Educating Accelerator Scientists & Technologists for Tomorrow – A View from the U.S.

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DOE accelerators train future physicists, chemists & biologists

Estimated number of students/year at DOE/SC accelerator facilities

- 6100 BES
- 1500 HEP
- 1300 NP

Prior to Tevatron shutdown

~ 50% non-US users

~ 1400 PhD/yr in physics in US

Roughly 2/3 of facility users are students
Accelerators for future science…

- Will be challenging to design & build
- Will be challenging to operate
- Will need outstanding physicists & engineers to realize

Yet only a handful of universities offer formal graduate training in accelerator science & technology
Needs in the US for Research Institutes

- Past CD-3
  - NSLS-II

- Past CD-1
  - SLAC – LCLS-II
  - ANL – APS-upgrade
  - SNS – Second target station
  - FRIB at MSU

- Passed CD-0
  - NGLS

- Not yet on the project track
  - MaRIE
  - EIC
  - Project X
Some root causes in the US

- Accelerator science is inherently cross-disciplinary
- Prejudices:
  - Many physics departments view accelerator science as “just technology”
  - Electrical engineering departments have evolved toward micro- & nano-technology and computing science.
- Practicalities:
  - It is difficult to get the minimum number of students enrolled in a class for university approval
    - Even Cornell, UCLA, & MSU only offer core courses
  - Interest at individual universities is not sufficient to support a strong faculty line
  - Funding agency support of university-based accelerator research infrastructure is insufficient to develop new faculty lines
Categories of historical & present practice

- Self-instruction as part of one’s experimental activities in an accelerator-based science
- Apprenticeship training after formal education in physics or an engineering discipline
- Formal academic training in accelerator science & technology in a university program
- Study at regional or international accelerator schools
Core knowledge & skills

- **Physicists:** Electromagnetics, Hamiltonian mechanics, & applied mathematics
- **Electrical engineers:** waveguides, transmission lines & antennas
- **Mechanical engineers:** structural analysis, heat & mass transfer thermodynamics
- **Undergraduate & graduate level introduction to physics, technology, design, & operation of particle accelerators**

*Then, specialty courses*
US universities with strong programs (alphabetic ordering)

- Cornell University
- Indiana University
- Michigan State University
- Stanford University
- University of California at Los Angeles
- University of Maryland (College Park)

Even these universities offer only 2 or 3 regular courses in accelerator physics & technology

- Also initiating structured Ph.D. programs
  - Colorado State University
  - Massachusetts Institute of Technology
  - Old Dominion University (in affiliation with Jefferson Lab)
  - Stony Brook University (in affiliation with Brookhaven Lab)
Major US universities rely on USPAS as an essential partner in education

- Universities with strong graduate programs in accelerator physics provide the largest student attendance at USPAS
  - Only Maryland, Cornell, MSU, UCLA, & Stanford have strong faculty lines (>2 professors)

**Accelerator-based science needs several more such universities to assure an adequate, well trained professional workforce**

- Universities with research accelerators
  - Emphasize innovation in accelerator science
  - Promote undergraduate awareness
    - MSU - 50 UGs annually; Cornell - 60 UGs annually
  - Offer exciting opportunities to engineering students
  - Encourage student experimentalists to learn about accelerators
  - Are a vanishing breed
US historical context & present population

Number of Ph.D.'s 1982 - 2010

Graduate students in 2011

- Maryland
- MSU
- Cornell
- UCLA
- Indiana
- Wisconsin
- Stanford
- MIT
- Berkeley
The US Particle Accelerator School provides graduate-level educational programs in the science of beams and their associated accelerator technologies.

We grant more academic credit in accelerator science & technology than any university in the world.
US Particle AcceleratorSchool

USPAS charter: educational stewardship
Founded & nurtured under HEP auspices

- Partnership of sponsoring institutions that fund all program costs
  - 7 SC laboratories (FNAL, ANL, BNL, JLAB, LBNL, ORNL, SLAC)
  - 2 NNSA laboratories (LANL, LLNL)
  - 2 NSF funded universities (Cornell, MSU)

- DOE/HEP directly funds USPAS Office at FNAL (Managing Institution)

- SC reaffirms commitment to USPAS governance formula (2010)
  - “we have reviewed the school's history, its successes, & promised benefits of its continuation… if the members of the USPAS Board of Governors... decide that a given school is needed for training personnel, we will support that decision.”
  - “we will, as a consequence, accept the Board of Governors' collective judgment as adequate justification for funding the USPAS with the Federal funds that our programs provide to the respective laboratories.”
Consortium laboratories are strongly committed to this 3-fold partnership.
USPAS stresses academic rigor as required by our host universities

- 2 sessions annually hosted by a major research university
  - 8 intense university, courses run in parallel (45 contact hours in 2 weeks)
  - Courses cover all major topics of interest to government, industry & medicine
  - **Balance physics v. engineering, lectures v. hands-on**

- Average attendance per school ~ 135 students (past 3 years >155)
  - Scholarship support for matriculated students who take courses for credit
  - ~65% of students take courses for credit
  - Credit-student workload during course > 10 hr/day
  - Graded homework & exams

- 48 university-style schools with >3600 individual students
  - Attended more than >1x / >2x / 3x :: >1030 / > 450 / >200
  - >250 have become intellectual leaders in their field
  - >25 USPAS graduate students have become USPAS instructors
  - ~150 USPAS instructors have taken USPAS courses
USPAS covers *all* areas of central interest for government, industry & medicine

**Average class size**

*Our one undergraduate course is essential to undergraduate outreach*

Data S1997 - W2010

**RF courses are very popular; recent enrollments are ~ 20 per class**

*Medical courses also draw >20 since 2008*
Our enrollments show a steady increase.

**USPAS Attendance by Year**

**Our Winter 2014 session was unusually small (119 students)**
USPAS attendance from major US research universities

- PhDs granted (1982 - 2010)
- Graduate students (2012)
- USPAS Enrollments (1999 - 2012)

These universities account for ~90% of USPAS attendees

Historical Database as of Winter 2011
We provide extensive scholarship support

Almost all degree seeking students receive scholarships
USPAS is an unparalleled source of continuing education for the consortium.

Attendance at USPAS sessions from sponsoring institutions from 1987 – 2011
Management training is also important to this constituency.
We are making steady progress in increasing attendance by women.

Our approach begins with increasing the number of women lecturers.

My undergraduate class last summer had 30% women.
Attendees who come to the US for USPAS sessions

This number is sensitive to visa issues. Since 2006 we no longer can issue credit to these participants.
What does this cost?

The USPAS office is funded separately
Session fee is set at the cost neutral marginal rate
Indiana University & USPAS offer

**Master of Science in Beam Physics & Accelerator Technology**

9 degrees awarded; 7 Students currently enrolled in program

Requirements: 30 Credit Hours with grade point average of B or above

IU/USPAS Courses, Master's Thesis (3 - 9 credits), Final Exam or oral defense of thesis

**Old Dominion University** is establishing a **USPAS-affiliated Ph.D.**

- First step: all USPAS courses will be co-listed as ODU courses
- Full set of academic requirements is being vetted by the faculty
- USPAS Director is an Adjunct ODU Physics faculty

Several universities have or are considering routine co-listing of USPAS courses: Indiana, MIT, MSU, ODU, Stony Brook, Cornell, U Chicago
Laboratory undergraduate outreach: Teng Internship at Argonne & Fermilab

- Engage highly, promising post-junior undergrads to study accelerator science & technology
- Encourage them to pursue graduate research & education in these fields
- Interns study Fundamentals at USPAS
- During remainder of summer, students undertake research project at the labs
- ANL & FNAL selected 11 Teng interns each year in 2008 - 2011

Lee Teng Undergraduate Internship in Accelerator Science & Engineering

The Lee Teng Internship is a highly competitive education and research opportunity, open to students from US universities who have just completed their junior year in physics or engineering. Teng scholars will receive a full scholarship to attend the US Particle Accelerator School Summer Session followed by an eight-week research internship at Fermilab or Argonne National Laboratory. Research projects will be of sufficient depth for a senior thesis. The internship offers full travel support and a generous stipend.

For further information and to apply see www.leetengscholar.org
Our outreach over the oceans:
Joint International Accelerator School

- Organized by USPAS & CAS together with the Budker Institute for Nuclear Physics & KEK
  - Strengthens collaborative relationships by working together on an advanced topical course
  - Venues alternate among the four regions

- Focused on specialized topics in accelerator physics & technology
  - Follows the symposium style used by the CERN School

- The First Topical Course (Nonlinear Dynamics) was held in Europe 1985 under joint USPAS-CAS sponsorship

- The most recent was the 11th Topical Course in 2011 on synchrotron light sources & FELs in Erice
Our students will be the future leaders for our field...

For industry a summer internship program would train students to system oriented thinking
Thank you