Coupled modeling of dust and edge plasma transport in NSTX

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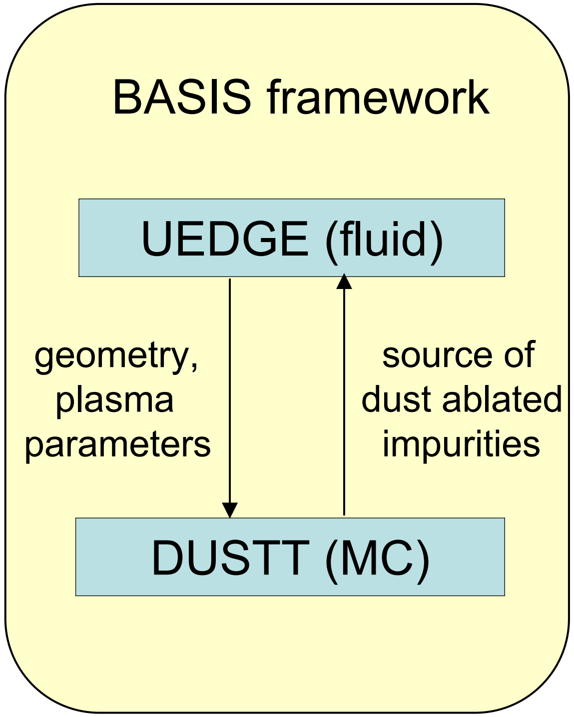
DUSTT/UEDGE coupled codes

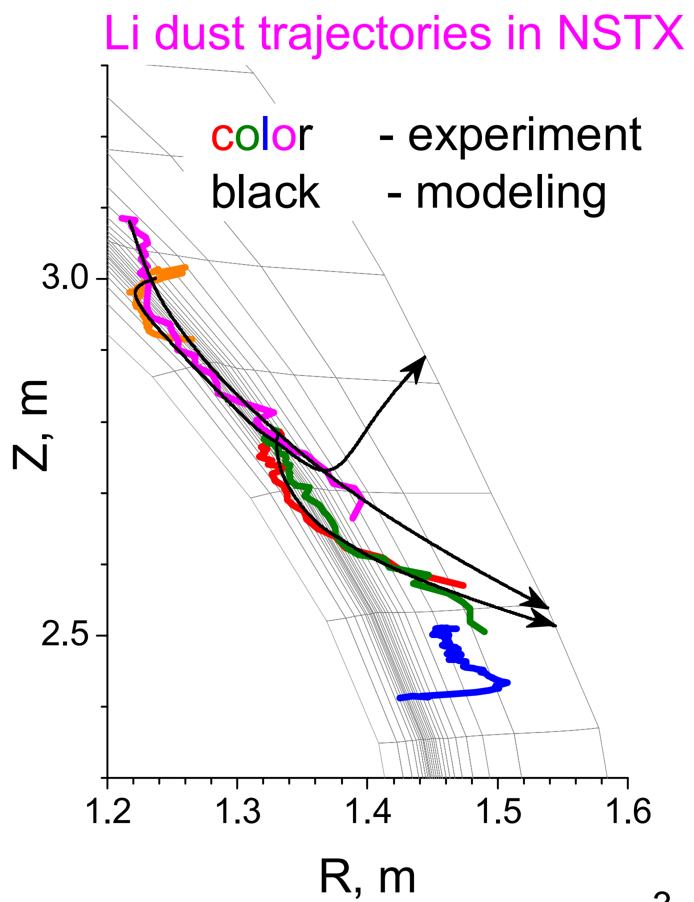
- DUSTT solves coupled dust dynamics equations including temporal evolution of dust charge, temperature, mass, and radiation
- The DUSTT code operates with plasma parameters simulated with multi-fluid edge plasma transport code UEDGE
- The statistical averaging over an ensemble of test dust particles is used to obtain dust profiles and impurity source from ablated dust
- DUSTT/UEDGE are iteratively coupled for self-consistent modeling of dust impact on edge plasmas
- Present modeling is limited to 2D toroidally symmetrical plasmas



DUSTT code validation

- The experimental trajectories of 22μm Li dust measured on NSTX are compared with the DUSTT simulated ones

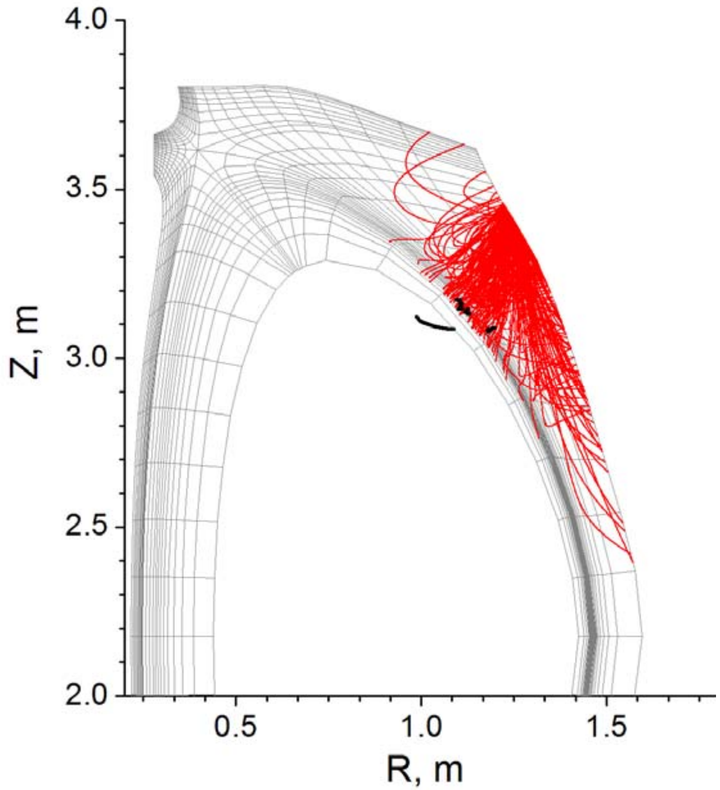
Experiment	Modeling
dust speeds ~10-100m/s	matched for dust sizes 10-20μm
Li dust lifetime ~10ms, some grains can reach separatrix	reproduced with introduction of heat flux reduction factor (~50) approximating dust shielding by ablation cloud
dust grains with opposite toroidal flight directions are observed, some grains change toroidal direction (curvature ~few cm)	shear plasma flows in SOL with Mach~1 can cause change in toroidal flight direction in near separatrix regions



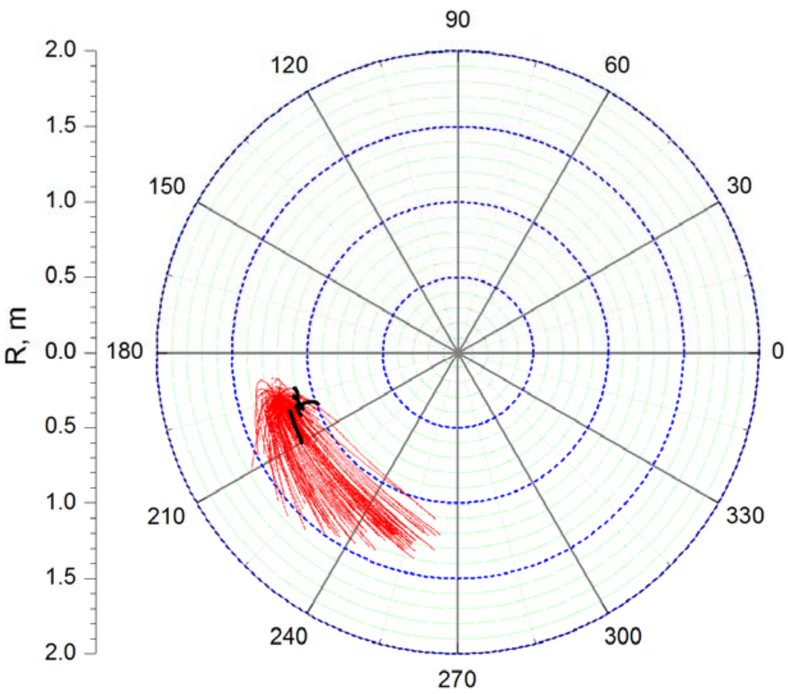
Tungsten dust modeling

- Trajectories of tungsten dust of radius 2.5μm injected in NSTX are modeled with DUSTT code
- The dust life time, penetration depth and general dynamics of observed dust trajectories are reproduced well with the modeling using tungsten dust shielding factor ~20

Poloidal view



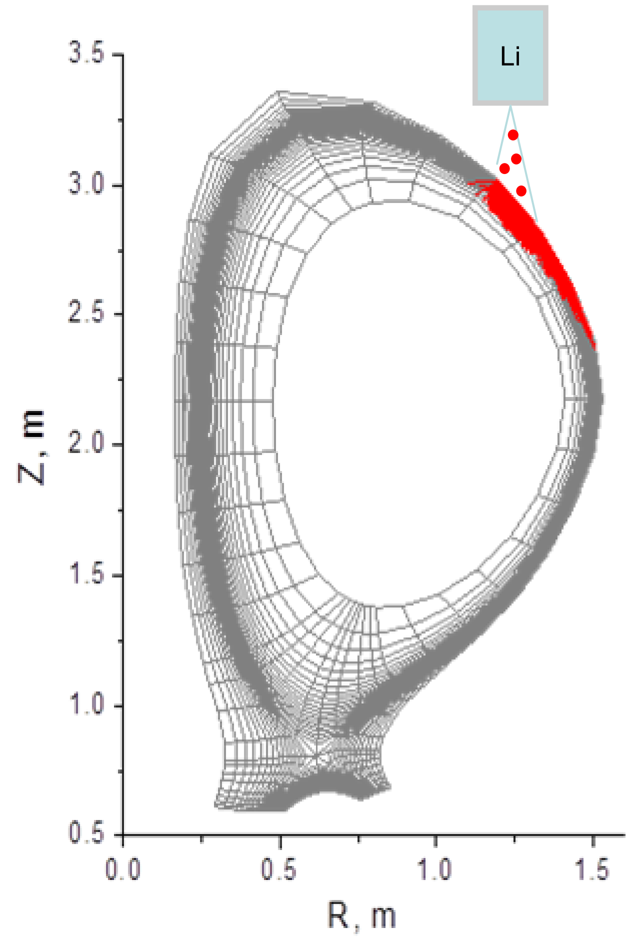
Top view



Modeling of Li dust injection

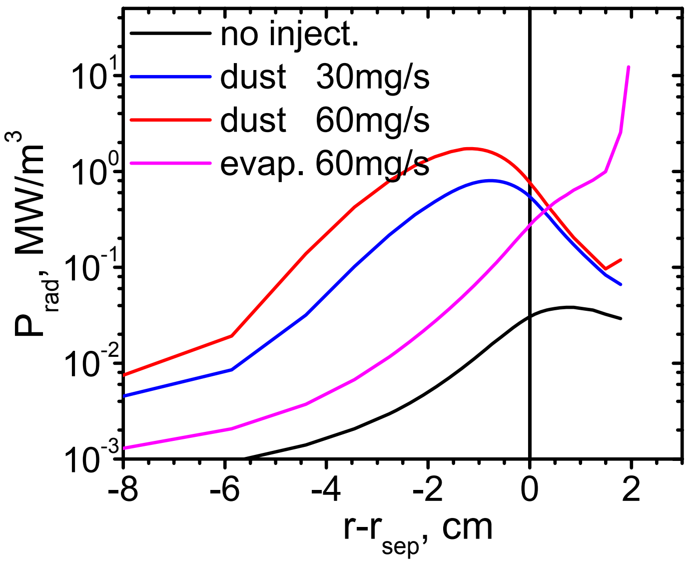
- NSTX L-mode LSN configuration is modeled
- ~20μm radius Li dust is injected in the upper outer poloidal position
- Dust hit the plasma with average speed ~5m/s and with shifted downward cosine angle distribution relative to vertical direction
- Divertor plates are assumed to be covered with Li film with recycling coefficients set at 0.8 for D and at 0.5 for Li (low-recycling regime)
- Core D^+ density is fixed at $5.1 \times 10^{13} cm^{-3}$
- Core heating power 3MW
- Plasma transport coefficient are fixed

Configuration of modeled Li dust injection

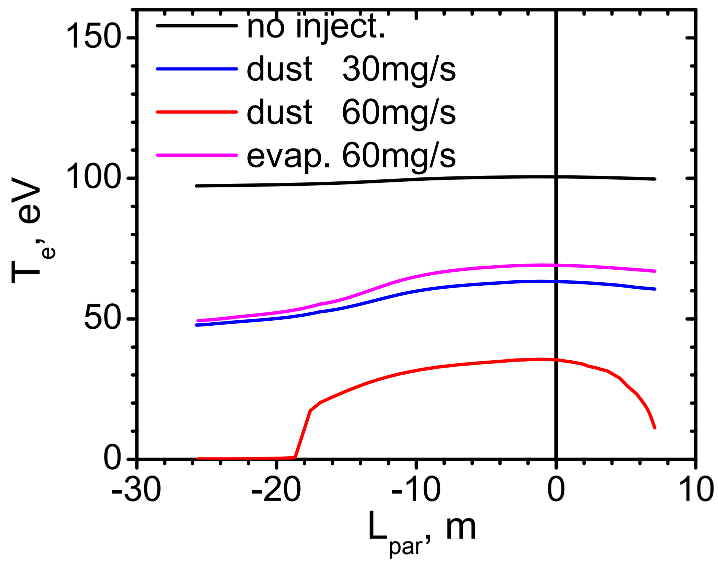


Dust originated impurities

Impurity radiation



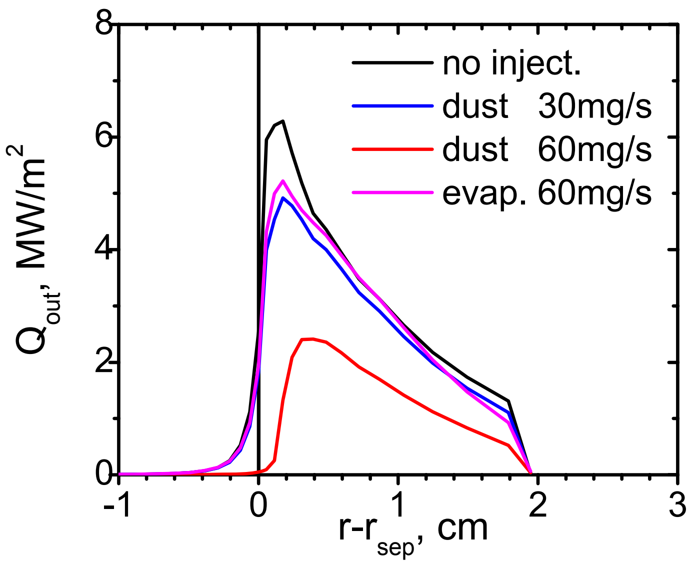
Electron temperature



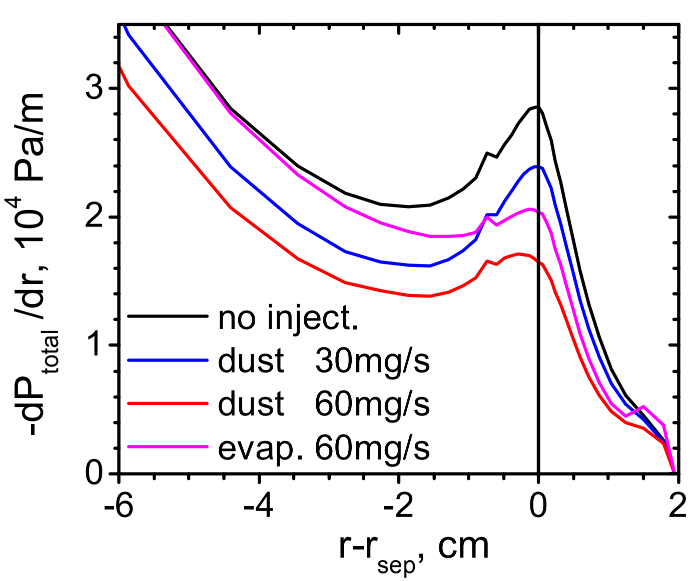
- Dust injection with rates ~ a few10mg/s can significantly increase impurity concentration and radiation power losses in the edge
- Gaseous impurities do not penetrate as deep into the plasma as the dust does
- Complete plasma detachment in the inner divertor at ~60mg/s Li dust injection rates is developed

Impact of Li dust on edge

Divertor heat load profiles



Radial pressure gradient



- The power load to the outer divertor plate is reduced
- Radial plasma pressure gradient is substantially (up to ~40%) reduced in the edge
- Peeling/ballooning stability of the edge plasma may be improved, suppressing anomalous transport and ELM formation

Summary

- The validation of the coupled DUSTT/UEDGE code has been performed using 3D dust trajectories measured on NSTX
- It has been shown that dust injection with rates ~ several 10mg/s in modern tokamaks can cause significant effects on edge plasma parameters, transport and stability
- Injected gaseous impurity do not penetrate into plasma as deep as the dust does
- Modeling of tungsten dust injection in NSTX is in progress
- Modeling of different dust injection scenarios for evaluation of possibility of divertor heat load mitigation in NSTX-U is planned
- Further code development (including plasma recombination on dust surface, intermittent phenomena) and validation for different dust materials is required