Bruce Winstein

Early History

- Bruce was born in 1943 in Los Angeles, and attended primary and secondary school (University High) in LA
- He got his BA at UCLA in 1965 and his PhD from Caltech in 1970 ("Recoil Proton Polarization in η photoproduction")
- 1970-1972: Postdoc with MPI Munich working at CERN. He proposed and led a free quark search at the ISR.
- 1972: Came to the University of Chicago as a senior research associate; he joined the faculty in 1976.
- In Chicago, he initially worked with Telegdi on a series of experiments on K_S regeneration, including a classic measurement of the charge radius of the K^0.

Joan and Bruce in 1973

PUBLIC LECTURE SERIES

Sponsored by the ENRICO FERMI INSTITUTE
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UNIVERSITY OF CHICAGO

THE ARTHUR H. COMPTON LECTURES

First Series by

Bruce D. Winstein
Enrico Fermi Institute

Saturdays January through March 1976

"What's Interesting About Elementary Particles"

This first series is designed to give the curious individual an exposure to what we are doing today in experimental High Energy Physics, and will convey the excitement of recent discoveries at the high energy accelerators. In addition to new phenomena, aspects of particle physics which are well-understood will be presented, with an emphasis on the simplicity of the description of just how nature works on the scale of the very small.

There will be ten lectures, to be given on successive Saturdays, beginning January 17, 1976, in Eckhart Hall, Room 133, University of Chicago, 58th St. and University Avenue.

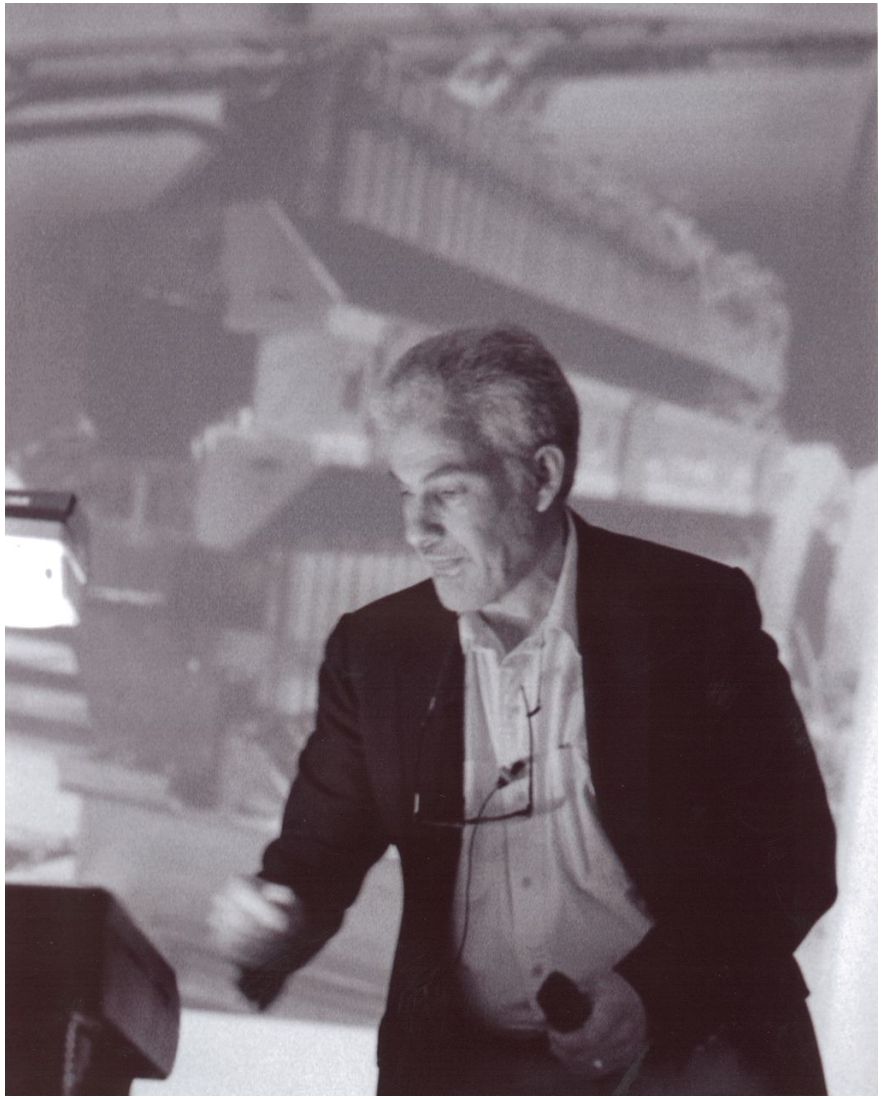
Reading lists will be provided for each lecture.

First Lecture: "Why High Energy"

Saturday, January 17, 1976 at 11 A.M.
Eckhart Hall-Room 133-1132 E. 58th St.

For further information, phone 753-8302.

The Search for Direct CP Violation



For more than two decades, starting in 1979, Bruce led a series of beautiful experiments at Fermilab to measure direct CP violation in the neutral kaon system.

CP Violation

In 1964, Christenson, Cronin, Fitch, and Turlay observed $\pi^+\pi^-$ decays from long-lived kaons ➔ **CP Violation**

Indirect vs. Direct CP Violation:

- "Indirect" - asymmetric $K^0 - \bar{K}^0$ oscillations

$$K_s \sim (1+\varepsilon)K^0 + (1-\varepsilon)\bar{K}^0$$
$$\sim K_{even} + \varepsilon K_{odd}$$
$$K_L \sim (1+\varepsilon)K^0 - (1-\varepsilon)\bar{K}^0$$
$$\sim K_{odd} + \varepsilon K_{even} \rightarrow \pi\pi$$

$|\varepsilon| = 2.28 \times 10^{-3}$

- "Direct" - CP violation in decay amplitude

  $K_{odd} \rightarrow \pi\pi$, parameterized by ε'

$$K^0 \rightarrow \pi^+\pi^- \neq \bar{K}^0 \rightarrow \pi^+\pi^-$$

To distinguish between direct and indirect CP violation, we compare decays to different final states.

If $$\frac{K_L \to \pi^+\pi^-}{K_S \to \pi^+\pi^-} \neq \frac{K_L \to \pi^0\pi^0}{K_S \to \pi^0\pi^0},$$

then CP is violated in decay amplitude (i.e., direct CP violation).

$$\mathrm{Re}(\varepsilon'/\varepsilon) \approx \frac{1}{6}\left[\frac{\Gamma\left(K_L \to \pi^+\pi^-\right)/\Gamma\left(K_S \to \pi^+\pi^-\right)}{\Gamma\left(K_L \to \pi^0\pi^0\right)/\Gamma\left(K_S \to \pi^0\pi^0\right)} - 1\right]$$

$\varepsilon'/\varepsilon \neq 0$ ⟹ direct CP violation

Predictions:

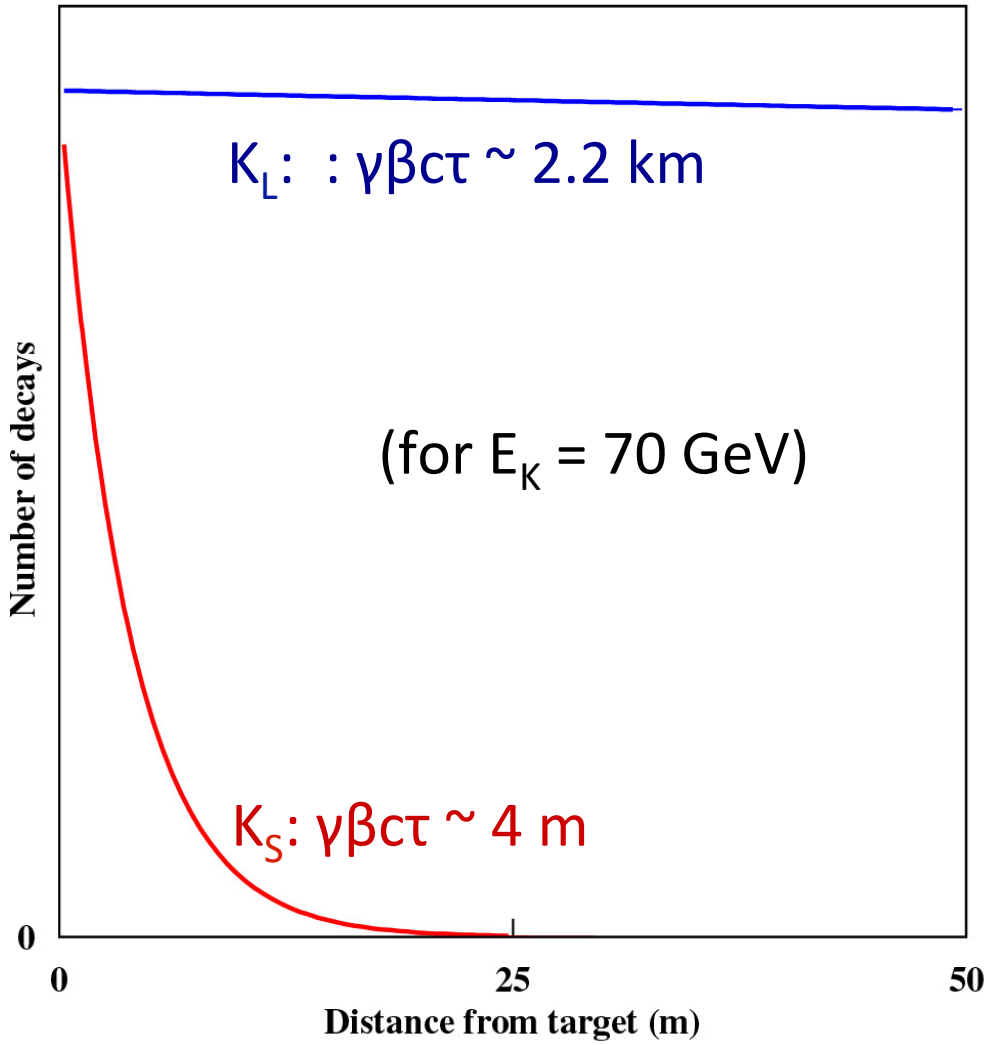
- Standard Model: $\mathrm{Re}(\varepsilon'/\varepsilon) \sim (0\text{-}30)\times 10^{-4}$

(first calculations by Ellis, Gaillard, and Nanopoulos in 76)

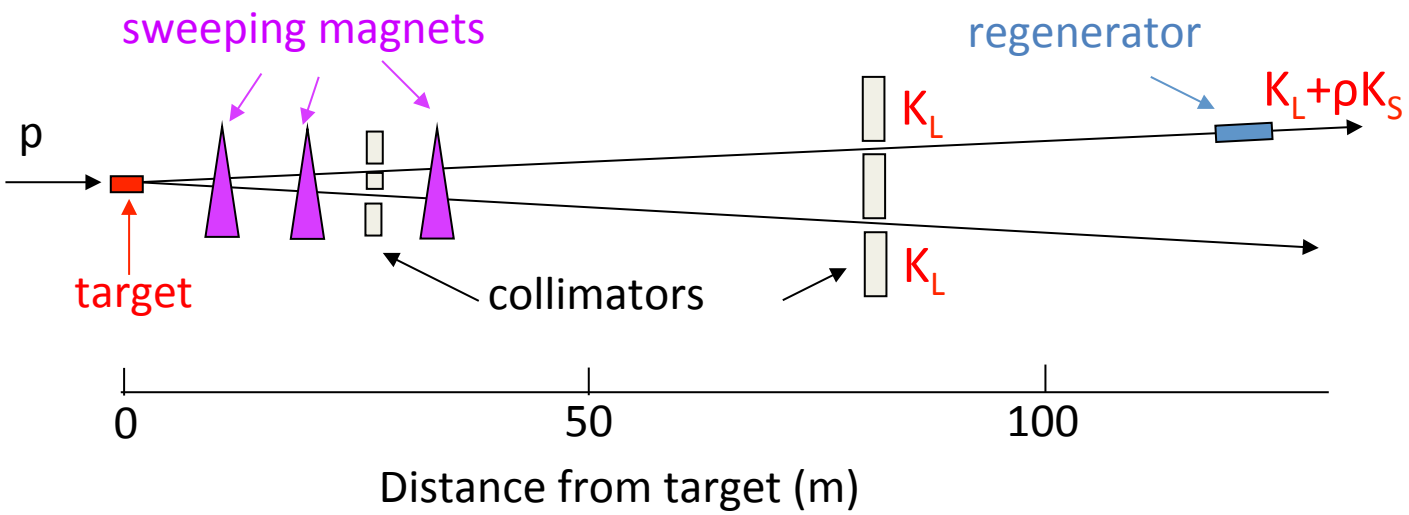
- Superweak Model: $\mathrm{Re}(\varepsilon'/\varepsilon) = 0$

Experimental problem / challenge: Collect large numbers of events in each decay mode with excellent systematic precision.

⟶ Best to collect all modes simultaneously.

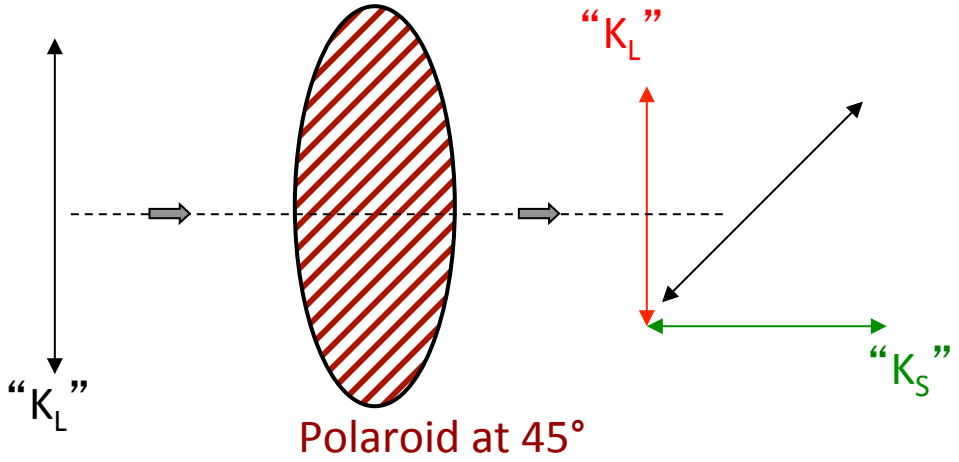


Double Beam Technique



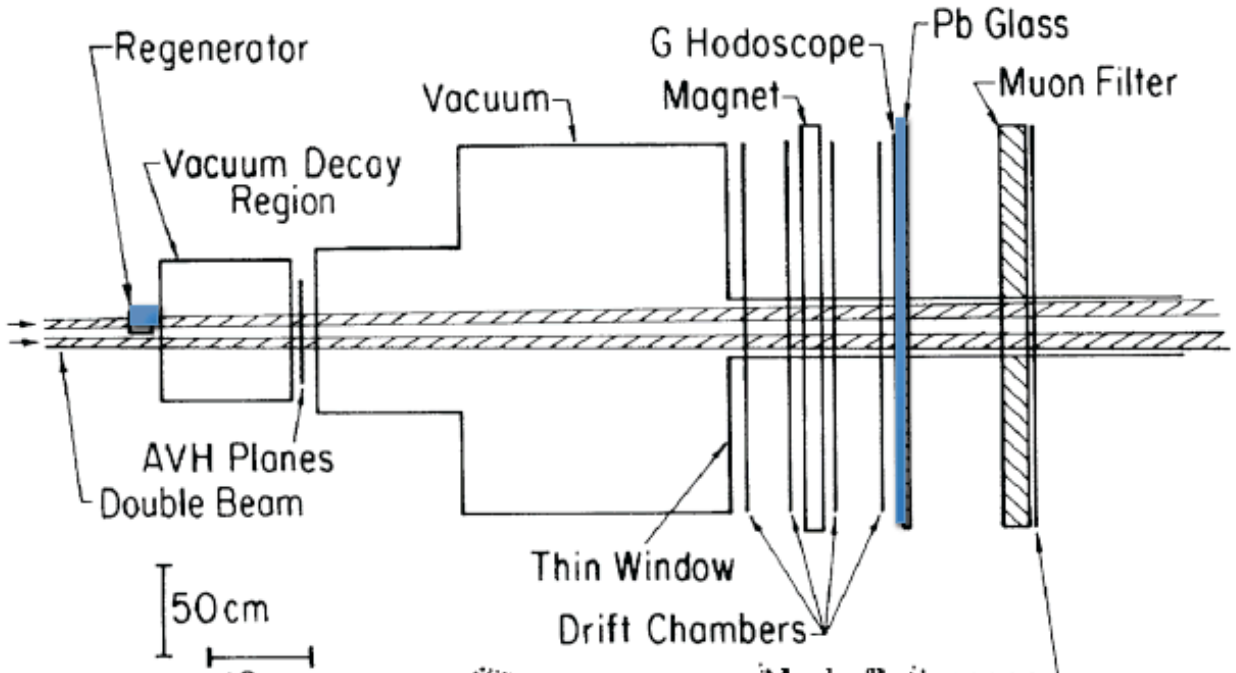
Kaon regeneration: $K_L \sim K^0 - \overline{K}^0 \Rightarrow \boxed{\begin{array}{l}\sigma(\overline{K}^0 N) \\ > \sigma(K^0 N)\end{array}} \Rightarrow K_L + \rho K_S$

Process is analogous to passing polarized light through a filter that transmits at 45°.



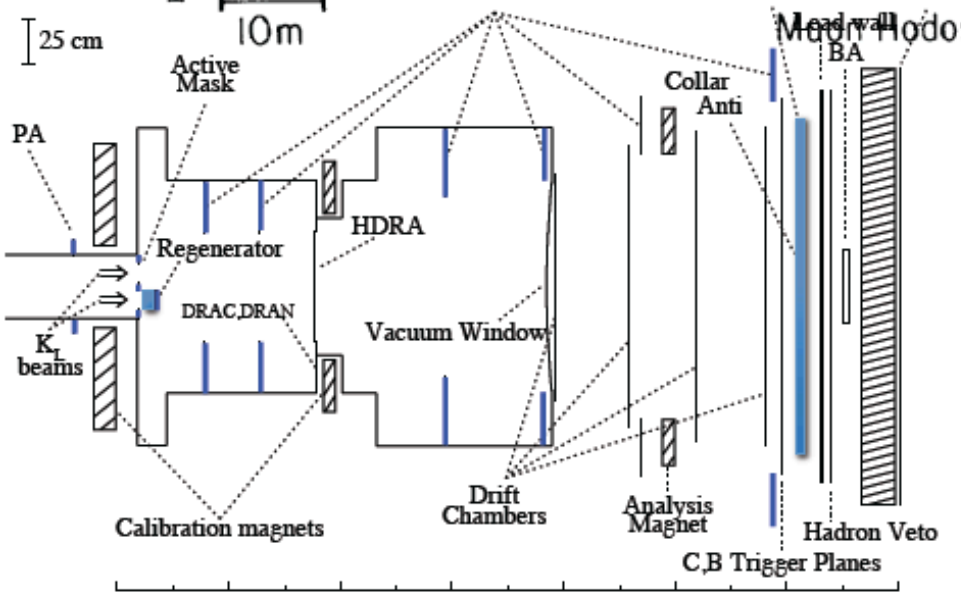
The Detectors

E617



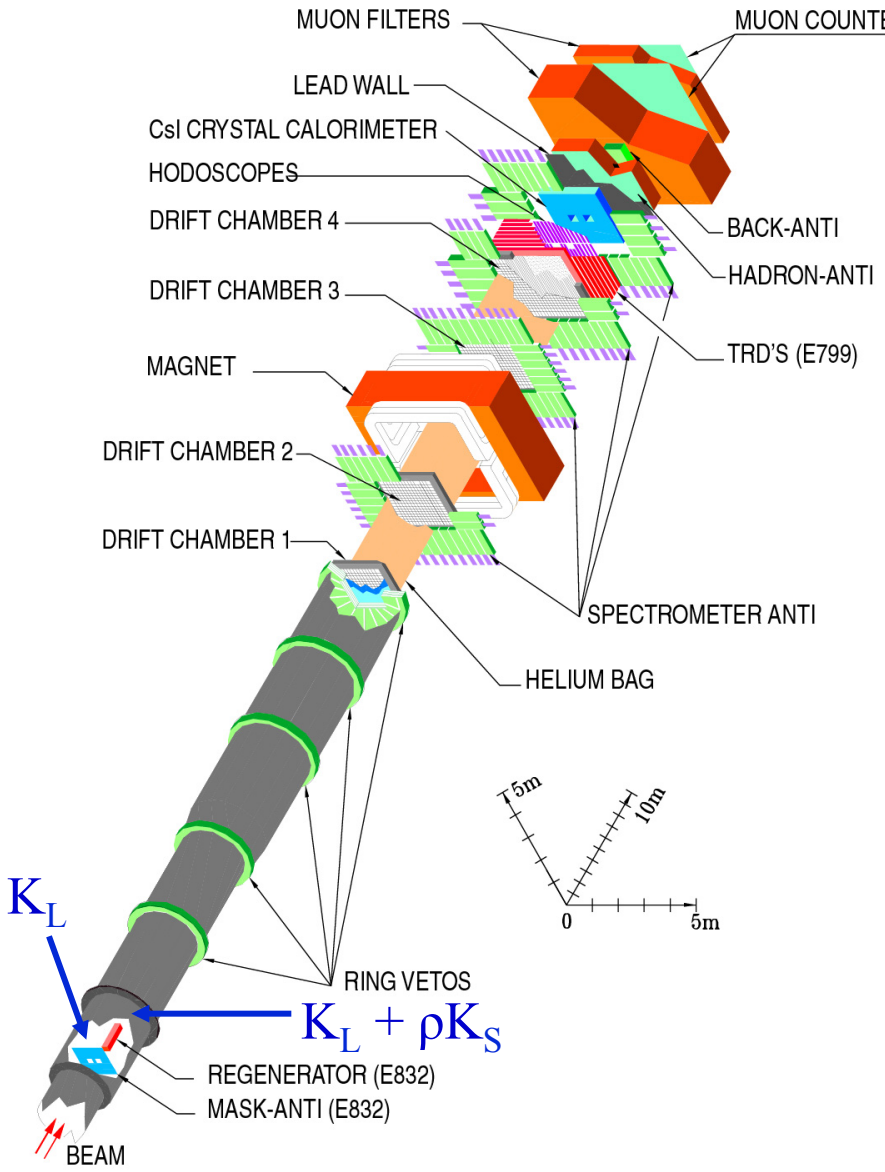
~3k $K_L \rightarrow \pi^0\pi^0$ events

E731



~400k $K_L \rightarrow \pi^0\pi^0$ events

KTeV Detector

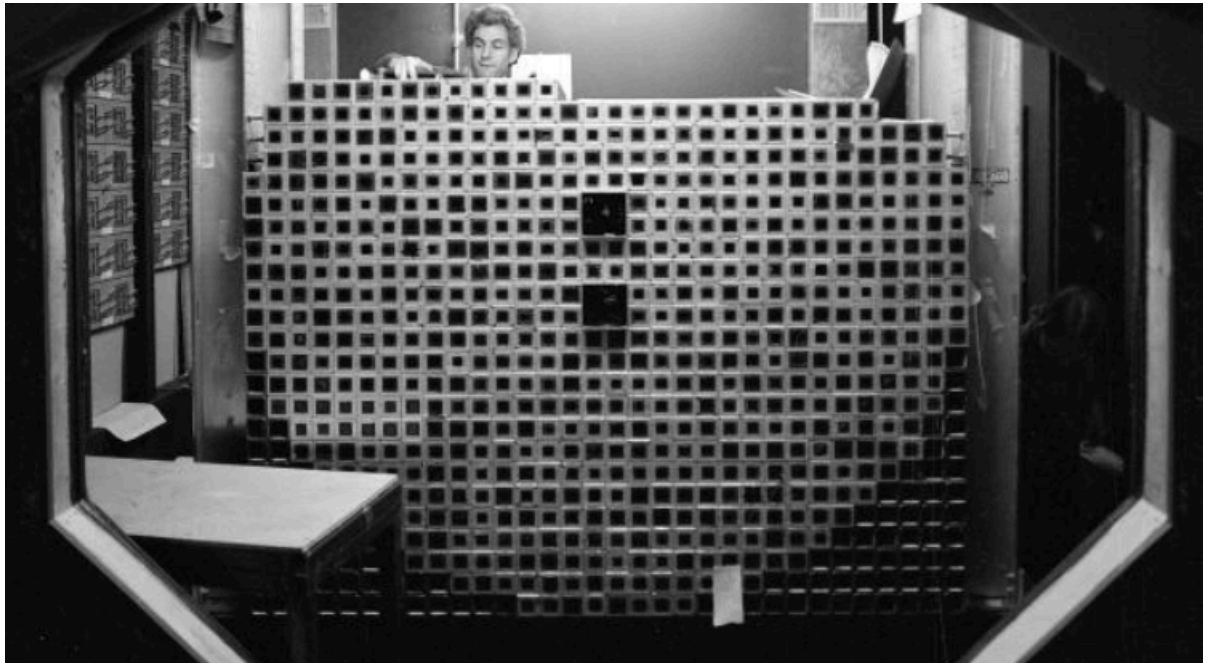


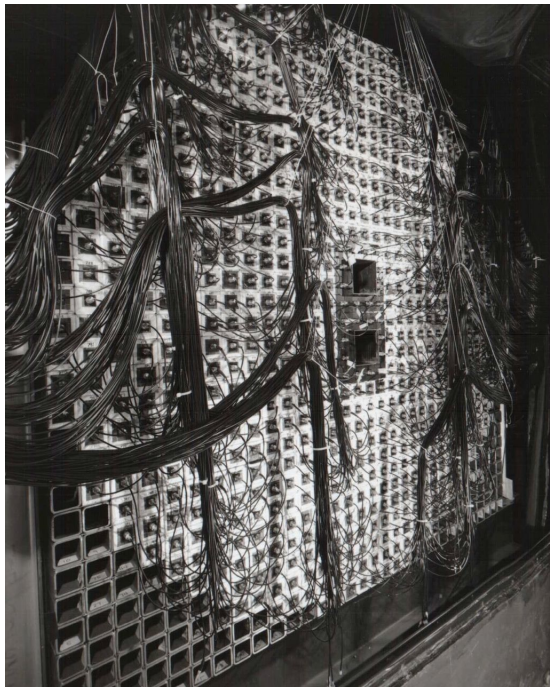
- Charged particle momentum resolution < 1% for p>8 GeV/c; momentum scale known to 0.01% from $K \rightarrow \pi^+\pi^-$

- CsI energy resolution < 1% for $E_\gamma > 3$ GeV; energy scale known to 0.1% from $K \rightarrow \pi e \nu$.

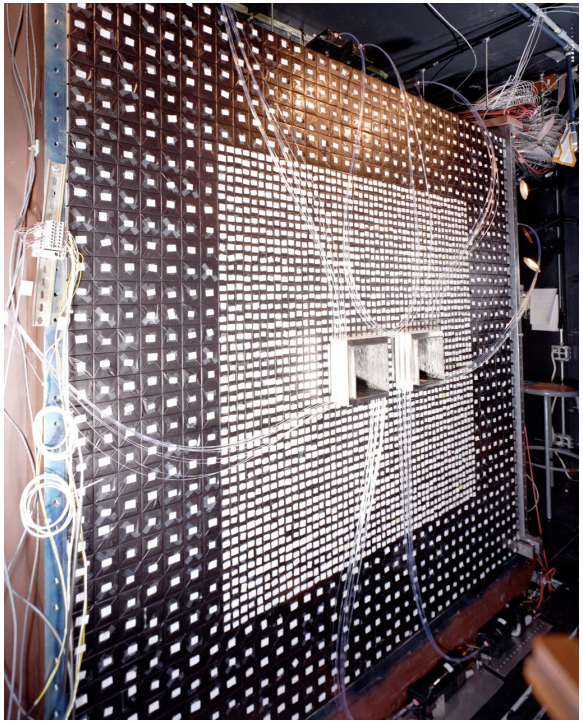
~6 million $K_L \rightarrow \pi^0\pi^0$ events

Restacking Lead Glass for E731





Stacking the last CsI Crystal for KTeV



$K_S \rightarrow \pi^+\pi^-$

KTEV Event Display

Run Number: 9097
Spill Number: 210
Event Number: 40284859
Trigger Mask: 1
All Slices

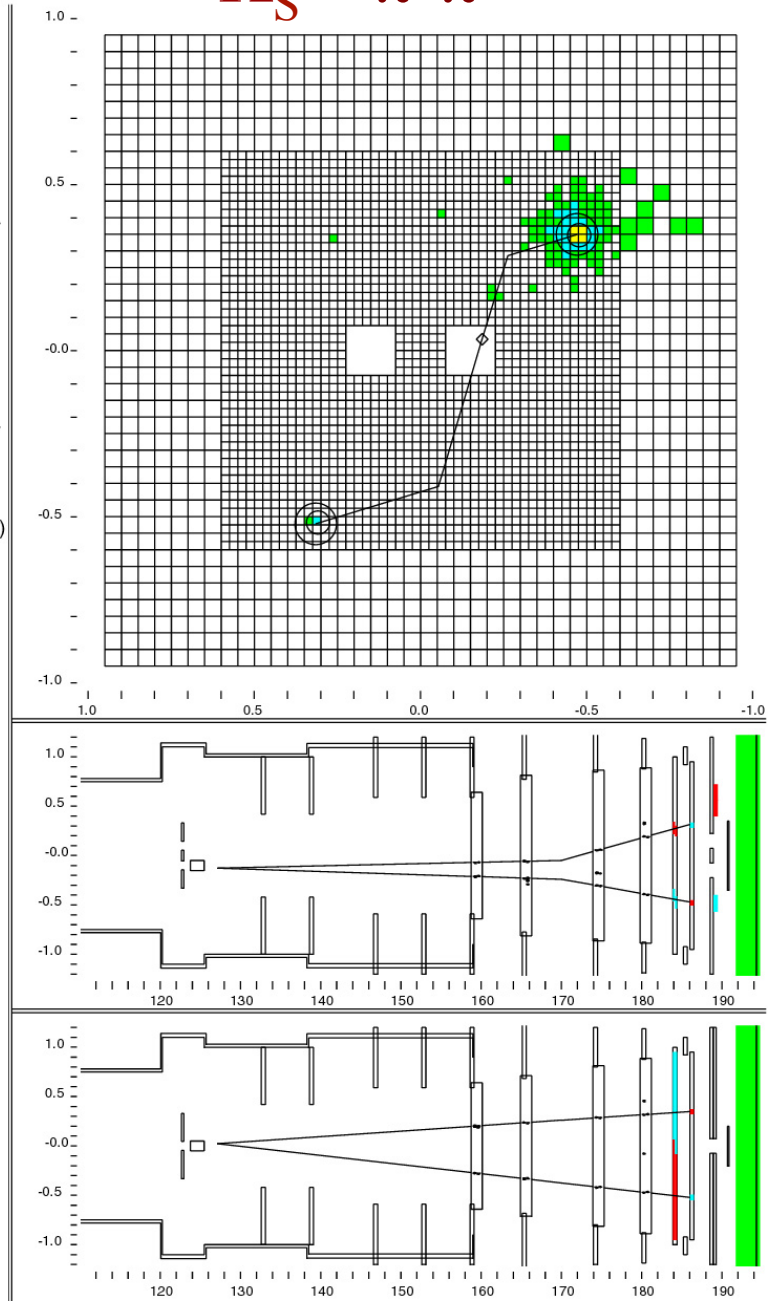
Track and Cluster Info
HCC cluster count: 2

ID	Xcsi	Ycsi	P or E
T 1:	-0.4710	0.3490	-34.98
C 2:	-0.4769	0.3477	17.30
T 2:	0.3155	-0.5218	+19.68
C 1:	0.3088	-0.5177	0.44

Vertex: 2 tracks

X	Y	Z
-0.1265	0.0232	127.122

Mass=0.4994 (assuming pions)
Chisq=0.00 Pt2v=0.000010



KTEV Event Display

/usr/kpasa/data06/data/postcard_2pi0.dat

Run Number: 6918
Spill Number: 3
Event Number: 337734
Trigger Mask: 8

All Slices

Track and Cluster Info

HCC cluster count: 4

ID	Xcsi	Ycsi	P or E
C 1:	0.5621	0.6272	1.41
C 2:	0.2722	0.0836	26.95
C 3:	0.2656	-0.1320	16.01
C 4:	-0.4359	-0.2878	8.03

Vertex: 4 clusters

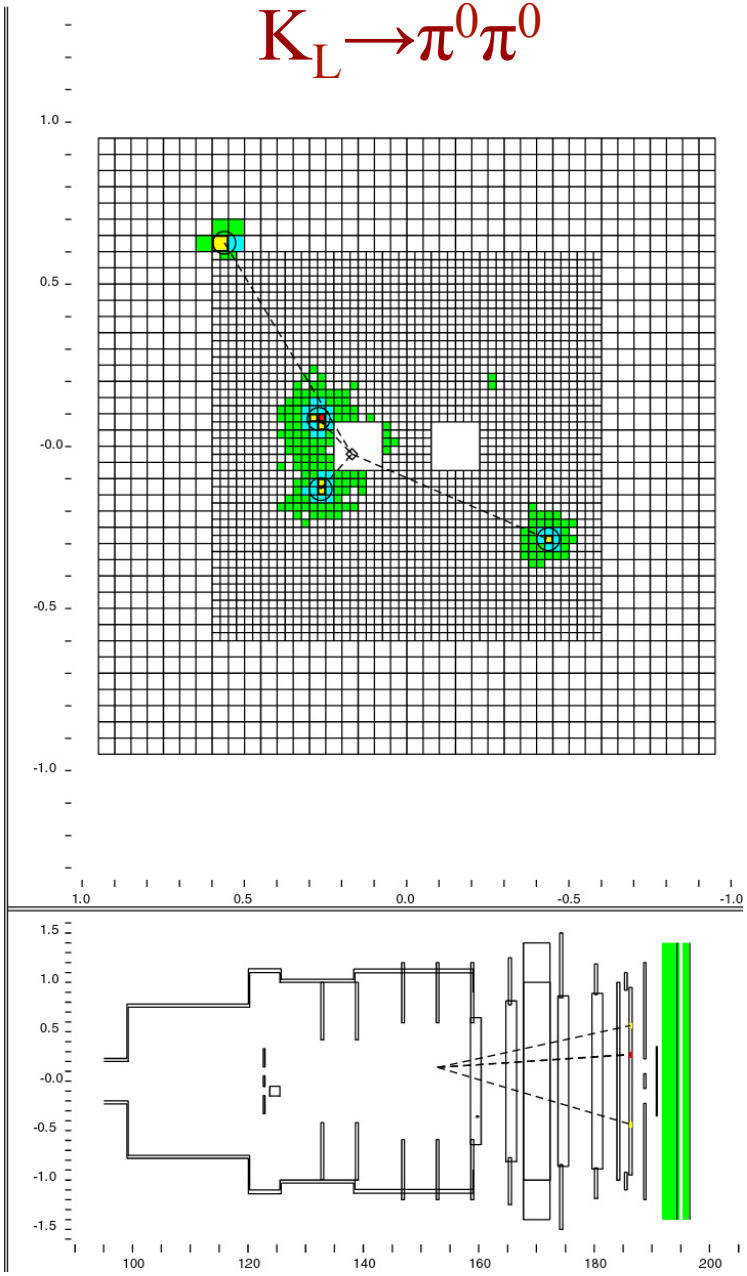
X	Y	Z
0.1390	-0.0202	152.811

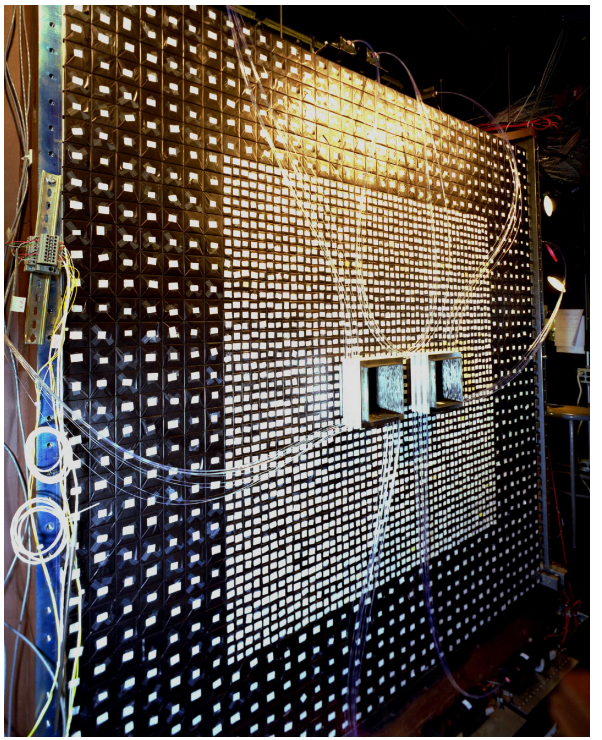
Mass=0.4969

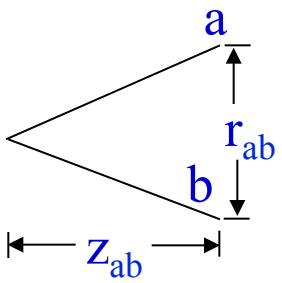
Pairing chisq=1.52

- 10.00 GeV
- 1.00 GeV
- 0.10 GeV
- 0.01 GeV

$K_L \rightarrow \pi^0\pi^0$

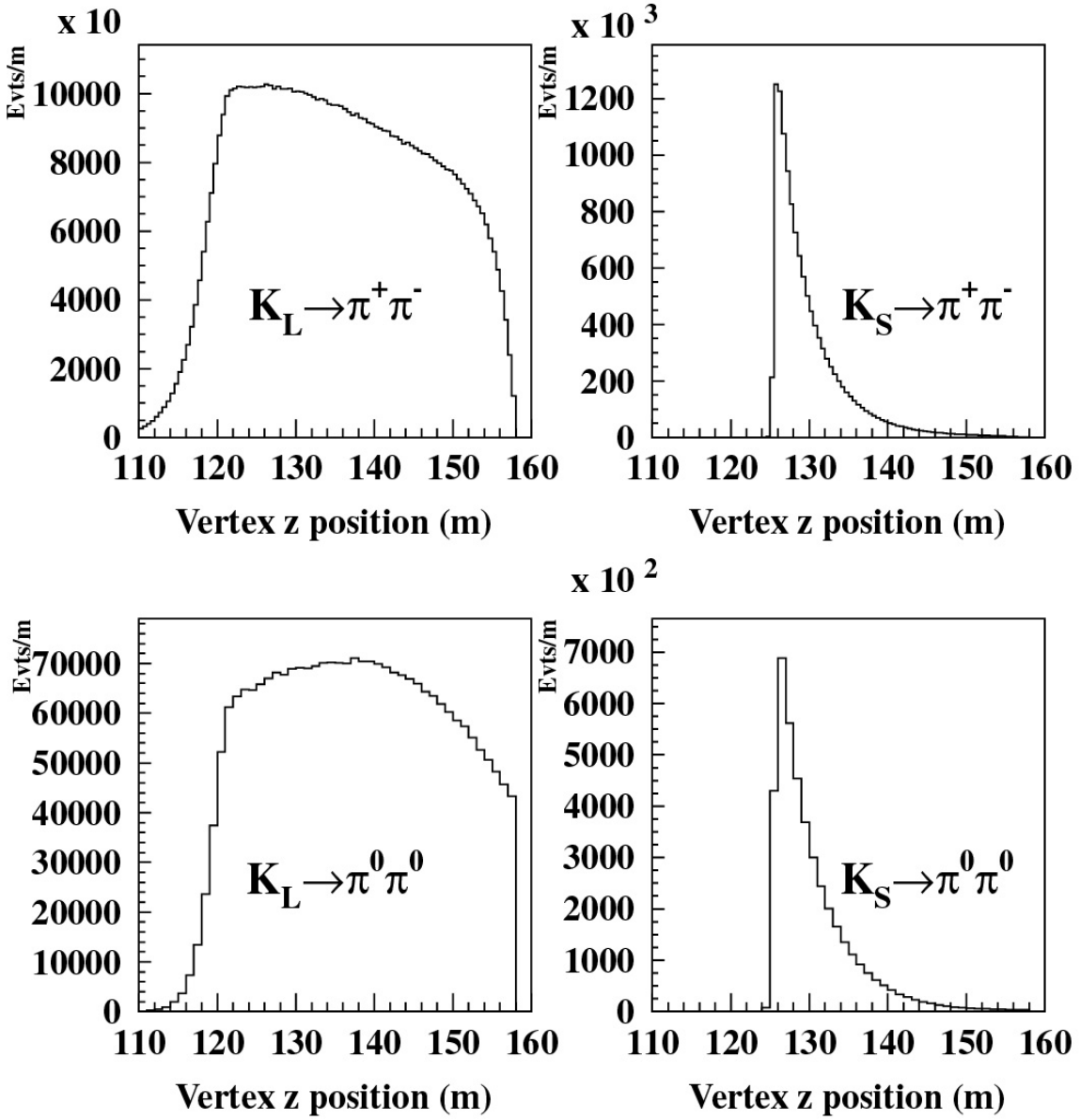






$$z_{ab}^2 \approx \frac{E_a E_b r_{ab}^2}{m_{\pi^0}^2}$$

Reconstructed Vertex z Distributions

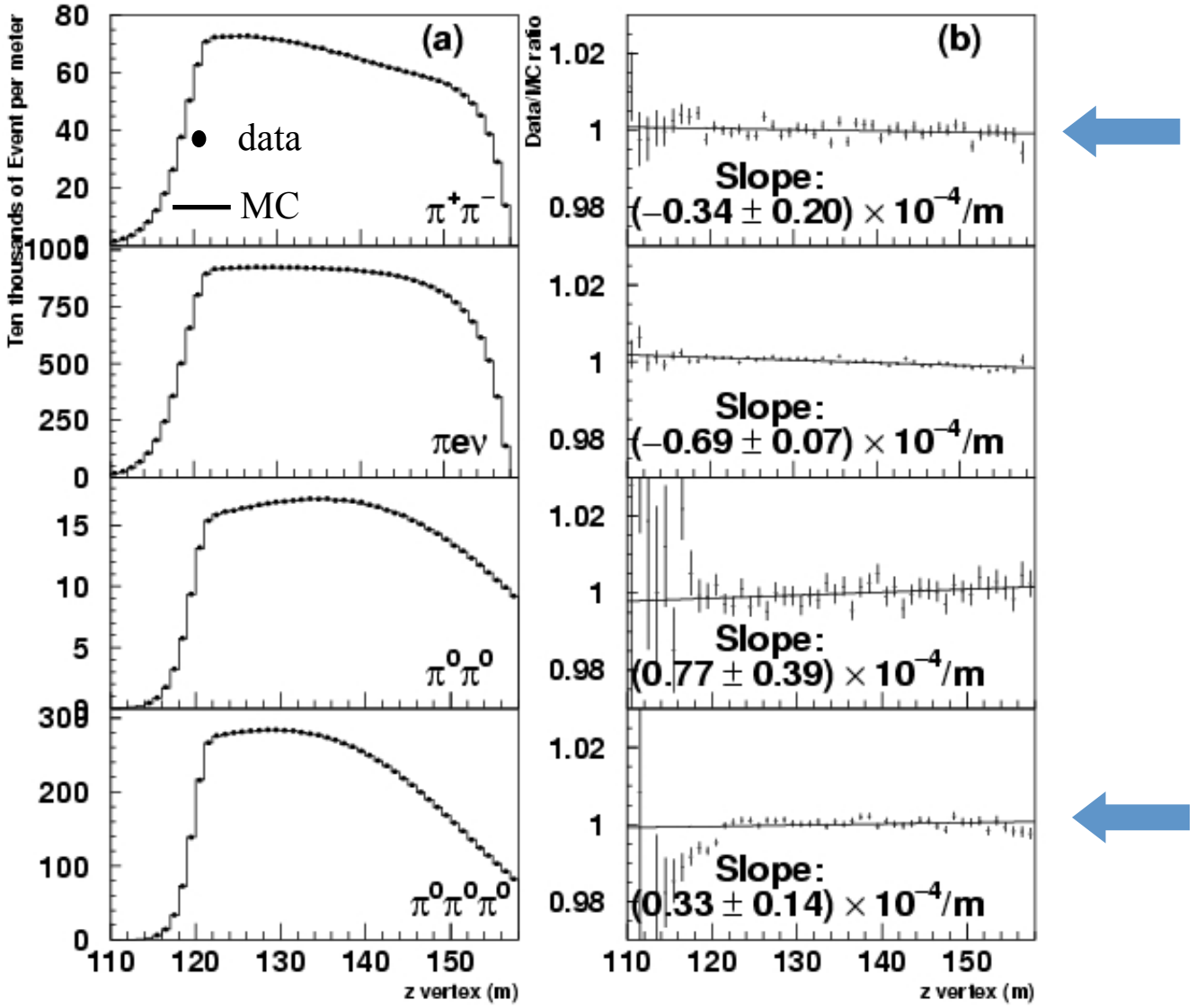


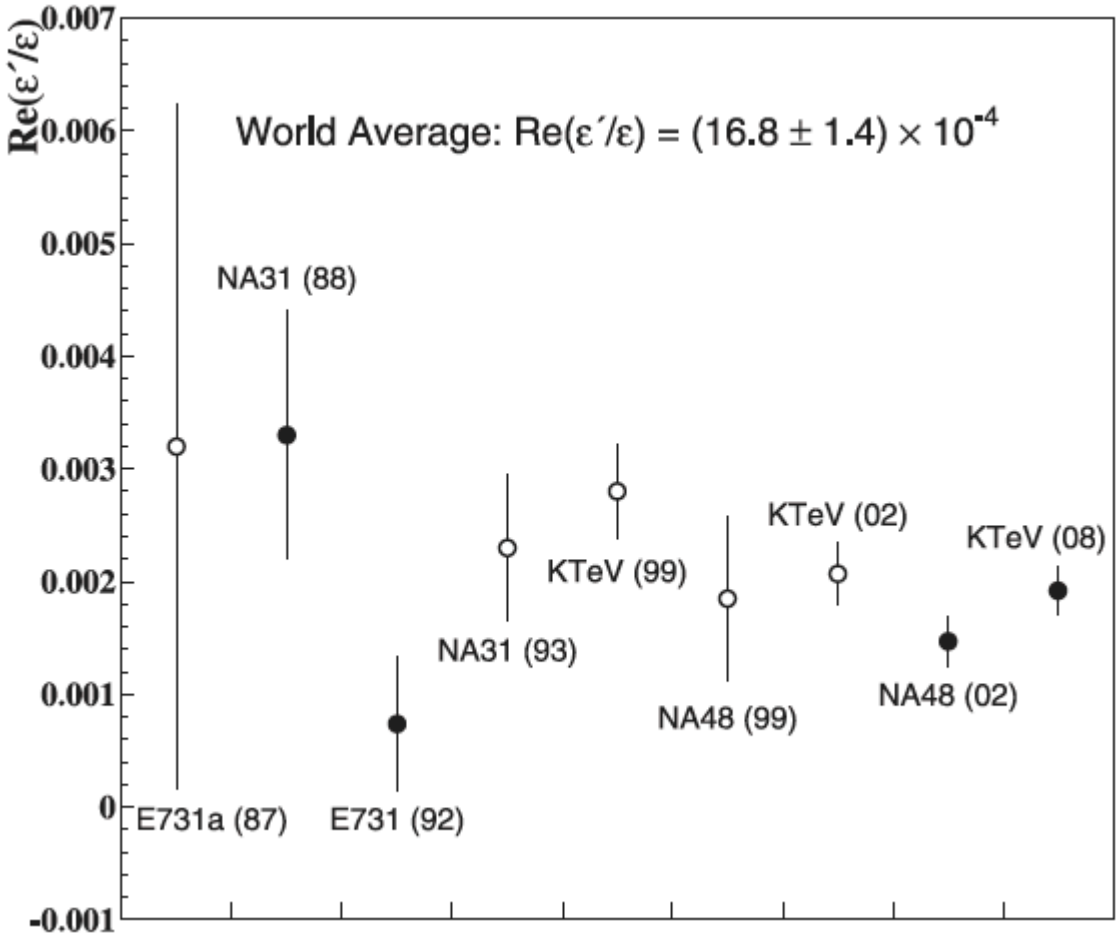
Data – MC comparisons of z vertex distributions

Difference between mean z vertex in reg and vac beams is about 6 m

⇒

$\delta \mathrm{Re}(\varepsilon'/\varepsilon)$ ≈ data/mc slope



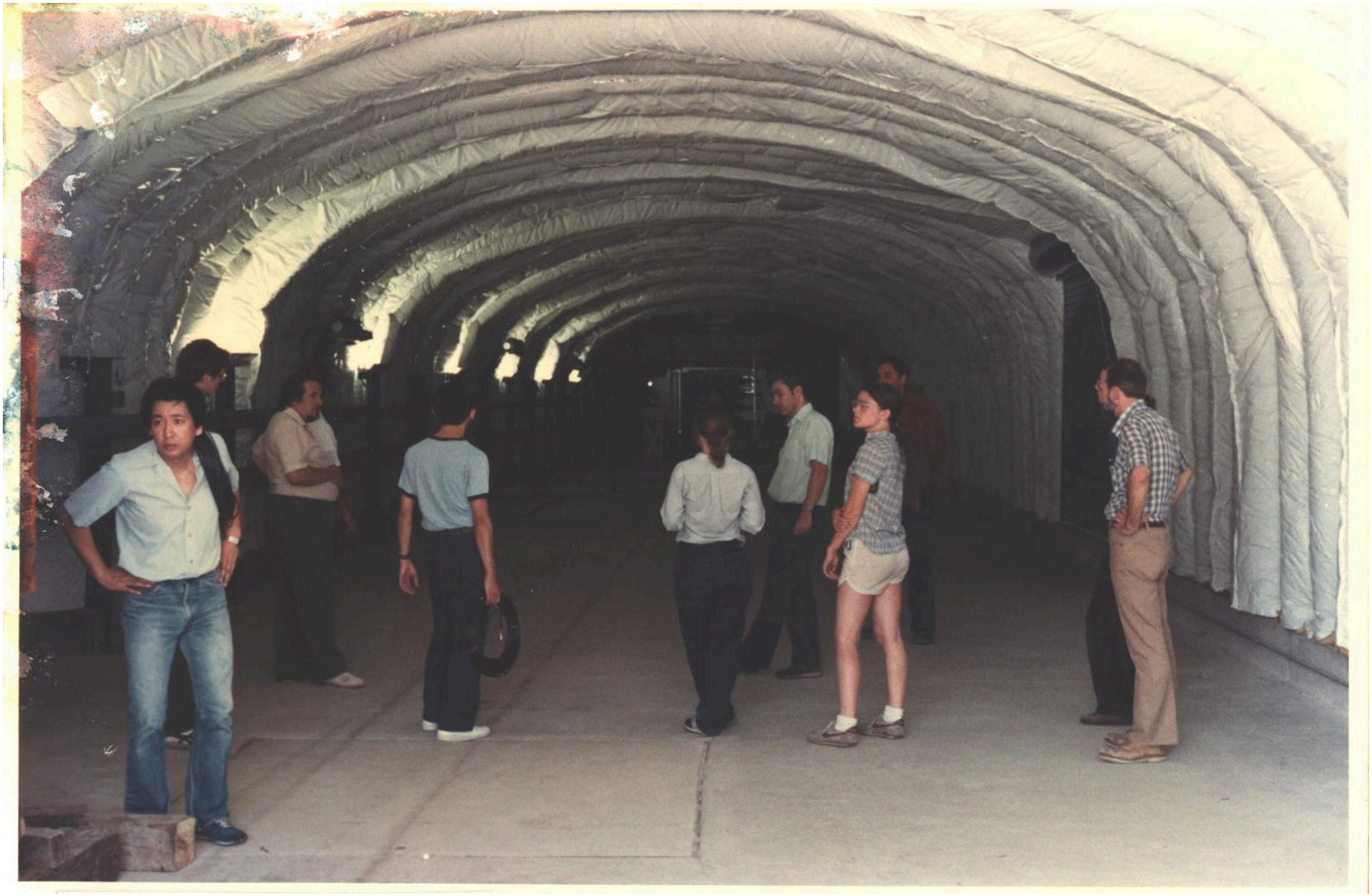


Observation of Re(ε′/ε)≠0 eliminated the Superweak Model as a viable explanation of CP violation, and strongly supported the complex phase in the CKM matrix as the source of CP violation.

E617 Group Meeting

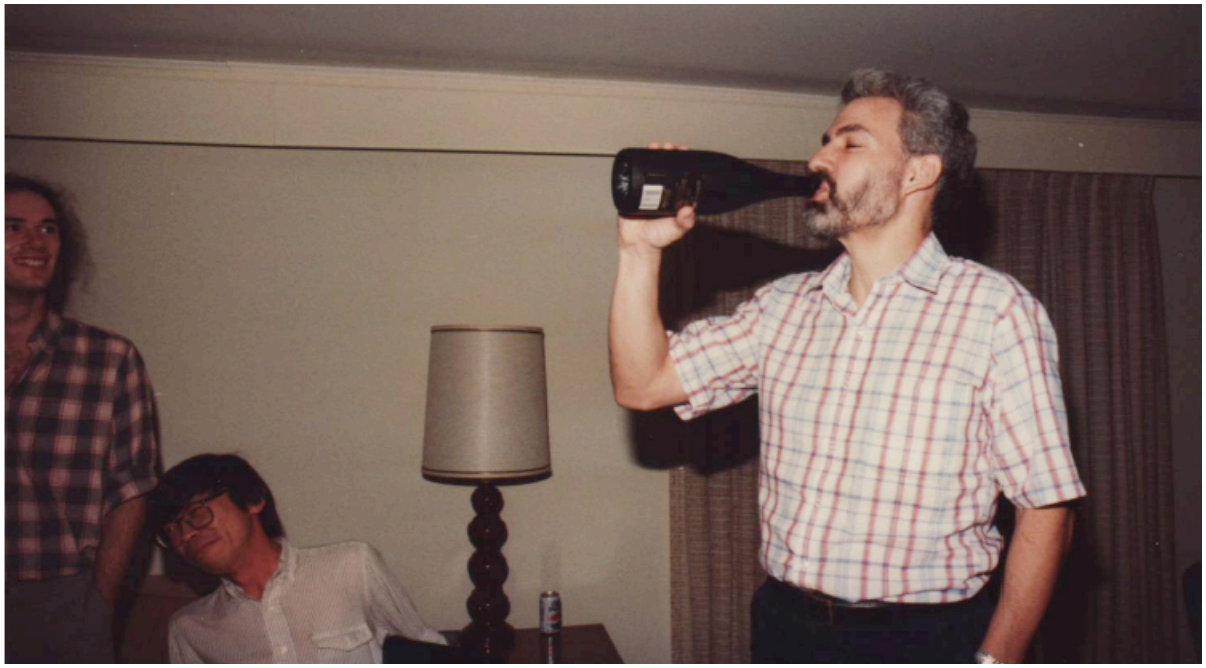
Bruce appreciated the beauty of Fermilab

Bruce appreciated the beauty of Fermilab



1984: The newly completed wonder building for E731

1989: First E731 Results




KTeV
E799 / E832
CHICAGO
COLORADO
ELMHURST
FERMILAB
OSAKA
RICE
RUTGERS
UCLA
UCSD
VIRGINIA
WISCONSIN

KTeV Control Room
1996

1997: KTeV End-of-Run Party

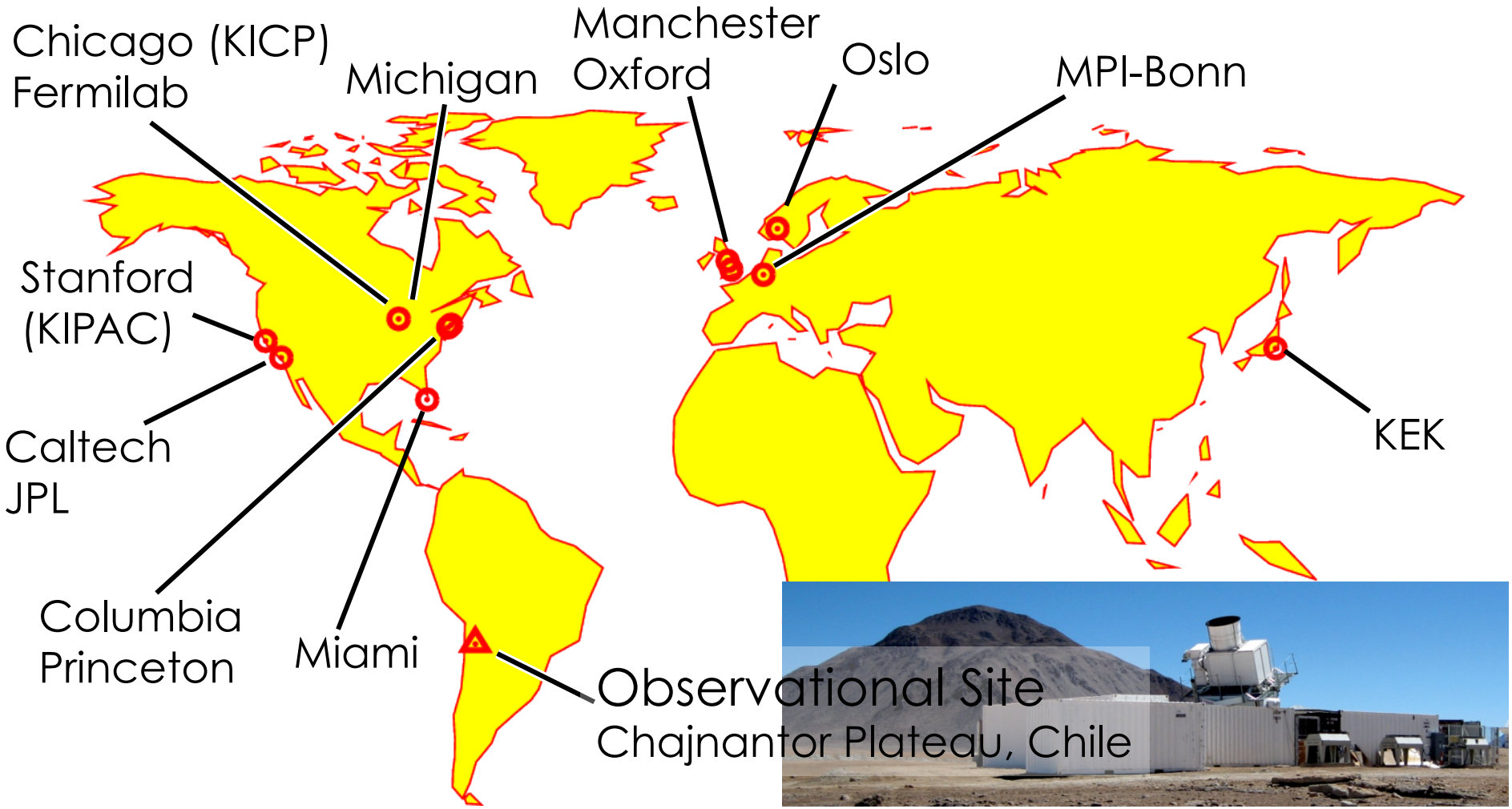
In 1999, Bruce decided to try something different.

After considerable reflection, he decided to try searching for the gravitational wave signature of inflation in the cosmic microwave background (CMB).

He took a sabbatical at Princeton to work with Suzanne Staggs on PIQUE.

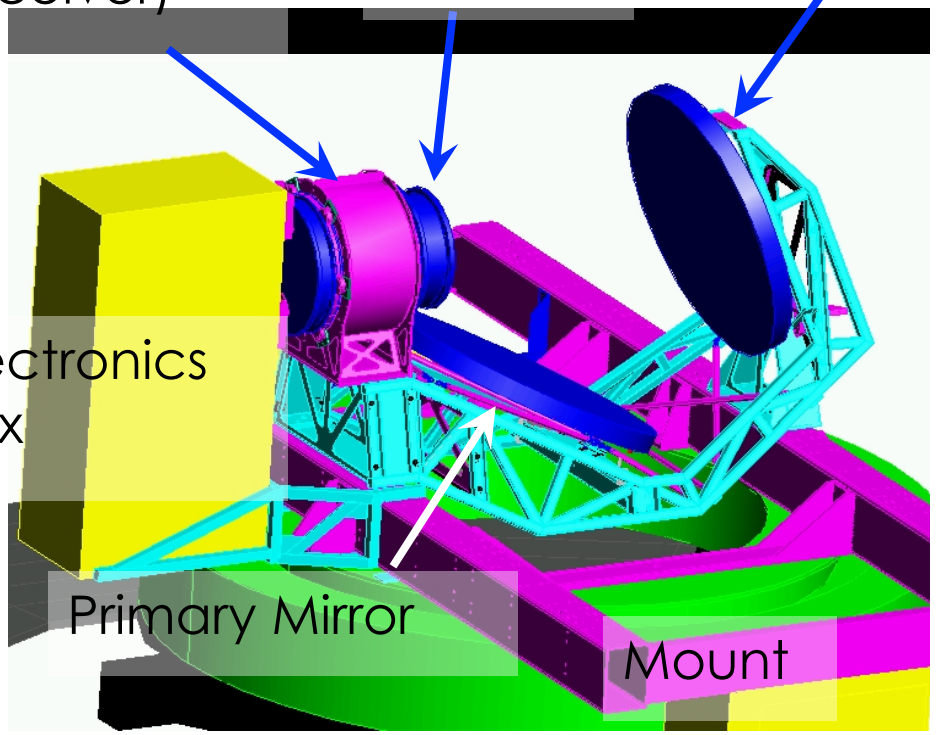
After returning to Chicago, he led the formation of what is now the Kavli Institute for Cosmological Physics, and continued to work on CMB experiments, eventually leading the QUIET experiment.

QUIET collaboration

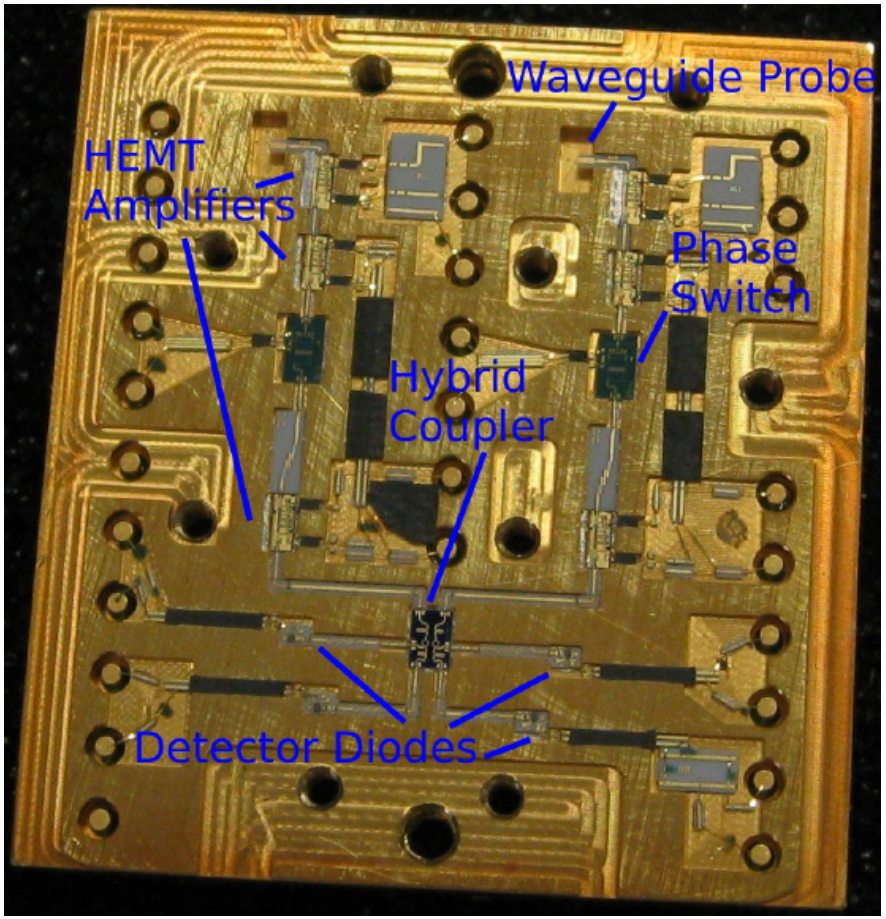


5 countries, 14 institutes, ~50 scientists

QUIET instrumentation



Key Technology: Polarimetor on Chip

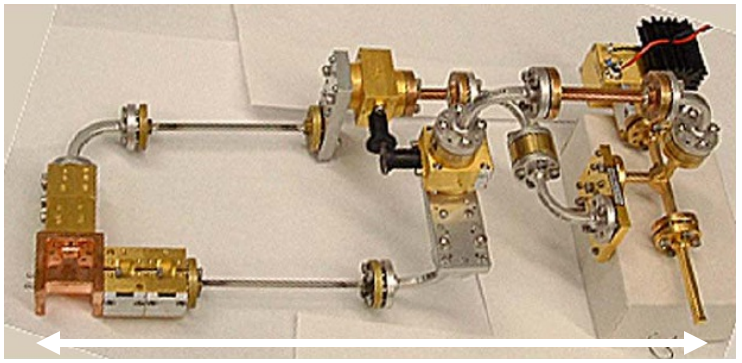


~3cm

QUIET HEMT Module

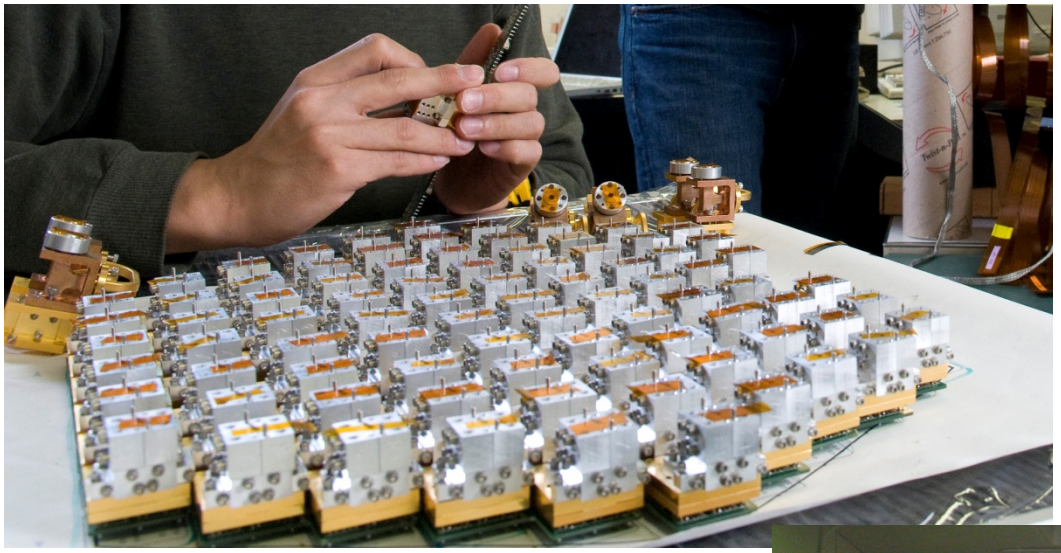
"Polarimetor On Chip"
A key technology for large array (JPL)

c.f. CAPMAP polarimeter



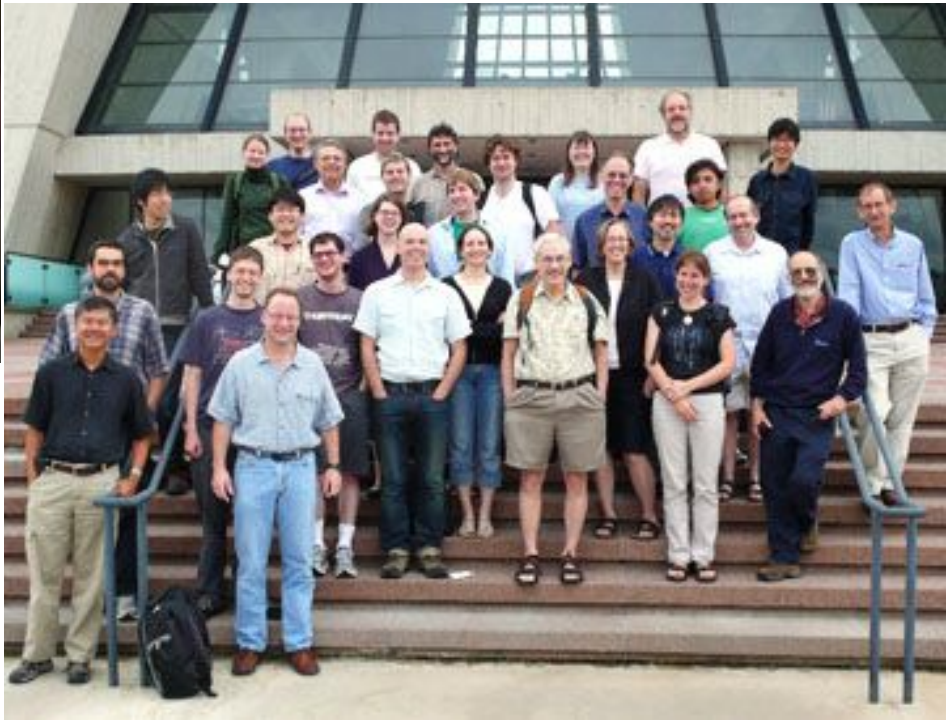
~30cm

QUIET W-band Array



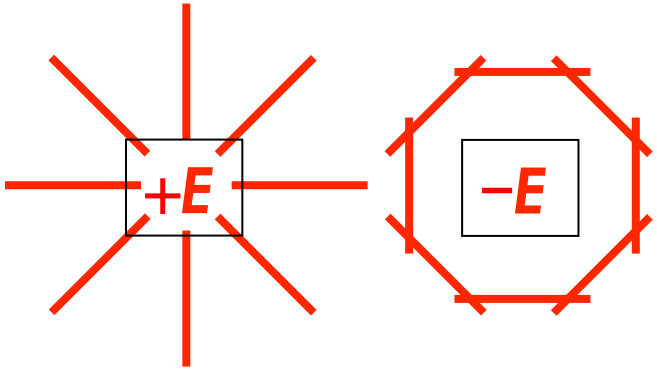
The world largest HEMT array polarimeter

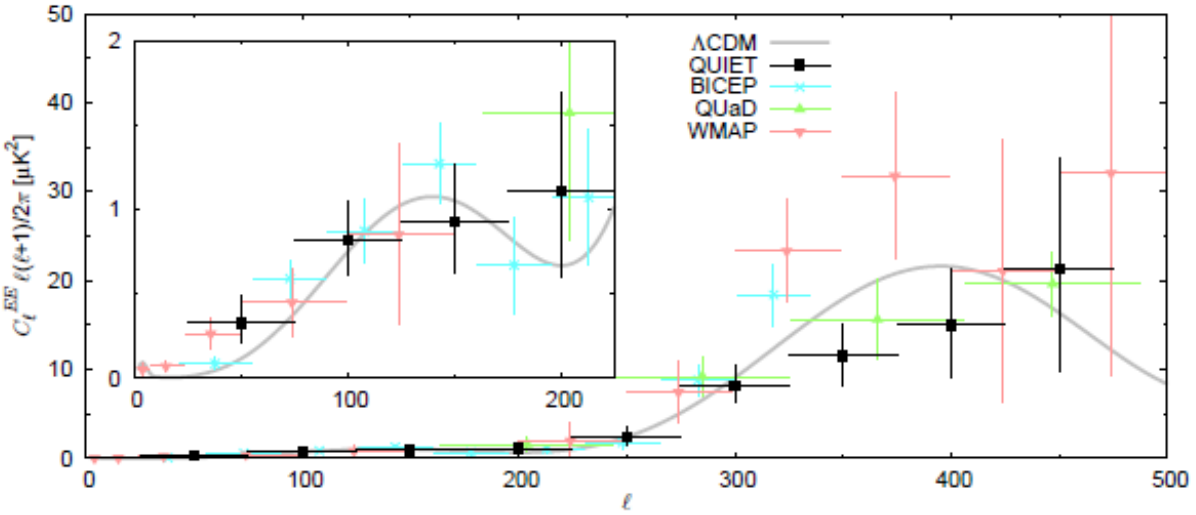
QUIET



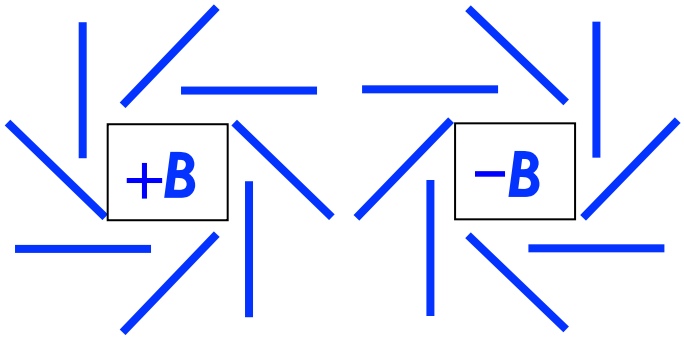
2010: First Quiet Results

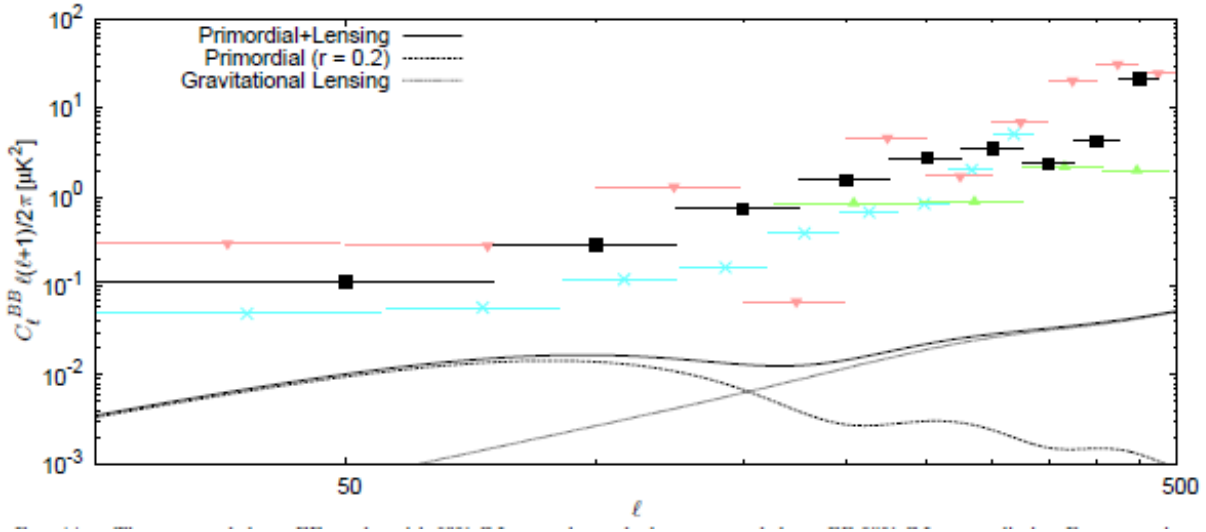
E-modes



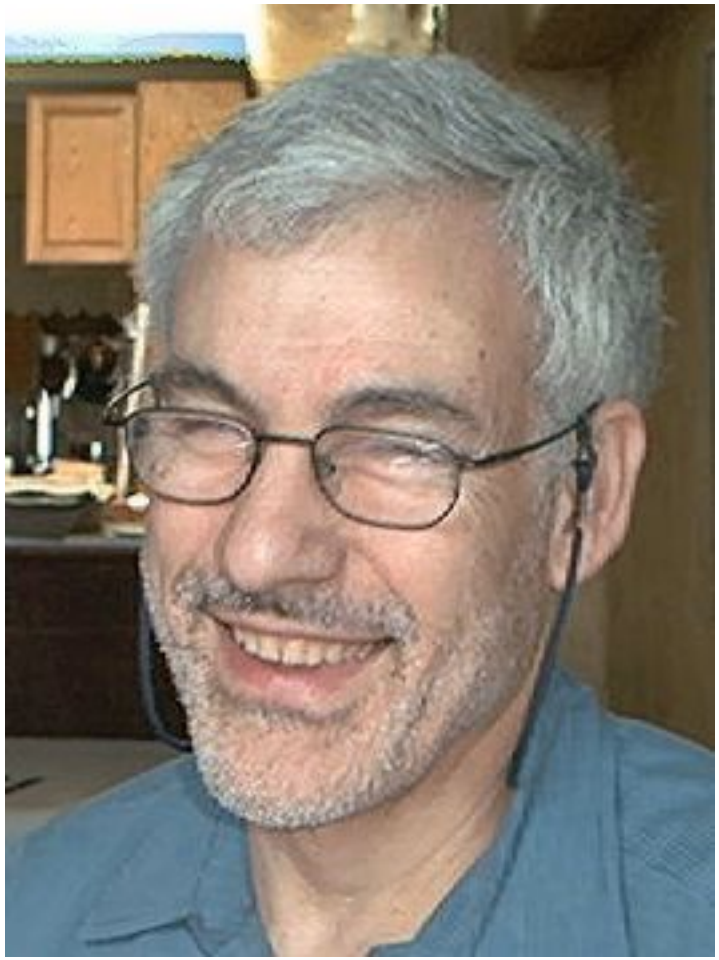


B-modes





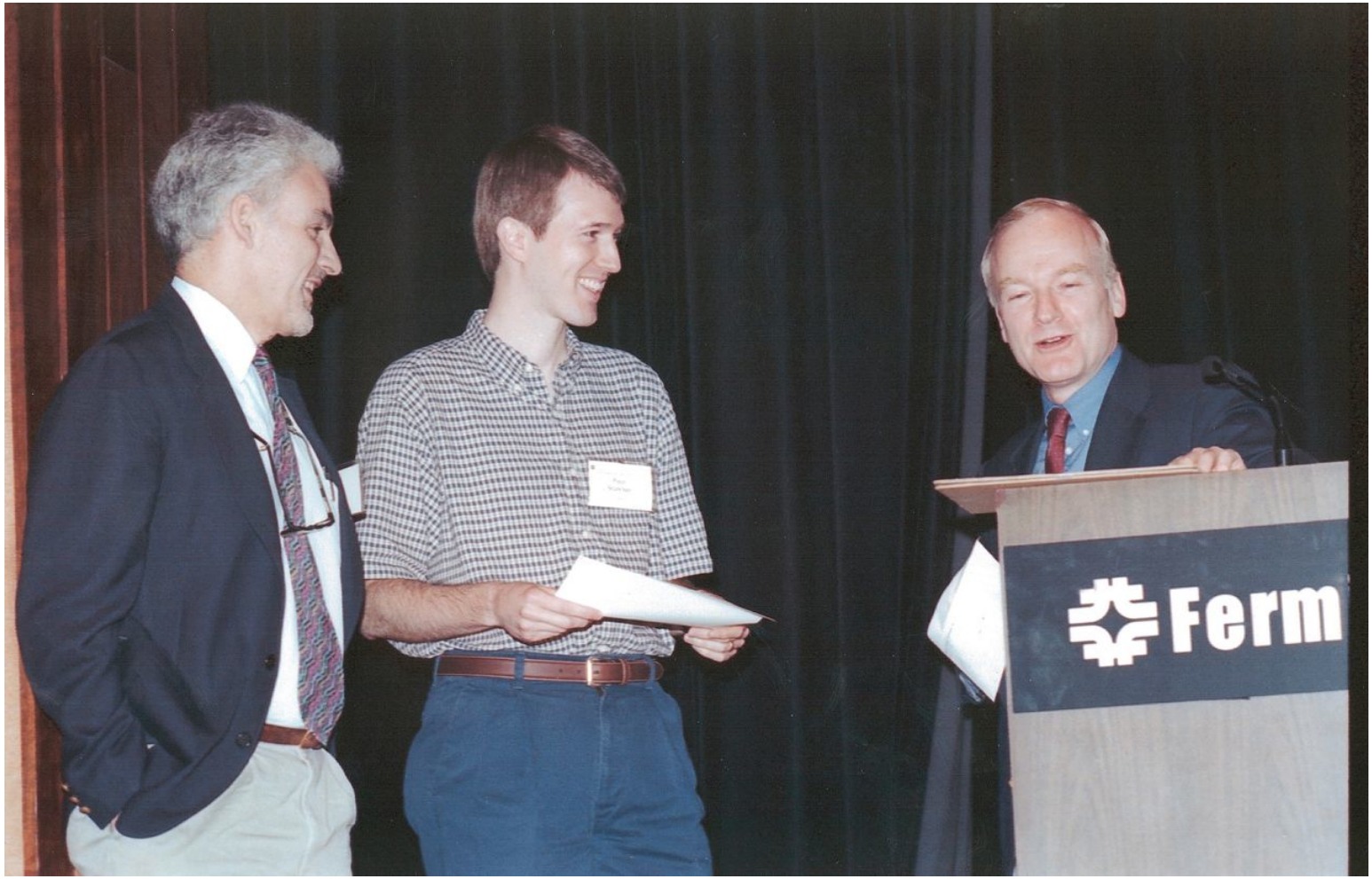
Bruce's approach to physics (and other things)



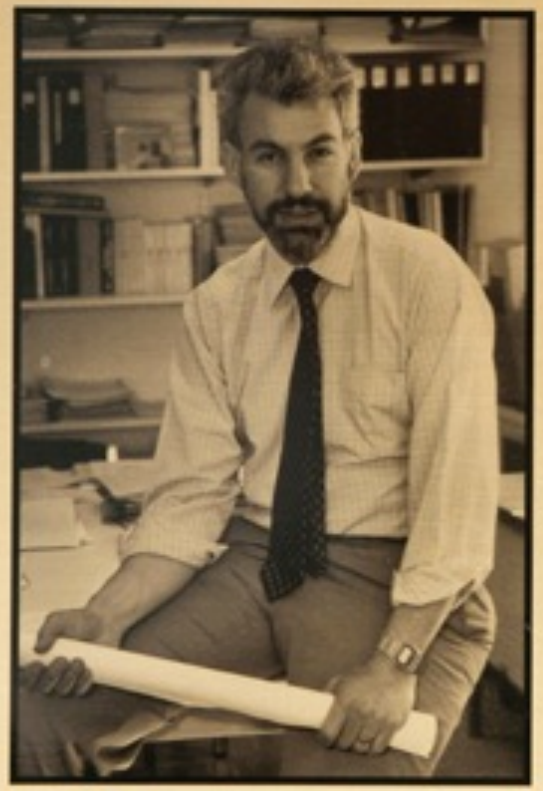
Depth, passion, and original perspective

+ Unique ability to motivate others around him to do their best work

Bruce cared deeply about education of students, and took great pleasure in the success of his students and junior colleagues.



Bruce was a remarkably talented and broad physicist. He was also a wonderful friend and colleague. In addition to his scientific work, he has left us with a model of what a true physicist can be, giving all of us something to aspire to.



In recognition of

Bruce Winstein

for his

leading contributions

to the Fermilab

research program.

Fermilab

U.S. DEPARTMENT OF ENERGY