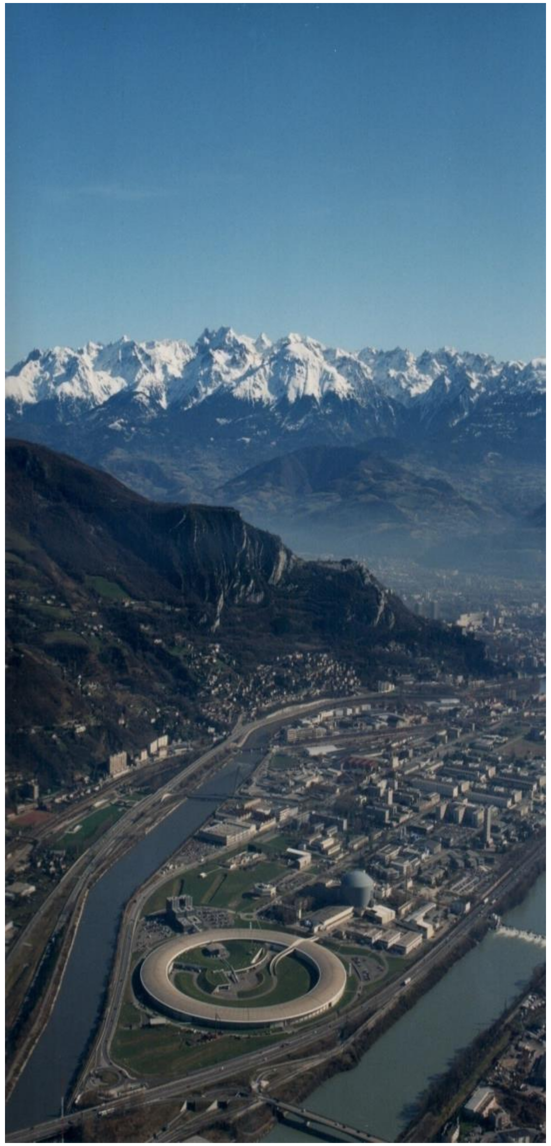


High flux nano-XRD beamline for Science under extreme conditions

Beamline Team:
S. Bauchau, G. Garbarino, V. Svitlyk and M. Mezouar

Project Contributors:

Beamline conceptual design: K. Martel
Ray tracing simulations: J. Reyes Herrera and M. Sanchez del Rio
Heat load calculations: P. Brumund
Mirrors geometry and coatings: R. Barrett and C. Morawe
X-ray source definition: J. Chavanne

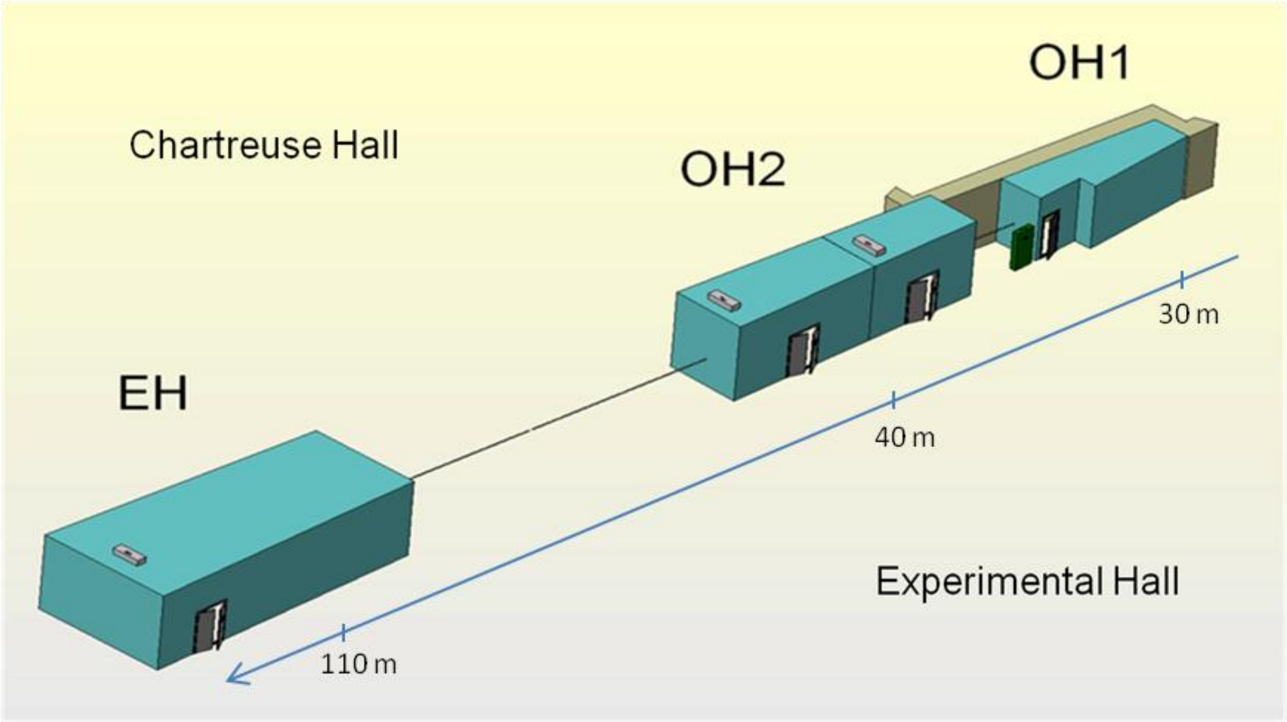
+Experts at the ESRF: P. Cloetens, R. Tucoulou, M. Di Michiel, V. Honkimaki, P. Boesecke, Y. Dabin, L. Eybert

and from external companies: Microplan, Cinel

GENERAL BEAMLINE CONFIGURATION

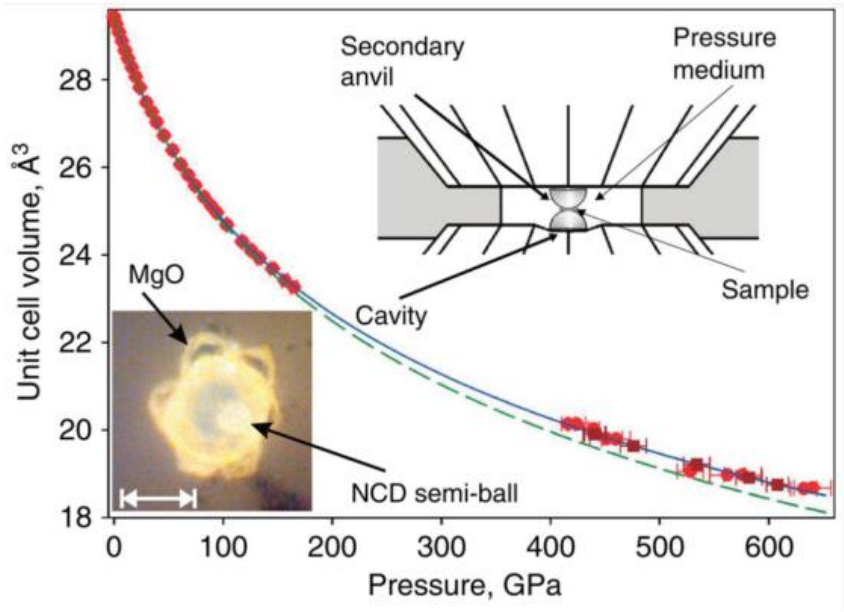
Main objectives:

- Build a new high pressure X-ray diffraction, fluorescence and imaging beamline.
-Take full advantage of the EBS to address the challenges defined in the scientific case.



Materials at and beyond the current limits of static pressures and high temperatures

Double-stage diamond anvil cell

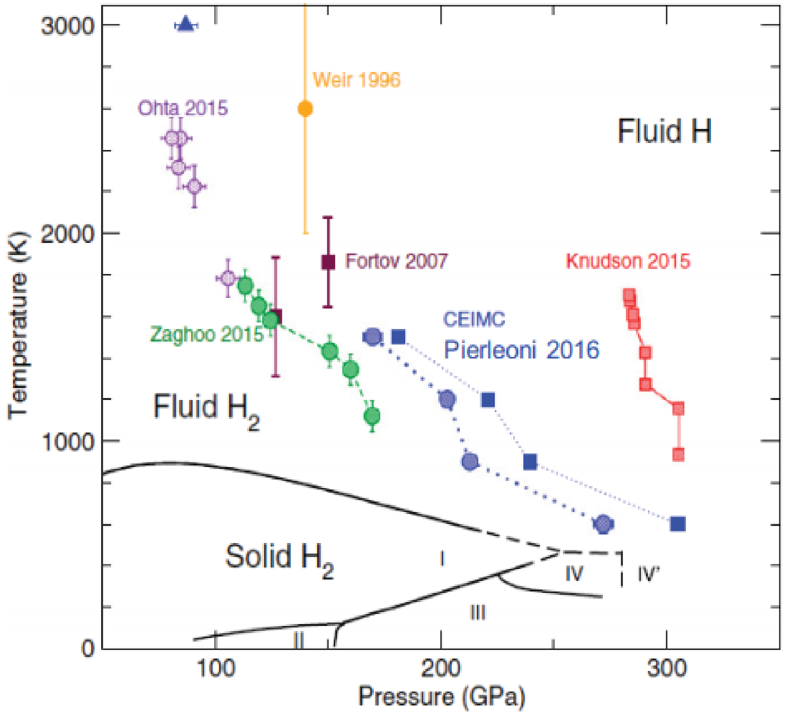


Pressure to 1000 GPa (10^7 bars)

Dubrovinsky et al., Nat. Comm., 2013

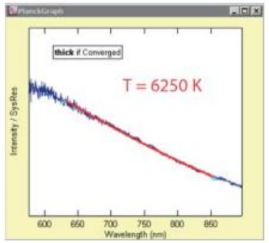
micro → nano-XRD

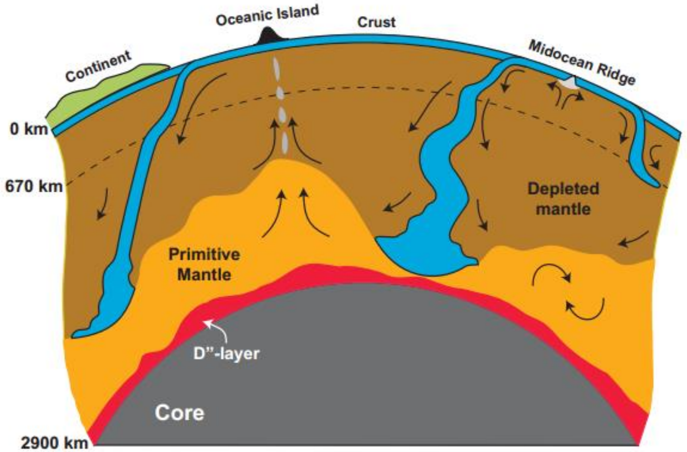
Solving the fluid H_2 to fluid H transition



High photon flux
Monochromatic → Pink beam

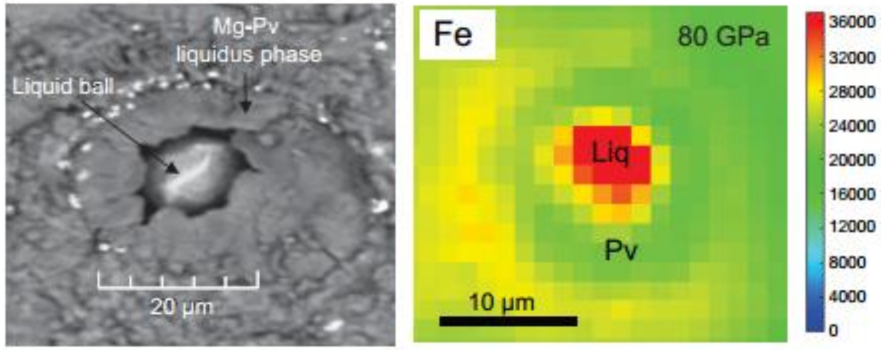
Fast melting, kinetics of chemical reactions at extreme conditions





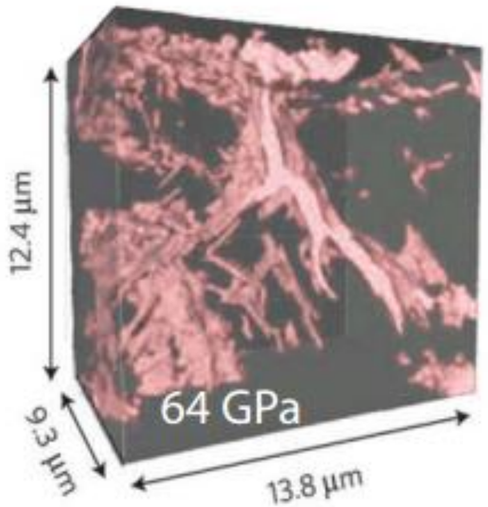
Derived from Kellog et al. 1999

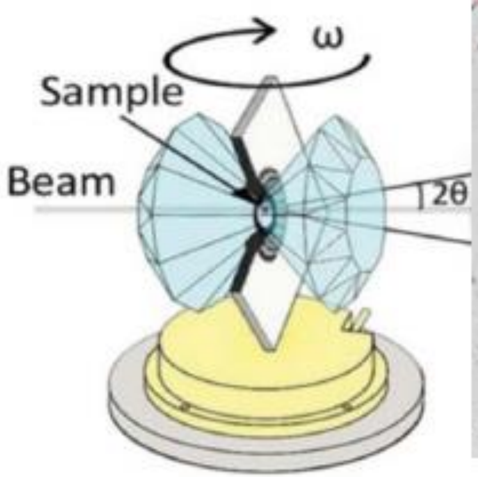
Exploring extreme temperature states using laser heating

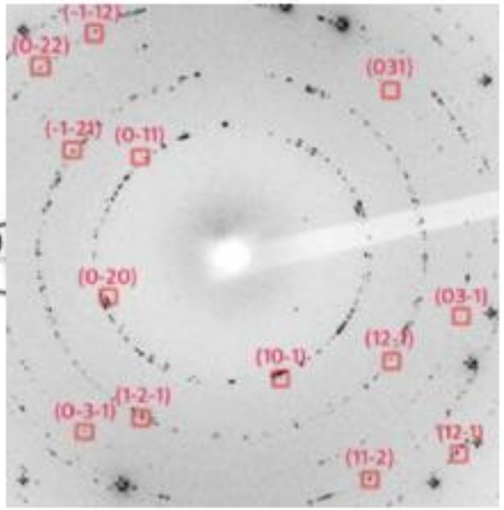


Converting ID27 into a nano-XRD/XRF beamline

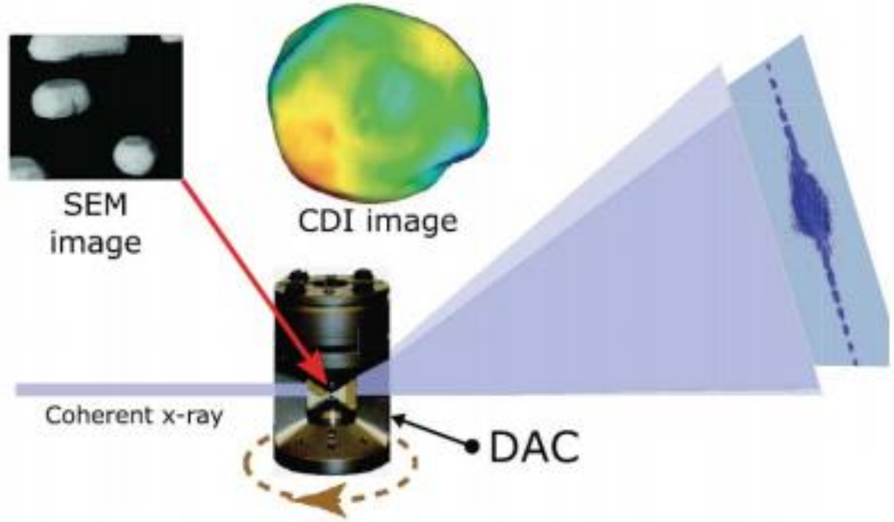
New type of experiments: Tomography







Exploiting
X-ray beam
Coherence



Providing XRI capabilities

OPTICAL DESIGN

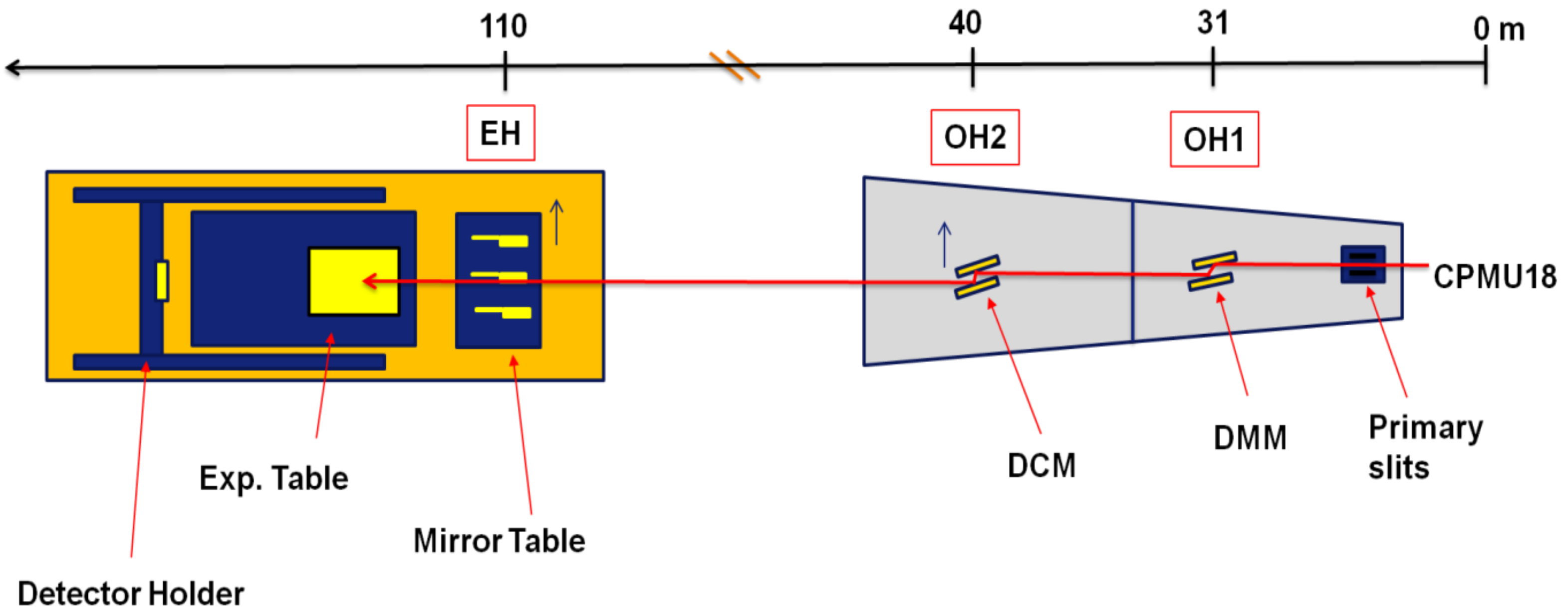
basic principles:

-Reduce the number of optical elements to a minimum to improve the stability of the beamline and optimally exploit the intrinsic beam properties.

-Exploit the very low horizontal emittance of the EBS (No need for a secondary source)
→Simplified optical configuration in "horizontal geometry"

Main elements:

-Water-cooled DMM
-LN2-cooled Si(111) DCM
-Three KB mirrors

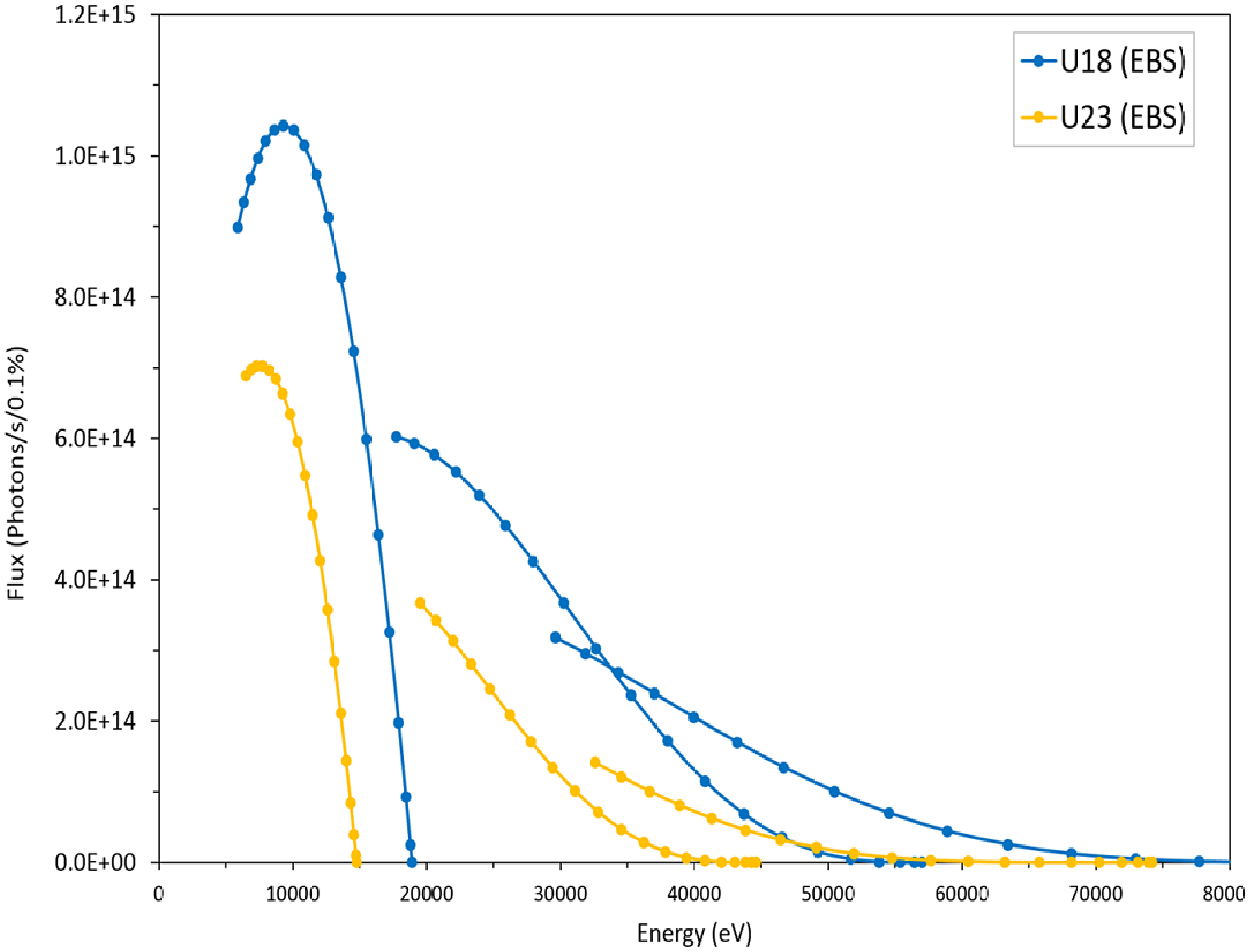


X-RAY SOURCE

-U18 cryo-undulator (CPMU18) placed in the middle of the ID27 straight section →minimum gap of 5mm (Kvalue=2.127).

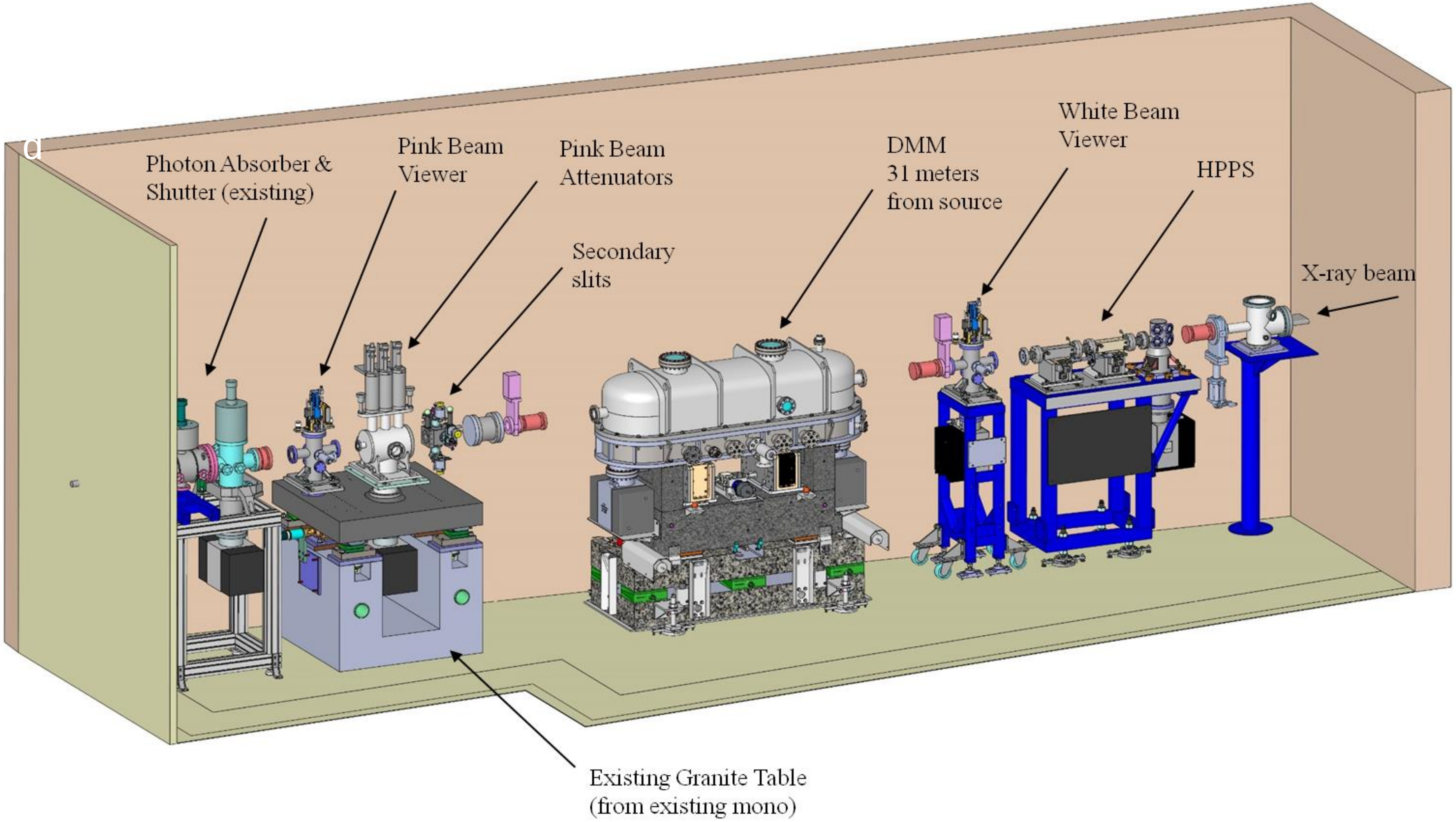
-Best system in terms of photon flux and tunability.

-It will replace the two currently installed U23 in-vacuum undulators.



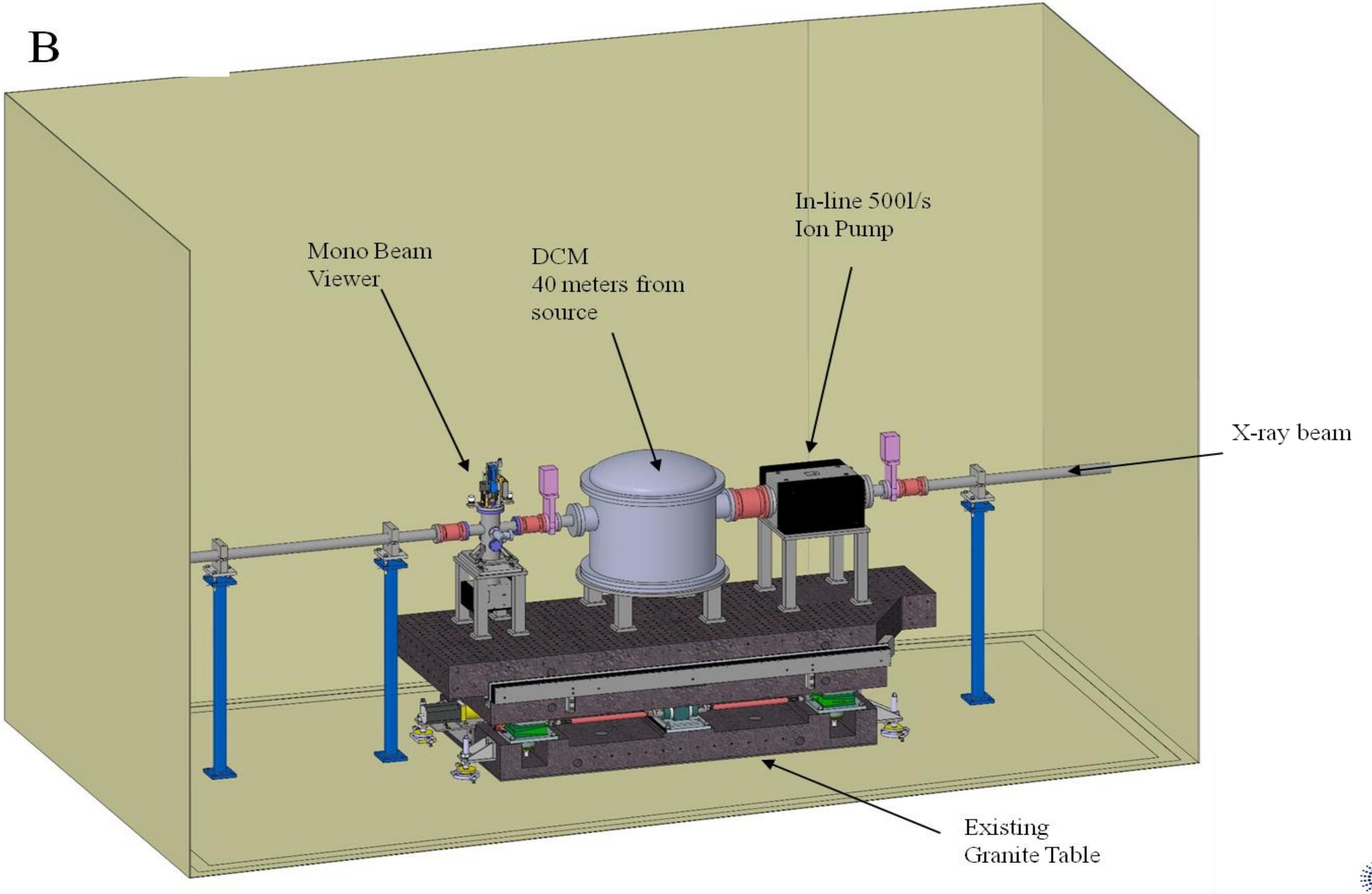
OPTICAL DESIGN – OH1 WHITE BEAM OPTICAL HUTCH

Re-used ID27/OH



OPTICAL DESIGN – OH2 “PINK” BEAM OPTICAL HUTCH

Re-used ID27/EH1



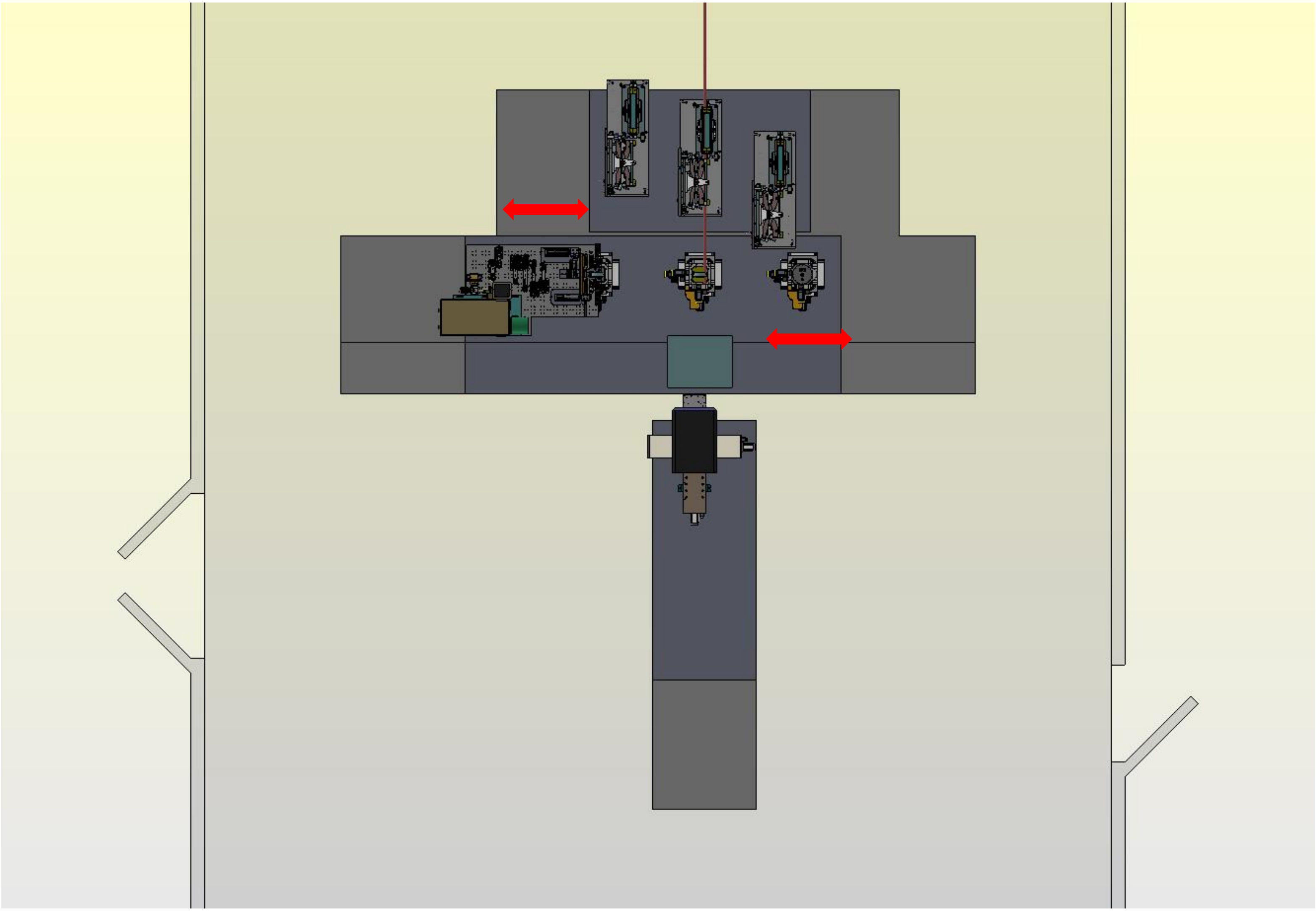
BEAMLINE END-STATION

Large thermo-stabilized experimental hutch (+-0.1 K)

3 KB mirror systems for different beamspot sizes and energy domains

3 goniometers:
- Laser heating (YAG and CO_2)
- Heavy duty (PE press, cryostat)
- Nano-goniometer

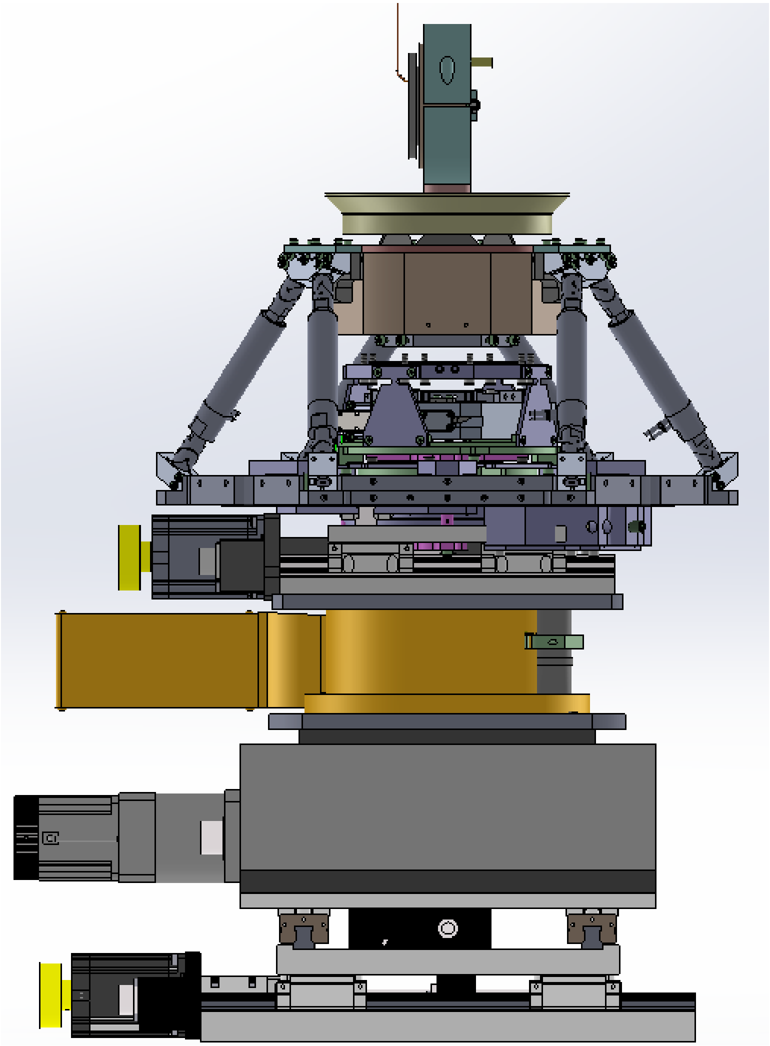
3 detectors
Eiger2/CdTe for XRD
PCO/CMOS for XRI
Vortex SSD for XES



NANO-GONIOMETER

hexapod with 6 piezo-actuators

YZ scanning with 20 nm precision



	KB#1	KB#2	KB#3
Coating/Multilayer	Pt	W/B_4C	Ir/Al_2O_3
Energy range (keV)	15-25	33(fixed)	30-60
Total Transmission	60-70%	74%	64% (at 30 keV)
ΔE/E FWHM	>10%	2%	2%
Length L_h/L_v (mm)	200/200	170/170	300/300
Useful M_h/M_v (mm)	180/180	140/140	250/250
$p_h(m)/q_h(m)$	110/0.30	110/0.50	110/1.2
$p_v(m)/q_v(m)$	110/0.55	110/0.70	110/0.80
Working distance from enclosure (mm)	200	450	550
Incidence angles at centre Maximum	θ_H=2.48 mrad θ_v =2.71 mrad θ_{max} =3 mrad	θ_{cen}=7 mrad	θ =7 mrad at 30 keV
Aperture H/V (mm)	0.47/0.5	1.0/1.0	1.8/1.8
Slope errors (nrad)	100	100	300
ideal spot HxV (nm)	210/190	380/340	1700x2000
Target spot size VxH (nm)	200x300	350x500	2000x2000
Metrology	Fixed	Fixed	Bending

EXPECTED FLUX AT SAMPLE POSITION

Energy [keV]	15 (KB1)	33 (KB2)	60 (KB3)	ID27 old storage ring
Beam spot size HxV (µm)	0.22x0.28	0.47x034	2x2	2x3
Photons/s $\Delta E/E=1.5.10^{-4}$ DCM	7.10^{12}	$1.1.10^{13}$	$2.2.10^{12}$	$0.9.10^{11}$ (at 33 keV)
Photons/s $\Delta E/E=2\%$ Pink beam	$5.0\ 10^{14}$	7.10^{14}	1.10^{14}	NA

Gain x100 in monochromatic to x1000 in pink beam

Frame rate: 0.2 Hz
Sensitivity <20 % at 30 keV
dynamic range: 13 bits

Frame rate: 250 Hz
Sensitivity >90 % at 30 keV
dynamic range: 20 bits

Timetable of the project:

-Nov. 2019: Technical Design Report

-Feb. 2020: Beginning of construction

-March 2021: Radiation test

-April: Beamline commissioning

-Mai-June 2021: User operation