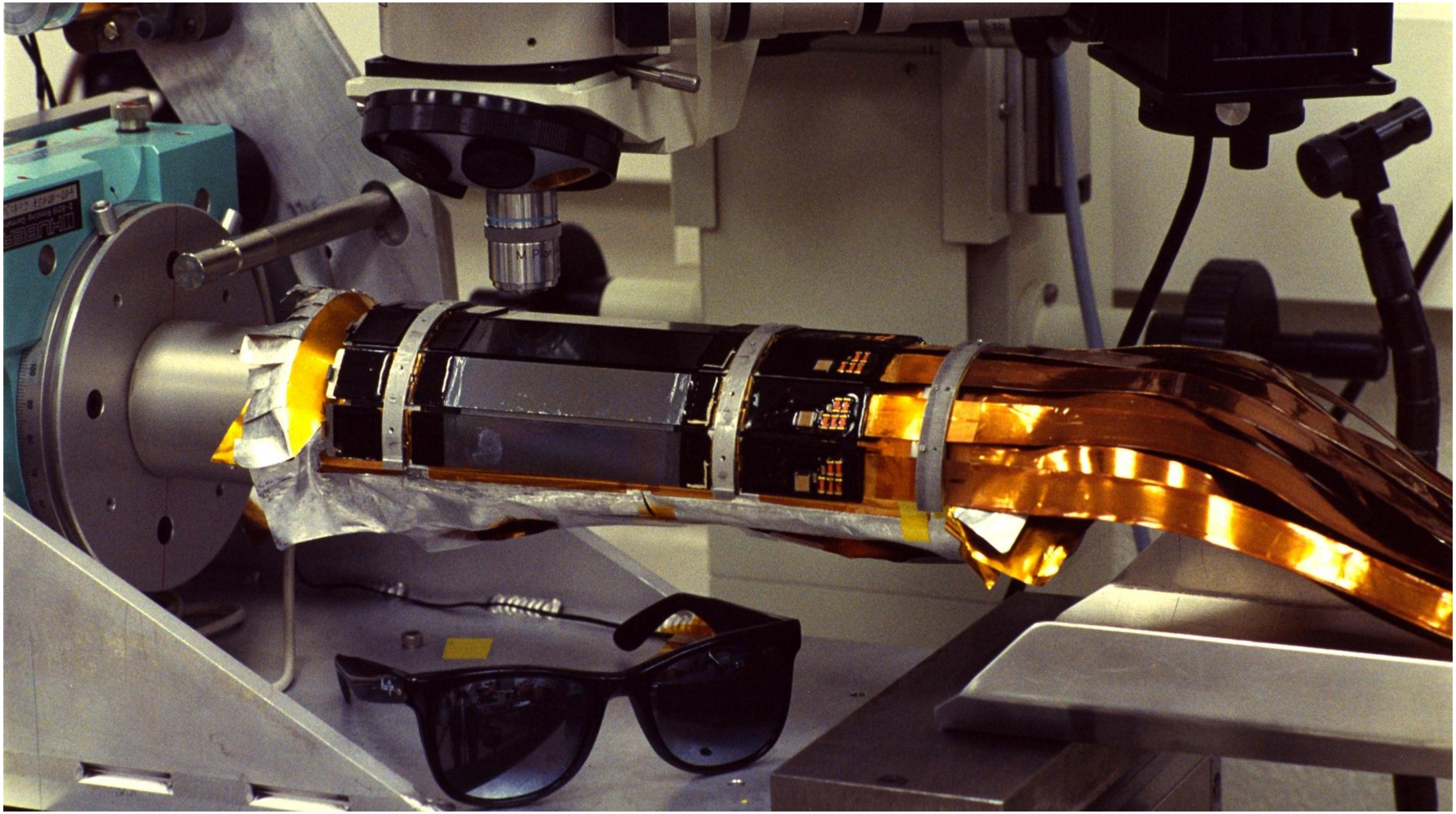
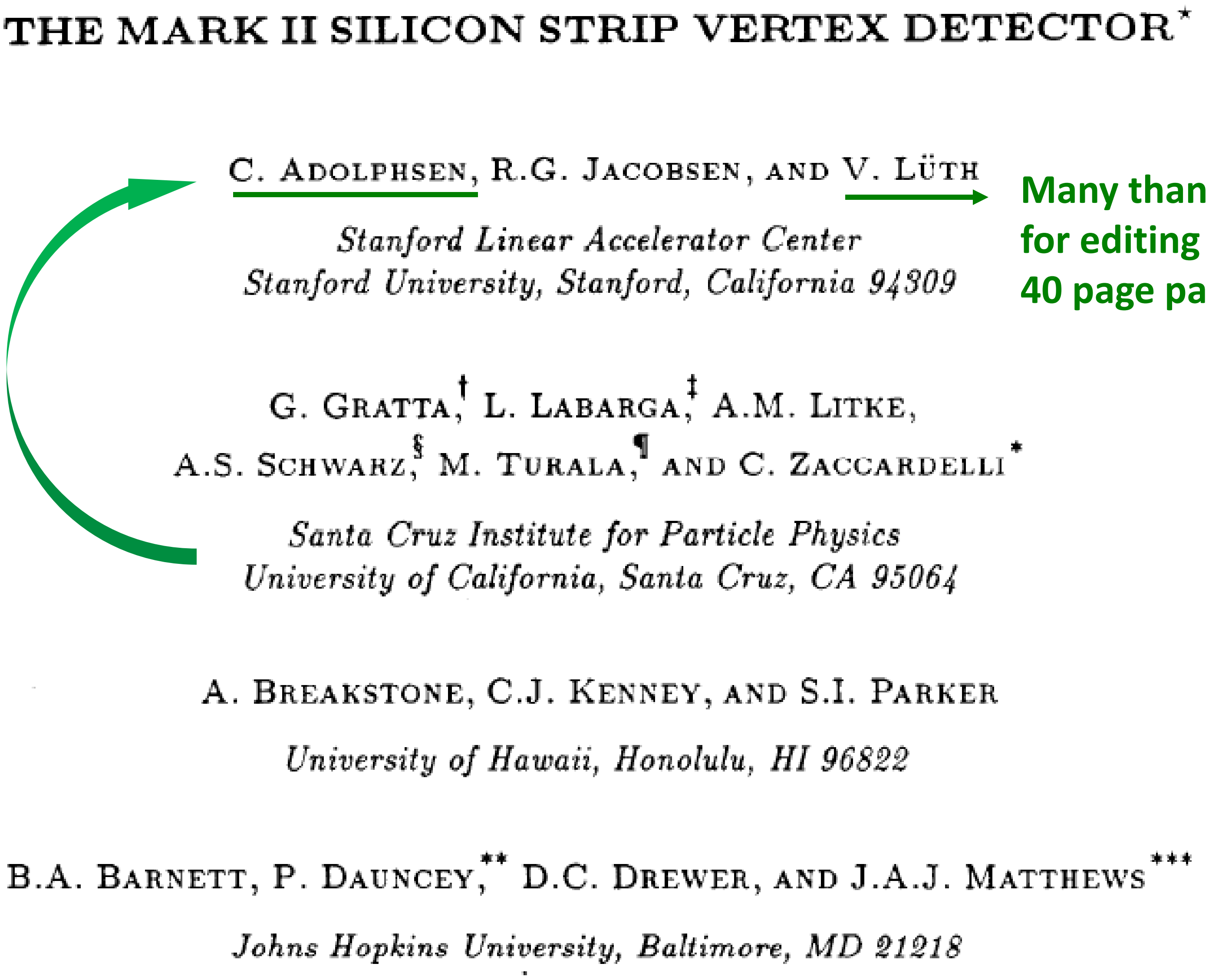
The Mark II Vertex Detector

A Perfect Detector for an Imperfect Collider



Chris Adolphsen, SLAC, 3/31/2012



THE MARK II SILICON STRIP VERTEX DETECTOR[*]

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Many thanks for editing this 40 page paper !

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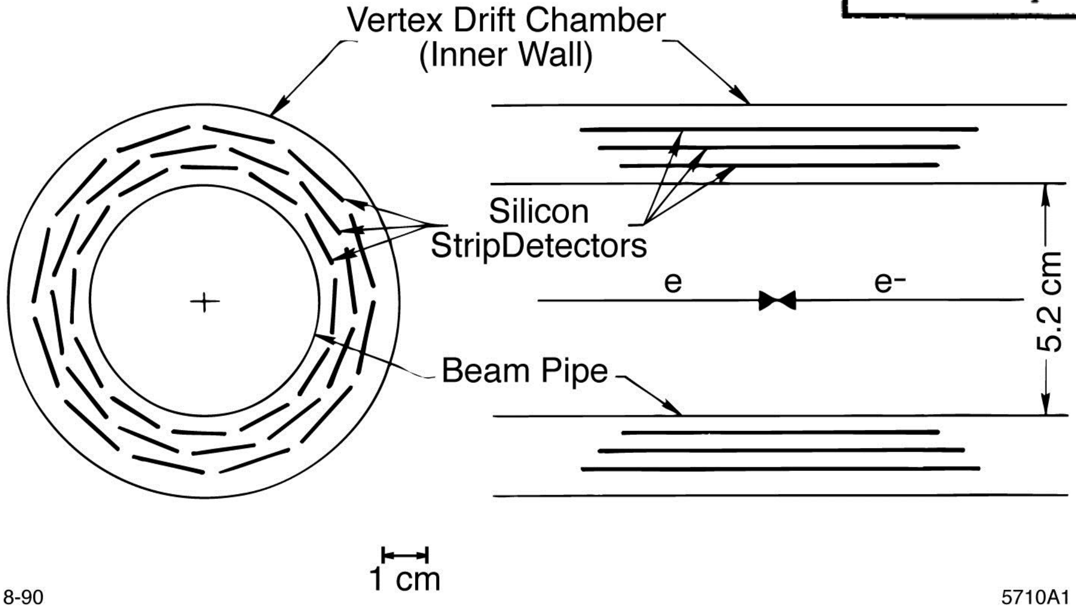
* NIMA, Volume 313, Issue 1-2, p. 63-102, March 1992

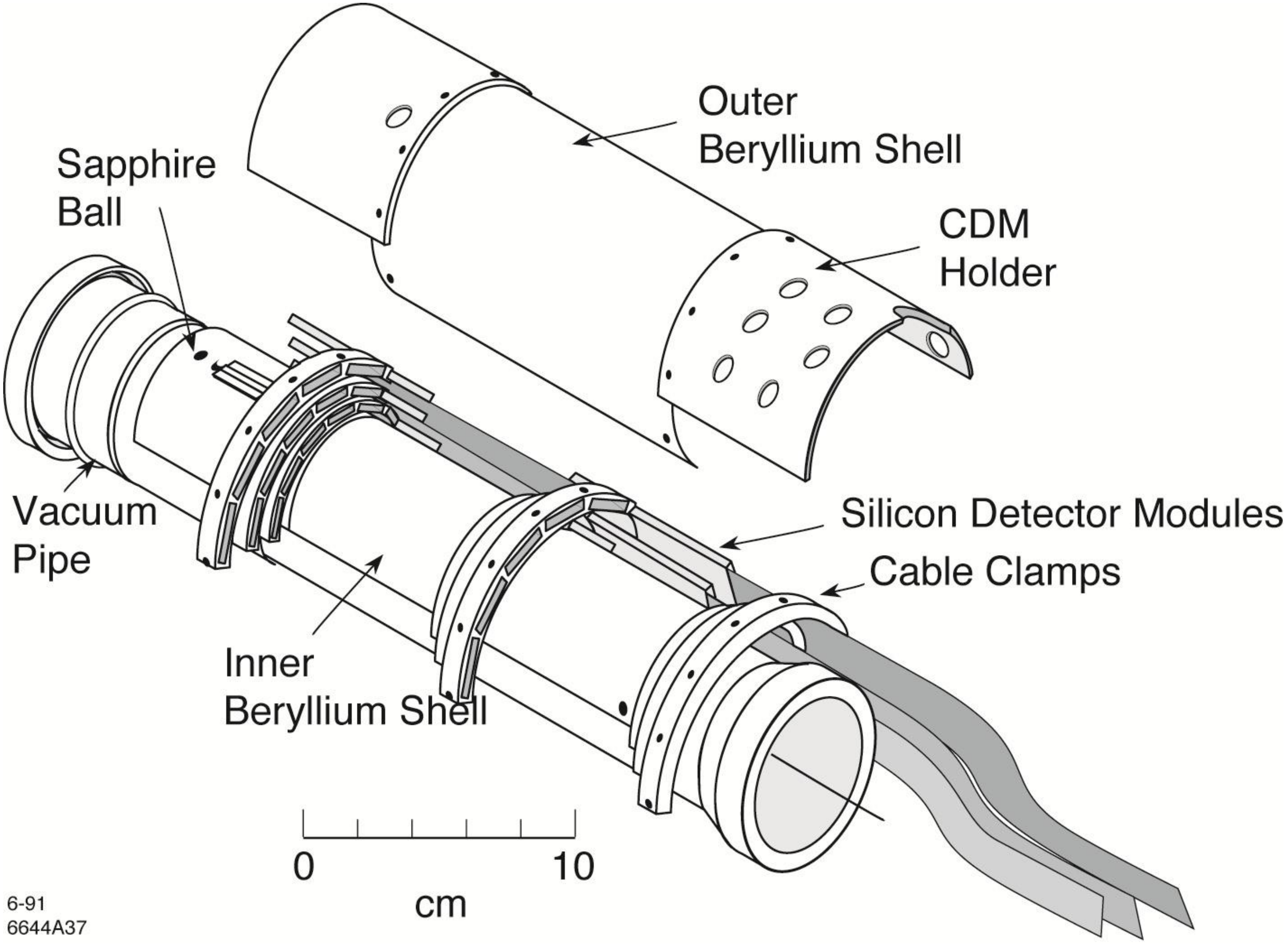
Detector Properties

Detector Property	layer 1	layer 2	layer 3	units
layer radius	29.4	33.7	38.0	mm
strip pitch	25	29	33	μm
strip width	8	8	8	μm
number of strips	512	512	512	
detector size	13.8 × 74.8	15.8 × 85.1	17.9 × 93.5	mm^2
sensitive area	12.9 × 72.0	14.9 × 82.0	17.0 × 90.0	mm^2
thickness	314	314	314	μm
capacitance to other strips	8.2	8.8	9.3	pF
capacitance to back plane	0.6	0.8	1.0	pF



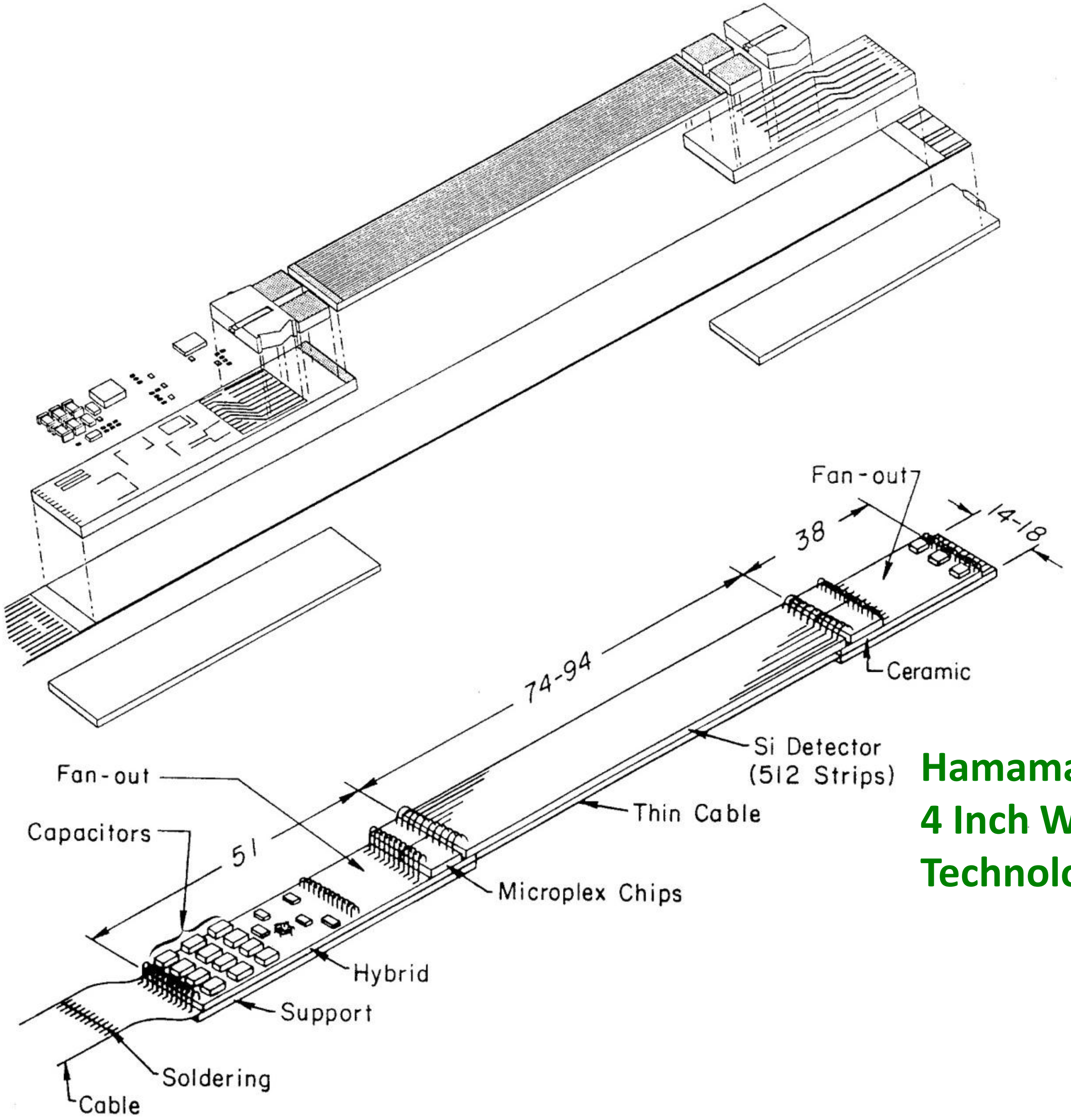
First Use of Silicon Strip Technology in a Colliding Beam Detector

SSVD Layout

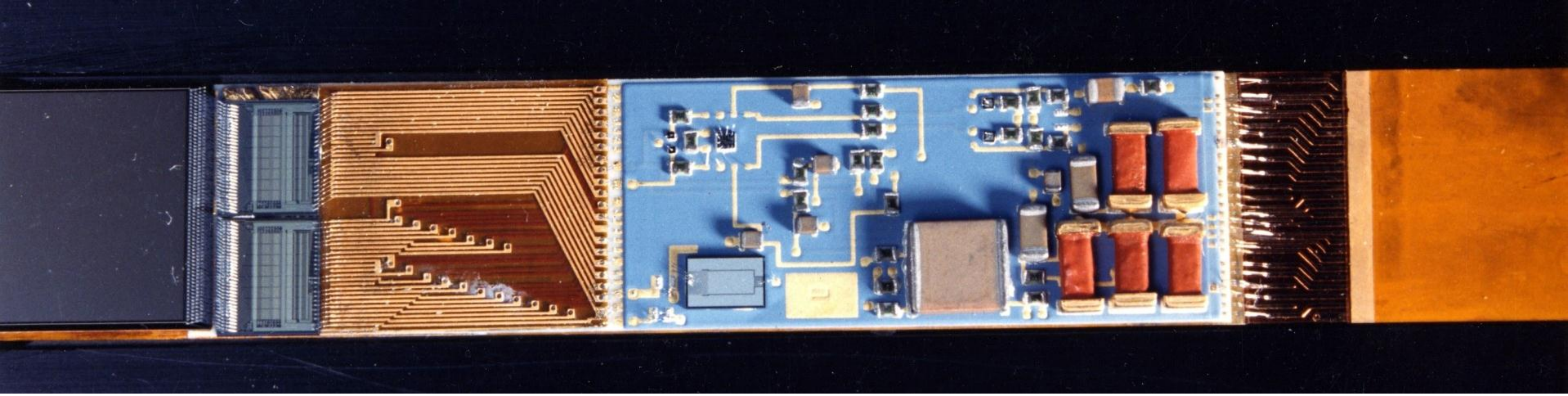

Outer
Beryllium Shell
Sapphire
Ball
CDM
Holder
Vacuum
Pipe
Silicon Detector Modules
Cable Clamps
Inner
Beryllium Shell
0
10
cm
6-91
6644A37

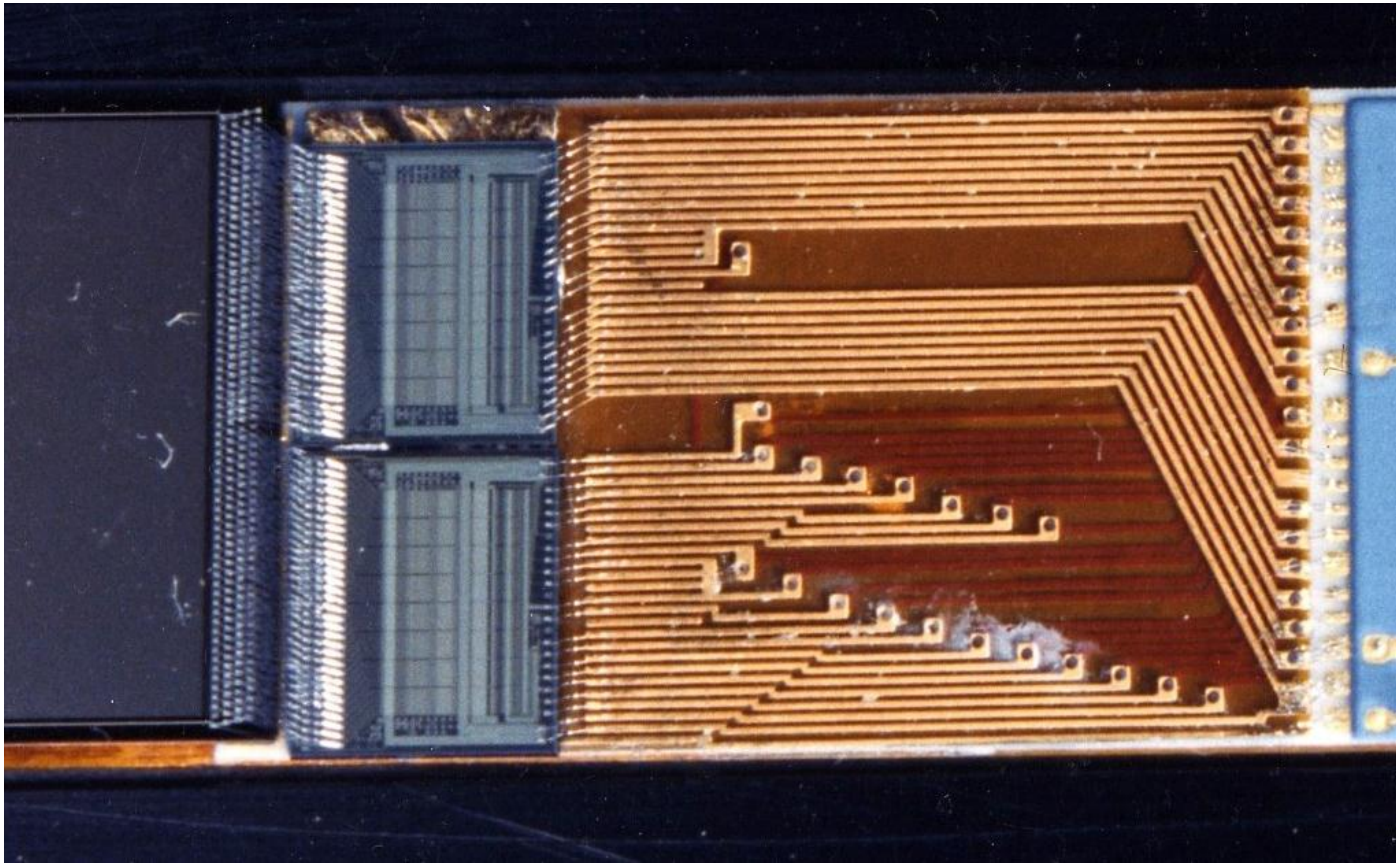

mm 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290

Detector Layout



Hamamatsu
4 Inch Wafer
Technology





Microplex Chip – Enabling Technology

(128 channels on a 4.7 by 6.4 mm chip)

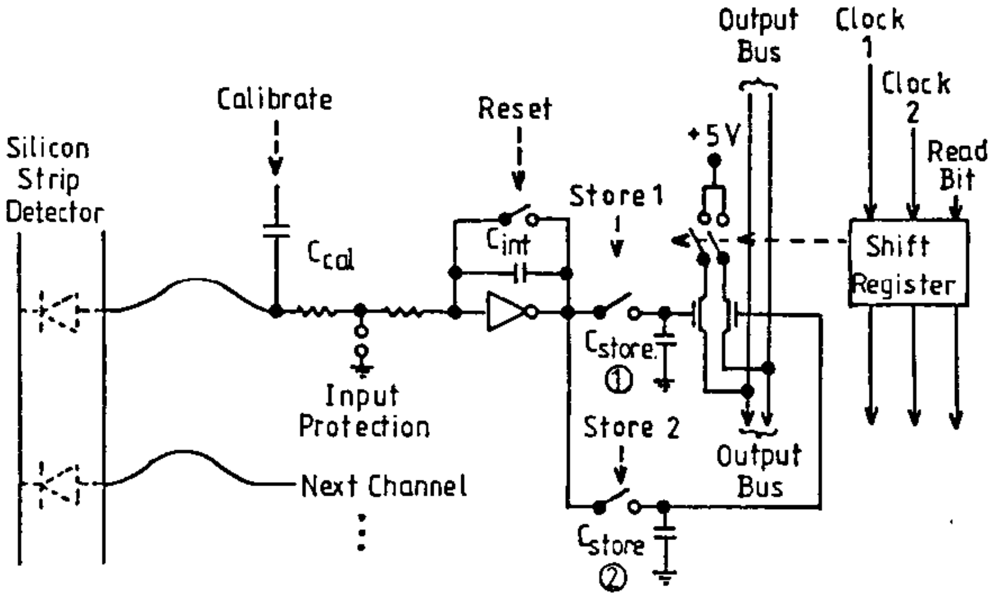
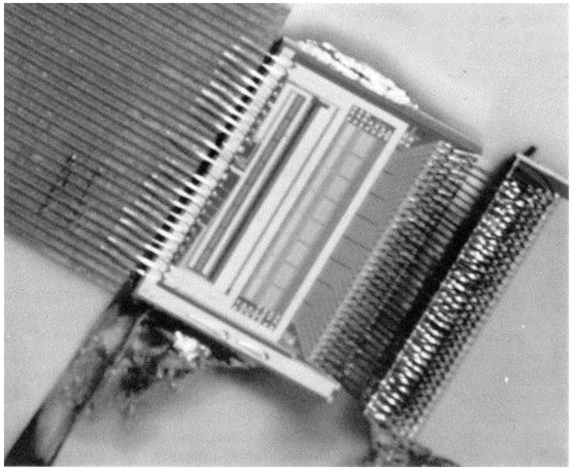


Figure 1. Block diagram of the Microplex circuit



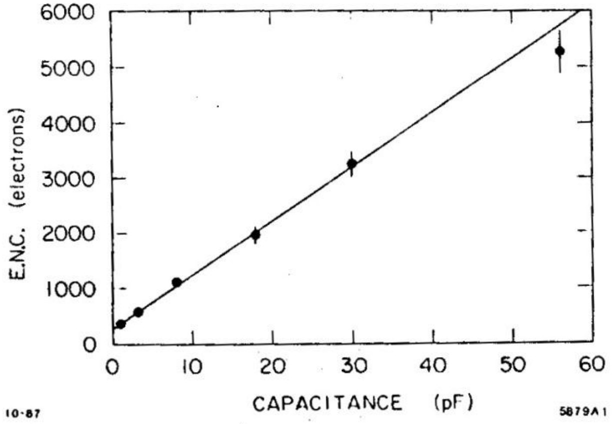
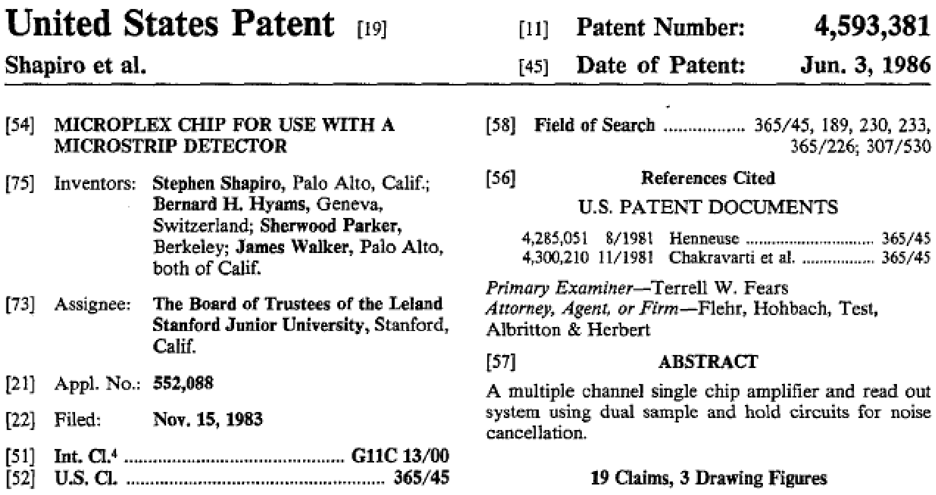


Figure 4. The equivalent charge noise (ENC) of Microplex 3 as a function of external input capacitance. The line fit to the data has an intercept of 280 electrons and a slope of 97 electrons/*pF*.

Microplex Patent



United States Patent [19]

Shapiro et al.

[11] **Patent Number:** **4,593,381**

[45] **Date of Patent:** **Jun. 3, 1986**

[54] **MICROPLEX CHIP FOR USE WITH A MICROSTRIP DETECTOR**

[75] Inventors: **Stephen Shapiro**, Palo Alto, Calif.; **Bernard H. Hyams**, Geneva, Switzerland; **Sherwood Parker**, Berkeley; **James Walker**, Palo Alto, both of Calif.

[73] Assignee: **The Board of Trustees of the Leland Stanford Junior University**, Stanford, Calif.

[21] Appl. No.: **552,088**

[22] Filed: **Nov. 15, 1983**

[51] **Int. Cl.⁴** **G11C 13/00**

[52] **U.S. Cl.** **365/45**

[58] **Field of Search** 365/45, 189, 230, 233, 365/226; 307/530

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,285,051	8/1981	Henneuse	365/45
4,300,210	11/1981	Chakravarti et al.	365/45

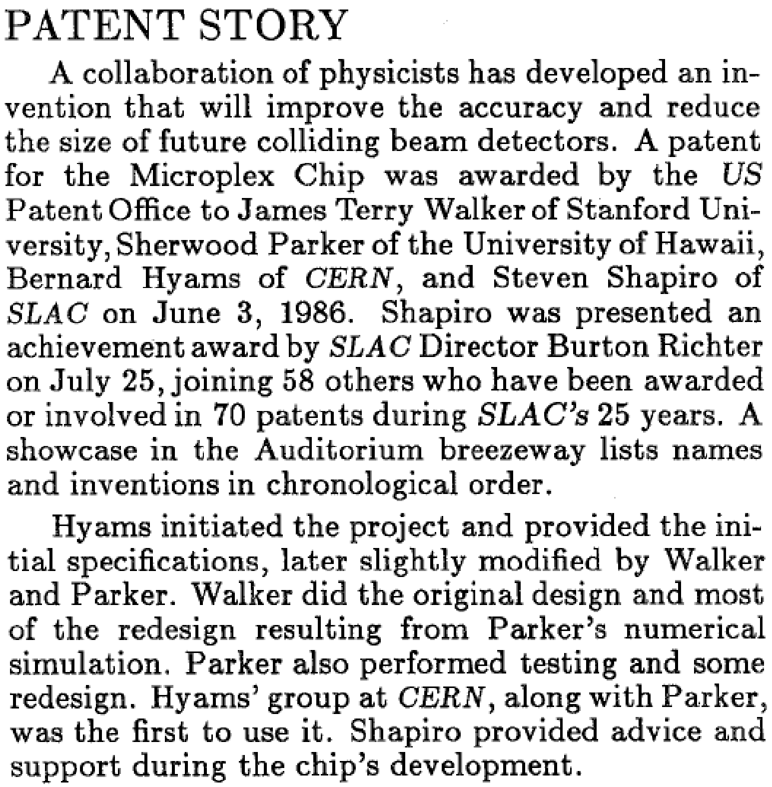
Primary Examiner—Terrell W. Fears
Attorney, Agent, or Firm—Flehr, Hohbach, Test, Albritton & Herbert

[57] **ABSTRACT**

A multiple channel single chip amplifier and read out system using dual sample and hold circuits for noise cancellation.

19 Claims, 3 Drawing Figures

SLAC Beam Line Sept, 1986

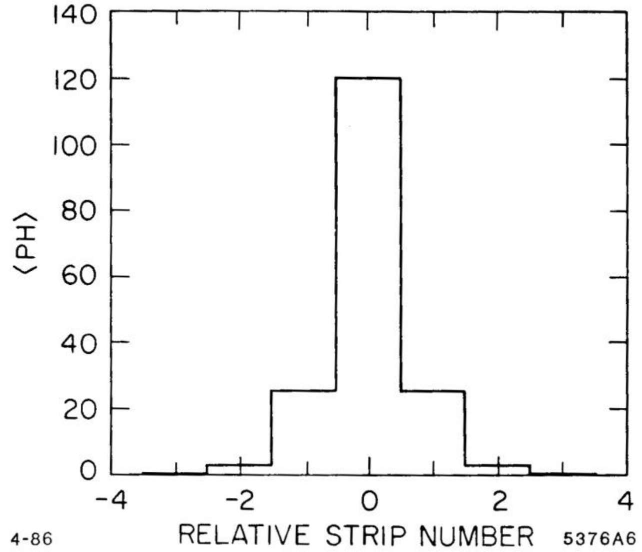


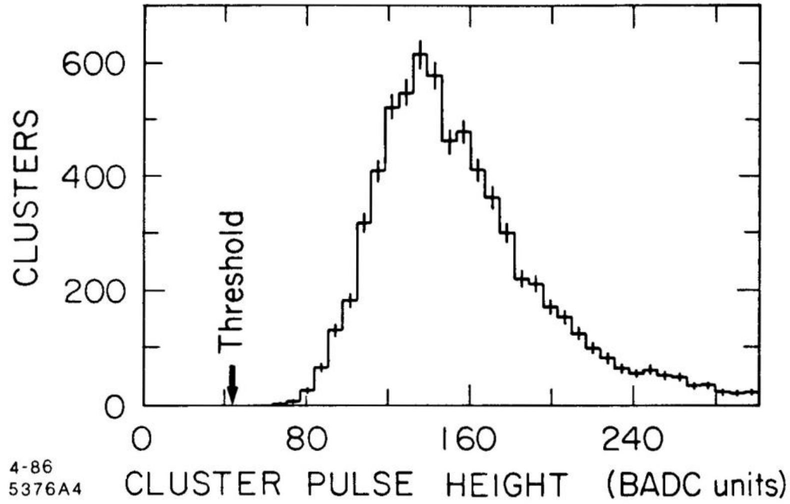
PATENT STORY

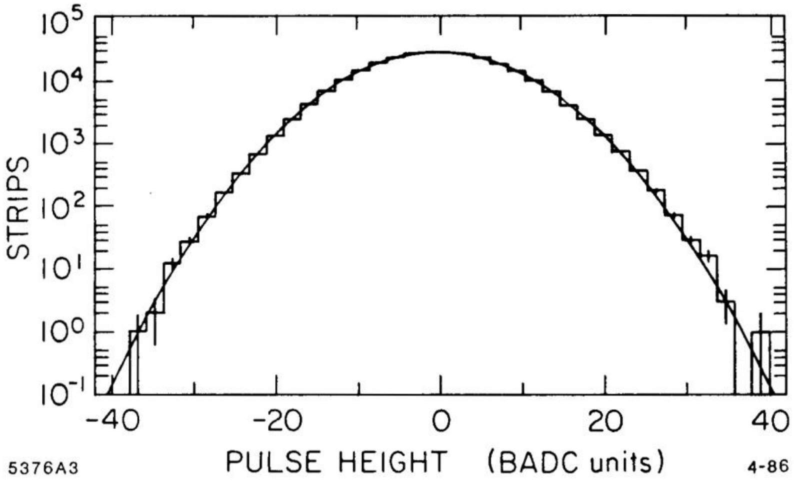
A collaboration of physicists has developed an invention that will improve the accuracy and reduce the size of future colliding beam detectors. A patent for the Microplex Chip was awarded by the *US* Patent Office to James Terry Walker of Stanford University, Sherwood Parker of the University of Hawaii, Bernard Hyams of *CERN*, and Steven Shapiro of *SLAC* on June 3, 1986. Shapiro was presented an achievement award by *SLAC* Director Burton Richter on July 25, joining 58 others who have been awarded or involved in 70 patents during *SLAC's* 25 years. A showcase in the Auditorium breezeway lists names and inventions in chronological order.

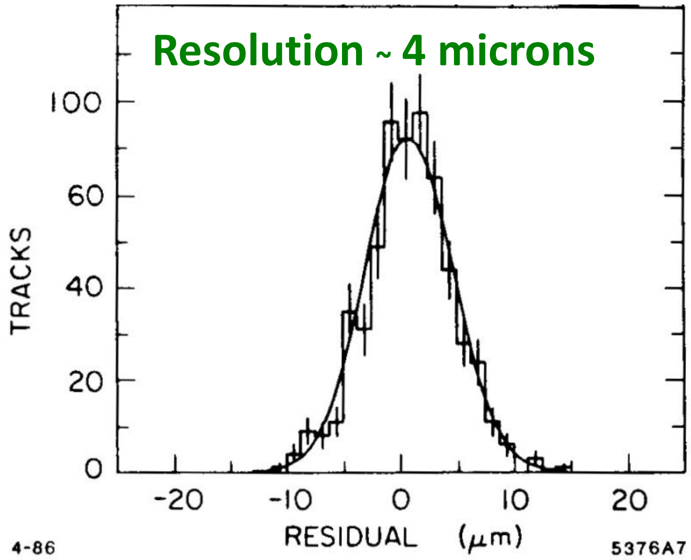
Hyams initiated the project and provided the initial specifications, later slightly modified by Walker and Parker. Walker did the original design and most of the redesign resulting from Parker's numerical simulation. Parker also performed testing and some redesign. Hyams' group at *CERN*, along with Parker, was the first to use it. Shapiro provided advice and support during the chip's development.

Min. Ionizing Particle Detection







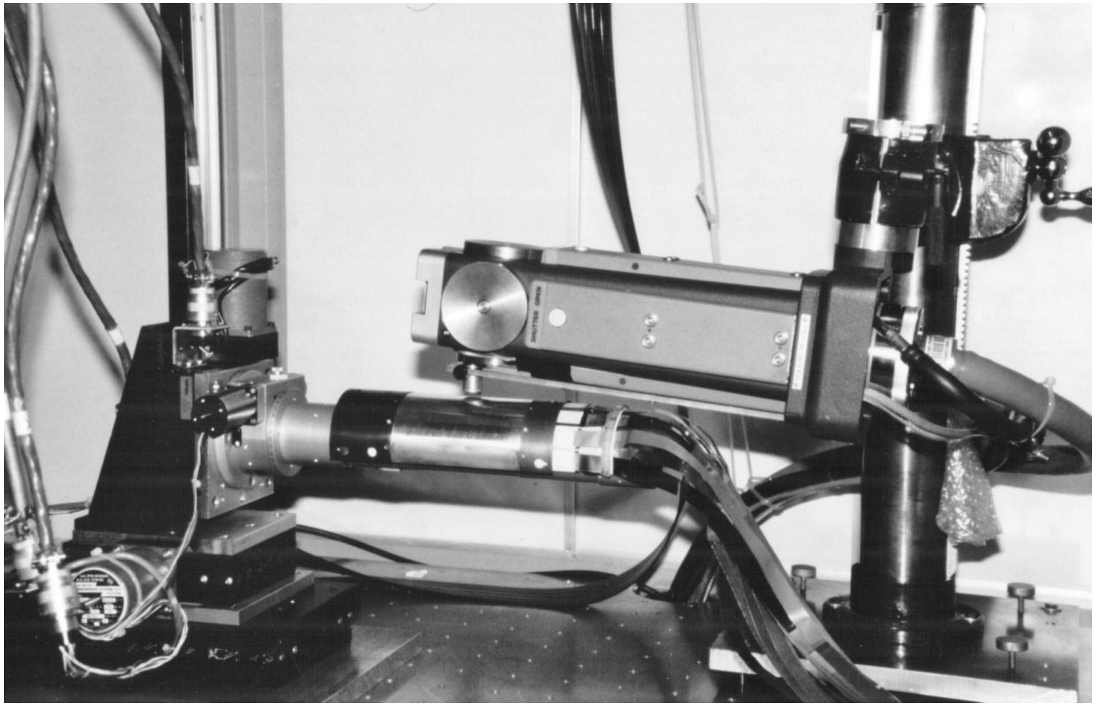

Resolution ~ 4 microns

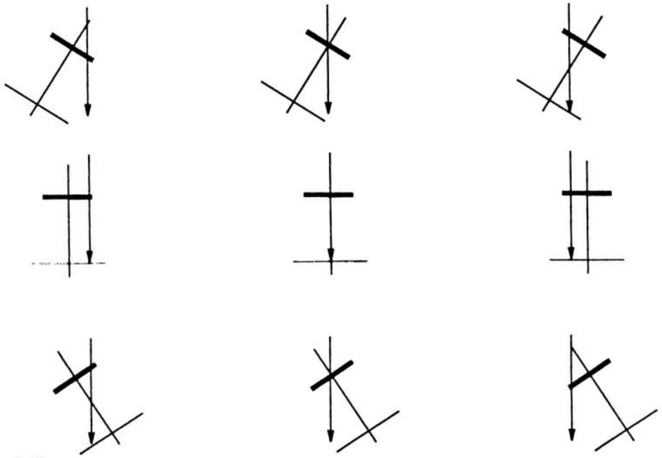
Much Testing and Development

- Microplex chip qualification
- Radiation damage studies (chip good to 10’s of krad)
- Electronics to compensate radiation damage
- Detector leakage current and depletion voltage meas.
- Support structure design
- Optical alignment during SSVD assembly
- X-ray alignment after assembly
- In-situ global alignment with capacitors
- X-ray and light calibration of detectors
- Cable and BADC testing

Detector Alignment with an X-Ray Beam

Vary angle and position of collimated X-ray beam in each detector to determine its position and orientation relative to others (few micron accuracy)





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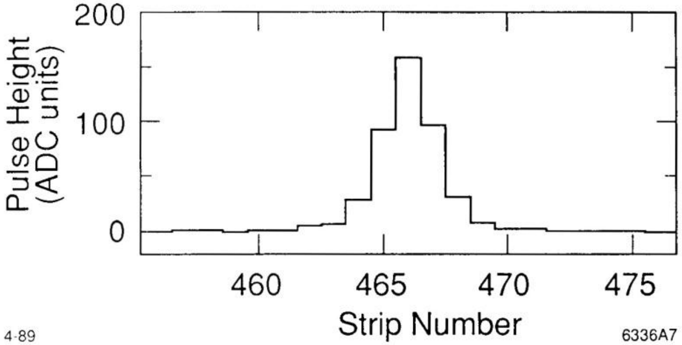
6336A9



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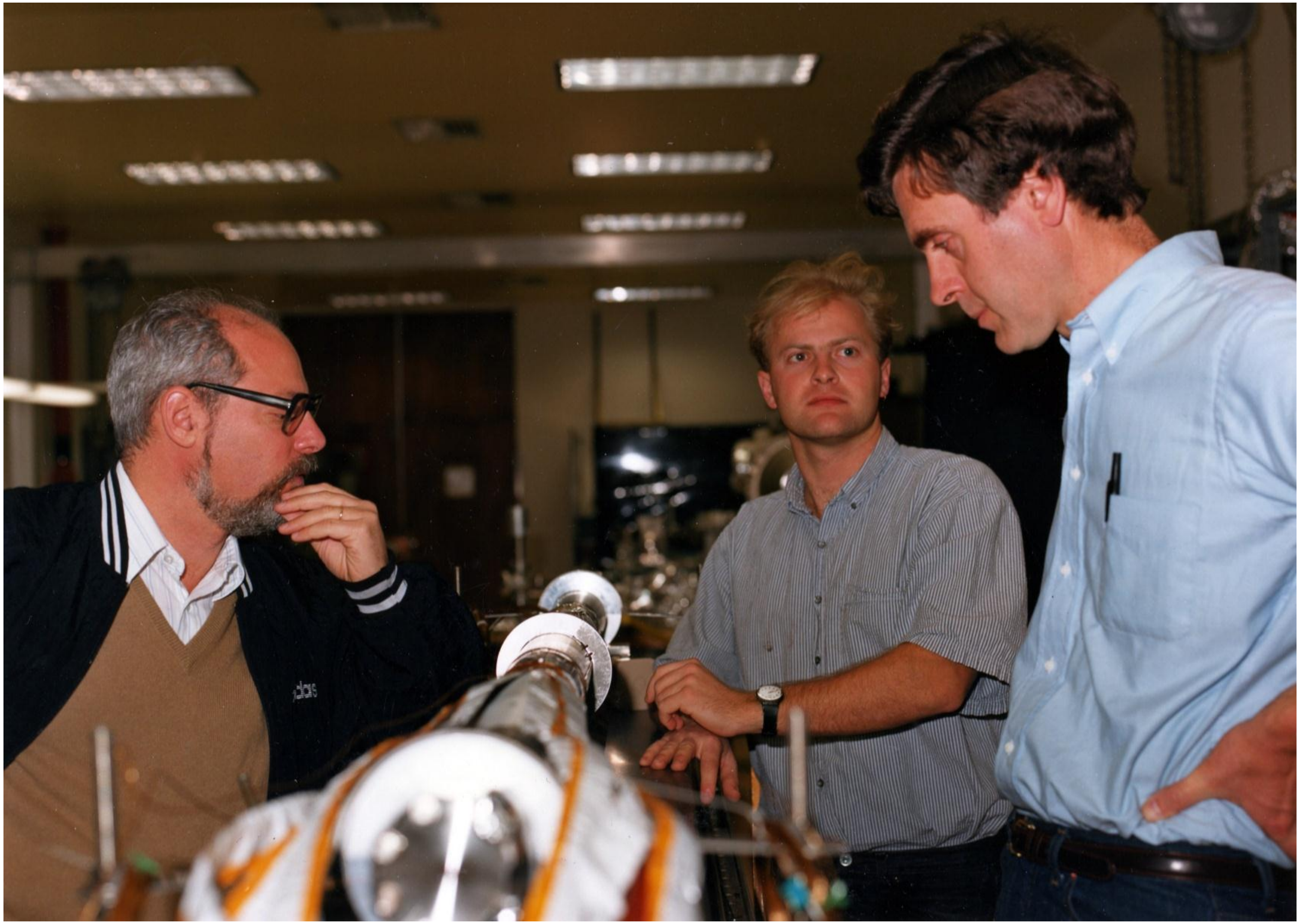
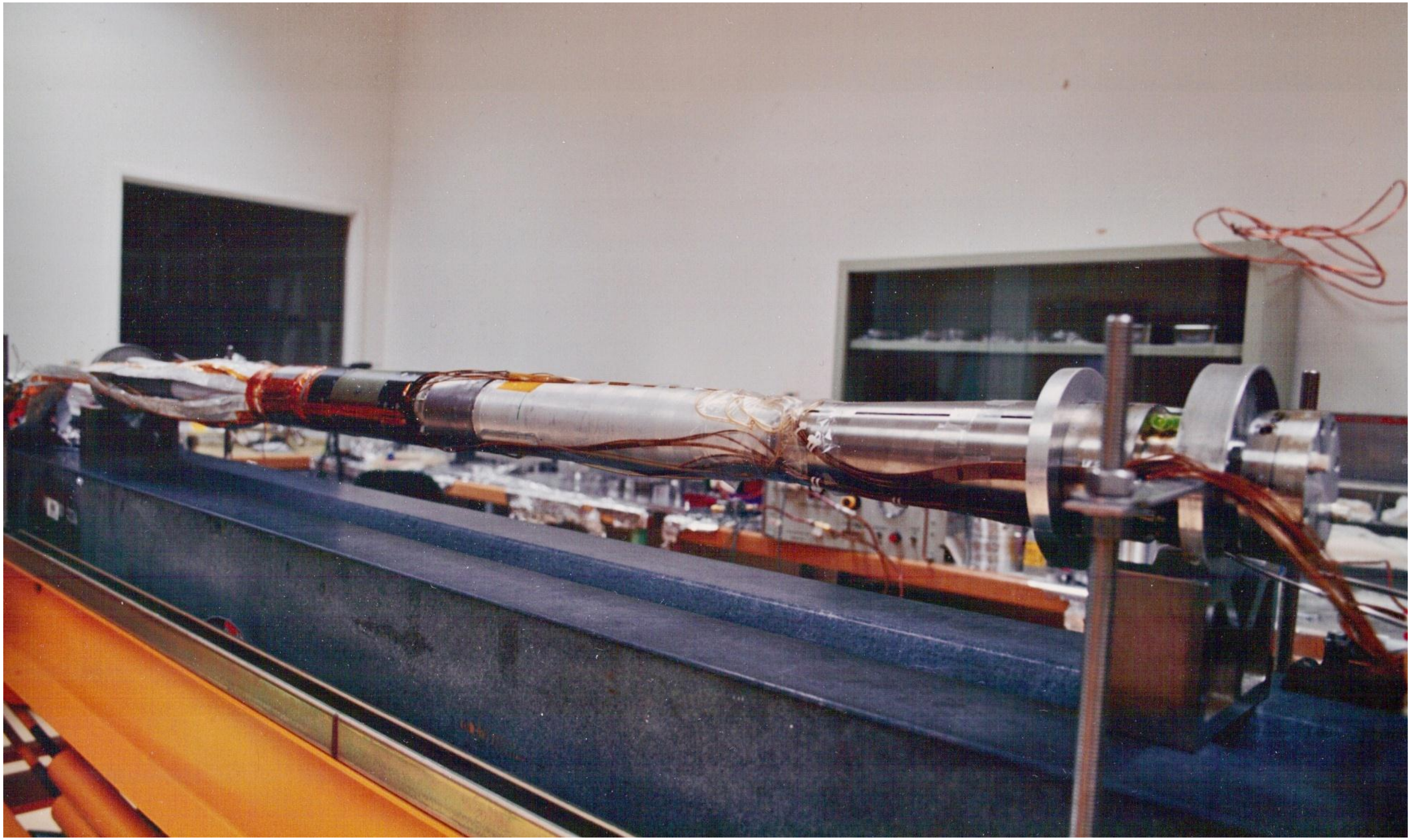
Staring Intently at the Detector to Ensure Optimal Performance



Ready to Go



SLC 1989 - 1991

From Nan Phinney's History of the SLC

April 11, 1989 - 1st Z detected by Mark II

October, 1989 - Task force disbanded

Mark II had ~ 500 Zs

LEP had begun physics in September, 1989

Loma Prieta earthquake

SSVD and the Drift Chamber Vertex Detector installed

December, 1989 - SLC 'White Paper'

Breidenbach, Burke, Himel, Paterson,
Ruth, Seeman, Sheppard

1991 … will be the first full year of physics running with the new detector, the SLD.

The integrated luminosity goal for 1991 is 10^5 Z particles with polarized electrons.

August, 1990 - Program Coordinator (NP)

balance conflicting Mark II/ PEP/ SLD needs

November, 1990 - Mark II Run ended

Record day was 15 Zs on tape

PEP physics program terminated

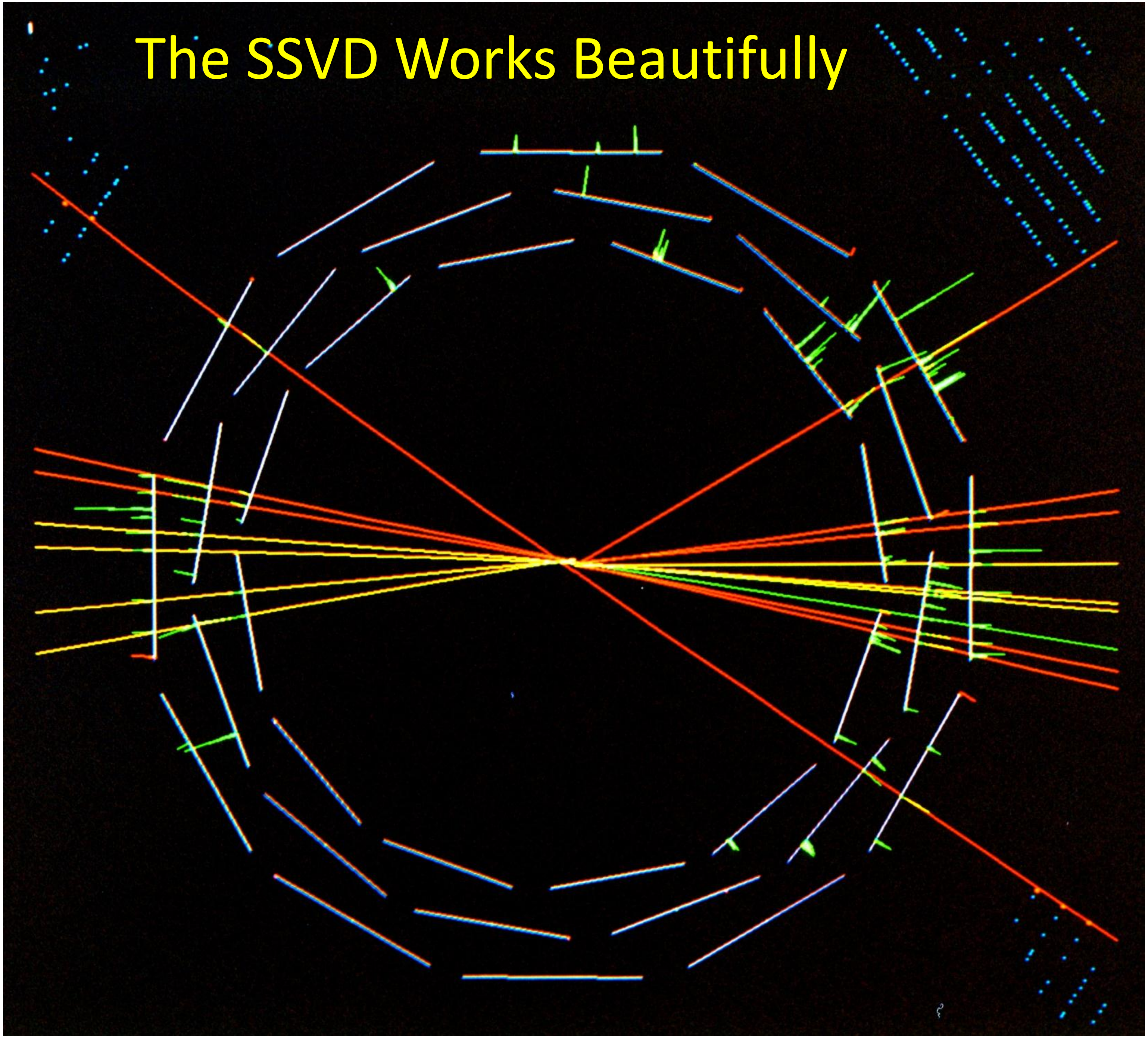
Only ~ 300 Z's recorded with the SSVD before the SLD detector (with CCDs) installed

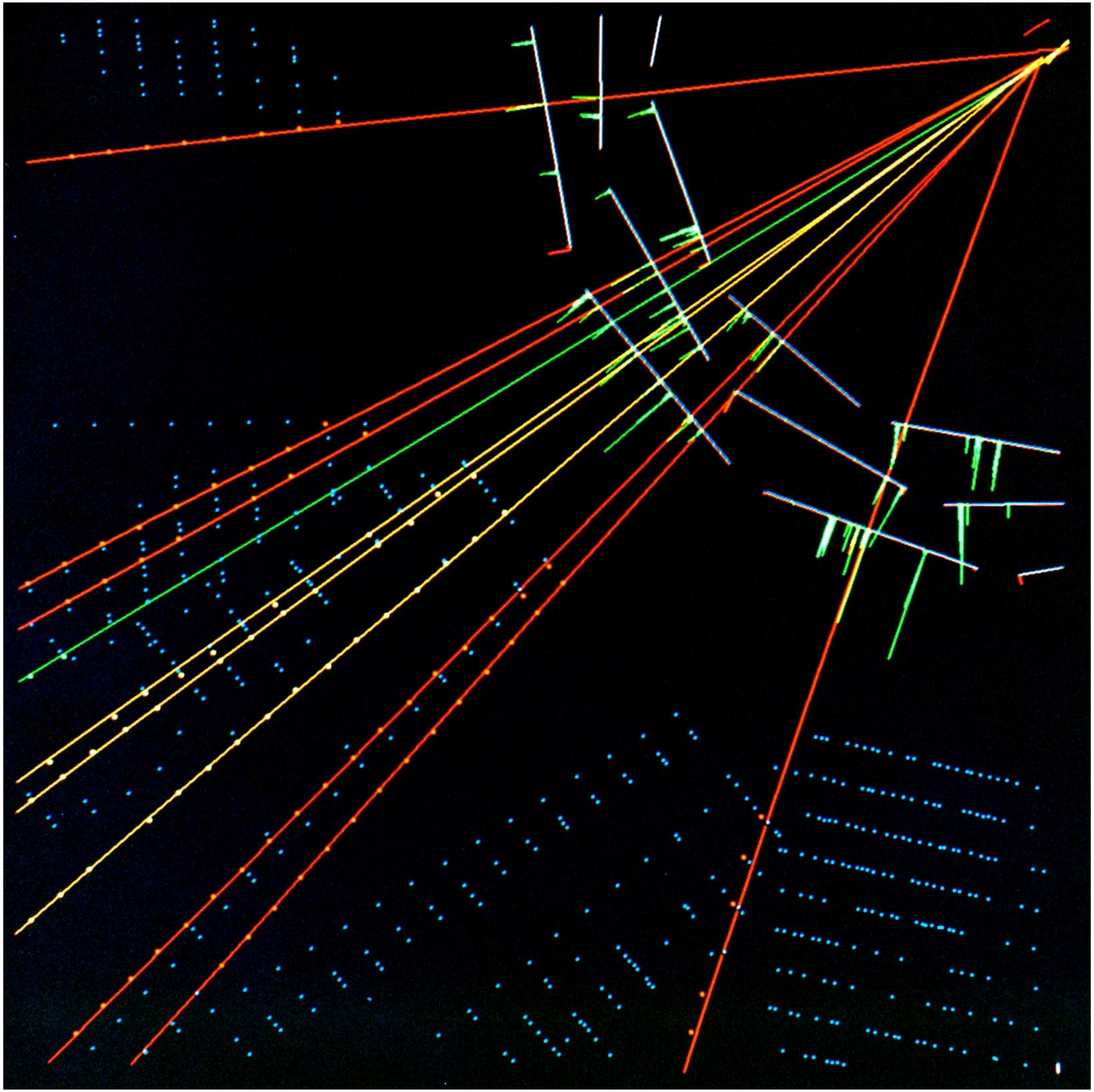
January, 1991

100-year freeze - December 23, 1990

SLC Steering committee formed

The SSVD Works Beautifully





Indentifying Displaced Vertices

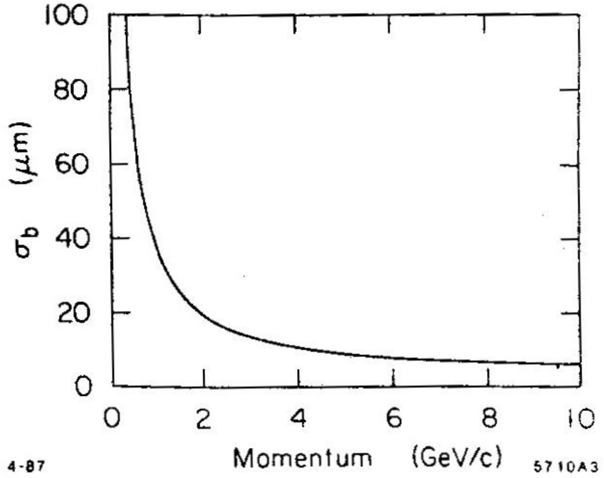


Figure 2. Impact parameter resolution (σ_b) as a function of momentum for tracks produced at 90° to the beam axis.

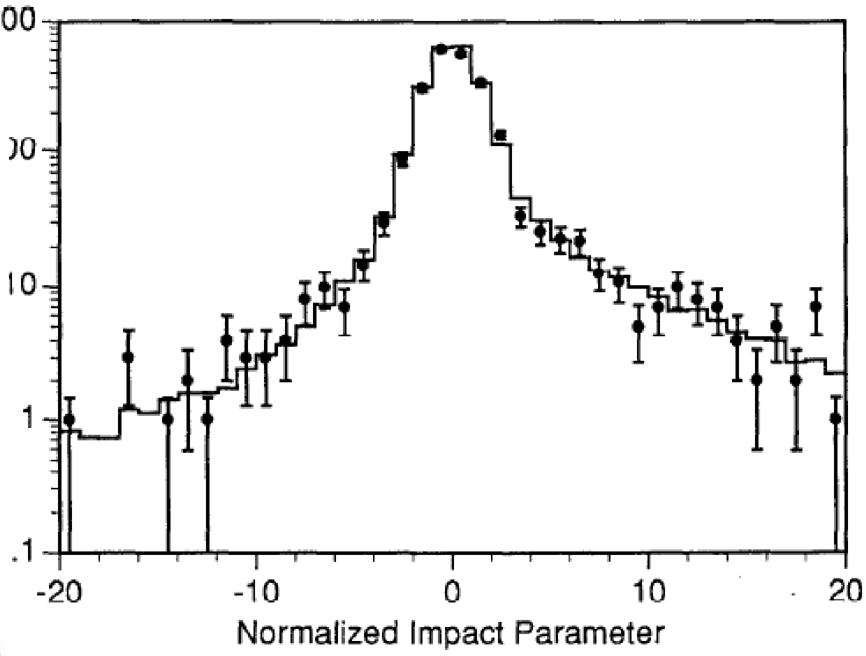
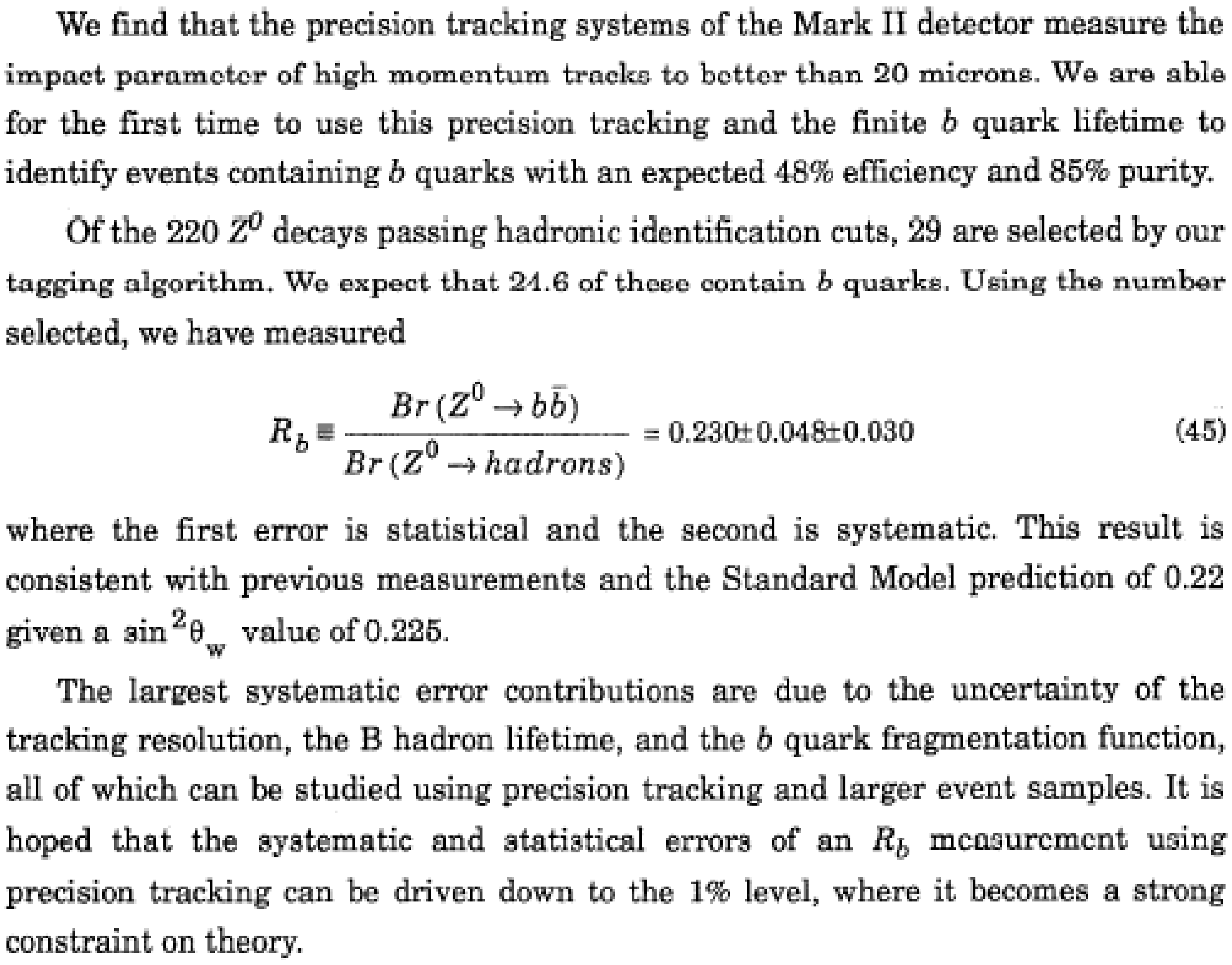


Figure 72 Comparison of normalized error (S) in data and Monte Carlo. This plot includes all 2341 data tracks passing cuts. The Monte Carlo includes 5 micron additional core smearing and a 15% tail of 75 microns width. The Standard Model bottom quark branching ratio of 22.5% is used.

Physics at Last

(Conclusion from Bob Jacobsen's Thesis in 7/91)



We find that the precision tracking systems of the Mark II detector measure the impact parameter of high momentum tracks to better than 20 microns. We are able for the first time to use this precision tracking and the finite b quark lifetime to identify events containing b quarks with an expected 48% efficiency and 85% purity.

Of the 220 Z^0 decays passing hadronic identification cuts, 29 are selected by our tagging algorithm. We expect that 24.6 of these contain b quarks. Using the number selected, we have measured

$$R_b \equiv \frac{Br\,(Z^0 \to b\bar{b})}{Br\,(Z^0 \to hadrons)} = 0.230 \pm 0.048 \pm 0.030 \qquad (45)$$

where the first error is statistical and the second is systematic. This result is consistent with previous measurements and the Standard Model prediction of 0.22 given a $\sin^2\theta_w$ value of 0.225.

The largest systematic error contributions are due to the uncertainty of the tracking resolution, the B hadron lifetime, and the b quark fragmentation function, all of which can be studied using precision tracking and larger event samples. It is hoped that the systematic and statistical errors of an R_b measurement using precision tracking can be driven down to the 1% level, where it becomes a strong constraint on theory.

2011 PDG: Rb = 0.216 +/- 0.0007