

11th BGC collaboration meeting Liverpool 2nd December 2024

Summary of 2024 experimental results at LHC

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Overview of 2024 run

YETS / machine commissioning

- resolution and focusing studies
- development of data processing tools

Proton run

- re-commissioning with beam, addressing open points from 2023
- systematic measurements

lon run

- re-commissioning with ions
- systematic measurements with real time emittance monitoring



Collisions with First Stable May VIP, visit Jun Apr beams @ 6.8 TeV 1200 bunches 16 17 18 19 20 21 22 23 24 25 26 Wk 14 15 Mo Whitsun 20 22 Tu Interleaved MD 1 commissioning 1st May We 2 TC1 intensity ramp up Th Ascension VdM program Fr rvo reconfi MD 2 Sa spare Scrubbing Su Jul Aug Sep Oct 27 28 29 30 31 32 33 34 35 36 37 38 39 Wk Мо Tu







System re-commissioning



Focusing and resolution assessment



Magnification and resolution of the optics needed to get beam size from the image size

$$\sigma_{image} = M \sqrt{\sigma_{source}^2 + \sigma_{res}^2}$$

Several tests during YETS \rightarrow independent techniques yield consistently \sim 65 um resolution







Data processing



ETS

System re-commissioning

BGC re-commissioned during LHC intensity ramp-up

- optics centered and focused
- recommissioning of gas injection system in steps
- beam losses confirmed well within BLM limits









Photon counting vs frame stacking

Photon counting and intensity stacking approaches compared

- generally consistent, except for counting failure due to clustering
- no evidence of major advantage with photon counting.
 Stacking used in regular operation (simpler and faster)



For large beams, counting and stacking coincide (e.g. injection energy)

For small beams, counting is systematically larger, due to failure of photon counting at high photon density.

Exposure < 25 ms required in single photon studies. Data recorded for offline analyses.







Example of photon detection in a single frame of 50ms exposure

Highlights from proton run



Accuracy validation

Assessing accuracy and reproducibility of absolute measurements

- observing visible neon transition (no space charge)
- considering horizontal direction (no jet thickness effect)

Noisy measurements (±10% peak-to-peak) but values **consistent** with emittance scans and **reproducible** over several fills





Limitations with visible fluorescence



Working with the neutral line has drawbacks

- poor signal \rightarrow noisy measurements
- long exposures \rightarrow limited use for transients
- low profile quality \rightarrow impossible to deconvolve



Injection





Using visible line with existing configuration, BGC is effective mostly for accurate assessment of horizontal emittance in stable beams





Combining visible and UV fluorescence



BGC optics allows observing the **more intense UV lines** of neon





Non-destructive profile measurement of intensive heavy ion beams, F. Becker 2010

Apparent gain in signal quality

- exposure time < 1 min
- lower statistical fluctuation of fitted size
- better profiles



Combining visible and UV fluorescence



Better signal quality comes at the **cost of poorer resolution** due to space charge effects

Problem of UV resolution handled in semi-empirical way

- assume visible measurement provides "true" beam size
- derive UV resolution as a correction parameter, polynomial function of the beam current



Obtained resolutions in the order of 200 µm, vs 65 µm measured with visible light.

This is not ideal for flat-top beam size but **good for injection and ramp**, where the higher signal is actually demanded



Combined results for horizontal plane

Combined UV and visible measurements allows accurate measurements every 40s

Fluctuations within **±5% in emittance**, compliant with specifications from operation

Absolute values still compatible with emittance scans at start and end of fill

This configuration was setup towards end of proton run, **long term reproducibility to be assessed**





Combined results for horizontal plane



Overall **positive results**

- quantitative agreement with BSRT at injection
- "smooth" behavior in ramp
- qualitative agreement with BSRT at FT (e.g. dynamic beta effect on collision)
- quantitative agreement with emittance scan



BGC UV acquisition during energy ramp (ROI follows beam size)



Vertical direction (perpendicular to jet)





Ideally, the vertical profile of the image has

- intensity plateau from uniform jet distribution
- Gaussian edges from beam distribution

 \rightarrow beam size information only encoded in the edges, retrievable from $\ensuremath{\text{deconvolution}}$

If jet thin enough, deconvolution can be replaced by simple Gaussian fit and correction in quadrature

In reality,

- deconvolution works with low-noise profiles \rightarrow only BGC UV usable
- real jet profile not perfectly rectangular → jet edges further correction to beam size
 ... these issues are mitigated if beam size is larger (low energy)



Vertical direction

Deconvolve BGC UV profiles to assess beam size

Larger fluctuations at flat-top than horizontal, ±15% emittance, due to extra correction for jet thickness

No accurate reference from BGC VIS. Deconvolution seems to match emittance scans but reproducibility to be assessed...





Vertical direction during ramp

Still some positive results:

- BGC, BSRT and BWS are compatible within 10% at injection
- "smooth" behavior in ramp, not so different from horizontal case
- within larger BGC fluctuations, good agreement with BSRT and emittance scan at FT

As size decreases, jet thickness effects appear

- simple Gaussian fit deviates from deconvolution
- measurements become noisier







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Highlights from ion run



Performance with ion beams

More favorable conditions with ion beams

- stronger fluorescence signal
- larger beam sizes

sufficient signal with visible configuration, no need to combine UV signal



Limited availability of BSRT with ions:

- no light at injection
- rarely calibrated at flat-top

there is already the case for extra diagnostics



Highlights from 2024 ion run

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BGC continuously running throughout 2024 ion run, close to an operational way

Average emittance measurements available online





Conclusion

BGC performance as emittance monitor thoroughly assessed in 2024

Achievements with proton beams

- accurate and reproducible measurements for horizontal direction in stable beams
- combined UV-visible operation best option for injection and ramp
- reducing jet thickness beneficial for vertical direction in stable beams

Achievements with ion beams

- stronger fluorescence and larger sizes simplifies BGC operation
- effective online emittance monitoring during ion physics production



Towards 2025...

2025 run will be shorter due to the extended YETS 24-25

Yet, dense program for BGC

- assessment of long term stability
- operational implementation of combined UV-visible operation
- improve vertical measurements with thinner jet (hopefully)
- extra O-O ion run planned
- studies to upgrade to loss-based diagnostics (but this is another story...)



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Thank you for your attention!

