SDC-91-110

SDC
SOLENOIDAL DETECTOR NOTES

PHYSICS GOALS FOR THE SDC TRACKING SYSTEM

B. Hubbard
University of California, Santa Cruz

Physics Goals for the SDC Tracking System

Bradley Hubbard*
University of California, Santa Cruz, Santa Cruz, CA 95064
and
SSC Laboratory, 2550 Beckleymeade Ave., Dallas, TX 75237

ABSTRACT

The Solenoidal Detector Collaboration (SDC) is preparing a proposal for a large general-purpose experiment at the SSC, which will include: a charged-particle tracking system in a 2 Tesla magnetic field; electromagnetic and hadron calorimeters to measure energies of single particles and jets; and a toroidal muon system outside the calorimeters. Following the experience of CDF, a large emphasis is placed on the tracking system. Considering the order-of-magnitude increases in beam energy and luminosity from the Tevatron to the SSC, the tracking system proposed will need to achieve comparable inprovements in momentum precision and reconstruction efficiency to justify this emphasis. A number of detector configurations are being considered for this task. This paper will attempt to specify some of the design requirements for the system and summarize the progress being made towards the proposal.

Tracking System Goals

The goals for the tracking system include (note that these specifications are not final nor agreed upon, and need further study): a) Fully hermetic coverage within $|\eta| < 2.5$ ($10° < \theta < 170°$), giving $\sim$ 100% efficiency for isolated tracks with $P_t > 0.5$ GeV/c; b) Momentum precision at high P_t of $\sigma_{P_t}/P_t^2 \lesssim 0.2$ TeV^{-1} for $|\eta| < 1.5$, without beam constraint; c) High efficiency for track finding within jets of P_t up to $\sim$ 1 TeV/c, with a relatively small number of false tracks; d) Transverse impact parameter precision $\sigma_b \lesssim 20\mu$ at high P_t, sufficient to identify b-quark jets; e) Precision on the Z coordinate $\sigma_Z \lesssim 0.5$ cm, sufficient to distinquish tracks from the primary interaction and also for tight extrapolation to calorimeter and muon systems. (comparable resolution on this quantity to σ_b would be very useful for secondary vertexing, but may not be achievable); f) First level trigger with resolution $\sim$ 10TeV^{-1} operable as low as $P_t = 5 - 10$ GeV/c with an acceptable number of fakes (< 100%?); g) Capability to check calorimeter calibration with electrons and hadrons.

⋆ Representing the SDC Collaboration [1]

Additional considerations on the system design are: h) Integration time should be at most a few times the 16 ns bunch crossing interval; i) Occupancies should be low enough for sytem to operate reasonably well at several times the design luminosity of $L = 10^{33}\text{cm}^{-2}\text{sec}^{-1}$; j) radiation damage should not degrade performance appreciably after 10 years operation at $L = 10^{33}$, allowing perhaps for replacement of some inner layers; k) Individual components should be aligned and stable to a fraction of their position resolution; l) The number of radiation lengths should be small to avoid compromising electron measurement (through bremsstrahlung) and keep photon conversions to an acceptable level; m) The cost should not be excessive compared to other systems, in order to keep within the overal SDC budget of $\leq$\$500M.

The configurations being considered have an inner system of silicon strip and/or pixel detectors covering $|\eta| < 2.5$, an outer system of straw tubes and/or scintillating fibers covering $|\eta| < 1.5$, and a scintillating fiber or gas microstrip intermediate tracker covering $1.5 < |\eta| < 2.5$. Individual components are described in detail in subsystem proposals [2–5] and summarized in the SDC Letter of Intent[1]. The inner system, besides providing precise vertex measurement, will be crucial for pattern recognition due to its fine segmentation and low occupancy, whereas the outer system provides a trigger and also a large lever arm for the momentum measurement.

The tracking volume planned for the proposal is 170 cm radius by 350 or 400 cm half length. Towards the ends of the volume, the magnetic field varies by as much as 50%, depending on whether the calorimeter absorber acts as a return yoke. This variation causes the momentum resolution to worsen at large $|\eta|$ by $\sim 20\%$, but has little effect for $|\eta| < 1.5$, and is not expected to affect the pattern recognition capability.

Simulation and Reconstruction

Substantial effort has been devoted towards developing a simulation program realistic enough to adequately study the above issues, and also software reconstruction algorithms which will enable us to draw conclusions that aren't entirely algorithm dependent. The simulation program uses GEANT 3.14, which transports particles through the detector and handles decays and interactions with the material.

The track reconstruction algorithms generally begin by forming 'segments' within individual superlayers. Segments from the various detectors are linked to form tracks using one of a few algorithms. Alternatively, tracks can be reconstructed fully in one subsystem and pick up segments or hits along a road in another, which will probably be necessary to associate stereo information in cases where it is not locally resolved, and also to join hits from detectors of very different geometries (*i.e.*, between 'barrel' and 'forward' detectors). Preliminary simulation results (Fig. 1) show reasonable agreement with calculated momentum and position resolutions.

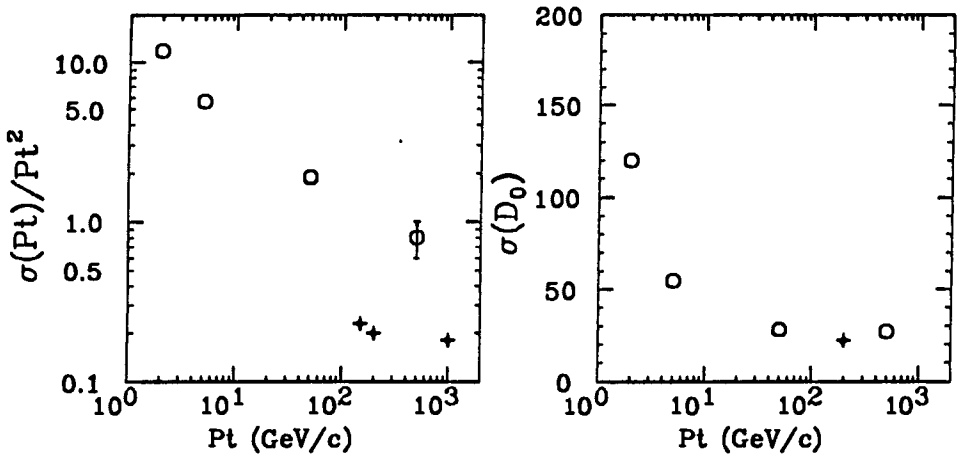

Fig. 1 Resolutions evaluated with GEANT simulation: a) transverse momentum resolution σ_{P_t}/P_t^2 without beam constraint for combined system (crosses) and for inner tracker only (circles); b) impact parameter resolution for combined system (crosses) and for inner tracker only (circles).

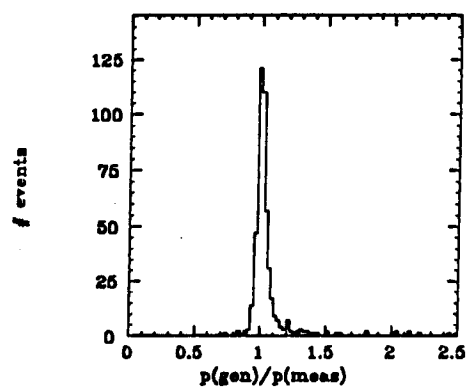

Fig. 2 Distribution of E/p for electrons of 10 GeV/c using the inner tracker only.

Physics Issues

Isolated Leptons from Higgs Decay

An intermediate mass Higgs decaying $H \rightarrow ZZ \rightarrow 4l$ ($l = e$ or μ) will give 4 isolated leptons within $|\eta| < 2.5$ about 70% of the time. The efficiency for detecting these leptons is crucial, since it enters to the 4th power. For the tracking system, two issues are involved. First, the occupancy of the outer system must be low enough to avoid losing many segments on these tracks. Preliminary estimates suggest this not to be a serious problem at anticipated luminosity for either the straw or fiber system.

Second, material in the tracking volume should not substantially compromise electron identification. Electrons which undergo bremsstrahlung can be measured with too low momenta and fail an E/p cut, may fail calorimeter isolation or track matching criteria, or may be lost or fail track quality cuts. By comparing simulated

electrons with muons, using a fitting program that drops hits with large residuals, we find the track finding efficiency to be comparably high in either case. However, as shown in Fig. 2, the electrons exhibit a tail in the E/p distribution, and if a cut $E/p < 2$ is imposed, there may be a several percent inefficiency beyond that due to internal bremsstrahlung. Preliminary conclusions are that the material should be $\lesssim 10\%\chi_0$ in order to efficiently observe $H \rightarrow 4e$.

Top Quark Physics: Secondary Vertexing and Non-Isolated Leptons

Detailed measurements of the Top quark mass and decay modes will be rewarding at the SSC. The tracking system contributes in two ways: by helping to identify isolated leptons from the W decays; and by recognizing which jets in the event are from the b quarks, using secondary vertices and/or non-isolated electrons and muons. To tag b jets from heavy Top, it is important to efficiently reconstruct tracks inside jets with P_t up to several hundred GeV/c. Simulation studies have shown this to be feasible with a 10 layer silicon system; the performance of a system with less layers combined with an outer system is being investigated.

Identifying b jets through secondary vertices was studied with a parametric Monte-Carlo using a simple algorithm to count the number of non-primary tracks in a jet. A combined system with $\sim 25\mu$ impact parameter resolution at high P_t was seen to be capable of tagging b jets with $\sim 50\%$ efficiency. Including an inner Pixel detector down to 6 cm radius improved this efficiency to $\sim 70\%$, and would be useful for vertexing in the Z coordinate and help the pattern recognition considerably.

Summary

The goals suggested above for the SDC tracking system are ambitious. Whether they can be achieved given cost and other constraints remains to be seen. In particular, there may be a compromise between the requirements for electron ID and efficient tracking in high multiplicity events. Further work is in progress to refine these goals so that the technology choices and specific implementation can be decided upon.

REFERENCES

[1] G.H.Trilling *et al.*, "Letter of Intent by the Solenoidal Detector Collaboration", Preprint SDC-90-00151, November, 1990.

[2] A.J.Weinstein *et al.*, "Subsystem R&D Proposal to Develop a Silicon Tracking System", Preprint SCIPP-90/24, (1990).

[3] "SSC Detector Subsystem Summary Report and Proposal for FY1991", Preprint SDC-90-00146 (1990).

[4] "Hybrid Central Tracking Chamber Collaboration, Summary Report", Preprint SDC-90-00122 (1990).

[5] "Summary Report of the Fiber Tracking Group", Submitted to SSC Lab, (1990).