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Interface Specification

ATLAS BEAM VACUUM SYSTEM INTERFACES

Abstract

This document describes the main interfaces between the LHC beam vacuum system and the ATLAS detector.

Prepared by :	***Checked by :***	***Approval Leaders:***
Raymond VENESS LHC/VAC Raymond.Veness@cern.ch	**Vacuum approval meeting**	**Pierre Strubin** **Keith Potter**

Distribution list:

O. Bruning, F. Butin, W. Cameron, P. Fassnacht, D. Giugni, V. Hedberg, B. Jeanneret, J. Jowett, P. Lebrun, S. Myers, M. Nessi, M. Olcese, S. Stapnes, F. Ruggiero

History of Changes

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0.2	2002-04-16		Updated draft, circulated for comment.
0.3	2003-07-25		Updated following ECRs and internal comments
0.4	2003-11-21		Draft for Vacuum Approval
0.5	2004-01-20		Updated with comments from approval meeting
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1.0	2004-03-01	6,7,10	Updated with approval circuit comments
	2004-05-14	All	Released version

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1. INTRODUCTION

The aim of this document is to concisely describe the main interfaces between the LHC beam vacuum and the ATLAS detector. It will serve as the basis for detailed design of the vacuum system components. As such, it should be considered as the official definition document for the system.

The initial functional requirements and design has been presented in detail in the ATLAS Technical Co-ordination TDR [1]. However, since then a number of design details have changed. The revised design was reviewed in May 2000 [2] and May 2002 [3]. This document takes into account these design modifications, and recommendations made by the review panels.

In addition, ATLAS have requested design changes to the detector or vacuum system which have had an impact on the vacuum chamber and support designs. These design changes to the PIXEL [4], JD shield [5], VI beam pipe [6] and VA beam pipe [7] are documented in Engineering Change Requests.

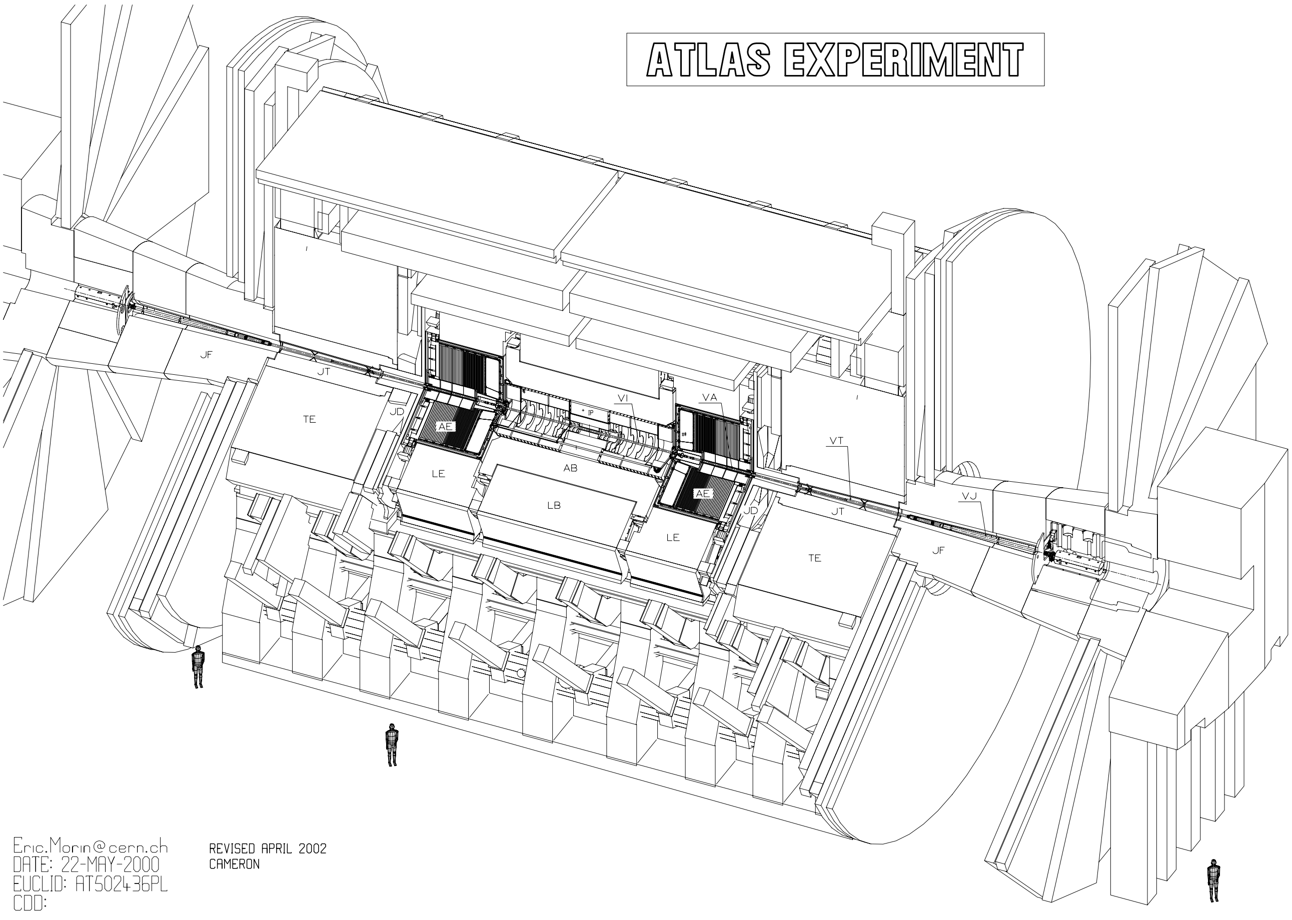

Figure 1: Part Section of the ATLAS Experiment Showing Main Detector and Beam Vacuum Systems

2. SCOPE OF THE DOCUMENT

The design presented here covers the beam vacuum system up to ±19.2 m from interaction point (IP) 1 of the LHC. The vacuum sector extends further to ~ ±21 m from the IP before connecting to the first machine sector. However, the other vacuum equipment in this area, notably the TAS, is, or will be covered by other documents [8,9]. In addition, this document only covers the vacuum system in its working configuration. Requirements for opening, closing and other interventions were covered in the TDR [1].

3. GENERAL DESCRIPTION

The beam vacuum system is divided into seven elements, connected in series. The central element is positioned symmetrically about the IP. The other elements are installed symmetrically on both sides of this central section, giving a total of four different elements. These elements have a name in the ATLAS PBS corresponding to the detector which surrounds them, and an equivalent name in the LHC PBS *(given in italics):*

- Inner detector beam vacuum: ATL-VI *(LHC-VC1I)*, supported from the inner detector (ATL-I)
- Argon end-cap beam vacuum: ATL-VA *(LHC-VC1A)*, supported from the argon end-cap calorimeters (ATL-AE) and the JD shielding (ATL-JD)
- Toroid end-cap beam vacuum: ATL-VT *(LHC-VC1T),* supported from the toroid end-cap (TE) and shielding (JTT)
- Forward shielding beam vacuum: ATL-VJ *(LHC-VC1J),* supported from the forward shielding (JF)

Drawings are numbered according to the LHC PBS system.

The ATLAS beam vacuum system is a fully in-situ baked UHV system, pumped by a combination of lumped sputter-ion, lumped Non-Evaporable Getter (NEG) cartridge pumps and distributed NEG film. The NEG film system consists of a thin sputtered coating along the whole internal surface of the vacuum chambers (see section 5.1).

4. DETAILED DESCRIPTION

Table 1 gives the main geometrical and material parameters for the vacuum chambers. There is also a drawing showing the layout of each chamber. These drawings will be updated to represent the vacuum chamber description from this document. Further details for each section are given in the following sub-sections.

Descriptions of materials and components referenced in this table are given in sections 5 and 6.

Table 1: Main geometrical and material parameters

ATLAS PBS	Name	Z inner	Z outer	OD Nominal	Material	Nominal Thickness	Supports on detector	Inner flange	Outer flange	Comments
		mm	mm	mm		mm				
VI	VI chamber	0	3550	59.6	Be	0.8	4	-	-	LHCVC1I_0009
		3550	3650	60	Al	1		-	minimised Al	
	VI bakeout equipment	0	3550	70	Foil heater + Aerogel	4.4		-	-	See figure 2
VA	VA chamber	3650		59.6	St.Steel	0.8	4	minimised St.Steel	minimised St.Steel	LHCVC1A_0001
	VA bakeout equipment	3650	9000	70	Foil heater + Aerogel	4.4		-	-	See figure 2
VT	VT chamber	9000	10507	59.6	St.Steel	0.8	3	minimised St.Steel		LHCVC1T_0001
		10507	13007	82	St.Steel	1			Conflat St.Steel	
	VT bakeout equipment	9000	13007	70 / 93	Foil heater + Aerogel	4.4				See figure 2
VJ	VJ chamber	13007	14416	82	St.Steel	1	1	Conflat St.Steel		LHCVC1J_0001
		14416	18650	123	St.Steel	1.5				
	VJ bakeout equipment	13007	18650	102/145	Ceramic powder	10				

4.1 INNER DETECTOR BEAM VACUUM (VI)

A drawing of VI is available at LHC VC1I_0009. Interfaces with the inner detector are given in drawing ATL I____0009. This element consists of a beryllium beam pipe with an electron beam welded transition to an aluminium pipe at each end. The aluminium pipe is connected to VA at each end by minimised aluminium flanges with stainless steel bolts.

The outer surface of the chamber is permanently equipped with Kapton foil bakeout heaters and insulation shown schematically in figure 2. The Kapton layer outside of the insulation provides a hermetic seal enclosing the beryllium and particulate insulation material. The aluminium layer provides both an electro-magnetic shield for the inner detector and a reflective coating to minimise heat transfer by radiation to the inner detector. It will be electrically connected at the ends to the inner detector. The installation procedure for this bakeout equipment is given in [10].

VI is supported from the inner detector in 4 planes. The inner 2 planes are wire crosses, supported from the pixel support tube (PST) and adjustable from the ends of the inner detector. The outer two planes are supported from the inner detector end plate. The ‘C’ side outer plane is a wire cross, similar in design to the inner planes, but with different adjustors. The ‘A’ side outer plane is a rigid beam support. The Vespel spacer and aluminium support block shown in figure 2 are present both in the 4 support planes and also in 4 other planes where inner detector gas barriers close around the beam pipe.

Heat loss during bakeout at 250°C is expected to be less than 200 W/m [6].

Nominal clearance between VI and the ATL-I PIXEL B-layer (the closest detector to VI) is 9mm radially.

Design and manufacture activities for the vacuum chamber and support collars are the responsibility of AT/VAC. Support wires will be provided by AT/VAC. Wire support actuators, and the fixed support structure will be provided by ATLAS. Electrical grounding to ATL-I will be provided by ATLAS.

The alignment procedure for VI is described in detail in [11].

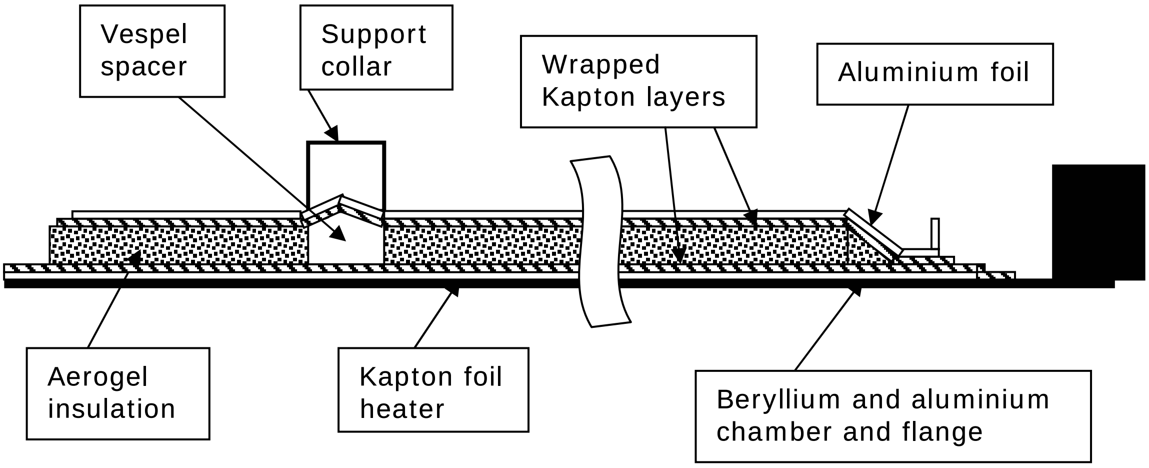

Figure 2: Schematic of the heating and insulation layout in VI and VA (not to scale)

4.2 ARGON ENDCAP BEAM VACUUM (VA)

A drawing of this element is available at LHC VC1A_0001. This element consists of a stainless steel tube. It is connected to VI by a stainless steel rotatable minimised flange and bolts. It contains a minimised sputter ion pump, described in [12] and 3 unshielded stainless steel bellows (two on IP side, one behind AE). It is connected to VT by a stainless steel fixed minimised flange and bolts.

The section inside the AE is equipped with a mass-minimised bakeout system, schematically similar to that in figure 2. The minimised pump and bellows are fitted with a permanently installed bakeout system consisting of heaters and a 4 mm thick silica aerogel insulation jacket.

The temperature of the AE will be controlled during bakeout by passing a cooling fluid through the inner bore. This is described in [7]. The detailed design and thermal performance of this system is described in [13].

The element is supported concentrically inside the AE warm bore on rollers, and from the face of JD with adjustable struts. These struts will be designed to be quickly removable due to the high levels of activation in the zone.

Alignment is provided by AE, as there is no possibility for independent adjustment. This implies that AE must be maintained within ±7.5 mm of the nominal beam axis during machine operation to ensure adequate beam aperture. This will be ensured by ATLAS.

Design and manufacture activities for chamber and supports are the responsibility of AT/VAC. ATLAS will supply details on the JD end face to locate supports as per drawing TBD. ATLAS will design and integrate the cooling in ATL-AE and ensure a smooth continuous surface along the inside bore of AE.

4.3 TOROID ENDCAP BEAM VACUUM (VT)

A drawing of this element is available at LHC VC1T_0001. It consists of stainless steel tubes of two different diameters connected by a conical transition. The interface with VA is via a rotatable minimised stainless steel flange, and to VJ by a fixed conflat stainless steel flange.

The section is equipped with a mass-minimised bakeout system, schematically similar to that in figure 2. Heat transfer to the environment during bakeout at 250°C will be less than 200 W/m.

The element is supported in 3 planes from the JT shield. This shield has three grooves in which support rails are mounted. These rails contain two planes of retractable support jacks, actuated from the JT back face. A third support plane is mounted directly to the back surface of ATL-JTT

The element is aligned with the JF shield removed, relative to the nominal beam axis with an initial 2σ alignment probability of 2.6 mm. From this point, alignment is governed by the stability of the TE relative to the beam axis.

On first installation, the JTT axis may be offset from the nominal beam axis within a radius of up to 25 mm, due to the difference between magnetic and mechanical axes of ATL-TE. This will be compensated by the support jacks, allowing VT to be aligned relative to the nominal beam axis.

AT/VAC will design and supply vacuum chamber, supports and support rails. ATLAS will supply grooves and other details in JTT, according to drawing ATLJ__0019.

4.4 FORWARD SHIELDING BEAM VACUUM (VJ)

A drawing of this element is available at LHC VC1A_0001. It consists of two stainless steel tubes of different diameters connected by a conical transition. It is connected to VT via a stainless steel conflat flange and bolts. The interface with the TAS vacuum chamber is a special flange constructed for remote handling. There are 2 unshielded bellows at the VT end and 2 at the TAS end of this element.

There is a permanently installed bakeout system consisting of heaters and a 10 mm thick ceramic powder insulation jacket. Heat transfer to the environment during bakeout at 250°C will be less than 200 W/m.

The element is supported inside an aluminium cone, cantilevered from the TX1S shielding nose. This interface is given in drawing LHC TX1S_0005. The chamber will be initially aligned relative to the beam axis within this cone. Alignment tolerances achievable may be limited by access due to the high level of activation predicted in the zone.

TX1S, including agreed interface will be supplied by ATLAS. TAS, TAS vacuum chamber and associated remote flange interface will be provided by the CERN-US collaboration. Design and supply of the vacuum chamber, supports, support cone, vacuum pumping station, remotely operated flange and final shielding plate on TX1S will be performed by AT/VAC

4.5 CABLING AND SERVICES

Services inside the detector are symmetric with respect to the IP. On each side they can be divided into two parts. Services for VI and VA pass through the ‘gap’ between VI and VA; services for VT and VJ pass through the TX1S shielding block.

Outside the detector, services for vacuum instrumentation (pumps, gauges) pass directly to the USA15 cavern. Services for bakeout (heaters and control) pass to racks in the UX cavern.

4.5.1 GAP LOCAL SERVICES

Services required for bakeout, insulation vacuum and ion pump supply in VI and VA pass through the 'gap' between inner detector and argon endcap. They are listed in table TBD.

4.5.2 VT/VJ CONNECTOR

Services for the VT chamber must also pass along the VJ chamber to join the TX1S service package. In order to facilitate the installation and removal of chambers, intermediate connectors will be installed close to the VT/VJ flange.

4.5.3 TX1S LOCAL SERVICES

Services required for bakeout of VT and VF, and vacuum pumping station supply pass through a groove in the TX1S shield as defined in drawing LHC TX1S_0005.

4.5.4 SERVICES IN THE CAVERN

Services for bakeout are routed to racks in the UX cavern [14]. Standard CERN mobile racks can then be attached, and bakeout controlled remotely from this location. The beam vacuum chamber can in principle be baked out without opening the detector.

5. DESCRIPTION OF MATERIALS

5.1 GETTER FILM COATING

The whole length of the beam vacuum chamber will have a coating of ~5 µm thick sputtered Ti-Zr-V coating along the whole internal surface. In order to maintain sufficient pumping speed, this coating needs periodic re-activation by baking-out to a maximum temperature of 250°C. Initially this process will be done at temperatures around 200°C.

5.2 BERYLLIUM CHAMBERS

Beryllium material used is commercially pure beryllium, equivalent to Brush-Wellman specification S-200.

5.3 ALUMINIUM SECTIONS

Aluminium sections will be manufactured from AA 2219 alloy (containing 6% copper), machined from forged block.

5.4 STAINLESS STEEL CHAMBERS

Steel chambers will be made from AISI 316L or equivalent. For reasons of beam impedance, all steel chambers will be lined with ~ 100 μm of copper.

5.5 ALUMINIUM FOIL

50 μm thick commercially pure aluminium foil.

5.6 THERMAL INSULATION

5.6.1 CERAMIC POWDER INSULATION

This consists of a 10 mm thick jacket of 'Microtherm' ceramic fibre insulation of density 250 kg/m^2.

5.6.2 AEROGEL INSULATION

This consists of a flexible silica aerogel in a quartz fibre carrier equivalent to Pyrogel-UQS from Aspen Aerogels. It has a density of 90 – 130 kg/m^2.

6. COMPONENTS

6.1 BELLOWS

All bellows on the beam vacuum line will be made in AISI 316L stainless steel, with a thickness of ~0.15 mm. The depth of convolutions will be minimised for beam impedance reasons. However, for reasons of material budget and space availability, the bellows will not be shielded [15].

6.2 FLANGES

Aluminium flanges will be made from AA 2219 T6 forged blocks. Steel flanges from AISI 316LN forged flange blanks. All bolts, will be high strength grade stainless steel, with appropriate nuts and washers.

6.3 MINIMISED ION PUMP

The ion pump in section VA has been specially developed for this application [12]. It consists of an ion pump element of ~1 kg, manufactured in stainless steel and titanium. This is contained inside a stainless steel (AISI 316L) body, massing ~ 1 kg, including the perforated pumping screen. It is powered by a single 7 kV cable of ~1 cm^2 section, which passes from vacuum via a high voltage feedthrough. The magnetic field of ~0.15 T required for operation is supplied by the ATLAS solenoid.

It is fitted with a permanently installed bakeout system consisting of heaters and a 10 mm thick ceramic powder insulation jacket.

Space is reserved for a system of permanent magnets or EM coil in order to operate the pump in the absence of the ATLAS solenoid field. This system would be supported from the inner detector end plate.

6.4 KAPTON FOIL HEATERS

Heaters consist of sheets of 25 μm Kapton, supporting resistor circuits of 16 μm thick inconel. Two parallel circuits are provided in case of failure. The sheets are attached to the vacuum pipe with a wound, self-polymerising Kapton tape 25 μm thick, giving a total of 3 layers of Kapton in the installed configuration.

Two parallel heating circuits are installed for redundancy. Only one will be physically connected at any time.

6.5 VACUUM PUMPING STATION

The vacuum pumping station is housed in a cut-out in the TX1S shielding block. It consists of an ion pump, NEG cartridge and pressure gauges, all mounted on a 'T' section, in order to minimise radiation damage and activation of components.

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