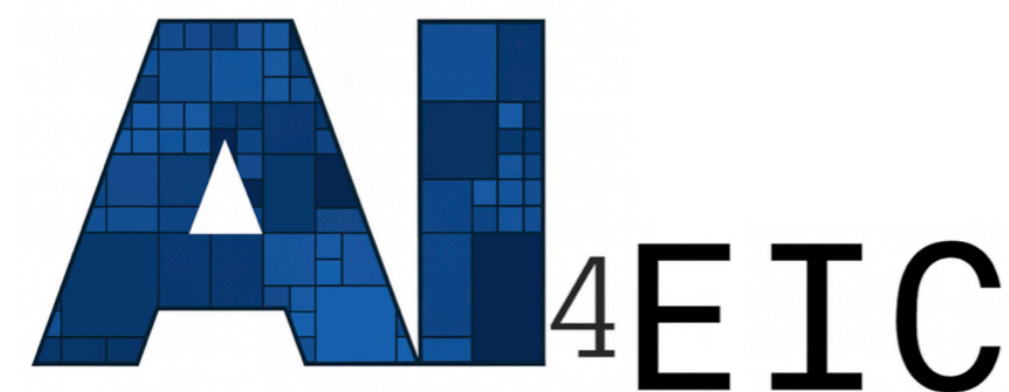
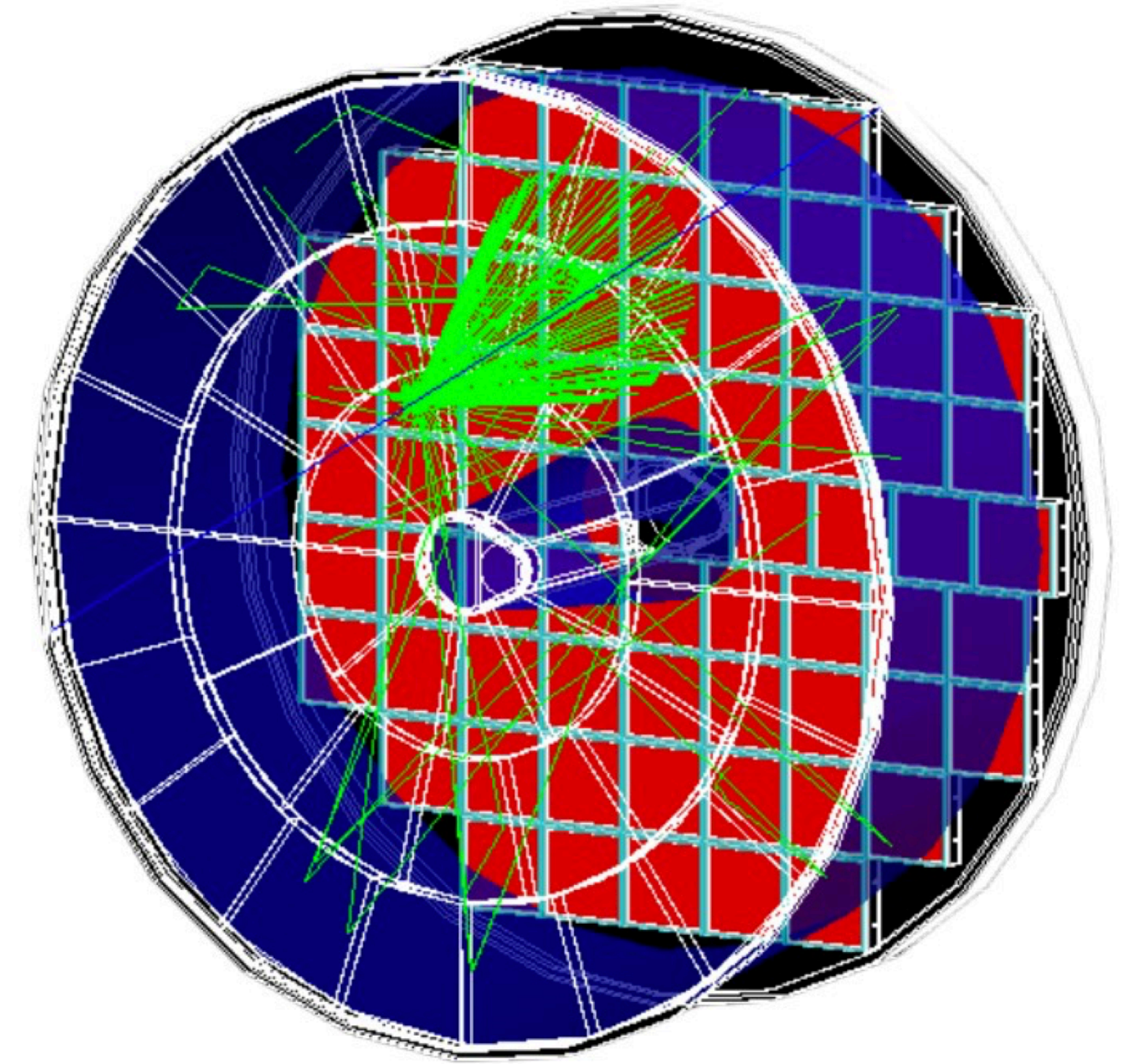


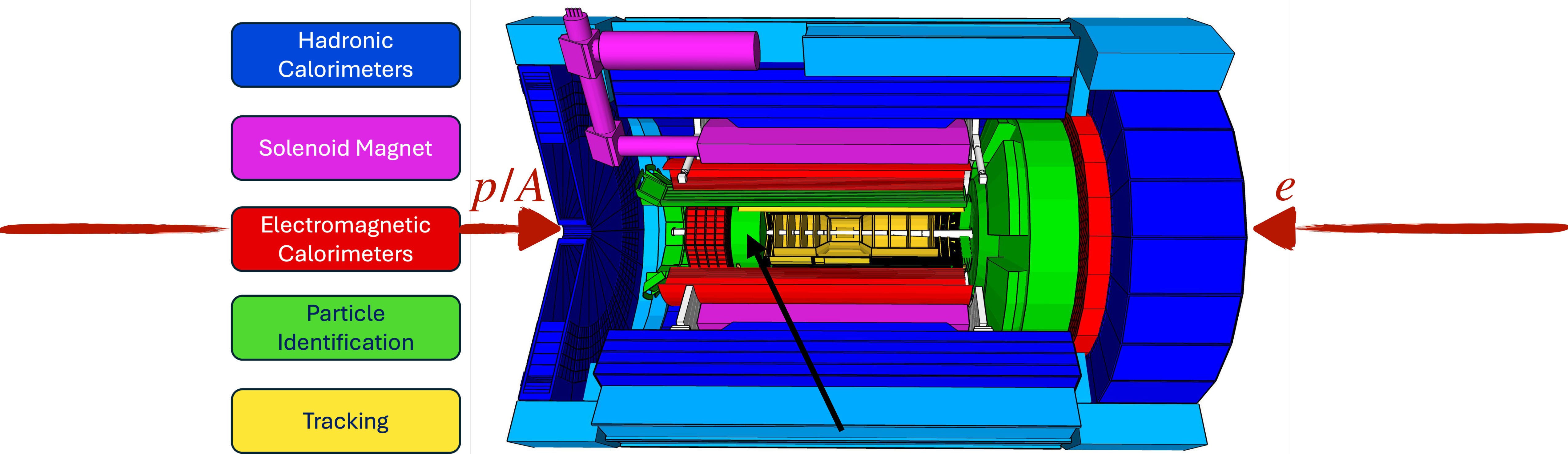
Machine Learning for the pfRICH Particle Identification subsystem

D.H Dongwi, C-J. Naïm and L. Rhode

Artificial Intelligence for the Electron Ion Collider (2025)
October, 28, 2025



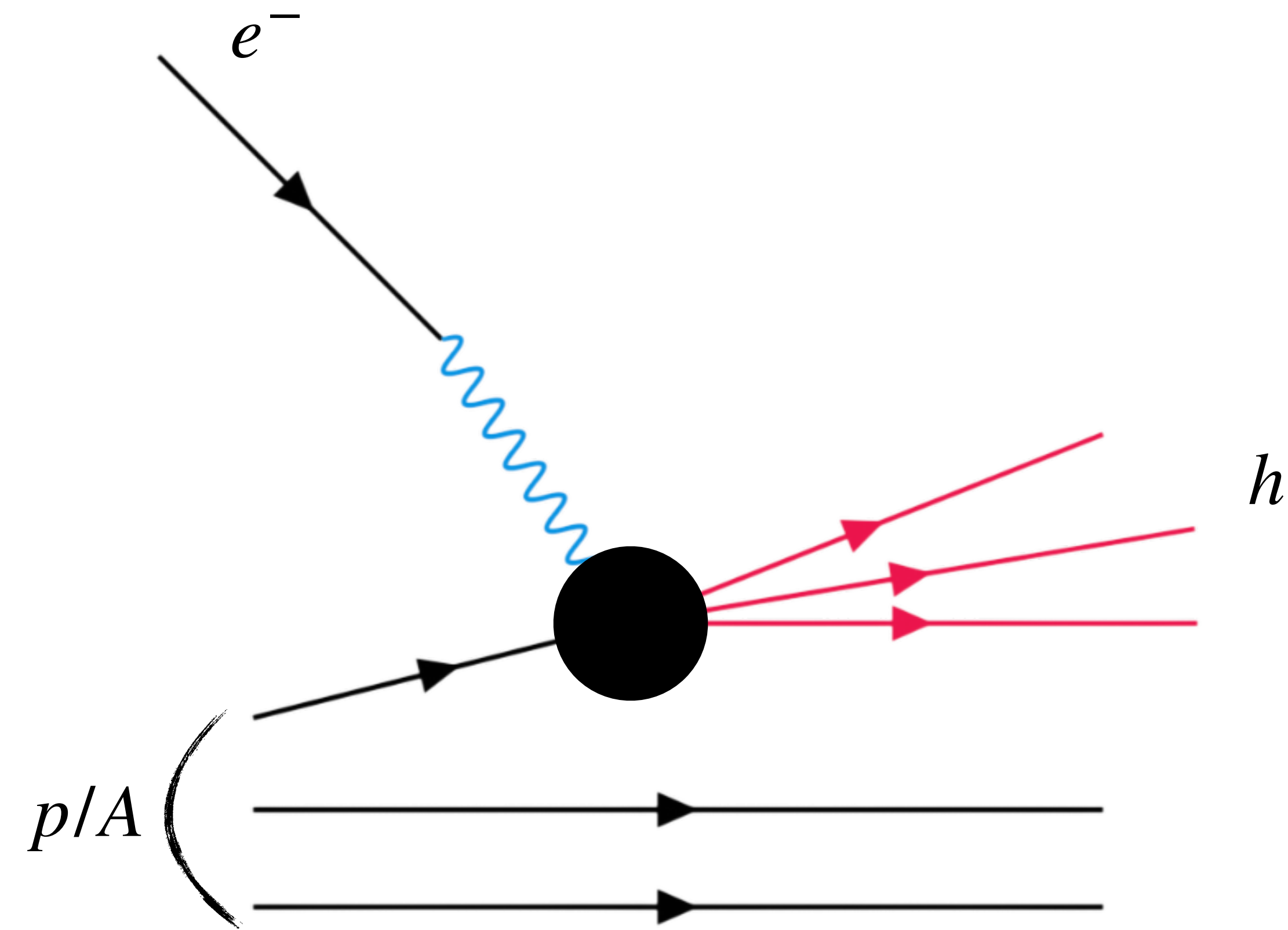
The ePIC detector at the EIC



pfRICH subsystem in backward region

- A compact central detector with several subsystems
- Hermetic coverage: $-3.5 < \eta < 3.5$ (tracking, calorimetry, **particle identification**)

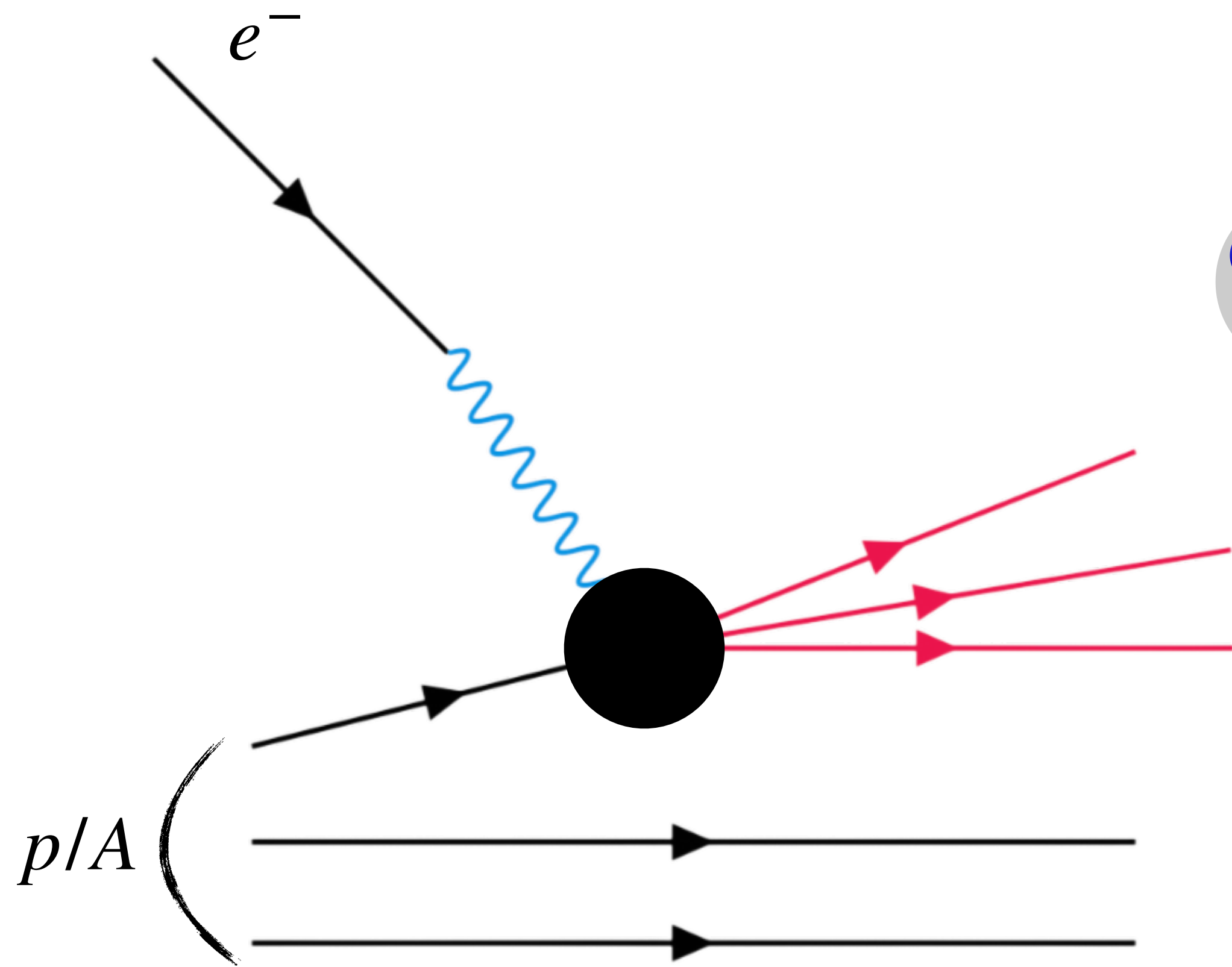
Physics Motivations at the EIC



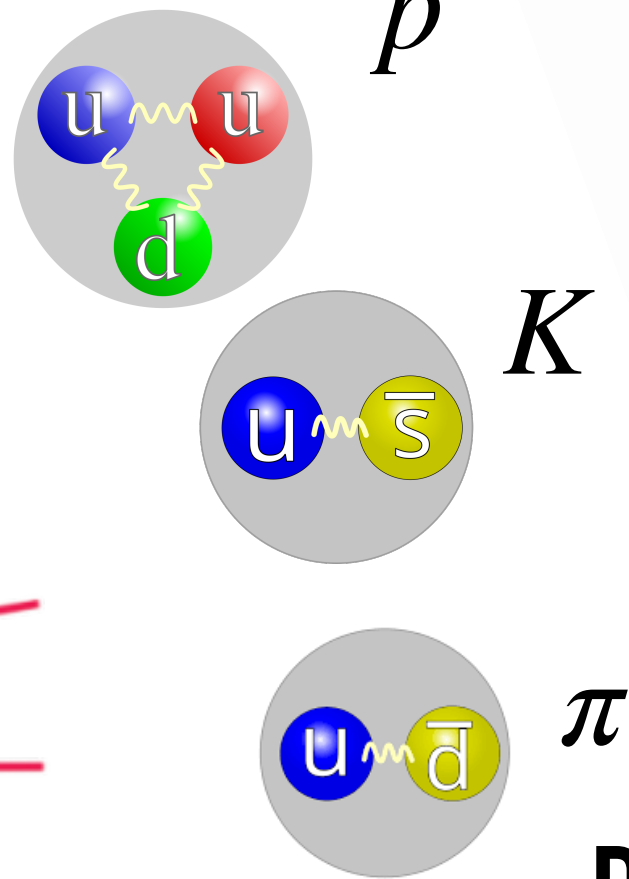
- **Semi-Inclusive Deep Inelastic Scattering**
- **Production of hadrons in final-state**
- Provide information on:
 - the *fragmentation process (hadronization)*
 - the *hadronic structure*

Particle Identification detectors are crucial

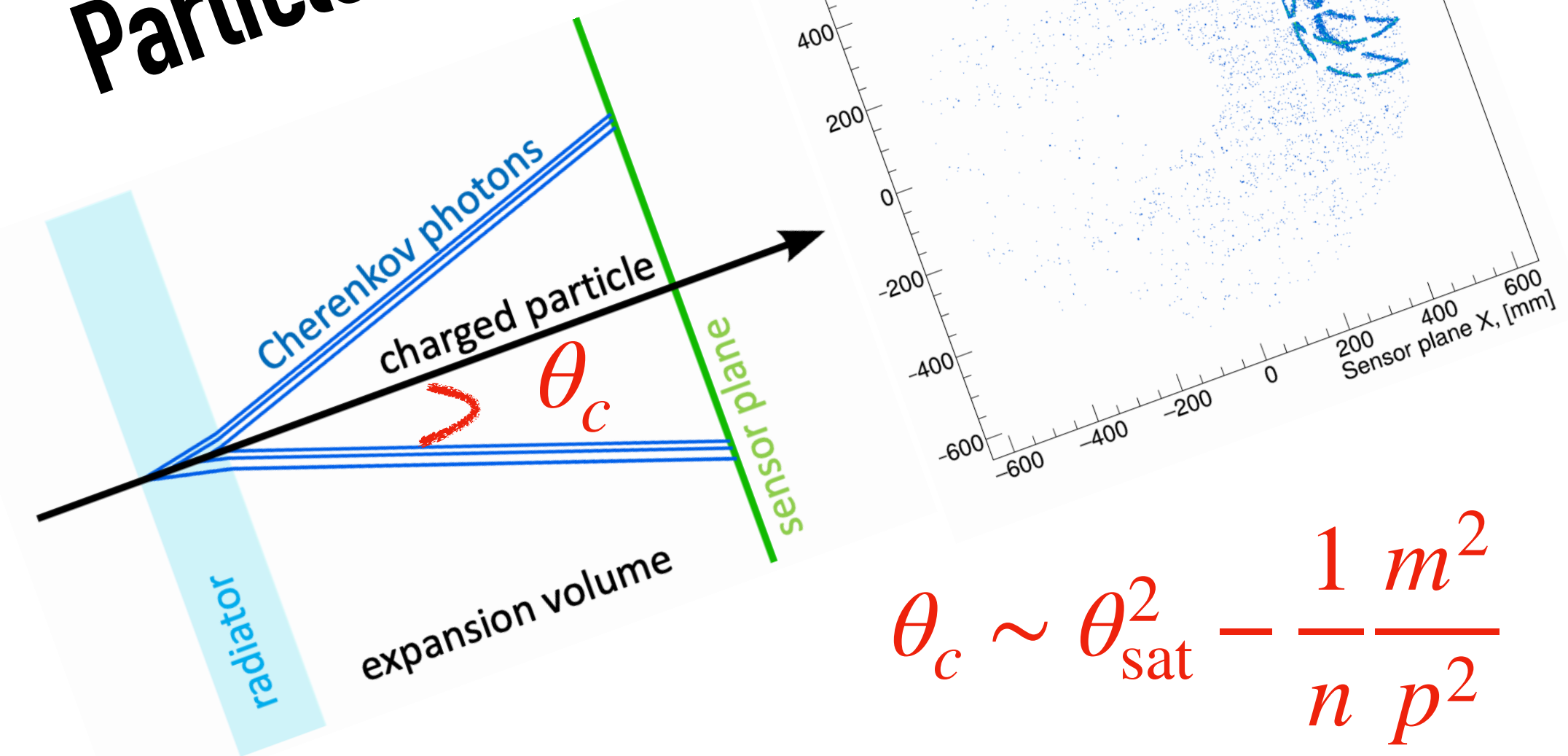
The pfRICH Concept



The pfRICH will provide $> 3\sigma$ π/K separations for momentum up to 7 GeV/c for $-3.5 < \eta < -1.5$



Particle Identification

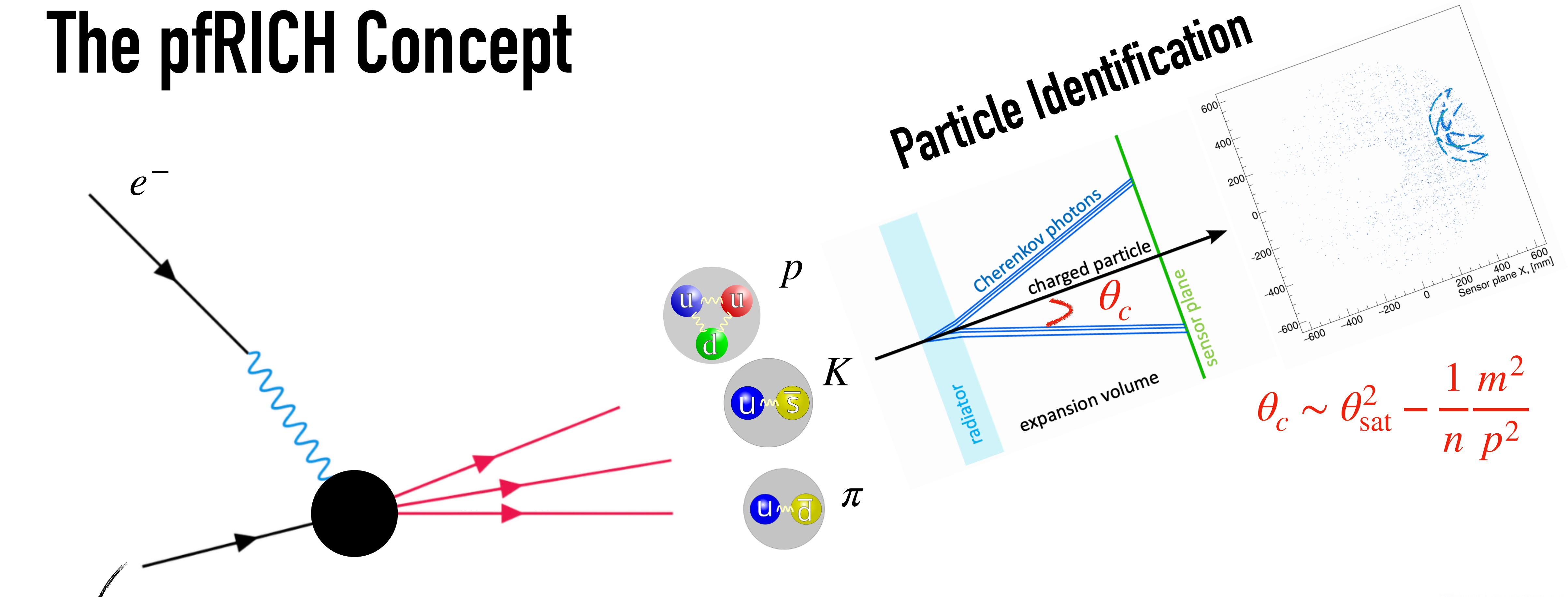


$$\theta_c \sim \theta_{\text{sat}}^2 - \frac{1}{n} \frac{m^2}{p^2}$$

Detection Principle

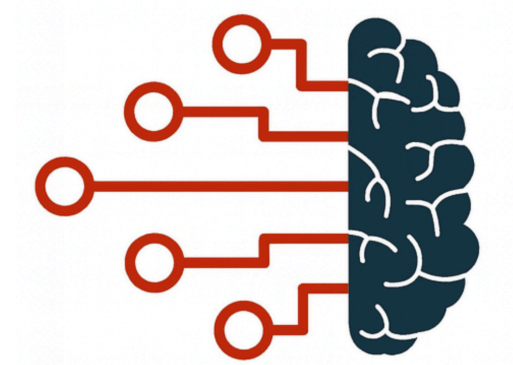
- Charged particle \rightarrow emits Cherenkov photons at angle θ_c
- Photons project onto photodetectors \rightarrow form a **ring**
 \rightarrow Ring radius $\propto \tan \theta_c$
- Measuring ring size \rightarrow deduce $\theta_c \rightarrow$ **particle mass**

The pfRICH Concept



$$\theta_c \sim \theta_{\text{sat}}^2 - \frac{1}{n} \frac{m^2}{p^2}$$

Can we use machine learning to improve particle identification?



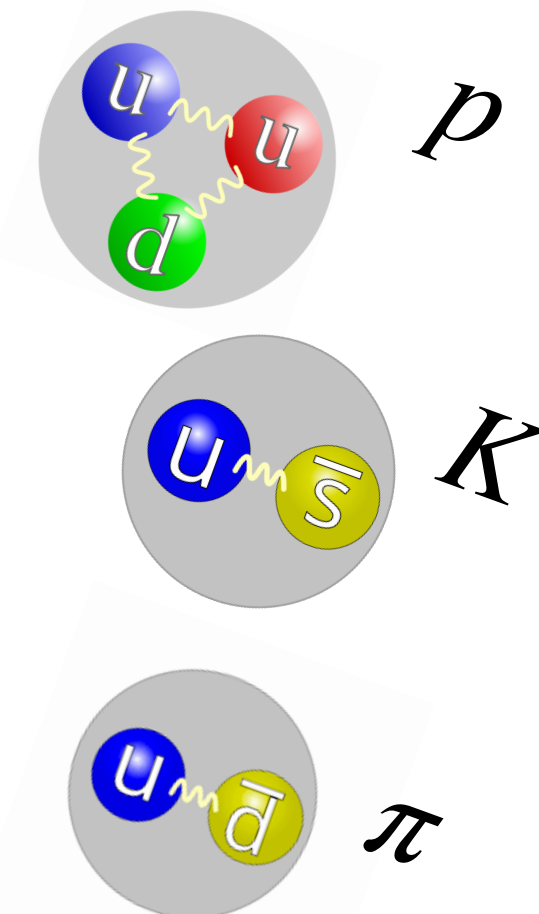
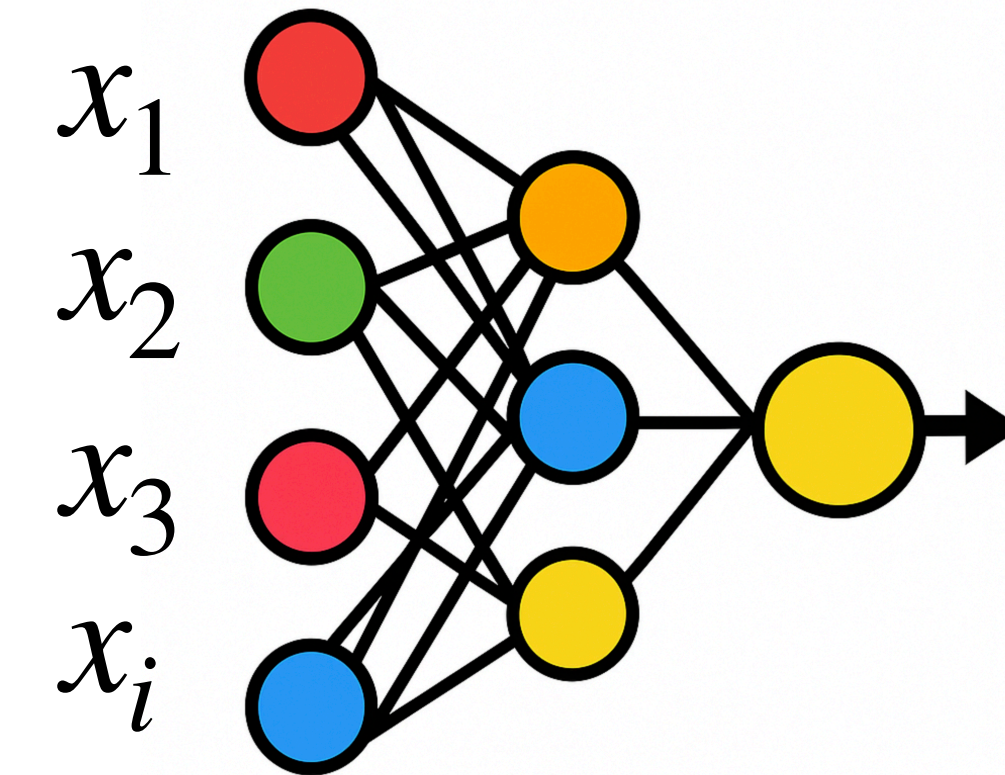
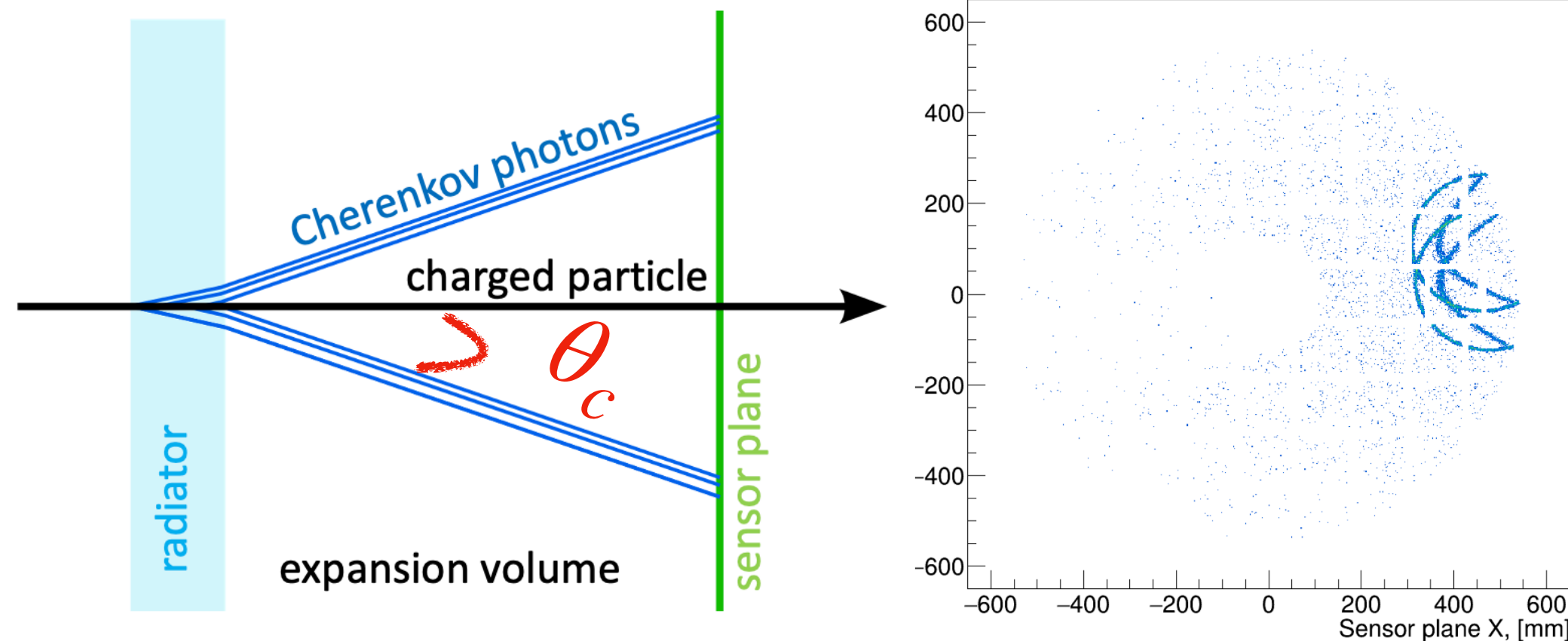
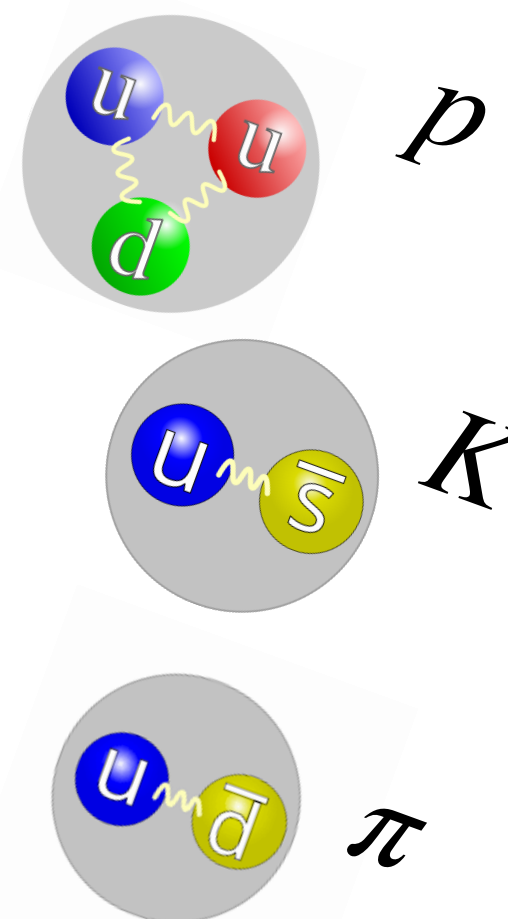
The approach

Physics

pfRICH

AI/ML model

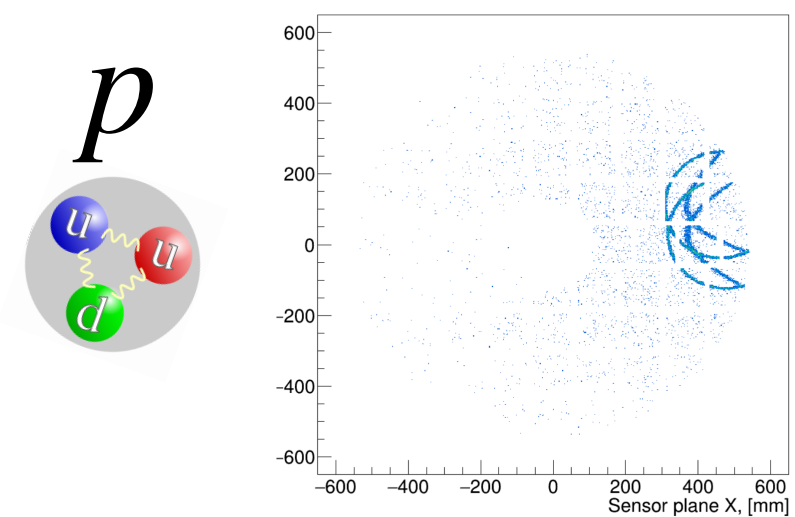
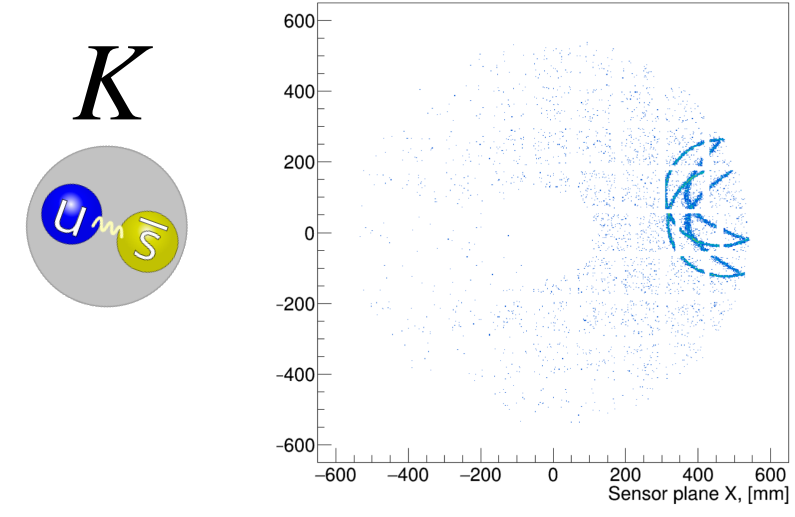
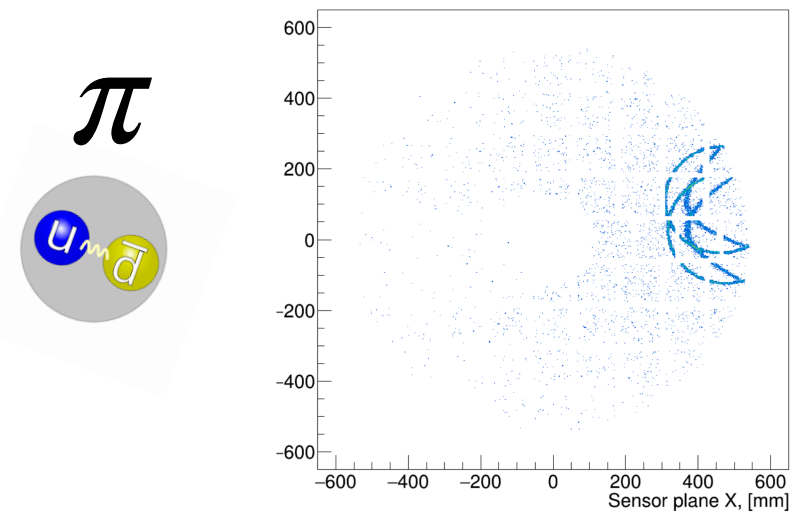
PID



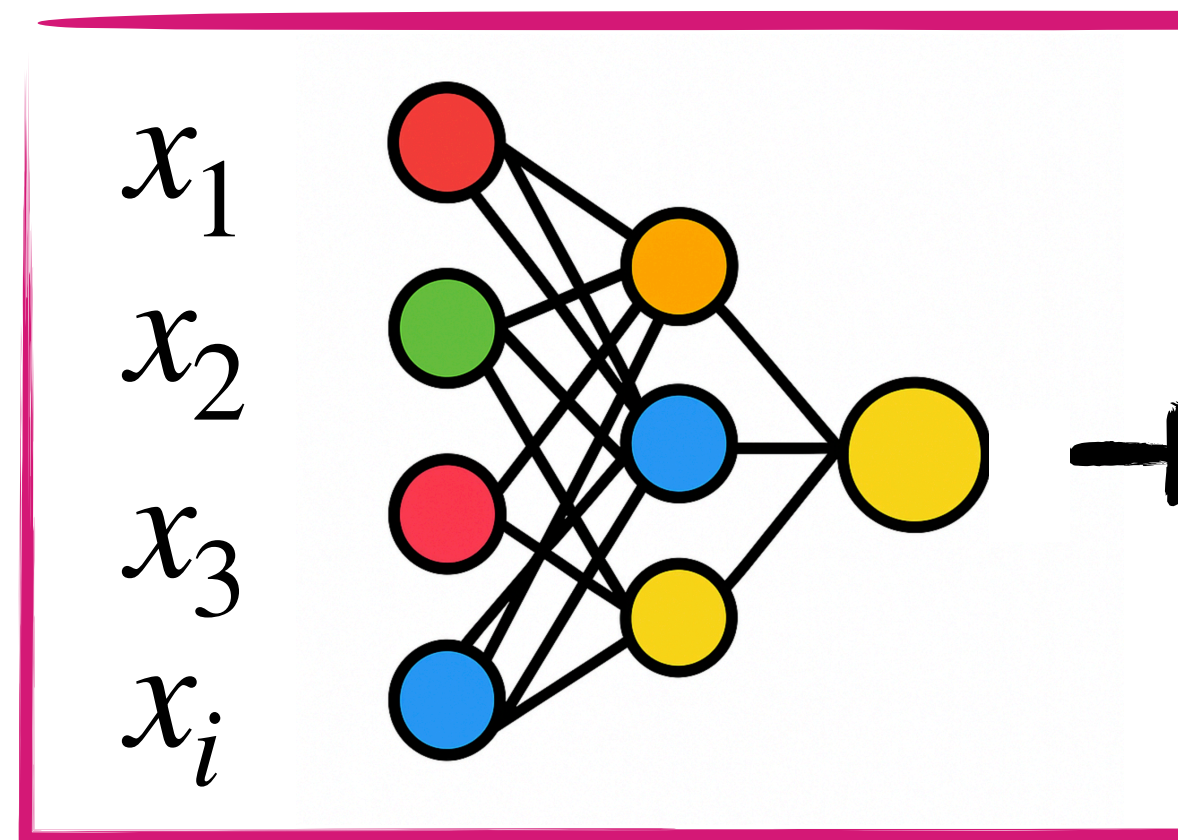
Can we use machine learning to improve particle identification?: Yes!

An ideal use case for AI/ML, since the signal is well defined and fully understood

Model training



Training



AI/ML model

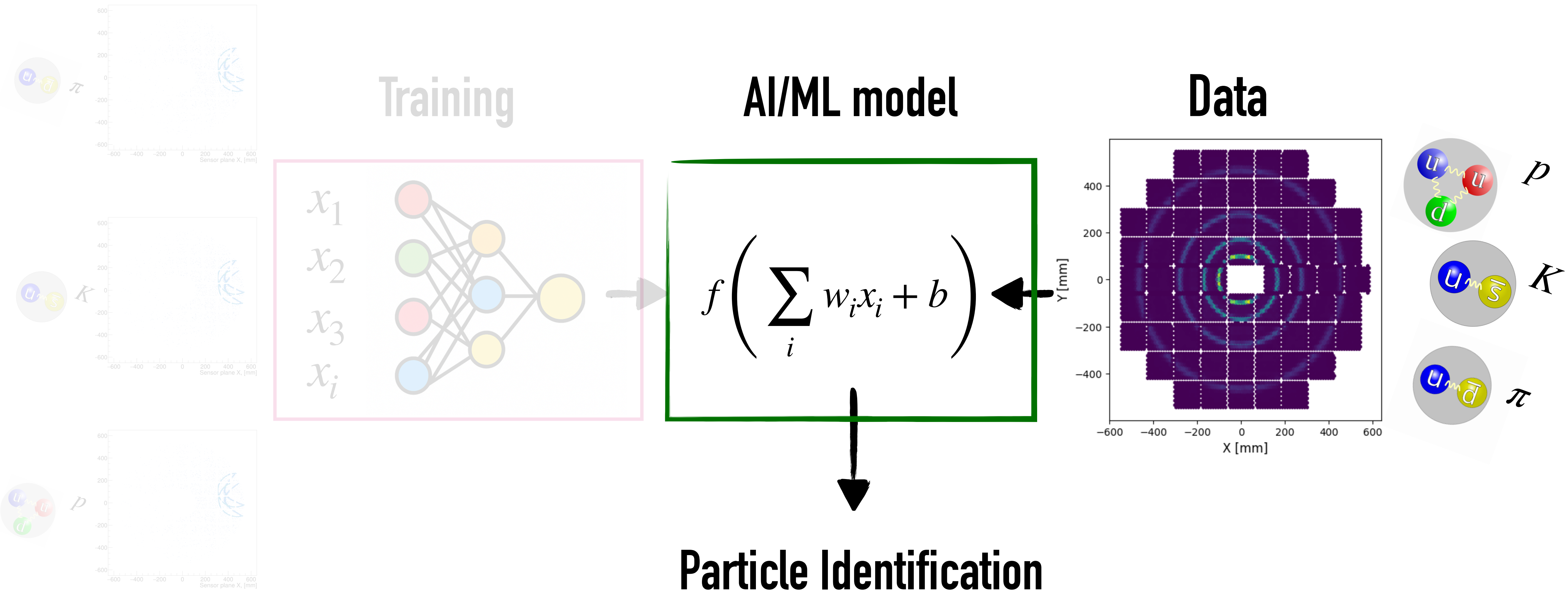
$$f\left(\sum_i w_i x_i + b\right)$$

XGBoost
Gradient-boosted hybrid
Diffusion model (ongoing)

Standalone ePIC pfRICH GEANT4:

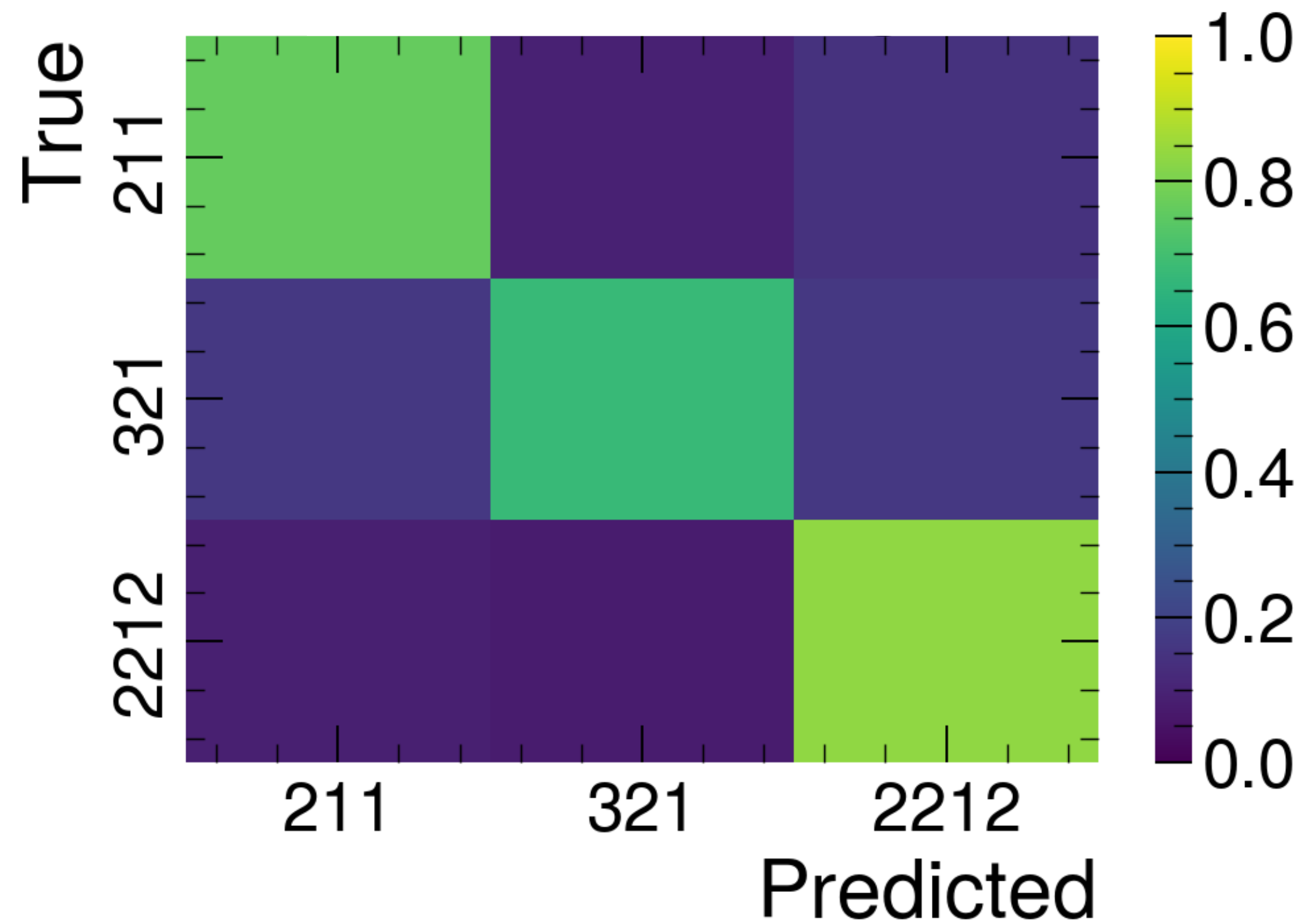
- Timing, hits position, momentum ...
- More (good) data → better training

Model inference

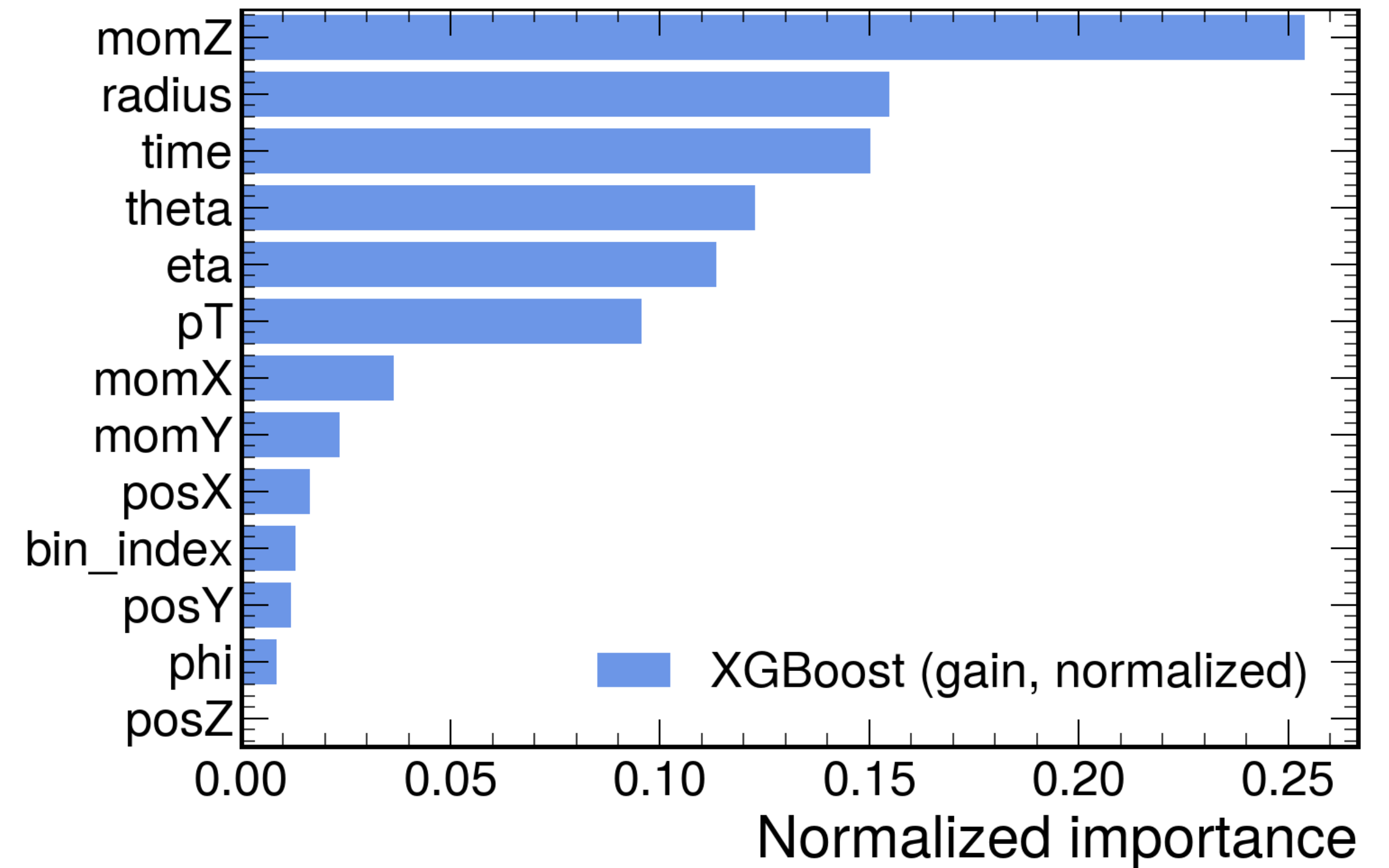


Results

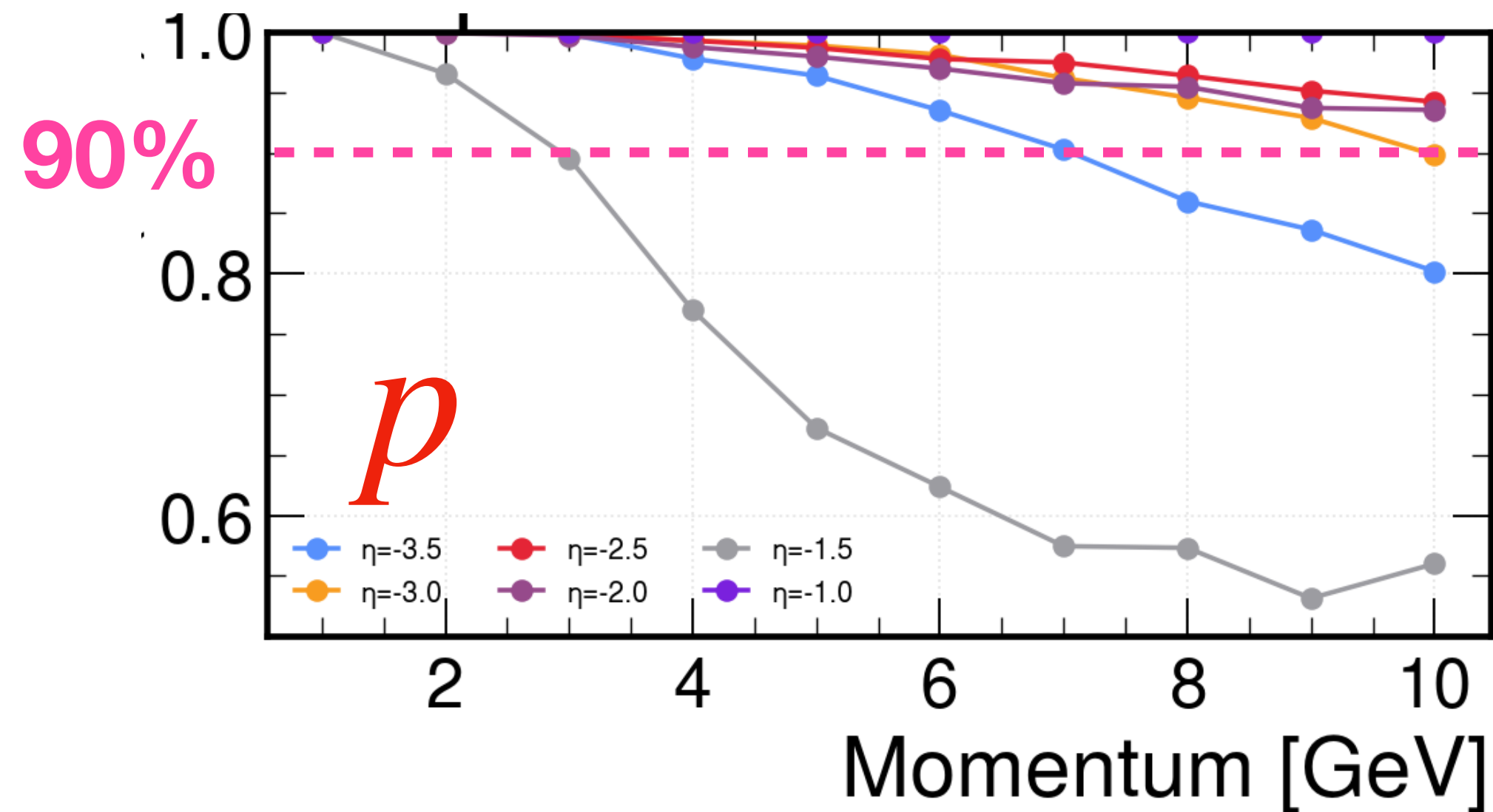
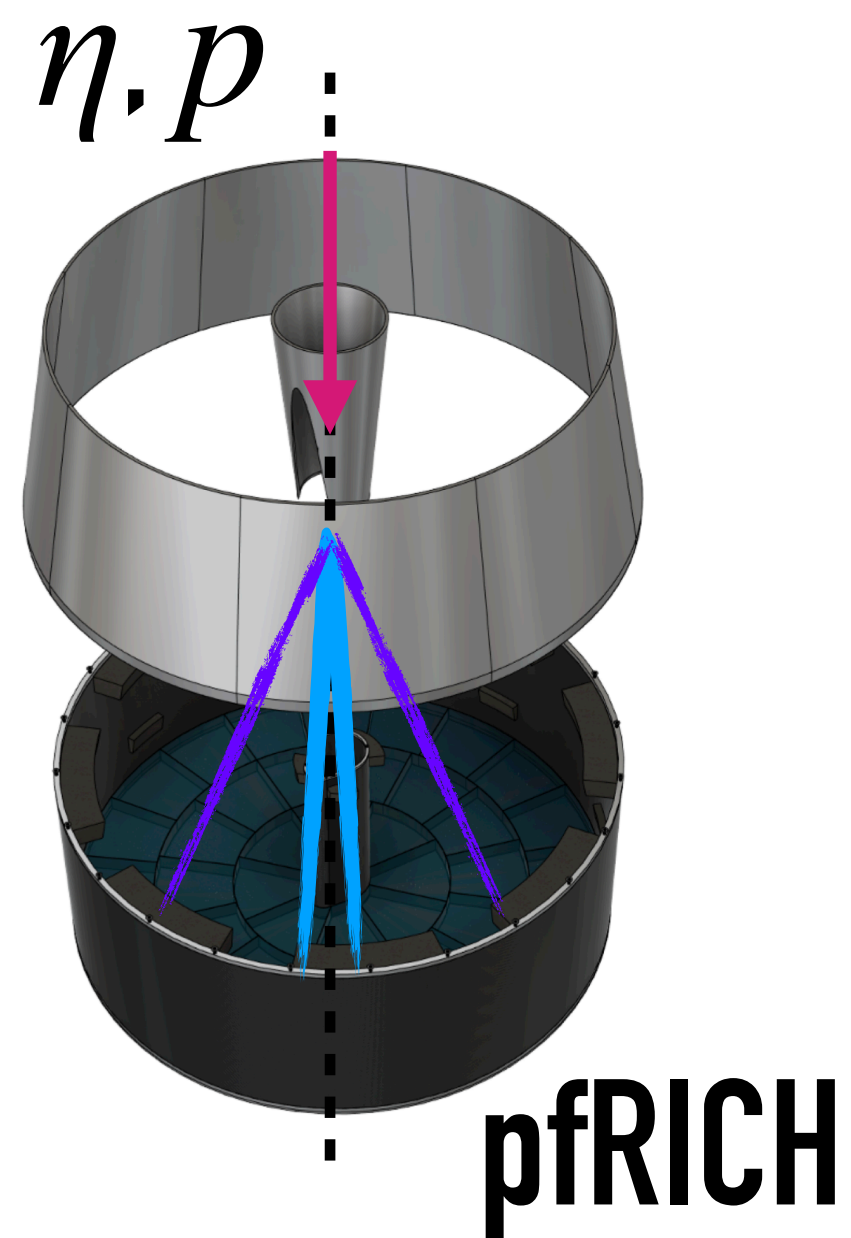
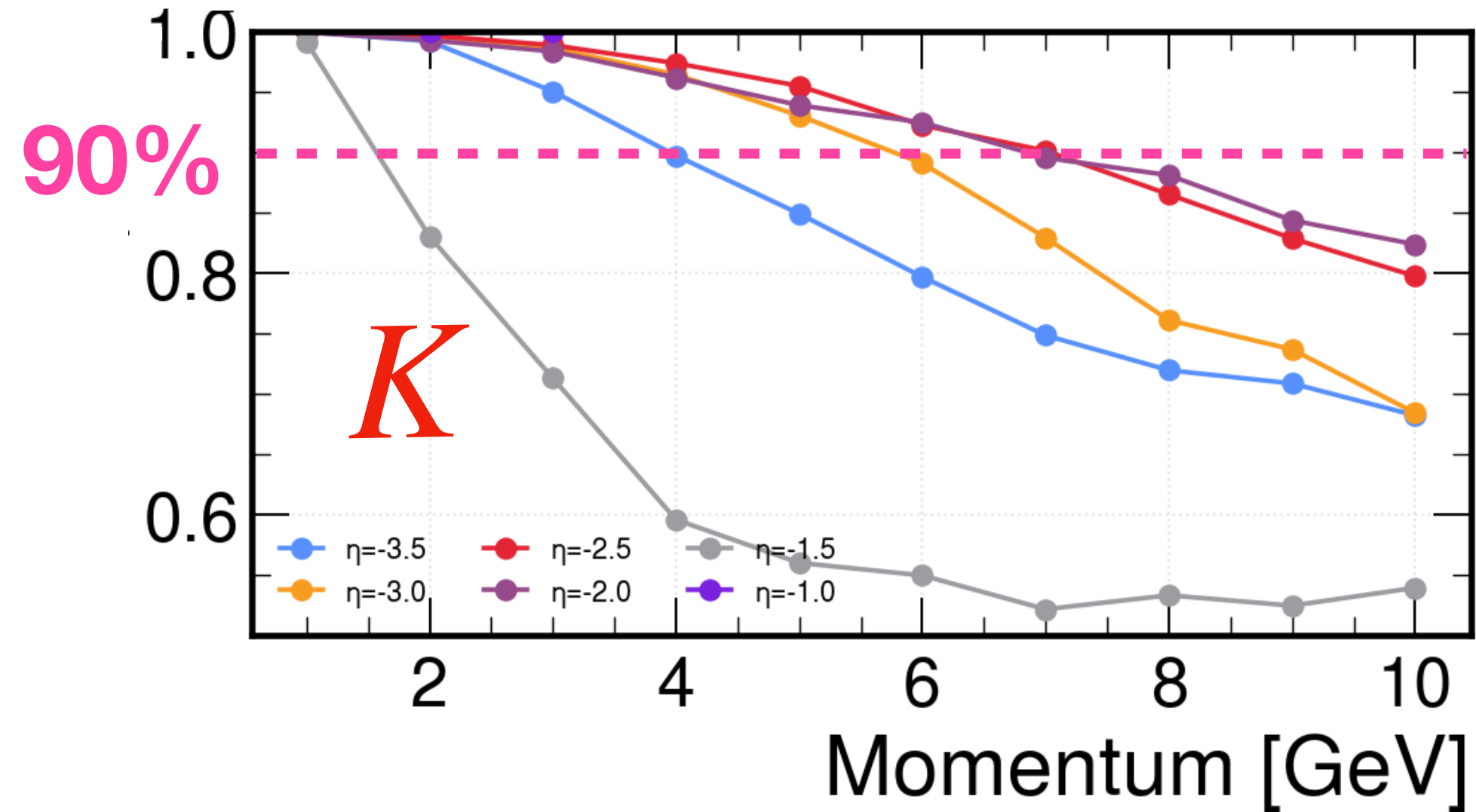
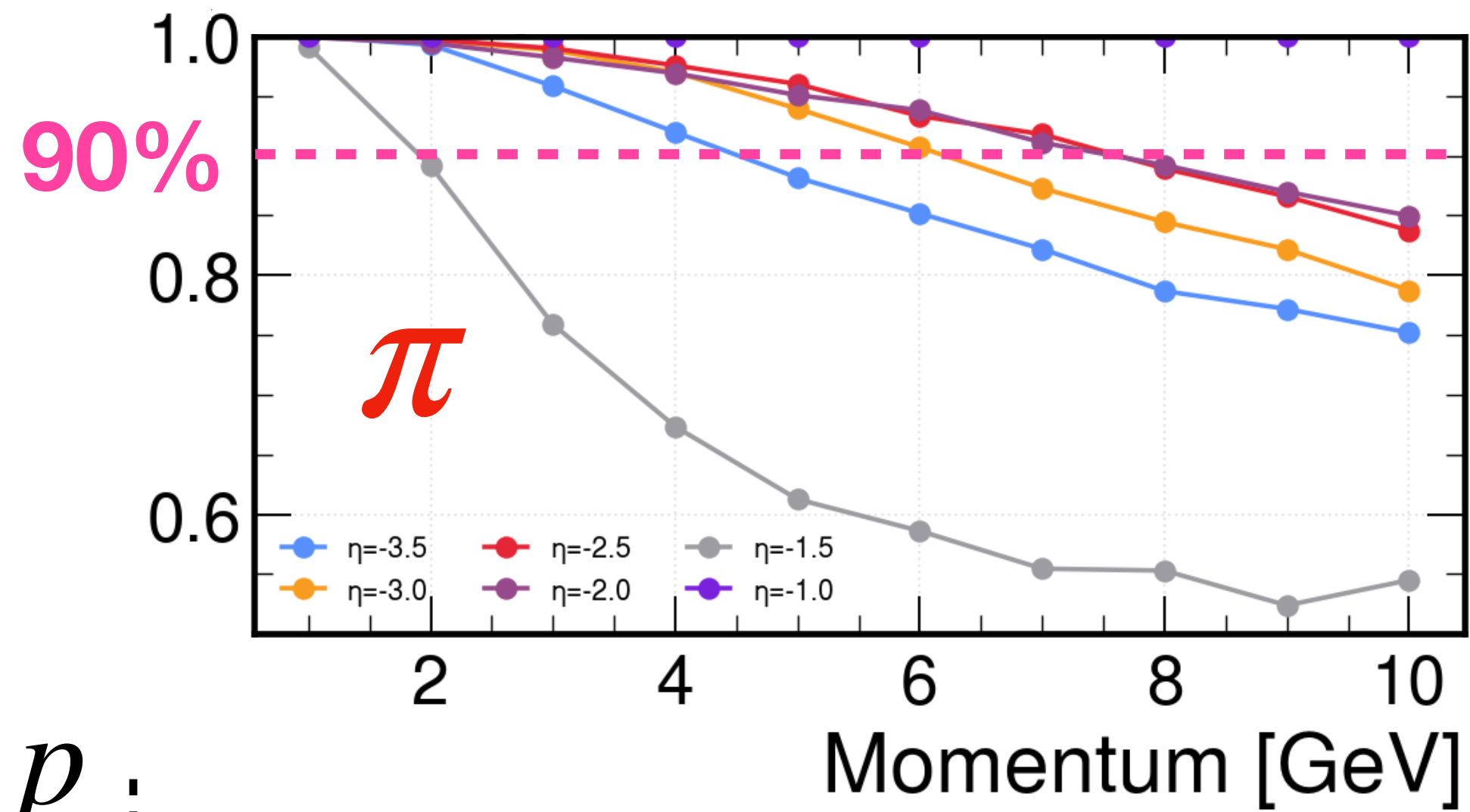
Confusion matrix



Feature importance



Separation efficiency



Promising results!

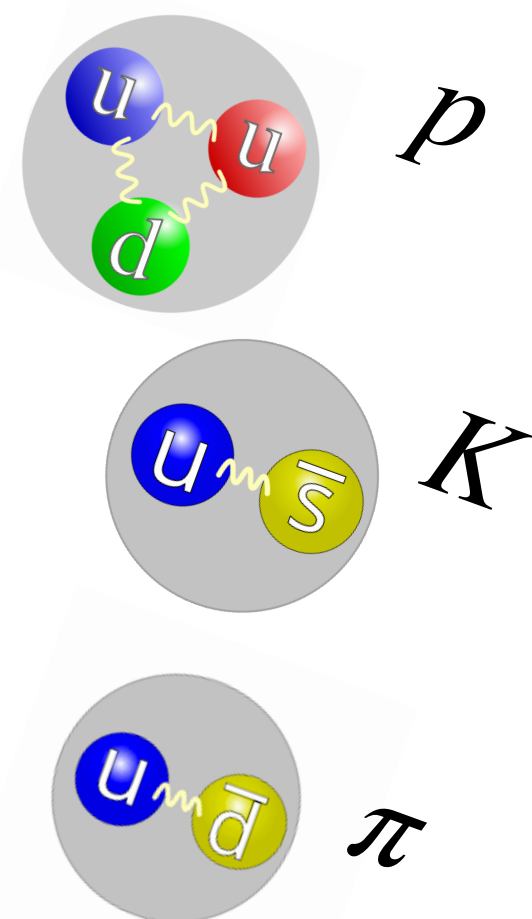
Generalize the approach

Physics

Subsystems

AI/ML model

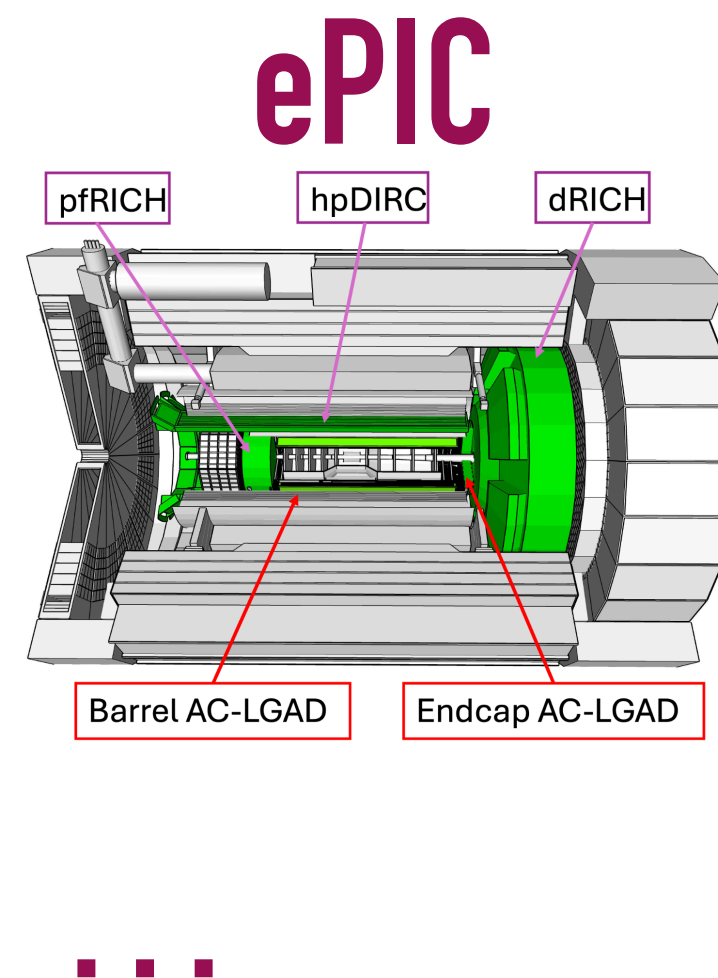
PID



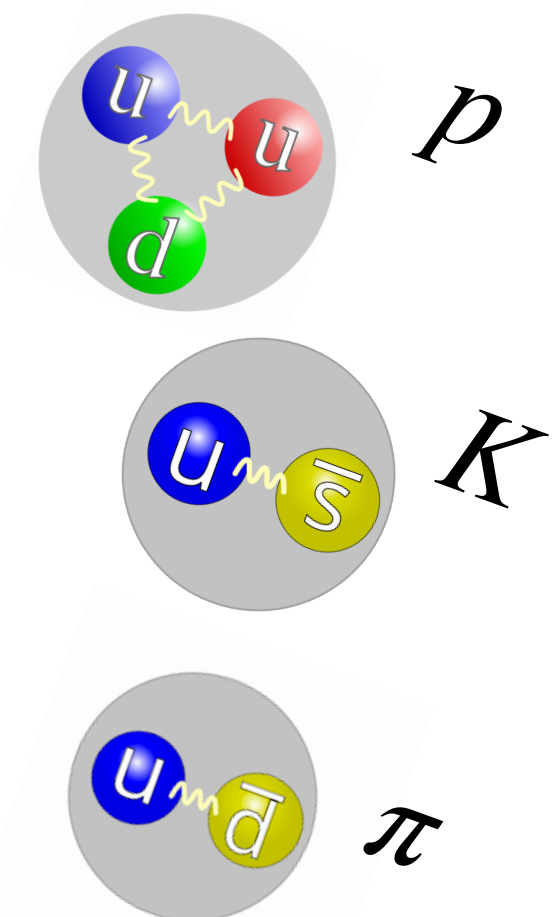
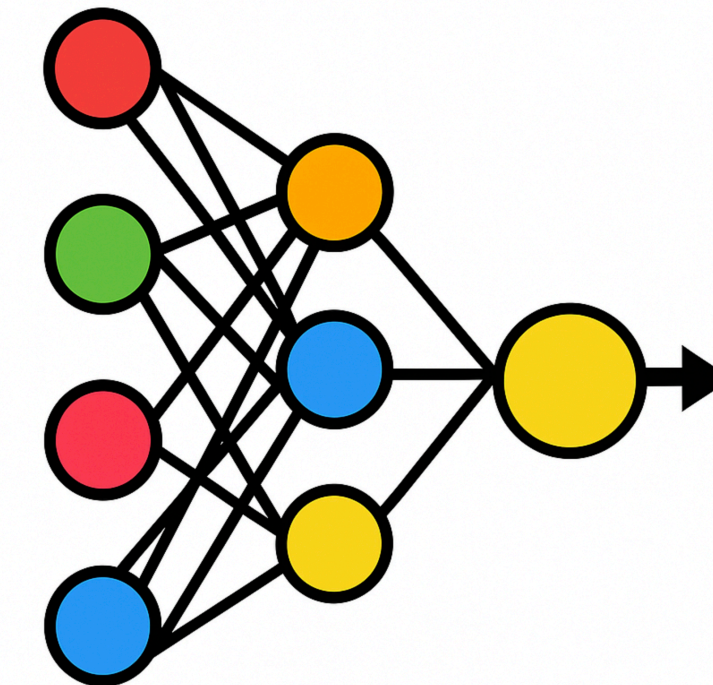
pfRICH

hpDIRC

dDRICH



x_1
 x_2
 x_3
 x_i



This method can be extended to all ePIC PID subsystems

The more information available, the better the model will perform

Conclusion

- **Promising separation** observed — clear distinction between particle species
- Overall, a solid step toward robust and reliable particle identification
- AI/ML methods can be generalized to all ePIC subsystems **See Dmitry's talk**

Next steps:

- Optimize PID parameters + diffusion model (work in progress)
- Use data produced using NVIDIA OptiX and GDML-based detector geometries
- Generate true SIDIS events within the ePIC software **See Gabor's talk**



Backup slides

Diffusion model (work ongoing)

t=0

t=50

t=100

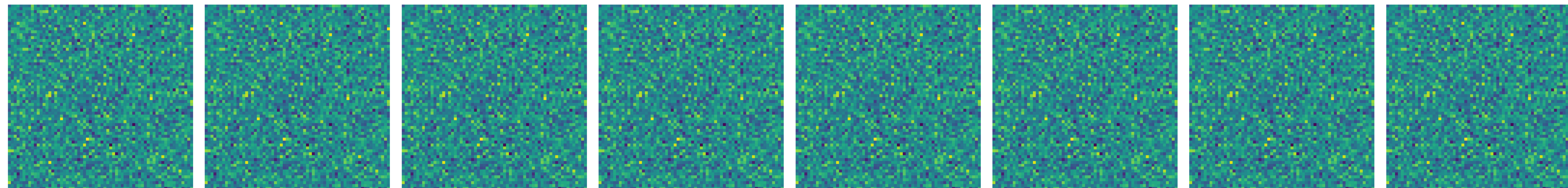
t=200

t=400

t=600

t=800

t=999



Original

Denoised t=900

Denoised t=700

Denoised t=500

Denoised t=300

Denoised t=100

Denoised t=0

Final Denoised

