# Replication of near-supersonic, runaway electron induced dust-wall impacts using a two-stage light-gas gun

F. Suzuki-Vidal[1*], H.W. Doyle[1], T. Ringrose[1], J. Shadbolt[1], S. Kelly[1], P. Jarvis[1], G. Daminelli[2], Marco De Angeli[2], Monica De Angeli[2], D. Ripamonti[3], P. Tolias[4]

[1] First Light Fusion, UK; [2] ISTP, CNR, Italy; [3] ICMATE, CNR, Italy; [4] KTH, Sweden - *francisco.suzuki-vidal@firstlightfusion.com

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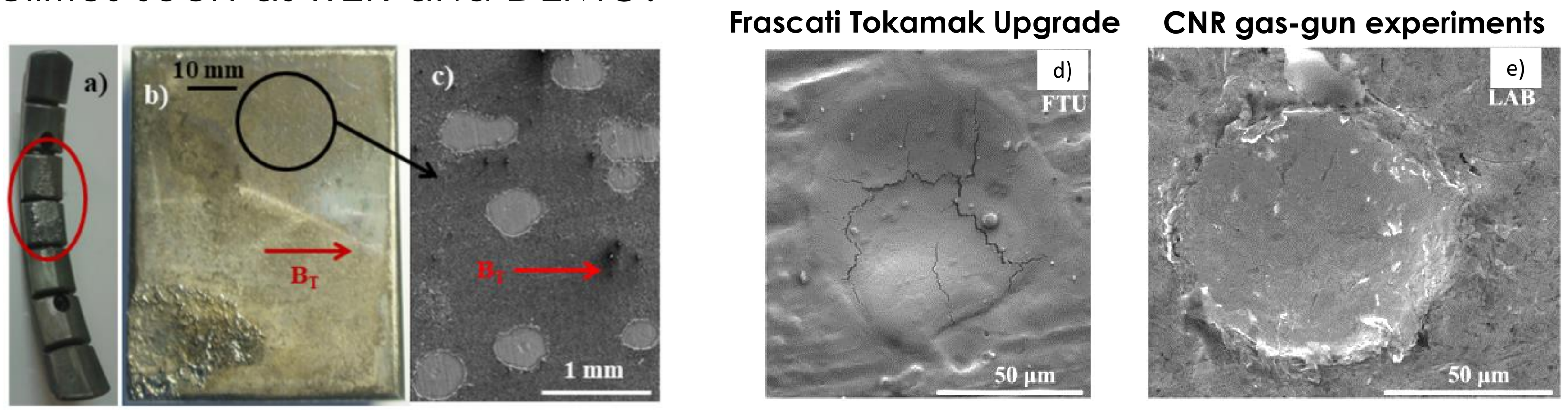
## Dust-wall mechanical impacts in tokamaks

Tokamak disruptions can generate relativistic runaway electrons which terminate on plasma-facing components leading to bulk melting [1], material explosion and the release of fast solid debris [2].

The solid dust particles are ejected with speeds of the order of ~km/s and their impacts on the vessel yield further delocalized damage [3].

Understanding dust-wall mechanical impacts is critical for fusion research facilities such as ITER and DEMO.



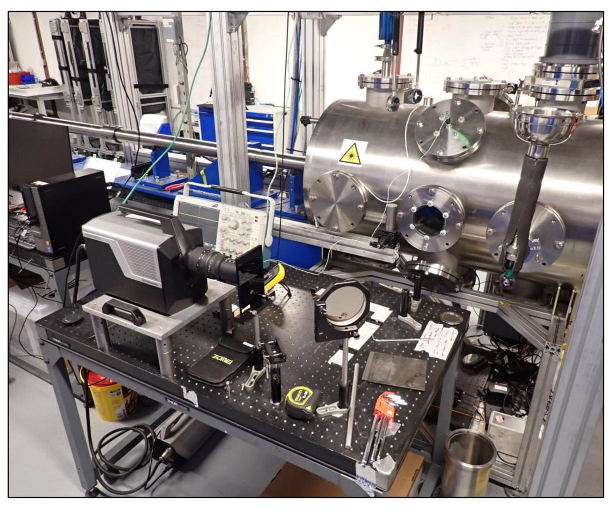

(a) Direct, relativistic-electron induced damage on the poloidal limiter tiles at FTU.
(b,c) Indirect damage due to dust impacts on the line-of-sight toroidal limiter tiles.
(d,e) Reproduction of craters in gas-gun experiments at CNR allows identification of dust size and speed [2].

## Experiments using First Light Fusion's two-stage light-gas gun

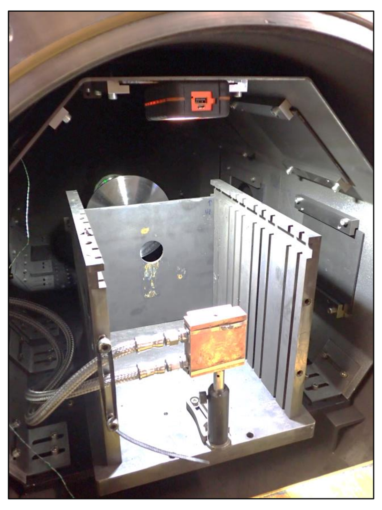
The dust-wall mechanical damage at FTU was replicated by accelerating solid molybdenum particles into a cryogenic TZM target using FLF's "small" gas-gun [4].

- 7.5 m long, 12.7 mm diameter bore, powder driven
- Can accelerate a ~3 g projectile up to ~7 km/s

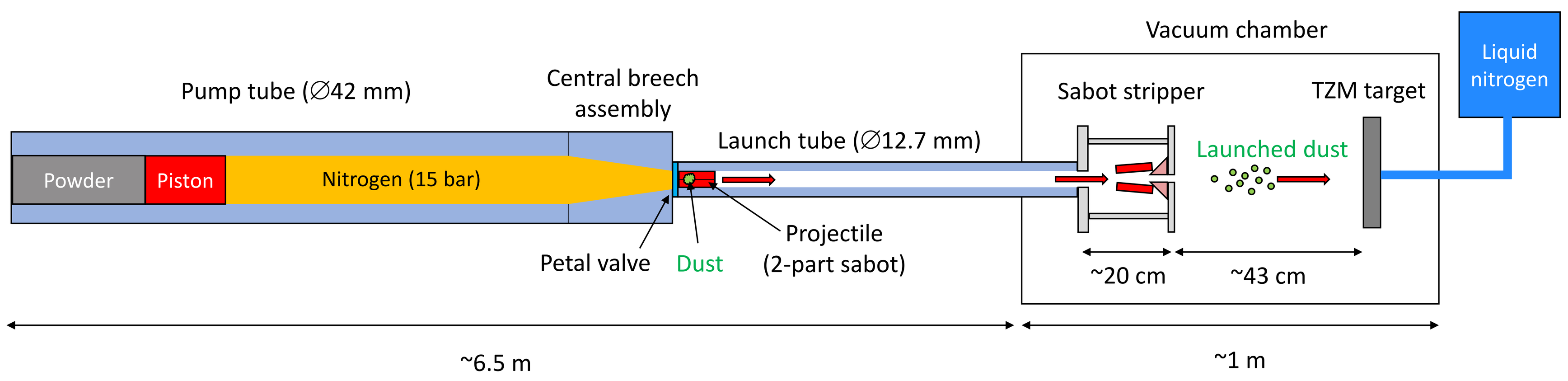
FLF's small gas-gun.



Fast-framing optical camera diagnostic.



Cryogenic TZM target.

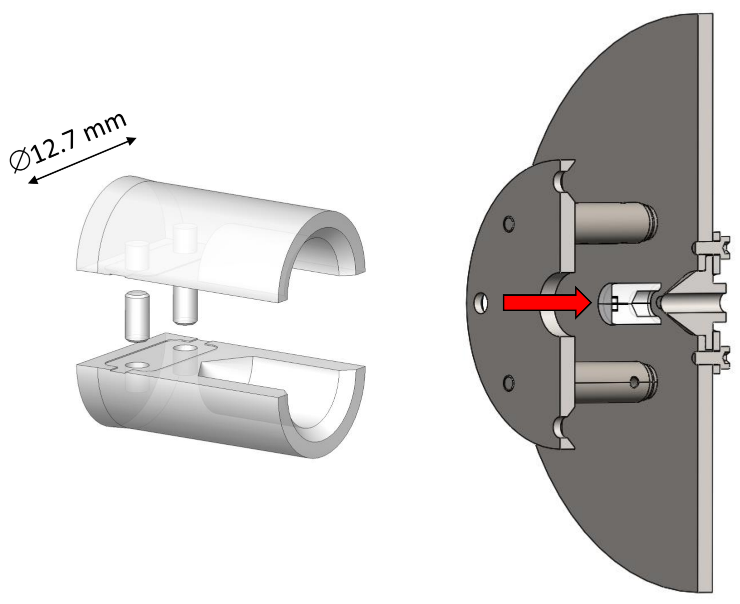



Schematic experimental setup to launch dust particles into a cryogenic TZM target.

Two-part sabots and a sabot-stripper were designed and tested.

The sabot exiting the gun's barrel was imaged optically (128 frames, 500 ns interframe, 200 ns exposure).

An optical laser ($\lambda$ = 632 nm, 30 µs pulse duration) was used to perform side-on backlighting imaging.

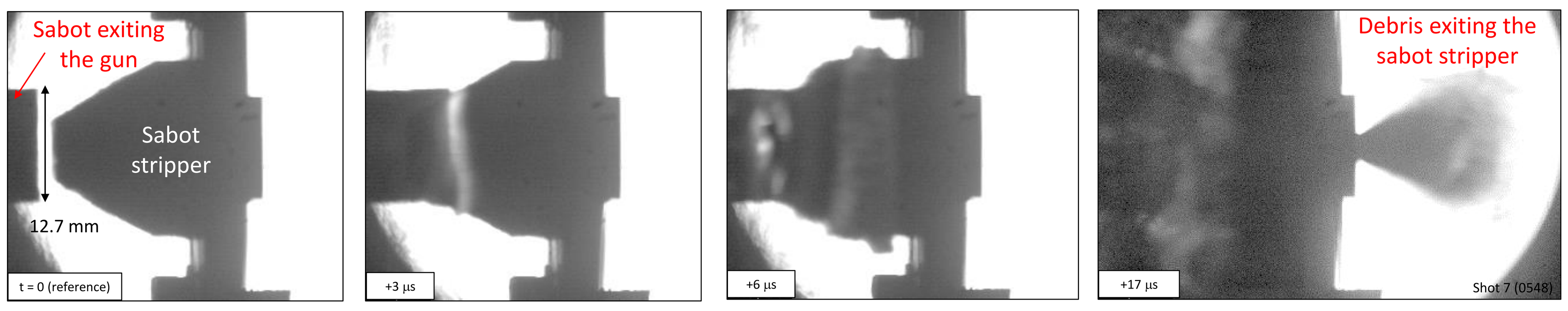



Two-part sabot and cut-view of the sabot stripper.

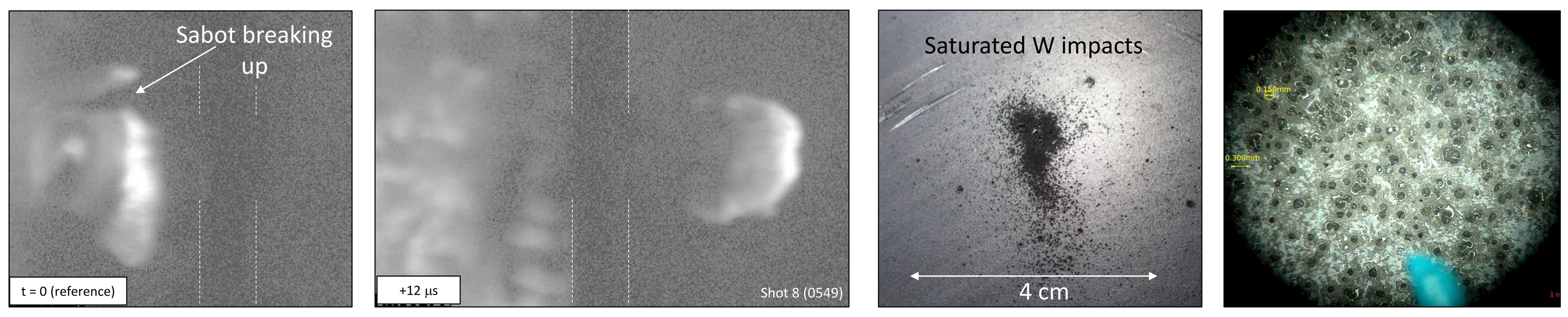
## References

[1] G.F. Matthews et al., Physica Scripta **T167**, 014070 (2016)
[2] M. De Angeli et al., Nuclear Fusion **63**, 014001 (2023)
[3] P. Tolias et al., Fusion Engineering and Design **195**, 113938 (2023)
[4] T. Ringrose et al., Procedia Engineering **204**, 344-351 (2017)

## Testing two-part sabots



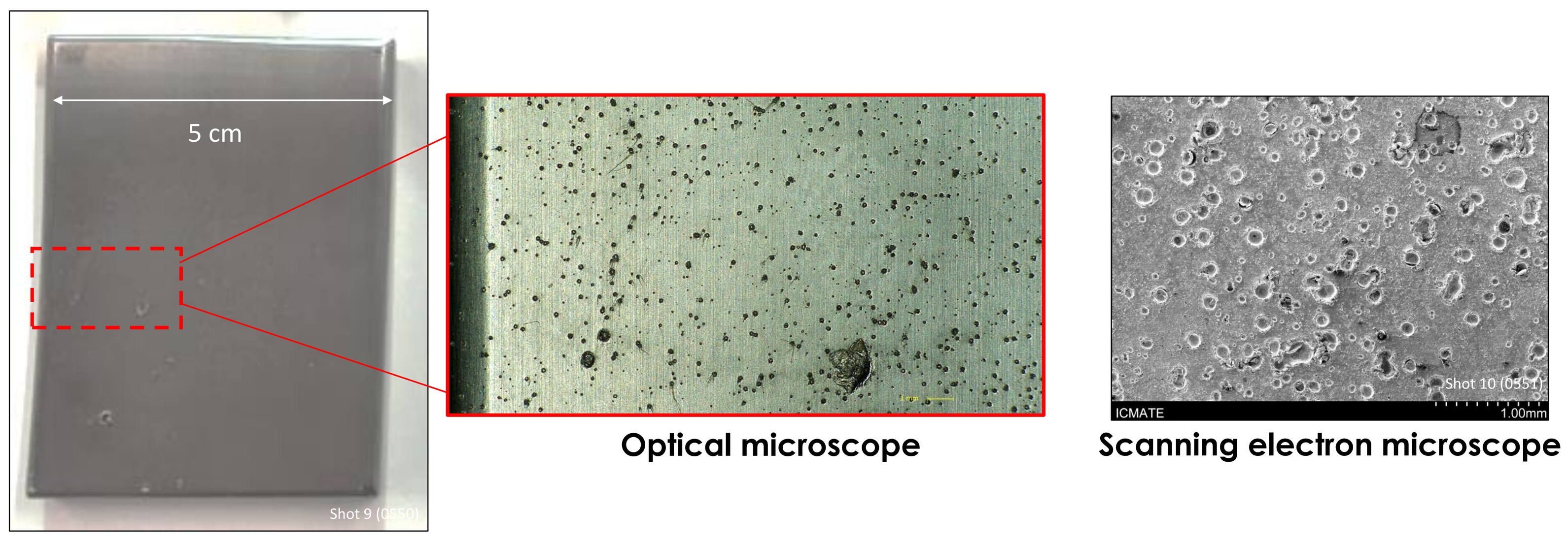

Optical laser backlighting showing the two-part sabot in flight towards the sabot stripper.



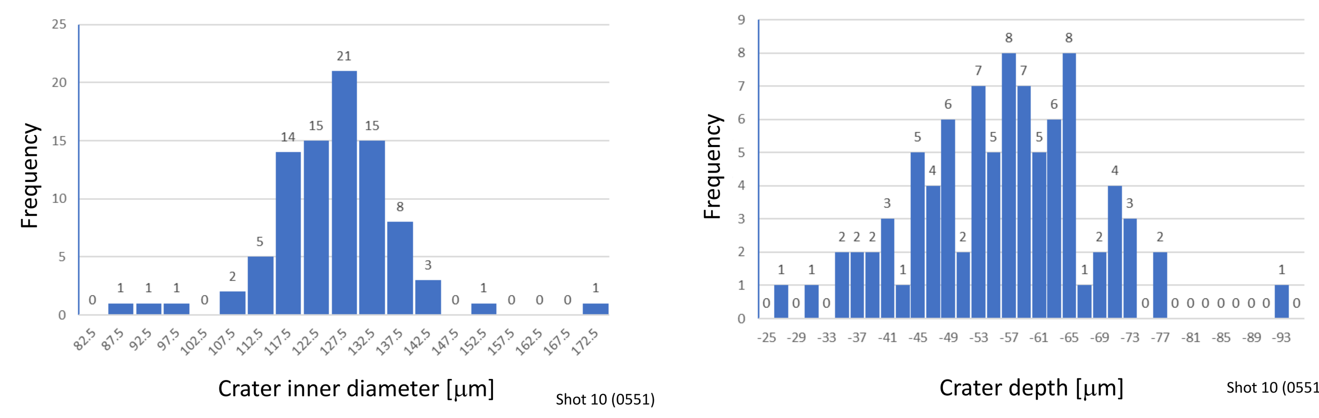

Optical self-emission showing the two-part sabot breaking up. This test experiments used unmeshed ∅ 45-90 µm diameter tungsten dust, resulting in saturated crater impacts.

## Crater analysis from Mo dust impacts into cryogenic TZM tiles

Molybdenum dust particles (∅71 um diameter) were placed inside the sabot and accelerated to ~2 km/s before impacting a TZM (Ti-Zr-Mo) tile cryogenically cooled to ~170K (-100 C).



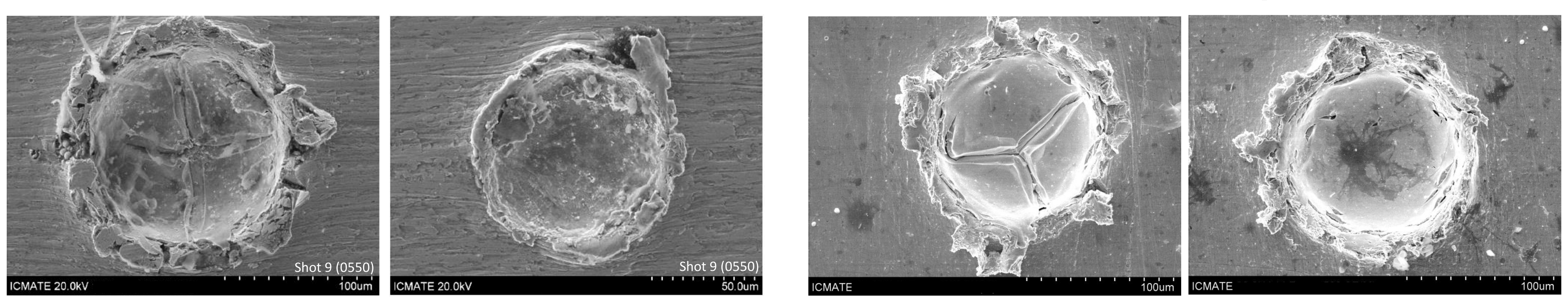

Post-shot TZM tile showing craters from Mo dust impacts.




Distribution of crater inner diameter and depth from SEM images of a cryogenic target at FLF.

The crater morphology between cryogenic and room temperature experiments is very similar, despite the -80 C ductile-brittle transition temperature (DBTT) of TZM.

**Data from FLF's gas-gun TZM at -100 C** | **Data from CNR's gas-gun TZM at room temperature**



SEM images comparing Mo impacts on TZM tiles at cryogenic and room temperatures.

## Summary

- New capabilities were developed on FLF's two-stage light-gas gun: Open sabots and a sabot stripper to study solid dust impacts.
- Impacts from molybdenum particles at ~2 km/s into TZM targets at -100 C were obtained, aimed at replicating the damage of plasma facing components on the cryogenically cooled FTU tokamak.
- Preliminary comparison between cryogenic and room temperature impacts reveals similar crater morphology and small differences in the crater diameter and depth.



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