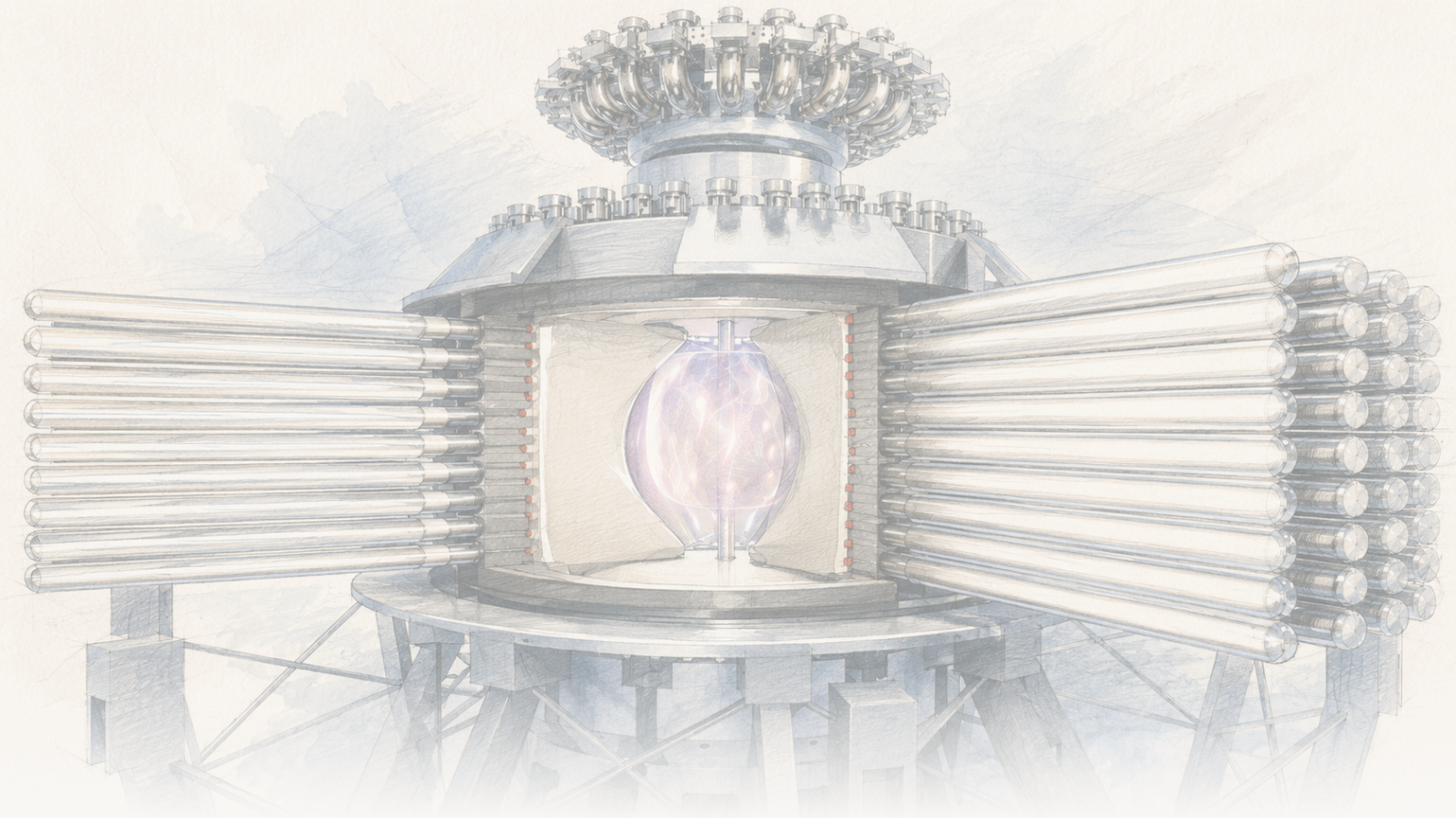


The Clean Paper

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

Maashiniin fusion tokko plasma isaa cuunfuun ho'ise — tarkaanfii dhugaa, garuu power plant miti

General Fusion LM26 plasma deuterium magnetized ta'e lithium liner keessaa cuunfamuun compress godhee ho'achuu isaa agarsiise — electron temperature isaa 3× ol guddisuun peak measured naannoo 0.72 keV (718 ± 80 eV, naannoo 8 million °C) ga'e — fi analysis company sanaa ho'ina keessaa baay'een compression irraa akka dhufe tilmaama, mechanism magnetized-target-fusion route irratti hirkatu. Kun engineering checkpoint dhugaa dha. Garuu shots 11 jalqabaa, company preprint peer review hin dabarre, temperature burning plasma barbaadu caalaa naannoo yeroo kudhan gadi, net energy, breakeven fi electricity homaa hin jiru. Mechanism agarsiifame; power plant hin ijaaramne.

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

Maashiniin fiyuushinii tokko pilaazmaa isaa cuunfuun ho'ise — tarkaanfii dhugaa, garuu humna plant miti

Fiyuushinii reactor tokko humna itti galfamu caalaa humna deebisuuf, fuel pilaazmaa yeroo tokko keessatti ho'aa gahaa, density gahaa fi yeroo gahaa walitti qabamee turuu qaba — wantoota sadii physicists **Lawson criterion** jedhu keessatti walitti qabaman. Qorannoo baay'een kana superconducting magnets gurguddoo (tokamaks akka ITER) yookaan arrays leezerii gurguddoo (inertial confinement, akka US National Ignition Dhaabbata) fayyadamuun hordofa. dhaabbilee muraasni ammoo karaa sadaffaa irratti abdatu: **magnetized galma fiyuushinii (MTF)**. Pilaazmaa ho'aa xiqqoo, magnetized ta'e uumi; achiis saffisaan karaa mechanical ta'een **cuunfi**, akka Cuunfaa sun pilaazmaa ho'isu — akkuma diesel engine spark osoo hin fayyadamin fuel compressioniin ibsu.

Waxabajjii 2026 keessatti dhaabbata Kaanaadaa **Waliigalaa Fiyuushinii** bu'aa **Lawson Machine 26 (LM26)** maxxanse; bu'aan sun yaada ijoo kana kallattiin qoru: pilaazmaa magnetized ta'e karaa mechanical ta'een cuunfuun dhugumaan akka moodeela jedhu ho'isaa? yaaliiwwan cuunfaa 11 jalqabaa keessatti — spherical-tokamak diyuteeriyamii pilaazmaa **jajjabaa lithium liner** keessaa keessaa cuunfamuun — shots gaariin pilaazmaa yeroo compressed ta'u caalaatti ho'aa, density ol'aanaa fi magnetization cimaa akka ta'e agarsiisan. Xiinxala dhaabbata sanaa ho'ina keessaa harki guddaan Cuunfaa mataa isaa irraa akka dhufe tilmaama.

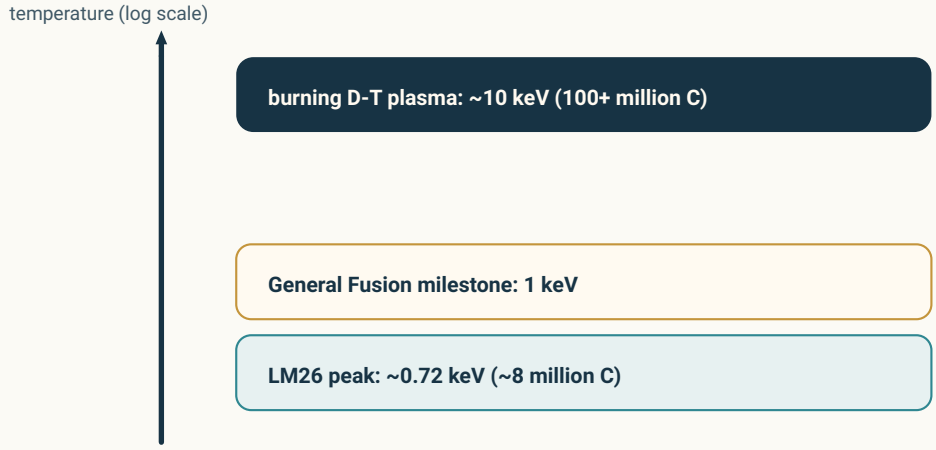
Kun magnetized-target-fusion route'f engineering bu'aa ifaa fi addaa dha. Garuu shots jalqabaa muraasa qofa, **dhaabbata barruu duraa gamaaggama ogeessotaa hin dabarre** keessatti ibsame; ho'a isaa burning pilaazmaa barbaadu caalaa fagoo dha. Kun fiyuushinii anniisaa miti, breakeven miti, humna plant miti.

[video pending]

Kun promotional footage Waliigalaa Fiyuushinii irraa, LM26 akkam akka fakkaatu agarsiisuuf as galfame; machine kun fuuldura fiyuushinii milestones isaa ni ga'a jedhuuf ragaa walaba miti.

A real heating step, far below a burning plasma

Temperature is only one Lawson quantity: density and confinement time still matter.



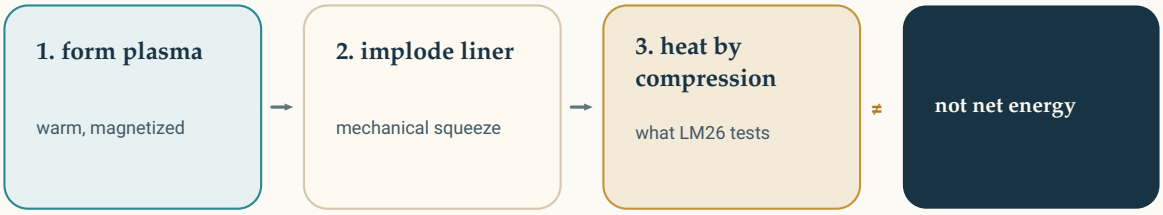
Boundary: heating shown; a burning plasma is an order of magnitude, and two more quantities, away.

Ho'a ladder: LM26 ~0.72 keV, milestone Waliigalaa Fiyuushinii 1 keV, fi burning diyuteeriyamii–tritium pilaazmaa'f barbaachisu ~10 keV. Ho'a hangawwan Lawson sadii keessaa tokko qofa.

Original diagram — The Clean Paper CC BY 4.0

The magnetized-target-fusion bet

Form a warm magnetized plasma, then squeeze it so compression does the heating.



Boundary: compression heats the plasma; it does not show net energy or confinement long enough for a burn.

Magnetized galma fiyuushinii: pilaazmaa magnetized ho'aa xiqqoo uumi; achiis liner keessaa cuunfamuun cuunfi, Cuunfaa sun ho'ina uuma — yaada diesel-Cuunfaa fakkaatu. LM26 Cuunfaa pilaazmaa ho'isu qore; net

anniisaa yookaan confinement gahaa hin qorre.

Original diagram — The Clean Paper CC BY 4.0

“Magnetized galma fusion,” “keV” fi Lawson criterion maal jechuu dha

Fiyuushinii keessatti pilaazmaa ho’a yeroo baay’ee degrees caalaa **kiloelectronvolts (keV)** keessatti ibsama: 1 keV naannoo **11.6 miliyoona °C** dha. Diyuteeriyamii–tritium fuel fiyuushinii haala gaariin gochuuf naannoo **10 keV** (100 miliyoona °C ol) barbaada — garuu ho’a waan sadii keessaa tokko qofa. **Lawson criterion** reactor tokko **density** gahaa fi **confinement yeroo** gahaa illee qabaachuu akka qabu jedhu; yeroo baay’ee isaan ho’a waliin “triple product” tokko keessatti walitti qabamu. Pilaazmaa ho’isuun barbaachisaa dha, garuu qofti isaa gahaa miti.

Magnetized galma fiyuushinii (MTF) karaalee mainstream lama gidduu jiru. Huge magnets fayyadamuun pilaazmaa ho’aa yeroo dheeraaf qabuu yookaan lasers fayyadamuun galma xixiqqoo battalumatti ho’isuun alatti, MTF pilaazmaa magnetized uuma; achiis microseconds keessatti mechanically compress godha. Yoo hojjete, Cuunfaa ho’a fi density lamaan ol kaasa; kanaan magnets ITER-guddaa yookaan lasers NIF-guddaa malee fiyuushinii haalawwan bira ga’uun danda’ama. Cuunfaa dhugumaan machine keessatti ho’ina kana geessisaa? Qorannoon akka LM26 gaaffii kanaaf dha.

Barreessitoonni maal godhan

- **LM26**, machine magnetized-target fiyuushinii Waliigalaa Fiyuushinii, ijaaran fi shots godhan: spherical-tokamak diyuteeriyamii pilaazmaa jalqaba uumama, achiis **jajjabaa lithium liner** keessaa gara keessatti socho’u irraa compressed ta’a — naannoo **3× radial Cuunfaa**.
- **yaaliiwwan cuunfaa 11 jalqabaa** raawwatan; instruments hedduun pilaazmaa ho’a, density fi magnetic damee yeroo waliin reconstruct godhan, neutrons, X-rays fi mul’ataa ifa galmeessan, akkasumas fast-camera images interaction pilaazmaa–wall fudhatan.
- **Integrated fiiziksii moodeela** tokko ijaaran; moodeela kun heating Cuunfaa irraa, Ohmic heating (ammaa pilaazmaa mataa isaa irraa) fi anniisaa dhabamuu daangaa irraa wal-bira qaba. Safarame daataa waliin walitti fiduun ho’inni eessaa akka dhufe tilmaaman.

Maal argatan

- **Pilaazmaa yeroo cuunfamu ho’ate.** Shots gaarii keessatti elektiroonii ho’a **3× ol**, elektiroonii density naannoo **10×**, fi poloidal magnetic damee naannoo **10×** ol ka’an; kun 3× radial Cuunfaa waliin wal qabata. Shot gaarii keessaa tokko keessatti, barruun **peak elektiroonii ho’a naannoo 0.72 keV** (718 ± 80 eV, Thomson scattering’n) safare — naannoo 8 miliyoona °C.
- **Ho’inni baay’een Cuunfaa irraa dhufe jedhamee tilmaamame.** Integrated moodeela isaanii ho’a rise keessaa **majority** mechanical Cuunfaa irraa akka dhufe, Ohmic heating caalaa, xumura. Kun

adeemsa hojii route MTF guutuun irratti hirkatu dha.
- **Neutron emission Cuunfaa yeroo ol ka'e**, pilaazmaa diyuteeriyamii ho'aa fi density ol'aanaa waliin wal-simu.

Kun maal hin agarsiifne

- Kun **fiyuushinii anniisaa, breakeven yookaan net gain miti**. Yaalii kun humna itti galfame caalaa humna hin oomishne. Bu'aan pilaazmaa ho'isu — fiyuushinii marsaa keessaa tarkaanfii tokko — irratti dha, reactor anniisaa balance irratti miti.
- Ho'a isaa **burning pilaazmaa barbaadu caalaa naannoo yeroo kudhan gadi** dha. 0.72 keV naannoo 8 miliyoona °C; diyuteeriyamii–tritium fuel naannoo **10 keV (100 miliyoona °C ol)** fi density × confinement yeroo gahaa barbaada. Milestone dhaabbata itti aanu **1 keV** dha — innis ignition irraa fagoo dha.
- "**Ho'inni baay'een Cuunfaa irraa dhufe**" jechuun **model-based xumura** dha, safartuu kallattii qofa miti. Integrated fiiziksii moodeela diagnostics waliin fit godhame irraa dhufa; Cuunfaa, Ohmic heating fi dhabamuuwwan gidduutti qoodni hammam akka ta'e moodeela sana irratti hirkata.
- Kun **dhaabbata barruu duraa, gamaaggama ogeessotaa keessa darbe miti**. Gareen machine ijaare fi abdii isaa irratti maallaqa walitti qabe ofumaa gabaase; gamaaggama walaba ammallee hin jiru.
- Neutron daballii kun **fiyuushinii yield humnaaf barbaachisaa** miti. Haalawwan kana keessatti diyuteeriyamii irraa neutrons muraasni eegamu, garuu humna'f faayidaa qabu irraa baay'ee gadi dha.
- dhaabbata'n "fuuldura plant electricity grid irratti kenna" jedhe irratti yaalii kun homaa hin mirkaneessu; himannaa sun addaa dha fi walaba gabaasuu'n of-eeggannoo cimaa itti godhe.

Ragaan hammam cimaa dha

- **Himannaa ijoo daangeffamee fi qorachuun danda'amu dha.** "Pilaazmaa magnetized compress goone, ho'ate; ho'inni baay'een Cuunfaa irraa dhufe" jechuun adeemsa hojii qormaata MTF barbaadu sirriitti. barruun shots heavily instrumented fi moodeela energy-balance ifaa qaba. Yoo gamaaggama ogeessotaa keessa darbu, route kanaaf validation jalqabaa dhugaa ta'a.
- **Caveats structural dha, cosmetic miti.** Shots 11, machine tokko, team tokko, gamaaggama hin dabarre, fi peak ho'a burning pilaazmaa caalaa order of magnitude tokko gadi. Himannaa load-bearing — majority heating Cuunfaa irraa — moodeela irratti hirkata; kanaaf gaaffiin gamaaggama ijoo qoodni moodeela sun jabaataa ta'uu isaa dha.
- **Status sirrii: adeemsa hojii agarsiifame, anniisaa milestone miti.** MTF "Cuunfaa pilaazmaa ho'isuu qaba" irraa gara "Cuunfaa pilaazmaa ho'isa"tti tarkaanfii tokko fudhata; kana caalaa himannaa hin godhu.

Maaliif barbaachisaa dha

Wanti magnetized galma fiyuushinii nama hawwatu galmeewwan miti; economics dha. Mechanical Cuunfaa pilaazmaa fiyuushinii haalawwan bira ho'isu yoo danda'e, magnets ITER-guddaa yookaan lasers NIF-guddaa malee karaan gatii gadi-aanaa fi saffisaan iteration godhu jiraachuu danda'a — **yoo hojjete**. "Yoo" sun rakkoo guutuu dha; checkpoints akka kana irratti hirkata: Cuunfaa moodeelota abdatan ho'ina dhugumaan geessisaa? LM26 shots jalqabaa irratti deebii eeyyee, garuu daangeffame kenna. Kana jechuun akka rungs ladder dheeraa keessaa tokkootti ilaaluun sirrii dha — namoota isa ol ba'aa jiran irraa gabaasa ta'e, namoota biroon ammallee hin mirkaneessine, fi gubbaa ladder irraa fagoo.

Cuunfaa gabaabaa

Waliigalaa Fiyuushinii LM26 pilaazmaa diyuteeriyamii magnetized ta'e lithium liner keessaa cuunfamuun compress godhee ho'achuu isaa agarsiise — elektiroonii ho'a 3× ol guddisuun peak safarame naannoo 0.72 keV (718 ± 80 eV, ~8 miliyoona °C) ga'e — fi xiinxala dhaabbata sanaa ho'ina keessaa baay'een Cuunfaa irraa akka dhufe tilmaama, adeemsa hojii magnetized-target-fusion route irratti hirkatu. Kun karaa fiyuushinii kanaaf engineering tarkaanfii dhugaa fi addaa dha. Garuu shots 11 jalqabaa machine tokko irratti, dhaabbata barruu duraa gamaaggama ogeessotaa hin dabarre keessatti ibsame; ho'a burning pilaazmaa barbaadu caalaa naannoo yeroo kudhan gadi, net anniisaa, breakeven fi electricity homaa hin jiru. Adeemsa hojii agarsiifame; humna plant hin ijaaramne.

Maddoota

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