0.1 Particle Identification

In addition to tracking and calorimetry, Particle IDentification (PID) is a crucial component of the ePIC experiment's physics program. The identification of stable particles is achieved either by analyzing the way they interact, or by determining their mass measuring their velocity and momentum simultaneously. The difference in interaction is primarily used for identifying leptons, photons and neutral hadrons, which leave very different signatures in the elctromagnetic calorimenter. Charge hadrons cannot be distinguished by their interaciton in the calorimeter, but their velocity can be measured using dedicated time-of-flight and Cherenkov detectors.

ePIC has stringent requirements on its PID capabilities as detailed in the Yellow Report cite AbdulKhalek:2021gbh. The two-dimensional histogram in Fig. 1 illustrates the simulated yield of charged hadrons as a function of momentum and pseudorapidity, η, over the range $-5 < \eta < 5$ at the highest EIC energy of $\sqrt{s} = 141$ GeV. Studies of the key semi-inclusive and exclusive processes define the upper limit requirements for 3σ separation of $\pi/K/p$ for different pseudorapidity regions cite AbdulKhalek:2021gbh:

- $p \leq 10$ GeV/c for $-3.5 < \eta < -1.0$
- $p \leq 6$ GeV/c for midrapidity $-1.0 < \eta < 1.0$
- $p \leq 50$ GeV/c for the forward region or $1.0 < \eta < 3.5$

Pure and efficienct kaon identification is particularly relevant to semi-inclusive DIS studies, where quark flavor tagging provides critical insights into the transverse momentum distribution and potentially the orbital angular momentum of the strange sea quarks. Kaon identification is also needed to reconstruct charmed hadrons, which are sensitive probes of gluon distributions in protons and nuclei.

Achieving the PID goals of the ePIC experiment requires multiple detection technologies tailored to specific momentum and pseudorapidity ranges. Cherenkov radiation detection is the primary method at higher momenta but is limited in its low-momentum reach. After the Yellow Report, it was realized that improving low-momentum PID is critical for light vector meson and charm meson/baryon reconstruction. To address this, Time-of-Flight (ToF) detectors based on AC-LGAD sensors were added in the barrel and forward regions. The η-dependence of the momentum spectrum along with space constraints necessitate different technologies in the forward, backward, and barrel regions. The solution chosen by ePIC involves:

- A dual radiator RICH (dRICH) in the forward region utilizing aerogel and gas radiators, a set of focusing mirrors, and instrumented by SiPMs.
- Additional low-momentum PID in the forward region is achieved by an AC-LGAD based ToF that also provides an additional layer of tracking points.

- A large radius high-performance DIRC (hpDIRC) in the barrel, which adds focusing to the original DIRC design.
- The hpDIRC is complemented by an AC-LGAD ToF detector at smaller radius. The AC-LGAD layer provides PID information for low momentum particles that do not reach the hpDIRC or are too slow to leave Cherenkov signal in it.
- A proximity-focusing aerogel RICH (pfRICH) to cover the electron endcap region. This design features minimal material budget and can simultaneously function as a threshold gas Cherenkov detector providing excellent ToF through its novel HRPPD photosensors.

Figures 1 illustrates the achieved coverage in the η vs. p plane of the various PID subsystems. The contours indicate the 3σ range for e/π, π/K, and K/p-separation, respectively. This unprecedented wide coverage of PID in momentum and over a wide range of η makes ePIC a truly unique collider detector. As shown, the PID systems provide, in addition to hadron PID, a significant contribution to the e-identification and its purity (e/h). When combined with the EM calorimeters, these subsystems will provide excellent suppression of the low-momentum charged-pion backgrounds, which otherwise limit the ability of the EMCal to measure the scattered electron in kinematics where it loses most of its energy.

ePIC's Cherenkov detectors, dRICH, pfRICH, and hpDIRC, must overcome various challenges related to their respective photosensors. One is the strong magnetic field that rules out the use of conventional photomultipliers. Figure 2 shows the realistic ePIC magnetic field with highlighted Cherenkov PID detectors envelopes. In the region of the hpDIRC detector plane, where the MCP-PMTs will be located, the magnetic field is at a level of 0.2-0.3 T. The field at position of the pfRICH HRPPD sensors is about 1 T and the field at the dRICH is 0.3-0.6 T.

Another significant challenge is the sensors' sensitivity to radiation, particularly in the forward region where the dRICH is located. Figure 3 depicts the radiation map for ePIC with the PID subsystem contours. Shown are the estimates of the 1-MeV neutron equivalent fluence and (b) the sum of electromagnetic and charged-hadron dose simulated with 10x275 GeV ep Pythia events. SiPMs, while ideal in terms of quantum efficiency and wavelength sensitivity, do suffer from increased dark currents due to radiation exposure. However, cooling during operation and thermal annealing have been demonstrated to mitigate this issue cite Calvi:2018ulw, Preghenella:2023hgq. Other photosensors used, show enough radiation hardness (HRPPD) or are situated in less radiation-intensive areas (MCP-PMT).

In the following subsection the different PID subsystems in ePIC are discussed in detail.

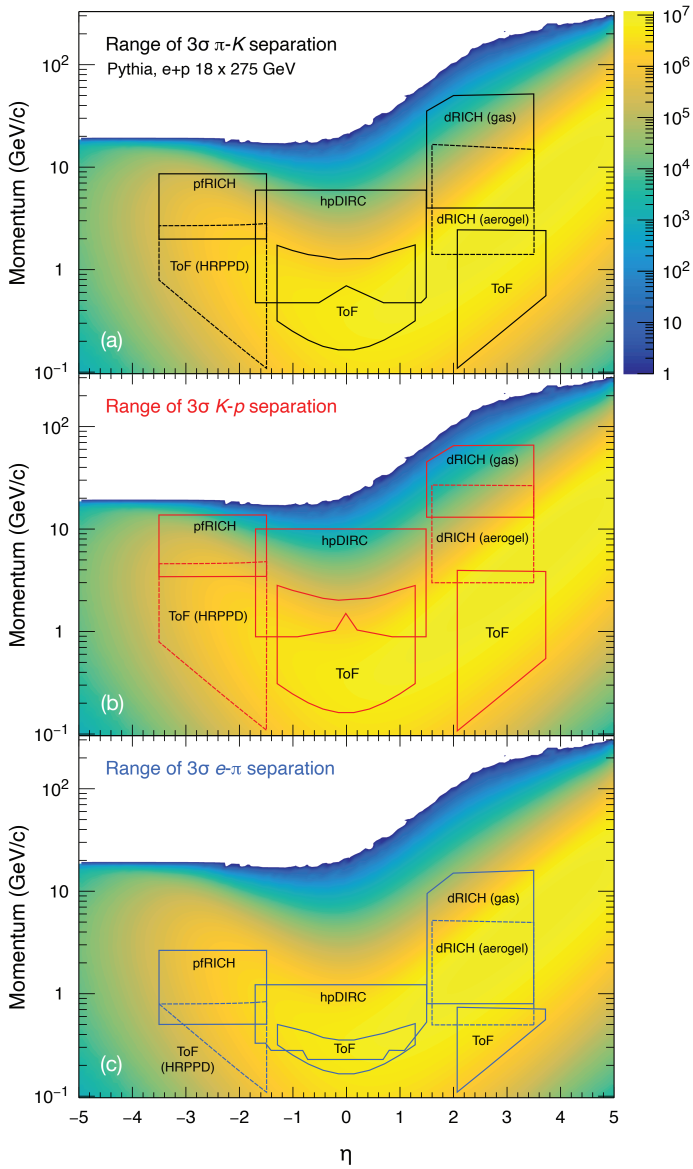

Figure 1: The histogram shows the relative yield of charged hadrons from Pythia simulations for 18x275 GeV *ep* collisions as a function of momenta and pseudorapidity, η. The contours indicate the 3σ separation region of the different ePIC PID subsystems for π/K (a), K/p (b), and e/π (c), respectively.

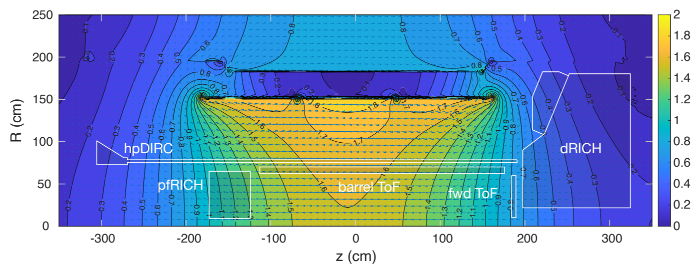

Figure 2: EPIC magnetic field map with the PID detector envelopes overlaid.

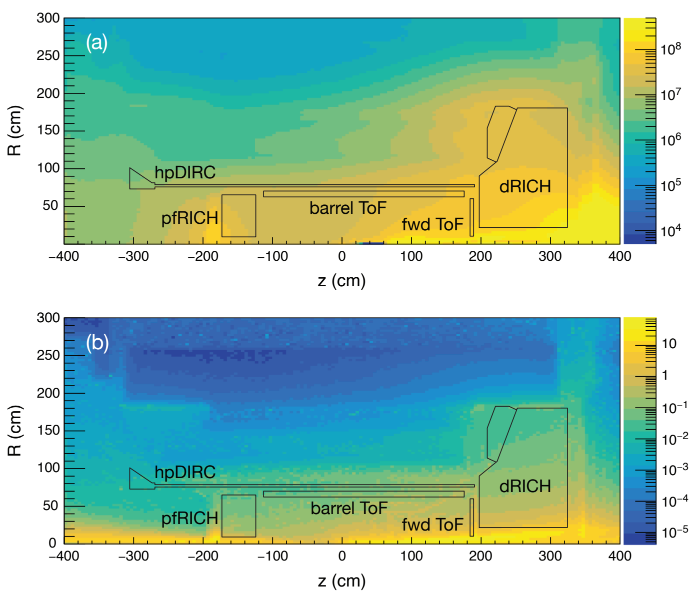

Figure 3: (a) Estimates of the 1-MeV neutron equivalent fluence in cm^{-2}/fb^{-1} and (b) the sum of electromagnetic and charged-hadron doses in rads/fb^{-1} integrated in 1 fb^{-1} equivalent Pythia events for 10x275 GeV *ep* collisions. The values shown are averaged over the azimuthal angle.