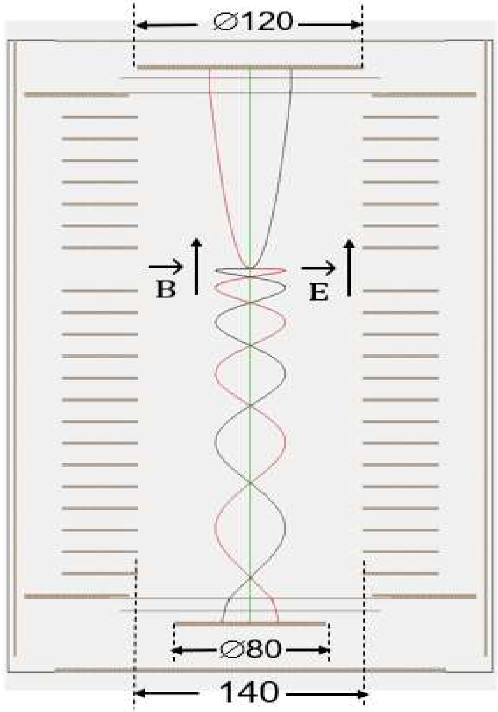
Spectrometer & detectors

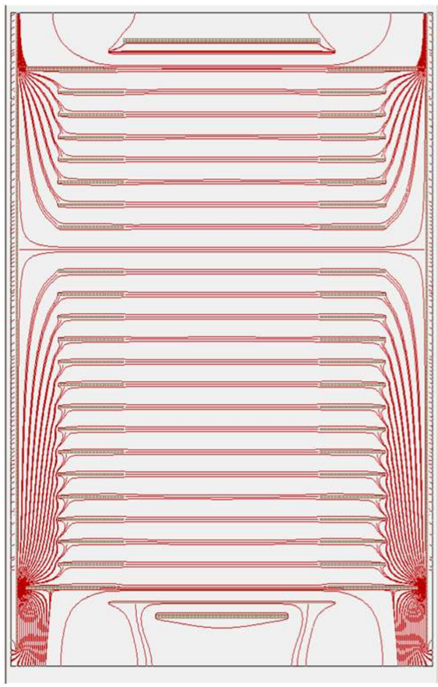
DLD 120 for ion detection



Hex 75 for electron detection

- ✓ 1mm thick ring electrode: inner diameter 130mm
- ✓ 12 mm period with 300k Ohm resistance
- ✓ 22 mm spacing at collision center
- ✓ 96 mm for ion and 184 mm for electron
- ✓ Meshes at the end of the accelerate region & before MCP front

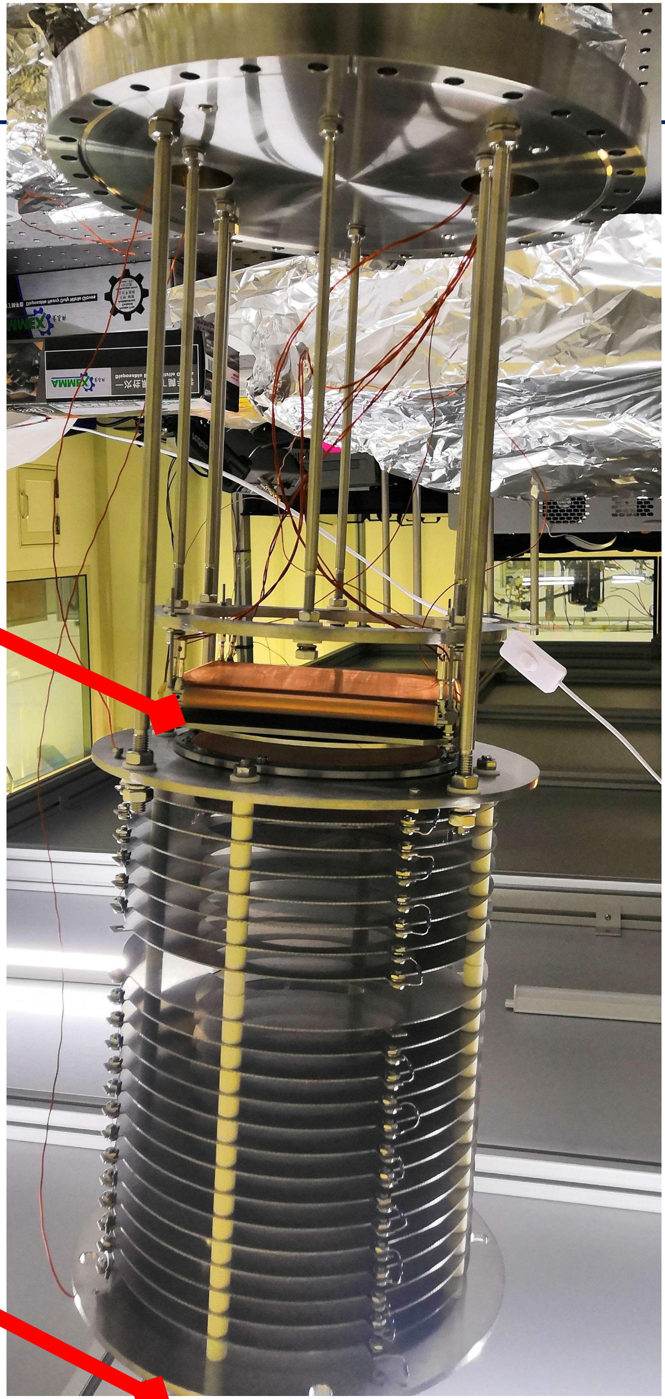




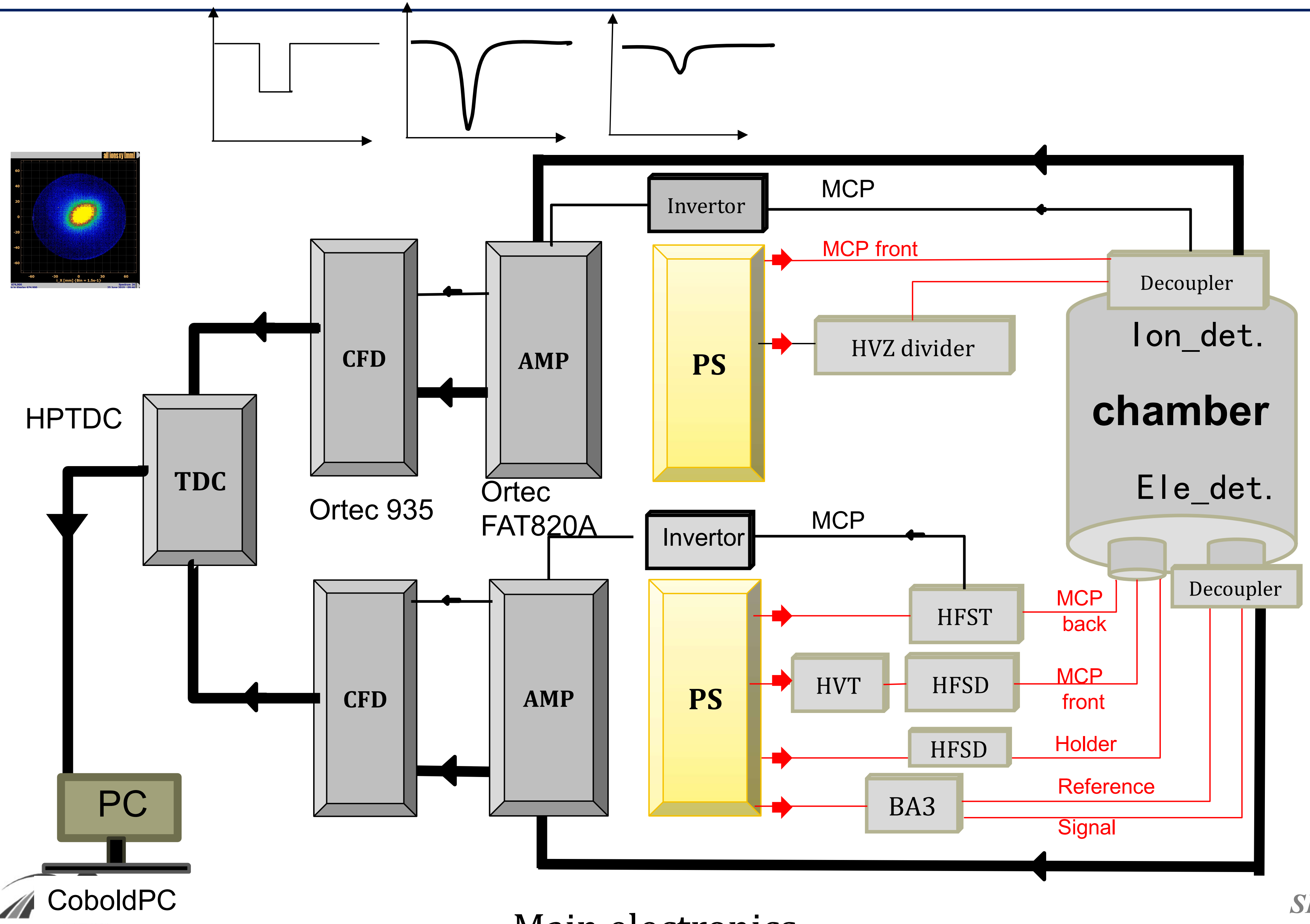
Similar to FLASH2

J. Synchrotron Rad. (2019) 26, 854–867

Spectrometer & detectors

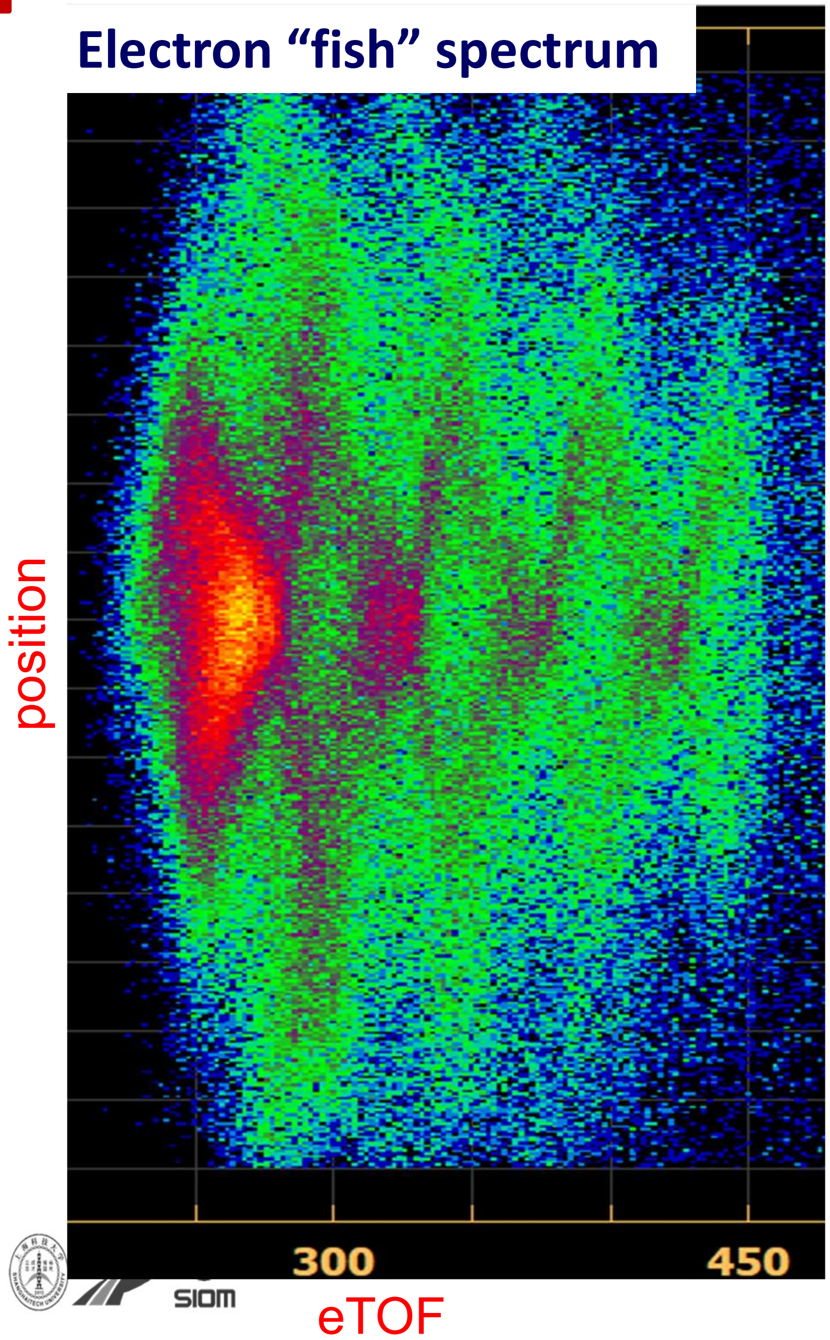


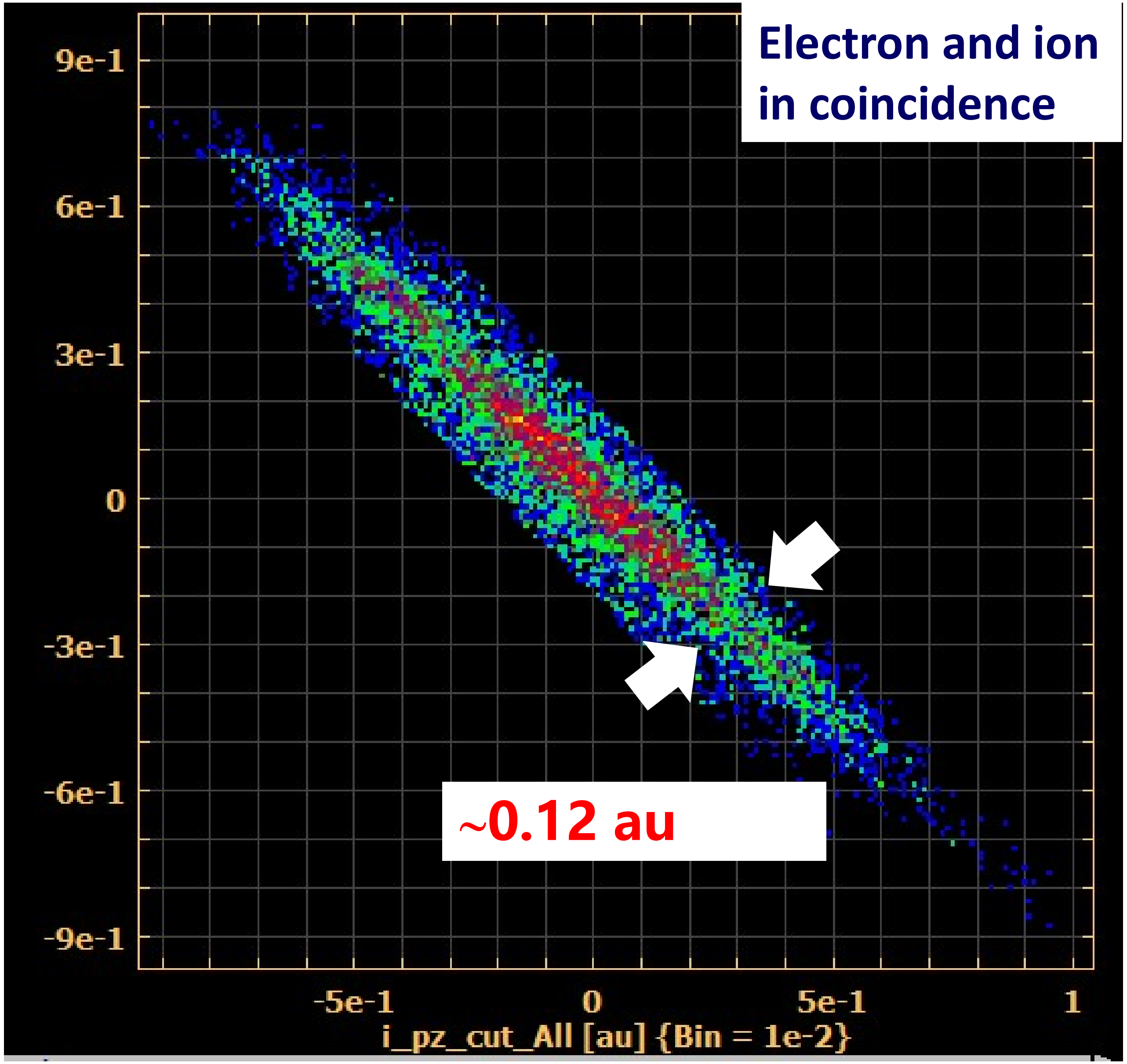
Electronics & DAQ



Main electronics

Preliminary signals with IR laser

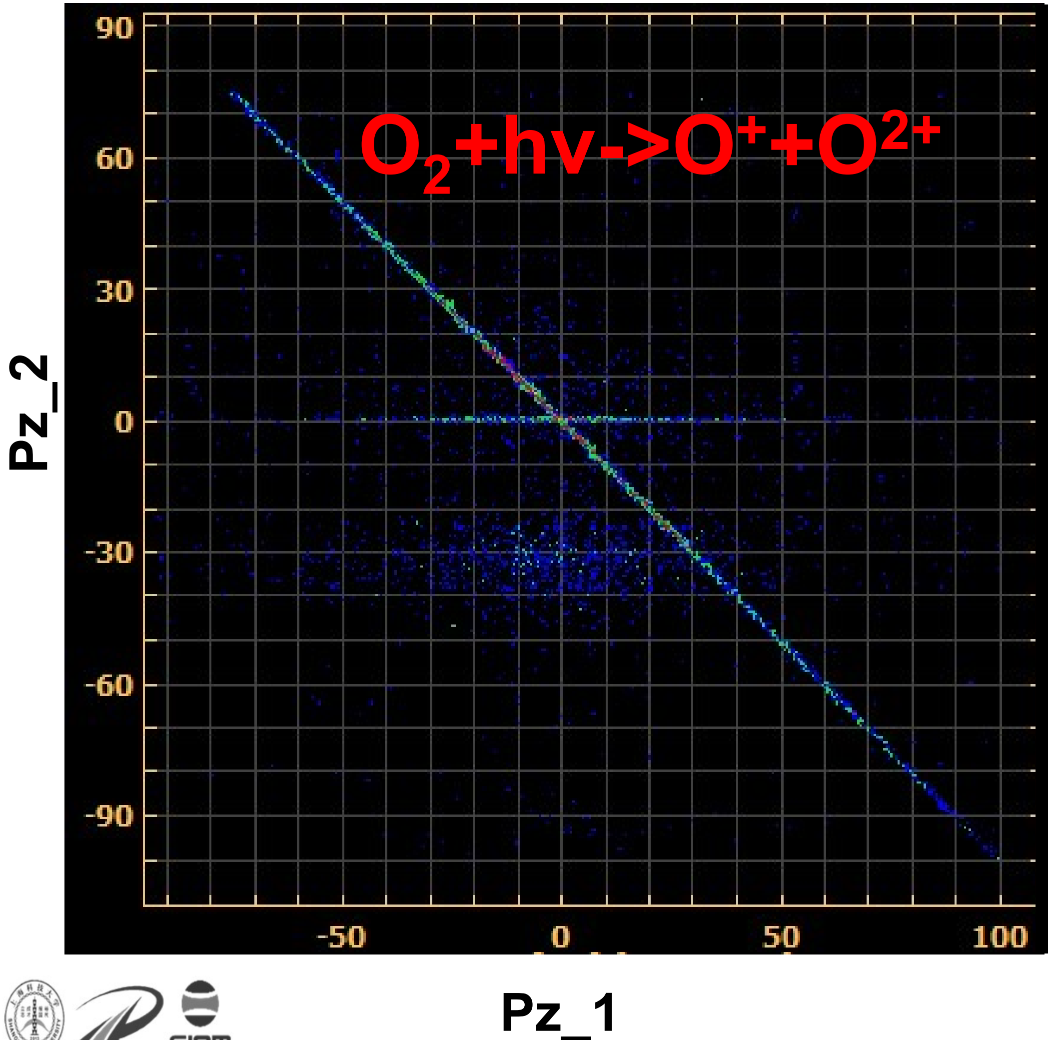


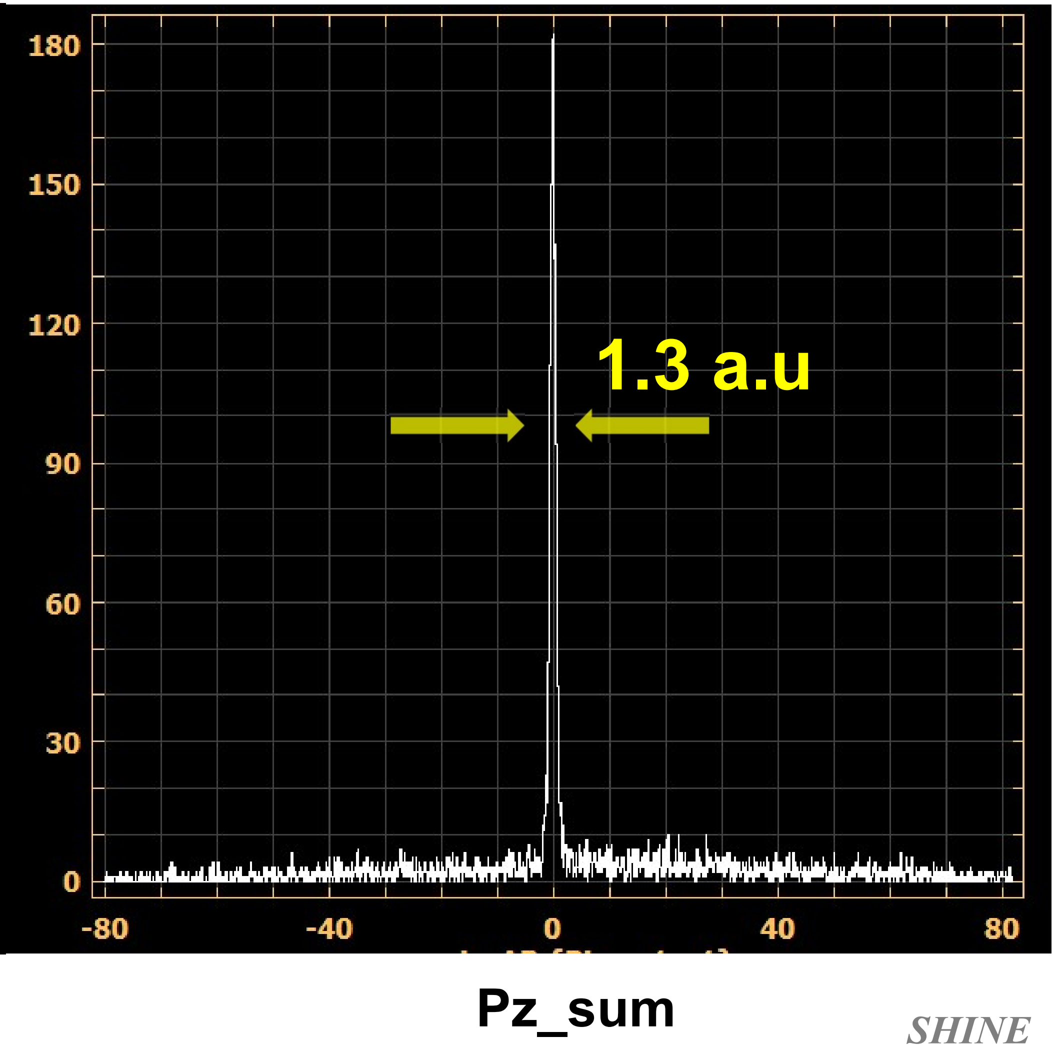


Preliminary results with IR laser

Ionic momentum resolution 1.3/130=1%

PIPICO

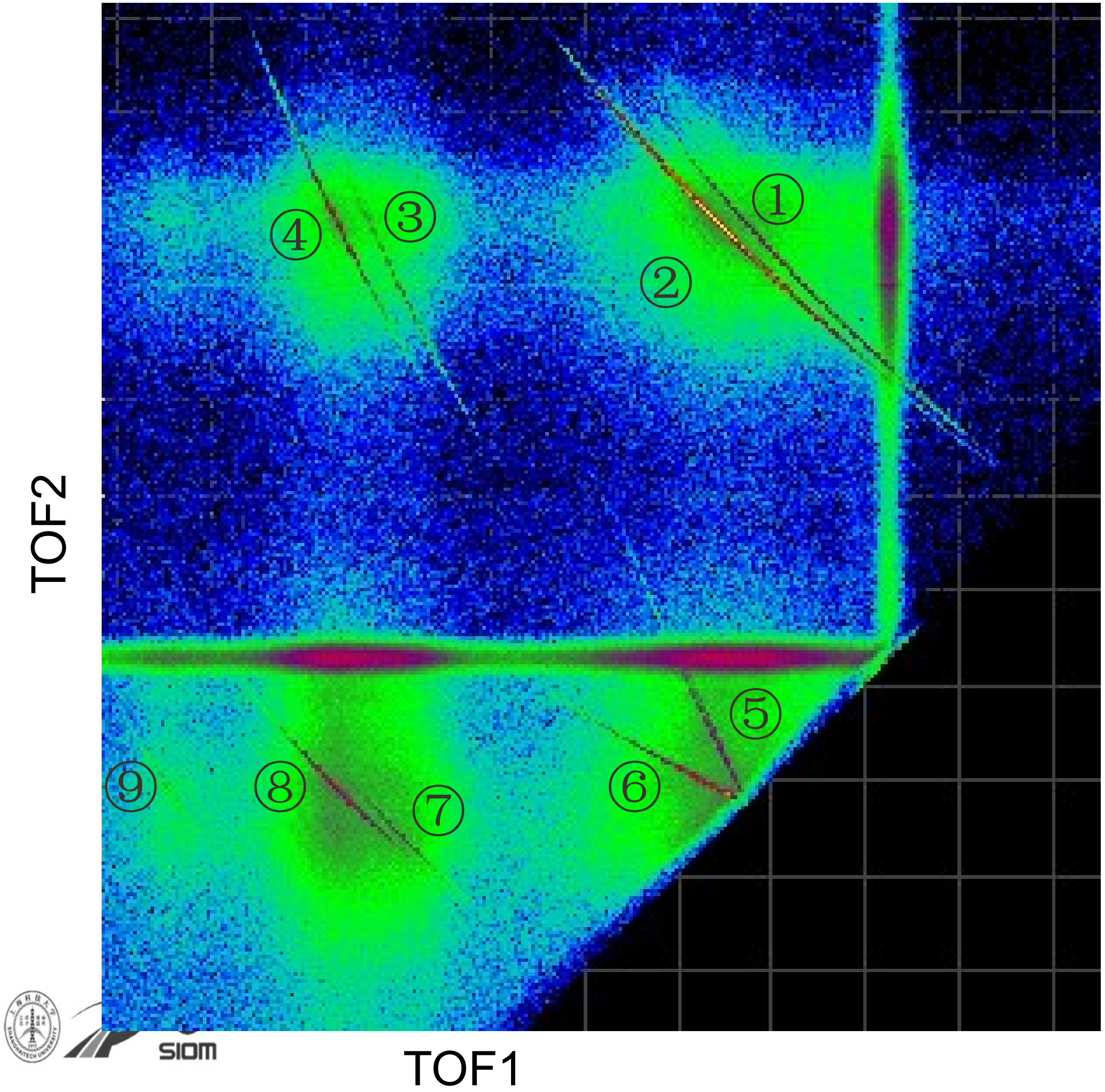




Preliminary results with IR laser

Ionic momentum resolution 1.3/130=**1%**

PIPICO



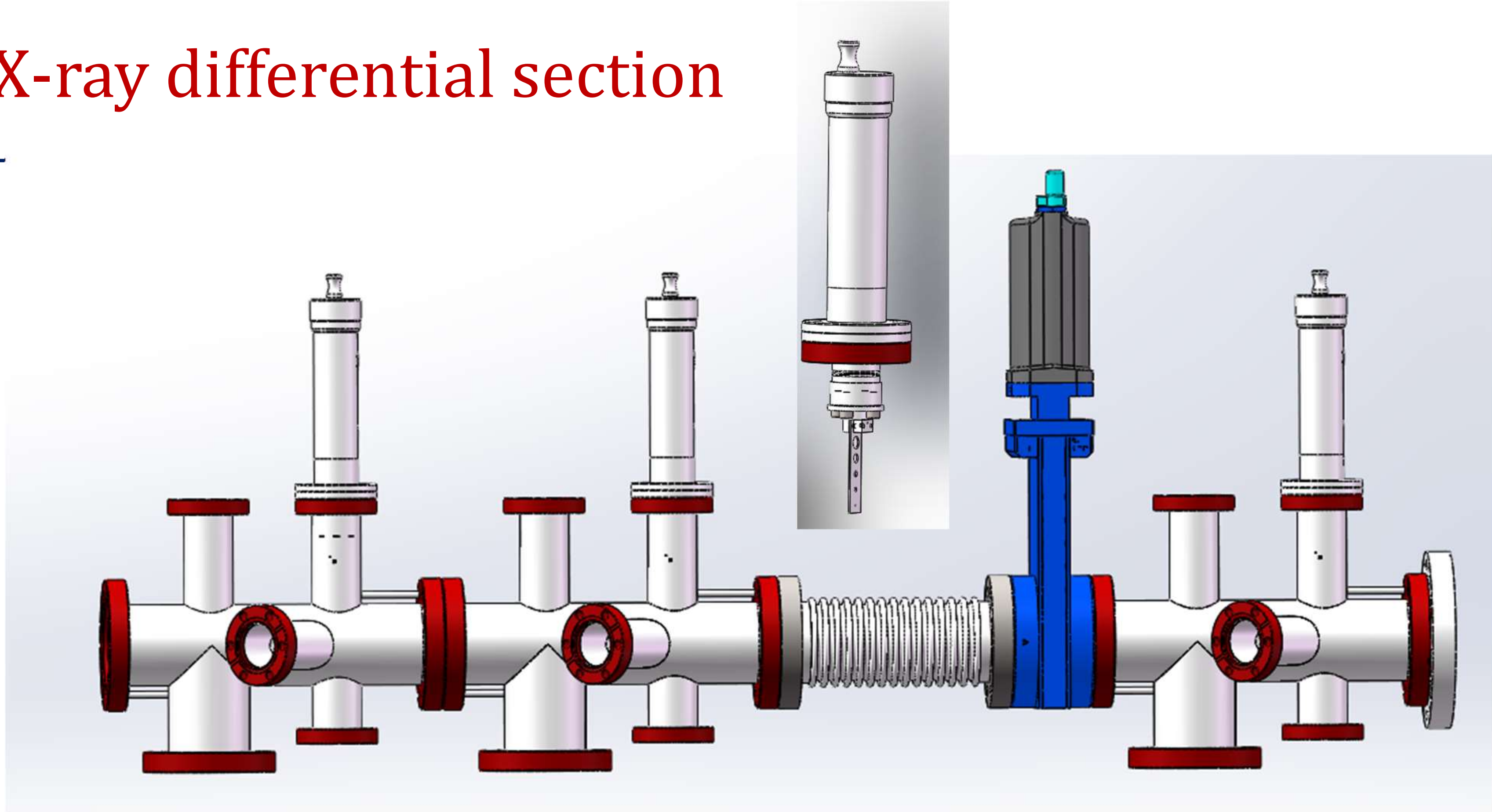
① $N_2O^{2+} \rightarrow N_2^+ + O^+$
② $N_2O^{2+} \rightarrow NO^+ + N^+$

③ $N_2O^{3+} \rightarrow N_2^+ + O^{2+}$
④ $N_2O^{3+} \rightarrow NO^+ + N^{2+}$
⑤ $N_2O^{3+} \rightarrow N_2^{2+} + O^+$
⑥ $N_2O^{3+} \rightarrow NO^{2+} + N^+$

⑦ $N_2O^{4+} \rightarrow N_2^{2+} + O^{2+}$
⑧ $N_2O^{4+} \rightarrow NO^{2+} + N^{2+}$

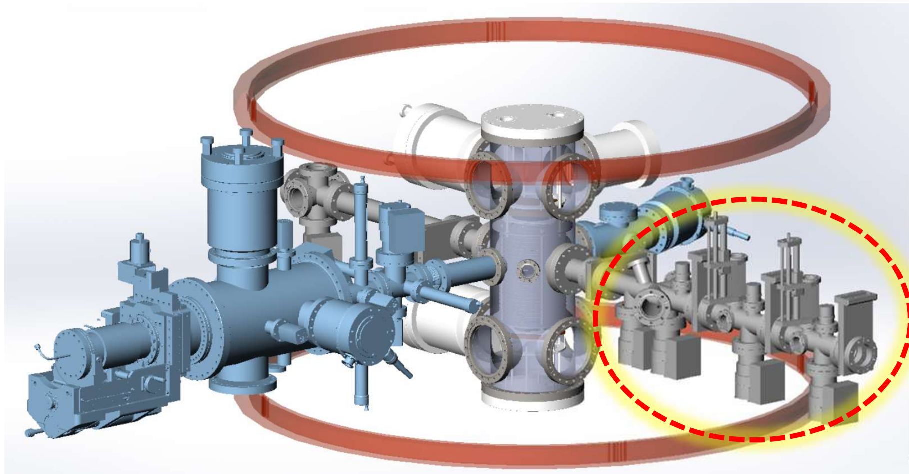
⑨ $N_2O^{5+} \rightarrow NO^{2+} + N^{3+}$

Next step: X-ray differential section

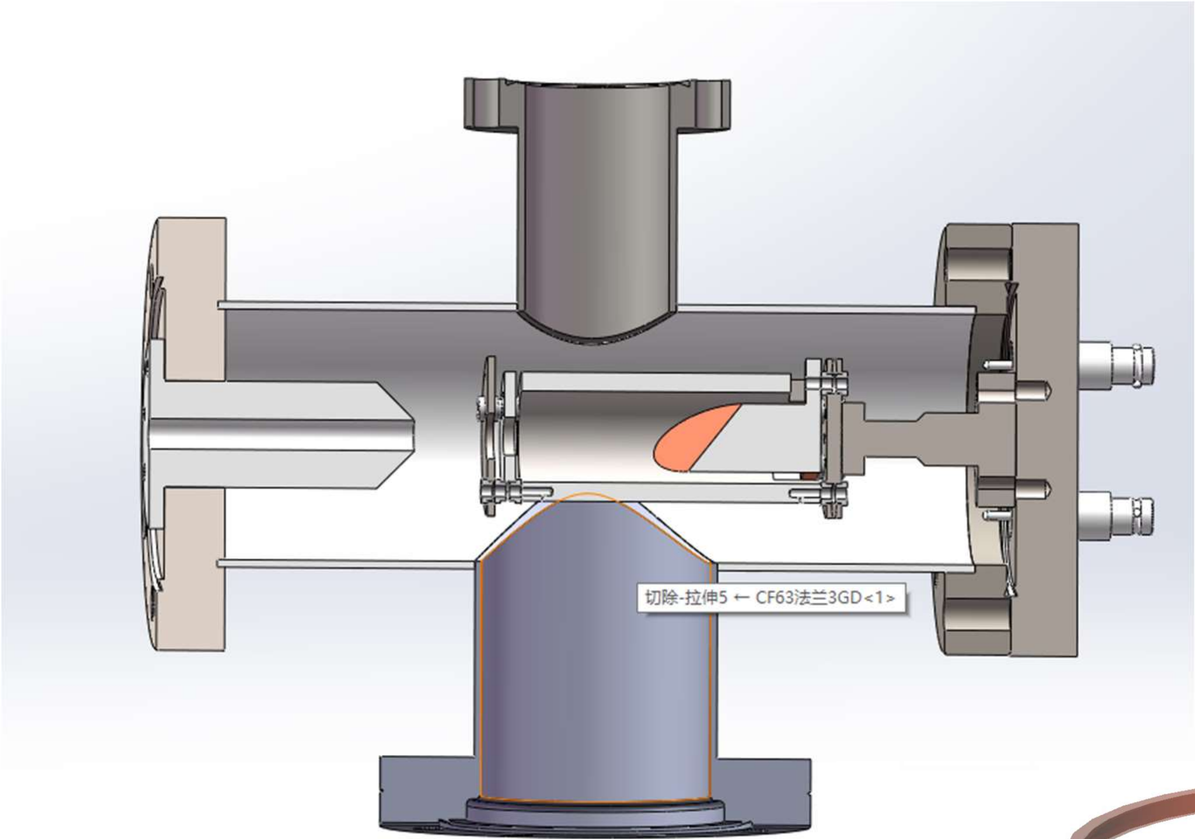


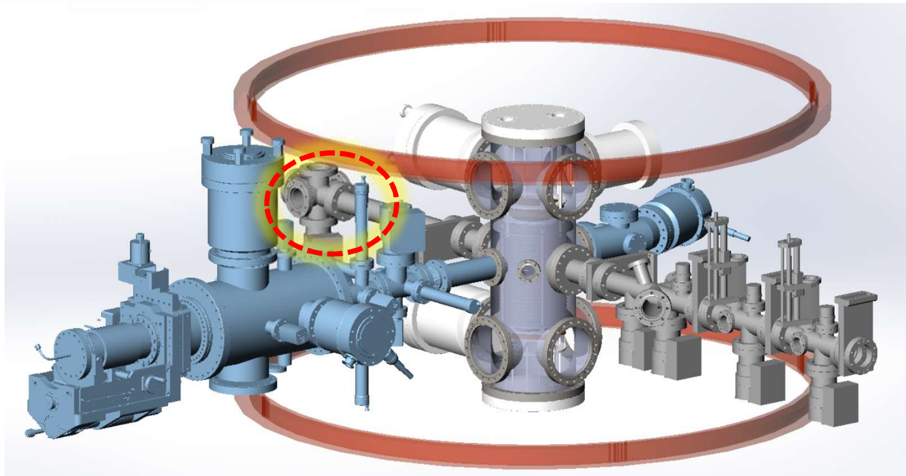
EM mirror

- ✓ The focal length of the EM mirror is 2 meter and the distance of 1.3 m is available
- ✓ 3 aperture guiding systems are placed between the mirror chamber and the main chamber
- ✓ Optical laser coupling chamber is being designed.

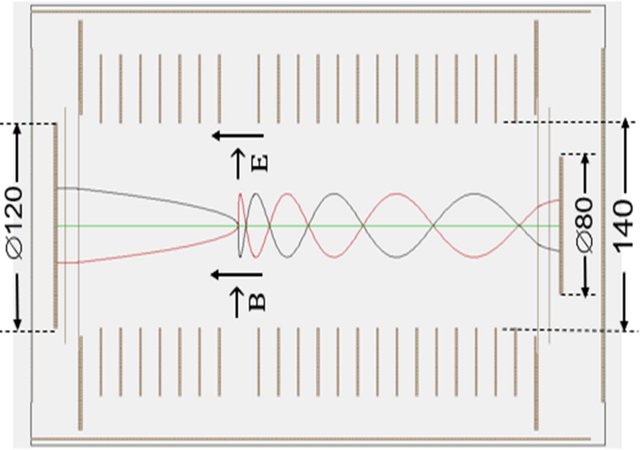


Next step: FEL Dump (Faraday cup)





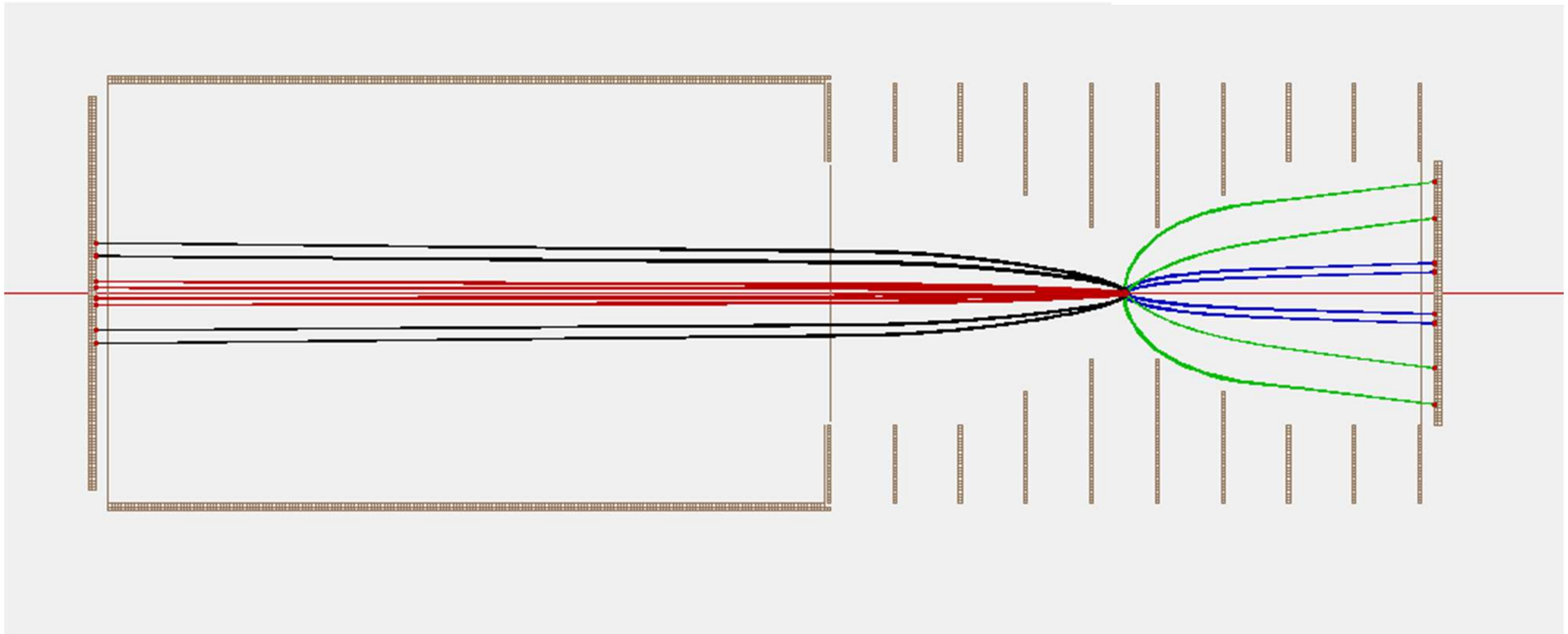
Ongoing: Two-mode Spectrometer



Coltrims mode + VMI mode

Coltrims: coincident ions

VMI: electrons,ions



Ion：

E： 1， 20 eV

Position Y： -0.5mm~0.5mm

ΔE/E： 2%

Electron：

E： 10， 300 eV

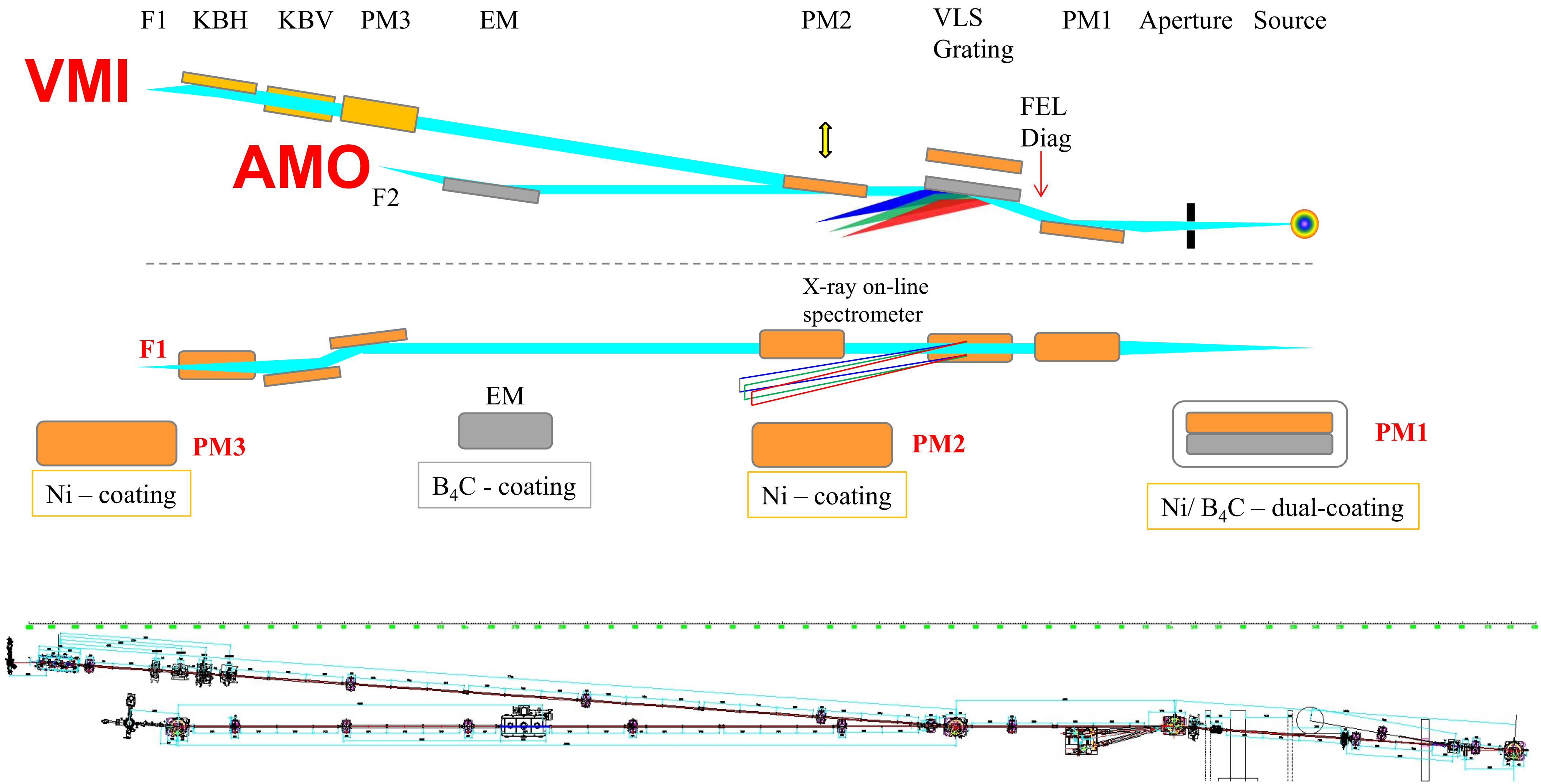
Position Y： -0.5mm~0.5mm

Δ E/E： 1%

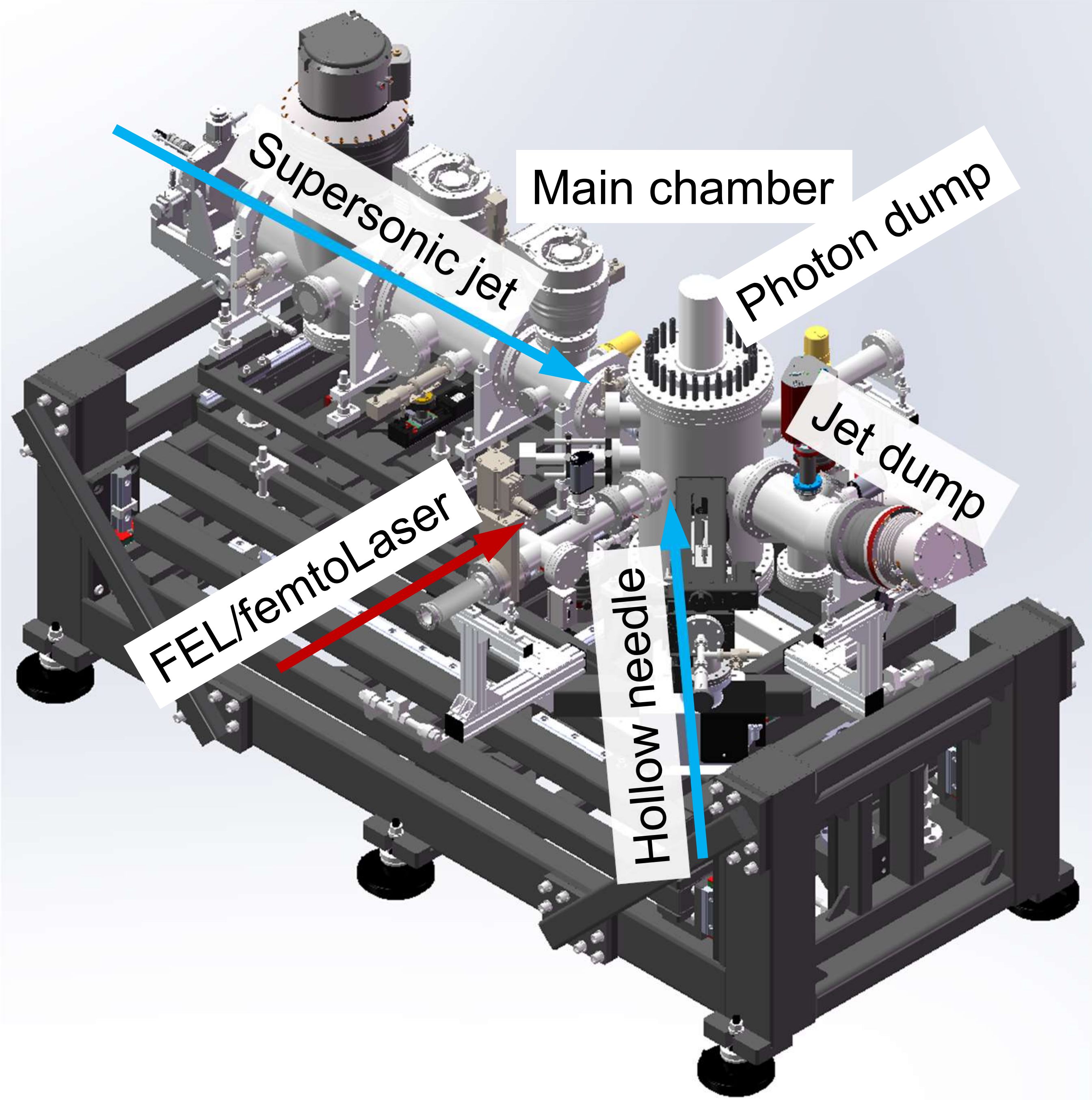
Problems and solutions

- Vaccum: 2*10^-10 mbar→5*10^-11 mbar, NEG pump
- Fast ADC: (2*4 channels, 10 bits, 1.25 Gs/s)
- Less volatile targets: Even-Lavie Valve
- Focus and overlapping: YAG screen for spatial overlapping (under discussions)
- FEL dump： faraday cup
- Optical laser coupling: holey mirror and coupling chamber

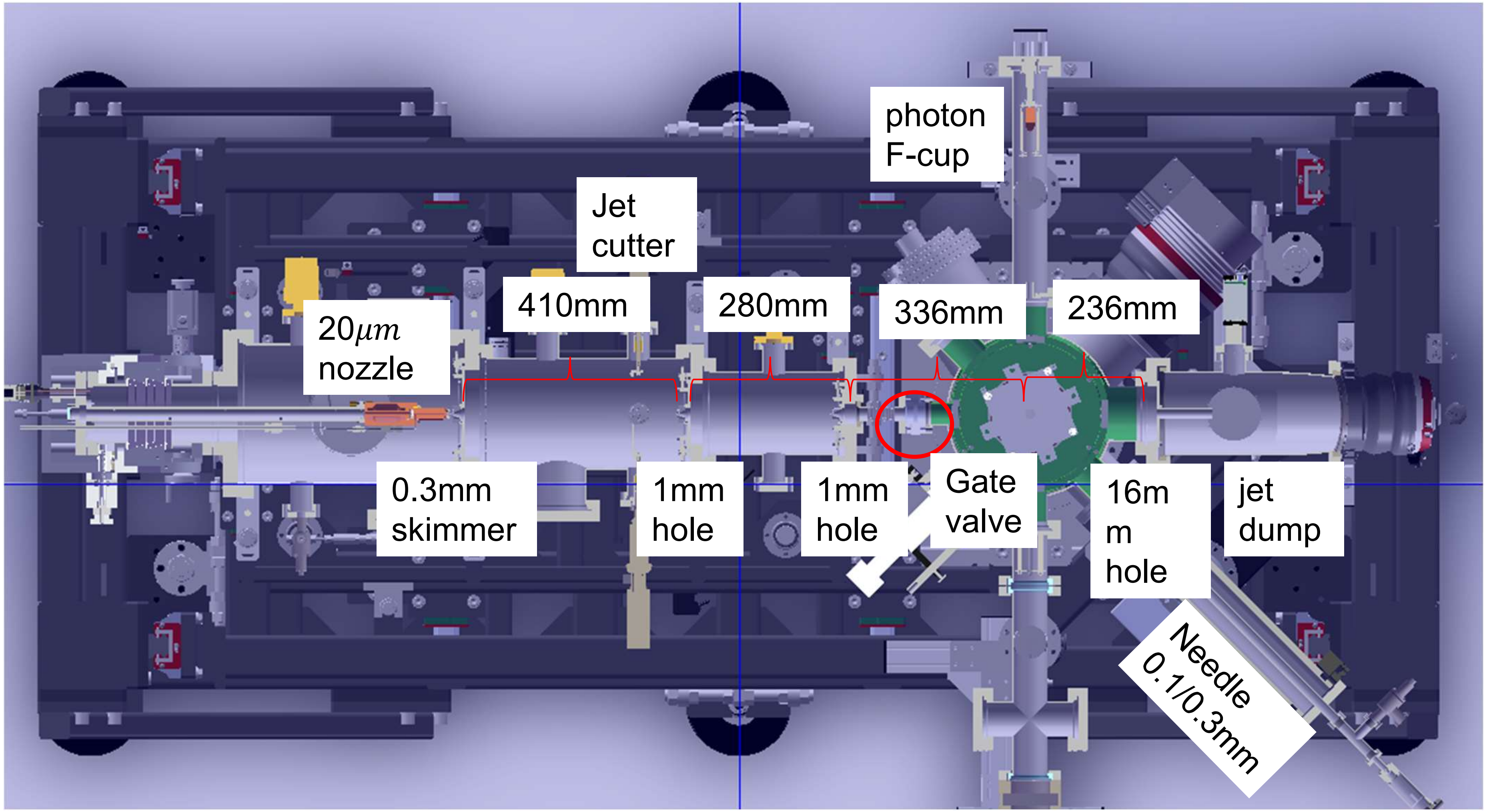
Seeding FEL Beam-line Layout



Composite VMI Spectrometer(Liu Xiaojing)



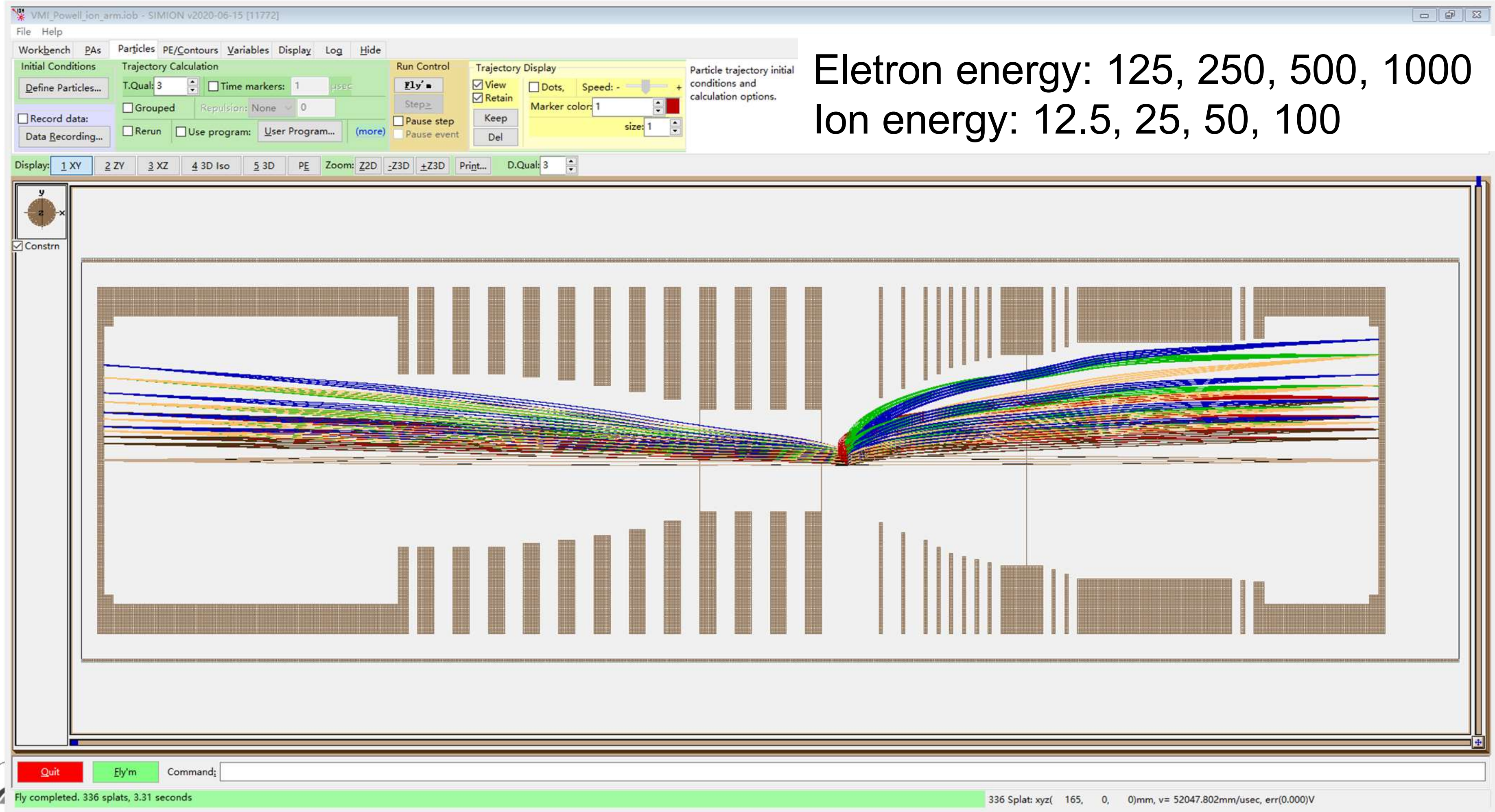
Reaction plane-TOP view



Vacuum:					
Jet off:	5E-8,	2E-9,	7E-11,	7E-11,	1E-10 mbar
Jet on:	1E-3,	3E-6,	2E-10,	7E-11,	1E-10 mbar

Simulation and test results

Electron resolution: 1.7%@500 eV, hv=600 eV
Ion resolution: 3.7%@5.6 eV, 800 nm



Eletron energy: 125, 250, 500, 1000
Ion energy: 12.5, 25, 50, 100

AMO Perspectives at SXFEL

- ✓ **Multiphoton measurements**

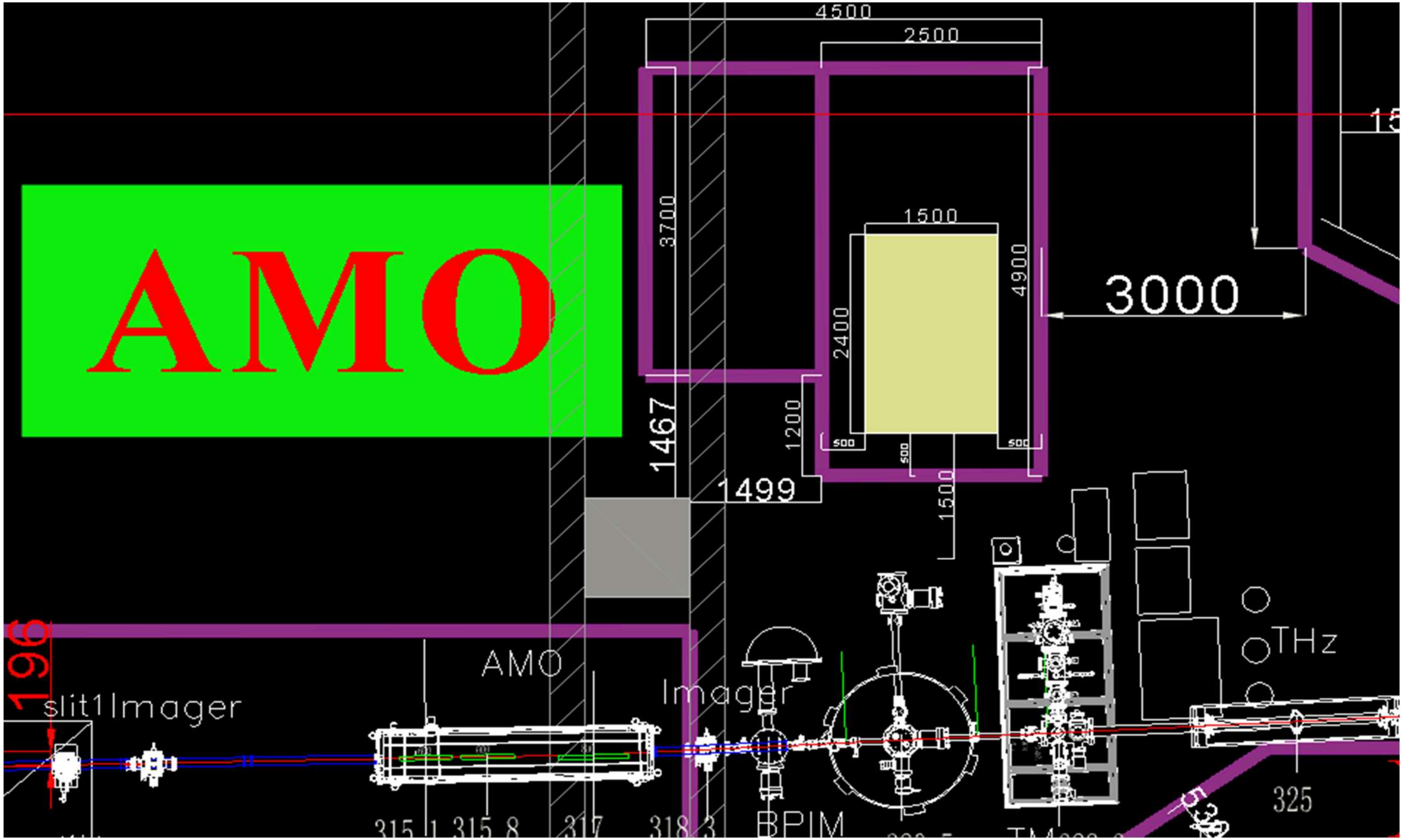
  nolinear processes of atoms; coherent two-photon control; (limited by SXFEL intensity)

- ✓ **Time-resoved molecular coulomb explosion**

  XUV-pump/IR-probe (limited by pusle duration and repetition rate)

AMO endstation at SHINE (design conception)

AMO layout (three focuses separated by about 1.5 m)

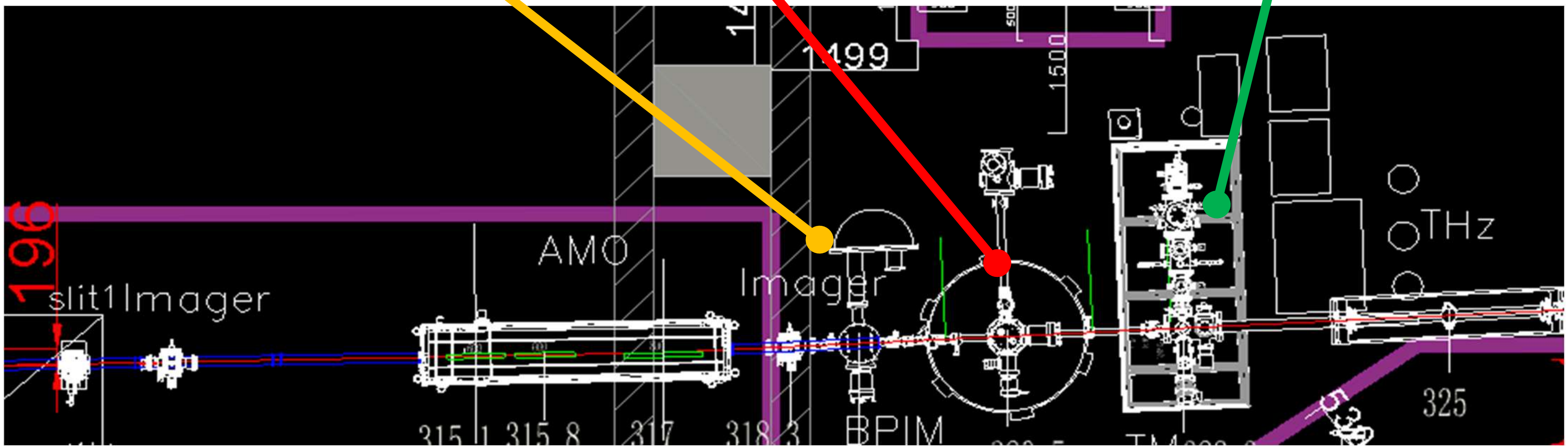


AMO endstation at SHINE (design conception)

eTOFs:
High resolution electron spectroscopy (fast electron, up to 1MHz)

COLTRIMS: Coincident electron and ion measurements (slow electron, up to 1MHz)

MB/VMI: electron and ion measurements (up to 10 KHz)



AMO endstation at SHINE (design conception)

Beamline Performances:

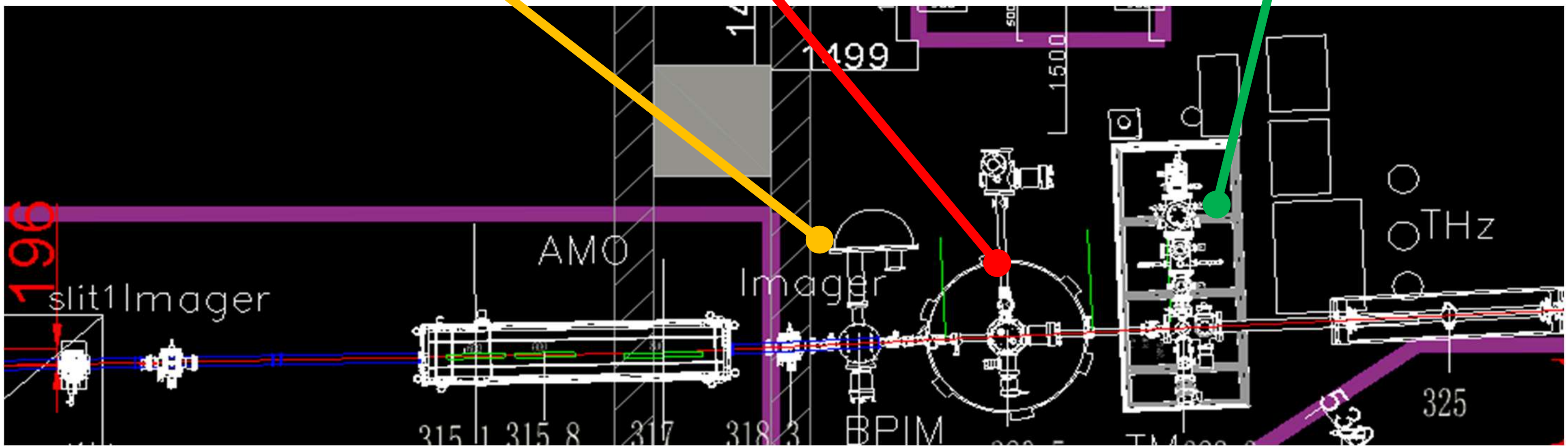
- ✓ **Photon energy: 0.4–3 KeV**
- ✓ **Repetition rate: up to 1 MHz**
- ✓ **Intensity: 10^{11} – 10^{16} W/cm^2**
- ✓ **Focus: <2 μm**
- ✓ **Pulse duration: 10 fs**

More requirements and suggestions for AMO endstation are highly welcome!

eTOFs: High resolution electron spectroscopy (fast electron, up to 1MHz)

COLTRIMS: Coincident electron and ion measurements (slow electron, up to 1MHz)

MB/VMI: electron and ion measurements (up to 10 KHz)



AMO Science at FELs

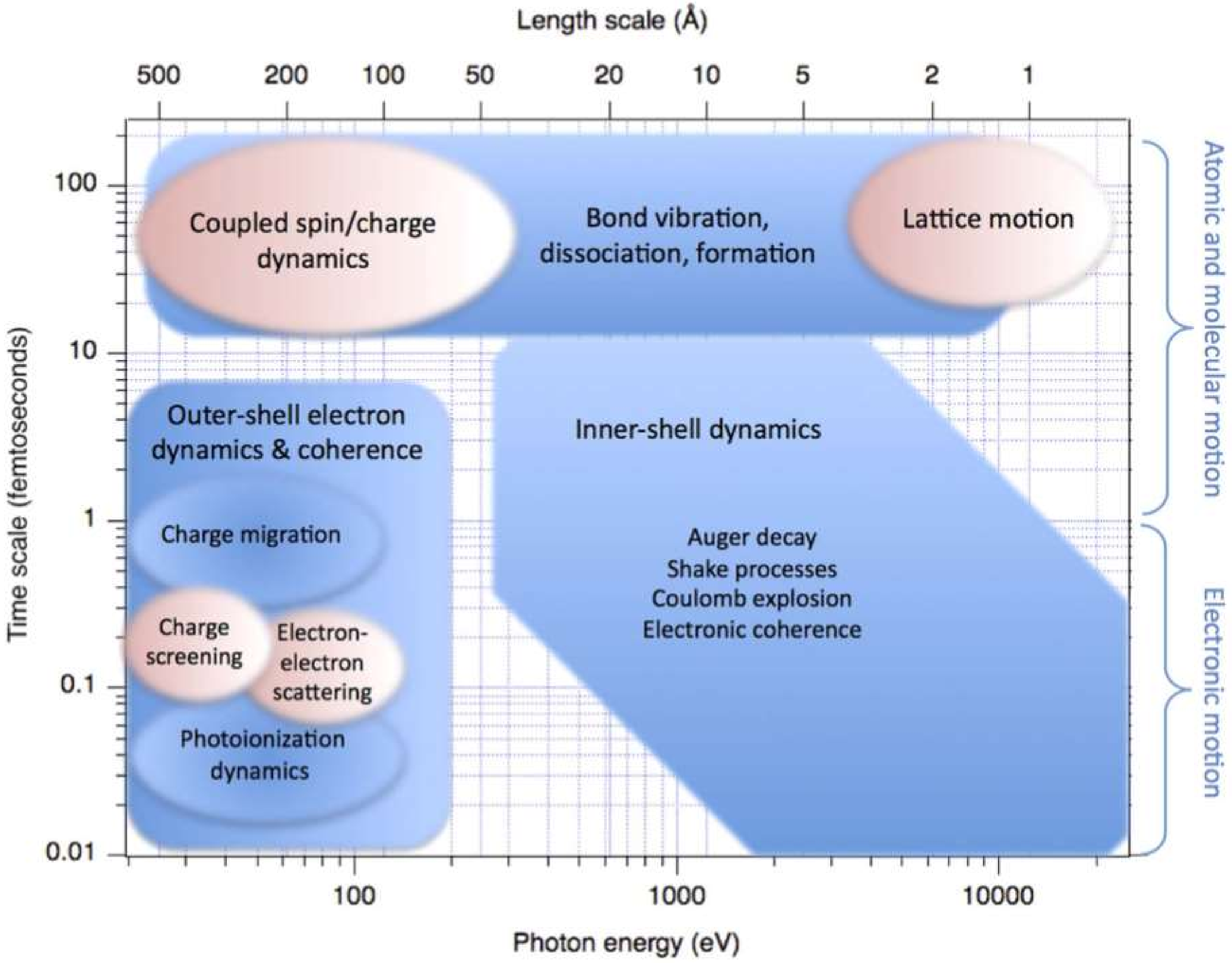
- ✓ **Multiphoton processes in atoms and molecules**

  inner shell excitation ionization, Auger decay, Autoionization, super-excitation, coherent control etc.

- ✓ **Ultrafast atomic and molecular dynamics**

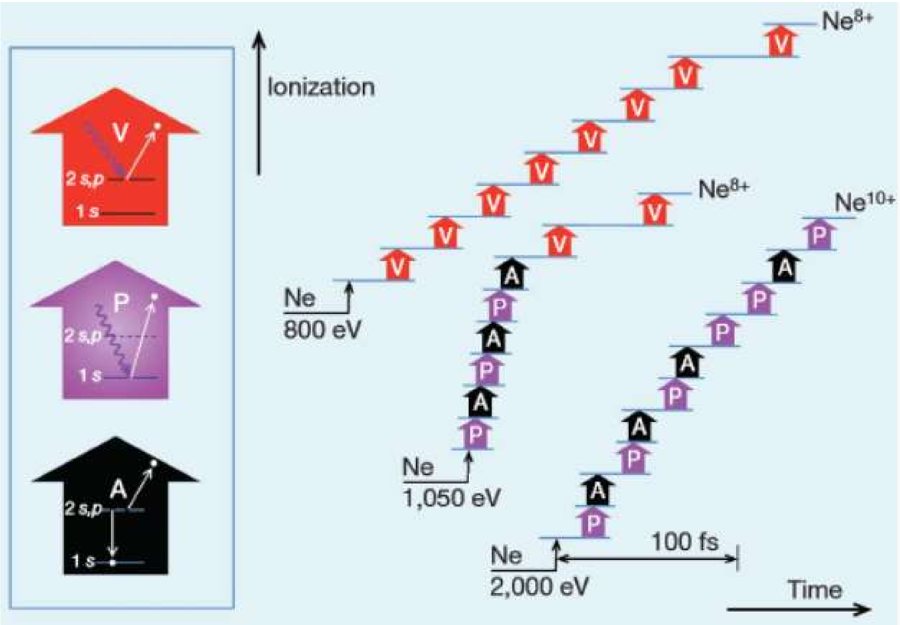
  electron relaxation, change of molecular structures, charge transfer, ICD, isomerization, breaking and formation of molecular bond, diffraction of molecular structures, nuclear motion, electron ionization in reaction coordinate etc.

AMO Science at FELs

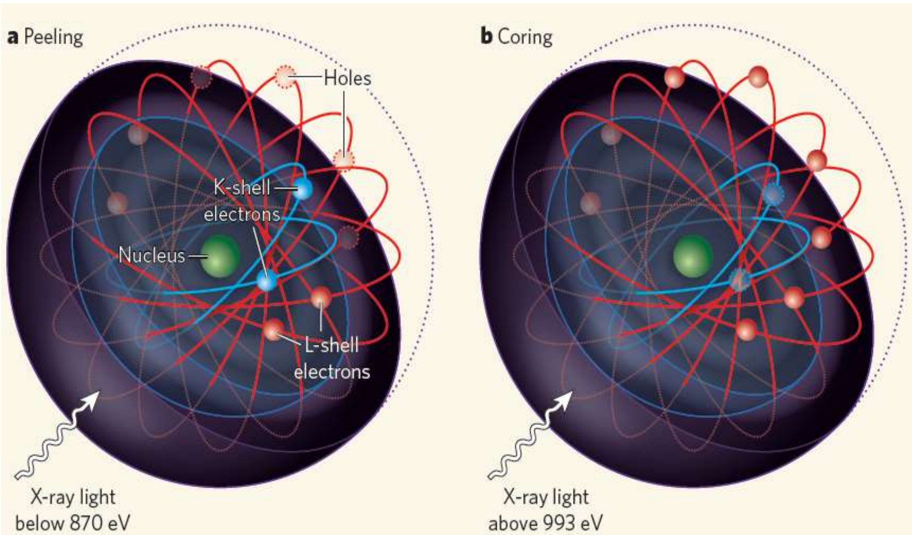


L. Young et al., JPB 51, 032003 (2018)

Multiple ionization of atoms and molecules

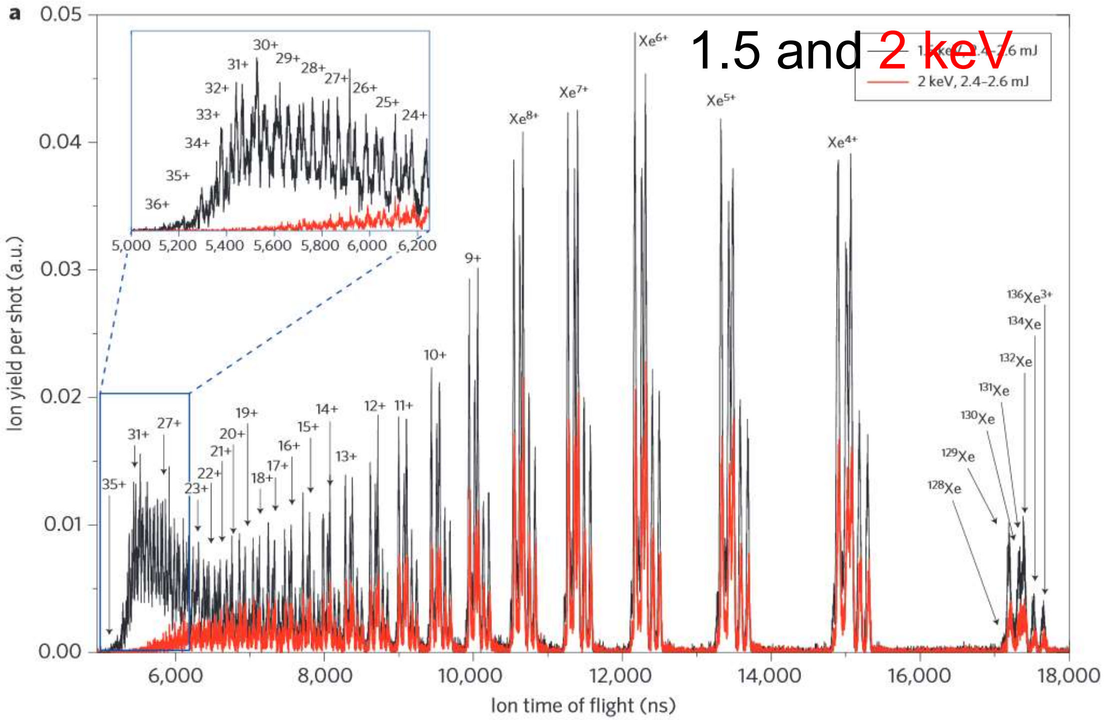


hollow atoms， inner shell vacancies，
Young, Nature 466, 56–61 (2010)



Resonance-enhanced ionization for heavy atoms

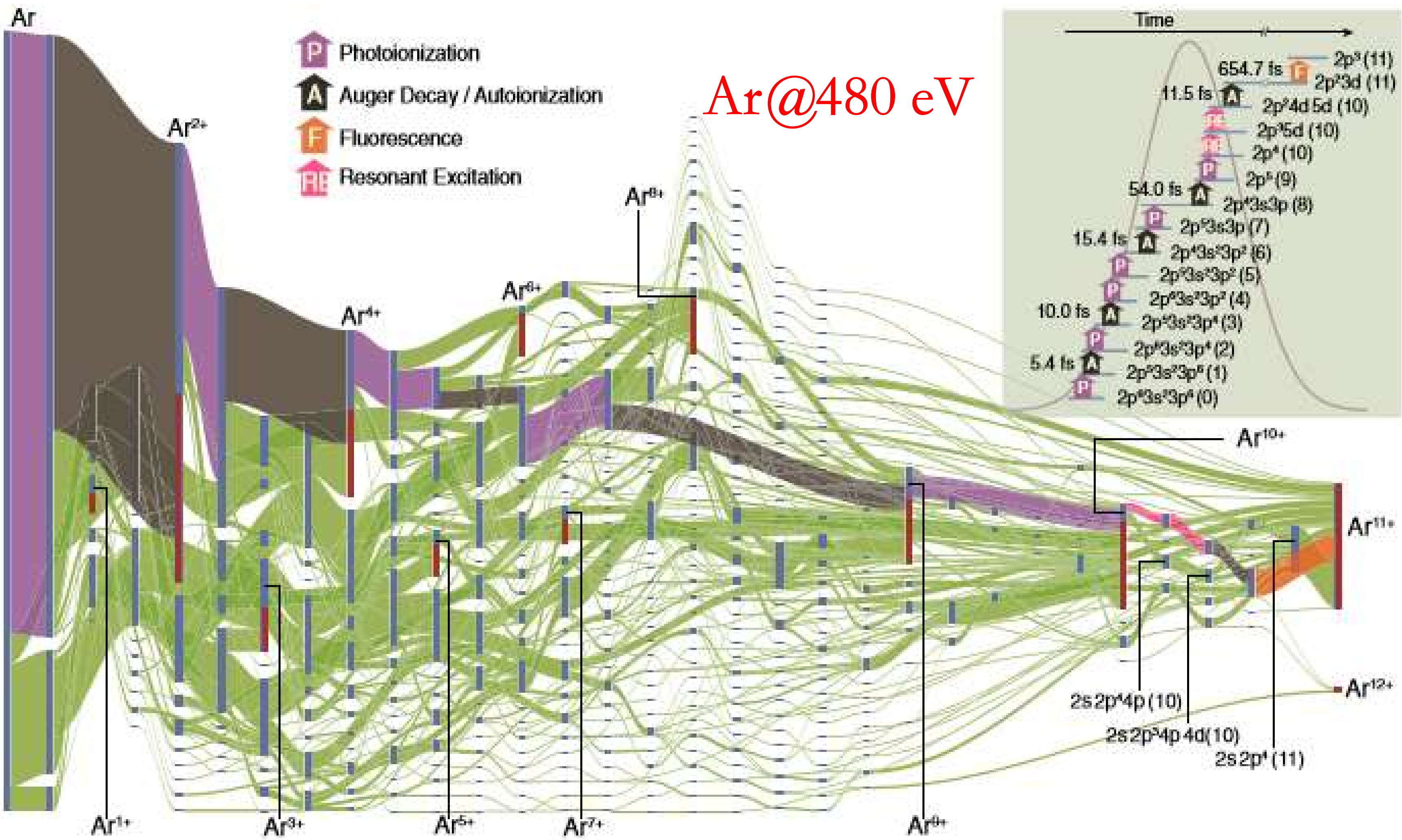
1.5 and 2 keV



Rudek, Nature Photonics 6, 858 (2012)

Multiple ionization of atoms and molecules

Monte Carlo simulations: photoionization, resonance-enhanced, Bound-bound transitions, Auger decay, and fluorescence processes



Electron configurations

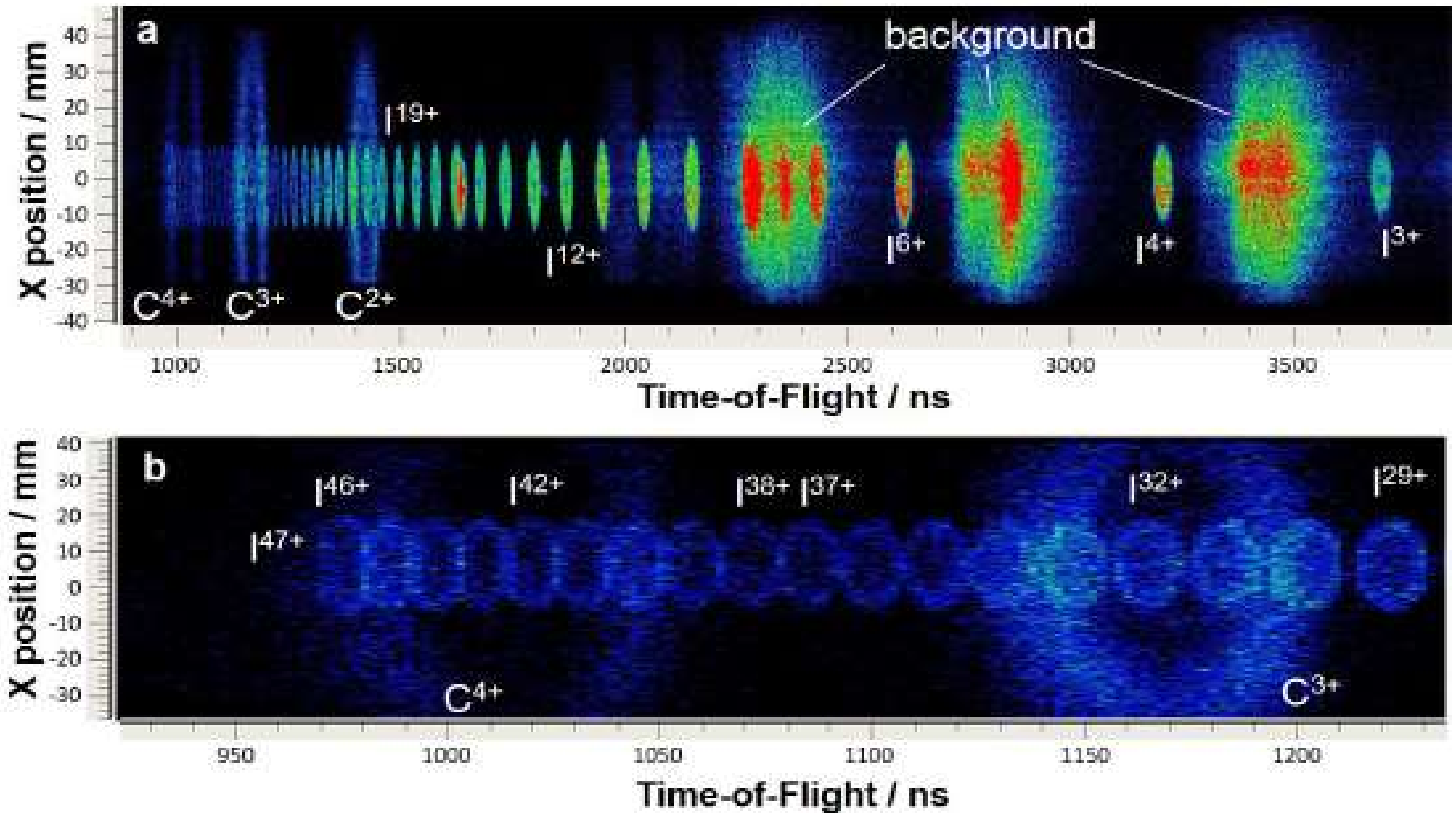
Transition probabilities

Ho et al PRL 113, 253001 (2014)

Multiple ionization of atoms and molecules

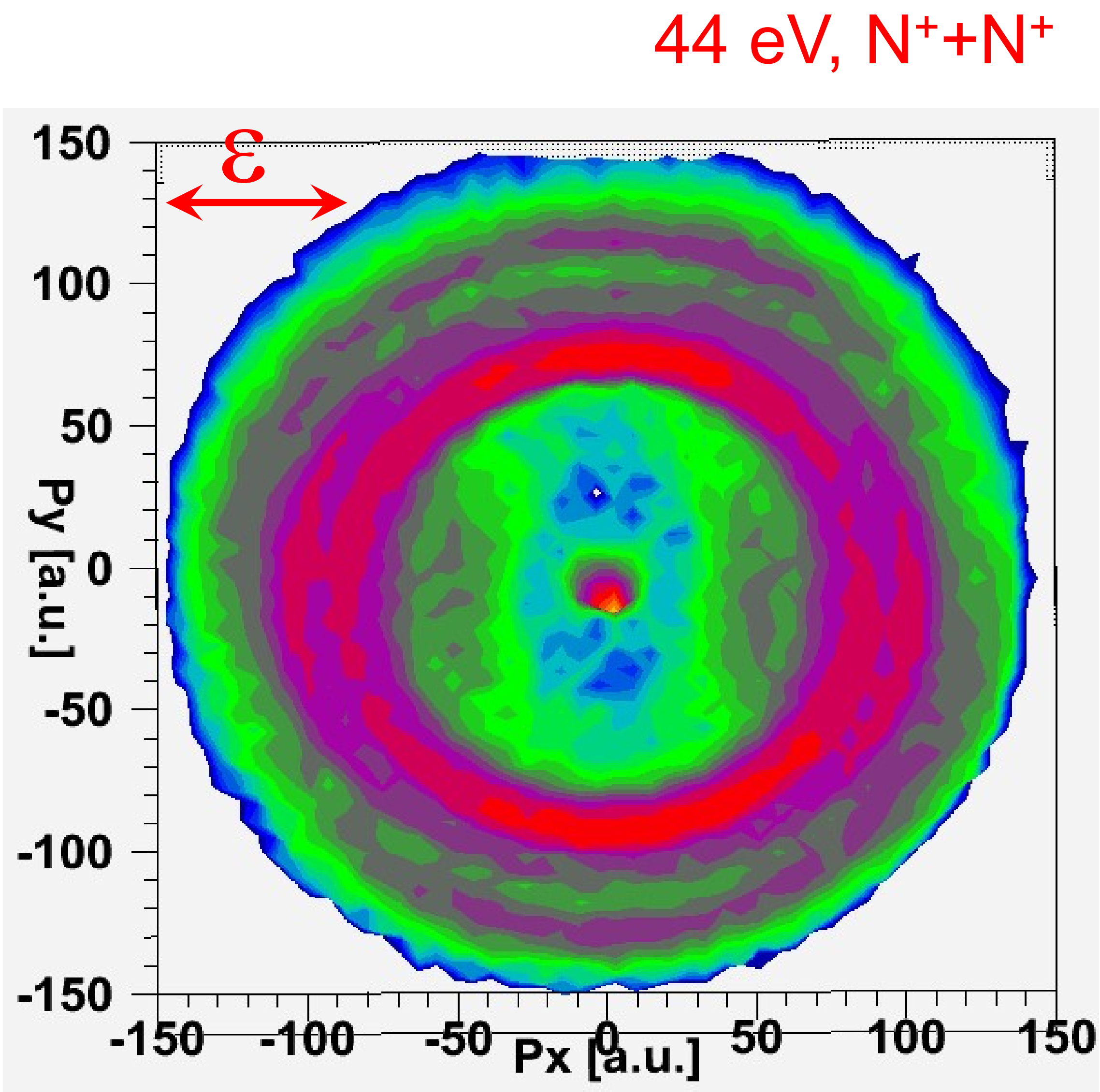
Molecular black hole： up to I^{47+},
complex charge transfer

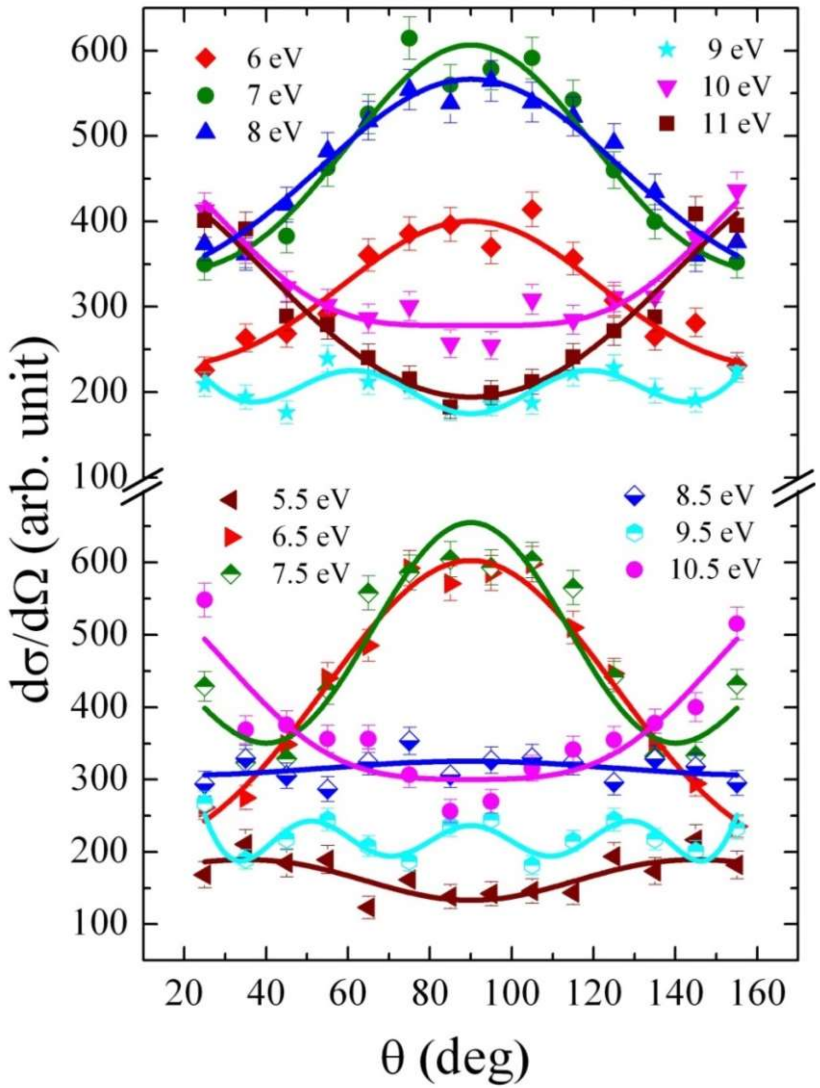
CH_3I



Artem et al., Nature 546, 129 (2017)

Multiple ionization of atoms and molecules

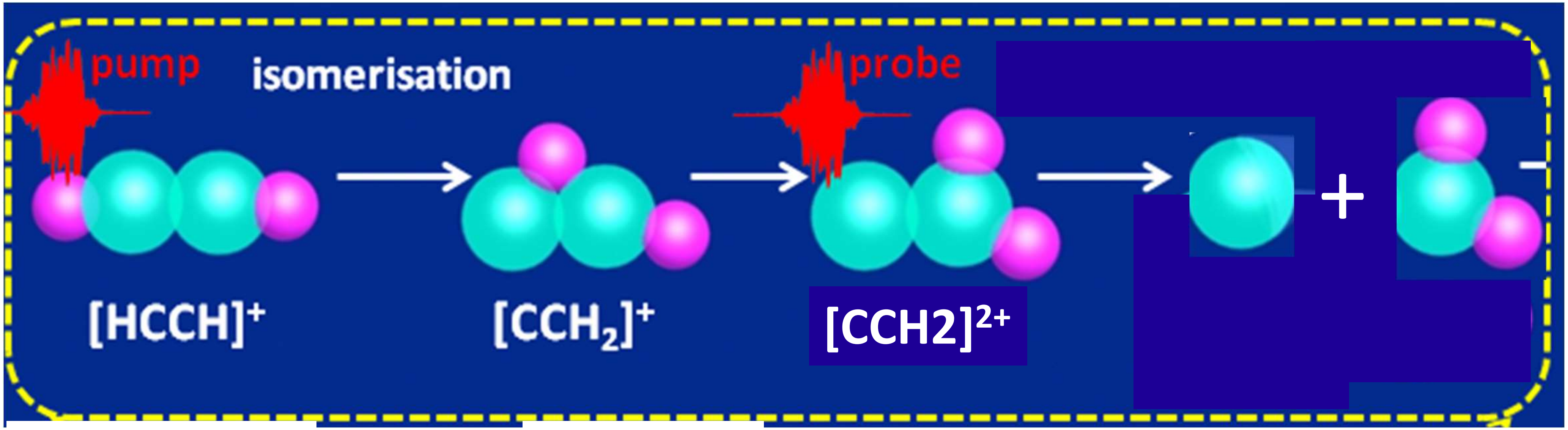


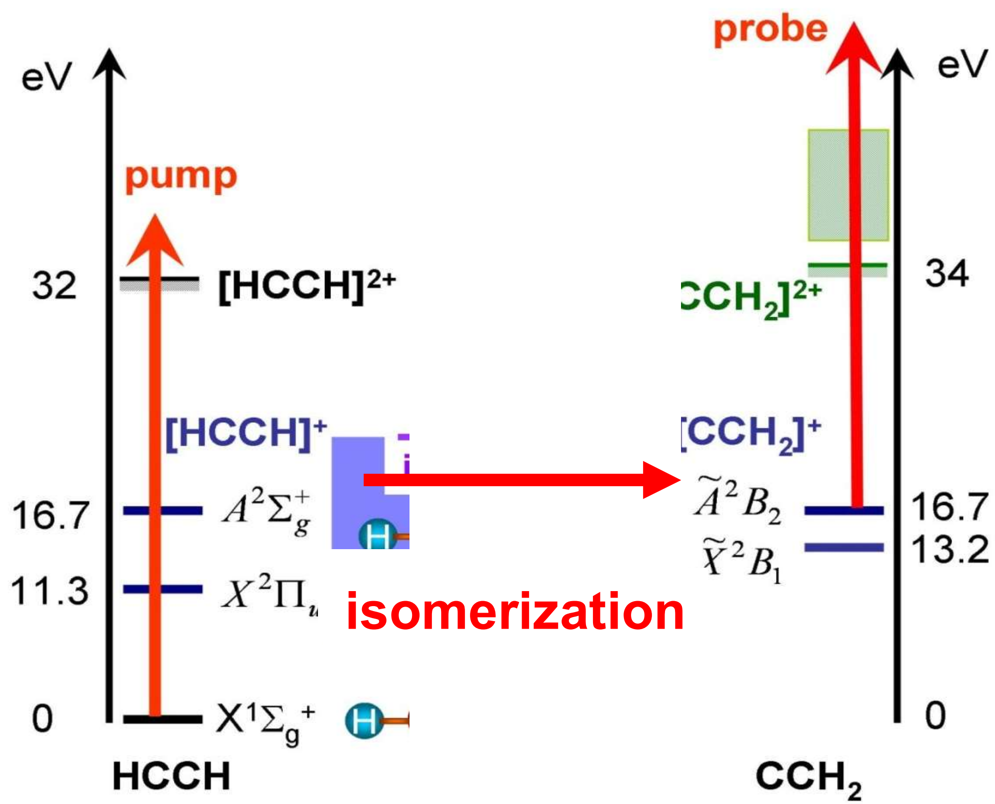


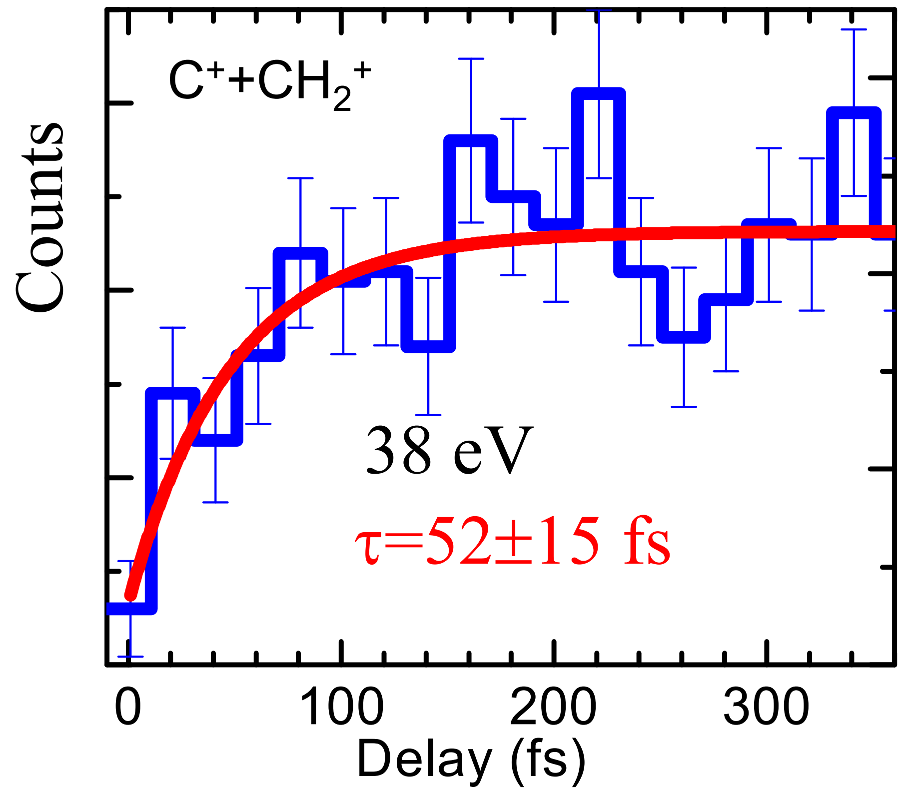
Jiang et al., Phys. Rev. Lett. 102,123002 (2009)

Molecular reactions: isomerization

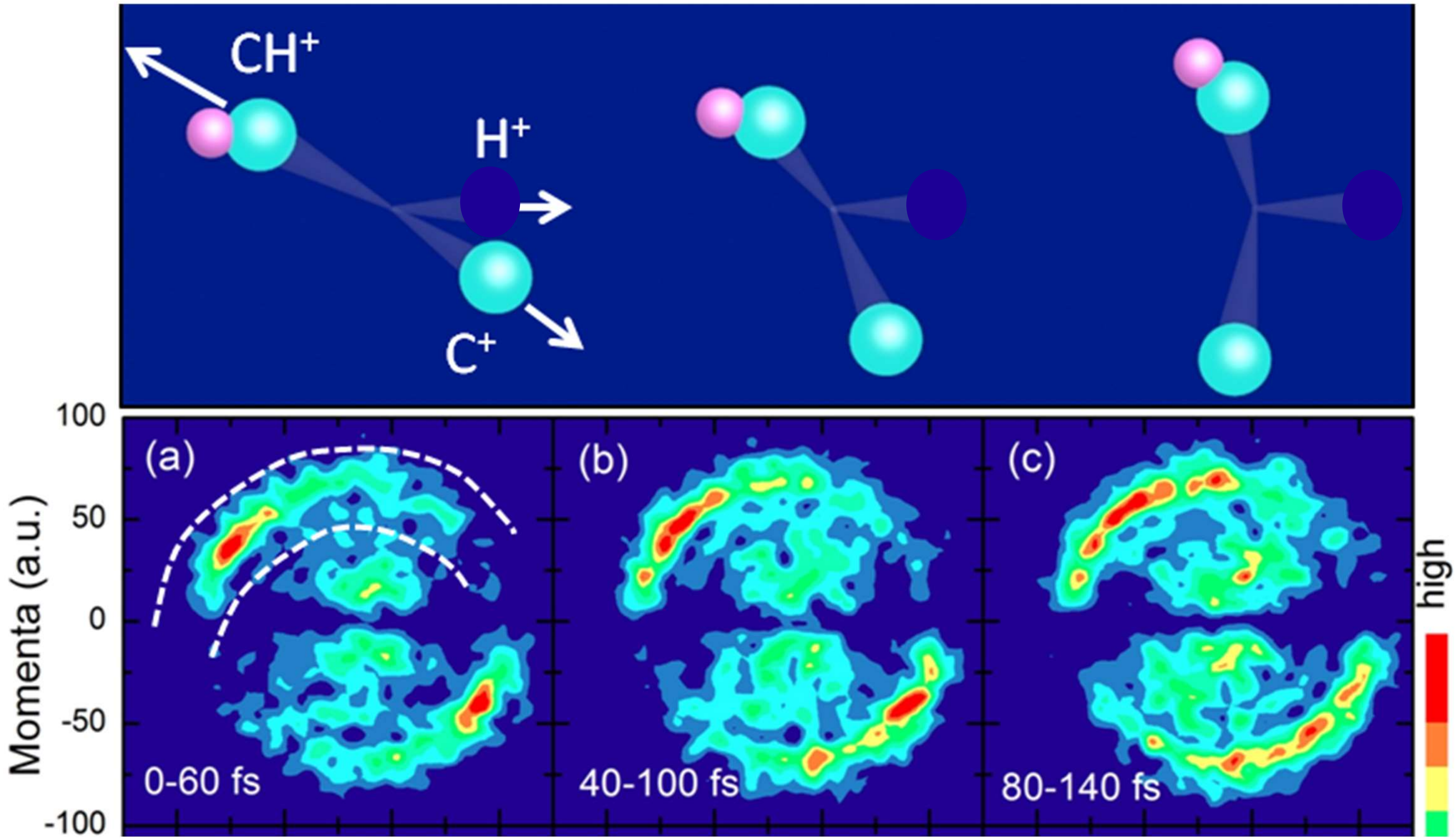
Jiang et al., Phys. Rev. Lett. 105, 263002 (2010)





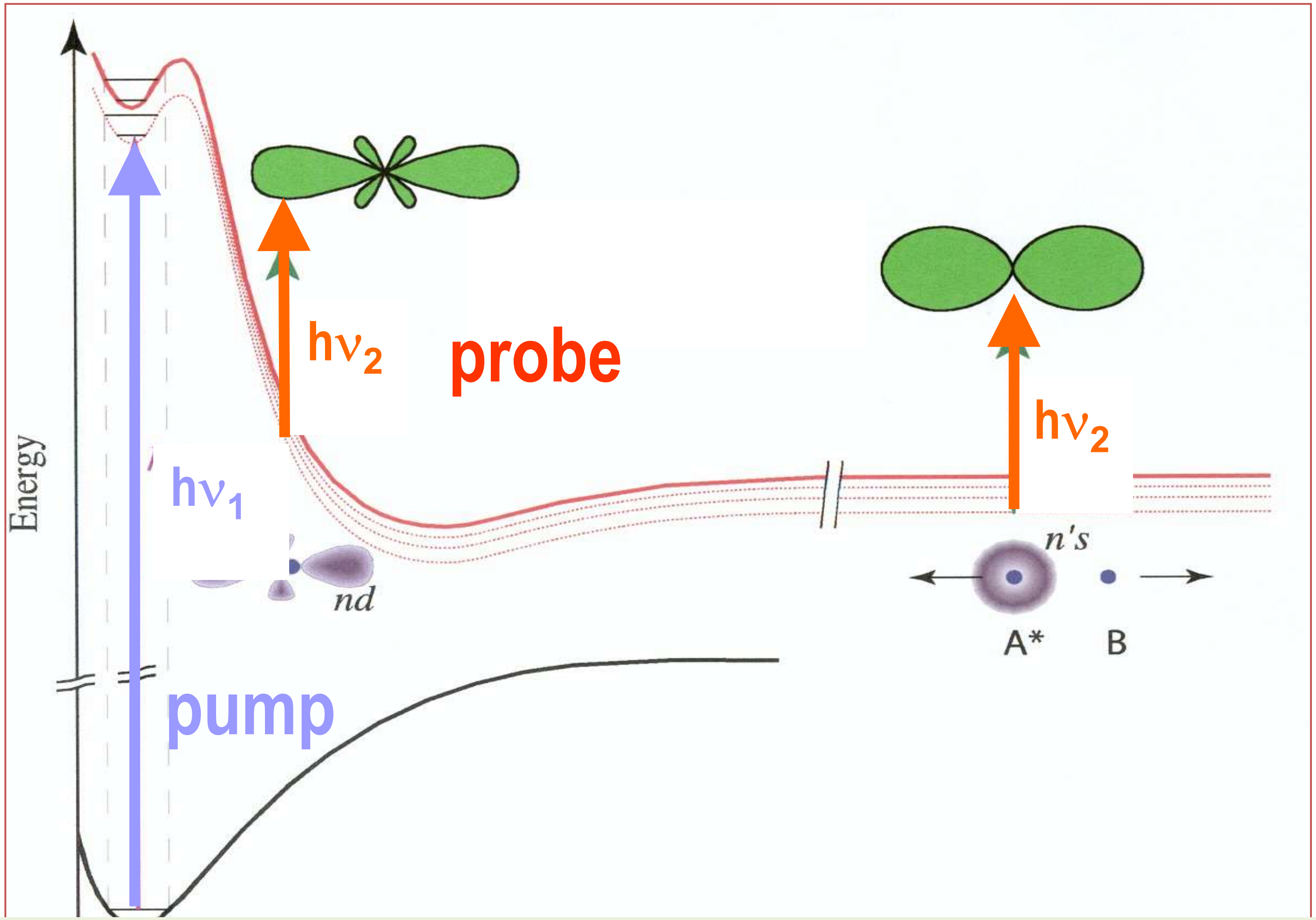


Molecular reactions: isomerization



Y.H. Jiang et al. arXiv:1402.4874

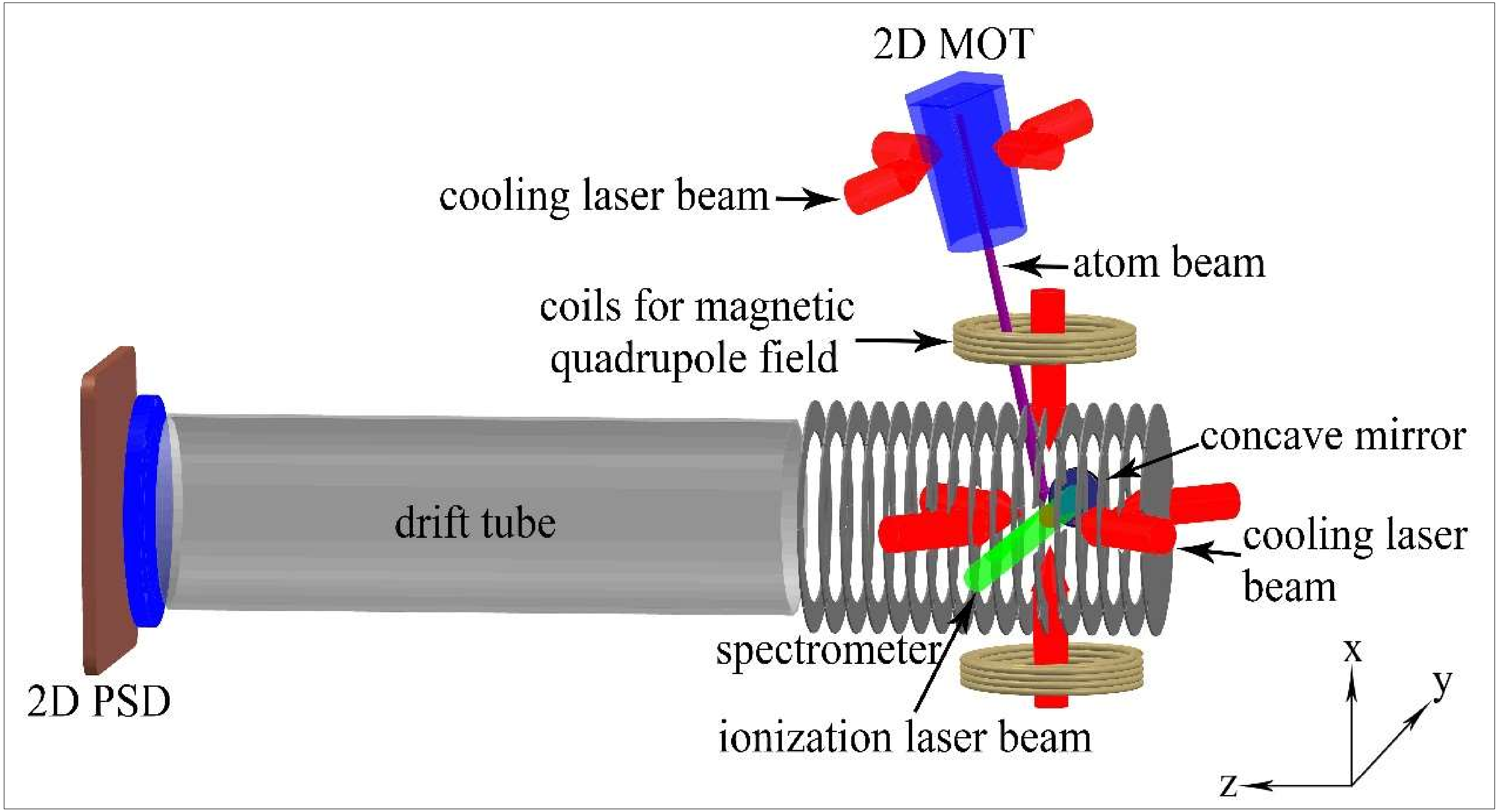
Time-evolution of electron distributions in the molecular frame



High repetition FELs are needed for photoelectron photoion coincident detection!!

Magneto-optical trap recoil ion momentum spectroscopy (MOTRIMS) for Rubidium: combination of ultrafast and cold atom

Structures: Laser locking system; 2D MOT; 3D MOT; spectrometer and science chamber; electron and ion detectors; data taking system; vacuum system, femtosecond laser



Li et al., Journal of Instrumentation 14, 02022 (2019)

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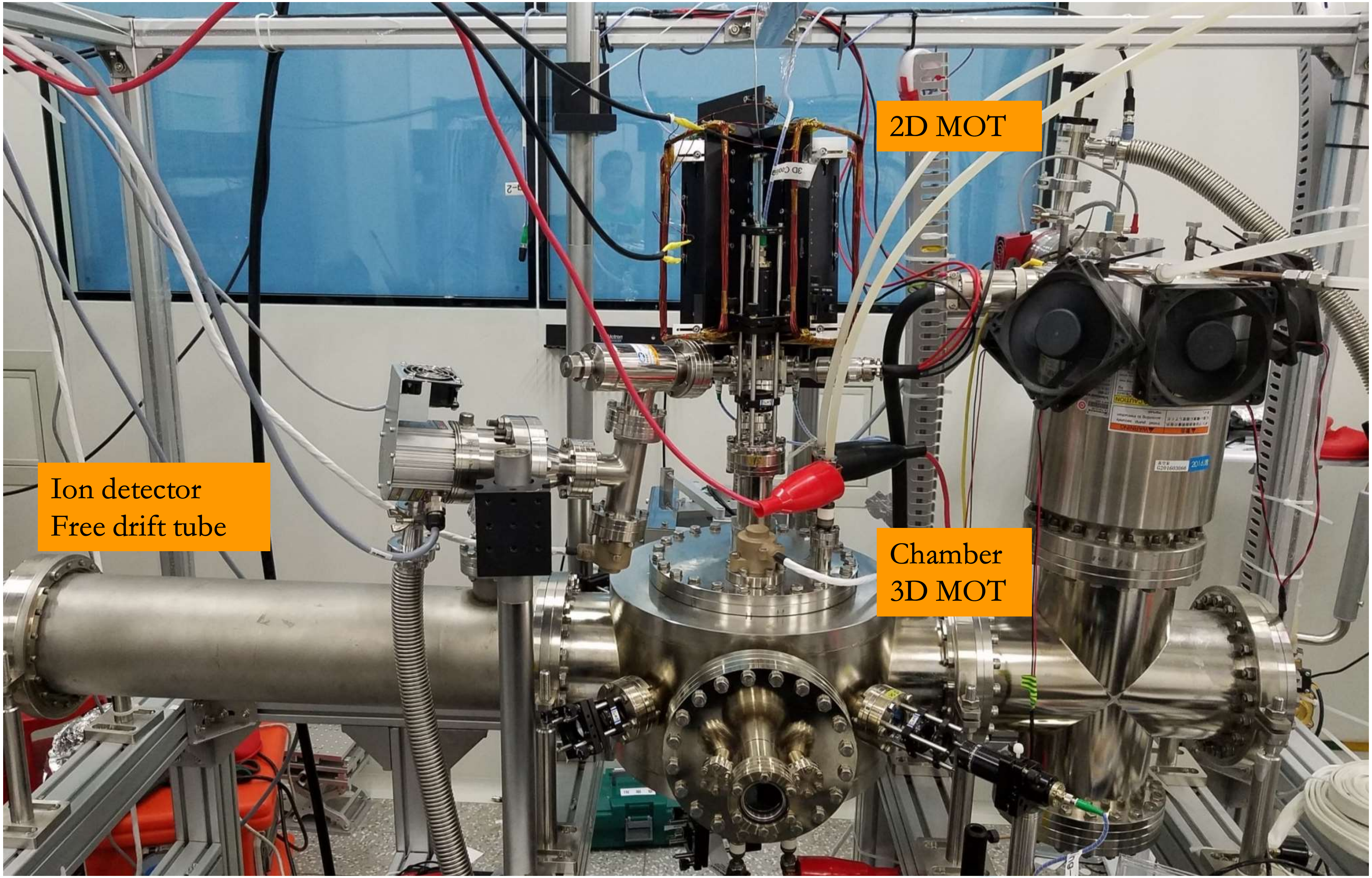
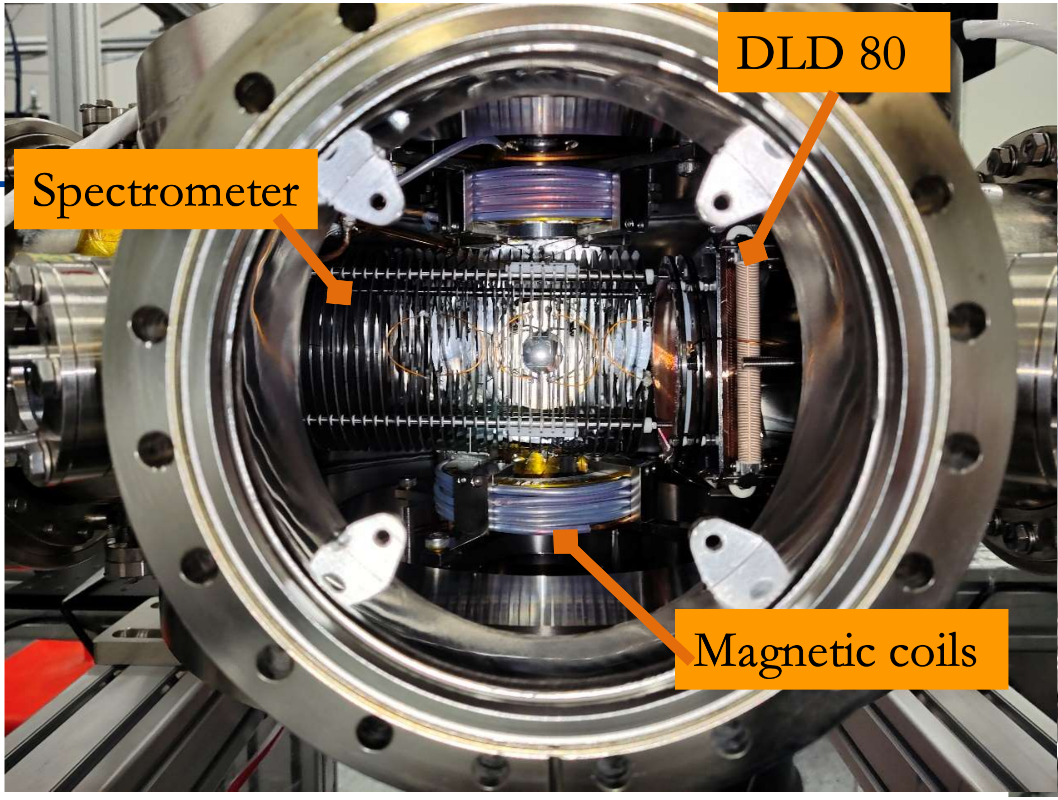
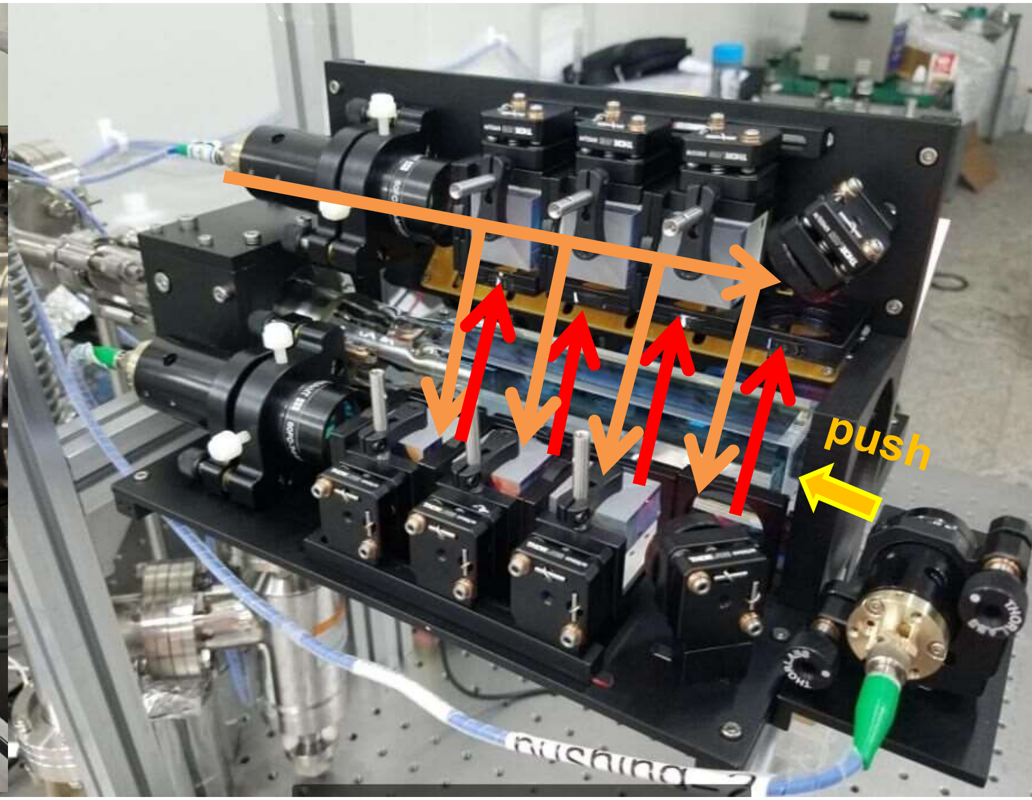
SHANGHAI ADVANCED RESEARCH INSTITUTE, CHINESE ACADEMY OF SCIENCES

Rb-Motrims




DLD 80
Spectrometer
Magnetic coils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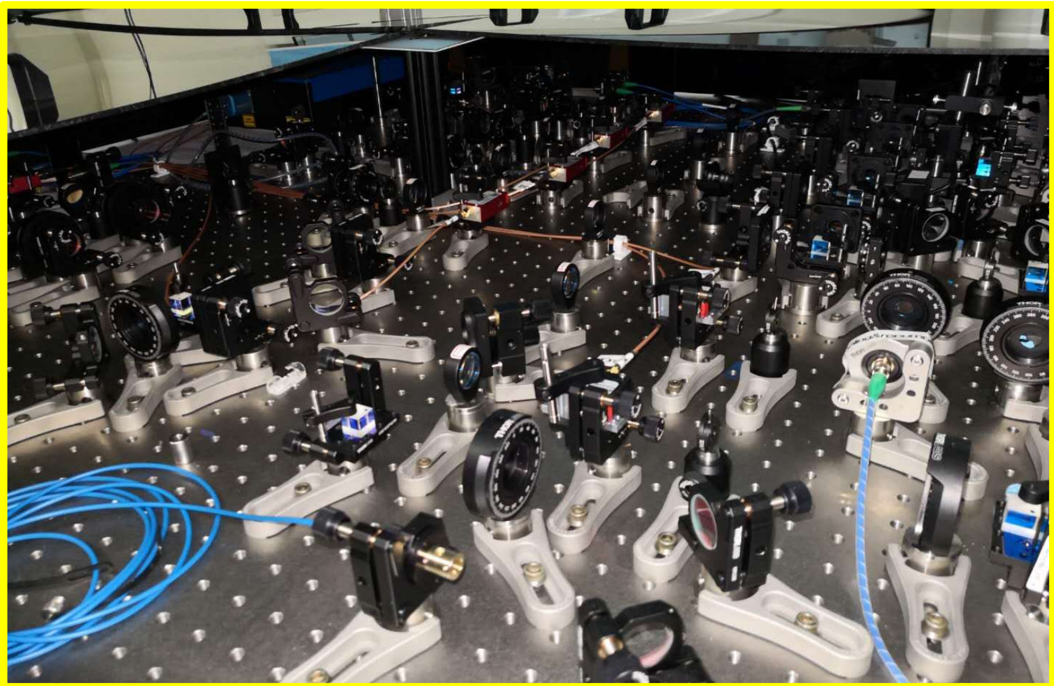


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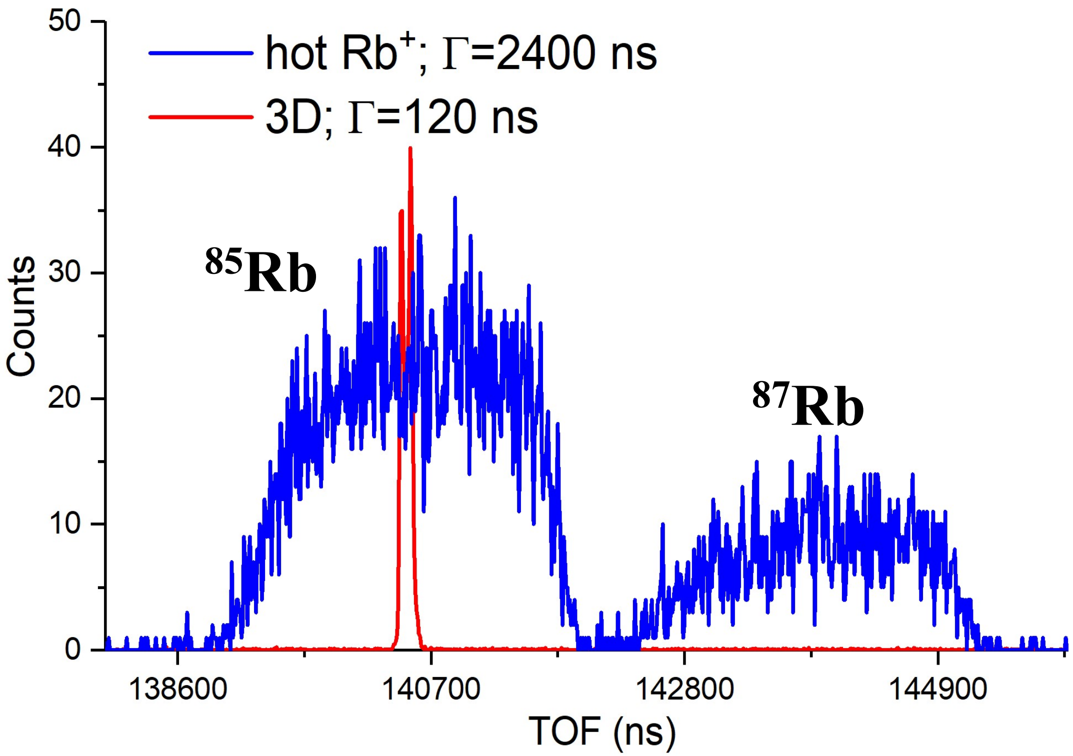
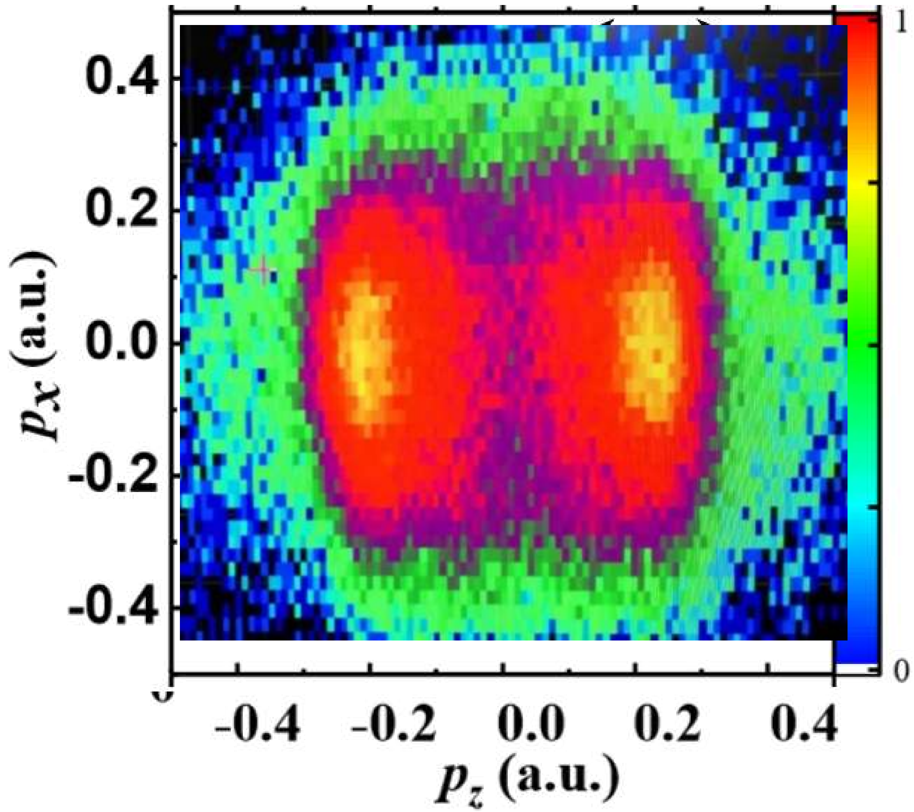
Rb-MOTRIMS

Li et al., Journal of Instrumentation 14, 02022 (2019)

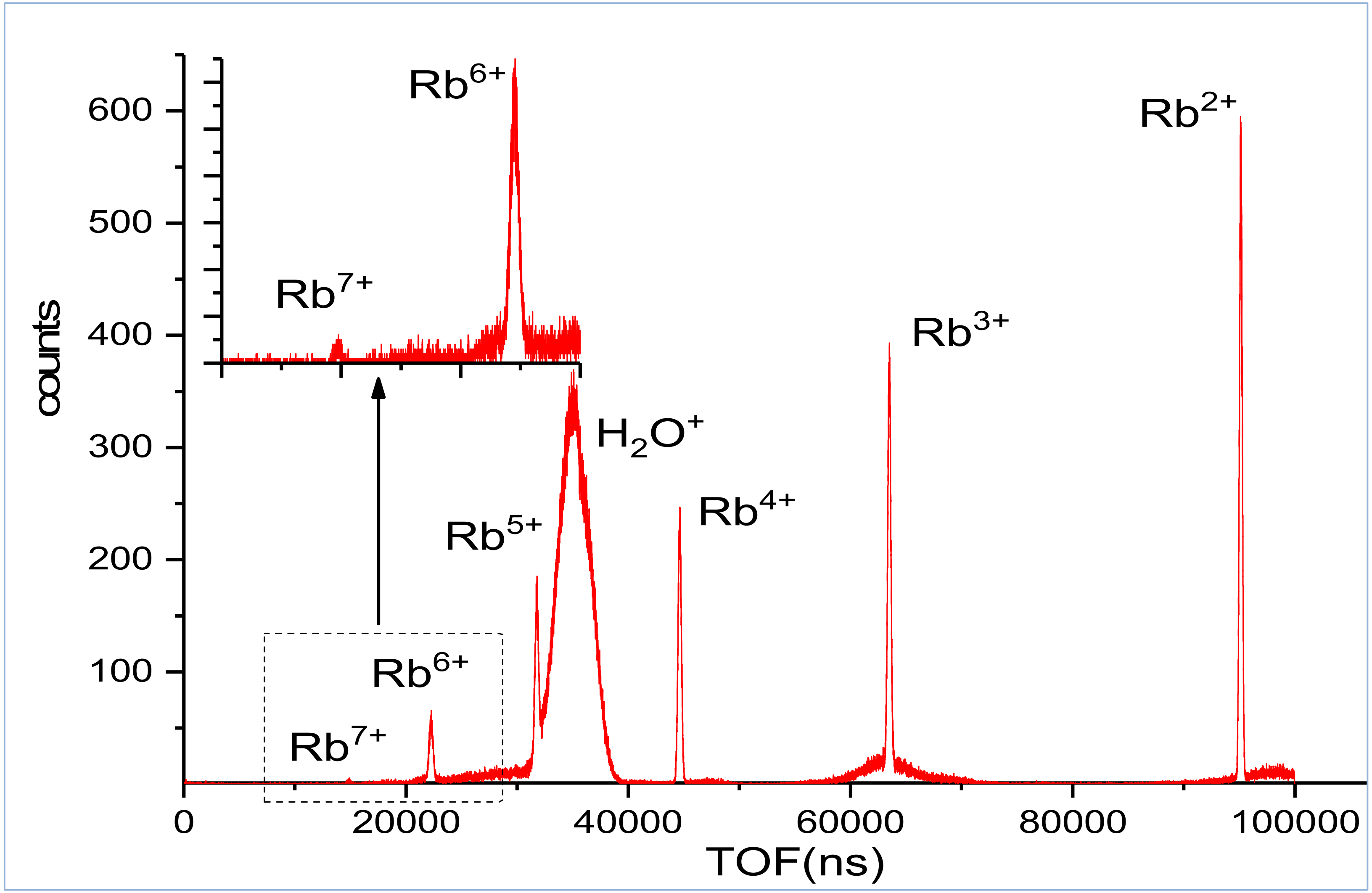




- Temperature: 130 μK, three orders lower than supersonic jet
- TOF: Δt/t=2/10000
- Momentum resolution: 0.12 a.u., one order more than same mass target with the supersonic jet

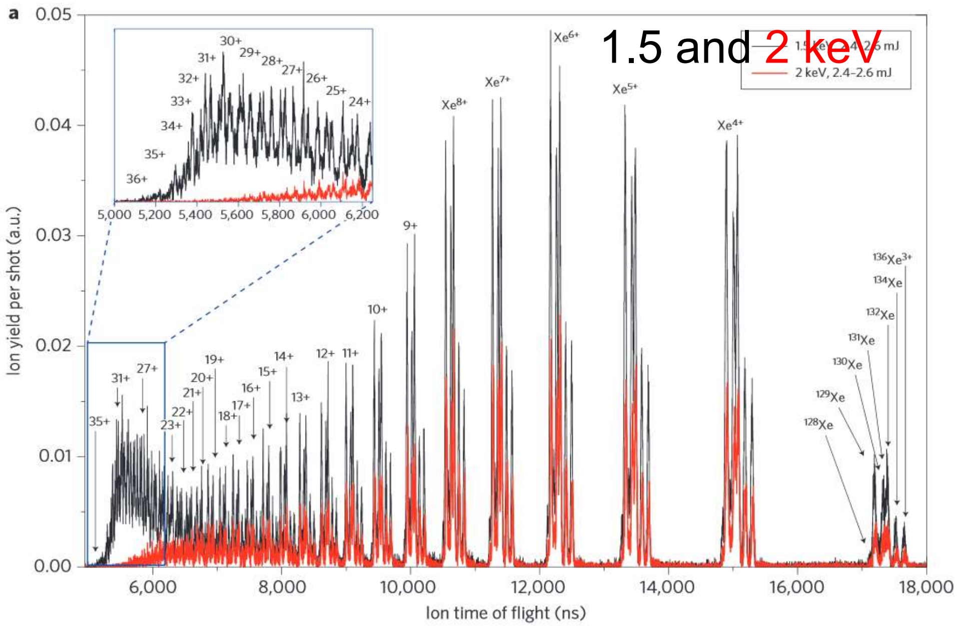
High resolution TOF spectroscopy

Intensity： 10^{16} W/cm^2
Pulse duration： 35 fs
Wavelength: 800 nm

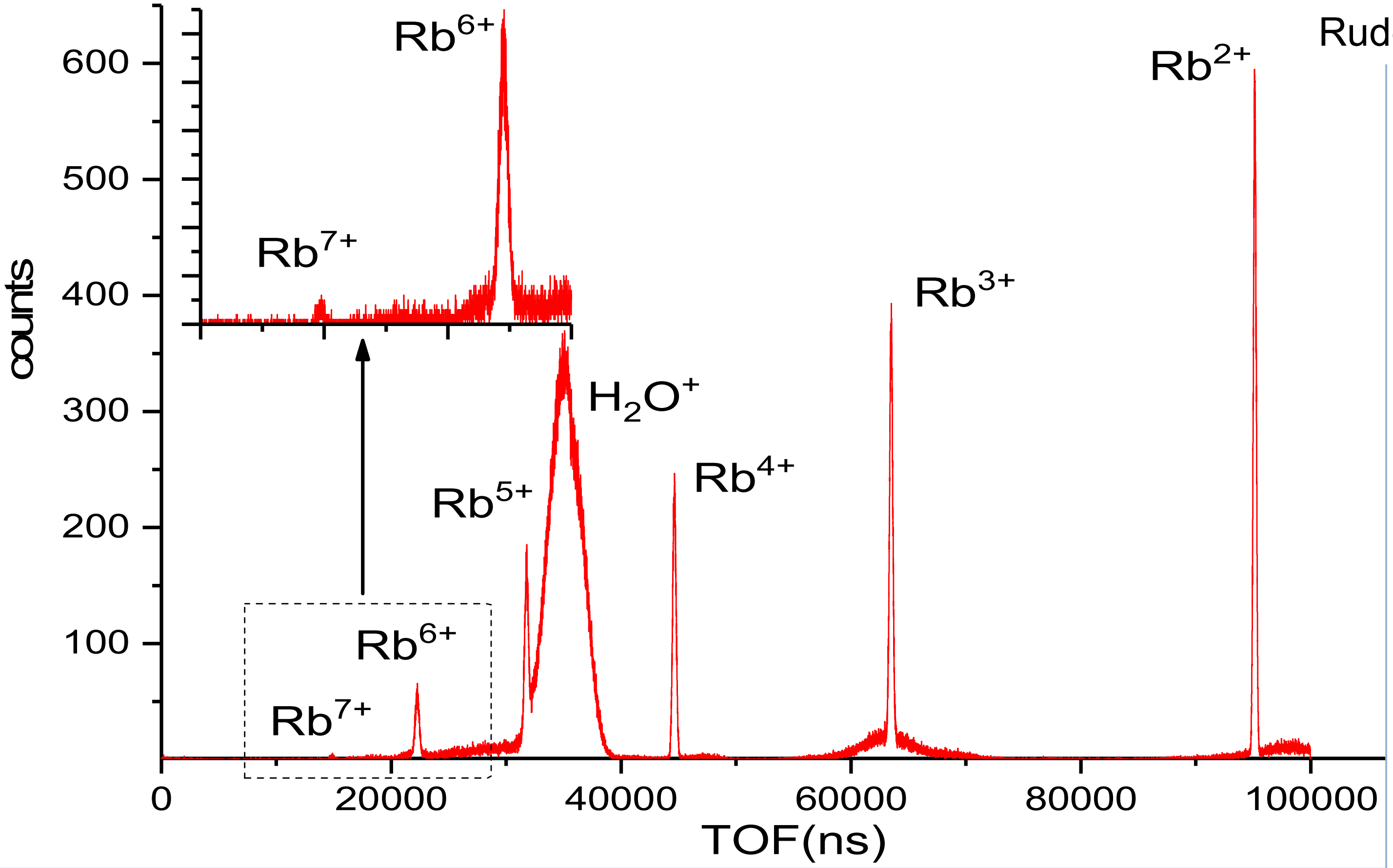


High resolution TOF spectroscopy

Resonance-enhanced ionization for heavy atoms



Rudek, Nature Photonics 6, 858 (2012)

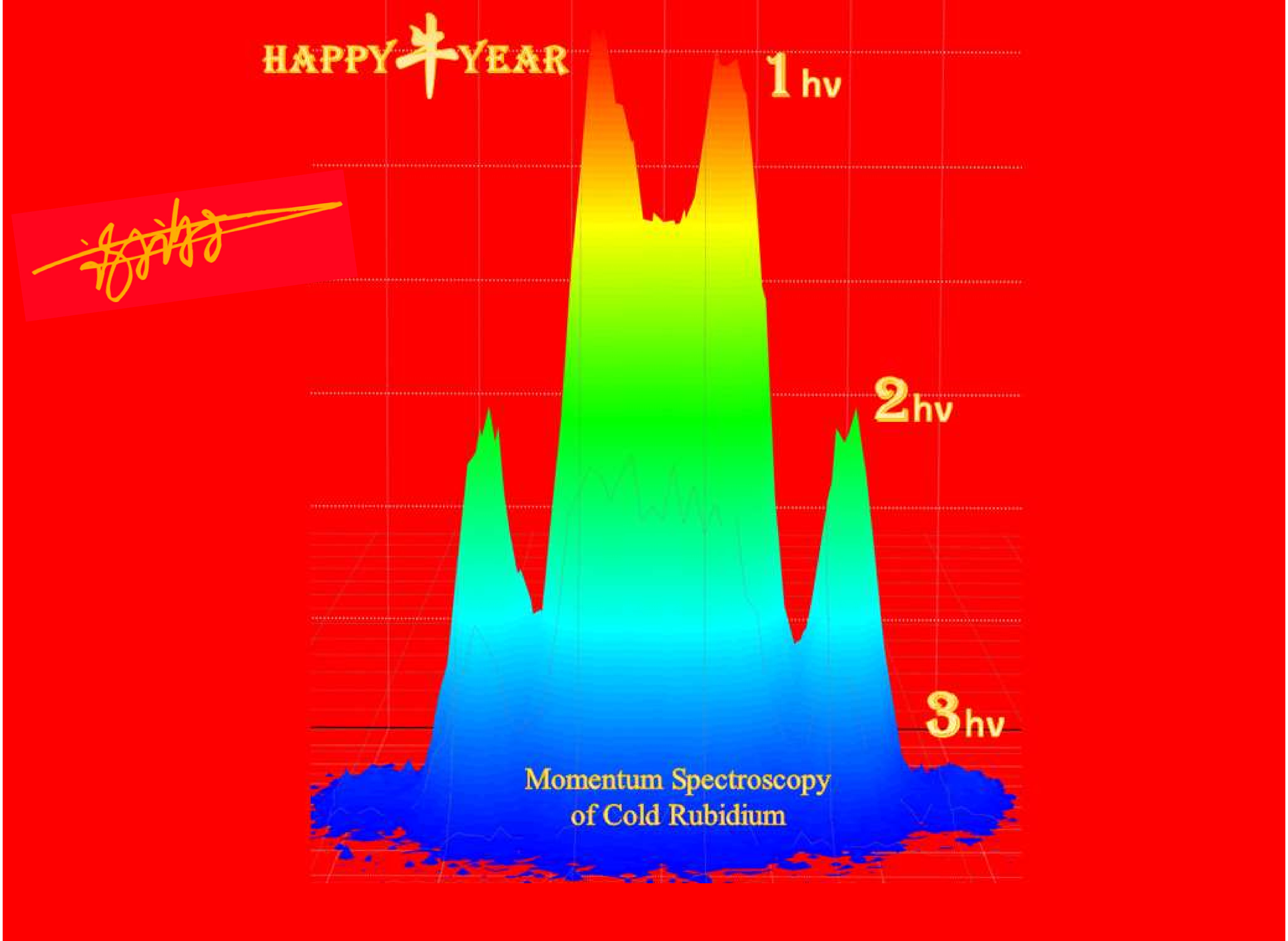


Profiles:
- Heavy alkaline atoms
- Isotope free
- High resolution TOF
- Momentum distributions

Results:
- Multiple ionization of cold rubidium (linear and elliptical polarization)
- Photoionization of polarized atoms

Plan:
- Coherent control
- Rydberg interactions

Chin. Phys. Lett. 37, 053201 (2020)
Phys. Rev. A 102, 043112 (2020)


HAPPY 牛 YEAR
1 hv
2hv
3hv
Momentum Spectroscopy
of Cold Rubidium