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SOLENOIDAL DETECTOR NOTES

IMPACT OF VARIOUS MAGNET OPTIONS ON HIGGS PHYSICS

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I. Outline of Comparison.

I have investigated the performance of various magnet configurations for measuring the Higgs > 4 muon signal. This is a prototypical example of a physics process requiring a large detector acceptance for tracks with momenta in the range from 20 to 1000 GeV/c. The study is based on three ISAJET files generated by Frank Paige on the SSC VAX for Higgs masses of 300, 500, and 800 GeV. These files each contain 1000 Higgs events before cuts. In the following analysis, I demand that all muons be in the rapidity interval $-3.0 < y < 3.0$. I make no momentum cuts. The magnitude (but not direction) of each muon momentum vector is smeared according to four different magnet configurations:

	y<1.5	y>1.5
1) "Iron":	solenoid	iron toroid
2) "Air 1"	solenoid	air-core toroid #1
3) "Air 2"	solenoid	air-core toroid #2
4) "All Iron"	central iron toroid	iron toroid

I have included configuration 4) since it is a candidate for operation at very high luminosities. Air-core toroids #1 and #2 differ in their field integrals as described below.

II. Assumed Resolution Parameters.

All resolutions are parametrized by Gaussian functions with variance: (dp/p)**2 = a**2 + b**2
where "a" is the multiple scattering term and "b" the intrinsic track resolution term. Their assumed values are as follows:

i) solenoid:
a=0.005
b=0.00020*pt

ii) iron toroid:
a=0.120*sqrt(costh)
b=0.000066*p*costh**2

iii) air-core #1:
a=0.0052*R*sqrt(N*costh)
b=0.000037*R*p*costh**2 = 0.00050*pt*costh
where R is the radius (in m) of the muon impact at the center plane of the magnet (z=13.5 m), and where N is the number of radiation lengths of the magnet given by N = 7.08 - 0.8*R (= 6 at y=3.0 =2 at y=1.5)

iv) air-core #2:
a=0.0026*R*sqrt(N*costh)
b=0.0000185*R*p*costh**2 = 0.00025*pt*costh

v) central iron toroid:

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a=0.160*sqrt(sinth)
b=0.00018*p*sinth**2
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The parametrizations are based on:

1) A central solenoidal magnet and tracker as assumed for SDC.
2) Forward toroids centered at z=13.5 m with a depth of 3 m. Muon tracks are measured with 4 chamber stations, 2 in front and 2 in back, separated by 2.0 m in each case. Each station has an effective position resolution of 0.100 mm. The assumed magnetic fields are:

   iron toroid: B=1.7 tesla independent of R
   air-core #1: B=3.0/R tesla
   air-core #2 B=6.0/R tesla

   If the last value is too high, the same field integral is assumed to be achieved with a deeper magnet.
3) A central iron toroid of 1.5 m thickness and with a uniform 1.8 tesla field. Sets of measuring stations in front and back are assumed to be separated by 1.4 m each. Their effective position resolution is 0.100 mm.

III. Results.

Table 1 gives general properties of the events as a function of Higgs mass. Note that only about 30% of muons from Higgs decays detected within -3.0<y<3.0 fall into the forward region (abs(y)>1.5). This has the effect of diminishing the importance of the forward magnet choice. The average muon momentum in the central region is approximately 0.30*M(higgs) whereas in the forward region it is very roughly 0.8*M(higgs).

Table 2 summarizes the resolution results for the four magnet configurations. Values are given for the average fractional momentum resolution dp/p in the central (y<1.5), forward (y>1.5), and complete (y<3.0) rapidity regions. The fractional Higgs mass resolution dM/M(higgs) is also indicated and should be compared to the ratio of intrinsic half-width to mass in Table 1. The air-core options give Higgs mass resolutions that are equal to or better than the intrinsic half-width for all cases studied here. The forward iron toroid option fails to do this at low Higgs mass (300 GeV) but, nevertheless, has good resolution (<5%) at all masses. Even the all-iron, high-luminosity configuration gives decent mass resolutions (<8%) for Higgs masses from 300-800 GeV.

Good mass resolution of the muon pairs from the Z decays may also be important for rejecting spurious backgrounds such as from semi-leptonic t-quark decays. I have calculated the fraction of events, f(ZZ), that satisfy the requirement that there be at least two mu+mu- combinations in each event that have masses within (1) 20 GeV, or within (2) 10 GeV of the Z mass. The broader 20 GeV cut preserves nearly all Higgs events in all 4 magnet configurations. The only significant loss (6%) is seen in the "all iron" option. The tighter 10 GeV cut has a significant impact on the iron options, as shown in Table 2, and gives some justification for air-core toroids.

IV. Conclusions.

The results of this study favor but do not strongly justify the forward air-core toroids unless their cost is reasonably competitive with that of iron toroids. The air-core option should, of course, be pursued until these costs (as well as engineering risks) are understood. It should also be emphasized that no full simulation has been attempted here. For example, fluctuations in energy losses of muons in matter were not included. It is interesting to note that the "all-iron" option does not do badly and should be kept in mind when considering high-luminosity running of SDC at SSC.

TABLE 1. Higgs Event Properties.

M(higgs) (GeV)	Width (GeV)	Width/(2M) (higgs)	muon tracks y<1.5 fraction	y<1.5 <p> (GeV/c)	y>1.5 fraction	y>1.5 <p> (GeV/c)
300	8.95	0.015	0.70	88	0.30	265
500	63.0	0.063	0.67	151	0.33	424
800	261	0.163	0.71	253	0.29	605

TABLE 2. Resolution Results.

M(higgs) (GeV)	Magnet Config.	dp/p (rms) y<1.5	y>1.5	all y	dM/M (higgs) rms	f(ZZ) 71-111 GeV	81-101 GeV
300	"Iron"	0.016	0.120	0.067	0.038	0.997	0.923
	"Air 1"	0.016	0.050	0.030	0.018	1.000	0.999
	"Air 2"	0.016	0.025	0.019	0.012	1.000	1.000
	"All Iron"	0.138	0.120	0.133	0.072	0.968	0.674
500	"Iron"	0.026	0.121	0.073	0.042	0.997	0.881
	"Air 1"	0.026	0.065	0.043	0.028	1.000	0.992
	"Air 2"	0.026	0.033	0.029	0.019	1.000	1.000
	"All Iron"	0.139	0.121	0.134	0.078	0.941	0.586
800	"Iron"	0.041	0.126	0.076	0.049	0.986	0.871
	"Air 1"	0.041	0.097	0.063	0.045	0.989	0.927
	"Air 2"	0.041	0.049	0.043	0.030	1.000	0.984
	"All Iron"	0.140	0.126	0.136	0.079	0.940	0.577

NOTES:

(1) One expects very roughly dM/M(higgs) = <dp/p>/2
dM/M(Z) = <dp/p>/sqrt(2)

(2) f(ZZ) is the fraction of Higgs events in which at least two mu+mu- pairs have effective masses in the indicated intervals of 71<m<111 GeV and 81<m<101 GeV.