Summary

Muography is an emerging imaging method that utilizes the muon particles present in the cosmic rays on Earth. These naturally occurring high-energy muons are able to penetrate even kilometers of rock. The principle of imaging is that denser matter absorbs more muons, similar to X-rays in bones. To a first approximation, the detected muon flux depends only on the zenith angle of the arriving particles and the material density integrated along the muon path (density-length). The strictly monotone function between the muon flux and density-length is the core of absorption muography, thus providing a powerful tool to image the average densities of 10—1000 m rock layers by detecting muon trajectories in a given direction unit. The research field is interdisciplinary by nature, which has been one of the main challenge to the development in recent decades. From the measurement technology side, different muon tracking detector technology trends have emerged for muography, originating from high energy particle physics experiments. In my PhD dissertation, I present my gaseous detector research and development works and data evaluation efforts for muography applications.

I will elaborate on developments of the advanced MWPC (Multi-Wire Proportional Chamber) detector type for the applicability in a wide range of muography situations (thesis statement 1), which sets the following requirements for the detectors: long-term stability in underground or surface measurements, withstand ambient temperature, pressure, and humidity variations, mobility and robustness against transportation stresses, in addition to the cost efficiency, safety, and autonomous operation.

I will present the research on low gas consumption of MWPCs in order to significantly reduce the detector maintenance (thesis statement 2). The autonomy of the detector, and hence the low gas consumption to reduce maintenance, is crucial in specific muography applications. Because remote data collection can span over several months, frequent maintenance requirements (gas cylinder replacement) could render muography surveys infeasible in certain cases, particularly when local infrastructure is lacking. I objective was to investigated how to operate the gaseous detectors with the lowest possible gas flow, keeping in mind the simplicity, which still results safe detector performance.

I will introduce my reasearch and developments on our “Leopard” nicknamed scanner for an exclusive diagnostic examination of GEM (Gas Electron Multiplier) detectors (thesis statement 3), which is also a promising technology for muography. I enhanced the system resolution so not just Thick GEMs (300—400 µm diameter holes on the surface) but standard GEM foils (50—70 µm hole diameters) can be scanned, furthermore not just gold plated surfaces but the widespread copper-plated ones (much lower quantum efficiency, thus lower photoelectron yield) can be examined. As a result of the developments, my motivation was to investigate the gain-homogeneity of GEMs and the effect of manufacturing defects in order to optimize the technology and quality control.

In the final sections of the dissertation, I will describe my efforts to produce muographic images to reconstruct density distributions (thesis statement 4). In addition to muographic data processing, my goal was to develop a tomographic inversion method for determining the spatial location of density anomalies. I processed experimental data from the Királylaki tunnel to determine the three-dimensional structure of an underground rock layer containing a complex density anomaly system, and I identified the essential experimental conditions that make reconstruction possible (measurements quality and quantity, necessary *a priori* information, and methodological issues).