HESEB Helmholtz-SESAME Soft X-Ray Beamline for SESAME

Introduction of the HESEB Beamline

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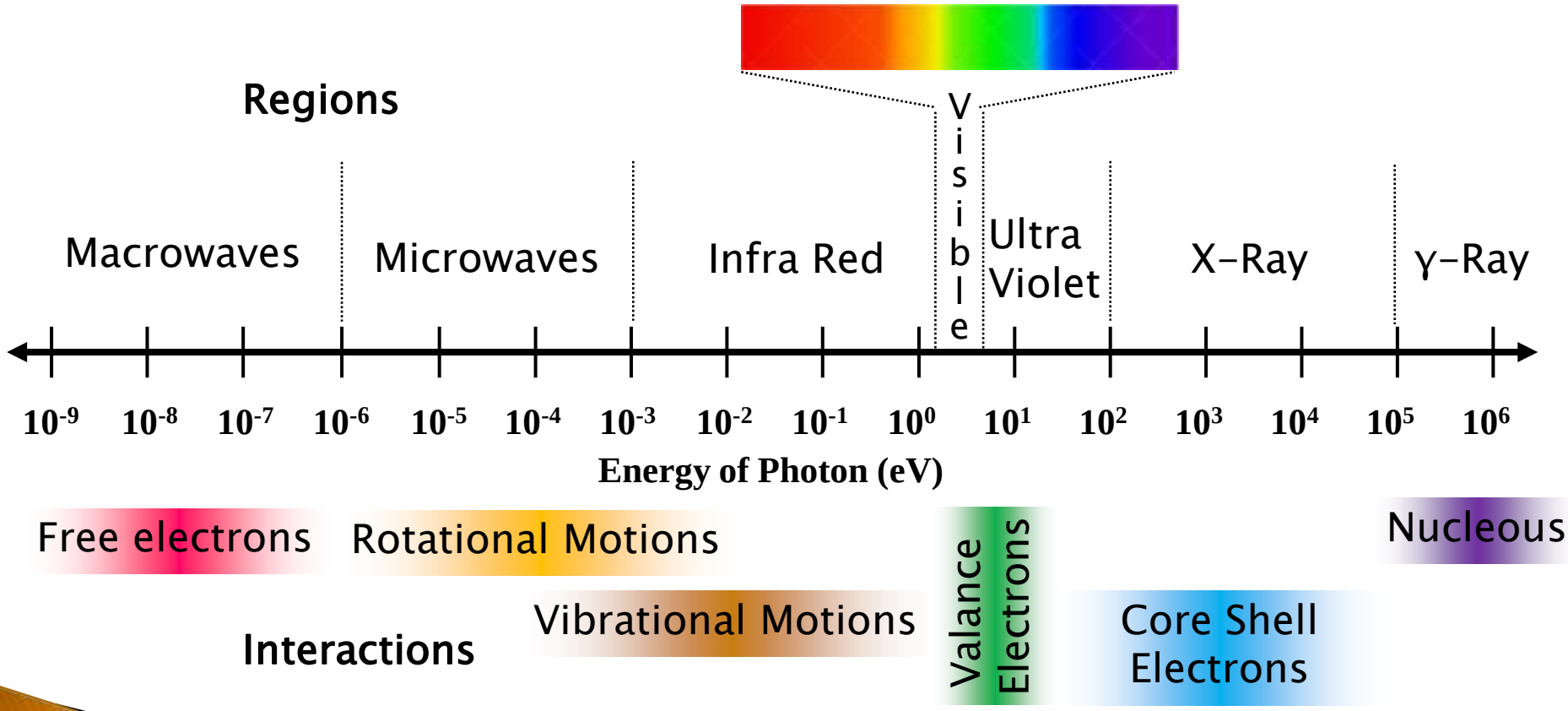
HESEB Soft X-ray Lecture & Training Course at SESAME - 08/05/2023

HESEB (Helmholtz-Sesame Beamline) Project

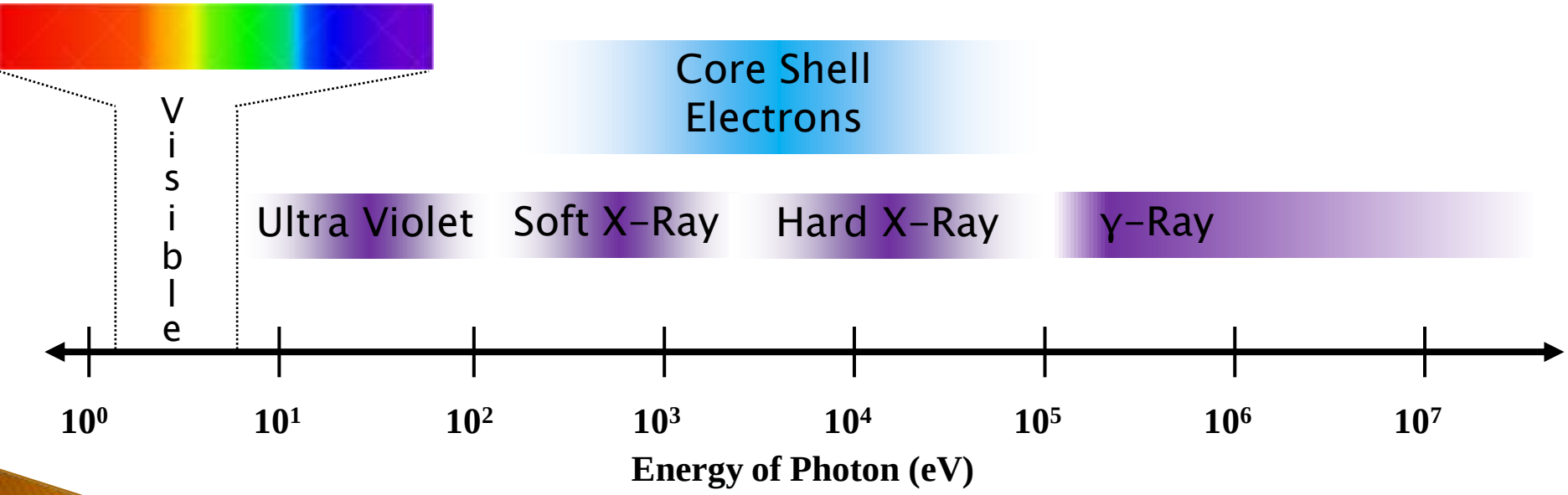
- Project period: 4 years, project start 01/2019
- Project funding: **3,5 M€** from Helmholtz Association
- Project execution:
  - Deutsches Elektronen-Synchrotron (DESY)
  - Forschungszentrum Jülich (FZJ)
  - Helmholtz-Zentrum Dresden-Rossendorf (HZDR)
  - Helmholtz-Zentrum Berlin (HZB)
  - Karlsruhe Institute of Technology (KIT)
- Partners: SESAME, user communities from SESAME member
- First Soft X-Ray beamline in SESAME
- First Undulator in SESAME

Electromagnetic Spectrum and Interaction with Materials



Electromagnetic Spectrum and Soft X-Ray

200 eV – 2000 eV
or
~ 6nm – 0.6 nm



Energy of Some Core Electrons (200 – 2000 eV)

Table 1-1. *Electron binding energies, in electron volts, for the elements in their natural forms.*

Element	K 1s	L_1 2s	L_2 $2p_{1/2}$	L_3 $2p_{3/2}$	M_1 3s	M_2 $3p_{1/2}$	M_3 $3p_{3/2}$	M_4 $3d_{3/2}$	M_5 $3d_{5/2}$	N_1 4s	N_2 $4p_{1/2}$	N_3 $4p_{3/2}$
1 H	13.6											
2 He	24.6*											
3 Li	54.7*											
4 Be	111.5*											
5 B	188*											
6 C	284.2*											
7 N	409.9*	37.3*										
8 O	543.1*	41.6*										
9 F	696.7*											
10 Ne	870.2*	48.5*	21.7*	21.6*								
11 Na	1070.8†	63.5†	30.65	30.81								
12 Mg	1303.0†	88.7	49.78	49.50								
13 Al	1559.6	117.8	72.95	72.55								
14 Si	1839	149.7*b	99.82	99.42								
15 P	2145.5	189*	136*	135*								
16 S	2472	230.9	163.6*	162.5*								
17 Cl	2822.4	270*	202*	200*								
18 Ar	3205.9*	326.3*	250.6†	248.4*	29.3*	15.9*	15.7*					
19 K	3608.4*	378.6*	297.3*	294.6*	34.8*	18.3*	18.3*					
20 Ca	4038.5*	438.4†	349.7†	346.2†	44.3 †	25.4†	25.4†					
21 Sc	4492	498.0*	403.6*	398.7*	51.1*	28.3*	28.3*					
22 Ti	4966	560.9†	460.2†	453.8†	58.7†	32.6†	32.6†					

K– Shell

Sensitive to Air
Require Vacuum

L– Shell

Hard X ray region

Table 1-1. *Electron binding energies, in electron volts, for the elements in their natural forms.*

Element	K 1s	L_1 2s	L_2 $2p_{1/2}$	L_3 $2p_{3/2}$	M_1 3s	M_2 $3p_{1/2}$	M_3 $3p_{3/2}$	M_4 $3d_{3/2}$	M_5 $3d_{5/2}$	N_1 4s	N_2 $4p_{1/2}$	N_3 $4p_{3/2}$
23 V	5465	626.7†	519.8†	512.1†	66.3†	37.2†	37.2†					
24 Cr	5989	696.0†	583.8†	574.1†	74.1†	42.2†	42.2†					
25 Mn	6539	769.1†	649.9†	638.7†	82.3†	47.2†	47.2†					
26 Fe	7112	844.6†	719.9†	706.8†	91.3†	52.7†	52.7†					
27 Co		925.1†	793.2†	778.1†	101.0†	58.9†	59.9†					
28 Ni		1008.6†	870.0†	852.7†	110.8†	68.0†	66.2†					
29 Cu	8979	1096.7†	952.3†	932.7	122.5†	77.3†	75.1†					
30 Zn	9659	1196.2*	1044.9*	1021.8*	139.8*	91.4*	88.6*	10.2*	10.1*			
31 Ga	10367	1299.0*b	1143.2†	1116.4†	159.5†	103.5†	100.0†	18.7†	18.7†			
32 Ge	11103	1414.6*b	1248.1*b	1217.0*b	180.1*	124.9*	120.8*	29.8	29.2			
33 As	11867	1527.0*b	1359.1*b	1323.6*b	204.7*	146.2*	141.2*	41.7*	41.7*			
34 Se	12658	1652.0*b	1474.3*b	1433.9*b	229.6*	166.5*	160.7*	55.5*	54.6*			
35 Br	13474	1782*	1596*	1550*	257*	189*	182*	70*	69*			
36 Kr	14326	1921	1730.9*	1678.4*	292.8*	222.2*	214.4	95.0*	93.8*	27.5*	14.1*	14.1*
37 Rb	15200	2065	1864	1804	326.7*	248.7*	239.1*	113.0*	112*	30.5*	16.3*	15.3 *
38 Sr	16105	2216	2007	1940	358.7†	280.3†	270.0†	136.0†	134.2†	38.9†	21.3	20.1†
39 Y	17038	2373	2156	2080	392.0*b	310.6*	298.8*	157.7†	155.8†	43.8*	24.4*	23.1*
40 Zr	17998	2532	2307	2223	430.3†	343.5†	329.8†	181.1†	178.8†	50.6†	28.5†	27.1†
41 Nb	18986	2698	2465	2371	466.6†	376.1†	360.6†	205.0†	202.3†	56.4†	32.6†	30.8†
42 Mo	20000	2866	2625		506.3†	411.6†	394.0†	231.1†	227.9†	63.2†	37.6†	35.5†
43 Tc	21044	3043	2793		544*	447.6	417.7	257.6	253.9*	69.5*	42.3*	39.9*
44 Ru	22117	3224	2967	2838	586.1*	483.5†	461.4†	284.2†	280.0†	75.0†	46.3†	43.2†
45 Rh	23220	3412	3146	3004	628.1†	521.3†	496.5†	311.9†	307.2†	81.4*b	50.5†	47.3†
46 Pd	24350	3604	3330	3173	671.6†	559.9†	532.3†	340.5†	335.2†	87.1*b	55.7†a	50.9†
47 Ag	25514	3806	3524	3351	719.0†	603.8†	573.0†	374.0†	368.3	97.0†	63.7†	58.3†

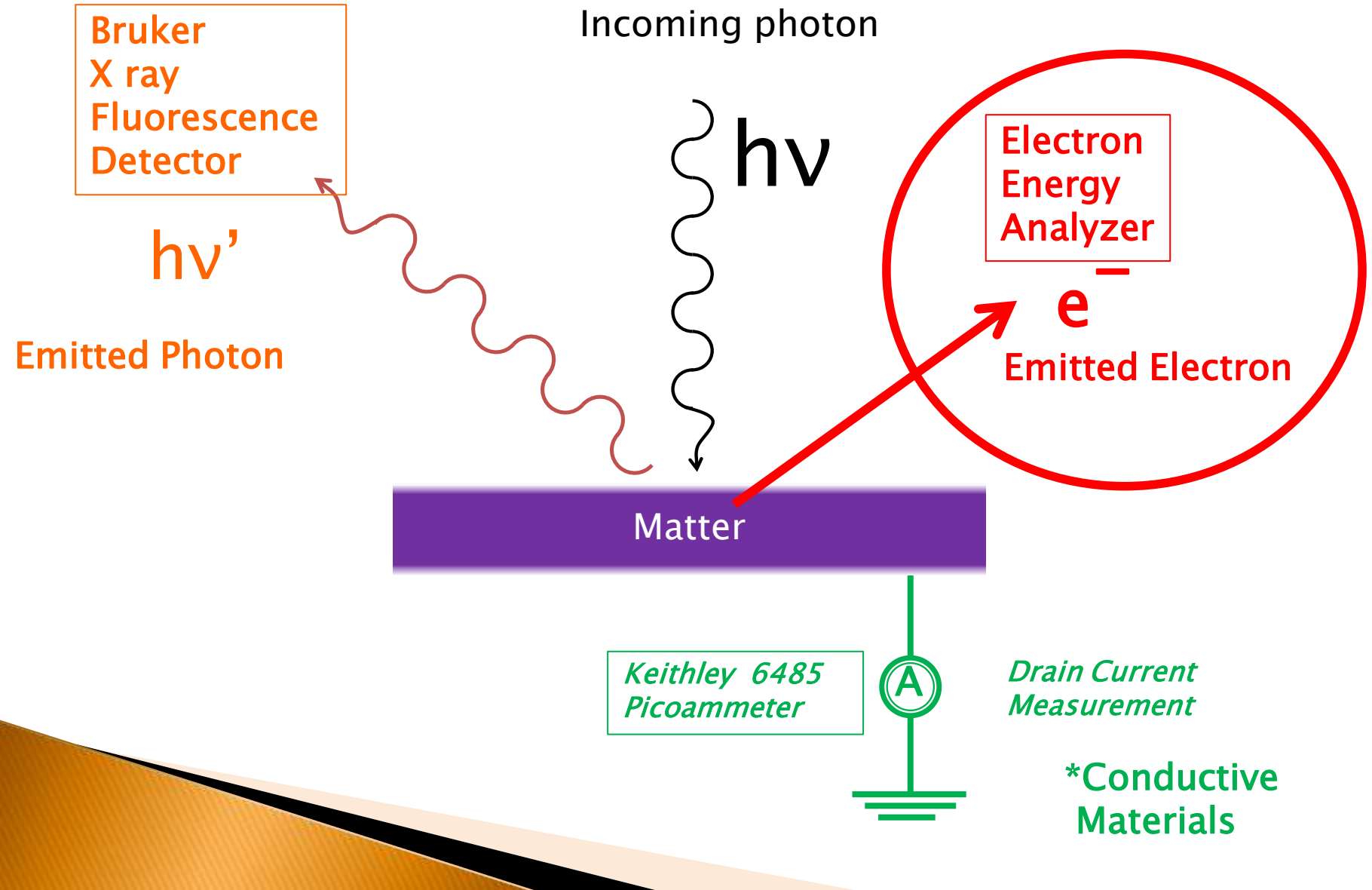
L– Shell

M– Shell

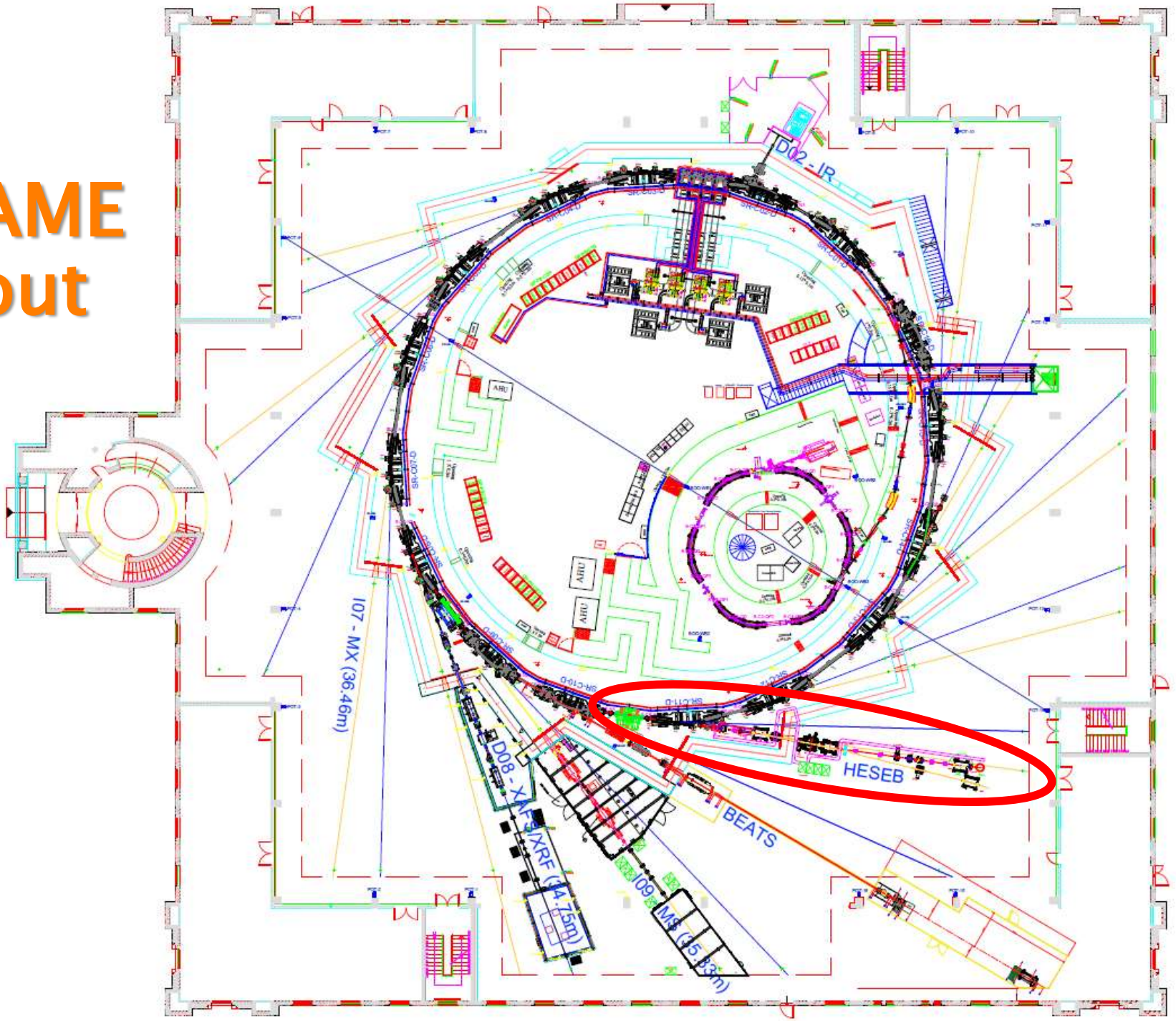
HESEB Related Techniques

Photoelectron Spectroscopy

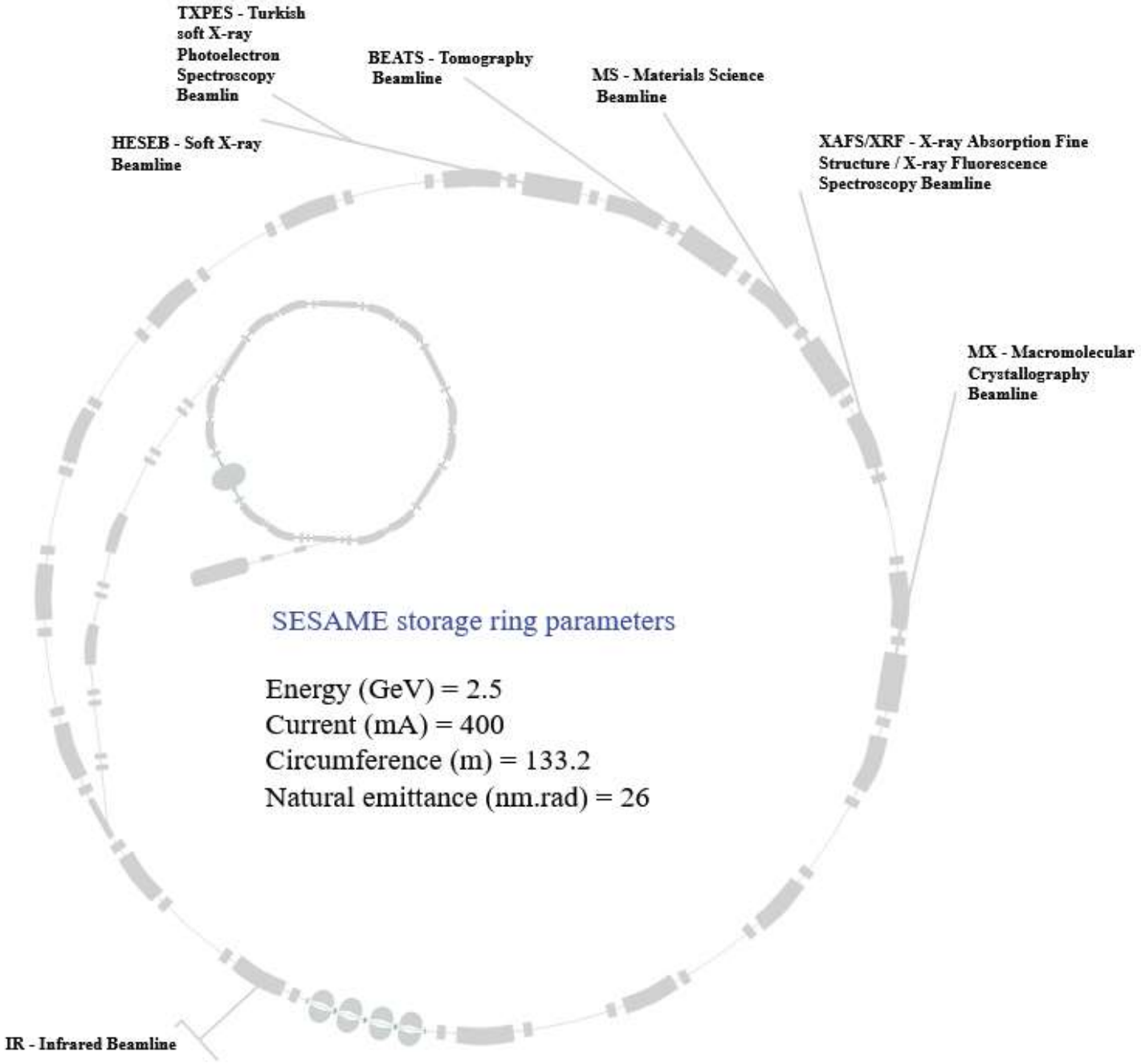
*TXPES



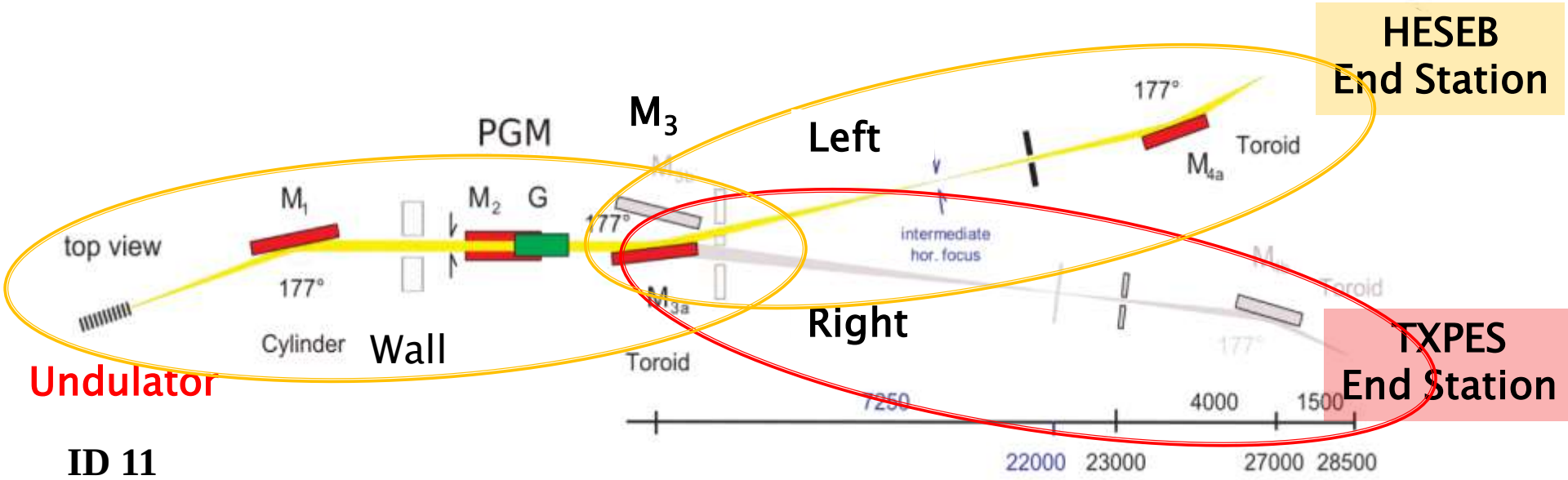
SESAME Layout



SESAME Layout



Plan View of HESEB and TXPES



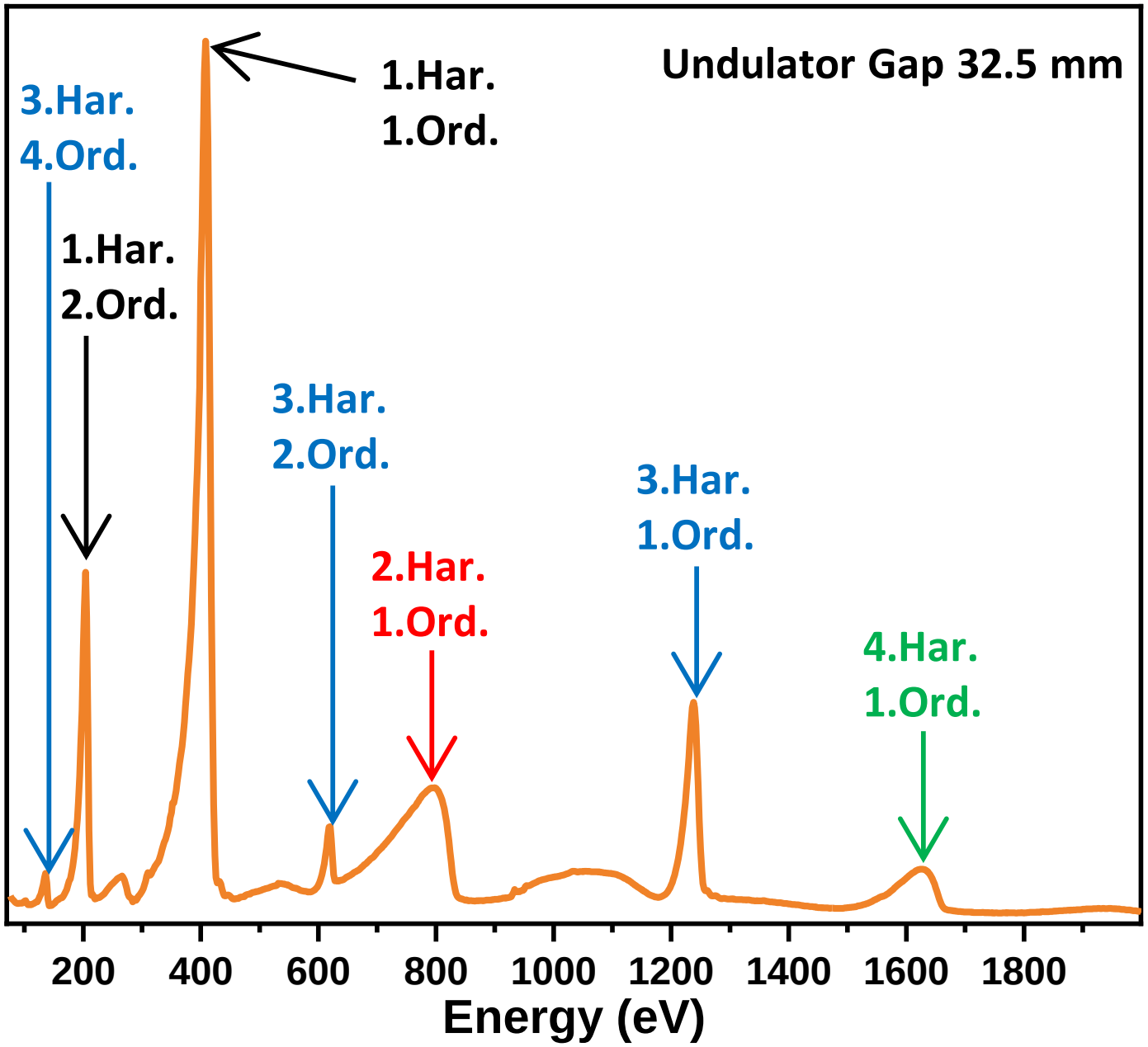
Properties of Undulator (ID11)

- Straight section between Cell10-Cell11
- Apple II type
- Minimum energy 70eV
- **Linearly or Circularly Polarized Light**
- Period Length 56mm
- 30 periods

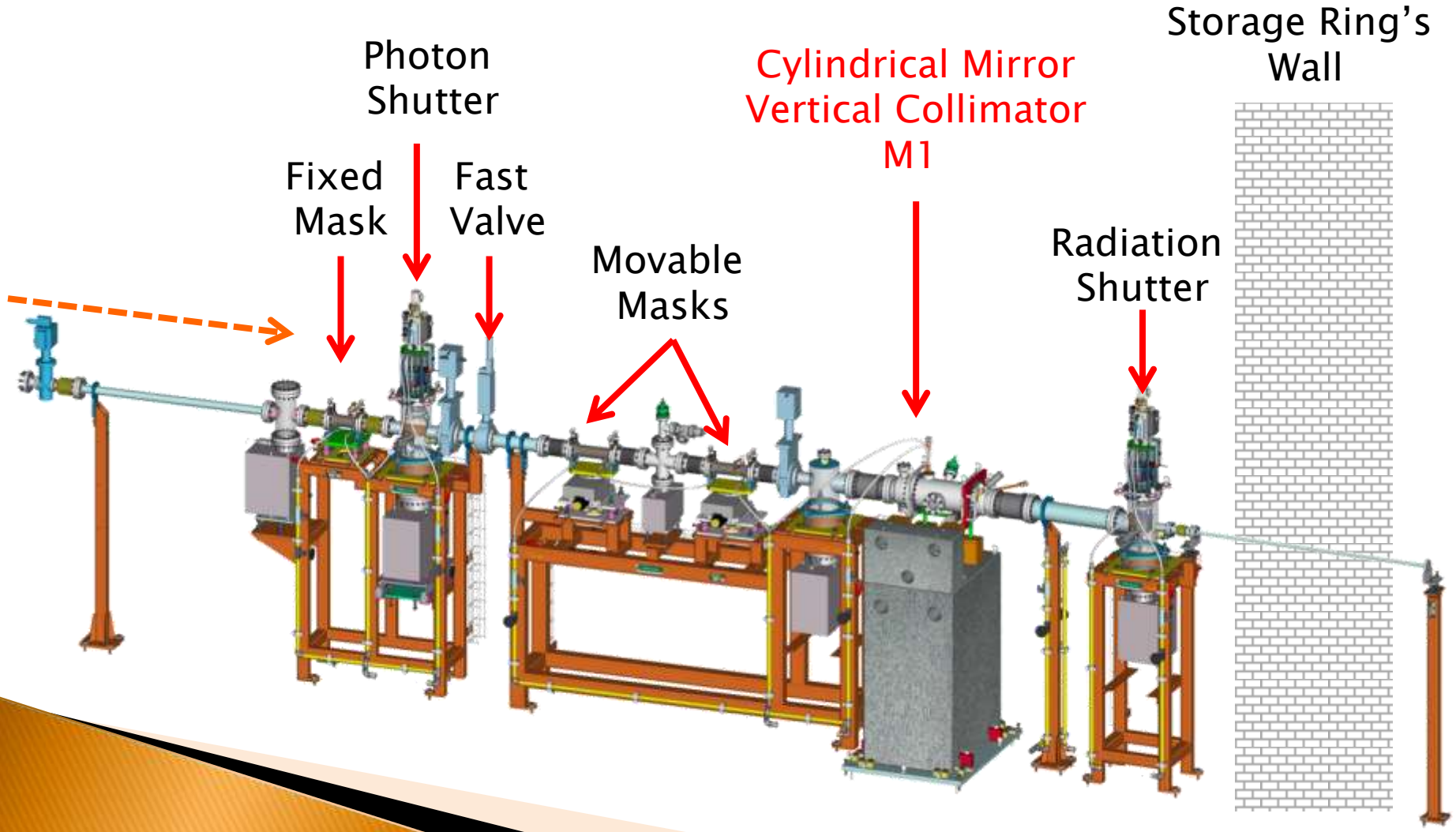
ID11-Undulator: BM10-BM11

Undulator: Apple II/UE56-SE

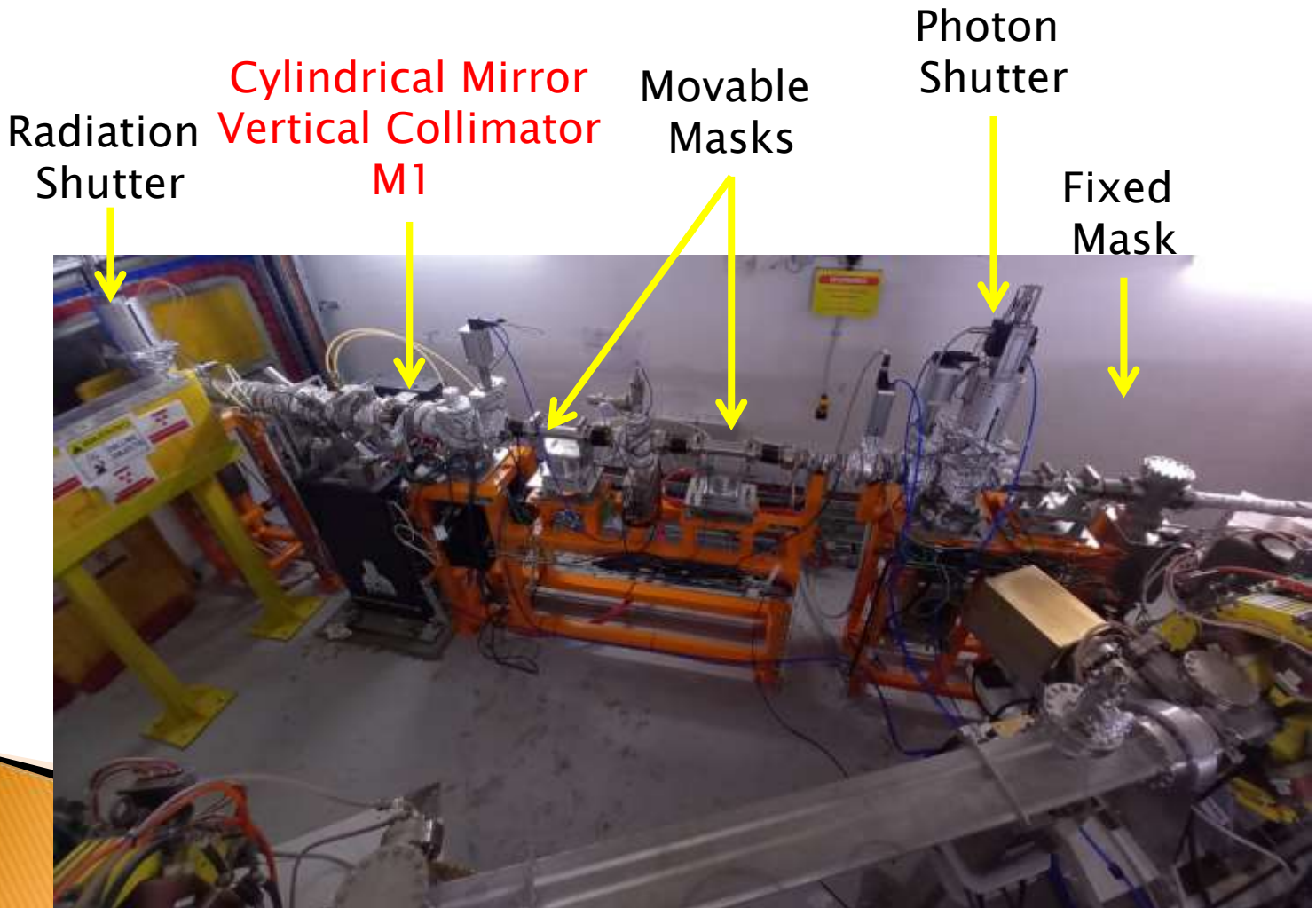
Undulator Harmonics and Their Orders



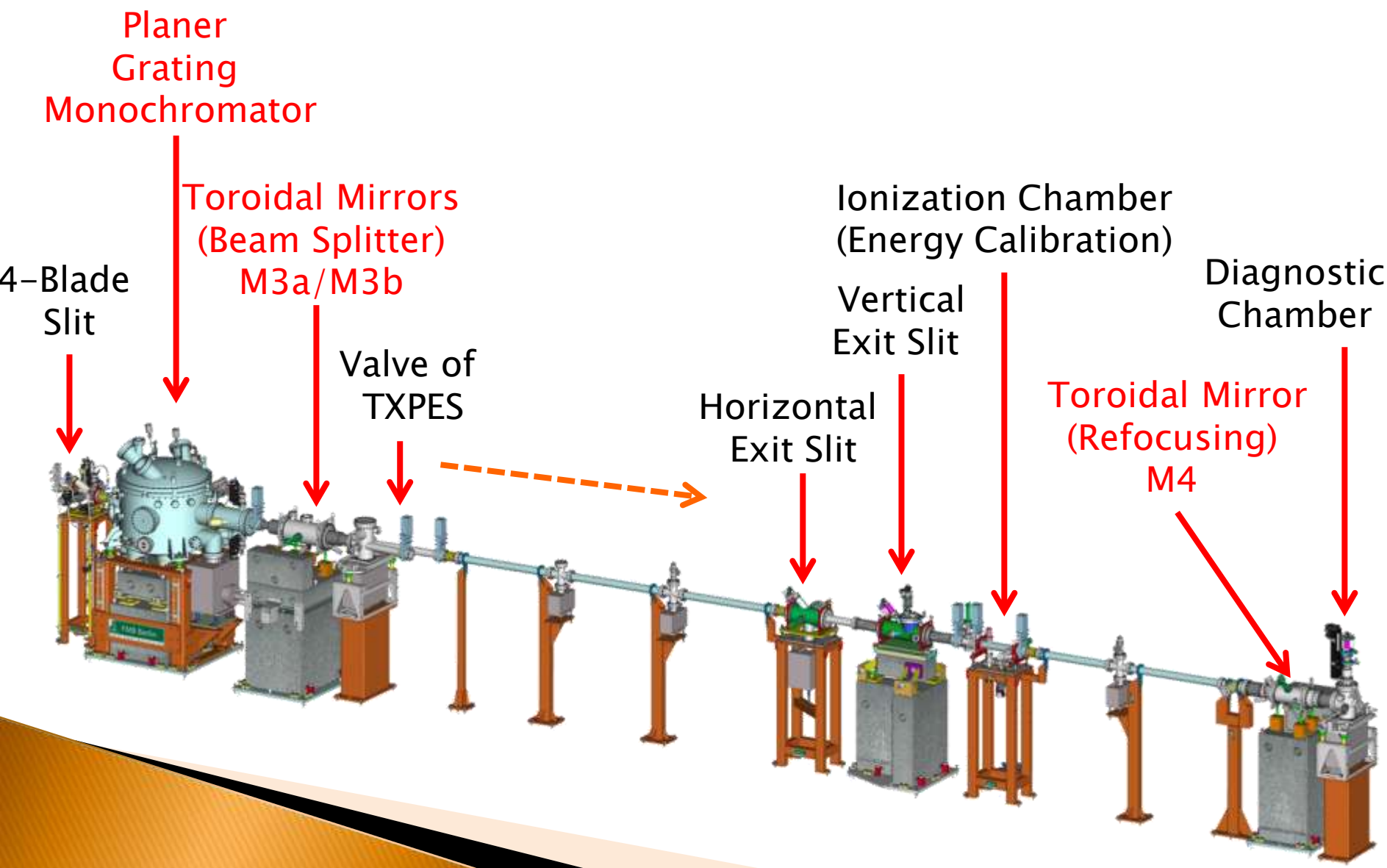
Front-End Section



Front-End Section



Beamline Section



Properties of HESEB Beamline

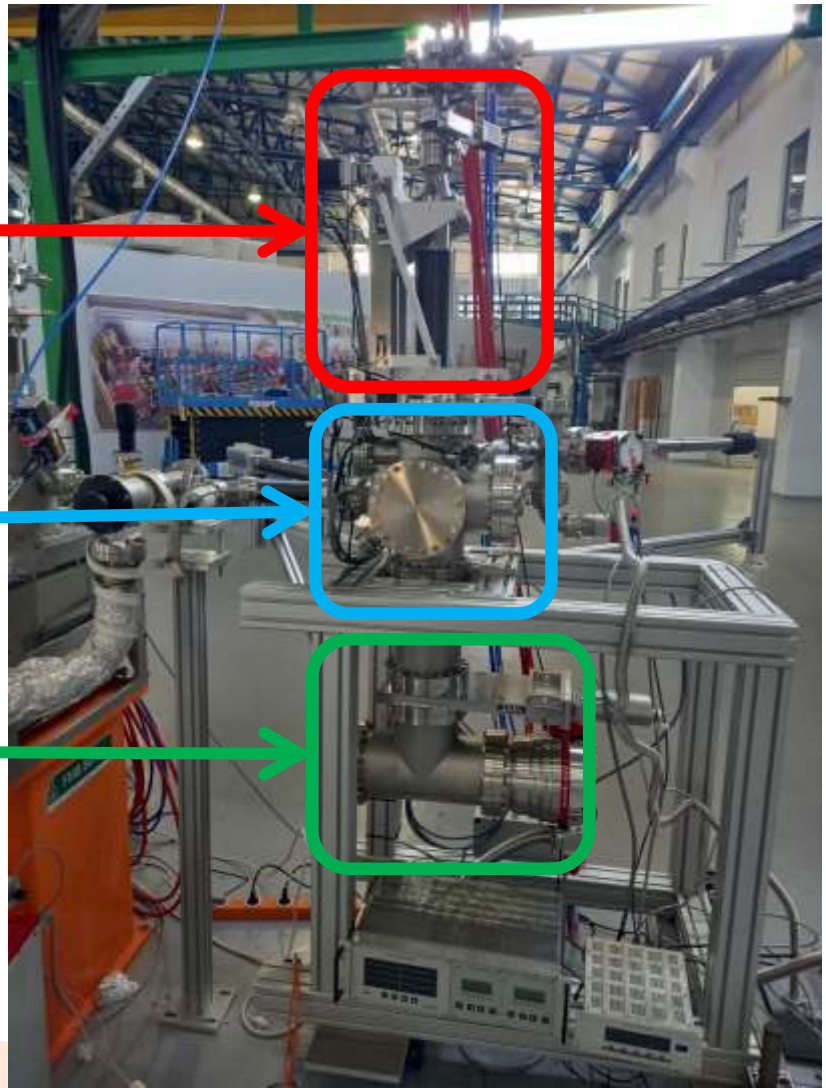
- Energy Resolution: 10^4 E/ΔE @400ev (40 meV)
- Two grating mirror 400 and 1200 grove/mm
- Can work Linear and Circularly polarized light
- Photon Energy Range: 90-1800 eV
- Cover Whole Periodic Table, except H, He, Li
- Flux on sample 10^{12} s^{-1}
- Spot size: 180x25 μm^2 (h x v)
  - With optical capillary 20x20 μm^2

HESEB End Station

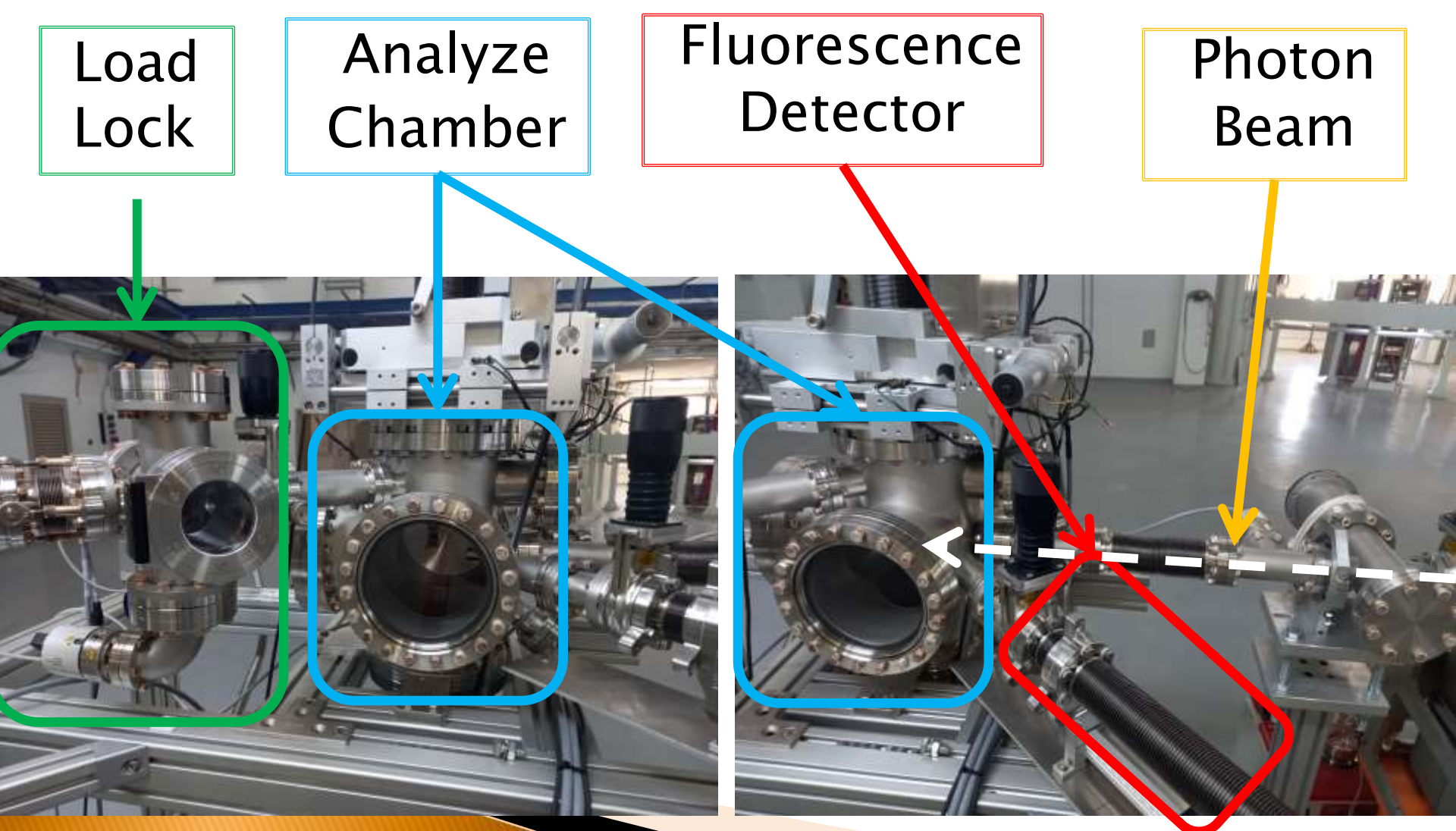
Motorized Manipulator

Analyze Chamber

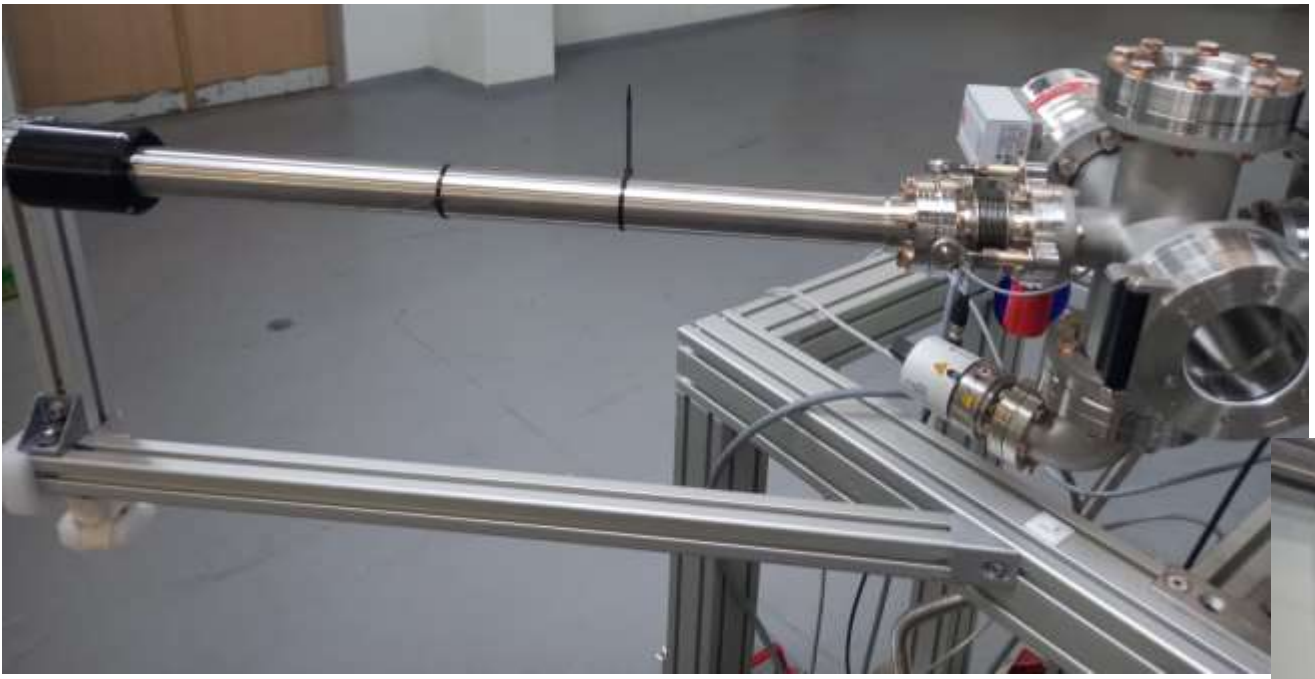
Vacuum Section



HESEB End Station: Chamber



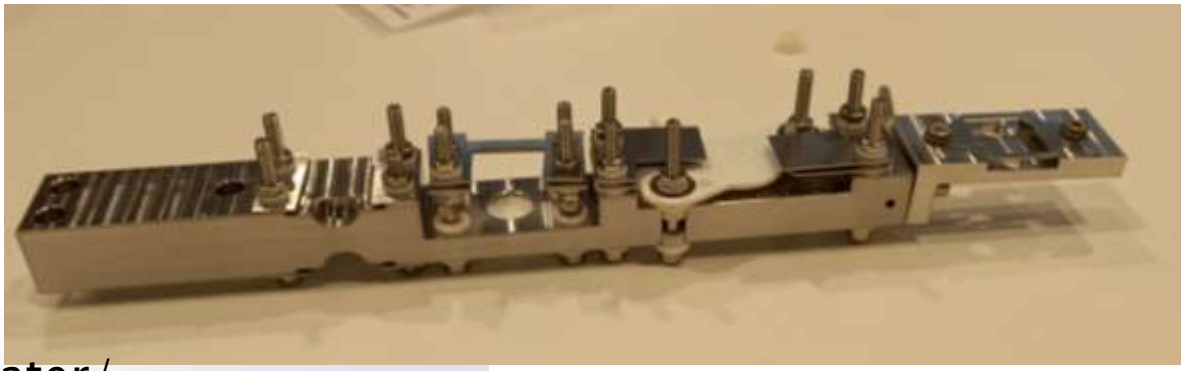
HESEB End Station: Load lock and Magnetic Transfer Arm



Properties of HESEB End Station

- Fluorescence Detector (XRF) (Bruker Xflash)
- Electron Yield Measurement (Keithley Picoammeters)
- LN_2 Cooling
- Sample Heating up to 800°C
- Magnetic Stage
- Motorized Sample Holder for 2D Mapping
  - lateral resolution 1µm
- Differential Pumping
  - Measurement at low vacuum at He atmosphere for vacuum sensitive samples (i.e. Historical samples)
  - Measurement at different atmospheres

HESEB: Sample holder and Receptacle Part



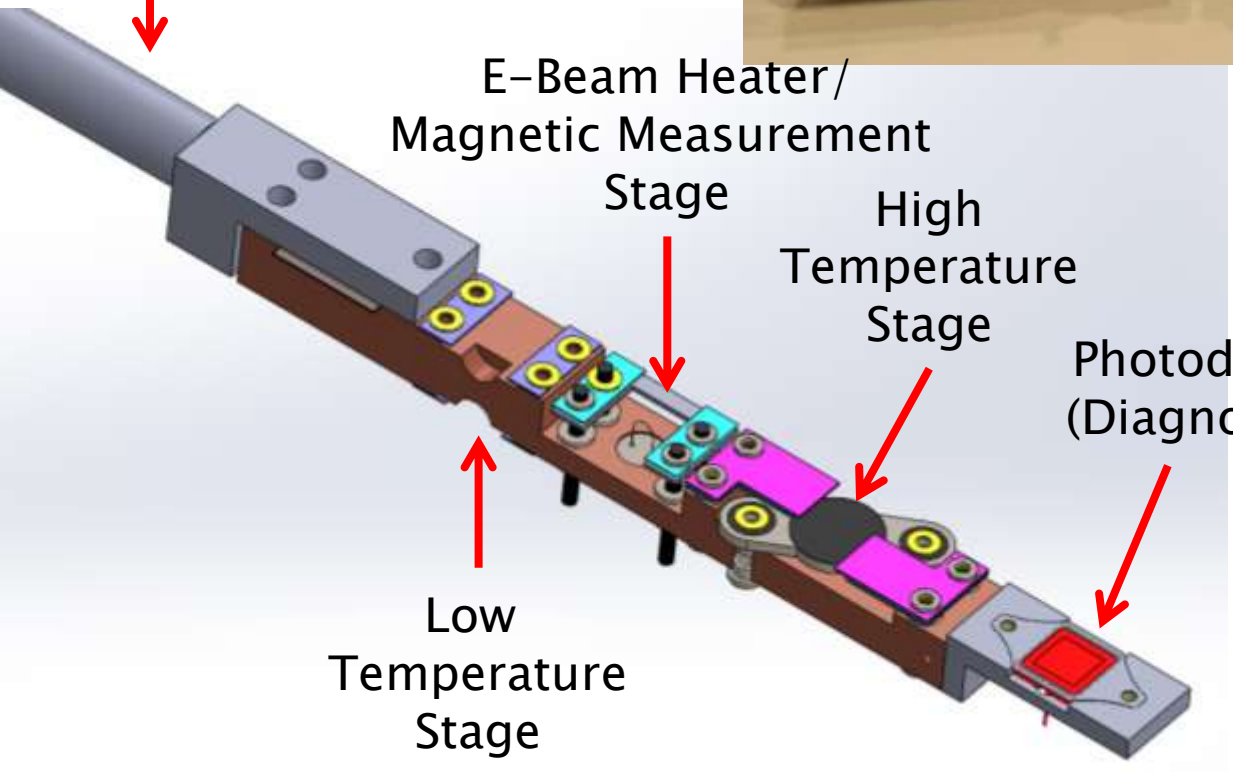
LN2 reservoir

E-Beam Heater/ Magnetic Measurement Stage

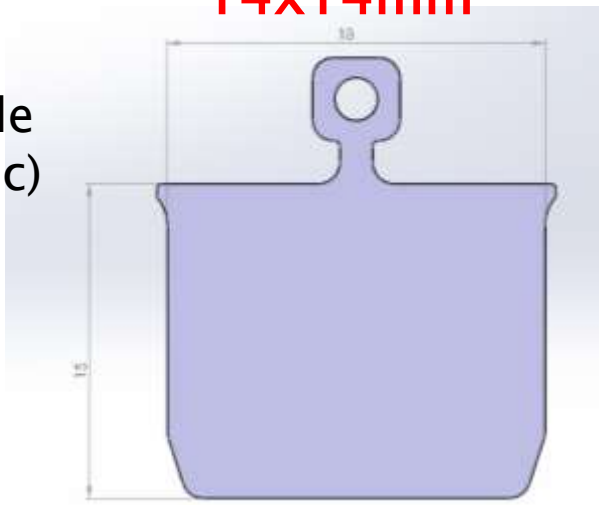
High Temperature Stage

Photodiode (Diagnostic)

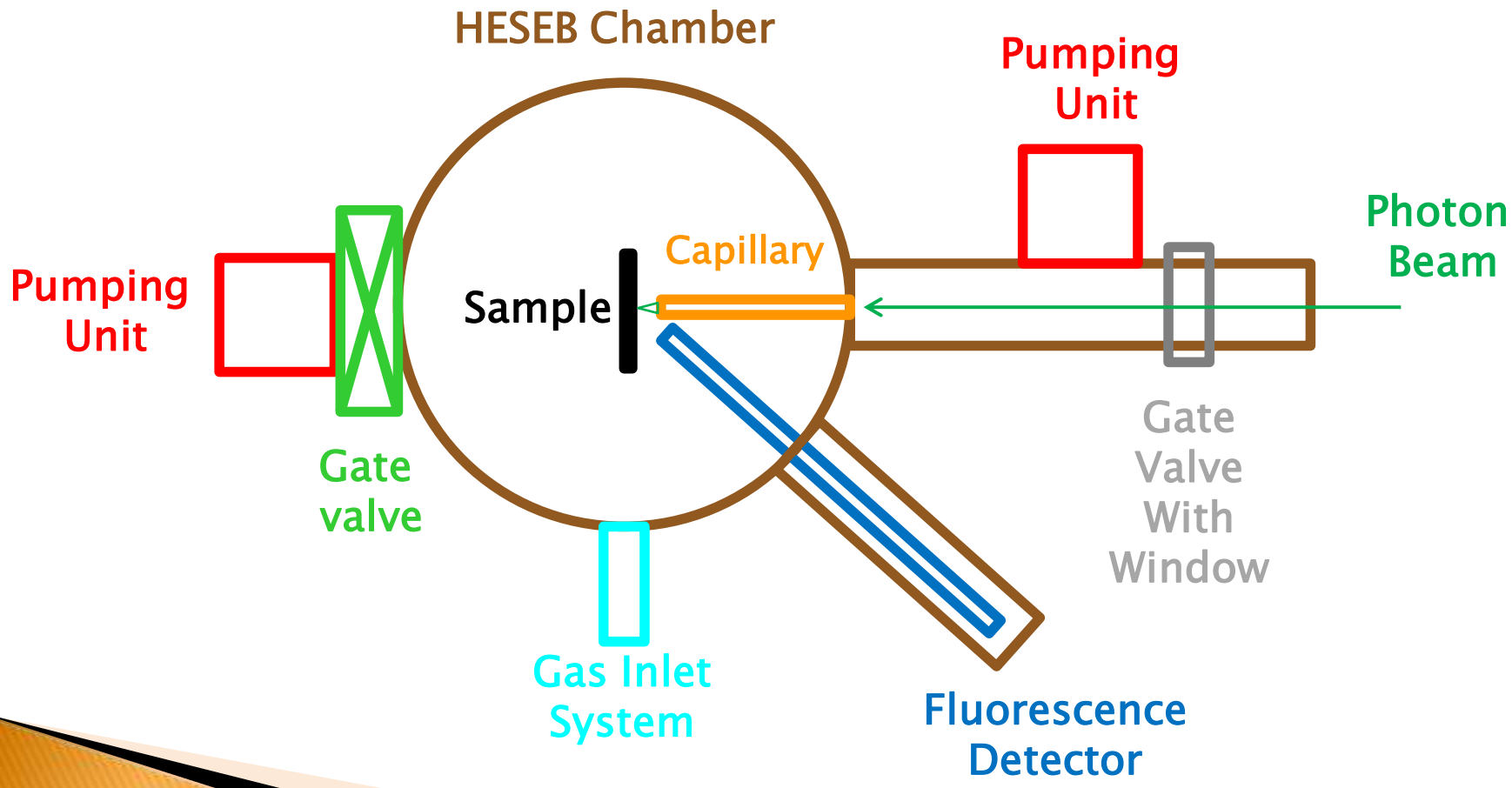
Low Temperature Stage



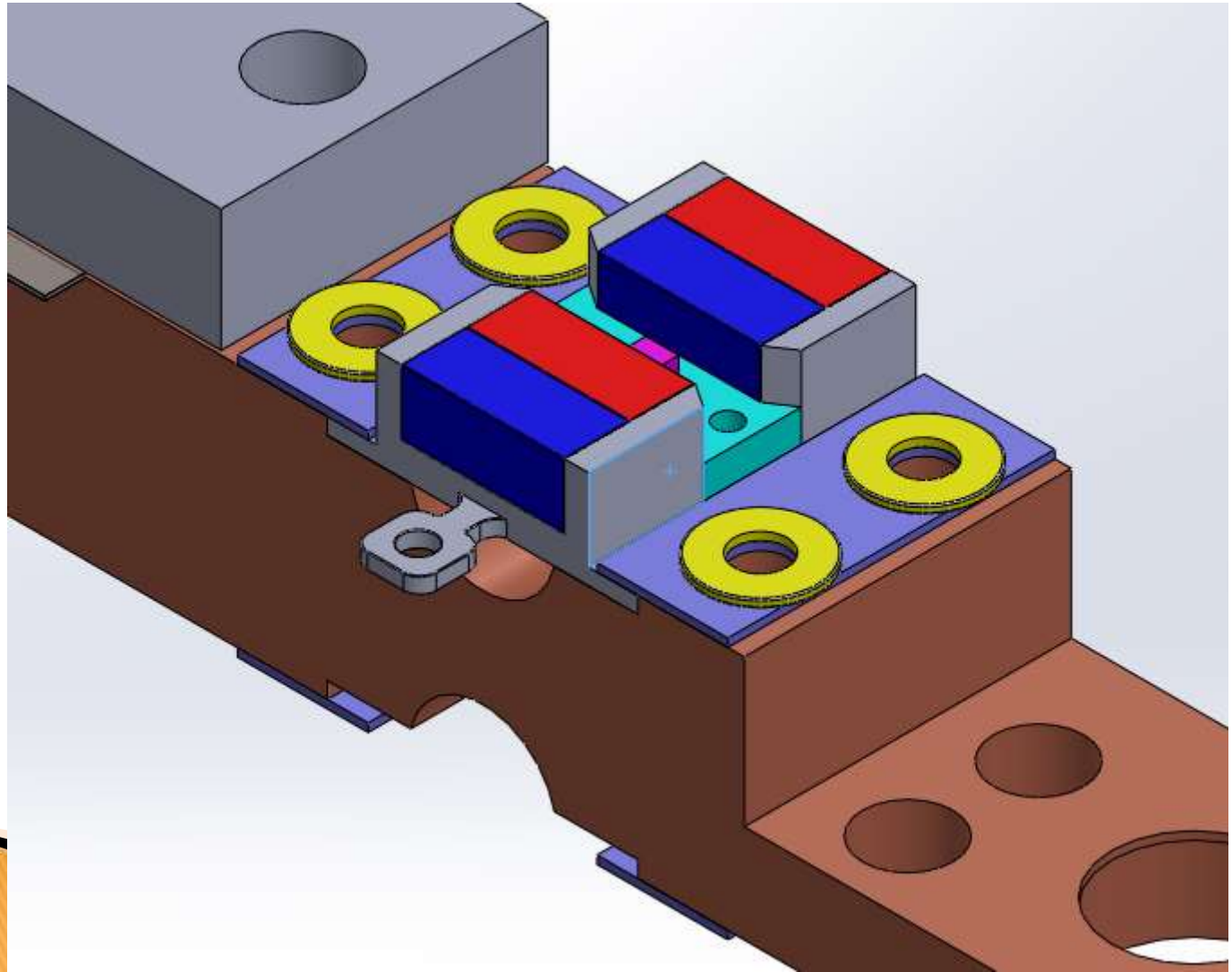
Sample Holder 14x14mm^2



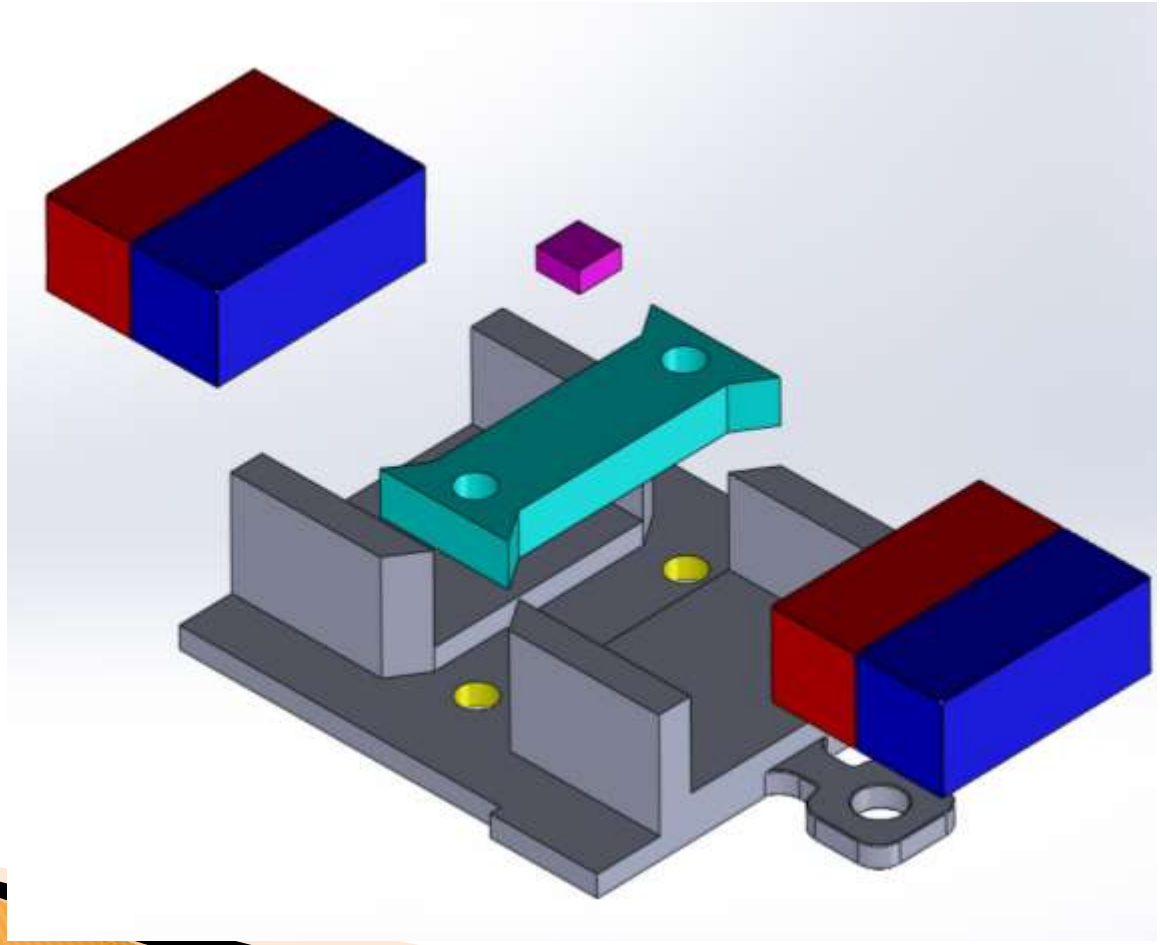
Optical Capillary and Differential Pumping Ability



The Permenant Magnet Assembly on the Cooling Slot of Receptacle Part

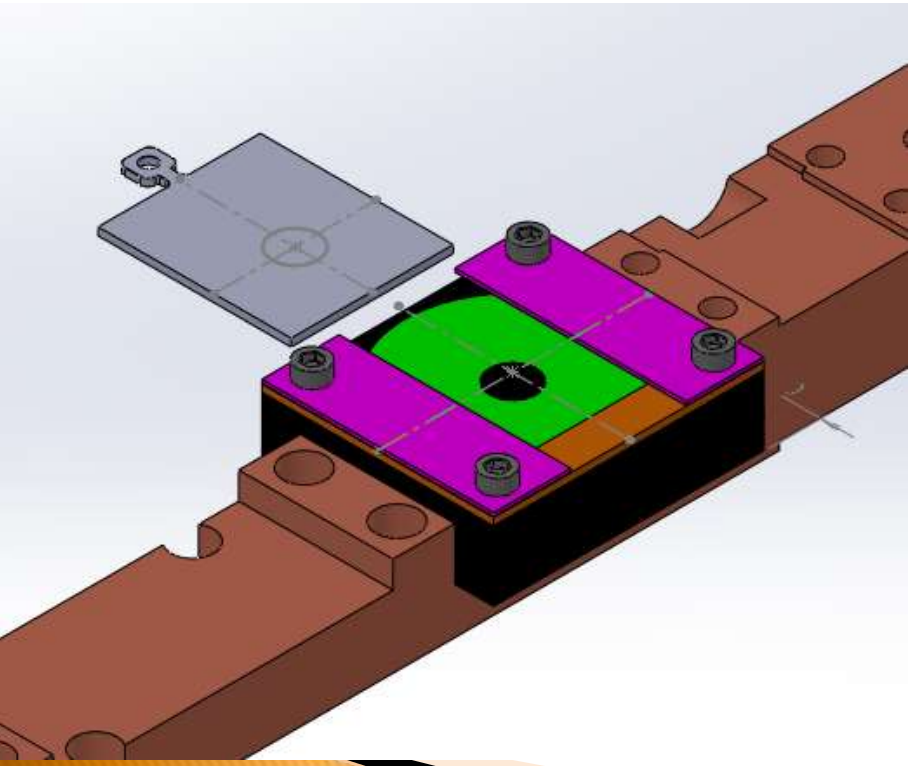


The Permenant Magnet holder design Explosion view

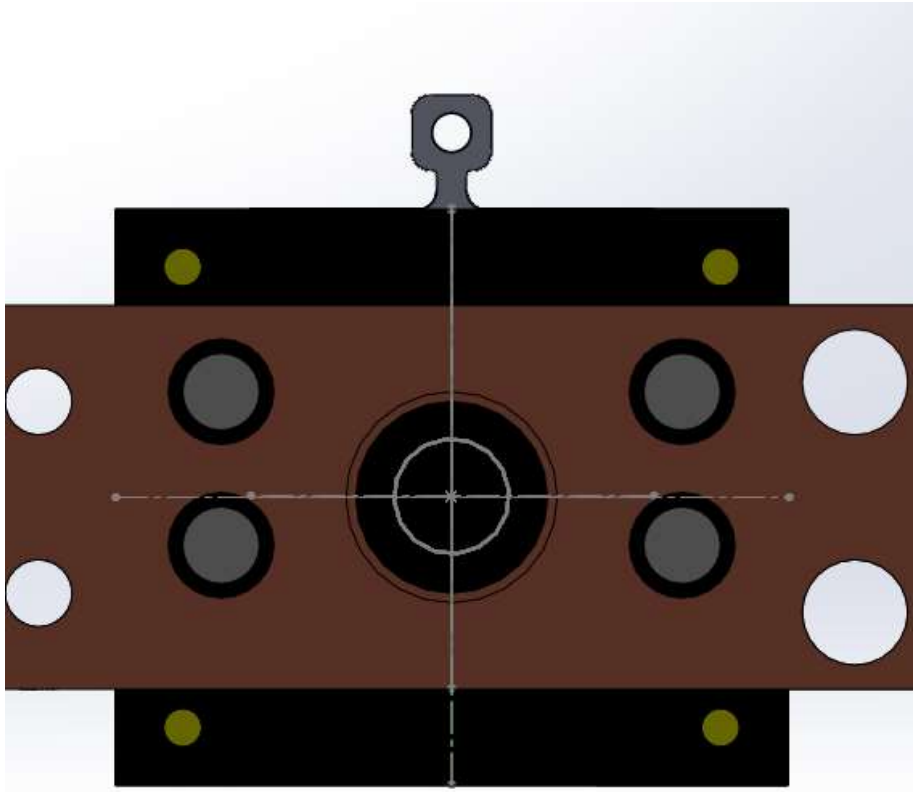


Electromagnet Design

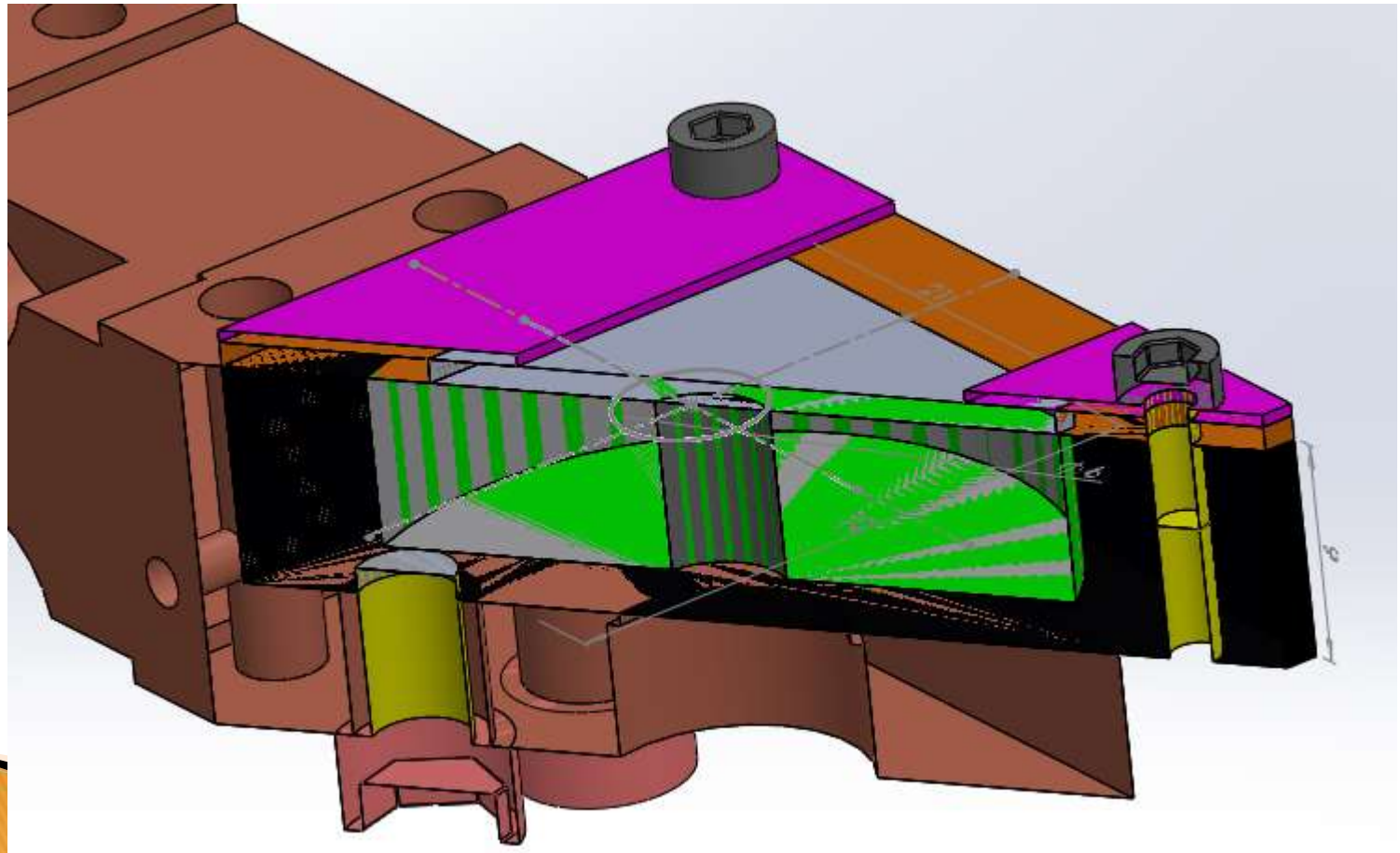
Top Isometric view



Bottom View



Electromagnet Design Section View



Electromagnet Design Explosion View

M2 Screws

Sample holder springs

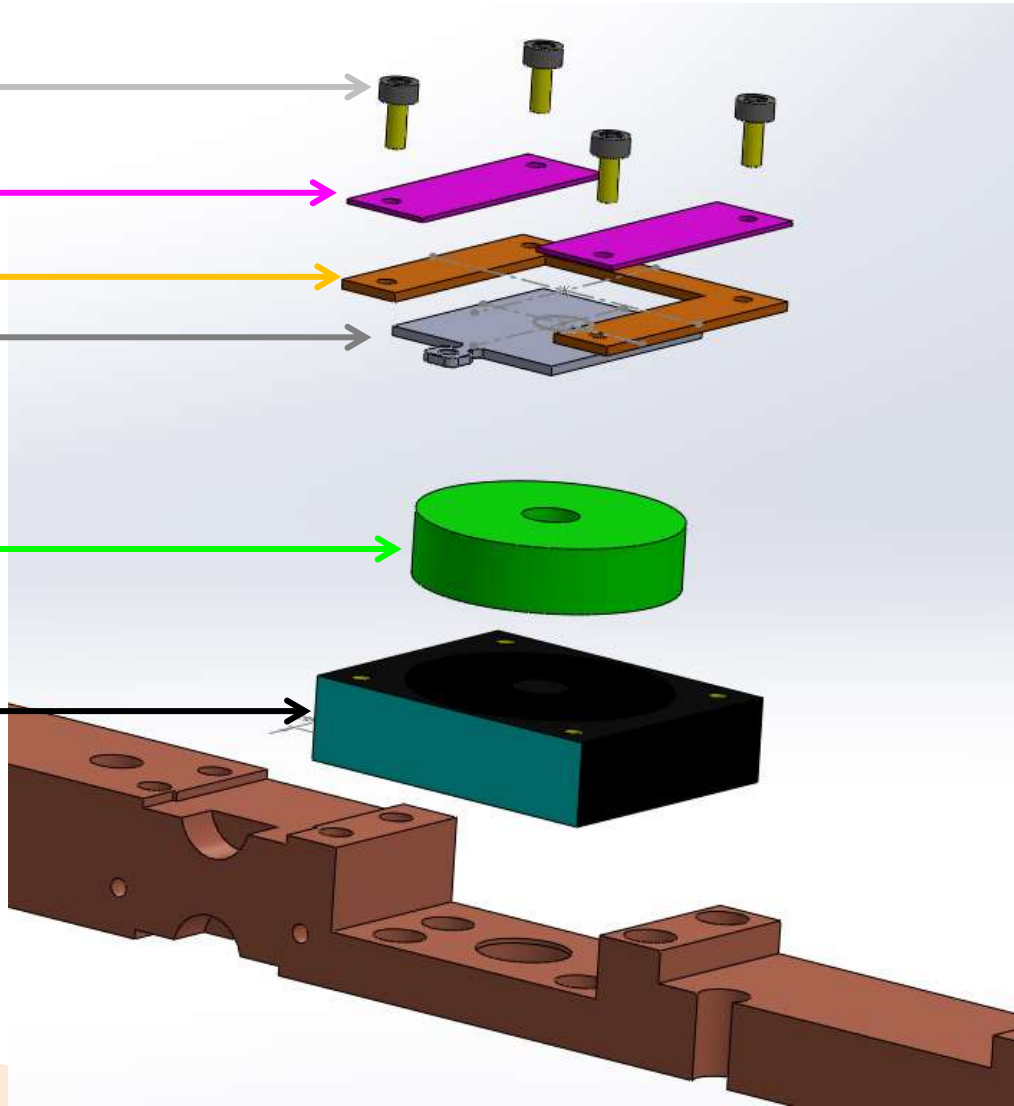
Sample holder positioner

Flag type Sample holder

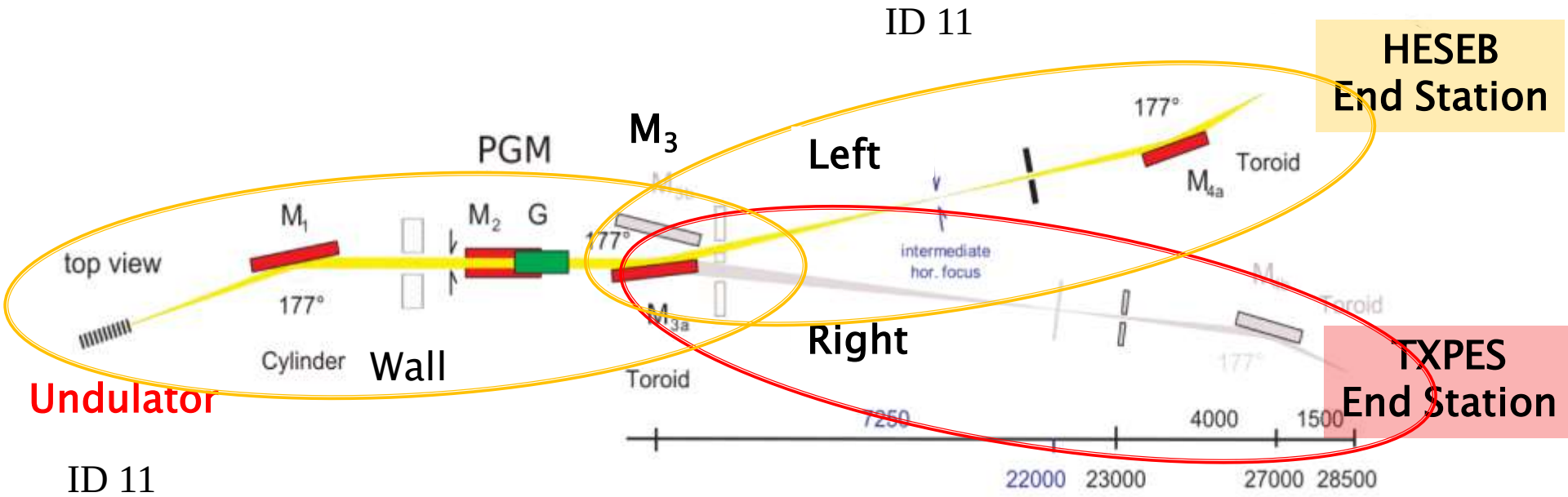
Solenoid 28mm

Pot and Core

Receptacle part backbone



Plan View of HESEB and TXPES

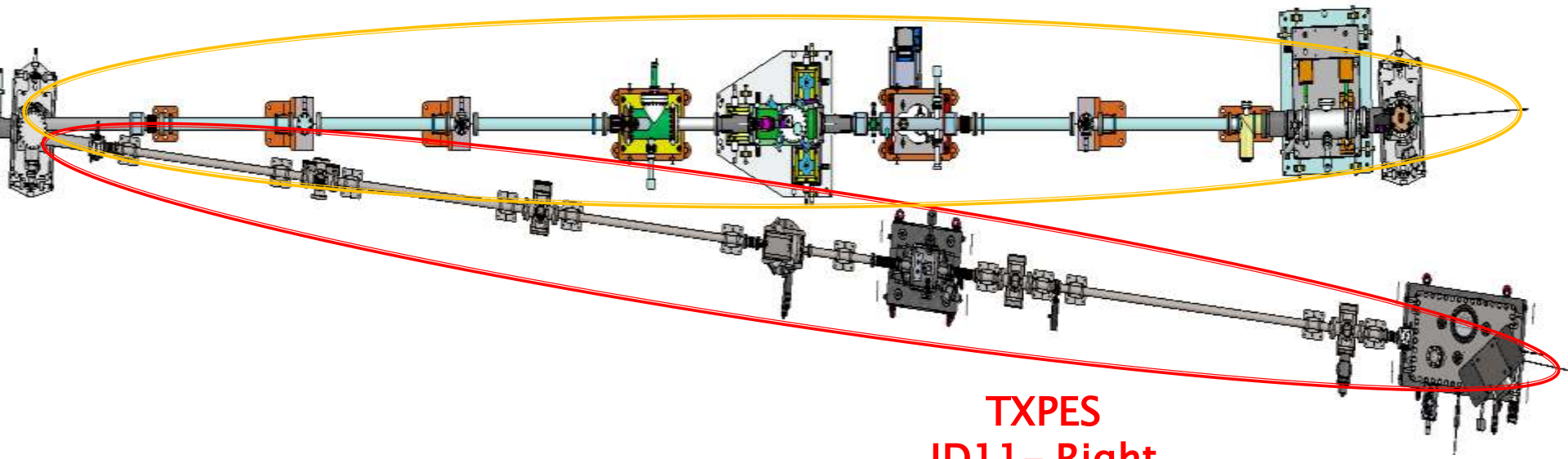


Turkish Soft X-ray Photoelectron Spectroscopy End Station (TXPES) Project

- **Project Duration:** 36 Months (02/2020 – 02/2023)
- **Project Budget:** ₺27 M (TC-SBB)
- **Project Coordinator:** Turkish Energy Nuclear and Mineral Research Agency (TENMAK)
- **Project Partners:** Bilkent University, Turkish Accelerator & Radiation Laboratory (TARLA), Koç University

TXPES Beamline

HESEB
ID11-Left



TXPES
ID11- Right

TXPES End Station Components: Chamber

- PHOIBOS 150 CMOS XPS/LEIS Analyzer
- XR 50: Dual Anode X-ray Source
- UVS 10: UV Source (for UPS)
- Electron Flood Gun
- Rastering Ion Gun for LEIS/Depth Profiling
- 4-Axis Manipulator with LN_2 Cooling & Resistive Heating to 1200 K

Analysis Chamber

- Ion Gun for Sputtering
- RF-Plasma Source
- Hydrogen Cracker
- LEED
- QMS
- Metal/Metal Oxide Evaporators
- Gas Dosers
- 4-Axis Manipulator with LN_2 Cooling & Resistive Heating to 1200 K

Preparation Chamber

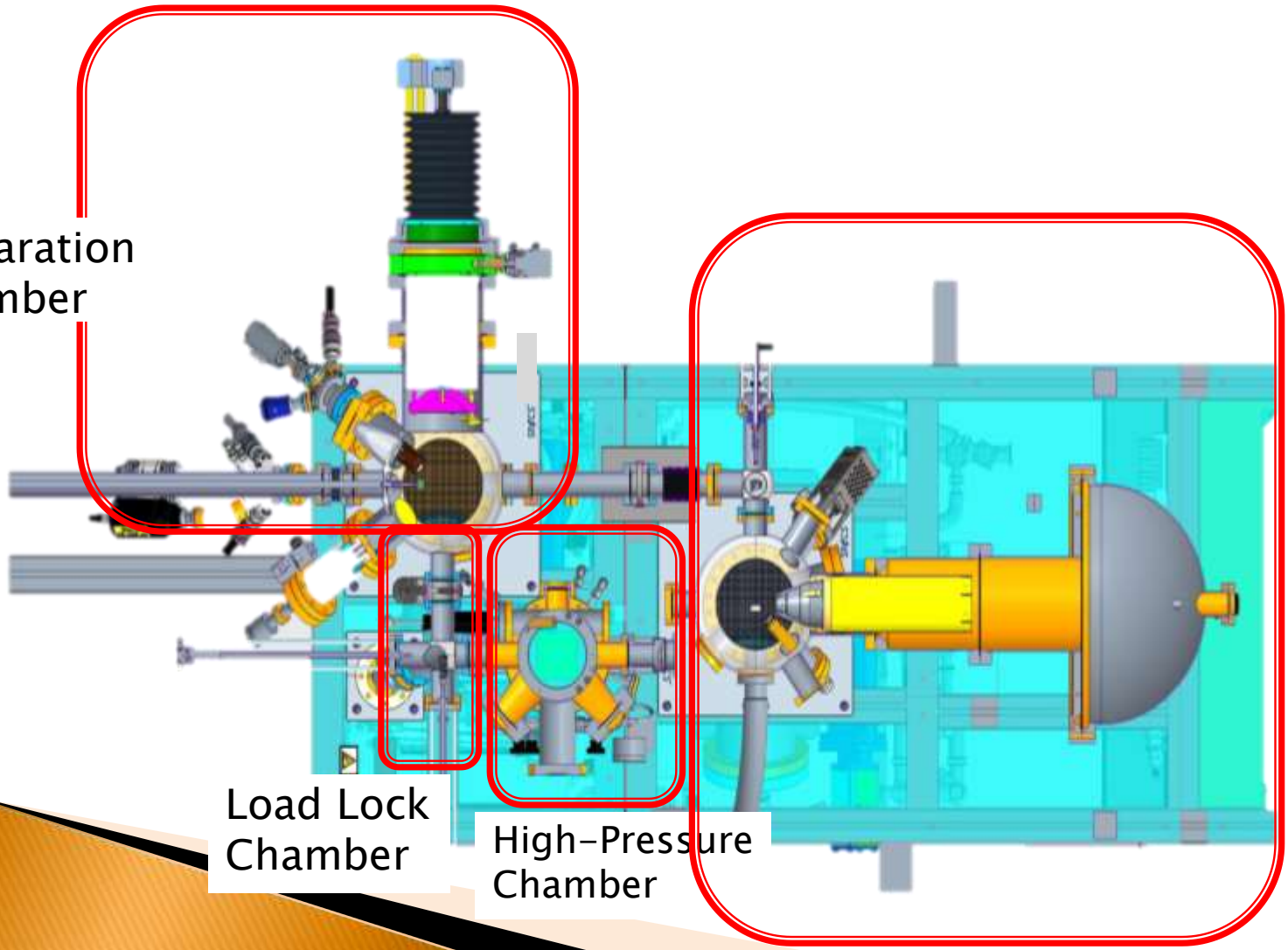
- Sample Loading/Removal

Load Lock Chamber

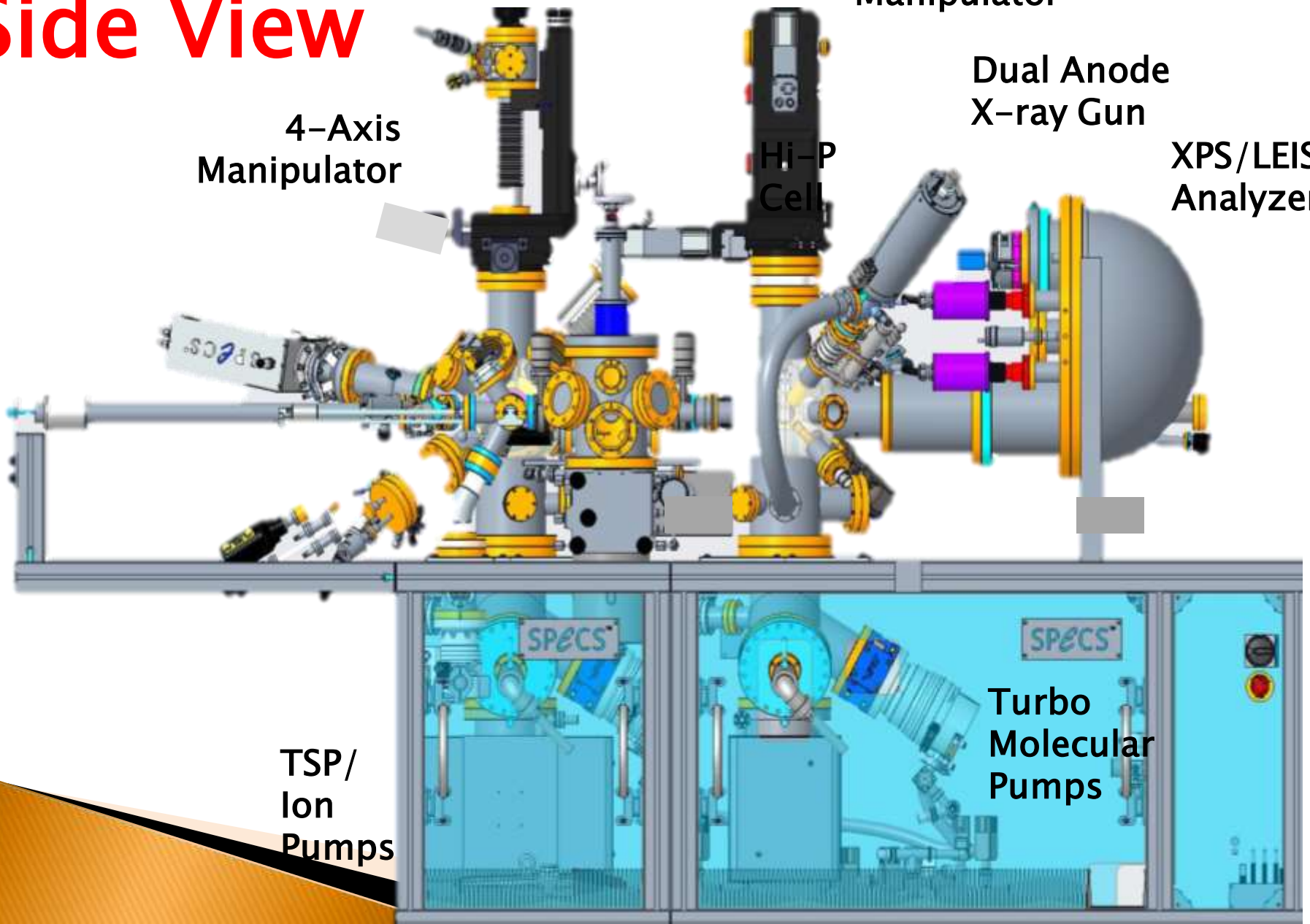
- HPC-20 High Pressure Cell for Reactive Sample Pretreatment

High-Pressure Chamber

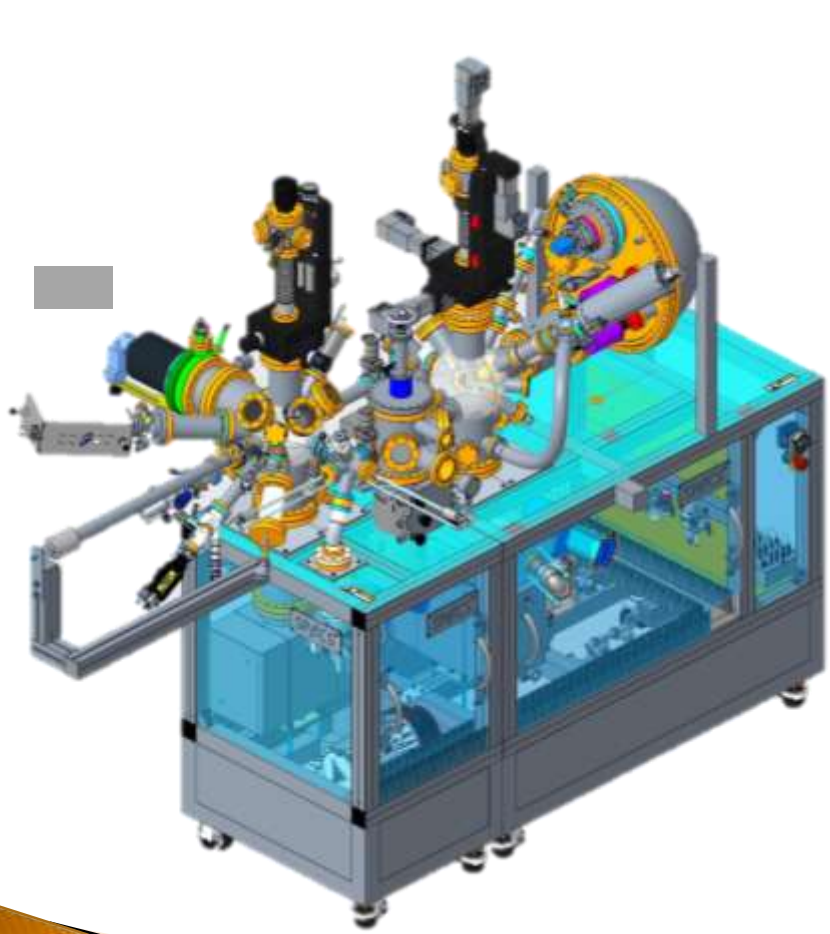
TXPES End Station: Top View (Mid-Cross Section)

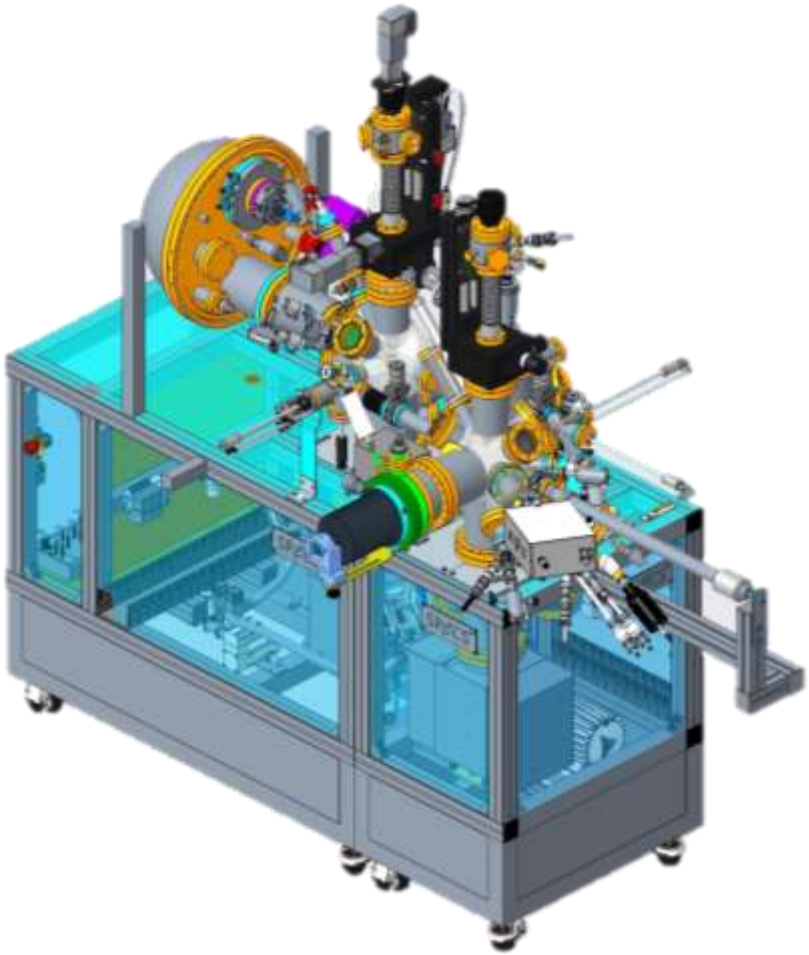


TXPES End Station: Side View



TXPES End Station: Isometric View





Acknowledgments

- HESEB project team

DESY.

JÜLICH Forschungszentrum

KIT Karlsruher Institut für Technologie

HZDR HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

HZB Helmholtz Zentrum Berlin

SESAME

- SESAME colloquies