U.S. DEPARTMENT OF ENERGY
Office of Science

BERKELEY LAB

ALS-U
ADVANCED LIGHT SOURCE

Recent Achievements in the NEG Technology in Application to Coating Vacuum Chambers of Constrained Geometries

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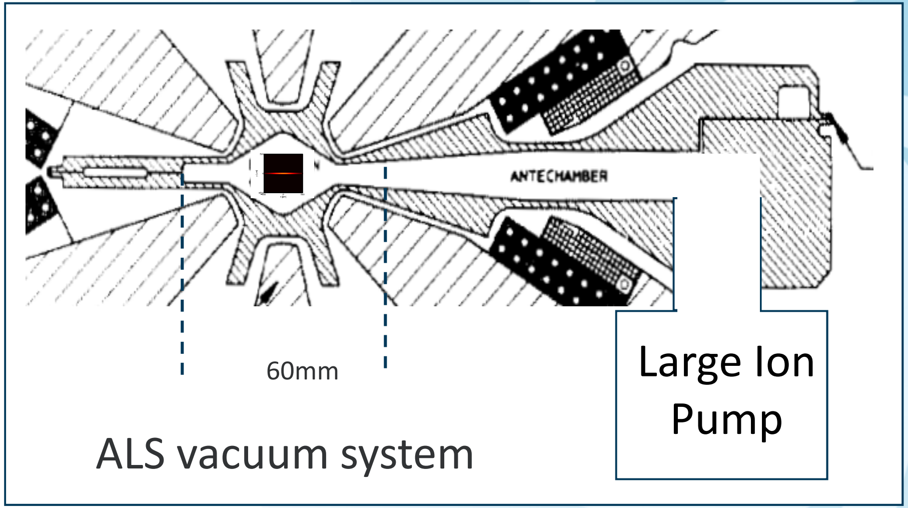
Contributors: Ken Tokunaga, Guobin Wang, Jim Curtis

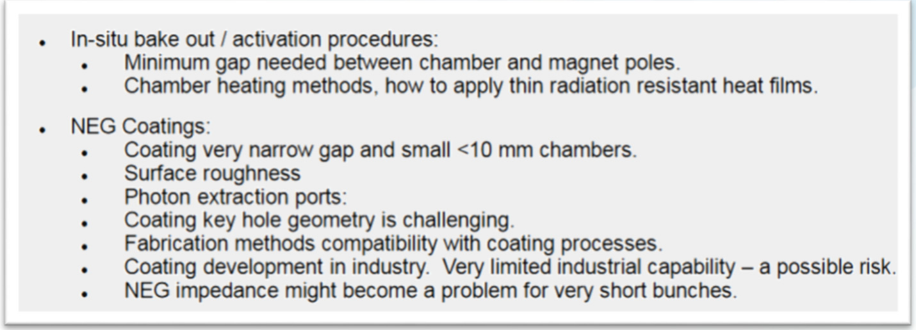
IPAC, 2022

Outline

- Motivation
  - The ALS-U project
- Overview of NEG coating R&D
  - Samples
  - NEG coating tools
  - Pumping measurement
- Result
  - Pumping
  - PSD
  - SEM



3rd DLSR Workshop SLAC 2013: Accelerator Session Close-Out Report: Vacuum

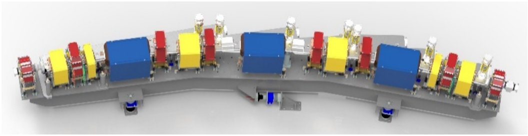


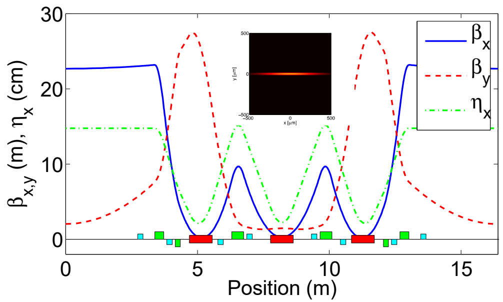
- In-situ bake out / activation procedures:
  - Minimum gap needed between chamber and magnet poles.
  - Chamber heating methods, how to apply thin radiation resistant heat films.
- NEG Coatings:
  - Coating very narrow gap and small <10 mm chambers.
  - Surface roughness
  - Photon extraction ports:
  - Coating key hole geometry is challenging.
  - Fabrication methods compatibility with coating processes.
  - Coating development in industry. Very limited industrial capability – a possible risk.
  - NEG impedance might become a problem for very short bunches.

ALS-U Project: Motivation – Lower Emittance & Higher Brightness

Storage Ring Parameters	Value
Electron energy	2.0 GeV
Average current	500mA
Bunch Length (FWHM)	110 ps
Total lifetime	>0.5h
Circumference	196.510 m

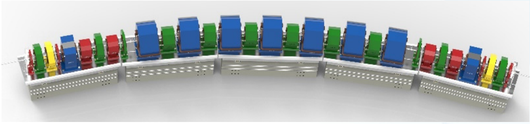
ALS today : triple-bend achromat

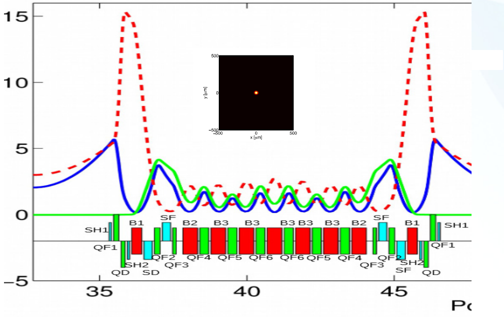




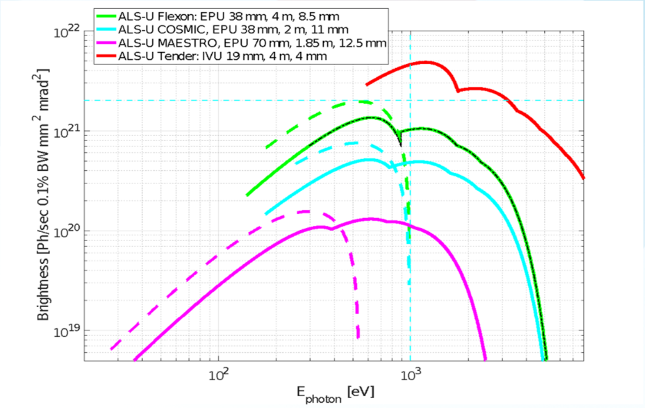
$\varepsilon_x \approx$ 2000 pm rad at 1.9 GeV

ALS-U: nine-bend achromat with reverse bends



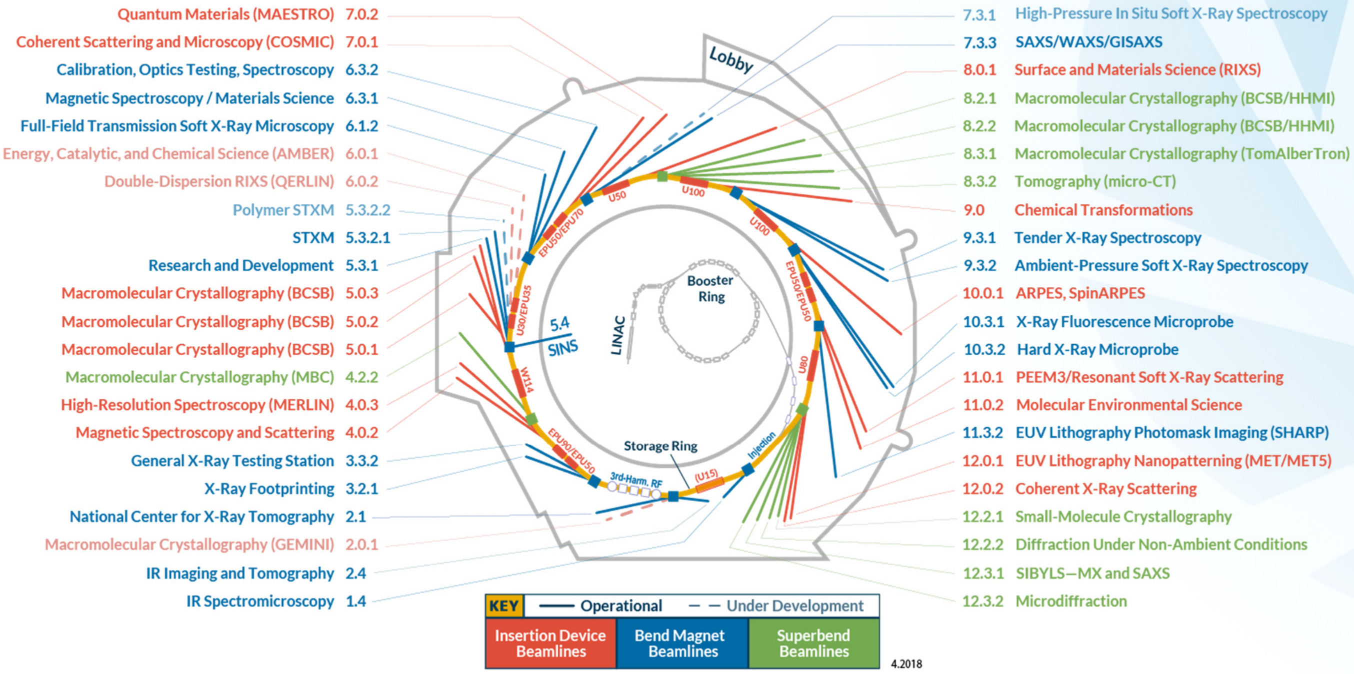


$\varepsilon_x <$ 71 pm-rad at 2.0 GeV



Large increase in coherent fraction due to lower emittance and smaller β-functions

Enabling new science frontiers



Infrared VUV Soft Tender Hard

Quantum Materials Research & Discovery

Multiscale Structure & Dynamics

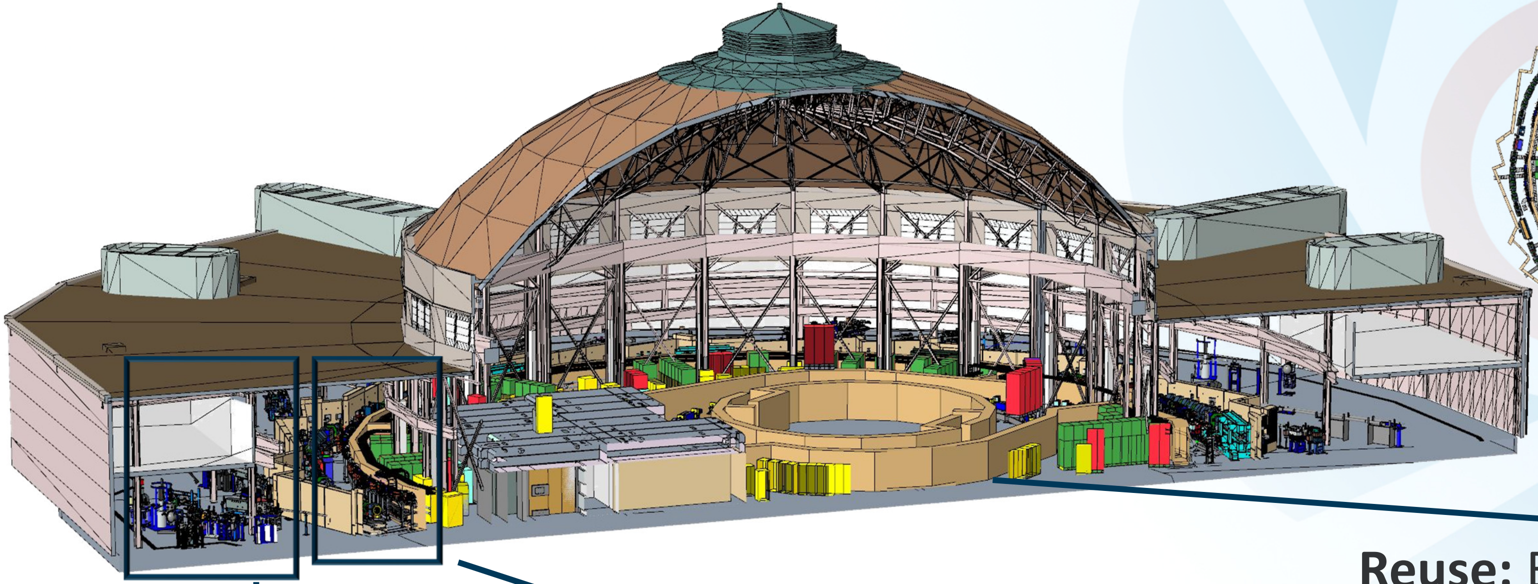
Chemical Transformations

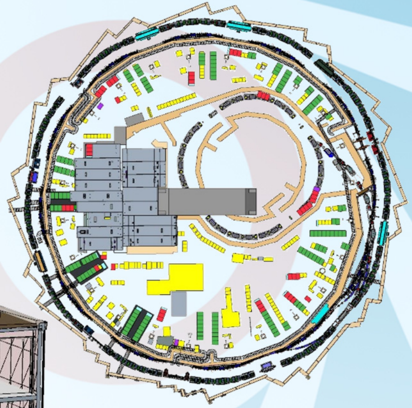
Earth, Environment & Biological Systems

Instrumentation Science

- 40 beamlines
- 2,100+ users/year
- 950+ pubs/year
- 20% in high-impact journals

ALS-U Accelerator Systems Complex





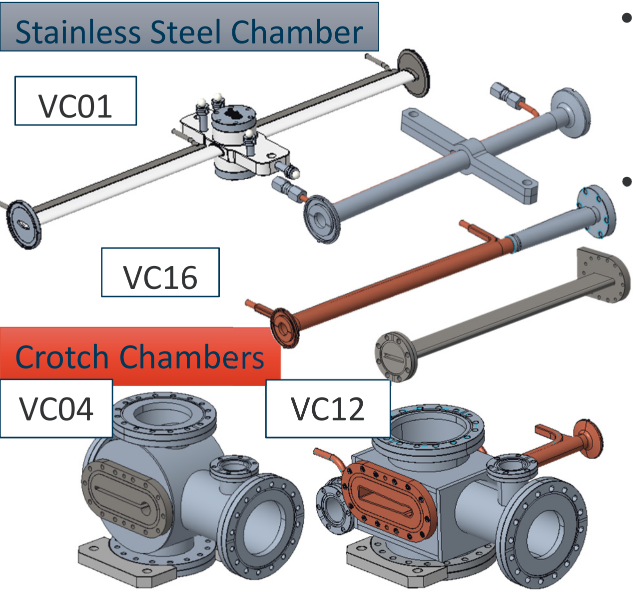
Reuse: Existing ~40 photon beamlines
Add: 3 New flagship beamlines

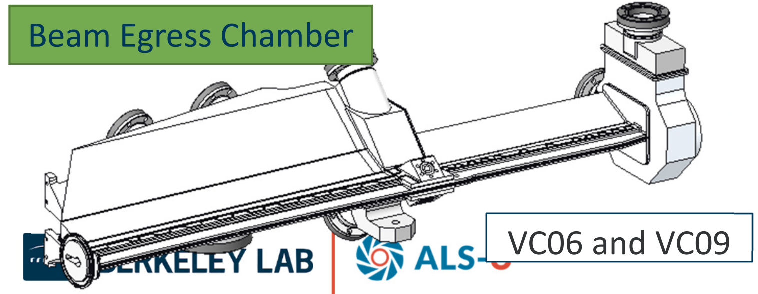
Replace: 3 bend storage ring with a 9 bend storage ring
Add: New accumulator ring + Transfer line

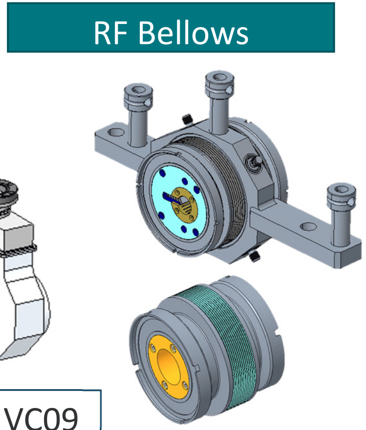
Reuse: Existing LINAC, Booster & Conventional facilities

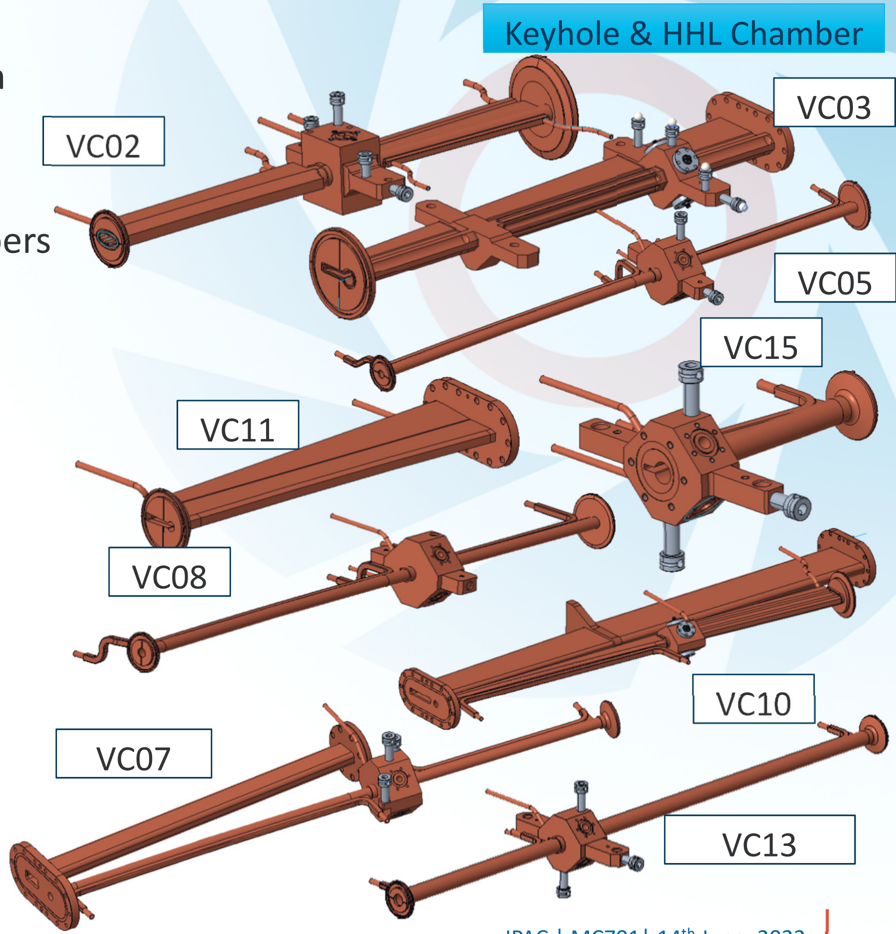
Vacuum Chamber Designs

- Broad array of vacuum chambers and components
- Majority of the chambers are NEG coated

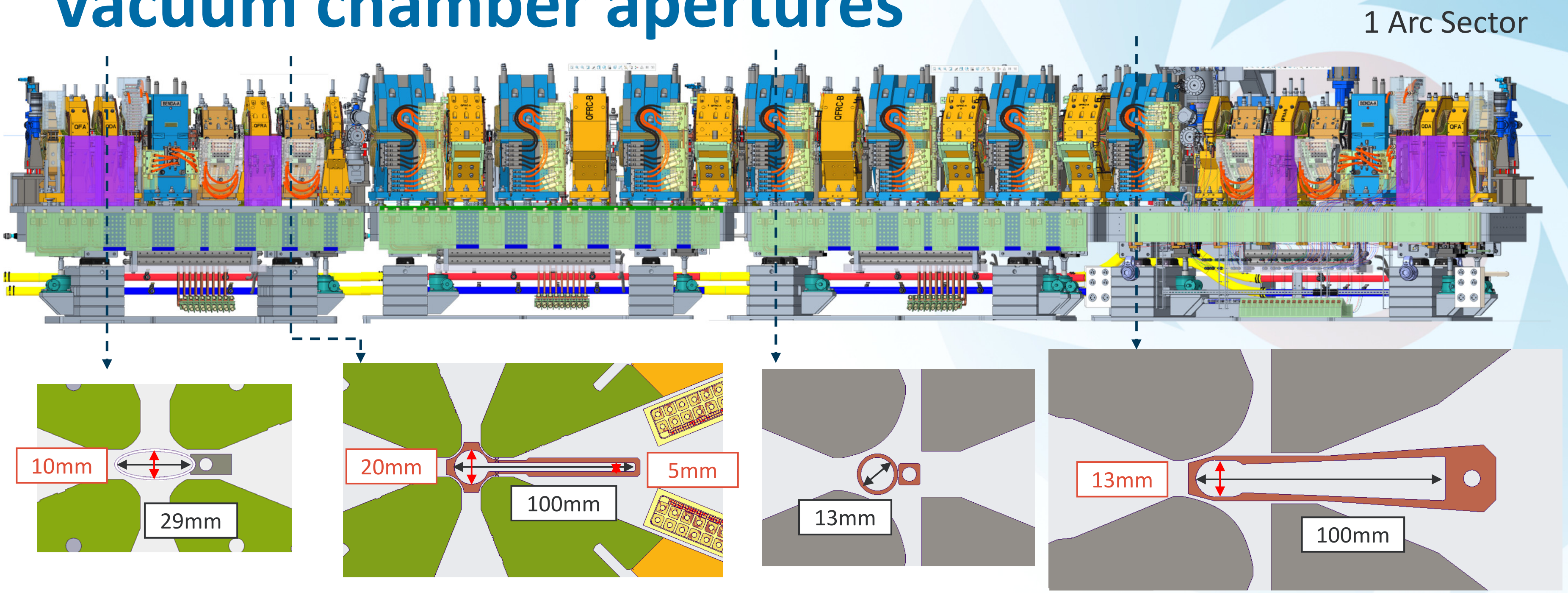




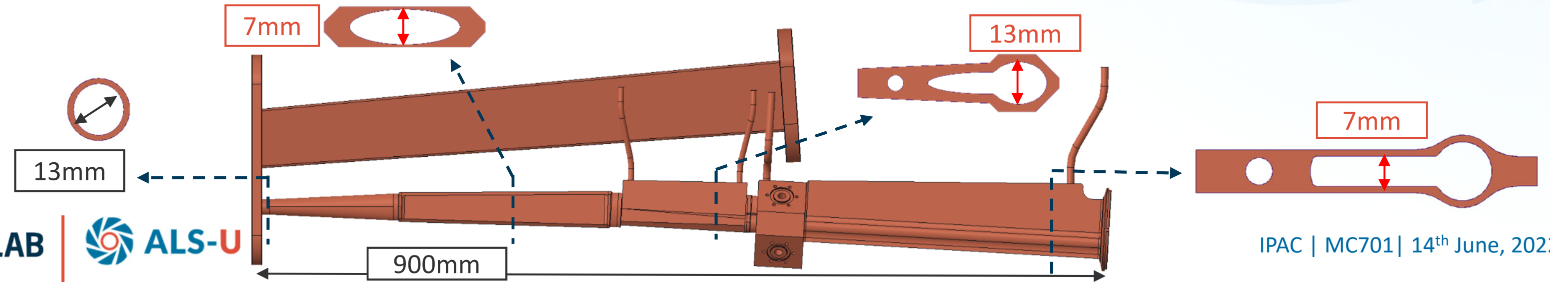




Vacuum chamber apertures

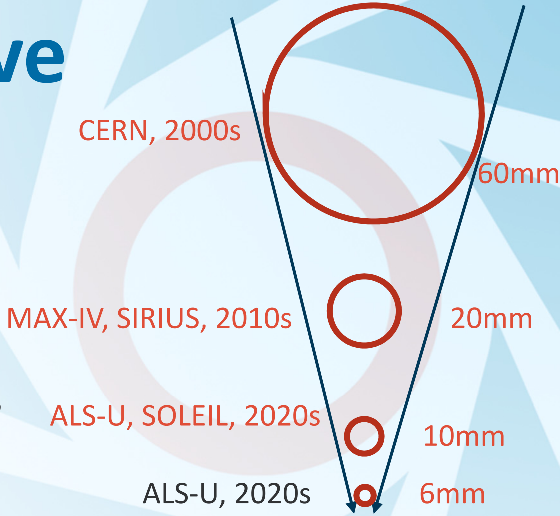


High Field
Magnet
Chamber



NEG Coating Development Objective

- Demonstrate current NEG coating technology is applicable to ALS-U relevant chambers
- Explore/develop industry and research capability and partnerships – SOLEIL, STFC, ESRF, SAES, FMB
- Develop in-house NEG coating capability



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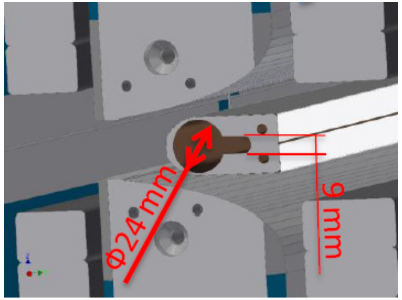
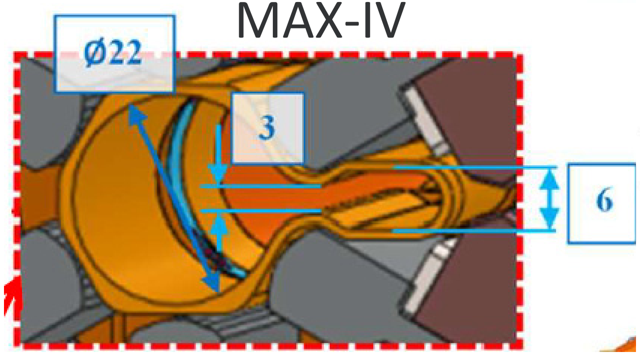
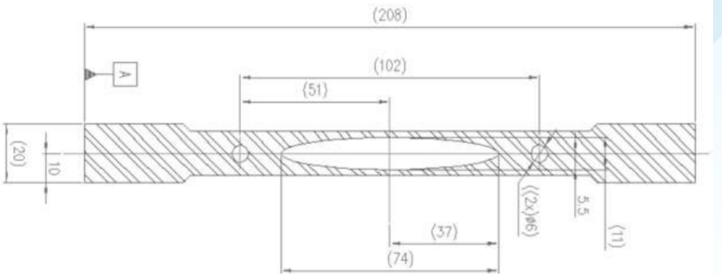


MAX-IV



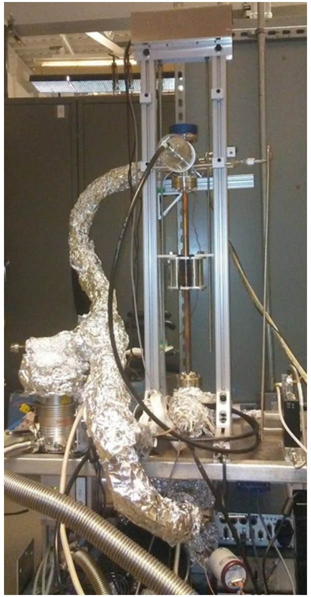
ESRF chamber CV5073 (L=5073 mm, 11 mm x 74 mm)



R. Kersevan, Proc. EPAC-2000 Conference, Vienna, June 2000, page 2289-2291, available at http://accelconf.web.cern.ch/accelconf/e00/PAPERS/THP5B11.pdf.

NEG Coating Systems

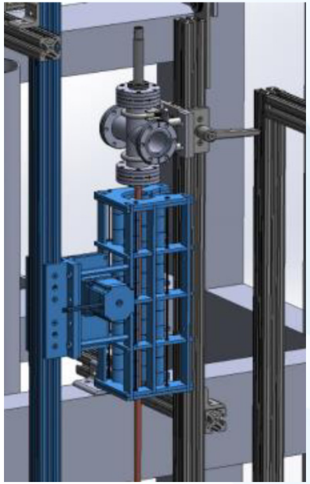
Lab size systems: 2016 to 2018

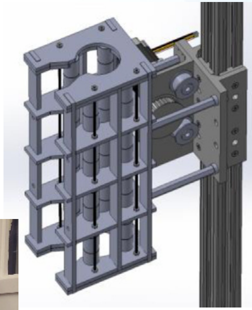


- Ultra pure Ar gas
- Permanent magnet and electromagnet solenoids
- Ti,Z,V twisted wire (0.2 -2mm thick)
- Coating at 100ºC
- Base pressure 5e-10 Torr
- Continuous gas flow
- Typically 12hr for coating 1 micron
- Silicon sample
- Standard UHV cleaning

Samples: 0.5m long, 6mm & 9mm ID Cu tubes

Production size systems: 2019 to now



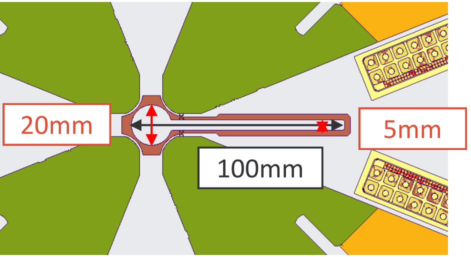


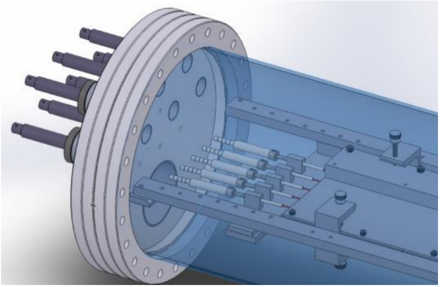
4m long narrow NEG coating rig

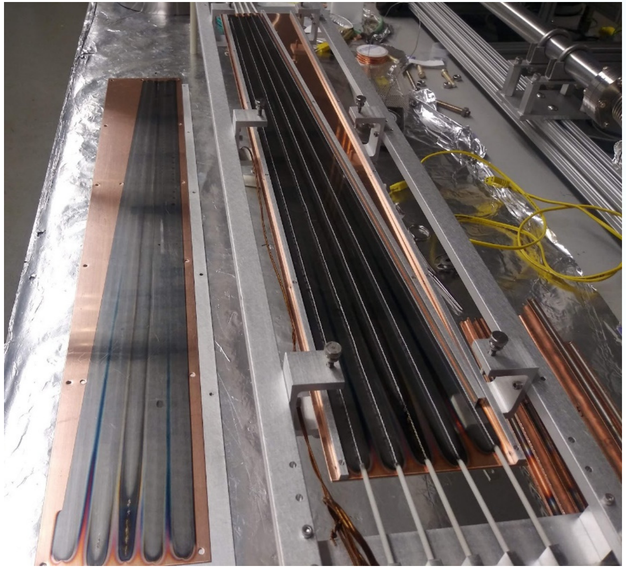
2m long X 300mm wide NEG coating rig

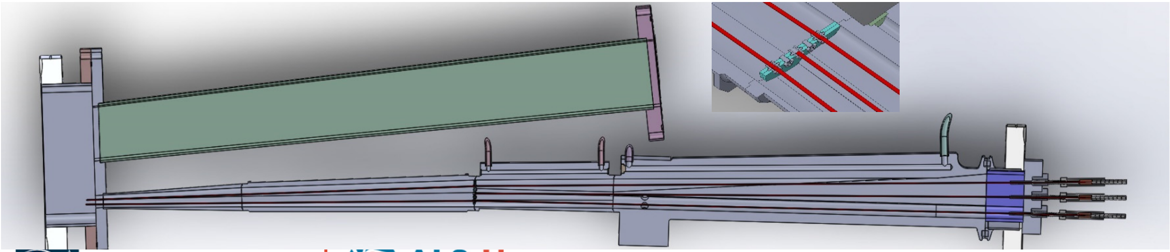
Complex Shape Chamber NEG coating Trials

Keyhole chamber NEG coating setup









Keyhole chamber NEG coated in industry

Pumping test system

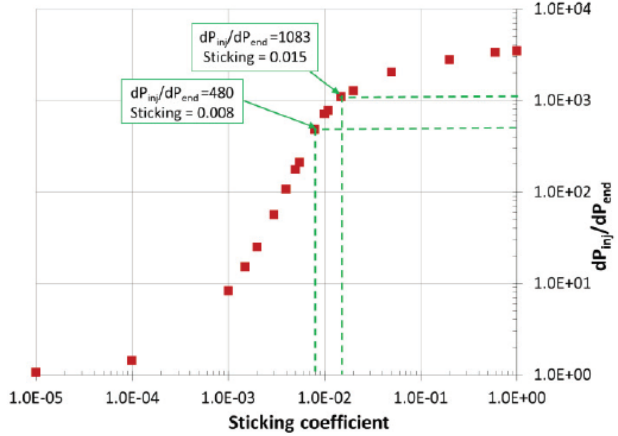
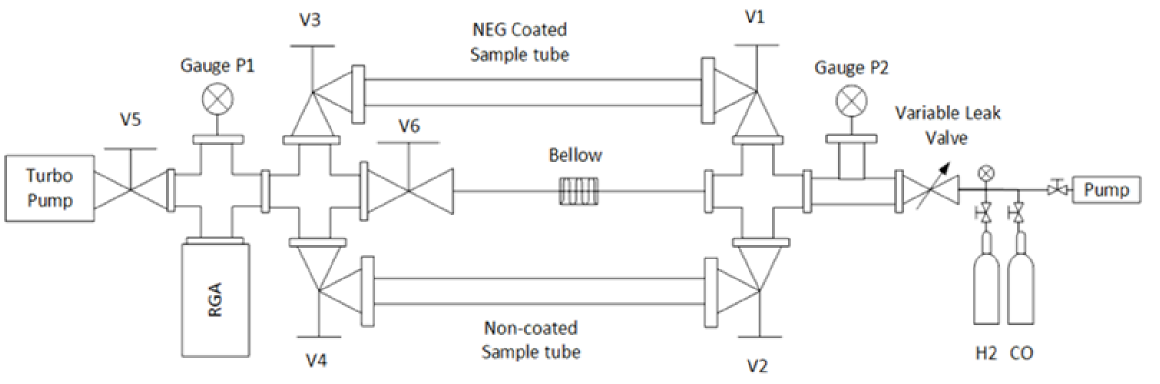


Figure 2: Monte Carlo simulations results for a 1 m long NEG-coated tube of 21 mm inside diameter.

NEG THIN FILM COATING DEVELOPMENT FOR THE MAX IV VACUUM SYSTEM

S. Calatroni, P. Chiggiato, P. Costa Pinto, M. Taborelli, CERN, Geneva, Switzerland
M. Grabski#, J. Ahlbäck, E. Al-Dmour, P. Fernandes Tavares, MAX IV Laboratory, Lund University, 22100 Lund, Sweden



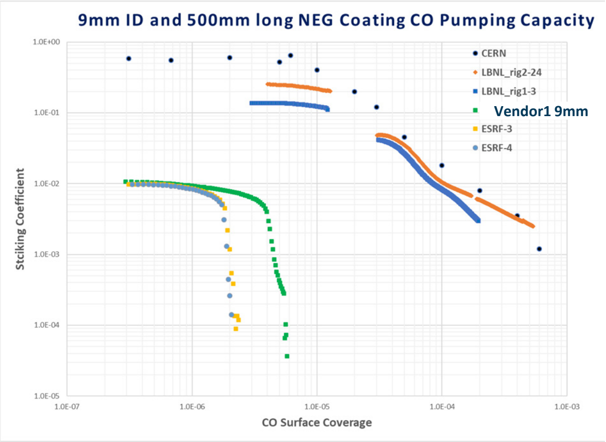
CERN Data based on 60mm ID tubes,

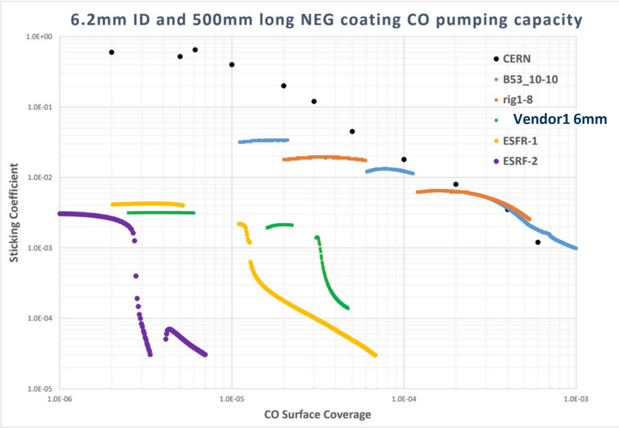
		H_2	CO	N_2	CH_4
Maximum sticking probability	smooth	8×10^{-3}	0.7	1.5×10^{-2}	
	rough	3×10^{-2}	0.9	3.0×10^{-2}	
Surface capacity [molecules cm^{-2}]	smooth		8×10^{14}	1.5×10^{14}	
	rough		8×10^{15}	1.5×10^{15}	
Electron stimulated desorption yields [molecules per impinging electron]	electron energy = 500 eV negligible dose	2×10^{-4}	1×10^{-4}		5×10^{-6}
Photon stimulated desorption yields [molecules per impinging photon]	Ec=194 eV [51] negligible dose, normal incidence	3×10^{-6}	$<2\times10^{-8}$		$<3\times10^{-8}$
	Ec=4.5 KeV [41, 42] 10^{21} ph m^{-1} 10 mrad incidence	1.5×10^{-5}	$<10^{-5}$		2×10^{-7}

Tab.1: Summary of the some functional properties of Ti-Zr-V film coatings. Pumping speed and gas capacity are referred to film coated at 100°C (smooth) and 250°C (rough). Electron and photon desorption yields are reported only for smooth films. Pumping speed and gas capacity can be improved by increasing the substrate roughness.

- Activation: 240^{o}C for 12 hrs
- Pumping test: Throughput
- MCTP simulations used to determine corresponding sticking coefficient to measured P_{INJ}/P_{INJ}
- Test carried out using CO & H2

Pumping performance





Sample	H2 Sticking Coeff.	CO Sticking Coeff.	CO Capacity
CERN Benchmark	0.007	0.7	8e-14 [molecules/cm]
LBL 6 mm	0.007	0.03	Comparable to CERN
LBL 9 mm	0.007	0.25	Comparable to CERN
Vendor1 6 mm	0.0025	0.003	low
Vendor1 9 mm	0.0065	0.015	low
ESRF 6 mm	0.003	0.004	low
ESRF 9 mm	0.005	0.01	low
Vendor2 10 mm	0.005	0.0015	poor

Factor that impact pumping performance

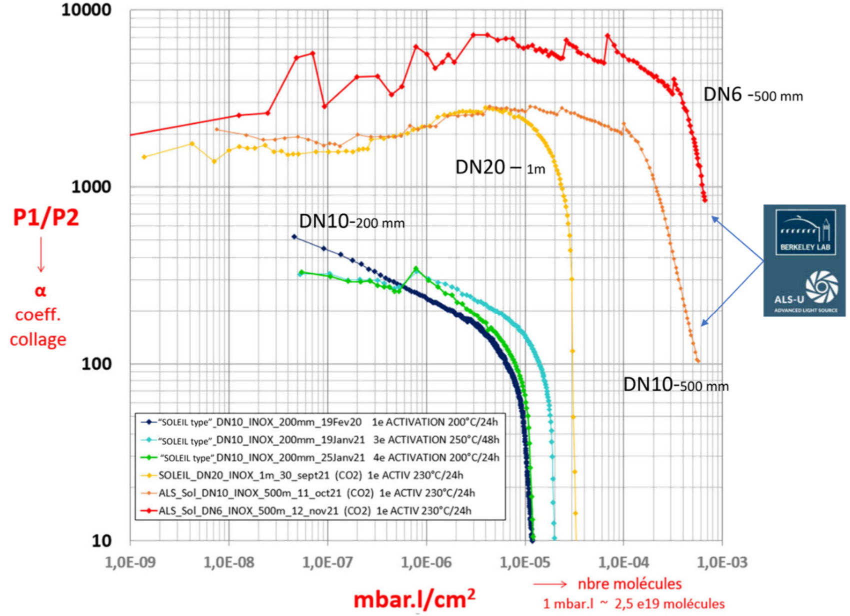
- Substrate temperature
- Cathode voltage
- Plasma power or deposition rate
- Initial base pressure
- Coating pressure
- Tube ID
- NEG wire contamination content
- Moving magnets vs full length solenoid
- Gas purity
- DC power vs pulsed-DC power
- NEG wire degassing
- Substrate roughness

Findings

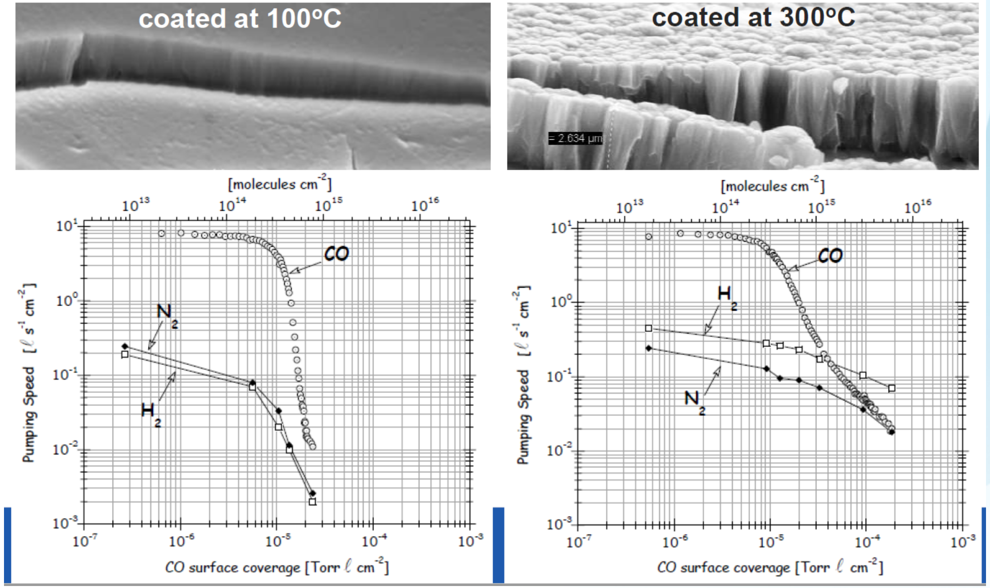
- 9mm samples consistently performs better than 6mm – aspect ration rules out
- In-house coated sample out performs those sourced externally
- Vendor and other labs struggle with coating 6mm. Some declined

Pumping comparison at SOLEIL

SOLEIL SYNCHROTRON UPGRADE

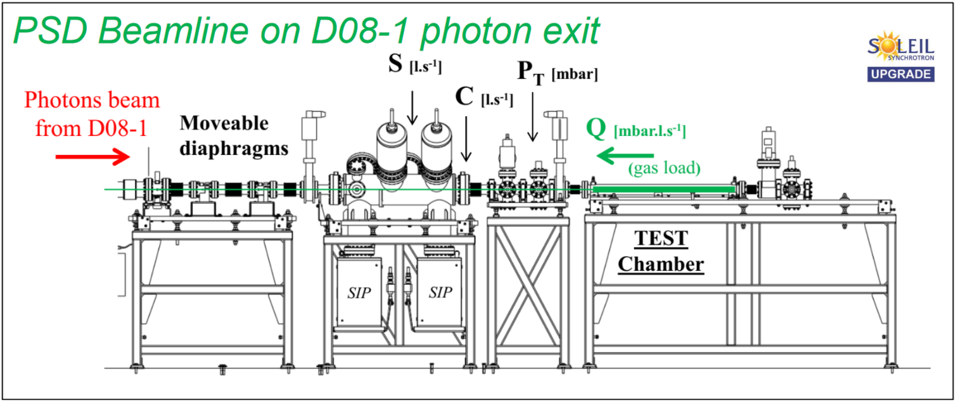


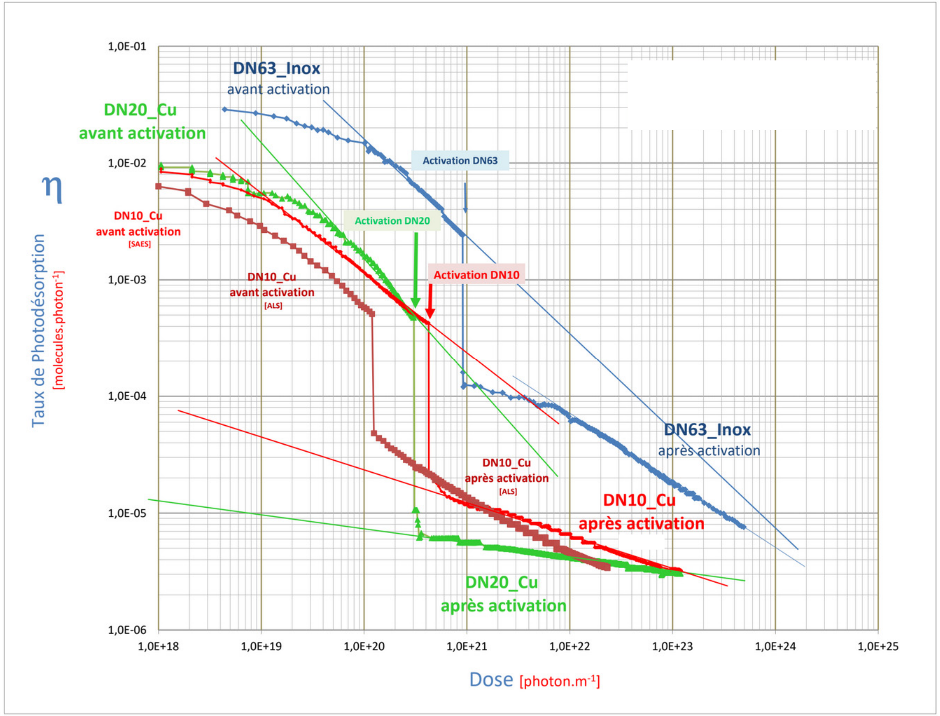
Pumping speed and surface capacity of TiZrV. (activation 24h@230°C)

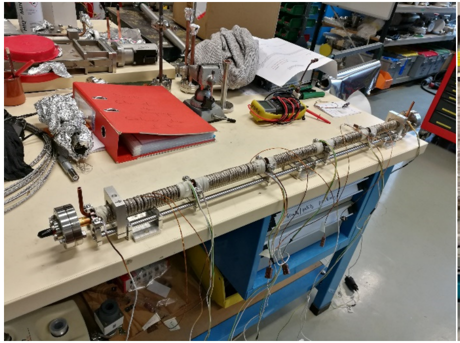


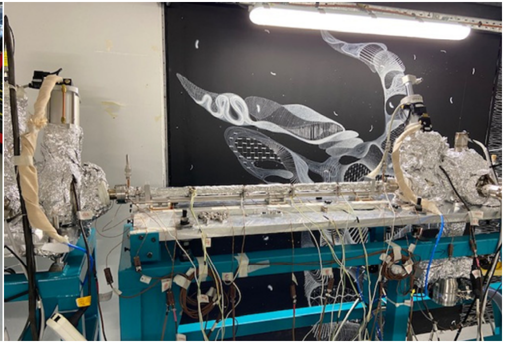
CERN-TS-2006-001(MME); Ti-Zr-V non-evaporable getter films: from development to large scale production for the Large Hadron Collider.

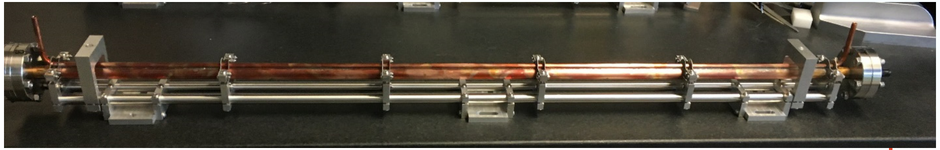
PSD Measurement at SOLEIL



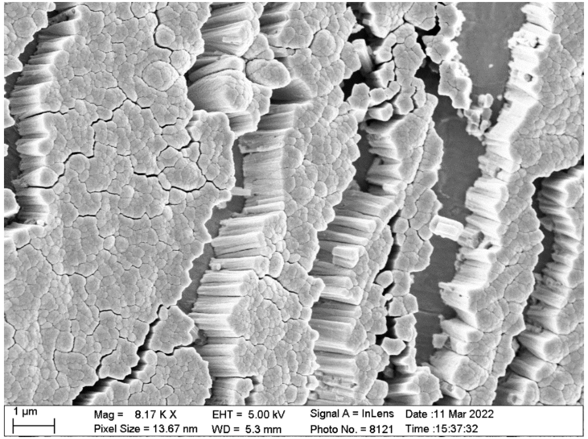


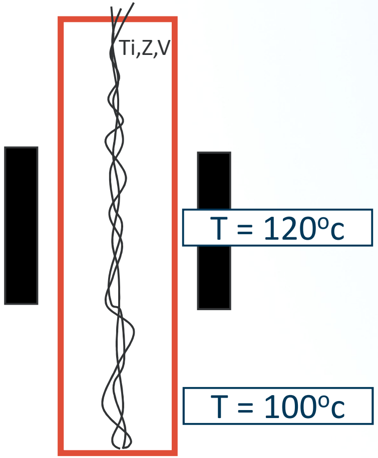


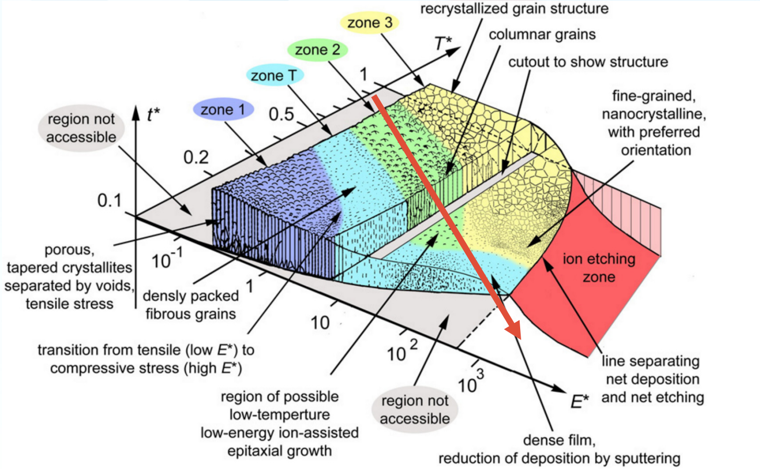




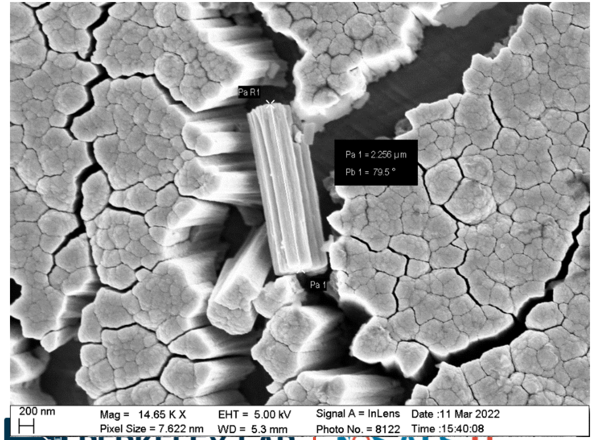
SEM Analysis of NEG film morphology

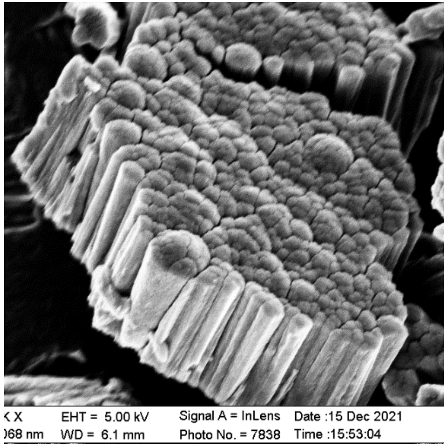




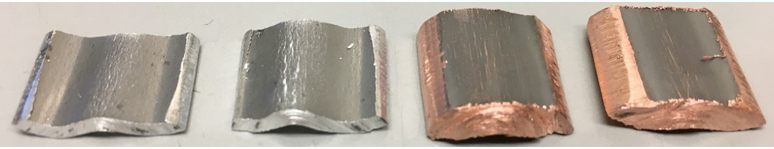


A.Anders, A structure zone diagram including plasma-based deposition and ion etching, Thin Solid Films, 2009





SEM samples



Summary

- NEG coating technology for narrow vacuum chambers demonstrated down to 6mm inner diameter round chambers
- Extensive vacuum testing performed to optimize pumping performance
- NEG coating pumping and PSD performance for narrow aperture chambers are comparable to larger chambers