Thesis Abstract

Quentin DUONG

Title: Electron cloud studies with the CERN LHC Vacuum Pilot Sector

Abstract: *Context.* Electron clouds – generated by synchrotron radiation, residual-gas ionisation and secondary electron emission – limit the performance of high-intensity accelerators. At the LHC, they induce pressure rises, transverse instabilities and heat loads on superconducting magnets, reducing luminosity. Their understanding and mitigation are crucial for the LHC, HL-LHC and future projects.

Method. This thesis exploits the Vacuum Pilot Sector (VPS, LSS8), combining photon, electron, gas and calorimetric diagnostics to measure photoemission, multipacting, energy spectra, desorption and electron-induced heating. A full calibration and analysis chain, coupled with PyECLOUD simulations, was developed to interpret Run 3 measurements and extract effective surface parameters comparable with laboratory data.

Results. Primary electron generation is dominated by photoemission at LHC energies, but photon flux strongly depends on beamline geometry. Materials show distinct behaviours: amorphous carbon efficiently suppresses multipacting, NEG coatings also reduce residual gas, while copper exhibits the highest electron activity but strong conditioning ($\delta_{\mathrm{true}}^{\mathrm{max}}$ ≈1.2-1.3). Differences are observed between stations of the same material, linked to synchrotron exposure and conditioning history, highlighting the heterogeneous nature of cloud dynamics. Energy spectra reveal that ~50\% of electrons have <140 eV and ~95\% <1400 eV, with two peaks corresponding to secondary electrons (low-energy, stable) and beam-accelerated electrons (~200 eV, intensity- and orbit-dependent). No ion densities above residual-gas predictions (~fA.cm^2) were detected. Heating estimation reaches a few W/m in copper, imposing a constraint on cryogenic margins; yet, calorimetric data couldn't clearly confirm or infirm those.

Contributions & Outlook. This thesis establishes an integrated VPS analysis framework and an operational method to extract $\delta_{\mathrm{true}}^{\mathrm{max}}$. The results benchmark and refine simulations, highlight material influence, and clarify electron-cloud heterogeneity. They provide guidance for HL-LHC optimisation and offer a transferable methodology for future high-intensity accelerators (coatings and filling schemes).