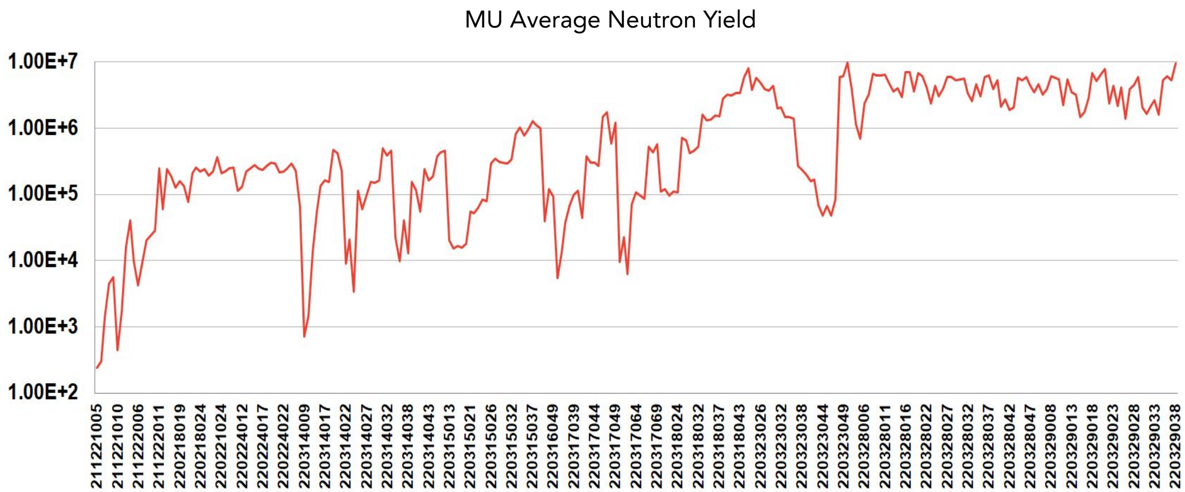
fuse

Accelerating the world's transition to fusion energy

At Fuse, it’s about experimental results.

While in stealth mode for the last 3 years, we’ve built and operated a low density flow through z-pinch for 2000+ shots: MU



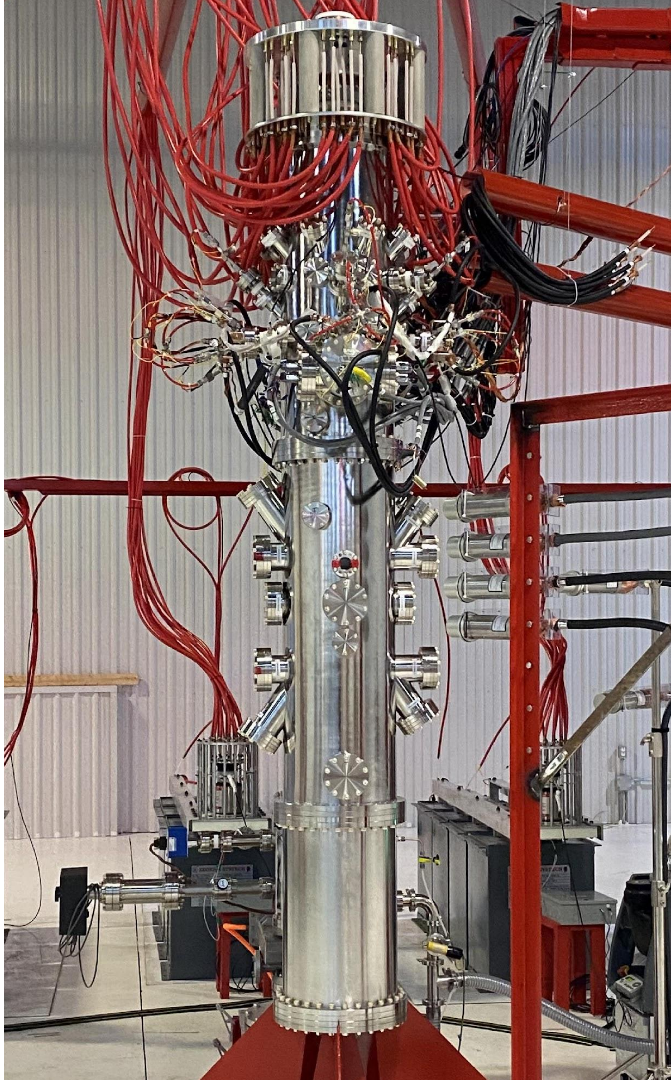
MU is the first and only fusion device producing thermonuclear neutrons in Canada

Magical Unicorn: MU

World's most advanced low density flow through Z-pinch

- Based on the Marshall Gun experiment produced at Los Alamos in the 1960s succeeded by the work at the University of Washington
- Demonstrates novel plasma injection technology
- Study Platform for the stabilization of low density plasma pinch
- 20+ patents filed on the concept
- Validates organization's subsystems capability:

1 Capacitor banks	4 Power electronics
2 Gas mixing	5 Control systems
3 Plasma sources	6 Diagnostics



Learning: Low density Z-pinch generators show limitations

World's most advanced low density flow through Z-pinch

- Current vs Yield Scaling Law
  - Typically for Z-pinch generators, the neutron yield (Y) is proportional to the current (I) such that : $Y \propto I^{3.3\text{-}5}$
  - Peer-reviewed theory led us to believe that $Y \propto I^{11}$ may be possible if a sheared flow can stabilize the pinch leading to perfect adiabatic compression with a given set of plasma parameters
  - Experimenting with the idea that a quasi-steady-state linear density and an optimized shear profile will lead to that scaling, we learned experimentally that the scaling is limited to $I^{3.3\text{-}6.6}$
- Engineering fusion "Q"
  - Maximum achieved from MU: $Q_{eng} = \sim 10^{-8}$

With the current scaling law & Q_{eng} results, we lost faith in Low Density Z-pinch Generators

What do we mean by Q_{eng}?

Total energy input into the system going "all the way back to the plug" divided by the total energy output.

How do we calculate Q_{eng} for MU:

1. Run device with D-D
2. Count neutrons
3. Multiply the number by 100x (generous assuming full theoretical cross-section occurring for D-T) *(knowing that a D-T fusion reaction produces 17.6 MeV)*
4. Calculate the total fusion energy output: Yield (neutrons / shot) * D-T reaction energy (17.6 MeV) * 1.6×10^{-19} (to convert to Joules).
5. Divide by total energy input

We believe that MU is the most efficient low density flow through z-pinch with $Q_{eng} = \sim 10^{-8}$

It’s all about results.
So, what’s next?

Fusion Metrics that matter

Focusing on the results that matter.

1 The Triple Product = n x T x t_E

n = Plasma Density

T = Plasma Temperature

τ_E = Plasma Confinement Time

2 Energy Gain ("Q")

Q Commercial ("Q_C") = E_V / C_T

E_v = Market Energy Value

C_T = Total Cost of Energy

Q Engineering ("Q_E") = E_F / E_T

E_F = Total Energy Output

E_T = Total Energy Input

Q Scientific ("Q_S") = E_F / E_P

E_F = Total Energy Output

E_P = Only Plasma Energy Input

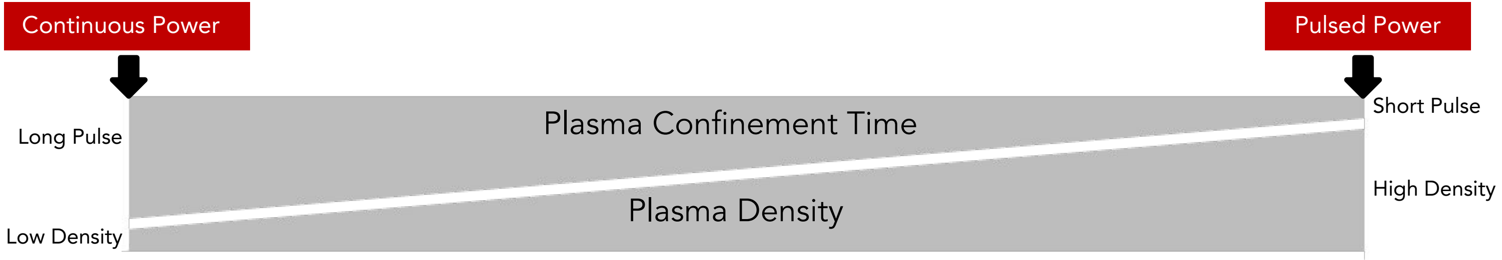
3 Neutron Production

Yield = Measured in Neutrons / second

Flux = Measured in Neutrons / cm^2 / second

Fusion Types – By Plasma Confinement Approach

There are three major types of plasma confinement with numerous “subtypes”



MCF — Magnetic Confinement

Utilizes Magnetic force to heat (thru acceleration & compression) and contain plasma to achieve low density Plasma.

- Tokamak
- Stellarator
- Spheromak
- Field Reversed Configuration

MIF — Magneto – Inertial

Utilizes MCF or ICF (or both) to achieve intermediate density of Plasma.

- Stabilized Compressed Liner
- Plasma Jet Driven (PJMIF)
- Z-Pinch
- Polywell

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ICF — Inertial Confinement

Utilizes Inertia of Plasma to produce shock wave to heat and compress Plasma to achieve ultra-high density of Plasma.

- Shockwave
- Liner Compression
- Target Implosion
- Laser
- Beam Target (IECF)

Industry Results

Most results are from governments and in MCF or ICF. All intermediate density concepts have a large delta

		Magnetic Confinement			Inertial Confinement				Magneto-Inertial	
		Tokamak	Field Reverse Configuration	Stellarator	Beam Target (Govt = Spallator)	Shockwave (Pulsed Power)			Z-Pinch	
	Commercial Companies									
		Commonwealth Fusion	Helion	Type One Energy	Shine	General Fusion Magnetized Target	First Light Fusion Advanced Implosion	LPP Fusion (DPF) Dense Plasma Focus (DPF)	MIFTI Staged	ZAP Energy Sheared Flow Stabilized
	Triple Product (m^{-3}KeVs)		1.00E+18		NA	N/A		1.00E+18	2.50E+18	5.0E+17
	Plasma Density (m^{-3})		8.00E+22			1.00E+23		1.00E+25	1.00E+26	1.0E+23
	Plasma Temperature (keV)		10			0.1		1	3-7	1.0E+00
	Plasma Confinement Time (s)		4.00E-05			1.00E-04		1.00E-07	5.00E-09	5.0E-06
Goal = 20-30	**Energy Gain - $Q_{Scientific}$**		NA		NA	n		0.002	NA	0.0000001
Goal > 1.0E+20	**Yield D-T (n/s)**	No Neutrons	No Neutrons	No Neutrons	5.0E+12	No Neutrons	No Neutrons	3.00E+12	3.00E+11	1.0E+10
	Governments									
		JET - Europe	Los Alamos	W7 - Germany	OakRidge National Lab	NIF - US	MagLif - US	Los Alamos		
	Triple Product (m^{-3}KeVs)	3.00E+20	NA	6.40E+19	NA	1.69E+22	2.39E+21	1.00E+18		
	Plasma Density (m^{-3})	3.90E+19	2.50E+23	8.00E+19		2.50E+31	2.75E+29	1.00E+25		
	Plasma Temperature (keV)	28	0.7	4		4.5	2.9	1		
	Plasma Confinement Time (s)	2	0.0005	0.2		1.50E-10	3.00E-09	1.00E-07		
Goal = 20-30	**Energy Gain - $Q_{Scientific}$**	0.67	NA	NA	NA	0.7	0.024	0.01		
Goal > 1.0E+20	**Yield D-T (n/s)**	2.00E+16	No Neutrons	No Neutrons	1.00E+14	4.75E+17	1.10E+15	2.00E+14	NA	NA

Fuse’s Next 12-month Mission

Fuse is building the world's highest energy pulsed power fusion generator among private companies

Objective: Produce 10^{15} D-T thermonuclear neutrons from a novel, high density Z-pinch generator

Scientific Advisors

Shepherded by some of the world's best minds to achieve our mission

DR. ANDREI SMOLYAKOV
- Professor, Univ Saskatchewan
- Ph.D – Moscow Institute of Physics & Technology
- Visiting Fellow, Isaac Newton Institute for Mathematical Sciences, Univ of Cambridge

DR. SING LEE
- 60+ years of experience on plasma focus & pinch devices. Emeritus professor

DR. SHANTI RAO
- Physicist at JPL
- PhD, Physics - Caltech

DR. MICHAEL BRADLEY
- PhD, Physics - MIT
- Assistant Prof. U of Saskatchewan

DR. CARLOS ROMERO-TALAMAS
- Associate Professor at University of Maryland, Baltimore County
- PhD, Physics - Caltech

DR. LENAIC COUEDEL
- Professor, Univ Saskatchewan
- French National Centre for Scientific Research

DR. CHIJIN XIAO
- Professor, Univ Saskatchewan
- Ph.D – Plasma Physics

DR. EMILE CARBONE
- Group Leader at Max Planck Institute of Plasma Physics
- Research Professor at INRS

Partners in Canada

Accelerating and compounding our rate of learning and understanding through tight collaborations with leading Canadian institutions. We continue to look for impactful partners!

University of Saskatchewan
Simulation, Plasma & Optical Diagnostics

Institut National de la Recherche Scientifique
Laser & X-Ray Diagnostics for high density plasma

In assessment phase for licensing of our reactor with the CNSC

We’re hiring!

Please check out: careers.f.energy

Please reach out: jc@f.energy