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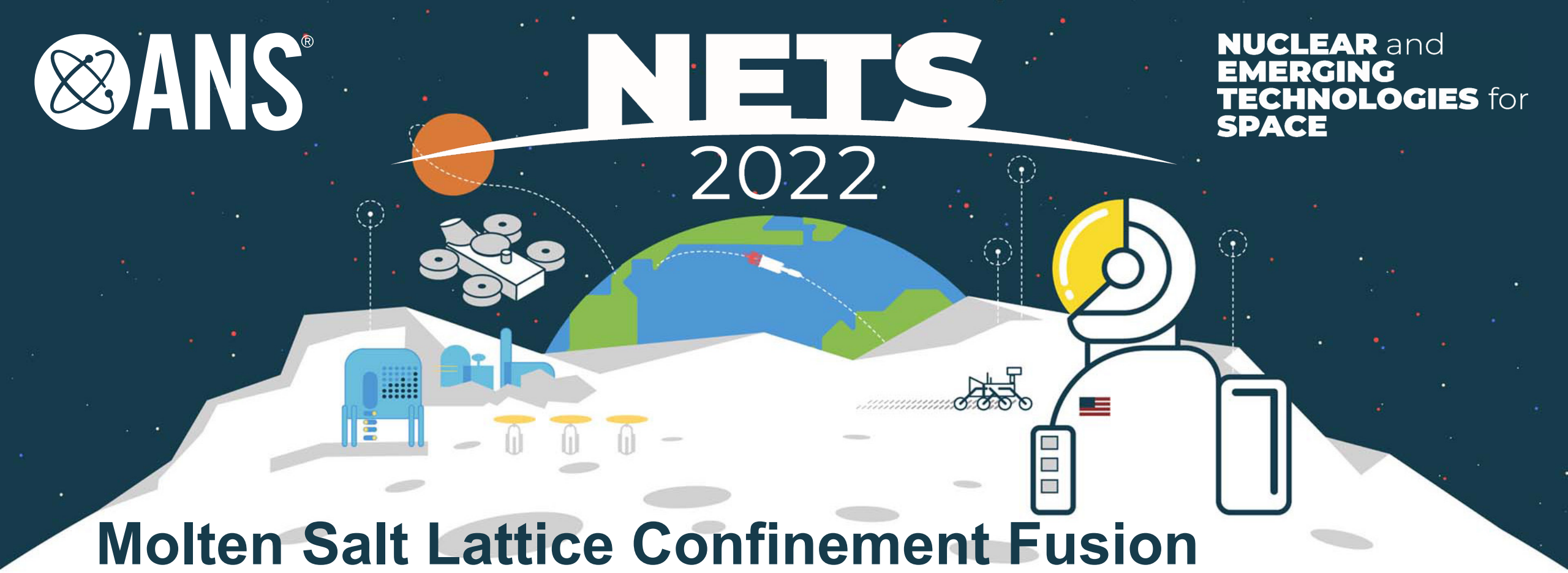
NUCLEAR and EMERGING TECHNOLOGIES for SPACE



Molten Salt Lattice Confinement Fusion (LCF) Fast Fission Reactor for Lunar and Planetary Surface Power

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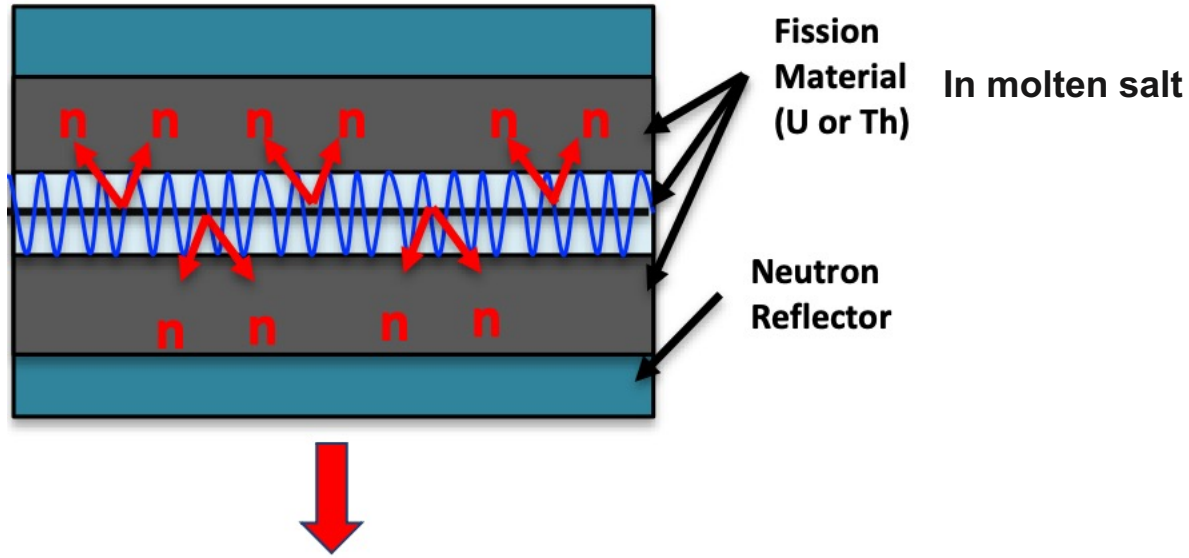
Generating Power from Lattice Confinement Fusion[1]

LCF Fusion Neutron Generator



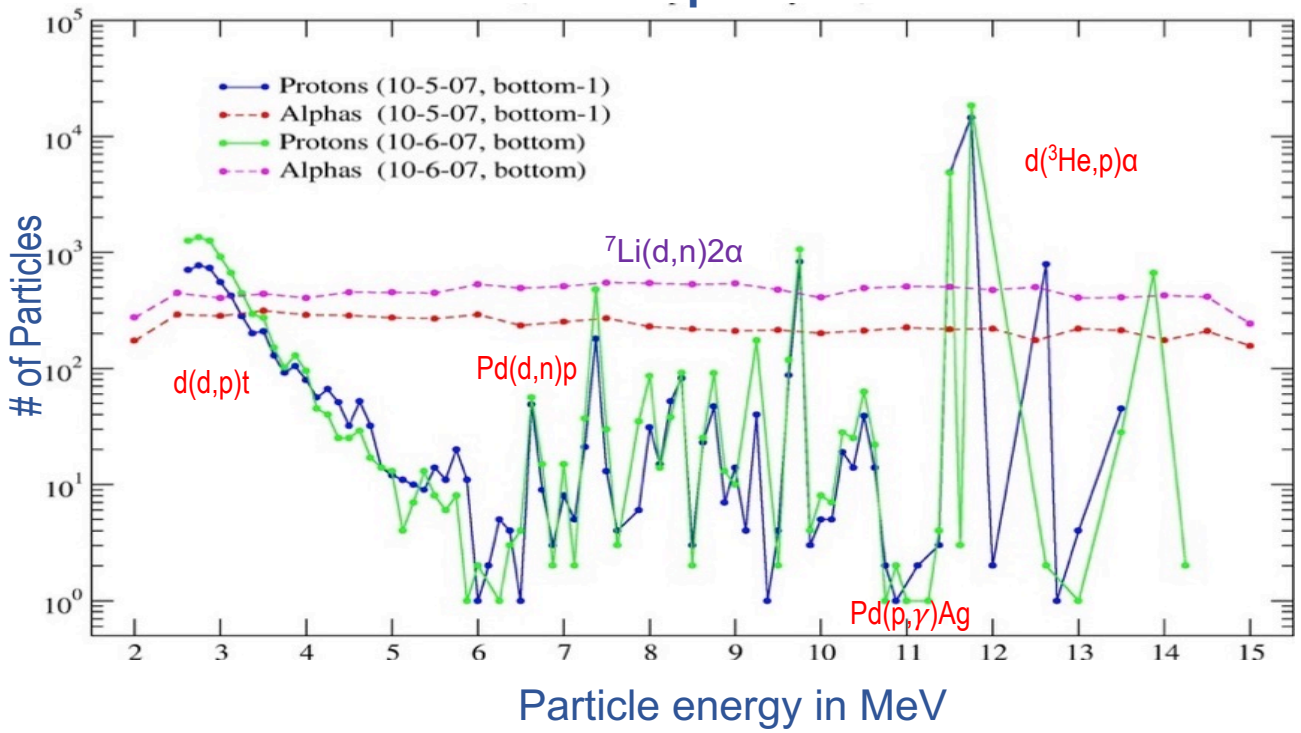
Drive Advanced Stirling Engine for thermal power conversion

LCF provides a fast neutron source to maintain actinide sub-critical fission.

[1] B. Baramsai, *et. al.*, "NASA's New Shortcut to Fusion Power: Lattice Confinement Fusion Eliminates Massive Magnets and Powerful Lasers", *IEEE Spectrum* (March, 2022). https://spectrum.ieee.org/lattice-confinement-fusion

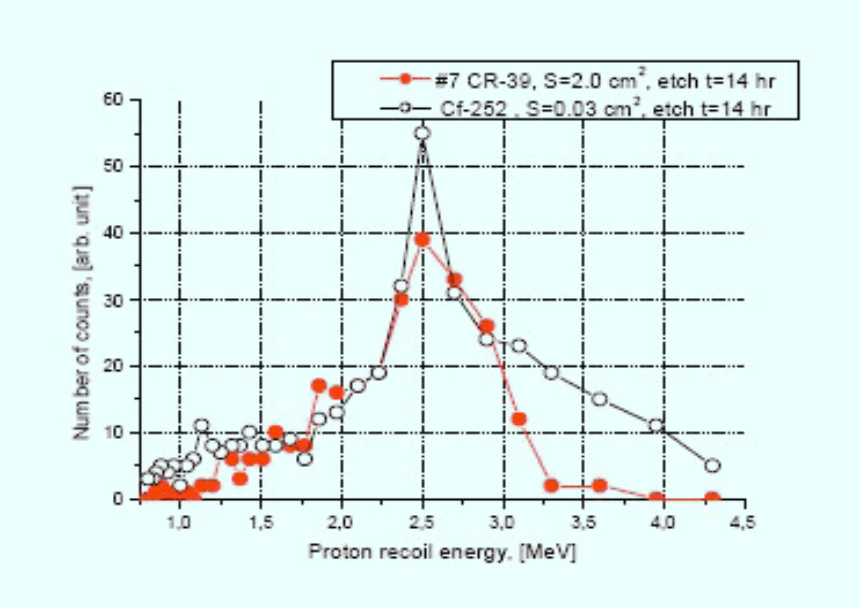
Lattice Confinement Fusion[1]: Nuclear Products

Protons and Alpha Particles



NASA JSC Linear Energy Transfer Analysis (CR-39) from two experiments[2,3]
e.g. ^{7}Li(*d,n*)2α 3-body nuclear reaction and neutron induced recoils.

Neutron recoils: 1 - 4.5 MeV



Recoil Particle energy in MeV

Grey: ^{252}Cf fission neutrons Red: LCF fusion neutrons

SRI, (Menlo Park, CA), replication of US Navy patented protocol[3] and analyzed at Lebedev Institute.[3,4]

Lattice Confinement Fusion (LCF) produces MeV charged particles and neutrons

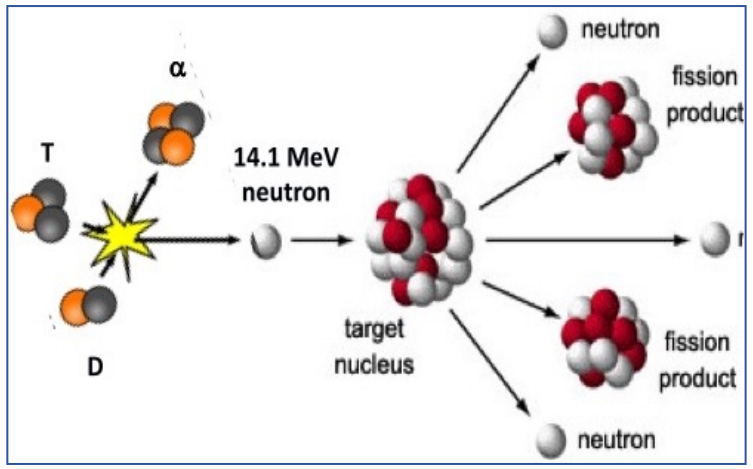
[1] B. Baramsai, *et. al.*, "NASA's New Shortcut to Fusion Power: Lattice Confinement Fusion Eliminates Massive Magnets and Powerful Lasers", *IEEE Spectrum* (March, 2022). https://spectrum.ieee.org/lattice-confinement-fusion

[2] P.A. Mosier-Boss, *et al.*," Detection of high energy particles using CR-39 detectors part 1: Results of microscopic examination, scanning, and LET analysis", *Int. J. of Hydrogen Energy,* **42**, 1 (2017) pp 416-428.

[3] US Patent #8,419,919, "System and Method for Generating Particles", (2013).

[4] A.G. Lipson, *et al.*, "Analysis of the CR-39 detectors from SRI's SPAWAR/Galileo type electrolysis experiments #7 and #5. Signature of possible neutron emission", 8th Int. Workshop on Anomalies in Hydrogen/Deuterium Loaded Metals, (2007).

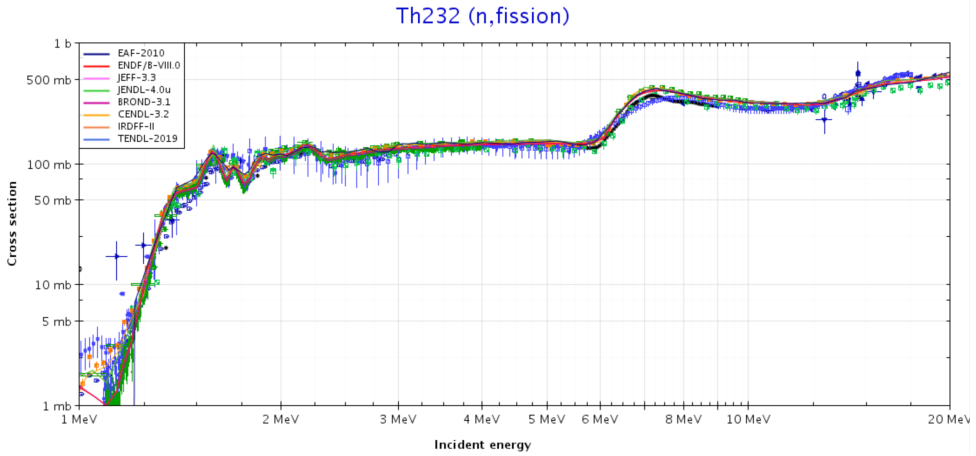
Hybrid Fusion-Fast-Fission Reactor using LCF Particles



DT and DD neutron driven fission are similar.

Reaction	MeV	Occurrence	driving particle/energy
$D(d,n)^3He$	4.0	primary ≈ 50%	n 2.45 MeV
$D(d,p)T$	3.25	primary ≈ 50%	p 3.0 MeV
$D(^3He,p)\alpha$	18.3	secondary	p 15.0 MeV
$D(t,n)\alpha$	17.6	secondary	n 14.1 MeV
$T(t,\alpha)2n$	11.3	low probability	n 1 – 9 MeV
$^3He(^3He,\alpha)2p$	12.86	low probability	p 1 – 10 MeV
$^{232}Th(n,\gamma)f$	200.	high probability	n 1 – 9 MeV
$^{232}Th(p,\gamma)f$	200.	low probability	p 1 – 10 MeV
$^{238}U(n,\gamma)f$	200.	high probability	n 1 – 9 MeV
$^{238}U(p,\gamma)f$	200.	low probability	p 1 – 10 MeV

LCF fissions U and Th

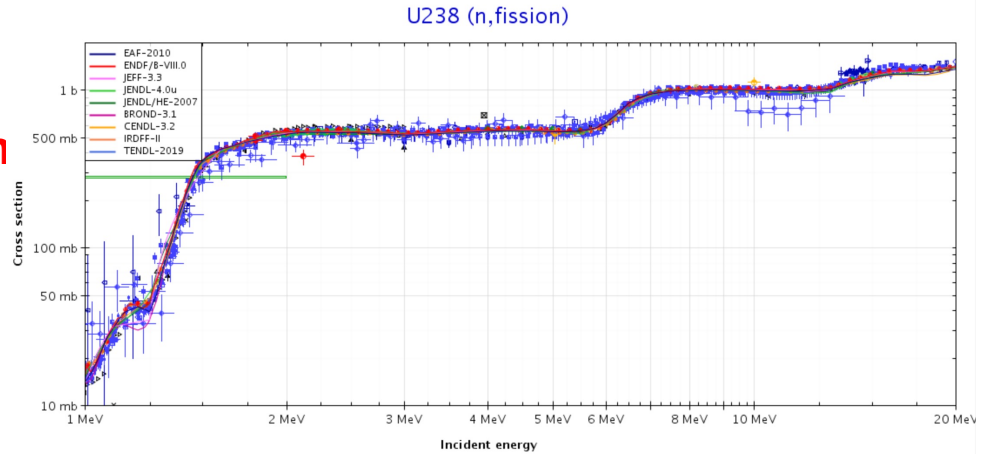


Measured 6.4 MeV LCF neutrons. Fission cross-sections σ_f:

$^{232}Th(n,f)$ σ_f = 267 mb

$^{238}U(n,f)$ σ_f = 821 mb

$^{235}U(n,f)$ σ_f = 1101 mb



Demonstrated with natural U and Th.

No Low Enriched U (LEU), No Highly Enriched U (HEU), No High Assay LEU (HALEU)

Molten Salt, Hybrid Fusion-Fast-Fission Reactor

- Build on previous (Fluorine-Lithium-Be) FLiBe-based[1] thorium salts
  - Molten salt metal interactions understood
  - Fast reactor without ^{232}Th > ^{233}Th> ^{233}Pa> ^{233}U cycle: *No chemical separation necessary*
  - *No LEU, HEU or HALEU necessary: natural U, depleted U or Th used*

- High temperature, low pressure molten salts
  - Efficient thermal-electric conversion, ΔT > 500 ^{o}C
  - Couple with an Advanced Stirling Engine for efficient power conversion

- Sub-critical, fast neutron economy maintained by Lattice Confinement Fusion[2]
  - No fission chain reaction using only fertile actinides
  - LCF Hybrid reactor is safer than conventional fission reactors

- Power for Lunar, Martian or other Planetary Surfaces

1. D. T. Ingersoll, *et. al*., "Core Physics Characteristics and Issues for the Advanced High-Temperature Reactor (AHTR)", https://technicalreports.ornl.gov/cppr/y2001/pres/122842.pdf

2. V. Pines, *et. al*., "Nuclear Fusion Reactions in Deuterated Metals", *Phys Rev C*., **101**, 044609 (2020)