11th BGC collaboration meeting
Liverpool
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BGC as halo monitor: some considerations

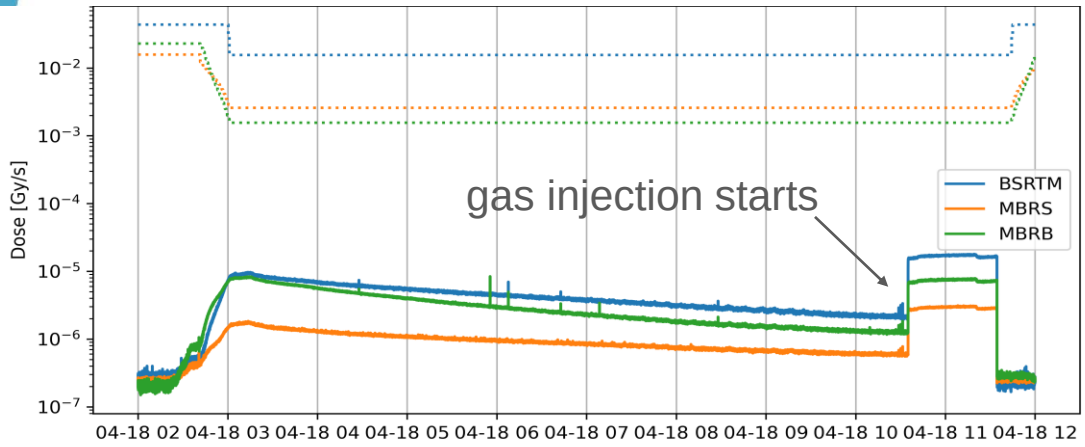
D. Butti on behalf of the BGC collaboration

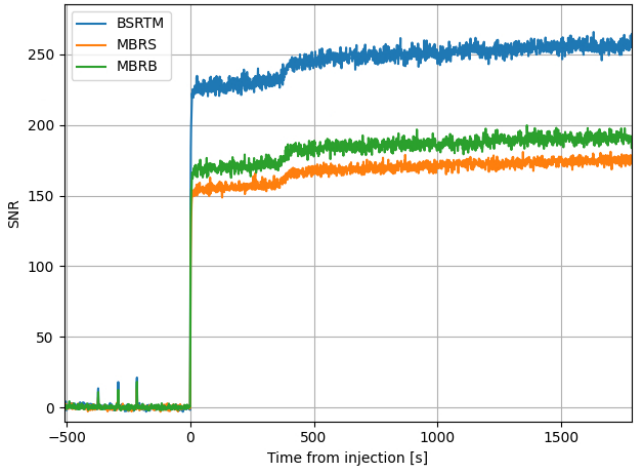
Introduction

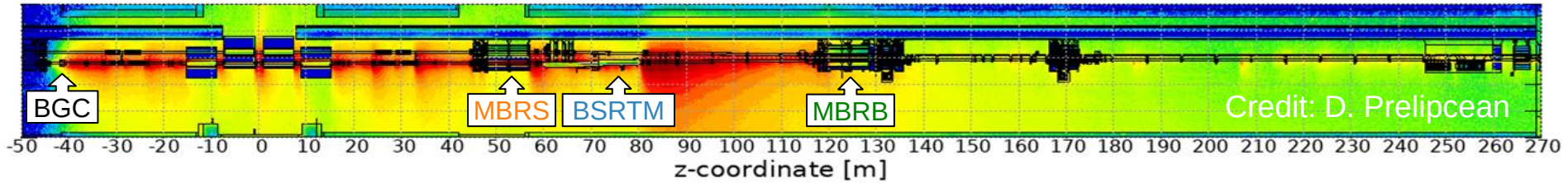
- Presently, beam halo measurements rely on scraping + BLM & BCT. Destructive, only possible in dedicated machine periods (e.g. Commissioning, MDs, End of Fill)
- Baseline proposal for non destructive measurements: detector based on SR imaging. High dynamic range sensors soon discarded in favor of coronagraph (core blocking) system, in collaboration with KEK)
- Coronagraph prototype installed on LHC B2, proof of principle presented at IPAC24. Ultimate performance more difficult to assess.
- **Beam Halo Working Group established in 2024** to define specifications and technologies

Beyond fluorescence

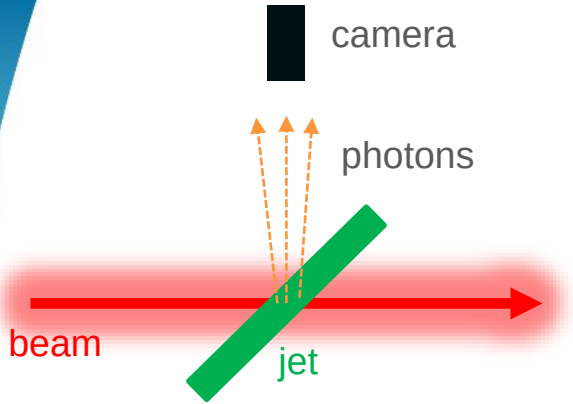
Fluorescence is not the only signal, **gas-induced losses detectable downstream**

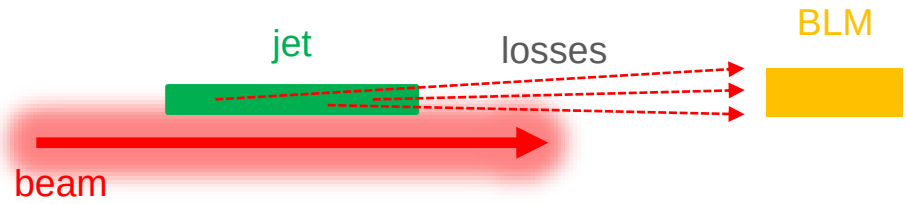






Concept





Present configuration→ jet as “gas screen”

Halo measurements → jet as “gas collimator” and detect losses

Points to study / improve…

- maximize jet-induced losses
- optimize detection of BGC-induced losses
- optimize jet sharpness-contrast
- minimize gas background

… possible experimental tests

→ make jet longer and align with beam

→ install dedicated BLMs

→ modify injection geometry

→ upgrade pumping system

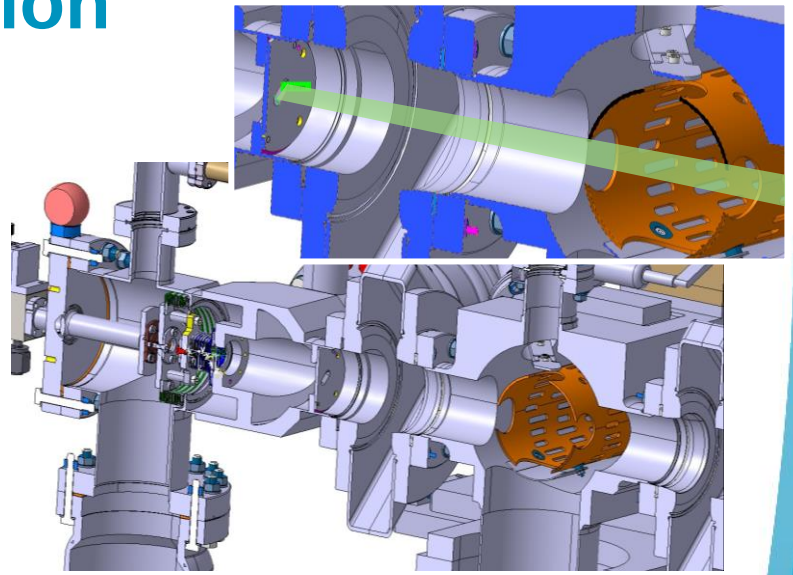
If this works as halo monitor, a bunch-by-bunch beam profiler (emittance monitor) comes for free!

Implementation

Can this concept be implemented?

BGC compatibility with LHC operation fully validated (e.g. impedance, losses, vacuum…).
Jet displacement (few mm) likely transparent

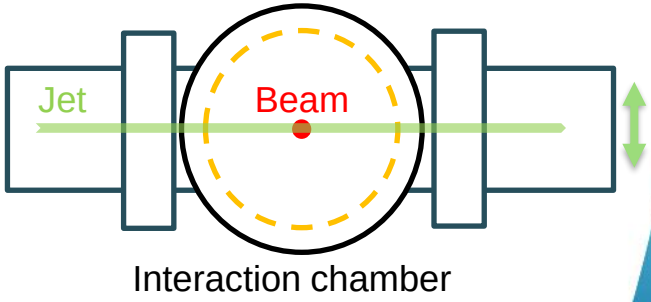
→ **no evident showstopper to switch configuration**



Integration in LHC is more challenging

- quite bulky instrument, can fit in few locations
- intrinsically 1D instrument, would need 2 per beam
- halo monitoring continuously required, would operate 24/7
- requires clean background to maximize losses sensitivity

→ **technical details still to be investigated**



Halo monitoring specifications (evolving)

Parameter	Remarks	Unit	Collimation	MP	Beam-Beam
ROI	e.g. 3.5 to $+\infty$	Sigmas $\epsilon_n = 2.5\mu m$	4.7 to 6.7, 6.5 to 8.5	4.7 to 6.7, 6.5 to 8.5	3.5 to 8.5
Contrast Required	Resolve halo at xx sigma / core-peak=1e-4	-	10^{-4} at upper bound	10^{-6} at 6.7σ	5×10^{-5} at 7σ
Relative Integral	(Halo/total) measurement range for ROI	# of p	5% to 0.5%	1.4% to 0.2%	
Absolute Integral	# of p in ROI	# of p	1.5×10^{12}	$(1-4) \times 10^{10}$	
Charge Required	Yes / No	-	Yes	Yes	No
Profile Required	Yes / No	-	No	No	Yes (complementary to BWS)
Profile Desirable	Yes / No	-	Yes	Maybe	-
2D Image Required	Yes / No	-	No	No	Yes
2D Image Desirable	Yes / No	-	Yes	No	-
Acq. Rate	for full machine	Seconds	≈ 60	≈ 10	≈ 60
Gating and Integration	Bunch per Bunch / Trains / other	-	Beam	Train of 48b	bunch per bunch
Integration over Multi Turns Acceptable	Yes/No	Yes	Yes	Yes	Yes
Interlocking Desired	Yes / No (=monitoring only)	-	No	Yes	No

F. Roncarolo, 14th HL collaboration meeting

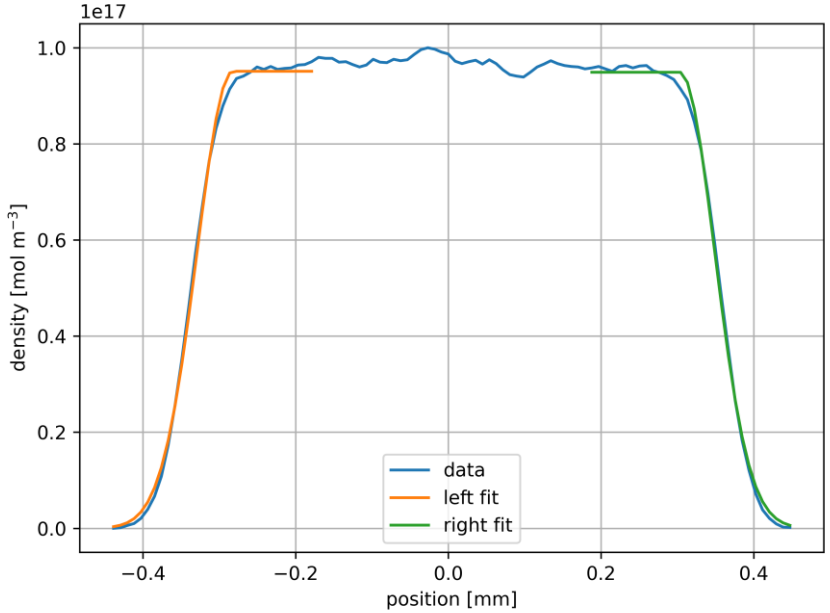
Minimal requirements are very tight

- region close to the core
- high contrast (punctual and integrated)
- gated measurements necessary
- ultra-high reliability (interlocked system)

Hard to satisfy all of them by start of HL-LHC, may split tasks across complementary systems

Spatial resolution

Spatial resolution determined by **jet sharpness and uniformity**



Current jet profile has Gaussian edges with $\sigma_{edge} \simeq 100\ \mu\text{m}$, acceptable to resolve beams with $\sigma_{beam} \simeq 300\ \mu\text{m}$

Alternative HL optics proposed to locally increase beta functions up to factor 4, specifically for diagnostics

Contrast

A halo monitor candidate should be immune to signal from core.
For BGC, this requires **minimizing the signal created outside of the jet**.

Consider two contributions for background

- ”**tails**” due to transverse gas motion, create background in the vicinity of the jet.
  Current factor ~50÷80, target is 100 (or better).
  Might be improved by optimized design of injection systems (skimmers).
- increase of **residual pressure** in vacuum chamber due to diffusing gas.
  Currently spreading for several meters around the BGC.
  Could be improved by increasing pumping power and optimize jet dump.

Investigations ongoing to find theoretical limit due to background, in optimized scenario

If sensitivity allows, background signal could be compensated by moving the jet away from the beam and subtract a reference (advantage of having a movable probe!)

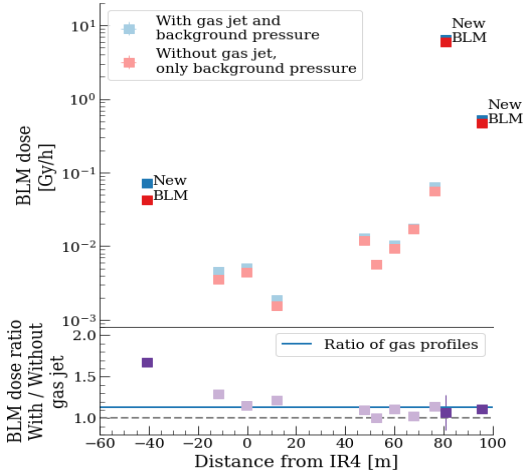
Sensitivity

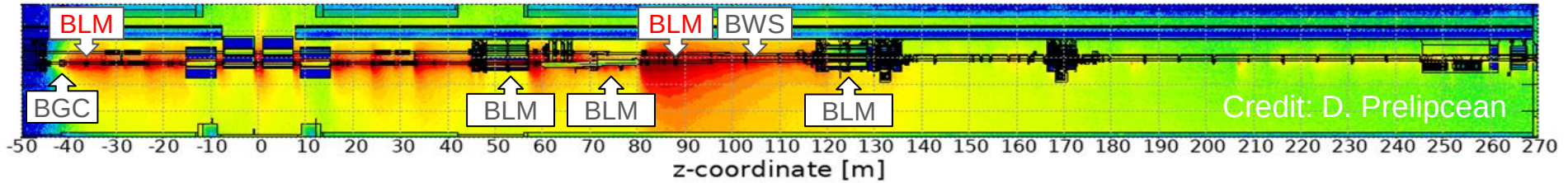
Optimizing sensitivity requires **maximizing the production and detection of losses**, specifically the ones of the jet

Production of losses given by max pressure (~fixed) and geometric overlap with beam (margin for improvement)

Detection of losses not optimized at present.
Additional BLMs installed in YETS:

- just downstream of BGC for maximum sensitivity to jet
- in radiation hotspot in 5R4 for maximum total dose





Acquisition rate and temporal requirements

Losses co-propagate with beams, **bunch-by-bunch measurements physically possible**

Requirement from machine protection is to resolve **trains**, increasing margin for signal

Most application requires “slow” average measurements (~10s), but some fast failure scenarios may require prompt intervention

Standard LHC ionisation chamber BLM are not gated, only average measurements. There are **operational systems for fast loss detection**

- wire-scanner scintillators (easily deployable as stand-alone detectors)
- diamond-BLM

Interlocking

Interlocking the halo monitor requires **ultra-high reliability of all subsystems** involved to avoid spurious dumps

Gas injection system

- very robust in regular operation (fully static system).
- if background compensation regularly required, need to define a suitable strategy.
- presence of pressure fluctuations and/or spikes to be assessed.

Losses detection system

- if standard LHC BLMs sufficient, not an issue.
  Otherwise, detector reliability to be validated.
- minimal signal processing required, little prone to failures in data handling.

Possible timeline before LS3

YETS 24-25: installation of additional BLMs dedicated to studies of losses

Run 2025

- experimental priority will likely remain full exploitation of emittance measurements
- investigation on losses induced on new BLMs and BWS scintillators.
  If we have signal with low intensity beams, we can ask for MD and try to bump the beam outside of existing jet (probably possible with safe beams)
- might consider switching skimmer to halo in TS (very ambitious and risky)
- studies to clarify open points (integration, optimum injection design, detection…)

mini-YETS 25-26: possible switch to halo configuration (more realistic)

mini-run 26: could be fully devoted to halo measurements

Thank you for your attention!