SP B.1 - Influence of dust impacts on W coatings.

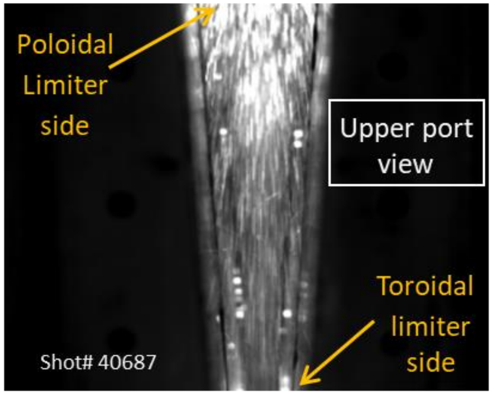
ENEA-CNR M. De Angeli, D. Ripamonti, G. Daminelli, M.Pedroni, E. Vassallo
KTH S. Ratynskaia, P. Tolias

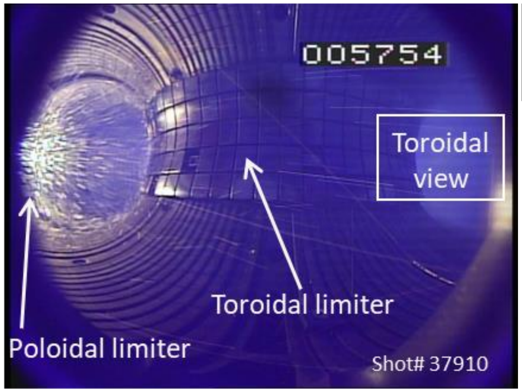
WP-PWIE Sp B1 Mid term Meeting, October 17th, 2024

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

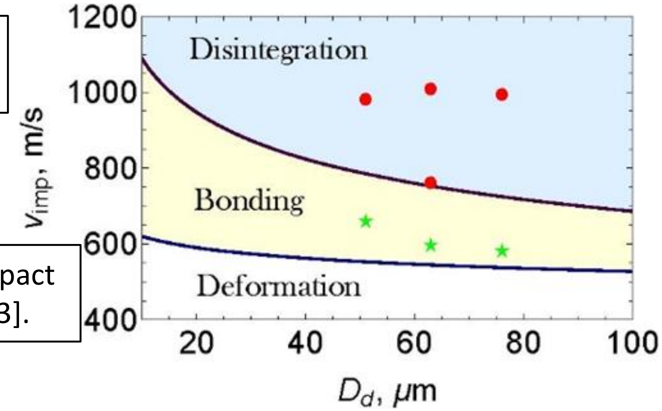
Background

- Fast dust impact has been observed in tokamaks during explosion-like events due to REs striking on PFCs (FTU, v_i ~800m/s [1], COMPASS [2], DIII-D [2]);
- In new devices (i.e. ITER & DEMO) are expected higher dust ejection kinetic energies.





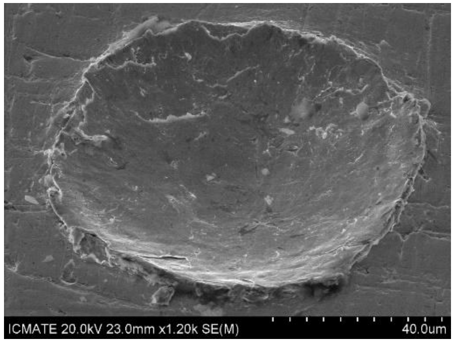
Explosion-like events in FTU.



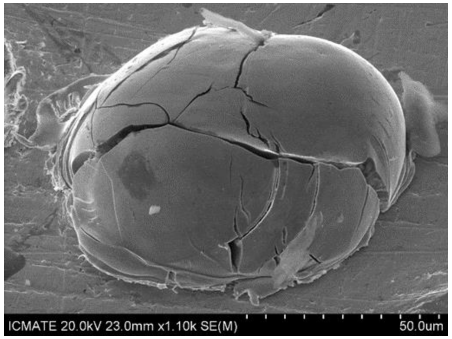
W-on-W impact diagram [3].

[1] M. De Angeli, P. Tolias, et al, NF 63 (2023) 014001. [2] Private communication. [3] P. Tolias, et al, FED 195 (2023) 113938.

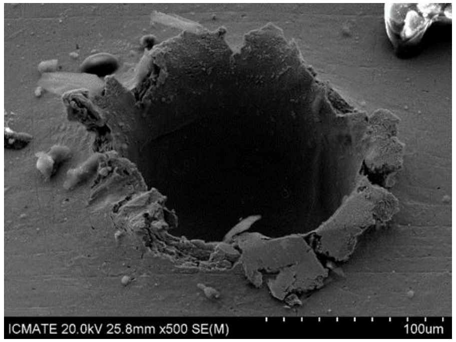
- Identified three impact regimes [3]; in the case of W dust on W target <u>without coatings</u>:



Deformation regime, 200 ÷ 600 m/s → shallow crater formation.



Bonding or cold spray regime, 600 ÷ 1000 m/s → sticking of dust on target.

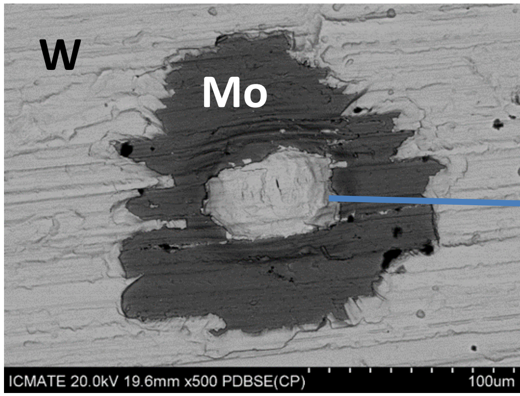


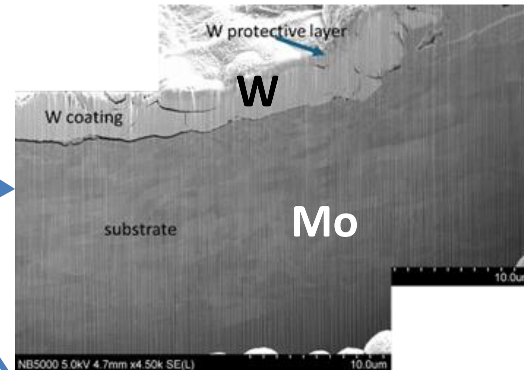
Partial disintegration regime, 1÷4 km/s → material splash ejection and partial fragmentation.

5µm W-O on Mo substrate (from IAP)

5µm W-O (15 at%) coating on Mo substrate, provided by IAP, shot with 70µm Mo dust.

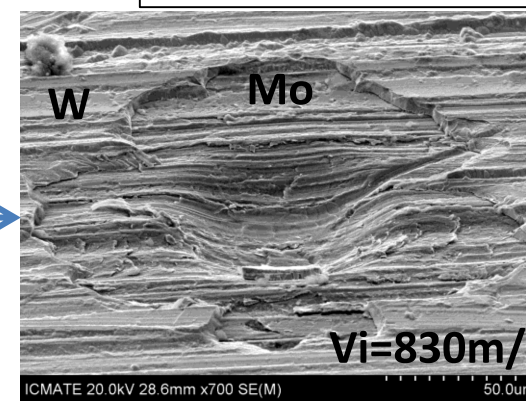
BSE image of a crater from IAP26 sample (Vi=830m/s).

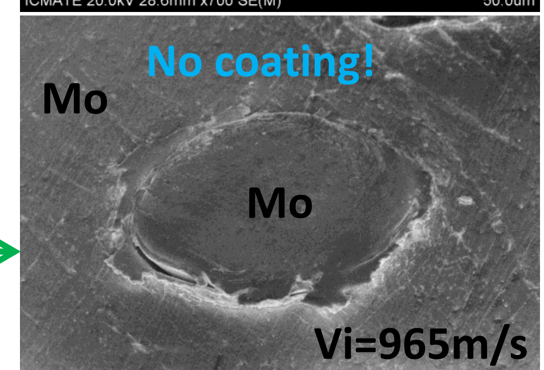




FIB Cross-section image of the bottom of a crater on IAP26 sample (Vi=830m/s). ***Analysis provided by IPPLM***.

Tilted SEM images craters from samples IAP26 (Vi=830m/s) and polished back side of a IAP sample (Vi=965m/s) .





Sample #	*Dust velocity, m/s*	***Average craters depth, µm***	*Impact regime*
IAP26	830	+15.6 ±1.5	deformation
IAP2	1014	+20.2 ±1.6	deformation
IAP8	1244	+26.5 ±2.2	disintegration
IAP9	1543	+34.7 ±3.4	disintegration
IAP10	2066	+49.1 ±2.1	disintegration
IAP27	3278	+76.8 ±3.9	disintegration
No coating	965	-23.1 ±6.9	Bounding!

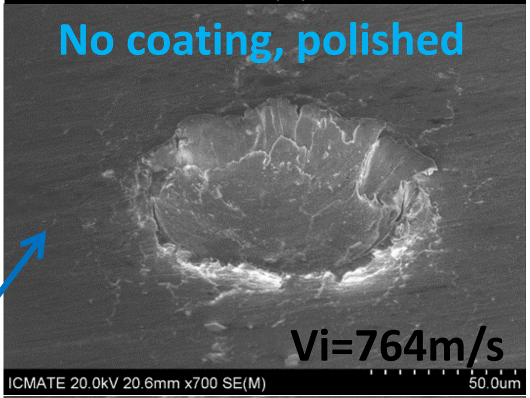
The bounding impact regime is disappeared on coated samples!

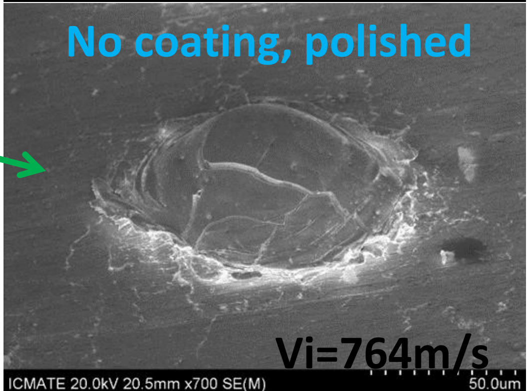
1µm W-O on W substrate (from ENEA-PoliMi)

1µm W-O (15 at%) amorph. coating on W sub., from ENEA, shot with 63µm W dust.

Sample #	*Dust velocity, m/s*	***Average depth, µm***	*Impact regime*
ENEA1016A	575	+8.9 ±0.7	deformation
ENEA1017B	648	+11.3 ±1.2	deformation
ENEA1017A	695	+12.3 ±1.7	deformation
ENEA1015A	772	+14.3 ±1.3	deformation
ENEA1015B	749	+14.0 ±1.0	deformation
1016A-bis	886	+18.5 ±1.7	deformation
1017B-bis	1008	+22.7 ±3.7	deformation
ENEA1016B	1464	+36.3 ±3.9	disintegration
Back side (*)	773	-	deformation
Polished back side	764	+14.4 ±1.5 -28.3 ±3.1	~72% deformation ~28% bounding
Polished back side	927	-18.6 ±3.9	~100% Bounding!

(*) Unpolished surface covered by "*oxidation layer of W and mixture with Cu*" (FZJ private communication).

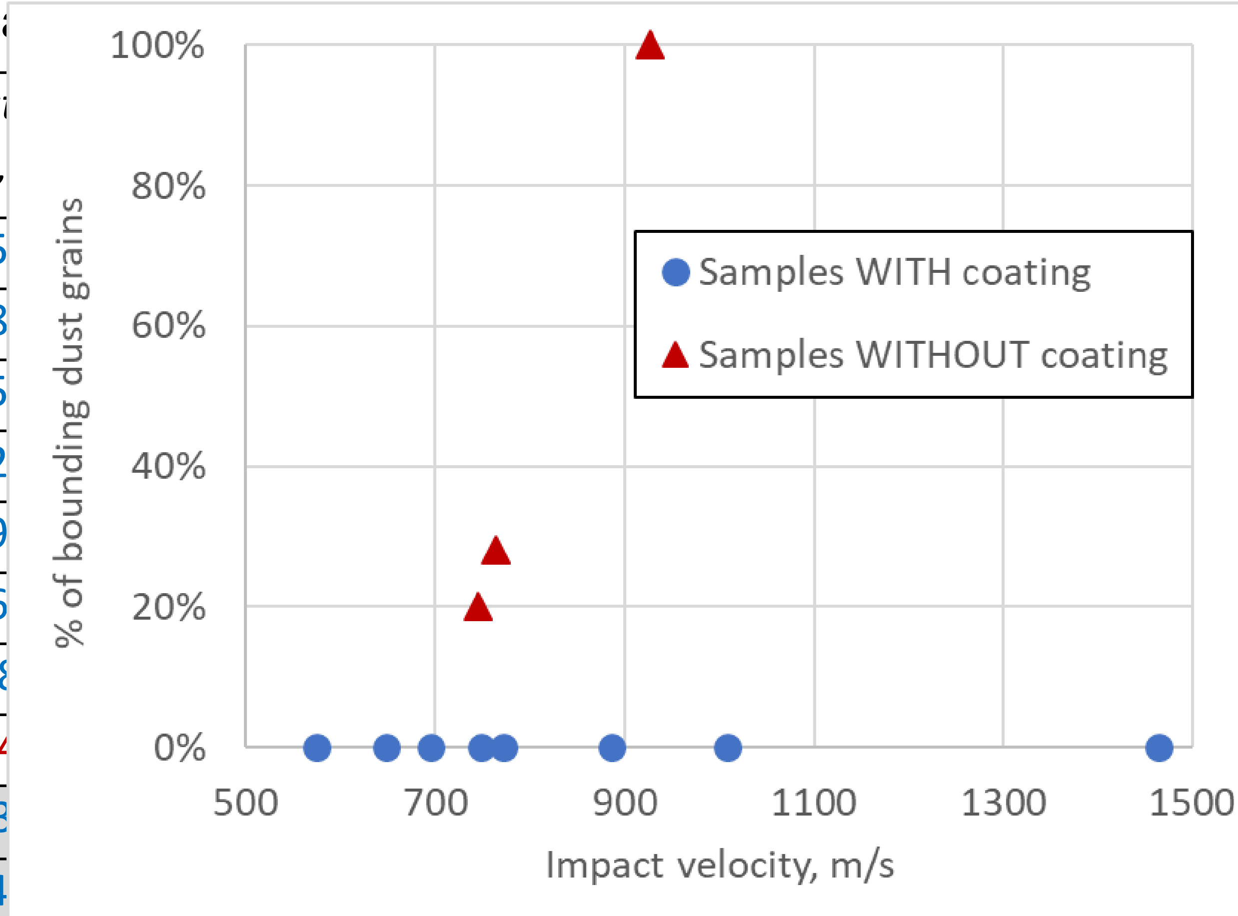


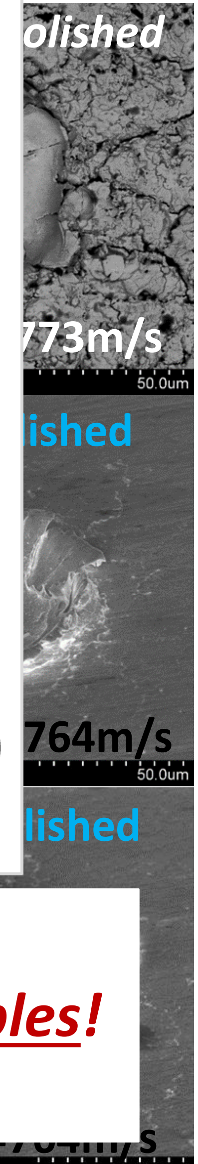


1µm W-O on W substrate (from ENEA-PoliMi)

1µm W-O (15 at%) … dust.

Sample #	Dust velocity, …
ENEA1016A	575
ENEA1017B	648
ENEA1017A	695
ENEA1015A	772
ENEA1015B	749
1016A-bis	886
1017B-bis	1008
ENEA1016B	1464
Back side (*)	773
Polished …	764





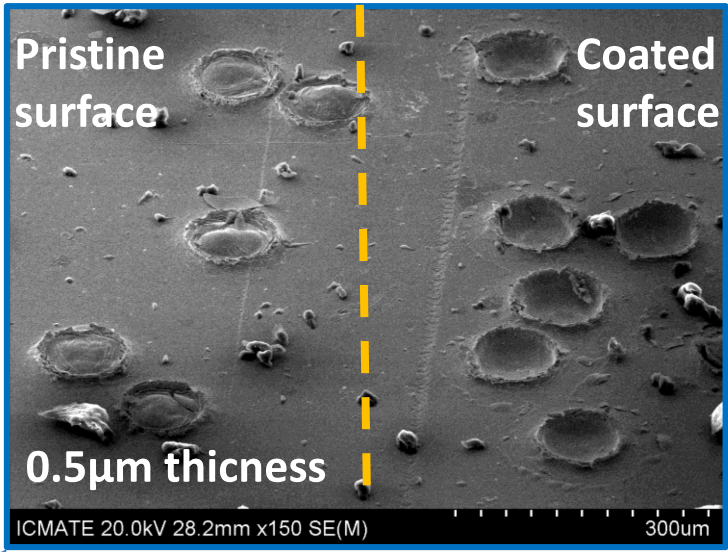
The boundary impact regime is disappeared on coated samples!

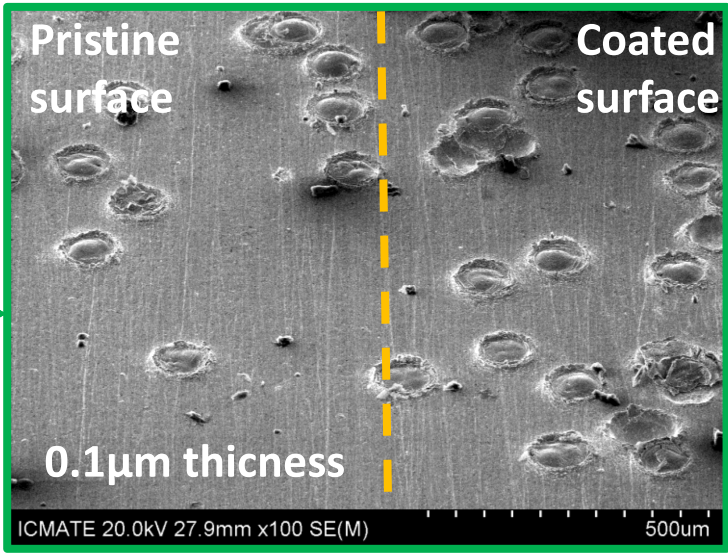
Bounding vs coating thickness (ENEA-CNR)

Dust bouncing vs W coating thickness on W substrate (ENEA-CNR samples produced by RF magnetron sputtering technique),
shot with 63μm W dust at Vi=990÷1037 m/s.

- Samples surface were semi masked;
- Bounding starts for W coating thickness <300nm;
- Bounding is independent from W coating density.

Sample	*Codeposit tickness, μm*	*Codep. W density, g/cm^3*	*Impact regime*
CNR1	1.0	11.75±0.38	deformation
CNR2	0.5	11.75±0.38	deformation
CNR3	0.25	11.75±0.38	~70% bounding
CNR4	0.1	11.75±0.38	~90% bounding
CNR5	0.5	9.0±0.19	deformation
CNR6	0.5	17.86±0.58	deformation

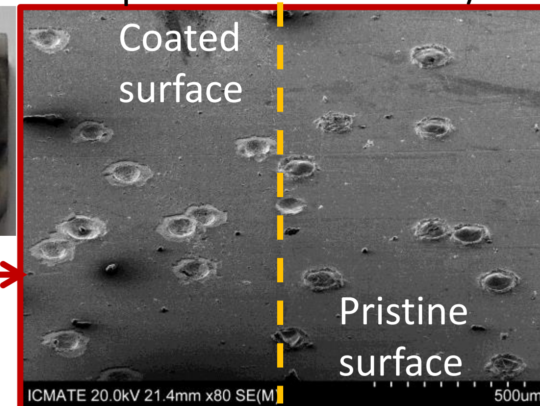


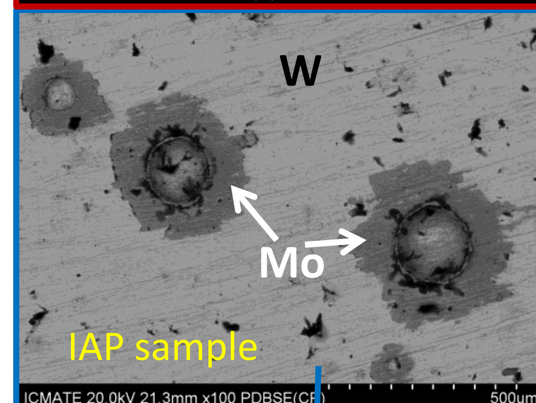


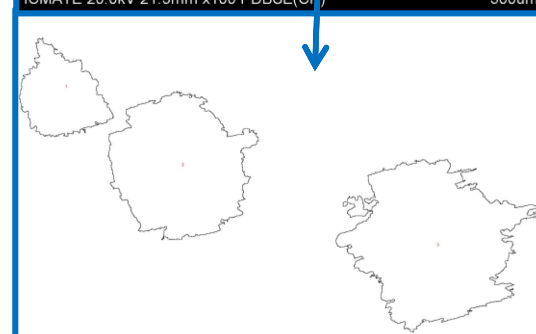
Delamination area vs dust impact velocity

Evaluation of delaminated area on coated samples provided by IAP (5μm W-O on Mo) and new ENEA-PoliMi (5μm W-O on W) semi-masked vs dust impact velocity.

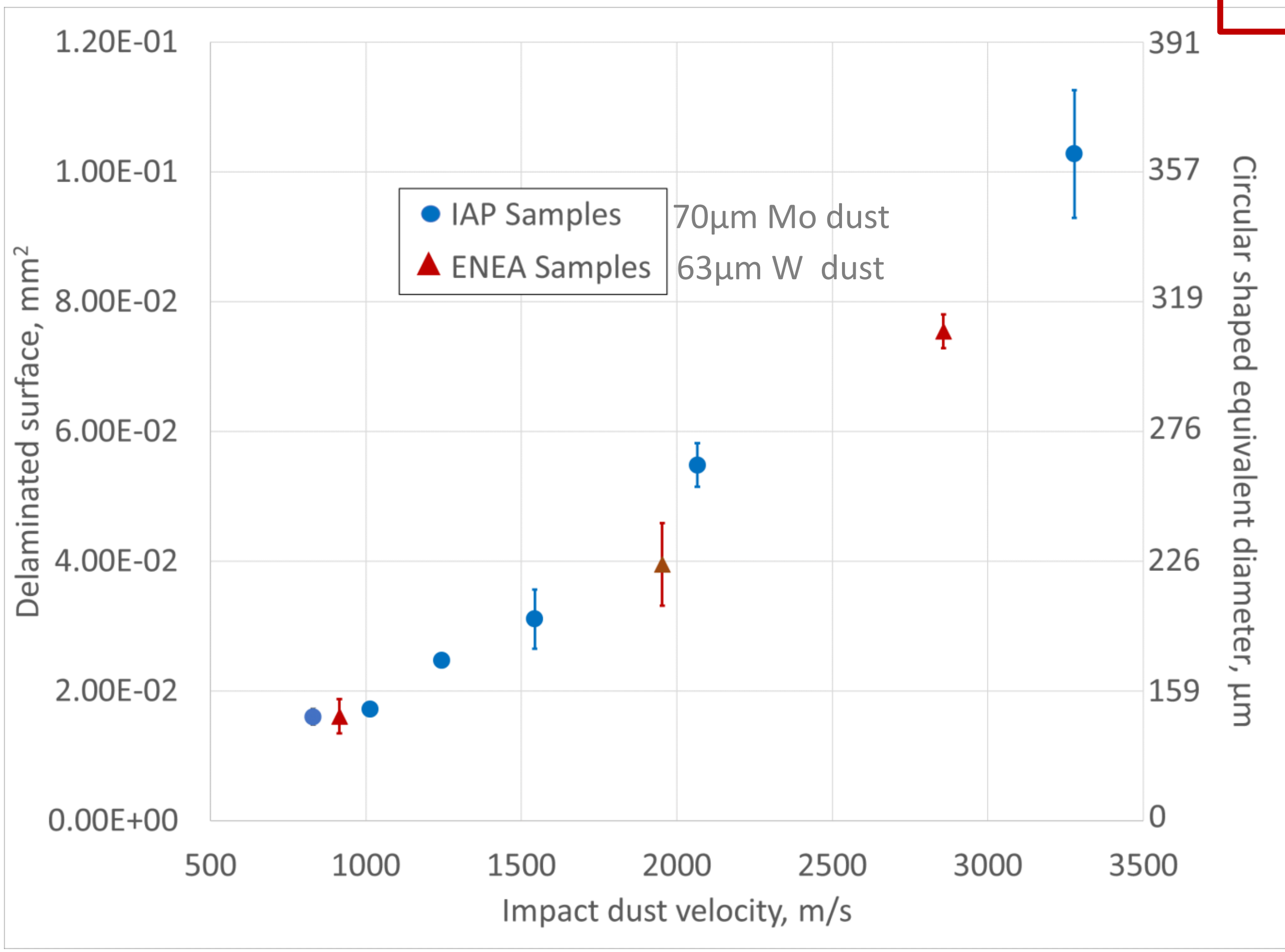
ENEA-PoliMi sample shot at Vi=915m/s







IAP sample, Vi=2066m/s



Final remarks

Preliminary conclusions:

- ✓ The presence of coatings and/or thick oxidation layers on samples surface inhibits the bounding impact regime of impinging dust;
- ✓ The bounding impact regime is vanishing even for thin coating layers (>250nm);
- ✓ Dust impact induces coating delamination areas bigger than dust dimension;

“Coating delamination” *means* “material migration”!

Open issues:

- ➢ How will be affected the delamination shape for oblique impacts ?
- ➢ Does the delaminated surface depend on the target temperature ?
- ➢ Does the impinging dust temperature play any role in the delamination shape ?

How will change the delamination behaviour with B-based coatings (different adhesion force, more fragile, different melting temperature,…) ??

Thank you for your attention!