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WEST capabilities for W studies

Joint WP TE and WP PWIE meeting. Aix en Provence 17-19 septembre 2024

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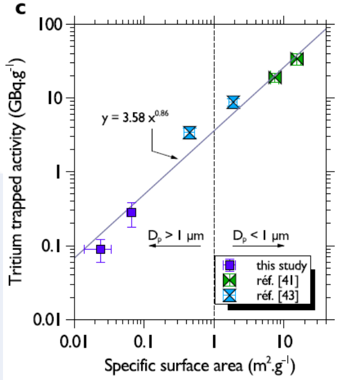
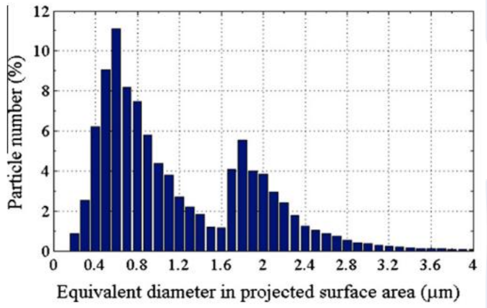
Dust in WEST : a collaboration between 3 organizations

Safety studies

- Development of a collection tool (Duster box) for studying the dust suspension behavior Granulometric analysis
- Behavior of tritium-loaded particles
- Impact of surface roughness on adhesion forces





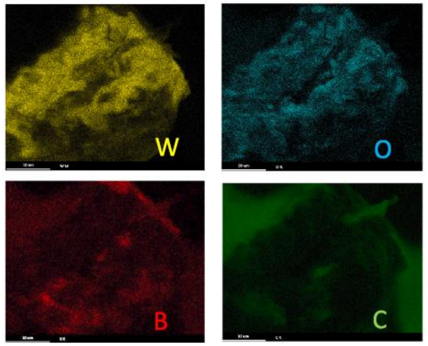
IRSN
Institute for radiation protection and nuclear safety

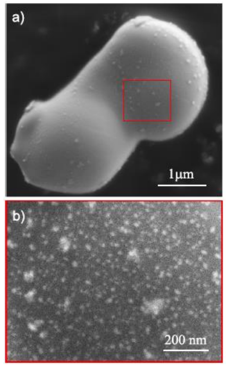
Aix Marseille université
Socialement engagée

cea

- High level of SEM/EDS analysis
- origin of dust : understanding of formation/transport
- Comparison with dust produced in laboratory

Link with tokamak operation



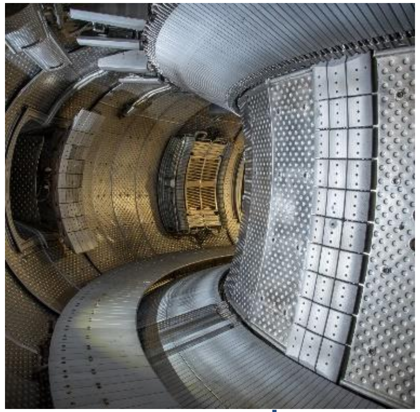


Dust collection
Dust-wall interactions and transport

- History of plasma events for dust production
- Collection inside the WEST vacuum vessel
- Radiation controls
- Development of a dust transport code (DUMBO)

A large experience in dust collection in WEST

W-coated C PFUs
+ 5 bulk W PFUs



W-coated C PFUs
+ 14 bulk W PFUs

W-coated C PFUs
+ 56 bulk W PFUs
BN tiles on inner bumpers

Divertor made of bulk W PFUs
BN tiles on inner bumpers

2017				2018				2019				2020				2021				2022				2023				2024			
T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4

C2 | C3 | C4 | C5 | Full ITER-like W divertor | C6-C7 | C8-C9

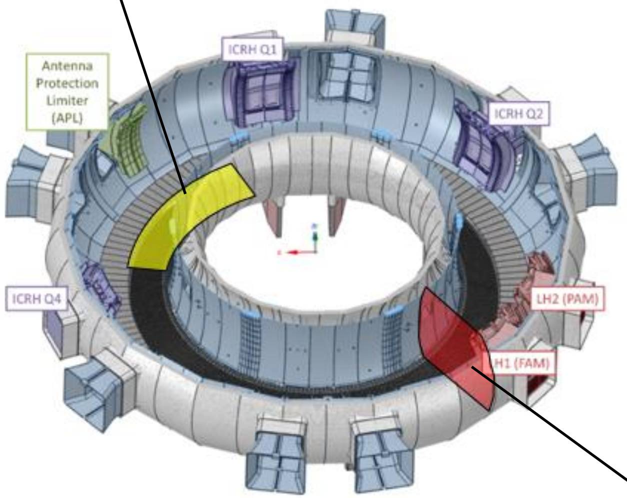
DUST COLLECTION

Collection on the lower divertor

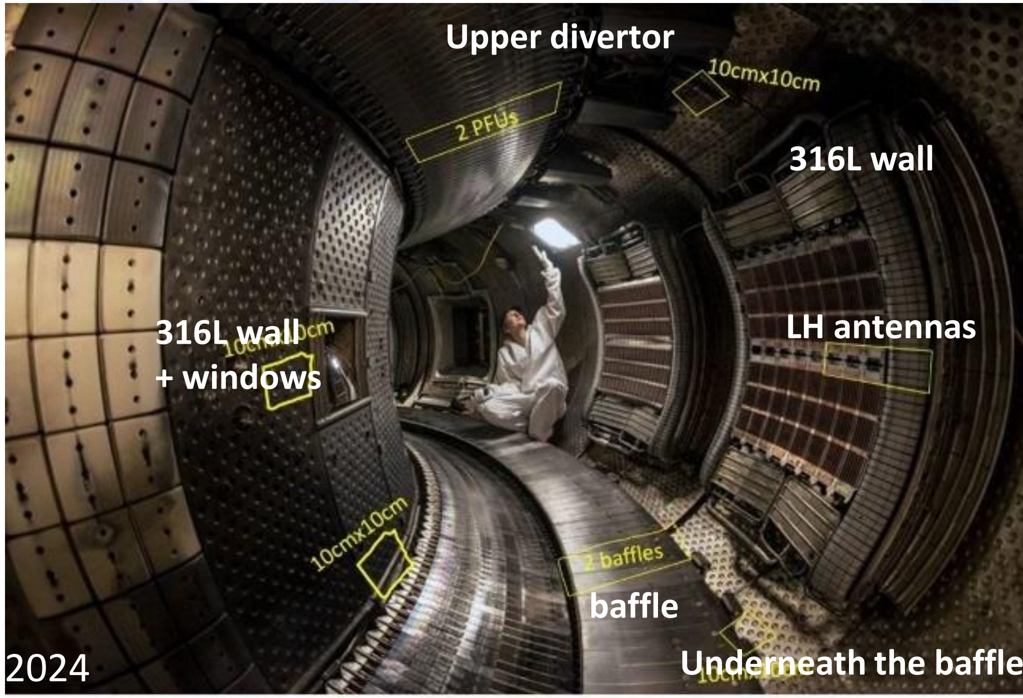
Collection on toroidal plan section (lower+upper divertor, walls, floor, etc..)

Several sampling locations

Collection on the lower divertor sectors Q3A/Q3B (2018-2024)



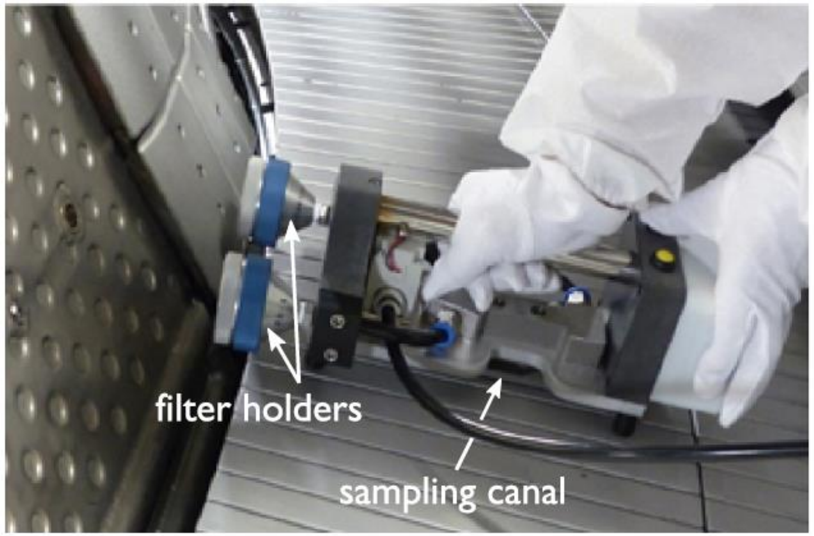
Collection on a poloidal plan (2024)



3 methods used to collect dust in WEST

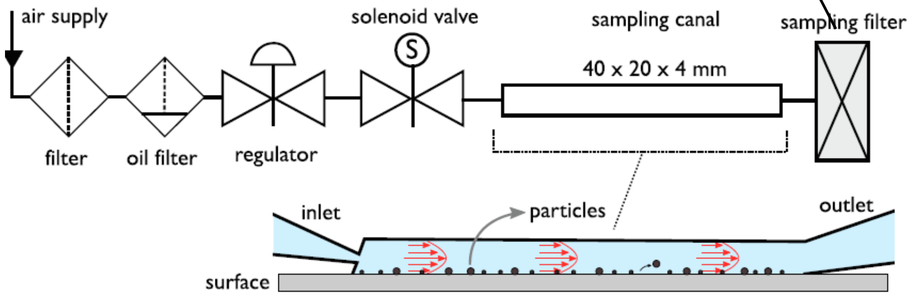
IRSN – Institut de Radioprotection et de Sûreté Nucléaire

‘Duster box’



[S.Peillon et al. NME2020]

3 µm pore size membrane



Particles > 300 nm collected with efficiency of 99,9%

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Double sided carbon tape

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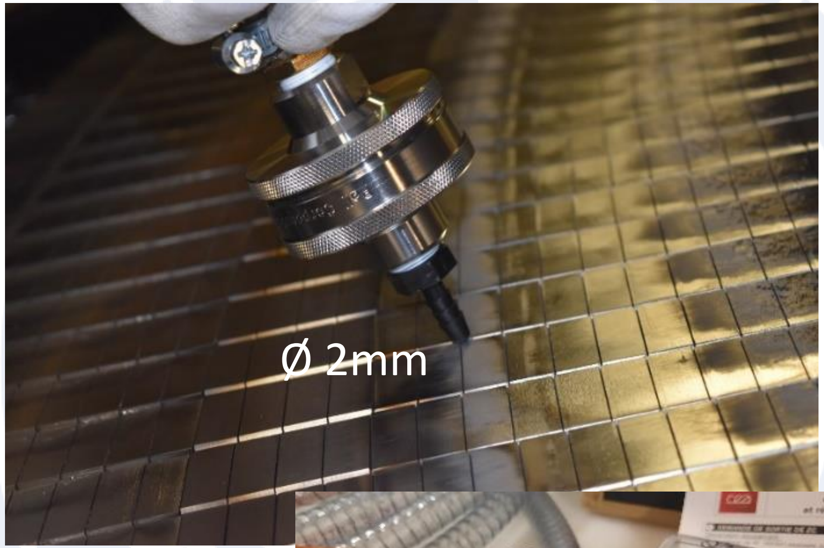
Filtered vacuum technique

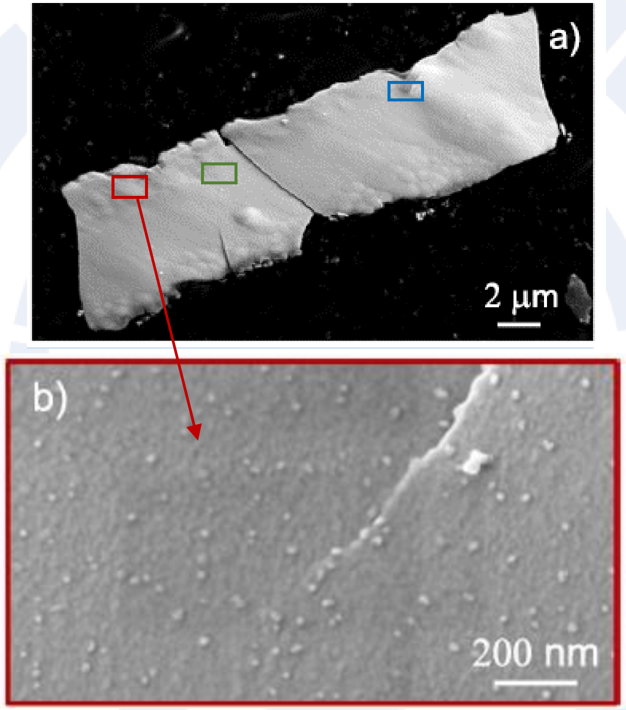


0,4 µm pore size filter substrate

Oil-free pumping system

Dust shape/size/composition analyzed by SEM/EDX

	Collection technique	Type/shape of dust	Dust size	Chemical Comp.	Collected mass
2018 ***After C2***	Duster box **[S.Peillon et al. NME 2020]**	• Few particles collected : 58 counted • 41% of the particles had spherical geometry, either dense or hollow like bubbles → attributed to anormal events • 59% with irregular shape	5-30 µm	W, 316L, Mo	Not measured
	Vacuum technique	• spherical geometry • irregular shape	Spheres usually < 10µm	W, Mo, 316L	Not measured
2020 ***After C4***	Duster box	Not usable results (very few particles collected - EDS not working)			
2020 ***After C4*** / **2021** ***After C5***	Vacuum technique **[C.Arnas et al. NME 2023]**	• Spheroids • Particles with irregular shape • Flat rectangular chips -> delaminated layers • nanoparticles	• W spheres < 10µm • Up to 90µm • Nanoparticles 5-50nm	W B,C,O, Cu, Ag	Not measured
2023 ***After C7***	Duster box	• flat, rectangular chips (sometimes with layers of nanoparticles on top) → delaminated coated/deposition layers ? • a few crystal-like particles	Up to 100µm long 1-2µm thick	Pur W, WO_x	Not measured
	Vacuum technique **[PSI 2024]**	• flat, rectangular chips • Spheroids • Irregular shape • nanoparticles	• Chips up to 1mm • 1-30 µm • Nanoparticles ≈25nm	Pur W chips W nanopart. B,C,N,O	Not measured but large amount !
2024 ***After C9***	Vacuum technique	Characterization foreseen for 2025 (size distribution, composition, dust shape)			

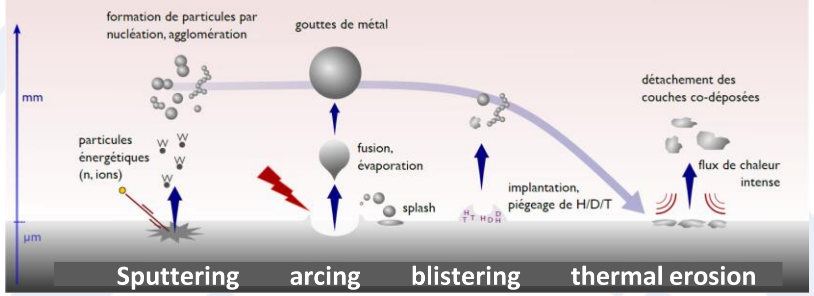


[C.Arnas et al. NME2023]

Several tools available to link the dust observed to their origin in the machine

Production mechanisms

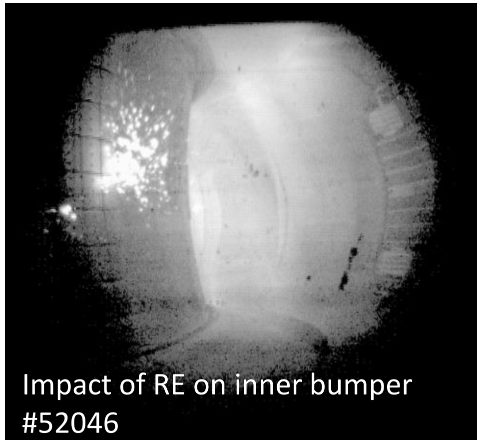
- Steady state heat flux -> erosion/transport -> flakes
- Transient heat loads (disruptions, RE, ELMs, arcing, ..) -> melting -> droplets
- Maintenance

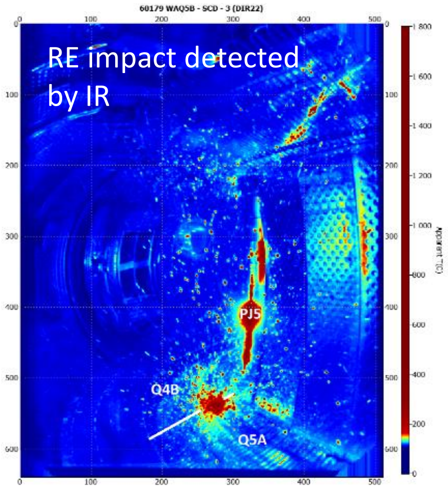


[S.Peillon et al. NME2020]

Tools available to identify dust-causing events

- In-situ diagnostics : visible cameras, IR cameras
- Observations from in-situ inspections and robotic arm inspections
- Results from post mortem analysis: erosion/redeposition patterns

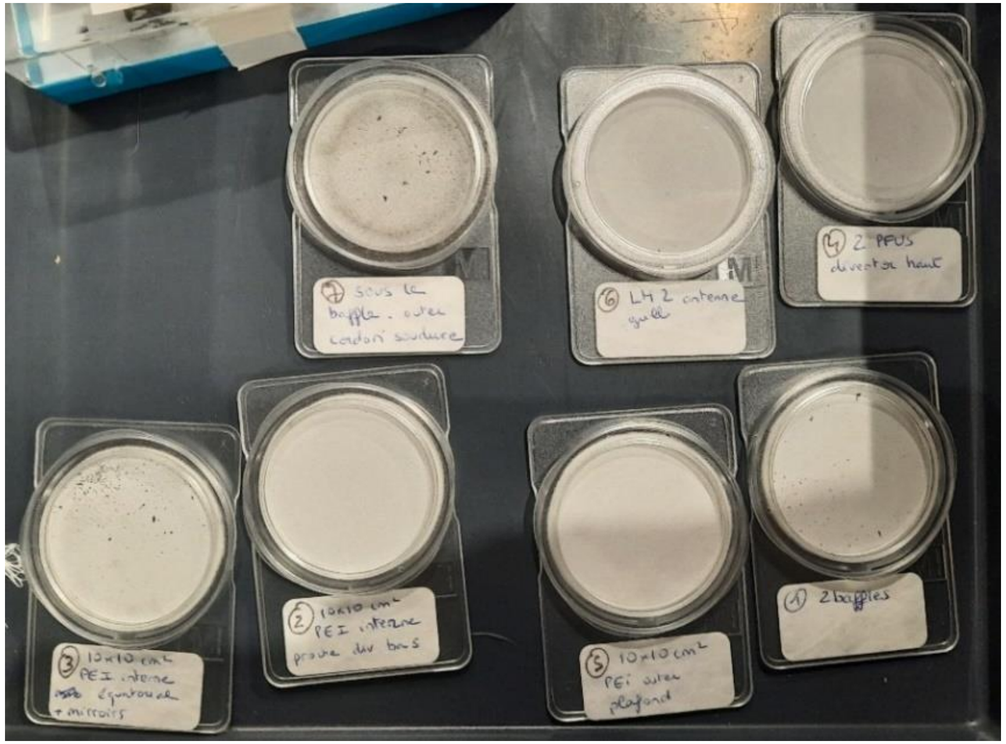




Mass of collected dust measured for safety studies

Total quantities and distribution of dust inside the vacuum chamber ?

- Mass measurements carried out in 2024 as part of WP SAE activities => mass concentration for specific locations
- As expected, the highest dust concentration was found underneath the baffle => in 2025, we foresee to study the toroidal distribution of dust under the baffle



Dust collected in 2024 after the C9 campaign

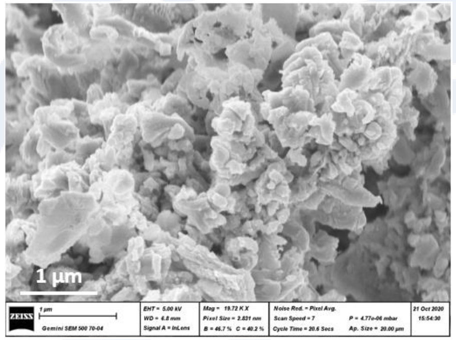
	Plasma facing locations	Surface area	Collected mass (mg)
Upper surfaces	Upper div.	26cm²	2 mg
	316L wall	10x10cm²	1 mg
Midplane	316L wall + windows	10x10cm²	72 mg
	LH antenna	10x10cm²	1 mg **Already vacuum cleaned by the technical team*
Floor surfaces	316L wall	10x10cm²	0,6mg
	baffle	907cm²	11,3mg
	Lower divertor	253cm²	*Experimental issues*
	Underneath the baffle	40x1cm²	3,418 g

Quantitative dust analysis under development

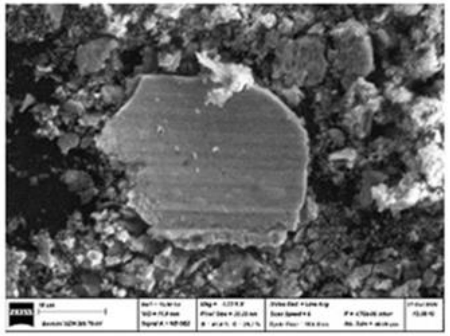
Lack of quantitative data on dust coming from W machines, which is essential for predicting their behavior in ITER

- Particle size distribution => information about confinement / mobilization
- Type of dust / families
- Shape of the dust, dust surface area => reactivity, quantity of trapped tritium
- Statistical data about composition => chemical reactivity

High SSA = high reactivity



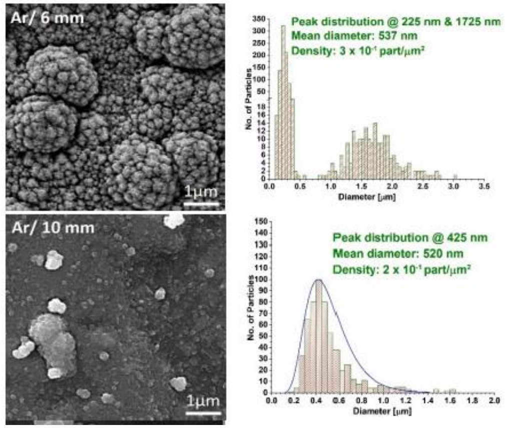
low SSA = low reactivity



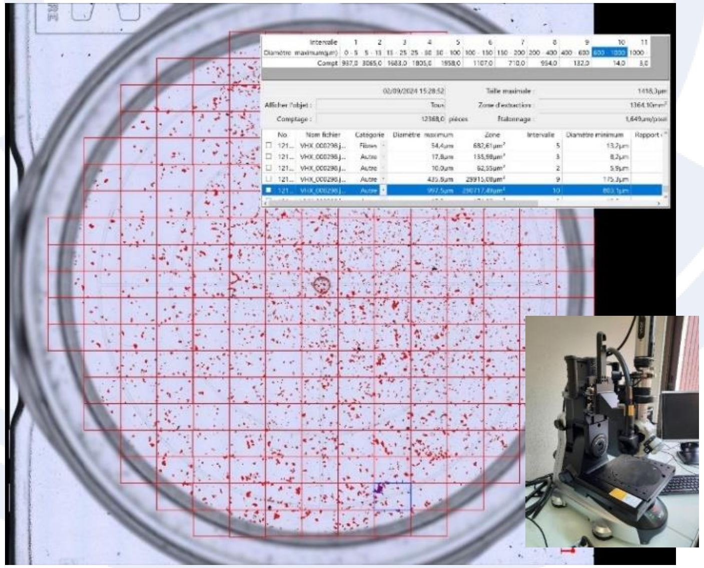
[images from C.Martin]

Several options to be studied

- SEM images with a post treatment (IAP, Aix Marseille Uni)
- Analysis directly using an optical microscope (CEA)



[W.J.Carmack et al., FED 2000]

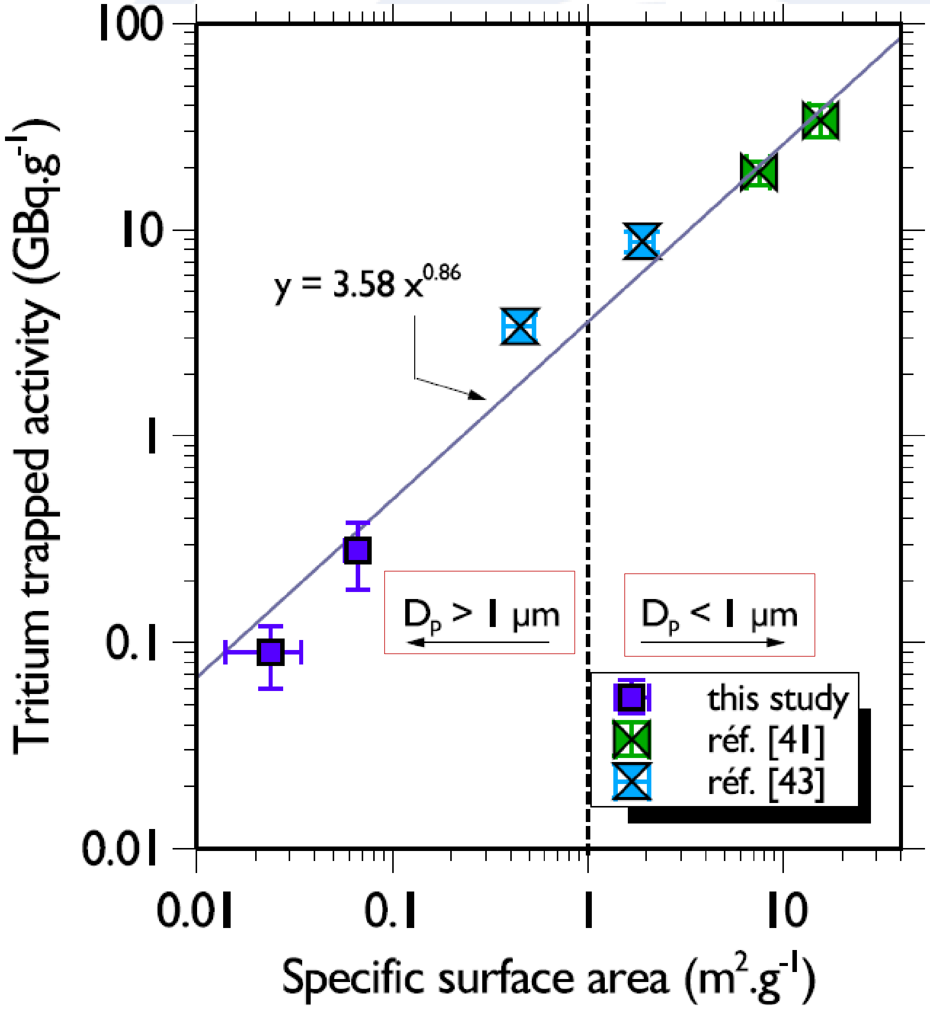


Evaluation of tritium activity in WEST-like dust

- dust collection in WEST
- dust characterization (surface composition, particle size distribution)
- production of tungsten particles representative of those produced by WEST
- tritium gas loading @CEA Saclay
- tritium desorption
- strong dependence between particle size (therefore SSA) and tritium trapped activity
- evaluation of tritium activity in WEST-like dust

Evolution with SSA of the tritium loading in W particles

[S.Peillon et al. NME2020]



Summary

- Good momentum and big amount of work on WEST dust in the past, in terms of modelling, collection, characterization and safety studies.

- High level of SEM/EDX characterization after each shutdown but lack of quantitative analysis
- Extension of characterization to mass measurements

- Difficulty in establishing a link between collected dust and the WEST operation despite the many tools and diagnostics available

- These activities have never been included within TE or PWIE. This year (2024) activities are supported by SAE.

- Future steps: provide more quantitative data about dust particules found in WEST, in terms of particles size distribution, dust surface area, mass concentration, toroidal distribution