Using plasma jets to solve a stand-off problem for magnetized target fusion*

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THE SCOPE

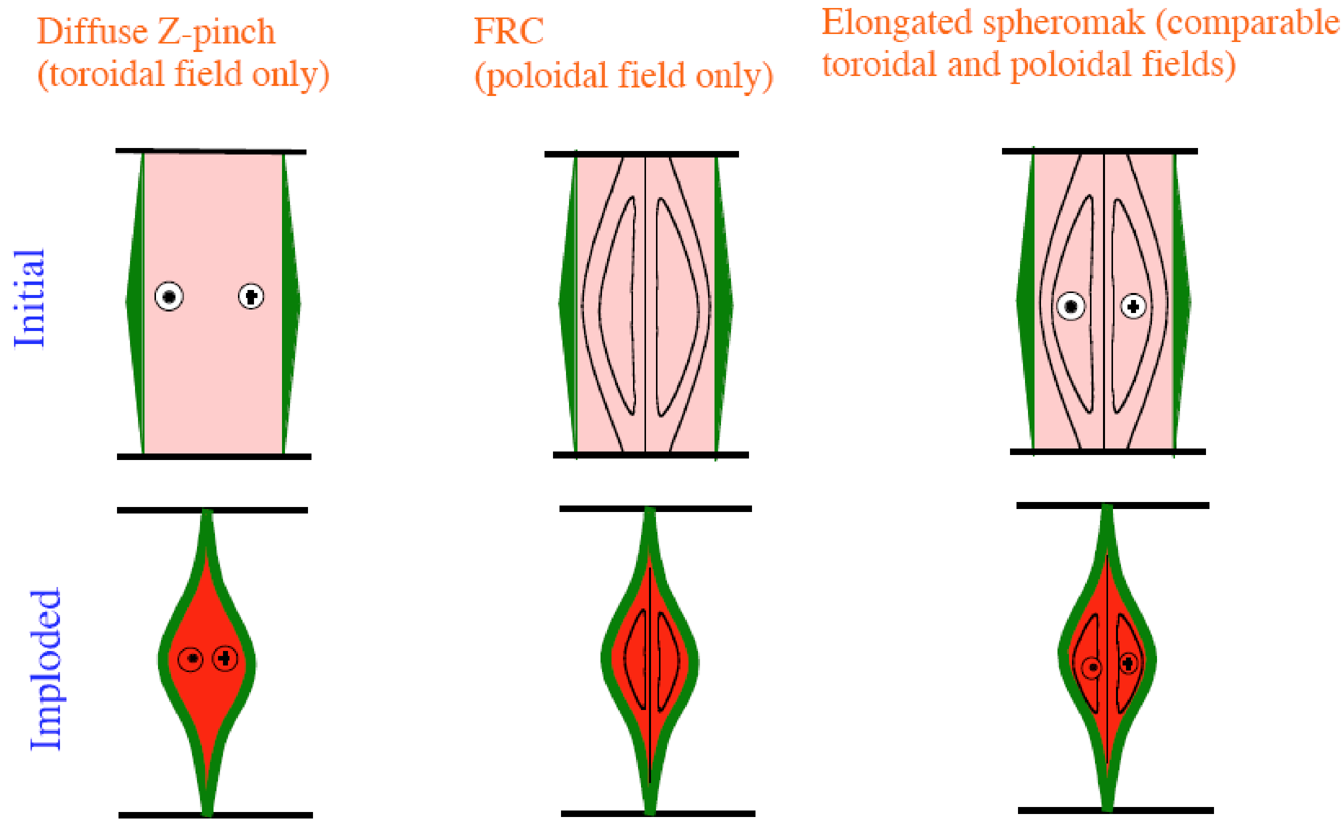
• Magnetized Target Fusion (MTF) is a term designating a broad variety of approaches based on a unifying idea of adiabatic compression of a pre-formed magnetized β>1 plasma by a conducting liner

• MTF systems span a broad range of plasma parameters intermediate between magnetic confinement and inertial confinement

• We concentrate on a version of MTF that involves 3D implosions of a wall-confined plasma with the density in a compressed state ~ 10^{22} cm^{-3}, with energy in ~ 10-30 MJ and energy out ~ 300 MJ; the current ~ a few MA, current pulse-length ~ 5-10 μs.

*This fusion concept has a long history; a summary of the earlier work can be found in R.P. Drake, J.H. Hammer, C.W. Hartman, L.J. Perkins, D.D. Ryutov. "Submegajoule liner implosion of a closed field line configuration," Fusion Technology, **30**, 310, 1996.*

A variety of targets can be imploded in a 3D fashion by a liner of a varying thickness



Initial configuration can be created *in situ*

FRC has to be created in a separate chamber and injected through a hole in the electrode (not shown)

Spheromak can be created in a "bubble-burst" fashion or *in situ*

Possible solutions of the stand-off problem

Mechanical insertion of the target and disposable transmission line to a large chamber. (R.W. Moses, R.A. Krakowski, R.L. Miller. *"A conceptual design of the Fast-liner Reactor (FLR) for Fusion Power."* LANL report LA-7686-MS, February 1979)

Driving a magneto-cumulative generator by a fast projectile. (R.P. Drake, J.H. Hammer, C.W. Hartman, L.J. Perkins, D.D. Ryutov. *"Submegajoule liner implosion of a closed field line configuration,"* Fusion Technology, **30**, 310, 1996)

Delivering the current by a particle beam (inverse diode technique). (R.P. Drake, J.H. Hammer, C.W. Hartman, L.J. Perkins, D.D. Ryutov. *"Submegajoule liner implosion of a closed field line configuration,"* Fusion Technology, **30**, 310, 1996)

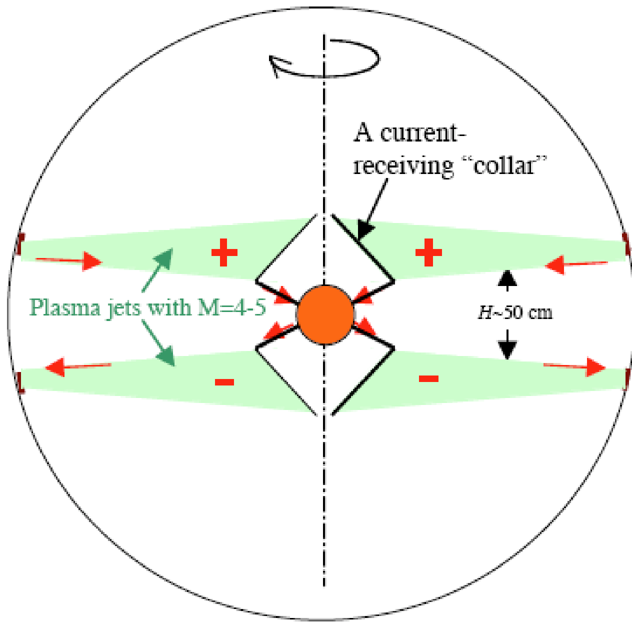
Using a set of converging, high Mach-number plasma jets. (Y.C.F. Thio, C.E. Knapp, R.C. Kirkpatrick, R.E. Siemon, P.J. Turchi. *"A physics exploratory experiment on plasma liner formation,"* J. Fusion Energy, **20**, 1, 2001; P.B. Parks, Y.C.F. Thio. *"The dynamics of Plasma Liners Formed by Merging of Supersonic Plasma Jets,"* Prepared for submittal to Phys. Plasmas)

Using a spherical liner made of high-Z plasma driven by subsonic thermal plasma. (D.D. Ryutov, Y.C.F. Thio. *"Plasma liner with an intermediate heavy shell and thermal pressure drive",* Fusion Sci. Technol., **49,** 39-55, 2006).

Using plasma streams as disposable electrodes. (D.D. Ryutov, Y.C.F. Thio. *"Solving the stand-off problem for Magnetized Target Fusion: plasma streams as disposable electrodes, together with a local spherical blanket."* Journal of Fusion Energy, **26**, 173, 2007; http://dx.doi.org/10.1007/s10894-006-9050-5, 2006).

Using a local spherical blanket and delivering the power by an array of plasma jets (plasma electrodes)

The voltage between the upper and the lower jet arrays is applied when the jets reach the current-receiving "collar"



Plasma gun muzzles (an azimuthal array)

The target, with the collar attached, is dropped to a 6-m diameter reaction chamber. The collar can be made of a frozen (minus 30-40 C) lithium, ~ 1 mm thick. It collects the current supplied by disc-shape plasma electrodes and directs it to the target.

More details about the central structure will be provided shortly

Possible scenario:

High Mach number gaseous jets, injected towards the “collar,” form two gaseous discs

Inner surfaces of the discs are ionized either by an external agent, or by virtue of a breakdown along the lowest inductance path*

Voltage ~ 1 MV is applied and drives a current through the implosion circuit

Electric insulation between discs is provided by azimuthal magnetic field

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* An alternative is using an array of plasma jets backed up by heavier gaseous discs

Characteristic parameters of the system

Distance between the disc plasma electrodes: $h \sim 20$ cm

Parameters of the conducting layer: $n \sim 10^{17}$ cm^{-3}, $T \sim 10$ eV, $\Delta h \sim 3$ cm

The magnetic field strength near the intersection with the "collar": $B \sim 1.5$ T

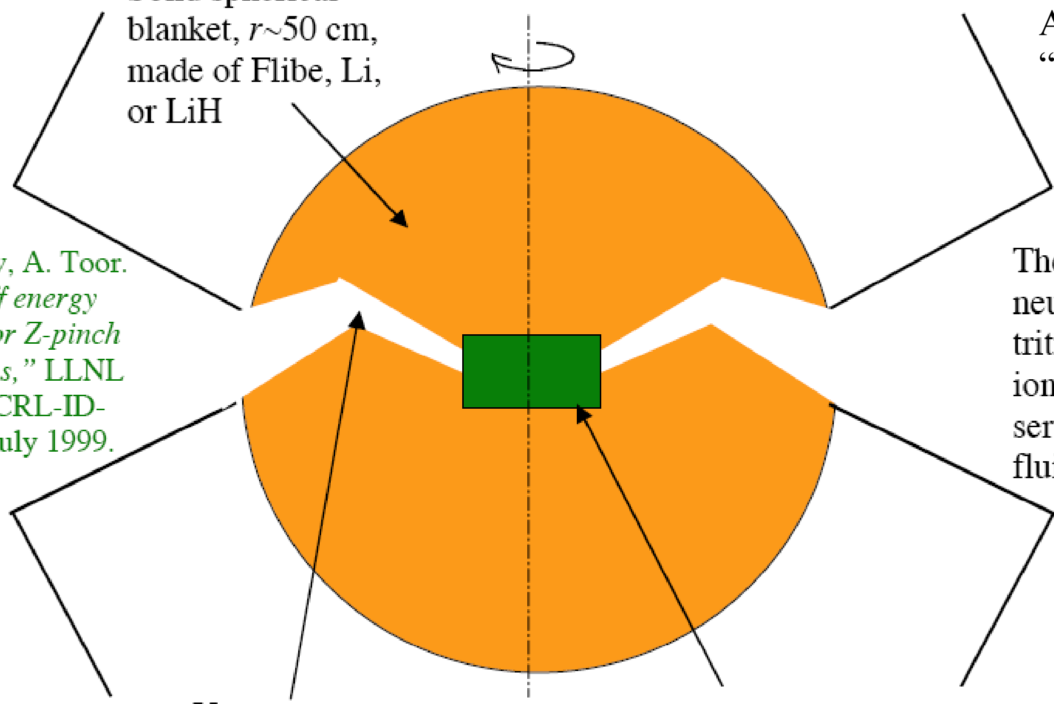
Pulse length $\tau \sim 10$ μs

Current transmitted to the target $I \sim 5$ MA

The magnetic energy stored in the gap $W_M < 1$ MJ

The target can be embedded in a solid spherical blanket

[See B.G. Logan, Fusion Engineering and Design, 22, 1953 (1993), and references therein]



D. Ryutov, A. Toor. "*Stand-off energy sources for Z-pinch implosions,*" LLNL Report UCRL-ID-135082, July 1999.

Summary

The general architecture of the MTF fusion reactor based on the localized (evaporating in every shot) spherical blanket, and energy delivered to the target by plasma electrodes (plasma jets) looks quite attractive

Most challenging technology issue is maintaining a low cost of an assembly (less than ~$ 1 per pulse!).