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SDC
SOLENOIDAL DETECTOR NOTES

SI DISK CONFIGURATIONS FOR SDC PATTERN RECOGNITION STUDIES

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Si Disk Configurations for SDC Pattern Recognition Studies

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1. Introduction.

This note is part of a process by which the SDC Si disks may be optimized and their scope may be defined, especially in relation to other tracking components and to the overall project cost. It is motivated in part by SDC's plan to build an intermediate tracker consisting of gas microstrips, which are expected to have better accuracy and track pair resolution than other solutions previously discussed for that region. It builds on the disk configuration presented by Hans Ziock at the 29 Jun 92 Si meeting at JHU, and it responds to recent SDC EB/TB discussions concerning reducing the Si budget by diminishing the number of disks.

2. Summary.

The conclusions of this study are:

- The smaller of the two SDC disks described in the TDR may readily be divided around the azimuth into 24 (inner) or 36 (outer) ladders, with wedge detector overlap in azimuth and especially in radius that is improved in comparison to previous designs. Thus it is possible to divide the disk into 2, 3, 4, 6 or 12 identical azimuthal sectors for readout purposes. Use of less convenient numbers of ladders, such as 26 or 38, is not necessary.

- If one may rely on the gas microstrip ITD to anchor the track near its largest measurable radius and thereby fix its curvature, one may distribute the Si disks to optimize pattern recognition, for which the number of Si hits is an important factor. This study finds that layouts using a single disk size are able to maintain essentially the same number of hits as in the barrel. From this perspective, it is not necessary to build two different sizes of Si disk.

- When the vertex is smeared in z by 50 mm rms, it is possible to arrange the disks' axial coordinates to nearly eliminate the eta-dependent fluctuations in average number of hits vs. eta observed in previous simulations.

- 13 small disks per end are required to maintain the average number of hits above 7 (compared to 8 in the barrel) over eta<2.4. This is the same as the number of disks (9 small + 4 large) in the TDR.

- If the outer 4 disks are cut from the 13 small disk layout, an average of at least 7 hits is maintained for eta<1.8. The average number of hits drops below 3 at eta=2.4.

- If no loss in performance below eta=1.5 can be tolerated, compared to the 13 small disk configuration, and if only 9 disks are allowed, the 9 disk configuration described above is close to optimum.

- The configurations with 13 or 9 small disks should reduce costs. Both require substantially fewer different components than in the TDR configuration, and in both cases a much smaller active volume is enclosed. The 9 disk version reduces the disk channel count by about 1/3.

- Based on the above, this study recommends that the 13 and 9 small disk configurations serve as the basis for SDC's pattern recognition study in the intermediate region.

The remainder of this note is devoted to a more detailed discussion of these points.

3. Assumptions.

In the ITD region (1.82<eta<2.8), this study assumes that the extent of the Si disk system should be determined mainly by the requirements of pattern recognition rather than momentum resolution. With a beam constraint, little change in simulated momentum resolution was found when 6/13 of the disks in the TDR layout were removed, leaving still a few Si hits (P. Estabrooks, reported 5/92 at KEK). This is because the ITD intercepts the track at larger radius, and its own spatial resolution is very good (of order 70 um per superlayer in the phi direction).

The main motivation for having two types of disk in the TDR, one with outer radius 390 mm, the other 465 mm, was to obtain a larger delta(r) for better curvature measurements. Knowing the curvature is important both for momentum and impact parameter determination. With the ITD anchoring the track at its largest measurable radius, the length of the track segment within the Si can be reduced slightly without appreciably degrading the curvature measurement. Provided that sufficient hits for pattern recognition exist on that segment, and that extrapolation to the ITD remains accurate enough, a disk layout which uses only one type of disk can suffice.

4. Wedge detector layout.

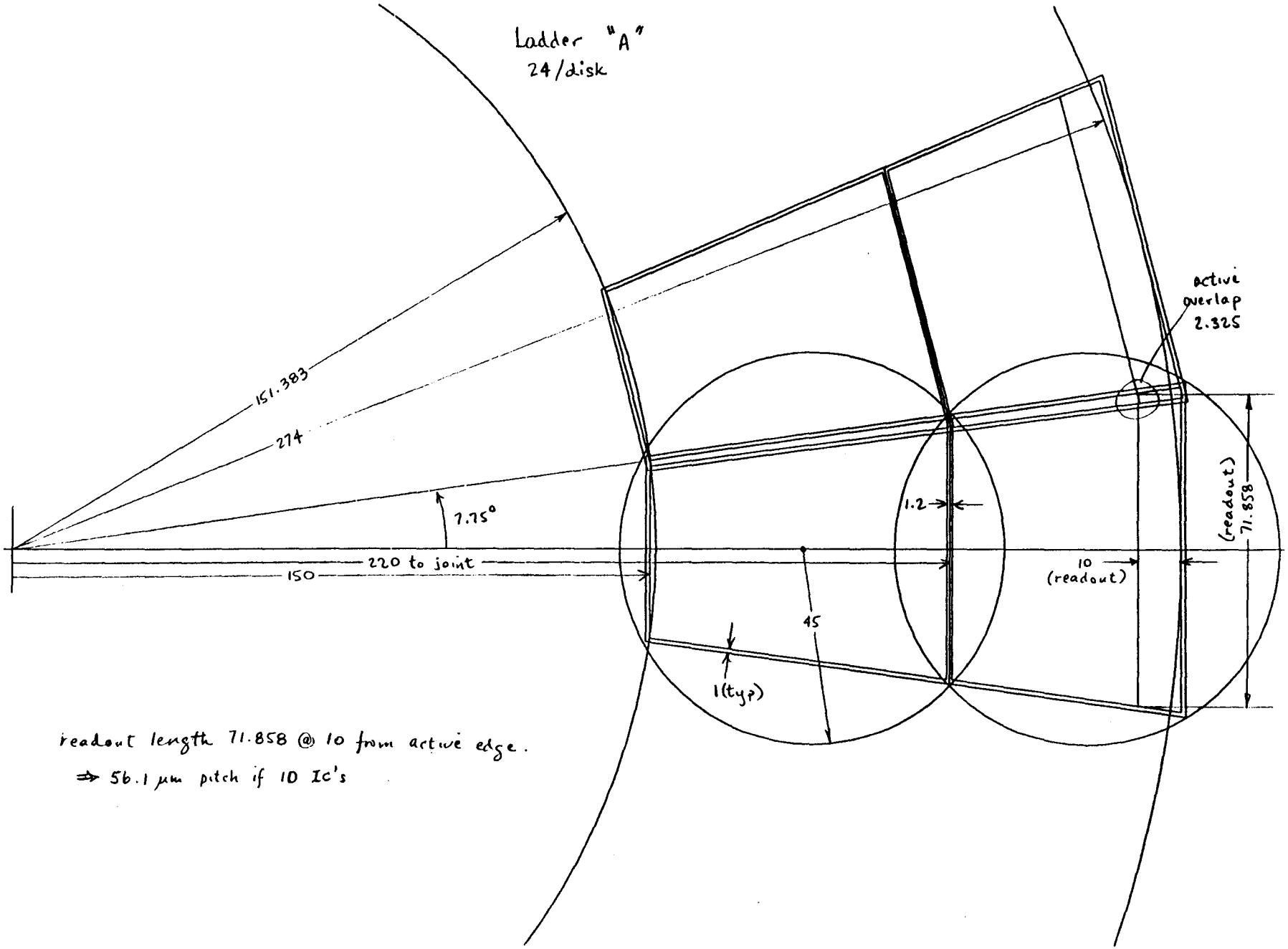
The wedge detector layout presented here varies only slightly from that of Hans' smaller disk. The main differences are:

-- The number of ladders around the disk (24 inner, 36 outer) permits azimuthal segmentation into 2, 3, 4, 6, or 12 identical readout units.

-- The radial overlap between inner and outer rings of ladders is larger (6 mm vs. -0.6 mm in Hans' design) to allow for the fact that particles may traverse the two halves of the disk, separated by delta(z) ~ 20 mm, at a substantial angle to the normal.

-- The azimuthal overlap between stereo active areas is larger (~1.2 vs. ~0.5 mm), again to allow for skew tracks.

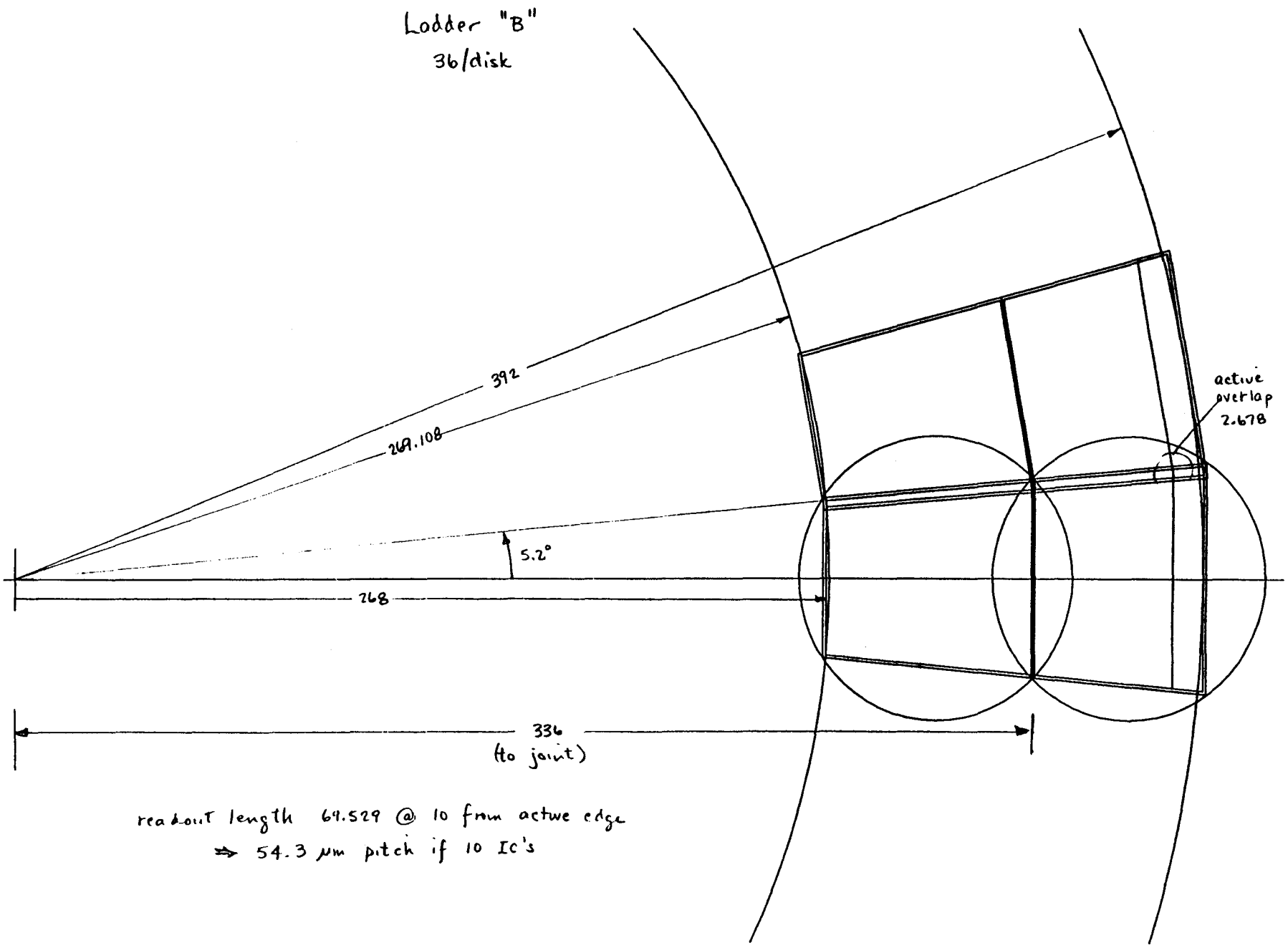
Figures 1 and 2 are scale drawings of two ladders in the inner ("A") and outer ("B") annuli that make up the disk. The detectors fit within the 90 mm dia circles shown. The geometrical detector parameters are summarized below:



readout length 71.858 @ 10 from active edge.

⇒ 56.1 μm pitch if 10 Ic's

FIG. 1.



readout length 69.529 @ 10 from active edge
⇒ 54.3 μm pitch if 10 IC's

FIG

	Ladder A detector Inner	Ladder A detector Outer	Ladder B detector Inner	Ladder B detector Outer
No. of detectors around azimuth	24	24	36	36
Azimuth between detectors (deg)	15	15	10	10
Active azimuth (deg)	15.5	15.5	10.4	10.4
Active inner radius (inscribed circle, mm)	150	220.6	268	336.6
Active inner radius (circumscribed circle, mm)	151.383		269.108	
Active outer radius (inscribed circle, mm)	219.4	274	335.4	392
Centerline active strip length (mm)	69.4	53.4	67.4	55.4
Bonded active strip length (mm)	122.8		122.8	
Dead region width at bond (mm)	1.2		1.2	
Total strip length including dead region at bond	124.0		124.0	
Typ. readout radius (inscribed circle, mm)		264		382
Typ. active width of detector at readout (mm)		71.858		69.529
Typ. readout pitch (10 IC's, mm)		0.0561		0.0543
Active azimuthal overlap* at readout (mm)		2.325		2.678
Typ. active radial overlap between ladders (mm)		6.0		

(* About 1.2 mm of the azimuthal overlap is dead on the stereo side.)

As an example in the above table, assuming that the readout radius is 10 mm inboard of the active outer radius of the outer detector in each ladder, one obtains (10 IC) readout pitches of about 55 um. This is 10% higher than Hans' readout pitch. Other choices of readout radius will produce small variations. The total numbers of detectors (60) and IC's (1200) per disk are about 94% as large as in Hans' design.

In the scale drawings it is assumed that the 3 dead borders of the wedges that do not contribute to geometrical inefficiency are 1 mm deep (the dead border at the edge where two detectors are bonded together is 0.6 mm deep). This 1 mm allowance is not an essential feature, and it does not affect any of the numbers in the table: any smaller dead zone would also fit within the 90 mm dia active portion of the Si wafer.

The possibility of allowing only 32 ladders on the outer annulus, as opposed to 36 in the above table, has also been investigated. This would allow 8 as well as 2 or 4 identical azimuthal segments, while eliminating the possibility of 3, 6, or 12 segments. Matching to the azimuthal organization of the rest of the detector would be easier, while matching to the barrel's organization might be more difficult. Allowing only 32 ladders would reduce the outer radius of the disk by 13 mm. This would create a geometrical acceptance problem at the interface of the barrel and the first disk. The 32-ladder choice would be more attractive if the outer radius of the Si barrel could also be slightly reduced.

5. Tuning the "baseline" layout: 13 small disks vs. TDR.

The new disk locations were optimized with the help of an Excel based program that computes and graphs the number of intersections of straight tracks emanating from a smeared vertex with cylindrical barrel layers and annular disks. No account is taken of the fact that a real disk is separated by delta(z) ~ 20 mm into two halves. This effect has been studied at Los Alamos (presented 29 Jul 92 at JHU by H. Ziock), where maximum differences of -0.3 hits at eta=0.8, and +0.3 hits at eta=1.7, were observed in comparison to planar disks.

The geometries of the TDR and new layouts are drawn to scale in Figs. 3 and 4. Figure 5 is the Los Alamos Monte Carlo calculation (presented 29 Jul 92 at JHU by H. Ziock) of hits vs. eta for the TDR (planar) disk layout with a 50 mm Gaussian smeared vertex. Figure 6 is the Excel plot for the same layout. The Monte Carlo plot shows combined barrel and disk hits. In the Excel plots, the graph for eta<0 is for the barrel only, while eta>0 shows both barrel and disk hits. Despite the slightly different appearance, the two calculations for the TDR geometry give the same result.

Figure 7 is the Excel plot for the new layout, in which the 13 new disks are approximated as annuli with 151<r<392 mm. It is seen that the average number of hits vs. eta varies smoothly from 8 at eta=0.6 to 7 at eta=2.4.

The following table summarizes the plots:

Averaged w/sigma(z_vtx)=50 mm	TDR Geometry		13 Small Disks
	Monte Carlo	Excel	Excel
Hits in barrel region (eta<0.6)	8	8	8
Maximum eta for >=7 hits	1.71	1.72	2.37
Maximum eta for >=6 hits	2.19	2.20	2.50
Maximum eta for >=5 hits	2.54	2.54	2.60
Maximum eta for >=4 hits	2.56	2.57	2.62

The new (13 small disk) geometry maintains 7 hits to a rapidity which is larger by about 0.65; maintains 6 hits to a rapidity larger by 0.3; and maintains 5 or 4 hits to rapidities which are larger by about 0.05 than for the TDR layout. The slightly extended eta coverage of the new geometry provides a slightly better match to the ITD, which extends to eta=2.8. The main reason for the improved coverage for >7 or >6 hits in the new geometry is that the variation of average number of hits with eta is smoother.

In addition to the average number of hits, it is of interest also to consider the fluctuations. In Figs. 8 and 9, corresponding respectively to the TDR and the 13 small disk layouts, curves of average number of hits vs. eta are presented separately on the same graph for tracks with vertex z<0 and z>0. If the distribution of hits were gaussian, the vertical distance between the two curves would be about 1.6 sigma. In these Figures it is seen that the fluctuations in the 13 small disk layout are milder than in the TDR layout. In the worst case for the newer layout, the standard deviation is about 1.2 hits.

6. Descoped layout.

In addition to cost savings resulting from simplifying the disk system (one size of disk rather than two), additional savings obtained from reducing the number of disks may be required. This would diminish the average number of hits in some eta range. The crucial question -- the effect on the pattern recognition capability of such a reduction -- is not answered in this note. Since the pattern recognition calculations will be tedious, it is nevertheless of interest to identify one possibly reasonable descoped geometry to be compared to the baseline (assumed here to be the 13 small disk layout described above).

The candidate descoped layout presented here is a 9 small disk geometry obtained from the 13 small disk layout by eliminating the outermost 4 disks. The graph of average hits vs. eta is shown in Fig. 10. It varies smoothly from

TDR

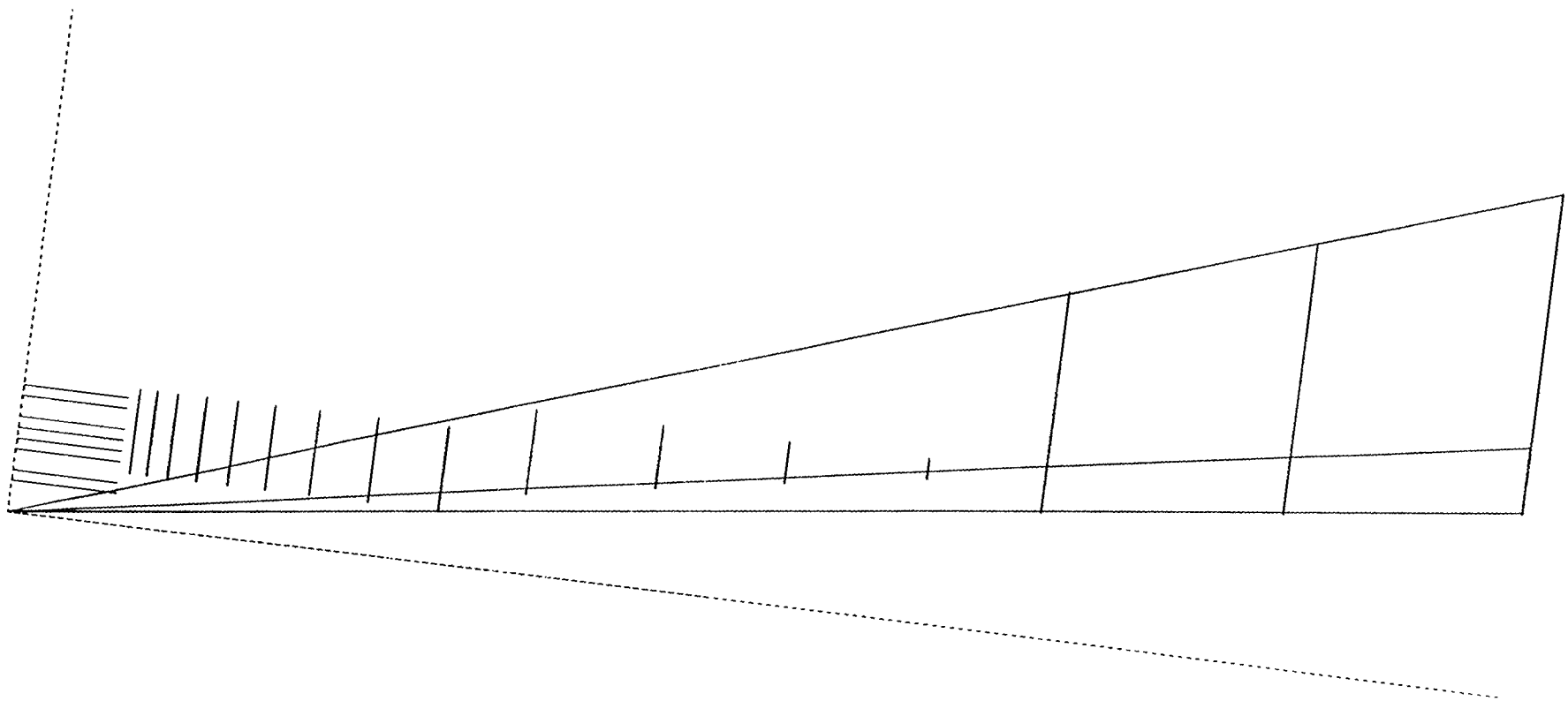


FIG. 3.

13 SMALL DISKS

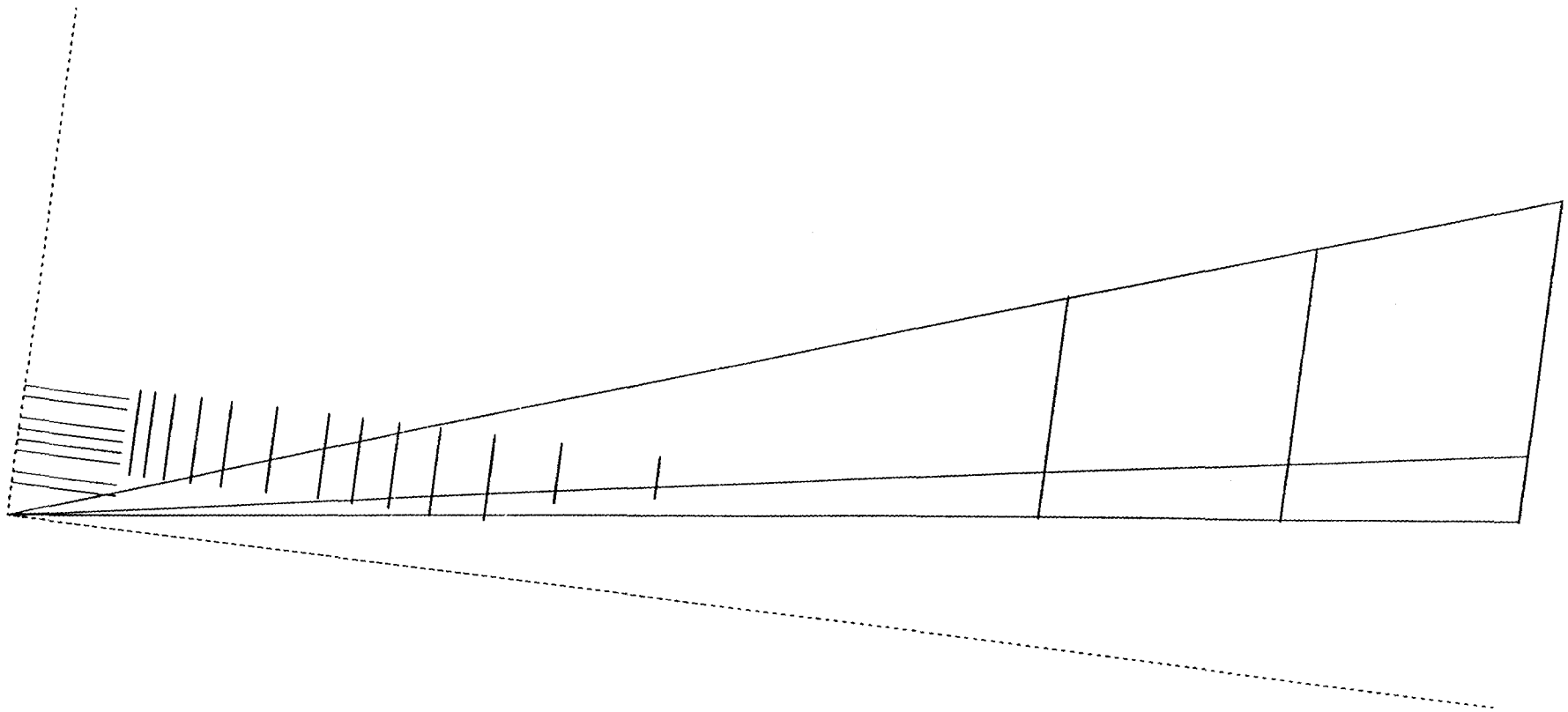


FIG.

TDR

26/06/92 11.48

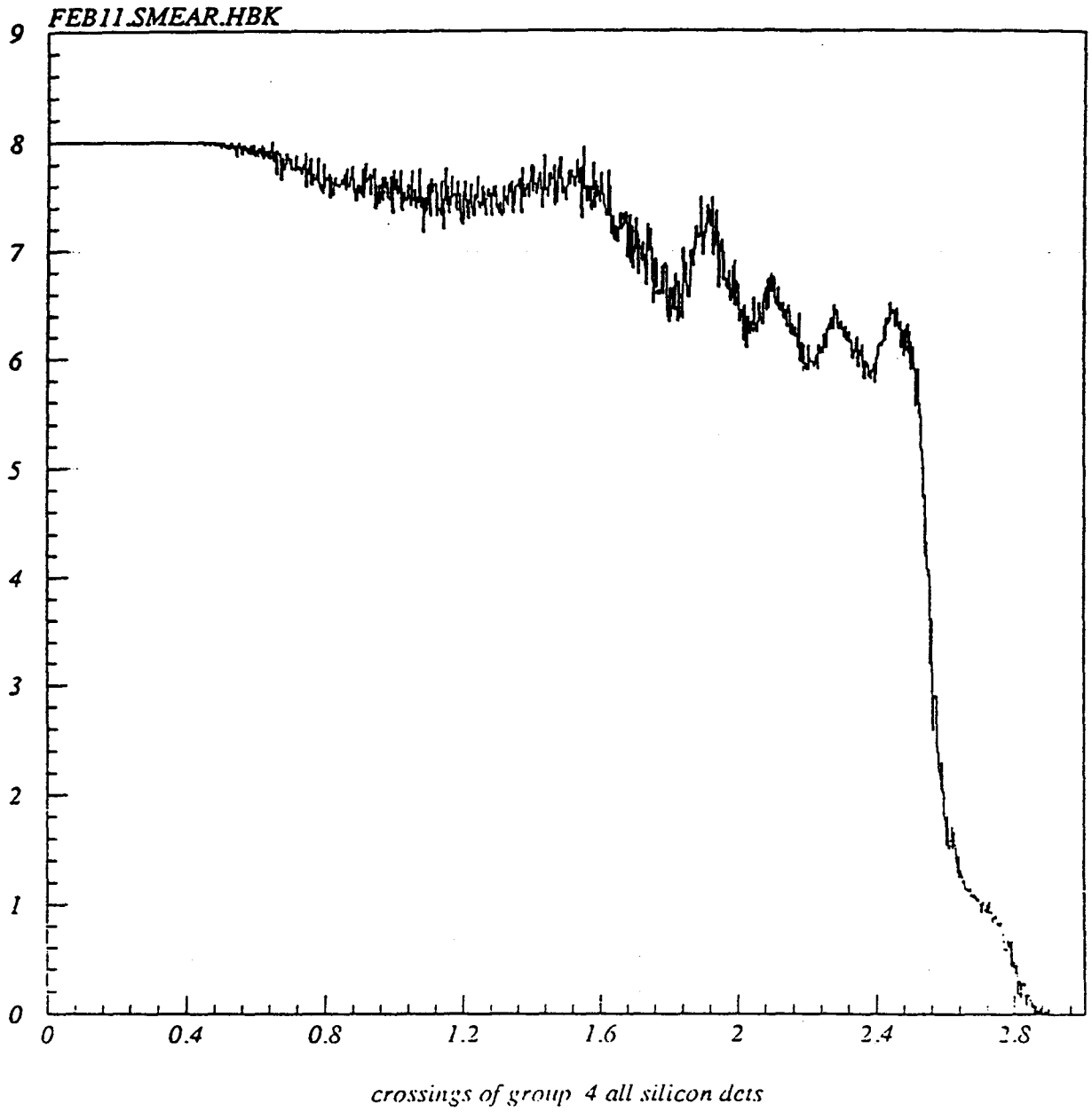


FIG. 5 (LASL)

TDR

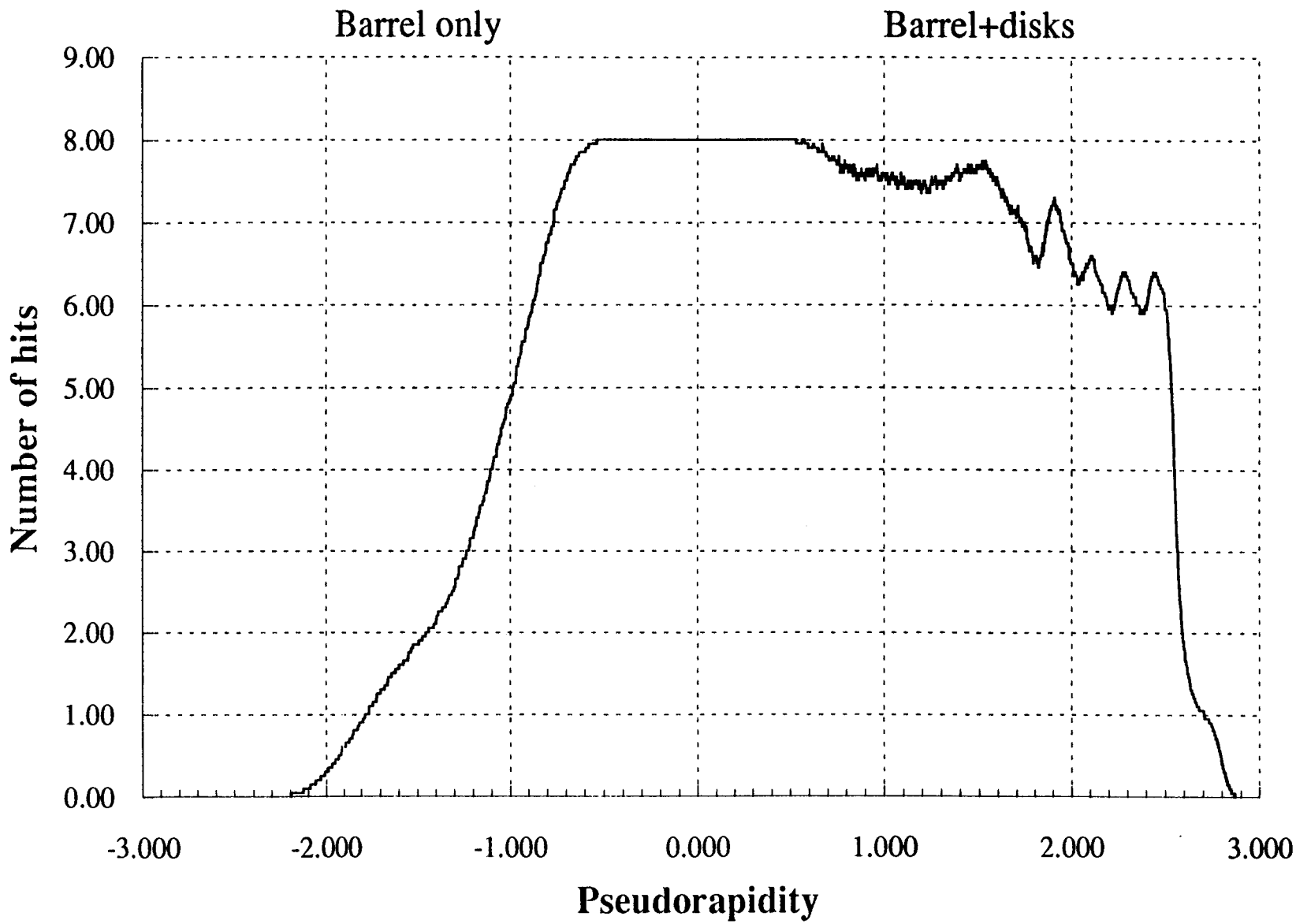

Barrel only
Barrel+disks
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Number of hits
-3.000
-2.000
-1.000
0.000
1.000
2.000
3.000
Pseudorapidity

FIG. 6.

13 SMALL DISKS

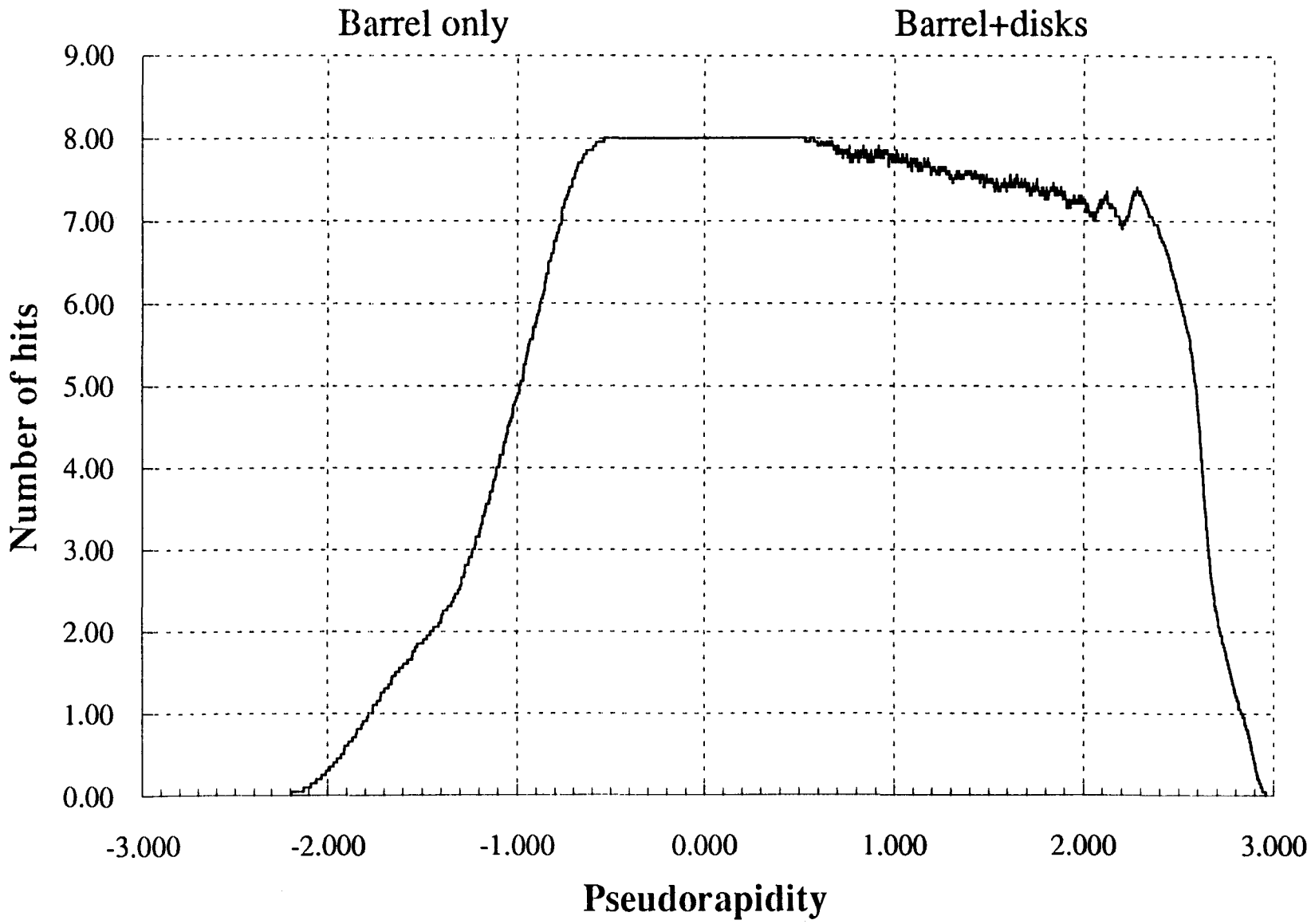
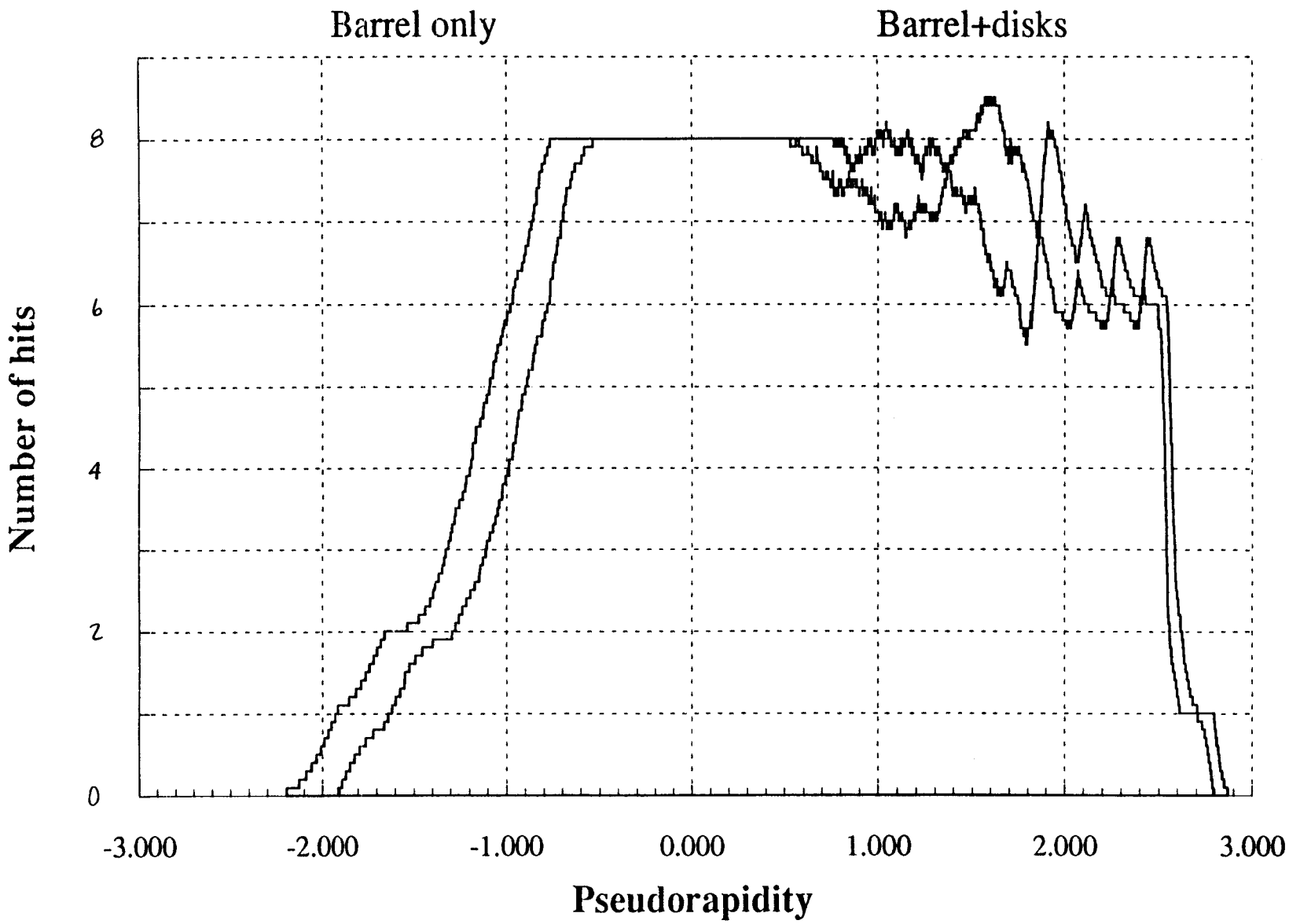


FIG. 7.

TDR


Barrel only
Barrel+disks
Number of hits
0
2
4
6
8
-3.000
-2.000
-1.000
0.000
1.000
2.000
3.000
Pseudorapidity

FIG

13 SMALL DISKS

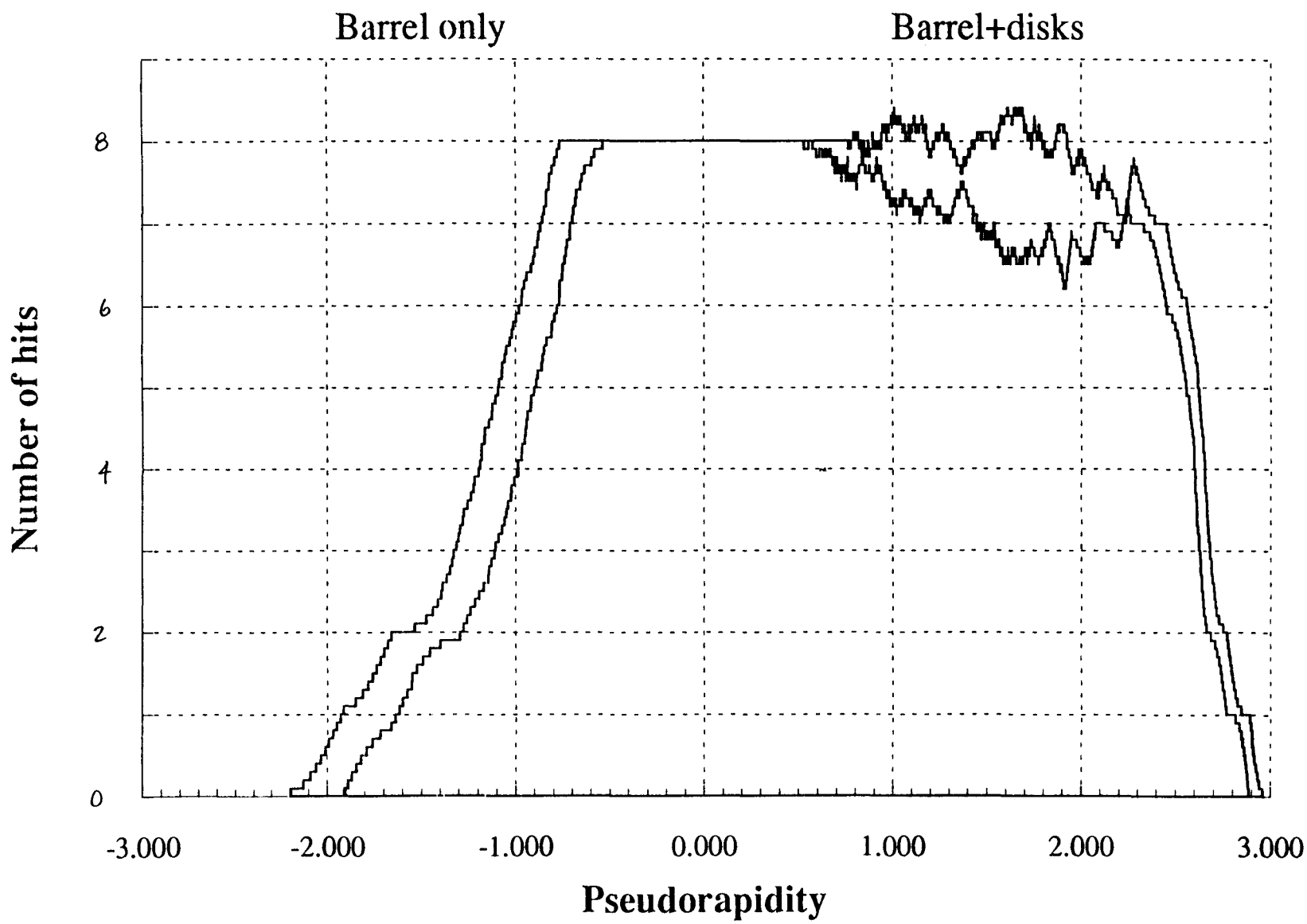


FIG. 9.

8 hits at eta=0.6 to 0.74 hits at eta=1.75, then falls sharply to 2.8 hits at eta=2.5. This is a compact layout with the outermost disk at z=1080 mm.

Within SDC there has been much casual discussion devoted to "re-optimizing the disk layout for smaller eta coverage." For example, in its presentations at KEK in 5/92, the ITD group chose to rearrange substantially the spacing of the Si disks including those closest to the barrel. Suppose, for present argument, that one is investigating the possibility of descoping disk coverage for eta>1.5. It follows immediately that disks whose minimum eta coverage begins significantly short of eta=1.5 CANNOT BE MOVED, if only the coverage at eta>1.5 is to be reduced. Of course, one may still consider reducing the number of early disks -- but this would be a form of descoping that is different from, and largely orthogonal to, reducing the disk coverage for eta>1.5.

In the 13 small disk layout, for a vertex at z=0, disk 6 begins coverage at eta=1.371 and ends at eta=2.269 (see Appendix). It cannot be removed without compromising the eta<1.5 coverage. The first six disks contribute ZERO hits at eta=2.5. To obtain, for example, a minimum of 4 hits at eta=2.5 would require adding 4 disks. The resulting 10 disk system would represent only a 23% reduction in disks (21% in channels), which is probably not as large a cut as might be desired for financial reasons. This suggests that a 9 disk system, with 3 hits at eta=2.5, is a descoping possibility that might be reasonable to investigate.

Where should the extra 3 disks go? In the 13 small disk configuration, disk 7 begins coverage at eta=1.540 and ends at 2.454. Thus it extends coverage nearly to eta=2.5. Then there is little motivation to move it to higher z. Again in the 13 disk configuration, disks 8 and 9 extend comfortably beyond eta=2.5 in coverage. In that configuration, these last two disks maintain close to 8 hits out to eta=1.8. The conclusion is that any reasonable placement of the additional 3 disks will provide 3 hits near eta=2.5; a placement that is identical to that for disks 7, 8, and 9 in the 13 small disk layout will also extend the "good" region out to eta=1.8, where the outer tracker interfaces to the ITD.

To summarize, maintaining the eta<1.5 performance of the 13 disk layout and requiring at least 3 hits near eta=2.5 requires 9 disks. If these are the same as the first 9 disks in the 13 disk configuration, the region with nearly 8 hits on average is extended to eta<1.8. The extra delta(eta)=0.3 comes for free.

7. Changes in parameters possibly affecting cost.

Without attempting to show the actual savings made possible by the new layouts, the table below lists some parameters that might affect the cost of the SDC Si disk system.

9 SMALL DISKS

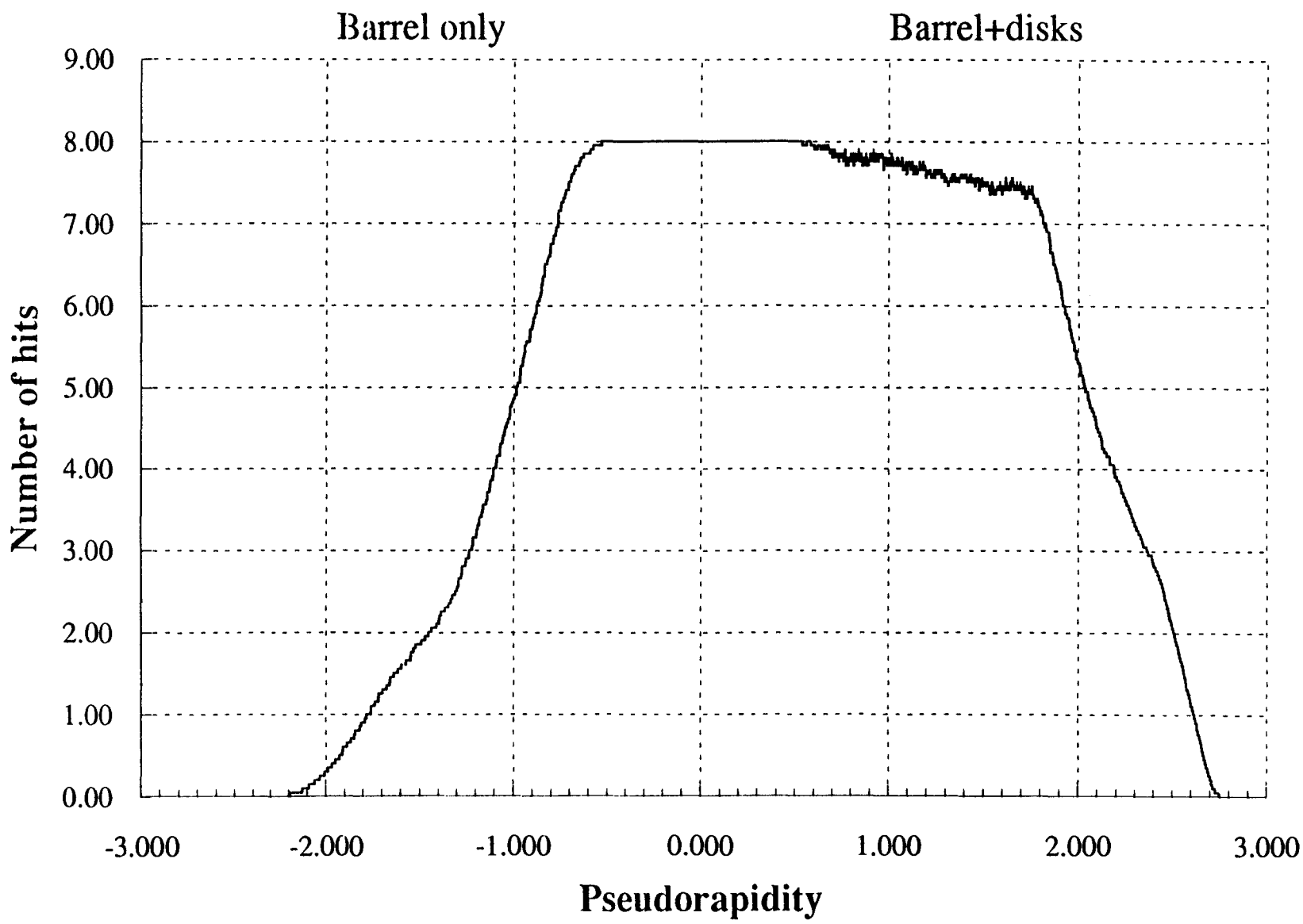


FIG. 10.

Disk system parameter (per end)	TDR	13 Small Disks	ratio	9 Small Disks	ratio
Number of disks	13	13		9	
Number of small disks	9	13		9	
Number of large disks	4	0		0	
Number of disk types	2	1	50%		
Number of cooling ring types	4	2	50%		
Number of support ring types	4	2	50%		
Number of detector types	8	4	50%		
Number of ladder types	4	2	50%		
Number of detectors	1576	1488	94%	1080	69%
Number of channels	2.12M	1.94M	91%	1.38M	65%
Active length (mm)	2580	1826	71%	1080	42%
Active radius (mm)	465	392	84%		
Cylinder with active radius and length:					
curved surface area (m^2)	7.54	4.50	60%	2.66	35%
volume (m^3)	1.75	0.88	50%	0.52	30%

Relative to the TDR layout, the savings in detectors and channels for the 13 small disk configuration are small (of order 8%). In the descoped 9 disk configuration, the number of detectors (channels) is reduced by 31% (35%). Especially in the 13 small disk layout, more significant are possible savings in EDIA and setup realized by halving the number of types of components (detectors, ladders, cooling and support rings, etc.) that need to be developed. Also, the physical size of the system is reduced. In particular, for 13 (9) small disks the active volume of the Si system is reduced by 50% (70%). This might reduce the cost of the spaceframe and the flammable gas enclosure.

Thanks are extended to Nobu Unno for finding an important typo in a draft version of this note, and to George Trilling for suggesting additional calculations that clarified the reasons for the original choice of descoped geometry.

8. Appendix.

The parameters of the new layout are given below. All disks have rmax=392 mm. The descoped (9 disk) layout is obtained by removing disks 10 through 13 with no change in the others.

Disk	z (mm)	rmin (mm)	etamin	etamax
1	328	151	0.761	1.518
2	370	151	0.841	1.629
3	427	151	0.943	1.763
4	505	151	1.071	1.922
5	593	151	1.202	2.077
6	722	151	1.371	2.269
7	872	151	1.540	2.454
8	971	151	1.639	2.560
9	1080	151	1.738	2.665
10	1199	151	1.837	2.769
11	1355	151	1.954	2.891
12	1545	221	2.080	2.643
13	1826	269	2.243	2.614