First results from dust detection during plasma discharges in Tore Supra

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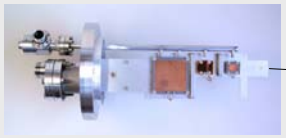
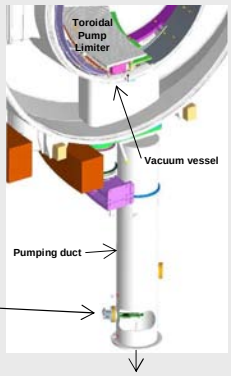
Context:

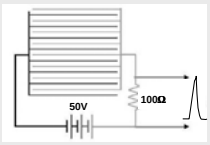
Dust has been recognized as a safety and operational issue for next step devices such as ITER
It is essential to develop methods for dust detection
An electrostatic detector has been developed by PPPL to detect dust particles on a remote surface
With its ability to perform long discharges, Tore Supra offers an opportunity to test this detector
A set of electrostatic detectors has been installed in one of the pumping ducts of the Tore Supra vacuum vessel



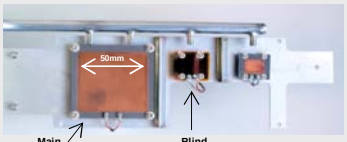
A set of 3 electrostatic detectors



A set of detectors has been set up in Tore Supra in 2010



Trace spacing = 25µm



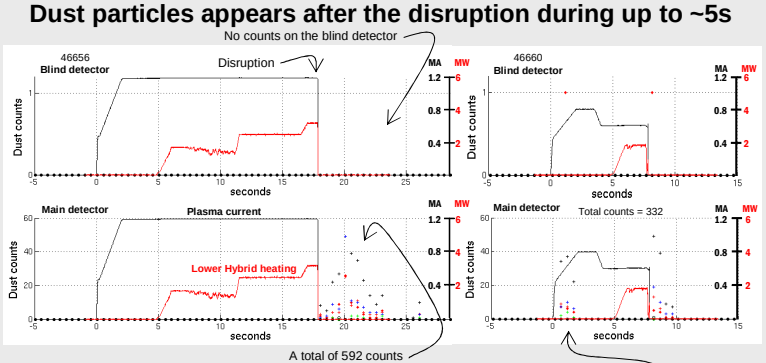
A fine grid of 2 interlocking combs of copper traces

A conductive particle which reaches the active surface creates a temporary short circuit, before the particle is ejected or vaporized by the current flowing across it
The resulting current pulses are counted and sorted depending on their level and duration

To discriminate pulses created by particles from electrical pickup, one of the detectors has been covered with a film of Kapton ® to protect its sensitive surface from dust

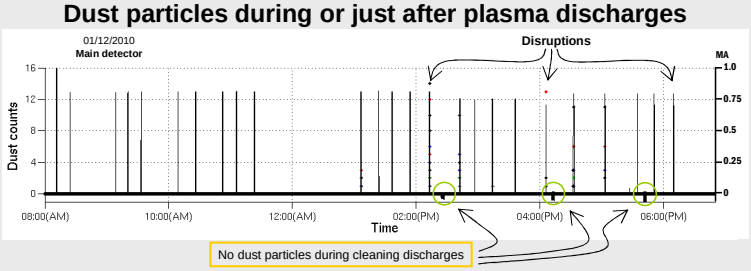
A mesh stops particles > 85µm

Dust particles appears after the disruption during up to ~5s



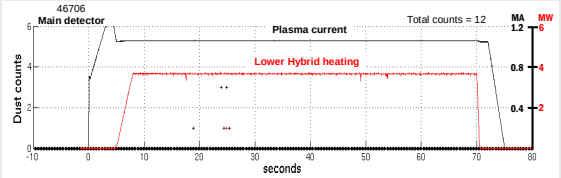
Up to several hundreds of counts only on the main detector
→confidence that counts are due to dust particles falling on the detector surface
Dust particles are typically detected after disruptions (25/27)
Sometimes dust particles are detected during plasma current ramp up on shots following disruptions (5/27)

Dust particles during or just after plasma discharges



No dust particles during cleaning discharges

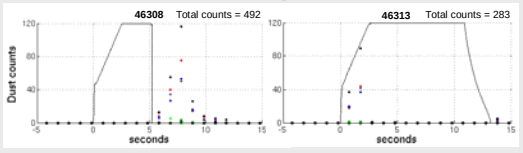
Dust particles observed during long plasma discharges

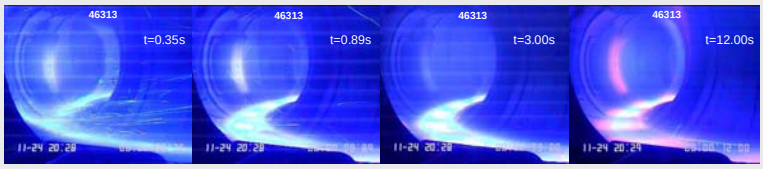


Very few dust particles during:
- plasma current plateau
- venting

No dust particles during:
- cleaning discharges
- glow discharges

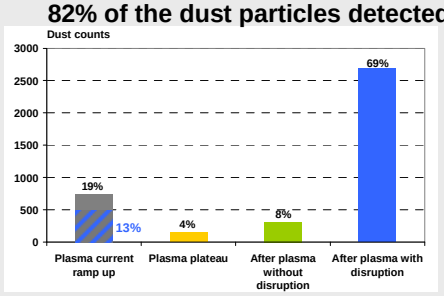
Correlation with particles observed on visible CCD





There is certainly a delay between the observation of the particles inside the in-vessel and their detection inside the pumping duct.

82% of the dust particles detected are due to disruptions

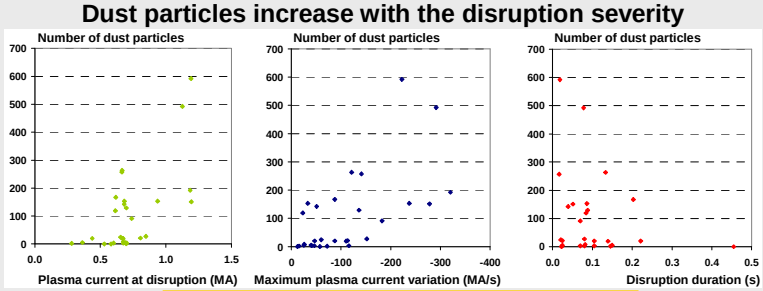


481 shots analyzed → ~10000s
27 disruptions
101 shots with dust particles detected
Total dust particles detected = 3896

Plasma events:
- Plasma current ramp up
- Plasma plateau
- After plasma without disruption
- After plasma with disruption
- Plasma current ramp up following a disruption

13% of the total dust are detected during plasma current ramp up, following a shot with disruption and are included in the ones due to disruptions

Dust particles increase with the disruption severity



The number of dust particles ↗ with Ip, ↗ with dIp/dt, ↘ with disruption duration

Dust size estimated from sublimation energy

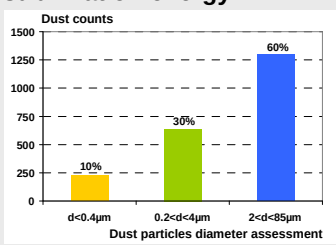
Hypothesis :
- **cylindrical dust particle, diameter d, length d**
- **entirely sublimated**

From the Energy (E) necessary to sublimate the entire dust particle with a certain power (P) during a certain time duration (τ), the diameter (d) can be extracted as a function of the pulse level measured (U) and the pulse duration measured (τ).

$E = P\tau \Rightarrow d = U\sqrt{\frac{\tau}{\frac{n}{A}\rho\theta_s}}$

With:
U = pulse level measured (V)
τ = pulse duration measured (s)
ρ= **1000 µΩ.m (amorphous C)**
θ_s= 355.8 kJ/mole
n = 1.8 g/m³
A= 12 g/mole

This size is underestimated in case of incomplete sublimation



Conclusions:

The detected signal is due to dust
Dust signals are closely correlated with particles observed by the visible CCD camera
Dust particles data can be distinguished from parasitic, using the "blind" detector

Dust particles are typically detected in a 5s period after disruptions
82% of dust particles detected are due to disruptions
Dust signals are correlated with the severity of the disruption

Dust particles are sometimes detected during plasma current ramp up on shots following disruptions

Very few dust particles are detected during plasma current plateau, and venting
No or few dust particles are detected without plasma discharges
No dust particles are detected during cleaning discharges and glow discharges

Future plans:

The sorting ranges for pulse duration and level will be further optimized to improve dust size assessment

A second unit of detectors will be installed in Tore Supra for comparison to improve knowledge about dust production

A large dust collection surface will be installed near the DUST detectors to measure the total dust flux (mass/area) over the next plasma campaign