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TRACK RECONSTRUCTION IN STRAW SUPERLAYERS

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Abstract

We have developed a program to reconstruct track segments in dense wire drift chamber arrays. We compare our ISAJET simulations of signal and background events for SSC parameters with previous studies and report measurements of the pattern recognition efficiency for a large solenoid detector geometry. We find that the tracking is quite reliable for superlayers placed more than 50 cm from the beam axis. Without accounting for detection inefficiencies we find comparable performance for either six or eight layers per superlayer.

Introduction

We have begun a study of the reliability of track reconstruction in a combined silicon strip and wire drift chamber detector with solenoidal magnetic field under design for operation at the SSC[1]. Previous studies[2,3,4] have delineated some of the parameters for such a system. To make the pattern recognition manageable, cylindrical layers of drift cells are organized into groups (superlayers). A preliminary phase of data reduction is performed to identify strings of consecutive measurements along a track (segments), resolve right/left ambiguities, and fit for local position and direction. High particle fluxes pose the potential problems of information loss caused by pileup and confusion of the pattern recognition. Qualitative evidence that the information of interest can be extracted has been presented previously[4]. Here we discuss a quantitative study of pattern recognition at the segment finding level. One of the objectives is to establish the appropriate number of layers required in a superlayer, bearing in mind that less is better from the perspective of minimizing cost and the amount of material in the particle path.

The following sections of this paper describe the model used for simulation, the pattern recognition scheme, results and conclusions.

Event simulation and occupancy estimate

To make sure that our performance tests will be sufficiently realistic we first made some simple calculations of occupancies with the available physics process simulation programs, putting in the appropriate detector geometry but omitting detailed tracing of particle progress through the detector. Some of the omitted effects are accounted for by hand after comparison of our results with previous studies.

We use the ISAJET package to generate signal events. In the present work, these are production of Higgs bosons of mass 800 GeV/c^2 and their subsequent decay to leptons through Z^0 pairs. For the background, we ran ISAJET with the TWOJET option and a minimum transverse momentum ($p_\perp$) of 4.5 GeV/c, the value that gives a two-jet cross section equal to the total inelastic cross section extrapolated from data (about 95 mbarns). The charged particle yield is about 10 per unit of rapidity.

The detector geometry is that of the barrel straw tracker described in the SDC expression of interest[1], namely, eight superlayers at radii between 0.73 and 1.80 m and maximum half length 3.0 m, in a magnetic field of 2 T. To measure occupancy in this detector we compute the intersections of helical trajectories with the cylindrical detector surfaces. The number of crossings of one track may be zero (looper never reaches the layer), one (track exits through the coil and does not return), a few (looper traverses the superlayer, then reenters), or many (looper passes through the superlayer tangentially). We take the number of loops made before a track leaves the detector through the ends to be two, a rough average inferred from event pictures.

The integration time is taken to be 40 ns, based upon a drift cell radius of 2 mm, drift velocity of 100 μm/ns, and allowance for time-of-flight plus signal propagation delays and pulse duration. This implies that the detector integrates over 2.6 bunch crossings on average. At the design luminosity of 10^{33} cm^{-2}s^{-1} there are 1.6 interactions per crossing, so the detector sees 4.2 events per trigger. The occupancy we find from this calculation is shown by the dashed curve in Fig. 1.

An earlier study by Makoto Asai[5] can be compared with this one, if we interpolate to the approximate rapidity acceptance of SDC and correct for the slightly different straw radius. Asai's calculation used the PYTHIA event generator. The present result at 1 m superlayer radius is about ten percent higher than Asai's for primary particles only. He finds that with secondary interactions the occupancy is about two times as large. Therefore we have

scaled our result to get the solid curve in Fig. 1.

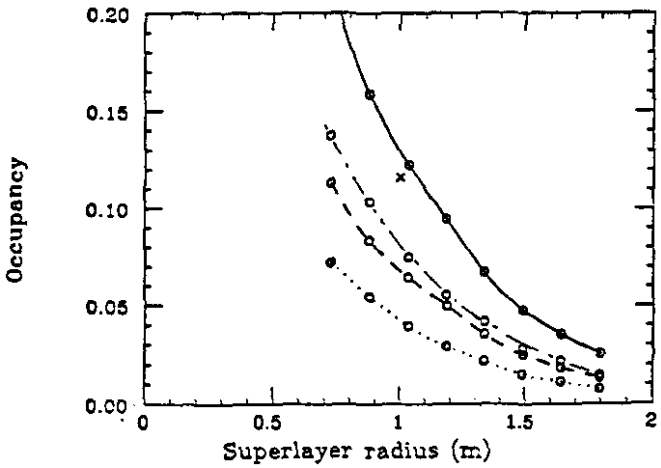

Figure 1. Occupancy vs radius in the SDC barrel straw tube tracker. The curves are: (dashed, dotted) primary charged tracks from (ISAJET,PYTHIA); (solid, dot-dashed) scaled by the factor 1.9 to account for secondary interactions.

Our calculation repeated with the PYTHIA event generator shows that the yield is about 60-70% of the ISAJET value (6.5 per unit of rapidity). The corresponding occupancy curves are included also in Fig. 1.

For the pattern recognition study discussed below we used a file of background events generated with ISAJET as described above, selecting the number of interactions from a Poisson distribution with mean of 4.2. Secondary interactions within the straw detector are included, but none in the silicon detector. The net occupancy is within the range of our present best estimates.

Pattern recognition

Each superlayer contains six or eight layers of straw tubes in a close-packed configuration. The time measurement can be converted into a simple circular contour of distance from the wire, to which the trajectory is tangent. This is true provided the time of arrival of the signal at the readout electronics is given solely by the drift time. In fact the delay from particle time of flight to the detector and propagation of the signal pulse along the wire to its end is not completely negligible: it amounts to the time equivalent of roughly 100 microns of track displacement, which is comparable to the measurement resolution from electron diffusion in the gas. Systematic variation of the pulse height may aggrevate this effect. Of course this delay is not random, and can be corrected for once a track is fully reconstructed and the axial position of the track is known. This information is not available, however, to the segment finder. It may be necessary to treat the track crossing time as a parameter to be inferred from the segment fit, along with the azimuth and direction of the track. In the present study, we have just set the resolution to 150 μm for the segment reconstruction to account for this effect.

The segment finder works as follows: one superlayer is considered at a time. A search over layers begins with the outer one (layer 8 if that is how many we have and we number from the interaction point outward). Each hit in that layer is a starting point for a candidate segment. The search continues in layers beginning with layer 1 for a hit with azimuth not too different from that of the first hit. This pair of hits is a seed for the segment; a segment is quite well determined for each of the four choices of right/left ambiguity for the seed hits.

The track is interpolated to layer 2 (or layer 3 if the second hit of the seed was found in layer 2, etc.). That layer is searched for a hit within a window of the interpolated track (both of the hit's ambiguity signs being considered). When one is found, the three hits are fed to a least-squares fit. The fit is subjected to a chi-squared test and, if passed, provides an updated set of segment parameters. The program is written so that this fit can be readily expanded to include additional parameters, such as the track crossing time, if needed. The search continues through all of the internal layers, with a chi-squared test and parameter update at each stage. When the layers and hits are exhausted, we ask are there enough hits; if so, the candidate is saved temporarily until all four right/left choices for the seed have been considered. Then the (up to four) condidates are compared. The test variable is: $(N_{layers} - N_{hits})^2 + \chi^2/\mathrm{dof}$. The candidate with smallest test variable value is saved as a segment. Hits on the segment are excluded from further consideration as the search for more segments proceeds. The results below were obtained with the requirement of at least four hits per segment.

Performance results

For the evaluation studies we have used GEANT, with a geometry package written by Hanson, Palounek, et al.[4,6], which we shall refer to as the Large Solenoid Detector (LSD) design. There are thirteen superlayers of eight layers each, with radii between 0.57 and 1.6 m. The lengths are stepped in three groups (superlayers 1-3, 4-7, and 8-13). The straw diameters are graded from 4 mm at the inner radius to about 6 mm at the outermost. The straws run the full length of the detector.

The question we address is: given a reasonably stiff track ($p_\perp > 1$ GeV/c), which has crossed a superlayer, is it found, in the sense that we have a segment all of whose hits came from that track. The results are given in the plot of Fig. 2. For each superlayer there are four histogram bins: from left to right, these are the number

of track crossings, the number of segments matching a generated track perfectly, the number containing one hit that does not belong, and the number with more than one wrongly assigned hit. For the inner superlayers, the efficiency is around 90%, if we take the strict criterion for success. If we accept one misassigned hit, the number is about 98%. Efficiency is higher for the outer superlayers, as expected from the decrease of occupancy with radius.

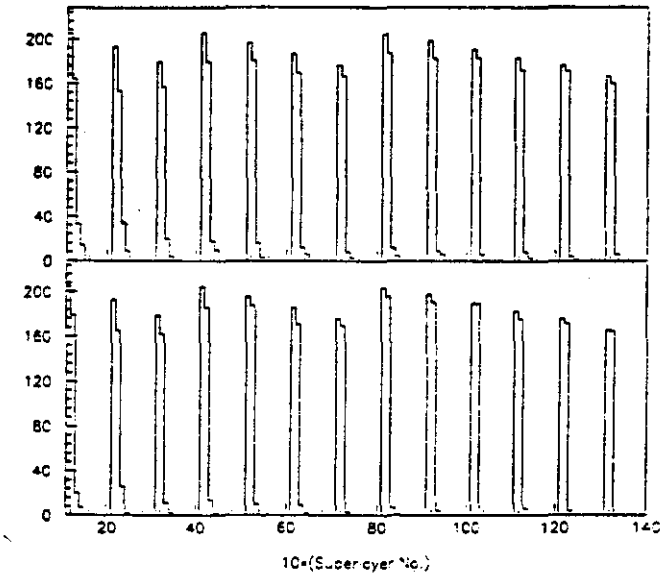

Figure 2. Segment finding efficiency and accuracy for (above) 8-layer and (below) 6-layer superlayers. For each superlayer (1-13) are plotted the reconstruction statistics described in the text.

Comparing the two histograms in Fig. 2, we find the efficiency is just as good if we have only six layers per superlayer as with eight. It should be noted here that we have not accounted for inefficiency of the cells.

A different accounting is illustrated in Fig. 3. The open histograms show the number of hits in each layer (identified with stiff tracks, as defined above); singly hatched histograms are those that have been correctly assigned to segments; doubly hatched histograms are the hits for which the correct choice of ambiguity sign was made. The performance with eight layers per superlayer is slightly better in terms of ambiguity resolution than with six.

Conclusions

We have developed a segment finding program that is quite efficient according to simulations for SSC conditions at design luminosity. Superlayers with either six or eight layers perform quite well, given that all cells are perfectly efficient (a limitation of the evaluation that will be removed in future work). These results are rather encouraging in view of the high occupancies at the smaller radii.

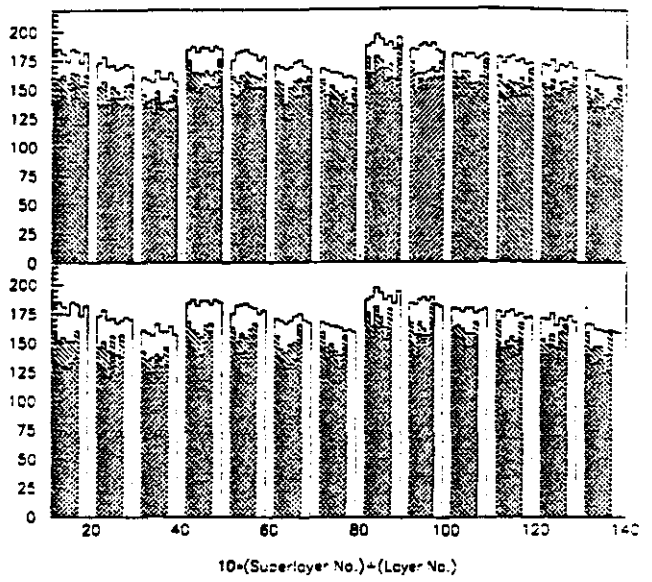

Figure 3. Linking accuracy by layer for (above) 8-layer and (below) 6-layer superlayers. Open histogram is number of layer crossings by stiff tracks; single hatched is hits correctly detected in the layer; double hatched is hits assigned the correct ambiguity sign.

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[1] Solenoidal Detector Collaboration, Expression of Interest (1990).

[2] D. G. Cassel, et al., "Report of the Central Tracking Group", in *Proceedings of the 1986 Summer Study on the Physics of the Superconducting Super Collider*, Snowmass, CO, June 23-July 11, 1986.

[3] R. Donaldson and M. G. D. Gilchriese, *Experiments, Detectors, and Experimental Areas for the Supercollider*, Berkeley, CA, July 7-17, 1987.

[4] G. G. Hanson, B. B. Niczyporuk, and A. P. T. Palounek, "Wire chamber requirements and tracking simulation studies for tracking systems at the superconducting super collider", *Proceedings of the Wire Chamber Conference*, Vienna, Austria, February 13-17, 1989 (SLAC-PUB-4860).

[5] M. Asai, "Hit rates of the straw chamber tracker", SDC Note SSC-SDE-28 (Hiroshima Institute of Technology preprint 9001, 1990).

[6] A. P. T. Palounek, "Simulating a central drift chamber for a large solenoid detector at the SSC, using GEANT3", SLAC-PUB-4787(1988).

Segment Finding Efficiency in Superlayers

	8 layers		6 layers	
	inner	outer	inner	outer
$\epsilon_{\text{tube}} = 1 : \langle N_{hits} \rangle$	7.1		5.5	
ϵ_{seg} (perfect)	0.98 (0.89)	0.99 (0.96)	0.98 (0.92)	1.00 (0.98)
$\epsilon_{\text{tube}} = 0.95 : \langle N_{hits} \rangle$	6.8		5.2	
ϵ_{seg} (perfect)	0.97 (0.89)	0.99 (0.96)	0.96 (0.91)	0.97 (0.97)
$\epsilon_{\text{tube}} = 0.83 : \langle N_{hits} \rangle$	6.0		4.8	
ϵ_{seg} (perfect)	0.96 (0.89)	0.97 (0.94)	0.86 (0.81)	0.87 (0.86)

Segment finding efficiency in straw superlayers, as a function of the assumed tube efficiency, for 8– and 6–layer superlayers. The efficiency ϵ_{seg} allows at most one hit not originating on the track the segment is matched to. The corresponding number for no false hits is given in parentheses. Also given are the average numbers of hits included on segments, $\langle N_{hits} \rangle$.