4π DETECTORS

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Summary

The 4π Detector Working Group initially reviewed the 4π magnetic detectors discussed by DCMAP in the SSC report SSC-SR-1023, Cost Estimate of Initial SSC Experimental Equipment.[1] The two detectors discussed in that report were used as a basis for further work with the intention of resolving technical differences between them and extending the work in order to achieve a more realistic definition of a 4π magnetic detector.

Since other working groups were to look at the details of each detector subsystem, the 4π Detector Working Group confined its work to:

1. Developing a series of questions for other groups to help specify detector subsystems,

2. Developing detector layouts in order to study service problems and space requirements for the SSC experimental halls, and

3. Studying the necessary cable routing and cracks required by real detector and the effect of those cracks on the hermeticity of the calorimetry.

A 4π Magnetic Detector

The design goals[2] of a 4π detector to explore the high mass range accessible at the SSC include:

- hermetic calorimetric coverage over the rapidity range of at least $|y| < 5.5$ to permit accurate measurement of missing transverse energy,

- measurement capability of jet energies up to the multi-TeV range with good energy resolution,

- optimized efficiency for multi-jet detection and mass reconstruction of particles decaying into jets or jets and leptons,

- detection of muons over the rapidity range $|y| < 5.0$ with the ability to determine, at least crudely, muon momenta at the trigger level over much the same rapidity interval,

- optimal detection and identification of electrons via calorimetry in conjunction with tracking or other devices,

- momentum measurement capability for charged tracks in the central rapidity interval $|y| < 2$, i.e., a magnetic detector,

- precision secondary vertex detection in at least the central rapidity interval for flavor tagging and the detection of relatively long-lived new states,

- some sensitivity to exotic new particles beyond a missing energy signature, and

- capability of operation at the SSC design luminosity (10^{33} cm^{-2} sec^{-1}) and at lower luminosities if desirable.

DCMAP proposed two designs of a 4π solenoidal magnetic detector:

1) Model A shown in Figure 1, essentially identical to that described in Snowmass-84[3] as the SCD Detector[4] which has the precision calorimetry located inside the solenoid magnet coil, and

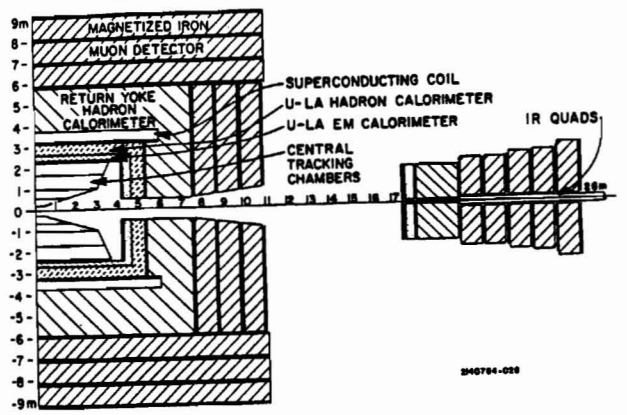

Figure 1: An elevation view of a conventional magnetic detector for the SSC designed at Snowmass 84 - referred to in text as Detector A.

2) Model B shown in Figure 2 based more on the CDF detector[5] which has the calorimetry located outside the magnet coil.

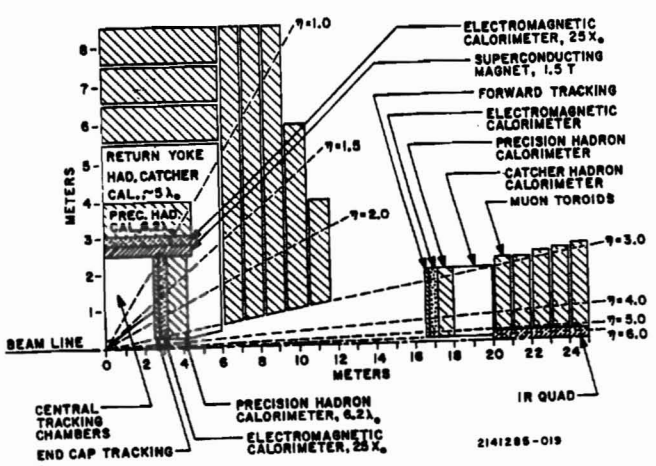

Figure 2: An elevation view of an alternate conventional magnetic detector for the SSC based generally on the CDF detector - referred to in text as Detector B.

Both detectors utilize uranium-liquid argon for the precision calorimetry although the location, thickness, and segmentation differ. Both use conventional drift chambers for the central tracking chamber. Both use superconducting solenoid magnets although of vastly different sizes. Both utilize the return yoke as a lower precision hadron catcher calorimeter. Both utilize massive magnetized iron muon detection and measurement systems as the outer layer.

The working group felt that these two detectors were representative of the general problems posed by a 4π magnetic detector and that we could best make progress by carrying forward these designs rather than by inventing a totally new design. If non cryogenic liquid or silicon sampling becomes a reality, it could be substituted for the liquid argon with few changes. The solenoid magnet was preferred over a dipole because of its better coverage in the central region where the highest mass states are expected to be produced.

Some updating of the two designs was required, the principal one concerning the 4π detector working group being the spatial thickness of the uranium-liquid argon calorimeters. A uranium-liquid argon precision calorimeter was defined as 25 X_0 of 3 mm U with 5 mm readout gaps followed by 5.2 λ_0 of 6 mm U with 5 mm readout gaps contained in a cryostat having 150 mm thick "walls", including the insulating vacuum. This yields a package with 25 X_0 of fine grain sampling for EM energy determination and 6.0 λ_0 for hadron energy determination contained in a cryostat 180 cm from inner radius to outer radius. These numbers are representative of the liquid argon calorimeters presently under construction by both D0[6] and SLD[7] although thicker in terms of hadron absorption lengths because of the higher energies.

Service Requirements:

In order to specify the overall service requirements, service requirements for each detector subsystem must be specified. We made the following assumptions for the subsystems:

1) Vertex Detector - would be silicon strip detectors with electronics mounted directly on package. Would require occasional access to entire surface for servicing.

2) Central Tracking - would be a conventional drift chamber with electronics mounted on each end. These ends would require periodic access for servicing.

3) Liquid Argon Calorimeter - would be contained in a sealed cryostat. Preamplifiers may or may not be located inside the cryostat. Signal leads would penetrate the cryostat wall either at inner or outer radius and electronics would be attached directly to those leads. The electronics will require periodic access for servicing. Repairs inside the cryostat would require a major disassembly of the detector and could only be done on a long shutdown.

4) Coil - would be a superconducting solenoid needing no servicing except in case of failure which would require a major disassembly of the detector.

5) Hadron Catcher/Flux Return - would be iron plates instrumented with proportional wire tubes and pad readout. The electronics would be located on the outer surface and require periodic access for servicing. Preamplifiers may or may not be buried in the steel. The chambers could be removed for repair with difficulty.

6) Muon Detector - would be magnetized iron instrumented with proportional wire tubes. The electronics would be located on the outer surface and require periodic access for servicing. Preamplifiers may or may not be buried in the steel. The chambers could be removed for repair with difficulty.

The first detector studied for its service requirements was Detector B, being the more conventional one. An end view of the central region of the Model B detector is shown in Figure 3. The most striking thing is the size and volume of the muon system. The central detector without the muon system weighs approximately 10,000 tons. The muon system alone weighs between 30,000 and 40,000 tons. The muon system is mainly passive iron and, with the exception of its electronics, requires little servicing. This immense size and small servicing requirement leads to the first recommendation of the 4π detector working group - that the muon system be built in place in the experimental hall and, that if an assembly area is built, the assembly area be designed to service the central detector only. As second, less strong recommendation is that, if possible, consideration should be given to building the entire detector in place, since this would greatly simplify the mechanical design and cabling.

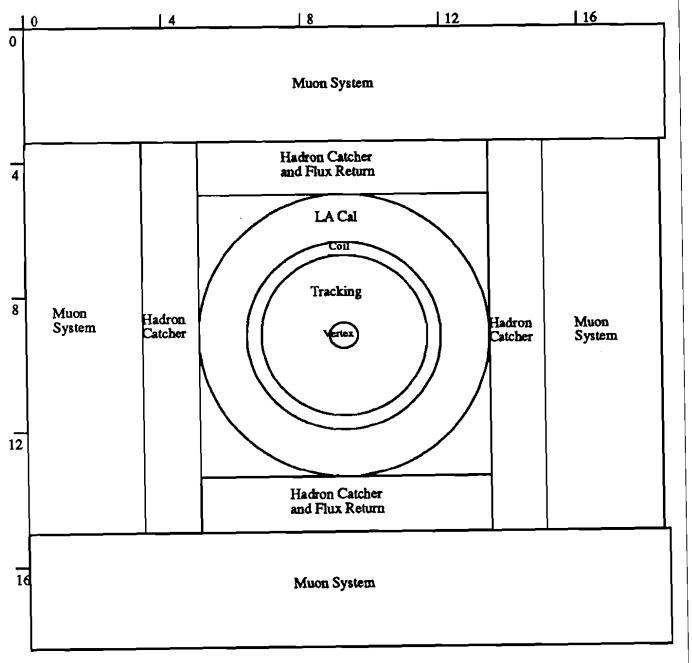

Figure 3: An end view of the central region of Detector B showing space allocation of the various systems as a function of radius.

Figure 4a shows a plan view of one variant of the Model B detector arranged along the beamline. The detector is immense - 18.8 m wide by 52 m long. Figure 4b shows the same view with the detector components open for service. The central muon detectors have been moved along the beamline to allow access to the central detector. The hadron catcher has been moved back transverse to the beam to allow access to the electronics mounted on the outside of the liquid argon calorimeter. The endplug has been pulled to allow access to the tracking and vertex systems.

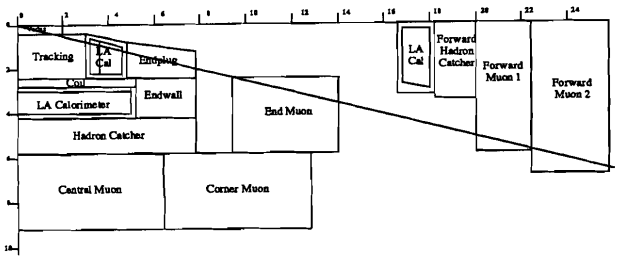

Figure 4a: A plan view of Detector B arranged along the beamline with all elements positioned for data taking.

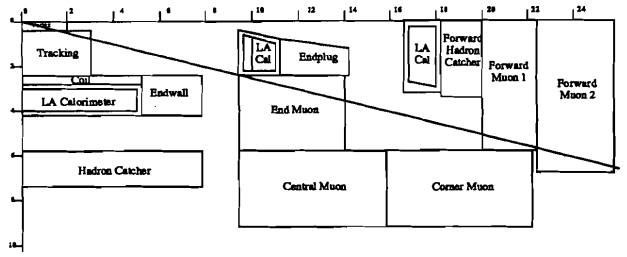

Figure 4b: A plan view of Detector B arranged along the beamline with elements open for weekly servicing.

Detector Model A represents a more serious challenge for servicing. In order to better preserve the hermeticity of the calorimetry (see section on Crack Studies), it was decided to split the detector for servicing at 90°. This simplifies the liquid argon calorimeter cryostat since it is only two pieces now without endplugs, but it complicates the superconducting solenoid coil which now must be in two pieces. It also complicates the servicing of the tracking and vertex systems, but after all, this is a summer study. Figure 5a shows the assembled Detector A along the beamline. It has a slightly larger radius than Detector B (10.5 m versus 9.4 m) because the larger magnet requires a thicker flux return. The length is identical, 52 m. Figure 5b shows the muon system moved along the beamline to allow access to the outside of the central detector. This would be required to service the electronics mounted on the round central detector in the four quadrants under the corners of the square muon detector. Figure 5c shows one-half of the central detector moved back to allow access to the tracking chamber and to the electronics mounted directly on the inside of the liquid argon calorimeter. Figure 5d shows the vertex chamber moved for servicing.

These detectors represent an extension beyond the present generation of detectors CDF, DO, SLD, etc., but the techniques being developed to build and service those detectors can be applied in a straightforward manner to either Detector A or Detector B.

Crack Studies

All detectors require cracks in the calorimetry in order to allow the cables of the central vertex and tracking chambers to exit. If the calorimeters use liquid argon for readout, the cracks become larger because of the space required for the cryostat walls and vacuum insulating space. Figure 6 shows such a crack for Detector B. The cables for the vertex detector and the central tracking exit through a 5 cm space around the end plug. This is the natural exit spot since Detector B has the central liquid argon calorimetry outside the magnet coil. The "crack" is composed of many parts: 1) 5 cm for cables, 2) 15 cm for the cryostat wall of the endplug liquid argon calorimeter, 3) 30 cm for the cryostat of the magnet coil, and 4) 15 cm of the cryostat for the central liquid argon calorimeter. The total of uninstrumented

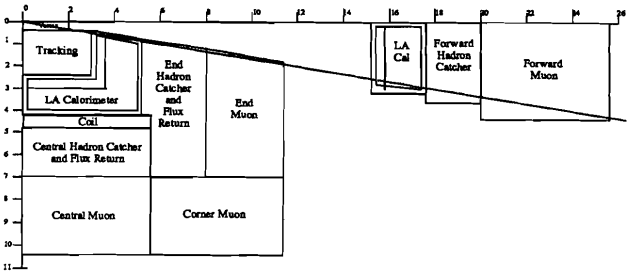

Figure 5a: A plan view of Detector A arranged along the beamline with all elements in position for data taking.

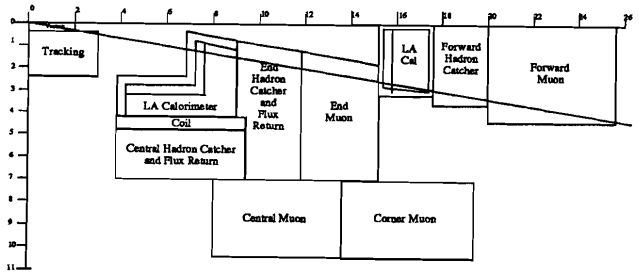

Figure 5c: A plan view of Detector A with the central detector opened to allow access to the tracking chamber and to electronics mounted on the inside of the central liquid argon calorimeter.

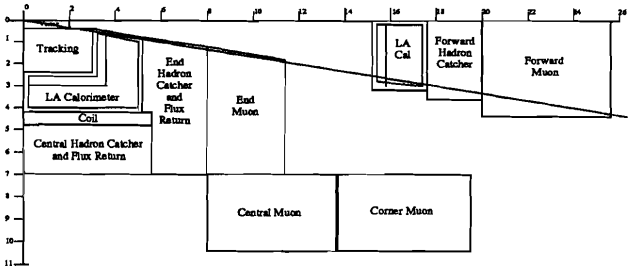

Figure 5b: A plan view of Detector A with the central muon system moved to allow servicing of the central detector electronics.

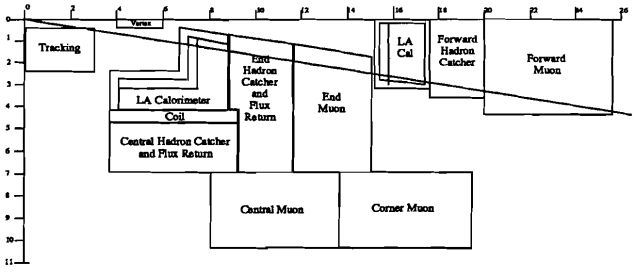

Figure 5d: Same as Figure 5c with the vertex chamber removed for servicing.

space is 65 cm. It can be arranged geometrically so that there is overlap for the EM parts of the liquid argon calorimeter by lengthening the central calorimeters. This is shown by the center diagonal line. However, one cannot easily arrange overlap of the precision hadron calorimeter parts. This calorimeter will have a degraded response between y = 1.02 and y = 1.47, a gap of almost a half unit of rapidity. This will occur around all 2π in azimuth and on both ends. One can compensate for this degradation by making the endwall hadron catcher thicker, thus measuring the energy although with reduced precision. If a warm liquid or silicon was

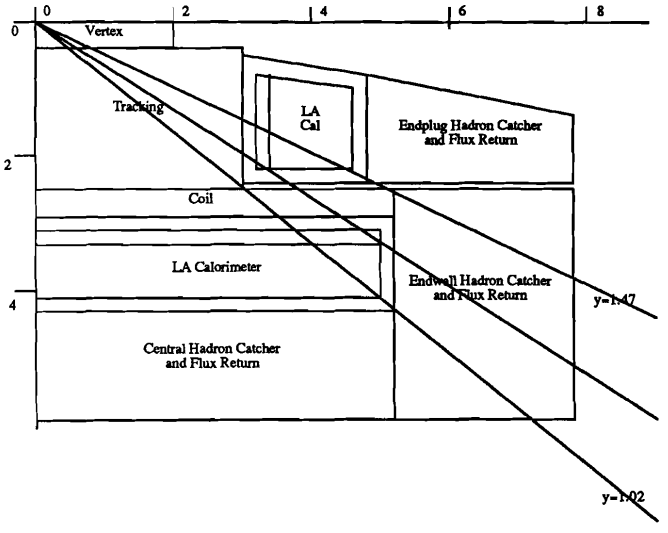

Figure 6: A crack at the ends of the coil for Detector B. The lines show the region of degraded calorimetry.

used for readout instead of liquid argon, the two calorimeter cryostat walls would be much thinner; the effect would be correspondingly reduced but not eliminated. If a similar analysis is done for Detector A with movable endplugs, a similar result is obtained.

An alternative crack was studied for Detector A in an attempt to minimize this effect. This is shown in Figure 7. Both the liquid argon calorimeter and the magnet coil were split near z = 0. The cables from the vertex and the central tracking chambers would come out a 5 cm crack near z = 0. The cryostat walls and vacuum space are again assumed to be 15 cm. The EM part of the precision calorimeter has no gap, but the hadronic part is for the most part not there. The hadronic energy is measured by the hadron catcher and a patch which extends into the central muon detector. The region impacted extends from y = 0.11 to y = -0.25, or a Δy of 0.36. The problem area is over 2π in azimuth, but only occurs once and not twice as with the axial cracks.

Which crack is preferable is a matter of debate and will not be settled here, but the radial crack at the center does impact a smaller region of pseudorapidity and thus gives a more hermetic calorimeter than the more traditional axial cracks at the endplugs.

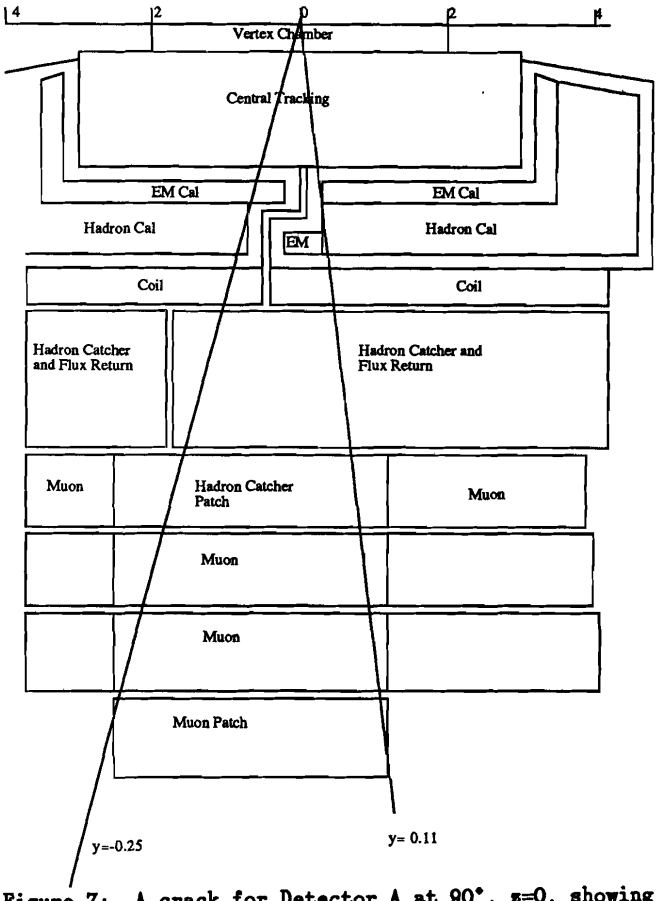

Figure 7: A crack for Detector A at 90°, z=0, showing a smaller region of degraded calorimetry.

Conclusions

The 4π Detector Working Group endorses the conclusions of both Snowmass 1984[3] and DCMAP[1] that a 4π magnetic detector can be built which can operate at the SSC luminosity and energy. Although the detectors are both large and expensive, most of the engineering problems presented can be solved with extensions of already applied techniques. Such detectors can be designed to be serviced and such detectors can be built with reasonably hermetic calorimeters.

References

*Operated by Universities Research Association Inc., under contract with the United States Department of Energy.

1. Cost estimate of Initial SSC Experimental Equipment, SSC-SR- 1023, June, 1986.

2. ibid, p. 18.

3. Proceedings of the 1984 summer Study on the Design and Utilization of the Superconducting Super Collider, June 23-July 13, 1984, Snowmass, Colorado, Editors Rene Donaldson and Jorge G. Morfin.

4. ibid, pp. 626-629.

5. Design Report for the Fermilab Collider Detector Facility (CDF), August, 1981.

6. Design Report for the DO Experiment at the Fermilab Antiproton-proton Collider, October, 1984.

7. SLD Design Report, SLAC-273, May, 1984.