Report on the Accelerator Workshop

Walter F. Henning / ANL

DOE-Symposium October 26, 2009

DOE-Workshop October 27/28, 2009

www.acceleratorsamerica.org

FY 2011 DOE Office of High-Energy Physics Budget Request

Basic and Applied R&D Coordination

Many of the broader applications of technology originally developed for HEP research have been serendipitous. In order to provide a more direct connection between fundamental accelerator technology and applications, the HEP program sponsored a workshop in October 2009 to identify the R&D needs of the various users of accelerators who would benefit from future technology R&D initiatives.

The workshop focused on the role of accelerators in the nation's efforts in science, medicine, energy, national security, and industry; the opportunities and research challenges for next generation accelerators; the most promising avenues for new or enhanced R&D efforts; and a path forward to stronger coordination between basic and applied research.

HEP will use this report to develop a strategic plan for accelerator technology R&D that recognizes its broader societal impacts.

Symposium Agenda

Chairs

Walter Henning, Argonne Distinguished Fellow, ANL and Charles Shank, Director, LBNL (Retired)

Draft Agenda

Time	Speaker	Affiliation	Title of talk
8:45 am	Dennis Kovar	Associate Director, Office of High Energy Physics, Office of Science, U.S. Department of Energy	Welcome
9:00	W.F. Brinkman	Director Office of Science, U.S. Department of Energy	Opening remarks
9:15	Norman R. Augustine	Retired Chairman & CEO, Lockheed Martin Corporation	*Science, Accelerators, Dinosaurs and Asteroids*
10:00	**Break**		
10:15	Fred Dylla	American Institute of Physics	Objectives and speaker introductions
10:30	Tom Katsouleas	Dean, Pratt School of Engineering Duke University	*Accelerators and Society's Grand Challenges of the 21st Century*
11:15	Bill Barletta	Professor, Massachusetts Institute of Technology	*Educating the Next Generation of Scientists and Technologists*
12:00 pm	**Lunch**		
1:30	Charles Shank	Director, Lawrence Berkeley National Laboratory (Retired)	Objectives and Speaker Introductions
1:45	Maury Tigner	Professor, Cornell University	*Modern Ships of Discovery*
2:15	Juergen Debus	Professor, University of Heidelberg	*Accelerators for Medicine: Achievements, Challenges and Opportunities*
2:45	Yves Jongen	CEO, Ion Beam Applications (IBA), Belgium	*Industrial Applications of Accelerators: Traditional and New*
3:15	**Coffee Break**		
3:30	Jay Davis	Former Director, Defense Threat Reduction Agency	*Accelerator Applications in National Security*
4:00	Richard Sheffield	Los Alamos National Laboratory	*Opportunities for Accelerators in Energy*
4:30	Walter Henning (Panel of all previous 5 Speakers)	Argonne Distinguished Fellow, Argonne National Laboratory	Round Table Panel: Question & Answers
5:15	**Break**		
5:30 – 7:00pm	**Poster Session & Reception**		

Symposium on Accelerators for America's Future

October 26, 2009
Washington Marriott
Wardman Park,
Washington DC

Sponsored by the Office of High Energy Physics of the US Department of Energy's Office of Science

Chairs: Walter Henning, Argonne Distinguished Fellow, ANL and Charles Shank, Director, LBNL (Retired)

Exploring the challenges and opportunities for the development of accelerators to meet the nation's needs in:

- Discovery Science
- Medicine and Biology
- Industrial Applications and Production
- Energy and Environment
- National Security

The Workshop

- **2 days (October 26 & 27)**
- **5 Working Groups (~ 20 members each):**
  Discovery Science
  Medicine and Biology
  Industrial Applications and Production
  Energy and Environment
  National Security
- **Each Working Group: ~ half stakeholders and ~ half technical experts**
- **Community input via White Papers & Poster Session**
- **2 co-chairs for each Working Group**
  (several pre-meetings with all co-chairs via tele-conference;
  as well as similar pre-meetings within working groups;
  list of suggested reading; guidelines on report sections etc.)

Discovery Science

Co-chairs: Lia Merminga (TRIUMF), Maury Tigner (Cornell University)

Chris Adolphsen (SLAC), Alexander V. Aleksandrov (ORNL), William Barletta (MIT), Ivan Bazarov (Cornell), Alex Chao (SLAC), Eric Colby (SLAC), Roger Falcone (LBNL), Anthony Favale (AES), Steve Geer (FNAL), Rod Gerig (ANL), Paul Grannis (Stonybrook), Mike Harrison (BNL), Kees de Jager (JLAB), Oliver Kester, (MSU), Geoff Krafft (JLAB), Wim Leemans (LBNL), Vladimir Litvinenko (BNL), David MacFarlane (SLAC), Richard Milner (MIT), Stephen Nagler (ORNL), Peter Ostroumov (ANL), Satoshi Ozaki (BNL), Hasan Padamsee (Cornell), Marc Ross (FNAL), Jochen Schneider (SLAC), Susan Seestrom (LANL), Gopal Shenoy (ANL), Christoph Steier (LBNL)

Medicine and Biology:

Co-chairs: Jose Alonso (LBNL (retired)), Herman Suit (Harvard Medical)

Ellie Blakely (LBNL), Paul Bolton (JAEA), Anders Brahme (Karolinska), Martin Brechbiel (NIH), John Cameron (ProCure), James Cox (MD Anderson), Laddie Derenchuk (IUCF), Jay Flanz (Mass General), Don Geesaman (ANL), George Laramore (U.of Washington), Anthony Lomax (PSI), Leonard Mausner (BNL), Jerry Nolen (ANL), Steve Peggs (BNL), Wolfgang Runde (LANL), Tom Ruth (TRIUMF), Andy Sessler (LBNL), David Whittum (Varian)

Energy and Environment:

Co-chairs: Stuart Henderson (ORNL), Steve Holmes (FNAL)

Andrzej Chmielewski (Institute.Nuc.Chem.), Bill Cooper (UC, Irvine), John Galambos (ORNL), Pascal Garin (IFMIF), Frank Goldner (DOE), Yousry Gohar (ANL), Gordon Jarvinen (LANL), Rolland Johnson (Muons Inc.), Rick Kurtz (PNNL), Shekhar Mishra (FNAL), Yoshi Mori (U. of Kyoto), Tim Myers (AES), Sergei Nagaitsev (FNAL), Eric Pitcher (LANL), Jean-Pierre Revol (CERN), Carter (Buzz) Savage (DOE), Peter Seidl (LBNL), Richard Sheffield (LANL)

Security:

Co-chairs: Sandra Biedron (ANL), Edward Hartouni (LLNL)

David Beach (NNSA), Ilan Ben-Zvi (BNL), Brandon W. Blackburn (Raytheon), Matt Bold (LMCO), George Caporaso (LLNL), Marty Carts (NASA), Keith Cartwright (Air Force), Cristian Coman (NATO), Jay Davis (Retired LLNL), William Fawley (LBNL), Leon Feinstein (DHS), Steve Gold (Navy), Frank Harmon (ISU), Marc Litz (ARMY), Thomas Mehlhorn (Sandia), Dinh Nguyen (LANL), Jonathan Pellish (NASA), Ed Pogue (Boeing), William Reed (Varian), Richard Sah (Muons Inc.), Quentin Saulter (Navy), Laura Skubal (ANL), Sami Tantawi (SLAC), Roy Whitney (JLAB), Peter Zielinski (DTRA)

Industry:

Co-chairs: Kathleen Amm (GE Global Research), Marshall Cleland (IBA-USA)

Tom Anyos (Tech.Ventures Corp.), Tony Berejka (MSN), Morgan Dehnel (D-Pace, Inc.), Bruce Dunham (Cornell), William Griffith (ORNL), Kenneth Kosiol (Sterigenics International), Bruce Miller (Ktech), Sam Nablo (Energy Sciences Inc.), Greg Norton (National Electrostatics Corp.), Rajendran Raja (FNAL), Suntharampillai Thevuthasan (PNL), Anne Testoni (Advanced Electron Beams, Inc.), Terrance Thompson (PCT), Peter Wasik (Wasik Associates, Inc.), Hans Wiegert (Sealed Air), Ferdinand Willeke (BNL), Peter Zavodszky (GE Global Research)

The Charge

Purpose:

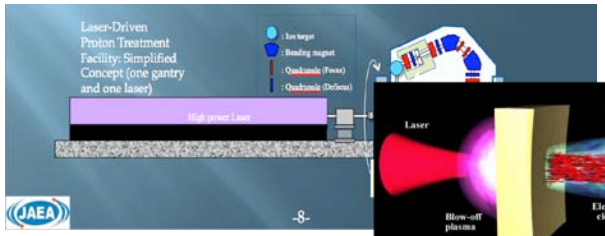
The meeting will examine what the challenges are for identifying, developing and deploying accelerators to meet the nation's needs in basic science, medicine, energy and the environment, national security, and industry. The results will be presented in the form of a report to the Office of Science and the Office of High Energy Physics.

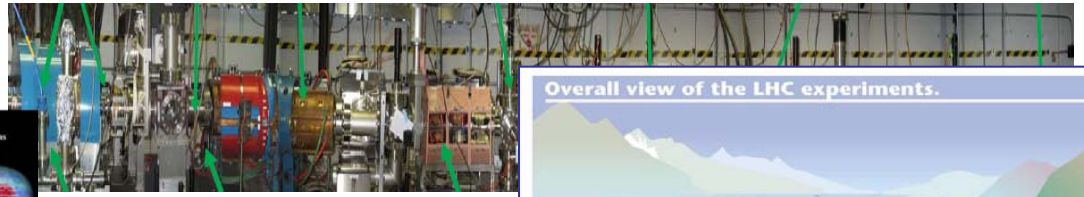
Key goals:

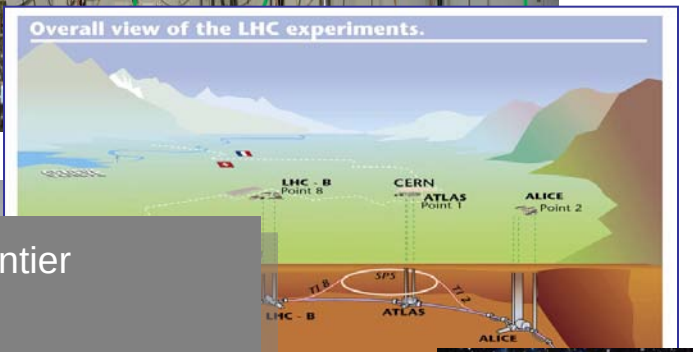
- To identify current and future needs of stakeholders
- To seek out crosscutting challenges-- technical, cost, policy, etc— whose solutions may have transformative impacts that represent opportunities for the future
- To provide guidance to bridge the gap between basic accelerator research and technology deployment
- To identify the areas of accelerator R&D that hold the greatest promise

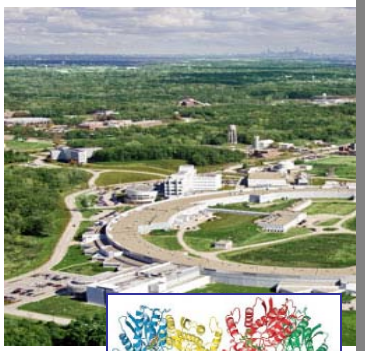
Working Group Schedule -- Tuesday October 27, 2009									
Time	Ballroom West	Ballroom South	Tyler	Truman	Taylor	Taft	Hoover	Coolidge	Harding
8:00 - 8:45	General Introduction								
9:00 - 12:00		Discovery Science I/II	Energy	Discovery Science I	Discovery Science II	Storage / Breakout	Medicine	Security	Industry
12:00 - 13:00	Working Lunch	Industry Gathering							
13:00 - 14:00		Industry Gathering	Energy	Discovery Science I	Discovery Science II	Storage / Breakout	Medicine	Security	
14:00 - 18:00		Discovery Science I/II	Energy	Discovery Science I	Discovery Science II	Storage / Breakout	Medicine	Security	Industry
18:00 - 20:00	Dinner								
20:00 - 22:00	Co-Chairs Meeting								

Discovery Science



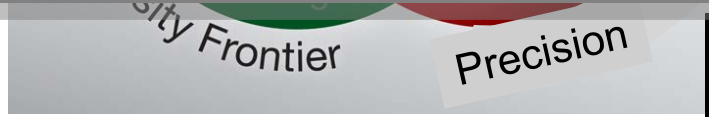


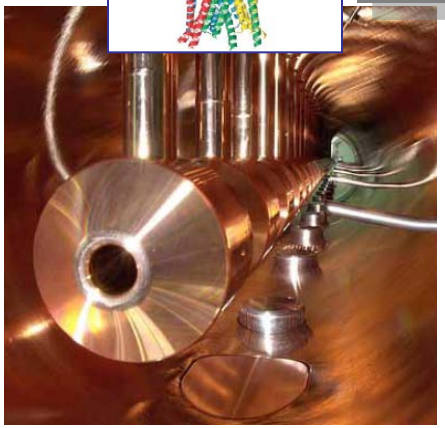


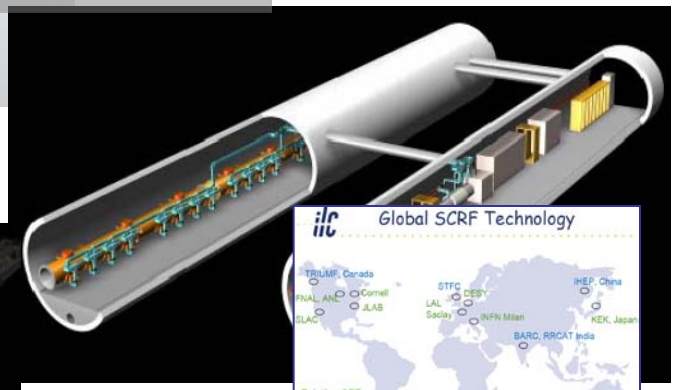


- Energy frontier, intensity frontier, precision frontier
  - particle physics
  - nuclear physics
  - basic energy sciences
  - (fusion research)
  - (other areas of science)

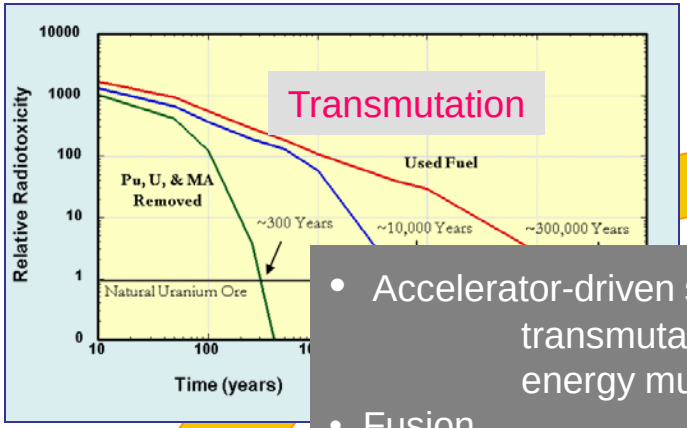
  } Other sections / WGs
- Technology advances to reach these frontiers
- Accelerator science: a science in itself
- Education and training

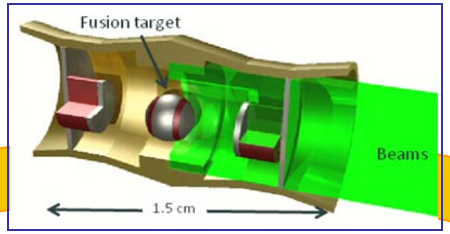


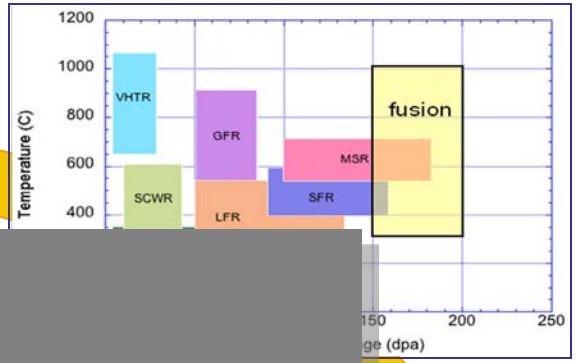




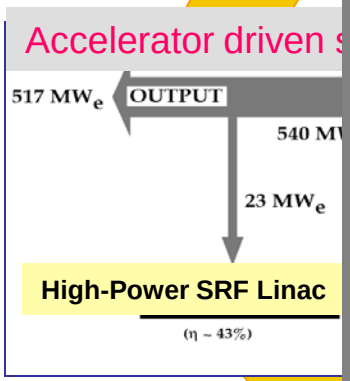
Energy and Environment

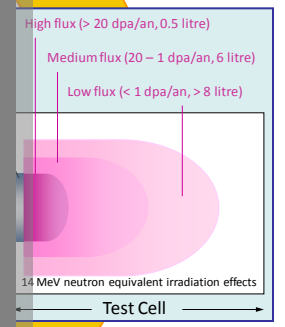


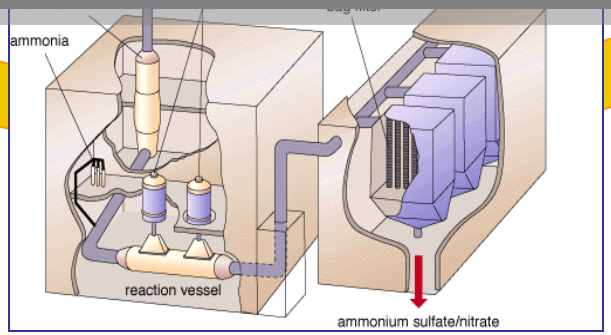


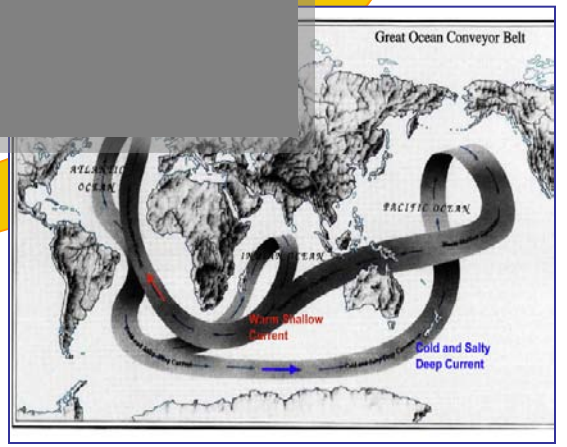


- Accelerator-driven systems for nuclear energy
  - transmutation
  - energy multiplier/generator
- Fusion
  - magnetic confinement fusion
    - ion beam current drive
    - materials research/testing
  - beam driven inertial confinement fusion
- Light-source and neutron-source based energy research
- Environmental research and applications
  - accelerator mass spectrometry
  - flue-gas treatment
  - waste water treatment



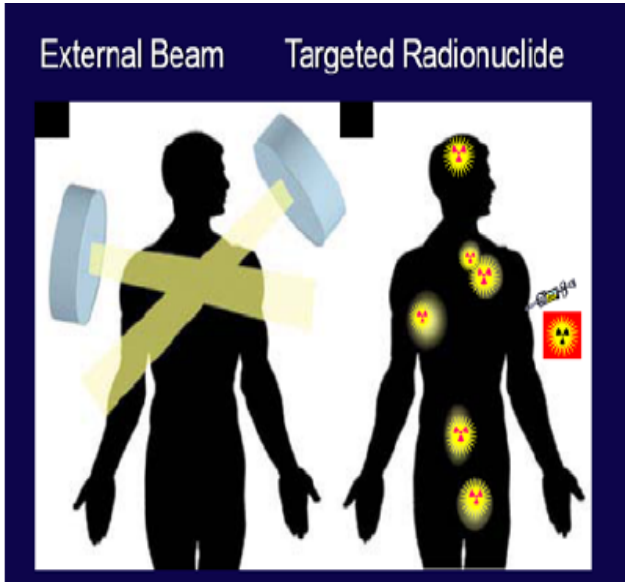


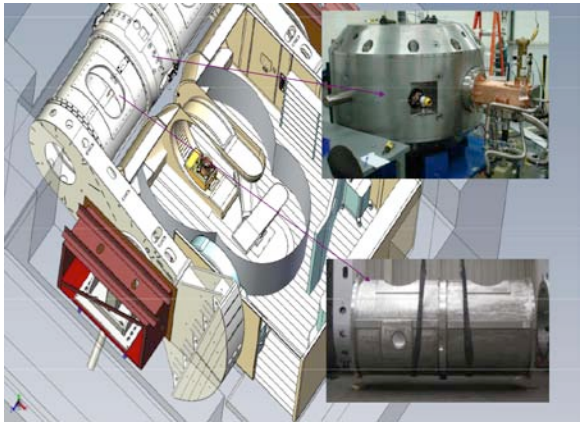


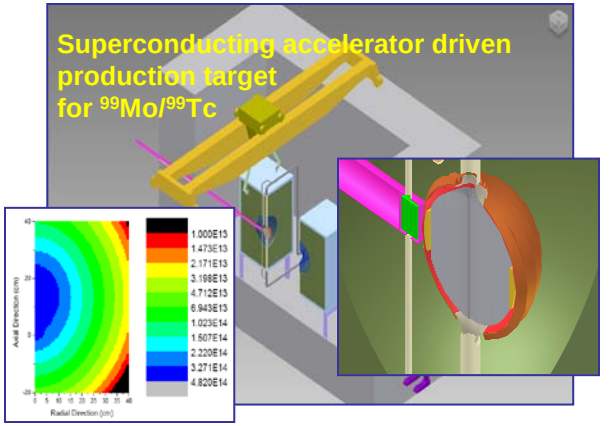


Medicine and Biology

Radioisotopes for diagnostics and therapy (PET & SPECT & targeted therapy)

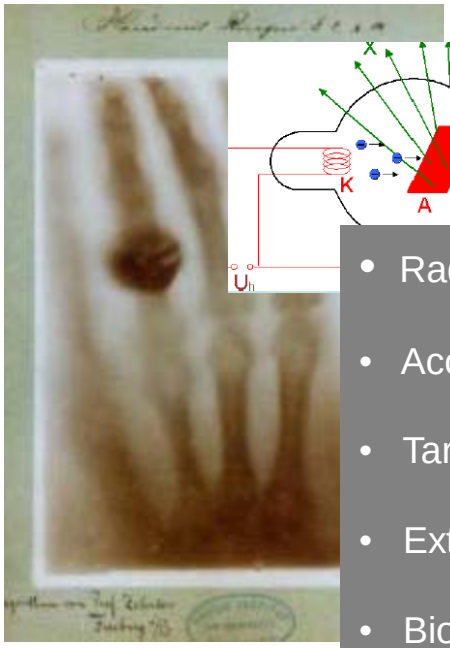


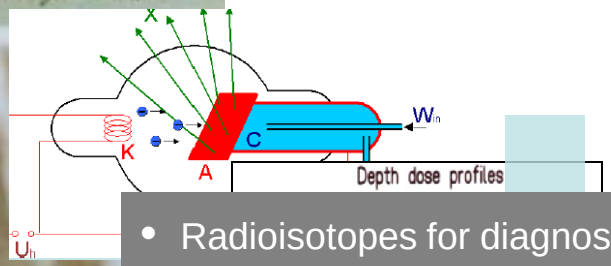


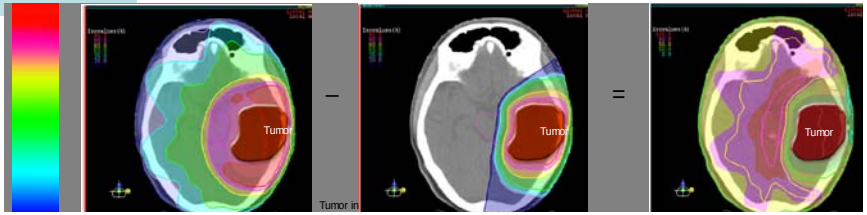


Medicine and Biology

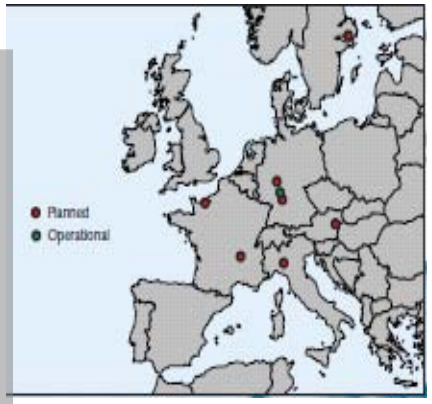
Cancer therapy with electron/x-ray and ion beams

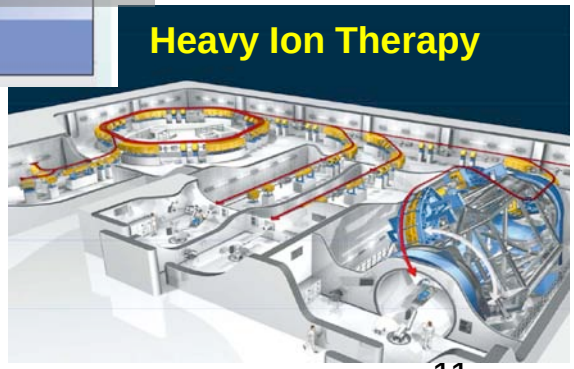




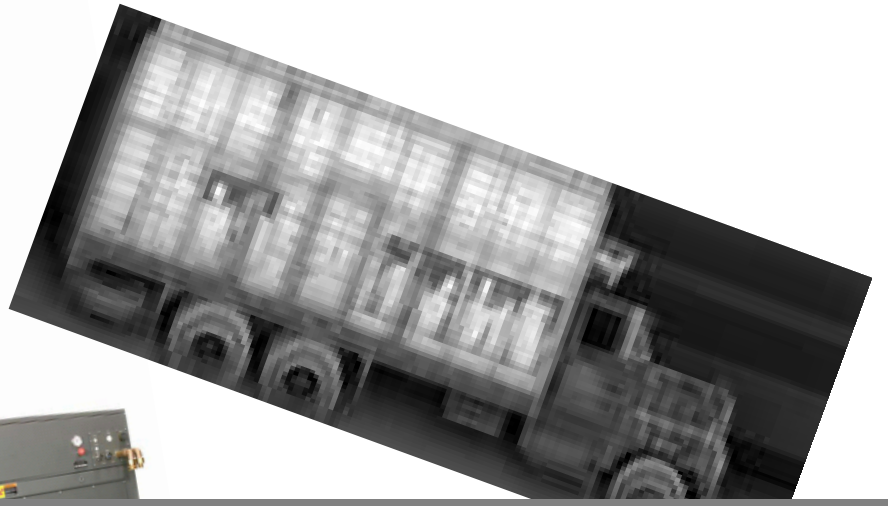


- Radioisotopes for diagnostics and therapy
- Accelerators to resolve reactor-based production issues
- Targeted radiotoxicity therapy
- External beam therapy with protons and heavy ions
- Bio-molecular studies and pharmaceutical developments





National Security



- Physics data on nuclear reactions
- High energy density environments
- Directed energy
- Cargo inspections and interrogation (large stand-off)
- Replacement of radioactive sources
- Isotope production
- Nuclear forensics
- Compact, fieldable accelerator systems
- Simulation tools
- Pulsed power accelerators
- Advanced RF and accelerator technologies

Industrial Applications and Production

- Manufacturing of accelerators (and/or accelerator components)
- Use of accelerators in industrial production

Application	Total systems (2007)	System sold/yr	Sales/yr ($M)	System price ($M)
Cancer therapy	~9100	500	1,800	2.0 – 5.0
Ion Implantation	~9500	500	1,400	1.5 – 5.0
Electron cutting and welding	~4500	100	150	0.5 – 2.5
Electron beam & X-ray irradiators	~2000	75	130	0.2 – 8.0
Ion beam analysis (incl. AMS)	~200	25	30	0.4 – 1.5
Radioisotope production (incl. PET)	~550	50	70	1.0 - 30
Non-destructive testing (incl. security)	~650	100	70	0.3 – 2.0
Neutron generators (incl. sealed tubes)	~1000	50	30	0.1 – 3.0
Totals	27,500	1400	3580	

Industrial Applications and Production

- Generally, high energy particle beams induce nuclear reactions and activation
- In contrast, in industrial applications, nuclear reactions and activation are undesirable and avoided, but other effects of ionizing radiations are researched
- These desired effects include:
  - Sterilization
  - Cross linking of polymers
  - Curing of composite materials
  - Modification of crystals
  - Doping of semi conductors
  - Beam aided chemical reactions
  - Thermal or mechanical effects of the particle beam

- Sterilization
- Cross linking of polymers
- Curing of composite materials
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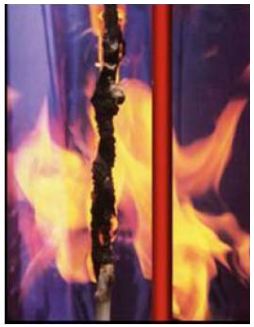
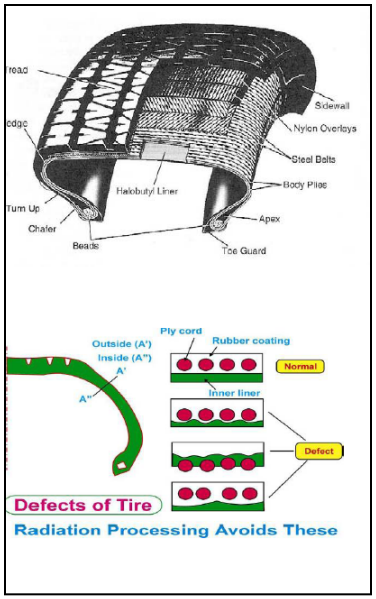
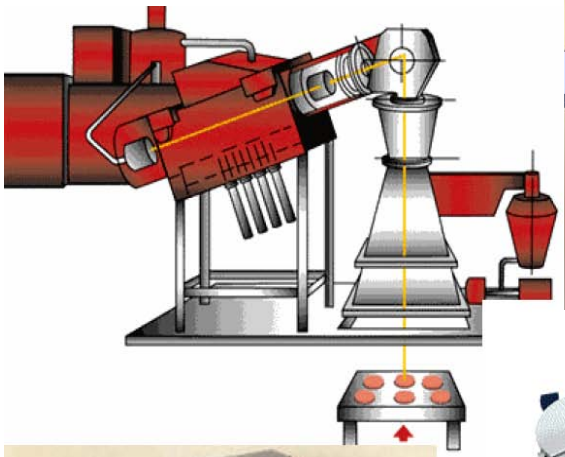
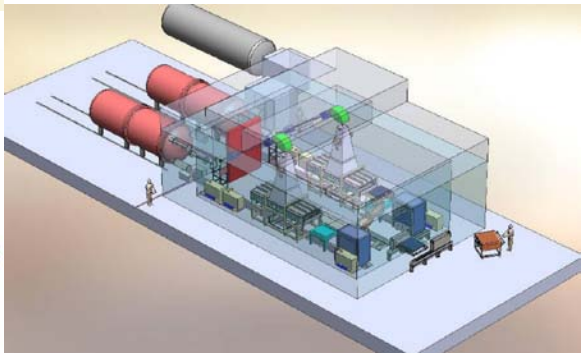
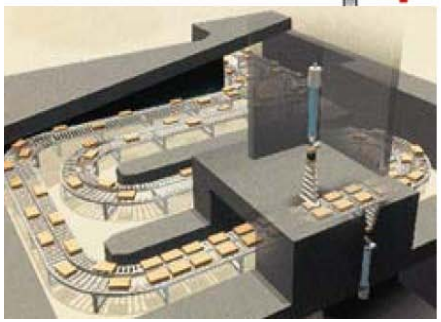
- Beam aided chemical reactions
- Thermal or mechanical effects

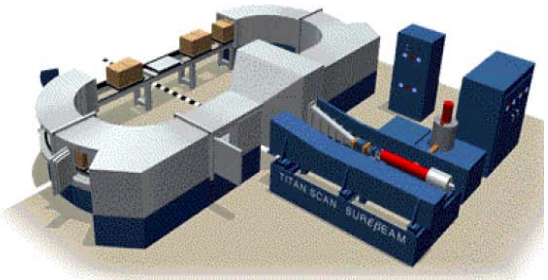












On-Site is a complete turn key operating system validated to ISO 11137 and delivered with all required training, documentation, dosimetry system and process certification.

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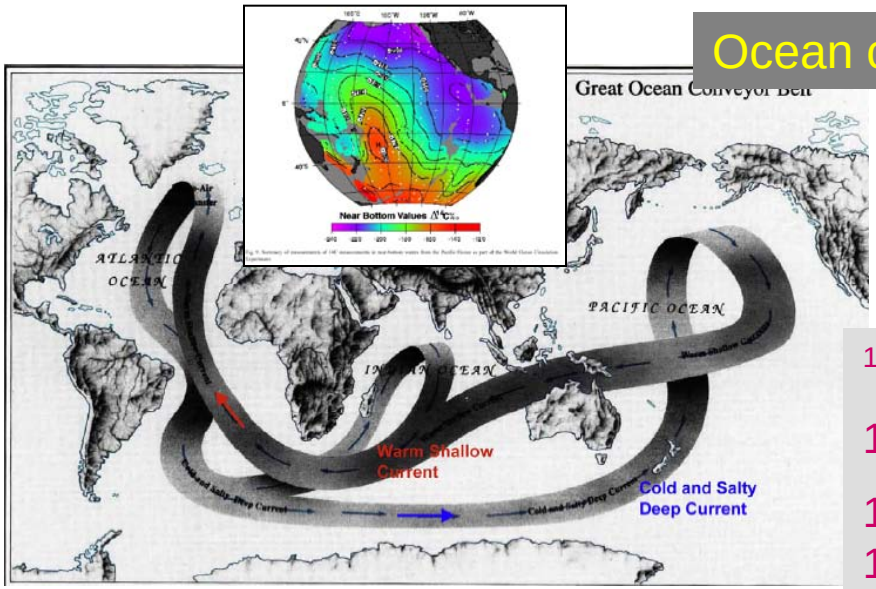
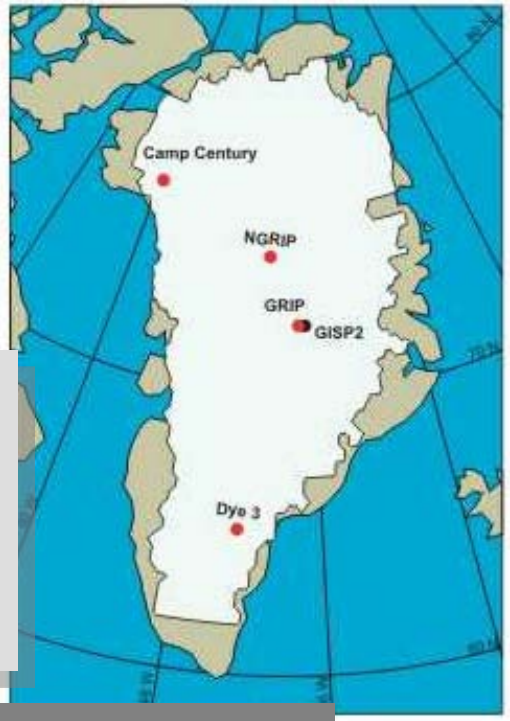
Accelerators at the Interface of Research and Industry

Example: Accelerator Mass Spectrometry (AMS) – Dating and Tracing

from archeology and art to geophysics, climate research, ocean circulation, erosion studies, forensics, atmospheric studies, groundwater & aquifers, actinides, pharmaceuticals and drug development...



Ocean circulation

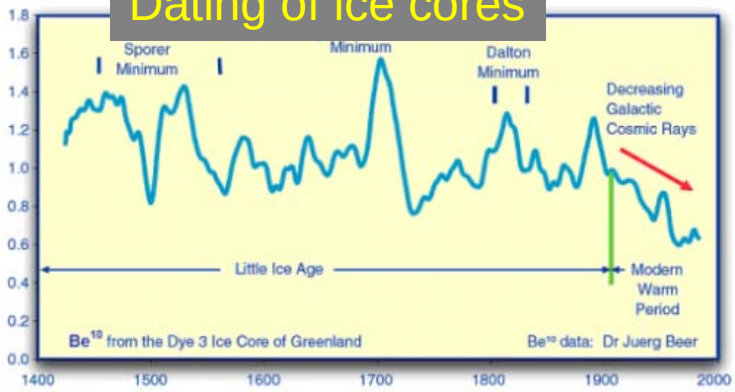


^{14}C ($T_{1/2}$ = 6000 yrs)

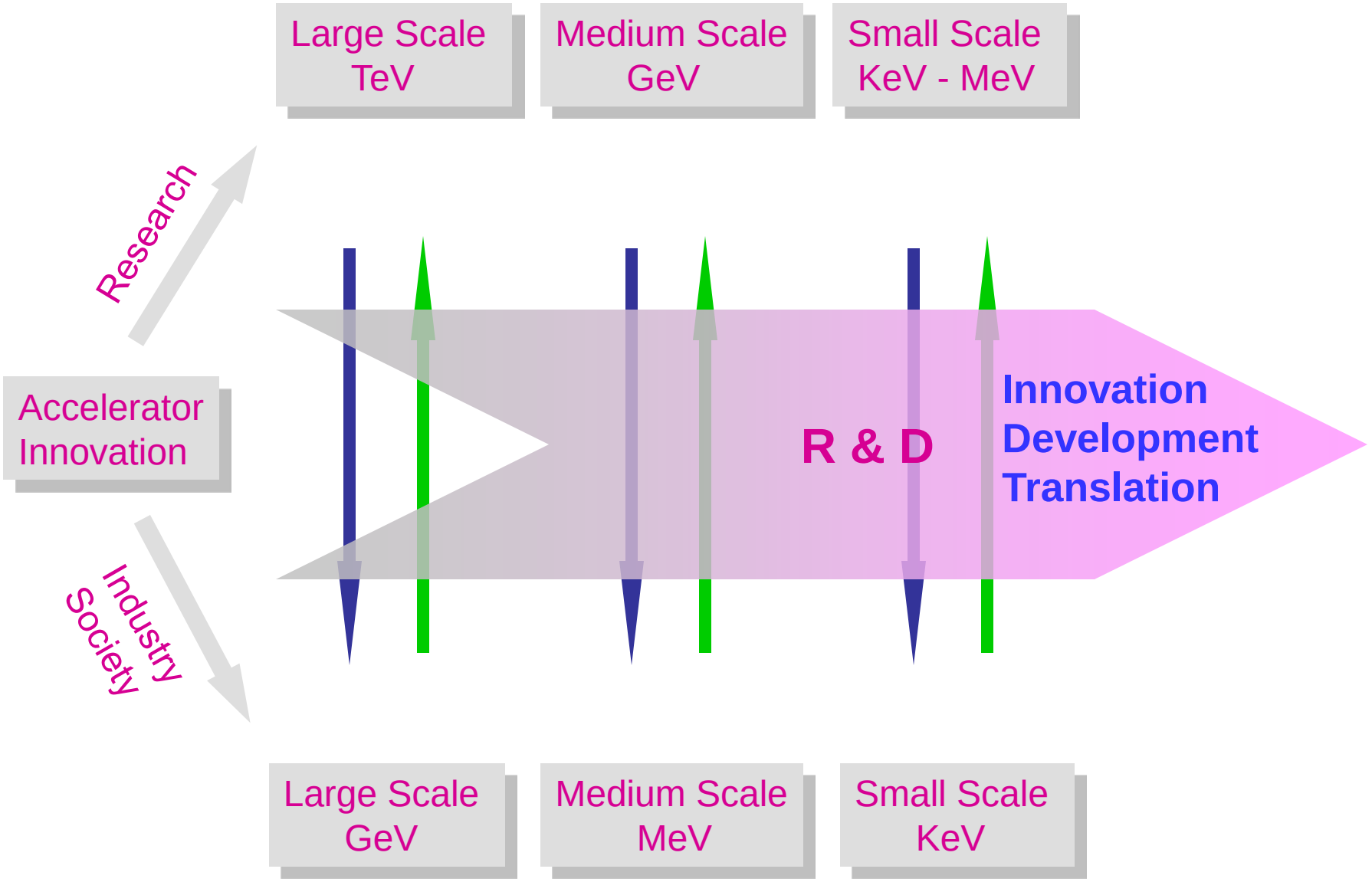
1 mg carbon sample:

1 decay count per hr
1 million accelerated atoms in detector

Dating of ice cores



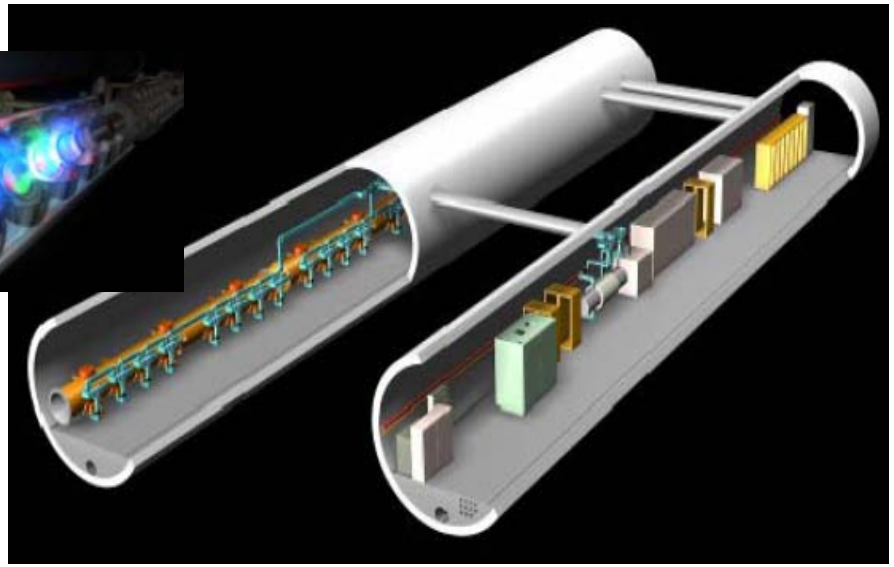
March 11-12, 201


Large Scale
TeV
Medium Scale
GeV
Small Scale
KeV - MeV
Research
Accelerator
Innovation
Industry
Society
R & D
Innovation
Development
Translation
Large Scale
GeV
Medium Scale
MeV
Small Scale
KeV

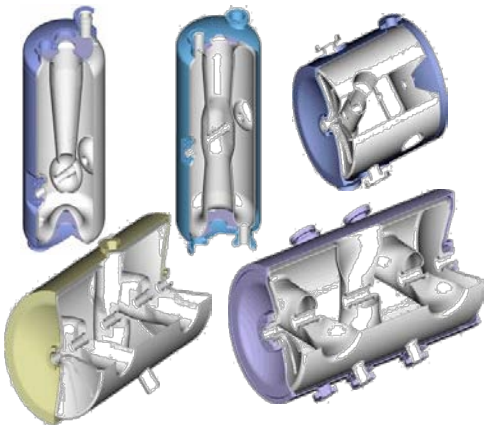
Example: Superconducting Radio Frequency (SRF)

30-40 MV/m

beta=1



low-beta (0.1-0.5)

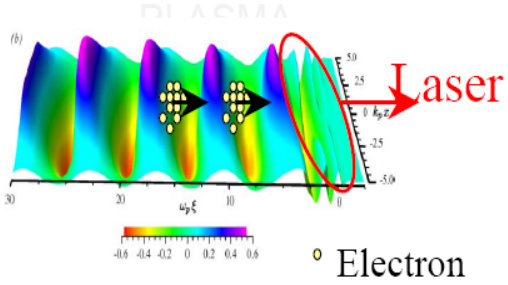


10-15 MV/m

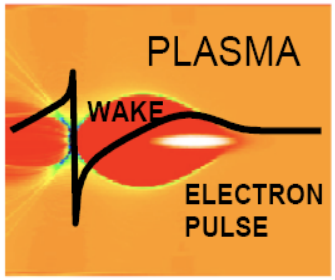
Example: Wakefield Technology

Wakefield technology proposes to miniaturize accelerators with ultra-high gradient acceleration of charged particles.

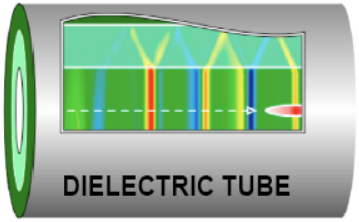
- A laser or electron beam pulse propagating through charged plasma or a dielectric tube excites a wake behind the pulse.
- The wake field is O(GeV/m), propagates at the speed of light, and accelerates a following beam bunch or plasma particles.
- A useful analogy has the particles "surfing" the wakefield.



Laser-Driven Plasma Wake



Beam-Driven Plasma wake



Dielectric wake field

Accelerator physics is at the forefront of science

Acceleration, Radiation Sources, Refraction, Medical Applications

Report Outline

- Introduction / Executive Summary
- Main Body: 5(+) sections on the areas discussed
- Findings / Outlook

Findings (Technology and R&D)

- Need important R&D towards technologies for major advances in performance:
  - high-gradient rf structures
  - superconducting radio frequency
  - hig-power RF
  - photonic band-gap structures
  - muon accelerators & colliders
  - wake field in plasmas and dielectrics
  - laser driven plasmas
  - beam cooling and coherence
  - advanced free electron lasers
  - energy recovery linacs
  - superconducting magnets
  - high intensity / high brilliance beam sources
  - advanced materials
- Need R&D towards more rugged, more reliable, more compact, and more economical accelerators ("fieldable")
- Accelerator research and development *is* science in itself

Findings cont'd (Policy)

- Inter-agency and inter-program communication and collaboration
- World-class facilities to help industrial users bridge the translational gap to commercial deployment ("valley of death")
- Mechanisms for new private-public partnerships (less risk-averse, long-term, contractually founded, with well-defined, industry-cognizant rules for intellectual property rights)
- Accelerator education
- 2005 National Academies report "Rising Above the Gathering Storm": The United States must compete by optimizing its knowledge-based resources, particularly in science and technology, and by sustaining the most fertile environment for new and revitalized industries and the well-paying jobs they bring

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