Observations of Dust in DIII-D Divertor and SOL

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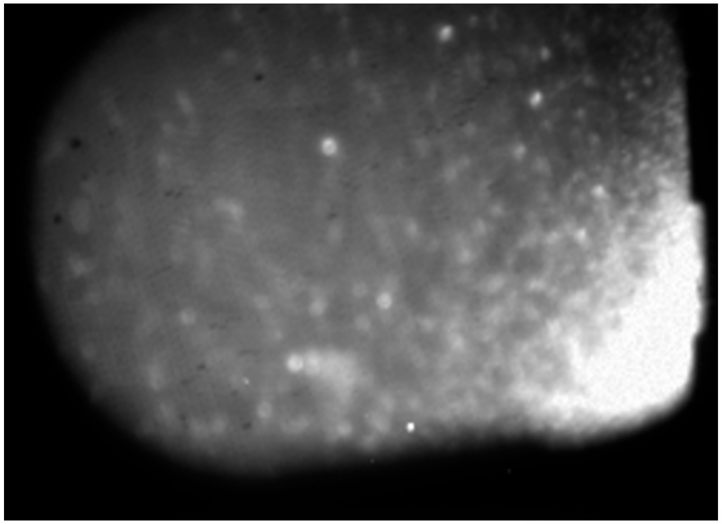

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UCSD

Motivation

- **Micron size dust is commonly found in tokamaks**
- **In today's tokamaks dust is generally not a large concern**
- **Dust can be a serious problem for ITER for a number of reasons:**
  - C: Tritium retention
  - W: accumulation radioactive material
  - Be: H explosion hazard
  - Dust may cause core contamination and degrade performance

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Observations of naturally occurring and unintentionally introduced dust in DIII-D

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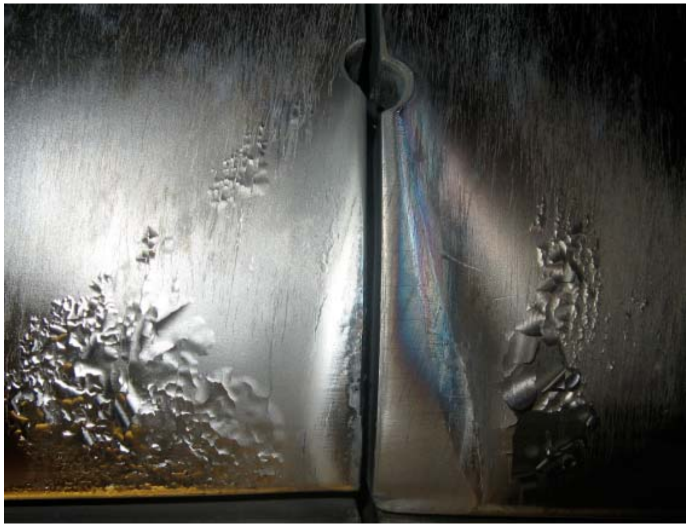
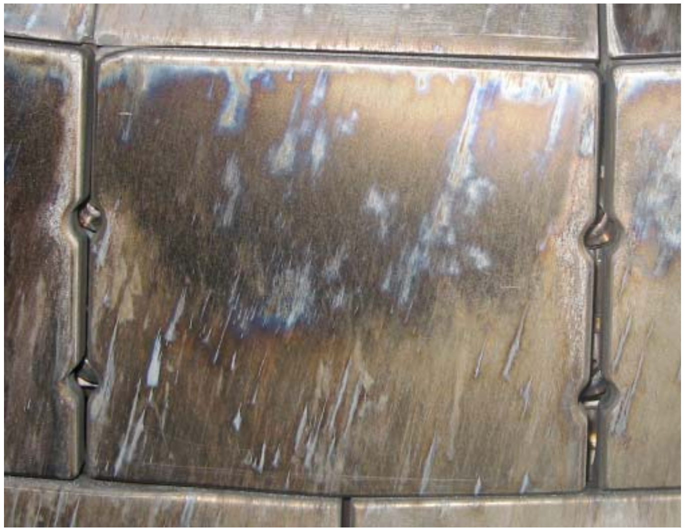
Sources of naturally occurring dust in DIII-D



- Flakes from redeposited CD films



- Monopolar arcs

- Thermal stress induced fracture

- Leading edges

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- **Particles left from entry vent activities** - ***unintentionally introduced dust***

Dust diagnostics in DIII-D

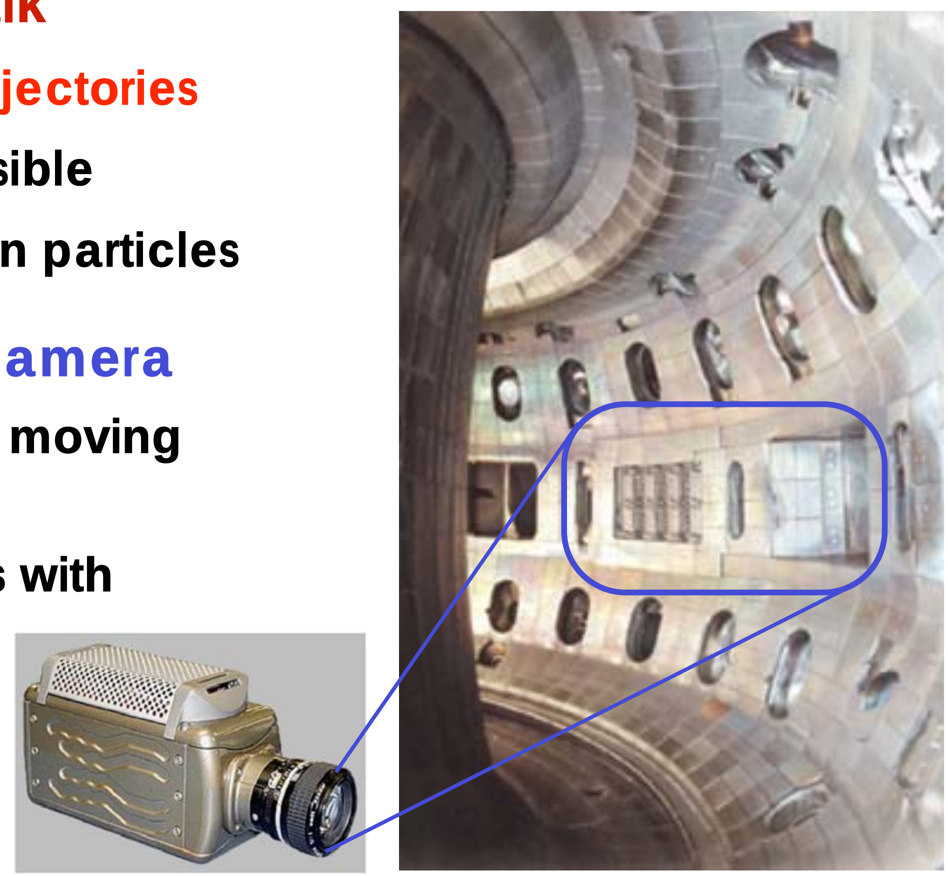
- Thomson scattering
  - \+ Can determine size of small dust particles in the edge plasma
  - \- Can not determine velocities
  - \+ Allows statistical analysis of the dust generation

    see B.D. Bray et al UP8.00042 for more detail

- Optical imaging – subject of this talk
  - \+ Can determine dust velocities and trajectories
  - \- Only a rough estimate of the size possible
  - \- Not sensitive enough to see submicron particles

New tool: Phantom 7.1fast framing camera

- Has much better contrast ratio for fast moving objects than standard cameras
- Can cover 5 s plasma shot at 4000 f/s with 256x256 pixel resolution
- Tangential view of the outboard wall



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Dust levels are high after an entry vent

- During normal operations dust observation rates in DIII-D are low, typically 0-10 events per discharge
- After an entry vent dust levels are elevated; we documented it in the beginning of 2007 experimental campaign
- In the first few plasma shots after the vent dust levels were quite high, order of thousand of particles observed by fast camera in every shot

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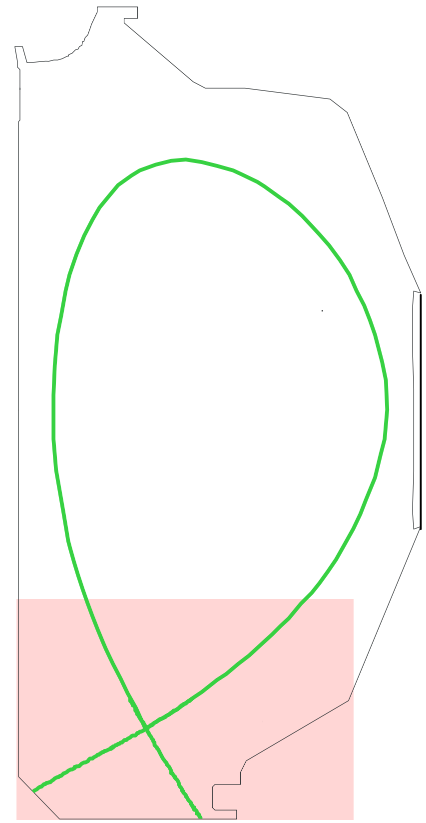
Dust levels are high after an entry vent

Shot number 127332 – third plasma shot of 2007



Tangential TV looking in the lower divertor,
near IR filter, 60 f/s

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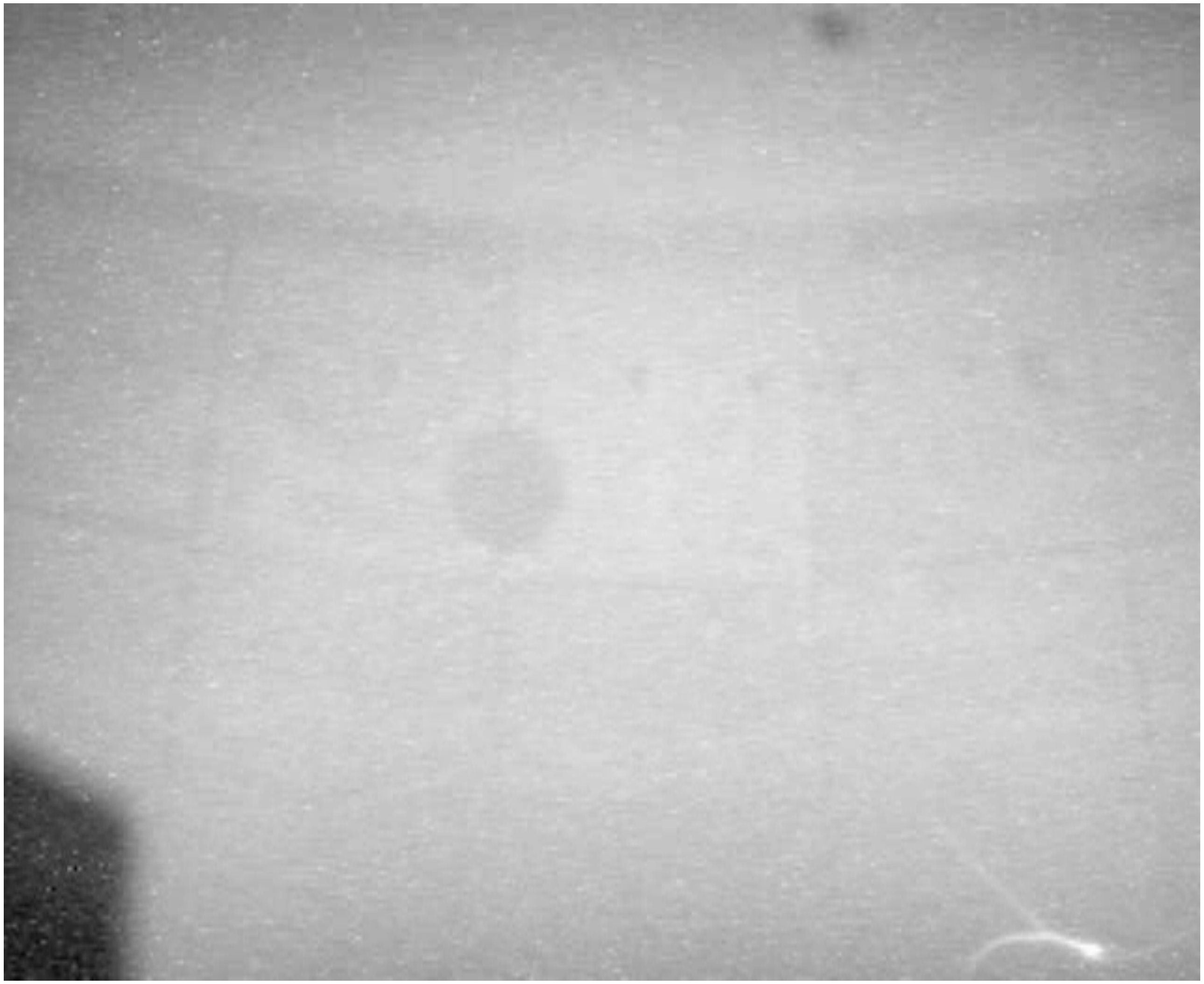
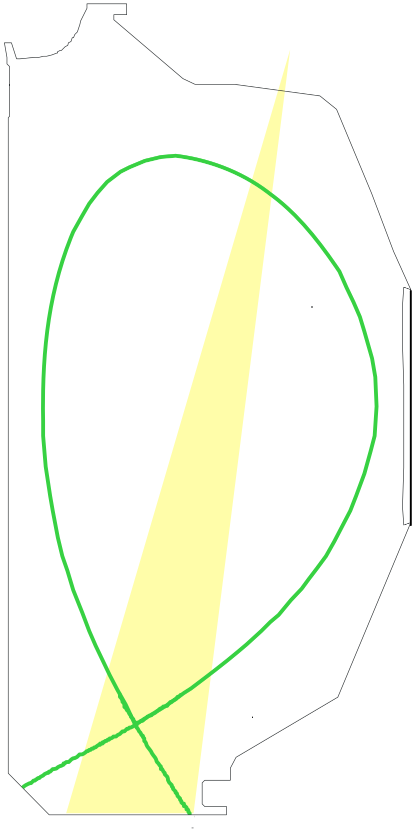
Dust levels are high after an entry vent

Shot number 127331 – second plasma shot of 2007





DiMES TV, looking down in lower divertor
near IR filter, 60 f/s

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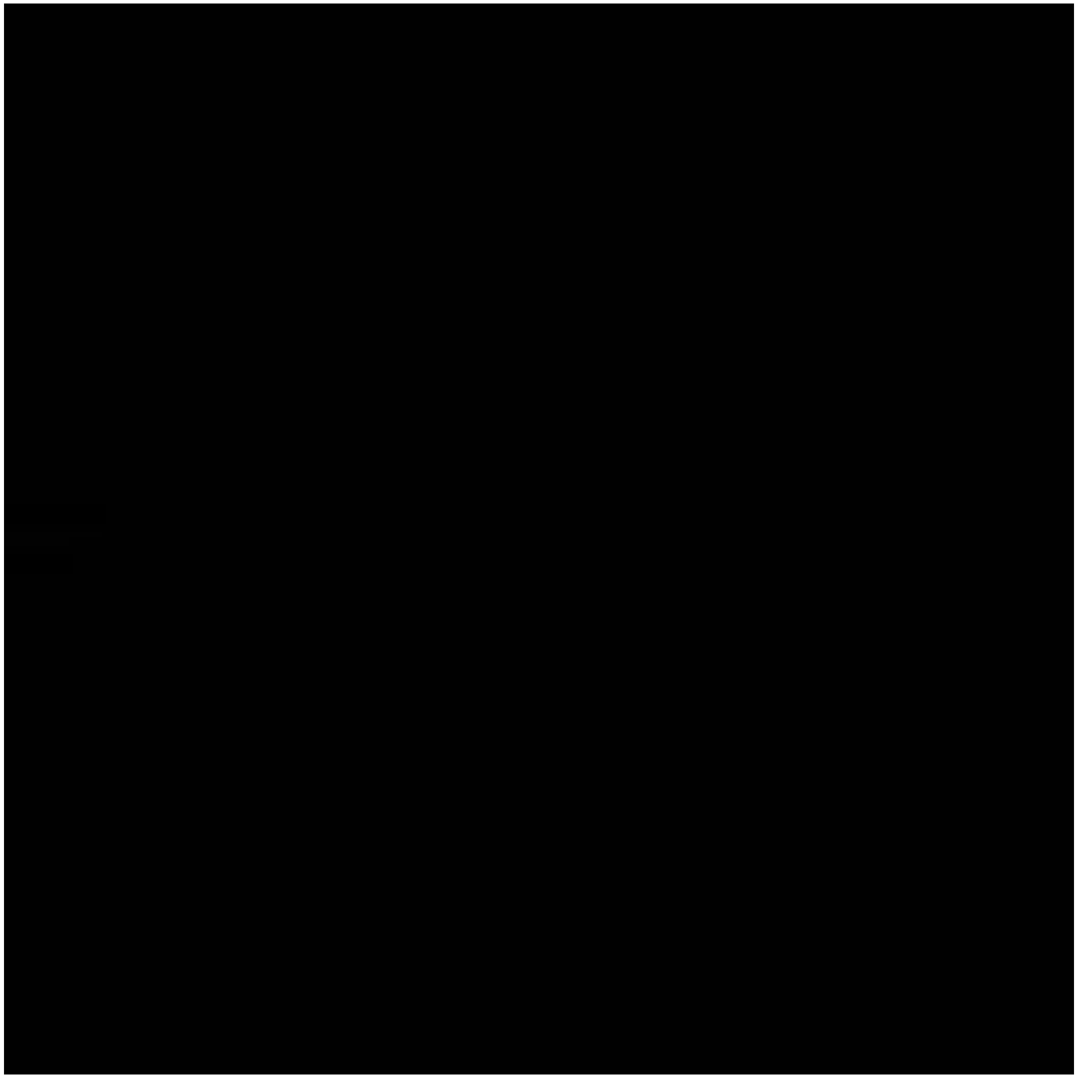
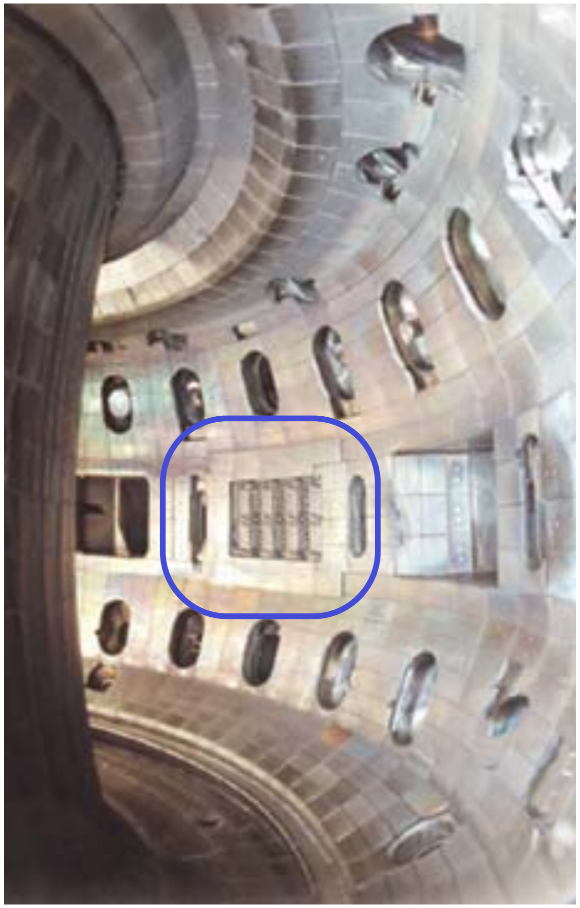
Dust levels are high after an entry vent

Shot number 127331 – second plasma shot of 2007





Fast camera, full light, 1000 f/s, total duration ~ 1 s

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Dust levels are back to normal after ~70 plasma shots

- During normal operations dust observation rates in DIII-D are low, typically 0-10 events per discharge
- After an entry vent dust levels are elevated; we documented it in the beginning of 2007 experimental campaign
- In the first few plasma shots after the vent dust levels were quite high, a few thousand of particles observed by fast camera in every shot
- **After ~10 plasma shots dust was observed mostly at the beginning and end of each shot; dust levels during flattop dropped significantly**
- **After ~70 plasma shots dust levels dropped to just a few observation per shot**

Characteristics of the dust observed by cameras

- **Velocities from a few m/s up to ~ 300 m/s**
- **Size hard to estimate, probably > 5 microns**

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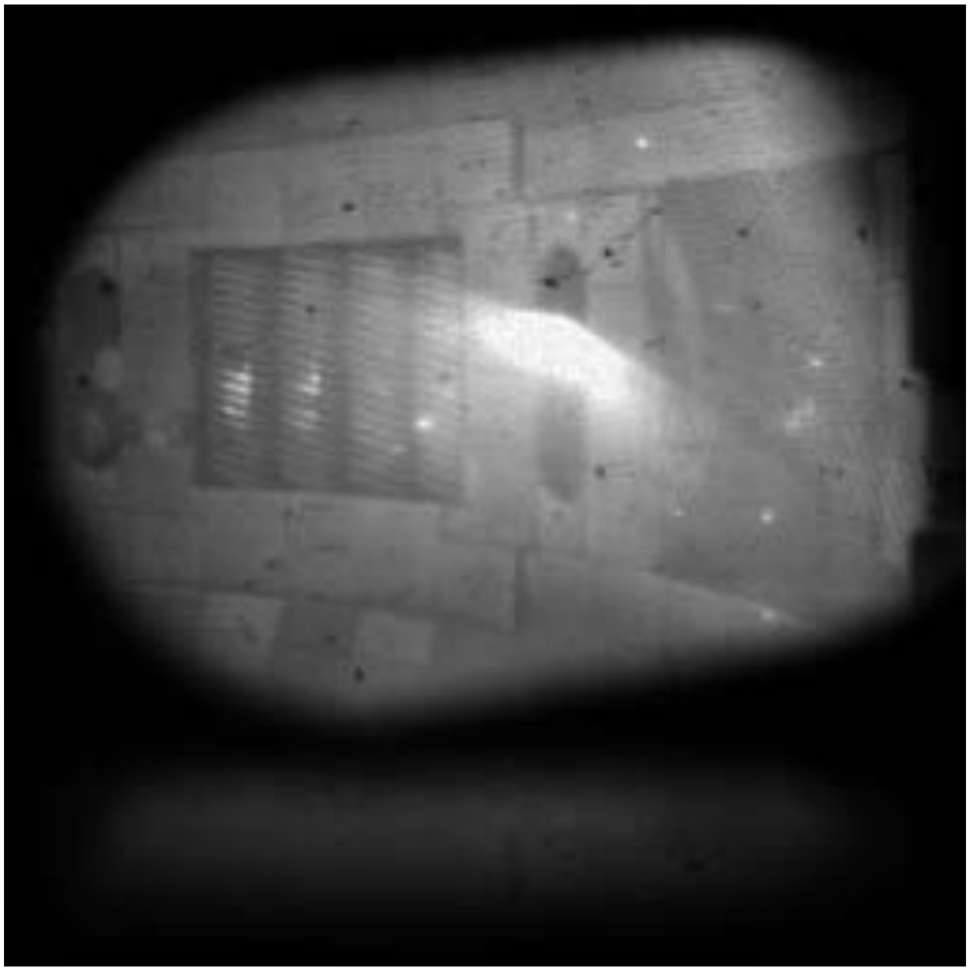
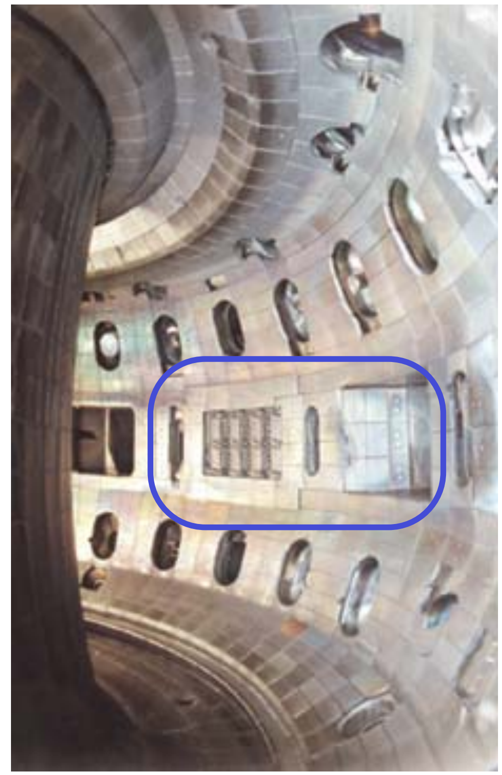
Characteristics of the dust observed by cameras

- Velocities from a few m/s up to ~ 300 m/s
- Size hard to estimate, probably > 5 microns
- Sometimes breakup of large particles into pieces is observed





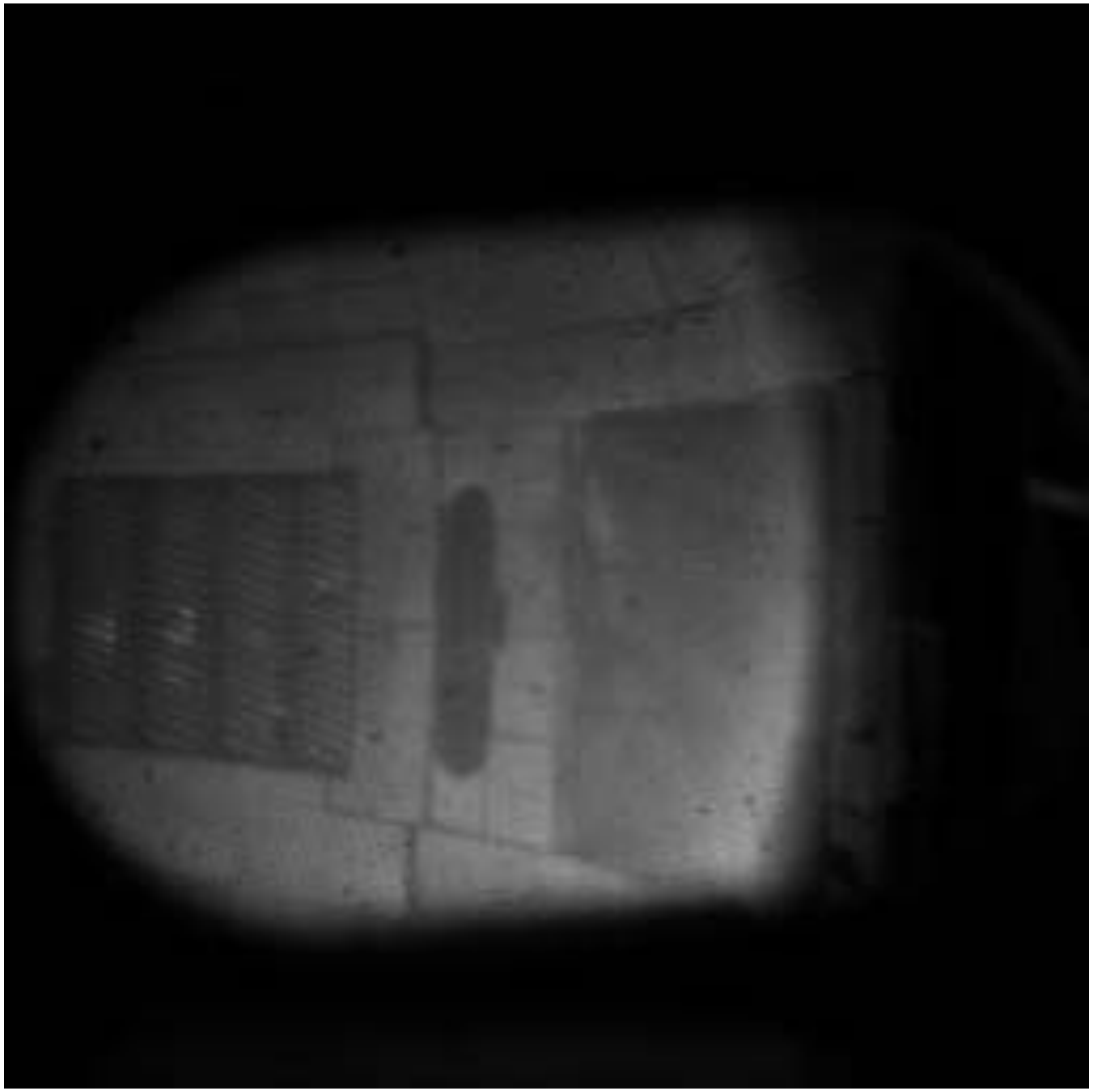
Full light, 2000 f/s, total duration ~100 ms

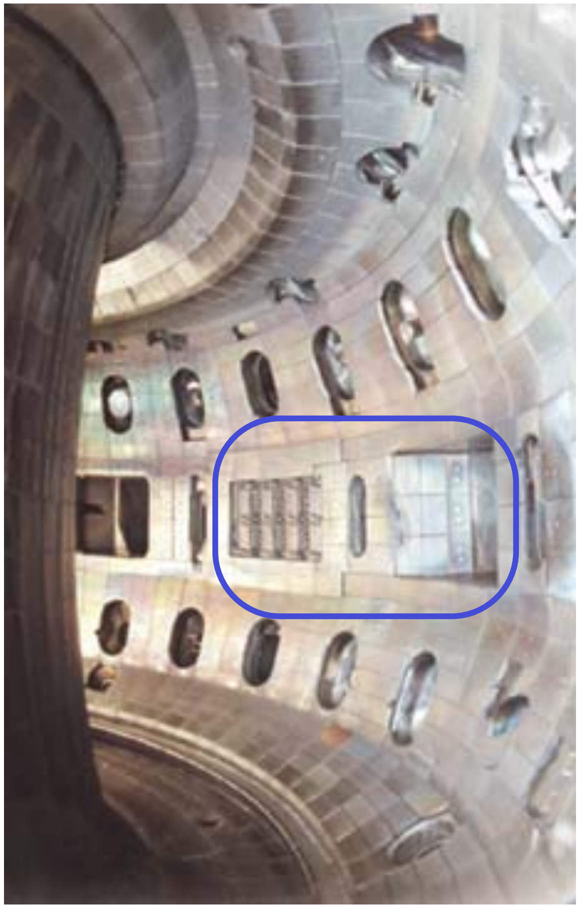
Disruptions are significant source of dust

- Assessing of various dust production mechanisms is important for ITER
- Dust production by transient effects such as ELMs and disruptions are of particular concern
- Statistical analysis of Thomson scattering data in DIII-D indicates that ELMs and disruptions are contributing to dust production
- Sometimes fast camera sees a “dust shower” following a disruption

Disruptions are significant source of dust

Shot number 129053





Full light, 3000 f/s, total duration ~ 200 ms

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Experiments with **intentionally introduced** carbon dust

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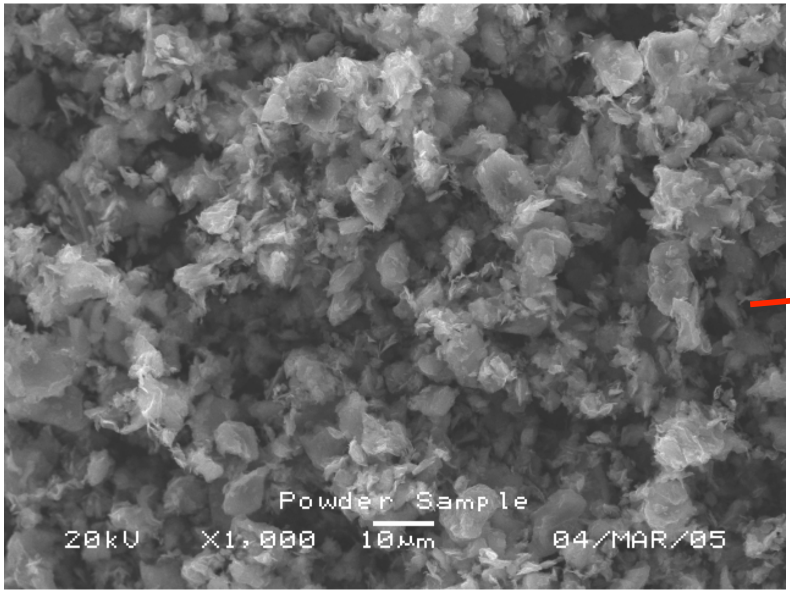
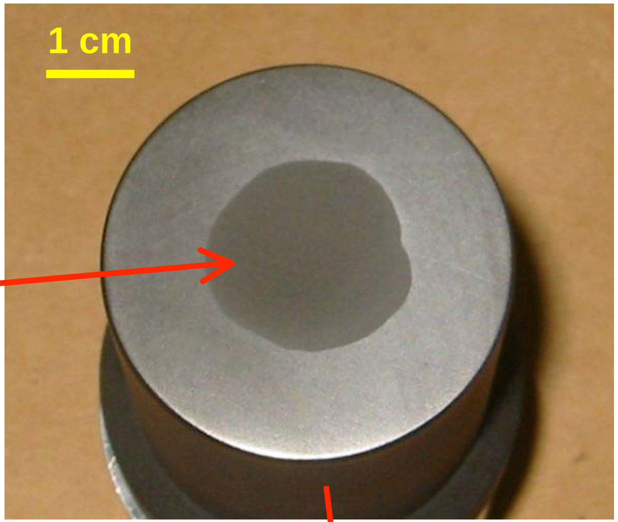
DiMES is used to introduce dust in the divertor floor

- A suspension of graphite dust in alcohol is applied to the holder
- Upon drying up the dust forms a rather uniform layer clinging to the holder
- The holder is inserted into lower divertor of DIII-D using DiMES mechanism





- Median dust diameter is ~6 µm
- The amount of dust in the holder is ~25-40 mg

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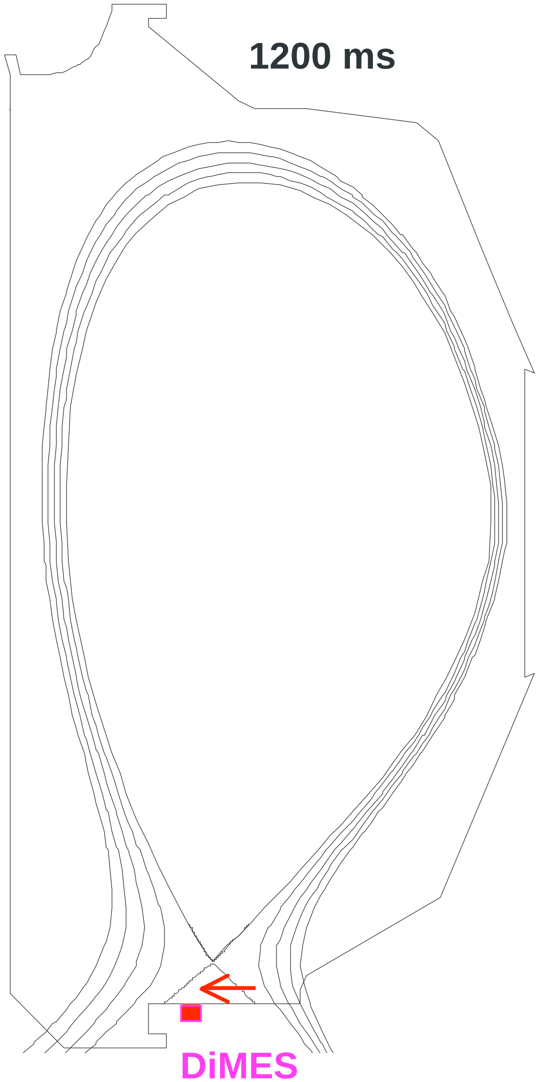
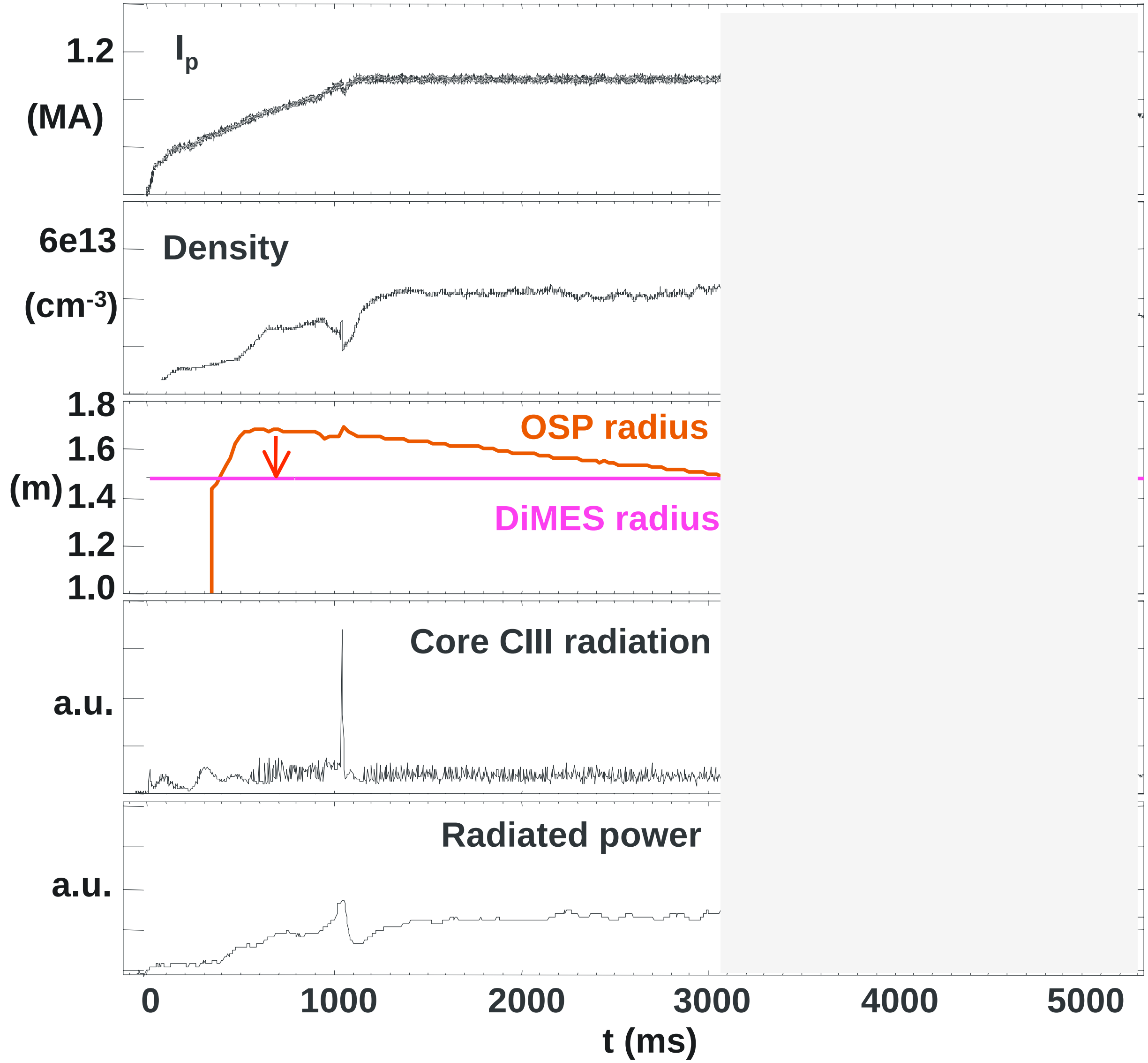
Dust exposed to LSN H-mode with swept strike points





- Between 0.5-3 sec DiMES is located in the private flux region
- Outer strike point is slowly swept towards DiMES

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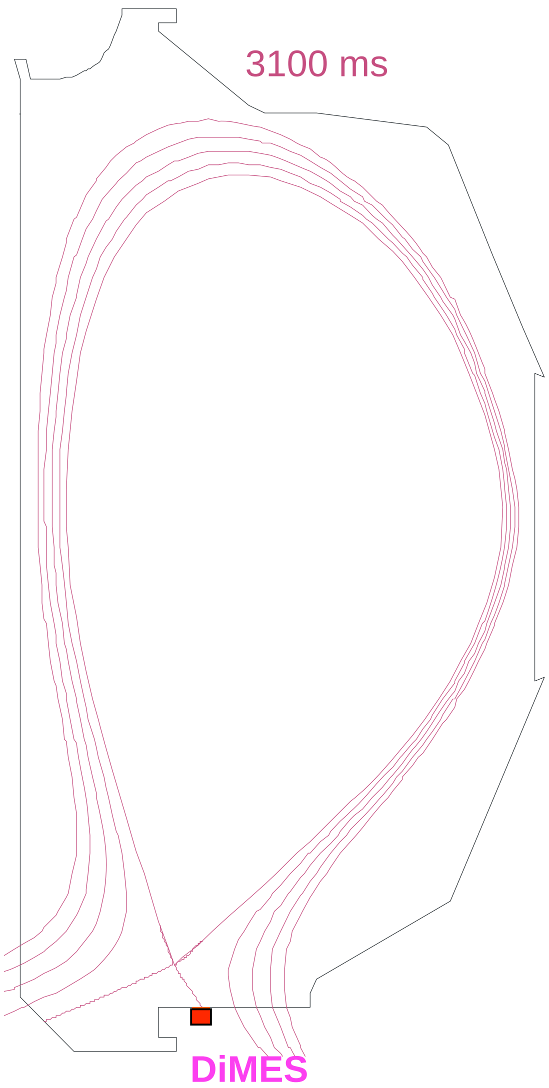
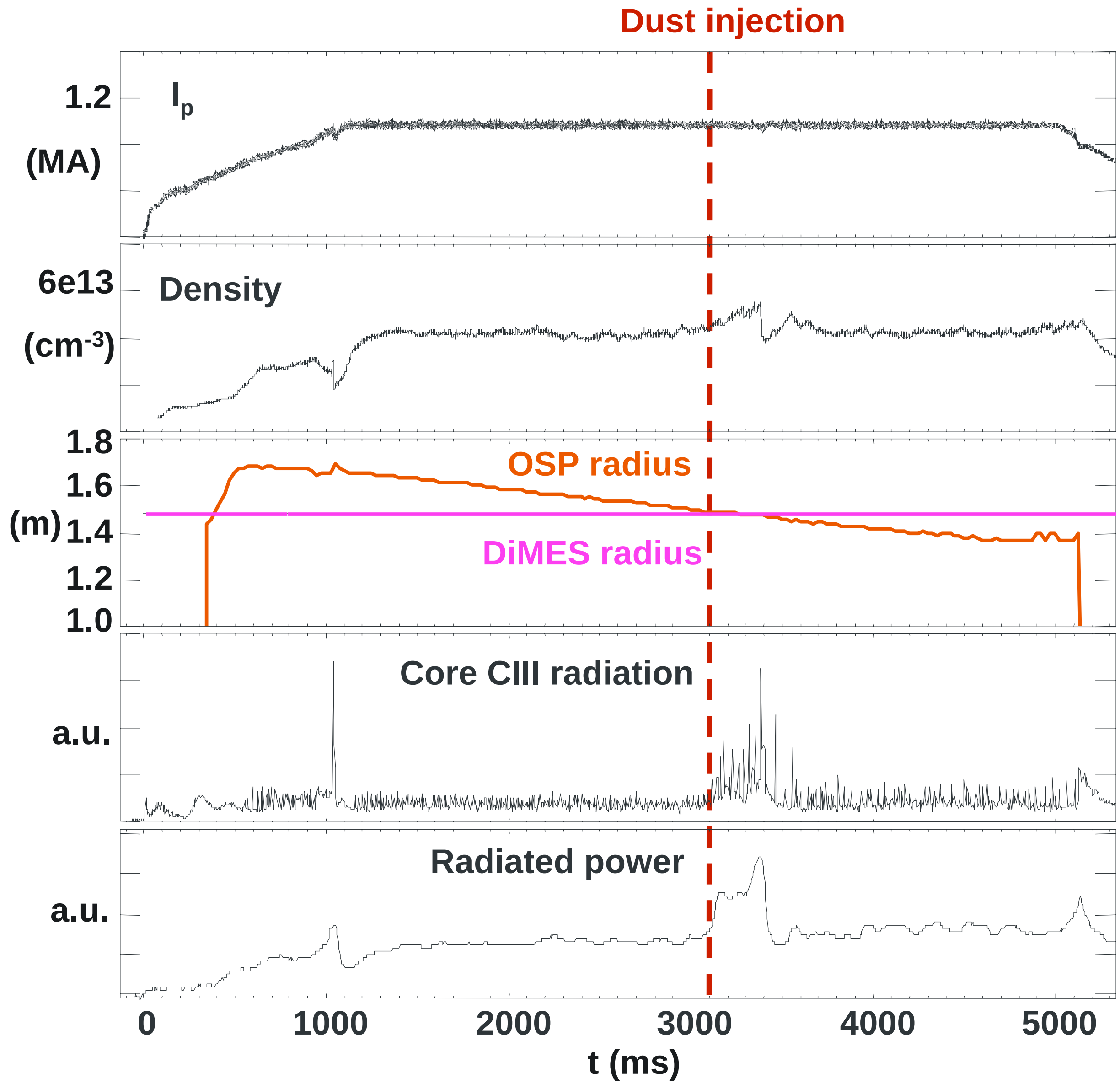
Dust exposed to LSN H-mode with swept strike points





- When OSP reaches DiMES, a massive dust injection occurs
- Core CIII light and radiated power double after the injection

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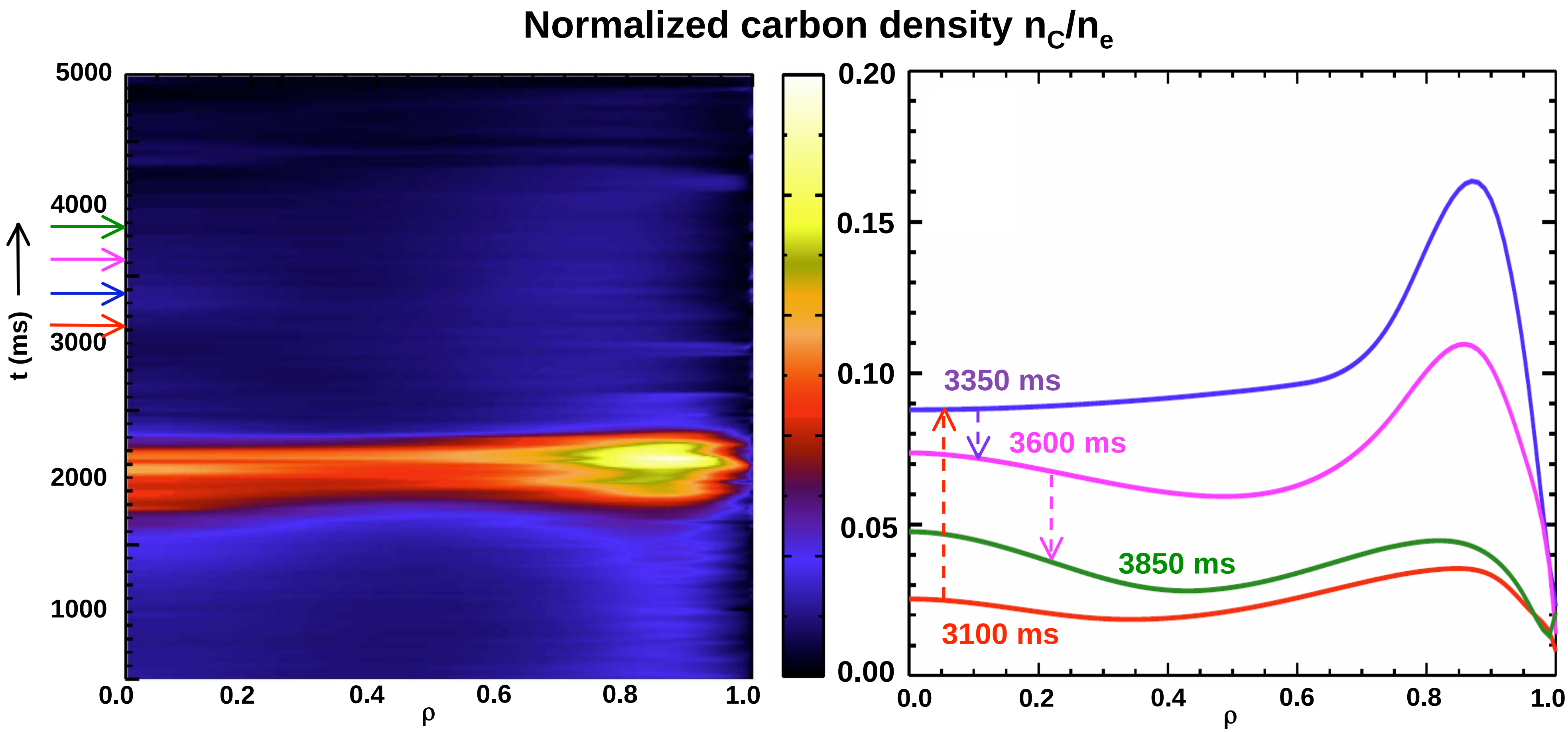
Core carbon density increased by a factor of 4-5



Amount of carbon reaching the core corresponds to 2-3% of the dust loaded in DiMES (a few million particles)

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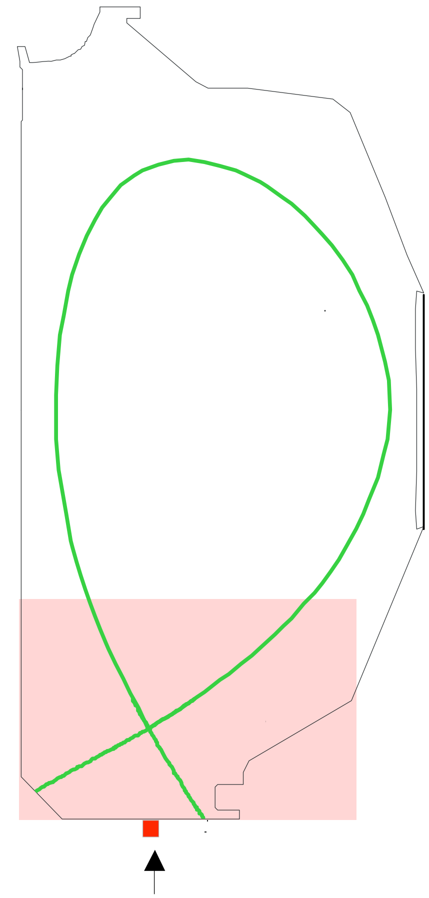
Dust injection from DiMES observed directly

Shot number 127641



DiMES

Tangential TV, near IR filter, 60 f/s

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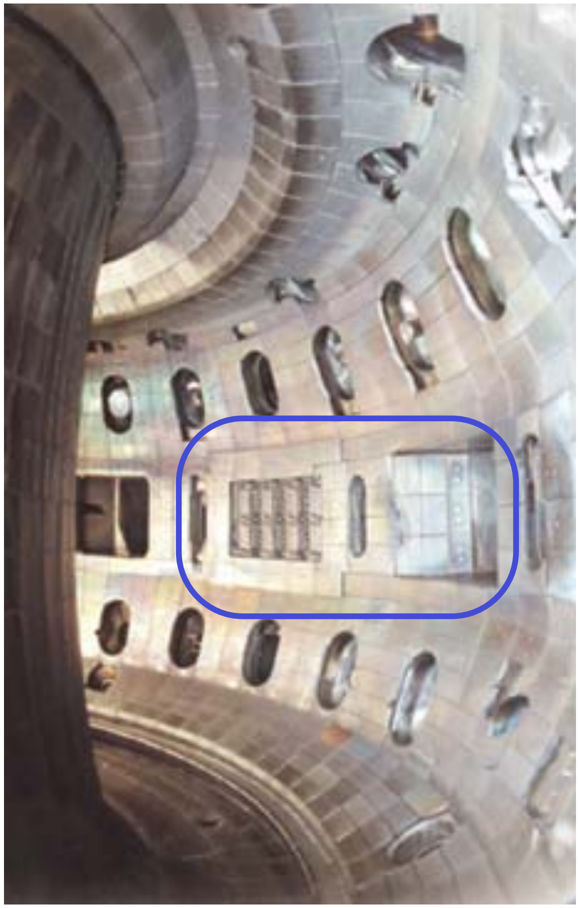
Dust injected from DiMES observed in outboard SOL

Shot number 127641



Full light, 3000 f/s, total duration ~ 1 s

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Comparison with modeling

Dust Transport *DustT* code developed at UCSD

- ***DustT*** **code solves equations of motion (r,v) for dust particle in 3D self-consistently with ablation model given by equations for dust temperature and radius**

- **The code uses magnetic equilibrium mesh and plasma background from UEDGE code**

- **Based on UEDGE data, the forces acting on dust particle from plasma are calculated**

- ***DustT*** **employs Monte Carlo method for incorporating the dust collisions with walls and micro-turbulence**

- **Dust of different chemical compositions can be modeled**

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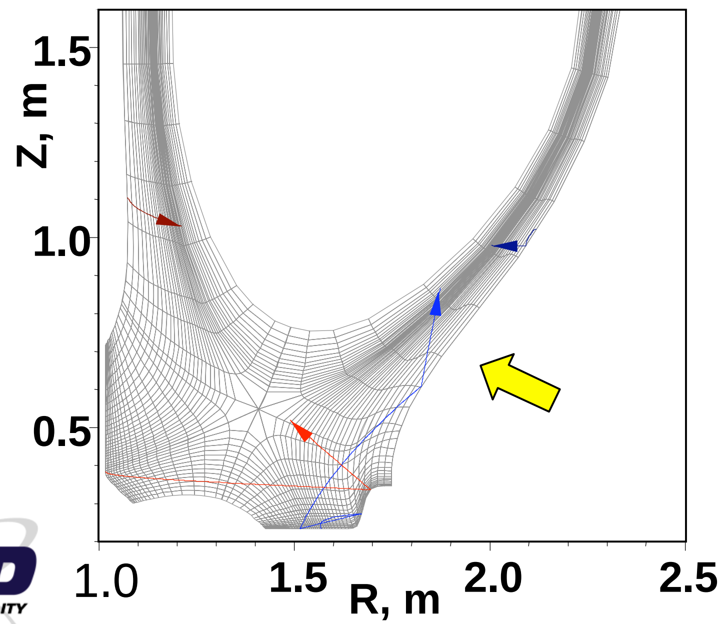
Experimental results are in agreement with *DustT*

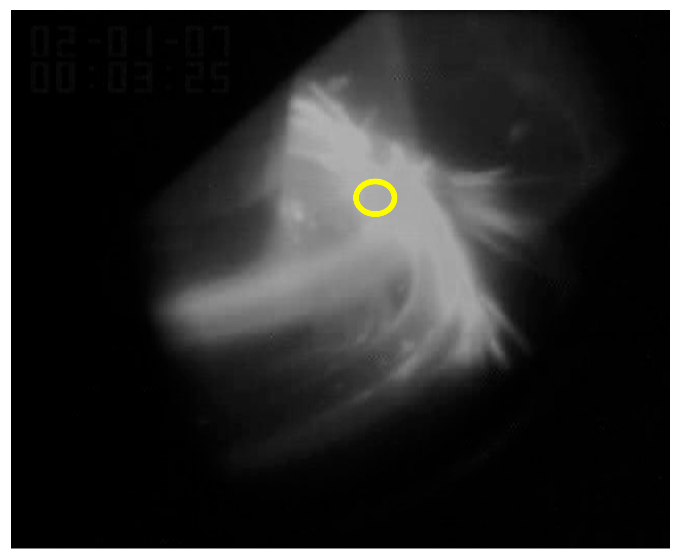
DustT

- Velocity of dust in plasma is 10-100 m/s
- Dust particles are accelerated in the direction of plasma flow
- Dust trajectories are “elongated” in the toroidal direction
- Micron size dust launched in the lower divertor can reach mid-plane



Experiment

Dust velocities ~3-300 m/s



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Summary

- Dust is not a concern during normal operation of DIII-D

  see also B.D. Bray et al UP8.00042

- Disruptions produce significant amounts of dust

- Following a dirty vent, dust levels are elevated, but they decrease considerably within the first day of operations and within 2-3 days are back to normal

- Micron-size dust introduced in the lower divertor becomes highly mobile when exposed at the strike point and migrates around the torus

- 3D modeling of dust dynamics using *DustT* code is capable of reproducing experimentally observed dust velocities and trajectory shapes

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