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Title: Using LGI experiments to achieve better understanding of pedestal-edge coupling in NSTX-U

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Using LGI experiments

To achieve better understanding of pedestal-edge coupling in NSTX-U

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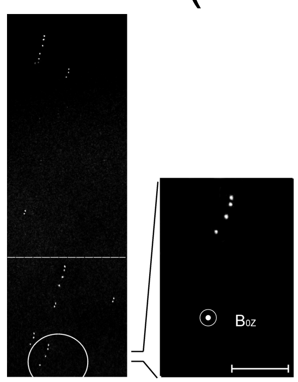
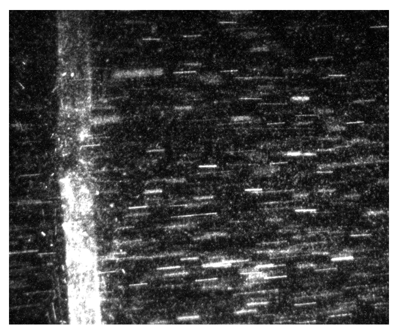
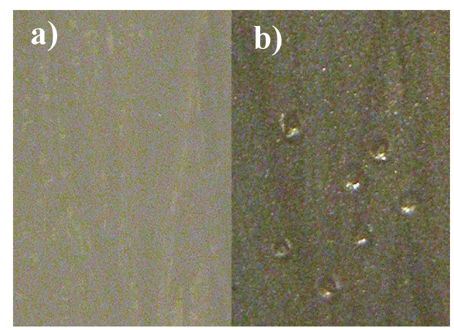
NSTX collaboration meeting, PPPL

(Feb. 22-27, 2015)







Abstract

Latest advances in granule or dust injection technologies, fast and high-resolution imaging, together with micro-/nano-structured material fabrication, provide new opportunities to examine plasma-material interaction (PMI) in magnetic fusion environment. Some of our previous work in these areas is summarized. The upcoming LGI experiments in NSTX-U will shed new light on granular matter transport in the pedestal-edge region. In addition to particle control, these results can also be used for code validation and achieving better understanding of pedestal-edge coupling in fusion plasmas in both NSTX-U and others.

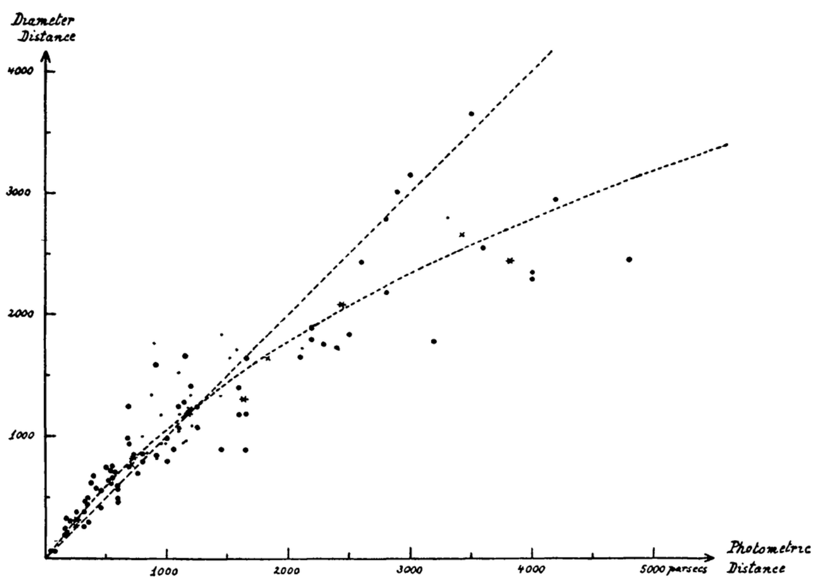
Outline

- **Intro & previous work**
  - Dust transport studies
  - hypervelocity dust injection for fusion energy
  - In-situ dust cloud imaging (micron & larger grains)
- **Opportunities with LGI experiments**
  - Imaging + Injector + Materials (dust/granules, wall)
  - The gap between observations & understanding
  - Better (high spatial resolution, non-invasive) characterization of edge/pedestal plasmas

Dust as ‘surprises’ in many fields → Interstellar dust

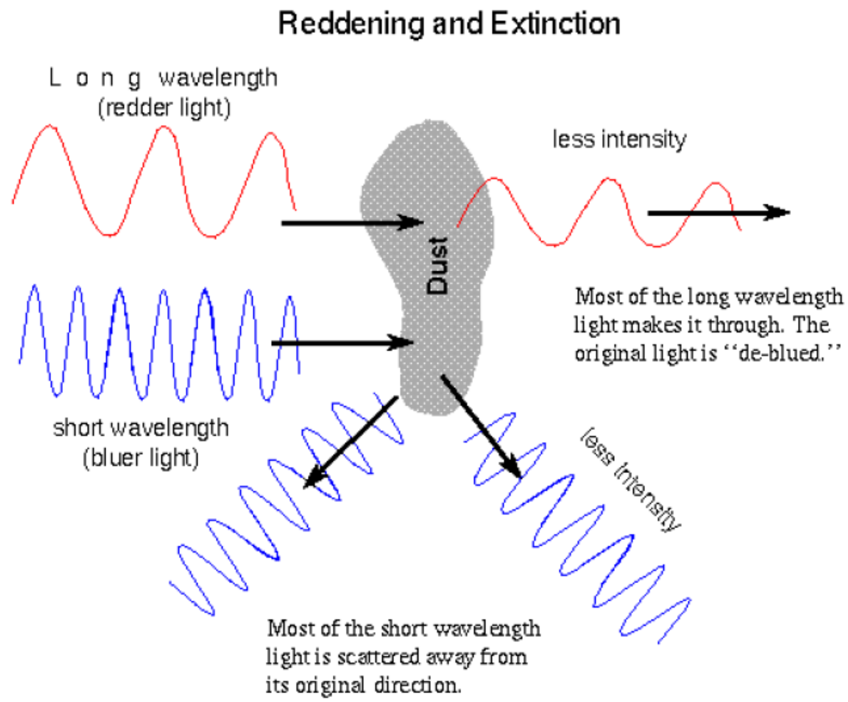
Robert J. Trumpler (1930)

Diameter distance



Photometric distance (parsec)

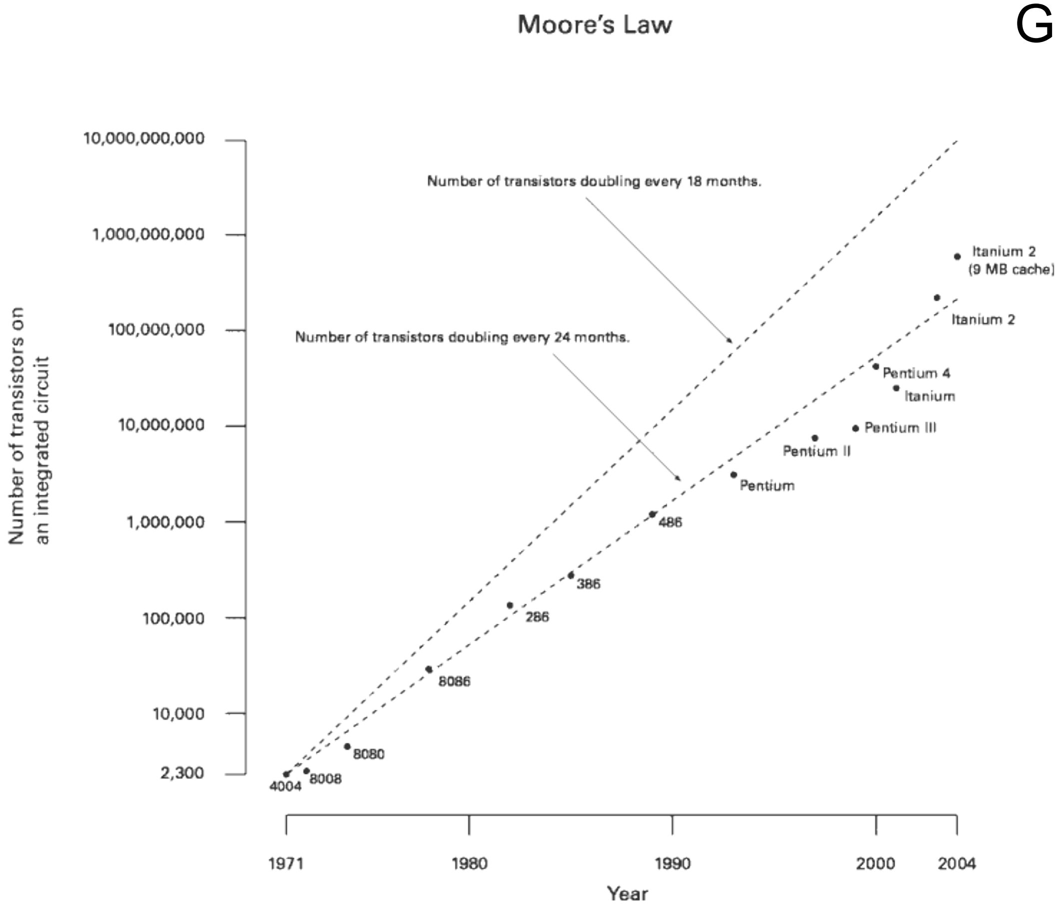
1 parsec = 2.06 ×10^5 AU = 3.26 ly



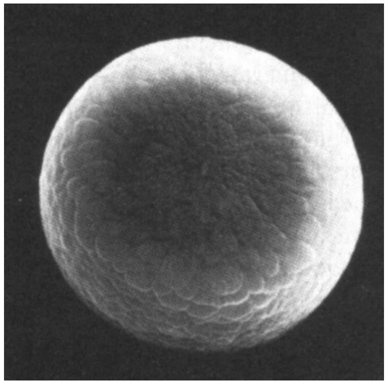
Rayleigh scattering

$$I_{scat.} \propto \lambda^{-4}$$

Semiconductor fabrication



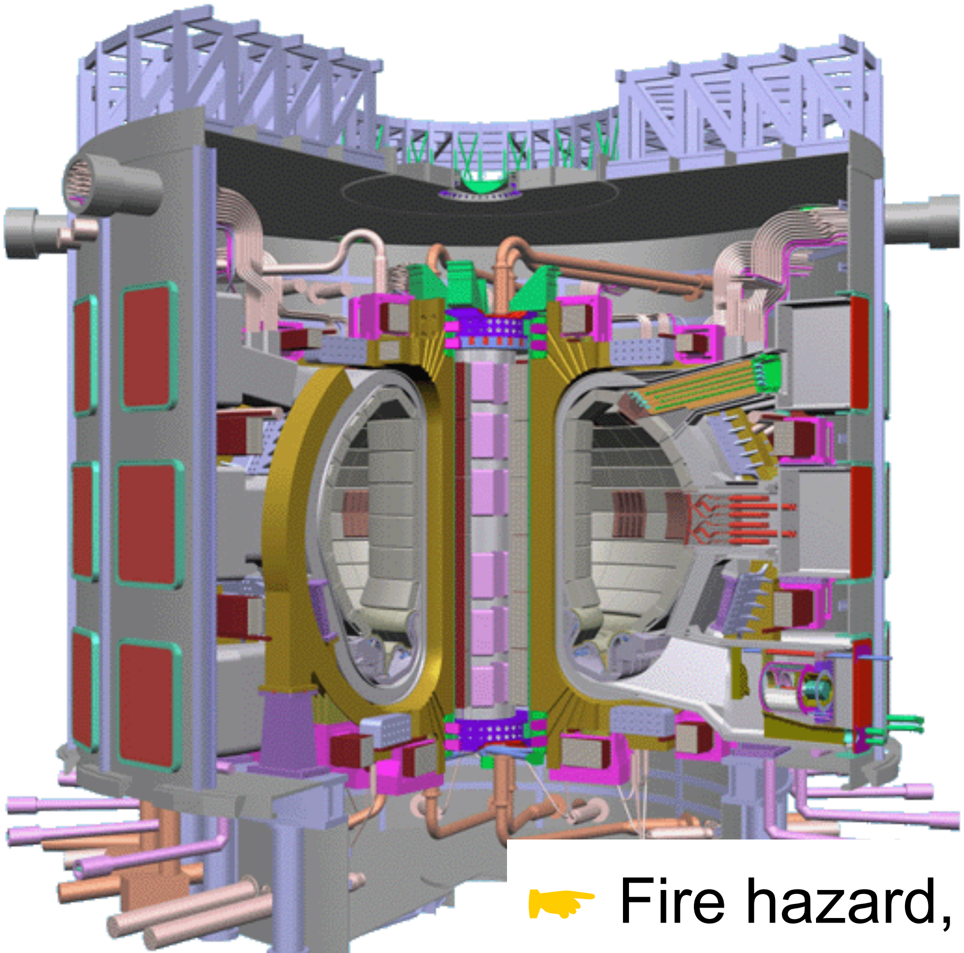
G. S. Selwyn, *et al*. JVST (1989)

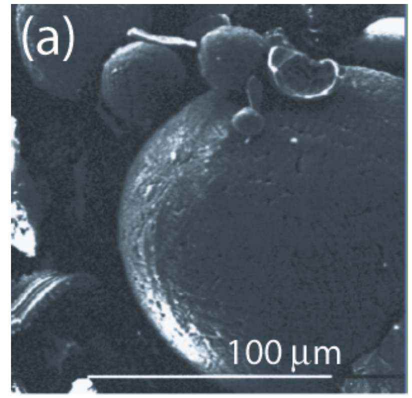


In-situ production of dust by processing plasma observed and analyzed.

☛ clean room is not a solution

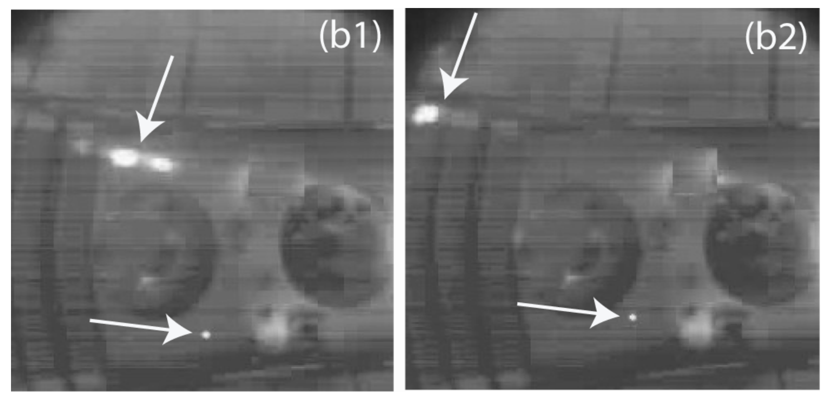
Dust in magnetic fusion: “seems all bad”





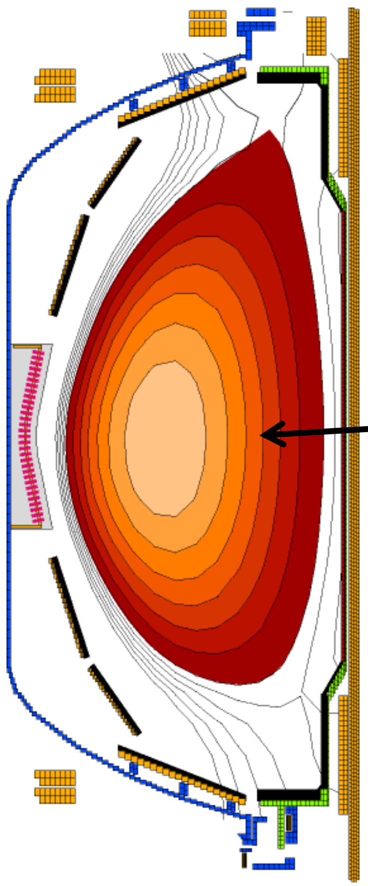
Winter, PoP (2000)

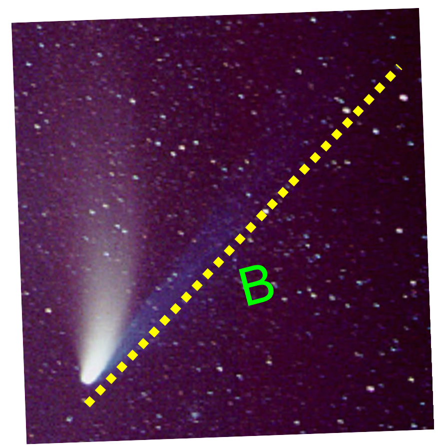
Roquemore et al. (2006)



- Fire hazard, radioactive material transport
- Radiative cooling of fusion reactor

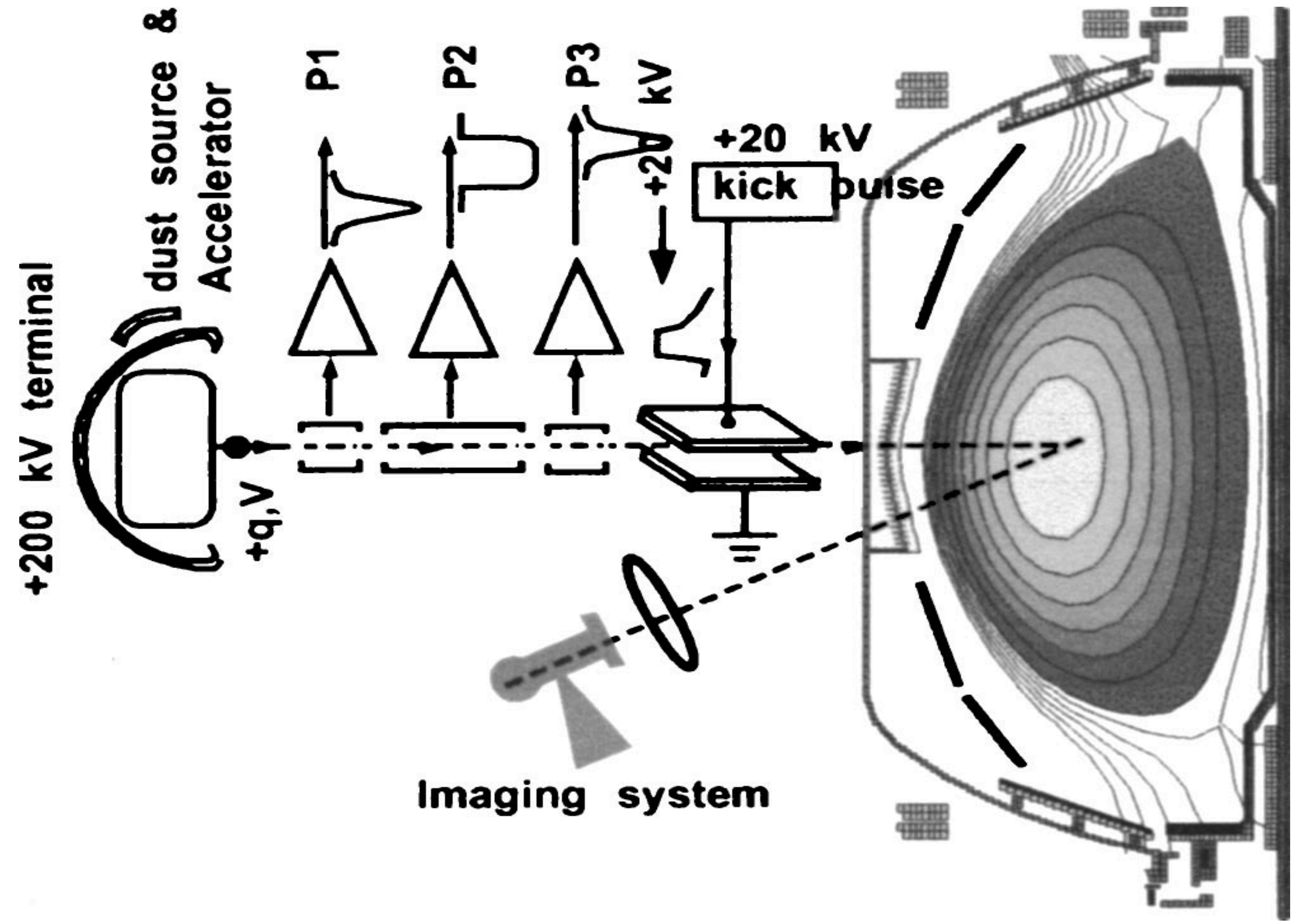
Hypervelocity dust injection



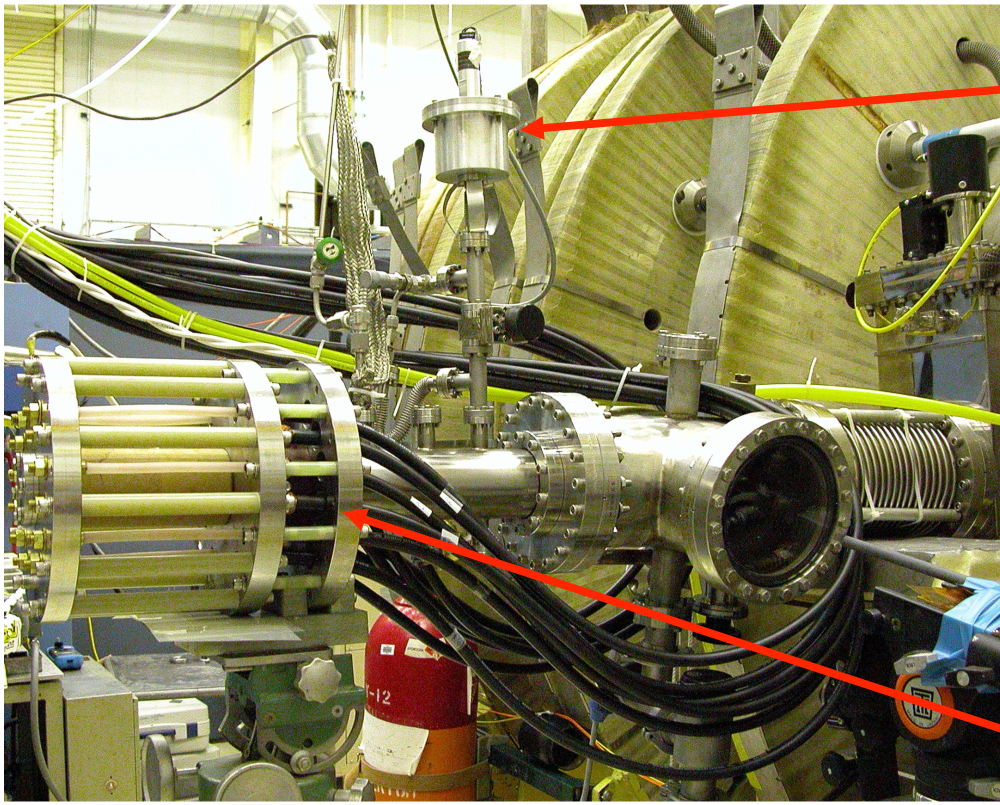


RSI (2003), RSI (2004)

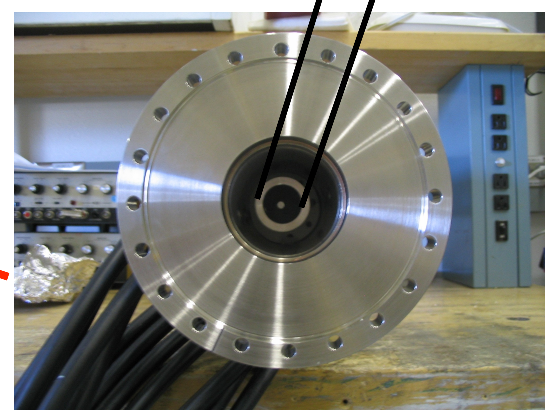
The electrostatic approach



The coaxial plasma accelerator

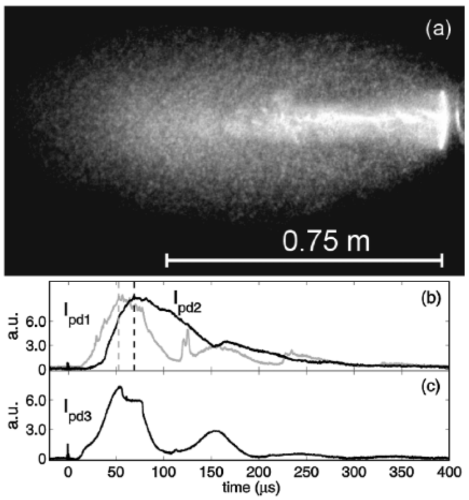


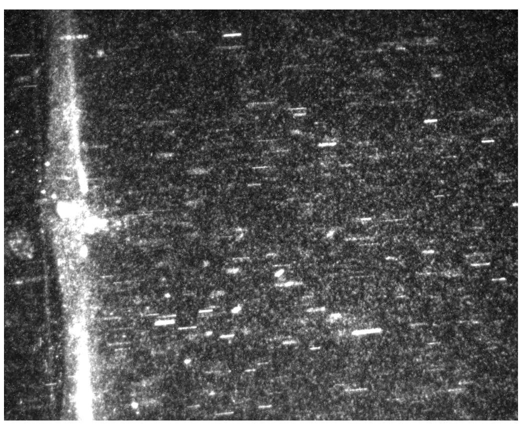
ϕ 4.4 cm

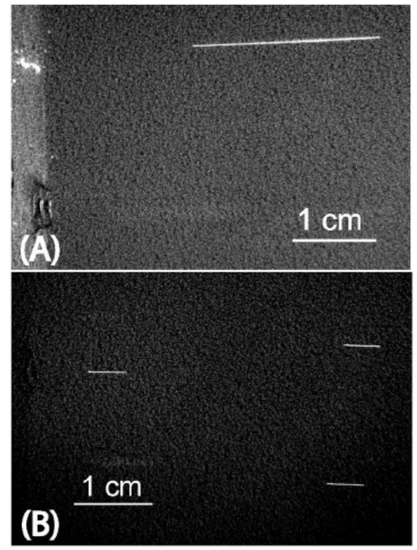


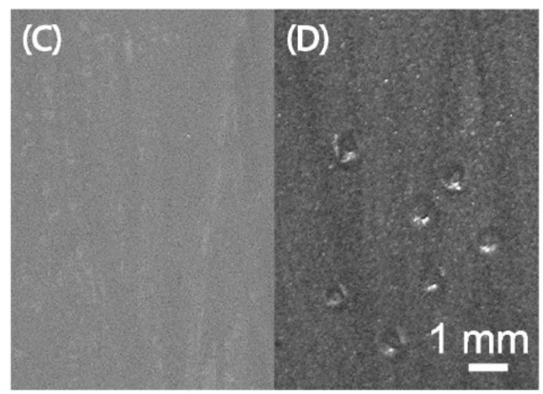
Ticos *et al*. RSI (2006)

Hypervelocity dust injection and in-situ measurement



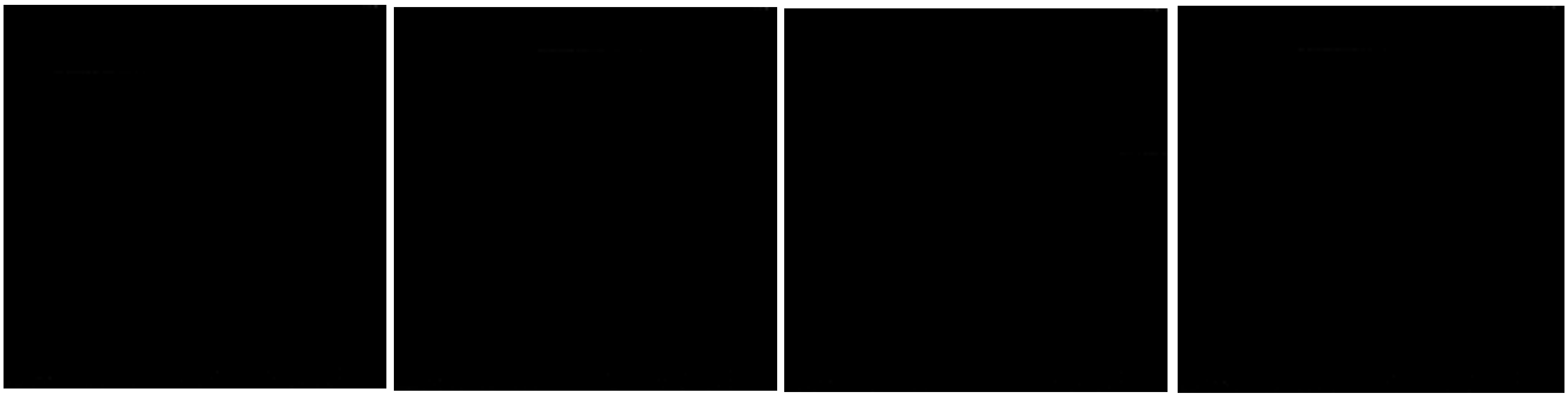






Z. Wang *et al*, PoP **14** (2007) 103701

Studying of plasma flows

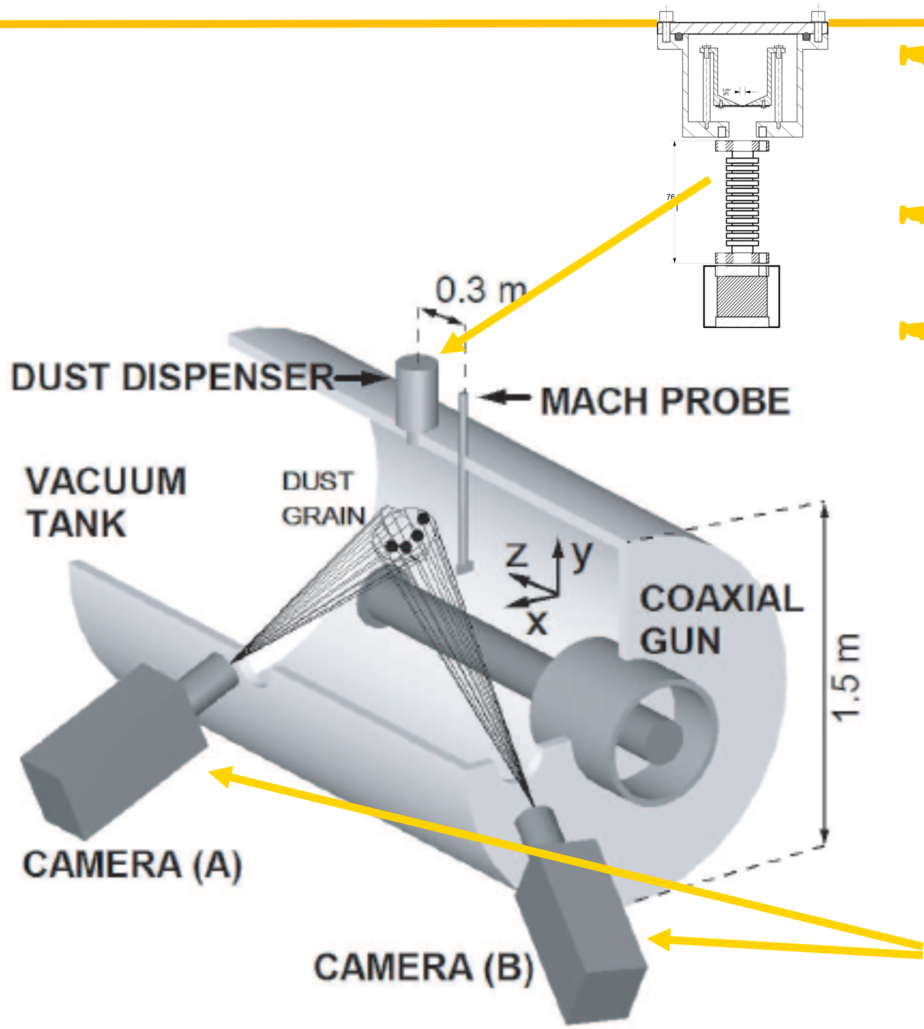


0 (G) 100 300 -300

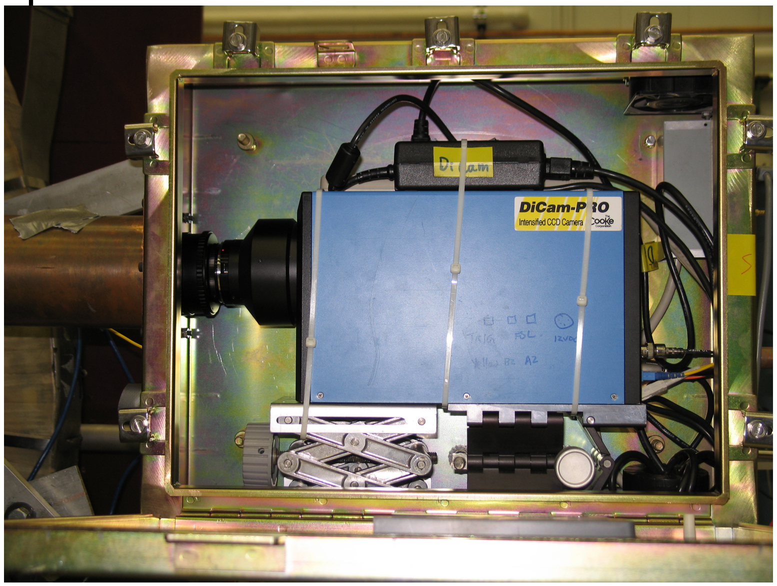
Bz ⊙ ⊗

- rotation direction is determined by J ×B torque

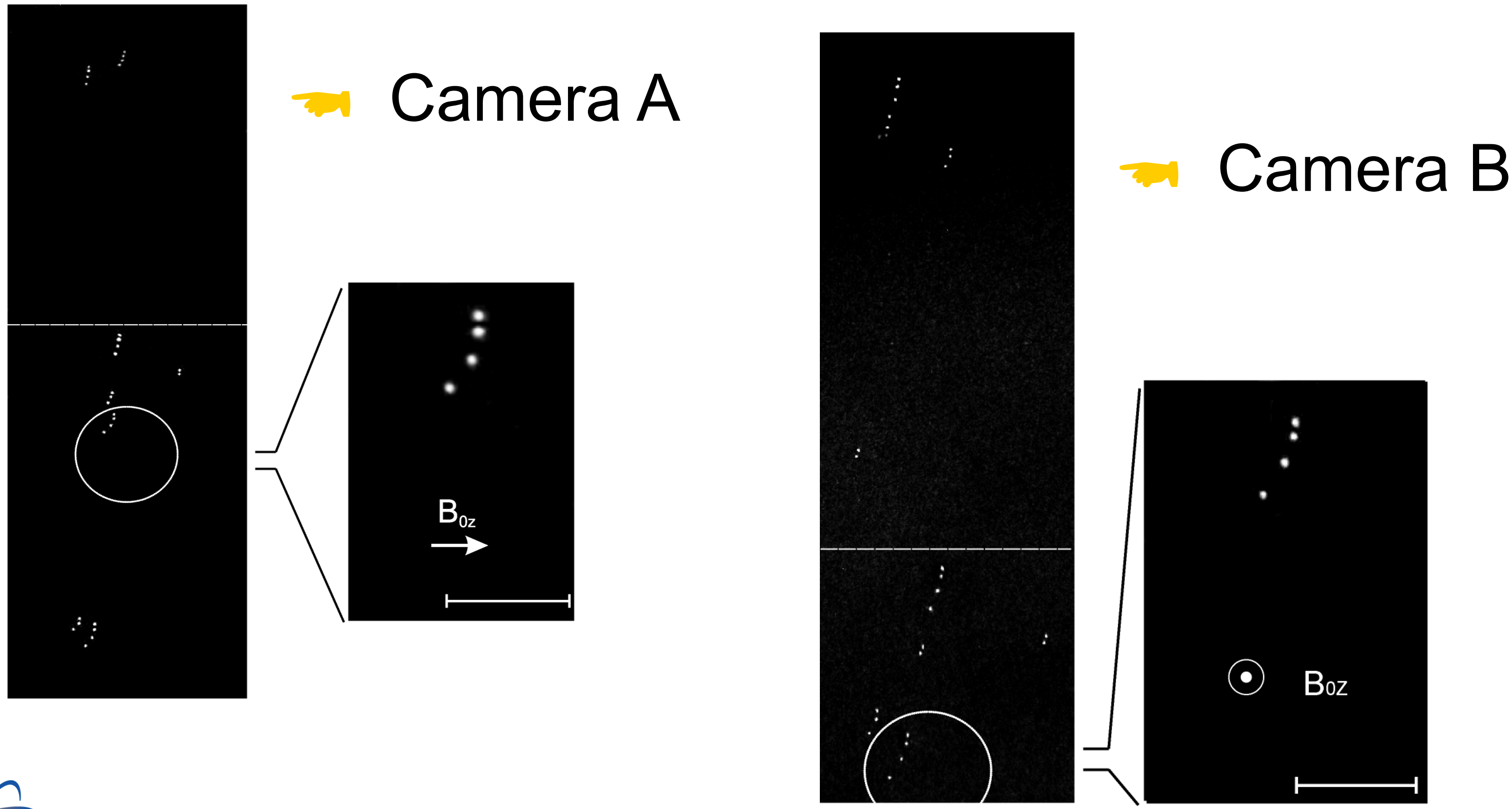
Using dust for flow measurements



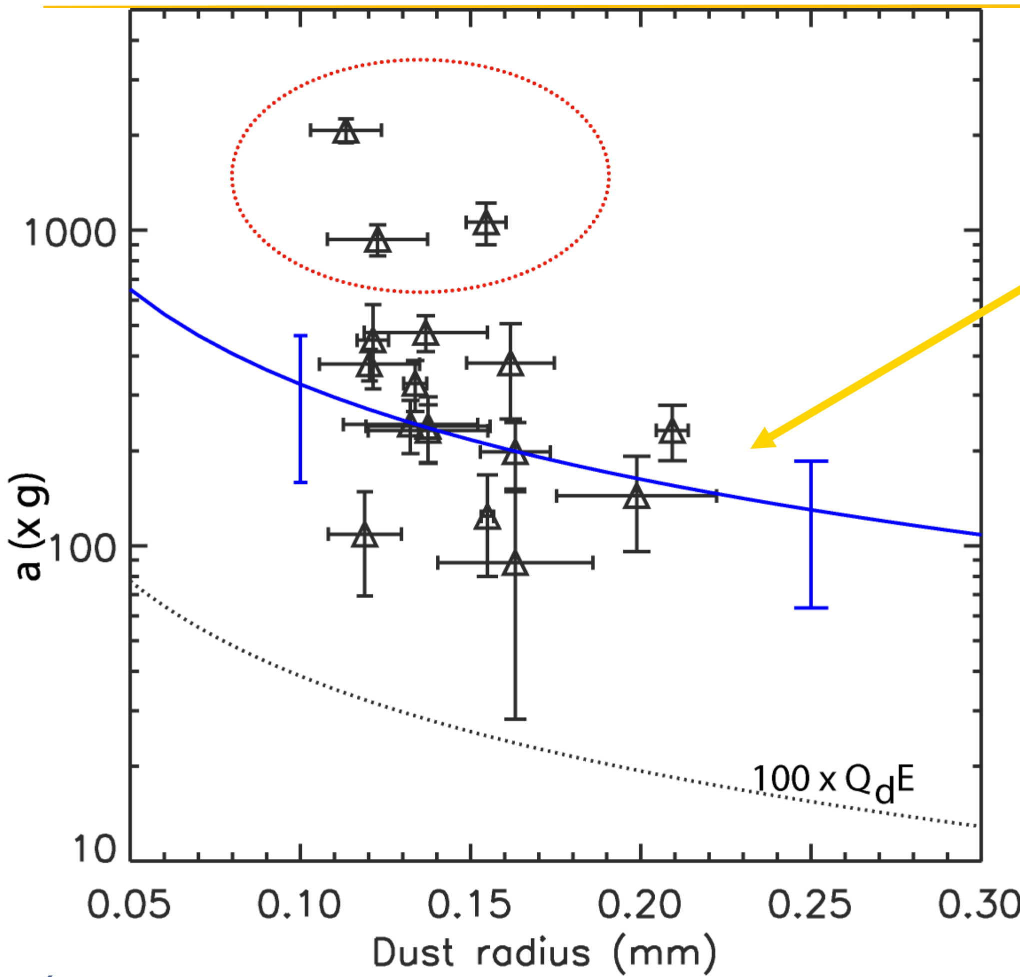
- The falling time (0.1-0.2 s) >> $\tau_{pl.}$ (~ 10 ms)
- Dust were pre-dropped before the plasma shot/discharge,
- The dust grains are ~ *at rest* relative to the rapid moving plasma.



Dust trajectories recorded



Dust motion is dominated by 'impact' drag



$$\mathbf{F}_{pf} = 2\pi r_d^2 k_B T_i n_i \xi \mathbf{w}$$

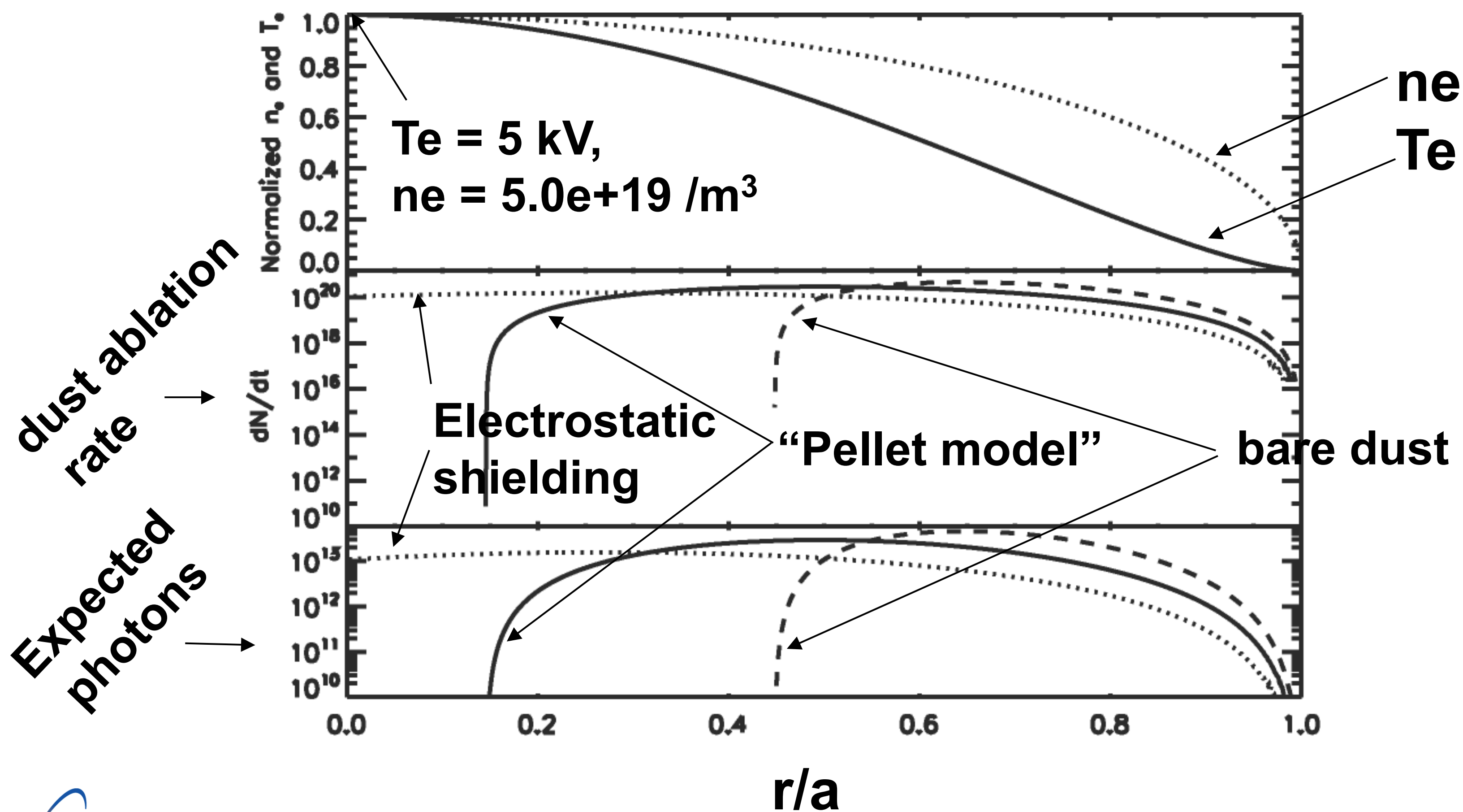
- other forces are small

Dust can become a new technique for plasma flow

R&D opportunities

- **Granule/dust –plasma interactions**
  - Fundamental physics of granule/dust – high-temperature plasma interactions
  - Safety, hazards (code validation)
  - Edge/pedestal plasmas (ELMs pacing, disruption mitigation)
- **Pedestal-edge coupling**
  - High spatial-temporal measurement
  - First wall (material) development
- **Injector technology + micro/nano-fabrication**
  - Tailored material properties
  - Tailored injection conditions
- **Imaging technology**
  - Real time particle tracking
  - High spatial and temporal resolutions

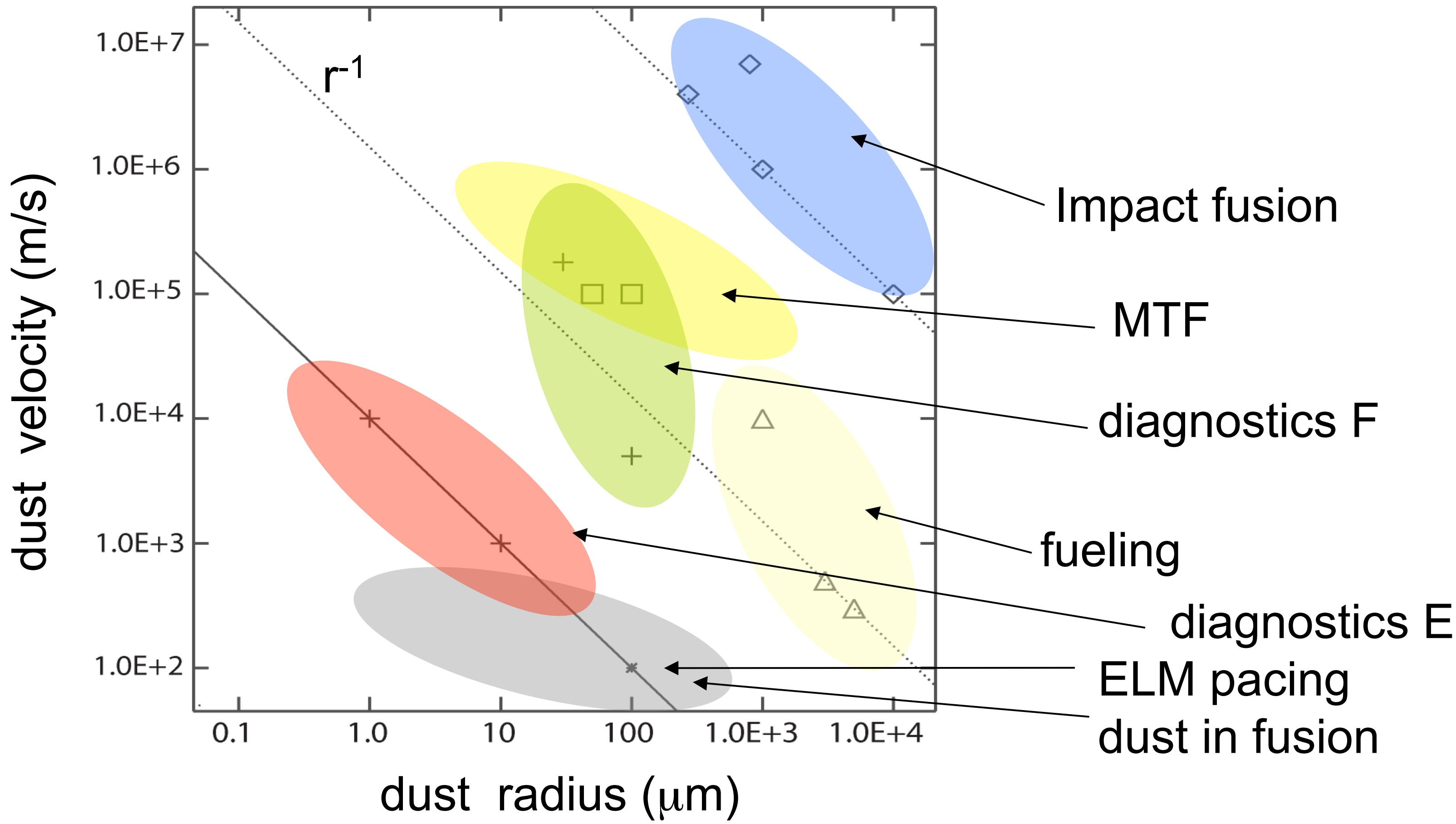
Transport varies significantly with models



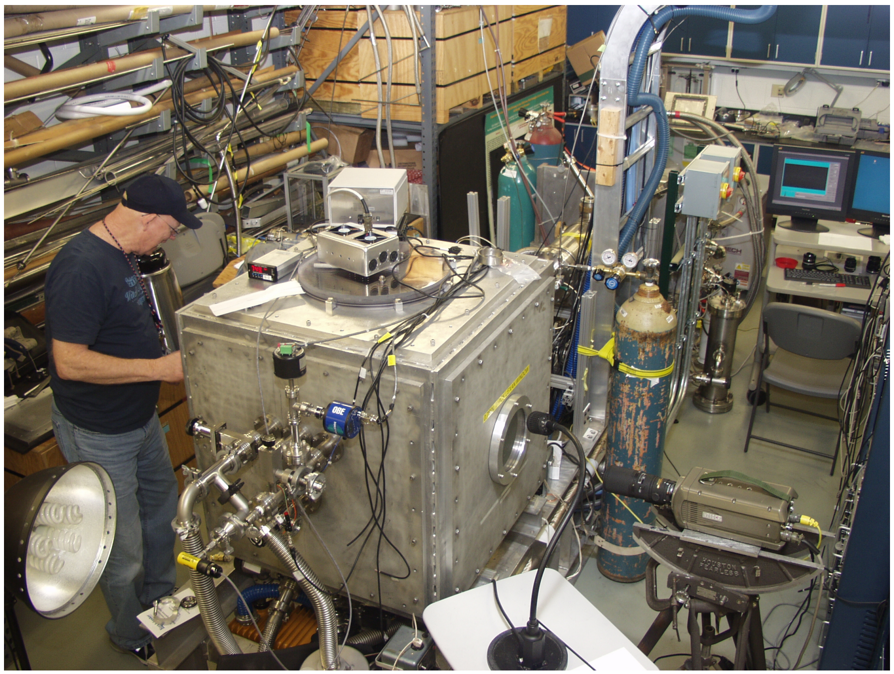
Carbon dust, 25 μm, 10 km/s

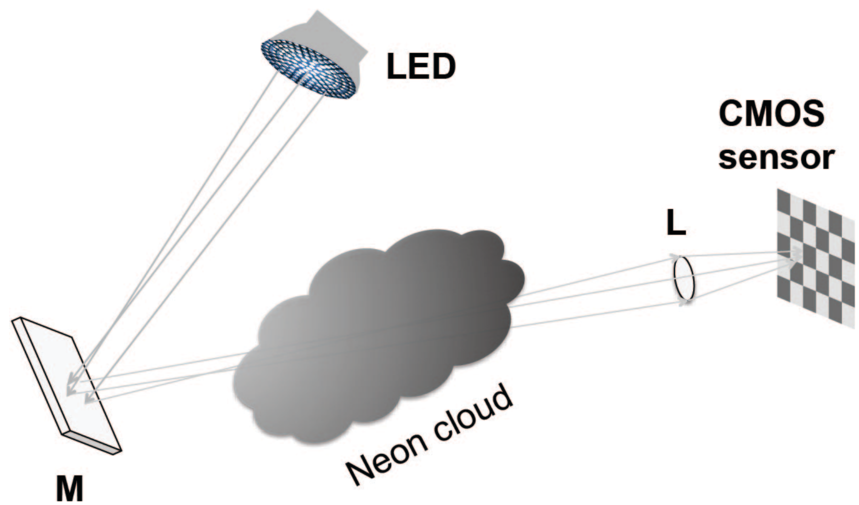
Injector technology roadmap

Z. Wang *et al*, AIP Conf. Proc. **1041** (2008) 135

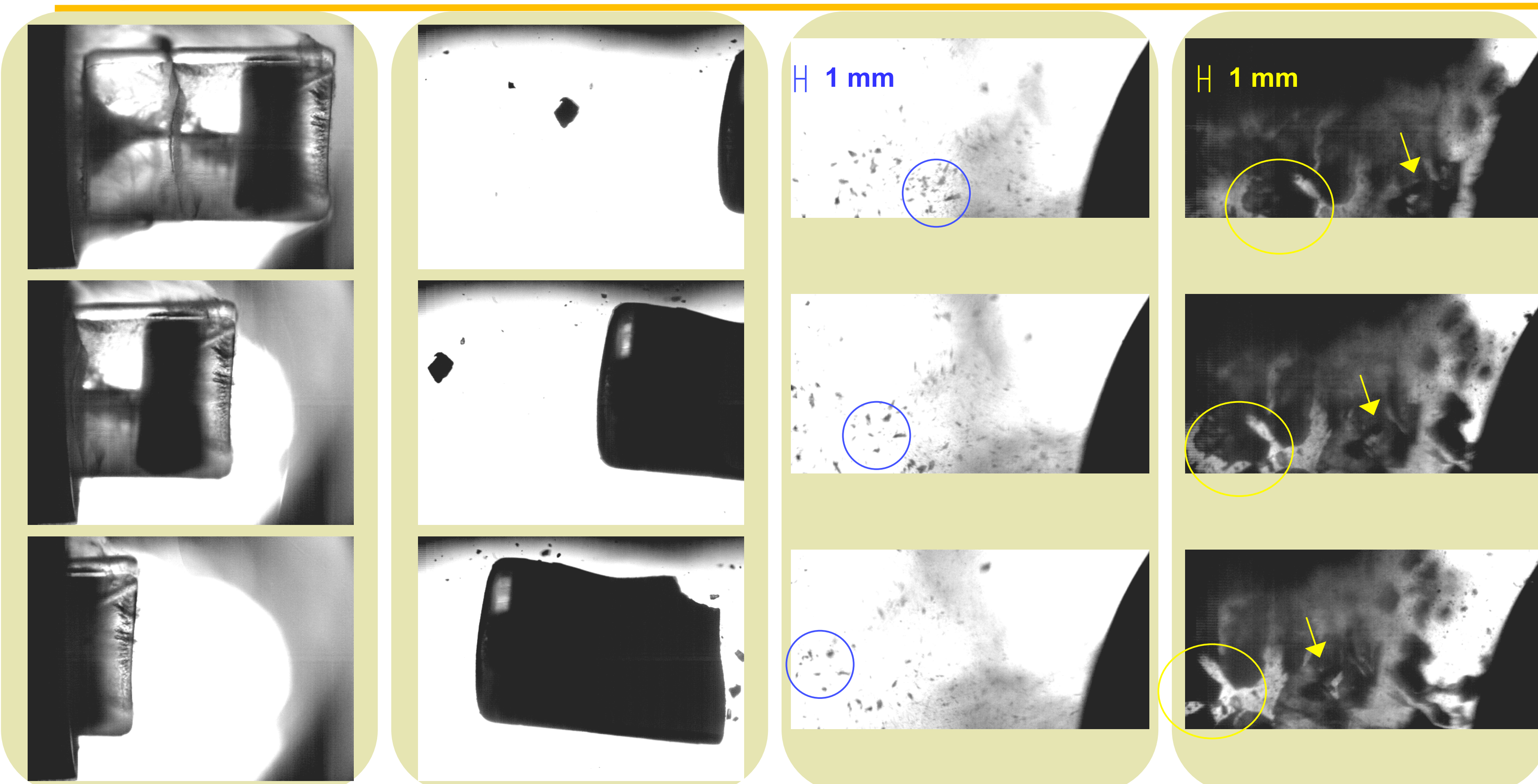


High-speed tracking of granular matter (1)



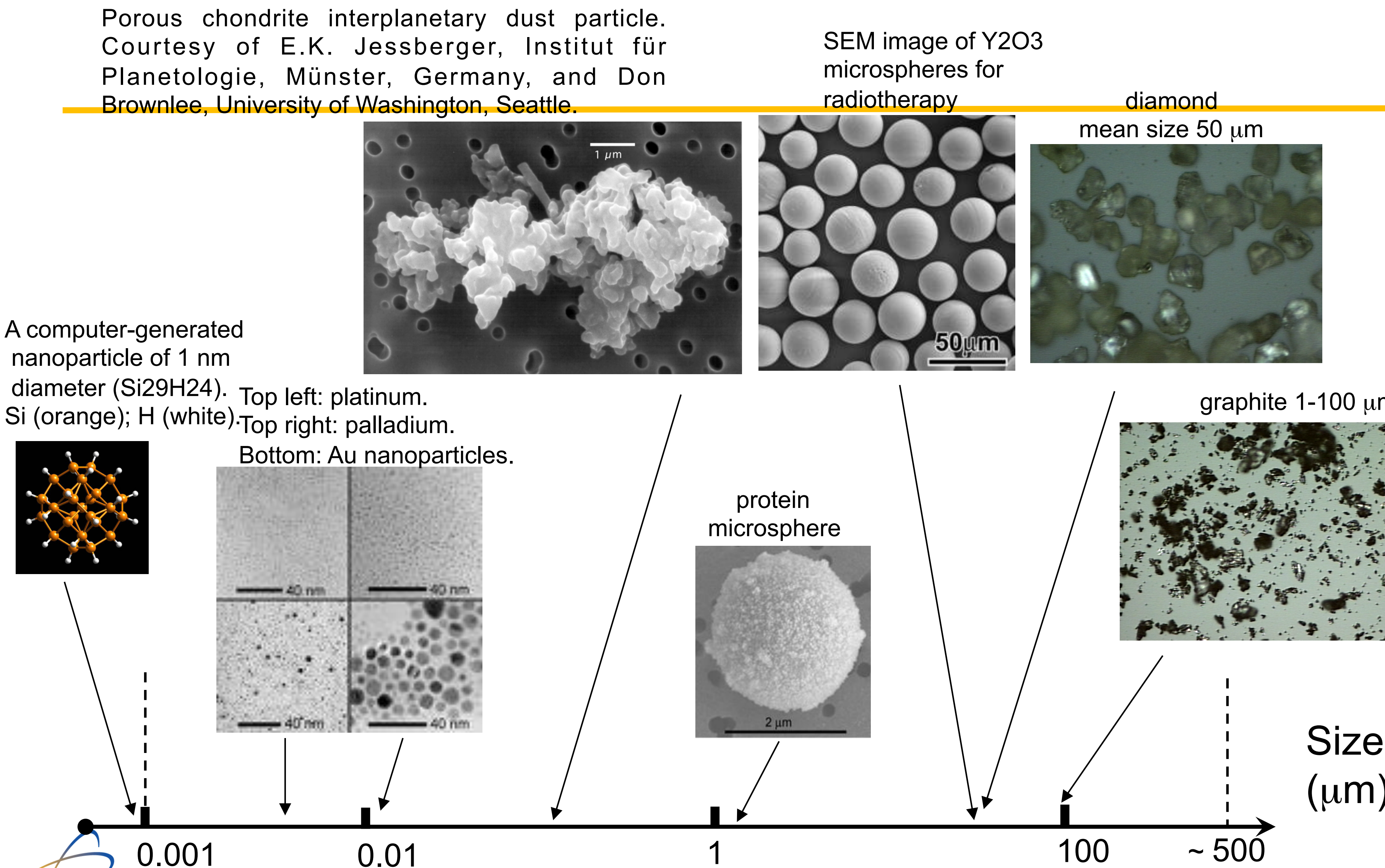


High-speed tracking of granular matter (2)



V=310 m/s V=220 m/s V=276 ± 30 m/s V=223 ± 8 m/s

Tailored material properties



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