Overview of SLAC Particle and Particle Astrophysics Program

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An Exciting Time in Particle Physics

- The Standard Model of quarks and leptons is fabulously successful
  - In only describes 5% of the Universe
- Dark Matter and Dark Energy make up 95% of the Universe
  - New forms of matter and energy outside of current understanding
- We don't understand why the Universe is matter dominated
- Compelling Questions confront us
  - Within this decade tools coming on line to make progress in our understanding
  - Developing tools for discovery in the next decade

A Challenging Time in Particle Physics

- Premier US HEP accelerators will turn off by the end of the decade
  - Tevatron (FNAL) 2009
  - B-Factory (SLAC) 2008
  - CESR (Cornell) 2008
- By end of decade, the frontiers of HEP may be off shore
  - LHC (CERN)
  - JPark (KEK)
  - KEK-B (KEK)
- Long term health and future of the field of HEP relies on ILC
  - Very expensive (~$8B)
  - Excellent progress towards international realization of such a machine
    - Not a certainty!

SLAC's Leadership Role in these Uncertain Times

- SLAC's HEP mission:
  - responsibility and an obligation to provide technical and scientific leadership to the national (and international community)
  - provide unique technical capabilities for the management and construction of large-scale projects
  - build and operate the accelerators that define the frontiers of the field
  - enable members of the University community to play leadership roles in the HEP program and have full access to the physics
  - participate in the education of a scientifically trained workforce, and in the training of the future leaders in the field
- Challenge:
  - carry out mission at a time when major changes from past way of doing business
    - No onsite frontier HEP machine
  - carry out mission at time when future options uncertain
    - ILC

Focus of Current and Future SLAC Scientific Program

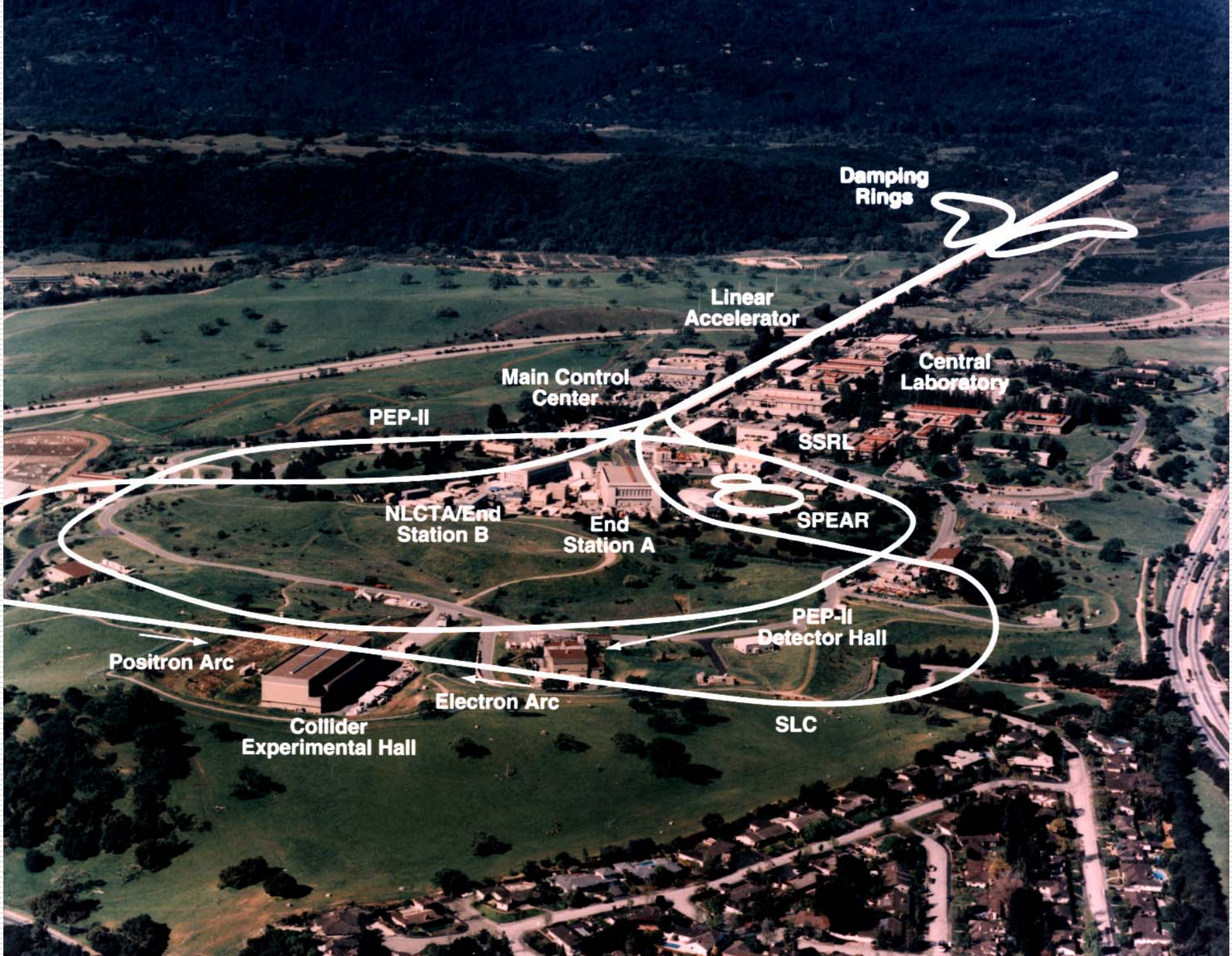
- SLAC HEP program is addressing compelling scientific questions facing the field
  - Where did the antimatter go? (B-Factory)
  - Are there new symmetries and forces of nature? (B-Factory, ILC)
  - Why are there so many particles? (B-Factory)
  - What is Dark Matter? How can we make it in the lab? (LSST, JDEM, GLAST, ILC)
  - Can we solve the mystery of Dark Energy? (LSST, JDEM, ILC)
  - Is there grand unification of particles and forces? (ILC, EXO)
  - What are neutrinos telling us? (EXO)
  - Are there extra dimensions of space? (ILC)
- SLAC HEP program is extremely broad

Particle Physics: Flavor Physics

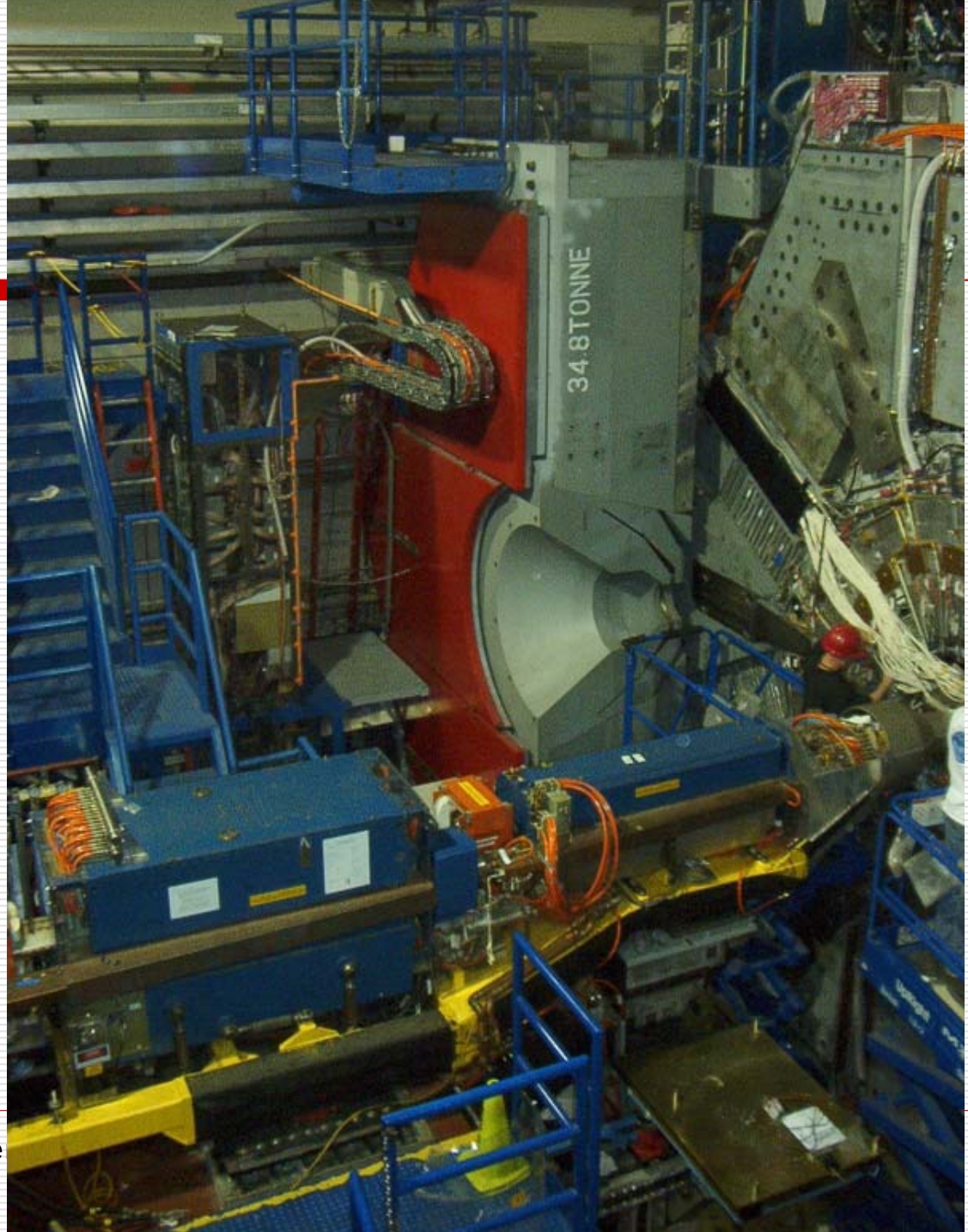
- BaBar

B-Factory Program

- PEP-II Accelerator
  - Collides e+ and e- with unequal beam energies at E_{CM}=10.58 GeV
  - Premier tool for studying physics of heavy flavor
- BaBar Detector
  - Optimized for B-physics at asymmetric energy collider
  - Run by International Collaboration of ~623 physicists from 80 institutions in 11 countries
- B-factory program operates until end of FY2008
  - Data analysis continues for several more years after data taking stops


Damping Rings
Linear Accelerator
Central Laboratory
Main Control Center
PEP-II
SSRL
NLCTA/End Station B
End Station A
SPEAR
PEP-II Detector Hall
Positron Arc
Electron Arc
Collider Experimental Hall
SLC

BABAR™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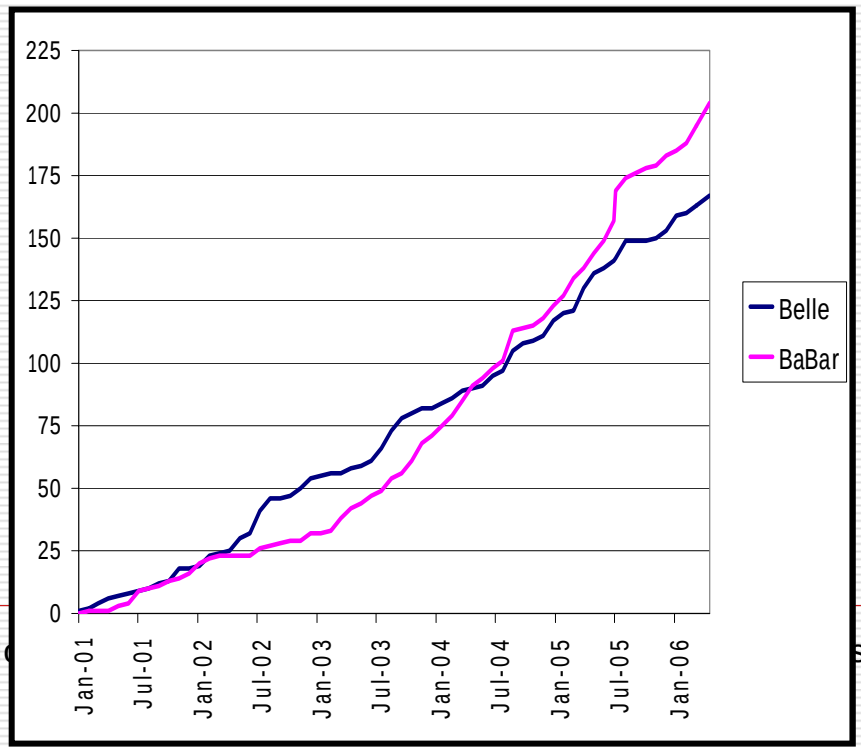
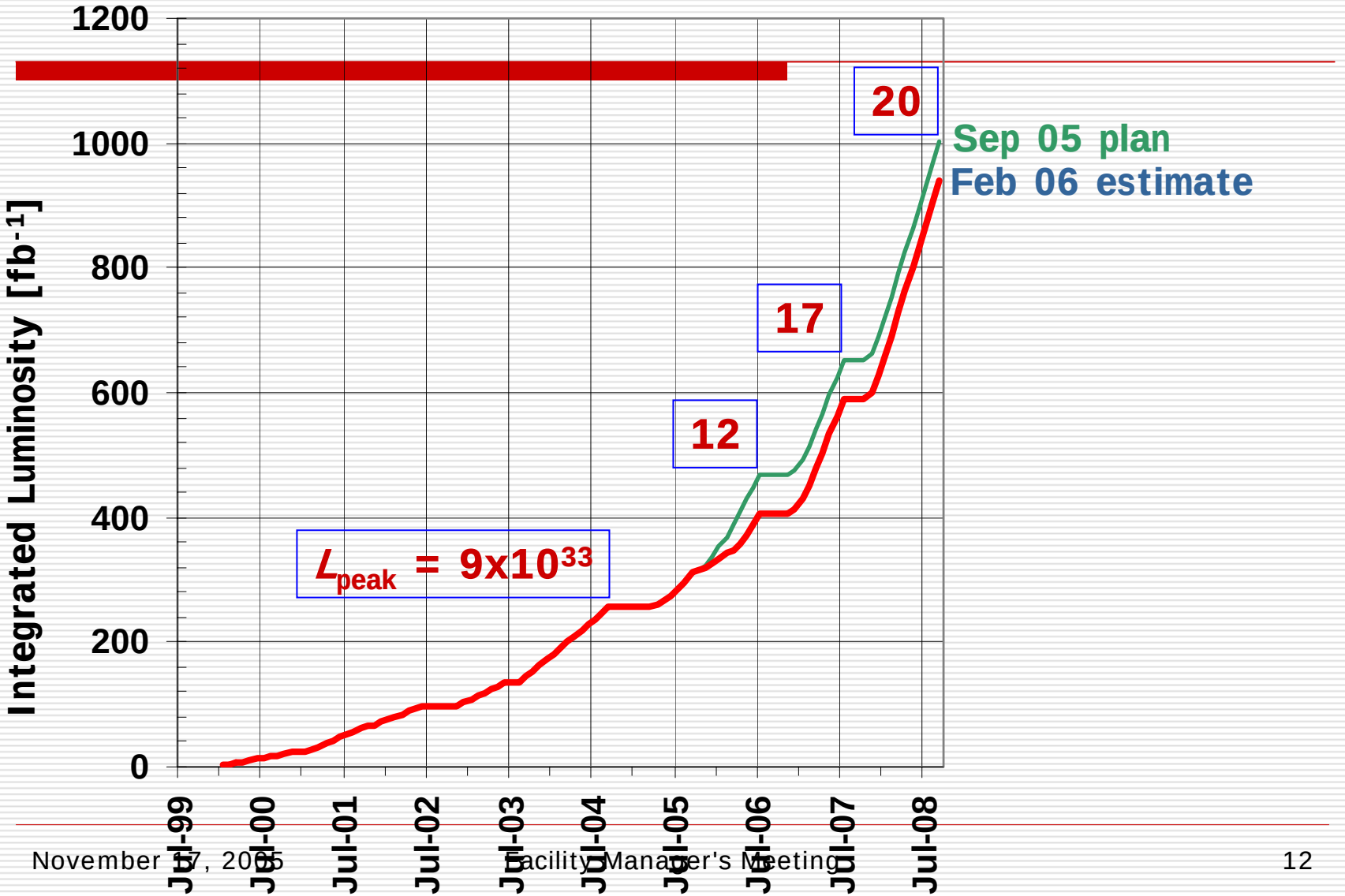
B-Factory Physics Performance

- SLAC B Factory continues to be tremendously productive
  - Babar produces, on average, one, high-quality journal publication per week. Many of these are “first-ever” measurements
  - By any metric, Babar’s productivity is outstanding; but it is especially impressive as measured by physics/fb^{-1}



Journal Papers	BABAR	Belle
<2003	32	54
2003	39	28
2004	52	35
2005	60	36
2006	22	15
Total	205	168

Projected data sample growth



B-Factory Science Program

- B-Factory science drivers:
  - What happened to the antimatter?
    - B mesons a laboratory for study of CP violation
      - Discovery measurement in 2001
      - CP in charmonium (b→c) modes now measured to +-7%
      - Quark mixing by weak interactions not the whole story
  - Are there new symmetries/forces of nature?
    - Unique access to flavor sector of 'new physics'
      - CP in b→sss modes provides crucial testing ground for SUSY
      - Intriguing discrepancy!
  - Can we determine the pattern and properties of the quarks and leptons?
    - e+e- b factories are also τ and charm factories
      - Surprises: new charm strange quark states

Particle Physics: High Energy Frontier

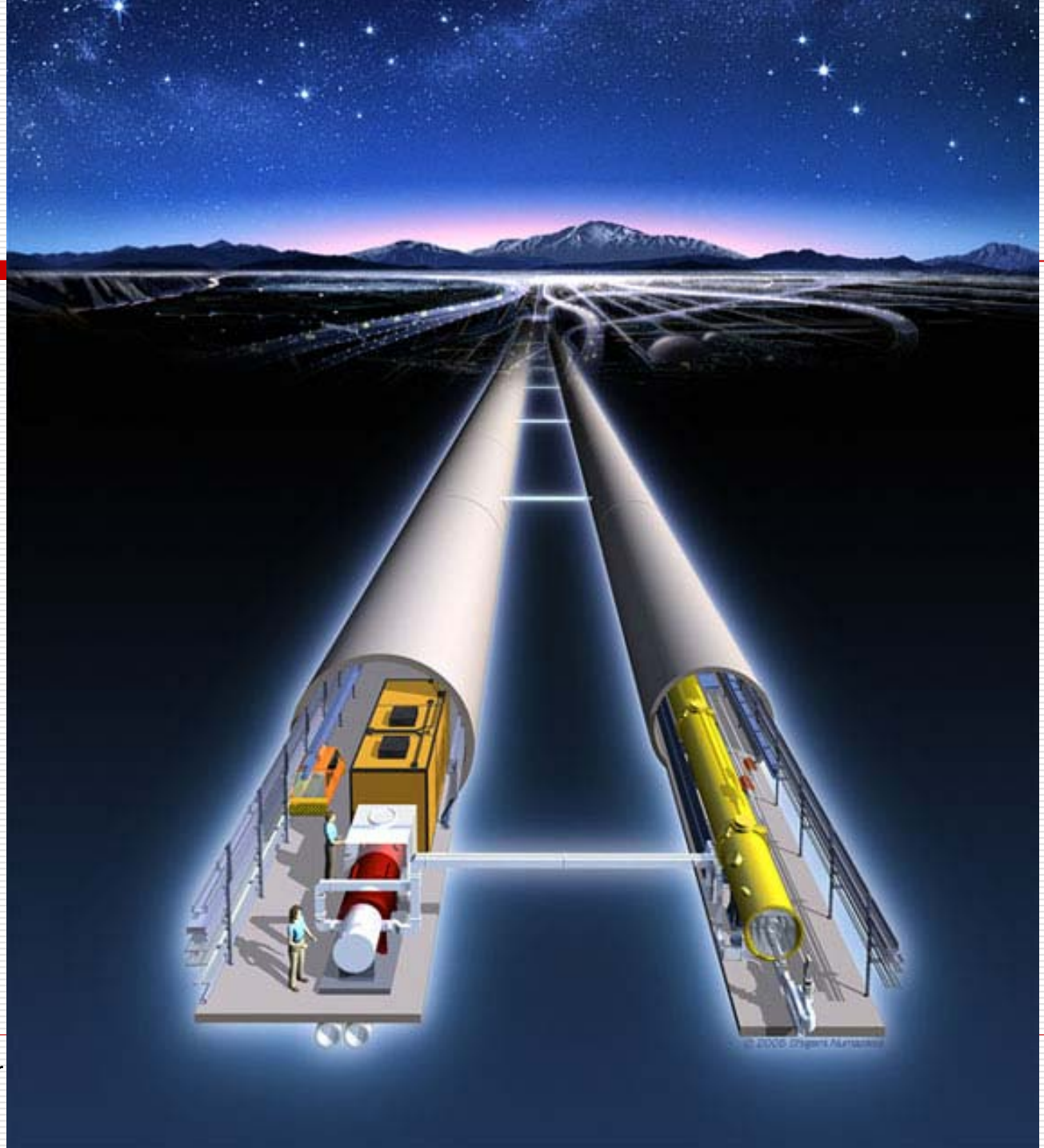
- Linear Collider
- Advanced Accelerator R&D

The Linear Collider

- Linear Collider Science Drivers
  - Are there new symmetries and forces of nature?
  - What is Dark Matter? How can we make it in the lab?
  - Can we solve the mystery of Dark Energy?
  - Is there grand unification of particles and forces?
  - Are there extra dimensions of space?
- Linear collider essential to establish quantum nature of the ‘dark universe’
  - Active work to articulate science case more broadly

Strategic Look at Linear Collider

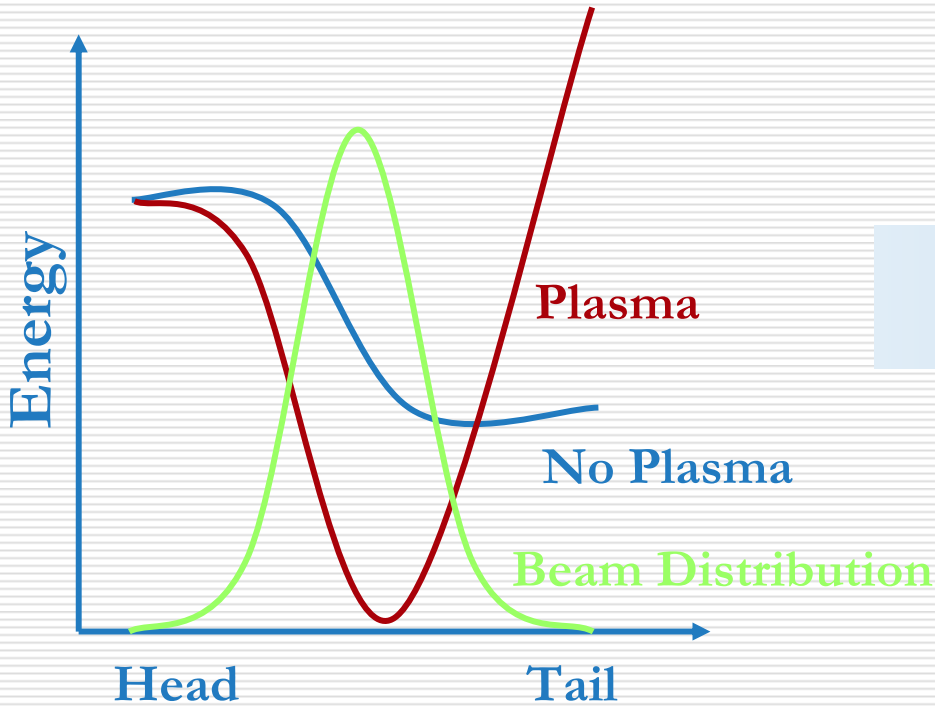
- High Energy e+e- LC highest priority new machine for world community
  - Two 20 km long linacs
    - Accelerating e+ and e- to collisions
  - Energy of 500-1000 GeV CM
  - Price tag ~ $8B
- SLAC has led the world in the design and development of the ILC
  - We will be major players, where ever in the world it is built
  - We very much hope it will be built in the US

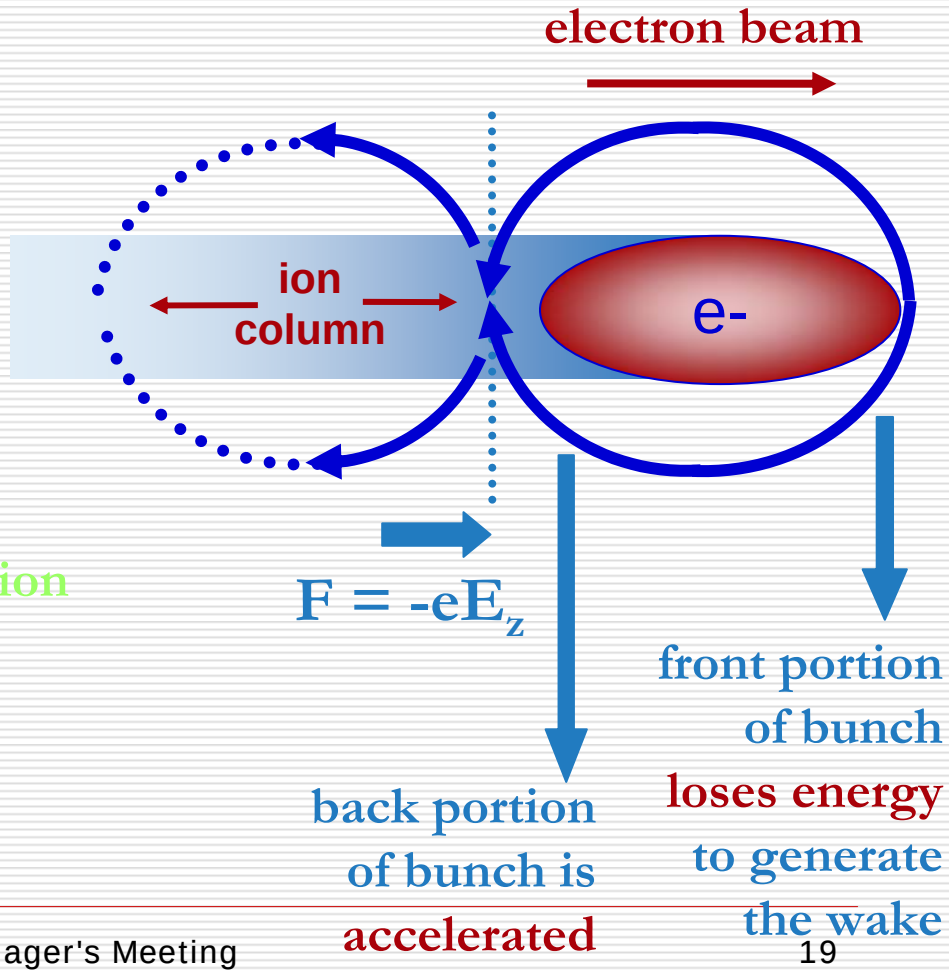


Advanced Accelerator R&D

- Preparing for challenges of longer term future fo field
- Explore underlying physics
  - Theoretical efforts in many areas supporting current experiments and aimed at longer term future
    - Beam Dynamics
    - Collective Effects
    - Accelerator Structures
- Proof of principle experiments
- Unique facilities for Accelerator R&D here at SLAC
  - FFTB→ Saber
  - NLCTA
  - ASTA
  - Klystron Test Lab
  - End Station A

Plasma Acceleration





E-167: Energy Doubling with a Plasma Wakefield Accelerator in the FFTB

UCLA USC

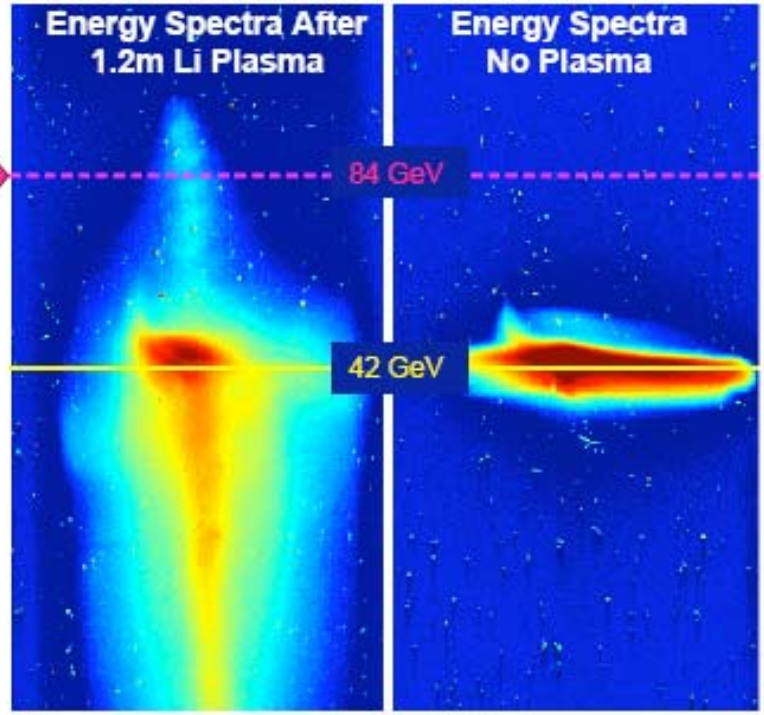
At the last SPC Meeting 6 months ago:

Set the ambitious goal of doubling the energy of some of the 28.5 GeV electrons…

- Earlier experiments by same collaboration demonstrated > 30GeV/m over 30cm
- Late 2005 realized modifications to beam line would allow longer plasma & energy doubling
- Started on new 1.2 meter plasma source in December 2005
- Beam line modifications in February 2006

Final Run in FFTB April 2006:

Particle Energies > 84GeV Routinely Observed!



- ❑ Linac Running All-out To Deliver Compressed 42GeV Electron Bunches to the Plasma
- ❑ Record Energy Gain
- ❑ Significant Advance in Demonstrating Potential of Plasma Accelerators

Particle Astrophysics and Cosmology

- GLAST
- KIPAC: Kavli Institute for Particle Astrophysics and Cosmology

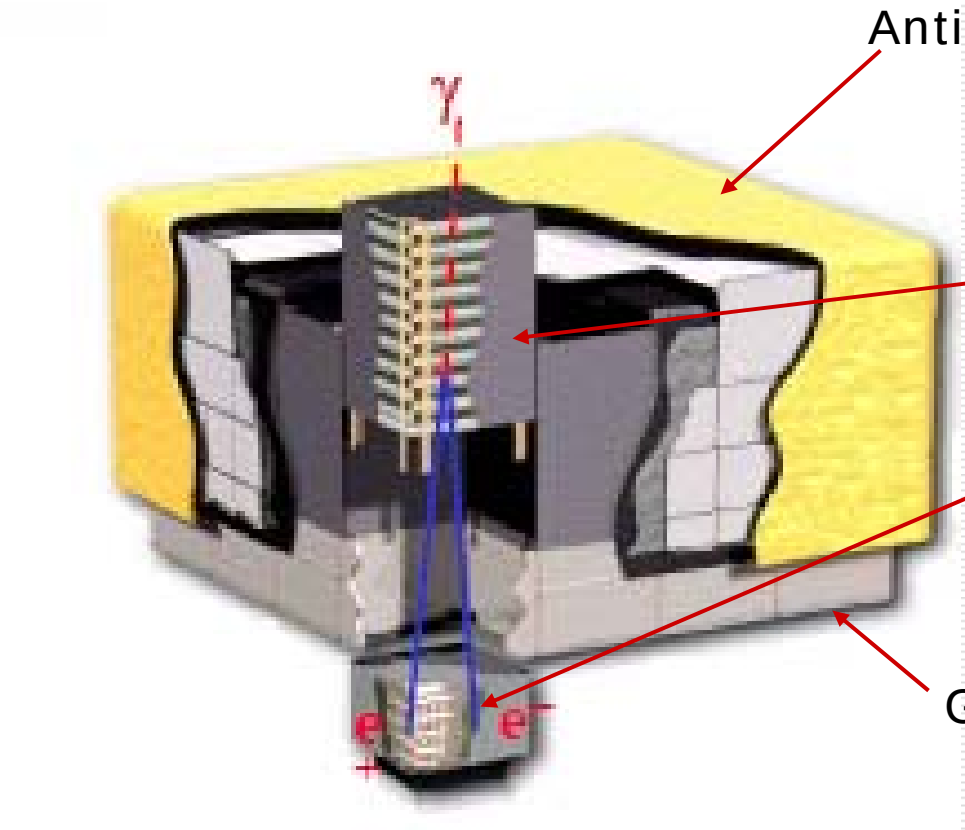
Particle Astrophysics and Cosmology at SLAC

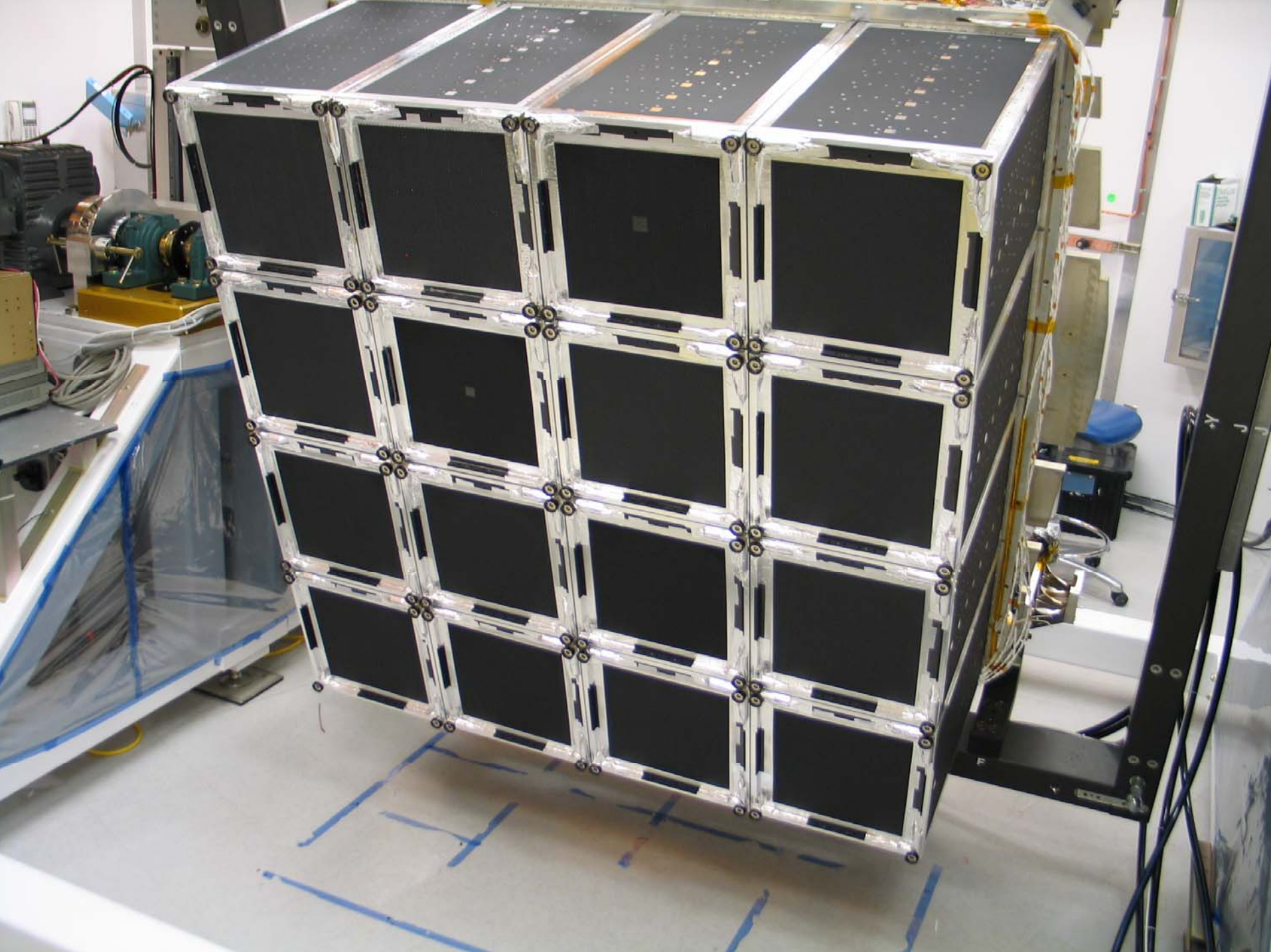
- SLAC's HEP mission has broadened to include particle astrophysics and cosmology
  - Science Drivers for Particle Astrophysics program
    - Understanding the "Quantum Universe"
      - What is Dark Matter? How can we make it in the lab?
      - Can we solve the mystery of Dark Energy?
- Look for opportunities where SLAC plays unique and enabling role
  - Any participation where SLAC resources are involved, the level and scope of participation should be significant and commensurate with status as a national laboratory

GLAST

- GLAST: γ-ray Large Area Space Telescope
  - GLAST measures direction, energy and time of celestial gamma rays from 20MeV – 300 GeV
  - Will Survey entire sky every 3 hours
    - A direct view into Nature's largest accelerators
    - Gamma rays probe cosmological distances in a largely unexplored energy range
    - Great potential for Discoveries:
      - Dark Matter Searches
      - Endpoints of Stellar Evolution: Black Holes, Neutron Stars, Sne remnants
      - Active Galactic Nuclei and Gamma Ray Bursts
  - Joint Particle Physics/Particle Astrophysics venture
    - Involves 5 nations, 9 funding agencies
- Launch August 2007

LAT Instrument





LAT Mounted on Shipping Container Friday Morning

KIPAC: Kavli Institute for Particle Astrophysics and Cosmology

- Institute of Stanford University
  - Institute building on the SLAC site funding by gift from Fred Kavli
- Director reports to Stanford Dean of Research
  - 9 new faculty (4 in place)
  - Establishes Stanford/SLAC/DOE as intellectual force in field
- Institute brings in funds from NASA and NSF in addition to DOE funds through SLAC
  - Highly leveraged by > $20M investment by Stanford University
- Growing fast!
  - Institute 100 strong and growing
    - > 20 new people
    - Others from existing SLAC and SU communities

KIPAC: Kavli Institute for Particle Astrophysics and Cosmology

Particle Astrophysics and Cosmology: The Future

- Potential SLAC/KIPAC Projects
  - SNAP Collaboration (JDEM)
    - 2m telescope, 0.7 sq deg field in space
      - Study high z SNe ➔ Dark Energy
      - Weak Gravitational lensing ➔ Dark Matter
      - Strong Lensing➔ Small scale structure
  - LSST
    - 8.4 m telescope, 8.6 sq deg field on the ground
      - Weak lensing survey of entire sky ➔ Dark matter power density spectrum➔ Constraints on Dark Energy
- Many other NASA funded KIPAC Projects under discussion (Exist, Next, POGO, ...)
- KIPAC effort already very visible and very productive
  - Over 100 publications in first 18 months..
  - 3 major conferences

The Future Program

Program Timelines: Exploiting the present and preparing for the future

- Science now or soon
  - BaBar (running now to 2008)
  - GLAST (2007 – 2012/17)
  - Proof of principle experiments in accelerator research
- R&D for near term science (2012)
  - Ground Based Dark Energy: LSST (first light 2012??)
  - Neutrinoless Double Beta Decay: EXO (2012?? if R&D successful)
  - Space Based Dark Energy: JDEM (20??)
  - ILC (2016?)
- R&D for farther future
  - Accelerator Research

Programmatic Priorities

- For the near term:
  - We must focus on B-factory performance and delivery of science to our largest user community
- For the mid term:
  - We must continue in our leadership role for the ILC
    - Highest priority new facility for the world community
  - We must complete GLAST construction and develop the ISOC to enable science for the collaboration
  - We must work to provide additional opportunities for science to the HEP and SLAC user community in ~2012
    - e.g. LSST, EXO, JDEM, new accelerator based initiatives....
- For the long term:
  - The R&D in accelerator science is our hope for the future of the field
    - To make the next accelerator *after* the ILC technically feasible and affordable

Programmatic Challenges

- Active workforce management needed
  - as transition from on site to off site accelerators
  - as non accelerator fraction of program grows
- ILC needs increased funding and continued government and community continuity of commitment
- To grow non accelerator programs will need to establish and execute a stable multi-agency research investment plan
- Must capitalize on spectacular KIPAC opportunity

Summary

- PPA in time of transition
  - Changes from past
  - Exciting opportunities for the future but also significant uncertainty
- SLAC's HEP programs and leadership central to national and international effort
- Working with community and agencies to develop balanced, forward looking, science driven programs