Status of detailed modeling of high foot implosions — where do we agree and disagree with the data

Kinetics Workshop

Dan Clark and the
Post-shot Working Group

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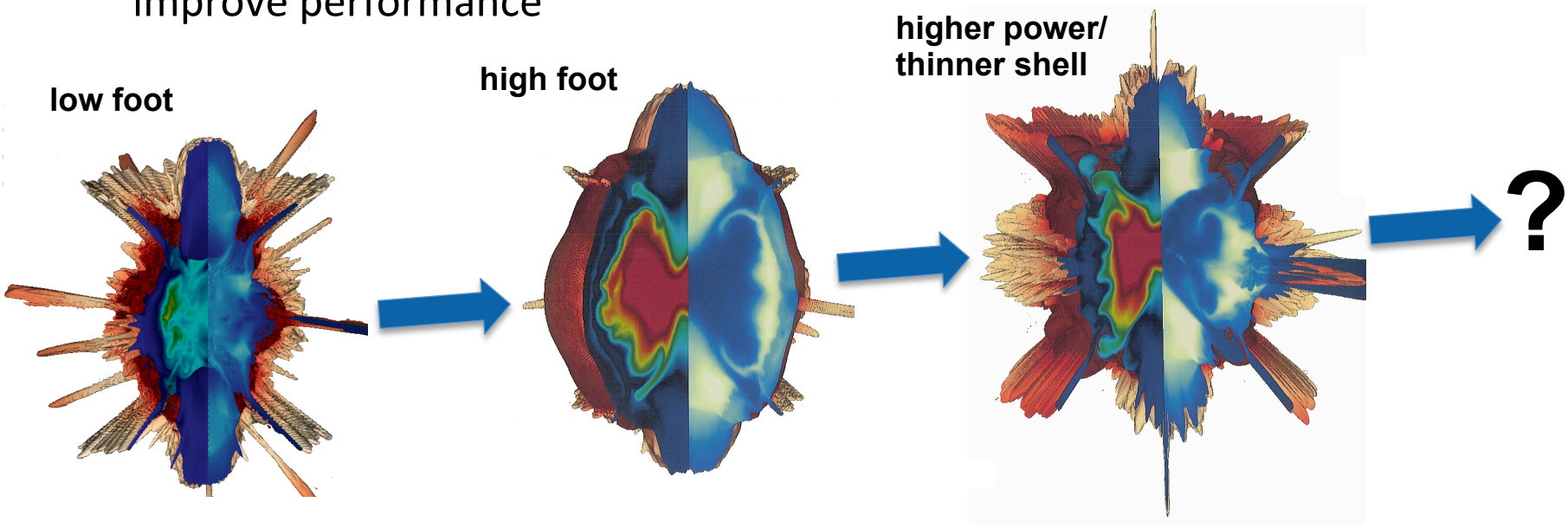
We run detailed post-shot simulations for several reasons

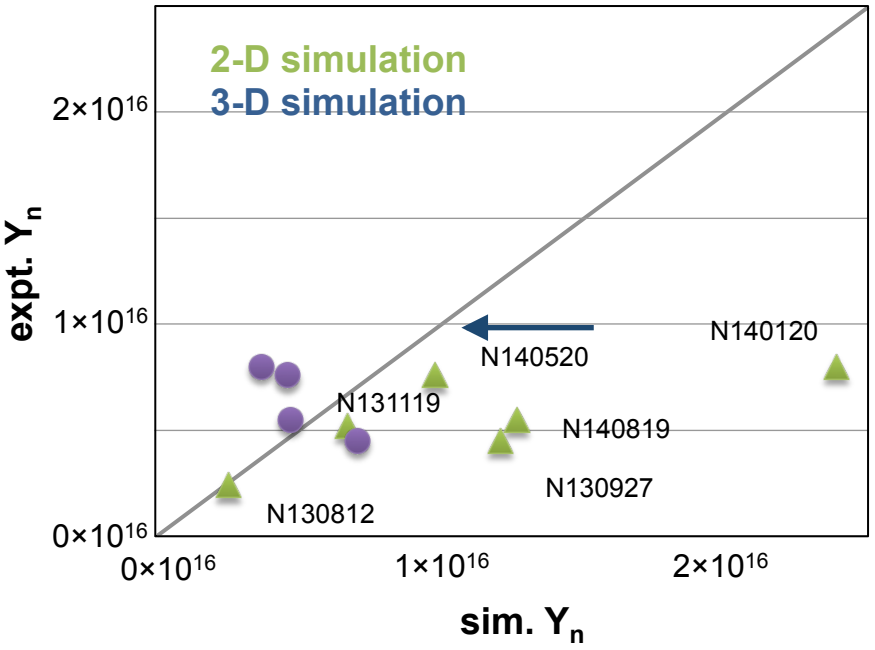
- Understand the sources of performance degradation in current implosions
- Quantitatively compare “best effort” simulations against the data to see where we agree and disagree — and by how much
- Use our semi-validated understanding to project the best ways to improve performance



This talk surveys the status of high foot post-shot modeling with an eye to where we disagree with the data and where additional effects outside of the current model might be important

Our best 2-D and 3-D simulations give a fair representation of the high foot data but do not capture all of the trends

- 2-D simulations including the known perturbations (asyms., tent, etc.) match Y_n for some shots but are ~ 2X too high for others.
- 3-D simulations of the highest power shots match the yield within 20 – 30%.
- 3-D simulations are still low in T_{ion} and high in DSR but only just outside of the error bars.

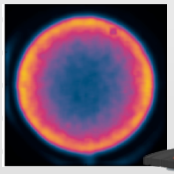


- The tent and hohlraum asymmetries are the largest degradation sources. Uncertainties in these are probably the best place to look for explaining our discrepancies, but uncertainties in the micro-physics are also a possibility.

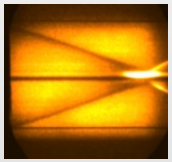
Our simulations are constrained by data and validated against dedicated experiments wherever possible

Drive characterization

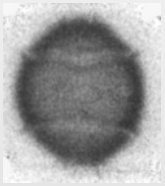
Early drive symmetry



Shell trajectory

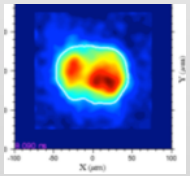


in-flight shape



Shock velocities

Hot-spot shape

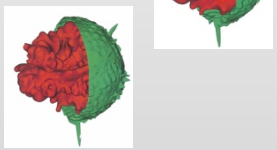


Used to constrain models & drive on capsule

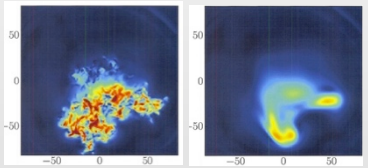
Code comparison

Miranda (High-order Eulerian)

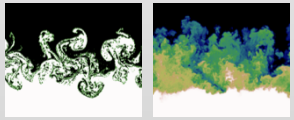
HYDRA (ALE)



viscous/inviscid



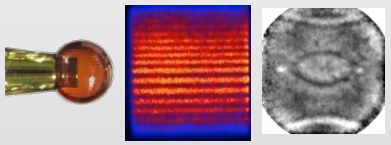
Interface RT mix



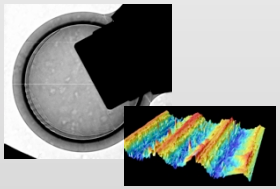
Used to test different models/physics

Hydrodynamics validation

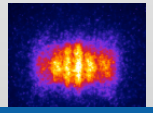
Ablation front growth



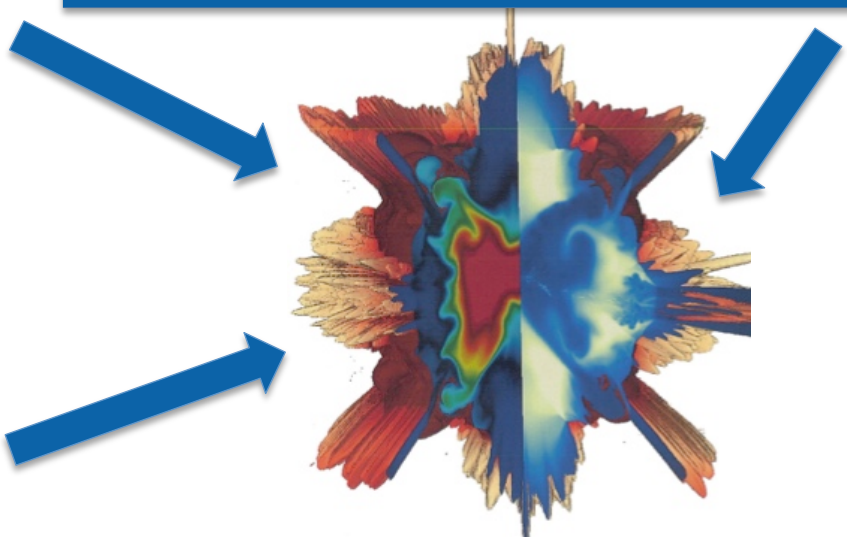
Interface growth



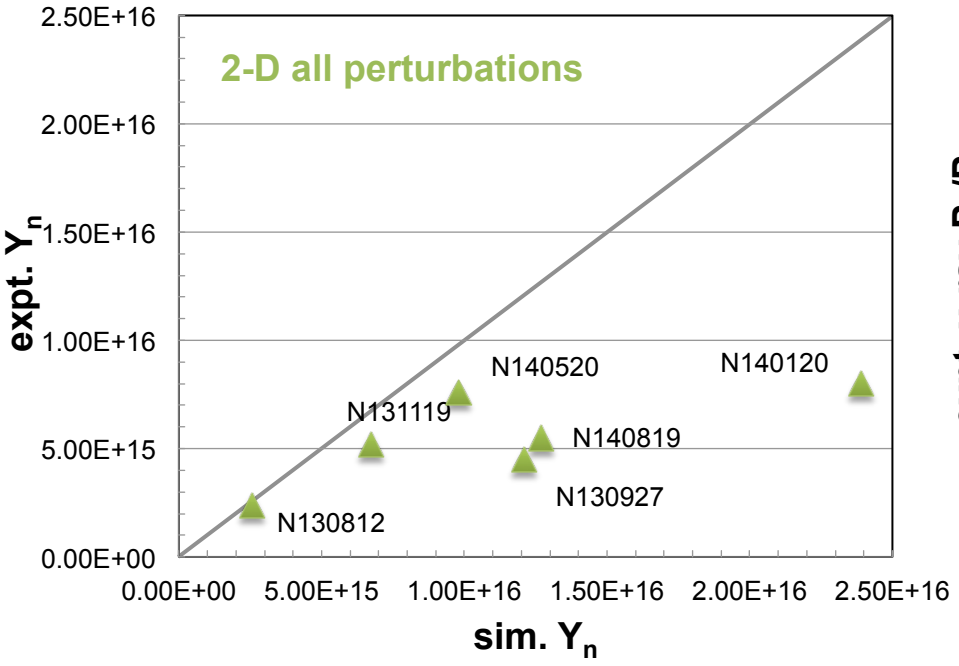
Stagnation hydrodynamics

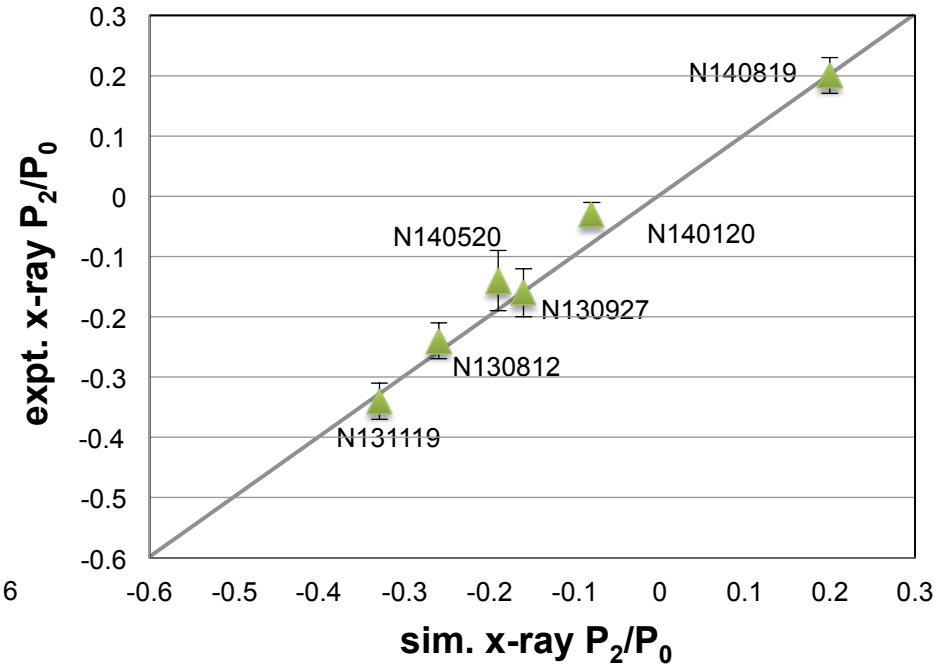


Used to validate models against experiments



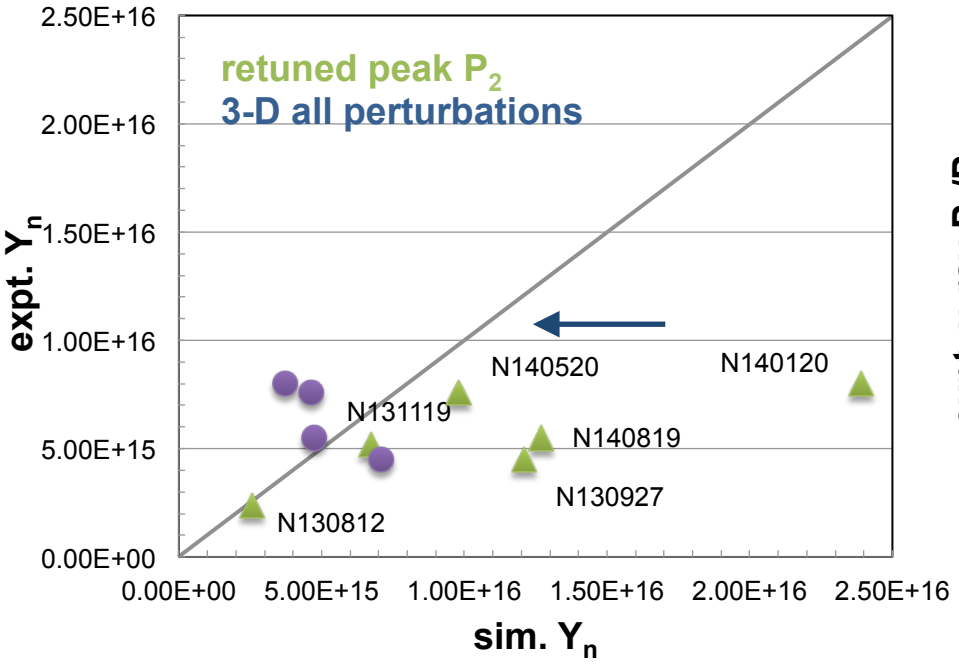
Our best 2-D simulations include the tent, surface roughness, and hohlraum asymmetries tuned to match VISAR data, 2-D ConA data, and the hot spot P_2/P_0

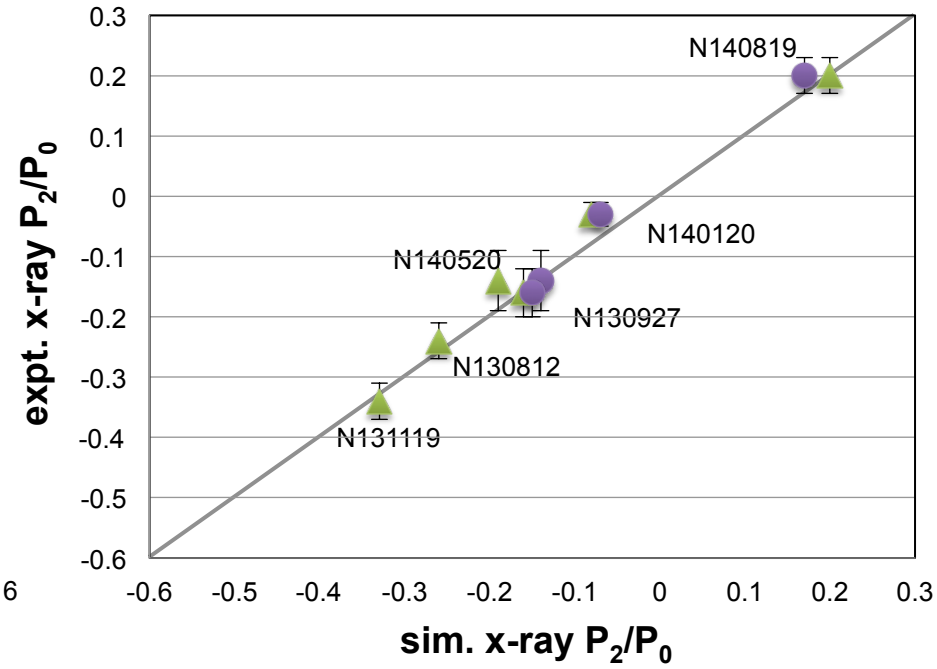




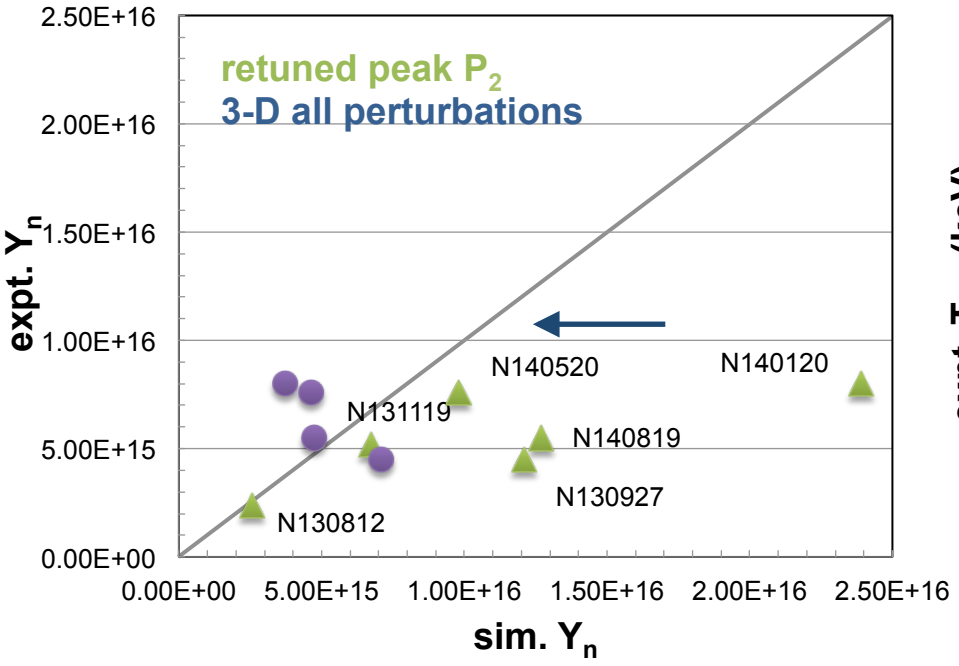
These simulations match Y_n for low energy shots reasonably well but are high by 2 – 3X for the higher energy shots.

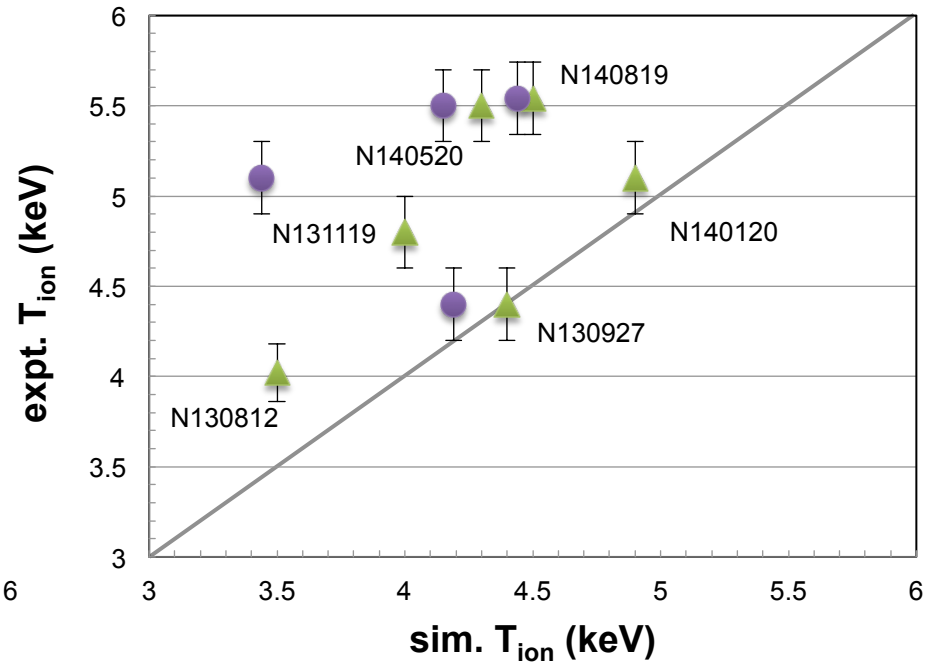
Rerunning the four outliers in 3-D roughly brings Y_n into agreement and P_2/P_0 is unchanged





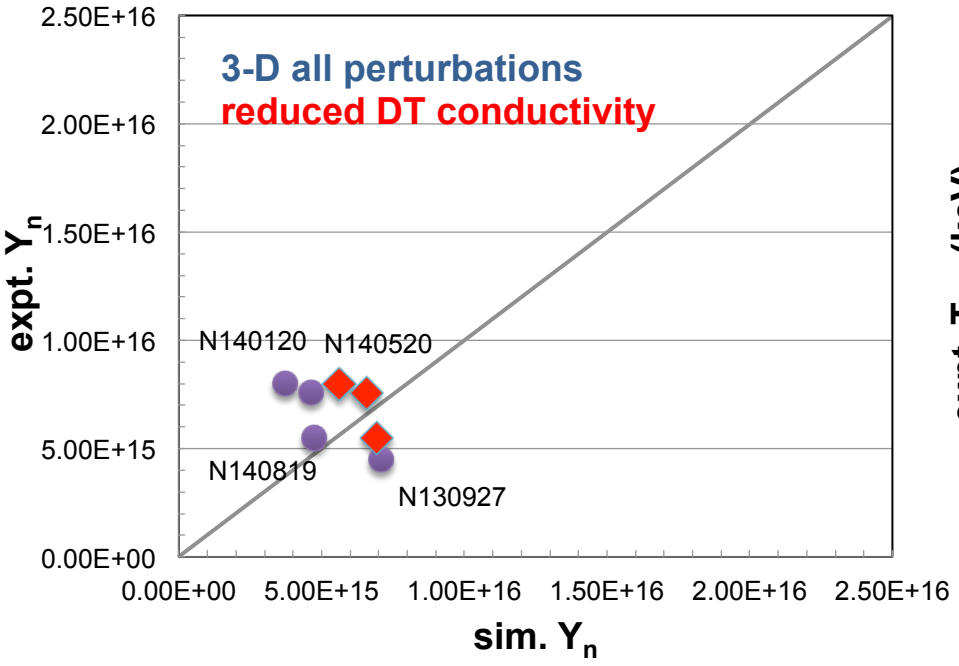
But 2-D and 3-D both under predict T_{ion} compared to the data

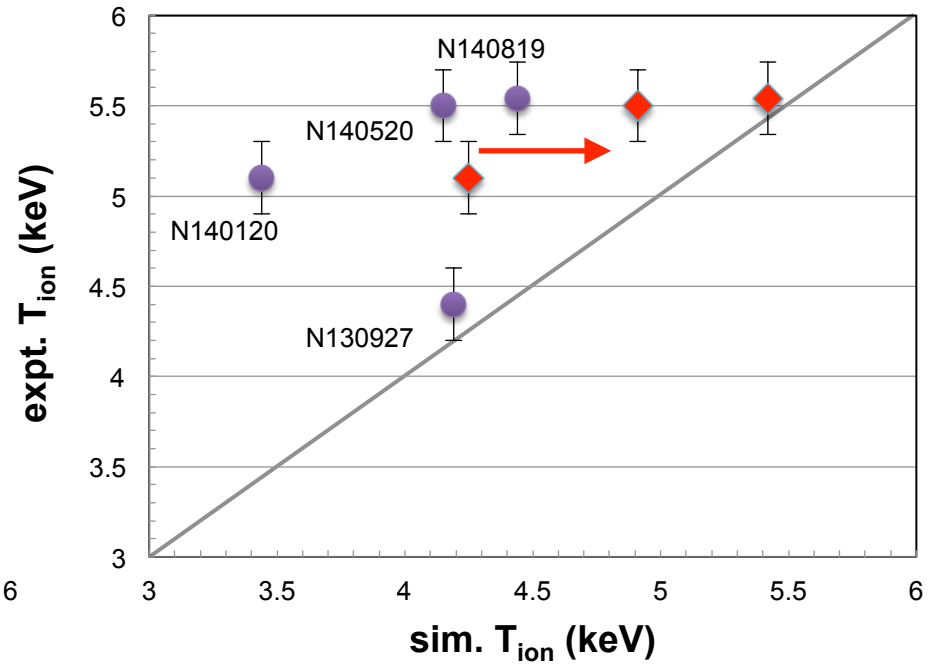




The 2-D T_{ion} values are properly time-averaged over the burn, but the 3-D values are instantaneous at bang time.

Rerunning the lowest T_{ion} cases with the DT thermal conductivity reduced by half improves the agreement for both T_{ion} and Y_n





This is a very simple modification to the DT conductivity, but a factor of two uncertainty is not unreasonable.

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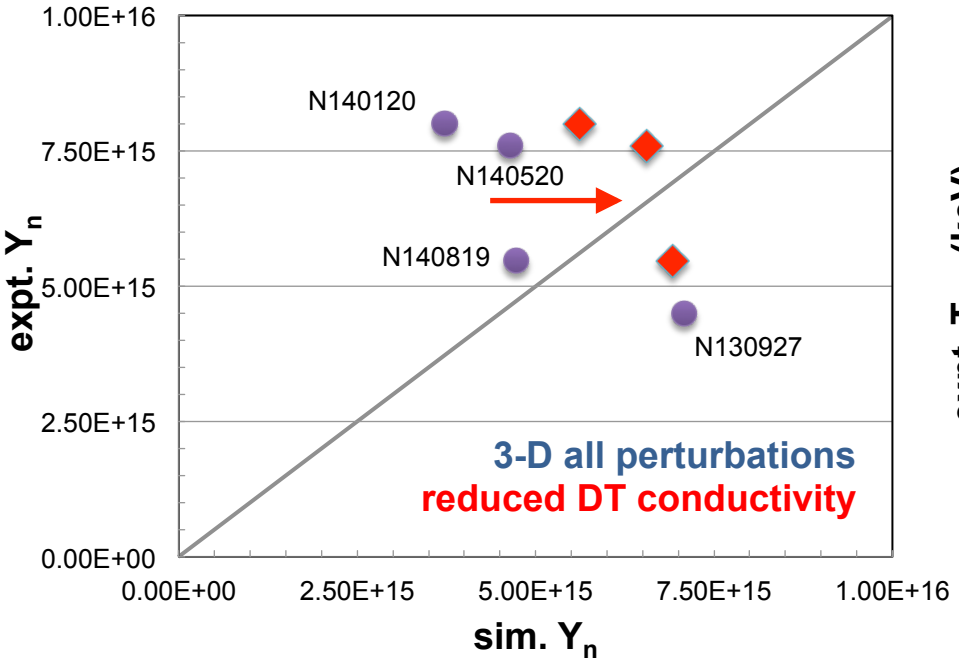

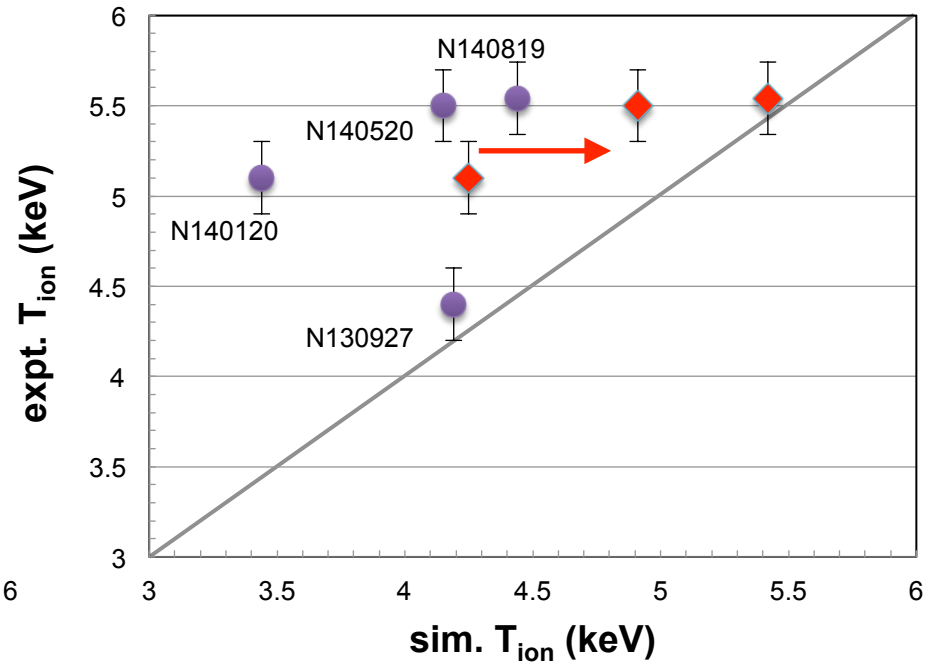

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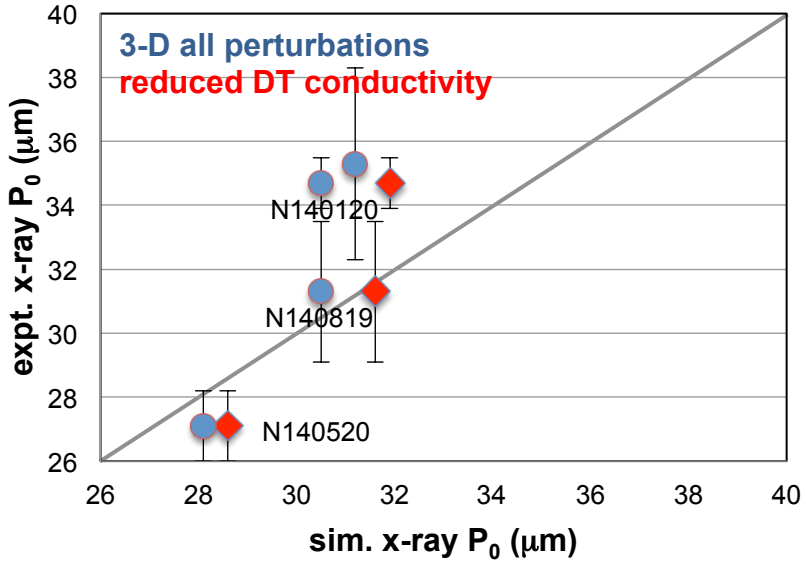
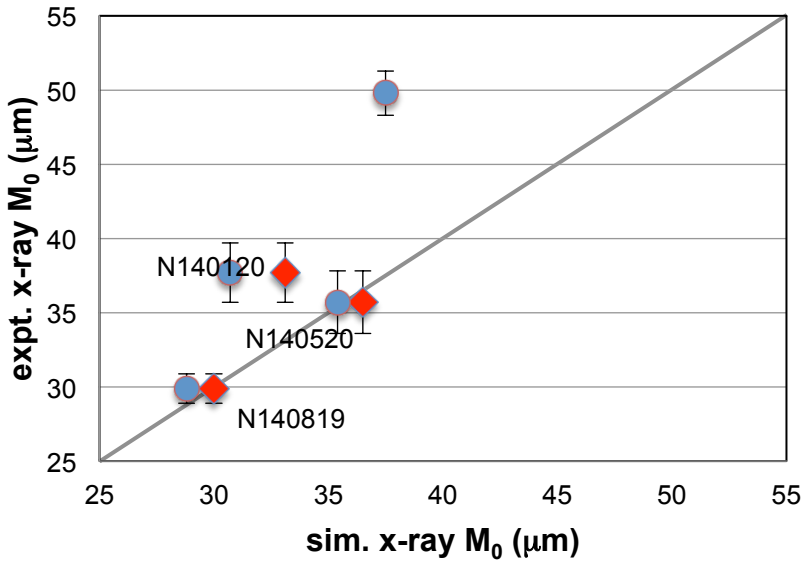
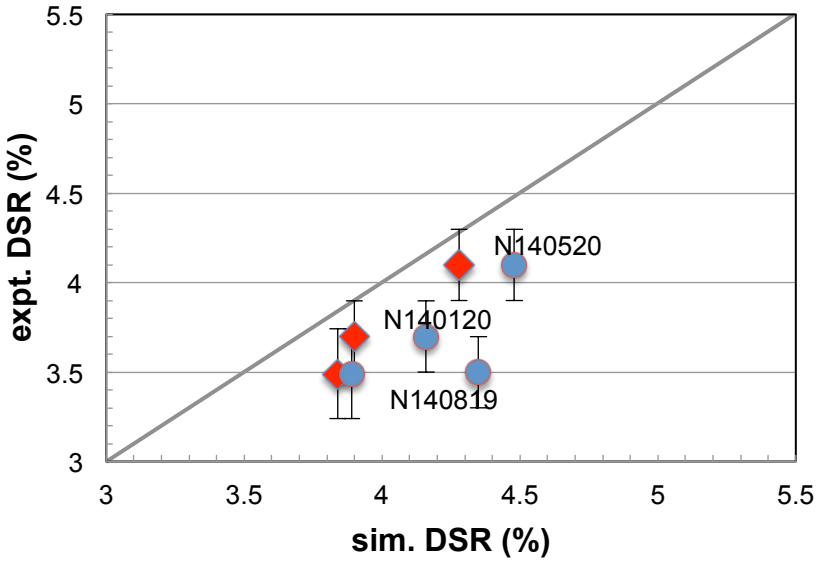
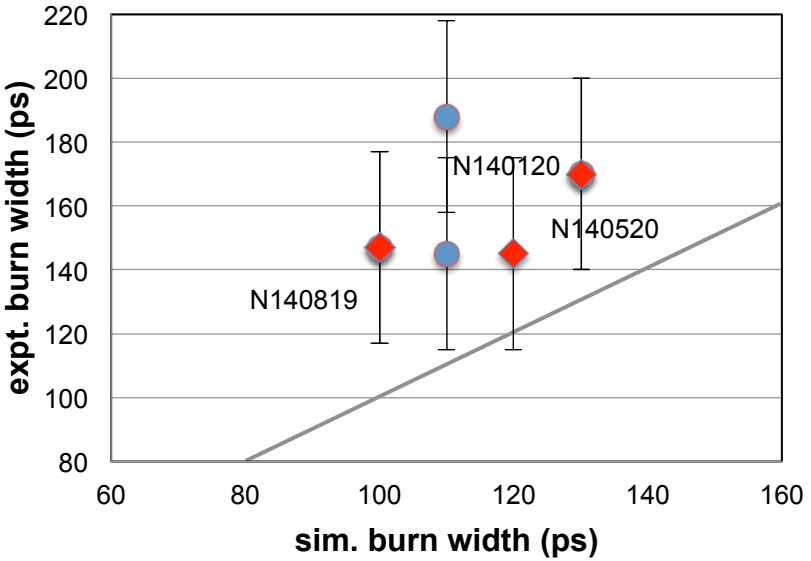
P_0 and M_0 are nearly within the error bars while the DSR is slightly high and the burn widths are slightly short









Where are the largest sources of uncertainty in current simulations and can kinetics play a role?

- Uncertainties in the magnitudes of the two largest degradation sources (the tent and the hohlraum asymmetries) are probably the largest drivers for the current discrepancies/uncertainties
  - We are working to improve our understanding of both of these
- However, given our current understanding, altering the hot spot thermal conductivity does seem to improve the agreement with the data
  - There is considerable sensitivity here and the uncertainties are large, but there are many candidates for causing this: degeneracy, B-fields,…
  - Inglebert *et al*., EPL (2014) has shown that hot spot **kinetics** can also have a similar effect (raise T_{ion} and Y_n). Is this what we are seeing?
- In 1-D, Steve Haan has shown a degeneracy in our sensitivity to conductivity and dE/dx uncertainties in terms of Y_n vs. T_{ion}
  - Should we be be looking at dE/dx uncertainties instead of conductivity? Can we tell the two apart?

Our best 2-D and 3-D simulations give a fair representation of the high foot data but do not capture all of the trends

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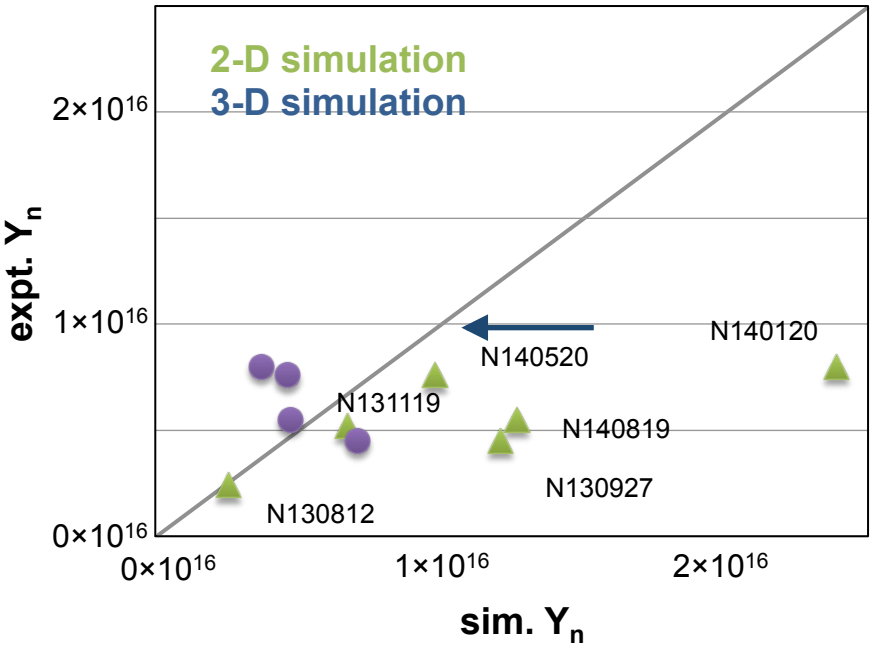

- The tent and hohlraum asymmetries are the largest degradation sources. Uncertainties in these are probably the best place to look for explaining our discrepancies, but uncertainties in the micro-physics are also a possibility.

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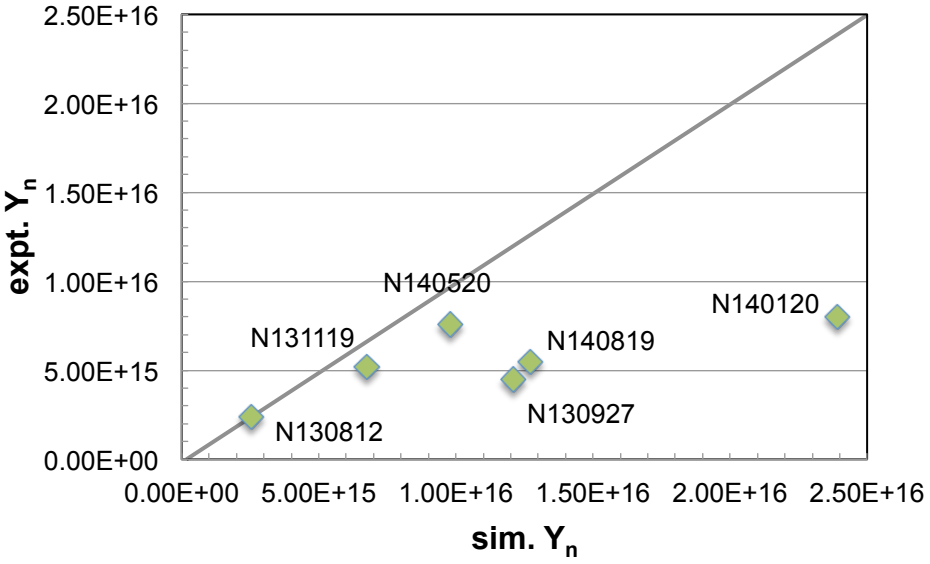
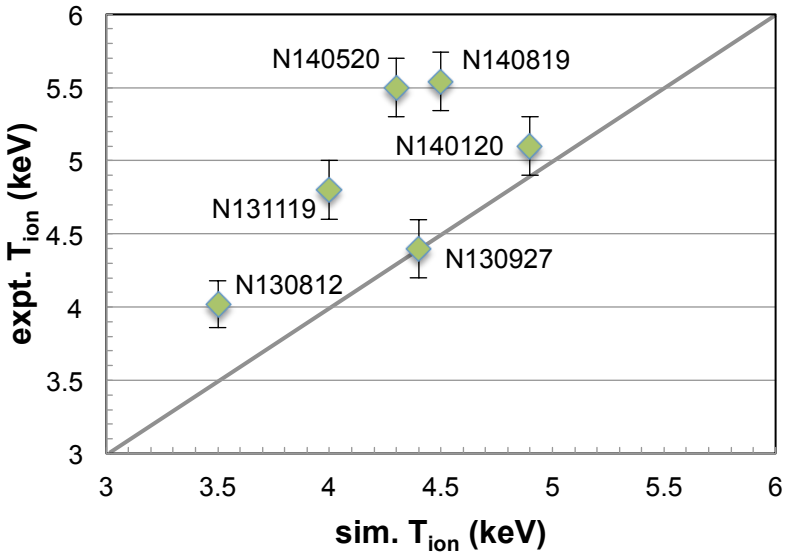
We have assembled a simulation data base of six high foot shots that cover a scaling in power, energy, and thickness

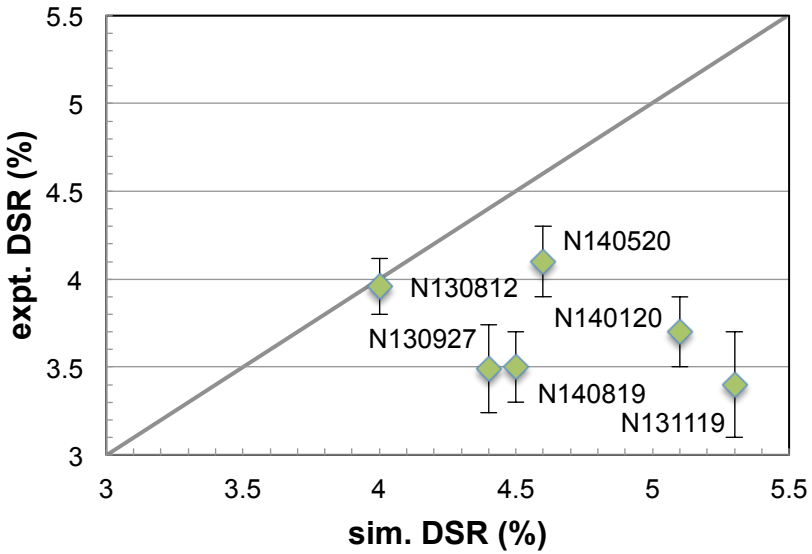
	N130812	N130927	N131119	N140120	N140520	N140819
hohlraum	Au	Au	Au	DU	DU	DU
shell thickness (μm)	195.0	195.0	195.0	195.4	178.5	164.8
tent thickness (nm)	45	45	45	16	45	45
E_{laser} (MJ)	1.7	1.8	1.9	1.9	1.8	1.8
P_{laser} (TW)	350	380	410	410	390	390
fuel vel. (km/s)	329	353	356	356	391	390
fuel adiabat	2.7	2.7	2.2	2.4	2.4	2.7
T_i (keV)	4.0	4.4	4.8	5.1	5.5	5.5
DSR (%)	4.0	3.5	3.4	3.7	4.1	3.5
$Y_{13-15\ MeV}$	2.4×10^{15}	4.4×10^{15}	5.2×10^{15}	8.0×10^{15}	7.6×10^{15}	5.5×10^{15}

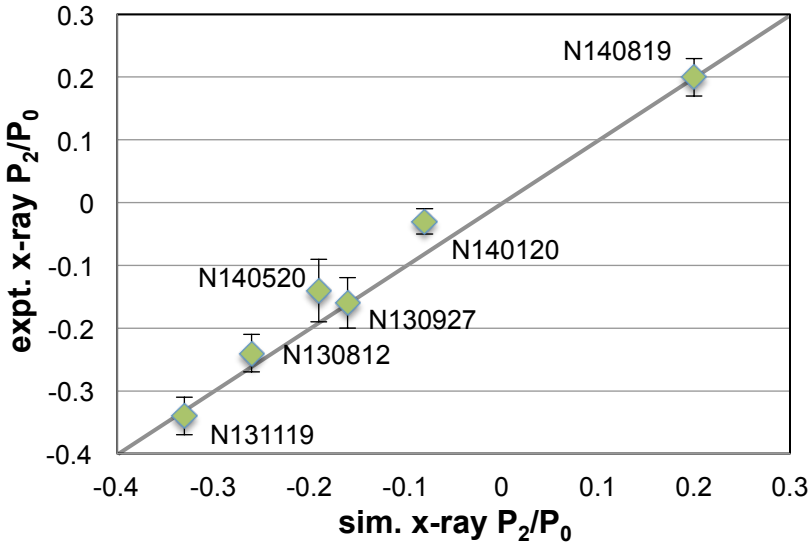
Four of the six have been run in 3-D as well as 2-D: N130927, N140120, N140520, and N140819.

2-D sims. with the tent, roughness, and tuned asymmetries are ~ 2X too high in Y_n, 20% too low in T_{ion}, and 20% too high in DSR

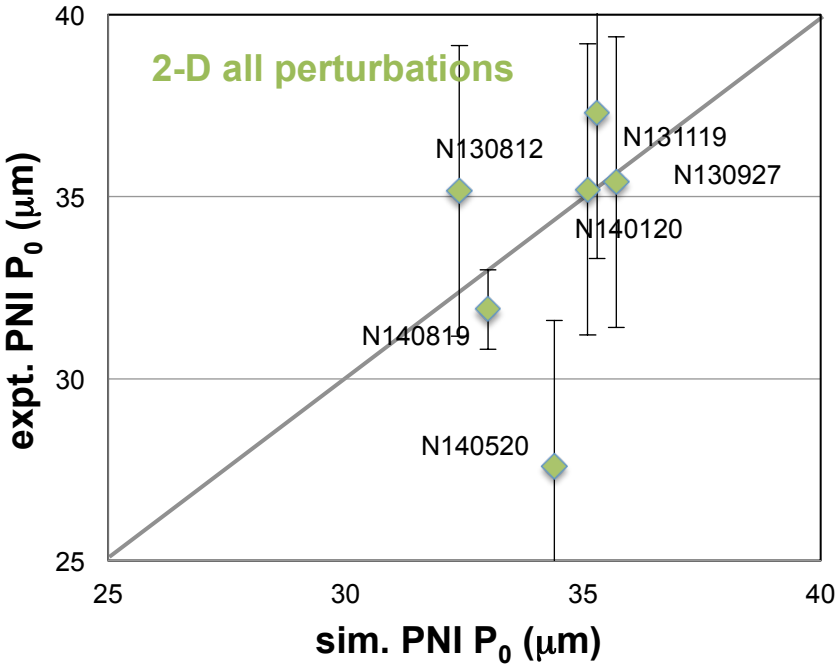


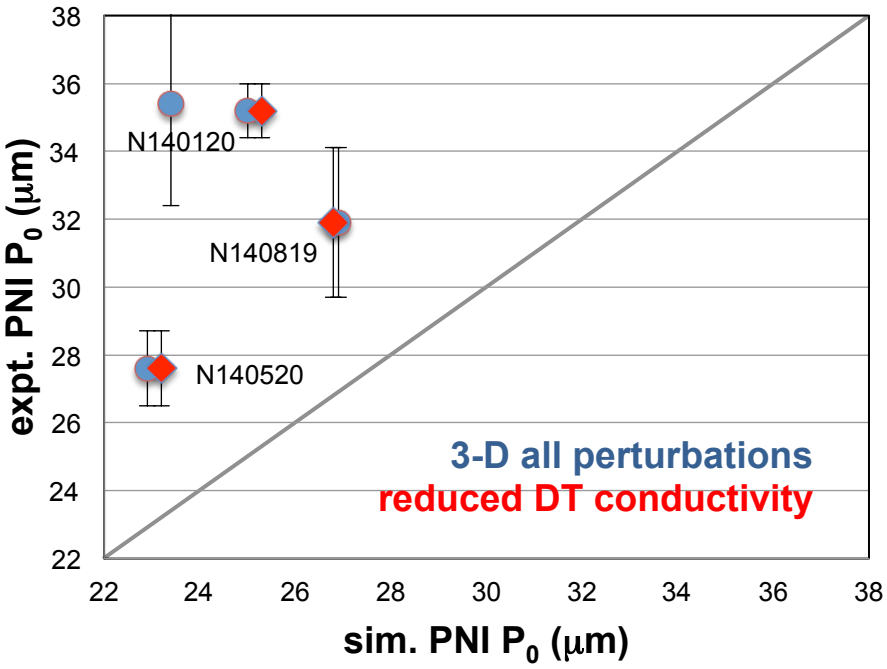






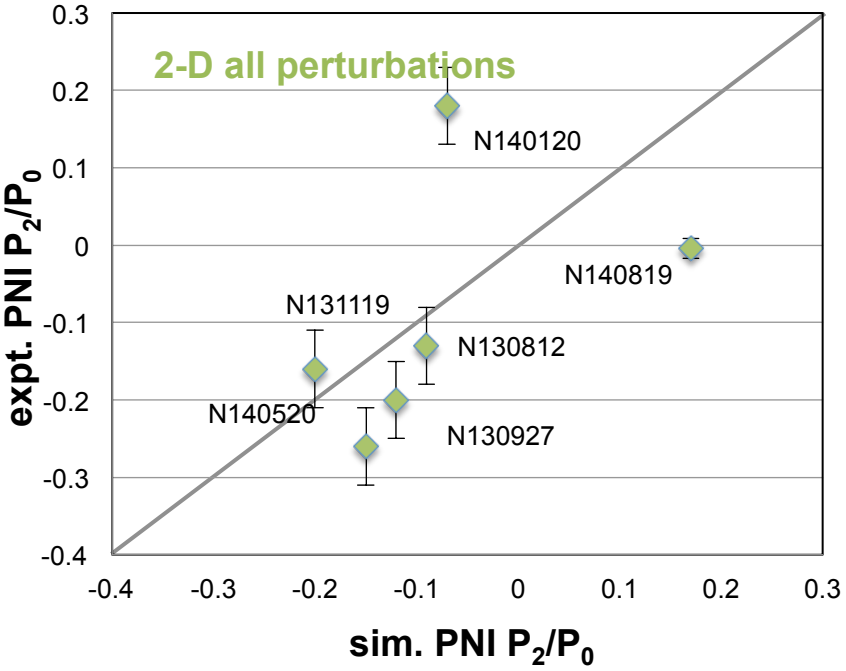
2-D simulations are close to the measured PNI P_0 but 3-D simulations are too low

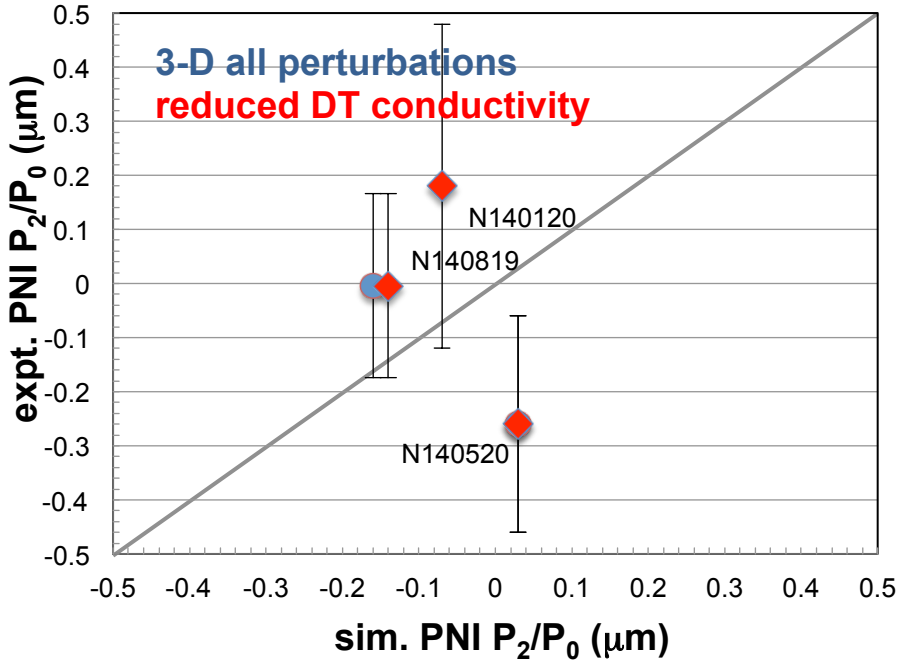




The 2-D values are properly time-averaged over the burn, but the 3-D values are instantaneous at bang time.

2-D and 3-D simulations are also close to the measured PNI P_2/P_0





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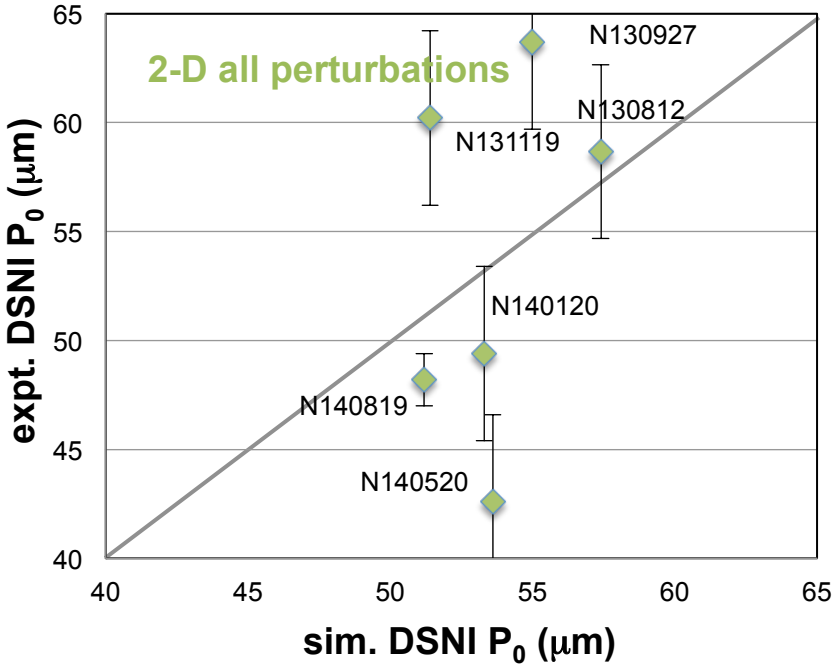
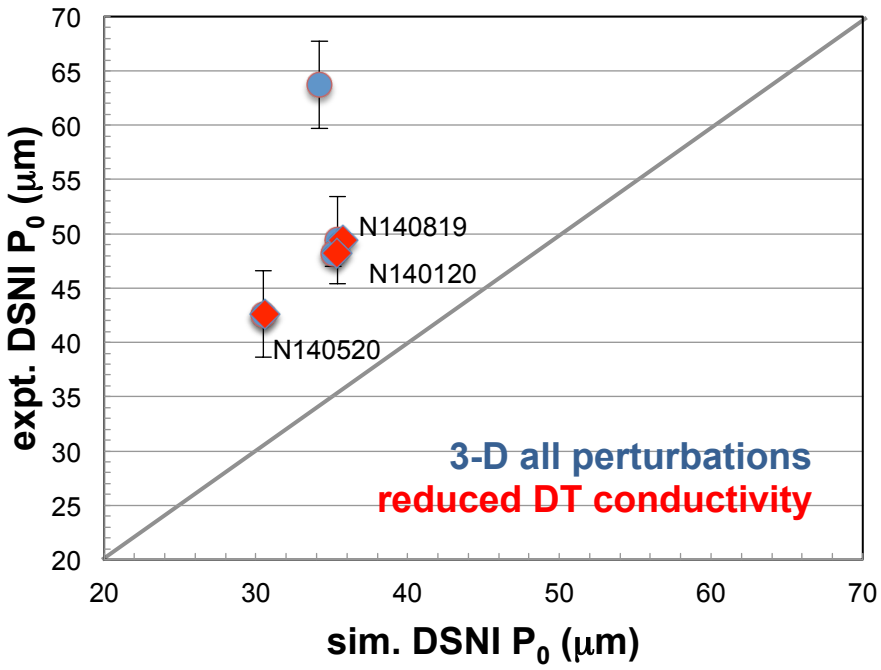
2-D simulations are close to the measured DSNI P_0 but 3-D simulations are too low





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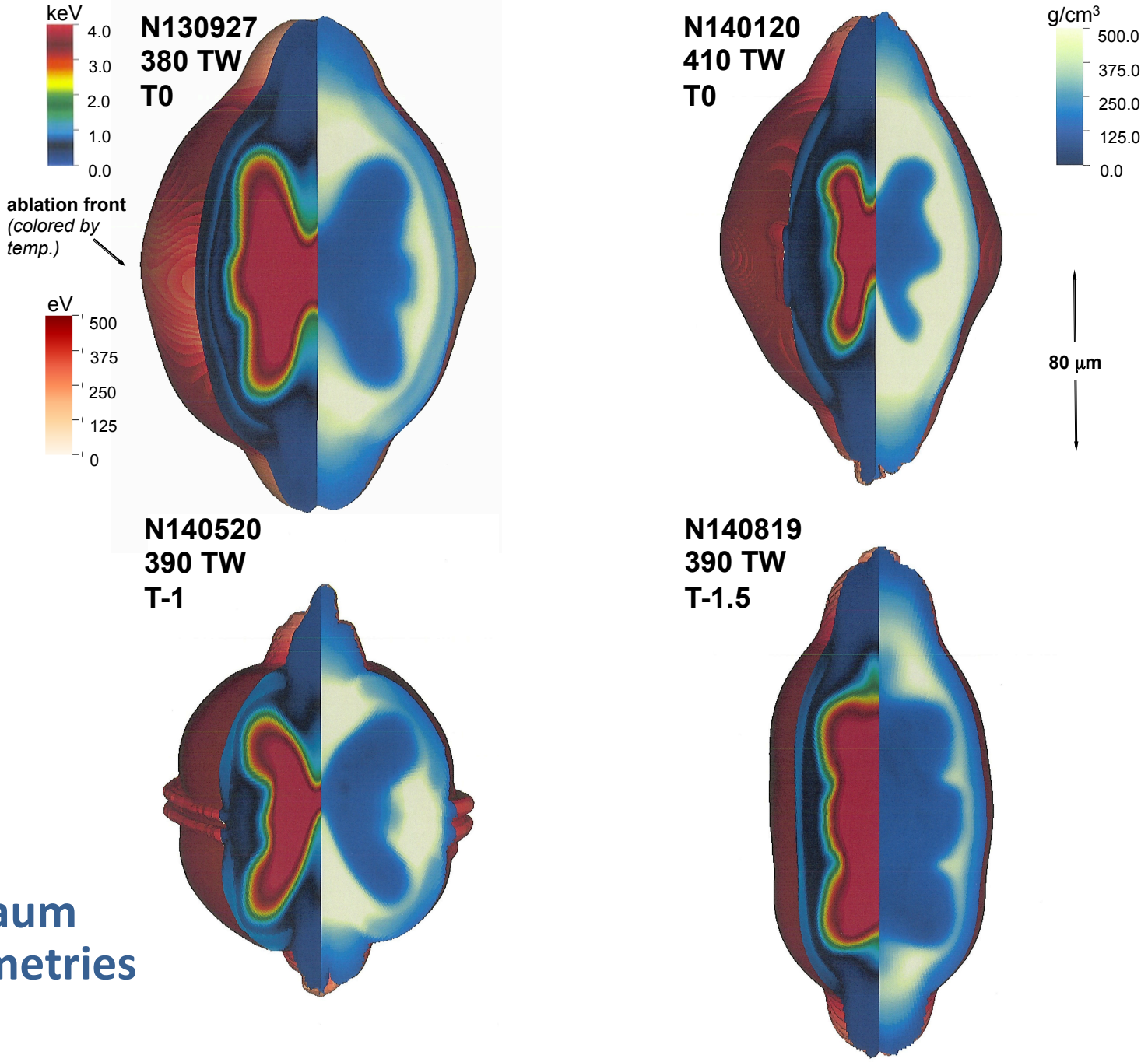
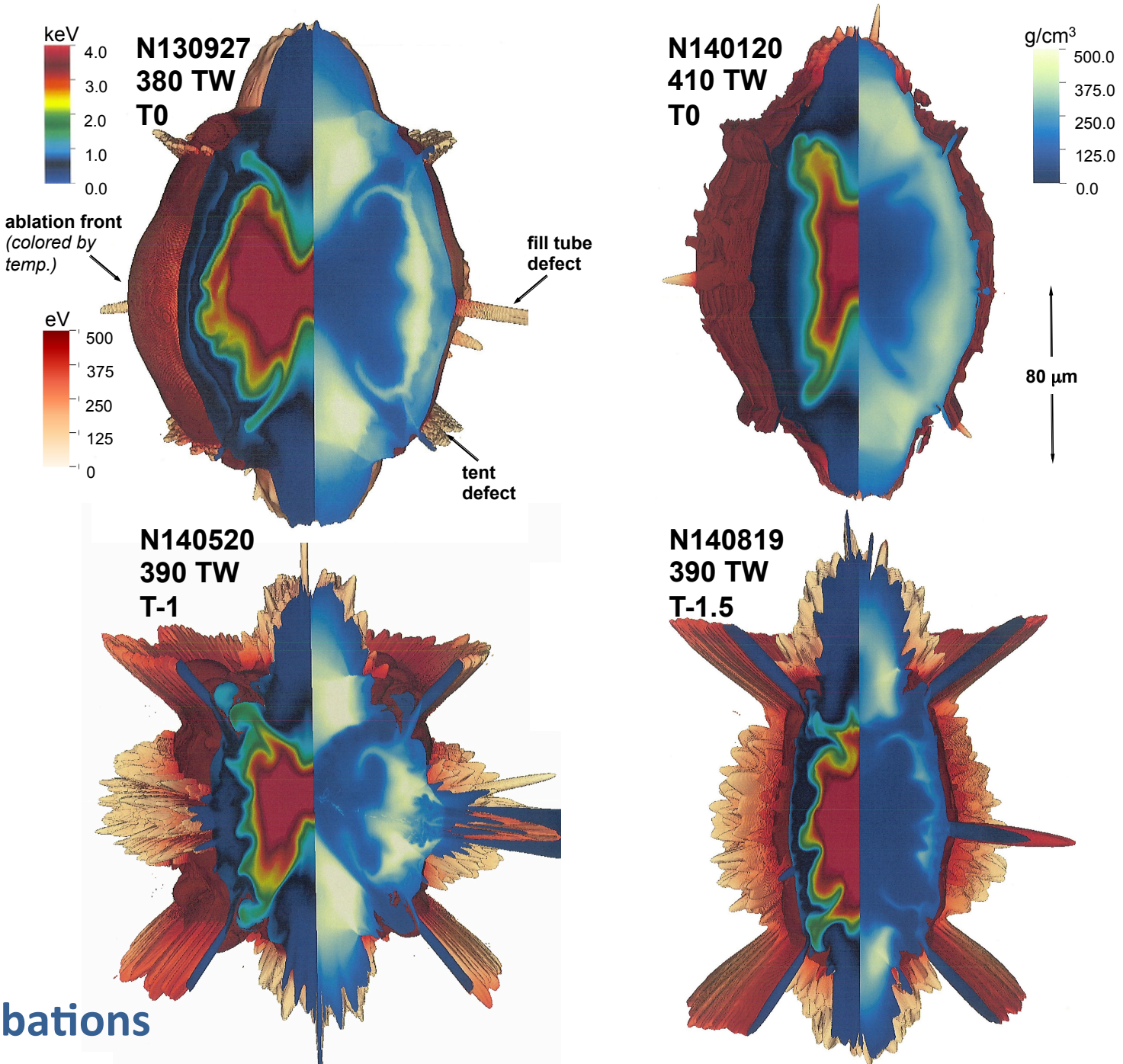


Hohlraum asymmetries only



All perturbations