Experimental Measurement of Sub-micron Ejecta from Hypervelocity Impact into Meteorites

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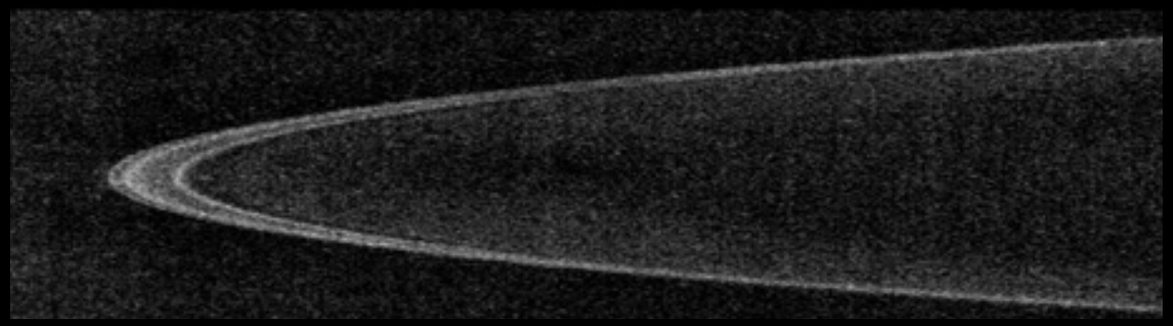
Throop *et al*, LPSC 2015, #46.2258



Dusty Jovian / Saturnian Rings

Problem:
The Solar System has large quantities of sub-micron dust in planetary rings and the zodiacal cloud, presumed to be created by hypervelocity impacts into silicates. ***But virtually no laboratory work has ever measured the production function in this regime directly, and nearly all models for this dust's distribution and abundance extrapolate from larger sizes.***

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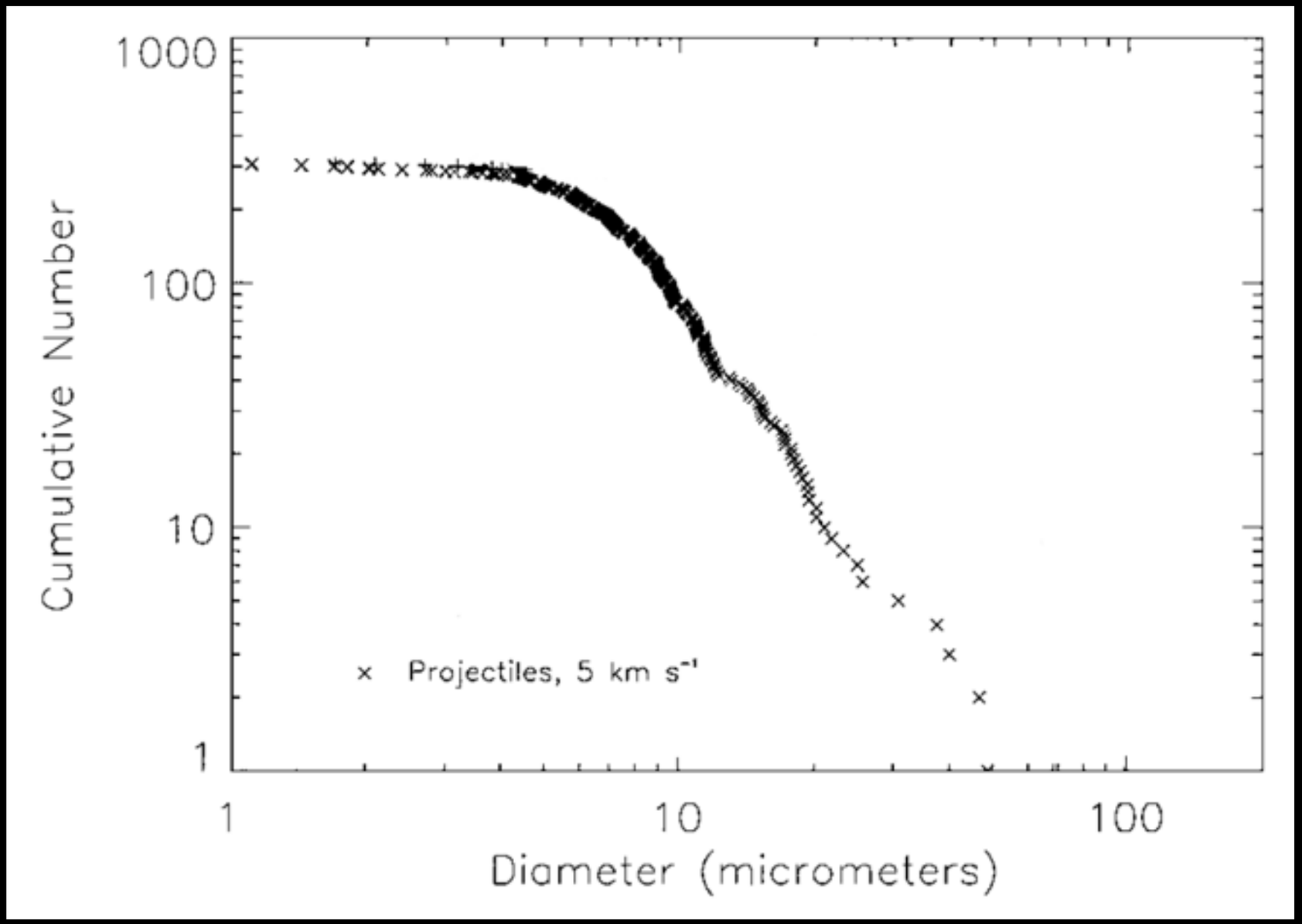

Challenges to measuring n(r), v(r) in laboratory at sub-um sizes

1) Impactors: Need large number of micron-sized impactors
2) Ejecta: Need way to count and analyze ejecta particles down to 0.1 um

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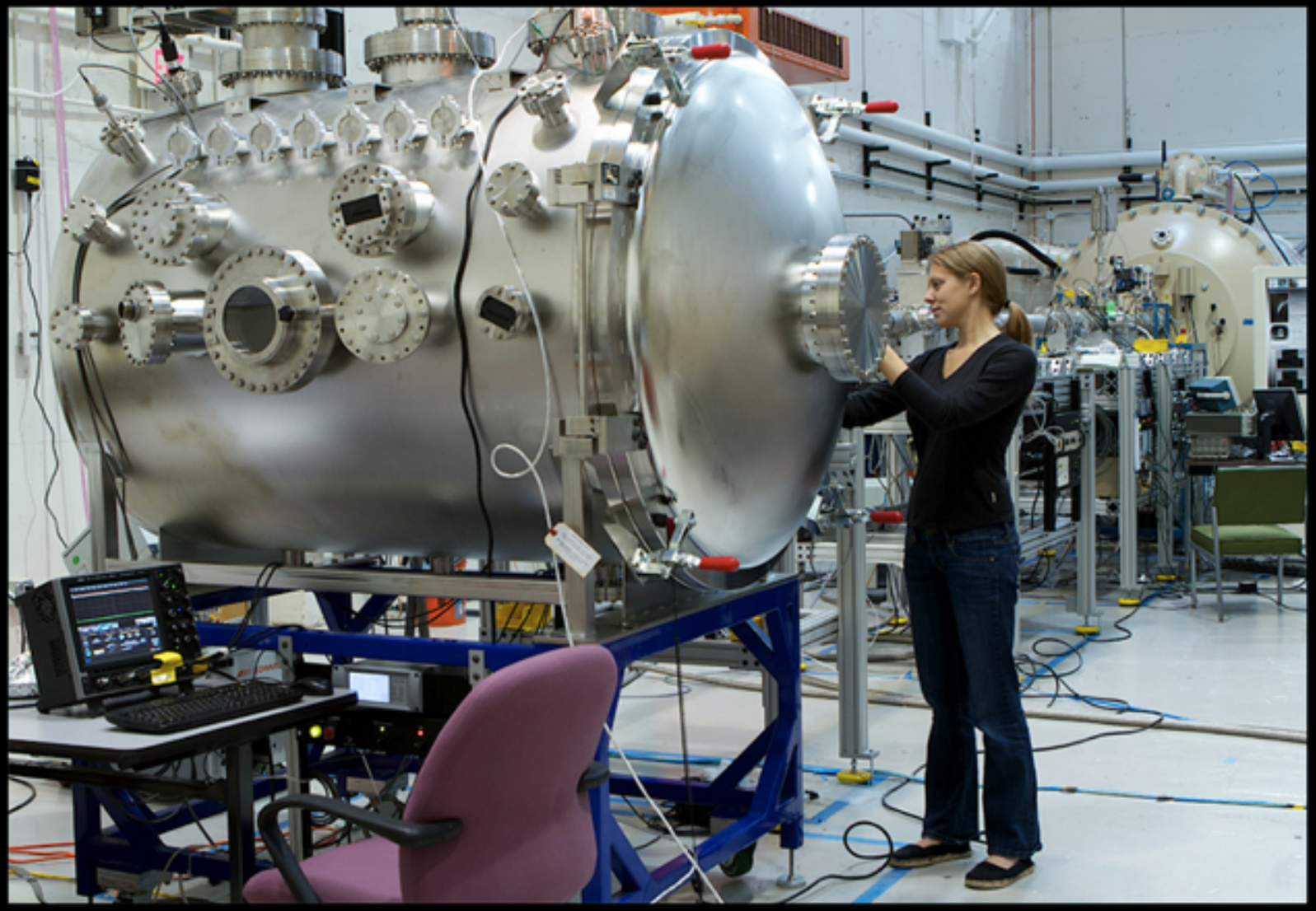
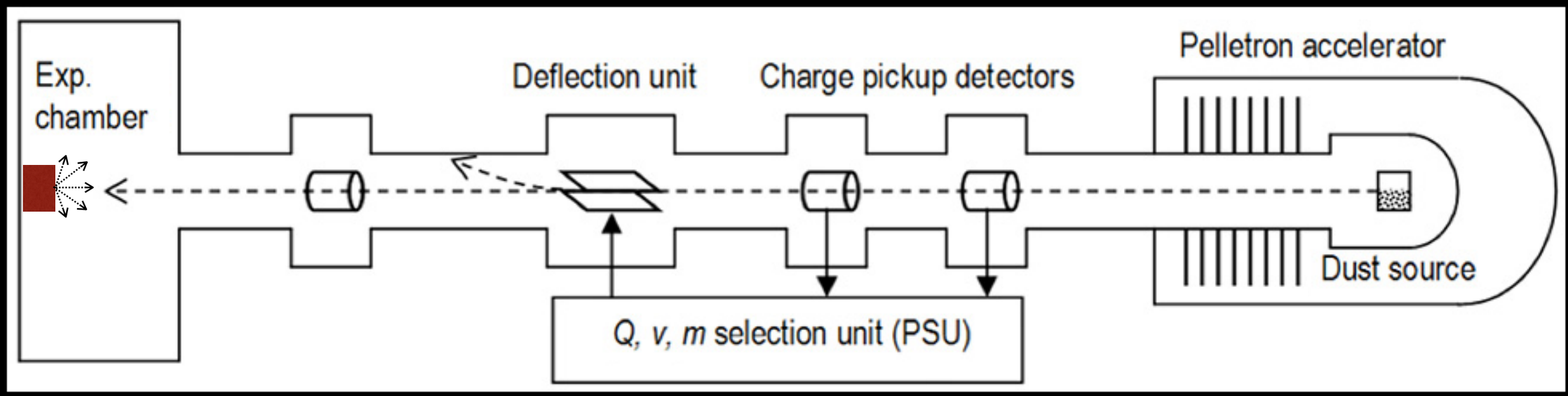


IMPACT dust accelerator (U. Colorado)

- 0.1 - 1 μm Fe grains, accelerated electrostatically
- ~1 particle/second
- v = 0.5 - 50 km/sec



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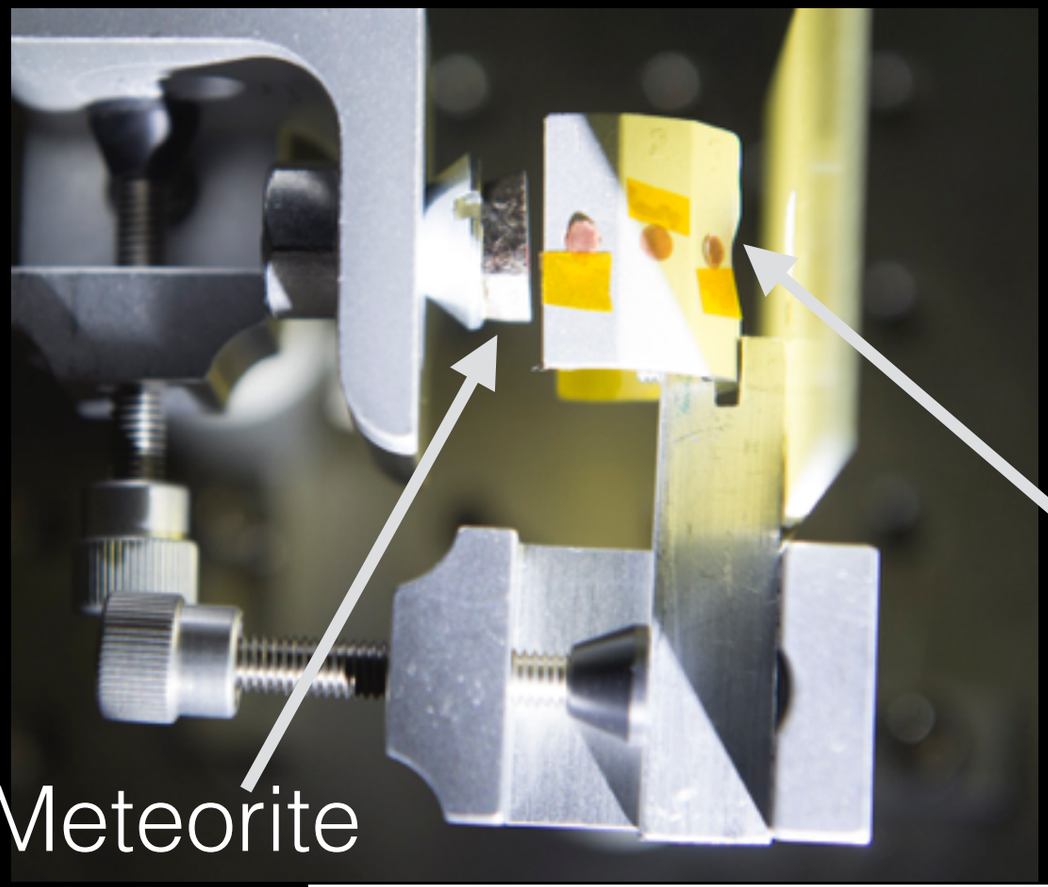

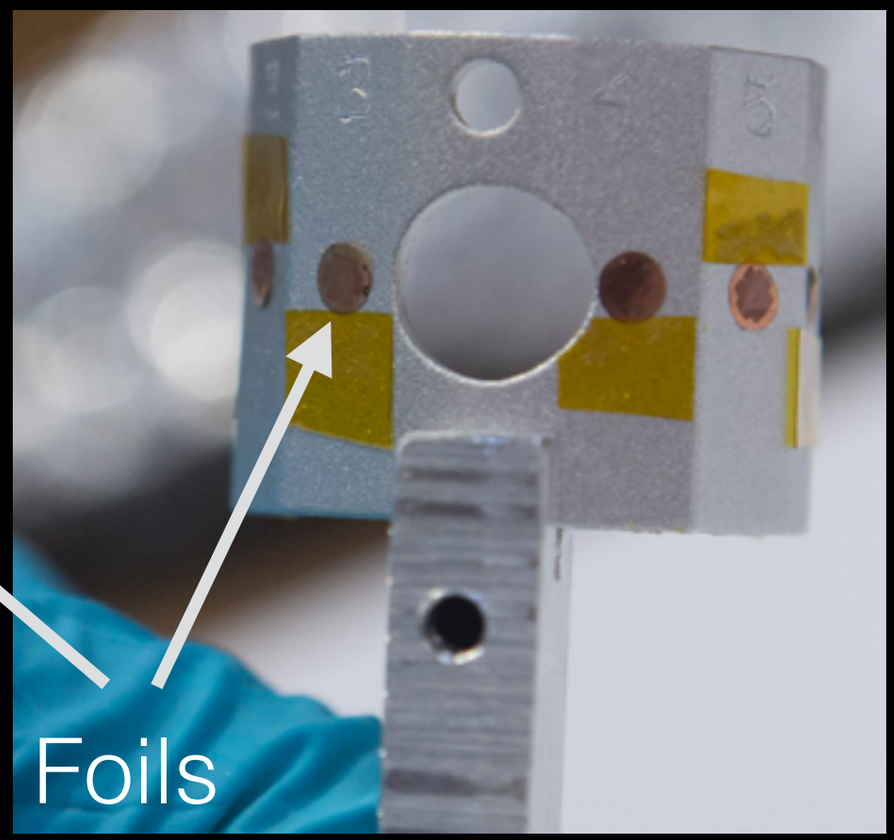

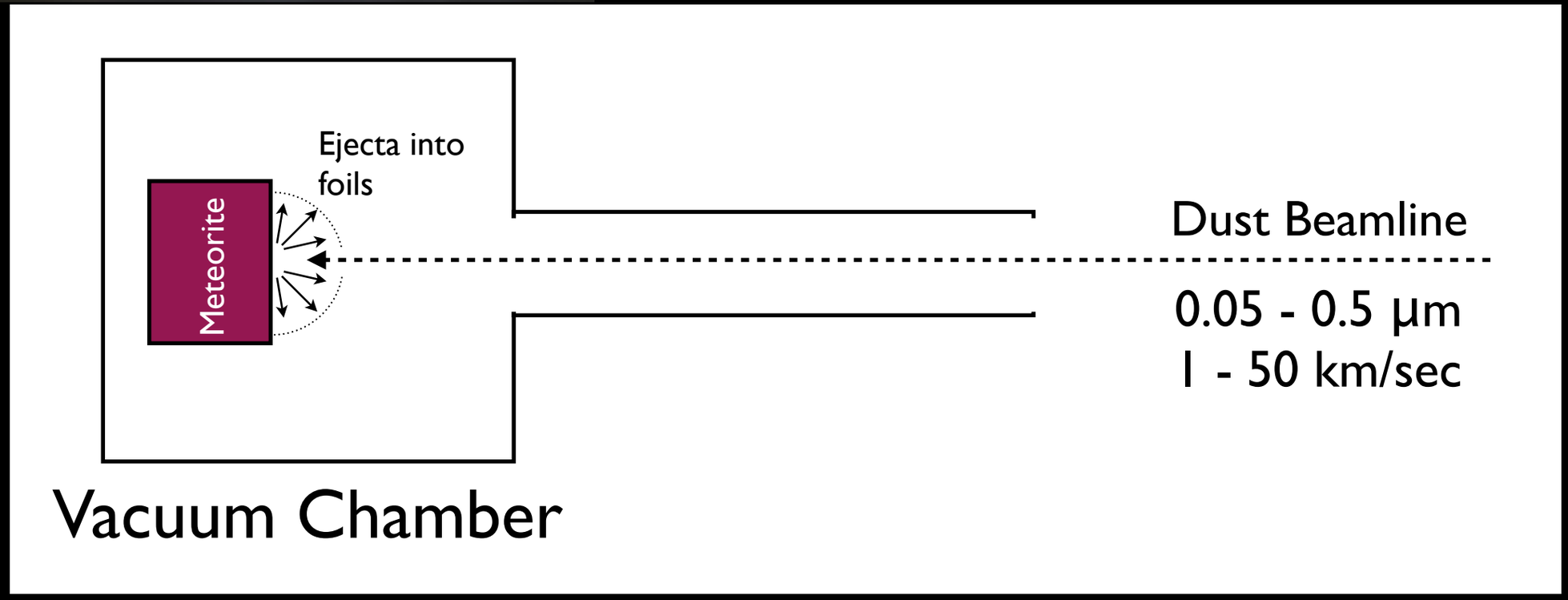

For science runs, we place foils to intercept ejecta in chamber to measure ejecta size.

For calibration runs, we place foils directly in beamline to measure particle:hole size ratio.

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Thin Foil Targets

- 3 mm diameter Cu mesh discs (‘TEM microscopy grids’)
- We vapor-deposit 0.1 um Au atop grids’ existing 0.005 μm C substrate. Particles penetrate Au and we measure holes.
- 400-mesh grid can be easily imaged in SEM
- Nominal SEM scan resolution 0.1 μm = 1600x; higher for features of interest.
  - Each foil mapped at 30,000 x 30,000 pixels (1 Gpx)

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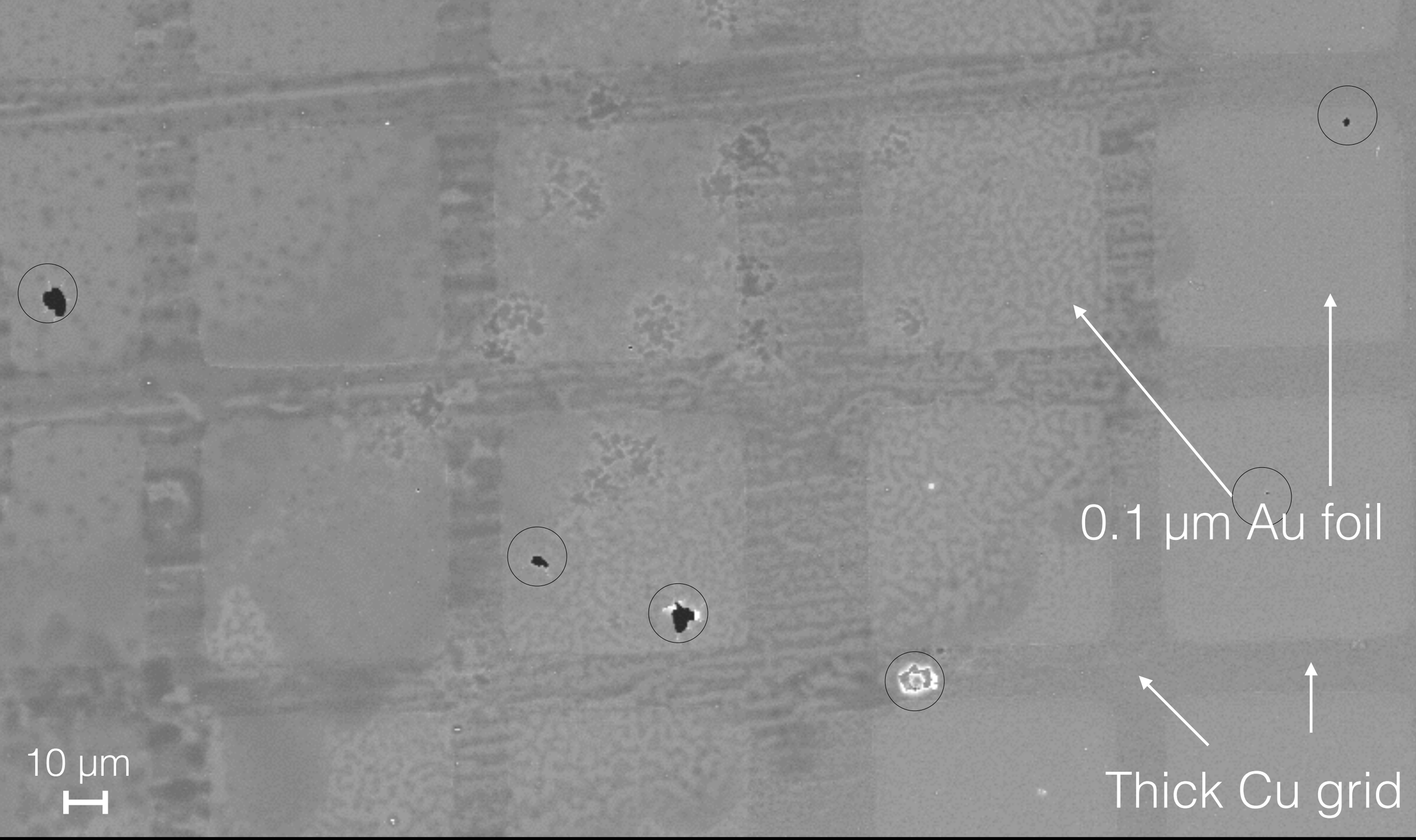

Typical calibration run after several hours of beam exposure, 100,000 particles

Several large impact holes visible, plus dozens of smaller holes not visible here

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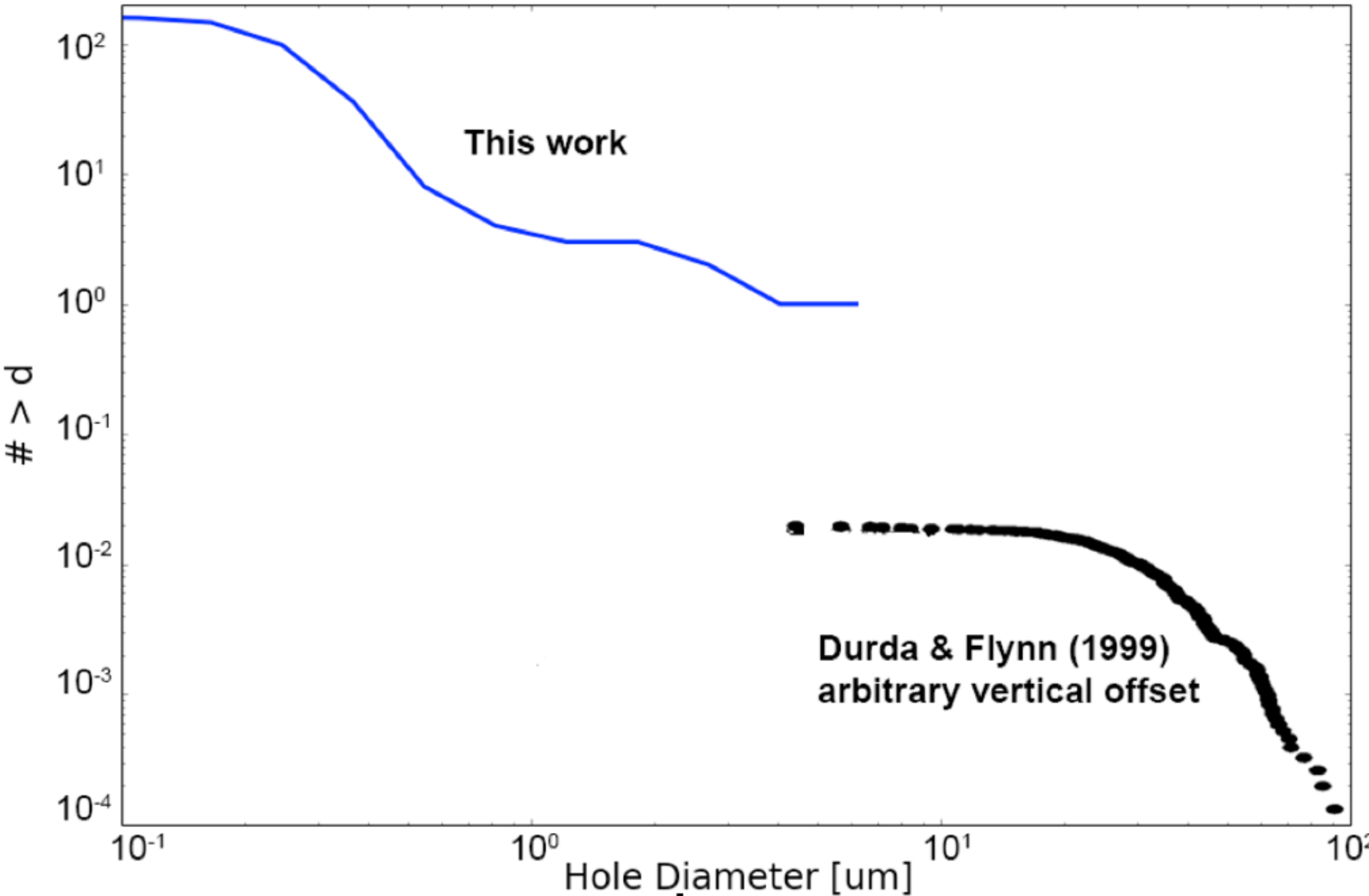
Preliminary Size Distribution Results



ZOO OF IMPACT MORPHOLOGIES...

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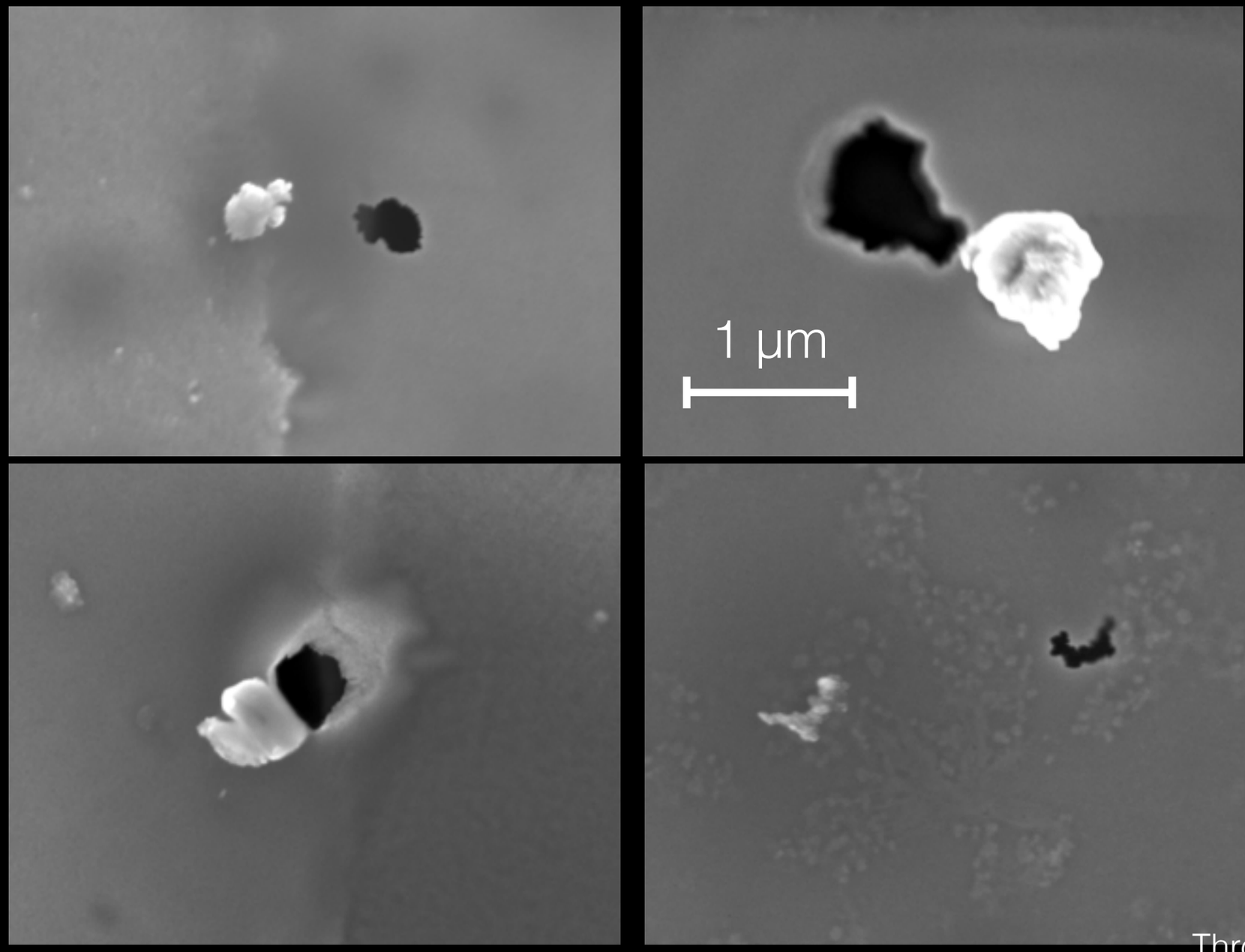
Flaps

Large fraction of puncture holes show irregular ‘flap,’ connected or nearby. Flap is often found on side facing incoming particles.



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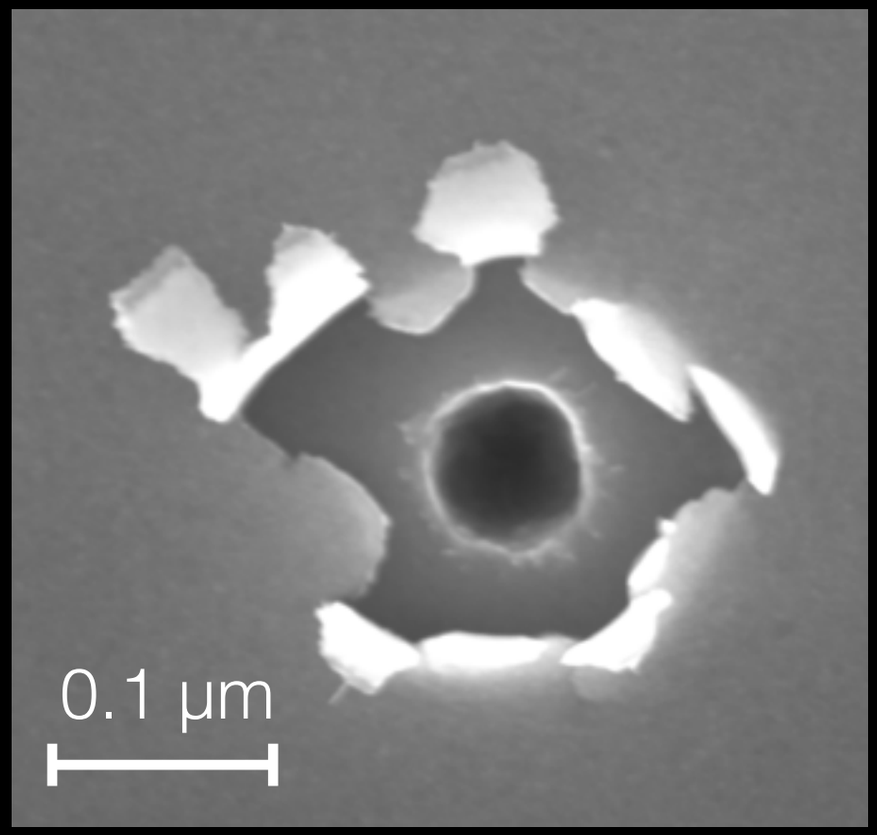
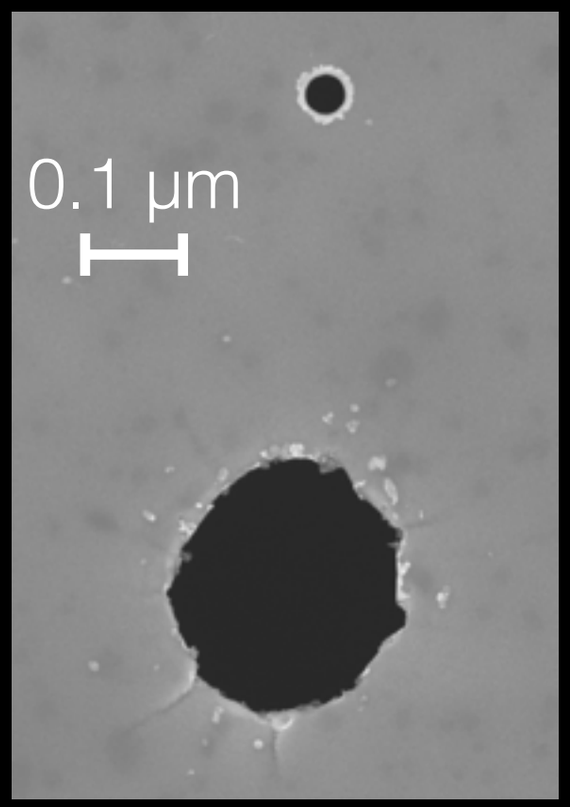
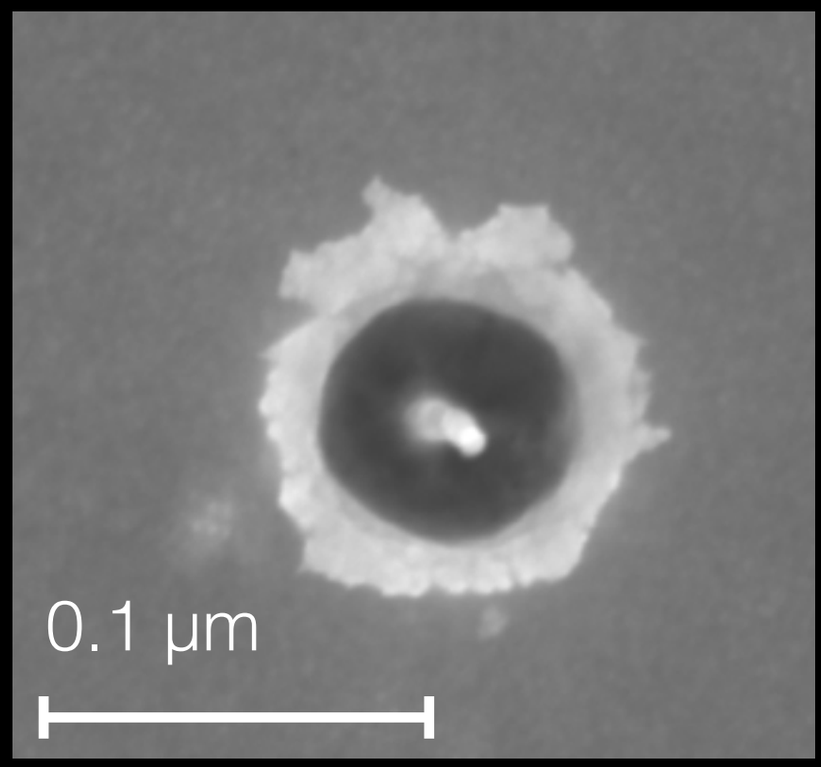
Craters



Impact into
0.1 μm Au foil
+ thick Cu



Penetration of
0.1 μm Au foil by
two Fe spheres



Central peak on
70 nm-diameter
crater into Cu

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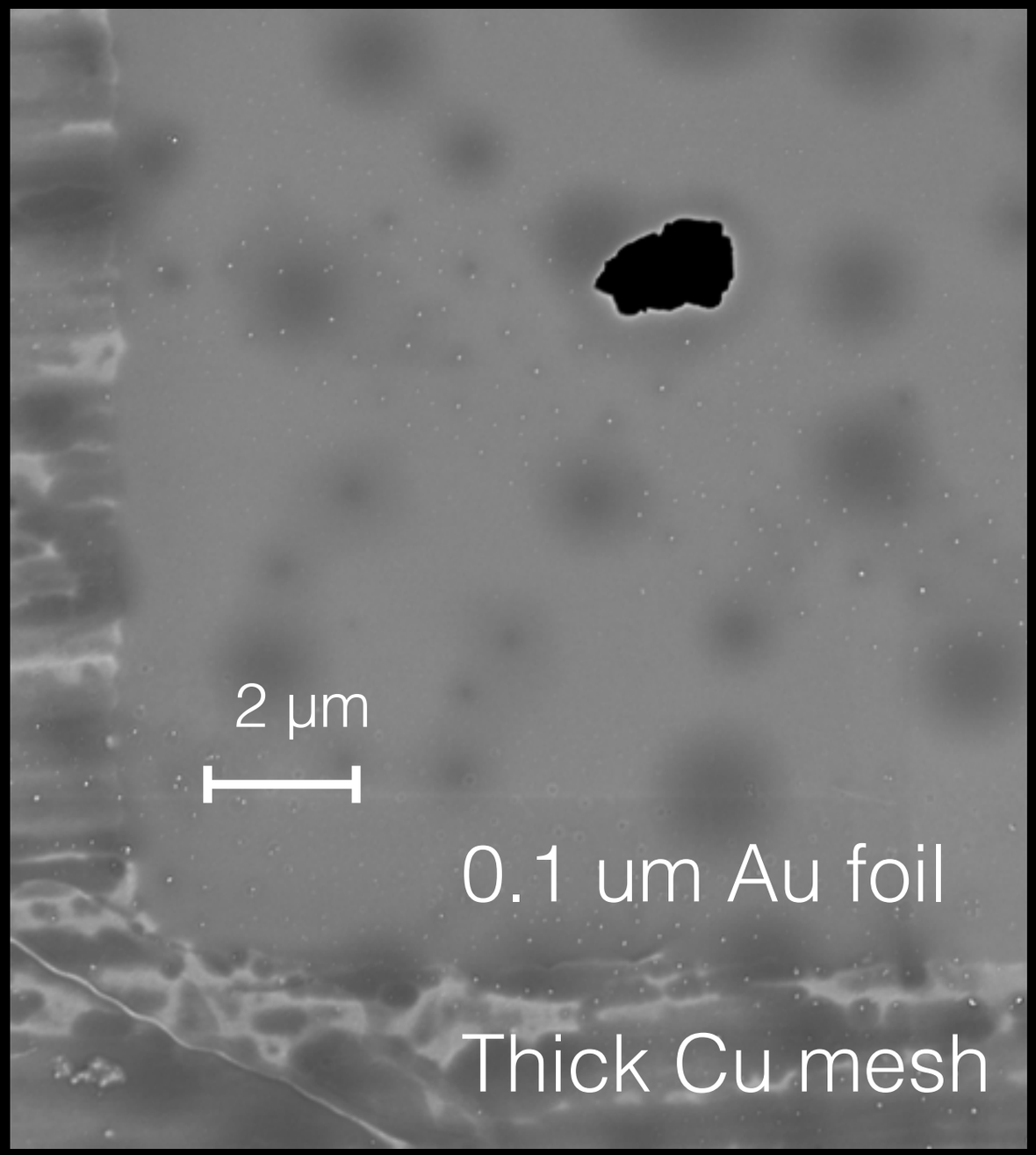
Irregular Holes



Despite impactor population of v > 10 km/sec, many holes are irregular, not circular.

We don't understand formation of these, but they are common and don't appear on our unexposed grids. Does not look like a rip/tear.

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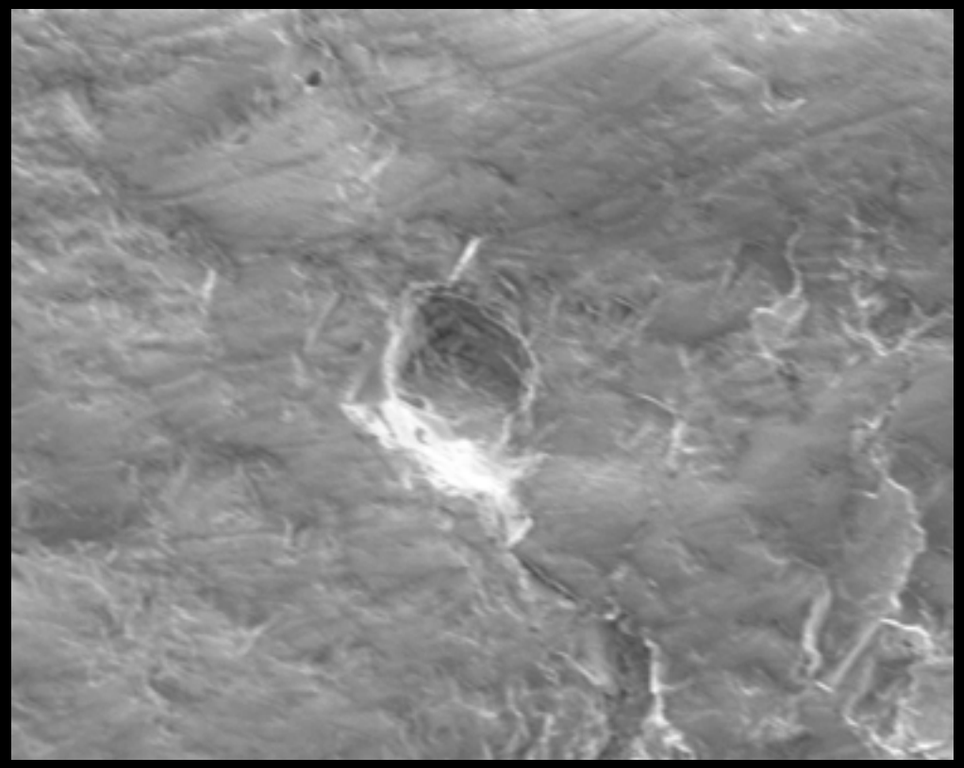
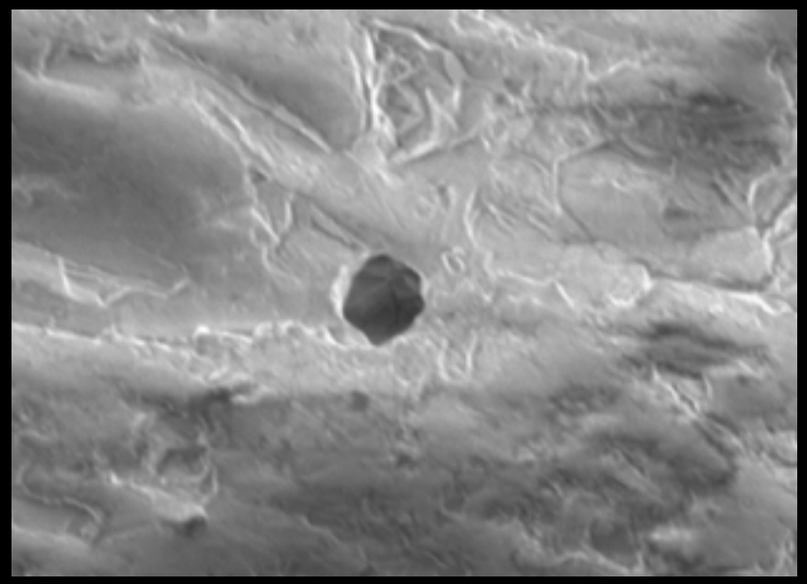
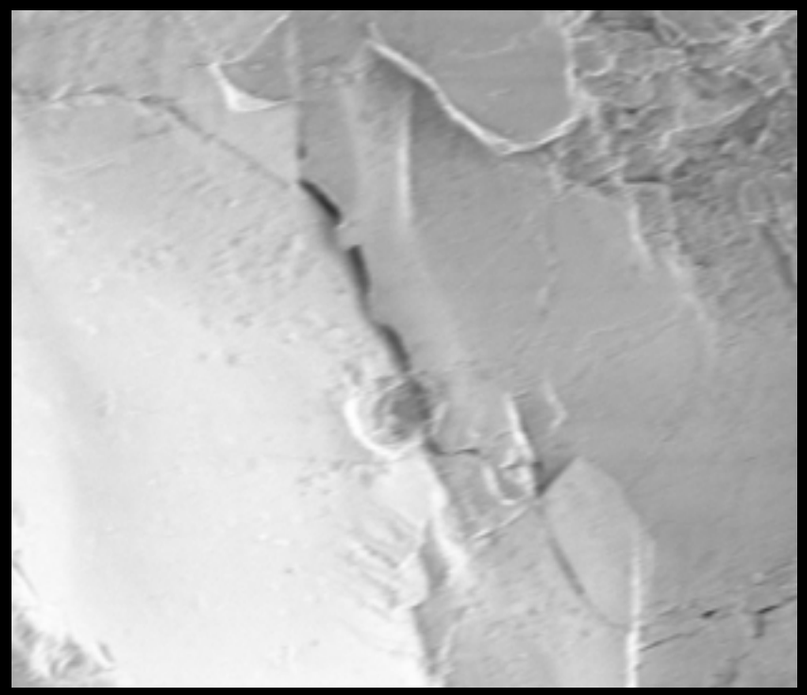
Impacts into Meteoritic Target



1 μm





Three possible impact sites into meteorite from Fe spheres, v ~ 10 km/sec.

Very little ejecta; preliminary results show there is more at 20 km/sec.

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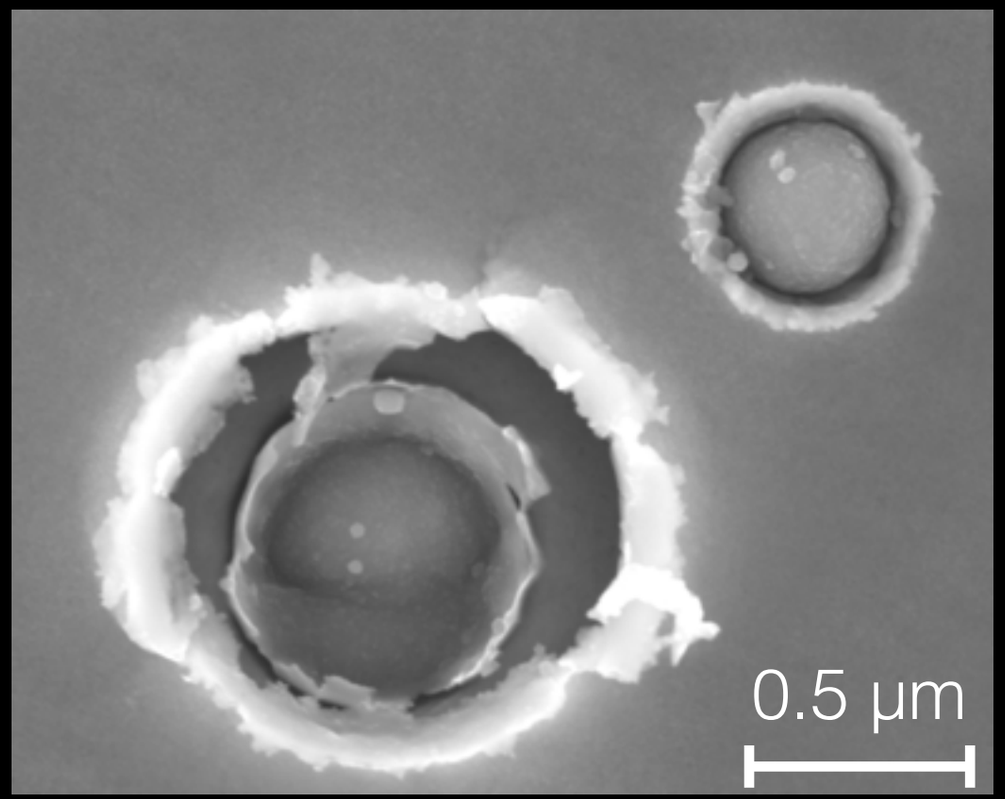
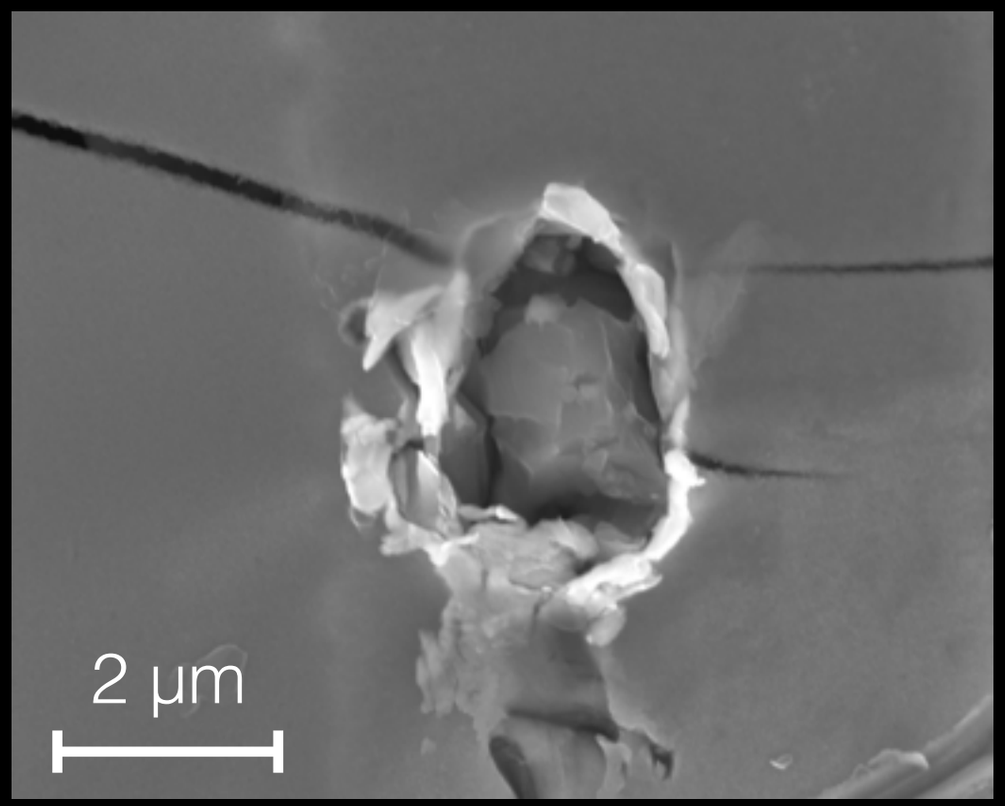
Embedded Grains



Two Fe grains embedded into Cu mesh.
Image width = 4 µm.

At velocities < 5 km/sec, nearly all impacts into our meteoritic surface are embedded or bounce back, with zero ejecta.



Meteoritic ejecta captured into Cu wire on TEM grid. Image width = 10 um.

Ejecta diameter > impactor diameter.

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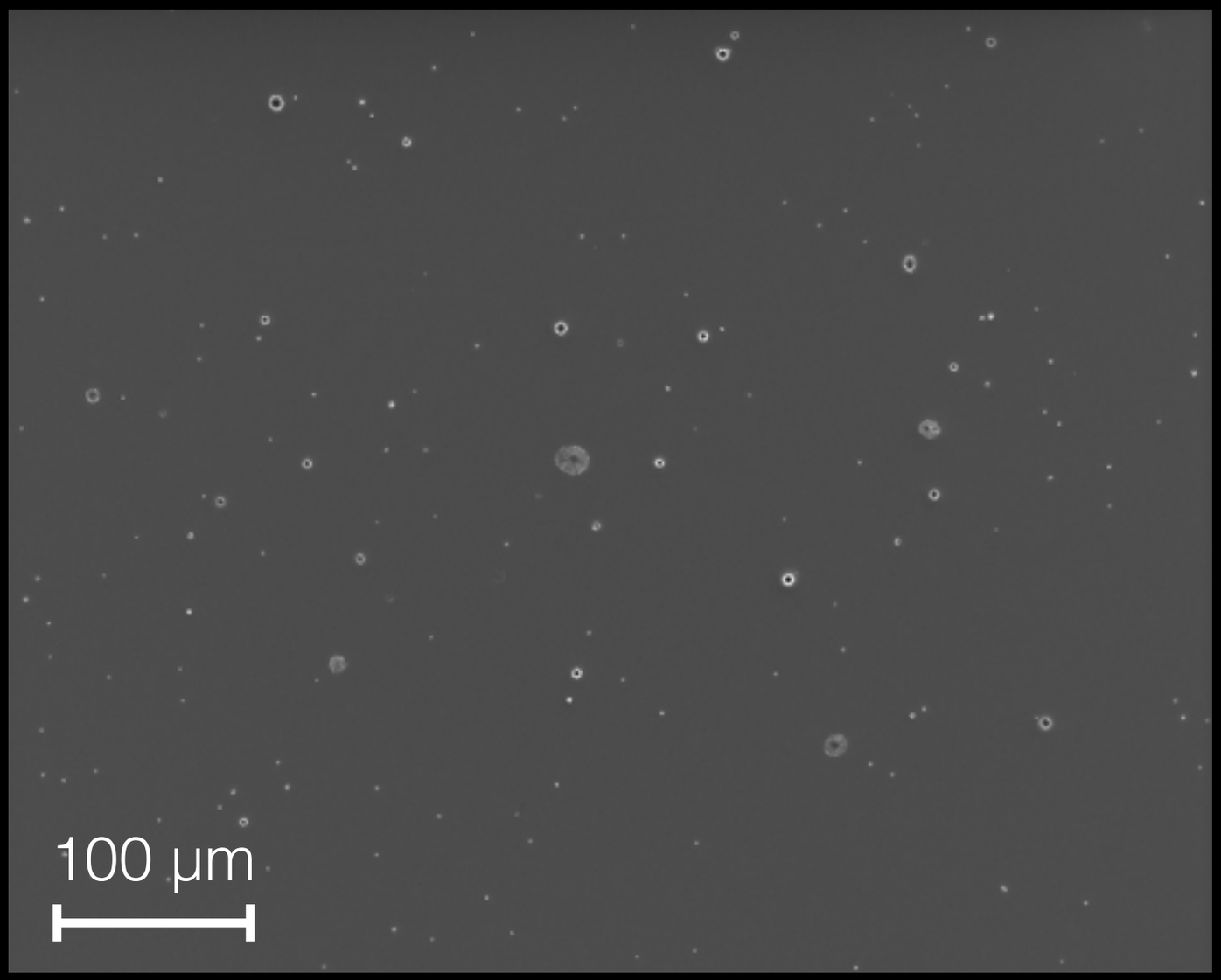
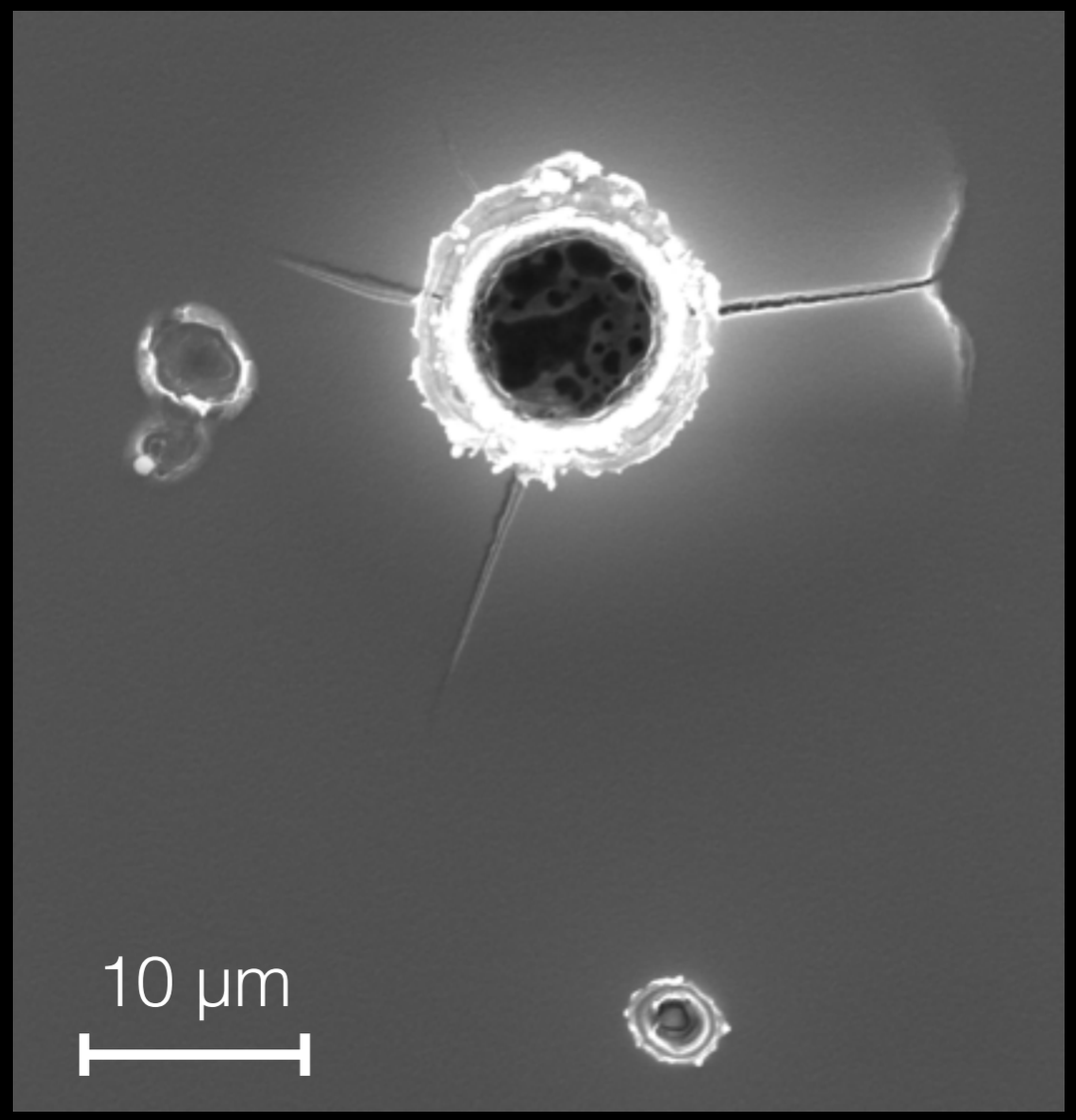
Glass target





Test shots into Al-coated glass mirror. Impact sites are much larger than in metallic targets for same energy.

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Conclusions

- We are well on our way to a measurement of the sub-micron size distribution for hypervelocity impacts.
- Preliminary results suggest a broad continuation of existing n(r) to 0.2 μm.
- Understanding sub-micron impact morphologies (flaps, irregularities, embedded grains) will keep us busy…

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