

BTeV IP Review

December 18, 2003

A review of the BTeV Interaction Point design was held on October 7, 2003. The Review committee consisted of Terry Anderson, Alexei Burov (absent), Bruce Hanna, John Johnstone, Mike Martens, Mike McGee, Nikolai Mokhov, King-Yuen Ng, Rob Roser, and Mike Syphers (chair). The presentations were well prepared and very enlightening to the reviewers, most of whom were not familiar with the BTeV project. The main issues presented and discussed during the review were: (a) vacuum, (b) impedance, (c) aperture and operations, and (d) radiation environment. Below we present, for each issue, bullets from the Review Close-out presented by Syphers, followed in each case by subsequent comments and questions from the other reviewers. (All reviewers responded with comments; extensive comments received are presented and duplications avoided where possible.) Also included are recent responses to some of the more outstanding issues, as compiled by Peter Garbincius (shown in **bold** type). The Charge to the Committee can be found at the end of the document.

-Mike Syphers

1 Vacuum

1.1 Close-out:

- Overall design-no issues in principle, but very big gas load...
 - Gas load likely higher than in mock-up
 - Design goal should be 1e-8 torr or better
- Regeneration frequency needs to be defined and assessed
- RGA scan of model with realistic (up-to-date) components should be performed
- Carbon near electrostatic separators may be a concern

1.2 Additional Comments:

Roser-

Does the cryogen pumping scheme impact the stability of the pixel detector? Are there vibration issues?

Will there be a separate LHe plant? Helium headers in the Tev have big pressure excursions during quenches. (This is why CDF does not use Tevatron helium at all.)

Response (Garbincius): BTeV has not described their LN2 and LHe systems with regard to supply and impact on ODH classification of the C0 Experimental Hall. BTeV has said that it would not be using the Tevatron LHe system for the experiment.

Vacuum that is good enough for BTeV may not be good enough if the other IP's (B0, D0) have work that they want to perform. F11 pressures had huge impact on CDF losses for instance. BTeV vacuum needs to be put in context with the overall experimental plan.

Regeneration time needs to be engineered. Without a heat load, it may take a long time to get the charcoal sufficiently warm to release its "crud." It would be useful if regeneration could be done on the time scale of a magnet swap for instance.

For the vacuum, I would like to see a pressure curve vs Z (along the beampipe). Is there a smoking gun somewhere?

The need for fast-acting valves should be clarified.

Response (Garbincius): As of December 11, 2003, these will be located just inside the C0 Experimental Hall, within the BTeV muon detector, downstream of the B2 magnets.

Anderson-

The committee recommends that 1E-8 Torr be used as the total pressure design goal, assuming the gas load is water. This should give a sufficient margin for error. The pressure can probably go as high as 5E-8 Torr without causing problems for Tev vacuum.

Comment (Garbincius): This agrees with V. Shiltsev, "Requirements on new Tevatron equipment", Beams-Doc-877, 10/17/03 which states $< 5 \times 10^{-8}$ Torr (locally).

A true model with the proper percentages of the materials that will be used needs to be tested to better understand the gas loads and pumping needs. Special attention should be given to how the gas loads are measured to insure accurate results.

The project should clearly define what the regeneration process will involve and what the frequency

will be. These requirements should then be reviewed by the Tevatron Department.

The committee did not fully understand the drive mechanism that will be used for moving the pixels in and out of the beam area. There is some concern that there may be a desire to use a lubricant that may be harmful to the vacuum or that there may be sliding surfaces that may generate particulates that may be harmful to the detector or the beam. The project should look carefully at this and convince themselves that this is not the case.

Hanna-

Effort needs to be spent to insure that the beam tubes used are treated in a manner suitable for UHV. This means they should use beam pipe that can be baked and cleaned ultrasonically. I know aluminum can be treated like this but I don't know about beryllium. Do they really need beryllium? Also they need to build and test their LHe cryopumps. Where will they get the LHe and how will they get it to the cryopumps?

The feedthrough board looks to be a serious vacuum load that has not been considered. Is there another material such as ceramic that the pc boards could be made of that is better for vacuum? Once all the material selection is complete they do need to perform vacuum tests using real material.

It was mentioned that the body of the detector will be stainless steel and the end caps aluminum. How are they going to seal this? Welding, o-ring seals or something else? This could adversely affect the vacuum. Also, the choice of what kind of aluminum is important; stay away from cast aluminum as it is porous. I know that they are planning on an o-ring seal for the feedthrough board; they should insure that the o-ring material will withstand the expected radiation doses.

2 Impedance

2.1 Close-out:

- Direct measurement is a good way to know the impedance(!). Broad band impedance estimates do not uncover sharp resonances, which are clearly present.
- RF shielding...
 - Measurements will show if necessary at all
 - If necessary, look for something other than wires
- Effects of beam on detector:
 - Parasitic heating of pixel detector from the beam current a problem? This may require a test with beam.
 - Noise on the system? (to be tested)

2.2 Additional Comments:

Ng-

The estimation of Burov (see below) is for a broad-band resonance centered at the cutoff frequency of the beam pipe. It gives $Z/n = 0.03$ Ohm, which is too small to drive any single-bunch instabilities. **(Comment (Garbincius): It should be pointed out that these impedances meet the general criteria by Shiltsev, which, to first order, requires all new devices to have impedances small compared to that of the rest of the existing Tevatron.)** However, the detector structure, because of its complication, may also generate narrow resonances, which are capable to drive coupled-bunch instabilities. We suggest

1. Experimental measurement of the impedance of the whole detector to verify Burov's estimation and to uncover narrow resonances. **The errors inherent in such measurements need to be evaluated carefully.**
2. Numerical computation of impedances using MAFIA or HFSS, for example. This computation is necessary because experimental measurement with a wire cannot cover frequencies above cutoff and it also cannot give us any knowledge of the transverse impedance. As an example, bellows contribute to resonances above cutoff.

Comment (Garbincius): Help for BTeV to implement MAFIA or HFSS studies should be included in Mike Church's request for calculational manpower. The Accelerator Division will also need to review these BTeV calculations.

Burov-

Estimates of broad-band impedance, conducted in September 2003, are presented on the following page.

BTeV Impedances

Alexey Burov
September 08 2003

Aperture of the BTeV detector is supposed to be 6 mm at collisions and 20 mm otherwise. When the surroundings are so close to the beam, questions about impedances have to be answered. An upper estimate for the longitudinal and transverse impedances is given by the so-called “careless limit”:

$$\left| \frac{Z_{\parallel}}{n} \right| \leq \frac{Z_0 l}{2C}; \quad Z_{\perp} \leq \frac{Z_0 l}{2\pi b^2},$$

where l is a length of the element, b is the aperture radius, C is the ring circumference and $Z_0 = 377$ Ohms. For 130 cm of the narrow space, it gives

$$\left| \frac{Z_{\parallel}}{n} \right| \leq 0.03 \Omega; \quad Z_{\perp} \leq \begin{cases} 2 \text{ M}\Omega/\text{m} & \text{at collisions} \\ 0.2 \text{ M}\Omega/\text{m} & \text{otherwise} \end{cases}$$

All the impedances are clearly small enough to be tolerable, including the transverse impedance in collisions: remember that the beam stability is determined by the transverse impedance weighted with the local beta-function. Taking into account that IP beta-function is about 0.01 of its ring-average value, and that the total transverse impedance of the Tevatron is about 1 MΩ/m, an insignificance of the BTeV impedance at collisions gets to be clear.

Peter H. Garbincius notes, after discussion with Alexey Burov on *October 1, 2003*:

General reference is

Alex Chao, Physics of Collective Beam Instabilities in High Energy Accelerators
Page 88 discusses the “careless limit” for maximal longitudinal impedance
Page 81 discusses the Panofsky-Wentzel relation for transverse impedance

For Tevatron, $Z_{\perp} \beta$ is estimated as about 100 MΩ at average $\beta \sim 100$ meters. For the C0 operating conditions, the upper limits for BTeV impedance are listed below.

Optics	BTeV Vertex Detector	β	Z_{\perp}	$Z_{\perp} \beta$
Collins Straight	retracted (inject)	75 m	0.2 MΩ/m	15 MΩ
Collins Straight	closed (collision)	71 m	2 MΩ/m	140 MΩ ***
low- β injection	retracted	2.6 m	0.2 MΩ/m	1.3 MΩ
low- β collision	retracted	0.5 m	0.2 MΩ/m	0.1 MΩ
low- β collision	closed	0.5 m	2 MΩ/m	1 MΩ

This worst case transverse impedance estimate is comparable with the Tevatron transverse impedance only for BTeV test mode configuration (closed) before low- β insertion is established. Since this mode is not important for luminosity, it can be concluded that the BTeV impedance would not limit the Tevatron performance.

Note added, 2 Oct. 03: Joel Butler states that BTeV does not intend to operate with the vertex detector closed (within 6 mm of IP) during the test mode with the existing Collins straight section. Therefore, the maximum $Z_{\perp} \beta$ would be 15 MΩ, which is small compared to the total Tevatron transverse impedance.

3 Aperture and Operations

3.1 Close-out:

- Ramping of bending magnets in C0 is preferred
 - Ramping of SM3 magnet needs to be studied further
- Should consider using other (new) magnets other than B2's.
 - Aperture not optimum during test mode (downstream end of C0)
 - Poorer field quality, old magnets
- Scenarios of switching from test mode to running mode not well defined. A “test” plan needs to be developed and reviewed.

3.2 Additional Comments:

Roser-

Do the quads need to be redesigned or re-examined if CDF and D0 keep their low beta quads off?

Response (Garbincius): CDF and D0 will always have their low-beta quads at injection settings. The design for C0/BTeV does include all possibilities for CDF/D0.

I would like to see a resource-loaded schedule for what it takes to install the infrastructure for these magnets. What is the testing strategy? Is the second floor on board with the proposal? How many reconfiguration of the C0 hall are they expecting? Does the TeV department have the resources to perform all of these gyrations? What is the impact to Run II physics?

What happens if the CDF detector is pulled out? Are they counting on this as shielding for kicker pre-fires etc or are they far enough around the bend that this is not an issue?

Response (Garbincius): Beam backgrounds and shielding are not yet understood. A calculation and shielding design study have been requested by Mike Church.

Presumably they have beam position monitors-how is that information fed into the position of the pixels? That needs to be carefully thought through. How far upstream are they located, Is it automated? Does the pixel window move during a store?

How long would it take to remove a B2 from the torroid? What has to be removed? Can engineering be used to speed up this process?

Response (Garbincius): Due to “capture” of B2s by the torroids, BTeV requests failed B2s be removed through the beam tunnel, and thus they which would have to pass over the LHC quads. This needs real design work. The transverse size of the B2

coils is an issue. Also an issue is the impact of Toroid field on B2 field which affects Tevatron beam orbit.

Hanna-

How are the wires connected to the pixels? Can they come loose?

Another question I would have for the BTeV collaboration concerns stands. At present the MI Dipoles are on stands that sit on shielding blocks. In the center of the straight section there is nothing but suspended beam pipe ie there are no shielding blocks. How will they support their detector in the beam line? How accurately will they need to align this box and how do they propose to do it. Are there any vibration issues; we know we see the affect of the CHL He compressor at 4.6 Hz in the TeV. What is the mechanical resonant frequency of the substrate and its supports; could they vibrate and scrape the beam?

Johnstone-

Each side of the C0 IP the beam pipe is 1" i.d. from 1→4 m, then 2" o.d. from 4→8 m. Centered at ± 9.7 m from the IP are two 10' B2 magnets which, in conjunction with the SM3 analyzing magnet create a vertical 3-bump displacing the beam by ~ 8 mm at the IP.

From my own calculations, I can assert that with low-beta IR optics there are no aperture conflicts throughout the C0 region at any energy and for any operational mode. (Pictures are attached below.)

At injection the nearest approach to the aperture limits occur at the D/S end of the 1" pipe. With Yuri's preferred "5-star" helix solution the "orbit+1cm" case narrowly clears the beam pipe wall.

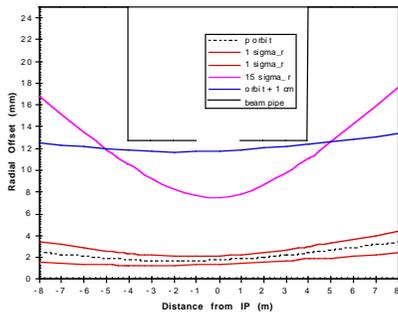
During C0 collisions 15-sigma is just 0.6 mm at the IP so bringing the silicon wafers as close as 4 mm to the beam shouldn't be an issue for the Tevatron.

During injection, with Collins optics, the 2" pipe accepts an aperture criteria of 8-9 sigma. The "orbit+1cm" envelope fits comfortably within the pipe, with clearance > 8 mm everywhere in both planes. Horizontally, the "x-orbit+10-sigma-x" fits as far as 8 m D/S of the IP. This should be sufficient and, without the compensating B2 at this spot, it may be that the 2" pipe could become a standard 3". (Pictures of the calculated injection vertical & horizontal apertures are attached below).

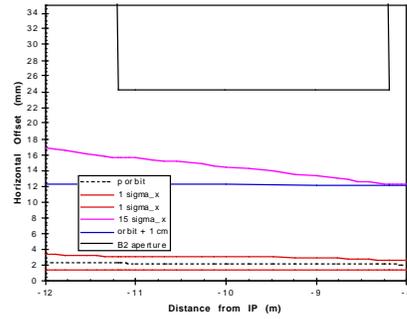
Comment (Garbincius): Part of the BTeV proposal, of which the Director is aware and has implicitly approved, includes modifications to the straight section at C0 by AD during the 2005 shutdown and the installation of the SM3 dipole and compensating dipoles within toroids during the 2006 shutdown.

BTeV needs to supply much more detail on their plans/requirements for implementing the test phase of the experiment to adequately assess the aperture issues further.

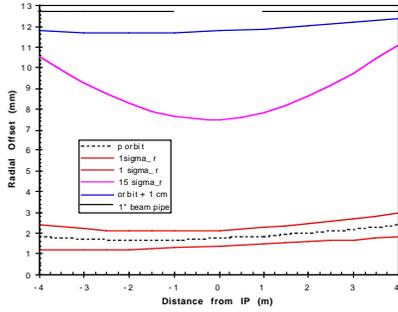
150 GeV Injection Clearance @ C0
 $\beta^* = 3.50 \text{ m}$ & $\epsilon = 20\pi \mu\text{m}$



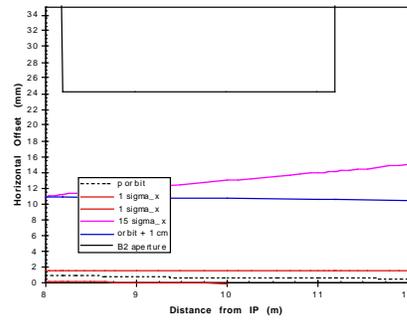
Injection Clearance @ C0 u/s B2 Magnet
 $\beta^* = 3.50 \text{ m}$ & $\epsilon = 20\pi \mu\text{m}$



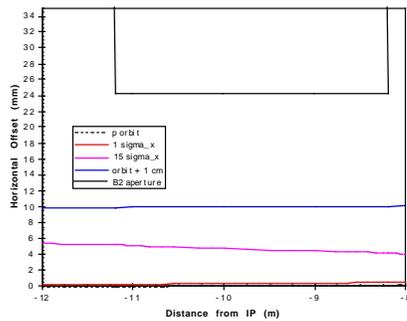
Injection Clearance @ C0 Narrow Pipe
 $\beta^* = 3.50 \text{ m}$ & $\epsilon = 20\pi \mu\text{m}$



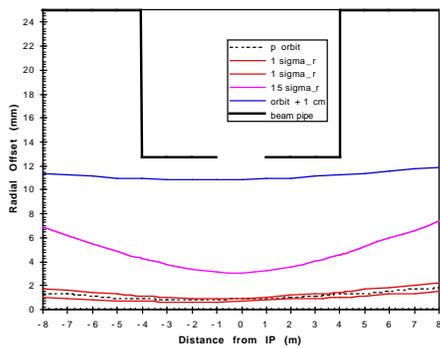
Injection Clearance @ C0 d/s B2 Magnet
 $\beta^* = 3.50 \text{ m}$ & $\epsilon = 20\pi \mu\text{m}$



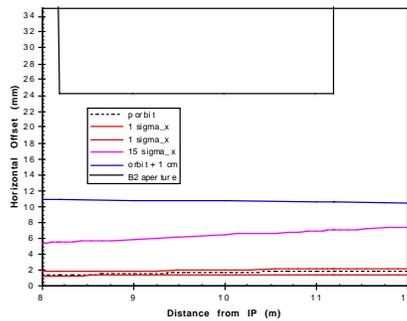
Clearance @ C0 u/s B2 Magnet with B0/D0 Collisions
 $\beta^* = 3.50 \text{ m}$ & $\epsilon = 20\pi \mu\text{m}$



Clearance @ C0 with B0/D0 Collisions
 $\beta^* = 3.50 \text{ m}$ & $\epsilon = 20\pi \mu\text{m}$

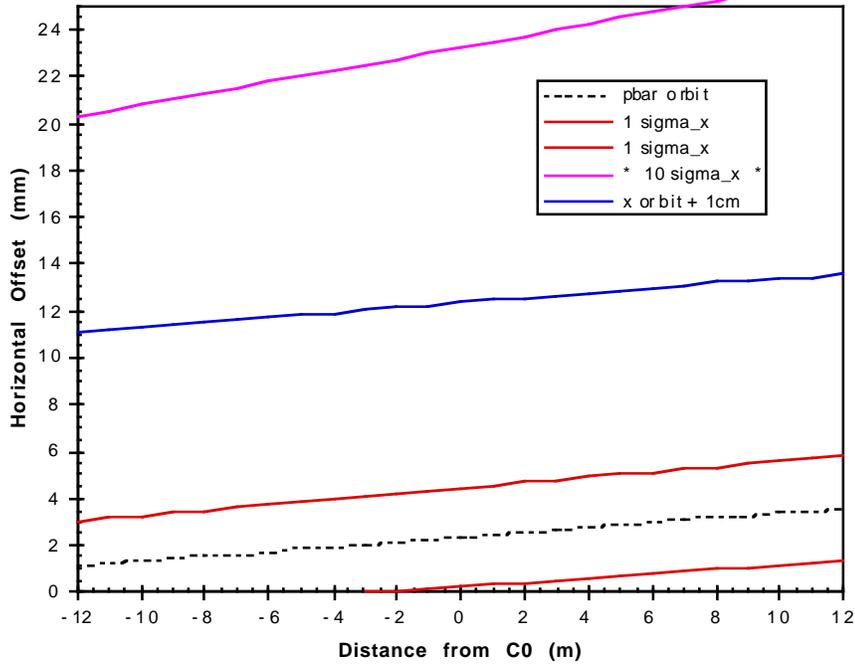


Clearance @ C0 d/s B2 Magnet with B0/D0 Collisions
 $\beta^* = 3.50 \text{ m}$ & $\epsilon = 20\pi \mu\text{m}$



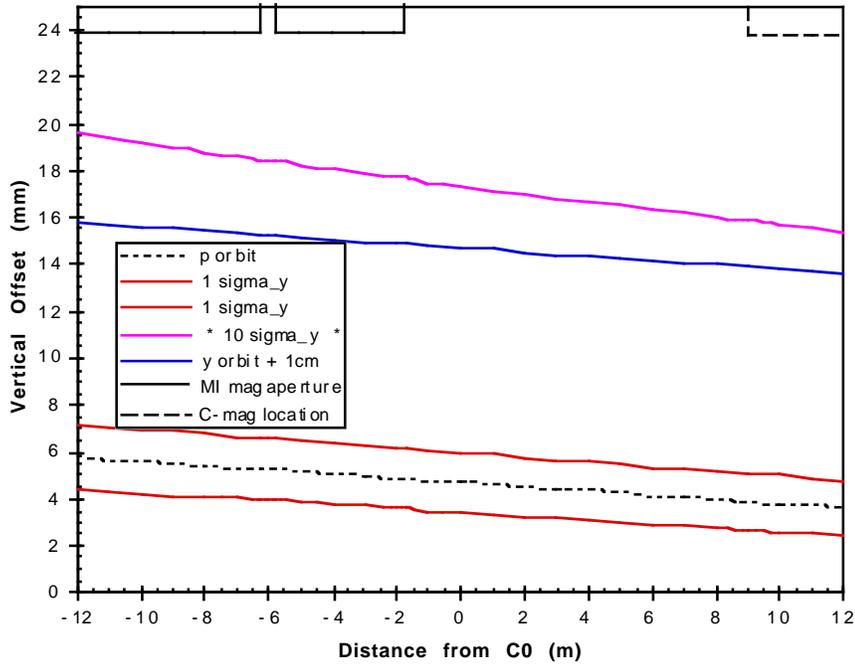
Horizontal Injection Clearance @ C0 Collins Straight

$\beta_x = 75\text{m}$, $\beta_y = 77\text{m}$, & $\epsilon = 20\pi \mu\text{m}$, $\delta_{95} = 14.E-4$



Vertical Injection Clearance @ C0 Collins Straight

$\beta_x = 75\text{m}$, $\beta_y = 77\text{m}$, & $\epsilon = 20\pi \mu\text{m}$, $\delta_{95} = 14.E-4$



4 Radiation Environment

4.1 Close-out:

- Radiation loads and residual dose rates to pixel detector (and other components), dipole magnets, and low-beta quads need to be refined.
- Machine-related radiation loads to the pixel detector during normal operation and for beam accidents need to be analyzed and, if needed, a collimation scheme designed.
- Study impact of BTeV operation on machine and other detector IRs and, if required, design collimation schemes.
- Establish collaboration with Accelerator Integration Department for items above.
- Need diagnostic tool(s) to provide guidance and protection while inserting pixel detector.

4.2 Additional Comments:

Mokhov-

Add to above list:

- Verify if the dose on the surface due to muons downstream of the 3-bump vertical bending is within the regulatory limits.

Comment (Garbincius): This is from the actual interactions at C0 I.P. This represents radiation due to “normal” operations (not accident), and, therefore, more stringent dose rate limits apply.

Appendix-Charge to the Review Committee

Charge to Tevatron Department Regarding Proposed I.P. Configuration for BTeV

Peter H. Garbincius

btev_ip_V7.doc

2 October 03

The final BTeV Technical Design is being developed. Before being approved for funding and construction, it must pass upcoming reviews by Ed Temple (internal Fermilab review) and Dan Lehman (DOE review).

A question that still requires answering is whether the Tevatron Department will approve the current BTeV baseline design, installation and operations. These include both the low beta insertion and those aspects of BTeV that are different from the solenoid geometries of CDF and D0. This charge does not address the low beta insertion issues.

There are two main differences between the CDF/D0 and BTeV installations:

- a. Unlike CDF and D0, BTeV's design calls for the silicon vertex detector to be located *within* the Tevatron vacuum. It will be remotely positioned to be withdrawn during injection, acceleration, low beta squeeze, and extraction, and to move close to the beams after collisions are established. In the baseline design, the distance from the beam to the edge of the sensitive region of the silicon detector is 6 mm and operation at 4 mm at low luminosities is desirable. This is closer than CDF and D0 currently run. Therefore, the issues that must be addressed, and resolved by design or performance demonstration include vacuum, RF-impedance and shielding, and apertures. The protection of the detector from stray beam and high losses must also be understood. The web location of the current design documents is shown at the end of this document.
- b. Although CDF and D0 use a solenoid spectrometer configuration, BTeV will use a dipole analysis magnet which bends vertically (out of the Tevatron bend plane) with compensating dipoles on each side. The issues that must be addressed include the slight trajectory deviations out of the Tevatron bend plane, the apertures of the compensating dipoles, small beam pipes, and silicon vertex detector, and the multipole errors in the analysis magnet. The current conceptual design of the vertical bending spectrometer is also referenced below.

I request that the Tevatron Department, along with assistance from the Accelerator Integration Department, initiate a review of these issues, including establishment of a review panel, reviewing available documentation, presentation by BTeV, and establishment of criteria to be met. The outcome of this process should be either an approval of the baseline concept, and/or performance criteria that would have to be demonstrated by BTeV before final approval of installation and operation in the Tevatron would be granted. Once a baseline design is approved, it is subject to strict change control processes, so it is essential to resolve these issues now.

It is important to have at least a first iteration of this process completed before the Temple review on October 21-23. The review meeting is scheduled for the afternoon of Tuesday, October 7. I ask that, at the end of the day, you present a verbal closeout

summary to the BTeV Spokespersons, Vladimir Shiltsev, and to me on that date and to present your written report (in electronic format) with recommendations by Monday, October 13.

The references can be found at the website:

http://www-ap.fnal.gov/~peterg/btev_ip_sept03/

with individual filenames =

This charge to the review panel:

ip_review_charge.pdf Charge Regarding I.P. Configuration for BTeV

a. Pixel Vertex Detector System: contact: Simon Kwan, x2329, swalk@fnal.gov

btev_1596_v7.pdf Main Ref – Pixel Detector Vacuum System Description
rev 19sept03 and its sub-references are also available as:

btev_0318_v1.pdf Analysis of BTeV Vertex Detector Vacuum System
btev_0812_v2.pdf Outgassing Rate of 5% Model of the Pixel Detector
btev_1096_v6_slides.pdf PPT – BTeV Silicon Detector Integration Issues
btev_1096_v6_text.pdf text – BTeV Silicon Detector Integration Issues
pixel_profile.pdf transverse detector positions - operating & retracted
btev_2005_v2.pdf Cryogenic Pumping System - BTeV Pixel Detector
BTeV_Impedances_1Oct03.pdf A. Burov upper limit estimate of Beam
Impedance of BTeV Vertex Detector

b. Vertical Bending Spectrometer: contact Chuck Brown, x3202, chuckb@fnal.gov

btev_spectrometer.pdf Geometry of BTeV Vertical Bending Spectrometer
SM3_magnetic_field.pdf Magnetostatic Analysis of BTeV Dipole Magnet
SM3_field_points.pdf Calculated Bx(x,0) and Bx(0,y) field points
SM3_multipoles.pdf Fit to Multipoles of SM3 Dipole Field

Date of BD Review of BTeV IP Configuration – **Tuesday, October 7, 2003, 1 PM**
location: West Wing WH10NW

Chairman: **Mike Syphers**
Vacuum: Bruce Hanna, Mike McGee, and Terry Anderson
Beam Impedance: Alexei Burov & Bill Ng
Radiation: Nikolai Mokhov - define scope of work at review
Vertical Bump/Apertures: John Johnstone, Mike Martens
General: Rob Roser