Characterizing fuel magnetization for MagLIF using neutron diagnostics

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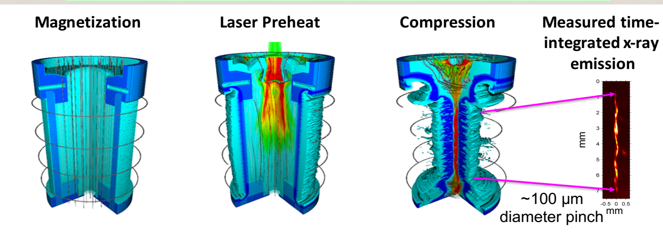
MagLIF is an inertial-confinement-fusion (ICF) concept that utilizes magnetic confinement to relax certain ignition requirements.

- Pre-magnetizing the fuel significantly reduces the pressures and densities needed to achieve ignition.

Magnetized liner inertial fusion[1-2] (MagLIF)



- The relaxed conditions are realizable because the magnetic field insulates the hot fuel from the cold pusher.
- For MagLIF, the compressed axial magnetic flux confines the charged burn products.
  - In the case of DT fuel, this leads to enhanced alpha particle self-heating.

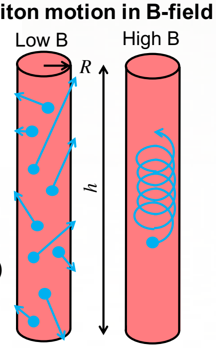
BR and *ρR* are two of the fundamental confinement parameters for MagLIF.[3-4]

- The degree of fuel magnetization at stagnation depends on the quantity BR, which is the product of the B-field and the fuel radius at stagnation.

$$\frac{R_{fuel}}{R_{L,\alpha}} = \frac{BR\,[T\cdot cm]}{26.5} = \frac{BR\,[G\cdot cm]}{2.65\times10^{5}}$$

$$\approx 4BR\,[MG\cdot cm]$$

Triton motion in B-field



- Initial B-field (~ 10 T) increases by a factor of ~1000x at stagnation.
- Charged-particle fusion products (alphas for DT fuel, tritons for DD fuel) execute helical orbits and become trapped in the plasma.

BR > 0.6 MG-cm is a goal for MagLIF.

BR ~ 0.4 MG-cm is what we have achieved.

Secondary DT neutrons reveal information about the degree of fuel magnetization at stagnation.

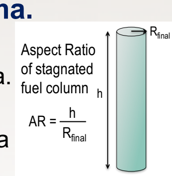
- Primary DD and secondary DT reactions:

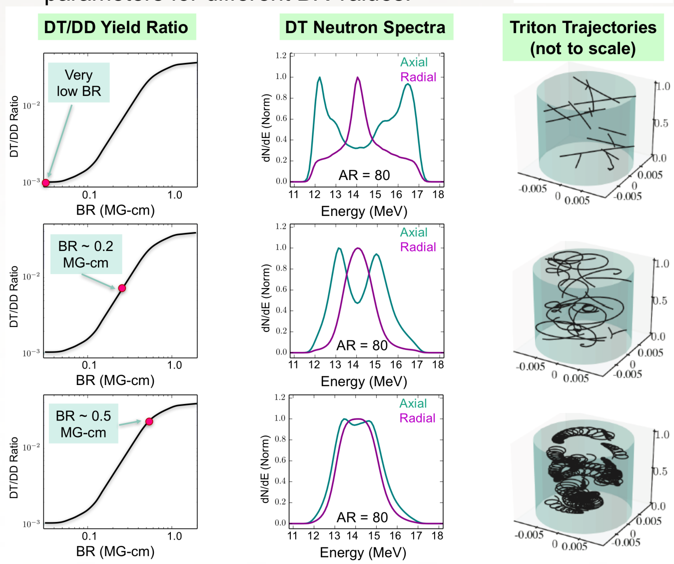
D + D → He^3 (0.8 MeV) + n (2.45 MeV)		~50%
→ T (1.01 MeV) + p (3.02 MeV)		~50%
D + T (1.01 MeV) → He^4 (1.4-6.7 MeV) + n (11.8-17.1 MeV)		~100%

- The 1-MeV triton from DD reactions serves as an excellent surrogate for studying alpha particle confinement and heating relevant for 50/50 DT fuel.

A 1D fully kinetic model is used to track the triton motion in the deuterium plasma.

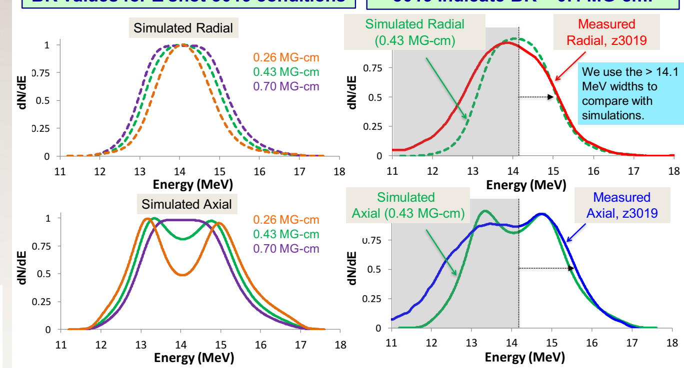
- A Monte Carlo code post-processes the results and produces synthetic neutron data.
- 2000+ simulations are run with experimentally measured stagnation plasma parameters for different BR values.

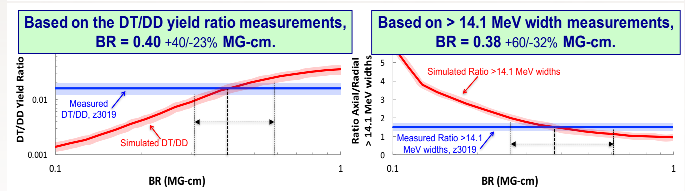




Asymmetry in the secondary DT neutron spectra is due to the cylindrical geometry.

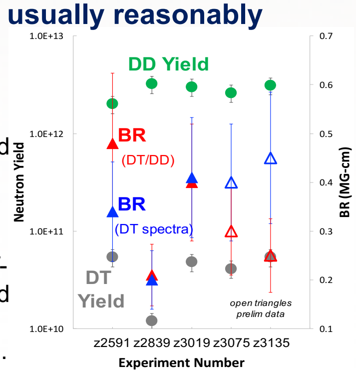
Differences in the radial and axial secondary DT spectra, and relative DT/DD yield ratios, are used to infer BR.





BRs inferred from the neutron spectra and the relative yield ratios are usually reasonably consistent.

- The BR inferred from DT/DD ratios may be less reliable because of mix and other issues not taken into account in the model.
- Because there is not yet a way to measure BR for DT-fuel, DD-tritons will be used to inform alpha heating for future DT-fuel experiments.



Using a *cylindrical geometry* and *deuterium fuel* allow us to diagnose fuel magnetization at stagnation.

1. S. Slutz *et al.* PRL (2012).
2. S. Slutz *et al.* PoP (2010).
3. P. F. Schmit *et al.* PRL (2014).
4. P. F. Knapp *et al.* PoP (2015).

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