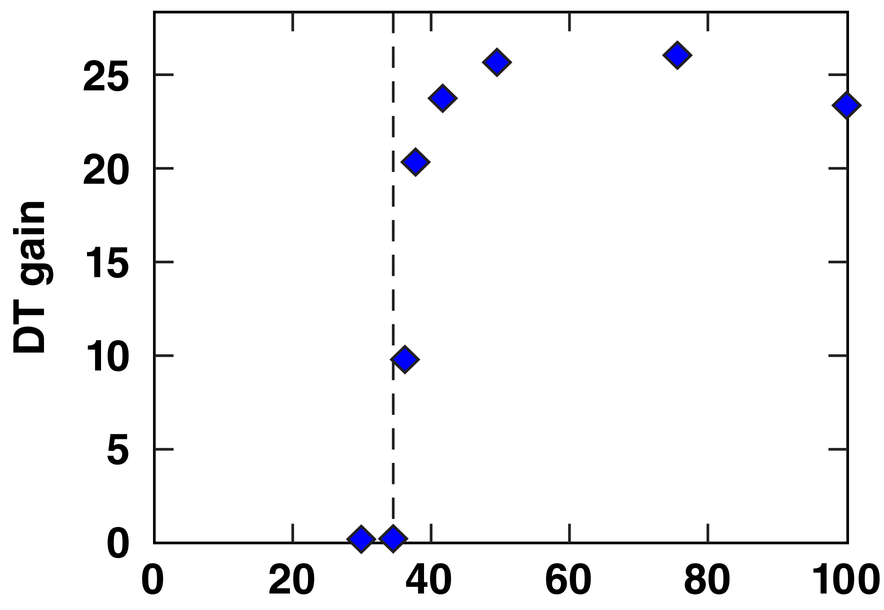
Single- and Multidimensional Robustness Studies of the NIF Ignition Point Design

Direct-drive surrogate
of NIF 1.0-MJ indirect drive



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Summary

The minimum yield-over-clean (YOC) in THD experiments required for ignition in DT equivalents is computed using 1-D and 2-D simulations

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- The one-dimensional (1-D) measurable Lawson criterion is extended to 3-D using YOC and clean-volume analysis
- A 1-D *LILAC* clean-volume model modifies the neutron rates to simulate multidimensional yield
- Good agreement with 2-D *DRACO* simulations is achieved with respect to target yields and the position of the ignition cliff
- The clean-volume model is used in sensitivity studies of the NIF point design

Minimum YOC for the NIF indirect-drive point design is ~35% YOC.

Collaborators

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[1] See R. Betti (PT3.00001).
[2] See P. Chang (TO5.00004).
[3] See B. Spears (UO5.00013).

The THD pre-ignition campaign on the NIF can be used as an indication of success in future ignition experiments

- The ITF (1-D) is defined as the ratio of the capsule kinetic energy to the minimum kinetic energy required for ignition in 1-D

$$\mathrm{ITF}\,(\text{1-D}) \equiv \frac{E_{\mathrm{kin}}}{E_{\mathrm{kin}}^{\mathrm{min}}}$$

- The THD campaign involves surrogate cryogenic targets that are hydrodynamically equivalent to DT shots, except are non-igniting
- The YOC of THD surrogates can be related to DT-equivalent target yield via simulation
- The minimum YOC (MYOC) in THD corresponding to marginal ignition (gain = 1) in DT is related to the ITF (1-D)

TC8715

The minimum YOC required of a THD surrogate to indicate ignition for an equivalent DT target can be calculated from the 1-D ITF and the YOC

$$(\rho R)_{st}^{nb}\left(T_{st}^{nb}\right)^2\left(YOC^{nb}\right)^{0.7} > 22\ \mathrm{g\,cm}^{-2}\,\mathrm{keV}^2$$ *

nb = non-burning
st = stagnation

Use scalings: $\langle \rho R \rangle_n \sim E_{kin}^{1/3}$, $\langle T_i \rangle_n \sim E_{kin}^{0.07}$

$$\frac{E_{kin}}{E_{min}^{ign}} = \mathrm{ITF\ (3\text{-}D)} \approx \left(\frac{\langle \rho R \rangle_n \langle T_i \rangle^2}{22}\right)^{2.16} \mathrm{YOC}^{1.5} \approx \mathrm{ITF\ (1\text{-}D)\ YOC}^{1.5}$$

$$\mathrm{ITF\ (3\text{-}D)} \approx \mathrm{ITF\ (1\text{-}D)} \times \mathrm{YOC}^{1.5}$$

$$\mathrm{MYOC}_{\mathrm{NIF\ pt.\ design}} = 5.3^{-0.66} \approx 33\%$$ **

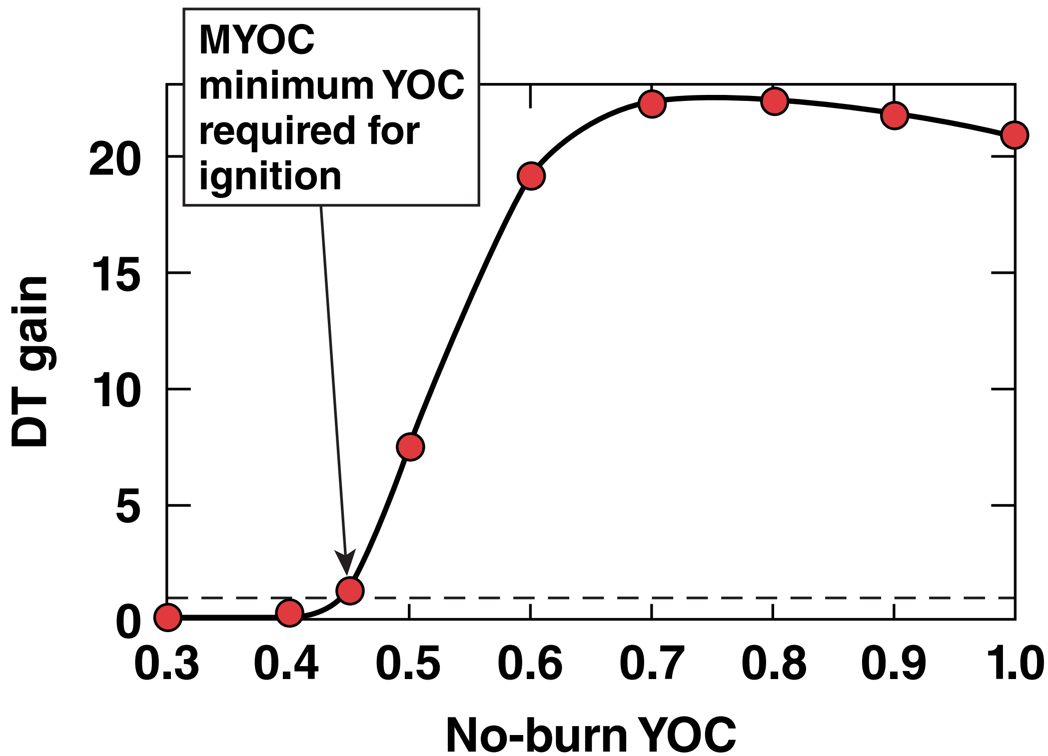
* See P. Chang (TO5.00004)

** J. D. Lindl, J. L. Edwards, and S. W. Haan, presented at the JASON meeting, San Diego, CA, 14–16 January 2009.

TC8568

The YOC is used as an input parameter for the 1-D clean-volume model

$$\int_{V_{\text{clean}}} \langle \sigma v \rangle dV \approx \int_{V_{\text{1-D}}} \langle \sigma v \rangle dV \frac{V_{\text{3-D}}^{\text{clean}}}{V_{\text{1-D}}} \approx \int_{V_{\text{1-D}}} \langle \sigma v \rangle dV \times \text{YOC}$$



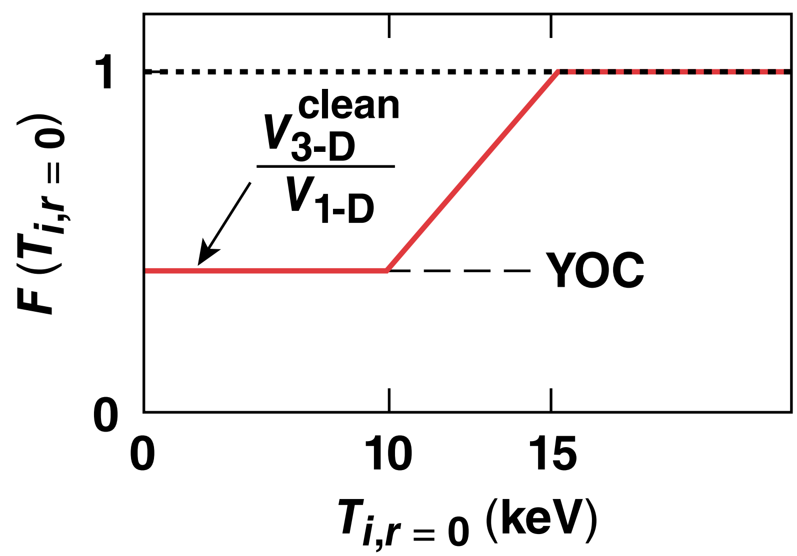
The minimum YOC from a 1-D clean-volume model can be used to determine the ITF (1-D).

TC8570

A 1-D clean-volume model in *LILAC* modifies the fusion rate before burn

- The fusion rate is modified at sub-ignition temperatures by the ratio of clean volume to the 1-D hot-spot volume

$$\langle \sigma v \rangle_{mod} = F\left(T_{i,r=0}\right) \langle \sigma v \rangle$$



- Gain in burn-on targets and YOC in burn-off targets from the 1-D model are compared with 2-D *DRACO* simulations

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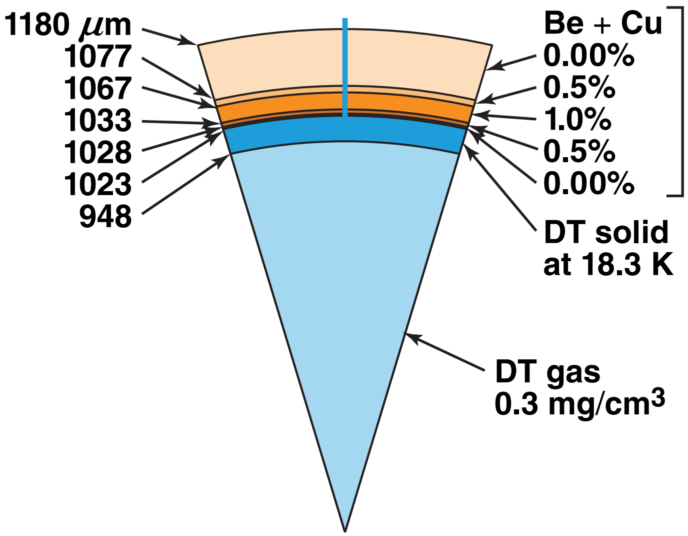
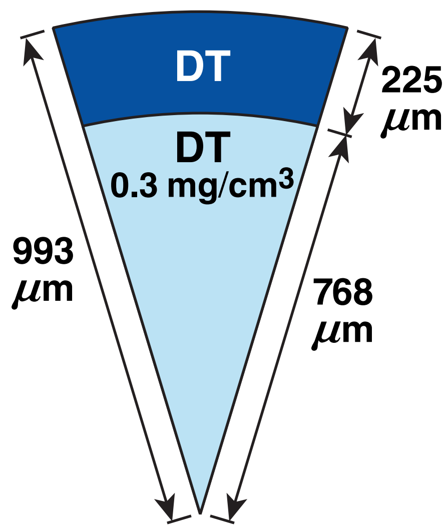
See P. Chang (TO5.00004).

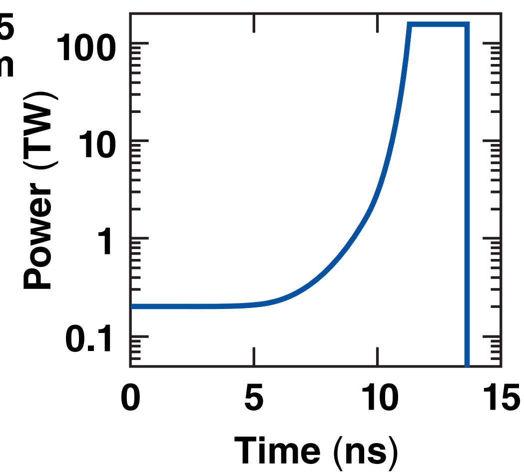
The NIF indirect-drive point design is modeled using a direct-drive surrogate with similar 1-D performance

Indirect-drive point design



Direct-drive surrogate



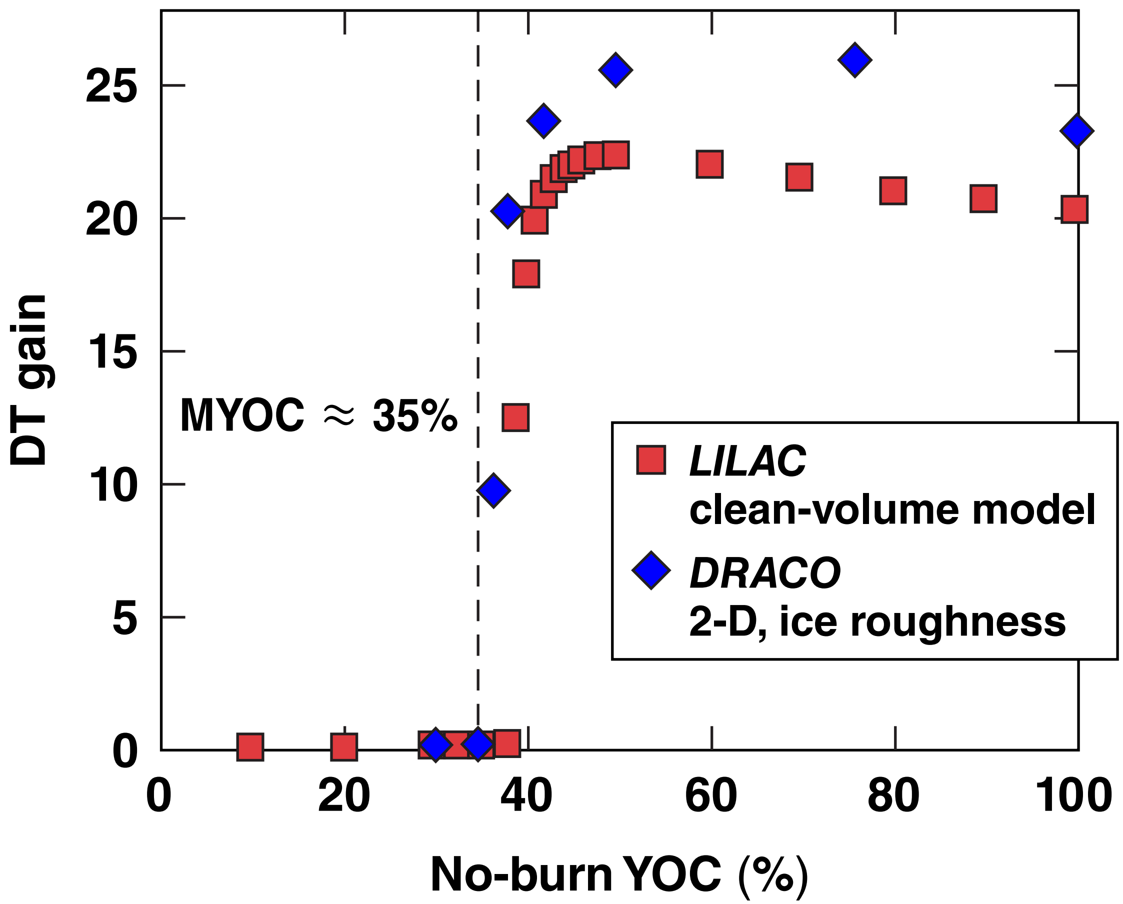


1-D no-burn performance	NIF point design	Direct-drive surrogate
$\langle \rho R \rangle_n$ (g/cm^2)	1.8	1.805
$\langle T_i \rangle_n$ (keV)	4.5	4.7
v_{imp} (km/s)	380	388
α_{if}	~1	0.92
Yield (MJ)	20	22.9

TC8664

$$\alpha_{if} = P(\text{Mbar})/[(2.18 * \rho(\text{g/cm}^3)^{5/3}]$$

Marginal ignition (gain = 1) in 1.0-MJ NIF indirect-drive point design is predicted for equivalent ~35% YOC (THD)



$\rho R_{THD} \approx 1.8$ g/cm^2

$T_{i,\,THD} \approx 4.7$ keV

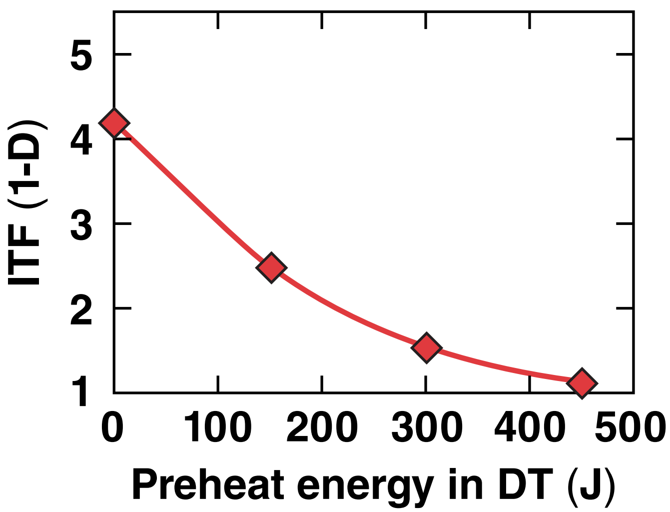
	MYOC	ITF
LILAC	39%	4.2
DRACO	35%	5.0
LLNL	33%	5.3

TC8665

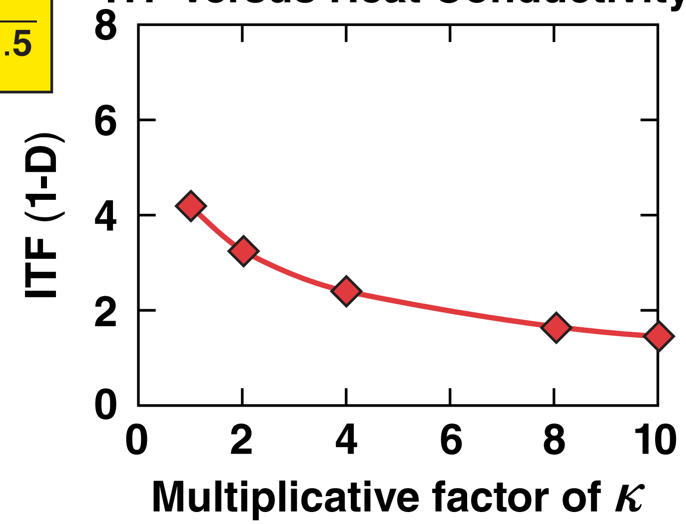
The clean-volume 1-D code can be used to perform sensitivity studies with respect to various 1-D physics parameters

$$\text{ITF}\left(\text{1-D}\right)=\frac{1}{\text{MYOC}^{1.5}}$$

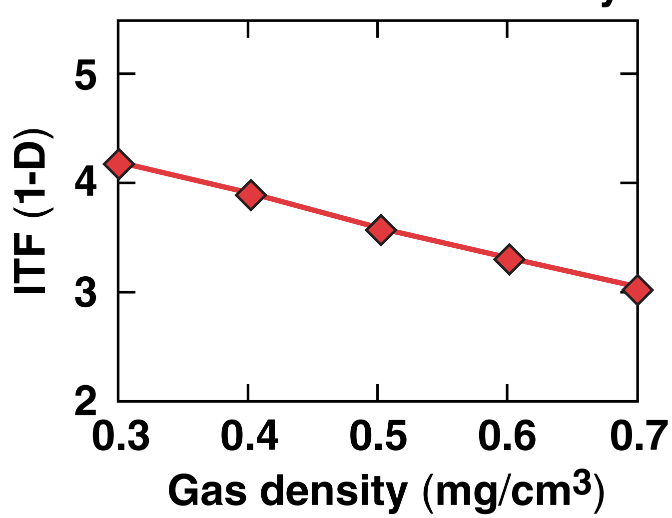
ITF versus Electron Preheat



ITF versus Heat Conductivity



ITF versus Gas Density



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Summary/Conclusions

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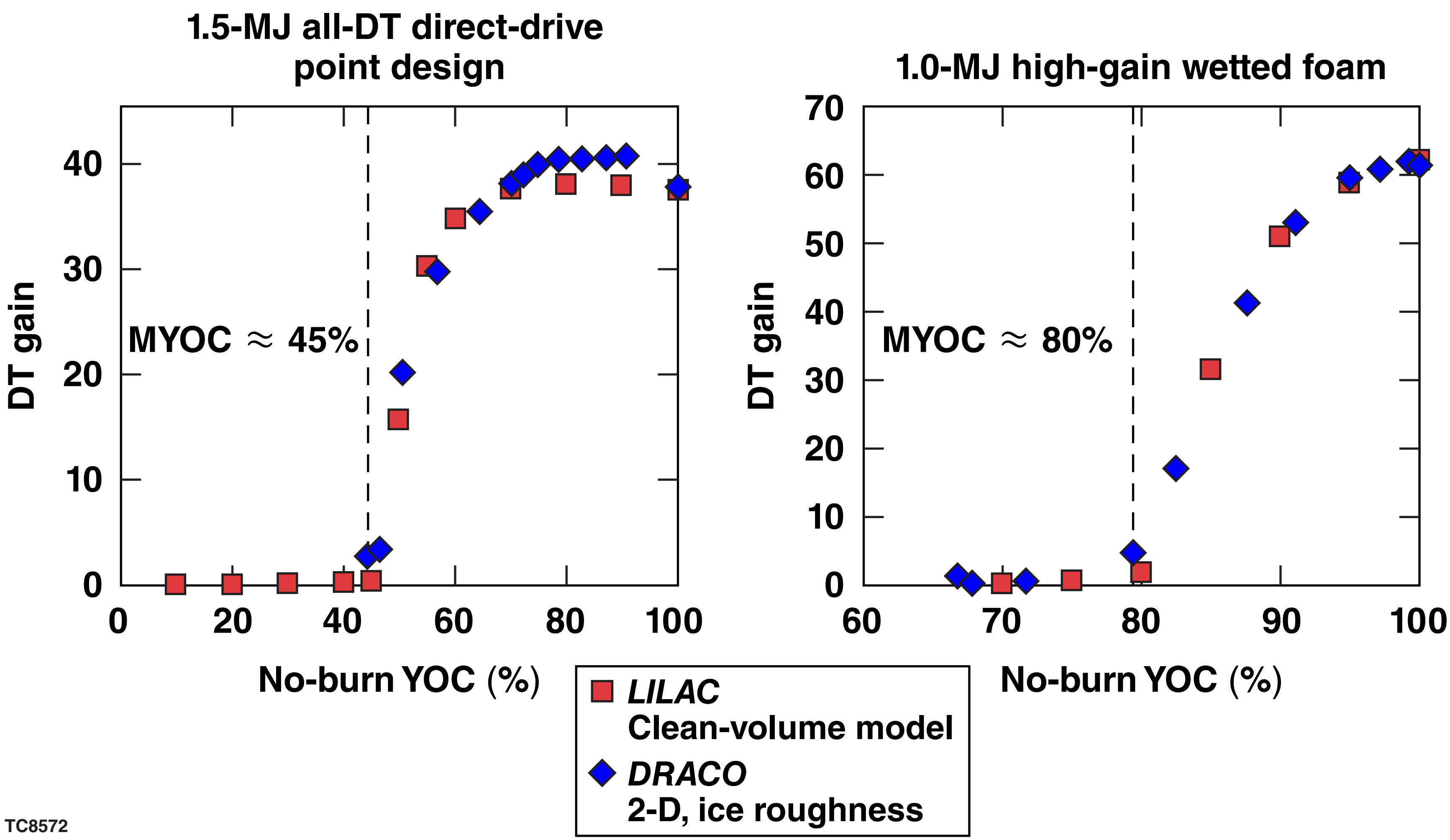
Minimum YOC for the NIF indirect-drive point design is ~35% YOC.

The 1-D *LILAC* clean-volume model agrees well with 2-D *DRACO* for minimum YOC required for ignition

DRACO modeled with NIF-spec ice-roughness modes ℓ = 2 to 50



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The minimum THD YOC required for DT ignition is similar for other perturbation modes

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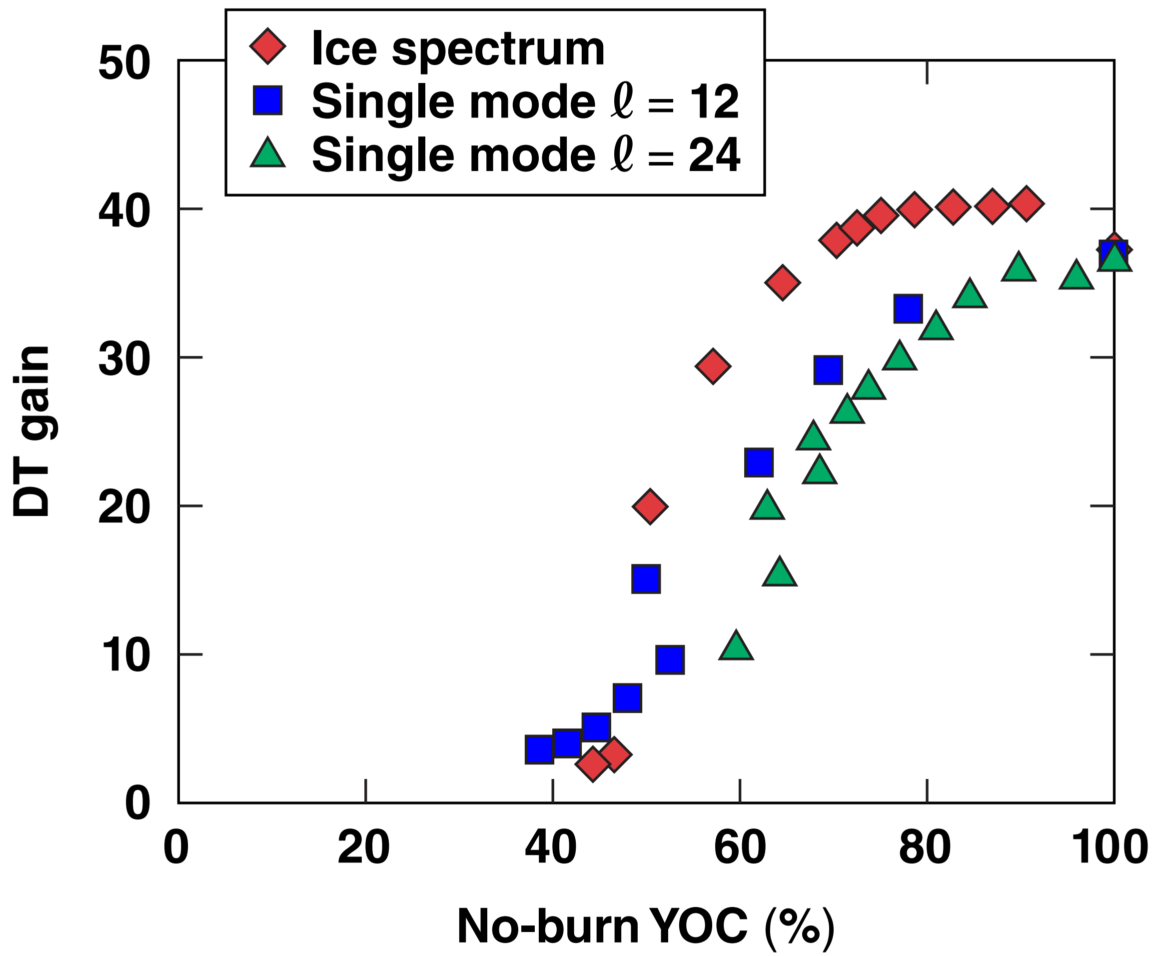

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