TECHNICAL SPECIFICATION

ACCEPTANCE CRITERIA FOR A BEAM GAS CURTAIN INSTRUMENT

Abstract

This document summarises the minimum criteria for accepting delivery of Beam Gas Curtain (BGC) instruments to be designed and manufactured as part of the HL-UK2 contribution to the HL-LHC project.

TRACEABILITY

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0.1	2020-03-30	First circulated draft

1 INTRODUCTION

1.1 Context

The Beam Gas Curtain (BGC) is the baseline instrument for on-line monitoring of the overlap and conformity of particle beams in the Hollow Electron Lens (HEL) [1] halo suppression device in the HL-LHC.

It has been designed as a collaboration between The Cockcroft Institute (CI), Liverpool University, GSI and CERN under the envelope of a HL-LHC Collaboration contract [2] and a collaboration between CERN and GSI [3].

The UK, through the Science and Technology Facilities Council (STFC) has accepted to deliver the final instruments for the HL-LHC as an in-kind contribution. This document outlines the key criteria for accepting each deliverable.

1.2 Description of the instrument

The BGC consists of two main elements.

- **A gas jet system** produces a supersonic jet of gas by expansion of bottled gas through a micrometric nozzle. This is progressively 'skimmed' through three apertures, removing off-momentum particles to produce a quasi two-dimensional gas 'curtain' which is projected at 45° to the beam axis across the beam aperture. This gas curtain is then removed on the far side of the beam aperture by an exhaust gas pumping system.
- **An optical system**, situated outside the beam vacuum envelope at 90° to the beam axis and the gas jet system images the light produced by beam-induced fluorescence (BIF) interactions between the particle beams and the gas curtain. This directly produces a optical image showing both the position of the LHC hadron beam and the electron beam profile.

2 CRITERIA TO BE MET

2.1 Design performance criteria

The instrument shall be designed to detect fluorescence signals for neon and nitrogen emitted from beam-gas interactions. It shall be designed for nominal intensity and emittance HL-LHC proton and ion beams from injection to top energy [X]. It shall also be designed to simultaneously detect fluorescence signals from a constrained hollow electron beam of energy from 5 to 15 keV and intensity 0.1 mA to 5 A with a total beam diameter of up to 40 mm.

The instrument shall be designed to:

• determine the beam centroid of a nominal intensity and emittance HL-LHC proton or ion beam to better than 100 μm within a fixed, 2D image plane in less than 10 seconds

• simultaneously produce the 2D image of the hollow electron beam in the same frame of reference within 1 second.

2.2 Key Performance Criteria

Table 1 summarises the key performance criteria that shall be met for acceptance of the final deliverables. Performance acceptance shall be based on the use of Neon gas.

Table 1: Key performance criteria

Criterion	Units	Value
Minimum gas density in the curtain	$mol.m^{-3}$	$2x10^{16}$
Minimum transverse curtain dimension	mm	20
~~Variation in transverse density over the e-beam dimension at injection~~	~~%~~	~~20~~
Maximum variation in transverse density over the full curtain	%	50
Maximum through-thickness curtain dimension	mm	1.5
Maximum residual gas pressure after 24h pumping with nominal system	mbar	$1x10^{-9}$
Maximum time for <how to define an e- profile? Data? >	second	1

2.3 Target Criteria

Table 2 summarises the target performance criteria that the final deliverable should attempt to achieve.

Table 2: Target performance criteria

Criterion	Units	Value
Gas density in the curtain	$mol.m^{-3}$	$1x10^{17}$
Transverse curtain dimension	mm	40
Maximum variation in transverse density over the full curtain	%	10
Through-thickness curtain dimension	mm	0.5
Residual gas pressure after 24h pumping with nominal system	mbar	$1x10^{-9}$
Time for <how to define an e-profile? Data? >	second	1

2.4 Required criteria

All in-vacuum materials shall be according to relevant CERN specifications, with the global assembly having a vacuum compatibility to LHC acceptance standards [4], and meeting the general criteria specified in Table 3.

The instrument shall be designed to:

- withstand bakeout/NEG activation to 250 °C
- function with both Neon and Nitrogen gases
- function within the environment of the Hollow e-lens, in particular respecting the given space constraints and compatible with the stray solenoidal magnetic field of 2 T.

The designs shall conform to CERN standards and be signed-off by CERN.

All equipment shall conform with CERN safety requirements for LHC installation.

Table 3: General required criteria

Criteria	Units	Value
Bakeout/NEG activation temperature	°C	250
Maximum solenoidal magnetic field in the HEL environment	T	2

3 METHOD OF ASSESSING CRITERIA

Design acceptance criteria shall be demonstrated by design calculation and simulations presented in the Final Design Report (FDR).

Key performance criteria as per Table 1 shall be demonstrated using measurements made with Neon gas on a dedicated test bench at CI equipped with an electron gun of 0.6 mA intensity and 5 keV energy. Results will be extrapolated to nominal performance based on final fluorescence cross section and background noise measurements provided by CERN at the time of the EDR.

4 DELIVERABLES

4.1 CI supplied deliverables

Deliverable Number	Deliverable Description	Complete by	Type
D3.2.1	Get-jet monitor engineering design: report that shows proposed design fits specification and can be built	31/12/21	Document
D3.2.2	Final design: report with final drawing, integration, costs production and commissioning plan	31/09/22	Document
D3.2.3	Delivery of interaction chambers for integration in Hollow Electron Lens build-up	31/3/23	Hardware
D3.2.4	Delivery of gas-jet monitor unit 1, pre-tested at CI, for integration in Hollow Electron Lens and testing, participation in commissioning tests	31/3/24	Hardware
D3.2.5	Delivery of gas-jet monitor unit 2 for integration at CERN, pre-tested at CI	31/12/24	Hardware

Two full instruments, each consisting of:

• The optical instrument, including lenses, intensifier, CCD camera, and associated support and alignment system for positioning and focusing

• All vacuum chambers, internal structures, skimmers, nozzles, viewports assembled and functioning according to the acceptance criteria

• All Vacuum pumps, valves, roughing pumps, controllers and gauges required to achieve the acceptance criteria.

• a spare set of skimmers and nozzles

• Design and manufacture file, plus all documentation required to operate and maintain.

Skilled manpower to commission the instruments

4.2 CERN-supplied elements

CERN shall supply all the LHC related infrastructure, namely:

- Integration drawings

- Nozzle manufacturing
- Vacuum valves required for LHC operation
- Off-instrument cabling
- Any electronics not forming part of the instrument
- Gas lines and bottles for LHC integration
- LHC vacuum control hardware and software
- LHC operational software

CERN can assist with procurement of standard vacuum components if requested.

5 STEPS TO BE TAKEN IF CRITERIA NOT MET

If the design is not demonstrated to fulfil the requirements at the time of the FDR, remedial actions shall be agreed and implemented by CI on an agreed timescale.

If the final instruments do not fulfil the acceptance criteria then a programme of additional test and/or corrective action by CI shall be agreed.

6 REFERENCES

[1] HEL reference

[2] HL-UK1 reference

[3] CERN-GSI reference

[4] CERN EDMS 1752123: ACC-V-ES-0001, CRITERIA FOR VACUUM ACCEPTANCE TESTS. https://edms.cern.ch/document/1752123

The most common short form consists of the last name of the author and the main title of the work cited, usually shortened if more than four words, as in examples 4–6 below. For more on authors' names, see 14.27. For more on short titles, see 14.28. For more on journal articles, see 14.196.

1. Samuel A. Morley, Poverty and Inequality in Latin America: The Impact of Adjustment and Recovery (Baltimore: Johns Hopkins University Press, 1995), 24–25.

2. Regina M. Schwartz, "Nationals and Nationalism: Adultery in the House of David," Critical Inquiry 19, no. 1 (1992): 131–32.

3. Ernest Kaiser, "The Literature of Harlem," in Harlem: A Community in Transition, ed. J. H. Clarke (New York: Citadel Press, 1964).

4. Morley, Poverty and Inequality, 43.

5. Schwartz, "Nationals and Nationalism," 138.

6. Kaiser, "Literature of Harlem," 189–90.