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SDC
SOLENOIDAL DETECTOR NOTES

A HYBRID CENTRAL TRACKING CHAMBER FOR SSC DETECTORS

A. T. Goshaw

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A Hybrid Central Tracking Chamber for SSC Detectors

presented by
A.T.Goshaw
for the
HCTC Subsystem Collaboration

Outline

I. Introduction to the Hybrid CTC Subsystem R&D project

II. Goals of a high precision, large volume CTC for an SSC detector

III. Reasons for choosing a hybrid of straw tubes and scintillating fibers

IV. Description of a HCTC design for the SDC detector

V. Review of R&D results supporting the HCTC concept
- Task 1: straw tubes
- Task 2: scintillating fibers
- Task 3: mechanical engineering
- Task 4: detector Monte Carlo simulation

VI. Conclusions

Introduction to the Hybrid CTC Subsystem R&D project

* A collaboration was formed in late 1988 to carry out the design of a high precision, large volume tracking chamber for SSC detectors.

* A key element in this design exercise was the interaction between research groups that had design experience with both straw tube and scintillating fiber detectors.

* Another essential catalist to the design was the early invovement of mechanical and material science engineers at ORNL. This give-and - take interaction lead to a fundamental change in the modularity and support structure for the detector elements.

* The design evolved over a period of 6 to 8 months and was proposed to the SSC Subsystem R&D Program in September 1989.

* The FY1990 Subsystem R&D program target those issues which were critical to the success of the Hybrid Central Tracking (HCTC) design. This research has confirmed the basic HCTC detector concept and lead to a refinement of the design.

* The revised detector design and a proposed second stage R&D program has been submitted to the SSC Lab's FY1991 Subsystem R&D Program. The HCTC Collaboration now consists of 40 people from 12 institutions.

HCTC

Collaboration Members

ntinuous Electron Beam Accelerator Facility	**Dr. Stan Majewski** Dr. Carl Zorn
Duke University	**Dr. Alfred T. Goshaw (Co-spokesman)** Dr. Seog Oh Dr. William Robertson
Florida State University	**Dr. Vaskan Hagopian** Mr. Phil Rulon
General Electric Canada Inc.	**Dr. Robert McIntyre** Dr. Henri Dautet
KEK	**Dr. Hirokazu Ikeda** Dr. Yasuo Arai
North Carolina State University	**Dr. John Paulos** Dr. Thomas S. Ellerman
Northeastern University	**Dr. Stephen Reucroft (Co-spokesman)** Dr. George Alverson Mr. Addison Grimes Dr. Mike Glaubman Dr. Ian Leedom
Oak Ridge National Laboratory	**Dr. Tony Gabriel** Mr. Gary Alley Mr. Hugh Brashear Mr. Charles L. Britton, Jr. Mr. Michael Emory Dr. Raymond E. Garvey, III Dr. Charles Glover Dr. Richard A. Lillie Mr. Brad Nelson Mr. Ted Ryan Mr. David Vandergriff
Quantum Research Services, Inc.	**Dr. William L. Dunn** Dr. Fearghus O'Foghludha Mr. Joseph D. Simpkins Dr. A.M. Yacout
Supercomputer Computation Research Institute	**Dr. Martyn Corden** Dr. Mike Mermikides
TRIUMF	**Dr. Martin Solomon** Dr. Robert Henderson Dr. Wayne Fraszer Mr. Robert Openshaw
University of Pennsylvania	**Dr. Rick Van Berg**
Primary Contact Person:	**Dr. Alfred T. Goshaw** Physics Department Duke University Durham, NC 27706 (919) 684-8134 DUKHEP::GOSHAW

General Goals of the HCTC Design
(based upon requirements of the SDC detector)

* precision => $\sigma(r,\phi)$ ~ 150 microns $\sigma(z)$ ~ 2 mm
* high data rate capabilities => 16 ns bunch crossing time
* good pattern recognition capabilities =>
  - detection cell occupancy < 10%
  - point measurements/track > 50
* large volume => $-1.6 < \eta < +1.6$ $0 < \phi < 2\pi$
  - $-4.0 <$ length $< +4.0$ m $0.5 <$ radius < 1.7 m
* hermitic and isotropic tracking coverage =>
  - no ϕ and η cracks
  - no termination plates within eta < 1.6
* rigid, low density, low creep mechanical support structure =>
  - place detector elements to < 75 microns
  - maintain placement for > 5 years
  - density of support structure 2-3% X_0 at 90°
* radiation hardness of all components to ~ 10^{14} neutrons/cm^2/year
  ($L = 10^{33}$ /cm^2/s) ~ 0.5 Mrad/year
* simplicity of detector fabrication =>
  - mass production techniques possible
* fail-safe detector operation =>
  - detector cells isolated
  - modular electronics boards
* affordable cost => 5 to 10 % of total detector $'s

Evolution of the Hybrid CTC Design (con.)

Scintillating Fibers

* precision of $\sigma(z) \sim 2$ mm =>
  use scintillating fibers with diameter ~ 1 mm
  wind fibers in helix on a cylinder with $\pm$ 5° stereo
  Advantages: 1) light output OK, satisfies measurement precision
  2) number of readout channels managable
  (~100K in HCTC design)
  3) hermitic and isotropic tracking coverage
  4) simplicity of mechanical fabrication

Conclusion: **Scintillating fibers are a good choice for the z measurements.**

Evolution of Hybrid CTC Design

Scintillating Fibers

* precision of $\sigma(r,\phi)$ ~ 150 microns =>
  use scintillating fibers with diameter ~ 500 microns
  Problems: 1) low light output for fibers of length ~ 4 m
  2) radiation hardness?
  3) number of readout channels > 1.5 million to maintain > 50 (r,ϕ) points/track
  4) affordable cost ??

Conclusion: Scintillating fibers are not a good choice for the (r,ϕ) measurements.

Evolution of the Hybrid CTC Design (con.)

Straw Tube Drift Cells

* precision of $\sigma(r,\phi)$ ~ 150 microns =>
use straw tubes with diameter 4 mm and a fast gas
[CF4-isobutane, CF4-argon-ethane]

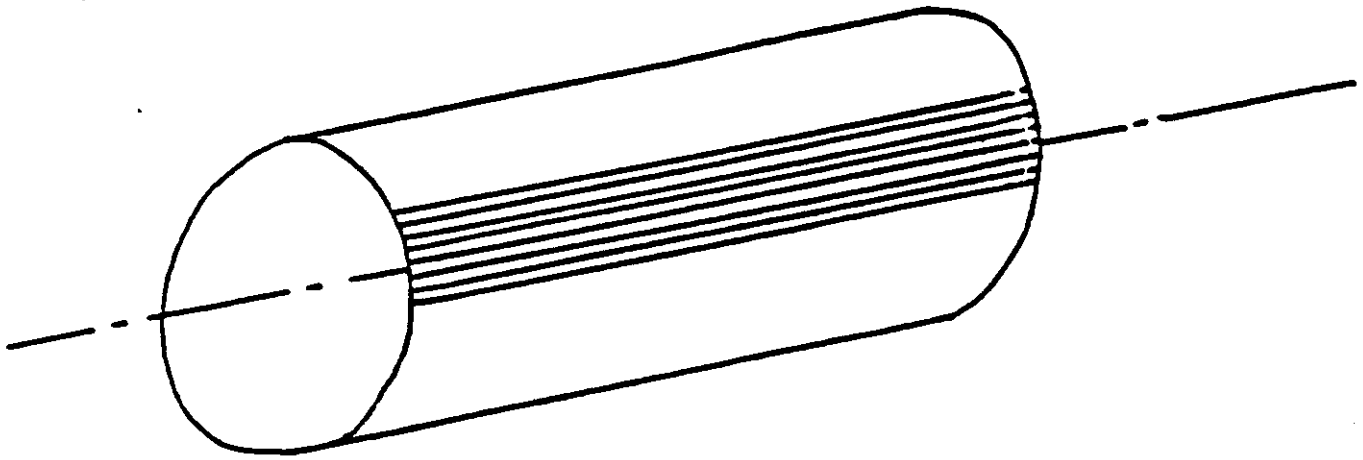
Advantages:
1) (r,ϕ) measurement precision can be attained
2) drift time across cells ~ 20 ns
3) active lengths up to 4 m practical
4) number of readout channels required for > 50 (r,ϕ) measurements is managable (~200K in HCTC design)

Disadvantages:
1) cell occupancies are relatively high [estimates 3 to 17%, outer to inner superlayers at $L = 10^{33}$ /cm^2/s]
2) mechanical construction is not simple

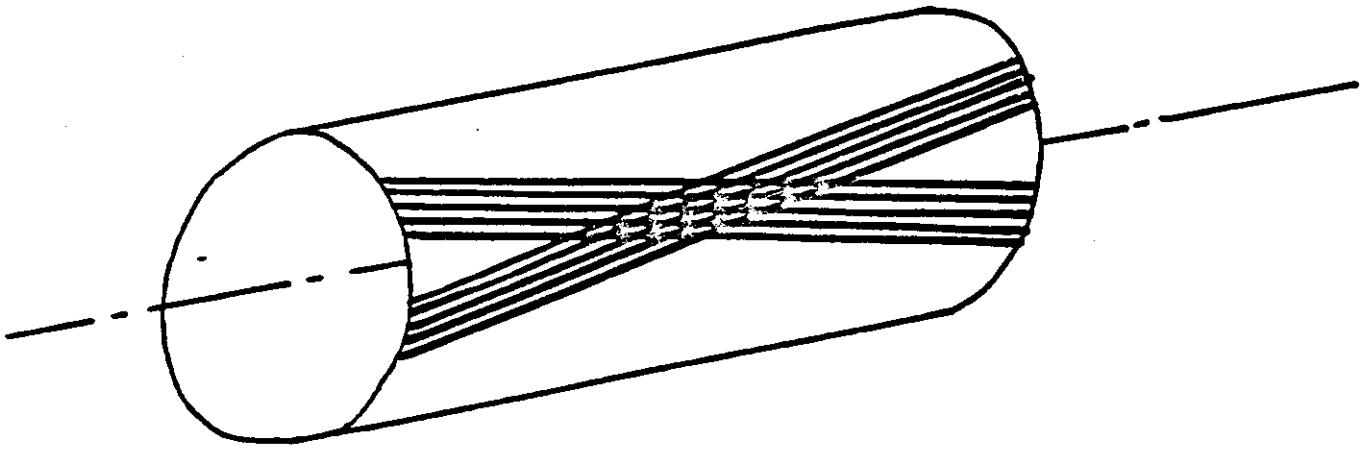
Conclusion: Straw tubes are a good choice for the (r,ϕ) measurements in the CTC during the first stage of SSC operation.

As the luminosity increases towards 10^{34}/cm^2/s some of the straw tube superlayers would be replaced by scintillating fiber superlayers. The optimum hybrid configuration is clearly luminosity dependent.

4 mm diameter
straw tubes
z wires
sigma (r,phi) - 150 microns



3/4 to 1 mm diameter
scintillating fibers
u-v stereo with ± 5° stereo
sigma(z) - 2 mm



Evolution of Hybrid CTC Design (con.)

Mechanical Support Structure and Fabrication

* large volume =>
* hermitic and isotropic tracking coverage =>
* rigid, low density, low creep support structures =>
* simplicity of detector fabrication =>
* fail-safe operation =>

All of the above design goals require careful consideration of the support structure and assembly proceedure for the CTC.

Conclusion: After discussions with mechanical and material science engineers at ORNL, our design evolved from a highly modular concept to one based upon large stable-base support cylinders.

Advantages of Stable-Base Support Structure

* large continuous cylinders can span the entire tracking volume
  => no support or termination plates within $-1.6 < \eta < +1.6$

* straw tube and scfi superlayers are directly supported and aligned by the precision outer surface of the cylinders
  => simplicity of fabrication
  => hermitic and isotropic tracking coverage
  => simpler trigger and pattern recognition

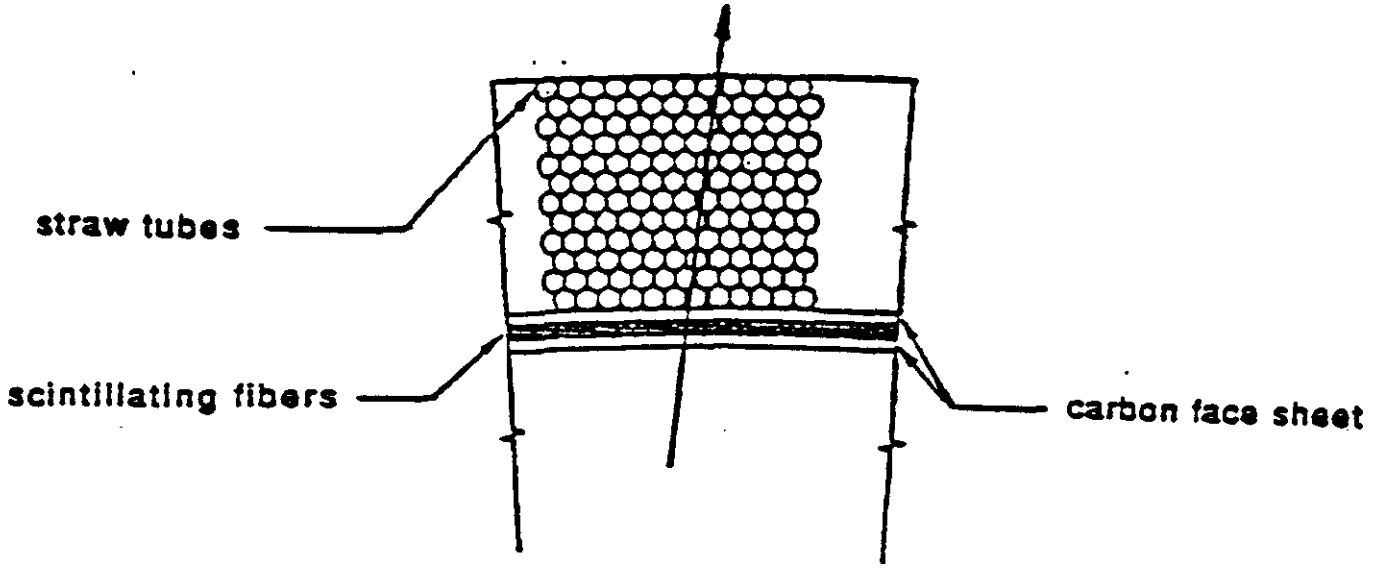
* cylinders can be fabricated from carbon fiber-epoxy skins outside a foam spacer
  => rigid structure (sag ~ 10's of microns)
  => long term stability (low creep)
  => low density (~ 0.3% X_0 cylinder thickness)

* automated procedures for laying the straw tubes and fibers on the outer surface of the cylinders seem feasible
  => lower cost

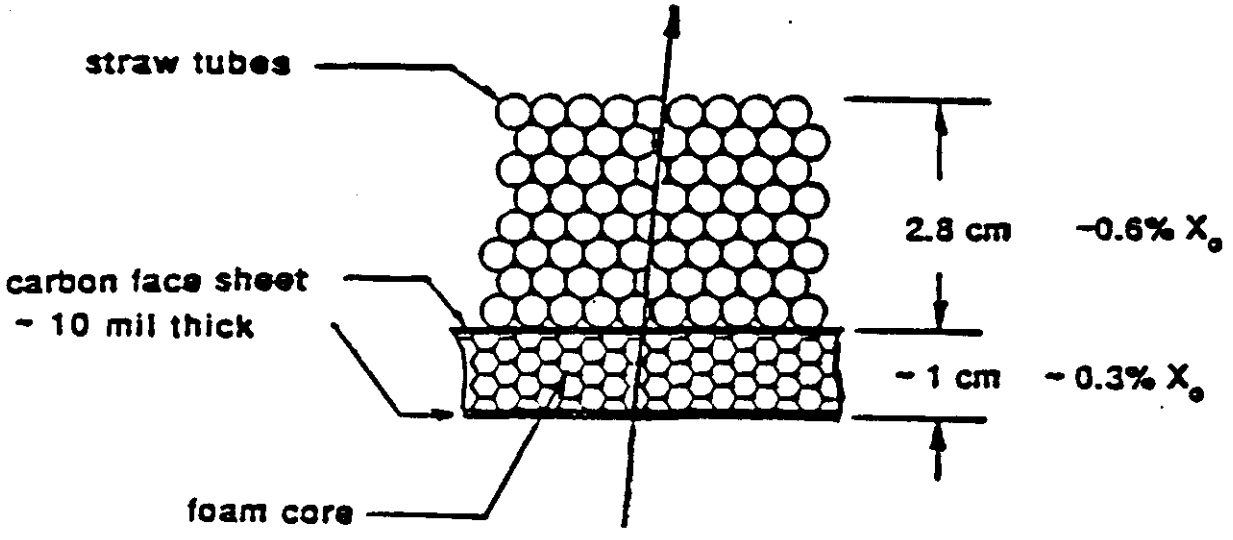
* the support structures at $\eta = \pm 1.6$ contain all gas and electronics
  => ease of incorporating modular electronics

Details of Stable-Base Cylinder Structure

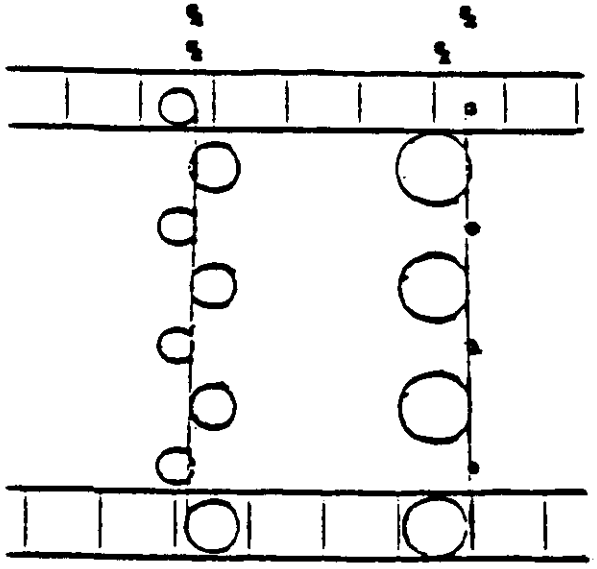
Initial Ideas



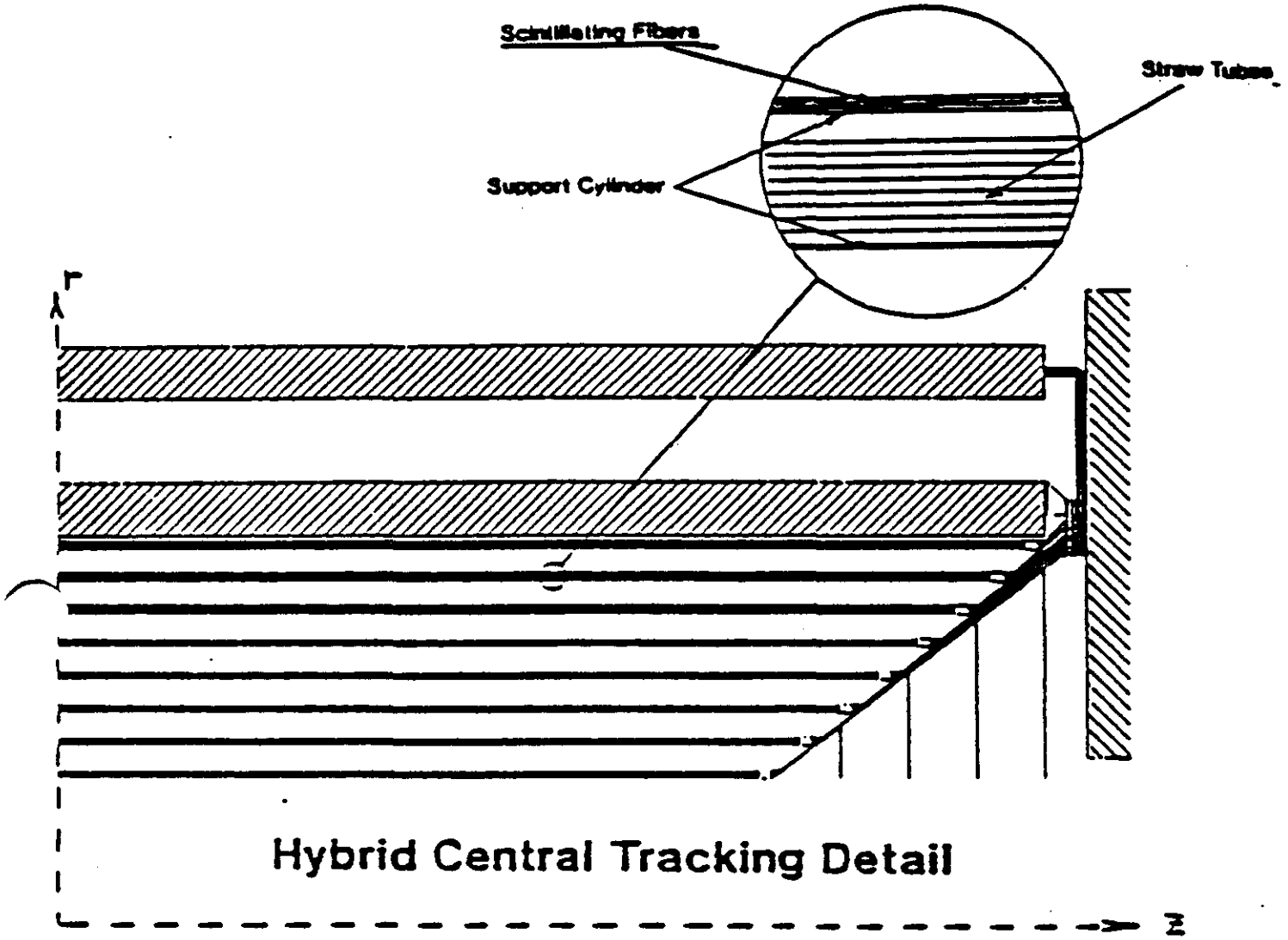
Design Based Upon FY1990 R&D



Straw Tube Superlayer (8 cells deep)
adjacent to a
Scintillating Fiber u-v Stereo Superlayer

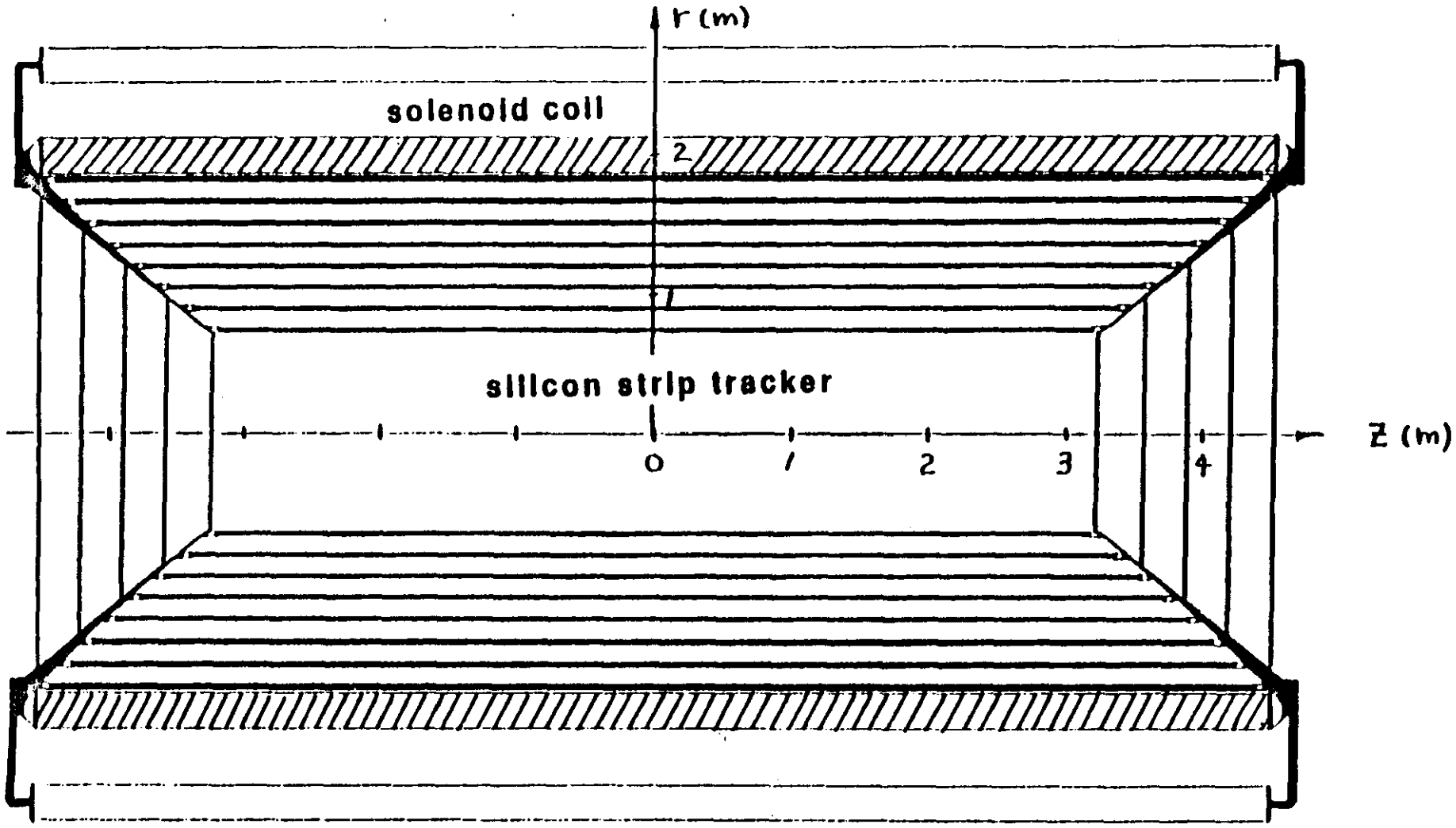


Monte Carlo simulation of straw tube and stereo scintillating fiber superlayers. The circles represent the distances measured from the straw_tube drift_times. The small squares indicate scintillating fiber hits. The left track is at z=0, the right at z=2cm (note the stereo displacement of the fiber hits).

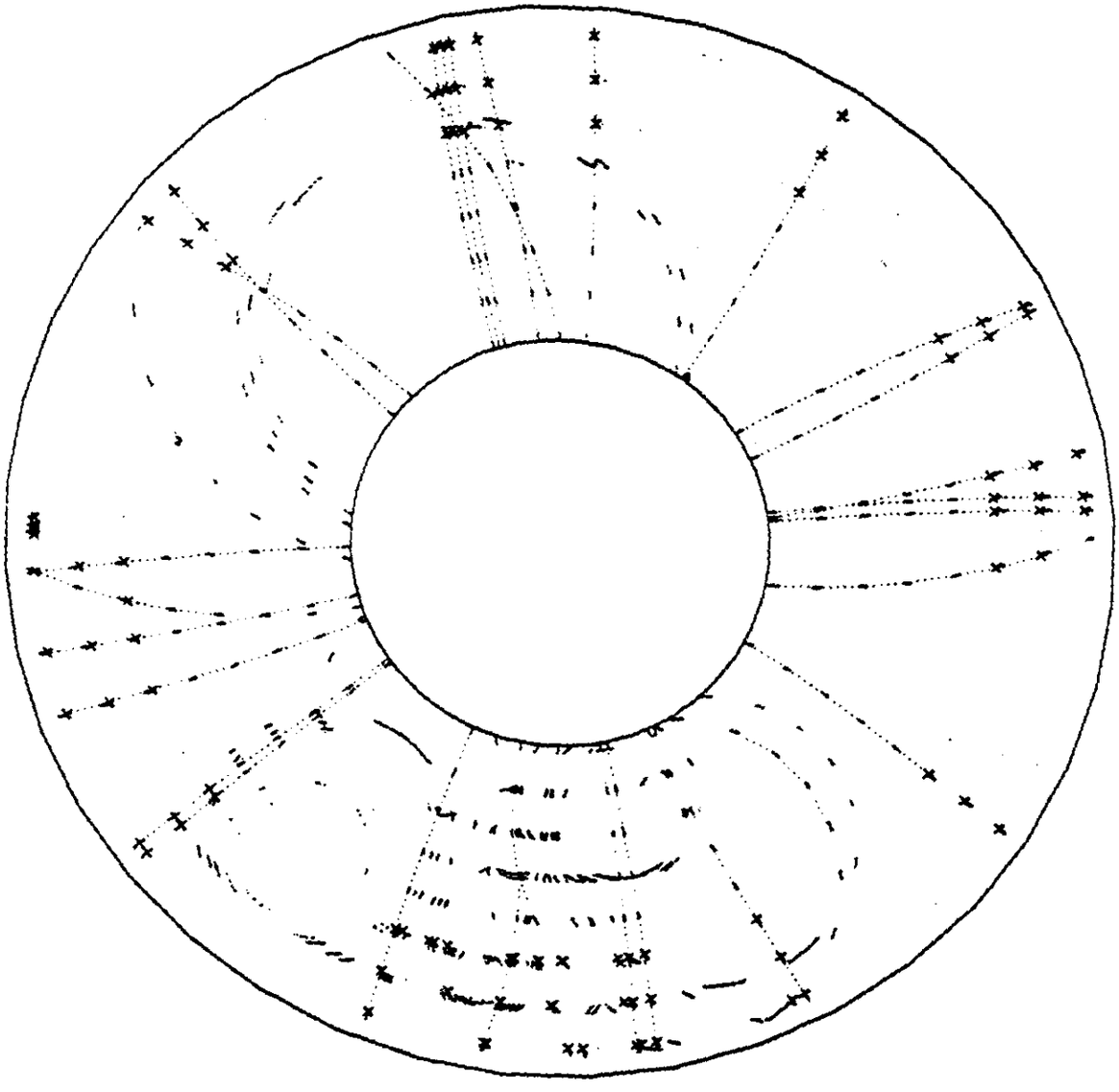


Cutaway view of one quarter section of a HCTC detector, with eight straw tube superlayers (z wires) and three outer scintillating fiber superlayers (stereo, u-v fibers).

Hybrid Central Tracking Assembly



HCTC detector in SDC outer tracking volume. The tracking within a radius of 0.5 m would be done with a silicon strip tracker.



Major HCTC R&D Results from FY1990

Task 1: straw tube drift chambers

* determination of E.S. stability requirements;
  solution of wire support problem
* construction and testing of 60 tube, 2.7 m long superlayer
* advancement of straw tube end plate design;
  zeroth order prototype on 2.7 m superlayer;
  first order design with gas manifolds, cooling, electronics
* radiation hardness study of gases, straw tubes and glues

Task 2: scintillating fibers

* evaluation of light output and radiation hardness of various fibers
  [Bicron, Kurary, Optectron]
* preliminary evaluation of avalanche photodiode performance in
  geiger mode at room temperature; measurement of susceptibility
  to neutron damage

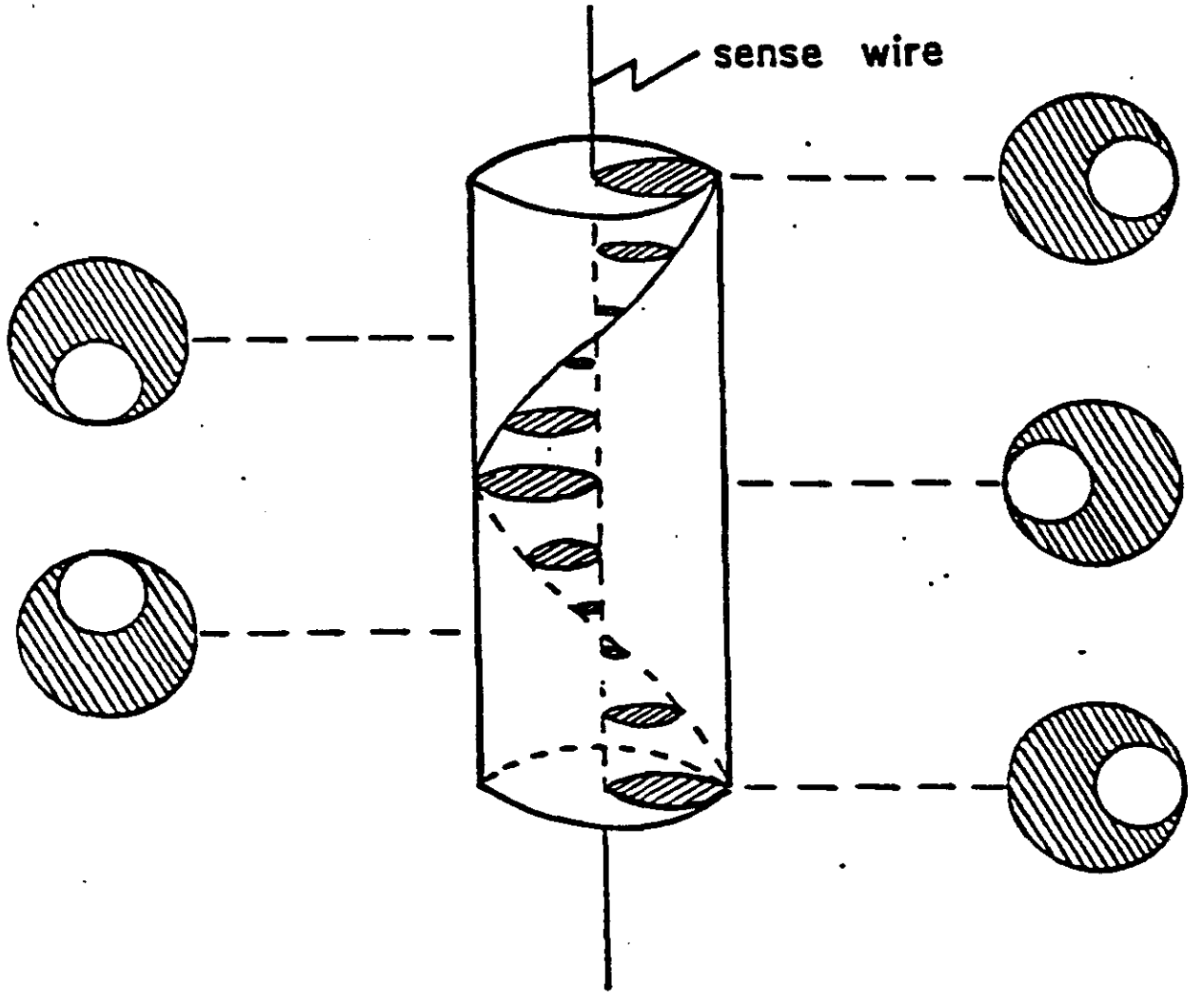
Major HCTC R&D Results from FY 1990 (con.)

Task 3: mechanical engineering

* analysis has shown that the large, rigid, low density cylinders needed for the HCTC design can be constructed
* progress has been made on the design of a support structure for the HCTC superlayers
* preliminary ideas for straw tube assembly automation have been developed

Task 4: Monte Carlo simulations

* a detailed simulation of the HCTC detector's response to SSC interactions has been made
* preliminary pattern recognition studies have been carried out


sense wire

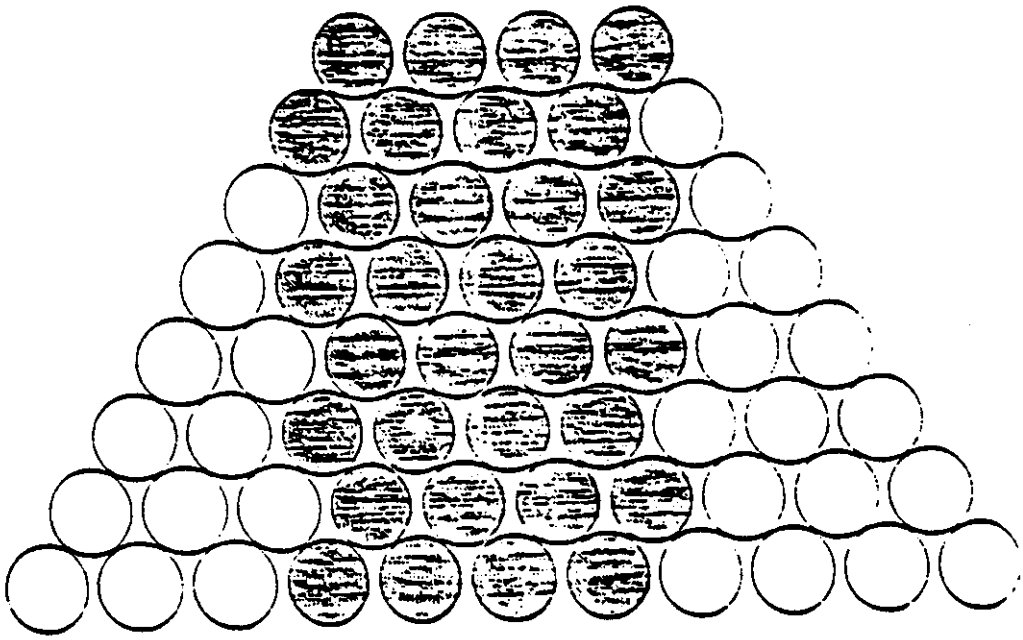


Figure 2-4(a). Cross section of the straw tube superlayer. The shaded tubes were instrumented with sense wires.

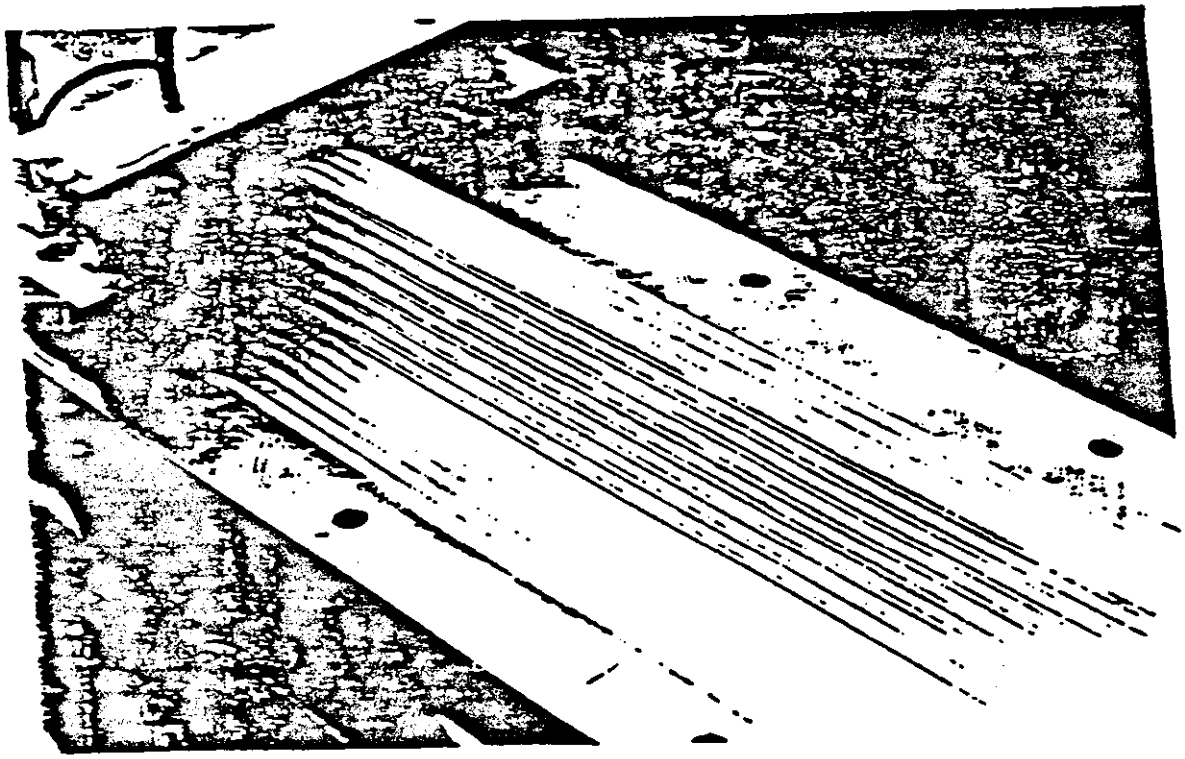
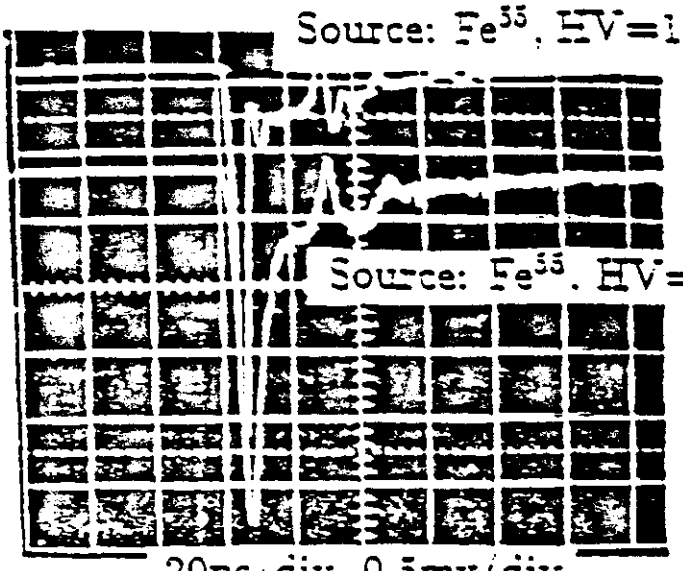


Figure 2-4(b). Photograph of superlayer.



Source: Fe^{55}, HV=1800. Gas:Ar-Ethane-CF_4

Source: Fe^{55}, HV=1650, Gas:Ar-Ethane .

20ns/div. 0.5mv/div

20ns/div. 0.5mv/div

Source: Sr^{90}, HV=1800.

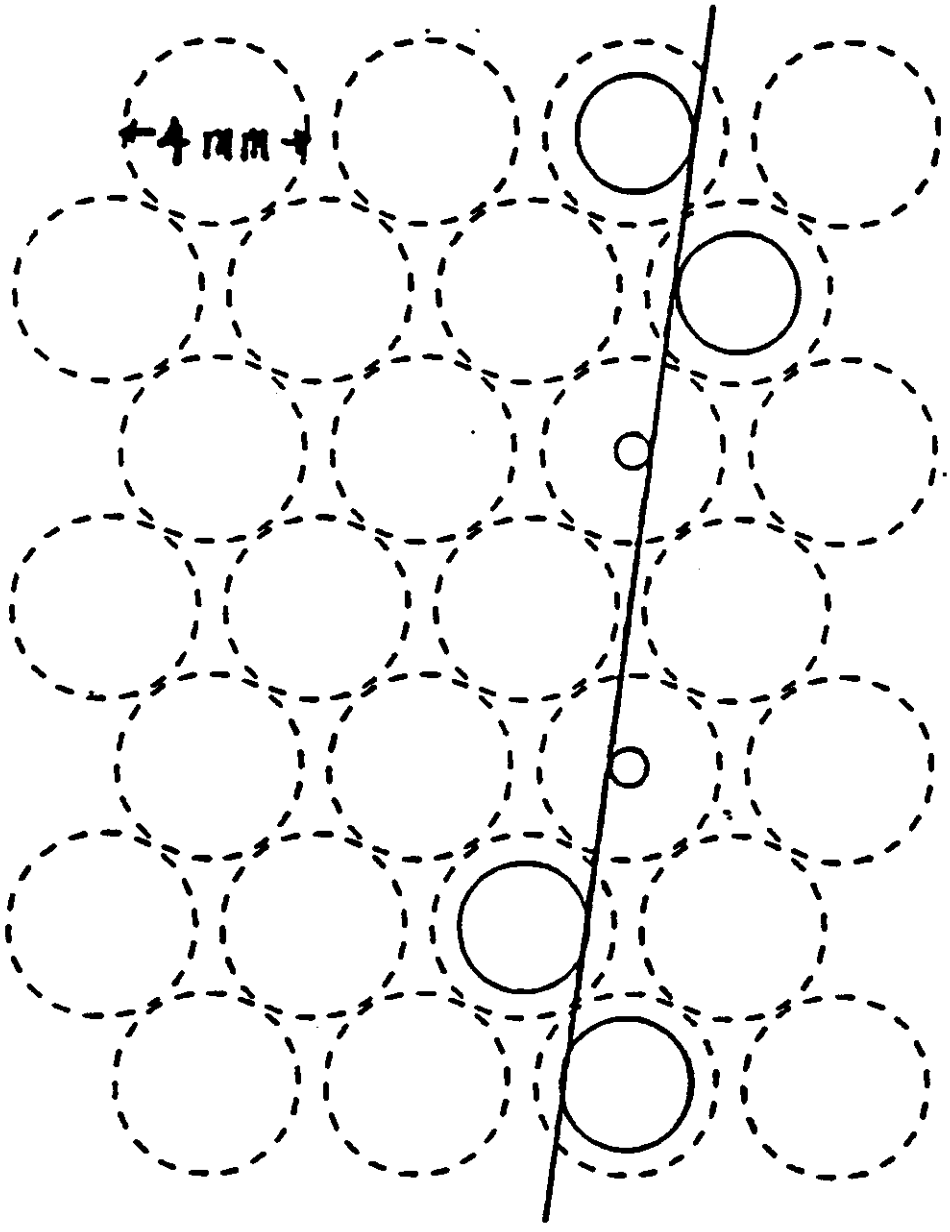
Gas:Ar-Ethane-CF_4

20ns/div, 0.5mv/div

Source: Sr^{90}, HV=1650,

Gas:Ar-Ethane .

Figure 2-10. Averaged signals from straw tubes directly into 50 Ω's under different conditions.


4mm

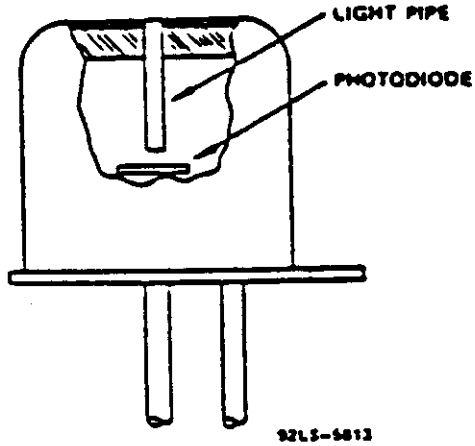


Figure 3-1. Cross-section of C30921S package. Light pipe core diameter and detector sensitive diameter are both 0.5 mm.

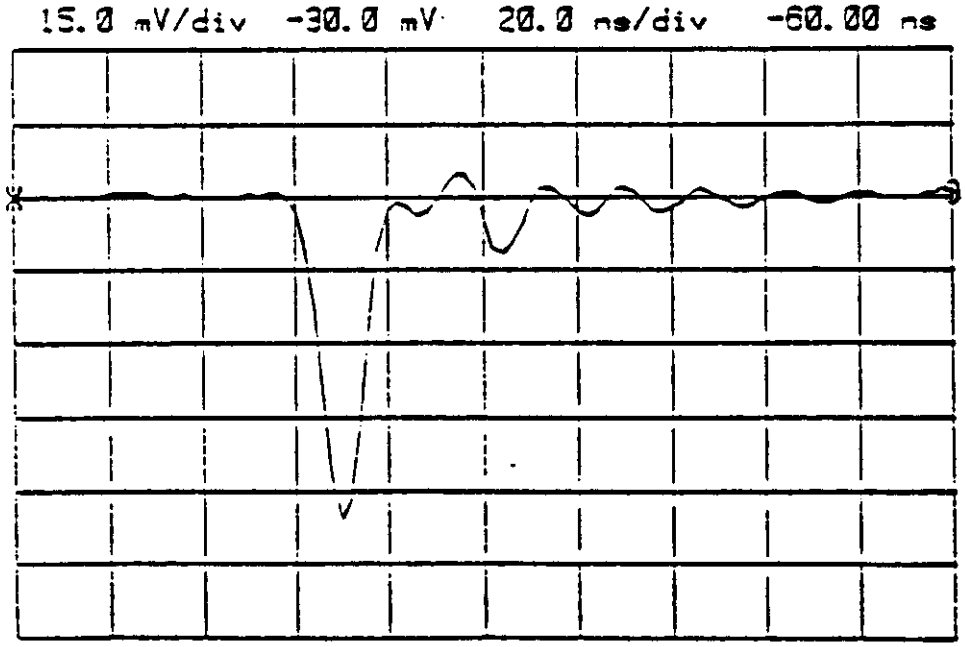


Figure 3-2. Signal obtained with prototype of hybrid circuit.

Table 3-2. Results of neutron irradiations of avalanche photodiodes

Test No.	Fluence (cm^{-2}) Fast	Thermal	Dark count rate Before	After	Dark count Ratio, R	Dark current Ratio
1	1.1×10^6	1.6×10^7	4778	5383	1.13	0.86
2	2.2×10^6	3.2×10^7	6052	5785	0.96	1.00
3	5.5×10^6	8.0×10^7	6900	8993	1.30	0.90
4	5.5×10^6	8.0×10^7	5776	21,255	3.68	1.00
5	1.1×10^7	1.6×10^8	5798	21,055	3.63	1.10
6	1.8×10^7	2.6×10^8	7693	24,342	3.16	0.94
7	2.6×10^7	–	5763	45,724	7.93	1.00
8	2.6×10^7	3.8×10^8	6836	39,556	5.79	0.87
9	1.6×10^7	1.3×10^8	5500	60,700	11.04	0.86
10	3.2×10^7	2.6×10^8	5190	68,062	13.11	0.83

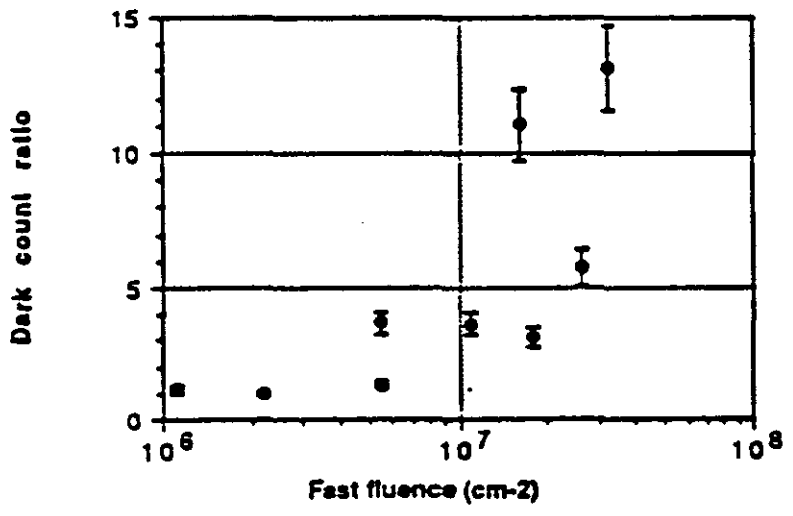


Figure 3-9. Variation with fast neutron fluence of the ratio of dark count rate after irradiation to that before irradiation.

Major HCTC R&D Goals for FY1991

Task 1: straw tube drift chambers

* continued evaluation of existing 2.7 m superlayer
* construction of long (~5 m) straw tubes with midtube terminators
* construction of a straw tube superlayer on cylindrical drum; study of assembly automation procedures
* frontend electronics testing and assembly into end plate ring
* gas selection and aging studies
* radiation hardness evaluation of all components

Task 2: scintillating fibers

* study optical and mechanical properties of fibers and ribbons
* development of readout electronics: avalanche photodiodes
  multianode photomultipliers
* radiation hardness evaluation of all components

Major HCTC R&D Goals for FY1991 (con.)

Task 3: mechanical and system engineering

* carbon fiber cylinder design and prototype fabrication
* end plate design and prototype fabrication
* support structure design
* development of assembly and automation procedures

Task 4: Monte Carlo simulations

* detector response and pattern recognition studies
* optimization of HCTC parameters for SDC detector
* evaluation of neutron backgrounds in central tracking region

CONCLUSIONS

* A hybrid of straw tubes and scintillating fibers is needed to optomize the design goals of a large volume CTC for the SSC.

* Our analysis indicates that a very low density support structure based upon large carbon fiber cylinders is desirable over alternative approaches.

* The HCTC design provides a natural path for upgrades to high luminosities.