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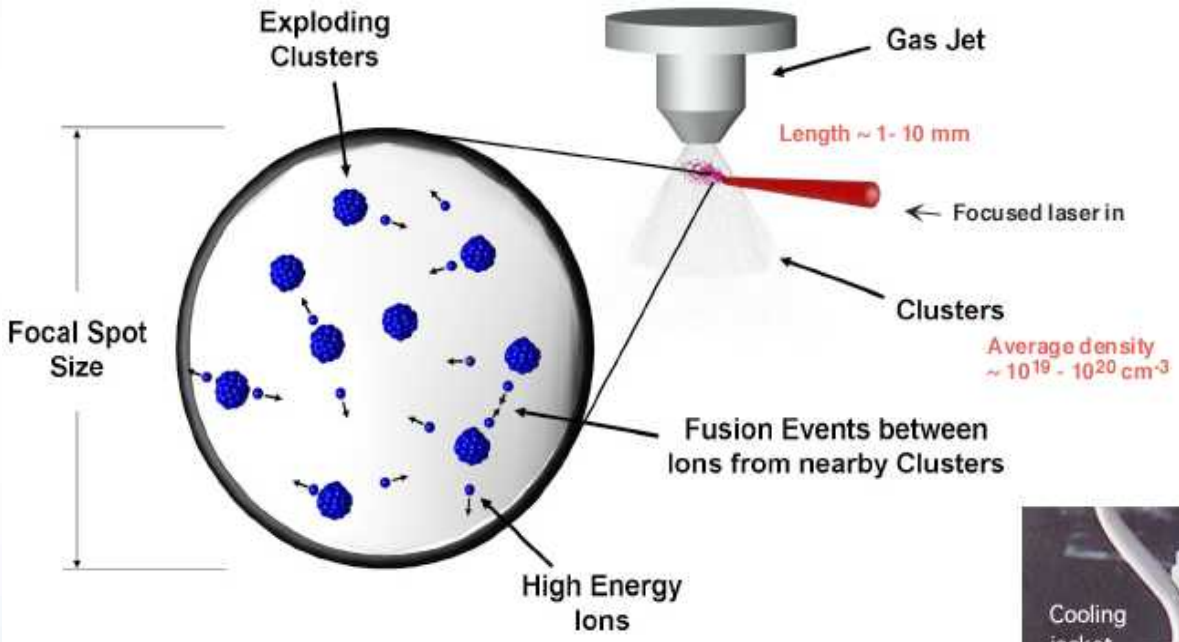
Pulsed Magnetic Field for Cluster Fusion Research at the University of Texas

- **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!**

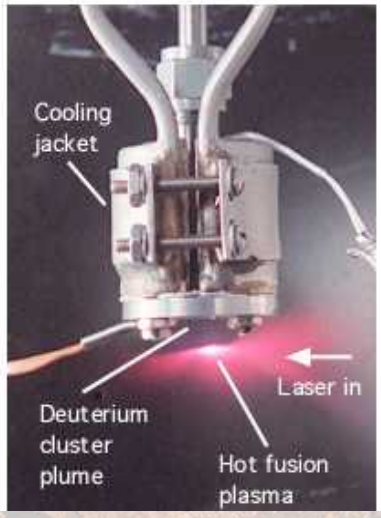
Deuterium Cluster Fusion Mechanism



Relevant fusion reactions:

$D + D \rightarrow He^3$ (0.82 MeV) + n (2.45 MeV)

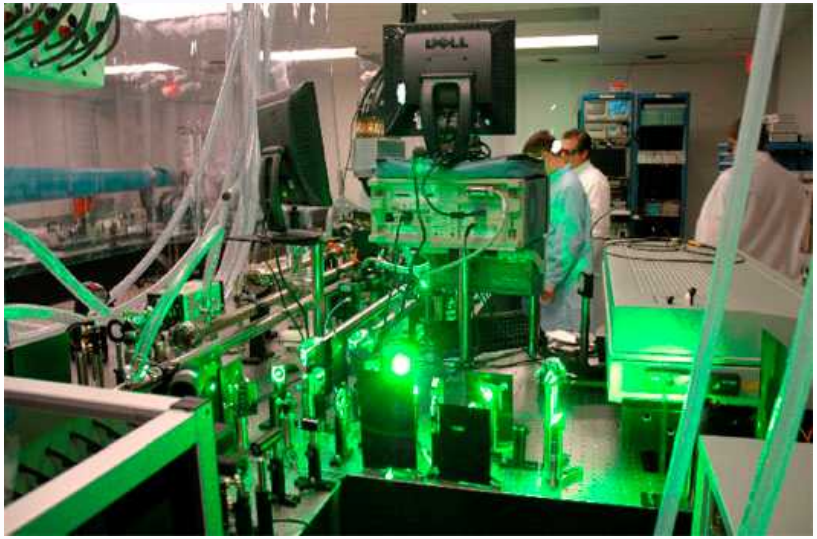
$D + T \rightarrow He^4$ (3.5 MeV) + n (14.1 MeV)



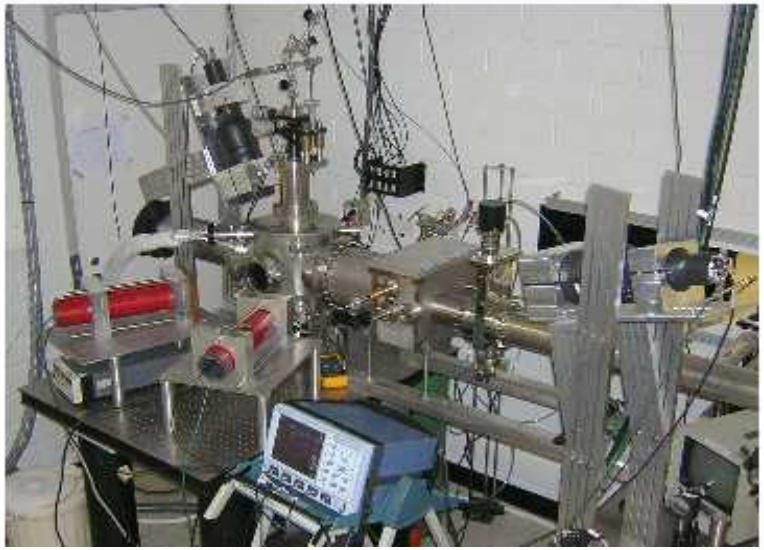
-Cold gas jet of Deuterium creates clusters held together by Van Der Waals forces

-High power laser blasts electrons away, ions repel and fly apart

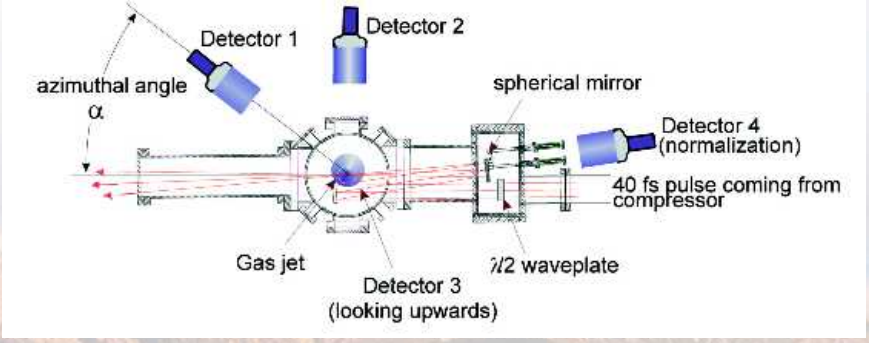
Cluster Fusion at University of Texas



The Texas Petawatt

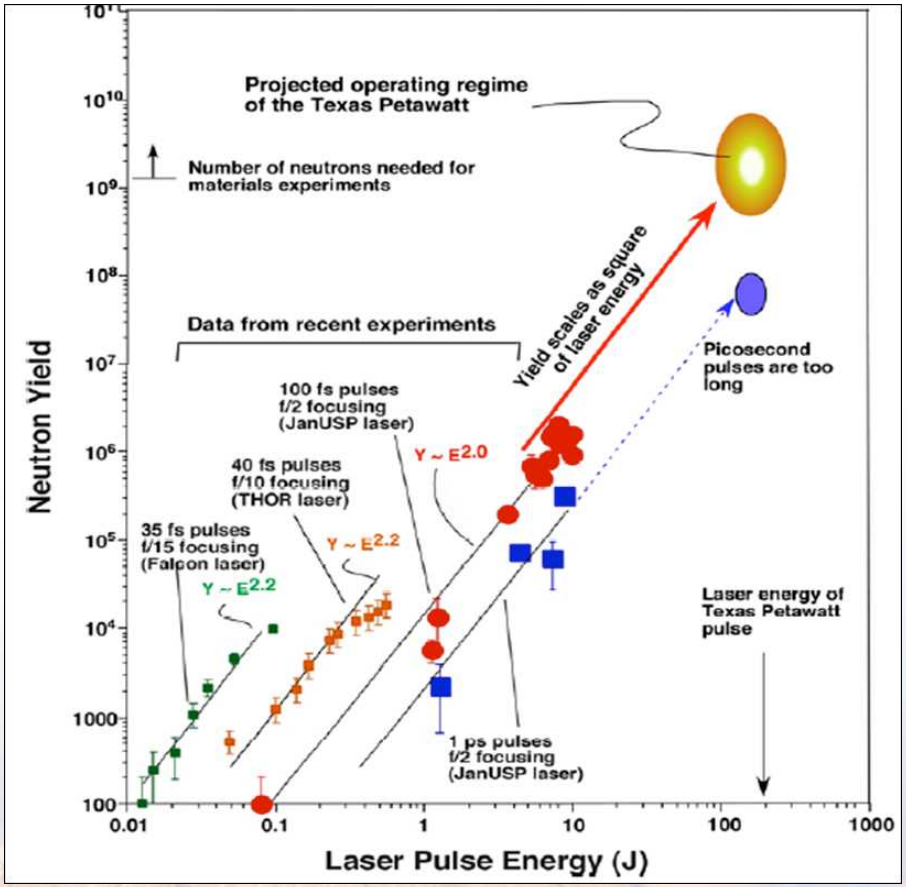


Cluster Experiments on the Thor laser



Deuterium Cluster Fusion Results

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



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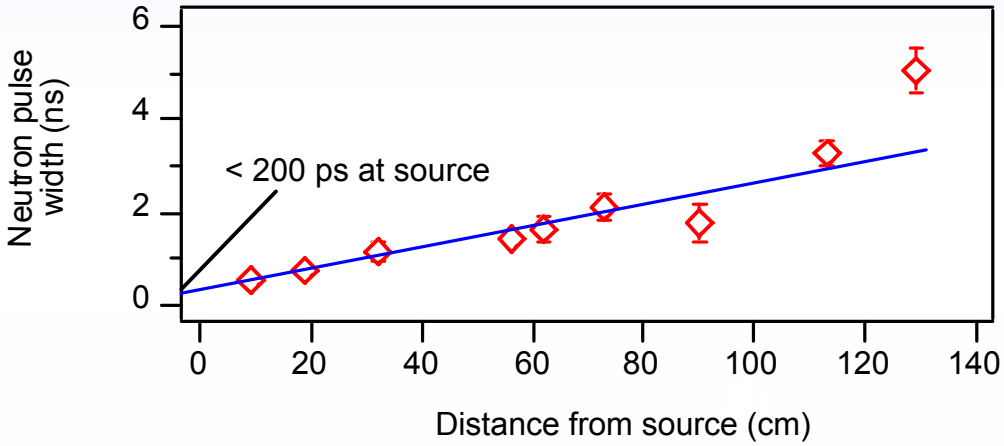
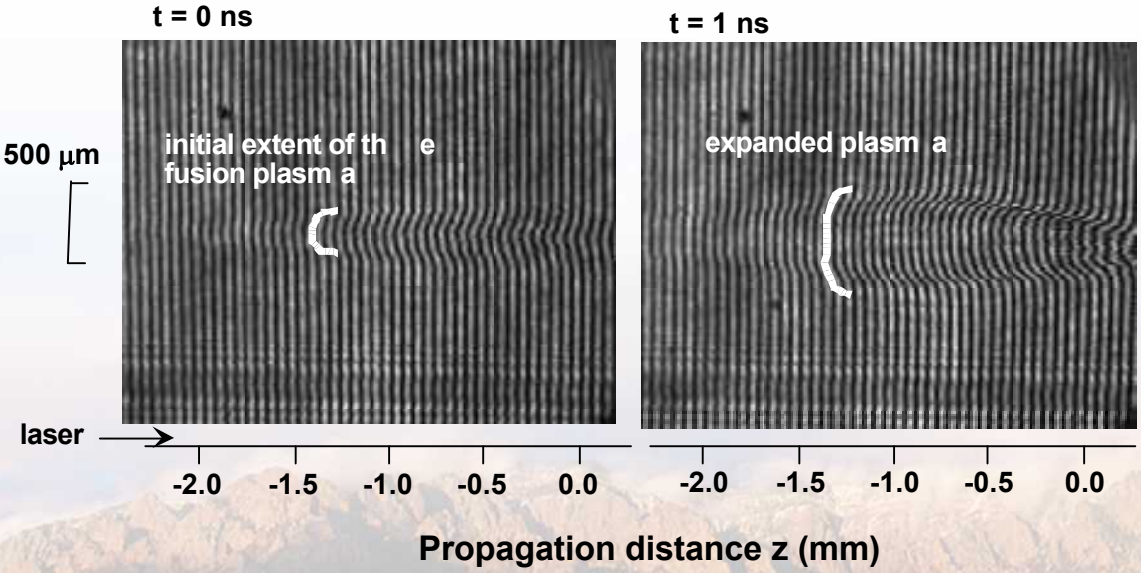
But Cluster Fusion burn time is very short!





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

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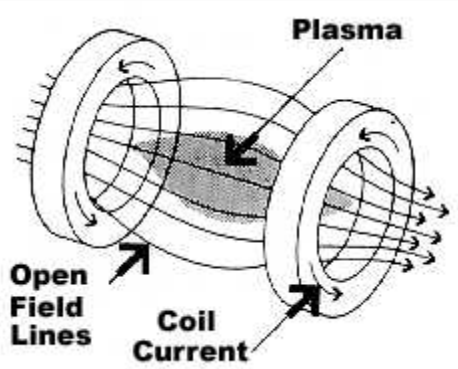
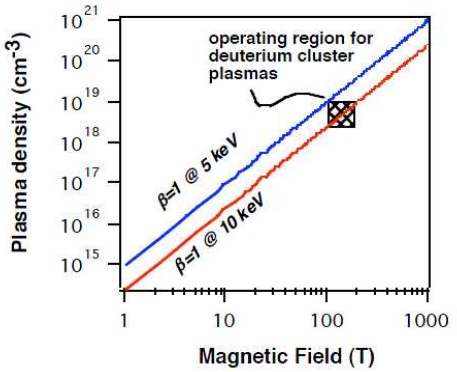
Trap the Plasma in a Magnetic Field!

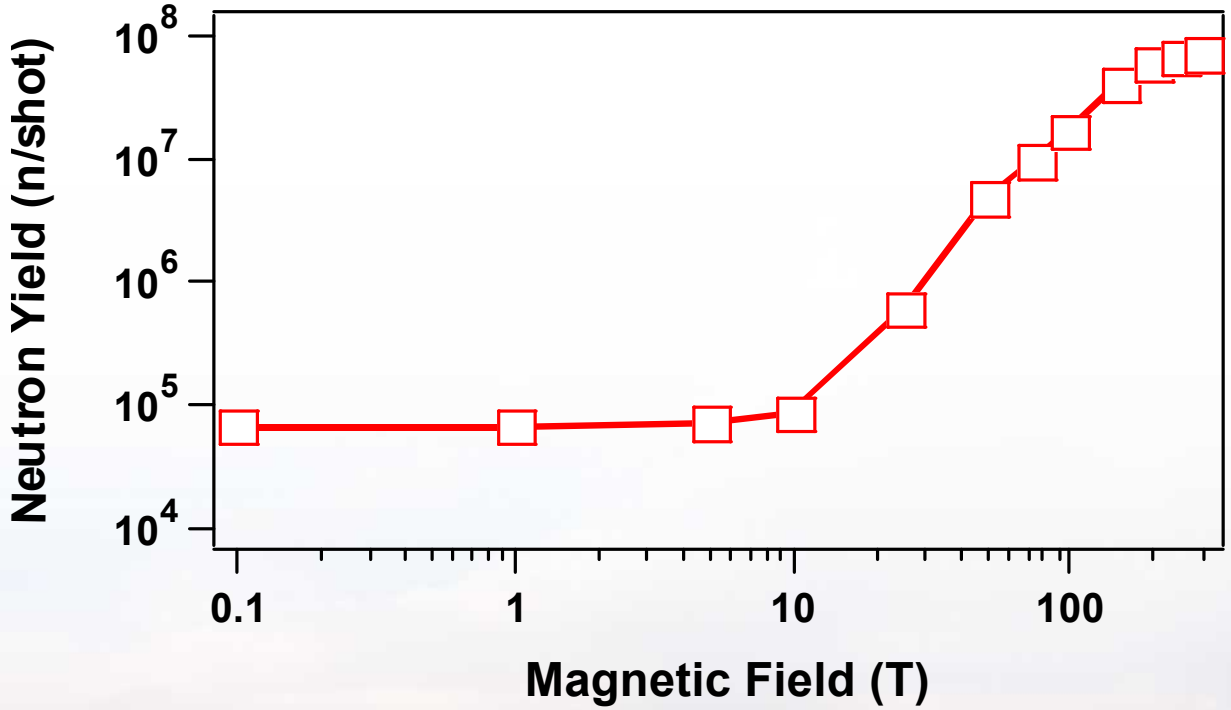
- Need 200 Tesla Magnetic Field to radially confine Plasma and increase fusion time
- Such fields possible for short times of Microseconds in small exploding coils with MegaAmp currents
- Sandia wields expertise in pulsed power systems and collaborates with UT-Austin on this experiment to supply the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



Magnetic Mirror



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



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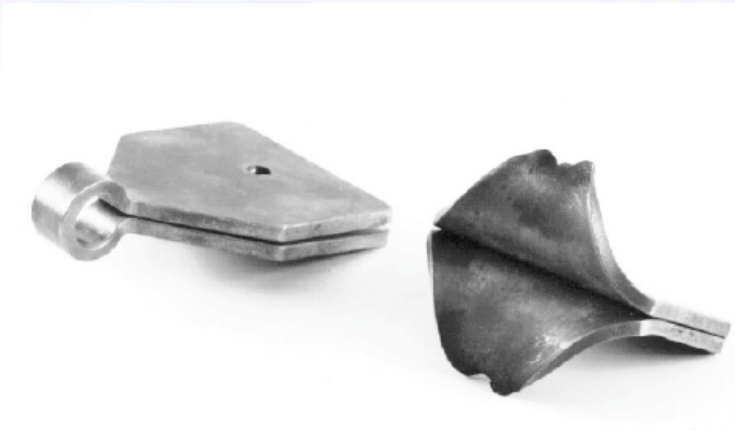
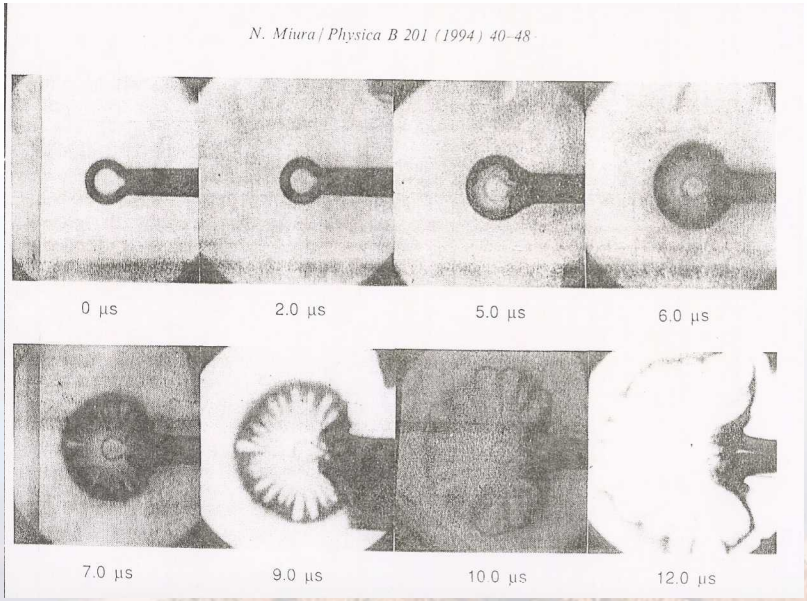
Single-Turn MegaGauss Field Driver at LANL

Before

After





Chuck Mielke, National High Magnetic Field Laboratory, LANL

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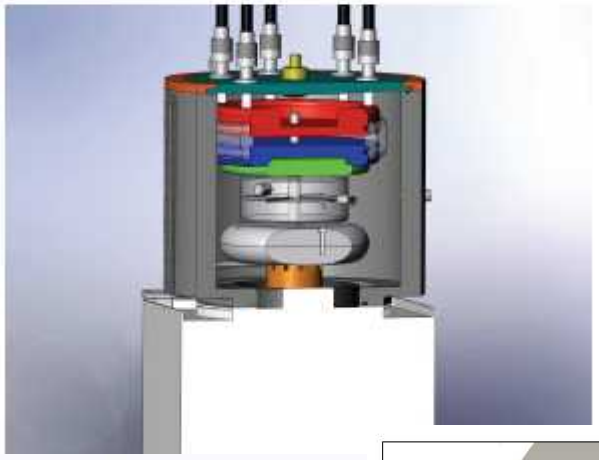
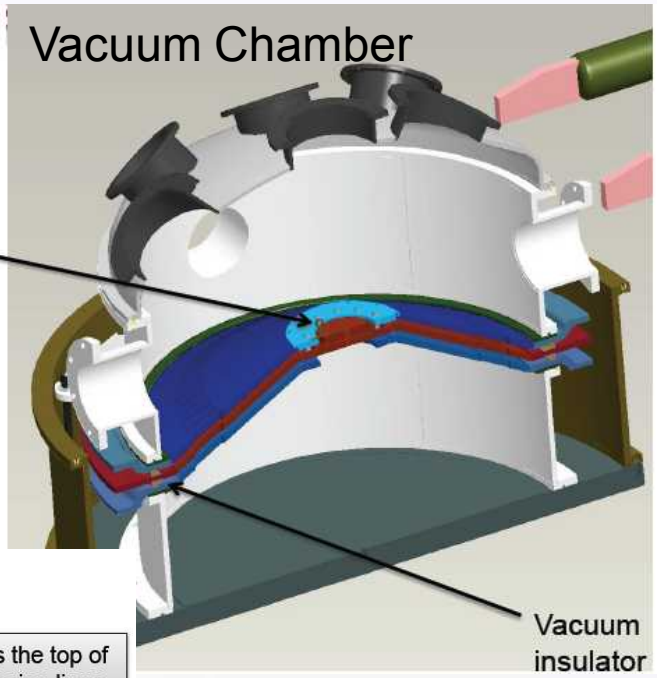
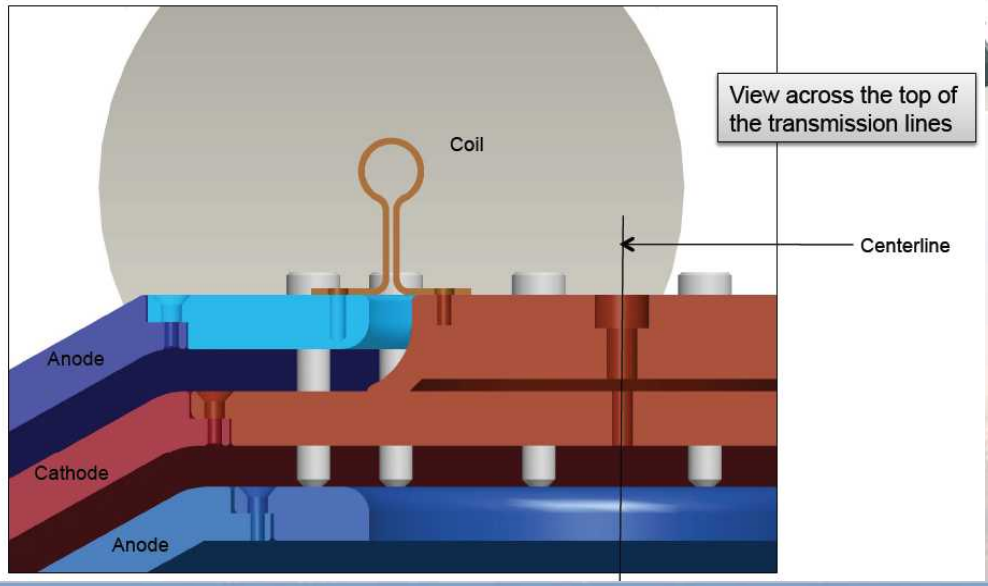
Sandia's 200T Pulser Design

L3 Communications 40364
(Marx trigger generator switch)





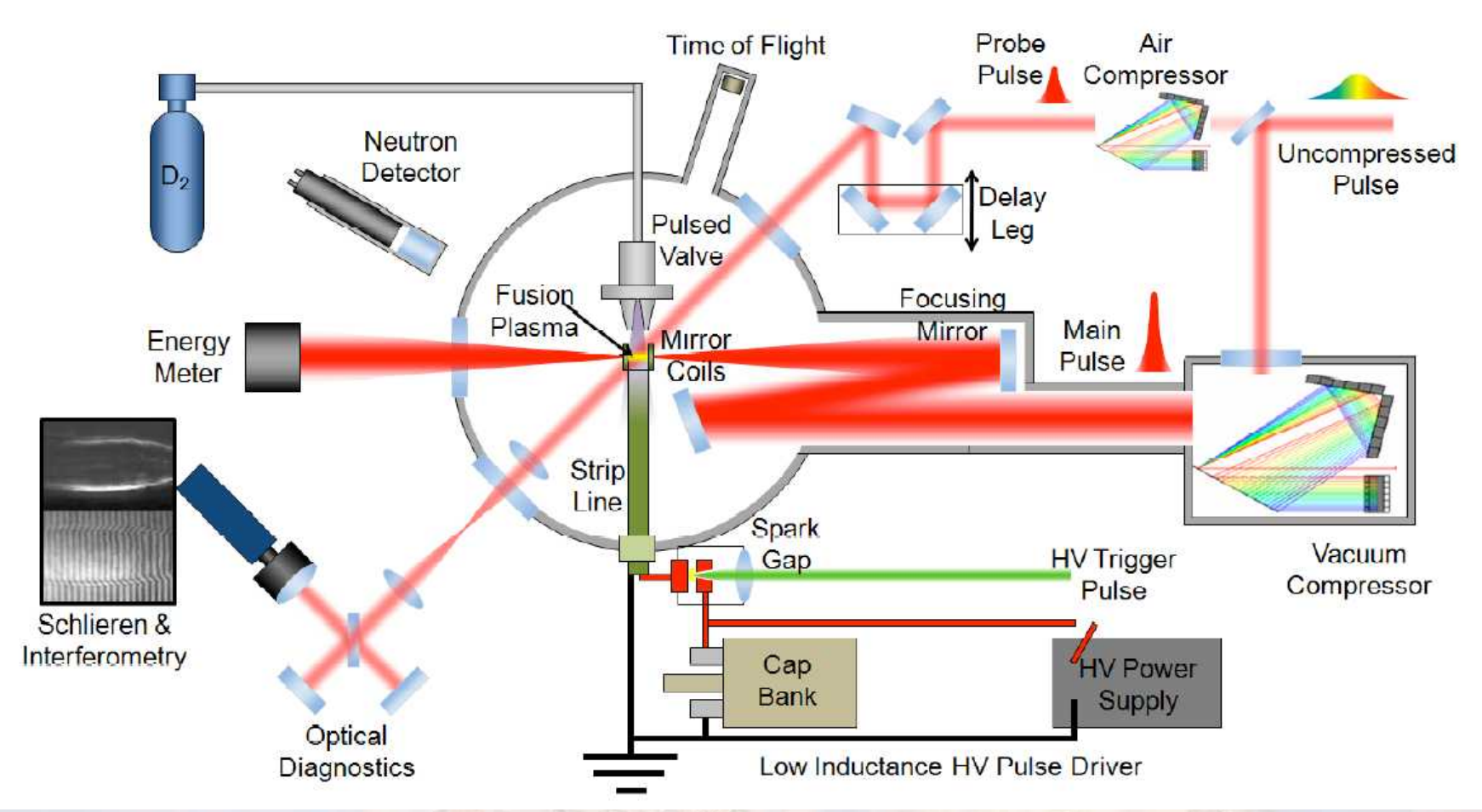


Ladder of Time Scales

- 15 Femtosec 10^-14 s
- Picosec 10^-12 s
- 200 Picosecs 2E-10s
- 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

- Laser pulse duration of Texas Petawatt
- Hot electrons ejected from D Clusters
- Coulomb explosion of D Clusters creates plasma, Ions achieve energies of ~10KeV 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 cold deuterium cluster gas 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

  nσ product of density and confinement time (nσ units of s/cm^3)

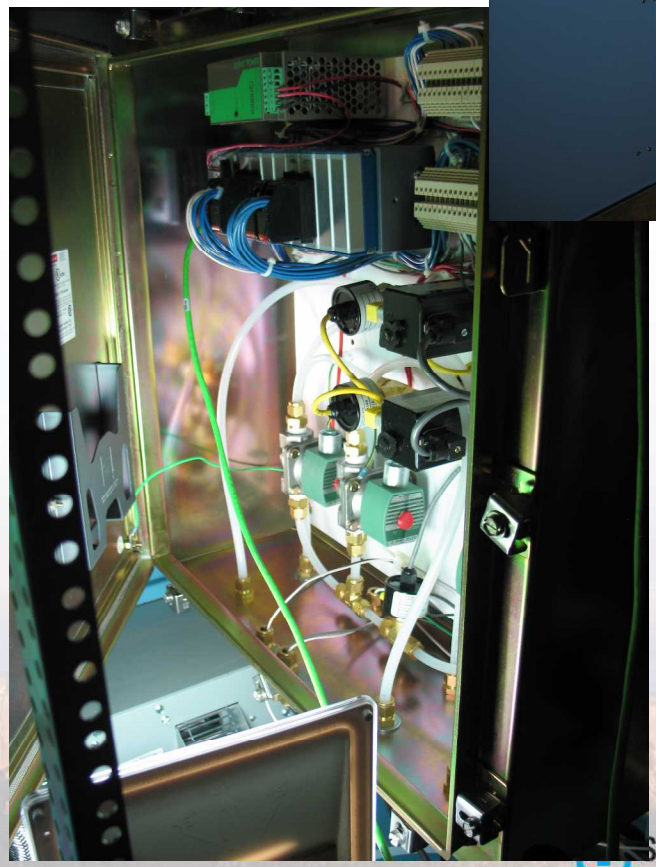
  ~10^14 for D-T, 10^16 for D-D

-Our nσ is ~10^11 for estimated 10ns burn at density 10^19/cm^3

-Very best case nσ ~10^13…

Current Status

- Version 1 of pulsed power supply is now at UT-Austin for coil testing
- 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

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