HiLumi
HL-LHC PROJECT

The Beam Gas Curtain as an instrument for HL-LHC

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for the
BGC Collaboration team

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CERN

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BGC Project Management

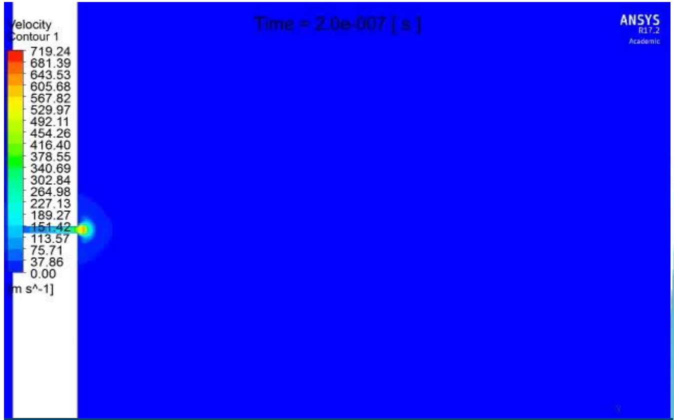
- Beam Gas Curtain (BGC) is the baseline instrument for on-line monitoring of the overlap between proton and electron beams in the hollow e-lens and as a general non-invasive profile measurement diagnostic
- BGC development is principally funded by HL-LHC collaboration KN 2970 (Cockcroft Institute), 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

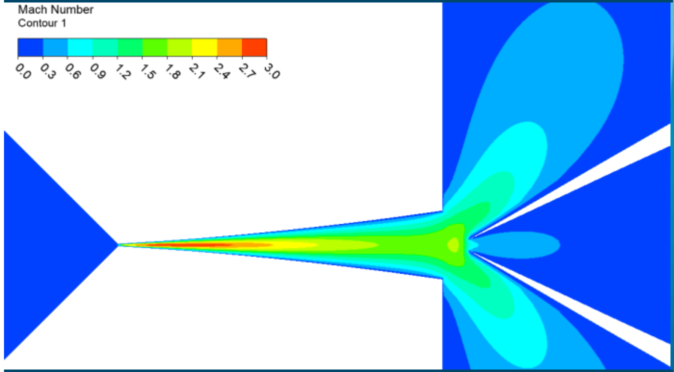
- Key decisions and results to define a baseline for a useable HL-LHC instrument
  - Selection of a baseline gas species and spectral line [see S.Mazzoni]
  - Combining high and low pressure gas flow calculations to produce a consistent value for the jet density in the interaction region
  - Design of 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 <u>electron beams</u>
- Design, production, installation and test programme for fluorescence in the LHC and TU Munich [see S.Mazzoni]
  - Experimental results with Ne and <u>proton beams</u>
- 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



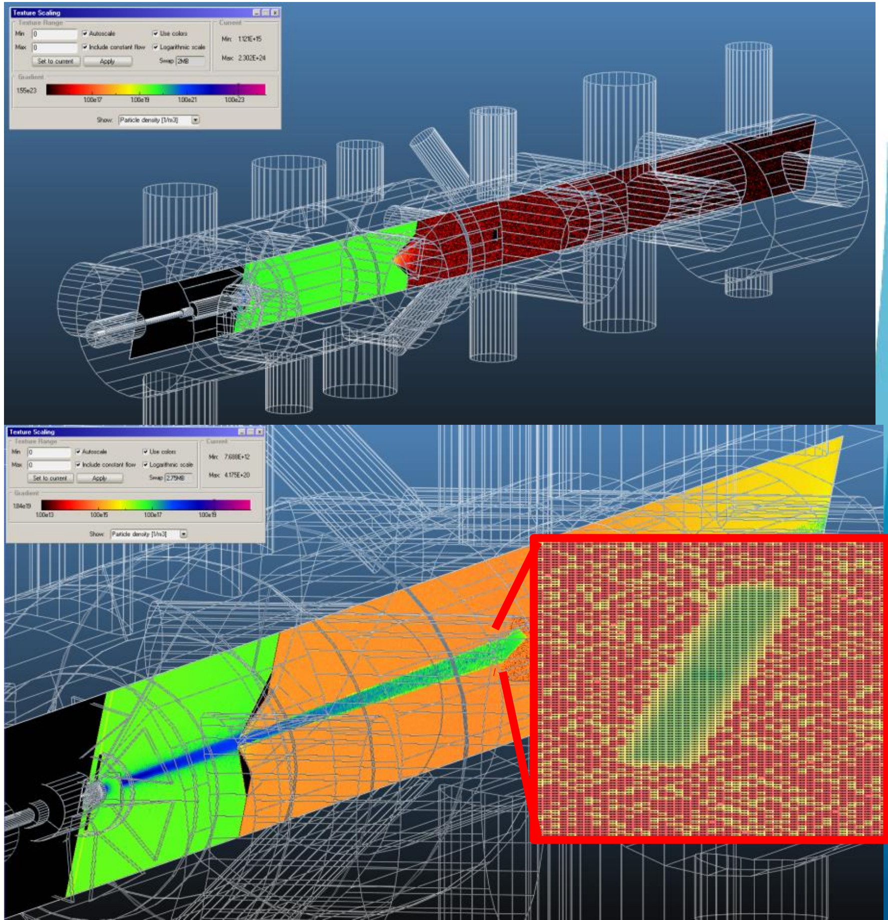
Free expansion from nozzle: 10^{-5} seconds



Velocity contours (Mach number, real gas model)

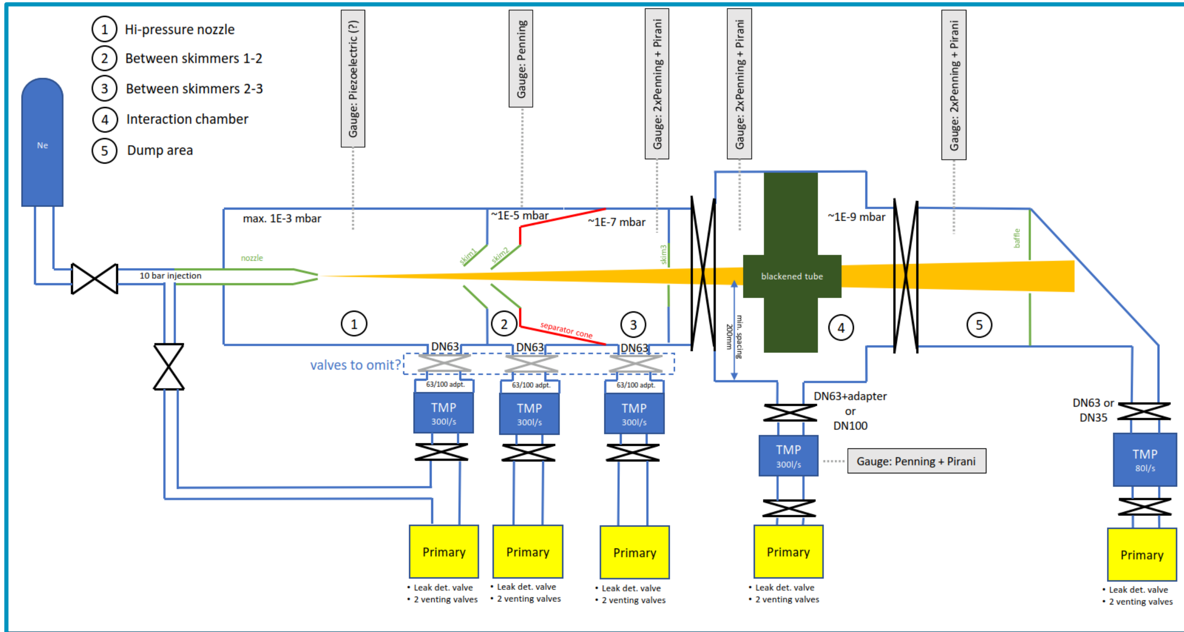
Low pressure (molecular flow) simulations

- 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

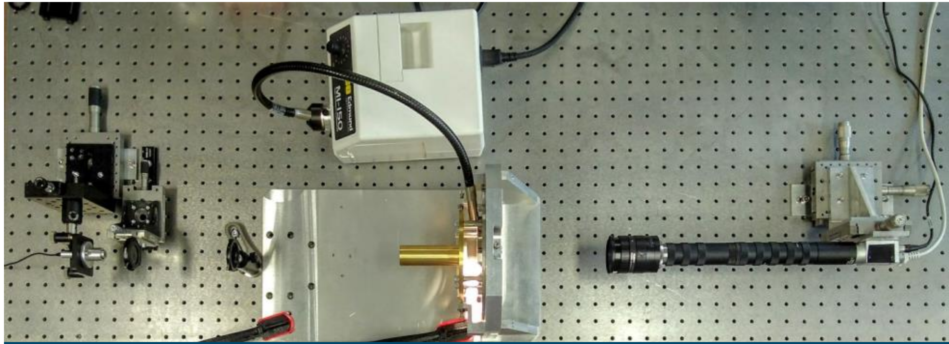
- TE-VSC are optimizing the vacuum layout for LHC installation
  - Minimising pump numbers and dimensions to facilitate integration both for prototype and final instrument
  - Taking advantage of VSC software tools and expertise in molecular flow
- Input for the Phase II ECR
  - Ensure continued reliable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



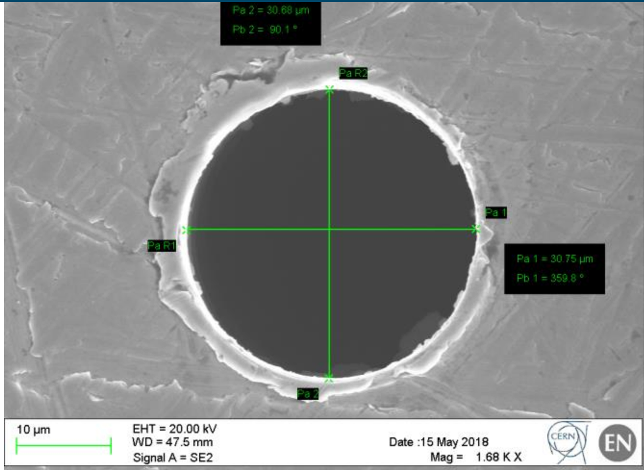
Proposed vacuum system schematic (Courtesy M.Ady/TE-VSC)

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)

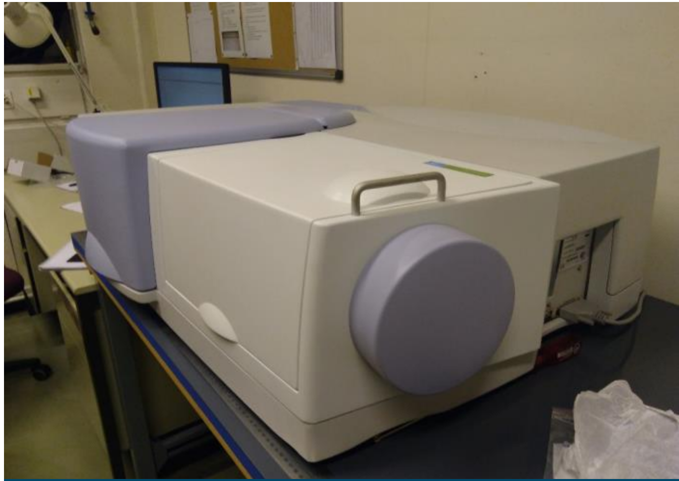


Component alignment system (J.Glutting Batchelor thesis)



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


Spectrometer courtesy EP/DT-EF

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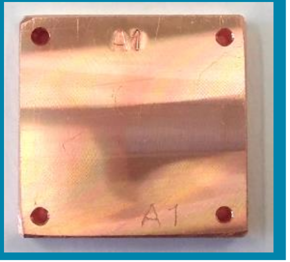
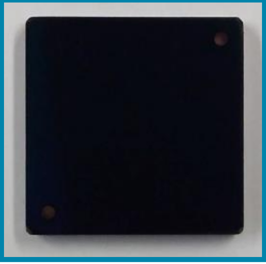
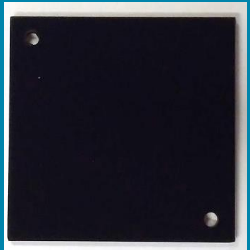
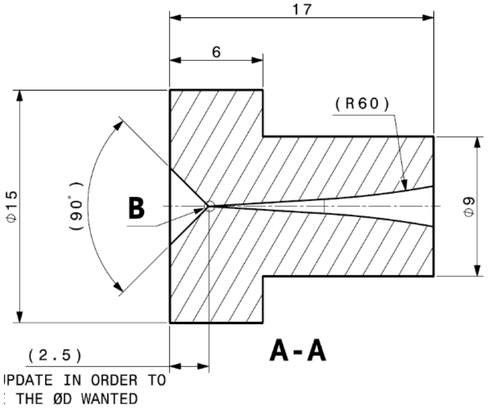
Reflectivity at neon wavelength 584nm

	Degreased no coating	NEG	Amorphous carbon	LESS (Dundee)	Multilayer sputtering (Polyteknik)
Copper	≈ 85% 	≈ 45% 	≈ 13% 	≈ 2% 	≈ 0.2% 
Steel	≈ 56% 	≈ 45% 	≈ 14% 	≈ 2% 	≈ 0.2% 

Slide: J.Glutting

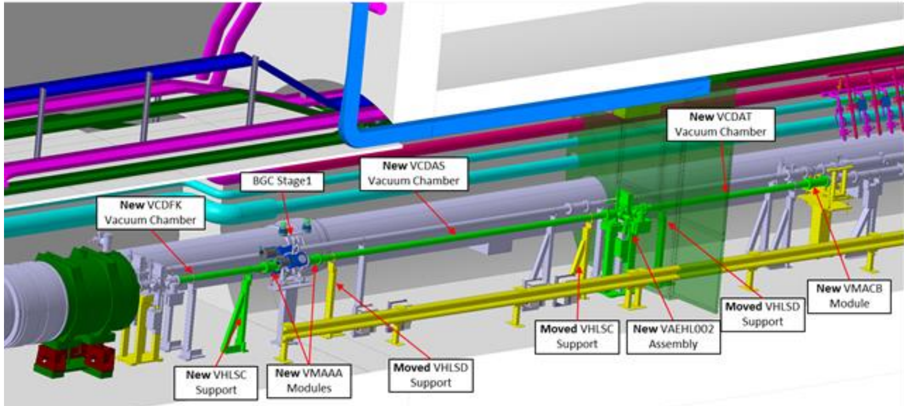
Convergent-Divergent (CD) Nozzles

- 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

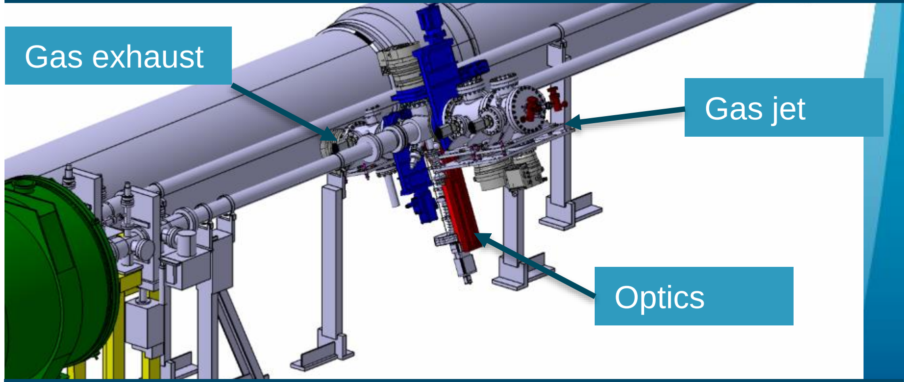


Status of preparations for LHC prototype

- 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



New vacuum layout for Phase I ECR



Addition of prototype instrument for Phase II ECR

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

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

Thanks to the BGC collaboration:

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