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# Compaction and High-Pressure Response of Granular $Ta_2O_5$

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# Previous Work on $Ta_2O_5$

Miller et al. reported results for laser shock of 0.1, 0.15, and 0.25 g/cm3 $Ta_2O_5$ aerogels (2007 Shock Conference)

data reanalyzed and presented by Lazicki at 2011 Shock Conference

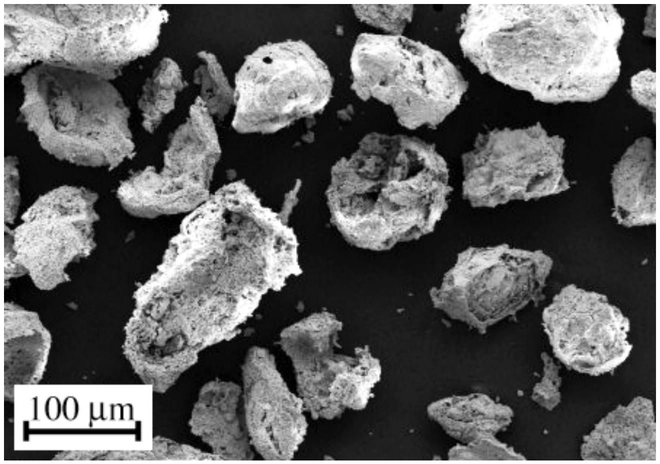
Fenton et al. utilized $Ta_2O_5$ results presented here as test case for extension of P-$\lambda$ model to high pressures using a Rice-Walsh formulation (J. of the Dynamic Behavior of Materials, 2015)

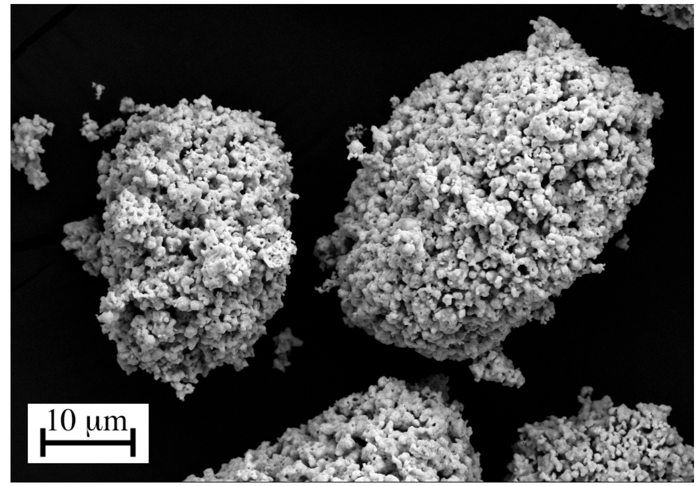
Cochran et al. presented DFT calculations for $\Gamma$ as a function of T and P as well as Hugoniot calculations for porous states (2013 Shock Conference)

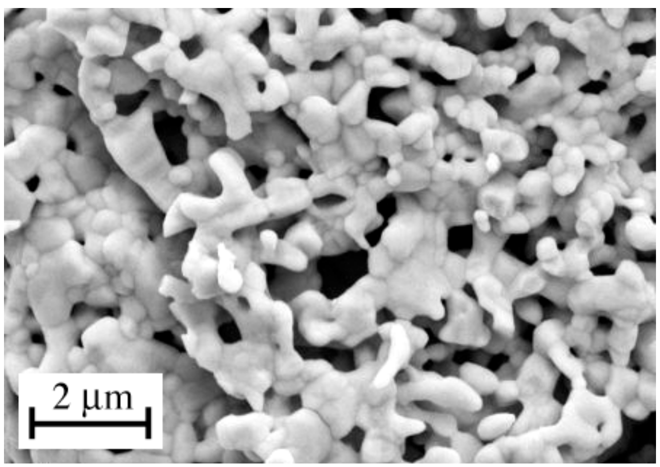
# Two Different Forms of Granular $Ta_2O_5$

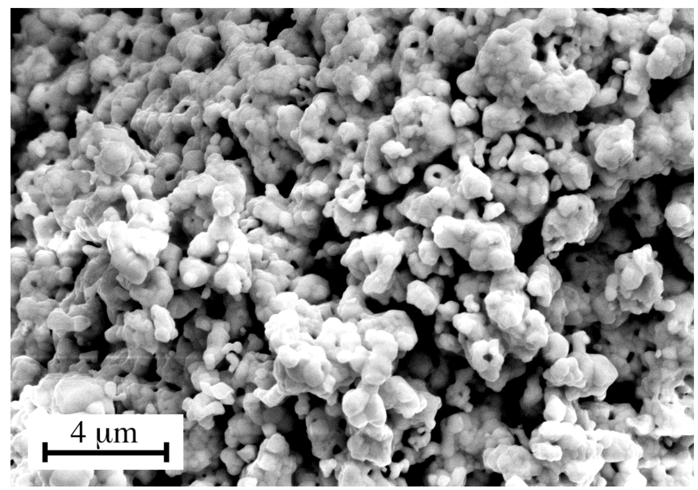
~1.3 g/cc from Cerac

~3 g/cc from American Elements



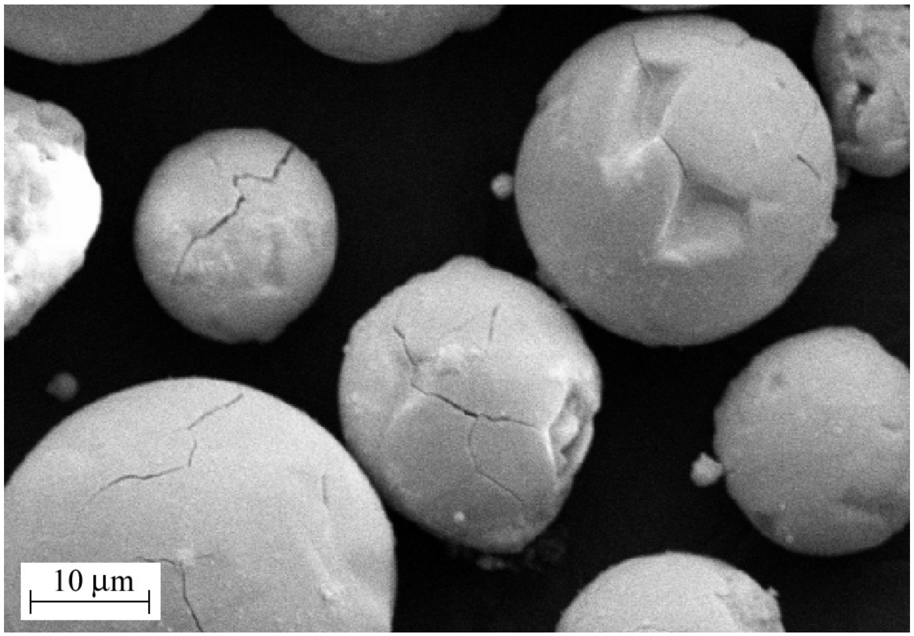



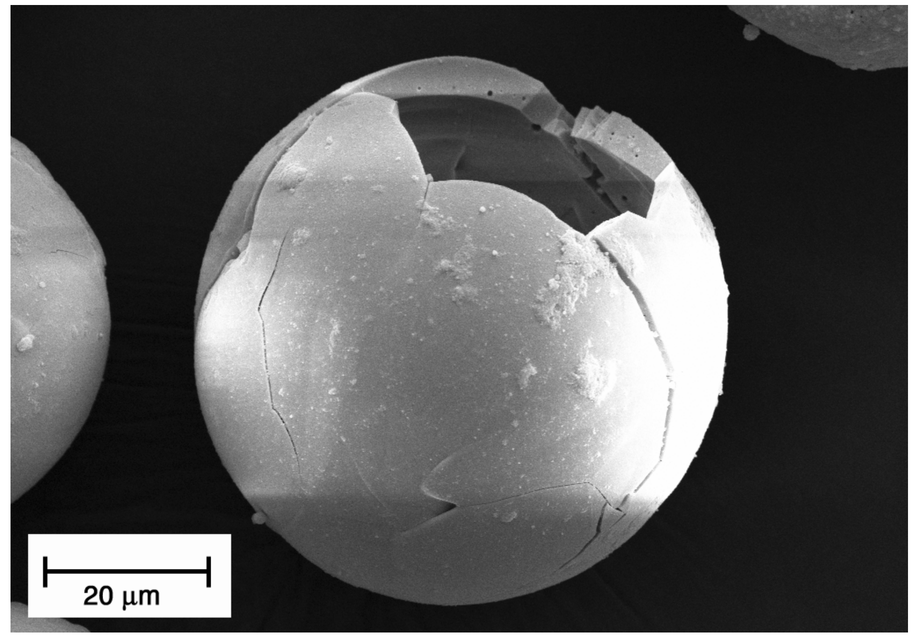




X-ray diffraction shows all material is in orthorhombic phase

*also 90% dense disks from cold pressing or low temperature sintering*

# Plasma Spheroidized $Ta_2O_5$

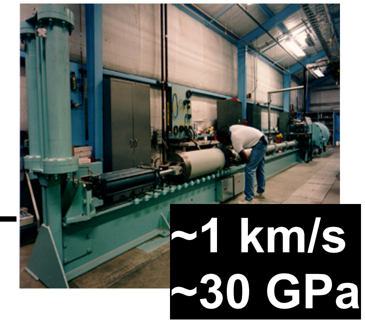


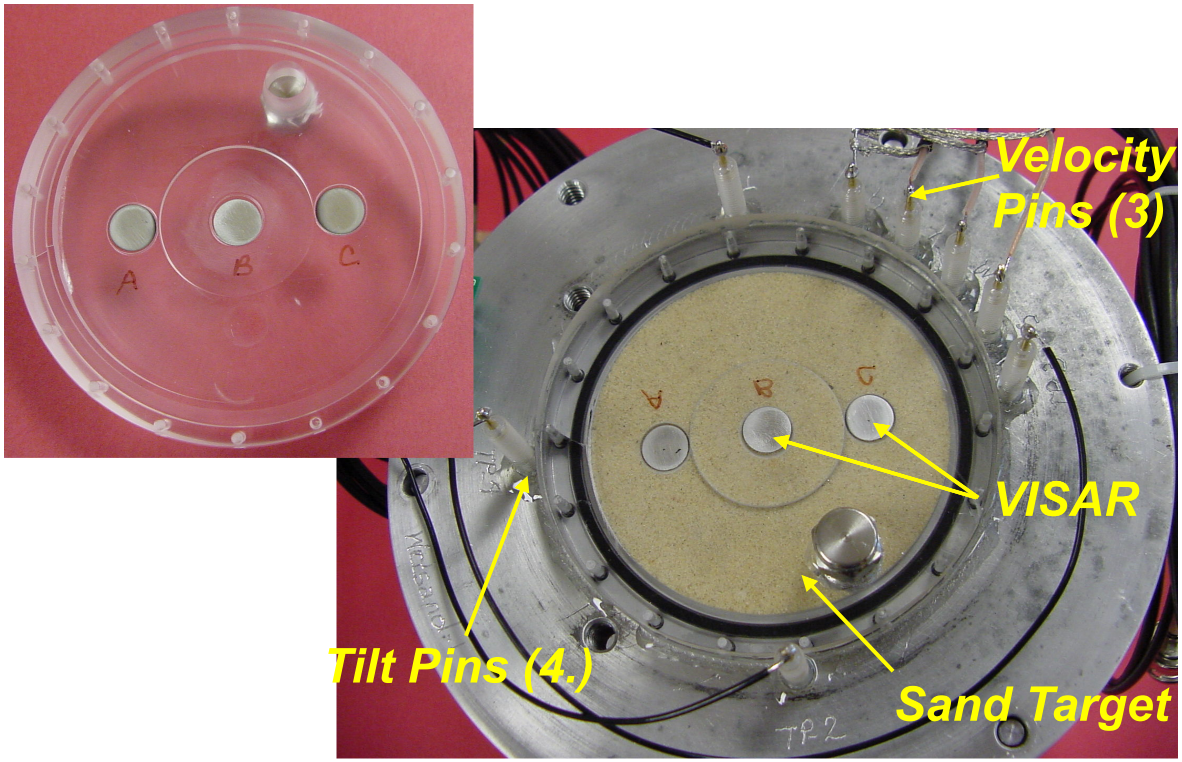



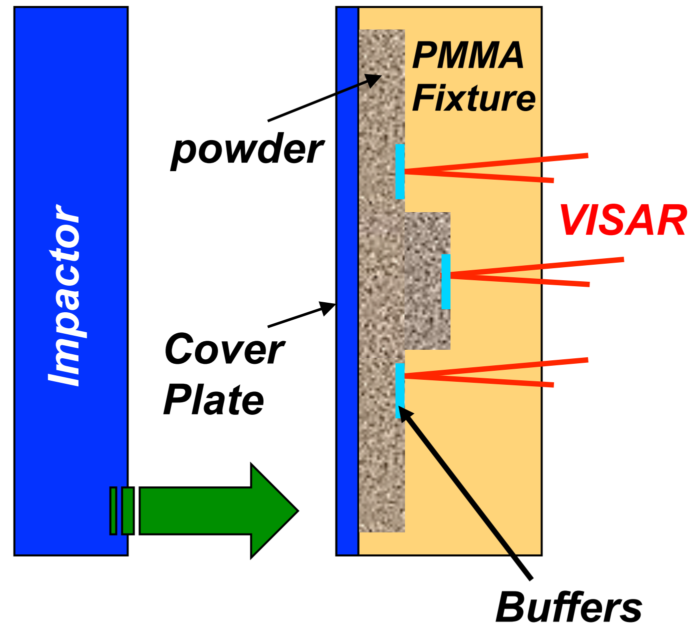

American Elements material plasma processed to modify particle morphology

- particle mass remains unchanged
- pour density similar (3.3-3.5 g/cm$^3$)
- appears to be a mixture of orthorhombic $Ta_2O_5$ and hexagonal $TaO_{1.67}$

# Planar Impact Experiments on Granular Materials



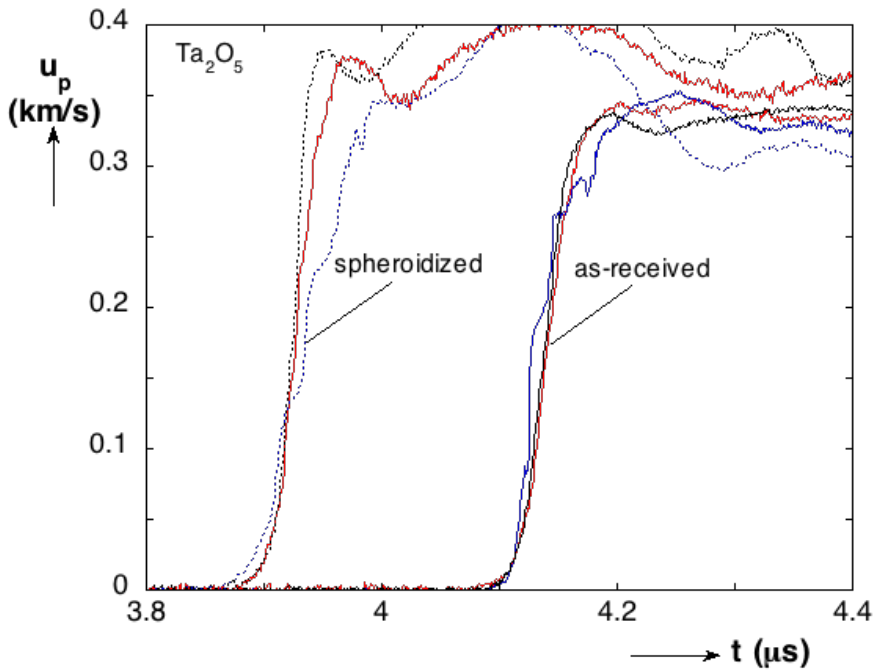



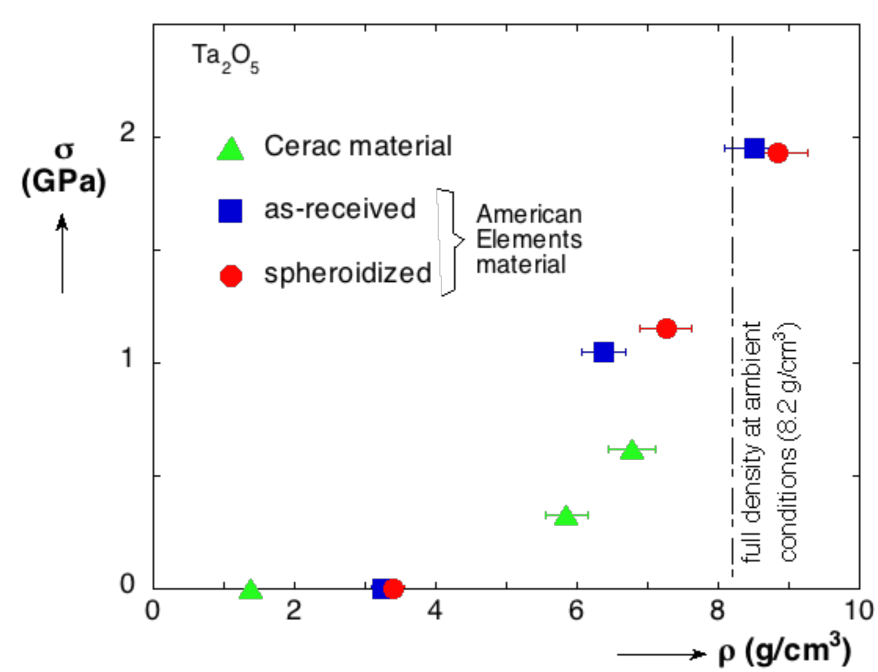

**stepped sample for accurate shock velocity and uniform powder density; sealed capsule allows fluid / powder mixtures**

Vogler, T.J., Lee, M.Y., Grady, D.E., 2007. "Static and dynamic compaction of ceramic powders." *International Journal of Solids and Structures* **44**, 636-658.

Brown, J.L., Thornhill, T.F., Reinhart, W.D., Chhabildas, L.C., Vogler, T.J., 2007. "Shock response of dry sand." in Shock Compression of Condensed Matter – 2007, American Institute of Physics, 1363-1366.

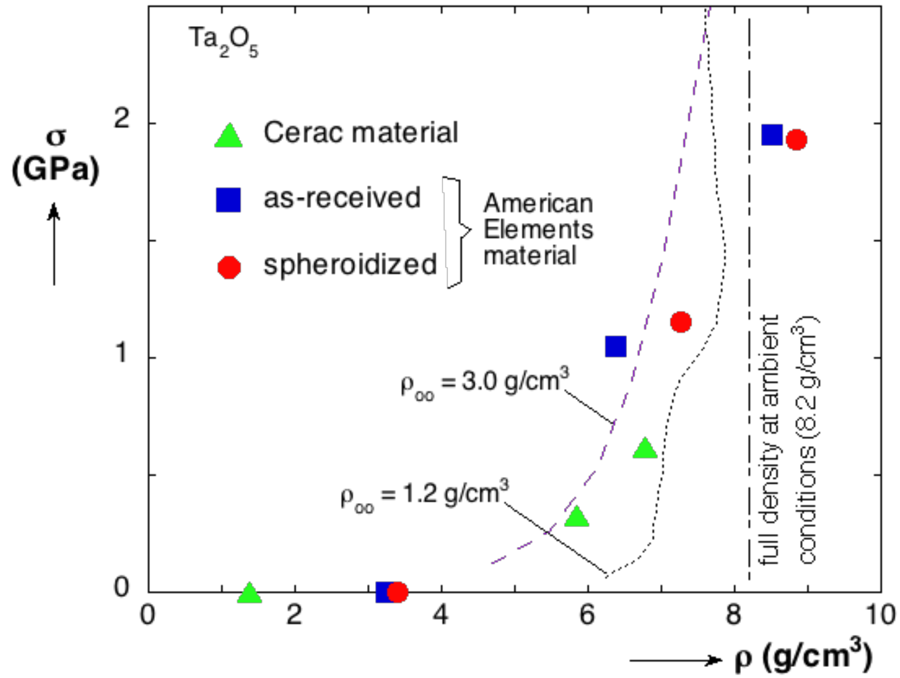
# Compaction Results



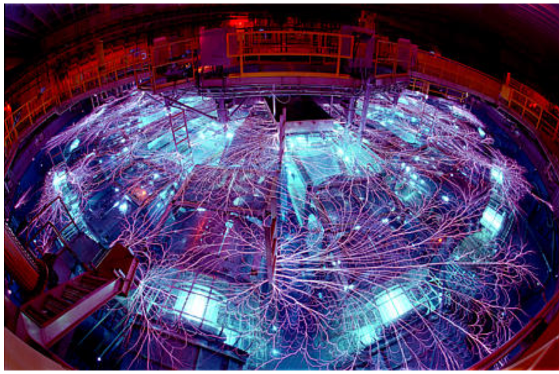

- Compaction results for as-received and spheroidized materials are essentially identical (consistent with $CeO_2$ results of Fredenburg)
- Cerac material (low $\rho_{oo}$) compacts more readily
- wave profiles indicate steady waves
- velocity histories similar for as-received and spheroidized versions

# Mesoscale Results for Compaction

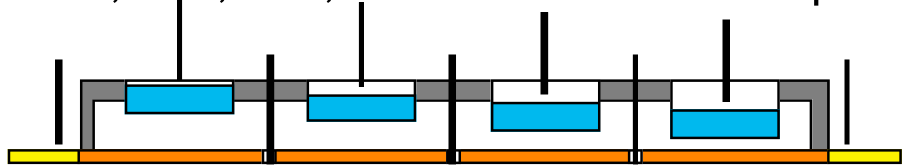



- agreement with experiment not very good, but general trend is consistent
- extra structure in compaction curve for Cerac material
- thermal effects show up earlier than expected

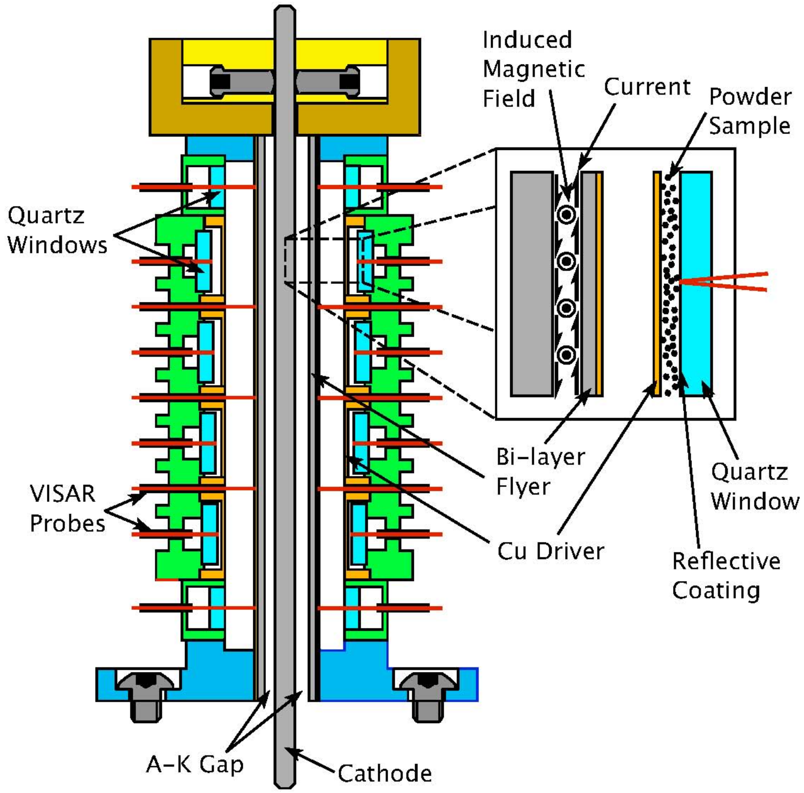
# High Pressure Experiments



400, 600, 800, and 1000 micron samples

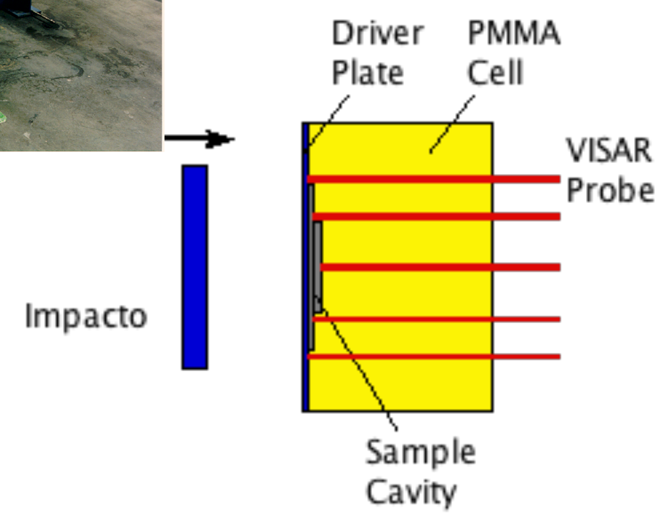


300 micron thick copper driver

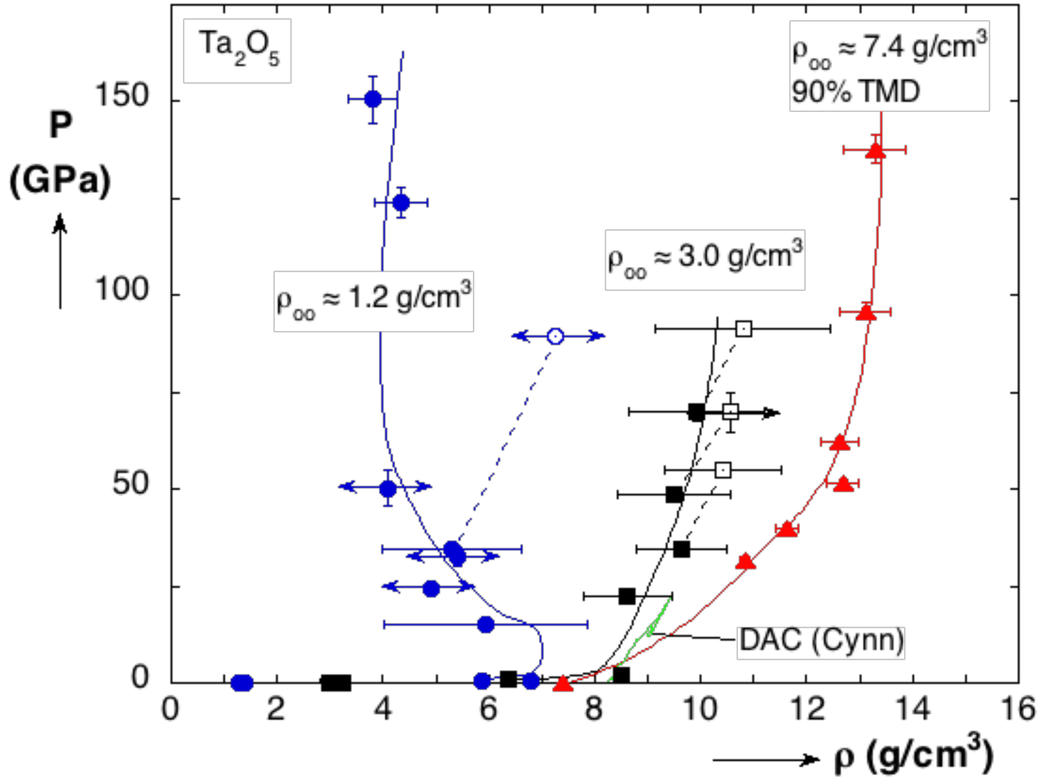



V = 9.9-10.3 and 11.2-11.4 km/s

***Two-Stage Gun  29mm***

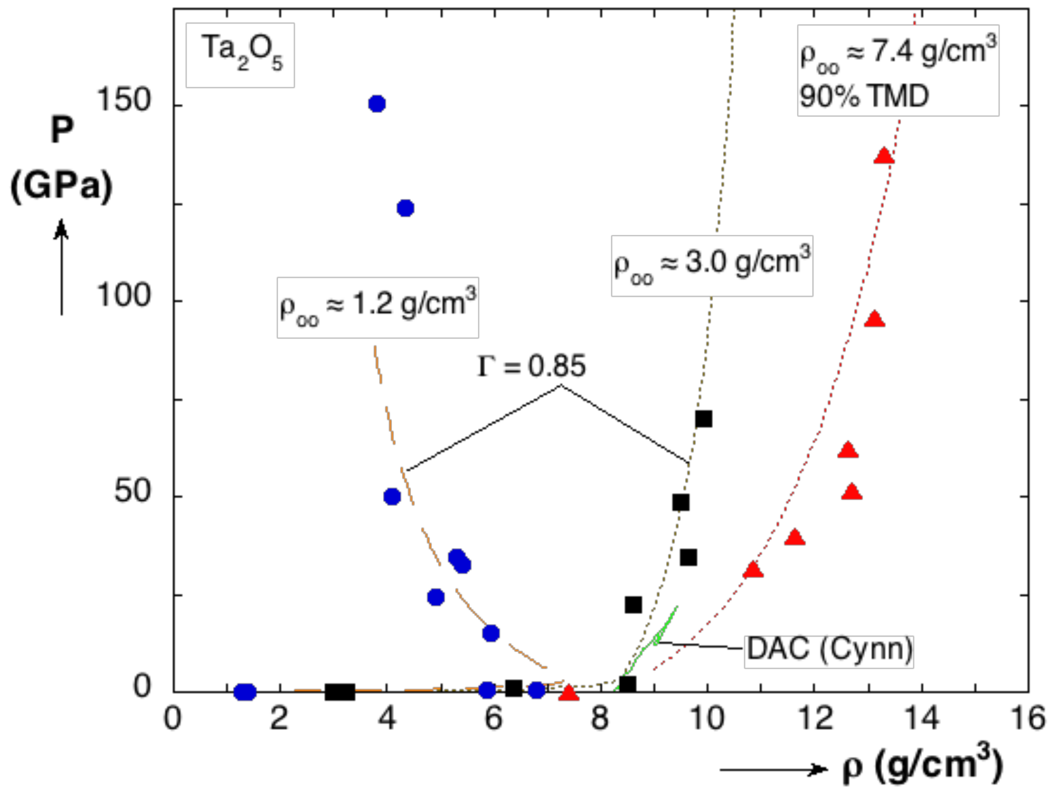



# Gas Gun and Z Data for $Ta_2O_5$



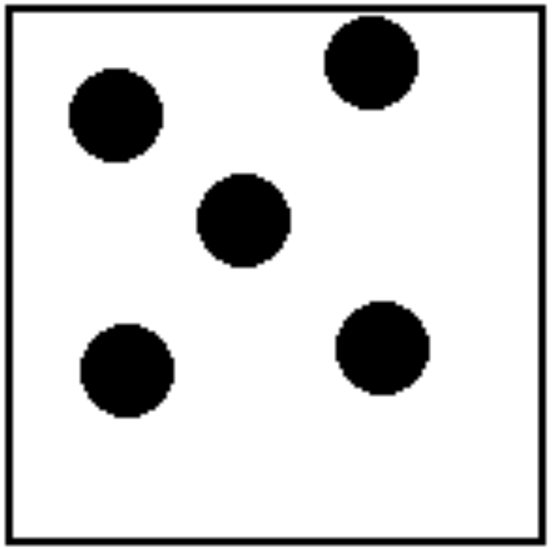

- consolidated results suggest mixed phase region from 20-50 GPa
- reshock from LiF window
- Monte Carlo impedance matching establishes error bars – bowing of impactor largest source of uncertainty
- apparent scatter not consistent with error bars for lowest density results

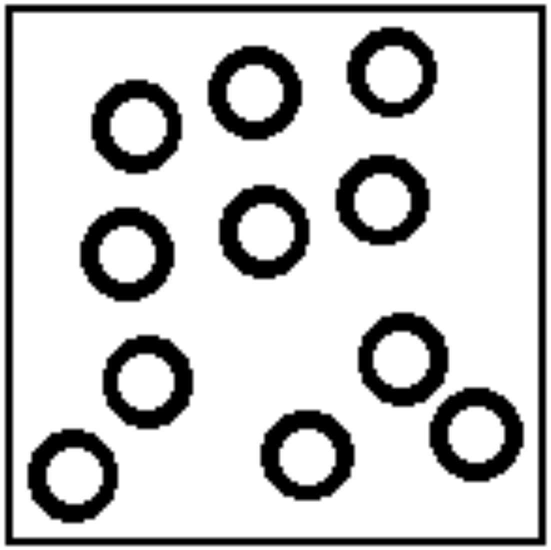
# 1-D Simulations Capture Porous Response




- simple models do not reproduce consolidated data accurately
- CTH phase transformation model can capture consolidated response but not distended response
- constant value of Γ=0.85 gives match for both porosities

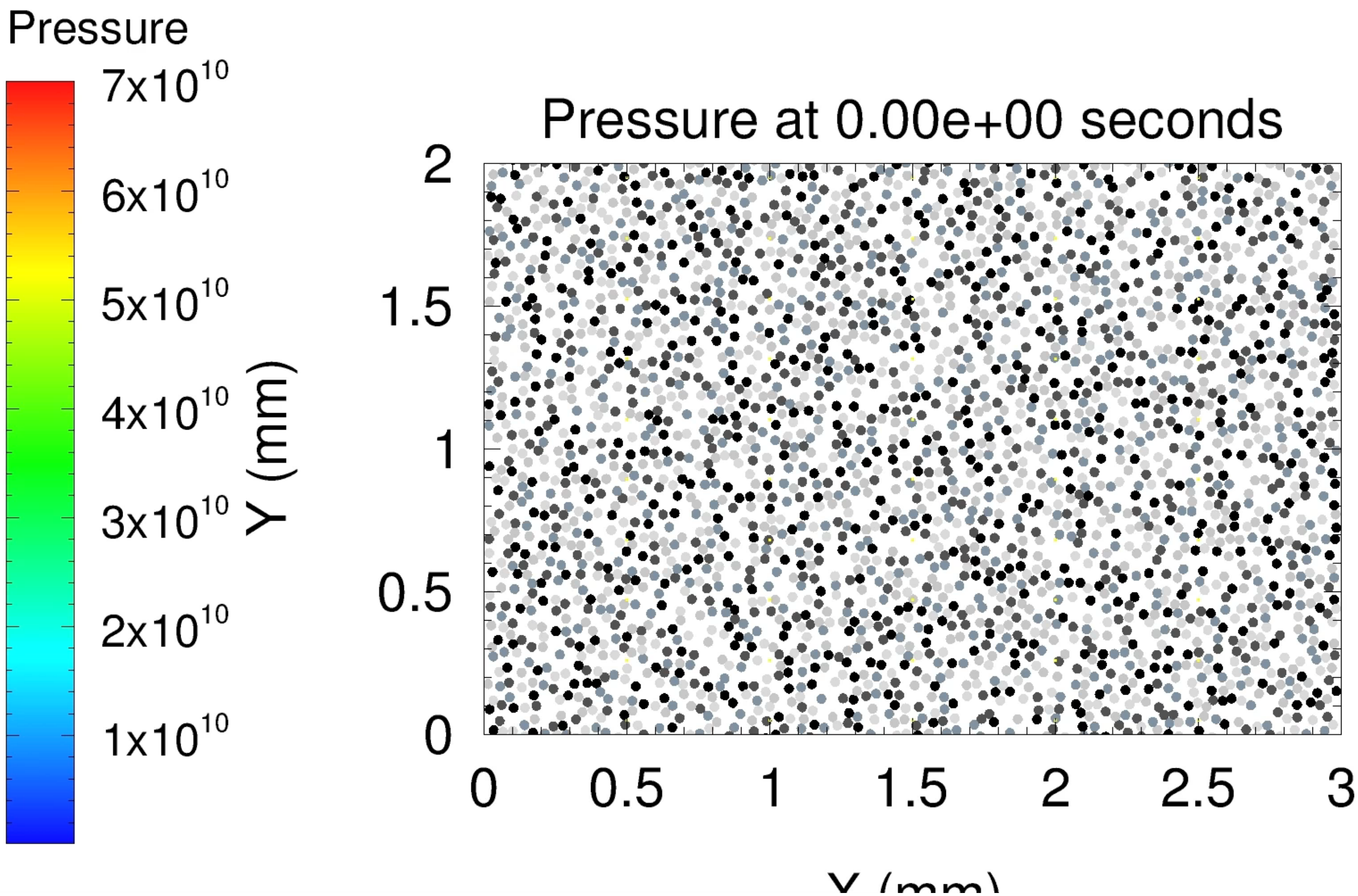
# 2-D Mesoscale Calculations



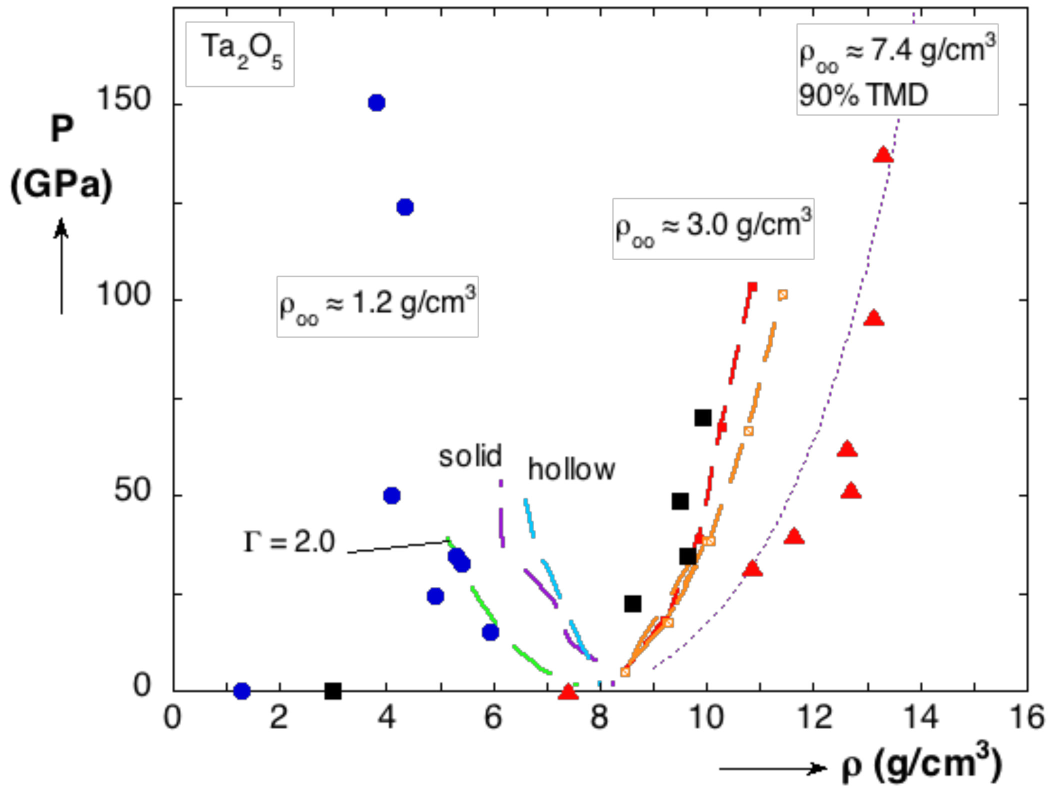


- powders with fully dense particles usually 50-60% dense (WC, sand, etc.)
- for densities much lower than this, removing smaller particles is unrealistic, so hollow circles are used with density of outer spheres ~55%

# 2-D Mesoscale Calculations

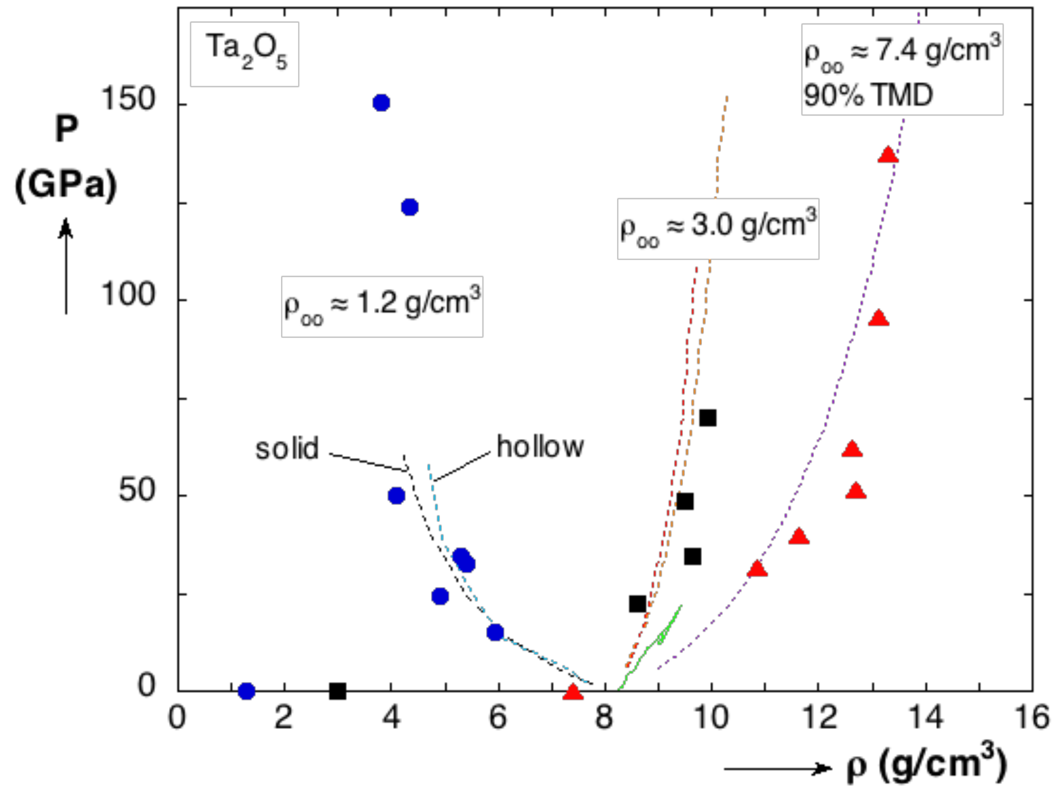


# 2-D Mesoscale Results




- mesoscale calcs give higher ρ than experiments
- increased Γ needed to match experiments
- modest differences for solid and hollow particles
- closer examination reveals that energy jump condition not being satisfied (even in average sense) due to non-conservative remap in CTH

# 2-D Meso Calculations with Alternate Thermodynamic Option




- alternate approach conserves energy better, thus giving “hotter” porous material
- mesoscale calcs give accurate responses with alternate convection option; continuum calcs only slightly affected
- only small differences for solid and hollow particles

# Conclusions and Future Work

- compaction and high-pressure response of $Ta_2O_5$ studied
- two morphologies purchased, one made through plasma spheroidization
- compaction is a function of initial density but not morphology; mesoscale model captures trend
- interplay between phase transformations and porosity not captured well
- convection approach important in mesoscale simulations

- approach to measure tilt at impact to reduce uncertainties

- additional low-pressure and Z experiments

- release state using TPX or aerogel