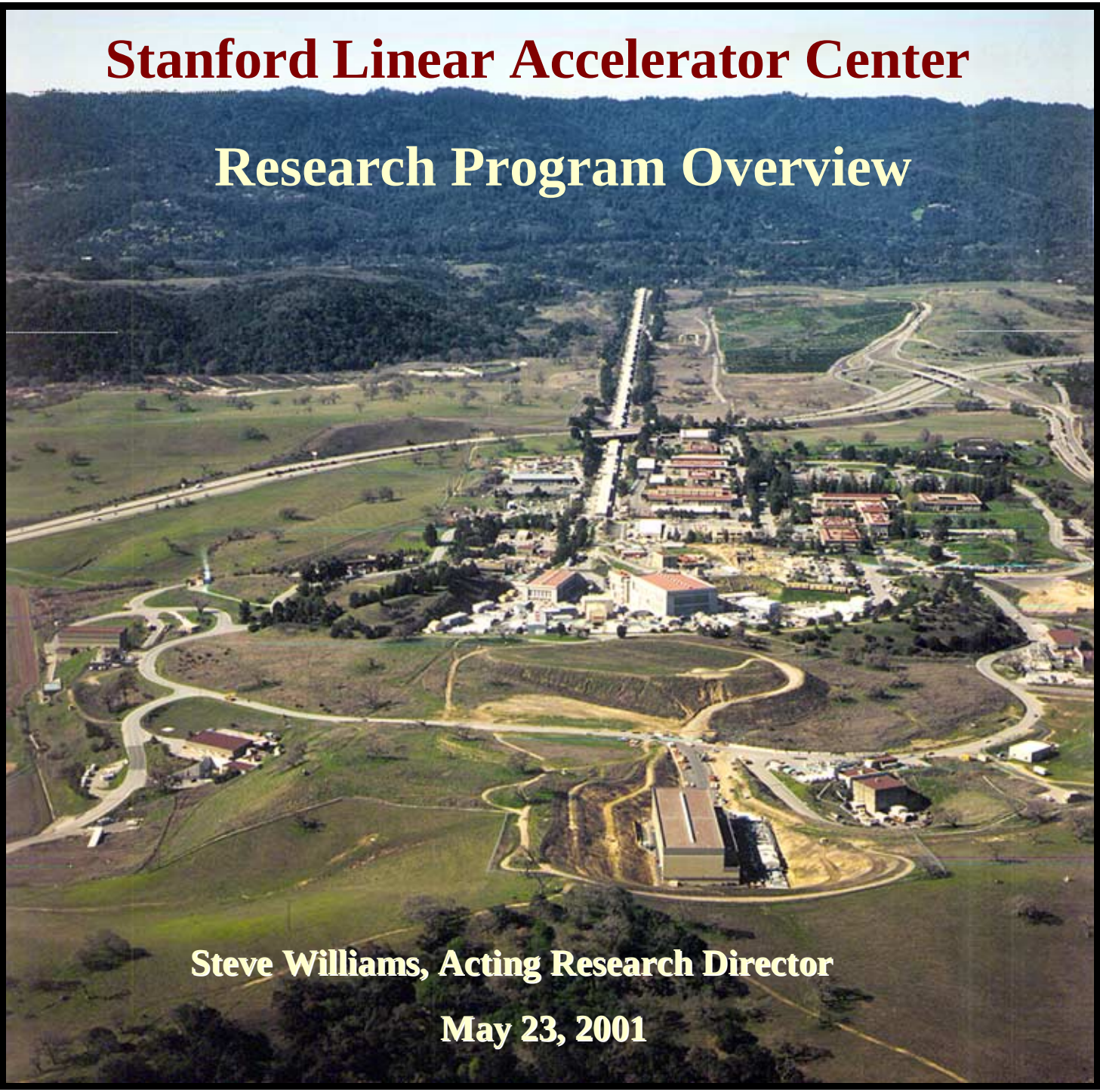
Stanford Linear Accelerator Center

Research Program Overview



Steve Williams, Acting Research Director

May 23, 2001

SLAC HEP Mission

- **Particle Physics and Accelerator Research – Theory and Experiment**
- **Electron Probes of the Standard Model**
- **Particle Physics connection to cosmology**
- **User facilities operation: PEP II/*BaBar*, ESA, FFTB, NLCTA, GLAST**

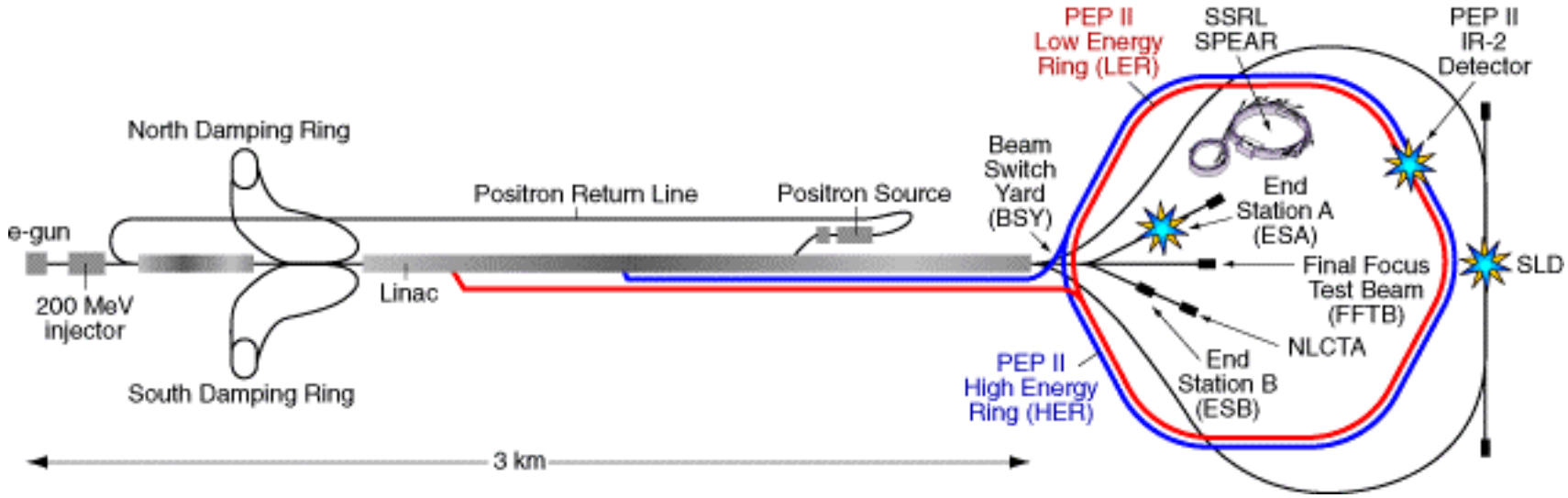
SLAC HEP Program

- **Main elements of the SLAC Program**
  - ***B* Factory – CP Violation test of electroweak Standard Model, heavy quark program**
  - **End Station A fixed Target Program –**
    - Uses of the unique 50 GeV polarized e- linac beam
    - Möller Scattering – test of electroweak SM away from Z
    - Polarized photon beam – virtual photon spin physics revisited with real photons
  - **Final analysis of SLD – polarized e- Z physics data set**
  - **Particle Astrophysics**
    - USA X-ray Timing Experiment – in analysis
    - GLAST construction – launch 2006
  - **High Energy Particle and Accelerator Theory**
  - **Accelerator R&D**
    - Next Linear Collider (NLC)
    - Diverse, user-based program of advanced accelerator R&D experiments and theory

The Ubiquitous SLAC Linac

- **The backbone of our accelerator-based high energy physics program continues to be the SLAC Linac. It remains today a facility unique in the world, providing simultaneously:**
  - **120Hz of ultra-high energy (50GeV), highly polarized (80%), very intense ($4x10^{11}$/pulse) electrons and**
  - **60Hz of ultra-high energy (50GeV), very intense ($4x10^{10}$/pulse) positrons**
- **The flexible timing system and pulsed hardware allows for an interleaved program of PEP-II injection and straight through beams**
- **Laboratory continues its history of innovative applications of the linac**
  - **New, unique dimension will be provided by the 4-45GeV, diamond-extracted, circularly polarized photon beam now in design. Will provide 10^7 photons / pulse**

Much More than a Linac!



The Ubiquitous Linac
(continued)

- **Consider the myriad functions of the Linac:**
  - **Front 2/3 used for simultaneous injection of both PEP-II rings. One of the key elements in the early success of the B Factory program is the power of the Linac as an injector**
  - **Source for the End Station A Physics program; new DR bypass to interleave long and short pulses.**
  - **Source for the Final Focus Test Beam. This facility is used for both physics experiments and an extensive program of accelerator R&D**
  - **The back 1/3 of the Linac will be used to produce a 15 GeV electron beam for the Linac Coherent Light Source (LCLS). A bypass system will preserve the 50 GeV to End Station A capability**
  - **Source for the ASSET facility - a unique capability for studying the performance of accelerating structures**
  - **Source for an active program of test beams. Test beams are critical for the development, testing and calibration of detector hardware**

B Factory

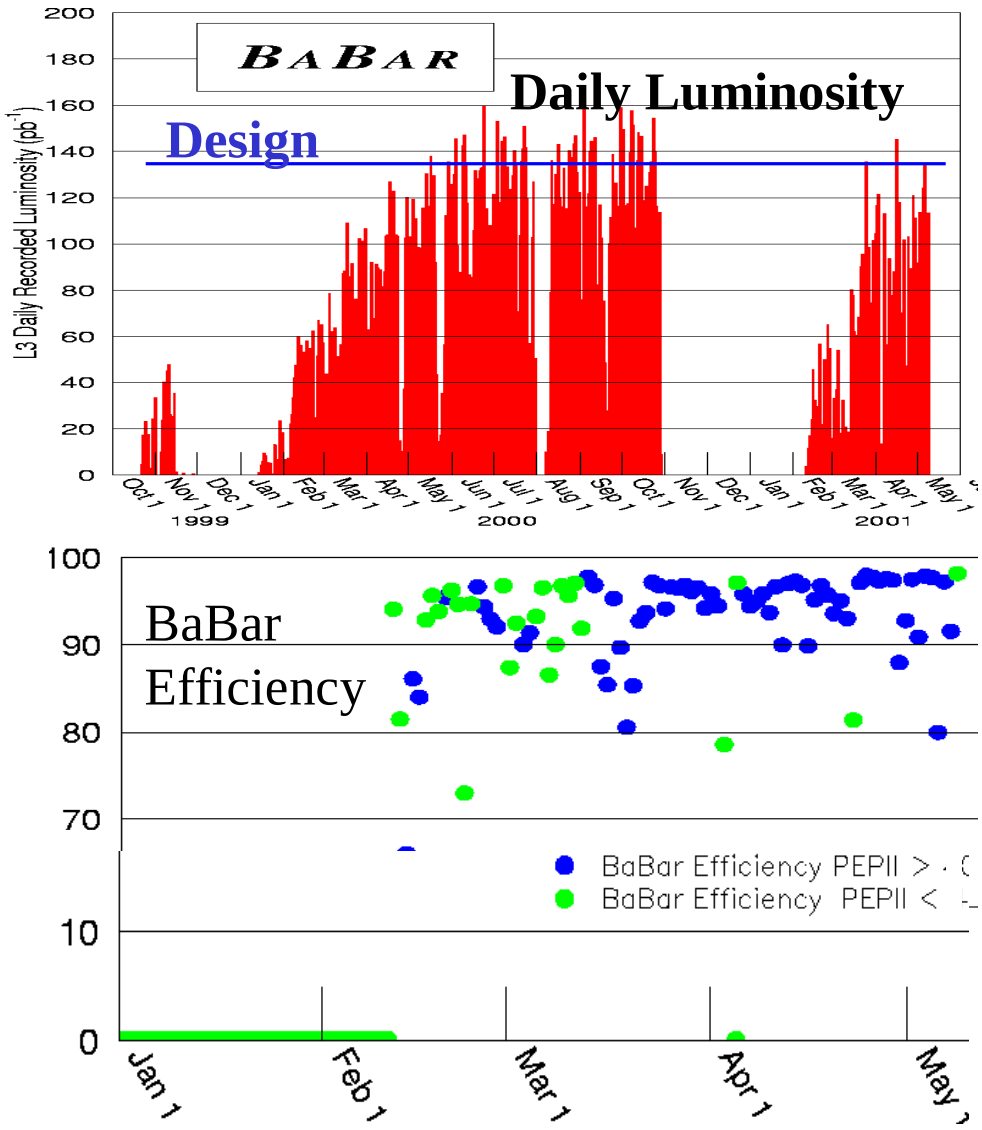
- **Exciting, broad physics program with excellent discovery potential**
  - **Accelerator and machine are performing well**
- **Machine has reached design performance quickly!**
  - **There is plenty of headroom for achieving higher peak luminosity**
- **Have begun the upgrade process. Goals are:**

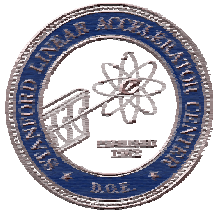
  A) $L = 10^{34}$ cm^{-2} sec^{-1} during 2003
  ~ 500 fb^{-1} by the end of 2005

  B) $L \geq 2 \times 10^{34}$ cm^{-2} sec^{-1} during 2006
  ~ 200 fb^{-1} per year, 2-3 years to double event sample

- **Provides at least 10 years of Frontier Science**
- **Positive physics competition with KEK and soon Run II at FNAL**

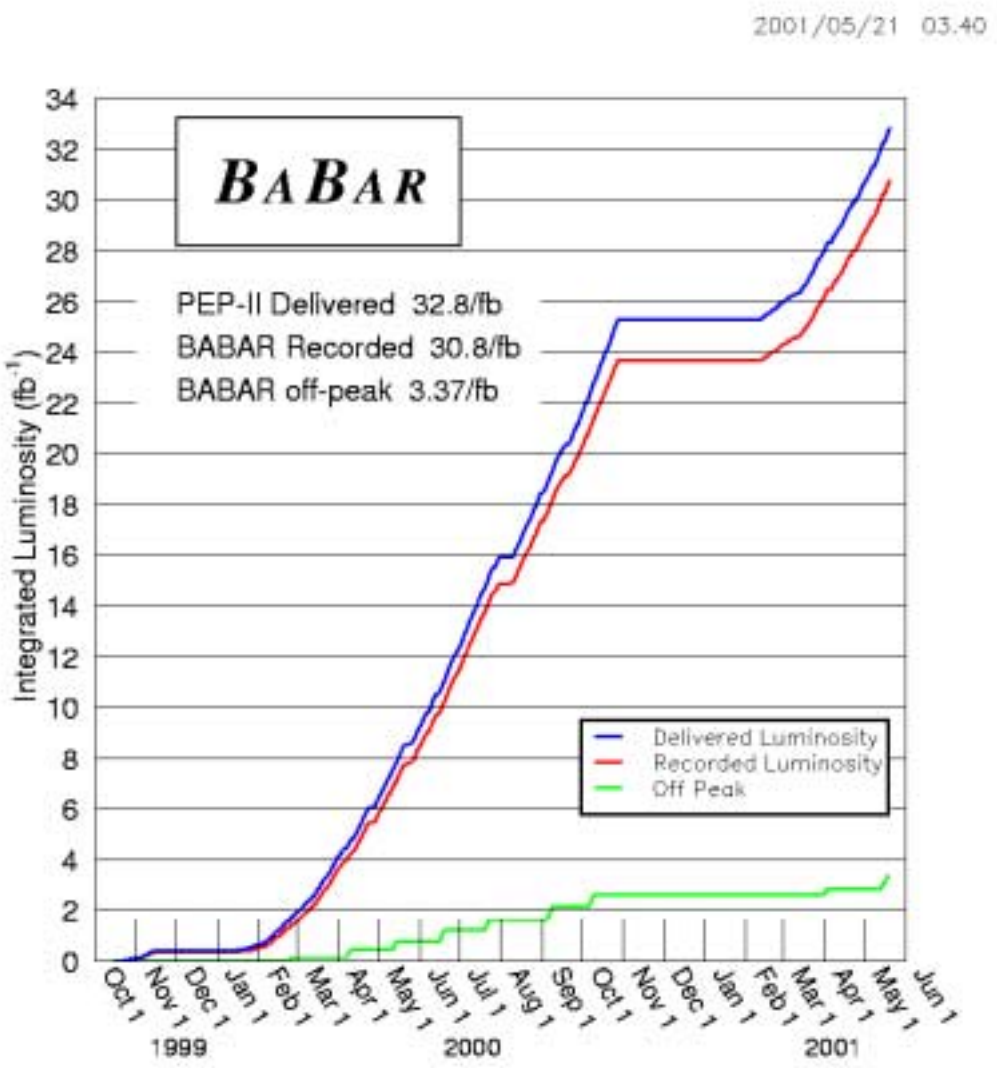
2000/01 PEP II-Babar Operations





- Detector is integrating efficiently
- Computing model is working
- Plans are in place to deal with the rising luminosity
- Collaboration management is working well
- International finance committee very supportive
- Impressive suite of results based on 21 fb-1 were presented at Winter/Spring conferences; many in the “best of” category.
  - Sin2beta paper published in February
  - Expect 50 papers in the coming year

2000/01 Operations



Beyond 2006

- If cracks in the Standard Model begin to appear in data from the B Factory program through 2006, .. this will be one of the most exciting arenas in HEP experimentation, world-wide ;

- At that point keeping the PEP II/BaBar data doubling time around 18 months, becomes an imperative ;

- The machine and detector communities working at the laboratory are studying several scenarios for further upgrades that would allow a credible response and keep the US heavy quark program in e+-e- physics at the world frontier beyond the end of the decade.

HEP Theory Group

Research in theoretical high-energy physics

- **A broad front from low-energy QCD to M-theory**

Theoretical support for experimental projects

- **Organization of `The BaBar Physics Book"**
- **Organization of many linear collider studies, including the `Linear Collider Physics Resource Book for Snowmass 2001'**

Training of young researchers

- **Direct Ph. D. thesis research for Stanford graduate students**
- **Postdoctoral fellows maximum freedom and stimulation**

Theory program has close ties to the physics departments of Stanford and UC Santa Cruz.

HEP Theory Research Topics

Physics at the B factory

- o Methods for model-independent extraction of CP angle
- o Influence of new physics on CP asymmetries, and methods for distinguishing new physics from the Standard Model

Physics at Linear Colliders

- o Basic theoretical studies for top and SUSY parameter determination in e+e- experiments

Computational Perturbative QCD

- o New theoretical methods for 1-, 2-, and 3-loop computations needed for precision QCD studies

Extra Dimensions

- o Broad study of experimental signatures of new space dimensions

Superstring Theory and M-Theory

- o Studies of nonperturbative phenomena in string compactifications with N = 1 supersymmetry
- o Study of the implications of extra space dimensions in explicit string realizations
- o Search for solutions to the cosmological constant problem

Fixed Target & Accelerator R&D

- B Factory uses only a fraction of the beam available from the Linac; opportunity for new quality science, therefore
- Fixed Target and Accelerator R&D complement the Babar Experiment, broadening the physics program of the lab
- Like Babar these are user driven programs
- Advance accelerator development collaborative with users
- E158 Moller scattering and the Real Photon Beam experiments led by external groups

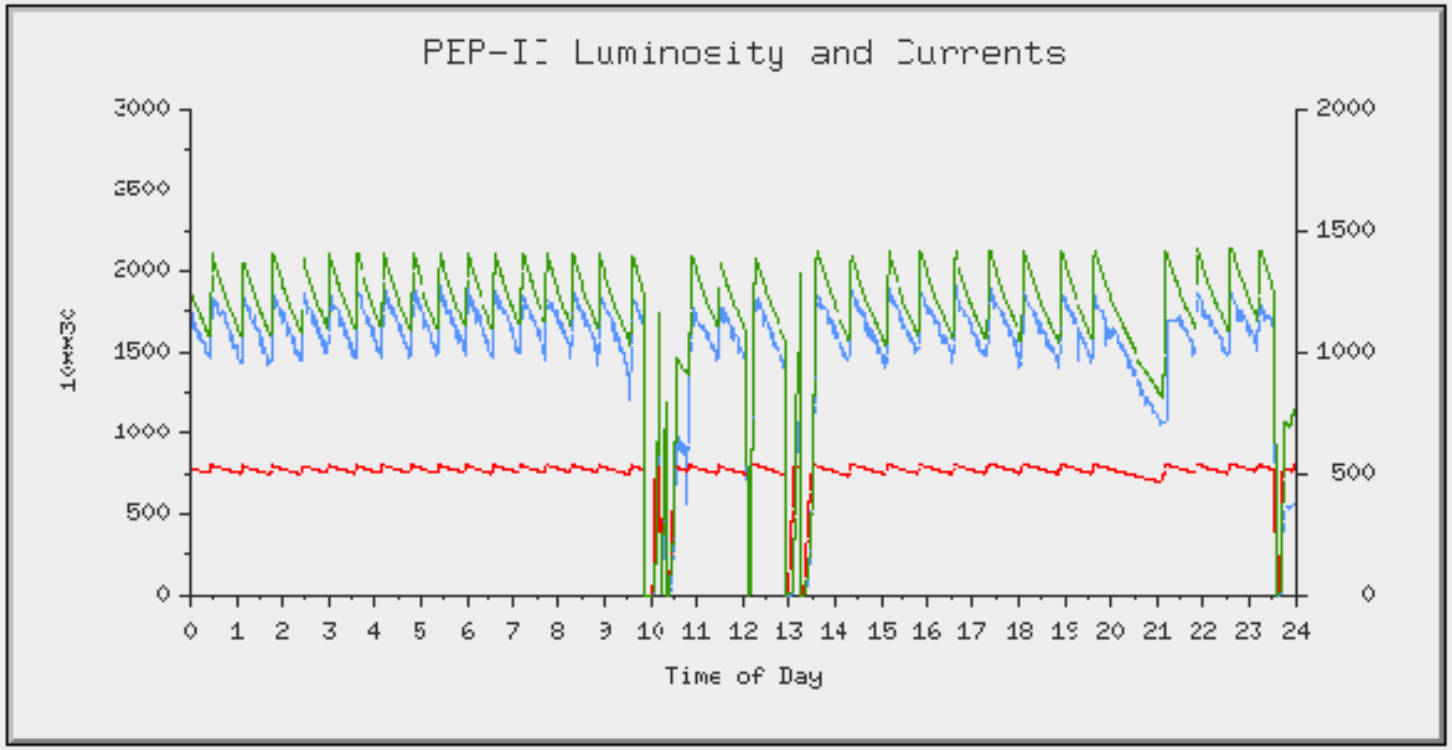
PEP Needs Beam only a Small Fraction of Each Hour

I HER	I LER	Luminosity	Spec Lum	E HER	E LER	E CM
540.3	750.81	554	0.90	3983	3124	10594
mA	mA	10**30/Sec	N*10**30 / mA**2/Sec	MeV	MeV	MeV

HER N Buckets / Pattern: 656 by4_trains_of_9-10_her

LER N Buckets / Pattern: 656 by4_trains_of_9-10_ler

Last Owl/Day/Swing/24hr	43.3	38.4	41.3	117.9	Shift:	0.00 /pb
Peak Luminosities	1925	1821	1319			569

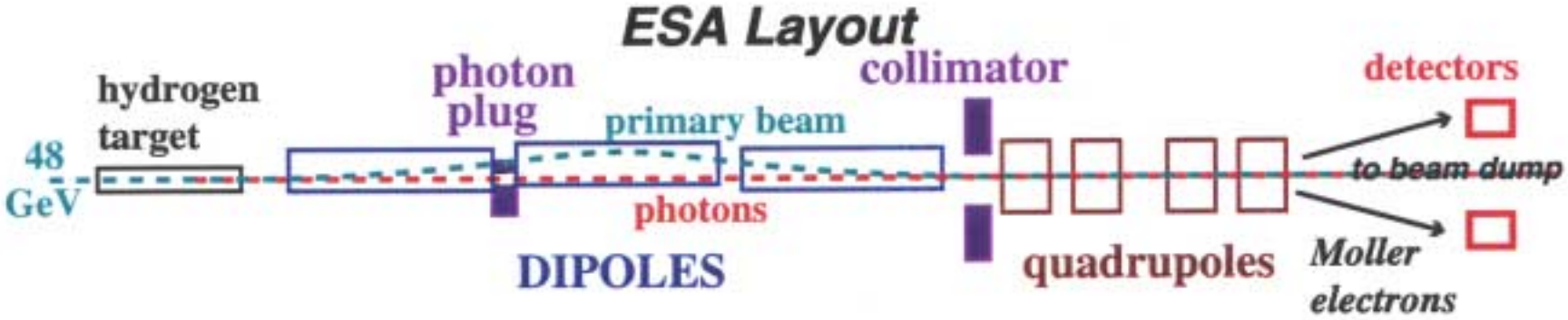


04/30/2001 00:00:21

E158 – Moller Scattering

E158 Collaboration

American University	Syracuse University
Caltech	Smith College
Kent State University	Jefferson Lab
Princeton University	UMass Amherst
SLAC	Saclay



SLAC E158 in End Station A

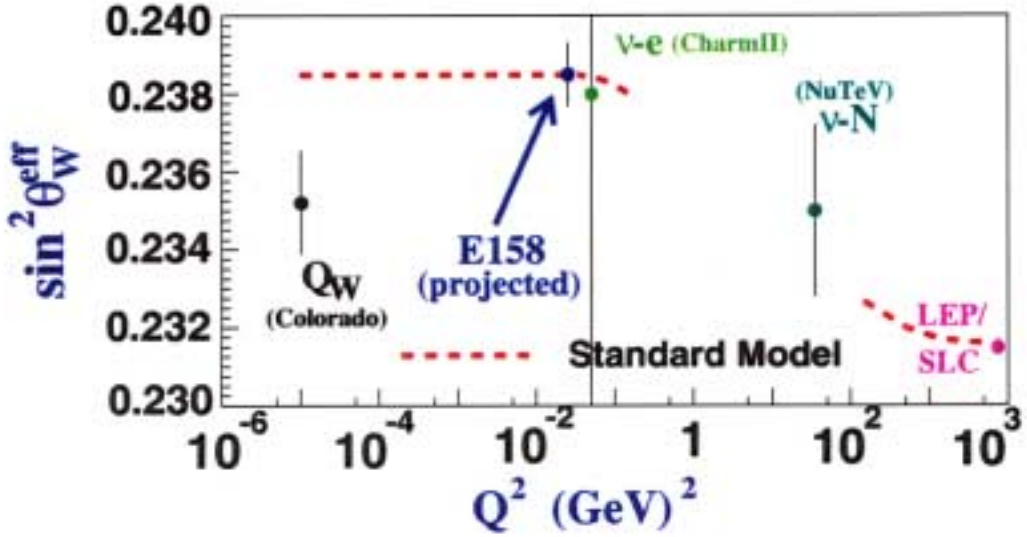
Precision Measurement of the Weak Mixing Angle in Moller Scattering

Goal: World's best $\sin^2\theta_W$ away from the Z pole

$$A_{LR} = \frac{\sigma_{\uparrow} - \sigma_{\downarrow}}{\sigma_{\uparrow} + \sigma_{\downarrow}} = \frac{A_Z}{A_\gamma} = 0.32 \text{ ppm}$$

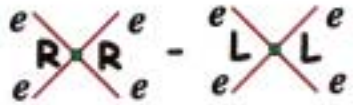
$$\delta(A_{LR}) = +/- 7\% +/- 3\%$$

Standard Model



New Physics

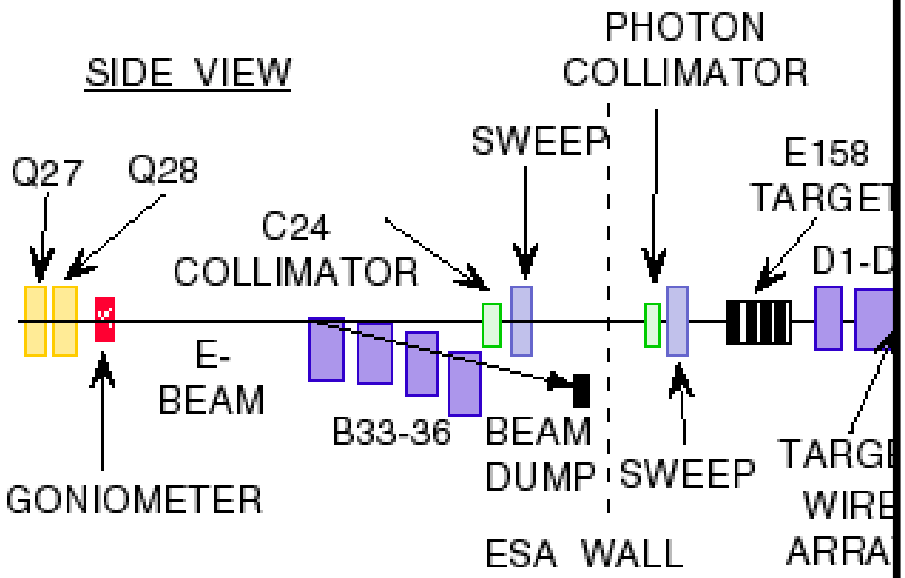
compositeness
$\Lambda \sim 15$ TeV



new forces
$M_{Z'} \sim 1.0$ TeV

Diamond Polarized Monochromatic Photon Beam

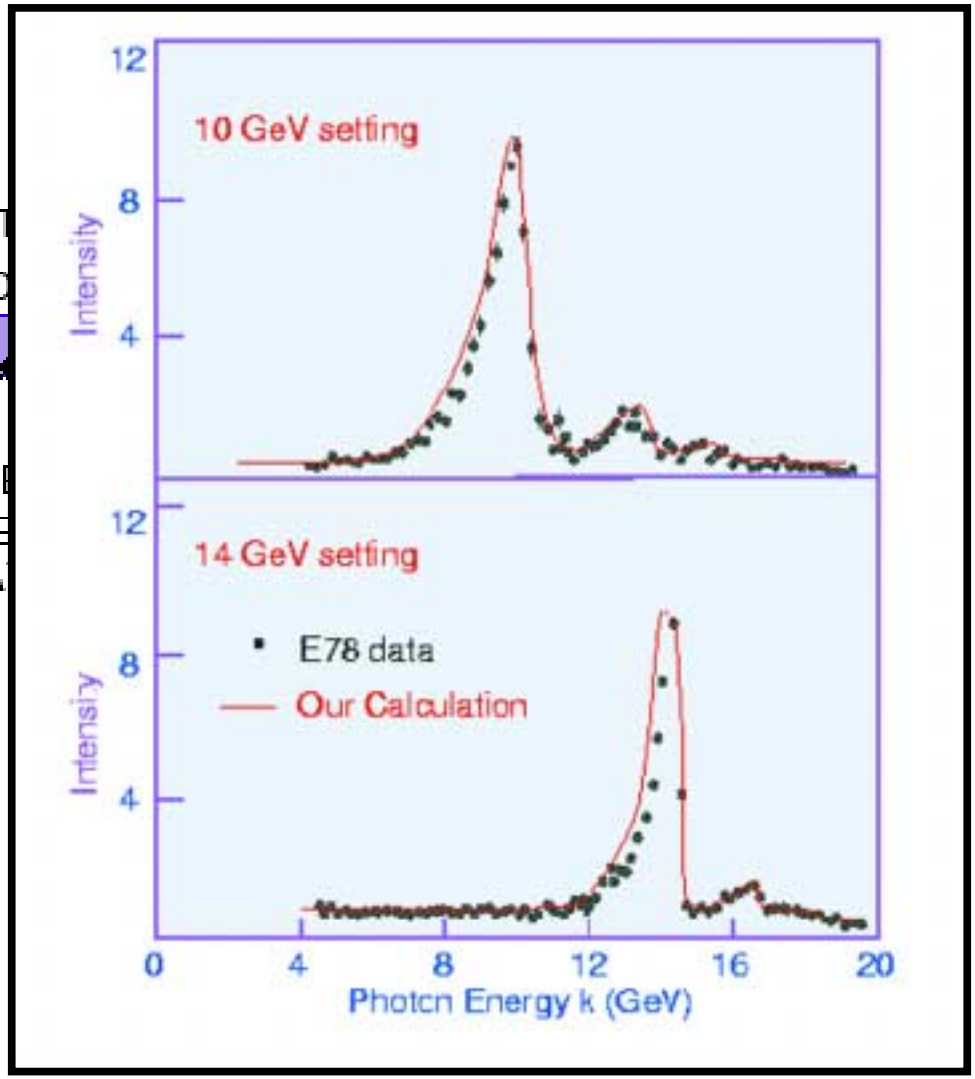
COHERENT BREMSSTRAHLUNG PHOTON BEAM LINE FOR E160



Comparison of Calculation with E78 Measured Spectra

Electron beam energy was 19.7 Gev

New beams to 40 Gev



Photon Beam Experiments

User led experiments which broaden program; met high standards of SLAC EPAC

- **E-160: first measurements of the A-dependence of J/ψ and ψ' production; obtain J/ψ- and ψ'-nucleon cross section. Simple probe to understanding gluon-quark plasma experiments (RHIC)**

- **E-161: determine gluon spin distribution within the nucleon by measuring asymmetry of polarized photoproduction of charm in a polarized nucleon target. Follow-on to '90s quark spin distributions measurements.**

- **E-159: Measure spin-dependent total cross sections for circularly polarized photons absorbed on longitudinally polarized protons and neutrons for $5 < k < 40$ GeV. Gerasimov-Drell-Hearn rule (analog of Bjorken Rule for virtual photons)**

Future Linear Collider

- The success of the SLC spawned a worldwide R&D effort to build a high energy linear collider
- SLAC wants to have a central role in construction and operation of the Linear Collider wherever it is built.
- R&D toward that end:
  - Next Linear Collider R&D
    - X-band Structures
    - RF systems
    - Interaction regions
    - Beam delivery
  - Linear Collider physics/detector study group
    - Participation in the International Study Group
    - Theoretical motivations
      - — Linear Collider Physics Resource Book for Snowmass 2001
    - Detection methods
    - Experimental methods
- Highest priority for a next generation, physics-motivated machine

Accelerator Physics

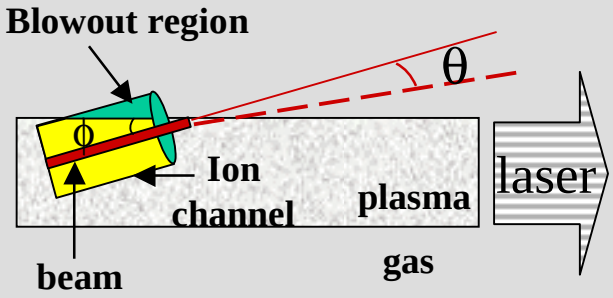
- SLAC has a large and outstanding group of Accelerator Physicists
- They contribute to SLAC's programs in many ways:
  - **Operations:** Performance enhancement of accelerators Linac, SLC, PEP-II
  - **Development:** Research and Design for near future facilities - upgrades to PEP-II, NLC, LCLS
  - **Research:** in fundamental accelerator/beam physics. Examples: High frequency / High gradient acceleration, ultra-low emittance, plasma based devices, laser acceleration, high polarization sources, two-beam acceleration…
- University community is encouraged to join and lead such efforts. We see increasing user involvement at SLAC….
- ORION will be a facility which supports a user - driven program of advanced accelerator experiments

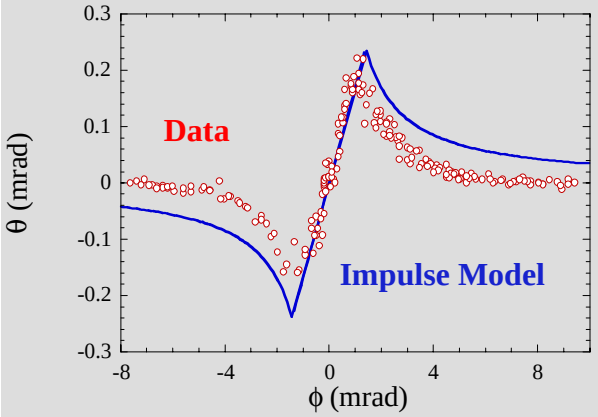
E-157 Highlights

Berkeley Lab | Stanford Linear Accelerator Center | UCLA | USC

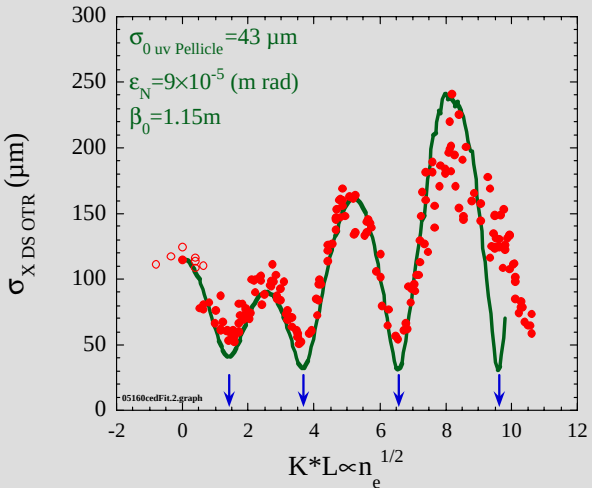
Three Highlights!

1. Electron Beam Refraction at the Gas–Plasma Boundary

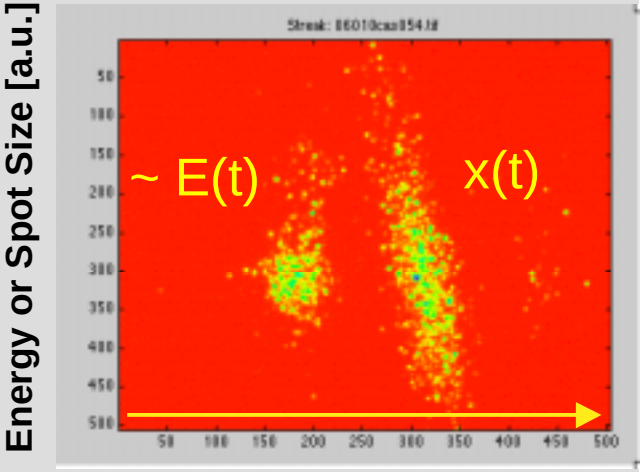


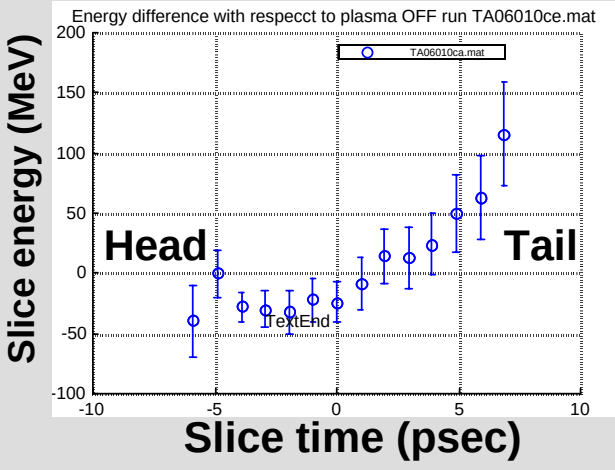


2. Transverse Wakefields and Mismatched Beam ⇨ Betatron Oscillations



3. Longitudinal Wakefields ⇨ Core De-acceleration and Tail Acceleration

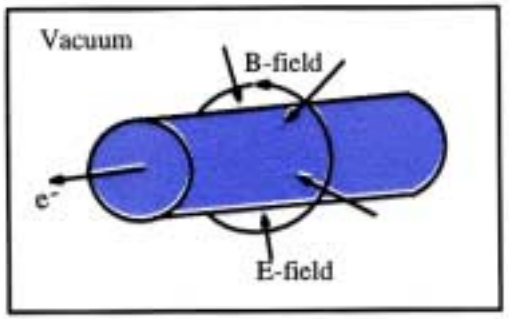




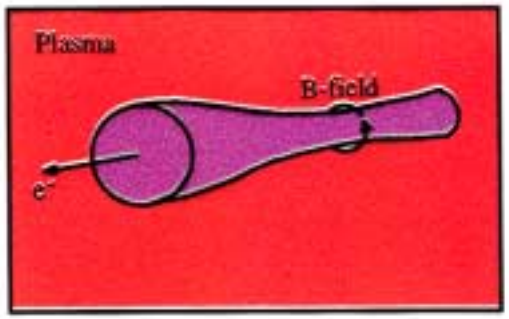
The SLAC Plasma Lens Experiment

FNAL, KEK, LBNL, LLNL, SLAC, Rochester, Tennessee, UCLA

- Principle of the plasma lens



In vacuum, there is no net Lorentz force on the beam.



In a plasma, E-field is neutralized; B-field pinches the beam.

- Motivations for the plasma lens:

  - 100 to 1000 times stronger field than conventional magnets
  - focuses beam in x and y simultaneously
  - focuses both e- and e+ beams

  ➡ smaller spot size and enhanced luminosity

  ➡ possible simplification of Final Focusing System

Particle Astrophysics

- The disciplines of particle astrophysics and HEP increasingly confront an overlapping agenda of fundamental physics — there are profound connections between these two disciplines
- The detector tools of choice for probing this agenda come mainly from HEP
- At SLAC, we have joined this non-accelerator based adventure by our participation in the GLAST experiment:
  - Outstanding science
  - Increases the breadth of our program, while drawing on our strengths
- Multi-national collaboration funded by the HEP and SPACE agencies of US, Italy, France, Japan ...

Particle Astrophysics Institute

SLAC will be the host to the:

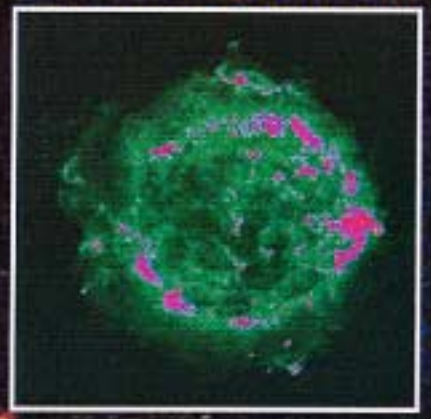
Pehong and Adele Chen Particle Astrophysics and Cosmology Institute

- **The Chen family has established this institute with a $15M gift. The institute will house about 90 people – theorists and experimentalists involved in many aspects of Particle Astrophysics and Cosmology**
- **This new institute will become a world leader in the study of fundamental physics using the universe as a laboratory, as well as using the laboratory to study the universe.**
- **What powered the Big Bang? What is the role of dark matter? What are the dynamics of black holes, neutron stars and other cosmic objects?**

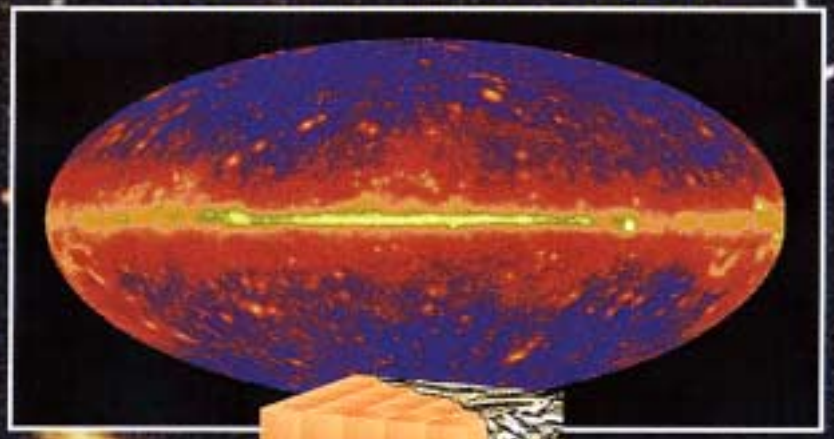
GLAST Science

0.01 GeV | 0.1 GeV | 1 GeV | 10 GeV | 100 GeV | 1 TeV

Supernova Remnant

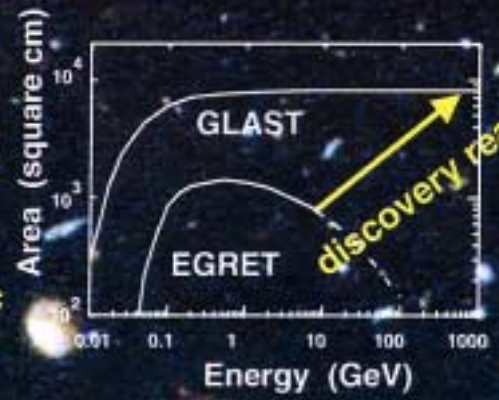


Map the High-Energy Universe



AGN

- GLAST pulsar survey: provide a new window on the galactic neutron star population
- "Map" pulsar magnetospheres and understand the physics of pulsar emission
- Origin of cosmic-rays: characterize extended supernovae sources
- Determine the origin of the isotropic diffuse gamma-ray background



- Physics in regions of strong gravity, huge electric & magnetic fields: e.g. particle production & acceleration near the event horizon of a black hole
- Use gamma-rays from AGNs to study evolution of the early universe
- Physics of gamma-ray bursts at cosmological distances
- Probe the nature of particle dark matter: e.g., wimps, 5-10 eV neutrino.
- γ decay of relics from the Big Bang,

GLAST
(Continued)

- **SLAC/Stanford: Strong science and management role**
  - **SLAC/Stanford provide scientific spokesperson, instrument manager, the central management team, the core engineering team, project management financial tools and staff, module assembly and testing infrastructure and staff**
  - **SLAC is providing the electronics and software leadership and supporting staff and will provide the computing for data reduction, storage, ….**
  - **SLAC is providing expertise in integration/test: balloon flight and beam tests**
  - **SLAC's major contribution to device specific hardware is in the silicon tracker, in collaboration with UCSC, Japan and Italy**

SLAC Program : The 10 Year Perspective

Project	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
PEP-II	Design Luminosity +++ → Luminosity Upgrades →									*B* Factory →	
BABAR	← Integrate 500 fb^{-1} →						← Detector Upgrades →			1000-1500 fb^{-1} →	
Linear Collider	NLC R&D and LC Detector Study →							LC & Detector Eng. & Constr. Participation →			
GLAST	← GLAST Construction & Test →							← Launch & Science →			
Fixed Target	← Moller Scattering →					← Photoproduction Experiments →				Future ESA Experiments ?	
Advanced Accelerator	← Plasma Acceleration →					ORION User Facility →				Advanced Accelerator R&D →	
Small Experiments	USA Analysis, Guest Investigator, small experiments, R&D for future ParticleAP project										
HEP and Accelerator Theory	← →										