Yorktown Clean Energy Center

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BSCE Systems, Inc.
Yorktown, Virginia, USA

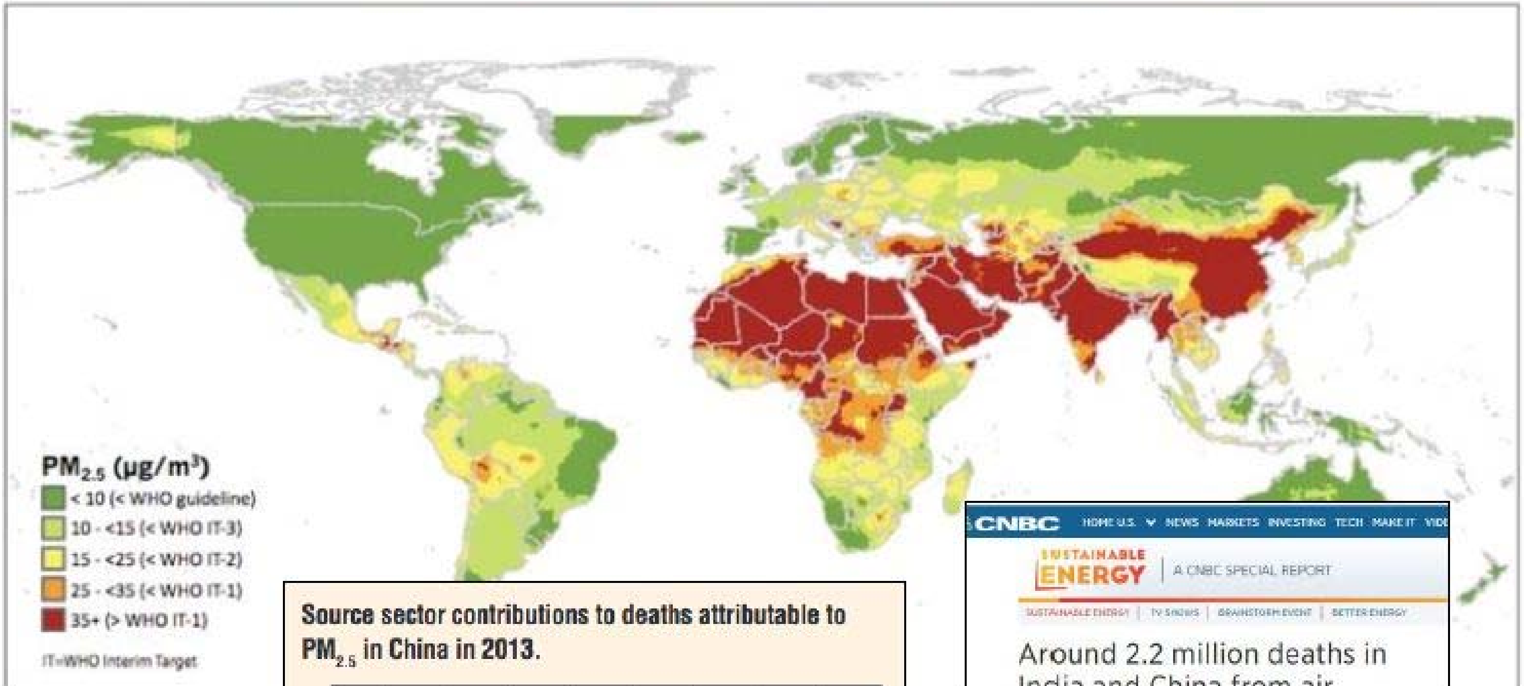
October 1, 2019
TEAC 10, Oak Ridge, USA

Overview

- Clean air & water - sustainable clean energy
- Critical & subcritical NE technologies
- Accelerator driven subcritical systems (ADS)
- Electron linacs for ADS
- Summary

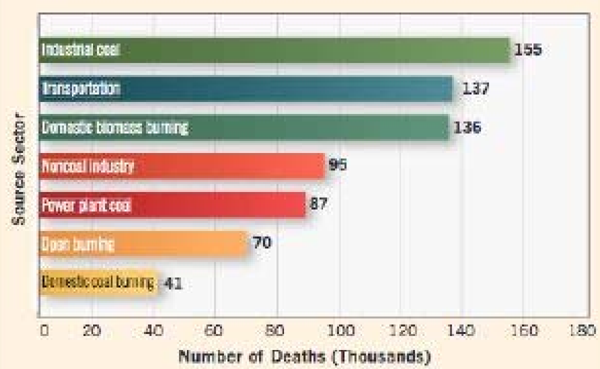
Driver for Nuclear in Asia: Deadly PM 2.5 Pollution

Comparison of annual average $PM_{2.5}$ concentrations in 2015 with WHO Air Quality Guidelines.



www.meo.life/state-of-global-air-2017/

Source sector contributions to deaths attributable to $PM_{2.5}$ in China in 2013.

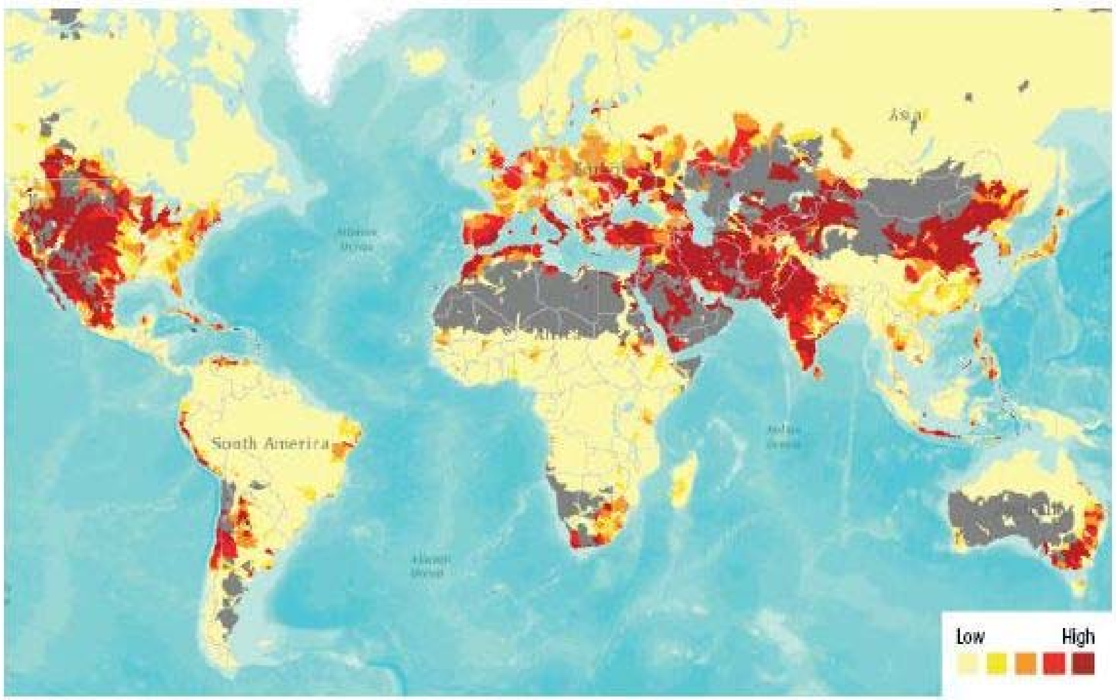


Andrew Paterson

WRI: Global Water Stress – and National Security

WRI: Water stress is not just a Developing World problem. Western USA.
WHO: Impact of urbanization -- "By 2025, half of the world's population will be living in water-stressed areas." Could Nuclear boost fresh water supply?

Projected Water Stress in 2030



Business as usual scenario
aqueduct.wri.org

AQUEDUCT™ WORLD RESOURCES INSTITUTE

Battle for Nile River Resources

200m people affected

6.5 GW
Renaissance Dam [Ethiopia]

WRI (2017) www.wri.org/blog/2017/02/what-does-water-have-do-national-security

Andrew Paterson

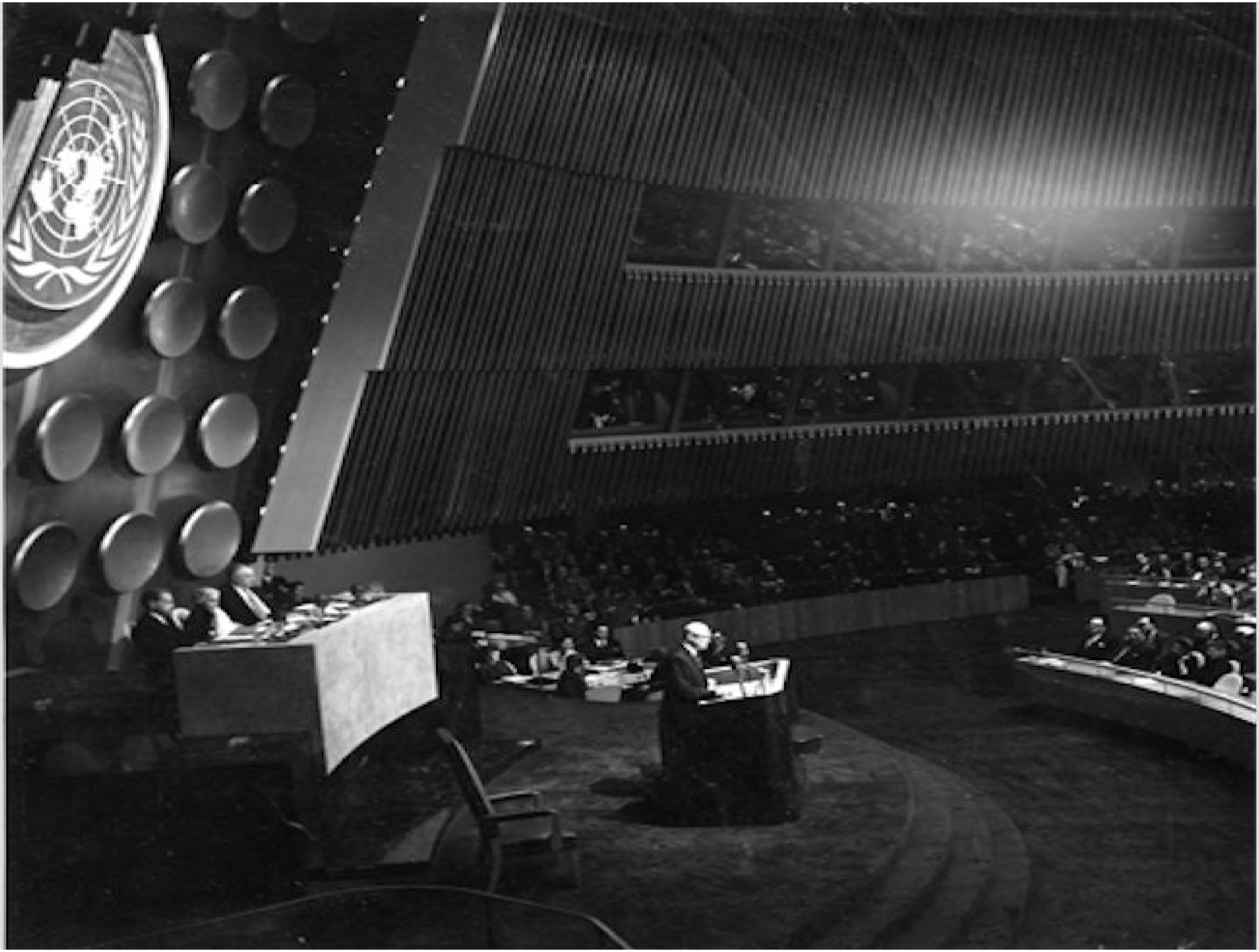
Critical Subcritical Nuclear Energy Technologies

Nuclear technology began with the development of nuclear weapons in the 1940s based on an uncontrolled and growing chain reaction with neutron multiplication greater than one ($k>1$).

Nuclear technology advanced into electricity production in the 1960s with the introduction of today's light water reactors (LWRs) operating in chain reaction mode with controlled neutron multiplication equal to one ($k=1$).

LWR technology supplies 20 % of the world's electricity and dominates in worldwide nuclear power production. However maintaining the neutron equilibrium in an LWR requires several design features that introduce safety issues that have given rise to capital costs for new nuclear reactors that have priced them out of business in the U. S.

Sub-critical technology ($K<1$)

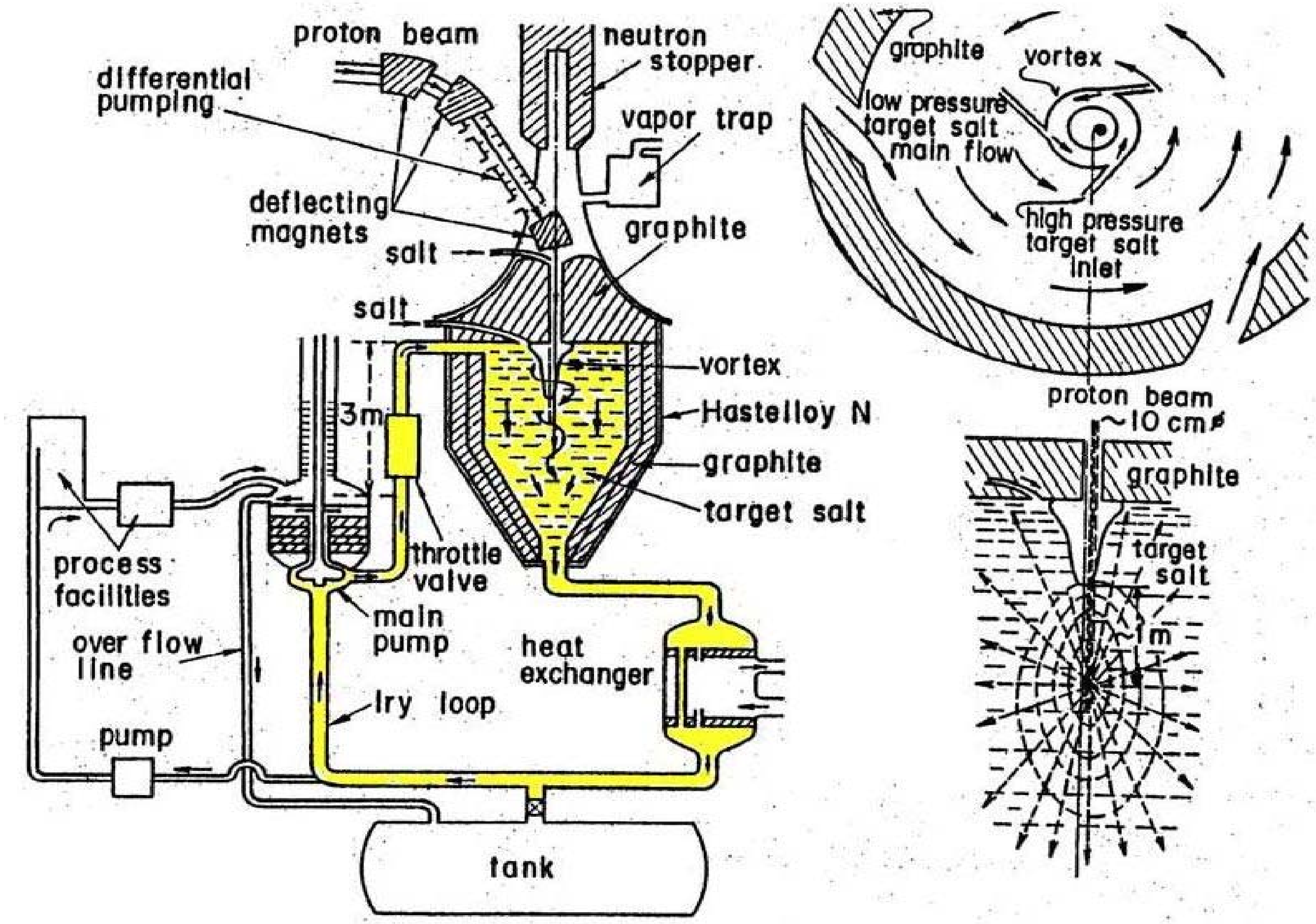



PRÉSIDENT

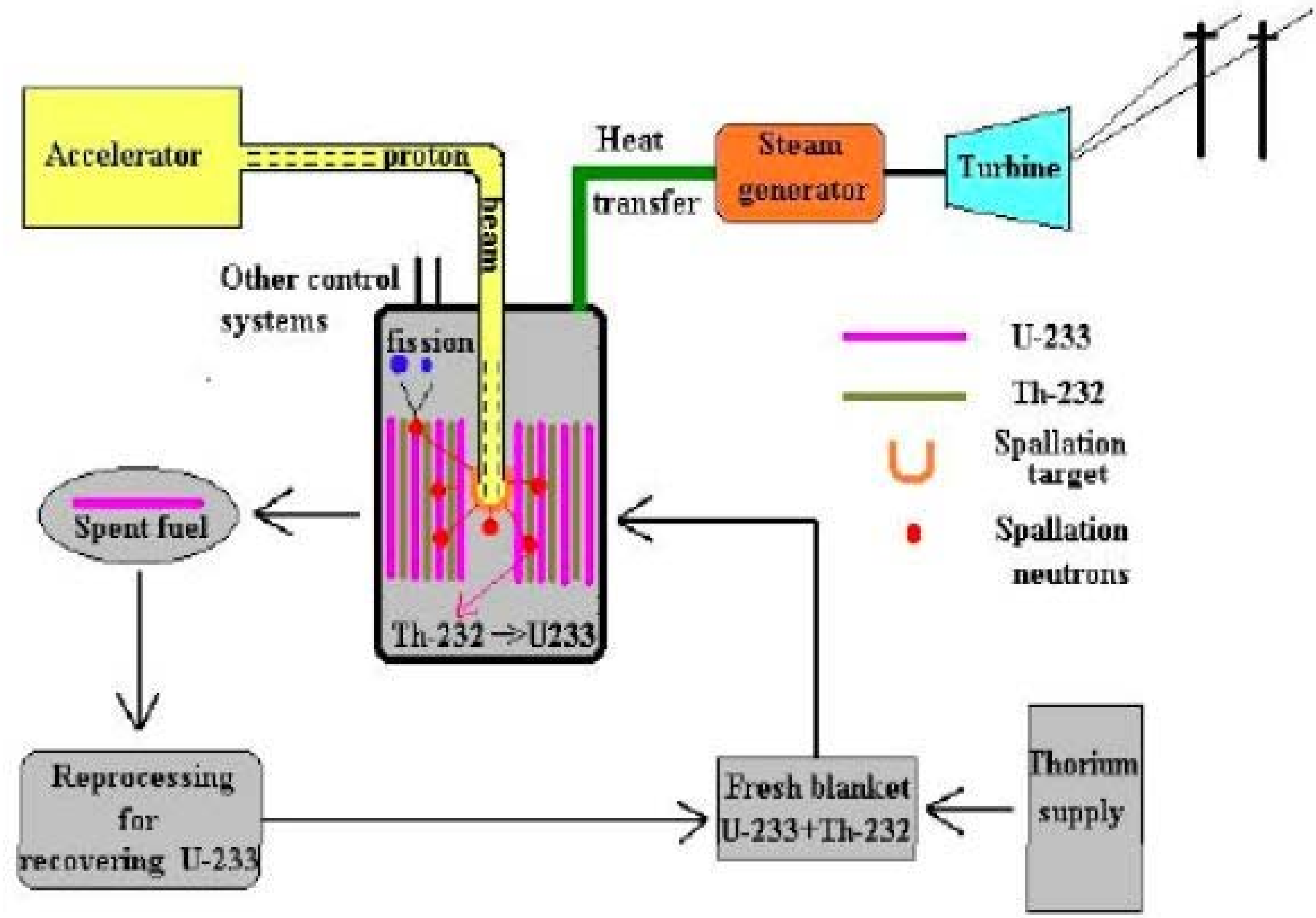
Accelerators & fissile materials

- 1950 – U. E. O. Lawrence, high power accelerators for producing fissile materials
  - Accelerator Molten-Salt Breeders, Kazuo Furukawa et al, Energy Conversion and Management 49 (2008) 1832-1848
- 1952 – W. B. Lewis, proposed use of thorium with intense neutron generators
  - India's ADS Program with proton linac
  - BSCE Systems, Inc. sub-critical micro-reactors with high power electron linacs

K. Furukawa's AMSB



India's Thorium utilization scheme



Dr. S. Banerjee, University of Virginia Presentation,
May 2010

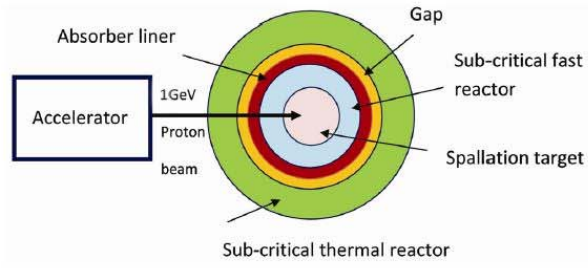


Figure 15. One-way coupled accelerator driven sub-critical system.

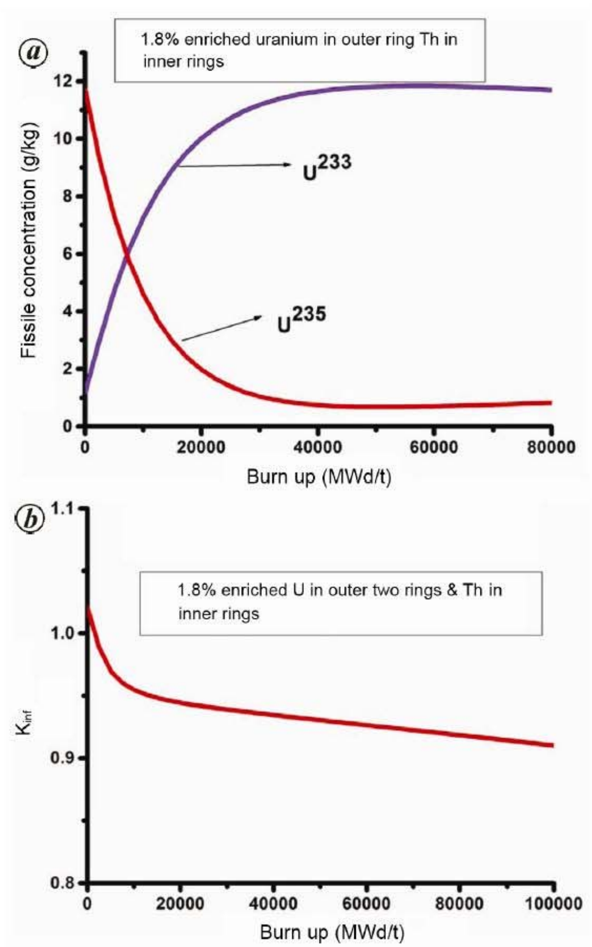


Figure 16. *a*, variation of fissile concentration with burn-up; *b*, Variation of k_∞ with burn-up.

Natural uranium or slightly enriched (1.6%) is the
Start up fuel for each plant and U^{233} will be bread
and used for for ever closing the fuel cycle

Electricity costs will be reduced considerably

Dr. Srikumar Banerjee et al

CURRENT SCIENCE, VOL. 111, NO. 10, 25 NOVEMBER 2016

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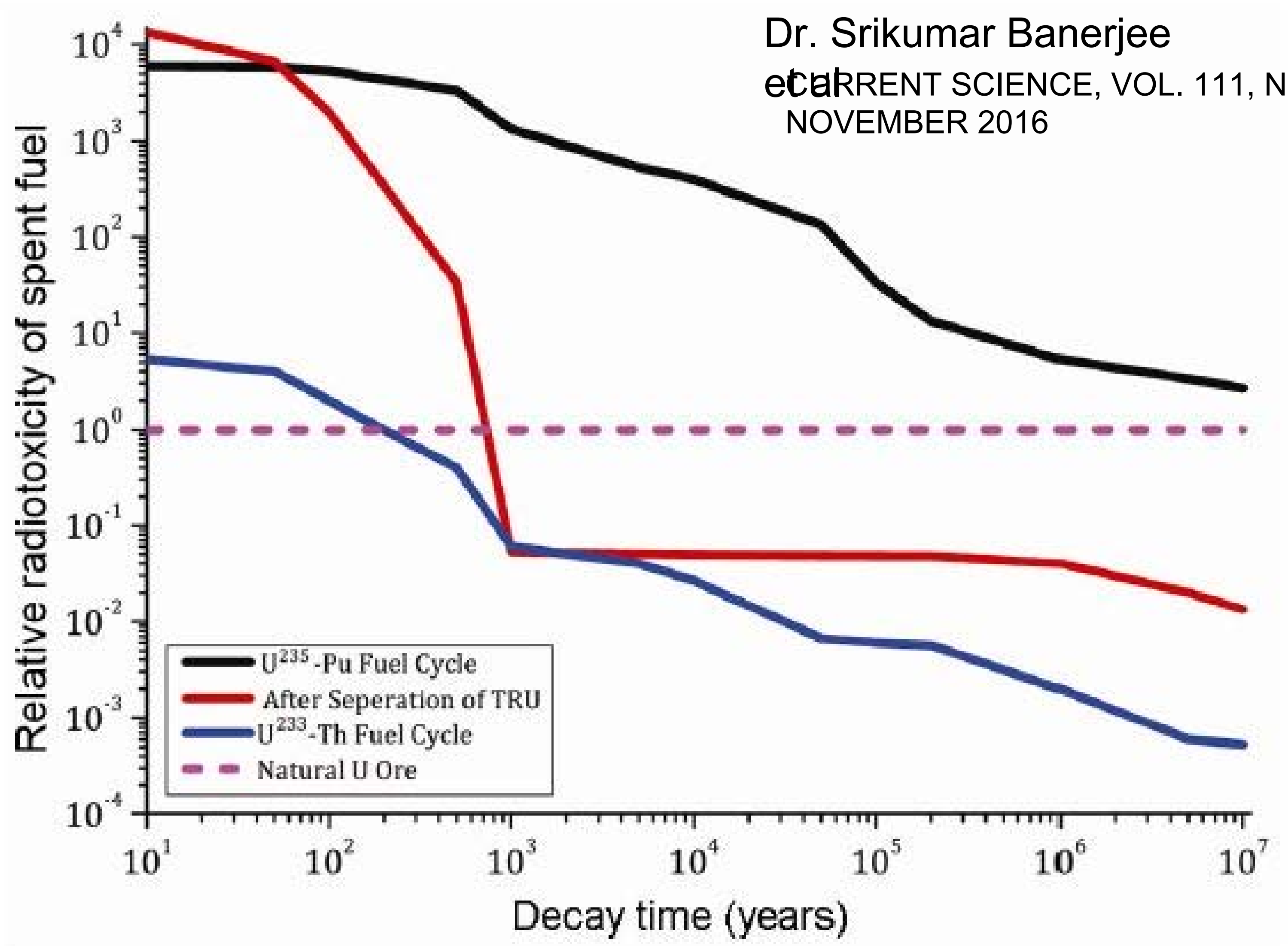
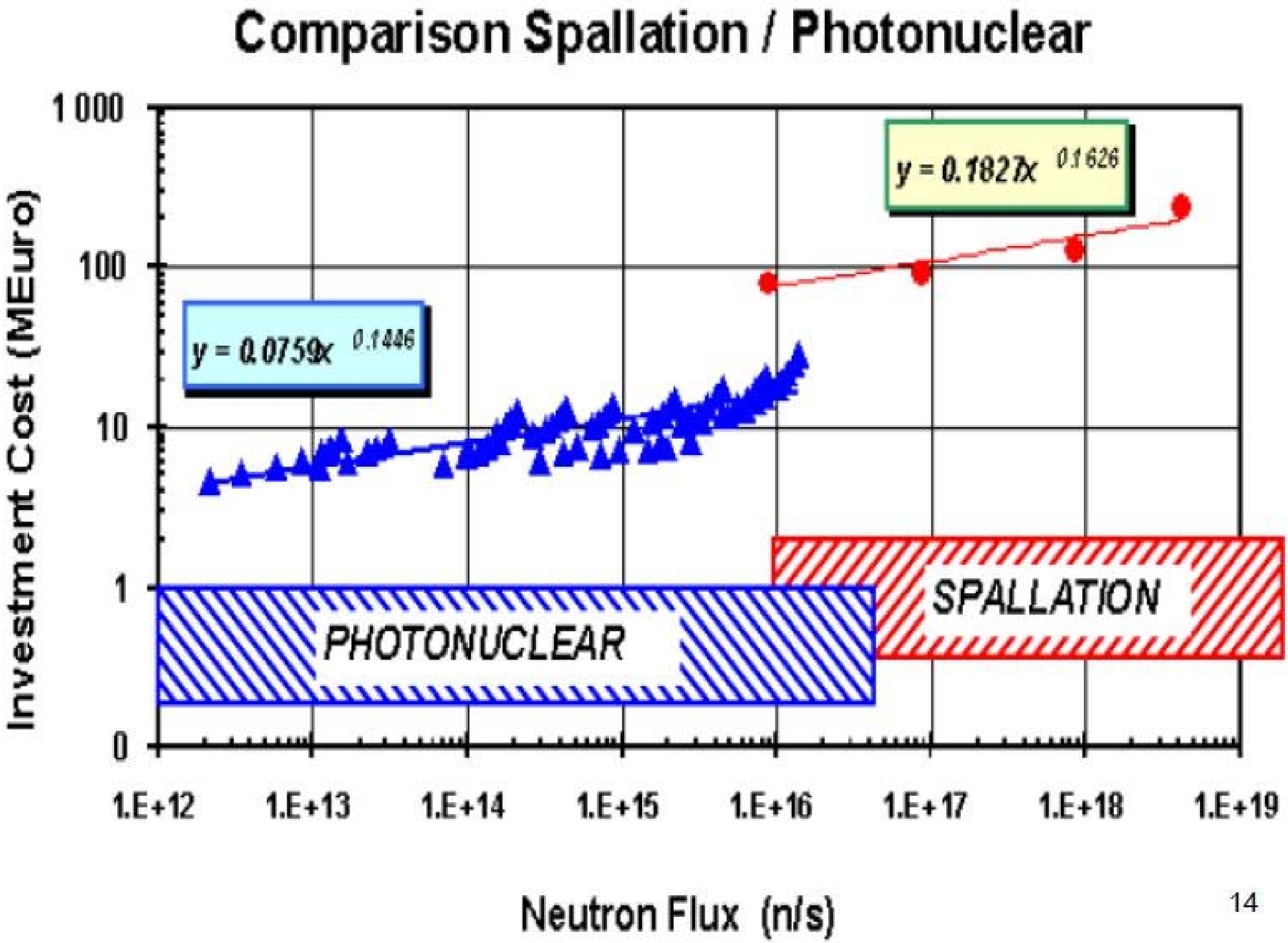


Figure 3. Relative radiotoxicity of nuclear waste in different fuel cycles as function of time.

S


Comparison Spallation / Photonuclear
Investment Cost (MEuro)
1 000
100
10
1
0
y = 0.1827x 0.1626
y = 0.0759x 0.1446
SPALLATION
PHOTONUCLEAR
1.E+12
1.E+13
1.E+14
1.E+15
1.E+16
1.E+17
1.E+18
1.E+19
Neutron Flux (n/s)

Neutron yield comparison of 10 MeV vs 100 MeV electron beam of equal power

S. N0	Neutron Yield n/s in 4π solid angle for 1 Ampere x 10^{15}						Neutron Yield n/s (x10^{15}) at 100 MeV for W/Ta for Equal Beam Power
		Be	D_2O	LiD	CD_4 (liquid) /BeD_2	W/Ta	
1	8 MeV	2.1	4.4	7.5	11.5	-	-
2	10MeV	5.5	9.3	12.5	15.0	1	20
3	15MeV	10.2	14.0	22.3	34.3	3.5	30
4	20MeV	14.9	20.0	28.6	44.8	20	40

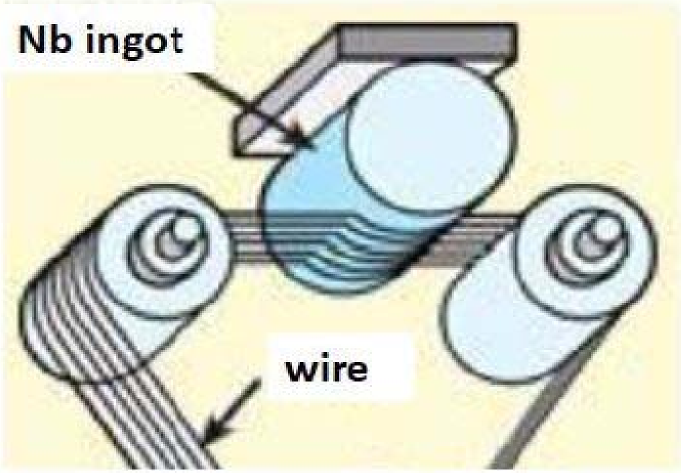
To be presented at 5th ADS&Thu Workshop Mol, Belgium, Nov 6-8, 2019, Mittal & Myneni

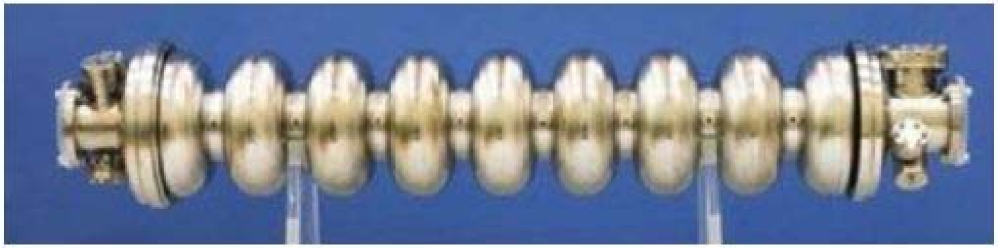
A-1. Niobium material preparation (with new processing for sheeting and piping)

Motivation

- Niobium material cost for fabricating SRF cavity cell and end-groups is relatively high.
- If we can accept lower residual resistivity ratio (RRR) material, the ingot cost becomes cheaper.
- We will try to simplify the manufacturing process (like direct slicing from the ingot).

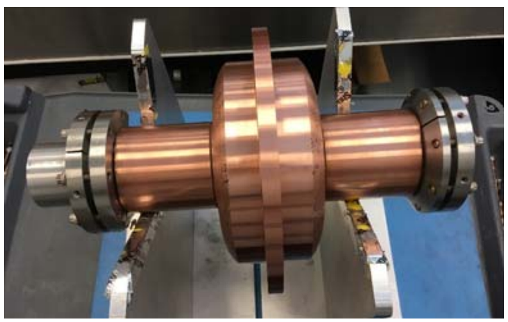
Niobium ingot



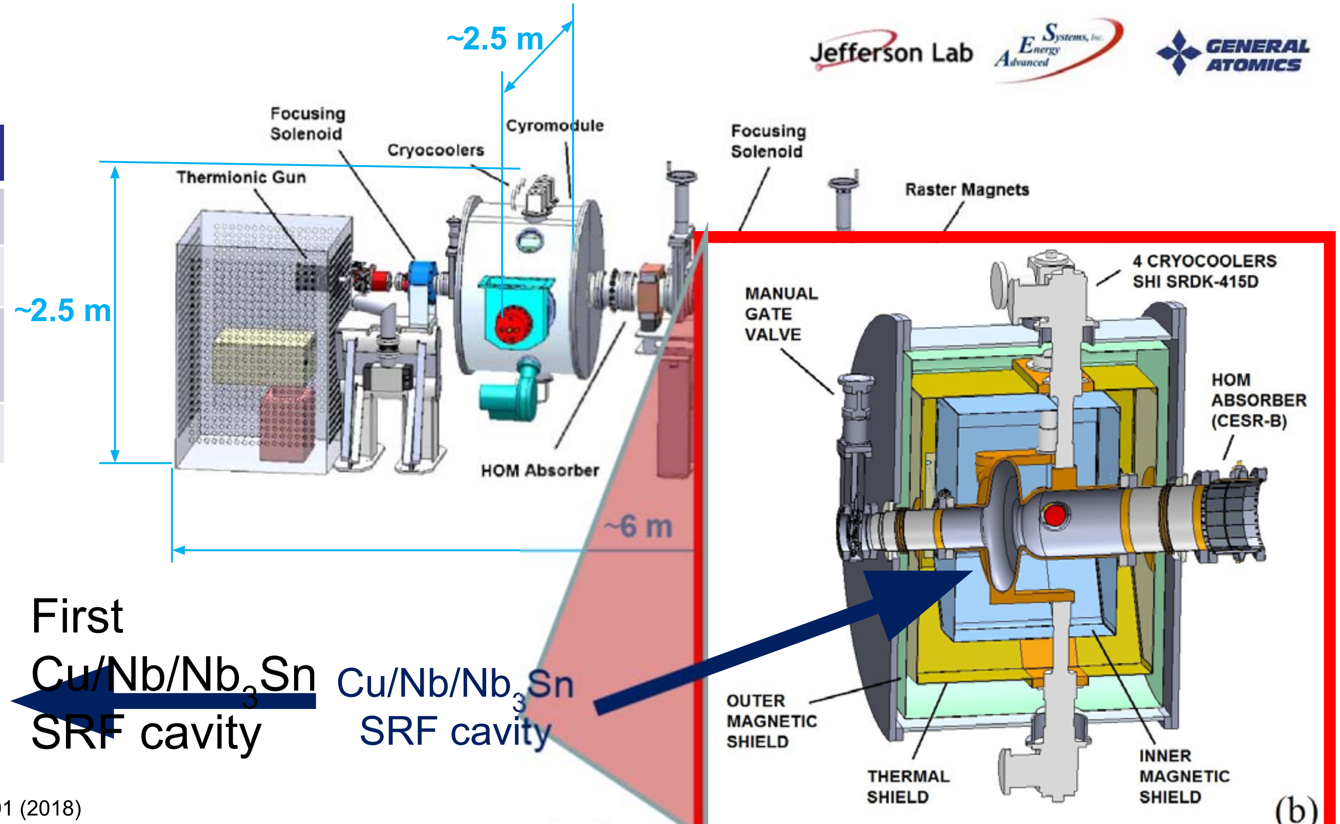


Design of a compact, low-cost SRF LINAC for Environmental Remediation

Beam current (mA)	**1000**
Final energy (MeV)	1
Beam power (kW)	1000
Fundamental RF (MHz)	750
Source energy (keV)	100



First $Cu/Nb/Nb_3Sn$ SRF cavity



G. Ciovati et al., Phys. Rev. Accel. Beams **21**, 091601 (2018)
G. Ciovati et al., "A multi-layered SRF cavity for conduction cooling applications", Proc. SRF'19, TUP050, Dresden, Germany, July 2019

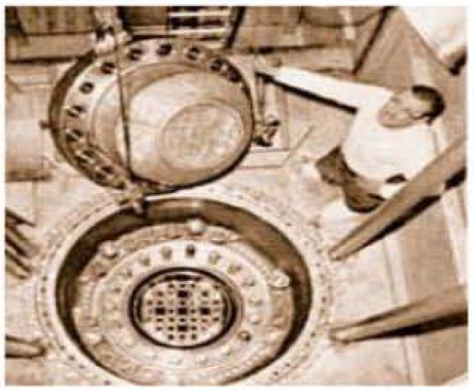
Specifications of the one way coupled sub-critical micro-reactors

- CW Electron Linac
  - Energy 10 -15 MeV
  - Current 1 to 3 A
  - Frequency 915 MHz
  - Thermionic gun
  - Operating temperature 4.25 K
  - Forged ingot Nb cavity with Nb3Sn inner surface

- Sub-critical Core
  - Molten salt burner/breeder
  - Breed and burn in equilibrium
  - Thorium in the central breeding zone
  - Natural or slightly enriched uranium in the outer zone

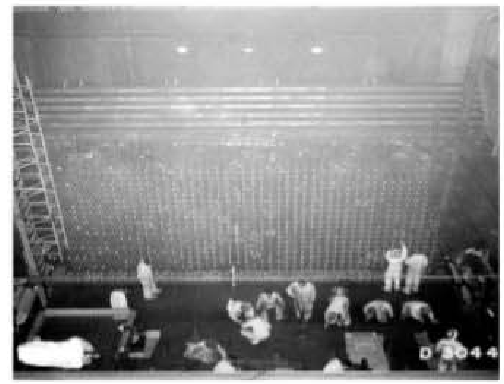
- Applications
  - High temperature heat sources
  - Medical isotope generators in parallel
  - Water desalination plants
  - Back up to renewable energy sources close to cities and townships

A Prototype Power Plant Can be Built Quickly



Camp Century
2 MWe
Greenland glacier
American Locomotive
factory modules
1959 +2 years

Nautilus
10 MWe
First ever PWR
Electric Boat
full scale prototype
1949 + 4+2 years



Hanford
250 MWt
Pu production
Dupont, GE
1942 + 2 years

International Symposium On Hydrogen In Matter (ISOHIM) Publications

Hydrogen in Materials and Vacuum Systems AIP CP 671

http://www.virtualjournals.org/dbt/dbt.jsp?KEY=APCPCS&Volume=671&Issue=1

Hydrogen in Matter AIP CP 837

http://www.virtualjournals.org/dbt/dbt.jsp?KEY=APCPCS&Volume=837&Issue=1

Single Crystal Large Grain Niobium AIP CP 927

http://www.virtualjournals.org/dbt/dbt.jsp?KEY=APCPCS&Volume=927&Issue=1

Superconducting Science and Technology of Ingot Niobium AIP CP 1352

http://scitation.aip.org/dbt/dbt.jsp?KEY=APCPCS&Volume=1352&Issue=1

Science and Technology of Ingot Niobium For Superconducting Radio Frequency Applications AIP CP 1687

https://aip.scitation.org/toc/apc/1687/1?expanded=1687

ADS&ThU International Workshops

1st International ADS&ThU Workshop 2010, USA

•http://www.phys.vt.edu/~kimballton/gem-star/workshop/index.shtml

2nd International ADS&ThU Workshop 2011, India

•http://www.ivsnet.org/ADS/ADS2011/

3rd International ADS&ThU Workshop, 2014, USA

• http://adsthu.org/index.html

4th International ADS&ThU Workshop 2016, UK

• https://indico.cern.ch/event/509528/contributions/

5th International ADS&ThU Workshop 2019, Belgium

•https://events.sckcen.be/event_website_pages/view/5c87a995-edd4-4c2e-9c19-041f0a340409/5c87a990-a15c-4fa4-946c-041f0a340409/9f207fff04

6th International ADS&ThU Workshop, July 2021

Yorktown, Virginia, USA

Summary

Let us Walk the
Talk

Declining Coal - Enthroning Nuclear - Fizzling out Gas -
Enabling Renewables – Pathway to Zero Carbon

We propose to build a one way coupled subcritical micro-reactor under a PPP
In Yorktown, Virginia in collaboration with Indian Partners while a similar
micro-reactor could be also built in parallel at Visakhapatnam BARC