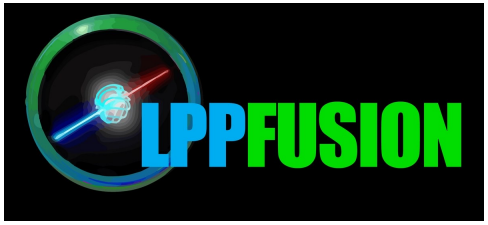
Community Planning Process
Webinar Oct. 30, 2019



A Fast Path to Economical Fusion Power

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LPPFusion, Inc., NJ, USA

LPPFUSION

FASTEST ROUTE FOR PROGRAM

WE DON'T KNOW YET (and certainly did not in 1974!)

Which Devices/Fuels will produce net energy?

.... Which will get there the fastest?

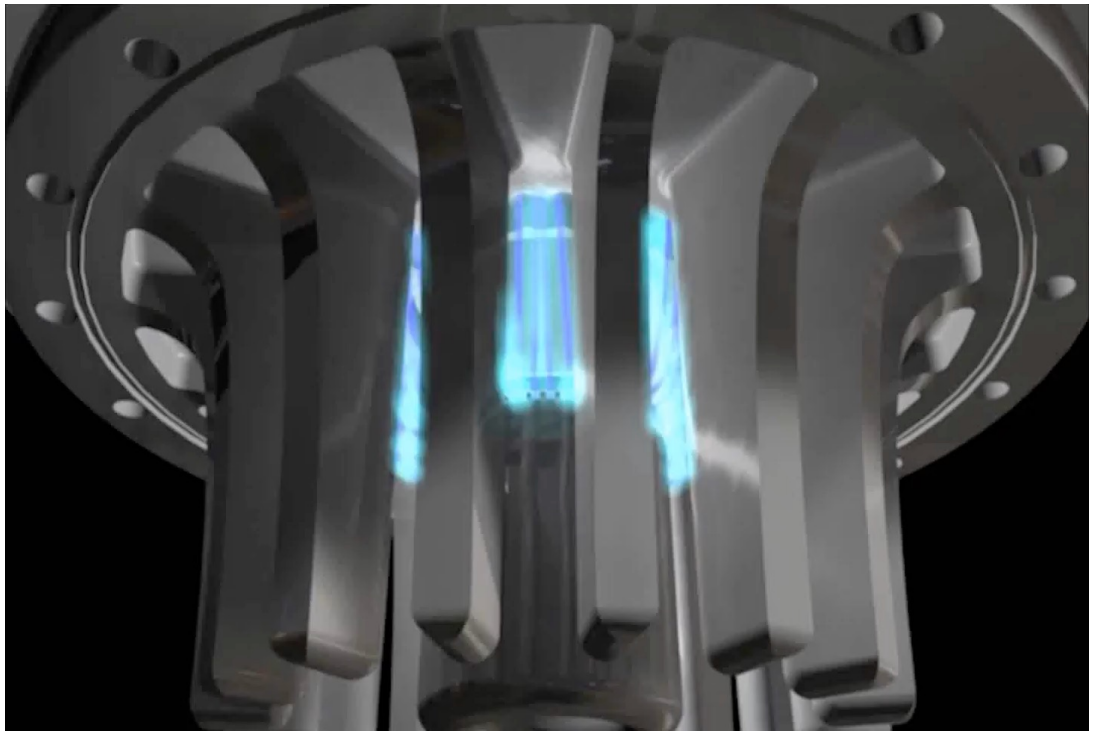
...Which will produce the cheapest energy in a practical generator?

Solution—

AN ALL-OUT CRASH PROGRAM THAT FUNDS ALL POSSIBLE ROUTES

(start with matching funds)

FOCUS FUSION:
DENSE PLASMA FOCUS +
PB11 FUEL



J Fusion Energy (2011) 30: 367.

KEY ADVANTAGES

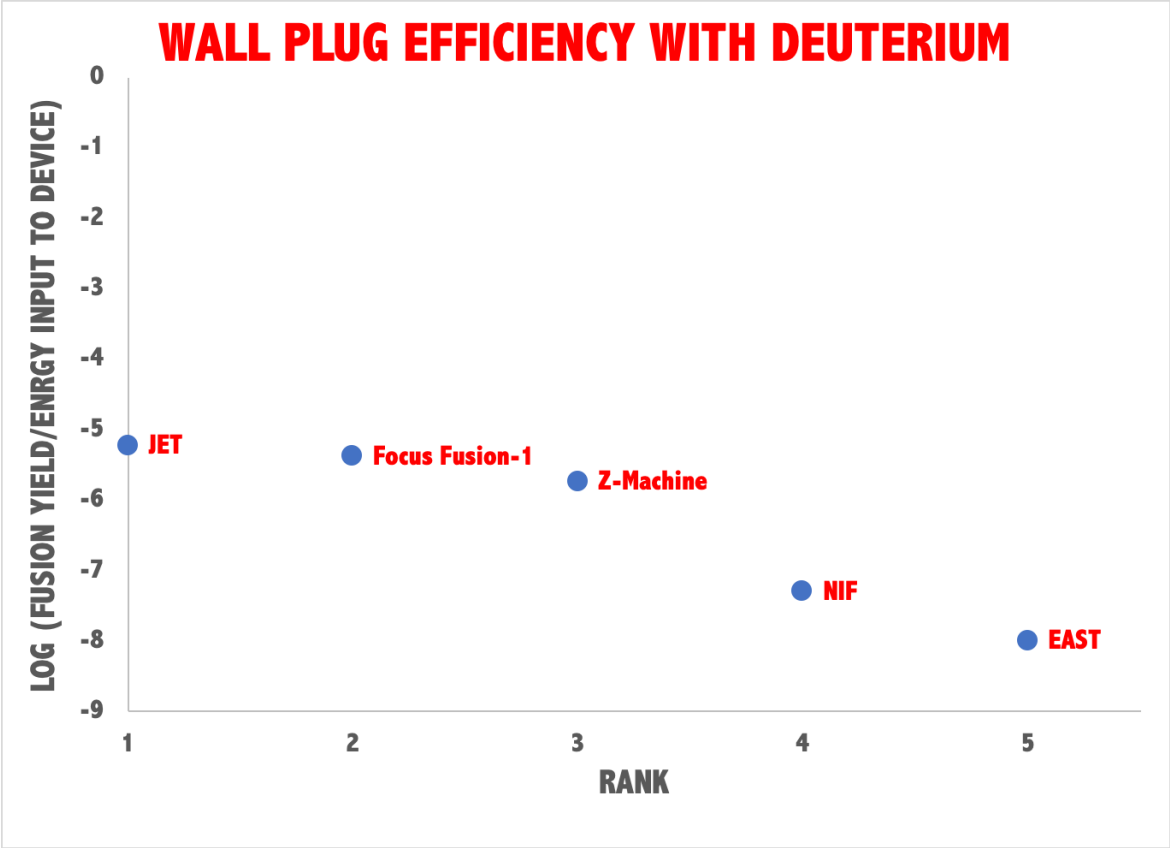
DPF:

Uses Plasma Instabilities Instead of Fighting Them—
Imitating Nature
Extremely Compact, Low Cost

pB11:

Direct Energy Conversion
No Neutron Damage Allows Small Size,
High Energy Flux

RESULTS CLOSE TO LARGE EXPERIMENTS



2016: FF-1 Achieved 0.25 J yield with 60 kJ device input

$6 million total project cost

Physics of Plasmas 24, 102708 (2017)

RECORD CONFINED ION ENERGY NEEDED FOR PB11 ALREADY ACHEIVED

FF-1 Results:

T_i	> 200 keV (mean ion energy)
n	$3 \times 10^{19}/cm^3$
τ	30 ns
$n\tau T$	2×10^{14} keV s/cm^3

Physics of Plasmas 24, 102708 (2017)

FF-1 DD burn fraction in plasmoid: 4×10^{-5}

JET DD record burn fraction : 6×10^{-5}

NIF DD record burn fraction: 5×10^{-4}

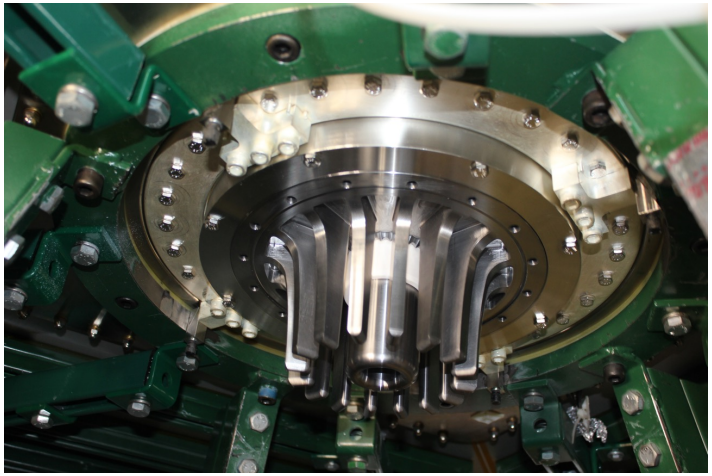
ARE THESE RESULTS REALLY COMPARABLE?

Fusion reactions in FF-1 mainly from confined ions,
not beam passing through
Observations: neutron anisotropy < 1.4

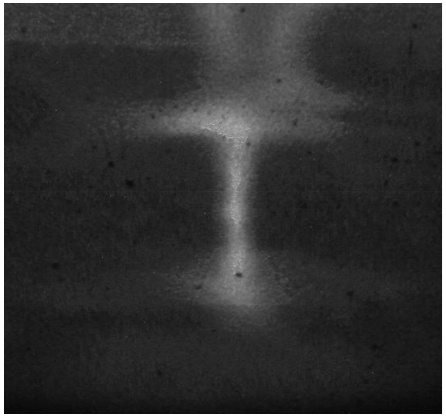
Fusion from hot ion collisions,
not from hot ions with cold plasma
Observations: calibrated x-ray measurements
limit cold/hot ratio < 1.5

Fusion from ions with velocity distribution
giving high reactivity
Observations: calibrated x-ray measurements
limit plasmoid/Maxwellian reactivity > 0.4

CONSISTENT DATA FROM MANY INSTRUMENTS

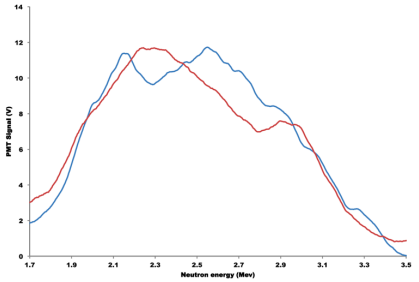


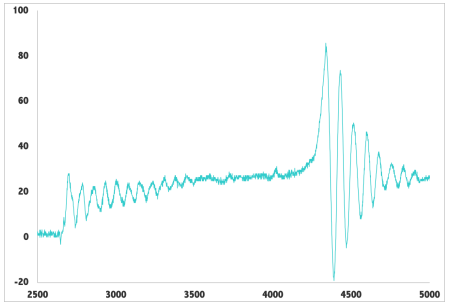
I CCD
Optical/NUV



Filtered
X-ray PMTs

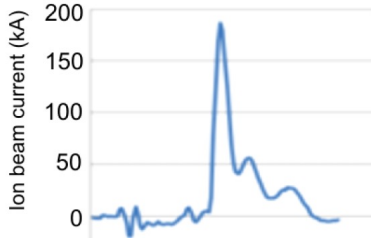
Neutron
Time of
Flight PMTs





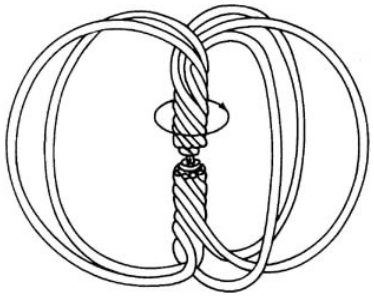
Voltage
Probe,
Main RC

Ion Beam
Rogowski
Coils



Silver Activation Neutron Detectors, Bubble Detectors, Beam Langmuir Probes,
Optical-UV Spectrometer, Axial Field Coil, Switch Detectors, Geiger Counter

THEORY: SCALING, HEATING



$$Y \sim (aI/\mu^{1/2}v_A)^4 f(T)$$

$$a = \#\text{loops of current} \sim (\mu z)^{1/3}$$

Viscous ion heating:

$$T_i \sim z_{eff}^{1.6} \left((z/\mu^{1/2})^{1/3} a I^2 \ln \Lambda / r_a\right)^{2/5}$$

REDUCING X-RAY EMISSION: QUANTUM MAGNETIC FIELD EFFECT

Landau energy levels:

$E_b = (n+1/2)\, ehB/mc = 11.6\text{eV}\ B\ (GG)$

Since maximum momentum transfer is mv, where v is relative velocity, for $mv^2/2 < E_b$ very little excitation from ground level, very little energy transfer.

$E_i < (M/m)\, E_b$

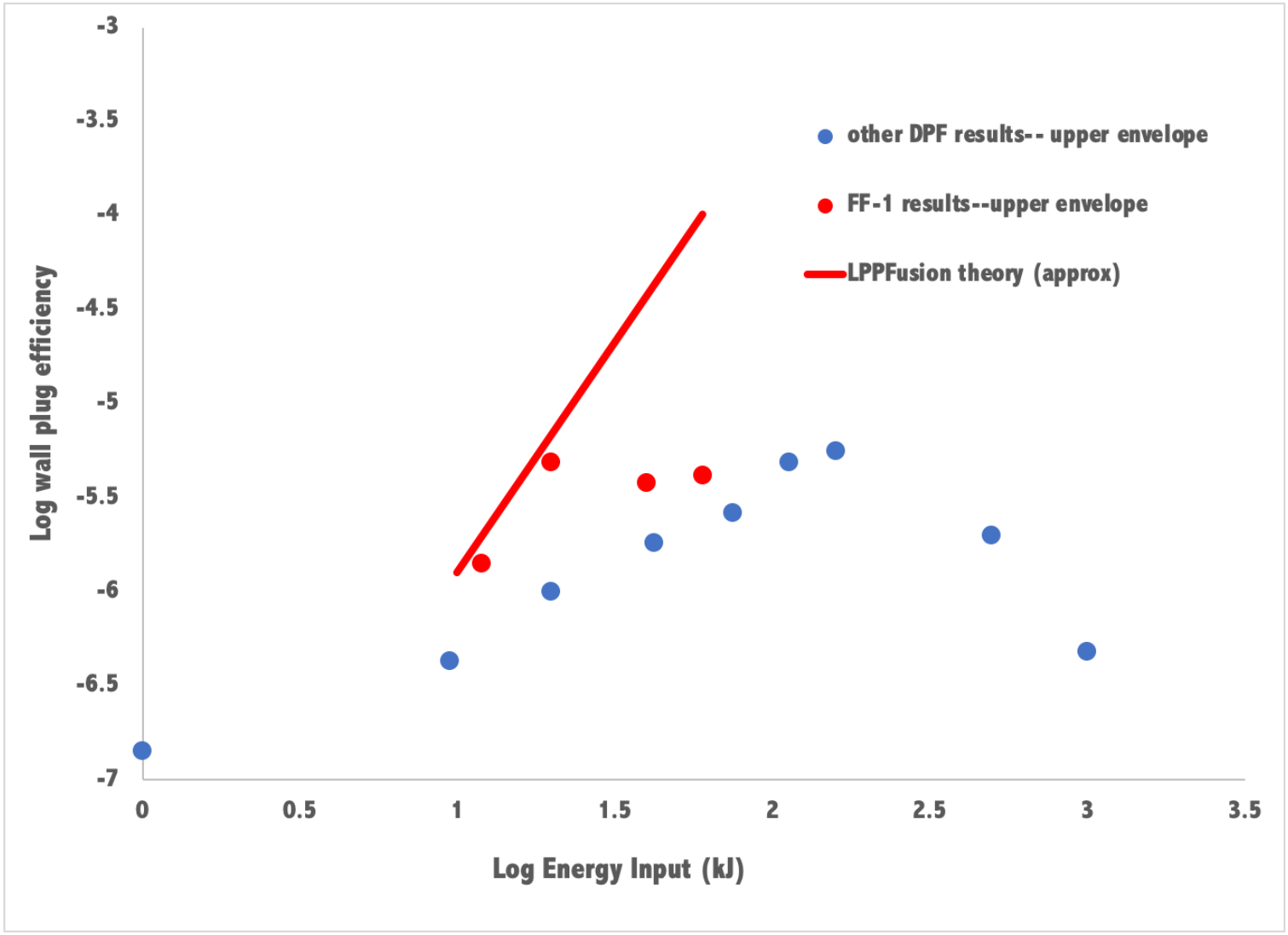
Ion to electron energy transfer << electron to ion

$T_i >> T_e$

Up to 5 x reduction in x-rays

J Fusion Energy (2011) 30: 367.

PROBLEM—WHY CEILING ON WALL PLUG EFFFICIENCY?



IMPURITY HYPOTHESIS AND SOLUTIONS

High-z Impurities Increase Plasma Resistivity, Disrupt Filaments

This reduces helicity, plasmoid density,
fusion yield

Physics of Plasmas 21, 102706 (2014)

Solutions: Monolithic electrodes, Preionization

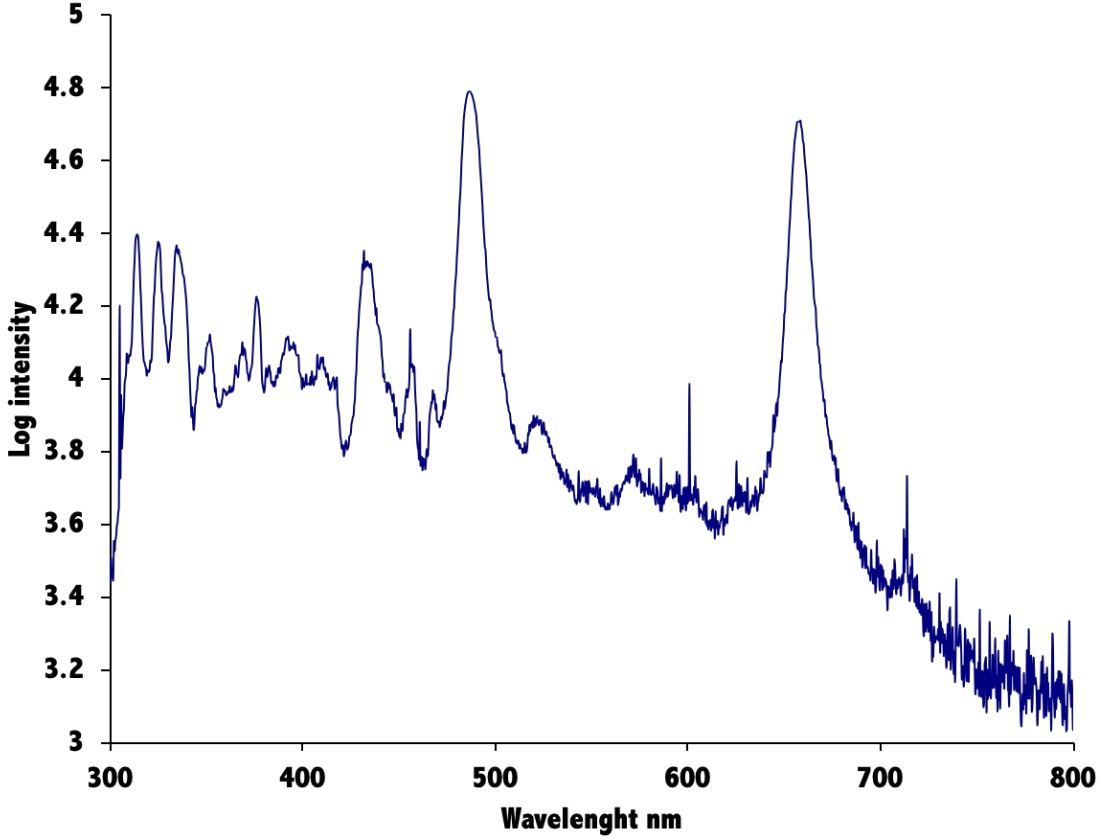
Eliminate high-z materials with beryllium electrodes

FF-2B --shots started June , 2019

Achieved: low impurity functioning

$Fz^2<0.1$

SPECTRUM SHOWS ONLY D, BE AND O
NO HIGH-Z IMPURITIES OBSERVABLE



PLAN: STEPS TO NET ENERGY

3 J: Optimizing FF-2B with pure D

10 J: D-N mix

40 J: doubling number of switches, less inductance, more current, faster rise-time

300 J: full 12 capacitor bank, 45 kV, 2.4 MA peak current

Gain for pB11:

6x higher reaction rate, energy per reaction

4 x better compression

4 x fusion burn energy addition

Goal 30 kJ

ENERGY CONVERSION

Most energy will be emitted as 2-3 Mev ion beam, including most input energy

(in FF-1 up to 7% of bank energy already)

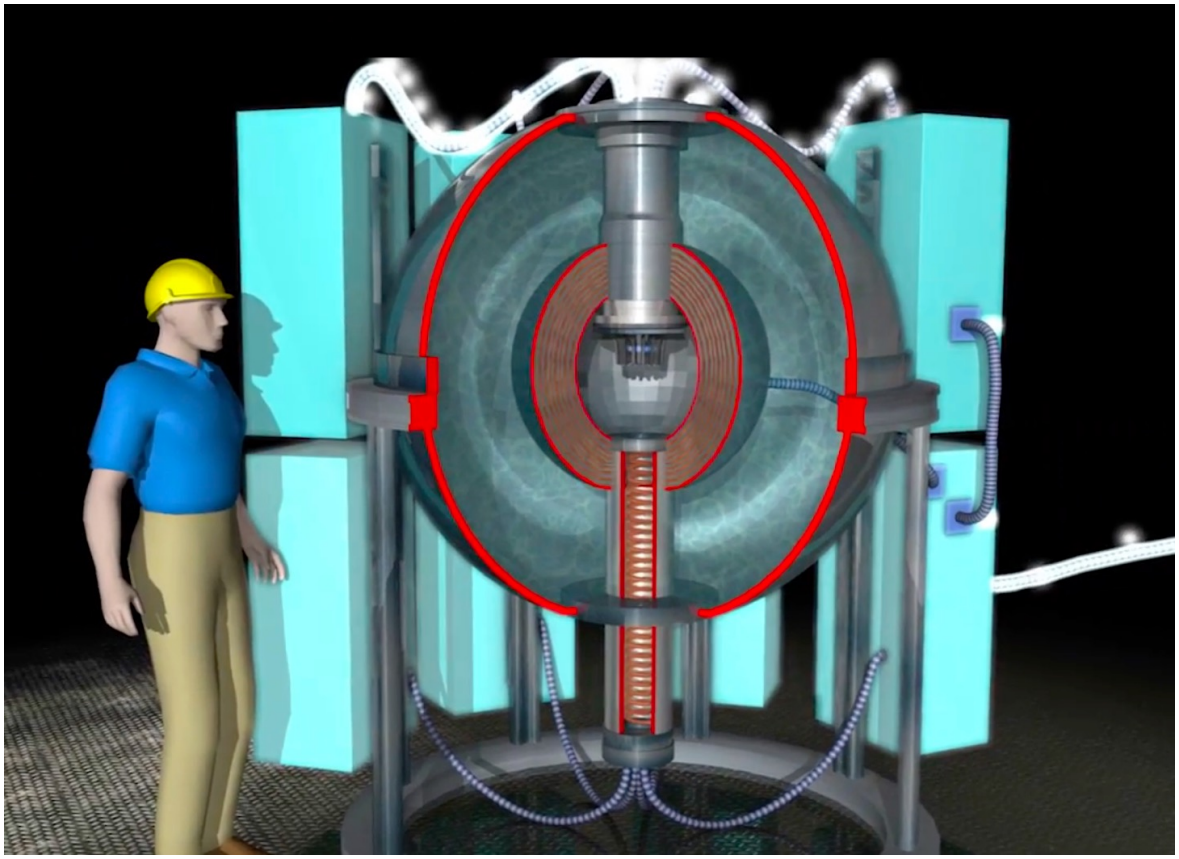
Rest of energy as x-ray pulse 3-50 keV

Ion beam inductively converted—mature technology demonstrated >80% efficiency

X-rays converted with multi-layer photoelectric device—our patent –calculated 80% efficiency

Patent #7,482,607

GOAL: COMPACT 5 MW GENERATOR



200 HZ Net energy per pulse :25 kJ

40% overall eff. without co-generation

Capital cost with mass production: $0.1/w

Electric energy cost: 0.5 cents/kWH

SUMMARY

Need all-out program, matching funds

Focus Fusion route:

Record ion energy, high WP eff

Extremely compact, cheap experimental device

Path to net energy

Goal: fusion in coming decade

10 x cheaper than any existing energy source

THANK YOU