Modeling of Dust in Tokamak Plasmas

R.D. Smirnov[1], A.Yu. Pigarov[1], M. Rosenberg[1],
S.I. Krasheninnikov[1], D.A. Mendis[1],
T.D. Rognlien[2], T.K. Soboleva[3]

[1]*University of California - San Diego, CA, USA*
[2]*Lawrence Livermore National Laboratory, CA, USA*
[3]*UNAM, Mexico D.F., Mexico*

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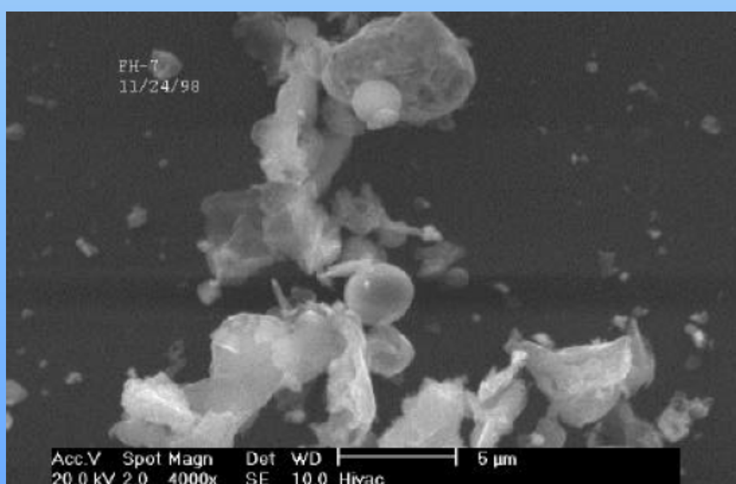
Dust in tokamaks

- **Observations**:
  - Dust was observed in tokamak plasmas (camera view, Rayleigh laser scattering channel) and collected from inner wall surfaces
- **Production mechanisms**:
  - Erosion of plasma exposed surfaces
  - Flaking of deposited layers
  - Volumetric growth
- **Possible impact on fusion operation**:
  - Safety and radiological issues: highly reactive dust posses risk of explosion, small volatile particles may absorb large amount of tritium
  - Operational issues: dust may accumulate in or damage diagnostic ports and devices
  - Plasma issues: transport of impurities

Tokamak dust examples

◀ DIII-D[1]

▼ NSTX[2]



[1] W.J. Carmack, DIII-D Dust Particulate Characterization (June 1998 Vent) INEEL/EXT-99-00095
[2] A.L. Roquemore, N. Nishino, C.H. Skinner et al. (private communication)

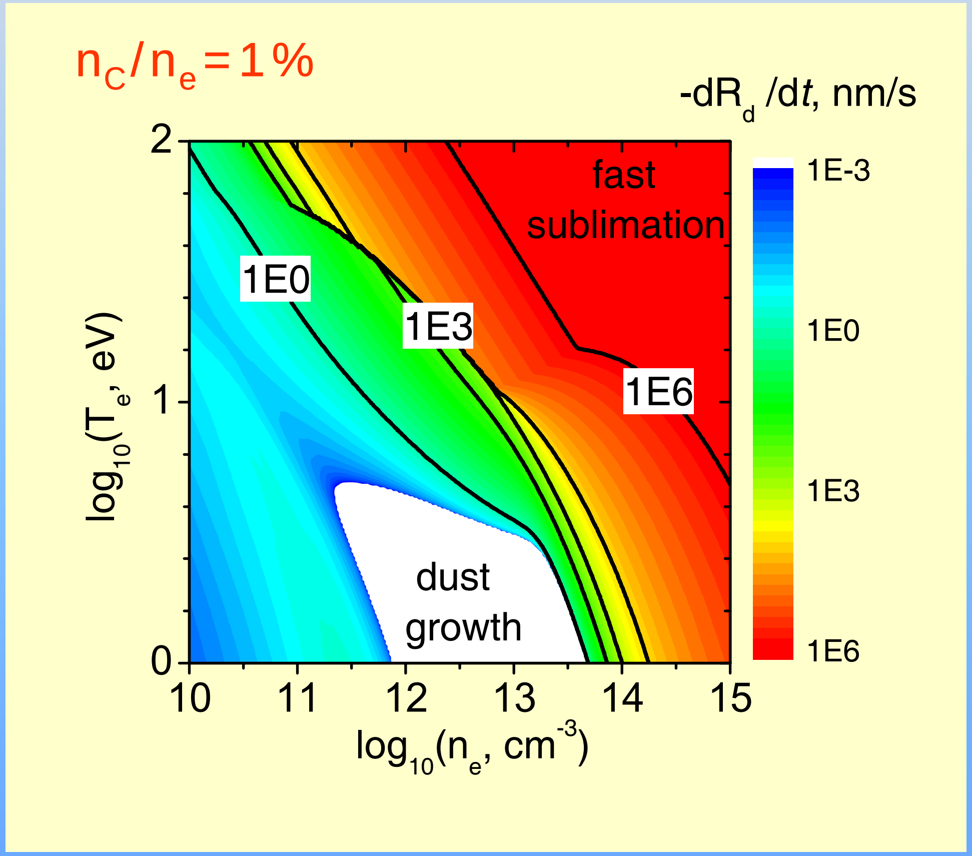
Modeling of dust transport

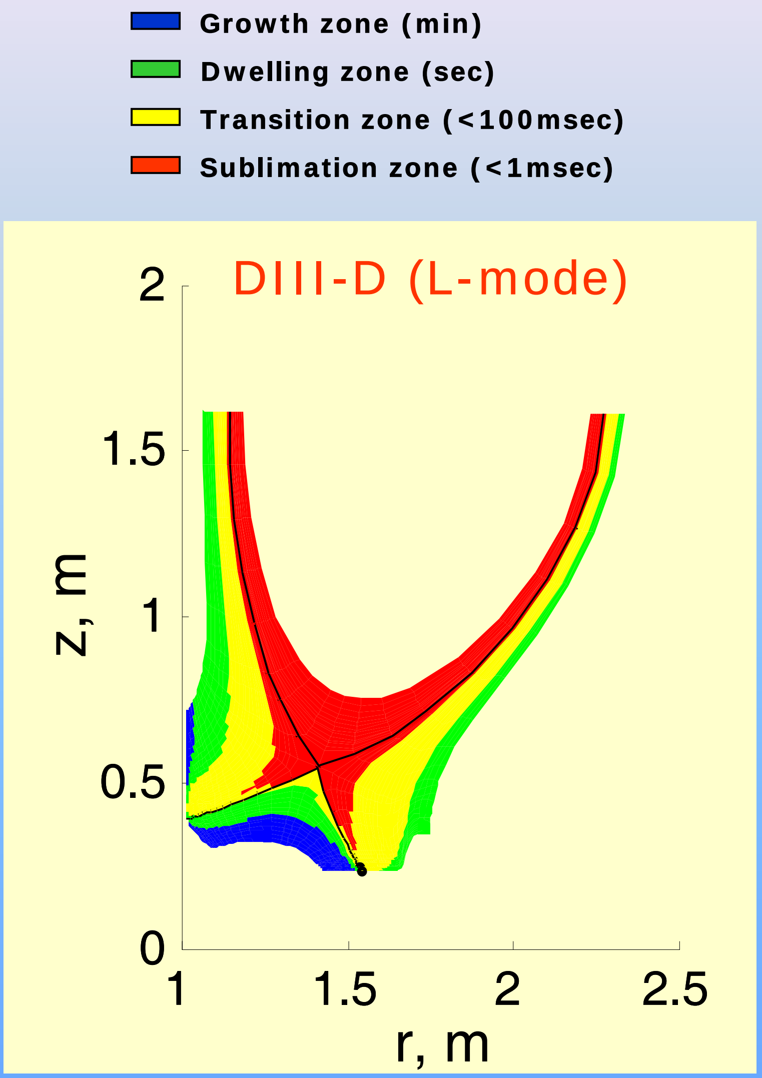
- The 3D Dust Transport in Tokamaks (DUSTT) code has been developed:
  - Curvilinear non-uniform mesh based on MHD equilibrium
  - Plasma, neutral and impurity parameters calculated by UEDGE code[3]
  - Tracking of dust trajectories in 3D with resulting force, current, energy flux, dust ablation dynamics and phase transitions, dust-surface and dust-turbulence collisions
  - Obtaining statistically averaged spatial profiles of dust density, radius, velocity, temparature etc. in tokamaks
  - Variety of dust materials can be simulated

[3] T.D. Rognlien, J.L. Milovich, M.E. Rensink, and G.D. Porter, *J. Nucl. Mater.* **196-198** (1992) 347

Carbon dust survival and growth

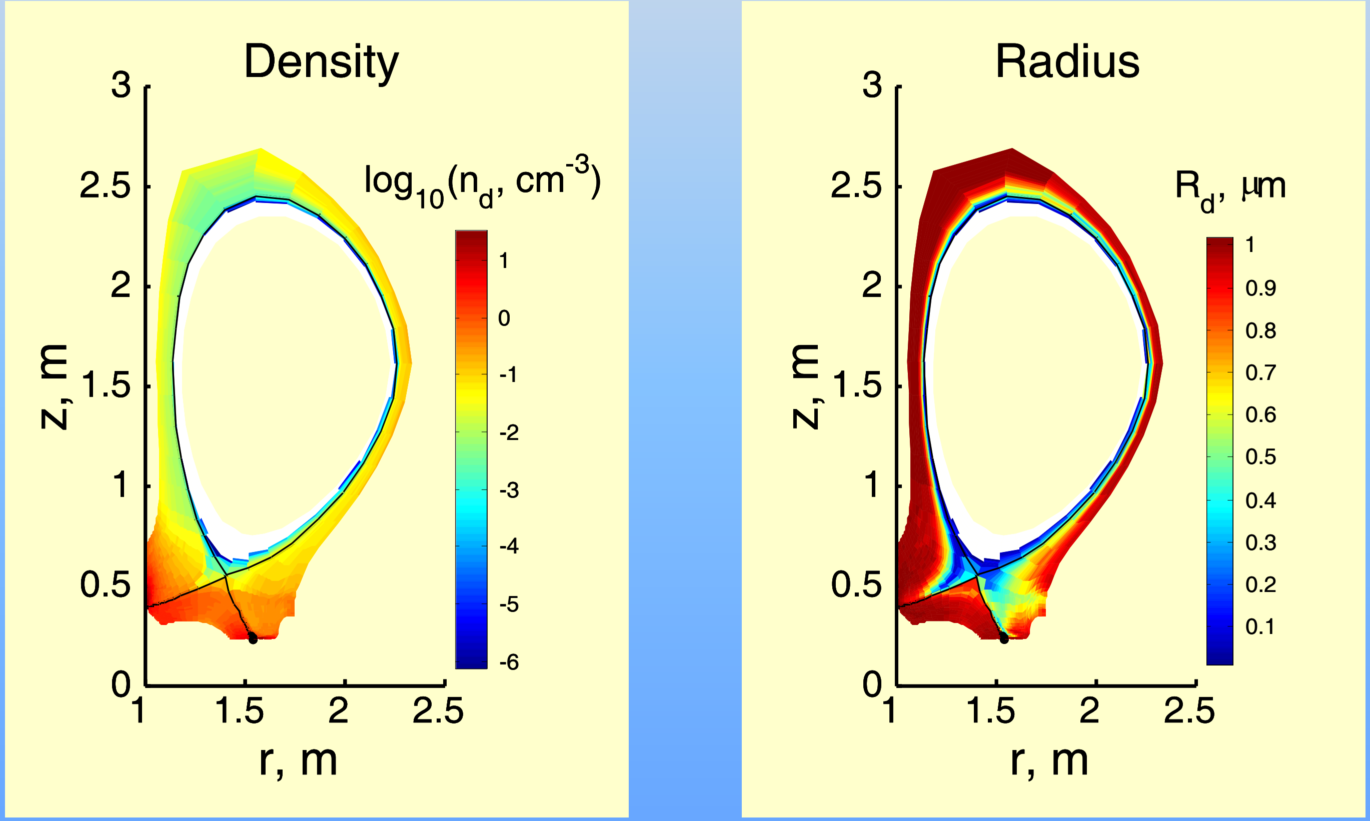
- Dust can grow in relatively cold contaminated plasma regions





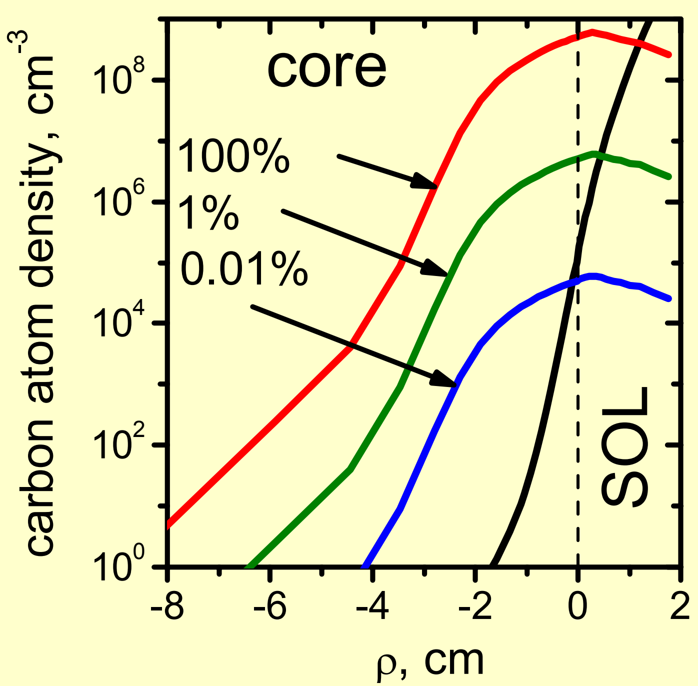
Simulated dust profiles in DIII-D

- **1 micron** carbon dust is launched from all plasma exposed surfaces
- **1%** of sputtered wall material is assumed to form dust locally



Dust impurity transport

- Dust can bring much more impurity atoms toward the separatrix than transport of neutrals

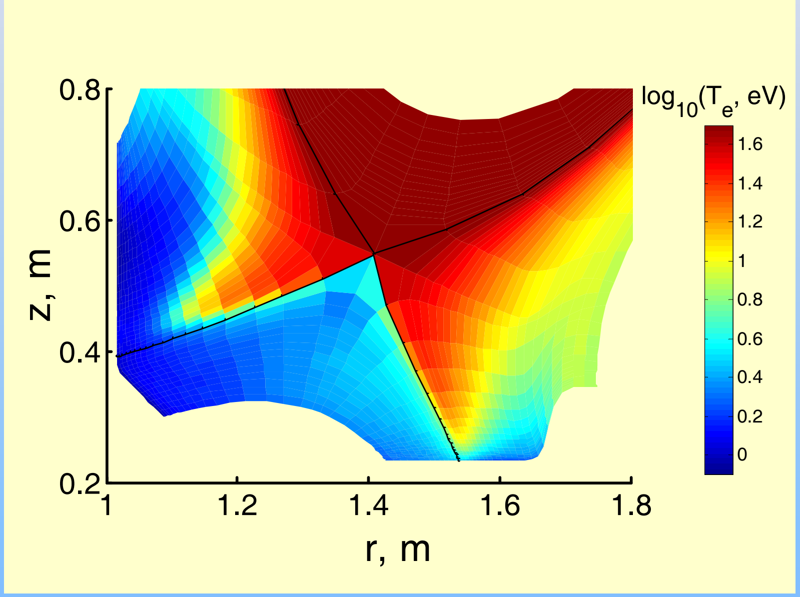


The density of carbon atoms ablated from dust at the separatrix is about the same as transported from the wall for **0.01%** of sputtered wall material converted to dust

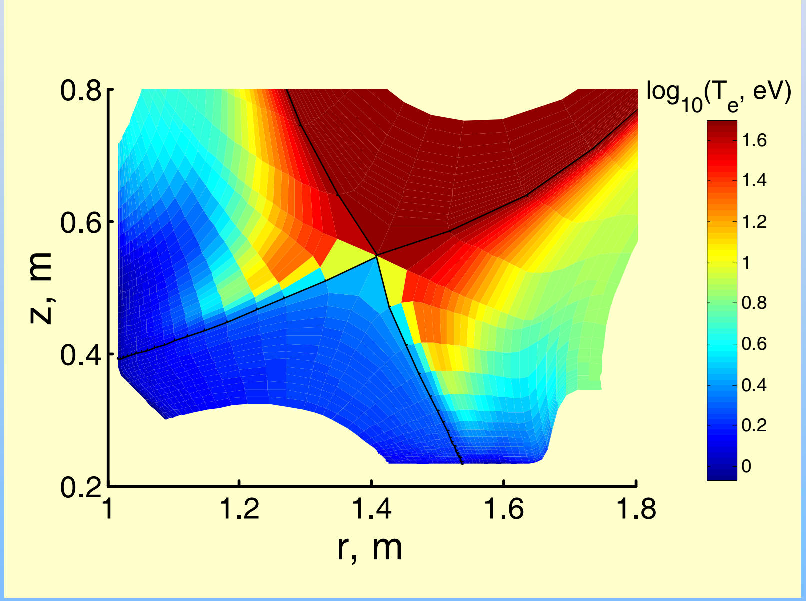
1% of the sputtered wall material in form of 1 micron dust brings **~$3.6 \cdot 10^{17}$ atoms/s** through the separatrix

Profiles of electron temperature in DIII-D divertor

No dust (0% of wall sputtering)



Dust (8% of wall sputtering)



- Dust can enhance radiation power loss and force divertor detachment
- Cooling of the peripheral plasma due to detachment may further increase dust penetration toward the core

Conclusions

- The DUSTT code was developed allowing to simulate dynamics and transport of dust particles and obtain spatial dust profiles in tokamaks
- Dust survivability conditions were analyzed for range of tokamak plasmas. It was shown that dust can grow in relatively cold (T_e<10eV) contaminated plasma regions and penetrate deeply toward the separatrix
- Dust transport can cause much deeper penetration of impurity neutrals toward the core than transport of atoms sputtered from walls
- Dust may enhance radiation power loss and force divertor detachment