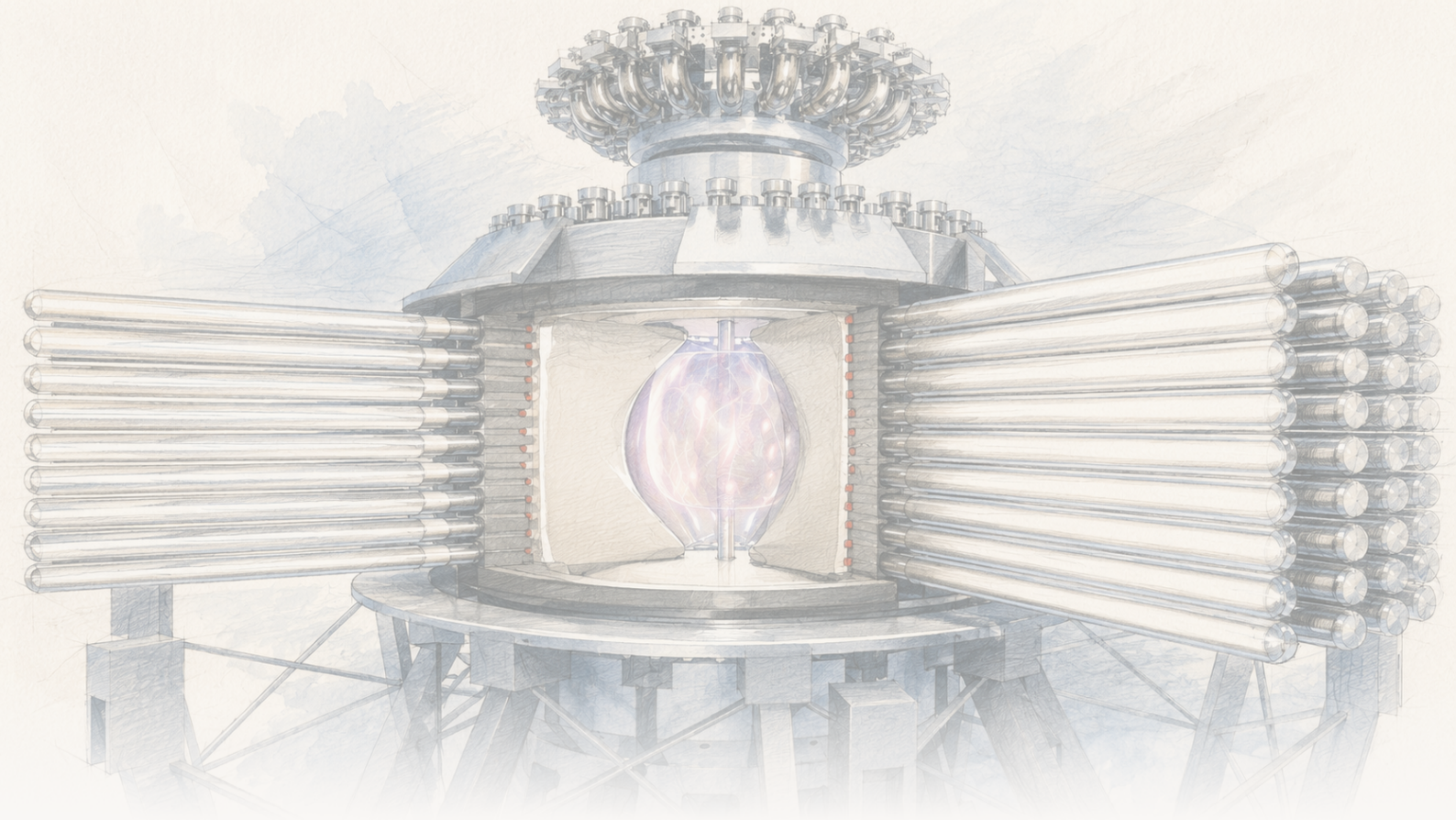


The Clean Paper

WHAT THE PAPER SAYS · WHAT IT DOESN'T · WHY IT MATTERS

Na'urar fusion ta dumama plasma ta hanyar matse shi — wannan ne ainihin matakin, ba tashar wutar lantarki ba

LM26 ta General Fusion ta matse magnetized deuterium plasma da lithium liner da ke imploding, ta kuma ga electron temperature ya fi ninki uku zuwa peak kusan 0.72 keV (718 ± 80 eV, kusan miliyan 8 °C), yayin da analysis na kamfanin ya danganta mafi yawan dumamar da compression kanta. Wannan checkpoint ne na engineering ga magnetized target fusion, amma shots 11 na farko ne, a company preprint da ba a yi peer review ba, a zafin da har yanzu ya yi kusan sau goma kasa da burning plasma — babu net energy, breakeven ko wutar lantarki.

Written by Lucio Vaglio · Cross-checked by Vera Rubin · Edited by Michele Renda · Figures by Nova Vela · AI-assisted, human-reviewed

Paper: *The science of compressional heating on the LM26 magnetized target fusion experiment*, S. J. Howard et al. (General Fusion), arXiv:2606.23974 [physics.plasm-ph] (preprint) · DOI: 10.48550/arXiv.2606.23974

Na’urar fusion ta dumama plasma ta hanyar matse shi — wannan ne ainihin matakin, ba tashar wutar lantarki ba

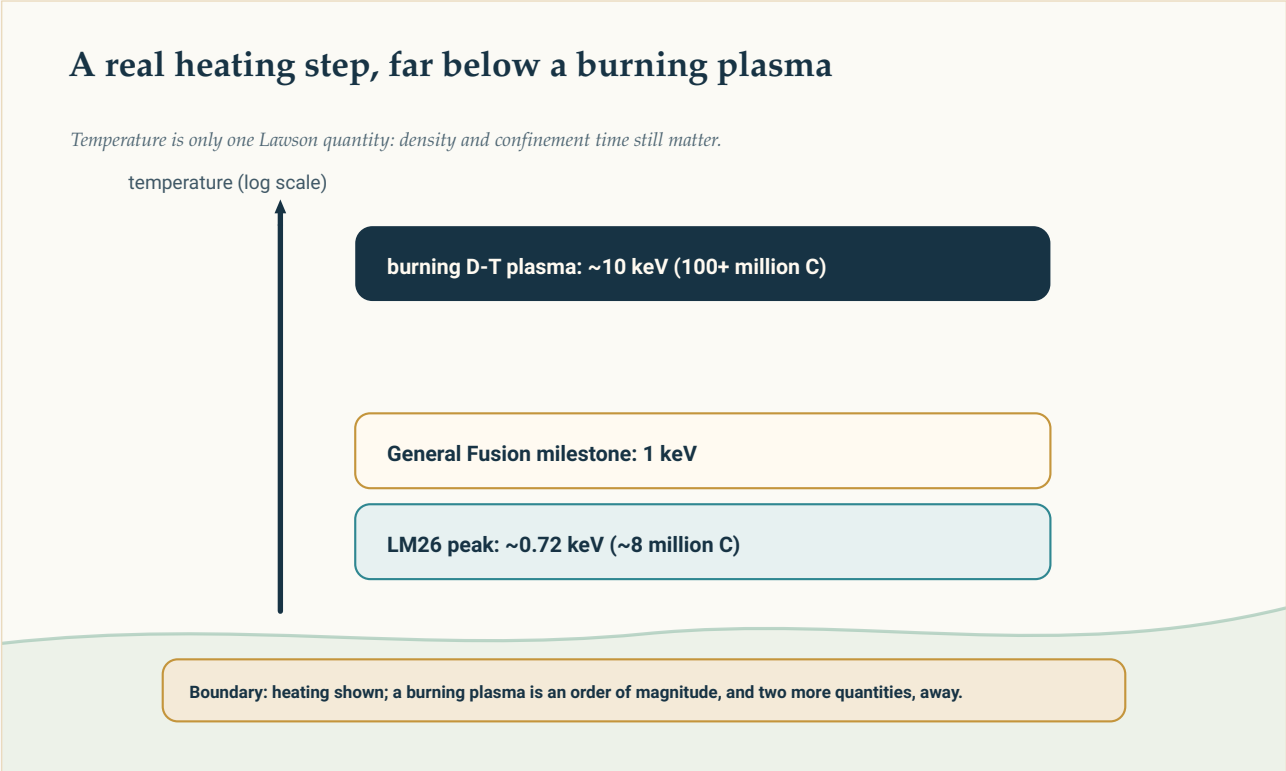
Domin reactor na fusion ya fitar da makamashi fiye da wanda ake kashewa wajen tafiyar da shi, plasma na man fetur dole ne a lokaci guda ya zama mai zafi sosai, mai yawa sosai, kuma a riƙe shi tare na tsawon lokaci — abubuwa uku da masana physics ke haɗawa cikin abin da ake kira **Lawson criterion**. Mafi yawan fannin yana ƙoƙarin cimma wannan da manyan superconducting magnets (tokamaks kamar ITER) ko manyan jerin lasers (inertial confinement, kamar a US National Ignition Facility). Kananan rukuni na kamfanoni suna yin fare a kan hanya ta uku, **magnetized target fusion (MTF)**: a fara da plasma mai ɗumi da magnetic field, sannan a *murƙushe* shi da sauri ta hanyar inji, domin matsewar kanta ta yi dumama — kamar injin diesel da ke kunna man fetur ta compression maimakon spark.

A Yuni 2026, kamfanin Kanada **General Fusion** ya wallafa sakamako daga **Lawson Machine 26 (LM26)** da ke gwada ko wannan babban zato yana aiki: idan an matse magnetized plasma da inji, shin da gaske zai yi zafi kamar yadda models suka yi hasashe? A cikin compression shots 11 na farko — inda spherical-tokamak deuterium plasma aka matse da **solid lithium liner** da ke ruɓewa zuwa ciki — mafi kyawun shots sun nuna plasma ya zama mafi zafi, mafi yawa kuma mafi ƙarfin magnetization yayin da aka matse shi. Binciken kamfanin ya danganta mafi yawan dumamar da compression kanta.

Wannan sakamakon engineering ne na gaske kuma takamaimai ga hanyar MTF. Amma kuma shots na farko ne kawai, a cikin **company preprint da ba a yi peer review ba**, a zafin da har yanzu ya yi ƙasa sosai da abin da burning plasma ke buƙata — kuma ba fusion energy ba ne, ba breakeven ba, ba tashar wutar lantarki ba.

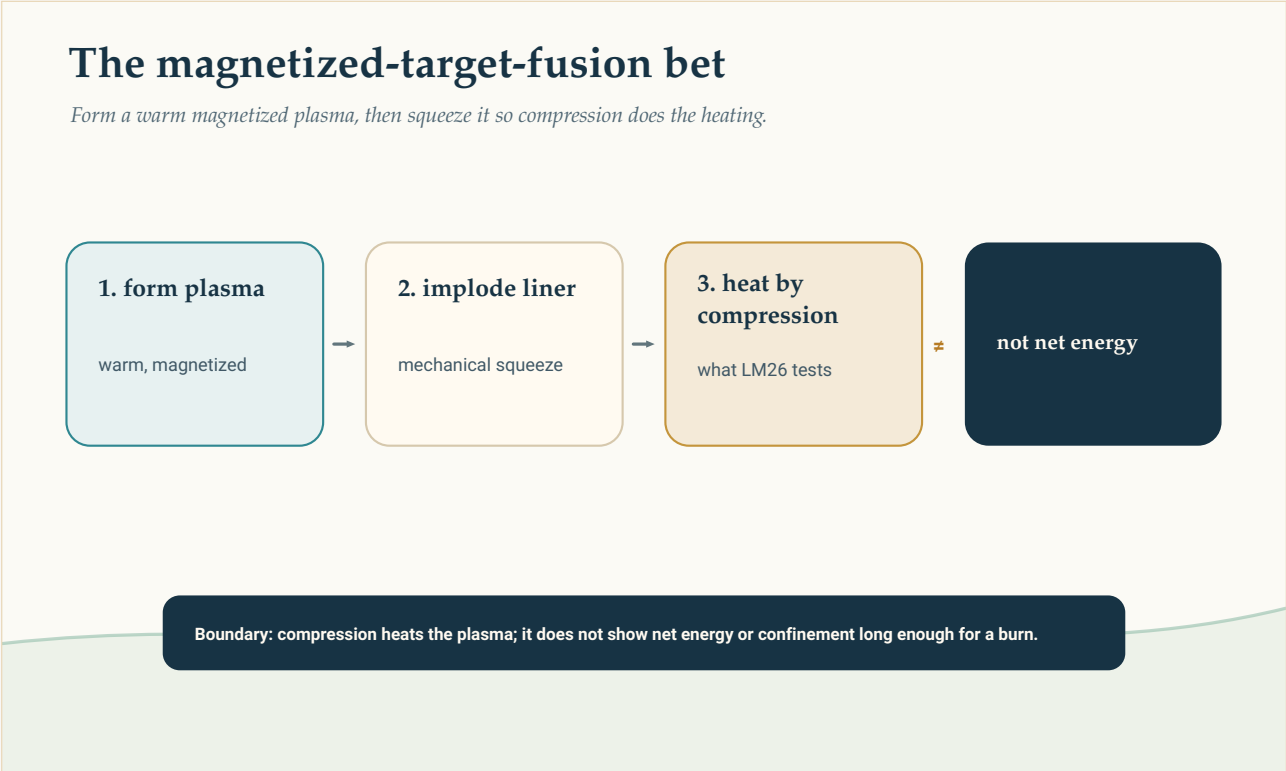
[video pending]

Wannan promotional footage ne daga General Fusion, an saka shi ne kawai don nuna yadda LM26 take; ba independent shaida ba ne cewa na’urar za ta kai future fusion milestones ɗinta.



Matakan zafi: LM26 kusan 0.72 keV, milestone na General Fusion na 1 keV, da kusan 10 keV da burning deuterium–tritium plasma ke buƙata. Zafi ɗaya ne kawai daga abubuwa uku na Lawson criterion.

Original diagram — The Clean Paper CC BY 4.0



Magnetized target fusion: a samar da plasma mai ɗumi da magnetic field, sannan a matse shi da liner da ke rushewa zuwa ciki domin matsin ya yi dumama — wannan ne “diesel-compression” bet. LM26 ta gwada ko

compression tana dumama plasma; ba net energy ko confinement ba.

Original diagram — The Clean Paper CC BY 4.0

Ma'anar "magnetized target fusion," "keV" da Lawson criterion

A fusion, ana yawan bayyana zafin plasma da **kiloelectronvolts (keV)** maimakon digiri: 1 keV kusan **miliyan 11.6 °C** ne. Deuterium–tritium fuel yana buƙatar kusan **10 keV** (fiye da miliyan 100 °C) domin fusion ya yi tasiri sosai — amma zafi ɗaya ne kawai daga abubuwa uku da ake buƙata lokaci guda. **Lawson criterion** ya ce reactor yana kuma buƙatar isasshen **density** da isasshen **confinement time**, waɗanda ake yawan haɗawa cikin "triple product" guda ɗaya (temperature × density × confinement time). Dumama plasma wajibi ne, amma shi kaɗai bai kusa isa ba.

Magnetized target fusion (MTF) hanya ce ta tsakiya tsakanin manyan hanyoyin biyu na yau. Maimakon a riƙe plasma mai zafi na dogon lokaci da manyan magnets, ko a dumama ƙaramar target kusan nan take da lasers, MTF tana samar da magnetized plasma sannan ta matse shi da inji cikin microseconds. Idan ta yi aiki, compression ɗin tana ƙara zafi da density — mai yiwuwa ta kai yanayin fusion ba tare da ITER-scale magnets ko NIF-scale lasers ba. Ko compression ɗin da gaske tana bayar da wannan dumama a na'ura ta gaske, shi ne ainihin abin da gwaji irin na LM26 yake duba.

Abin da marubutan suka yi

- Sun gina kuma suka harba **LM26**, na'urar magnetized-target-fusion ta General Fusion: ana samar da spherical-tokamak deuterium plasma, sannan **solid lithium liner** da aka tura zuwa ciki ya matse shi — kusan **3× radial compression**.
- Sun gudanar da **compression shots 11 na farko**, tare da kayan aunawa masu yawa, suna sake gina zafin plasma, density da magnetic field a kan lokaci, da kuma auna neutrons, X-rays, visible light da fast-camera images na hulɗar plasma da bango.
- Sun gina **integrated physics model** da ke daidaita dumamar compression da Ohmic heating (daga current na plasma) da makamashin da ke ƙacewa a boundary, sannan suka kwatanta samfurin da bayanan da aka auna domin tantance daga ina dumamar ta fito.

Abin da suka gano

- **Plasma ta yi zafi yayin da aka matse ta.** A mafi kyawun shots, electron temperature ya tashi da **fiye da 3×**, electron density da kusan **10×**, poloidal magnetic field kuma da kusan **10×**, sakamakon 3× radial compression. A mafi kyawun shot, takardar ta auna **peak electron temperature kusan 0.72 keV** (718 ± 80 eV, ta Thomson scattering) — kusan miliyan 8 °C.
- **An danganta mafi yawan dumamar da compression.** Integrated model ɗinsu ya nuna cewa *mafi yawan* hauhawar zafi ta fito ne daga mechanical compression kanta — mechanism da duk hanyar MTF ta dogara da shi — ba daga Ohmic heating ba.
- **Neutron emission ya ƙaru yayin compression**, abin da ya dace da deuterium plasma da ya fi zafi kuma ya fi

yawa.

Abin da wannan ba ya nuna

- Ba **fusion energy**, breakeven ko net gain ba ne. Babu wani abu a nan da ya fitar da makamashi fiye da wanda aka kashe. Sakamakon ya shafi *dumama plasma* — mataki ɗaya a fusion cycle — ba energy balance na reactor ba.
- Zafin har yanzu ya yi **ƙasa da burning plasma da kusan sau goma**. 0.72 keV kusan miliyan 8 °C ne; deuterium–tritium fuel yana buƙatar kusan **10 keV (fiye da miliyan 100 °C)** *tare da* isasshen density × confinement time domin burn ya ci gaba. Milestone na gaba na General Fusion kansa **1 keV** ne — wanda shi ma yana da nisa da ignition.
- "**Mafi yawan dumamar ta fito daga compression**" **model-based conclusion** ne, ba karatun kai tsaye daga sensor ba. Ya fito daga integrated physics model da aka daidaita da diagnostics; amincewar da za ka yi da rabon compression, Ohmic heating da losses ya dogara da amincewar da kake yi da wannan model.
- Wannan **company preprint ne, ba peer-reviewed ba**. Ƙungiyar da ta gina na'urar kuma ta tara kuɗi bisa alkawarinta ce ta ruwaito sakamakon; independent review bai faru ba tukuna.
- Ƙarin neutrons ba **fusion yield mai amfani ga makamashi** ba ne. Ana tsammanin wasu neutrons daga deuterium a waɗannan yanayi, amma suna da nisa ƙwarai da abin da zai amfani samar da wuta.
- Wannan ba ya tabbatar da wata sanarwar kamfanin daban cewa **future plant za ta ba grid wutar lantarki** — ikirarin da rahotanni masu zaman kansu suka yi wa taka-tsantsan sosai.

Yaya ƙarfin shaidar yake

- **Babban ikirarin yana da ƙunci kuma ana iya gwada shi.** "Mun matse magnetized plasma kuma ta yi zafi, mafi yawanci saboda compression" shi ne ainihin mechanism test da MTF ke buƙatar wucewa, kuma takardar ta goyi bayansa da shots da aka auna sosai da energy-balance model a sarari. Idan ya tsira daga peer review, zai zama ingantaccen — ko da na farko — tabbaci ga hanyar.
- **Caveats ɗin na asali ne, ba ado ba.** Shots 11, na'ura ɗaya, ƙungiya ɗaya, ba a yi review ba, da zafi mai kusan order of magnitude ƙasa da burning plasma. Load-bearing conclusion — *mafi yawan dumama daga compression* — ya dogara da model, don haka babban tambayar peer review ita ce ko wannan rabon yana da robustness.
- **Matsayin gaskiya shi ne an nuna mechanism, ba an kai milestone na makamashi ba.** Yana matsar da MTF daga "compression *ya kamata* ta dumama plasma" zuwa "compression *tana* dumama plasma," ba fiye da haka ba.

Me ya sa wannan yake da muhimmanci

Abin da ya fi jan hankali game da magnetized target fusion shi ne economics, ba records ba. Idan mechanical compression za ta iya dumama plasma zuwa yanayin fusion, watakila za a iya kaiwa can ba tare da ITER-scale

magnets ko NIF-scale lasers ba — hanya mai rahusa kuma mai saurin maimaita gwaji, *idan* ta yi aiki. Wannan "idan" shi ne duk wasan, kuma ya dogara da checkpoints marasa kyalli kamar wannan: shin compression da gaske tana bayar da dumamar da models suka yi alkawari? A shots na farko, amsar LM26 ita ce eh, amma da sharudda. Wannan ya cancanci lura da shi saboda sharuddan — mataki ɗaya ne a doguwar tsani, mutanen da ke hawa tsanin ne suka ruwaito shi, ba a duba shi daga waje ba tukuna, kuma yana nesa da saman.

Taƙaitaccen bayani

LM26 ta General Fusion ta matse magnetized deuterium plasma da lithium liner da ke imploding, kuma ta nuna plasma ta yi zafi — electron temperature ya fi ninki uku zuwa peak da aka auna na kusan 0.72 keV (718 ± 80 eV, ~miliyan 8 °C) — yayin da nazari na kamfanin ya danganta mafi yawan dumamar da compression kanta, mechanism da hanyar magnetized-target-fusion ɗinsu ta dogara da shi. Wannan matakin engineering ne na gaske kuma takamaimai ga wannan hanyar fusion. Amma shots 11 na farko ne kawai a na'ura ɗaya, an bayyana su a company preprint da ba a yi peer review ba, a zafin da ya yi kusan sau goma ƙasa da burning plasma, ba tare da net energy, breakeven ko wutar lantarki ba. An nuna mechanism; ba a gina power plant ba.

Majiyoyi

S. J. Howard et al. (General Fusion), The science of compressional heating on the LM26 magnetized target fusion experiment, arXiv:2606.23974 [physics.plasm-ph] (2026)
https://arxiv.org/abs/2606.23974

General Fusion, 'General Fusion Achieves Compressional Plasma Heating with LM26 Magnetized Target Fusion Machine' (company announcement, June 2026)
https://generalfusion.com/post/general-fusion-achieves-compressional-plasma-heating-with-lm26-magnet

Nature news, 'Nuclear-fusion firm says plant will deliver electricity to grid - but big questions remain' (2026)
https://www.nature.com/articles/d41586-026-01795-z