



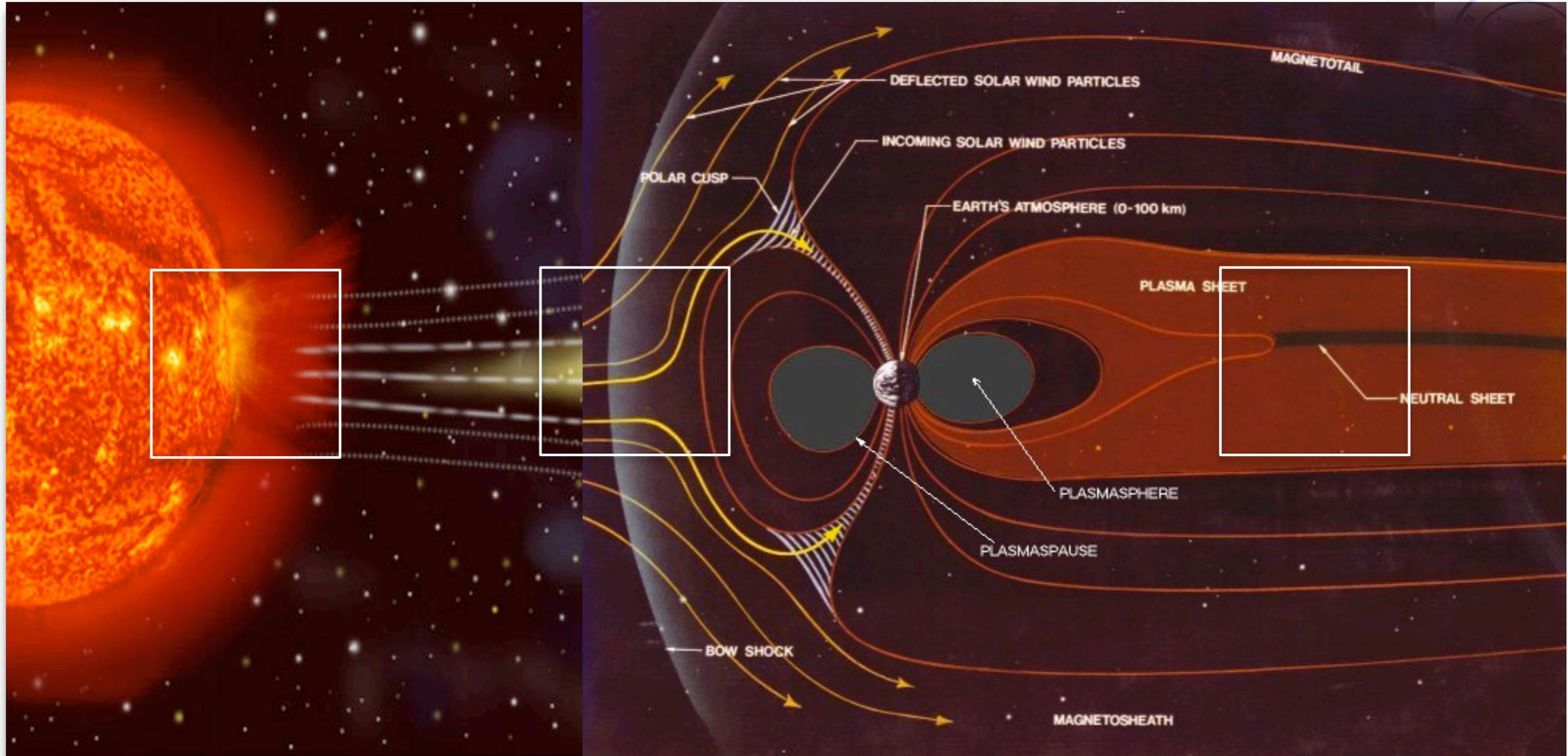


# Outline

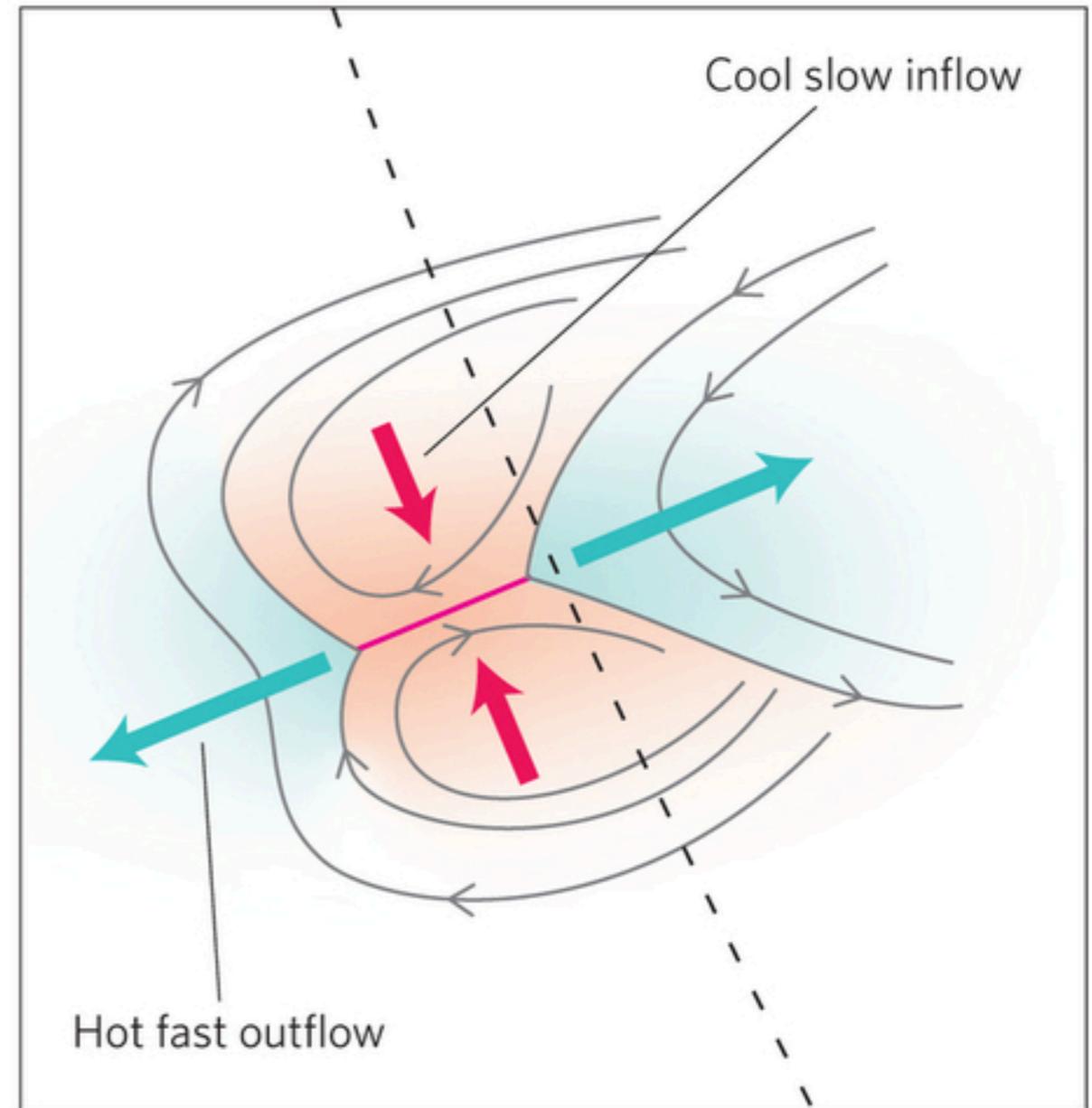
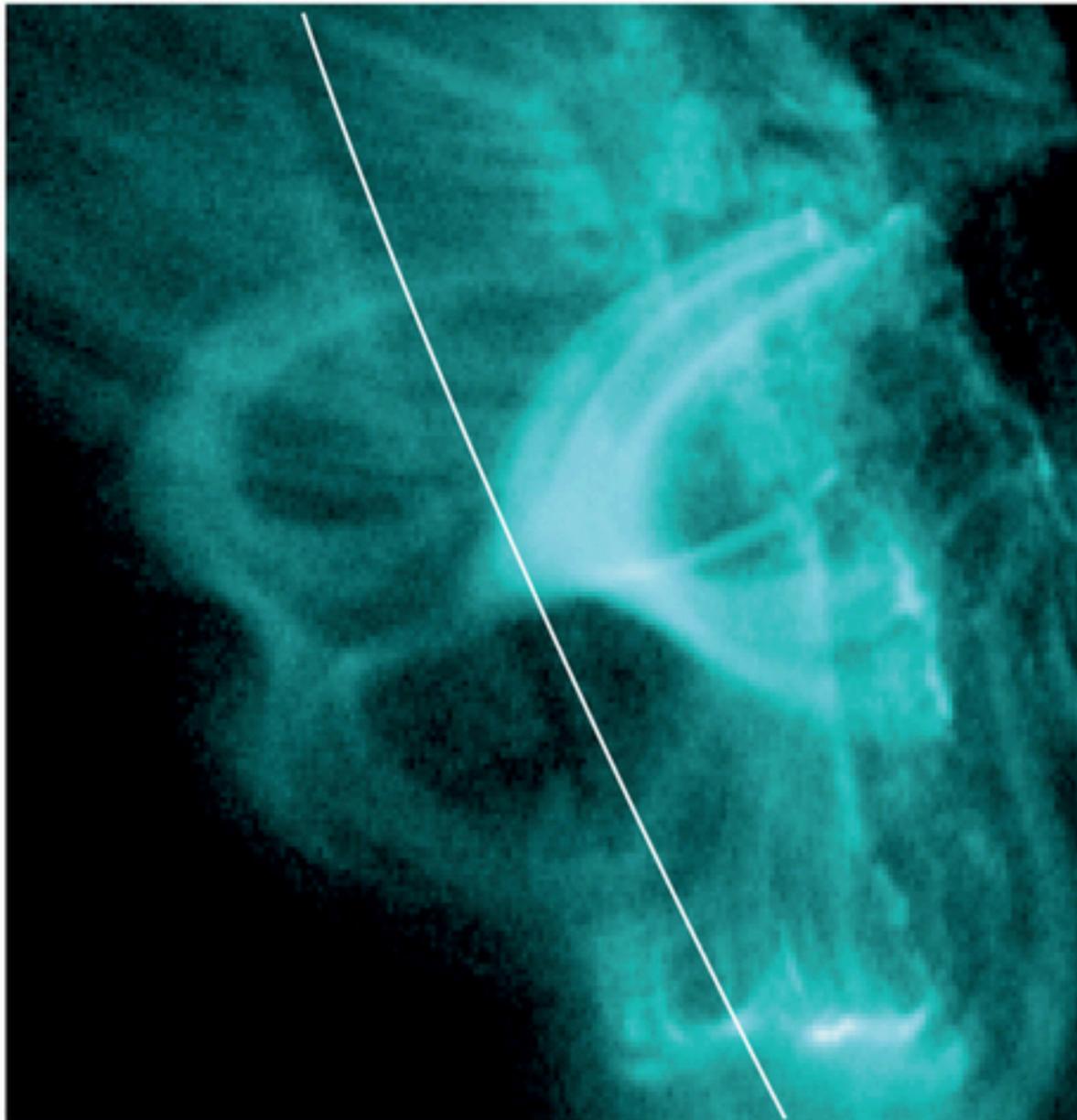
1. Magnetic reconnection Phenomena
2. Magnetic reconnection experiments on SGII
3. Opportunities for Laser driven reconnection
4. Summary

# 1. Magnetic reconnection Phenomena

- In solar flares and space environment



**Observations from NASA's Solar Dynamic Observatory provide compelling evidence for the central role of magnetic reconnection in solar flares.**



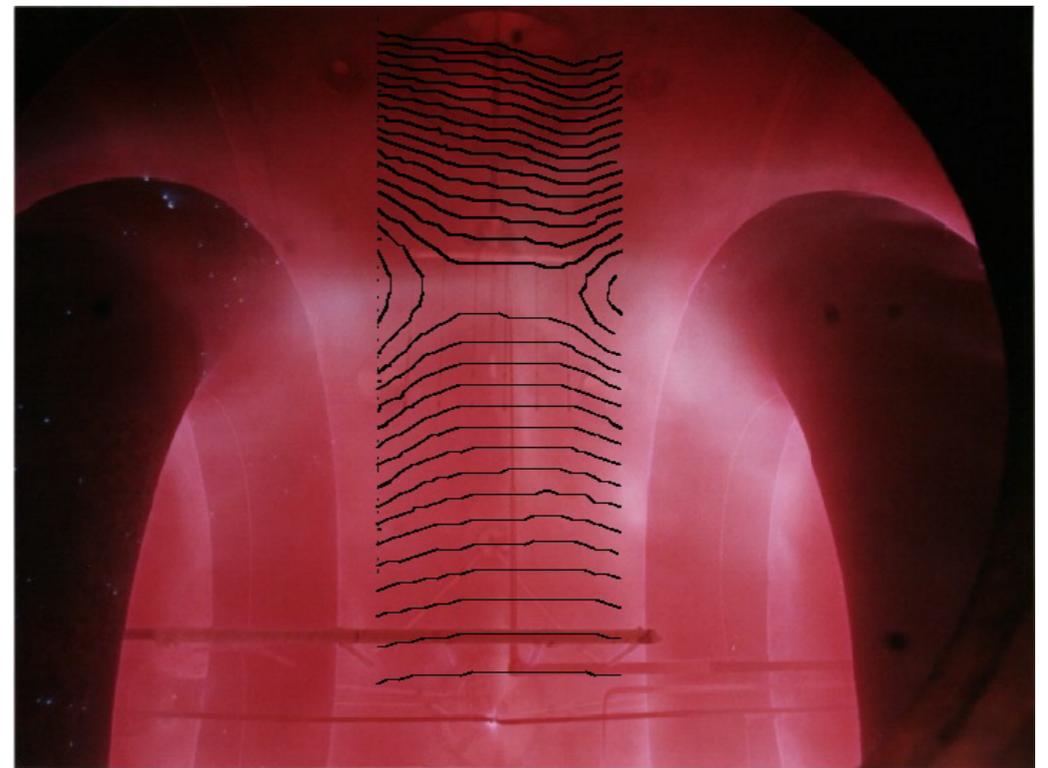
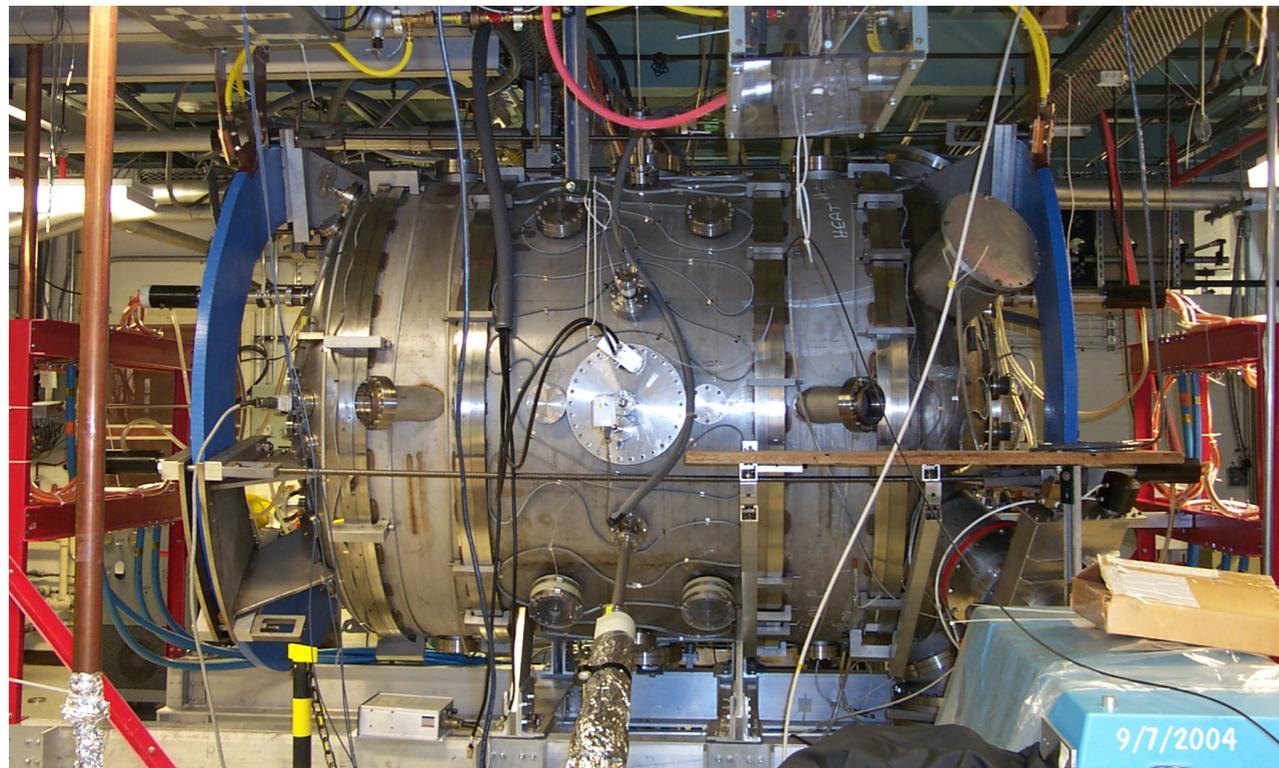
*Y. Su et al (2013)*

# Magnetic reconnection Phenomena

## - In Lab plasmas



### *Magnetically driven systems*



*MRX at Princeton for reconnection studies*

**$n_e = 1-10 \times 10^{13} \text{ cm}^{-3}$ ,  $T_e \sim 5-15 \text{ eV}$ ,  $B \sim 100-500 \text{ G}$**

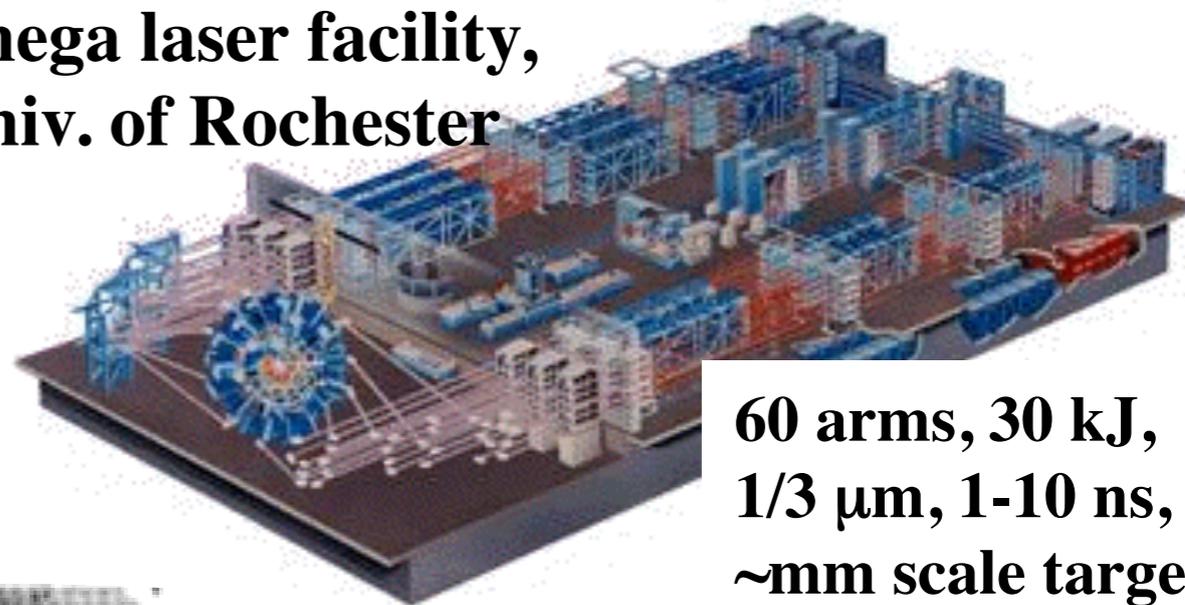
# Magnetic reconnection Phenomena

## - In Lab plasmas



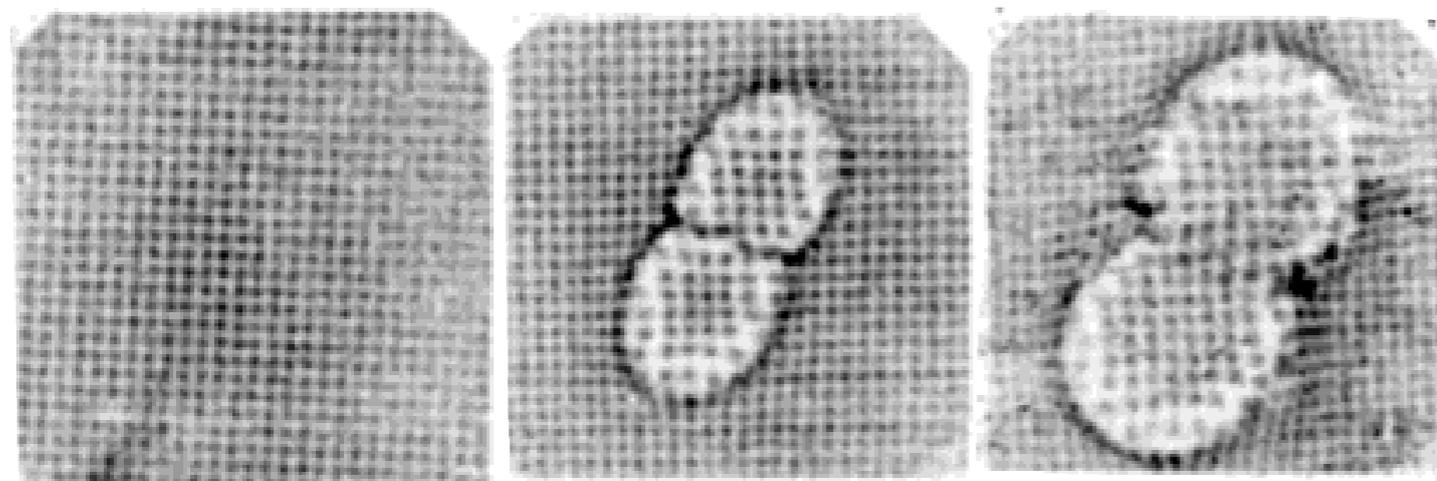
*Flow driven systems*

**Omega laser facility,  
Univ. of Rochester**



**60 arms, 30 kJ,  
1/3  $\mu\text{m}$ , 1-10 ns,  
 $\sim\text{mm}$  scale targets  
( $E/V \sim 10^{14}$  erg/cm<sup>3</sup>)**

Laser on from 0 – 1 ns

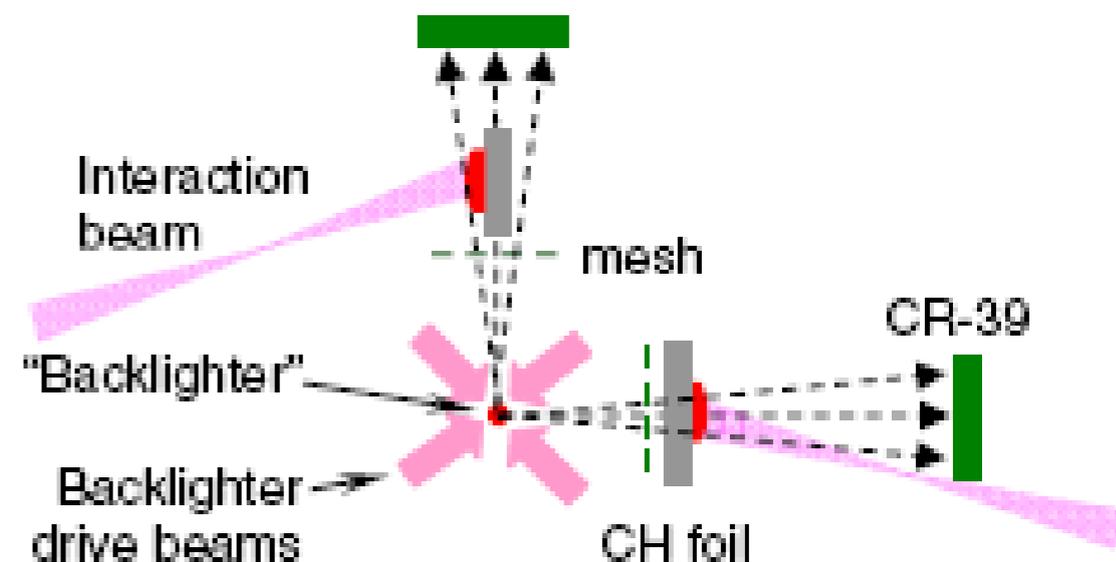


**0.04 ns**

**0.67 ns**

**1.42 ns**

C. K. Li et al. (2007)



## 2. Magnetic reconnection experiments on SGII



- What is SGII



SG II Lasers

Beams: 8

Pulse: 1 ns

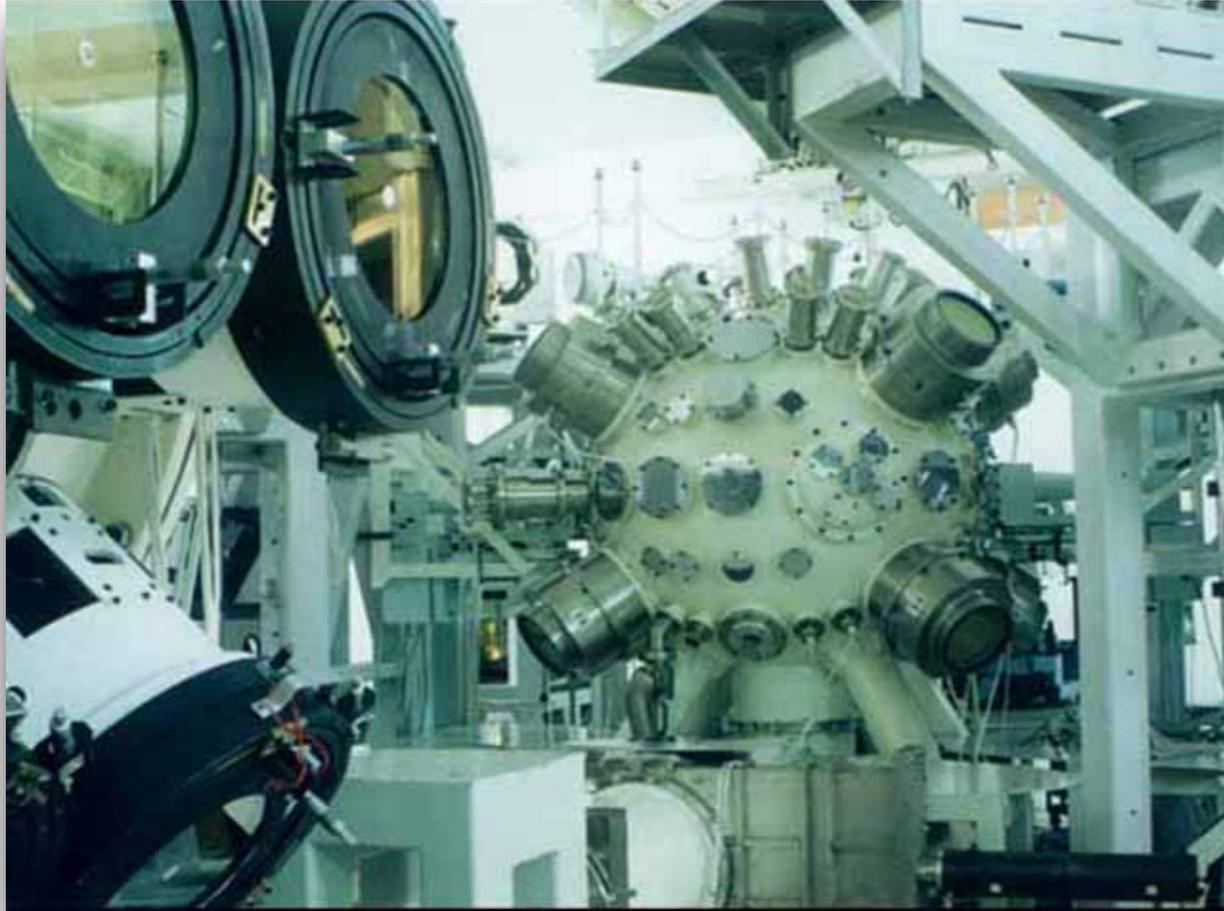
Energy: 260 J/beam for  $3\omega$

Focus spot: 50-100  $\mu\text{m}$

Intensity:  $1-5 \times 10^{15} \text{ W/cm}^2$

**$n_e = 1-10 \times 10^{19} \text{ cm}^{-3}$ ,  $T_e \sim 1 \text{ keV}$ ,  $B \sim 10^6 \text{ G}$**

- What is SGII



Diagnostics:

X-rays: **pinhole**, framing,...

Optical devices:

**shadowgraphy**,

Interferometry,

Faraday, ...

Particles: EMS, RCF...

- Like other Advanced HEDP Facilities: **NIF, OMEGA, Z, ... ..**
- SG II is used to study fusion, laboratory astrophysics, .....
- **In China, 20% shots of Shengguang II for each year are given for the study of Laboratory astrophysics**

# High energy density laboratory astrophysics (HEDLA)- similar with IPELS

**5th High Energy Density Laboratory Astrophysics**

**10th HEDLA Conference 2014**

**HEDLA 2014**  
10th International Conference on High Energy Density Laboratory Astrophysics  
12-16 May 2014  
Bordeaux (France)

**Web site**  
<http://hedla2014.sciencesconf.org>

**MEETING TOPICS**

- Plasma physics
- Stellar explosions
- Magnetized HED laboratory astrophysics
- Astrophysical disks, jets and outflows
- Stellar, solar and nuclear astrophysics
- Computations in HED physics
- Radiative hydrodynamics
- Warm dense matter

**Scientific Organisation Committee**

John Bally	Yutong Li
James Bailey	Roberto Mancini
Tony Bell	Mikhail Medvedev
Paul Bellan	Claire Michaut
Nancy Brickhouse	Peter Norreys
Serge Bouquet (co-chair)	Norimasa Ozaki
Andrea Ciardi	Tomasz Plewa
Werner Dappen	Marc Pound
Melissa Douglas	Thomas Ray
Paul Drake	Bruce Remington
Adam Frank	Steven Rose
Patrick Hartigan	Dongsu Ryu
John Hillier	Youichi Sakawa
Hantao Ji	Luis Silva
Michel Koenig	James Stone
Yasuhiro Kuramitsu	Hideaki Takabe
Carolyn Kuranz	Feilu Wang
George Kyrala	Michael Wiescher
Sergey Lebedev (Chair)	Robin Williams

**Local Organisation Committee**

Serge Bouquet (Chair)
Andrea Ciardi
Brigitte Flouret
Emmanuelle Lesage
Dominique Maillet
Claire Michaut
Denis Penninckx
Xavier Ribeyre
Valentine Wakelam

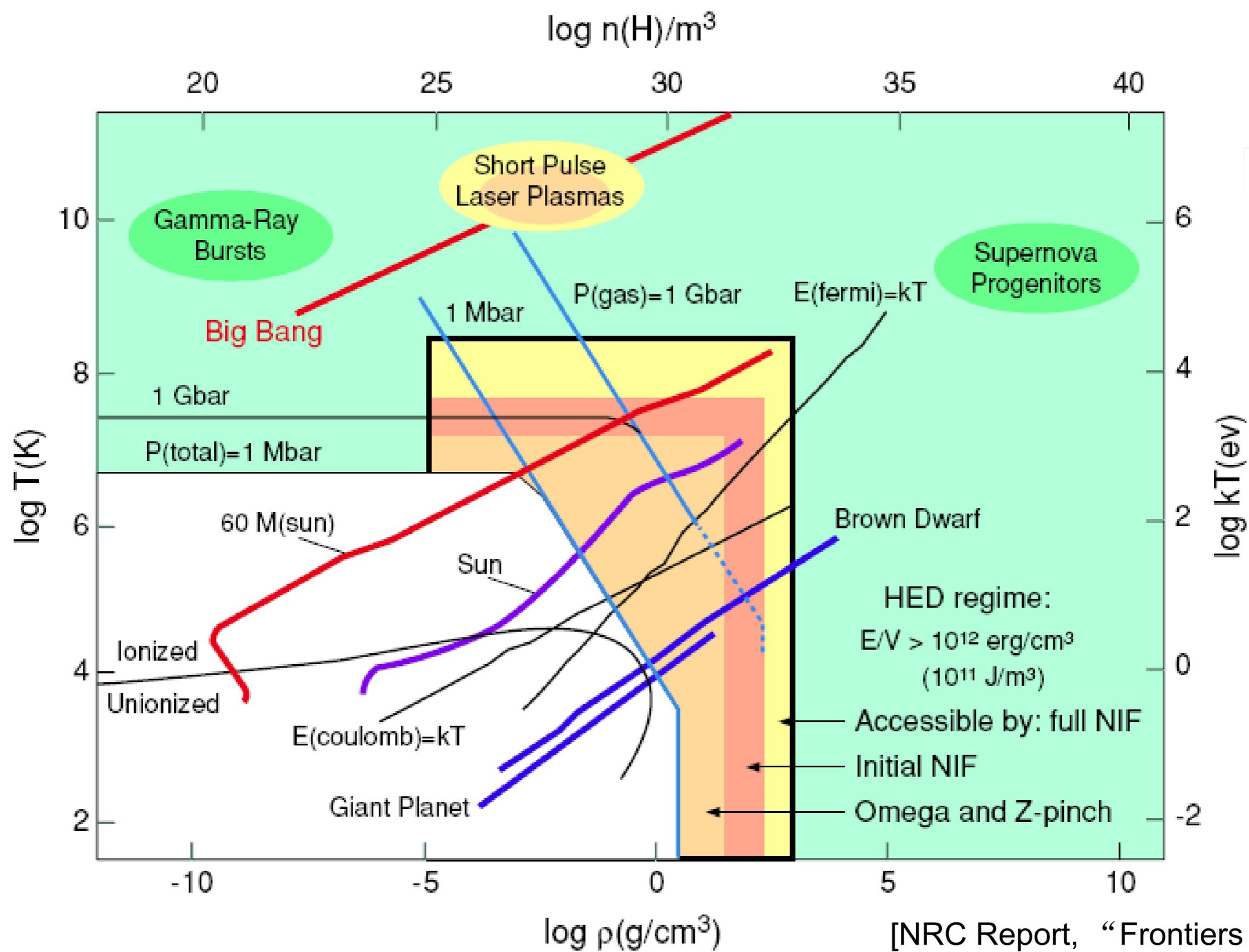
**Edison Liang**  
Rice University  
Dept. of Space Physics & Astronomy  
liang@space.rice.edu

**Conference Administrator**  
Umber Cantu  
Rice University  
umbc@rice.edu  
713.548.4826 (tel)  
713.548.5143 (fax)

**Edison Liang**  
Local Committee  
Rice University  
liang@space.rice.edu

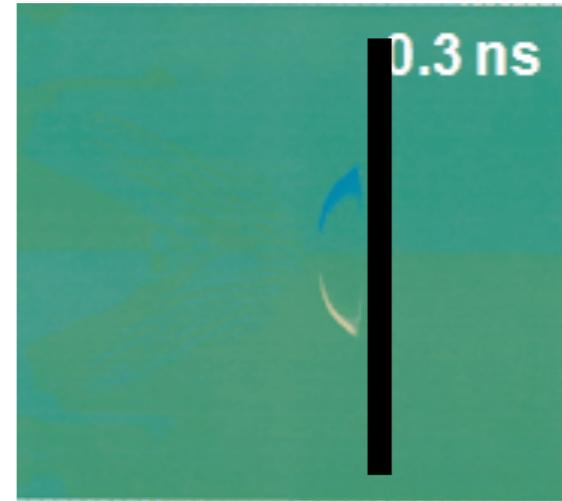
**George Kyrala**  
Program Chair  
LANL  
kyrala@lanl.gov

**Mercurio**  
HOTEL CENTRE



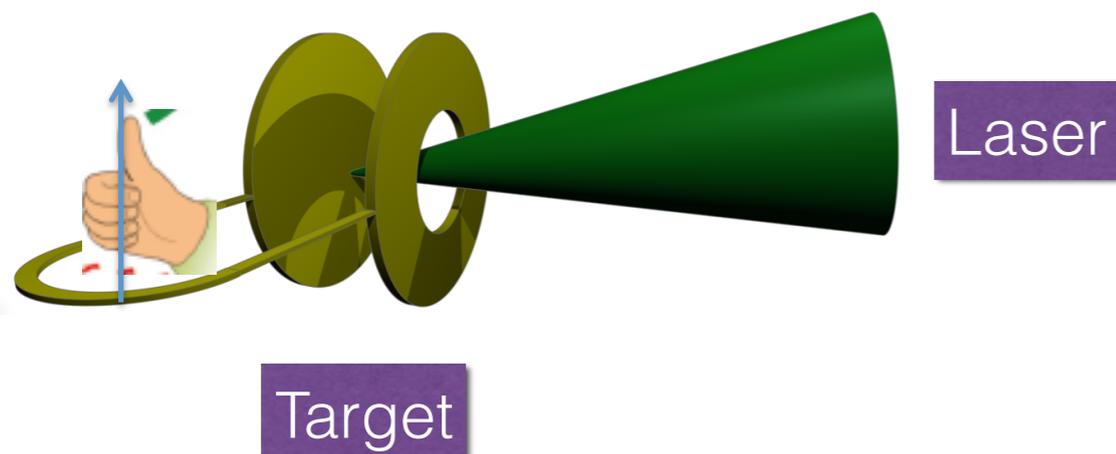
[NRC Report, "Frontiers in HEDP<sub>6</sub>"  
Ron Davidson et al. (2003), Fig. 1.1

# Magnetic field in ns laser plasmas



$$\frac{\partial \mathbf{B}}{\partial t} \approx -\frac{\nabla n_e \times \nabla T_e}{en_e} + \nabla \times (\mathbf{v} \times \mathbf{B}) - \nabla \times (D_m \nabla \times \mathbf{B}) + \frac{m_e}{e} \nabla \times \left[ \frac{\partial \mathbf{v}}{\partial t} + \mathbf{v} \nabla \mathbf{v} \right] - \frac{\nabla \times \mathbf{R}}{en_e} + \nabla \times \mathbf{Q} - \nabla \times \mathbf{G}$$

## Capacity mechanism



$$I(t) \propto \frac{T_h \log \left[ \frac{E_{laser}}{T_h^2} \right]}{n} \left( 1 - e^{-\frac{\eta t}{\mu}} \right)$$

$$B(t) \propto \frac{\mu_0 I(t)}{2a}$$



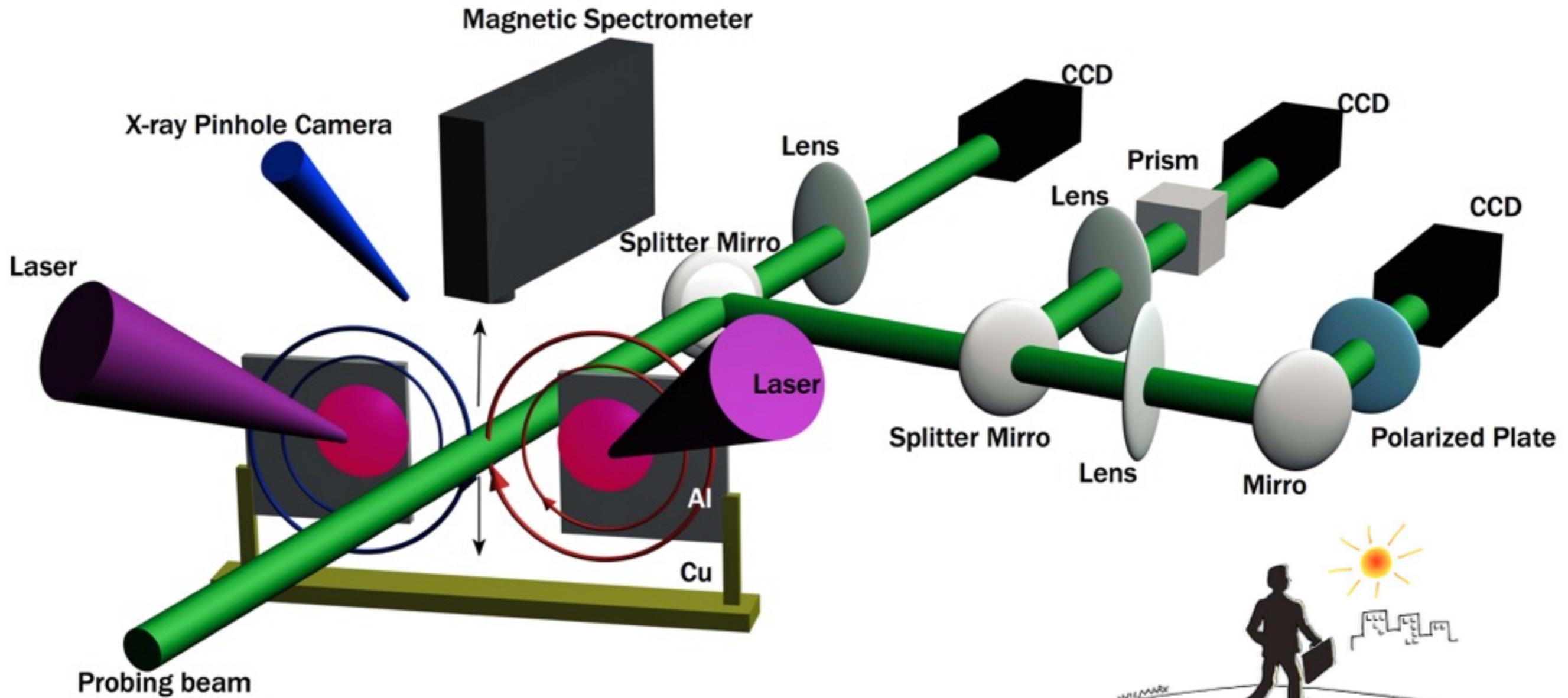
# Laser driven magnetic reconnection opens a new territory of study for magnetic reconnection in a parameter regime not covered before

Parameters	Laser-produced plasmas	Coil plasmas
Length (cm)	$10^{-1}$	$10^{-1}-1$
Time (s)	$10^{-9}$	$10^{-9}-10^{-8}$
Pressure (Pa)	$10^7$	
Density ( $\text{cm}^{-3}$ )	$\sim 10^{19}-10^{20}$	$< 10^{18}$
Velocity ( $\text{km s}^{-1}$ )	$\sim 100$	100-1,000
Magnetic field (G)	$\sim 10^6$	$10^{6-7}$

$$\beta = 4.03 \times 10^{-11} n T B^{-2} \quad 0.001-100$$



# Experiments on Laser-Flow driven MR



Experimental setup



# Experiments on Laser-Flow driven MR

## 1. Reconnection effects in hydro-interaction

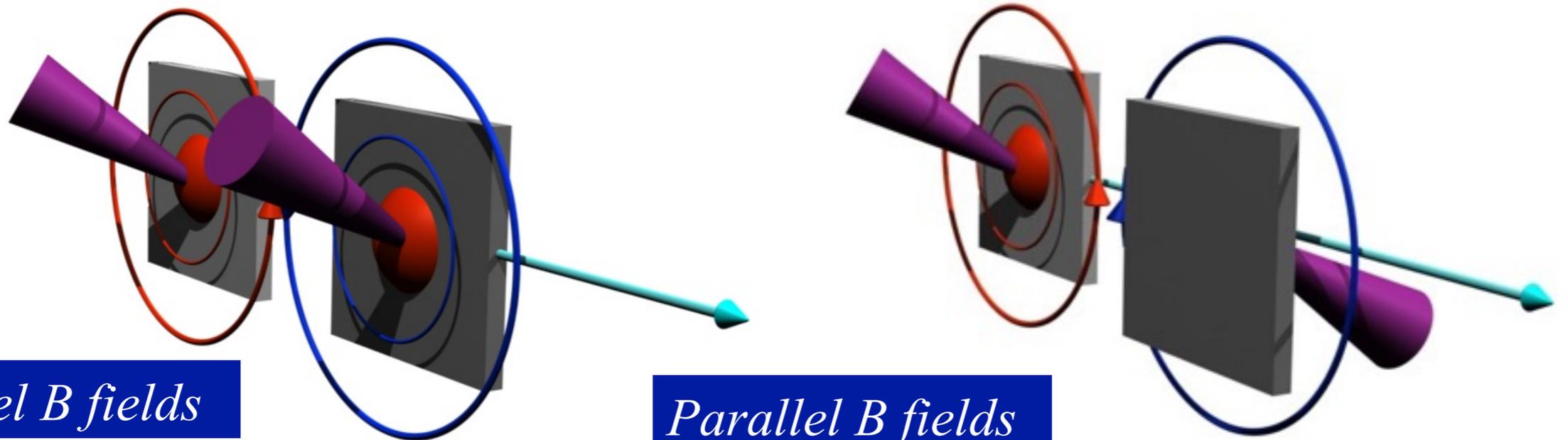


$$\rho \frac{du}{dt} = -\nabla \left( \frac{B^2}{2} + p \right) + B \cdot \nabla B$$

Magnetic repulsion

Hydro

Magnetic reconnection



*Anti-Parallel B fields*

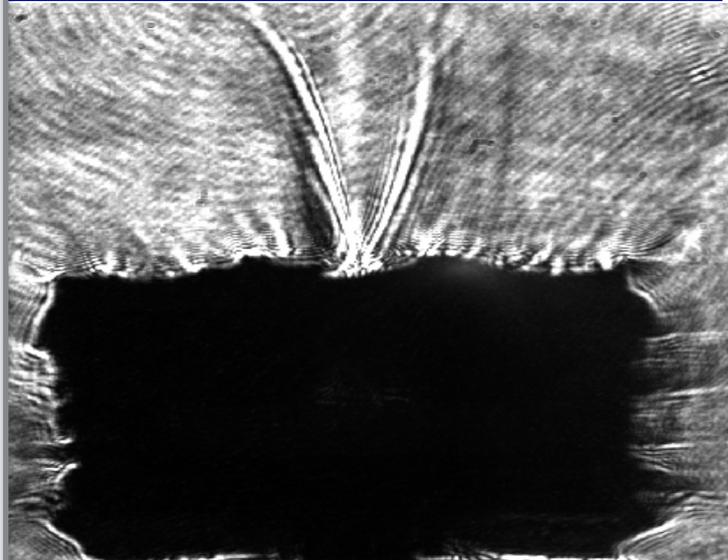
*Parallel B fields*

$$\rho \frac{du}{dt} = -\nabla \left( \frac{B^2}{2} + p \right) + B \cdot \nabla B$$

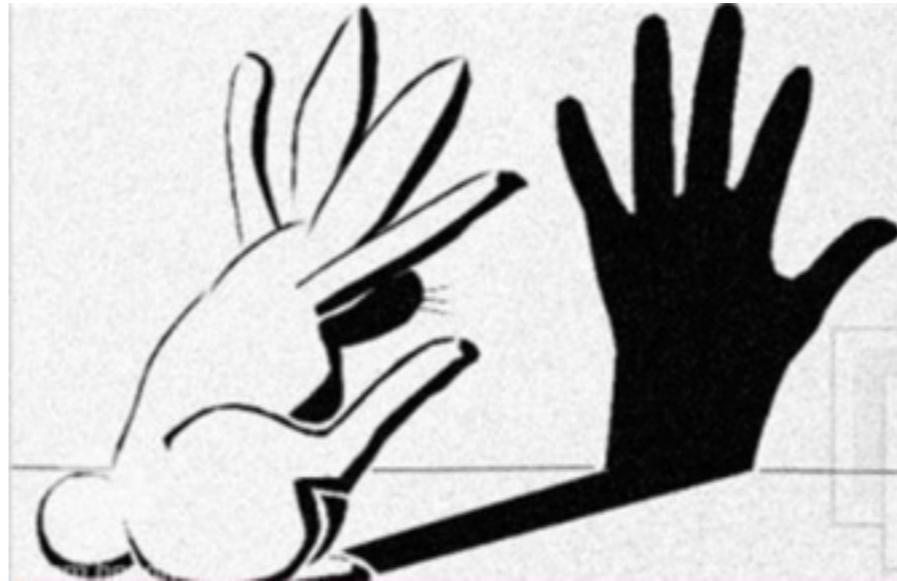
$$\rho \frac{du}{dt} = -\nabla \left( \frac{B^2}{2} + p \right)$$

The shadowgraph together with X-ray images show the topology of magnetic reconnection with laser driven flow plasmas, confirmed by MHD simulation.

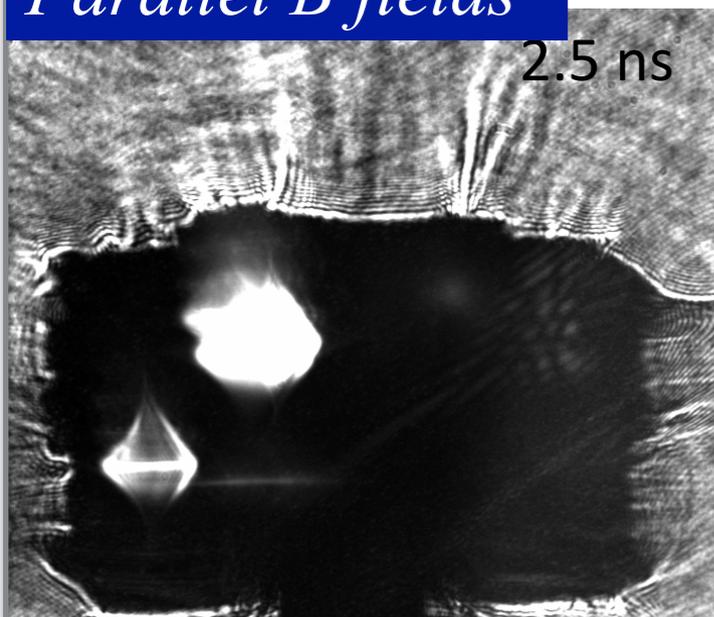
### *Anti-Parallel B fields*



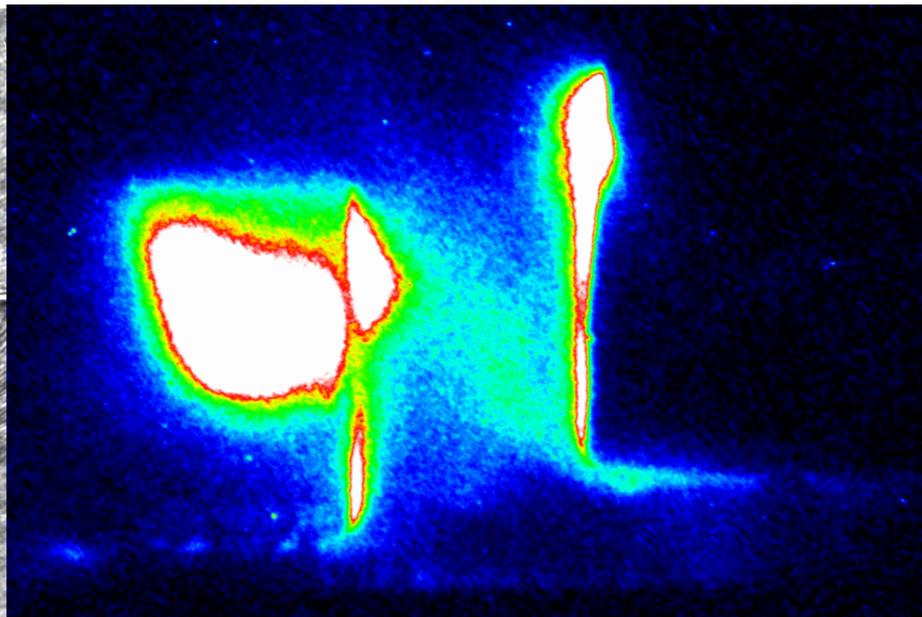
Optical shadows



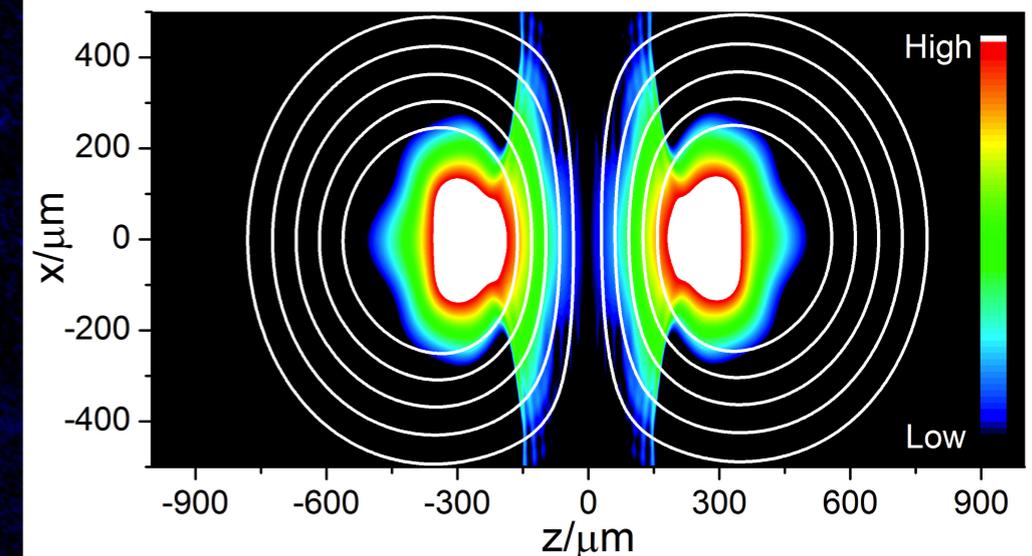
### *Parallel B fields*



Optical shadows



X-ray image

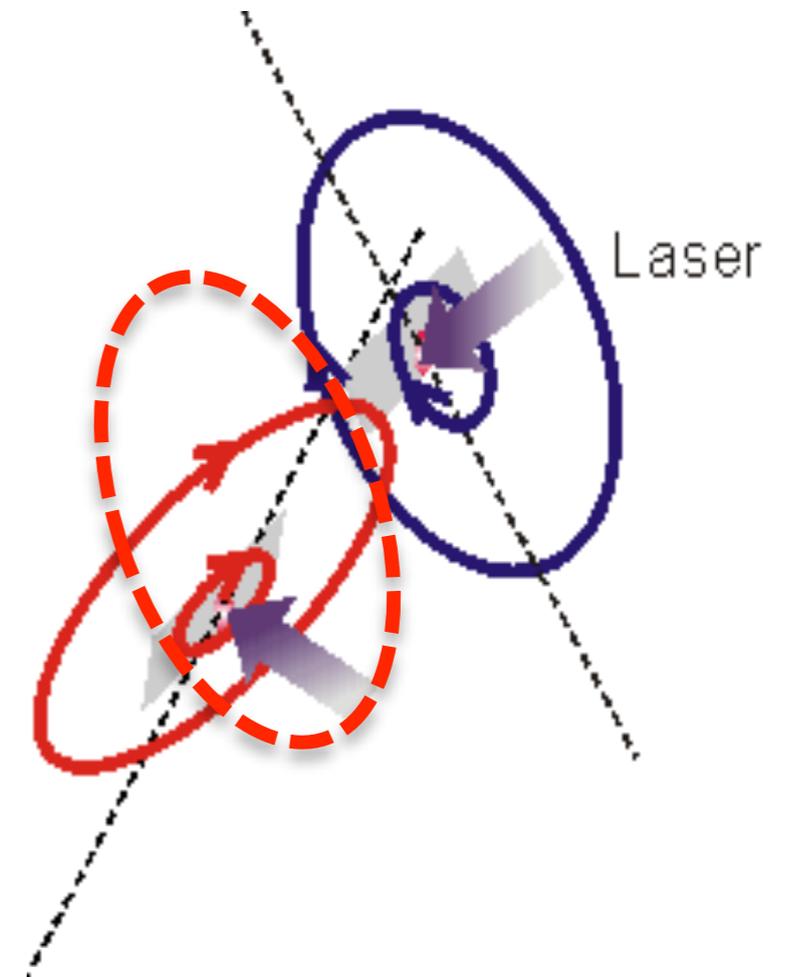
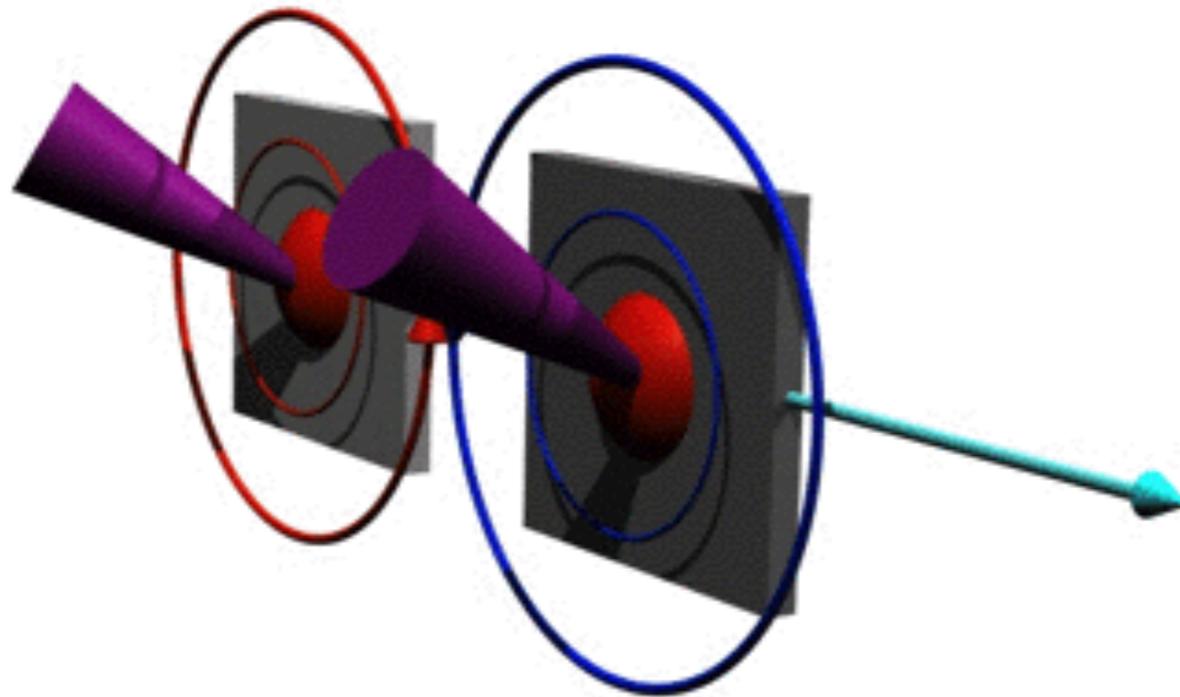


MHD simulation

# Experiments on Laser-Flow driven MR



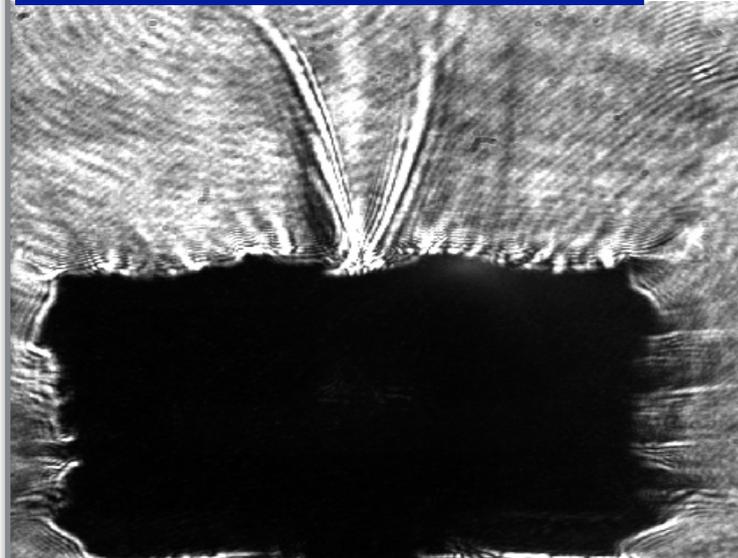
## 2. Reconnection effects for guide fields



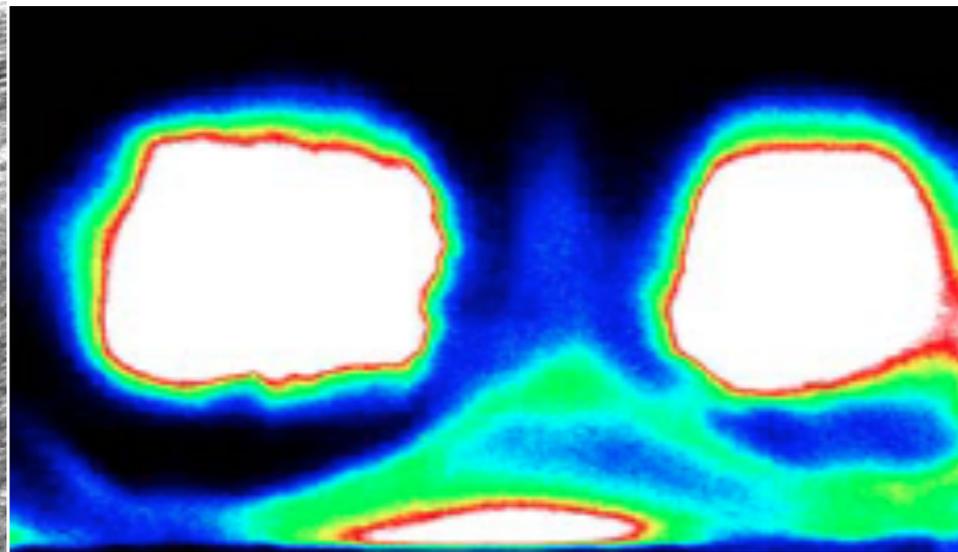
The toroidal magnetic field on the target will produce a magnetic field component at the reconnection plane which is similar provide an applied guide field with the level of the reconnection field.

Guide field do affect the reconnection both for the current sheet and outflows.

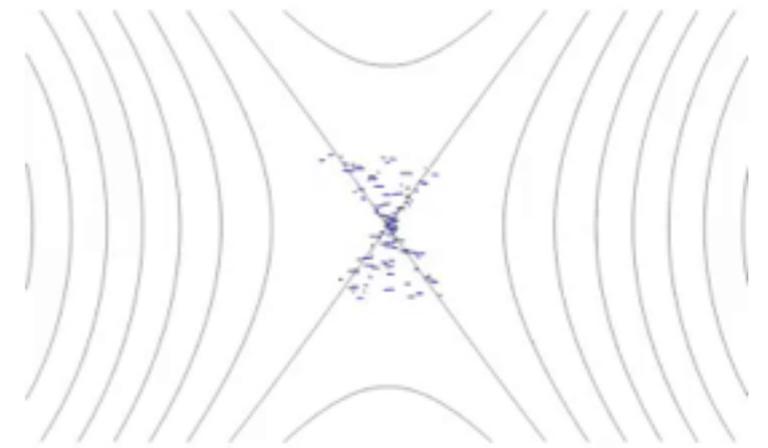
*Without guide field*



Optical shadows

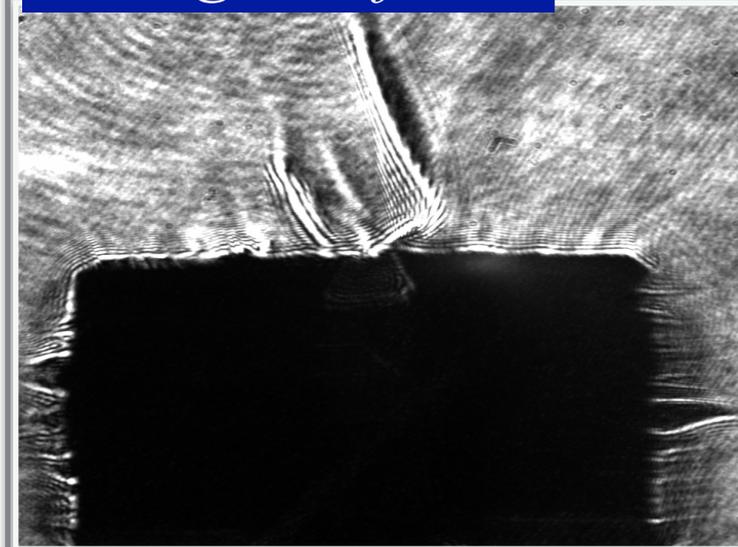


X-ray image

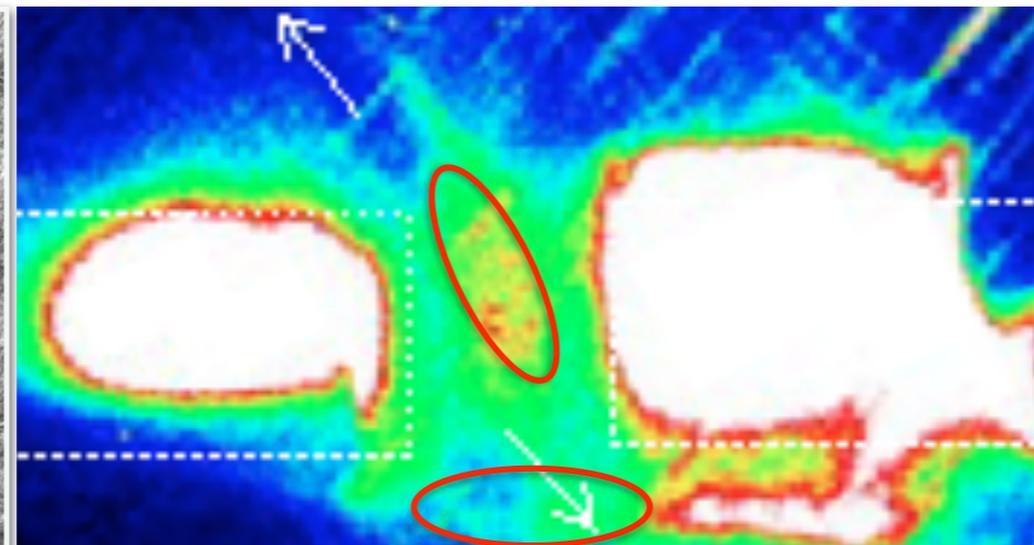


MHD +test particles simulation

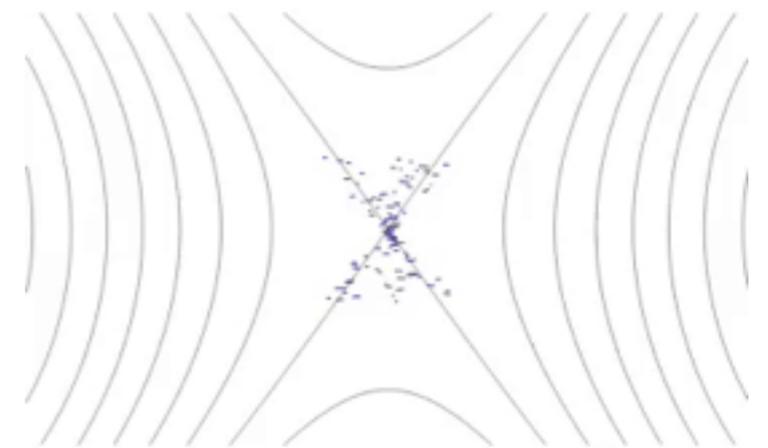
*With guide field*



Optical shadows

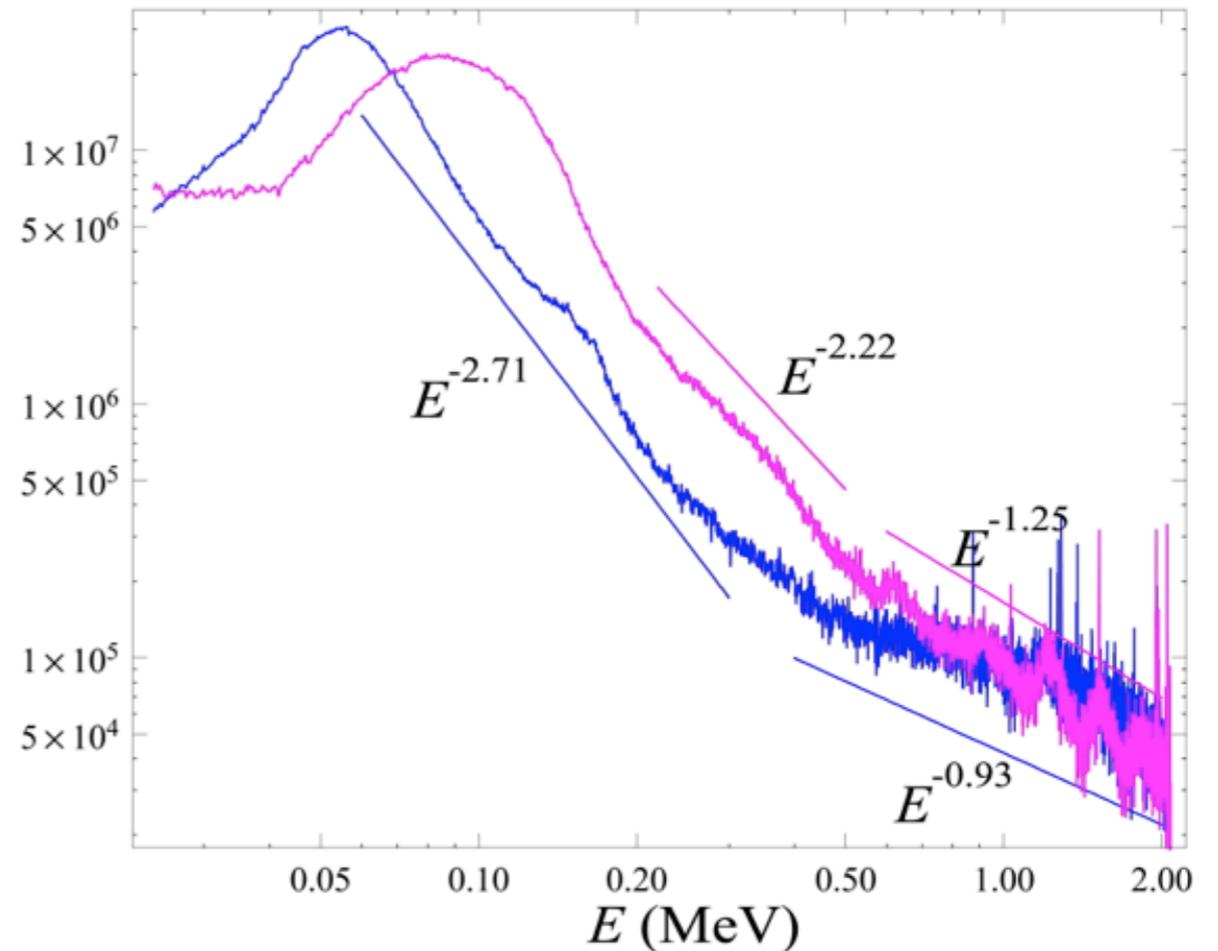
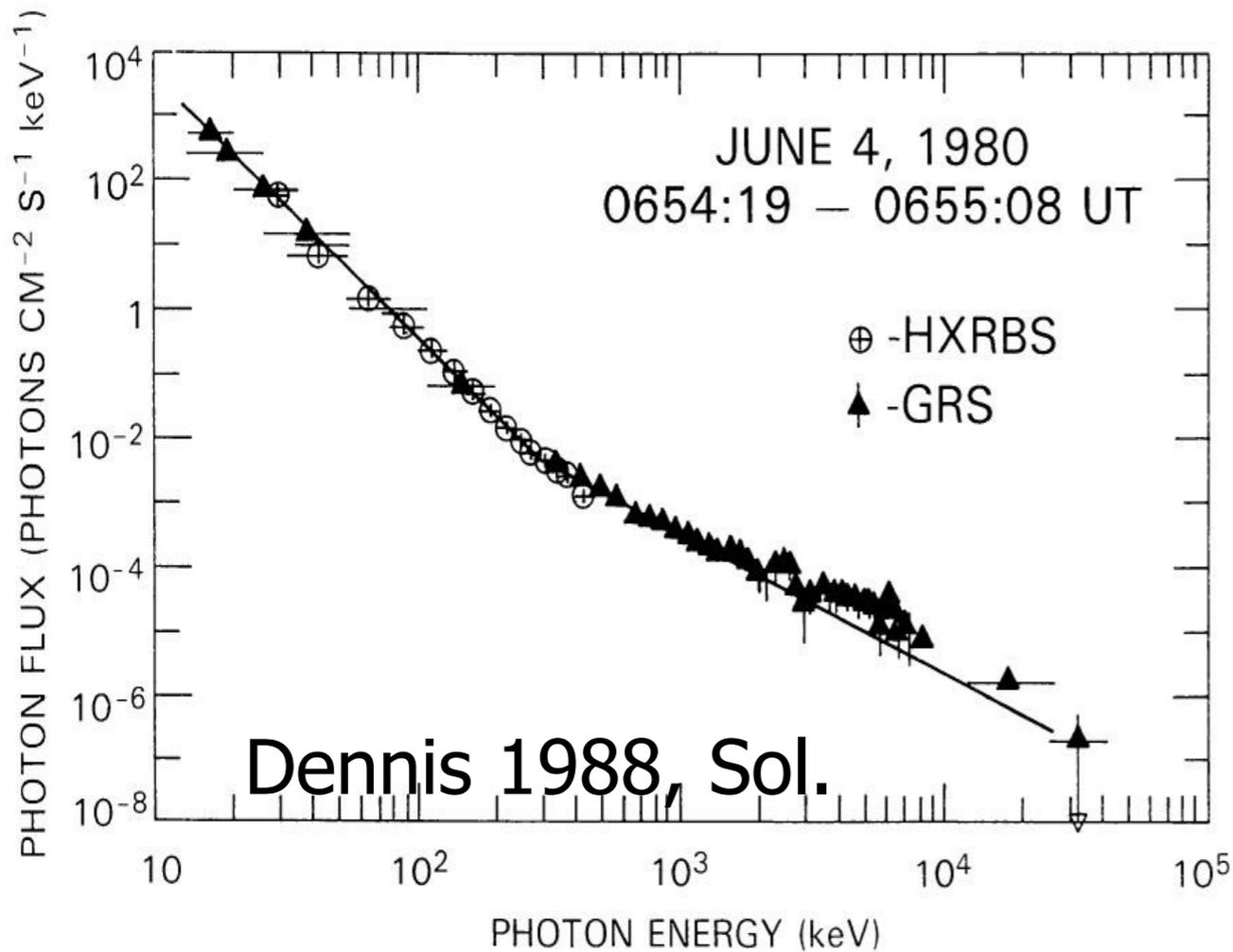


X-ray image



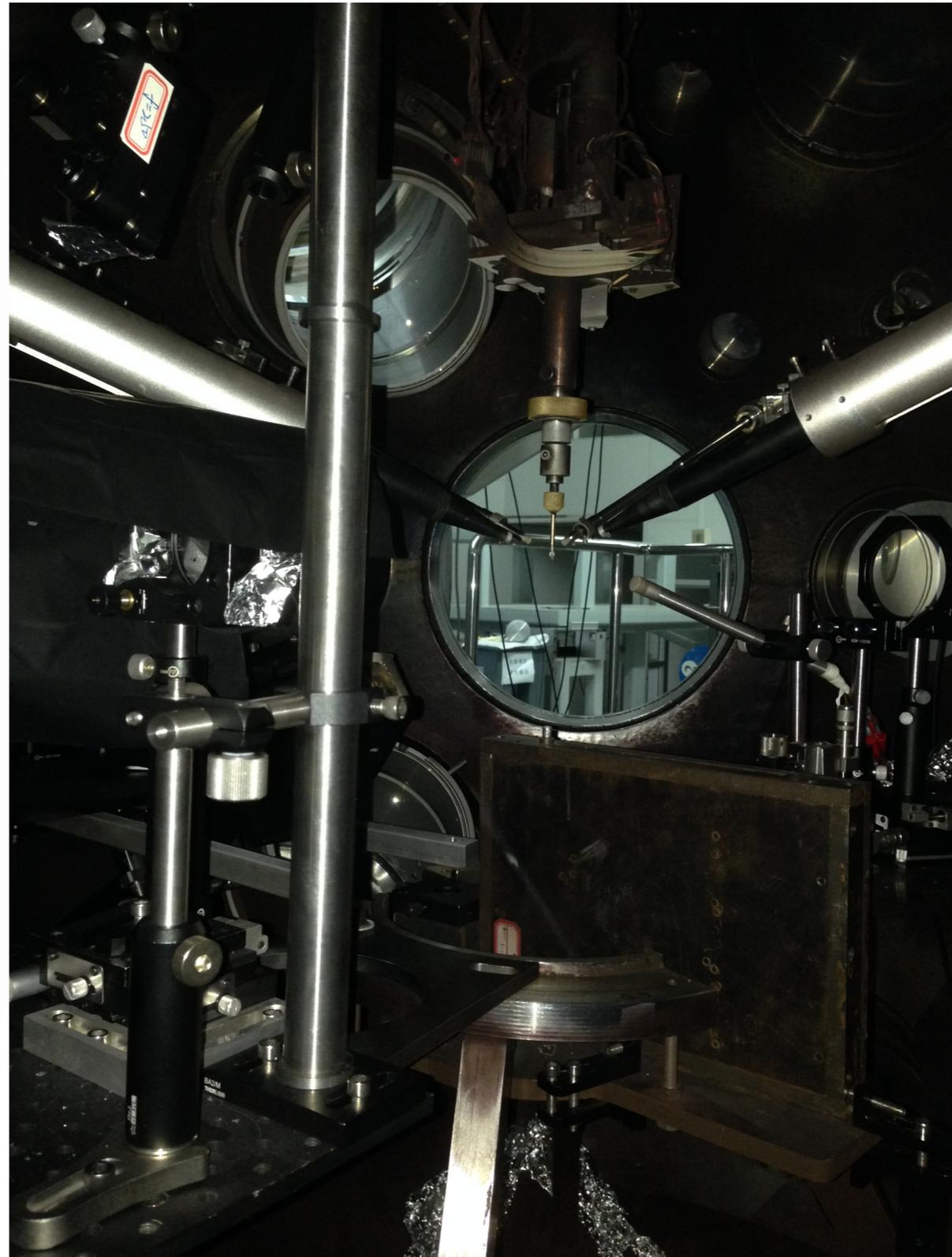
MHD +test particles simulation

The observed energy spectra of energetic electrons shows the similar distribution with the one observed in space plasmas.



The spectra are obviously of the so-called Kappa distribution that is quasi-Maxwellian at low and thermal energies, while its non-thermal tail decreases as a power law at high energies, as generally observed in space plasmas.

# Experiments on Laser-magnetically driven MR



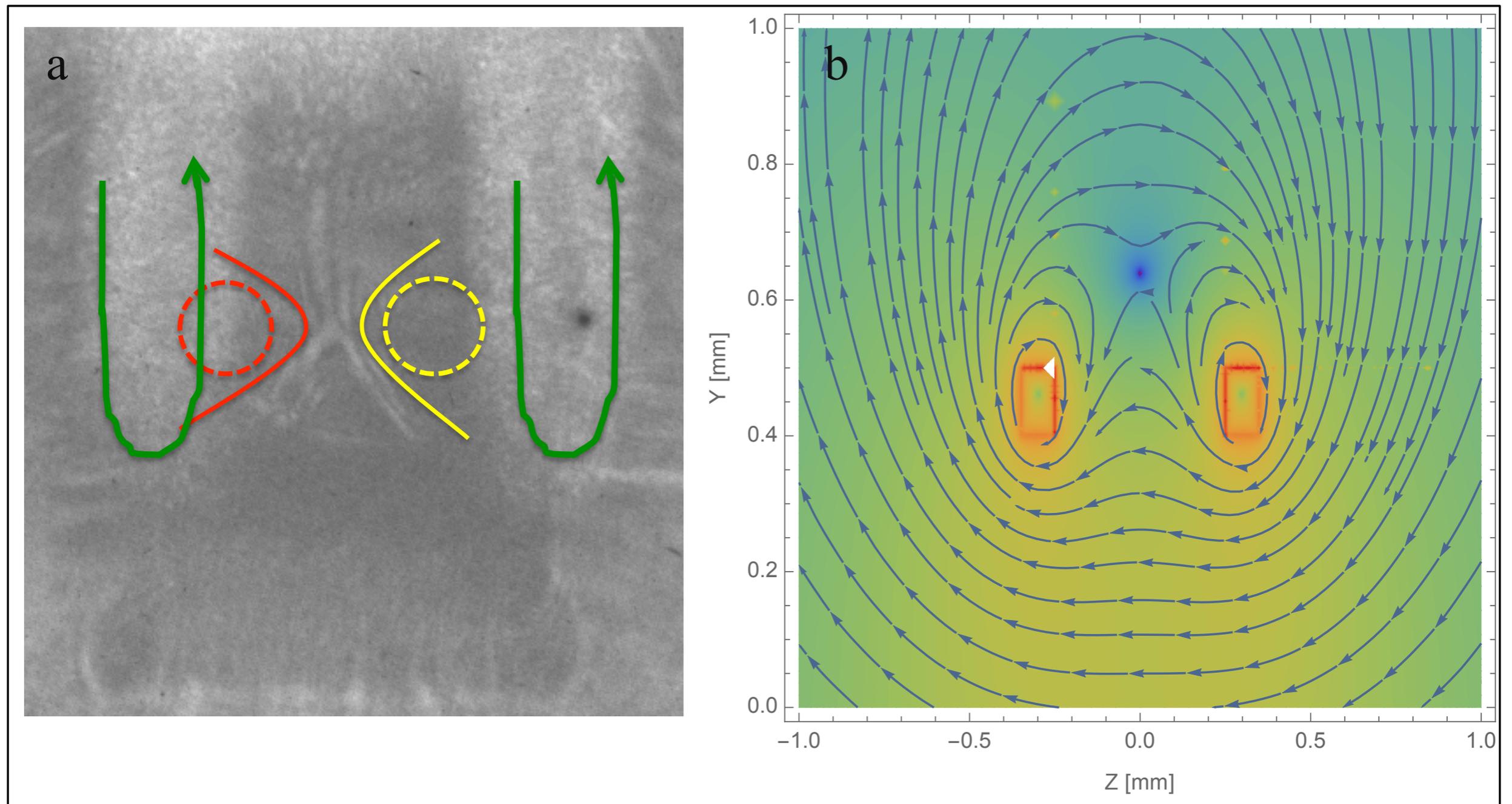
Side view



coils

Front view

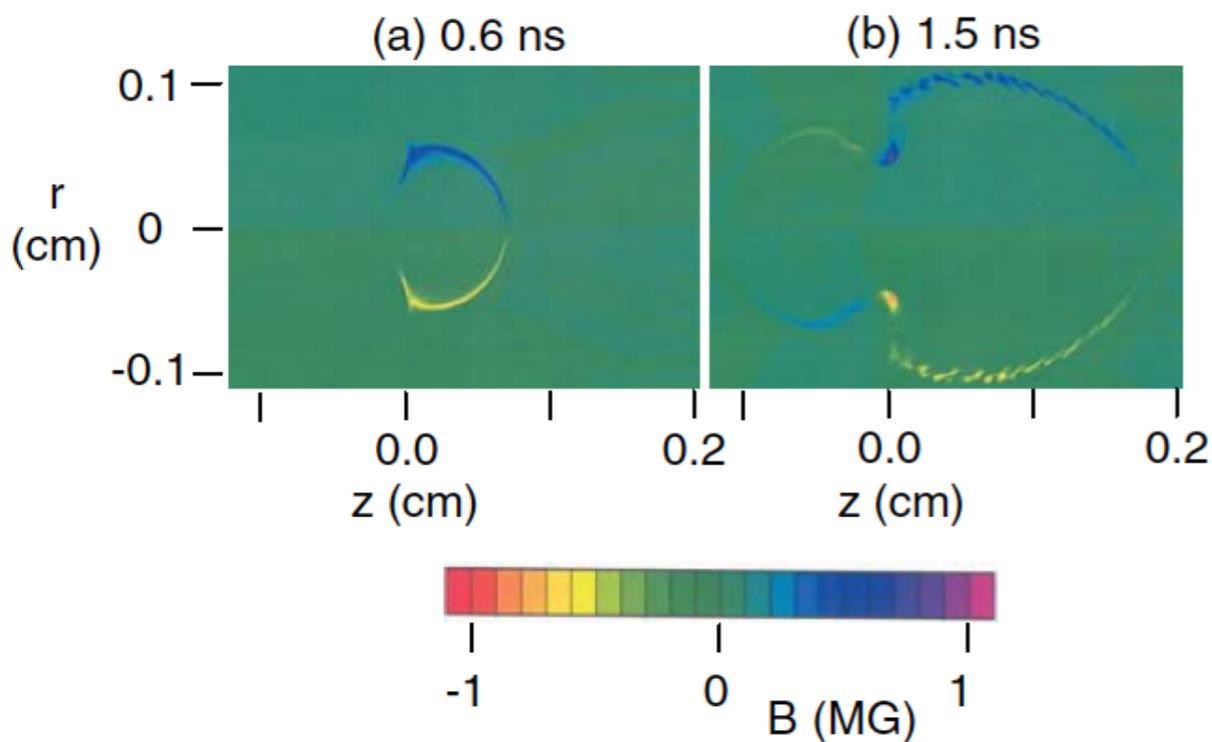
Shadowgraphy shows the shape of plasmas exhibiting with a  $X$ -type reconnection. A magnetostatics computer code Radia is applied to construct magnetic topology of the present coil target.



# Opportunities for Laser driven reconnection

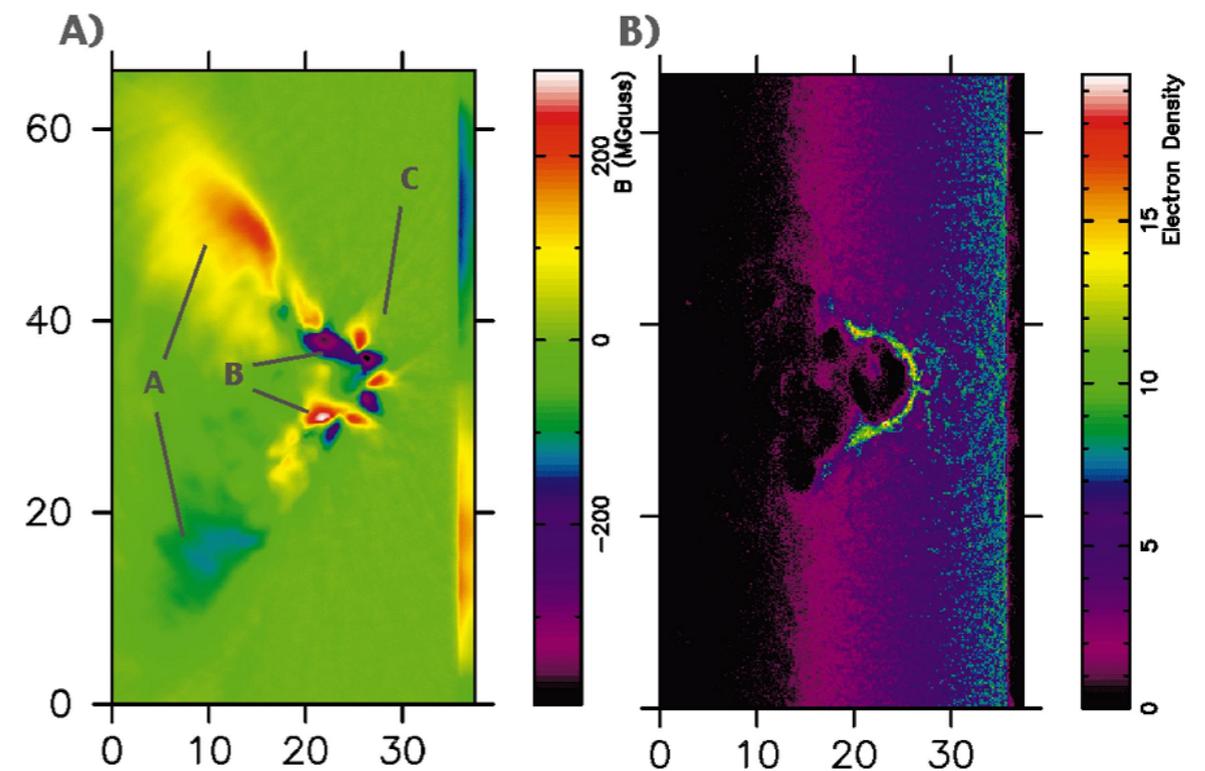
*Magnetic fields from “long pulse” laser to “short pulse” laser*

ns lasers



C.K. Li et al 2007

fs lasers



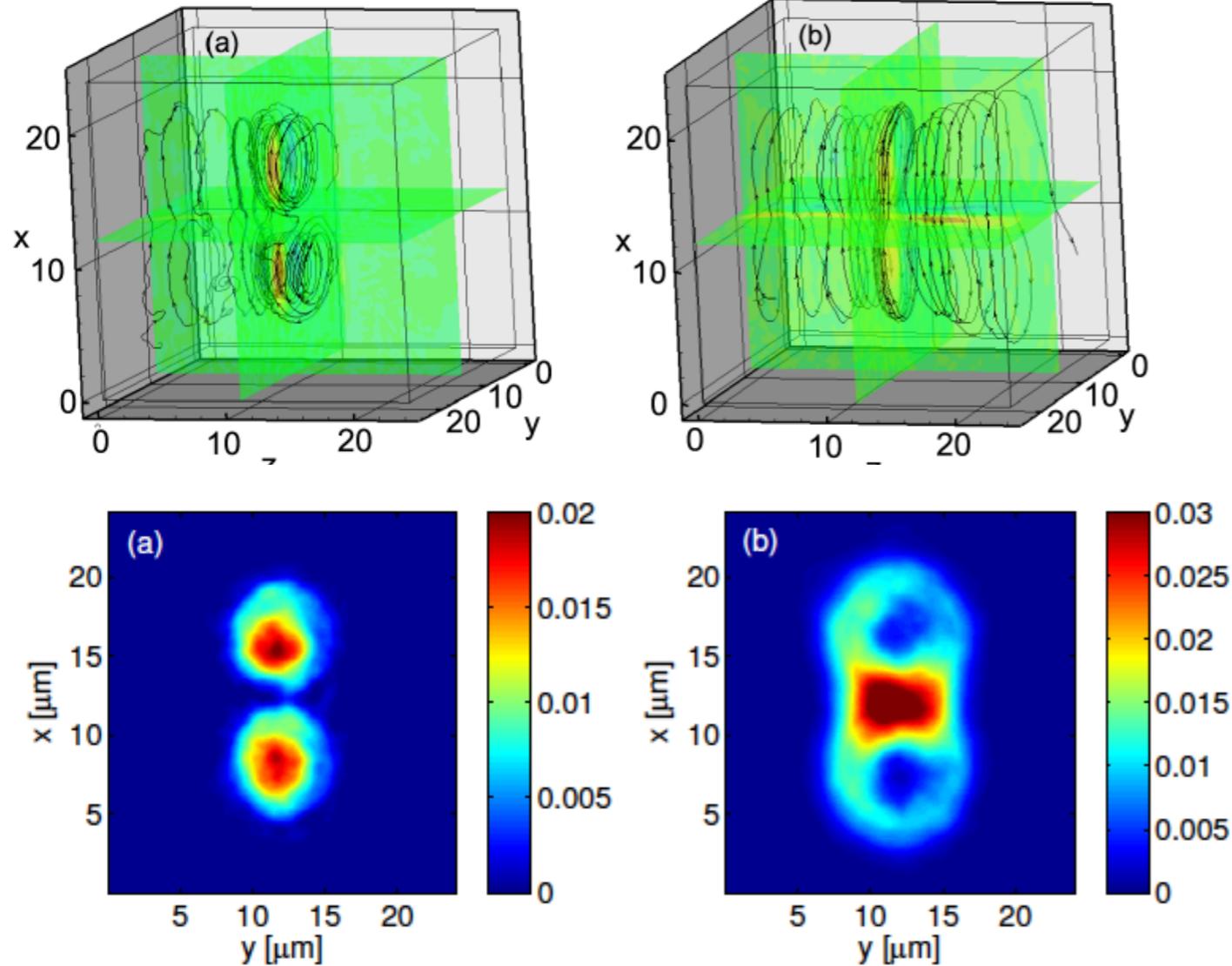
U. Wagner et al 2004

$10^6$  Gauss to  $10^9$  Gauss

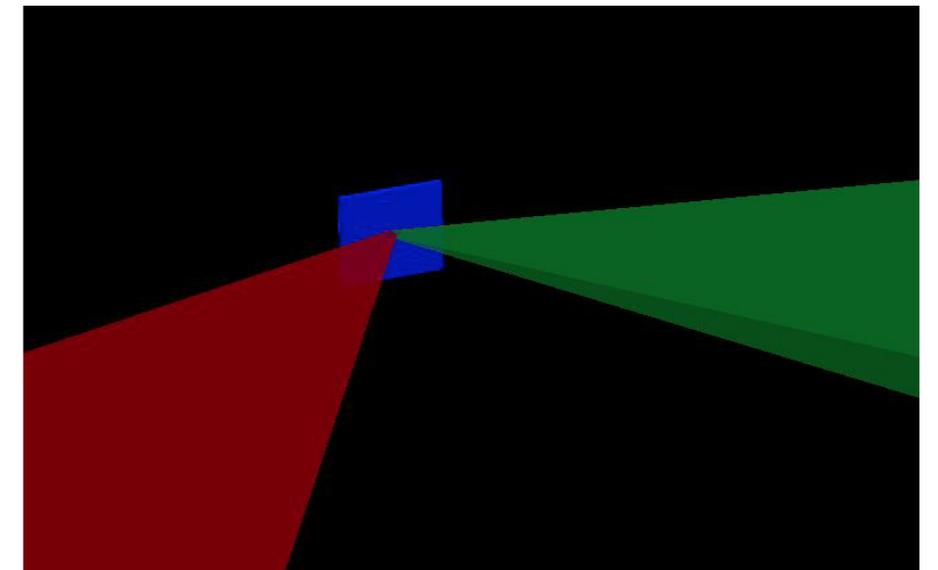
# Opportunities for Laser driven reconnection

Before

After



**Omega EP**



Key challenges:

- co-time of multi beams
- effect from beam itself
- diagnostic ...

Three-dimensional fast magnetic reconnection driven by *two ultraintense femtosecond laser pulses* is investigated by relativistic particle-in-cell simulation



# Summary

- Magnetic reconnection is a basic dissipation process in laboratory, space and astrophysical plasmas.
- Some basic reconnection physics is being studied in *flow driven systems, such as guide field, electron acc.*
- New opportunities for **HED experiments** to study reconnection.
- Relativistic intensity **short pulse lasers** are hoping to perform the reconnection experiments with GG-B field.
- With special target, such as **capacity target**, realizing *magnetically driven systems* and *flow driven systems*, enable to extend a large rang of parameter space for reconnection.