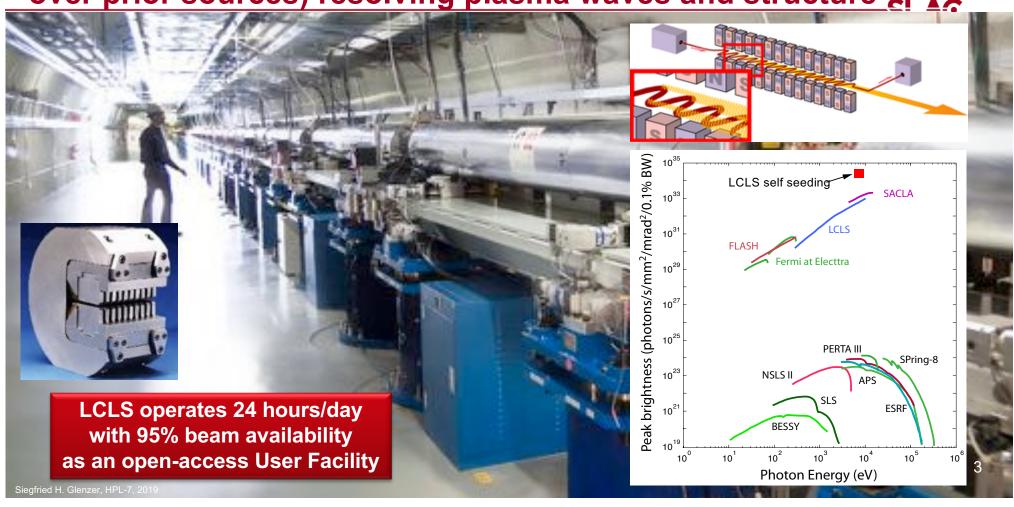




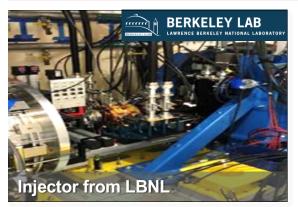
LCLS: coherent, extreme brightness x-rays (>109 increase over prior sources) resolving plasma waves and structure color



10 years after LCLS, we successfully turned on LCLS-II in the summer of 2020 and are in the middle of Run 18



LCLS-II project >93% complete; commissioning in 2022













Partner labs have delivered; installation and commissioning are in final stages at SLAC; Run 18 uses the commissioned 120 Hz, 25 keV X-ray capability 5

World's leading X-ray FEL laboratory for decades to come

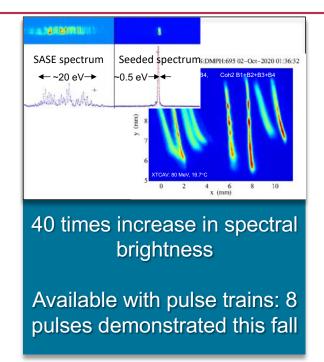
XFELs are still in their infancy and will define X-ray science in the 21st century. We envision:

- New capabilities for new science applications; e.g. X-rays with extremely narrow linewidths and much higher X-ray energies and peak power
- XFEL facilities with numerous dedicated, optimized instruments for particular classes of science

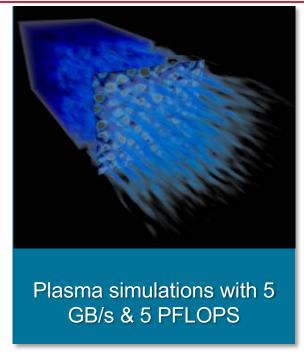


SLAC has required vision, scientific leaders and infrastructure to execute; HED physics capabilities will be developed with our national partners

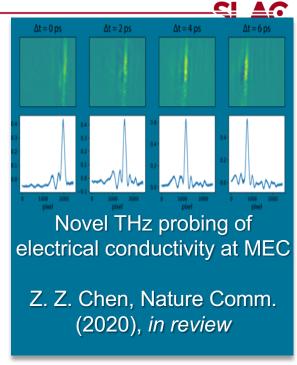
Innovative R&D vital to maintain leadership in HED with XFELs



Experiments with SNL and LLNL's Icarus detector



Innovations in particle acceleration and gamma sources



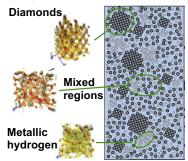
B. Ofori Okai led first successful MEC experiment during the pandemic

Building on rich history of technology development and collaboration across DOE complex

SLAC has delivered a world-leading program in HED science; 6 Nature & Nature-class papers

LCIC

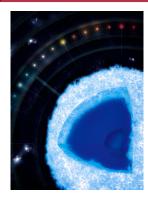
S. Frydrych et al., Nature C. (2020)



X-ray
Thomson
scattering at
MEC
measures
miscibility of
C and H in
dense
plasmas



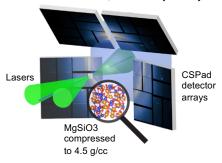
(2020)



Calibrating cosmic clocks by testing EOS models at white dwarf interior conditions

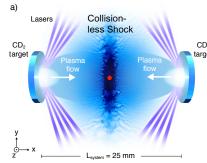


G. Morard et al., PNAS (2020)



MEC experiments reveal a common high-P structural evolution of glasses and liquid silicates

F. Fiuza et al., Nature Physics (2020)

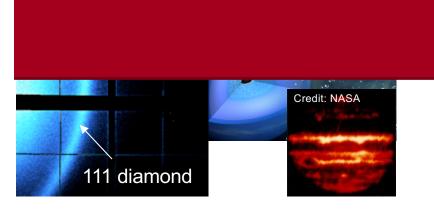


Demonstration
of 1st order
Fermi
acceleration
process in the
laboratory

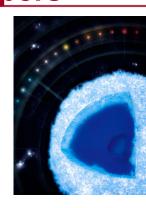


High-impact science enabled by DOE investment in HED physics at SLAC

SLAC has delivered a world-leading program in HED science: 6 Nature & Nature-class papers

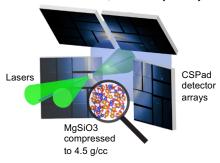


A. Kritcher et al., Nature (2020)



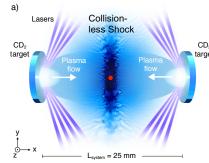
Calibrating cosmic clocks by testing EOS models at white dwarf interior conditions

G. Morard et al., PNAS (2020)



MEC
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reveal a
common high-P
structural
evolution of
glasses and
liquid silicates

F. Fiuza et al., Nature Physics (2020)



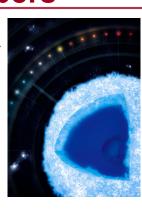
Demonstration of 1st order CD₂ Fermi acceleration process in the laboratory

High-impact science enabled by DOE investment in HED physics at SLAC

SLAC has delivered a world-leading program in HED science: 6 Nature & Nature-class papers



New NIF
discovery
science
project
on the
EOS of
White
Dwarfs

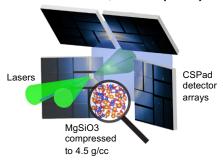


SLAC's LLST: Vera Rubin Observatory will survey type 1a supernovae on the Southern hemisphere



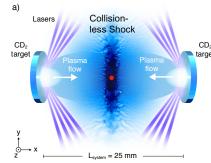
3.2 gigapixel focal plane

G. Morard et al., PNAS (2020)



MEC
experiments
reveal a
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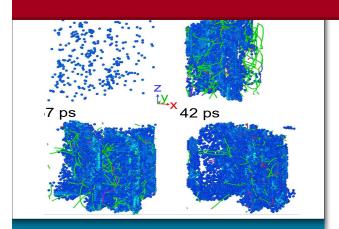
F. Fiuza et al., Nature Physics (2020)



Demonstration of 1st order CD₂ target Fermi acceleration process in the laboratory

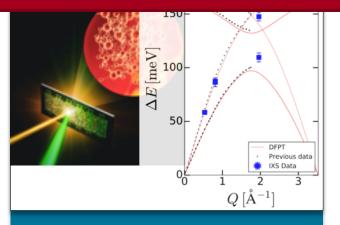
High-impact science enabled by DOE investment in HED physics at SLAC

LCLS-II enables new HED science capabilities



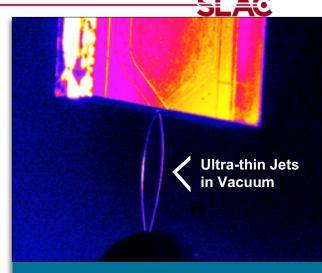
Higher X-ray Energies:

25 keV X-rays will resolve the Pair Correlation Function and visualize radiation damage in fusion materials



Higher Resolution:

Ion acoustic wave detector resolution will allow first-principles temperature measurements in dense plasma

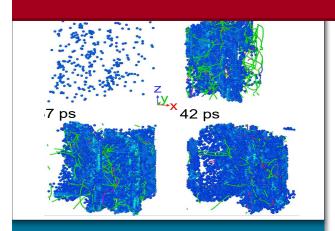


Higher Repetition Rate:

Novel jet target, 360 Hz pump-probe measurements already demonstrated; goal: 3 kHz at 100 mJ

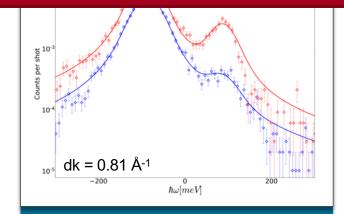
LCLS-II opens up a significant new phase space for MEC

LCLS-II enables new HED science capabilities



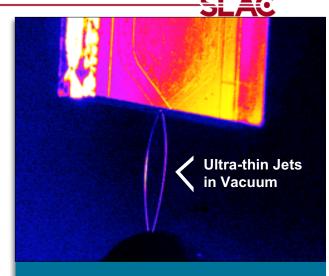
Higher X-ray Energies:

25 keV X-rays will resolve the Pair Correlation Function and visualize radiation damage in fusion materials



Proof of principle:

Ion acoustic waves measured at LCLS and EuXFEL; this fall, MEC demonstrated backscatter measurements as well

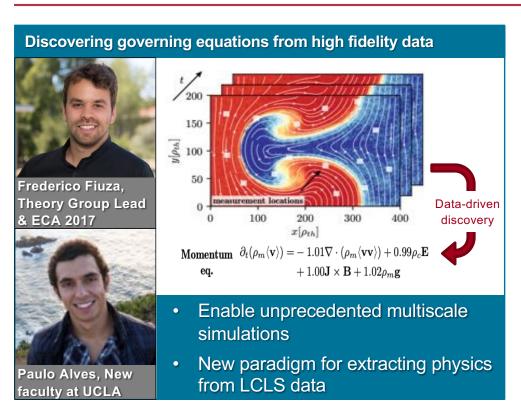


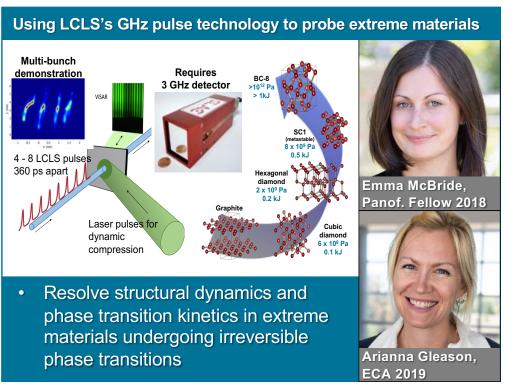
Higher Repetition Rate:

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LCLS-II opens up a significant new phase space for MEC

Investing in ML and extreme materials to push new frontiers





HED research at SLAC attracts talented early-career scientists

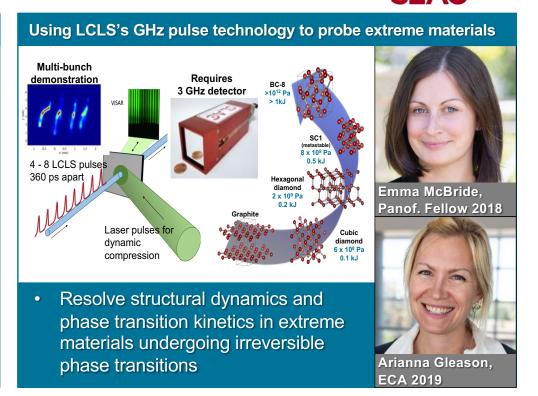
Investing in ML and extreme materials to push new frontiers

Discovering governing equations from high fidelity data Frederico Fiuza, Theory Group Lead & ECA 2017 Momentum $\partial_t(\rho_m\langle \mathbf{v}\rangle) = -1.01\nabla \cdot (\rho_m\langle \mathbf{v}\mathbf{v}\rangle) + 0.99\rho_c \mathbf{E}$ eq. $+1.00\mathbf{J} \times \mathbf{B} + 1.02\rho_m \mathbf{g}$

Anna Grassi, New

faculty at Sorbonne

- Enable unprecedented multiscale simulations
- New paradigm for extracting physics from LCLS data



HED research at SLAC attracts talented early-career scientists

MEC and MEC-related studies have delivered outstanding publications in HED science with X-ray Lasers

75 publications since 2014

15 in Nature

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- A. Descamps et al., Nat. Sci. Rep. 10, 14564 (2020)
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- E. E. McBride et al., Nat. Phys. (2019)
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- S. White et al., Phys. Rev. Research 2, 033366 (2020) C. B. Curry et al., J. Vis. Exp. 159 (2020)
- M. Makita et al., Optica 7, 404 (2020)
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- A. K. Schuster et al., Phys. Rev. B 101, 054301 (2020)
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- D. Kraus et al., Phys. Plasmas 25, 056313 (2018)
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- J. Lua et al., Journal of QSRT, 187, 247 (2017)
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- C. Bostedt et al., Rev. Mod. Phys. 88, 15007 (2016) T. Kluge at al., Phys. Rev. X 8, 031068 (2018)
- P. Heimann et al., J. Synchrotron Radiat, 23, 425 (2016)
- F. Dorchies et al., Phys. Rev. B 92, 144201 (2015)
- A. Schropp et al., Microscopy 21, 2167 (2015)
- M. Harmand et al., Phys. Rev. B 92, 24108 (2015)
- S. M. Vinko, J. Plasma Phys. 81, 365810501 (2015) E. J. Gamboa et al., Phys. Plasmas 22, 56319 (2015)
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- M. MacDonald et al., Appl. Phys. Lett. 116, 234104 (2020)
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- A. E. Gleason et al., Phys. Rev. Lett. 119, 25701 (2017) B. B. L. Witte et al., Phys. Rev. Lett. 118, 225001 (2017)
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- M. G. Gorman et al., Phys. Rev. Lett. 115, 95701 (2015)
- P. Sperling et al., Phys. Rev. Lett. 115, 115001 (2015)

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LCLS: Linac Coherent Light Source

Transforming HED science with a versatile petawatt facility



LCLS's Materials in Extreme Conditions upgrade

Preparing for CD-1 of the MEC upgrade based on clear science

- World-leading combination of high-power lasers with XFEL
- Capacity to serve a broad plasma & fusion materials community

MEC upgrade at LCLS will provide world-leading capability in HED science

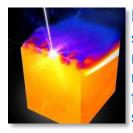
'LaserNetUS'

Target Chamber (TC-2)

The Laser specs for the MEC upgrade are driven by the scientific missions within DOE

SLAC

- PW Laser: 150J, 150 fs, 1 μm, 10 Hz
- 10¹⁸ Pa light pressure, Bright ion beams, Collision-less shocks
 - Compared to international competition
 - 10x higher repetition rate
 - 6x higher energy
 - 2x higher power



Producing bright sources of ions, neutrons and magnetic fields for fusion material science

- Compression Laser: 1 kJ, 5 ns, 0.5 μm, shot/minute
 - 10¹² Pa material pressure, Ablator physics, Unearthly materials
 - Compared to international competition
 - 10x higher energy at shot/minute
 - 2x higher energy at 10 Hz

Producing
extreme material
states through
near isentropic
compression

These lasers provide unparalleled capabilities to access and probe new states of matter

MEC is a charter member of LaserNetUS (FWP #100472)





- User experiments: Three out of Twelve proposals have been awarded time
- We supported the launch of LaserNet, lasernetus.org website, etc.

Many Thanks to our collaboration





Thank you

