Educating the Next Generation of Scientists & Engineers for America

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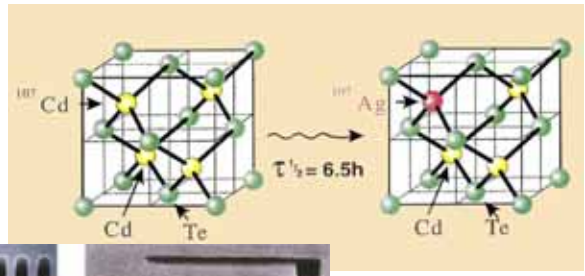
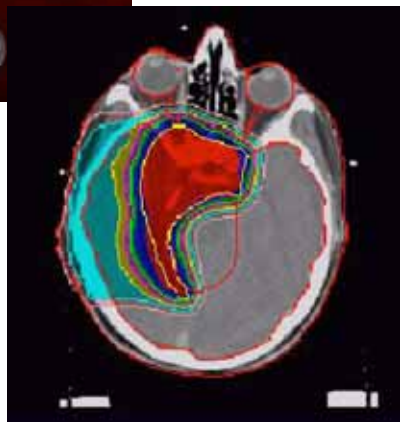
Motivations: Why does the Nation care? Why should students care?

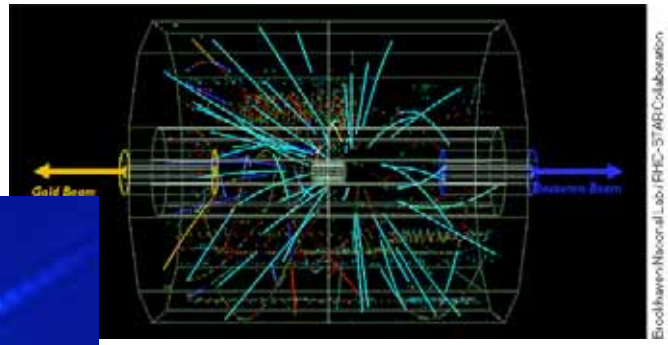


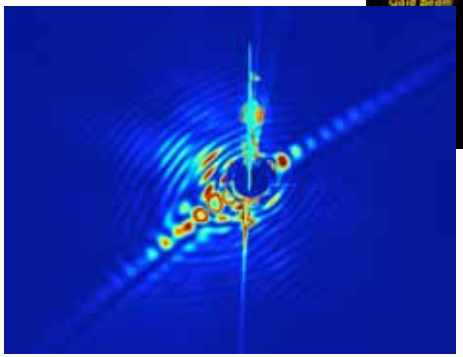
Materials

Medicine



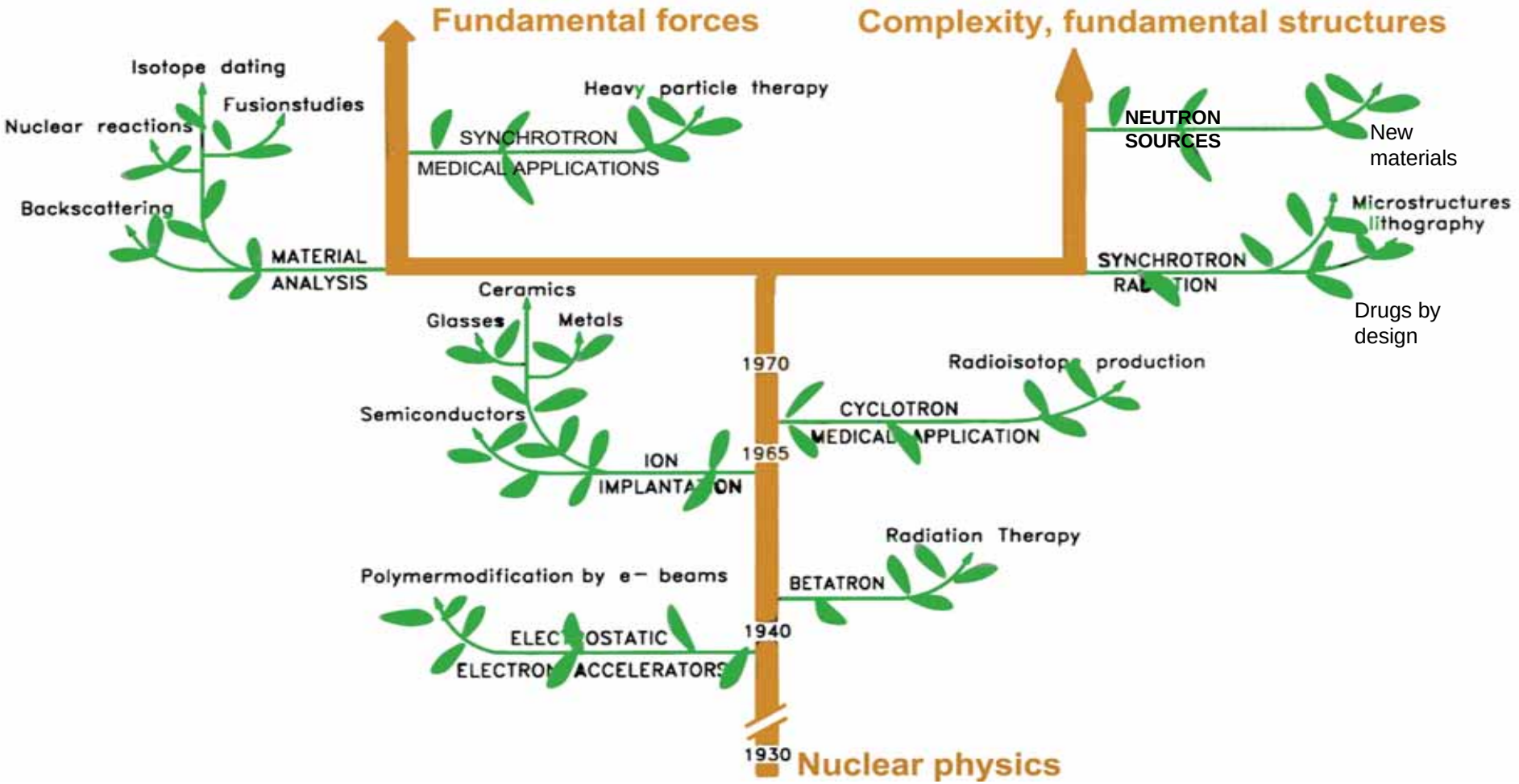
Basic Research





Exciting products…
exciting opportunities

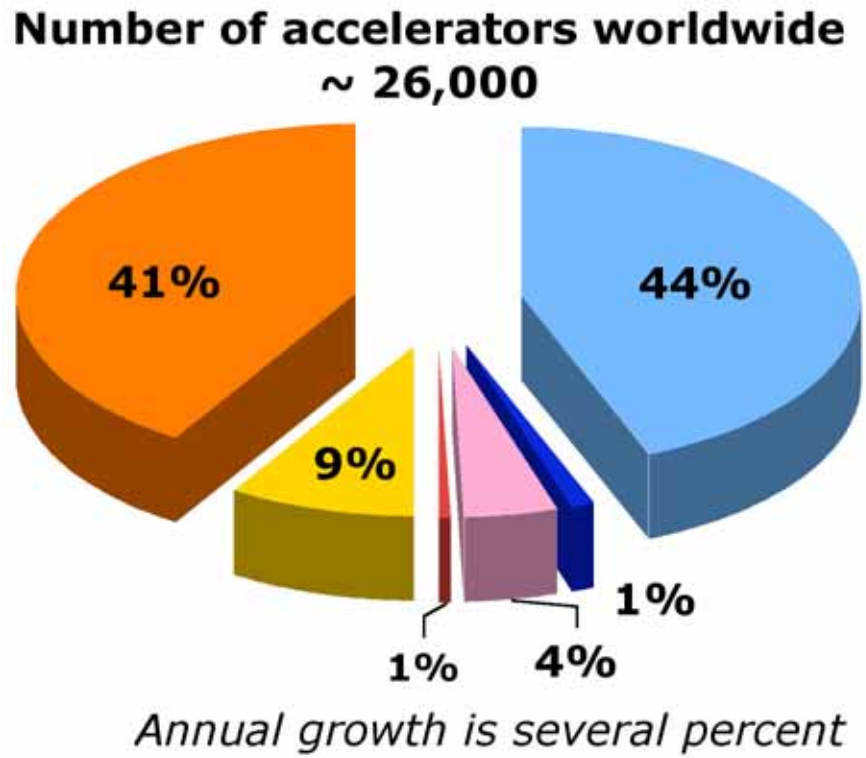
Accelerators are the hallmark of highly technological societies



Societal applications & their technolgy develop from basic research

Source: U. Amaldi

Accelerators are big business



Radiotherapy (>100.000 treatments/yr)*

Medical Radioisotopes

Research (incl. biomedical)

>1 GeV for research

Industrial Processing and Research

Ion Implanters & Surface Modification

Sales >3.5 B$/yr

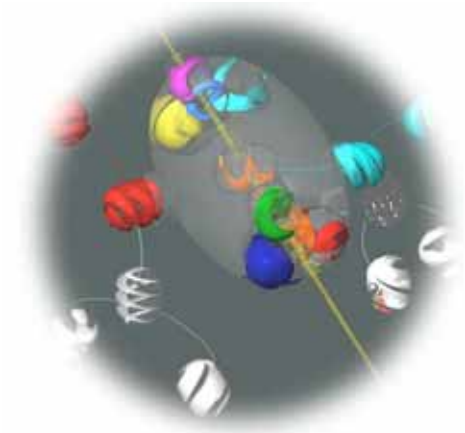
Value of treated good > 50 B$/yr **

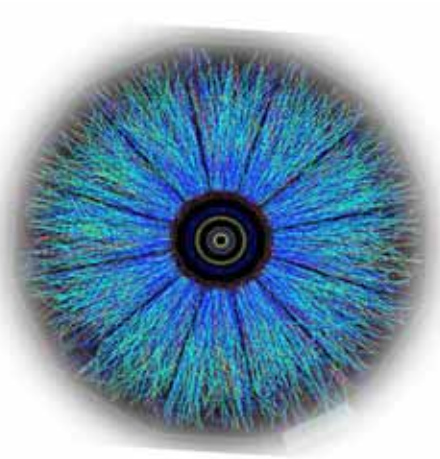
Major research machines are a tiny fraction of the total, but…

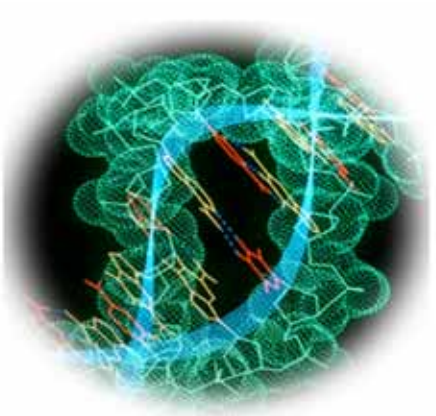
Sources: W. Maciszewski & W. Scharf, L. Rivkin, * EPP2010, ** R. Hamm

World-leading discovery science is America's competitive advantage

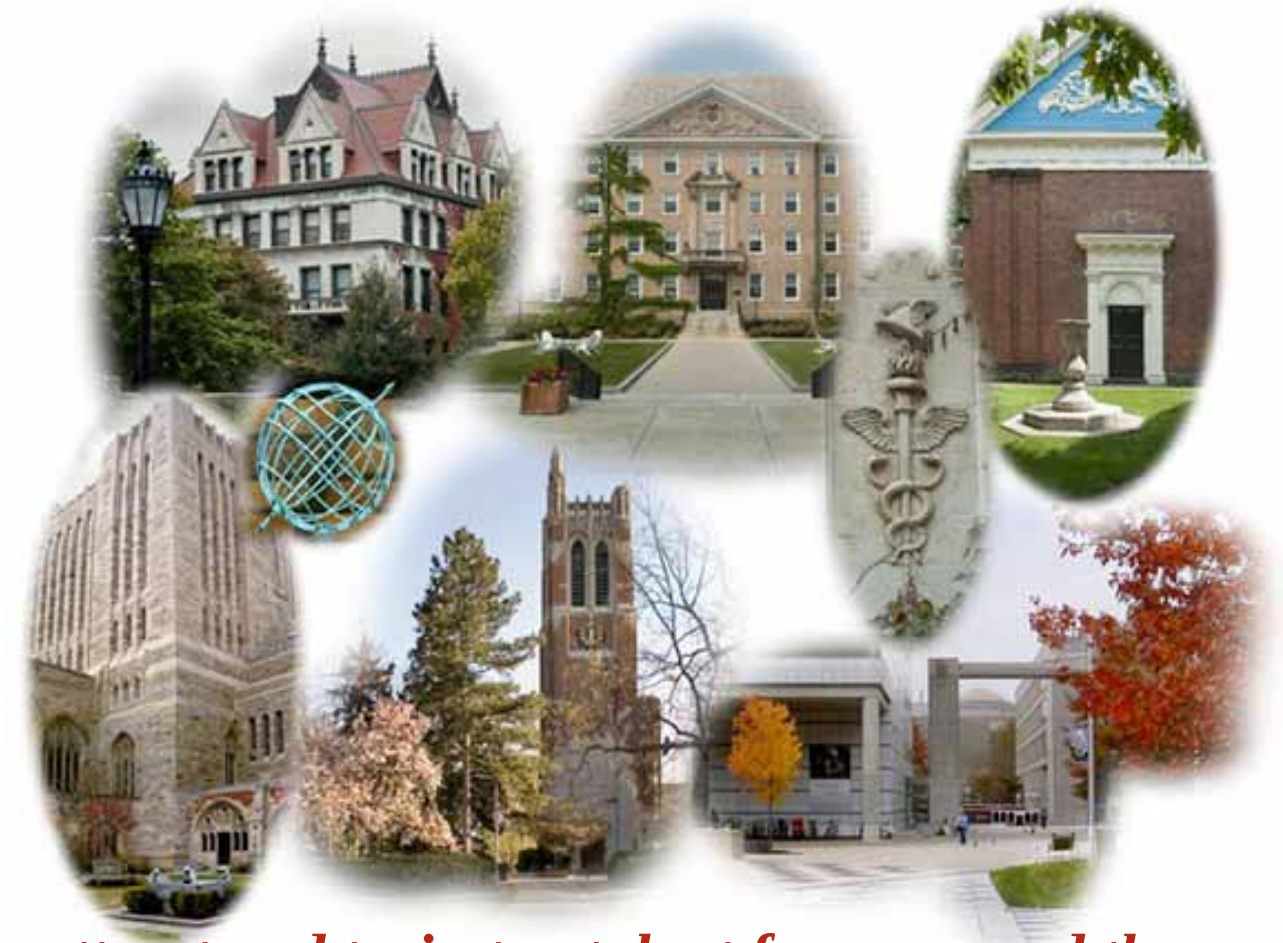
Accelerators are essential tools for discovery in physics, chemistry & biology







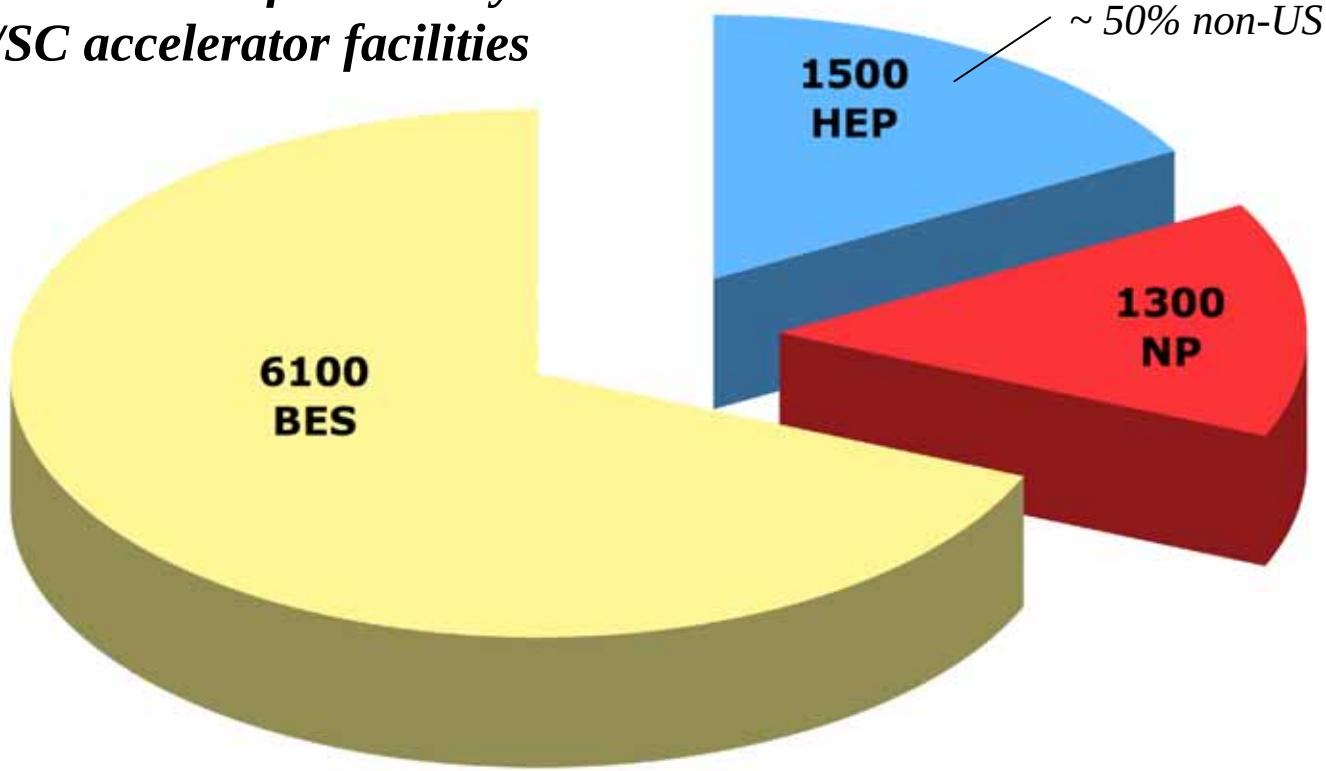
World-leading scientific education is also America's competitive advantage



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



~ 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

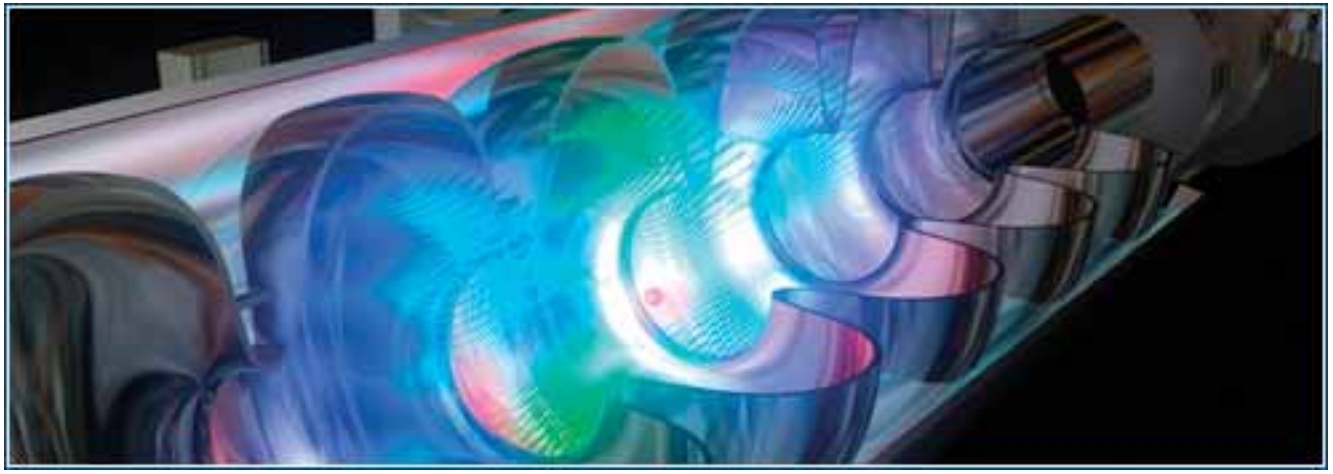
- Accelerators are essential tools for discovery science
- DOE spends almost 1 B$ on major accelerator facilities
- > 26,000 accelerators in medicine, industry & national security constitute a multi-billion dollar/yr industry
- > 55,000 peer-reviewed papers having accelerator as a keyword are available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

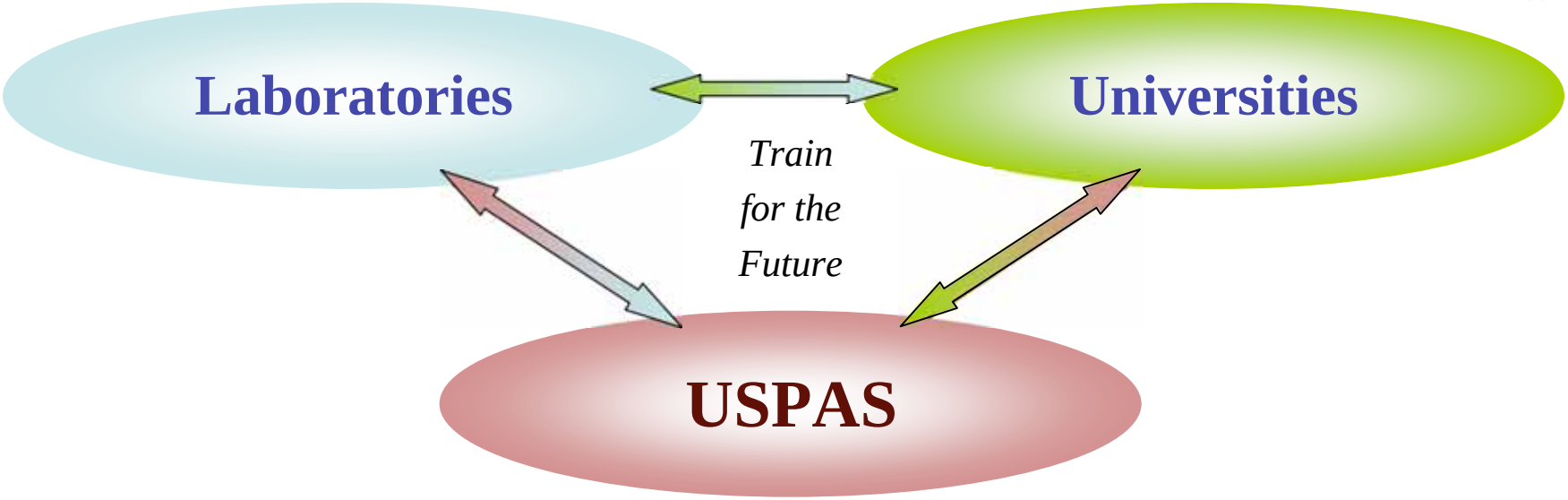
DOE & its laboratories must…

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

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 USPAS Partnership Vision



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

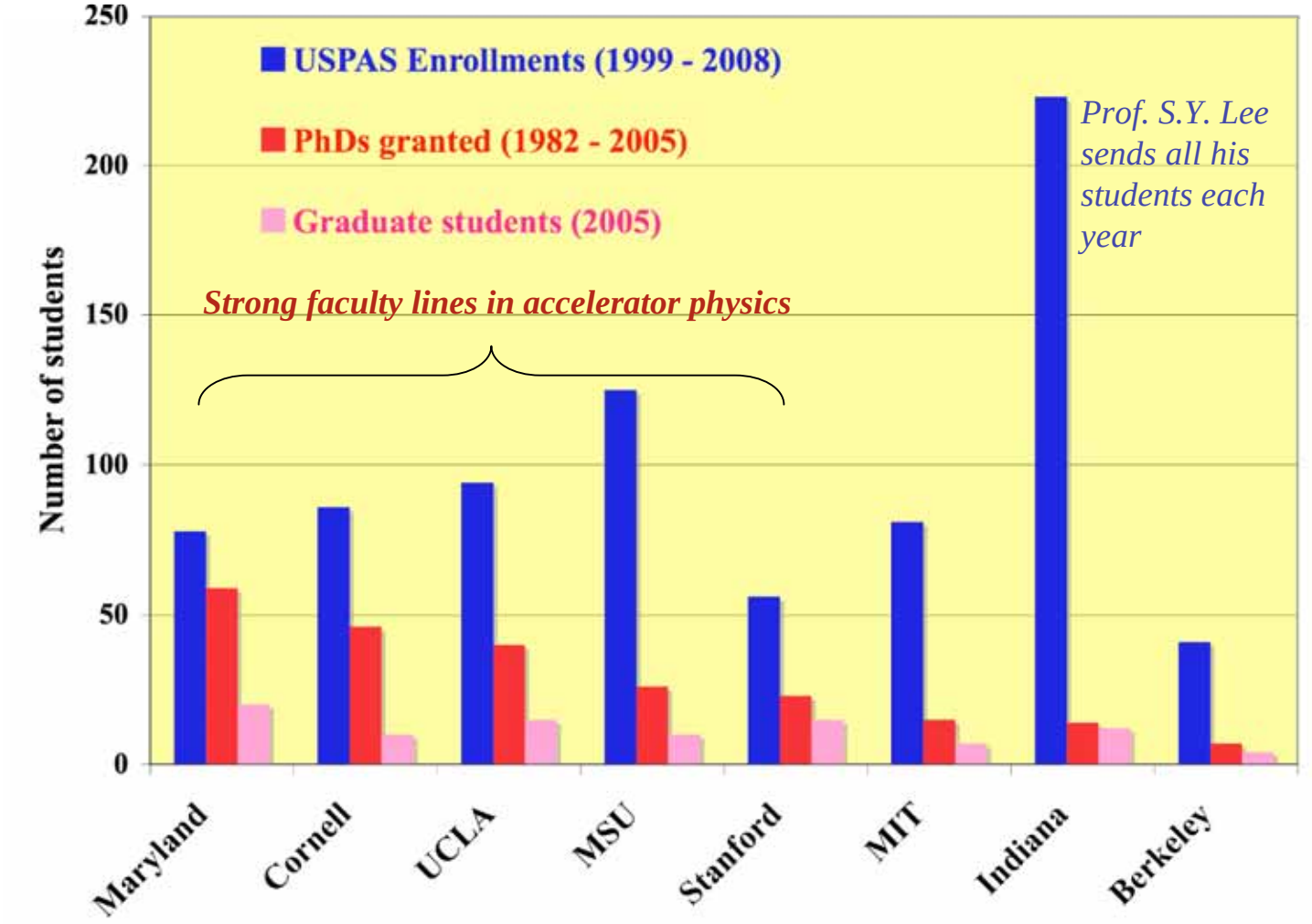
Major US universities are our essential partners in education

- 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

Source: AARD 2005 Year Book, private communications (2008)

USPAS charter & financial model for educational stewardship

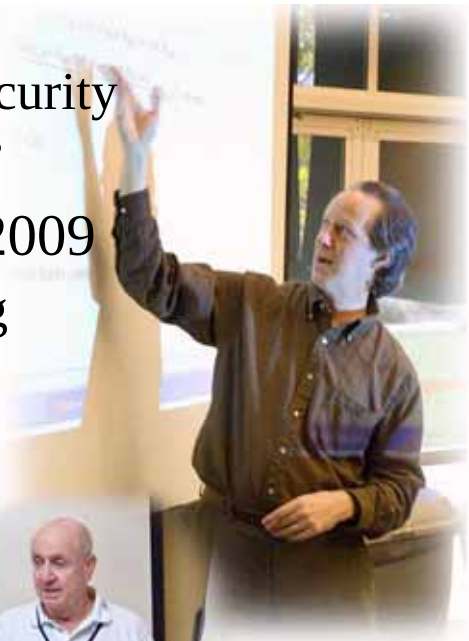
- Founded & nurtured under HEP auspices
- Letter from the four Energy Research AD's allows & encourages national laboratory sponsorship & support (1992)
  - → Re-confirmed by DOE/SC & NSF in 2008
- Constituted as a partnership of sponsoring institutions
  - → 7 SC laboratories (FNAL, ANL, BNL, JLAB, 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

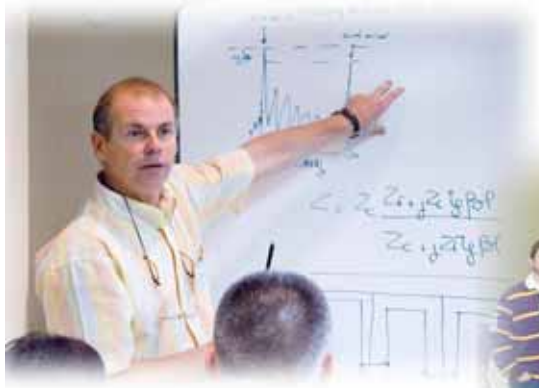
USPAS educational operations stress academic rigor

- 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

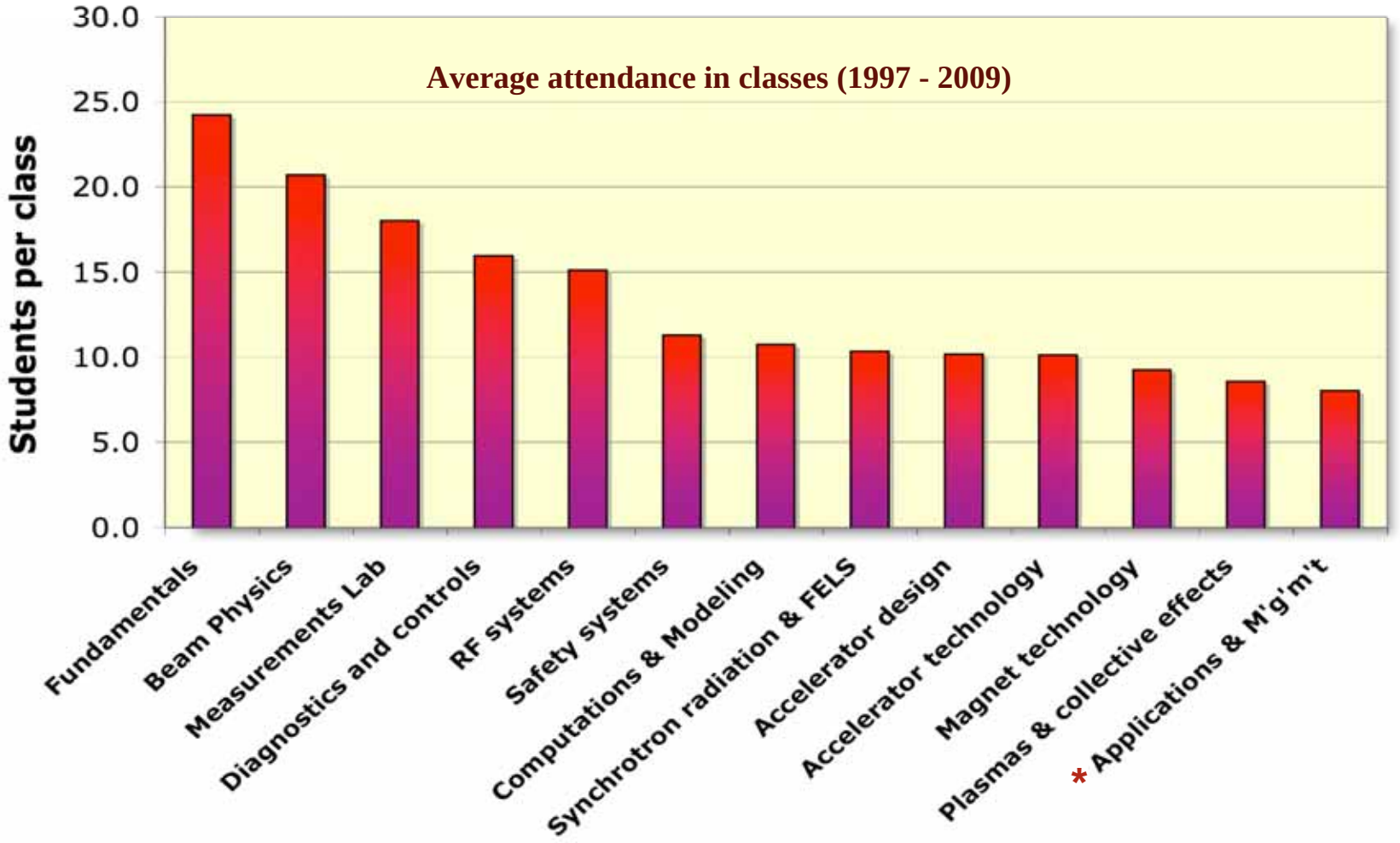
We continually develop new offerings for our constituency

- 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



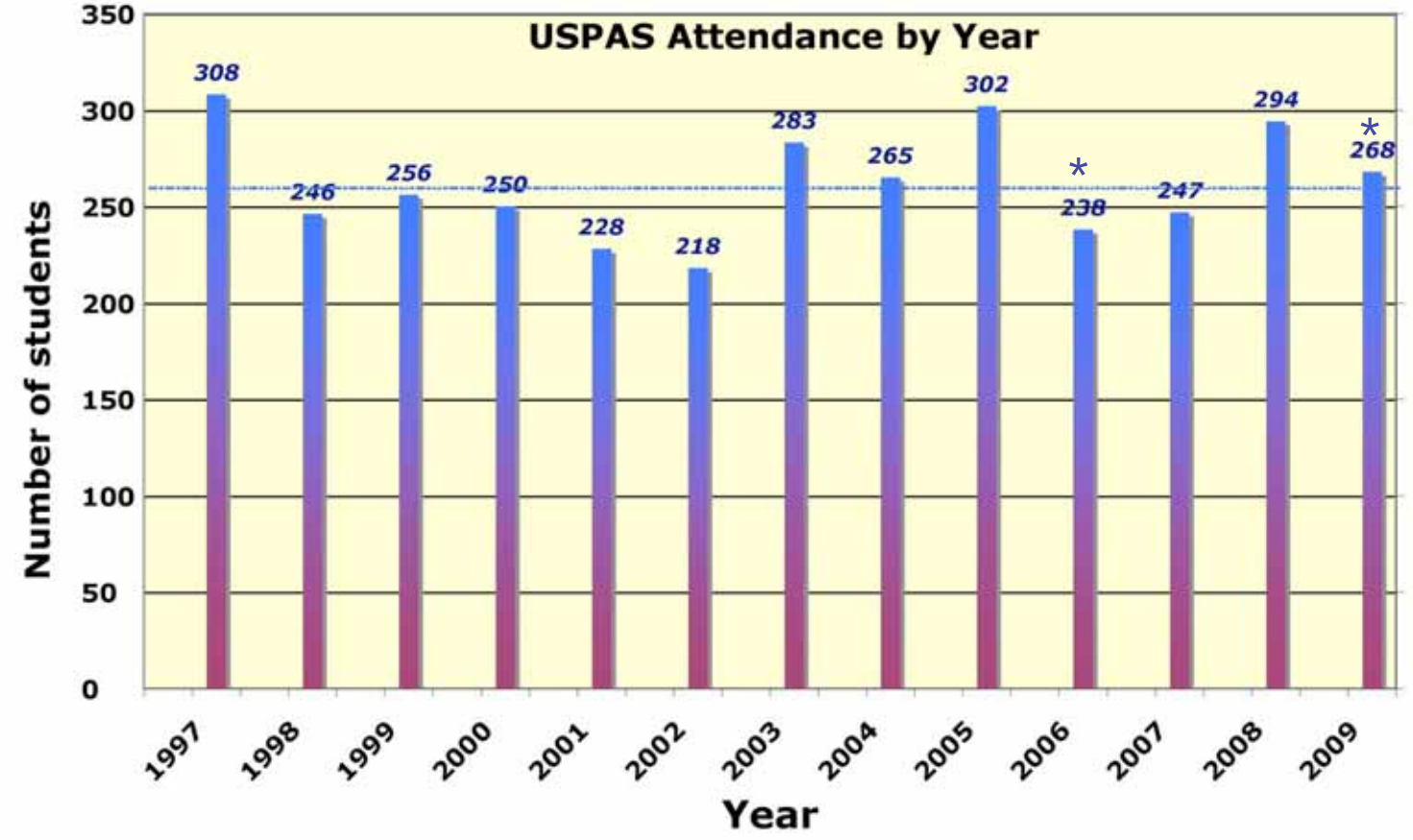


The strongest demand is for fundamentals



** 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



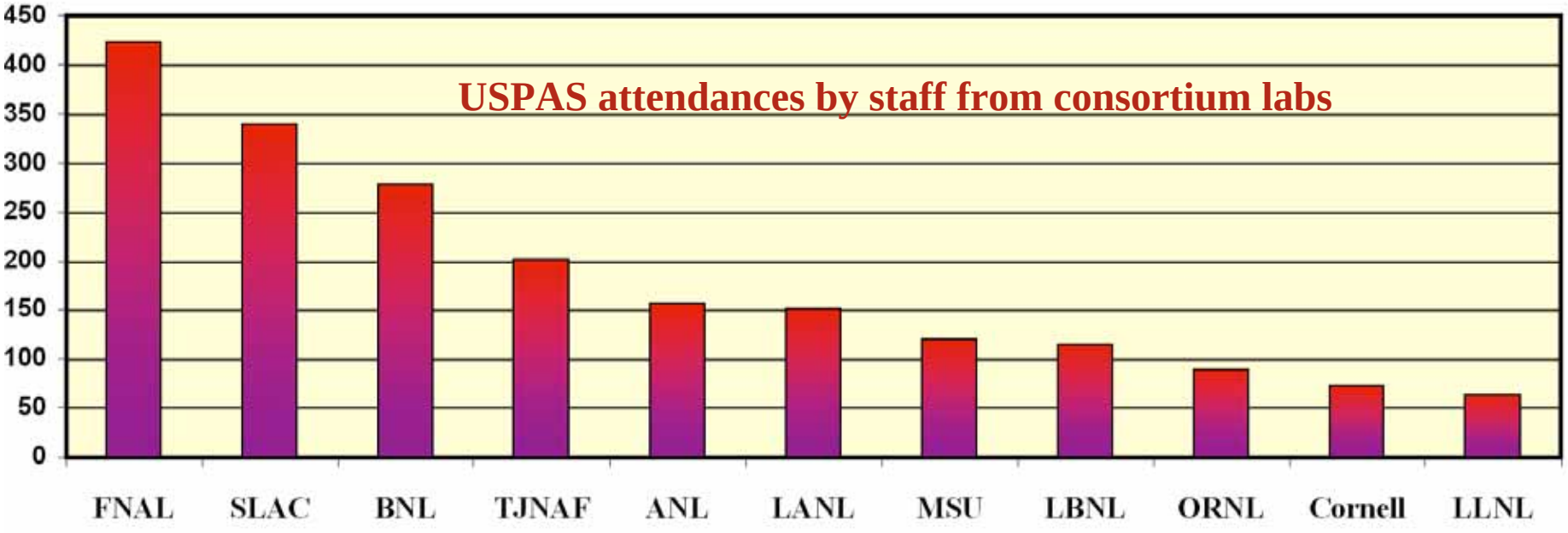
* Years with visa issues; ~25% of attendees come from outside the US

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

USPAS partners provide 2/3 of our faculty

We thank our instructors for their dedicated work

DOE labs have made excellent use of USPAS



Normalizing MSU & Cornell by operating budget
==> interest level equivalent to Fermilab and SLAC

Degree Programs

&

Academic Outreach

USPAS Degree Program

Master of Science

in

Beam Physics and Accelerator Technology

from

Indiana University & USPAS

7 degrees awarded

6 Students currently enrolled in program

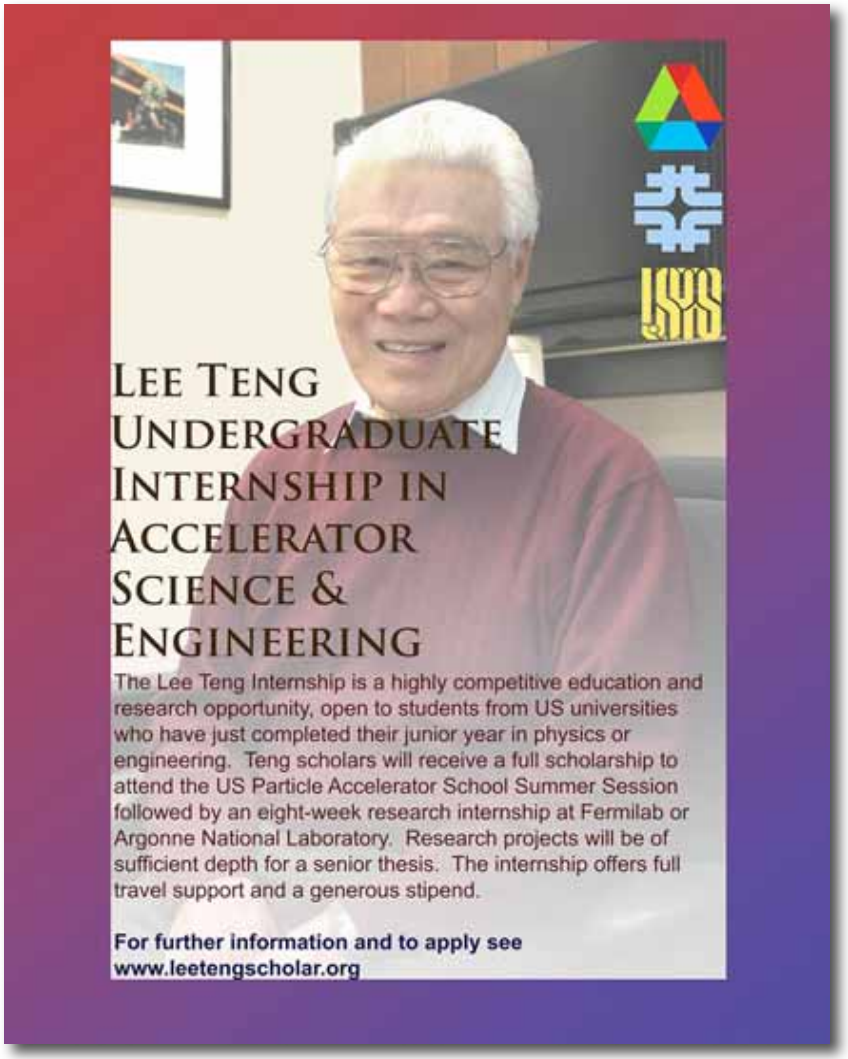
Requirements: 30 Credit Hours: with grade point average of B or above

* 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

Joint University-Fermilab Program: Accelerator Physics PhD

- 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

BNL & Stony Brook University: Center for Accelerator Science & Education

- 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

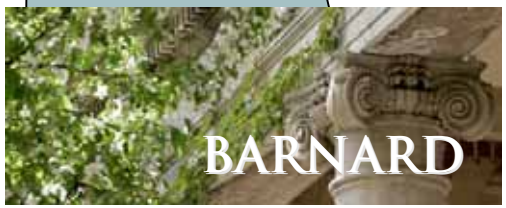
Our students will be the future leaders for our field…

MIT … and not just leaders in accelerator physics

AGS operator

Physics
PhD

Yale Professor
Bonnie Fleming



B.A. Physics

Spokesperson:
MicroBooNE
ArgoNeut

The time to invest is

now!

Thank you

Schools across the Sea

CERN Accelerator School

- 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

The Joint Universities Accelerator School

- 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

	USPAS	CAS	JUAS	JIAS
Rigorous for-credit courses	Y	N	Y	N
Degree program available	Y	N	N	N
Frequent regular sessions	2/yr	2/yr	1/yr	N
Standing organization w. staff	Y	Y	Y	N
Duration (weeks)	2	1.5 -2	10	1.5 -2
On campus	N	N	N	N
Conference center/ hotel	Y	Y	Y	Y
Scholarships available	Y	Y	Y	Y
Specialty courses	Y	Y	Y	Y
Fundamental courses	Y	Y	Y	N
Hands-on courses	Y	N	N	N
Proceedings	N	Y	N	N
Lecture notes on web	Y	Y	N?	Y?

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