Realizing the Benefits of Fusion Energy in Our Lifetime

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Why Are We Concerned About the Timetable for Demonstrating Benefits from Fusion Energy?

- Commercial electricity from fusion is now perceived as being 50 years or more away
- Developing the first fusion reactor is a 20$B+ program
- Keeping Americans' attention on a multi-billion, multi-decade project will be difficult

What Can We Do to Demonstrate Benefits from Fusing Plasmas on a Much Shorter Timeframe (≈5-10 years) and for Much Less Money (<<100 $M)?

In the Near Term (where Q<<1), What Does the Fusion Community Have to Sell That is Unique?

- **Portable Source of Neutrons**

  Non-proliferating technology,
  No fission products,
  Small source possible (few watts fusion power),
  Thermal to 14 MeV Energy

- **Portable Source of Protons**

  Up to 14 MeV Energy
  Little auxiliary radioactivity
  Competes with accelerators or cyclotrons

- **Portable Source of Electromagnetic Radiation**

There are Several Useful High Energy Particles from the Most Promising Fusion Reaction

	Particles Emitted/s per Watt of Fusion Power		
Reaction	*neutrons (MeV)*	*protons (MeV)*	*Helium atoms (MeV)*
DT	3.6×10^{11} (14.1)	--	3.6×10^{11} (3.52)
DD	8.6×10^{11} (2.45)	8.6×10^{11} (3.01)	--
D^3He (100 keV)	5.3×10^{10} (2.45)	3.4×10^{11} (14.7) 4.4×10^{10} (3.01)	3.4×10^{11} (^4He, 3.67) 5.3×10^{10} (^3He, 0.82)
$^3He^3He$	--	9.7×10^{11} (~5.7)	4.9×10^{11} (1.4)
$p^{11}B$	--	--	2.2×10^{12} (2.9)

Potential Non-Electric Commercial Opportunities Associated with the Long Range Development of Fusion Electrical Power

	Near Term	*Intermediate Term*
Medical	– Isotope Production – Cancer Therapy	
Civilian Commercial Market	– Positron Emitter Production – Proton Activation Analysis – Gemstone Enhancement – Neutron Radiography	– Production of Tritium – Neutron Irradiation Facility – Production of Hydrogen
Environmental	– Detection of Chemical Spills	– Destruction of Fission Products
Defense	– Detection of Explosives – Detection of Chemical Weapons	– Destruction of Pu & Actinides – Production of Tritium

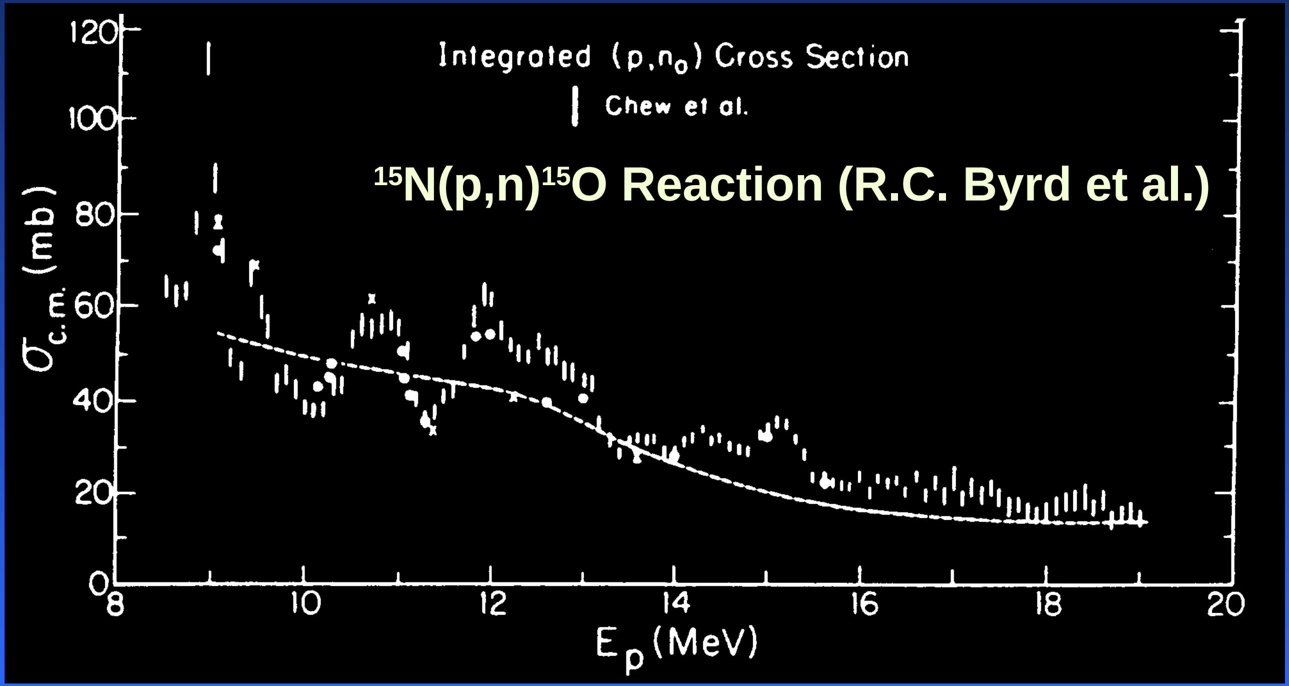
What Use Can Society Make of Small, Compact ($Q<1$) Fusion Neutron or Proton Sources?

Neutron Applications	•Detection of Clandestine Materials •Trace Elements	PET Isotopes- ^{18}F	Isotopes- ^{99}Mo	•Destruction of Fission Waste •Tritium Production
Proton Applications	PET Isotopes - ^{15}O, ^{11}C, ^{13}N	PET Isotopes- ^{18}F	Isotopes- ^{99m}Tc	•Destruction of Long Lived Radioisotopes
Fusion Power Level	1–10 Watts	10 – 1000 W	1 – 100 kW	10 – 1000 MW

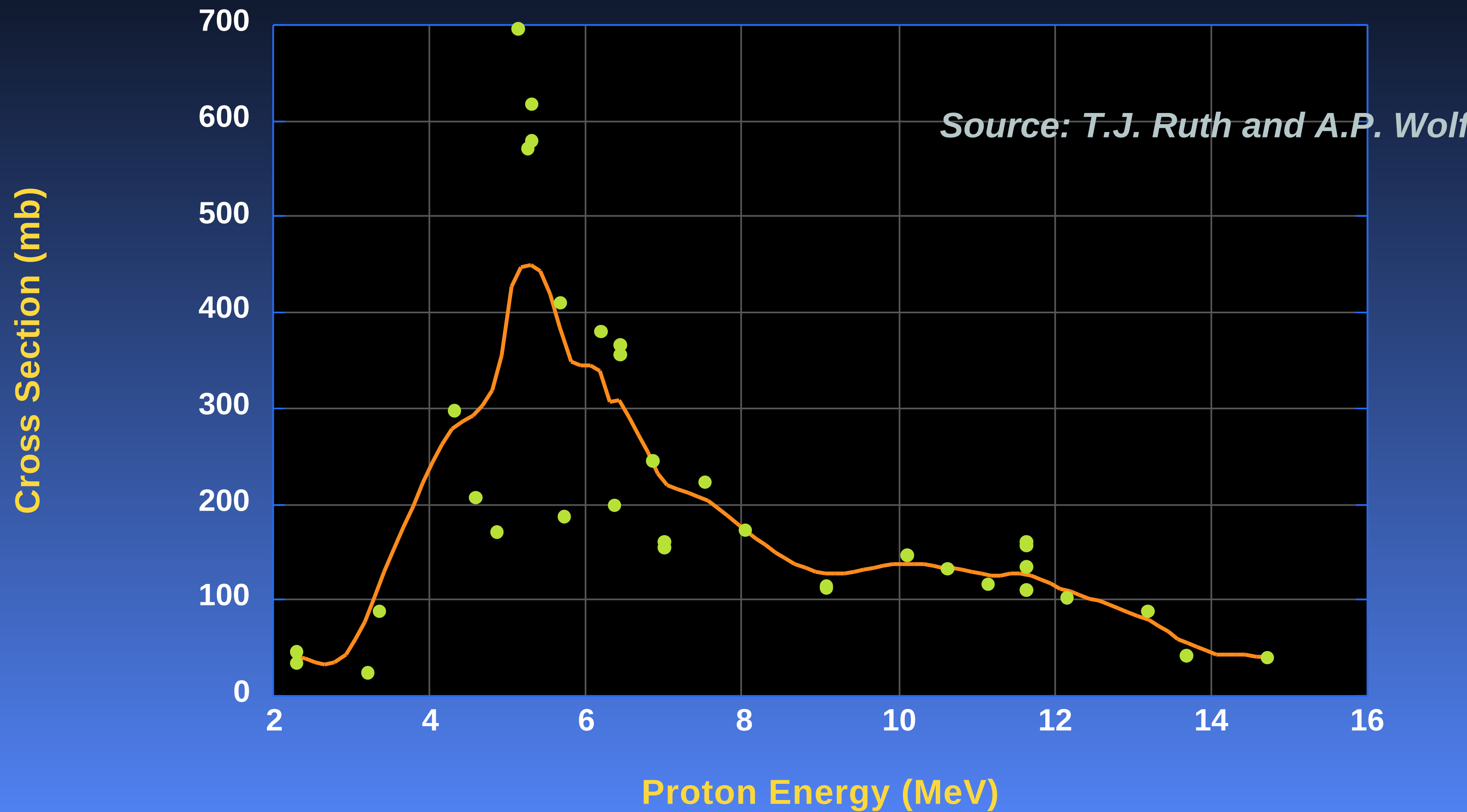
← *nearer term*

Small Mobile PET Generators Could Reduce Radiation Exposure to Patients

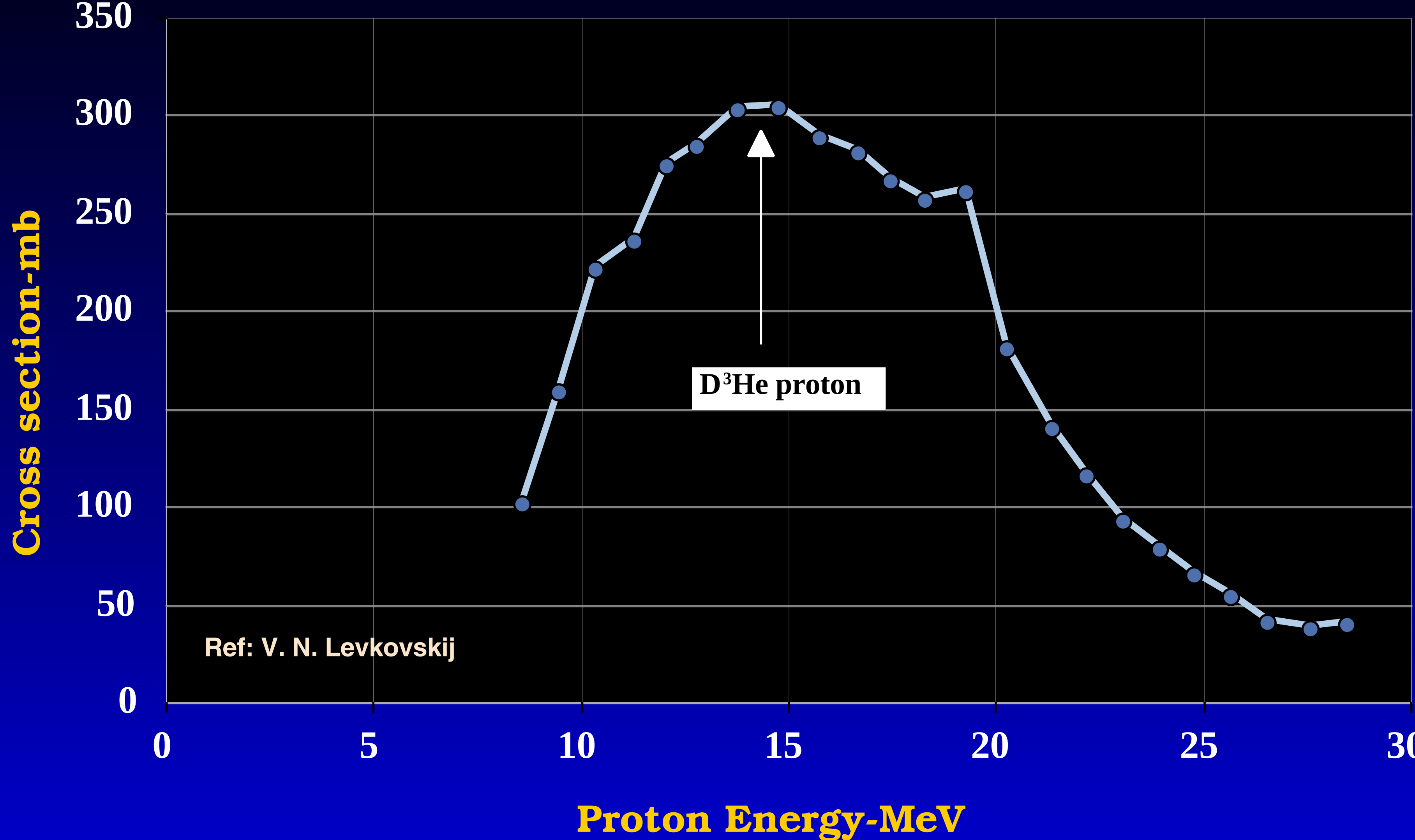
- Presently ^{18}F ($t_{1/2}$ = 1.83 h) is used extensively for brain scans
- Current regulations preclude the repeated use of ^{18}F on young children and pregnant women
- An ideal PET isotope would be ^{15}O ($t_{1/2}$ = 2.03 min)
- 1 Watt of D^3He fusion could produce ≈8 mCi of ^{15}O (steady state)



The $^{18}O(p,n)^{18}F$ Cross Section Peaks Between 5–6 MeV



The $^{100}Mo(p,2n)^{99m}Tc$ Cross Section Peaks at the Energy of the D^3He Proton

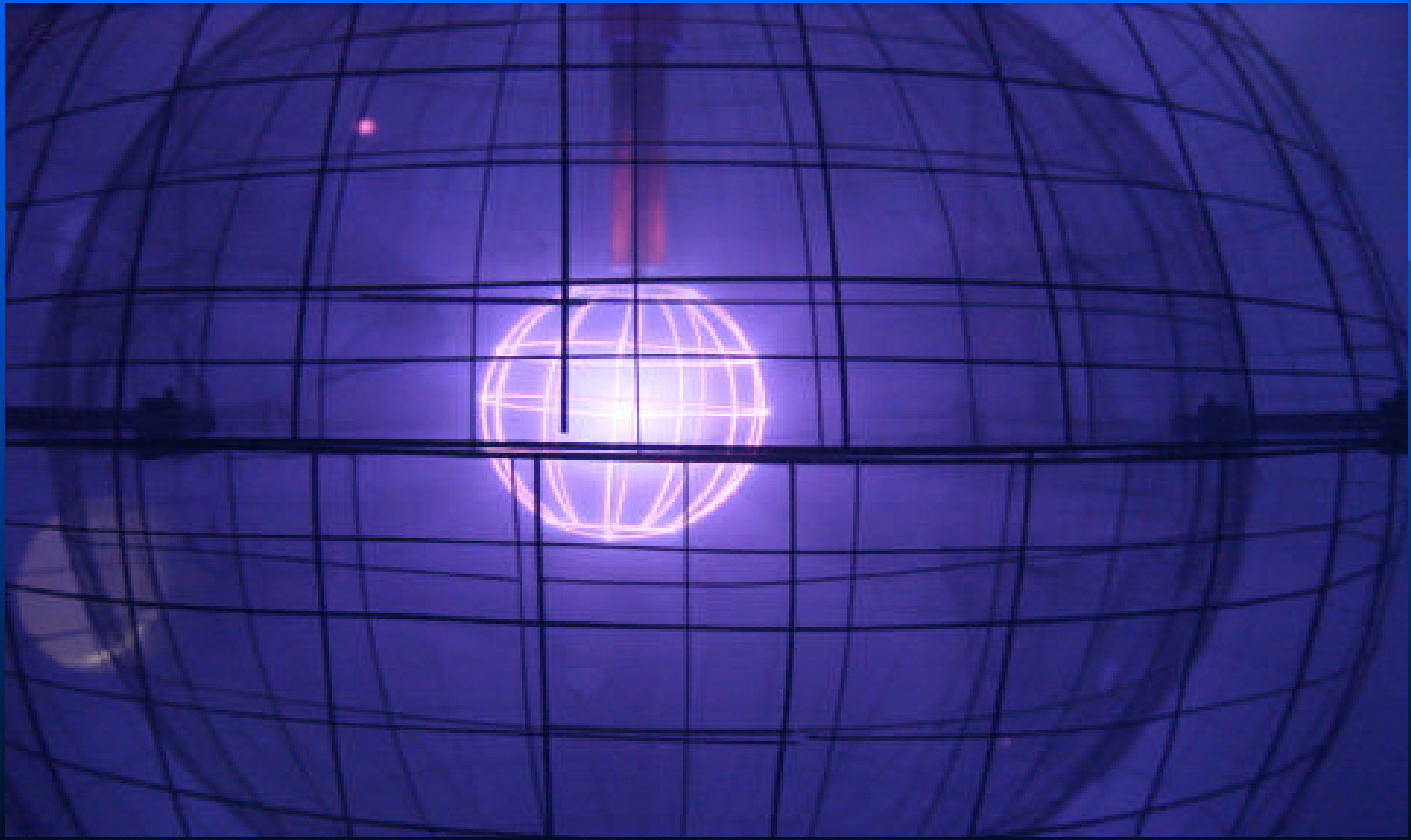


Record Steady State D-^{3}He Reaction Rate Achieved in Wisconsin IEC Device

1.5×10^5 protons/s (14.7 MeV)

Record Steady State D-D Reaction Rate Achieved in Wisconsin IEC Device

$2.2x10^7$ neutrons/s (2.45 MeV)



Radioisotopes Particularly Suited For Production With Protons From D-^{3}He Fusion

Isotope	$t_{1/2}$	Parent Isotope	Maximum Steady State Production at Equilibrium (mCi/watt D-^{3}He)	Useful Dose (mCi)
^{15}O	2.03 m	^{15}N	8	~ 1
^{18}F	1.83 h	^{18}O	14	1 – 10
^{99m}Tc	6.01 h	^{100}Mo	4	1 – 25

Conclusions

- The U.S. fusion program could have a positive near term impact on the production of very short half life PET isotopes for applications in hospitals.

- Research into advanced fuel, very low Q fusion devices, is relatively inexpensive and could contribute to our understanding of the long-range potential of the "second generation" fusion fuels.