Empowering Physics Experiments: The Vital Role of Simulations at SLAC

OZENCON

February 22, 2024

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SLAC NATIONAL ACCELERATOR LABORATORY

The Crucial Role of Simulations at SLAC

- Simulations provide a critical tool for decision-making based on a synergistic combination of models and data.

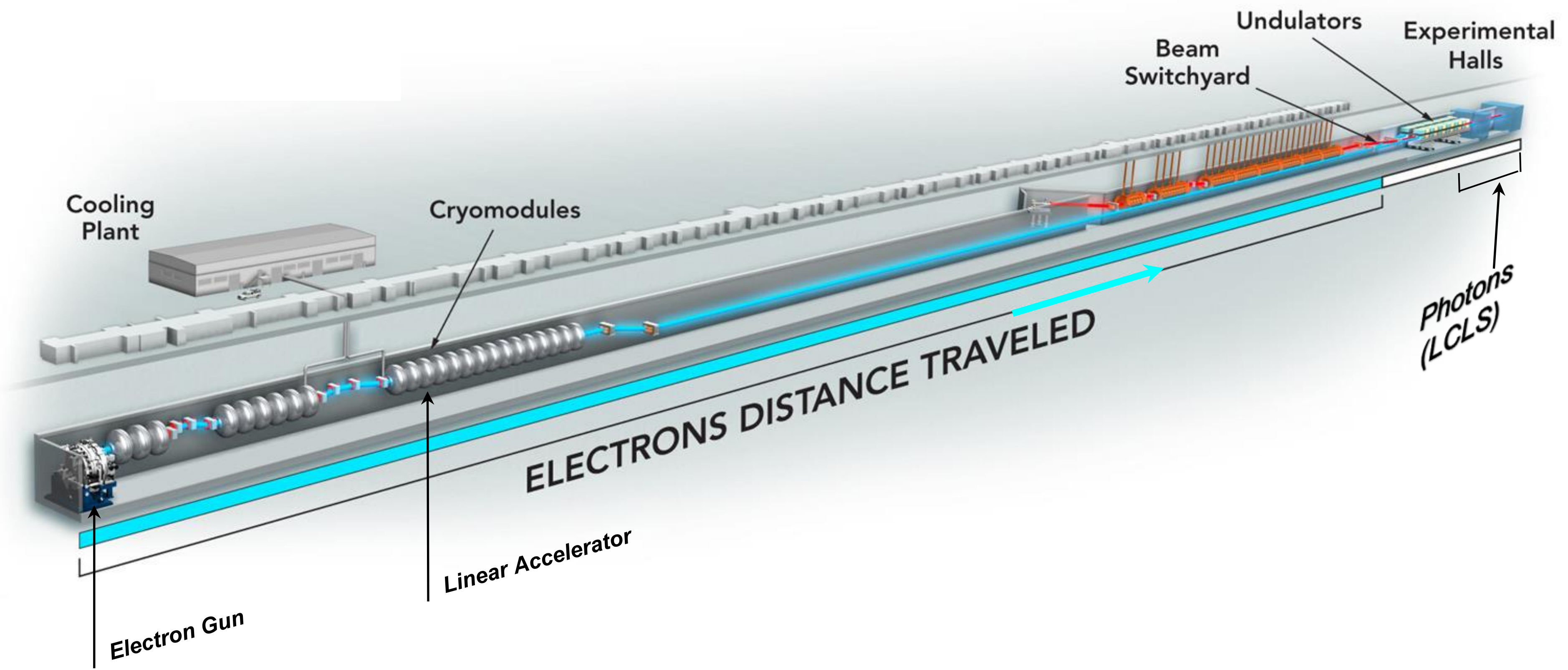
Predictive Modeling

Parameter Exploration

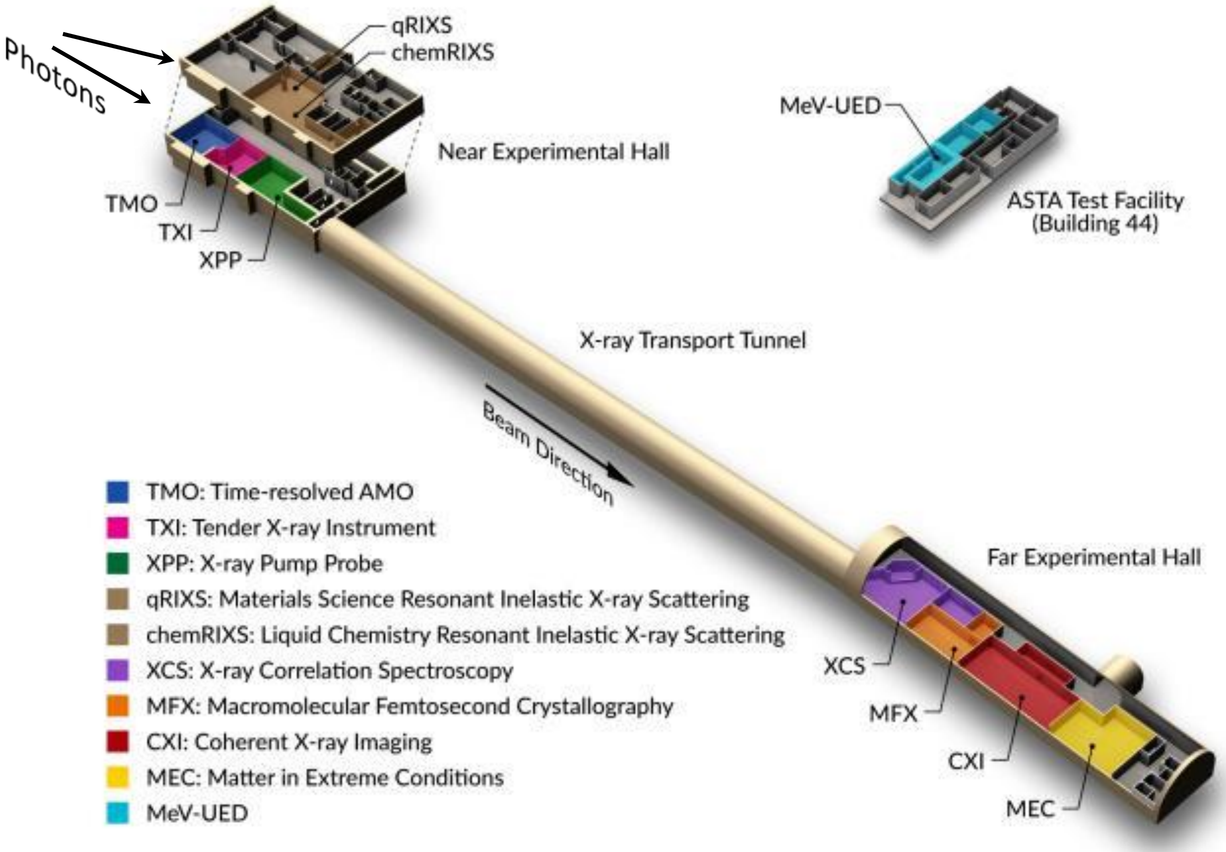
Virtual Prototyping

- Simulations hold immense promise in accelerating scientific discoveries at SLAC.

SLAC Engineering Layout (LCLS-II)

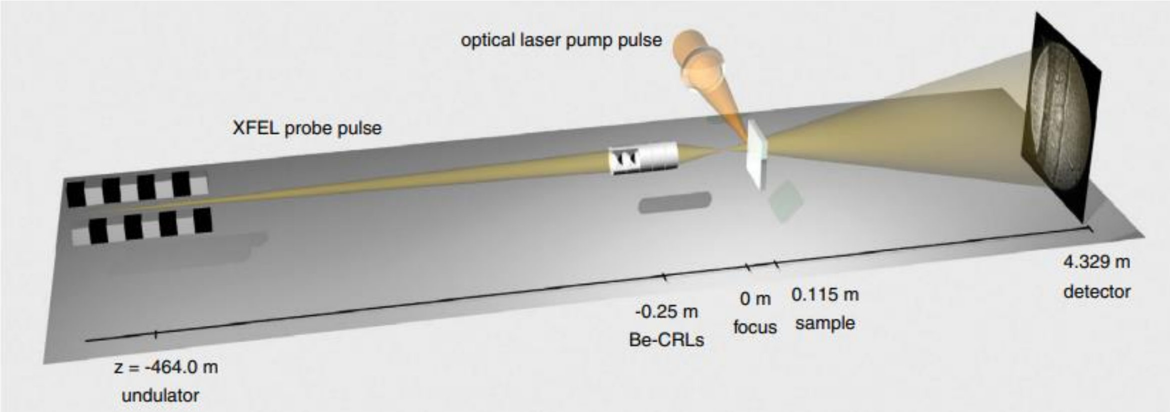


Linac Coherent Light Source (LCLS)



Matter in Extreme Condition (MEC) Pump and Probe Experiments at LCLS

- LCLS takes X-ray snapshots of atoms and molecules at work, providing atomic resolution detail on ultrafast timescales to reveal fundamental processes in materials, technology and living things.
- Imaging shock wave propagation in material (MEC Hutch)



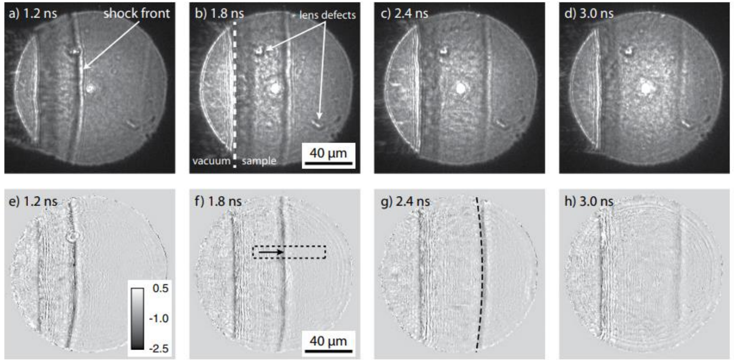
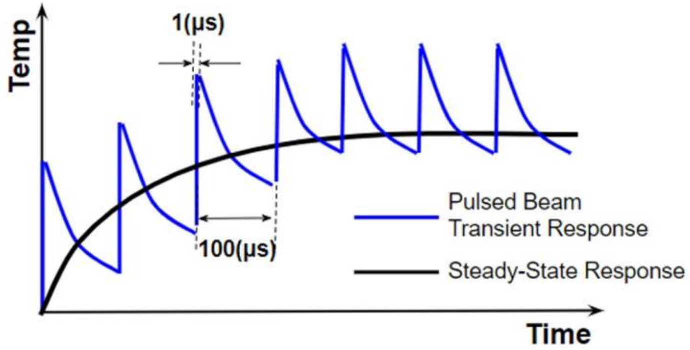


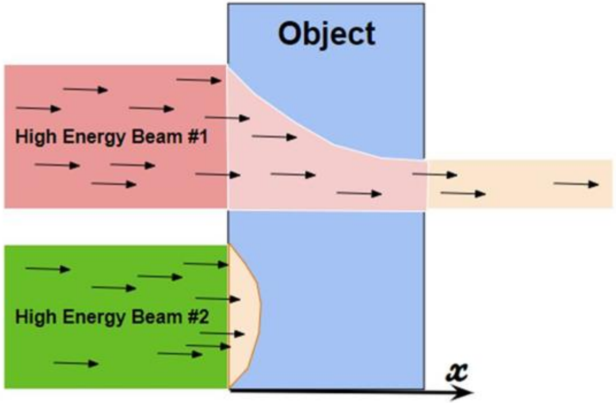
Figure 2. (**a–d**) Phase-contrast images measured with a high-resolution x-ray detector at a distance of 4214 mm behind the sample. Specific time delays are indicated in each image. (**e–h**) Corresponding phase maps obtained by iterative phase retrieval from the images above. In order to enhance the visibility of shock-related features, the phase map obtained from just the sample without shock wave was subtracted from the phase map with shock wave. Gray values indicate the phase shift in radians [cf. inset in Fig. e)]. In Fig. f) a rectangular box highlights the area used to quantitatively determine the compression of the material.

[Nature Journal Publication Link](#)

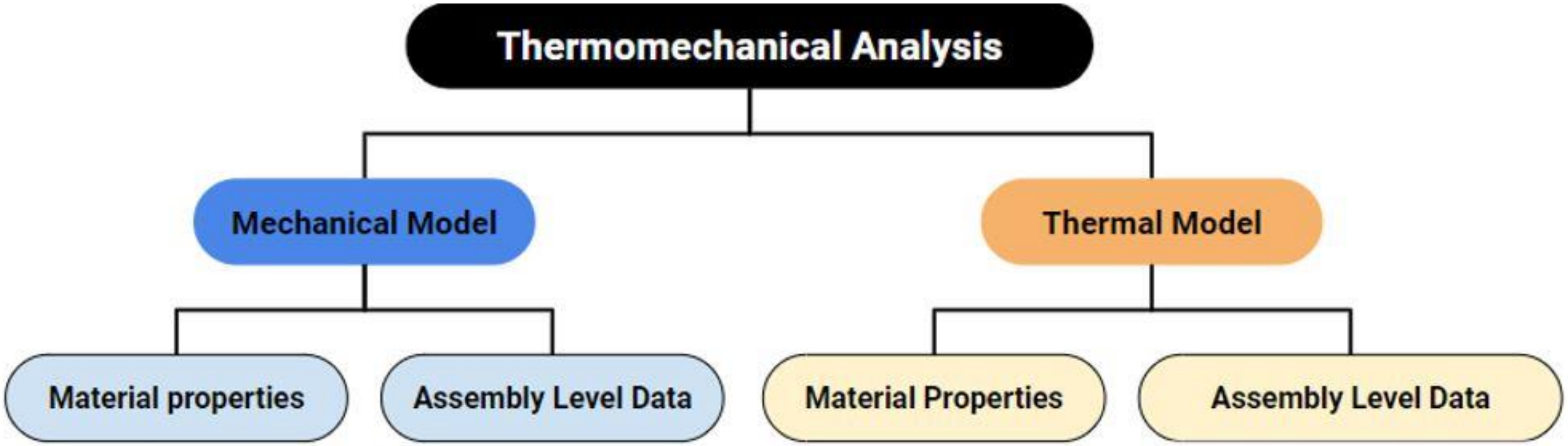
Beam intercepting devices subjected to high energy high rep rate photon beams

- High-energy particles possess the capability to penetrate materials and deposit energy within them.
- The degree of absorption depends on both the energy and type of particles, as well as the properties of the materials with which they interact.
- This energy deposition can manifest either at the material's surface or throughout its volume, potentially resulting in various failure modes.





Beam intercepting devices subjected to high energy high rep rate photon beams



Mechanical Model – Material properties

- Young Modulus*
- Poisson's ratio*
- Density*
- (Plasticity*)
- (Damage*)

Mechanical Model – Assembly Level Data

- Interaction definition (Contact, Tie, etc.)
- Mechanical boundary condition
- Mechanical loading condition

Thermal Model – Material Properties

- Thermal conductivity*
- Thermal expansion*
- Specific heat* (transient)

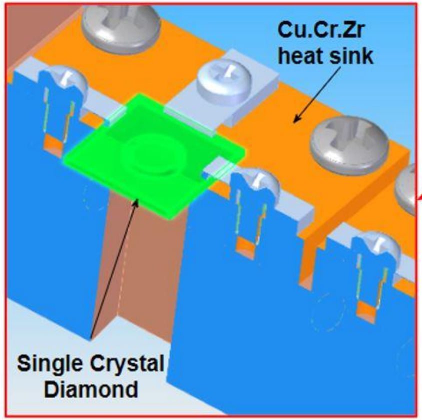
Thermal Model – Assembly Level Data

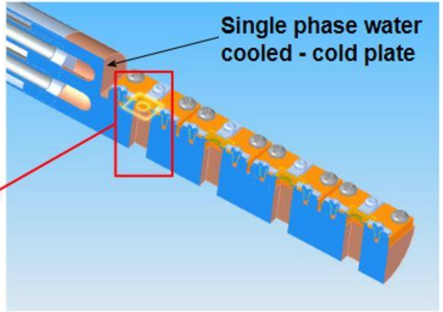
- Interaction definition (Thermal Contact)
- Thermal boundary condition
  - Fixed temp
  - Convection/Radiation etc.
- Thermal loading condition
  - Surface heat flux
  - Body heat flux
  - Concentrated heat flux

****To adequately address the range of expected temperatures, properties should exhibit temperature dependence.***

Beam intercepting devices subjected to high energy high rep rate photon beams

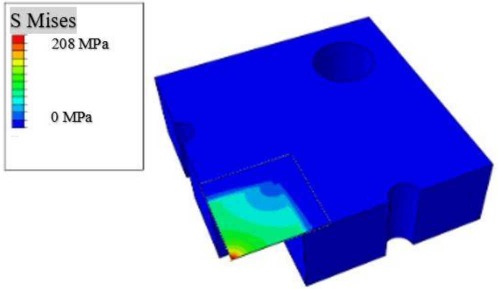
SLAC





Results summary for 100 (um) Crystal

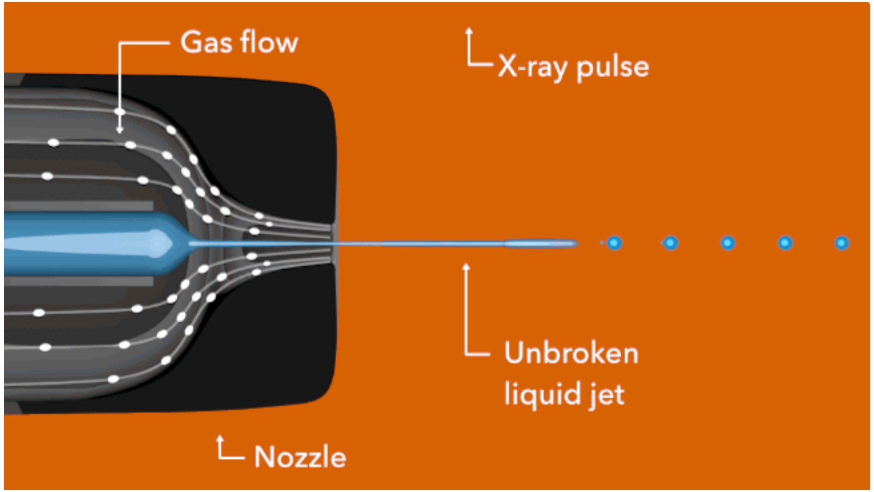
- Max Temp beneath the beam
- Max von Mises Stress beneath the beam
- Safety factor = 1000(MPa)/von Mises

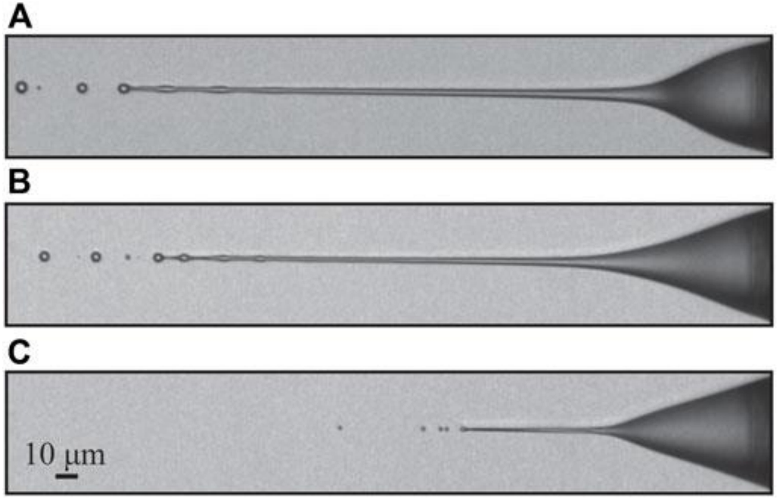


6KeV Unfocused	Incident (Absorbed) Average Power (W)	400 (30)
	Max Temp (C)	115
	Stress Under the Beam (MPa)	208
	Safety factor	4.81
9 KeV Unfocused	Incident (Absorbed) Average Power (W)	400 (9.6)
	Max Temp (C)	49
	Stress Under the Beam (MPa)	53
	Safety factor	18.87
12 KeV Unfocused	Incident (Absorbed) Average Power (W)	400 (4.2)
	Max Temp (C)	34
	Stress Under the Beam (MPa)	21.8
	Safety factor	45.87
20 KeV Unfocused	Incident (Absorbed) Average Power (W)	400 (1.2)
	Max Temp (C)	24
	Stress Under the Beam (MPa)	6.8
	Safety factor	147.06

LCLS Microfluidic Sample Delivery

Gas Dynamic Virtual Nozzle

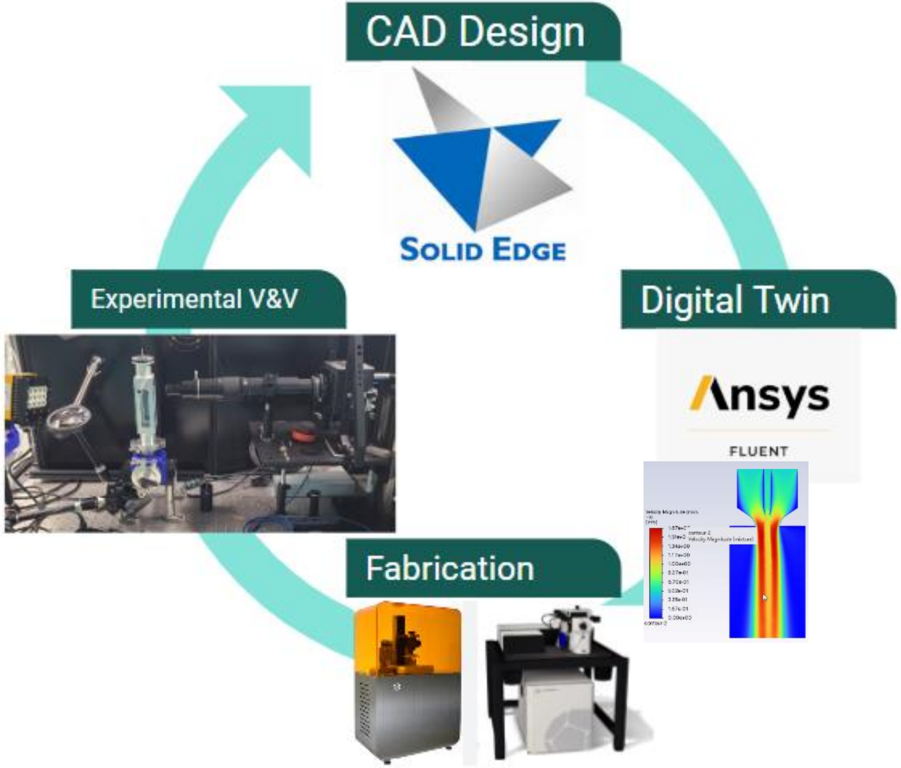




https://www.frontiersin.org/articles/10.3389/fmolb.2023.1006733/full

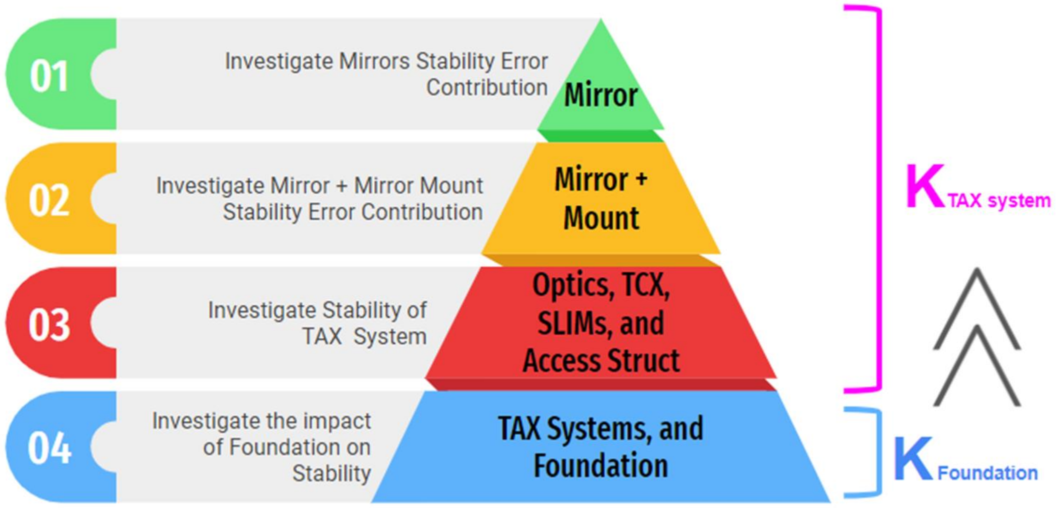
LCLS Microfluidic Sample Delivery

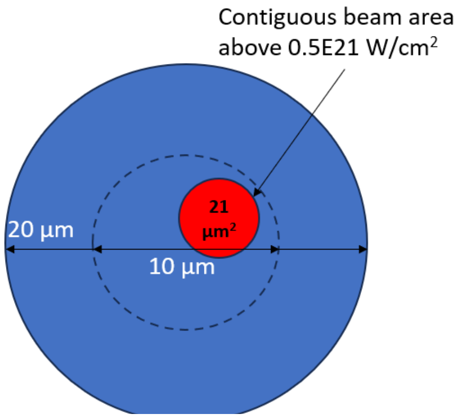
Simulation-driven Manufacturing and Experimentation



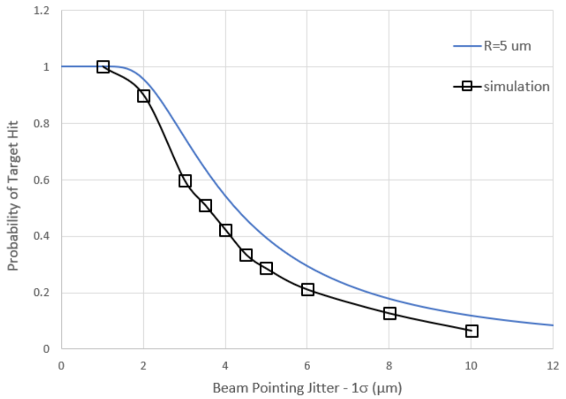
Structural Engineering to Maximize Stability for Experimental Systems

- Design for stability is critical for increasing the rate of success in our physics experiments.
- Thermal or Random vibration jitter sources must be studied and addressed at the design level



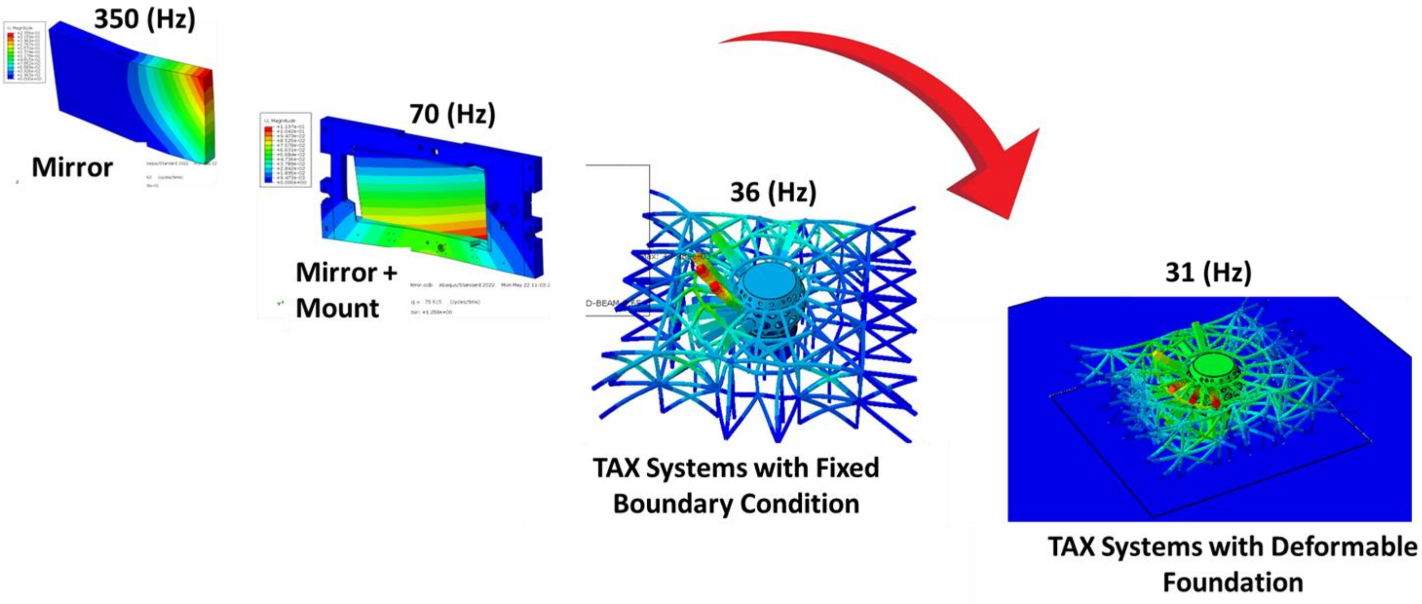


Target hit success rate vs. beam + target jitter

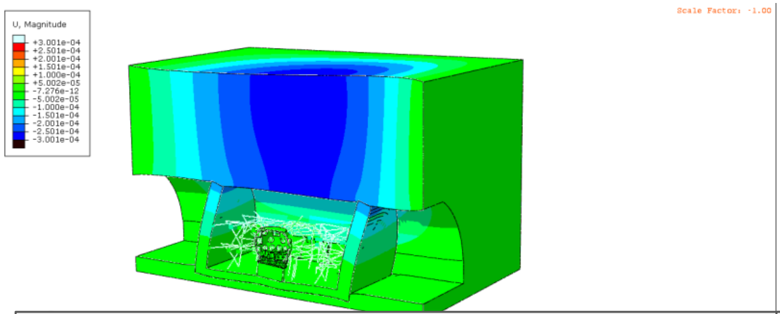


Structural Engineering to Maximize Stability for Experimental Systems

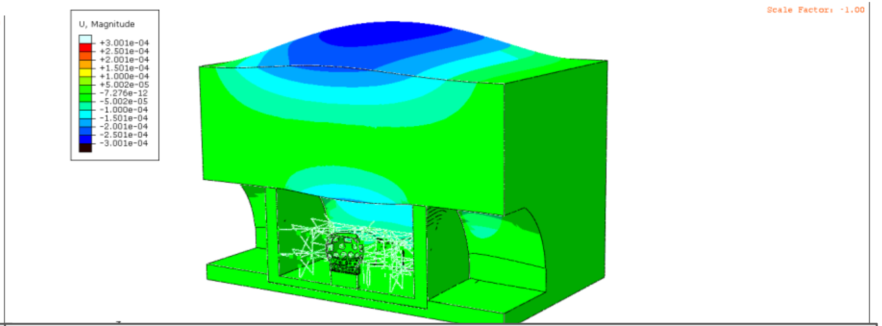
- Stability Optimization of our MECU new experimental facility provides critical feedback to the design
- Natural frequency is related to the stiffness via $\omega_0 = \sqrt{\frac{k}{m}}$



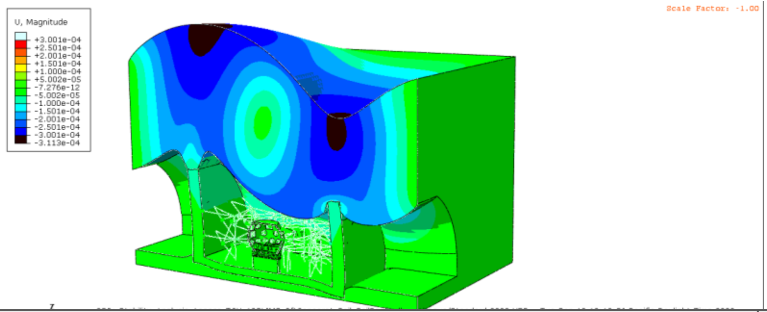
Structural Engineering to Maximize Stability for Experimental Systems



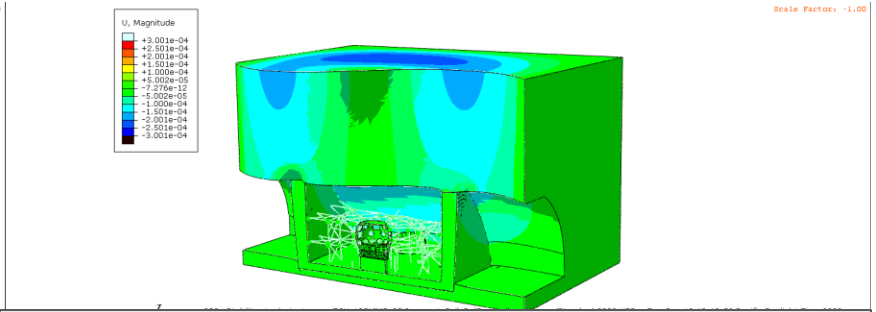
Mode - I



Mode - II



Mode - III



Mode - IV

Concluding remarks

- As a global leader in conducting cutting-edge physics experiments, simulation software and tools are an integral part of our day to day activities

- We are constantly looking at new technologies and tools to empower our scientific capabilities

- Embracing innovation remains at the core of our mission, enabling us to push the boundaries of discovery and maintain our position as pioneers in the world of scientific exploration.

THANK YOU!