Brookhaven National Laboratory

Burt Richter: An Appreciation

JoAnne Hewett

Director, Brookhaven Lab

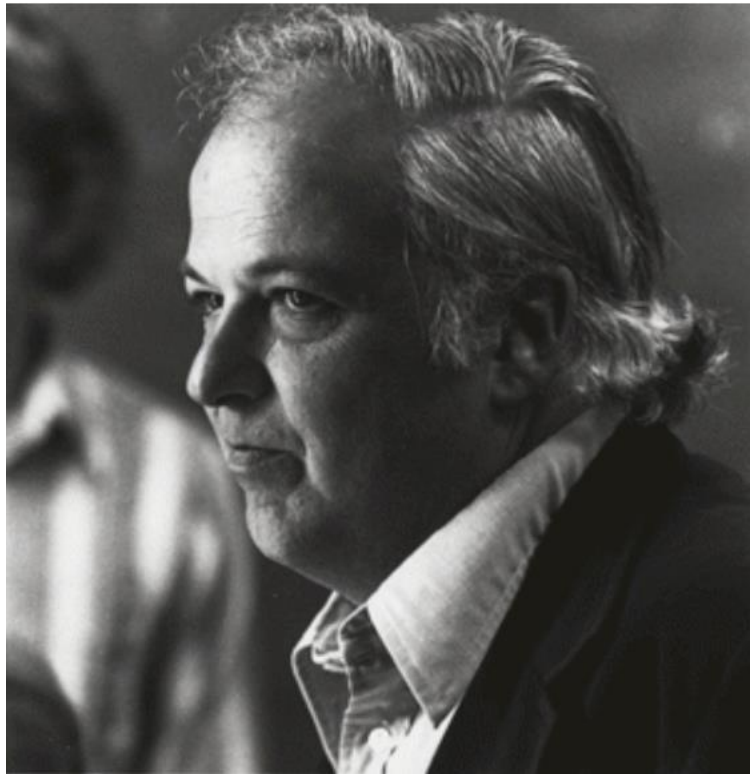
November 8, 2024

SLAC NATIONAL ACCELERATOR LABORATORY

U.S. DEPARTMENT OF ENERGY

Burt: The Career

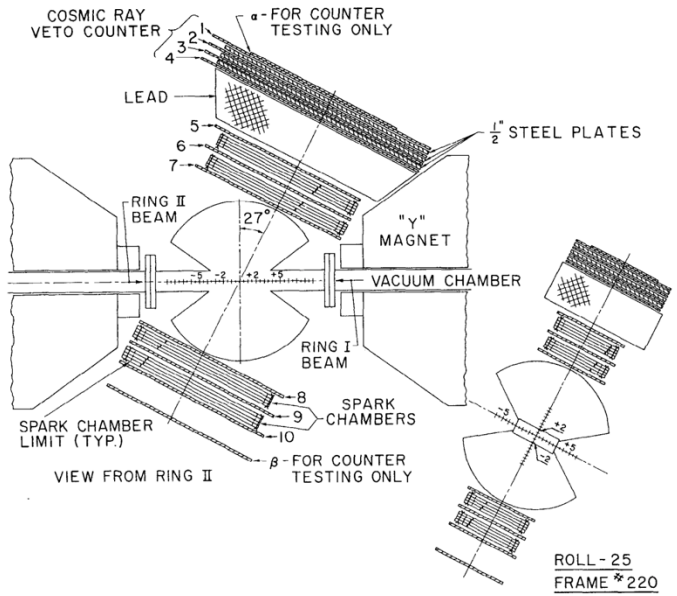
1956: Ph.D. MIT
1956: Postdoc, HEPL/Stanford
1960: Assistant Prof, Stanford
1963: Associate Prof, SLAC
1967: Professor, SLAC
1982: Technical Director, SLAC
1984: Director, SLAC
1999: Director Emeritus
2005: Professor Emeritus



Burt: Ingredients for SPEAR

1st exp't: Photo-production of e^+e^- at large angles to probe QED

2nd Project: Stanford-Princeton e^-e^- storage ring to probe QED @ 1 GeV



SPARK CHAMBER – COUNTER GEOMETRY WITH COLLINEAR EVENT

Burt Richter Nobel Lecture, Reviews of Modern Physics 1977

(To be submitted to Phys. Rev. Letters) HEPL - 438
SLAC-PUB-194

A TEST OF QUANTUM ELECTRODYNAMICS BY ELECTRON-ELECTRON SCATTERING*

W. C. Barber†, B. Gittelman‡, G. K. O'Neill‡, and B. Richter**
Stanford University
Stanford, California

There was much to learn about the behavior of beams in storage rings, but what we learned during that long and often frustrating time opened up a new field of particle physics research

Let me digress here for a moment to recount a formative experience. In 1959, as the work on the HEPL rings progressed, I was also trying to learn something about how to calculate cross sections in QED under the tutelage of Stanford theorist J. D. Bjorken. One of the problems Bjorken gave me was to calculate the cross section for the projection of a pair of pointlike particles having zero spin (bosons) in electron–positron annihilation. I carried out this calculation, but I was troubled by the fact that no pointlike bosons were known to exist.

Burt learned to combine theory, experiment, & accelerator physics

Burt: Ingredients for the Psi

SPEAR

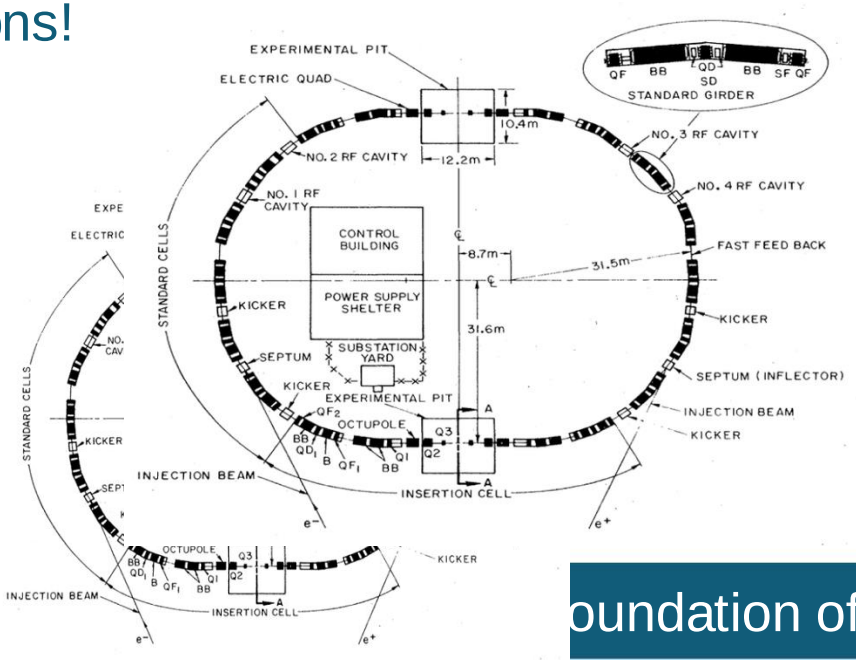
1961: Design began with Ritson

1963: Set up group @SLAC and finalized E_{CM} @6 GeV

1965: Formal proposal submitted to Atomic Energy Commission

1970: Funding Received for a reduced project

21 months from start of construction to first collisions!



Mark-I Magnetic Detector

- Recognized importance to learn as much as possible about final states
- Other SLAC groups and LBL joined the team
- Ready for data-taking in Feb 1973

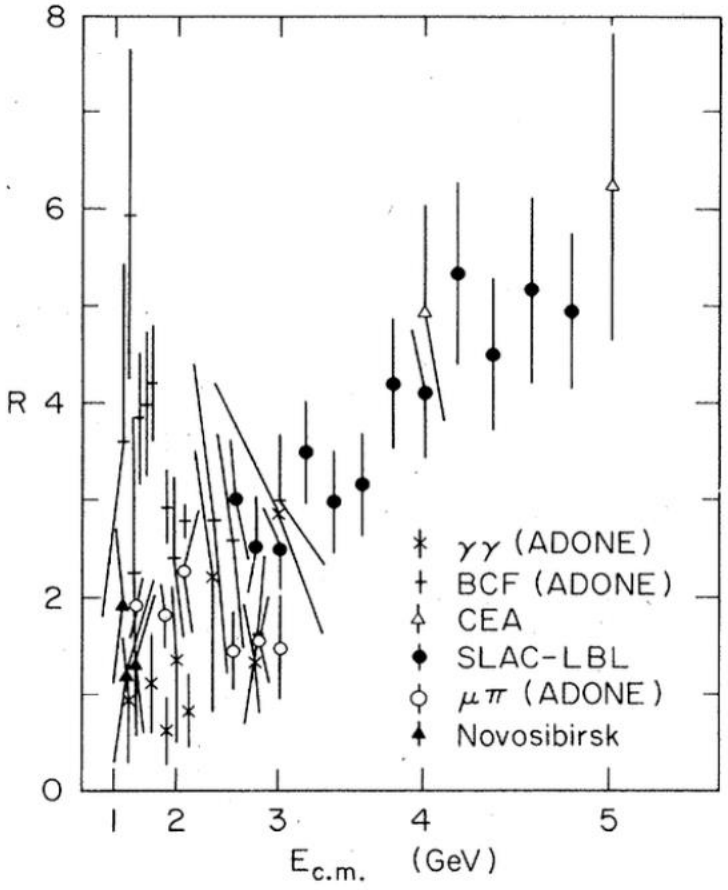
The first 4-pi detector!

magnet produces a solenoidal field, coaxial with the beams, of about 4 kG throughout a field volume of about 20 m^3. Particles moving radially outward from the beam-interaction point pass successively through the following elements: the beam vacuum pipe; a trigger counter; 16 concentric cylinders of magnetostrictive wire spark chambers that provide tracking information for momentum measurements; a cylindrical array of 48 scintillators that act as both trigger and time-of-flight counters; the one-radiation-length-thick aluminum magnet coil; a cylindrical array of 24 lead-scintillator shower counters that provide electron identification; the 20-cm-thick iron flux-return plates of the magnet; and finally an additional array of plane spark chambers used to separate muons from hadrons.

oundation of all modern colliders and detectors

R-Ratio: Status in Summer 1974

Experimental Summary of R-ratio



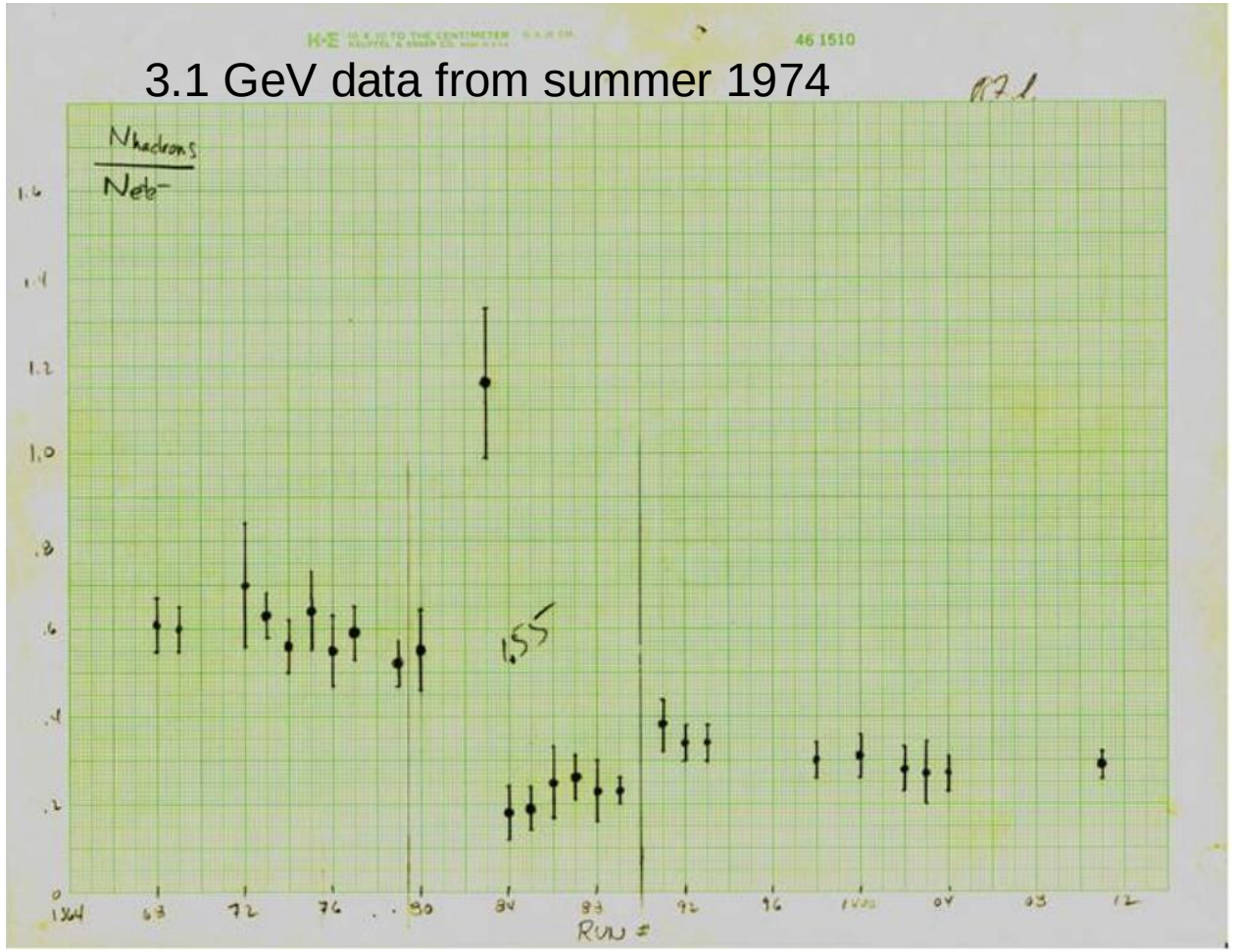
Theoretical Predictions for R-ratio

TABLE I. Tables of values of R from the talk by J. Ellis at the 1974 London Conference (Ellis, 1974). The references in table are from Ellis's talk.

Value	Model	References
0.36	Bethe–Salpeter bound quarks	Bohm *et al.*, Ref. 42
$\frac{2}{3}$	Gell-Mann–Zweig quarks	
0.69	Generalized vector meson dominance	Renard, Ref. 49
~1	Composite quarks	Raitio, Ref. 43
$\frac{10}{9}$	Gell-Mann–Zweig with charm	Glashow *et al.*, Ref. 31
2	Colored quarks	
2.5 to 3	Generalized vector meson dominance	Greco, Ref. 30
2 to 5	Generalized vector meson dominance	Sakurai, Gounaris, Ref. 47
$3\frac{1}{3}$	Colored charmed quarks	Glashow *et al.*, Ref. 31
4	Han–Nambu quarks	Han and Nambu, Ref. 32
5.7 ± 0.9	Trace anomaly and ρ dominance	Terazawa, Ref. 27
$5.8^{+\frac{3}{5}}_{-\frac{2}{5}}$	Trace anomaly and ϵ dominance	Orito *et al.*, Ref. 25
6	Han–Nambu with charm	Han and Nambu, Ref. 32
6.69 to 7.77	Broken scale invariance	Choudhury, Ref. 18
8	Tati quarks	Han and Nambu, Ref. 32
8 ± 2	Trace anomaly and ϵ dominance	Eliezer, Ref. 26
9	Gravitational cutoff, universality	Parisi, Ref. 40
9	Broken scale invariance	Nachtmann, Ref. 39
16	$SU_{12} \times SU_{12}$ gauge models	Fitzsch and Minkowski, Ref. 34
$35\frac{1}{3}$	$SU_{16} \times SU_{16}$ gauge models	Fitzsch and Minkowski, Ref. 34
~5000	High Z quarks	Yock, Ref. 73
70,383	Schwinger's quarks	Yock, Ref. 73
∞	∞ of partons	Cabibbo and Karl, Ref. 9 Matveev and Tolkachev, Ref. 35 Rozenblit, Ref. 36

Burt Richter Nobel Lecture, Reviews of Modern Physics 1977

Eureka!



An Interesting Weekend in 1974

- Friday, November 8
  - Report from Berkeley: excess kaons in Run 1383
    GLR *Search for Charm* arrived yesterday!
  - SPEAR ready to begin hi-*E* running—appeal to stay at 1.5 GeV! Meeting in Burt's office: he gives us the weekend.
  - Prepare for run
- Saturday, November 9
  - early, unauthorized "hand-scan" at 1.55 GeV
  - follow run plan—establish "baseline"
  - vague peak seems to emerge by late evening
- Sunday, November 10
  - 10:00: "we bumped the energy to 1.555 GeV"
  - 1.5 μb cross section!
  - SPEAR control room gets crowded!
- Monday, November 11
  - call from Hamburg; Richter/Ting in Panofsky's office
  - PAC, noon talks, … , first mention of "Charmonium"
  - name that particle

From R. Schwitters

8

[3]The physicists of the SLAC/LBL group who were responsible for building the detector and for the experiments I will discuss are S. M. Alam, J.-E. Augustin, A. M. Boyarski, M. Breidenbach, F. Bulos, J. M. Dorfan, G. J. Feldman, G. E. Fischer, D. Fryberger, G. Hanson, J. A. Jaros, B. Jean-Marie, R. R. Larsen, D. Lüke, V. Lüth, H. L. Lynch, C. C. Morehouse, J. M. Paterson, M. L. Perl, I. Peruzzi, M. Piccolo, T. P. Pun, P. Rapidis, B. Richter, R. H. Schindler, R. F. Schwitters, J. Siegrist, W. Tanenbaum, and F. Vannucci from SLAC; and G. S. Abrams, D. Briggs, W. C. Carithers, W. Chinowsky, R. G. DeVoe, C. E. Friedberg, G. Goldhaber, R. J. Hollebeek, A. D. Johnson, J. A. Kadyk, A. Litke, B. Lulu, R. J. Madaras, H. K. Nguyen, F. Pierre, B. Sadoulet, G. H. Trilling, J. S. Whitaker, J. Wiss, and J. E. Zipse from LBL.

Burt: Larger Storage Rings

Feasibility Study for a 15-GeV electron Positron Storage Ring: E(CM) = 30-GeV

S.M. Berman (SLAC), S.D. Drell (SLAC), John R. Rees (SLAC), Burton Richter (SLAC) (Dec, 1976)

cite claim reference se

First order design for PEP

SLAC-PUB-1738
April 1976
(T/E/A)

VERY HIGH ENERGY ELECTRON-POSITRON COLLIDING BEAMS
FOR THE STUDY OF THE WEAK INTERACTIONS*

B. Richter
CERN, Geneva, Switzerland
and
Stanford Linear Accelerator Center
Stanford University, Stanford, California 94305

ABSTRACT

We consider the design of very high energy electron-positron colliding-beam storage rings for use primarily as a tool for investigating the weak interactions. These devices appear to be a very powerful tool for determining the properties of these interactions. Experimental possibilities are described, a cost minimization technique is developed, and a model machine is designed to operate at centre-of-mass energies of up to 200 GeV. Costs are discussed, and problems delineated that must be solved before such a machine can be finally designed.

Established the dependence of both cost and radius on E_{CM}

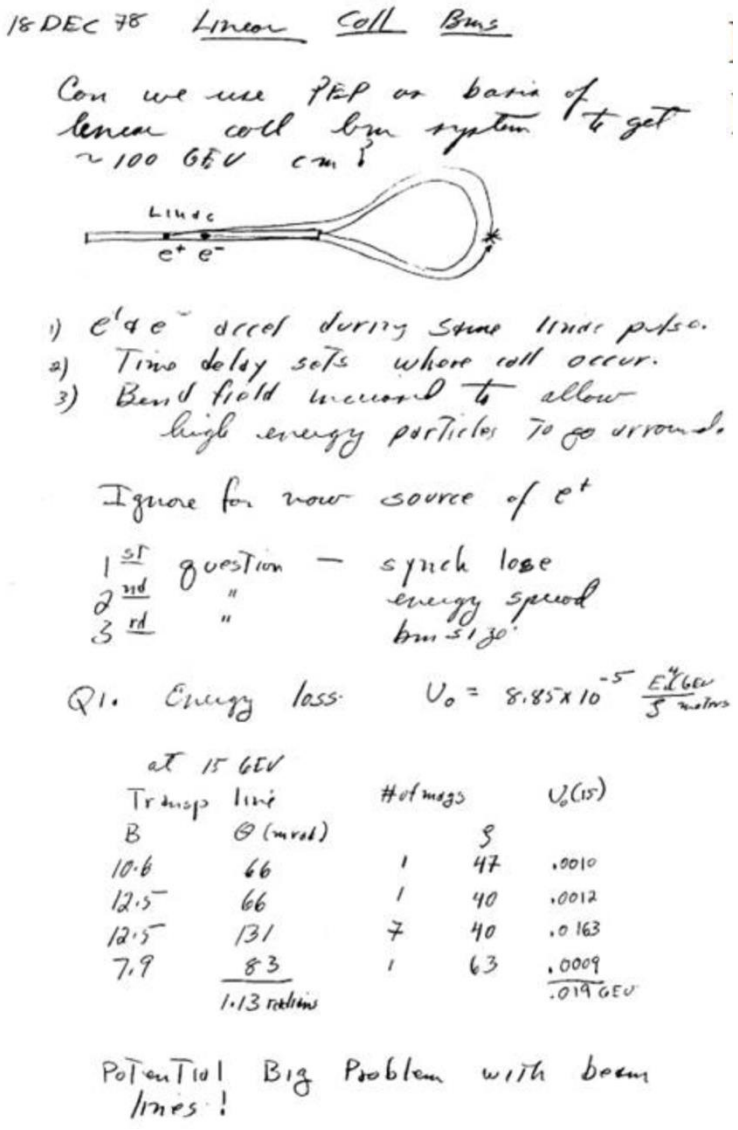
"This study turned into the first order design of the LEP project at CERN…." B. Richter

Yet, realization such a collider could not be built on the SLAC site

Nucl. Instrum. Methods 1976

Burt: The Stanford Linear Collider

Burt's Lab Notebook


18 DEC 78 Linear Coll Bms

Can we use PEP as basis of linear coll bm system to get ~100 GEV cm ?

Linac
e+ e−

1) e+ & e− accel during same linac pulse.
2) Time delay sets where coll occur.
3) Bend field increased to allow high energy particles to go around.

Ignore for now source of e+

1st question — synch loss
2nd " energy spread
3rd " bm size

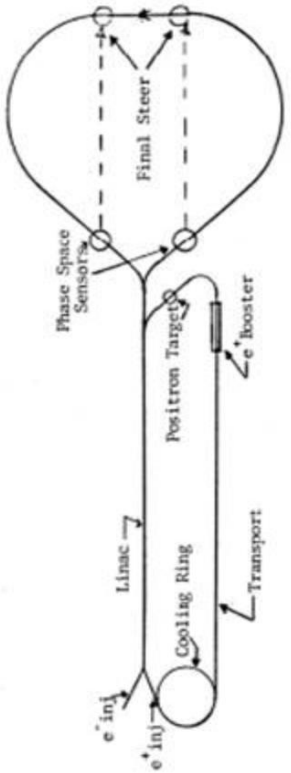
Q1. Energy loss $U_0 = 8.85 \times 10^{-5} \frac{E^4_{GeV}}{\rho \text{ meters}}$

at 15 GEV

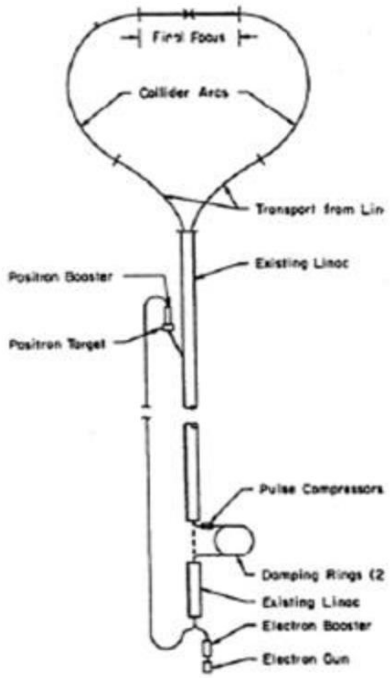
Transp line		# of mags		$U_0(15)$
B	Θ (mrad)		8	
10.6	66	1	47	.0010
12.5	66	1	40	.0012
12.5	131	7	40	.0163
7.9	83	1	63	.0009
	1.13 radians			.019 GEV

Potential Big Problem with beam lines !

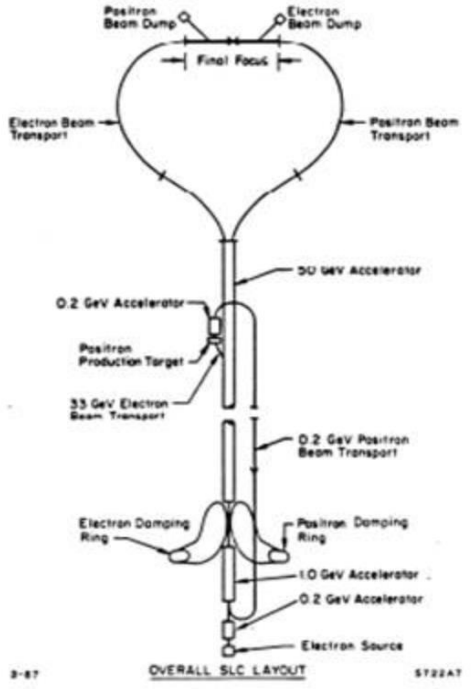
Evolution of the SLC



B. Richter
AATF Note 79/3
August 1979



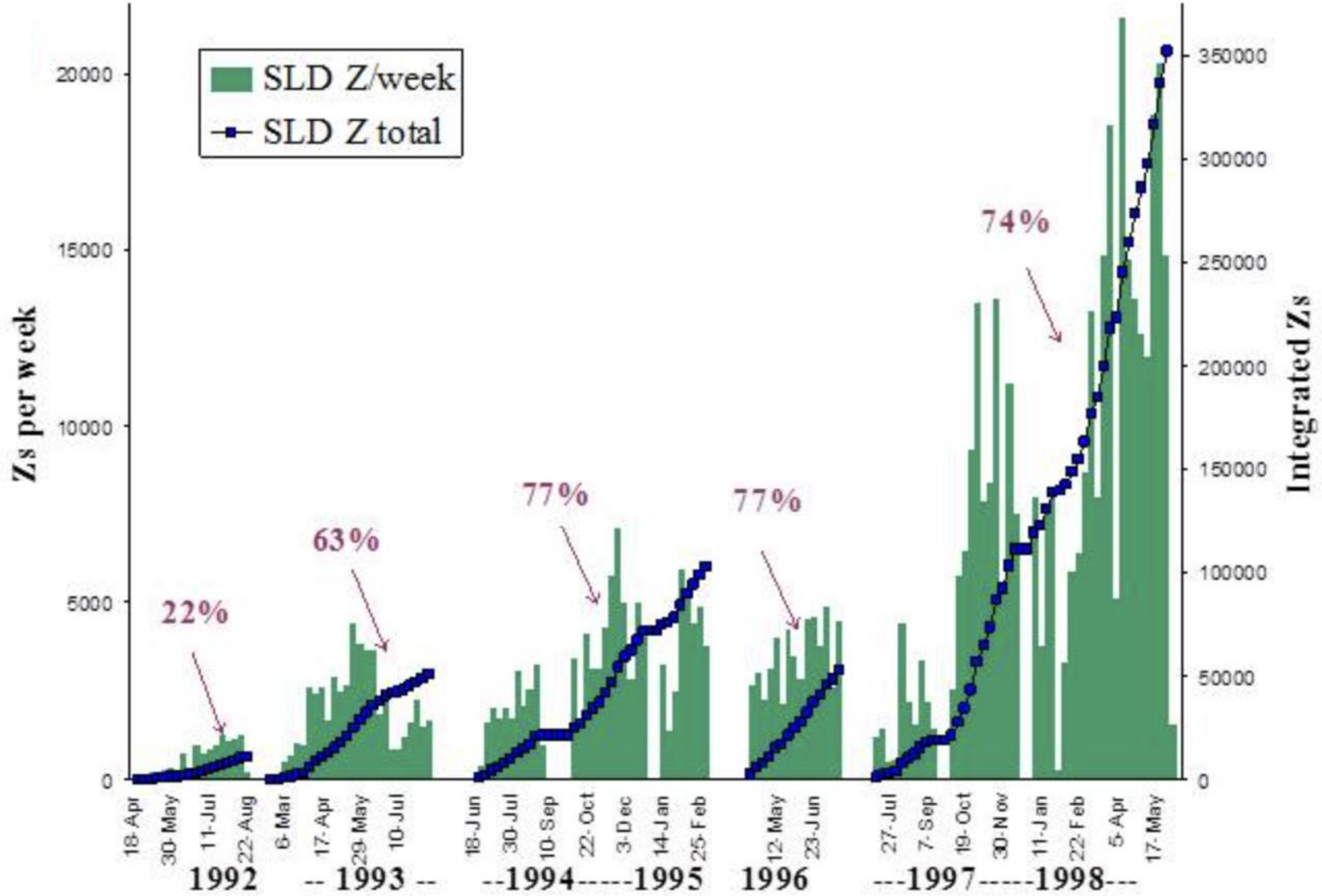
SLC CDR
June 1980



SLC as completed
In 1987 with Mark II
First Z - 4/13/1989

From J. Dorfan & G. Loew

SLC: A Difficult Start

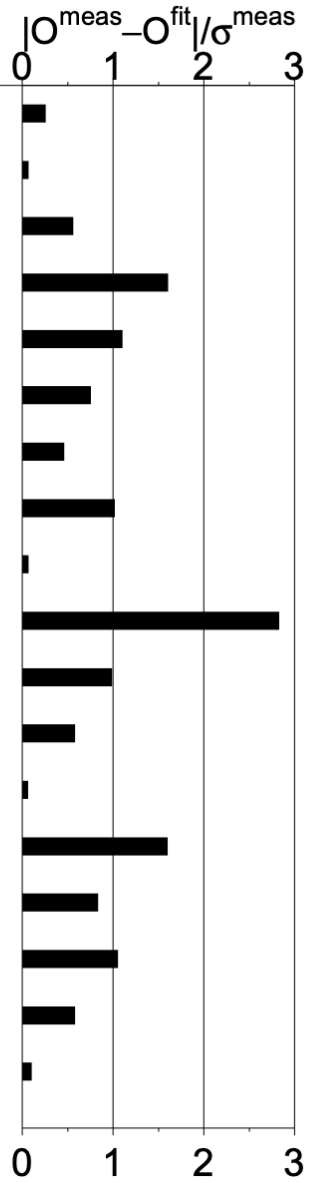


Attestation of Burt's formidable nature

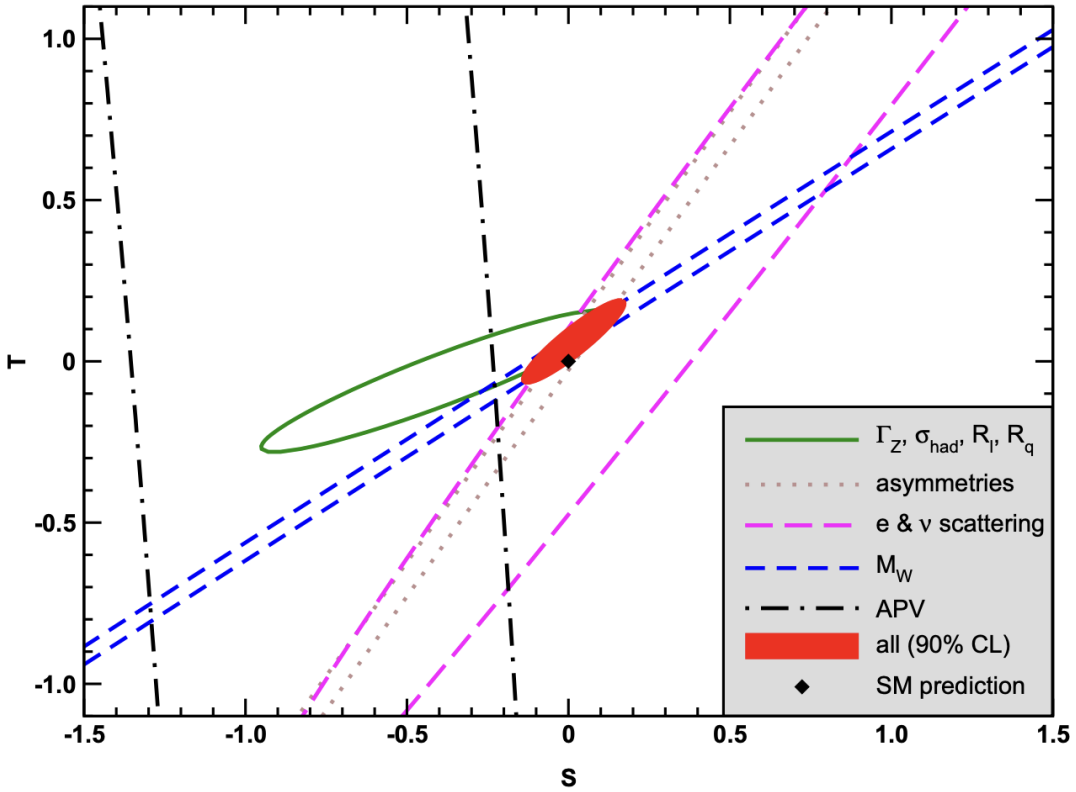
- Hard work resolved the issues
- SLAC budget kept intact

Legacy: The Z-Pole Observables

	Measurement	Fit
$\Delta\alpha^{(5)}_{had}(m_Z)$	0.02758 ± 0.00035	0.02767
m_Z [GeV]	91.1875 ± 0.0021	91.1874
Γ_Z [GeV]	2.4952 ± 0.0023	2.4965
σ^0_{had} [nb]	41.540 ± 0.037	41.481
R_l	20.767 ± 0.025	20.739
$A^{0,l}_{fb}$	0.01714 ± 0.00095	0.01642
$A_l(P_\tau)$	0.1465 ± 0.0032	0.1480
R_b	0.21629 ± 0.00066	0.21562
R_c	0.1721 ± 0.0030	0.1723
$A^{0,b}_{fb}$	0.0992 ± 0.0016	0.1037
$A^{0,c}_{fb}$	0.0707 ± 0.0035	0.0742
A_b	0.923 ± 0.020	0.935
A_c	0.670 ± 0.027	0.668
★ A_l(SLD)	0.1513 ± 0.0021	0.1480
$\sin^2\theta^{lept}_{eff}(Q_{fb})$	0.2324 ± 0.0012	0.2314
m_W [GeV]	80.425 ± 0.034	80.389
Γ_W [GeV]	2.133 ± 0.069	2.093
m_t [GeV]	178.0 ± 4.3	178.5



Oblique parameter fit to the SM



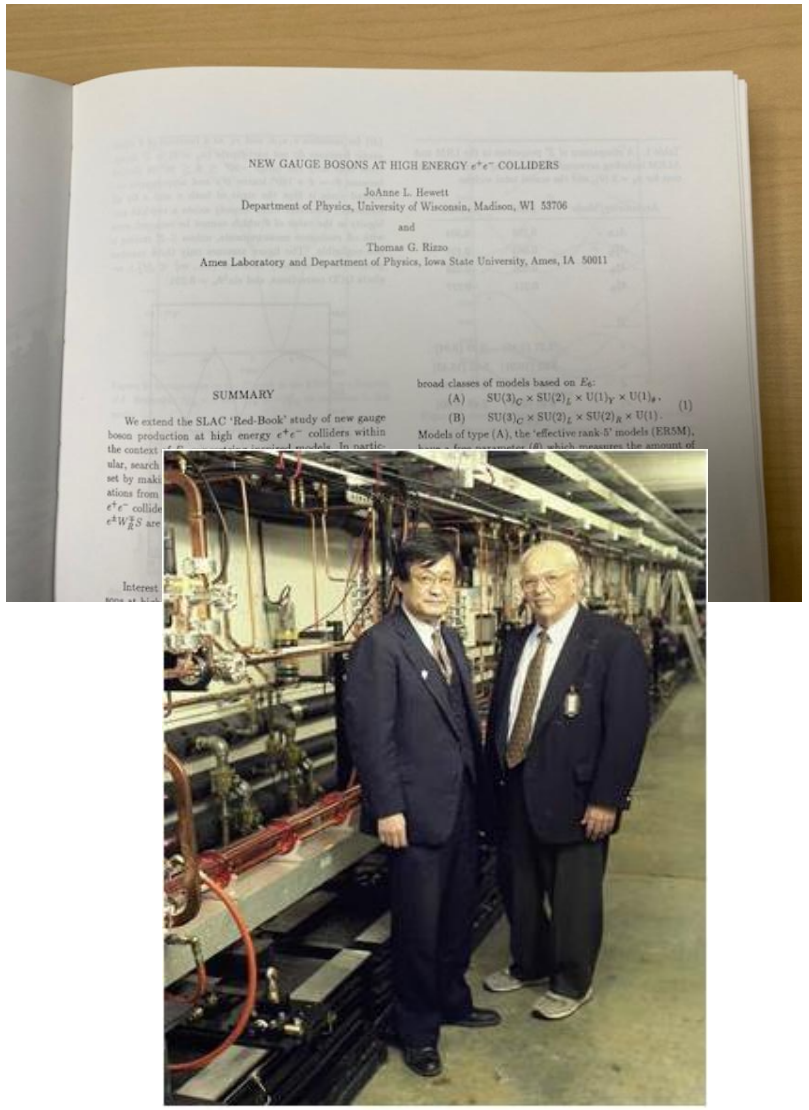
PDG 2020

LEP EW WG, Final results, Phys. Rep. 2005

Burt: The Next Linear Collider

Convinced of linear colliders, Burt wanted to go to higher energies. Ended up being a life-long dream. Still not realized.

- 1986 Red-book study of science case led by M. Peskin
- 1988 Workable design for Snowmass led by D. Burke
- 1995 Burt took lead in forging an international approach: "Thus scientists have to find effective ways to share their major costs across national boundaries
  - Bjorn Wiik (DESY) and Hirotaka Sugawara (KEK)
- 1996 NLC 0th order design completed
- 1997 formed 1st international study group (ISG) with SLAC-KEK (accelerator design)
- 1998 US NLC Physics and Detector working group formed
- …..uncountable number of meetings and studies and designs since….


NEW GAUGE BOSONS AT HIGH ENERGY e^+e^- COLLIDERS

JoAnne L. Hewett
Department of Physics, University of Wisconsin, Madison, WI 53706
and
Thomas G. Rizzo
Ames Laboratory and Department of Physics, Iowa State University, Ames, IA 50011

SUMMARY

Burt and Hirotaka at the NLC Test Accelerator

Burt: Lab Director 1984-1999

Burt: The B-Factory

- In the mid 1980s the TPC collaboration at PEP, led by its co-spokesman Elliott Bloom, were pushing SLAC to upgrade PEP in pursuit of high statistics studies of B mesons and τ leptons. The proposal was called *HiLum PEP*
- *HiLum PEP* was not adopted by SLAC
- Burt coined the phrase "Boutique Physics", certainly a term of derision
- It took about 8 years to turn Burt into a supporter of "Beauty/CP Physics", but once on board, he was a powerful advocate

	HiLum PEP NEXT
circumference(m)	2200
#rings	1
#IR'S	1
n	3
β^*_y	4
$\Delta\nu$	0.07 (@12.5)
Wigglers	no
L_{peak} ($\times 10^{32}$ cm^{-2}sec^{-1})	
@12.5 GeV/beam	1.4
@5.4 GeV Υ(4S)	NA
<L> (pb^{-1}/day)	
@12.5 GeV/beam	4.0
@5.4 GeV Υ(4S)	NA
P_{beam} (MW)	
@12.5 GeV	0.3
@5.4 GeV Υ(4S)	NA
I_{bunch} (ma)	
@12.5 GeV	8.3
@5.4 GeV Υ(4S)	NA
I_{beam} (ma)	
@ 12.5 GeV	24.9
@5.4 GeV Υ(4S)	NA
$B\bar{B}$ pairs/200 days ($\times 10^6$)	
@ 12.5 GeV	0.04
@5.4 GeV Υ(4S)	NA

B-Factory Program

- ❑ It is a very important missing element in the standard model.
- ❑ It is a difficult machine.
- ❑ $\mathcal{L} \geq 3 \times 10^{33}$ is required to do CP.
- ❑ e^+e^- is needed to do the full problem.

Can be done within constraint of constant purchasing power SLAC budget. Requires refocusing of the laboratory and sharing people between operations and maintenance and B project.

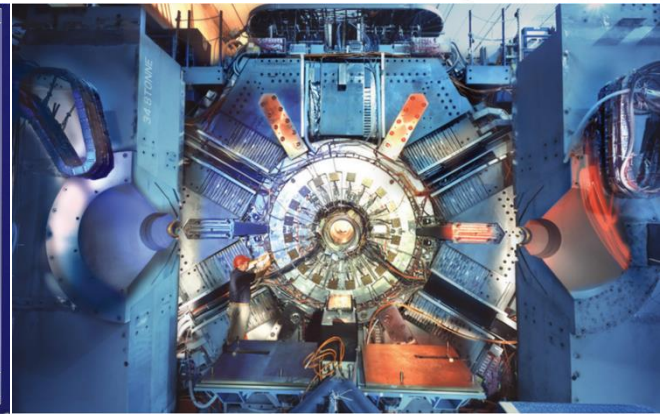
We have been working on this in the U.S. for many years. There is a large U.S. (and foreign) user interest. We should do it.

Thanks to J. Dorfan

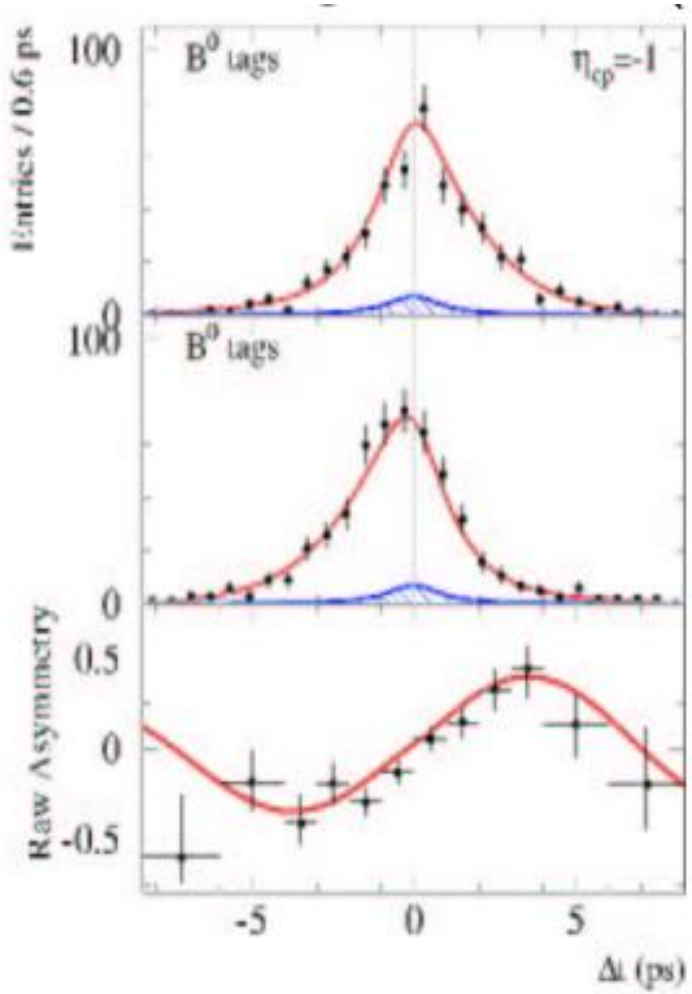
1992 Witherall subpanel - needed to find ~120M in the HEP budget for the SSC

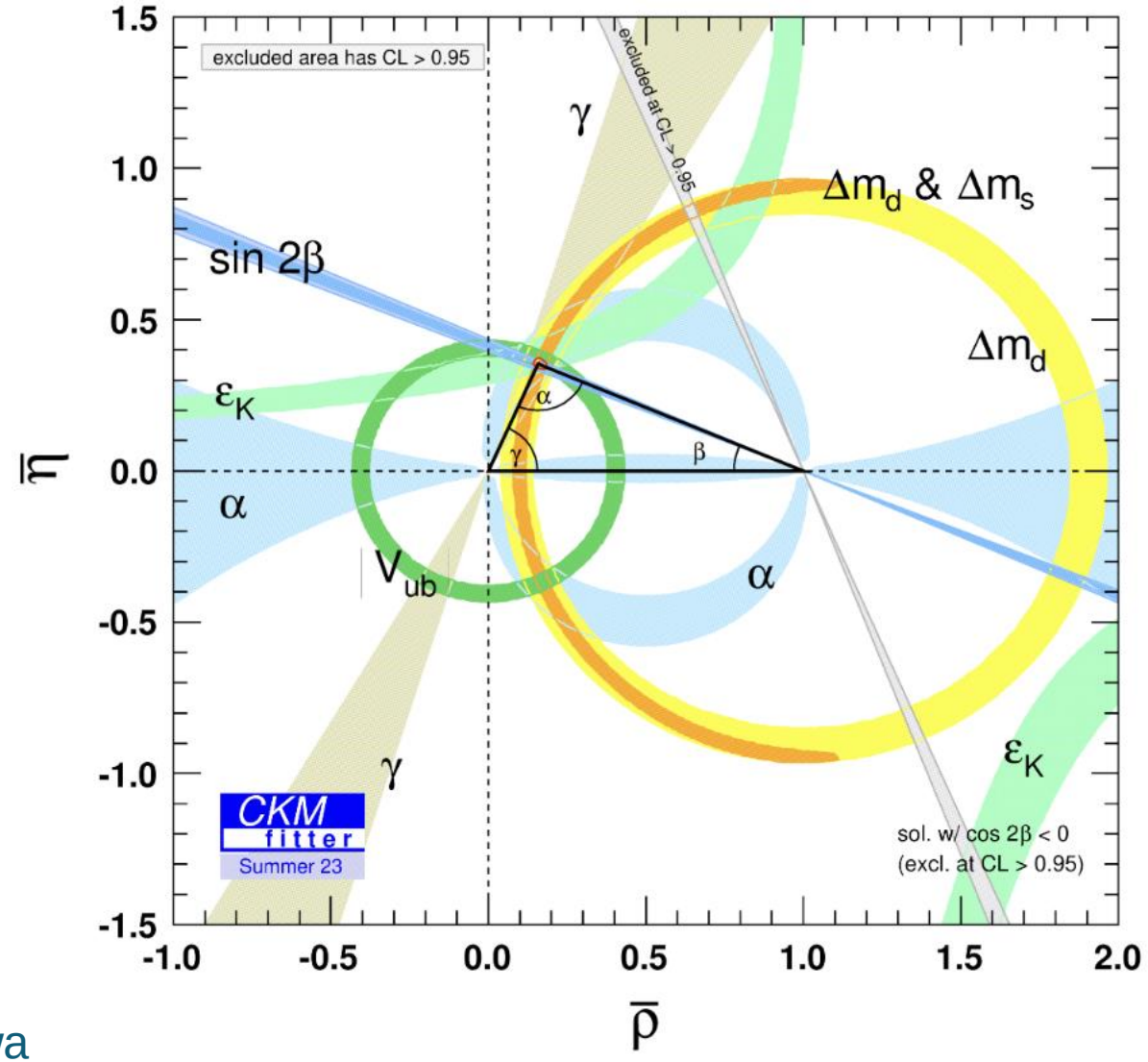
Considered closing SLAC

Burt became a strong advocate for the B-Factory



B-Factory Legacy





Asymmetry between B^0 and B^0 tags @BaBar
Led to 2008 Nobel prize for Kobayashi and Maskawa

Burt: Fermi Gamma-Ray Space Telescope

One of the things that got brought to me (in mid 1990s) as a potential was a space mission – the Fermi Satellite as it's called now – a creation of Peter Michelson, Elliot Bloom and Bill Atwood. Again, looking at the community and the potential users it was a clear winner and the Director's job is to sell those things. So off I went to Washington…and I didn't have any trouble with NASA, they thought this was absolutely terrific. The problem was the DOE, it took a long time to get the DOE to do it and it wasn't until Dorfan was Director that DOE finally signed off.

Launch, June 11, 2008

A particle detector in space

Oral History, April 2015, SLAC Archives

GLAST is Still Going Strong!

Orbiting 90,670 days since launch!

No noticeable degradation of LAT performance

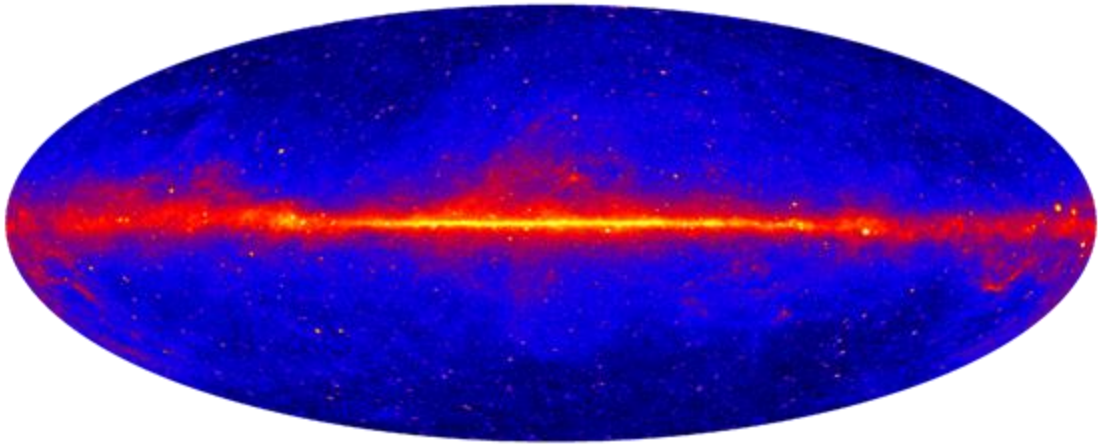
Joins LIGO/VIRGO/Kagra and IceCube for multi-messenger studies

On-board event triggers: 977 Billion (expected to reach 1 trillion in March 2025)

Events transmitted to SLAC for processing: 196 Billion

Transient class photon events delivered to NASA for public release: 4.7 Billion

High purity events delivered to NASA for public release: 1.8 Billion

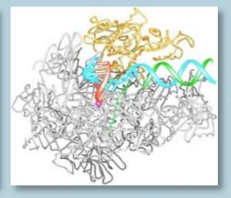


14 yr intensity sky map, > 1 GeV

Burt: Stanford Synchrotron Radiation Project

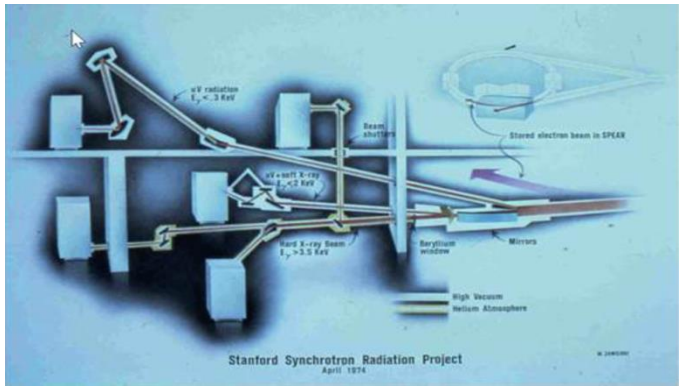
First multi-GeV storage ring based synchrotron radiation source

- HEP scientists originally considered X-ray beams to be a waste of energy and a nuisance
- Humble beginnings – 1st beamline literally hole in the wall constructed by Lindau and Pianetta
- SSRP began in 1973 with 3 X-Ray options on 5 beamlines
  - $E_\gamma > 3.5$ keV, $E_\gamma < 2$ keV, $E_\gamma < 0.3$ keV
  - 1st Director Seb Doniach

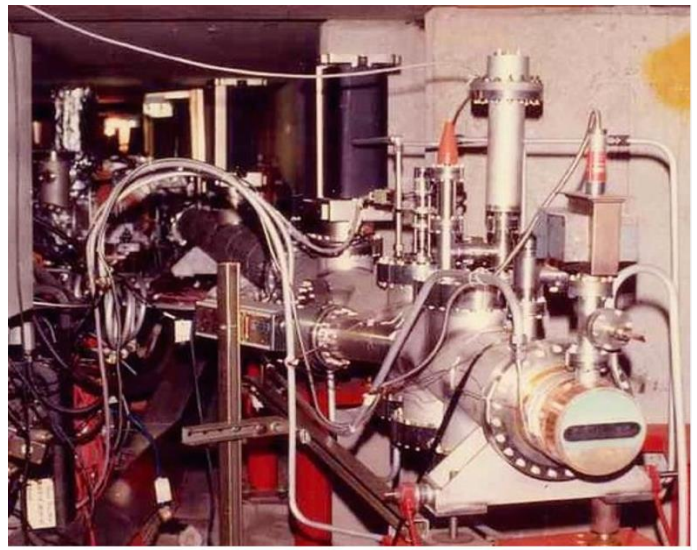


3D atomic images of RNA polymerase II

Roger Kornberg, 2006 Nobel Prize in Chemistry for determining how DNA's genetic blueprint is read and used to direct the process of protein manufacturing



Burt bought a Sears garden shed to house the experiments



Stanford Synchrotron Radiation Project

Burt: Joining SSRL with SLAC

In Burt's words:

"....DoE forced Stanford to move the synchrotron radiation program in as part of the SLAC contract. ....Everybody was nervous, the HEP Faculty didn't want to do it; they thought they would get swallowed,...
I went and arranged a conspiracy with the DoE ... DoE would say that OMB says we cannot have two M&O contracts in a single Laboratory -- so you two have to get married. And get married we did (in 1988).

So I started funneling them money to expand the facilities at SPEAR and to begin the design of what became the X ray Laser, the LCLS....I didn't know what you could do with an X-ray laser .... They came up with a notion about an energy for the X-rays and I said I want you to have a workshop on what is the right energy for this facility.....something the community of users thinks is right – and that (1992) workshop called for a much higher energy .... We started on the design ... didn't get realized until the Dorfan and Drell eras.....but it got put in the queue before I stepped down as Director.

Oral History, April 2015, SLAC Archives

Burt: LCLS

Promoting Photon Science: LCLS
May 1994 email from Herman Winick to Burt

Date: Tue, 24 May 1994 11:47 PDT
From: <WINICK@SSRL750>
Subject: Participation in the LCLS Collaboration Meeting
To: Director@slacvm
Original_To: JNET%"Director@slacvm"
Original_cc: A,ARTHUR,MATERLIK,JNET%"JMP@SLACVM",
JNET%"Tor@slacvm",WINICK

Burt;

You asked me to summarize the important parts of the LCLS Collaboration meeting this Friday and Saturday so that you can plan your participation. Below are the objectives and agenda.

Your observations at the previous scientific applications meetings have been very important in guiding the direction of this project. We are now getting strong interest from the Japanese and Germans in forming a collaboration. This could be very helpful in expanding our present R&D program. Since your time is limited, let me point out the most important parts of the meeting for you to attend:

Early 1990's design of LCLS

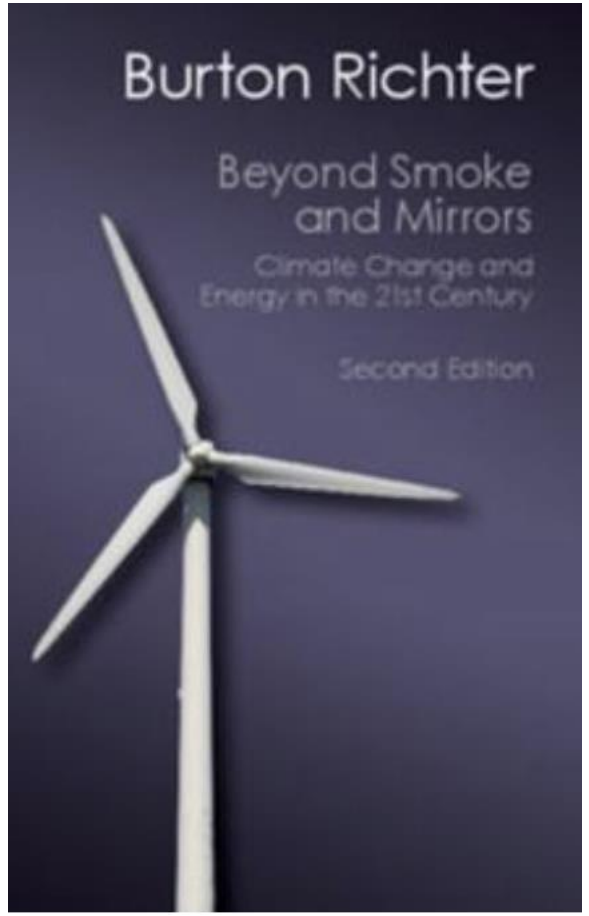
From J. Dorfan, APS Talk

Burt: Energy Policy

Burt started looking at climate science as a hobby in 1978

Became more involved through the JASON advisory group

Worked with George Schultz through the Hoover Institution task force on energy policy



Review

"The climate naysayers will surely challenge Burton Richter: What makes a mere physics professor an expert on climate change, even if he holds a Nobel Prize for finding some exotic particle inside the atom?

The answer: The Stanford professor has been researching issues of energy and climate since 1978 as a member of Jason, an independent group of scientists who advise the government on major policy questions, and he is increasingly concerned that controversies over climate change and energy have become ominously political, and the debates are flaring beyond reason.

Richter's book is the clearest guide yet to the facts and issues of climate and energy - without smoke or mirrors.

Richter has no special interest, and his book's survey of all the evidence for climate change and all the available energy sources is a model of rational discourse in this time of inflammatory arguments." -SF Chronicle

Stephen M. Curry

★★★★★ **Finally a reasonable voice in the climate debate**

Reviewed in the United States on July 8, 2010

Verified Purchase

Customer reviews

★★★★½ 4.3 out of 5

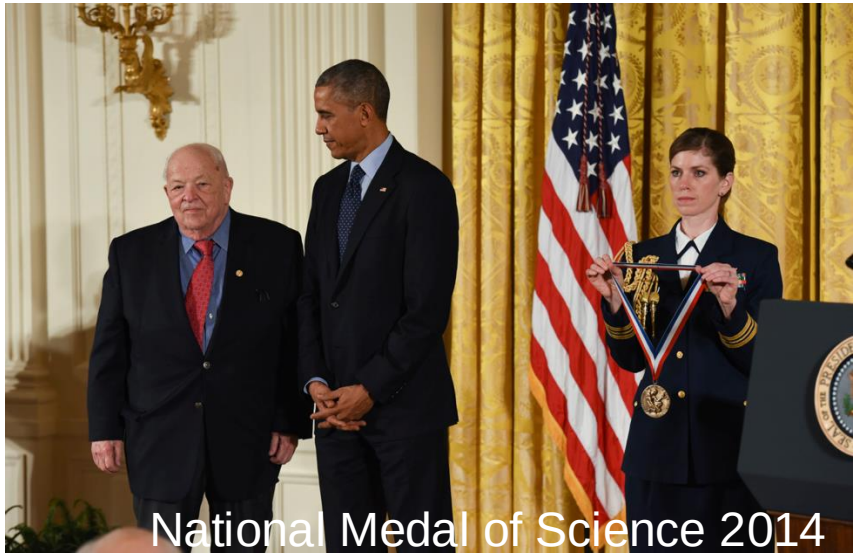
26 global ratings

5 star	73%
4 star	10%
3 star	0%
2 star	5%
1 star	11%

Burt: Major Awards

Nobel Prize in Physics 1976

Fermi Medal 2012



National Medal of Science 2014

Burt: Community Service

RICHTER ELECTED VICE PRESIDENT, COUNCIL IS EXPANDED

Members of The American Physical Society have elected Burton Richter, director of the Stanford Linear Accelerator Center, to be the society's next vice president. Richter's term begins in January, when he will succeed Donald Langenberg of the University of Maryland, who will become president-elect. Richter will become president in 1994. The 1992 president is Ernest M. Henley of the University of Washington.

In his candidate's statement Richter said that APS should increase its efforts to inform government officials and the general public of the intellectual and practical benefits of physics research. In particular, he said APS should emphasize the importance of achieving a balance between big science projects and basic research. He also mentioned the need to bridge the gap between physicists in industry and academia.


Burton Richter

PHYSICS TODAY DECEMBER 1991 87

APS President 1992-1995
IUPAP President 1999-2002
Member of JASON

International Union of Pure and Applied Physics

To stimulate and facilitate international cooperation in physics and the worldwide development of science.

The Role of IUPAP

Presented at the Third World Congress of Physical Societies
Berlin, Germany
December 15-16, 2000

Burton Richter, President
International Union of Pure and Applied Physics

Mission

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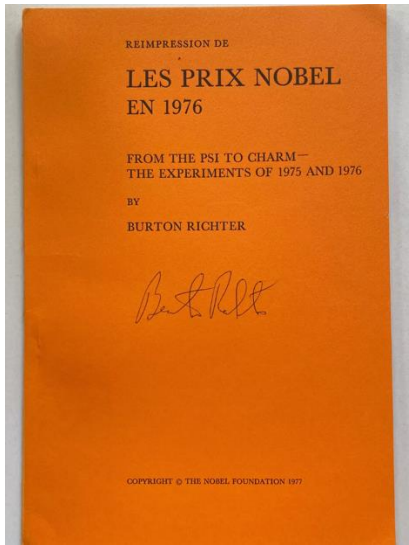
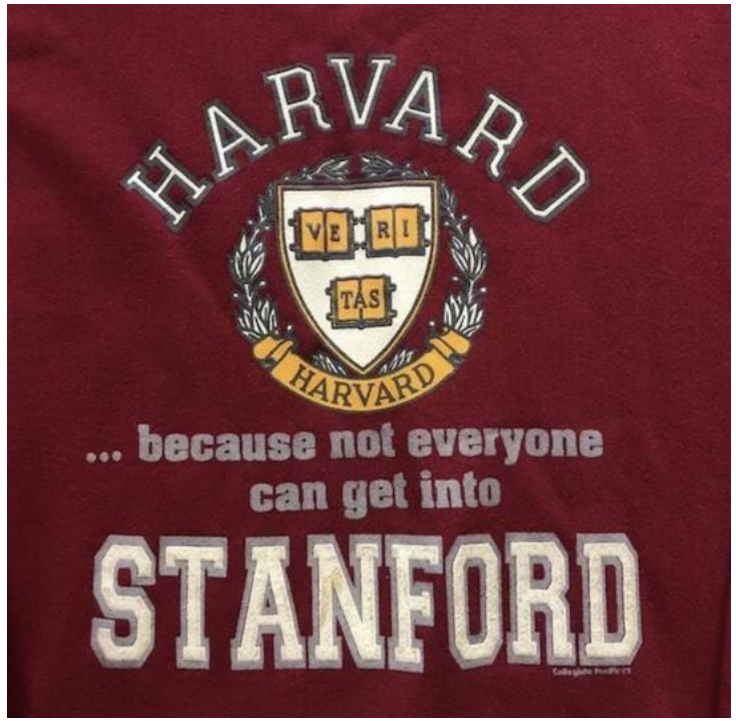


Burt: His Sense of Humor



1994: Only time I have seen Burt lose it.

SLAC DEPARTMENTAL COLLOQUIUM

Advantages of Hadron Fixed Target Experiments over e^+e^- Colliders for B Physics

Speaker: Prof. Burton Richter
SLAC

April 1, 1996

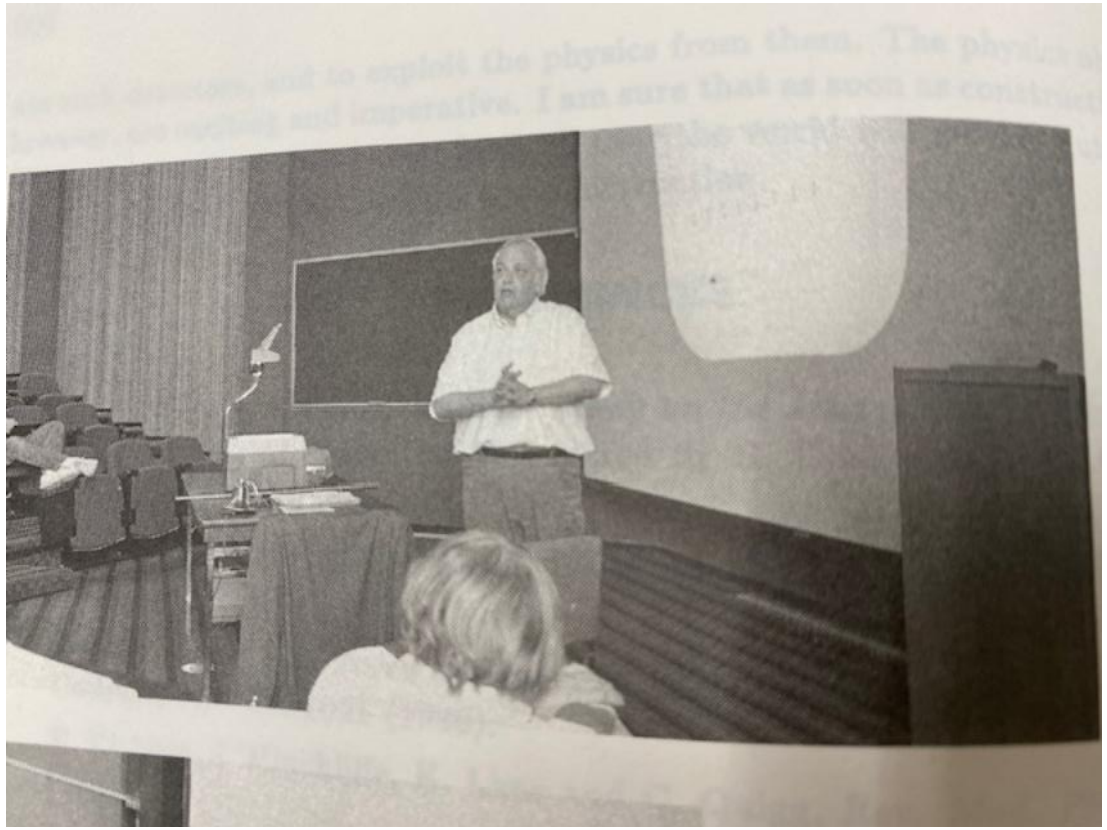
4:15 PM

Due to routine ES&H surveys in progress in the Large Auditorium, the venue will be Building 117 with overflow seating in Building 61.

Refreshments – 3:45 P.M. – Beluga Caviar, Pâté de Foie Gras, Cold Lobster, 1985 Pol Roger Cuveè Sir Winston Churchill, 1961 Chateau Petrus, and 1945 Domaine de la Romannee-Conti

Dinner – 7:00 P.M. Pacific's Edge Restaurant, Carmel

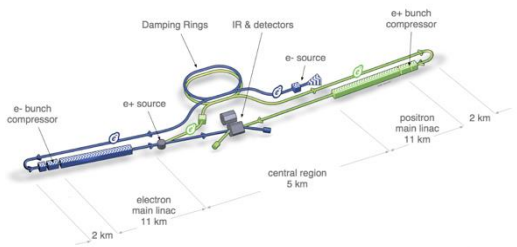
Burt: Some Personal Comments

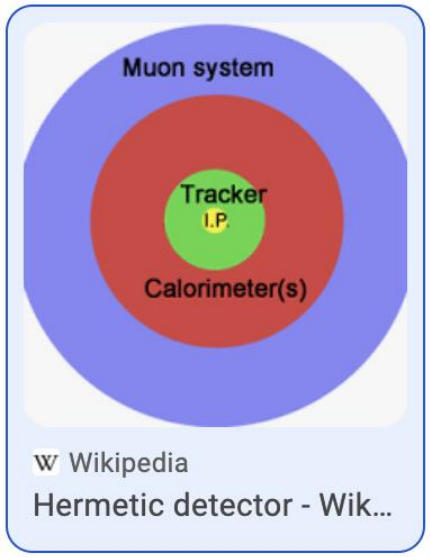


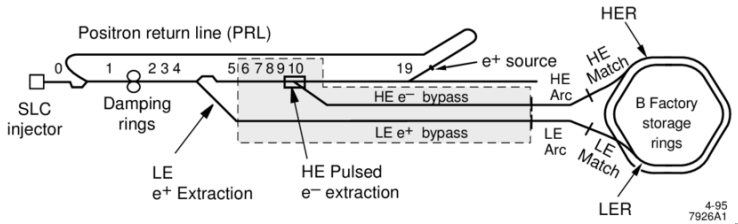
TASI lecture, UC Santa Cruz 1986

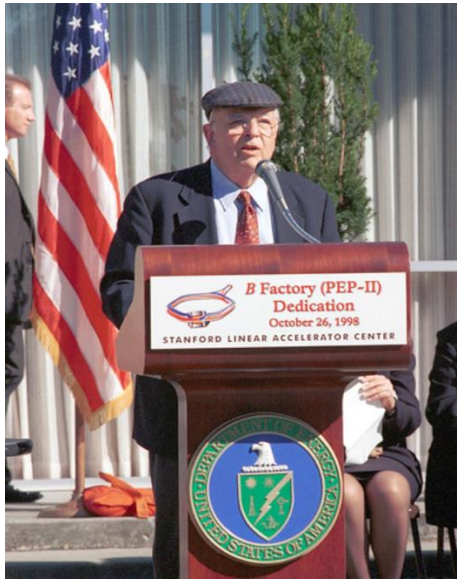
- Burt's office was in the midst of the theory group
- My first impression was "sink or swim"
- Could be quite gruff
- I ended up swimming (it took awhile)
- He became a father-figure, routinely checked in, never offered advice unless asked
- Would go out of his way to help if he could
- He and Laurose liked my tomatoes

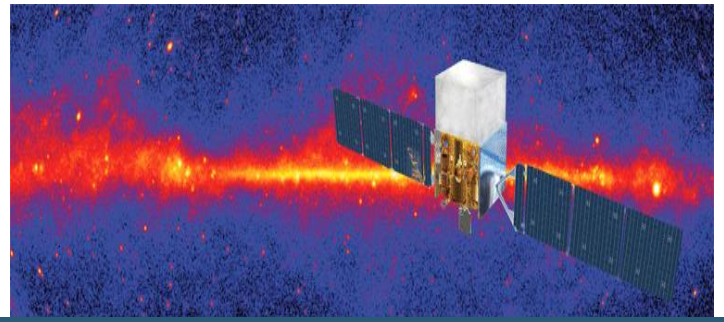
Burt: The Legacy

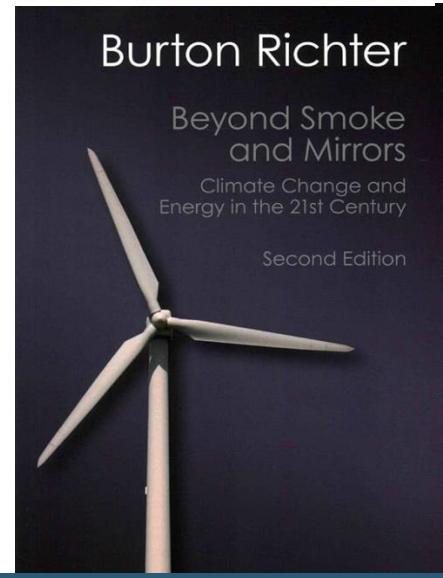




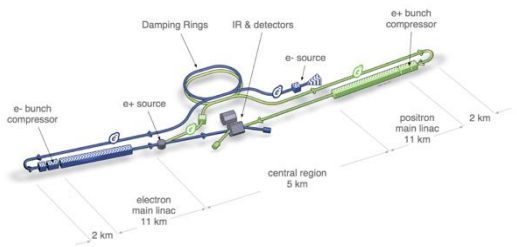


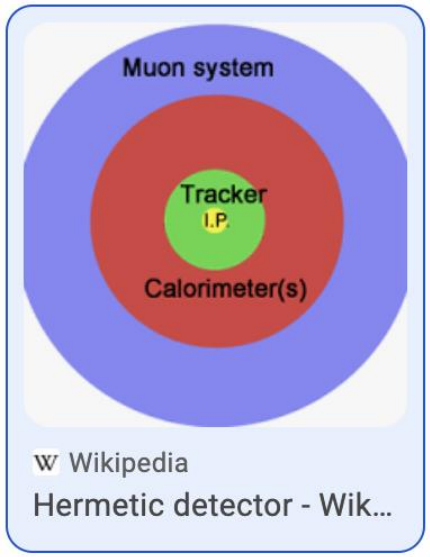


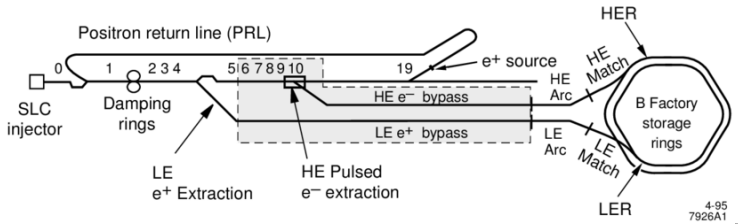


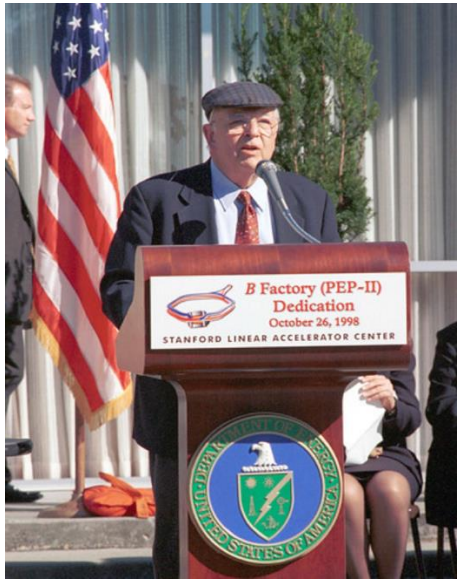


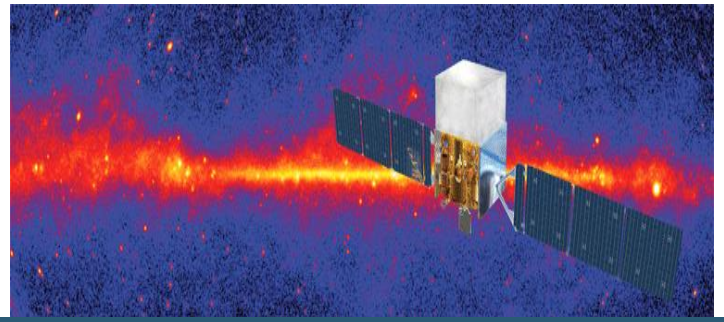
Burt: The Legacy

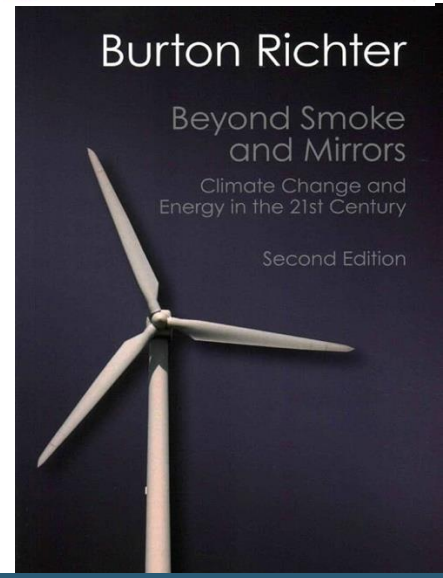












Burt's last words to me: "What is next for SLAC?"