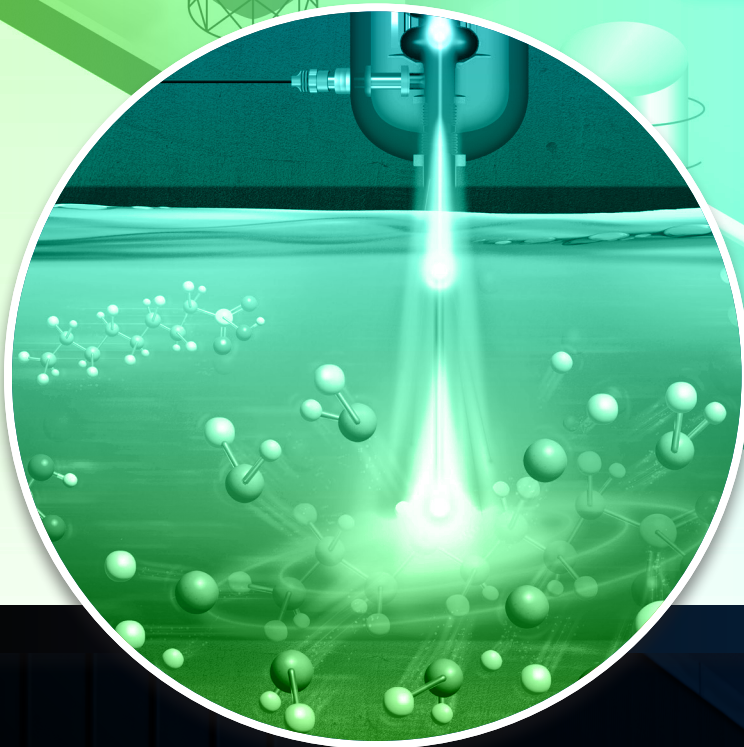


Environmental Remediation

Science and Technology for Society:
PFAS Degradation



Fermilab's Illinois Accelerator Research Center

The mission of IARC

The Illinois Accelerator Research Center, or IARC, which is located at Fermilab, was built and established in conjunction with the State of Illinois. Its mission is to facilitate and actively promote technology transfer and partnerships.



IARC engineers and scientists work side by side with industrial partners, universities and federal agencies to research and develop accelerator science and technology breakthroughs and translate them into applications that benefit the nation's health, wealth and security.

Accelerator research and PFAS

What are PFAS?

- Commonly known as forever chemicals
- Perfluoroalkyl and polyfluoroalkyl substances, a suite of thousands of chemicals that have been around for decades
- Widely used for everything from clothing and linens to food wrappers
- Natural processes cannot break down PFAS, so they accumulate in the environment and body
- May cause serious health issues

What are we doing about them?

- Experts in science and industry are seeking ways to prevent PFAS contamination from occurring in the future. They also endeavor to reduce what already exists in the environment.
- Engineers at Fermilab's IARC are experts in high-energy electron beams. These electron beams are excellent at destroying PFAS in the environment. Recently, experts demonstrated that an electron beam can effectively destroy common types of PFAS and PFOS in water.

Some popular products that contain PFAS



Pesticides



Firefighting foam



Food packaging



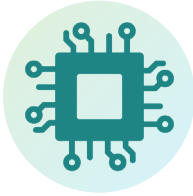
Non-stick cookware



Personal care products



Stain resistant fabrics



Semiconductor fabrication



Lithium ion batteries

How do PFAS enter the environment?



Industrial manufacturing



Firefighting foam



Wastewater



Biosolids applied to land



Landfills

How are people exposed to PFAS?



Water



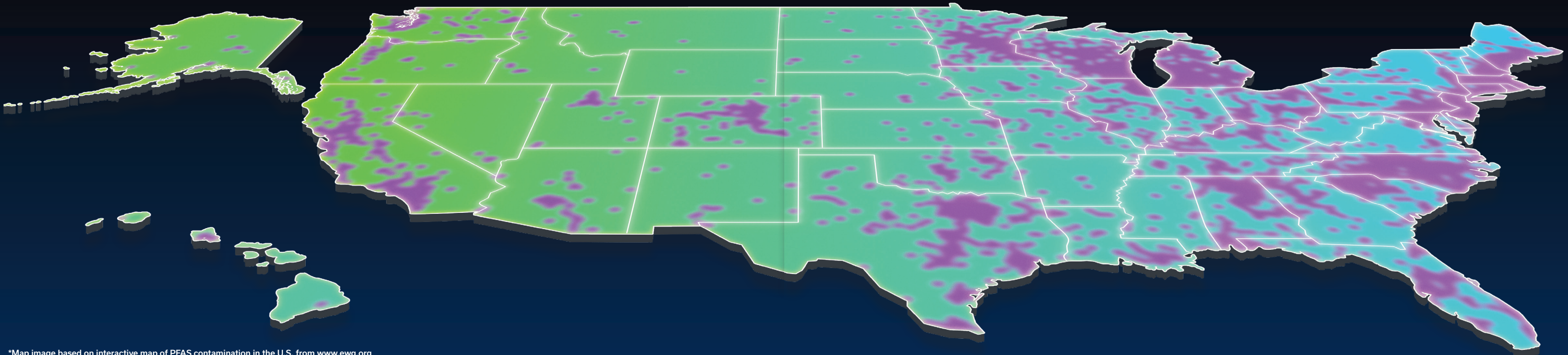
Food



Air/dust

PFAS chemicals cycle through the environment via the air, water and soil, accumulating in plants, animals and humans.

Known PFAS impact areas in the United States:

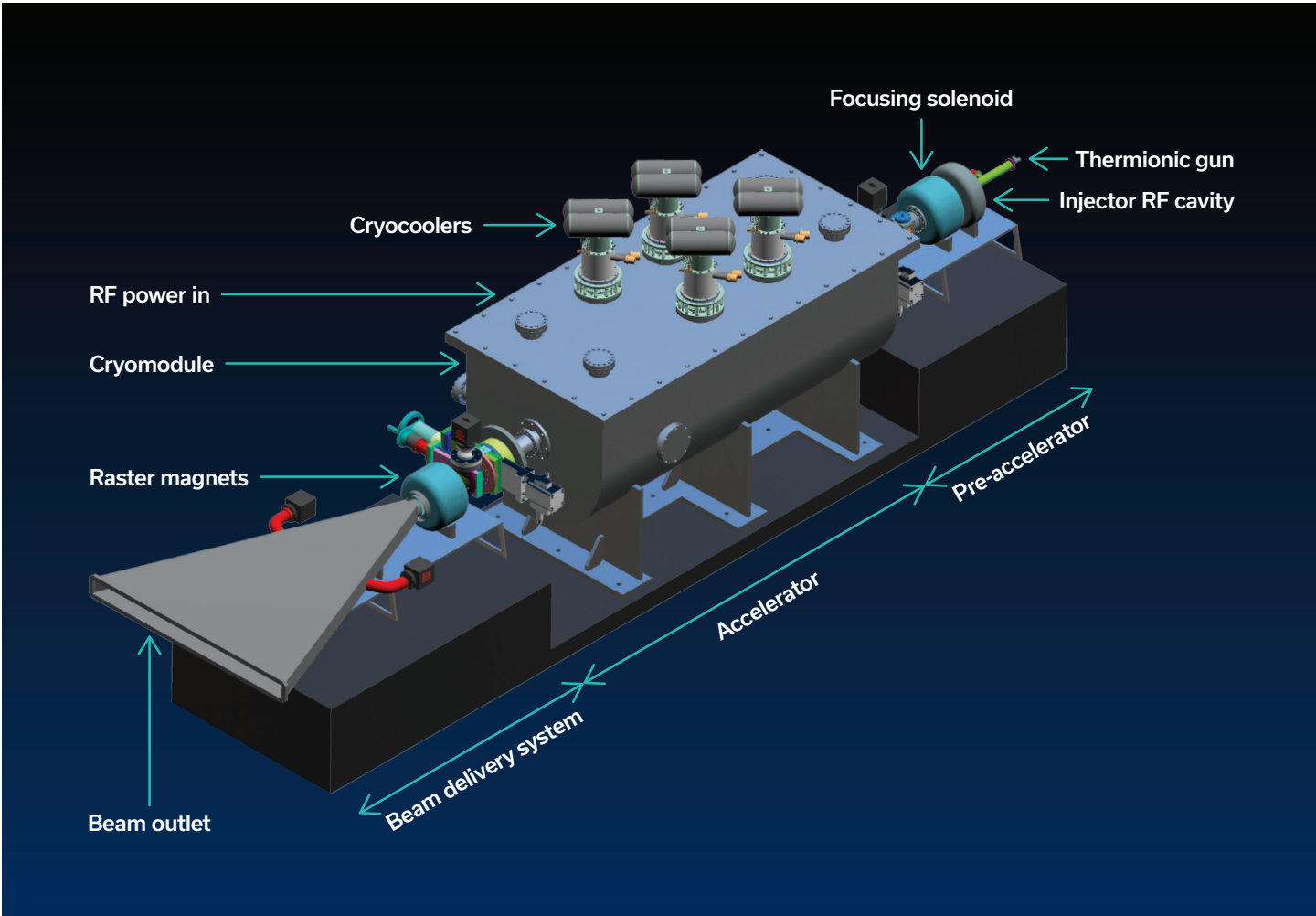
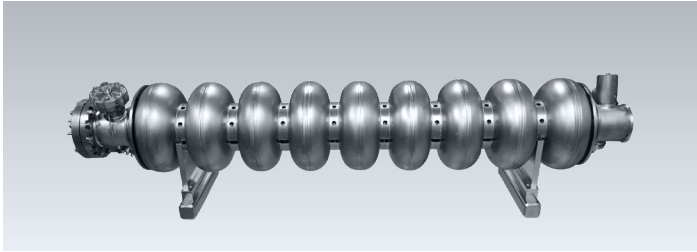


*Map image based on interactive map of PFAS contamination in the U.S. from www.ewg.org

Our solution

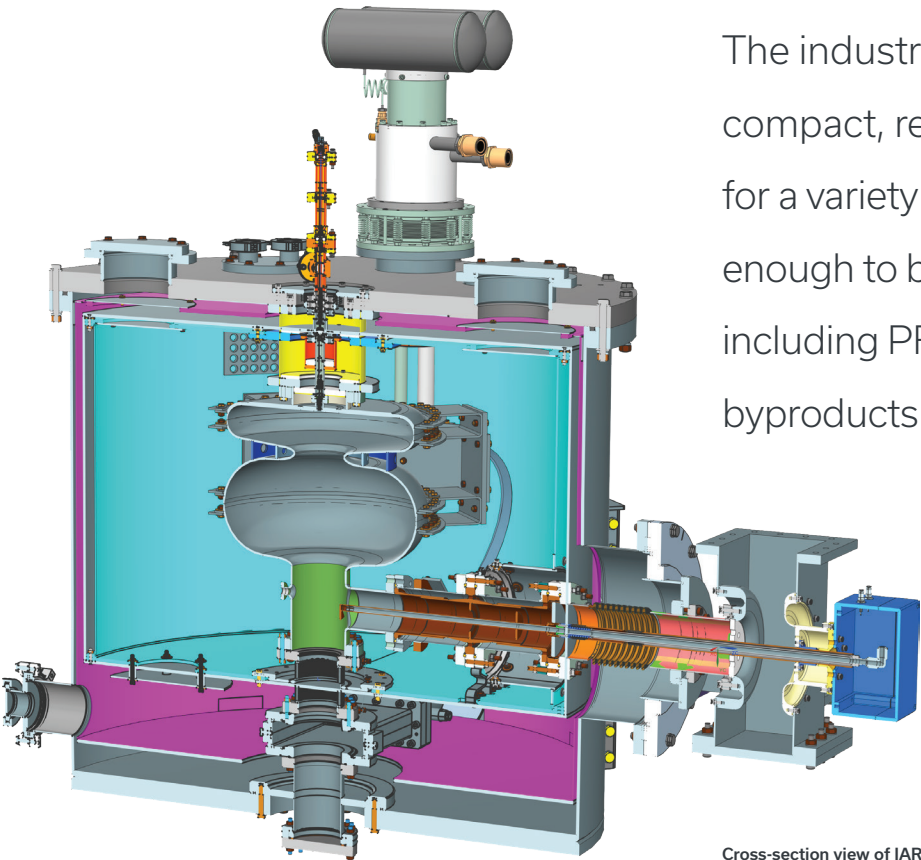
Industrial SRF accelerators

By leveraging Fermilab's world-leading expertise in particle accelerators and decades of research and development experience, IARC scientists and engineers developed a superconducting radiofrequency (SRF) accelerator that can be used for environmental remediation and other industrial needs.



Key accelerator features

Type	Superconducting electron beam accelerator	Cooling method	Conduction cooled via crycoolers
Energy	10 MeV	Length	25 ft+
Power	20 kW+	Width	6 ft
Frequency	650 MHz / 1.3 GHz	Height	6 ft
Operation mode	Continuous wave	Weight	3,000 lbs



The industrial SRF accelerator is compact, reliable and designed to work for a variety of applications. It is powerful enough to break down chemicals, including PFAS, without creating any byproducts or hazardous materials.

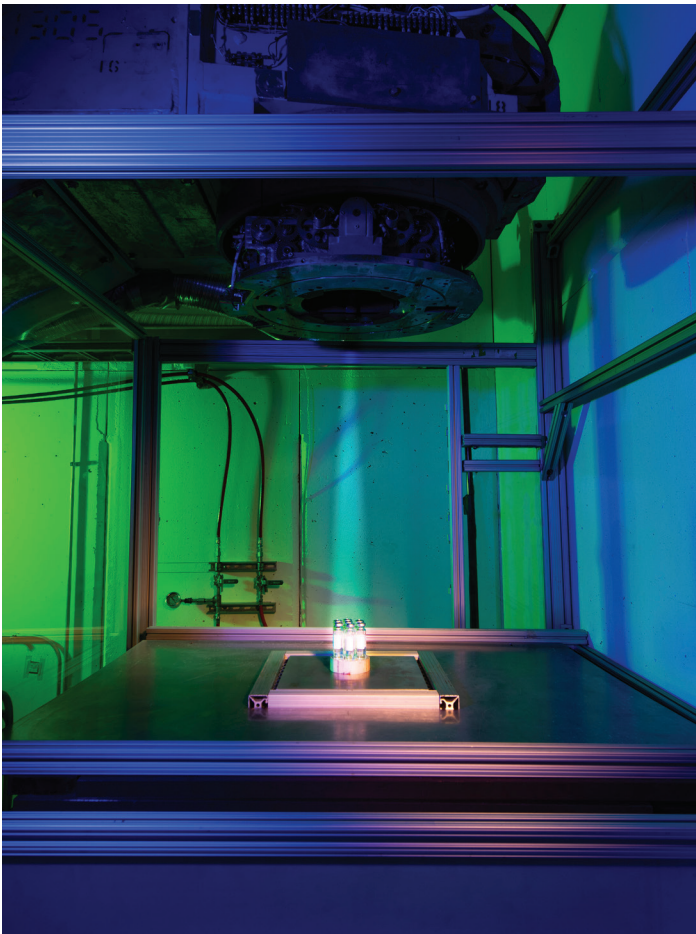
Cross-section view of IARC's vertical industrial SRF accelerator

Testing and results

Sample testing capabilities

The Accelerator Applications Development and Demonstration tool, or A2D2, is a repurposed medical 9-MeV electron accelerator scientists and engineers use to verify electron beam proofs-of-concept for individual applications.

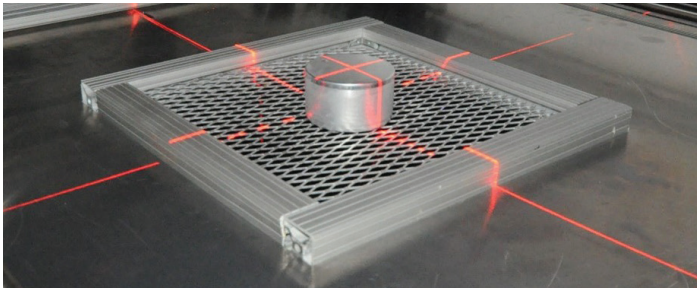
With adjustable dose rates and sample positions available, A2D2 is used by industry, universities and other government labs.



A2D2 test stand specifications

Beam energy	9 MeV
Nominal beam power	1.2 kW
Beam orientation	Vertical
Dose rate	0.2 to 1.2 kGy/sec

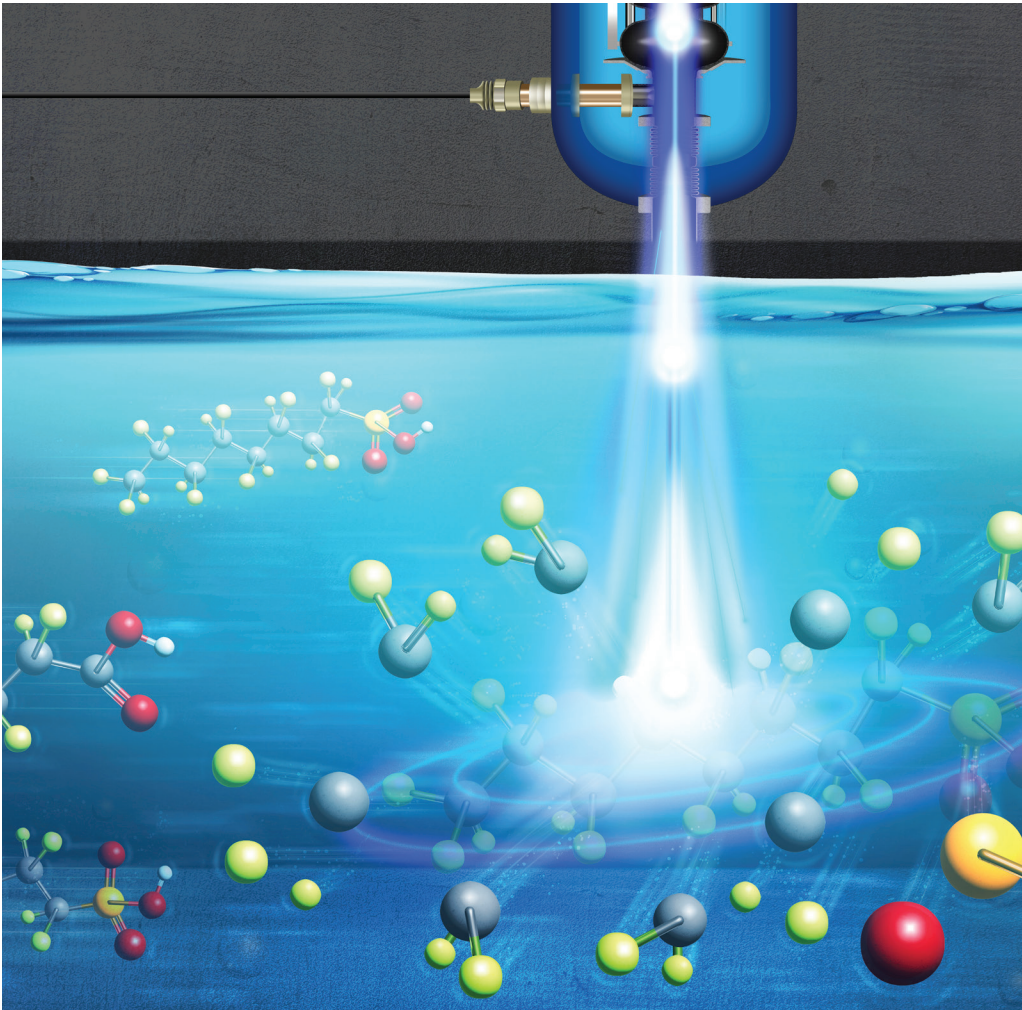
A2D2 can accommodate a wide variety of sample containers and flat stock. A typical sample size container is 3.5 inches in diameter and 2 inches high.



Using electron beam to destroy PFAS

IARC is engaged in environmental remediation of PFAS in water and soil. In a process called water radiolysis, the electron beam creates active species that break down PFAS.

Fermilab has demonstrated that electron beams can be used to create aqueous electrons which effectively destroy a wide range of PFAS in water including PFOA, PFOS, PFBS, PFHxS, PFNA and HFPO-DA.

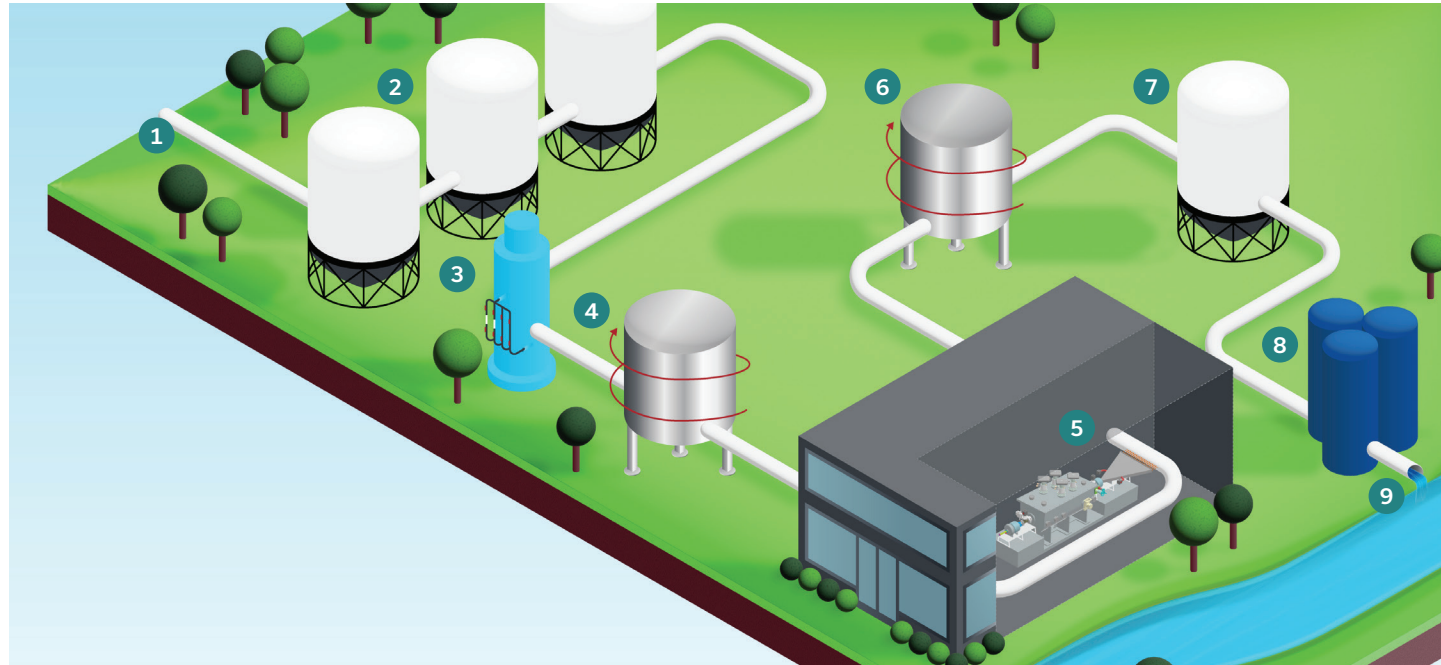


This work is described in a joint Fermilab/3M study, "Degradation of Poly- and Perfluoroalkyl Substances (PFAS) in Water via High Power, Energy-Efficient Electron Beam Accelerator."



www.osti.gov/biblio/2349585

Fermilab's flexible industrial SRF accelerator solution



The water treatment process

- 1 PFAS-contaminated water from different sources enters water treatment system
- 2 Holding tanks store water as it goes through the preconcentration process
- 3 PFAS chemicals are preconcentrated with a nitrogen purge
- 4 PFAS-saturated water cycles through a mixing tank where pH is adjusted
- 5 Electron beam accelerator destroys PFAS in stream
- 6 PFAS-free water cycles through a mixing tank where pH is adjusted prior to discharge
- 7 Holding tank stores clean water as it gets cycled through the polishing process
- 8 Water goes through the polishing process to filter out any additional unwanted impurities (step optional)
- 9 Clean water flows out

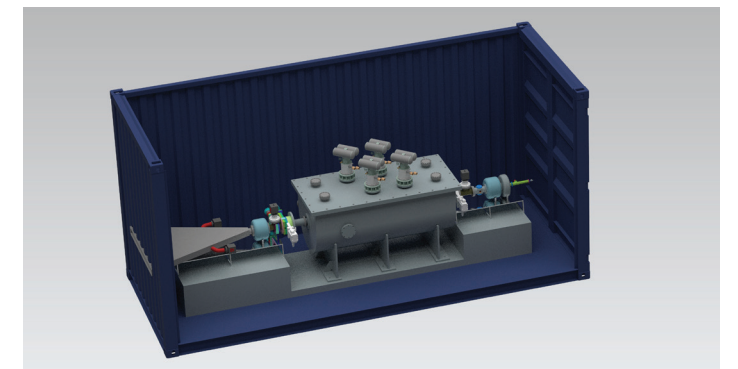
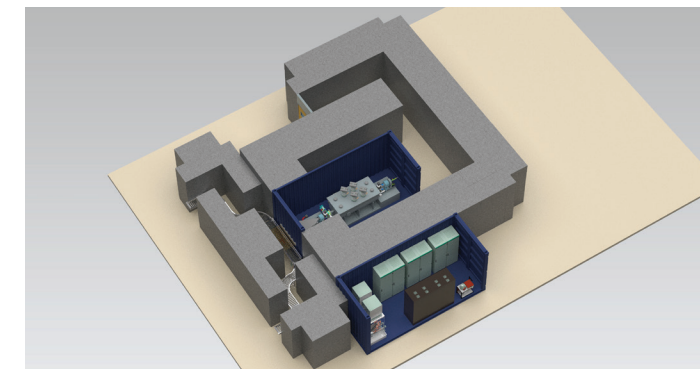
The key components

- 1 Injector
- 2 Cryomodule
- 3 Scan horn
- 4 Instrumentation racks
- 5 RF power
- 6 Cryocoolers

A drop-in solution

To address the problem where it exists, IARC has developed a transportable accelerator solution that enables the accelerators to be deployed at any location.

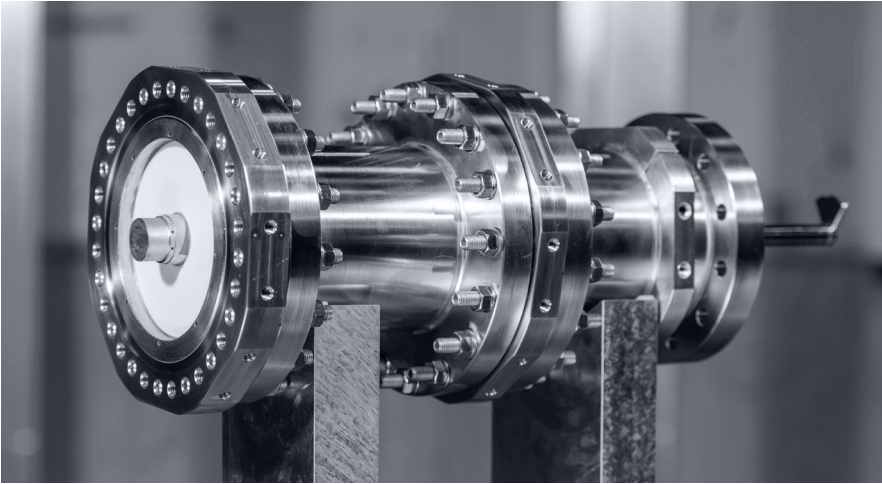
The accelerator can be powered by generators, cooled with mobile chiller systems and transported in standard containers to allow for deployment in a variety of spaces.



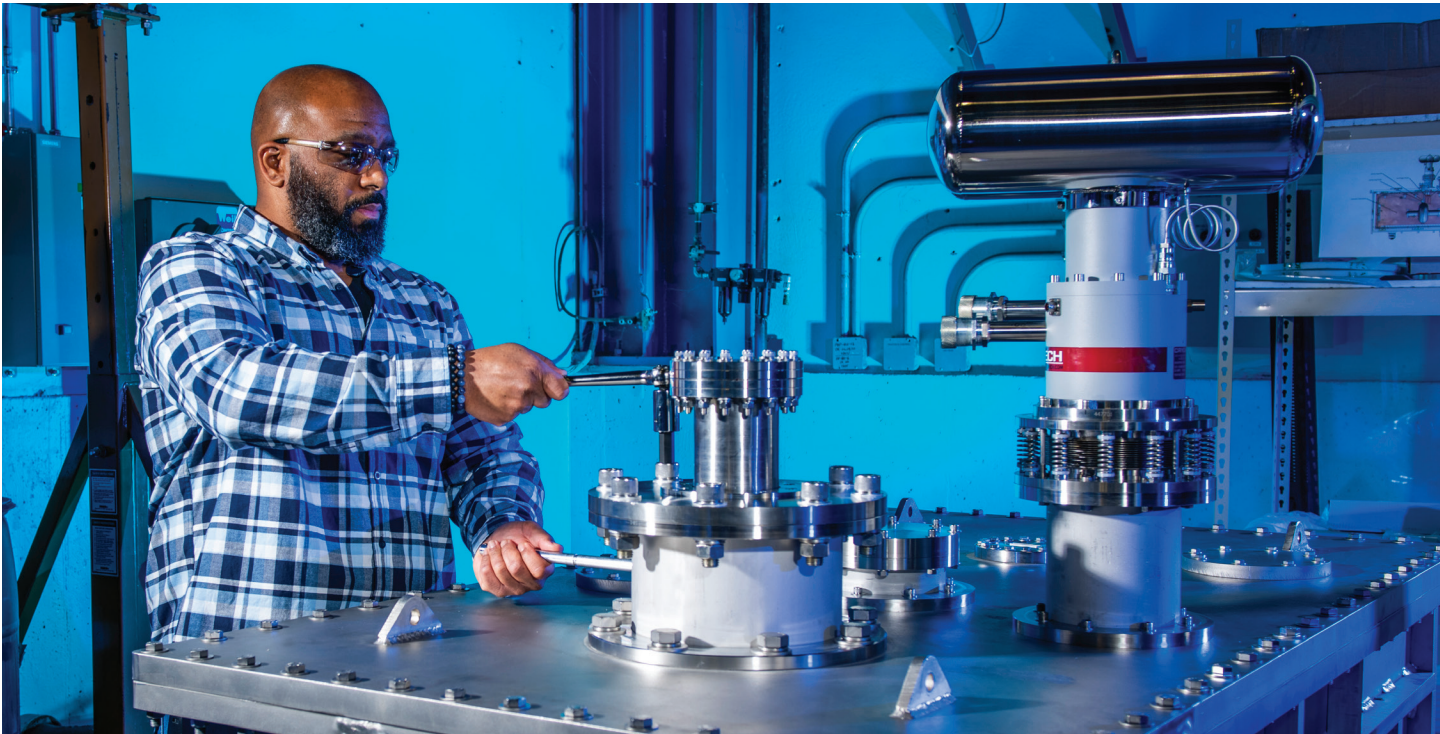
Cutting-edge accelerator technology

Globally recognized leadership

At IARC, industrial accelerator assembly and testing is underway with commissioning of the system to come. For more than 50 years, Fermilab engineers have been developing and testing the cutting-edge technology used to deliver world-class accelerators and science. For the past two decades, they have honed their expertise in superconducting radiofrequency technology.



Radiofrequency power coupler



An engineer assembles a conduction cooled super radiofrequency cryomodule



An IARC engineer assembles a radiofrequency power coupler for an industrial SRF accelerator

Fermilab engineers are continually pushing boundaries to keep America at the forefront of accelerator-based science and technology.

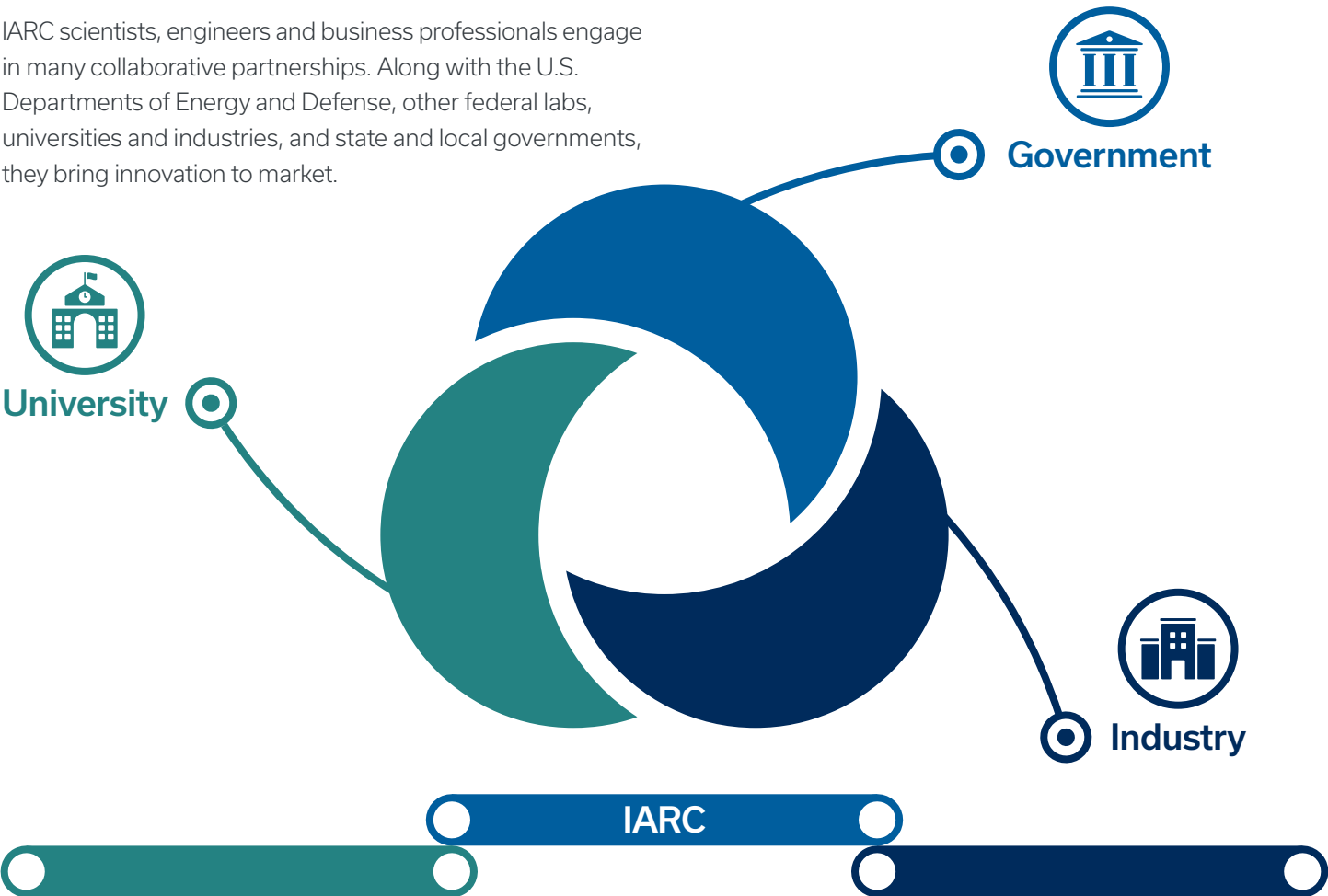


Cavity interior

Collaborative partnerships

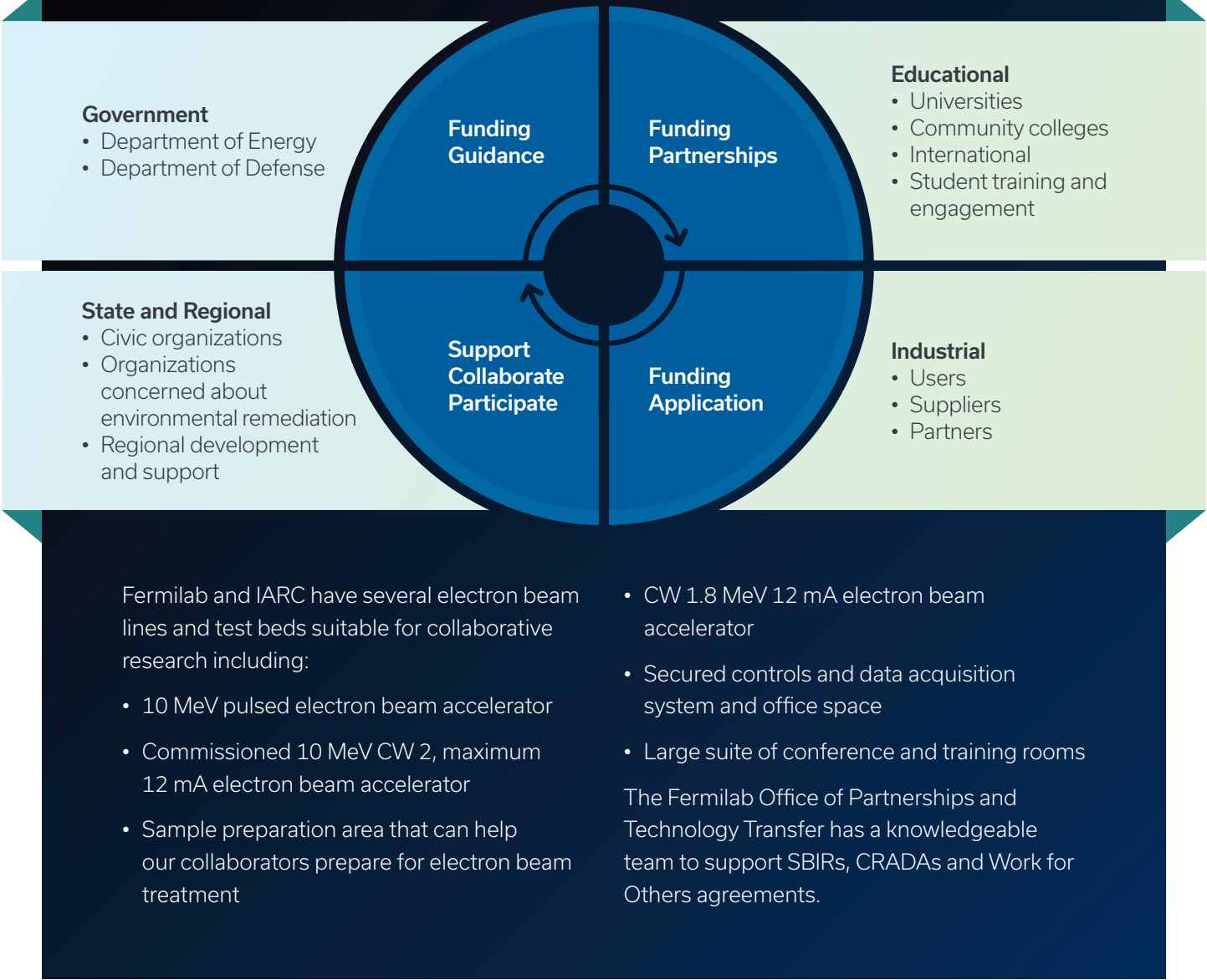
Fermilab is built on collaboration.

IARC scientists, engineers and business professionals engage in many collaborative partnerships. Along with the U.S. Departments of Energy and Defense, other federal labs, universities and industries, and state and local governments, they bring innovation to market.



IARC is focused on bridging the gap between research and development and community and commercial readiness.

Fostering partnerships for innovation





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The Illinois Accelerator Research Center, also known as IARC, was established with support from the State of Illinois to industrialize Fermilab's technologies and, with its partners, to advance the next generation of technologies, products and applications to assist U.S. industry and support our science mission.



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ENERGY

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Science