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ABSORBERS FOR THE HIGH LUMINOSITY INSERTIONS OF THE LHC*

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Abstract

The conceptual designs of the front quadrupole and neutral absorbers in the high luminosity insertions of the Large Hadron Collider (LHC) are described.

1 INTRODUCTION

At design luminosity 10^{34} cm^{-2}s^{-1} and inelastic cross section σ_{pp} = 80mb there are 8×10^{8} inelastic collisions per second at the high luminosity interaction points IP1 and IP5 of the LHC. These interactions give rise to ~0.9kW of power in collision products leaving an IP in each direction. The inelastic collision power carried off by neutrals, mostly neutrons and photons, in each direction and intercepted by neutral absorbers (TAN) has been estimated with the MARS13 code [1] to be 210W. Similarly the collision power escaping the beam tube and incident on the front face of the inner triplet quadrupole absorber (TAS) has been estimated to be ~ 270W, mostly carried by charged pions and photons. Special purpose absorbers must intercept this power to prevent quenching the inner triplet quadrupoles (Q1 to Q3) and the twin aperture magnets outside the second beam separation dipole D2. Because of the high incident flux of collision products near zero degrees the absorbers are natural places to consider for the location of radiation hard gas ionization detectors which could be used for: (1) measurement of luminosity, (2) measurement of the beam transverse dimensions at the IP and (3) feedback control of the colliding beam centers at the IP's to maximize luminosity.

The following sections describe: (1) the conceptual design of the absorbers, (2) the radiation deposition and activation calculations and (3) the possibilities for instrumentation.

2 DESCRIPTION OF THE ABSORBERS

A horizontal mid plane section of the neutral absorber (TAN) conceptual design is shown in Fig. 1. The TAN contains the transition from two beams in a single vacuum tube facing the IP to two beams in two tubes away from the IP. The composite beam tube is manufactured from OFHC copper and held in place by a rectangular 25cm x 30cm cross section copper clam shell with an outer steel jacket comprising the inner collimator box. The septum dividing the beam tubes has a gentle taper (angle to beam line < 10°) for beam impedance reasons and details of its final shape are being studied. The inner collimator box weighs ~ 5 Tonne and is equipped with heaters to allow 150°C in situ bake out of the beam tube. The collimator box is supported on the bottom by two full length 20cm thick steel plates and surrounded on the top and sides by a steel cap extending to an outer radius 55cm. There is a 5mm gap for thermal isolation between the outer steel and the collimator box. The bulk of the incident neutral radiation and shower products is absorbed by the copper clam shell between the two beam tubes. The iron surrounding the collimator box is primarily for reducing the exposed surface activation to allow tunnel access. Similarly the length of the collimator box has been chosen to reduce surface activation of the back surface to a level that allows access. The most activated piece of the TAN is the copper septum dividing the two beam tubes. The septum has been recessed inside the surrounding copper and steel to partially shield it from the tunnel. The bottom base plate and the top cap have been subdivided into two and three roughly equal weight pieces respectively as a compromise between a minimum number of pieces for ease of assembly/disassembly and a maximum weight limit ~5 Tonnes for an individual subassembly.

Slots have been placed in the TAN for installation of detectors to measure the flux of ionizing shower particles near the axis of the absorber and between the two beam axes. Similar slots surrounding the beam tube are being analyzed for the TAS. Some possibilities for instrumentation are discussed in Section 4.

The front quadrupole absorber (TAS) conceptual design includes an OFHC copper beam tube, clam-shell copper absorber and an adjustable support and alignment structure shown in Fig. 2. The vacuum chamber is a 2250mm long assembly with a 1800mm long straight section and tapered sections attached on either end of the tube. The tube is an OFHC extrusion with a 60mm OD that will be machined to match the mating clam-shell. The commissioning beam tube will have a 40mm ID and will be replaced with a 34mm ID tube for high luminosity operation. This simple construction should allow for remote disassembly if required. For in situ bakeout of the vacuum chamber, heaters and thermocouples are installed to provide a chamber bakeout temperature of 150°C .

A critical requirement for the TAS is supporting it in a way that allows alignment from outside the shielding for the ATLAS and CMS experiments within ±0.5mm

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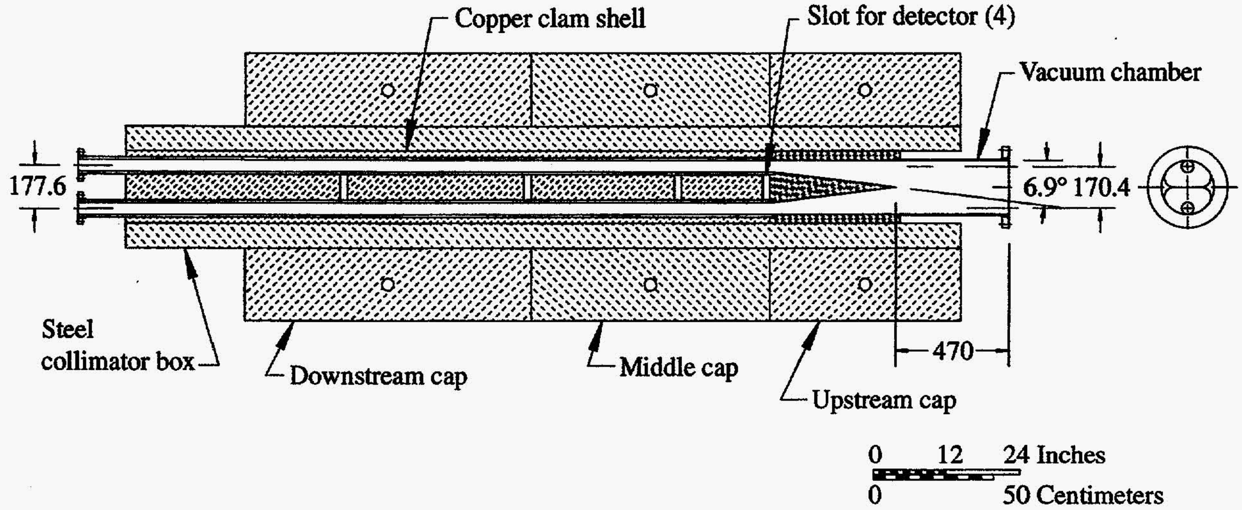

Figure 1: Horizontal mid plane section through the neutral absorber (TAN).

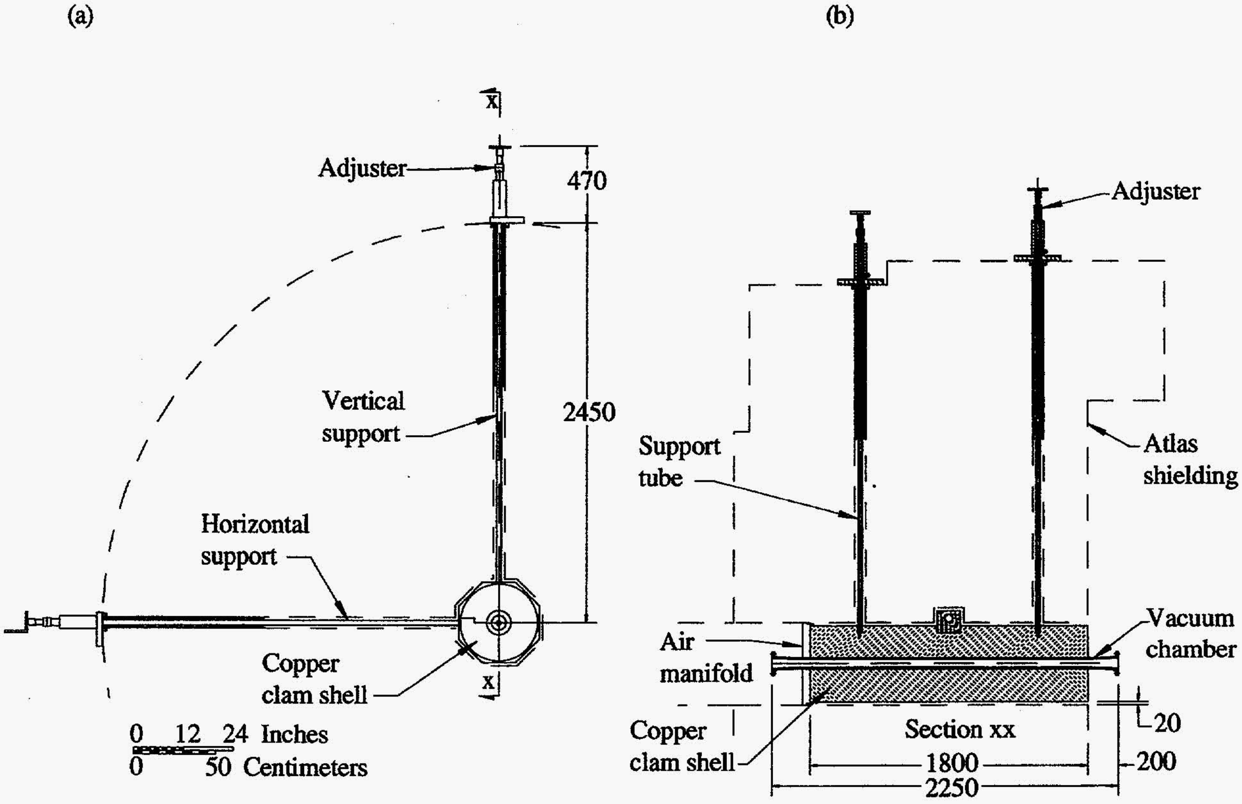

Figure 2: Schematic of the front quadrupole absorber with the ATLAS shielding shown in outline;

(a) front and (b) side views.

relative to the axis of the final focus quadrupole magnets Q1-Q3. There is a 20mm gap between the TAS and theexperiment shielding. The support system is a four tube adjustable system, without moving parts at the absorber, which allows vertical, pitch, transverse and yaw positioning of the absorber. As shown in Fig. 2, the quad absorber is hung from the outside of the shielding by two of the adjustable structural tubes which can provide vertical and pitch motion over a ± 20mm range. Likewise, a similar arrangement of two structural tubes is mounted horizontally for transverse and yaw adjustment over a ±20mm range. There is a differential lead of 1mm per turn. To survey the location of the absorber, an invar rod with alignment fixtures slips through the inside of each structural tube and contacts the absorber.

The design shown in Fig. 2 is an example of how the TAS absorber could be installed in the ATLAS shielding. The shielding designs of the CMS and ATLAS detectors are currently under development and details may change but it is expected that the concept shown in Fig. 2 will remain viable.

Thermal analysis of the TAN and TAS indicates that the beam tube temperature at design luminosity can be kept below ~ 50^{o}C with forced ambient air cooling.

3 RADIATION DEPOSITION CALCULATIONS

Table 1 summarizes MARS results for the mean number and energy of particles incident on the TAN and TAS per inelastic pp interaction and updates earlier calculations.[2] For example for inelastic cross section 80mb, luminosity 10^{34}cm^{-2}s^{-1}, 2835 bunches and 11.25kHz revolution frequency, 8.3 neutrons strike the TAN per bunch crossing. The neutron energy extends up to the full 7TeV beam energy and has a mean value 2.185TeV. The energy striking the TAN is about evenly divided between neutral hadrons (mostly neutrons) and photons; the energy striking the TAS is divided primarily between charged pions and photons.

Detailed MARS calculations of the power density and activation in the volume of the absorbers have been carried out.[3] The peak power density in the TAS is ~9mW/gm at a depth ~13cm and is reduced to ~0.2mW/gm at 180cm (the length of the absorber). This is a factor of six less than the nominal quench limit for the LHC IR quads ~1.2mW/gm. Similarly the peak power density in the TAN reaches ~ 4.5mW/gm at a depth ~20-30cm but is negligible at the end of the much longer TAN (l = 350cm). Since it was possible to do so, the length of the TAN was chosen so the back surface activation would allow access (< 0.1mSv/hr, 30 days irradiation, 24hr cooldown). Activation of the TAS and inner pieces of the TAN will require special handling procedures.

4 INSTRUMENTATION

Owing to the high particle fluxes in Table 1 we have analyzed the possibility of using radiation hard gas ionization detectors to measure luminosity and beam-beam separation at the IP's.[4] Beam-beam separation is measured by superimposing a small circular modulation of the transverse position of one of the beams at the IP ($\pm0.1\sigma^*$) and analyzing the modulation of luminosity. The modulation vanishes when the beams are aligned. A parallel plate Argon ionization chamber with 3mm gap, 1 kV/cm electric field, 100cm^2 area and one atmosphere pressure located near the shower maximum in the TAN was found to have an ion collection current ~ 8μA at luminosity 10^{34}cm^{-2}s^{-1}. The integration times required for measurement of luminosity to 1% precision and beam-beam separation to $\pm0.1\sigma^*$ were estimated to be ~1.8x10^3 and ~3x10^4 bunch passages respectively. If the cathode ion current is measured the slow drift speed of the ions integrates over many successive bunch passages. In this mode the ionization chamber is self integrating and the luminosity and beam-beam separation measurements are an average over all the bunches in the machine. Electrons arrive at the anode with average current equal to the ion current reaching the cathode but with velocity ~10^3 times the ion drift velocity. We are currently evaluating a mode of operation with the electrons clearing the gap between bunch passages, utilizing a circulating memory to record the electron current at 40 MHz and measuring bunch by bunch luminosity.

Table 1: The mean number, mean energy and total energy per pp interaction striking the absorbers.

(a) TAN

Particle type	<n>	<E> (GeV)	<n><E> (GeV)
Neutral hadrons	.33	2185.	725
Protons	.06	1215.	73
Charged Pions	.71	125.	88
Photons	151	5.	736
Electron/ positron	12.5	1.	8
Muons	.01	25	.25

(b) TAS

Particle type	<n>	<E> (GeV)	<n><E> (GeV)
Neutral hadrons	.58	261.	152
Protons	.29	292.	83
Charged Pions	6.8	159.	1081
Photons	8.3	87.	725
Muons	.06	33	.2

5 REFERENCES

[1] N.V. Mokhov,"The MARS Code System Users Guide",Fermilab-FN-628(1995).

[2] N. Mokhov and G. Stevenson, "Radiation Considerations in the Design of the Neutral Dump Close to the LHC Interaction Regions", CERN/TIS-RP/IR/94-17(1994).

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[4] W.C. Turner, " A Neutral Beam Absorber Beam-beam Centering and Luminosity Monitor for the High Luminosity Insertions of the LHC", LBNL internal memorandum, CPB Note 251(Mar. 1998).