B FACTORY WITH HADRON COLLIDERS

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Abstract
The opportunities to study B physics in a hadron collider are discussed. Emphasis is placed on the technological developments necessary for these experiments. The R&D program of the Bottom Collider Detector group is reviewed.

1 Introduction

The emerging opportunities to study B physics in a hadron collider are primarily as a result of several new things. One factor is the very large cross section for producing B pairs from gluon-gluon collisions. At the Fermilab collider, the cross section for B pair production, $\sigma_{b\bar{b}}$ is estimated to be 40-50 μb[1,2,3]. At the SSC, a 1 millibarn cross section will lead to a B pair being produced roughly 1 in 100 collisions. This cross section is 10^6 times the $\Upsilon(4s)$ cross section at CESR and DORIS. After the first level trigger, the ratio of B events to non-B events at the SSC is similar to the 1 in 4 ratio of B-$\bar{B}$ events relative to continuum production at the $\Upsilon(4s)$. This makes the SSC a very attractive place to study high sensitivity B physics. In addition to the cross section, the B lifetime is sufficiently long that the decay vertex can be observed and separated from the beam collision point. Identifying the decay vertex , used so successfully in fixed target charm experiments, enables great reduction in the combinatoric background associated with the the heavy meson mass peak formation. The observed large B^0-$\bar{B}^0$ mixing[4] indicates the CP violating effects maybe larger in the B system than originally expected if the Standard Model is correct. Theoretical work shows the B system to be an excellent laboratory for measuring the Cabibbo-Koboyashi-Maskawa (C-K-M) parameters. Finally, the rapidly advancing technologies of solid state vertex detectors, integrated circuits, fast RICH detectors, and high-speed data acquisition systems has made a dedicated B experiment in a hadron collider an excellent candidate for a second generation B factory.

2 Overview - Bottom Collider Detector BCD

The BCD[5] is planning a program of physics that begins at Fermilab and has the final experiment installed at the SSC with an expanded physics objective to include intermediate P_t physics[6] at 40 TeV. The B physics aspects of the experiment are discussed here.

The physics goal of this experiment is the complete and thorough study of the CP violating decay modes of the B meson. Only B mesons that decay into all charged final states are considered. There are a couple of popular modes, $B \rightarrow \psi K_s$ and $B \rightarrow \pi^+\pi^-$. These modes may have asymmetries as large as 30 % and small branching ratios, typically less than 10^{-5} for final state particles[7,8]. Hadron colliders can produce sufficient numbers of events to observe CP violation if the detectors can trigger on and reconstruct the decay modes with combined efficiencies of about 1%.

In this note an overview of the physics goals are given, followed by a general description of the BCD experiment. After this, more detail is given on the R&D program underway that is addressing some crucial aspects of the BCD. These include the silicon vertex detector, straw tracker and Barrel Switch Event Builder. Finally, simulations, that address backgrounds to physics signals due to finite vertex resolution, are presented to give some indication of the ongoing work in this area.

3 Brief Overview of B Physics for the BCD

There are many interesting topics in B physics to discuss [9, 10, 11, 12, 13, 14, 15]. However, in this paper we emphasize the importance of CP Violation in the B system. CP violation has great importance within the standard model and is a subject of much interest for theorists and experimentalists. There are several reasons to support this statement.

- Cosmological models that try to explain the matter anti-matter asymmetry in the universe usually invoke CP violation and a Grand Unified Theory. Thus the existence of the universe is thought to be related to CP in some way.
- Multiple Higgs bosons can lead to relative complex phases that in turn have CP violating effects. Thus the understanding of mass generation and CP violation is related.
- CP is relevant to the generation puzzle. Of the 21 free parameters in the standard model, 18 are related to the fact we have 3 families. If there were two families, no complex phase would exist in the standard model and thus no simple explanation of CP violation. With 3 families, there is one complex phase, and this is consistent with present data. If there are 4 families, then there are 3 complex phases and new CP phenomena might expected.
- Measurements of CP violation in the $\bar{B}$-B system can determine C-K-M angles with little strong interaction uncertainty. By the study of several B decay modes the C-K-M system can be overconstrained.
- When the C-K-M elements are well determined it may be possible to deduce regularities in the mass matrices of the quarks and hence among their Yukawa couplings. This is an approach that might lead to discovery of a higher symmetry beyond the present standard model.
- The left-right symmetric models predict smaller CP violating effects in the B-$\bar{B}$ system than does the standard model.

Table 1 summarizes the number of B-$\bar{B}$ pairs produced at the various colliders. The SSC affords the greatest opportunity to make a comprehensive study of the CP violating decay modes.

The study of CP violation in the B-$\bar{B}$ system can be accomplished by measurement of an asymmetry in the decay of B mesons to all-charged final states:

$$A = \frac{\Gamma(B \to f) - \Gamma(\bar{B} \to \bar{f})}{\Gamma(B \to f) + \Gamma(\bar{B} \to \bar{f})}.$$

Collider	$\sqrt{s}$ (TeV)	$\sigma_{\bar{B}-B}$ (μb)	$\sigma_{\bar{B}-B}/\sigma_{tot}$	$\mathcal{L}_{ave}$ ($cm^{-2}sec^{-1}$)	$N_{\bar{B}-B}/10^7$ sec
TEV I	1.8	45	1/1000	5×10^{31}	2×10^{10}
SSC	40	1000	1/100	10^{32}	10^{12}
CESR/DORIS	0.01	0.001	1/4	10^{33}	10^7
LEP	0.09	0.005	1/5	10^{32}	5×10^6

Table 1: B-$\bar{B}$ production at various colliders.

While the asymmetry A may be as large as 30%, this occurs only in modes with branching fractions $\Gamma \sim 10^{-5}$. This requires at least 10^8 reconstructable decays for a significant signal to be discerned. The cleanest signals are for modes with $f = \bar{f}$, so the particle-antiparticle character of the parent B must be 'tagged' by observation of the second B in the interaction. Of course, a detailed study should include measurement of asymmetries in several different decay modes.

Some of the elegance of measurements in the B-$\bar{B}$ system may be inferred from consideration of the C-K-M matrix (in the Wolfenstein notation):

$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \approx \begin{pmatrix} 1 & \lambda & \mu\lambda^3(\rho - i\eta) \\ -\lambda & 1 & \mu\lambda^2 \\ \mu\lambda^3(1-\rho-i\eta) & -\mu\lambda^2 & 1 \end{pmatrix}.$$

Parameter λ is the Cabibbo angle, μ is known via the B lifetime, while $\eta \neq 0 \leftrightarrow CP$ violation. But, ρ and η are not well determined from the K-$\bar{K}$ system. Rather, the B-$\bar{B}$ system will be the place for detailed measurements of these parameters.

Further, as pointed out by Bjorken, unitarity of V_{CKM} implies

$$V_{td} + \lambda V_{ts} + V_{ub}^* \approx 0.$$

Hence if these three complex matrix elements are regarded as vectors they form a closed triangle. On dividing their lengths by $\mu\lambda^3$, we obtain the picture of Figure 1 in the (ρ, η) plane. Since the base is known, the experimental challenge of measuring the amplitudes V_{ub} and V_{td} is equivalent to measuring the three interior angles ϕ_1, ϕ_2, ϕ_3.

A favorable theoretical result is that for decays $B \to f$ with f a CP eigenstate, the asymmetry A depends only on $\sin\phi$:

$A \sim \sin 2\phi_1$ for $B \to \psi K_S$, $D\bar{D}K_S$, $\psi\pi\pi$, $D\bar{D}$, $D^0\pi^+\pi^-$, ...

$A \sim \sin 2\phi_2$ for $B \to \pi^+\pi^-$, $p\bar{p}$, ...

$A \sim \sin(\phi_2 - \phi_1)$ for $B \to \bar{D}^{*0}K_S$, ...

Hence the experimentally accessible asymmetries rather directly measure the V_{CKM} amplitudes.

The time dependence of the CP asymmetries has been studied and it is generally believed that this will allow in some cases dramatic illustration of the CP violating effects. It will require a powerful detector to take full advantage of this physics opportunity.

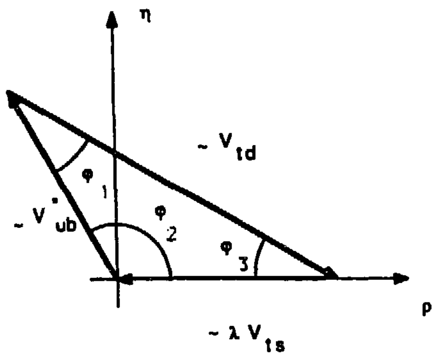


Figure 1: The unitarity triangle.

4 The BCD Experiment

A Letter of Intent was submitted to Fermilab in October 1988, entitled, A Bottom Collider Detector for the Fermilab Tevatron [16]. This letter states that the BCD is a dedicated B physics experiment and would study the physics associated with 10^{10} B-$\bar{B}$ pairs per year.

The SSC Beauty Spectrometer experiment[17] is shown in figure 2. A dedicated B physics

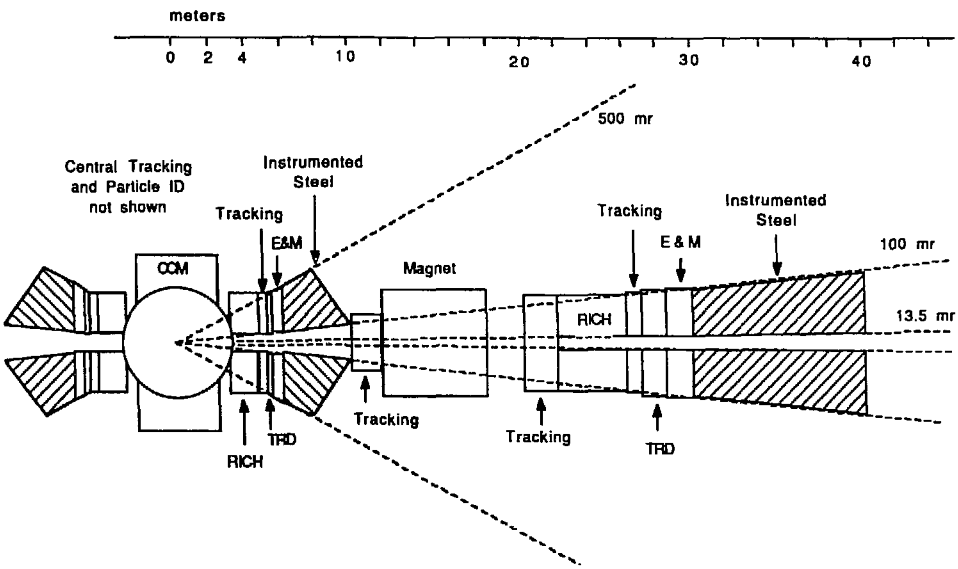


Figure 2: The SSC Beauty Spectrometer - Snowmass 1988

detector of limited coverage in pseudorapidity, -4 < η < +4, and limited in scope, could be built and tested by 1995 for use in the proposed new Main Injector and collision hall at Fermilab. The experience gained from a few runs of this detector, before moving to the SSC, would be very valuable. Forward arms, a central RICH system, a muon system, and other upgrades would be required for the full SSC BCD experiment. As schedules become more clear, the scope can become more definite.

An Expression of Interest (Letter of Intent) will be submitted to the SSC Laboratory by the BCD collaboration for the deadline of May, 1990. The design is driven by the need for large acceptance which is necessary for detecting decay products of both B mesons. In particular, the SSC coverage may require a forward arm to increase the acceptance. This feature is not as important at Fermilab, where the production is peaked less forward. Other important factors are good momentum resolution for low P_t charged tracks, precision vertexing and good particle identification. An overview of design details are given in the following list[18].

- A dipole magnet is chosen to optimize the detection of tracks between $2^\circ < \theta < 178^\circ$ (pseudorapidity of $-4 < \eta < 4$). A dipole centered on the interaction point has very good acceptance for the daughters of both B particles in each event. Identifying both B's is necessary for CP studies. A one tesla field makes possible a mass resolution of 0.3%. This cyclotron style magnet has a 4 meter gap allowing detectors to be placed inside the field. Sufficient space that allows about 75-100 points of tracking, particle identification in the form of time of flight and RICH counters, and electromagnetic calorimetry has determined the gap.

  As shown in figure 2., the coverage of the central dipole is extended at the SSC to accept down to η of 5 units on one side and η of 3 units on the other side. This is accomplished by adding a forward arm with its own dipole magnet and fully instrumented detector elements. The arm appears only on one side simply for economical reasons.

- The beam size at the Fermilab is $\sigma_{x-y} \sim 50\mu$ and $\sigma_z \sim 30$ cm. The expected beam pipe radius is 1.25 cm. The Main Injector Proposal and a new collision hall at C0 could reach a luminosity of $5 \times 10^{31} cm^{-2} sec^{-1}$ using present calculations.

  The beam size at the SSC is $\sigma_{x-y} \sim 7\mu$ and $\sigma_z \sim 7$ cm. The expected beam pipe radius is 1.25cm. The region is capable of a luminosity of 10^{33} $cm^{-2} sec^{-1}$ but the intention is to run initially at 10^{32} $cm^{-2} sec^{-1}$.

- The vertex detector is designed to find secondary vertices of B particles with high efficiency. The technique of requiring a track entering the B mass plot to have come from a secondary vertex enables the combinatoric background to be reduced substantially. In the vertex detector design, every track from the B must pass through at least 3 double-sided planes with an angle of incidence $< 45^\circ$. This requirement and the long Z extent of the luminous region $\sigma_z \sim 30$ cm led to a hybrid design of barrels and planes. More detail will be given in the R&D section.

- The straw tracking system is used as the primary means of pattern recognition and in the determination of the charged track momenta. There are typically 75-100 hits along each track. This system should allow a mass resolution of about 20 MeV/c^2. It is important to separate B_d from B_s and to set a narrow mass window around the B as a rejection against combinatoric background.

- Particle identification is important for reducing the combinatoric background, especially in modes such as $B \rightarrow K\pi$ and $B \rightarrow p\bar{p}$. The design presently incorporates RICH counters, and a time of flight system[19, 20, 21].

- The Small Angle Fiber Tracking System is designed to measure tracks at rapidities beyond those covered by the central detector. It provides a minimum bias trigger, luminosity measurements, and a fast method of determining the longitudinal location of the primary vertex to ± 1 cm [22].
- Electron identification is important for both triggering and in tagging the identity of the B meson in the CP studies. The the electron P_t distribution peaks around 1 GeV/c making identification difficult because sources of nonprompt electrons, conversions and Dalitz decay, have a soft P_t spectrum.
- The trigger consists of two levels, a prompt and nonprompt trigger. The distinction is the event data remains stored on the detector in buffers until a prompt trigger decision is received. Fast, dedicated hardware will determine the prompt trigger status and a farm of parallel processors will determine the nonprompt trigger status. The prompt trigger counts the number of tracks in the event above a given P_t and based on this number makes a decision. This is expected to give a rejection factor of about 50 while losing about 30% of the signal from $B \rightarrow \pi^+\pi^-$. This decision will be made in about $5\mu sec$. The nonprompt trigger must build and process of order 100,000 events per second. The rate to write events to tape can be in the range 100-1000 events per second. A very powerful online computer is needed to effect this reduction. Discussions with Intel Scientific Computers indicates that a farm of parallel processors delivering about 1 Trillion instructions per second will be available by 1995[23, 24].

5 R&D Vertexing, Tracking, and Data Acquisition

A three phase R&D program[25] of research has begun at Fermilab that will study issues associated with 3-D vertex detection in the Tevatron Collider, a gas tracking system based on straws, and a high rate data acquisition system that uses a Barrel Switch Event Builder. The Fermilab Physics Advisory committee approved the first two years of this program in January, 1989. This work involves hardware and electronics development that aims towards a system test in the Tevatron collider, C0 region, in the final year of the proposal, late 1991.

5.1 Vertexing

The vertex detector will be used to reduce greatly the combinatorical problem in the high multiplicity environment of the collider. Simulations[26] indicate that 3-D vertex reconstruction is needed to untangle the B decay tracks from the underlying event. The desire for complete geometric acceptance has led to a novel design. A side view of the vertex detector as presently planned for the SSC is shown in figure 3.

The vertex detector is logically spaced into two regions. All parts of the detector are outside the vacuum vessel. The "central" region covers most of the interaction region with a combined geometry of equally spaced silicon planes and three segmented barrels. The "rapidity spaced" region covers the outer limits of the interaction region with silicon planes covering equal intervals in pseudorapidity. The inner disk radius is 1.5 cm and the outer radius is about 13.5 cm. The inner barrel is at 1.5 cm in radius. It may be possible to get into 1.25 cm radius. The proposed vertex detector test in the existing C0 collision hall next collider run will be very helpful in determining the minimum inner most radius.

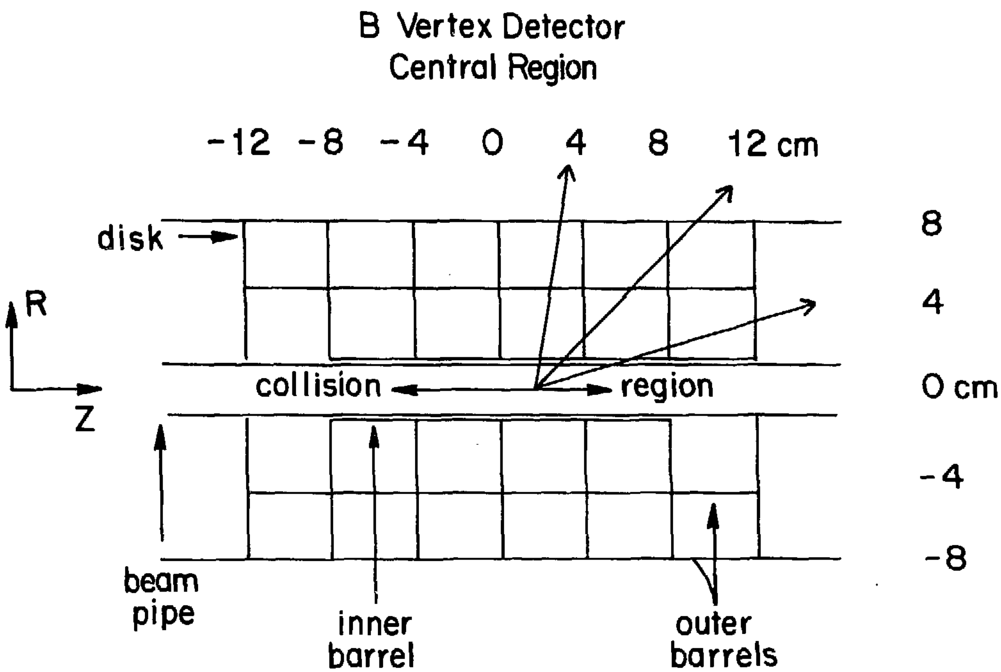


Figure 3: The SSC *B* Vertex Detector Central Region.

A cross section view of the vertex detector mechanical support and contents is shown in Figure 4.

The silicon detectors are self supporting in structures called modules. A module contains two discs and 3 barrel sections in the central region, glued together in an hexagonal structure. The modules will be housed in a beryllium tube-like structure called a gutter. It is the mechanical support for all the detectors and providess a means of cooling. The amplifiers are the main heat source. Air is blown through the gutter to maintain a constant temperature inside. Veins on the skin provide the conduit for a temperature controlled liquid which cools the forced air circulating around beryllium separators in the gutter. We refer the reader to Fermilab note TM-1616 of Hans Jöstlein *et. al.* for detail on the mechanical study[37].

The need for 3-*D* vertex reconstruction creates a technical problem which is illustrated in Figure 5. The strips must be oriented both parallel and perpendicular to the beam directions. The long *Z* extent of the beam and the desire for high geometric acceptance implies a substantial number of tracks enter the silicon at non normal incidence. A 45° angle of incidence track has a path length of 71μ in 200μ thick silicon. The electronics must be able to detect signals of about 6000 electrons with good signal to noise. We determine the required amplifier noise performance based on this argument. It has been pointed out by G. Lutz that the strip to strip noise is correlated and that the actual noise may be less by about a factor of two.

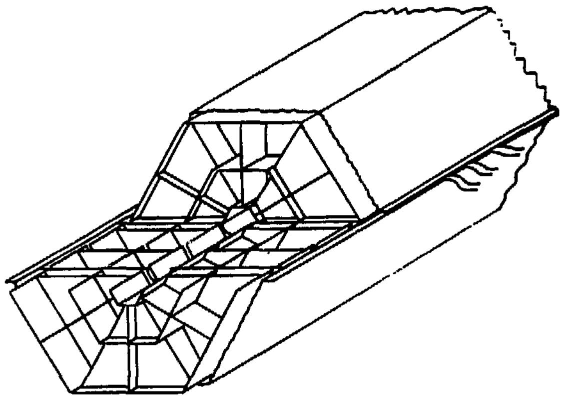


Figure 4: The Vertex Detector Model built by Hans Jostlein of Fermilab. This is being used to study heat dissipation and alignment issues.

The silicon detectors are double sided and the direction of the strips are shown along with the placement of the front end amplifiers in Figure 6. The Oklahoma group is collaborating with Micron Semiconductor in the development of double sided silicon strip detectors[28].

The development of a readout chip is a major part of the R&D program. The chip is called the BVX. It is planned to have 128 low noise, low power CMOS amplifiers followed by a capacitor storage array and an integrated analog-to-digital convertor. The BVX will digitize only after a prompt trigger signal is received. The design goals are roughly 600 electrons when connected to 5 picofarads , and dissipating roughly 1 milliwatt per channel. The amplification and storage is to be completed in time for the next crossing in $\sim$ 400ns. These goals are ambitious but not too far from the present state of art on VLSI amplifier design. This is illustrated in Figure 7. Noise and power performance in the range required by the BCD have been achieved by existing chips, though at slower speeds. The BVX chip must withstand about 100 Krads at the Tevatron collider and about 10 times that at the SSC [30, 31, 28, 29].

5.2 Straw Tracking

Multiple scattering, excessive cost, and high power dissipation leads to a design where the vertex detector acts only as a vernier on the track. Pattern recognition and the momentum measurement are made in a gas system.

Tracking designs based on straw tubes have several attractive advantages for BCD. The small drift distances allow high rates, there are no massive end plates, permitting 4π steradian tracking, and broken wires are localized. An overview of the present straw tracker design and the silicon vertex detector are shown in Figure 8. This early design configuration is largely due to N. Stanton of Ohio State University. The performance of this configuration is presently being studied in the simulation work of the BCD group.

BCD at present is beginning to setup a facility at Princeton University that will wind

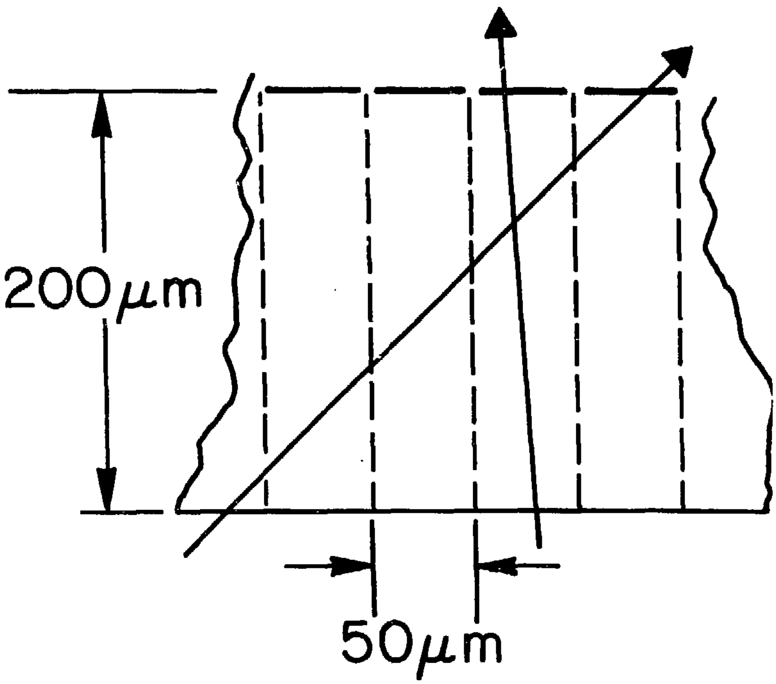


Figure 5: Tracks at incident at 45° deposit < 6000 electron/hole pairs. Observation of this small signal requires very low noise amplifiers.

straws of various radii. The readout system is being developed as a project associated with the SSC generic R&D program[32]. The BCD plan to use electronics developed by H. H. Williams *et al.* as part of their program[33]. These VLSI readouts consist of bipolar amplifier-shaper and discriminator, a CMOS Time-to-Voltage convertor, storage array, and Analog-to-Digital convertor[33]. At present, the amplifier is available in small numbers and is being used by BCD. The VLSI TDC work of J. Watase and Y. Arai is also of great interest to the BCD straw tracker and progress is being followed closely. The BCD plans to test about 500-1000 instrumented straws in the Fermilab test beam in 1990.

5.3 Data Acquisition

Shown in Figure 9 is the Generalized System Architecture[34].

The data flow from the detector components into storage buffers on the detector. After receipt of a prompt trigger, data is transferred from the detector to an event builder. This device receives parallel streams of digitized data from the different detector systems, reorganizes this data, and transmits serial streams to a processor farm or permanent storage. The Barrel Switch Event Builder , based on the principle of a telephone switch, can build events at the rate of several hundred thousand per second. This is being developed by the

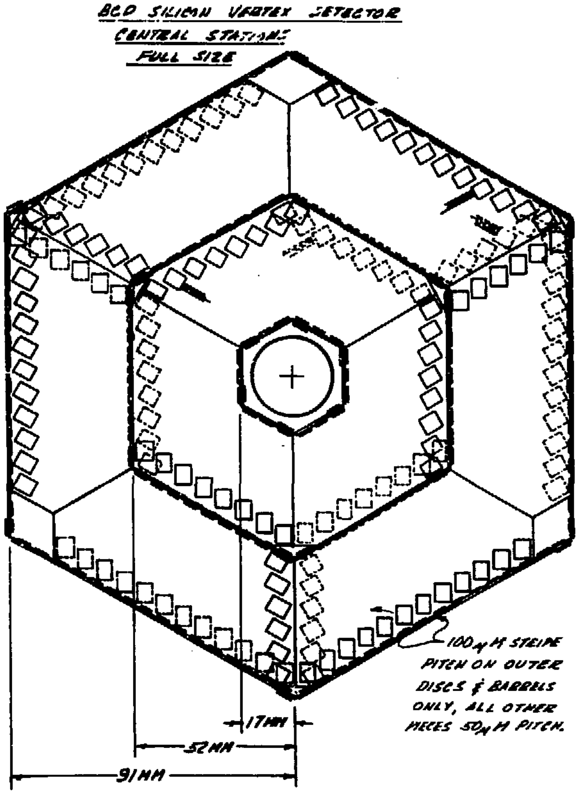


Figure 6: Fermilab BCD Silicon Vertex Detector Central Station. The view is in the x-y plane. Three barrels can be seen in projection and inner and outer disks are shown with the chips mounted. Solid boxes are amplifiers on near side and dashed boxes are amplifiers on the underside. Beam pipe is shown as a circle and lines represent strips.

group of E. Barsotti *et al.* at Fermilab. The logical switch operation and physical switch operation are shown in figure 10 and figure 11. The shift matrix or barrel shift event builder is illustrated in figure 12. Data from event number 1, data fragments from detector A, B, C, ... enter the event buffer. Each clock cycle the switch changes the inputs to be directed to the next output address. This clocking sequence is repeated until all of event number 1 is a serial stream. Event number 5 can be seen to follow event 1.

Events are not equal in size. The switch requires the incoming to data to be a fixed number of bits. This task is accomplished by intercepting the data before and after the event builder switch. This sequence is shown in figure 13 and figure 14. The events of unequal size enter the Input Time Slot Interchanger. This unit breaks the event into equal size packets in preparation for transmission to the barrel switch. The data packet boundaries are shown as dashed vertical lines in the figure. The data packets are stored in columns. The Output Time Slot Interchanger reassembles the data after the switch in order to obtain the

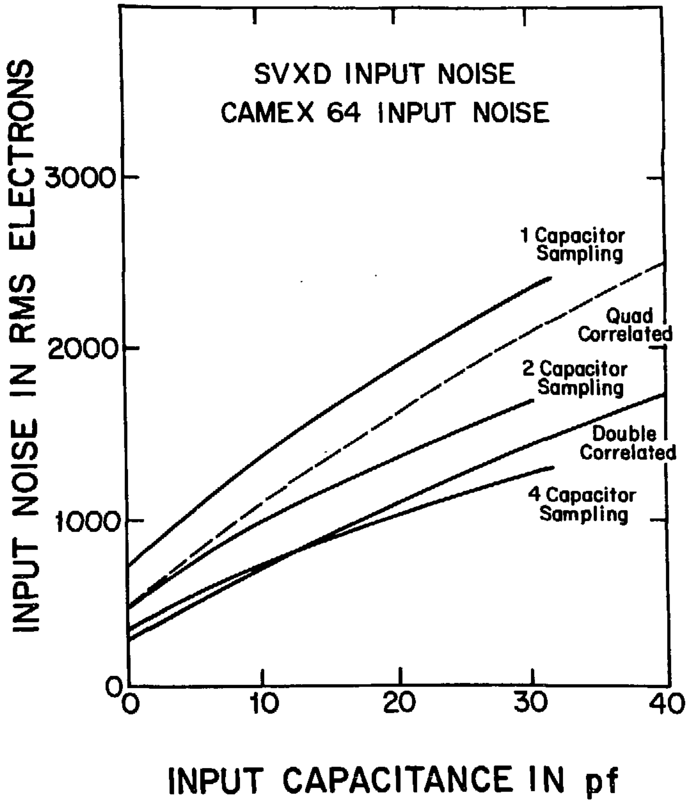


Figure 7: The Noise versus Input Capacitance for the SVXD chip and the CAMEX chip. The different modes of operation are shown. This data courtesy R. Yarema of Fermilab.

correct event ordering. The figures are courtesy of M. Bowden of Fermilab. Error checking is an important aspect of the design but a discussion is beyond the scope of this paper. This work is being pursued as part of the SSC Generic R&D program. The BCD group will test the barrel switch event builder in the proposed collider test in the C0 region in 1991.

6 Simulation

An ever increasingly more detailed simulation is underway by the BCD group. We present here some vertex simulation studies that estimate the amount of physics background in the decay mode $B \to \pi^+\pi^-$. The Isajet 6.21 generator with the Geant Simulation package is used to study 150,000 $B\bar{B}$ events, where one B decays freely and the other always decays to $\pi^+\pi^-$.

For this specific study, the simulation contains a beam pipe and silicon vertex detector. This is adequate for multiple scattering studies. Finite detector resolution effects are added

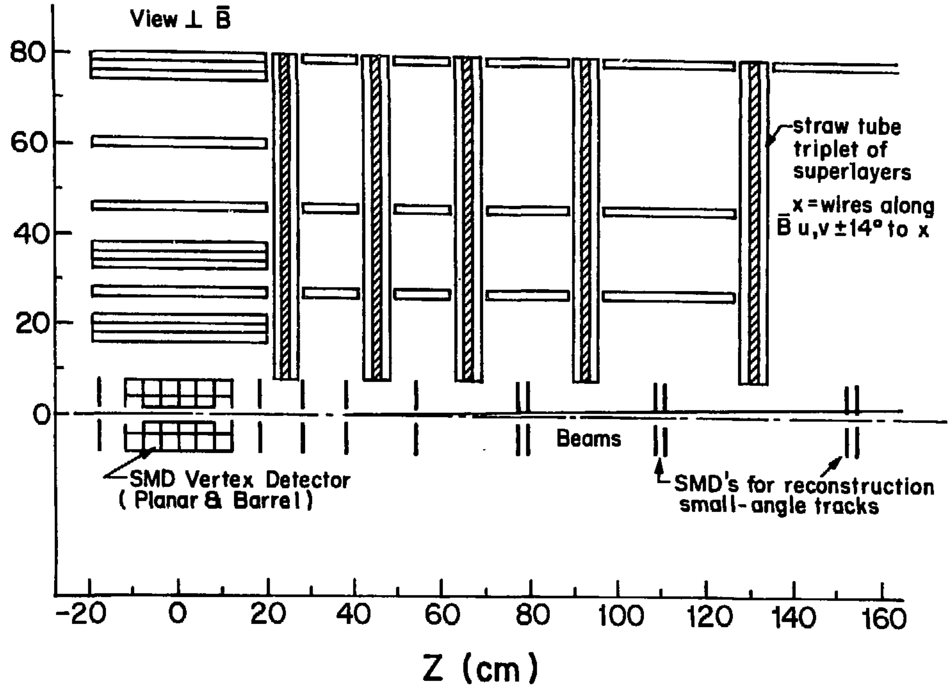


Figure 8: View of the BCD straw tracker showing box-like structure. There are roughly 250,000 4mm diameter straws in this design. Also shown are the silicon vertex detectors.

with gaussian errors and the magnetic field value is set to zero. ISAJET is used to generate events at 2 TeV center of mass energy. GEANT decays the particles and tracks them through the beam pipe and vertex detector layers. The hit arrays are generated for each track and the resolution is computed only for tracks with angle of incidence into the silicon of less than 45°. Using the correct assignment of hits to the track , a straight line is fit to the points, giving a slope, intercept and error matrix. Having found all the tracks in the event, tracks with $P_t >$ 1 Gev/c are then passed to a vertexing algorithm from the CERNLIB. The P_t distribution of tracks from $B \to \pi^+\pi^-$ and for non-B decay products are shown in figure 15. Tracks that fit poorly to a common point hypothesis were saved the next iteration of the vertexing procedure. A cut in chisquare was used to determine the quality of the fit. This poorly fit sample of tracks is assumed to come from the decays of long-lived particles and scatterers. The first set of well fit tracks were considered to originate from the primary interaction point. It is found that with the present vertex detector design, it is possible to locate the primary vertex to typically 20-40 μ. This fit did not include information of the beam size which would reduce the size significantly if the experiment was located at the SSC. The next group of tracks were constrained to a single point in space and again poorly fit tracks were removed for later analysis. This fitting procedure was interated until all tracks were associated with a vertex. These found vertices, if they contained only two tracks of opposite sign, were considered $B \to \pi^+\pi^-$ candidates.

A variable was formed that reflected the significance of the separation of the primary vertex from the secondary vertex and it was called S/ ΔS, where S was the distance traveled by the B meson and ΔS is the uncertainty in the flight path. This variable was computed from the fit information, ie. vertex coordinates and error matrix. The results for the B and non B sample of two track vertices are shown in figure 16.

The distribution of path lengths from found vertices of the decay $B \to \pi^+\pi^-$ is shown in figure 17. The plot indicates the efficiency for finding this mode is about 20%. The average distance traveled by the found B events is about 2 mm and the detector and search technique is quite efficient for finding decay vertices with flight paths of $\sim 100\mu$. To aid in background rejection, a cut is applied to the distance of closest approach of the momentum vector of the secondary decay. The distribution is shown for two samples of events in figure 18.

The result of this analysis is that the background from events that have no long-lived particles present is negligible. The amount of background coming from charm appears not to be a problem since we select on the flight path. The analysis shows that the softer charm spectrum and shorter charm lifetimes are easily identified and removed. The major source of background for B decay comes from other B decays. Shown in figure 19 is the mass spectrum for 2-track secondary vertices from $B\bar{B}$ events. The background is at the level of 10^{-5} events. Further study indicates we can lower this significantly. This background appears to come from confusing tracks from different secondary vertices in the event. Results on pattern recognition studies in the silicon vertex detector are expected soon.

7 Summary

The goal of the BCD group is to study CP violation in the B system. An upgraded Tevatron provides an opportunity to begin these studies. The SSC is the ultimate B factory. It will produce in excess of 10^{12} $B\bar{B}$ pairs per year and every 1 in 100 events will be a B pair. The challenge for the experimentalist is to build an experiment capable of detecting and studying the rare decay modes in detail.

The detector must reconstruct secondary vertices in the collider environment with high efficiency over a large solid angle. The particle identification must include electrons, muons, kaons and protons. The study of decay modes with small branching ratios requires very high statistics. The data acquisition system must have high through-put, both in the transmission of the data from the detector and into the processor farm where the complex trigger decisions will be made. An R&D program is well underway to address these technical challenges. The possibility of studying CP violation in the B system seems much closer now that the SSC has been approved.

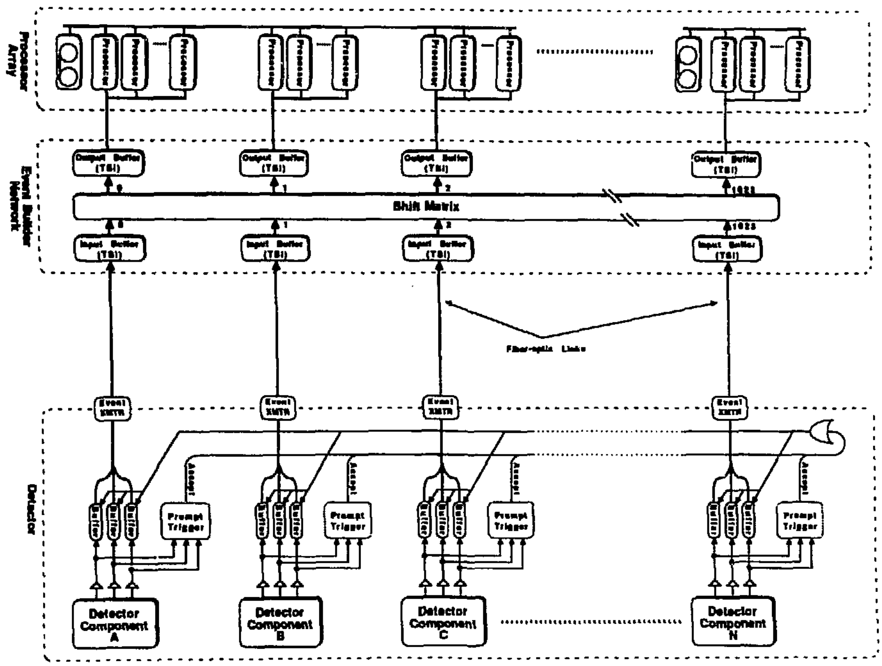


Figure 9: Generalised System Architecture is shown. The data flows upward. The dashed line indicates electronics mounted directly on the detector. The data is transmitted from the detector to the event builder switch after a trigger decision via fiber optic links. The event builder passes the data to a processor farm with a serial link.

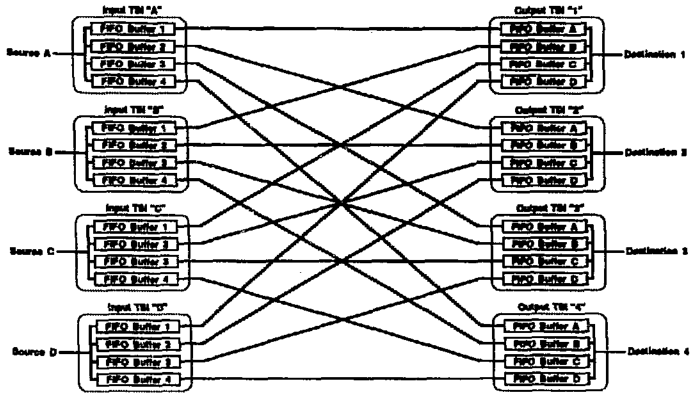


Figure 10: Logical Switch Operation

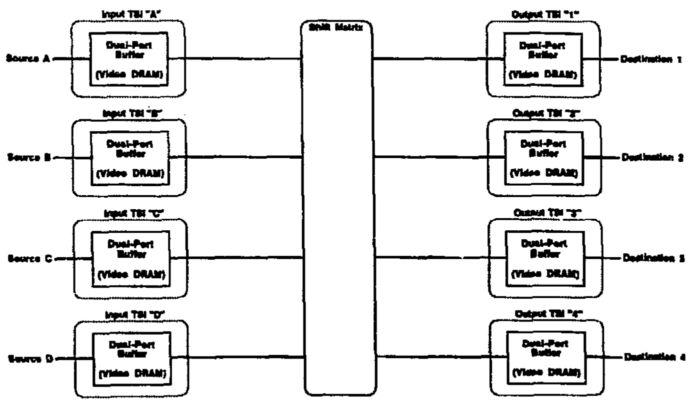


Figure 11: Physical Switch Operation

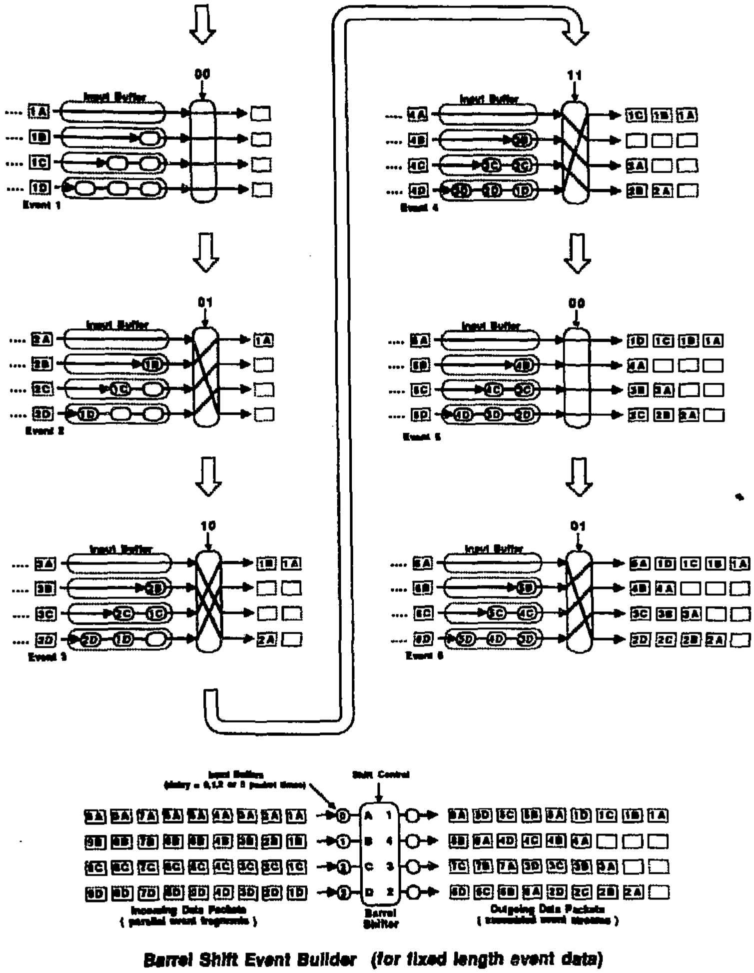


Figure 12: Barrel Shift Event Builder

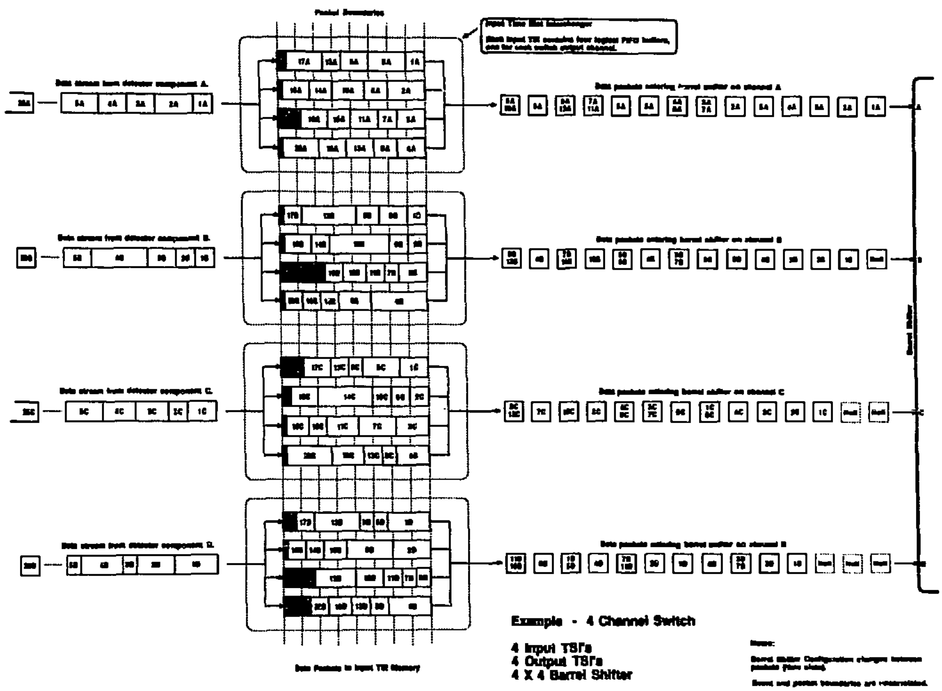


Figure 13: Input Time Slot Interchangers. See text for description.

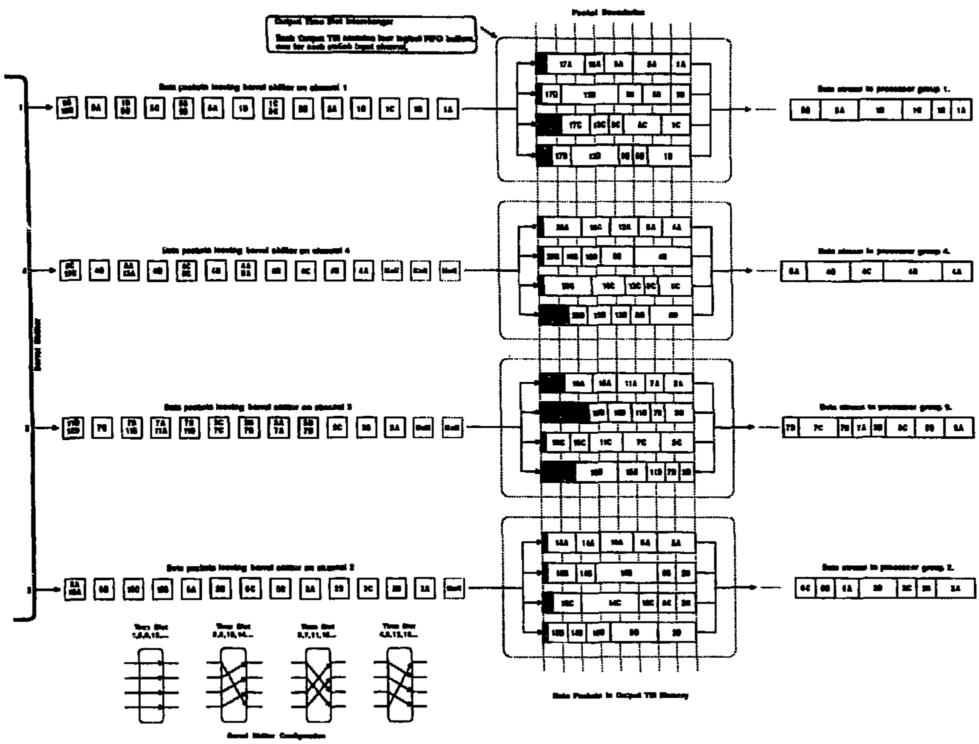


Figure 14: Output Time Slot Interchangers. See text description.

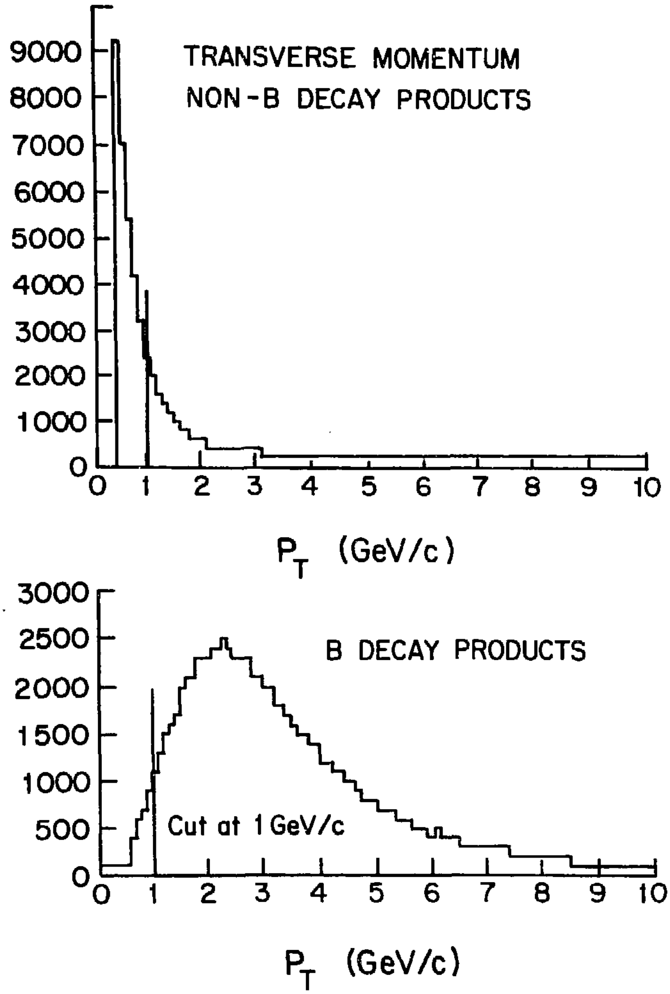
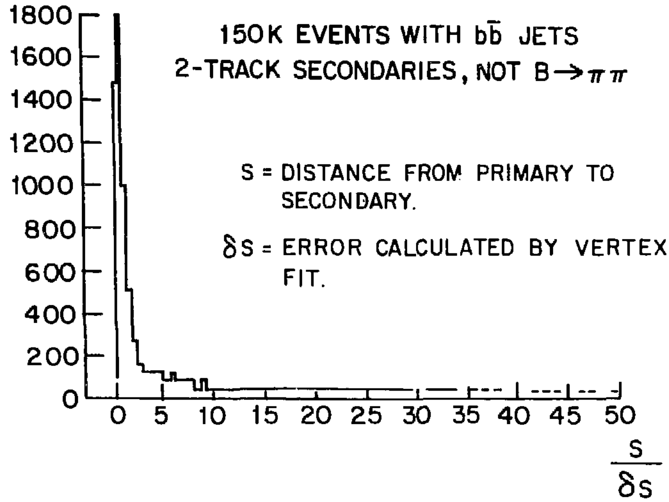


Figure 15: P_t of $B \rightarrow \pi^+\pi^-$ and Non-B Decay products



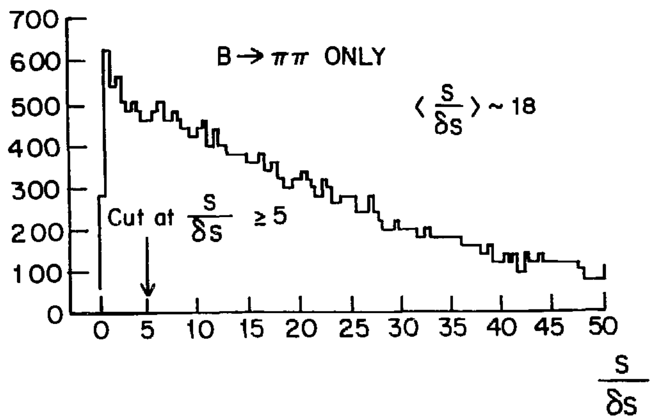


Figure 16: S/ ΔS for $B \to \pi^+\pi^-$ and non-B Decay products

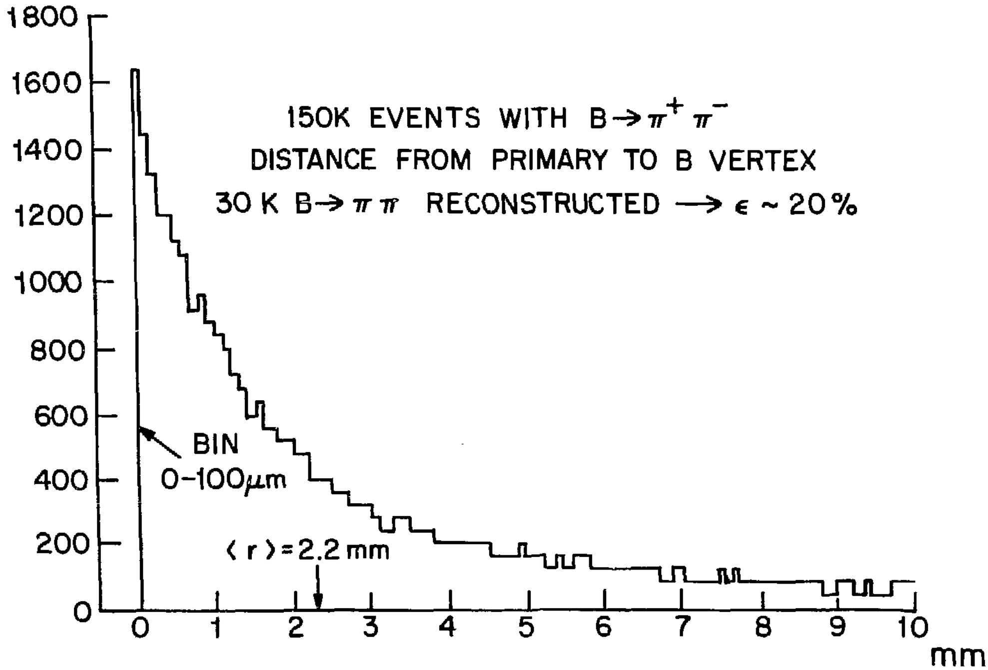


Figure 17: Distribution of path lengths from found vertices

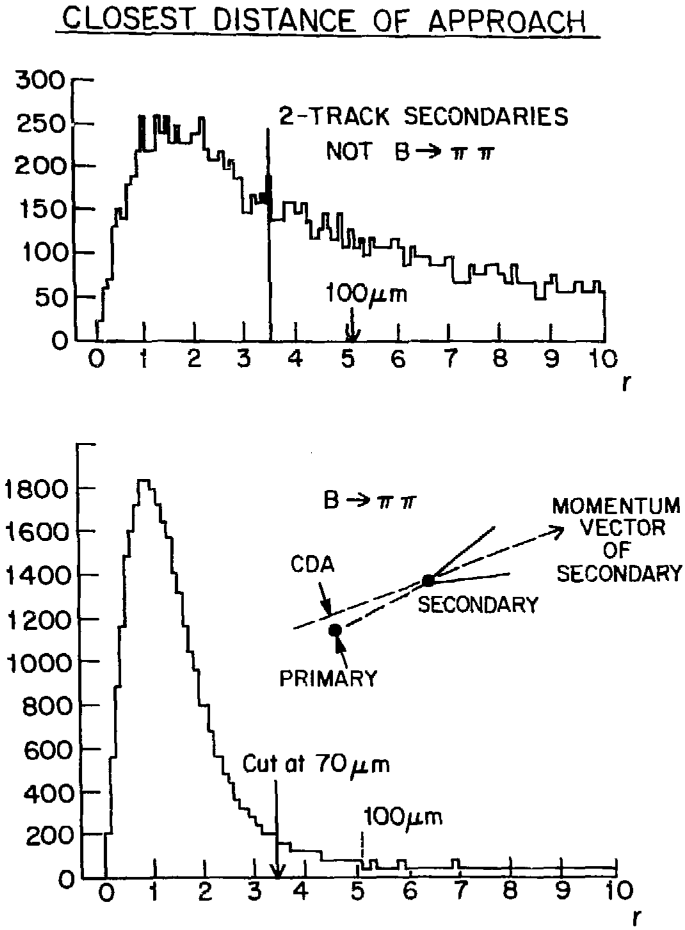


Figure 18: Distance of Closest Approach for the Vertex Momentum Vector.

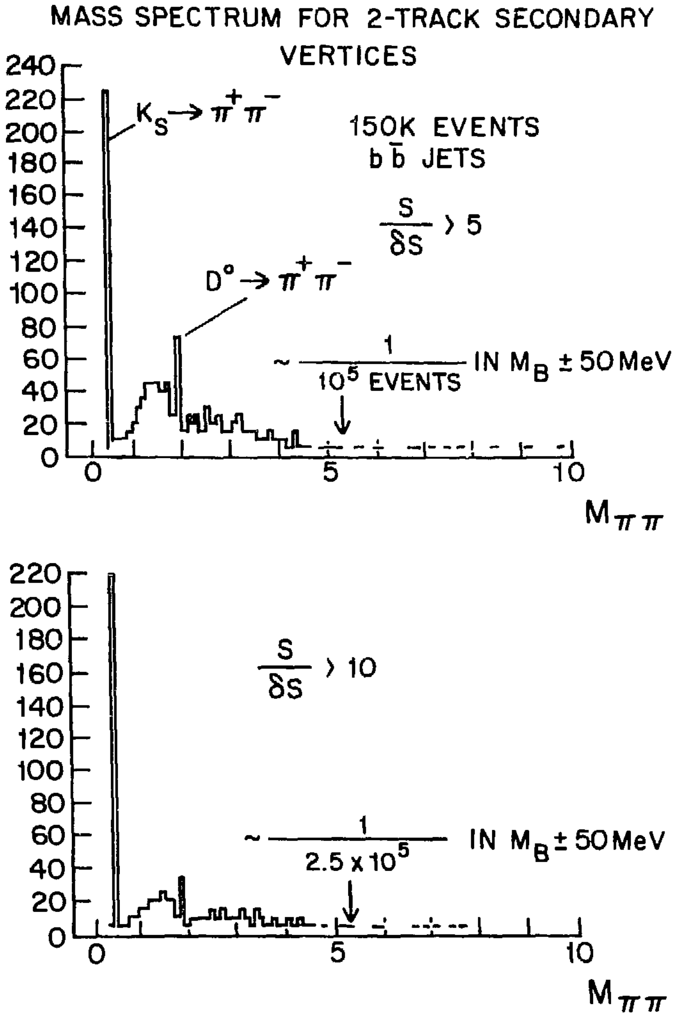


Figure 19: Mass Spectrum for 2-Track Secondary Vertices.

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