

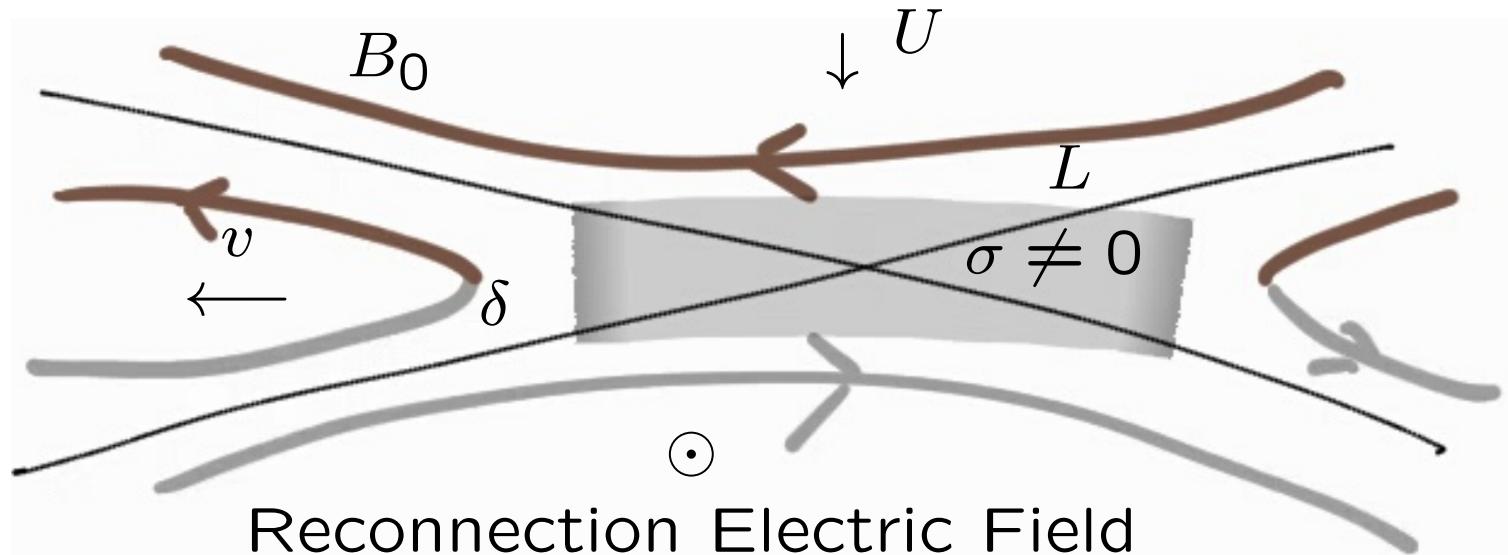
Laboratory investigation of reconnection weakened by a guide field

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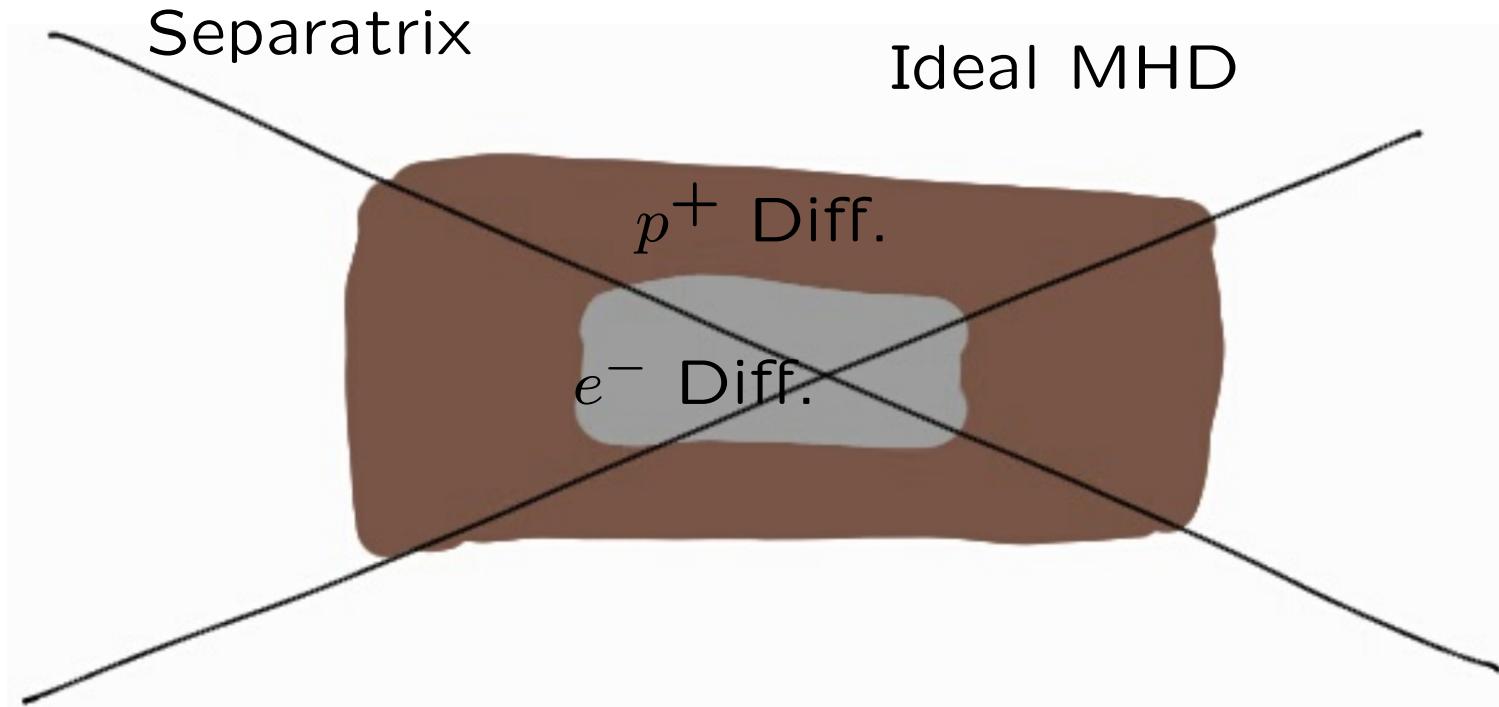
"Lab7 meeting", 21 december 2022

2D Magnetic reconnection



- converts magnetic energy into kinetic energy
- we rarely observe reconnection, but the consequences...

Fast Reconnection & Hall effect [Birn et al., JGR 2001]

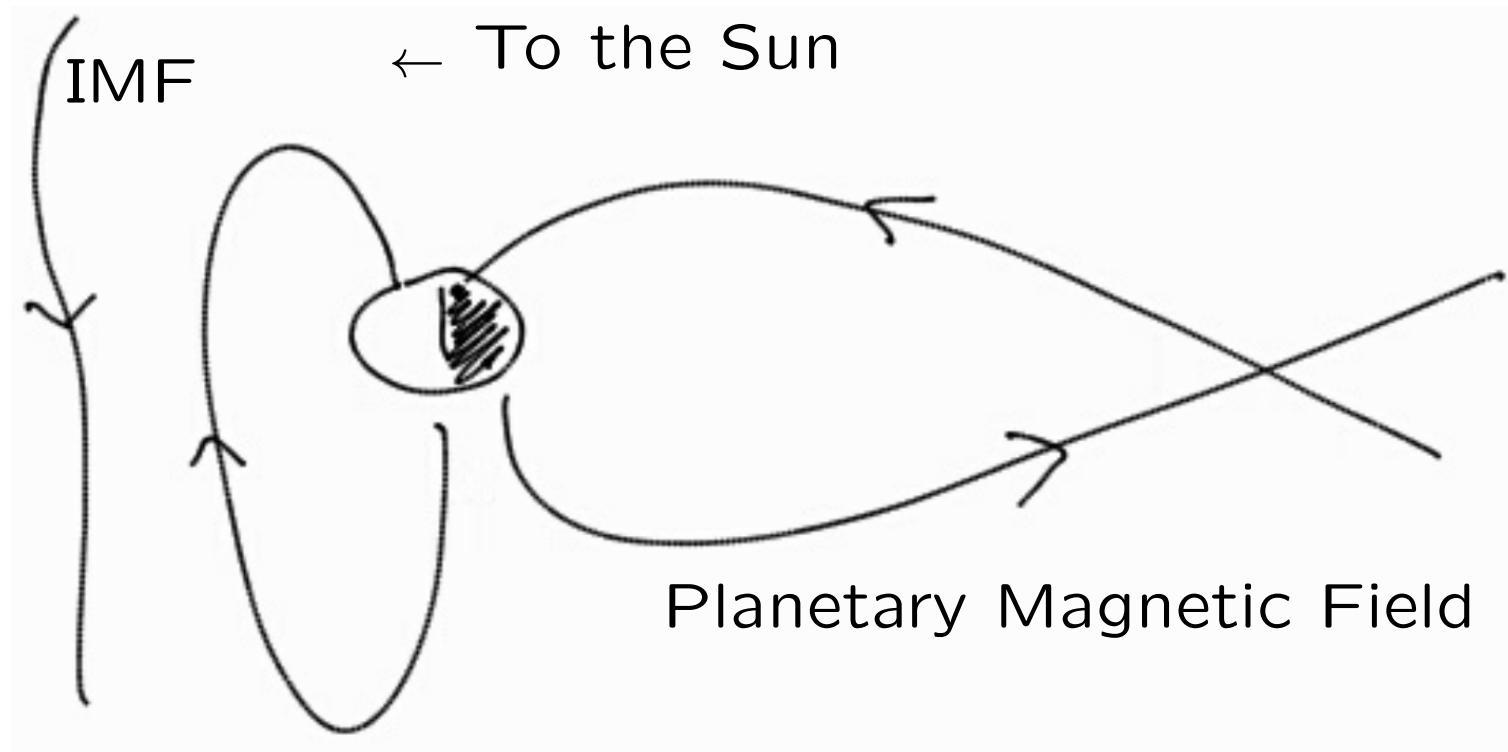


Ideal MHD : $\mathbf{E} = -\mathbf{U} \times \mathbf{B}$

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

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

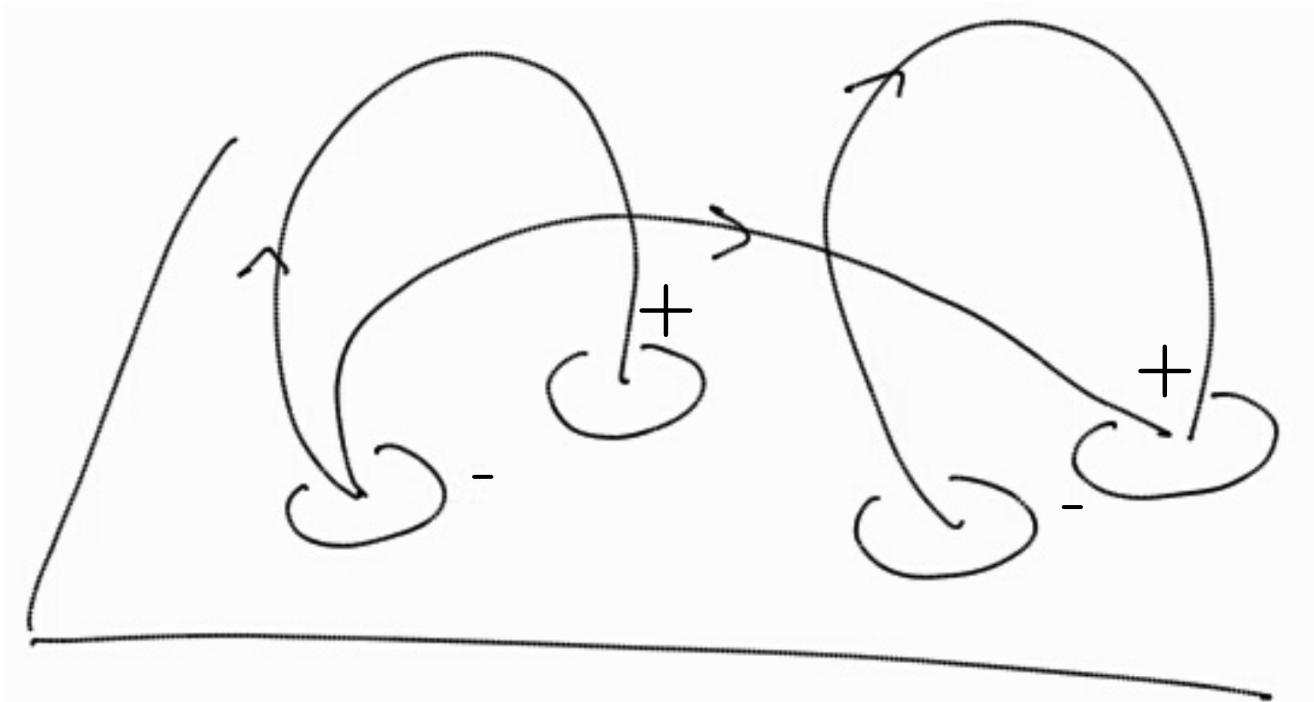
Planetary Magnetospheres [Dungey, PRL 1961]



At day-side Magnetopause & in the Magnetotail

$\rightarrow \beta \sim 1, L \rightarrow \infty, \gamma \sim 1$

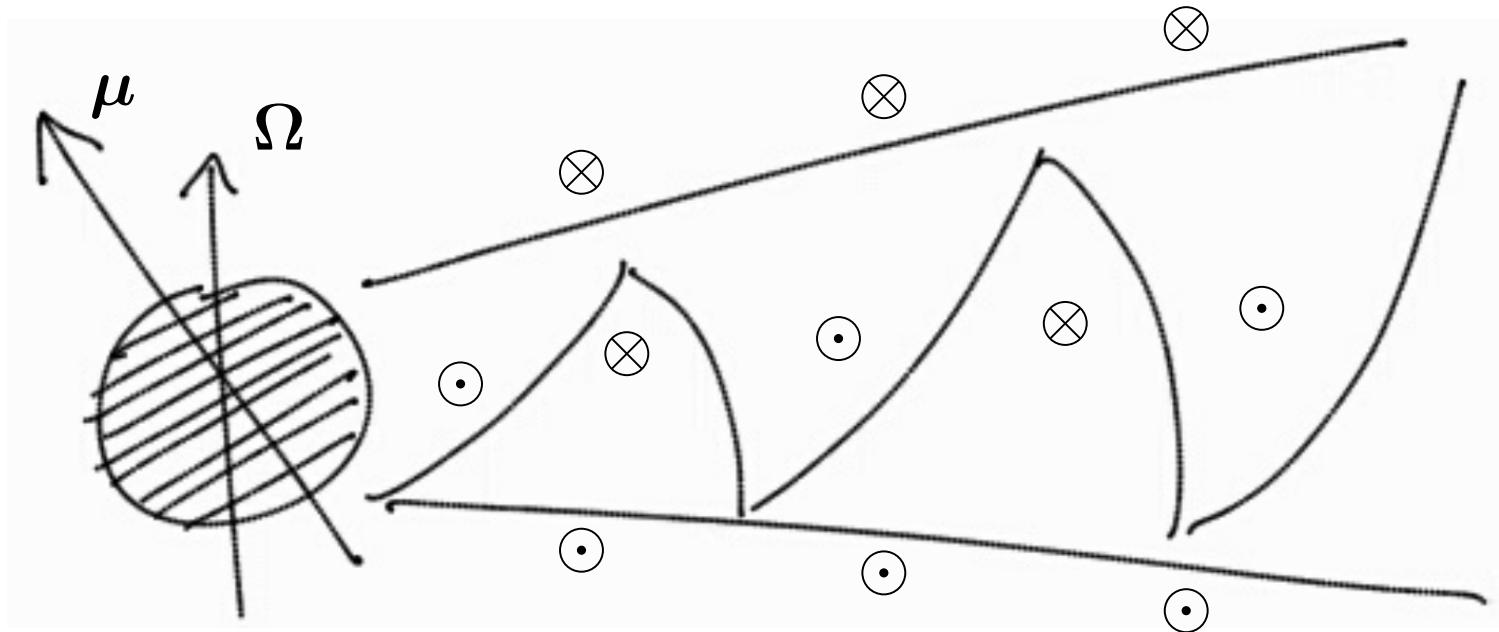
Solar prominence merging [Aulanier et al., ApJ 2005]



Cold dense tube in hot tenuous corona, highly 3D

$$\rightarrow \beta \sim 10^{-2}, L \rightarrow \infty, \gamma \sim 1$$

Striped pulsar wind [Bogovalov, A&A 1999]

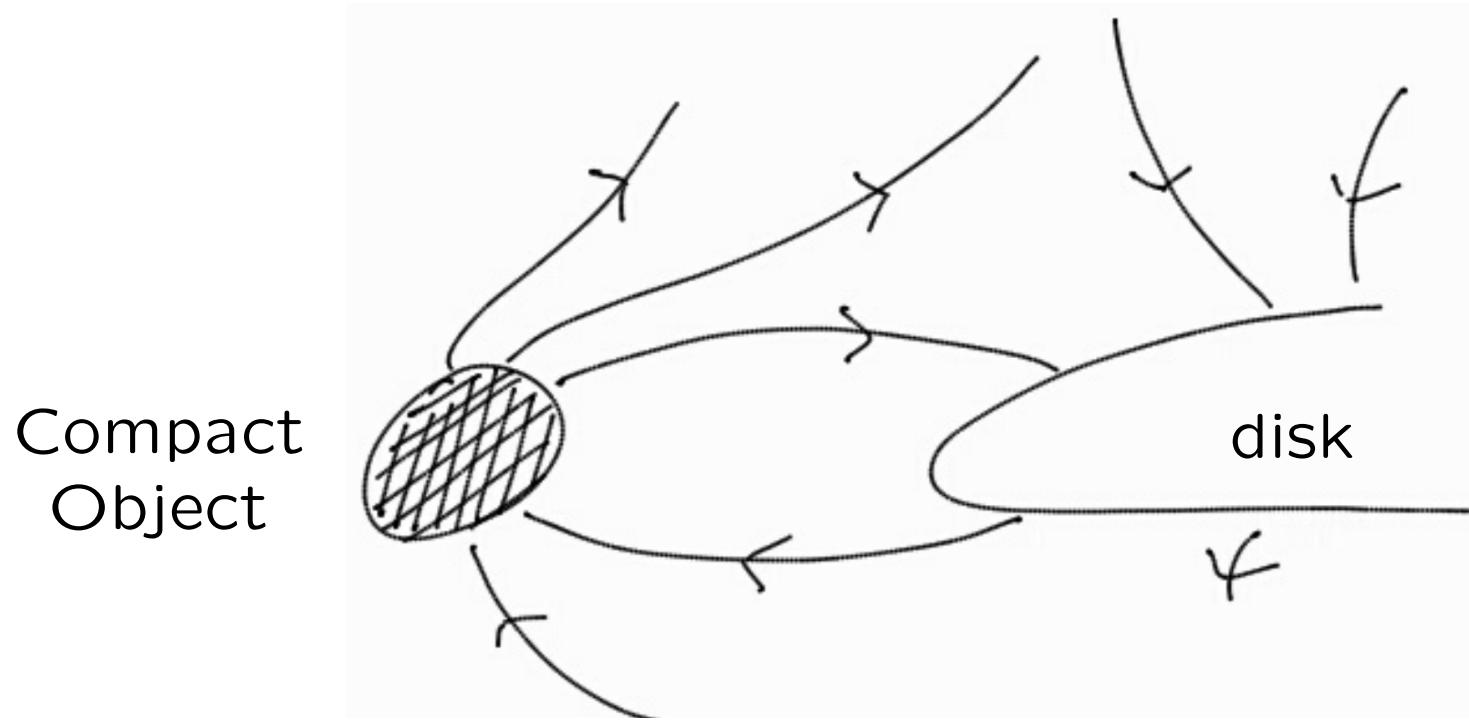


Shock-driven reconnection in a pair-plasmas

$\rightarrow \sigma \sim 10^4$, $L \rightarrow \infty$, $\gamma \sim 10^3$

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

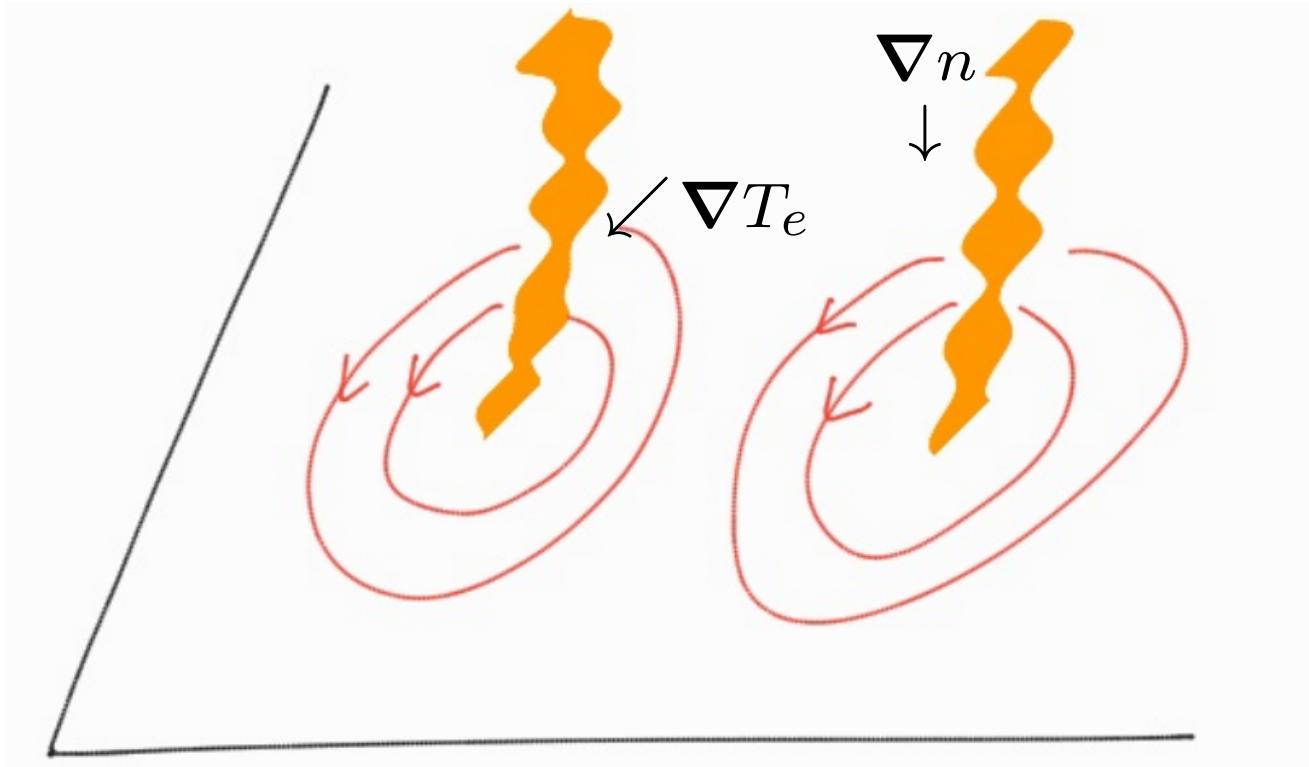
Microquasar [de Gouveia dal Pino & Lazarian, A&A 2005]



Can explain the steep power-law state of photons

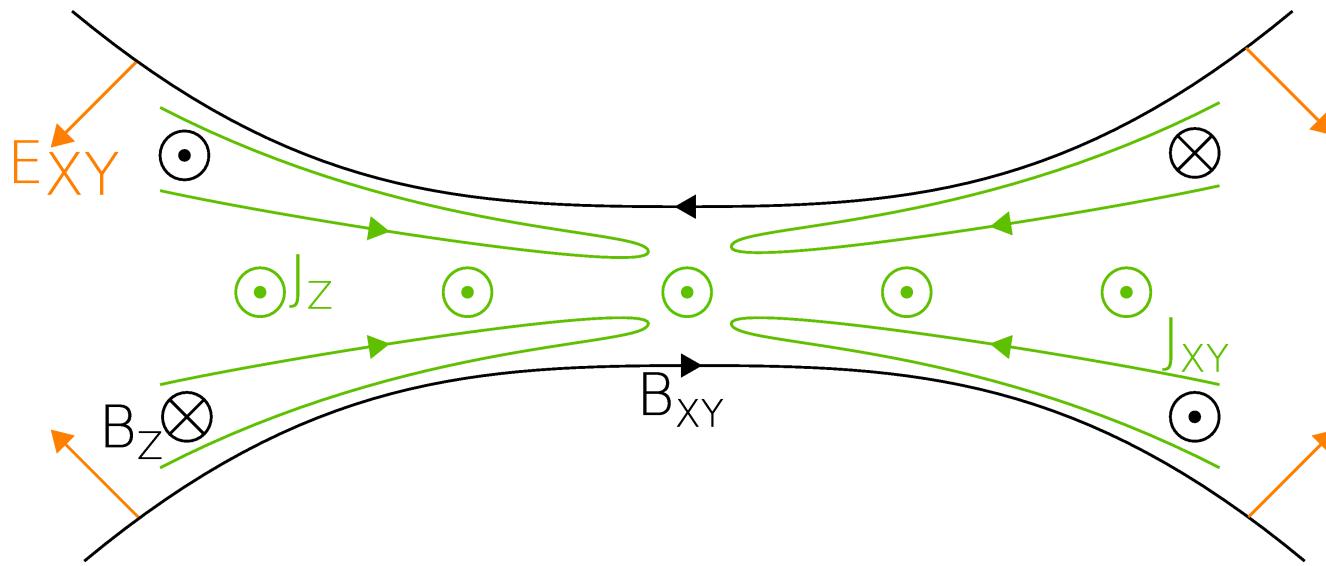
$$\rightarrow \beta \leq 1, L \rightarrow \infty, \gamma \gg 1$$

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



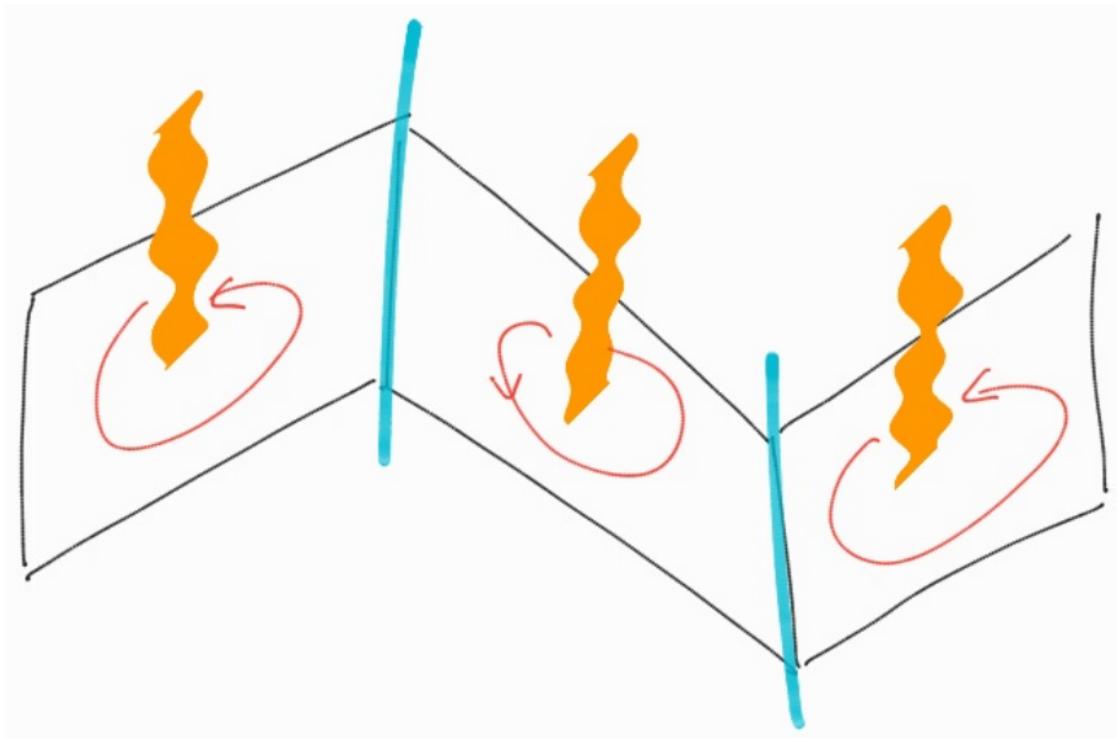
- Two closeby hotspots on solid target :
 - 2 magnetic loops created by Biermann-Battery effect
 - newly created magnetic flux expeled by reconnection

Importance of Hall effect for fast reconnection



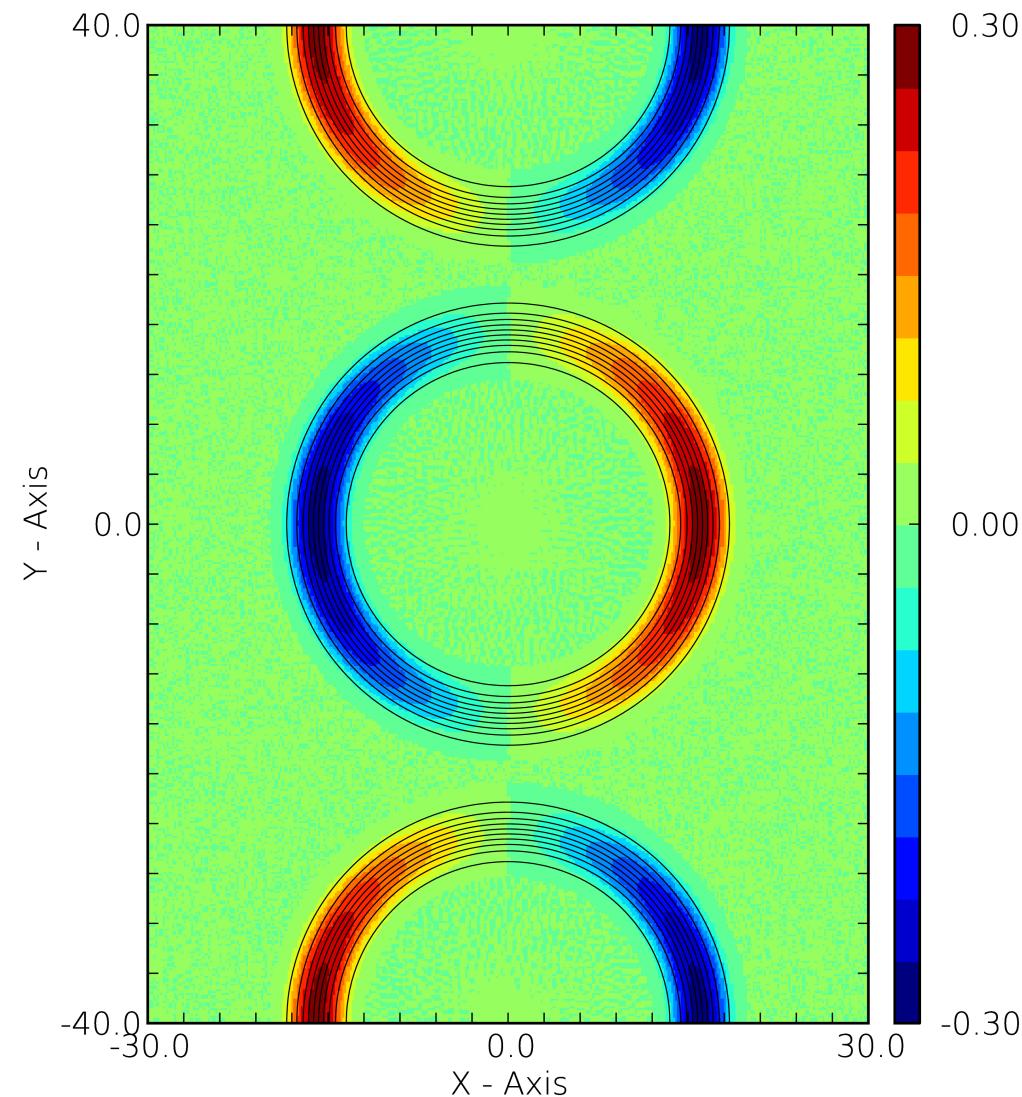
- (Hall) E_{XY} electric field associated to J_Z and B_{XY}
- J_Z grows at the tip of each loops when colliding
→ quadrupolar B_Z grows because E_{XY} is no more curl-free
- J_{XY} associated to this out-of-plane magnetic field
→ carried by electrons because protons are demagnetized

When folding targets [Smets et al., 2014]

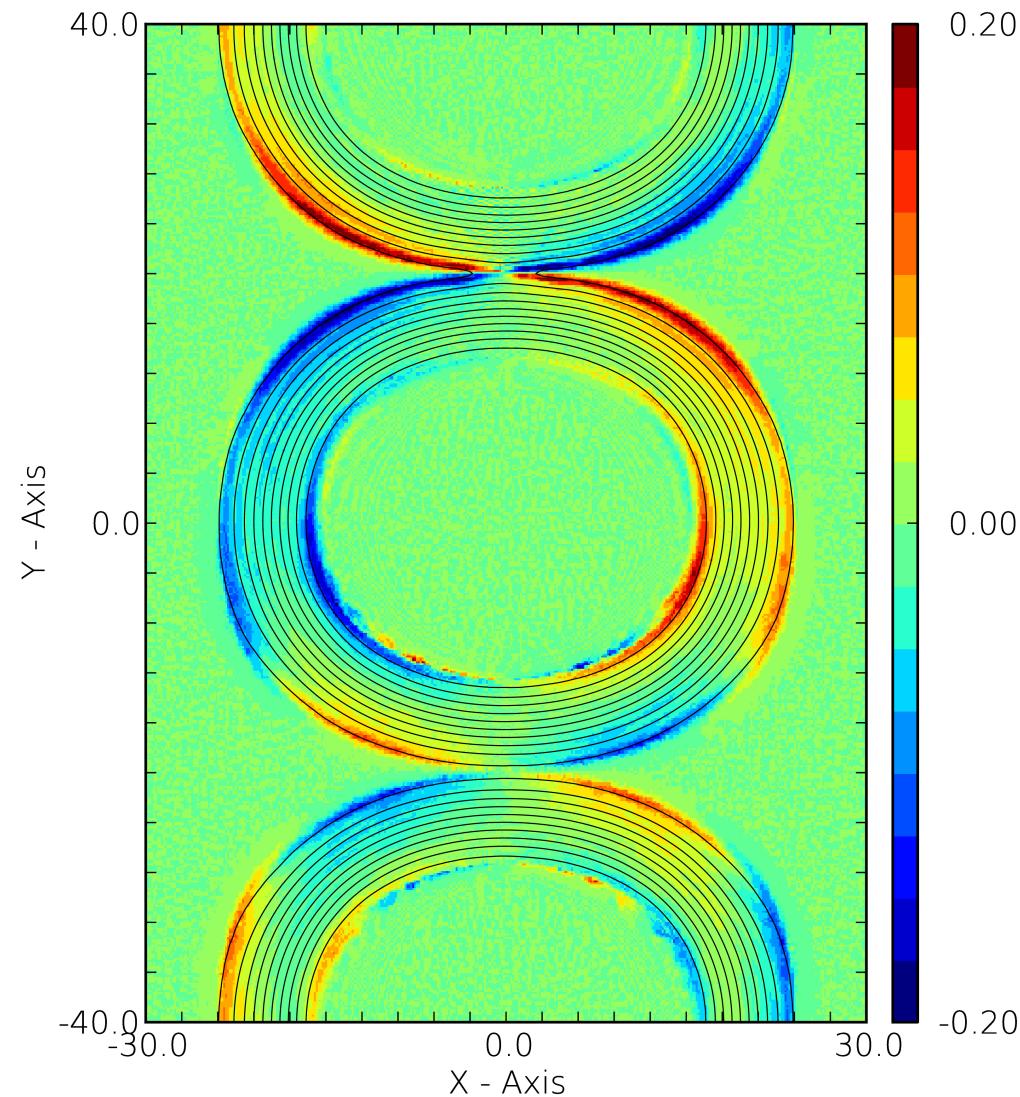


- Initial quadripolar out-of-plane magnetic field
→ reconnection rate depends on sallient/reverse angle
→ experiment (to be published) at LULI2000 in 2015

Non-Coplanar Hybrid simulation : t=0



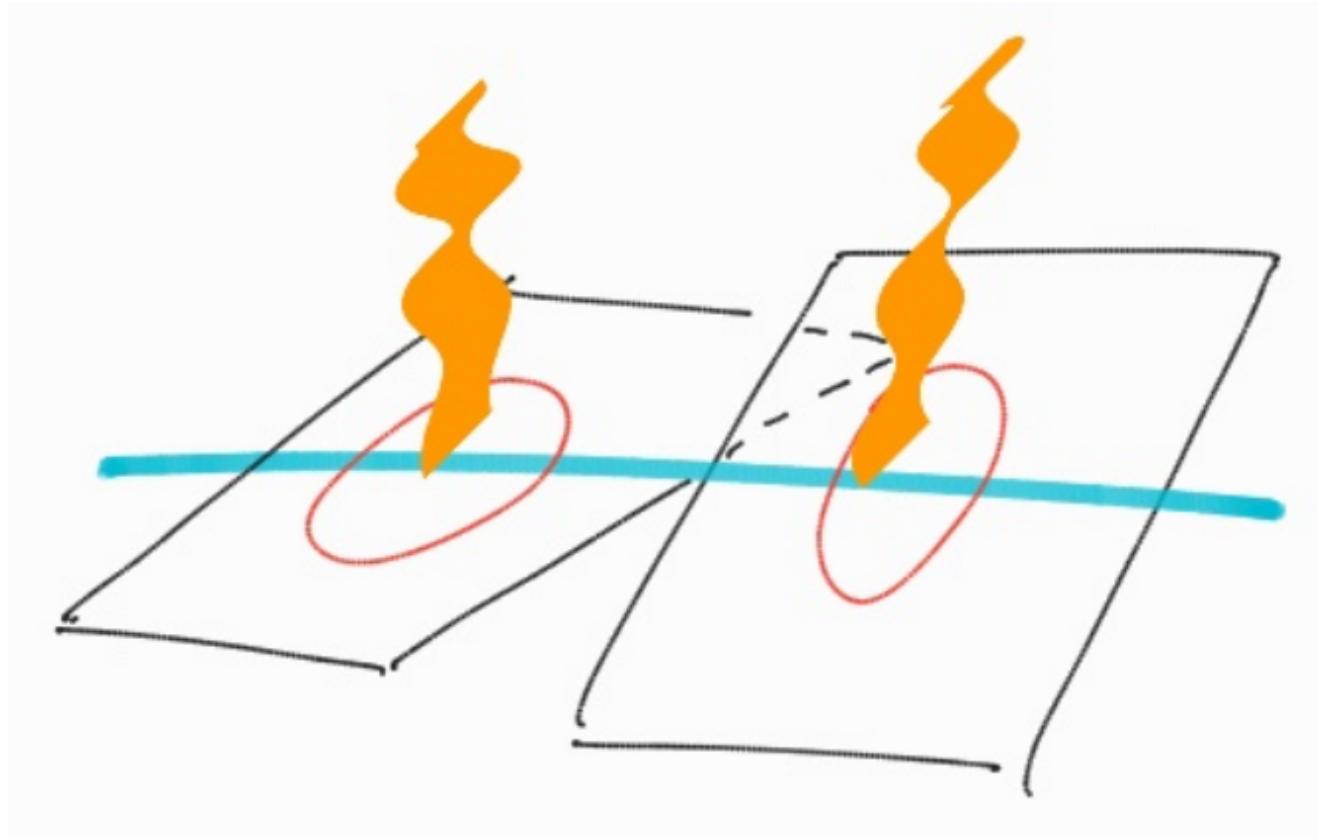
Non-Coplanar Hybrid simulation : t=16



Main result of [Smets et al., 2014]

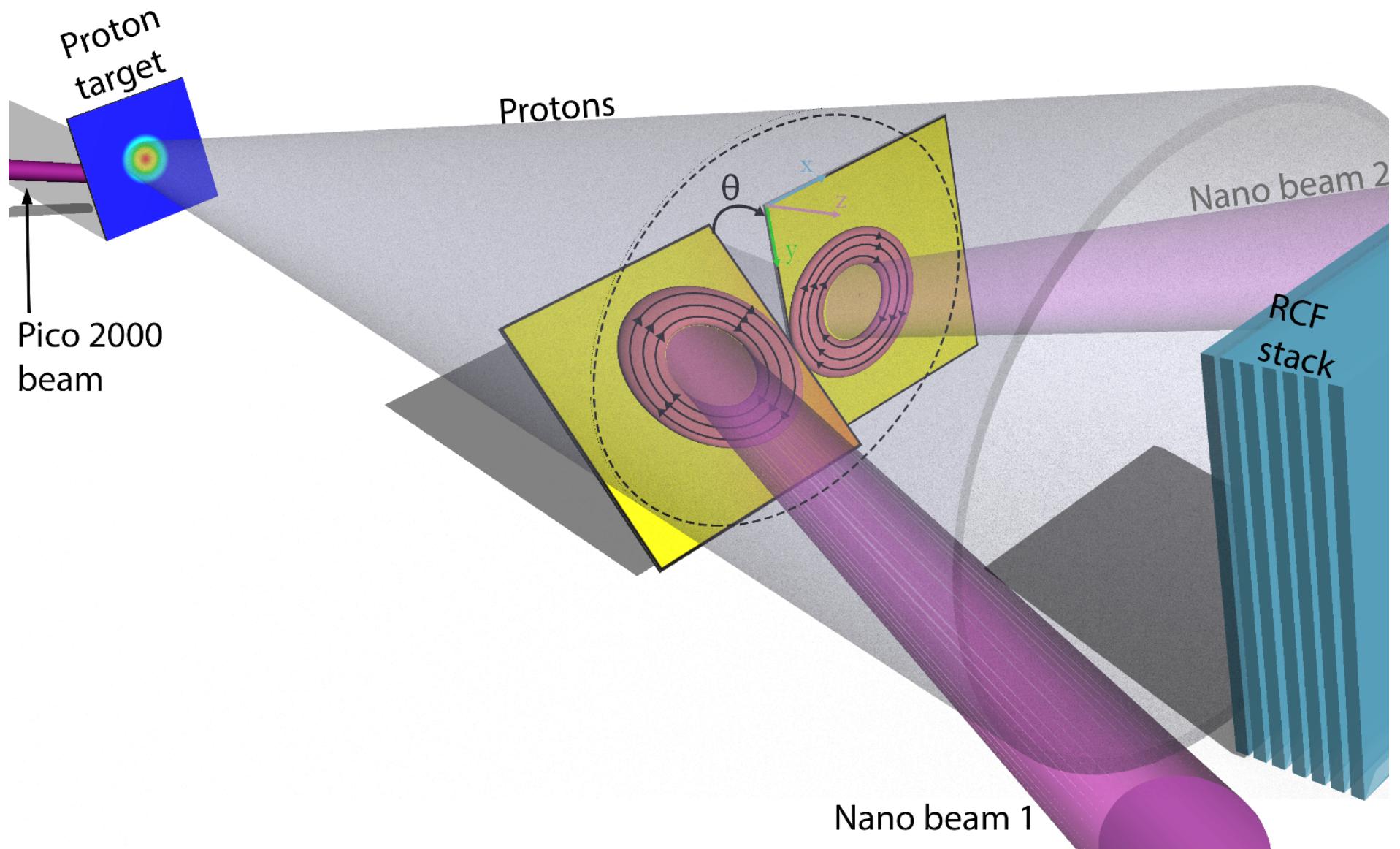
- A quadrupolar B field develops in thin & compressed current sheet
- These are also the condition to trigger magnetic reconnection
→ hence quadrupolar B field develops before reconnection
- The quadrupolar B field is not a consequence of reconnection
→ neither a cause... but "concomitant" with reconnection

With a different folding

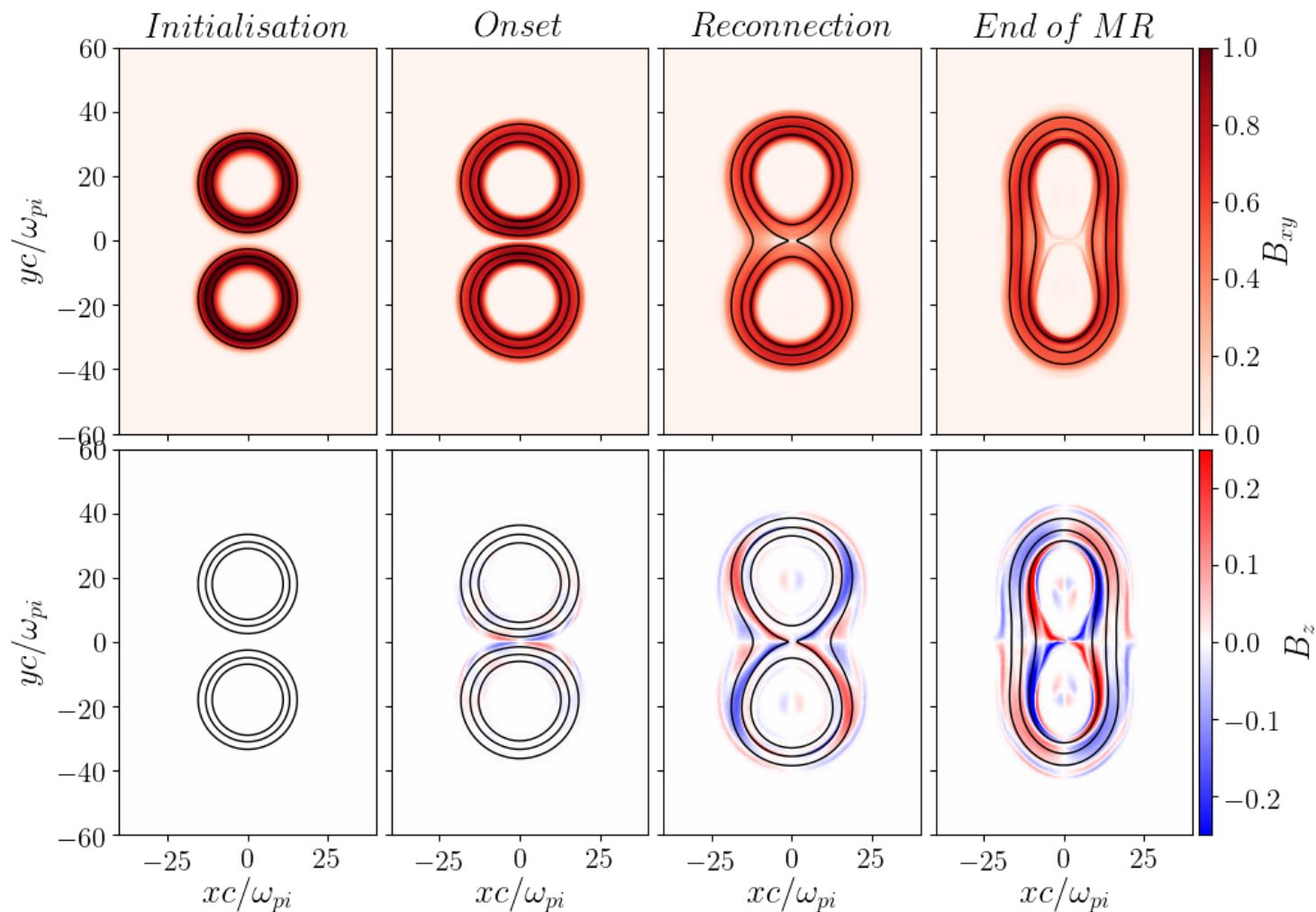


- Initial non-uniform Guide-field
→ generally slows-down the (symmetrical) reconnection

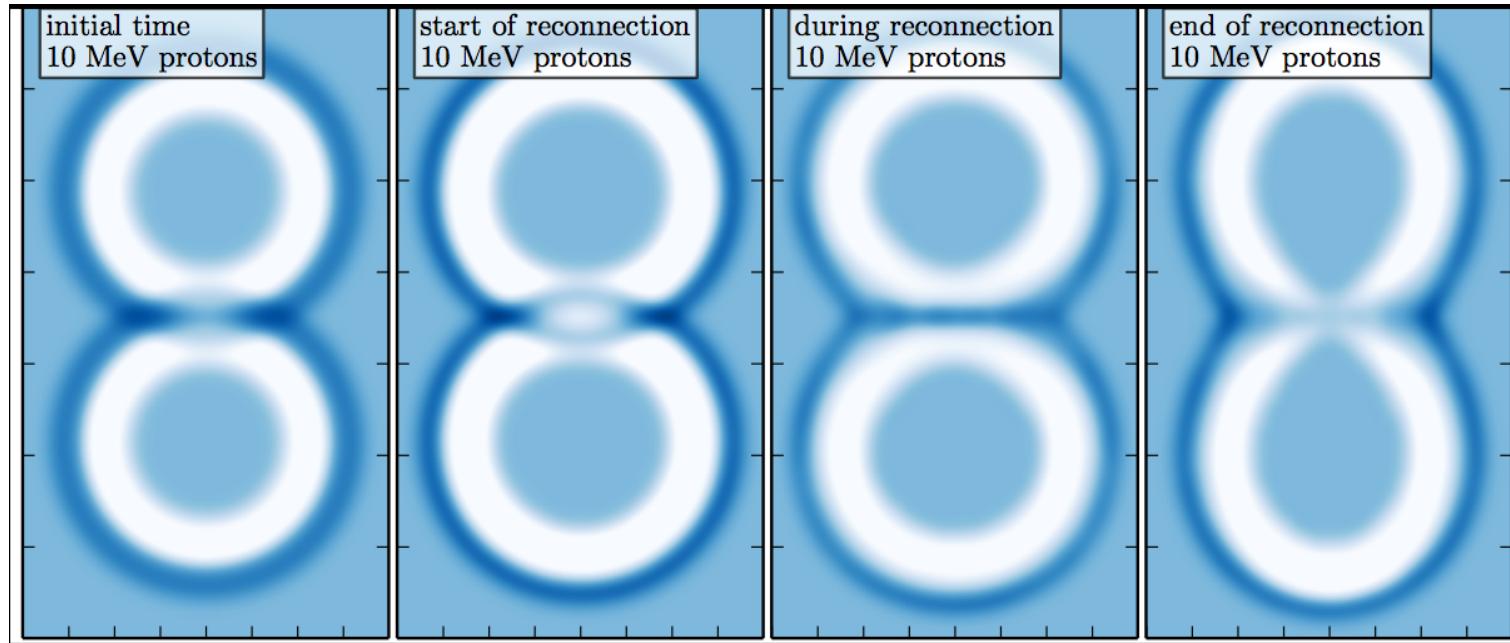
Experimental setup at LULI 2000 (in 2017)



Hybrid-PIC simulation for simplified 2D case

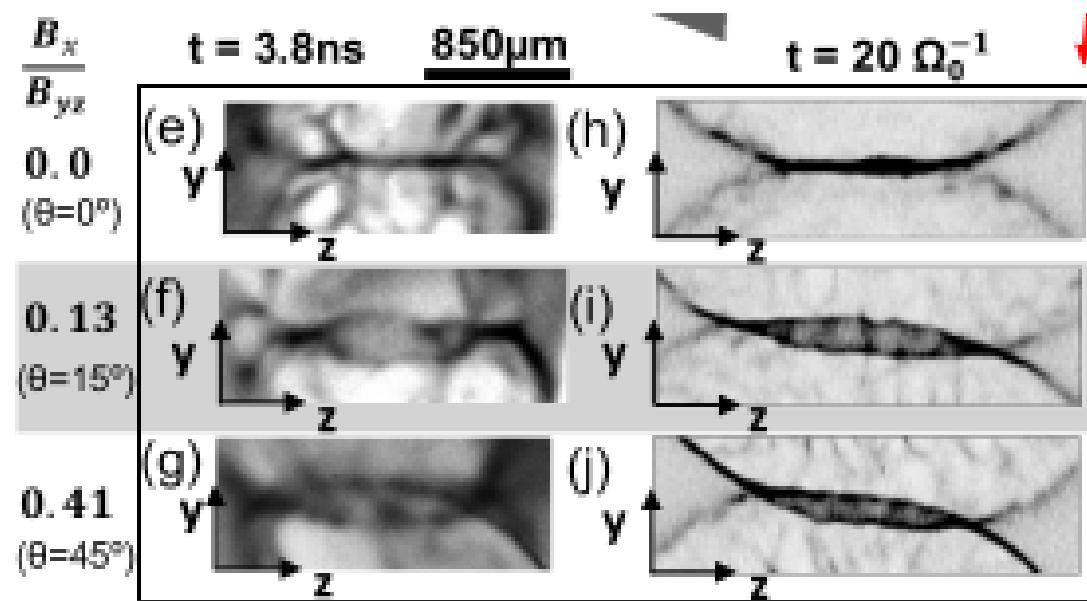


Synthetic RCF for 10 MeV proton beam



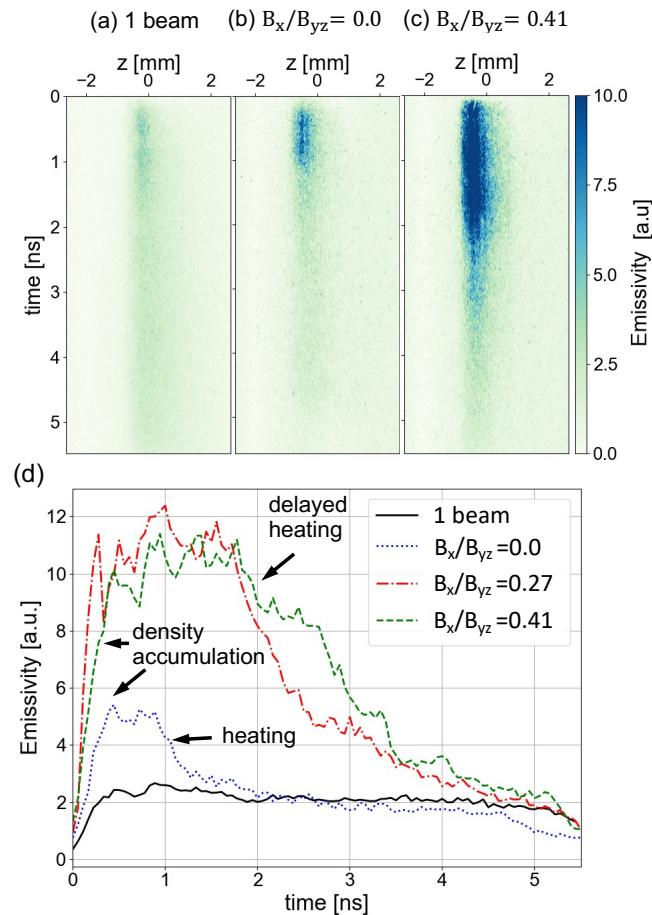
- a "mouth" open when B field is compressed
- but closes when reconnection operate (and decrease B)

Synthetic RCF for 10 MeV proton beam



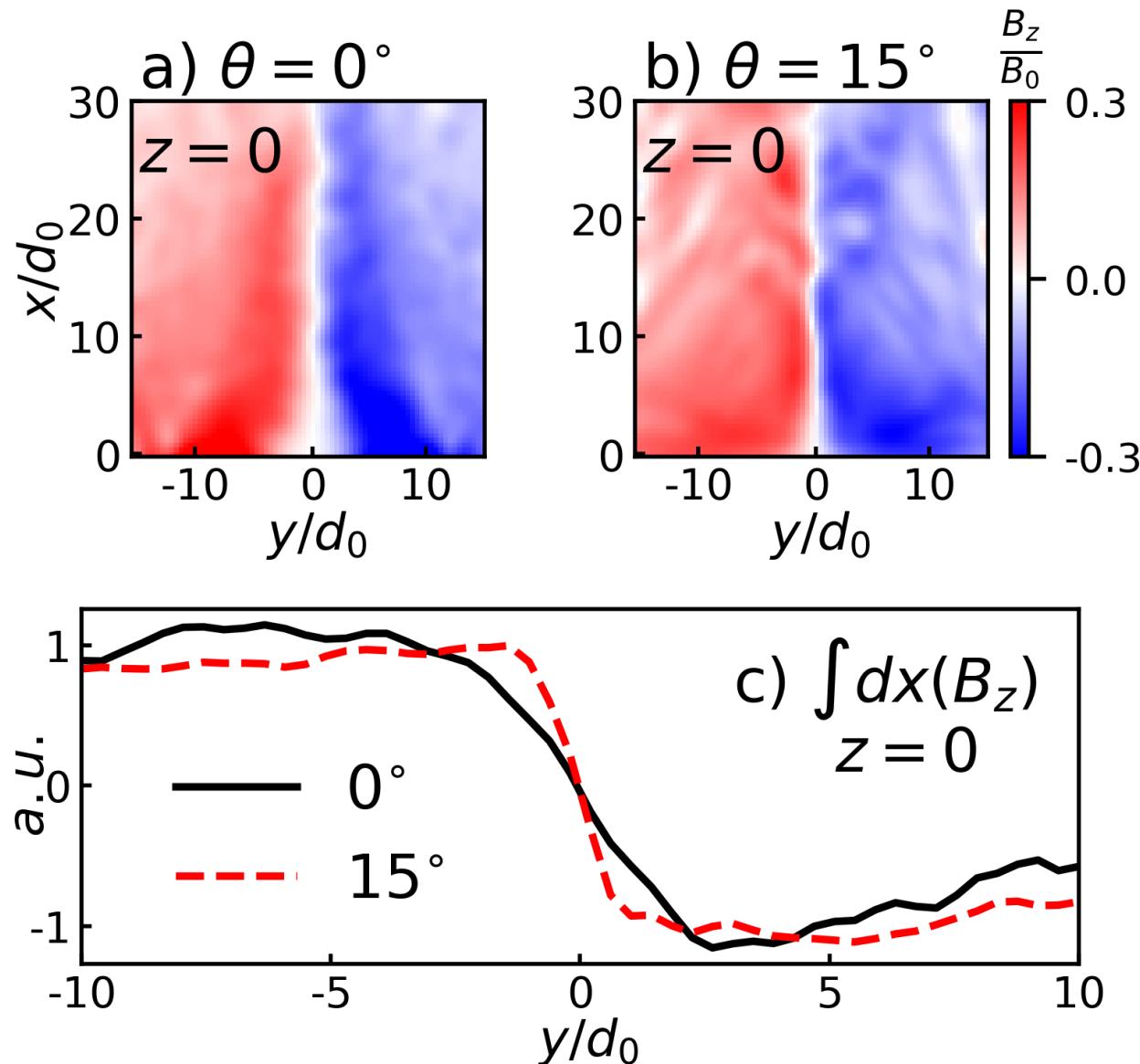
- for coplanar reconnection, no magnetic field pile-up : magnetic flux is expelled by reconnection
- "guided" reconnection is triggering later and/or at a smaller rate

Streaked Optical Pyrometry

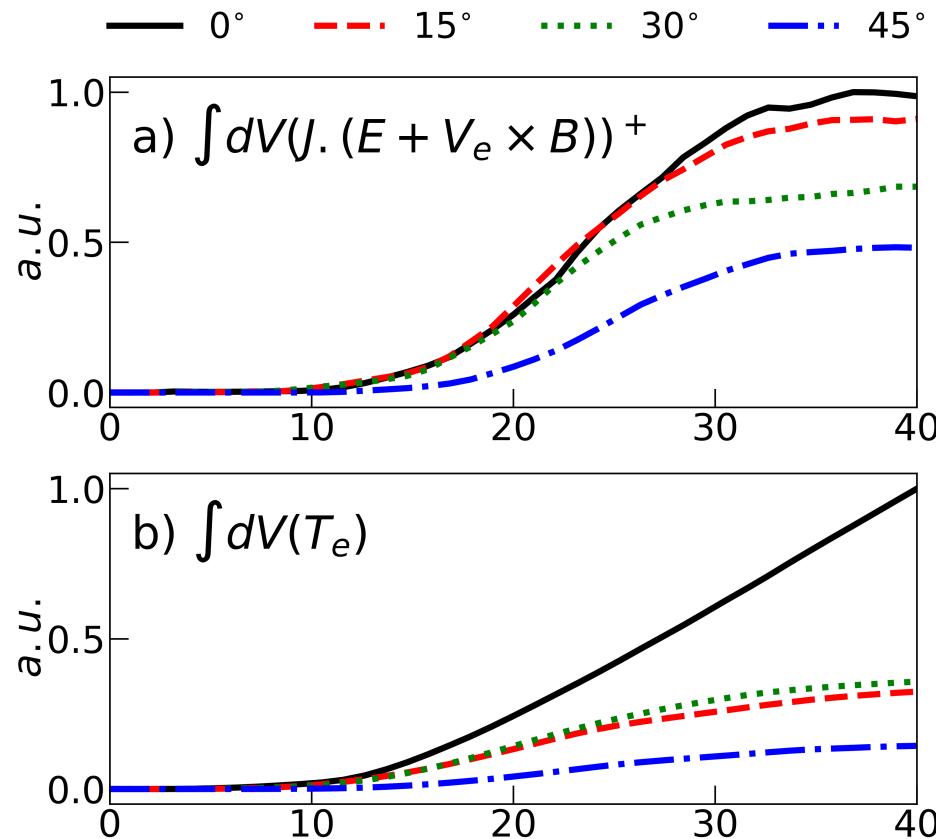


- emissivity increases with density because of the pile-up
- emissivity decreases for hot plasma

3D Hybrid-PIC simulations : "heated" and "feeded"



Energy dissipation and electron heating



- smaller energy dissipation for larger angles
- and also less efficient heating of the electrons

Concluding remarks : [Bolanos et al., Nat. Comm., 2022]

- Magnetic reconnection becomes less efficient when increasing the tilt angle between two flux-tubes
- Experiment point that when increasing the angle between the two targets :
 - enhancement of the magnetic compression
 - larger electron density
 - smaller electron temperature in the current sheet
- 3D hybrid-PIC simulations concur with the observations
→ drop of efficiency of the reconnection process