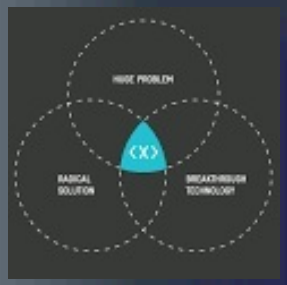


Fusion Energy:
Visions of the Future
Dec. 10-11, 2013

FOCUS FUSION

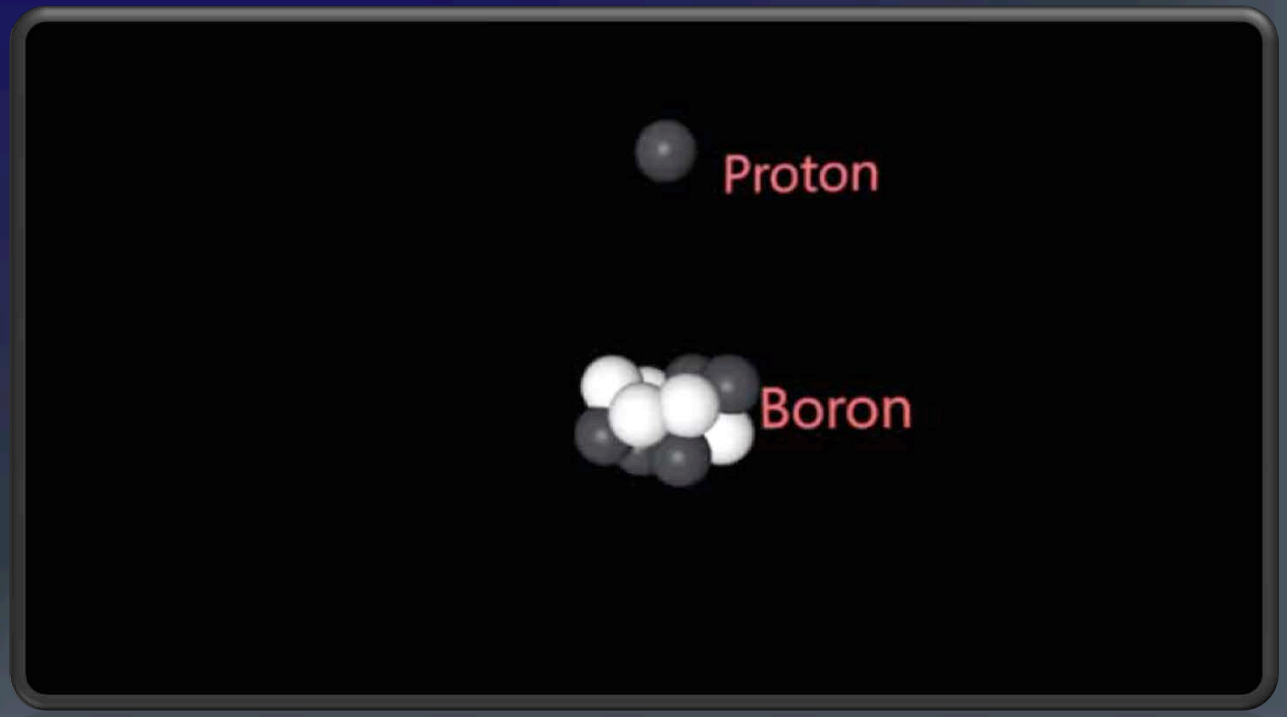
Cheap, Clean, Safe & Unlimited Energy

What Is Focus Fusion?

Controlled Nuclear Fusion With a Dense Plasma Focus Device Running on Aneutronic Fuel

What Is Aneutronic Fusion?

It's a fusion using aneutronic fuel, ideally made of hydrogen and boron, pB11, which produces no neutrons and thus no radioactive waste.



Aneutronic → No neutrons → No Radioactive waste

Why Is Aneutronic Fusion Cheap?

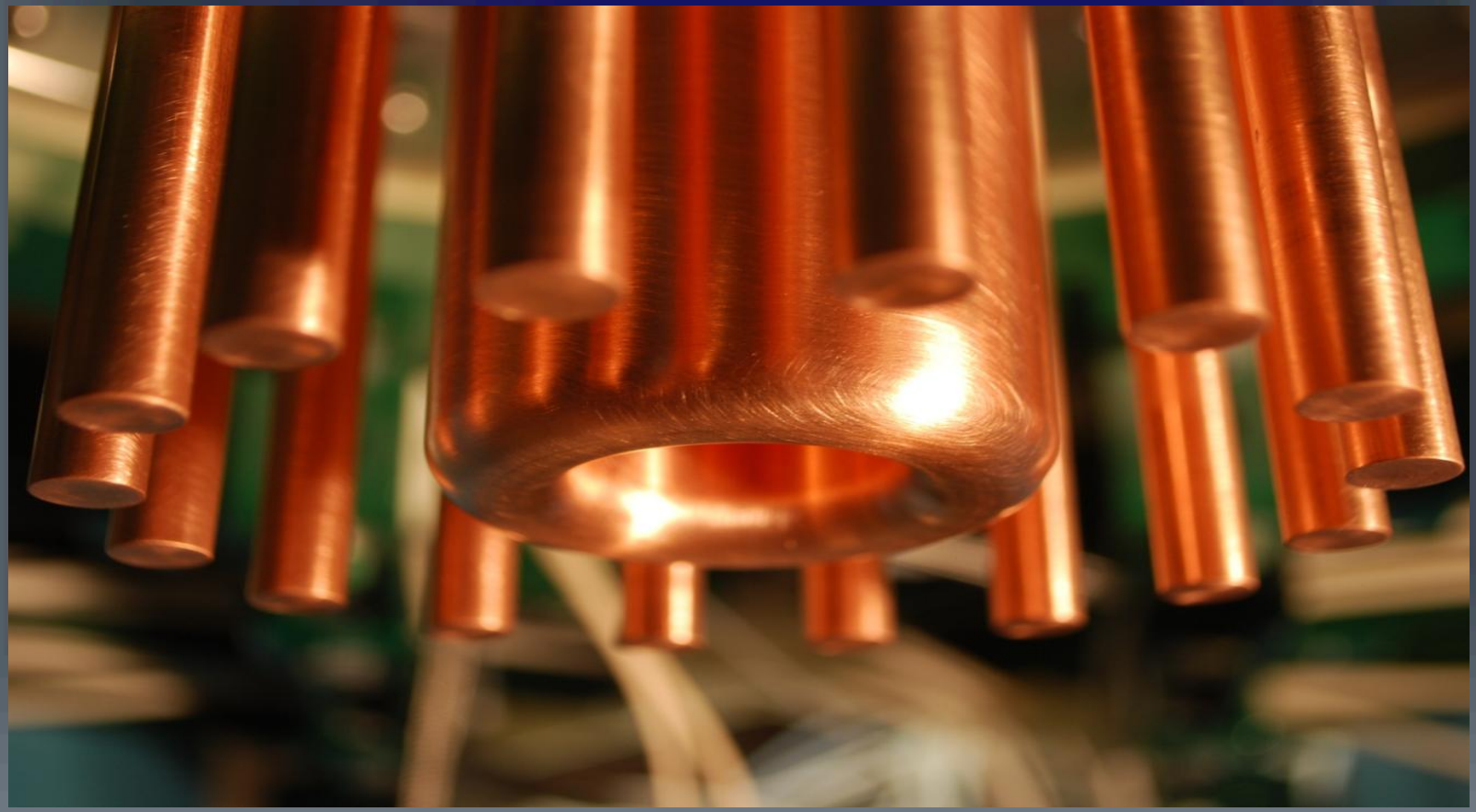
Aneutronic → No neutrons

No neutrons → No Radioactive waste

Aneutronic → Direct energy conversion

Direct energy conversion → No $$$ turbines

Dense Plasma Focus : small inexpensive device



Inside of FF-1's Generator

REPRODUCING NATURAL INSTABILITIES

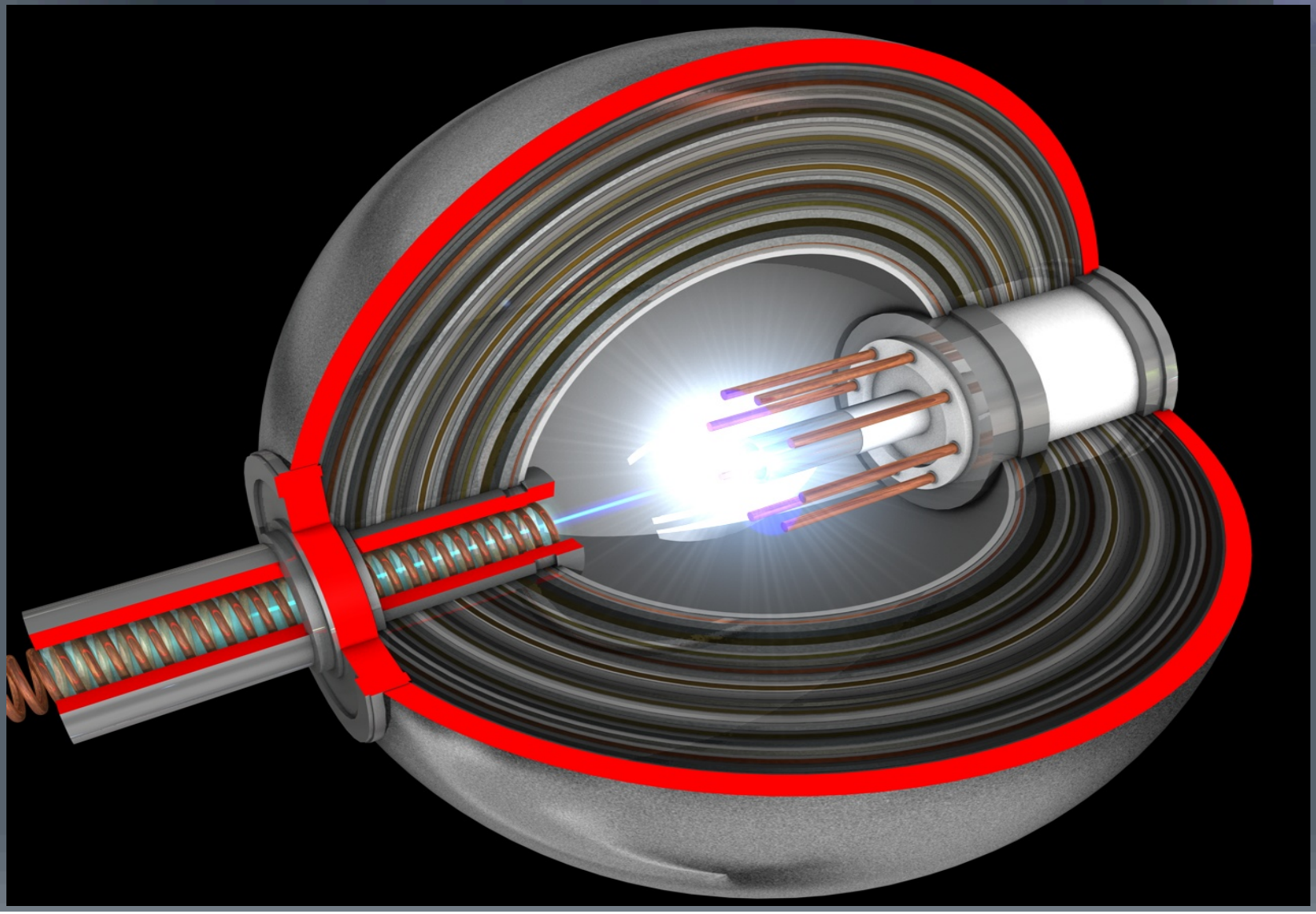
Solar Flares

Beam From Star Formation

Quasars

Spiral Galaxy

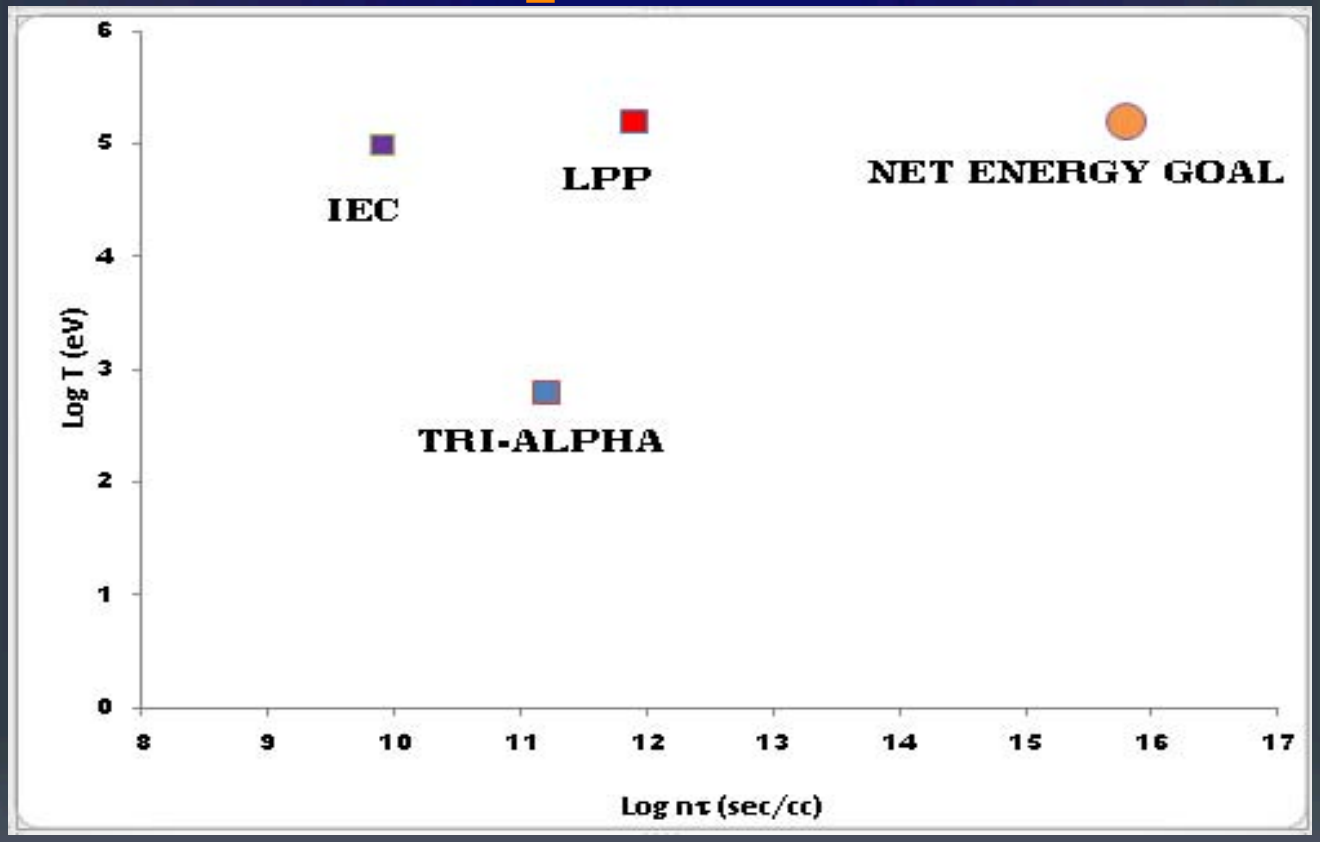
Energy (X-rays, Ion Beams) Capture Device



Where Are We?

- Ion temperature—goal achieved—over 1.8 billion degrees, enough to ignite pB11
- Confinement time—goal achieved 20 ns—more than 8 ns goal
- Energy transfer to plasmoid—over 50% of goal
- Density—must increase by 10,000

Aneutronic Fusion Comparison



Log Temperature (eV)

Log (Density x Confinement Time) (sec/cc)

Our Scientific Peers are Excited

AIP | Physics of Plasmas

What your peers have been reading...

A Listing of the **Most Read Articles** in 2012 Published in

Physics of Plasmas

Fusion reactions from >150 keV ions in a dense plasma focus plasmoid

Eric J. Lerner, S. Krupakar Murali, Derek Shannon, Aaron M. Blake, and Fred Van Roessel

Phys. Plasmas **19**, 032704 (2012)

Development of the indirect-drive approach to inertial confinement fusion and the target physics basis for ignition and gain

John Lindl

Phys. Plasmas **2**, 3933 (1995)

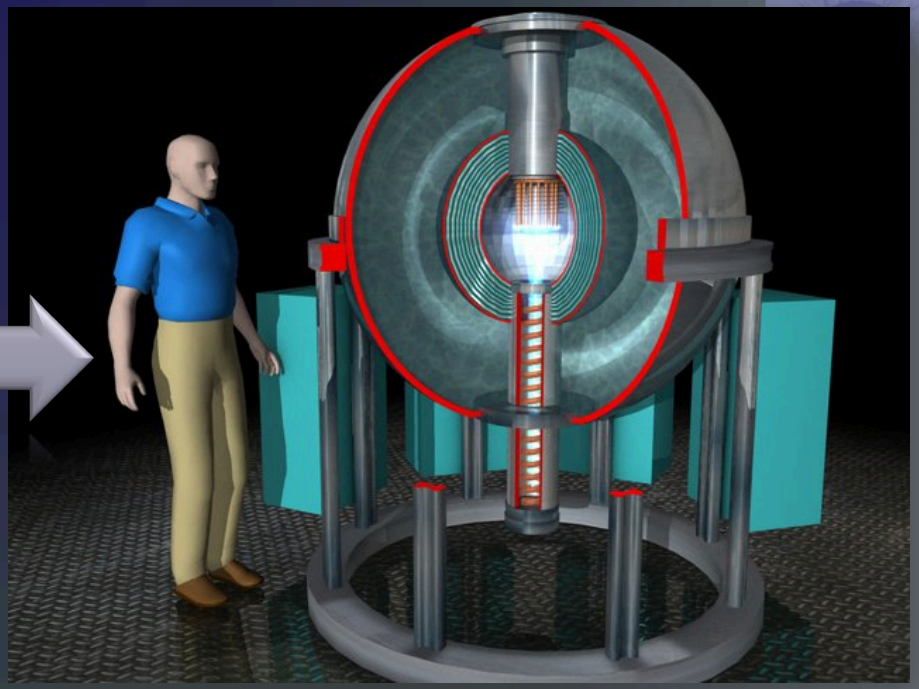
Steps To Increase Density

- 50x-- Achieve theoretical density—tungsten electrodes to eliminate impurity
- 10x-- Increase current to 2.8 MA
- 20x-- Better compression with heavier pB11

From NJ to your neighborhood

FF-1, 2014

FF-X, 2018



1 Year – conclude scientific feasibility

4 Years – for commercial generator

COSTS

For 5 MW generator, mass production

$0.08-$0.20/W

Electric cost

Less than 0.3 cents/kwH

Vs best today of 6 cents/kwH

Finances

- $3.2M raised from Abell Foundation, 50 investors
- Raising $1 M more for scientific feasibility, transition to eng. phase
- $50M for development, engineering

What Our Peers Say:

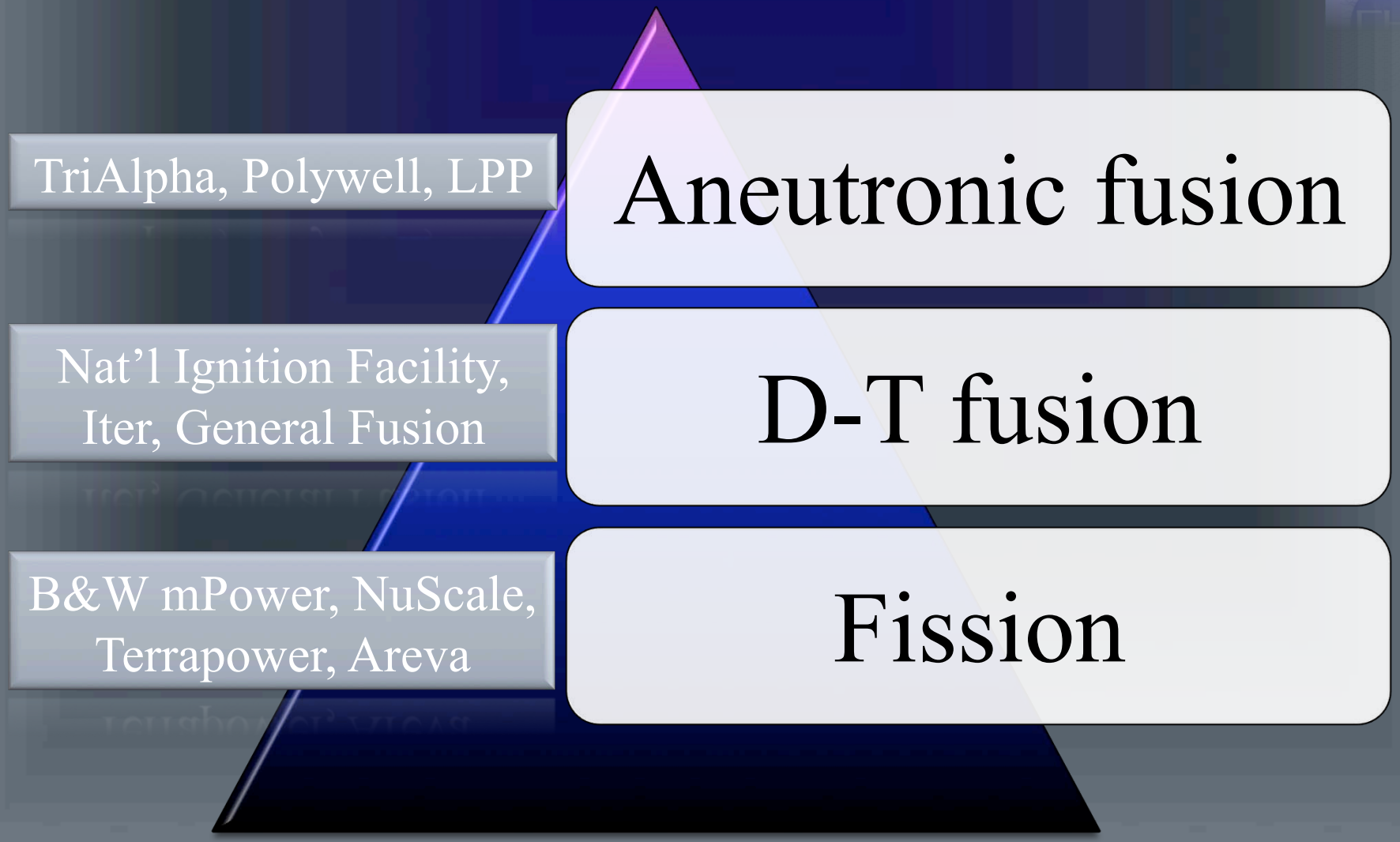
- "...the committee feels that the promise of the LPP DPF approach to fusion power has considerable merit and that a much higher level of investment is warranted, based on their considerable progress to date. "
- Review by Robert L. Hirsch, Steven O. Dean, Gerald L. Kulcinski, and . Dennis Papadopoulos

Our Intellectual Property:

- US patent 7,482,607
- Chinese Patent No. 200780007065.7
- Australian Patent 2007314648

- Patent applications , same priority date: Europe, Canada, India

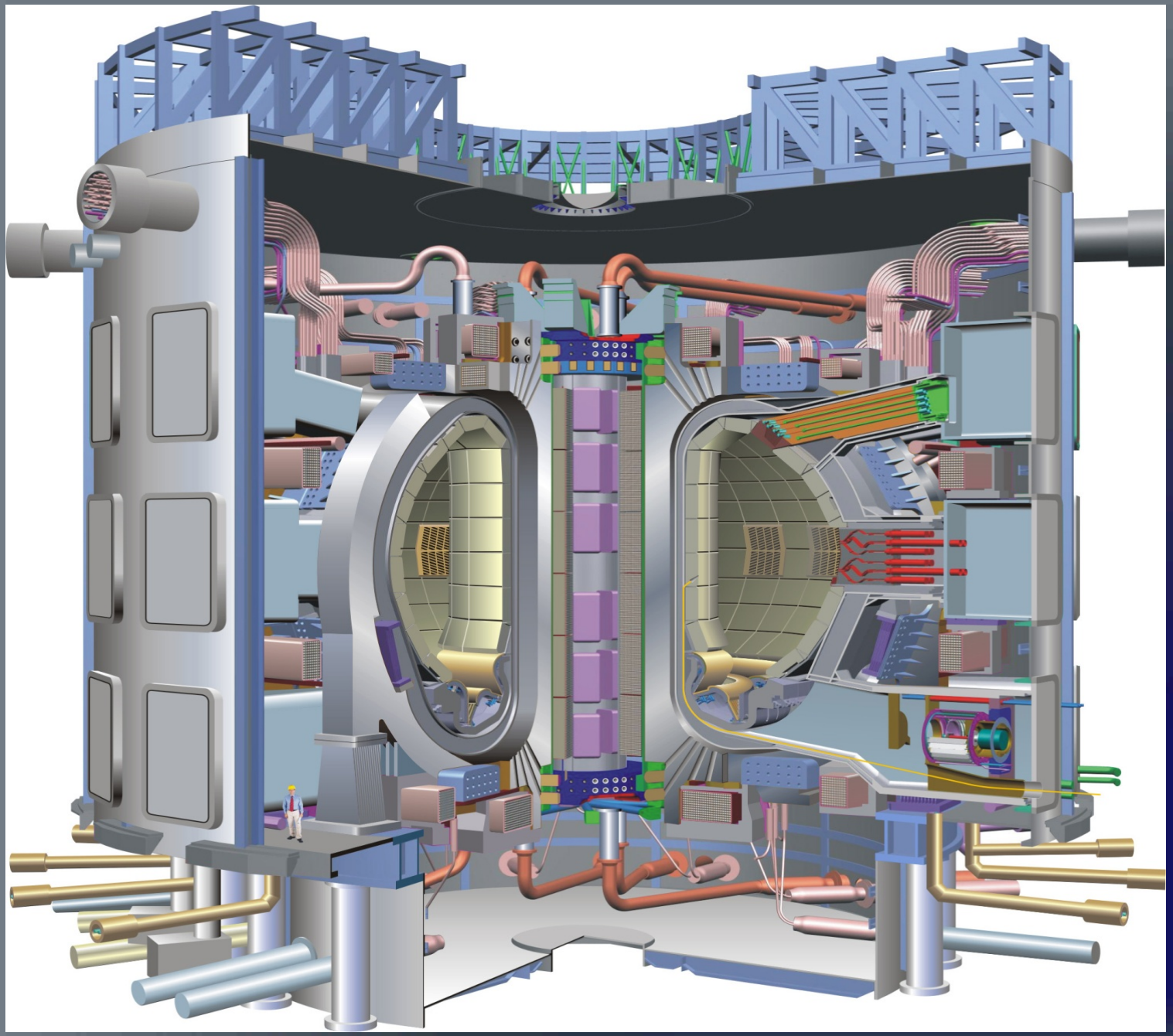
Why Is Focus Fusion Cheap?



Deuterium & Tritium vs. Hydrogen & Boron

Deuterium – Tritium		Hydrogen-Boron
Low Ignition at 400 Million K	vs.	1.6 Billion K

But LPP has already achieved 1.8 billion K

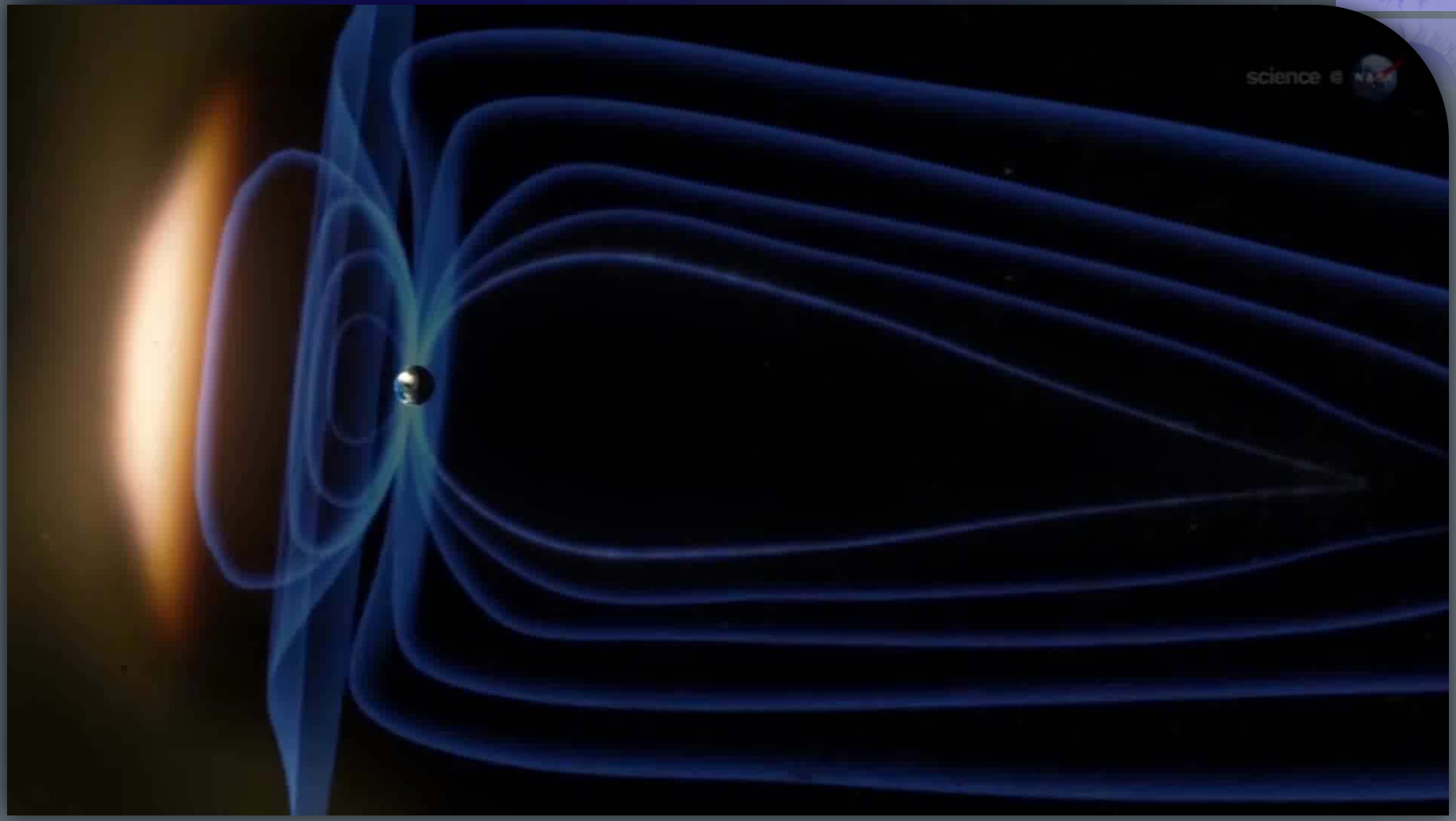


Tokamak

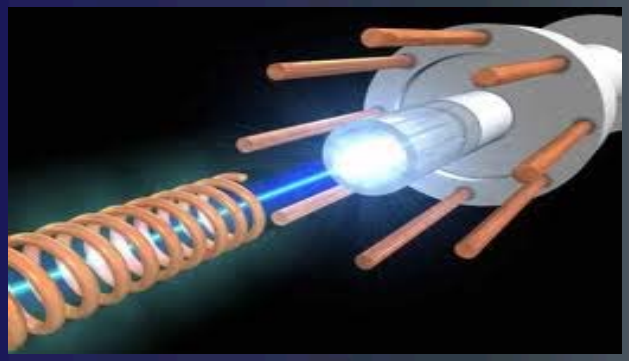
DIFFERENCE #2:

Use Instabilities, don't fight them!

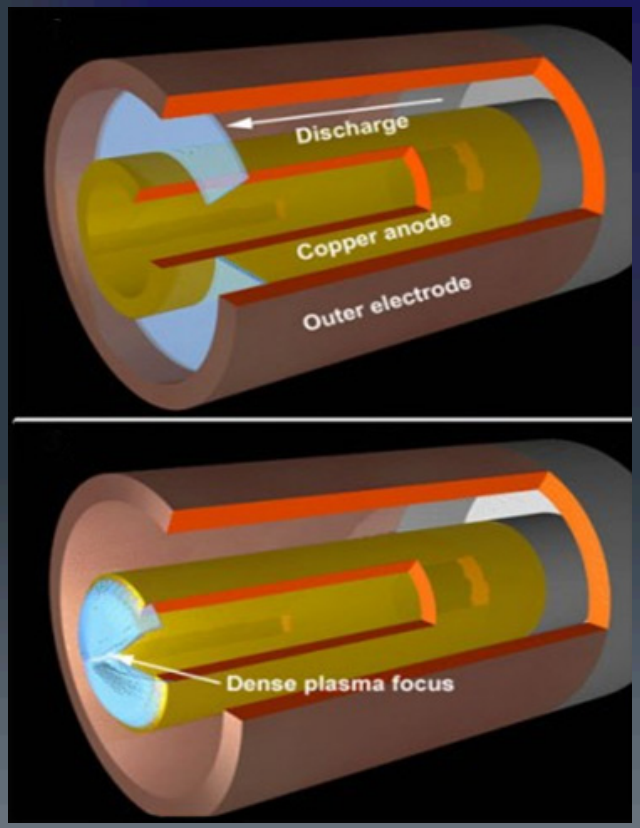
Pinch Effects!

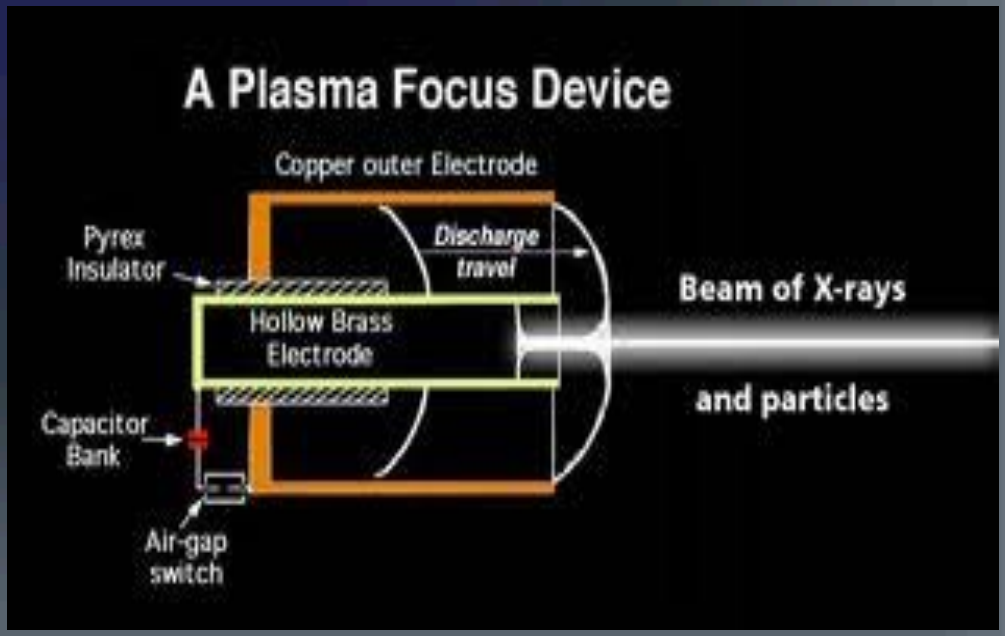


WHAT IS DPF?

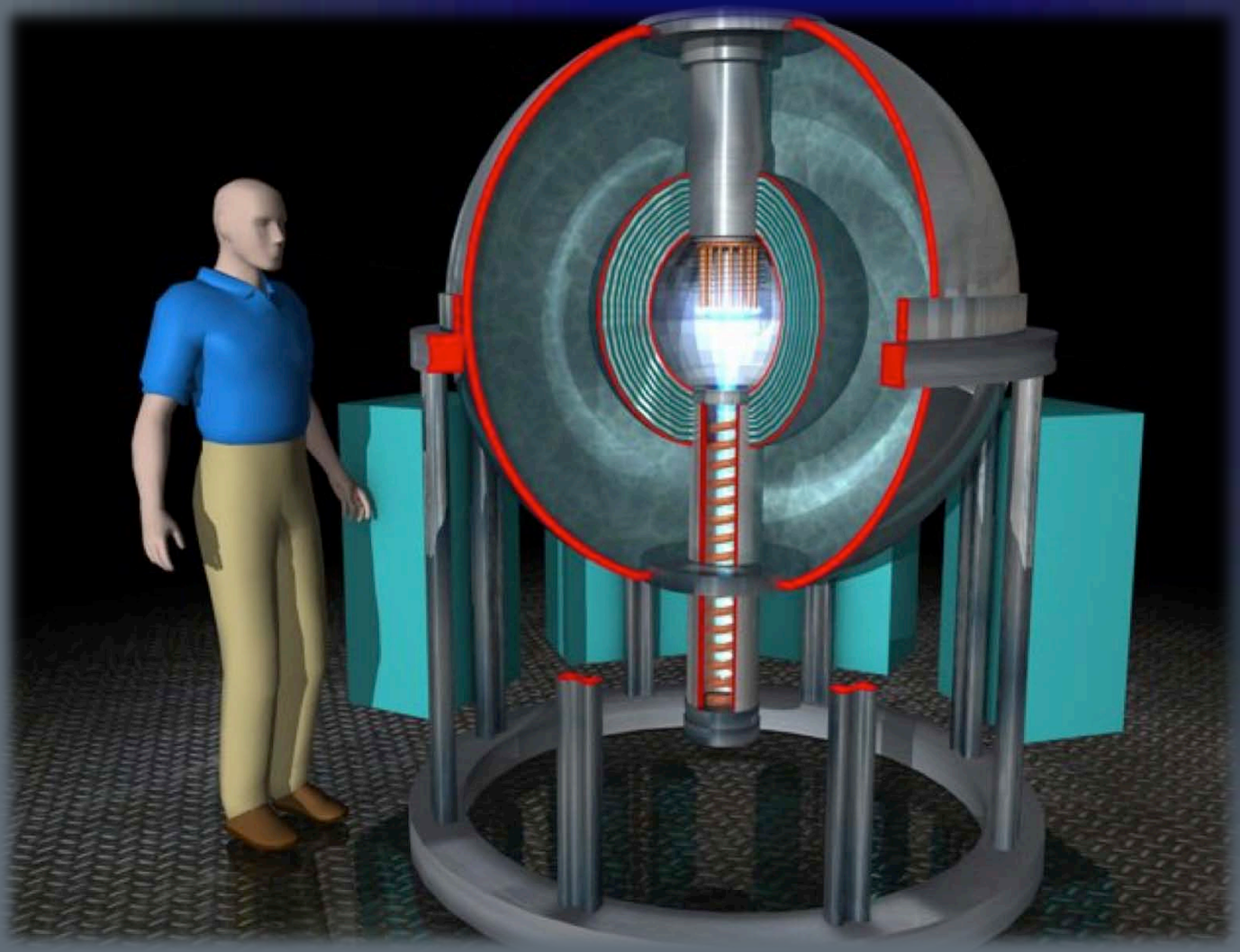


- **Dense Plasma Focus is a DEVICE!**





Garage Use 5 MW – Generator



Clean

Inexpensive

Safe

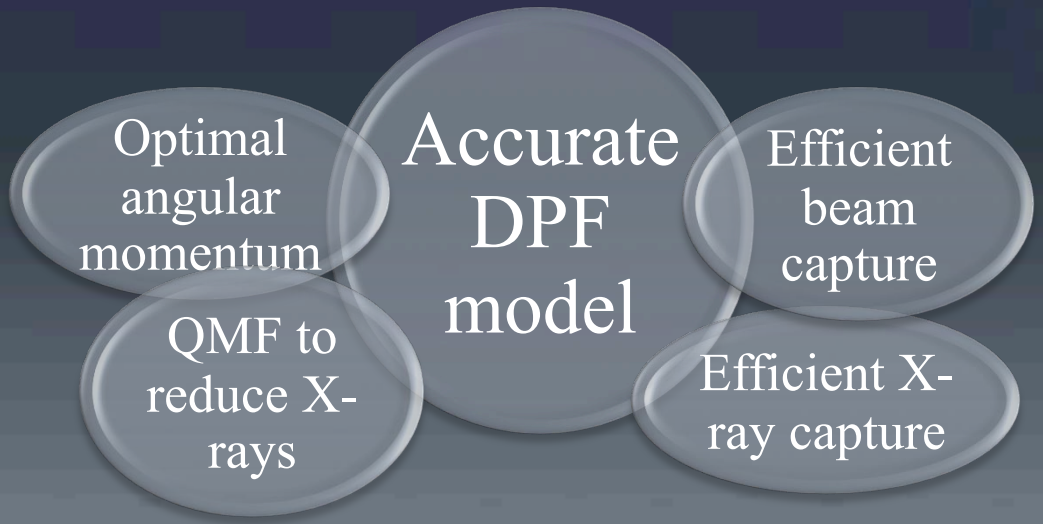
Compact

LPP's Advances On Other DPF Work

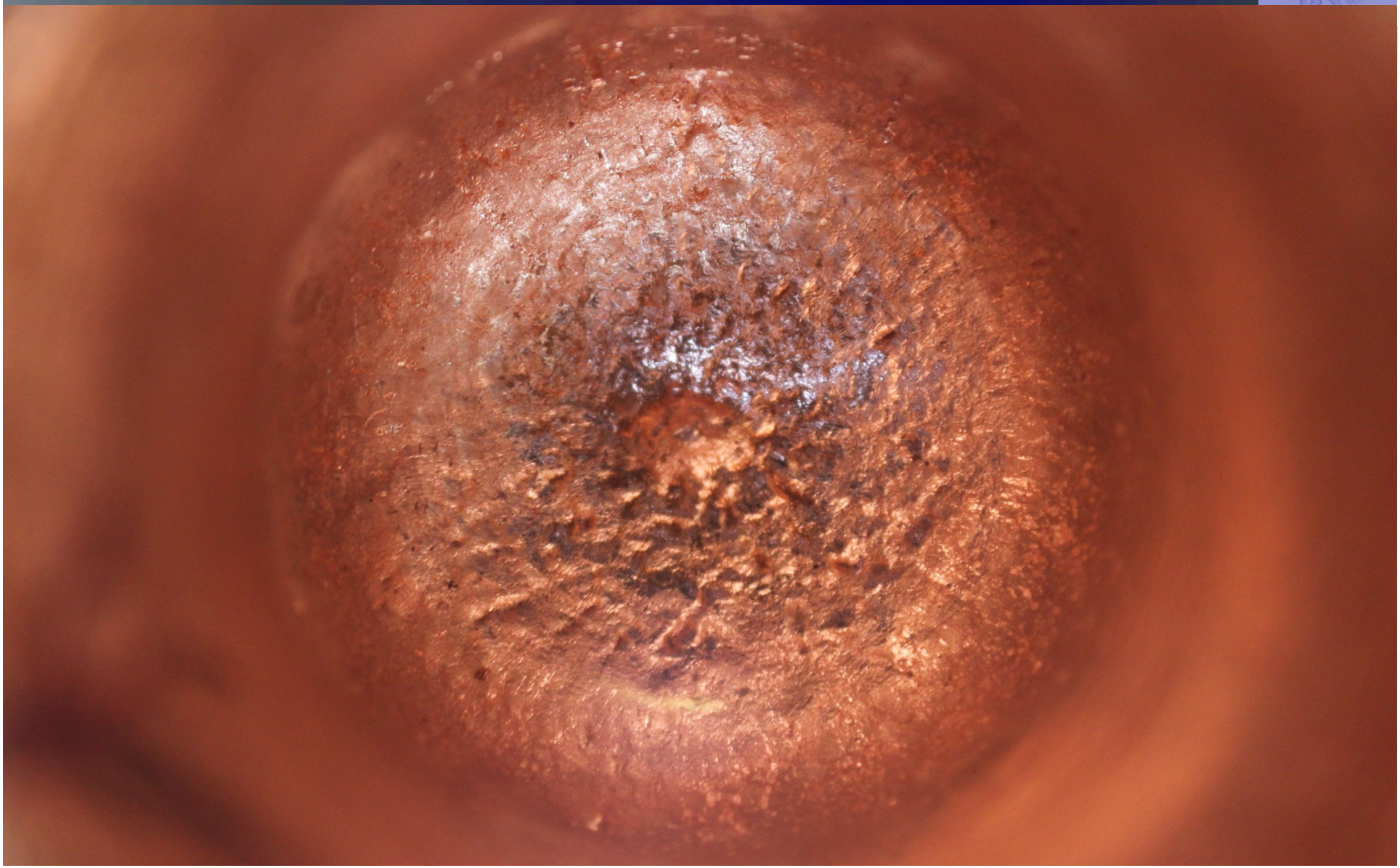
- **Theory—leads to small size**
- **Axial Field coil controls spin**
- **Quantum magnetic field effect suppresses x-ray cooling**

Innovation On The Shoulders Of Giants

- Rich body of DPF scientific literature since invention in '60's
- Dozens of research groups worldwide
  - X-ray/neutron applications
  - US teams at KSU, NSTec
- 2009: LPP Focus Fusion-1 lab begins experiments
- Testing our key innovations to demonstrate scientific feasibility of focus fusion



Ions go one way, electrons the other



THE CHALLENGES: Two Down, One To Go

1. Enough heat achieved; 1.8B K
2. Enough confinement time achieved; 20 ns
3. Density: give-number- here; Not enough!

AIP | Physics of Plasmas

PHYSICS OF PLASMAS **19**, 032704 (2012)

Fusion reactions from >150 keV ions in a dense plasma focus plasmoid

Eric J. Lerner, S. Krupakar Murali, Derek Shannon, Aaron M. Blake, and Fred Van Roessel
Lawrenceville Plasma Physics, 128 Lincoln Blvd., Middlesex, New Jersey 08846-1022, USA

(Received 23 December 2011; accepted 25 February 2012; published online 23 March 2012)

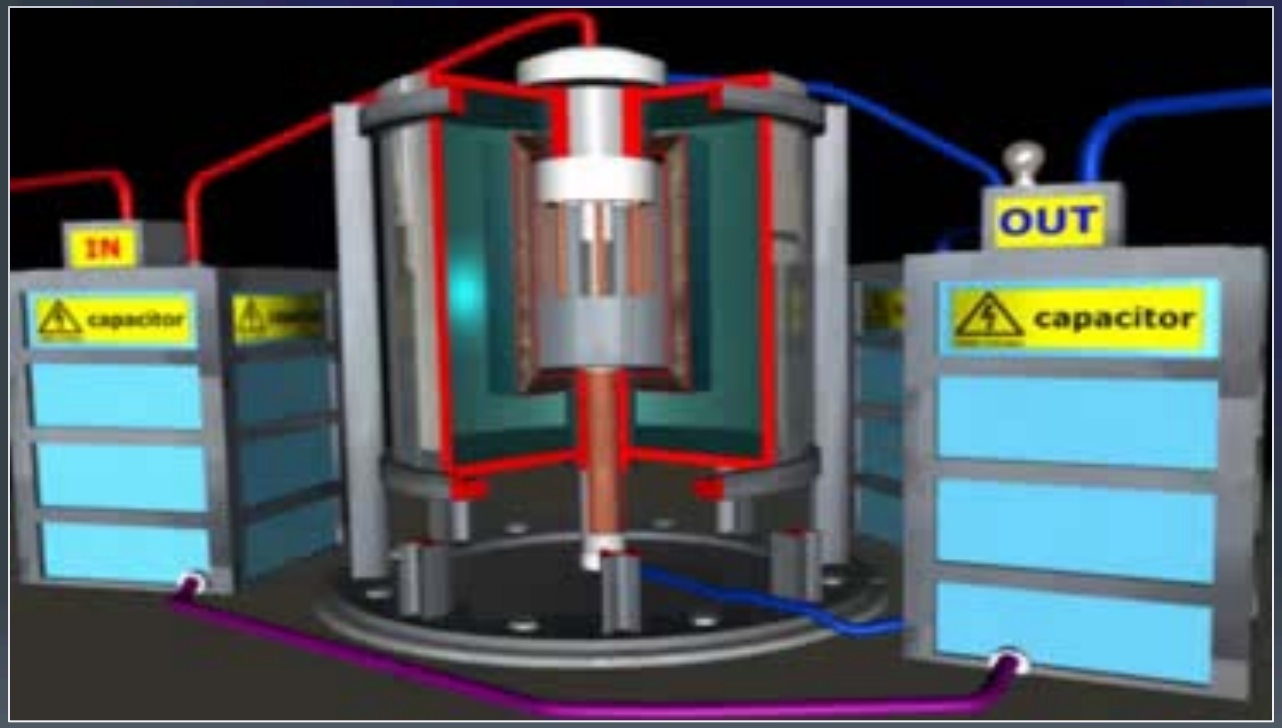
Using a dense plasma focus device with a 50 kJ capacitor charge, we have observed fusion reactions from deuterium ions with record energies of >150 keV, which are confined for durations of 7–30 ns in the cores of plasmoids with typical radii of 300–500 μm and densities $\sim 3 \times 10^{19}$ cm^{-3}. We have for the first time simultaneously imaged the plasmoid at high (30 μm) resolution and measured trapped ion energy and neutron anisotropy. The isotropy of the neutron emission as well as other observations confirms that the observed neutrons per pulse of up to 1.5×10^{11} are produced mainly by confined ions, not an unconfined beam. The conditions achieved are of interest for aneutronic fusion, such as with pB11 fuel. © *2012 American Institute of Physics*. [http://dx.doi.org/10.1063/1.3694746]

I. INTRODUCTION

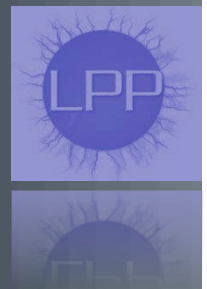
The dense plasma focus (DPF) device has long been known to be an efficient source of neutrons from fusion reactions and of MeV-energy ion and electron beams.[1,2] It

and higher if the high-energy ions are not yet thermalized. integrated charge-coupled device (ICCD) images, low anisotropy in neutron production, energy considerations, and the strong correlation of ion energy with fusion power all combine to

Getting Net Power



Engineering Challenges:



- Removing waste heat (helium cooling)
- X-ray capture device
- Ion beam conversion (MW magnetron designs already get 87% efficiency)

What Our Colleagues Say:

- **"I think that the "Focus Fusion" approach of Lawrenceville Plasma Physics, Inc. should be funded as the science behind it is very interesting. "- Bruno Coppi, Professor of Physics and Senior Fusion Researcher, MIT**
- **"According to the results of this paper, it could be said that p11B fuelled plasma focus device is a clean and efficient source of energy." S. Abolhasani, M. Habibi and R. Amrollahi, Amirkabir University of Technology, Tehran, Iran in *Journal of Fusion Energy***
- **"The experimental program that LPP plans to carry out has great potential to show how the plasma focus can be used to generate fusion energy and to demonstrate the feasibility of hydrogen-boron fusion. "- Dr. Julio Herrera, Professor of Physics, National Autonomous University of Mexico**

Accelerating Feasibility Through International Collaboration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Environment › Nuclear power

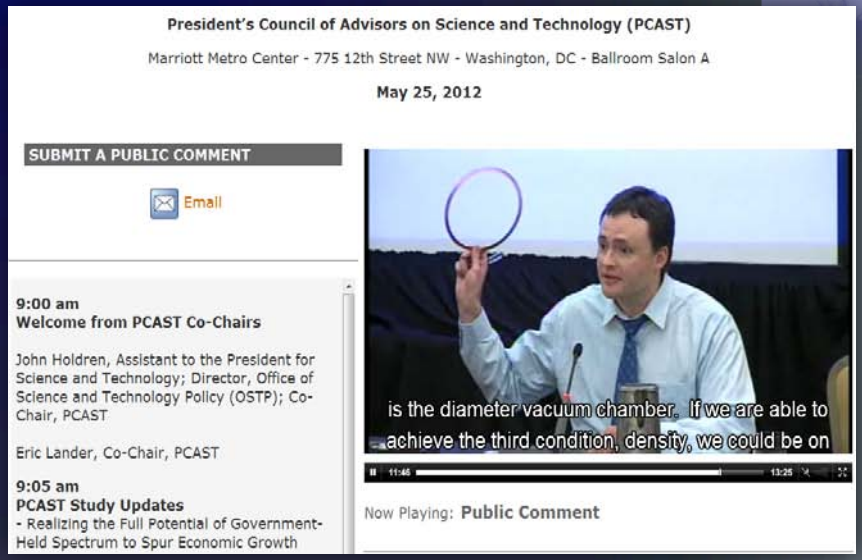
Iranian team to collaborate with US company on nuclear fusion project

New Jersey company says it has permission for unique partnership to work toward the holy grail of energy sources

Share 403 Tweet 136 +1 16 Email

Mark Halper
guardian.co.uk, Friday 25 May 2012 13.59 EDT

Article history


President's Council of Advisors on Science and Technology (PCAST)

Marriott Metro Center - 775 12th Street NW - Washington, DC - Ballroom Salon A

May 25, 2012

SUBMIT A PUBLIC COMMENT

Email

9:00 am
Welcome from PCAST Co-Chairs

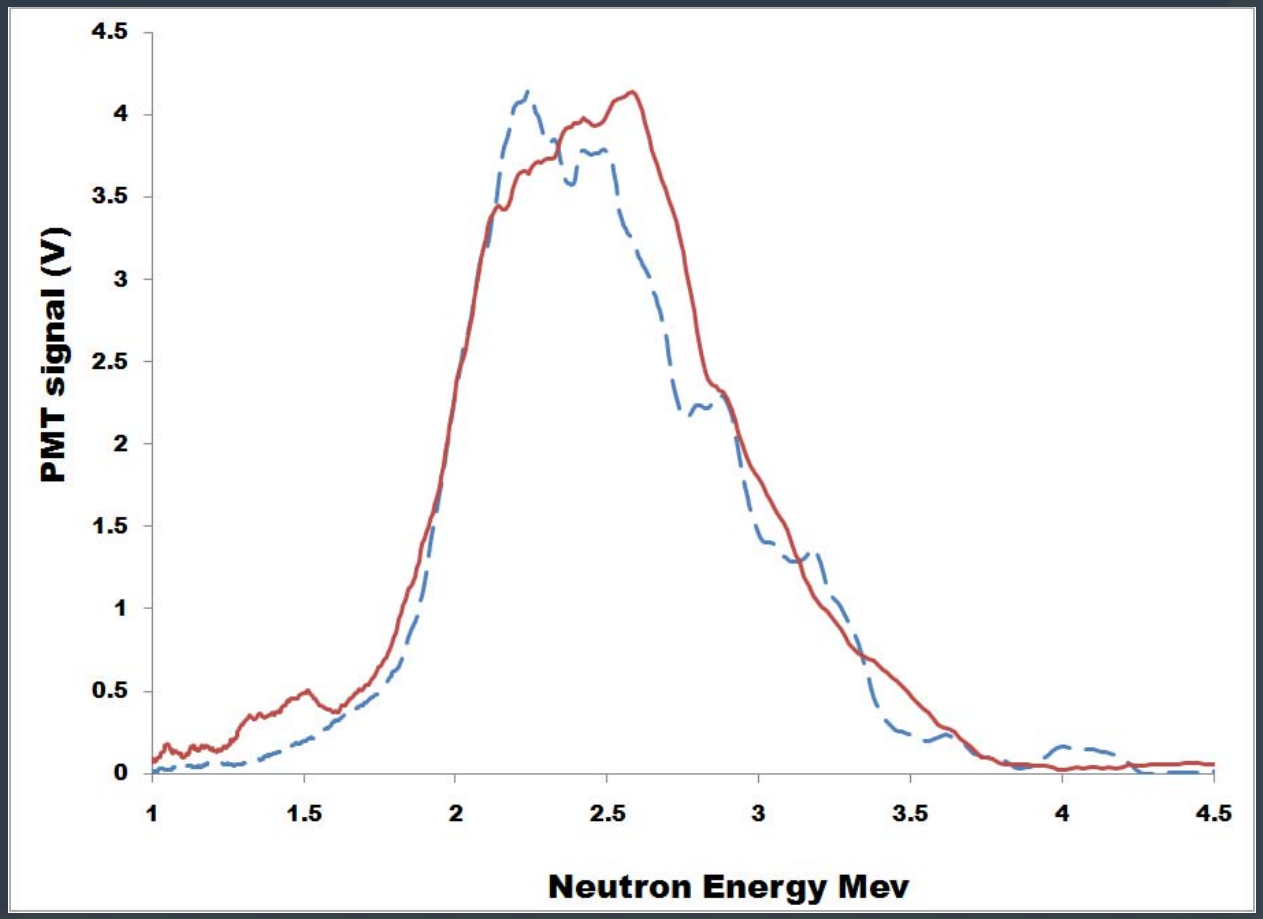
John Holdren, Assistant to the President for Science and Technology; Director, Office of Science and Technology Policy (OSTP); Co-Chair, PCAST

Eric Lander, Co-Chair, PCAST

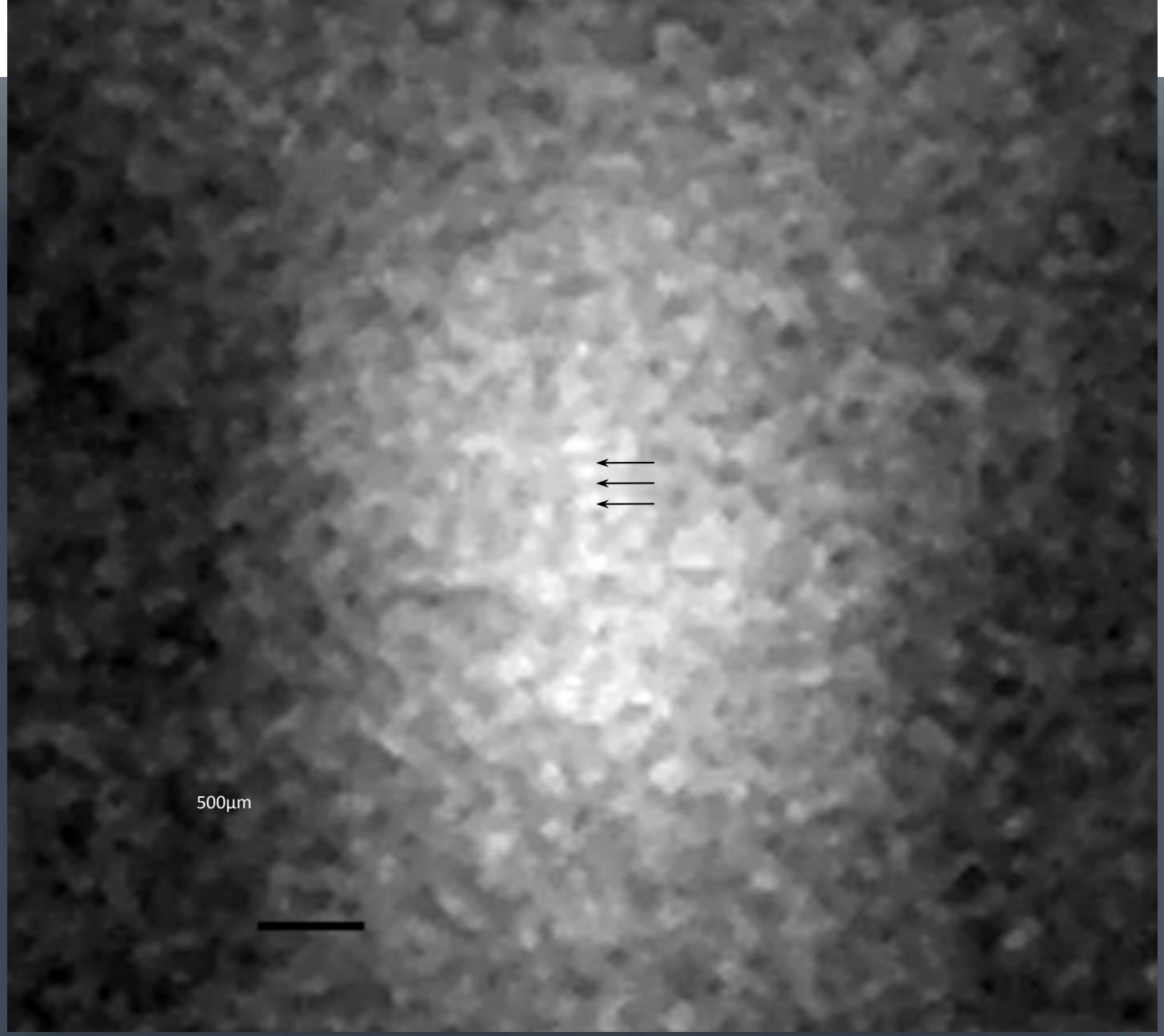
9:05 am
PCAST Study Updates
- Realizing the Full Potential of Government-Held Spectrum to Spur Economic Growth

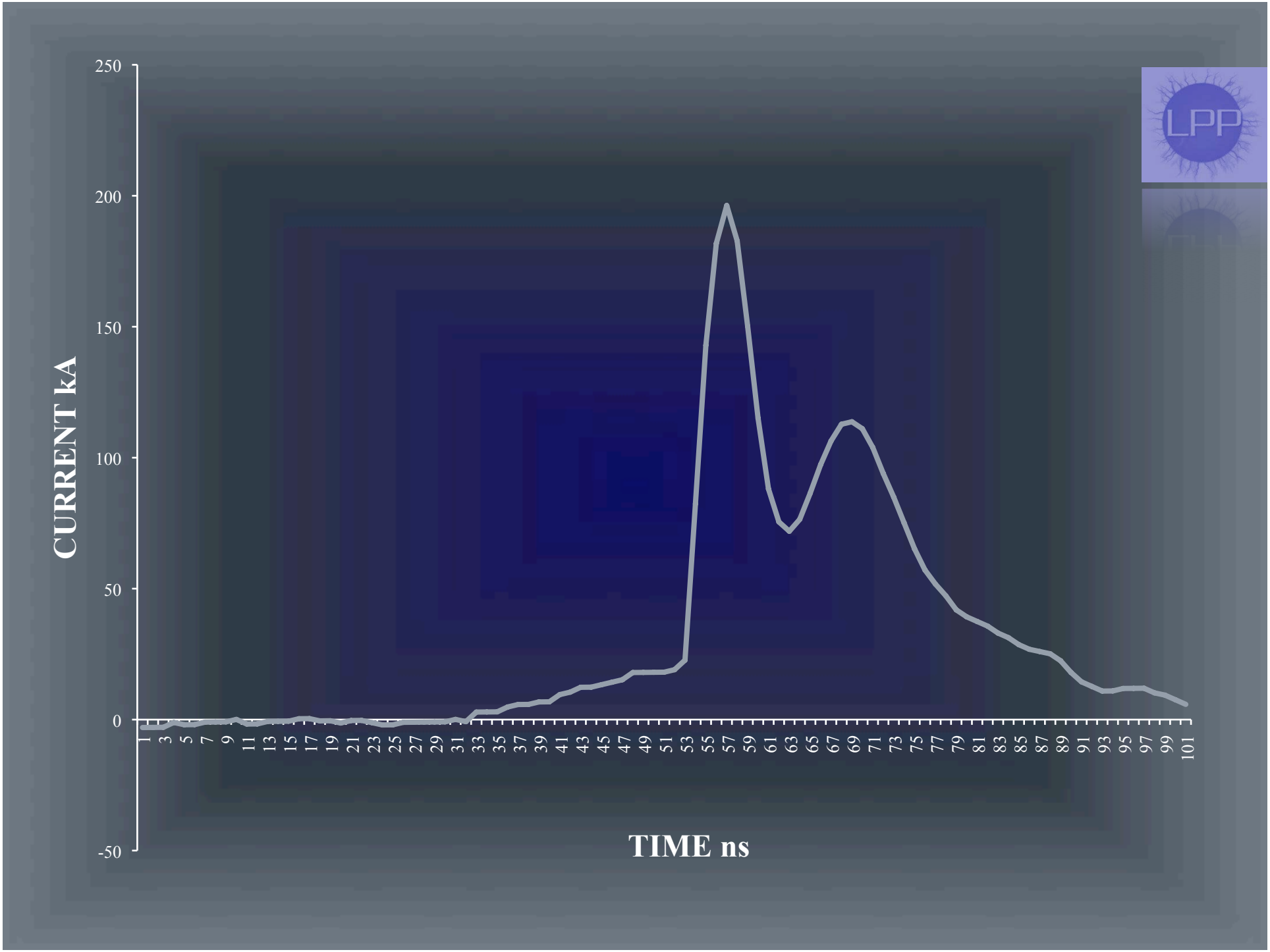
Now Playing: Public Comment

- Agreement signed with Plasma Physics Research Center in Tehran to cooperatively publish papers
- 150 graduate students, including 50 PhD students
- 90 plasma physics PhD students in the entire US
- PCAST briefed May 25th in DC
- Working to expand cooperation to Japan, elsewhere



PROOF OF 160 KEV—1.8 BILLION DEGREES K


500µm


250
200
150
100
50
0
-50
CURRENT kA
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3
5
7
9
11
13
15
17
19
21
23
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27
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73
75
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81
83
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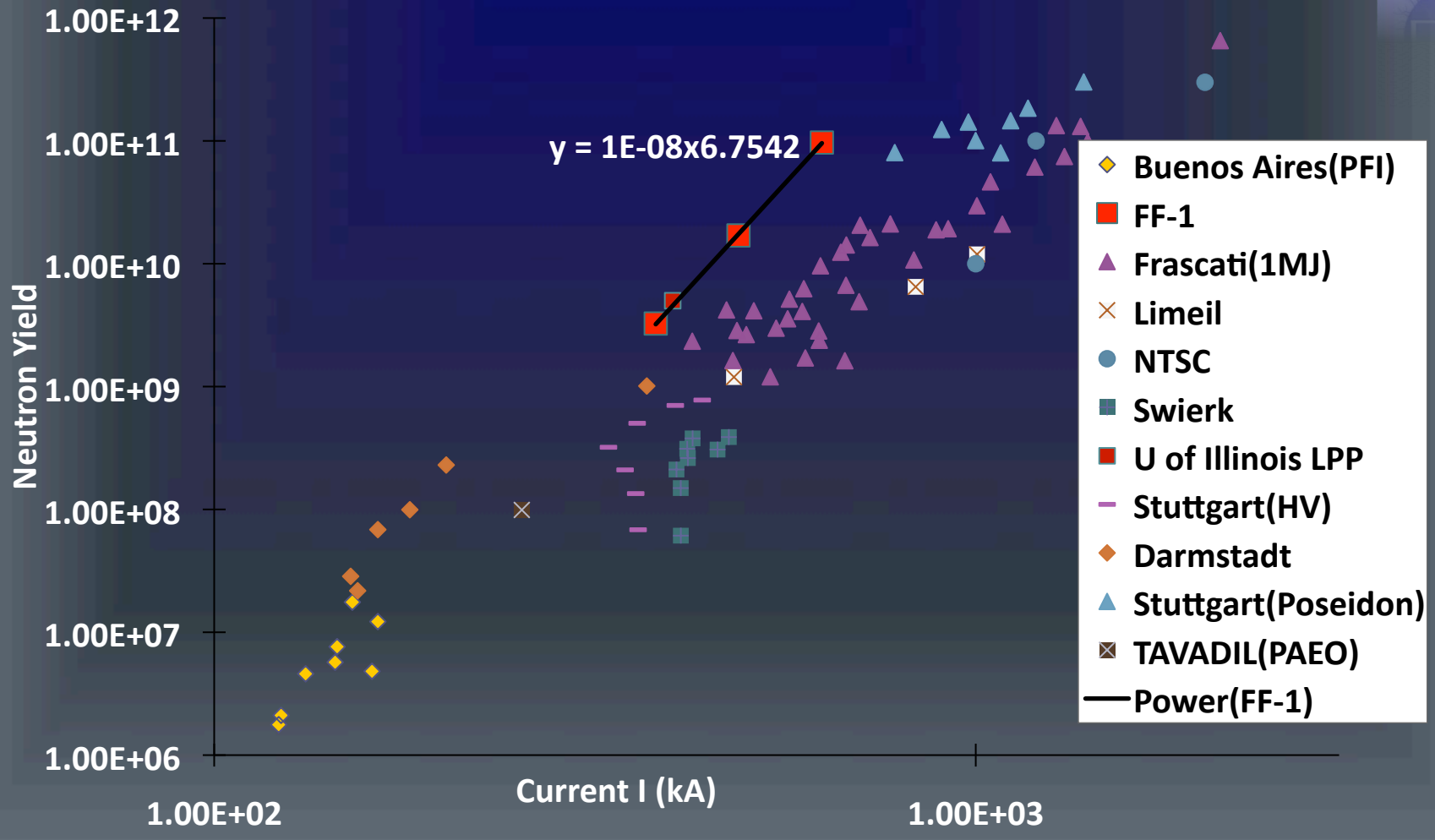
95
97
99
101
TIME ns

Improvement in Yield/Current Scaling



Timeline for Total Energy Transformation

Example: Tesla Model S, 1st year (2012) production 5-7k vehicles

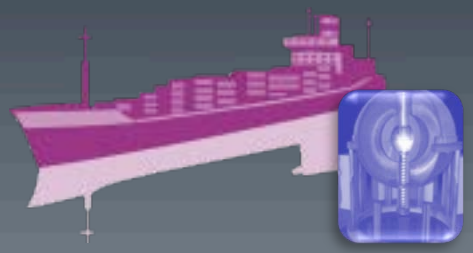
Example: 2M total EV's in 2014

SIMILAR POTENTIAL FOR FOCUS FUSION GENERATORS ENABLES HUGE POSITIVE GLOBAL IMPACT

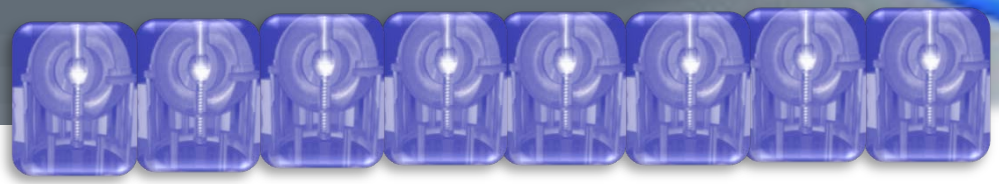
2012-2013: Scientific demo

2015-2016: Commercial prototype

2016: Mass manufacture with worldwide JV partners and licensees



They'll stack!

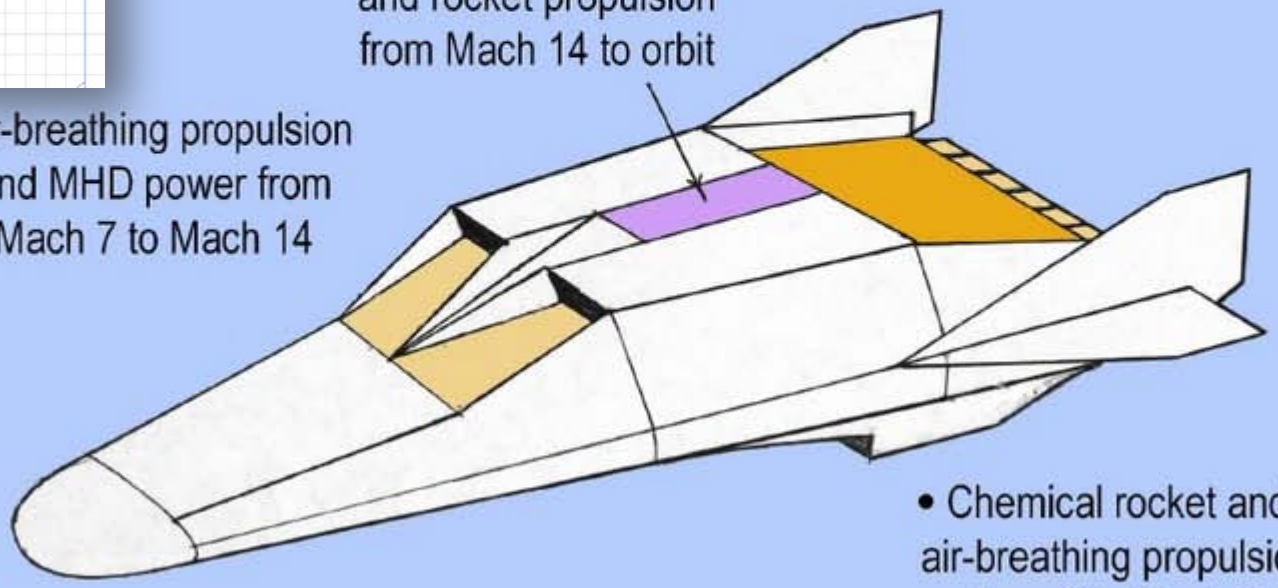


Propulsion and Power Generation Capabilities of a Dense Plasma Focus (DPF) Fusion System for Future Military Aerospace Vehicles

Presented by **Sean D. Knecht** for the Space Technology & Applications International Forum (STAIF – 2006), Albuquerque, NM
15 February 2006

Air Breathing and Rocket Propelled Vehicle-with MHD and Fusion Power

- A neutronic fusion power and rocket propulsion from Mach 14 to orbit
- Air-breathing propulsion and MHD power from Mach 7 to Mach 14

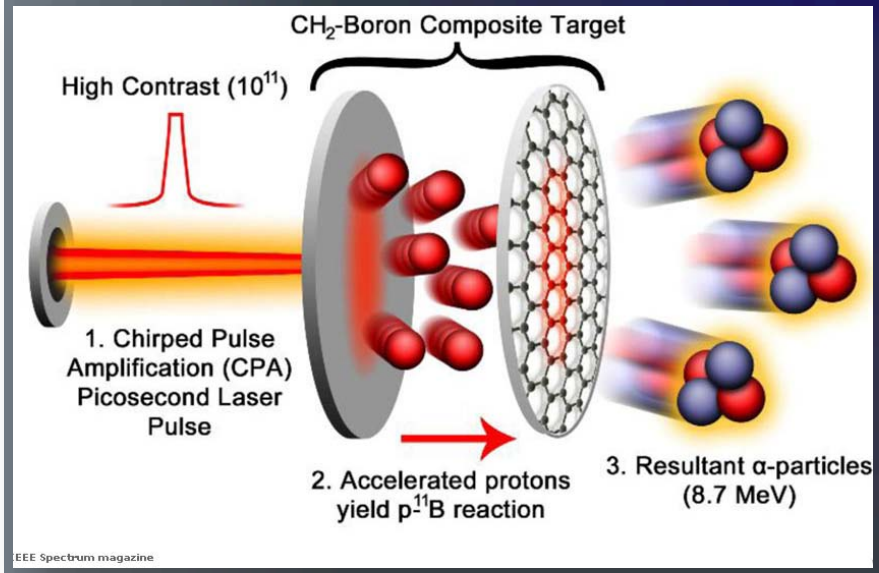


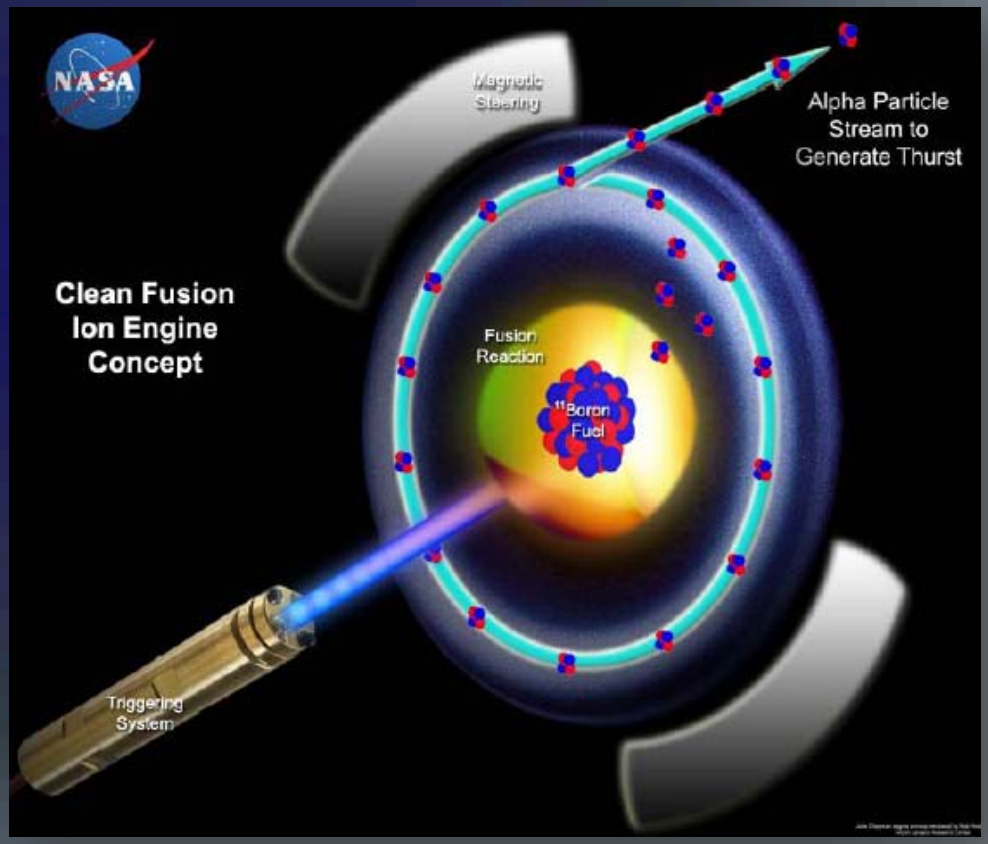
- Chemical rocket and air-breathing propulsion from 0 to Mach 7
- 2025 time period • LOX and LH2 propellants


1
NASA
1

Fusion in Space

Advanced Fusion Reactors for Space Propulsion and Power Systems
J. J. Chapman (2011), Engineering Division, NASA, Hampton, VA, United States



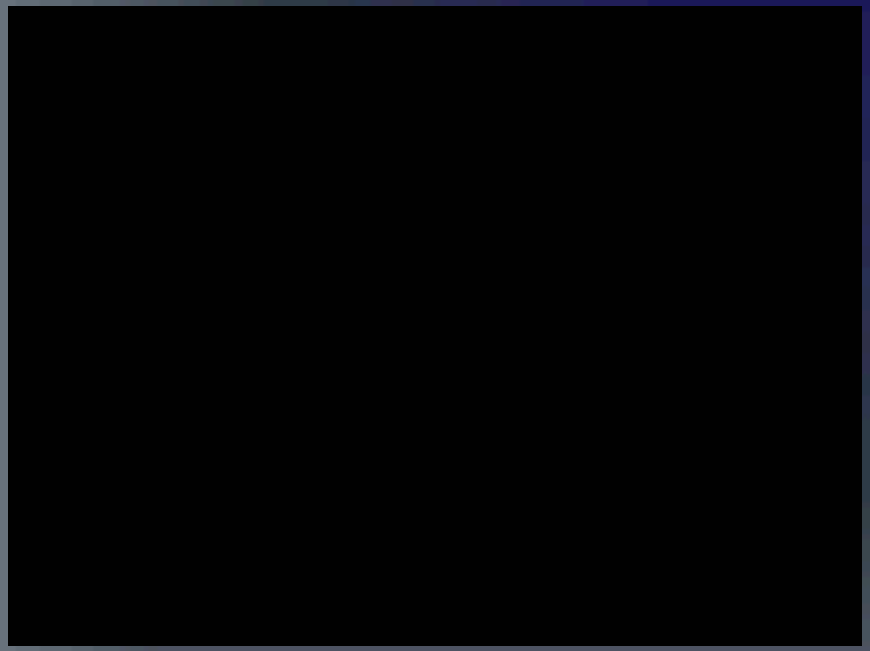


Tweet
@LPPX
#fuseMars

*not 'would' or 'must'!

Fusion for Peace

"make uranium enrichment obsolete, block proliferation everywhere, liberate the world from oil, and open up a new source of cheap, clean unlimited energy."



- **Iranian, Japanese, & US physicists propose working together on clean energy to defuse conflict**
- **Iran has 6 DPF research groups**
  - **Also IEC and tokamak**
- **Open to more countries**
- **FusionForPeace.org**

Tweet
@FusionForPeace
#fusePeace