

Virginia Nuclear Energy Frontier Research Center

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**Virginia Nuclear Energy Consortium Authority
International Symposium On Hydrogen In Matter
Jefferson Lab**

ThEC2013, CERN

Oct 27-Nov 1, '13 Geneva

Outline

**Virginia Nuclear Energy Consortium
Authority**

**Nuclear Energy Frontier Research
Center**

Nuclear Medical Isotope Developments

Summary

Virginia Nuclear Energy Consortium Authority

- Established during the 2013 Virginia General Assembly Session → **Effective July 2013**
- Paved a way for the creation of a non profit **Virginia Nuclear Energy Consortium (VNEC)** → **January 2014**
- The VNEC consortium will foster strategic partnerships to expand the nuclear energy business sector in Virginia.
- Jobs in the nuclear energy industry are high paying jobs that require strong STEM-H education, and unique training and skills.
- Nuclear energy is an important source of safe, reliable base load electricity. Nuclear power is a zero emissions energy resource.
- Virginia is one of only 2 or 3 states that is home to a large number and broad variety of businesses and institutions involved in nuclear energy related activities.

Stakeholders of VNECA

- AREVA
- Babcock & Wilcox
- Bechtel
- Center for Advanced Engineering & Research
- College of William and Mary
- Dominion Virginia Power
- George Mason University
- Huntington Ingalls (Newport News Shipbuilding)
- International Symposium on Hydrogen In Matter (ISOHIM)
- James Madison University
- Thomas Jefferson National Accelerator Facility
- Liberty University
- Longwood University
- Mitsubishi Nuclear Energy Systems (MNES)
- Nuclear Energy Institute (NEI)
- Old Dominion University
- Sweet Briar College
- University of Virginia
- URENCO
- American Nuclear Society and its Virginia affiliate
- VCCS
- Virginia Commonwealth University
- Virginia Military Institute
- Virginia Tech

The goals of the VNEC

- **To bring all of Virginia's nuclear industry players together around a single table to identify opportunities and develop strategies for supporting and expanding the nuclear industry in Virginia, across the country and around the globe.**
- **To maximize the return on Virginia's investment in nuclear energy higher education and research initiatives by facilitating partnerships and collaborative programs between and among Virginia higher education and the private sector for nuclear energy related research.**
- **To assist and support successful applications for federal grants.**

Our Vision

- Creation of a “**Science & Technology Center (STC) for the Application of High-Power Accelerators for the Advancement of Innovative Multidisciplinary Science**” → **Virginia Nuclear Energy Frontier Research Center (VNEFRC)**
- This center would foster:
 - Integration of education and training in all aspects relevant to the Application of High-Power Accelerators for the Advancement of Innovative Multidisciplinary Science. The need to educate a new generation of highly qualified professionals in the areas of science and technology covered by the STC has been identified in several recent studies
 - Leading edge research to explore materials and cavity design to push current linac limits, in order to achieve the technical and cost requirements needed for these practical applications.
 - Integrated target analysis to speed up the development of targets for specific medical isotopes, waste processing and power generation applications.
 - Evaluation of the chemical processing infrastructure required to take advantage of the output of ADS systems for new medical isotopes and other applications

Virginia NE Frontier Center Institutions

The VNEC includes members from outside Virginia

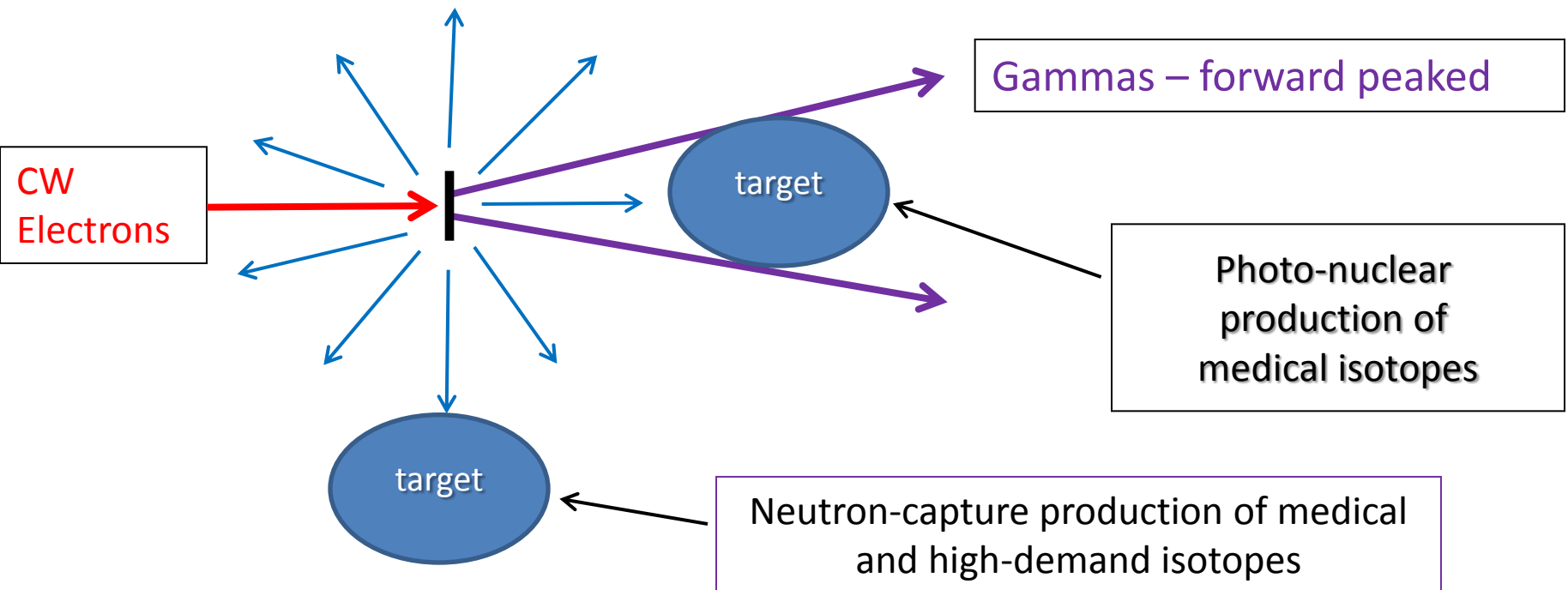
- **Casting Analysis Corp.**
- **International Symposium On Hydrogen In Matter (ISOHIM)**
- **Jefferson Lab**
- **Muons, Inc.**
- **Longwood University**
- **Oak Ridge National Laboratory**
- **Old Dominion University**
- **South Dakota School of Mines and Technology**
- **University of Virginia**
- **Virginia Commonwealth University**
- **Virginia Tech**

Immediate Focus

- Nuclear Medical Isotope Developments
 - **Entry-vehicle technology to show early success**
 - **High need for affordable and plentiful medical isotopes for use as medical imaging agents and for cancer treatment.**
 - **More Positive public perception than other ADS applications**

Neutron/gamma source for isotope developments

Neutrons – emitted in all directions: approximately isotropically



A 100 kW, 100 MeV electron linac is capable of producing 100% of the U.S. demand for many high-priority research isotopes for medical, industrial and other kinds of research. Such a device could also produce nearly 10% of the entire U.S. demand for ^{99}Mo .

Multi cell cavity fabrication

Forming



Machining



Welding

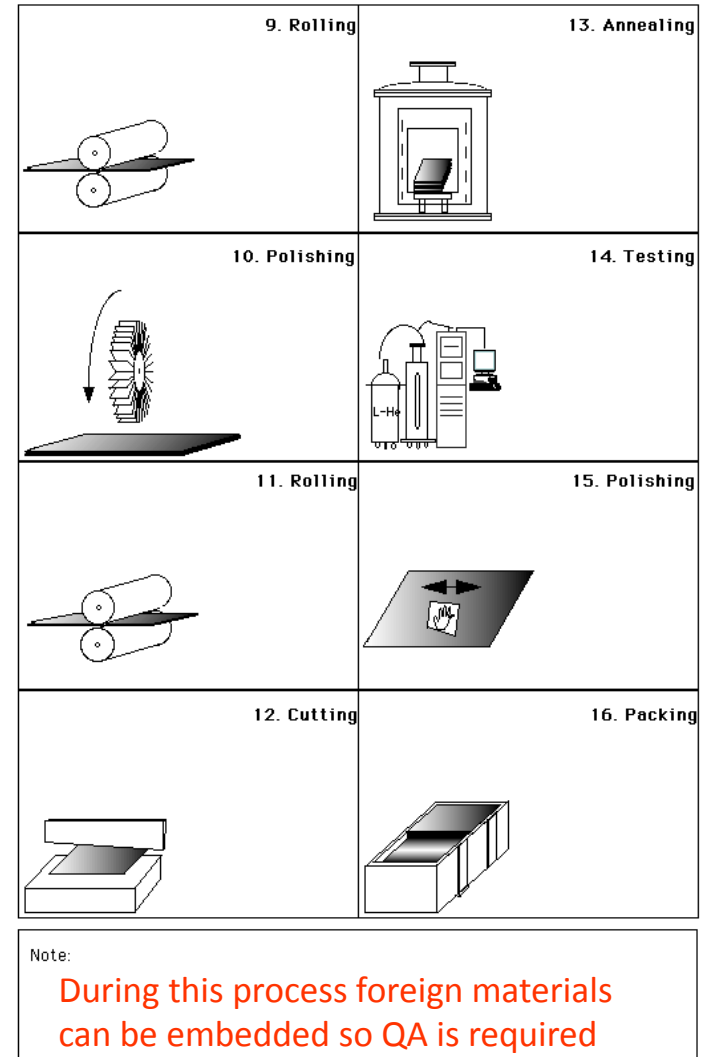
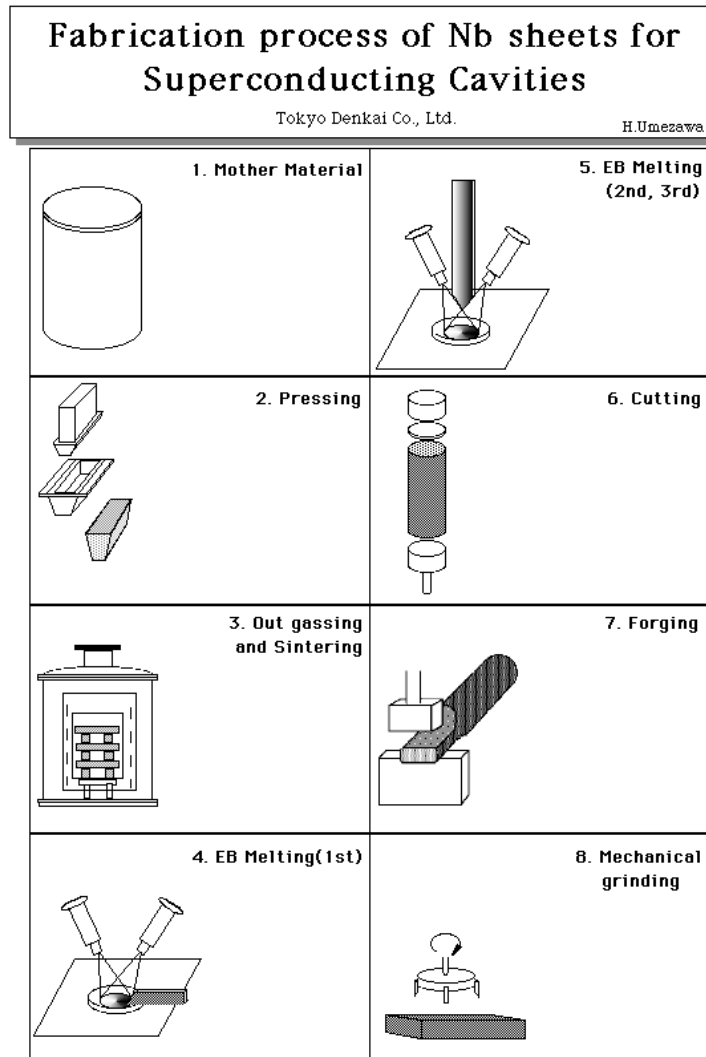


Tuning



**~90% of CEBAF cavities were made with CBMM Pyrochlore ore based niobium
In comparison to present day use of Tantalite/Columbite ore based niobium**

Process steps - fine grain Niobium



Araxá Mine in Brazil & Ingot Niobium

From ore to oxide to large grain ingots

The CBMM open cast mine



Conveyor belt bringing the ore to concentration plant


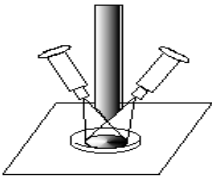
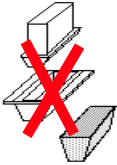
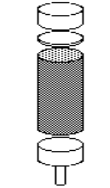
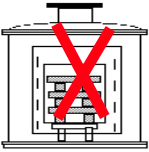
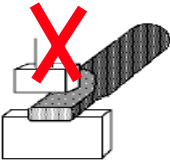
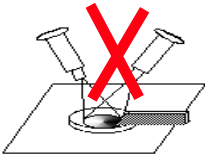
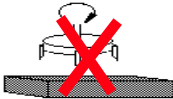


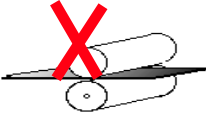
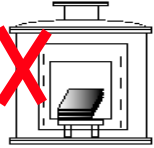
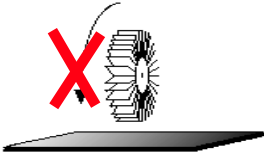
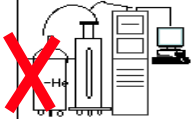
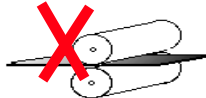

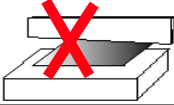
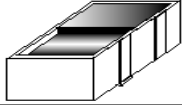
Electron beam furnace for the refinement of Niobium metal, producing 210 tonnes per annum

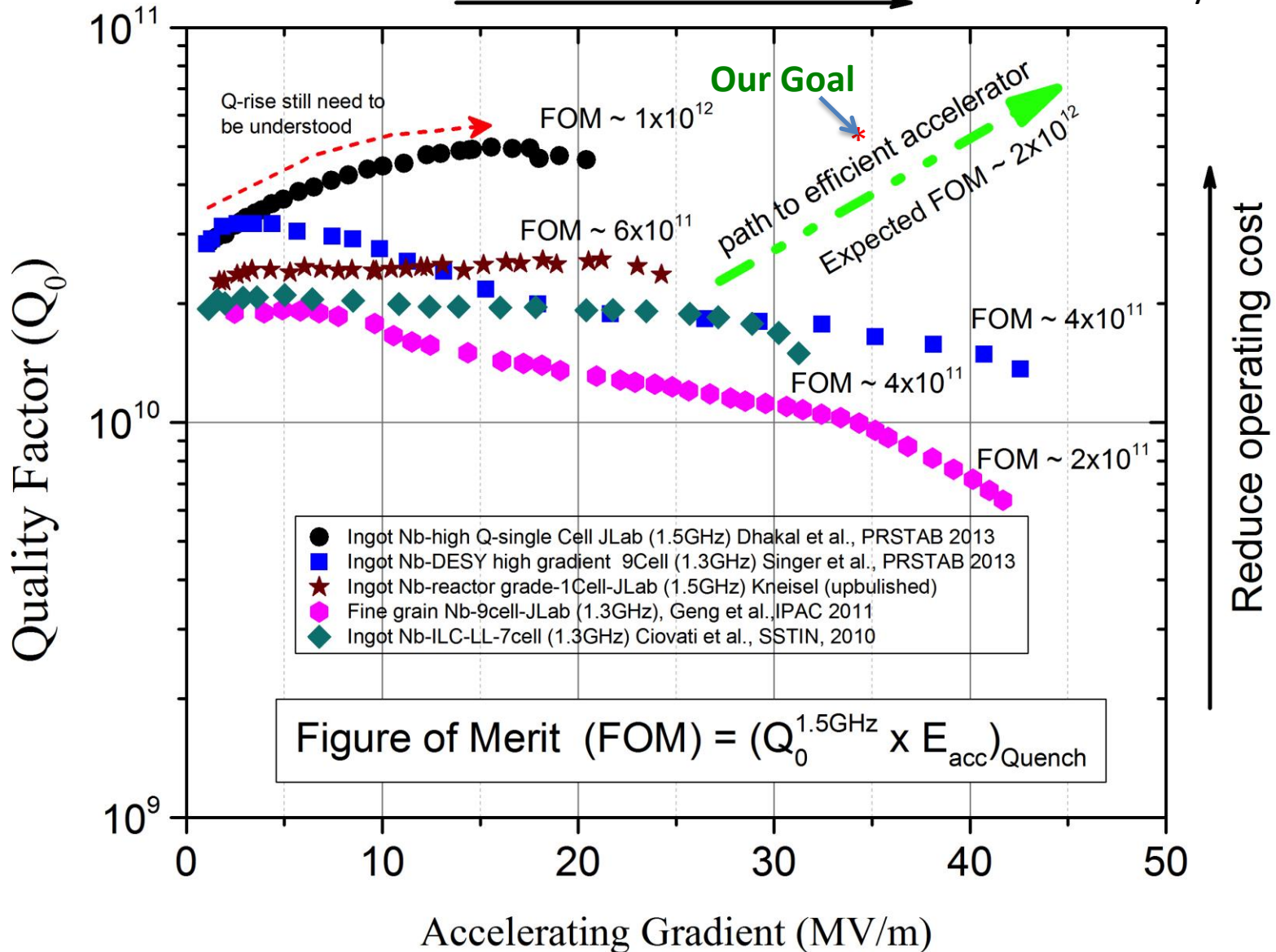


Finished RRR Nb ingot from the Pyrochlore ore

Economic path for CW applications

Fabrication process of Nb sheets for Superconducting Cavities	
Tokyo Denkai Co., Ltd. H.Umezawa	
<p>1. Mother Material</p> 	<p>5. EB Melting (2nd, 3rd)</p> 
<p>2. Pressing</p> 	<p>6. Cutting</p> 
<p>3. Out gassing and Sintering</p> 	<p>7. Forging</p> 
<p>4. EB Melting(1st)</p> 	<p>8. Mechanical grinding</p> 

<p>9. Rolling</p> 	<p>13. Annealing</p> 
<p>10. Polishing</p> 	<p>14. Testing</p> 
<p>11. Rolling</p> 	<p>15. Polishing</p> 
<p>12. Cutting</p> 	<p>16. Packing</p> 
<p>Note: Cost of the ingot sliced Nb sheets anticipated to be less than a third of polycrystalline Nb & no QA</p>	



Future Outlook

- Ingot niobium technology (low RRR, high tantalum content) has proven to be ideal for CW SRF applications
- We expect that this technology will be the preferred choice for future superconducting CW linacs world-wide
- Several Labs from the three continents are discussing a joint program to optimize the ingot niobium multi cell cavity processes for high efficiency & high intensity CW linac applications

Schematic of the VNEFRC 100 MeV, 100 kW system

Thermionic Electron Gun, 200 keV & 1 mA

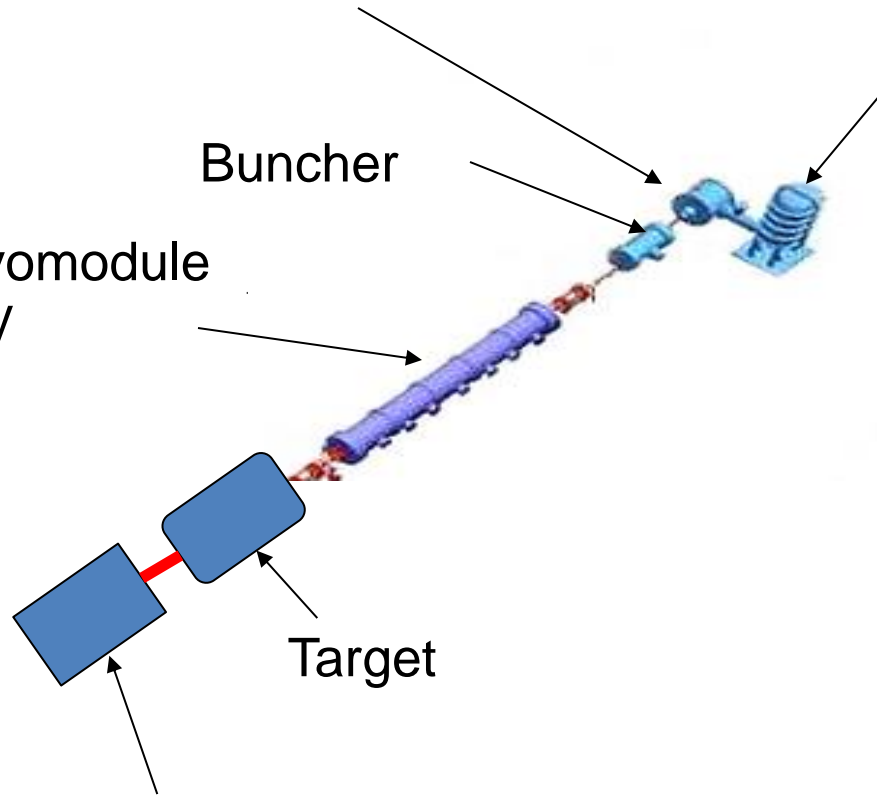
200 kV High Voltage Power Supply for Gun

Buncher

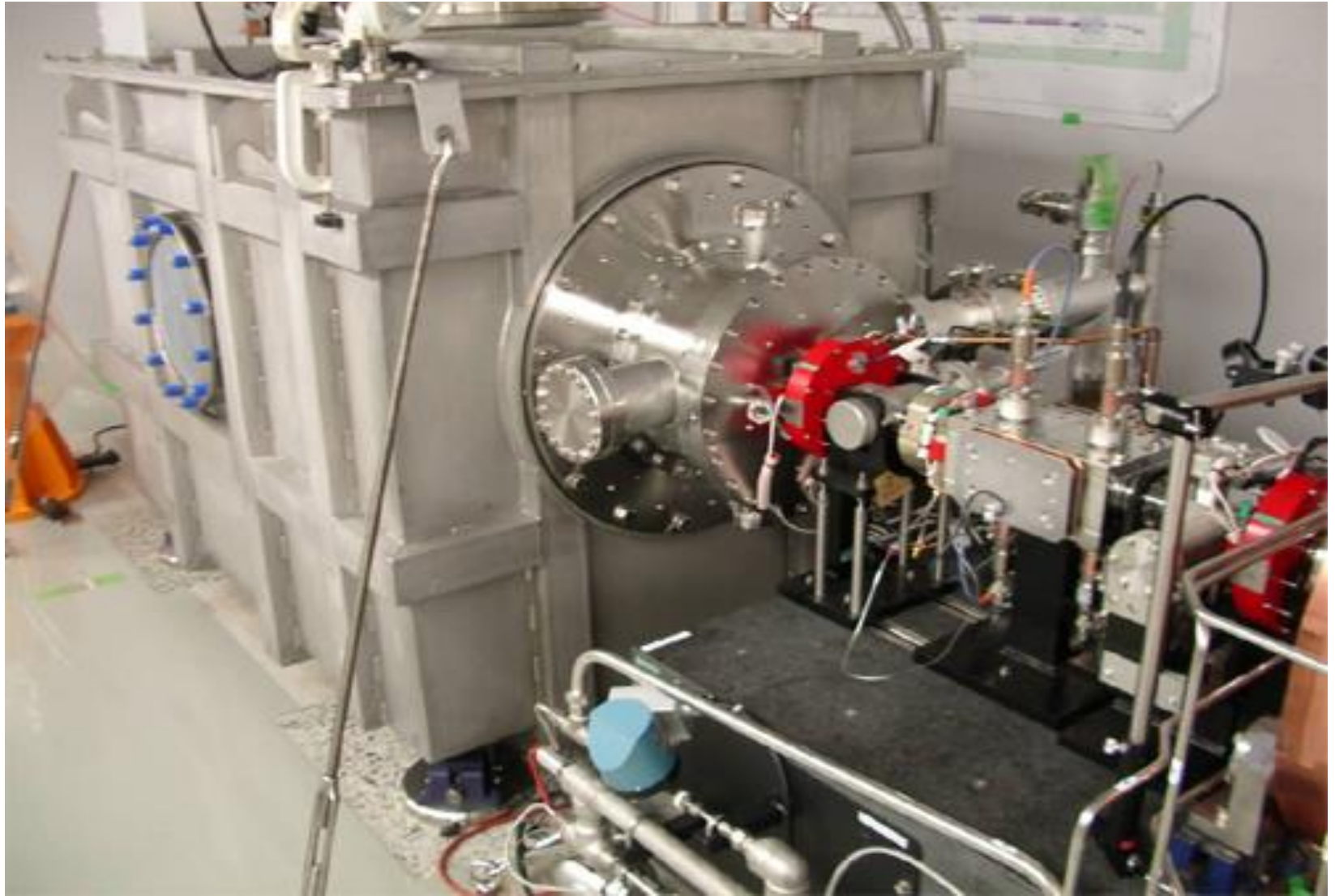
SRF Cryomodule
100 MeV

Target

100 kW Electron
Beam Dump



JLab Thermionic Gun



JLab's 100 MeV CW SRF Linac



Potential VNEFRC location adjacent to JLab



Cu-67 for Theranostic applications

Half Life: 2.58 days (61.83 hours)

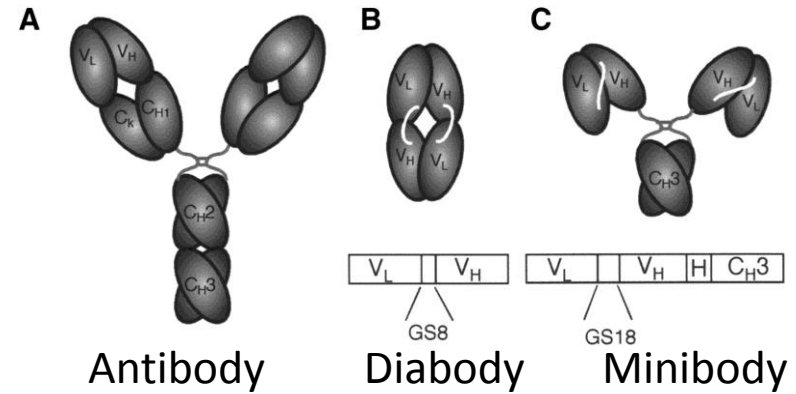
Radiation: Decay Mode: Beta

Gamma Constant: 0.97 mR/hr per 1 mCi at 30 cm

Max. Beta Range in Air : 200 cm

Max. Beta Range in Water : 0.21 cm

β^- (MeV)	γ (MeV)
0.377 (57 %)	0.093 (16.1 %)
0.468 (22 %)	0.185 (48.7 %)
0.562 (20 %)	0.3 (0.8 %)

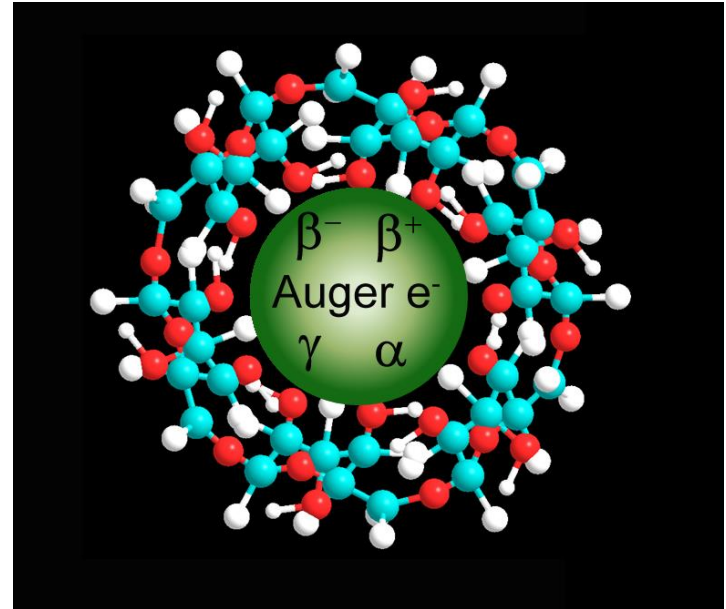
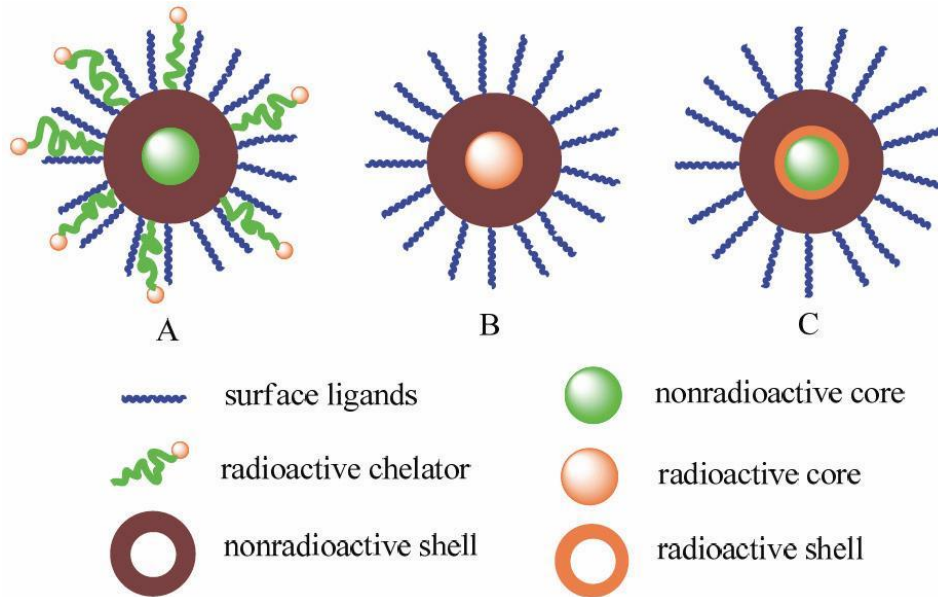


^{67}Cu is the longest living copper radioisotope

- **^{67}Cu is one of the best suited isotopes for radioimmunotherapy**
- **Its long half-life is similar to biological half-life of many monoclonal Antibodies (mAbs)**
- **Gamma radiation can be used for Single-Photon Emission Computed Tomography (SPECT)**
- **Simple radiolabeling procedure**

Dynamic growth of radioimmunotherapy applications can increase demand for this isotope

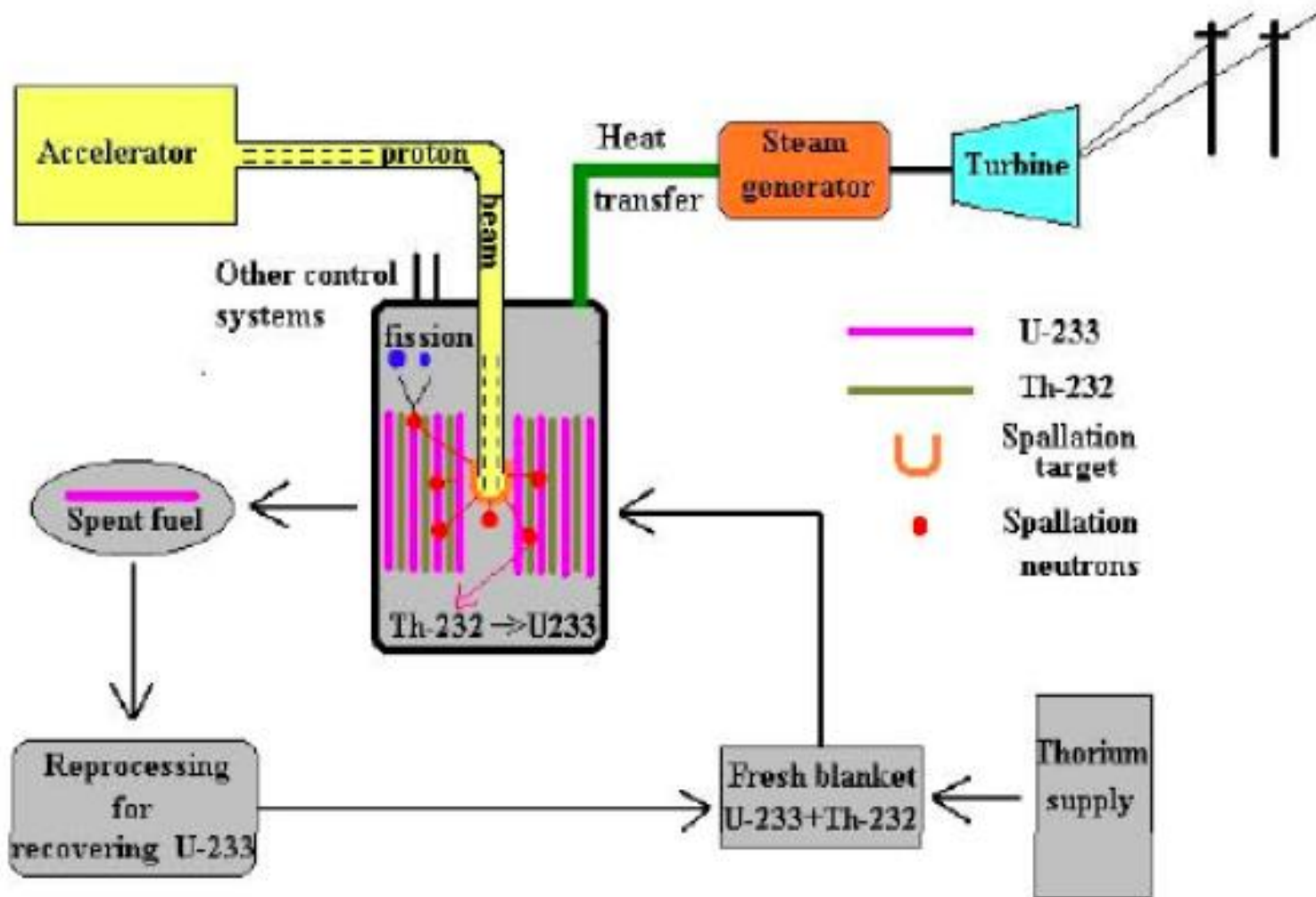
Radio-intrinsic Nanoparticle Technology Developed at the Center for Molecular Imaging, Virginia Commonwealth University



A: Conventional method uses radioisotopes attached to the nanoparticle surface

Novel technology developed at VCU incorporates the radioisotopes in the core (**B**) or shell (**C**) of the nanoparticles thereby allowing the entire nanoparticle surface for addition of targeting ligands and other coatings to tailor the *in vivo* pharmacokinetics. This is a potential advantage to manipulate the *in vivo* pharmacokinetics of the radio nanoparticles.

Thorium Utilization Scheme



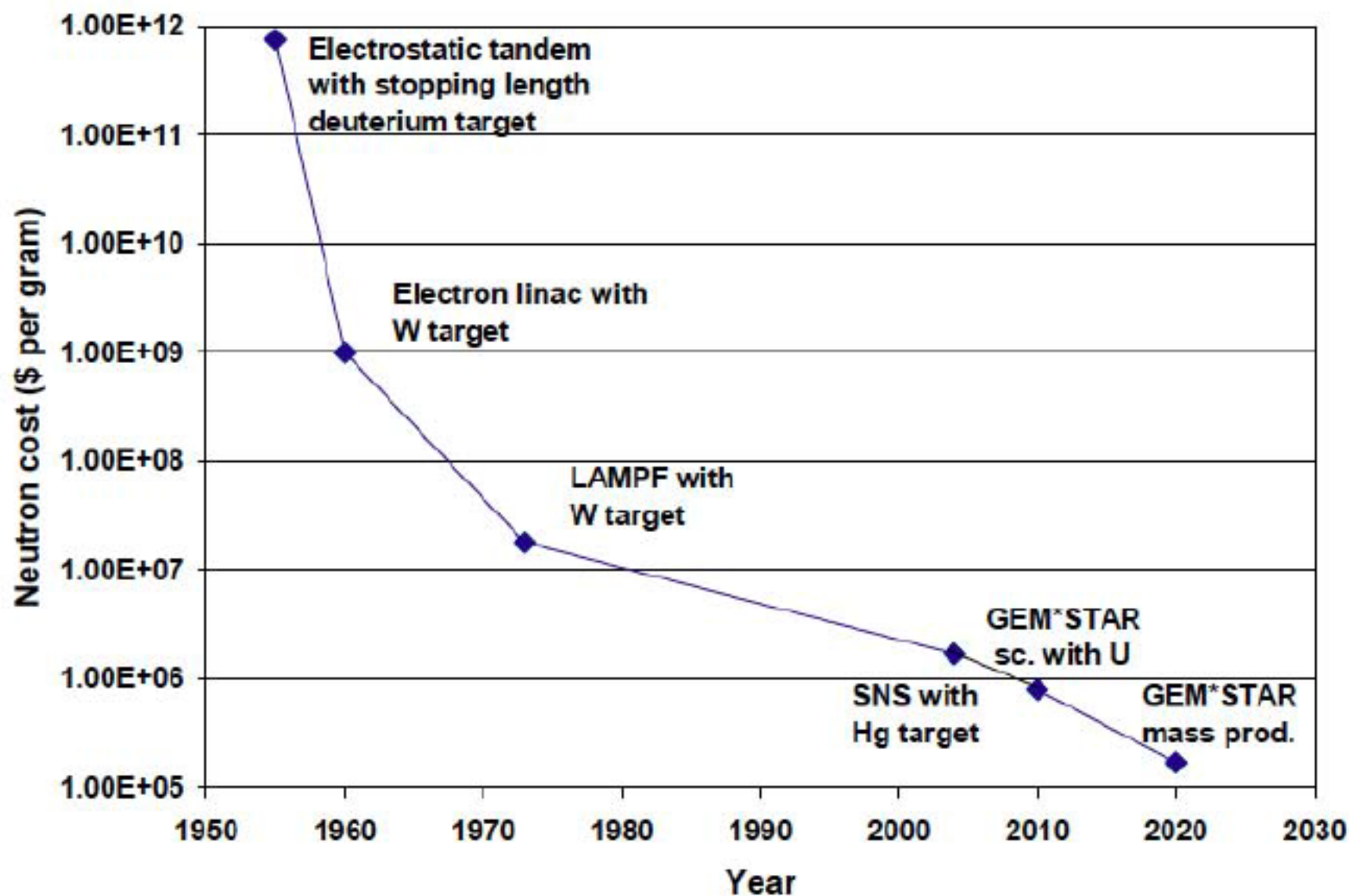
Brief Early History of ADS



- ❖ **1950 – U. E. O. Lawrence, High power accelerators for producing fissile materials**
- ❖ **1952 – W. B. Lewis, proposed use of thorium with intense neutron generator**
- ❖ **1992 – V. Bowman, Energy generation with ATW**
- ❖ **1993 – C. Rubbia, Energy amplifier**

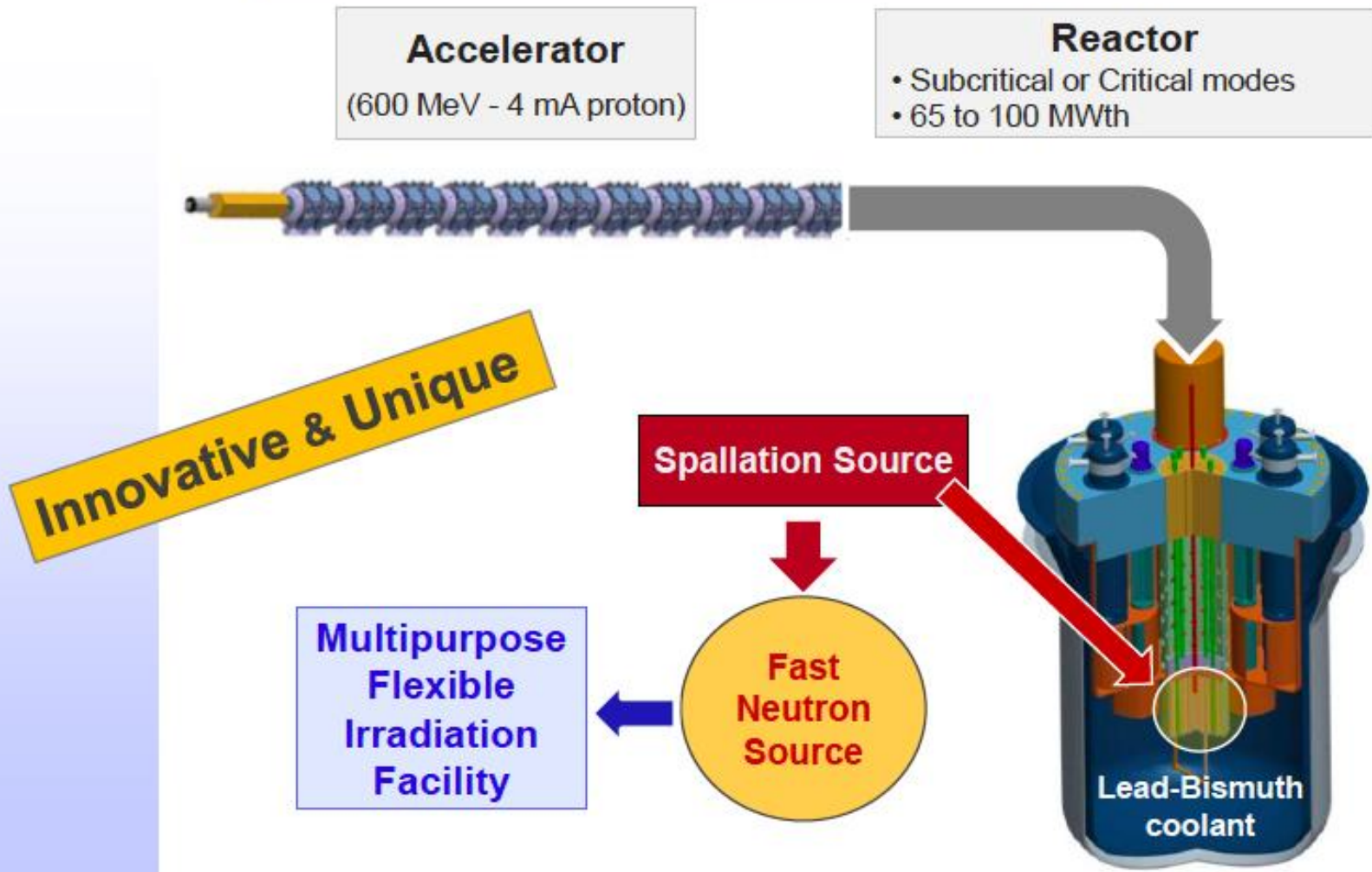
Thorium – non proliferation, no melt down, safe and least NRC involvement

Charlie Bowman's Neutron Cost Estimates



World's 1st ADS Project

MYRRHA - Accelerator Driven System



Long Term Goals

- **Energy Frontier Research considered by the STC:**
 - 1) **Isotope Production (both neutron-rich, like a reactor AND proton-rich)**
 - 2) **Radiation Damage of fuel-cycle materials, or other materials**
 - 3) **Activation Analysis (photon and/or neutron) for a variety of applications**
 - 4) **Energy Production – either electrical or direct heat applications**
 - 5) **Waste Transmutation**
 - 6) **“Breed” U-233, H-3, etc.**

ADS&ThU International Workshops

1st International ADS&ThU Workshop 2010

- <http://www.phys.vt.edu/~kimballton/gemstar/workshop/index.shtml>

2nd International ADS&ThU Workshop

- <http://www.ivsnet.org/ADS/ADS2011/>

3rd International ADS&ThU – Oct 14-17, 2014

- VCU in Richmond, Virginia

Summary

- **Virginia General Assembly establishes Virginia Nuclear Energy Consortium Authority (VNECA) to promote nuclear energy R&D and for educating future generation of Scientists and Engineers**
- **Virginia Nuclear Energy Frontier Research Center is being planned to initially develop nuclear medical isotopes for imaging and therapeutic applications based on a 100 MeV CW SRF electron linac technology under the VNEC umbrella**

Acknowledgements

**Virginia Nuclear Energy Frontier Research Center Institutions
& JLab colleagues for their encouragement and help**

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>