



BGC MONITOR: FIRST YEAR OF OPERATION AT THE LHC

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On behalf of the BGC collaboration

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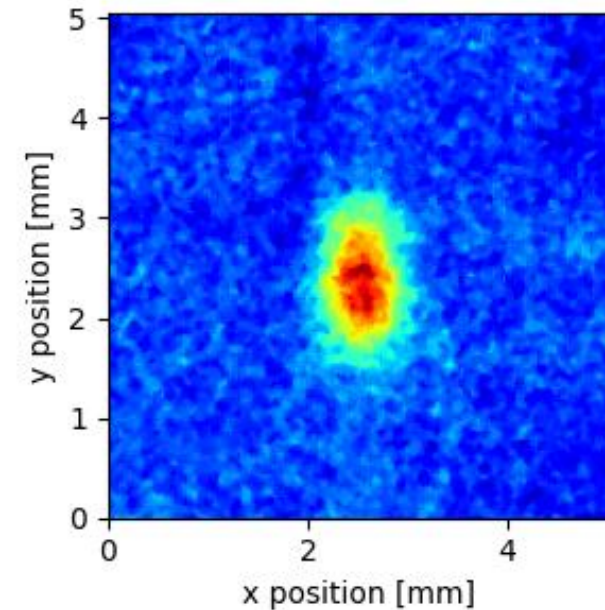
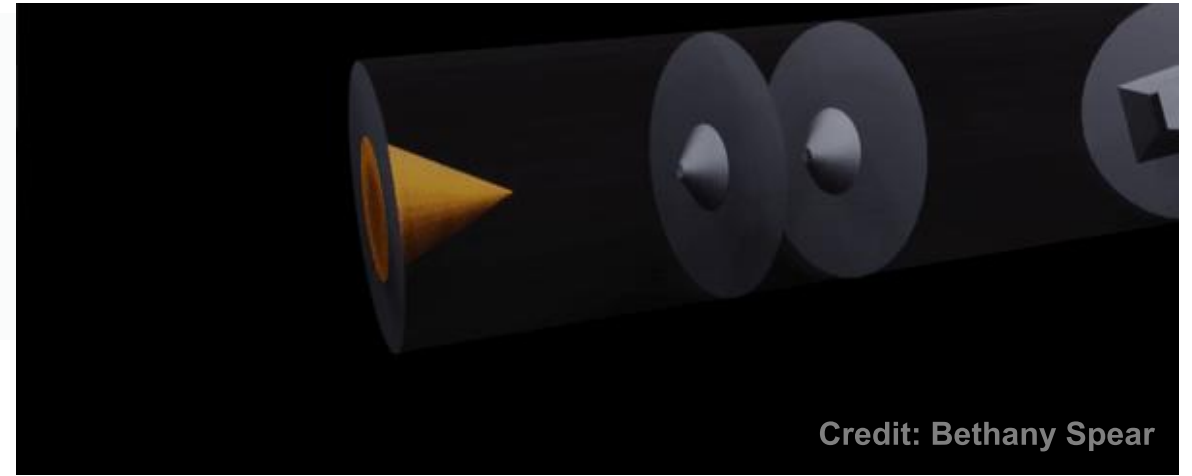
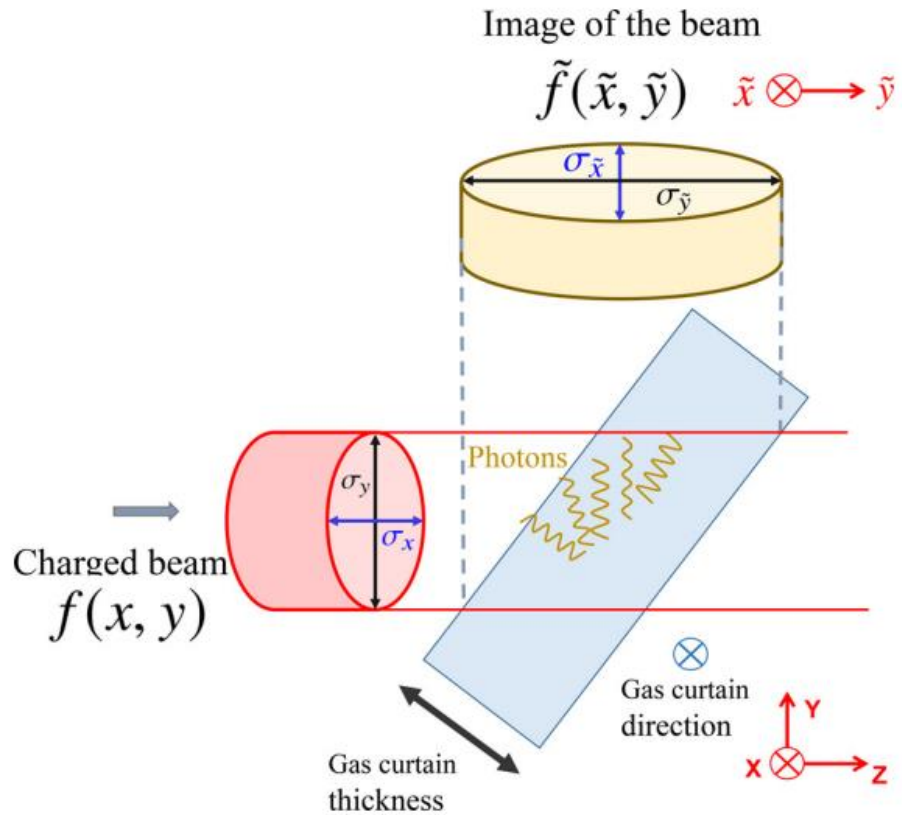
Outline

- Motivation of work.
- Beam Gas Curtain (BGC) working principles – fluorescence diagnostics.
- BGC installation and operations within the LHC.
- First beam profile measurements of proton and lead ion beam using beam-induced fluorescence.
- Performance and issues.
- Summary and outlook.

Motivation

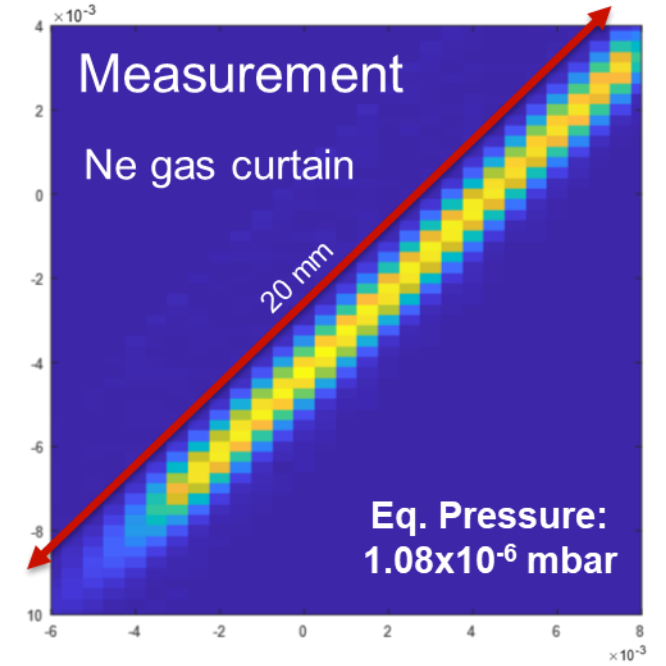
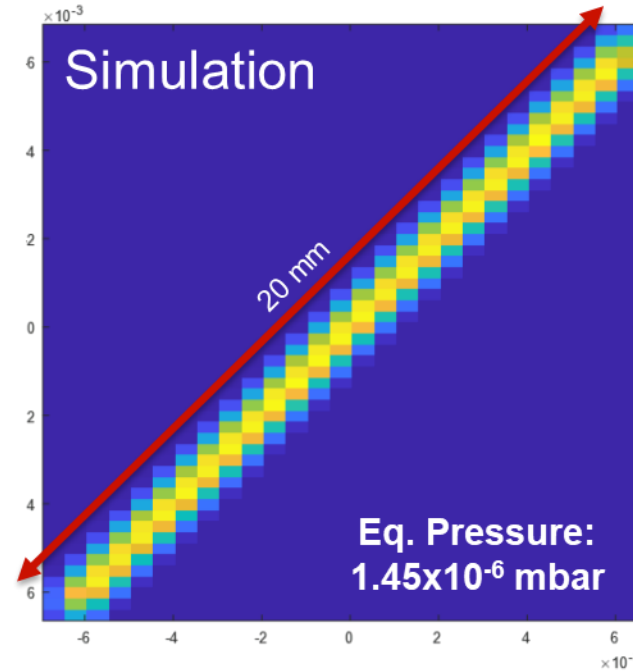
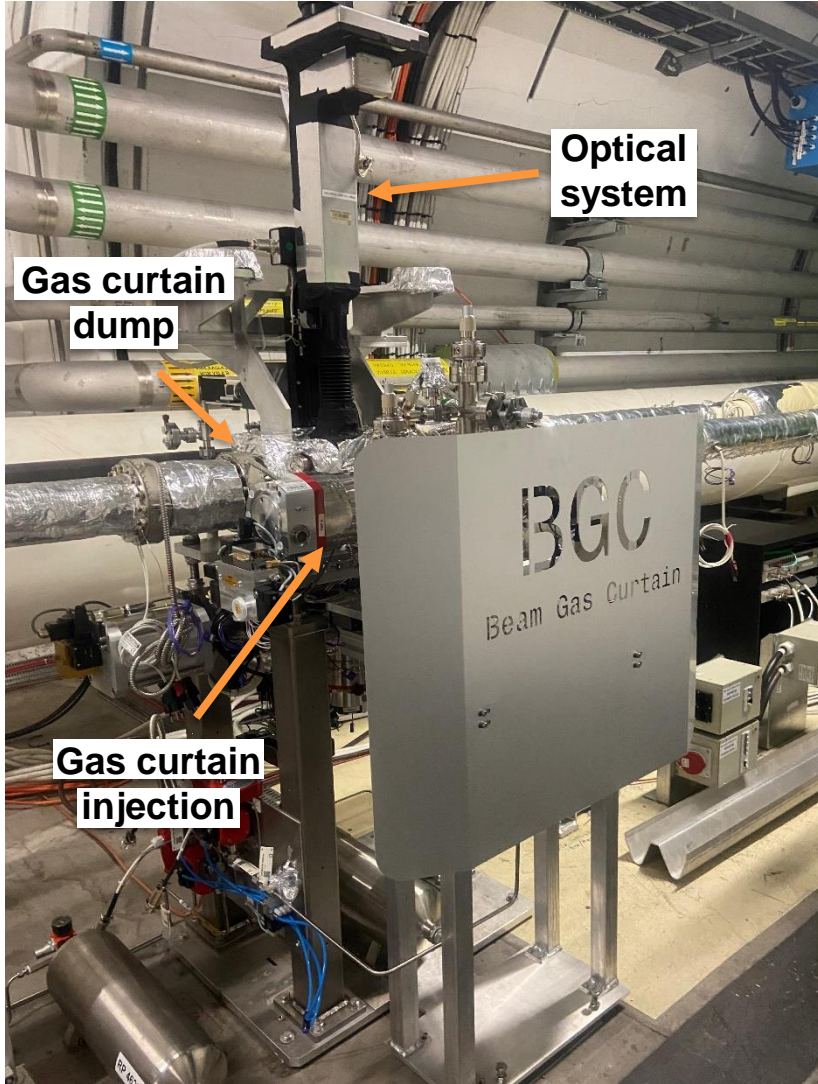
- It is essential to be able to measure **beam size** within accelerators to determine **emittance** which is essential for smooth operation.
- Current **transverse profile diagnostics** for the LHC include **wire-scanners** and **synchrotron radiation monitor (BSRT)**, both of which have **limitations**.
- The **High-Luminosity** upgrade will introduce **new challenges** for existing diagnostics.
- We present a **non-invasive** beam profile monitor that works for **all stages** of acceleration on the LHC.

Imaging a Beam Profile - Fluorescence



Using Ne as working gas and choose a fluorescence line of 585 nm

LHC Installation



H. Zhang et. al, Vacuum 208, 111701, 2023.

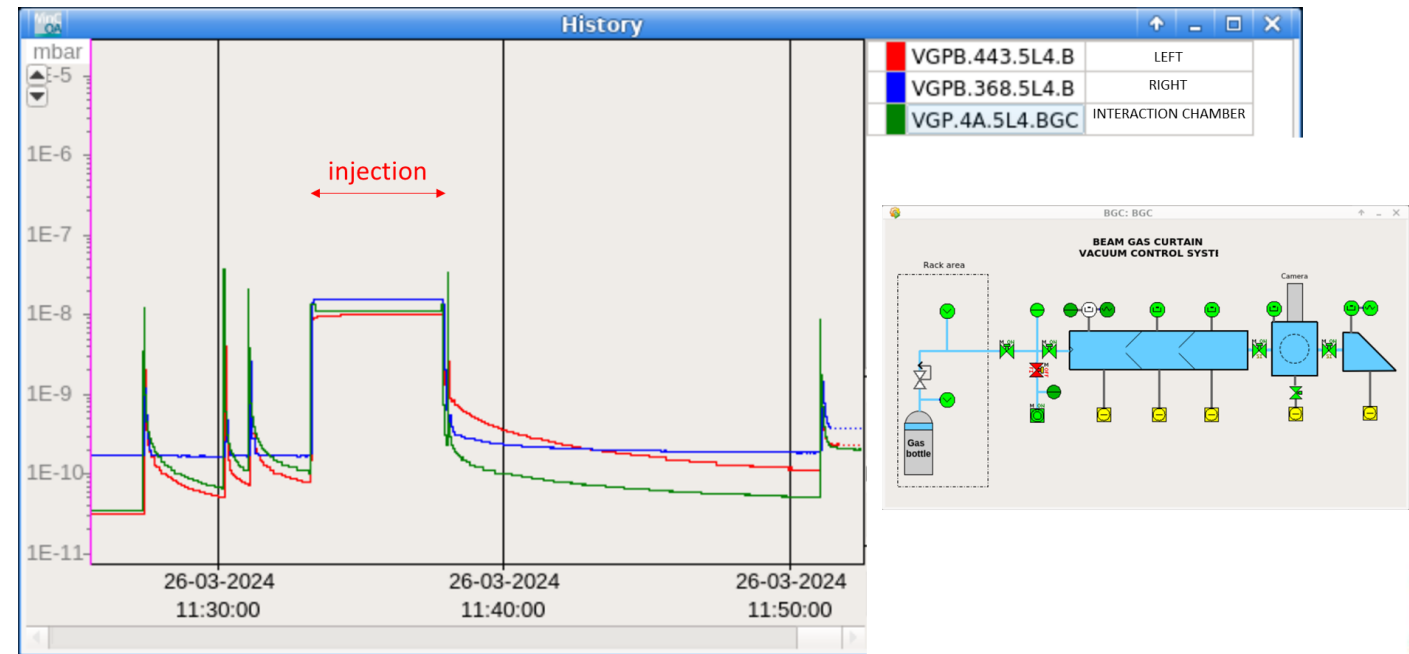
- Off-line tests performed before the installation in the LHC.
- Contributed to the LHC control system design, providing values for the pressure safety interlock.

C. Castro Sequeiro, PRAB 27, 043201, 2024.

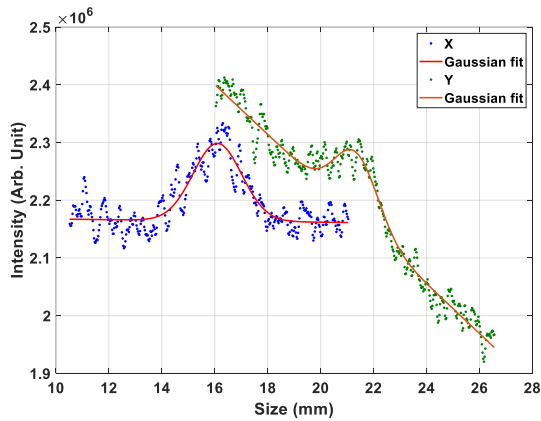
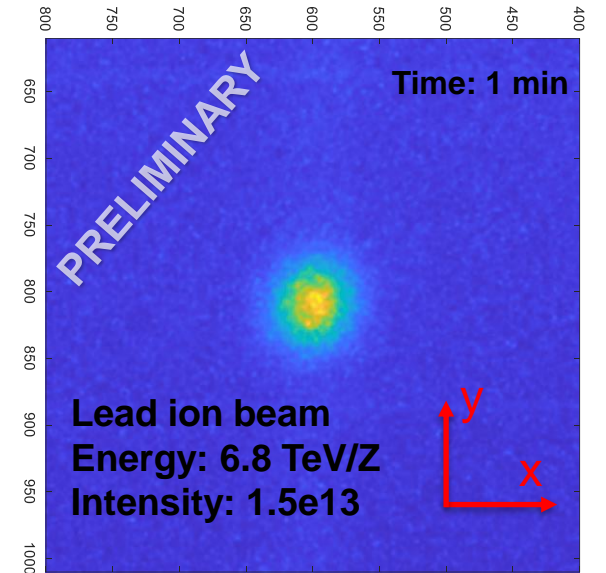
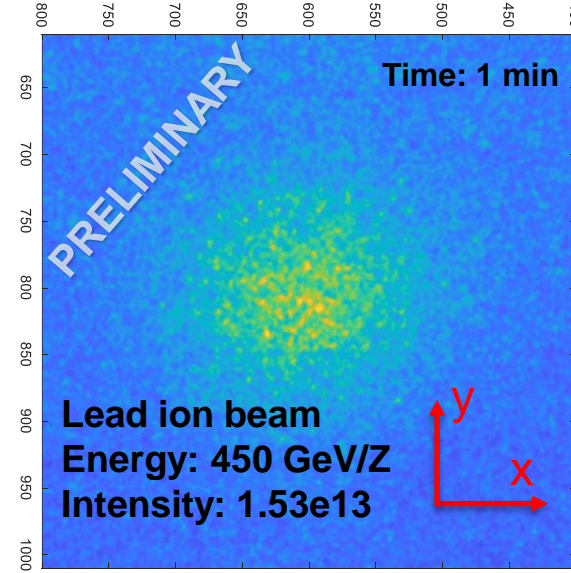
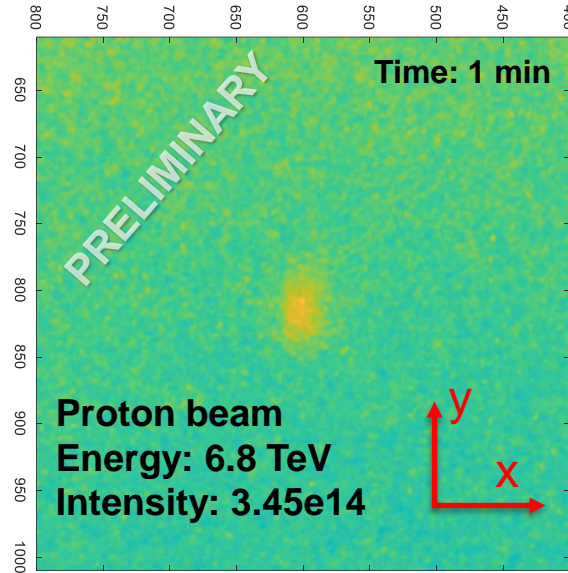
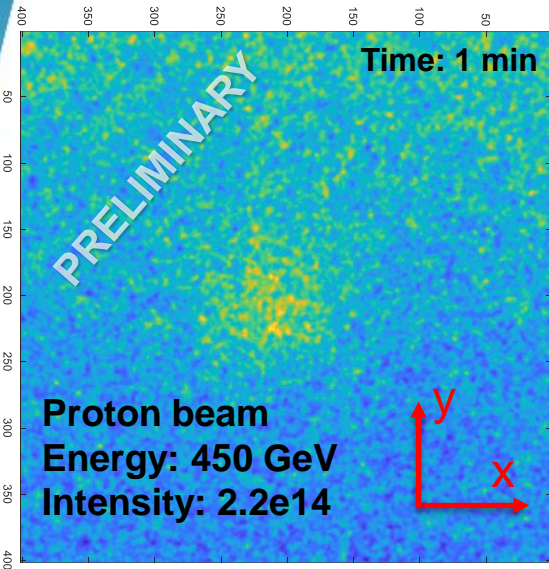
BGC integrated into the vacuum control system

- Dedicated vacuum control system. **Manual operation** is still required.
- Pressures are recorded before, at, and after BGC with injection on and off.

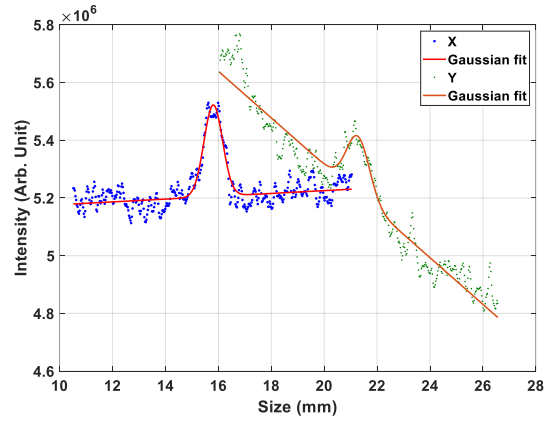
Interaction chamber (VGP.4a.5L4.BGC)	Pressure [mbar]
Ne gas Jet OFF	2.0e-10
Ne gas Jet ON	4.00e-8



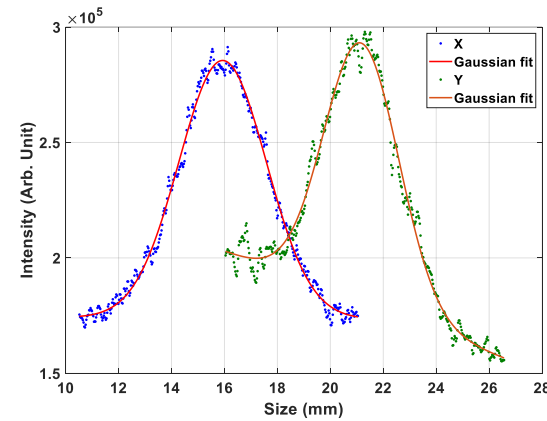
Typical measurement



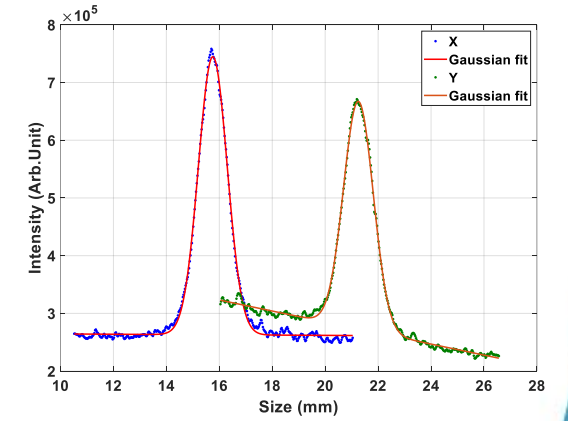
$\sigma_x = 0.917 \text{ mm}$ $\sigma_y = 0.817 \text{ mm}$



$\sigma_x = 0.308 \text{ mm}$ $\sigma_y = 0.432 \text{ mm}$



$\sigma_x = 1.653 \text{ mm}$ $\sigma_y = 1.418 \text{ mm}$

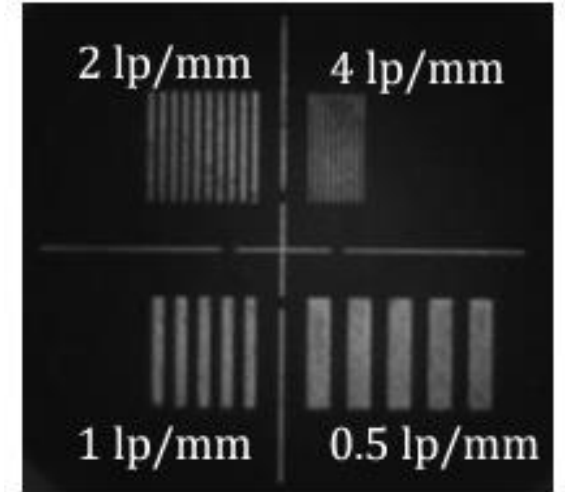
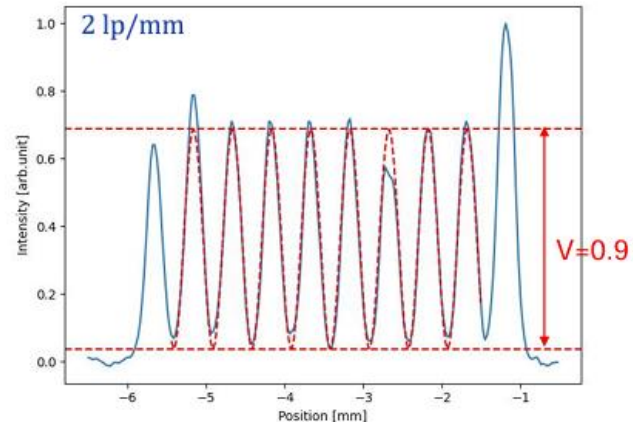
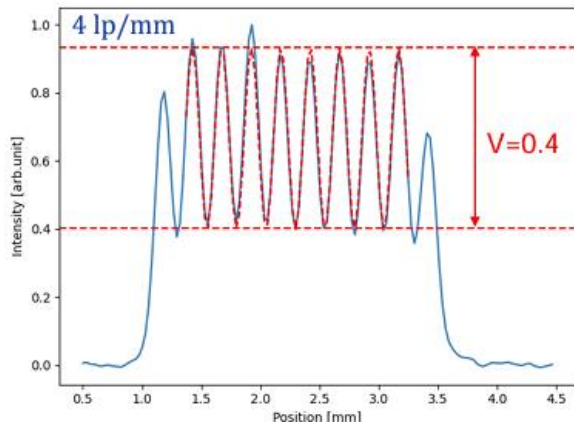


$\sigma_x = 0.543 \text{ mm}$ $\sigma_y = 0.589 \text{ mm}$

Resolution

For the LHC setup, the LSF = 65 μm (Gaussian sigma at object plane) found with the slanted edge method is compatible with the contrast measurement of the target lines.

The optimal LSF would be 61 μm , compatible with our tolerances.



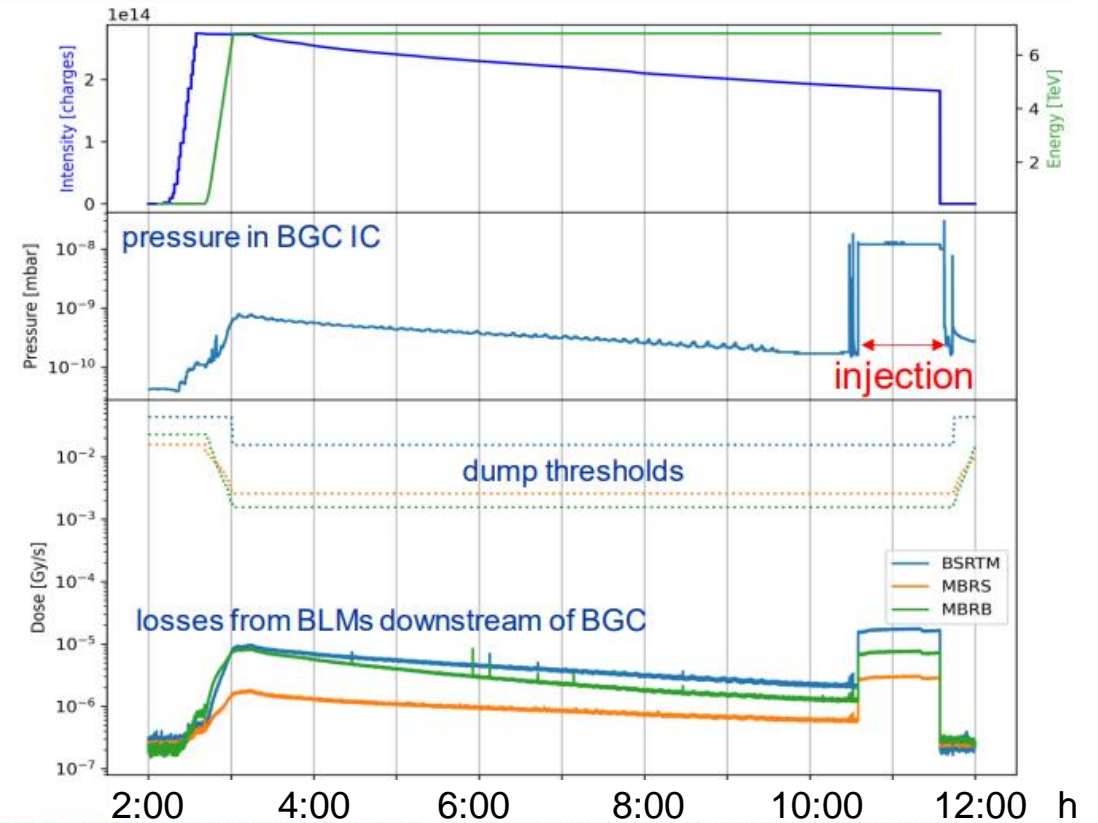
Credit: D. Butti

LHC Operation summary

- 2023
 - ~10 h gas injection for 2023 proton beams – Validation
 - >70 h gas injection for 2023 lead ion beams – Validation & systematic study
- 2024
 - Currently Gas injection for 2024 proton beams – Validation & systematic study & fluorescence cross-section study.
 - Planned Gas injection for 2024 lead ion beams – fluorescence cross-section study.

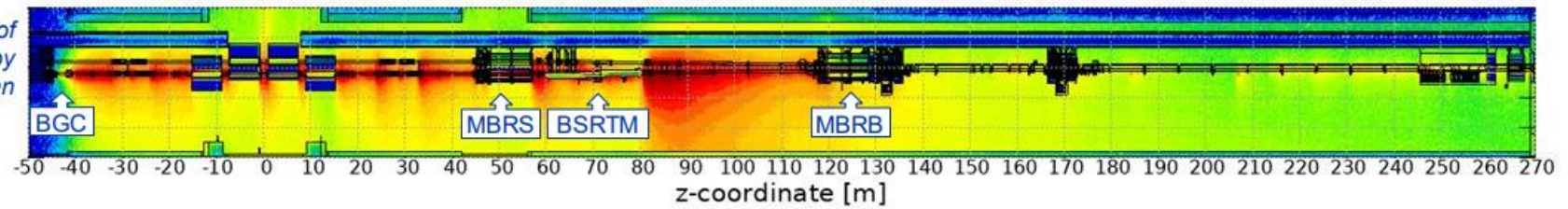
Beam loss due to BGC

- Beam Injection – **no losses** above noise in CCC Fixed display
- Stable Beams – local increase by $7.5e-20$ Gy/s/p in P4 (~2-3x above noise), **<1% of dump losses**
- Far from dump thresholds, but BGC effect clearly distinguishable on BLMs



Date: 18/04/2024

FLUKA simulation of
BGC induced dose by
D. Prelicpean

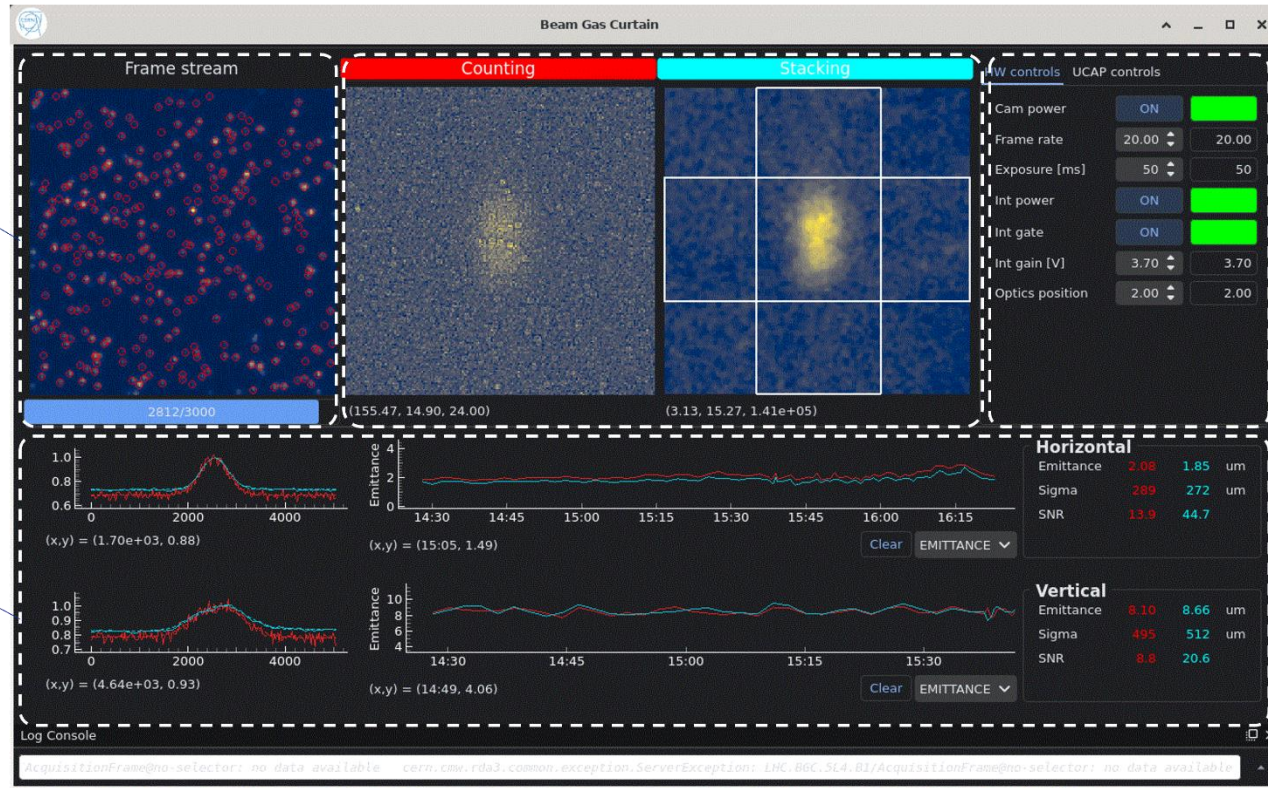


Real-time display of BGC images

Integrated images

Single frames with photon detection

Profiles and fit results

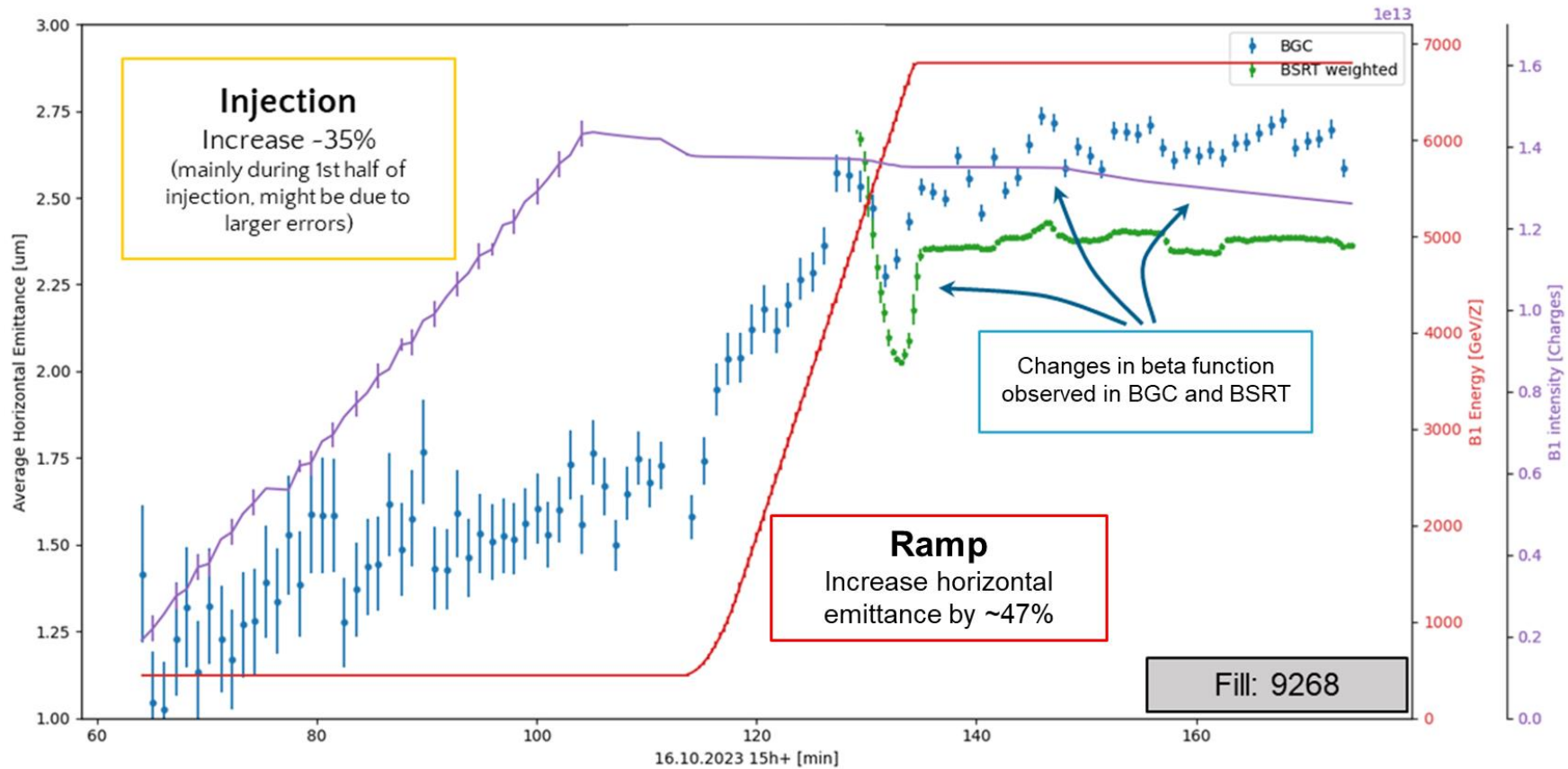


- 20 Hz processing @ 400x400 pixel ROI.
- Both photon counting and intensity stacking strategies available for direct comparison.
- Machine variables (optics, energy...) automatically imported from CERN control system.

Credit: D. Butti

BGC validation

- BGC operated and validated for standard full intensity (Injection -> Ramp -> Stable Beams) for proton and lead ion beams

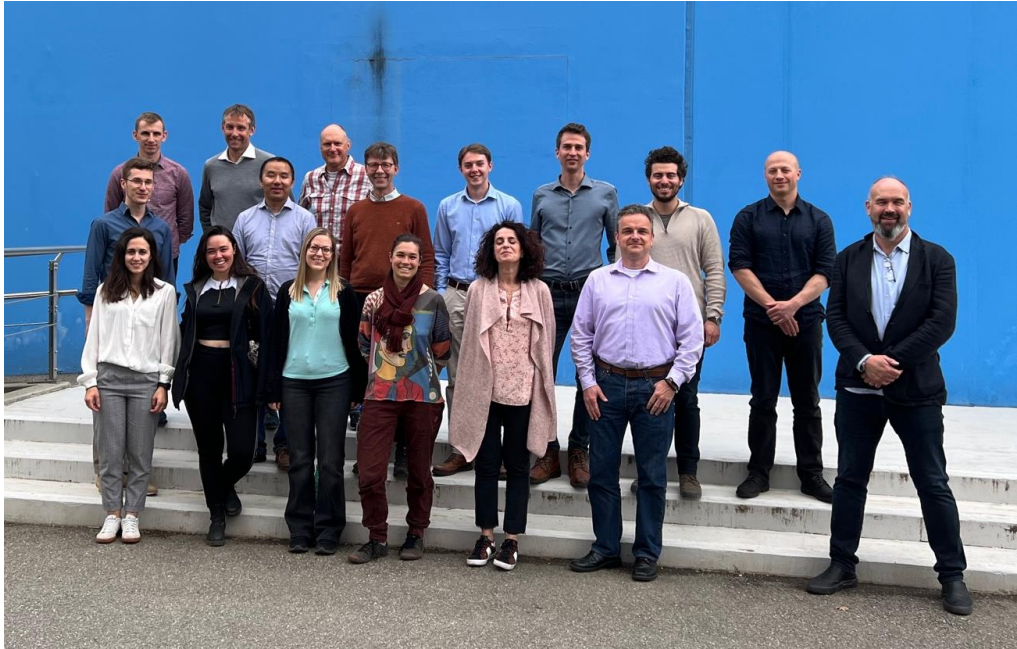


Pb Ions Horizontal Emittance

Summary and Outlook

- BGC monitor has been successfully installed and commissioned on the LHC.
- 2D beam profile of the LHC proton and lead ion beams during 2023 for the full cycle including injection, energy ramp-up and stable beam operation.
- Comparison for the horizontal size coincide within the expected uncertainty.
- Developing the monitor as a standard LHC operational instrument is in progress.
- Systematic study for the proton and Lead ion beams
- Compare with other available devices (wire scanner, BSRT) and understand the discrepancy.
- Study the fluorescence cross-sections for LHC beams with wide range of energy.
- Install a second BGC device for Beam 2 during LS3.
- Continue development of BGC technology for other applications (such as halo monitor)

Thank you for your attention

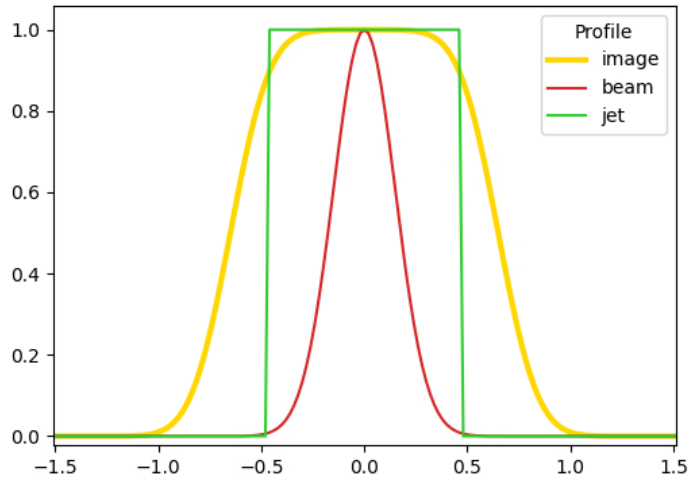


Many thanks to the whole BGC collaboration for their fantastic support and work over the past 10 years.

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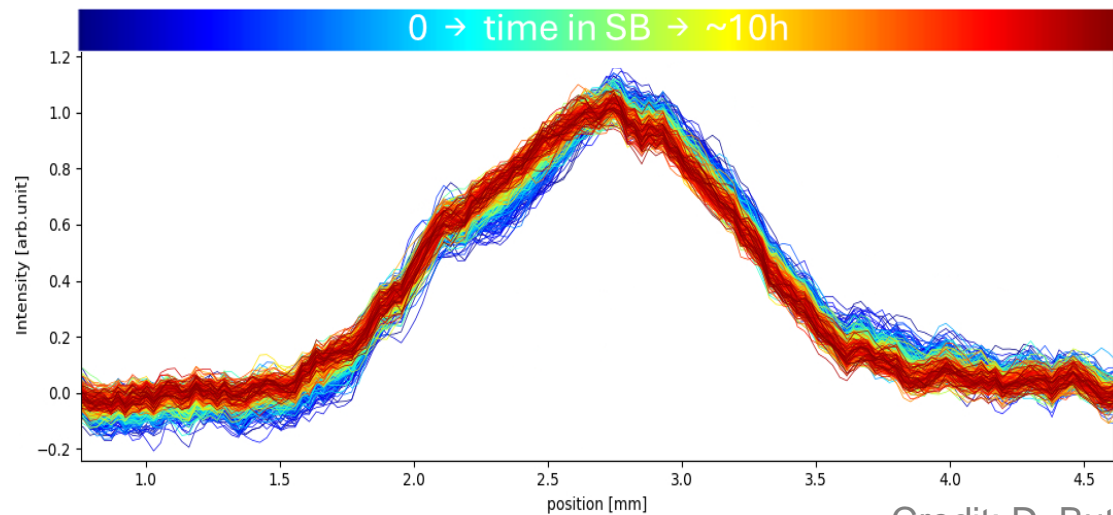
Issues with vertical measurement



Ideally, the vertical profile of the image should have

- intensity plateau determined by uniform jet distribution
 - Gaussian edges determined by beam distribution
- the beam size information is only encoded in the edges and a **deconvolution should suffice**

In reality, the profiles are not as straightforward
Work in progress...



Credit: D. Butti