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SDC
SOLENOIDAL DETECTOR NOTES

Report of the SDC ACT Task Force

May 1991

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Summary

This task force was appointed in June 1990 to make a recommendation by November 1990 concerning the desirability of pursuing an engineering design of superconducting toroids for the intermediate angle muon system. After making studies of physics benefits and costs, we recommended that iron toroids be used in the SDC design for the Letter of Intent (Nov 30, 1990). Our recommendation was based mainly upon cost-benefit considerations applied to the SSCL mandate to reduce the SDC cost as estimated in the EOI (May 1990). In this report, we briefly describe the physics benefit issues and cost estimates which we considered.

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1. Introduction

This task force was appointed in June 1990 to make a recommendation by November 1990 concerning the desirability of pursuing an engineering design of superconducting toroids for the intermediate angle muon system. This was a natural next step after the EOI [1] had included alternative SDC designs using either possibility- a superconducting air core toroid (ACT) at intermediate angles, or an iron core toroid (ICT). The text of our charge is given in Appendix A. Primary purposes of this report are to document the criteria which we considered, and to update the various issues to the present time (eg to the Letter of Intent [2]).

2. Physics Considerations

2A. Momentum measurement capability

The intermediate angle toroid system, whose angular coverage was fixed in the EOI at eta= 1.56 to 2.50 (theta= 23.7 deg to 9.4 deg), is

used to obtain momentum measurement of muons in this angular range. Charged hadrons and electrons will generally be absorbed in either the toroid material itself or in other material which is located between the i.p. and the toroid.

The accuracy of this momentum measurement depends on three factors: the field integral, the multiple coulomb scattering (thickness in radiation lengths), and the spatial precision of the muon chambers in the bend (theta) direction. Specific values for these factors and for the overall accuracy are described in the EOI.

Three attractive features of an ACT are: It can reasonably achieve a momentum precision of 2-3% at pt=100 GeV/c, to be compared to the value of 10% which is the lower limit for an ICT because of multiple scattering in the thick iron. Second, at a fixed value of pt, its percentage momentum error will be almost independent of eta. Third, it can match the momentum accuracy of the central solenoid tracker over the entire range of eta and pt [3].

By contrast, the ICT will have a slight advantage in accuracy for very high momentum tracks near eta= 1.6, where the ICT field integral can be larger than that of the ACT and multiple scattering in the ICT may be negligible (which means however that the momentum error is large compared to 10%).

2B. Physics requirements for momentum accuracy

One important goal of muon momentum measurement is to determine the invariant mass of a (+-) dimuon system in order to identify Z=> 2 mu decays. Such decays will be a key part of the signature of Higgs decays and other important reactions which yield Z bosons. The natural width of the Z is approximately equivalent to a fractional muon momentum error of sqrt(2)*sigmz/mz = 1.7 %. We conclude that measurements of muon momenta to 10%, typical of an ICT, can increase the background under the Z=> 2 mu peak by a factor of about 4 compared to an ACT.

Whether this will be a serious problem depends upon two other factors: the number of real and background muons in the events, and the extent to which the central tracking system (particularly the silicon tracker) gives momentum information to a few percent accuracy for the same intermediate angle muons. For running at the highest luminosities, say L=1E34, the muon background may be large and the silicon tracker information may not be available. In this case, the ACT would definitely enhance the SDC physics capabilities.

In addition to Z identification, these same considerations will apply to the search for undiscovered dimuon mass peaks, such as for a new Zprime. For large Zprime mass, say above 1 TeV, the ACT and ICT will have comparable accuracy, and dimuon mass resolution will be much worse than the dielectron mass resolution (see Fig 35. of the LOI).

2C. Monte Carlo results on dimuon mass resolution

S. Errede and J. Wiss have made an extensive Monte Carlo study [4] of the dimuon mass resolution of the SDC detector for various reactions. Their input parameters describing the SDC apparatus are based on the information used in the LOI. Physics reactions were simulated using Isajet v6.24.

Two cases were used: 1: Full detector capability, and 2: Stand alone (SA) capability at high luminosity. The standalone case was defined as having only the external muon system and the outer layer of the central tracker system operative. (Note that the standalone system as defined in the LOI assumed that the silicon tracker is still operative in the central region.)

The following table summarizes a few of their key results on dimuon mass resolution:

	Muon angular region (C=central, I=intermediate)					
	C-C		C-I		I-I	
	Full	SA	Full	SA	Full	SA
Z=>2mu						
sigmz/mz	0.9%	2.6%	1.0% ACT 1.3% ICT	2.0% ACT 5.8% ICT	1.1% ACT 1.9% ICT	1.5% ACT 8.2% ICT
xsect fraction	0.23		0.12		0.03	
ZP(500 GeV/c2)=>2mu						
sigmamzp/mzp	4.8%	7.5%	4.1% ACT 5.0% ICT	6.1% ACT 7.6% ICT	4.1% ACT 5.9% ICT	4.6% ACT 7.9% ICT
xsect fraction	0.35		0.21		0.04	

Not listed in this table are the results for Higgs=>2Z=>4mu, where the Z mass resolutions are similar to those shown in this table, and the Higgs mass resolutions (in percent) are also about the same. Of course, the percentage resolution in mz becomes larger as the Higgs mass increases. See [4] for further details.

One can see that the most substantial difference between ACT and ICT performance is for Z mass resolution in the standalone case. (As noted above, a useful "scale factor" is sigmamz/mz= 1.2%, the fractional natural width of the Z.)

3. Other Aspects of ACT/ICT Performance

There are several other kinds of differences which may have significant impacts on the design and performance of the SDC detector:

Mass - The ACT's have a mass of about 100 tons each, whereas the ICT's weigh about 4000 tons each. This means that installation and movement of the ICT are more difficult and costly than for the ACT. Furthermore, the ICT will generate more bremstrahlung which can prevent accurate measurement of the muon tracks. On the other hand, the greater mass of the ICT can be an advantage for radiation shielding of the downstream muon chambers and other devices.

Engineering Issues- The ACT's are certainly more of an engineering challenge. This means that engineering costs, technical risks, and development effort will be greater for the ACT's. The operational reliability is likely to be good for either ACT's or ICT's.

4. Cost Estimates

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The cost difference between superconducting toroids and iron toroids is fairly uncertain, due to the large range of estimates which we received for the former. We received two cost estimates for the superconducting toroids, one from Advanced Cryo Magnetics (ACM) [5] and one from Hitachi. The following table summarizes those two estimates:

	ACM	Hitachi
Stored energy	300 MJ	280 MJ
# of coils	continuous	32
Cooling	bath	indirect
Cost per ACT	$10M	$40M

It appears that part of the reason for the large difference in cost estimates is that the ACM design is specifically modeled upon earlier designs of bath-cooled bubble chamber magnets in order to achieve low cost, whereas the Hitachi design represents more nearly a scaling from existing indirectly cooled magnets such as the CDF solenoid.

For purposes of comparison, the ACT cost as listed in the SDC EOI is about $30M per ACT. The ICT cost as estimated in the SDC LOI is about $10M per ICT.

5. Conclusions

Based upon the physics benefits and cost estimates described above, we recommended that the LOI design be based on using ICT's rather than ACT's. In view of the SSCL mandate to decrease the cost of the SDC detector from $630M as estimated in the EOI, we gave considerable weight to the saving of $40M from the EOI which can be achieved by using ICT's. We judged that the detriment to the SDC physics goals was less than those which would result from other changes that could save a similar amount of money.

As far as impact on the physics is concerned, we felt that the reduced dimuon mass resolution with ICT's is not likely to seriously impede us from addressing any of our physics goals at normal SSC luminosities, based upon our present estimates of background. This conclusion rests heavily upon using silicon tracker information for intermediate angle muons at normal SSC luminosities.

We were not able to judge the extent of the ACT cost savings which might actually be achieved by using the ACM design. However, it is clear that, in view of the large range of the ACT cost estimates and of the possibility that the cost of an ACT might be comparable to that of an ICT, further study of these magnet design and cost issues would be of considerable value for planning future uses of air core toroids in SSC detectors.

References

1. SDC Expression of Interest, 24 May 1990.

2. Letter of Intent by the Solenoidal Detector Collaboration, 30 November 1990, SDC-90-00151.

3. T. Fields, Matching Forward Toroids to a Central Solenoid, October 1990, SDC-90-00129.

4. S. Errede and J. Wiss, Acceptance and Offline Mass Resolution Studies for SDC Muon LoI Subsystem Design, Univ of Illinois note, 8 January 1991.

5. Advanced Cryo Magnetics Inc., A Superconducting Toroidal Magnet Design, September 1990, SDC-90-00130.

Appendix A - Charge to Air Core Toroid Task Force June 1990

The text of the charge which we received from G. Trilling and M. Gilchriese is as follows:

Background

Possible implementation of superconducting air-core toroids must be considered as part of the overall conceptual design of the muon system. The expectation is that the Muon Group will present to the Technical Board and collaboration a conceptual design of the muon system at the November meeting of the collaboration. This design should be sufficiently detailed to allow the initiation of serious engineering design of the muon iron structure and supports, of the chamber/scintillator supports and of the intermediate toroids, whether they be iron or superconducting.

CHARGE TO TOROID TASK FORCE

The Task Force is charged to make a recommendation on the desirability of pursuing a conceptual engineering design of the superconducting toroids for the intermediate muon system. In support of its recommendation, the Task Force is requested to

1) compare the physics capabilities of a superconducting toroid vs iron toroid system

2) make a preliminary comparison of the cost and schedule of superconducting vs iron toroids

3) compare the impact on detector maintenance of superconducting vs iron toroids

If the Task Force recommends the superconducting toroid option, it is further charged to

4) specify the parameters, as much as possible, of the toroids for the purposes of beginning a conceptual engineering design. The Task Force is strongly encouraged to devise a single set of parameters(rapidity coverage, z location, field, etc) or at most two sets of parameters.

5) present a plan for initiating the conceptual design of the toroids. This plan should include

a) the collaborators and institutions of SDC responsible for overseeing the conceptual engineering design

b) if necessary, a schedule for comparison of discrete vs continuous coils for the toroids and a description of the process for selection of one of these methods

c) if industry is to be involved, a description of the process to perform some or all of the design. The issue of doing more than one design in parallel should be addressed. This should also include a draft request for proposal(RFP) for industrial participation and identification of the institution holding the contract for industrial design work.

The Task Force is requested to make a preliminary report(transparency level) at the September meeting of the collaboration. A written report containing the recommendations of the Task Force shall be completed by the November meeting of the collaboration.