SDC-92-190

SDC
SOLENOIDAL DETECTOR NOTES

SILICON & SCINTILLATING FIBER TRACKING AT HIGH LUMINOSITY

D. Adams

January 30, 1992

Silicon + Scintillating Fiber Tracking @ High Luminosity

D Adams
30 JAN 92
SSCL

Purpose: To demonstrate the robustness of the proposed SDC Silicon & scintillating fiber central tracker.

Method:

① Generate $H \to ZZ \to 2\mu\, 2e$

for $\mathcal{L} = 0, 1, 3, 6, 10 \times 10^{33}/cm^2/sec$

② Propagate through tracking system w/ GEANT

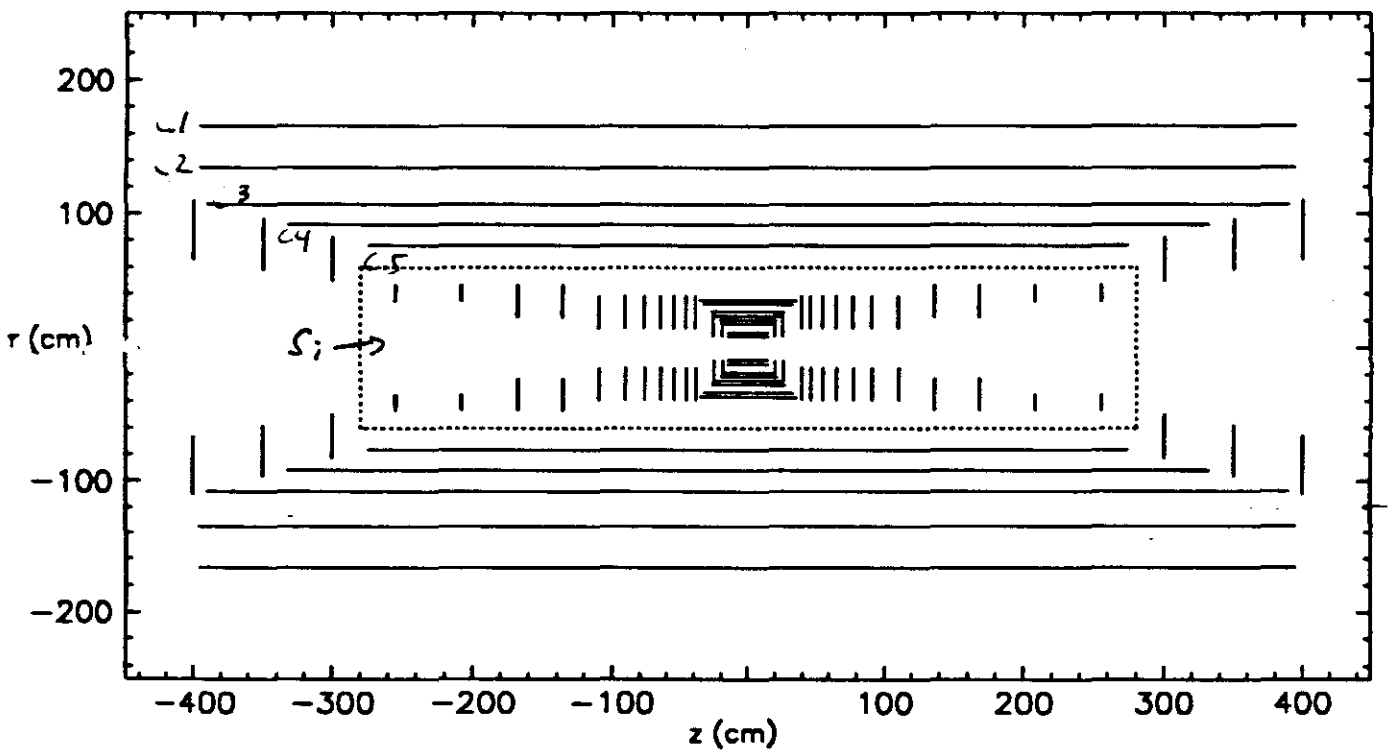
- occupancy for different layers

③ Reconstruct tracks w/ TRF

- efficiency
- fake track rates
- resolution

all as a function of $\mathcal{L}$

SDC Central Tracking System
used in this Simulation



Event Generation

Primary Event:

- 300 GeV Higgs
- use ISAJET
- Decay $H \to ZZ \to (2\mu)(2e)$
- Keep only events where all four leptons have $|\eta| < 0.88$

Background Events:

- Pythia QCD inelastic
- $1.6\left(\frac{\mathcal{L}}{\mathcal{L}_0}\right)$ events/crossing $\mathcal{L}_0 = 10^{33}/cm^2/sec$
- crossings (-4, 2)
- use Poisson distribution to select the number in each crossing
- discard tracks w/ $|\eta| > 3.0$

• All event vertices smeared: $\sigma_z = 5\,cm$

$\sigma_x = \sigma_y = 5\,\mu m$

Track Propagation

- GEANT based
- Silicon described by the ST package
  - Geometry from st-descope3a.kumac
  - $|z| < 0.9$ covered by 8 barrels
  - All layers include axial and 5 mrad stereo strips
- Scintillating Fiber described by SF pks.
  - geometry from sf_optc8.dat
  - $|z| < 2.0$ covered by 5 superlayers
  - Outer 3 superlayers include 15° stereo. 2u layers + 2 v layers
  - All superlayers have 4 axial layers w/ 1/4 fiber offsets
  - Time gate: signal must reach the end of the scintillating fiber in the window $9 < t < 31$ ns in order to be digitized.
  - MIP will produce 6.5 photoelectrons at near end of fiber at 3.0 at 4m. Use Poisson distribution + require at least one to digitize.
- See fig.

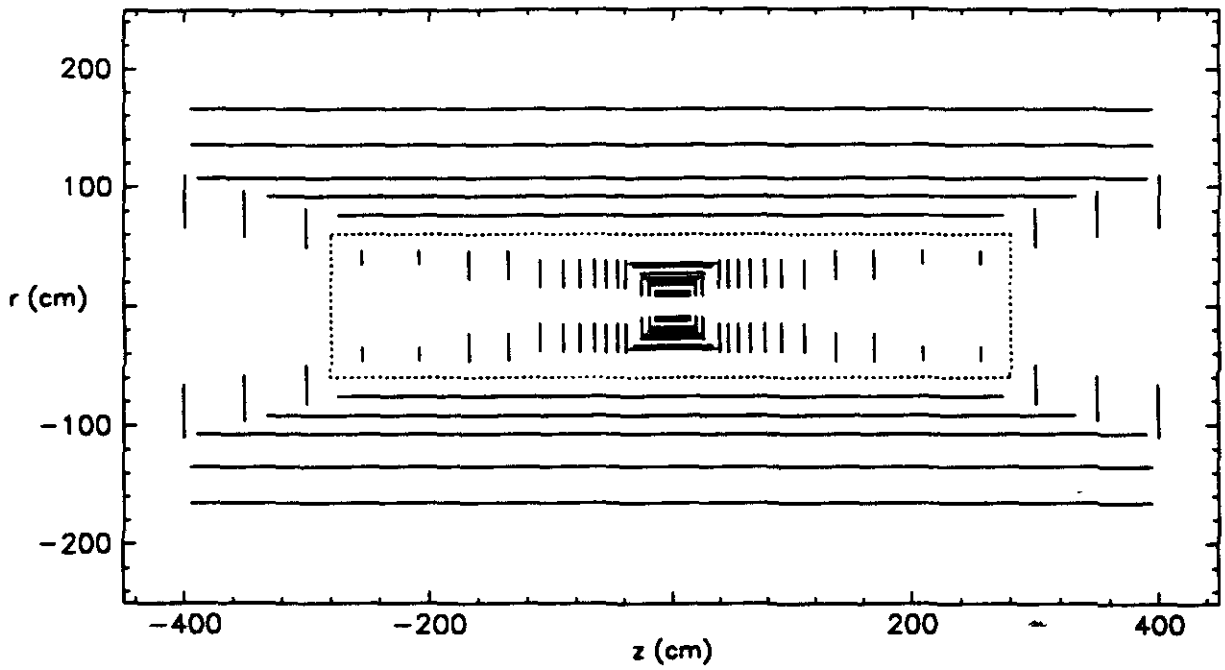


Figure 1. The SDC tracking system used in this study. The dotted lines show the boundary between the silicon and scintillating fiber systems. This study only makes use of the barrel detectors.

ticle crosses the center of the fiber near the readout fiber and 2.9 are produced if it crosses 400 cm away. The actual number of photelectons produced is randomly selected from a Poisson distribution and a fiber is digitized (i.e. recorded as being hit) if this number is at least one.

Event Generation

We generated a series of runs each containing 100 primary events with varying numbers of background events to simulate different SSC luminosities. The primary events were 300 GeV Higgs decaying into two Z-bosons with one Z decaying into two muons and the other into two electrons. These were generated using Isajet with the control file listed in Appendix B. The events were filtered to select only those for which all four leptons had $|\eta| < 0.85$.

Background was generated using Pythia QCD inelastic events in all crossings from four before the interesting event through two after. The SSC design luminosity of $10^{33}/\text{cm}^2/\text{sec}$ was simulated with an average of 1.6 such events per crossing where the actual number of generated events was selected from a Poisson distribution. Other luminosities were obtained by scaling this average. The vertex position of each generated event was independently selected from a distribution Gaussian in z with $\sigma = 5\text{cm}$ and in x and y with $\sigma = 5\mu\text{m}$.

Occupancies

After generating events and tracking them through the detector, the occupancy was measured separately for

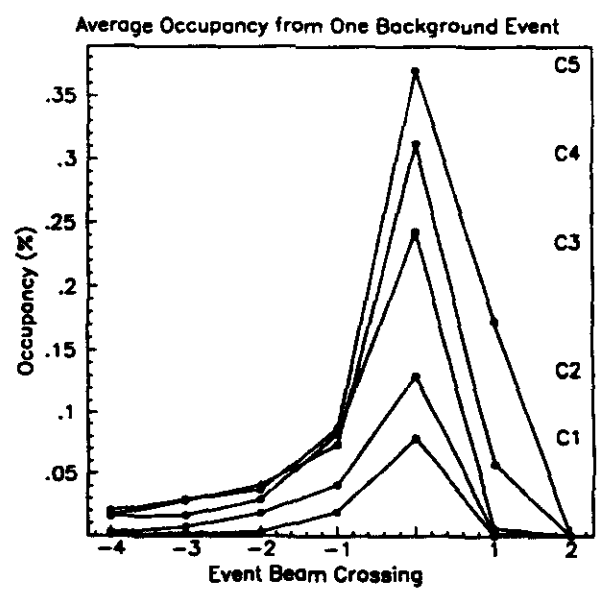


Figure 2. Occupancy contribution from one background event in different beam crossings.

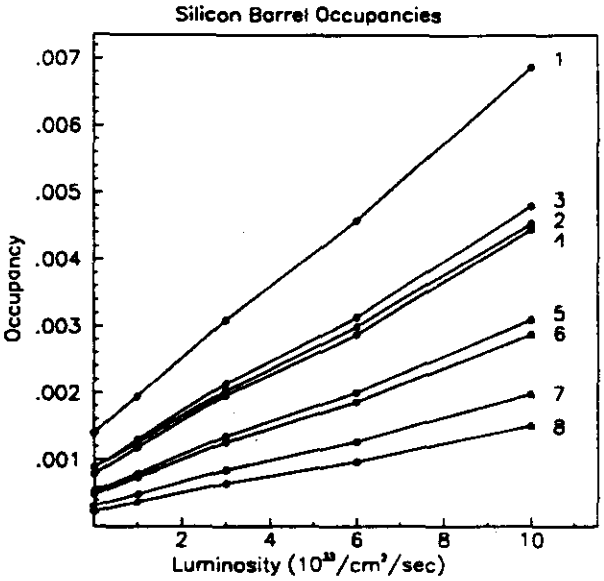


Figure 3. Silicon occupancies as a function of luminosity.

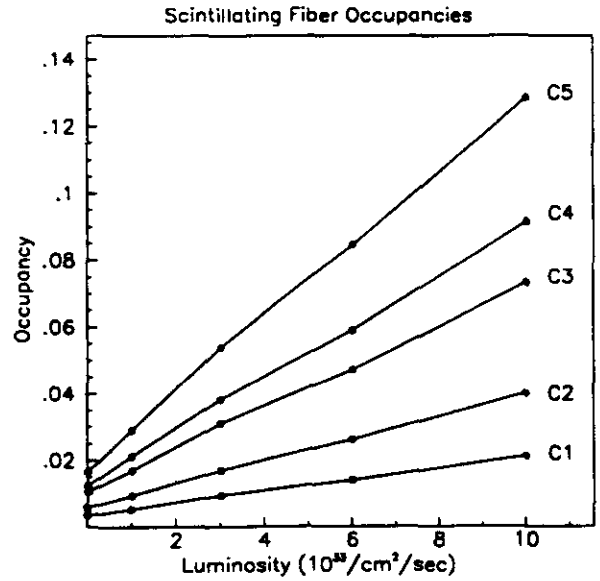


Figure 4. Scintillating fiber occupancies as a function of luminosity.

layer	L=0	L=L_0	L=3L_0	L=6L_0	L=10L_0
1	0.00140	0.00194	0.00309	0.00458	0.00687
2	0.00089	0.00126	0.00203	0.00299	0.00454
3	0.00088	0.00130	0.00214	0.00313	0.00480
4	0.00079	0.00118	0.00196	0.00287	0.00445
5	0.00053	0.00080	0.00135	0.00200	0.00310
6	0.00048	0.00074	0.00126	0.00186	0.00288
7	0.00031	0.00049	0.00085	0.00127	0.00198
8	0.00023	0.00037	0.00065	0.00097	0.00151

Table 1. Average ocupancies in each of the silicon barrel layers for our central $H \rightarrow ZZ \rightarrow 2\mu 2e$ events with different background luminosities ($L_0 = 10^{33}$/cm^2/sec). Layers are numbered startting at the inside.

layer	L=0	L=L_0	L=3L_0	L=6L_0	L=10L_0
C1	0.0035	0.0054	0.0095	0.0140	0.0211
C2	0.0058	0.0095	0.0170	0.0261	0.0400
C3	0.0106	0.0170	0.0310	0.0471	0.0731
C4	0.0124	0.0212	0.0382	0.0590	0.0914
C5	0.0165	0.0290	0.0539	0.0846	0.1283

Table 2. Occupancies for each of the scintillating fiber superlayers for our central $H \rightarrow ZZ \rightarrow 2\mu 2e$ events at different background luminosities ($L_0 = 10^{33}$/cm^2/sec). Superlayers are labeled from outermost C1 to innermost C5.

each superlayer. The occupancy is defined to be the fraction of channels which have been digitized. Figure 2 shows the average occupancy contributed by single background events in different beam crossings. The Higgs occupancies for each of the silicon layers are given in figure 3 and table 1 and the scintillating fiber occupancies appear in figure 4 and table 2.

Track Reconstruction

Track finding and reconstruction were performed with the program TRF (SDCSIM package TR). TRF uses a road-following technique with a road map provided by the user at run time. Tracks were found in three ways: in silicon only, fibers only and in the combined system. The combined fitting was done by extrapolating the silicon tracks in to the fibers. In all cases tracks were found and fitted with a radial vertex constraint imposed and then were refit without the vertex constraint.

Analysis

The performance of the tracking system is evaluated using the leptons from the Higgs decay. There are 200 of each in each of our runs. We define candidate tracks to be the subset of these that intercept all the silicon barrels and have p_T greater than 5 GeV/c. Approximately 10% of the generated leptons did not meet these criteria most because they missed some of the silicon detectors due to flutuations in the z-position of the vertex.

Each of the reconstructed tracks is compared with each Monte Carlo track by calculating the match chi-square defined by:

$$\chi^2_M = \sum_{i,j} (T_i^{rec} - T_i^{mc})\, E_{ij}^{-1}\, (T_j^{rec} - T_j^{mc})$$

Track - Finding

1) Use TS to combine Si axial and stereo strips to form 3D coordinates.

2) Use TRF to cluster hit fibers in each coordinate superlayer (i.e. 4x, 2u or 2v) to form 2D coordinates.

3) TRF uses a road-following technique to find tracks from these coordinates. Three methods:

Si Only - start in outer Si layer and move in. Require hits in 6/8 layers.

Si + SF - start w/ the Si only tracks
extend to scifi axial - 1/5
extend to scifi stereo - 3/4

SF only - start in outer scifi axial
extend through axial layers - 5/5
extend through stereo - 4/4

- Look for tracks w/ $p_T > 5.$ GeV/c
- Apply χ^2 cut at each layer.
  See fig's for final χ^2 vs χ (no change w/ χ!)
- Multiplicity of hits on track also constant - see fig's.

Analysis

- Select <u>candidate leptons</u> from the Monte Carlo list
  - $p_T > 5$ GeV/c (accepts almost all)
  - $|z + 18 \tan\lambda| < 18$ (rejects 10% - those which miss silicon layers)

  Each run has 100 events
  $\Rightarrow \sim 180$ $e^\pm$ candidates
  ~ 180 $\mu^\pm$ candidates

- Reconstructed and Monte Carlo <u>tracks are matched</u> by looking at the difference between their track vectors $\vec{T}_{rec} - \vec{T}_{mc}$. This difference is weighted by the inverse of reconstructed track error matrix to define χ^2_F:

$$\chi^2_F \equiv (\vec{T}_{rec} - \vec{T}_{mc})\, E^{-1}_{rec} (\vec{T}_{rec} - \vec{T}_{mc})$$

  - Each reconstructed track is matched to the nearest (smallest χ^2_F) M.C. track.
  - If 2 reconstructed tracks match to the same M.C. track, then the one with larger χ^2_F is left unmatched.
  - Fig's show χ^2_F distribution. No dependence on z but e has tail.

<u>Efficiency</u> is measured in two ways:

<u>Track-finding</u> efficiency is the fraction of M.C. leptons that are matched

<u>Reconstruction</u> efficiency is the fraction of M.C. leptons that are closely matched, i.e. have $\chi^2_F < 100$ [see fig]

- <u>Fake tracks</u>

  - There were ≤ 2 unassigned tracks/run (≤ 0.02/event) for S_i, $S_i + SF$ and low $\mathcal{L}$ SF.

  - There are significant numbers of tracks with $\chi^2_F > 100$ but these are not fakes:

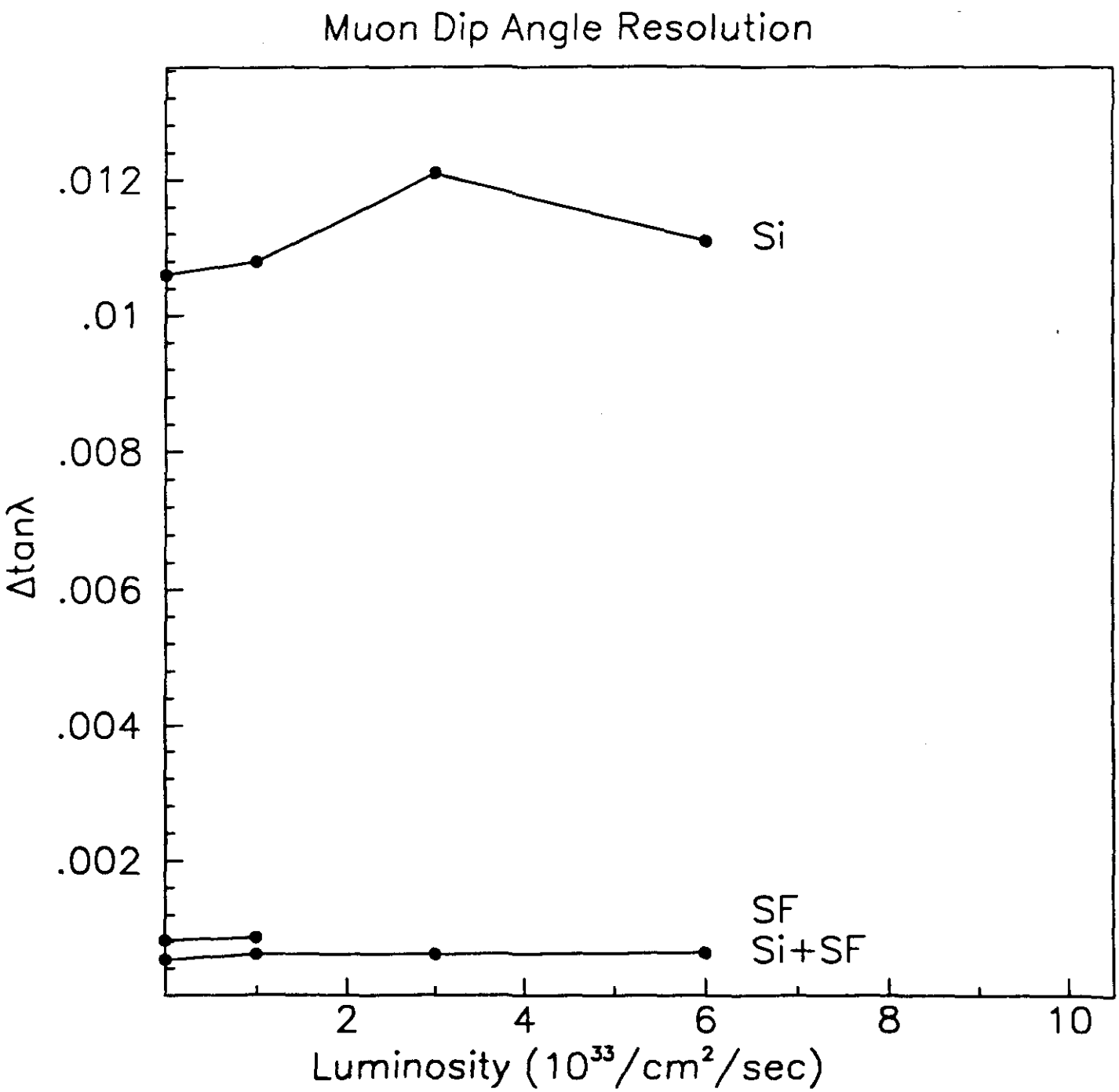
    - Rates do not increase significantly w/ $\mathcal{L}$.

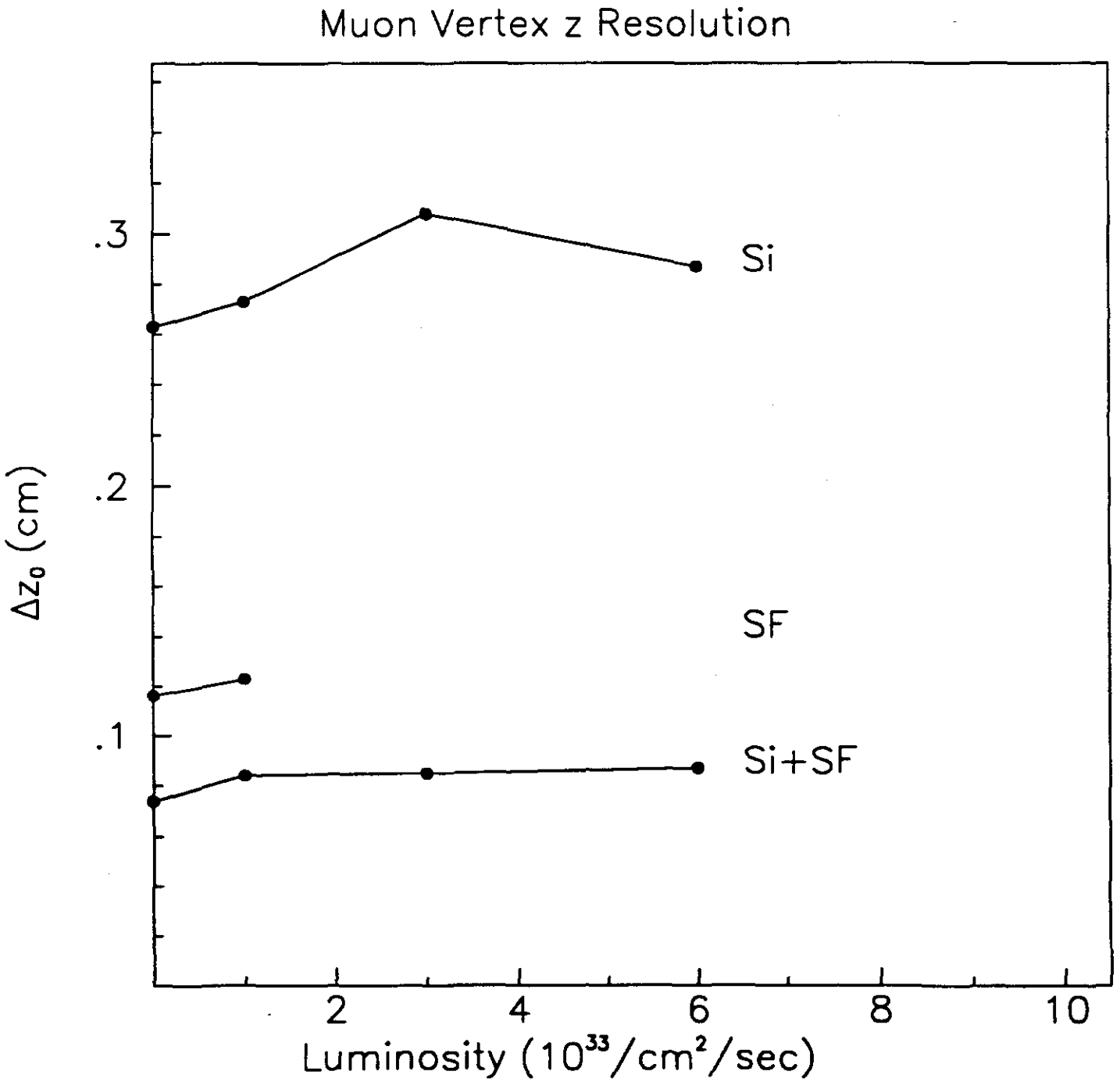
    - Many of these are the missing $e^{\pm}$'s.

Resolutions

Resolutions are defined as the RMS difference between reconstructed + MC track parameters.

See figs. for $\frac{\Delta p_T}{p_T^2}$, $\Delta \tan\lambda$, Δz_{beam}


Muon Dip Angle Resolution
.012
.01
.008
.006
.004
.002
Δtanλ
Si
SF
Si+SF
2
4
6
8
10
Luminosity (10^33/cm^2/sec)


Muon Vertex z Resolution
.3
.2
.1
Δz_0 (cm)
Si
SF
Si+SF
2
4
6
8
10
Luminosity ($10^{33}/cm^2/sec$)

Conclusions

The Si + SF tracking system described here is very robust for finding isolated leptons even at high luminosities.

New (Jan 92) Tracking System

Changes

- 4 layer barrels → 2 × 2 layer "vector" barrels
  ⇒ $r\varphi$ resolution degraded by $\frac{2}{\sqrt{2}} = \sqrt{2}$
- Fiber size 0.83 mm → 1.00 mm
  ⇒ $r\varphi$ & z resolution degraded by $\frac{1.00}{.83} = 1.2$

Implications

1) more layers (5 → 12) ⇒ better pattern recognition
2) $r\varphi$ parameters (φ, p_T) degraded by $\sqrt{2} \cdot 1.2 = 1.7$
3) z parameters ($\tan\lambda$, $z_{...}$) degraded by 1.2

PARAMETRIC PERFORMANCE

ACCEPTANCE	HIGGS → 4ℓ	50%	
P_T :	HIGGS → 4ℓ (50GeV/c) typ. P_T	$\frac{\Delta P_T}{P_T^2} \gtrsim 0.16 \left(\frac{TeV}{c}\right)^{-1}$	* BASED ON NOV. CDR.
	HIGH P_T μ (4TeV/c)	$\frac{\Delta P_T}{P_T^2} = 0.17 \left(\frac{TeV}{c}\right)^{-1}$	
$\Delta(\tan \lambda)$	0.0084		
Δz (shower max)	1.2mm		
Δz (beam line)	1.3 mm		
Δz (muon detector)	3.6mm		