Non-destructive beam profile measurements with an Ionisation Profile Monitor (IPM) based on Timepix3&4 Hybrid Pixel Detectors (HPD's)

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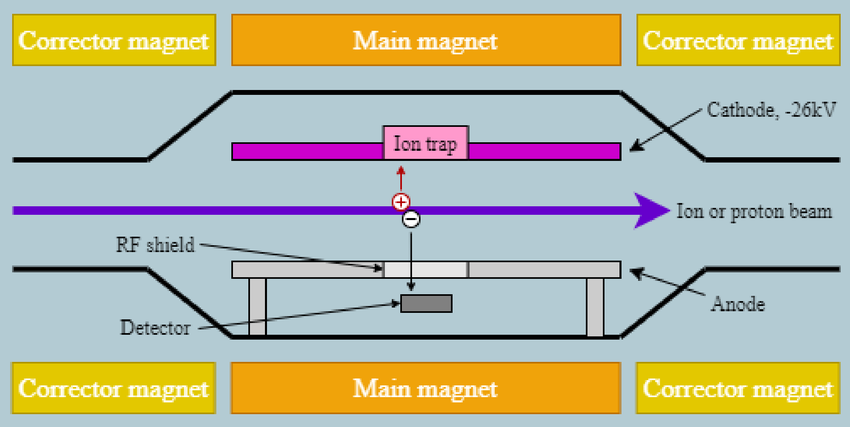
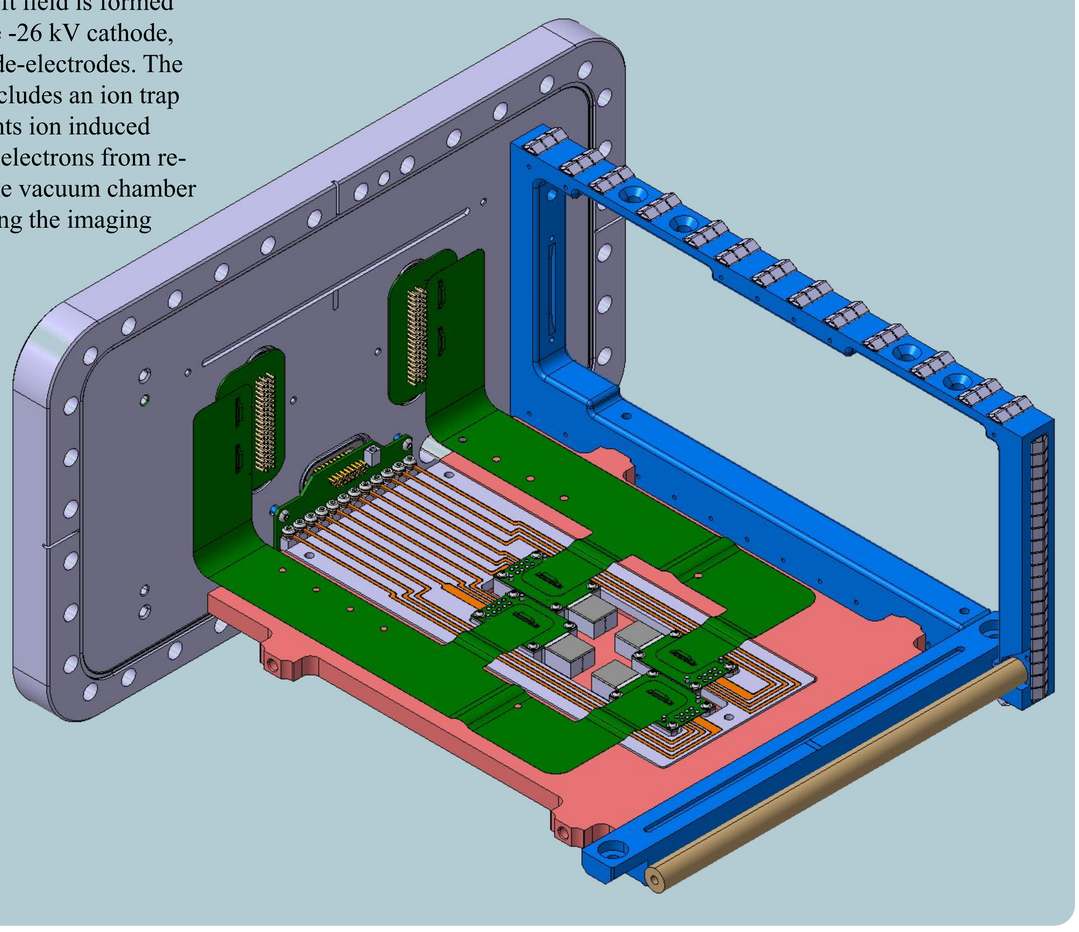
BGI Overview

The BGI is a transverse profile monitor.

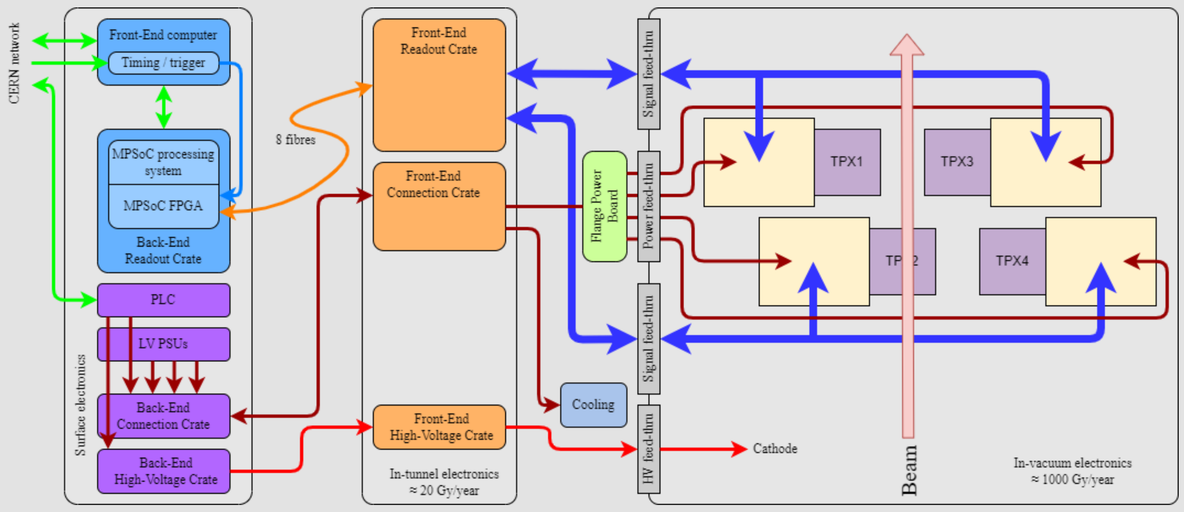
Rest gas ionisation electrons are accelerated by an electric drift field towards an electron imaging detector using 100µm thick P-in-N-bulk sensors, located beneath a radio-frequency shield. A magnetic field parallel to the electric field, formed by a self-compensating 0.2 T dipole magnet, helps to maintain the transverse position of the ionisation electrons during transport to the measurement plane. The electric drift field is formed by a single -26 kV cathode, without side-electrodes. The cathode includes an ion trap that prevents ion induced secondary electrons from re-entering the vacuum chamber and reaching the imaging detector.





Main developments

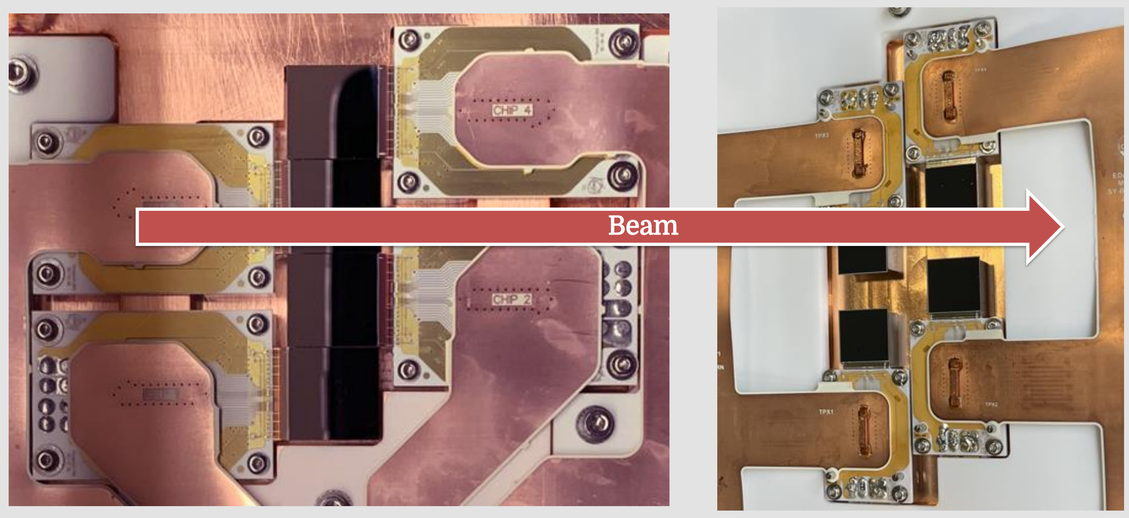
Radiation-hard readout using GBTx



Detector orientation changed to remove column bottleneck. The event data flows down the columns, so if the beam lies over just a few columns, the readout rate is limited.

PS arrangement

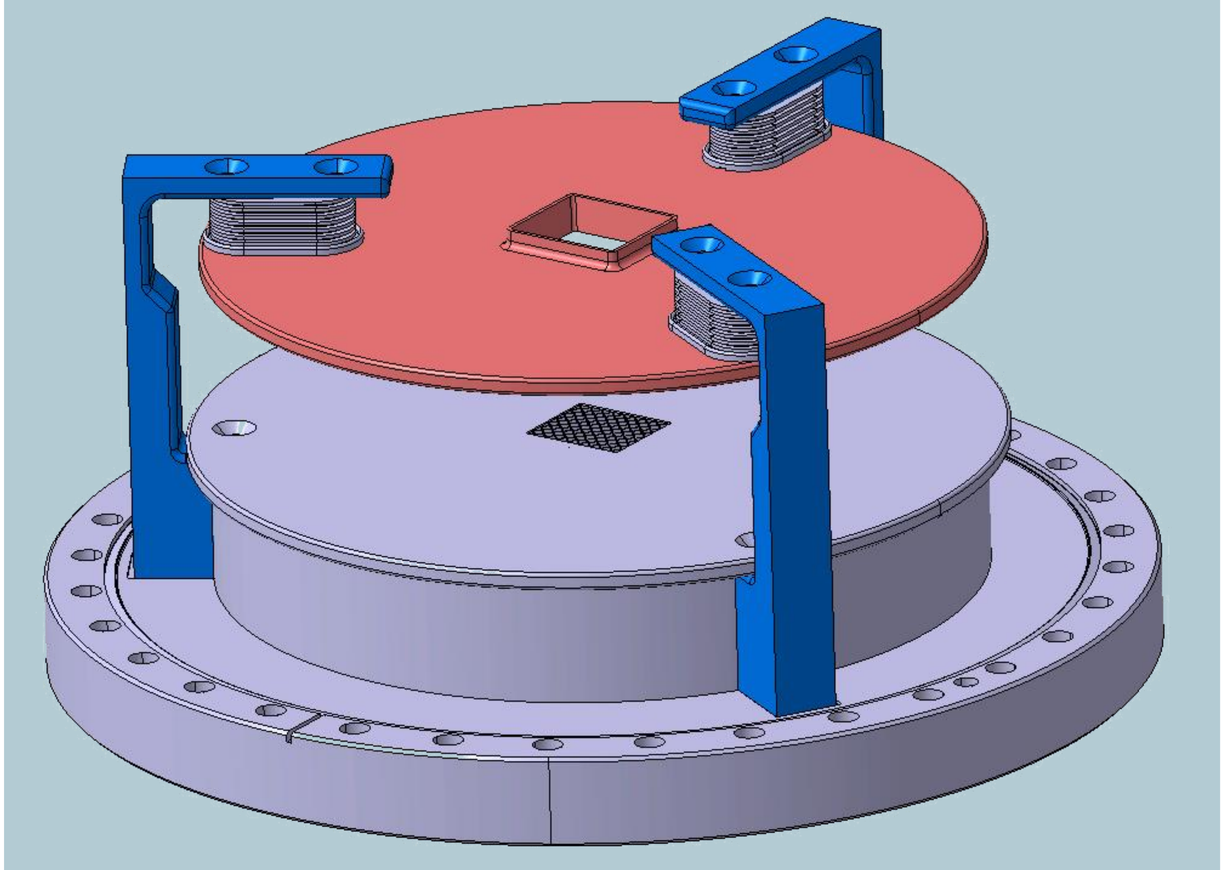
SPS arrangement



Next steps

Horizontal and Vertical BGIs are planned for the LHC. Several options for the design are being explored, using either Timepix3 or Timepix4. One elegant solution uses parts from the 4D Photon project for the vacuum feedthrough and Timepix4 support.

However, before we can go very far with the design of the HL-LHC-BGI, we need to understand a problem that we are facing in the SPS-BGI. This is that beams with strong high frequency components (large intensity and fast rising edges on the bunches) cause the Timepix3 to go into reset. We have largely ruled out beam loss and Single Event Upsets as the cause of the problem, but it is not yet clear if the problem relates to the power supply for the Timepix3, or the Timepix3 itself.

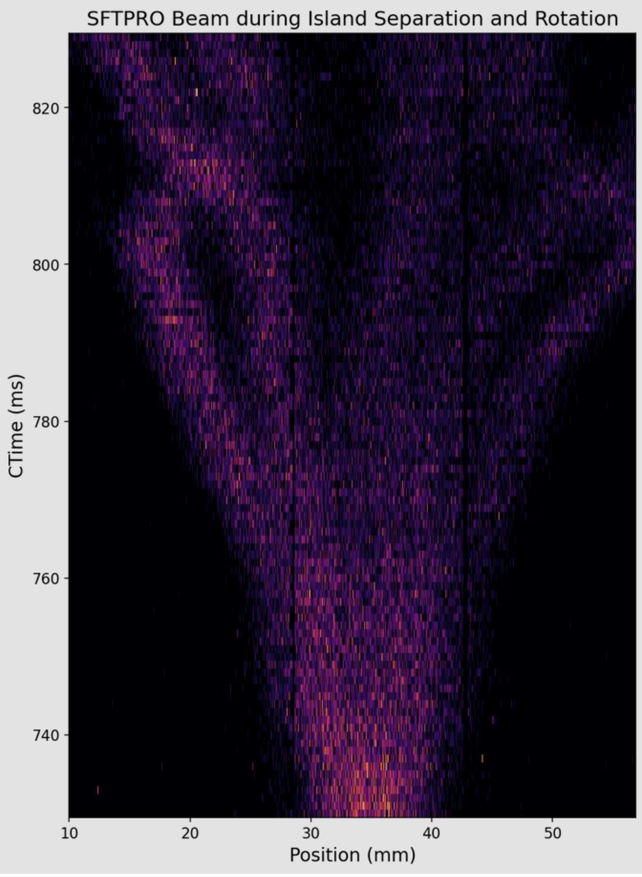


Operational experience

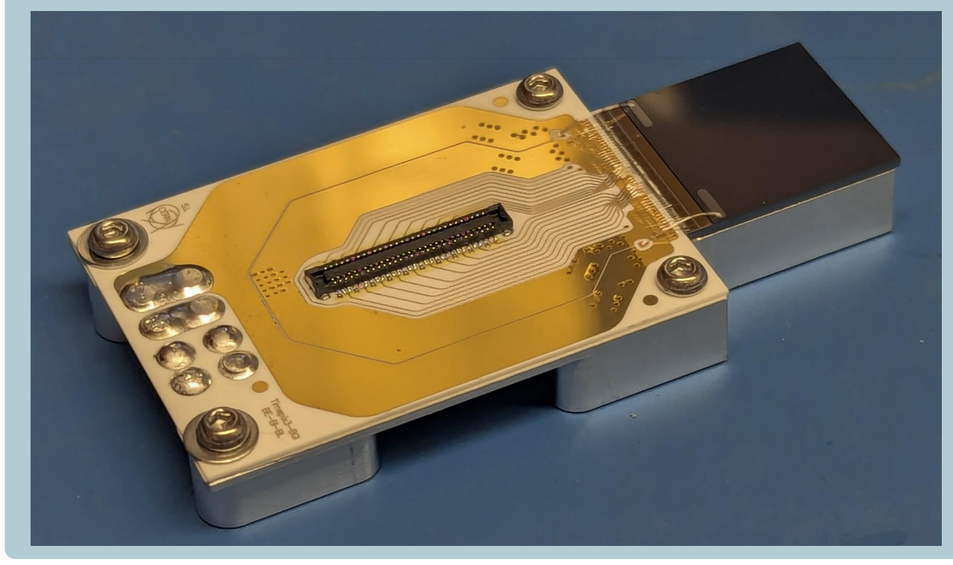
Since 2021, BGIs have been installed in the PS. We have obtained good results from comparison with the Wire Scanners and been able to collect nice plots of the beam evolution (see left).

Despite these successes, the operational adoption of the PS-BGIs has been slow, mostly because the instrument remains difficult to use. Outstanding issues include:

- Beam loss saturates the readout chain, causing subsequent profiles to be lost.
- Vertical instrument has an insufficiently strong electric field to give good profiles at flat-bottom.
- Noisy pixels appear from time to time, severely distorting the profile.



Detector module



Instead of mounting all the detectors on one ceramic board, we have changed to making individual modules. The Timepix has a good thermal connection to the aluminium base (using Staystik AIN672) and it is straightforward to change a single module in case of failure.

Conclusion

Much work has been done over the past few years to improve the BGIs and make them more suited for operational use. They are now installed in the SPS as well as the PS. Our next task is to help the operators to get the best from the instruments and for the engineering team to identify the features and improvements that are most needed. We look forward to these capable and flexible instruments finally fulfilling their potential.

Acknowledgements

The BGI would not exist without the many years of hard work that Swann Levasseur and Hampus Sandberg put into its development.