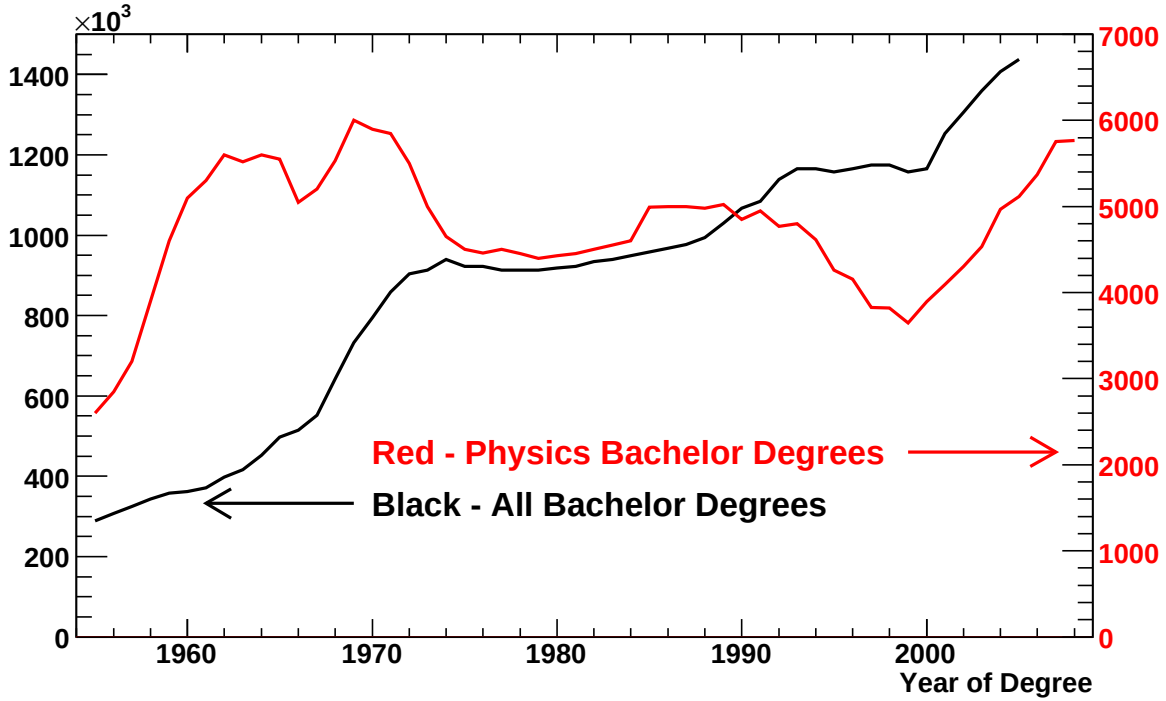
Physics Bachelor Degrees (Who and Where)

- Physics Majors:
  How many?



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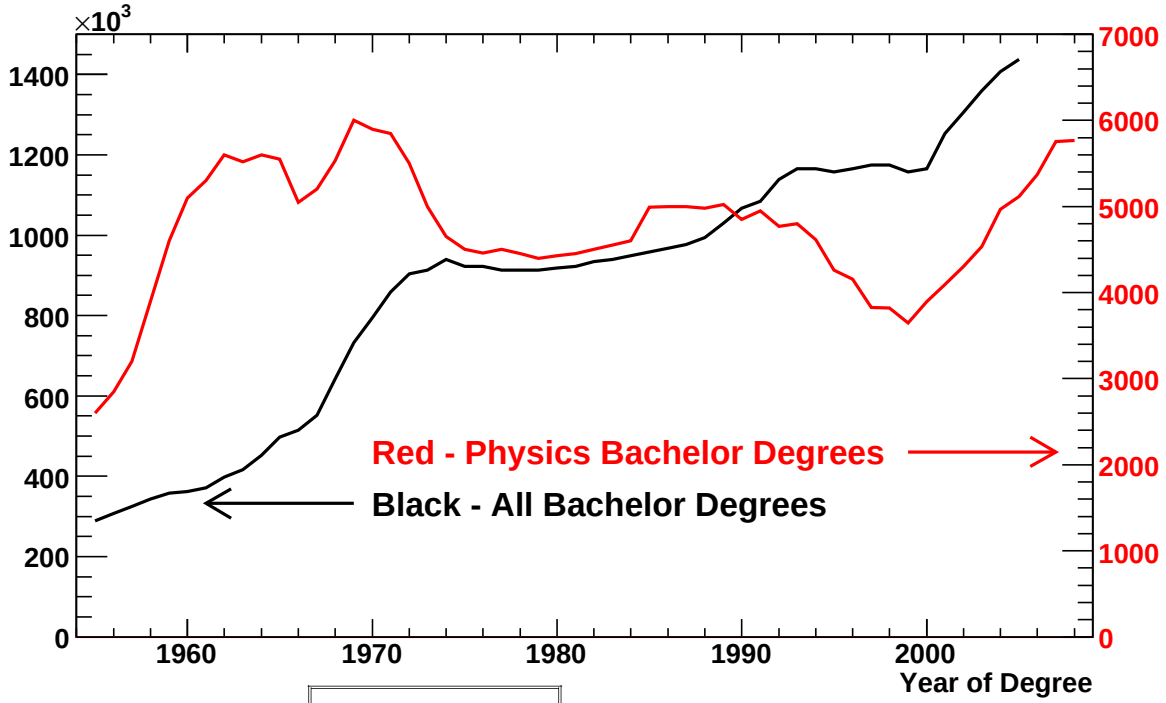

- Where do they go to school?

Number of Departments by Highest Degree Offered	
Bachelor's	509
Master's	64
PhD	189
Total Departments	762

Physics Bachelor Degrees (Who and Where)

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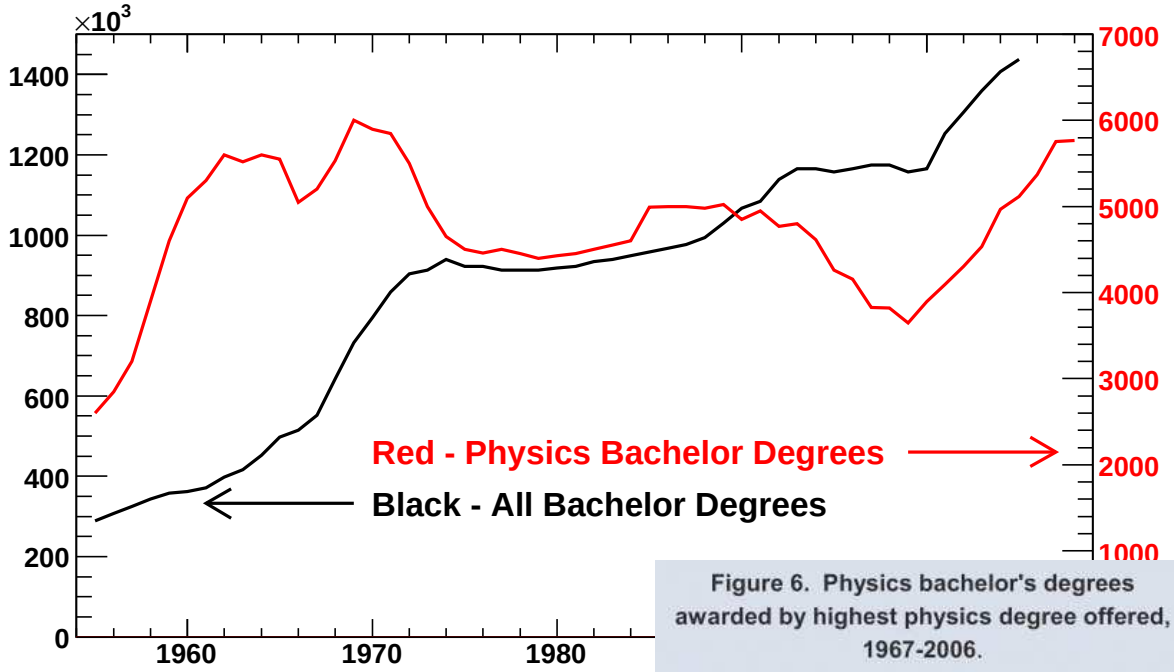

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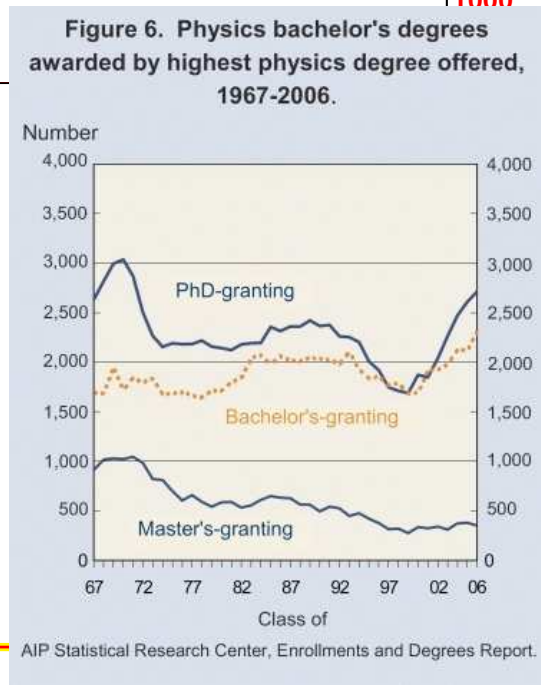
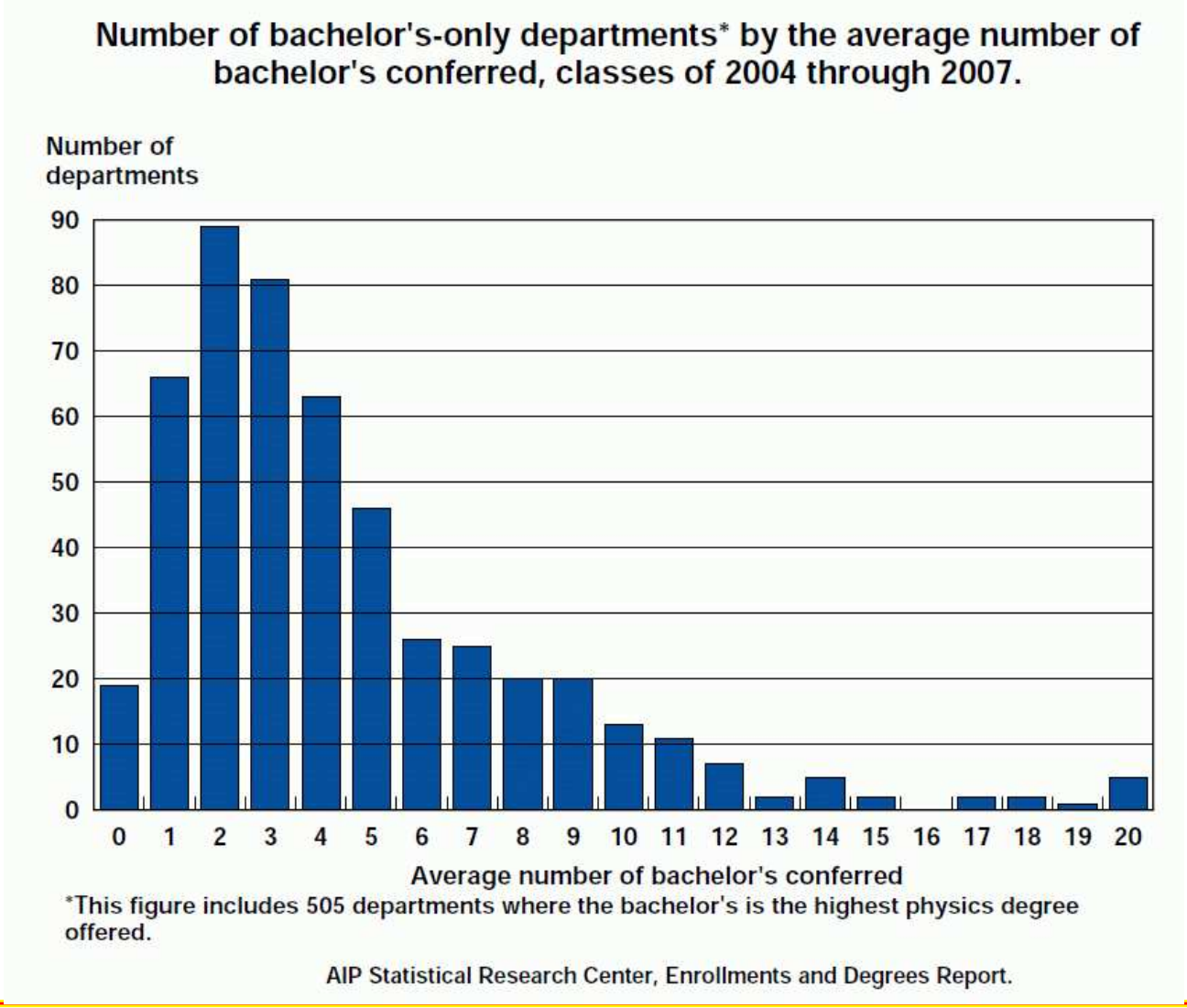


Data from the AIP Statistical Research Center and the NSF S&E Indicators 2008.

Undergraduate Physics Programs in the US

- How precarious are Primarily Undergraduate Institutions (PUIs)?



Undergraduate Physics Programs in the US

- Do we (at the PUIs) despair?

TABLE 2. Top 50 baccalaureate-origin institutions of 1997–2006 S&E doctorate recipients, by S&E doctorate recipients per hundred bachelor's degrees awarded in all fields 9 years earlier, institutional control, and 2005 Carnegie classification

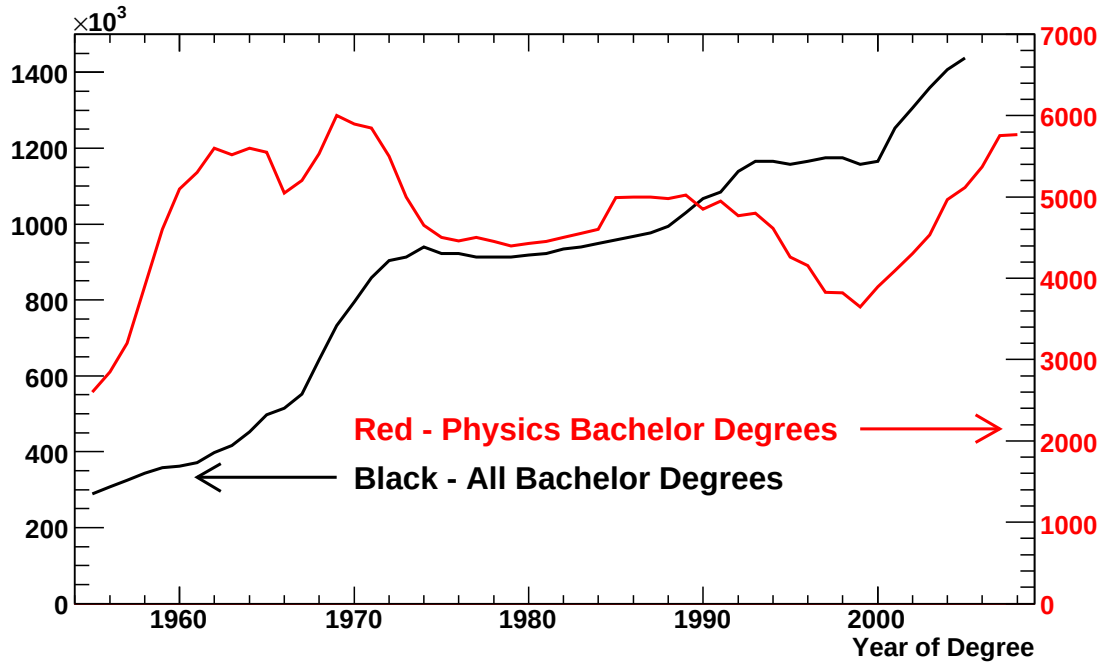
Rank	Academic institution	Institutional control	2005 Carnegie classification	1997–2006 S&E doctorate recipients	1997–2006 S&E doctorate recipients per hundred bachelor's awarded 9 years earlier
1	California Institute of Technology	Private	Research-very high	713	35.2
2	Harvey Mudd College	Private	Baccalaureate	329	24.9
3	Massachusetts Institute of Technology	Private	Research-very high	1,867	16.6
4	Reed College	Private	Baccalaureate	353	13.8
5	Swarthmore College	Private	Baccalaureate	482	12.9
6	Carleton College	Private	Baccalaureate	525	11.7
7	University of Chicago	Private	Research-very high	873	10.8
8	Grinnell College	Private	Baccalaureate	338	10.5
9	Rice University	Private	Research-very high	664	10.5
10	Princeton University	Private	Research-very high	1,135	10.3
11	Harvard University	Private	Research-very high	1,775	9.9
12	Bryn Mawr College	Private	Baccalaureate	276	9.7
13	Haverford College	Private	Baccalaureate	264	9.5
14	Pomona College	Private	Baccalaureate	323	9.1
15	New Mexico Institute of Mining and Technology	Public	Master's granting	118	8.7
16	Williams College	Private	Baccalaureate	428	8.4
17	Yale University	Private	Research-very high	1,087	8.4
18	Oberlin College	Private	Baccalaureate	577	8.2
19	Stanford University	Private	Research-very high	1,351	8.1
20	Johns Hopkins University	Private	Research-very high	691	7.7
21	Kalamazoo College	Private	Baccalaureate	195	7.7

National Science Foundation Report, 08-311, July, 2008.

Physics Bachelors (Who and Where: The Women)

- Physics Majors:

  How many?



Physics Bachelors (Who and Where: The Women)

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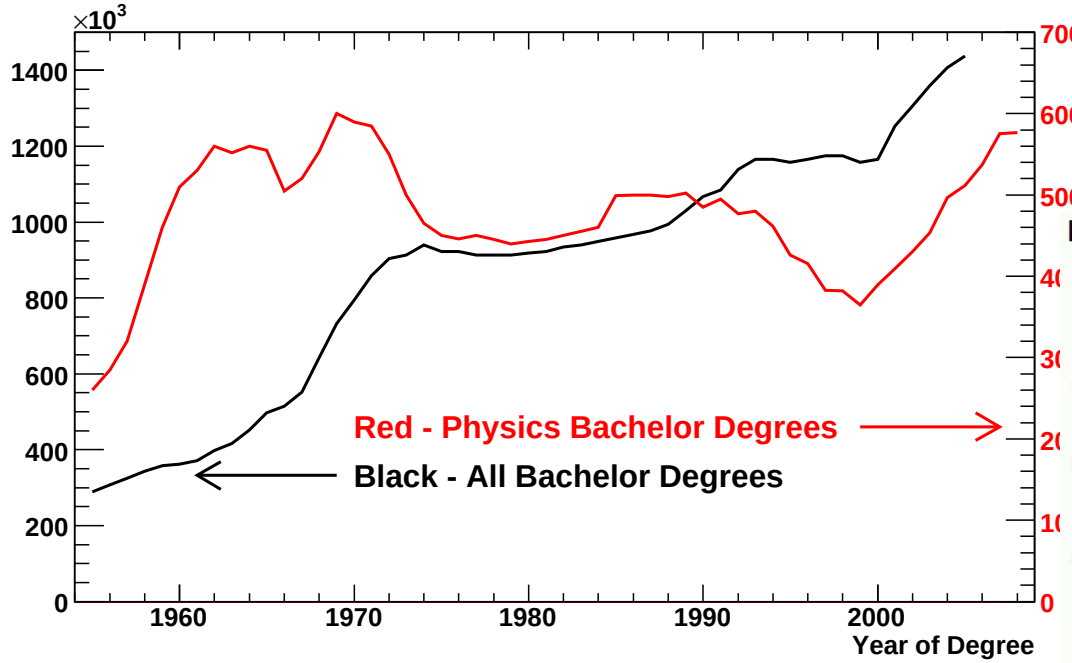
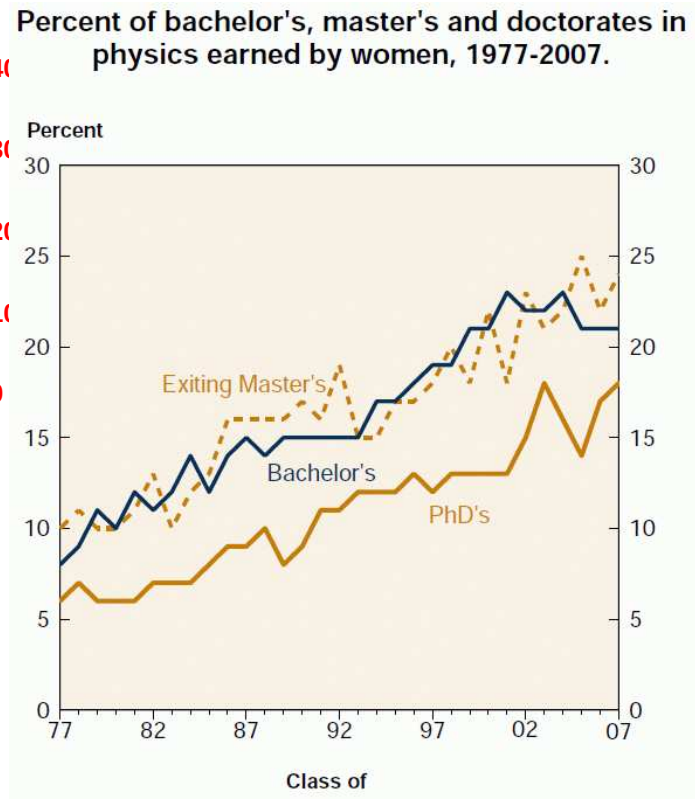


- Percentage of Women



Data from the AIP Statistical Research Center and the NSF S&E Indicators 2008.

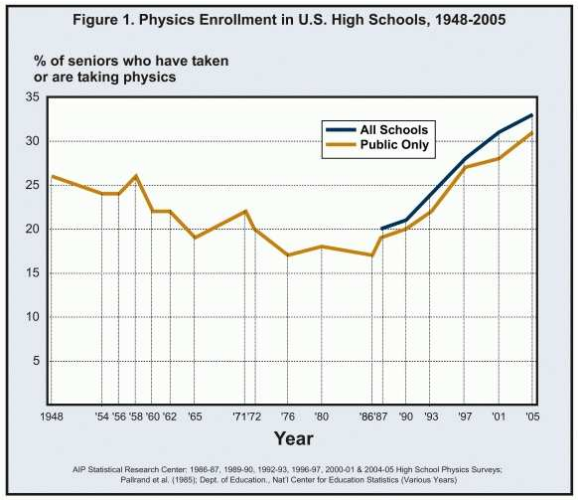
Undergraduate Physics Programs in the US

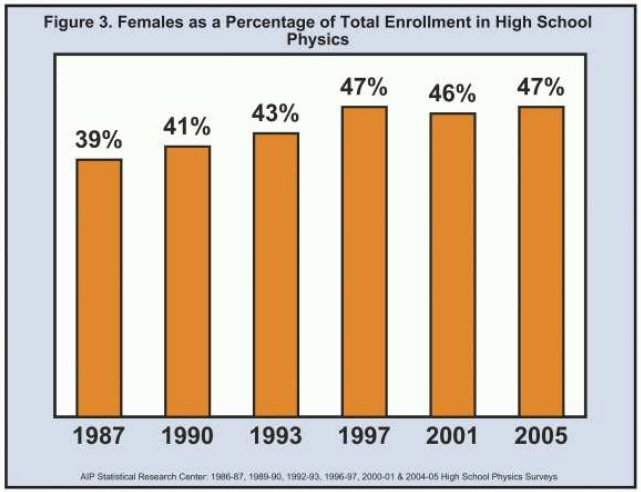
1. The number of physics bachelors degrees is small.
2. Primarily undergraduate institutions (PUIs) produce over 40% of the bachelors degrees.
3. PhD-granting institutions produce about half. There are a lot more PUIs than PhD-granting institutions.
4. Physics programs at many PUIs are more ‘precarious’ than at PhD-granting institutions.
5. Among elite liberal arts institutions, the PhD rate is high.
6. About one-fifth of the bachelors degrees go to women. They are an under-utilized source of potential physics majors.

Building undergraduate physics in the US requires attention across a wide range of institutions.

The ‘Leaky’ Pipeline

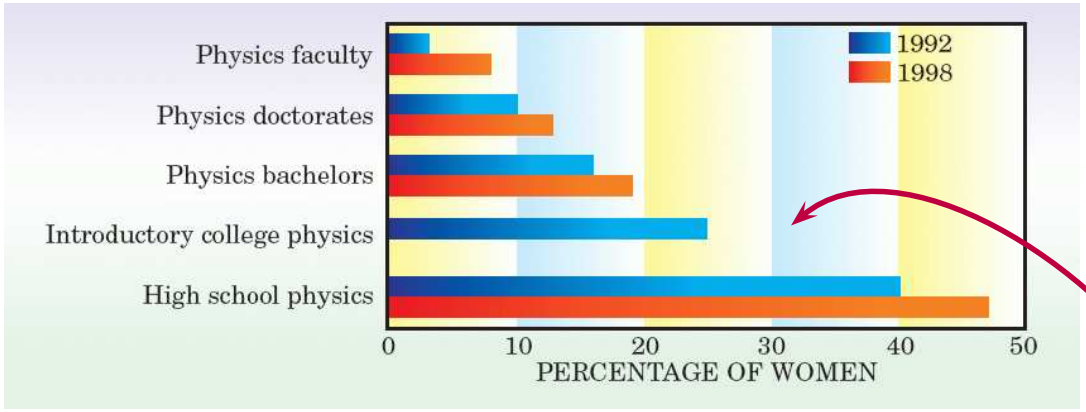
1. The number of boys and girls in high school taking physics is large.





AIP Statistical Research Center

2. Many go on to take physics in college, but go no further.



B. L. Whitten, S. R. Foster, and M. L. Duncombe, *Physics Today*, Sep, 2003, p 46-51.

The Gusher in the Pipeline

3. The fraction of students, women and men, who take physics beyond the introductory course is very small, about 6,000 out of 300,000.

   AIP Statistical Research Center.

Table 3. Introductory course enrollments at physics departments, academic year 2005-2006.

Highest physics degree offered	Calculus Based	Algebra Based	Conceptual	Physical Science
Bachelor's	46,000	45,000	32,000	33,000
Master's	17,000	17,000	13,000	8,000
PhD	100,000	79,000	29,000	17,000
Total	163,000	141,000	74,000	58,000

Note: In addition to the introductory course enrollments given above, a significant number of students take an introductory-level physics course at a two-year college. In 2002 this figure was approximately 120,000 students. (*Physics in the Two-year Colleges:2001-02*, Mark McFarling and Michael Neuschatz, June 2003, College Park MD: American Institute of Physics)

AIP Statistical Research Center, Enrollments and Degrees Report.

4. Switchers (those who left physics after intro physics) are similar to persisters in academic achievement and preparation. See testimony to Congress by Elaine Seymour, March 15, 2006 at `http://commdocs.house.gov/committees/science/hsy26481.000/hsy26481_0f.htm`.

More Leaks

5. There is a gender gap in introductory physics (and a learning gap too). The table below shows post-test results at Harvard for introductory physics taught in the traditional format.

Category	Women (%)	Men (%)
Low Scoring	43	20
High Scoring	10	27

Post-test scores on *Force Concepts Inventory* (assessment test) for introductory students at Harvard (M. Lorenzo *et al.*, Am. J. Phys. 74 2, February 2006.).

6. Women typically trail men in preparation for introductory physics (L.E.Kost *et al.*, Phys. Rev. ST Phys. Educ. Res. 5, 010101).

Additional Slides

Closing the Gap (and Recruiting too)

1. Interactive engagement (IE) methods have improved learning (R.Hake, Am. J. Phys. **66** (1), January 1998) and reduced or eliminated the gender gap (M. Lorenzo *et al.*, Am. J. Phys. 74 2, February 2006).
2. Some studies do not see this effect (L.E.Kost *et al.*, Phys. Rev. ST Phys. Educ. Res. 5, 010101).
3. Experience at the University of Richmond was very positive (Gilfoyle, Rubin, and Vineyard).
   - Notable increase in the number of women going on in physics.
   - Assessment tools showed clear and large gains.
   - We did NOT make a well-controlled study of the impact (limited time and resources).
   - We used the Workshop Physics approach (P.Laws, Phys. Educ. Res., Am. J. Phys. Suppl. **67** (7), July 1999).

Interactive Engagement Methods at Richmond

1. Classes meet three times a week for two hours (or twice a week for three hours) in small (maximum of 24) sections. Each class is staffed by a single professor and 0-2 undergraduate assistants.
2. The laboratory is everything! Well, it's a lot depending on the instructor.

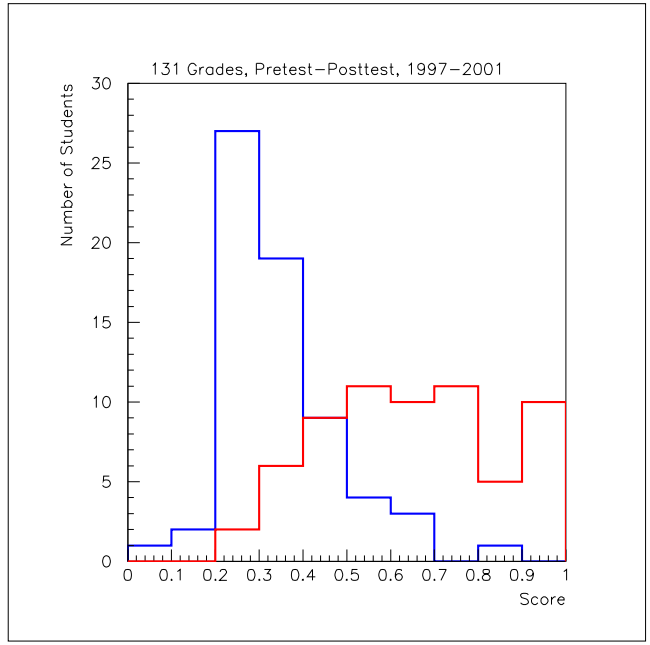
3. Many students already know lots of physics, but much of what they know is wrong! They come in loaded with preconceptions about motion and other topics.
4. The philosophical approach is based on cognitive research in physics. It requires identifying what they know that is wrong (the unlearning) and using observation to replace the preconception.

Interactive Engagement Methods at Richmond

1. A topic is introduced by the instructor in a limited way (*e.g.* some of the kinematic features of circular motion are presented).
2. Students make predictions and record qualitative observations (*e.g.*, toy airplanes on a string). Sometimes steps 1 and 2 are reversed.
3. Students develop the necessary mathematical 'hardware' to study the problem (*e.g.*, derive the relationship between the acceleration and the velocity and radius of circular motion). Done as part of the lab.
4. They go and test their equation experimentally with limited guidance (*e.g.*, film it with a digital camera and measure the kinematic quantities).
5. Last, they return to the original questions in step 2 and correct their preconceptions.
6. Strongly encourage discussion within and among groups (collaborative learning).

Do IE Methods Work?

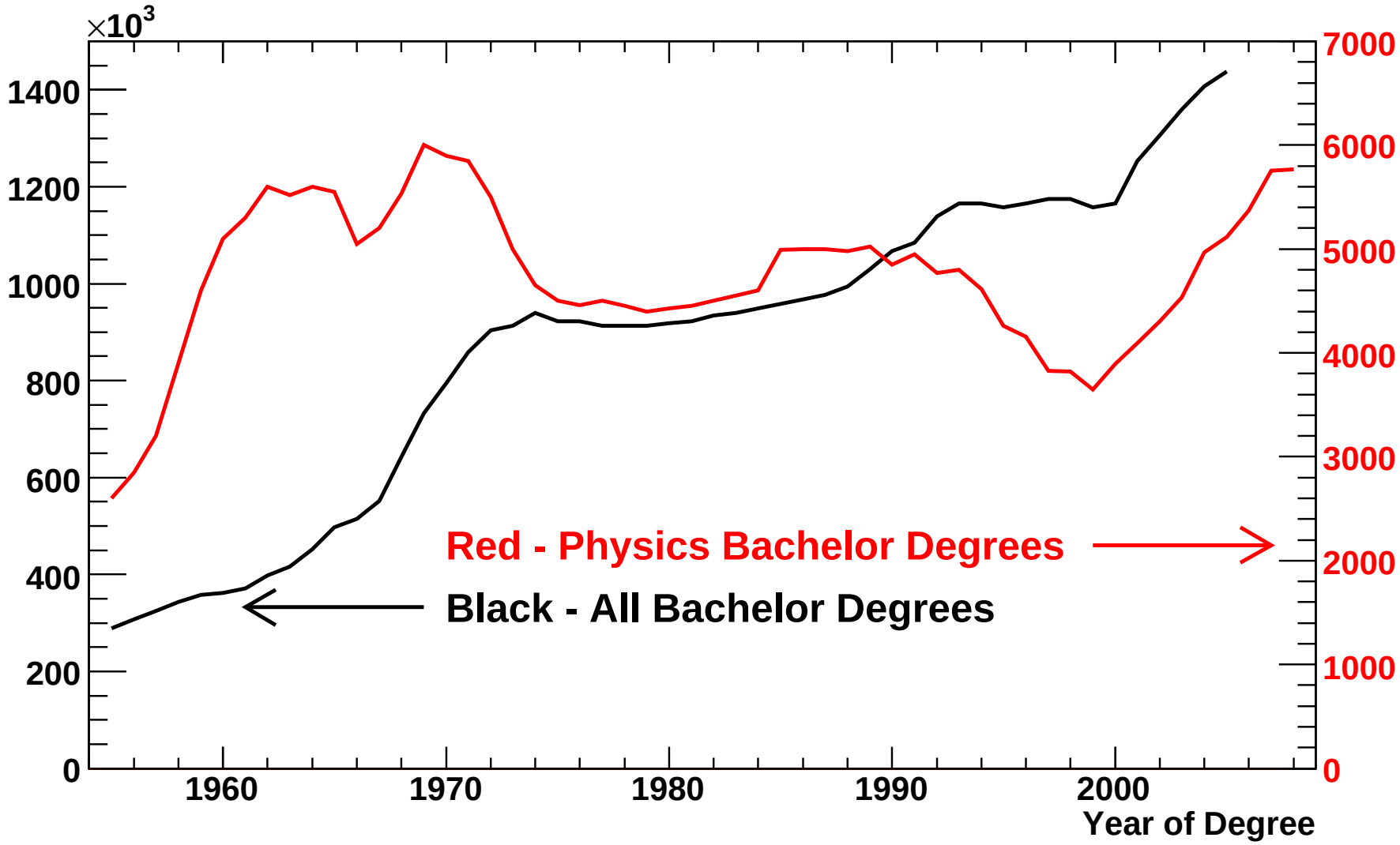
1. Results from some of my introductory physics classes using the *Motion and Force Concept Inventory* (MFCE). Typical pre-test averages are in the low 30s while post-test results are around 70.
2. Student responses to this format are varied. They have to 'sold' on the method and I routinely discuss why this class is so different from their other laboratory courses.
3. Tests should clearly connect to the labs otherwise they lose sight of their relevance.



IE Methods: Pros and Cons

1. Pros:
   (a) The MFCE assessment results point to the success of this approach.
   (b) We saw a noticeable increase in the number of women (and men) taking physics beyond the introductory course. The same effect was seen at Harvard (M. Lorenzo *et al.*, Am. J. Phys. 74 2, February 2006).
2. Cons:
   (a) Significant start-up costs for equipment, faculty training, *etc.*
   (b) Labor-intensive: Workshop Physics requires small (24) sections. Methods are available to use IE in larger sections (Mazur's *Peer Instruction*, NC State's Scale-Up program, MIT's TEAL).
   (c) Cover fewer topics than in traditional courses.

IE Methods: Why did the curve turn up?



Conclusions

1. The undergraduate physics enterprise in the US is small numerically and distributed roughly evenly between research institutions and liberal arts colleges.
2. Women make up a still small (about 20%), but growing fraction of those bachelors degrees. They represent an untapped talent pool.
3. The elite liberal arts institutions have a high rate of physics students going on to doctorates.
4. The pipeline does leak, but the introductory course loses the vast majority of possible physics students. There is also a gender gap in introductory physics.
5. Interactive Engagement methods have eliminated this gender gap though this result remains controversial.

Other Ways to Recruit Physicists

- No silver bullets.
- Sustained leadership and faculty buy-in.
- Do intro physics well!!!!!! $\rightarrow$ More modern physics.
- Clear undergraduate mission (the vision thing).
- Administrative support.
- Supportive environment: career mentoring, physics lounge, active Society of Physics Students, alumni relations, ...
- Undergraduate research!!
  - Conference Experience for Undergraduates at DNP.
  - Journal of Undergraduate Research at DOE.

Other Ways to Recruit Physicists

- Flexible programs: multiple tracks for majors, flexible scheduling, ...
- Recruit, recruit, recruit!
- Deconstruction night.
- LN_2 ice cream.
- Laser tag.
- Interdisciplinary physics with math, computer science, chemistry, biology, engineering.
- See, for example, *Strategic Programs for Innovations in Undergraduate Physics*, AAPT, 2003 for guidance on 'best practices'. Richmond version at `https://facultystaff.richmond.edu/~ggilfoyl/random/PhysicsBestPractices07.pdf`.

Unanticipated Benefits/Costs

- Administration liked the IE approach. It provided a strong justification for renovating labs, obtaining new equipment, *etc.*.
- Faculty can buy into the approach in flexible amounts. Some lecture more and follow a more traditional pace.
- NSF funding is available for innovative, new ideas.
- New ideas/labs can be published in peer-reviewed journals (AJP, Physics Teacher, ...).
- Scheduling can be difficult because of the long lab sessions (and students give us negative feedback about the length).
- It's essential to count instructor time properly (*i.e.*, contact hours versus credit hours versus units).