

PH0008 (Spring 2004) SR L02 (v01)
Quantum Mechanics and Special Relativity



Relativity's Renaissance!

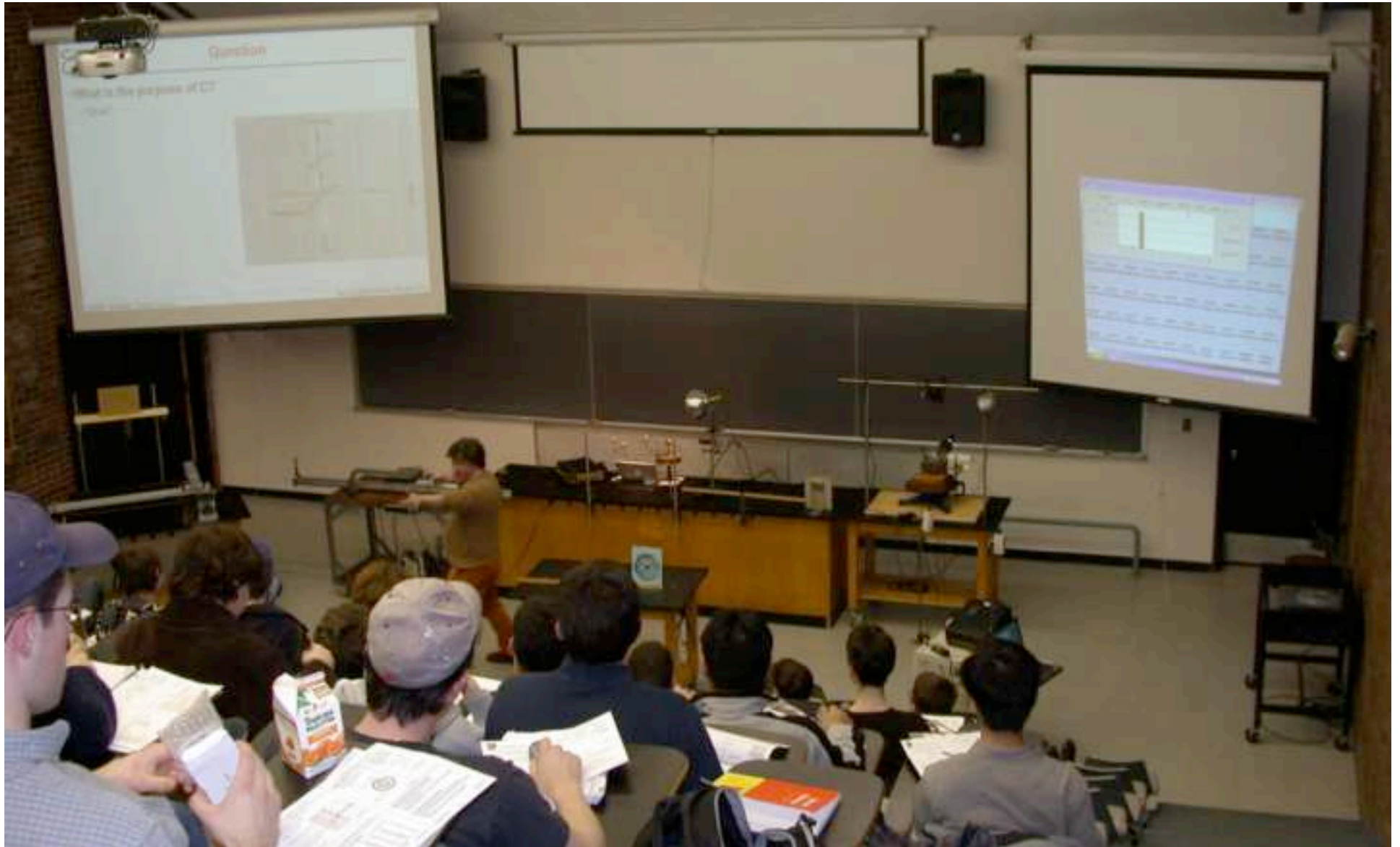
**From the Michelson-Morley Experiment
to Special Relativity & Time Dilation**

Prof Rick Gaitskell
Department of Physics
Brown University

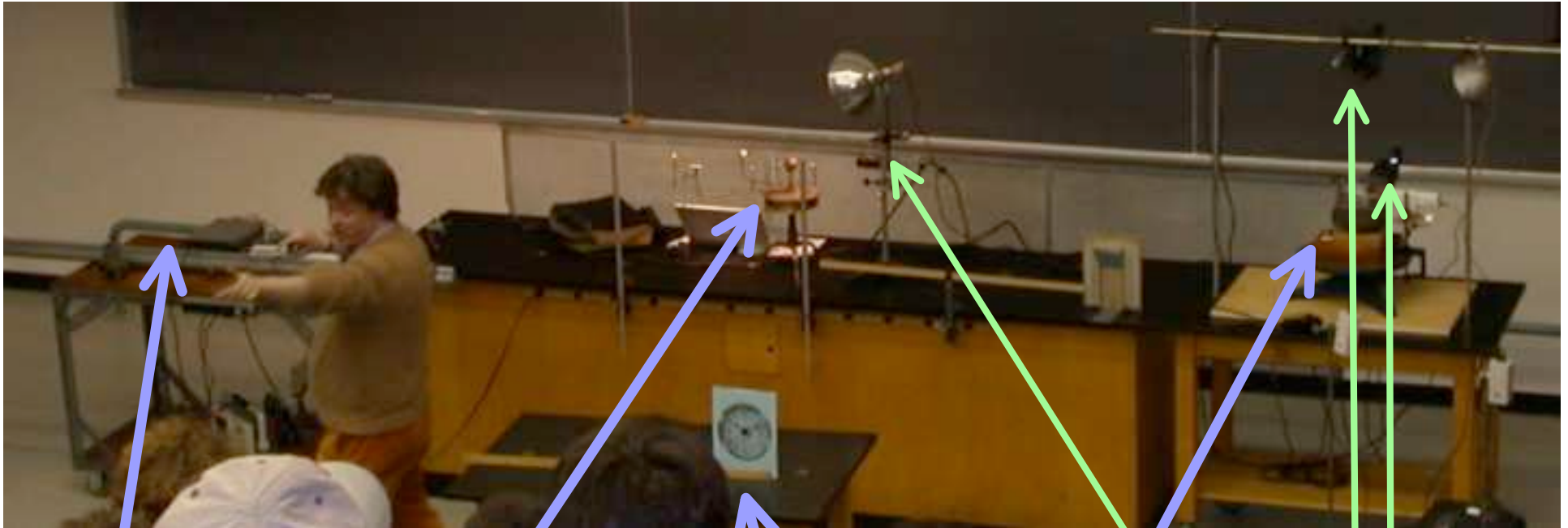
Main source at WebCT
See also research links at

<http://gaitskell.brown.edu> & <http://particleastro.brown.edu>

Physics 8 - Special Relativity & Quantum Mechanics



Practical Demonstrations



Speed of Light
Measurement

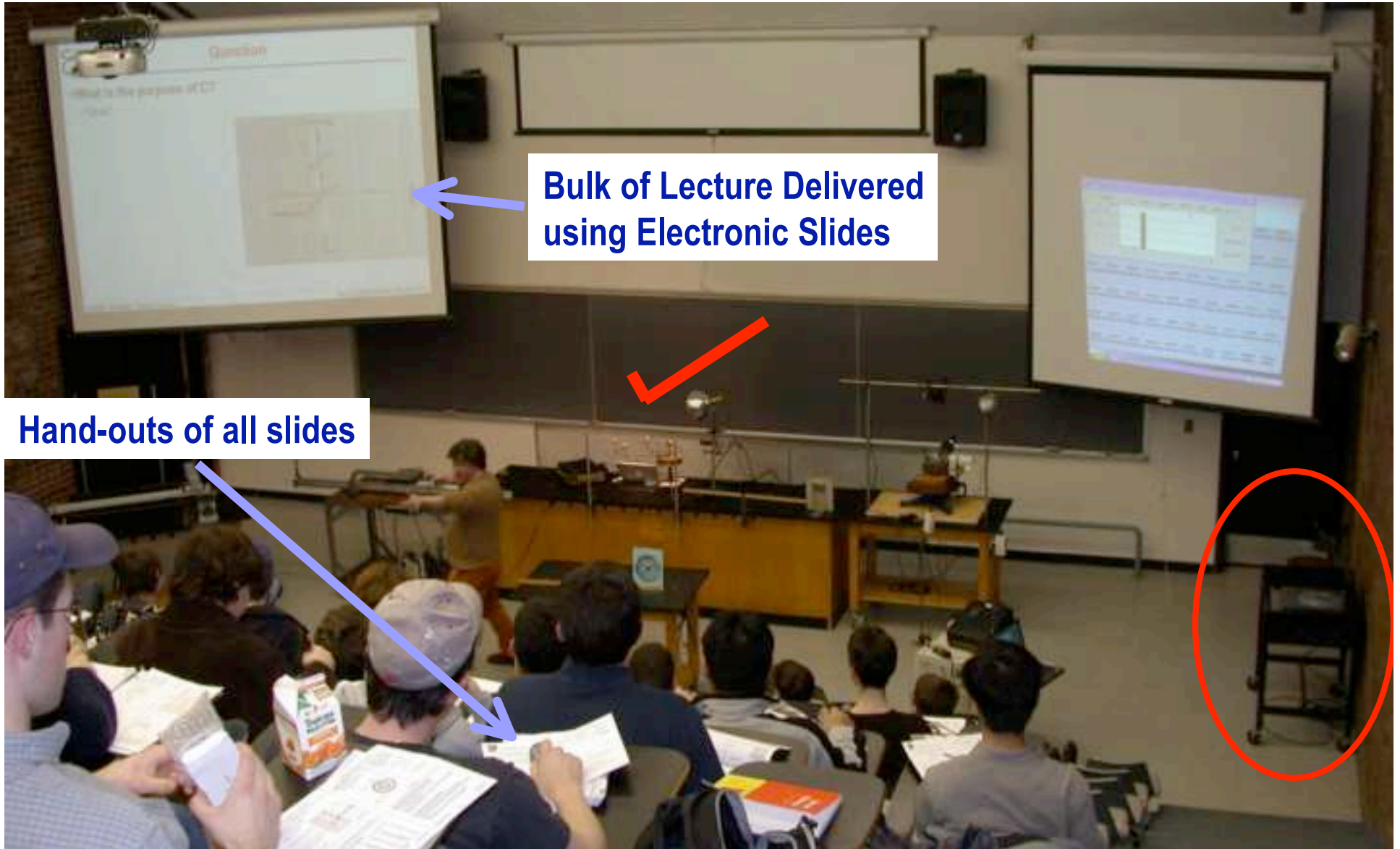
18C Martin Orrery

Michelson Interferometer

Relativistic Inertial Frame !

Cameras for obtaining
advantageous view point

Physics 8 - Special Relativity & Quantum Mechanics

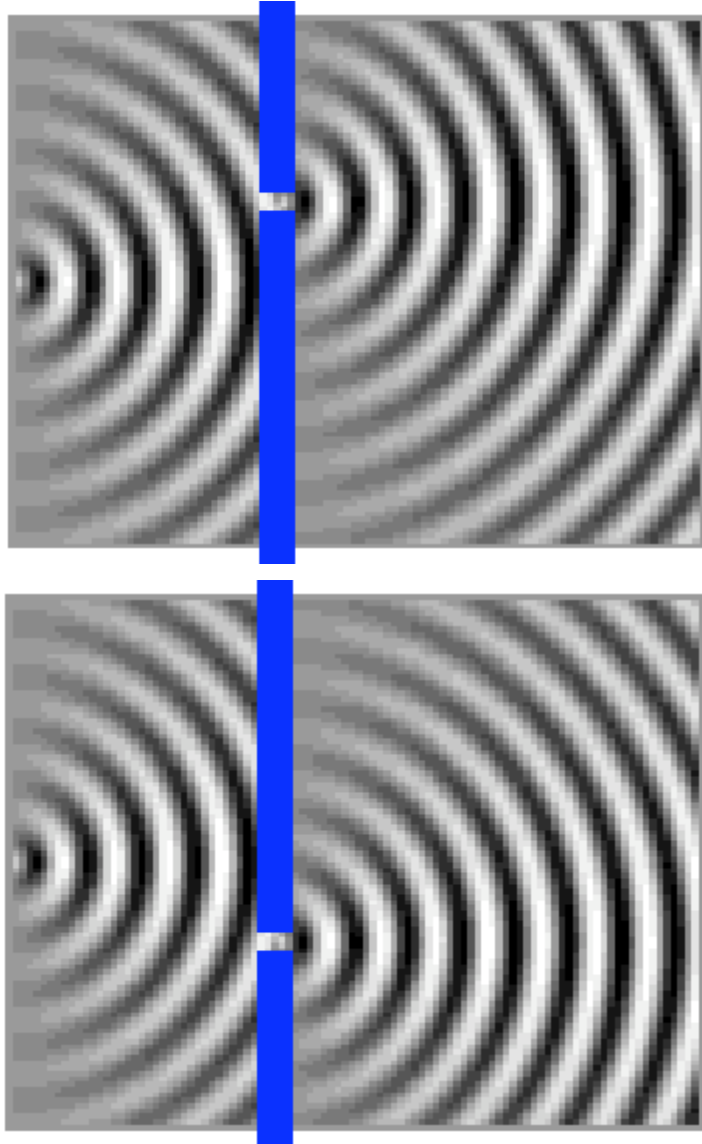


Bulk of Lecture Delivered using Electronic Slides

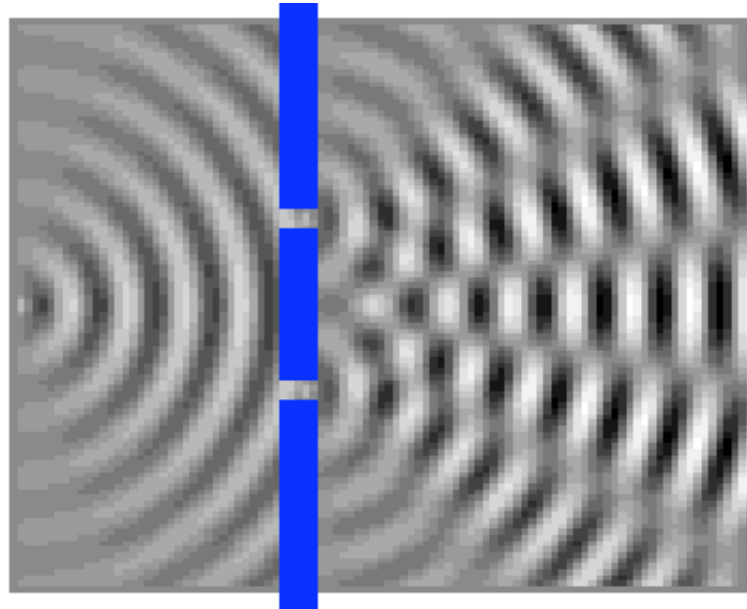
Hand-outs of all slides

A Few Examples of Slides in Use for PH8 ...

Interference - Young's Double Slits

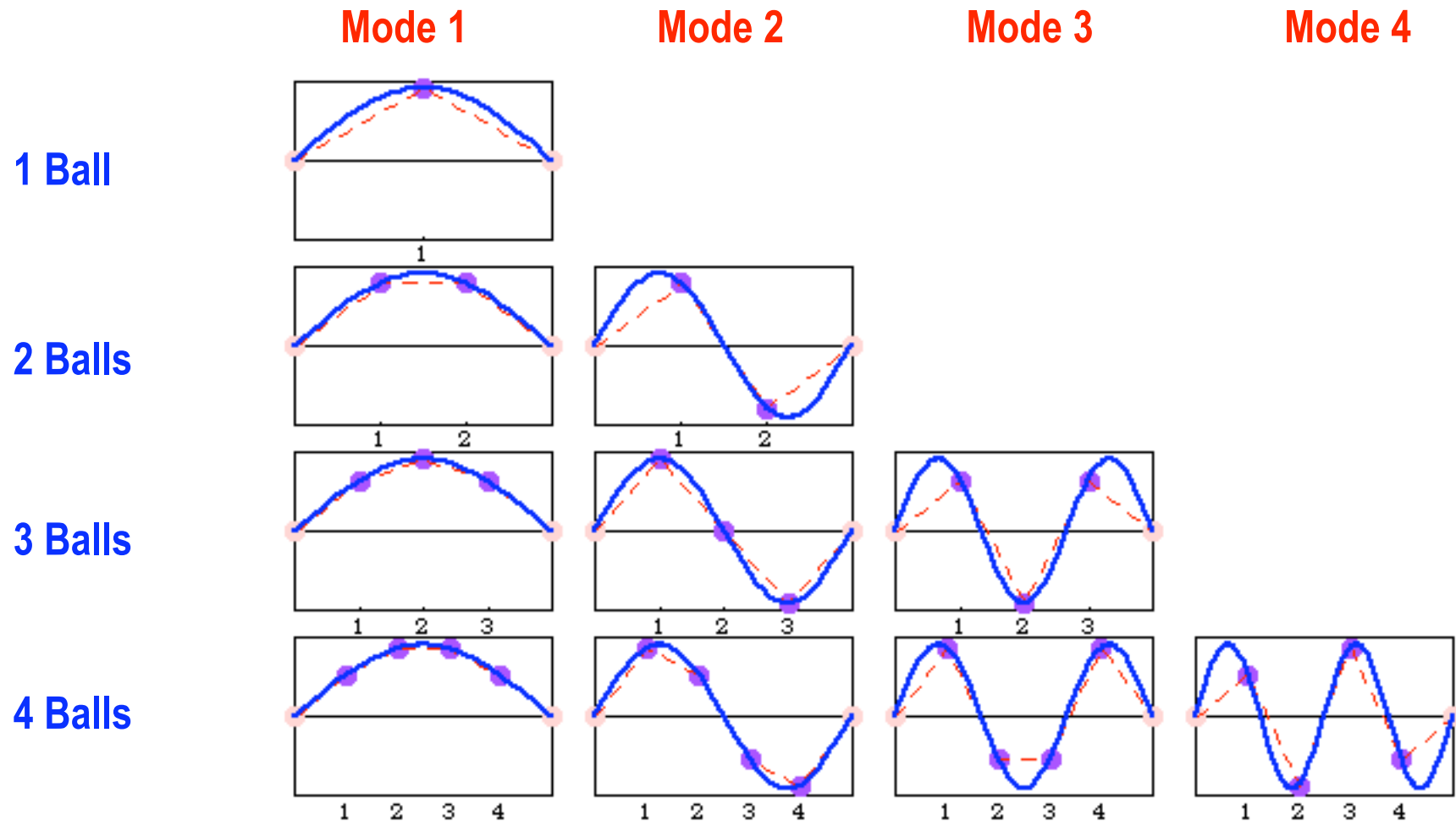


- Combination of two 2-D waves from different (spatially separated sources) which have a constant relative phase
 - As well as same wavelength & velocity



Transverse Normal Modes (for m's and k's symmetric)

- Balls lie on half integer cycle sine curves



Expression for each ball's vertical position with time

- The full description of p 'th ball's vertical position

in n 'th normal mode (this case $n=2$) where we have N ($=4$) total balls at a given time t is

$$y_{p,n}(t) = A_{pn} \cos(\omega_n t)$$

$$A_{pn} = C_n \sin\left(2\pi \left(\frac{n}{2}\right) \frac{p}{N+1}\right)$$

$$A_{p=0} \equiv 0$$

$$A_{p=N+1} \equiv 0$$

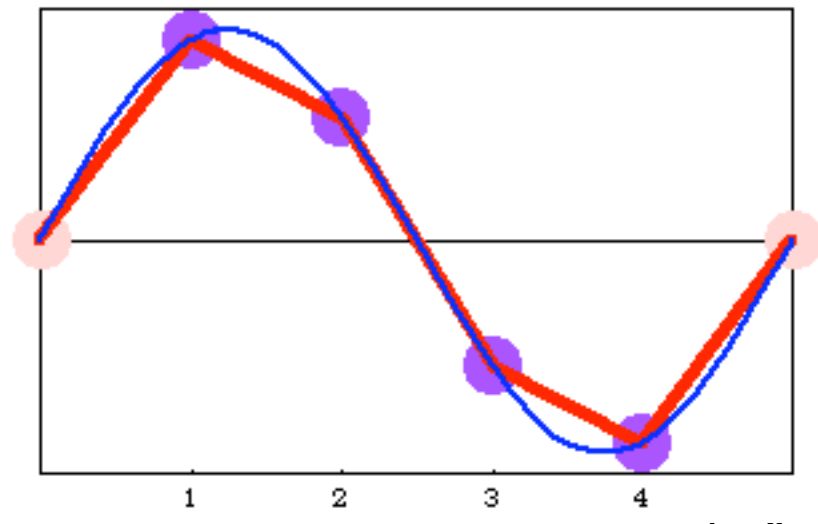
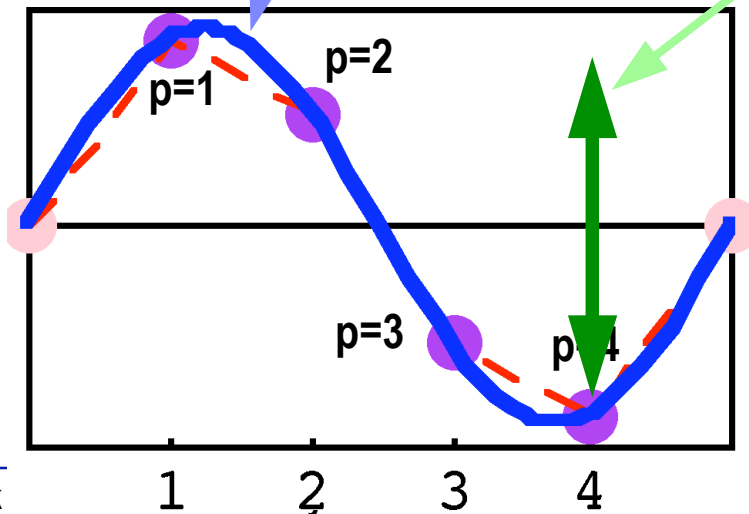
- All balls oscillate in given mode move with same frequency: $\cos(\omega_n t)$

- Freq. of each mode is different

$$\omega_n = 2\omega_0 \sin\left(\frac{\pi n}{2(N+1)}\right) \quad \omega_0 = \left(\frac{T_0}{ml}\right)^{\frac{1}{2}}$$

- Incl. phase gives more general case $\cos(\omega_n t + \delta)$

$N=4$



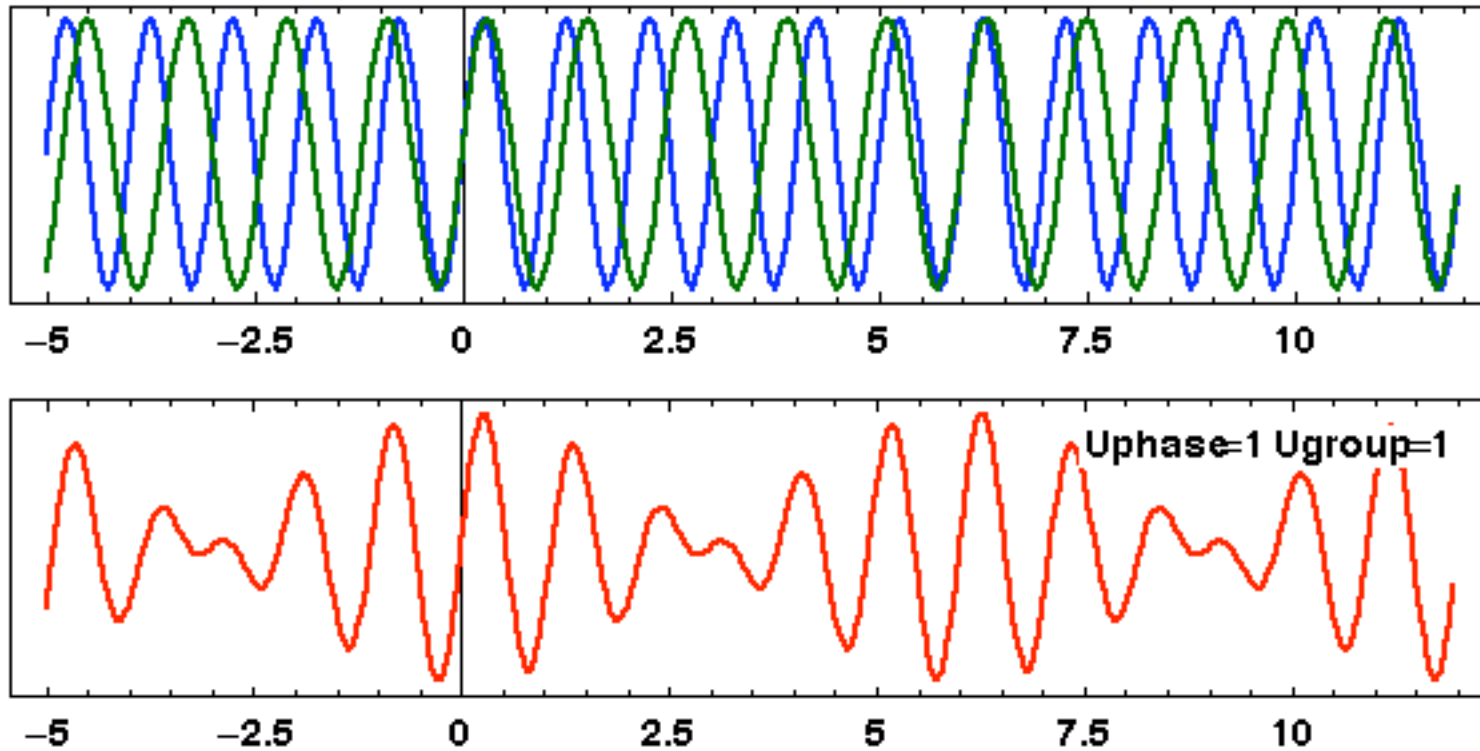
Dispersion Simulation (1)

- $u_g = u_p$

- The wave packets are fixed in shape

[Blue] $\lambda_1 = 1, u_1 = 1$

[Green] $\lambda_2 = 1.2, u_2 = 1$



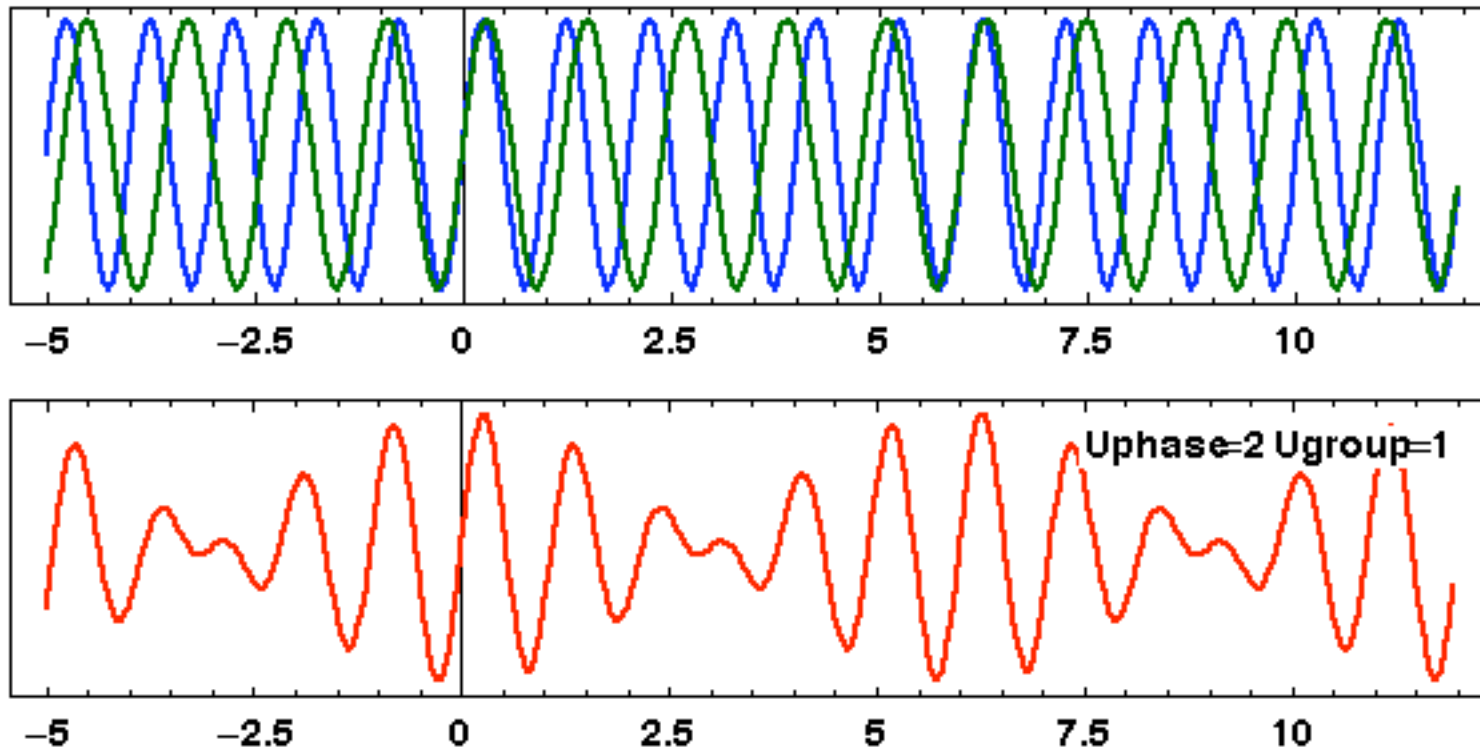
Dispersion Simulation (2)

- $u_g = 1, u_p = 2$

- Wave crests inside packets appear to move faster than wave packets

[Blue] $\lambda_1 = 1, u_1 = 1.92$

[Green] $\lambda_2 = 1.2, u_2 = 2.1$



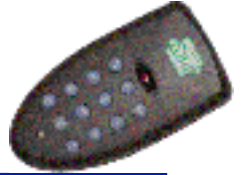


Video Material

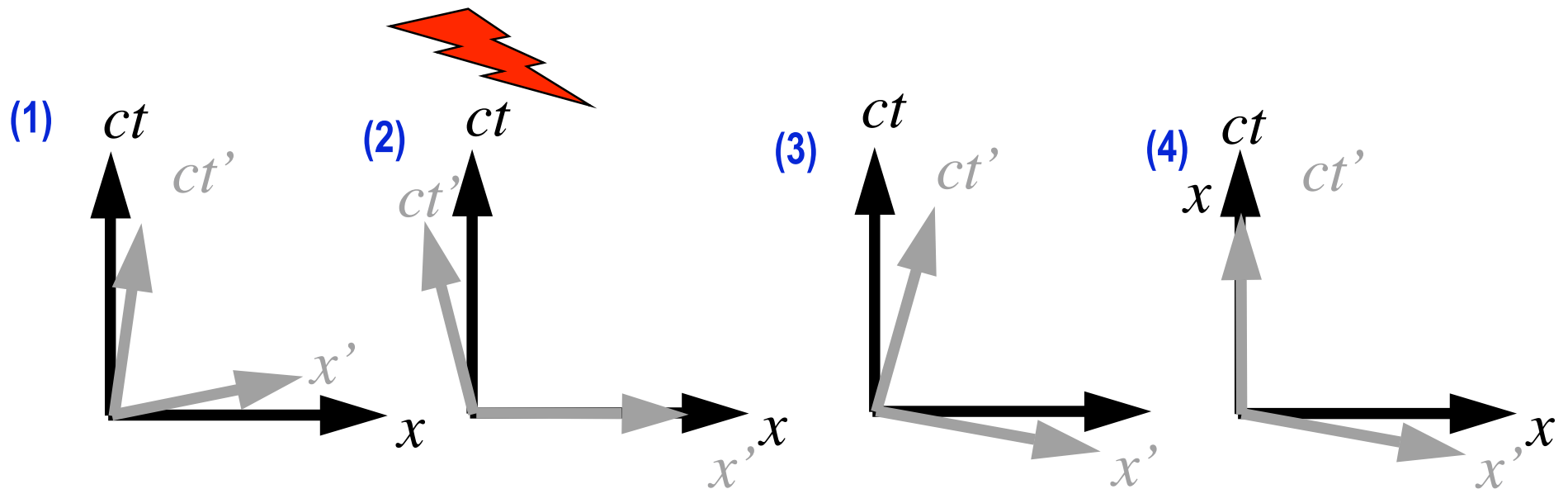
- **Video Clip from The Mechanical Universe Series, CalTech**
 - Will be broadcast on PBS in May 2004
- **Digital Editing allows more fluid inclusion of material**
 - Also permits viewing as part of course web site

Introduce PRS Q&A

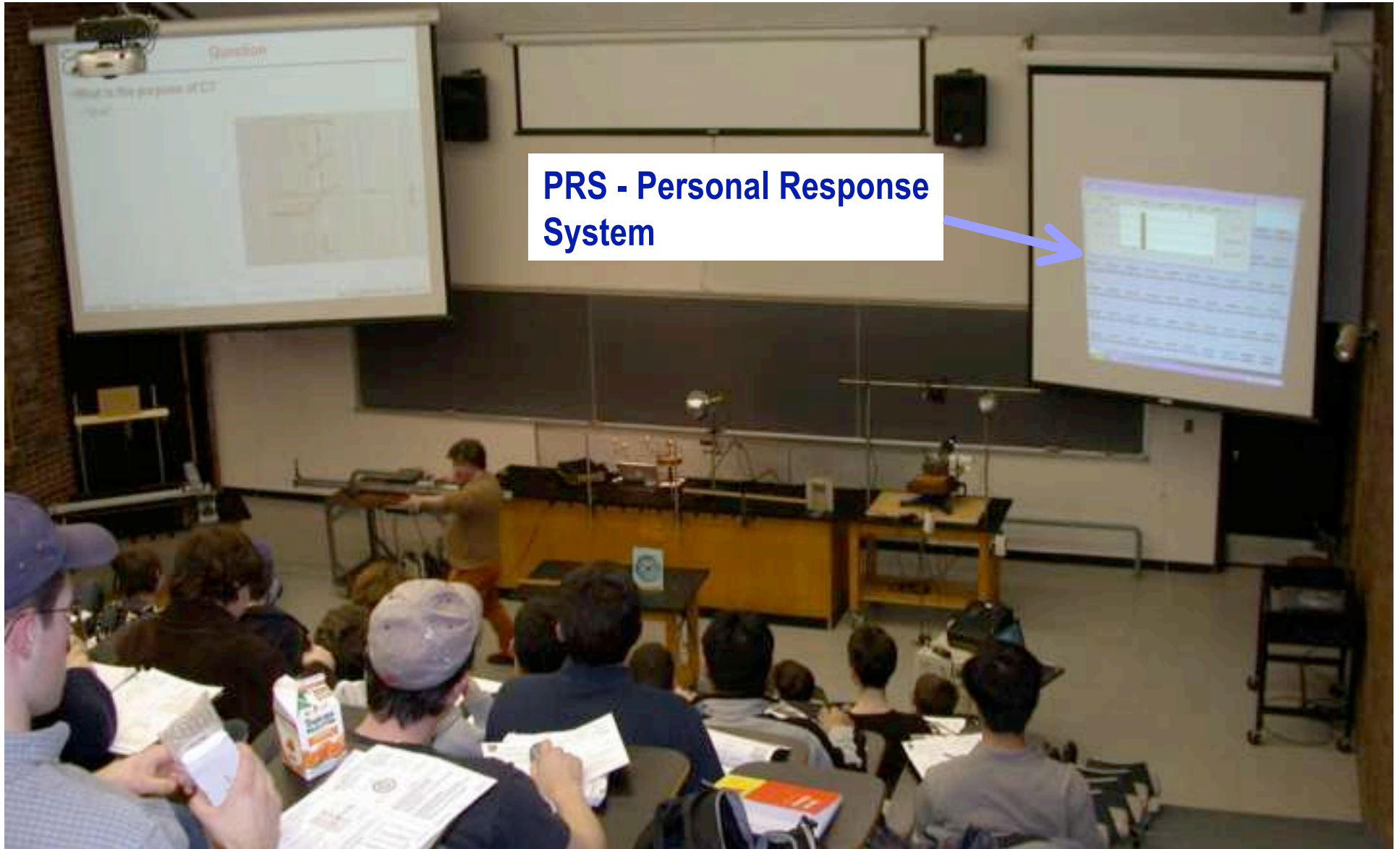
Question SpecRel L05-Q3



- Which graph best reflects a Galilean (rather than Lorentz Transform)?

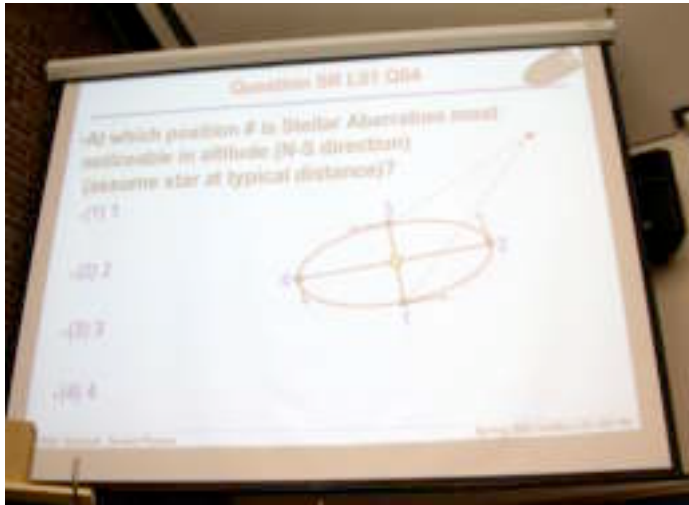


“Zappers”

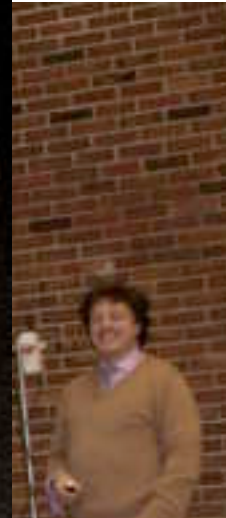
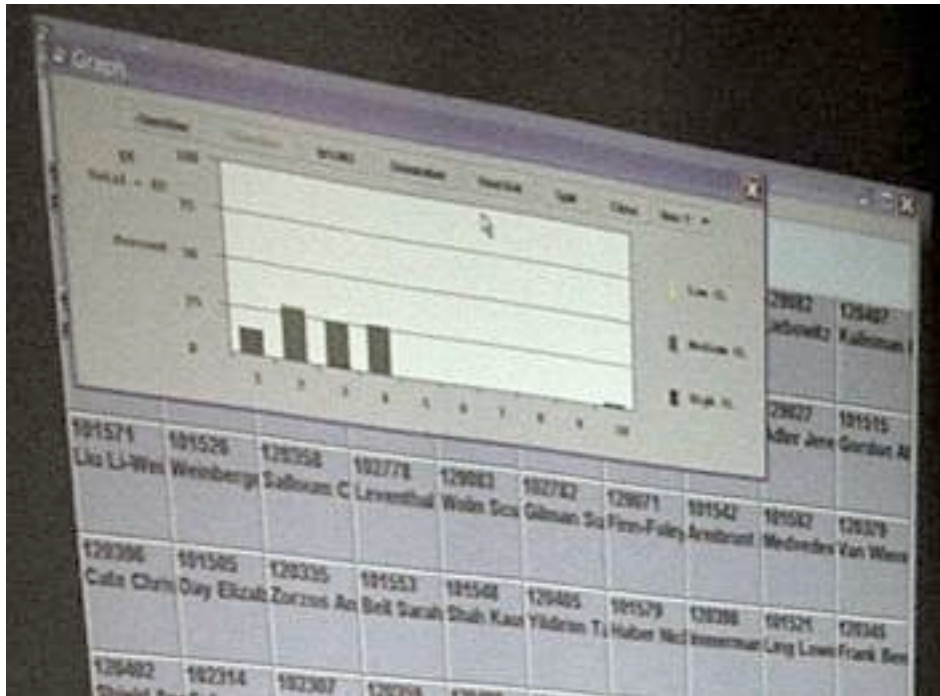


PRS - Personal Response System

Physics 8 - Special Relativity & Quantum Mechanics



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Course Material On-line (WebCT)



- Single Framework for All Course Material
- Additional Feedback Mechanisms
 - Just In Time Quizzes

Video Conferencing - Specialized Graduate Lectures

- **PH 232 Quantum Field Theory & PH234 Group Theory (Prof David Lowe)**
 - These classes are taught by one lecturer to grads at multiple campuses via Video Conferencing
 - Particularly effective for graduate student lecture series in which graduates from a number of schools can be exposed to an expert in very specific discipline

A Few Notes On Computing Use in Research Physics

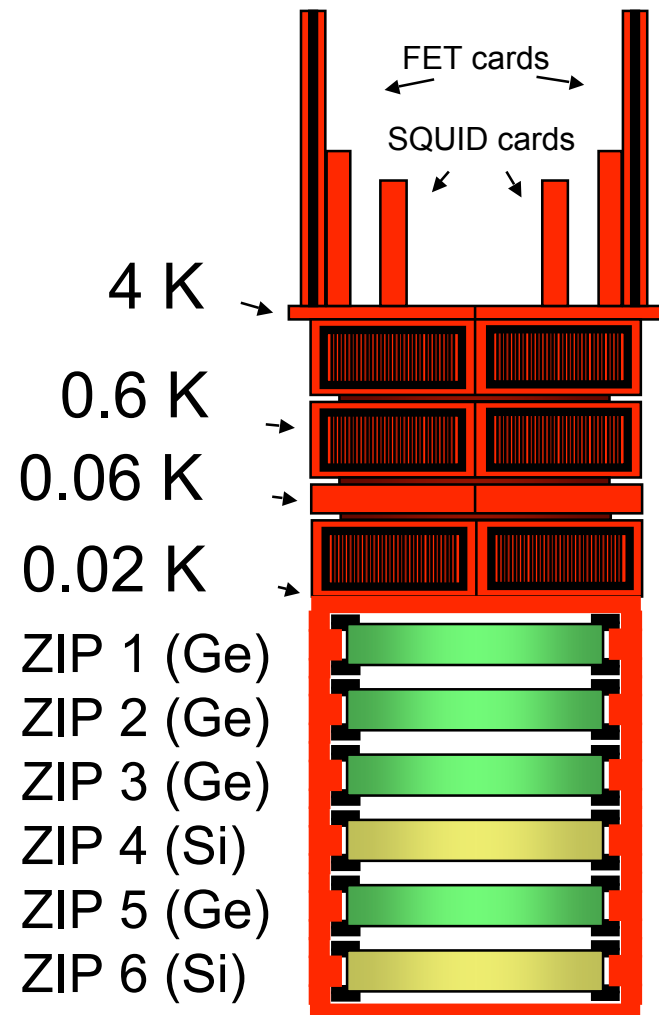
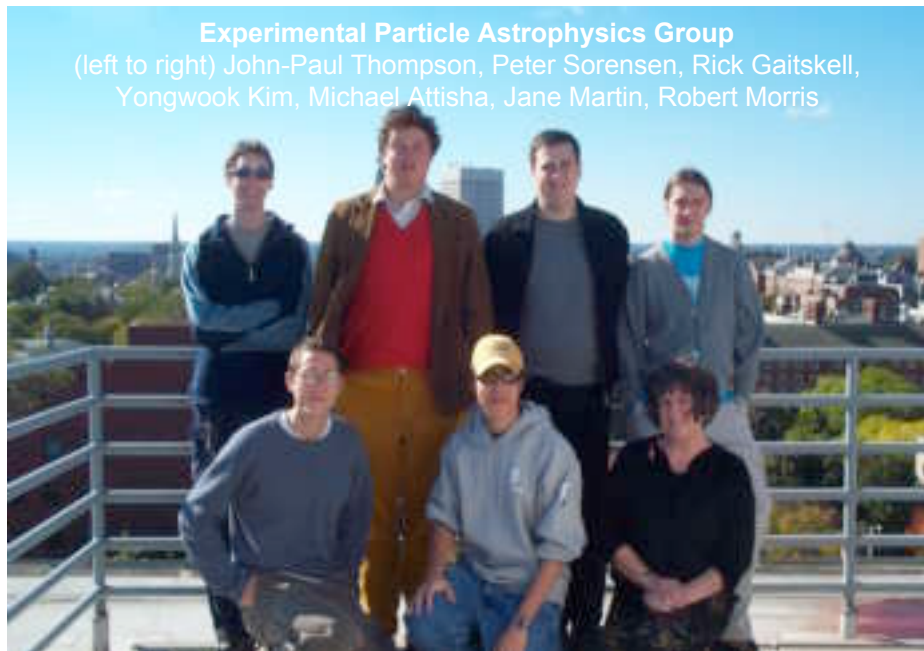
What nature has to offer

What you hope for!



Search for WIMP Dark Matter

- Gaitskell / CDMS Collaboration
- Looking for the very occasional interaction of WIMPs with (sub-) terrestrial detectors
 - Expected Signal Rates ~ 1 /kg/week - 1/100 kg/year
 - <http://particleastro.brown.edu>



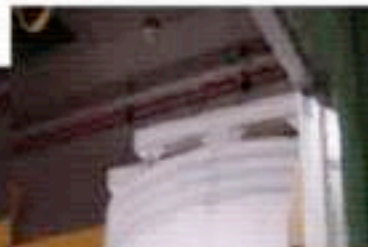
Working at Soudan, Minnesota



CDMS II at Soudan

March 2002

Upper poly & Pb shield will be winched into place



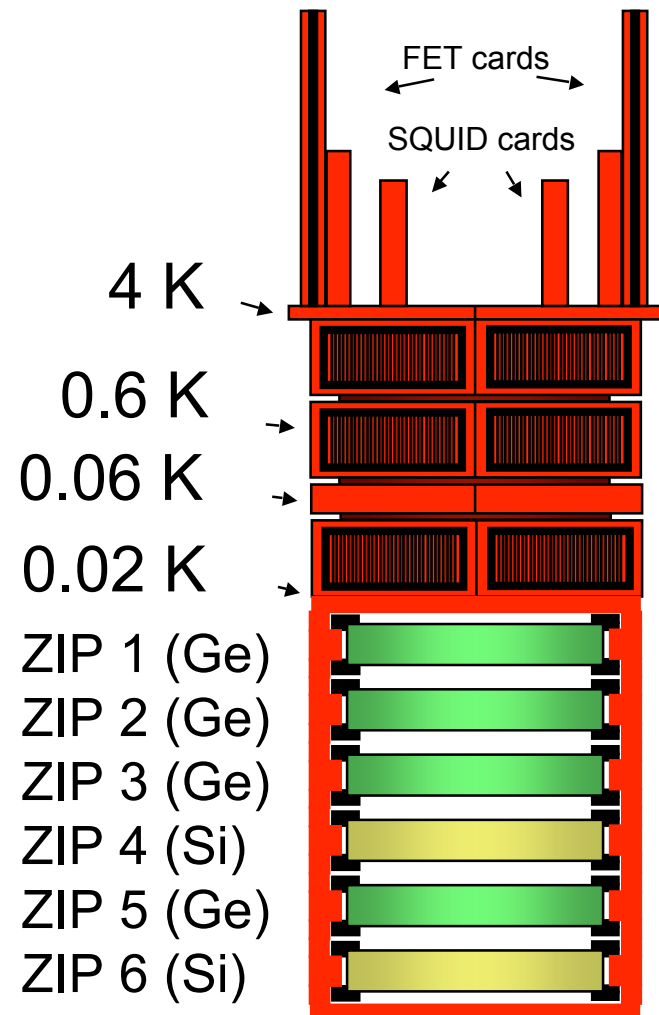
Icebox assembled including polyethylene and Pb shield ...now awaiting attachment to dilution fridge

Clean Room at depth of 2341 ft

Gaibelli (Brown)

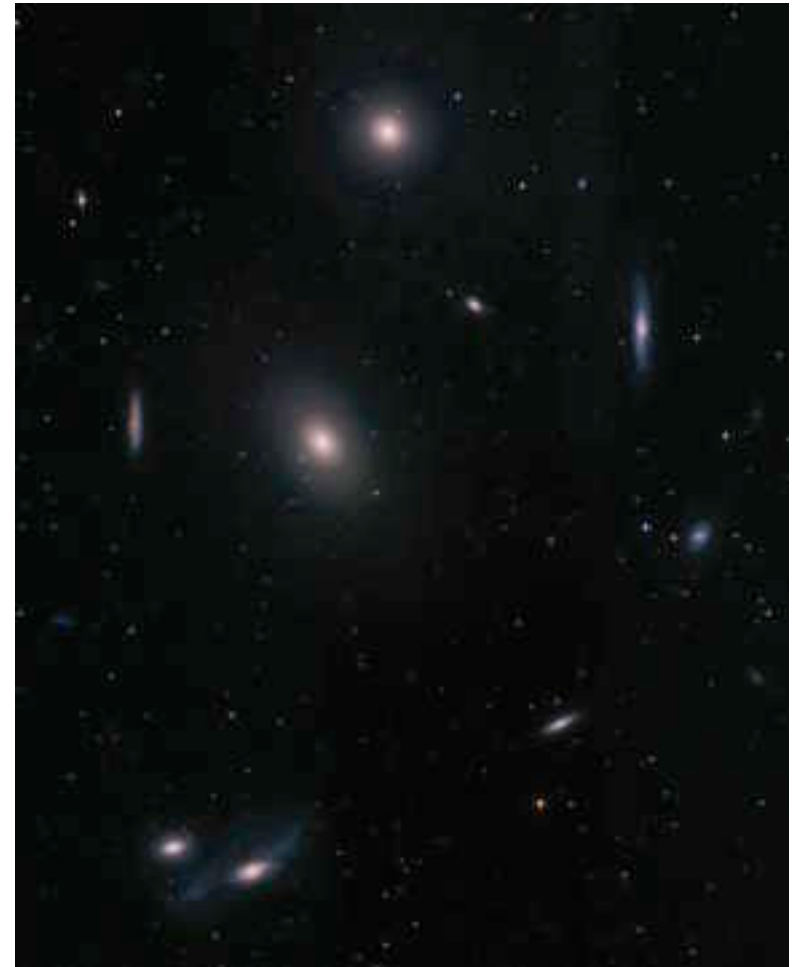
Search for WIMP Dark Matter

- Gaitskell / CDMS Collaboration
- Looking for the very occasional interaction of WIMPs with terrestrial detectors
 - Rates ~ 1 /kg/week - 1/100 kg/year
- Detectors Trigger ~ 0.1 Hz
 - Low Background Experiment
 - Current Exposures of 3-6 months
 - ~ 1 Million Events x ~ 0.1 Mbyte/event
 - We are looking to extract a few of them as evidence for Dark Matter
- Brown Group Programs/Runs Event Processing Farms
 - 16 CPU / 16 CPU / 80 CPU Farms
 - ~ 1 week to spool through data



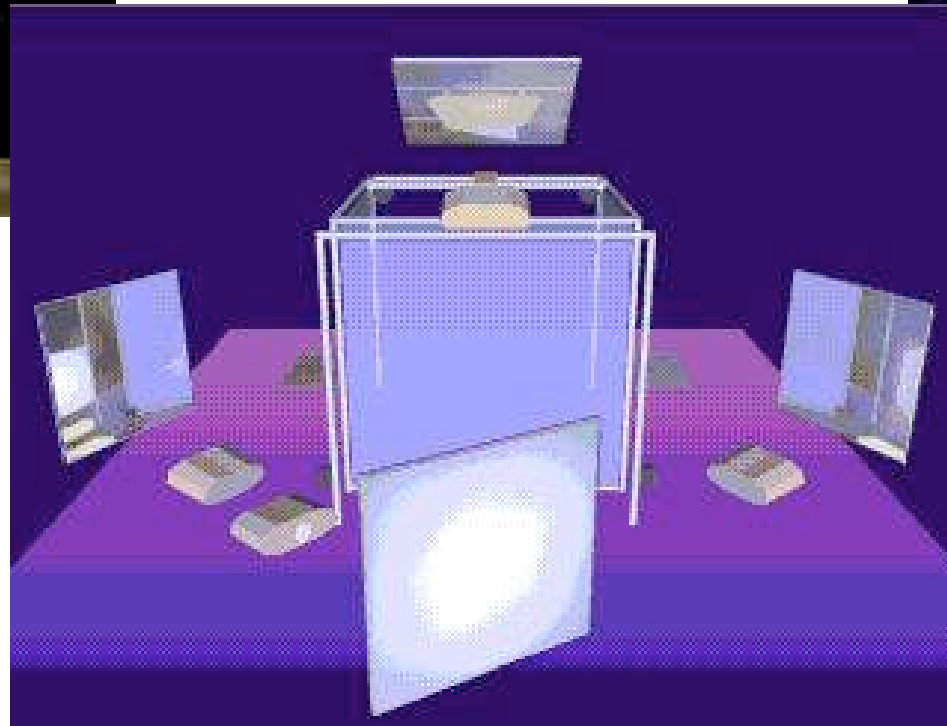
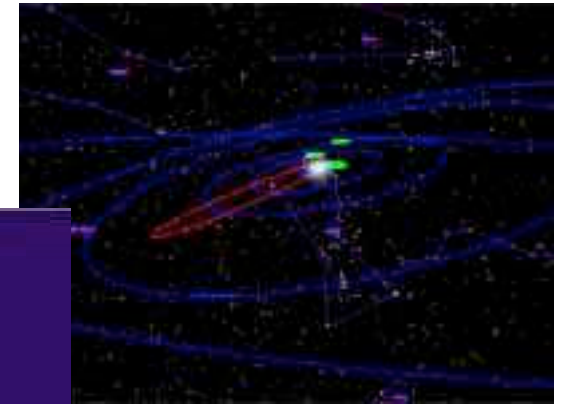
Gravitational Lensing “Deep Lens Survey”

- Prof Ian Dell’Antonio
- 4m Telescopes at Kitt Peak (Arizona) and Cerro Tololo (Chile)
- 64 MPix Camera
- 150 Mbytes/Exposure
- 100-150 exposures per night
- 15-25 Gbytes/night
- Processing at Brown
 - 10 Gbyte sets (from 2.5 TByte library)
 - Single analysis run
lasts ~6 hours on high end workstation
 - Multiple Runs required to form stats

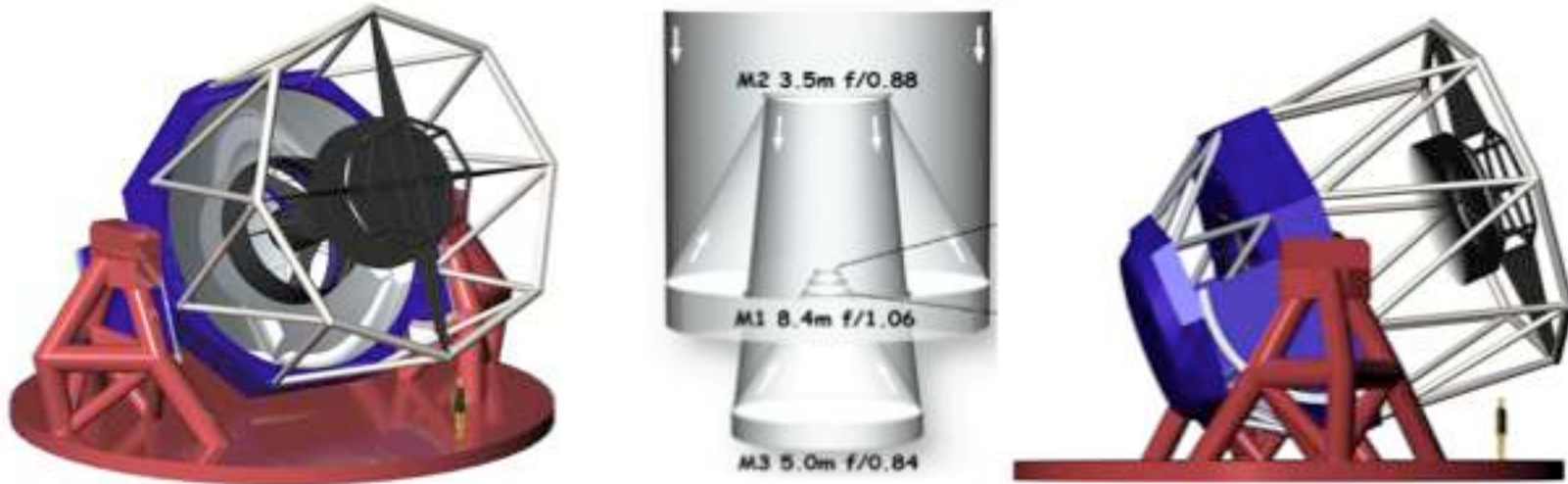


TCASCV @ Brown - 3D Planetarium

- Technical Center for Advanced Scientific Computing and Visualization
- Dell'Antonio/Singer (grad)/Prabhat (staff)



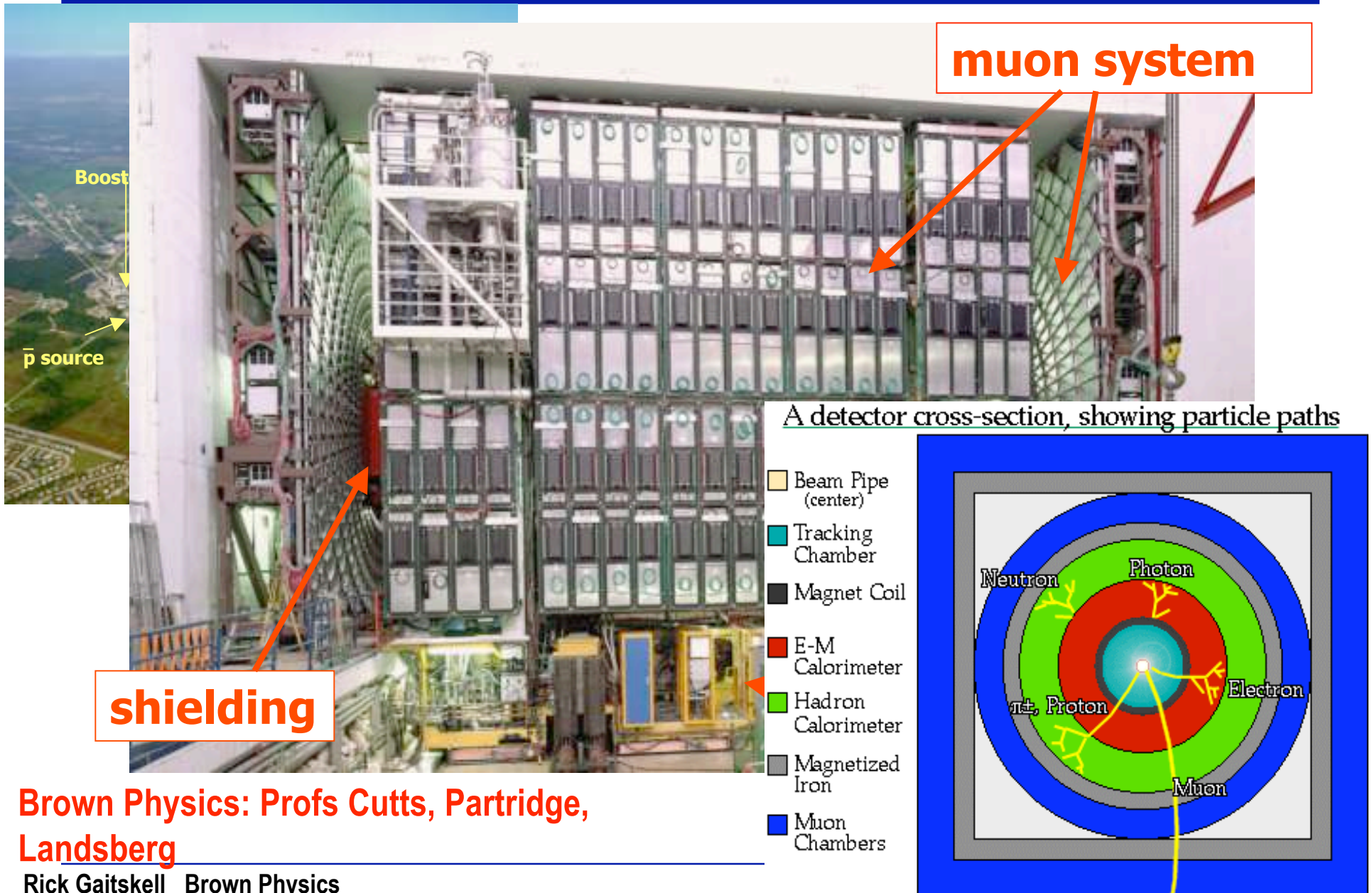
(Future) LSST - Large Synoptic Survey Telescope



- **Wide Field Ground Based Telescope** designed to survey the entire visible sky every few nights
 - **NEO Searches, transients, Dark Matter, Dark Energy, Outer Solar System**
- **Compact 8.4 m primary, 3.4 m secondary, 5.2 m tertiary**
- **2.3 Gpixel Detector**
- **10s exposure -> 9.2 GB / 17 secs , 10-20 TB/night, ~4 PB/year**
- **Goal First Light 2011 (if approved)**

Gordon Squires, CalTech

DØ Detector @ FermiLab



Brown Physics: Profs Cutts, Partridge, Landsberg

Rick Gaitskell Brown Physics

Tevatron Data Rates

- **Raw Interaction Rate 2.5 MHz**

- This is reduced by a series of triggers designed to identify interesting physics to ~50 Hz
 - Factor 50,000 reduction
- Saved events ~0.5 Mbytes
- Given duty cycle, this represents ~200 TB/year

The Large Hadron Collider Project

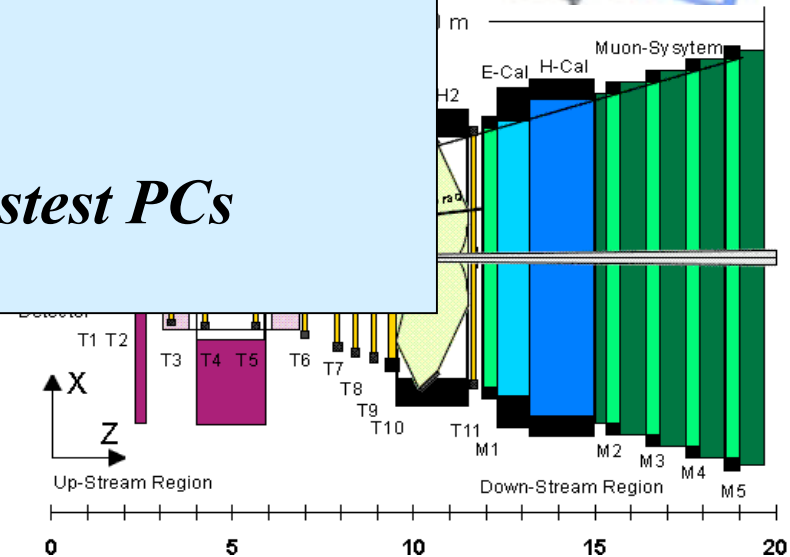
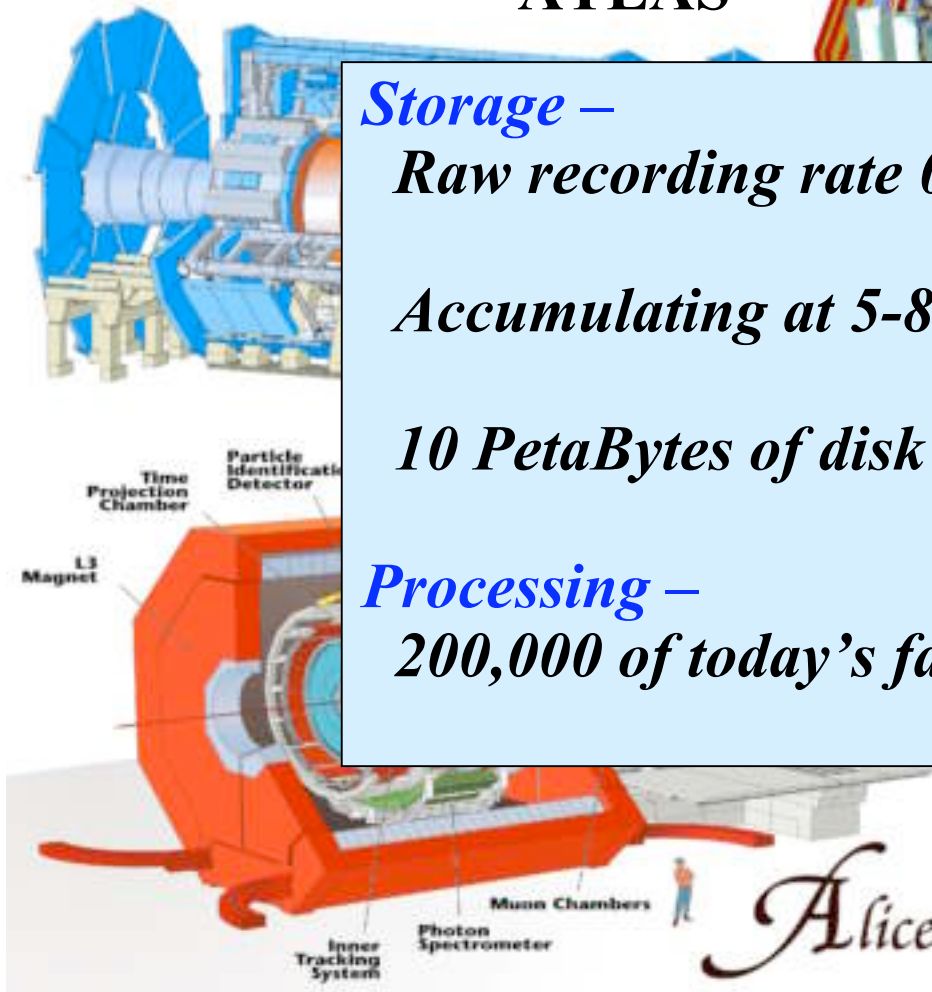
4 detectors

Begin operation 2007
Brown is part of CMS Collaboration

ATLAS

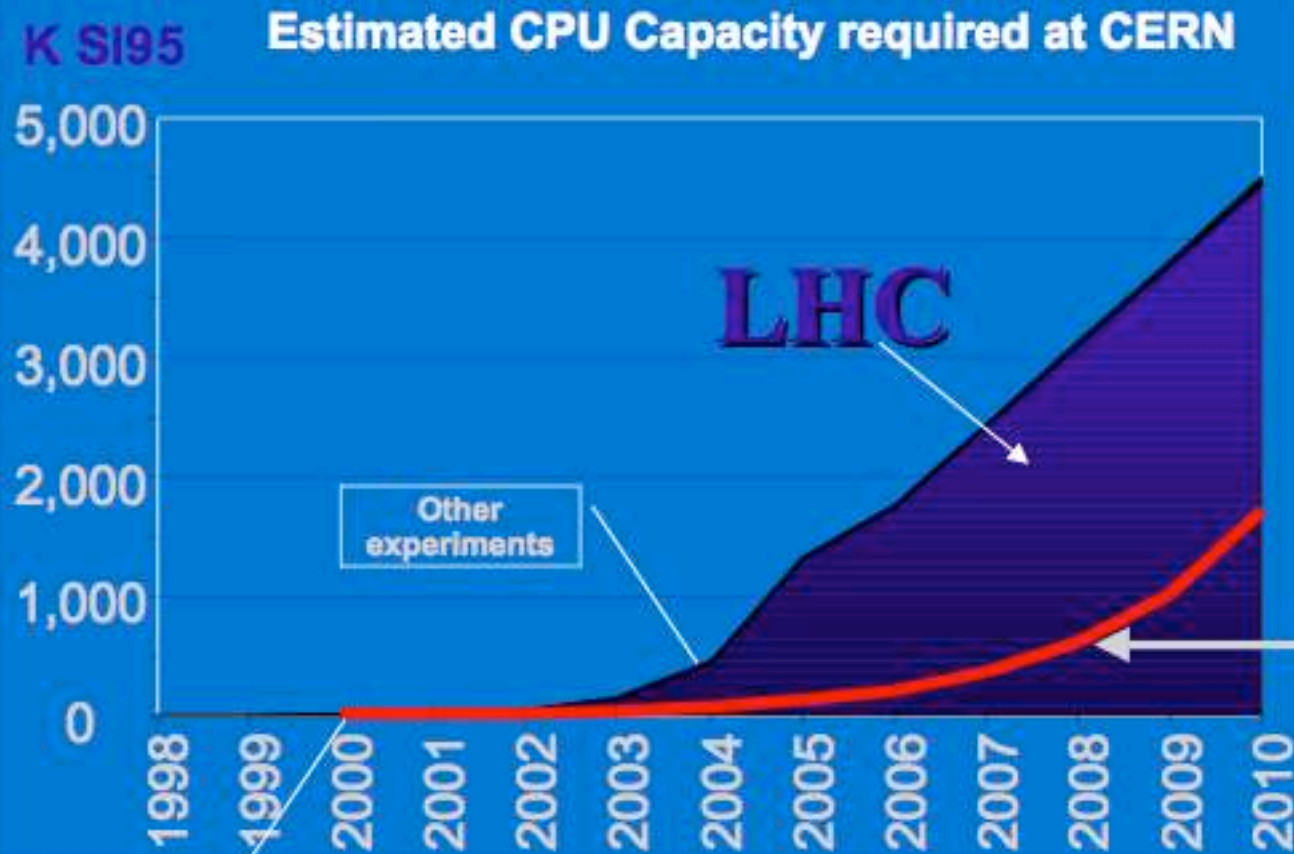
CMS

Storage –
Raw recording rate 0.1 – 1 GBytes/sec
Accumulating at 5-8 PetaBytes/year
10 PetaBytes of disk
Processing –
200,000 of today's fastest PCs



Les Robetson, CERN

: Complex Data = More CPU Per Byte



Moore's law – some measure of the capacity technology advances provide for a constant number of processors or investment



Jan 2000:
3.5K SI95

L.Maiani.13 July, 2001

RECFA. News from CERN

6

les.robertson@cern.ch

A Few Conclusions on Use of Technology in Teaching Present/Future

(Faculty Perspective)

- **Student Feedback has been very positive on new techniques**
 - Popular culture / speed of delivery
- **Looking for ways to leverage faculty teaching time**
 - **Compete Internationally on Research & Deliver Excellent Teaching**
 - **Load associated with preparation of electronic material can be considerable**
 - Expand access to support personnel - to date support from CIS Instruct. Tech. Group has been absolutely invaluable
 - **Looking to Create Multipliers**
 - Tailored Publishing, dynamic course texts
 - Previous development work on courses can be filtered/feed into subsequent courses incarnations (Archives)
 - Facilitate Inter departmental coordination of material (e.g. Math/Eng/Physics)
 - Use of on-line video to expand lecture access / change nature of classroom time
 - **Monitoring of work loads on students**
 - Promote best practices for time management / scholarship

... & Research

- **Physics Research invariably pushes Computing to its absolute limits**
 - **Writing of Software is a huge hidden cost in many physics experiments**
 - **Research Groups have an enormous wealth of experience with system creation / management**
- **Support required from University for Research Program like Physics**
 - **Emphasis Less of maintenance of individual machines**
 - **Emphasis More on Software Licensing / Network Infrastructure**
- **Visualization / Interaction with Data is clearly still in its infancy**
- **General Point...**
- **Universities are designed to be Open Environments, facilitating contact/discussion**
 - **Ensure that general technology strategy is consistent with this**
 - **Open Access / Open Standards**