



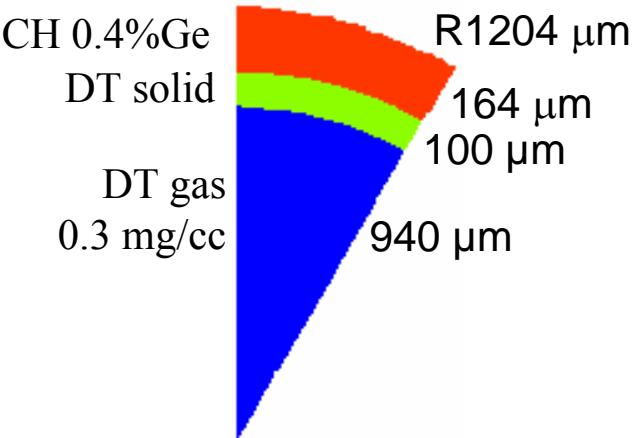
# Progress on Indirect-Drive Target Design for the Laser Mégajoule Facility.

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## SUMMARY

- 1** Our baseline design has not changed: the doped plastic capsule needs 1.4MJ of absorbed laser energy in a gold hohlraum.
- 2** We have now a complete study of yield degradation due to all sources of low mode deformation as ablator roughness and laser defects.
- 3** The first design with graded doped ablator has shown that we can substantially increase the tolerance to high mode initial perturbation.
- 4** We are investigating the possibility of using the green light.

# 1.1 LMJ baseline design has not changed: the doped CH capsule is encased in a HHe filled gold hohlraum.

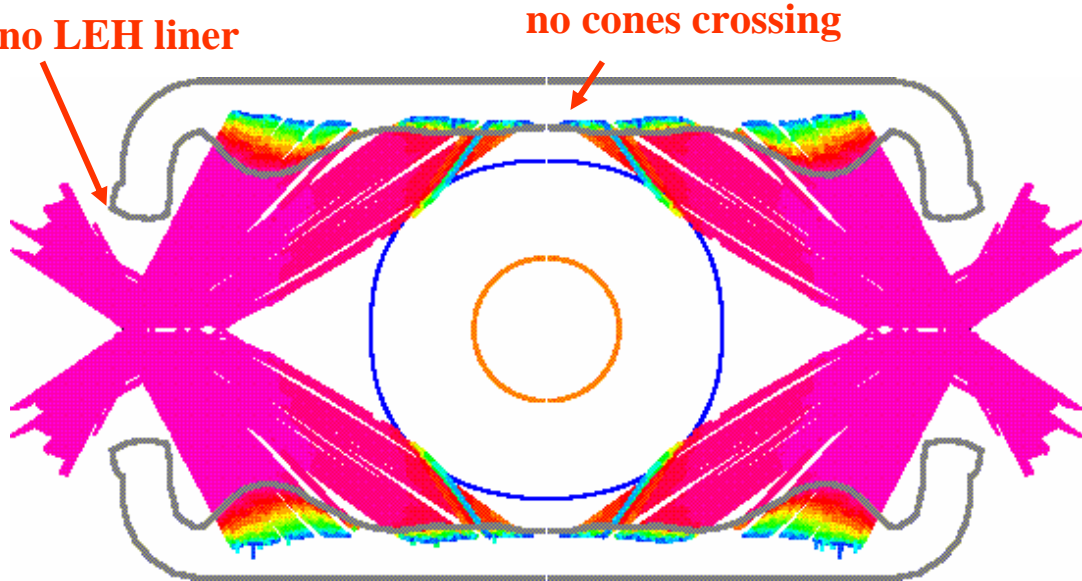


Doped plastic ablator:  
*first 0.25% Br, then 0.4% Ge, now graded Ge;*

DT filled by permeation

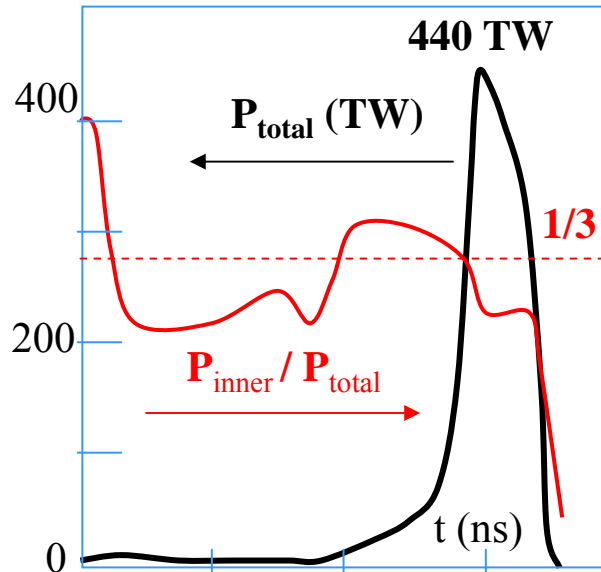
Tcryo = 18.2 K

300 eV - Convergence Ratio = 33

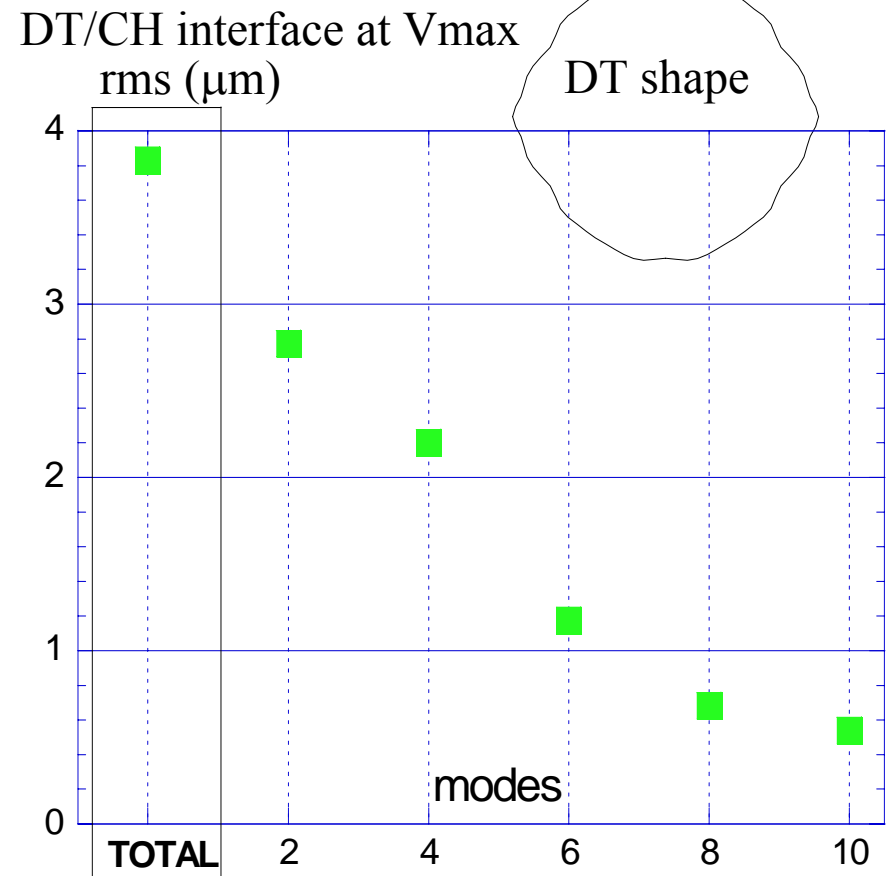


Gold hohlraum: L 10.4  $\phi$  6,2mm  
HHe 0.8mg/cc  
LEH  $\phi$ 3.4mm  
3 laser cones at 33°2, 49° & 59°5  
60 quadruplets of 4 beams each  
 $\lambda = 0.35 \mu\text{m}$

## 1.2 The capsule needs 1.4MJ of absorbed energy. DT/CH deformation is 3.8 $\mu\text{m}$ rms at maximum velocity.



**2D Yield = 25 MJ**



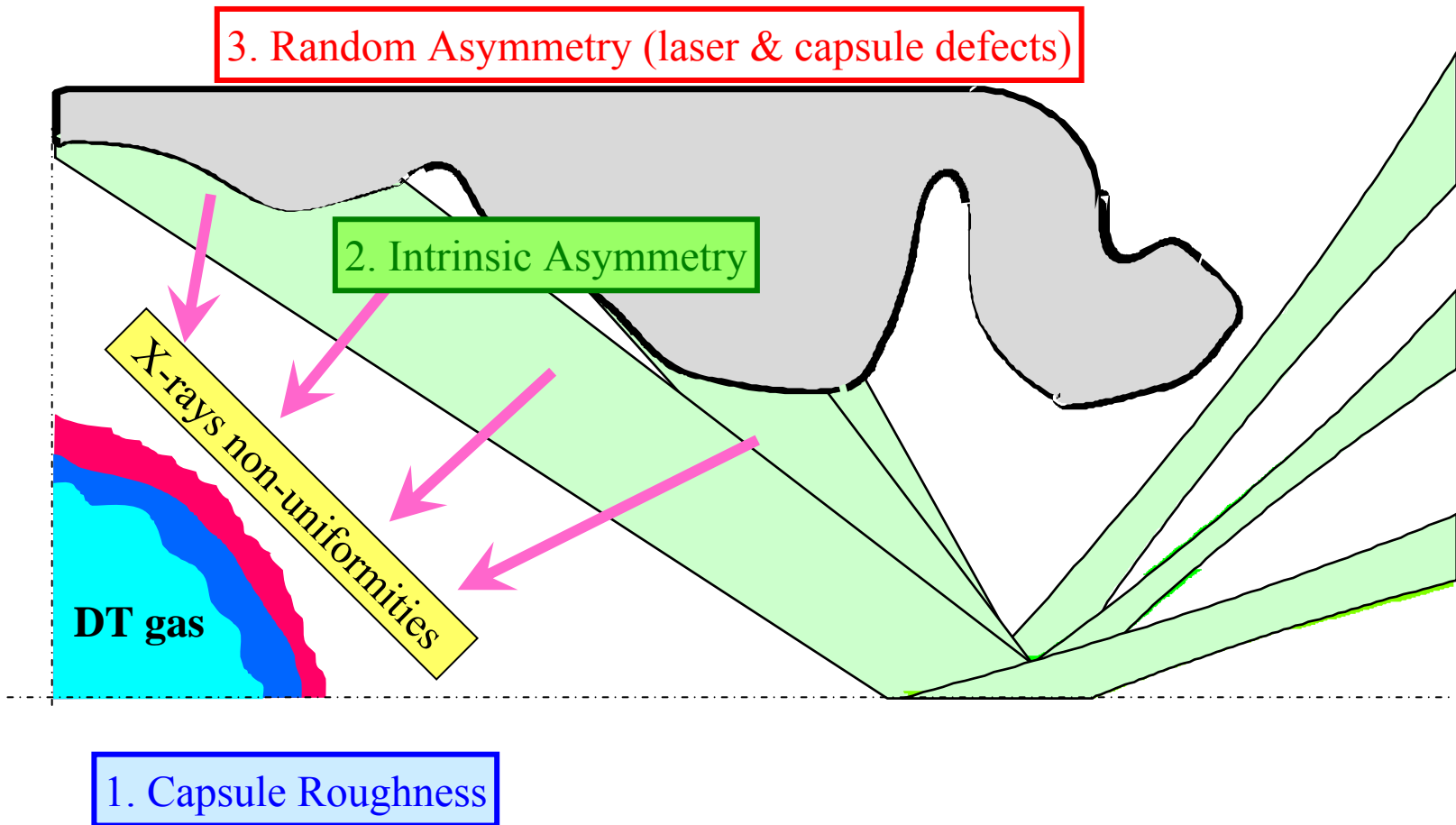
### Hohlraum energetics

Absorbed energy	1.4 MJ
Holes losses	360 kJ
In capsule	160 kJ (11%)

1.0 MJ on outer cones  
0.4 MJ on inner cone

## 2.1 We have now a complete study of yield degradation due to all sources of low mode deformation ( $l \leq 10$ )

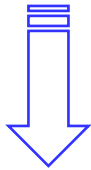
### 3 main causes of capsule deformation:



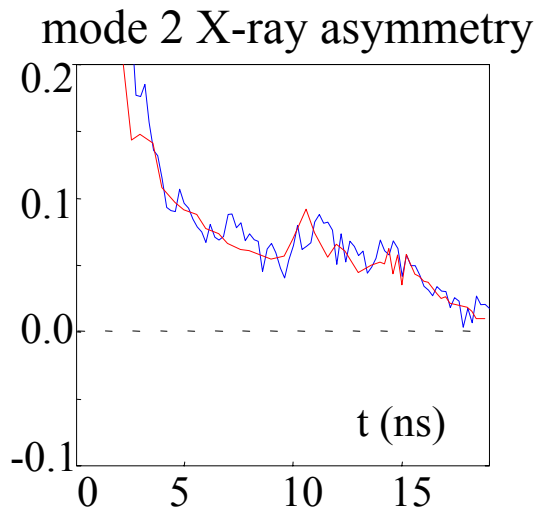
## 2.2 Low mode deformation is estimated at maximum velocity with a linear analysis.

1. Deformation due to capsule roughness => FCI2 growth factor.
2. Deformation due to intrinsic asymmetry => integrated simulation.
3. Deformation due to random asymmetry (small 3D defects):

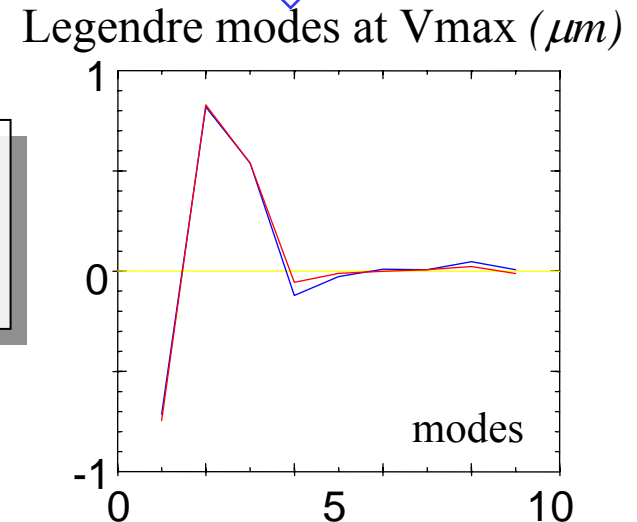
**a/** capsule irradiation:  
ray-tracing & view factor code



**b/** Final deformation:  
Perturbed Rocket Model



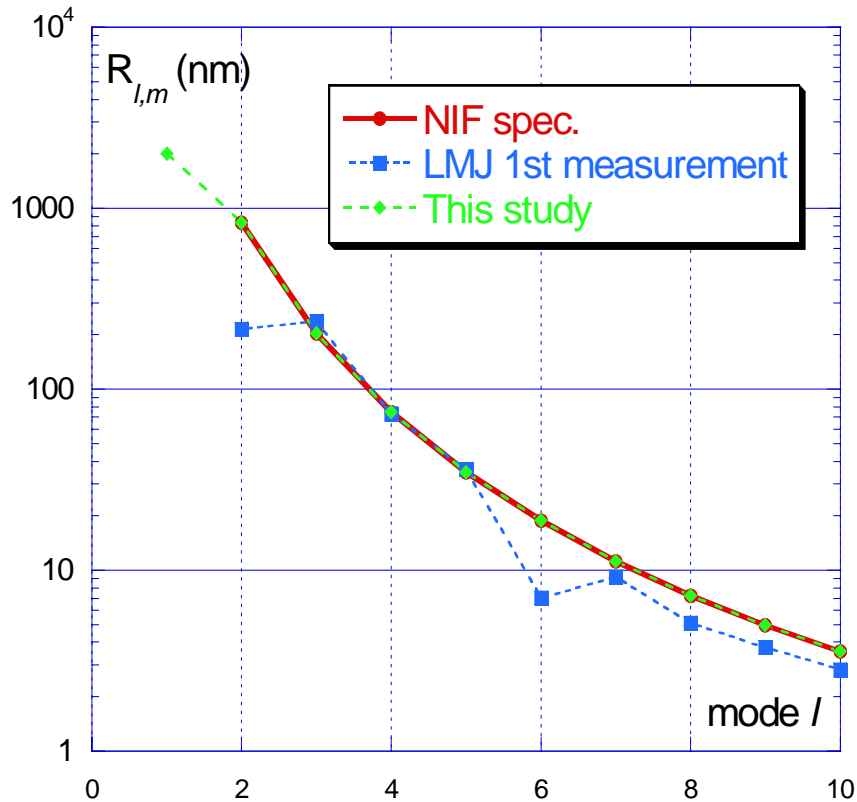
FCI2 & Model comparison  
for an internal power laser  
error



## 2.3 Initial capsule roughness are given by NIF spec (ablator) & $\Omega$ best characterization (DT ice).

ABLATOR

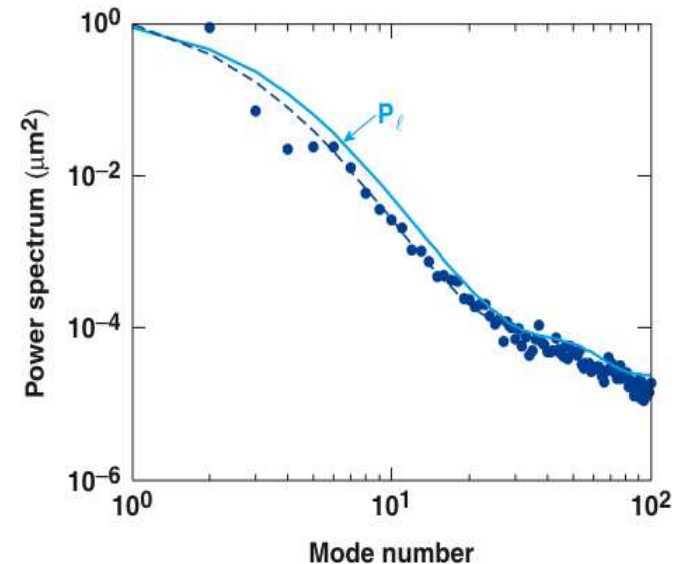
ICE



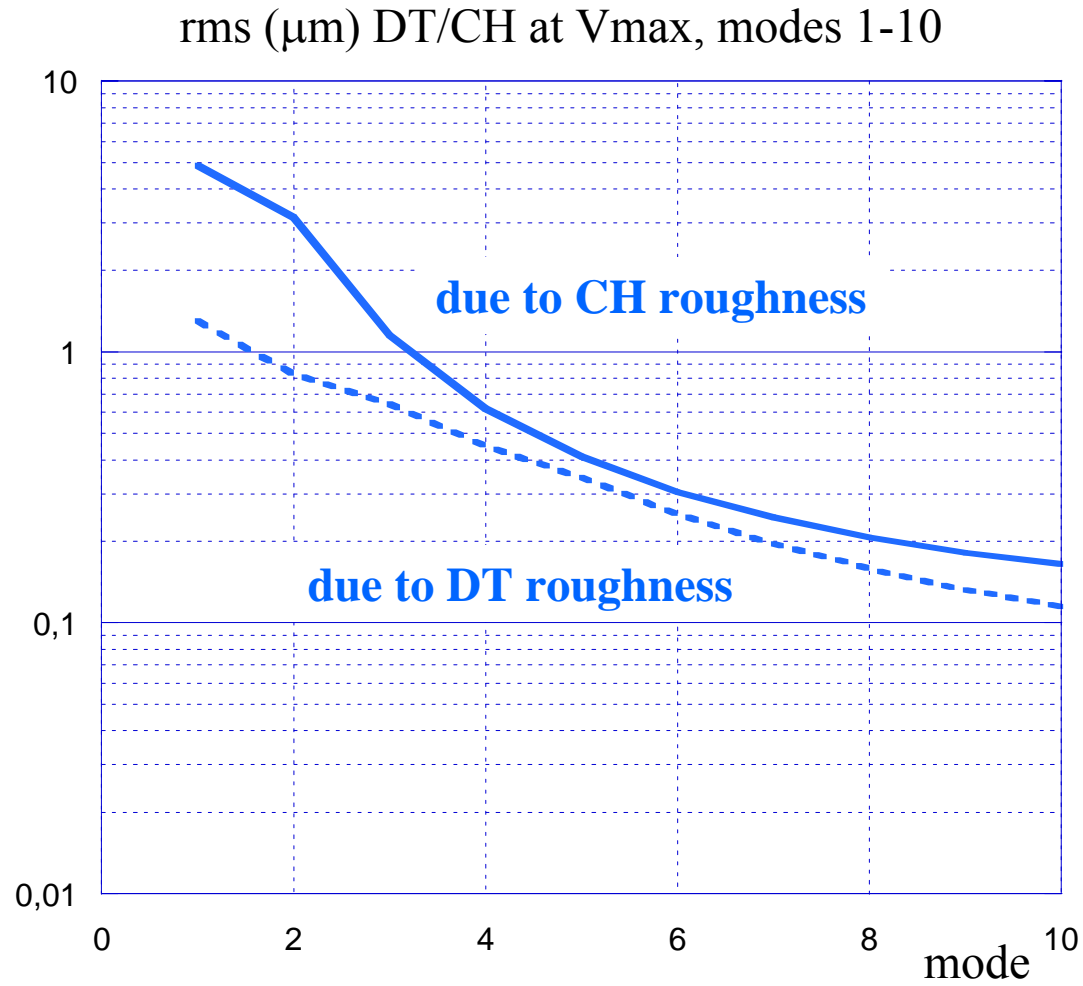
Mode 1 is an off-center error.

Best  $D_2$  Spectrum achieved at Rochester  
[Edgell, APS 2004]

- rms = 1  $\mu\text{m}$  for mode 1
- rms (modes 1 to 10) = 1.36  $\mu\text{m}$ .

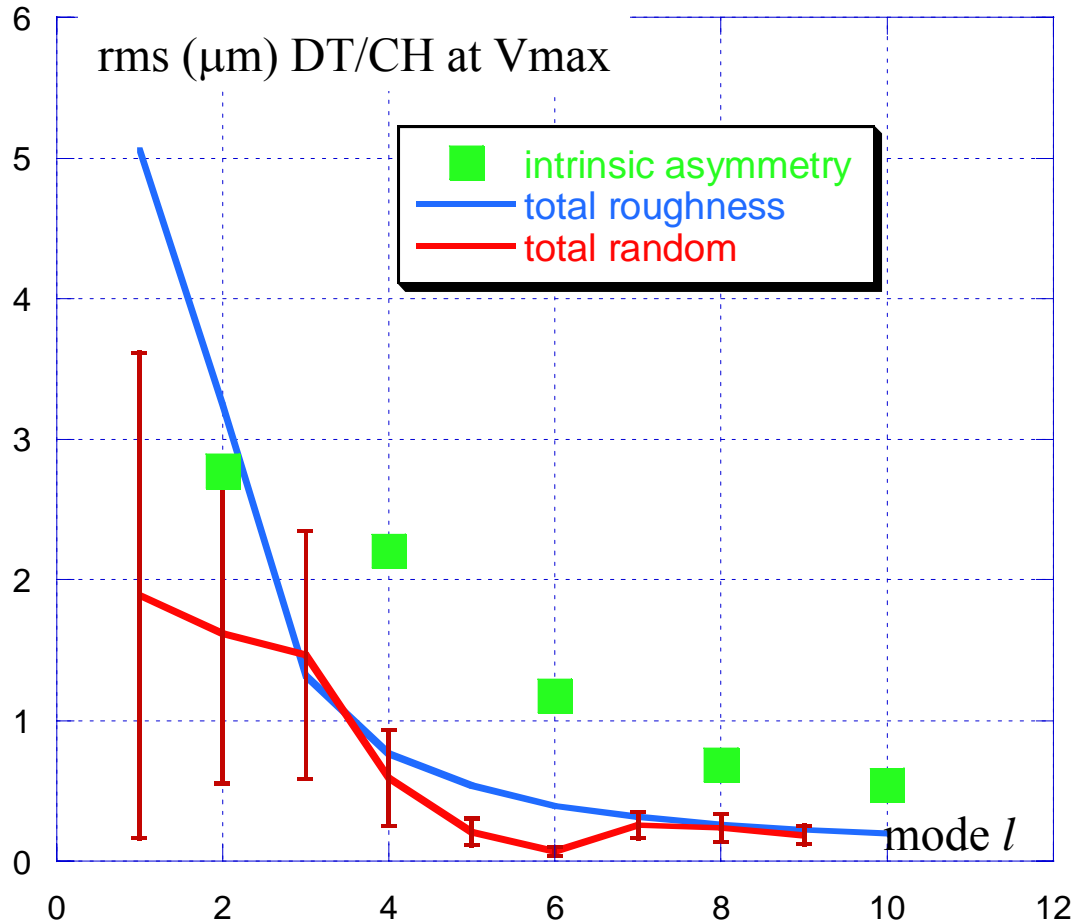


## 2.4 Final DT/CH interface deformation at maximum velocity due to ice & ablator roughness is about $6.3\mu\text{m}$ rms.



## 2.5 Deformation due to ablator roughness is preponderant for modes 1-2.

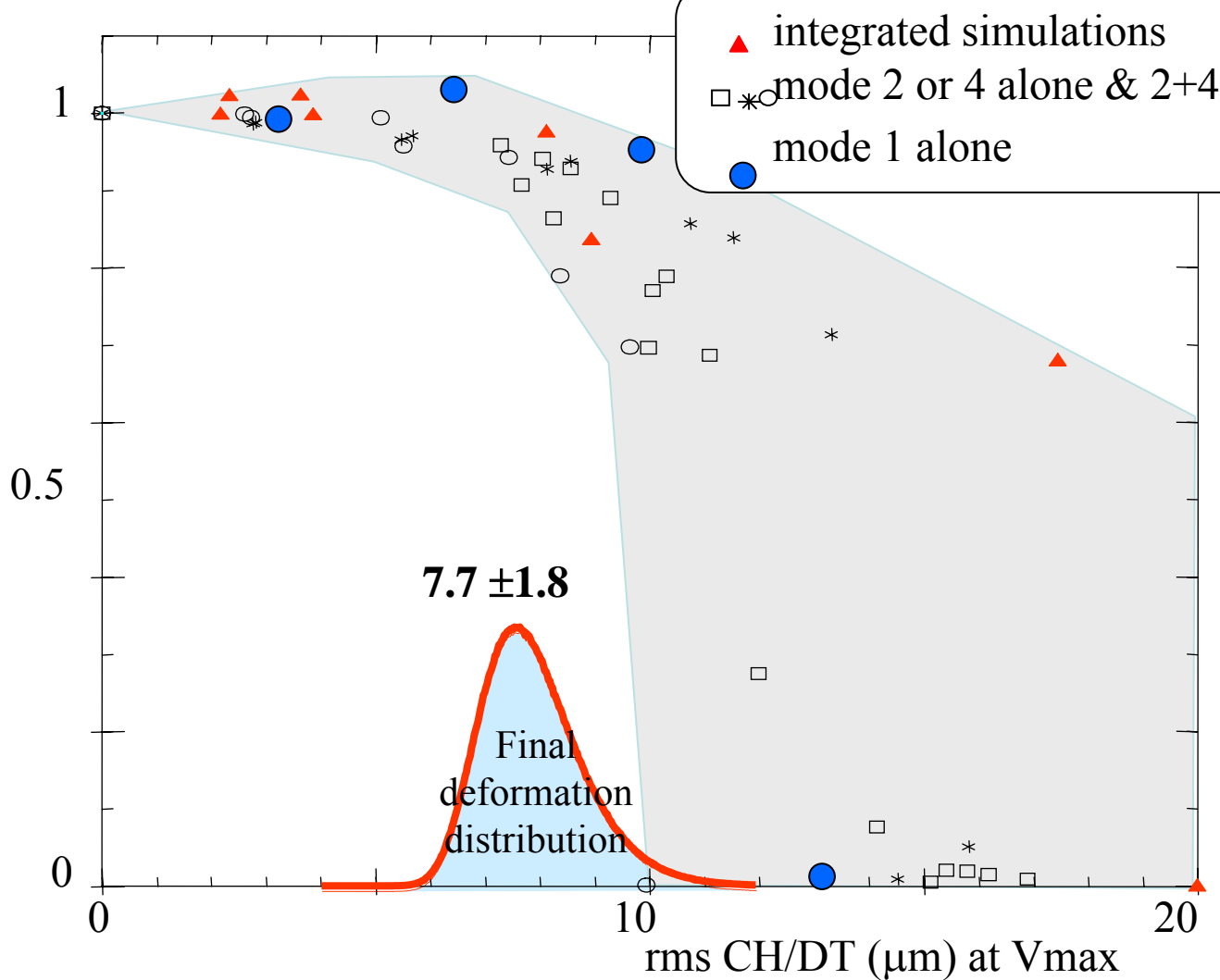
197 laser and target random 3D-defects are taken into account. Final deformation probability is given by a Monte-Carlo calculation.



rms $\pm 2\sigma$ ( $\mu\text{m}$ )	modes 1 - 10
laser defects	$3.0 \pm 1.3$
target defects	$1.0 \pm 1.1$
CH with NIF spectrum	6.0
DT with LLE spectrum	1.8
intrinsic asymmetry	3.8
<b>TOTAL</b>	<b><math>7.7 \pm 1.8</math></b>

## 2.6 Total final deformation is too high: initial ablator roughness must be smaller for modes 1-2.

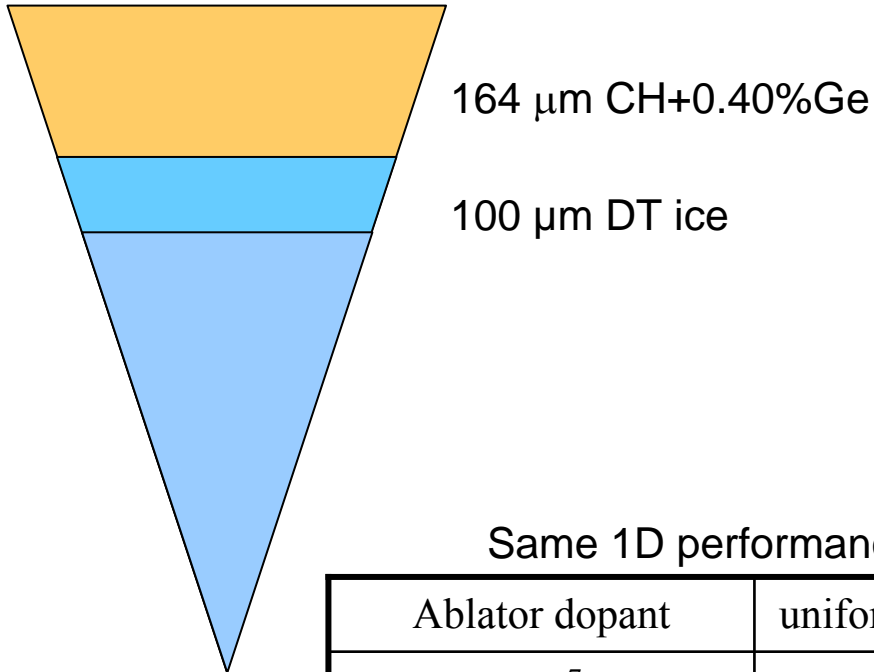
Yield over 1D



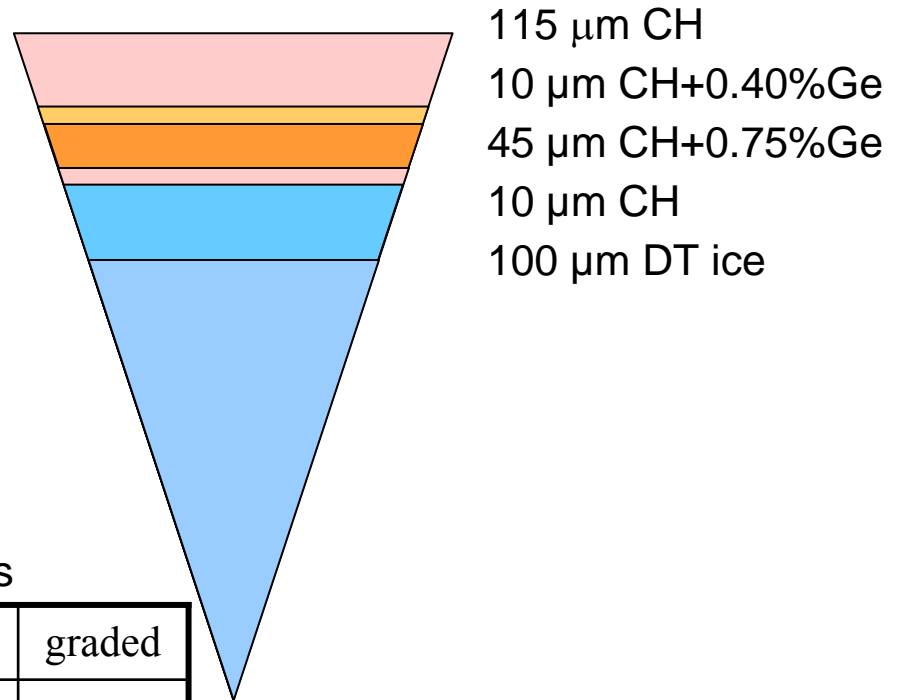
High modes and 1D defects (thickness, density...) not taken into account.

### 3.1 The first target with graded doped ablator was designed with 4 CH layers and same DT shell.

**uniform dopant CH design**



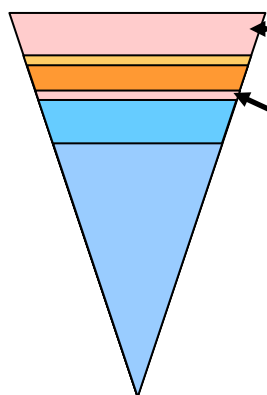
**graded dopant CH design**



Same 1D performances

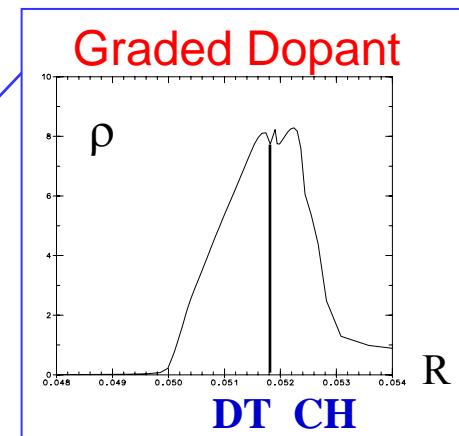
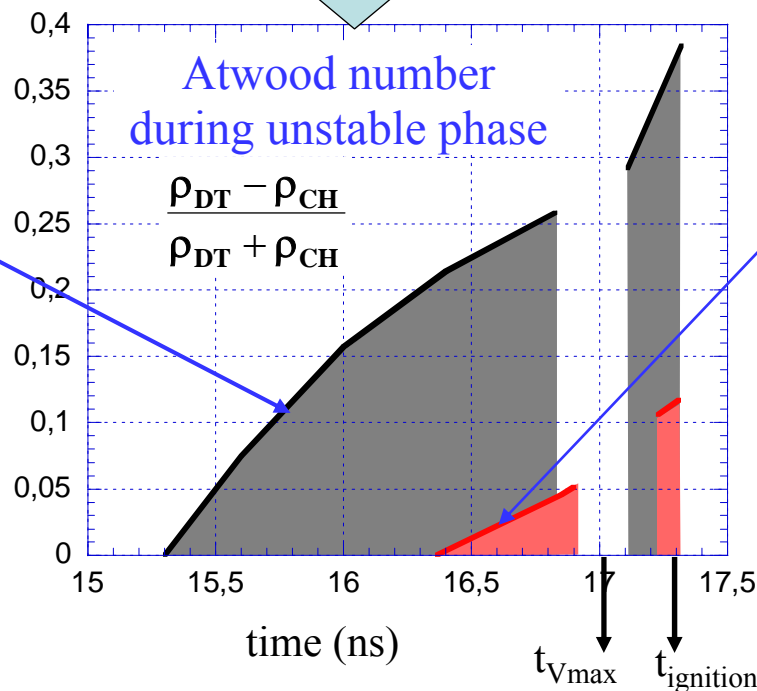
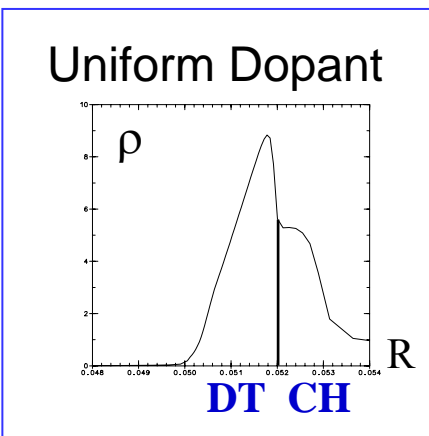
Ablator dopant	uniform	graded
Vmax ( $10^7$ cm/s)	3.81	3.74
Entropy parameter $\alpha_{10}$	0.87	0.90
Fusion Energy (MJ)	31.3	32.9
In Flight Aspect Ratio	35.6	34

## 3.2 Grading the dopant acts in two unstable locations.



**undoped outer layer** to reduce instability in the ablation front at early time (larger density gradient scale length)

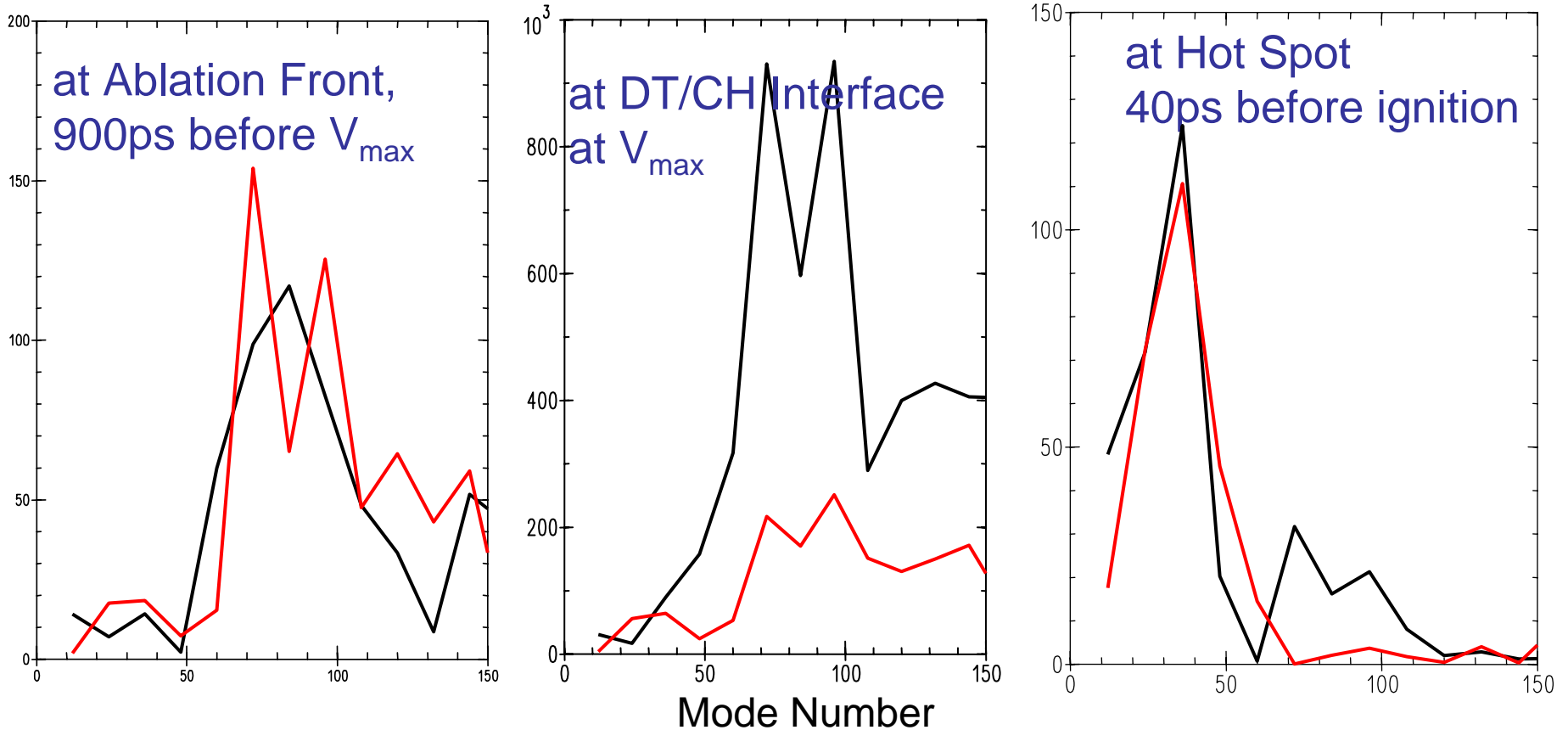
**undoped inner layer** to reduce instability at DT/CH interface (less heated by hard X-rays, then more compressed)



### 3.2 The graded design is more stable at DT/CH and hot spot interfaces.

Uniform Dopant  
Graded Dopant

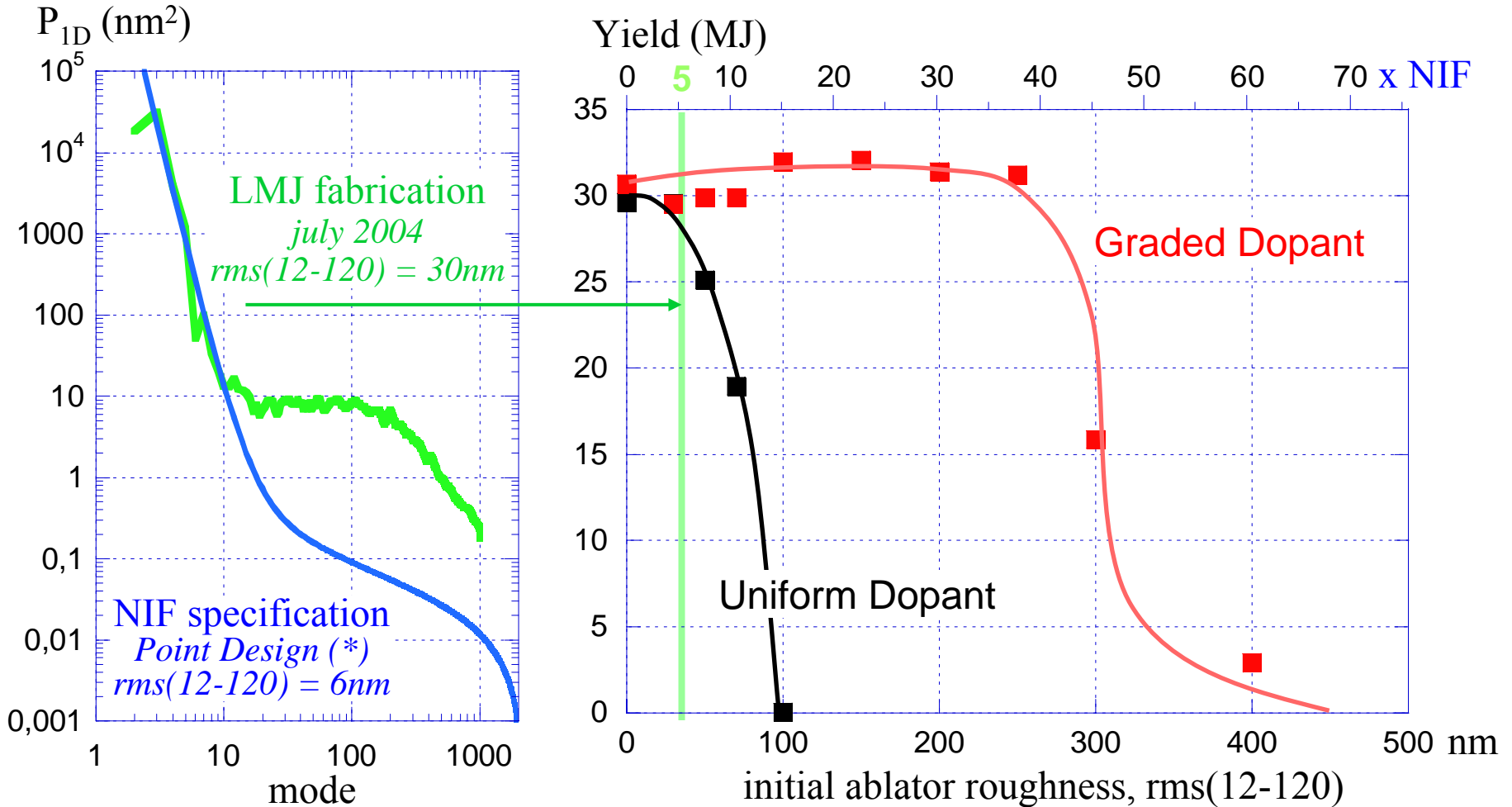
#### Growth factors



Multimode calculations with an initial ablator external roughness of 50 nm



### 3.4 The first design with graded dopant has shown that we can increase the tolerance to high mode deformation.



(\*) uniform CHGe



## 4.1 Advantages of green light would be more laser energy and less optic damage. Disadvantages would be more LPI.

LMJ facility would be able to deliver up to 3MJ at  $2\omega$  with optimized KDP (*Bruno Le Garrec et al., CESTA/DLP*).

**Laser Plasma Instabilities security factor:**

$$\text{FFOM} = I \text{ [W/cm}^2\text{]} \lambda^2 \text{ [mm}^2\text{]} n_e/n_c (3/T_e) \text{ [3keV]} (f\#/8)^2$$

$$\text{FFOM threshold} \approx 0.5 \text{ to } 1. \cdot 10^{13}$$

LMJ baseline design has  $\text{FFOM} = 0.9 \cdot 10^{13}$  at  $3\omega$

FFOM is maximal in outer laser beams (  $660 \cdot 2000 \mu\text{m}$  focal spot )

Integrated simulations with same laser intensity have shown that:

- $\text{FFOM}(2\omega) \approx 3.5 \text{ FFOM}(3\omega)$
- $T_R(2\omega) \approx T_R(3\omega) - 1.5\%$

**=> LPI would be too important at  $2\omega$  if same laser intensity.**

## 4.2 We have found baseline scaled targets which work with enough security factors at $2\omega$ & 3MJ.

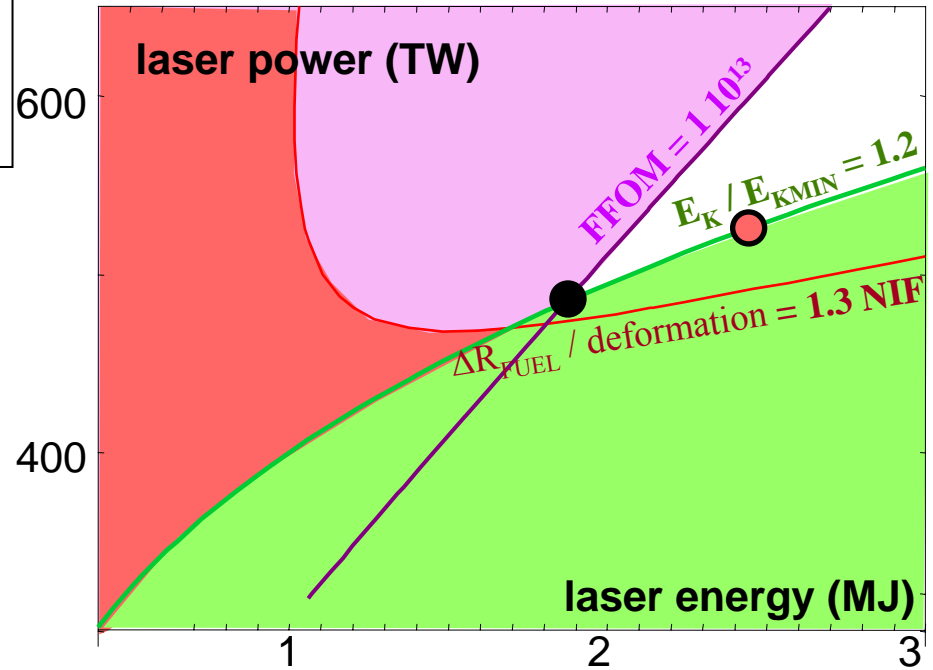
Operative region limited by 3 security factors better than baseline design ones:

1D margin:  $E_K / E_{KMIN} \geq 1.2$

Shell break-up:  $\Delta R_{FUEL} / \text{deformation} \geq 1.3 \text{ NIF}$

LPI:  $FFOM \leq 1 \cdot 10^{13}$


Scaled targets at  $2\omega$  with minimum laser intensity  
(scaled LEH & max focal spot)



●  $FFOM = 1 \cdot 10^{13}$   
1.9 MJ - 490 TW  
Tr = 275 eV - 1.25 scaled  
 $I = 5 \cdot 10^{14} \text{ W/cm}^2$   
1100\*2800 $\mu\text{m}$  focal spot

●  $FFOM = 0.5 \cdot 10^{13}$   
2.5 MJ - 530 TW  
Tr = 265 eV - 1.45 scaled  
 $I = 2.5 \cdot 10^{14} \text{ W/cm}^2$   
1500\*3600 $\mu\text{m}$  focal spot

20% margin for backscattering and beam phasing  
 $\Rightarrow \approx 3 \text{ MJ}$  needed at  $2\omega$ .



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