The Beam Gas Curtain as an instrument for HL-LHC

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for the
BGC Collaboration team

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BGC Project Management

- Beam Gas Curtain (BGC) is the baseline instrument for on-line monitoring of the overlap between proton and electron beams in the hollow e-lens and as a general non-invasive profile measurement diagnostic.
- BGC development is principally funded by HL-LHC collaboration KN 2970 (Cockcroft Institute), with participation of GSI experts under a separate agreement.
- Prototypes extensively tested with electron gun sources, but there are a number of performance criteria that can only be demonstrated by operation with 7 TeV coasting proton beams:
  - Operating scenarios in the LHC synchrotron light background
  - Hadron shower noise background reduction due to reduction of length of the gas pressure bump
  - Operations with VSC in the baked LHC vacuum environment
- If this instrument is to be operational post-LS3, then some preliminary steps need to be taken in LS2 to allow for prototype testing during Run 3:
  - This instrument includes a new vacuum sector and significant cabling, which would be difficult to implement outside of a long shutdown.
- BGC prototype installation for HL-LHC is now a stand-alone task (13.2) in HL-LHC WP13:
  - The instrument is a deliverable from the Cockcroft Institute under KN 2970.
Overview - Recent Progress

- Key decisions and results to define a baseline for a useable HL-LHC instrument
  - Selection of a baseline gas species and spectral line [see S.Mazzoni]
  - Combining high and low pressure gas flow calculations to produce a consistent value for the jet density in the interaction region
  - Design of an associated optical system with realistic parameters that can produce image integration times in the order of 1 second [see H.Zhang]
- Commissioning and experimental programme on a new BGC experiment at Cockcroft [see H.Zhang]
  - Developing and testing technology for a real instrument
  - Experimental results with N2 and Ne for electron beams
- Design, production, installation and test programme for fluorescence in the LHC and TU Munich [see S.Mazzoni]
  - Experimental results with Ne and proton beams
- Integration at CERN of a BGC prototype for installation in the LHC during LS2
Gas jet formation

Gas jet simulation challenges

- Transport over 13 orders of magnitude from 10 bar to 10^{-9} mbar
- Two different physics models – viscous and molecular flow
- Interface regions are challenging: gas expansion into a near-vacuum and large particle flux for entry to molecular flow regime
- Taking advantage of synergies and technology development from gas jet target experiments

High-pressure simulations

- Computational Fluid Dynamics using ANSYS/CFX
- Potential issues of gas condensation on expansion understood
- Optimisation of nozzle geometries, gas inlet pressure and component separation, now being verified experimentally
- Challenges of numerical stability with expansion into vacuum and interface with molecular flow still being studied
Low pressure (molecular flow) simulations

- Complete Test-particle Monte Carlo simulation of the experimental set-up with Molflow+
  - Virtual interface at first skimmer
  - Predicted forms and densities of gas curtain for beam-gas interaction
  - Simulation-led optimisation leads to addition of baffle between interaction and exhaust pump
Vacuum System Design

- TE-VSC are optimizing the vacuum layout for LHC installation
  - Minimising pump numbers and dimensions to facilitate integration both for prototype and final instrument
  - Taking advantage of VSC software tools and expertise in molecular flow
- Input for the Phase II ECR
  - Ensure continued reliable operation of LHC vacuum with this instrument
Gas jet components

Moving from a laboratory system to a LHC instrument with limited maintenance opportunities

- Design and qualification of a system for pre-installation alignment of critical components with a laser
  - Achieved tolerances of 7 and 34 um for the nozzle-first and second skimmers
- Development of accurate nozzle production with European industry (30 um diameter)
LHC-Compatible Non-reflective coatings

Measurement of low intensity optical signals in the LHC requires minimization of reflected light background
- See subsequent talks
- Coatings must also be UHV and impedance compatible

Outstanding issue: How black is black?
- Different coating technologies being qualified for reflectivity and vacuum compatibility
## Reflectivity at neon wavelength 584nm

<table>
<thead>
<tr>
<th></th>
<th>Degreased no coating</th>
<th>NEG</th>
<th>Amorphous carbon</th>
<th>LESS (Dundee)</th>
<th>Multilayer sputtering (Polyteknik)</th>
</tr>
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<tbody>
<tr>
<td><strong>Copper</strong></td>
<td></td>
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<tr>
<td>Reflectivity</td>
<td>≈ 85%</td>
<td>≈ 45%</td>
<td>≈ 13%</td>
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<tr>
<td><strong>Steel</strong></td>
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</tr>
<tr>
<td>Reflectivity</td>
<td>≈ 56%</td>
<td>≈ 45%</td>
<td>≈ 14%</td>
<td>≈ 2%</td>
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</tbody>
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Slide: J. Glutting
Convergent-Divergent (CD) Nozzles

- Studies show that replacing a simple aperture with a CD nozzle makes a significant improvement to gas directionality and velocity out of the nozzle.
- CERN has technology for making precision CD nozzles with definable geometries and 10 um+ diameters.
  - Initially developed for gas jet targets.
- Existing nozzle design will be tested at Cockcroft.
- Collaboration with EN-MME to produce specific nozzle geometries once best solution is found.
Status of preparations for LHC prototype

- Phased installation process approved by HL-TCC
  - **Phase I** ECR for interaction vacuum chamber, new LHC vacuum sector, cables and racks (EDMS 2025553)
  - **Phase II** will follow for full prototype instrument installation – will not require LHC beam vacuum access

- Status of Phase I
  - ECR approved by HL-TCC in May 2018
  - Circulated for approval and commented by all concerned groups
  - Awaiting final approval process in LMC
Safety, impedance and documentation

- **Global BGC project**
  - HL-LHC WP 13 BGC Safety Assessment Form
    - Preliminary identification of hazards (EDMS 1936384 status: Under Approval)
  - Integration Report for Installation Approval (IRIA),
    - [EDMS 1959700](#)

- **Fluorescence Measurement Test Chamber Installation (2018),**
  - Approved by HL-TCC, Impedance and LHC machine committee
    - LHC-EC-BGC-0001 (EDMS 1869099)

- **Phase I installation in the LHC**
  - ECR approved by TCC and circulated for comment, now awaiting LHC machine committee
    - LHC-EC-BGC-0002 (EDMS 2025553)
  - ECR approved by Impedance Working Group #17;
    - [https://indico.cern.ch/event/702251](https://indico.cern.ch/event/702251)
Summary and Conclusions

- Installation of a prototype BGC in the LHC, planned for LS2 is now a funded baseline activity in WP13
- Consistent simulations for the gas jet generation have provided input both for the system design and optical system simulation
- Key technologies required to produce a working instrument in the LHC have been identified and development is well under-way
- Good collaboration with key CERN partners (in particular vacuum, impedance, safety, integration) is in place with detailed designs under discussion
- Design and integration is well en-route for installation in the LHC in 2020
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