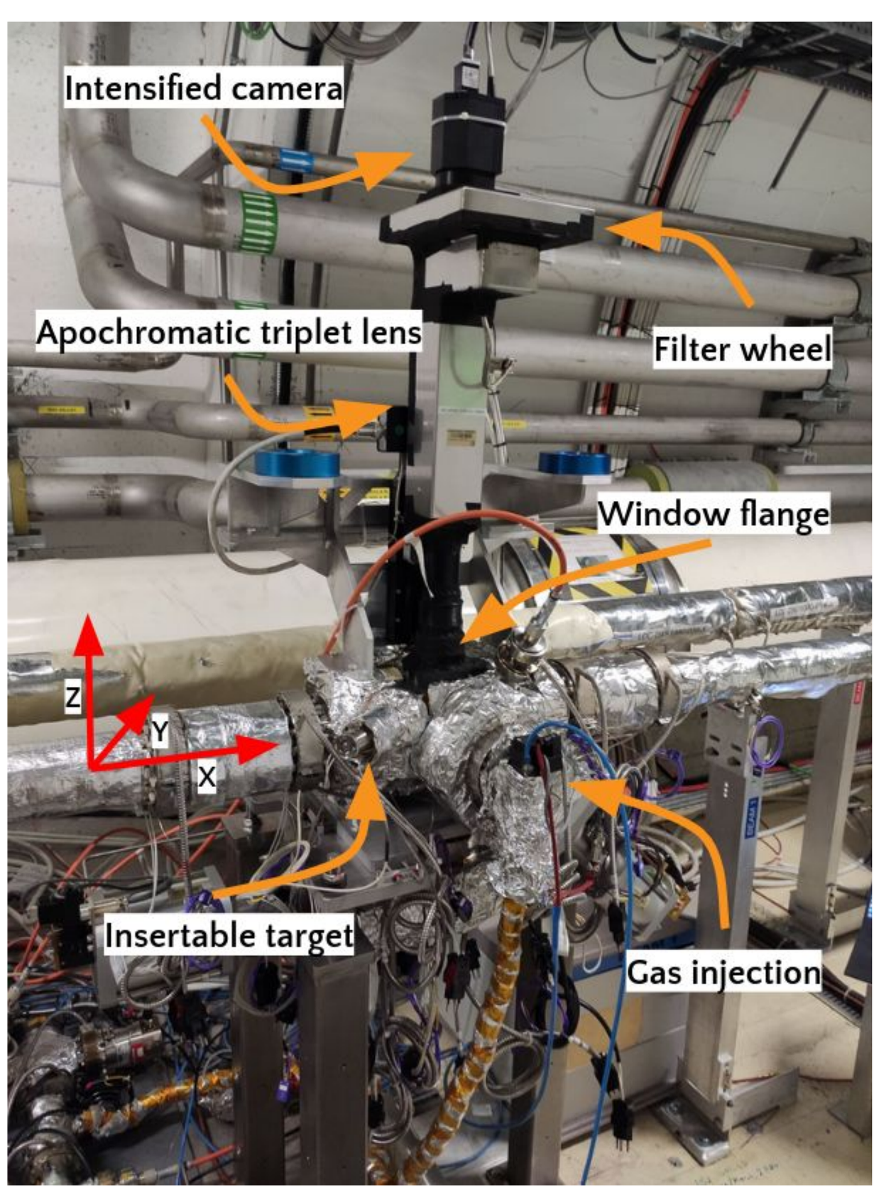
HL-LHC Beam Gas Fluorescence Studies for transverse Profile Measurement

O. Sedlacek[12], O. Stringer[2], C. Welsch[2], H. Zhang[2], University of Liverpool, Liverpool, UK
M. Ady, A. R. Churchman, S. Mazzoni, M. Sameed, G. Schneider, C. C. Sequeiro, K. Sidorowski, R. Veness, CERN, Geneva, Switzerland
P. Forck, S. Udrea, GSI, Darmstadt, Germany
[1]also at CERN, Geneva, Switzerland
[2]also at Cockcroft Institute, Daresbury, Warrington, UK

Abstract

In a gas jet monitor, a supersonic gas curtain is injected into the beam pipe and interacts with the charged particle beam. The monitor exploits fluorescence induced by beam-gas interactions, thus providing a minimally invasive transverse profile measurement. Such a monitor is being developed as part of the High Luminosity LHC upgrade at CERN. As a preliminary study, the fluorescence cross section of relevant gases must be measured for protons at 450 GeV and 6.8 TeV (i.e. the LHC injection and flat top energies). In these measurements, neon, or alternatively nitrogen gas, will be injected into the LHC vacuum pipe by a regulated gas valve to create an extended pressure bump. This work presents the optical detection system that was installed in 2022 in the LHC to measure luminescence cross-section and horizontal beam profile. Preliminary measurements of background light and first signals are presented in this paper.

EXPERIMENTAL SETUP



- Measurement of beam-induced fluorescence yield of neon at 585 nm with protons at 450 GeV and 6.8 TeV
  - Transition: $2s^2 2p^5\,(2P^0{}_{1/2})3p^2[½]_0 \rightarrow 3s^2\,[½]_1$
- New experimental setup on LHC Beam 1
- Neon gas injection to LHC at pressures up to 5×10^{-8} mbar in LHC pipe
- Low expected cross-section -> Blackening + optical optimization
- Vacuum chamber blackened by amorphous carbon coating: Reflectivity 14%
- Ultra-low reflectivity black contrast plate with multi-layered coating: Reflectivity 0.25%

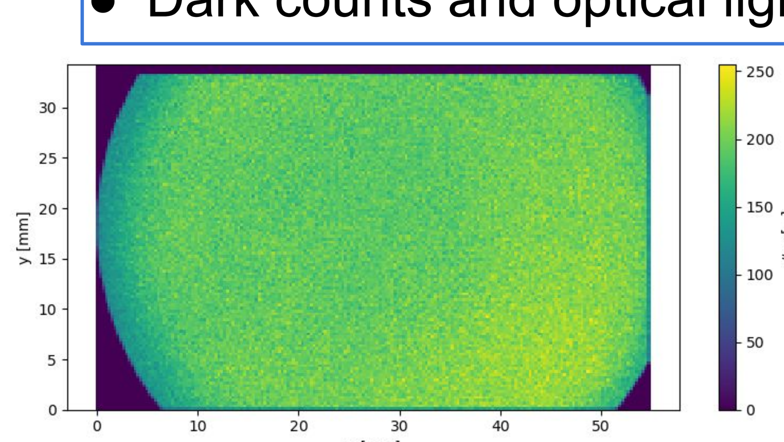
Optical system - Modulation transfer function

- Filter wheel: 585 ∓ 10 nm, Blocking filter and empty socket
- Apochromatic triplet lens t
  - trasmittace ~ 80% over wavelengths of interest
- Final trade-off magnification: 0.205
- 10.5pix per 300um corresponding to the LHC beam σ
- Solid angle - 1.8×10^{-2} sr
- Acceptance of 1.4^{-3}

MTF [%]	line/mm
46	1.000
38	0.500
26	0.250
13	0.125

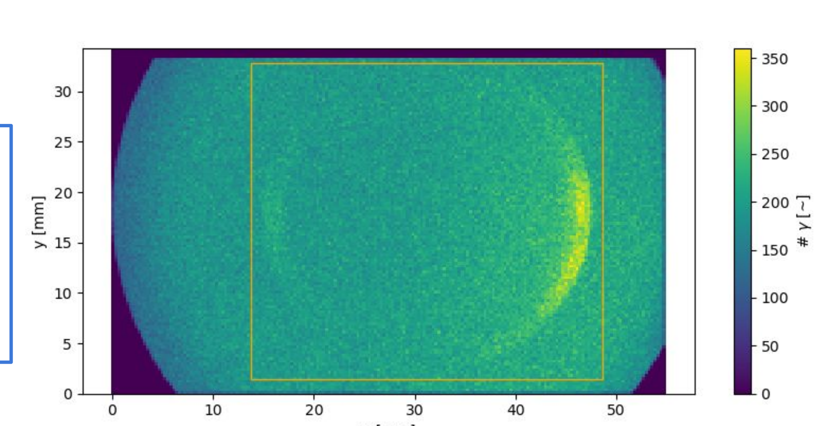
LHC background measurements

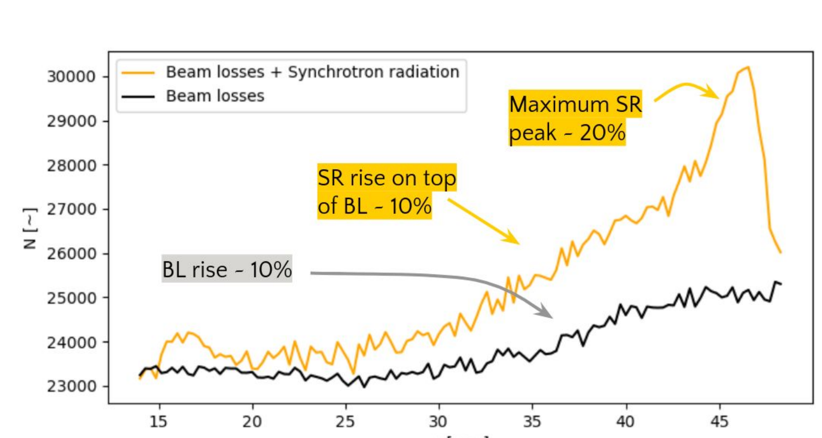
- Measurements of background in presence of LHC beam at 6.8 TeV without injecting gas
- Main background sources: Beam losses and Synchrotron radiation
- Dark counts and optical light background measured to be negligible



- Measurement with blocking filter
- Beam losses cause photon-like signal when traversing the camera module

- Measurement with 585 ∓ 10 nm filter
- Synchrotron radiation makes up 3.7% of all background signals

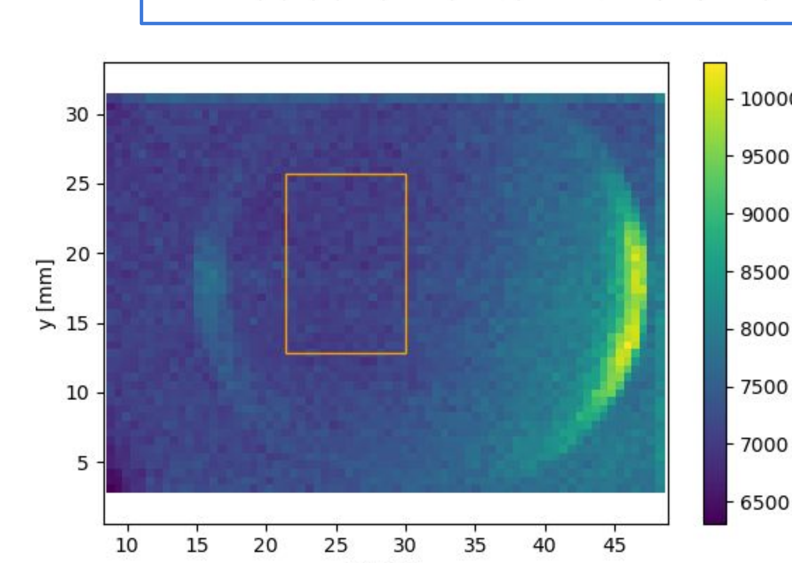




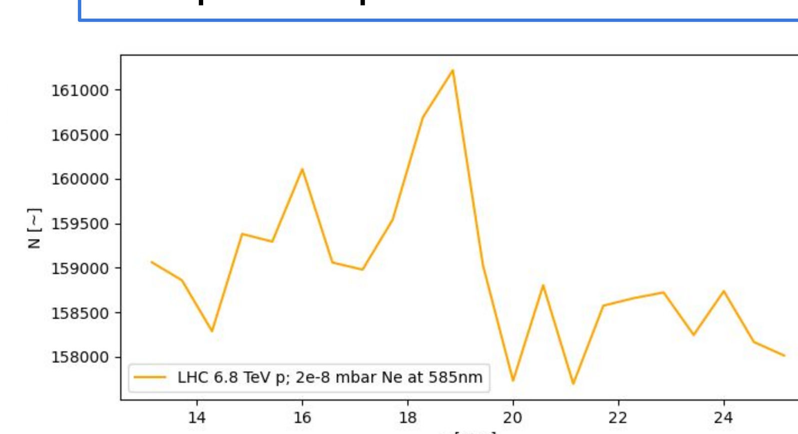
- Distribution of both beam losses and synchrotron radiation show inhomogeneity

Background vs signal

- Measurements with 6.8 TeV LHC proton beam and 2×10^{-8} mbar Ne



- First small fluorescence signal at expected position



Conclusions

- New imagining and gas injection system installed in LHC to measure neon fluorescence light yield with protons at 6.8 TeV.
- Background dominated by beam losses and synchrotron radiation signals
- Small fluorescence signal observed for very first time at 6.8 TeV with long integration times.
- Next phase using supersonic gas curtain increases of gas density by two orders and decreases integration time.
- This will result in more precise measurements of the fluorescence cross section and non-invasive beam profile measurements.

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