Non collision background studies in ATLAS detector during Run 2 data taking

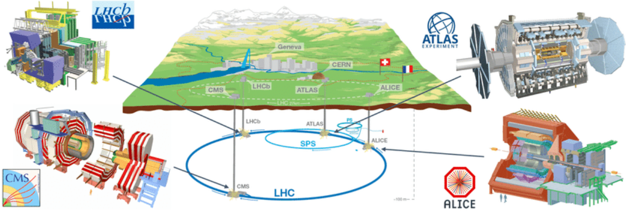
Fatima Zahra LAHBABI - on behalf the ATLAS collaboration
2025 joint meeting of the African Light Source (AfLS), the African Physical Society (AfPS)

November 20, 2025

جـامعة الحسن الثـاني بالدار البيضاء
ⵜⴰⵙⴷⴰⵡⵉⵜ ⵏ ⵃⴰⵙⴰⵏ ⵡⵉⵙⵙ ⵙⵉⵏ ⴳ ⴹⴹⴰⵕⵍⴱⵉⴹⴰ
UNIVERSITÉ HASSAN II DE CASABLANCA

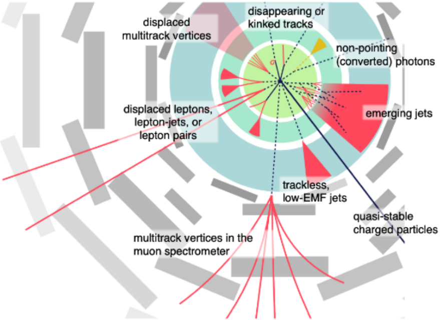
The Large Hadron Collider (LHC) accelerator and the ATLAS detector

- LHC is the world's largest and most powerful particle accelerator that pushes protons or ions to near the speed of light.
- The LHC accelerates two high-energy particle beams, of protons or heavy ions, in opposite directions at close to the speed of light.
- The beams are made to collide at four interaction points, where detectors, including ATLAS, monitor and analyze the resulting particle interactions.



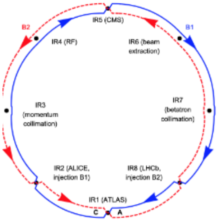
Introduction and motivation

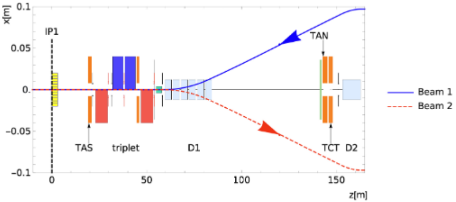
- The interactions of Long Lived Particles (LLPs) or their decay products with the detector are significantly impacted by their displacement.
- LLPs have signatures similar to events originating from beam induced background or cosmic background.
- Non Collision Backgrounds (NCBs) constitute an important source of background for these analyses.



The Large Hadron Collider (LHC) accelerator and the ATLAS detector

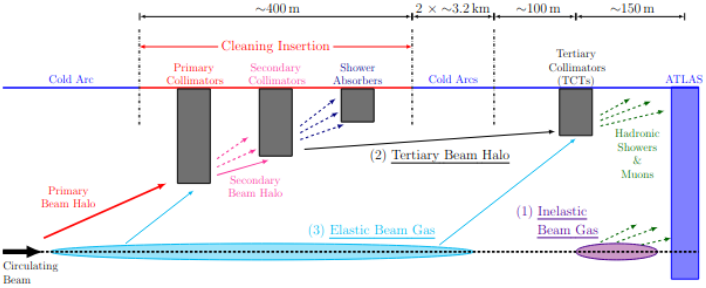
- Four interaction regions (IRs) house the radio frequency (RF) cavities for beam acceleration, the beam dump and the beam cleaning system formed by (IR3) and (IR7).
- Each IR is located at the centre of a long straight section (LSS).
- The main accelerator components in the LSS are dipole magnets D1 and D2, TAS and TAN absorbers and the tertiary collimator (TCT).





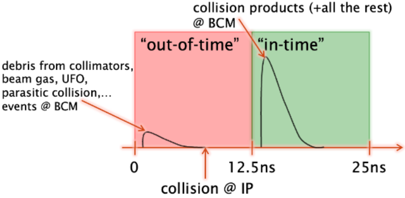
NCB origins

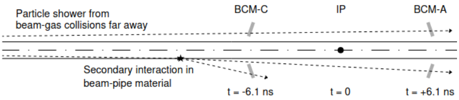
- Inelastic beam-gas: inelastic hits of protons with residual gas molecules can create showers of secondary particles.
- Beam-halo losses : due to beam protons that have escaped the beam core and impact on one of the beam cleaning collimators.
- Elastic beam-gas: protons with a small-angle deflection can result from beam-gas elastic scattering.
- Cosmic-ray showers: produced in the atmosphere, predominantly muons travelling downward.



NCB triggers

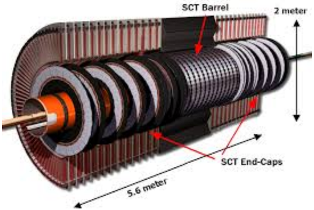
- To digest the data, ATLAS uses an advanced trigger system to tell the detector which events to record and which to ignore.
- The signature of beam-induced beam (BIB) in the beam condition monitor (BCM) is formed by one early hit on one side and an in-time hit on the other side of the interaction point (IP).
- Radiative energy losses of high-energy muons traversing the detector result in electromagnetic showers (fake jets) are selected by a jet trigger recording which fires on a transverse energy deposition above $E_T > 12$ GeV.

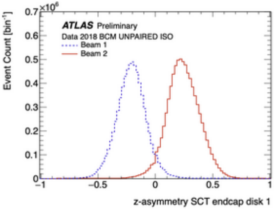


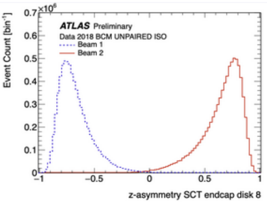


NCB in the inner detector

- The z-asymmetry quantifies the difference in the in-time hits in downstream and upstream endcaps of sub-detector.
- The separation between beam 1 and beam 2 distributions increases for the outer disks.

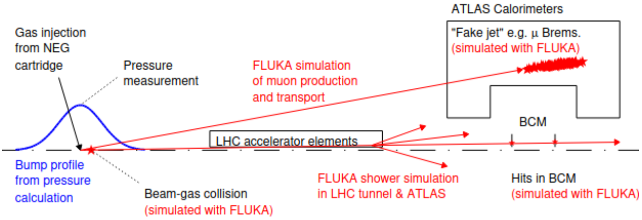






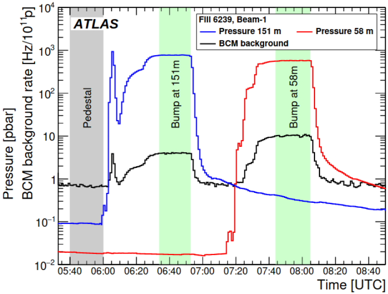
Pressure bump test https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/DAPR-2021-02/

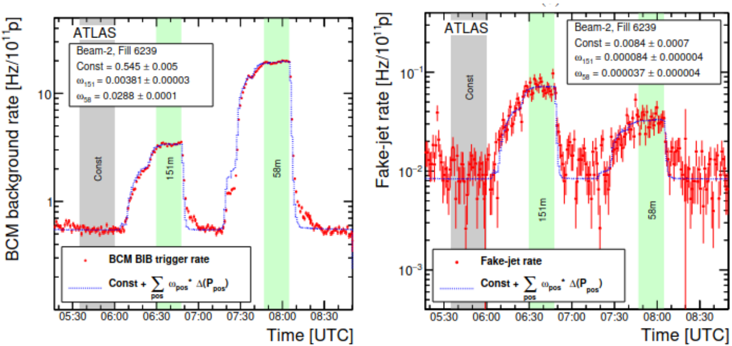
- Pressure bump test is done to estimate the efficiency of the ATLAS beam background monitors to detect beam-gas events.
- Non-evaporable getter (NEG) cartridges were heated such that some of the gas they had absorbed was re-injected into the LHC beam vacuum.
- Pressure bumps were created at four different locations z=$\pm 151m$, z=$\pm 58m$, z $\pm 22m$, and z=$\pm 19m$.



Fitting procedure https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/DAPR-2021-02/

- The grey-shaded area indicates the time periods over which the pedestal pressure and background are averaged.
- The green shaded areas correspond to the averaging over the stable pressure periods of each of the two bumps.
- In the pressure region the pedestal C is subtracted from the measured background rate in order to obtain B.
  $B = C + \omega(z_i)\Delta P(z_i)$ with $\omega(z_i) = \frac{\Delta B}{\Delta P(z_i)}$



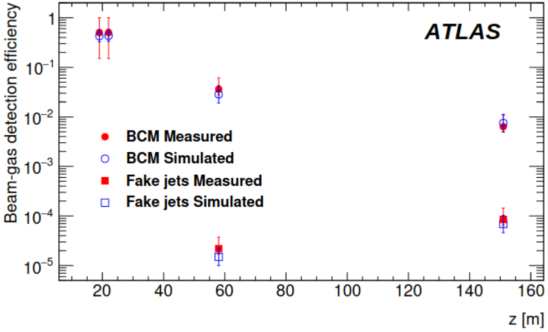


- The pressure parameterisations follow very closely the BCM backgrounds.
- Excess jet rates are clearly resolved even though the pedestal level is rather noisy.

Comparison with simulations

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/DAPR-2021-02/

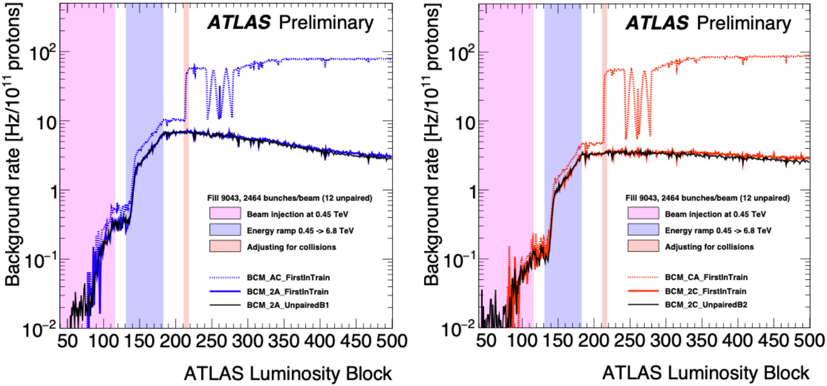
- The efficiency summary plot of the two BIB rates as function of z is shown.
- $\epsilon(z) = \frac{\Delta B}{\Delta R_{BG}}$ with ΔR_{BG} is the rate of additional beam gas events.
- The $\epsilon_{BCM}(z)$ decreases with distance from the IP while $\epsilon_{jet}(z)$increases.



Run 3 improvements in background measurement

https://cds.cern.ch/record/2919501/files/ATL-COM-DAPR-2024-035.pdf

- The new algorithms '2A' and '2C' with two early hits enable a beam background measurement on some paired bunches of colliding trains



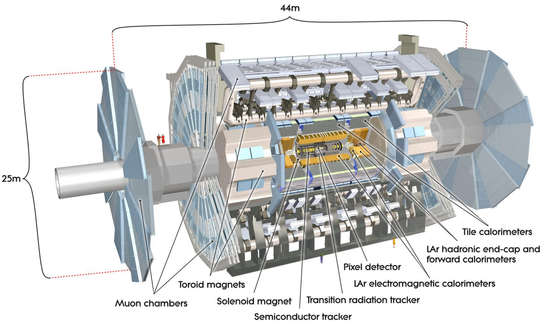
Conclusion

- NCBs have been characterised in terms of signatures in the detector, and rates.
- Understanding NCB events is an important task for providing feedback to the LHC accelerator, to ensure a good quality of recorded data, and to provide estimates for physics analyses, depending on unconventional signatures.
- These results, and the successful benchmarking of the simulation methods, provide important information for the study and optimisation of future accelerator configurations and BIB mitigation methods.

Thank you for your attention, any questions?

Backup

The ATLAS detector



LHC cycle machine