

## Non-Invasive beam diagnostic for making LHC more sustainable

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One major requirement for High Luminosity upgrade of Large Hadron Collider is to improve the interaction or collision cross-section of accelerating proton beam. To achieve this the density of interacting beam must be increased. This will be obtained by passing proton beam through the center of hollow electron beam moving in the opposite direction. The negatively charged hollow electron beam will further collimate the positively charged proton beam and at the same time strip off its halo. Precise, fast and real-time profile measurement of both the beam is required in order to get such results. As a solution to this, QUASAR group at Cockcroft Institute along with the collaboration with CERN and GSI has developed the minimally invasive Beam Gas Curtain (BGC) monitor. It uses a thin sheet of gas, moving at supersonic speed to produce the 2-D profile of beam.

### Working Principle

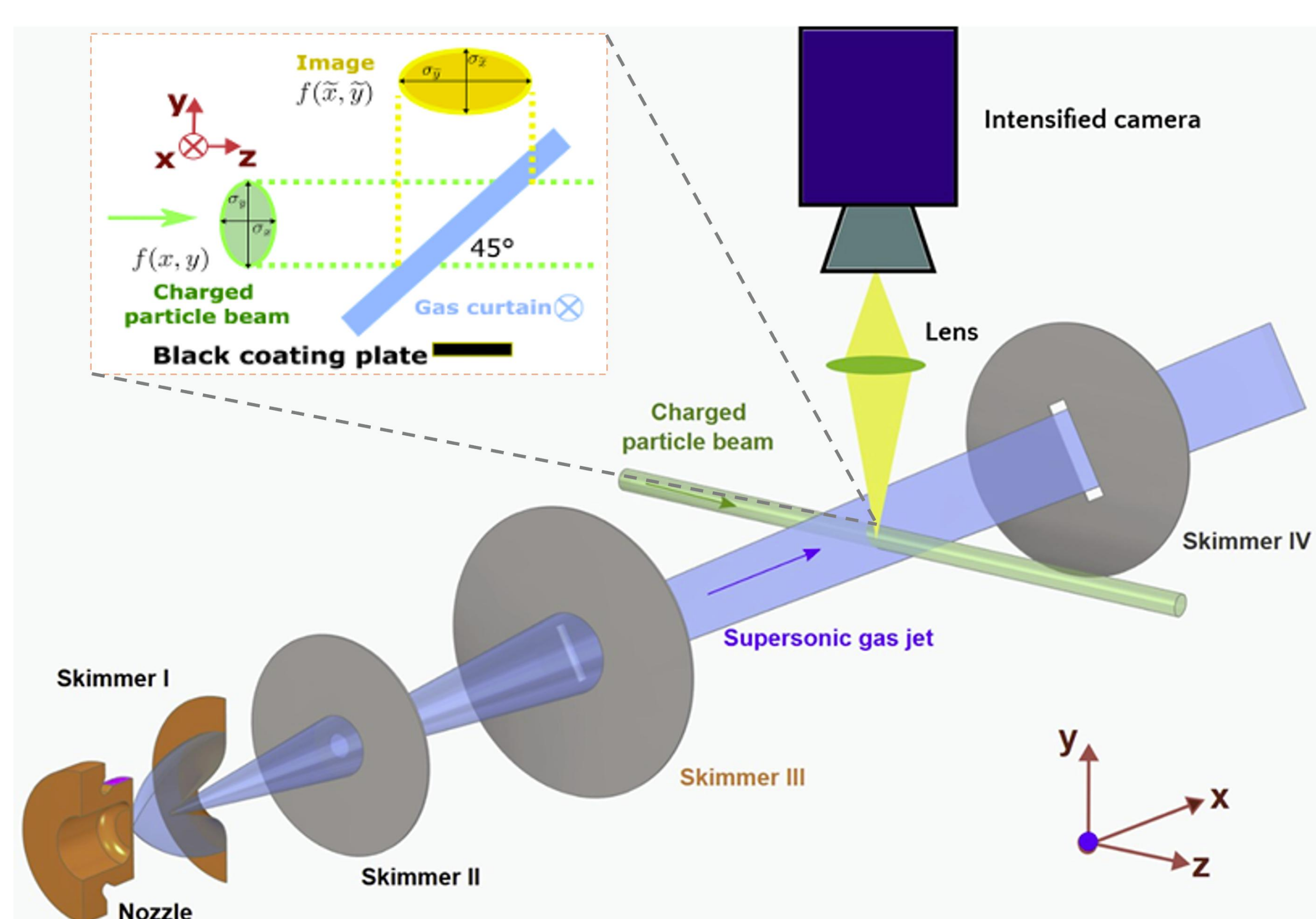


Fig 1: Schematic diagram showing working principle of BGC [1].

- Improved integration time due to increased local density of gas.
- 2-dimensional imaging.
- Minimum disturbance to the vacuum of accelerating system.

### BGC V3.0 and V4.0

#### V3.0

- It was previously installed at electron beam test stand (EBTS) and then moved to the LHC beamline 1.

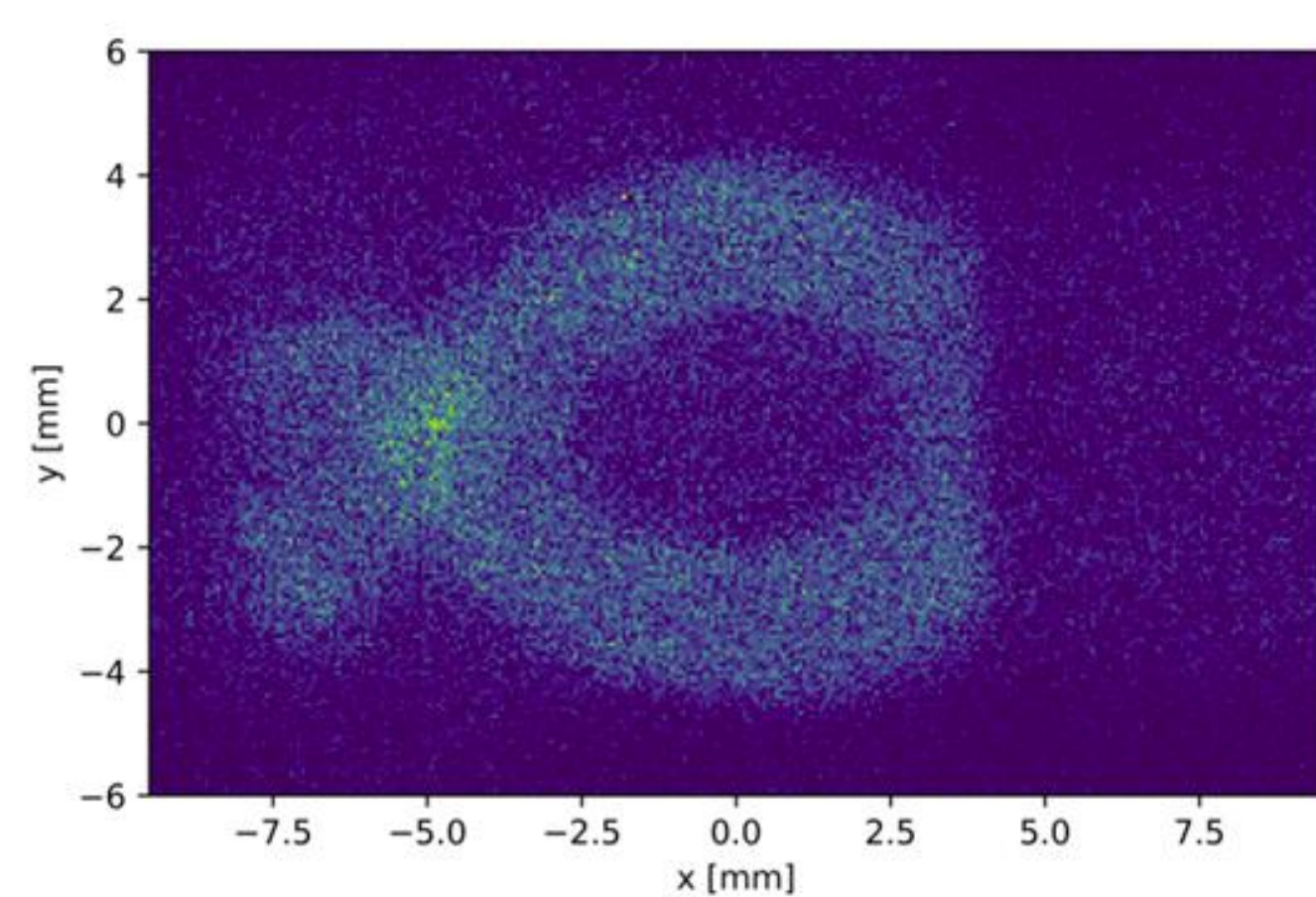


Fig 2: Hollow electron beam profile measured using V3.0 [3].

- Curtain is not large enough to capture entire beam profile.

#### V4.1

- Transported to CERN in February, 2026; and installed on EBTS.

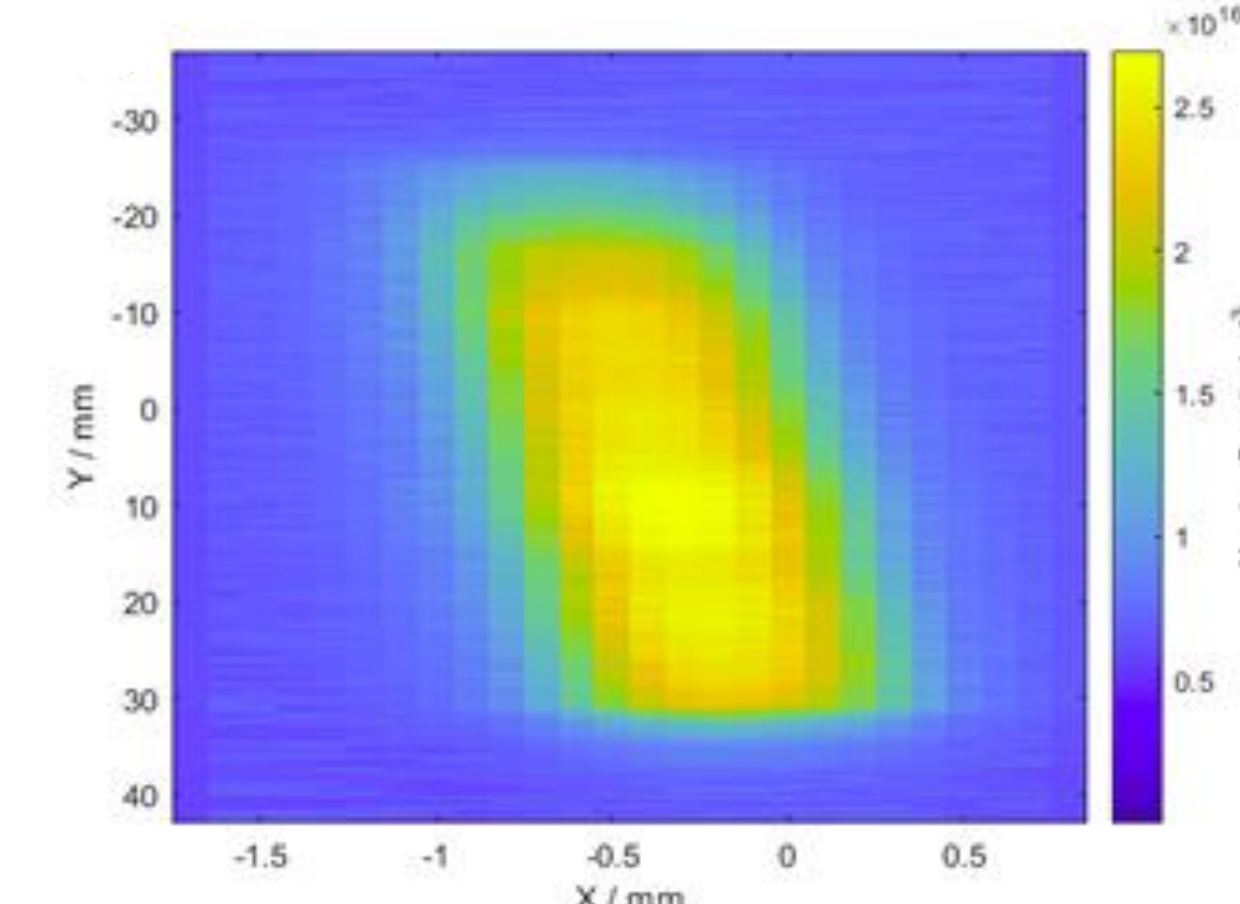


Fig 3: Improved curtain length in V4.1 [2].

- Cable of producing curtain of length ~60mm.
- Recent simulations have further optimized the assembly.

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### Sustainability

#### BGC [1-3]:

- Non-invasive diagnostics enable continuous monitoring while preserving the beam quality
- Consumable diagnostic targets are not required.
- Eliminates beam destruction associated with interceptive diagnostics.
- Compared to IPM or BIF only one monitor is required for 2-D imaging.
- Demonstrated to work well in full operation range of LHC i.e. injection, energy ramp up and collisional energy of 13.6 TeV.
- Same monitor can be used for the various beams like proton, electron, lead-ion
- Measurements are comparable with CMS and ATLAS detectors.

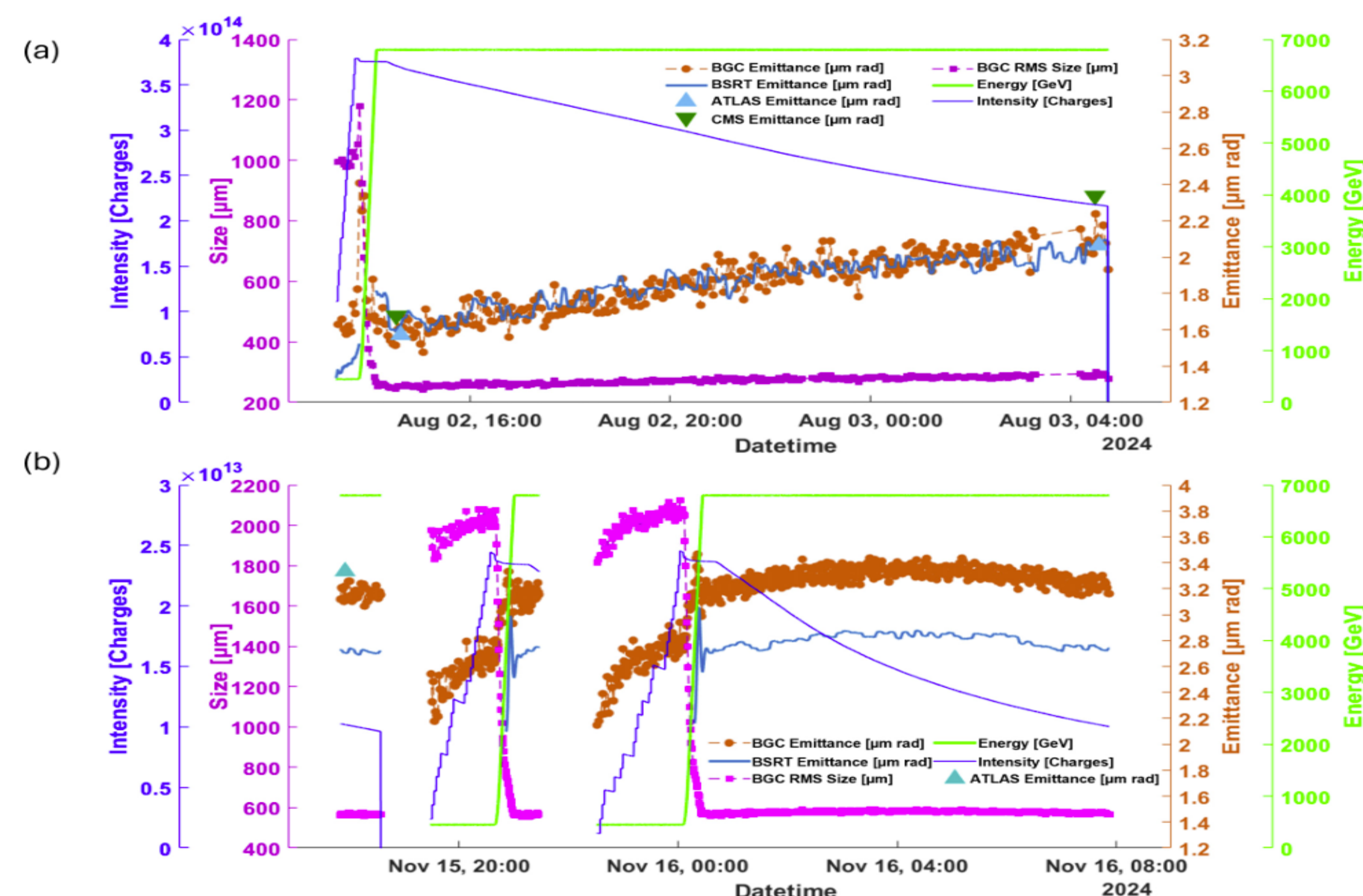


Figure 4: Horizontal emittance measurements from the BGC monitor for a) the LHC proton beam and b) the lead ion beam compared with other methods [1].

#### EBTS for HEL [4-5]:

- Test stand for Hollow Electron Lens (HEL).
- Active beam halo control is crucial for HL-LHC operation.
- Beam losses caused 7 out of 48 Pb-ion fills to be aborted in 2018.
- Heavy-ion collimation is ~100x less efficient than for proton beams.
- The Hollow Electron Lens (HEL) improves collimation, reduces beam losses, and enhances sustainable accelerator operation.

### Reference and Acknowledgment

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