



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.



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

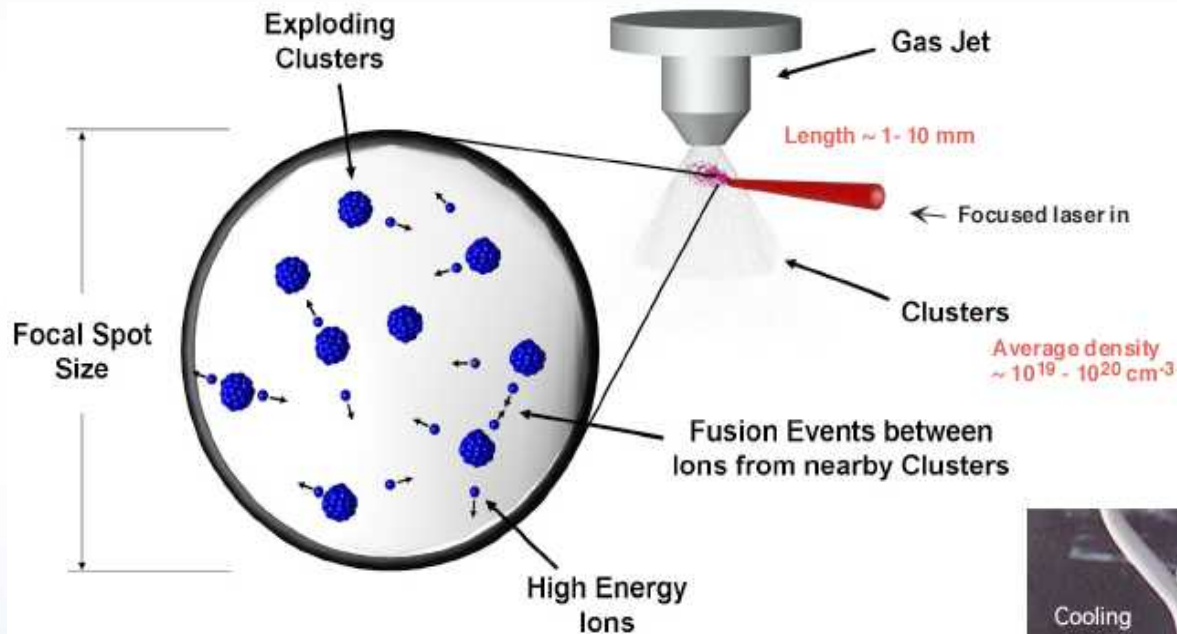
■ Overview:

- 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!



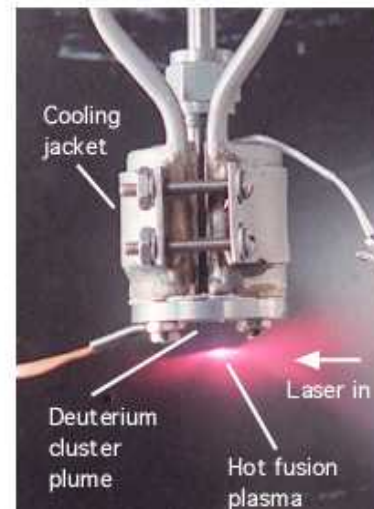
Deuterium Cluster Fusion Mechanism



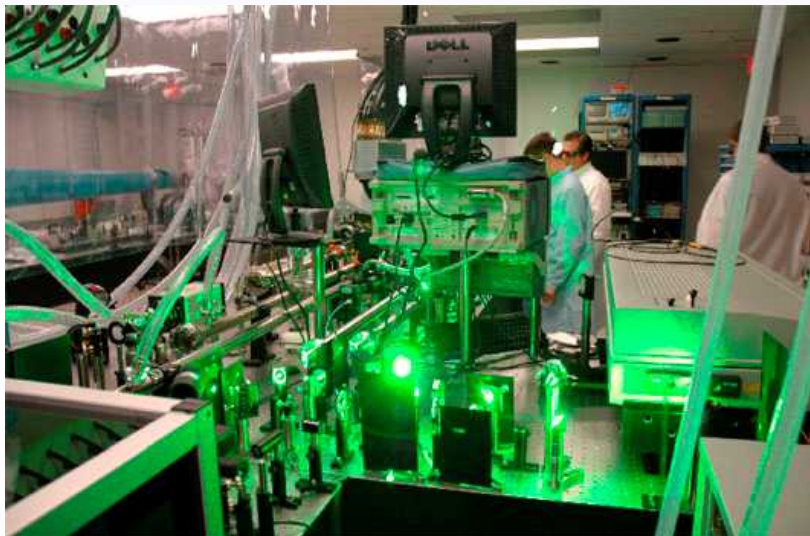
Relevant fusion reactions:



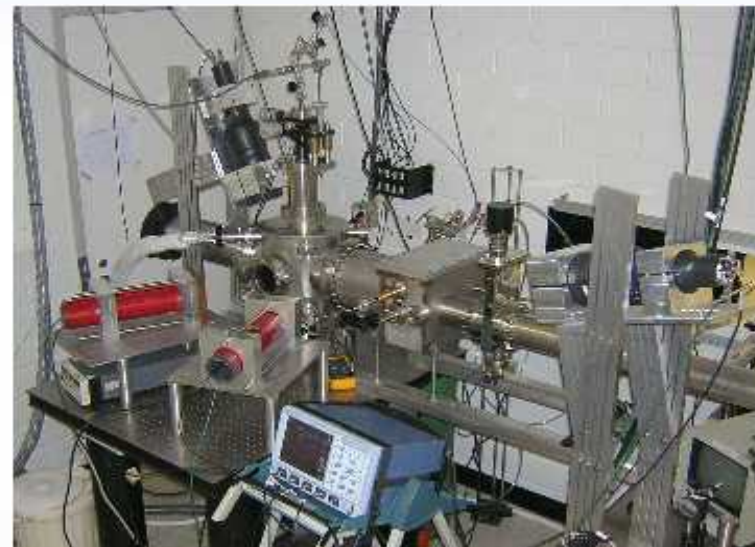
- Cold gas jet of Deuterium creates clusters held together by Van Der Waals forces
- High power laser blasts electrons away, ions repel and fly apart



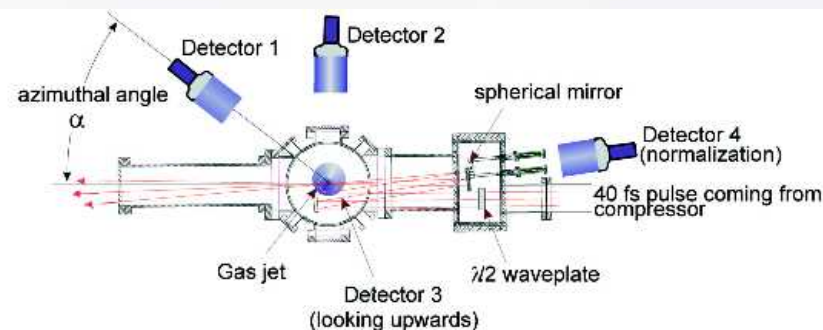
Cluster Fusion at University of Texas



The Texas Petawatt

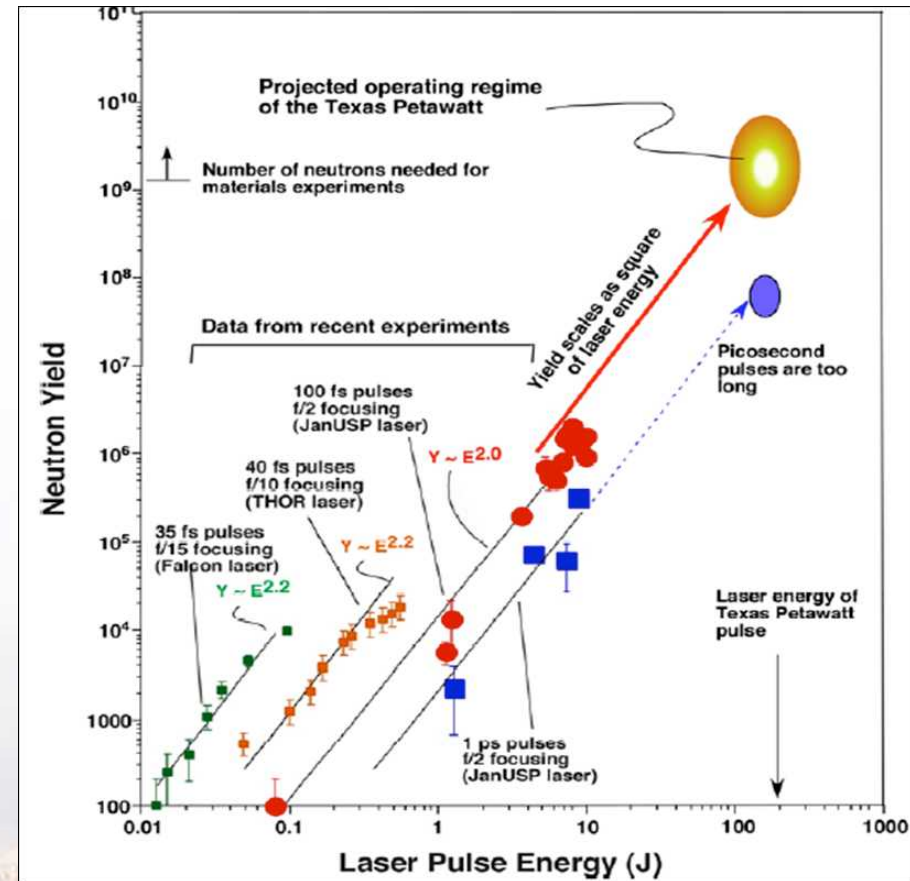


Cluster Experiments on the Thor laser

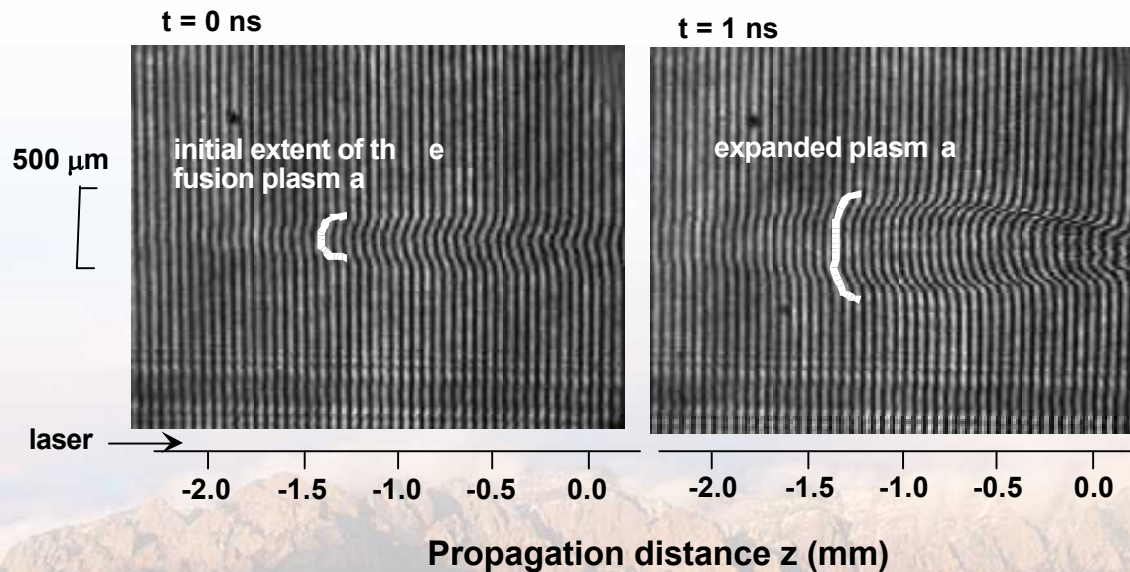
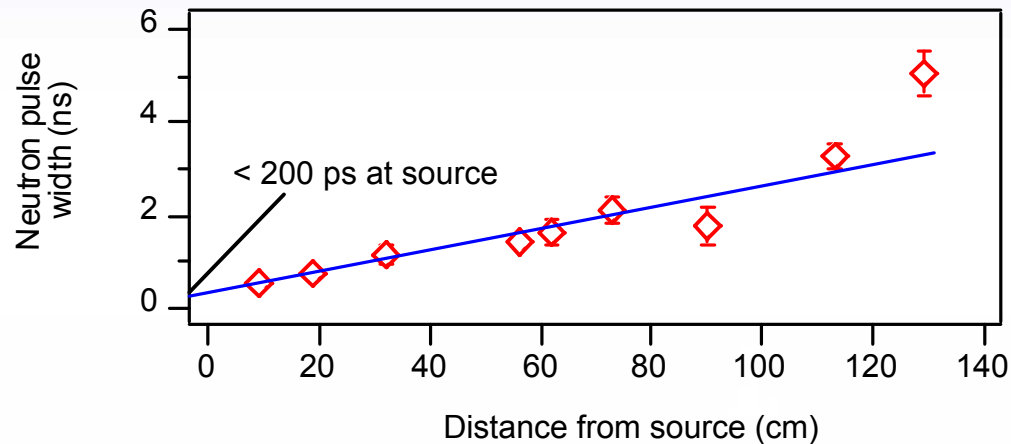


Deuterium Cluster Fusion Results

- 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!

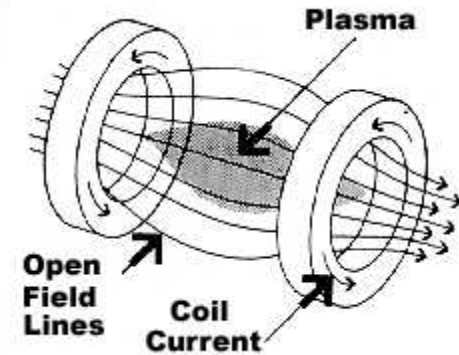


J. Zweiback, et al., "Characterization of Fusion Burn Time in Exploding Deuterium Cluster Plasmas," *Phys. Rev. Lett.*, **85**, 3640 (2000).

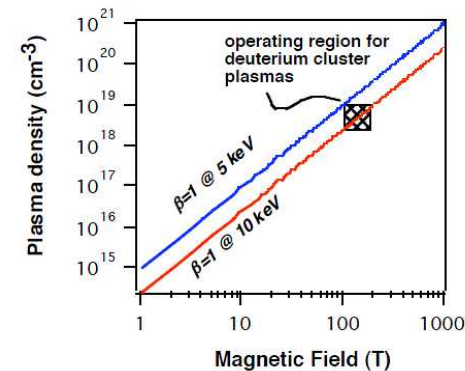


Trap the Plasma in a Magnetic Field!

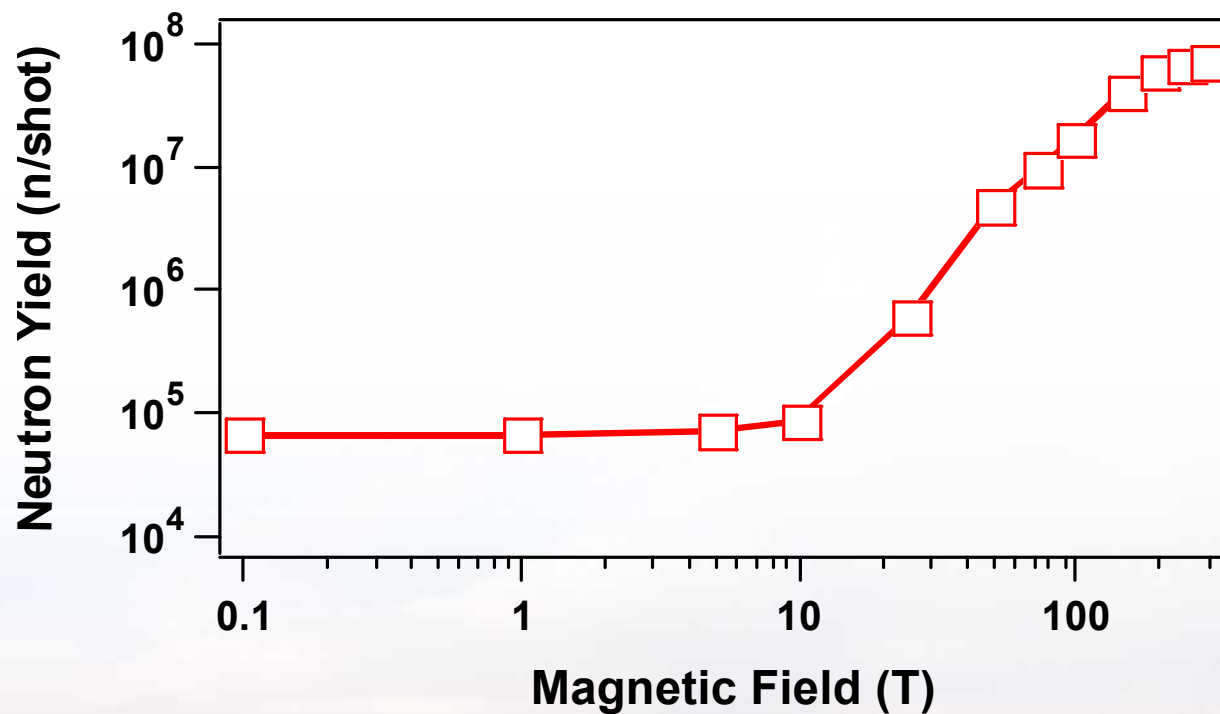
- Need 200 Tesla Magnetic Field to radially confine Plasma and increase fusion time
- Such fields possible for short times of Microseconds in small exploding coils with MegaAmp currents
- Sandia wields expertise in pulsed power systems and collaborates with UT-Austin on this experiment to supply the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



Magnetic Mirror



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



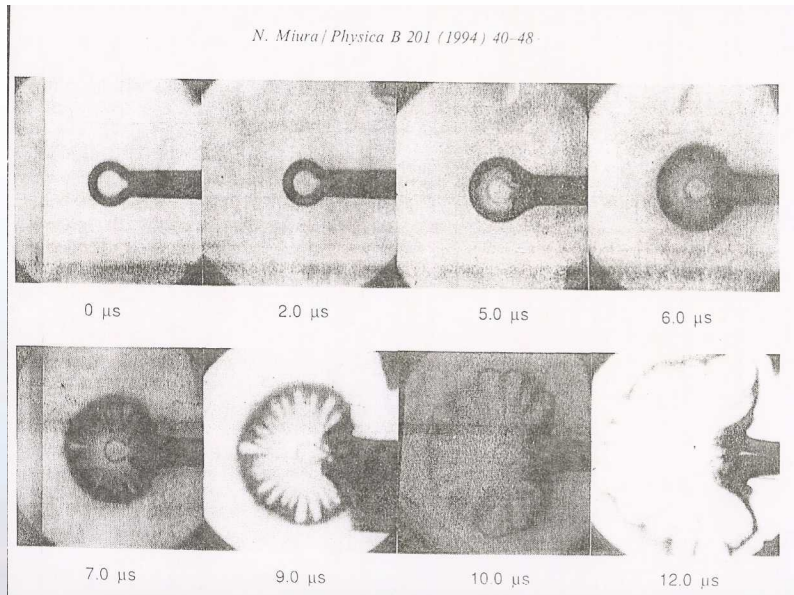
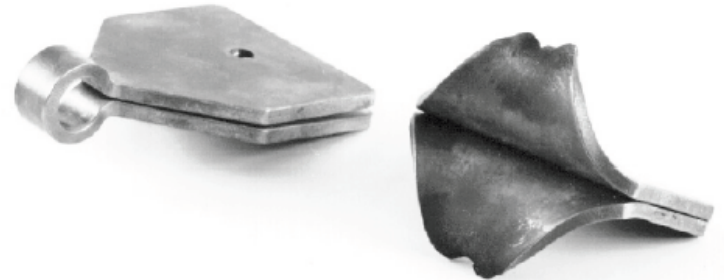
Single-Turn MegaGauss Field Driver at LANL



Before



After



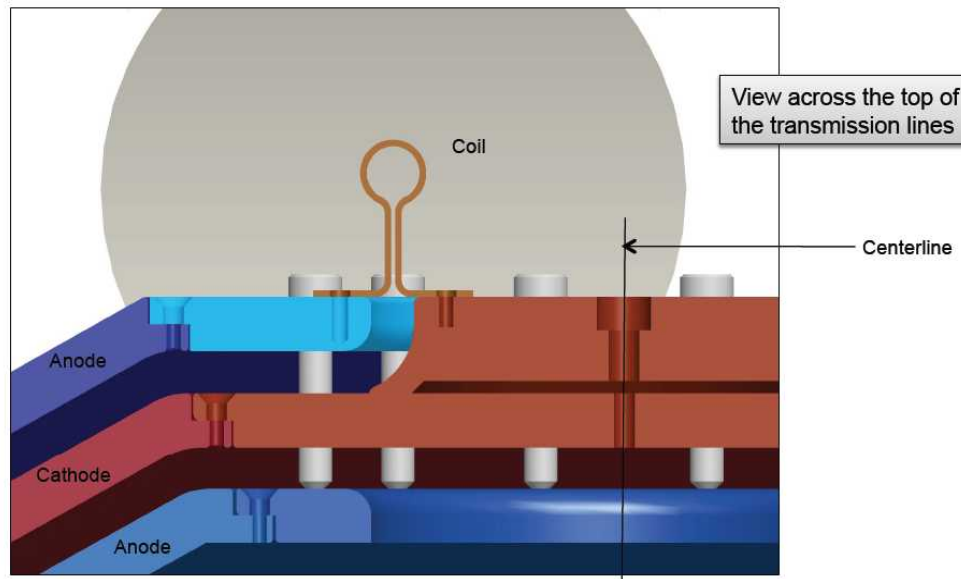
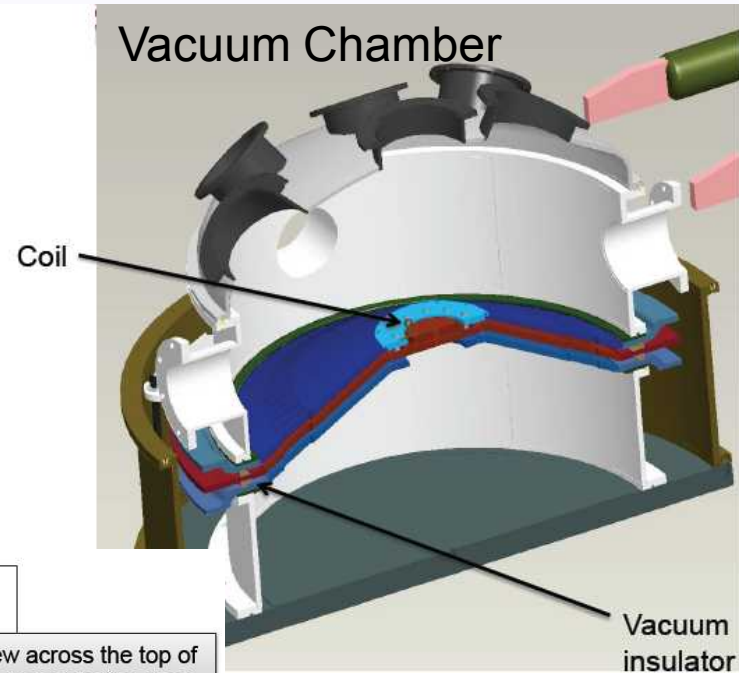
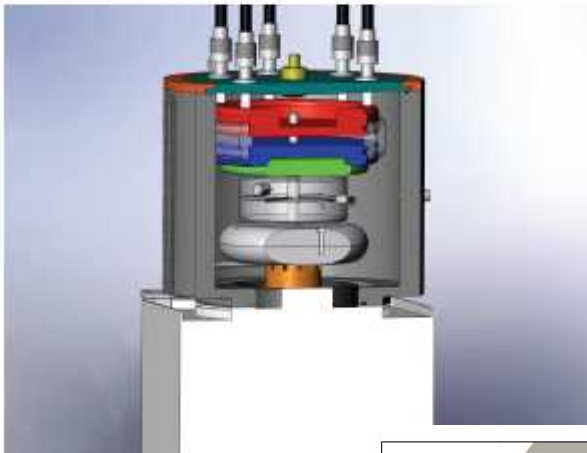
Chuck Mielke, National High Magnetic Field Laboratory, LANL



Sandia National Laboratories

Sandia's 200T Pulser Design

L3 Communications 40364
(Marx trigger generator switch)



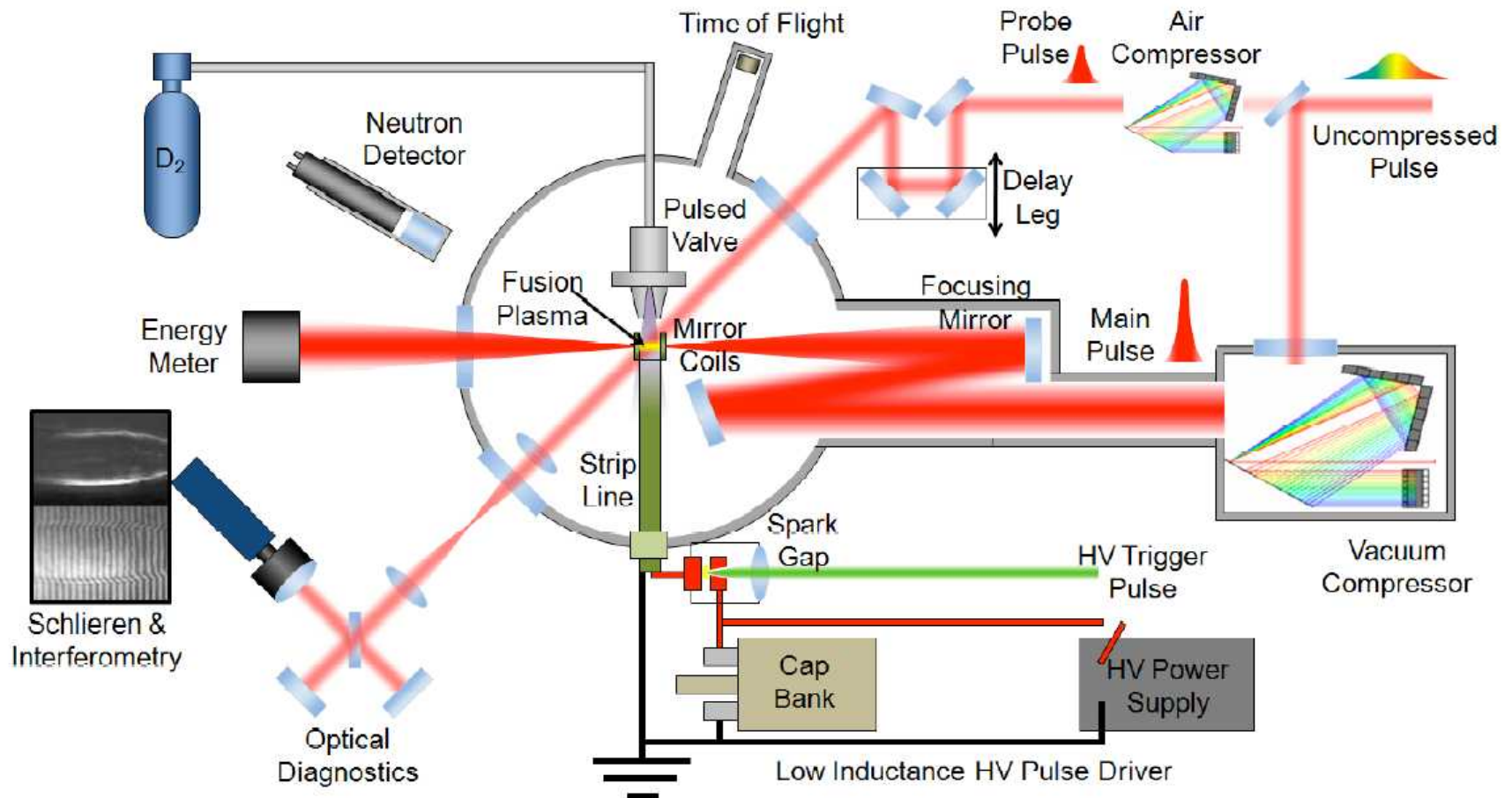


Ladder of Time Scales

- 15 Femtosec 10^{-14} s
- Picosec 10^{-12} s
- 200 Picosecs 2×10^{-10} s
- Nanosec 10^{-9} s
- 1-100 Nanosecs $1-100 \times 10^{-9}$ s
- 2 Microsecs 2×10^{-6} s
- 10 Microsec 10^{-5} s
- Millisecs 10^{-3}
- Seconds
- Laser pulse duration of Texas Petawatt
- Hot electrons ejected from D Clusters
- 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
- 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.



Experimental Design





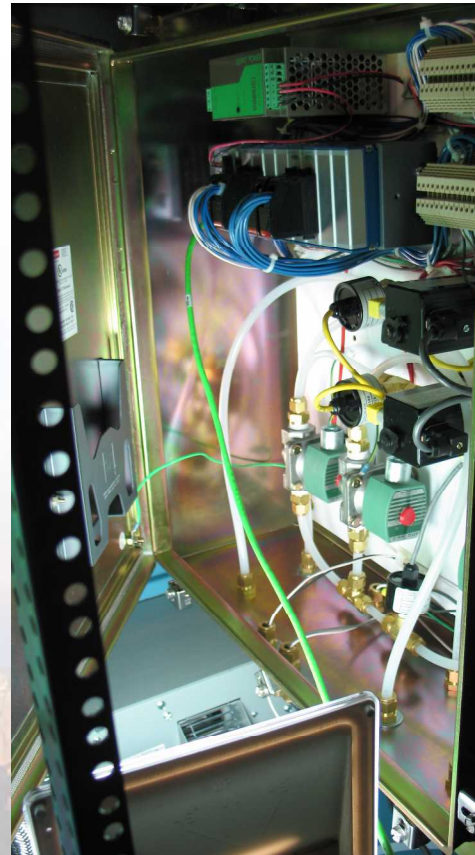
Motivations

- 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 $10^{19}/cm^3$
 - Very best case $n\sigma$ ~ 10^{13} ...



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. Stultzfus
- 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

