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Designing the ALICE 3 bRICH detector: simulation studies and beam test results

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The ALICE Collaboration is proposing a completely new apparatus, ALICE 3, for the LHC Run 5 and beyond. The design target of the ALICE 3 charged particle identification (PID) system is to ensure a better than 3σ e/π, π/K and K/p separation for momenta up to 2 GeV/c, 10 GeV/c and 16 GeV/c, respectively. A key PID subsystem in the barrel region ($|\eta|<2$) will be a proximity-focusing Ring-Imaging Cherenkov detector, the bRICH, using aerogel (n = 1.03 at 400 nm) as radiator and silicon photomultipliers (SiPMs) as photon sensors. The system must be optimized to ensure efficient particle identification in the high-multiplicity environment of Pb-Pb collisions. Dedicated reconstruction machine-learning based algorithms were developed to prove the bRICH physics reach. Various small-scale prototypes instrumented with aerogel tiles by Aerogel Factory Co., Ltd., different Hamamatsu SiPM arrays readout by custom boards equipped with front-end Petiroc 2A or Radioroc 2 coupled with PicoTDC ASICs, were successfully tested in beam test campaigns at the CERN PS T10 beam line between 2022 and 2024. Our measurements allowed us to validate both the bRICH geometry and the expected performance in terms of photon yield, angular resolution and the resulting separation power. With a measured single photon angular resolution at saturation of about 4.2 mrad and 6 detected photons with about 25% ring acceptance at the operation conditions, the target larger than 3σ π/K separation up to 10 GeV/c has been achieved. We also studied the contribution of uncorrelated and correlated background sources with respect to the signal and proved the effectiveness of time matching between charged tracks and photon hits to achieve efficient suppression of the SiPM dark count rate (DCR) background. Finally, we proved the stability of the reconstruction performance with the increasing DCR expected during ALICE 3 operation. In this talk, the bRICH concept, the expected performance from simulations and the main beam test results will be reported.

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