Planning for the National Ignition Campaign on NIF

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Lawrence Livermore National Laboratory

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Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

We have a clearly defined path forward to achievement of ignition on NIF

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- An extensive scientific data base forms the foundation for the NIF ignition point design target and experimental campaign
- We have requirements in place for the first ignition attempt in 2010
- A margin formalism allows us to evaluate the performance of the targets, and to assess and manage risk
- A copper-doped Be capsule driven at 285 eV is sufficiently robust to achieve yields>1 MJ (an ignition margin >1) with the expected precision of target experiments, laser performance, and target fabrication
- A simulated ignition campaign has verified our ability to achieve the required precision in the presence of physics uncertainties
- After the first ignition campaign, we have several paths forward to develop a robust ignition platform

The NIF point design has a graded-doped, beryllium capsule in a U hohlraum driven at 285 eV by 1.22 MJ

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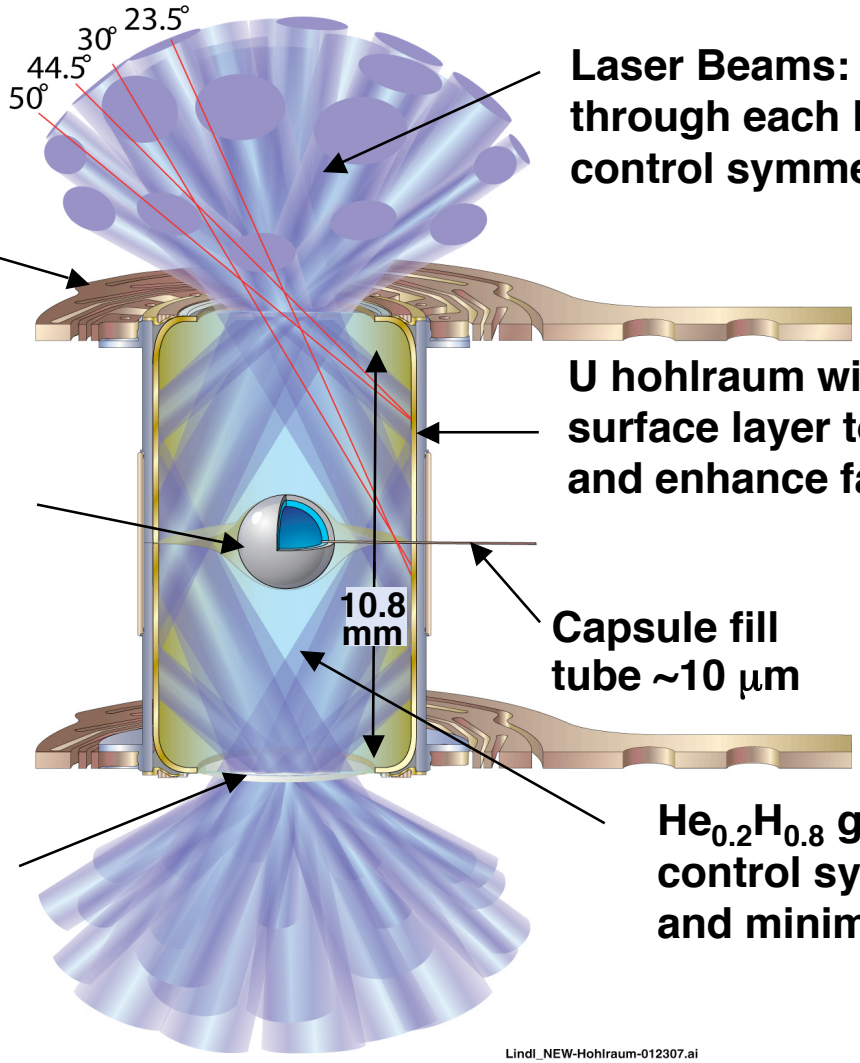

Cryo-cooling rings

Laser Beams: 24 quads through each LEH arranged control symmetry

U hohlraum with B doped Au surface layer to reduce LPI and enhance fabrication yield

Cu doped Be Capsule with cryo fuel layer

Capsule fill tube ~10 μm

$He_{0.2}H_{0.8}$ gas fill to control symmetry and minimize LPI

Laser Entrance Hole sized to balance LPI and radiative losses

We have developed detailed specifications for the point design hohlraum and capsule

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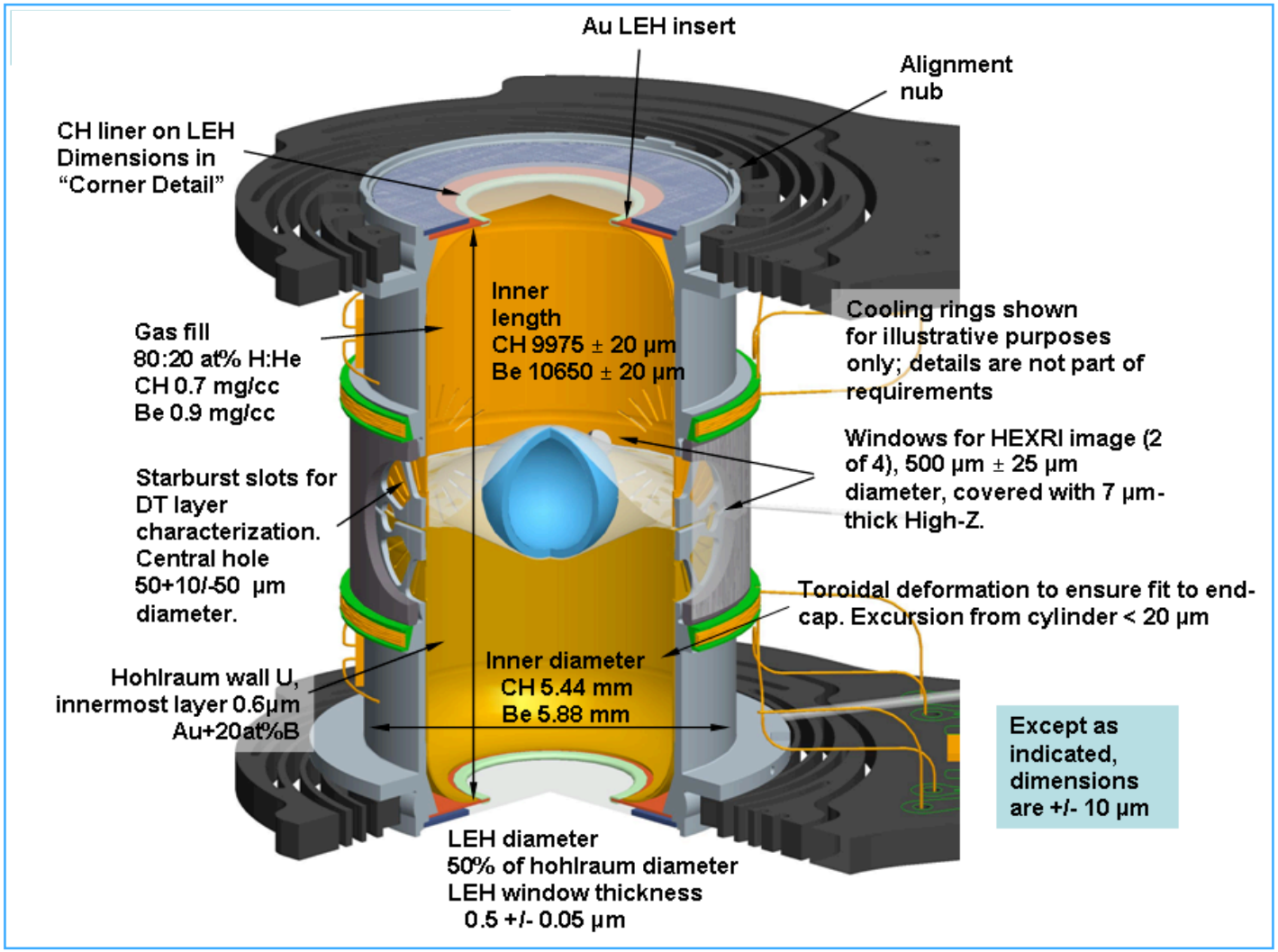

We have begun productions of targets for the National Ignition Campaign (NIC)

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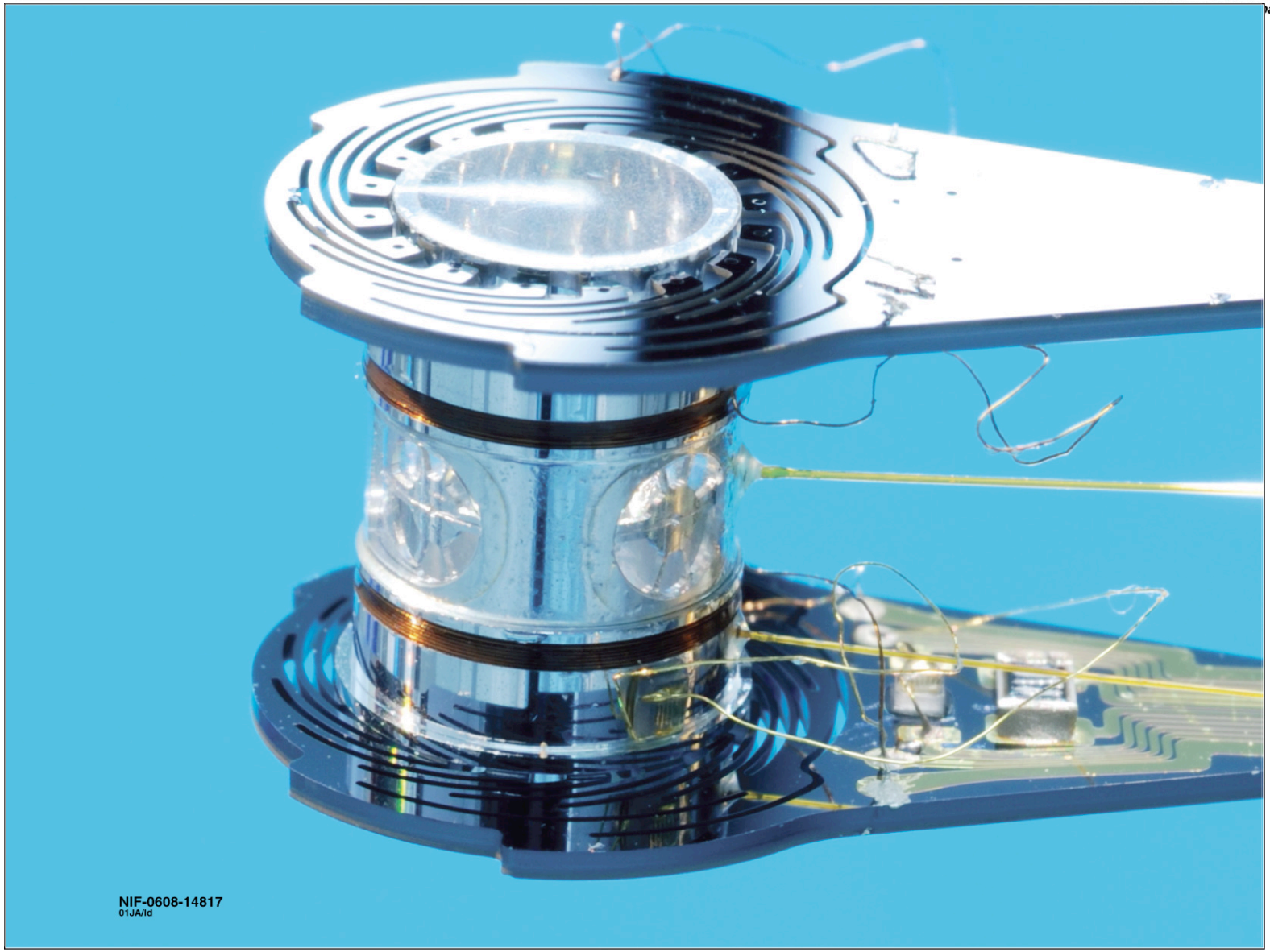

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We have selected a copper doped Be capsule driven at 285 eV for the first ignition experiments

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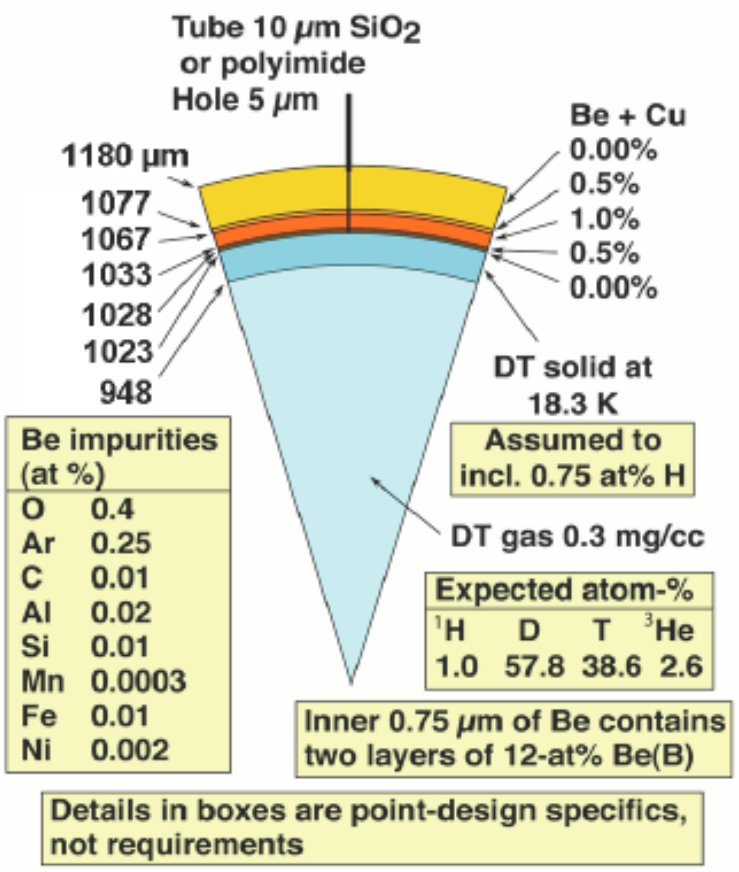
(Cu doped Be shell for 285eV, 1.22 MJ)



- Efficient ablator results in 1/3 more capsule absorbed energy than for an equivalent CH capsule
- Ablation front instability substantially reduced compared to CH
- Crystalline structure effects mitigated by melting with the first shock
- We predict an ignition margin >1 at the point design laser energy

A CH capsule at 300eV is the principal alternate to Be at 285 eV

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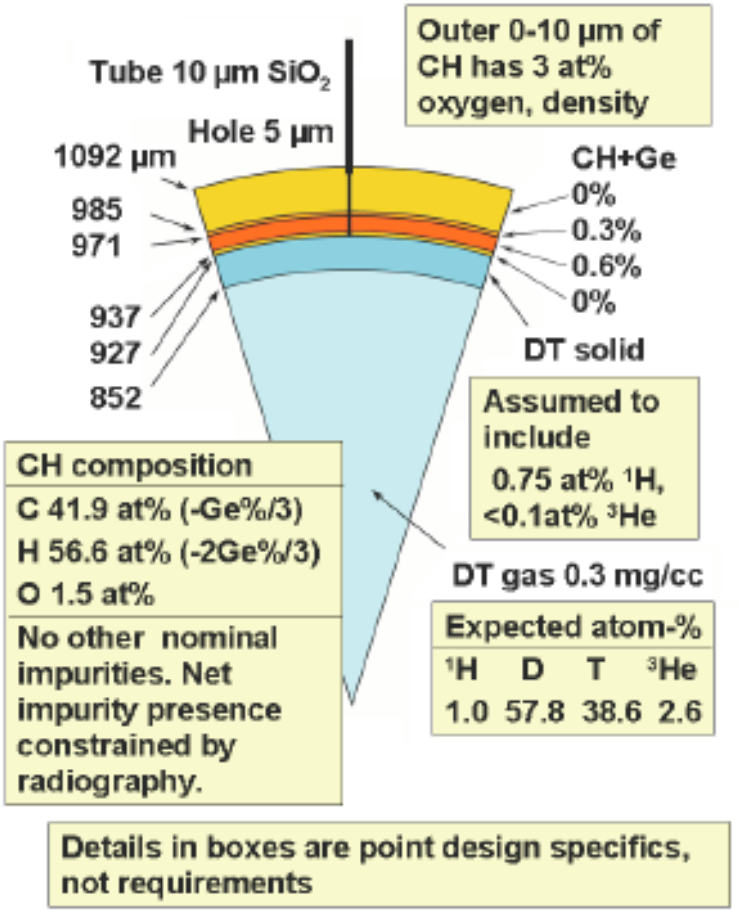
Ge doped CH capsule for 300 eV



- Hohlraum simulations at 300 eV indicate LPI equivalent to Be at 285eV
- Amorphous material with no crystal structure issues
- Large data base from Nova and Omega
- Less efficient ablator and higher ablation front instability result in margin <1 at 1.22 MJ

A Uranium hohlraum and Be capsule are chosen to optimize capsule absorbed energy

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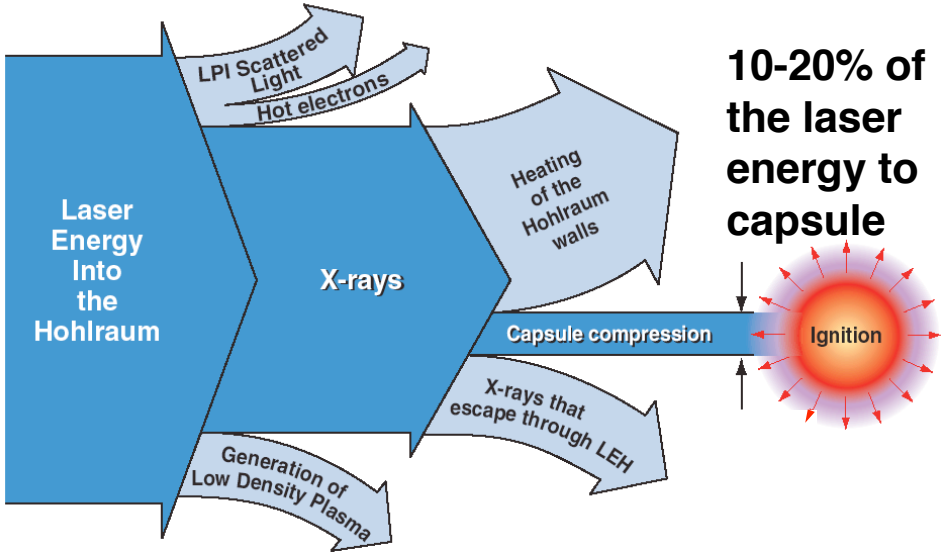

10-20% of the laser energy to capsule

	Au with Be Capsule (285)	U with Be Capsule (285)	U with CH Capsule (300)
Laser light (MJ)	1.31	1.22	1.22
Absorbed	1.23	1.15	1.15
xrays	1.05	0.98	0.98
wall loss	0.61	0.54	0.58
hole loss	0.24	0.24	0.25
capsule	0.2	0.2	0.15
efficiency (%)	15.3%	16.4%	12.3%

Ignition point design optimization must balance LPI effects, laser performance impacts, and capsule robustness

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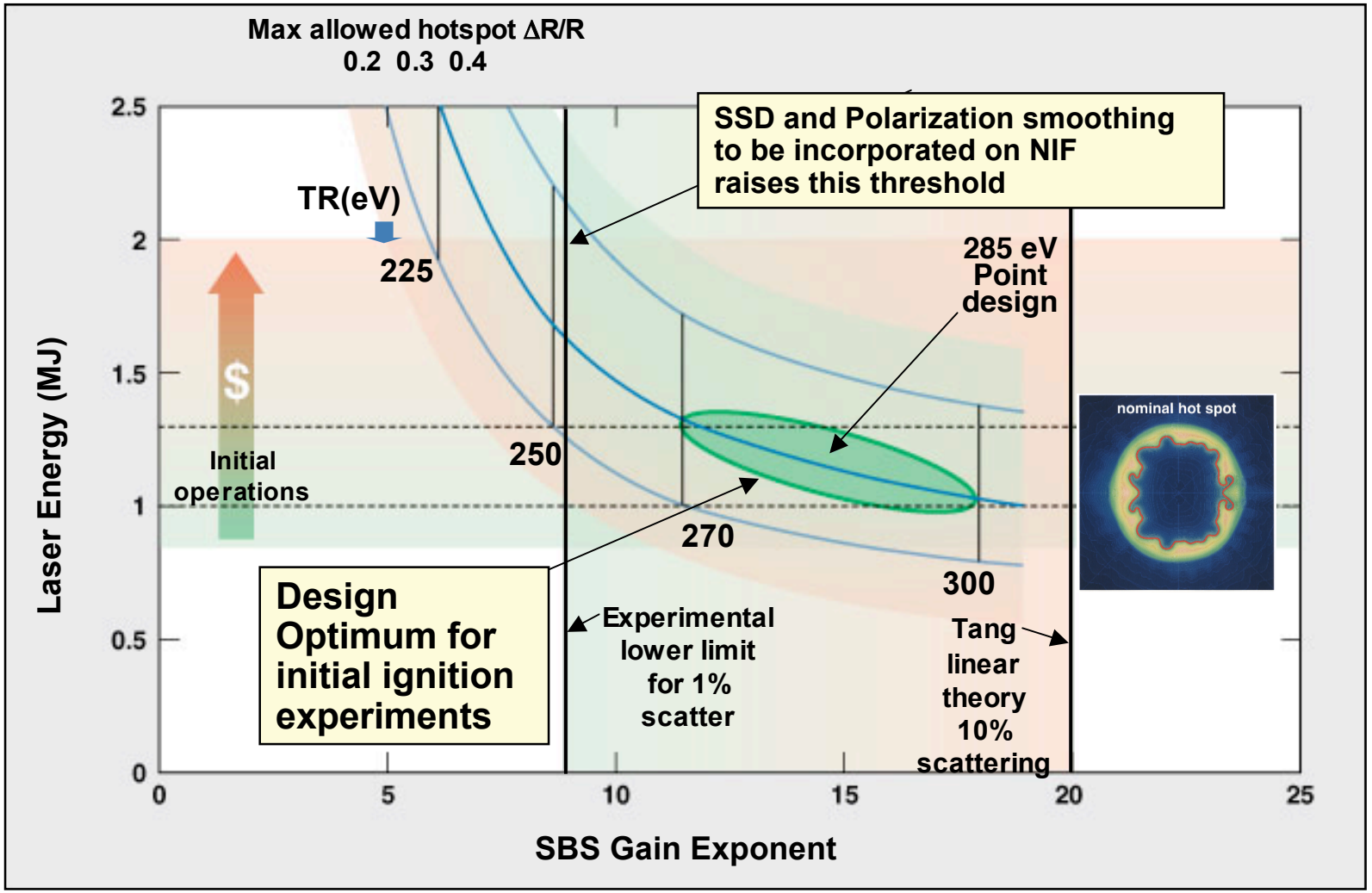

Success of ignition is crucially dependent on Mix, Velocity, Entropy and Shape ("MVSS")

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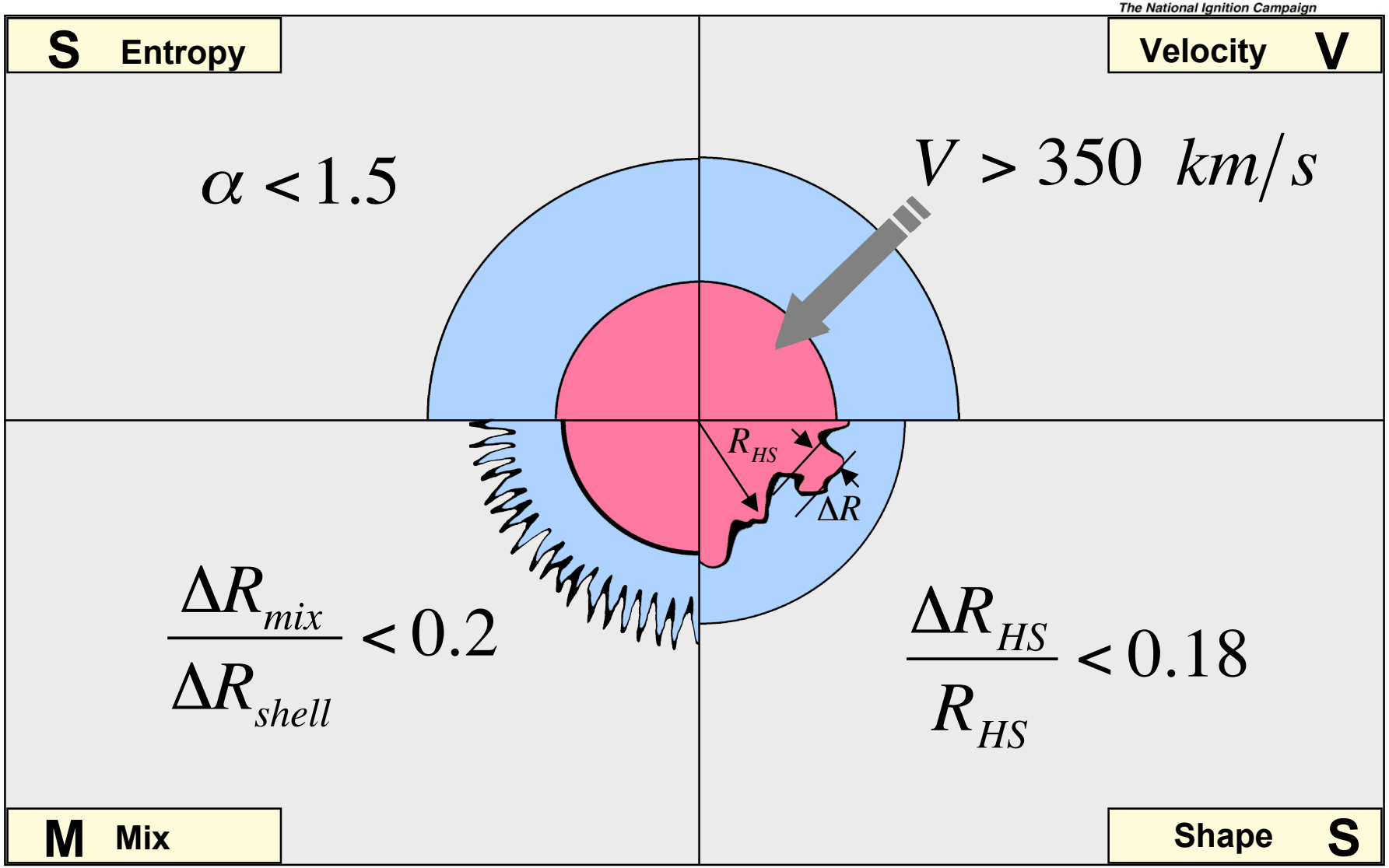

Achieving ignition requires constraining or adjusting multiple lower level parameters that roll up to set the ignition conditions

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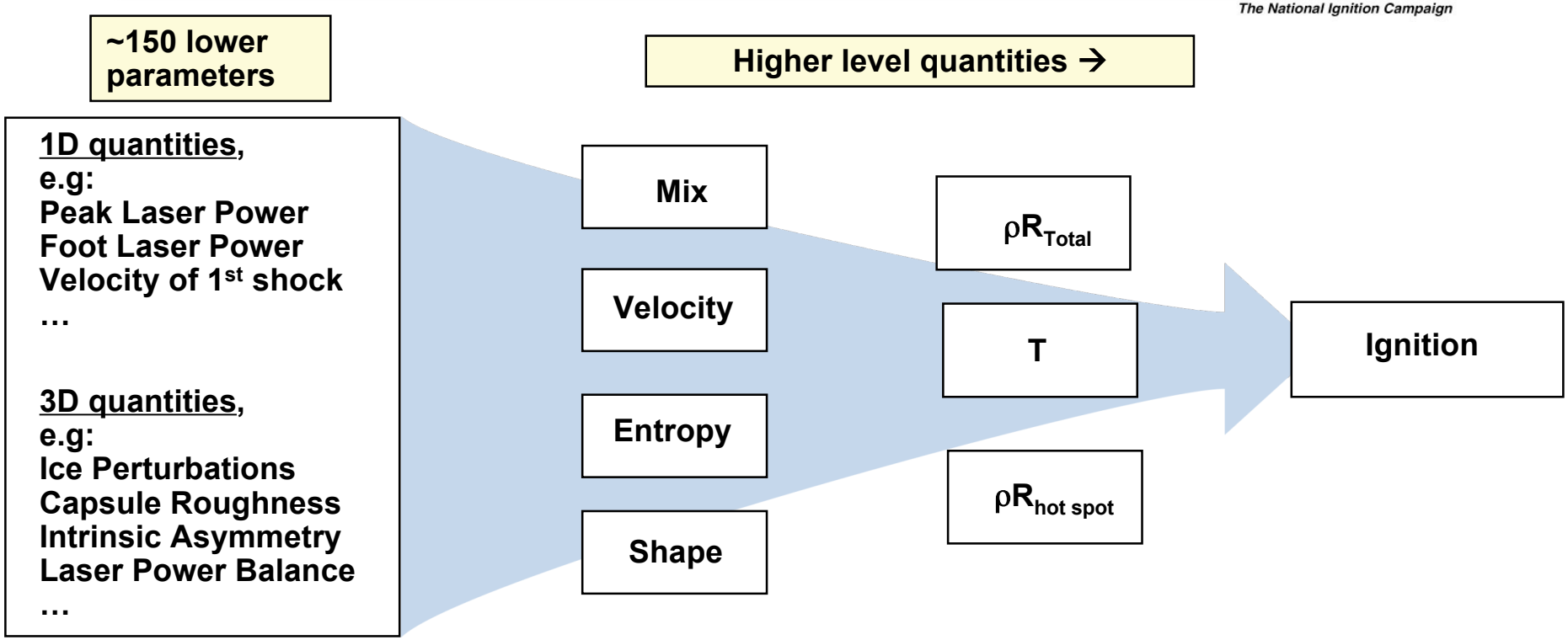
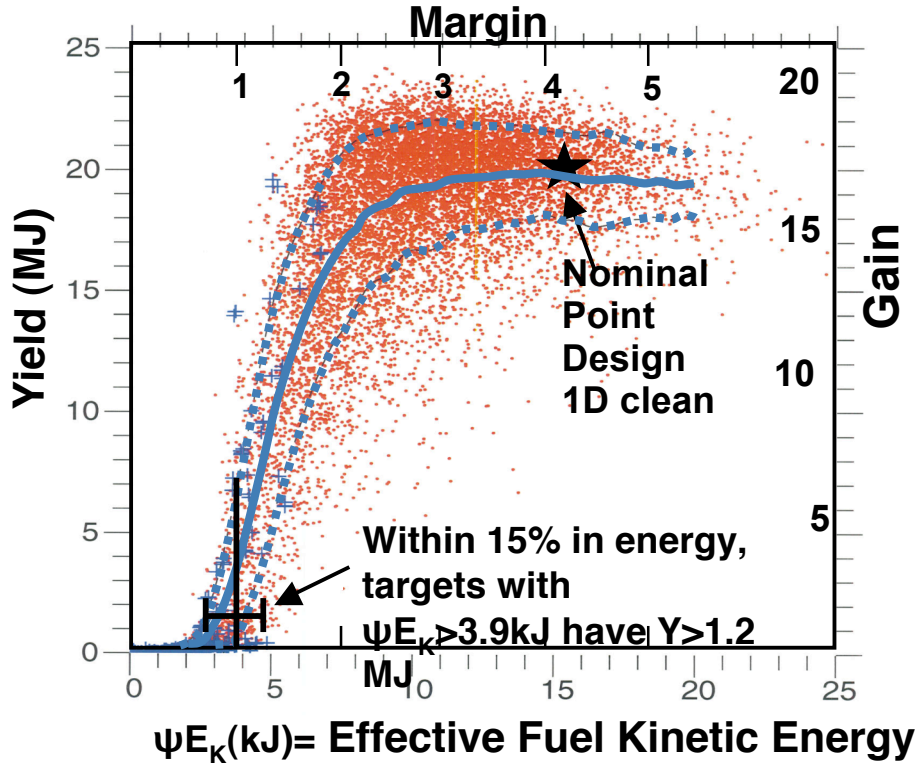


We can adjust or constrain the lower level parameters to affect the higher level parameters

Multivariable Sensitivity Studies of the 1D and 3D quantities allow us to specify acceptable values and reproducibility

We can define a Margin based on Mix Velocity Entropy Shape that correlates with the likelihood of ignition

- The Margin formula is based on a fit to a data-base of 1D and 2D calculations



$$Margin = \frac{E_{fuel}}{3.9kJ} * \psi = \frac{E_{fuel}}{3.9kJ}\left(\frac{<v>}{365km/\sec}\right)^{5.9}\left(\frac{<\alpha>}{1.46}\right)^{-3.9}\left(1-\frac{\Delta R_{hotspot}}{R_{hotspot}}\right)^{3.5}\left(1-\left[\frac{0.5\Delta R_{mix}}{\Delta R_{shell}}\right]\right)$$

Velocity Entropy Shape Mix

Success of ignition is crucially dependent on Mix, Velocity, Entropy and Shape ("MVSS")

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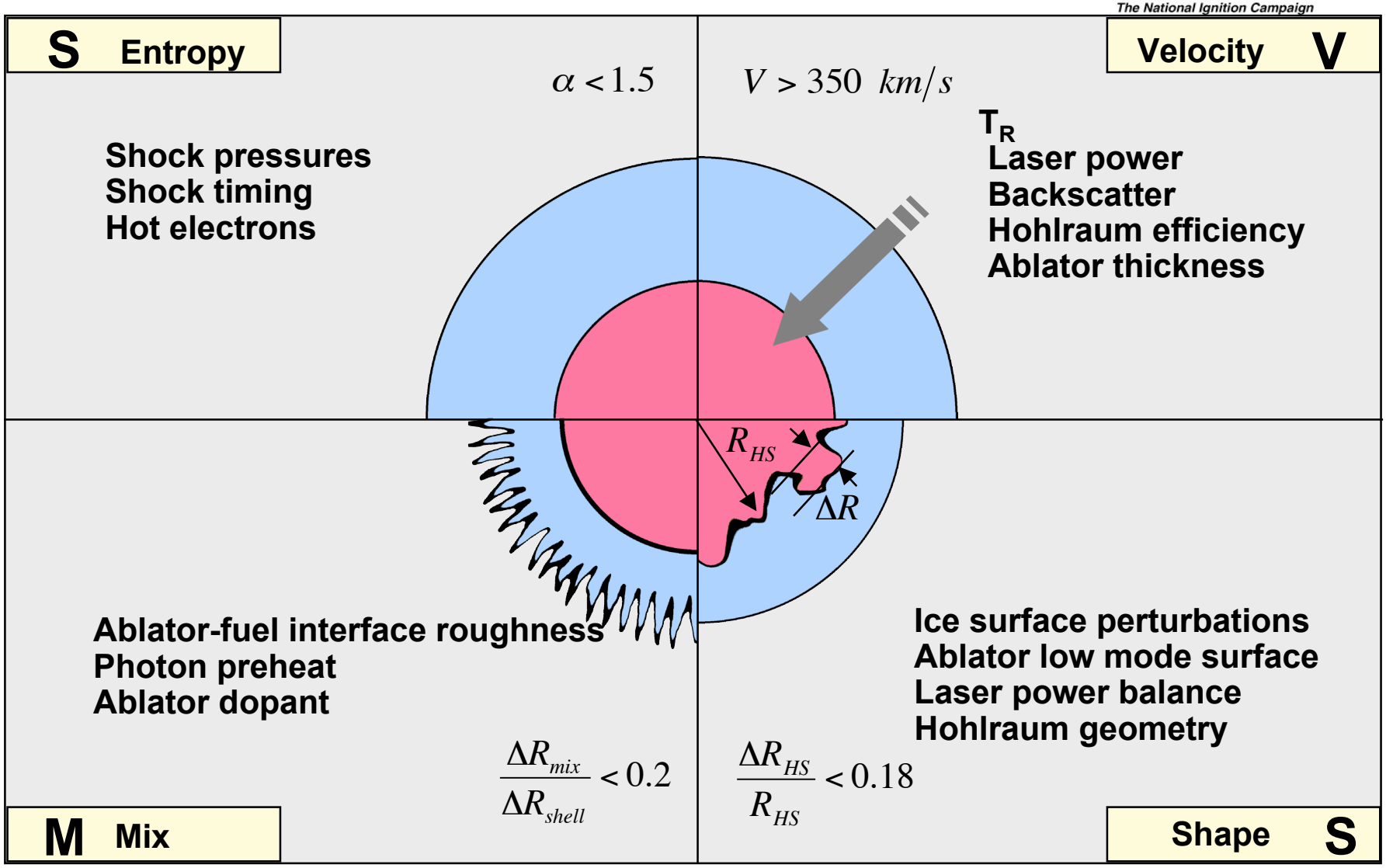

Targets must be made to tight tolerances so MVSS requirements can be met reproducibly

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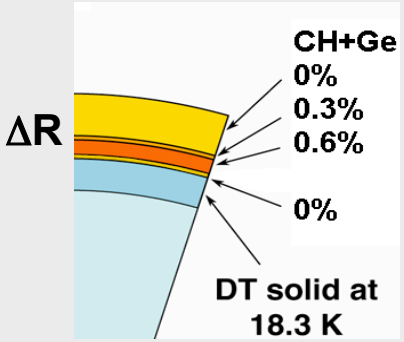
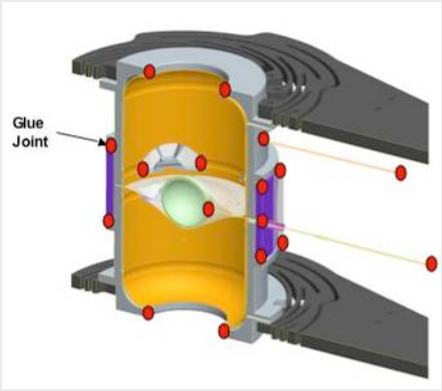
S Entropy

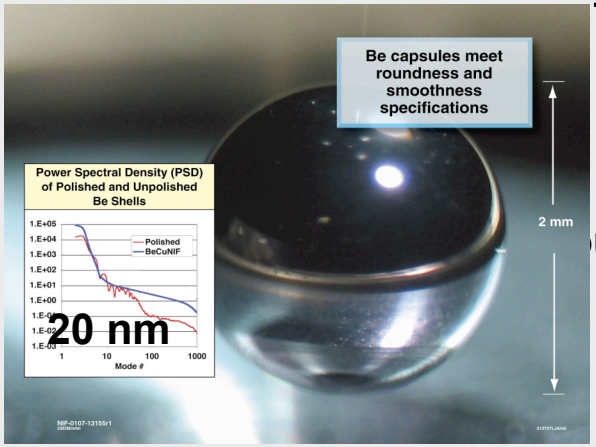
Ablator thickness
Fuel layer thickness
Contaminant reproducibility



Velocity V

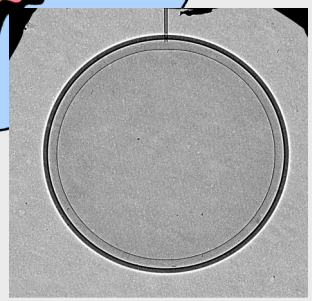
Ablator thickness
Contaminant reproducibility

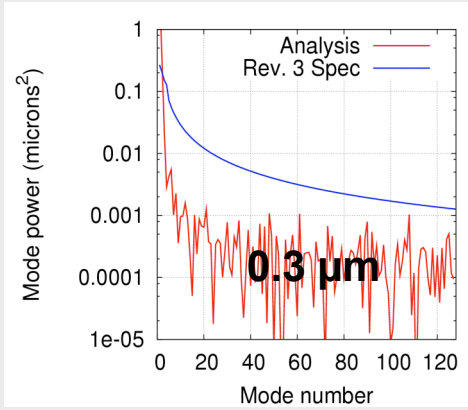




ughness

Capsule roughness
Dopant layer



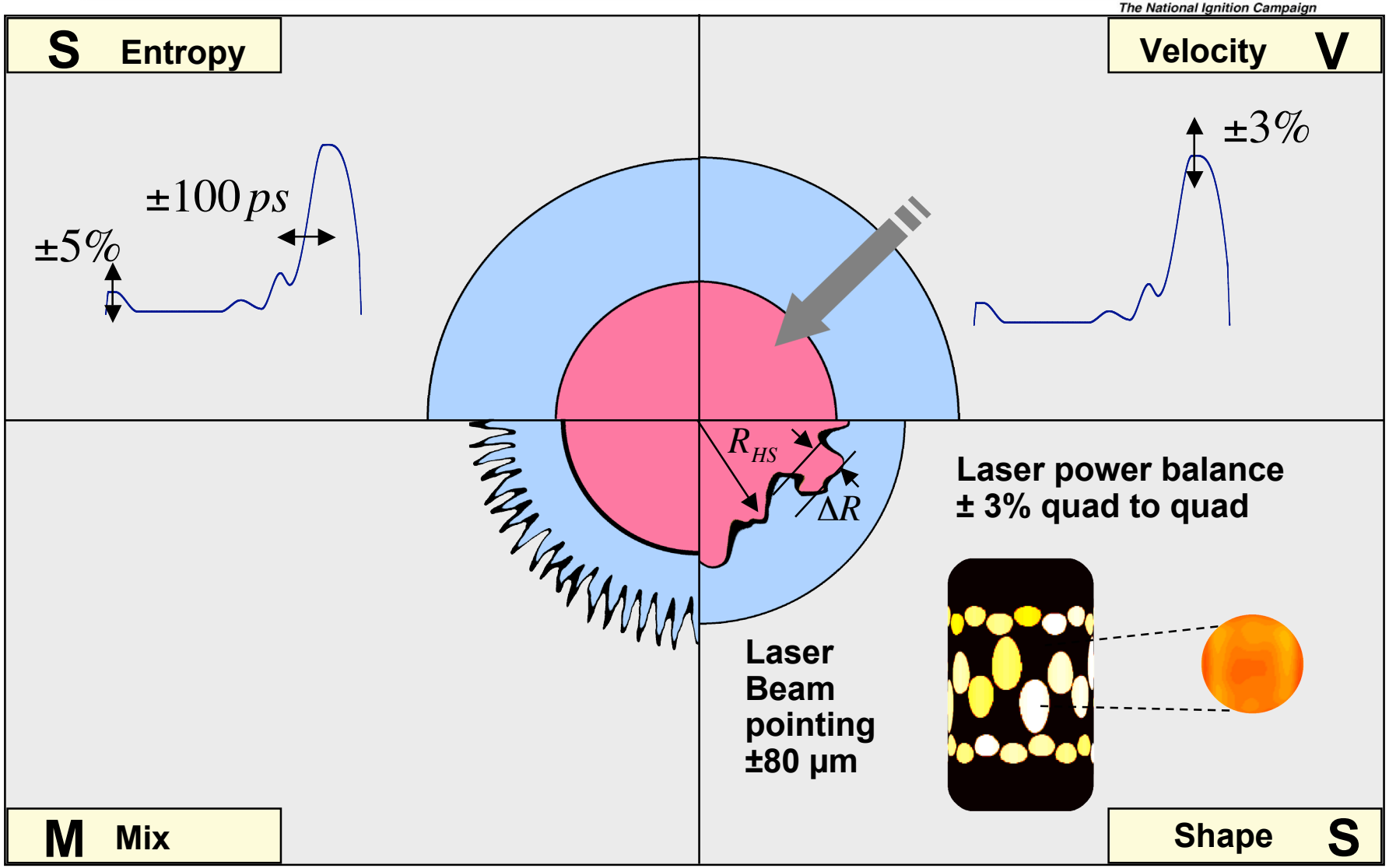


Ice perturbations Hohlraum assembly Capsule location

M Mix

Shape S

The laser must perform reproducibly to meet requirements



To compensate for physics uncertainties the laser and target parameters must be experimentally tuned

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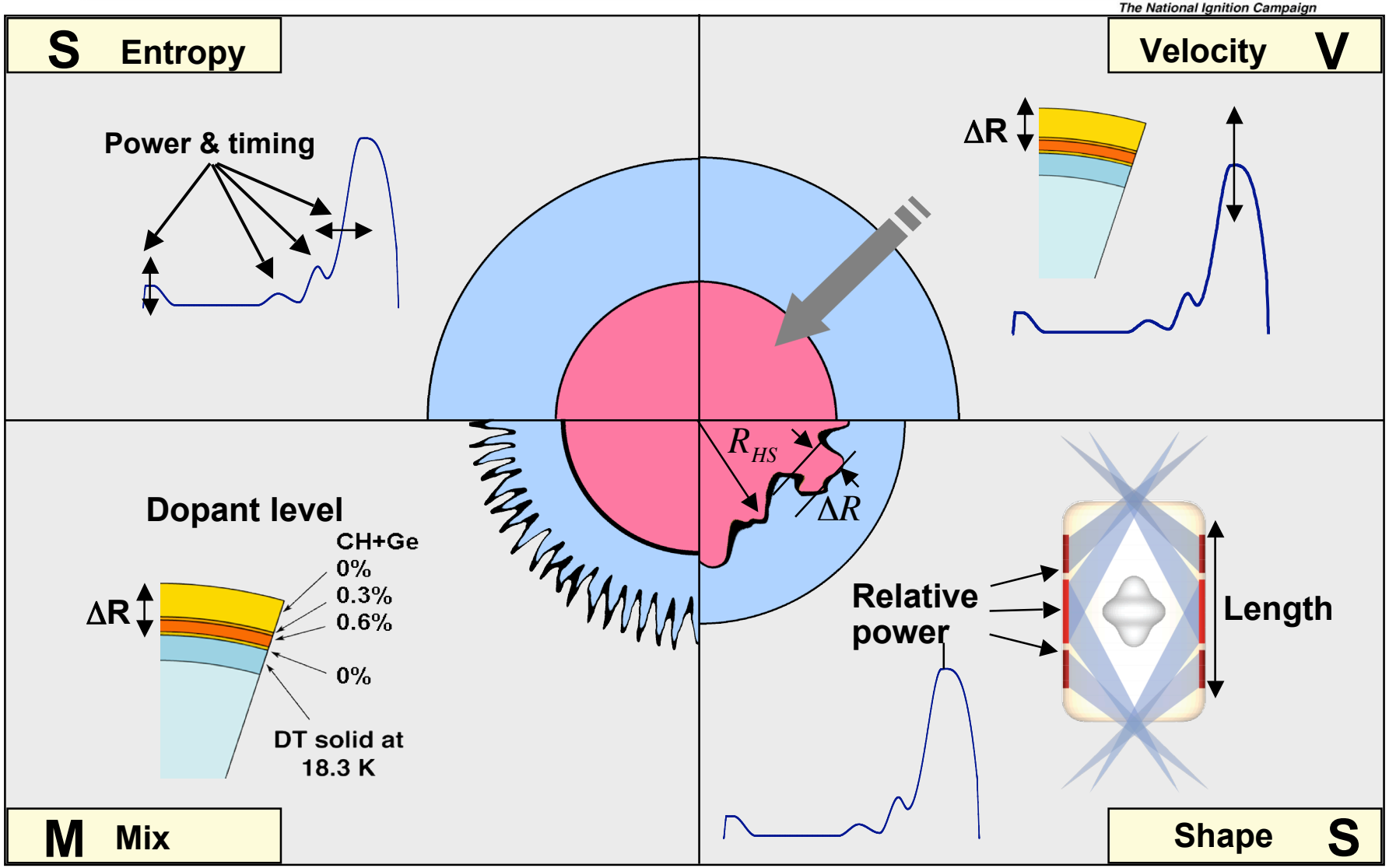

MVSS is adjusted using an array of measurement techniques using 6 surrogate targets and different diagnostics

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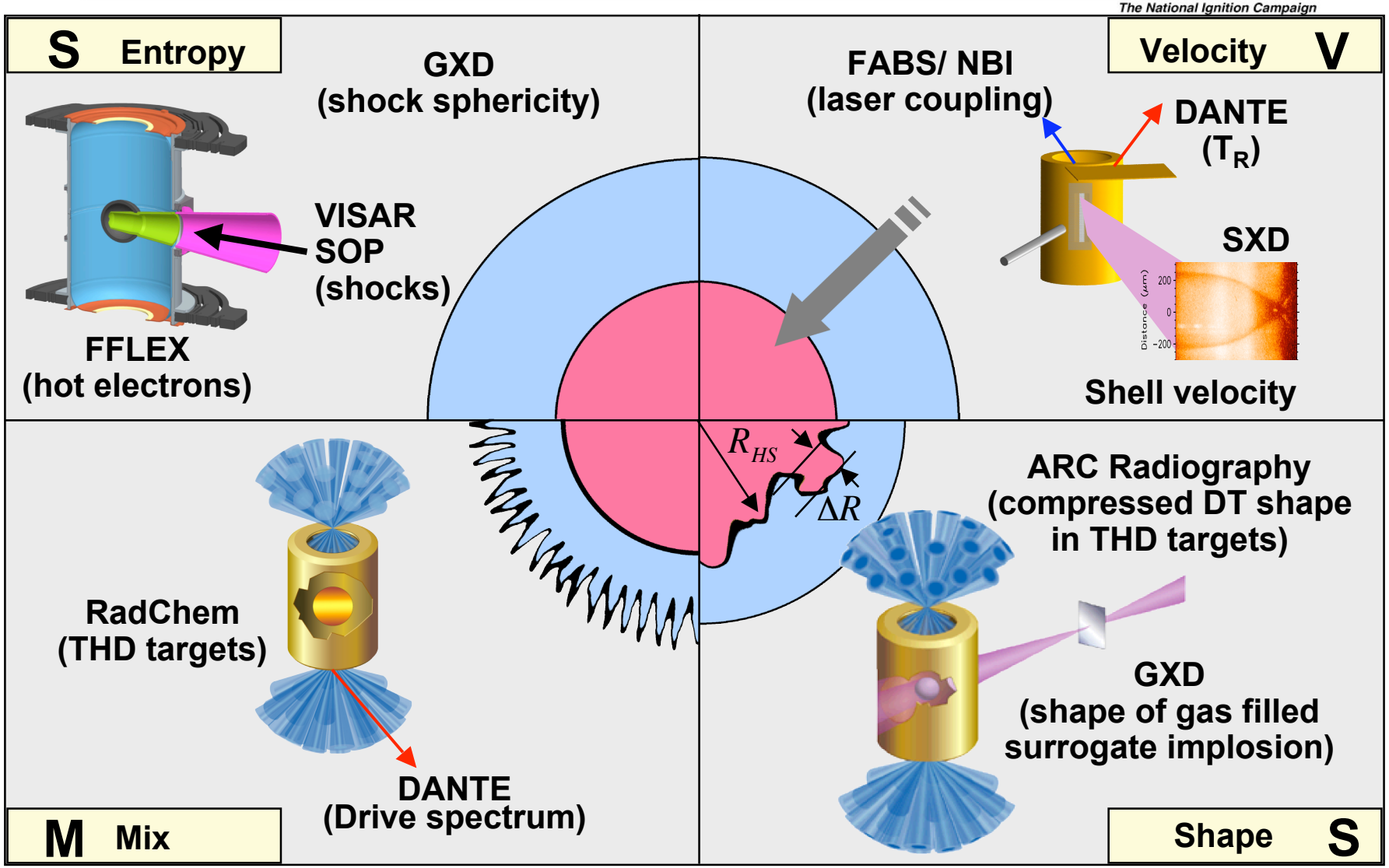

Our ignition campaign is focused towards DT implosions in 2010

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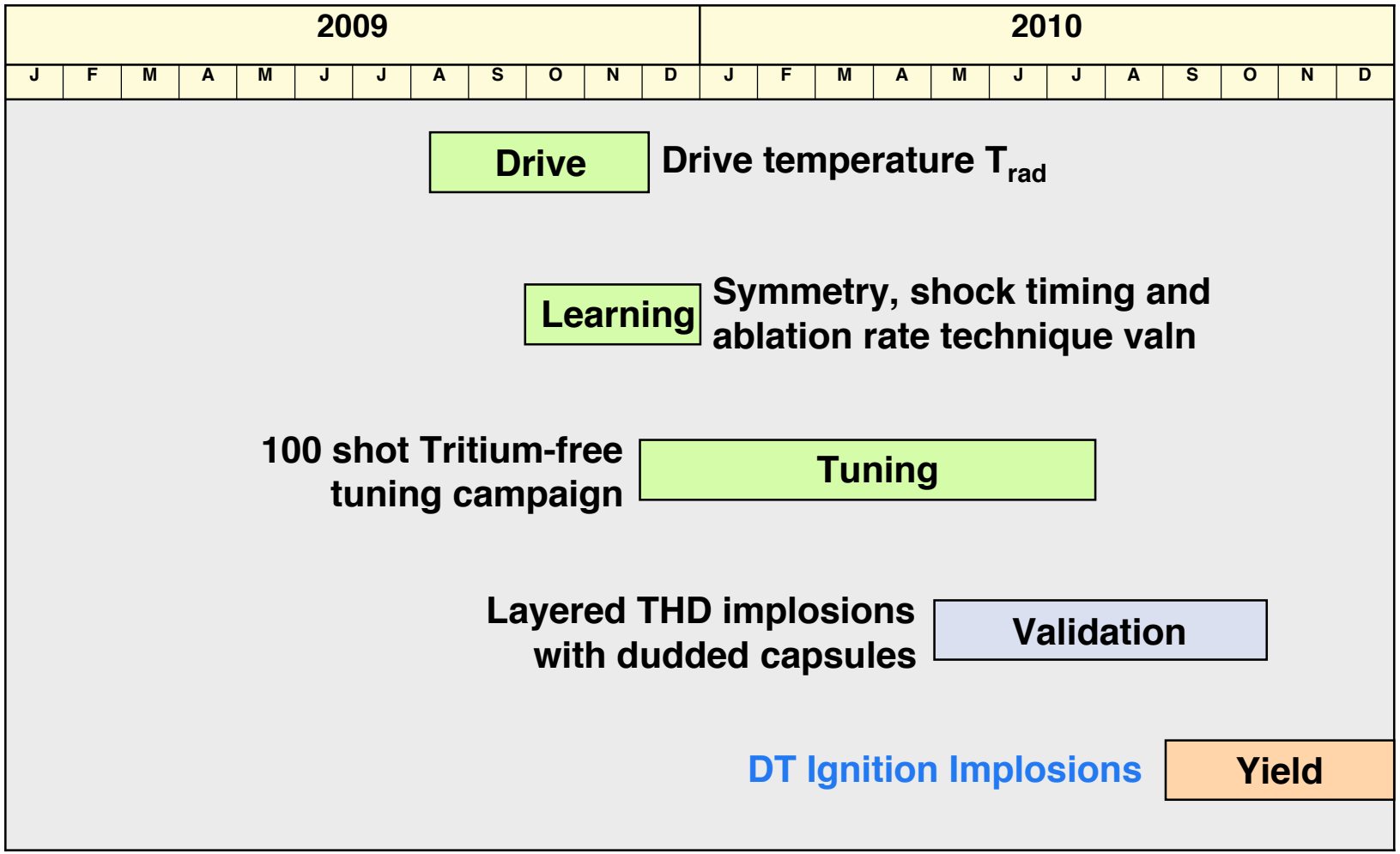

The National Ignition Campaign must bring together all of the components for the first ignition experiments

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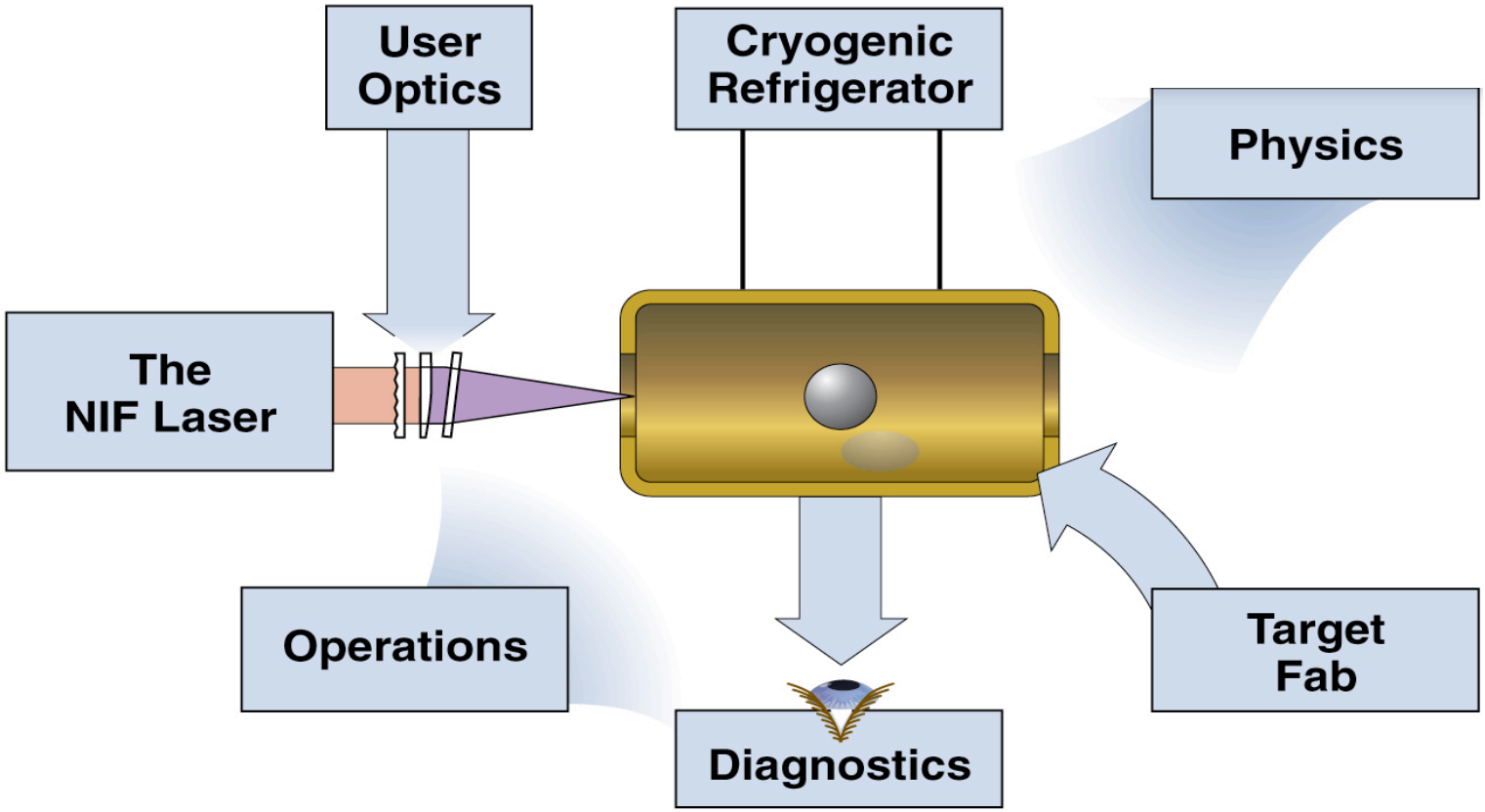

We are using simulated campaigns to test our strategy

Ignition experiments require management and coordination of complex processes

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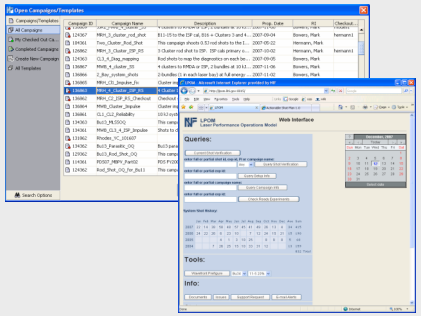
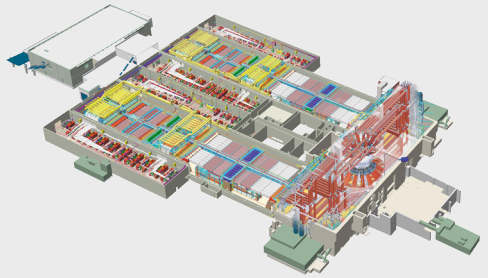
Campaign Management

- Shot plan Requirements
- Decisions

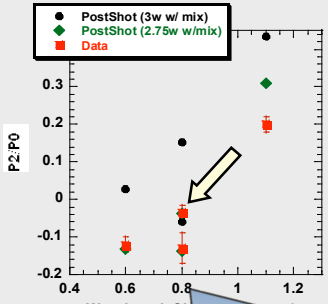
Campaign Management Tool



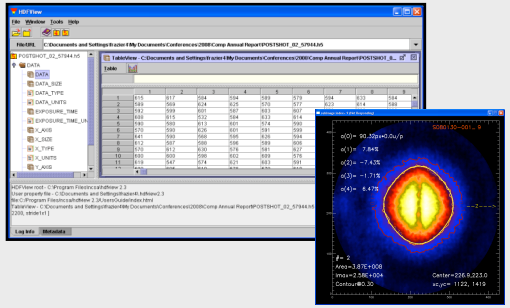
Facility prepares & executes shot



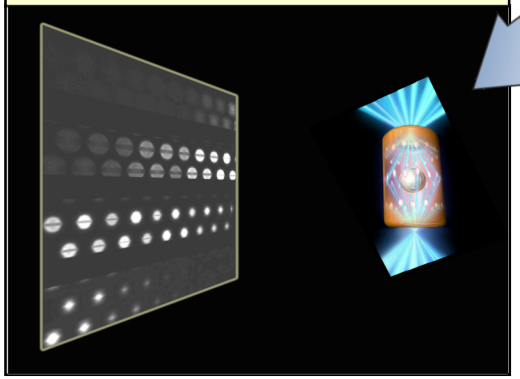
Shot Data Analysis



Archiving & visualization



Laser - target interaction & outputs



To test our experimental strategy and to improve our readiness, we carried out a simulated campaign (SimCam)

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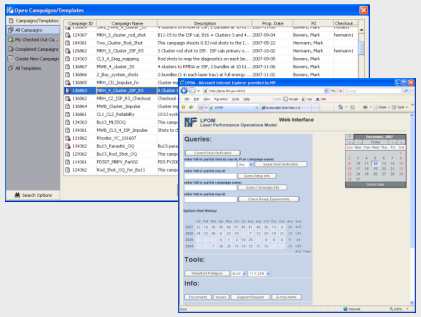
Campaign Management

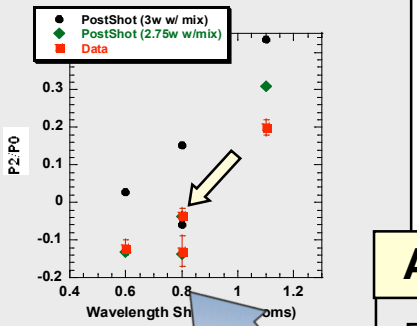
- Shot plan Requirements
- Decisions

Campaign Management Tool

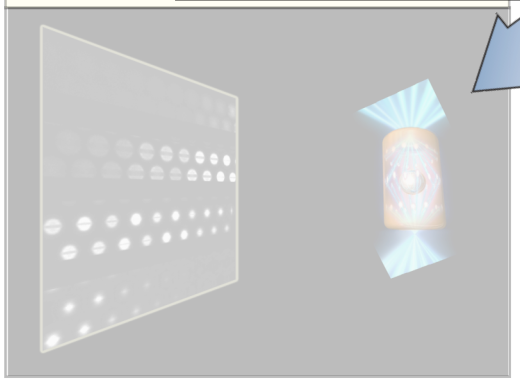


Facility prepares & executes shot

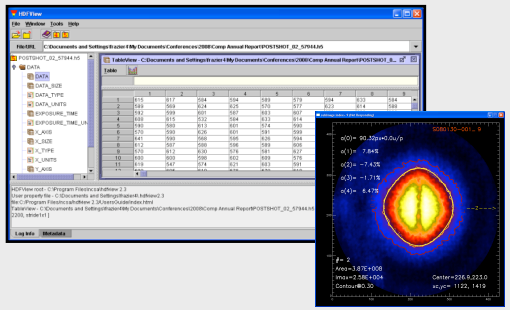
Shot Data Analysis



Numerical modeling is used to simulate facility & target performance



Archiving & visualization



The SimCam exercises the real preparation & decision making processes but simulates the facility & target performance

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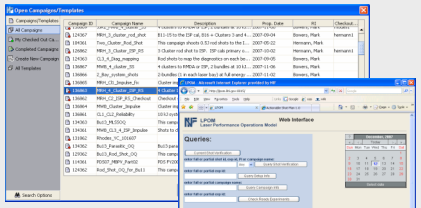
Campaign Management

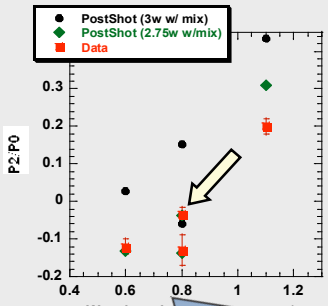
- Shot plan
- Requirements
- Decisions
- Targets

Campaign Management Tool

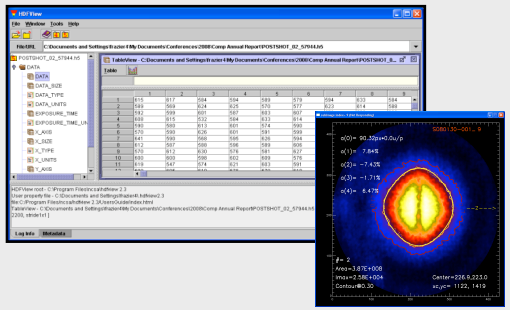


Blue Team

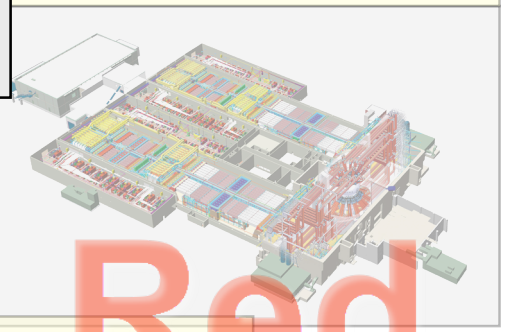
Shot Data Analysis



Archiving & visualization

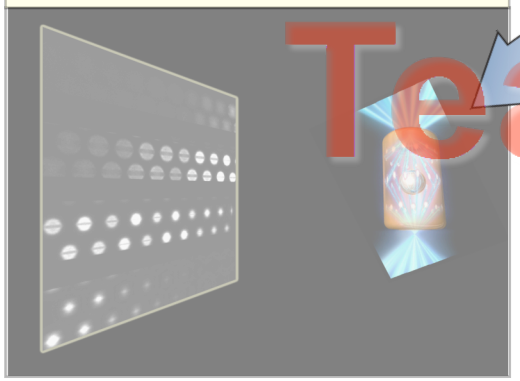


y prepares & executes shot



Red Team

Laser - target interaction & outputs



The Red Team developed an alternate 2D target physics reality based on model uncertainties

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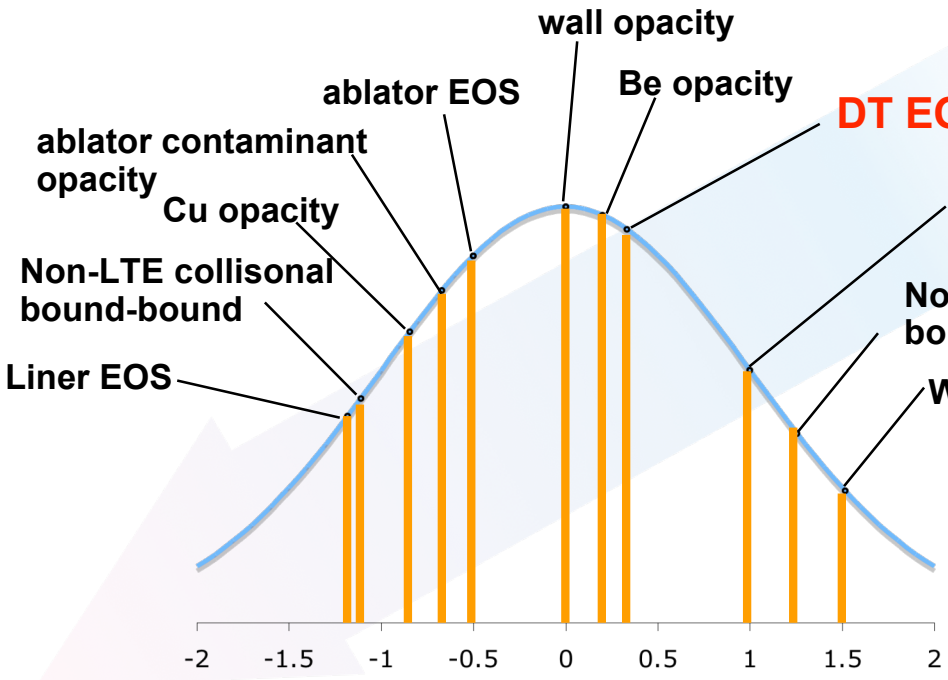
Red Team Physics



Blue Team Model

A roll of the dice determined the model "off-set" compared to the standard (blue team) model

Red Team Model

- Typical model uncertainties are 10-20%
- Non-LTE collision rates & electron flux limiter are factor 2

The target failed to ignite after the red team physics was introduced & before retuning

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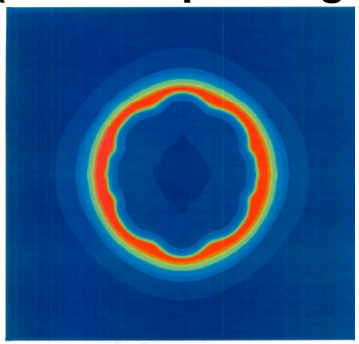
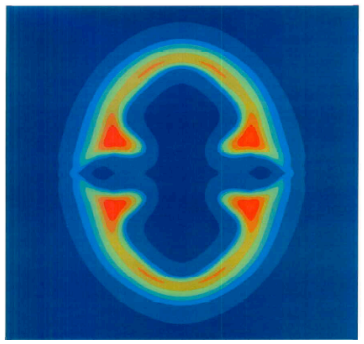
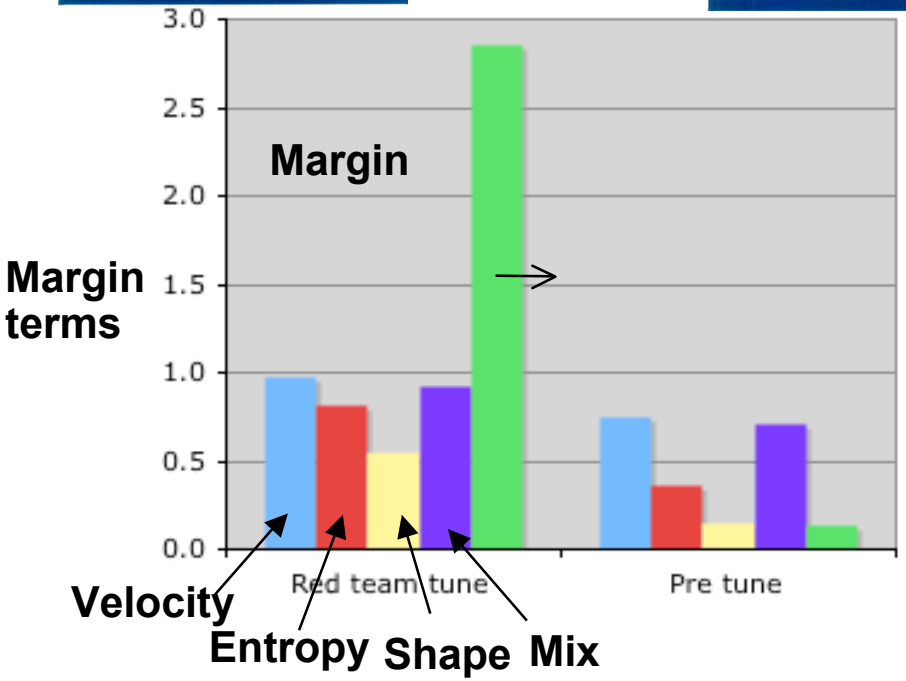
Blue team physics (nominal pt design)

Red team physics (before tuning)







The red team was able to re-optimize the ignition target performance using the new physics model using about 10% higher inner cone power

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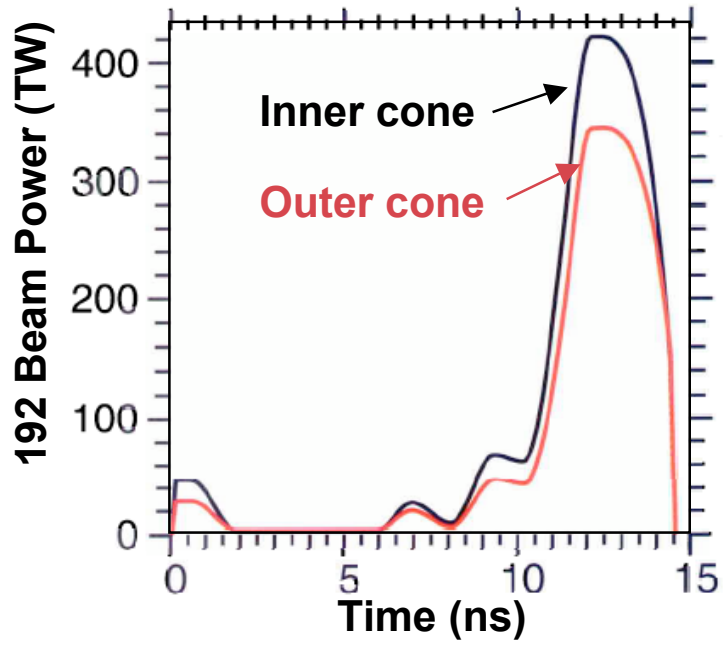
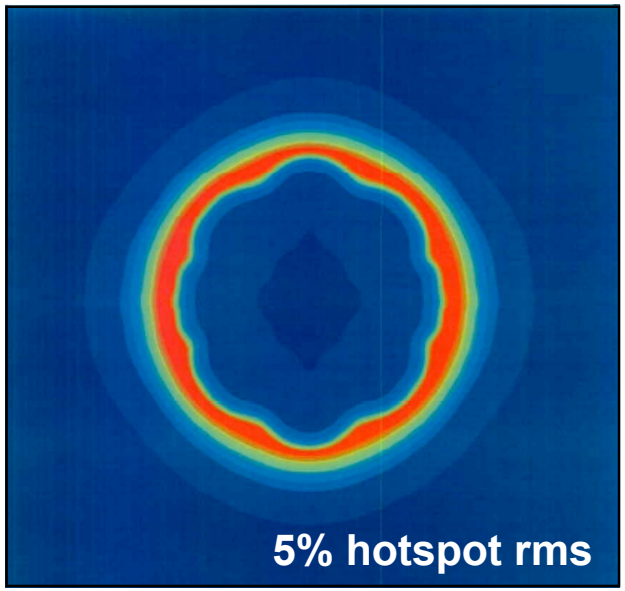
Laser Power Required with Alternate Model

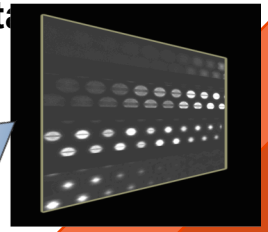


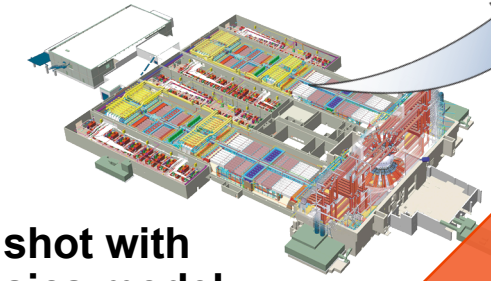


Changes in plasma conditions resulting from the red team model would imply a few percent more scatter

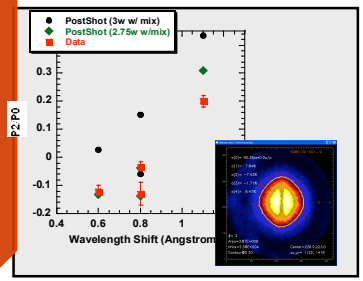
Red Team

Add errors to synthetic data





Simulate the shot with red team physics model



Data Analysis

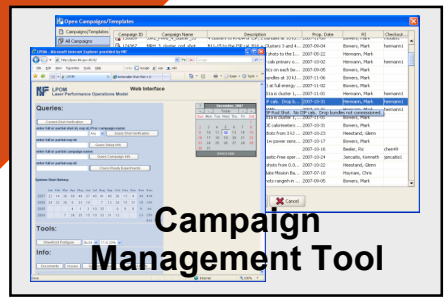
Shot request
Laser pulse
Target ID
Diagnostics

Decision making

Shot request
Laser pulse
Target ID
Diagnostics

Blue Team

Shot set-up



Campaign Management Tool

Target errors
Laser power imbalance
Random backscatter
Cross beam transfer

The Blue Team achieved the required precision using its scaling predictions and expected diagnostics without knowledge of the source of observed discrepancies

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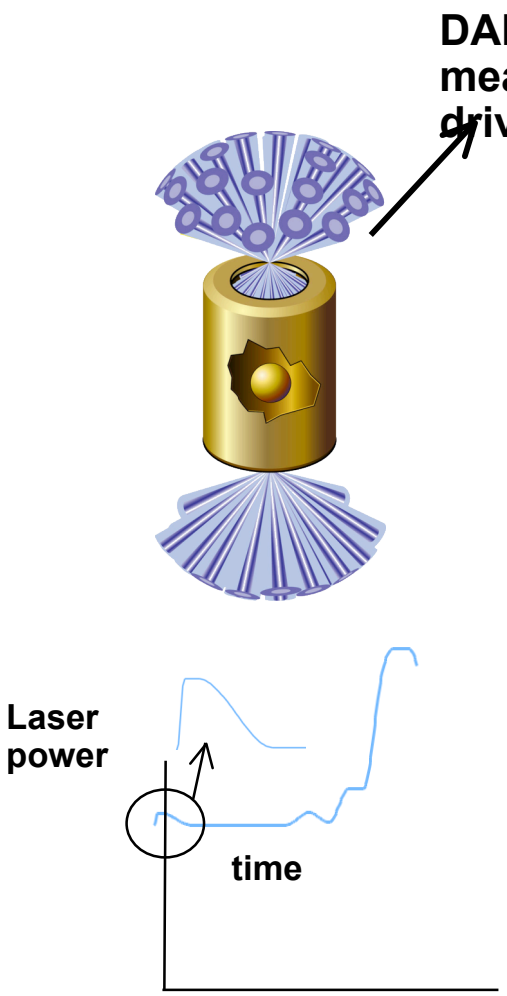
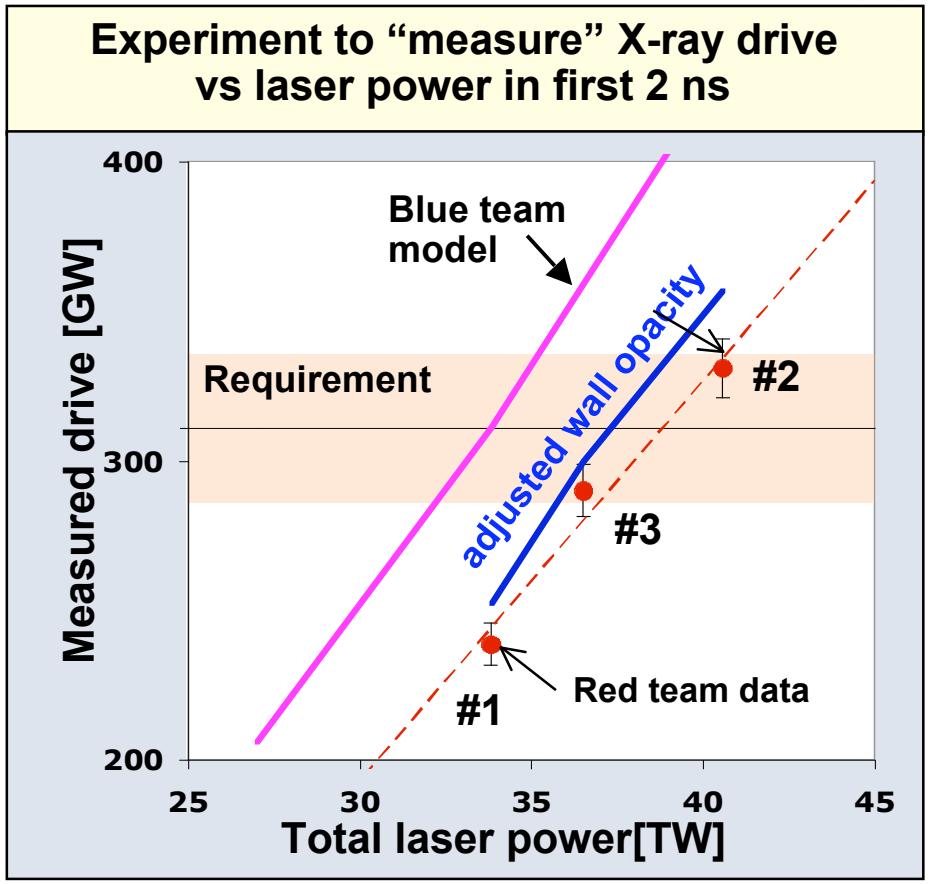
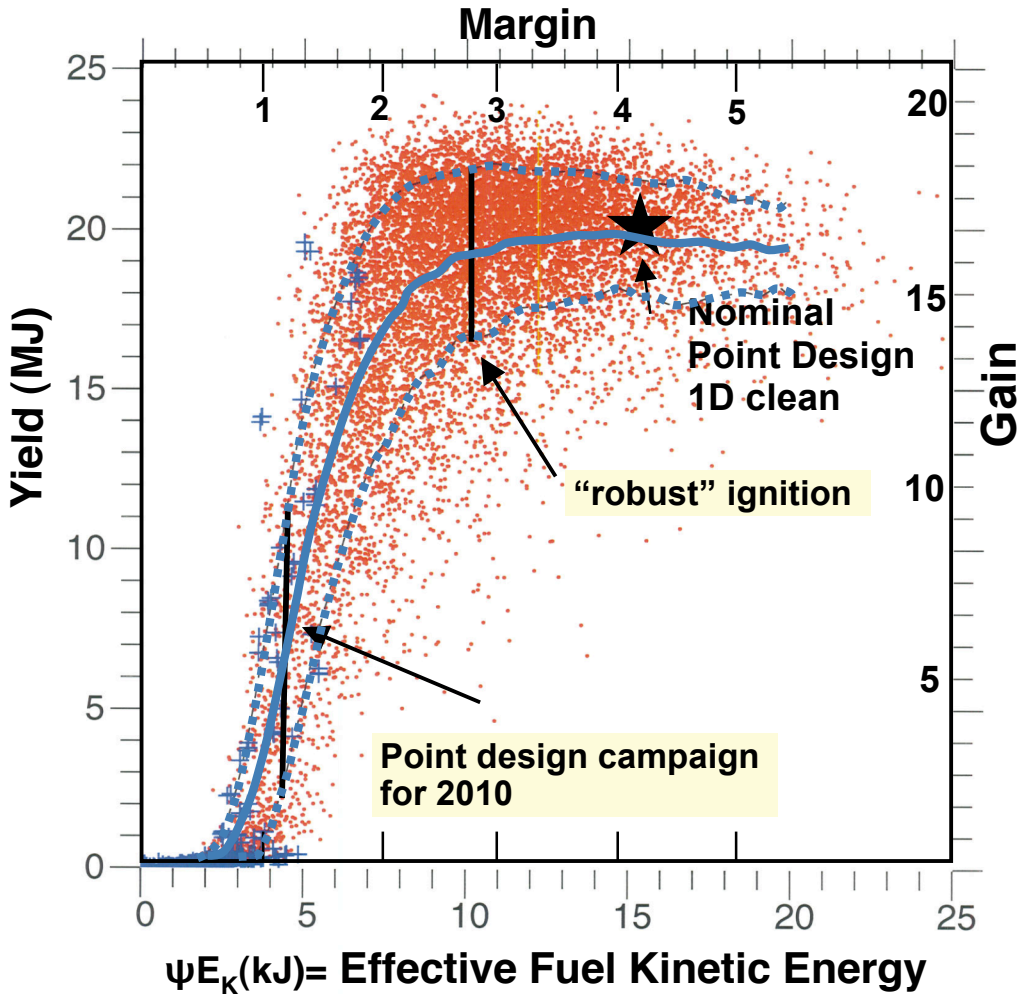
The National Ignition Campaign





The blue team succeeded in "tuning" symmetry and shock timing in a similar way

The goal for 2011-12 is to achieve a "robust" ignition platform



Several paths can take us to a robust ignition platform:

- **Improve the precision of the experimental campaign**
- **Reduce the statistical variability of the targets and laser performance**
- **Increase the capsule absorbed energy using:**
  - more laser energy
  - optimized coupling efficiency, e.g larger capsule in a fixed hohlraum

We have a clearly defined path forward to achievement of ignition on NIF

NIC
The National Ignition Campaign

- An extensive scientific data base forms the foundation for the NIF ignition point design target and experimental campaign
- We have requirements in place for the first ignition attempt in 2010
- A margin formalism allows us to evaluate the performance of the targets, and to assess and manage risk
- A copper-doped Be capsule driven at 285 eV is sufficiently robust to achieve yields>1 MJ (an ignition margin >1) with the expected precision of target experiments, laser performance, and target fabrication
- A simulated ignition campaign has verified our ability to achieve the required precision in the presence of physics uncertainties
- After the first ignition campaign, we have several paths forward to develop a robust ignition platform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