SLAC'S FLAVORFUL PAST PORTENDS AN EQUALLY FLAVORFUL FUTURE

Jonathan Dorfan
SLAC National Accelerator Laboratory
APS Meeting , May 3, 2009
Denver, Colorado

Guidelines For Talk

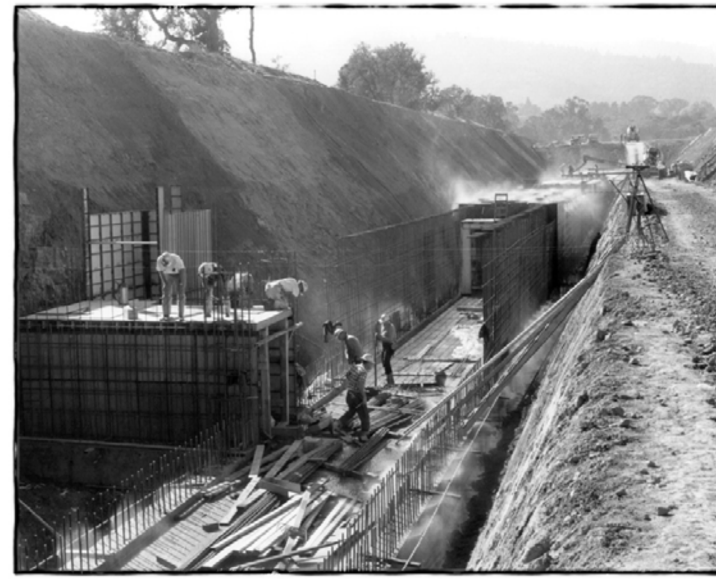
"A thought I had for one of the invited sessions was to include two talks that would each retrospectively celebrate the histories of both SLAC and CESR/CLEO, and look forward to how the physics and the accelerator accomplishments will influence the future of heavy flavor and advanced accelerator techniques. ……" Chip Brock

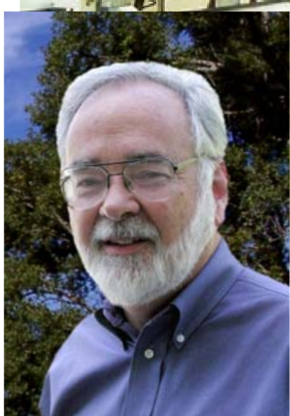
My talk will focus on the ***flavor*** *journey travelled by SLAC and where that points for the future. The talk will necessarily not speak about the parallel measurements made around the world, not because they weren't very important, but because the request was to focus on SLAC.*

1966 Linear Accelerator

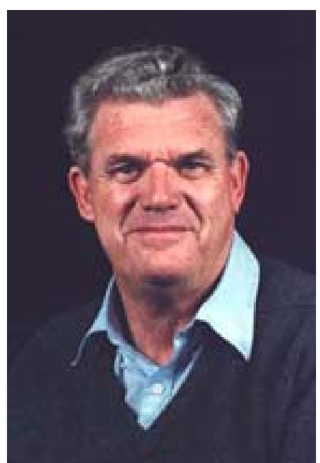
Discovery of quarks
Est. Weinberg/Salaam Model

James Bjorken
DIRAC Medal - 2004

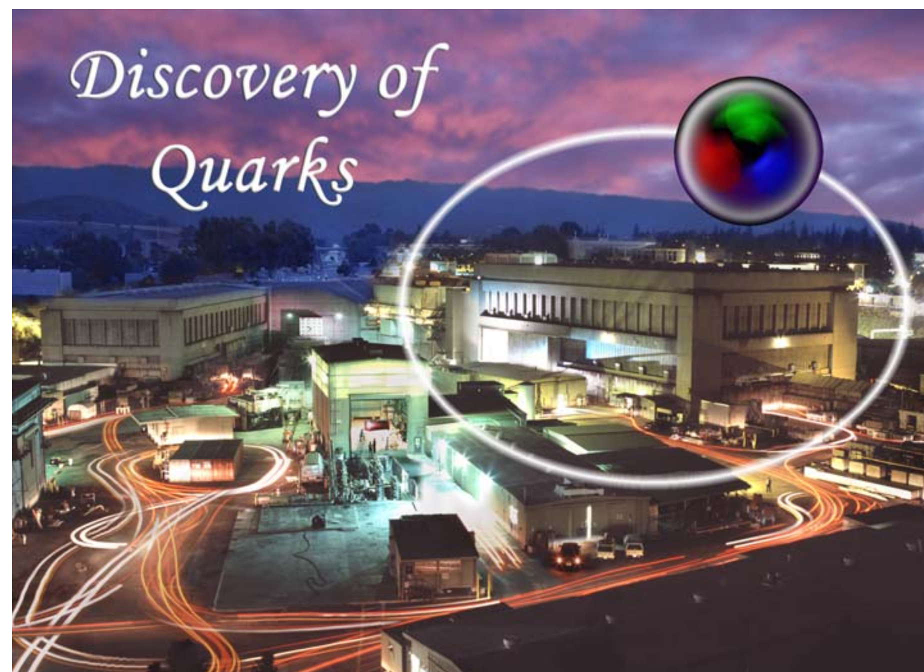


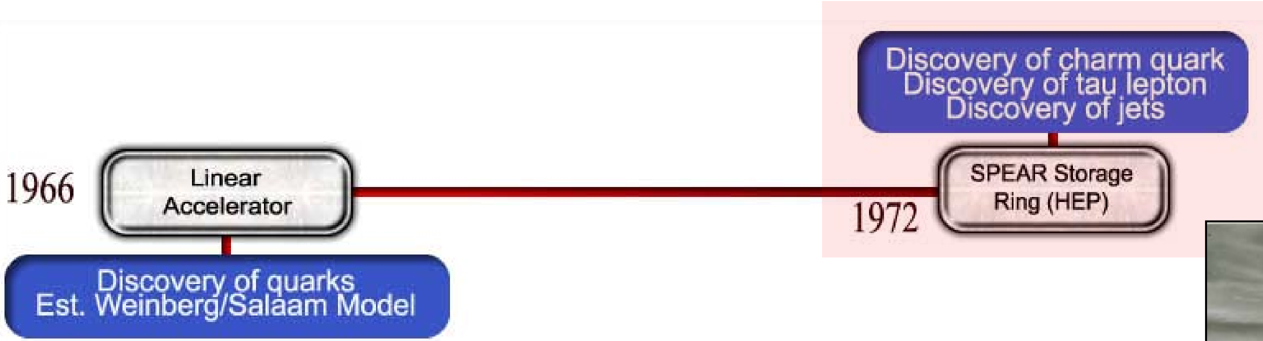


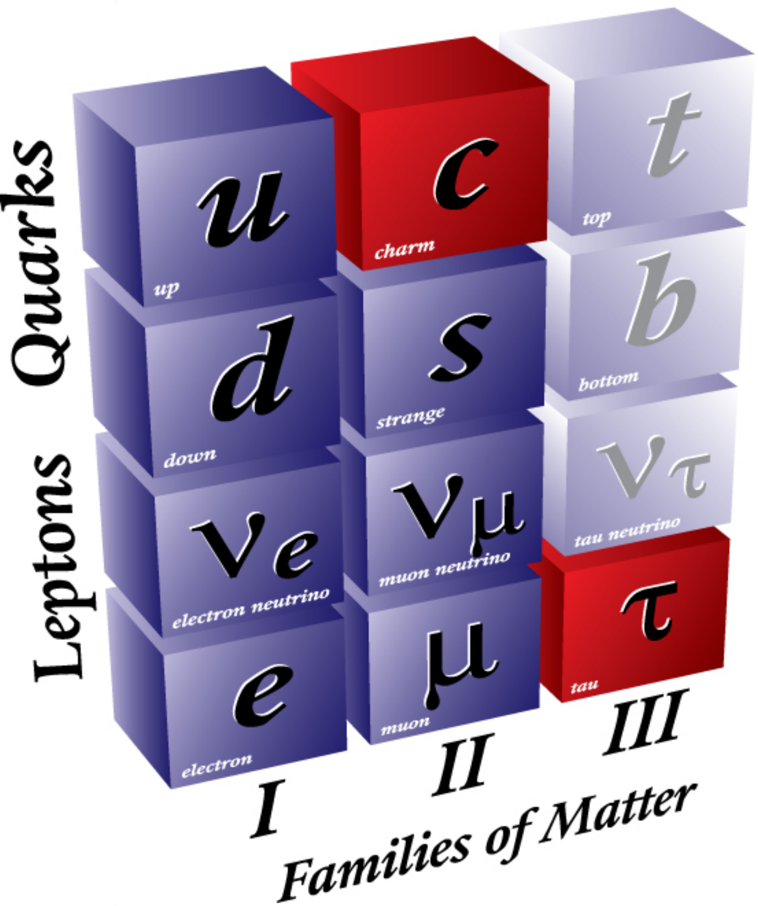
Charles Prescott
Panofsky Prize
1988



Richard Taylor
Nobel Prize - 1990





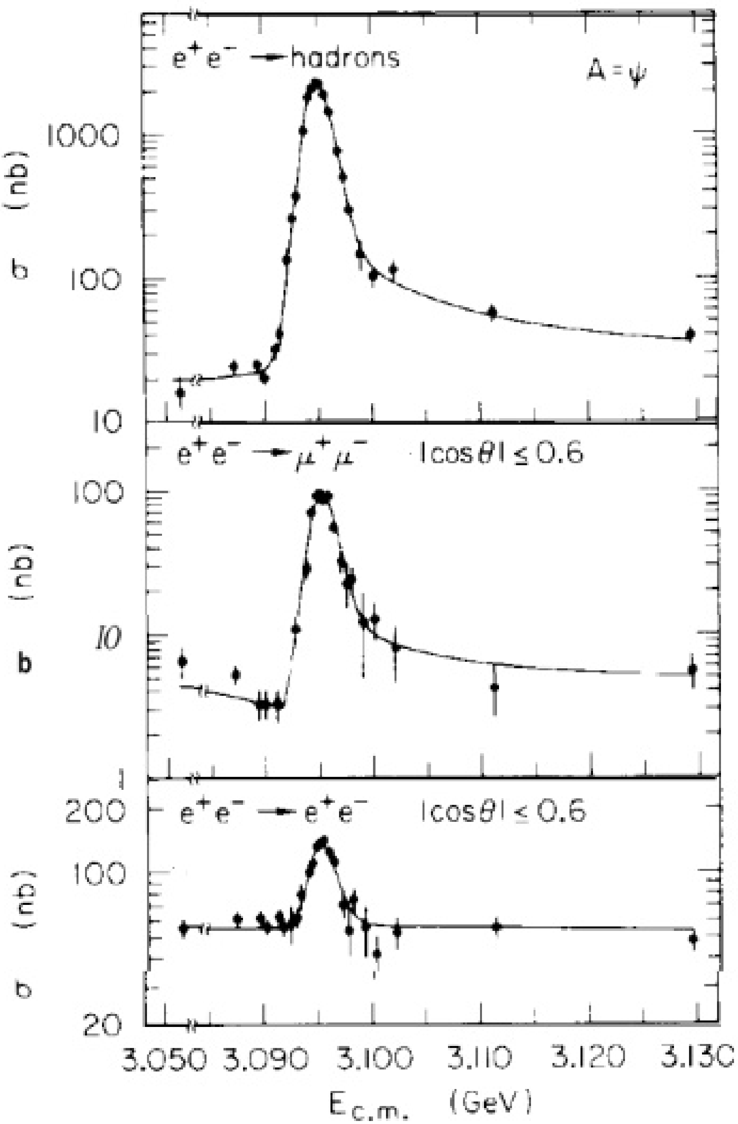


SPEAR

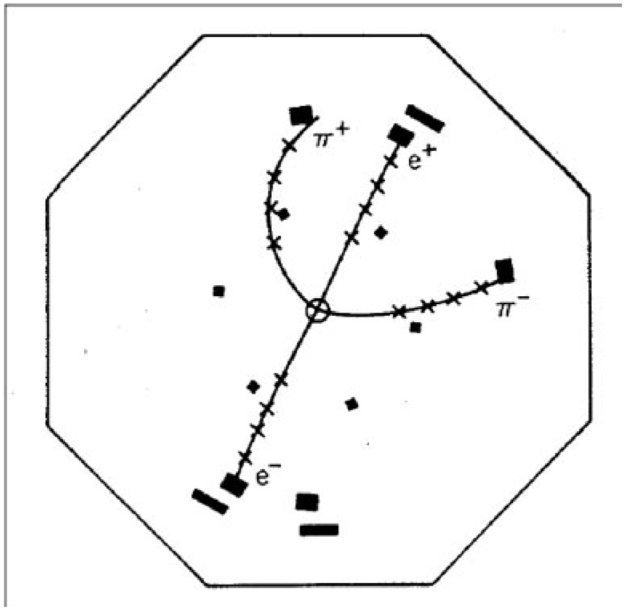
Martin Perl (Nobel Prize – 1995) and Burton Richter (Nobel Prize – 1976) at SPEAR 1975

Discovery of Charm (simultaneous with Ting's expt. at BNL)

Mark I at SPEAR. Nov 1974



Ψ(3095)



Ψ(3700)

VOLUME 33, NUMBER 24 PHYSICAL REVIEW LETTERS 9 DECEMBER 1974

Discovery of a Second Narrow Resonance in e^+e^- Annihilation*†

G. S. Abrams, D. Briggs, W. Chinowsky, C. E. Friedberg, G. Goldhaber, R. J. Hollebeek, J. A. Kadyk, A. Litke, B. Lulu, F. Pierre,‡ B. Sadoulet, G. H. Trilling, J. S. Whitaker, J. Wiss, and J. E. Zipse

Lawrence Berkeley Laboratory and Department of Physics, University of California, Berkeley, California 94720

and

J.-E. Augustin,§ A. M. Boyarski, M. Breidenbach, F. Bulos, G. J. Feldman, G. E. Fischer, D. Fryberger, G. Hanson, B. Jean-Marie,§ R. R. Larsen, V. Lüth, H. L. Lynch, D. Lyon, C. C. Morehouse, J. M. Paterson, M. L. Perl, B. Richter, P. Rapidis, R. F. Schwitters, W. Tanenbaum, and F. Vannucci‖

Stanford Linear Accelerator Center, Stanford University, Stanford, California 94305

(Received 25 November 1974)

We have observed a second sharp peak in the cross section for $e^+e^- \to$ hadrons at a center-of-mass energy of 3.695 ± 0.004 GeV. The upper limit of the full width at half-maximum is 2.7 MeV.

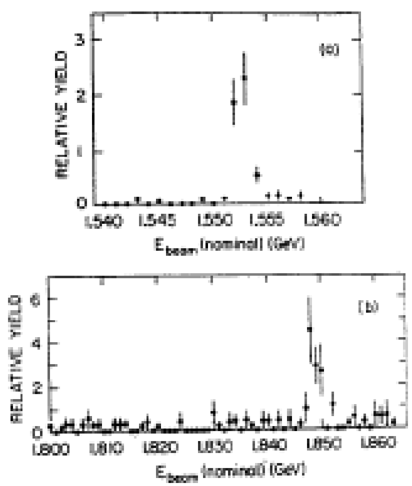


FIG. 1. Search-mode data (relative hadron yield) taken (a) in a 1-h calibration run over the $\psi(3105)$ (average luminosity of 2×10^{29} cm^{-2} sec^{-1}), and (b) during the run in which the $\psi(3695)$ was found (average luminosity of 5×10^{29} cm^{-2} sec^{-1}).

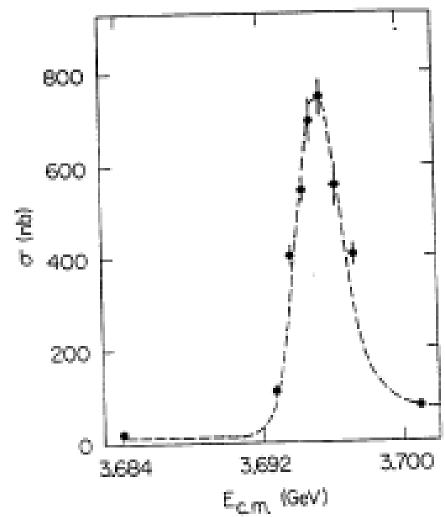


FIG. 2. Total cross section for $e^+e^- \to$ hadrons corrected for detection efficiency. The dashed curve is the expected resolution folded with the radiative corrections. The errors shown are statistical only.

Fig. 9. Announcement of the ψ' discovery in *Phys. Rev. Lett.*

Discovery of Open Charm: Mark I data from SPEAR

1976

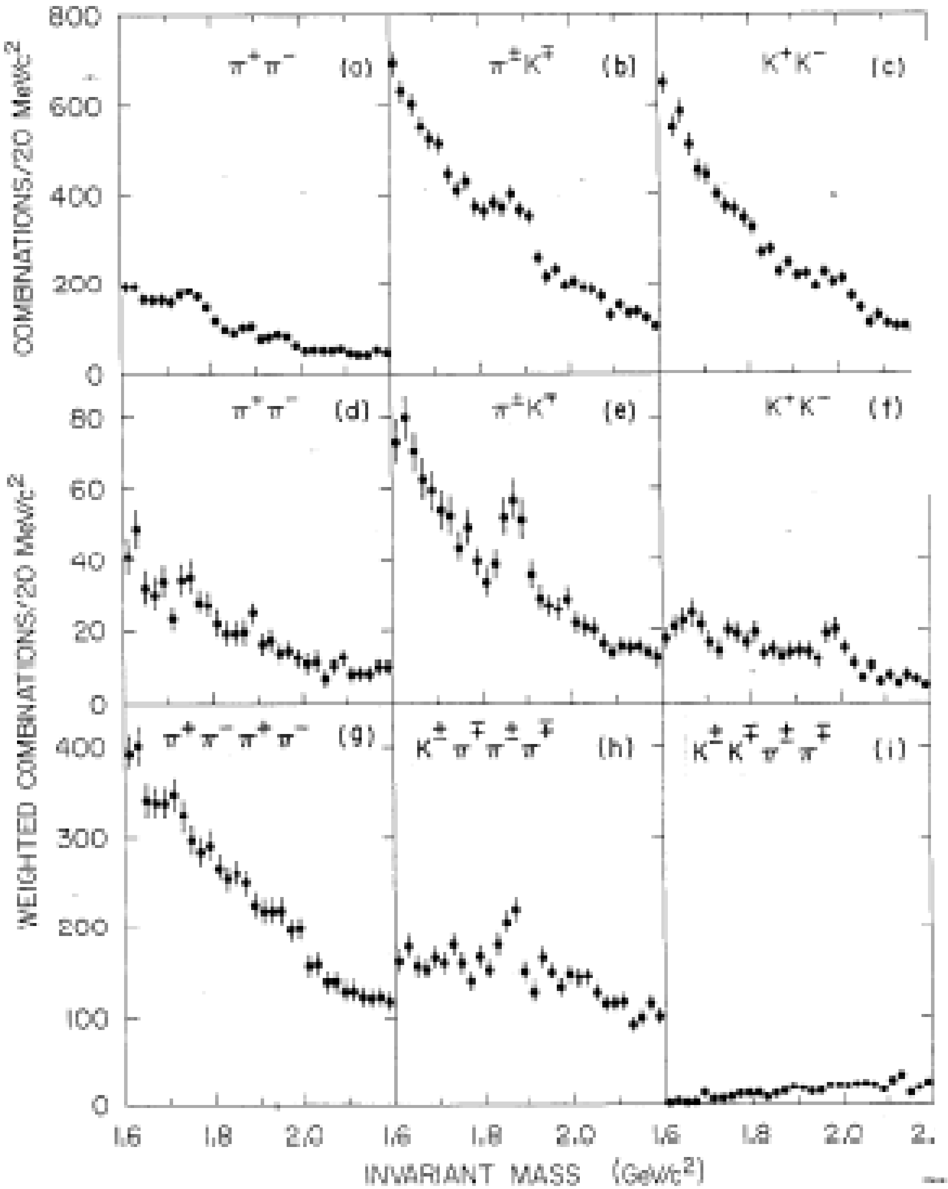


Figure Captions

1. Invariant mass spectra for neutral combination of charged particles. (a) $\pi^+\pi^-$ assigning π mass to all tracks, b) $K^{\mp}\pi^{\pm}$ assigning K and π masses to all tracks, c) K^+K^- assigning K mass to all tracks, d) $\pi^+\pi^-$ weighted by $\pi\pi$ TOF probability, e) $K^{\pm}\pi^{\mp}$ weighted by $K\pi$ TOF probability, f) K^+K^- weighted by KK TOF probability, g) $\pi^+\pi^-\pi^+\pi^-$ weighted by 4π TOF probability, h) $K^{\mp}\pi^{\pm}\pi^{\mp}\pi^{\pm}$ weighted by $K3\pi$ TOF probability, i) $K^+K^-\pi^+\pi^-$ weighted by $KK\pi\pi$ TOF probability.

On Monday and Tuesday I was looking for my colleague Francois Pierre—a visitor with our group at LBL from Saclay, France—to show him my result. Finally I met up with him on Wednesday for lunch. The reason I could not find him was that on Monday and Tuesday he had gone to SLAC. As I found out, he had also observed a $K\pi$ as well as a $K\pi\pi\pi$ signal. Right after lunch we compared distributions and realized we had each independently and with different criteria found the same mass peaks. We spent the next two hours writing a joint note to our collaboration showing our data. I called Roy Schwitters at SLAC, our spokesman at that time, to tell him about our results. There was much excitement both at LBL and SLAC. After our colleagues had a chance to check our results and convince themselves that we were right, a paper was sent off to Phys. Rev. Lett. One question came up. How could we prove that we had really identified K's? Jonathan Dorfan who had just recently joined our collaboration came up with the suggestion that we weight each track according to the probability that it be a K or a π and then plot the weighted $K\pi$ mass distribution. This is shown in our paper.(19)

Gerson Goldhaber

First Excited State of D^0 is Seen at SPEAR

July 1977
(T/E)

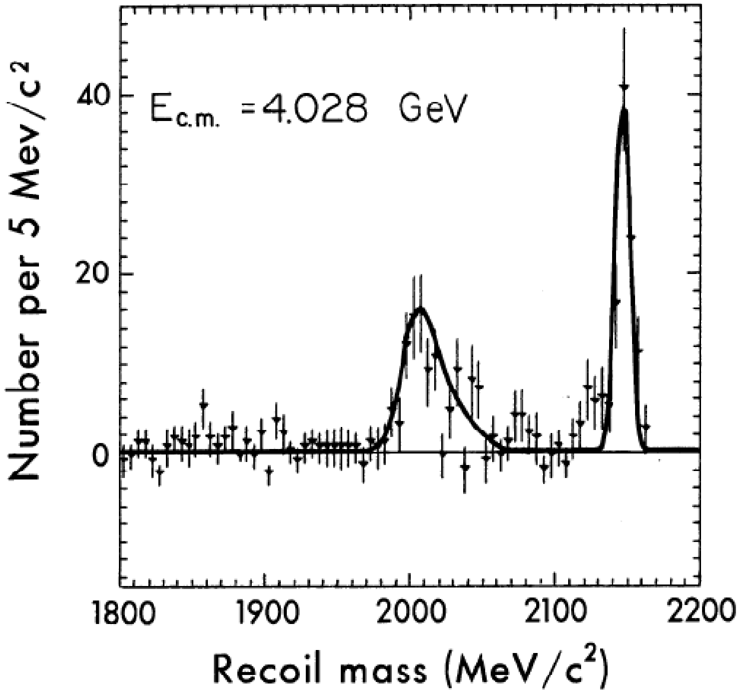
D AND D^* MESON PRODUCTION NEAR 4 GeV IN e^+e^- ANNIHILATION*

G. Goldhaber, J. E. Wiss, G. S. Abrams, M. S. Alam, A. M. Boyarski,
M. Breidenbach, W. Chinowsky, J. Dorfan, G. J. Feldman, G. Hanson,
J. A. Jaros, A. D. Johnson, J. A. Kadyk, D. Lüke,** V. Lüth, H. L. Lynch,†
R. J. Madaras, H. K. Nguyen,†† J. M. Paterson, M. L. Perl, I. Peruzzi,‡
M. Piccolo,‡ F. M. Pierre,‡‡ T. P. Pun, P. Rapidis, B. Richter,
R. H. Schindler, R. F. Schwitters, J. Siegrist, W. Tanenbaum, G. H. Trilling

Department of Physics and Lawrence Berkeley Laboratory
University of California, Berkeley, California 94720

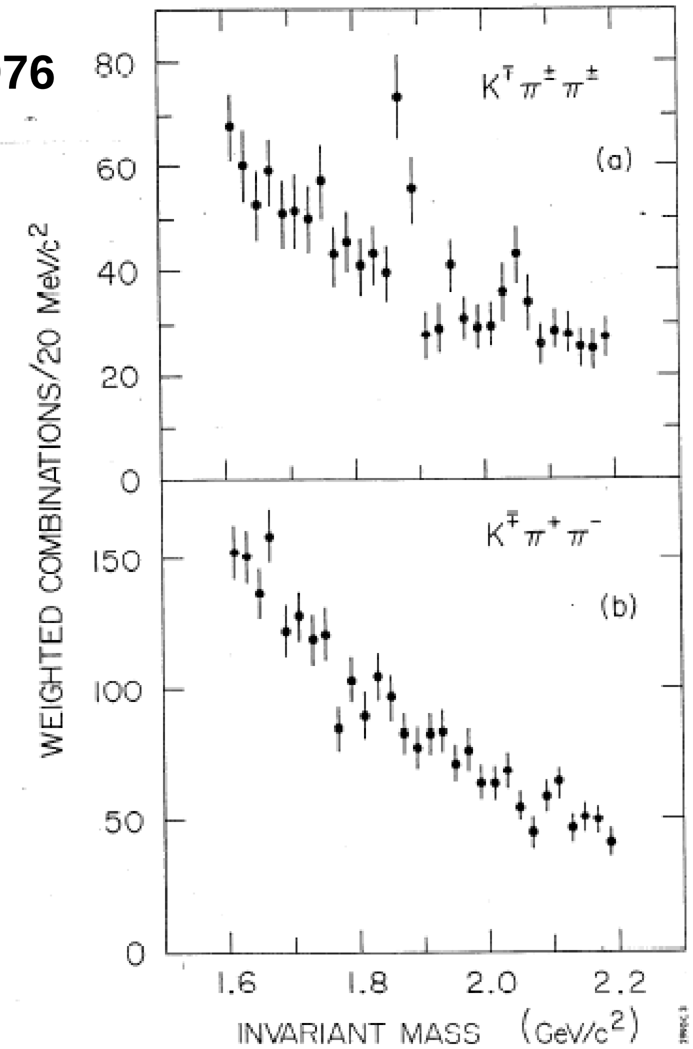
and

Stanford Linear Accelerator Center
Stanford University, Stanford, California 94305



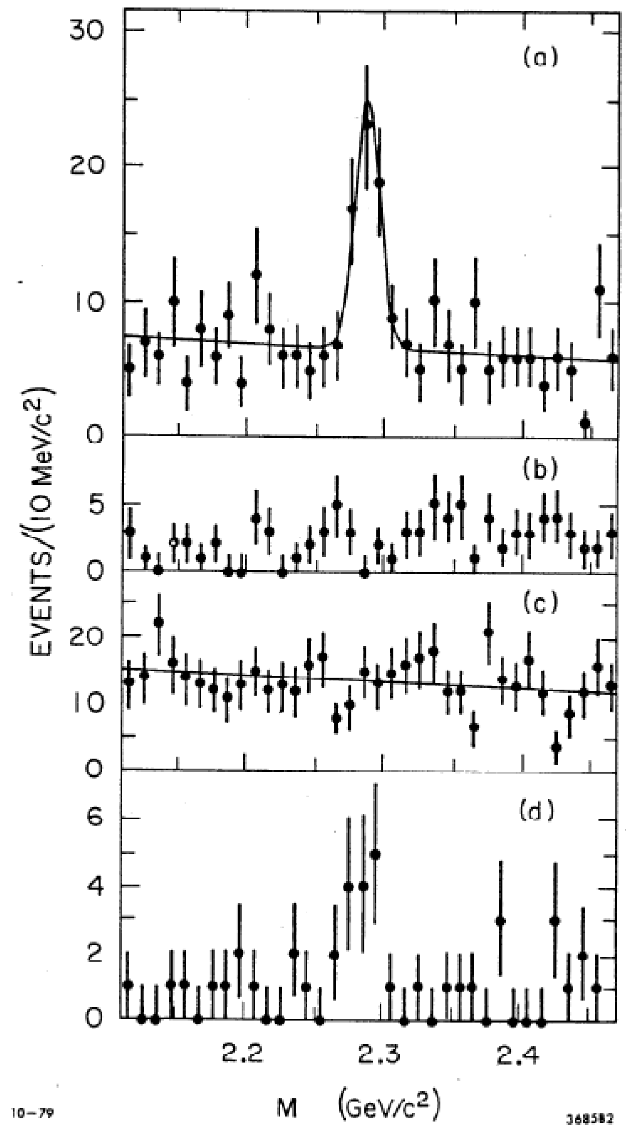
Mark I at SPEAR: D+-

1976



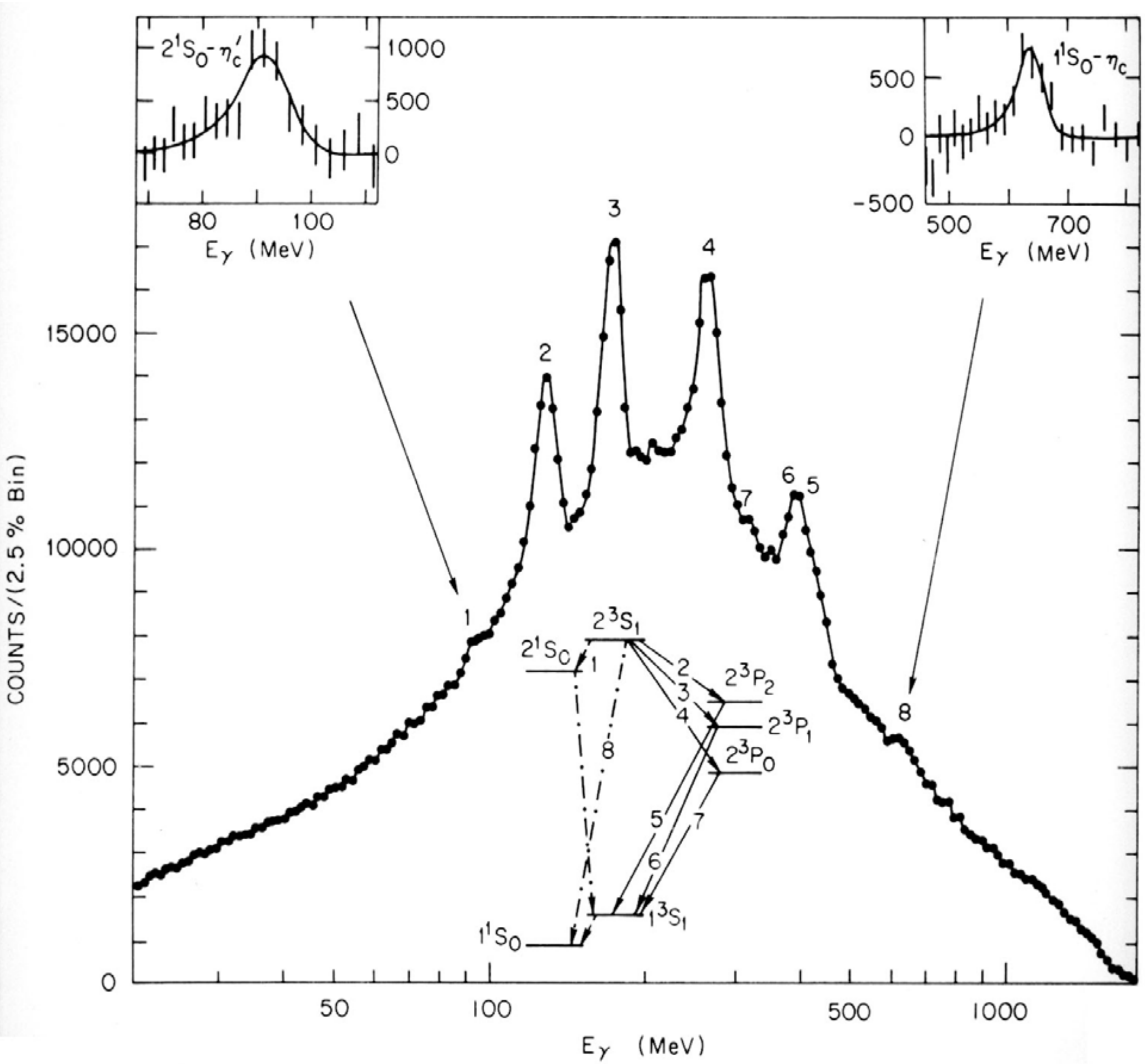
Mark II at SPEAR: Λ_c

1979



In rather a short time, the key elements of a bound charm anti-charm heavy quark system are revealed

CRYSTAL BALL AT SPEAR…..



….and DESY

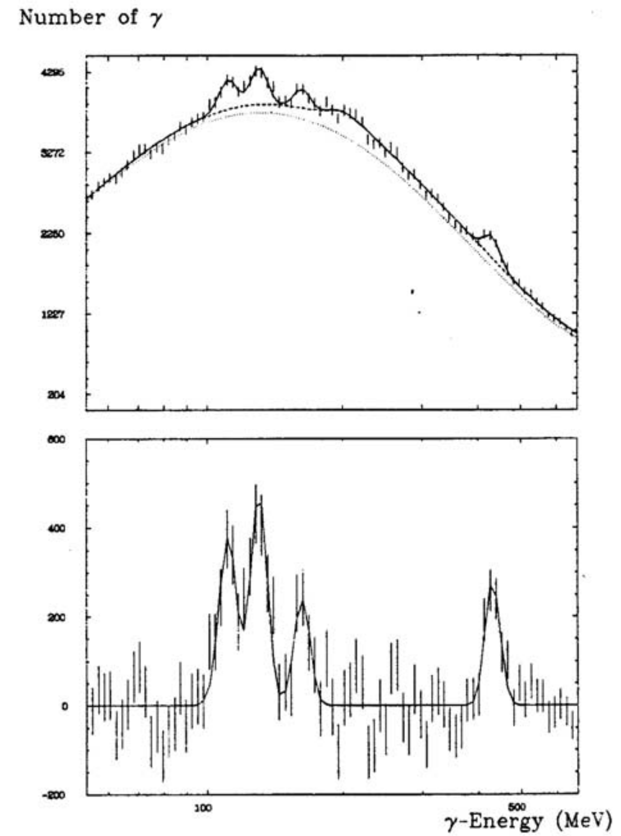
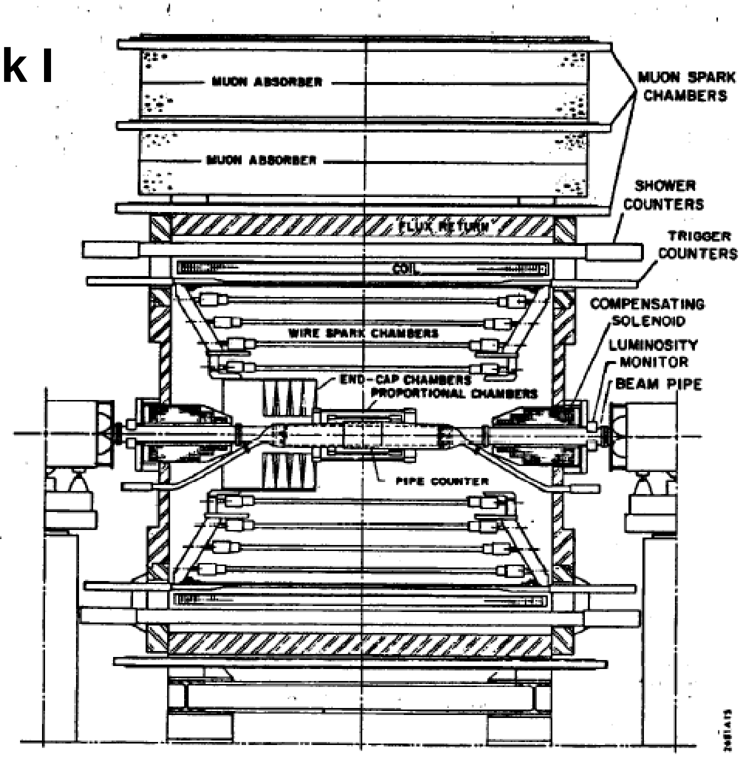


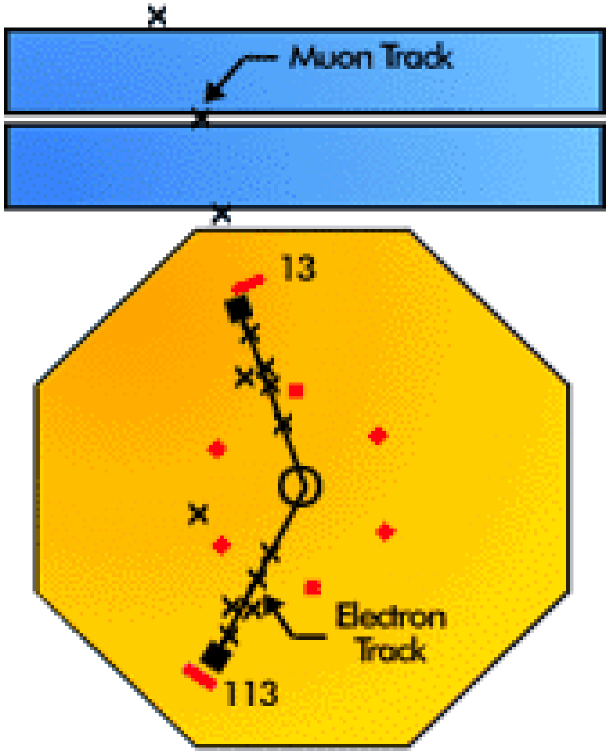
Figure 27. Fit to spectrum before(top) and after background subtraction (bottom).The dotted line in the upper plot represents the smooth polynomial background. The charged particle 'punchthrough' background is given by the difference between the dashed and the dotted line. In the lower figure these backgrounds have been subtracted.

Photon spectrum $\Upsilon(2S) \rightarrow \gamma + x$

1982 Crystal Ball $\psi' \rightarrow \gamma + X$

Mark I





Martin Perl Receives The Nobel Prize

(photo by Joseph Perl)

Discovery of the τ in 1975: 24 anomalous eμ events in Mark I

ABSTRACT

We have found events of the form $e^+ + e^- \to e^\pm + \mu^\mp$ + missing energy, in which no other charged particles or photons are detected. Most of these events are detected at or above a center-of-mass energy of 4 GeV. The missing energy and missing momentum spectra require that at least two additional particles be produced in each event. We have no conventional explanation for these events.

(Submitted to Phys. Rev. Letters, August, 1975)

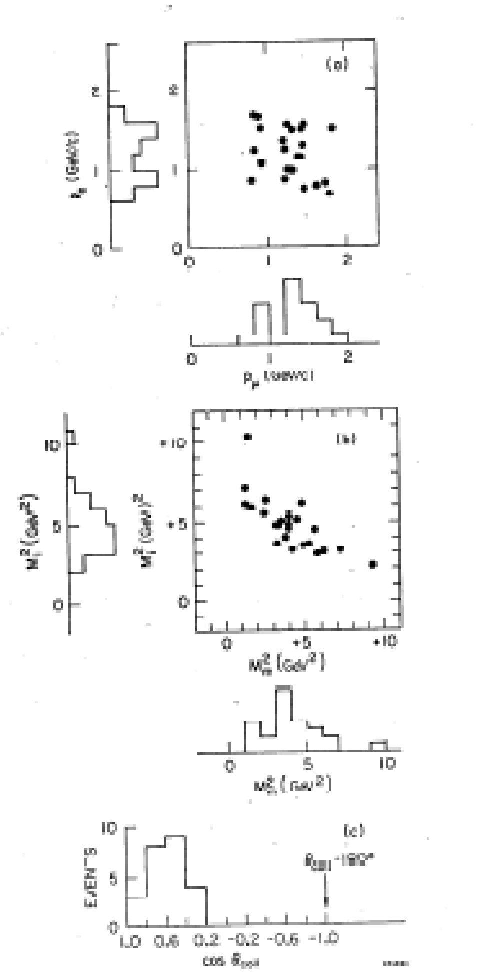


Fig. 1

A possible explanation for these events is the production and decay of a pair of new particles, each having a mass in the range of 1.6 to 2.0 GeV/c^2.

Early measurements of τ leptonic branching fraction, mass

Mark I 1977

PROPERTIES OF THE PROPOSED τ CHARGED LEPTON*

M. L. Perl, G. J. Feldman, G. S. Abrams, M. S. Alam,
A. M. Boyarski, M. Breidenbach, J. Dorfan, W. Chinowsky,
G. Goldhaber, G. Hanson, J. A. Jaros, J. A. Kadyk, D. Lüke**,
V. Lüth, R. J. Madaras, H. K. Nguyen†, J. M. Paterson, I. Peruzzi††,
M. Piccolo††, T. P. Pun, P. A. Rapidis, B. Richter,
W. Tanenbaum, and J. E. Wiss

Stanford Linear Accelerator Center
Stanford University, Stanford, California 94305

and

Lawrence Berkeley Laboratory and Department of Physics
University of California, Berkeley, California 94720

ABSTRACT

The anomalous $e\mu$ and 2-prong μx events produced in e^+e^- annihilation are used to determine the properties of the proposed τ charged lepton. We find the τ mass is $1.90 \pm .10$ GeV/c^2; the mass of the associated neutrino, ν_τ, is less than 0.6 GeV/c^2 with 95% confidence; V−A coupling is favored over V+A coupling for the τ−ν_τ current; and the leptonic branching ratios are $0.186 \pm .010 \pm .028$ from the $e\mu$ events and $0.175 \pm .027 \pm .030$ from the μx events where the first error is statistical and the second is systematic.

Mark II: Hadronic Decays of τ

August 1980
(T/E)

MEASUREMENT OF THE DECAYS $\tau^- \to \rho^- \nu_\tau$ and $\tau^- \to K^{*-}(892)\nu_\tau$
USING THE MARK II DETECTOR AT SPEAR*

Jonathan Dorfan
Stanford Linear Accelerator Center
Stanford University, Stanford, California 94305

ABSTRACT

Measurement of the branching fractions for the Cabibbo favored decay $\tau^- \to \rho^- \nu_\tau$ and the Cabibbo suppressed decay $\tau^- \to K^{*-}(892)\nu_\tau$ are presented. The energy dependence of the $\tau^+\tau^-$ production cross section is measured using the decay $\tau^- \to \rho^- \nu_\tau$ which yields a measurement $M_\tau = (1790 \pm 40)$ MeV. A 2σ upper limit for the forbidden decay $\tau^- \to K^{*-}(1430)\nu_\tau$ is also presented.

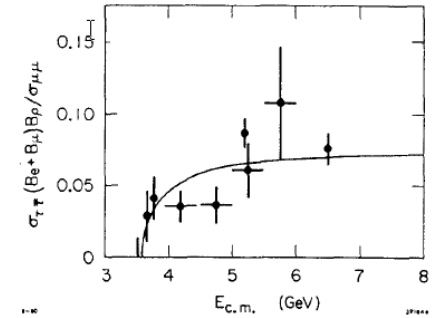


Fig. 2. The $\tau\bar{\tau}$ production cross section, normalized to the mu-pair cross section, as a function of $E_{c.m}$

$M_\tau = (1790 \pm 40)$ MeV/c^2

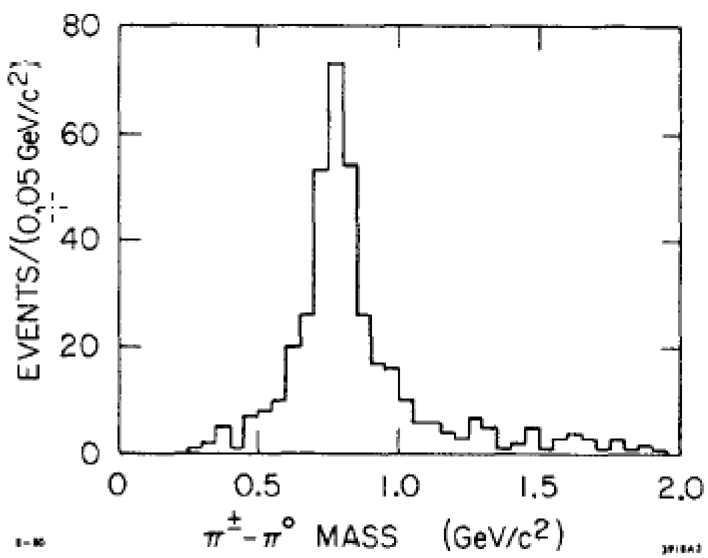


Fig. 1. The $\pi^+\pi^0$ invariant mass spectrum for $\ell^\pm\pi^\mp\pi^0$ events.

$B(\tau^- \to \rho^- \nu_\tau) = (21.6 \pm 1.8 \pm 3.2)\%$

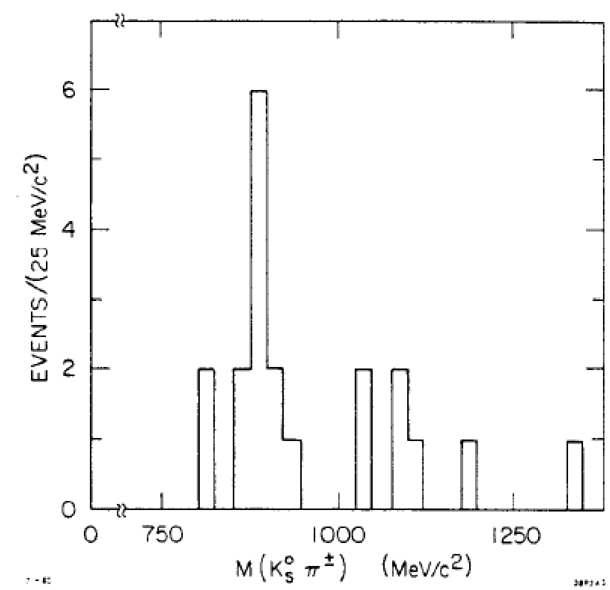
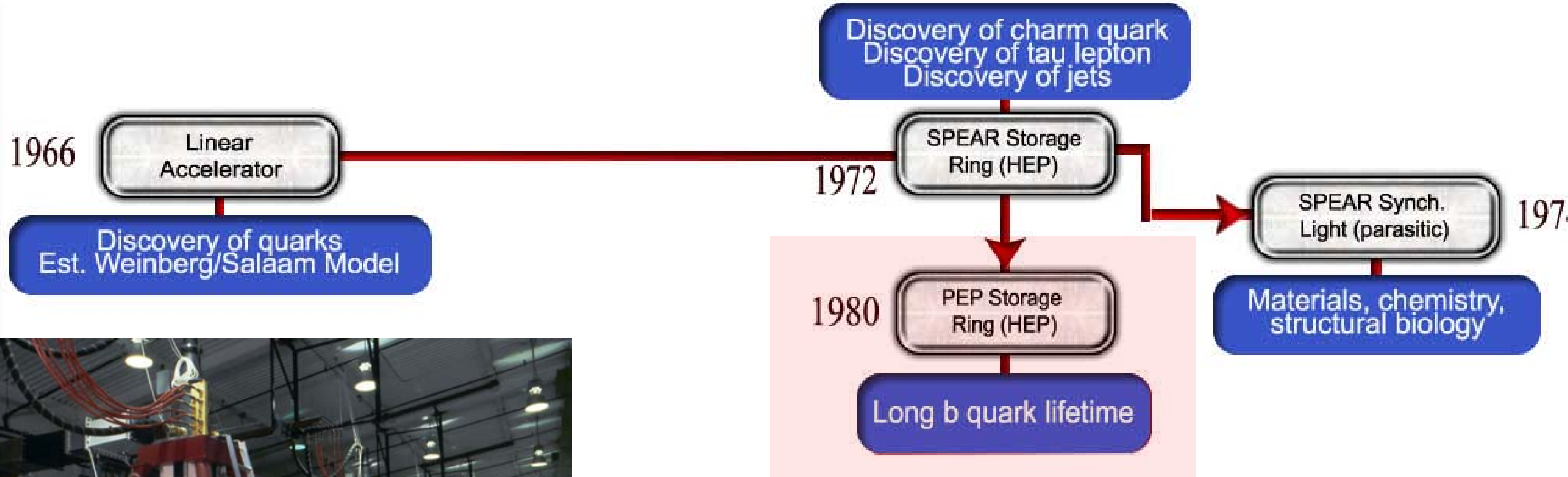
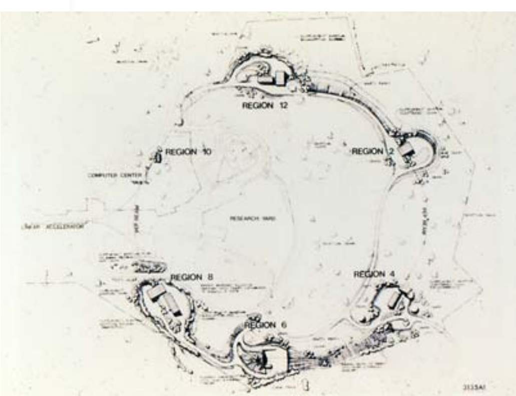


Fig. 3. $K_S^0\pi^\pm$ invariant mass spectrum for $K_S^0\pi^\pm\ell^\mp$ events.

$B(\tau^- \to K^{*-}(892)\nu_\tau) = (1.7 \pm 0.7)\%$


1966
Linear Accelerator
Discovery of quarks
Est. Weinberg/Salaam Model
Discovery of charm quark
Discovery of tau lepton
Discovery of jets
SPEAR Storage Ring (HEP)
1972
SPEAR Synch. Light (parasitic)
1974
Materials, chemistry, structural biology
1980
PEP Storage Ring (HEP)
Long b quark lifetime


REGION 12
REGION 10
REGION 2
REGION 8
REGION 4
REGION 6

PEP-II 1983: b quark lives much longer than expected

$\tau_b = 1.8 \pm 0.6 \pm 0.4$ ps. $\tau_b = 1.20 +.45 - .36 \pm .3$ ps.

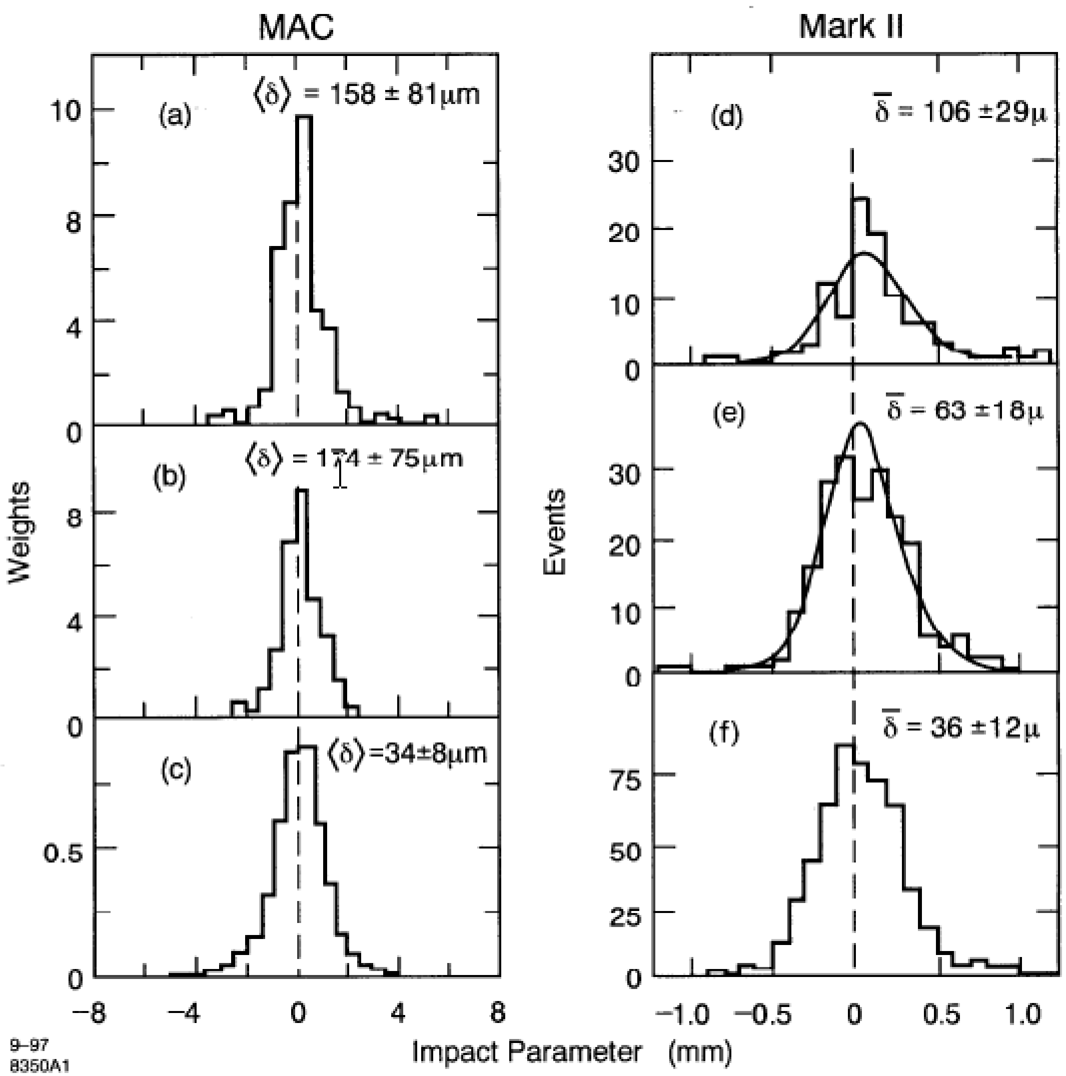


Figure 1. Impact parameter distributions from the two PEP experiments. MAC's results are shown for (a) muons, (b) electrons, and (c) hadrons. Mark II's results are shown for (d) "b leptons," with $P_t > 1$ GeV/c; (e) "c leptons," with $P_t < 1$ GeV/c; and (f) hadrons.

October 1988
(T/E)

A REFINED MEASUREMENT OF THE B HADRON LIFETIME

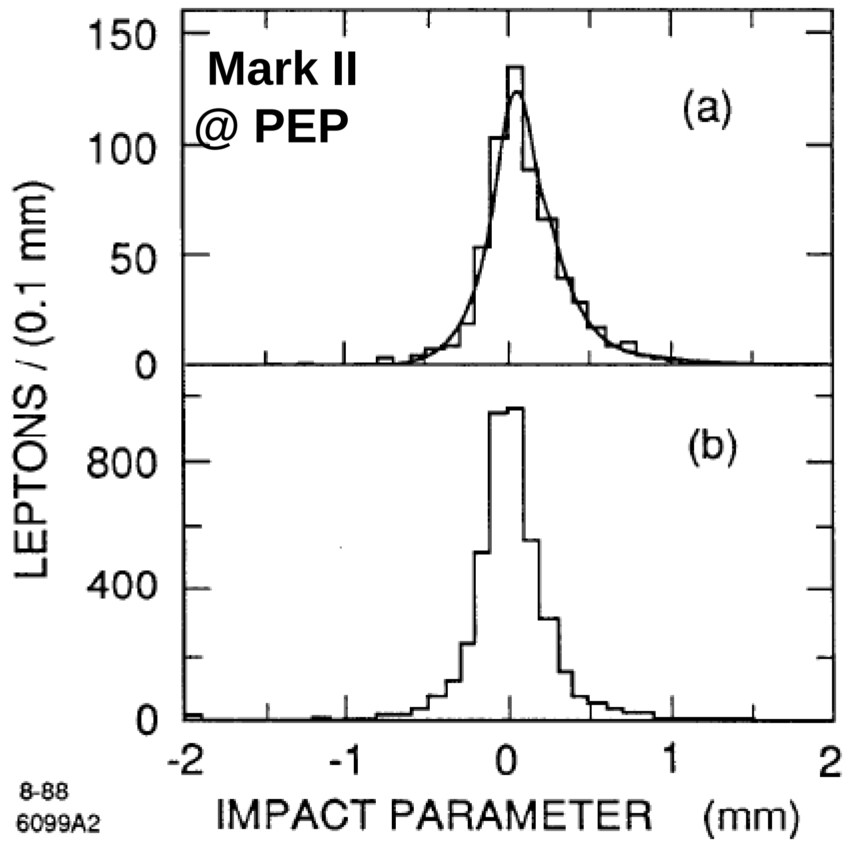
R.A. Ong,[a] J.A. Jaros, G.S. Abrams, D. Amidei,[b] A.R. Baden, T. Barklow, A.M. Boyarski, J. Boyer, P.R. Burchat,[c] D.L. Burke, F. Butler, J.M. Dorfan, G.J. Feldman, G. Gidal, L. Gladney,[d] M.S. Gold, G. Goldhaber, L. Golding,[e] J. Haggerty,[f] G. Hanson, K. Hayes, D. Herrup,[b] R.J. Hollebeek,[d] W.R. Innes, I. Juricic,[g] J.A. Kadyk, D. Karlen,[h] S.R. Klein, A.J. Lankford, R.R. Larsen, B.W. LeClaire,[i] M. Levi, N.S. Lockyer,[d] V. Lüth, M.E. Nelson,[j] A. Petersen,[k] B. Richter, K. Riles, P.C. Rowson,[g] T. Schaad,[l] H. Schellman,[b] W.B. Schmidke, P.D. Sheldon,[m] G.H. Trilling, D.R. Wood,[n] and J.M. Yelton[o]

Stanford Linear Accelerator Center
Stanford University, Stanford, California 94309

Lawrence Berkeley Laboratory and Department of Physics
University of California, Berkeley, California 94720

and

Harvard University, Cambridge, Massachusetts 02138



Abstract

We report a new measurement of the average lifetime of hadrons containing bottom quarks. The B hadron decays are tagged by identifying leptons at high transverse momentum. From a fit to the lepton impact parameter distribution, the average B hadron lifetime is found to be $(0.98 \pm 0.12 \pm 0.13) \times 10^{-12}$ sec.

1983 Mark II at PEP

PRECISE MEASUREMENT OF THE TAU LIFETIME*

J. A. Jaros, D. Amidei, G. H. Trilling, G. S. Abrams, C. A. Blocker, A. M. Boyarski, M. Breidenbach, D. L. Burke, J. M. Dorfan, G. J. Feldman, G. Gidal, L. Gladney, M. S. Gold, G. Goldhaber, L. Golding, G. Hanson, C. Hoard, R. J. Hollebeek, W. R. Innes, J. A. Kadyk, A. J. Lankford, R. R. Larsen, B. LeClaire, M. Levi, N. Lockyer, V. Lüth, C. Matteuzzi, R. A. Ong, M. L. Perl, B. Richter, P. C. Rowson, T. Schaad, H. Schellman, D. Schlatter[a], P. D. Sheldon, J. Strait[b], C. de la Vaissiere[c], J. M. Yelton and C. Zaiser

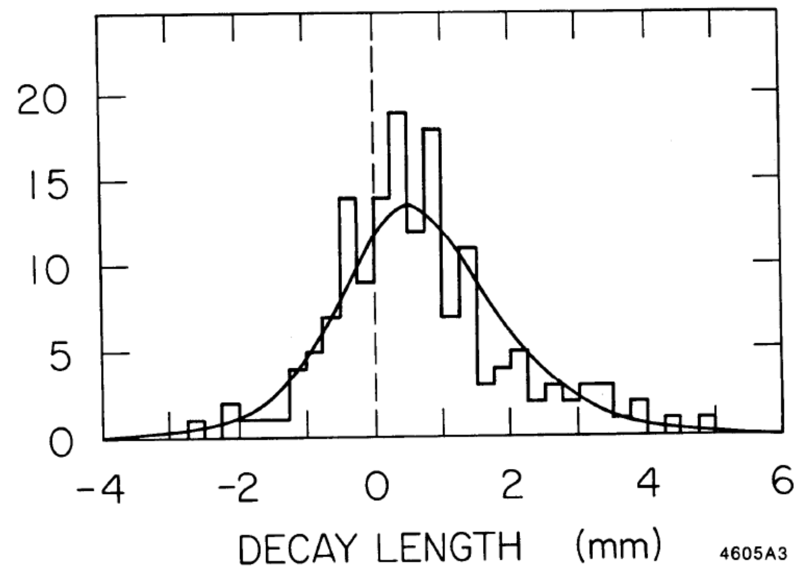
Stanford Linear Accelerator Center
Stanford University, Stanford, California 94305

Lawrence Berkeley Laboratory and Department
University of California, Berkeley, California 94720

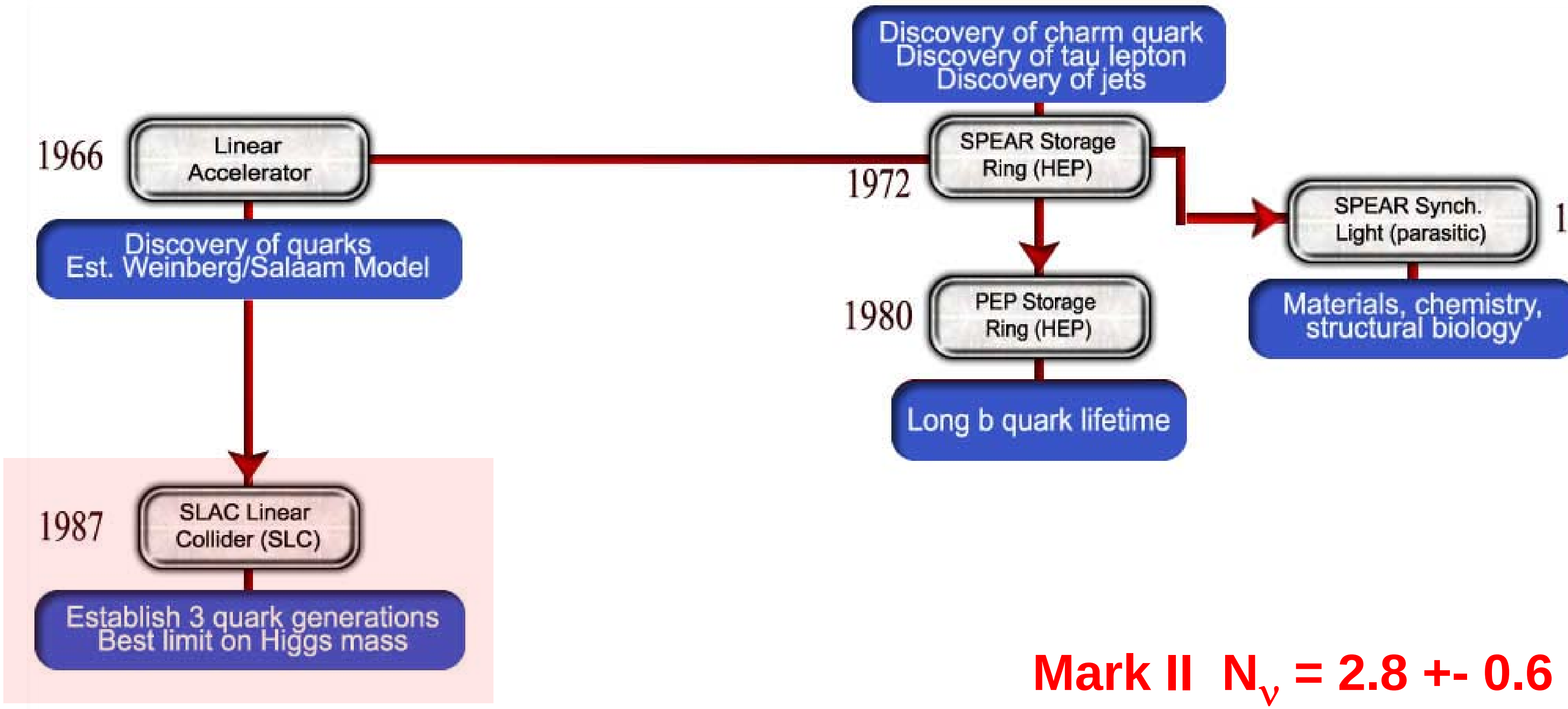
Department of Physics
Harvard University, Cambridge, Massachusetts 02138

ABSTRACT

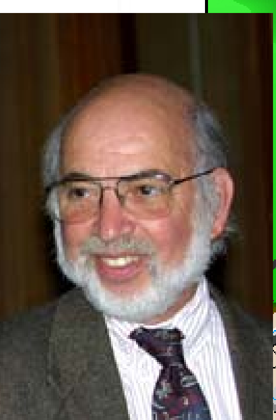
We have measured the τ lifetime with the Mark II Vertex Detector at PEP. We find $\tau_\tau = (3.20 \pm 0.41 \pm .35) \times 10^{-13}$ sec, which agrees well with $e - \mu - \tau$ universality.



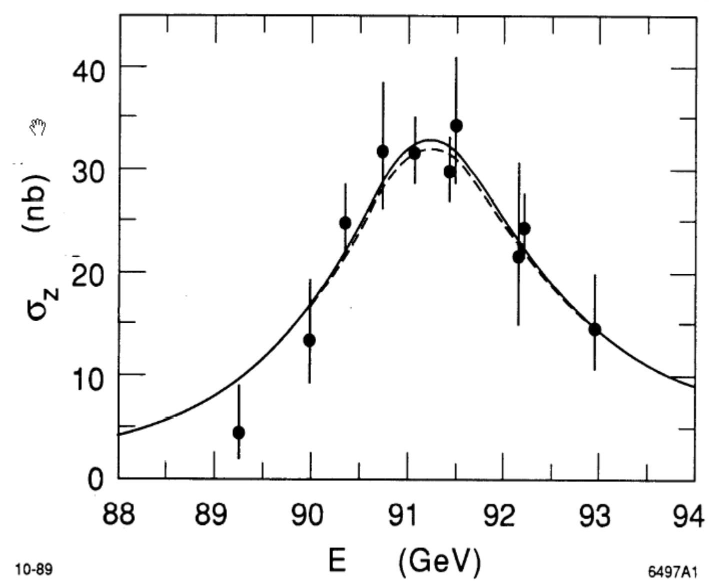
The τ is by now well established as a universal weak partner to the electron and muon. Self-consistency between the lifetime, mass and leptonic branching fraction. Hadronic modes seen with appropriate BRs and no hint of second class currents. World-wide experimental agreement



Mark II N_ν = 2.8 +- 0.6
Nov.1989



Martin Breidenbach
Panofsky Prize
1999



The Era Of Silicon Vertex Detectors Begins at Storage Rings

A Silicon Strip Vertex Detector consisting of 36 modules has been built and operated in the Mark II solenoidal detector at the Stanford Linear Collider.

The primary motivation for the construction of a high resolution vertex detector at the Stanford Linear Collider (SLC) was its potential to tag the presence of heavy flavor hadrons in the decay of the Z^o resonance. The ability to identify decays of particles with lifetimes in the range $10^{-12}s$ to $10^{-13}s$, both inclusively and exclusively, permits access to a wide range of fundamental physics questions, such as the test of the coupling of the charged and neutral weak current to charm and beauty quarks via the measurement of the lifetimes of charm and beauty hadrons or via measurements of the branching ratios of the Z^o to $c\bar{c}$ and $b\bar{b}$.

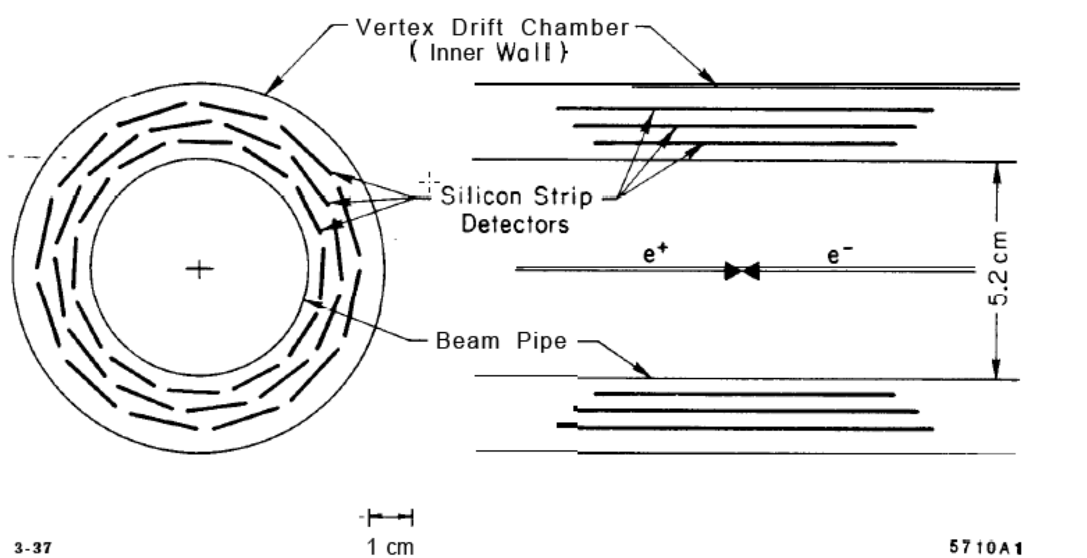


Figure 1: Overall layout of the Silicon Strip Vertex Detector.

1989 Mark II at SLC (Followed by SLD pixel Detector)

1966 Linear Accelerator

Discovery of quarks
Est. Weinberg/Salaam Model

1987 SLAC Linear Collider (SLC)

Establish 3 quark generations
Best limit on Higgs mass

Helen Quinn
DIRAC Medal - 2000

Discovery of charm quark
Discovery of tau lepton
Discovery of jets

1972 SPEAR Storage Ring (HEP)

1980 PEP Storage Ring (HEP)

Long b quark lifetime

1999 PEP-II Storage Rings (HEP)

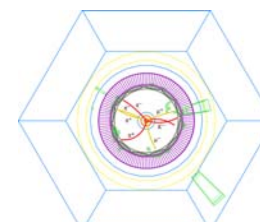
Discovery of CP violation in B decays
Discovery of new charm states

1974 SPEAR Synch. Light (parasitic)

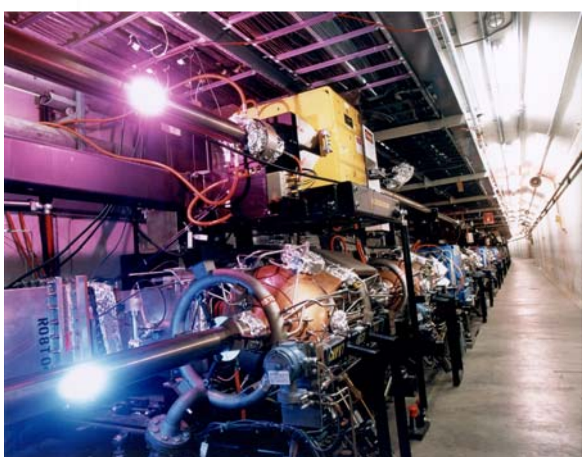
Materials, chemistry, structural biology

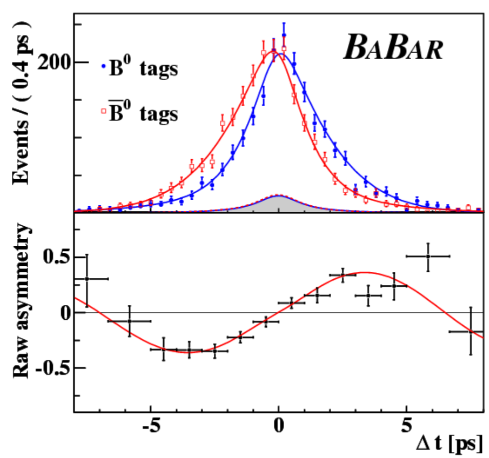
1991 SPEAR Synch. Light (dedicated)

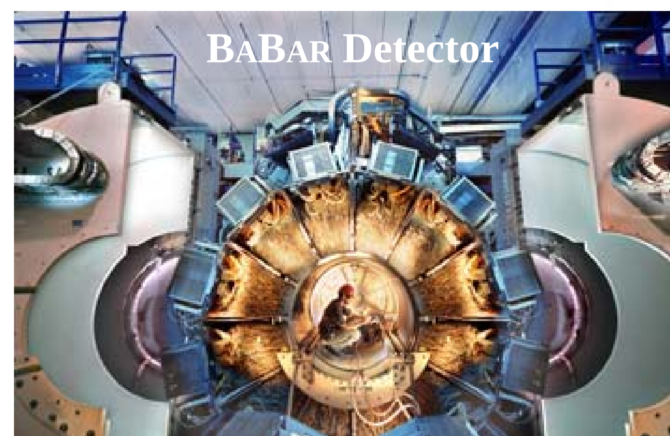
Environmental science



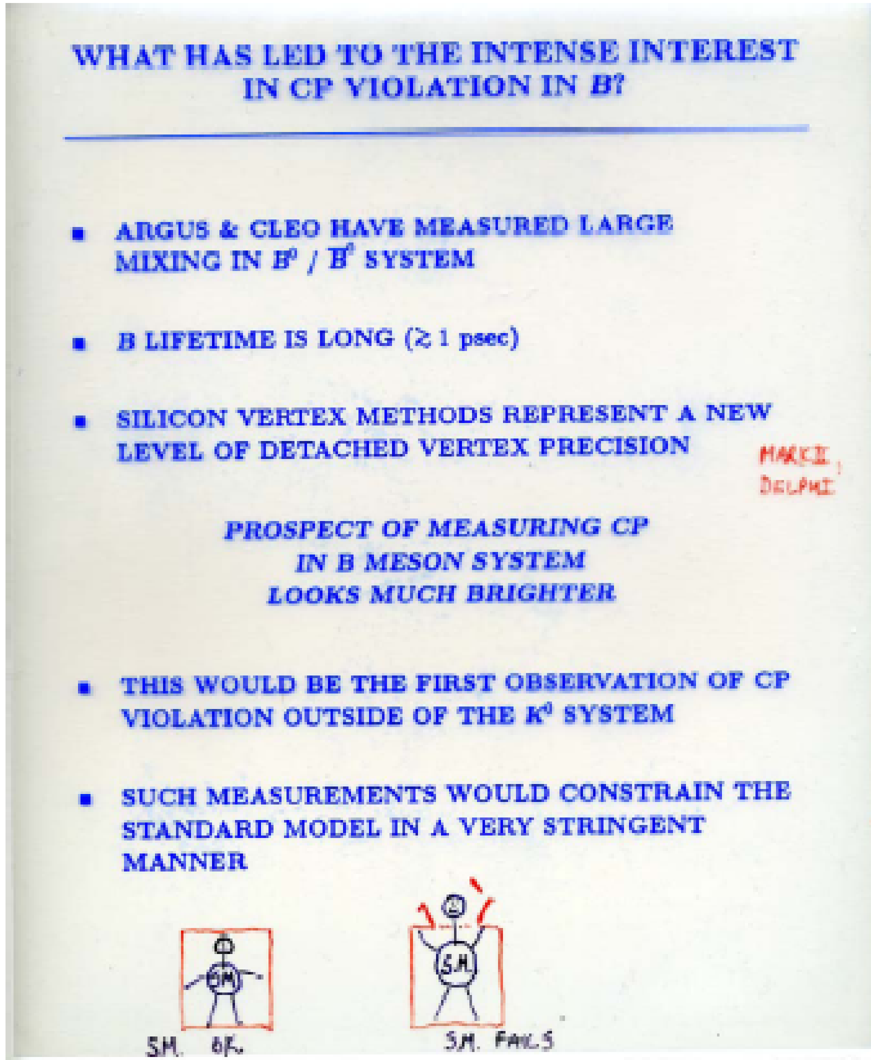
PEP-II Accelerator







B Factory Era – Capitalizing on Past Events



WHAT HAS LED TO THE INTENSE INTEREST IN CP VIOLATION IN B?

- ARGUS & CLEO HAVE MEASURED LARGE MIXING IN B^0 / $\bar{B}^0$ SYSTEM
- B LIFETIME IS LONG ($\gtrsim$ 1 psec)
- SILICON VERTEX METHODS REPRESENT A NEW LEVEL OF DETACHED VERTEX PRECISION

MARK II, DELPHI

PROSPECT OF MEASURING CP
IN B MESON SYSTEM
LOOKS MUCH BRIGHTER

- THIS WOULD BE THE FIRST OBSERVATION OF CP VIOLATION OUTSIDE OF THE K^0 SYSTEM
- SUCH MEASUREMENTS WOULD CONSTRAIN THE STANDARD MODEL IN A VERY STRINGENT MANNER

1989

Physics Requirements

1. Integrated luminosity of $\geq 30\ fb^{-1}$ / year
   This corresponds to

$$\begin{cases} \mathcal{L}_{peak} = 3x10^{33}\ cm^{-2}\ sec^{-1} \\ 2x10^{7}\ seconds \\ \varepsilon = 50\% \end{cases}$$

2. Two storage rings colliding asymetrically at $Y(4s)$ with $E_{hi} \geq 8$ GeV
3. Beampipe radius $\leq 3\ cm$
4. Detector well instrumented for
   $-0.95 \leq Cos\theta_{cm} \leq 0.9$
   This corresponds to restricting the machine components to $\theta_{lab} \leq 300$ mrad in forward direction

Given the critical importance of the CP physics, it is most desirable to have two *B*-Facories in the world

$30\ fb^{-1} = 3.3\ 10^{7}$ BB events

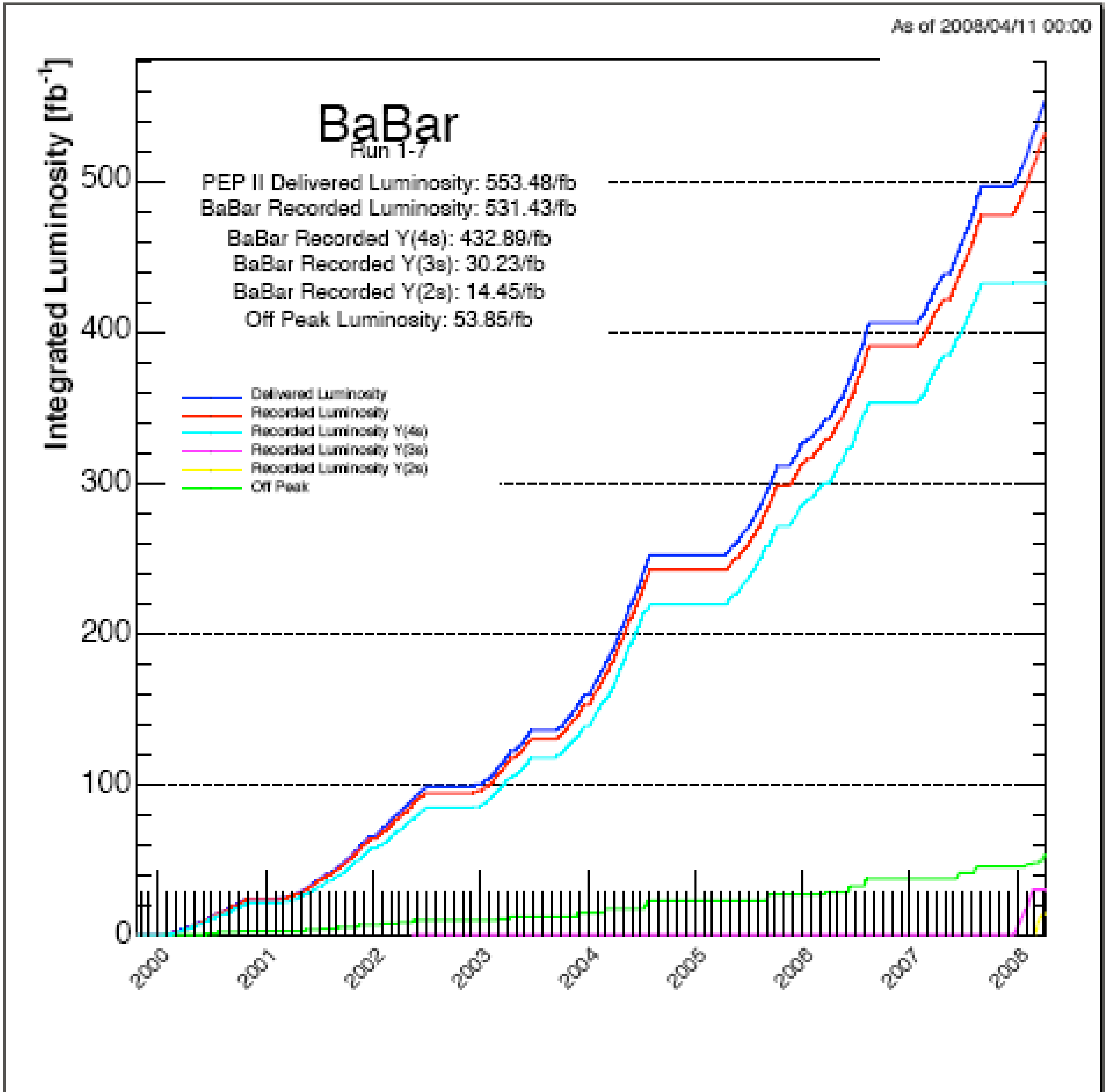
Integrated $\mathcal{L}$ Benchmarks:

- CESR: 10^{5} BB/yr in 1987
- CESR:1.1-1.5 fb^{-1}/yr, average 1991-1995

1990

KEKB/BELLE & PEP-II/Babar usher in a new era of heavy flavor meas.

Integrated Luminosity Came Fast and Furiously

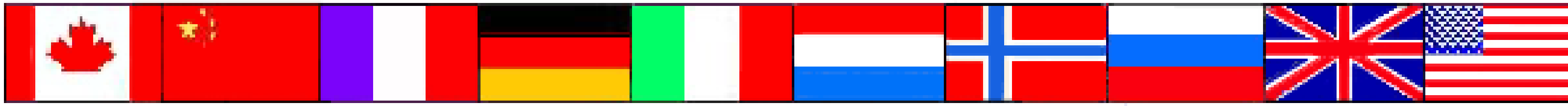


PEP-II Final Parameters

Parameter	Units	Design	Overall best
I+	mA	2140	3213
I-	mA	750	2069
Number bunches		1658	1732
β_y^*	mm	15-20	9-10
Bunch length	mm	15	10-12
ξ_y	tune shift	0.03	0.05-0.065
Luminosity	$x10^{33}$	3	12
Int lumi / day	pb^{-1}	130	911

4 times design

7 times desig



The *BABAR* Collaboration

10 Countries

77 Institutions

593 Physicists

USA [38/300]

California Institute of Technology
UC, Irvine
UC, Los Angeles
UC, Riverside
UC, San Diego
UC, Santa Barbara
UC, Santa Cruz
U of Cincinnati
U of Colorado
Colorado State
Florida A&M
Harvard
U of Iowa
Iowa State U
LBNL
LLNL
U of Louisville
U of Maryland
U of Massachusetts, Amherst
MIT
U of Mississippi
Mount Holyoke College
SUNY, Albany
U of Notre Dame
Ohio State U
U of Oregon
U of Pennsylvania
Prairie View A&M U
Princeton U
SLAC
U of South Carolina
Stanford U
U of Tennessee
U of Texas at Austin
U of Texas at Dallas
Vanderbilt
U of Wisconsin
Yale

Canada [4/20]

U of British Columbia
McGill U
U de Montréal
U of Victoria

China [1/5]

Inst. of High Energy Physics, Beijing

France [5/51]

LAPP, Annecy
LAL Orsay
LPNHE des Universités Paris VI et VII
Ecole Polytechnique, Laboratoire Leprince-Ringuet
CEA, DAPNIA, CE-Saclay

Germany [4/31]

Ruhr U Bochum
Technische U Dresden
Univ Heidelberg
U Rostock

Italy [12/101]

INFN, Bari
INFN, Ferrara
Lab. Nazionali di Frascati dell' INFN
INFN, Genova & Univ
INFN, Milano & Univ
INFN, Napoli & Univ
INFN, Padova & Univ
INFN, Pisa & Univ & ScuolaNormaleSuperiore
INFN, Perugia & Univ
INFN, Roma & Univ "La Sapienza"
INFN, Torino & Univ
INFN, Trieste & Univ

The Netherlands [1/5]

NIKHEF, Amsterdam

Norway [1/3]

U of Bergen

Russia [1/11]

Budker Institute, Novosibirsk

United Kingdom [10/66]

U of Birmingham
U of Bristol
Brunel U
U of Edinburgh
U of Liverpool
Imperial College
Queen Mary , U of London
U of London, Royal Holloway
U of Manchester
Rutherford Appleton Laboratory

A Fountain of Flavor Physics
No Way for me to Cover It All

Physics Dashboard: Projected Publication Schedule

Submitted!
Spring 2001
Summer 2001
Fall 2001
Winter 2002

Charmless B Decays
- Two-body $\pi\pi$, πK, KK, $\pi\pi^0$, πKs, $\pi^0 Ks$, $KsKs$
- ϕ modes (with K, Ks or K^*)
- η and η' modes
- ω modes
- Inclusive ϕ, η
- $a^0\pi$ modes
- 3-body decays
- $B \to K^* \pi$ modes

B Decays to Open Charm
- Branching fractions: $D^{(*)}D^{(*)}$ modes
- Branching fractions: $D^{(*)} D^{(*)}K$ modes
- Branching fractions: $D^{(*)} K$ modes
- ...ons: $D_s^{(*)} D^{(*)}$ modes

Time-Dependent Analyses
- CP-viol. in charmonium sample ($\sin 2\beta$)
- Mixing / Lifetimes with hadronic sample
- CP-violation & Mixing (PRD)
- Mixing & Lifetimes with semileptonics
- Mixing & Lifetimes with dilepton sample
- T, CPT invariance tests with dileptons

Tau/QED
- τ lifetime
- $\tau \to \mu\gamma$
- CP violation
- ISR Vector Mesons
- Two-photon

Charmonium Phy...
- J/ψ production in continuum
- Inclusive branching fractions
- $J/\psi K^*$ angular analysis
- Exclusive branching fractions
- $J/\psi K$ versus $J/\psi\pi$
- $\psi(2S)$ leptonic decays
- Direct CP-violation in $J/\psi K^+$

Penguins B Decays
- $B \to K^* \gamma$ (CP viol.)
- $B \to \gamma\gamma$
- $b \to s\gamma$
- $B \to K(^*) l^+ l^-$
- $B \to \rho/\omega\gamma$
- $B \to l^+ l^-$
- $B \to D^* \gamma$

Detector

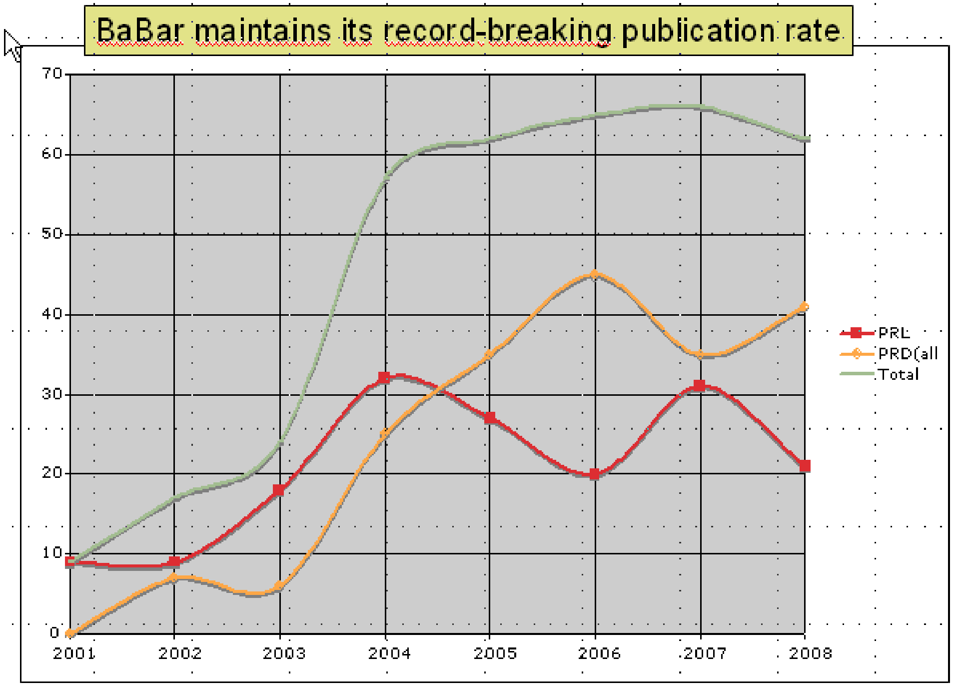
Charm Physics
- $D^0 \to K\pi$ absolute BF
- Charm at threshold (ISR)
- $\Lambda_c \to pK\pi$
- Dalitz analyses
- D^0 lifetime
- D^0 Mixing

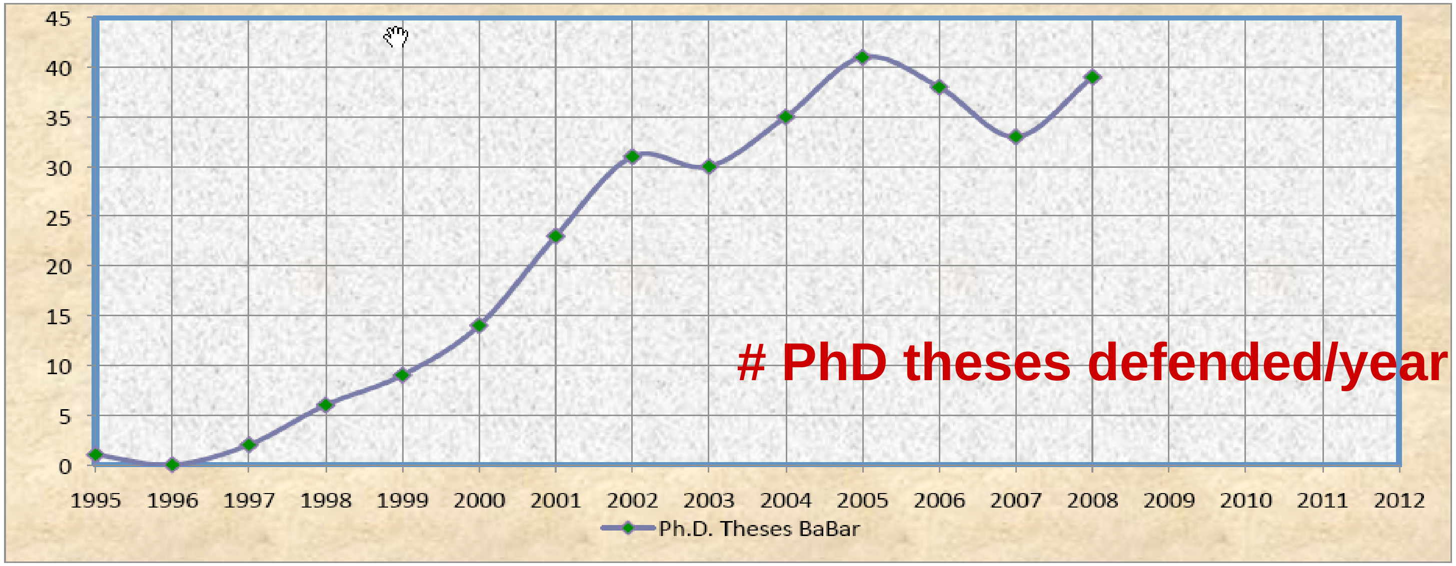
Vub & Vcb measureme...
- Semileptonic BF (lepton tag)
- Exclusive charmless semilep...
- Exclusive $D^* l\nu$ (Vcb)
- Semileptonic BF (fully rec)
- Exclusive $\rho/\omega l\nu$ (Vub)

Partially Reconstructed B Decays
- Branching fractions $D^*\pi/D^*K$
- $B \to D_s^{(*)} D^*$
- Lifetime & Mixing with $D^*\pi$, $D^*\rho$
- Lifetime & Mixing with $D^* l\nu$
- CP Violation in $D^*\pi$

Leptonic B Decays
- $B \to \mu\nu$
- $B \to \tau\nu$

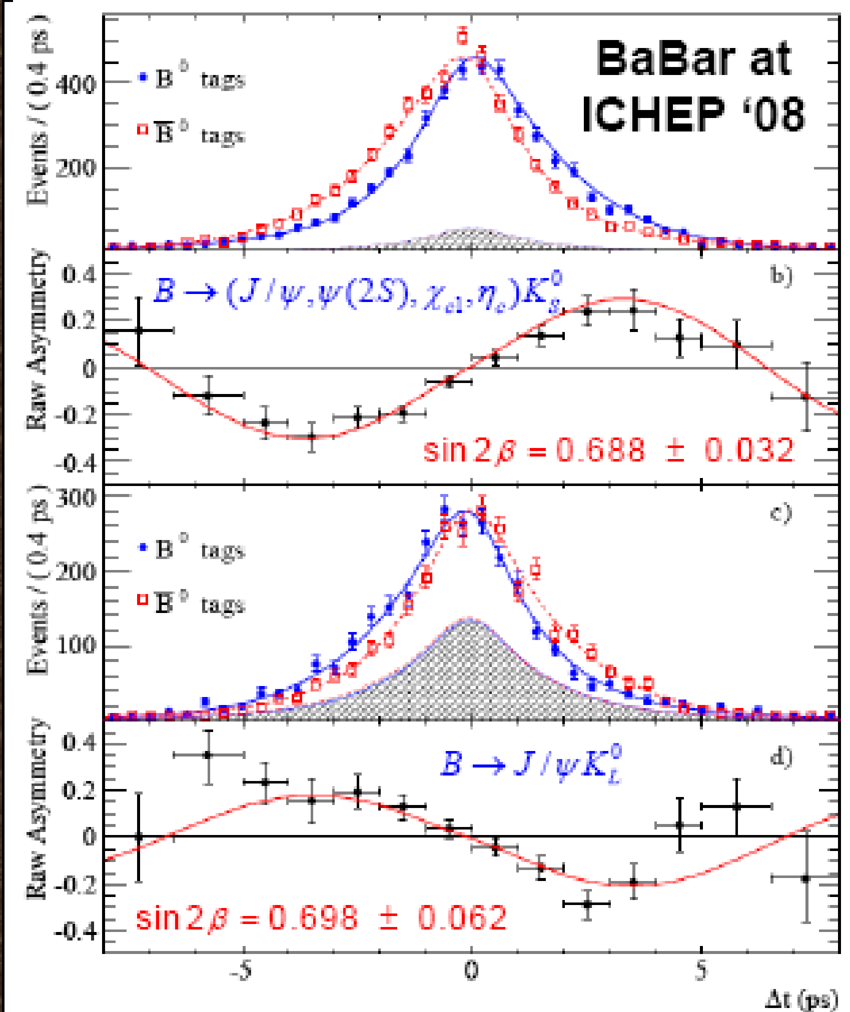
Inclusive Hadron Spectra
- π, K and p Production



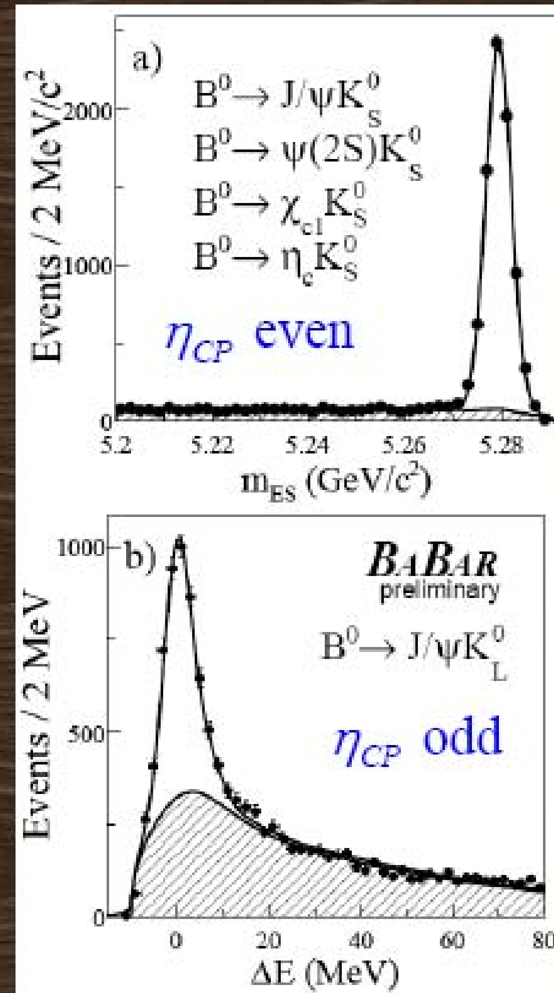


Of the 420 identified BaBar PhD theses, 300 have graduated

n2β Modes



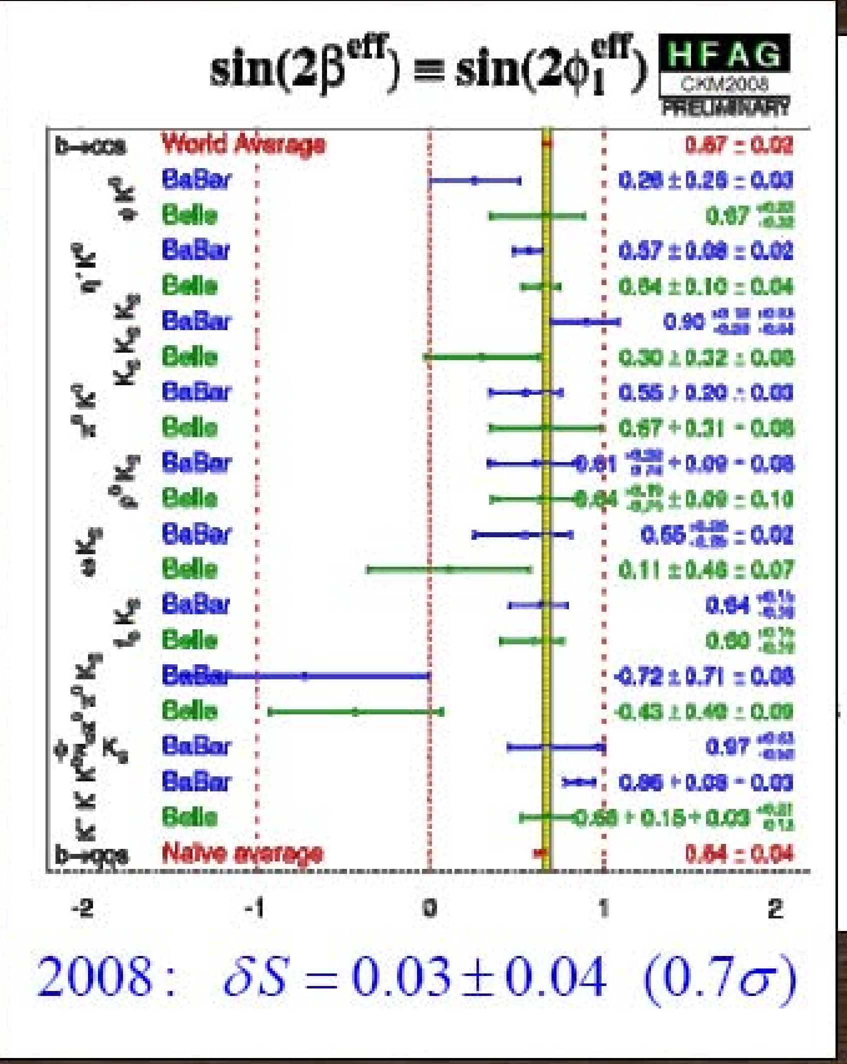
$$\sin 2\beta = 0.691 \pm 0.029 \pm 0.014$$
$$C = 0.026 \pm 0.020 \pm 0.016$$



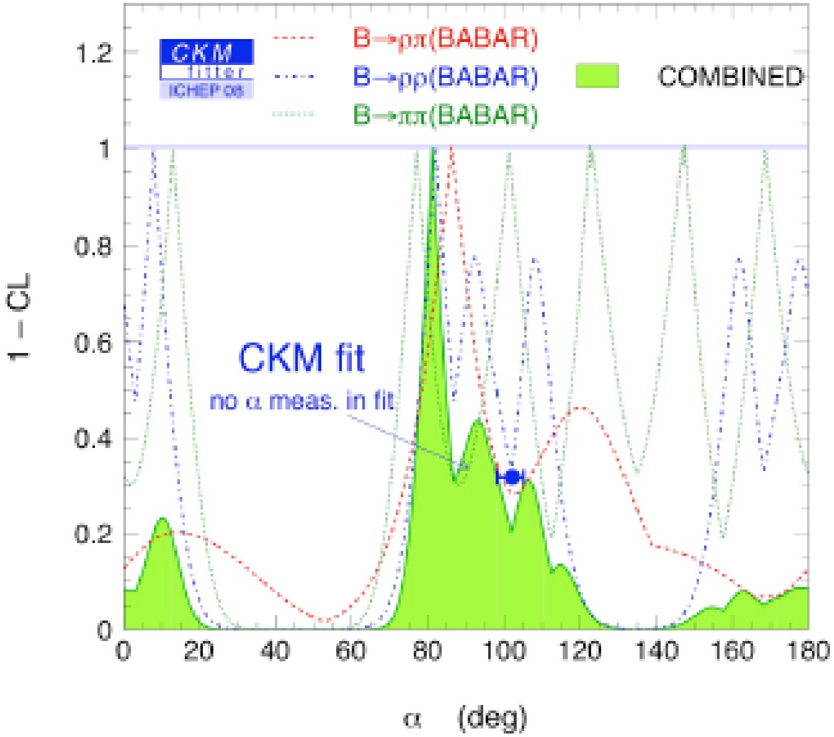
BaBar, arXiv:0808.1903

CP Asymmetries in Penguin Decays

- Measured S_{CP} in many penguin-dominated modes and compared to sin2β measured in $B^0 \rightarrow (c\bar{c})K$
- Most significant difference in "naïve" penguin average reached in 2004
- More precise measurements have decreased the significance of δS below 1σ
  - Some measurements come now from complicated 3-body time-dependent Dalitz analyses
  - S_{CP} in charmless penguin modes is still a good place to look for new physics, but no evidence with BaBar statistics



Summary on α



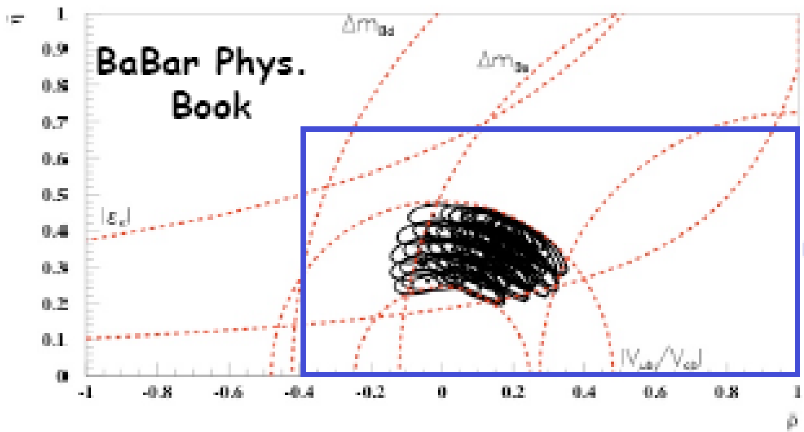
$$\alpha = 81.1^{\circ}{}^{+17.5^{\circ}}_{-\ \ 4.9^{\circ}}$$

- The 3 decays modes $B \rightarrow \pi\pi/\ \rho\pi$(Dalitz)/ $\rho\rho$ give **consistent and complementary** measurements of α.
- **Single solution** when combining the three methods!
- Eventually, better result for α than this expected in the BaBar Physics Book (1998)
- Stay tuned : new BaBar results are coming!!!

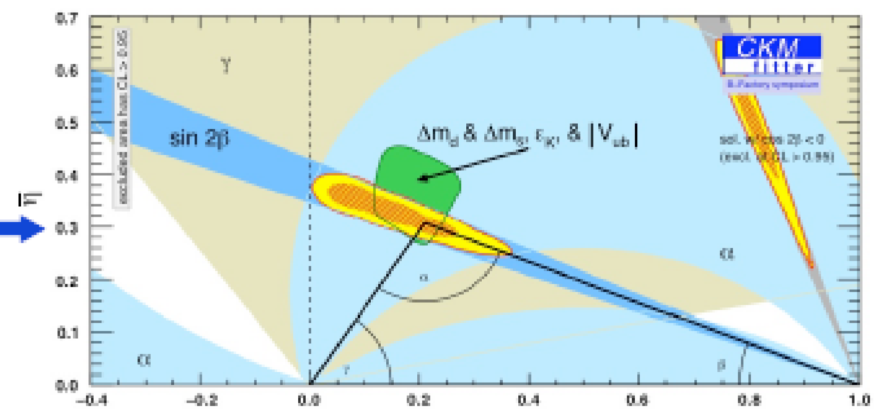
Conclusions

- Unitarity Triangle: Consistent results between the measurements of the angles (α, β and γ) and those of the UT sides (Δm_d, Δm_s, $|V_{ub}|$….).

Status in 1998

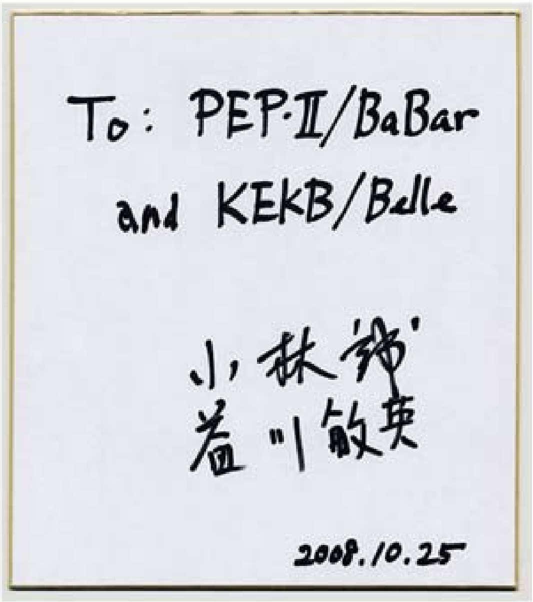


Angle constraints in 2008



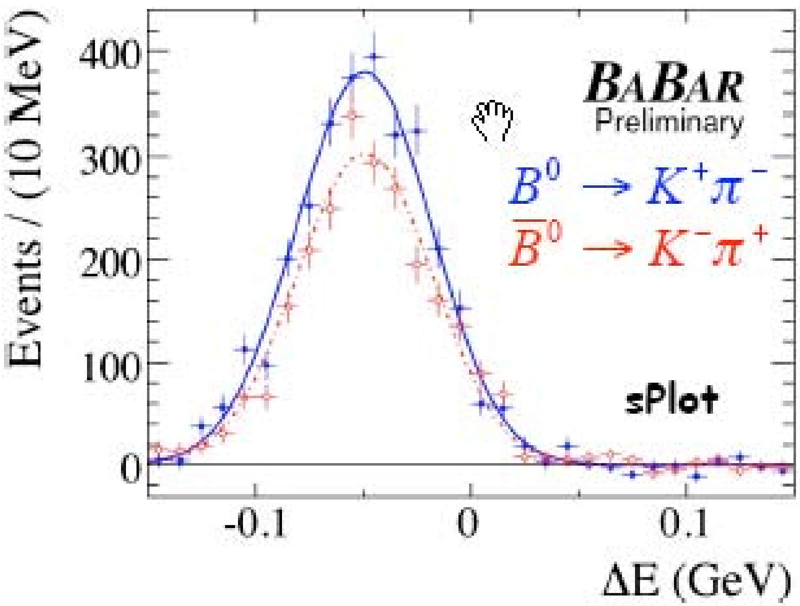
- Impressive confirmation of SM in quark-flavor sector!!!
  - Errors on UT angles α,β,γ are still decreasing and are still limited by statistics!!!
  - More to come with future accelerators and projects

B-factories confirm matter-antimatter asymmetry; leads to 2008 Nobel Prize in Physics



Kobayashi and Maskawa wrote: *"Please accept our deepest respect for the B-factor achievements. In particular, the high-precision measurement of CP violation and the determination of the mixing parameters are great accomplishments, without which we would not have been able to earn the Prize."*

First observation of direct CP Violation



467M $B\overline{B}$ arXiv: 0807.4226

$$A_{CP} = -0.107 \pm 0.016^{+0.006}_{-0.004}$$

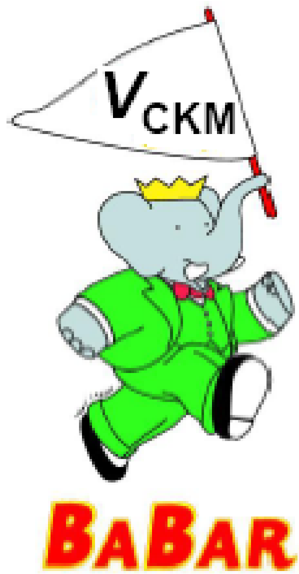
with 6.1σ significance

- In 2004, first observation of direct CP violation in $B^0(\overline{B}^0) \to K^+\pi^- / K^-\pi^+$ (4.2σ significance)

- Effect much larger than in K^0-$\overline{K}^0$ system and the discovery was much faster: K^0-$\overline{K}^0$ 1964 →1999
  B^0-$\overline{B}^0$ 2001 →2004

- Now, direct CP violation is observed in many other modes (for instance, $B^\pm \to D^0(\overline{D}^0)^{(*)}K^{\pm(*)}$ see next slides)

BABAR Publications on Quark Mixing



From 19 Mar 2001 to 20 Oct 2008

BABAR has published

349 Journal papers on physics results

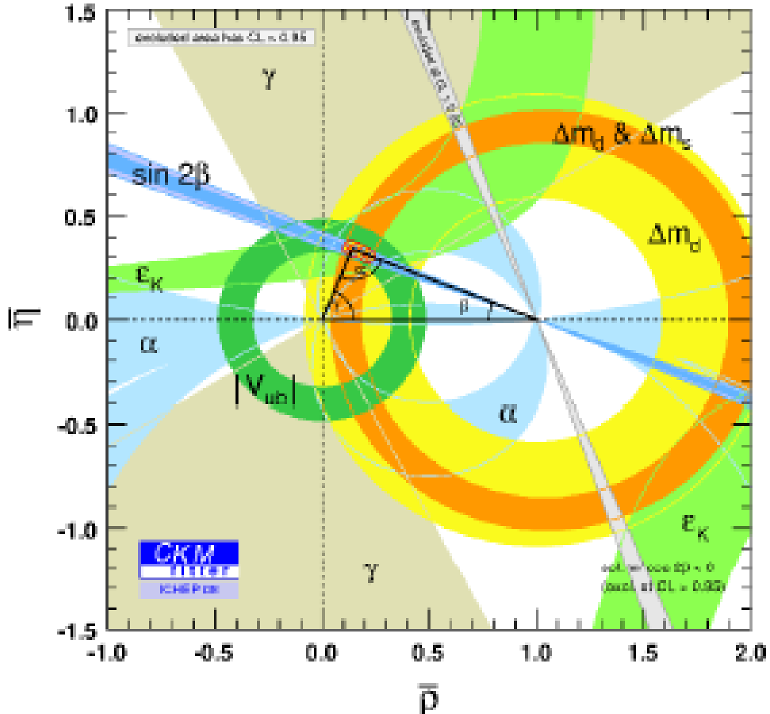
- 165 in Phys. Rev. Letters
- 184 in Phys. Rev. D

53 of them on Quark Mixing topics (15%)

- 7 on $D^0\bar{D}^0$ Mixing
- 8 on $B^0\bar{B}^0$ Mixing
- 13 on V_{cb} topics
- 18 on V_{ub} topics
- 4 on V_{ts} topics
- 3 on V_{td} topics

Main obligations: Check „if V_{CKM} is unitary“ and determine its 4 parameters

Summary



No deviation from the CKM description of quark mixing has been observed.

Precision of the agreement between $|V_{us}|$, $|V_{cb}|$, $|V_{ub}|$, $|V_{tb}V_{td}|$, $|V_{td}/V_{ts}|$, the phases of the invariant quartets $V_{ud}V_{ub}^*V_{tb}V_{td}^*$, $V_{td}V_{tb}^*V_{cb}V_{cd}^*$, $V_{ud}V_{ub}^*V_{cb}V_{cd}^*$, and $|V_{ud}|$, $|V_{cd}|$, $|V_{cs}|$, $|V_{ts}V_{tb}|$ is impressive.

CKMfitter 2008: $|V_{us}| = 0.2252 \pm 0.0008$,

$|V_{cb}| = 0.0405 \pm^{0.0011}_{0.0008}$,

$|V_{ub}| = 0.0034 \pm 0.0002$,

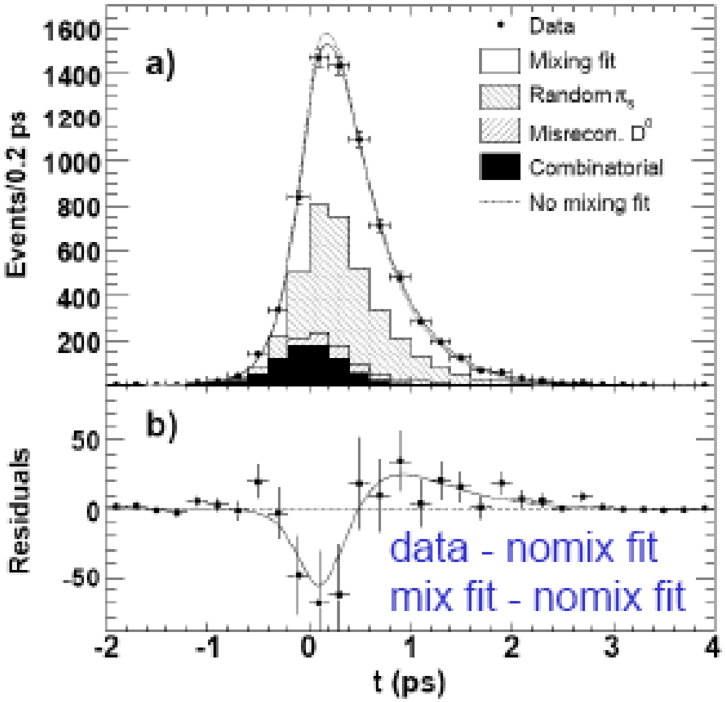
$\mathrm{Im}(V_{ub}V_{ud}^*V_{cd}V_{cb}^*) = +(2.8 \pm^{0.2}_{0.4})\,10^{-5}$.

Why is precision important? FutureTheory may reduce #of St.M. parameters

(when preparing this talk, I encountered only one 4σ discrepancy, the rate of $\tau \rightarrow K\nu$ disagrees with that of $K \rightarrow \mu\nu$ and lepton universality.)

$D^0\bar{D}^0$ Mixing: **y' and $x^2 + y^2$ in $D^0 \rightarrow \bar{D}^0 \rightarrow K^+\pi^-$**

$$N_{K^+\pi^-}(t) = N_{K^+\pi^-}(0)\, e^{-\Gamma t}\left[R_D + \sqrt{R_D}\, y'\,\Gamma t + \frac{x'^2 + y'^2}{4}(\Gamma t)^2\right] \quad \begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} \cos\delta & \sin\delta \\ -\sin\delta & \cos\delta \end{pmatrix}\begin{pmatrix} x \\ y \end{pmatrix}$$

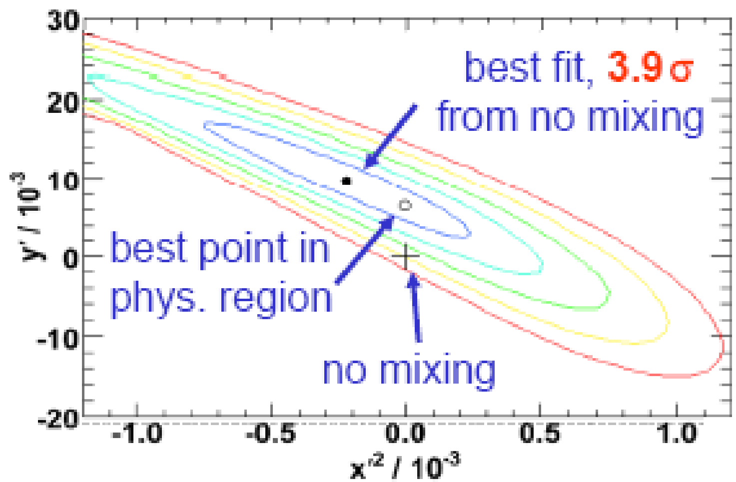


PRL 98(2007)211802 384 / fb

R_D: $(3.03 \pm 0.16 \pm 0.10) \times 10^{-3}$

x'^2: $(-0.22 \pm 0.30 \pm 0.21) \times 10^{-3}$

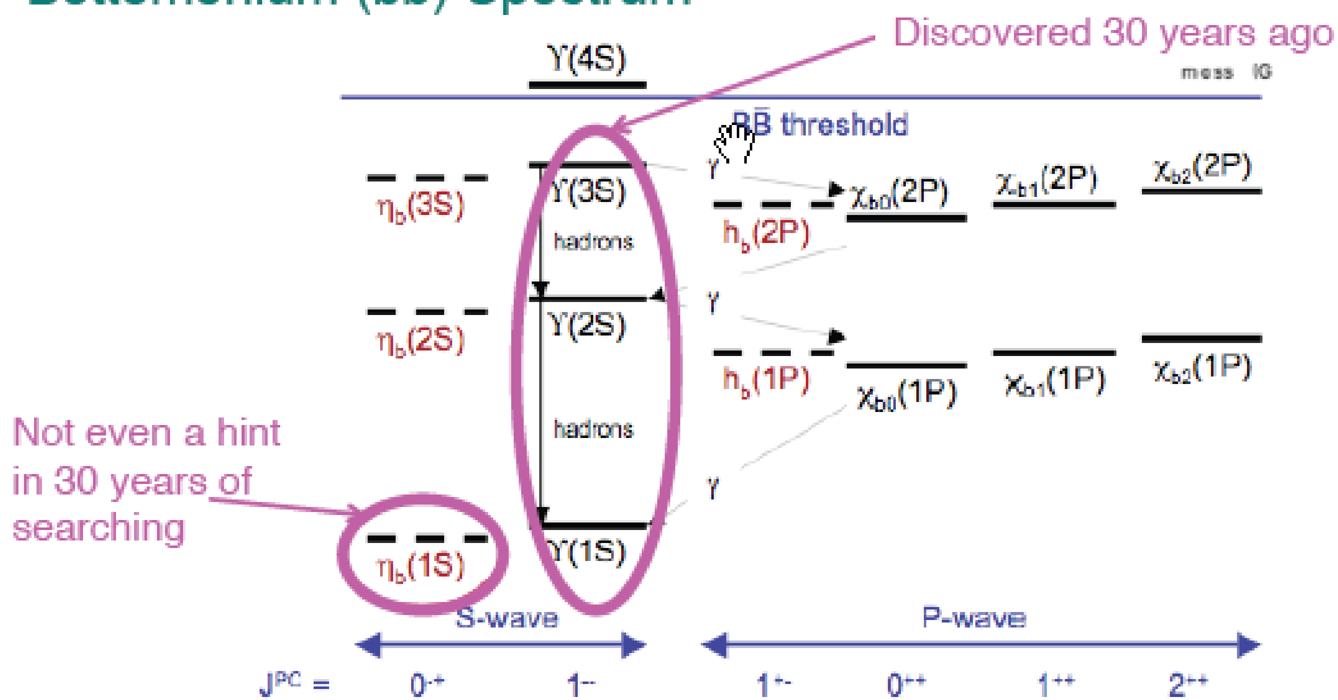
y': $(9.7 \pm 4.4 \pm 3.1) \times 10^{-3}$



CDF PRL 100(2008)121802 1.5/fb $x'^2 = (-0.12 \pm 0.35)10^{-3}$, $y' = (8.5 \pm 7.6)10^{-3}$, **3.8σ**

Observation of the η_b

Bottomonium ($b\bar{b}$) Spectrum



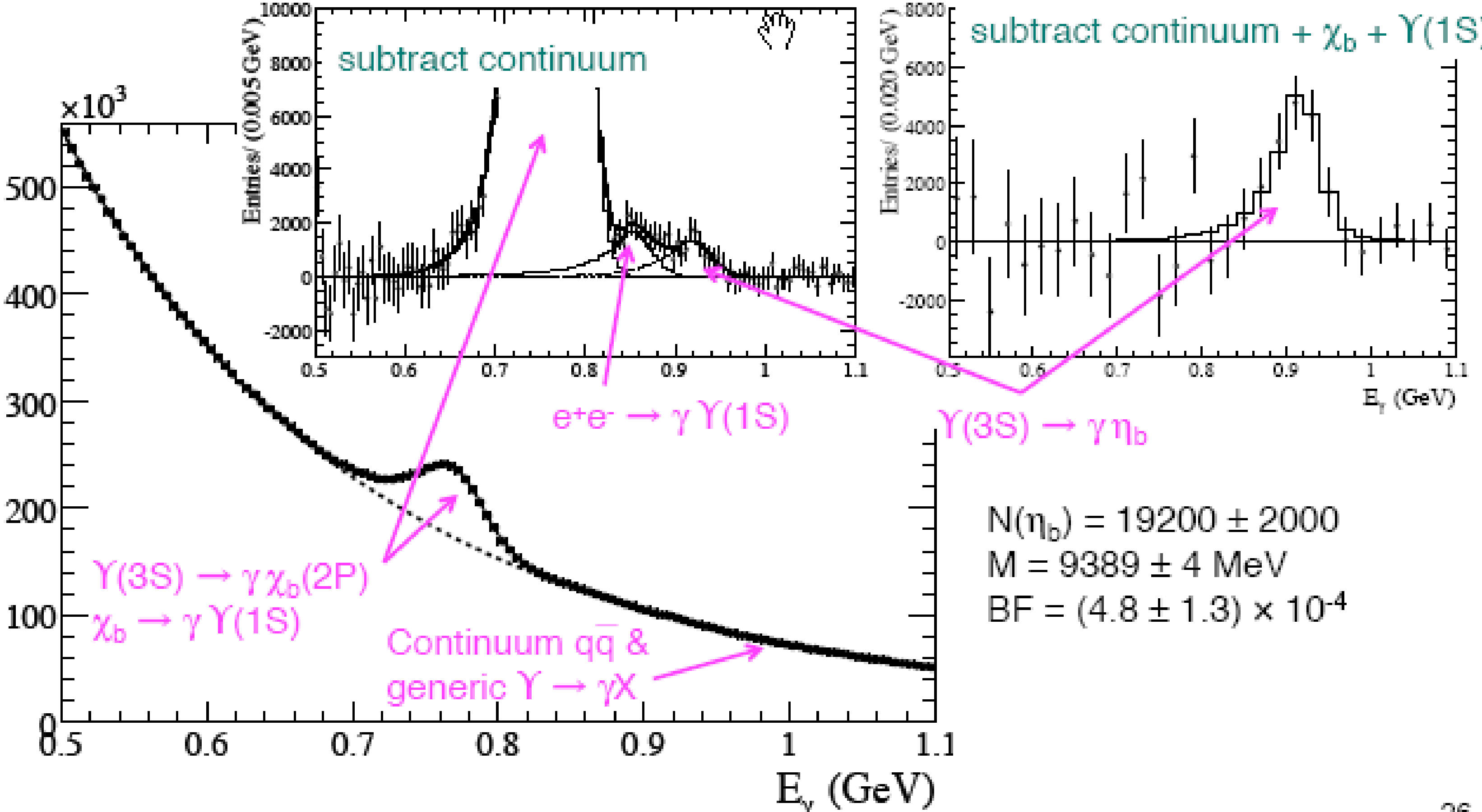
- QCD should be able to explain $\Upsilon(1S)/\eta_b$ mass difference (20–100 MeV).

Analysis Method

- $\Upsilon(3S) \rightarrow \gamma\, \eta_b$
- Look for photon only. E_γ = 911 MeV if $M(\eta_b)$ = 9.4 GeV.
- Problem: many other photons. Particular issue is $e^+e^- \rightarrow \gamma\Upsilon(1S)$ (E_γ= 856 MeV). Depending on $M(\eta_b)$, detector resolution leads to significant overlap with signal.

PRL 101:071801, 2008

Observed Spectrum



$N(\eta_b) = 19200 \pm 2000$

$M = 9389 \pm 4$ MeV

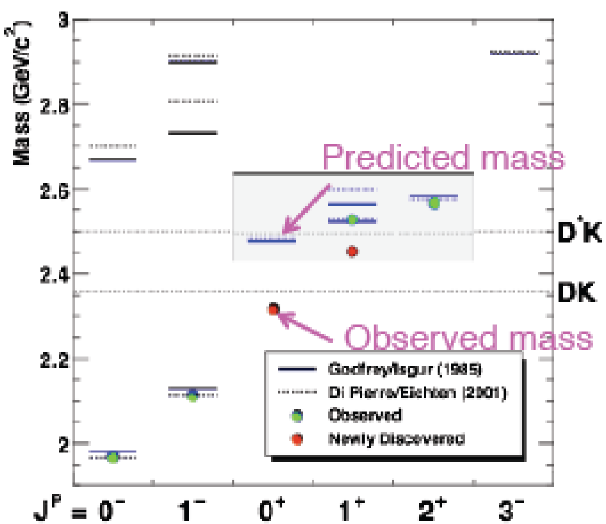
$BF = (4.8 \pm 1.3) \times 10^{-4}$

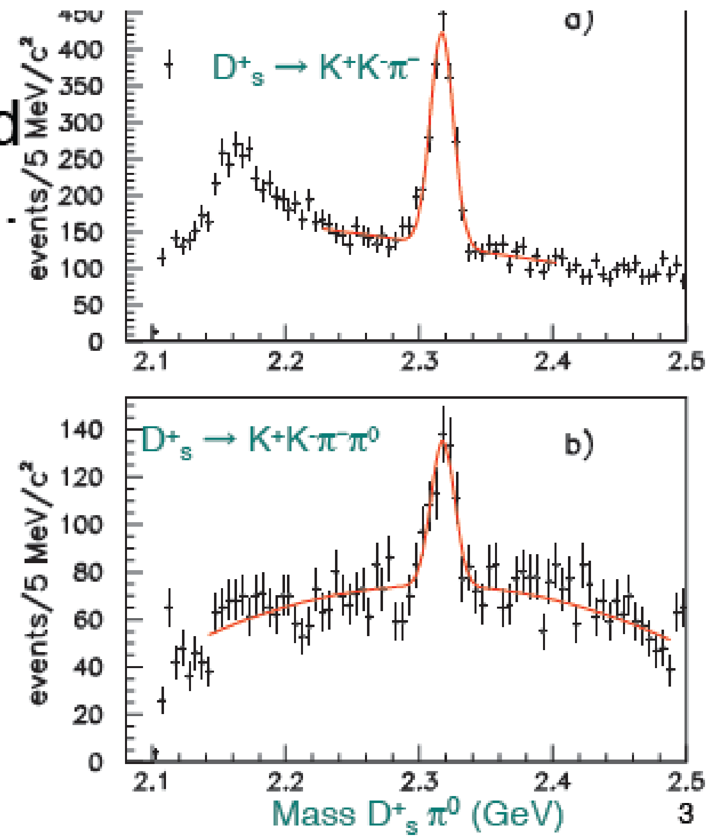
Rash of heavy charm states observed. Started with ………..

PRL 90:242001, 2003

$D^*_{s0}(2317)^+$

- Surprisingly light and narrow resonance found in $D^+_s\pi^0$ mass spectrum.



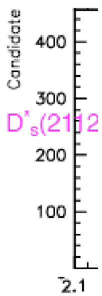


PRD 69:031101, 2004
PRL 97:222001, 2006

$D_{s1}(2460)^+$

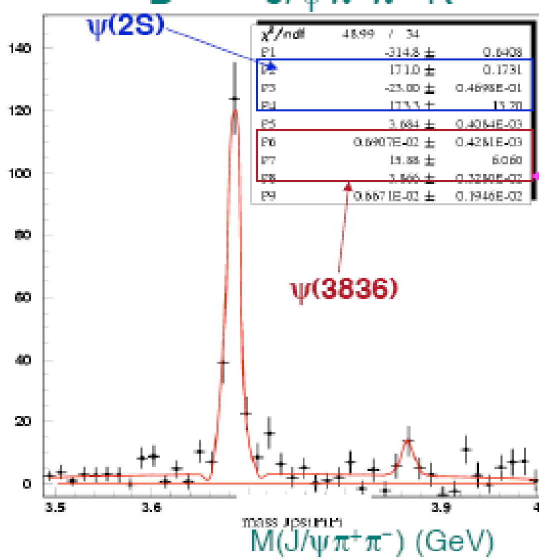
- Shortly thereaft... second narrow state observed in
  $D^*_s(2112)^+ \pi^0$. I
  $D^*_s(2317)^+$ + ra

PRD 71:071103, 2005



X(3872)

$B^+ \rightarrow J/\psi \pi^+ \pi^- K^+$

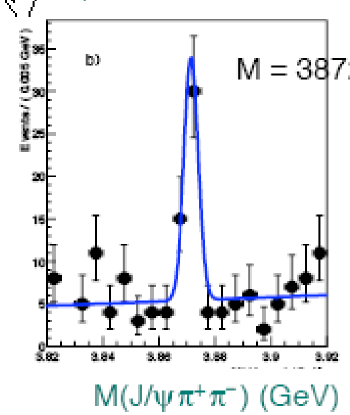


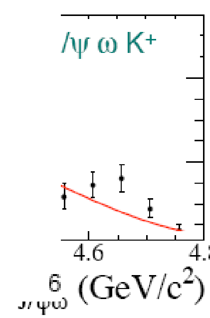
AWG meeting June 2003
motivation: background to
$J/\psi K_L$; test factorization…

- More recently,

Belle, later that summer

PRL 101:082001, 2008





M = 3915 ± 4 MeV (vs M = 3943 ± 20 MeV Belle)

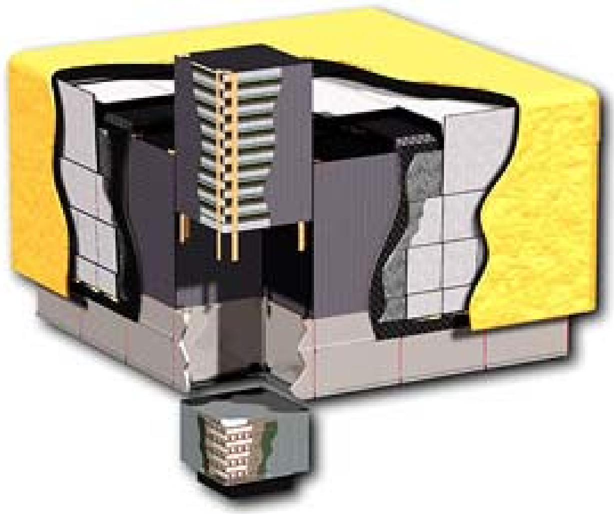
An Unexpected, and Unexplained, Spectroscopy

- May be $\chi_{c1}(2P)$, standard charmonium,
  - might expect larger DD* decay rate and radiative decays

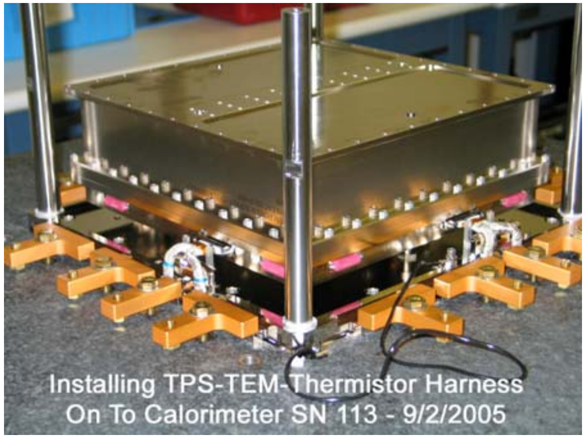
Where Has This Journey Taken Us to at SLAC?

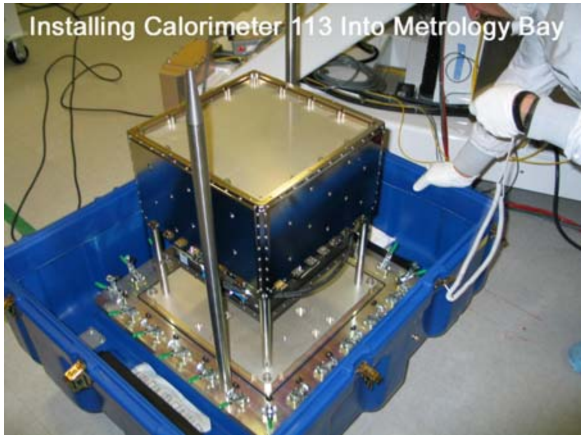
- The Legacy after B Factory
  - Transfer of vacuum and RF Technology to SPEAR3
  - GLAST : BaBar “hardware” in space.
  - Kavli Institute, LSST
  - EXO
  - SuperB in Italy. Main motivation is flavor sector couplings
  - ATLAS (trigger, vertex detector, computing, physics)
- Legacy of Linac, SLC
  - ILC
  - Advanced Accelerator R&D
    - FACET : Plasma Wakefield acceleration
  - Linac Coherent Light Source (LCLS), flavor of a different kind

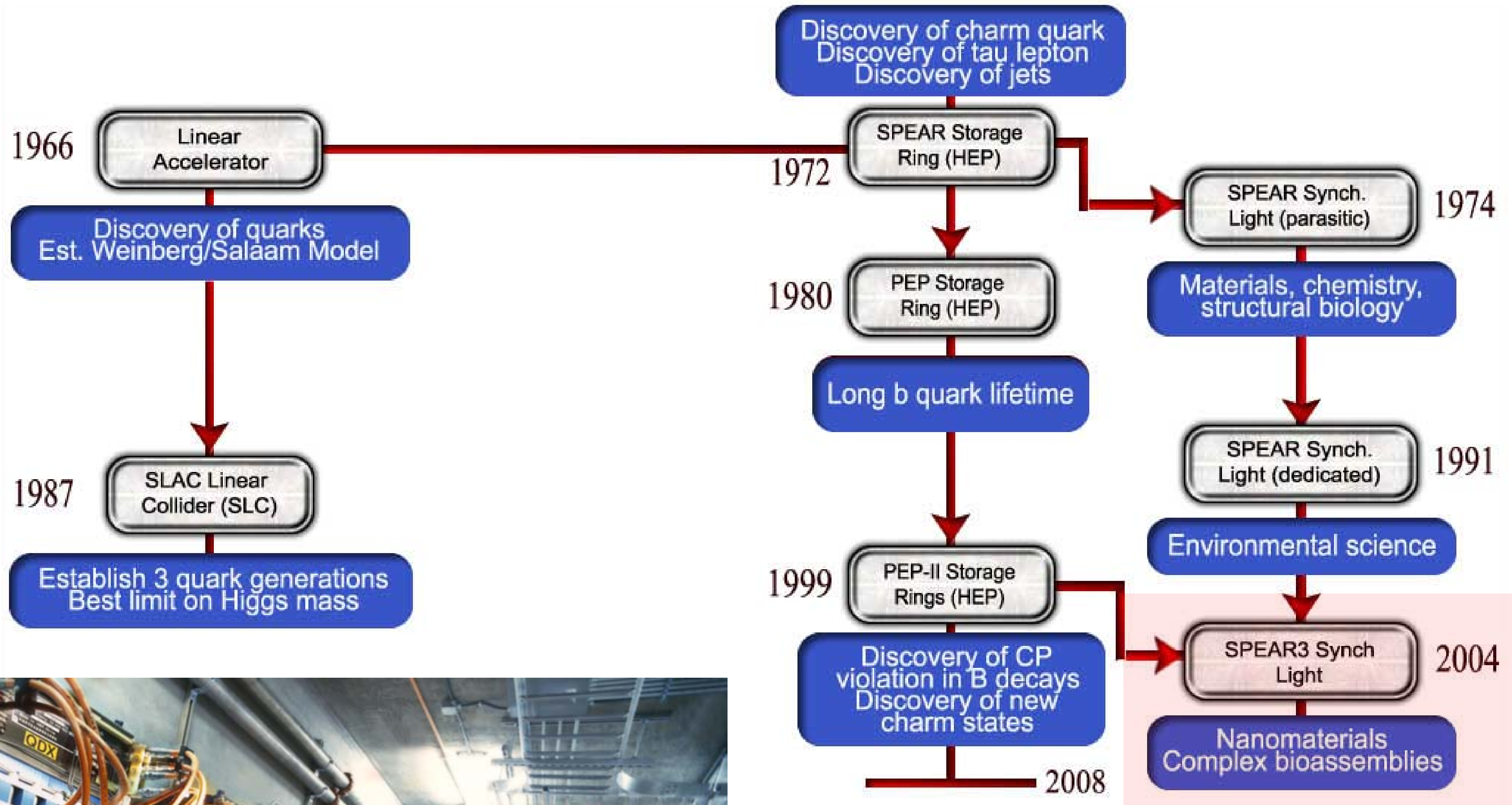
GLAST Construction



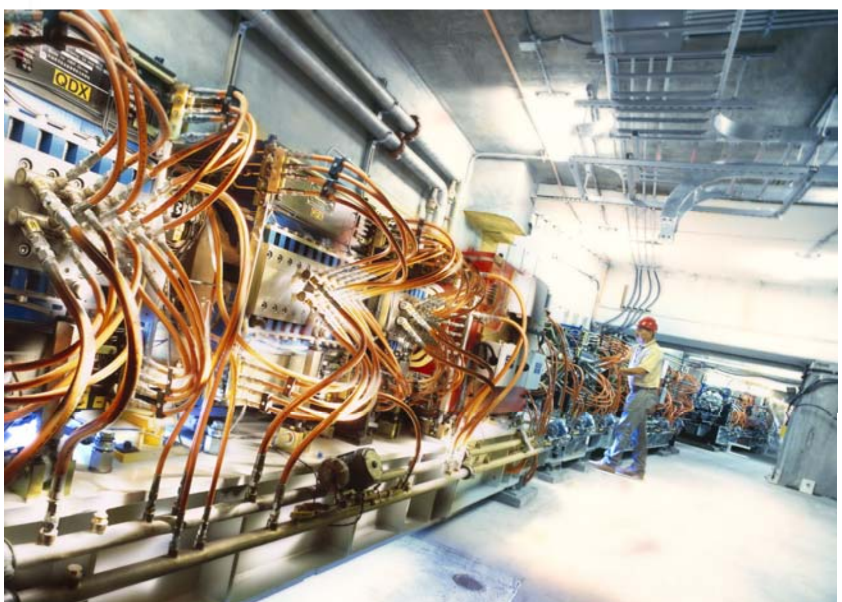
The Whole Instrument Was Assembled at SLAC







1966
Linear Accelerator
Discovery of quarks
Est. Weinberg/Salaam Model
1987
SLAC Linear Collider (SLC)
Establish 3 quark generations
Best limit on Higgs mass
Discovery of charm quark
Discovery of tau lepton
Discovery of jets
1972
SPEAR Storage Ring (HEP)
1980
PEP Storage Ring (HEP)
Long b quark lifetime
1999
PEP-II Storage Rings (HEP)
Discovery of CP violation in B decays
Discovery of new charm states
2008
1974
SPEAR Synch. Light (parasitic)
Materials, chemistry, structural biology
1991
SPEAR Synch. Light (dedicated)
Environmental science
2004
SPEAR3 Synch Light
Nanomaterials
Complex bioassemblies



The 2006 Chemistry Nobel Prize
Prof. Kornberg from Stanford Medical School

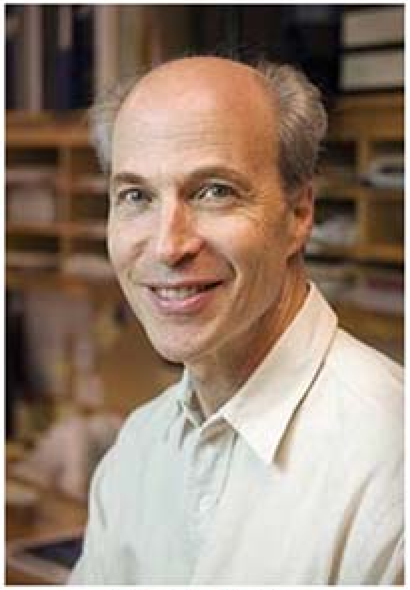
SLAC today

Thursday - October 5, 2006

SLAC was Indispensable, says Nobel Prize Winner

by Brad Plummer and Kelen Tuttle

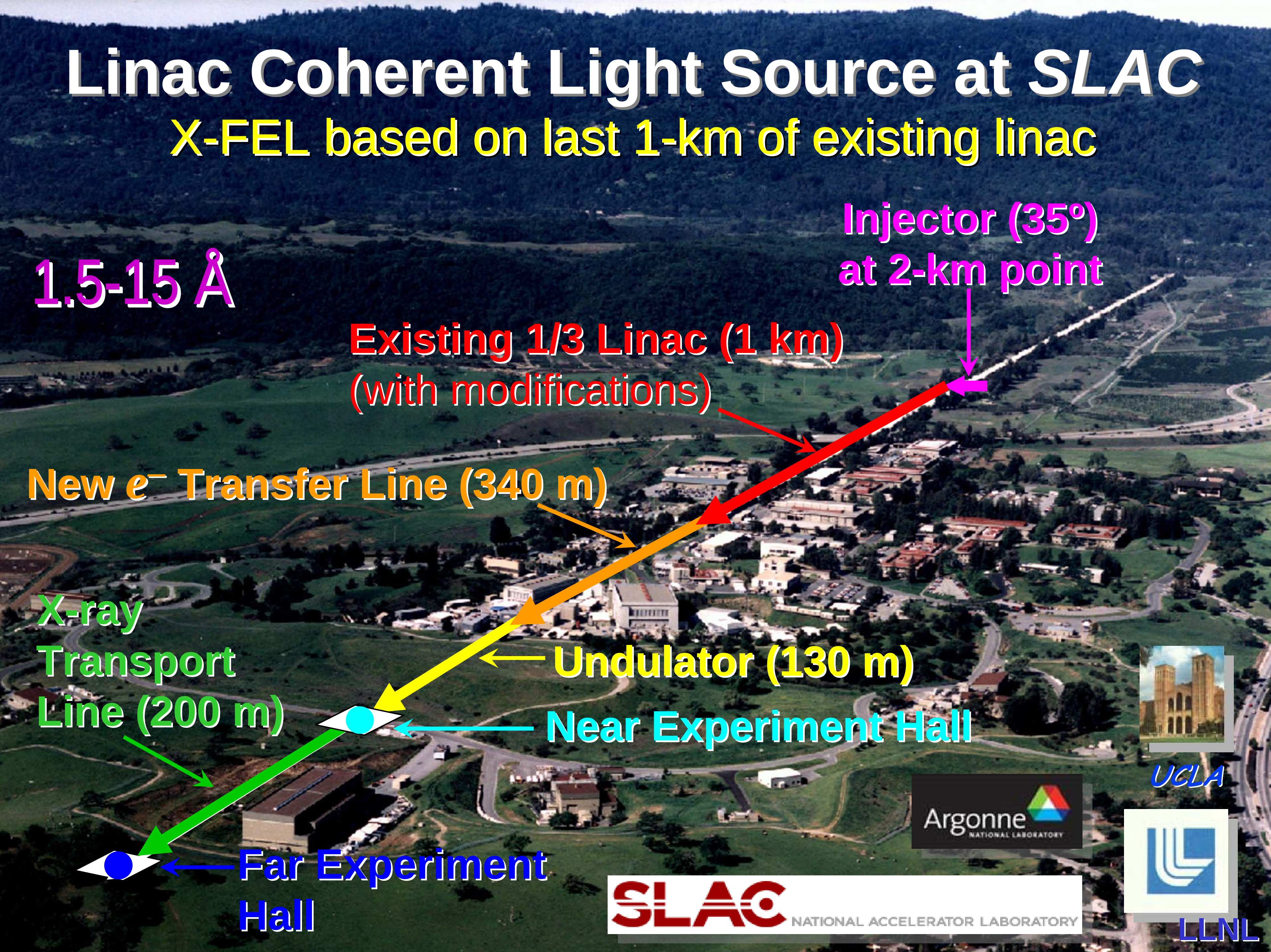
Upon receiving the Nobel Prize for Chemistry yesterday, Stanford Professor Roger Kornberg praised SLAC and the Stanford Synchrotron Radiation Laboratory facility. "We could not have solved the problem that was noted in the Nobel Prize announcement without the exceptional facilities given to us by SLAC. They were indispensable," Kornberg said.



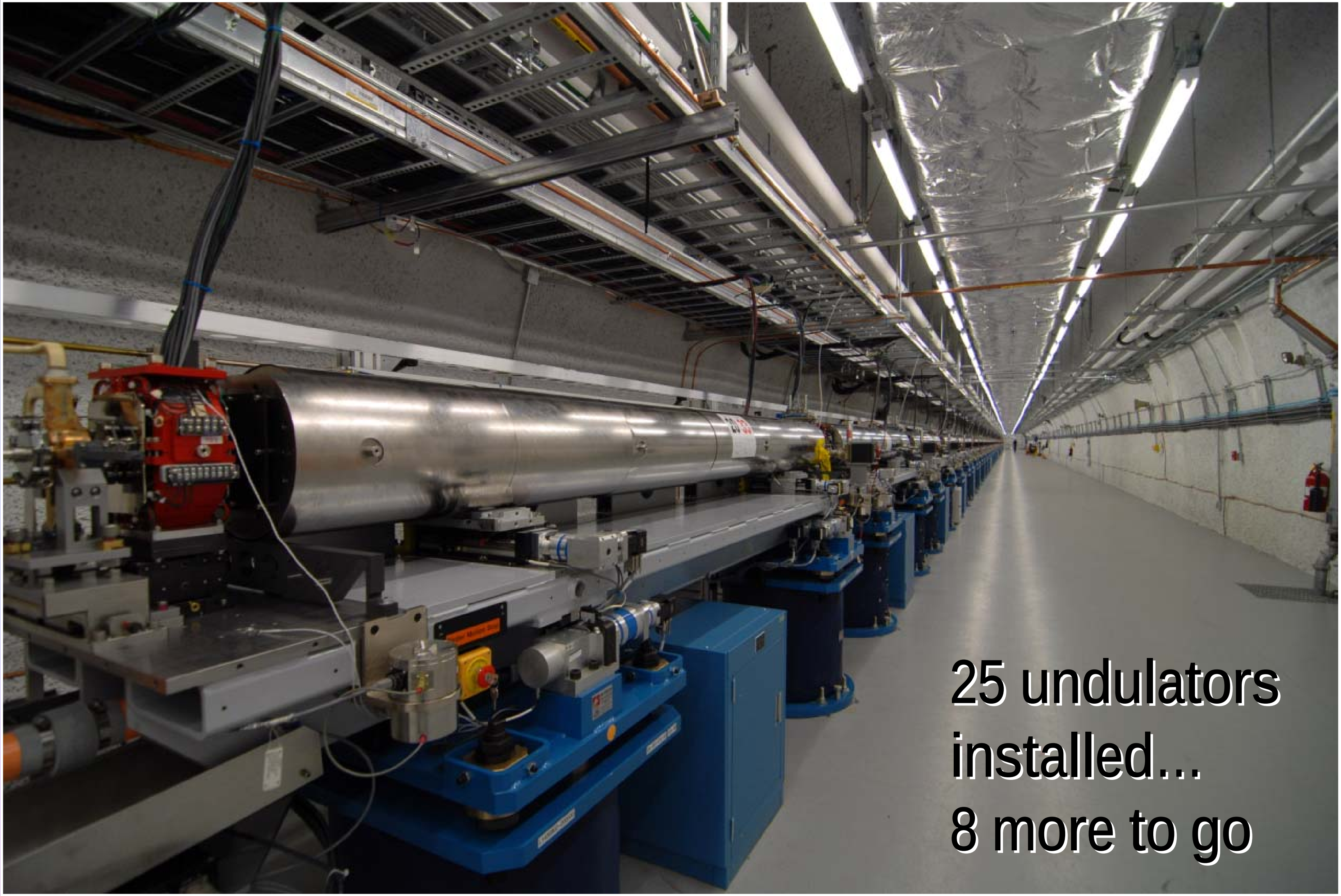
Roger Kornberg
(Image courtesy of Linda A. Cicero, Stanford News Service.)

Kornberg received the award for determining how DNA's genetic blueprint is read and subsequently used to direct the process for protein manufacture. Since the early 1990s, Kornberg has studied this transcription process at SSRL's Beamline 9-2 and 11-1. By passing the lab's extremely bright x-rays through crystallized proteins and watching how the x-rays scattered, Kornberg revealed the three-dimensional atomic structure of proteins in high resolution. The high level of detail in these images offered the first real understanding of the defining events of transcription.

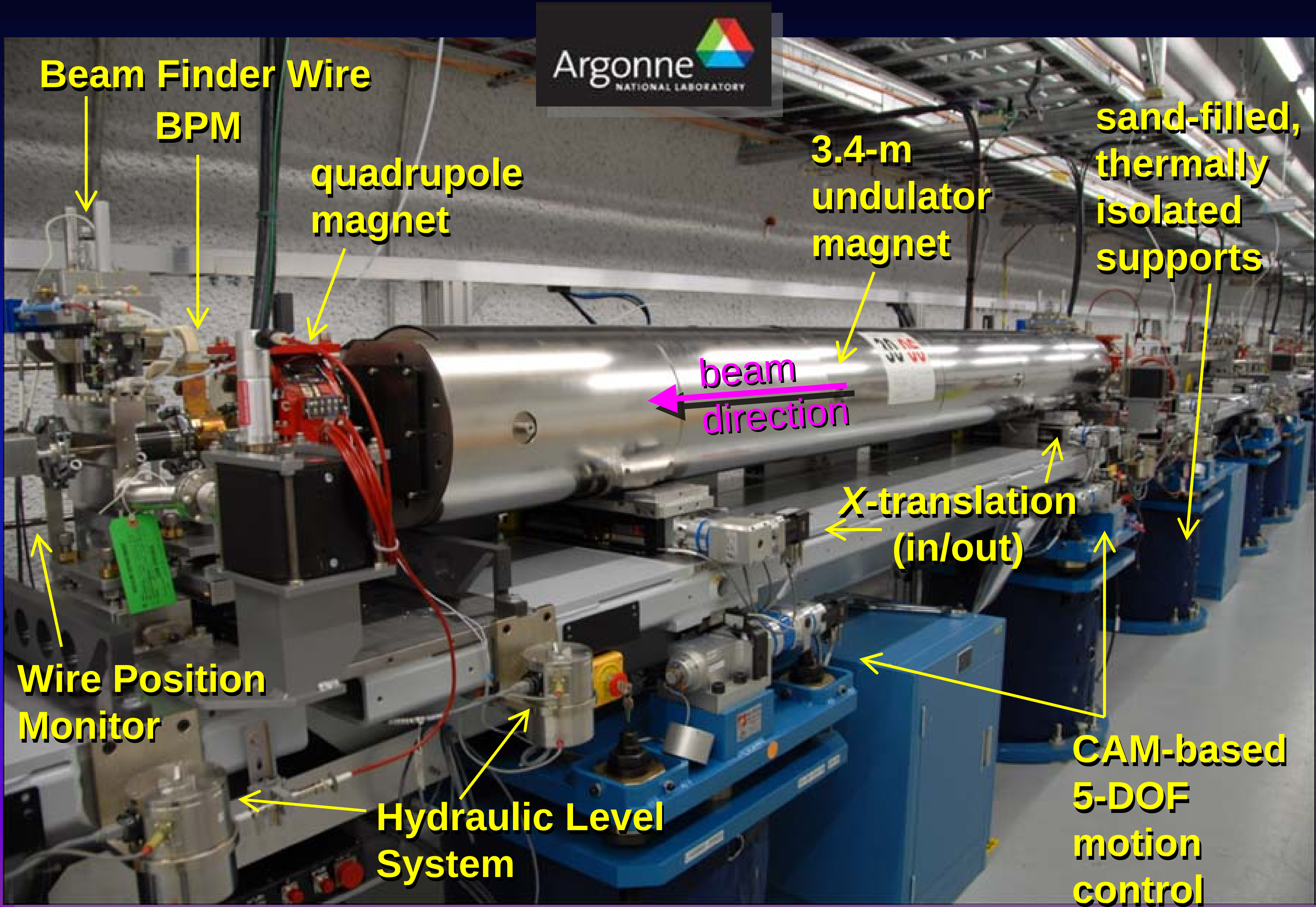
"Congratulations to Dr. Roger Kornberg for his outstanding research," said Under Secretary for Science Raymond L. Orbach. "I am pleased and proud that the experimental work that led to Dr. Kornberg's Nobel Prize award took place at two Department of Energy funded synchrotron radiation laboratories. I congratulate all the staff at these two world-class laboratories on their high quality work." Read SLAC's press release...


Linac Coherent Light Source at SLAC
X-FEL based on last 1-km of existing linac
Injector (35º)
at 2-km point
1.5-15 Å
Existing 1/3 Linac (1 km)
(with modifications)
New e⁻ Transfer Line (340 m)
X-ray
Transport
Line (200 m)
Undulator (130 m)
Near Experiment Hall
Far Experiment
Hall
UCLA
Argonne
NATIONAL LABORATORY
SLAC
NATIONAL ACCELERATOR LABORATORY
LLNL

84 meters of FEL Undulator Installed



Undulator Girder with 5-DOF Motion Control + IN/OUT



Undulator Gain Length Measurement at 1.5 Å: 3.3 m