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Introduction and Summary

Absorbers will be needed to protect the final focus system and twin-aperture beam separation dipoles from secondary particles from p-p collisions at the two high luminosity interaction regions, IR1 and IR5. LBNL is responsible for a providing room temperature front quadrupole absorber (TAS), located between the collision point and the first inner triplet quadrupole on each side of IR1 and IR5. LBNL is also responsible for providing a room temperature neutral beam absorber (TAN), located adjacent to the twin-aperture beam separation dipole on each side of IR1 and IR5. The TAN is to be instrumented for fast luminosity measurement.

The LBNL work scope includes:

- The design, development, fabrication, and shipping of the four TAN and four TAS absorbers, including the support system required to align them precisely with respect to the beam.
- Instrumentation for fast measurement of luminosity and of beam-beam separation.
- The design, development, and fabrication or procurement of shipping containers, internal and external systems of shipping restraints and instrumentation required to verify the condition of the absorbers during shipping.
- Participation, to the extent that resources are available, in the installation and commissioning of the TAS and TAN, together with associated support and alignment structures and instrumentation.

The design review committee consisted of the following: Chairman Phil Pfund, FNAL, Jim Strait, FNAL, Ranko Ostojic, CERN, Graham Stevenson, CERN, Ray Veness, CERN, Jean-Pierre Quesnel, CERN, Claude Arnaud, CERN, Sylvain Weisz, CERN, Gilbert Trinquart, CERN, Gerard Faber, ETH-Zurich, and Mika Huhtinen, CERN

The review was to cover the following items:

- Proposed design and plans for development of the four TAN and four TAS including testing to support design decisions.
- Radiation loads on the devices including design estimates of transmitted and residual radiation, temperature rise and cooling requirements.
- Arrangement of interfaces for alignment, transport and installations within the tunnel at CERN.
- Requirements on the TAN and TAS with respect to beam vacuum system, beam impedance, and beam aperture.
- TAN and TAS Functional Specification and the TAN Interface Specification documents that are being prepared which together define the requirements to be met by the design.

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The following items in particular were presented:

1) General Overview (W. Turner)
2) Beam induced radiation (N. Mokhov)
    a) Radiation sources
    b) Power dissipation and shielding
    c) Residual radiation in TAN, TAS, and tunnel
3) TAN conceptual design features (E. Hoyer)
    a) Functional requirements
    b) Tunnel requirements on the design
    c) Vacuum system requirements
    d) Alignment requirements
4) TAN mechanical design (D. Plate)
    a) Assembly
    b) Vacuum chamber
    c) Absorber box
    d) Outer shielding
    e) Support and alignment
5) TAS conceptual design (E. Hoyer)
    a) Design parameters
    b) Installation requirements
    c) Alignment requirements
    d) Tolerances
6) TAS mechanical design (D. Plate)
    a) Vacuum chamber
    b) Copper absorber
    c) Support system
    d) Cooling system

The review did not explicitly cover the instrumentation planned for the TAN and proposed for the TAS. TAN/TAS instrumentation will be covered by a separate review in the future.

Committee Recommendations

The committee concluded that the conceptual designs for the TAN and TAS absorbers were feasible and that an adequate program was planned to develop and prove the designs. However, the committee felt that the schedule for developing the detailed design of the TAS cannot be met because of design uncertainty of some of the CERN supplied equipment which interfaces with the TAS.

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The committee concluded that most of the design requirements for the TAN are well known at this time. The Functional Specification that the designers have submitted to CERN for entry into the EDMS was available to the committee. An Interface Specification is under preparation and is expected to be submitted soon. The committee recommended that the designers proceed with details in preparation for the Engineering Design Review that is scheduled for completion in July 2000. The committee also recommended that a spare TAN be added (either a central absorber or complete assembly).

The establishment of design requirements for the TAS are lagging behind those of the TAN. In particular, many of the interfaces between the TAS and the experiments, vacuum system, alignment system, shielding, and beam tube still need to be finalized. The committee felt that these interfaces, necessary for the detailed design of the TAS, are not likely to be established according to the schedule proposed by the designers. The US Project, in co-ordination with CERN, needs to identify the milestone dates for establishing interface details that are needed to support the schedule for the design, fabrication and delivery of the TAS.

Findings and Observations Affecting both the TAN and TAS

1) Verification of Minimum Allowable Aperture (Applies to TAN and TAS)

Specific findings and observations for both the TAN and TAS impact the allowable apertures for each device. The committee believes that the minimum allowable aperture for each device needs to be verified. This information is needed as input to the beam induced radiation calculations. It would be useful if the CERN Apertures Working Group produced a file of the $n_1 = 7$ aperture calculated around the circumference of the machine for injection and for top energy.

***Action**: The designers should work with US LHC and CERN LHC project management to obtain verification of minimum allowable apertures from the CERN Apertures Working Group.*

2) Capacity of Bake-out Heaters (Applies to TAN and TAS)

The designers have included considerable excess capacity in the bake-out heaters. The committee expressed a concern with possible overheating if the heaters are allowed to run at full capacity.

***Action**: The designers need to work with the vacuum group to ensure that the bake-out power supplies have current limiters (e.g. fuses).*

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3) Effect of Instrumentation Slots (Applies to TAN and TAS)

The extent of instrumentation in the TAN and TAS is currently under discussion and will be the subject of a future workshop and design review. The committee noted that sufficient instrumentation slots have been included in the design of TAS to accommodate the additional proposed instrumentation, effectively resulting in less absorber material. (The instrumentation slot volume remains the same in the TAN.) If the additional instrumentation is not added, these slots will be filled with copper, returning the absorbers to their design effectiveness.

***Action**: the designers are asked to re-verify the effectiveness of the TAS due to the potential additional instrumentation. This information should be available by mid-April, 1999, in time for the absorber instrumentation workshop and design review.*

4) Specification of Tolerances (Applies to TAN and TAS)

Tolerances were presented as 3-sigma values and combined as root mean square values. There was some discussion whether this was appropriate in the case of the TAN and TAS where only four items of each type would be produced. The committee was unable to reach a consensus opinion on the appropriate means to combine tolerances. There was agreement however that stated tolerances should represent absolute limits for the hardware supplied to CERN.

***Action**: the designers should define the tolerance specifications for the TAS and TAN to be absolute dimensional limits for the items delivered to CERN.*

Findings and Observations Affecting the Design Concept of the TAN

5) TAN Aperture and Z - Position

The designers were aware that the final z – position of the TAN is still under discussion. The committee pointed out that the final position will have some effect on the functionality of the TAN. If the TAN is located closer to the IP than currently assumed by the designers there will be a decrease in beam separation, unless there is proportional decrease in beam tube aperture there will be a reduction in absorber mass between the beams.

***Action**: The designers are requested to compare at least one alternate z – position of the TAN to evaluate the effect on the functionality of the TAN. The committee recommends evaluation at the position 10 m closer to the IP where the beam separation is reduced by*

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25 mm and a larger beam tube may be required to maintain the aperture restriction of $n_1 > 7$. The evaluation should use the appropriately sized slot for instrumentation.

***Action**: the Apertures Working Group at CERN needs to provide the designers with an estimate of the $n_1 = 7$ aperture for the alternate z-positions of the TAN.*

6) Transportation / Installation / Replacement Strategies

There was considerable discussion on strategies for the transportation and installation of the TAN in the tunnel and the strategy for replacement of the TAN. The designers presented scenarios for transporting the TAN as a complete assembly weighing 30 tonnes and as eight subassemblies each weighing less than 5 tonnes. There is no clear choice between the alternatives at the present time as both strategies will pose difficulties. The committee felt that while the choice would be CERN's, the designers will be able to provide valuable input.

The most likely reason for replacement is a failure of the vacuum boundary. Two replacement strategies were discussed: the removal of the complete TAN assembly and removal of only the absorber box assembly. In the case of removal of the complete TAN assembly, there are questions of access, handling capability, etc. In the case of removal of the absorber, there were questions of available work and lay-down space, etc. If replacement is to be considered, the question of spares must also be considered. The committee noted the design of the outer shielding is slightly different at IP1 and IP5. The diameter of tunnel is slightly smaller at IP5 and has resulted in the design of a small notch in the outer shielding of the TAN at the location. This results in lack of complete symmetry in the design, raising the question of interchangeability of spares.

***Action**: the designers are requested to add provisions for a spare absorber to their scope and to assume the requirement of interchangeability at all points.*

***Action**: the designers should work with CERN to develop and recommend a comprehensive strategy for installation and replacement of the TAN.*

***Action**: the designers are asked work with CERN to evaluate the two most likely replacement scenarios: removal of the entire TAN and removal of the absorber module. The evaluation should include a clear rendering of the advantages and disadvantages associated with each of these two scenarios for transportation and installation.*

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Findings and Observations Affecting the Design Details of the TAN

7) Glow Discharge Cleaning

The committee noted that it was not clear whether glow discharge cleaning (GDC) would be required. GDC becomes more complex in the area of the transition region where two beam tubes become one (referred to as the "pair of pants") and where two wires would be needed to perform the operation. The designers had been advised by the CERN vacuum group that the warm vacuum system would require GDC to be ion desorption stable. However, very little data is available on ion desorption coefficients, most of that being over 20 years old.

***Action**: the designers should work with the CERN vacuum group to re-verify the conclusion that GDC is required. If GDC is required, they should provide static and dynamic vacuum profiles to the vacuum group.*

8) Load Bearing Capacity of the Concrete Floor

The designers have assumed a floor load bearing capacity of 0.5 Mpa for support of the TAN. The load limit of the concrete floor is unknown by the designers. The designers noted that a visual inspection of the floor at IR1 at the location of the TAN indicates cracks in the concrete floor. They believe the capacity needs to be checked to determine whether steel plates are needed under or above the nominal floor. This information is available from the ST Division.

***Action**: The designers should contact G. Trinquart who has agreed to obtain the information from the CERN ST Division.*

9) Alignment Fiducials

The designers have assumed that alignment points on the absorber will be referenced to alignment fiducials on the outside shielding. The committee expressed concern that the reference may be lost if the shielding is removed for any maintenance. The committee recommends the alignment fiducials be referenced directly to the absorber and not to the shielding.

***Action**: the designers should work out the means by which to reference the alignment fiducials directly to the absorber.*

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10) Hot Surfaces during Bake-out

The committee observed that the back part of the TAN would reach temperatures as high as 200 C during bake-out. This is regarded as a potential safety hazard.

Action*: the designers should make provisions to add personnel barriers, such as bake-out blankets, to the TAN during bake-out.*

11) Collimator Box Stand-off

The supports for the collimator box are currently designed to be ceramic pads, primarily to minimize heat transfer. The committee expressed some concern that the ceramic pads might be too fragile for this application. It was suggested that stainless steel, because of its relatively poor thermal conductivity, could be used to advantage in this application.

Action*: the designers should evaluate the feasibility of using stainless steel pads in place of ceramic pads.*

12) Deflection of the Absorber Box Assembly

The committee questioned the amount of deflection of the heavy components of the TAN, in particular the inner box which supports the absorber and beam pipe and is itself supported only by ceramic pads. These calculations have not yet been done.

Action*: perform the deflection calculations for the absorber box assembly of the TAN.*

Findings and Observations Affecting the Design Concept of the TAS

13) Residual Doses Behind the TAS

Contact dose rates are only indicative in the presence of small objects or large activation gradients. Dose calculations in the complicated region around the TAS should not be based on omega factors but on more detailed photon transport. It was pointed out that residual doses on vacuum equipment behind the TAS are very close to maximum limits for human intervention. If necessary, this could be somewhat mitigated by increasing the radius of the vacuum equipment.

***Action**: the designers should repeat the calculations for residual doses behind and around the TAS by considering explicit transport of the induced activity photons and using the vacuum equipment dimensions supplied by the CERN vacuum group.*

14) Support Cavities

The committee observed that the cavities in the absorber to accommodate gearboxes, support rods, and alignment rods appear to be large. This may have an effect on the background radiation for the experiment.

***Action**: the designers should provide the design details of the cavities to CERN so that simulations can be conducted to determine the effect on radiation levels.*

15) Shielding Configuration at IP1 (ATLAS)

The ATLAS shielding will be designed to be pulled back from the TAS due to the needs of the experiment. The committee observed that this places additional demands on the concept of routing the absorber support and alignment rods radially out through the shielding. A possible alternative routing is toward the rear of the TAS although this would pose problems due to the need to support the weight of the absorber through a cantilever mechanism.

***Action**: the designers should re-evaluate the feasibility of routing the support and alignment rods radially through the shielding. They should evaluate an alternate such as routing the rods toward the rear of the TAS without passing through the outer shielding.*

16) Cooling of the TAS

It was pointed out that the heat loads on the TAS used by the designers are based on peak luminosity. This heat load has led the designers to include active cooling of the TAS. The average heat load over a run is expected to be only 40-50% as high. It is possible that active cooling may not be required.

***Action**: The designer should re-calculate the cooling requirements and evaluate the need for active cooling of the TAS.*

Findings and Observations Affecting the Design Details of the TAS

17) Flange in Front of the TAS

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The flange in front of the TAS is currently envisioned to be a "quick connect" type. The flange is in an area of intense radiation and is expected to be the hottest flange in the system. The committee felt that this flange may have to be fully remote.

***Action**: the committee recommends that the choice of flange be kept open. Meanwhile the designers should allow for the possibility that the flange may have to be of a type that can be handled completely remotely.*

18) Effect of Heat-up and Cool-down on Position

The committee observed that heat-up and cool-down, especially during bake-out could affect the position of the absorber. The primary effect is expected to be due to differential expansion which could be mitigated by the use of thermal radiation shields installed between the absorber and outer shielding.

***Action**: the designers should evaluate the effects of heat-up and cool-down on position and make design modifications if necessary.*

19) Radius of TAS Absorber at IP5 (CMS)

The design assumes a 25 cm radius for the TAS absorber with a 3 cm radial air gap. It was pointed out that shield dimensions for the vicinity call for a 20 cm radius and a 2 cm radial gap. The experiment is still maintaining the need to keep the smaller radius in front of the TAS. The committee believed this would not pose a problem for the design of the TAS.

***Action**: the designers need to compare the current working dimensions of the TAS with the existing dimensions for the shield and resolve any conflicts. The designers should evaluate the advantages and disadvantages of an absorber of 20 cm radius.*

20) Alignment from the Tunnel

The committee believes it is desirable to align the TAS from the tunnel rather than from the cavern. This may affect the positioning of alignment fiducials. It was also pointed out that until this is determined, both possibilities should be retained.

***Action**: the designers need to work with the CERN LHC alignment group to establish the feasibility of installing fiducials on the rear of the TAS to support alignment from the tunnel.*

21) Adjustment Travel of Alignment System

The absorber in the TAS is positioned by rods with an adjustment range of +/- 20 mm. While the committee felt this amount of travel was appropriate for set-up, the committee felt that after set-up this amount of travel could result in excessive offsets in the bellows, potentially damaging the vacuum equipment. It was felt that a limit of +/- 10 mm should be imposed on the travel after connection.

***Action**: the designers are asked to include a design feature which would limit the travel to +/- 10 mm after connection to the vacuum system.*

22) Position of TAS

There were several points of discussion on the location of the TAS, particularly at ATLAS and primarily to resolve conflicts for space in front of the TAS. While nothing has been finalized, there are scenarios being considered that would call for the front face of the TAS to be moved further away from the IP. The committee felt strongly that movement of the front face away from the IP should not result in a shorter absorber in the TAS. More likely alternatives are less space between the TAS and Q1, a shortening of the flange-to-flange length of the TAS , or a combination of both. In view of the radiation calculations presented, the committee questions whether shortening the TAS is a viable solution, but remains open to consideration of the possibility. If absolutely necessary, design alternatives such as the use of pure lead (no antimony) at the rear of the TAS might be considered.

***Action**: The designers need work with the CERN vacuum group and the ATLAS experimental group to obtain a better determination of the allocation of space in front of the TAS. If the front face of the TAS must be moved, the designers should include design alternatives such as the use of lead and the use of space between the TAS and Q1 among those they evaluate.*

***Action**: the committee requested that residual dose calculations be re-run to evaluate the effect of replacing the last 5 cm of the copper absorber at the rear of the TAS with pure lead.*

***Action**: the committee requested that the designers evaluate the impact of shortening the absorber at the outer radius without compromising the length at the inner radius.*

23) Dimensions of the Shielding Block

The committee observed that the dimensions of the shielding block supporting the TAS are in conflict with the assumptions of the CMS experiment.

***Action**: the designers need to verify the correct dimensions for the shielding block with CMS.*

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24) Removal / Replacement of TAS

There was considerable discussion on the potential need to remove or replace the TAS. There are two issues: (1) change out of the beam tube from 40 mm ID to 34 mm ID during initial commissioning of the LHC and (2) change out of the beam tube/TAS due to a vacuum leak in the beam tube. The designers pointed out that for change out of the beam tube during initial commissioning the intention is to replace the beam tube only and not the entire TAS by opening the absorber clamshell. It has not been determined whether the TAS will be sufficiently activated at that point to require remote handling. Changing the beam tube after a vacuum leak would have to allow for the TAS being too activated to allow anything but remote handling for removal and disassembly. This may require the use of a spare TAS but this has not been determined.

Action*: the designers should work with CERN to evaluate the activation at the point in time that the beam tubes will be switched and establish the design requirements for accommodating the change out.*

Action*: the designer should work with CERN to decide whether the best option is to have a spare beam tube or an entire spare TAS.*

Conceptual Design Review – Charge
IR Absorbers

Background:

Absorbers will be needed to protect the final focus system and twin-aperture beam separation dipoles from secondary particles from p-p collisions at the two high luminosity interaction regions, IR1 and IR5. LBNL is responsible for a providing room temperature front quadrupole absorber (TAS), located between the collision point and the first inner triplet quadrupole on each side of IR1 and IR5. LBNL is also responsible for providing a room temperature neutral beam absorber (TAN), located adjacent to the twin-aperture beam separation dipole on each side of IR1 and IR5. The TAN is to be instrumented for fast luminosity measurement.

The LBNL work scope includes:

- The design, development, fabrication, and shipping of the four TAN and four TAS absorbers, including the support system required to align them precisely with respect to the beam.
- Instrumentation for fast measurement of luminosity and of beam-beam separation.
- The design, development, and fabrication or procurement of shipping containers, internal and external systems of shipping restraints and instrumentation required to verify the condition of the absorbers during shipping.
- Participation, to the extent that resources are available, in the installation and commissioning of the TAS and TAN, together with associated support and alignment structures and instrumentation.

Planned Design Reviews:

This Conceptual Design Review is the first of a series of design reviews to ensure the adequacy of the engineering design prior to the start of fabrication. These reviews will also address the proper functioning and integration of the components into the LHC, the budget impact of the procurement or fabrication method proposed, the schedule and the program plan. The CDR is generally conducted once the basic engineering design has been established. For a system to pass the CDR, it must be demonstrated that the engineering design is feasible and that an adequate R&D program has been planned to develop and prove the design.

This CDR will be followed by at least two other major design reviews, the Engineering Design Review (EDR) and the Production Readiness Review (PDR). The EDR will be conducted when most of the R&D is complete and the engineering design has been finalized. For a system to pass the EDR, it must be demonstrated that all of the technical and engineering challenges have been adequately addressed allowing the design and purchase of parts and tooling for full-scale prototypes and production deliverables to proceed. The PRR will occur after final proof-of-design is complete, i.e., after prototypes are delivered and tested successfully, etc. It will occur before the final production of the deliverables for the LHC. The PRR must include a strategy for fabrication or procurement, quality assurance, and a component test plan. In the case of the TAN and TAS, it is anticipated that the EDR and PDR will be combined into one review.

Design Team:

The design is represented by:

- W. Turner, LBNL Project Manager
- E. Hoyer, LBNL TAN/TAS Lead Engineer
- D. Plate, LBNL
- M. Knolls, LBNL
- N. Mokhov, FNAL

Design Review Committee:

The design review committee members are as follows:

- Phil Pfund, FNAL, Chairman
- Jim Strait, FNAL
- Ranko Ostojic, CERN
- Graham Stevenson, CERN
- Ray Veness, CERN
- Jean-Pierre Quesnel, CERN
- Claude Arnaud, CERN
- Sylvain Weisz, CERN
- Gilbert Trinquart, CERN
- Gerard Faber, CERN
- Mika Huhtinen, CERN

Scope of the Review:

The review will cover the following items in particular:

- Proposed design and plans for development of the four TAN and four TAS including testing to support design decisions.
- Radiation loads on the devices including design estimates of transmitted and residual radiation, temperature rise and cooling requirements.

- Arrangement of interfaces for alignment, transport and installations within the tunnel at CERN.
- Requirements on the TAN and TAS with respect to beam vacuum system,beam impedance, and beam aperture.
- TAN and TAS Functional Specification and the TAN Interface Specification documents that are being prepared which together define the requirements to be met by the design.

The review will not explicitly cover the instrumentation planned for the TAN and possibly the TAS. This will be covered by a separate review in the future.

The design review committee has the usual freedom to investigate other areas of the DFB design that present a risk to the successful completion of the project, installation, and operation in the LHC.

Date of the Review Committee Meeting:

The review is scheduled for March 2, 1999 at CERN. It is anticipated to take one day.

Results of the Review:

This review is a Level-3 project milestone, scheduled for completion March 1, 1999. The review will be complete with the issuing of a report summarizing the technical designs reviewed, committee recommendations, and action items. The forecast date for completion is April 1, 1999.

Schedule for the Review:

CDR Schedule – TAN/TAS Absorbers

2 Feb 99	Contents of Preview Package Selected
9 Feb 99	Preview Package Sent to Design Reviewers
16 Feb 99	Reviewer Preliminary Comments Returned to Chairman
23 Feb 99	Agenda Revised Based on Preliminary Comments from Reviewers
2 Mar 99	Design Review Meeting Conducted
9 Mar 99	Draft Report Sent to Reviewers
16 Mar 99	Reviewer Comments Returned to Chairman
1 Apr 99	Final Report of CDR Issued

Conceptual Design Review – Charge
IR Absorbers

Agenda for the Review Meeting:

CDR Agenda – TAN/TAS Absorbers
2 March, 1999
CERN

8:30 am	Design Review Committee Planning Session (committee only)
9:00 am	Presentation and Discussion of Design Overview – 30 min. Radiation Deposition – 45 min. Break – 30 min. TAN Requirements, Design Parameters – 60 min. TAN Mechanical Design – 45 min.
12:30 pm	Lunch
1:30 pm	Presentation and Discussion of Design (continued) TAS Requirements, Design Parameters – 45 min. TAS Mechanical Design – 45 min. Break – 15 min.
3:15 pm	Design Review Committee Planning Session (committee only)
3:45 pm	Design Review Committee Working Session (with designers)
5:30 pm	Design Review Wrap-up, Reviewers and Designers
5:45 pm	Adjourn