Future Challenges in Accelerator Health Physics

Technological Advances
Operational Changes
Regulatory Requirements

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Acknowledgements

- I asked a question:
  - I have been asked to prepare a talk on "Current and future challenges in accelerator health physics program management". I would be pleased to include any current and future challenges you might wish to share with me.
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- Thank you.

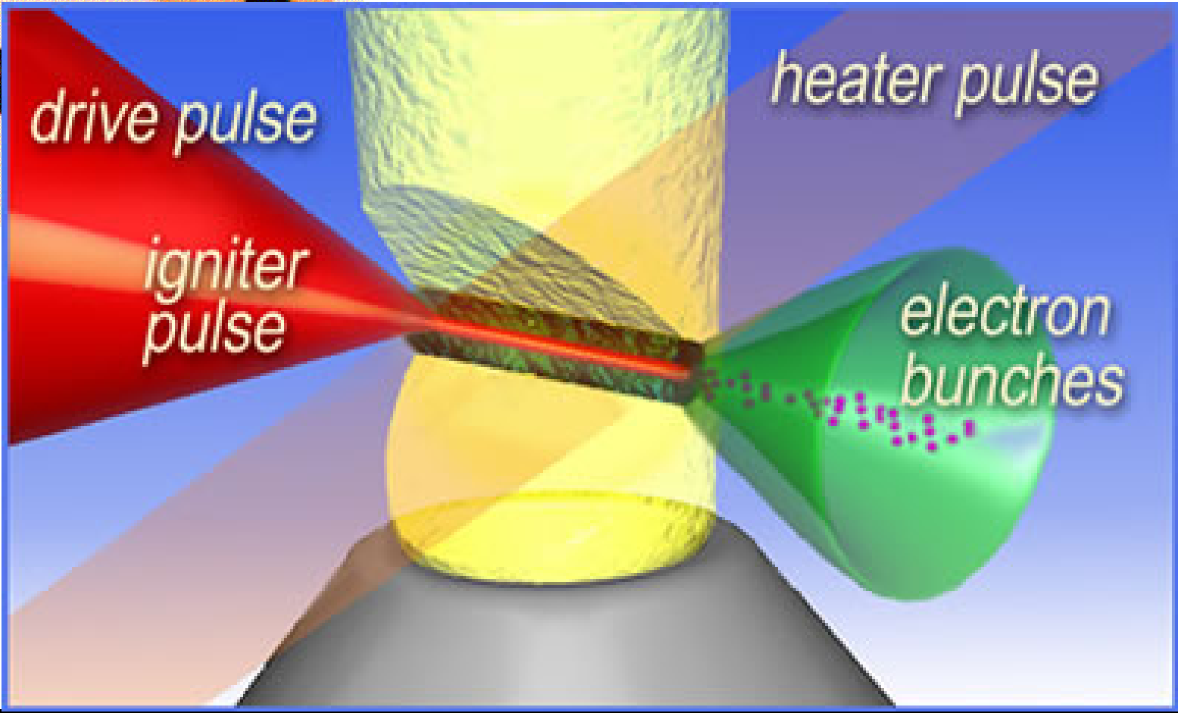
- **Technological Advances**
  - Laser Wakefield Acceleration
  - High Intensity Beams
  - Emerging technologies

- **Operational Changes**
  - Complexity
  - Interlocks
  - Inherently Safe Design Features
  - User Safety
  - Quality Assurance

- **Regulatory Requirements**
  - US NRC
  - OSHA
  - DOE
  - ANSI

Cyclotron

The first cyclotron was an unimpressive looking contraption made of glass, sealing wax and bronze, not much bigger than the palm of Lawrence's hand. The cyclotron would go on to win Lawrence the 1939 Nobel Prize in physics and usher in a new era in the study of subatomic particles.



Wakefield Acceleration

An igniter laser pulse forms a "wire" of plasma in a plume of hydrogen gas; a heater pulse expands the wire to a plasma channel; the drive pulse accelerates bunches of electrons inside the channel to nearly uniform high energy. (LBNL)

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From Zero to a Billion Electron Volts in 3.3 Centimeters

Highest Energies Yet From Laser Wakefield Acceleration

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BERKELEY, CA — In a precedent-shattering demonstration of the potential of laser-wakefield acceleration, scientists at the Department of Energy's Lawrence Berkeley National Laboratory, working with colleagues at the University of Oxford, have accelerated electron beams to energies exceeding a billion electron volts (1 GeV) in a distance of just 3.3 centimeters. The researchers report their results in the October issue of Nature Physics.

High Intensity Beams

- Response of monitoring instruments to fs pulses.
- The minor issues of radiation chemistry of air, water and material become very serious.   Radiolysis and radiolytic production of corrosive chemicals - shorten the life of the beam line equipment.
- Another big component to safety systems is radiation damage to system components, how to choose components, and system verification to insure systems are not failing.
- Radiation damage to material will limit the options, which will drive the design of the equipment. The demand for rad hard alternatives to materials such as cables, insulators, sensors, oils etc. will go up

High Intensity Beams (cont.)

- Shielding will require better/more sophisticated materials and designs to protect the environment. Modern computational tools allow more precise optimization of shielding.

- Incorporate remote handling into portions of the design. Robots take dose without a whimper, and are ideally suited to some of these tasks IF the features are considered during design.
  - SNS did an extensive ALARA evaluation of a variety of designs to factor the maintainability aspects of operations into the machine. We spent a lot of money ($10s of millions) up front to reduce operational dose, and to date the evaluations seem to have been accurate.

- Neutrino beams will become more intense and minor issues such as dose due to neutrinos become significant. Currently there are calculation of "Equivalent Dose" due to neutrinos, but measurements will be required.

Emerging technologies

- CARIBU – Californium Rare Isotope Breeder Upgrade
- Tera-, peta-, and exa-watt laser driven systems with femto- and atto-sec pulses
- Issues with X and Gamma ray class coherent photon sources, e.g. 4GLS (4th generation light source), and LCLS (linac coherent light source)
- Modeling and dynamic-particle accelerators, e.g. RIA, muon, and neutrino class machines where the primary particles change form within accelerator segments.
- Nano-scale science

Complexity

- Complexity and its affect on determinism, availability, human factors, and safety are very much leading issues as we try to manage risk in increasingly diverse machines.

- Interlocked enclosures, will become more complex and sophisticated. To make them friendlier for lots of users, we will have to move toward programmable electronics, programmable systems and biometric systems.

- As an example, we're figuring out how to integrate institutional laser and robotic interlock requirements into our hutches that also have oxygen deficiency alarms....

Interlocks

- Issue: integration of rad with other interlocked systems:
  - The PSS (personnel safety system) is dedicated for beam safety only. In cases where a stand-alone X ray machine operates inside a beam hutch, the unit gets its own interlock sensors and logic controller.
  - Laser interlocks are kept entirely separate from other interlock systems. In fact, it is prohibited to piggyback other systems on the beam access interlock systems – they must be independent.

Interlocks (cont.)

- System lockout of electrical systems. We rely on Protection Systems to protect workers from radiation and other hazards, but can’t seem to get over the hump of using such a system to protect workers from electrical energy.
  - BNL Lab Electrical Safety Committee wrote a Subject Area that forbade use of interlocks for personnel safety for all energy sources.
  - OSHA and NFPA 70E have very strict requirements in regards to lockout/tagout. There is a specific requirement in NFPA 70E, for example, to establish an “electrically safe work condition”. An interlock does not meet these requirements. Per 10 CFR 851, we must abide by OSHA regulations and the NFPA 70E standard.

Inherently Safe Design Features

- Design features such as
  - Simplification to make repairs and replacements easy and affordable.
  - Robust radiation hard design to reduce the failure frequency
  - Modular design with remote removal, storage and replacement capability
  - Design requirement that a failure does not cascade down or upstream to other elements
  - Built in easy accessibility to defunct equipment.
  - Possibility of selective redundancy in the beam line to extend operations until an opportune time for repairs.
  - Integral simulations projecting the future conditions of the whole complex of the beam line,
  - Equipment, structure, regulatory req. and the equipment, training and tools requirements.
  - Inherently safe design features will also affect D&D obviously.

Inherently Safe Design Features (cont.)

- The physics of accelerator operation will often limit the magnitude or duration of fault.
  - The duration of a design basis accident is often selected on the basis of some convention or the cycle time of some protection system - a few seconds, for example - rather than an analysis of the physics of beam transport.
  - If a reliable analysis indicates that beam transport stops in 1 sec or less anyway, why are we spending resources on systems (that have their own failure modes) to limit it?
  - We have not been allowed to account for the physics of beam transport in analysis of a design basis accident in a DOE facility

Inherently Safe Design Features (cont.)

- Shielding requirements for energy recovery linacs (ERLs).
  - The injected beam intensity from an energy recovery linac depends on the energy that is recovered from a previously accelerated electron. If the energy from the accelerated electron is not recovered (e.g. the electron is lost prior to recovery), there will be insufficient energy to continue the acceleration process for subsequent pulse trains.
  - The question becomes: given this process, can shielding be reduced from what we normally be expected for a linac operating at a given energy and current.
  - As always, the answer is not as clear as it might look from first principles.

User Safety

- “Radiological risks to users are minimal compared to other hazards.”

- “Diligence by all and continued management attention creates the atmosphere which can establish a proper attitude regarding safety. It does require exactly that – diligence and management attention.”

- Larger and larger numbers of users with highly diverse backgrounds, operating in larger facilities with little or no contact time.
  - Life safety issues and physical size - from "table top" multi-GeV class accelerators to the 30km ILC.
  - Remote operation and cognizance, e.g. Global Accelerator Network (GAN)

Quality Assurance

- Complex protective systems depend on good QA methods, including software QA, in a way that is much stricter than many of the other accelerator components.

- With higher beam intensities, reliability of sensors, system testing, system verification, operating practices, etc. will need to be better defined and controlled.

- Planning for evolution: history shows that accelerators evolve well past the original scope over 10's of years. What are some radiation management life-cycle considerations to be included in the up-front planning process?

Regulatory Challenges

- **US NRC**
  - Section 651(e) of the Energy Policy Act of 2005 (EPAct) on "Treatment of Accelerator-Produced and Other Radioactive Material as Byproduct Material" gave NRC regulatory jurisdiction over NARM. http://nrc-stp.ornl.gov/narmtoolbox.html

- **OSHA:** Stakeholder Meetings on Occupational Exposure to Ionizing Radiation
  - OSHA will use the data and materials obtained through these information collections efforts to determine, in conjunction with other Federal agencies, whether regulatory action is necessary to protect employees from ionizing radiation exposure.
  - http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=FEDERAL_REGISTER&p_id=19349

Regulatory Challenges (cont.)

- DOE
  - 2007 change to 10CFR835
  - Neutron radiation weighting factors replace fluence-to-rem factors

- ANSI
  - ANSI N43.1

Summary

Q: How can the health physics team best add value to research operations?

A: Stay at the forefront so that when
new discoveries are made,
you will be prepared to identify the hazards
and how to control them.