The role of fusion energy in a decarbonized electricity system

October 17, 2024

The Role of Fusion in a Decarbonized Electricity System

Summary of Findings

A study from the MIT Energy Initiative in collaboration with
the MIT Plasma Science and Fusion Center

September 2024

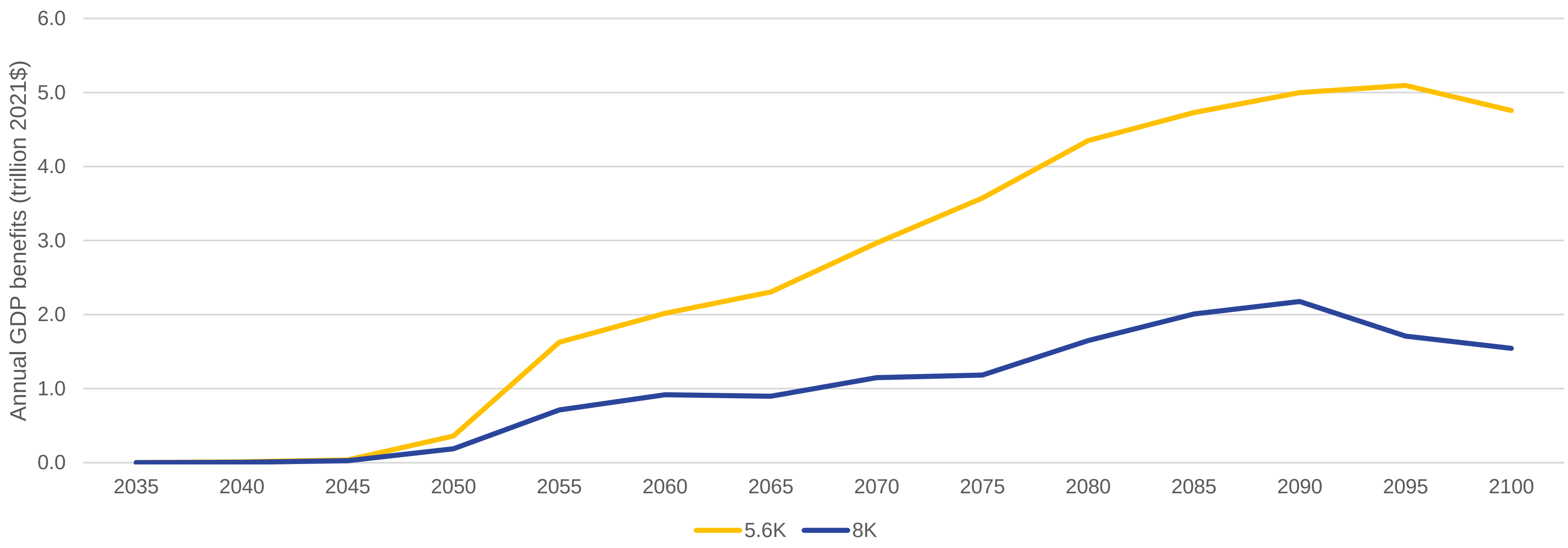
Overview of Fusion - Opportunity and Challenge

- When two nuclei combine they release enormous amounts of energy:
  - More than 1,000,000 times the energy of combustion on a mass basis
  - More than nuclear fission on a mass basis
- Required conditions for fusion:
  - Very high temperatures (>> 100 million degrees C)
  - Confinement of fusion fuels to bring them together long enough to fuse
- Primary confinement methods:
  - Magnetic confinement
  - Inertial confinement
  - Magneto-inertial confinement
- The Challenge:
  - Building an economically viable system that can handle the temperatures and high-energy particles released, plus the ability to convert that energy into electricity

Timeline and Structure of this Study

- Project period: fall of 2022 through spring 2024
- Structured with core workstreams:
  - Global deployment
  - Subregions of United States
  - Critical materials and supply chains
  - Key cost drivers
- We do not predict:
  - When fusion will first be deployed commercially
  - Which fusion technology will deploy first
  - What it will cost
- Instead, we focus on conditions required for fusion commercial viability

Fusion has a potential societal value in the trillions of dollars

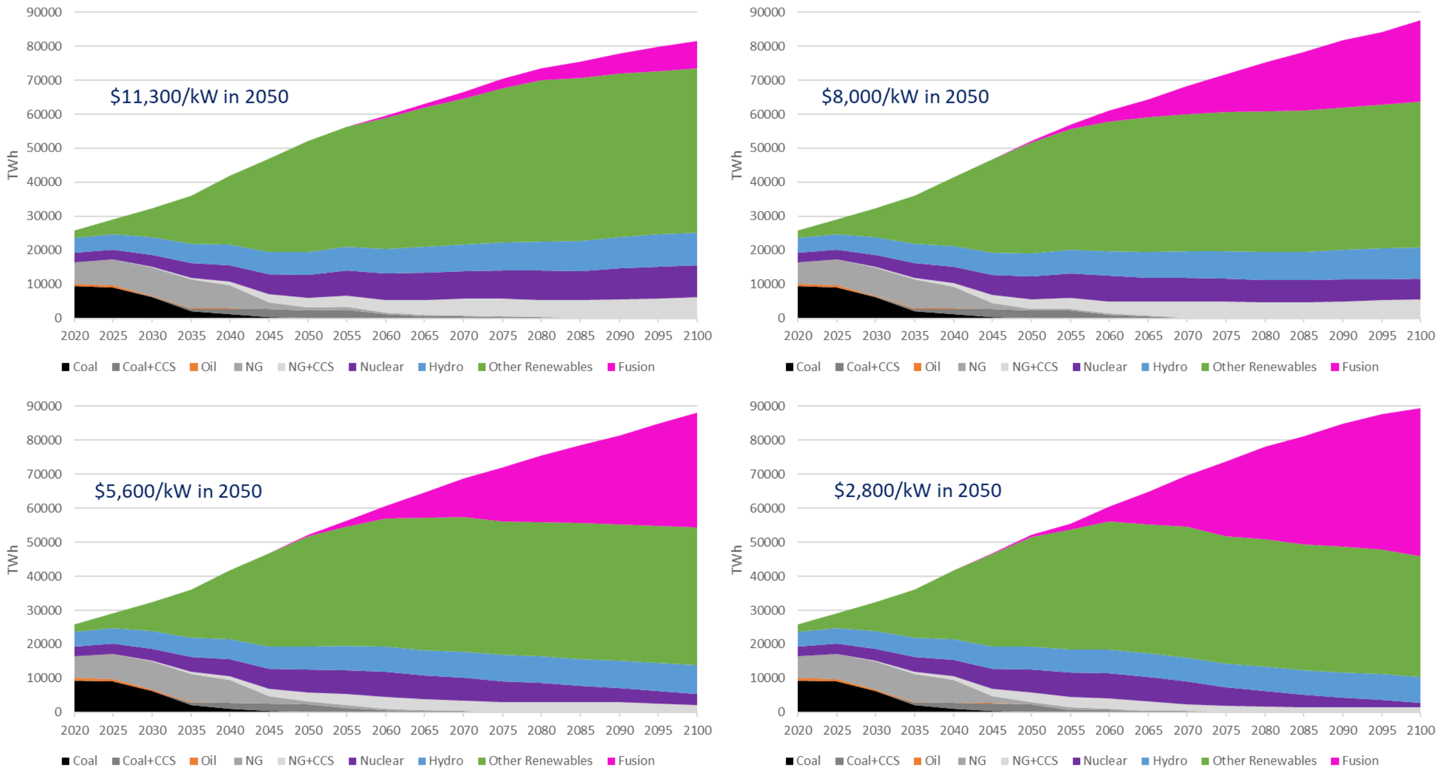


- Fusion technology can reduce the total cost of decarbonization by a cumulative discounted $3.6 trillion if fusion power plants cost $8,000/kW in 2050 and fall to $4,300/kW in 2100
- Fusion technology can reduce the total cost of decarbonization by a cumulative discounted $8.7 trillion if fusion power plants cost $5,600/kW in 2050 and fall to $3,000/kW in 2100

Note: Dollars in this presentation are reported in 2021 dollars, except were explicitly indicated

The scale of fusion deployment will depend on costs

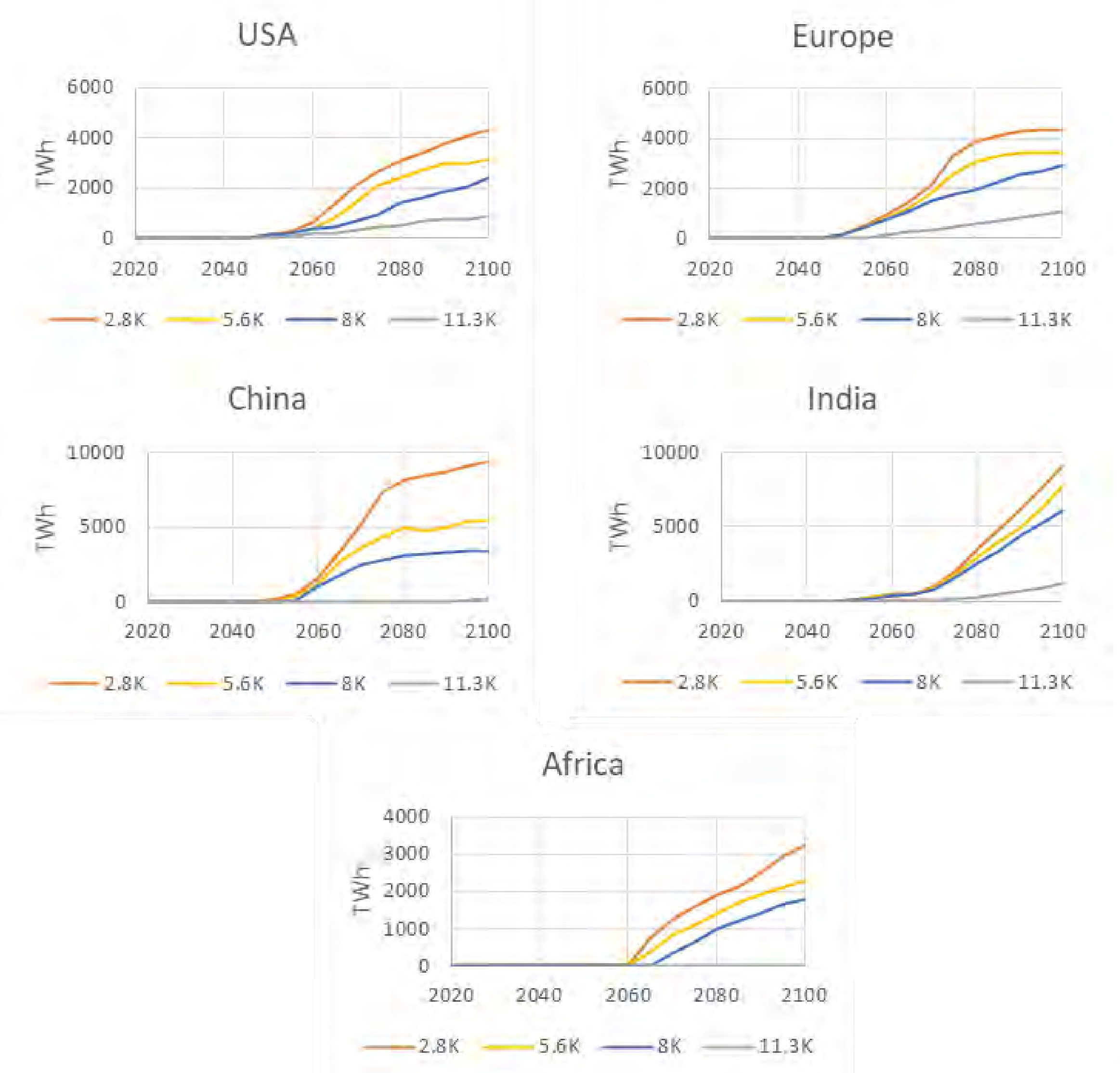
- For a 1.5°C stabilization decarbonization scenario, the total global share of electricity generation from fusion in 2100 ranges from less than 10% to about half depending on the assumed cost for fusion.



- Fusion costs shown are for the overnight cost of constructing a fusion power plant in the U.S. in the year 2050. At the end of the century, costs are about half the assumed 2050 costs.

The scale and timing of fusion deployment is highly variable across regions

- Initial deployment is strongest in the United States and Europe
- Largest increase in fusion takes place in India during the last three decades of the century
- Africa is a late adopter of fusion but sees strong growth late in the century
- These trends are driven by
  - economic growth
  - population density
  - electrification needs
  - regional costs
  - decarbonization targets
  - relative prices of electricity
  - limits on fission-based nuclear generation
  - renewable resource availability



Fusion deployment will highly depend on the availability and cost of other low-carbon technologies

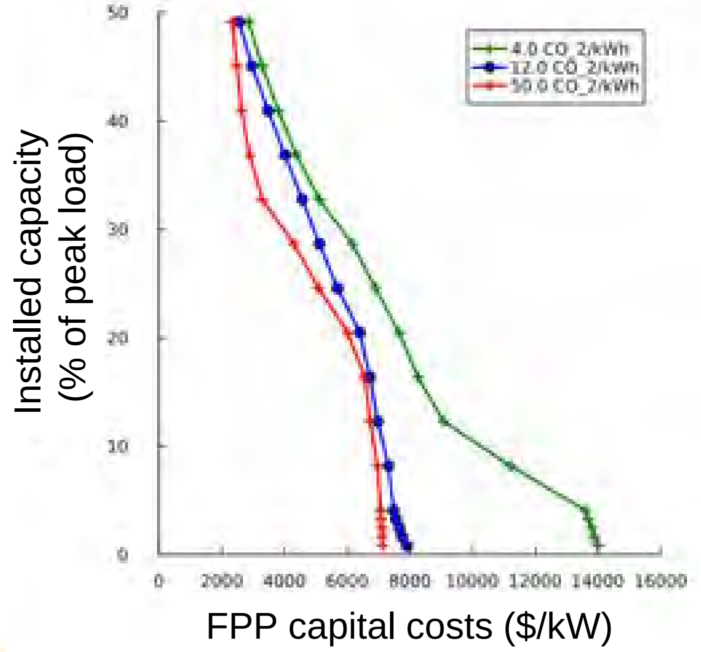
	High Penetration, Low Sensitivity*	**Medium Penetration, Medium Sensitivity***	**Low Penetration, Low Sensitivity***	**Low Penetration, High Sensitivity***
U.S. Subregions	Atlantic and Southeast	California, Northeast, Southwest	Northwest	Central, North Central, Texas
Renewable attributes	Poor onshore wind, hydro, and geothermal resources	Northeast has best offshore wind; California has best geothermal; Southwest has best solar; all three have modest onshore wind capacity or quality	Below average solar and wind resources, but excellent diversity of renewable resources including good hydro and moderate geothermal	Abundant, high-quality, and low-cost onshore wind; limited renewables beyond onshore wind and solar
Fusion penetration at $6,000/kW	Required at all emission caps from 1 to 50 gCO_2/kWh	No penetration at 50 gCO_2/kWh, but capacity reaches 33%–55% of demand at 1 gCO_2/kWh	Required at all emission caps 1–20 gCO_2/kWh but capacity is never more than 26% of demand	Required only at 4 gCO_2/kWh and below, but capacity reaches 25%–45% of demand at 1 gCO_2/kWh

* **Sensitivity** refers to the sensitivity of fusion penetration with respect to changes in the emissions cap

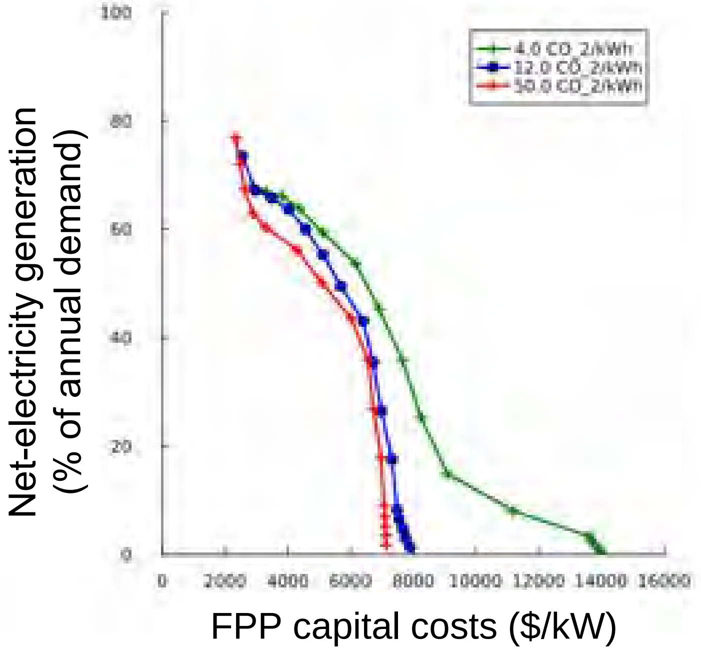
The role of fusion power plants is also highly sensitive to costs

- Fusion power plants serve as
  - Low-capacity-factor, dispatchable electric generation when fusion costs are high
  - Baseload resource when FPP costs are moderate
  - Dispatchable generation with a moderate capacity factor when FPP costs are low.
- This trend was observed in our analysis of the New England subregion of the U.S.

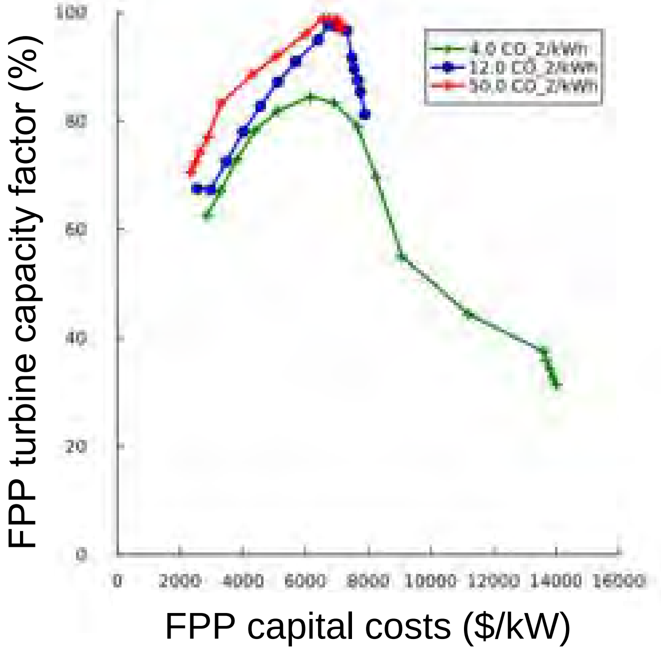
Fusion installed capacity as % of peak load



Fusion fleet generation capacity as % of annual demand



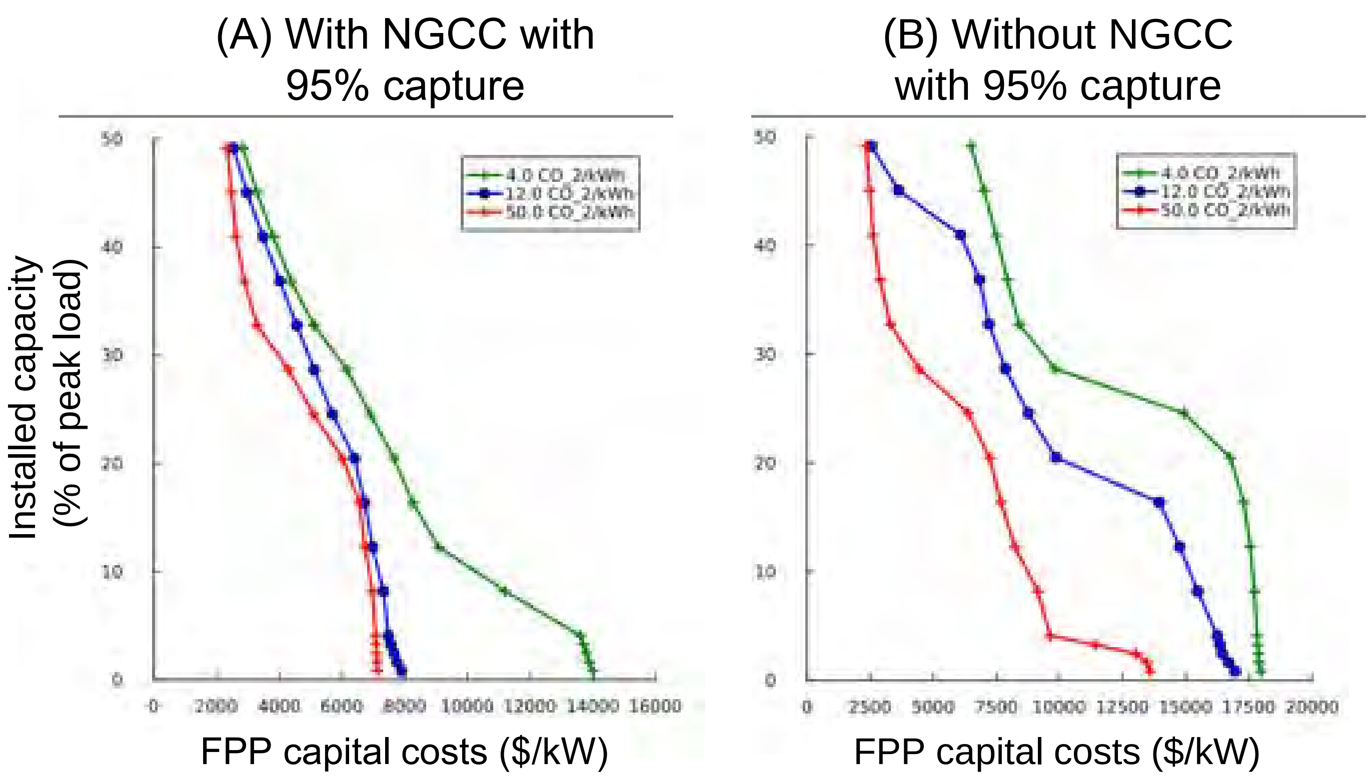
Fusion annual capacity factor



The availability of firm, low-carbon natural gas power plants can have a large impact on the deployment of fusion power plants

- NGCC power plants with high carbon capture and low upstream methane emissions can have a large impact on fusion deployment

- Threshold cost point at which fusion becomes competitive is $4,000/kW lower when NGCC with 95% carbon capture is available than when NGCC with 95% carbon capture is not available.



Supply chains for the processed materials and manufactured parts needed to build fusion power plants vary widely in maturity

- Different technologies are at varying stages of maturity with identifiable issues and bottlenecks
- R&D is needed to develop materials and manufacturing capabilities essential for fusion at the scale outlined in this report
- Fusion components can be broken up into two categories:
  - Niche (e.g. tungsten heavy) with limited non-fusion market opportunities
  - Components (e.g. high-temperature superconductor, radio-frequency devices) with strong potential for commercial non-fusion use
- For raw materials, there are no anticipated showstoppers, however beryllium resources and markets remain an uncertainty

Key cost drivers for fusion power plants include reactor equipment cost, regulatory considerations, and operations and maintenance costs

- Fusion reactor equipment is the leading cost contributor at 30% to 65% of the total capital cost
- Regulation can be a potentially large cost driver and motivates
    - fusion companies to minimize their footprint with respect to fuels and activated materials
    - governments to adopt appropriate and effective regulatory policies to maximize their ability to use fusion energy in achieving decarbonization goals
- Operating and maintenance (O&M) costs can be significant for a fusion power plant

Key Takeaways

- Fusion has potential societal value in the trillions of dollars in a decarbonized world.
- Deployment and operation of fusion power plants is highly dependent on:
  - Fusion costs
  - Cost and availability of alternative low-carbon technologies in each region
  - Carbon emission constraints
  - Economic and electricity demand growth
  - Market design
- The ability of fusion to scale requires development of materials and manufacturing capabilities for niche components
- For raw materials, there are no anticipated showstoppers

Acknowledgements

Study Participants

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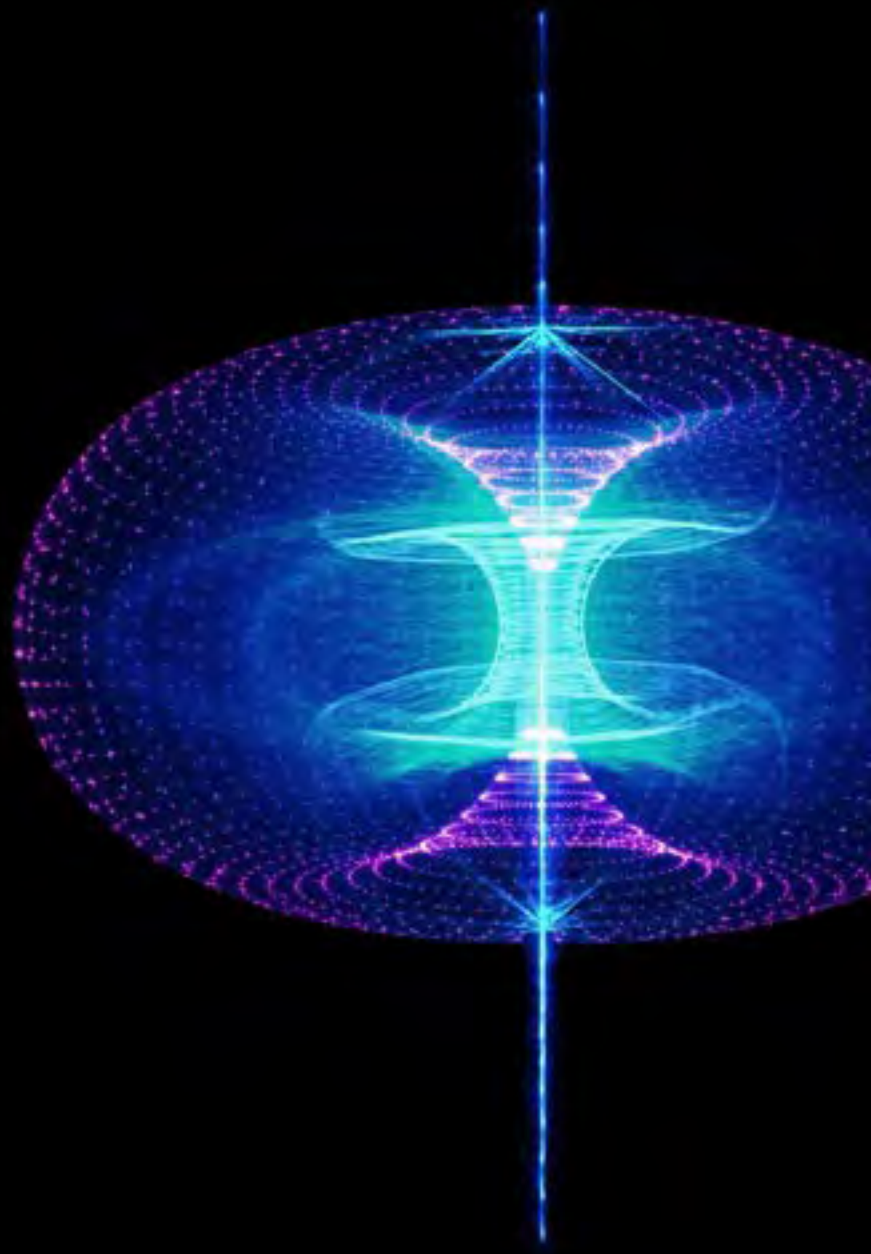
Plasma Science & Fusion Center

Overview of PSFC's mission

Nuno Loureiro
Director, Plasma Science and Fusion Center
MIT



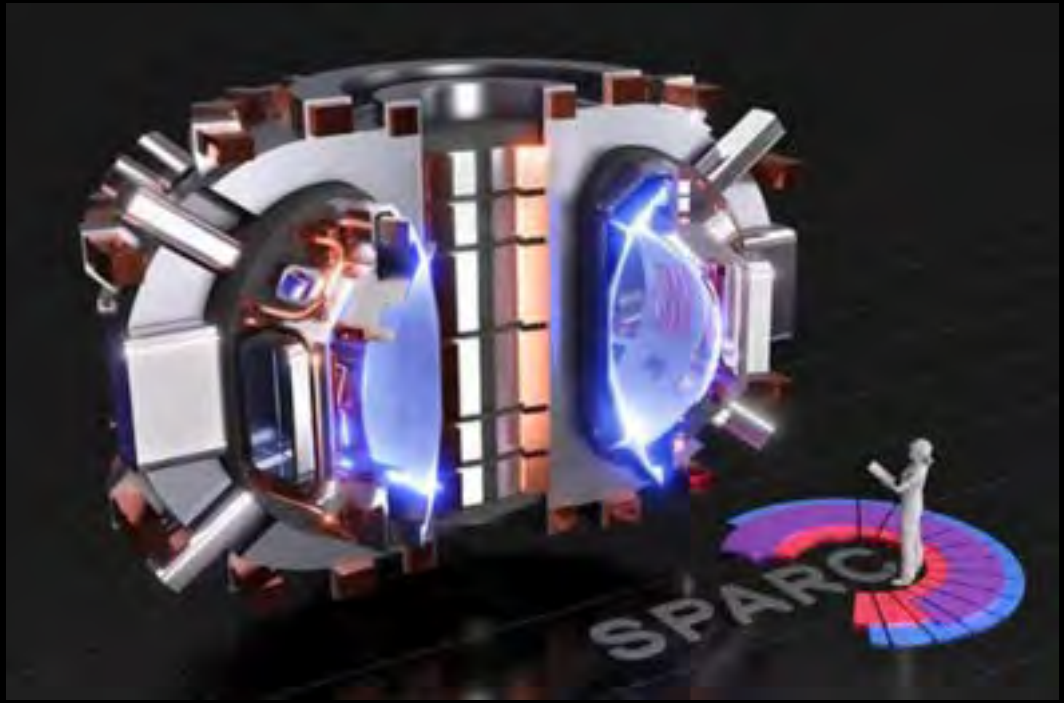
This is the PSFC.

Great things happen here.

Founded in 1976 | 160,000 sq ft of lab space | 150 employees | 90 graduate students | 5 research divisions | 86 ongoing research projects

The fusion world is unrecognizable compared to what it looked like five years ago

- We launched the MIT-CFS partnership about 5 years ago
- SPARC's success has spurred on the financing and commercial world to take fusion seriously as a disruptive new energy source
- Goal is to *bring fusion energy to the world NOW.*



US government aggressively pursuing fusion

Department of Energy

DOE Announces $46 Million for Commercial Fusion Energy Development

MAY 31, 2023

Commonwealth Fusion Systems

FOCUSED ENERGY

Princeton Stellarators

REALTA FUSION

tokamak energy

TYPE ONE ENERGY

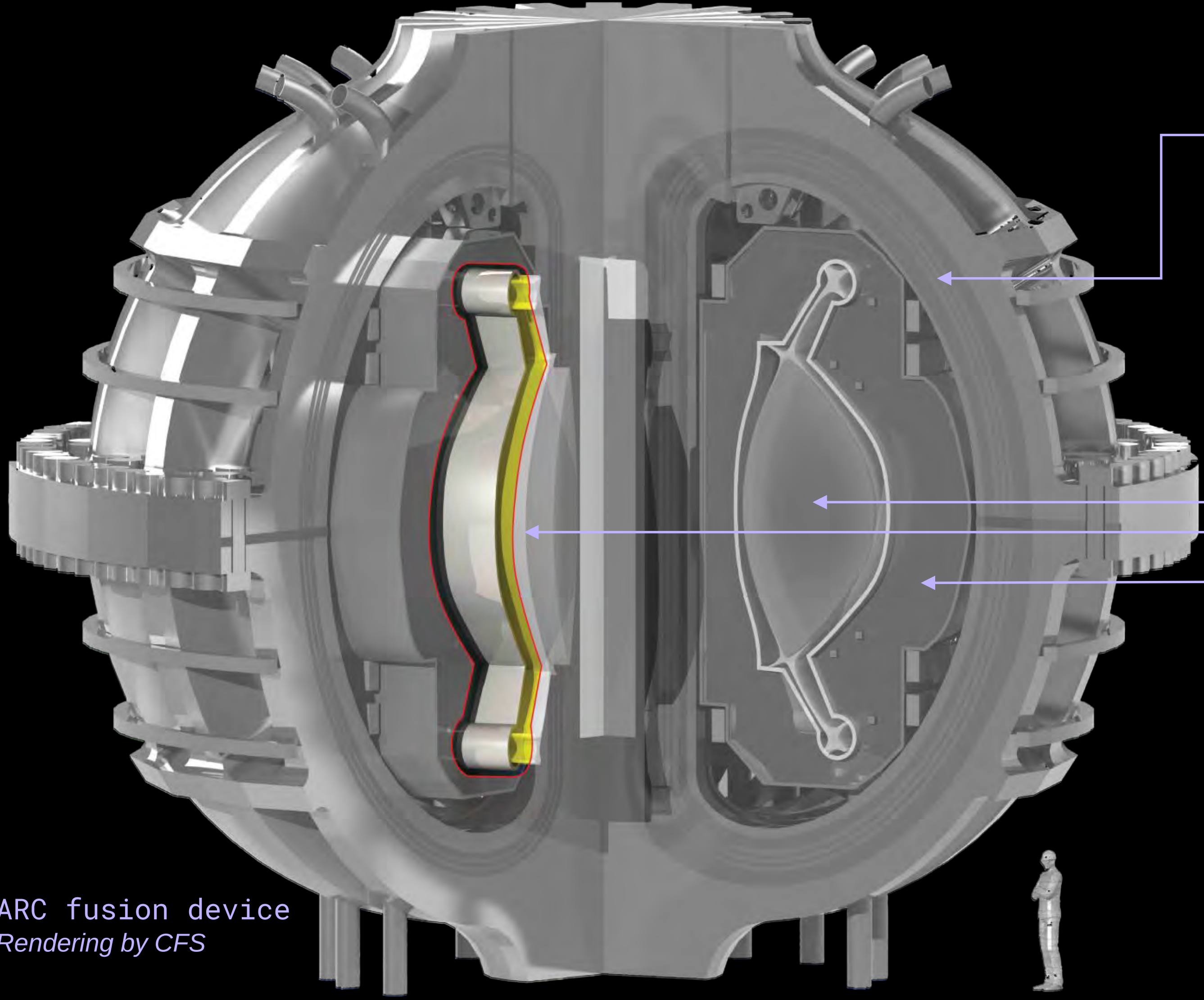
XCIMER ENERGY CORPORATION

ZAP ENERGY

Private Fusion Industry has experienced staggering growth

- >6 B$ raised
- Over 40 companies
- Industry association
- Wider geographic spread
- Wide array of technical approaches
- Competition is good
- Private funding encourages breakthroughs with higher risk on faster timelines

To create a device that can produce more energy than it consumes, we need:



ARC fusion device
Rendering by CFS

Strong and efficient magnets to confine fusing plasmas.

TFMC and CSMC

Peak plasma fusion performance.

Machine learning, quantum computing

A way to convert energy into power.

LIBRA lithium blanket

Extra-durable materials that can withstand plasma and neutron exposure

Cyclotron materials testing

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NIF laser facility demonstrated scientific fusion energy gain in Dec 2022

National Ignition Facility demonstrates net fusion energy gain in world first

14 Dec 2022

Big gains: the record-breaking shot at the National Ignition Facility was made at just after 1 a.m. local time on 5 December. (Courtesy: LLNL)

- 2 MJ laser, 3 MJ fusion energy
- The important science is that the improved fusion energy was driven by the alpha heating resulting from the fusion reactions themselves
- This feature is common to all fusion and so should be celebrated as another important science milestone
- MIT (PSFC) is the leading university in measurements of fusion products
- Now being adapted for SPARC!

We have made amazing progress but..

- Need to expand and innovate on fusion education. At MIT and beyond!
  - The US academy is not prepared
  - We are strapped for fusion instructors.

& Fusion Center

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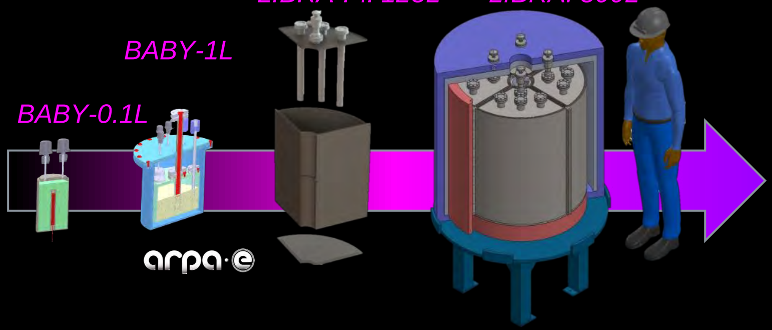
- Capable, but fast, experimental facilities for addressing the next set of technical innovations that make fusion economical.



LIBRA experiment progression

We have made amazing progress but..

- Need to expand and innovate on fusion education. At MIT and beyond!
  - The US academy is not prepared
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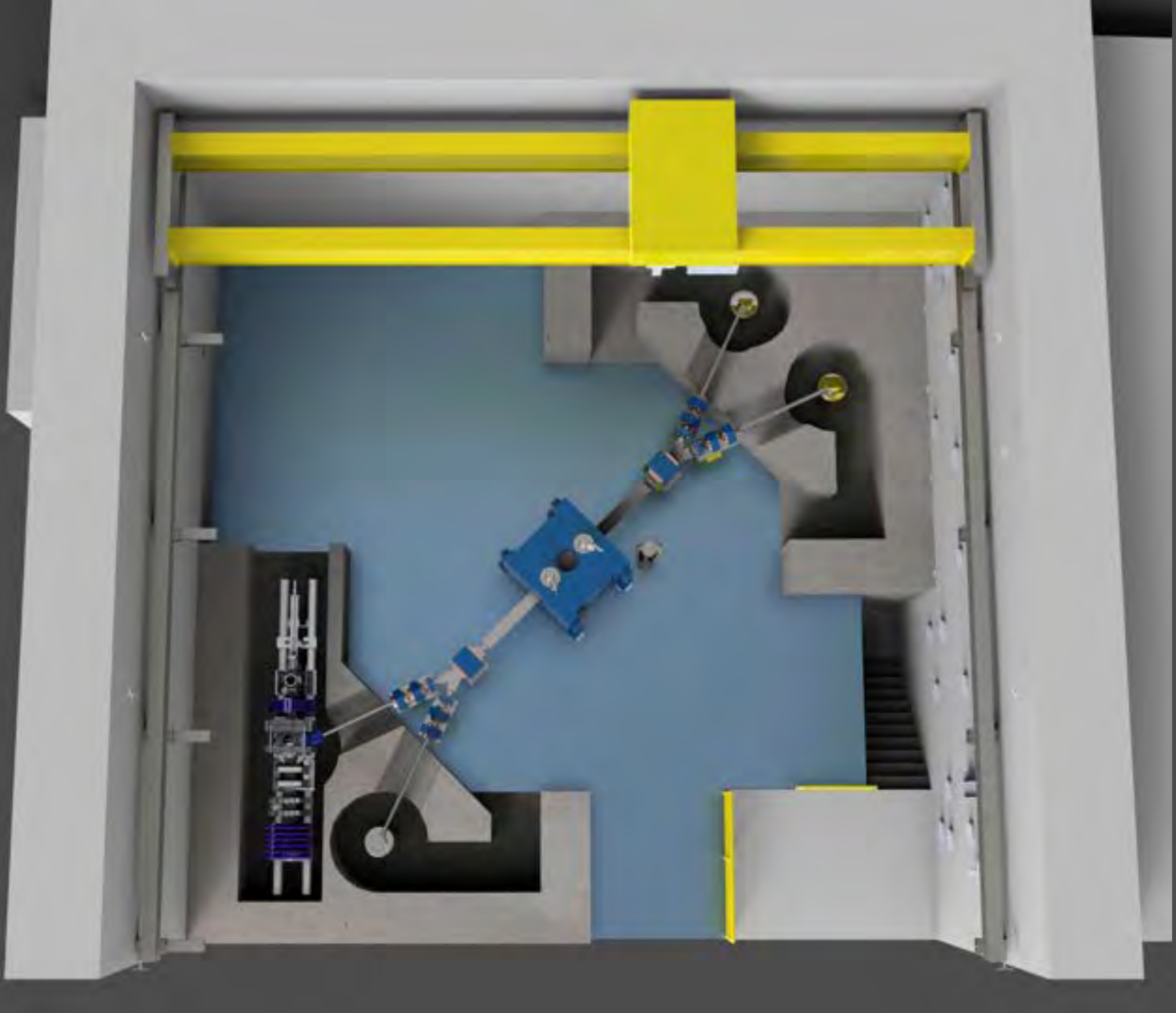
- Capable, but fast, experimental facilities for addressing the next set of technical innovations that make fusion economical.

- Need to launch the next generation of companies that will provide critical new technologies for industry.



Materials testing under fusion relevant conditions

Zach Hartwig

Nuclear Science and Engineering
Plasma Science and Fusion Center

“Fusion energy is becoming a materials problem”

Plasma Science & Fusion Center

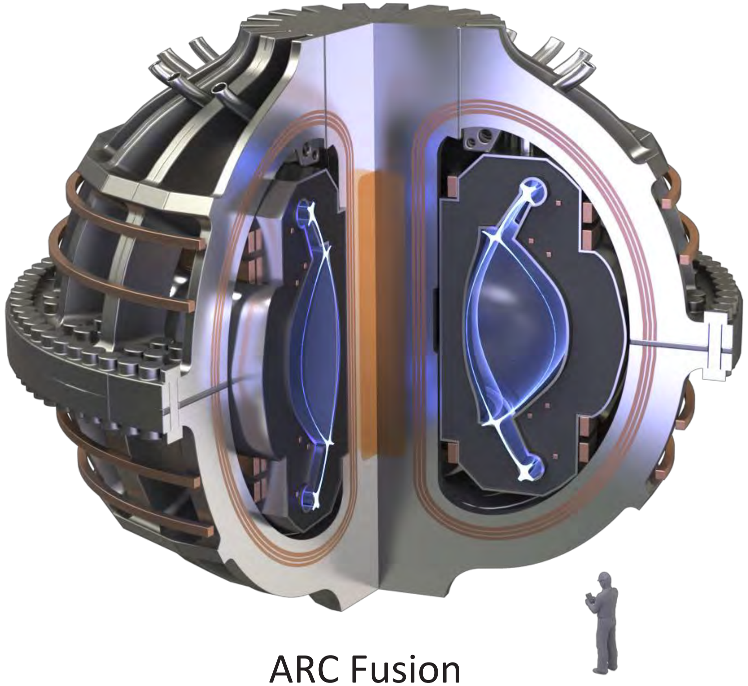
Dozens of private fusion companies (>$7B investment) are developing fusion for power production **in the 2030s.**

National programs (US, UK, China, etc.) are supporting these efforts and/or launching their own programs with objectives **in the 2030s.**

Every approach to fusion energy requires solving materials challenges. These challenges are ultimately linked to economic viability.

Some materials challenges in a fusion power plant

MIT Plasma Science & Fusion Center



ARC Fusion
Power Plant [1,2]

Common challenges:

- D-T fusion makes 14.1 MeV neutrons, causing bulk H and He generation in addition to cascade damage
- Neutron energy spectrum varies widely depending on subsystem of interest, and material response will vary accordingly

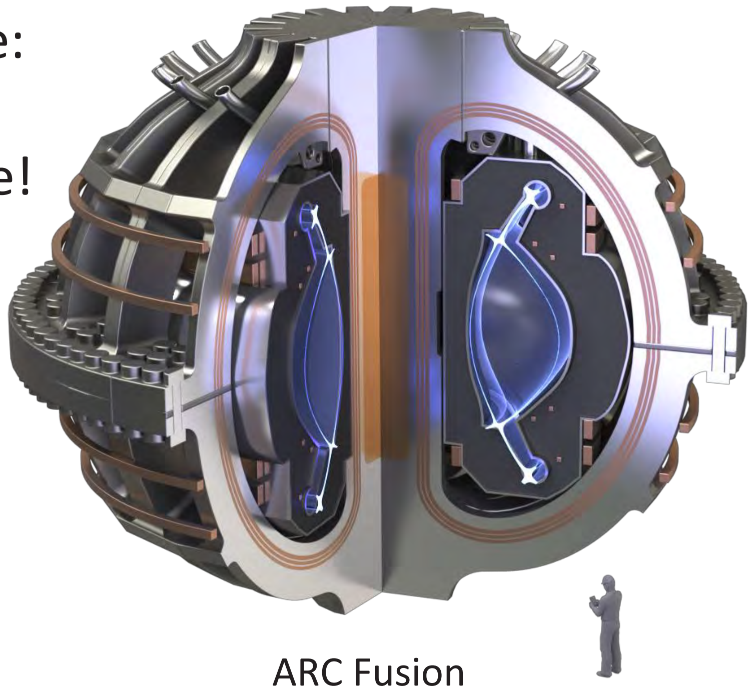
[0] B. N. Sorbom *et al*, FED **100** (2015) 378-405
[1] A Q. Kuang *et al,* FED **137** (2018) 221-242

Some materials challenges in a fusion power plant

MIT Plasma Science & Fusion Center

Structural material examples:

- Radiation induced damage: embrittlement, swelling, enhanced creep, and more!
- Chemical compatibility with molten salt under simultaneous irradiation



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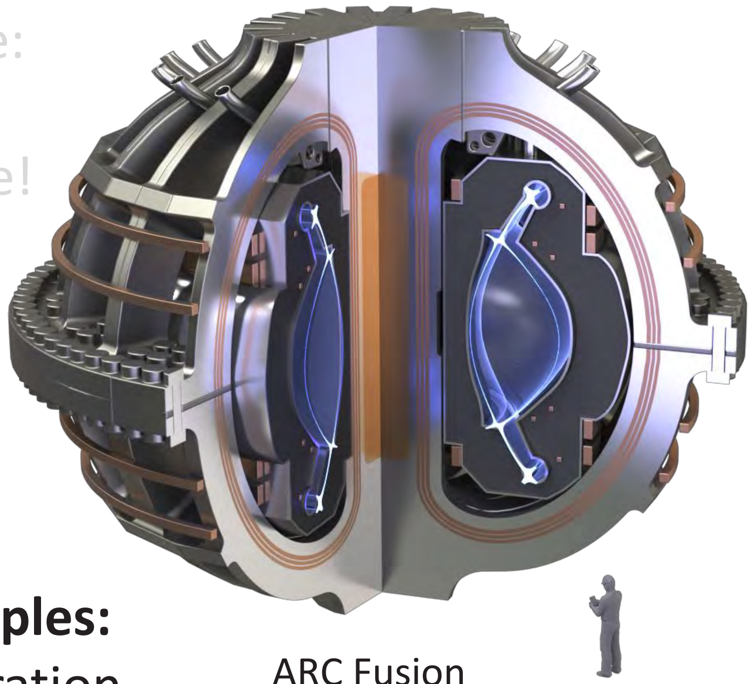

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Plasma-facing material examples:

- Tritium retention and migration in bulk damaged materials
- Radiation damage changes to material properties required for high heat flux handling (10 MW/m^2)

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Plasma Science & Fusion Center

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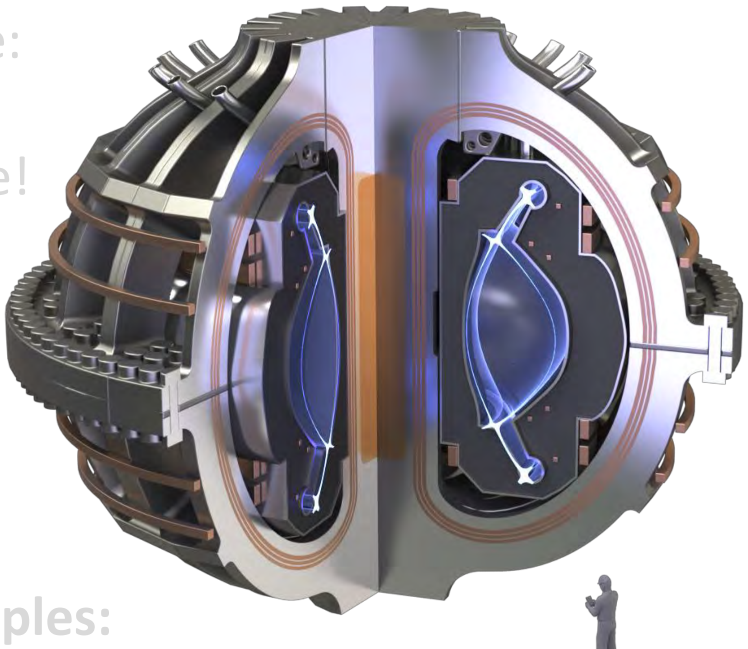

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Functional material materials:

- Degradation of the superconducting magnets while irradiated at cryogenic temperatures (~20 K)
- Browning of optical glass and mirrors required for plasma diagnostics

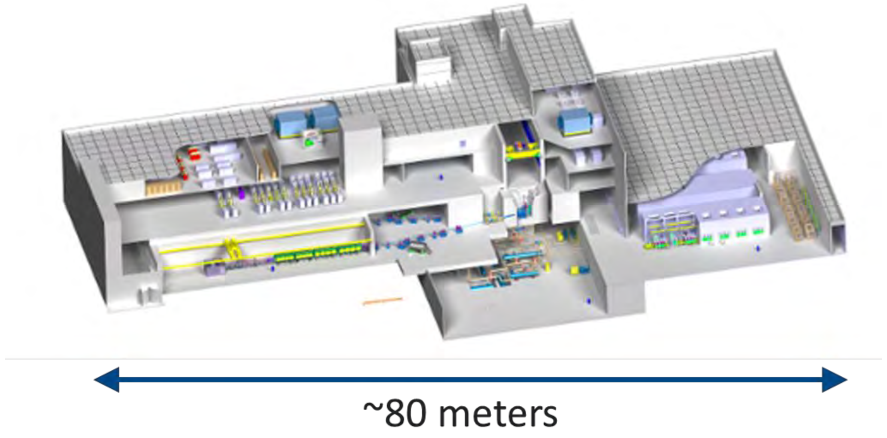
[0] B. N. Sorbom *et al*, FED **100** (2015) 378-405
[1] A Q. Kuang *et al,* FED **137** (2018) 221-242

Neutron irradiation of materials is insufficient

Today: Irradiation in reactors

Disadvantages:
- Low damage rates
- High cost and rare facilities
- Long + few learning cycles
- Low fidelity for fusion

2040s: Irradiation in IFMIF



Disadvantages:
- Low damage rates
- Limited exposure conditions
- Operational in the 2030s? 2040s?
- Impossible to scale to meet demand

We have to think differently and boldly to tackle fusion materials on relevant timescales.

Facility example #1:

Cryogenic proton irradiation in high fidelity conditions

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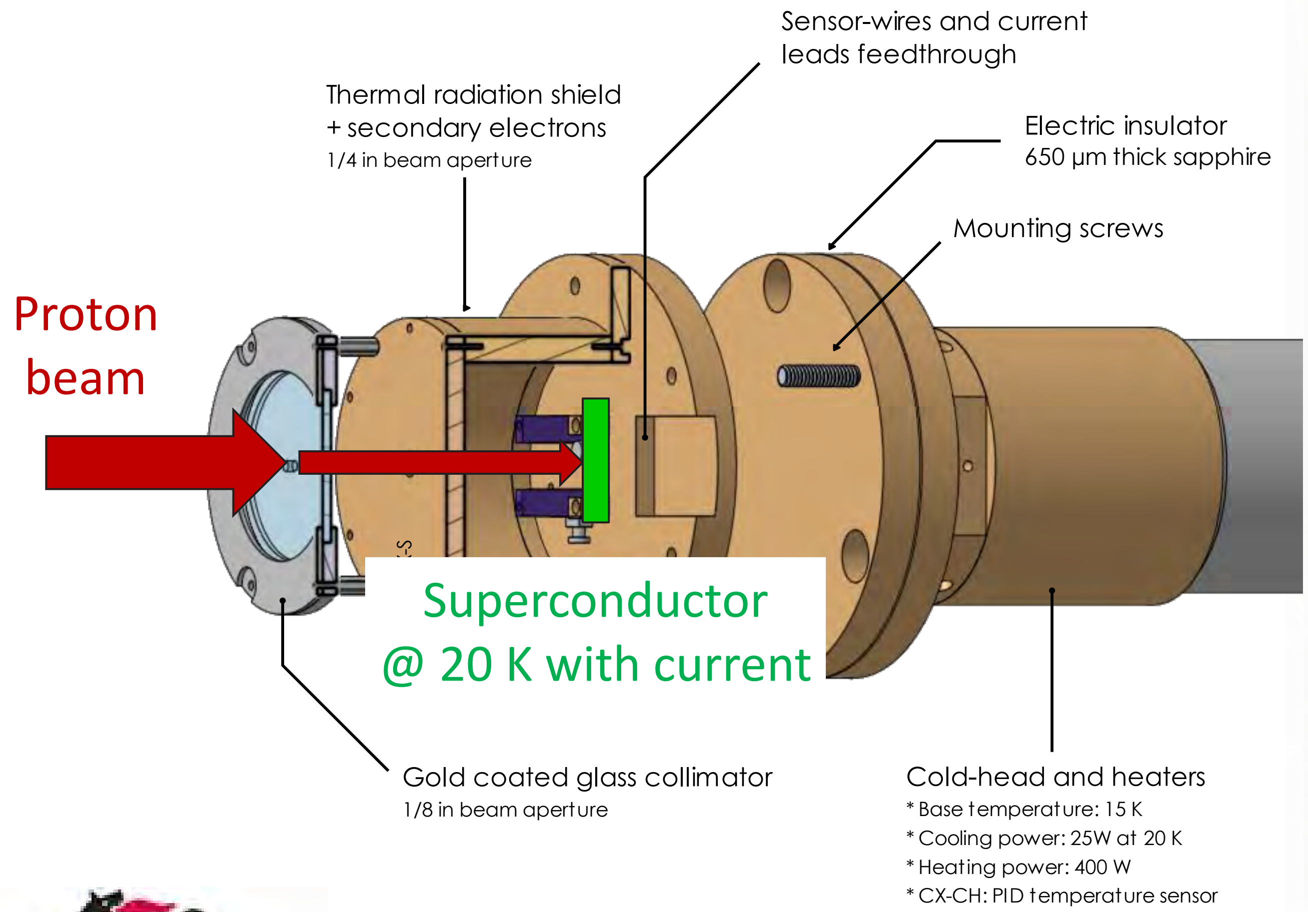

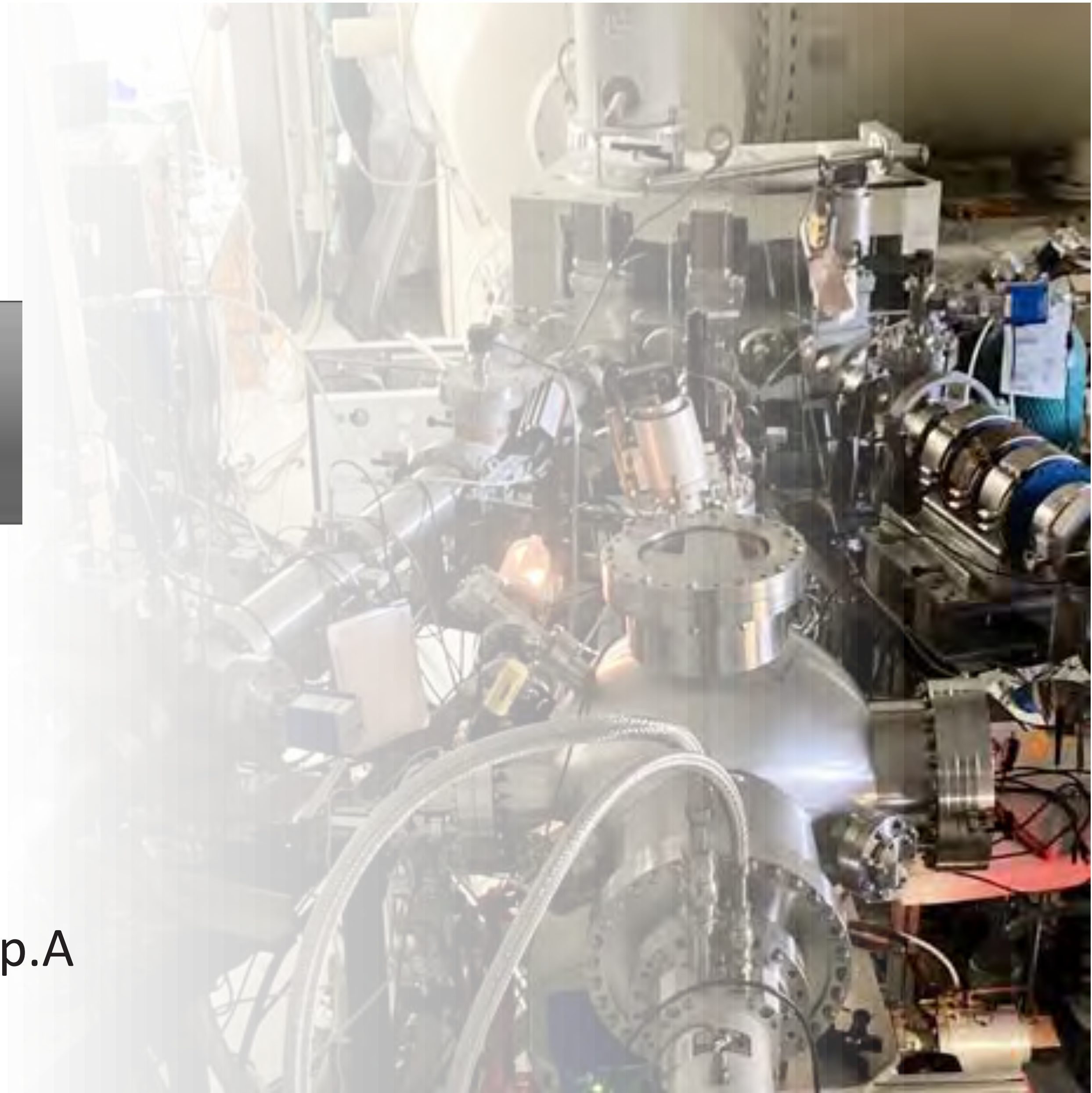

Facility generously supported by Eni. S.p.A

A. Devitre *et al.* Rev. Sci. Instr. **95** (2024) 063907.

Facility example #1:
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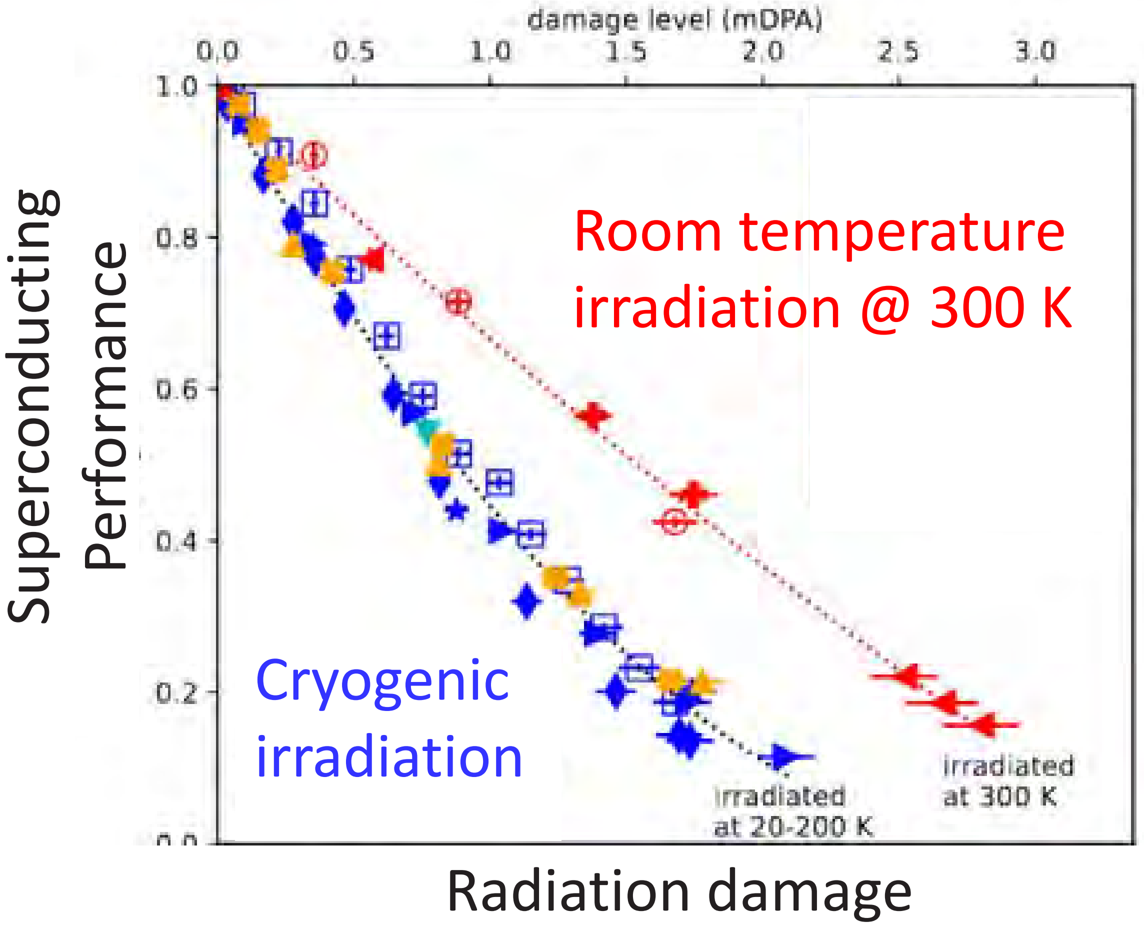
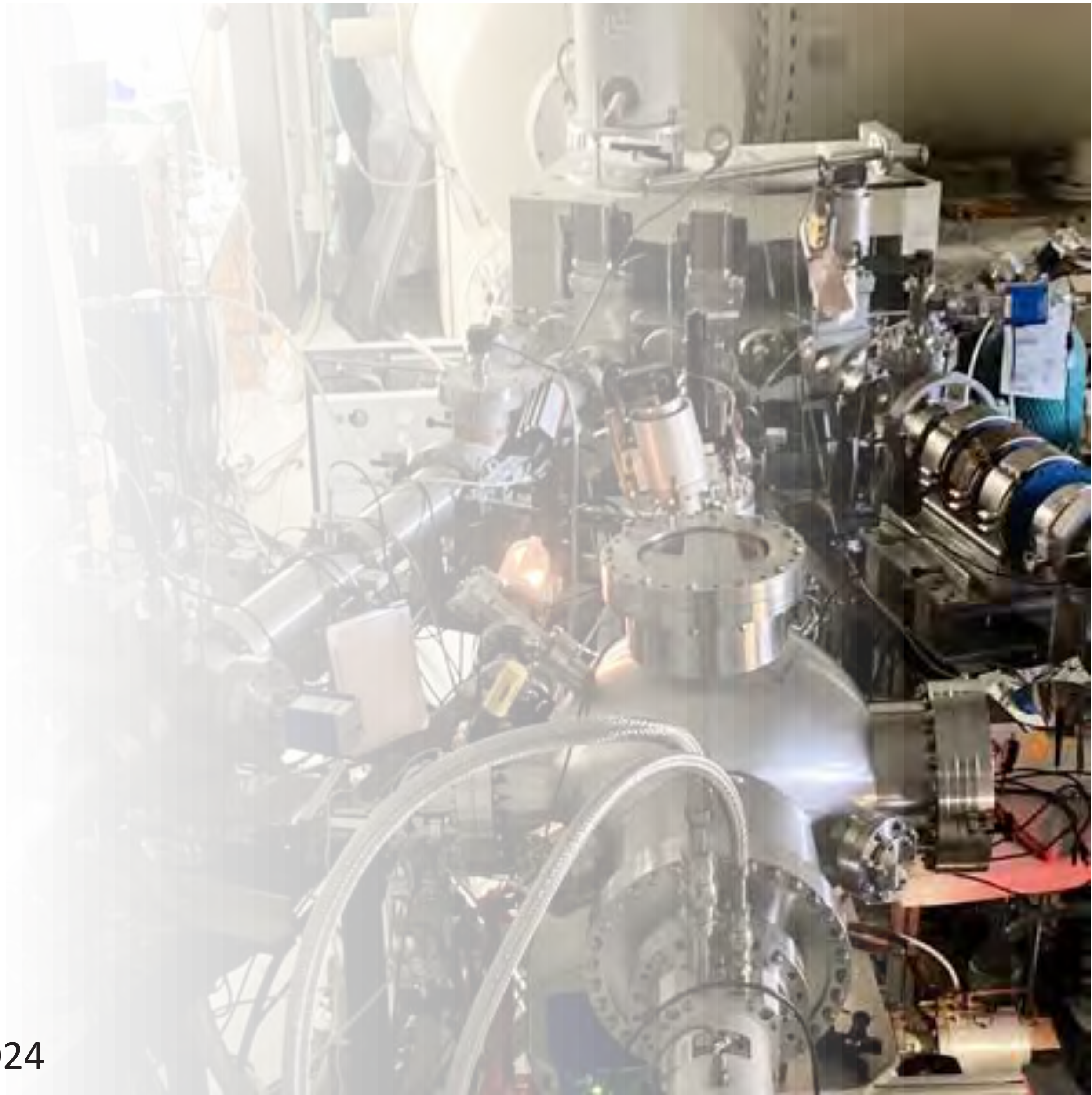
MIT Plasma Science & Fusion Center





D. X. Fischer, *et al.* Submitted to Supercond. Sci. and Tech., 2024

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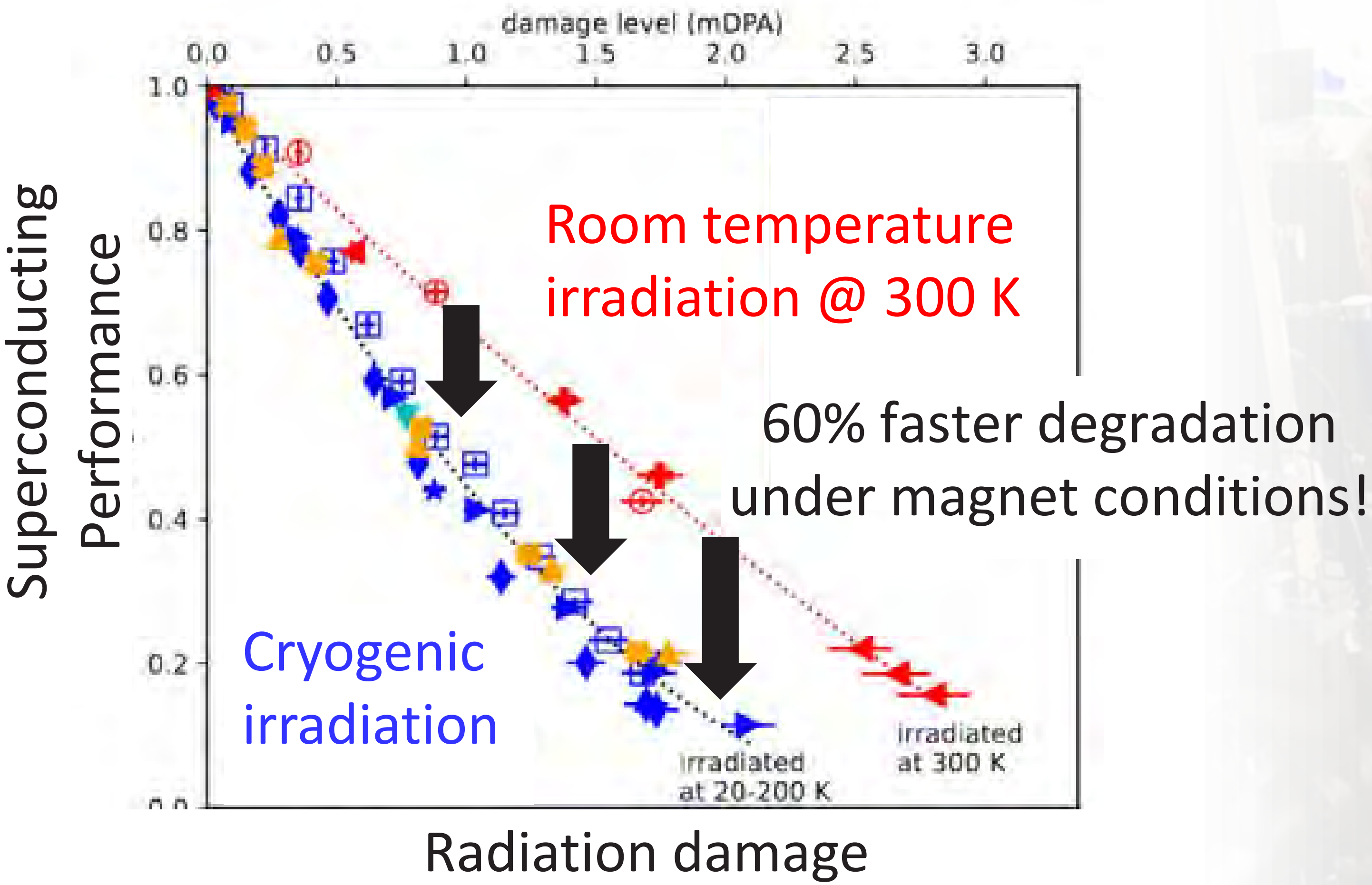
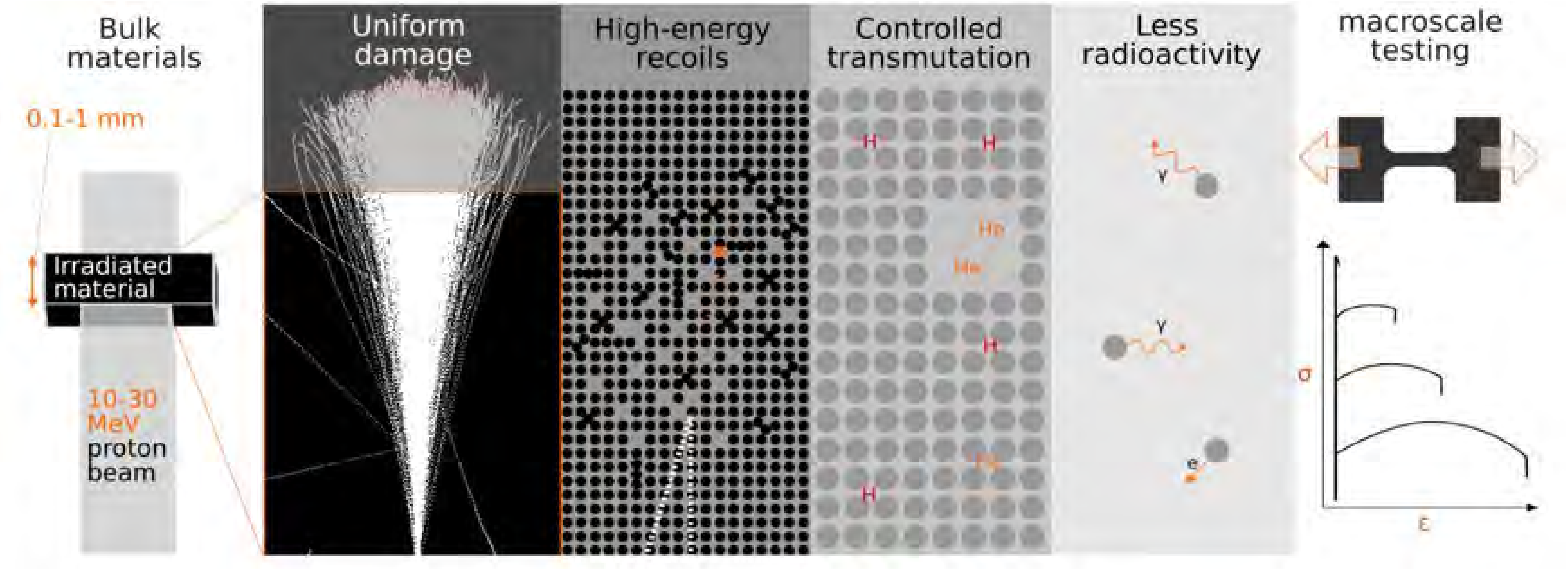


Innovative facilities can get answers in the right conditions on fast timescales

D. X. Fischer, *et al.* Submitted to Supercond. Sci. and Tech., 2024

Facility example #2:

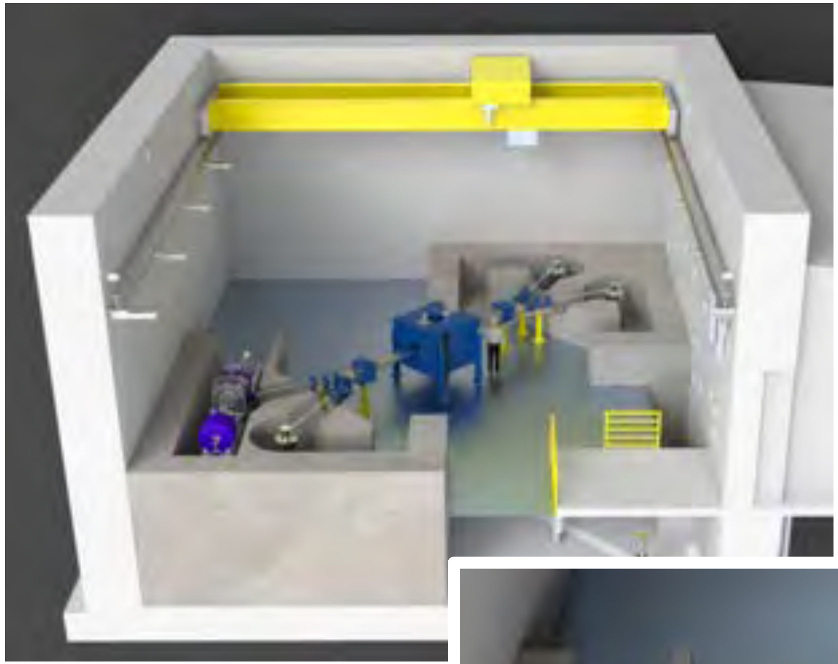
A high throughput bulk materials irradiation facility

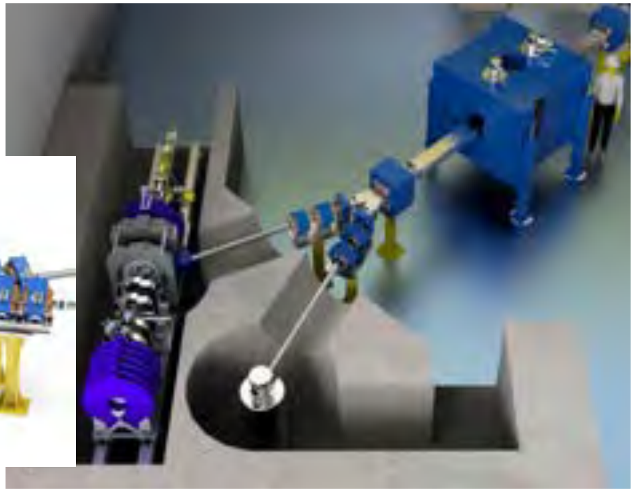


A technique that is faster, lower cost, lower activity, higher fidelity, and scalable

S. J. Jepeal, L. L. Snead, Z.S. Hartwig. *Materials and Design,* **200** (2021) 109445.

Facility example #2:
A first-of-kind irradiation facility for fusion materials





PSFC is readying to construct a new facility capable of high fidelity, high throughput bulk materials irradiation

- Replicate fusion irradiation responses in materials
- Damage materials up to 100x faster than application
- Reuse existing experimental space at PSFC worth $50M
- Utilizes commercial off-the-shelf accelerator technology
- Ready to begin science operation 18 months from funding

4 beamlines with user-driven modular end station to maximize science output

- Thin-film and bulk materials irradiation (*in-situ* and post-irradiation examination)
- Complex environmental conditions like
    - Linear plasma device for plasma-material
    - Molten salt radiation-corrosion issues

Provide decision-quality materials data for fusion companies in years not decades.

Artificial Intelligence for preventing plasma disruptions

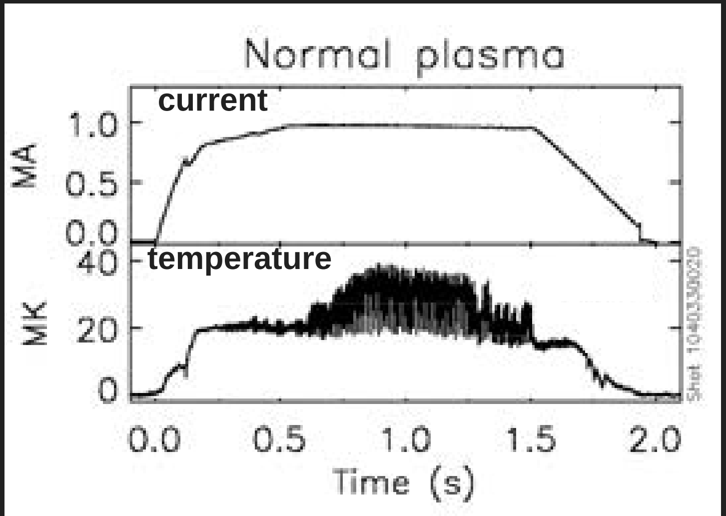
MIT Plasma Science & Fusion Center

Cristina Rea

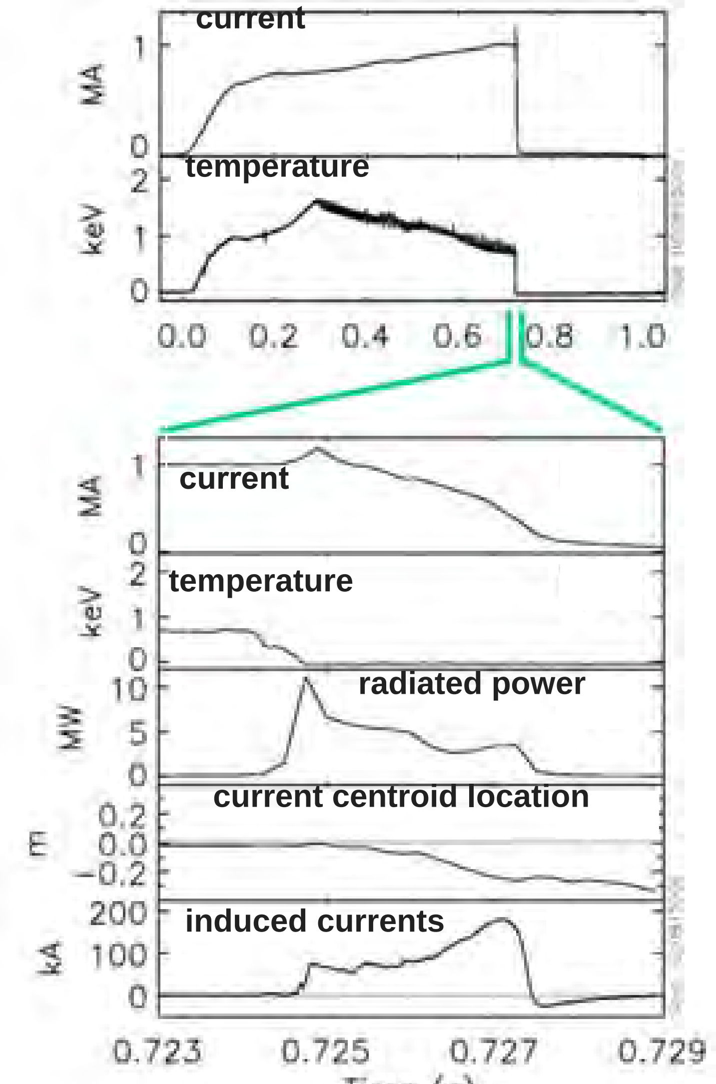
Principal Research Scientist, Group Leader

MITEI - 10/17/2024

Fusion plasmas → highly nonlinear interactions + loss of control = disruptions!



disruptive plasma



Courtesy: R.S. Granetz

Final loss of control evolving on timescales of milliseconds:

- Fast current drop leads to loss of confining poloidal field
- Fast current transient causes **large induced currents & forces**
- Rapid thermal losses cause **surface damage**

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Different instabilities grow when plasma pushed to controllability limits

Visible camera view of RE beam hitting Alcator C-Mod first wall. Courtesy R.A. Tinguely

Disruption prevention strategies needed for next generation devices

Visible camera view of RE beam hitting Alcator C-Mod first wall. Courtesy R.A. Tinguely

melting!

JET runaway electrons damage. https://www.iter.org/newsline/-/2234

Accept the damage and live with it

Mitigate the damage by [...] to radiate away as much/fast as possible

Avoid altogether by detecting precursors & steer plasma away from disruptive boundary

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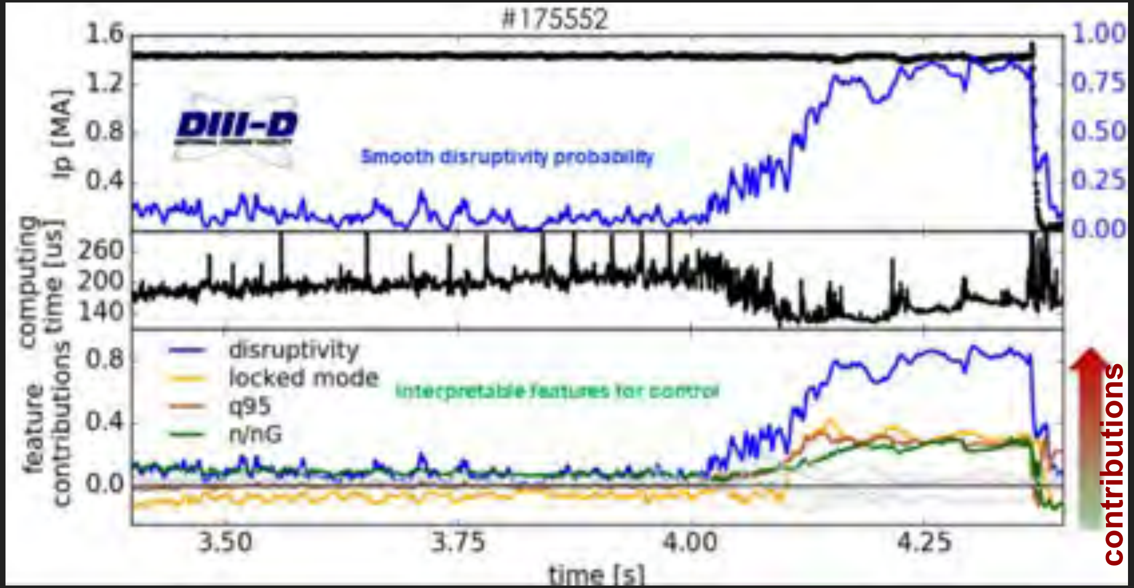
While first principle models lack, data-driven / ML ones can provide:

Explainable proximity to unstable operational space

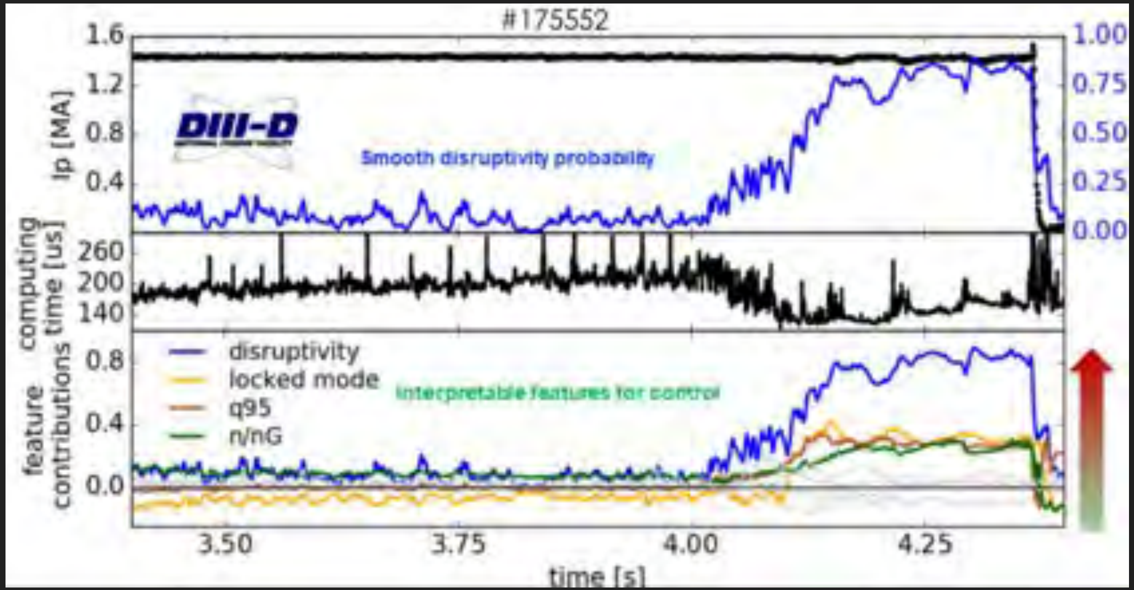


- Probability of impending disruption + contributions
- Available on DIII-D and EAST in real-time systems for proximity control [1,2]

[1] Rea et al, Nucl. Fusion 59 (2019) 096016
[2] Rea et al, 2021 IAEA EX/P1–25

While first principle models lack, data-driven / ML ones can provide:

Explainable proximity to unstable operational space & interpretable tracking of instability onset



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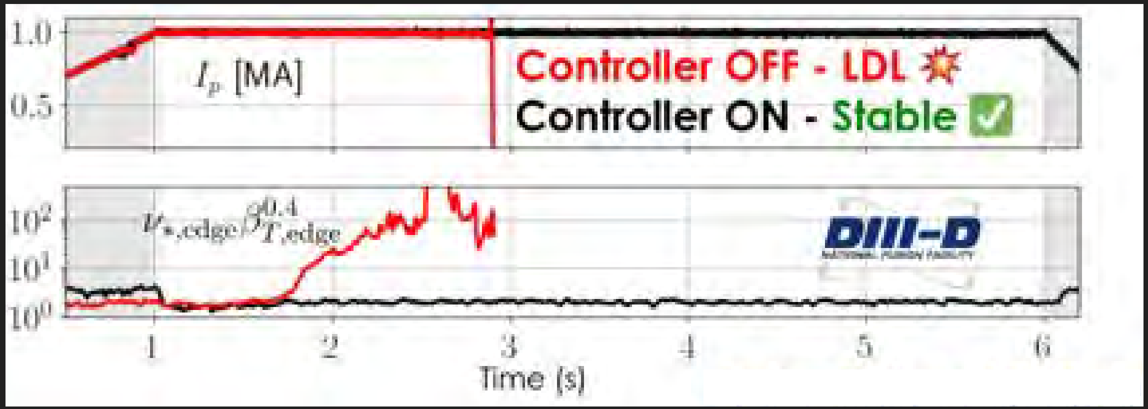

- Collisionality at plasma edge identified as indicator for precursor to L-mode density limit [3]

[3] Maris, Rea et al, under review Nuclear Fusion, 2024

- Yields 6x fewer false positives than literature results
- Algorithm available in DIII-D real-time control system

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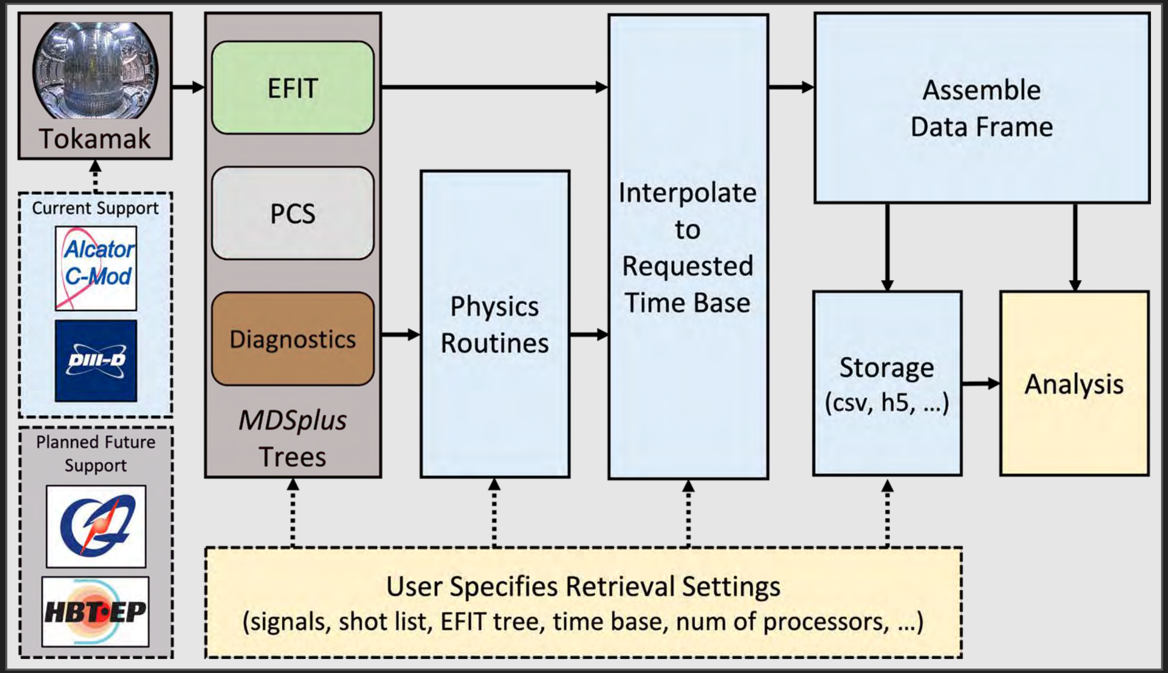
Additional examples of ML/AI research aiding disruption prevention

- **Disruption-py**: interoperable, open-source Python library for data access across different fusion devices**
- Enables assembly of big databases for ML applications



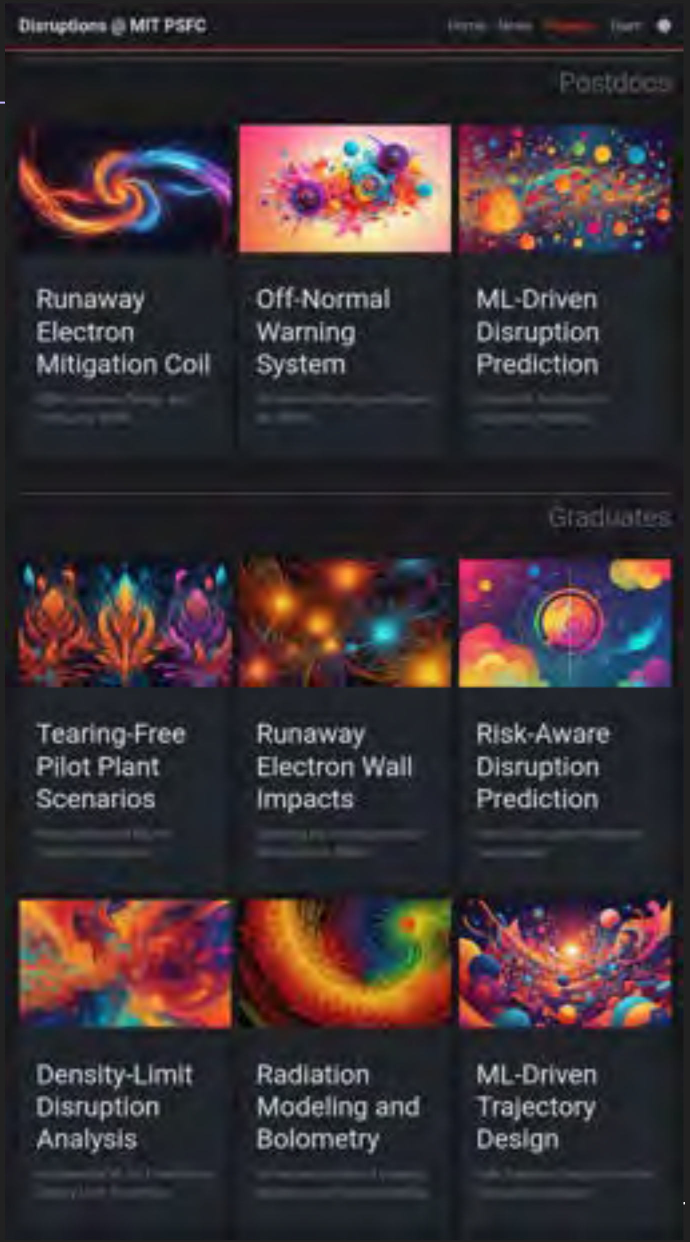
*** Trevisan et al, APS-DPP 2024 PP12.9*
Wei et al, APS-DPP 2024 PP12.10
https://github.com/MIT-PSFC/disruption-py
https://zenodo.org/records/13935224

The Disruptions team includes >20 scientists / postdocs / students / collaborators

https://disruptions.mit.edu/

Notable collaborations include: CFS, Google, Eni, international universities and entities, …

ML/AI tools used ubiquitously across different projects



IAEA Collaborating Centre in AI in Fusion and Plasma Science: Enabling Research and Education

5yr cost-free agreement (2023-2027). Builds on IAEA Coordinated Research Project “AI for Fusion” [1] and DOE-funded activities sharing focus on:

- Open Science and FAIR access to fusion data/metadata
- Accessible research products (data, software, …) enabling cross-pollination
- Education, training, capacity building in ML-applied fusion science
- Selected examples:
  - Computational Physics School for Fusion Research (CPS-FR) [2]
    - HPC, Parallel Programming, Computational Statistics, and ML (grad students + postdocs)
  - $5M multi-institutional collaboration (W&M, U. Auburn, U. Wisc-Madison, HDFG) to develop open research products [3]
    - AI for Fusion Energy Summer School (undergrads)
  - ITU data challenge [4] leveraging raw Alcator C-Mod dataset

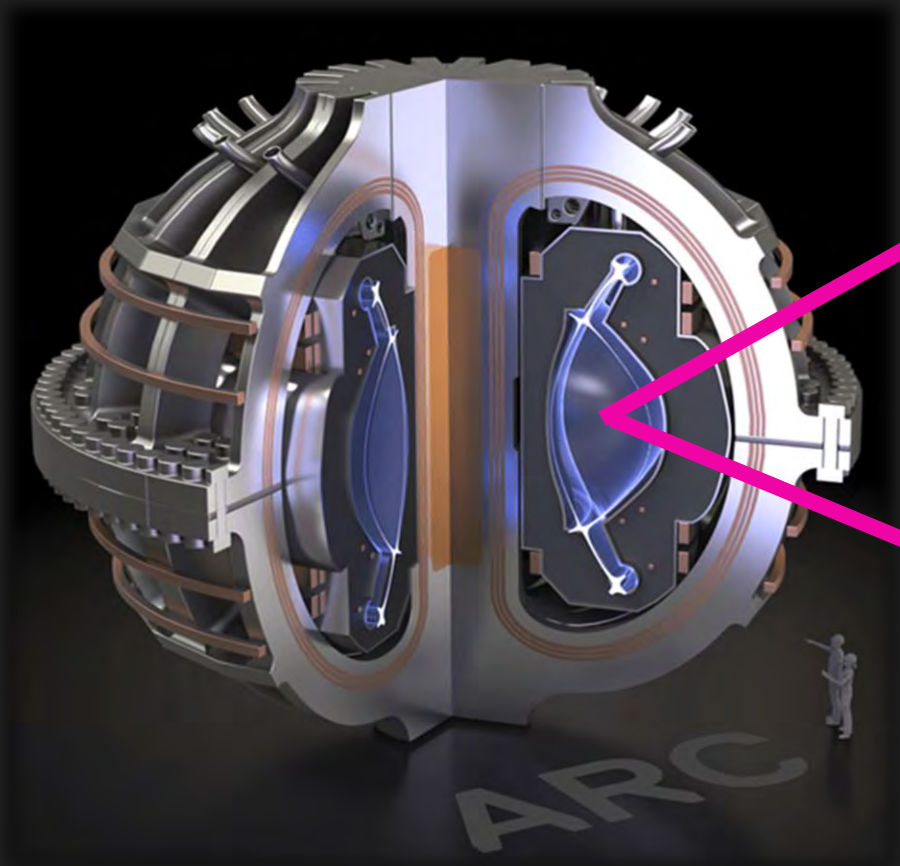
[1] https://nucleus.iaea.org/sites/ai4atoms/ai4fusion/SitePages/AI4F.aspx
[2] https://sites.google.com/psfc.mit.edu/cps-fr-2024/home
[3] https://crea-psfc.github.io/open-fair-fusion/
[4] https://aiforgood.itu.int/about-ai-for-good/ai-for-fusion-energy-challenge/

Tritium management

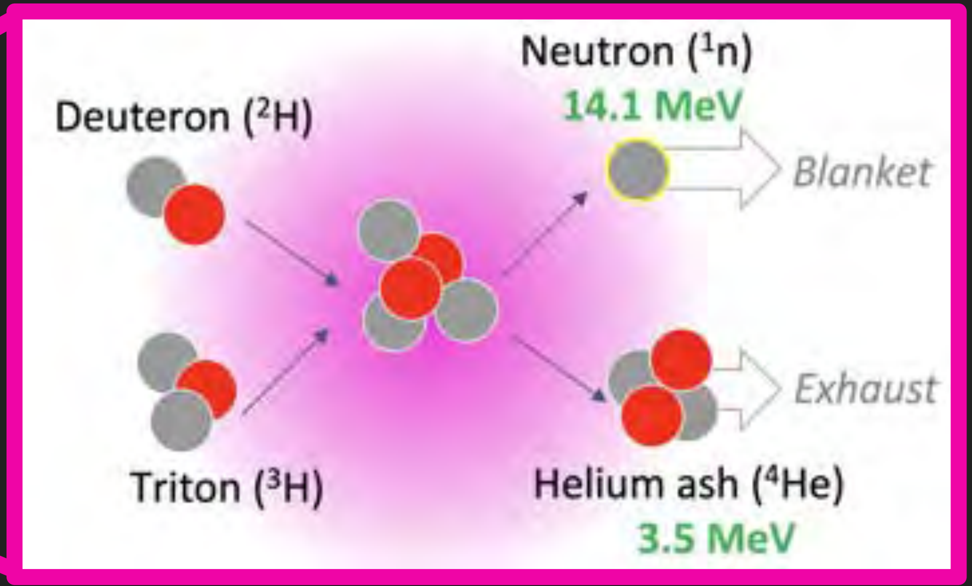
Plasma Science & Fusion Center

Sara Ferry

Most proposed fusion power plant concepts use deuterium and tritium as fuel.

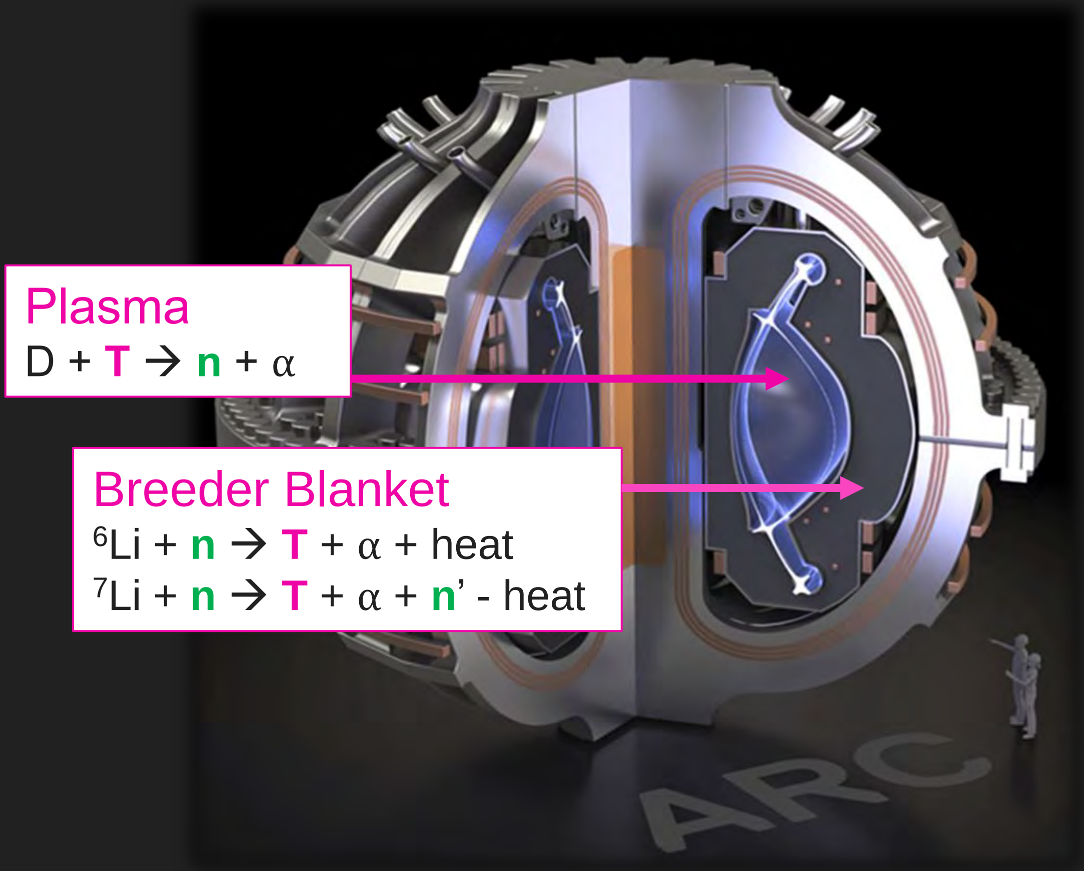


Rendering of an ARC-class fusion power plant courtesy of Commonwealth Fusion Systems



The D-T fusion reaction in the plasma produces high-energy neutrons and helium particles.

Tritium is scarce, so D-T fusion power plants must breed their own.

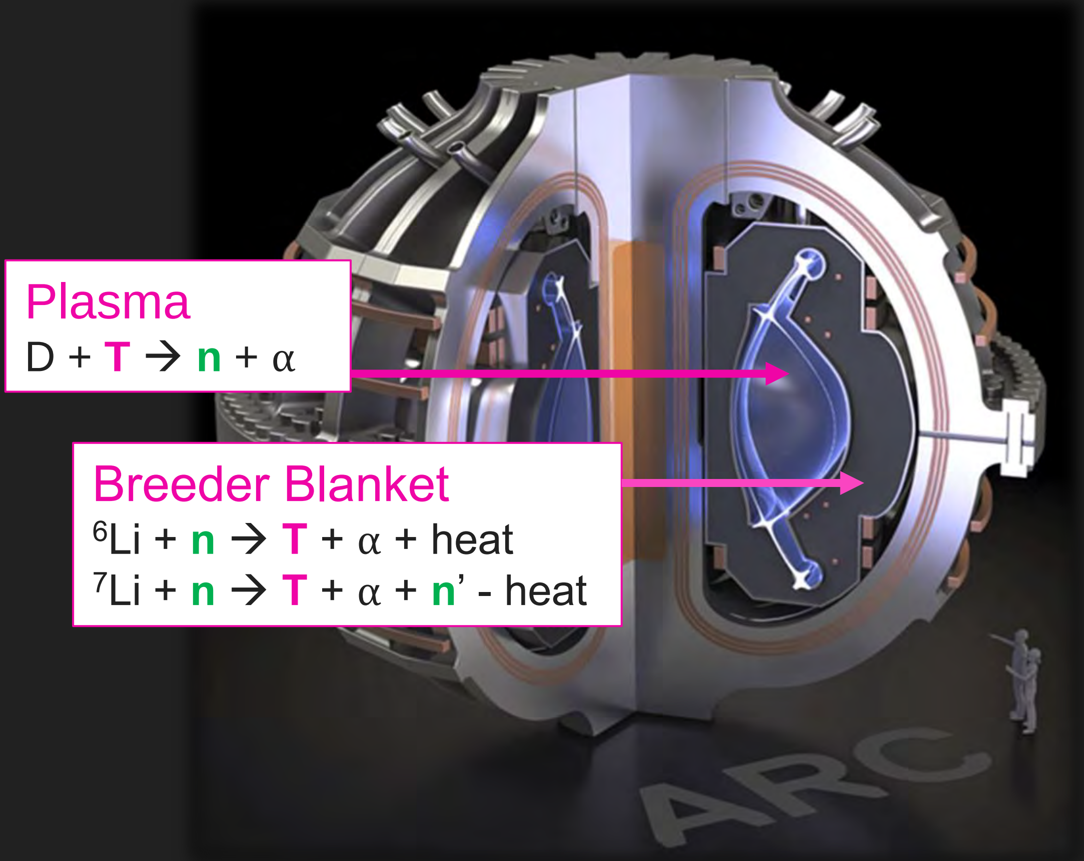


Rendering of an ARC-class fusion power plant courtesy of Commonwealth Fusion Systems

Functions of the breeding blanket:

1. **Shielding**: Moderate + absorb neutrons to shield the magnets
2. **Heat capture**: Generate power
3. **Tritium breeding**: Make more fuel in the breeder, which contains **lithium**

Tritium is scarce, so D-T fusion power plants must breed their own.

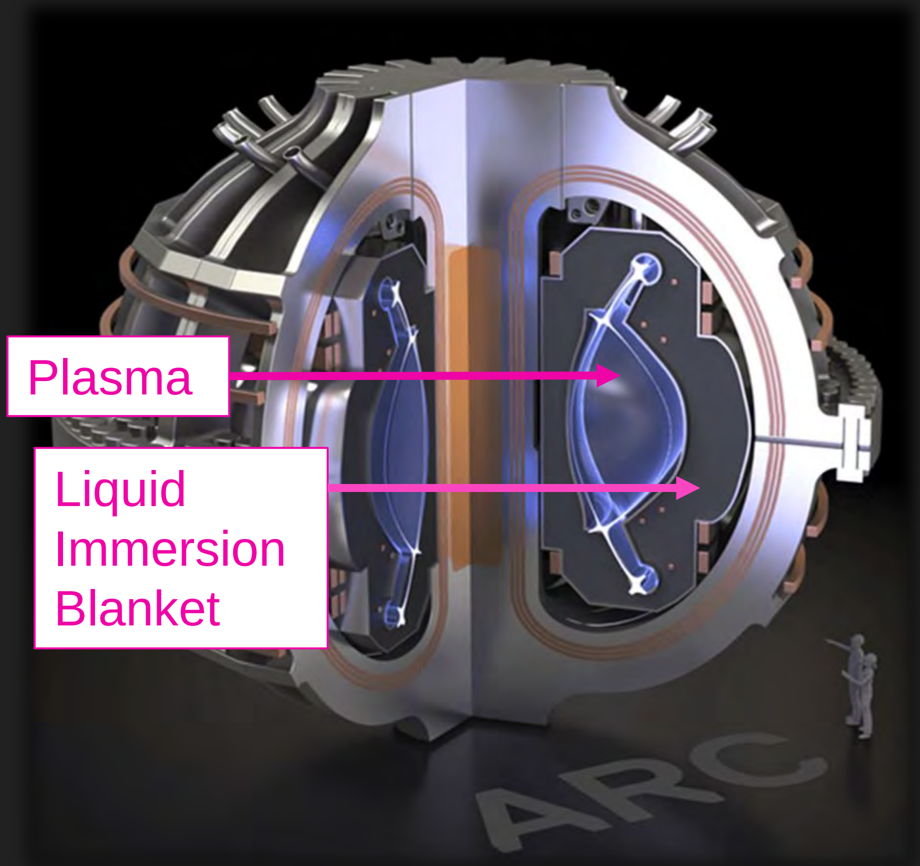


Rendering of an ARC-class fusion power plant courtesy of Commonwealth Fusion Systems

- Breeding material contains **lithium**
  - Lithium ceramic solids (e.g. Li_4SiO_4)
  - Pure liquid lithium
  - Molten lead-lithium (PbLi)
  - Molten salts like FLiBe
- Beryllium and lead are neutron multipliers and boost breeding
- Blanket also needs infrastructure for chemistry control and heat removal
- Blanket performance characterized by the tritium breeding ratio (**TBR**)

$$\textbf{TBR} = \frac{\text{\# of tritons produced in the blanket}}{\text{\# of tritons consumed in the plasma}}$$

MIT PSFC is investigating molten salt “liquid immersion blankets” for ARC-class fusion power plants.



Rendering of an ARC-class fusion power plant courtesy of Commonwealth Fusion Systems

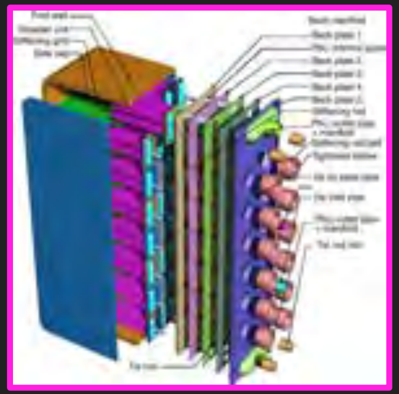
Key advantages of the LIB approach:

- **Maximize solid angle coverage of the neutron source (the plasma) to increase TBR**
- Can pump out breeder for maintenance
- Online chemistry control
- Minimize complexity
- Efficient heat removal

Drawbacks of conventional blankets:

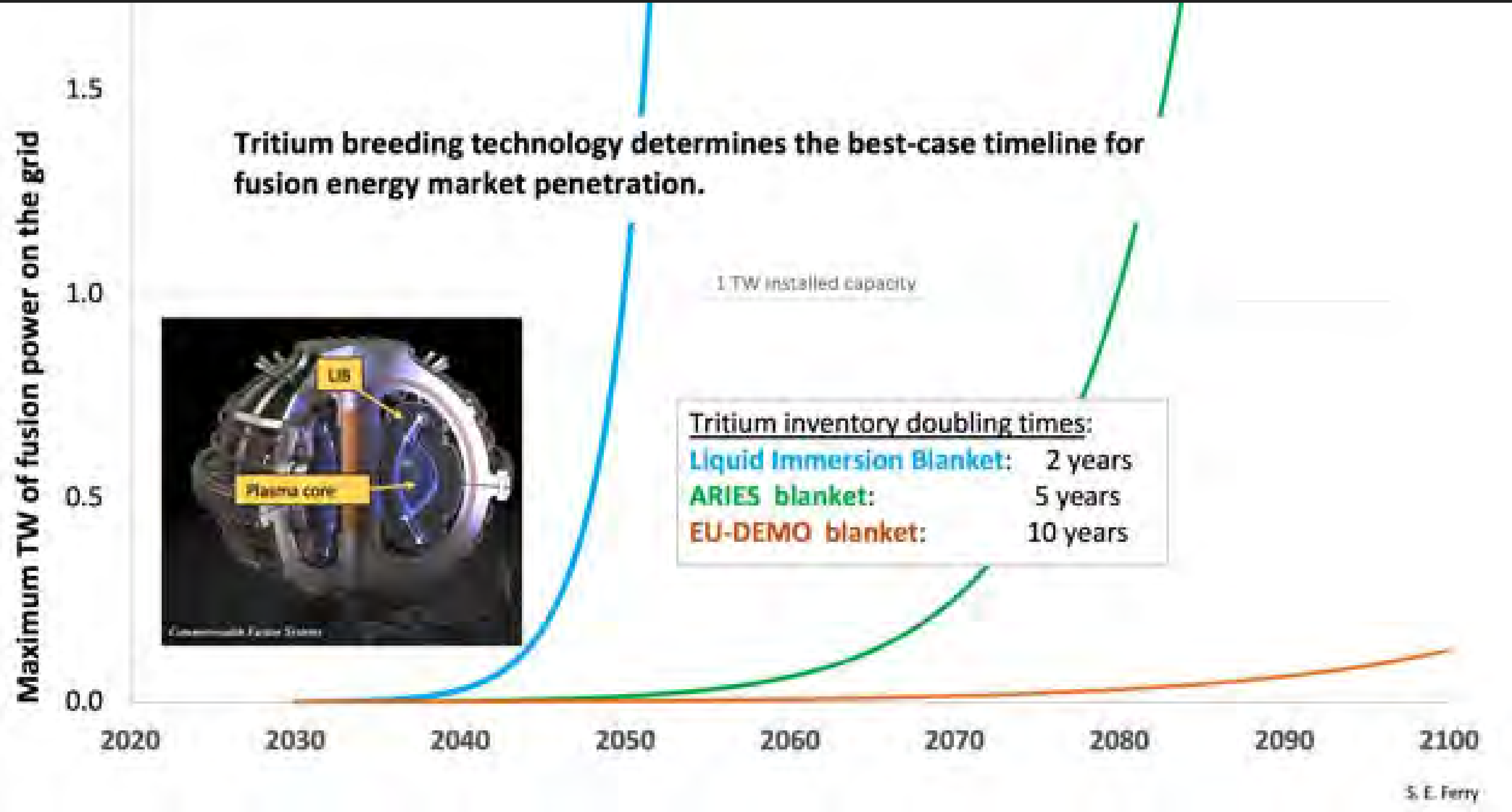
- Complex solid structures are challenging for fabrication, maintenance, and assembly
- Activation concerns
- More structural material = less breeder = **lower TBR**

Aiello G, de Dinechin G, Forest L, *et al.* HCLL TBM design status and development. Fusion Engineering and Design 2011; 86:2129–34.



Example: the design for a helium-cooled lead-lithium test blanket module for ITER (representative of a possible blanket for DEMO) devotes lots of volume to non-breeding structures.

The high breeding efficiency of the LIB will let us put fusion plants on the grid much faster.

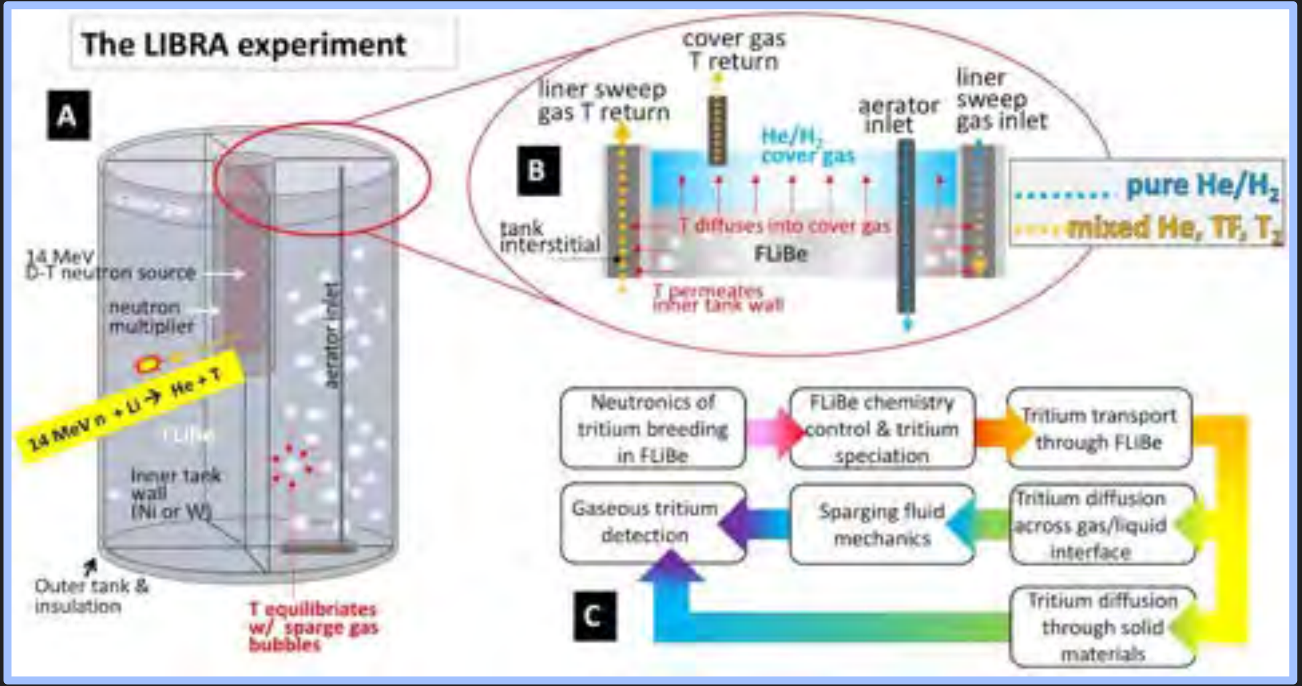


Assume we were able to begin building fusion power plants in 2030, and tritium supply was our only rate-limiting step.

Using conventional blankets, it would take ~70 years to reach 0.1 TW of installed fusion power capacity (<10% of U.S. installed capacity as of 2023). This isn't fast enough!

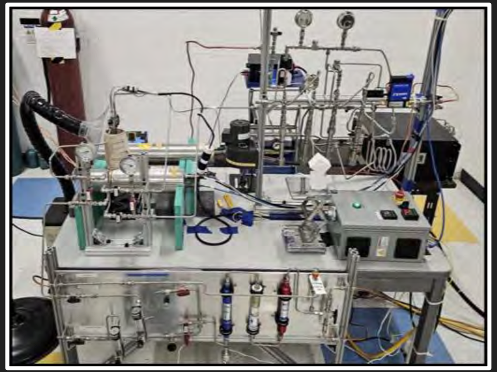
The LIBRA experiment at MIT is advancing molten salt breeder blanket technology.

LIBRA (**Liquid Immersion Blanket: Robust Accountancy**) enables us to study tritium breeding and behavior in FLiBe in a prototypical neutronic and chemical environment.



LIBRA requires a **staged experimental approach** of increasing complexity and volume.

Experimental setup for **BABY-0.1L** in the MIT PSFC Vault Laboratory on Albany Street →



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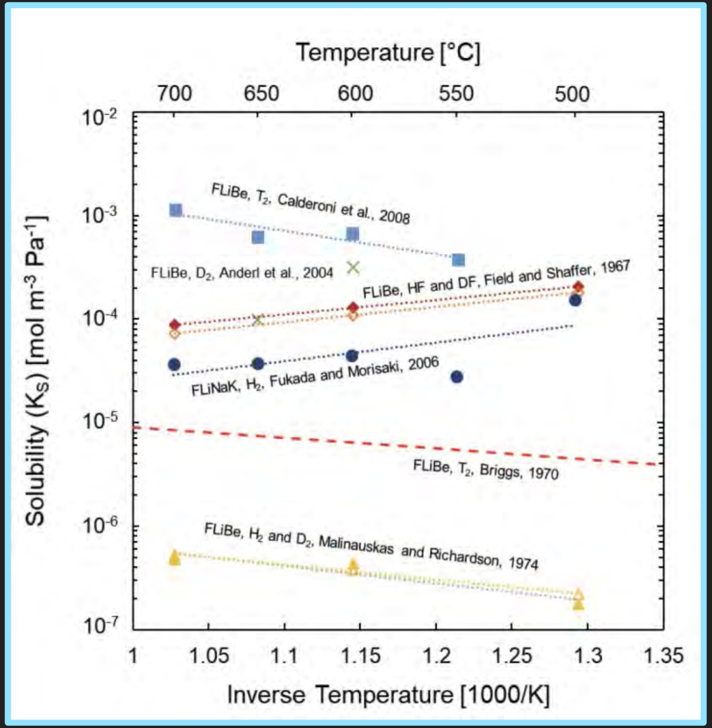
The LIBRA experiment at MIT is advancing molten salt breeder blanket technology.

Humrickhouse, Paul W., and Thomas F. Fuerst. *Tritium Transport Phenomena in Molten-Salt Reactors*. No. INL/EXT-20-59927-Rev000. Idaho National Lab.(INL), Idaho Falls, ID (United States), 2020.



There are **enormous uncertainties** regarding how tritium behaves in FLiBe. Literature data shows a 3-4 order-of-magnitude spread for solubility of tritium in FLiBe at the same temperature!

The LIBRA initiative will provide **reliable, repeatable data** on tritium behavior in prototypical breeder blanket environments that can be used to reliably design full-scale blanket systems for power plants.

See also: the U.S. fusion blanket and fuel cycle technology community roadmaps published by EPRI (available for download on the EPRI website)

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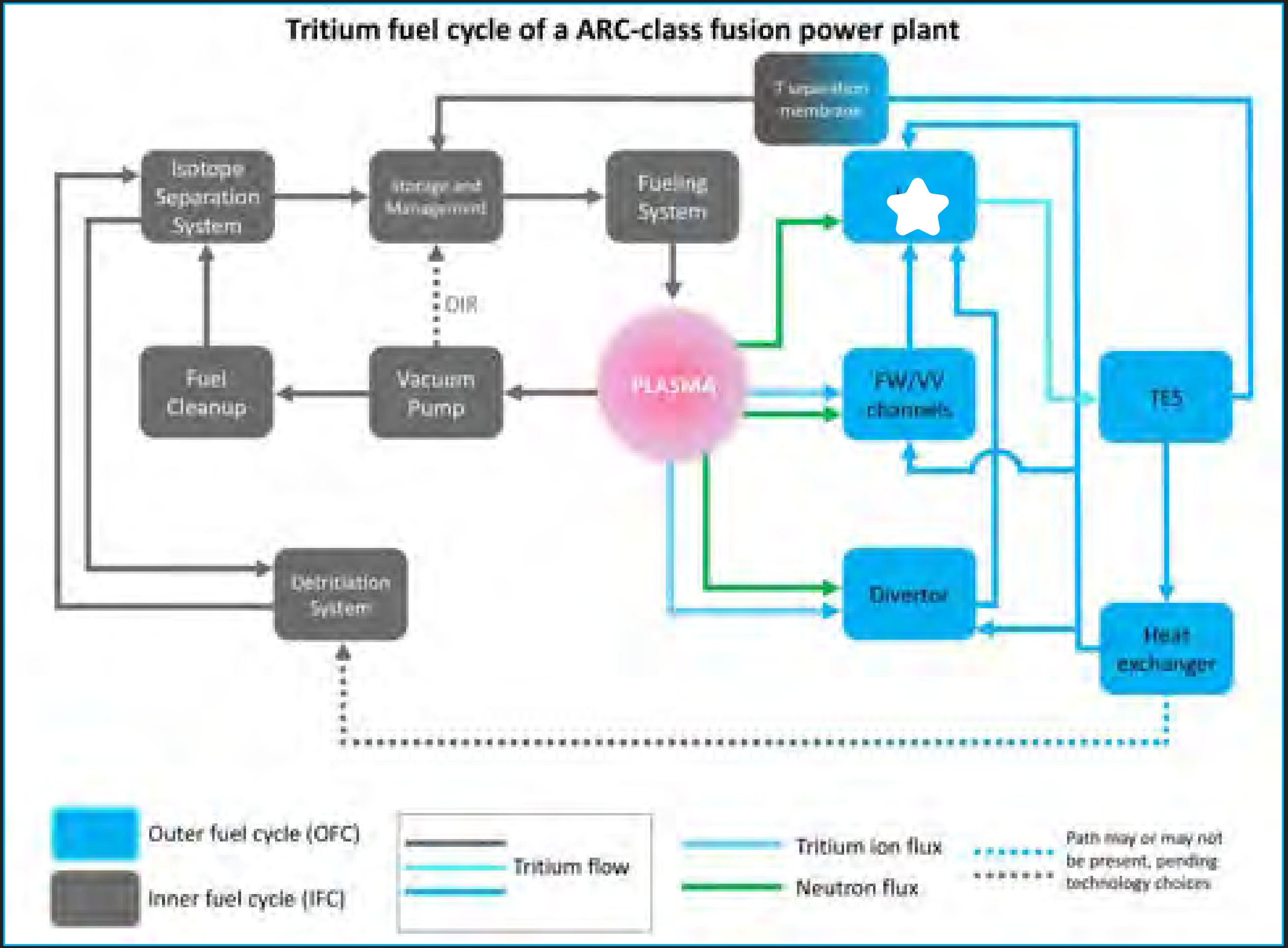
The breeder blanket (marked with a ★) is just one piece of a complex fuel cycle system.



- We need to understand tritium's dynamics through the **entire** fuel cycle: achieving high breeding rates in the blanket is just part of the engineering challenge!
- Tritium is highly mobile, and **losses** due to trapping and permeation (as well as radioactive decay) must be accounted for
- Most of the necessary technologies have not been demonstrated at scale, but are critical to the success of the fusion industry

S. Meschini, S. E. Ferry, R. Delaporte-Mathurin, D. Whyte "Modeling and analysis of the tritium fuel cycle for ARC- and STEP-class DT fusion power plants," Nuclear Fusion **63** (2023)

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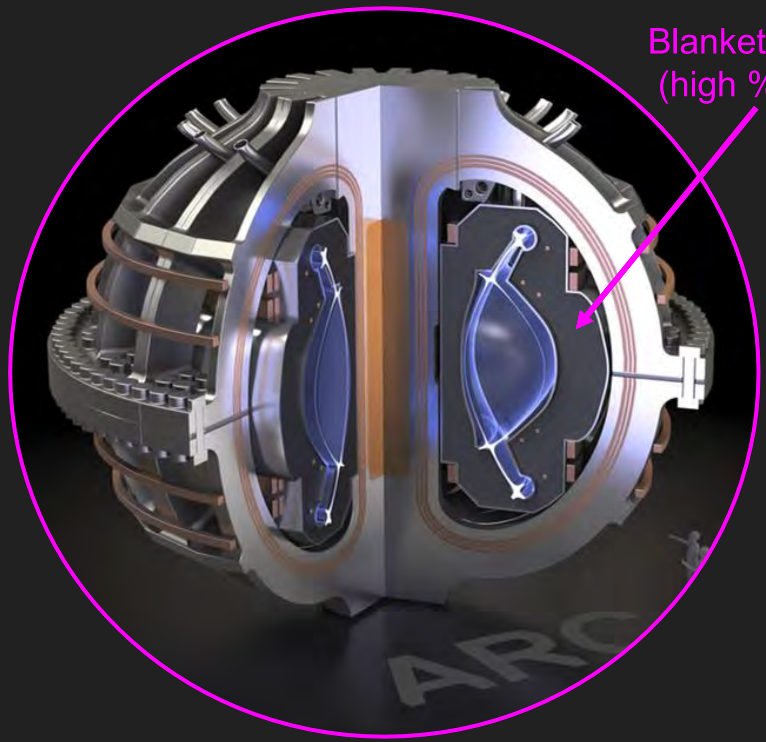
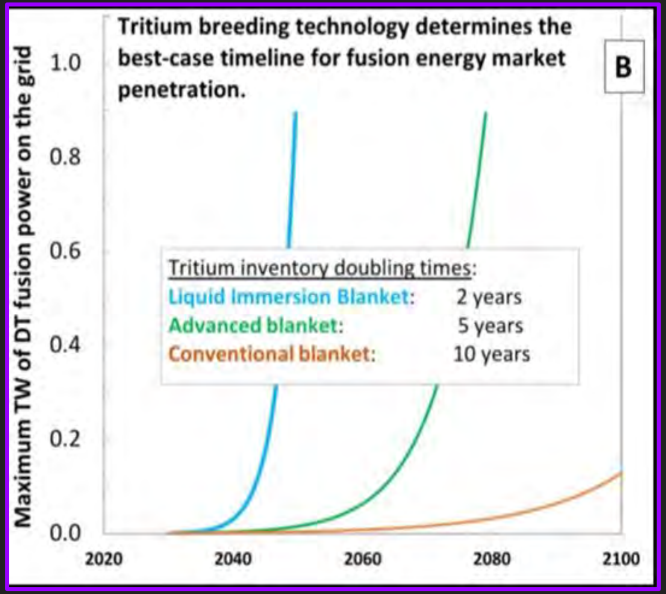
MIT PSFC is working to fuel the future fusion industry.

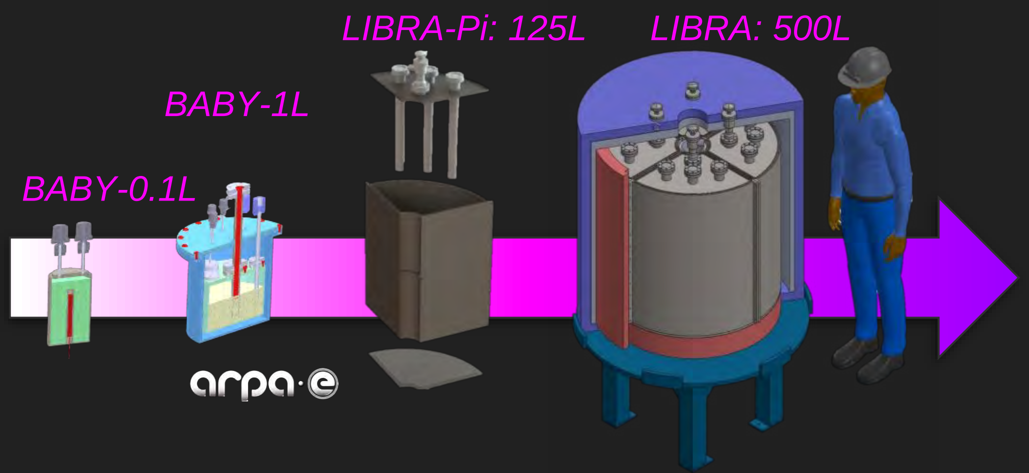
D-T fusion plants must breed their own tritium.



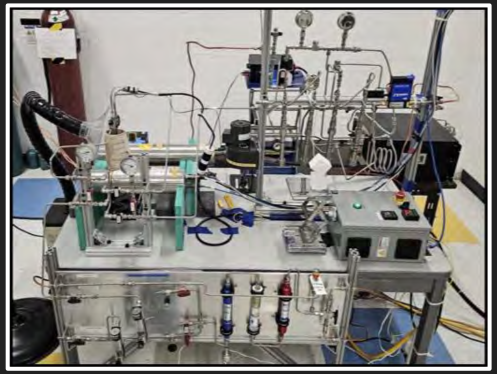
- The D-T fusion reaction produces neutrons
  Deuterium + Tritium → neutron + He
- The neutrons are captured in the blanket
- The blanket contains lithium
- Neutron + Lithium → **Tritium** + He

Advanced tritium breeding technology is the key to unlocking fusion power's market potential.





MIT PSFC is undertaking an ambitious, staged approach to derisk the FLiBe liquid immersion blanket.



BABY-0.1L just prior to irradiation

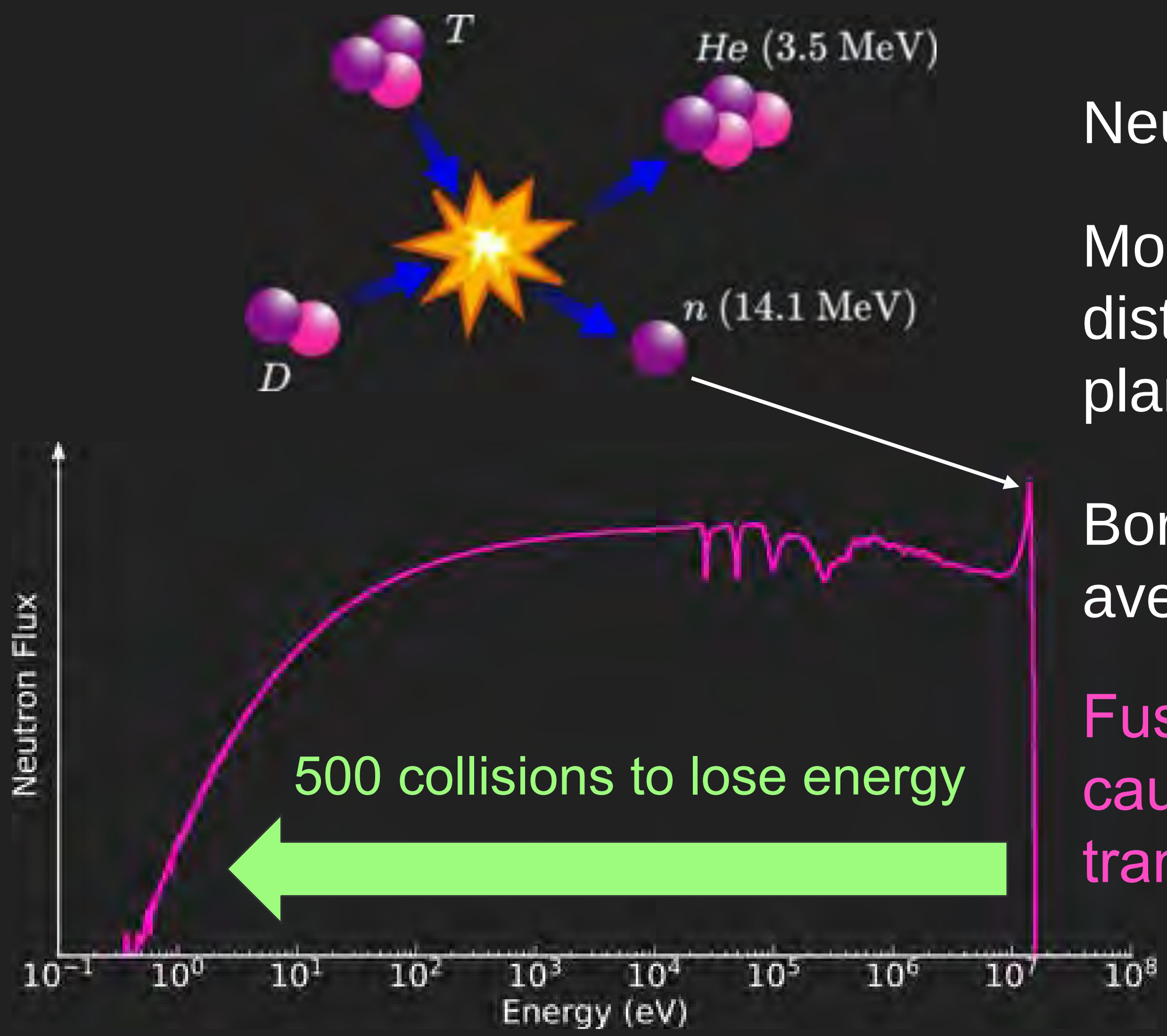
LIBRA team:
Kevin Woller **PI**
John Ball, Remi Delaporte-Mathurin, Collin Dunn, Kaelyn Dunnell, Emily Edwards, Sara Ferry, Nikola Goleš, Ed Lamere, Andrew Lanzrath, Rick Leccacorvi, Samuele Meschini, Ethan Peterson, Stefano Segantin, Rui Vieira, Colin Weaver, Dennis Whyte, Weiyue Zhou

Impacts of neutron transport on fusion power plant design

MIT Plasma Science & Fusion Center

Prof. Ethan Peterson

Neutrons greatly impact fusion power plant design



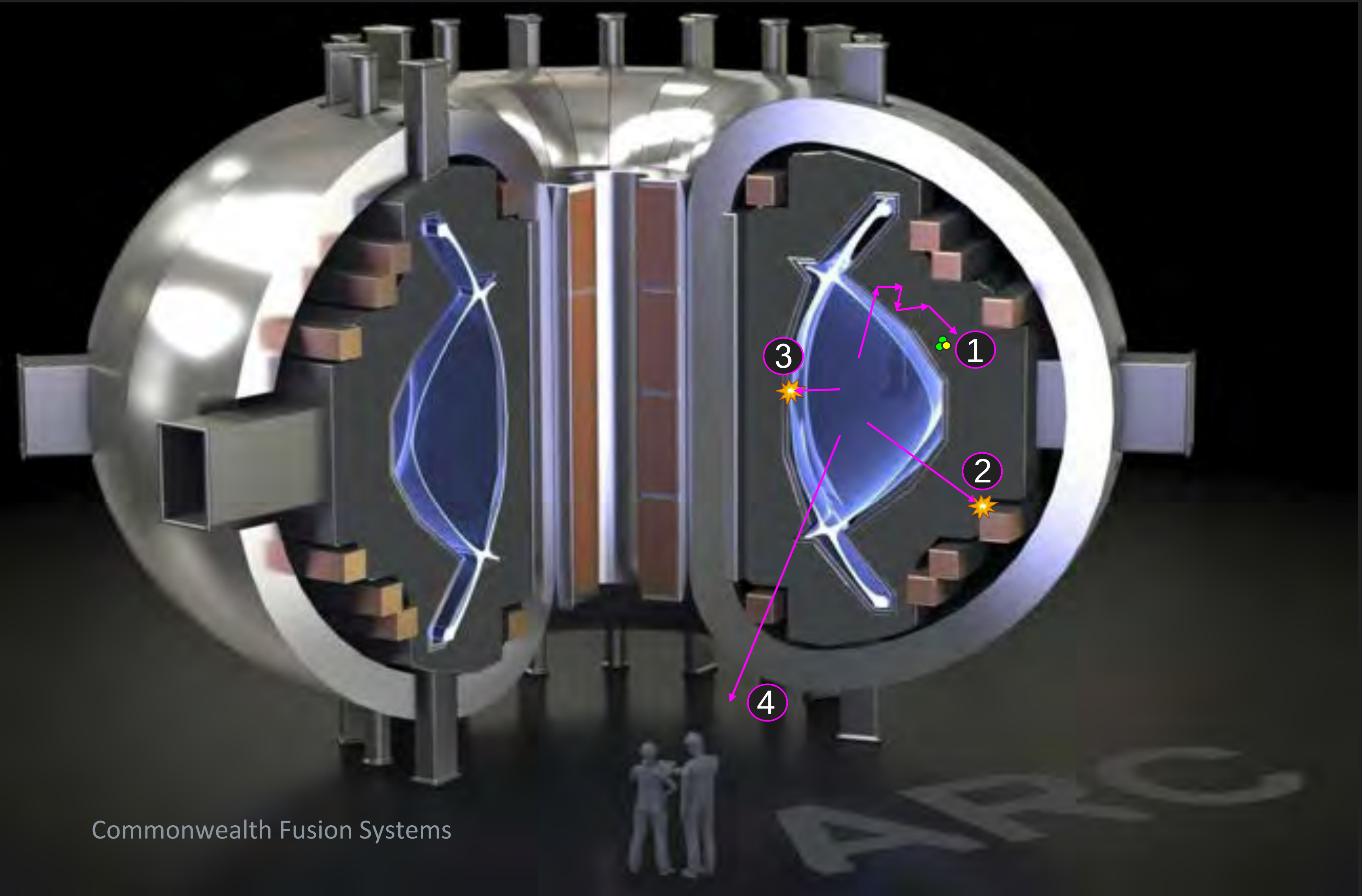
Neutrons carry 80% of D-T fusion energy

Monte Carlo simulations compute the distribution of neutrons throughout the power plant and their effects

Born at 14 MeV where they travel 5 cm on average between collisions in steel

Fusion neutrons travel far, at high energy and cause damage, heating, dose, and transmutation

Neutrons greatly impact fusion power plant design



Commonwealth Fusion Systems

1. Capture neutron energy and generate tritium
2. Protect magnets from nuclear heating and radiation damage
3. Engineer plasma facing materials that can withstand high fluence
4. Protect workers and the public from direct and shutdown dose

Neutron responses determine system requirements, yet take the longest to execute.

We need fast, accurate methods to compute them as well as their uncertainty.

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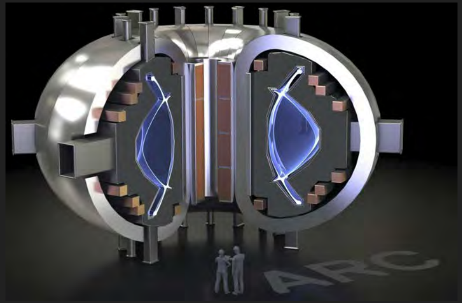
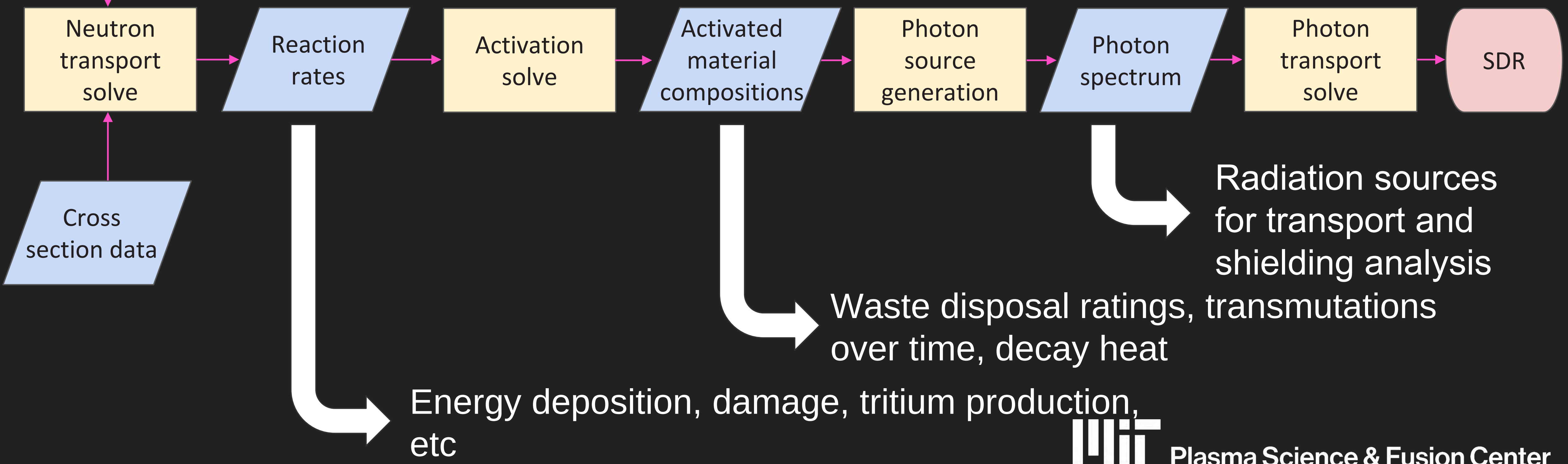
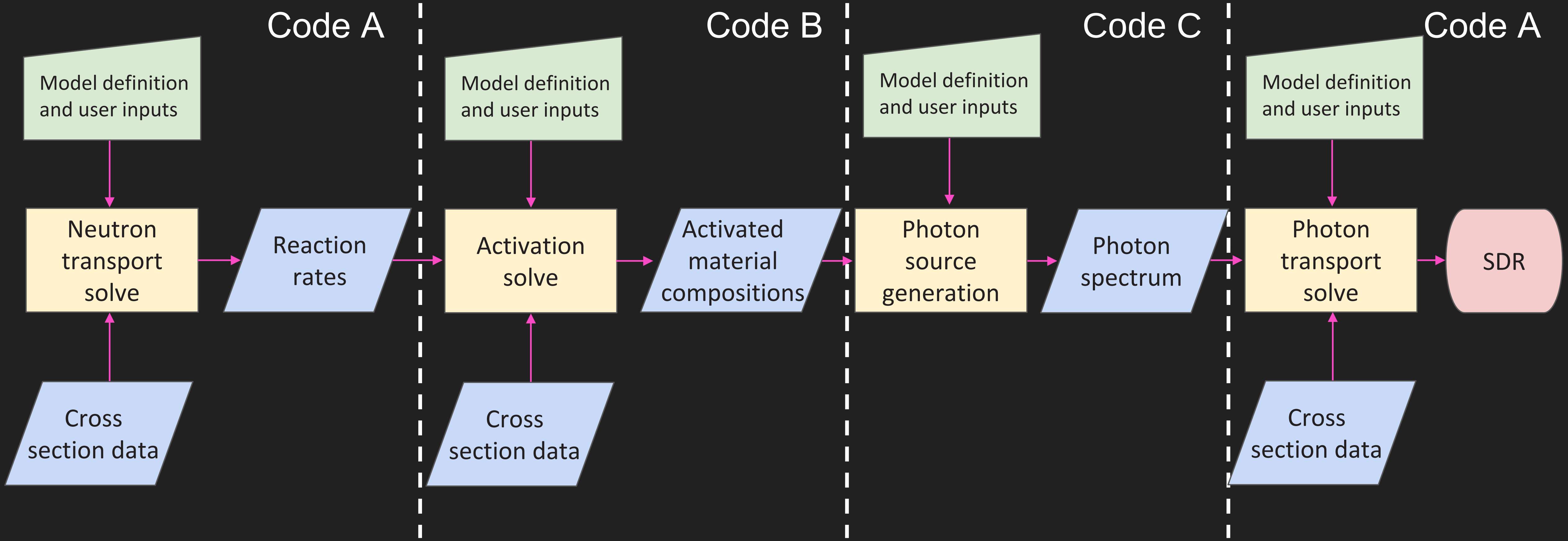
Fragmentation of fusion neutronics workflows impedes analysis speed and uncertainty quantification



Consider the analysis of “shutdown dose rate” (SDR) for the maintenance of fusion power plants



Fragmentation of fusion neutronics workflows impedes analysis speed and uncertainty quantification



Barriers prevent uncertainty propagation, solution acceleration, and robust verification and validation (V&V)

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Streamlining these workflows enables scalable and sustainable nuclear analysis for fusion power plants

- Open-source, community-driven ecosystem
- Designed for exascale architectures
- Extensible for coupling with other applications
- Single source of truth for transparent V&V

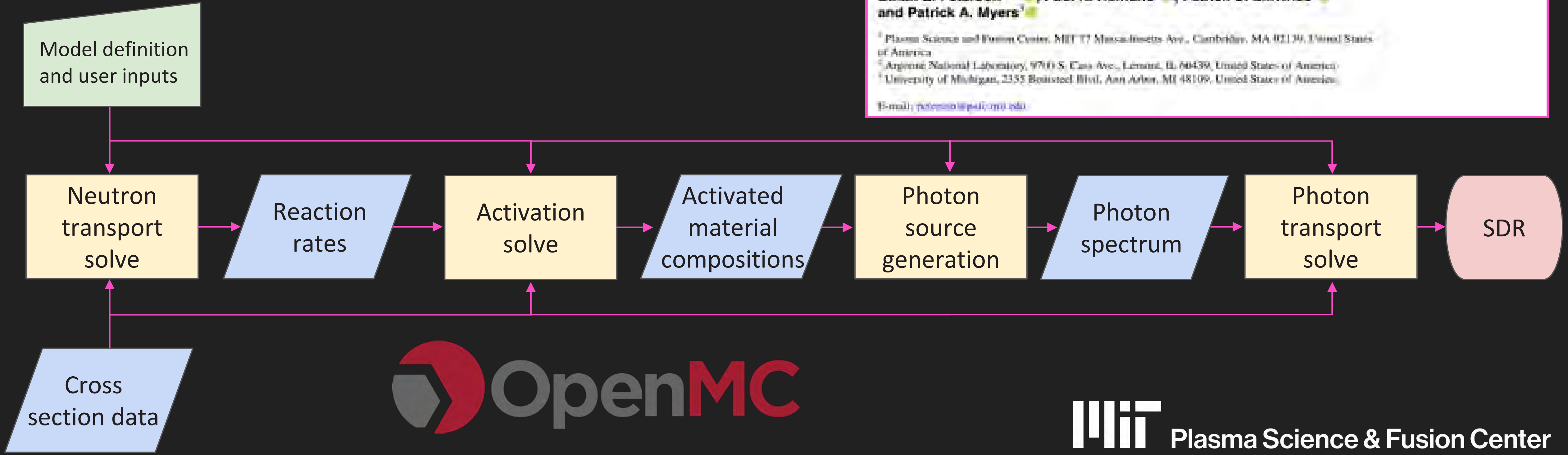
OPEN ACCESS
IOP Publishing
Nucl. Fusion 64 (2024) (15pp)

Development and validation of fully open-source R2S shutdown dose rate capabilities in OpenMC*

Ethan E. Peterson[1,*], Paul K. Romano[2], Patrick C. Shriwise[2] and Patrick A. Myers[3]

[1] Plasma Science and Fusion Center, MIT 77 Massachusetts Ave., Cambridge, MA 02139, United States of America
[2] Argonne National Laboratory, 9700 S. Cass Ave., Lemont, IL 60439, United States of America
[3] University of Michigan, 2355 Bonisteel Blvd, Ann Arbor, MI 48109, United States of America

E-mail:



OpenMC

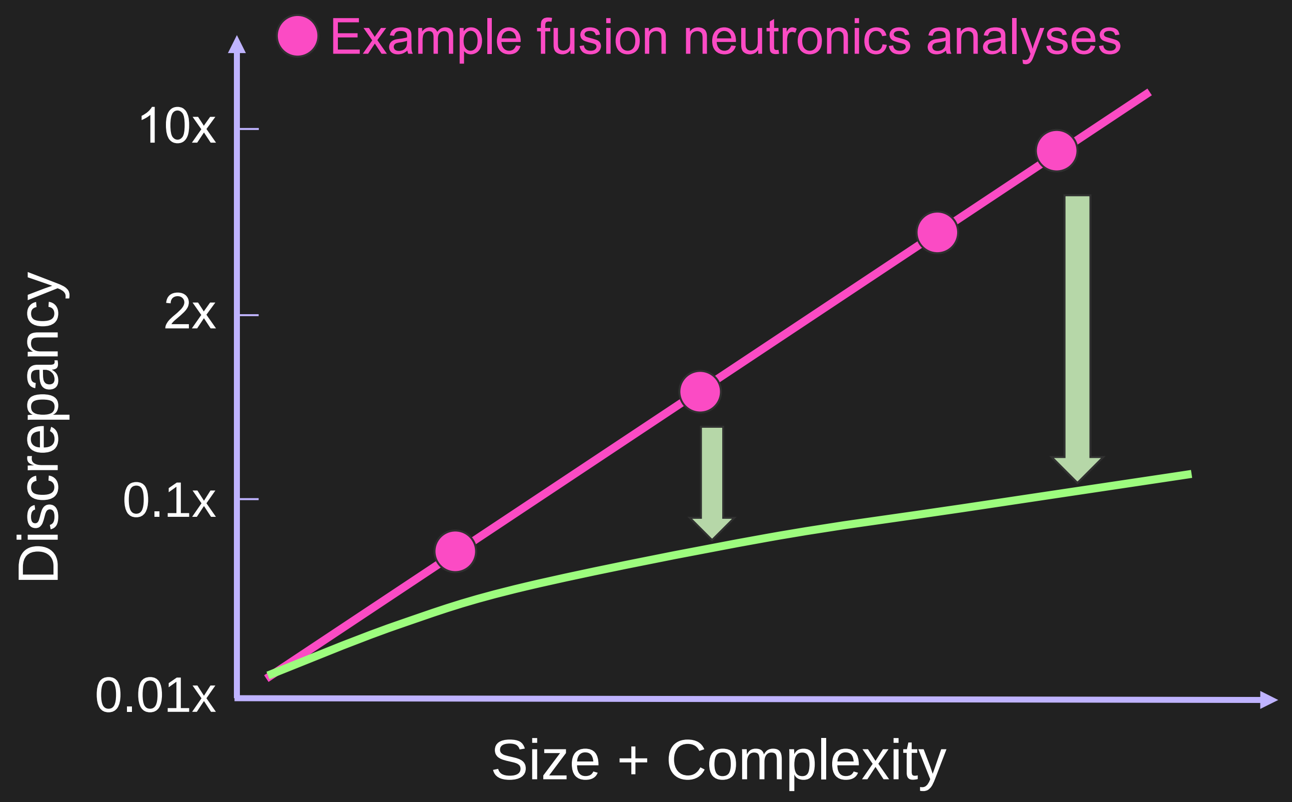
MIT Plasma Science & Fusion Center

Goal: An analysis platform for the first rigorous assessment of nuclear-driven engineering margins in fusion power plants

Streamlining analyses was the first step towards a comprehensive assessment and reduction of uncertainties for complex workflows

Uncertainties come from many places: nuclear data, material and geometry specifications, method approximations

To have confidence in our predictive modeling tools we have to find better agreement between experiments and simulations for large complex systems



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The role of fusion energy in a decarbonized electricity system

October 17, 2024