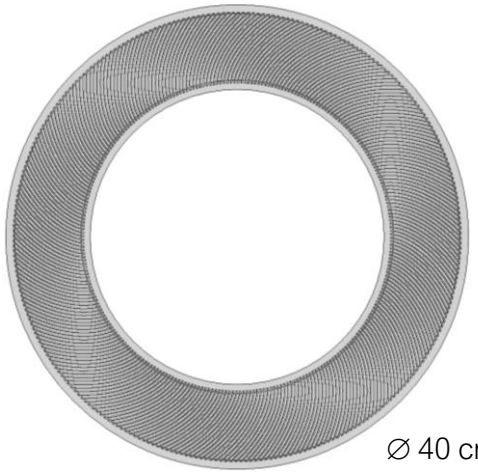
THE FRM II AND TUM CENTER FOR NUCLEAR SAFETY AND INNOVATION

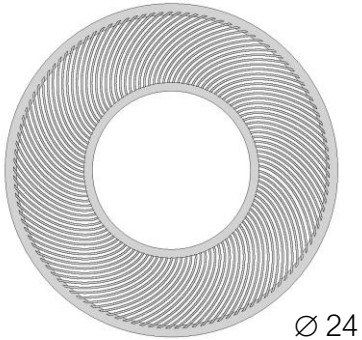
DR. CHRISTIAN REITER

Serpent UGM
August 29th 2022

THE FRM II

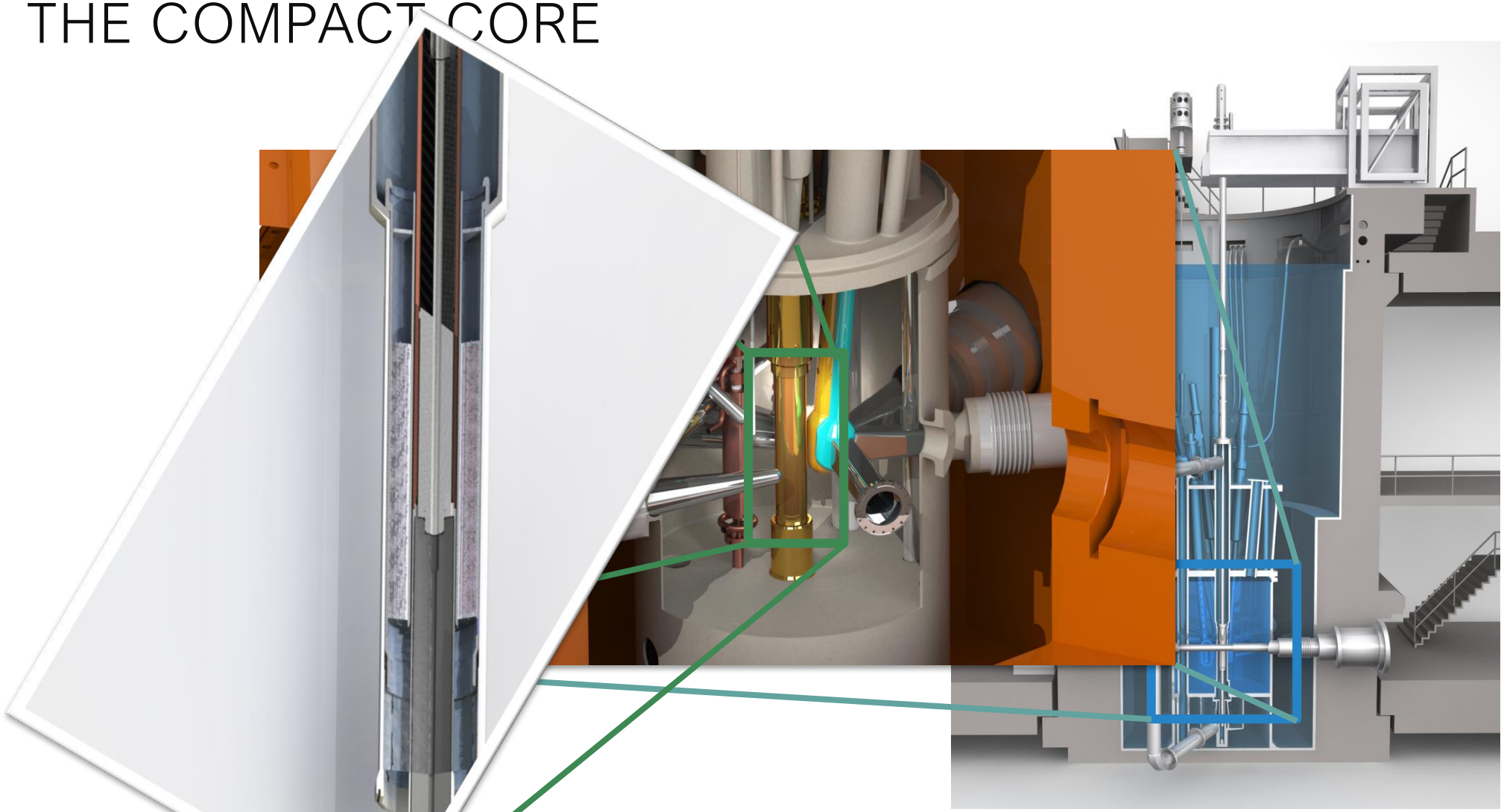
INVOLUTE REACTORS





Reactor	HFIR, USA	RHF, France	FRM II, Germany
First criticality	1965	1972	2004
Thermal Power	100 (85) MW	58 MW	20 MW
Flux-to-Power ratio [10^{13}/(cm² s MW)]	3,1 @ 85 MW	2,6	4,2
Number of fuel plates	540	280	113
Coolant/Moderator	H_2O / H_2O	D_2O / D_2O	H_2O / D_2O
Current Fuel	U_3O_8 / 1,15 gU/cm³	UAl_x / 1.17 gU/cm³	U_3Si_2 / 3.0 gU/cm³

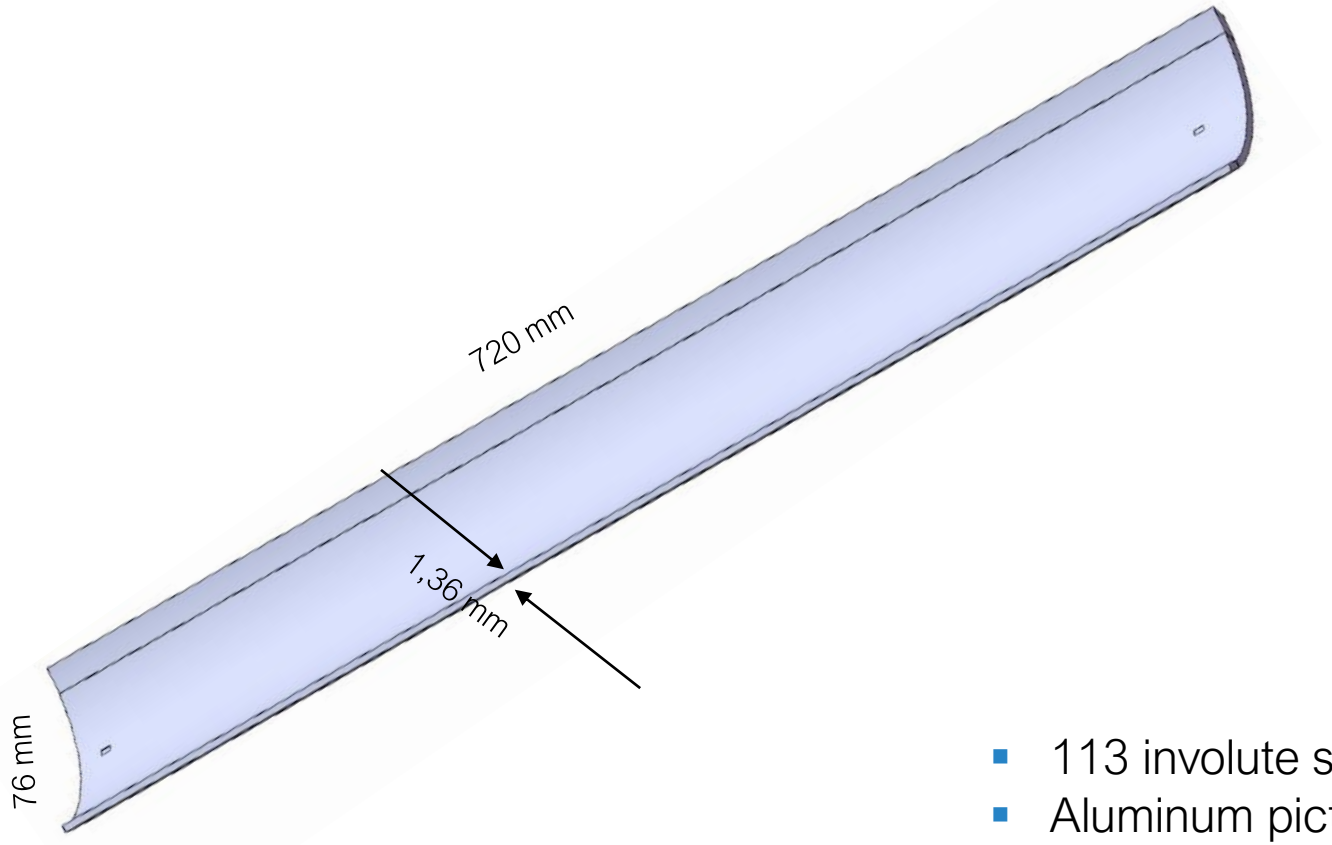
THE COMPACT CORE



THE COMPACT CORE

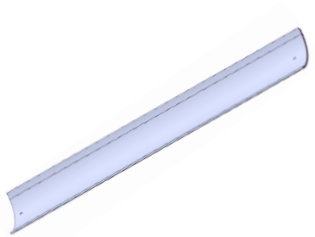
CAD model of the fuel element

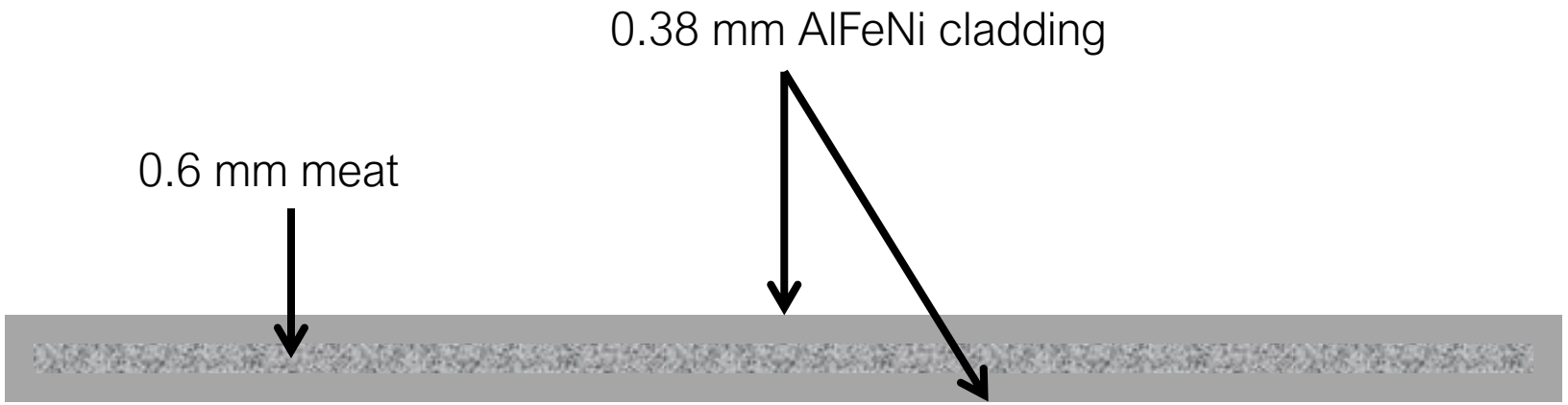
THE COMPACT CORE



- 113 involute shaped fuel plates
- Aluminum picture frame on the edges

THE COMPACT CORE





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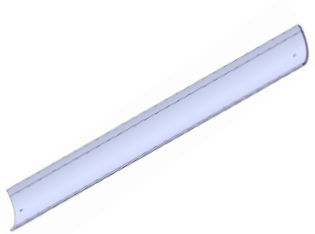
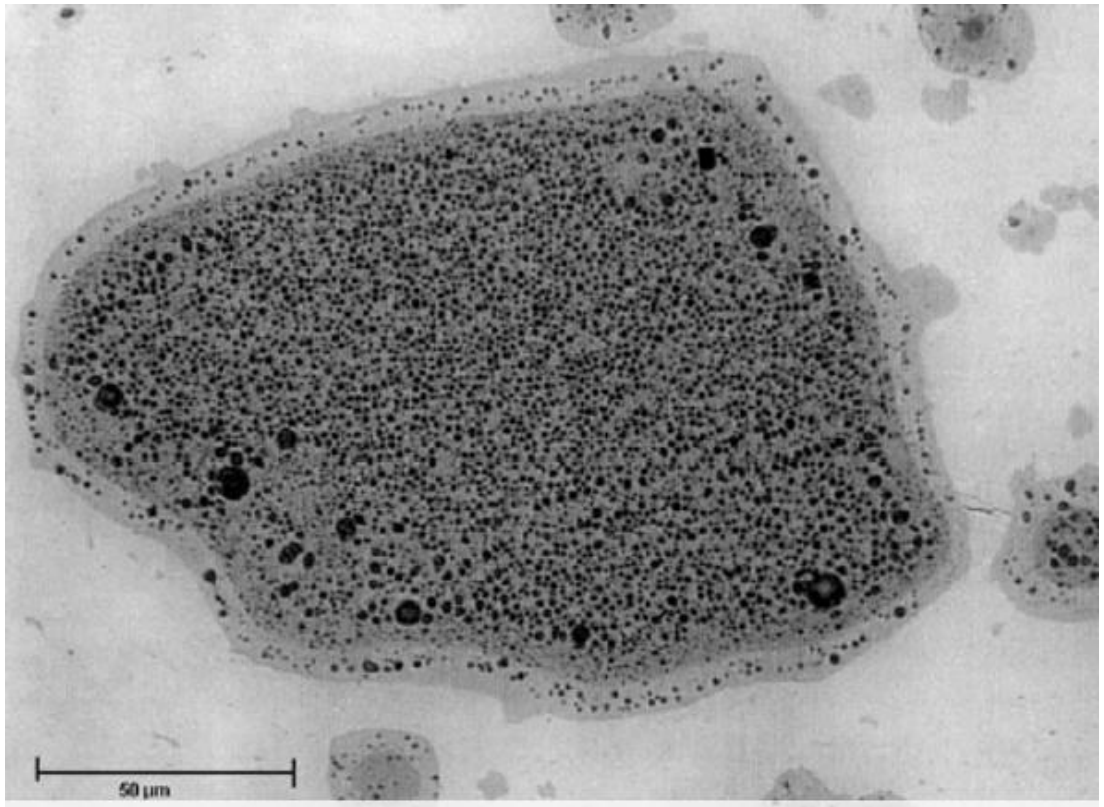




1.5 gU/cm³, Fission Density 12 · 10^{21} f/cm³, from FRM II qualification

K. Böning, W. Petry, Test irradiations of full-sized U3Si2–Al fuel plates up to very high fission densities, Journal of Nuclear Materials, Volume 383, Issue 3, 2009, Pages 254-263, ISSN 0022-3115,

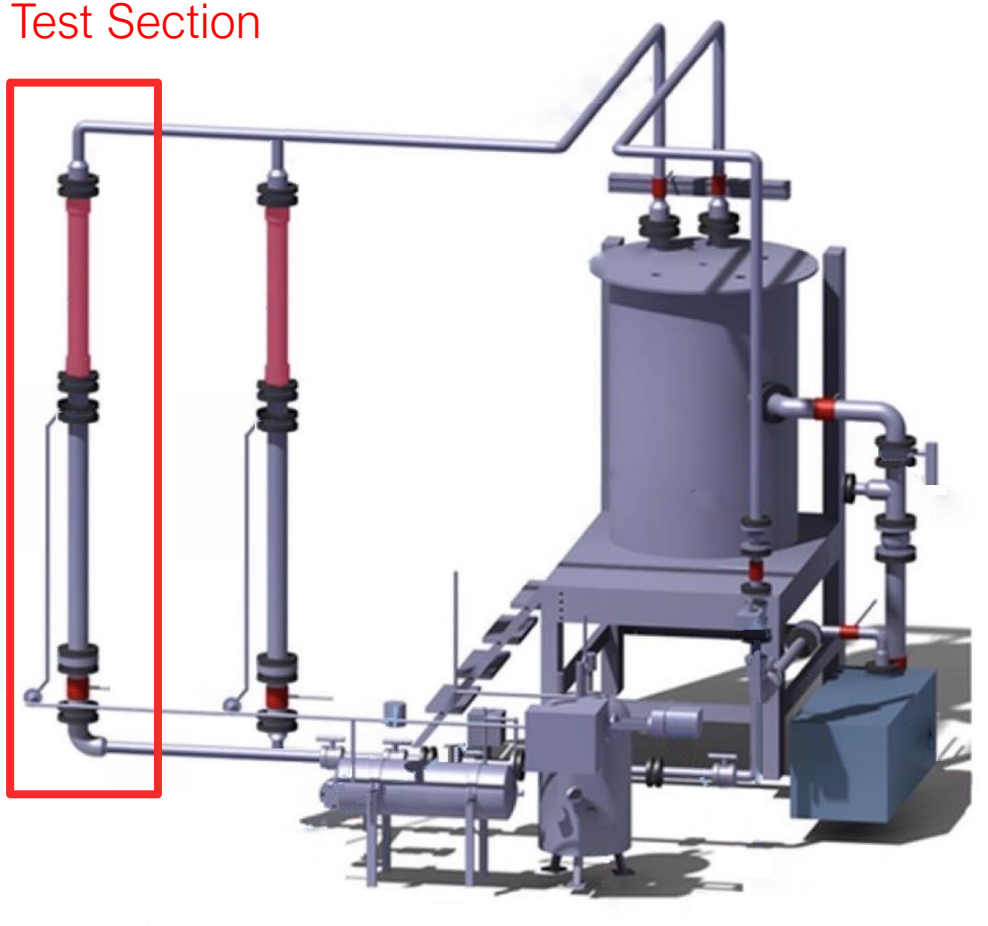
FUTURE PLANS

TUM THOR

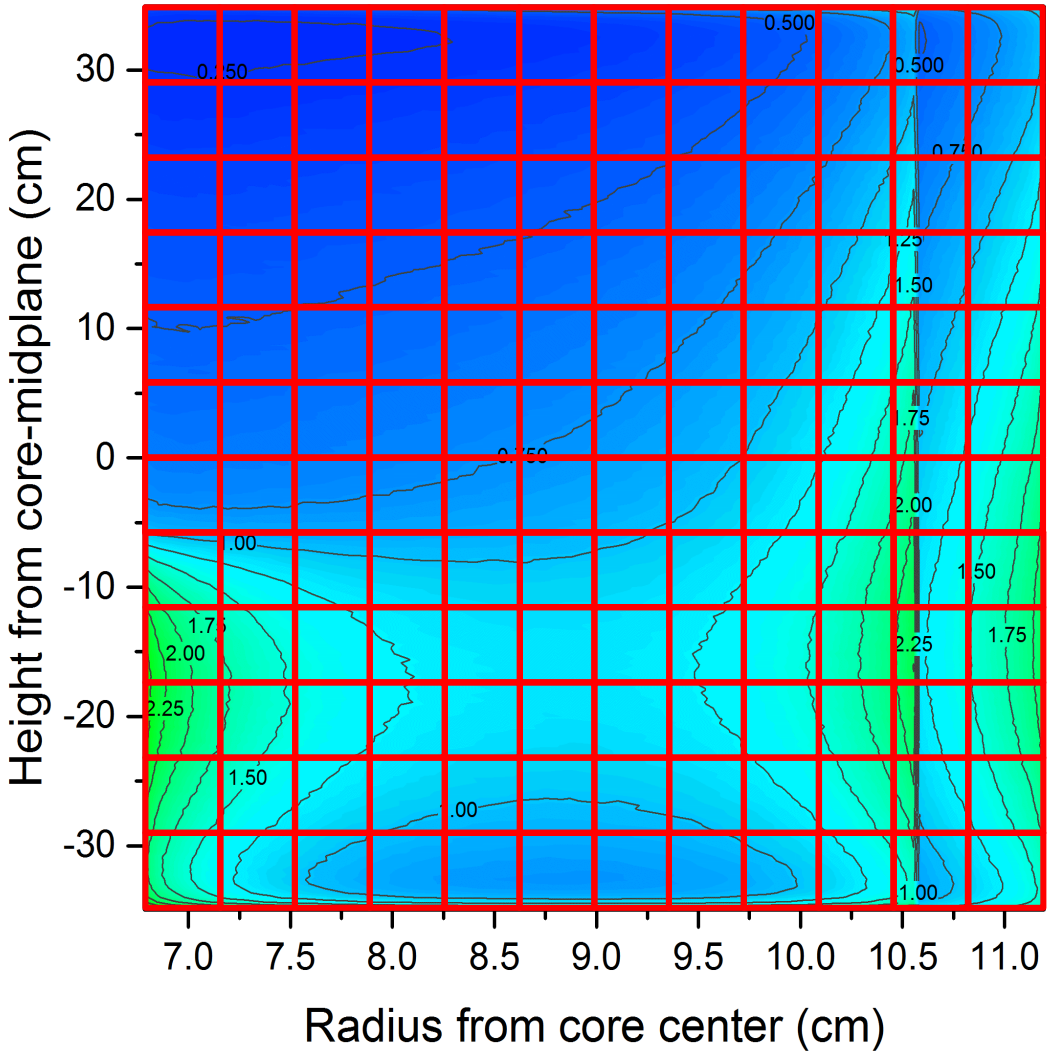
- Perfect to validate CFD simulations
- Reconstruction of the hydraulic loop for HPRR geometries
- Study of Heat Transfer and Turbulence Phenomena
- Partners are welcome

Hydraulic		
Mass Flow	kg/s	4 - 5
Inlet Pressure	bar	20
Inlet Temperature	°C	< 100
Coolant Velocity	m/s	< 20
Heating		
Total heating	kW	250
Heat Flux (maximum)	W/cm²	≈ 500
Heat Flux (average)	W/cm²	≈ 200
Heatable Length	m	1

New Test Section



SHAPING THE POWER PROFILE



TUM CENTER FOR NUCLEAR INNOVATIONS

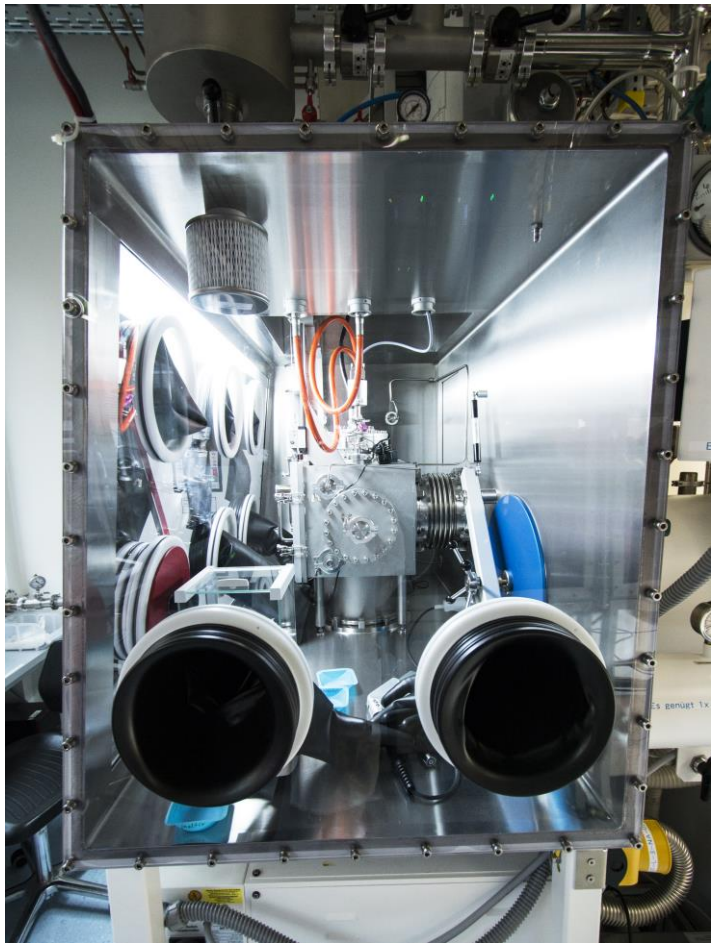
center for nuclear innovation

REACTOR OPERATIONS	Radioprotection and Waste Disposal Irradiations
NUCLEAR SAFETY	Reactor Physics Thermal-Hydraulic and -Mechanic Reactor Safety
NUCLEAR INNOVATIONS	Innovative manufacturing techniques Material characterization
NUCLEAR ANALYTICS	Nuclear security and forensics Product control of radioactive waste Repository safety and nuclide migration
MEDICAL APPLICATIONS	Radioisotopes for diagostics and therapy Radiation planning and dosimetry Hadron therapy

TUM FUEL FABRICATION AND CHARACTERIZATION LABORATORY

Phase 1 (since 2013): Focus on conversion research

- Licensed for open handling of enriched U-Mo foils and other U alloys (depleted uranium)
- Equipped mainly for PVD coating of U-Mo foils with Zr diffusion barrier
  - Successful fabrication of mini-size LEU U-Mo foils for the EMPIrE irradiation test
  - Since 2019: upgrade to substrate sizes up to 30in x 2in (European full-size geometry)
- Metallographic sample preparation and optical microscopy
- Arc-Melter and annealing furnace for metallurgical studies

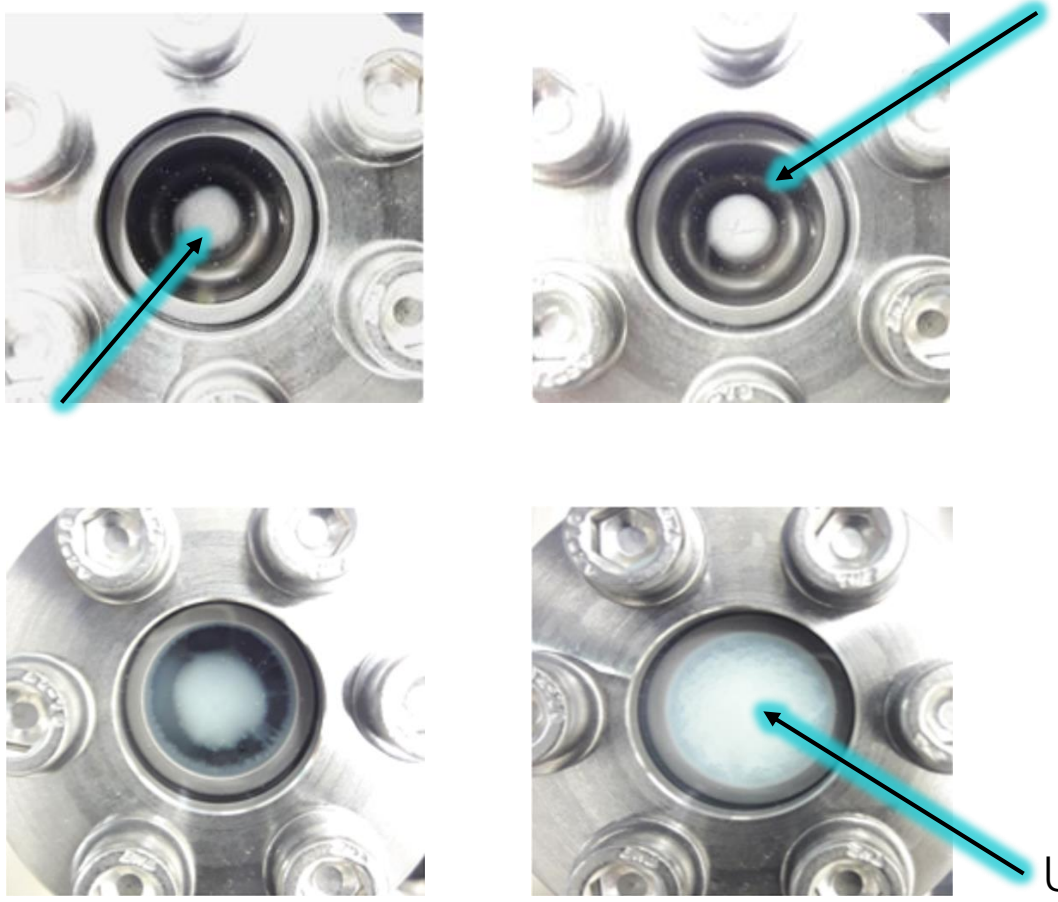


TUM FUEL FABRICATION AND CHARACTERIZATION LABORATORY

Phase 2 (starting January 2022): Scope extension to become an integrated center for fuel development beyond research reactors

- License extension towards all kinds of solid U-based fuels and natural uranium
- Construction work to double the current space of the laboratory
- New dedicated fuel characterization area, separated from the noisy fuel fabrication room
- Will be equipped with state-of-the-art FIB-SEM and thermophysical property management capabilities
- Still some space left for other equipment

CHEMICAL SEPARATION WITH SUPERCRITICAL CO



	mixture before	After separation Mo side	After separation U side
U [mg]	26.8 ± 0.3	2.99 ± 0.60	20.96 ± 0.63
Mo [mg]	7.5 ± 0.3	7.35 ± 0.06	0.08 ± 0.06
wt% Mo	21.9 ± 0.7	71.2 ± 1.7	0.4 ± 0.3

U: 29.8%
Mo: 71.2%

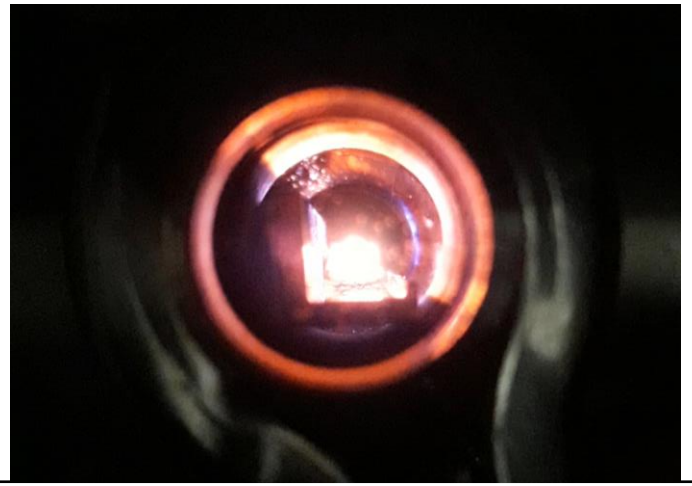
U: 99.6%
Mo: 0.4%

Mo recovery
98.0%

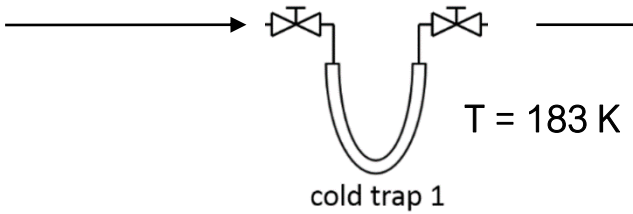
U recovery
78.2%

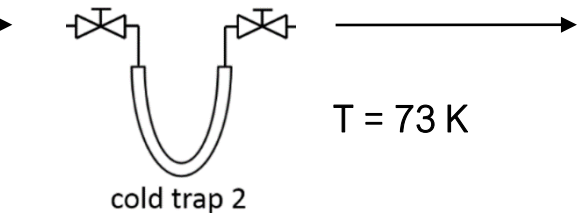
U_3SI_2 FLUORINATION

before



after





element	percentage [%]
U	95.3
Si	0.5

element	percentage [%]
U	1.8
Si	n.m.

THANK YOU