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EVALUATING ENERGY FLUXES DURING COMPASS DISRUPTIONS

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KEY RESULTS

- A method to estimate global energy losses during disruptions, based exclusively on magnetic measurements, is proposed
- The method does not require equilibrium reconstruction procedures, making it compatible to eventual real time or monitoring applications
- For a set of COMPASS disruptions the method is compared with data from IR and AXUV pinhola cameras, showing good agreement in terms of overall losses
- The greater magnetic energy available for conversion to heat is verified experimentally and compared to simplified theoretical models
- Preliminary validation against quasi-static MHD simulations is illustrated

COMPASS

Key parameters [1]

- Small machine ($R_w = 0.56\,\mathrm{m}$, $\langle b_w \rangle = 0.3\,\mathrm{m}$) with ITER-like shape (@ IPP CAS 2009-2021)
- Typical toroidal plasma current 160 kA
- Typical TF coil magnetic field at the plasma axis $0.9 - 2.1$ T.

Diagnostics used in this work

- Poloidal, radial and toroidal Mirnov coils, 24 diagnostics per group, equally spaced along the poloidal angle;
- 8 toroidal full flux loops for the measurement of the poloidal flux;
- Diamagnetic flux loop for the toroidal flux measurement (+TF coil current meas.)

METHODOLOGY

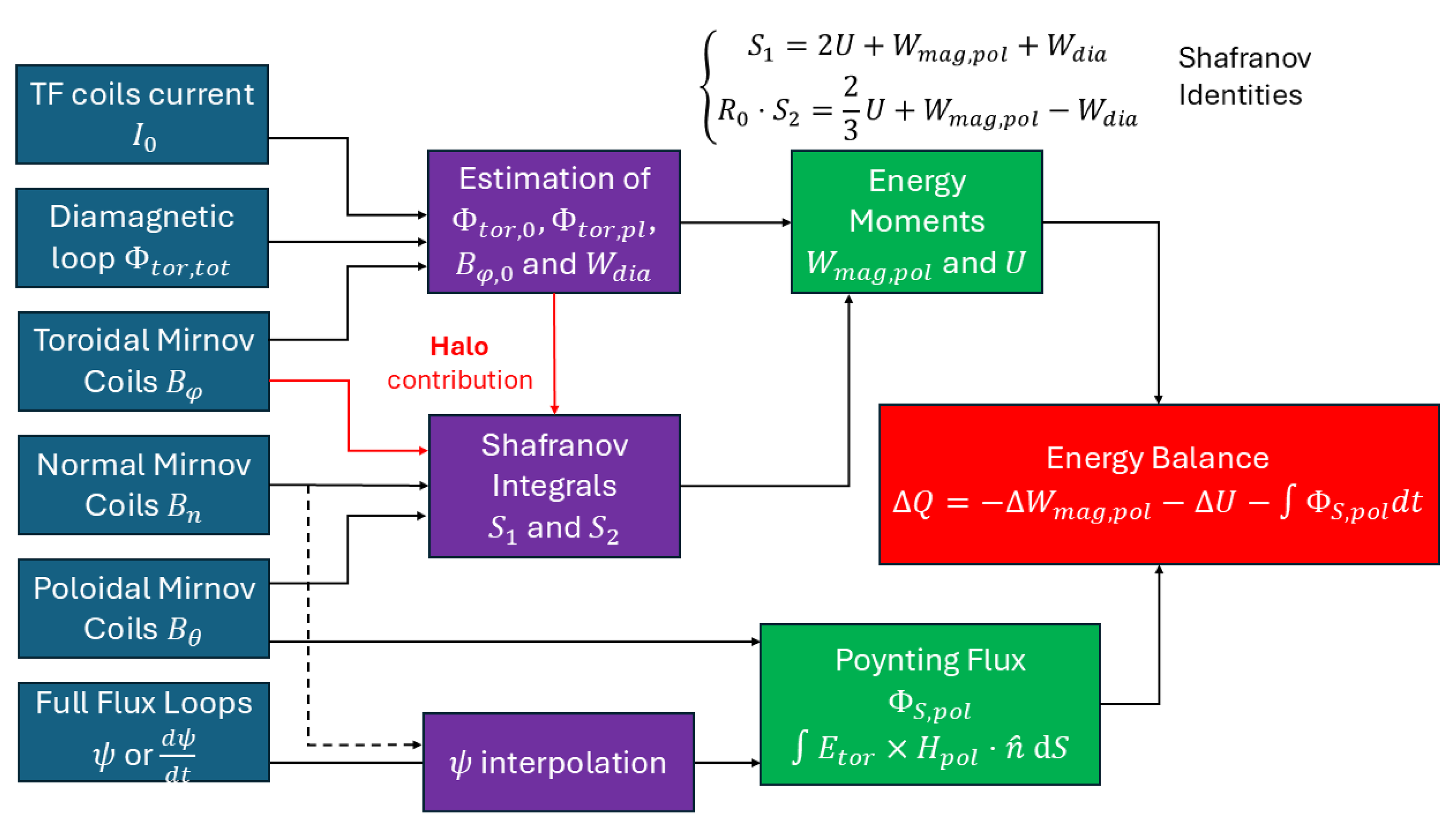

Figure 1: Schematic of the proposed magnetic method for losses estimation.

- Definition of a control volume enclosed by a well-diagnosed *Diagnostic Surface;*
- Proper discretization of Poynting and Shafranov integrals according to avaiable diagnostics;
- Smart use of normal magnetic field to the *Diagnostic Surface* to estimate poloidal flux at other locations, choosing automatically non-saturate measurements.

BENCHMARK WITH OTHER DIAGNOSTICS

- Benchmark against sum of conducted and radiated heat as measure by IR camera and AXUV pinhole diodes respectively;
- IR camera points to the divertor region → only downard VDEs considered for benchmark;
- Toroidal Mirnov coils signals need lots of processing, dedicated experiments with tuned range or toroidal Rogowski coils may help.

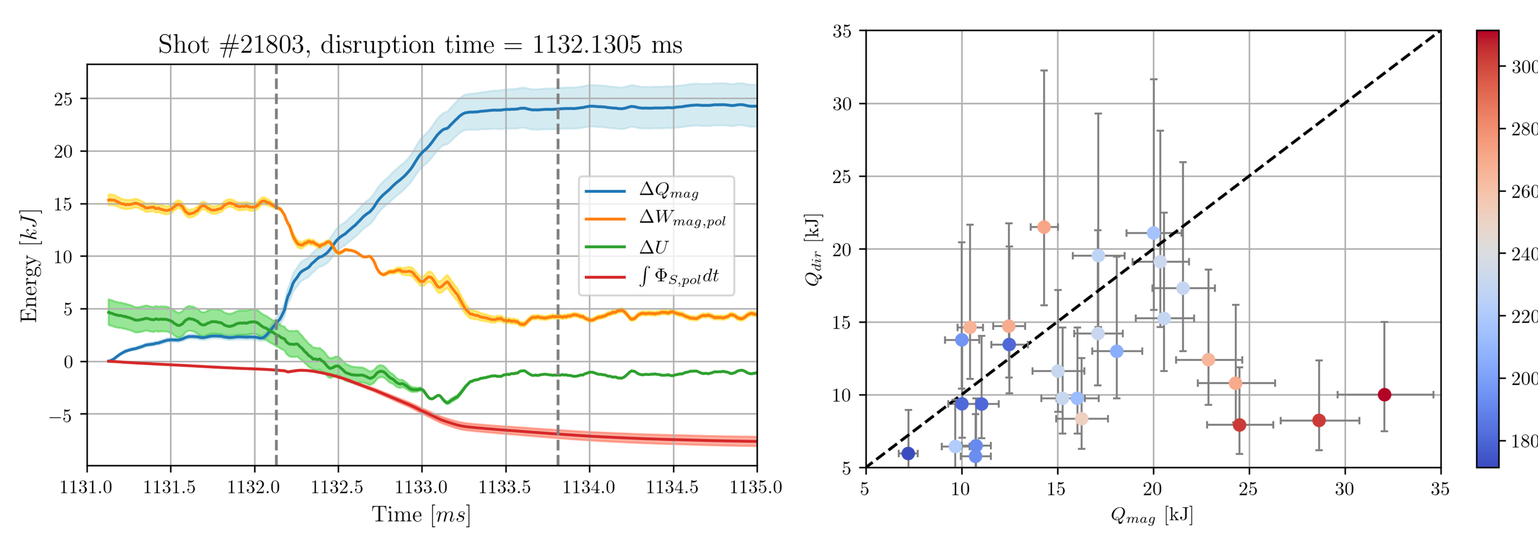

Figure 2: (a) Example of time integrated Poynting integral and energy moment variation estimated magnetically during a COMPASS disruption; (b) Parity plot comparing proposed magnetic method and direct conducted and radiated heat measurements.

BENCHMARK WITH THEORETICAL PREDICTIONS

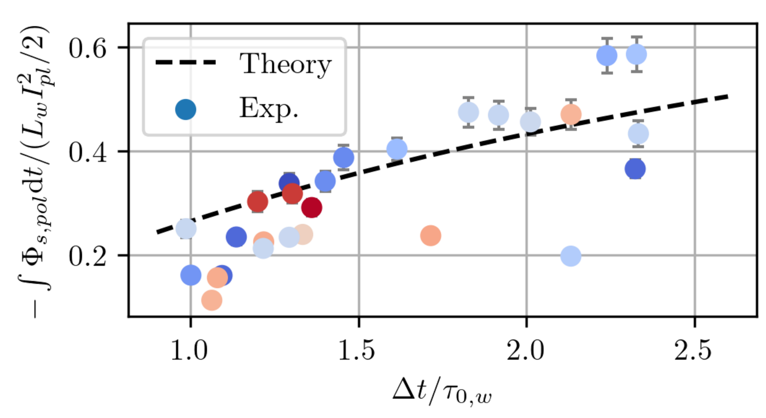

Figure 3: Magnetic energy influx as function of disruption duration.

- Longer CQ duration → larger the fraction of magnetic energy penetrating inside the vessel → more magnetic energy is converted to heat within the plasma [2]
- $L_w = 49.6\,\mu$H, $\tau_{0,w} = 0.84 \pm 0.21$ ms
- Analytical expression for the normalized energy influx:

$$\frac{2}{(\Delta t/\tau_{0,w})^2}\left[1 - \frac{\Delta t}{\tau_{0,w}} + \frac{1}{2}\left(\frac{\Delta t}{\tau_{0,w}}\right)^2 - \exp\left(-\frac{\Delta t}{\tau_{0,w}}\right)\right].$$

BENCHMARK WITH SIMULATIONS

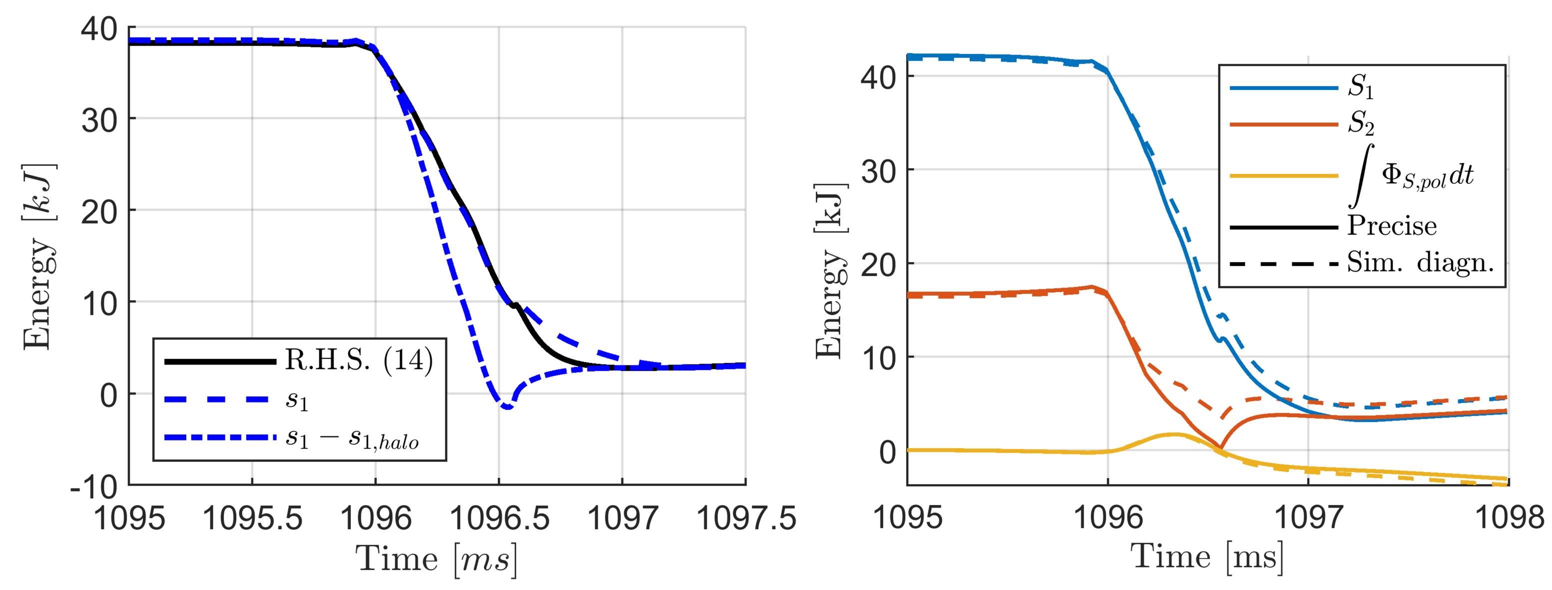

Figure 4: (a) Relative weight of halo contribution in the Shafranov identity for S_1. (b) Error introduced considering a discretization of the surface integrals at Mirnov coil locations.

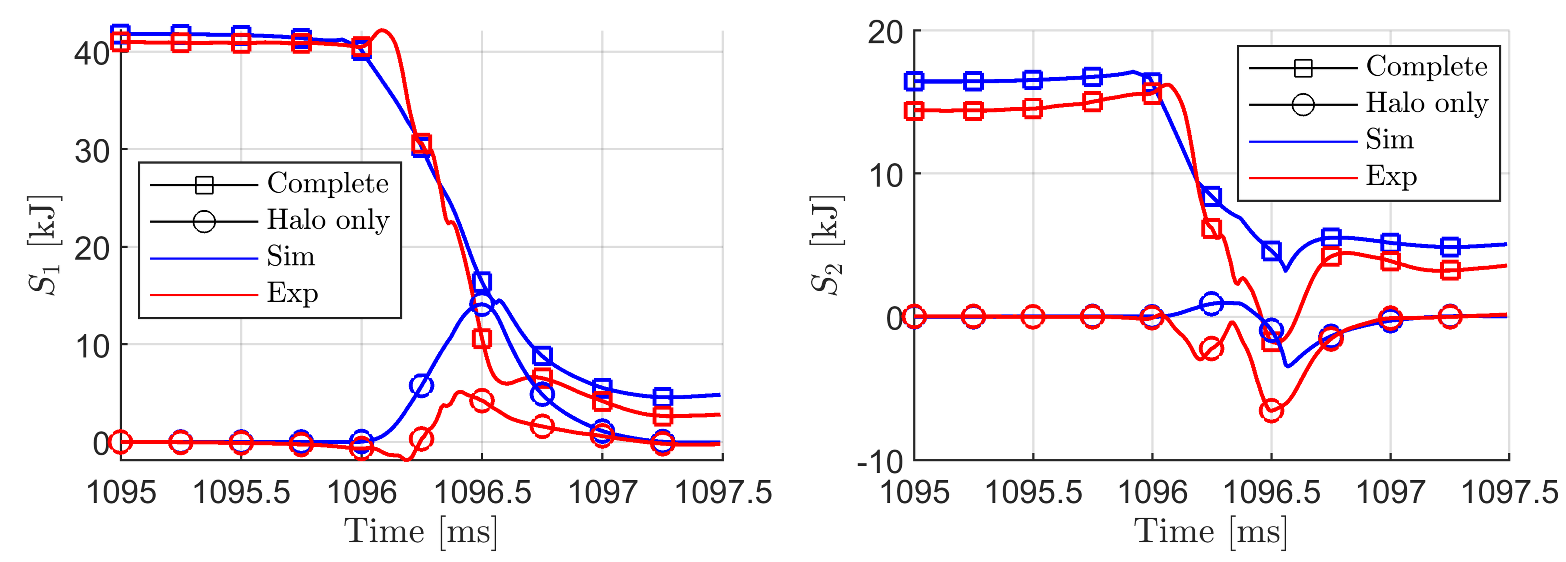

Figure 5: Comparison of Shafranov integrals in experiment #19172 and respective CarMa0NL simulation. Halo contribution is highlighted.

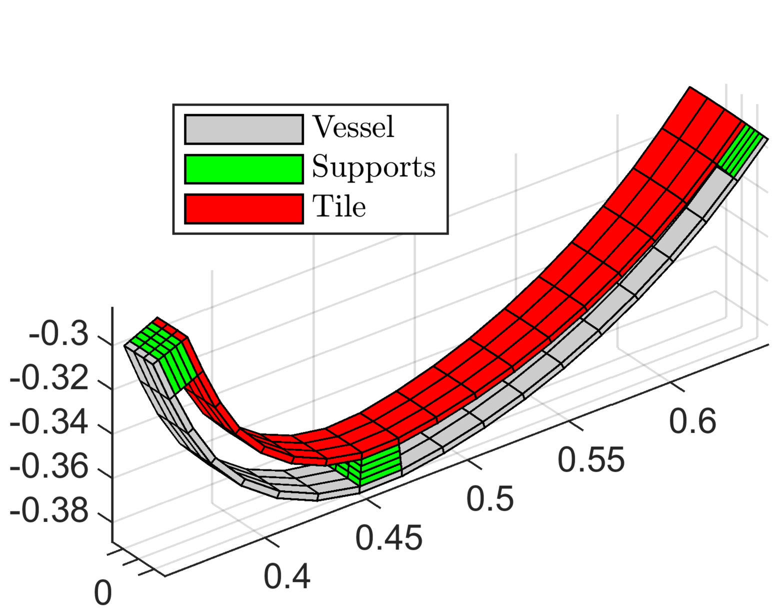

Figure 6: Approximate tiles representation to study halo current patterns.

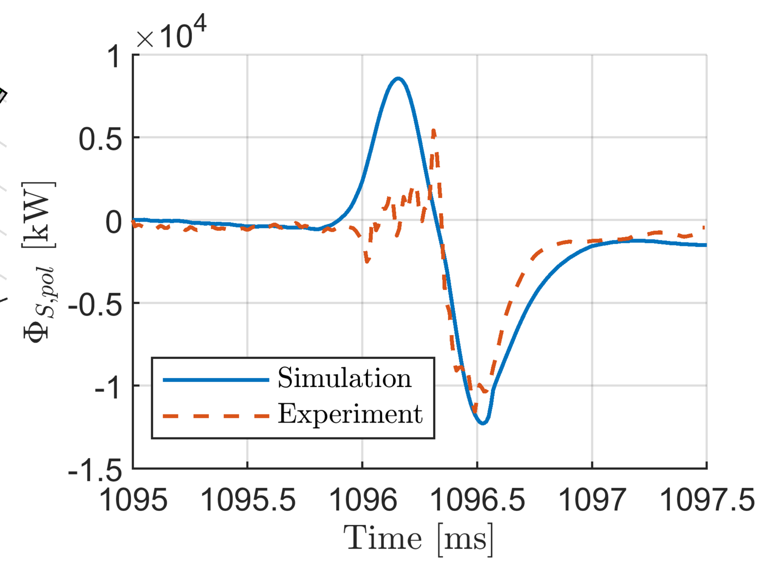

Figure 7: Flux of Poynting vector across Diagnostic Surface.

- Mass-less MHD models share the fundamental assumption of the proposed method → CarMa0NL simulations [5];
- Halo currents are important in the correct determination of poloidal magnetic energy and plasma thermal energy;
- COMPASS diagnostics set up has sufficient resolution for determining correctly the Shafranov and Poynting integrals;

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