Educating the Next Generation of Scientists & Engineers for America

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Motivations: Why does the Nation care? Why should students care?

Medicine

Materials

Exciting products… exciting opportunities

Basic Research
Accelerators are the hallmark of highly technological societies

Societal applications & their technology develop from basic research

Source: U. Amaldi
Accelerators are big business

Number of accelerators worldwide

~ 26,000

- Radiotherapy (>100,000 treatments/yr)*
- Medical Radioisotopes
- Research (incl. biomedical)
- >1 GeV for research
- Industrial Processing and Research
- Ion Implanters & Surface Modification

Annual growth is several percent

Sales >3.5 B$/yr
Value of treated good > 50 B$/yr **

Major research machines are a tiny fraction of the total, but…

Sources: W. Maciszewski & W. Scharf, L. Rivkin, * EPP2010, ** R. Hamm
World-leading discovery science is America’s competitive advantage

Accelerators are essential tools for discovery in physics, chemistry & biology
World-leading scientific education is also America’s competitive advantage

We attract and train top talent from around the world to attend US universities & use US scientific facilities
DOE accelerators train future physicists, chemists & biologists for America

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

- 6100 BES
- 1500 HEP
- 1300 NP

~ 50% non-US users

~ 1400 PhD/yr in physics in US

Roughly 2/3 of facility users are students
Who pilots the machines?

- These machines are conceived of, design, built, operated & up-graded by a few hundred accelerator physicists
  - A large fraction of these were trained outside the US

- Many of my generation were HEP & NP experimentalists who learned about machines at accelerators on campus
  - Very few of these now exist

- Modern accelerators also require a much larger (2 - 3x) cadre of knowledgeable engineers
  - Many critical courses are no longer offered in engineering departments
    - e.g., power electronics, microwave & rf-systems
To summarize the problem

- Accelerators are essential tools for discovery science
- DOE spends almost 1 B$ on major accelerator facilities
- > 26,000 accelerators in medicine, industry & national security constitute a multi-billion dollar/yr industry
- > 55,000 peer-reviewed papers having accelerator as a keyword are available on the Web

Yet...

*Only a handful of universities offer any formal training in accelerator science & technology*
Moreover, accelerators for future science...

- Will be more challenging to design & build
- Will be more challenging to operate
- Will need outstanding physicists & engineers to realize
- Will need experimentalists knowledgeable about accelerators to exploit fully
Reasons & excuses

Structure:
- Accelerator science is inherently cross-disciplinary

Prejudices:
- Physics departments, “accelerator science is ‘just technology’”
- EE departments prefer nano-technology & computing science

Practicalities:
- It is difficult to enroll enough students for university approval
  - Even Cornell, UCLA, & Stanford can only offer core courses

→ *Accelerator R&D at universities is insufficient to support strong faculty lines*
This serious challenge was recognized by HEPAP sub-panels

• “The education & the training of the next generation of accelerator scientists & engineers is a serious concern.”

• “The limited number of educational opportunities at universities is insufficient to meet anticipated future needs.”
  Advanced Accelerator R&D Sub-panel Report

• "The present University Grant Program level of effort shortfall is not consistent with US intentions to host the ILC.”
  University Grant Program Sub-panel Report

The USPAS is dedicated to responding to this challenge
DOE & its laboratories must…

…Attract top undergraduate talent to graduate study of accelerator physics as well as accelerator-based science

USPAS students won all top prizes at PAC2009

Satomi Shiraishi (Chicago)  Evelyn Meier (Monash)  Anna Grasselino (Penn)  (not pictured) Marsh Roark (MIT)

The USPAS is a central element in accelerator education in America
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.
Major US universities are our essential partners in education

 Universities with strong graduate programs in accelerator physics provide a large 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
Eight universities represent 80% of university attendees at USPAS (‘99 - ‘08)

Of remaining PhDs granted (30%) many are from other lab-associated universities

US Particle Accelerator School

USPAS charter & financial model for educational stewardship

- Founded & nurtured under HEP auspices
- Letter from the four Energy Research AD’s allows & encourages national laboratory sponsorship & support (1992)
  - Re-confirmed by DOE/SC & NSF in 2008
- Constituted as a partnership of sponsoring institutions
  - 7 SC laboratories (FNAL, ANL, BNL, JLAB, LBNL, ORNL, SLAC)
  - 2 NNSA laboratories (LANL, LLNL)
  - 2 NSF funded universities (Cornell, MSU)
  - 1 DHS office (DNDO/TARD)
- Partner institutions have funded all program costs
  - Partner support - 30 k$/yr + faculty (only increased once in ~20 years)
- HEP funds USPAS Office at FNAL
  - Managing Institution
2 schools annually hosted by a major research university

- 8 intense university, courses run in parallel (45 contact hours in 2 weeks)
- Balance physics v. engineering, lectures v. hands-on

Typical attendance per school ~ 130 students (recently ~150)

- Scholarship support available for matriculated graduate students who take courses for credit
- Credit-student workload during course > 8 hr/day
- Graded homework & exams

40 university-style schools with >3100 individual students

- Attended more than >1x / >2x / 3x >1030 / > 450 / >200
- >200 have become intellectual leaders in their field
- >25 USPAS graduate students have become USPAS instructors
We continually develop new offerings for our constituency

- New lecture courses in 2008
  - Optics of High Energy Accelerators
  - Radiation Imaging for Medicine & Homeland Security
  - Special opportunity: “Vacuum Electron Devices”
- 2 new, *hands-on* courses introduced in 2008 & 2009
  - Synchronization, Timing & RF Signal Processing
  - Synchrotron Light-based Beam Diagnostics
  - Accelerator Diagnostics
The strongest demand is for fundamentals

Average attendance in classes (1997 - 2009)

* In 2008 two medicine related courses had more than doubled to > 20 students
We expect another session of ~150 students; two-thirds receive financial support.

The present USPAS financial model cannot sustain this level of student enrollment / support.

* Years with visa issues; ~25% of attendees come from outside the US.
USPAS partners provide 2/3 of our faculty

We thank our instructors for their dedicated work.
DOE labs have made excellent use of USPAS

![Graph showing USPAS attendances by staff from consortium labs]

**Normalizing MSU & Cornell by operating budget**

==> interest level equivalent to Fermilab and SLAC
Degree Programs
&
Academic Outreach
Master of Science
in
Beam Physics and Accelerator Technology
from
Indiana University & USPAS

7 degrees awarded

6 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 Examination or oral defense of thesis

Nearly all are lab employees who get a promotion as a result
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 and FNAL selected 11 Teng interns in 2008 & 2009
- We provide advice on graduate programs
Established in 1987

- 1st graduate M. Syphers (UIC)
  - Taught 11 USPAS courses

On average 5-8 students in the program simultaneously

- 37 PhD graduates in 22 years

Students apply & propose course of research

- Admitted after passing university qualifying exams
- Each has an University advisor & FNAL mentor
- Research supported by FNAL

http://phd.fnal.gov
Joint effort to nurture & grow existing efforts in accelerator science

- BNL’s RHIC, NSLS & ATF provide unique opportunities for cutting-edge graduate & undergraduate accelerator research

The **CASE** Mission:

Pursue cutting edge accelerator R&D,

*Train next generation accelerator scientists* - graduate & post doctoral

*Attract undergraduate students to the graduate program* through introductory courses, laboratory work & summer internships at BNL

Growth opportunities:

- Expand successful Ph.D. and M.S. program
- Attract the next generation students
  - Write & teach a curriculum for undergraduates
  - Sponsor a Scholarship Program to attract top undergraduates to USPAS

Now operating from SBU seed grant & matching funds from BNL
National Laboratory programs alone will not provide the accelerator professionals that America needs.

Assuring the future vitality of accelerator-based science & business requires a new DOE investment in education.
Impediments we face…

- Undergraduates must be aware of the intellectual challenge & excitement of accelerator science
- Top undergraduates expect to study at a great university
- Students should spend a large fraction of time on campus
  ➤ An education at a great lab is not an education at a great university

*But, where?*
How to begin…

- Some universities have occasional courses
  - Make them regular not just special topics

- DOE lab facilities offer thesis research opportunities
  - Augment with student support (tuition, assistantships, etc.)

- ANL & FNAL have Lee Teng accelerator internships
  - Other labs should follow suit

- USPAS offers the opportunity to co-list core courses

*But, campuses need accelerator physics/engineering faculty*
  - Strong university-based research programs to support faculty lines
1) Expand university-based programs

- Vigorous, PI-driven program at universities allows growth of targeted, high priority R&D relevant to DOE/SC
  - Essential for innovations in accelerator science
  - Students can be trained & educated in accelerator science and technology in proximity to top experimentalists & theorists

- University programs can take a broad perspective with relation to exploratory accelerator science & technology
  - Offer broad intellectual resources both within physics and allied fields such as engineering, optical sciences, & materials sciences
  - Optimize incubation of new ideas & fundamental understanding

- Highly trained cadre of accelerator scientists will be essential to DOE/SC mission & national competitiveness
2) Assure USPAS financial stability

- Broad variety of USPAS offerings & scholarship support are crucial to existing programs in American universities
- USPAS provides an ideal attraction point & launching pad for undergraduates
- Maintaining the present level of enrollment & student support requires direct SC funding of USPAS sessions
Our students will be the future leaders for our field...
US Particle Accelerator School

... and not just leaders in accelerator physics

AGS operator

Physics PhD

B.A. Physics

Spokesperson: MicroBooNE ArgoNeut

BARNARD

Yale Professor
Bonnie Fleming
The time to invest is now!

Thank you
Schools across the Sea
Training courses for accelerator physicists & engineers twice a year
  ➡️ Began in 1983
  ➡️ The courses take place in different member states of CERN
  ➡️ Consist of lectures & tutorials spread over a period of one or two weeks.
    • Participants from CERN member states & other countries world-wide
  ➡️ Director: Daniel Brandt

Pattern of courses
  ➡️ Spring course on a specialist topic
  ➡️ Autumn course on accelerator physics
    • at the introductory level in even years
    • at the intermediate level in odd years
  ➡️ In even years an autumn course in the framework of the Joint Accelerator School (JAS) program
    • JAS is a collaboration between US, CERN, Russia and Asia

_sessions lead to high quality, written proceedings
  ➡️ See http://cas.web.cern.ch/cas/Proceedings.html
Intensive program for students & modular courses for professionals

The full program covers many subjects during 10 weeks from January to March
  ➔ Two five-week courses taught by Europe's accelerator specialists
  ➔ Whole program includes about 180 hours of lectures, tutorials, guided studies & seminars
  ➔ Lectures and tutorials are backed up by site visits / demonstrations

Organized by European Scientific Institute
  ➔ With support of CERN Accelerator School & several major European Universities
  ➔ Examinations under the control of one of the partner universities validate the courses
    • Successful candidates may obtain credits at their home university through the European Credit Transfer System (ECTS)
    • It is recommended that all students take the examinations, which are mandatory for those students who receive a grant
### We make different choices to serve different needs

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There are also specialty schools such as the recent Linear Collider Schools