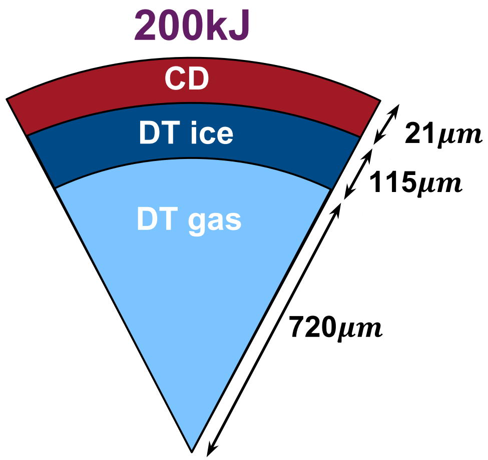
OMEGA Next Laser Facility --- Target Design Space

OmegaNext: evaluated @{200kJ}



J. A. Marozas
University of Rochester
Laboratory for Laser Energetics

64th Annual Meeting of the American Physical Society
Division of Plasma Physics
17-21 October 2022

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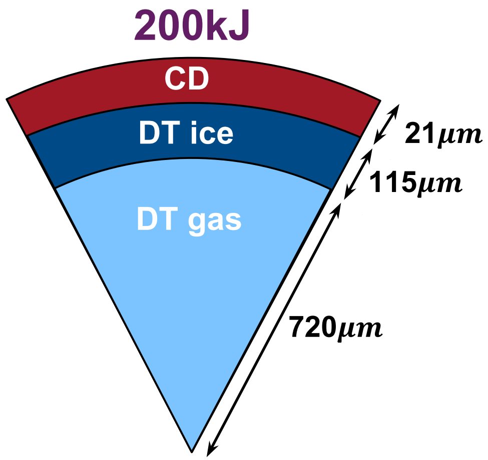

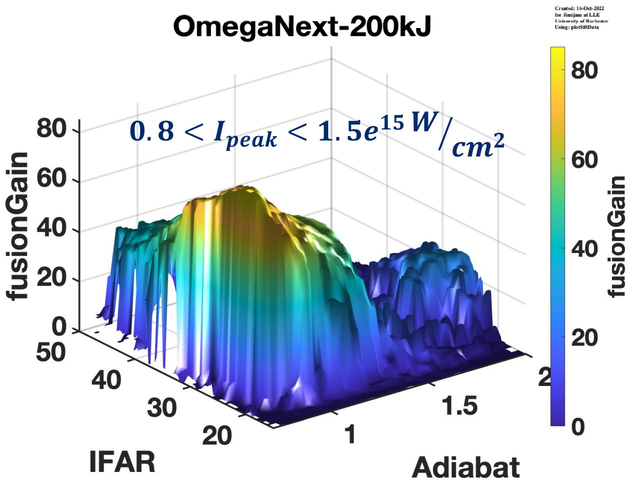

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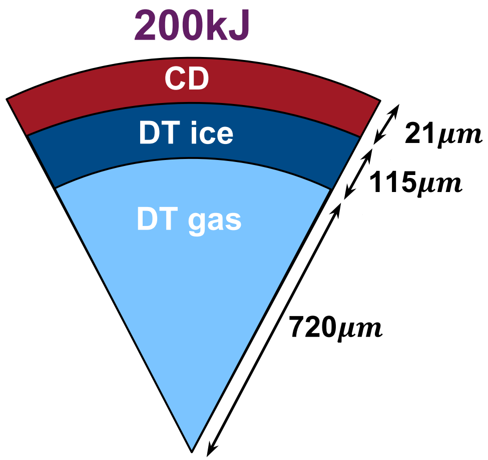

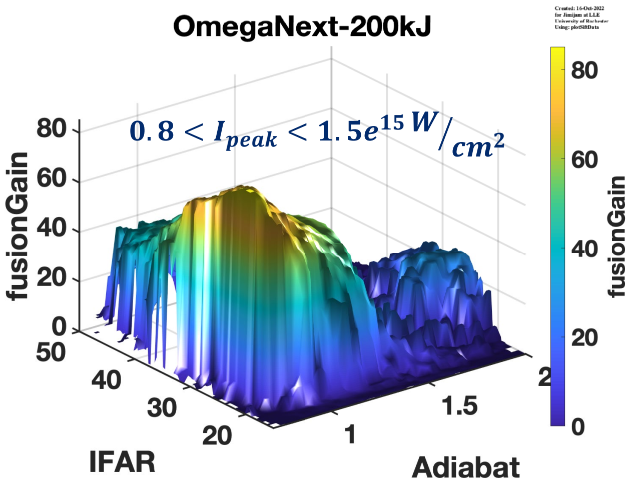

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Adiabat	1	1	2.5	3
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Gain	47	68	15	5

Modest gain, mid-α

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Summary

OmegaNext design-space mapping discovered stable regions with substantial fusion gain for each facility energy

- The Optimization-guided* tool, *aanji'Lilac*, maps the complex topology of the multi-dimensional design space (20-D)
  - Interactive visualization tools explore and evaluate promising regions to down-select the facility's proposed maximum energy over the range {50 – 300kJ}

- Higher facility energy offers expanded high-yield design-space accessible at smaller IFAR values and larger adiabats
  - Broadband laser driver expands ignition design-space
    - Improves absorption, smoothing and I_{peak}
  - Substantial gain has been found for IFAR < 30 and adiabat < 5, at a peak intensity I_{peak}~1e15 W/cm^2
  - Above I_{peak}>1e15 W/cm^2, increased performance is accompanied by increased risk of LPI

*aanji'Lilac --- new MATLAB-based Optimization-guided design space scoping toolset
IFAR --- In Flight Aspect Ratio
LPI --- Laser Plasma Instabilities
**2-D Draco sims of OmegaNext – see P. McKenty [JO04.00014] this conference

Collaborators

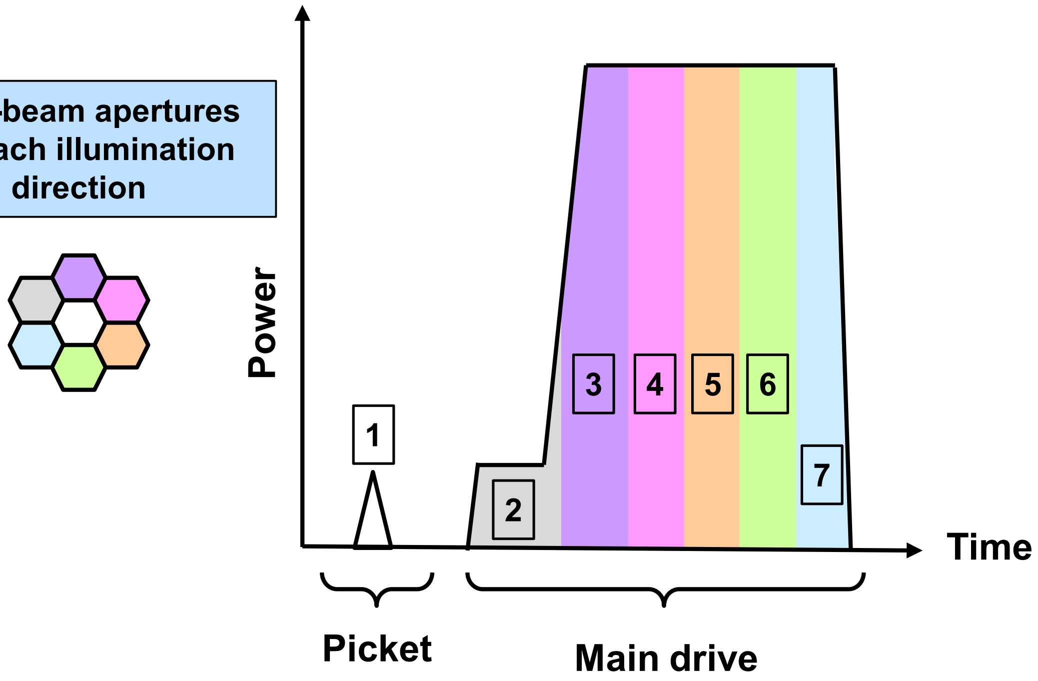
T. J. B. Collins, D. Cao, P. W. McKenty, W. Trickey, V. Goncharov

University of Rochester, Laboratory for Laser Energetics

The proposed OmegaNext facility consists of multi-beam clusters illuminating laser direct-drive (LDD) targets with wide-bandwidth driver lines mitigating LPI* effects

OMEGA Next**

Multi-beam apertures for each illumination direction



Clusters of composite apertures illuminate an LDD ICF target

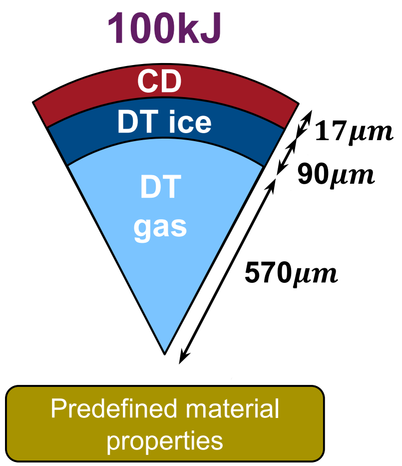
- **The OmegaNext facility is being evaluated over the 50 – 300kJ range for ICF target performance tradeoffs with facility cost and size**
  - **Broadband laser expands ignition design-space**
    - **Improves absorption, smoothing and I_{peak}**

- **Flexible aperture arrays can be repurposed to alter aspects of beams on target during an implosion**
  - **The spot-size can match an imploding target; Zooming**
  - **Combine multiple apertures in time to increase intensity & energy; shock ignition**

*LPI --- Laser Plasma Instabilities
**OmegaNext wide-bandwidth laser concept --- J. Zuegel, C. Dorrer

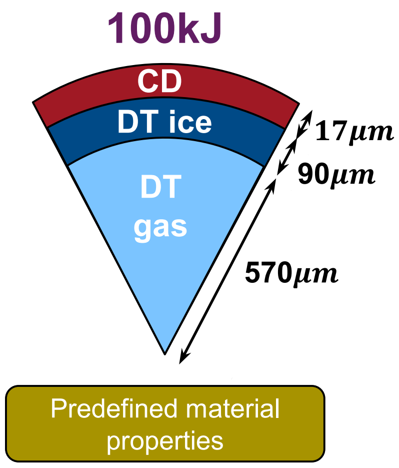
The design-space covers an enormous 20-D range of input parameters

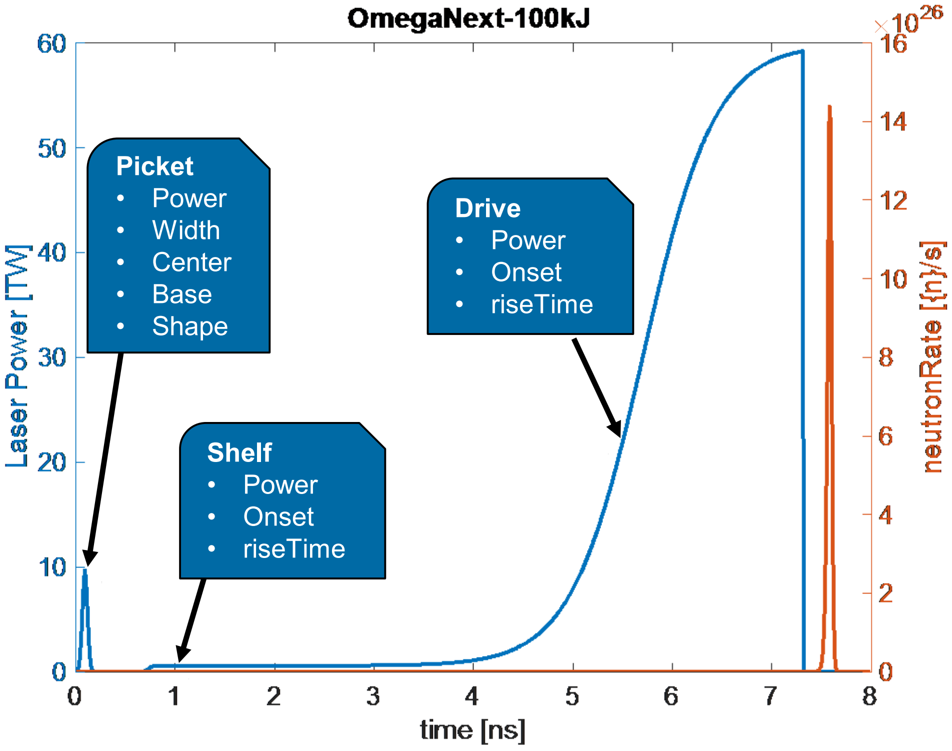
- **The design space is 20-D = {3-target,**



The design-space covers an enormous 20-D range of input parameters

- **The design space is 20-D = {3-target, 5-picket, 3-shelf, 3-drive**





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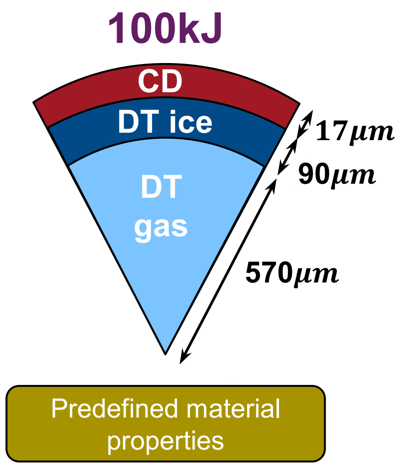

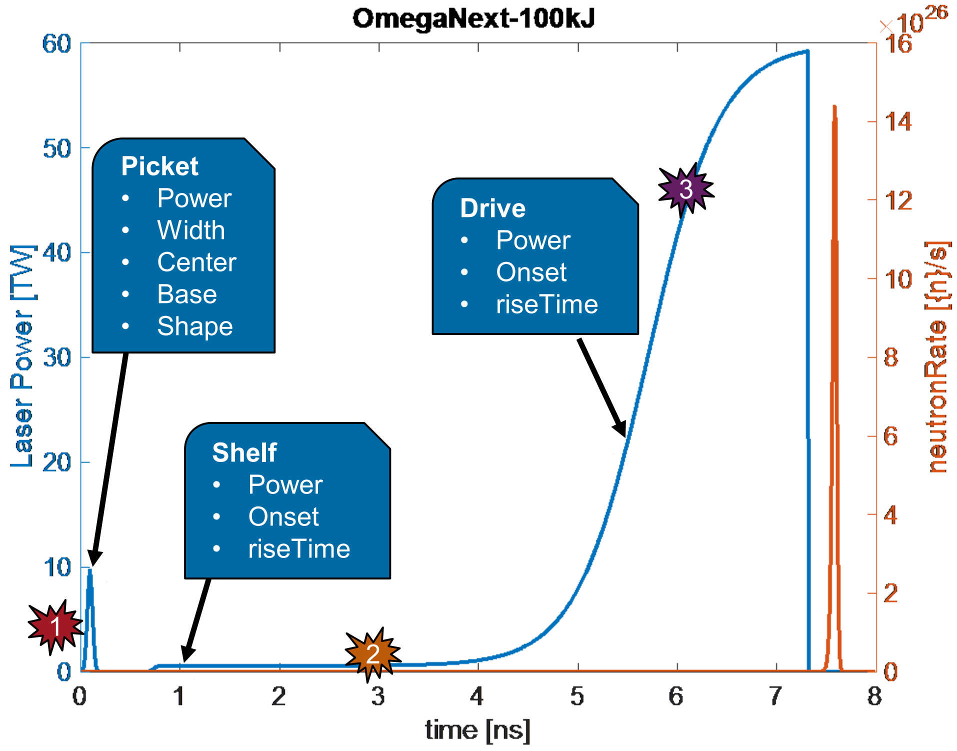

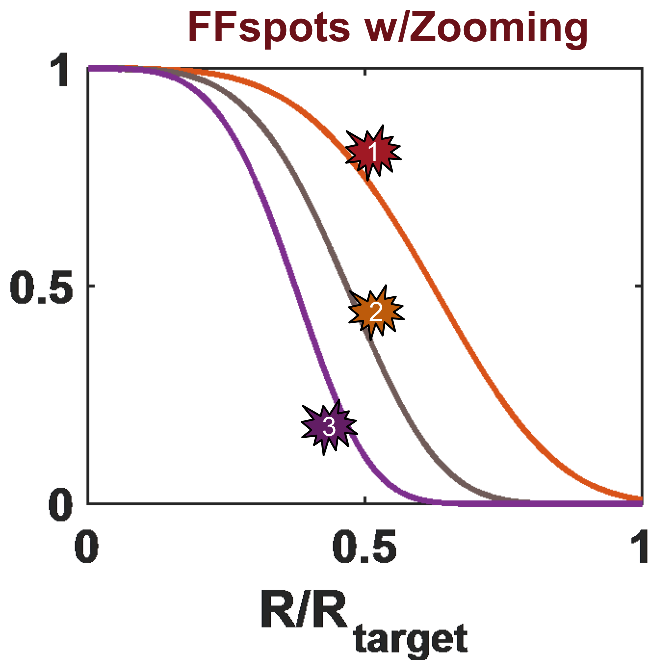

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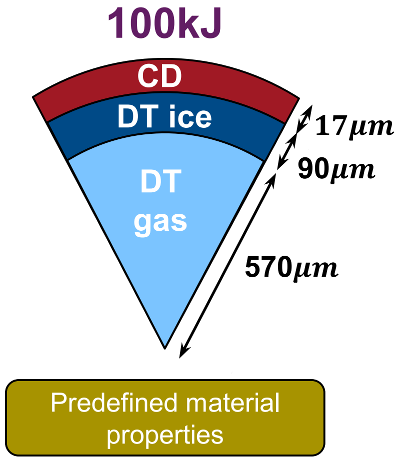
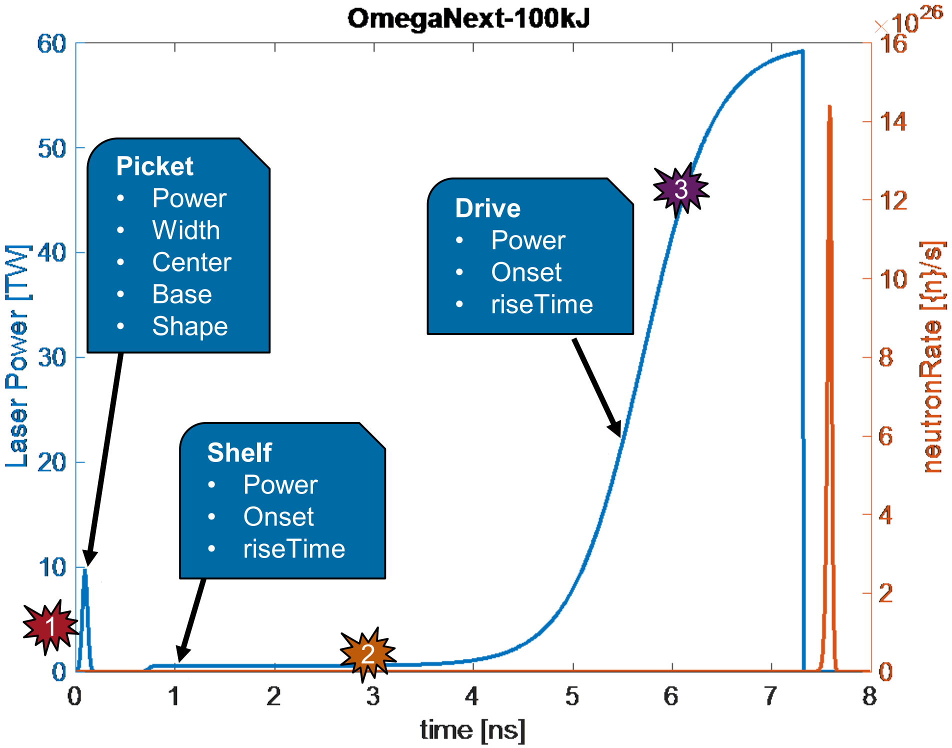
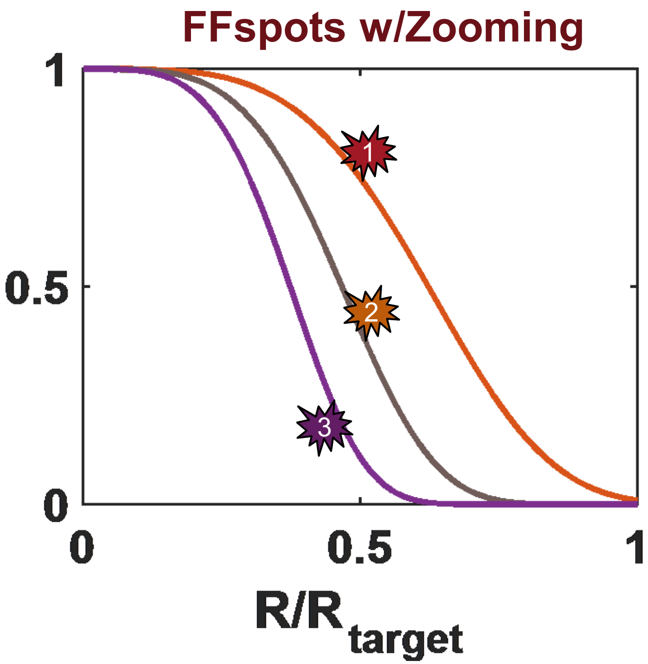


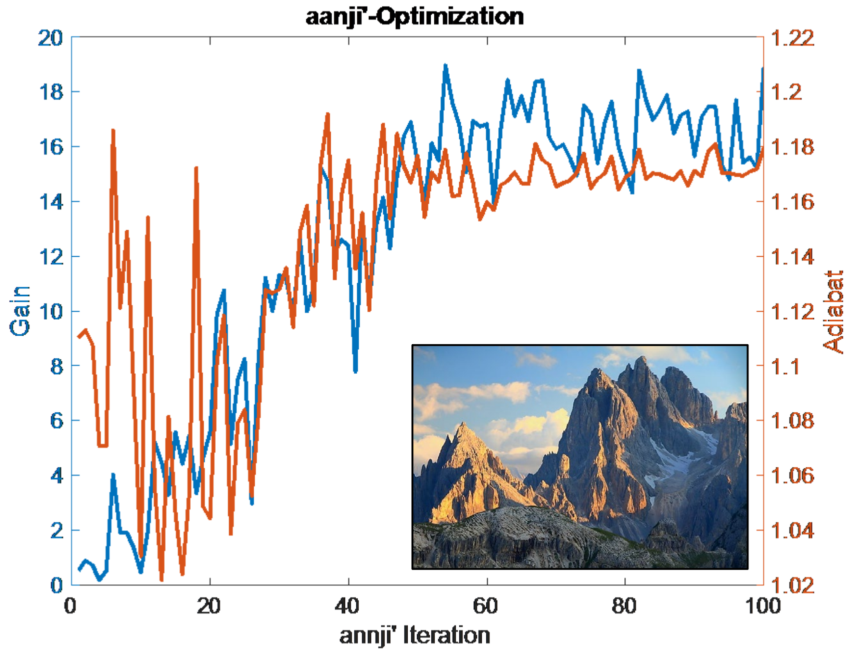




- The 20-parameter prescription completely defines the simulation, which evaluates the ICF target performance
  - ➔ Only 20 numbers needed to reconstruct any simulation

As the *aanji'Lilac* optimization progresses towards its goal, it traverses the varied terrain while mapping out the design space along the way

- An optimization algorithm, *aanji'Lilac*, guides the exploration using a highly parallel system across nodes using a "shotgun" (scattered/diffusion) technique
  - The underlying algorithm is selectable {simplex [default], Levenberg-Marquardt, etc.}
  - *Aanji'Lilac* supports an arbitrary optimization metric function of {gain, adiabat, T_{ion}, etc.}
  - The choice of input parameters to vary is selectable
    - e.g. {R_{gas}, shelf onset, drive onset, drive riseTime} for timing
  - The 1-D rad-hydro code, *Lilac*, evaluates each iteration for ICF physics results, e.g. Y_{DT}, T_{ion}, P_{abl}, V_{imp}, etc.
- A variety of starting points map-out the rugged terrain, which is reminiscent of a craggy mountain range



- The terrain doesn't always follow conventional intuition
- e.g., in this example, gain increases with α due to its strong dependence on V_{imp}

Two OmegaNext facility options (100,200kJ) show a wide variety of ICF performance ranges

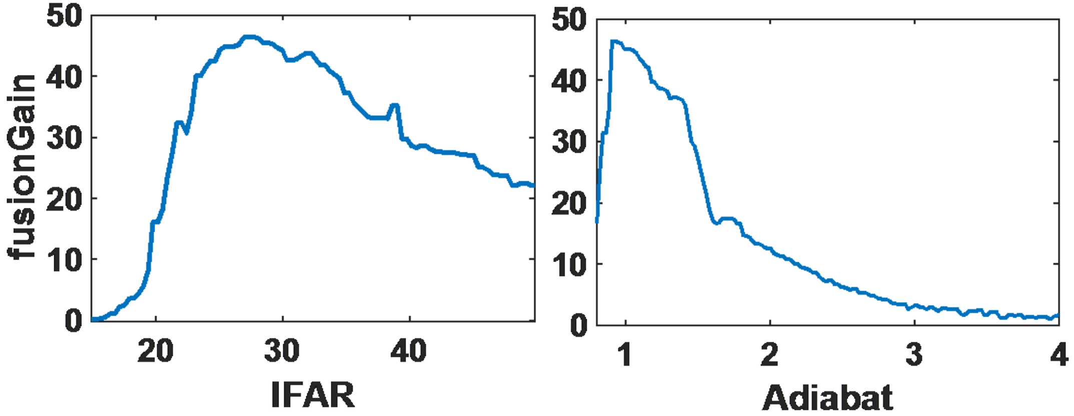
100kJ

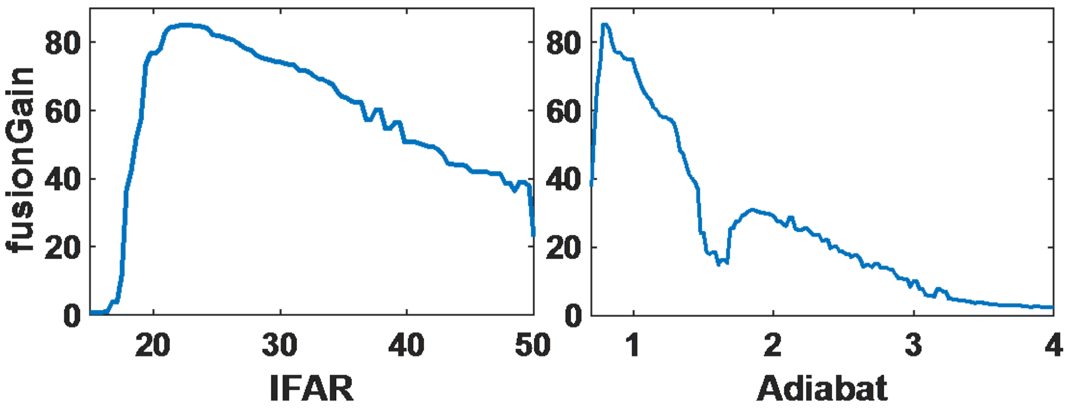
$$0.8 < I_{peak} < 1.5e^{15}\, {}^{W}\!/_{cm^2}$$

200kJ

Sifting algorithms compile the conglomerate data into organized structures for visualization

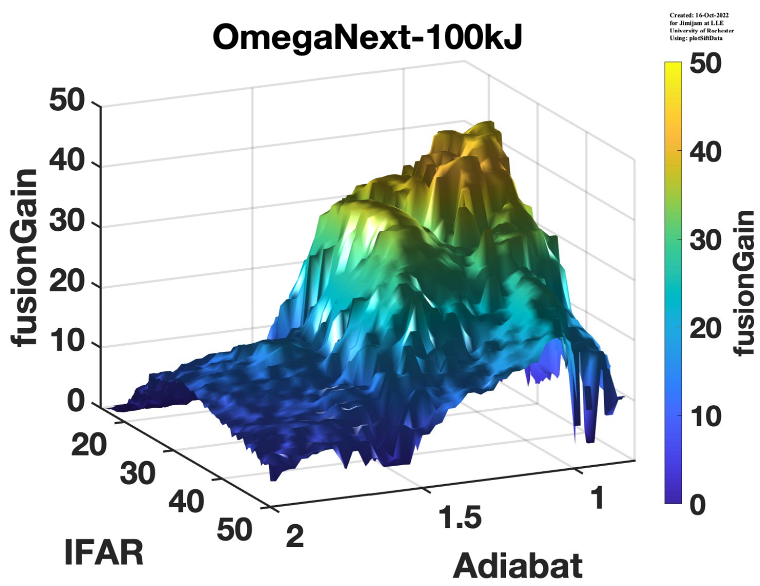
Can use any input- or output-parameter for the 3 surface-plot axes

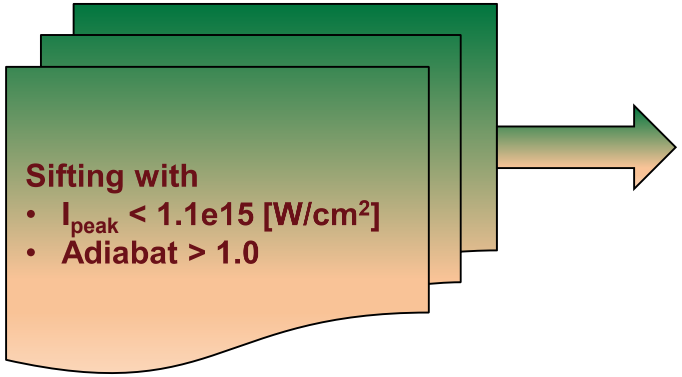


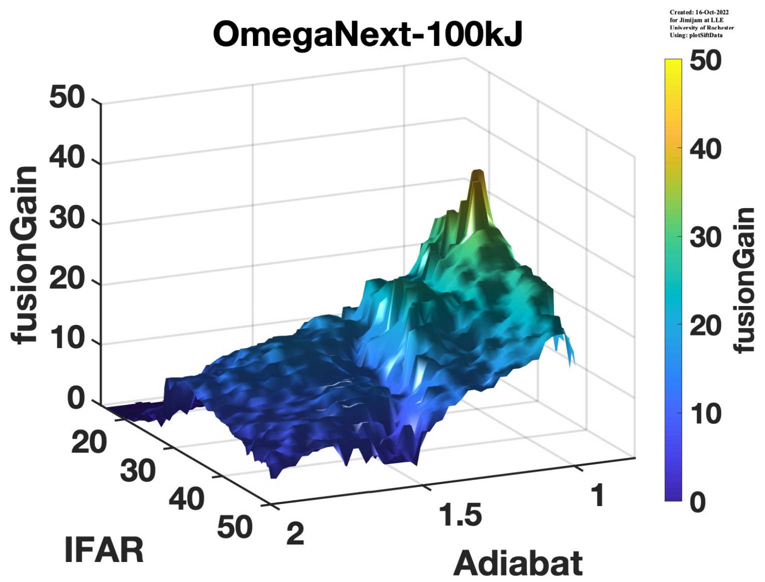


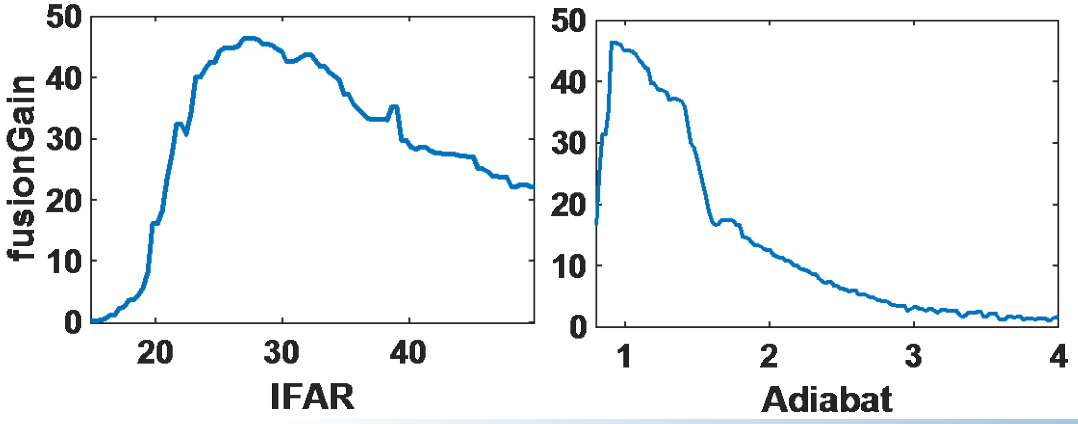
The sifting algorithms include multiple logical criteria options to peel back the maximal surface to find other suitable domains

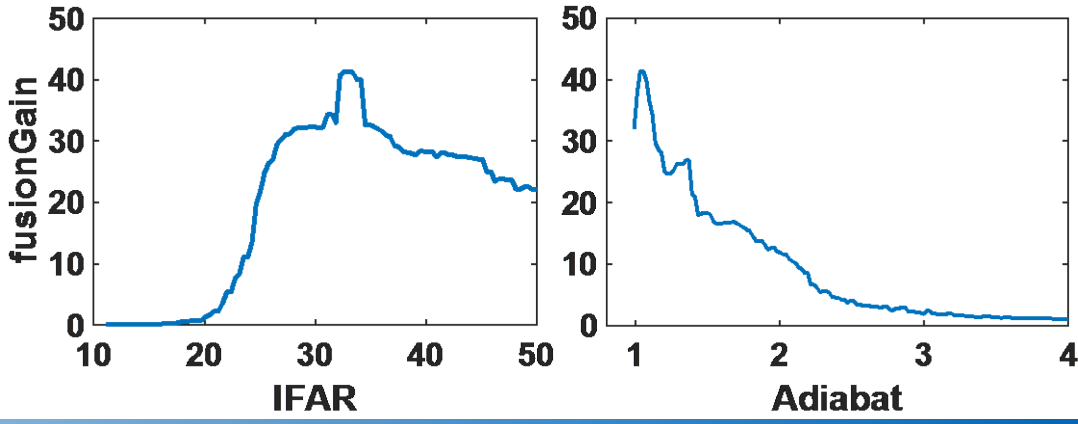
100kJ



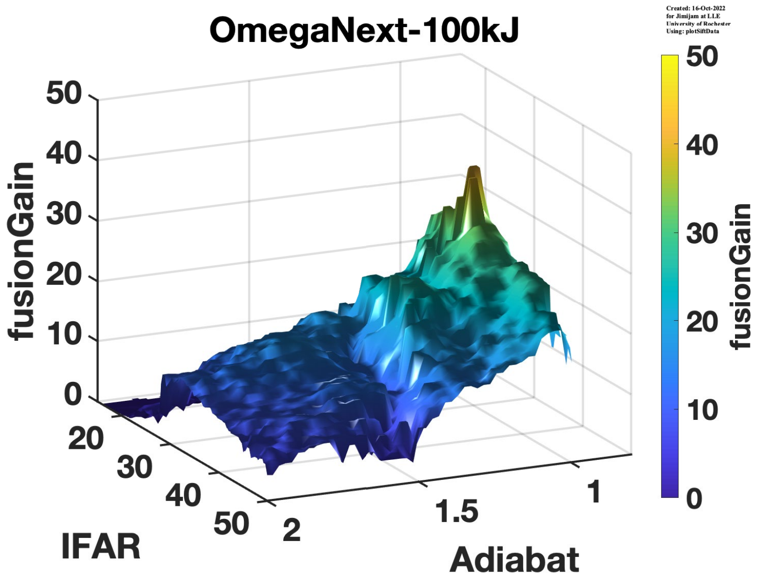








The sifted data visualization plots allow interactive manipulation* to probe ICF performance metrics and launch subsequent optimizations



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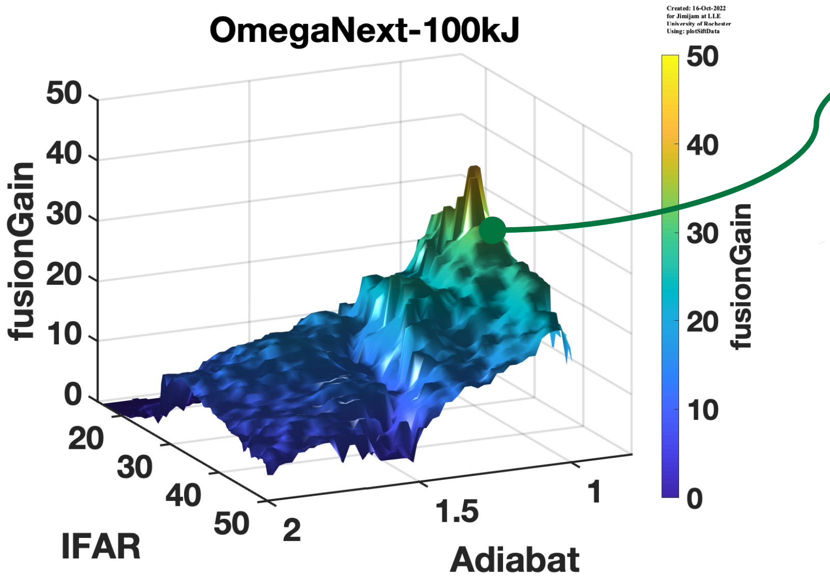

Parameter	
IFAR	30
Adiabat	1
V_{imp} [µm/ns]	385
…	…
Gain	32

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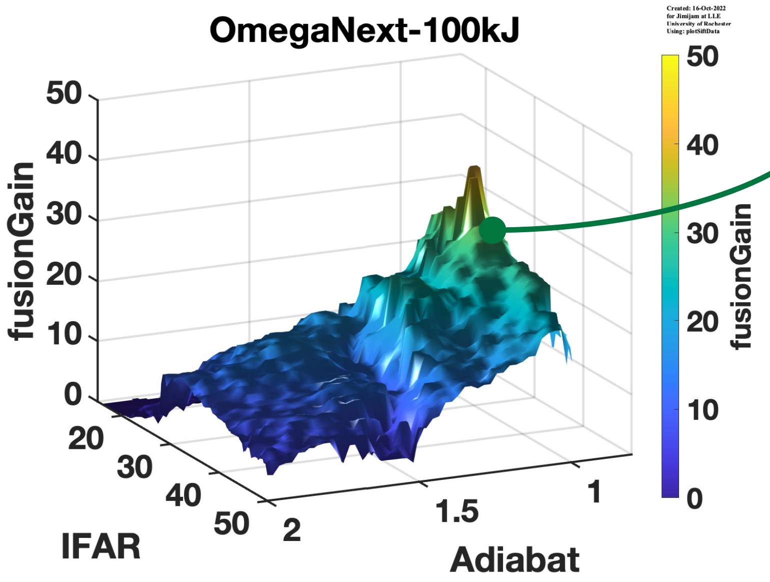

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Options	
Run Lilac	At point
Run Draco	At point
Launch aanji'Lilac	Diffuse "shotgun"
Extract	underlying

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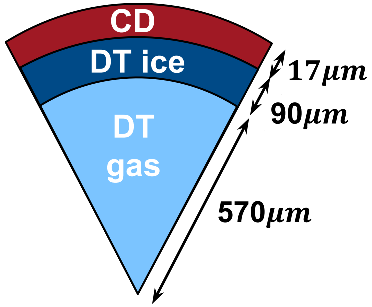
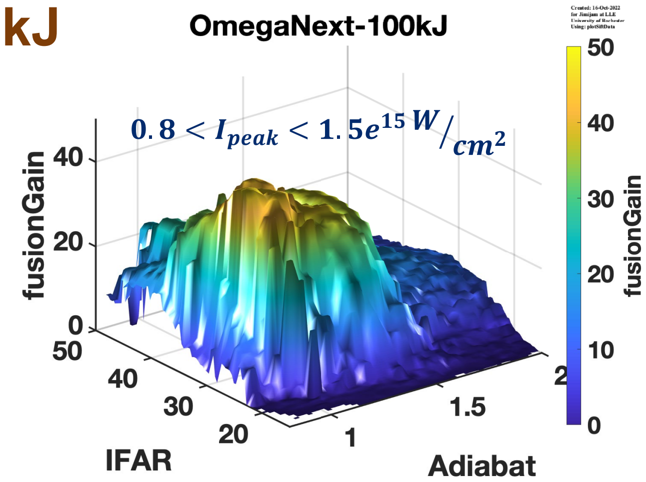
The expanding datasets of the OmegaNext facility energy options expose stable regions with substantial gains suitable for a wide variety of ICF experiments

OmegaNext: 100kJ cf. 200kJ





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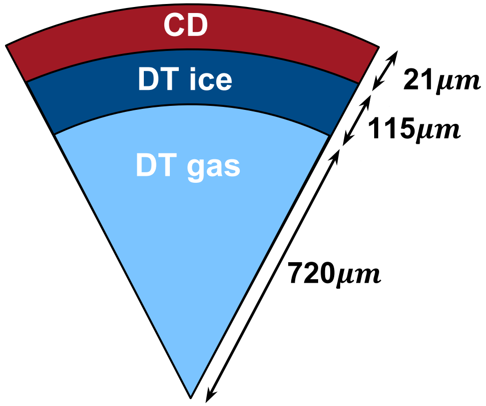

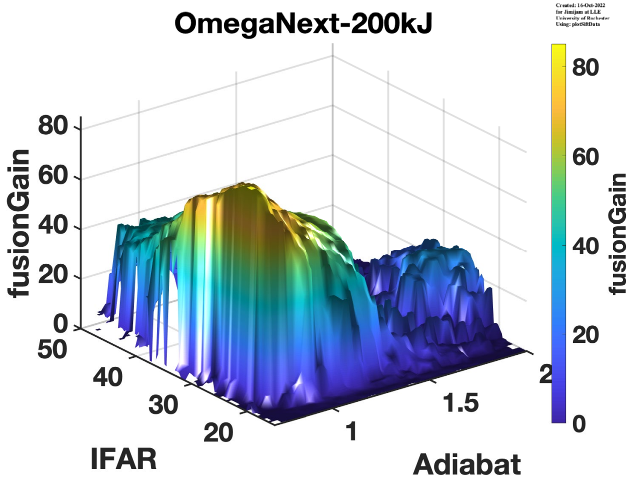

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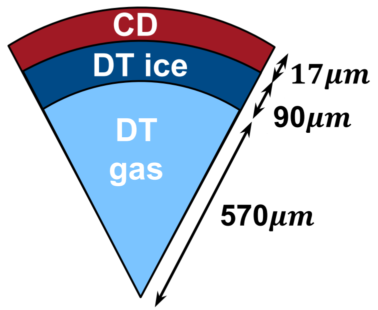

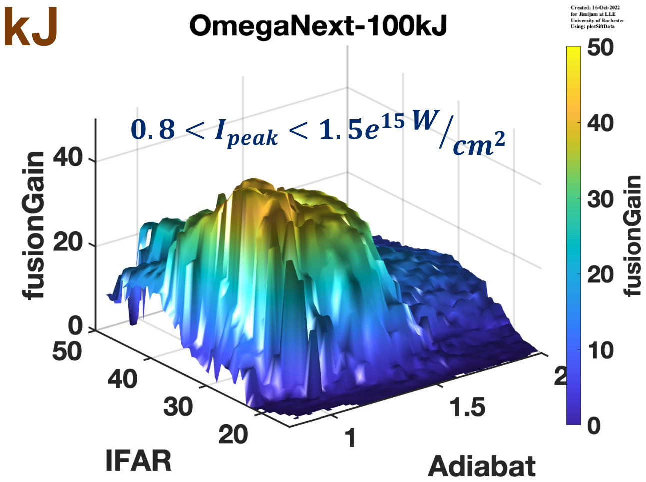

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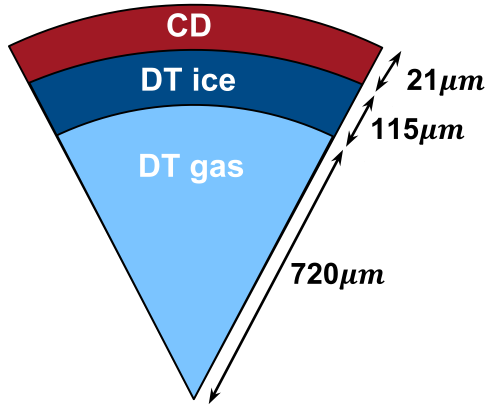

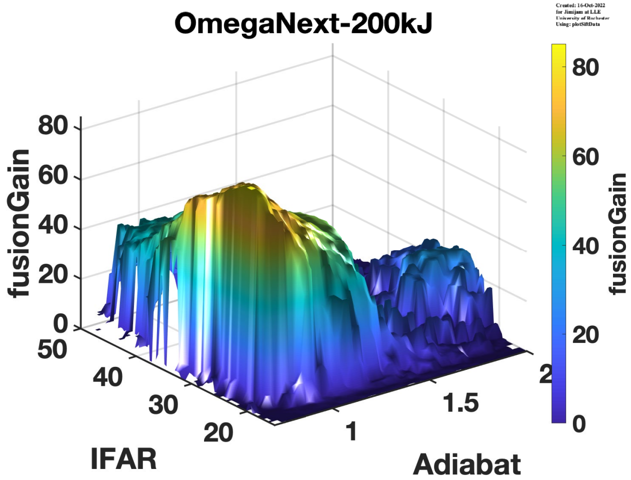

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High gain,
low-IFAR,
low-α

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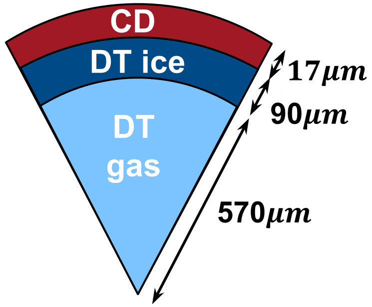

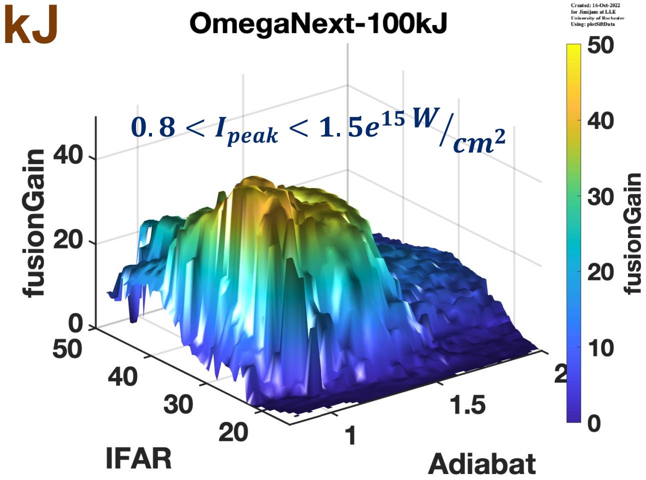

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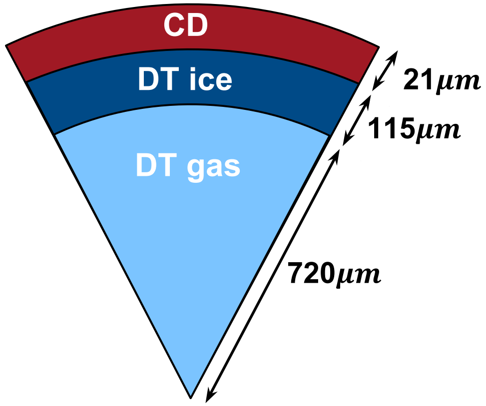

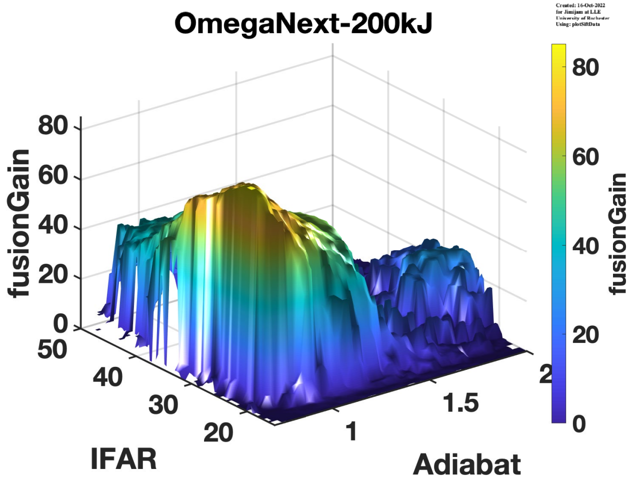

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IFAR --- In Flight Aspect Ratio
LPI --- Laser Plasma Instabilities

Backup --- Slides

200kJ @full 0.8 < I_{peak} < 1.5 e15 W/cm^2 range; Illustrate different contour plotting views