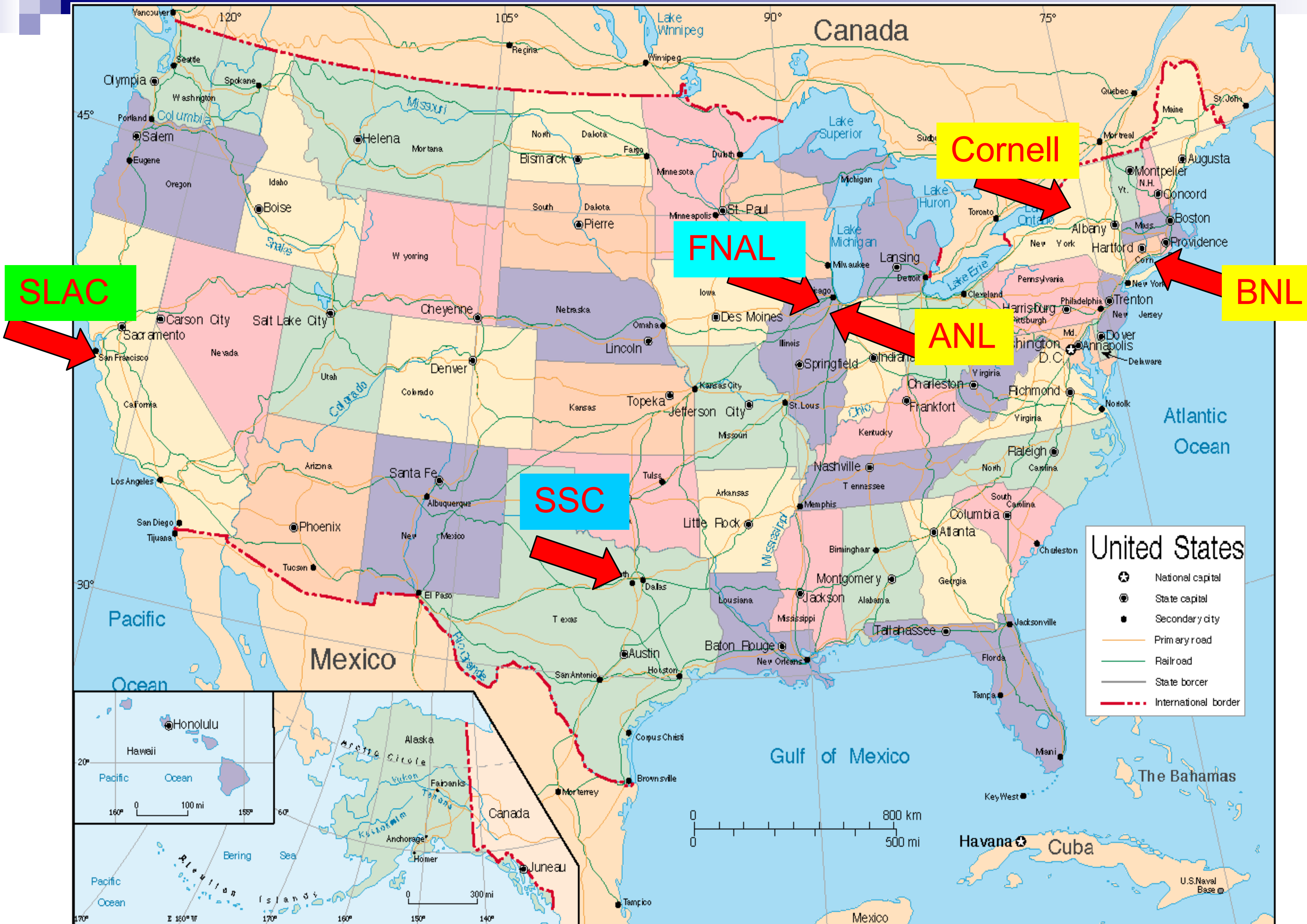

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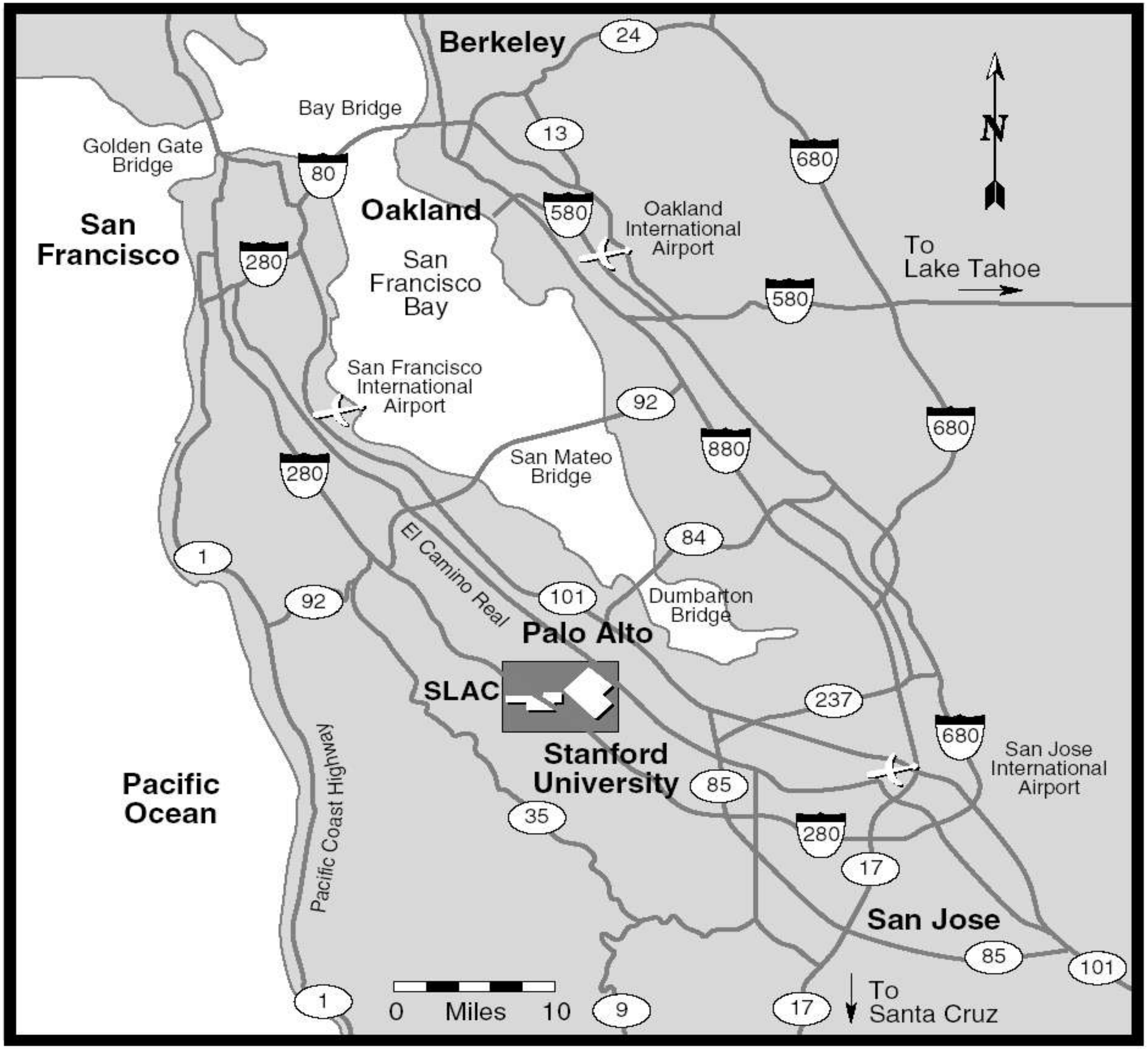
Stanford Linear Accelerator Center

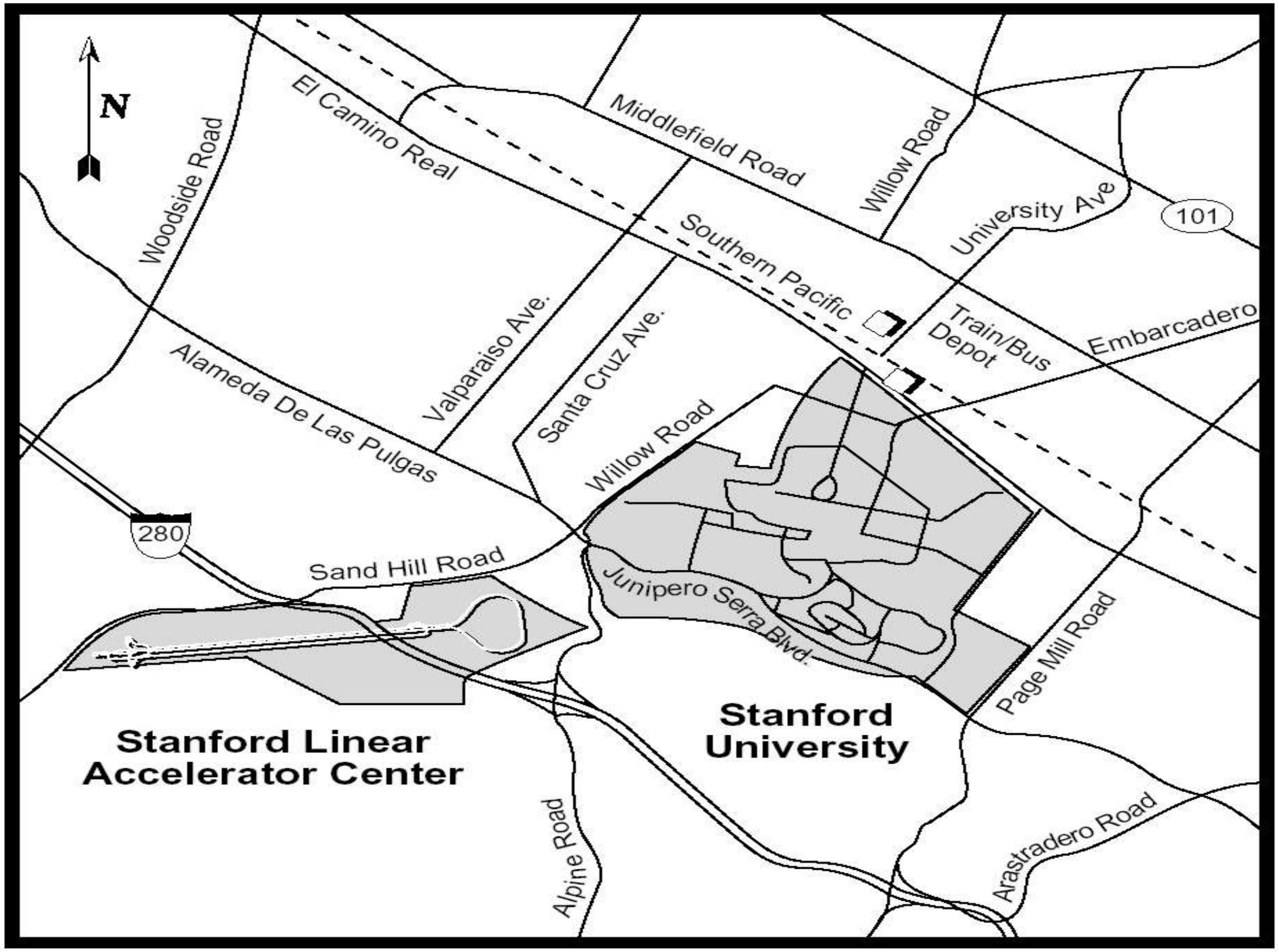
SLAC



San Francisco Peninsula Area Map

11-2002
8356A2

SLAC



Stanford Area Map

SLAC – основные этапы развития

- **1962 Начало сооружения ускорителя**
- **1966 Начало физических экспериментов**
- **1968 Получение первых свидетельств существования кварков**
- **1972 Начало экспериментов на установке SPEAR**
- **1973 Начало работы с источником синхротронного излучения**
- **1974 Открытие ψ- частицы**
- **1976 Открытие с-кварка и τ лептона**
- **1976 Присуждение Нобелевской премии B.Richter за открытие J/ψ**
- **1980 Начало физических экспериментов на установке PEP**
- **1989 Начало физических экспериментов на установке SLC/SLD**
- **1990 Присуждение Нобелевской премии R.Taylor за открытие кварков и структуры нуклонов**
- **1995 Присуждение Нобелевской премии M.L.Perl за открытие τ лептона**

SLAC – базовые установки.

- **Линейный ускоритель электронов и позитронов. Длина 3 км. Максимальная энергия пучка 50 GeV.**
- **SPEAR – накопительное кольцо частиц. Диаметр 80 м. Использовалось для организации встречных пучков e^+e^- с энергией 8 GeV. Сейчас используется как источник синхротронного излучения с энергией 3 GeV.**
- **PEP – Накопительное кольцо. Диаметр 800 м. Использовался для организации встречных пучков e^+e^- с энергией 30 GeV. Переделан в «ассиметричную B-фабрику ($E_{см}$=10 GeV)» PEP-II/BaBar детектор.**
- **Линейные встречные пучки - SLC и универсальный детектор – SLD $E_{см}$=100 GeV.**

SLAC

Facts at a Glance (as of 11/00)

- Budget **184 million $**
- Staff (FTE) 1314
- Users 2904
- User Institutions

  Universities147

  Industry 46

  Government Labs 30

  Foreign162

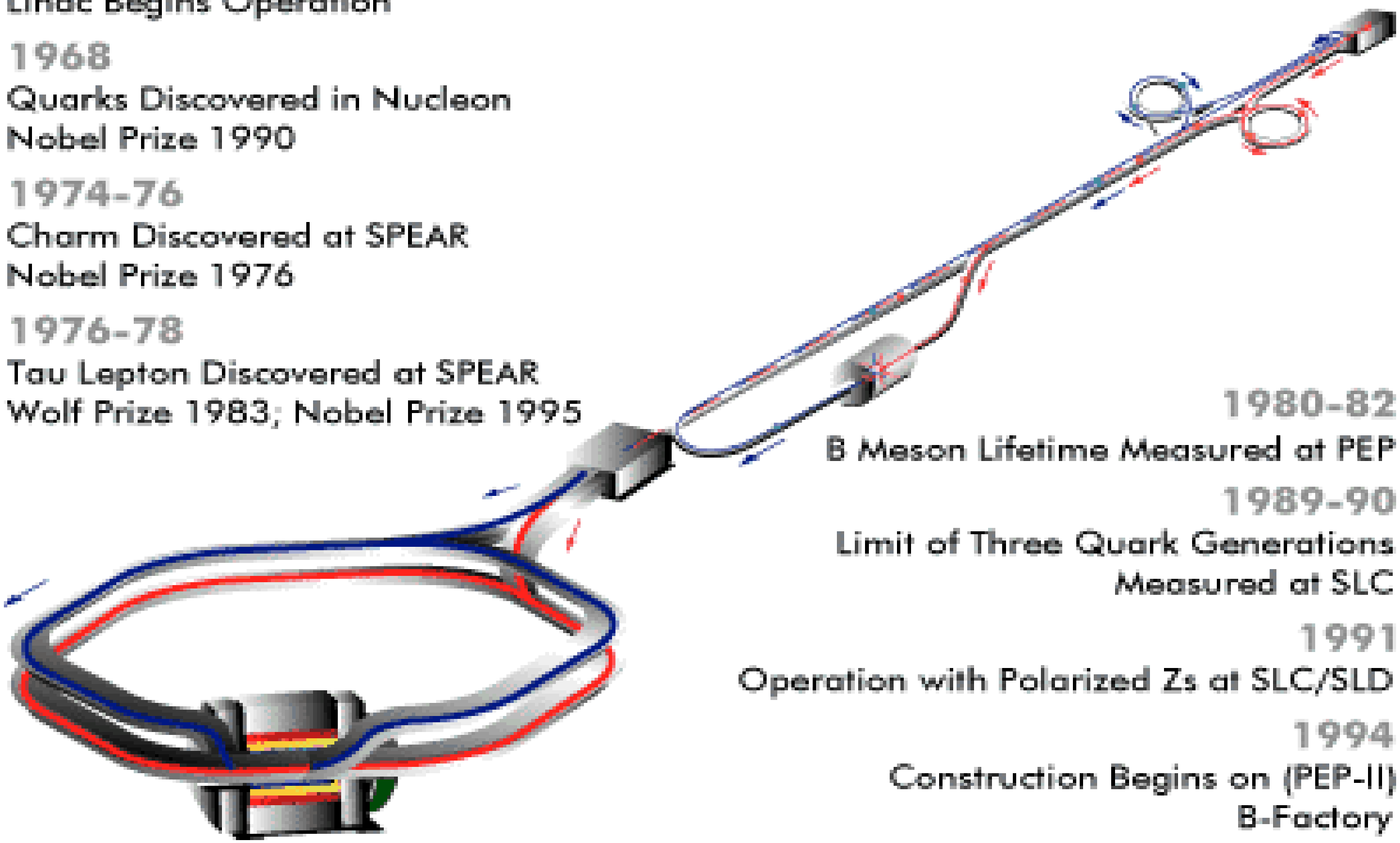
1962
SLAC Ground Breaking

1966
Linac Begins Operation

1968
Quarks Discovered in Nucleon
Nobel Prize 1990

1974-76
Charm Discovered at SPEAR
Nobel Prize 1976

1976-78
Tau Lepton Discovered at SPEAR
Wolf Prize 1983; Nobel Prize 1995



1980-82
B Meson Lifetime Measured at PEP

1989-90
Limit of Three Quark Generations
Measured at SLC

1991
Operation with Polarized Zs at SLC/SLD

1994
Construction Begins on (PEP-II)
B-Factory

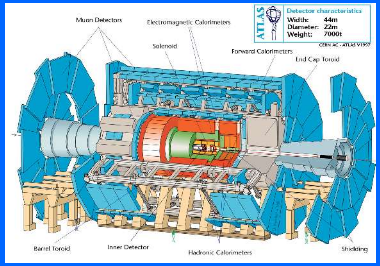
Как нашли структуру в адроне (кварки)?

- Идеология таких измерений восходит к опытам Резерфорда в которых обнаружили структуру атома. Для таких измерений прежде всего необходимо найти достаточно «тонкий» щуп – пробник.

Зачем нужны ускорители - I?

1. **Длина волны "луча" с помощью которого исследуется "объект" должна быть меньше размера "объекта" !**

$$\lambda << h/P = hc/E$$

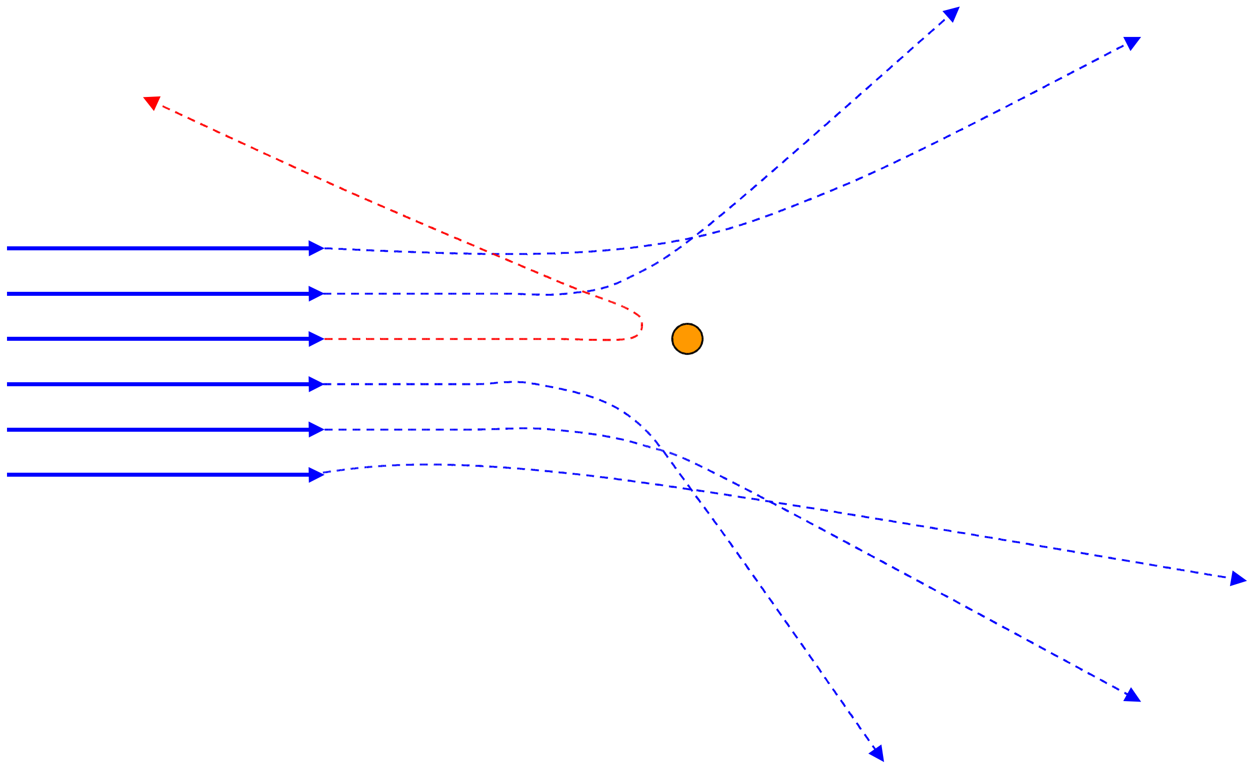


Объект	Размер	Энергия "луча"
Атом	10^{-10} м	10^{-5} ГэВ (10 эВ)
Ядро	10^{-14} м	10^{-2} ГэВ (10 МэВ)
Нуклон	10^{-15} м	0.1 ГэВ
Кварк	??	> 1 ГэВ

Как нашли структуру в адроне (кварки)?

- Одно из преимуществ линейного ускорителя – он может работать начиная с малой общей длины (энергии), которая будет возрастать по мере увеличения длины ускорителя
- Решающее преимущество электронного ускорителя в том, что электрон «точечная частица».

Опыт Резерфорда



1990 Nobel Prize in Physics

The prize was awarded jointly to:
•Friedman, Jerome I., U.S.A., Massachusetts Institute of Technology, Cambridge, MA, and
•Kendall, Henry W., U.S.A., Massachusetts Institute of Technology, Cambridge, MA, and
•**Taylor, Richard E.**, Canada, ***Stanford Linear Accelerator Center***, Stanford University, Stanford, CA.
"for their pioneering investigations concerning deep inelastic scattering of electrons on protons and bound neutrons, which have been of essential importance for the development of the quark model in particle physics

Обнаружение τ- лептона

Matter | Interactions

$\begin{pmatrix} u \\ d \end{pmatrix} \begin{pmatrix} c \\ s \end{pmatrix} \begin{pmatrix} t \\ b \end{pmatrix}$ Кварки

$\begin{pmatrix} e \\ \nu_e \end{pmatrix} \begin{pmatrix} \mu \\ \nu_\mu \end{pmatrix} \begin{pmatrix} \tau \\ \nu_\tau \end{pmatrix}$ Лептоны

} **<u>Фермионы</u>**

<u>Бозоны</u> { $W^{\pm}$, Z^0, γ, g, H ?

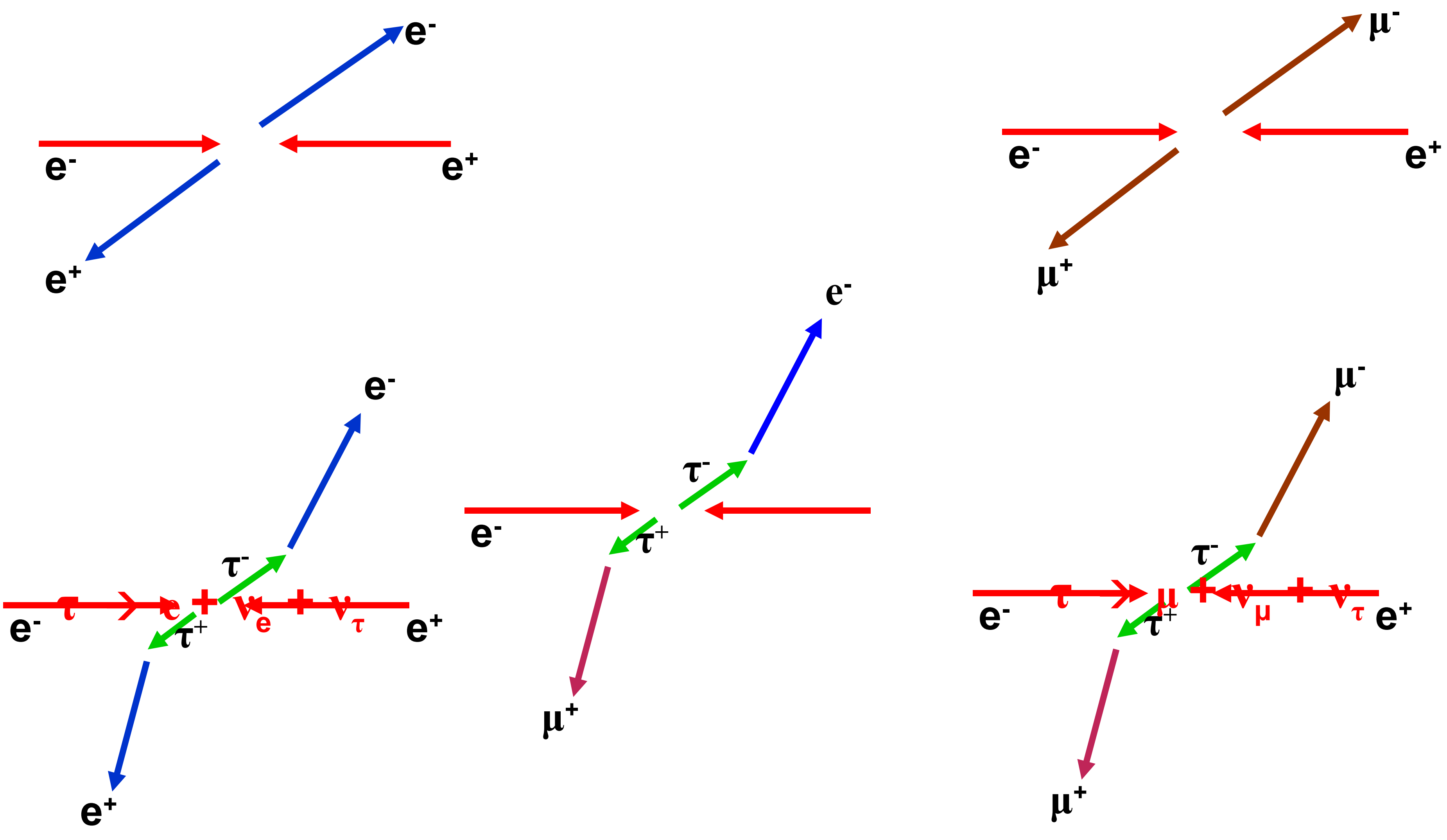
e – stable; $m_e \sim 0.5$ MeV

$\mu \rightarrow e + \nu_e + \nu_\mu$ $m_\mu \sim 100$ MeV

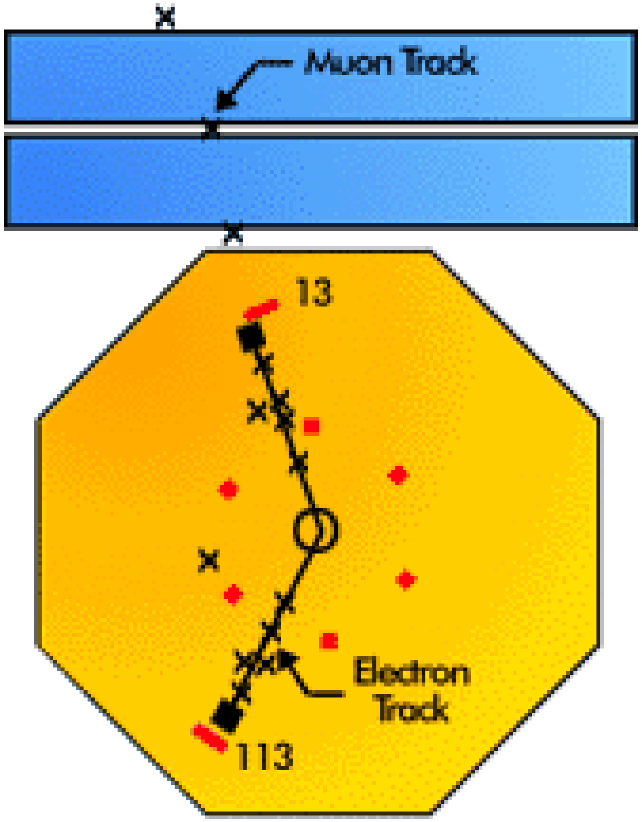
$\tau \rightarrow ? e + \nu_e + \nu_\tau$ $m_\tau > m_\mu$

$\tau \rightarrow \mu + \nu_\mu + \nu_\tau$

Стратегия поиска τ- лептона



Установка для поиска τ- лептона (MARK-III)



1995 Nobel Prize in Physics

The prize was awarded jointly to:

•**Perl, Martin L.**, U.S.A., ***Stanford Linear Accelerator Center***, Stanford University, Stanford, CA

"for pioneering experimental contributions to lepton physics, specifically for the discovery of the tau lepton";

and

•Reines, Frederick , U.S.A., University of California at Irvine, Irvine, CA,

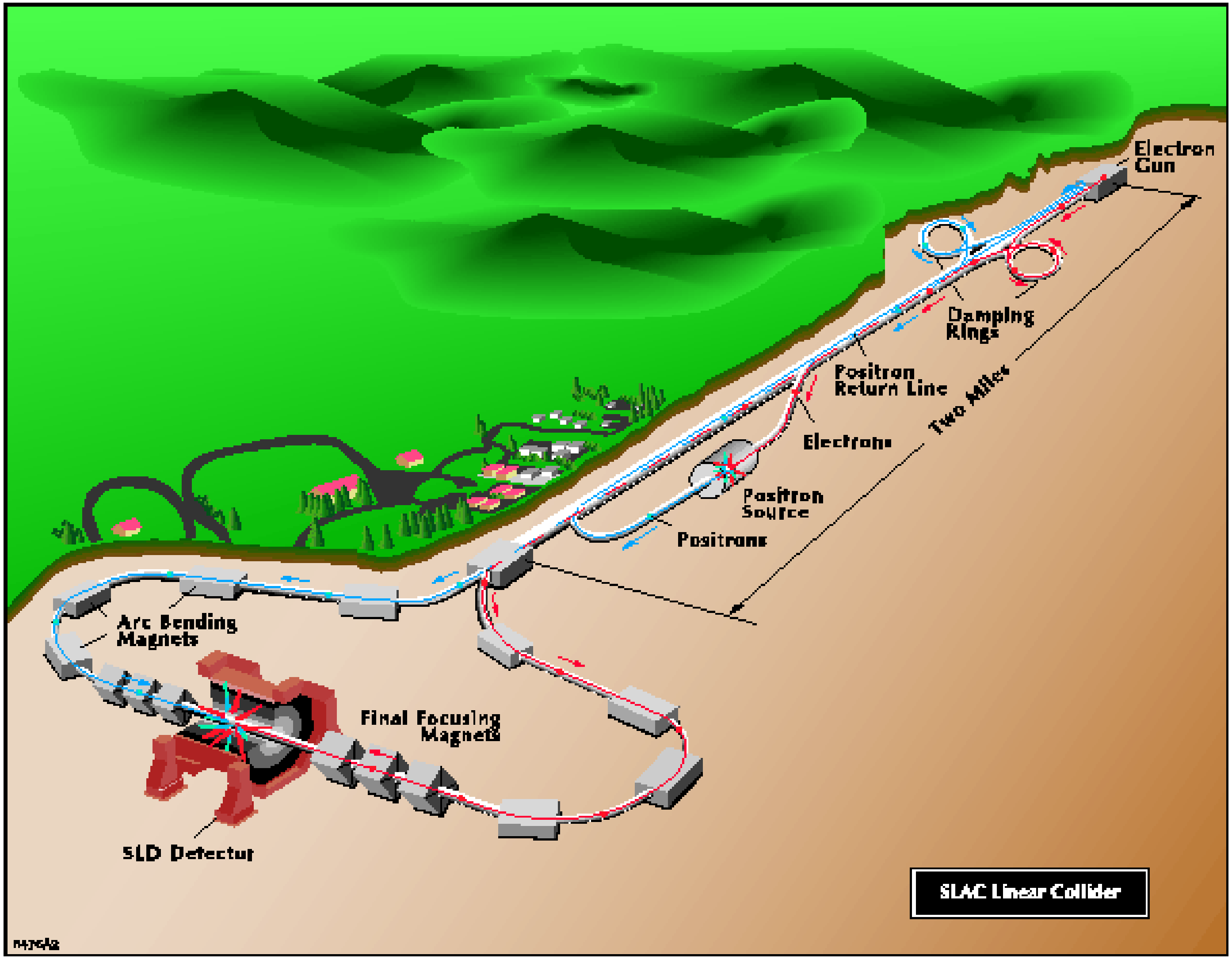
"for pioneering experimental contributions to lepton physics, specifically for the detection of the neutrino".

Tau: The 3rd Electron-like Particle

In 1975, Martin Perl (SLAC) scanned the 1973-1974 SPEAR experimental data, searching for a particularly unusual type of **event . What if, he supposed, sometimes an electron and positron annihilate, and the detector records only one electron-type track, and one muon-type track?**

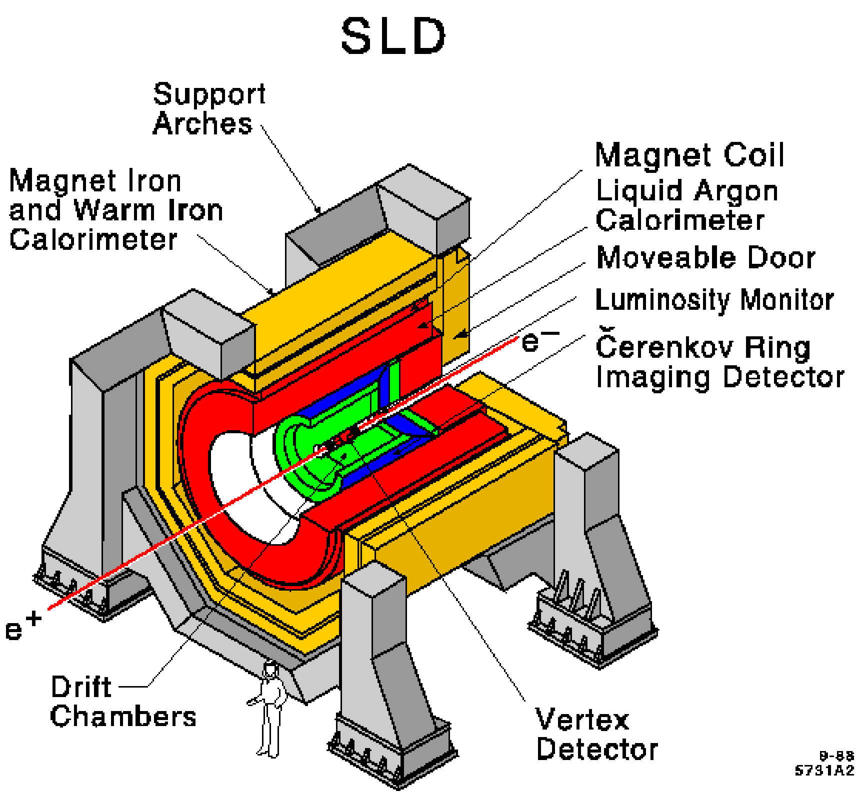
These theoretically-predicted events were found, and at rates that could only be explained by postulating another new particle type, one just like the electron but 3,000 times more massive. (The muon, too, is just like the electron, but 200 times more massive and no one -- yet -- understands why there are three electron-like particles.)

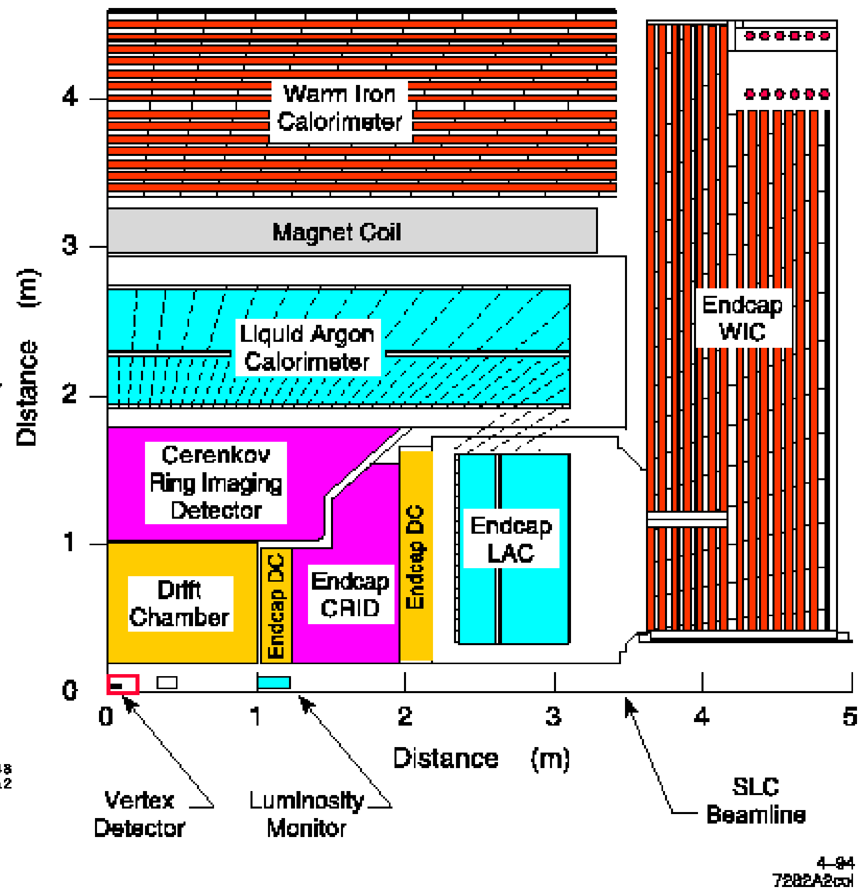
SLD + SLC



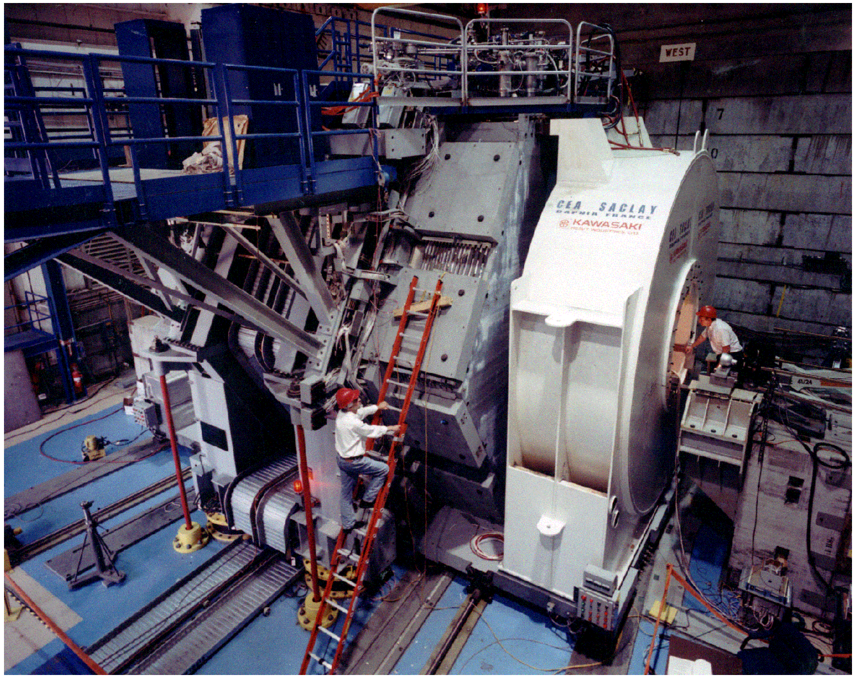
Electron Gun
Damping Rings
Positron Return Line
Two Miles
Electrons
Positron Source
Positrons
Arc Bending Magnets
Final Focusing Magnets
SLD Detector
SLAC Linear Collider

SLAC


SLD
Support Arches
Magnet Iron and Warm Iron Calorimeter
Magnet Coil
Liquid Argon Calorimeter
Moveable Door
Luminosity Monitor
Čerenkov Ring Imaging Detector
e−
e+
Drift Chambers
Vertex Detector
9-88
5731A2


Warm Iron Calorimeter
Magnet Coil
Liquid Argon Calorimeter
Cerenkov Ring Imaging Detector
Drift Chamber
Endcap DC
Endcap CRID
Endcap DC
Endcap LAC
Endcap WIC
Distance (m)
0
1
2
3
4
5
Distance (m)
Vertex Detector
Luminosity Monitor
SLC Beamline
4-94
7282A2col

SLAC



Laboratory Report: SLAC

Jonathan Dorfan

ICFA Seminar, Kyungpook National University, Daegu, Korea. September 28th, 2005

SLAC Future – Responding to the Changing Scientific Landscape

The balance of the scientific elements of the Lab are changing:

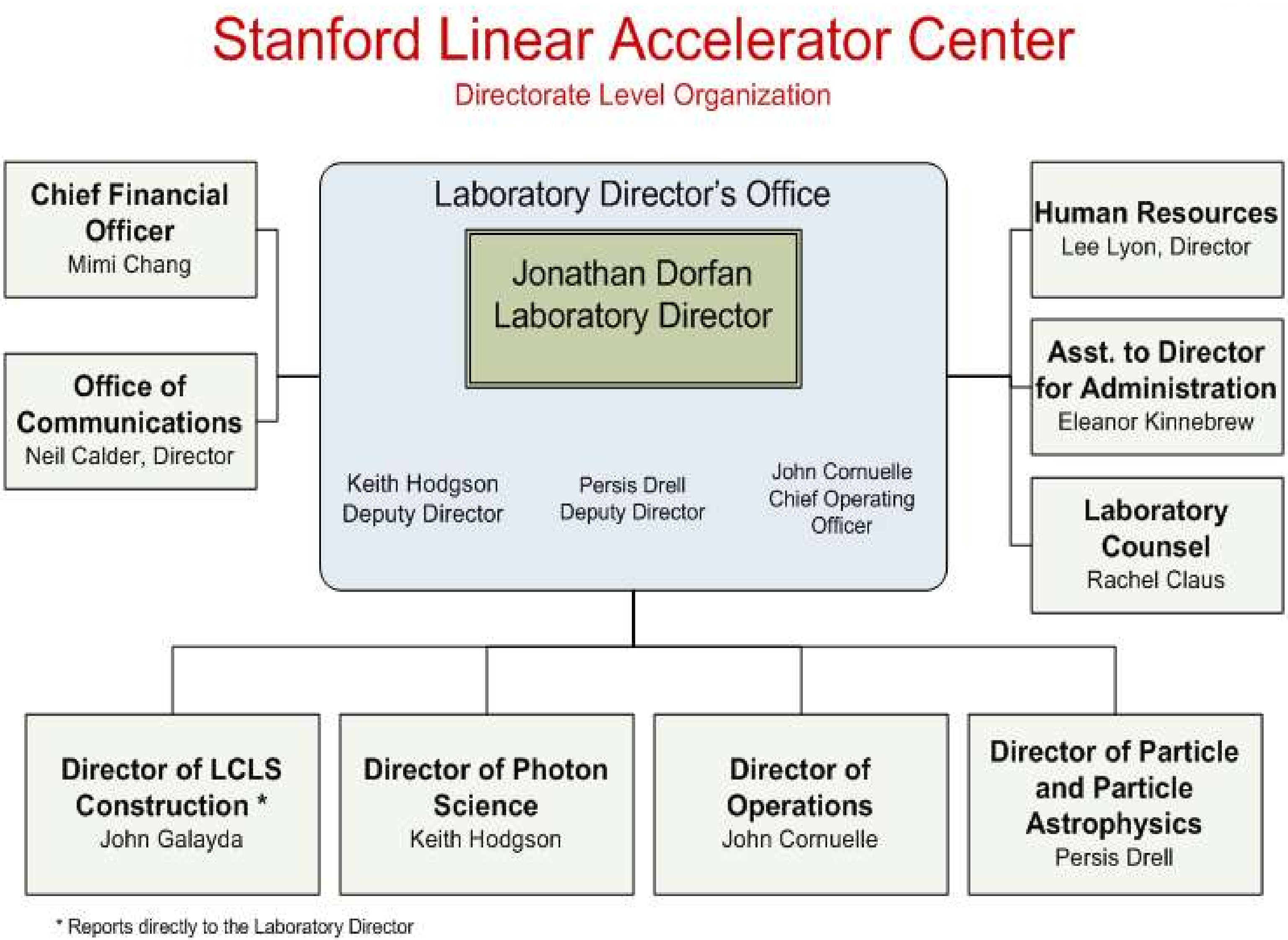
The size of the photon science program will grow significantly in the next three years. By 2009, the on-site accelerators, SPEAR3 and Linac Coherent Light Source (LCLS), will both be doing Photon Science

B Factory will run through FY2008

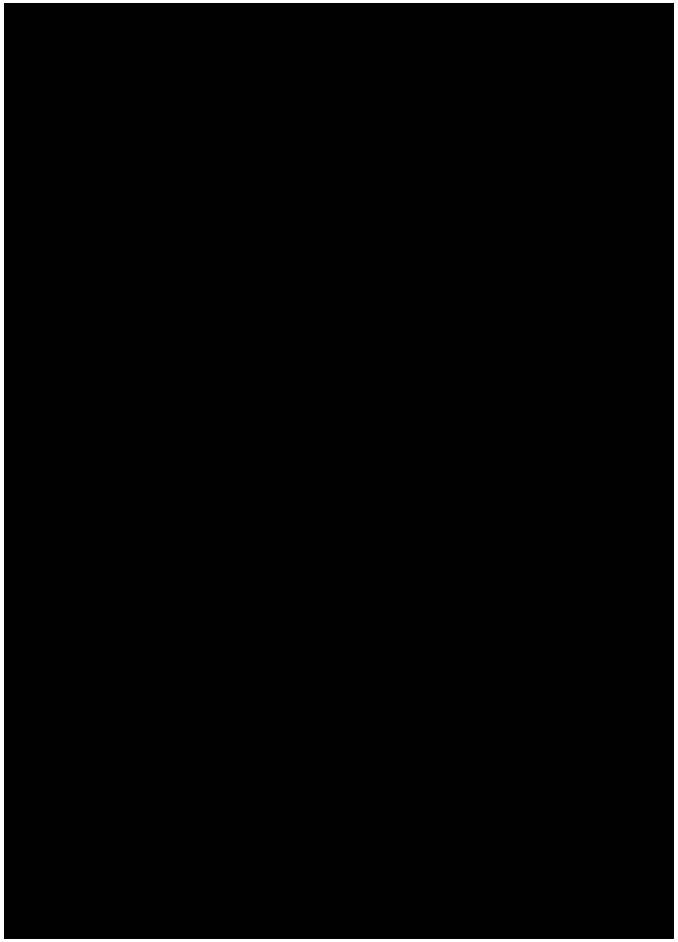
Post FY2008, Particle and Particle Astrophysics will be focused on: BABAR analysis, the ILC machine and detector, accelerator science/R&D, Gamma ray Large Area Space Telescope (GLAST), Large Synoptic Survey Telescope (LSST) , Enriched Xenon Observatory and particle/astro/cosmology theory

Scientific Computing challenges abound in both focus areas

As of May 2005, the SLAC Organization has been changed



Jonathan DORFAN, Director



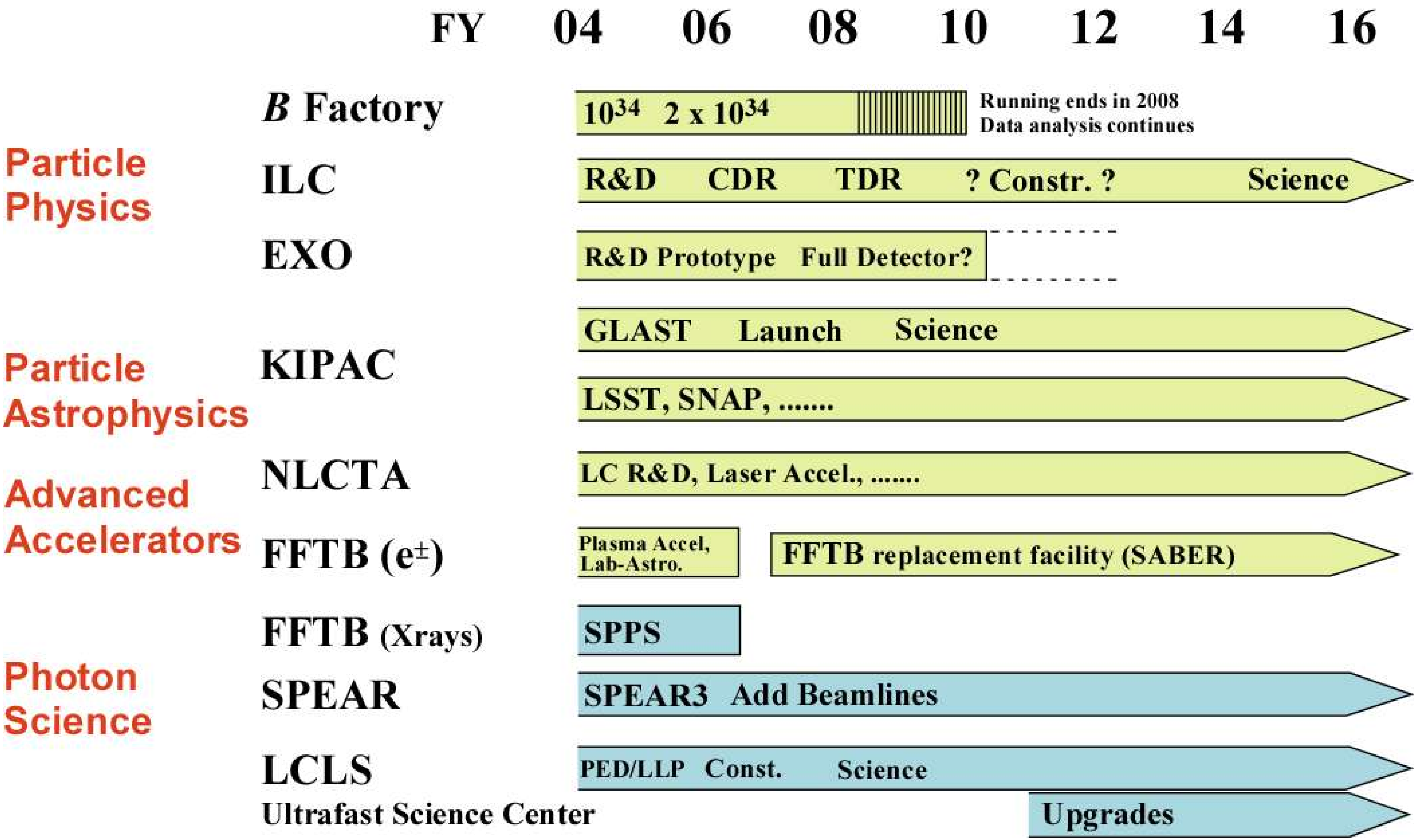
Mission

- Photon Science Discoveries
  - To make discoveries in photon science at the frontiers of the ultrasmall and ultrafast in a wide spectrum of physical and life sciences
- Particle and Astroparticle Physics Discoveries
  - To make discoveries in particle and astroparticle physics to redefine humanity's understanding of what the universe is made of and the forces which control it
- Operate Safely; Train the Best
  - To operate a safe laboratory that employs and trains the best and brightest, helping to ensure the future economic strength and security of the nation

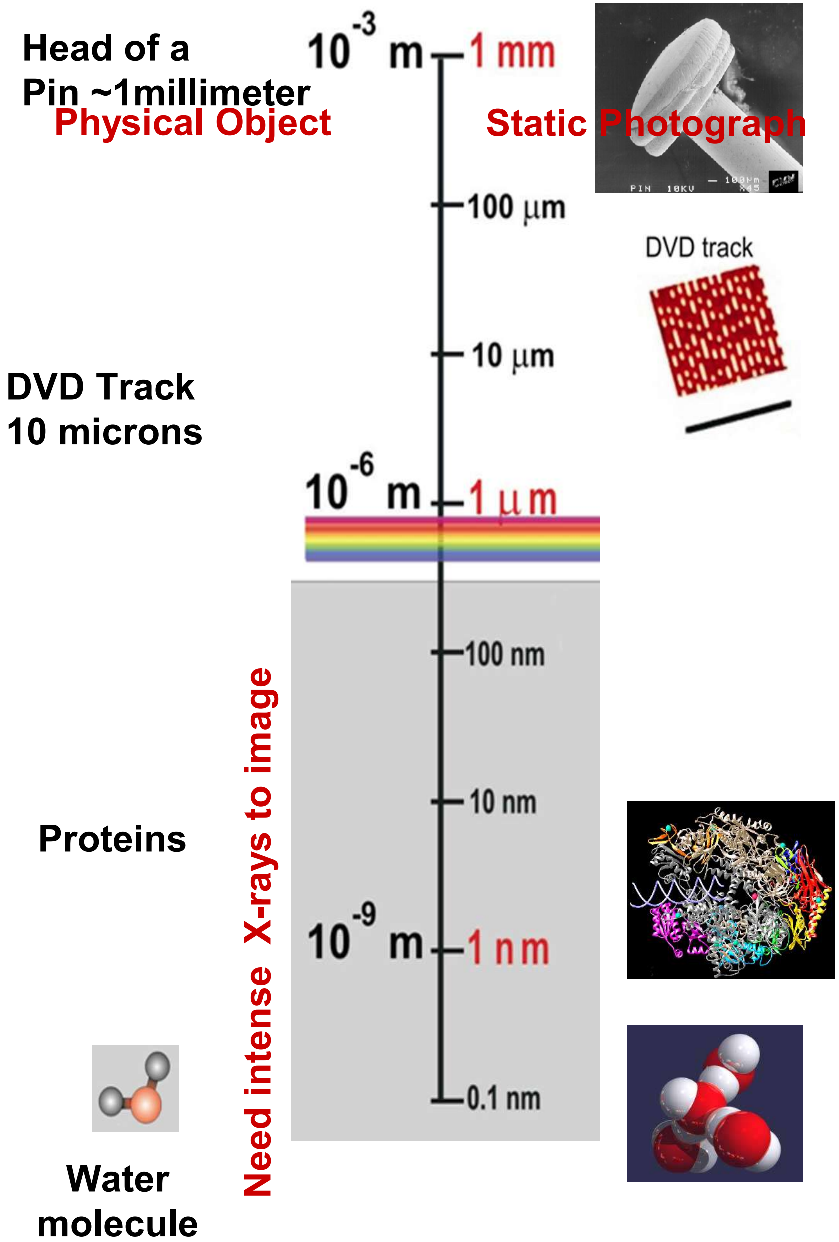
SLAC as an International Research Facility

- **3000 scientists from ~25 nations use SLAC facilities to do their research**
- **1400 Laboratory staff**
- **Annual budget ~$250M**

SLAC Future Experimental Program



X-Rays have opened the Ultra-Small World -- Realm of SPEAR3



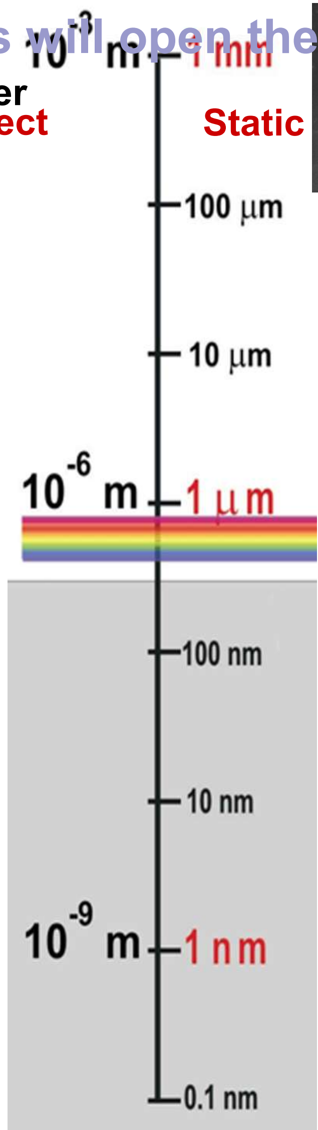
X-Rays have opened the Ultra-Small World -- Realm of SPEAR3

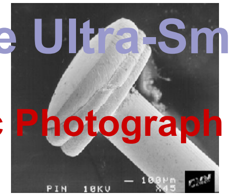
X-ray Lasers will open the Ultra-Small and Ultra-Fast Worlds –Realm of LCLS

Head of a Pin ~1millimeter

Physical Object

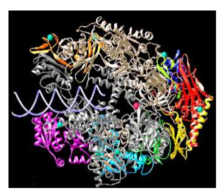
Static Photograph

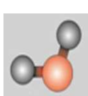




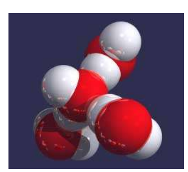
DVD Track
10 microns

Proteins



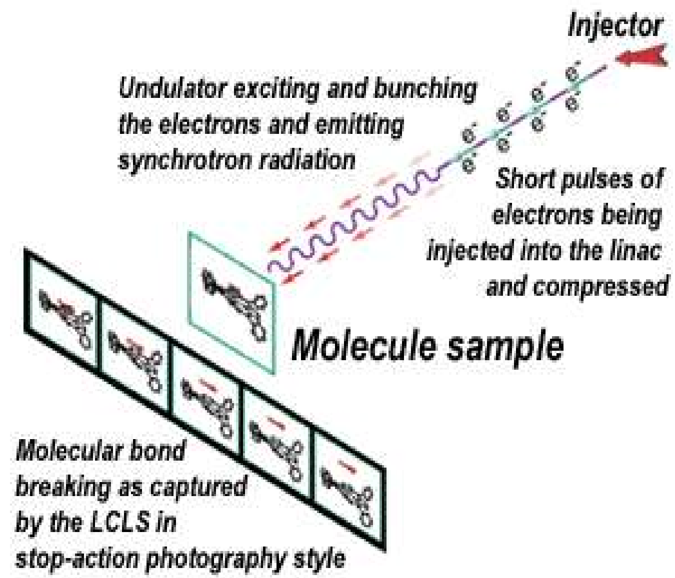


Water molecule

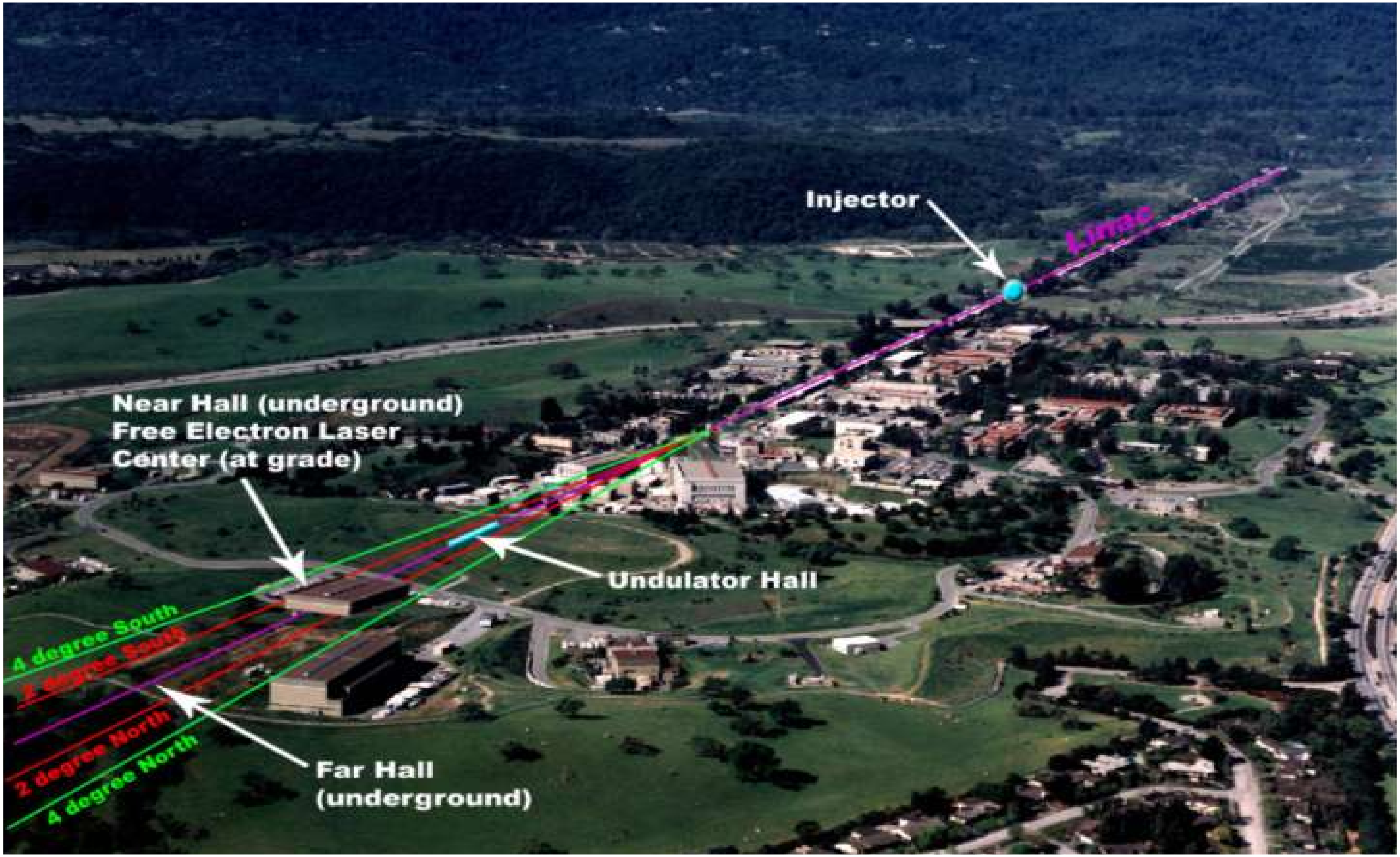


Need intense X-rays to image

What if I wanted to see the ultra-fast motion of ultra-small objects?
Can I take a “movie” of ultra-small objects performing their tasks?



Linac Coherent Light Source at SLAC



LCLS Will Be The World's First X-ray Laser

LCLS Construction

- **Budget - $379M through 2009. Commissioning in FY2008. Operations start in April 2009**

Linac Coherent Light Source Funding Profile (AYM$)

	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09	Total
TEC Funding	0.00	5.93	7.46	50.08	85.54	105.50	50.50	10.00	315.00
OPC Funding	1.50	0.00	2.00	4.00	3.50	16.00	15.50	21.50	64.00
Total Funding	1.50	5.93	9.46	54.08	89.04	121.50	66.00	31.50	379.00

- LCLS is a major endeavor. Will achieve femtosecond time-scales at 10^9 times the instantaneous brightness of third generation light sources
- Anticipate major upgrades to begin ~2012
- Stanford/SLAC in partnership with DOE has created the Ultrafast Science Center (UFC) to provide a broad-based intellectual focus to underpin the LCLS program.

  Professor Phil Bucksbaum will move from Michigan to Stanford/SLAC as the first Director of UFC

Scientific Focus of Current and Future SLAC Particle/Astroparticle Program

- Current and planned 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? (LSST,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)
- Doing accelerator research and technology development to meet current challenges and for the longer term future of the field
  - PEP-II
  - ILC
  - Multi-TeV LC--Higher Gradient + Two Beam acceleration
  - Future acceleration concepts (laser and plasma-wakefield)

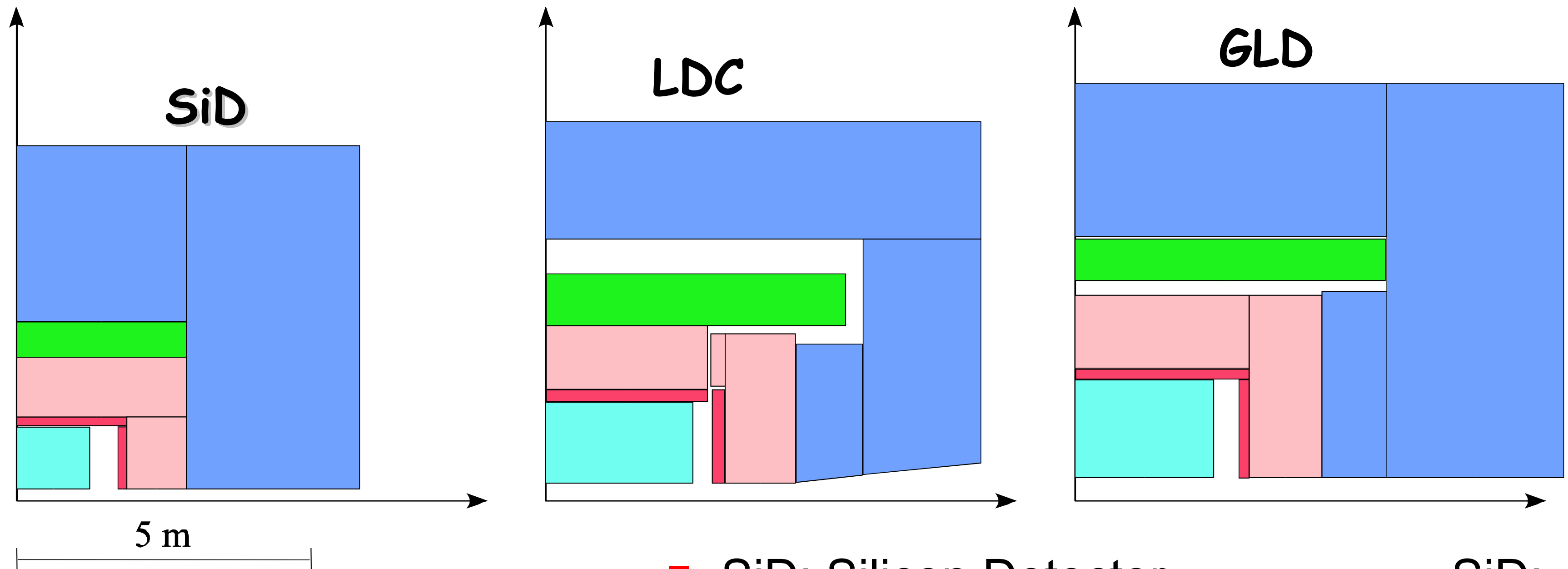
BABAR results – A Physics Fountain

Journal Papers	BABAR
<2003	32
2003	39
2004	52
Sept 2005	51
Total	174

Conference Contributions	BABAR
Papers submitted to ICHEP04	72
Abstracts submitted To LP05	75

ILC Detector Concepts

- Three + 1 detector concepts



Main Tracker
EM Calorimeter
Had Calorimeter
Cryostat / Solenoid
Iron Yoke / Muon System

- SiD: Silicon Detector SiD: BR^2
  - Small, ‘all’ silicon
- LDC: Large Detector Concept LDC: $B R^2$
  - TPC based
- GLD: Global Large Detector GLD: $B R^2$

SLAC has central involvement with SiD

SLAC People Working on SiD

- Simulation
  - N. Graf, T. Johnson, R. Cassell, J. McCormick
- MDI & Backgrounds
  - M. Woods, T. Maruyama, T. Markiewicz, K. Moffeit
- EMCal
  - G. Haller, D. Freytag, R. Herbst, mb
- Tracker Studies
  - T. Nelson, J. Jaros
- Physics Benchmarks
  - T. Barklow
- VXD Studies
  - Su Dong

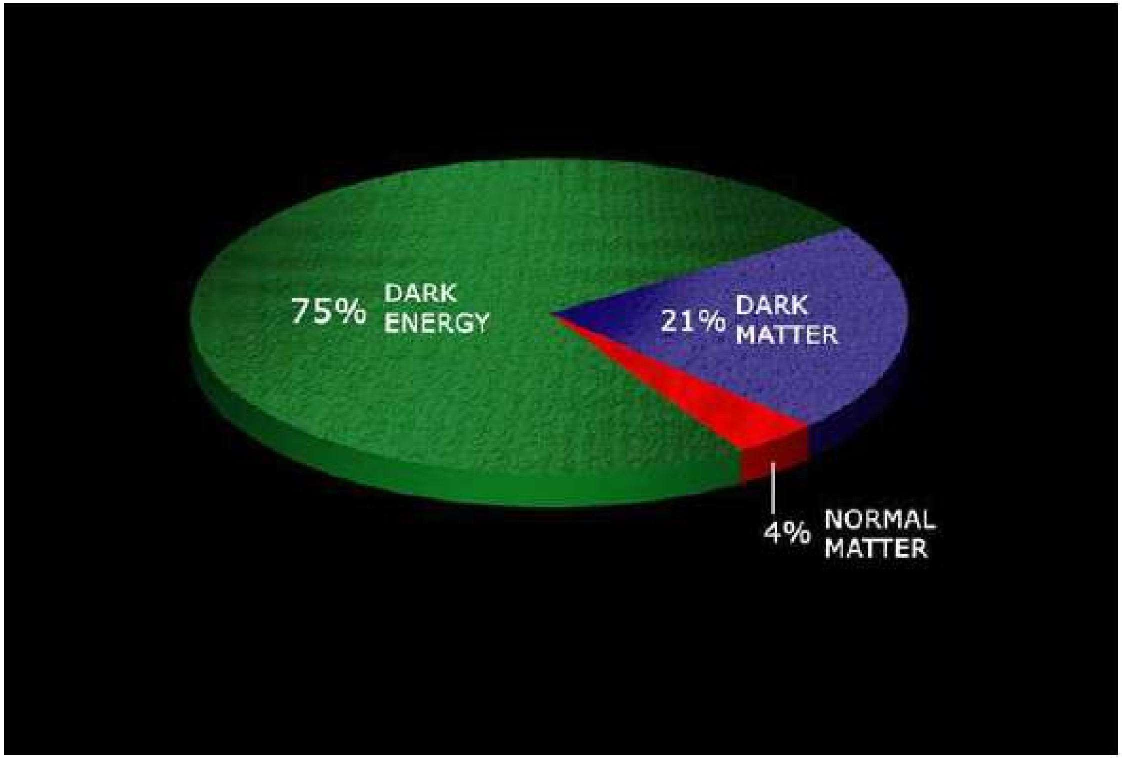
Kavli Institute for
Particle Astrophysics and Cosmology

Founded 2003
Director: Roger Blandford
Deputy Director: Steve Kahn
~60 members (30 new)
Two new buildings, labs

Instrumentation, data analysis, particle astrophysics, relativity, computational astrophysics, observational cosmology, theoretical cosmology…

KIPAC is a major commitment by Stanford

What is the Universe made of?



- This discussion is only about the 4 % 'ordinary matter'
- We hopefully are on the verge of finding out what the 21 % dark matter are made of

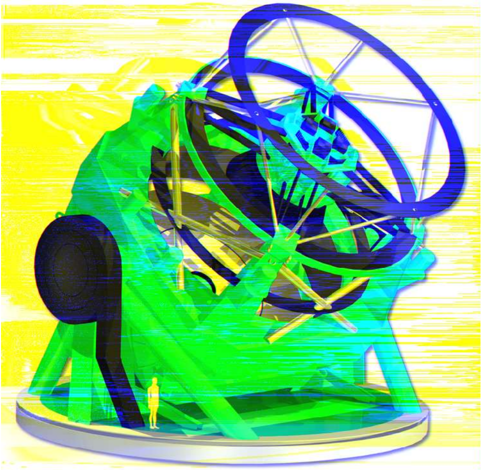
Construction of Kavli Building

Occupancy January 2006

KIPAC Projects

Dark Energy and Matter

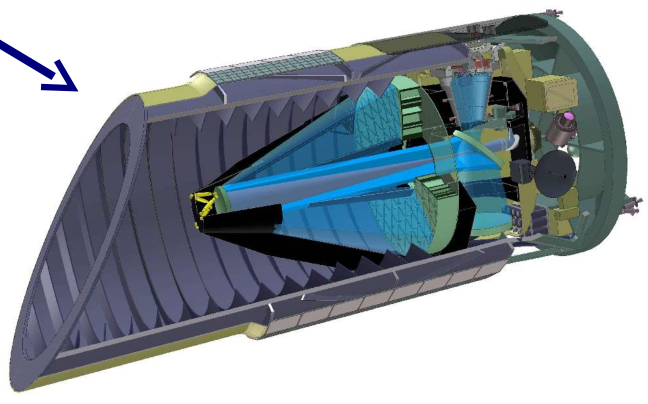
LSST
First Light ~ 2012



All Sky

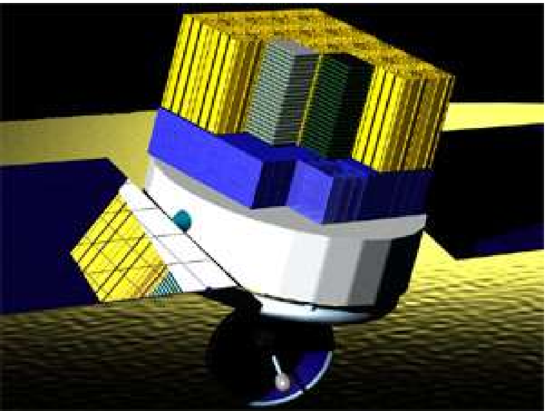
High Resolution

SNAP
Launch ~ 2014



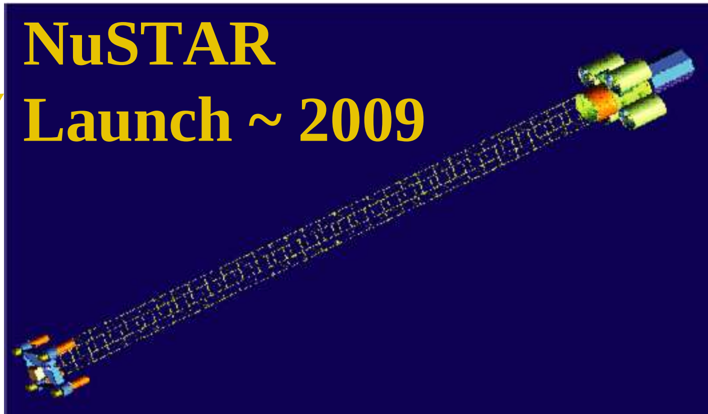
Combining:
- **Physics and Astronomy**
- **Theory and Experiment**
- **SLAC and Campus**
- **DOE, NASA and NSF**

GLAST
Launch 2007



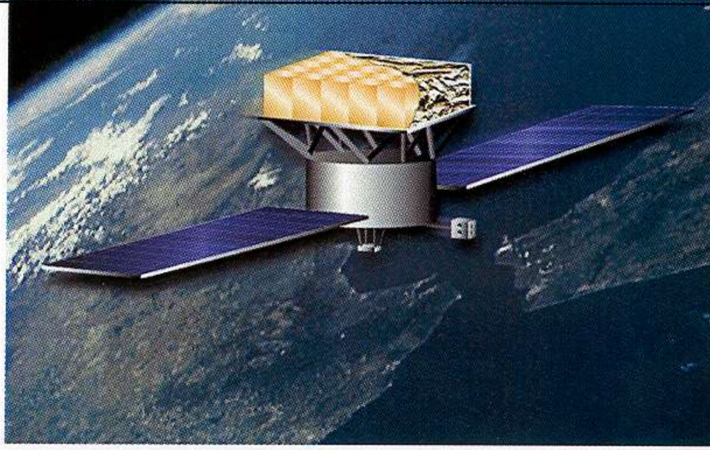
All Sky

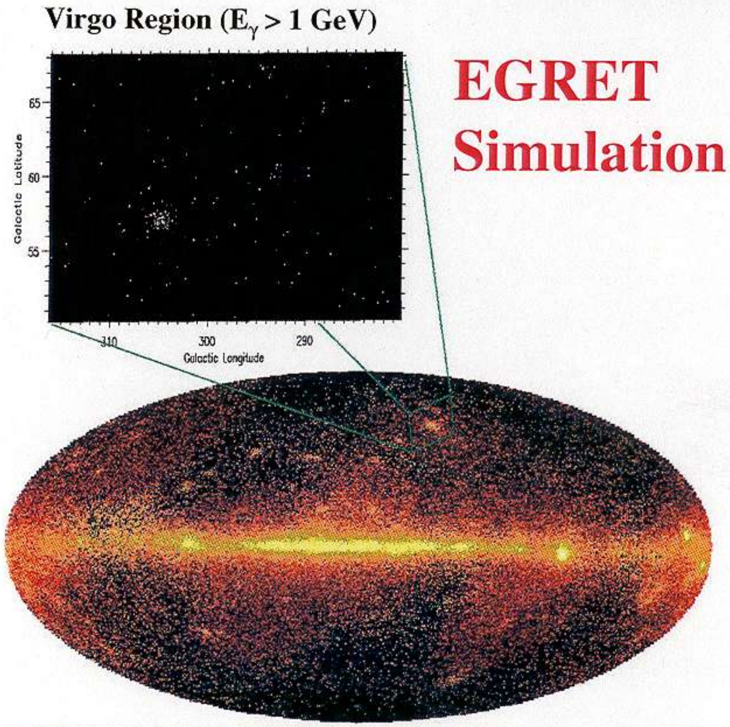
High Resolution



Cosmic Accelerators and Black Holes

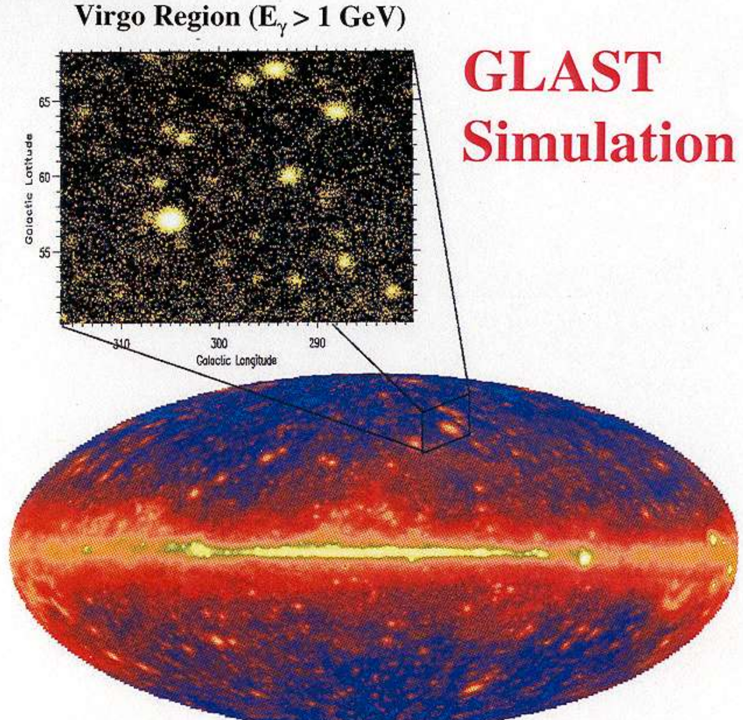
GLAST: Gamma-ray Large Area Space Telescope





EGRET Simulation

EGRET 1 Year All-Sky Survey (E_γ> 100 MeV)



GLAST Simulation

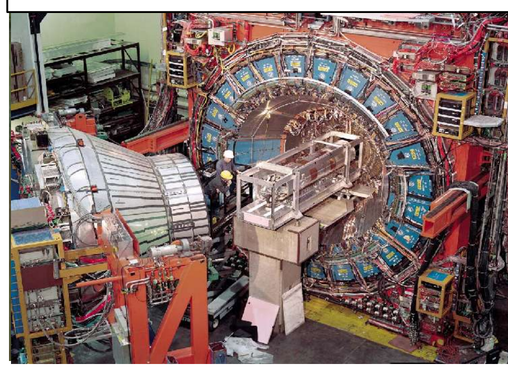
GLAST 1 Year All-Sky Survey (E_γ> 100 MeV)

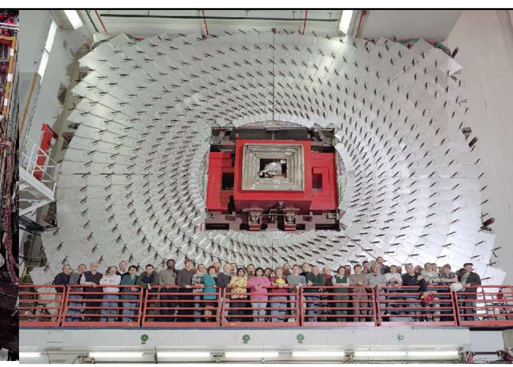
Fermi National Accelerator Laboratory

FNAL

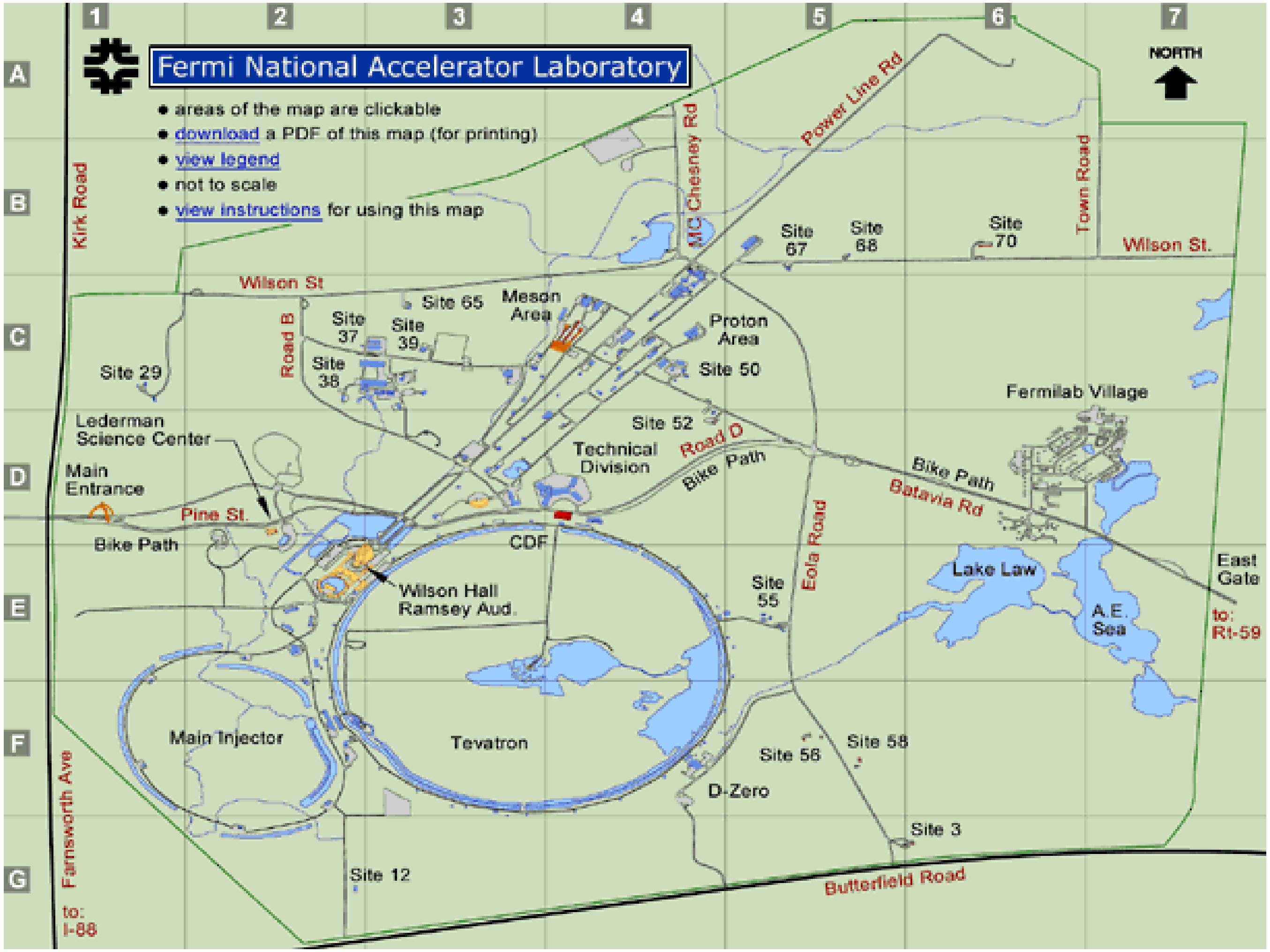
Many generations of Accelerators created
with higher and higher energy given to the beam particle

CDF ~1500 Scientists D0



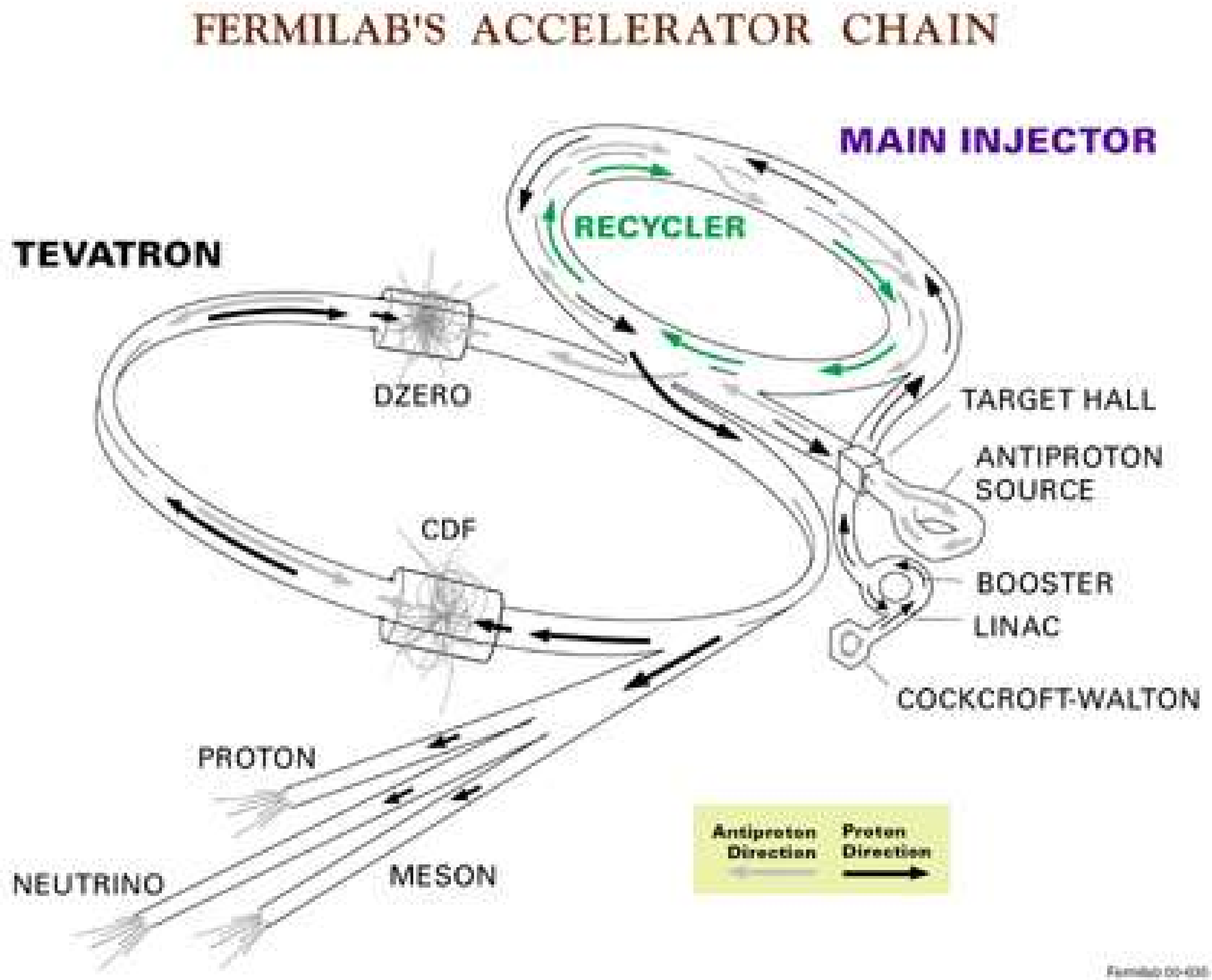


FNAL



Fermi National Accelerator Laboratory
areas of the map are clickable
download a PDF of this map (for printing)
view legend
not to scale
view instructions for using this map
NORTH
Kirk Road
Wilson St
Road B
Site 29
Site 37
Site 38
Site 39
Site 65
Meson Area
MC Chesney Rd
Power Line Rd
Site 67
Site 68
Site 70
Town Road
Wilson St.
Proton Area
Site 50
Site 52
Technical Division
Road D
Bike Path
Fermilab Village
Batavia Rd
Lederman Science Center
Main Entrance
Pine St.
Bike Path
CDF
Wilson Hall Ramsey Aud.
Eola Road
Site 55
Lake Law
A.E. Sea
East Gate
to: Rt-59
Main Injector
Tevatron
Site 56
Site 58
D-Zero
Site 3
Site 12
Farnsworth Ave
to: I-88
Butterfield Road

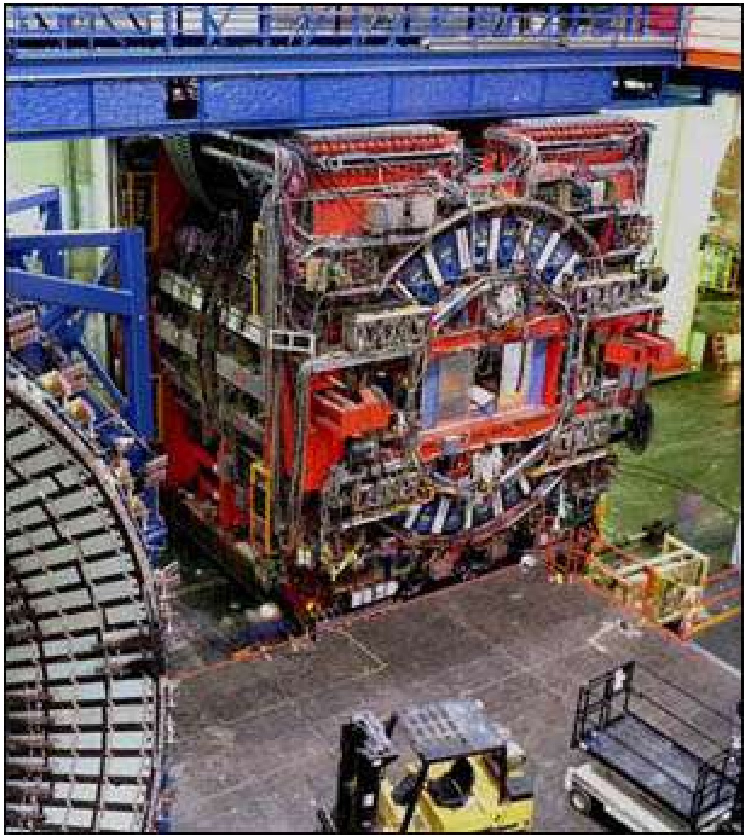
FNAL



FERMILAB'S ACCELERATOR CHAIN
MAIN INJECTOR
RECYCLER
TEVATRON
DZERO
CDF
TARGET HALL
ANTIPROTON SOURCE
BOOSTER
LINAC
COCKCROFT-WALTON
PROTON
NEUTRINO
MESON
Antiproton Direction
Proton Direction

FNAL

FNAL (CDF & D0)

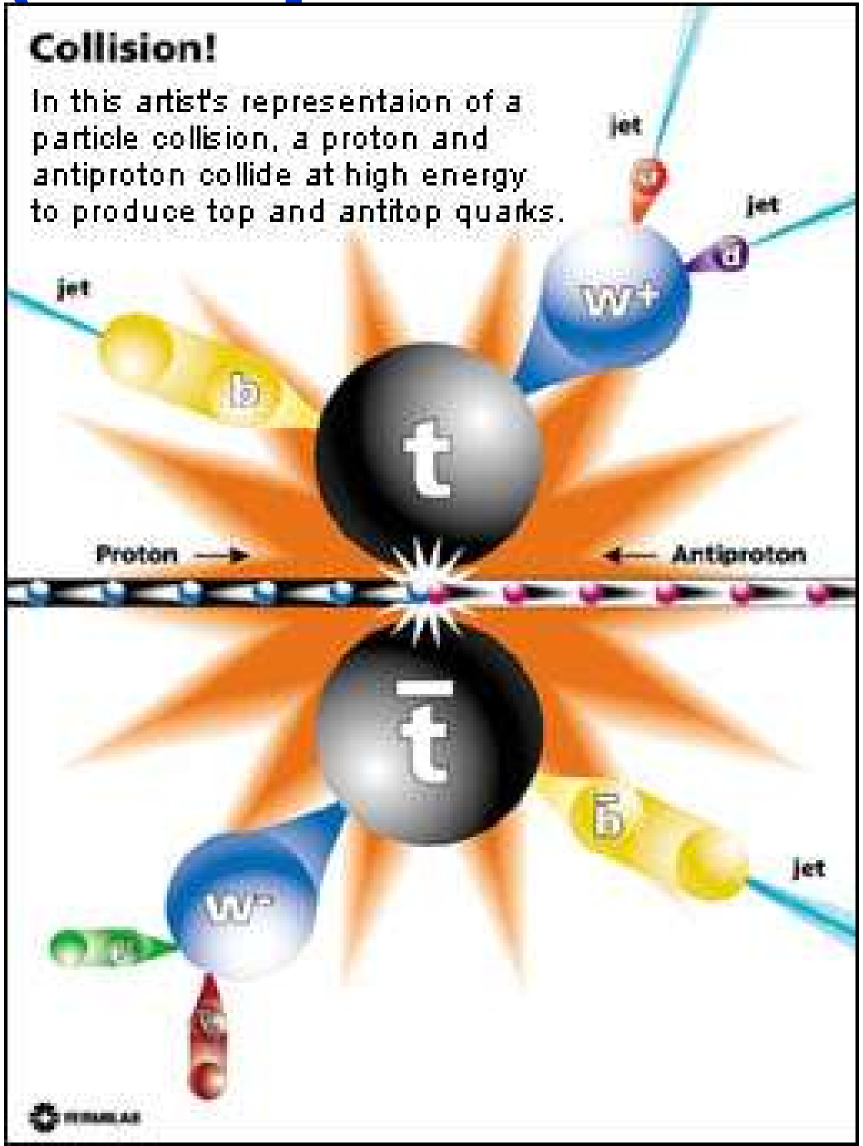


FNAL
Budgets and Statistics

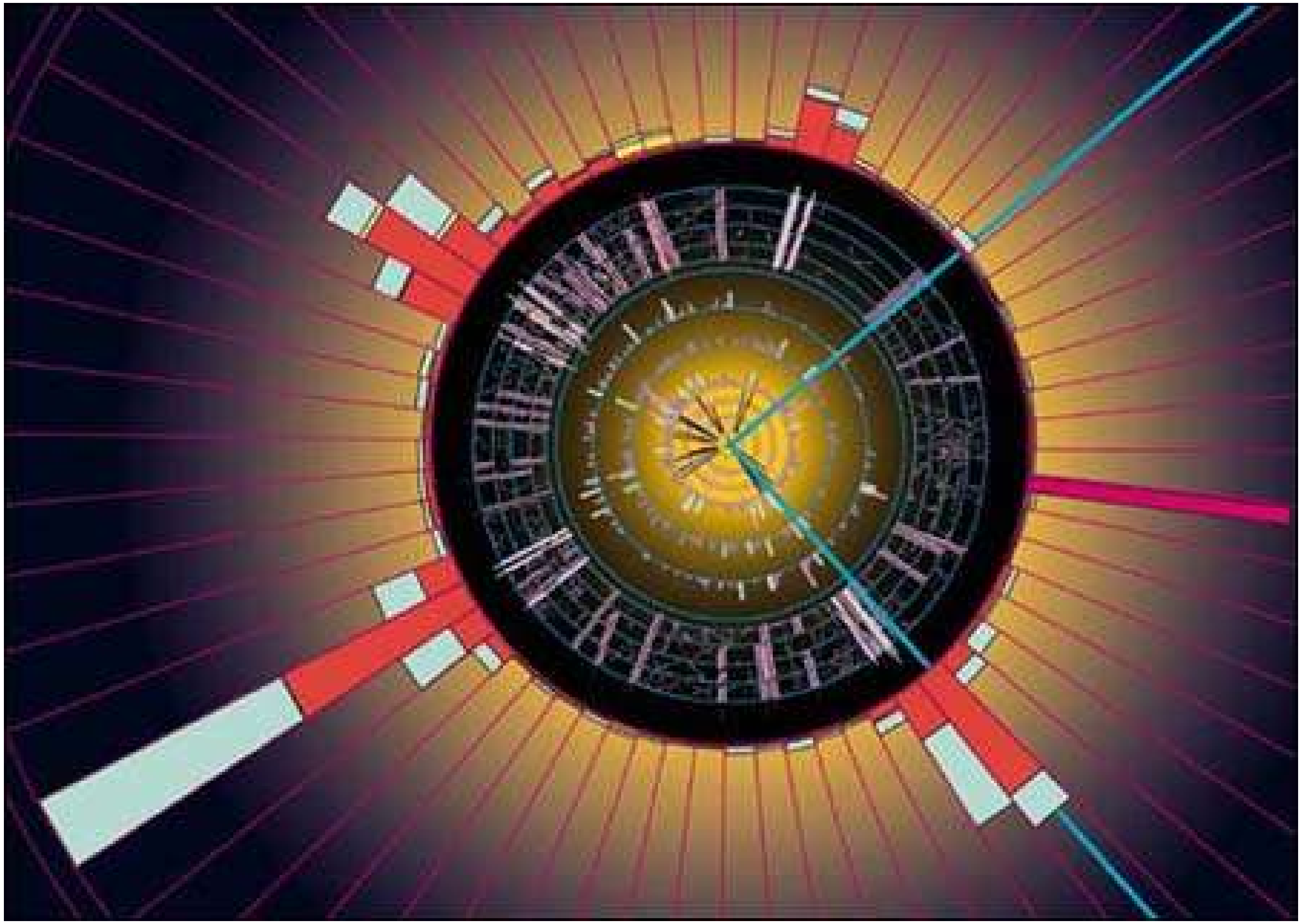
Type of funding	Budget ($ millions)	Expenditure ($ millions)
Operating	240	235
Capital equipment	41	47
Construction/Plant	26	39
Totals	**307**	**321**

There are approximately 2200 people working at Fermilab, including Cooperative students.
Fermilab has also almost 2300 users. A user is a researcher from an outside institution who uses Fermilab to carry out research in particle physics or related disciplines.

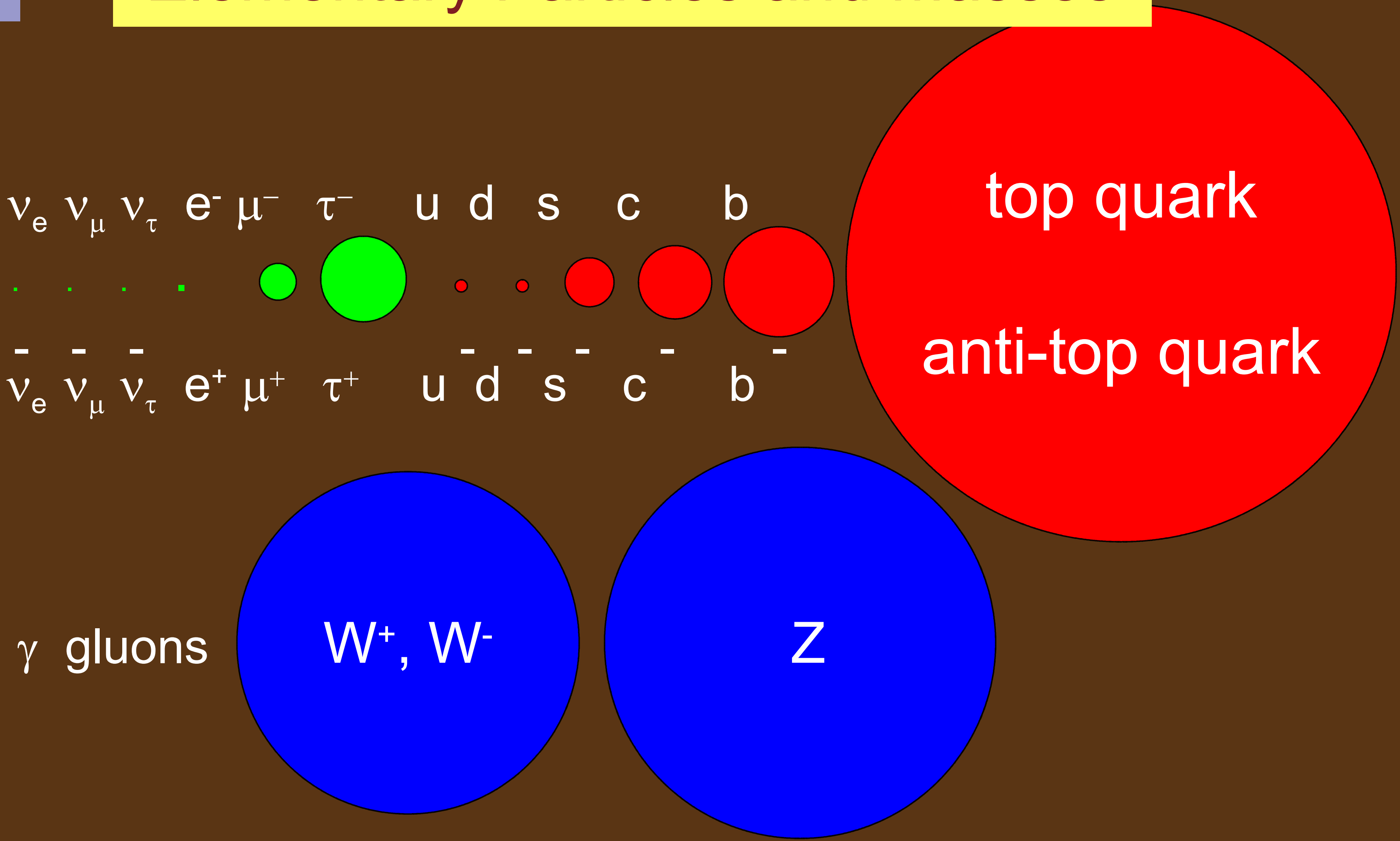
FNAL (T – quark observation)



FNAL (T – quark observation)



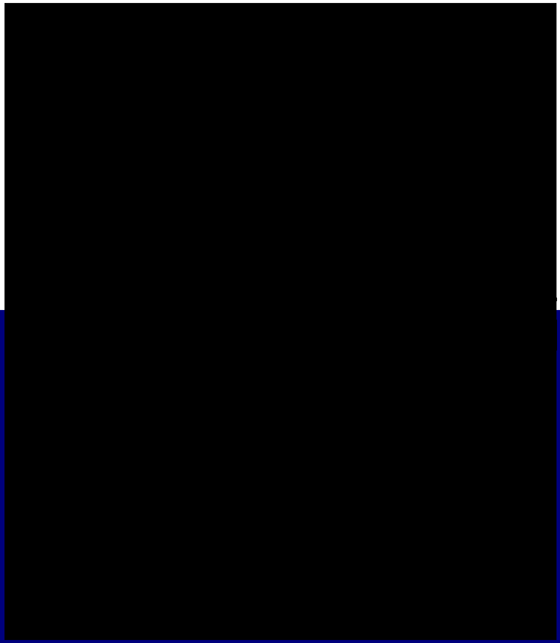
Elementary Particles and Masses



(Mass proportional to area shown but all sizes still < 10^{-19} m)

Why are there so many? Where does mass come from?

Pier Oddone



Report from Fermilab

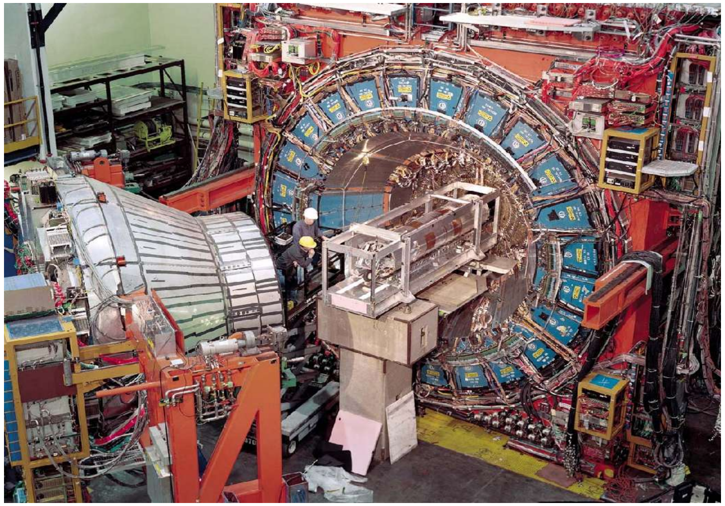
Presentation to ICFA Symposium
Daegu, Korea
September 2005

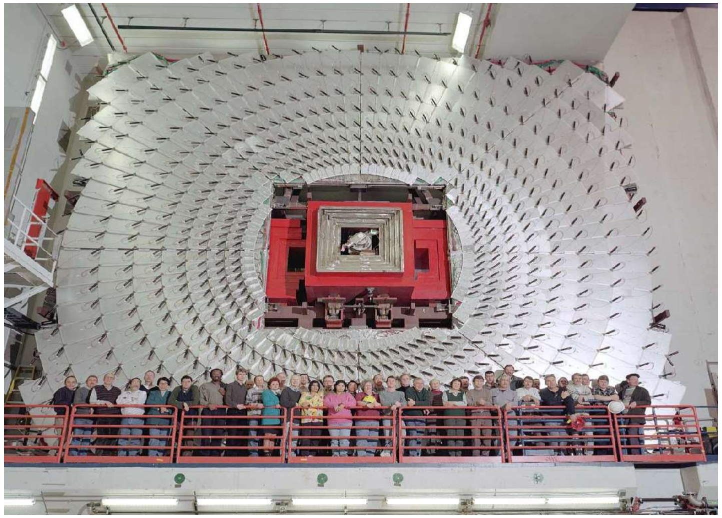
The "ships of the line"

- In the near term:
  - Tevatron Program CDF and D0
  - The neutrino program MiniBoone and MINOS
  - Large Hadron Collider and CMS
- In the future:
  - Neutrinos: NOvA
  - International Linear Collider

Tevatron Program

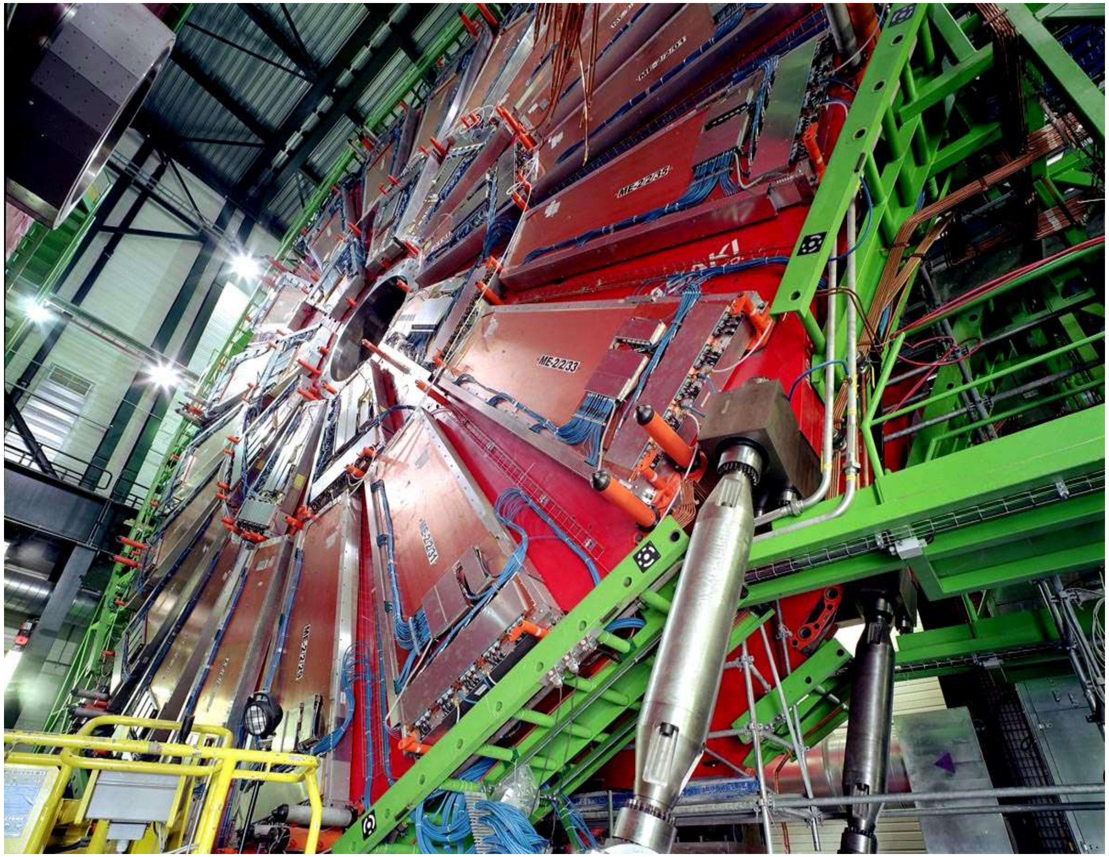
- Greatest window into new phenomena until LHC is on
- 1500 collaborators, 600 students + postdocs
- Critically dependent on Luminosity
- Doubling time a major consideration



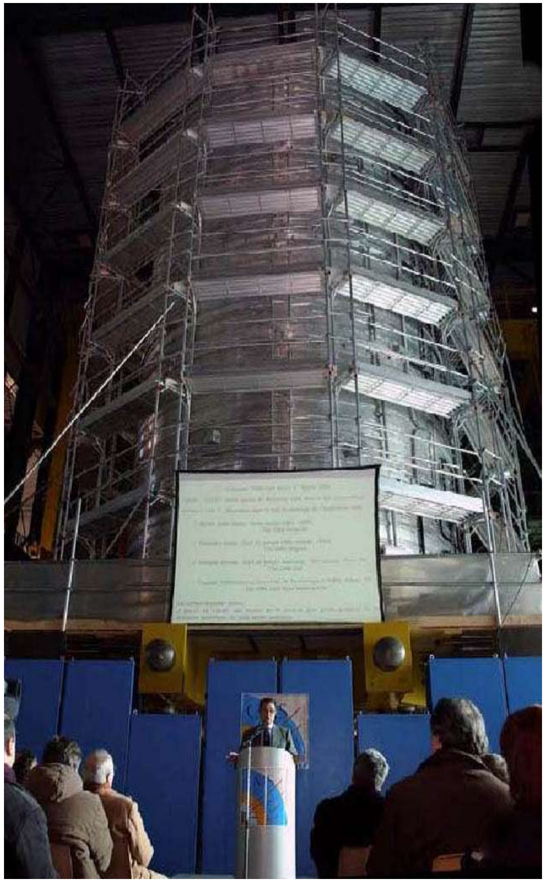


CMS: Compact Muon Detector

- Coming together: aimed at completion by end of 2007



Muon detectors



Magnet cold mass

CMS: Compact Muon Detector

- US collaboration doubled in the last three

>300
Collaborators

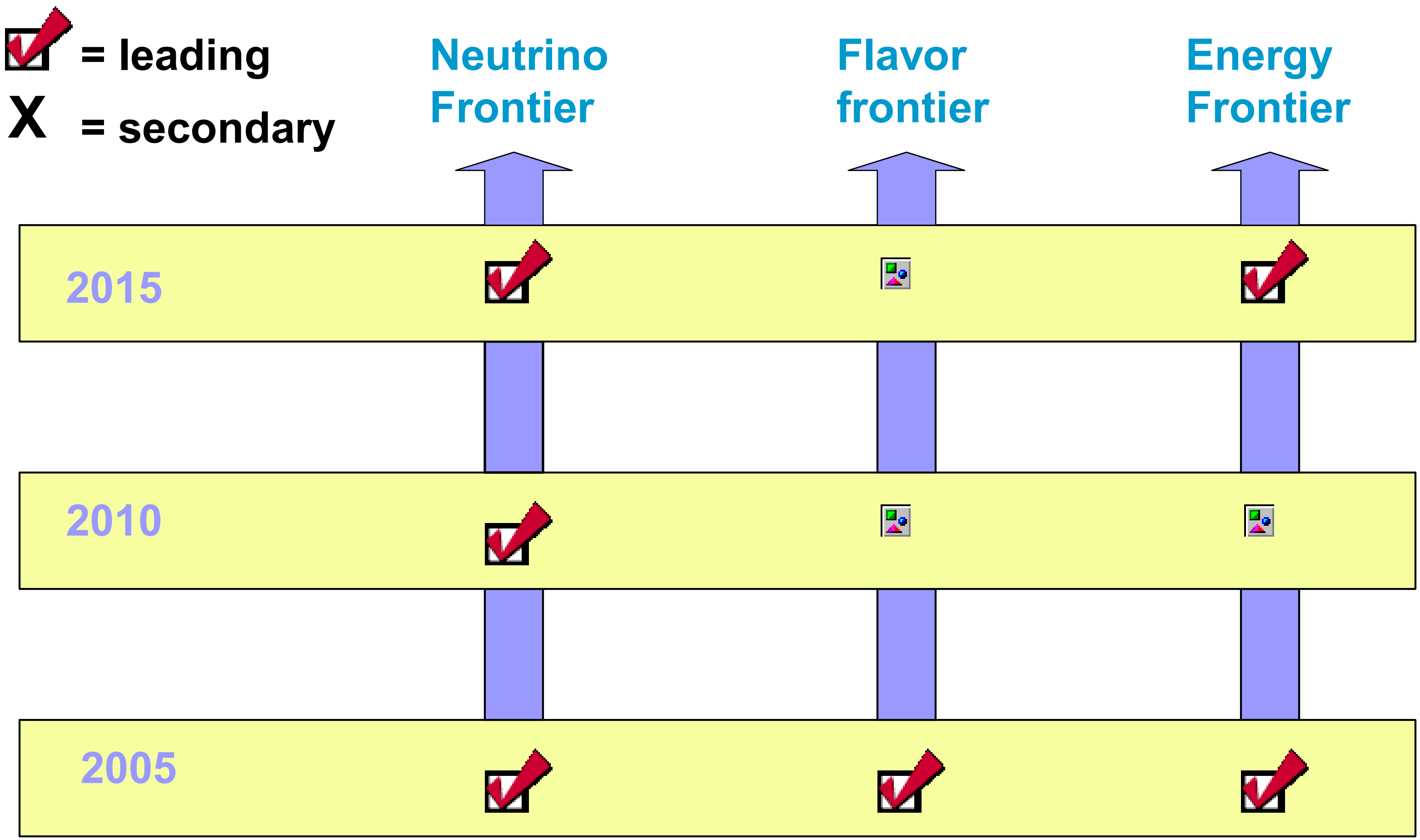
>40
Institutions

US CMS: and Fermilab’s role

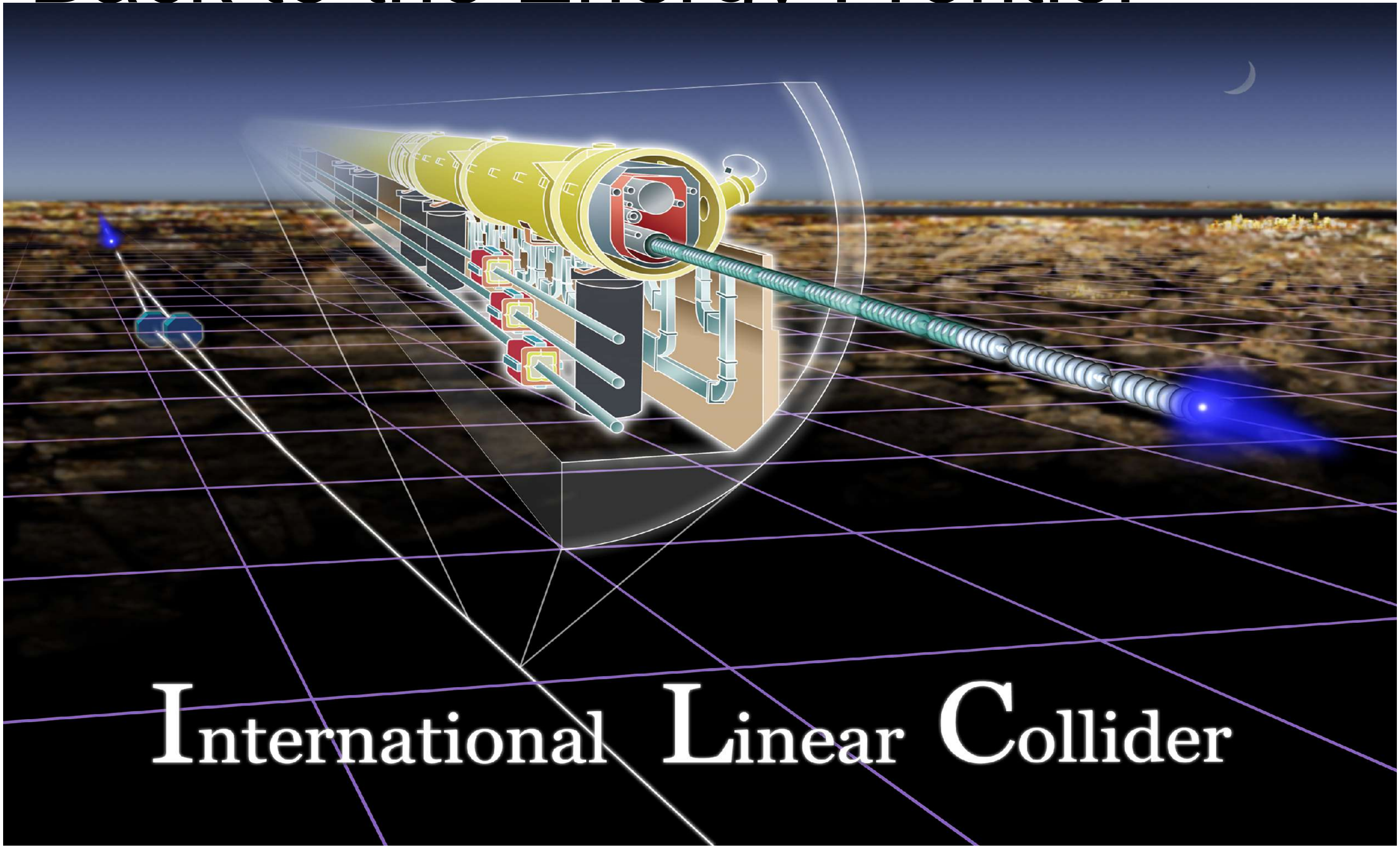
- Only major US lab associated with CMS: a central support role for the US community
- This was the case during construction
- Attention now to huge data and physics discovery challenge: the LHC Physics Center (LPC)

Strategic context: U.S. contribution

Domestic accelerator program with new and redirected investment



Back to the Energy Frontier



The Energy Frontier (ILC)

- Goals:
  - Establish all technical components, costs, engineering designs, management structures to enable “early” decision (by 2010) as part of the global effort.
  - Position US (and Fermilab) to host the ILC.
  - Position US (and Fermilab) to play major roles in detector development and physics analysis.
- ***This is the highest priority initiative for the laboratory, WHEREVER the ILC is finally built***