



SAND2011-7329C



Sandia National Laboratories Overview

SEERI Summer Student Presentations

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.



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Pulsed Magnetic Field for Cluster Fusion Research at the University of Texas

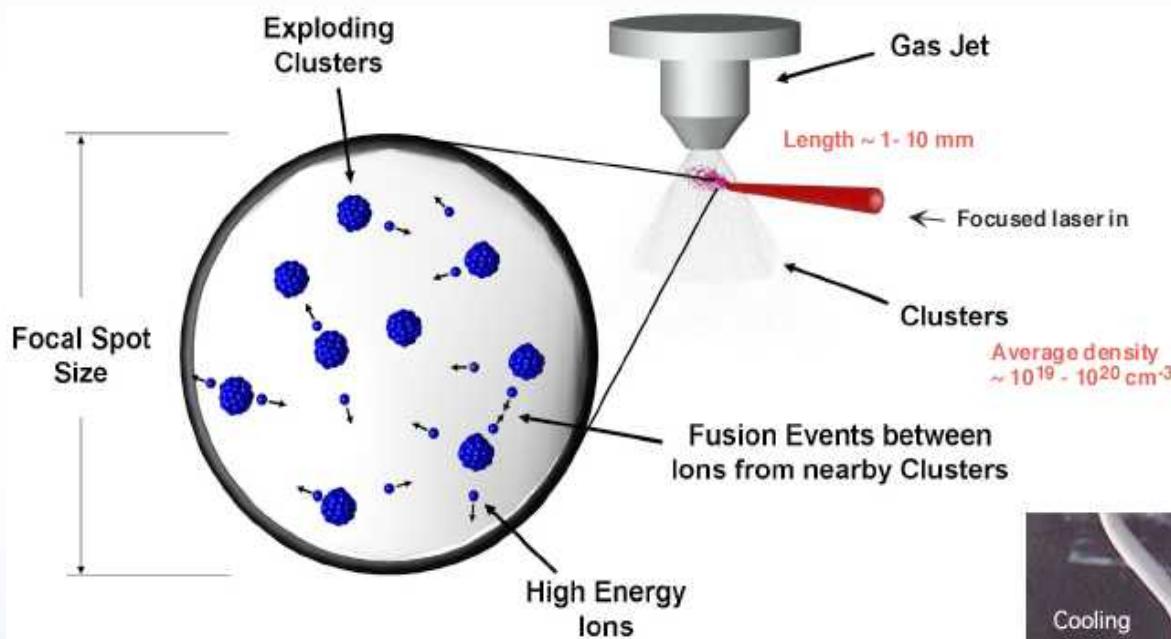
- **Overview:**

- Previous work leading to the experiment
- Explanation of experimental design
- Motivations
- Sandia's design for 200T driver
- Current Status

- **The Experiment: Take the worlds most powerful laser, combine it with some of the strongest magnetic fields obtainable on a laboratory tabletop, and make nuclear fusion!**



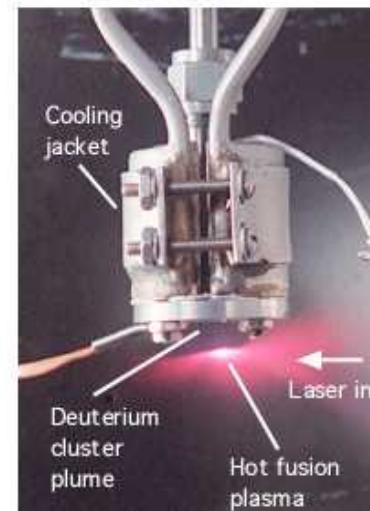
Deuterium Cluster Fusion Mechanism



Relevant fusion reactions:



- Cold gas jet of Deuterium creates clusters held together by Van Der Waals forces
- High power laser blasts electrons away, ions repel and fly apart



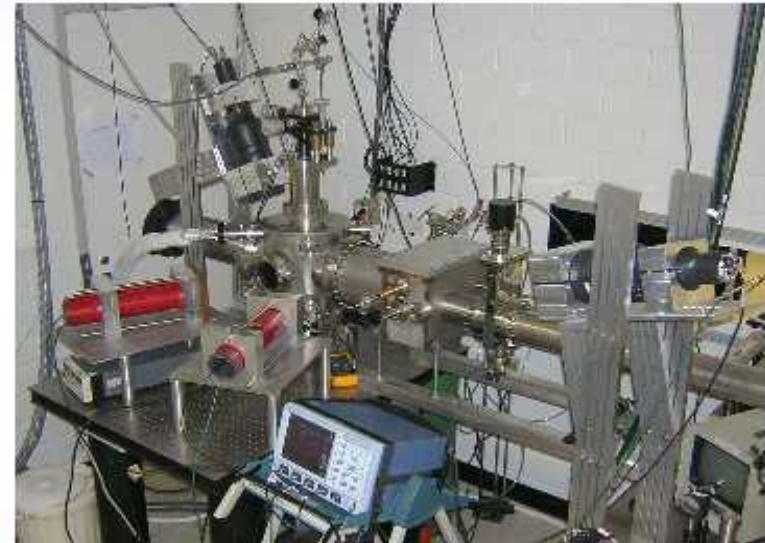
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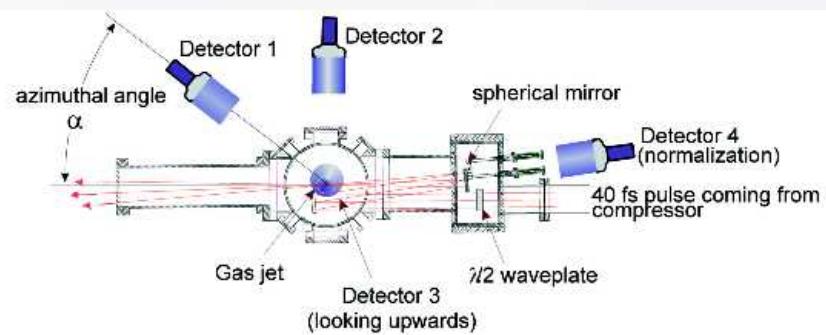
Cluster Fusion at University of Texas



The Texas Petawatt



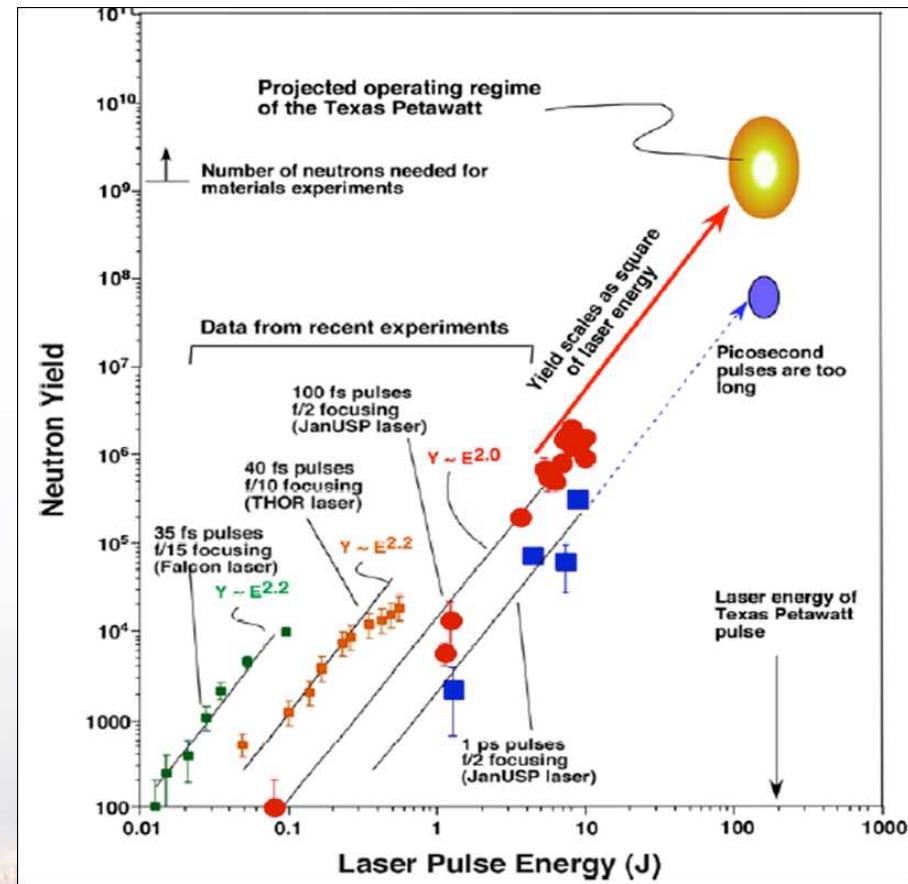
Cluster Experiments on the Thor laser



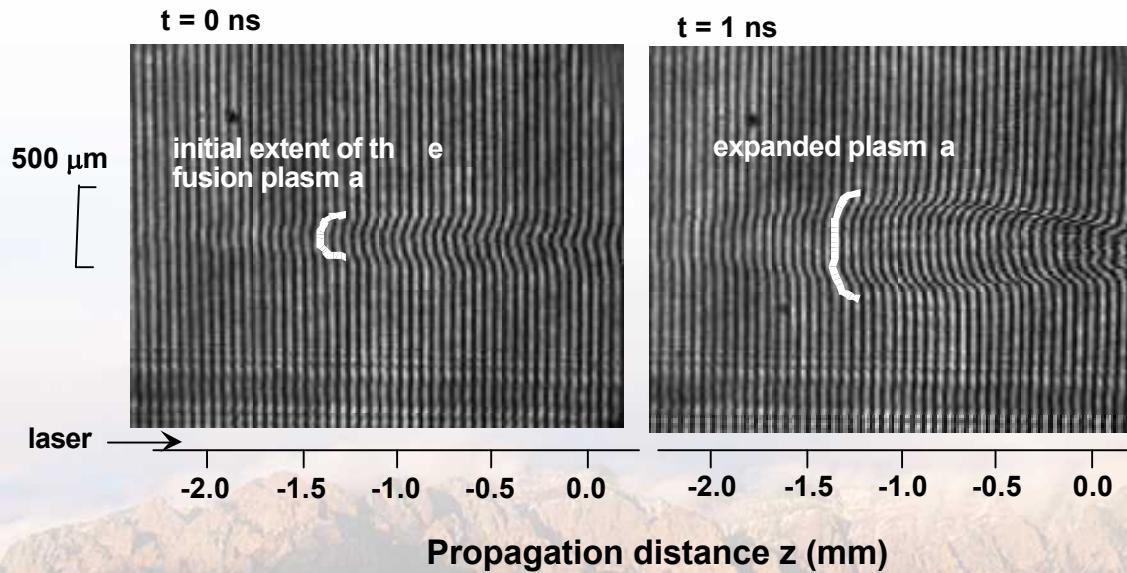
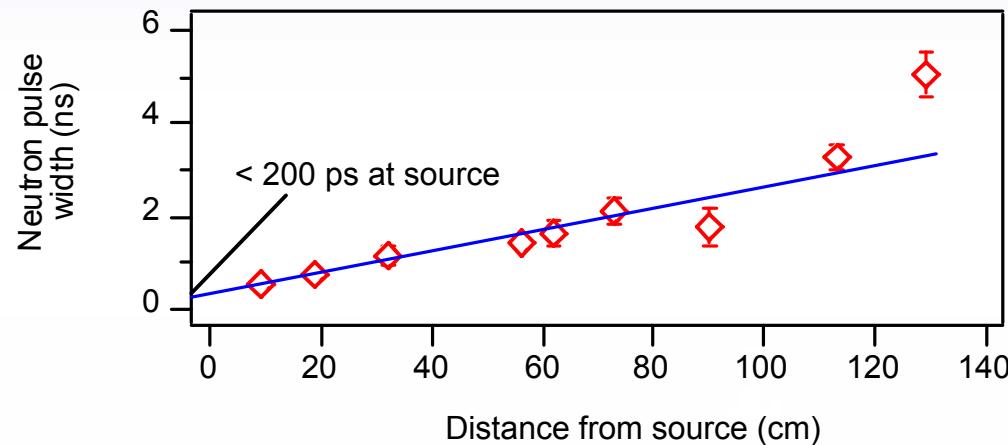
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Deuterium Cluster Fusion Results

- High Density, High Temperature plasmas created $10^{19}/\text{cm}^3$ (close to atmospheric density) and Ion Energies $\sim 10\text{KeV}$
- Fusion neutron count scales as square of laser energy
- Texas Petawatt Laser expected to produce $\sim 10^9$ Neutrons through this mechanism



But Cluster Fusion burn time is very short!



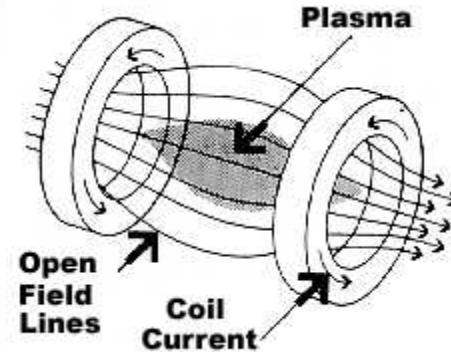
J. Zweiback, et al., "Characterization of Fusion Burn Time in Exploding Deuterium Cluster Plasmas," *Phys. Rev. Lett.*, **85**, 3640 (2000).



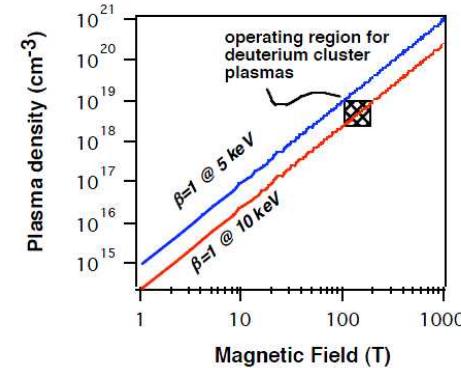
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Trap the Plasma in a Magnetic Field!

- Need 200 Tesla Magnetic Field to radially confine Plasma and increase fusion time
- Such fields possible for short times of Microseconds in small exploding coils with MegaAmp currents
- Sandia wields expertise in pulsed power systems and collaborates with UT-Austin on this experiment to supply the 200T driver
- Magnetic field coil design borrows from successful LANL high field lab

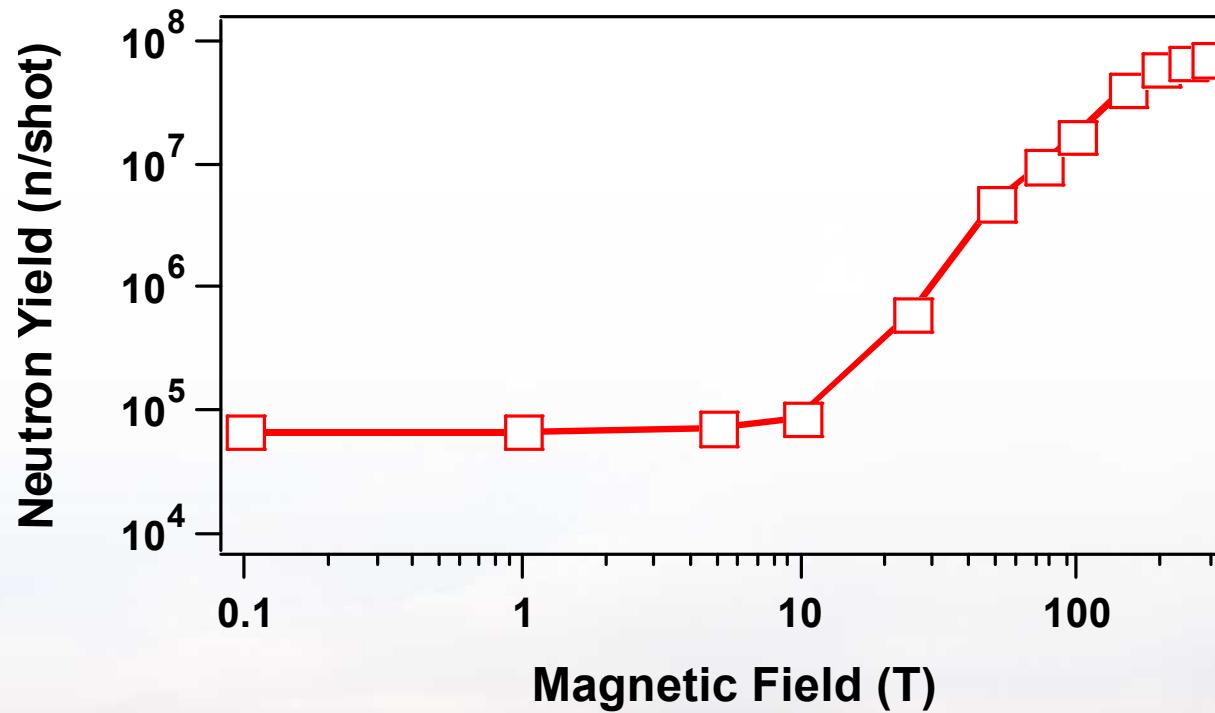


Magnetic Mirror



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Calculations suggest that 2 to 3 orders of magnitude improvement in neutron yield can be achieved



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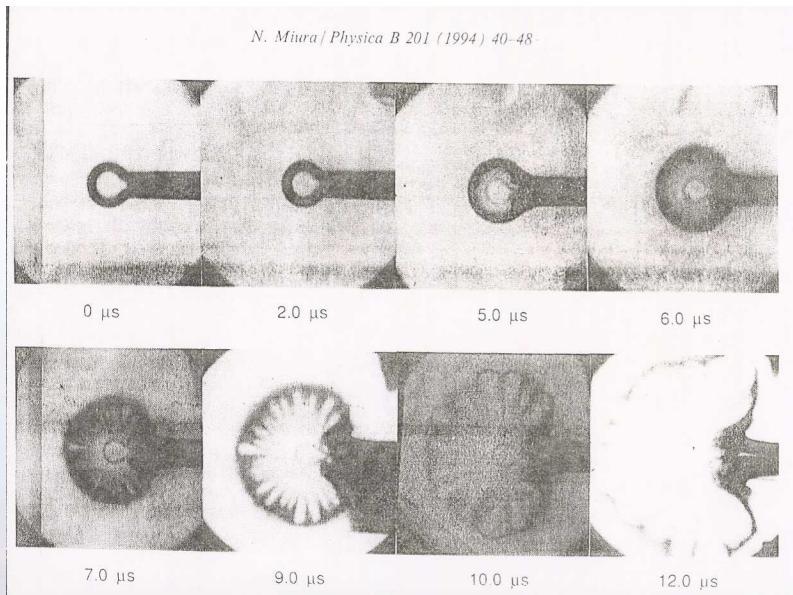
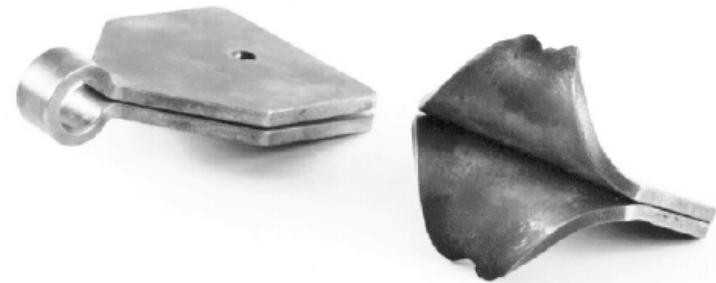
Single-Turn MegaGauss Field Driver at LANL



Before



After



Chuck Mielke, National High Magnetic Field Laboratory, LANL

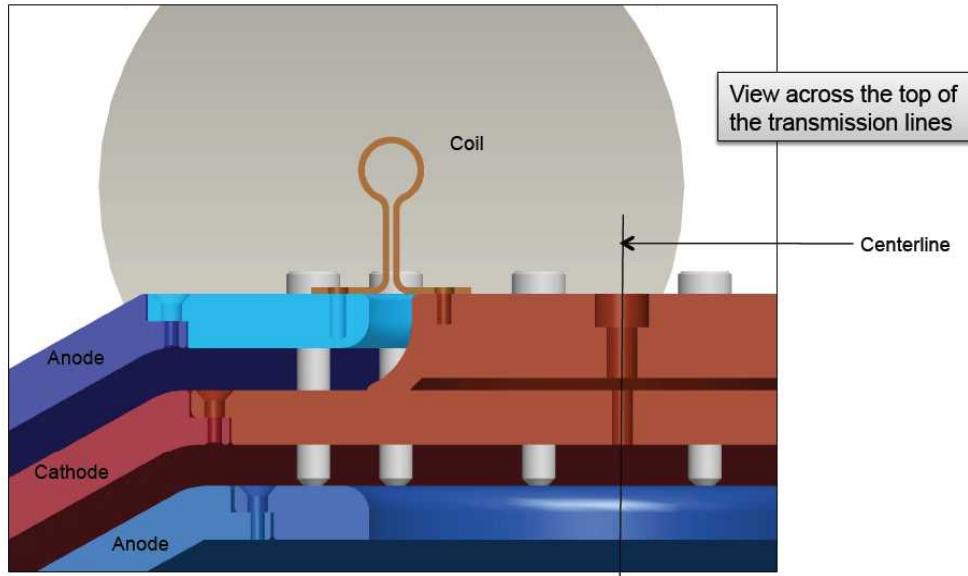
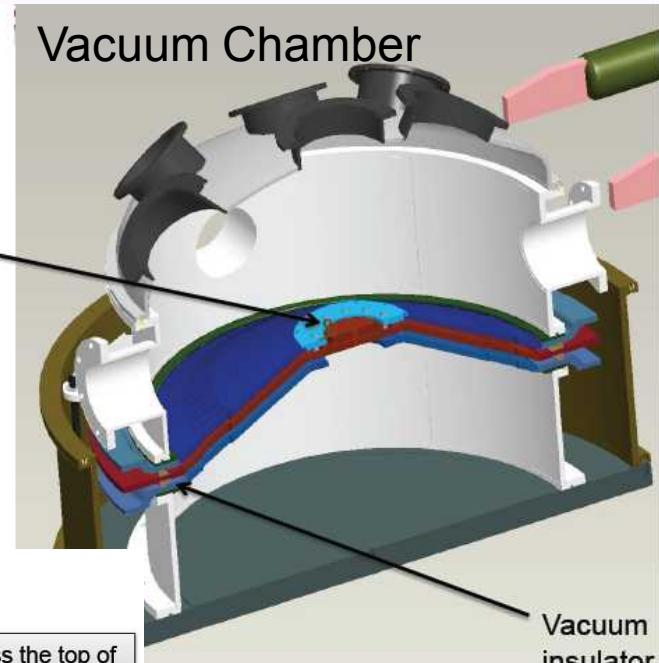
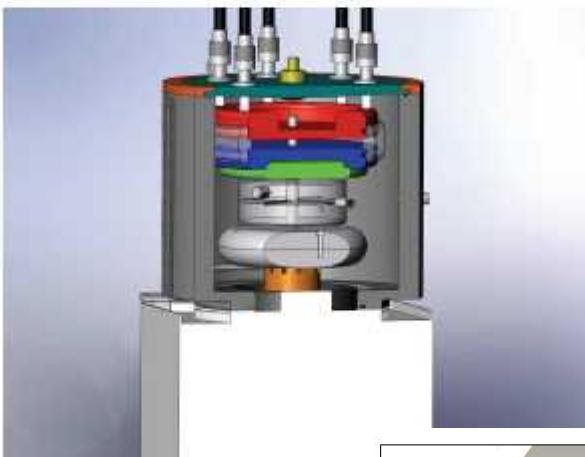


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Sandia's 200T Pulser Design

L3 Communications 40364
(Marx trigger generator switch)



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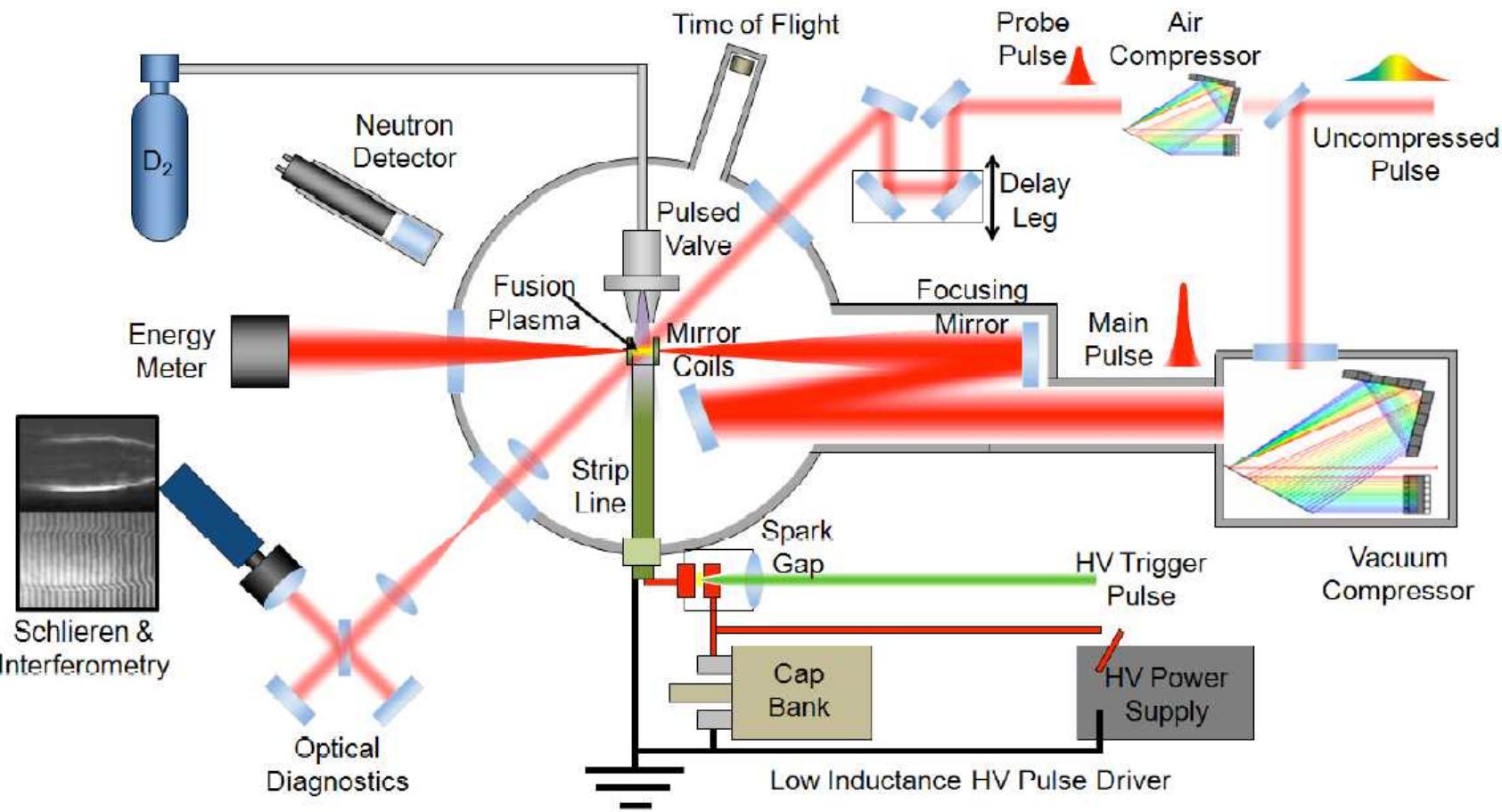


Ladder of Time Scales

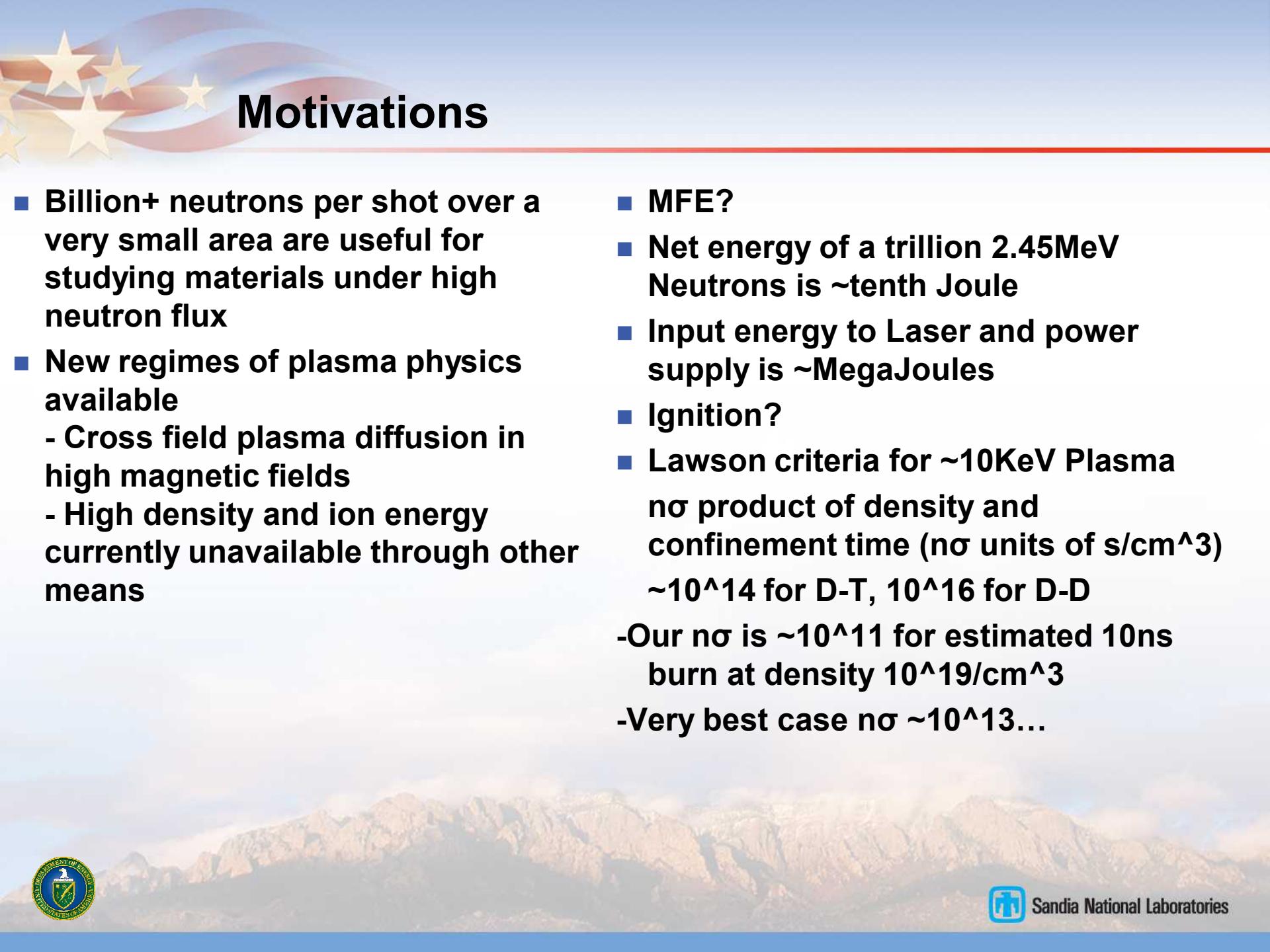
- 15 Femtosec 10^{-14} s
 - Laser pulse duration of Texas Petawatt
 - Hot electrons ejected from D Clusters
- Picosec 10^{-12} s
 - Coulomb explosion of D Clusters creates plasma, Ions achieve energies of ~ 10 KeV necessary for fusion
 - Fusion reactions in unconfined plasma would be essentially over without 200T field
- 200 Picosecs $2E-10$ s
 - 200T Field confines plasma, stops radial expansion, pressures equilibrate, magnetized electrons slow motion
 - Fusion reactions continue, UV, X-ray, and neutron emissions produced, plasma eventually leaks out ends
 - Duration of 2.2 Mega Amp pulse to 200T magnetic coils
 - Coil flies apart and no longer produces a useful magnetic field, but experiment is long over anyway
 - Duration of the deuterium cluster puff, plenty long
 - Crack of shock wave hitting vacuum chamber, and shrapnel! But the experiment was over eons ago.
- Nanosec 10^{-9} s
- 1-100 Nanosecs $1-100E-9$ s
- 2 Microsecs $2E-6$ s
- 10 Microsec 10^{-5} s
- Millisecs 10^{-3}
- Seconds



Experimental Design



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Motivations

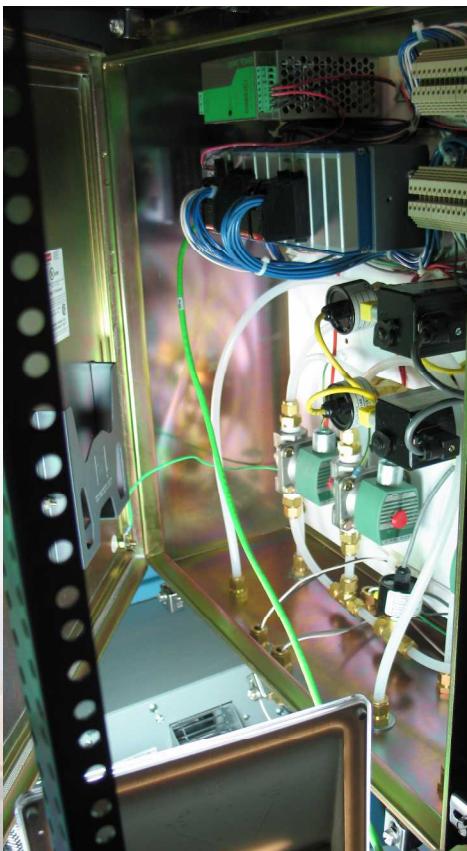
- Billion+ neutrons per shot over a very small area are useful for studying materials under high neutron flux
- New regimes of plasma physics available
 - Cross field plasma diffusion in high magnetic fields
 - High density and ion energy currently unavailable through other means
- MFE?
- Net energy of a trillion 2.45MeV Neutrons is ~tenth Joule
- Input energy to Laser and power supply is ~Megajoules
- Ignition?
- Lawson criteria for ~10KeV Plasma $n\sigma$ product of density and confinement time ($n\sigma$ units of s/cm^3)
 - ~ 10^{14} for D-T, 10^{16} for D-D
 - Our $n\sigma$ is ~ 10^{11} for estimated 10ns burn at density $10^{19}/\text{cm}^3$
 - Very best case $n\sigma$ ~ 10^{13} ...

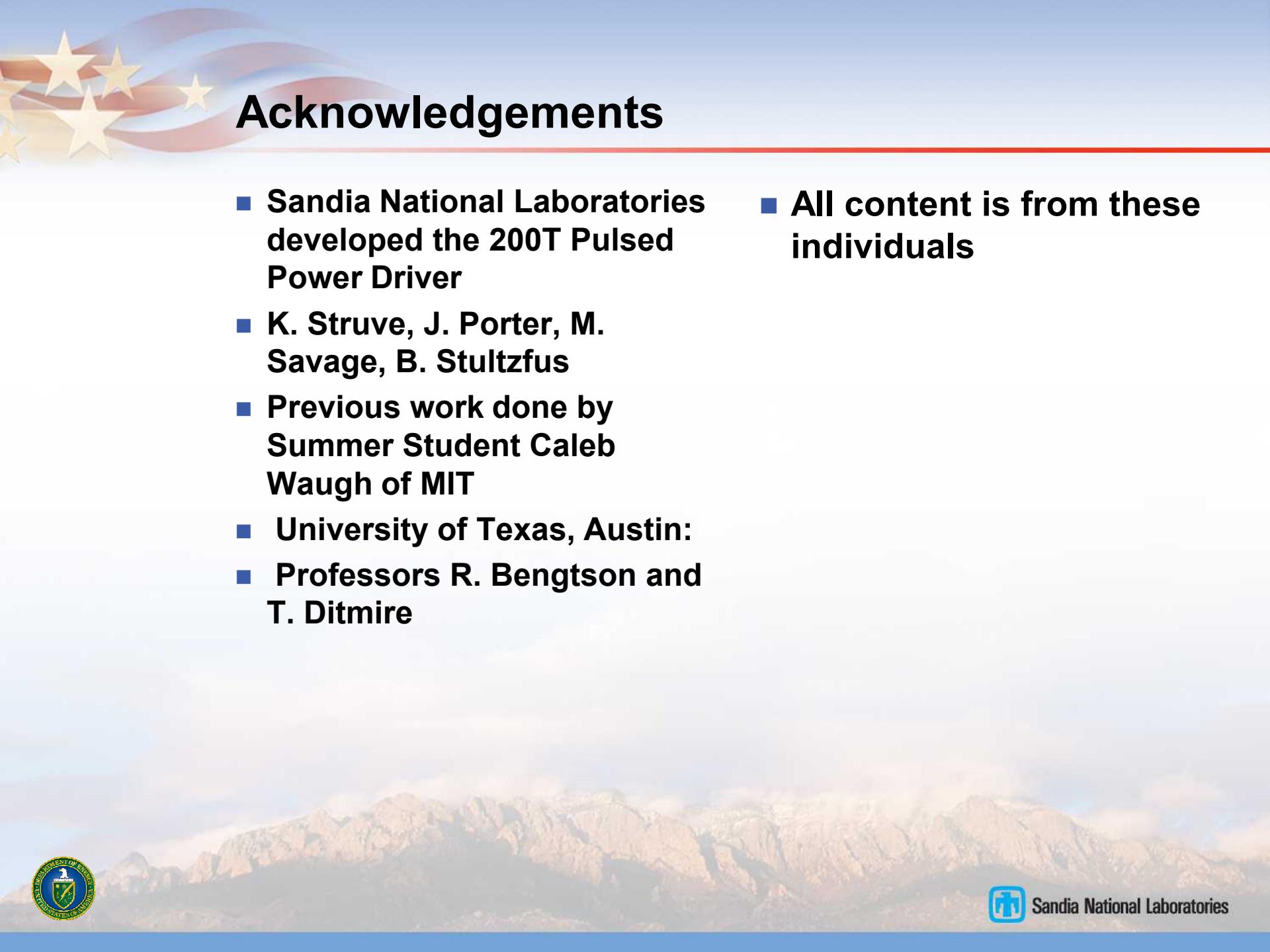


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Current Status

- Version 1 of pulsed power supply is now at UT-Austin for coil testing
- Full power version 2 is under construction, control box is completed
- Expect delivery of version 2 to UT Spring of 2011
- Continued coil testing at UT have problems with electrical breakdown





Acknowledgements

- Sandia National Laboratories developed the 200T Pulsed Power Driver
- K. Struve, J. Porter, M. Savage, B. Stutzfus
- Previous work done by Summer Student Caleb Waugh of MIT
- University of Texas, Austin:
- Professors R. Bengtson and T. Ditmire
- All content is from these individuals



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