

Simulation based performance of the ePIC-dRICH for Forward PID at the Electron Ion Collider

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(on behalf of dRICH Simulation Team)

OUTLINE

- Electron Ion Collider and ePIC
- PID in ePIC and dRICH detector
- dRICH Simulation Framework
- Simulation Studies
- Results & Conclusion

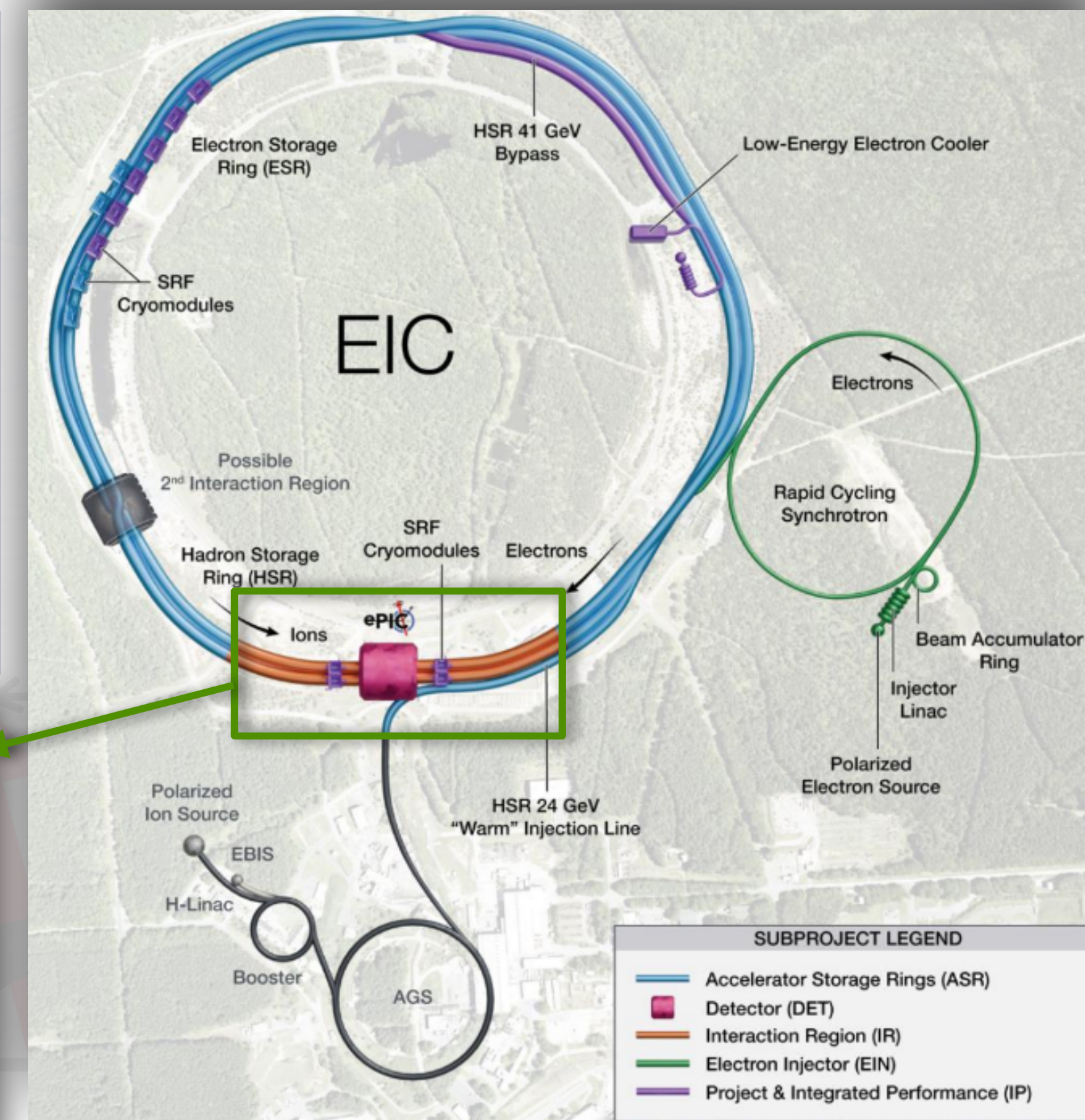
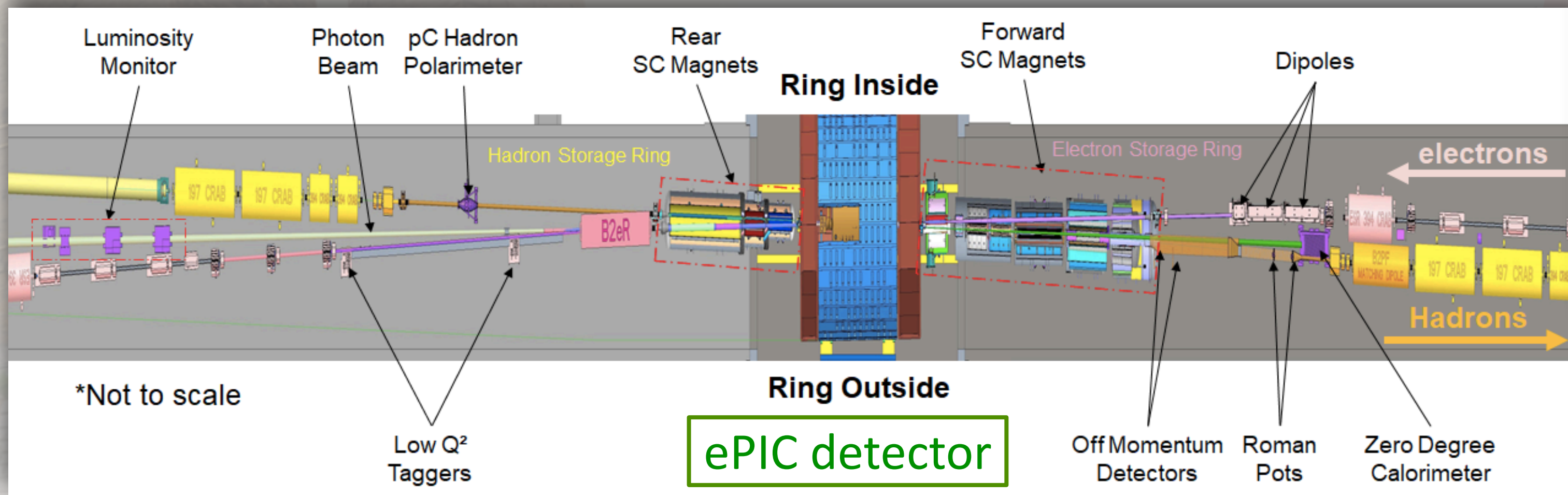
Electron Ion Collider (EIC)

Five Key Physics Questions:

- Origin of nucleon spin
- 3D tomography of nucleons
- Emergence of nucleon mass
- Emergence of hadronic matter
- Gluon saturation and high density QCD

A machine beyond the current state-of-the-art

- Highly polarized electron, nucleon and light ion beams (~70%)
- Capability to collide light to heavy ion beams (e.g., up to U)
- Wide and variable centre-of-mass energy (20-100 GeV and upgradeable up to 140 GeV)
- High collision luminosity ($10^{33} - 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$)



Electron Beam: 5-10 GeV (upgradeable to 18 GeV)
 Ion Beams: 40 - 275 GeV

First collider with polarized electron and light ion beams!

The only new high-energy collider in upcoming decades

ePIC detector @ EIC

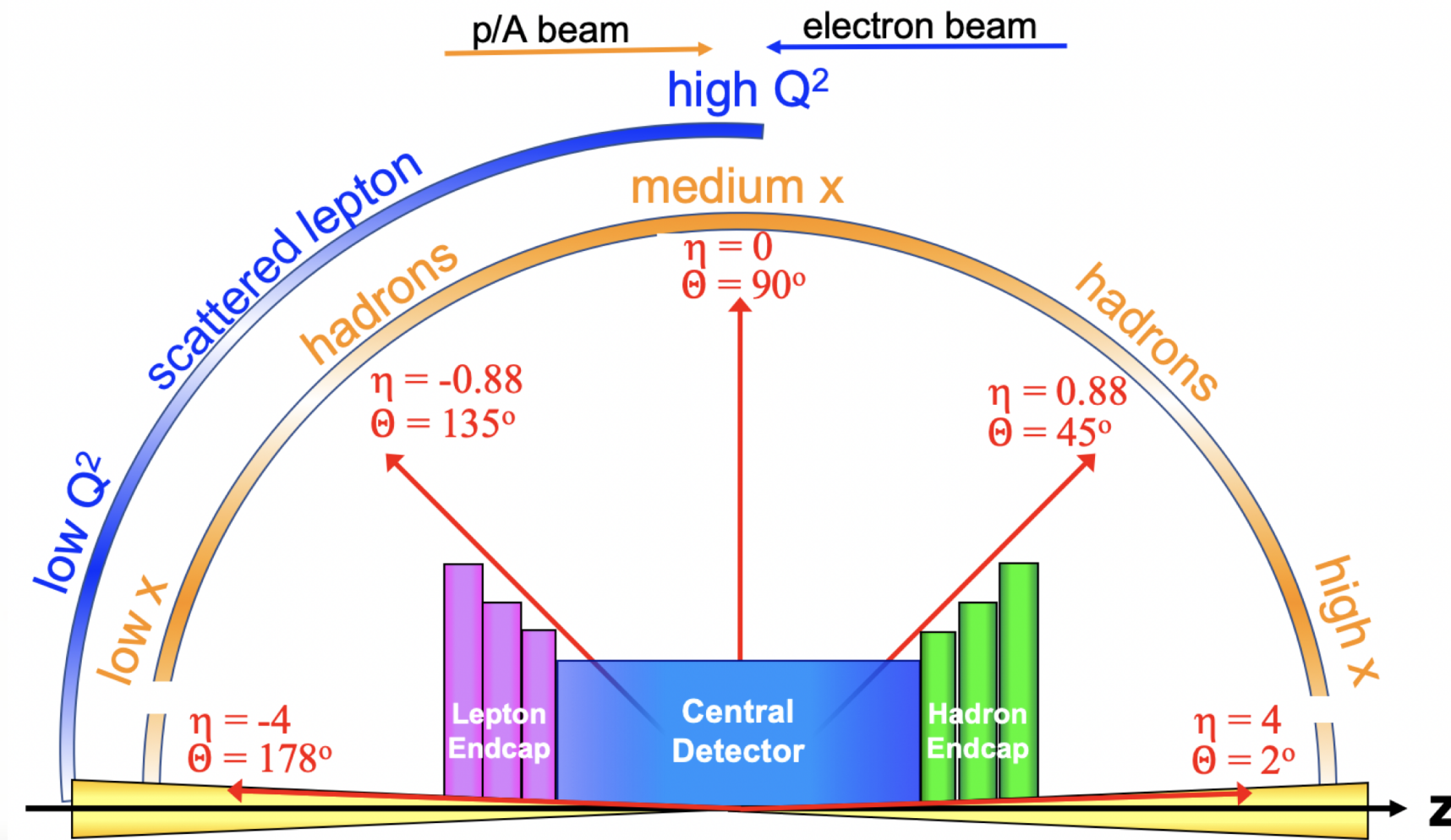
Detector Requirement @ EIC

- $\sim 4\pi$ hermetic (wide kinematic coverage)
- Good momentum resolution
- Excellent to good energy resolution
- **Excellent PID for $\pi/K/p$ separation over a wide momentum range**
- **Excellent PID for e-hadron separation**

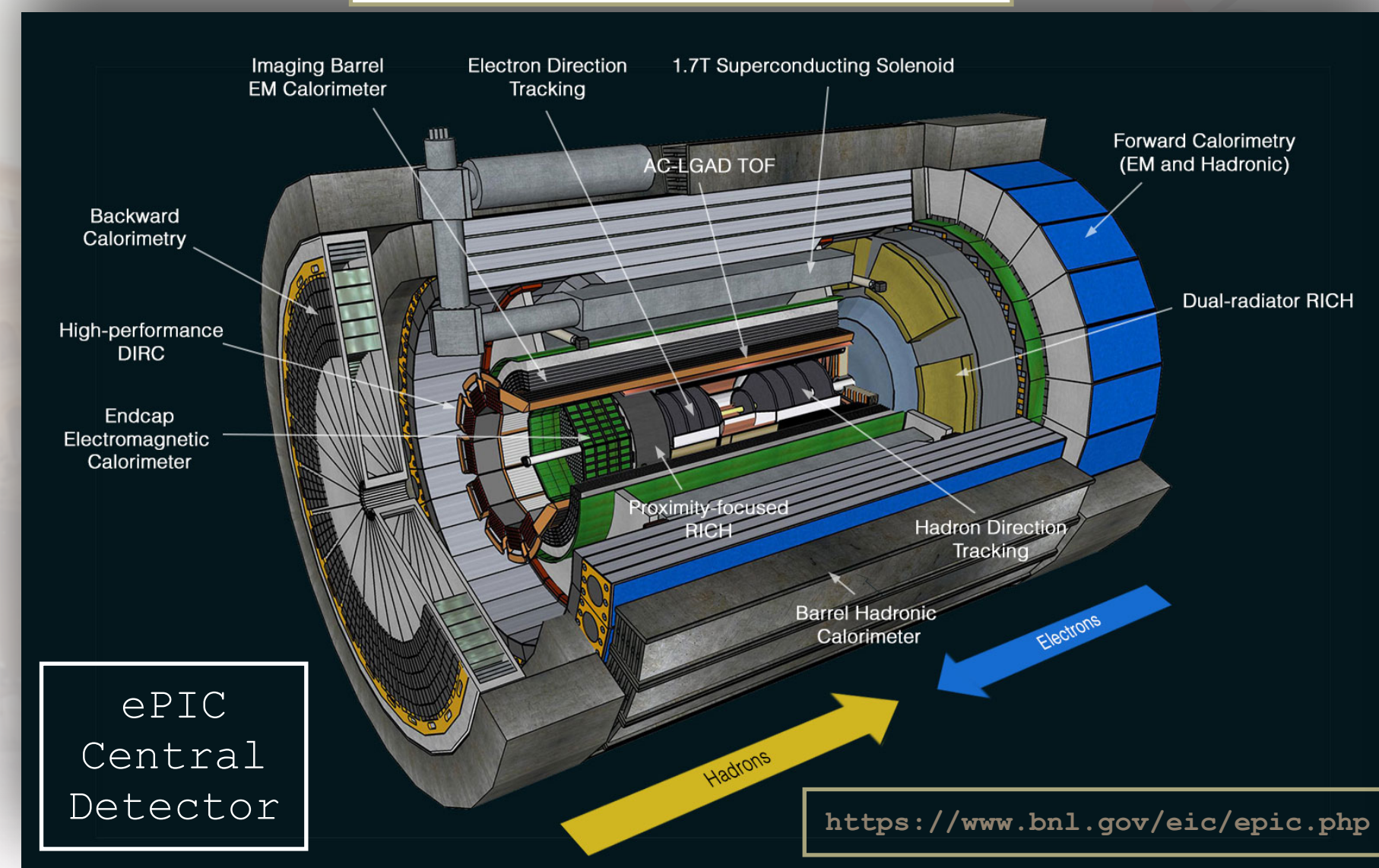
Hybrid Detector System @IP6 (ePIC)

- Compact (~ 9 m) cylindrical barrel detector
- 26 sub-systems over ± 40 m
- ~ 2 T superconducting magnet
- High-precision tracking system (Si, MPGD)
- EM Calorimeters (forward/backward)
- Hadron Calorimeters (Forward/Barrel)
- Extended far-forward, backward detectors
- **PID detectors:**
 - * dRICH, pRICH, TOF, hpDIRC

ePIC: Large (& growing) collaboration



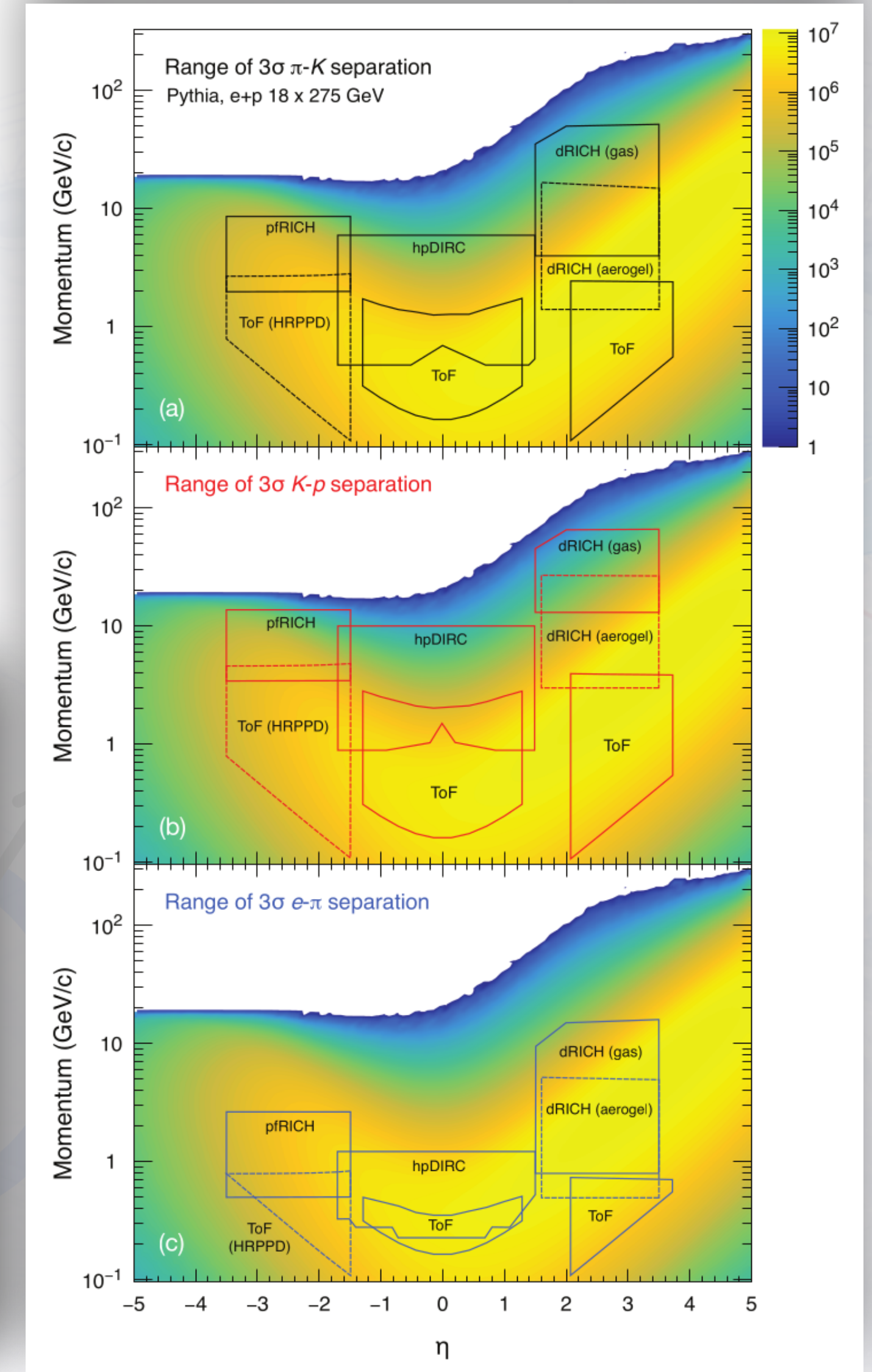
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ePIC
Central
Detector

<https://www.bnl.gov/eic/epic.php>

Relative yield of hadrons



A dual-radiator Ring Imaging Cherenkov (dRICH) detector

- Identification (3σ -separation) of $\pi/K/P$ (3 to 50 GeV/c)
- e/π separation from few hundred MeV/c to 10 GeV/c

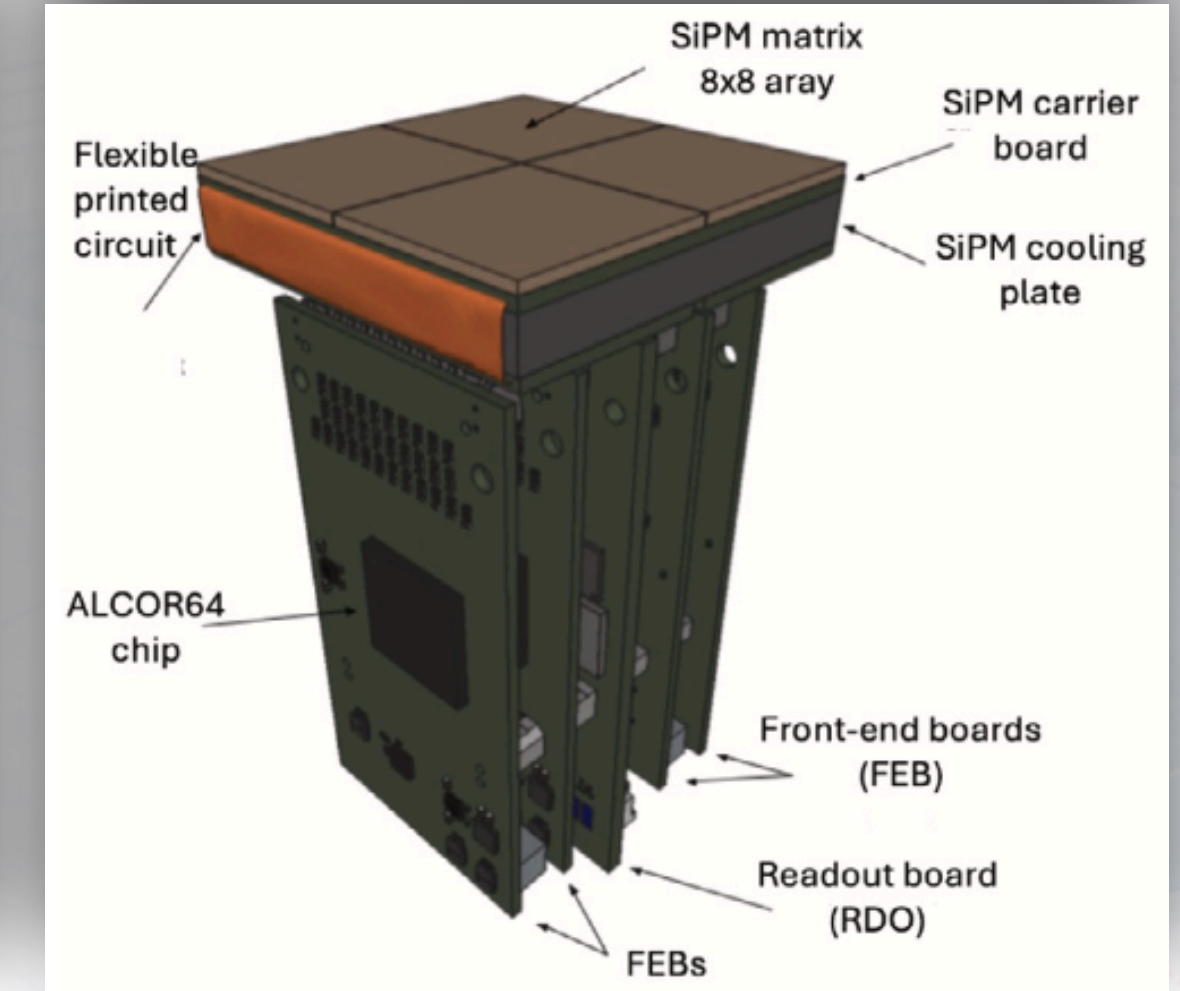
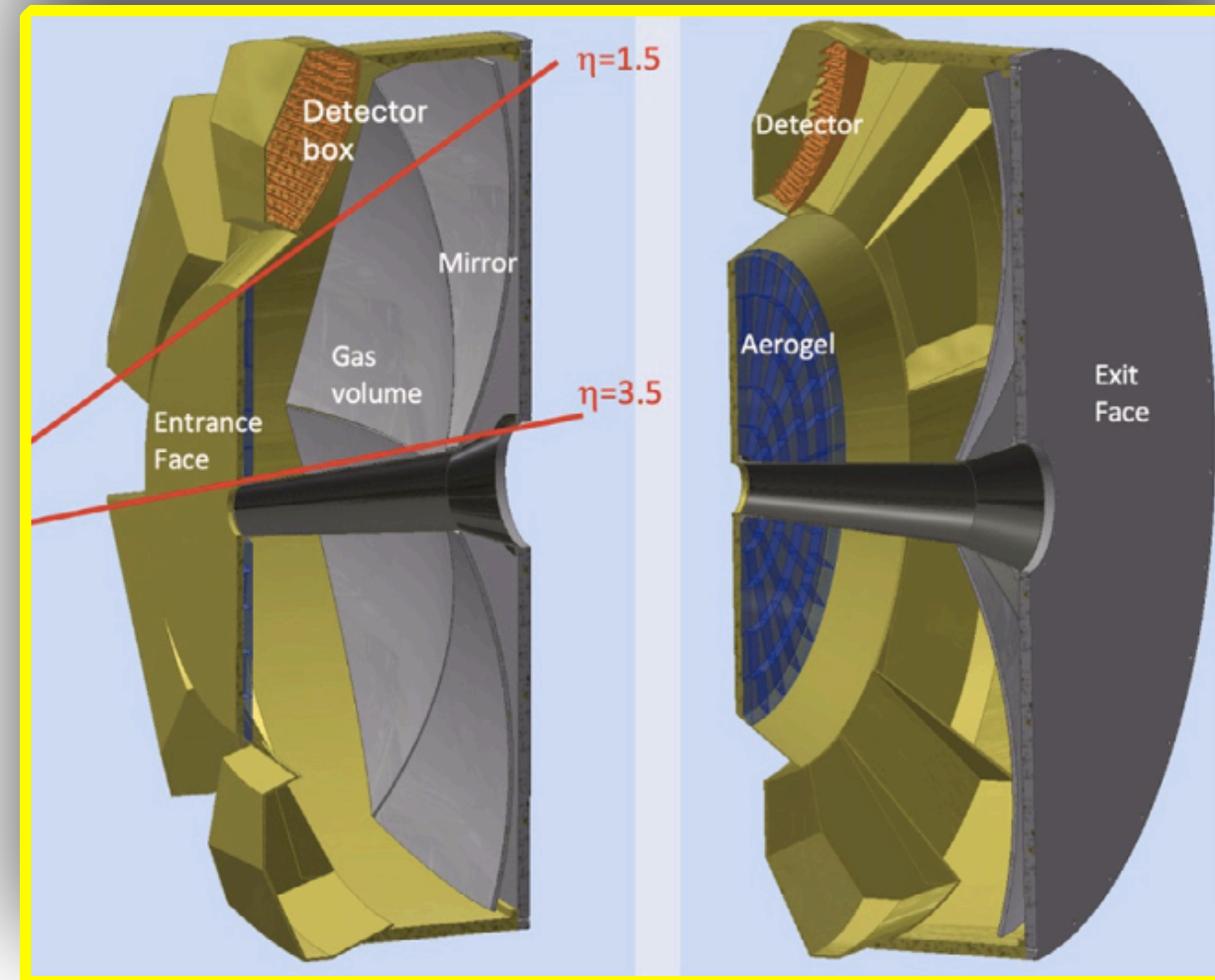
Dual Radiator (for broad momentum coverage)

- ◆ **Aerogel:** for low-intermediate momenta
 - Word record size of tile (~ 20 cm)
 - Baseline refractive index = 1.026 (optimized)
 - Chromatic dispersion: $6 \times 10^{-6} \text{ nm}^{-1}$ at $\lambda = 400 \text{ nm}$
- ◆ **Gas (C_2F_6):** for high-momenta particles
 - Nominal refractive index = 1.00086 (STP)
 - Chromatic dispersion: $0.2 \times 10^{-6} \text{ nm}^{-1}$ at $\lambda = 350 \text{ nm}$

Optical System (spherical focusing mirrors $\sim 10 \text{ m}^2$ area)

- ◆ Precise imaging of Cherenkov Rings
- ◆ Designed to minimize aberrations and maximize the resolution

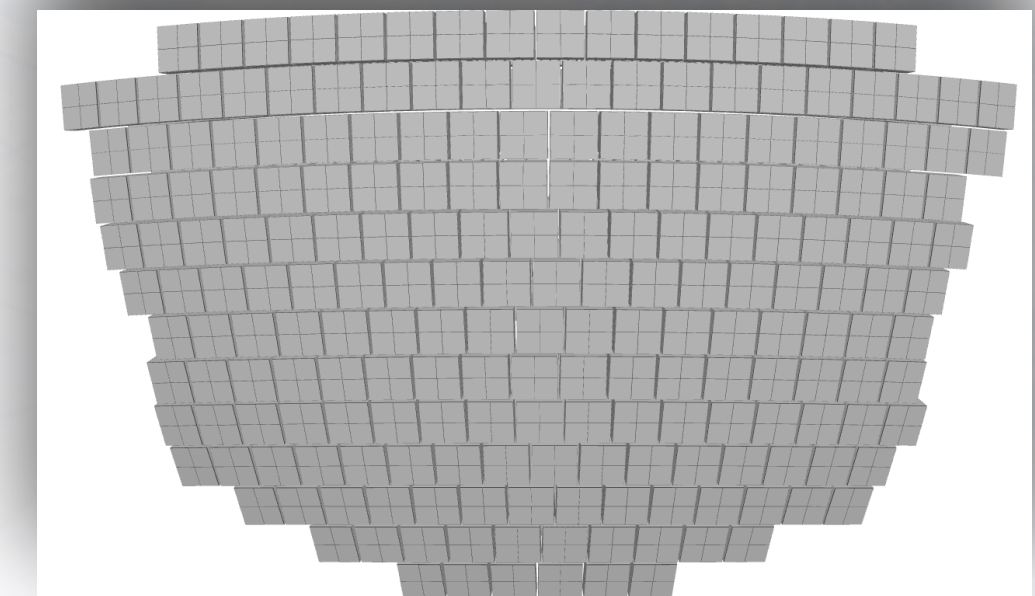
dRICH is base-lined; further studies for detailed optimization



dRICH PDU

Photosensors (SiPM)

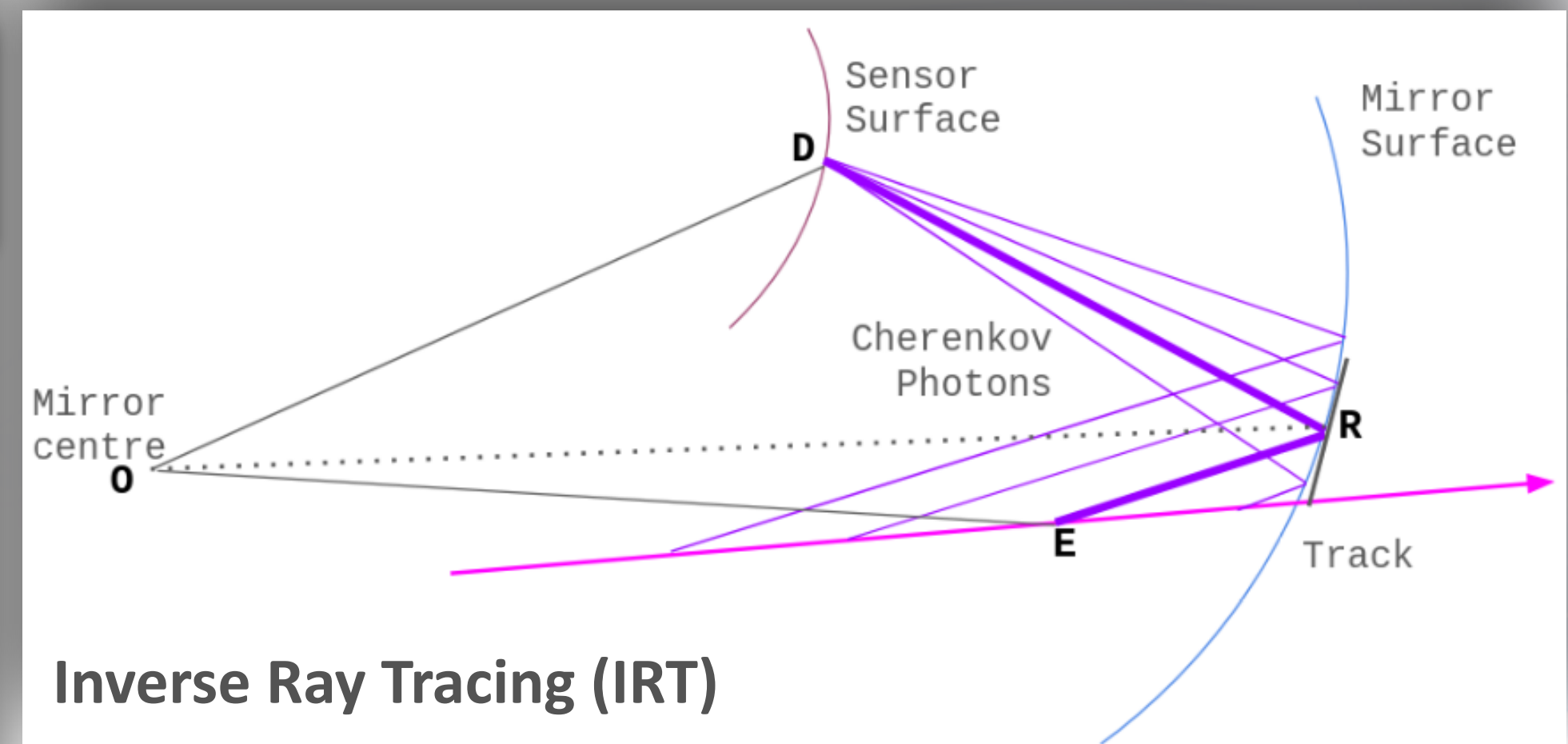
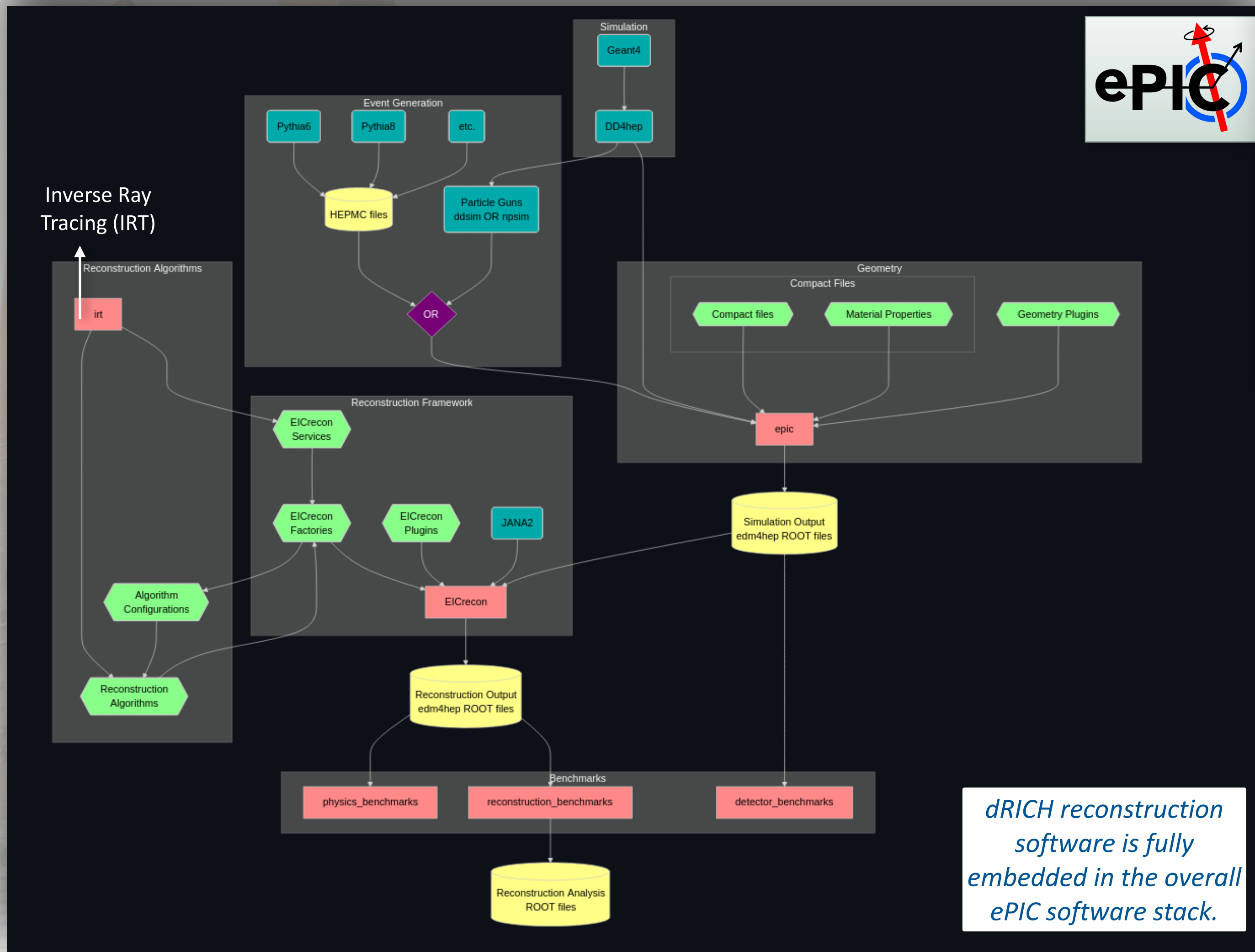
- ◆ Distributed in 6 sectors associated with six 60° spherical mirror sectors
- ◆ Compactness and B-tolerance
- ◆ High PDE in UV-visible range
- ◆ Fast timing ($\sim \text{ns}$)
 - * 208-209 PDUs per sector
 - * 4 SiPMs per PDU
 - * 64 channels per SiPM



PDUs arrangement

Lightweight mechanical structure with minimum material budget

Software Stack & Reconstruction Algorithm

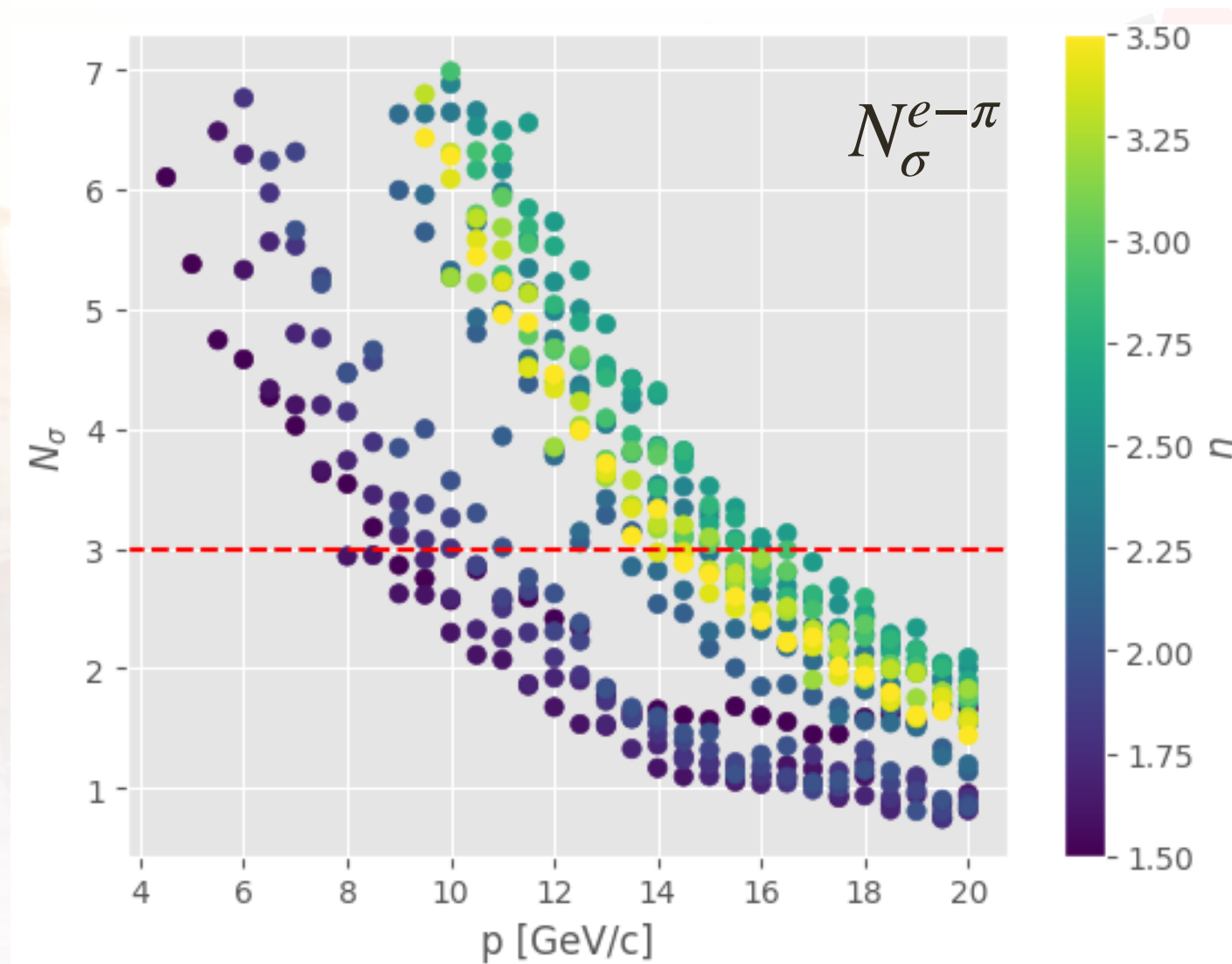
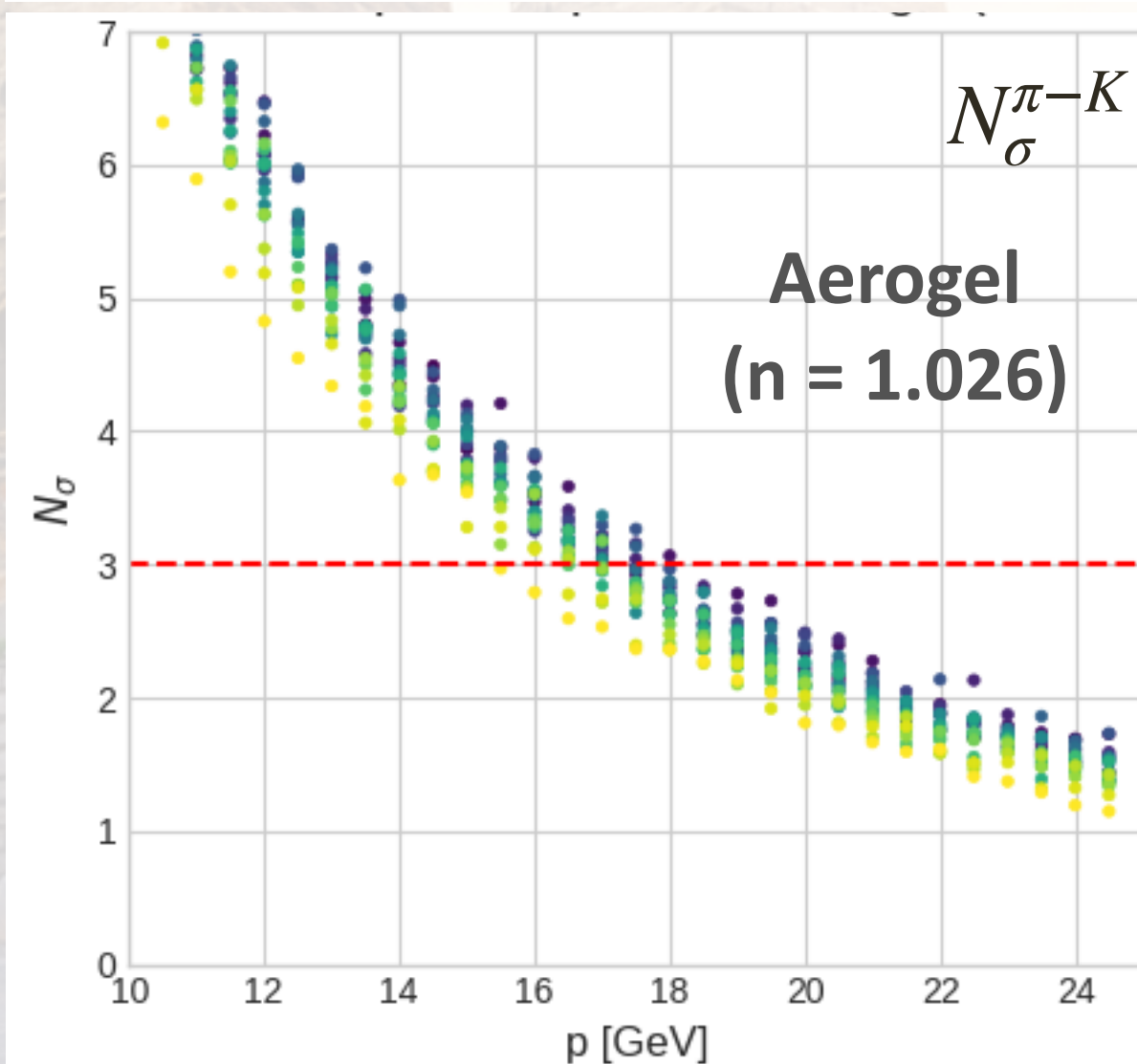
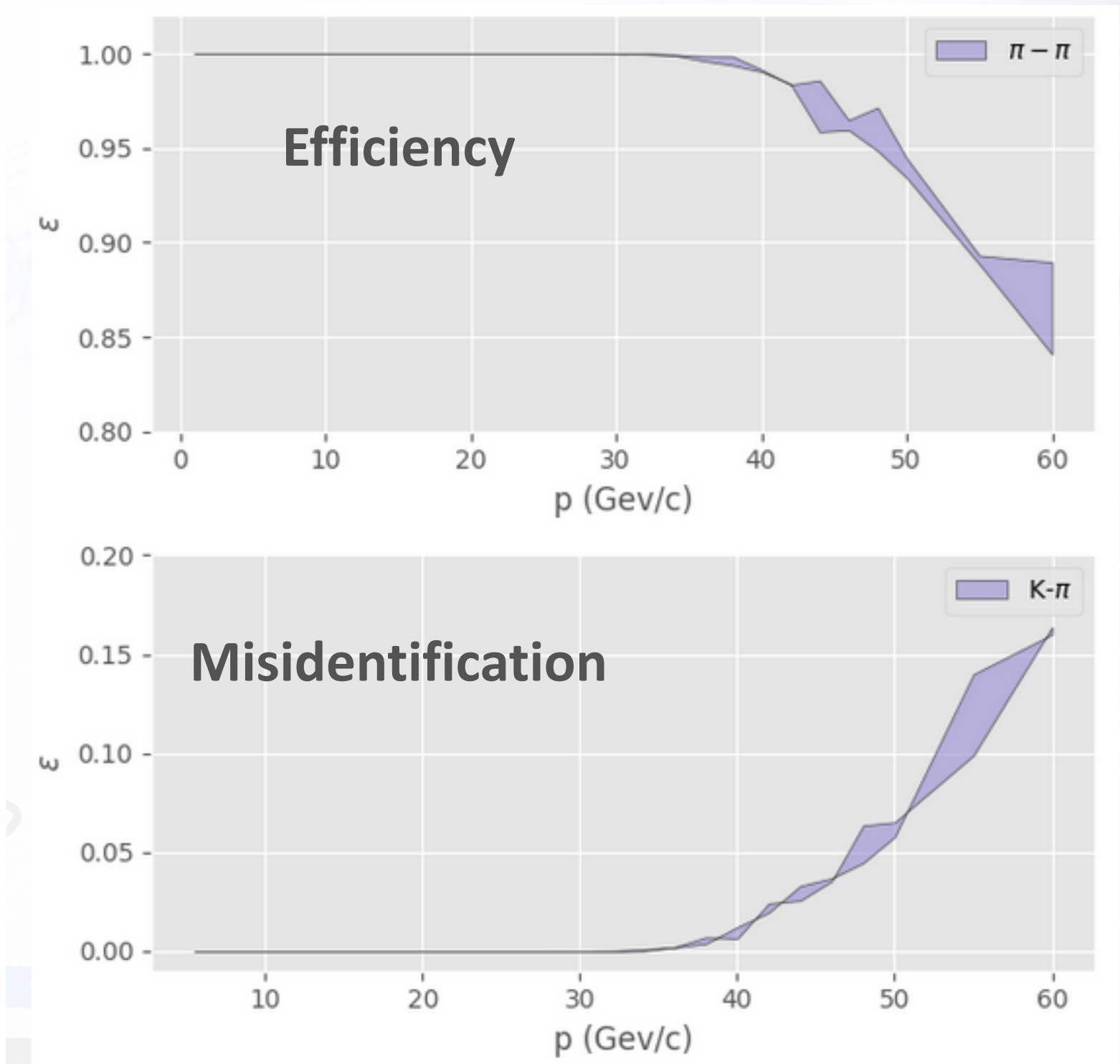
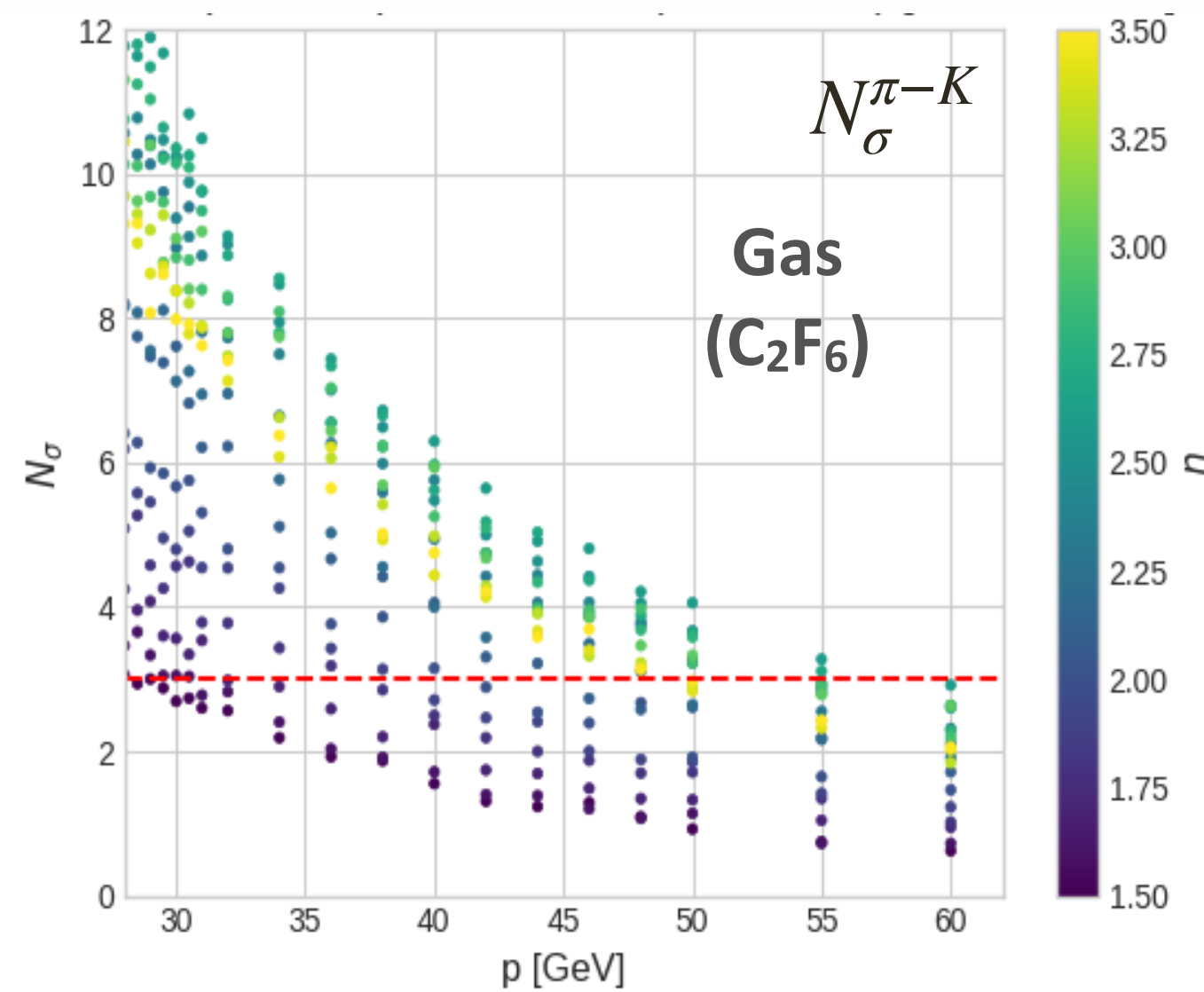
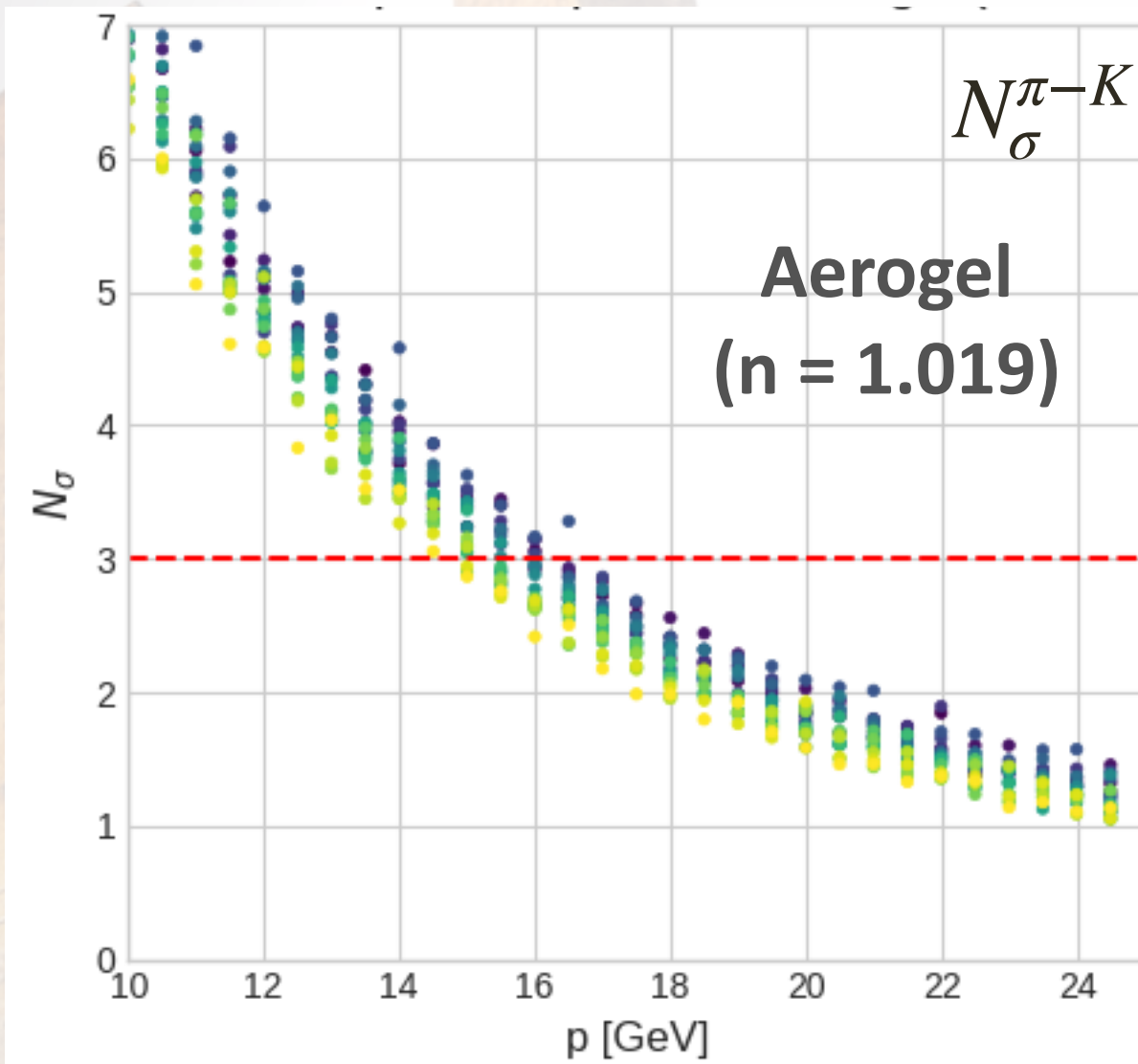


- Backward reconstruction from detected hit (D) to photon direction
- Focussing of photons by spherical mirror -> reduces emission point uncertainty
- Methodology:
 - Assumption of emission point (E) and finding photon vector following the law of reflection at R.
 - Provide single photon Cherenkov angle
 - For each track and mass hypothesis, event-based χ^2 is estimated for detected photons and associated with the track within a $\pm 2\sigma$ -window

Followed by robust validation & optimisation protocol

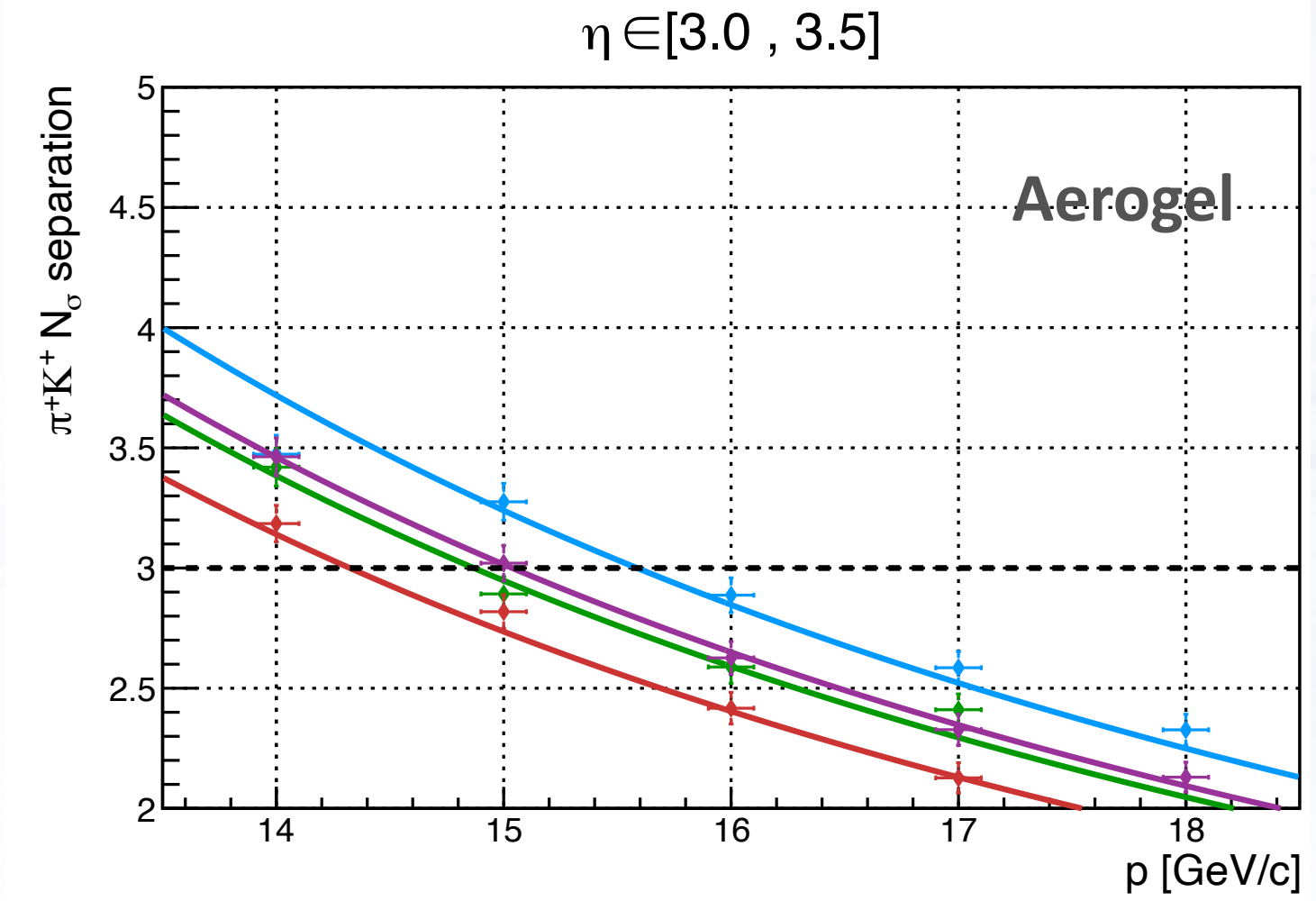
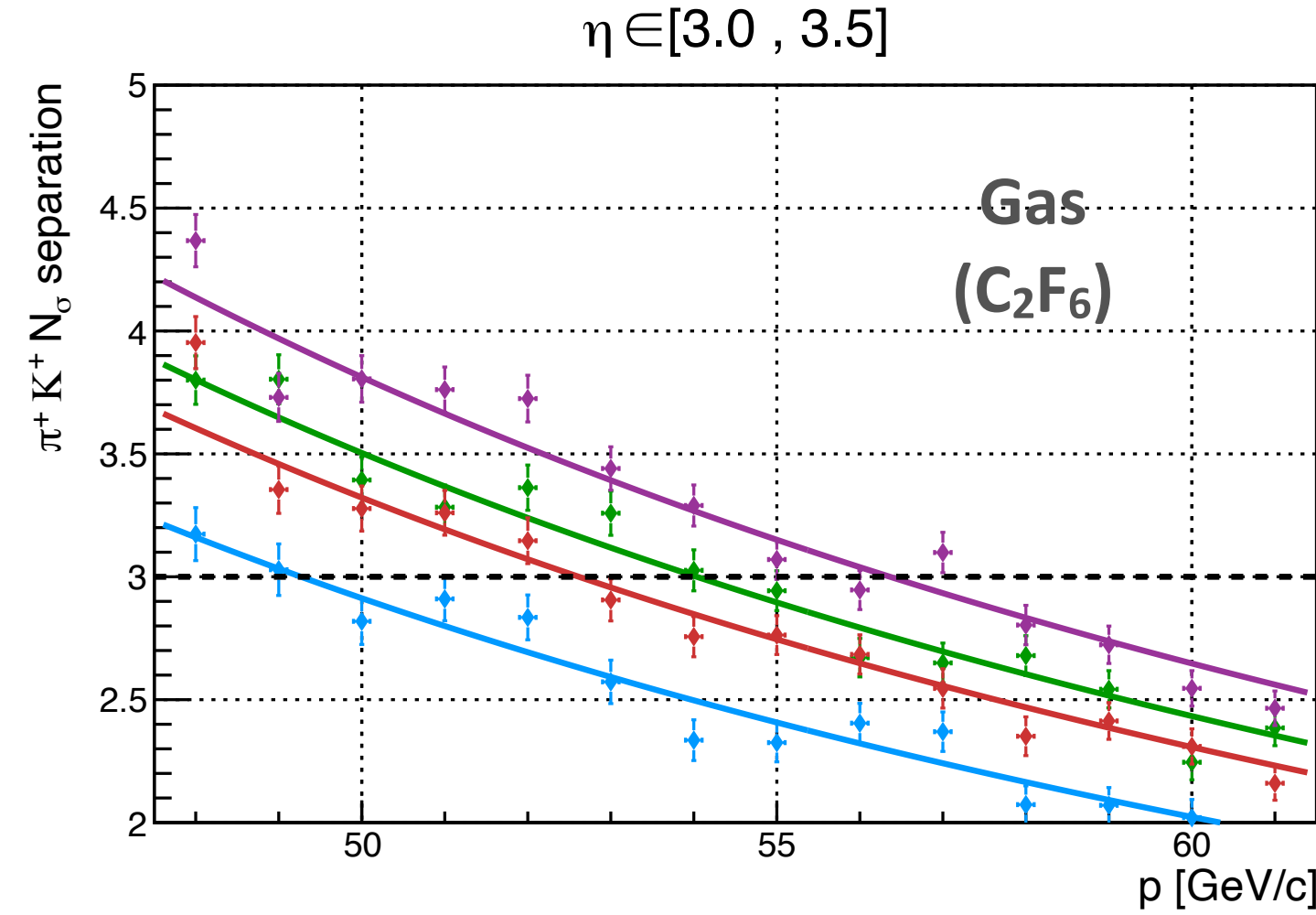
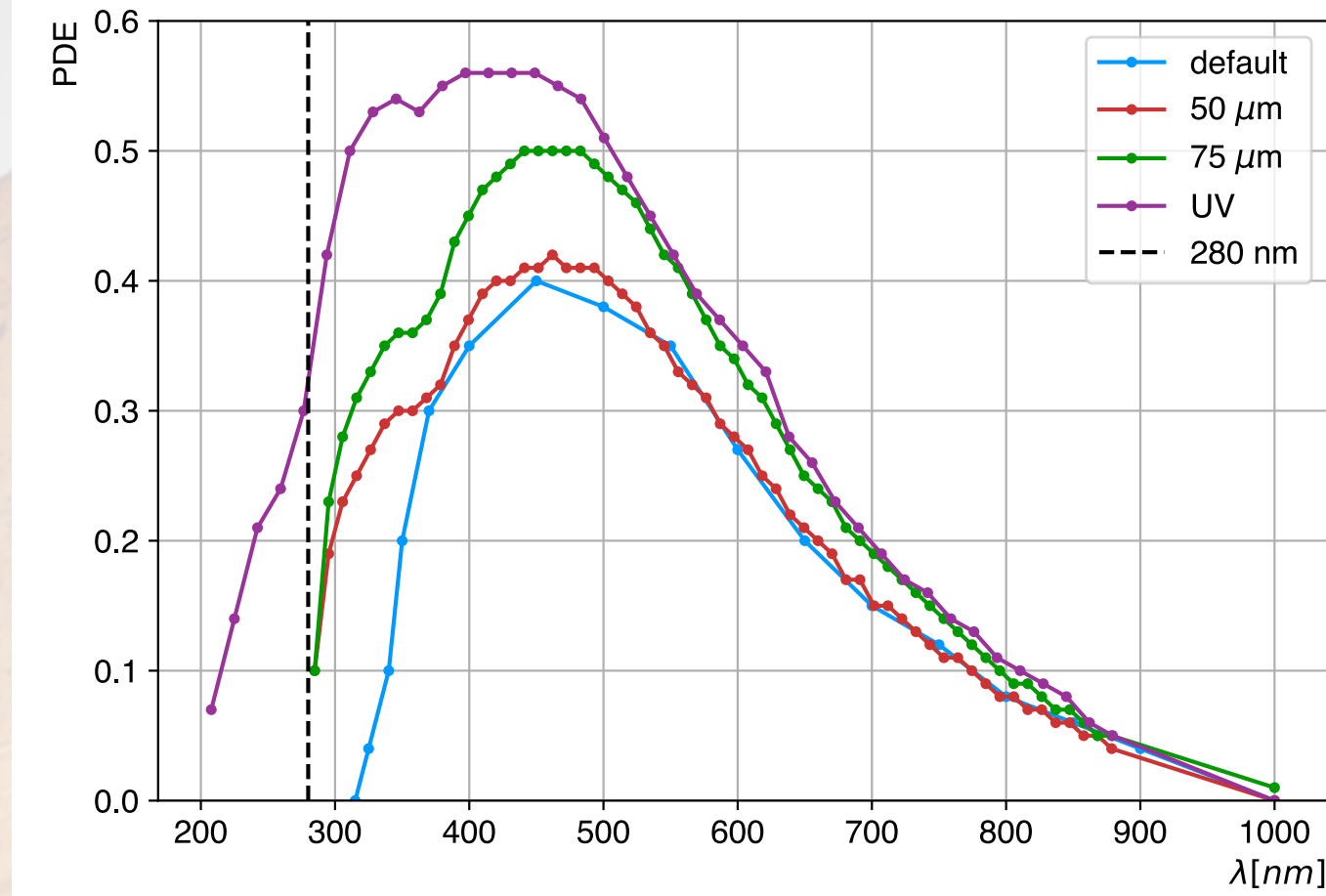
dRICH performance (Simulations)

$$N_{\sigma}^{\pi-K} = \frac{\langle \theta_C^{\pi} \rangle - \langle \theta_C^K \rangle}{\text{Mean}(\sigma_{\theta}^{\pi}, \sigma_{\theta}^K)}$$

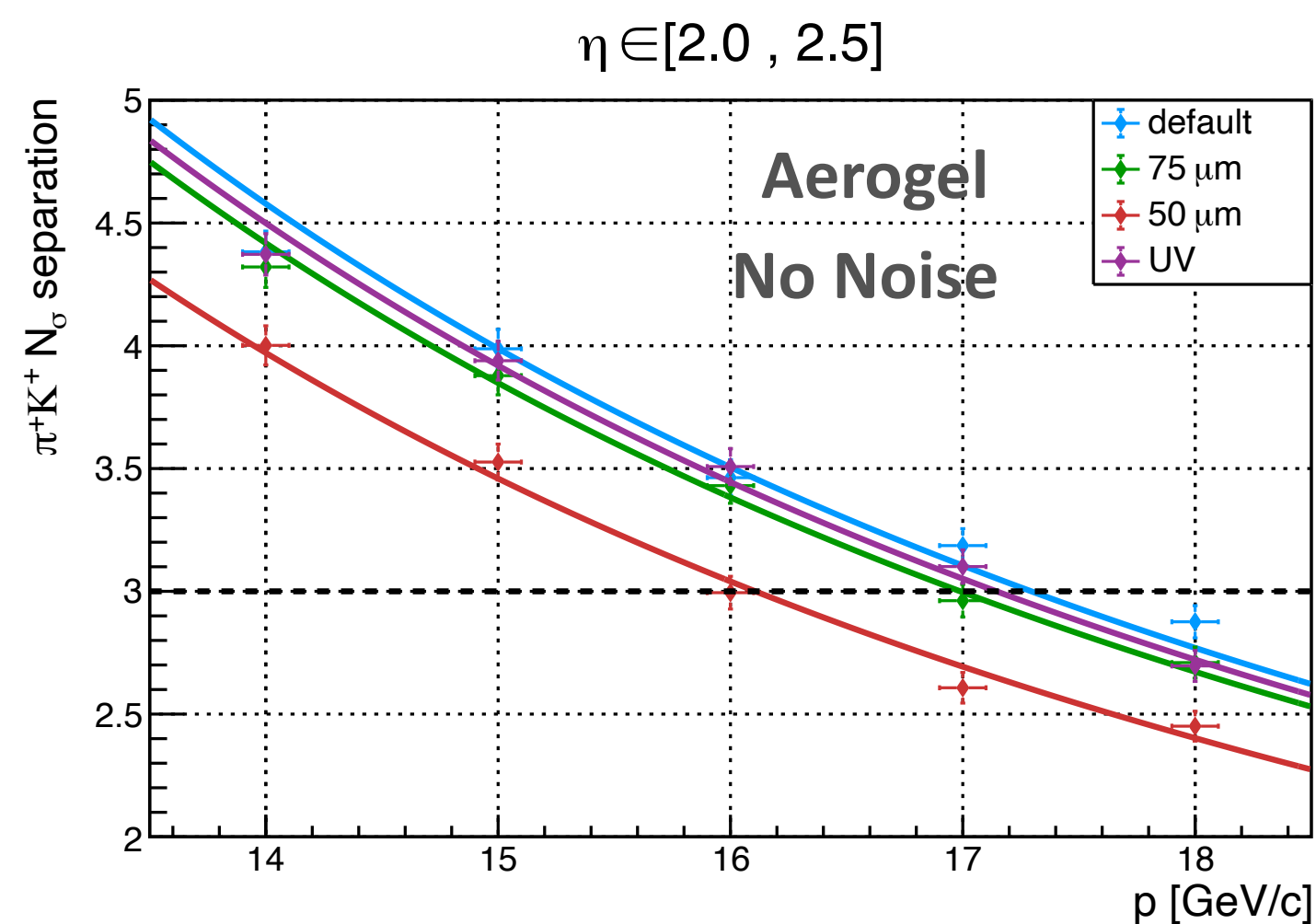


- Optimization of aerogel parameters
- Aerogel: Excellent π/K separation ($p < 15$ GeV/c)
- Continuous PID with dual radiators
- Excellent e/π separation ($p < 15$ GeV/c)

Effect of different SiPM sensors & noise

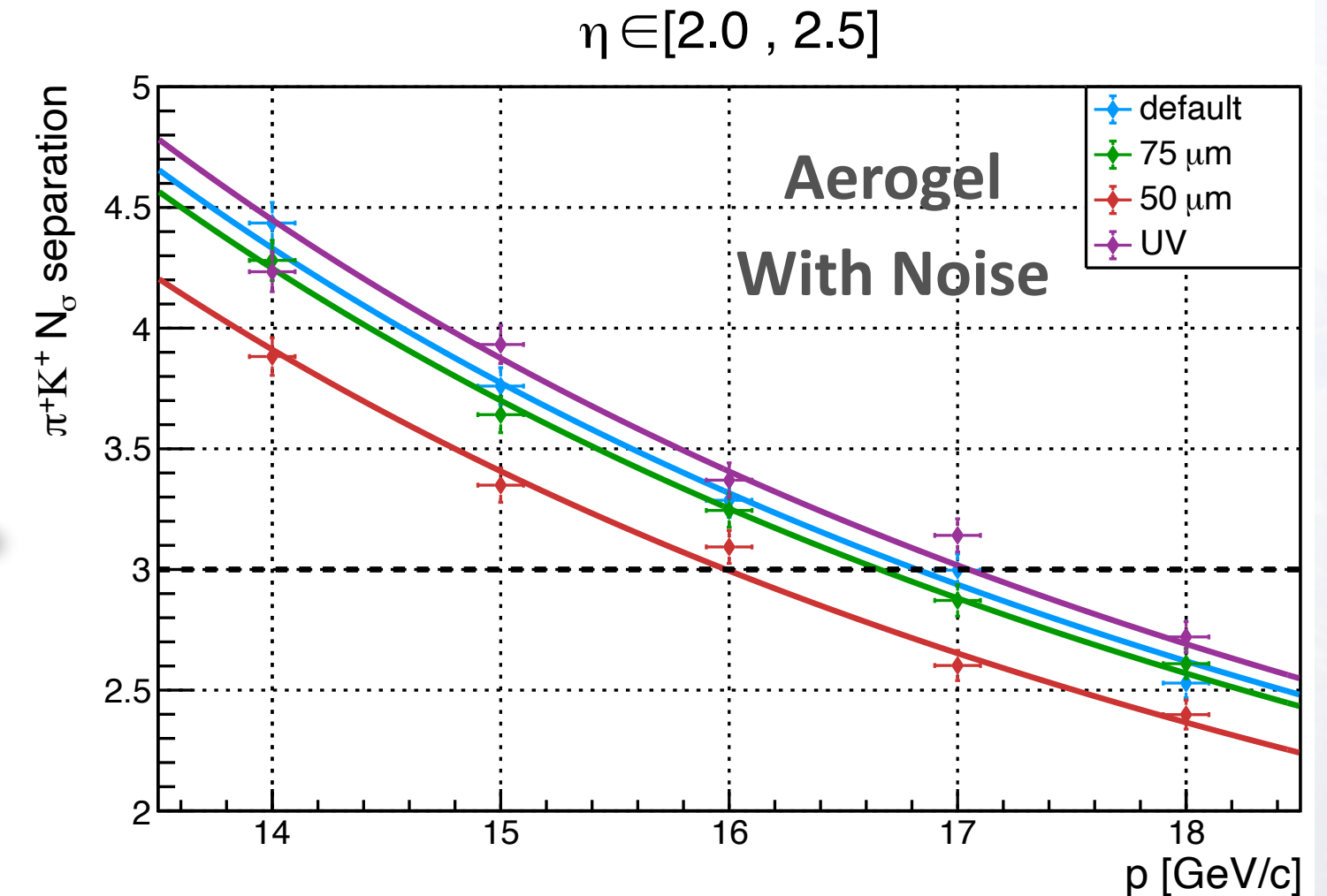


- UV SiPM in Gas → more photons but worse SPR (chromaticity), but increased photon count (dominates) → Net improvement
- In aerogel, acrylic filter limits the gain for UV SiPM & Overall (gas & aerogel), 75 μm SiPM provides better performance; thanks to the reduced dead area!



- SiPM dark count noise at the maximum expected rate of 300 kHz/SiPM is added randomly
- More effect on aerogel (~0.5 dark count hits) per aerogel ring due to the much larger aerogel radius w.r.t. the gas ring radius

- Performance degrades (more for default SiPM)
- But, more than $3\text{-}\sigma N_{\sigma}^{\pi-K}$ for momentum higher than kaon threshold in gas.



Summary

- Efficient hadron PID is essential for EIC physics programme
 - **dRICH:** Central for success of SIDIS programme of ePIC experiment; supports the reconstruction of heavy flavour particles by the identification of the decay products
 - **Challenges:** detector space, solenoidal B, high radiation (sensor region)
- dRICH simulations are playing a significant role in providing the information/feedback for detector design optimization:
 - Properties of two radiators & Optical parameters of the sensors
 - Impact of noise on detector performance
- **End-to-end established** simulation and reconstruction framework (physics performance forthcoming)
- **Future:** AI/ML (involving CNN) based algorithm for future dRICH PID

Other Relevant Highlights (DIS-2026)

- ◆ Simone Vallarino: [5 May 2026](#) (WG6)
 - Emphasis on R&D and Engineering activities
- ◆ Jihee Kim: [6 May 2026](#) (WG6)
 - Ongoing developments on pfRICH at ePIC
- ◆ Lorenzo Polizzi: [6 May 2026](#) (WG6)
 - ePIC PID performance in SIDIS processes
- ◆ Sandro Geminiani: [6 May 2026](#) (WG6)
 - ePIC-dRICH streaming R/O system
- ◆ John Lajoie: [8 May 2026](#) (Planery 5)
 - **EIC: physics, status and perspectives**

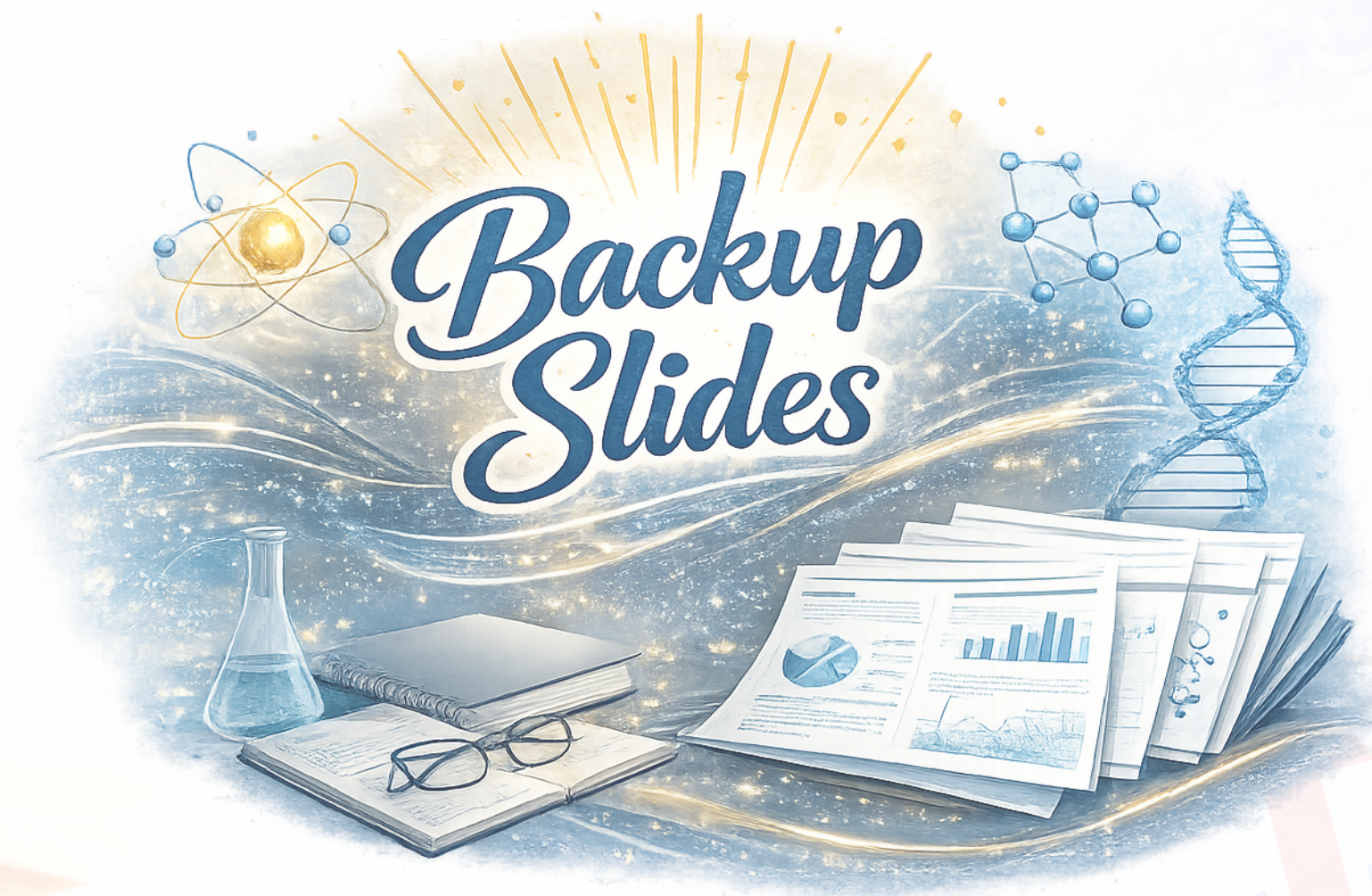
Acknowledgements

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- ◆ DIS-2026 Organizers
- ◆ ICTP-TRIL Programme
- ◆ INFN Trieste

Our Collaborators



Any comments & questions...



ePIC detector @ EIC

