Progress in the development of an “all DT” NIF shock ignition target

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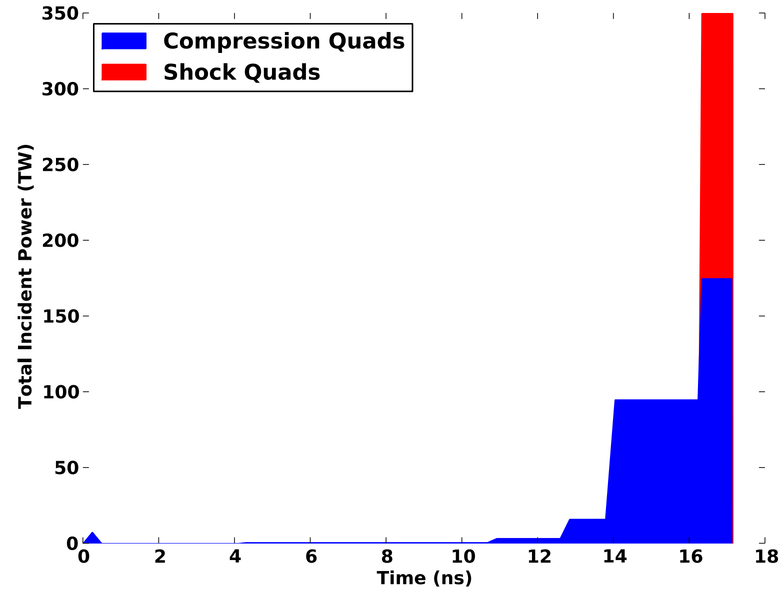
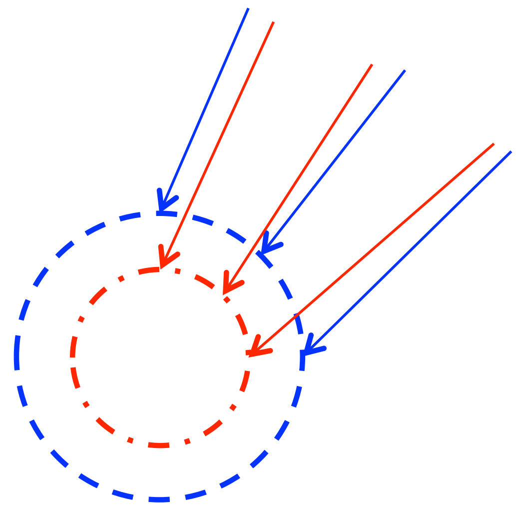
Laser pulse shape for the all-DT design uses a picket + 3 pedestals for fuel compression

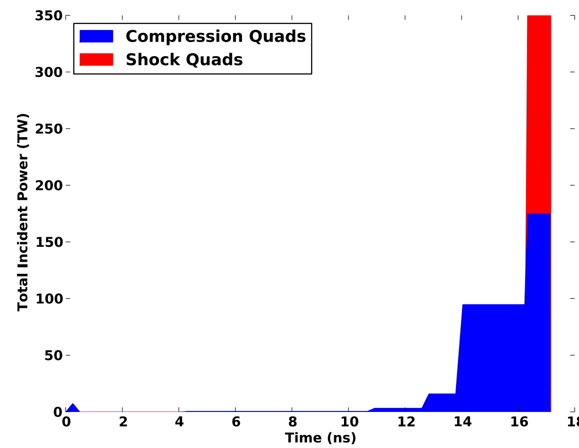
- Triangle picket
    - Sets adiabat
    - Smoothes laser imprint
    - Sets shock breakout time
- 3 pedestals
    - "foot," "shock 2," "shock 3"
    - Compress fuel in-place to high density
- Moderate intensity main compression pulse
    - Implodes target
    - Less intense, slower implosion than conventional "fast compression"
    - Large ρR, but temperature too small to burn
- High intensity shock
    - Launches a strong shock
    - Additional compression
    - Temperature > 10 keV



NIF is a viable platform for demonstrating shock ignition

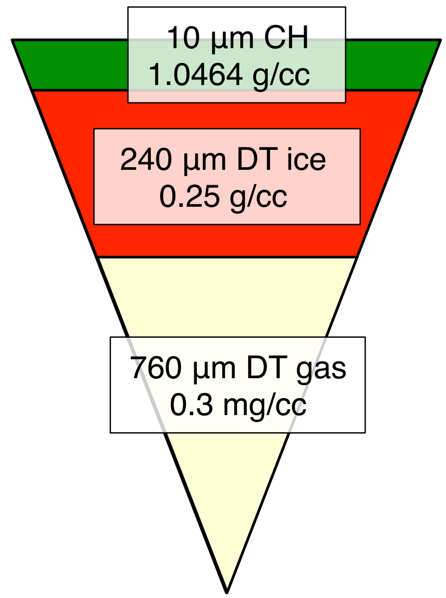
- **Polar direct drive configuration**
- **24 compression quads focused at initial radius**
- **24 shock quads focused at shock-launch radius**
- **Sufficient energy**
  - **~0.6MJ for near-term high-gain targets**
  - **≥1.3 MJ for high yield designs**
- **Strong ignitor shocks due to**
  - **large peak power (400 TW)**
  - **250 ps rise time (upgradable to 100ps?)**
- **Would need a new cryostat**





Slow, thick DT ablator design should mitigate Rayleigh-Taylor growth during implosion phase

Aspect Ratio	3.16
Implosion velocity (km/s)	303
In flight adiabat	1.56
Max rhoR	1.95
Convergence ratio	32
IFAR (at 2/3 r0)	20
Yield (MJ)	32
Gain	52
Compression energy (kJ)	308
Shock energy (kJ)	<300
Total energy (kJ)	<608
Integrated laser energy efficiency	56%



Segment	**Power (TW)**	**Launch (ns)**
Picket	8.55	0.
Foot	0.75	2.85
Shock 2	3.48	8.08
Shock 3	16.15	9.85
Main	115.	10.85
Shock (all beams)	350.	13.41

Updated target improves on previously circulated all-DT design

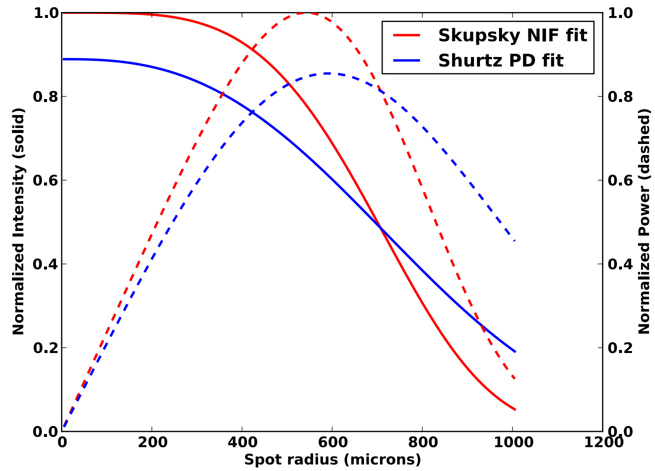
Changed Quantity	Old Target	Updated Target
Electron Flux Limiter	100% at late time	6% sharp cut-off, all times
DT Gas Density	0.2 g/cc (IFE specs)	0.3 g/cc (NIF quench specs)
Beam Intensity Profile	Skupsky's NIF fit	Shurtz's fit to Craxton's PD pointings
Picket shape	Zero rise-time flat-top	Finite rise-time triangle
Main pulse power	95 TW	115 TW

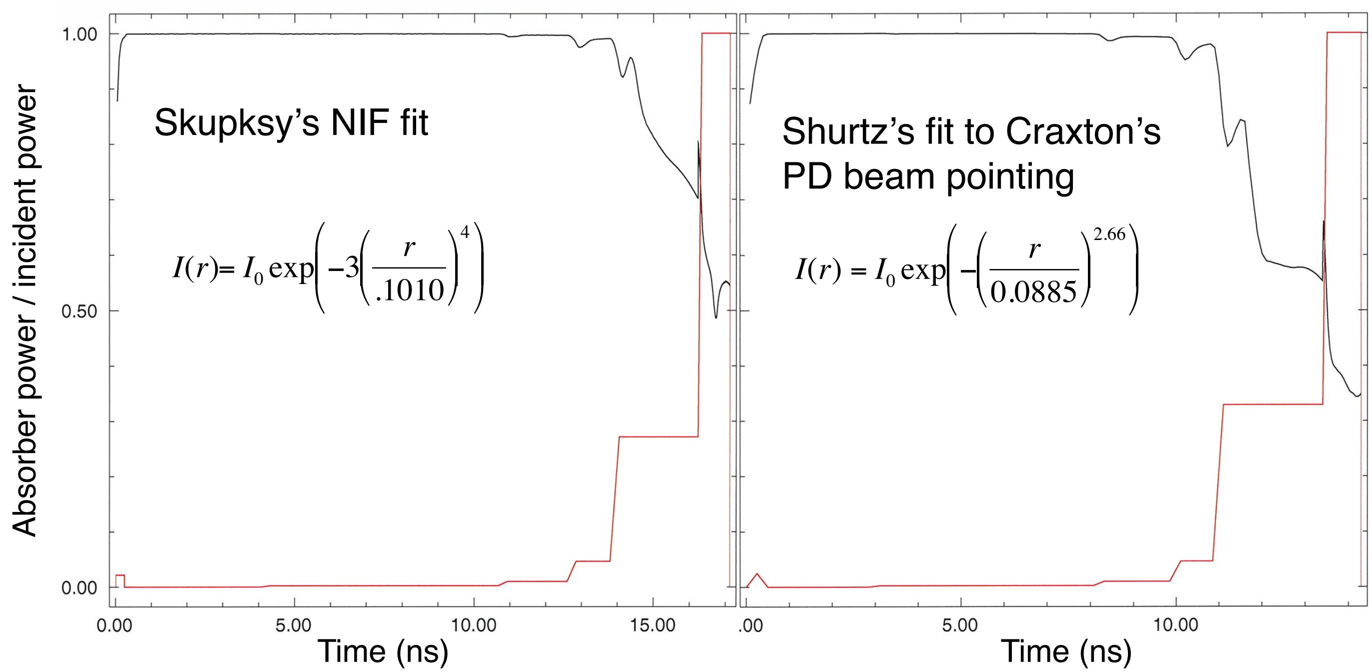
Polar drive intensity profile results in lower drive efficiency

- Need 2D laser intensity (radius, angle of incidence) to reasonably approximate PD laser absorption

- Refraction and shrinking targets amplify difference in efficiency

- Main pulse power increased to take advantage of larger efficiency at beginning of main pulse





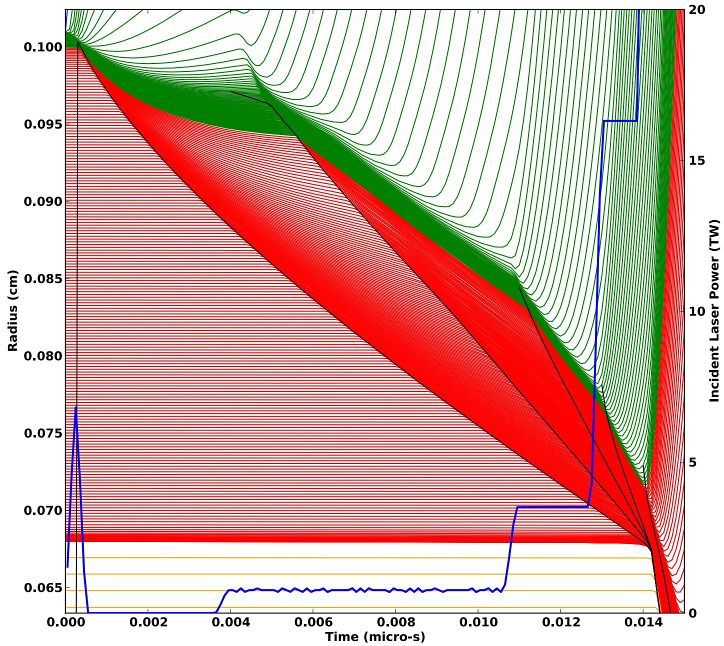
Laser pulse tuning

• Time picket and 3 compression pedestal shocks to coalesce at gas/ice interface at same time

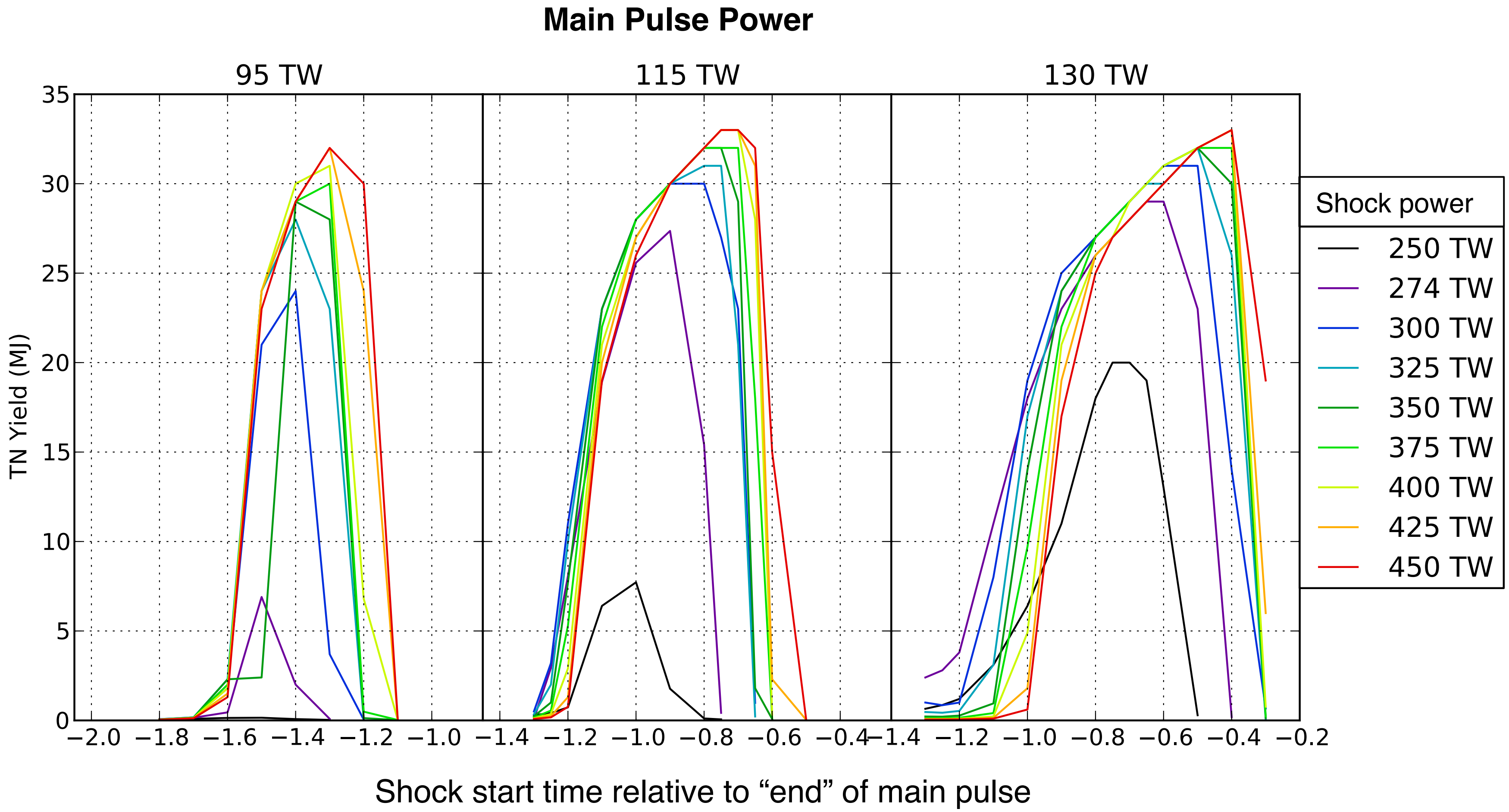
• Maximize ρR(main launch time, main power) for fixed compression energy
  • LPI thresholds limit main power
  • Falling laser efficiency

• Scan yield(shock launch time, shock power) for fixed shock energy
• Shock power based on:
  • Yield
  • Ignition window
  • Optics damage threshold

• Actual laser energy used less than design assumptions
  • Shock pulse starts before compression energy exhausted
  • Shock remains on after burn initiates
  • 607kJ / 700 kJ for current design



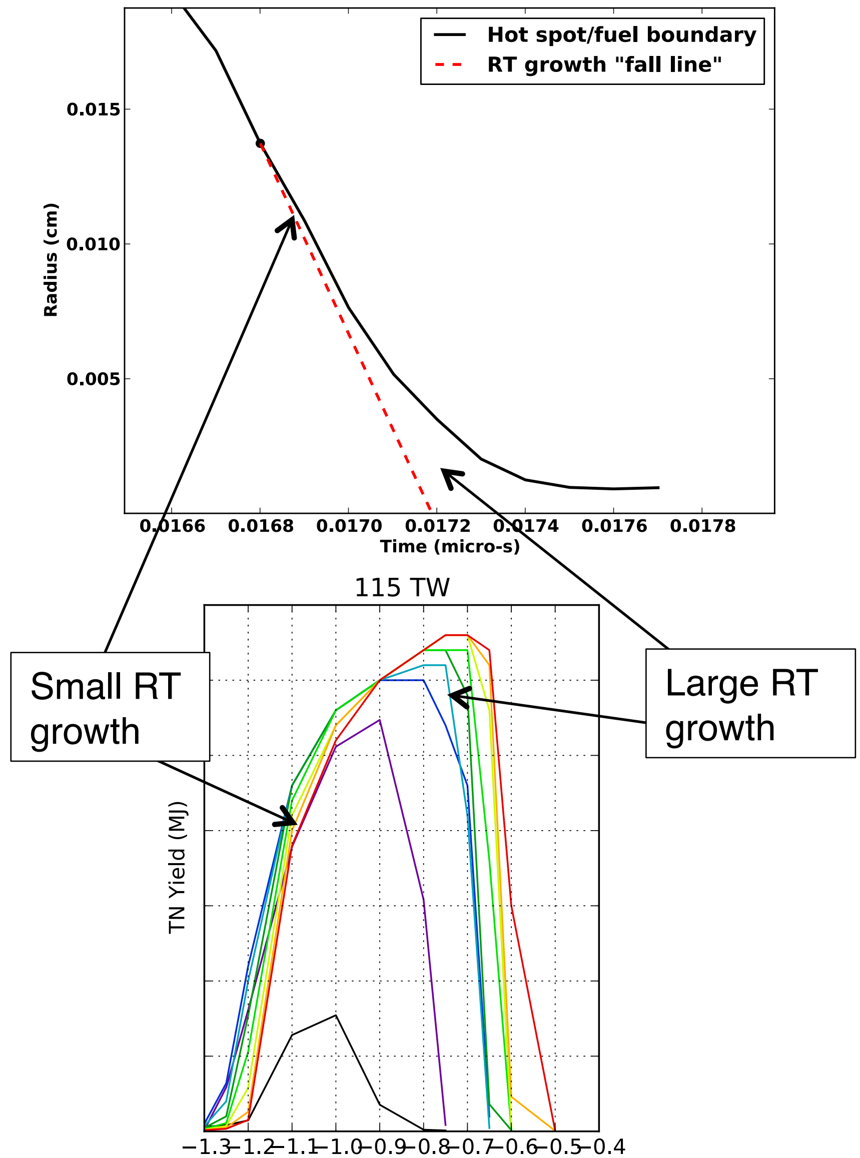
Higher intensity main pulses have larger ignition windows and comparable yield



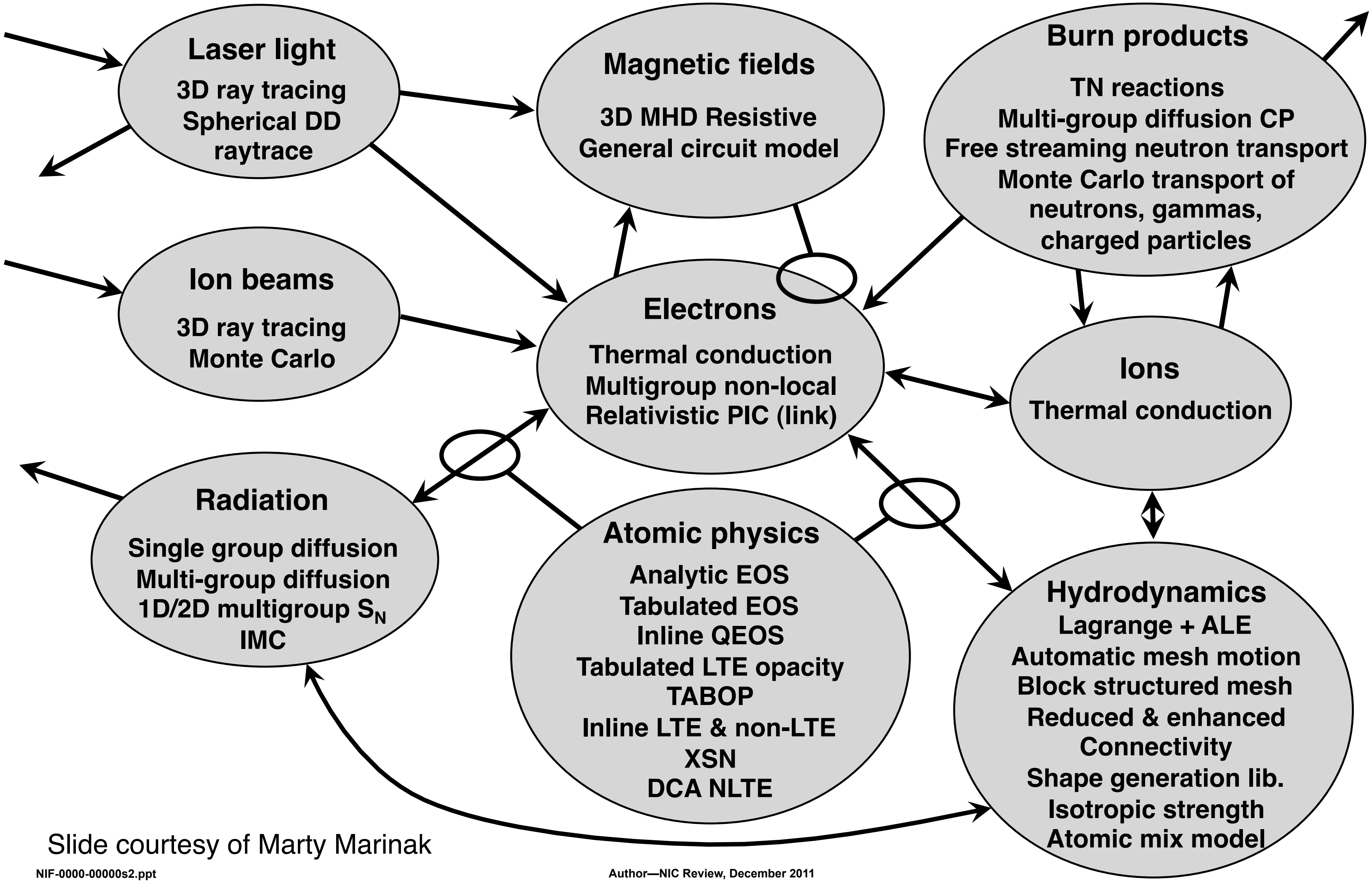
No Rayleigh-Taylor in 1D
~<400 kJ compression energy
300 kJ shock energy

Deceleration Rayleigh-Taylor and fall line behavior

- Interface between the hot spot and decelerating fuel is RT unstable
- Projecting peak velocity to r=0 is a useful metric for tracking RT growth
- Timing of igniter shock determines when on fall line burn initiates
- Optimal 2D/3D/reality shock timing may occur early within ignition window



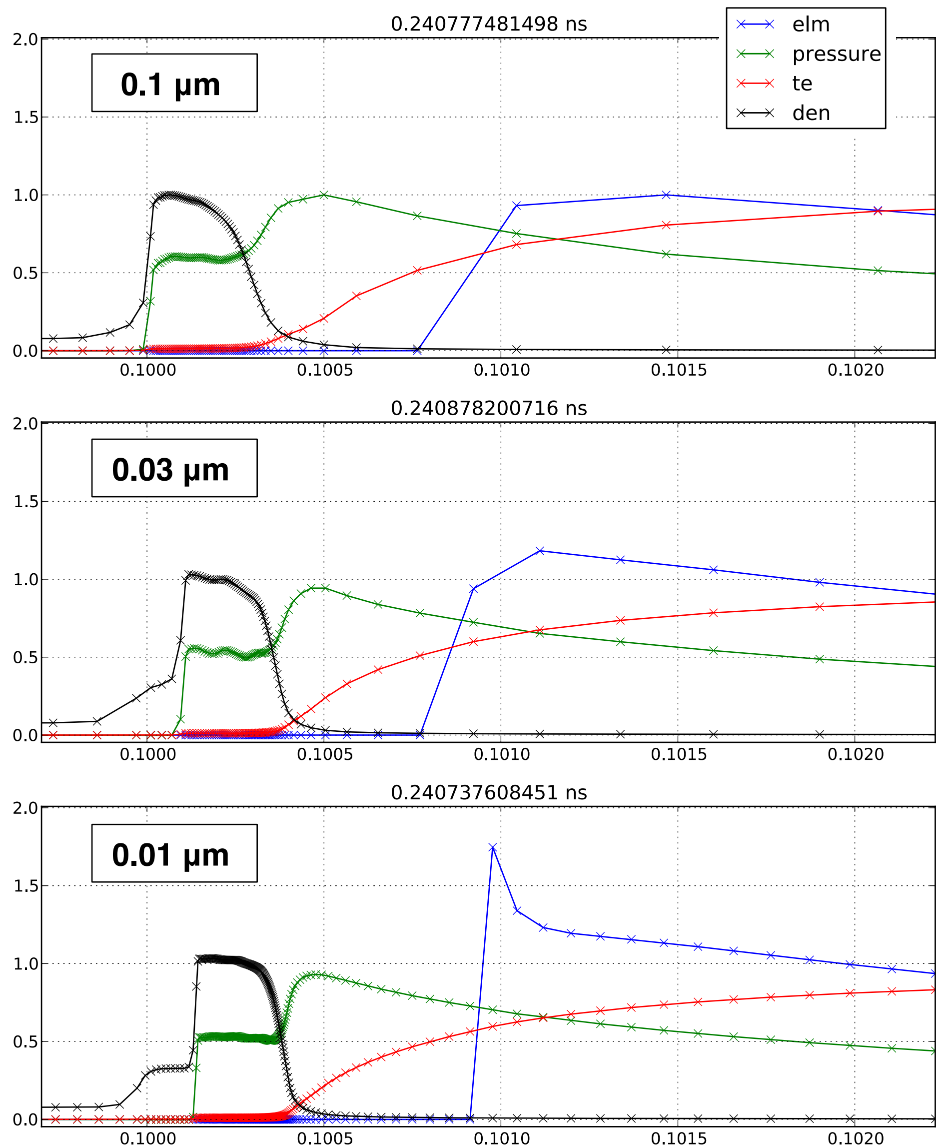
Physical processes modeled by the HYDRA code for ICF simulations



Slide courtesy of Marty Marinak

Early time resolution of the critical surface is hard

- Folklore: outer surface of ablator should have ~0.1 μm wide zones
- “Thick” zones seem to poorly resolve critical absorption for picket
- Energy deposits deeper than critical surface, leading to faster shocks
- Shifts shock tuning, but small effect on target performance
- Suggestions/experience from the audience?



Work left to be done

- Finish transition to HYDRA

- Fill out 1D gain curve of hydrodynamically equivalent all-DT targets
    - Scale target quantities by factor "s"

$$\frac{m}{m_0} = s^3 \quad \frac{E_{laser}}{E_{laser,0}} = s^3 \quad \frac{P}{P_0} = s^2 \quad Y \sim s^3 \rho R(s)$$

at ~constant IFAR, v, CR, α

    - Expect $G = Y / E_{laser} \sim c \cdot s^b$ (but need coefficients!)

- 2D stability (single mode→ multimode)

- Optimum beam pointings, focusings and time-dependent powers (laser PD uniformity) for entire implosion

- Iteration between 3D beam pointing constraints and 1D target build/pulse shape