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SDC
SOLENOIDAL DETECTOR NOTES

STATUS OF THE SDC BEAM VACUUM PIPE DESIGN

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ABSTRACT

The present status of the conceptual design of the vacuum pipe for the SDC interaction region is sketched. Emphasis is placed on the physics and technical arguments driving the design.

A committee has been meeting monthly over the last several months to try to outline the design of the SDC beam pipe in the interaction region. This has involved discussions with a number of physicists representing central tracking, forward calorimeter and other areas, as well as a number of engineers. Tim Thurston, Norm Wells, Don Clark, John Worden, David Veal, Jerry Chapman and others have contributed considerably to our deliberations, starting us on the long road changing our physicist sketches into real designs and along the way pointing out the many impossible things we have suggested.

We have chosen a design in which the center section of the pipe is Be and the rest is non-magnetic stainless steel. The center section (± 1.1 m) is a 2.5 cm radius Be pipe. This joins to a conical section which starts at 2.5 cm radius at 1.1 m and goes to 25 cm radius at 11.0 m. This then tapers down to 2.5 cm by $z = 11.5$ m and it then continues at 2.5 cm radius for the next 8.5 m. See Figure 1.[1] Further specifications are given in Table 1.[1]

There are a number of arguments leading to this design. We first discuss physics arguments.

A. Shielding of the forward muon chambers. For a given amount of shielding for the forward muon chambers, Kulik has shown for Monte Carlo calculations with a similar but not identical conical pipe, that the conical pipe had about a factor of 50 or so fewer background particles than a straight 2.5 cm radius pipe.[2] See Figure 2. This calculation needs to be redone with the present pipe design.

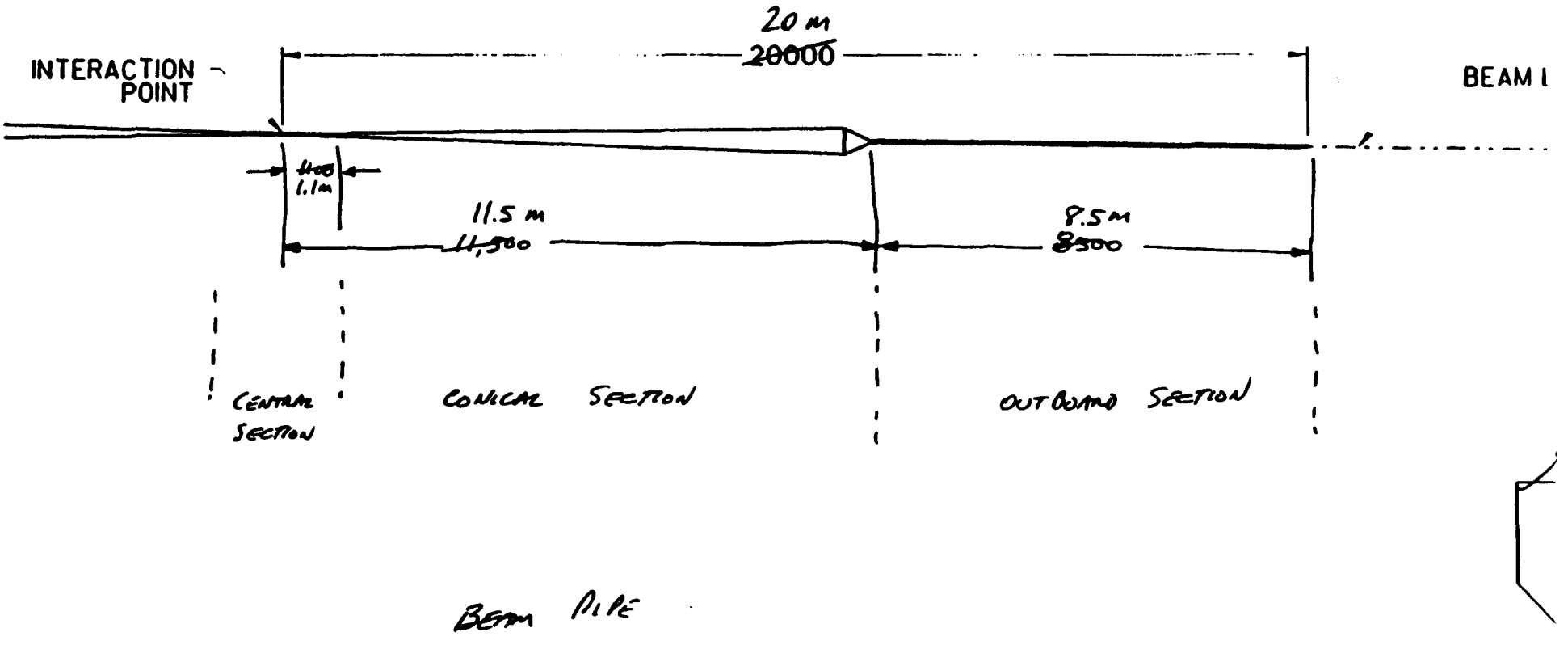


Figure 1: Drawing of Proposed SDC Beam Pipe.

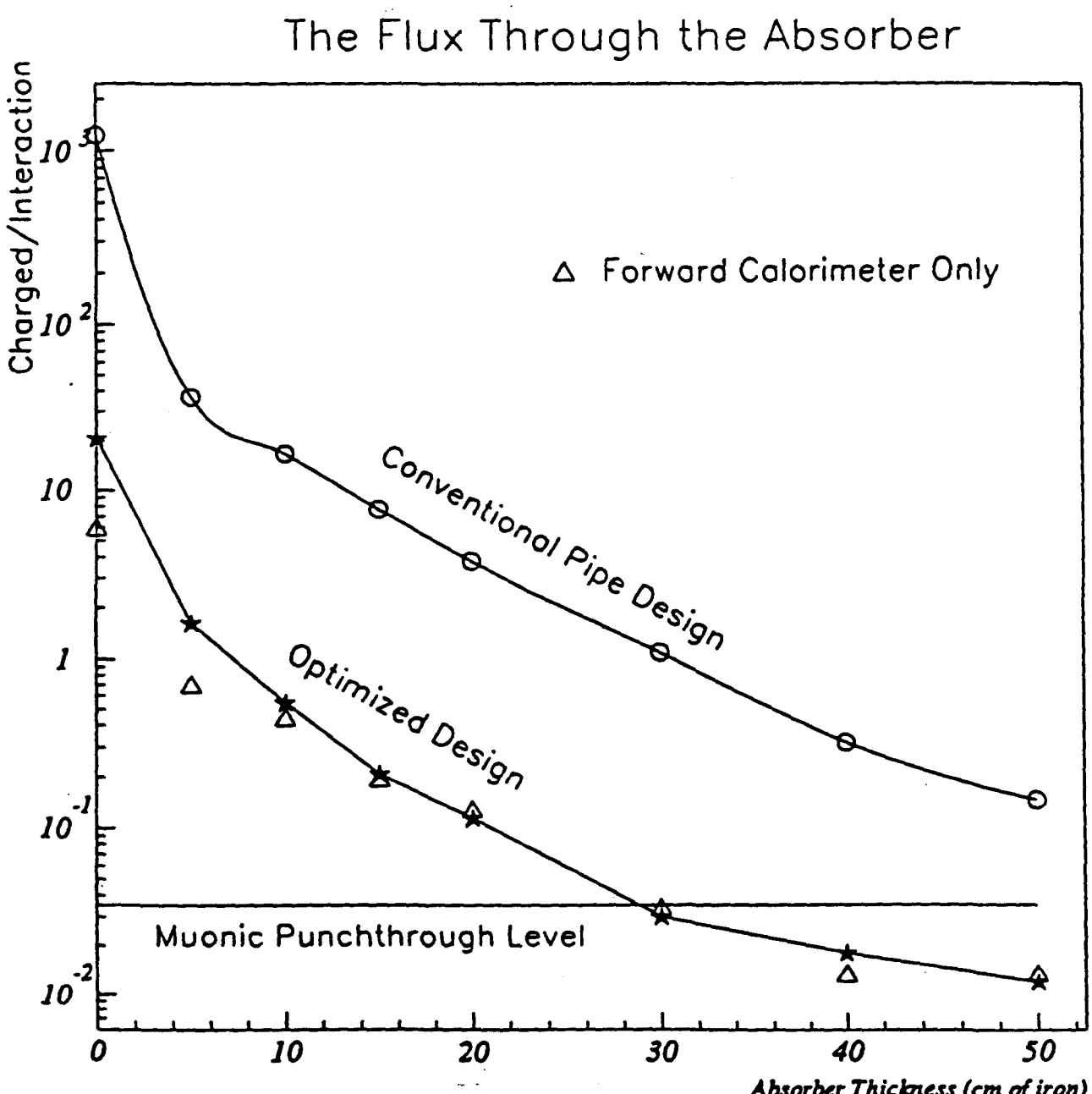


Figure 2: Rate of Charged Punchthrough vs Iron Absorber for Two Different Beam Pipe Configurations.

The curves "Conventional Pipe Design" and "Optimized Design" don't include the Forward Calorimeter influence. The latter is shown separately.

Table 1: Specifications for SDC Interaction Region Beam Pipe

Central Section	
Total Length (mm)	2200
Diameter (mm)	50
Wall Thickness(mm)	0.65
Material	Be
Cross Section	Circular
Conical Section A (Each)	
Length (mm)	9,900
Minimum Diameter (mm)	50
Maximum Diameter (mm)	250
Minimum Wall Thickness (mm)	0.65
Maximum Wall Thickness (mm)	6.5
Conical Section Angle (from IP)	1.302°
Material	Non-Magnetic Stainless Steel
Cross Section	Circular

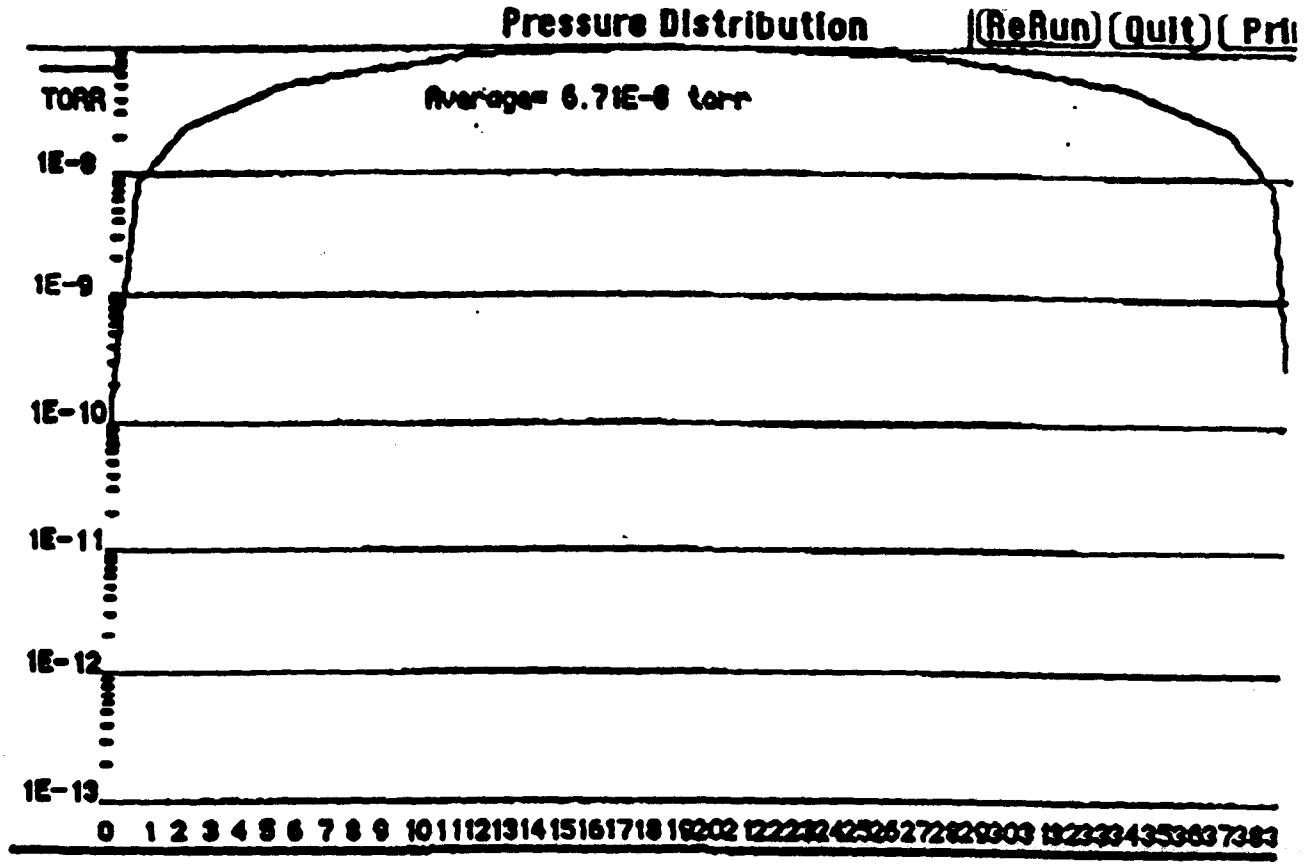
B. The cone is shaped to point back to the interaction point. The advantage of this is that as we show below only a very small region of η is obscured, about $\Delta\eta = .05$ for a given ϕ angle, centered around $\eta = 4.479$. For the rest of the angular region, the pipe provides minimal material, less than 8% radiation length going through the central pipe, and about 82% radiation length maximum going through conical section B which is near the forward calorimeter. The material in section B is expected to be less serious because it is near the forward calorimeter and the effect of spray reducing the E_T resolution is expected to be less important. This spray which can go to the opposite ϕ angle of the forward calorimeter was a major consideration in the choice of the shape of the forward calorimeter. If this thickness does seem high then conical section B could be made of Al. If, to get a rough idea, we ignore the thickness (in cm) difference between the Al and the stainless steel section B, then an Al section would have only 16% radiation length maximum. (The radiation lengths of Be, Al, and Fe are 35.3 cm, 8.9 cm and 1.76 cm respectively)

Table 1: Continued

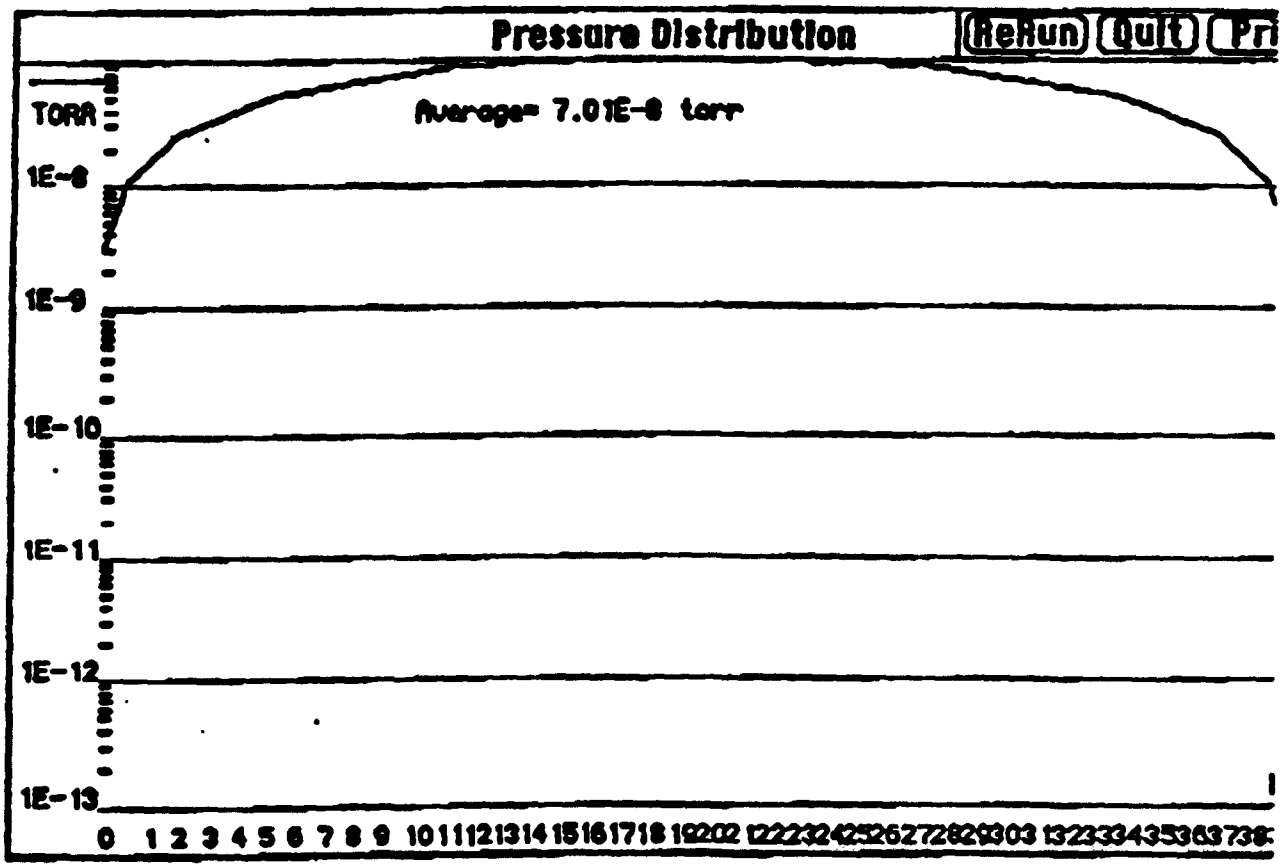
Conical Section B (Each)	
Length (mm)	500
Maximum Diameter (mm)	250
Minimum Diameter (mm)	50
Maximum Wall Thickness (mm)	6.5
Minimum Wall Thickness (mm)	0.65
Conical Section Angle	24.228°
Material	Non-Magnetic Stainless Steel
Cross Section	Circular
Outboard Sections (Each)	
Length (mm)	8500
Diameter (mm)	50
Wall Thickness (mm)	0.65
Material	Non-Magnetic Stainless Steel
Cross Section	Circular
Vacuum	
Design Goal (torr)	10^{-8}
Vacuum Pump Candidates	Roughing Ion Non-Evaporative Getter

Next we consider technical arguments.

A. The problem of producing a vacuum in the pipe is simplified if the conical section is used. A straight 40 m pipe restricts the pumping speeds severely. See Figure 3.[3] Using a straight pipe would require pumping manifolds closer in to the interaction region than the present design which would introduce more material into sensitive regions. Furthermore, because the cone points at the interaction point, the radiation length of the material used is not important, because for a particle travelling at the cone angle there are effectively an infinite number of radiation lengths anyway. This



Average Pressure Distribution for VACUUM PIPE 5cm dia by 40m long with 2000l/s pumps at each end. Clearly pumping speed is not useful



50L/S Pumping

Figure 3: Pressure Distribution in a 5 cm Vacuum Pipe Pumped at the Ends.

allows us to use stainless steel for conical region A. The outgassing rate from stainless steel is about 10 times smaller than the outgassing rate from aluminum.

B. A conical section is more rigid than a straight pipe. Supporting this pipe without sag is very important.

Let us calculate the region obscured by conical section A. $\Delta\theta = t/D$, where t is wall thickness and D the distance from the interaction point (i.p.) to the point of interest. In order to keep the stress in the wall constant, we need to have the wall thickness proportional to the radius, $t = aD$ and thus $\Delta\theta = a$.

How big is a? We have a 0.65 mm thickness SS pipe at r = 2.5 cm, z = 1.1 m and a 6.5 mm thick pipe at r = 25 cm, z = 11 m. Then $a = \Delta\theta = 0.59 \times 10^{-3} = 0.59$ mrad.

Thus the central obscuration angle is 22.73 mr = 1.3° or $\eta = 4.479$. The obscured region corresponds to $\Delta\eta = 0.026$ for an interaction at the nominal i.p.

However, the interactions are not always at the nominal i.p. We must calculate the effect of the beam being off center. We have been informed by the alignment group (David Veal) the accelerator coordinate system and the SDC coordinate system may differ by up to 3 mm. We will know the offset, but only a few weeks before beam time. Suppose the beam is 3 mm off center. The difference between θ at 1.1 m and at 11 m is 2.72 mrad. In the opposite direction $(\phi + \pi)$, the signs are reversed and the $\Delta\theta = 5.44$ mrad. This is 9.2 times bigger than the natural size. It is clear that we must be careful to align the pipe to the beam to better than 3 mm. Before setting a reasonable tolerance let us continue calculating.

Next we calculate the effect of a finite beam size in z. Suppose that the variation of interaction size in z has σ=6 cm. This is a conservative estimate and the actual size may well be smaller. At 22.73 mrad, 6 cm corresponds to a transverse size of 1.36 mm. This again gets doubled because of $\pm$ and we find a size due to this of 2.44 mrad. This gives a $\Delta\eta = 0.11$. Note that for a given value of ϕ, the azimuthal angle, the $\Delta\eta$ value is at most half this. The 0.11 is the total region that is obscured for any ϕ, and the region obscured for a given ϕ is $\Delta\eta = 0.055$.

In order to keep the obscuration from a transverse offset to the same size as that of the longitudinal beam size we conclude that we want the beam pipe offset from beam center

to be $<\approx 1$ mm in the central region. For z larger than about 1.1 m, the accuracy needed is reduced (proportional to z). In the central region the pipe will probably be attached to the central tracker which has even more severe alignment problems so the accuracy in the center will be obtained automatically. The obscured region will be about the size of about 1 barrel calorimeter tower, and less than that for the forward calorimeter. We also note that the size of a jet is about $\Delta\eta = 0.5$ and the size of a shower from a given particle in the forward calorimeter in this angular region also corresponds to an η region in the calorimeter of about 0.5. Furthermore, if a particle scatters out of the tube it stays out, whereas in a large solid target, particles scatter in as well as out. It seems as if this small angular region obscuration will have minimal effect. However, it needs simulation, and this should be done reasonably soon.

Next we discuss some reasons for the choice of the size and material of the center pipe. For an Al center pipe of the same thickness, a particle would go through about four times the number of radiations lengths it would for a Be pipe. For the central tracker region we wish to keep the thickness traversed to an absolute minimum. It is important to be able to tell gammas from electrons and we wish to prevent the gammas from converting into electron-positron pairs before reaching the detector. Furthermore we are also lead to a thin pipe in order to have the best ability to tell whether a particle comes from the primary or a secondary vertex. Since the wall thickness is proportional to radius and therefore for the fixed 22.7 mrad angle, the thickness of wall traversed is proportional to radius, we are pushed to use the smallest feasible pipe diameter. David Veal has indicated that for alignment reasons he strongly prefers the pipe have $r \geq 2$ cm, and this lead to the present parameter of 2.5 cm.

Also we must consider how to put the tube together, to install and to remove it. The tube will undoubtedly be in pieces, and the center sections brazed together to add minimum mass. However, we do not wish to do brazing too close to the central tracker (≈ 0.5 m needed). The present design keeps us well away from the barrel part of the central tracker which ends at 0.3 m. However, we are still within the disks, which will be at r= 0.15 m at this point. If we wished to extend the Be part in order to get farther away then suppose that we go to 2.2 m. At this point the disks are at r = 0.345 m, the pipe radius would be 5 cm, and the maximum wall thickness traversed would be 0.16 radiation lengths. To get completely clear of the disks by 0.5 m requires that we go to about 3 m at which the

pipe radius would be 7 cm, the maximum wall thickness traversed would be .22 radiation lengths, and we would have a 6 m long Be pipe. It is preferable to arrange to have other joints on the flared part. These would be opened first so the central part could slide out a bit to be joined or taken apart. With the present cone angle the central tracker should be able to have a sufficient clear radius that this can be done without interference. The central tracker group must keep this constraint in their design considerations.

Be is a very brittle material. The effect of a sudden fracture of the beam pipe could be catastrophic if the fracture thrust the pipe into contact with the beam. To avoid this it will probably be necessary to put strain relief into the pipe near the Be to stainless steel (or more likely Be to Al to stainless steel) join, perhaps in the form of an omega bellows.

The bellows, various supports for the tube, the vacuum pumps, openings, brazes and/or flanges, *etc.* all add material to the region. The favorable radiation length figures quoted at the beginning of this report will be compromised. We will try to reduce this extra material to a minimum, but these pieces are all essential parts of a working, safe device.

The various constraints strongly constrain the design. It is difficult to change the cone angle to make a meaningful change in η. The central tracker group has indicated they wish the region of $\eta \leq 2.5$ covered by a Be pipe to obtain the minimum thickness in that region. Suppose, for example, we tried to use a cone angle corresponding to the interface between the endcap calorimeter and the forward calorimeter, $\eta = 3$ ($\theta = 0.0995$ rad). This would put the small glitch in response associated with the cone wall on top of the inevitable glitch between the two detectors, and would minimize the total region with any glitch. If for some sensitive tests one wanted to exclude any glitched region, this would then minimize the cuts. However, the cone angle here is nearly four times that for $\eta = 4.48$. We could not extend the cone out to 11 m and would have to have a large inverse cone region to avoid a straight pipe and its problems before the forward calorimeter. This inverse cone region would then be a source of albedo and we would again have the problem of spray reaching parts of the forward calorimeter distant from the original direction. In addition we would be unable to put the device together, because we couldn't slide it far enough through the central tracker to get the cone-pipe join region into a place where we could braze it. Finally since the central beam pipe size, the cone angle, and the size of the pipe are related, we would have to go to a much larger pipe, at least r = 5 cm, in order to cover the central tracker region with Be pipe.

There may well be other important arguments leading to a change in the conceptual design of the beam pipe. Please let me know if you prefer another design, indicate the reasons for it, and how a new design is compatible with the constraints indicated here.

REFERENCES

1. N. Wells, Private Communication.
2. A. Kulik, SDC Forward Muon Chamber Rates and the Optimal Beam-Pipe/Absorber Design IHEP Preprint 9/8/91 IHEP,Protvino.
3. J. Chapman, Private Communication.