Instability modeling for NIF ignition targets and Omega experiments

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Summary: We are continuing to explore hydro instability issues on NIF targets, and verifying modeling with Omega experiments

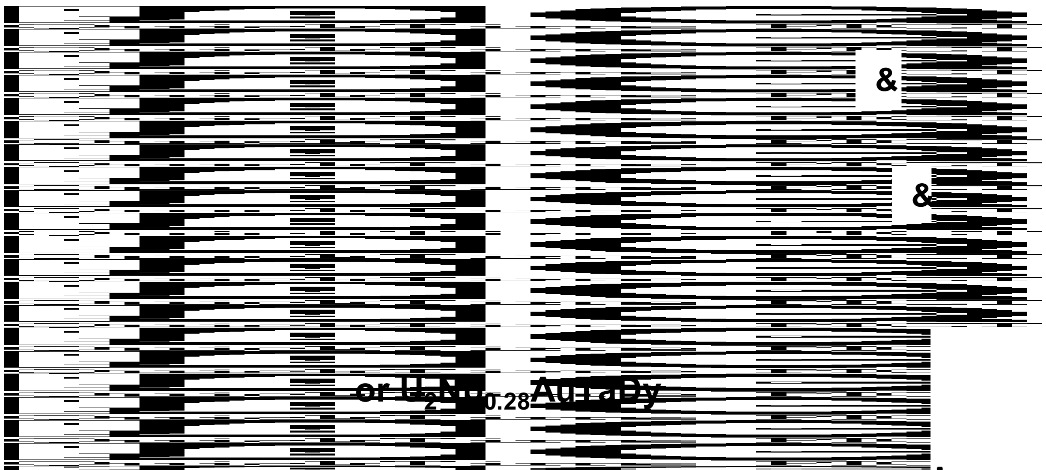
Specifications are being completed for a variety of indirect drive targets:
- Beryllium, polyimide, CH(Ge) ablators
- Drive temperatures 250 - 350 eV, spectra for gold or cocktail hohlraum
- Scales from 100 kJ to 600 kJ into capsule (NIF energy ~1.8 MJ)

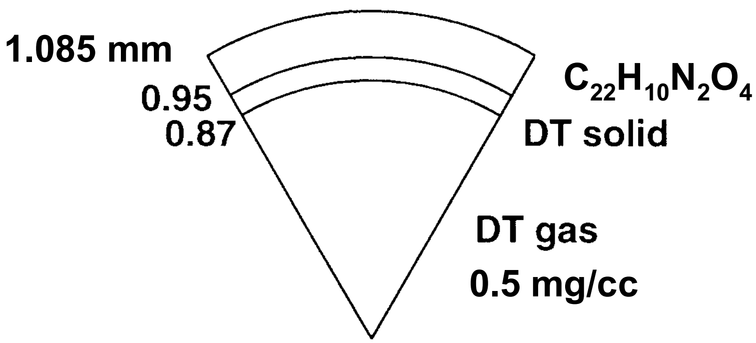
Details such as ^{3}He buildup in the core are being analyzed

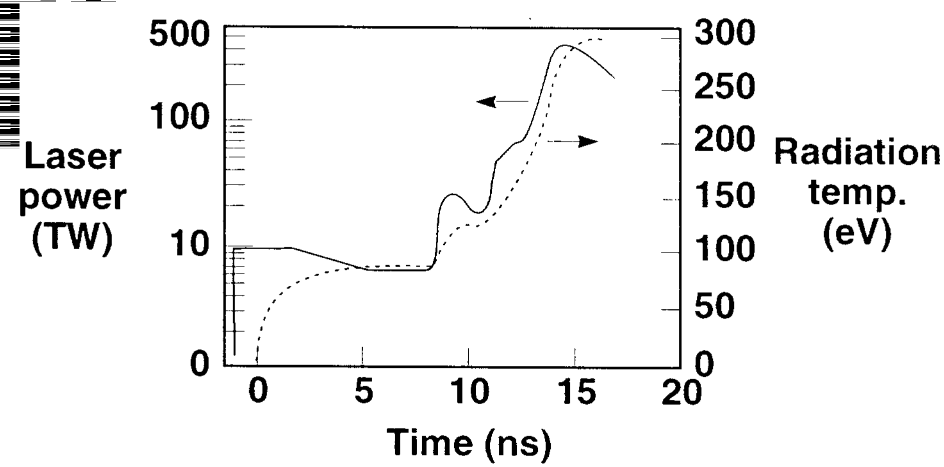
Modeling of Omega planar polyimide Rayleigh-Taylor foils is close to experiments

A new design for convergent Rayleigh-Taylor experiments on Omega will test other aspects of the modeling

Generically the ignition targets all look the same as for the last 10 years or so







Our current instability modeling is based entirely on explicit full simulations of perturbation growth and its impact on ignition and burn

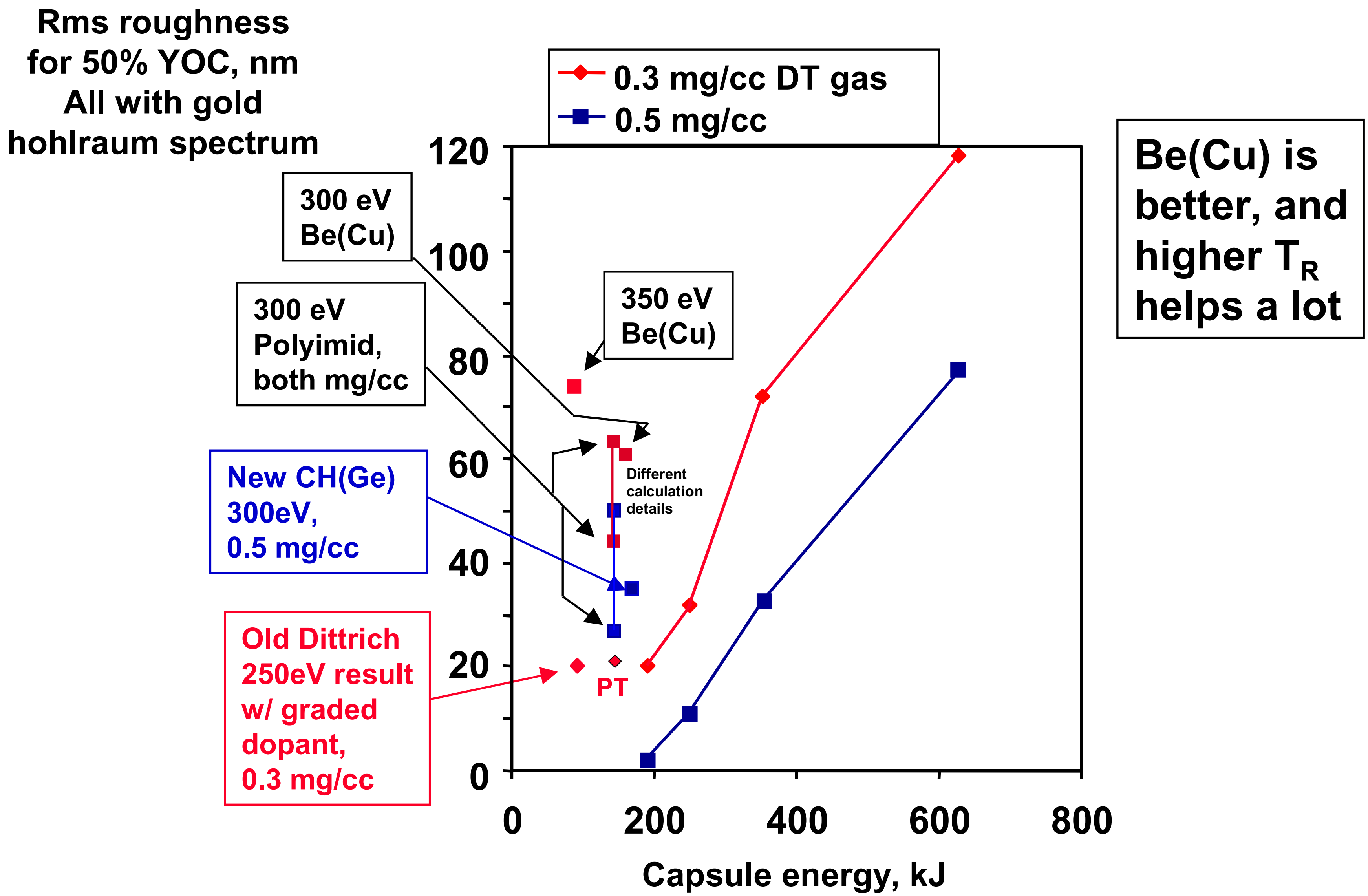
- Single shell cryogenic capsules are ablatively stabilized on outside during acceleration, and on inside during deceleration
- Simulations indicate that modes beyond about 120 do have any appreciable amplitudes at any times of interest
- Experiments have generally been compatible with simulations giving us confidence in them
- Modeling is done in 2D (LASNEX and Hydra) and 3D (HYDRA) for single modes, and for multiple modes over various solid angles
- Biggest uncertainties are considered to be in the input: spectrum of drive radiation, opacities, characterization of initial perturbations

There are three failure modes we see in our simulations

- **Acceleration: Modes *l* ~100 grow and disrupt the shell**
  Especially a problem if shell is too thin
- **Deceleration: Modes *l* ~15 create spikes that cool the hotspot**
  Especially a problem if shell is too thick
- **Low modes: If there is much solid angle with ρr < 1 g/cm^2, bubbles blow out and yield is reduced**

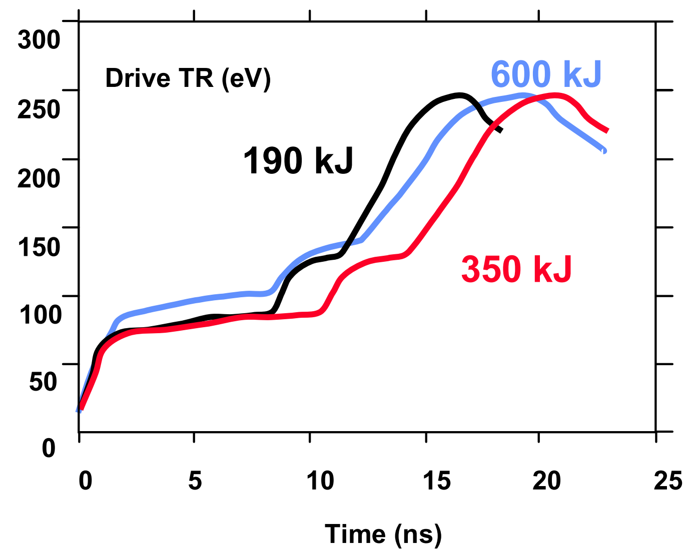
A successful target is optimized to trade off the first two issues, and has enough 1D ρr to minimize the third. Requires power and energy to have room to trade them off!

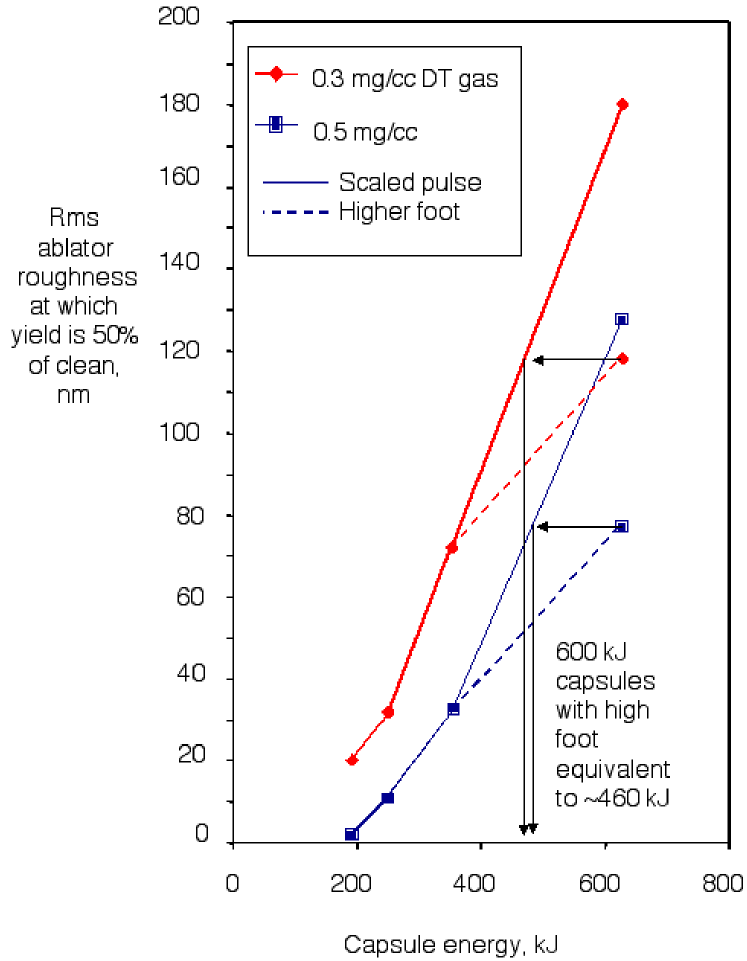
This plot summarizes ablator-seeded Rayleigh-Taylor results for the different capsules



600 kJ capsules might be constrained in foot length, at a significant energy price

Largest scale might have foot increased in order to keep total pulse length close to 20 ns

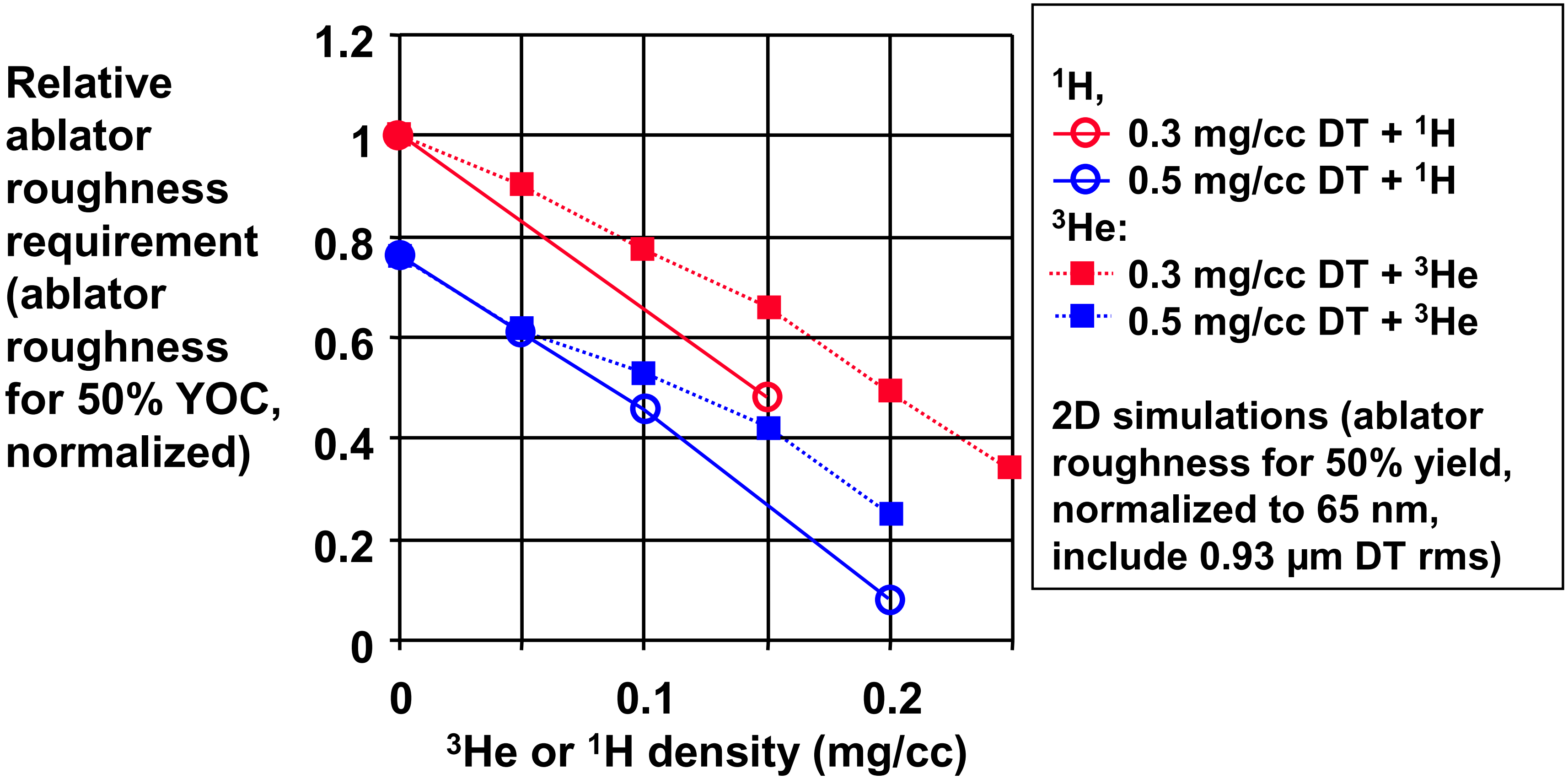




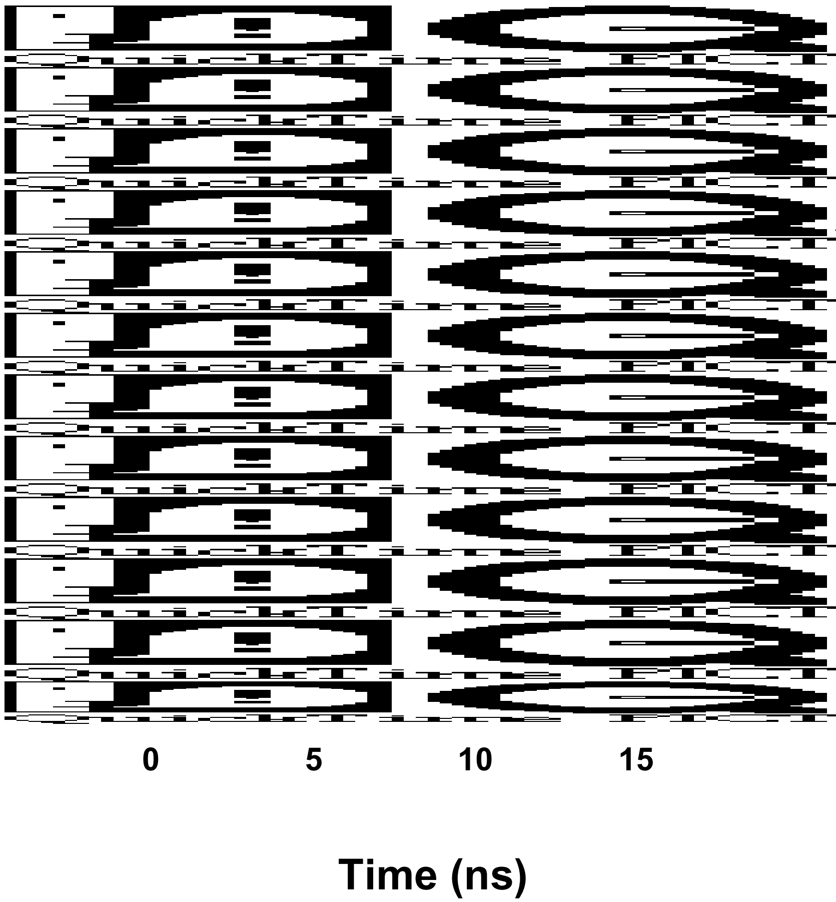
If shock-crossing time is fixed,
velocity ~ S^1
foot level flux F ~ S^2
Adiabat β ~ $S^{1.2}$
Margin ~ $S^3\beta^{-1.5}$ ~ $S^{1.2}$ ~ $E^{0.4}$ instead of E^1

Surface roughness specifications are tighter if there is ^{1}H or ^{3}He in the central gas

- Both are "dead weight" w/ respect to hydro, ignition & burn
- Atom-for-atom, ^{3}He is worse—more electrons and ion charge, increases radiative and conductive losses
- But gram-for-gram, ^{1}H is slightly worse—3x more atoms/g



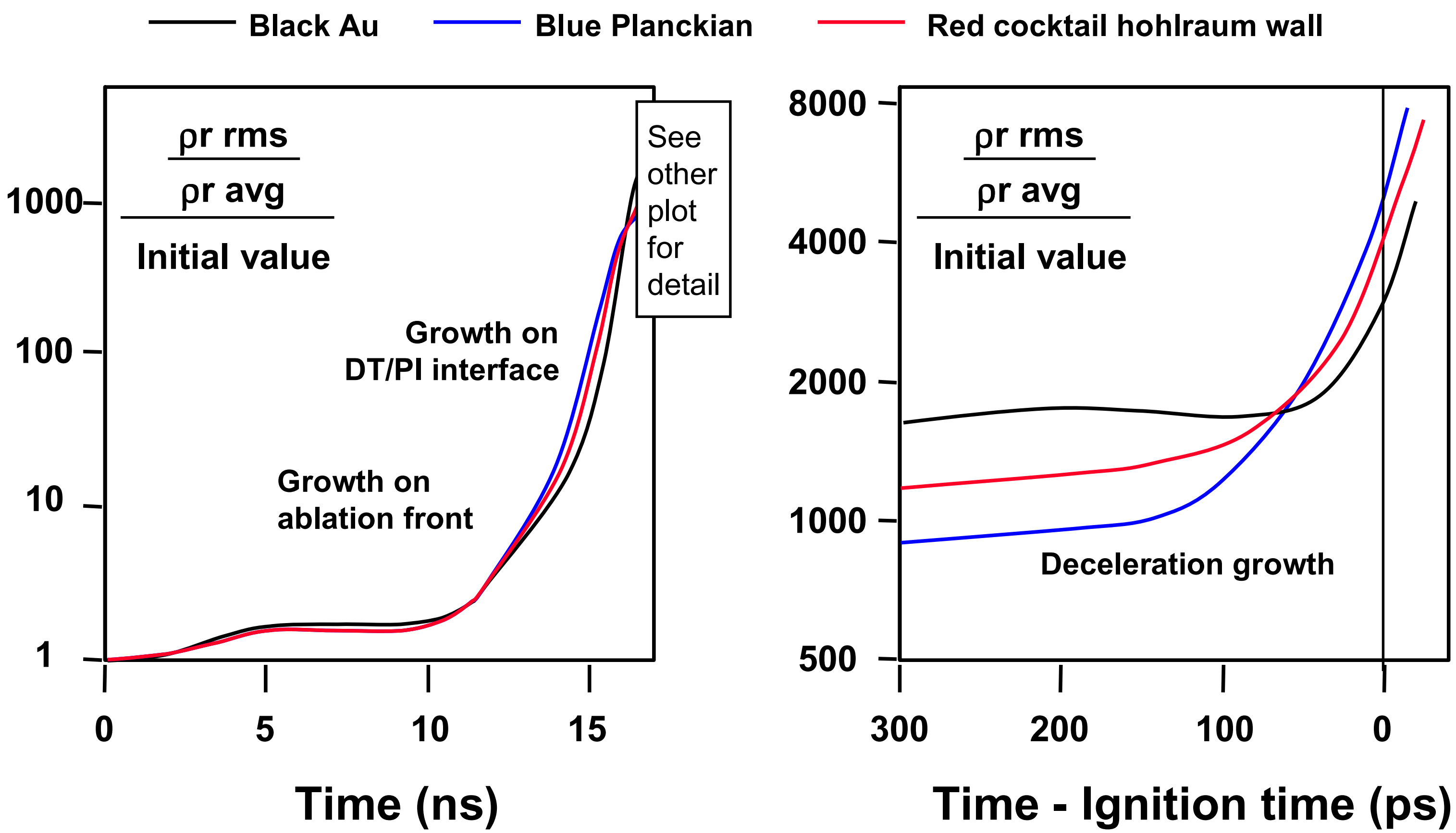
The calculated NIF cocktail spectrum is intermediate between Planckian and gold



Need to do simulations of effect on Rayleigh-Taylor of actual cocktail spectrum

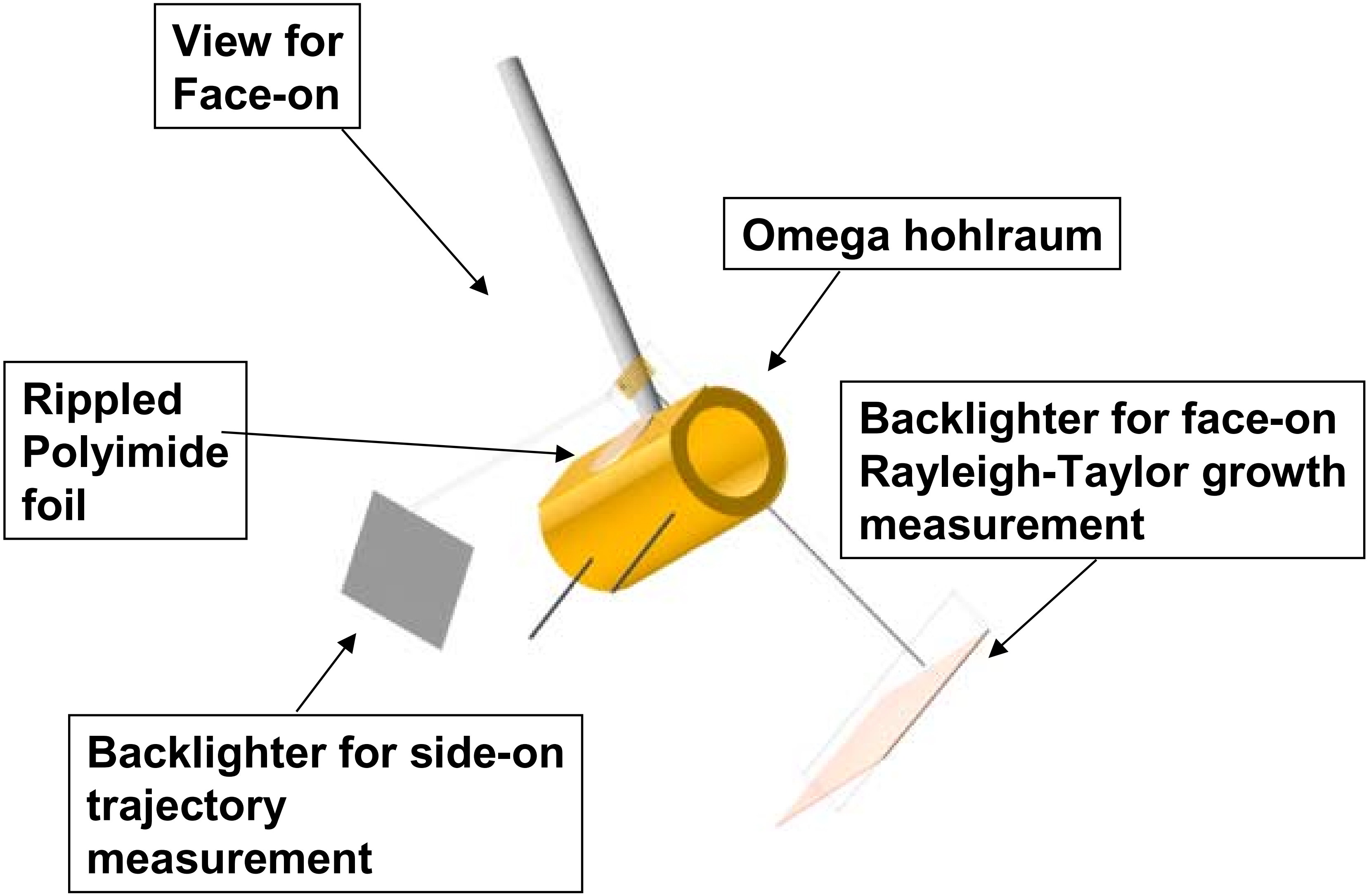
With a Planckian drive, baseline polyimide NIF capsule shows 85% more Rayleigh-Taylor growth

Growth in 2D simulations, very small multi-mode pert on ablator initially

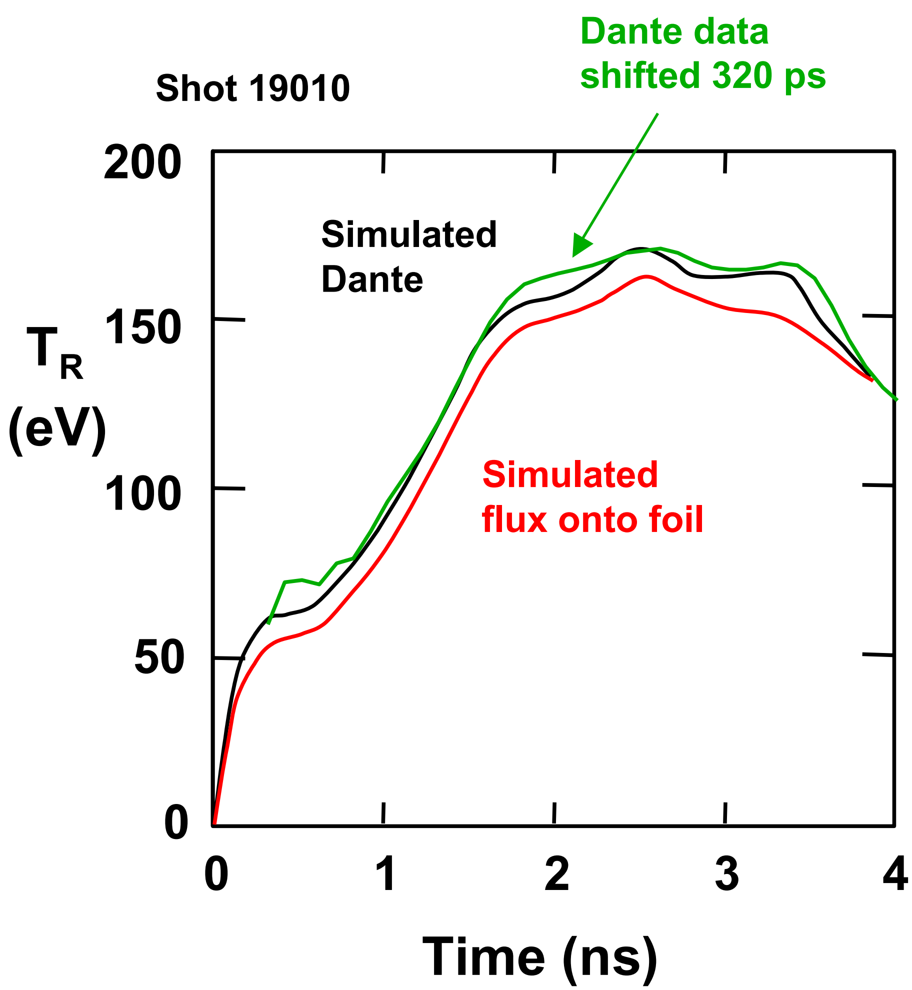


Complicated interplay of growth on the various interfaces
With doped ablators, may be able to reoptimize w/ cocktail wall

We are doing Rayleigh-Taylor experiments on Omega to verify modeling of polyimide



Peter Amendt has done hohlraum simulations that fit the Dante flux measurement

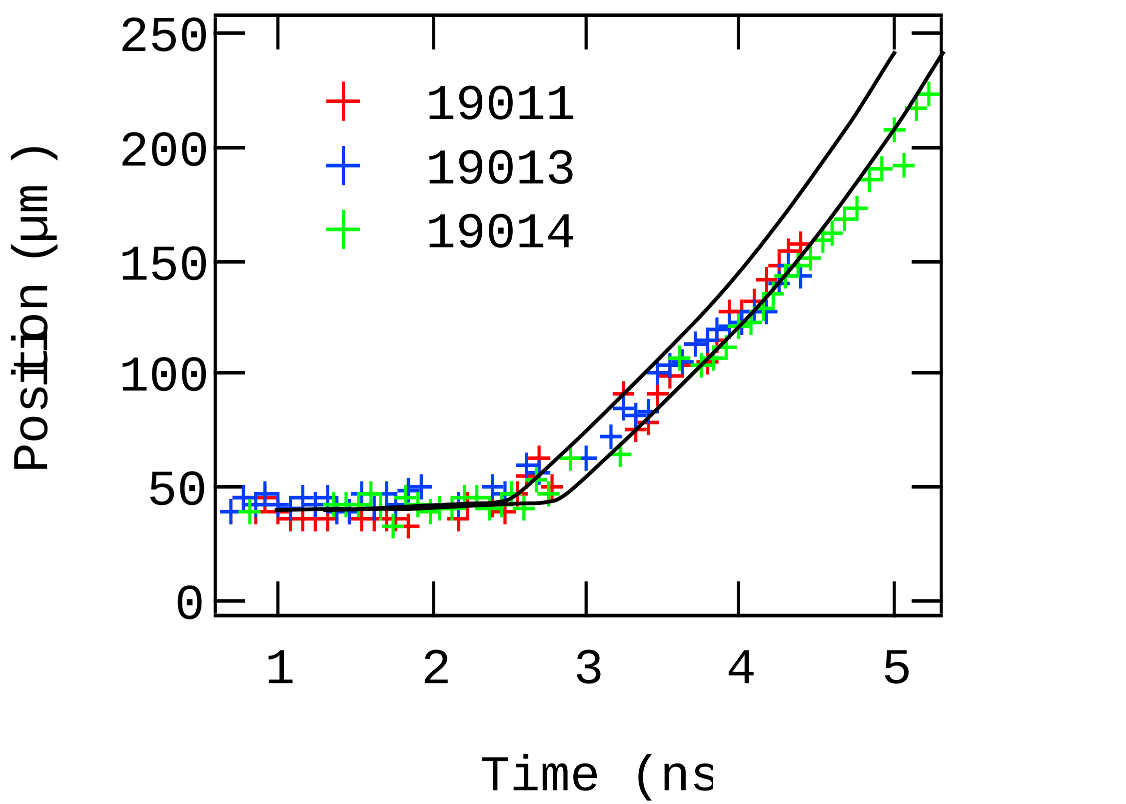


Post-process to simulate Dante: almost high enough to fit data (black curve compared to green).

Simulated drive for package is red curve, about 10 eV lower

There's a significant geometrical correction (like the old albedo correction, but now in the other direction) that we need to incorporate

Simulated drive extracted from Peter's hohlraum calculations makes sideons very close to data



Simulation using Peter's simulated drive

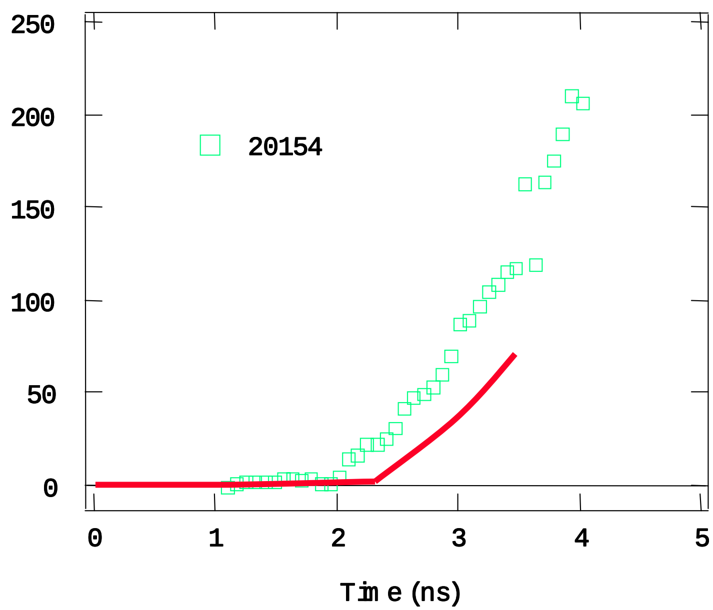
Also shown shifted in time, improves fit

Peter's hohlraum simulations include a foil, its side-on motion agrees with my foil-only simulation

I have finished one case faceon and sideon from June 00 shots with the new source info

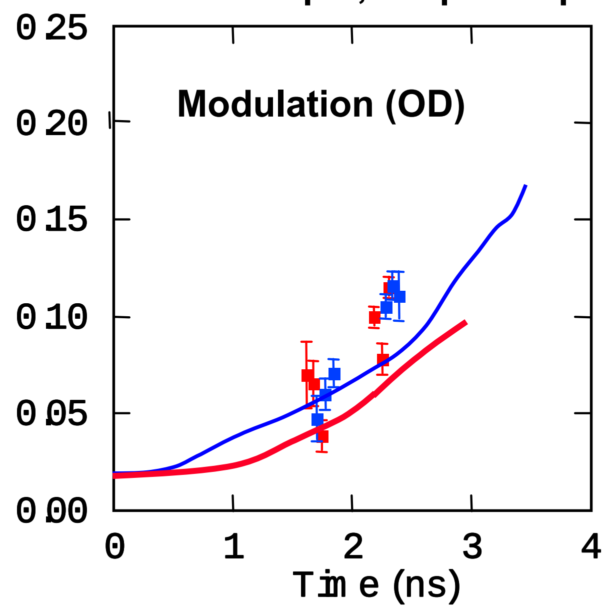
Source was Dante-25eV, with M-band adjusted (by factor of several) to match Dante M-band fraction

Gail says this is the one reliable side-on from this series



Face-on

λ = 30 μm, 2.0 μm amp



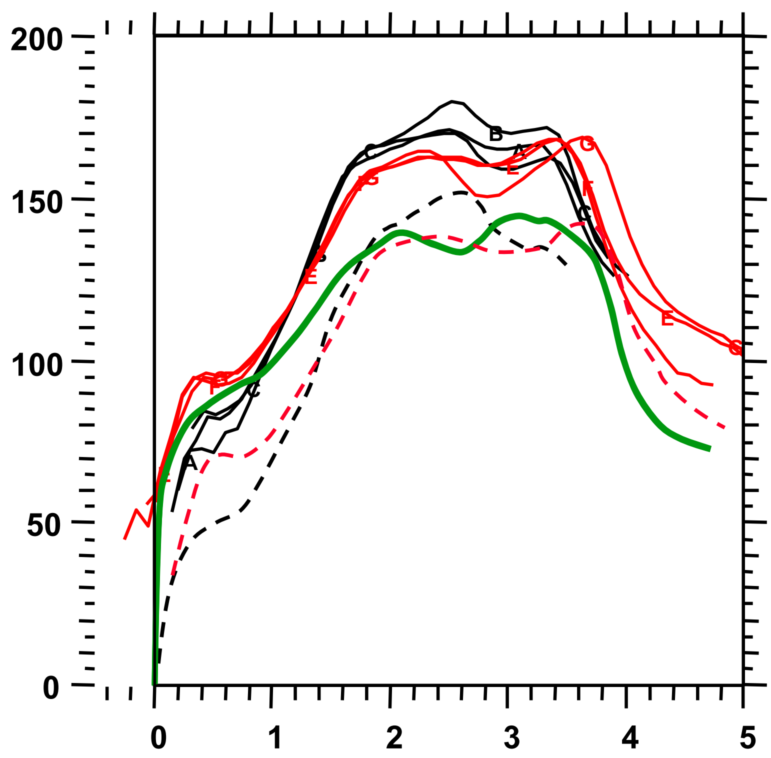
Old drive
New drive

This is late and slow, meaning we've overcorrected the drive, which is very good news

The simulations I've shown previously for the June 00 faceons used this drive profile

Profile I used for old face-on work

19010 simulated source from Peter (aruguably fits sideons)



Dante:

Black 19010, 1, 3 (Feb 00) (sideons we've been trying to fit)

Red 20154 5 6 (June 00) (faceon shots)

All Dante retimed to go through (1.2 ns ,120 eV)

All plots are with CEA calibration

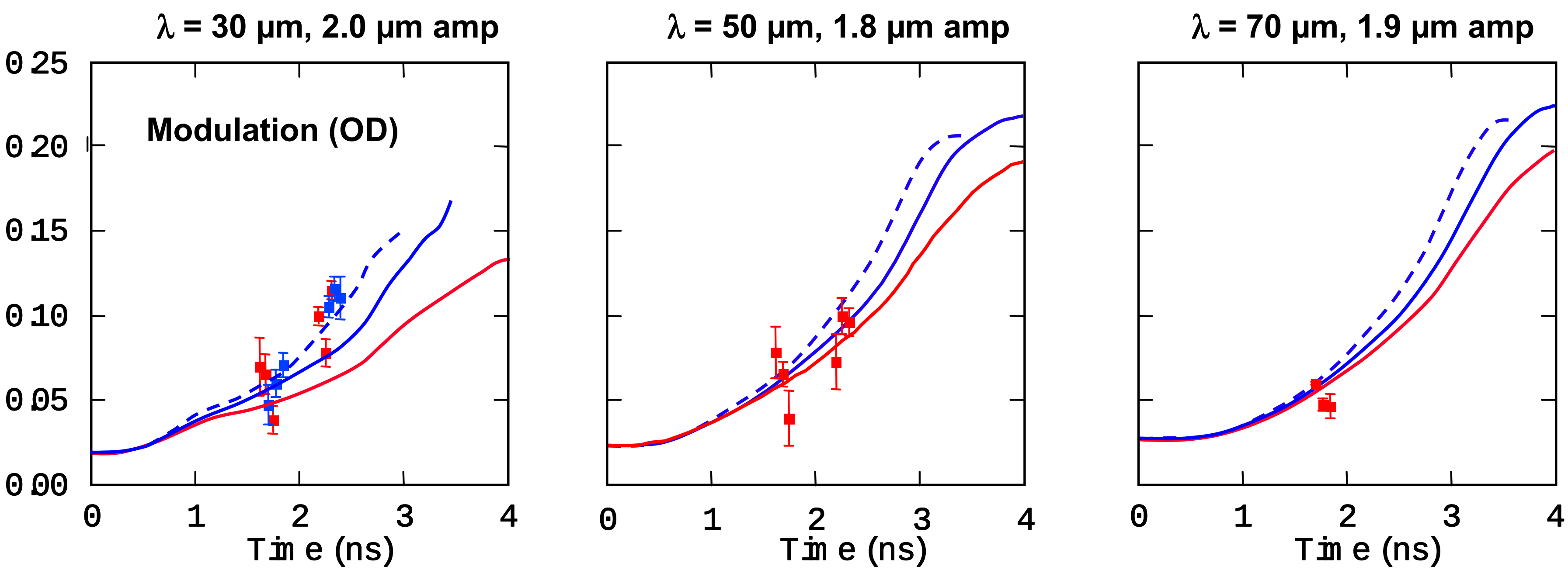
Black solid to black dashed is geometry correction + ~10 eV that Dante is still high compared to simulations. (Arguably fits sideons) Same correction to red curves would be "right" profile, compare to green curve.

Red dash is face-on Dante -25eV, shifted 0.1ns to get good time 0 -- best guess at drive for faceons 20154-6. On old green profile, foot was too high, peak not bad

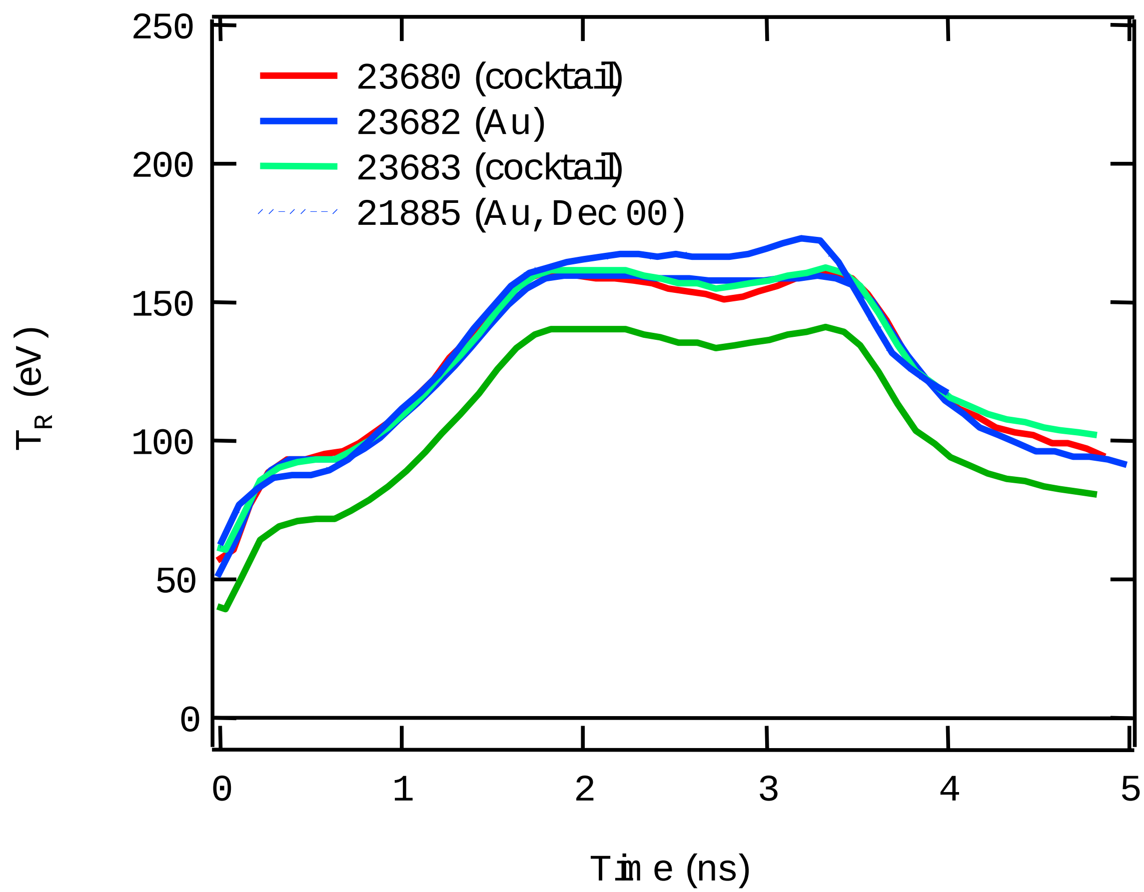
With that profile I had a decent fit, need to revisit now that sideons are more or less sorted out

- Better simulations use opacity tables generated from OPAL code
- Increases growth slightly, improves agreement at 30 microns

Simulations using XSN opacities, Dante drive, calculated spectrum (same as above)
OPAL opacities, drive shown above and calculated spectrum
OPAL opacities, Planckian spectrum

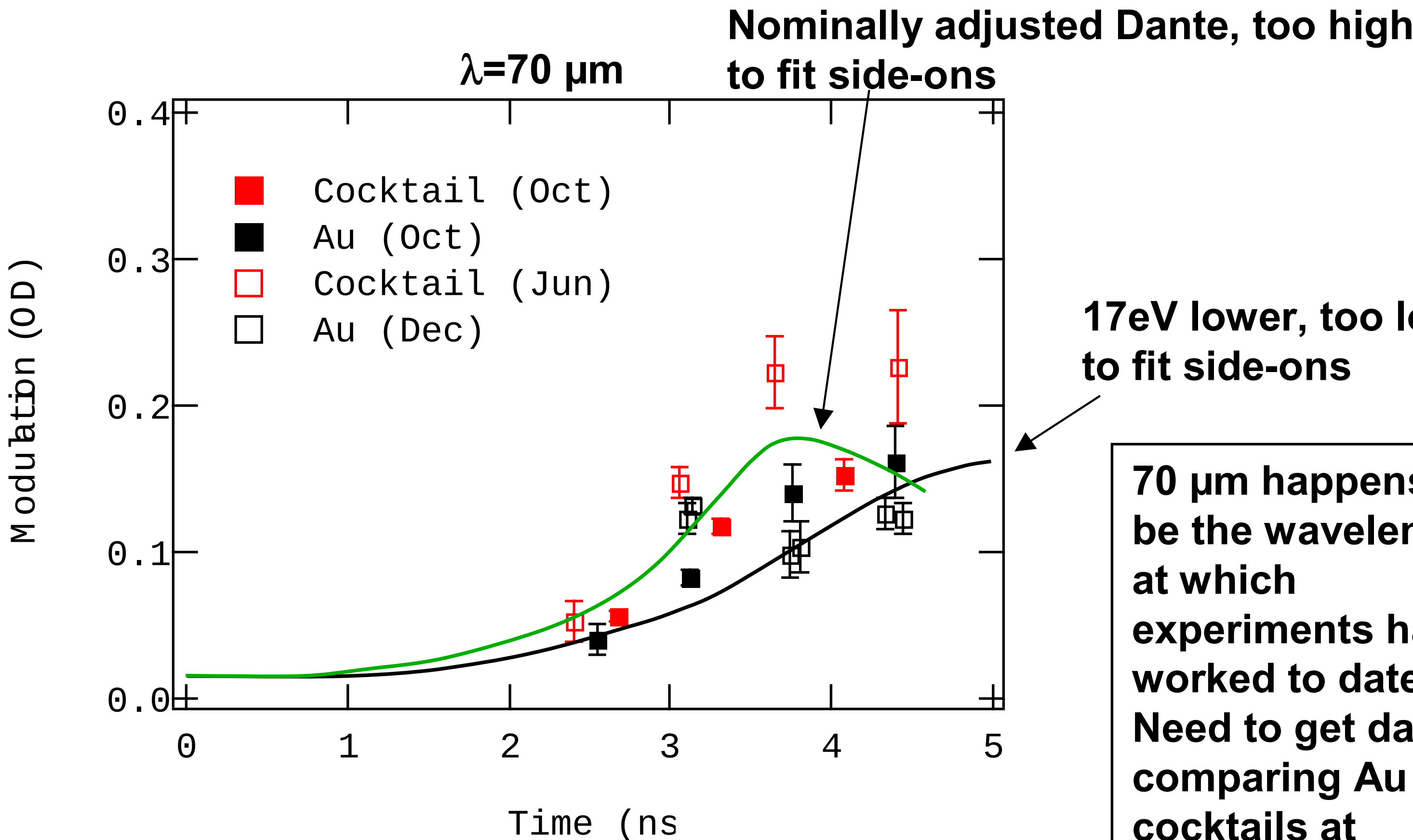


Recent shots in cocktail hohlraum had this drive



Dante curve 23683, minus 25 eV from "typical" temperature for this series, shifted +200ps for Dante timing -- used as source for foil simulations

At 70 micron wavelength, we see good agreement between simulated and observed perturbation growth



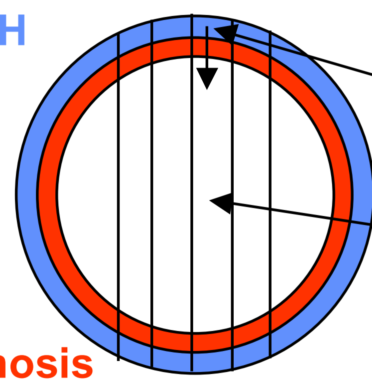
70 μm happens to be the wavelength at which experiments have worked to date. Need to get data comparing Au and cocktails at smaller wavelengths!

At 70 μm wavelength there is no difference between Au and cocktail drives in modulation growth. Early shots seemed to show experimental difference, but not more recent data

We are also planning convergent Rayleigh-Taylor experiments with a mock fuel layer

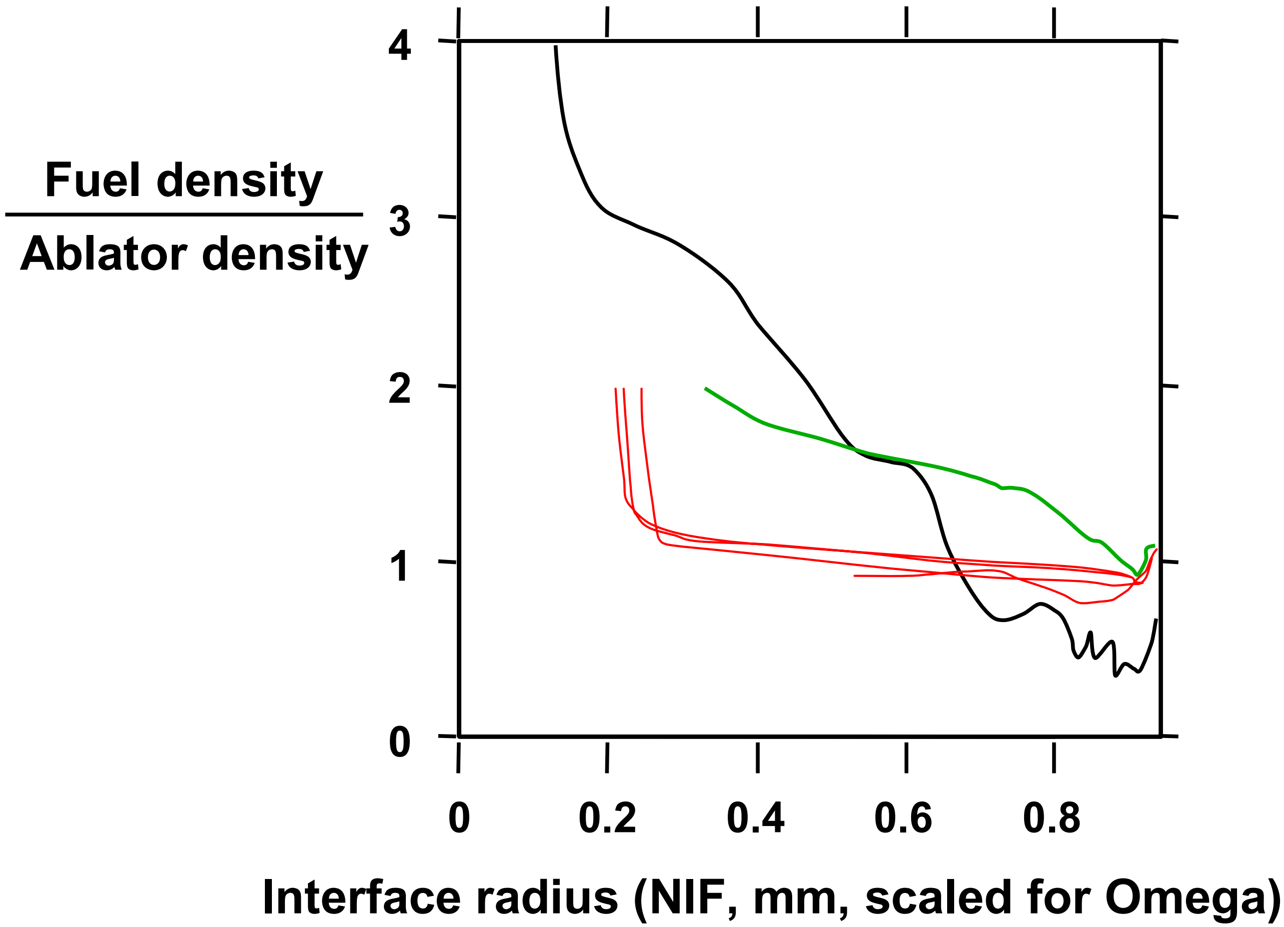
- On NIF capsules, perturbation ends up growing on interface between ablator and fuel, which becomes increasingly unstable as shells implode

- Converging geometry is a big part of the physics determining densities, plus something we haven't done enough with yet



Similar to experiment calculated by Dittrich for 0.6-scale NIF noncryo

With a beryllium mock fuel layer we do a decent job of mocking up the interface instability



Black NIF

Green CH over Be(Cu)

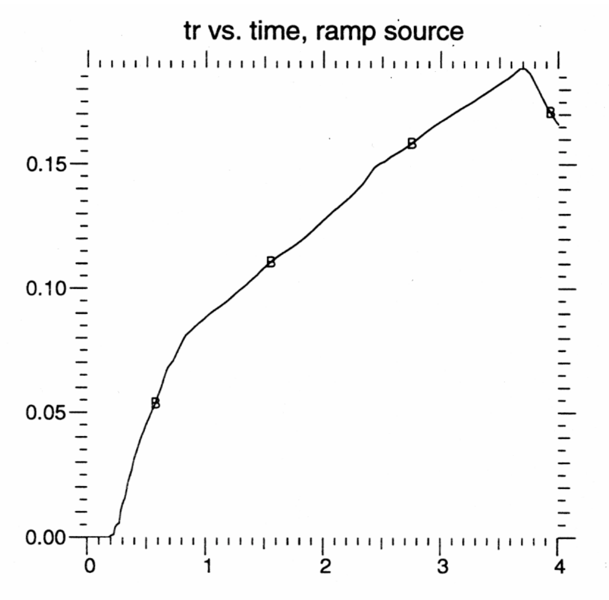
Also tried
CH(Ge) over CH(Ti)
Ge= 0,1,2.5, and 4%
(red curves)

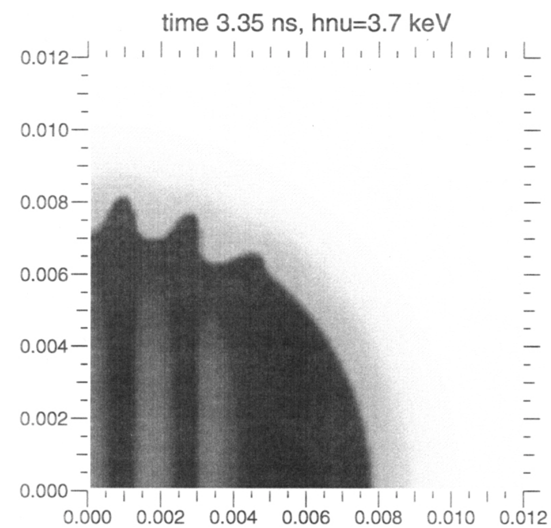
We are working on optimizing this experiment

Current thinking: ramp pulse that pushered single shell program developed, they are verifying symmetry

Capsule 210 μm outer radius,
23 μm CH / 4μm Be+0.5% Ag / 3 μm mandrel

Gives good density profiles, and good images





Simulated image from 1 μm initial amp, 50 μm initial wavelength, 2 1/2 waves at waist cut into ablator