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# Integrating Research Experiences into the Undergraduate Education

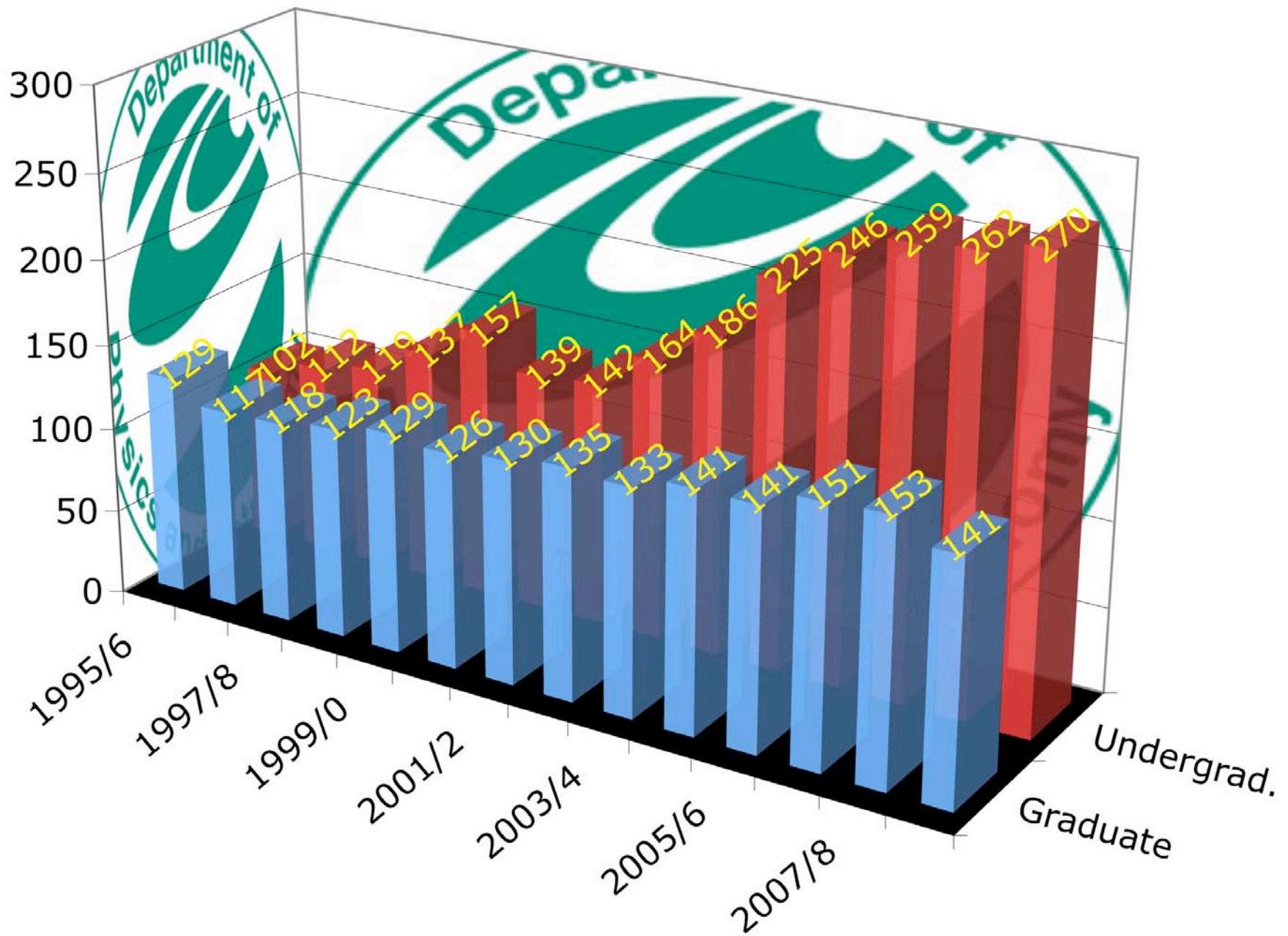
*Wolfgang Bauer*

MICHIGAN STATE  
UNIVERSITY

## What I plan to cover ...

- Changes in curriculum
- Outreach efforts to increase recruiting base
- Building a community for our undergraduates
- Research integration into the introductory curriculum
- Research experiences
- ... a final thought on demographics

# Physics Astronomy Enrollment



# Curriculum Changes

# Our Old Way of Offering Courses

- > Take calculus first
- > Take no physics class in 1<sup>st</sup> semester
- > Start with calculus-based physics in 2<sup>nd</sup> semester (mechanics)
- > Take E&M in 3<sup>rd</sup> semester, wait with modern physics until 4<sup>th</sup> semester
- > Wait with exciting (advanced) physics labs until at least the junior year
- > Pick up computer skills at your own peril

## Our Old Result

- > Physics majors did not take physics in the first semester
  - Top students moved to math in early semesters
- > Physics majors saw very little of current interest until their junior year
  - Top students moved to engineering in sophomore and junior years
- > Bottom line: Less than 80 physics majors in a university of  $\sim 40,000$  students!
  - Compare:  $>150$  grad students,  $\sim 60$  faculty

## Curriculum changes

- > Get student to do some kind of meaningful experiments right away
  - Teach them the scientific method by inquiry
- > Get them into small classes
  - Establish a community
- > Enable students to use the computer right away
  - Allow them to tackle problems, for which they "do not have the math" yet

# PHY170 (1st Semester Lab Course)

## > Socratic method

**Physics 170** is a special course in EXPERIMENTAL PHYSICS for first year students. The main aim of the course is to have you learn something about REAL physics as done in a research laboratory. There will be no formal lectures (or exams) so that all of **your learning** will be done by: (1) reading, (2) having discussions with your lab partner and the instructors, and (3) performing "hands-on" experiments.

## > Just the basics

1. How to conceive, set up, and perform experiments in a few selected areas of physics.
2. How to use the computer to:
  - a) Acquire, graph and analyze your data.
  - b) Simulate your experiment.
3. How to keep a neat and meaningful laboratory notebook.
4. How to present your results in both written and oral format.

## > Just two topics: Vacuum physics, optics

## > 6 hours per week



# Computers in Physics Classes

- > Only open to physics and astronomy majors
  - Optional, but may be made mandatory in the future
  - Hands-on, experiential, small-class
- > PHY102: Mathematica
  - Non-linear pendulum, chaos, maps, motion in gravitational field, ...
- > PHY201: Fortran 90
- > PHY301: C/C++
- > PHY480: Computational Physics

Outreach

# Active physics outreach



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# Active Physics Outreach

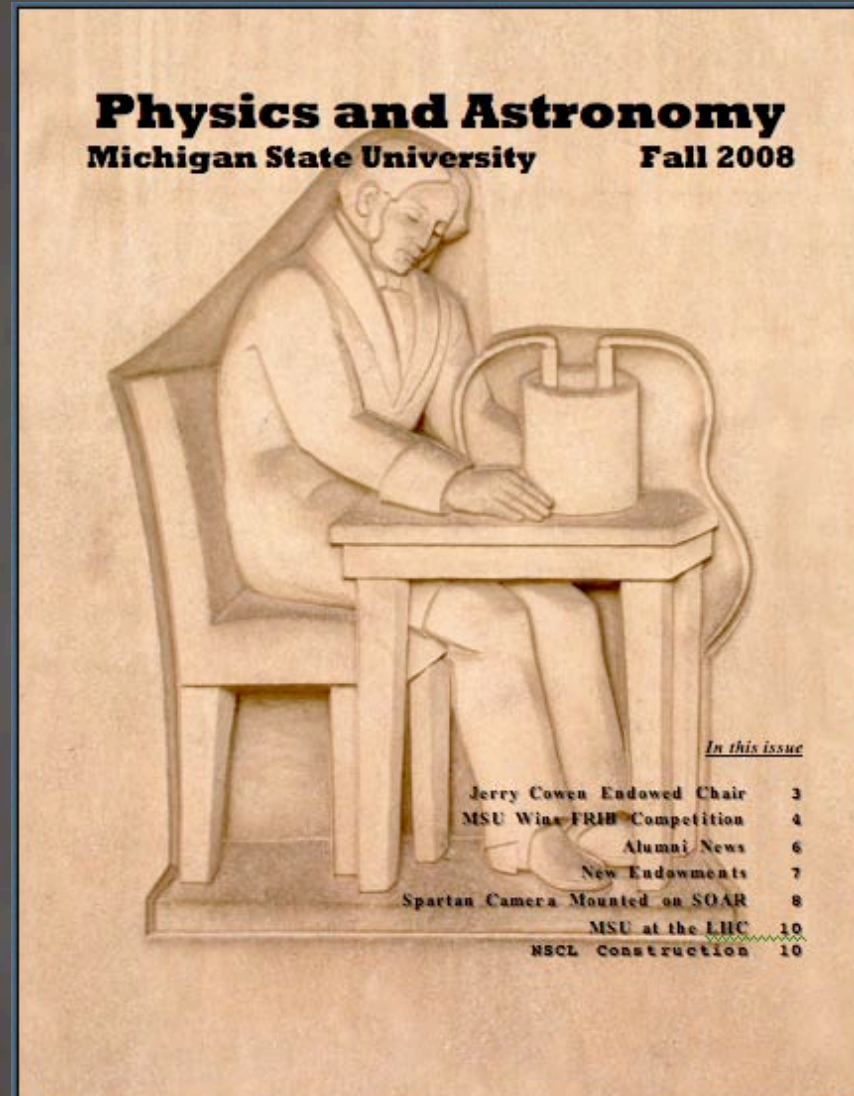
- > Science & Engineering Day
- > Grandparents University
- > Science Olympiad
- > PAN (Physics of Atomic Nuclei)
- > QuarkNet
- > LON-CAPA
  - Many local high schools as partners
  - THE DUMP (Teachers Helping Everyone Develop User Materials and Problems)
  - See <http://www.lon-capa.org/>

# lon-capa: the dump



# Newsletter

- > Once per year
- > ~2,500 copies
- > As PDF on the web



# Website

- > It's where prospective students look
- > Free opportunity for self-promotion

MSU Physics and Astronomy Department

http://www.pa.msu.edu/

Department of Physics and Astronomy

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Dept. Office: 8  
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**GIVE NOW**

NSCL SOAR Telescope Planetarium INSTITUTE FOR QUANTUM SCIENCES Center for the Study of Cosmic Evolution JINA

Courses

### US Department of Energy Selects MSU for FRIB Site

$\tau$  [s]

$>10^{12}$   
 $10^8$   
 $10^4$   
1  
 $10^{-4}$   
 $10^{-8}$

100  
80  
60  
40  
20

20 40 60 80 100 120 140 160

Z N

FRIB

[Full story | Past features]

MSU's Department of Physics and Astronomy is one of the **top-ranked** departments in the country.

In addition to our Physics degree programs, we offer a separate undergraduate and graduate program in **Astronomy & Astrophysics**.

Just published: **[more recently published textbooks by MSU PA authors]**

Recent Pictures from Events in the Department

#### OUR NEW BUILDING:

Randy Cowen adds \$1,000,000 to the Cowen Chair endowment fund.

Krauss Family Foundation endows Graduate Fellowship in High Energy Physics.

George Brown donates **Endowed Chairs** for physics and chemistry

Kyoko Makino & Martin Berz receive **3rd R. E. Moore Prize for Applications of Interval Analysis** at SCAN 2008.

Martin Berz receives honorary **doctorate** from St. Peterburg University in Russia.

Georg Bollen shares **2008 SUNAMCO Medal** awarded by IUPAP Commission C2.

Alexandra Gade named **2008 Alfred P. Sloan Research Fellow**.

David Tománek receives the **2008 Japan Carbon Award for Life-Time Achievement**.

Tim Beers and Wolfgang Bauer named **University Distinguished Professors**.

Physics senior Victoria Moeller wins prestigious **Gates Scholarship**.

Jack Baldwin wins **2007 MSU Distinguished Faculty Award**

Adjunct Professor **Albert Fert** wins prestigious prizes.

**Michael Thoennessen** (2005) and **Timothy Beers** (2006) receive the MSU Distinguished Faculty Award.

PA-alumnus Parker wins **Kyoto Prize**, donates 1/4 to SOAR.

Brad Sherrill and Gary Westfall named **University Distinguished Professors**.

Milton Muelder endows **distinguished lectureship**.

**Carl L. Foiles** Award for Physics Students endowed.

**Hantel Fellowship** for undergraduate students established with \$300,000 gift.

Milton Muelder gives over **\$300,000** to the SOAR Telescope project.

[More News Items]

Maintained by PA Web Developers; E-mail comments to [web@pa.msu.edu](mailto:web@pa.msu.edu)

# Feature Undergrads & Recent Alumni

- > Newsletter, website features
  - Scholarships (Goldwater, Gates, Rhodes)
  - Departmental scholarships (a lot of "advancement" work)
  - Other awards



W. Bauer, MSU



5/22/09





Community

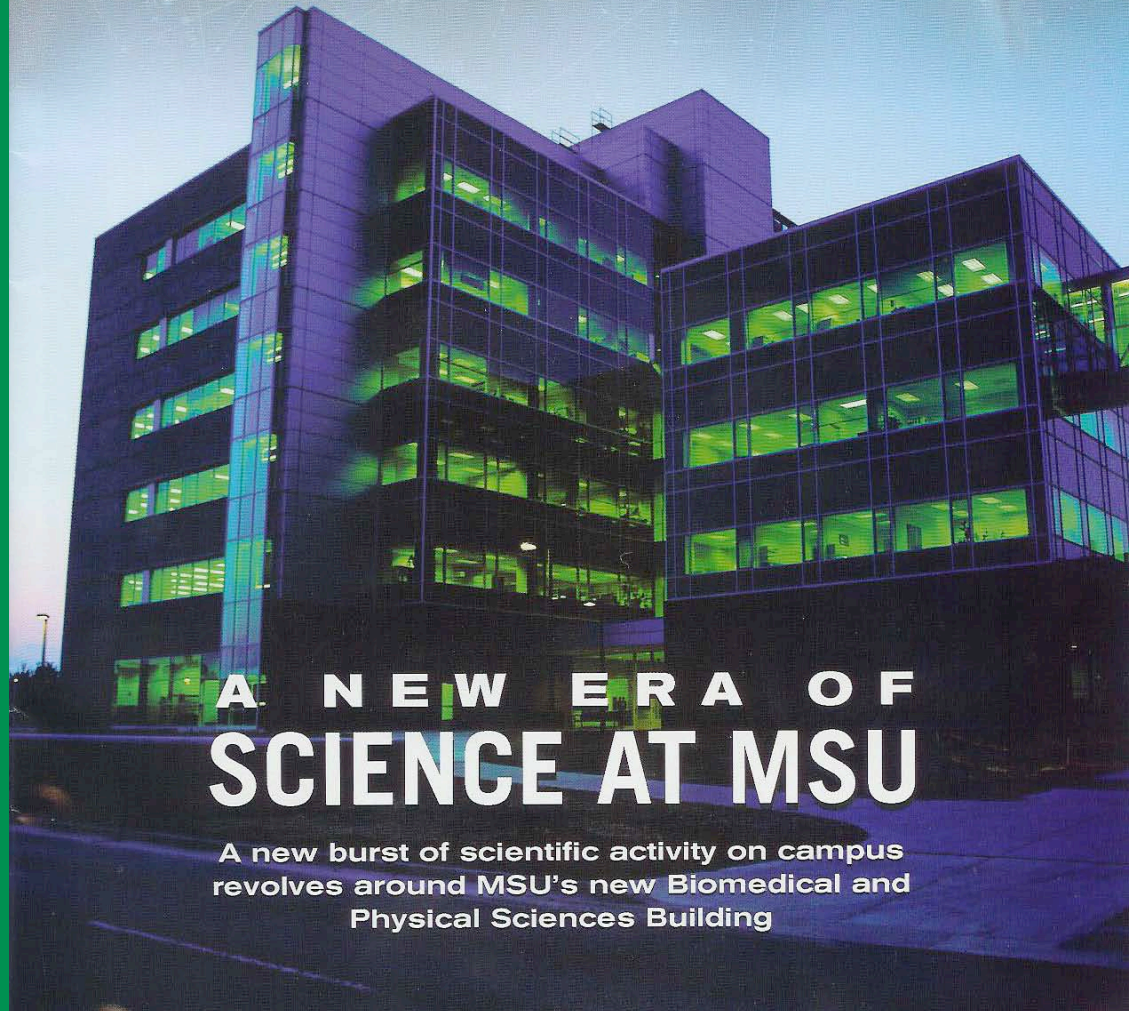
A new building  
REALLY helps!

# MSU ALUMNI

M A G A Z I N E

[WWW.MSUALUM.COM](http://WWW.MSUALUM.COM)

MICHIGAN STATE UNIVERSITY • SPRING 2003



## A NEW ERA OF SCIENCE AT MSU

A new burst of scientific activity on campus  
revolves around MSU's new Biomedical and  
Physical Sciences Building

# BPS Building



- > Completed 04/2002
- > 362,700 sqft
- > \$93 million
- > Microbiology
- > Physiology
- > Physics/Astronomy



# 1<sup>st</sup> Floor



W. Bauer, MSU



- > Atrium with coffee shop
- > WiFi, plenty of plugs
- > Attractive space to hang out, do homework, discuss, meet friends
- > Open even on the weekend

5/22/09

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# Department BBQ



> Building community with undergraduates

# "March Madness"



W. Bauer, MSU

5/22/09

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# Student Organizations

## > SPS

- Receives annual funding from department
- Has own lounge
- Holds weekly seminars, but also movie nights

## > Science Theatre

- Initially founded by PHY grad students (Leslie-Pelicky, Mader, Kortemeyer)
- Hands-off faculty advisor
- Now more undergraduate students



## > WAMPS

- Women and Minorities in the Physical Sciences

# Science Theatre





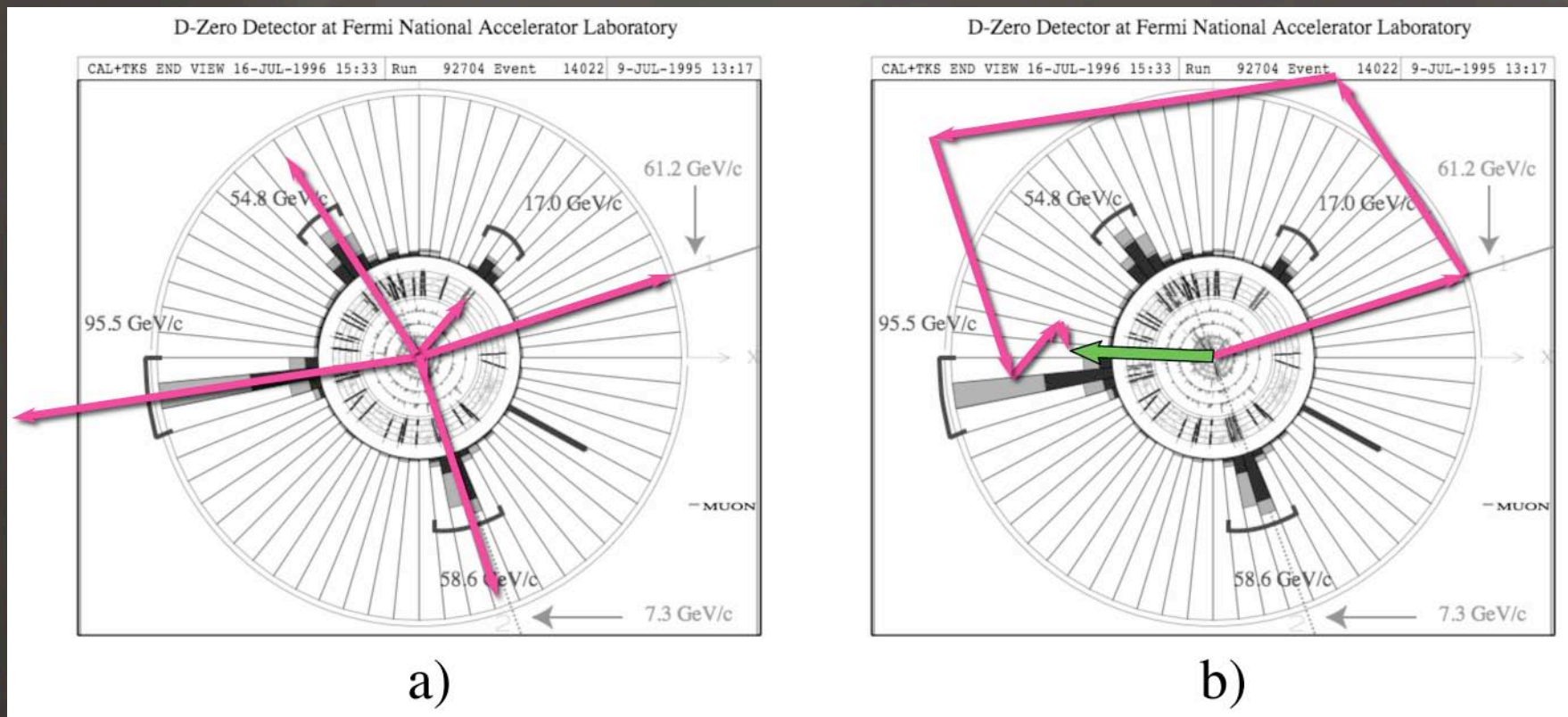
# Modern Research Results in the Introductory Curriculum

## Recent Research Results

- > Conventional lecture sequence emphasizes results that are older than 100 years
  - Biology: last 2 decades
- > Can include recent results from particle physics, non-linear dynamics, astrophysics, nuclear physics, atomic physics into first year physics curriculum
  - Speaks to the relevance of the field
  - Lets students envision that they can contribute
  - Lets students see that physics is alive

# Recent Research Results

- > Example: Momentum conservation and top-quark discovery



# Research Experiences

## Professorial Assistants

- > Year-long one-on-one research experience for top incoming MSU freshmen in "lab" of a professor
- > \$3,000 stipend
- > Renewable for subsequent years
- > 100 students each year across MSU
- > ~6-8/year in PHY
  - (0.5% of MSU students major in PHY)
  - More than 10 times more PAs than our "fair share"
- > Excellent recruiting tool for PHY majors!

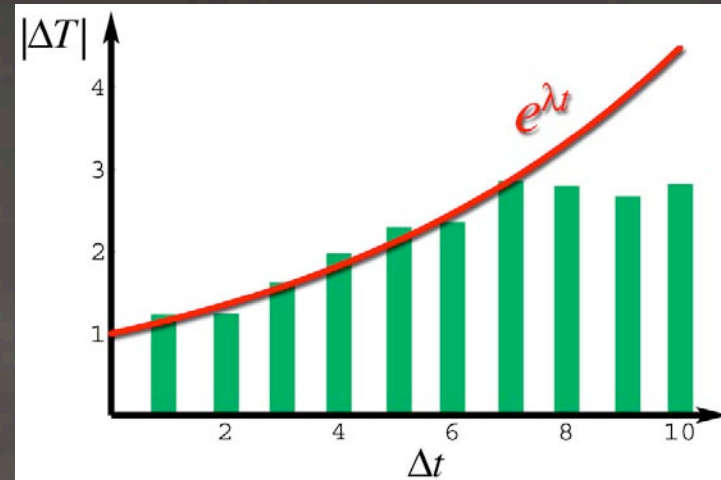
# Weather Research

> Brad Keusch

- MSU Freshman
- Professorial Assistant

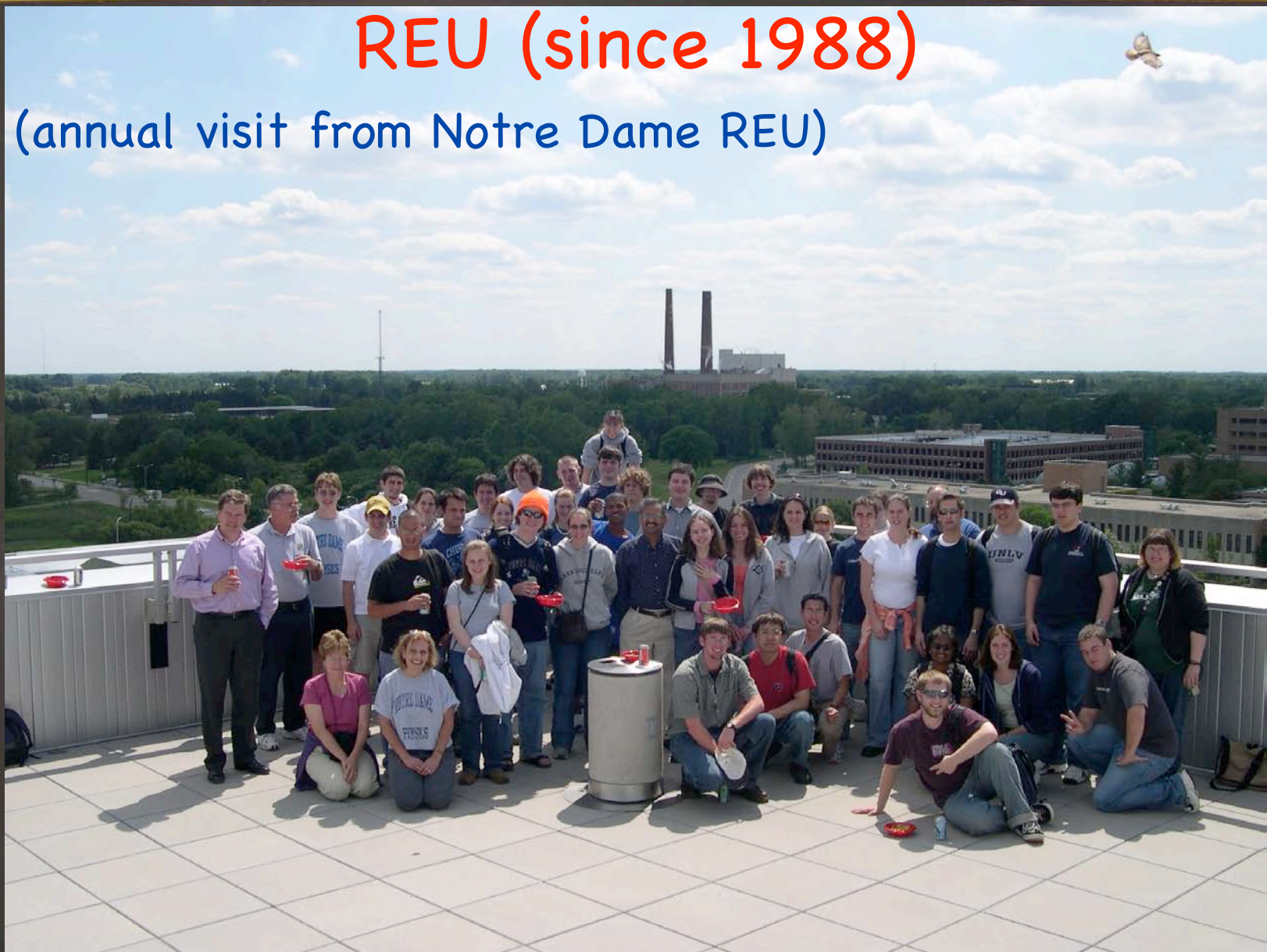
> Research project

- Examine how chaotic the weather is in different parts of the country
- Extract Liapunov exponents from comparing 10-day forecasts to the actual daily highs and lows



# REU (since 1988)

(annual visit from Notre Dame REU)







# Real Involvement in Real Research

## > ATLAS Calorimeter



# Real Involvement in Real Research

- > SOAR Telescope (Andes, Chile)



# SOAR Remote Control & Observing Room







# The Modular Neutron Array at the NSCL



NSCL MICHIGAN STATE UNIVERSITY MICHIGAN STATE UNIVERSITY MICHIGAN STATE UNIVERSITY MICHIGAN STATE UNIVERSITY MICHIGAN STATE UNIVERSITY MICHIGAN STATE UNIVERSITY MICHIGAN STATE UNIVERSITY MICHIGAN STATE UNIVERSITY MICHIGAN STATE UNIVERSITY

## Michael Thoennesen

### Issues and Events

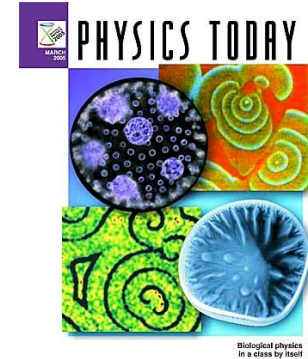
#### Undergraduates Assemble Neutron Detector

Spreading the construction of a detector across several institutions brings project visibility to participants.

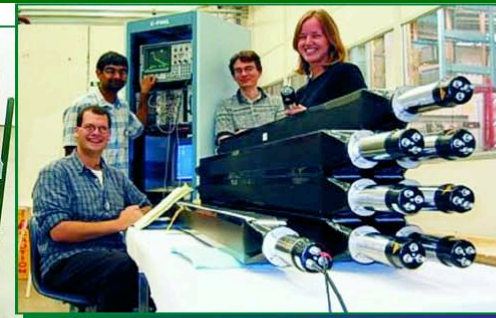
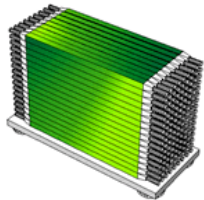
**T**he undergraduates come running.” So says Ruth Howes about student participation in the Modular Neutron Array, or MoNA, a detector built in large part by undergraduate physics majors. Howes, chair of the physics department at Marquette University in Milwaukee, Wisconsin, says it is unusual and significant that students can work on MoNA without leaving their home institutions. The detector was installed last summer at National Superconducting Cyclotron Laboratory (NSCL) at Michigan S

The facilities offering the biggest competition for MoNA, he adds, are GSI in Darmstadt, Germany, RIKEN in Tokyo, and GANIL in France. Ranking right up with the project’s scientific potential is student involvement, which helped drum up funding. Recalls Jim Brown, a physicist at Wabash College in Crawfordsville, In-

rectly through their physics departments. “Increasingly, undergraduate physics departments are seeing non-traditional students,” says Howes. “One of my undergraduates had been a funeral director. He was 30 and had a steady girlfriend. Another had worked in industry and had a wife. They appreciate being involved in real, publishable research, but they can’t leave home the way 20-year-olds can, for the whole summer.”



T. Feder, Physics Today March 2005, p.25



The Modular Neutron Array (left) was assembled by undergraduates (above) at Concordia College and nine other institutions.

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March 2005 Physics Today 25

“That’s what NSF is about” (Bob Eisenstein, NSF Assistant Director in 2001)



NSCL

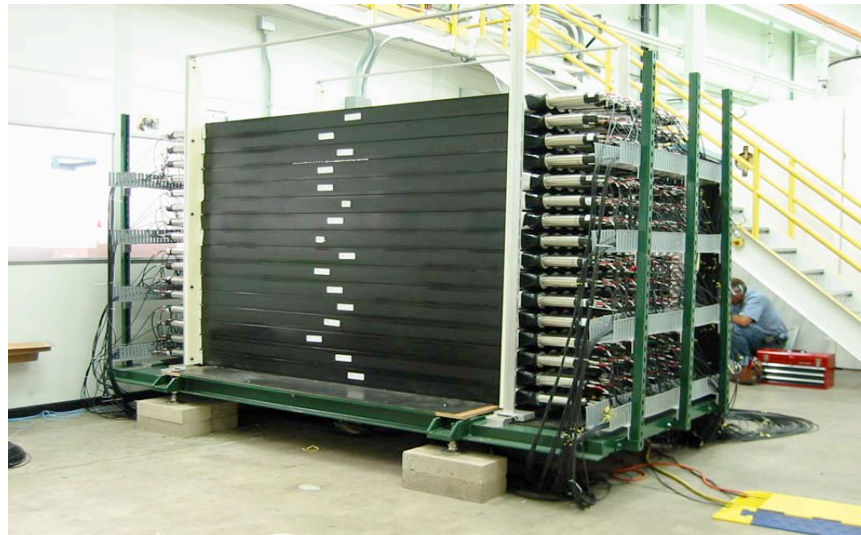
MICHIGAN STATE UNIVERSITY

# The Modular Neutron Array (MoNA)



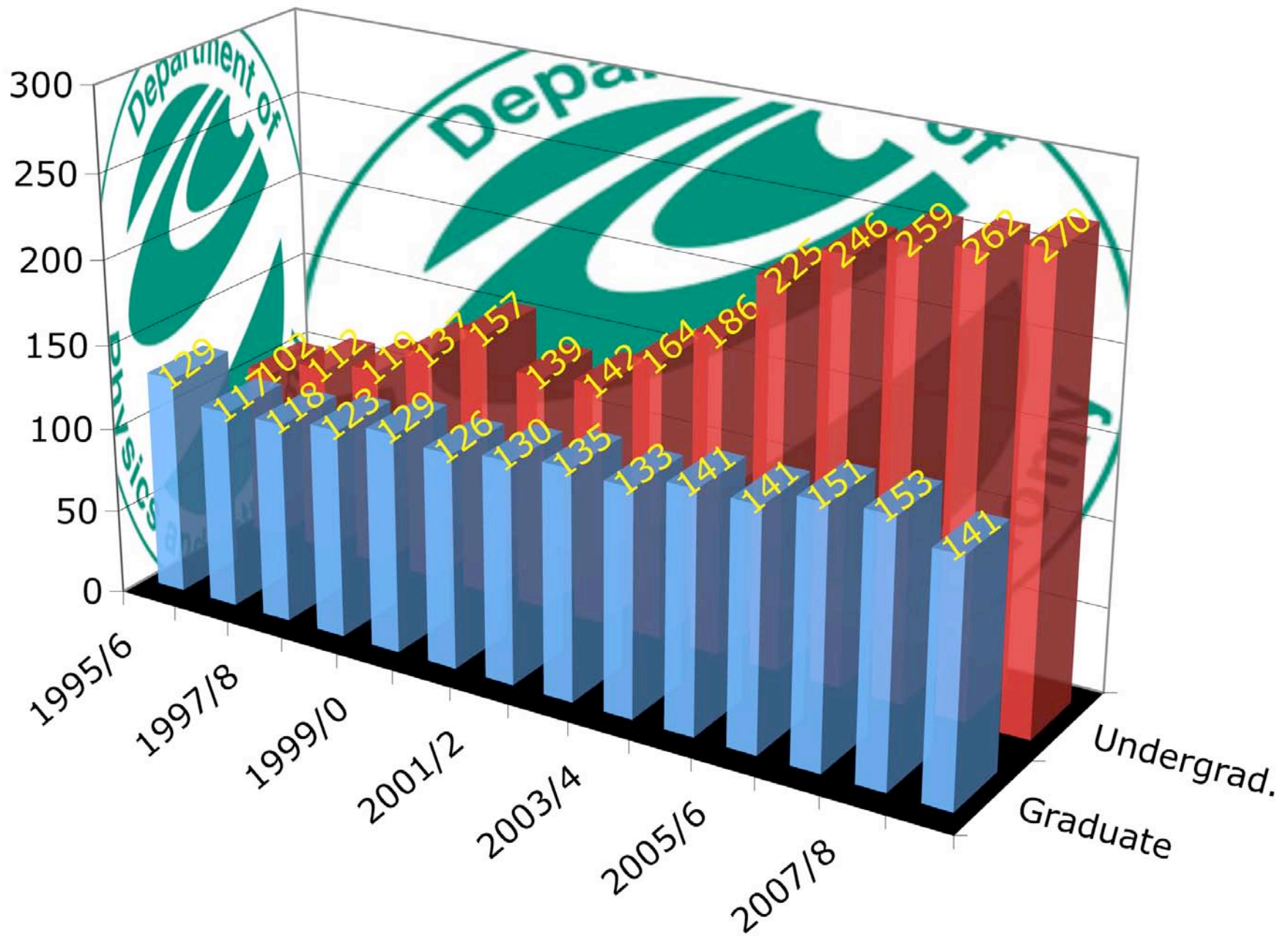
Michael Thoennesen

- ToF Neutron Detector
- 10 X 10 X 200 cm Bar of Plastic Scintillator
- 9 Layers of 16 Stacked Bars
- Time Resolution < 1 ns
- Position Resolution ~ 10 cm
- Detection Efficiency ~ 70 % for 85 MeV/A Neutrons



... a final thought, perhaps

# Physics Astronomy Enrollment





# Physics Astronomy Enrollment

