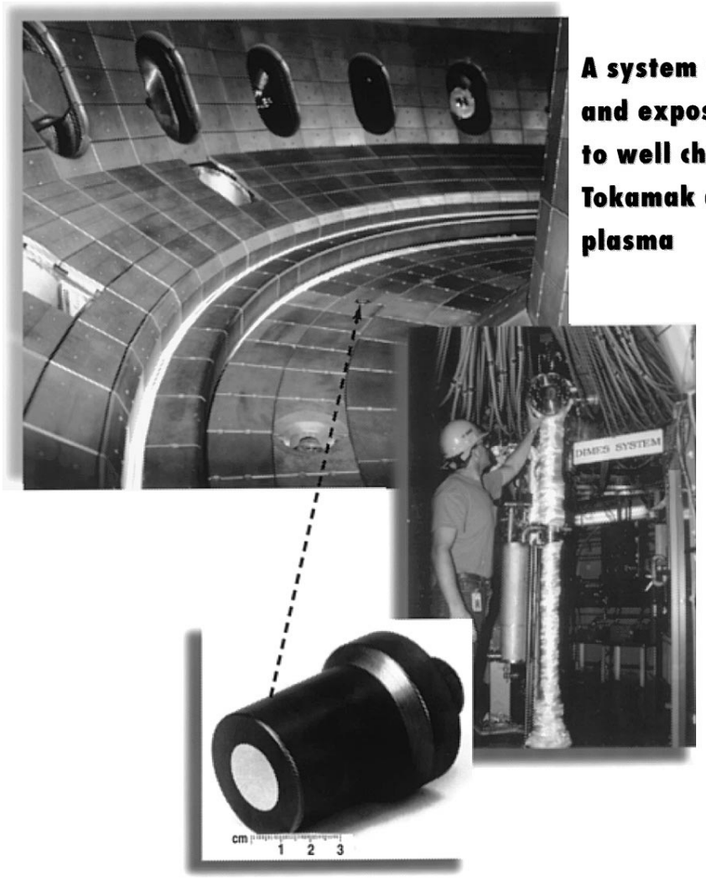
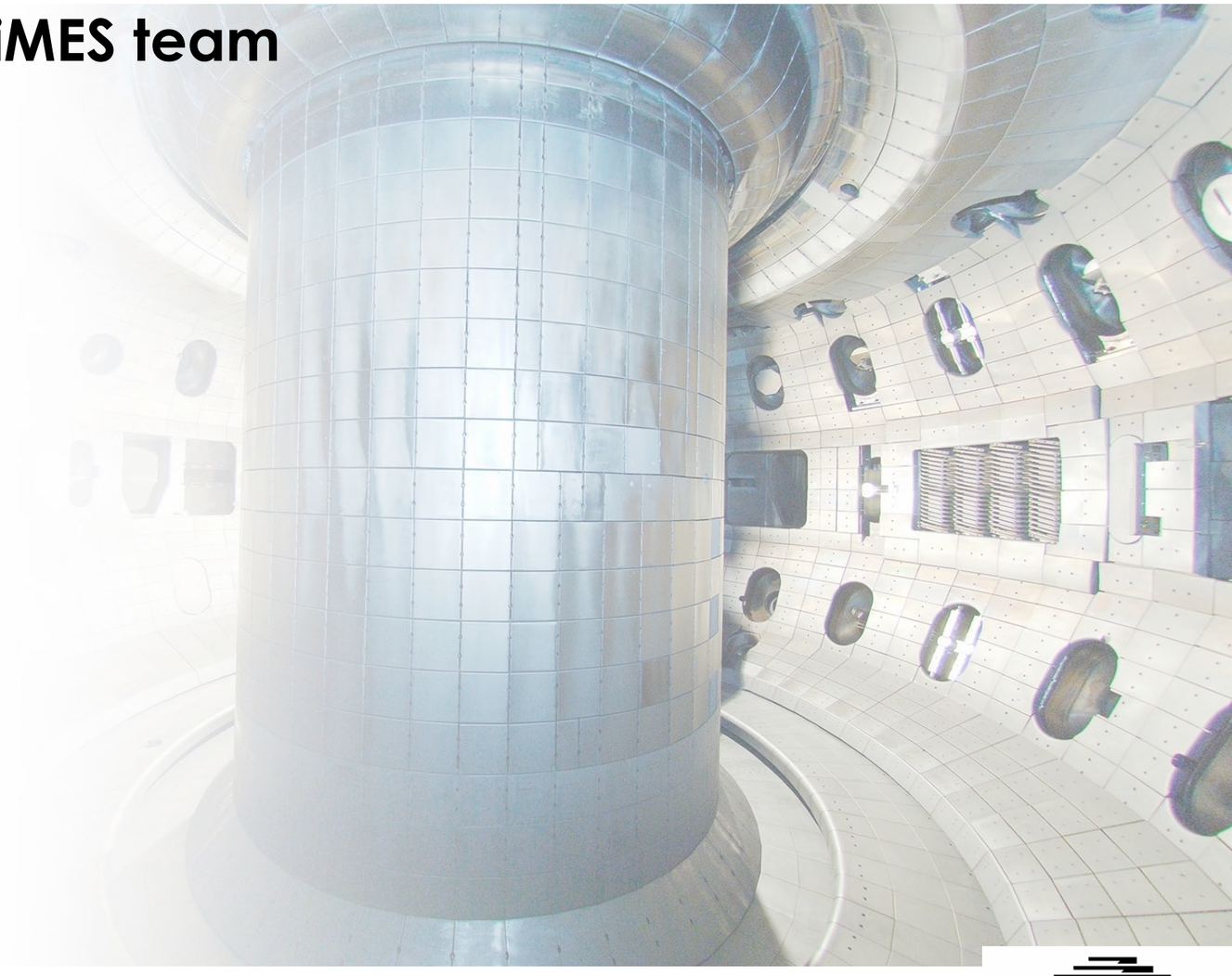
Divertor Material Evaluation System (DiMES) at DIII-D: 30 years of PMI research

D.L. Rudakov for the DiMES team



A system to insert and expose materials to well characterized Tokamak divertor plasma



DIII-D Industry Day, November 14 2025

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UCSD

DiMES has been around for about 3 decades and is still one of the leading material testing facilities in the world

- Controlling the Plasma-Material Interactions (PMI) is one of the key issues to be resolved for the success of machines like ITER and SPARC and the following generation of the magnetic fusion devices like FPP and DEMO
- Divertor Material Evaluation System (DiMES) at the DIII-D tokamak was a workhorse of PMI research for about three decades and still remains one of the leading material testing facilities in the world with an exceptional diagnostic coverage
- One of the main strengths of the DiMES program lies in a worldwide network of collaborating institutions, and we always welcome new collaborators
- In recent years DiMES has become the primary point for the private fusion industry engagement at DIII-D
- Here we present a historical prospective and describe DiMES capabilities as they evolved
- Details of the recent experiments will be presented in the following talks

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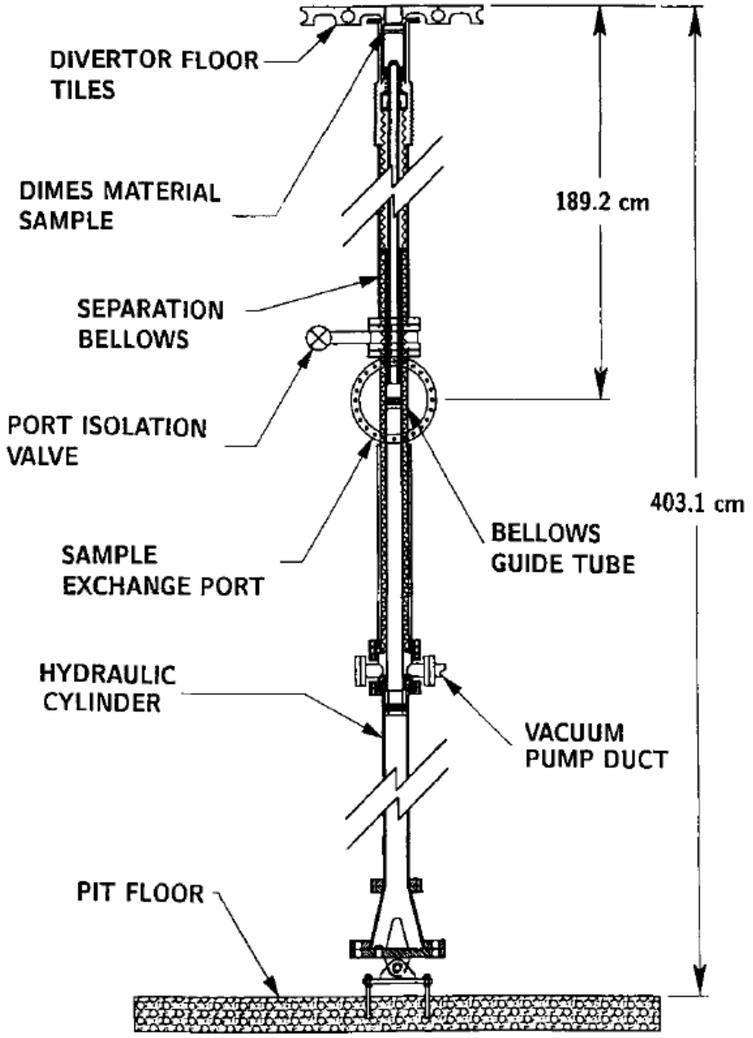
How it all started

- The DiMES program was started in 1992 as a collaborative project between General Atomics (GA), Sandia National Laboratories (SNL) and Argonne National Laboratory (ANL)
- The DiMES manipulator was fabricated and installed on DIII-D in mid-1990s
- The manipulator is a three-stage telescopic hydraulic-driven system with 10 electrical leads running through it, allowing connecting external and internal electrical loads
- DiMES allows inserting material samples up to ~5 cm in diameter in the lower outer divertor of DIII-D, typically flush with the divertor tile surface



C.P.C. Wong et al, J. Nucl. Mater. 196-198 (1992) 871
C.P.C. Wong et al, J. Nucler. Mater. 258-263 (1998) 433

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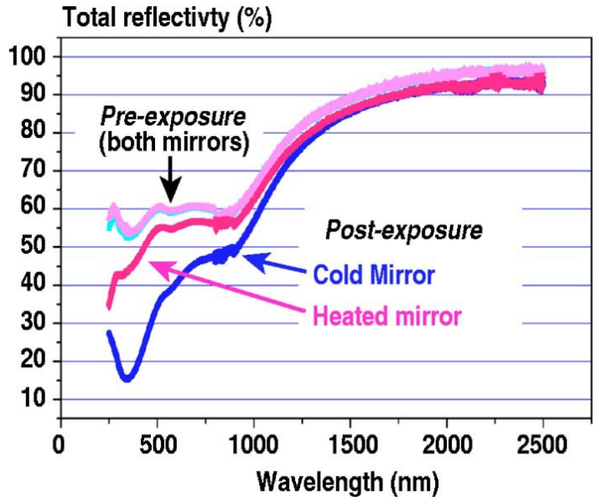
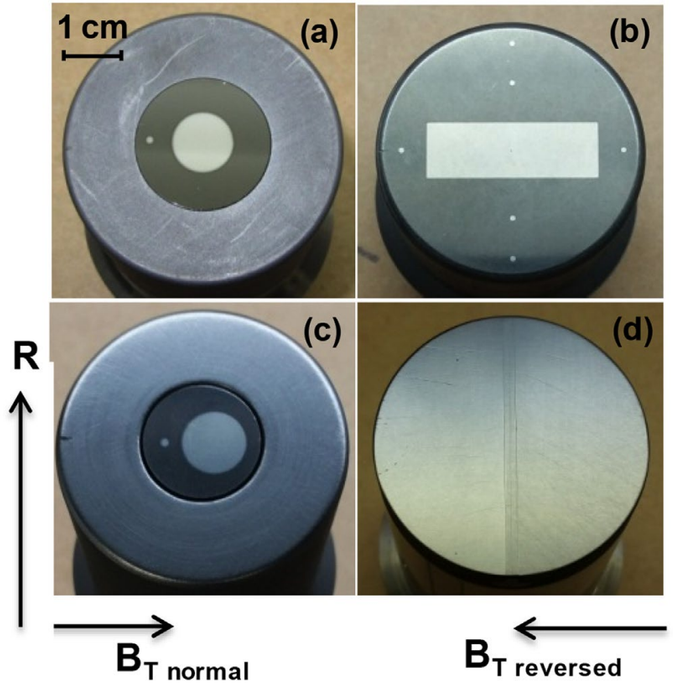
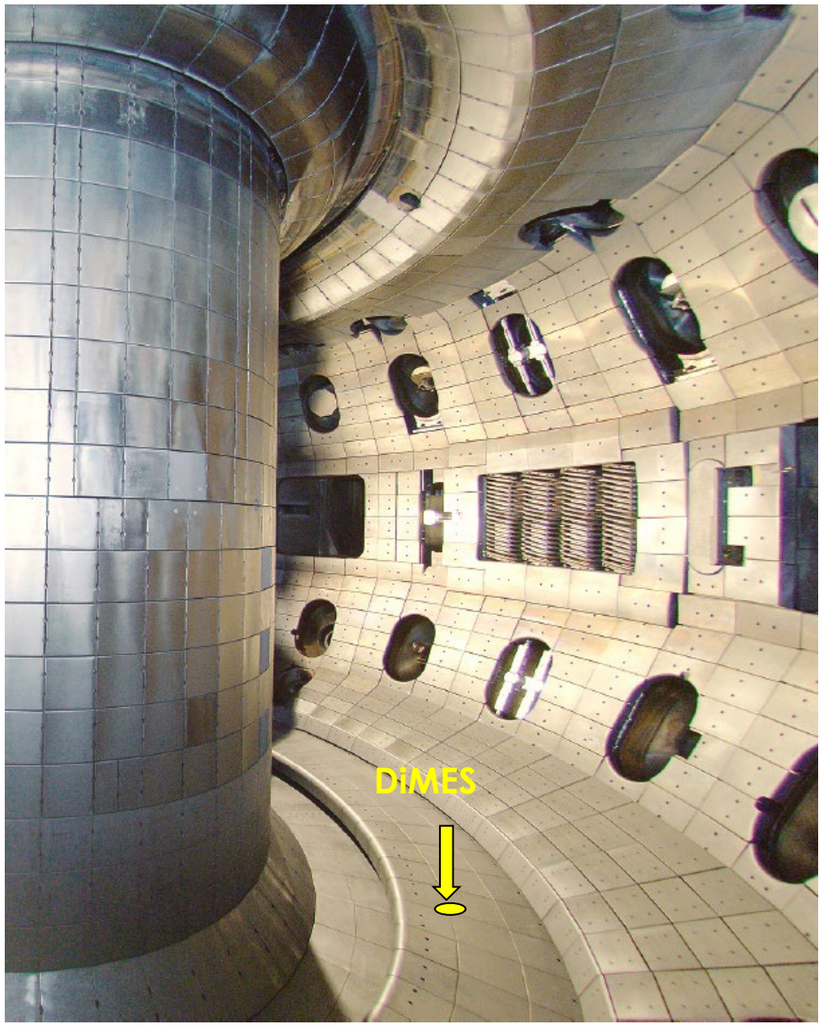
How it evolved

- In the early DiMES days carbon was considered a reactor relevant PFC material (it was in the original ITER design), so the initial DiMES studies largely concentrated on studies of C erosion/deposition
- Alternative PFC options were also investigated, experiments with Li were conducted back in 2003
- A sample heating capability was added in 2004, allowing studies of the temperature effects on C erosion/deposition and mitigating the diagnostic mirror coating with C
- As the fusion community started to move away from C PFCs and C was excluded from the ITER design, DiMES was used to test high-Z PFC materials (W, Mo, V, Zr, Ta)
- DiMES pioneered the small spot high-Z coating technique allowing non-spectroscopic estimate of the gross erosion rate, the idea of Peter Stangeby

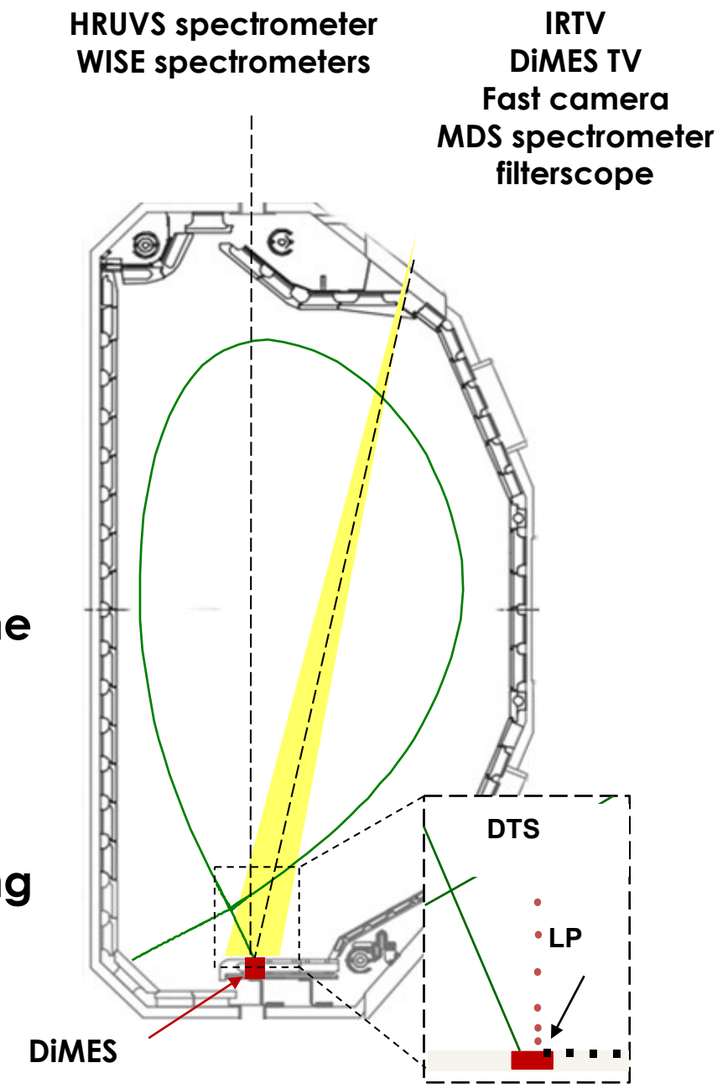




Where we are now



- **World-leading diagnostic coverage**
- DiMES samples are imaged by IR and visible cameras and a few spectrometers
- Plasma parameters at DiMES radial location are measured by the Langmuir probers (LPs) and Divertor Thomson Scattering (DTS)
- Exposures of samples raised above the surface and angled towards the incident plasma flux at up to 15° are available, providing steady state reactor relevant heat fluxes exceeding 10 MW/m^2



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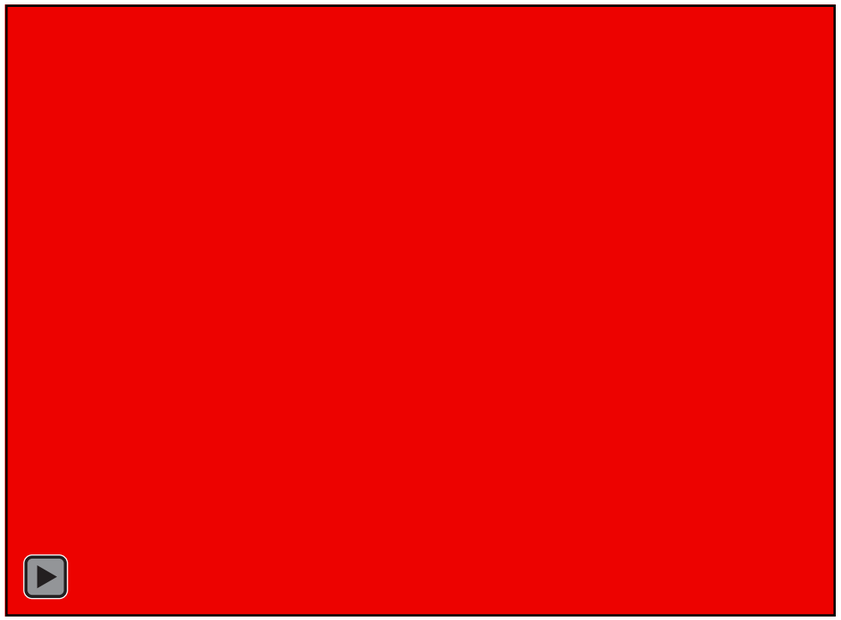
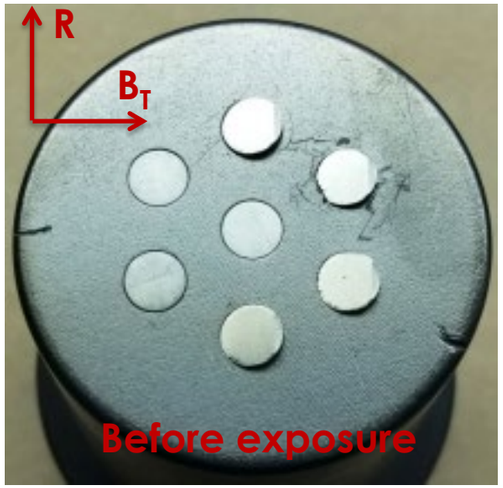
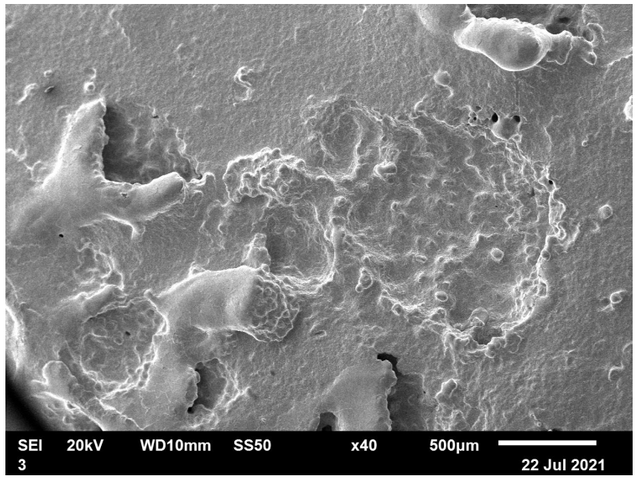
First private company engagement with DiMES: 2021 SPARC WHA exposure

- The first private industry inspired DiMES experiment, where tungsten heavy alloy (WHA) samples were exposed, was performed in 2021 (M. Reinke et al.)
- After the exposure, the DiMES cap was covered with ‘milky layer’ also seen in AUG tests
- Local melting of the angled sample surface was observed







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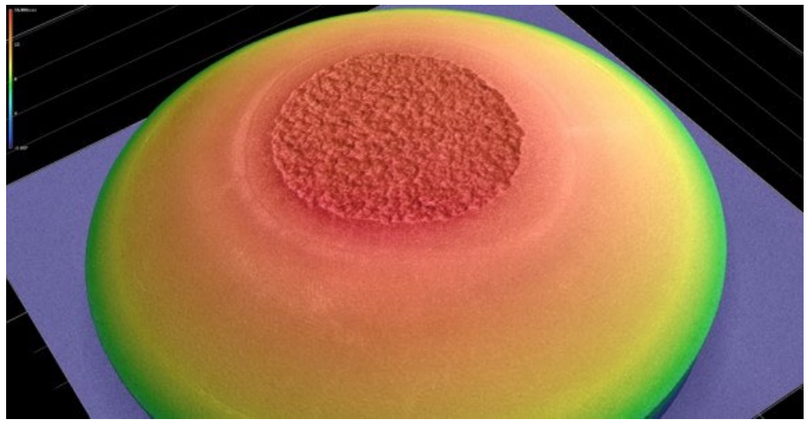
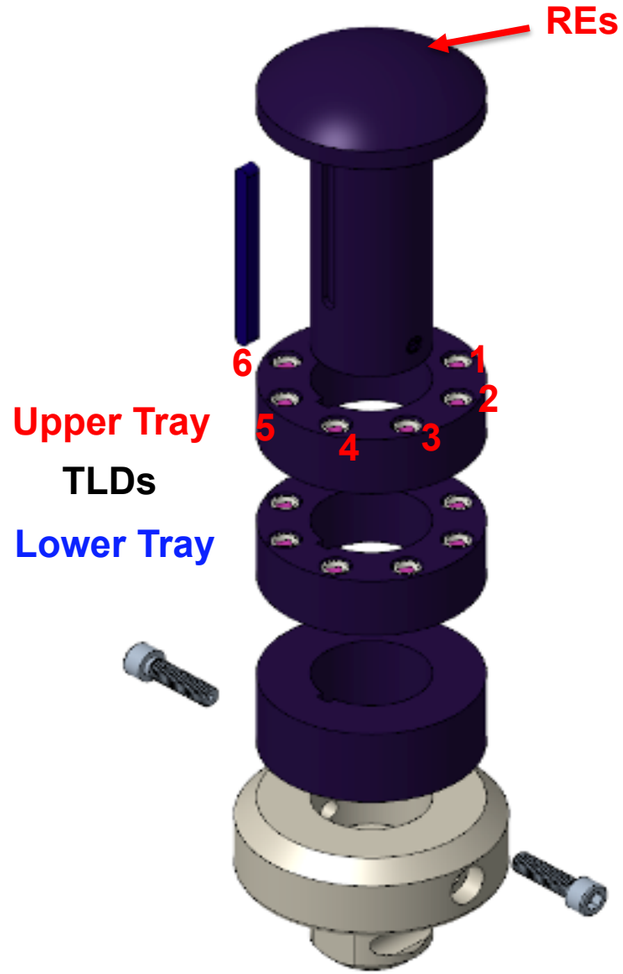
We can do what nobody else does, like hitting a material sample with a runaway electron (RE) beam

- First RE-PFC impact experimental data obtained on a shot-to-shot basis allowing to estimate RE energy and impact angle, the essential parameters for extending the damage modeling to the future devices
- Tangential IR periscope observed the impact and dust ejection



Post exposure confocal microscopy image



IR periscope imaging of RE beam impact on DiMES dome limiter

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End note

This was a historical prospective and an invitation for future collaborations

See the next talks for more recent results and consider joining the DIII-D program as a User if you haven't already ☺

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