Magnetic reconnection in astrophysical plasmas

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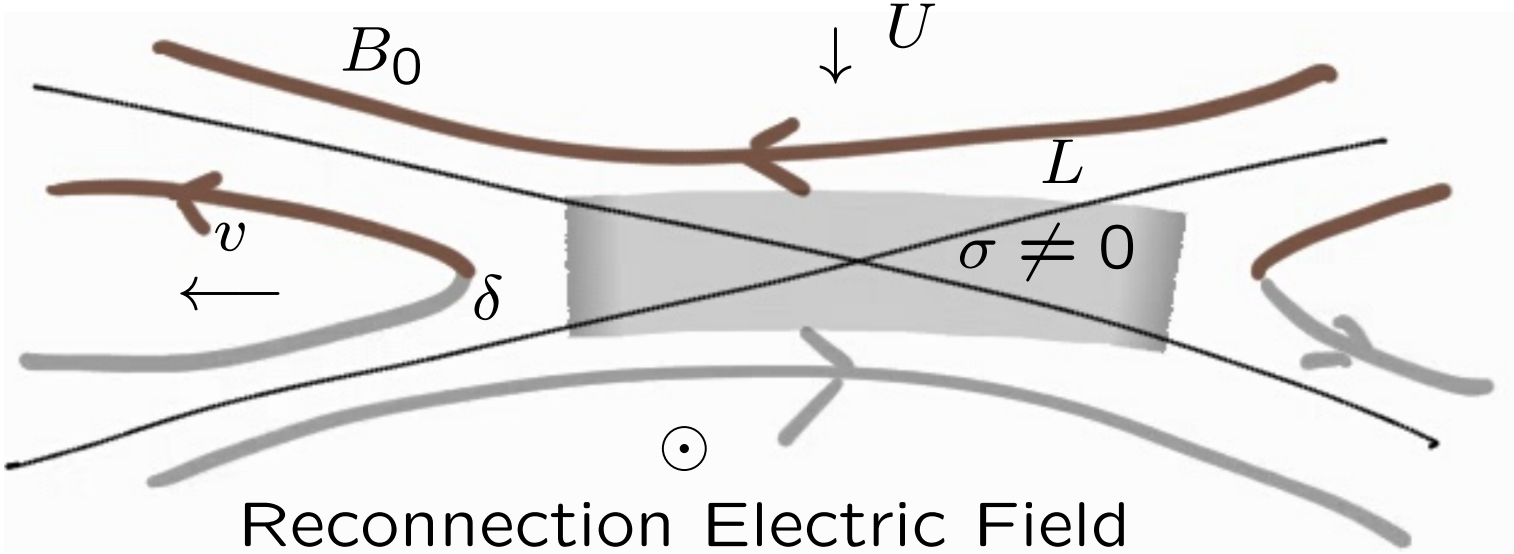
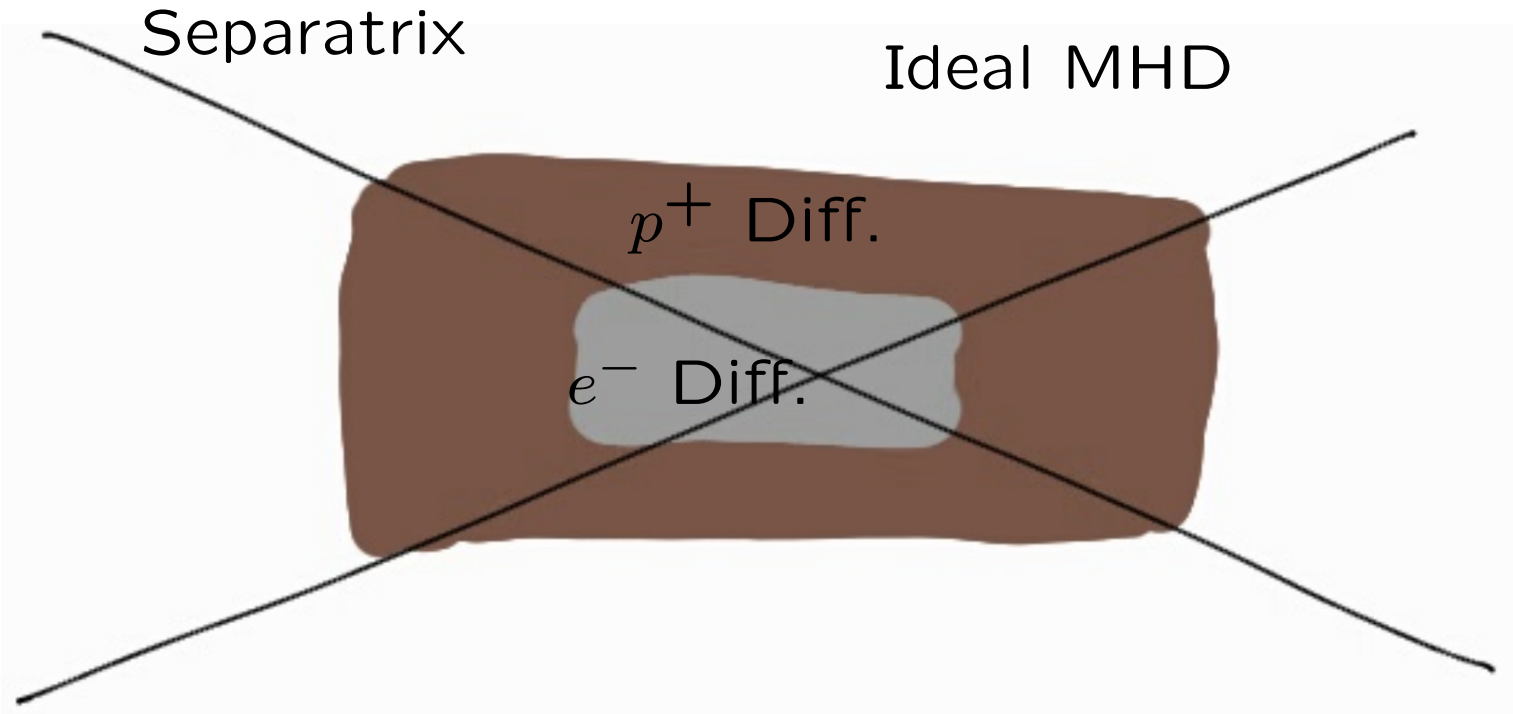
Reconnection converts Mag. energy into Kin. energy



Sweet-Parker model needs resistivity : slow

Petschek model : needs a fast shock

Fast Reconnection : Hall effect [GEM Challenge, 2001]

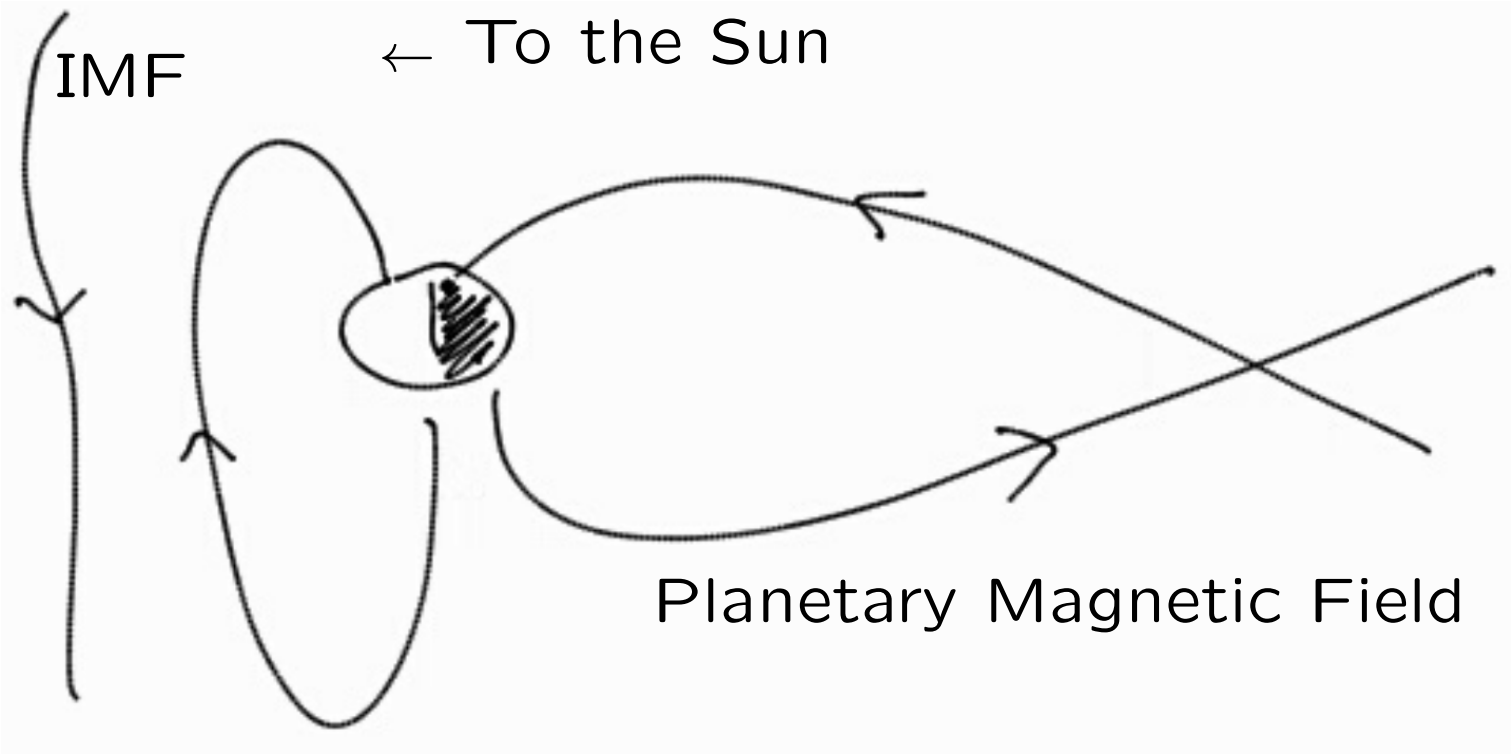


Ideal MHD : $\mathbf{E} = -\mathbf{v}_i \times \mathbf{B}$

p^+ Diff. region : $\mathbf{E} = (\mathbf{J} \times \mathbf{B})/en$

e^- Diff. region : $\mathbf{E} = -\boldsymbol{\nabla}.\,\mathbf{P}_e/en$

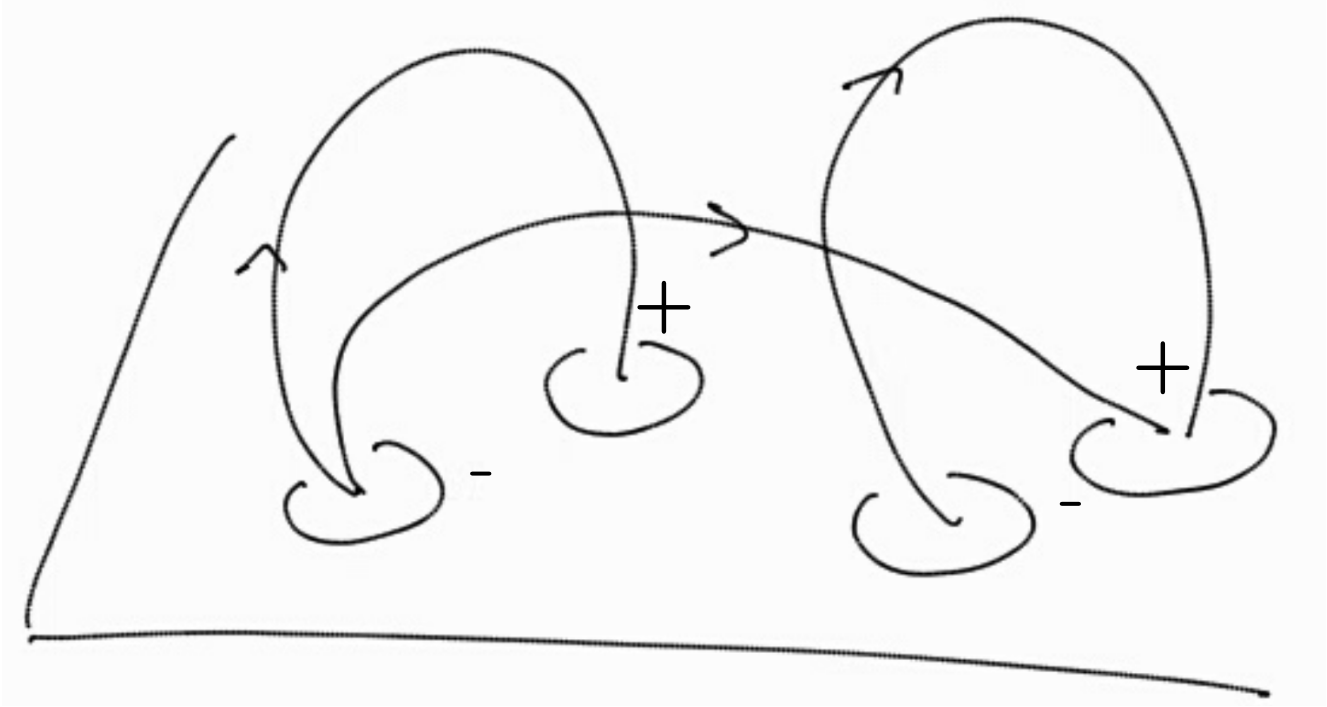
Planetary Magnetospheres [Dungey, 1961]



At day-side Magnetopause & in the Magnetotail

$\beta \sim 1$, $L \to \infty$, non-relativistic ($T \sim 100$ keV)

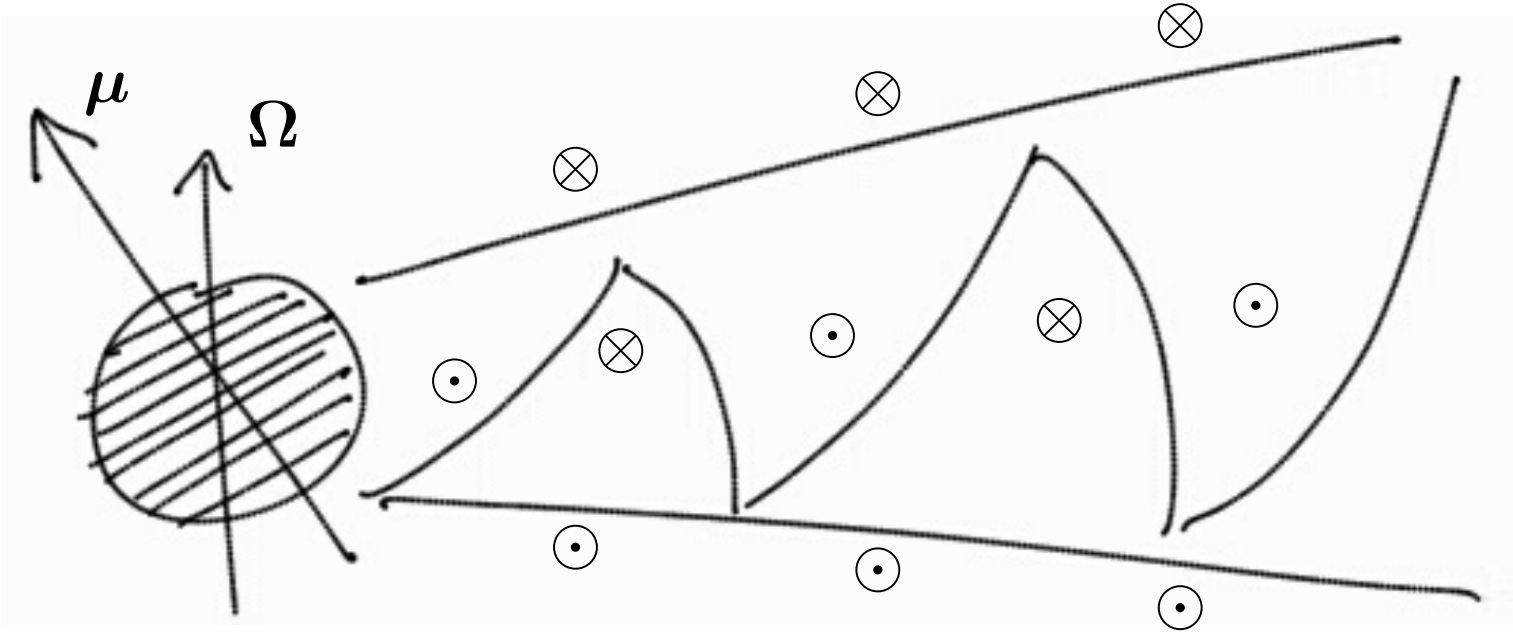
Solar prominence merging [Aulanier et al., ApJ 2005]



Cold dense tube in hot tenuous coronna, $\beta \sim 10^{-2}$

$\longrightarrow$ 3D geometry very important,

Striped pulsar wind [Bogovalov, A&A 1999]

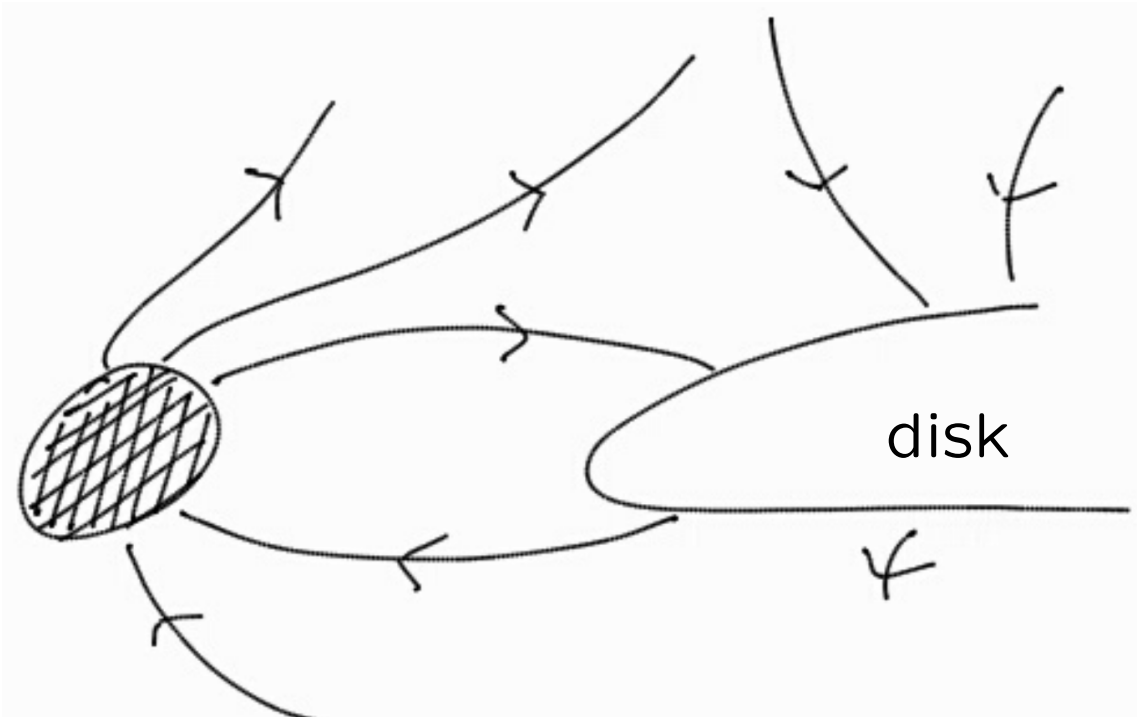


Ultra-relativistic pair-plasmas ($\gamma \sim 10^3$, $\sigma \sim 10^4$)

(collisionless) Shock-driven reconnection

$\rightarrow$ EM energy to synchrotron emmitting electrons (X & γ)

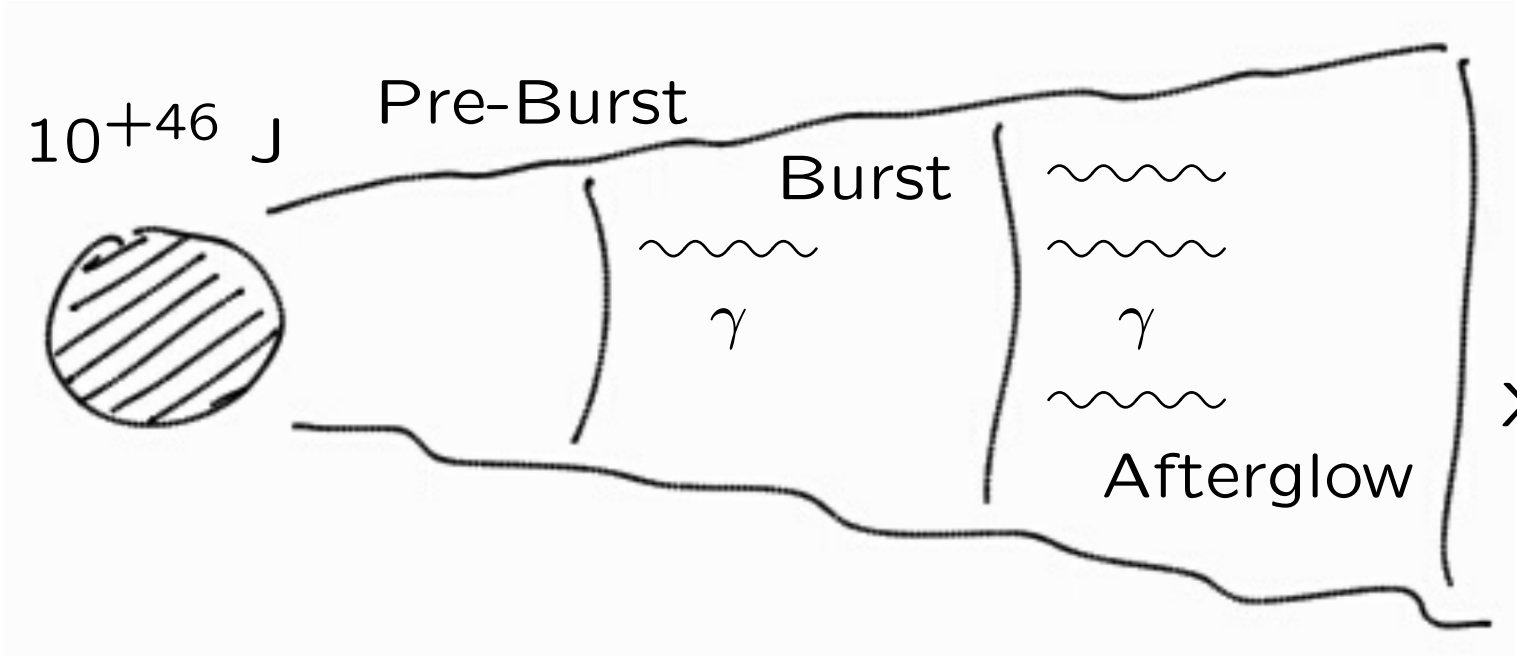
Accretion disks [Gouveia dal Pino & Lazarian, 2005]



Can explain the steep power-law state of photons for $\beta \leq 1$

$\rightarrow$ Could be extended to AGNs & YSOs,

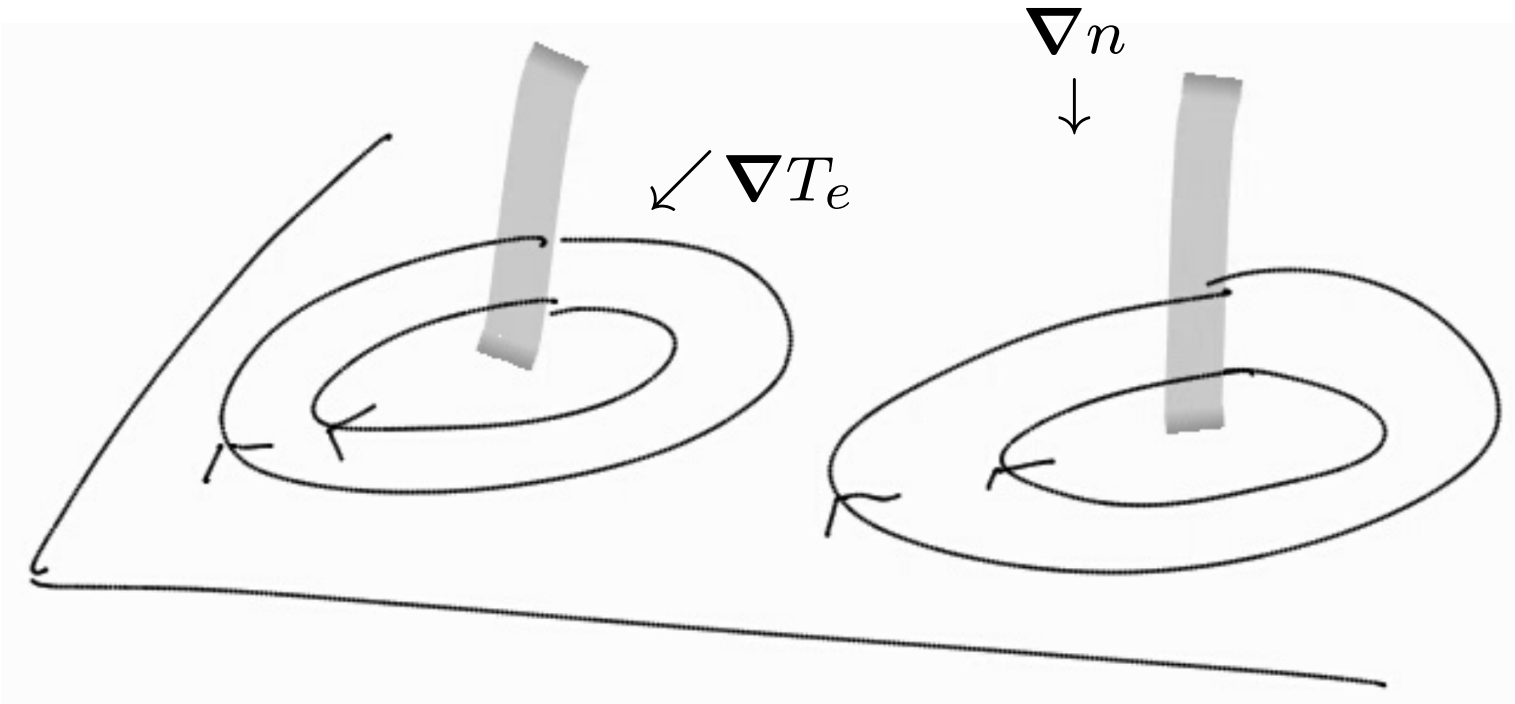
γ ray bursts (Fireball model) [Thompson, 1994]



Ultra-relativistic with $\beta \leq 10^{-4} \rightarrow f(\gamma) \propto \gamma^{-\delta}$ with $p \sim -2.2$

$\rightarrow$ Associated $\delta \sim -1.6$ for synchrotron photons

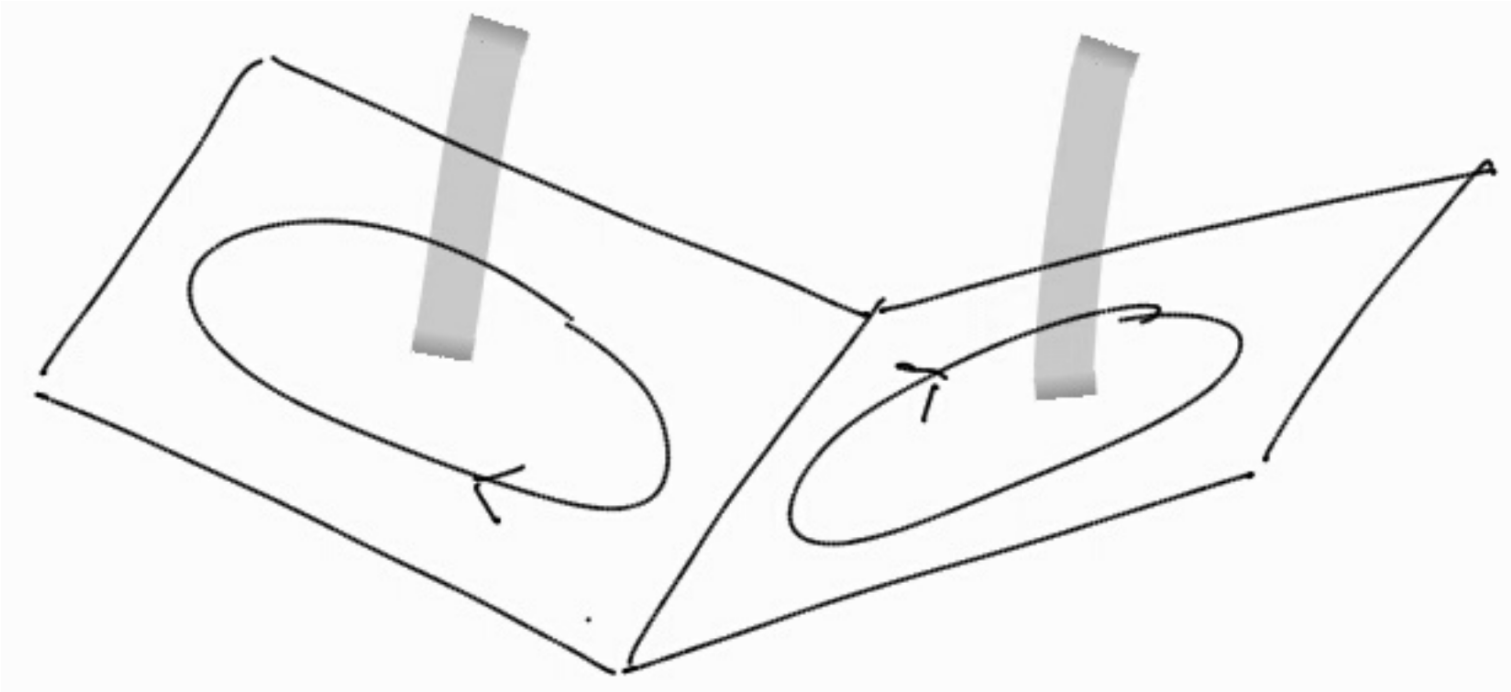
With high-intensity Lasers... [Nielson et al., 2006]



2 hotspots on solid target :

$\rightarrow$ 2 anti-parallel Magnetic loops (Biermann-Battery effect)

When folding targtets [Smets et al., 2014]

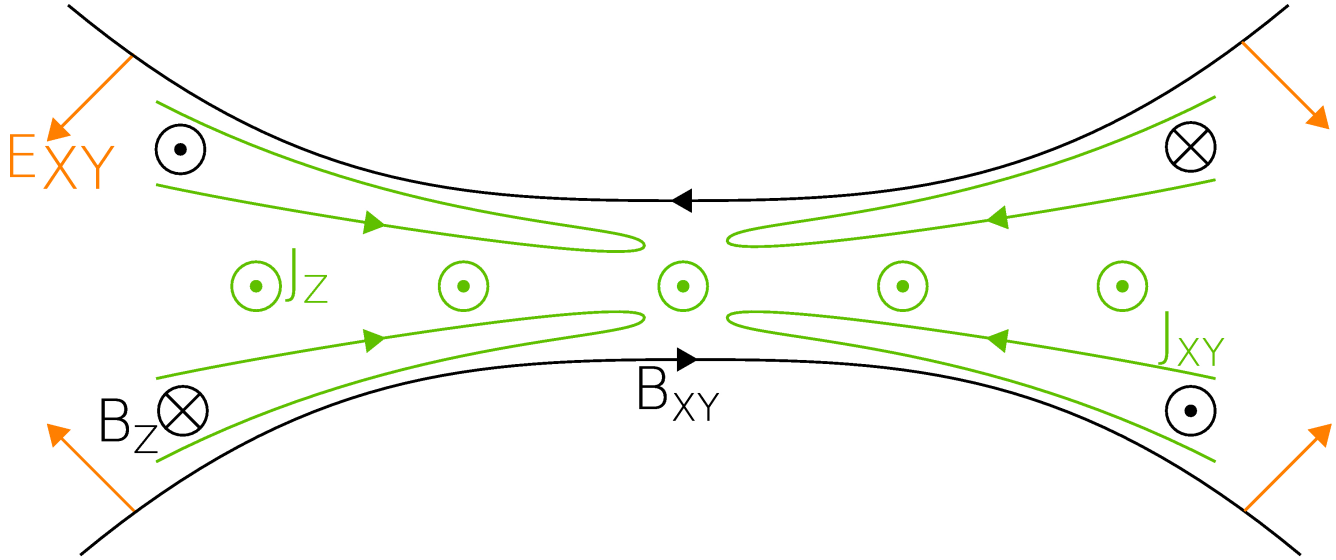


Initial out-of-plane magnetic field : Quadripolar structure

$\rightarrow$ Reconnection rate depends on sallient/revers angle

$\rightarrow$ 6 shots scheduled on LMJ/PETAL : end of 2017

About the Hall effects



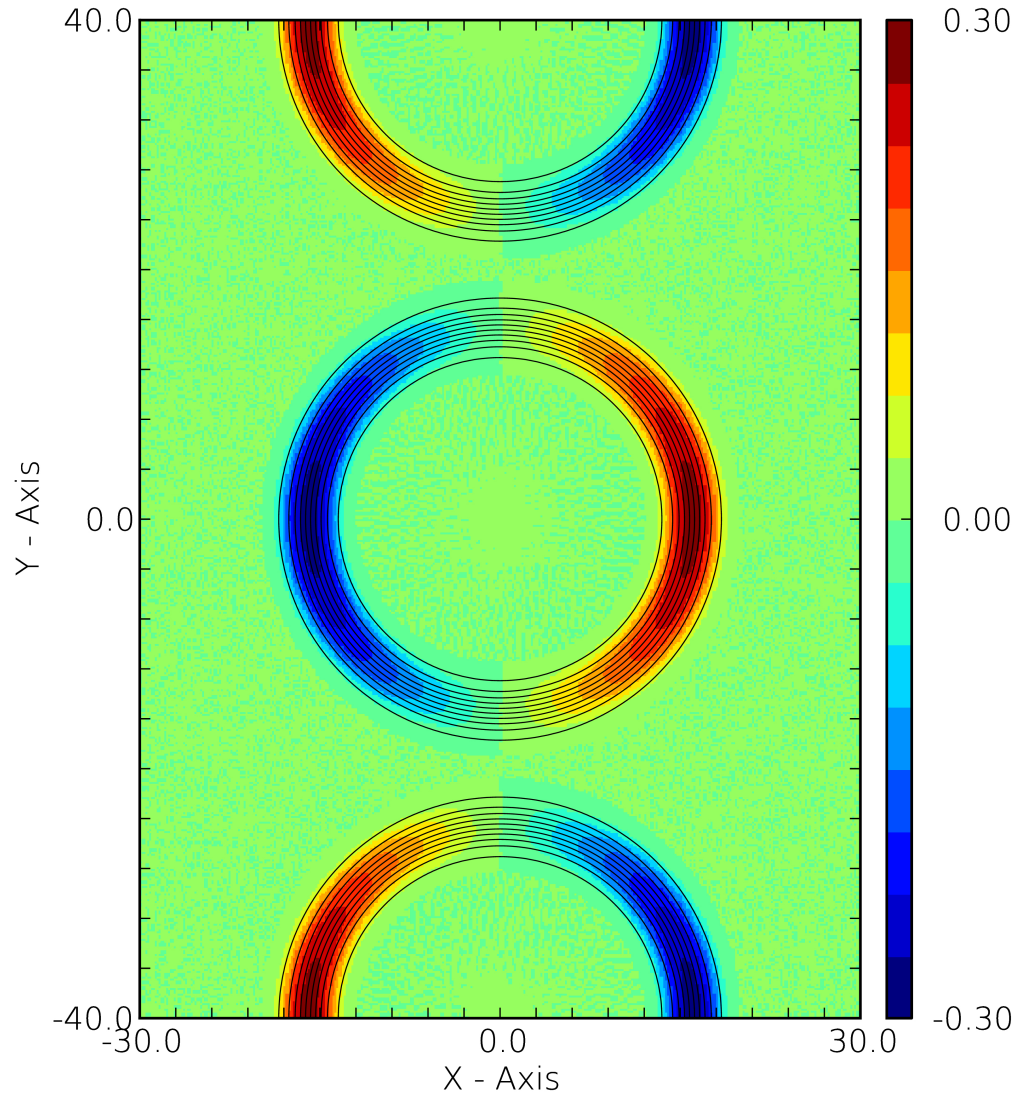
- (Hall) E_{XY} electric field associated to J_Z and B_{XY}
- J_Z grows at the tip of each loops when colliding

$\rightarrow$ quadrupolar B_Z grows because E_{XY} is no more curl-free

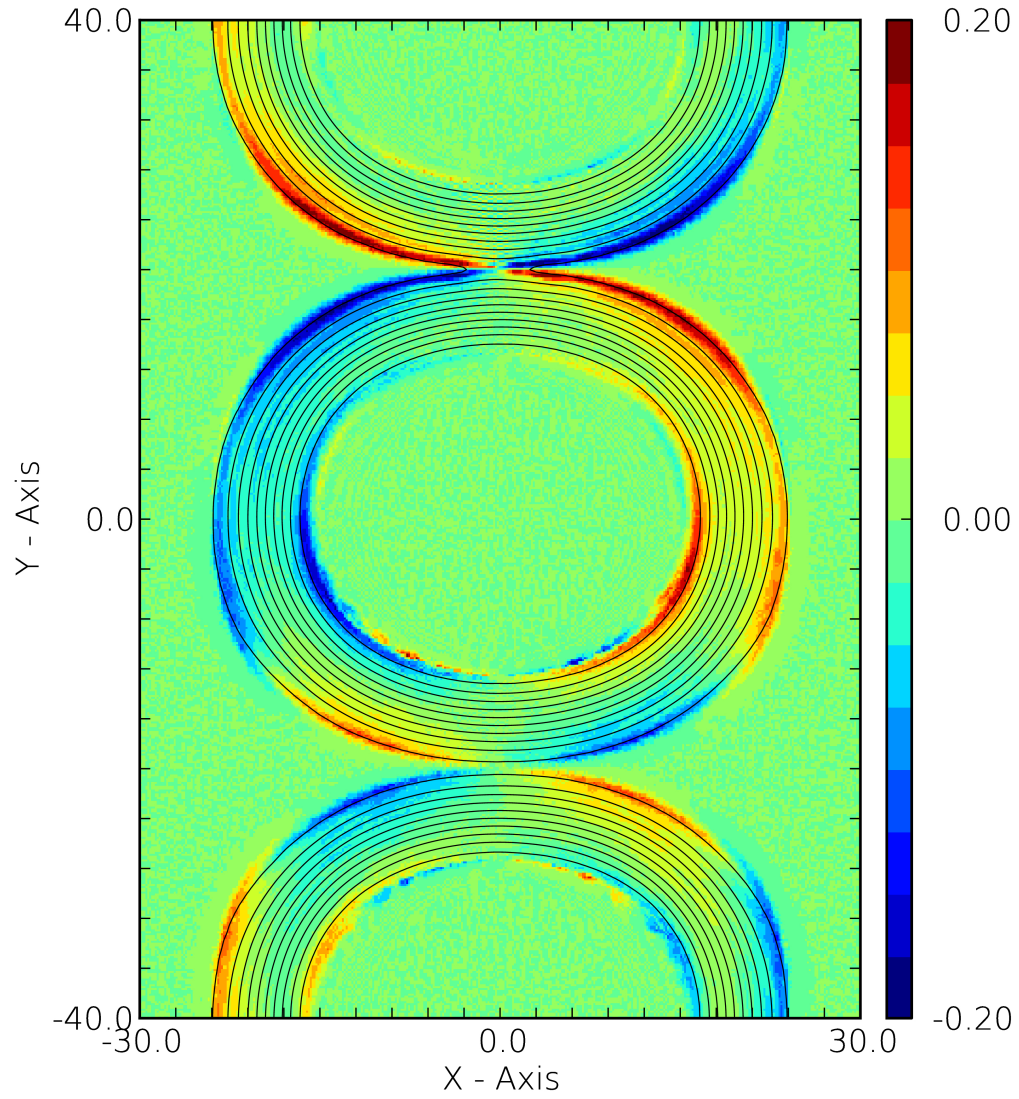
- J_{XY} associated to this out-of-plane magnetic field

$\rightarrow$ Carried by electrons (protons are demagnetized)

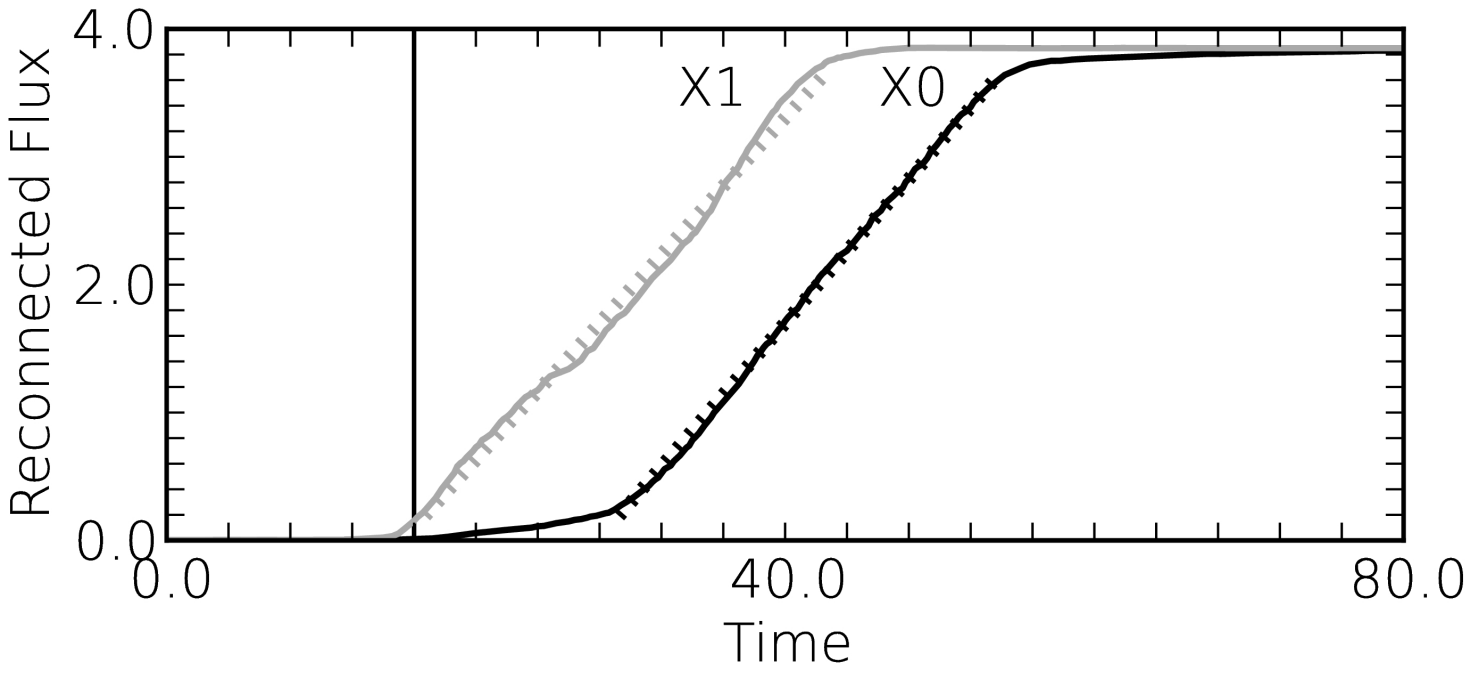
Non-Coplanar Hybrid simulation : t=0



Non-Coplanar Hybrid simulation : t=16



Reconnected flux

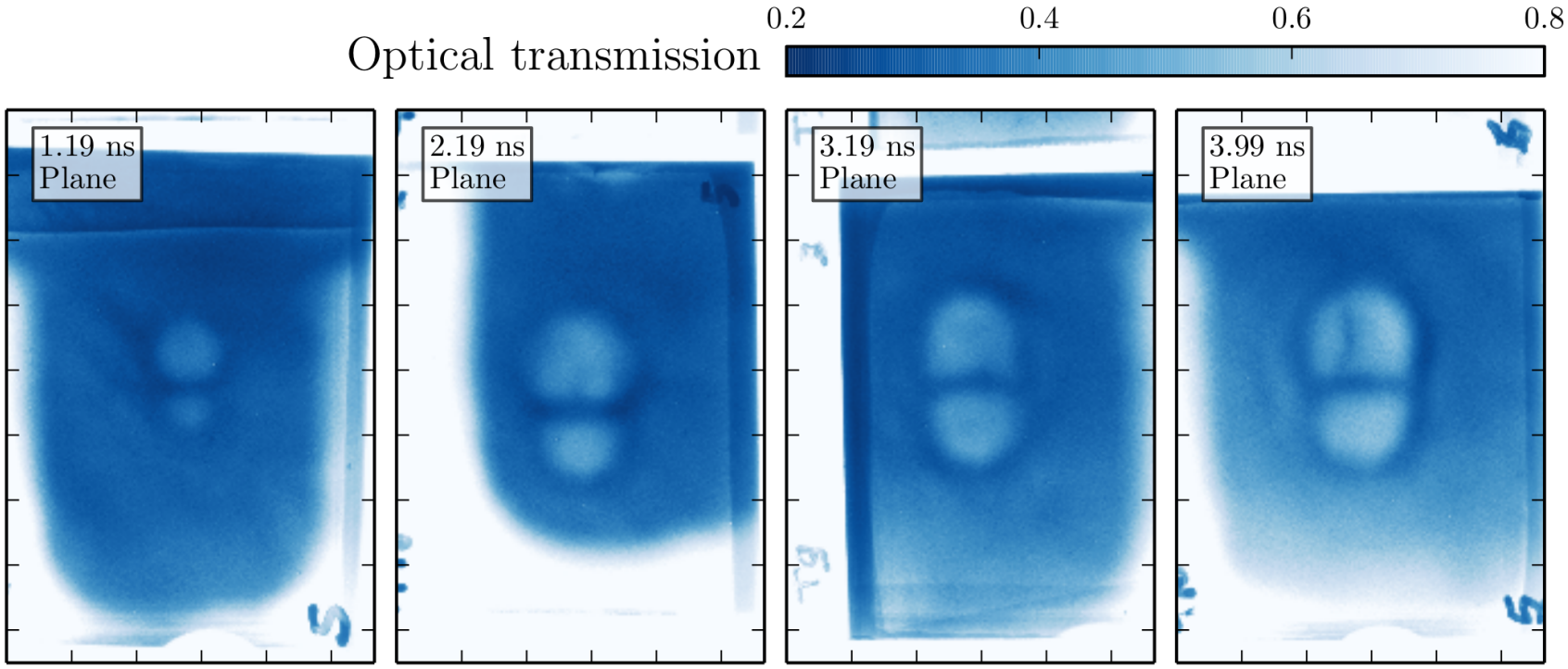


B_Z develops prior the reconnection onset (t=16)

Same reconnection rate at each loci (slope of A_Z)

Time lag between the 2 onsets of reconnection

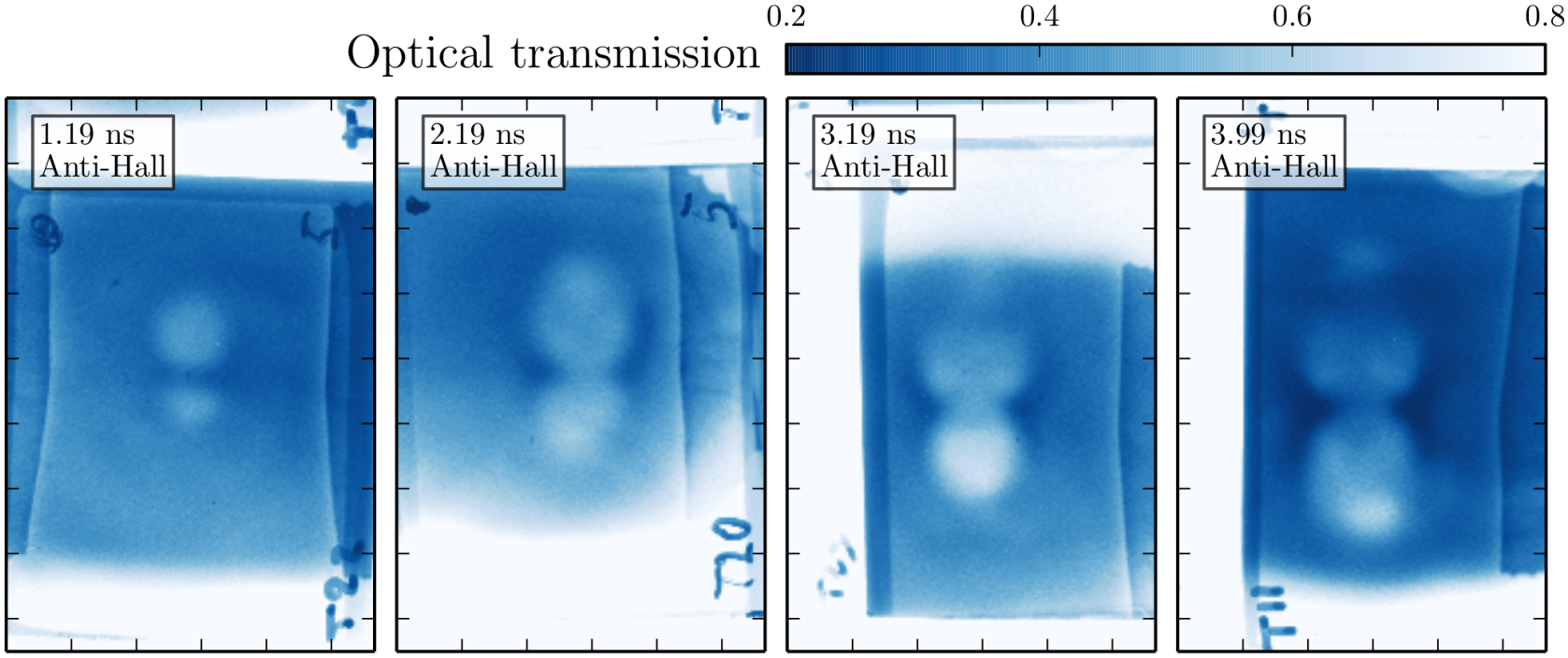
LULI 2000 : 2 beams with 200 J & 4.0 ns each



→ The 2 magnetic shells get compressed and get flat

→ On the reconnection sheet, protons are weakly scattered

LULI 2000 : 2 beams with 200 J & 4.0 ns each



→ No more flat sheet betweens the 2 shells

→ Reconnection inhibited ?

LULI 2000 Exp. in 2017

If folding along the other direction : Initial Guide-field

$\rightarrow$ Supposed to slow-down the (symmetrical) reconnection

LMJ/PETAL shots end of 2017

- 800 kJ, 4 ns with 4 quads
- Increase magnetization & shorten reconnection process
- High Z target decreases the associated β value
- Proton radiography

$\rightarrow$ Get (integrated) E & B fields at different times

- DP1 X-ray imager : 12 images with resolution of 130 ps

$\rightarrow$ a sequence of 2D images

- DMX Spectrometer : X-rays spectra resolved in time

$\rightarrow$ measure the black-body spectrum of $T \sim 100$ eV plasma