Kaon Semi-Inclusive Deep Inelastic Scattering

Simone Vallarino
INFN Genova
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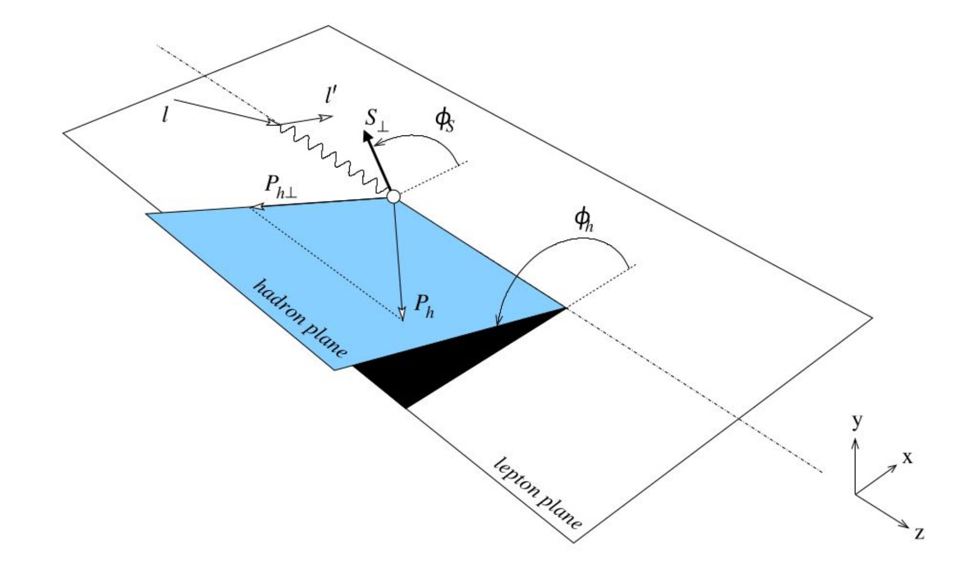
Semi-Inclusive DIS

SIDIS is the scattering of a lepton over a nucleon, producing a final state on which the scattered lepton and at least one hadron are detected.

$$\ell(l) + N(P) \rightarrow \ell(l') + h(P_h) + X$$



$$\frac{d\sigma}{dx\,dy\,d\psi\,dz\,d\phi_h\,dP_{h\perp}^2} =$$

$$\frac{\alpha^2}{xyQ^2}\frac{y^2}{2(1-\varepsilon)}\left(1+\frac{\gamma^2}{2x}\right)\Big\{F_{UU,T} + \varepsilon F_{UU,L} + \sqrt{2\varepsilon(1+\varepsilon)}\cos\phi_h F_{UU}^{\cos\phi_h}$$

$$+ \varepsilon\cos(2\phi_h) F_{UU}^{\cos 2\phi_h} + \lambda_e\sqrt{2\varepsilon(1-\varepsilon)}\sin\phi_h F_{LU}^{\sin\phi_h}$$

$$+ S_{\|}\left[\sqrt{2\varepsilon(1+\varepsilon)}\sin\phi_h F_{UL}^{\sin\phi_h} + \varepsilon\sin(2\phi_h) F_{UL}^{\sin 2\phi_h}\right]$$

$$+ S_{\|}\lambda_e\left[\sqrt{1-\varepsilon^2}\,F_{LL} + \sqrt{2\varepsilon(1-\varepsilon)}\cos\phi_h F_{LL}^{\cos\phi_h}\right]$$

$$+ |\boldsymbol{S}_\perp|\Big[\sin(\phi_h-\phi_S)\left(F_{UT,T}^{\sin(\phi_h-\phi_S)} + \varepsilon F_{UT,L}^{\sin(\phi_h-\phi_S)}\right)$$

$$+ \varepsilon\sin(\phi_h+\phi_S) F_{UT}^{\sin(\phi_h+\phi_S)} + \varepsilon\sin(3\phi_h-\phi_S) F_{UT}^{\sin(3\phi_h-\phi_S)}$$

$$+ \sqrt{2\varepsilon(1+\varepsilon)}\sin\phi_S F_{UT}^{\sin\phi_S} + \sqrt{2\varepsilon(1+\varepsilon)}\sin(2\phi_h-\phi_S) F_{UT}^{\sin(2\phi_h-\phi_S)}\Big]$$

$$+ |\boldsymbol{S}_\perp|\lambda_e\Big[\sqrt{1-\varepsilon^2}\cos(\phi_h-\phi_S) F_{LT}^{\cos(\phi_h-\phi_S)} + \sqrt{2\varepsilon(1-\varepsilon)}\cos\phi_S F_{LT}^{\cos\phi_S}$$

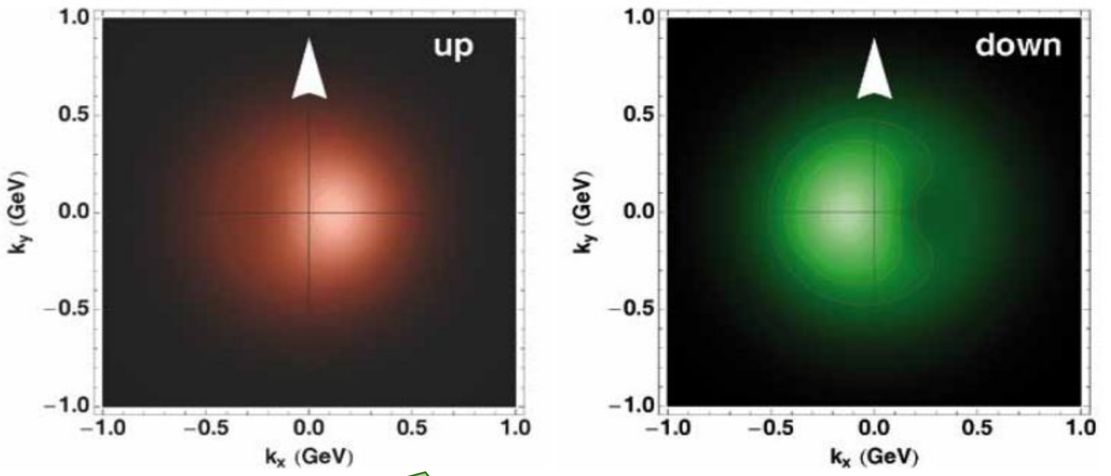
$$+ \sqrt{2\varepsilon(1-\varepsilon)}\cos(2\phi_h-\phi_S) F_{LT}^{\cos(2\phi_h-\phi_S)}\Big]\Big\}$$

$F_{\text{beam,target,virtual photon polarization}}$

Polarized SIDIS to investigate the 3D nucleon structure

Measuring the structure function $F_{XY,Z}$ can provide access to Transverse-Momentum Dependent (TMD) Parton Distribution Functions and TMD Fragmentation Functions.

$$F_{LU}^{\sin\phi} = \frac{2M}{Q}\mathcal{C}\left[\frac{\hat{\mathbf{h}}\cdot\mathbf{k}_T}{M_H}\left(x_B e H_1^{\perp} + \frac{M_h}{M} f_1 \frac{\tilde{G}^{\perp}}{z}\right) + \frac{\hat{\mathbf{h}}\cdot\mathbf{p}_T}{M}\left(x_B g^{\perp} D_1 + \frac{M_h}{M} h_1^{\perp} \frac{\tilde{E}}{z}\right)\right]$$



Up and down momentum distribution inside a polarized nucleon.

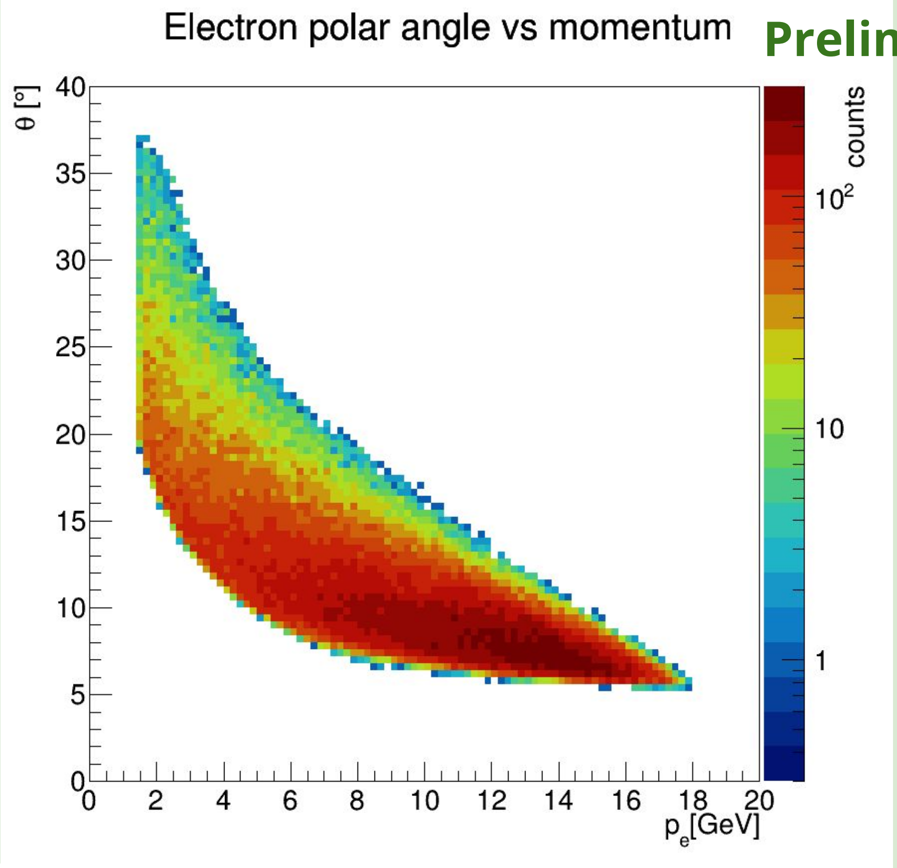
Strange quark:

That’s why we need to study kaon SIDIS!

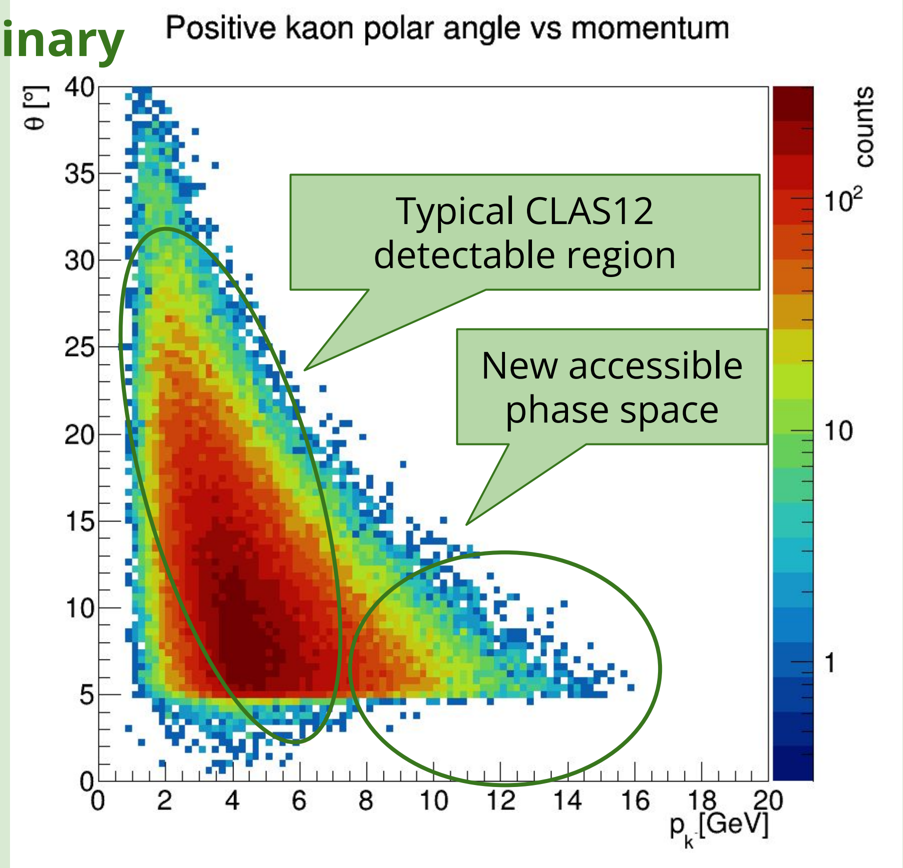
Simulation

Courtesy of Matthew McEneaney

eK⁺X phase space

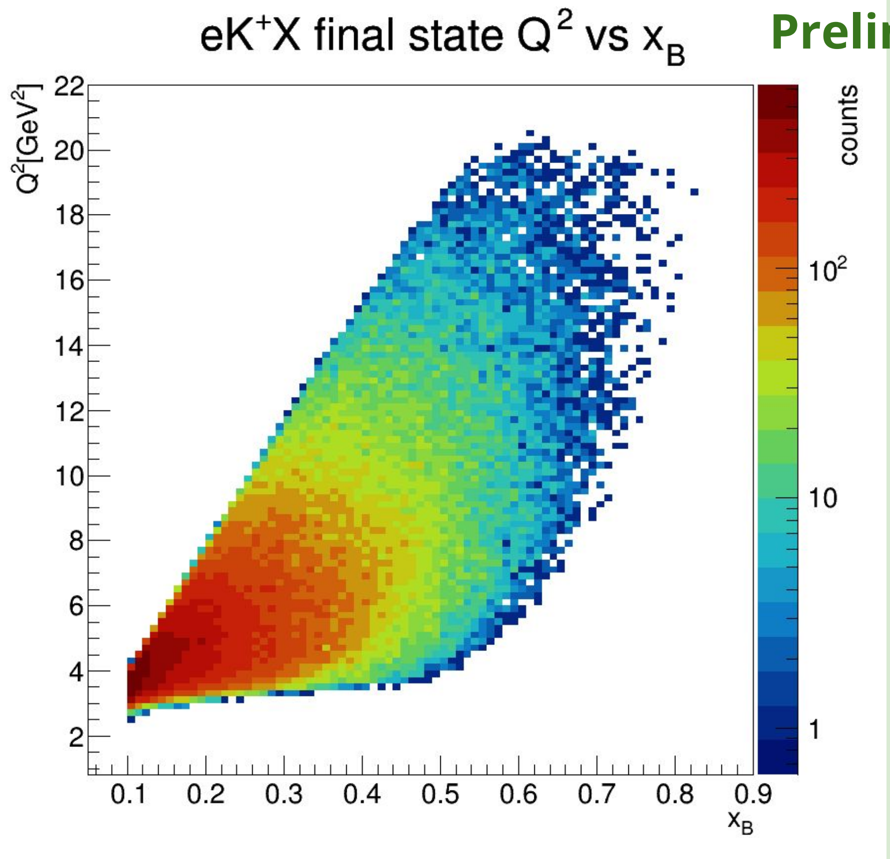


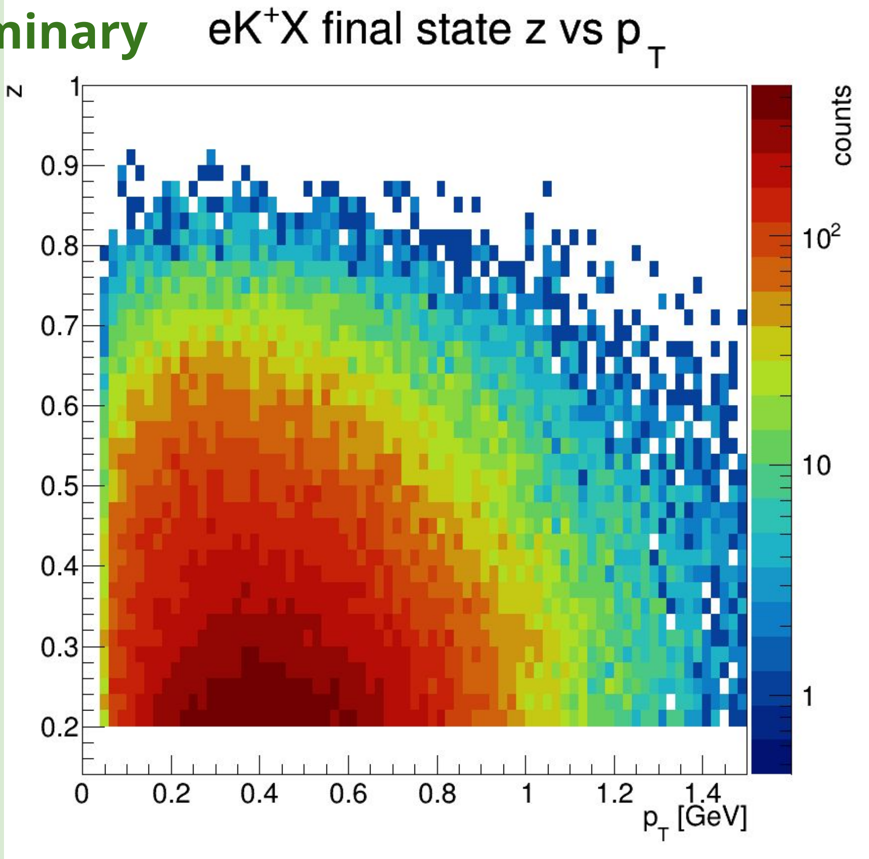
Preliminary



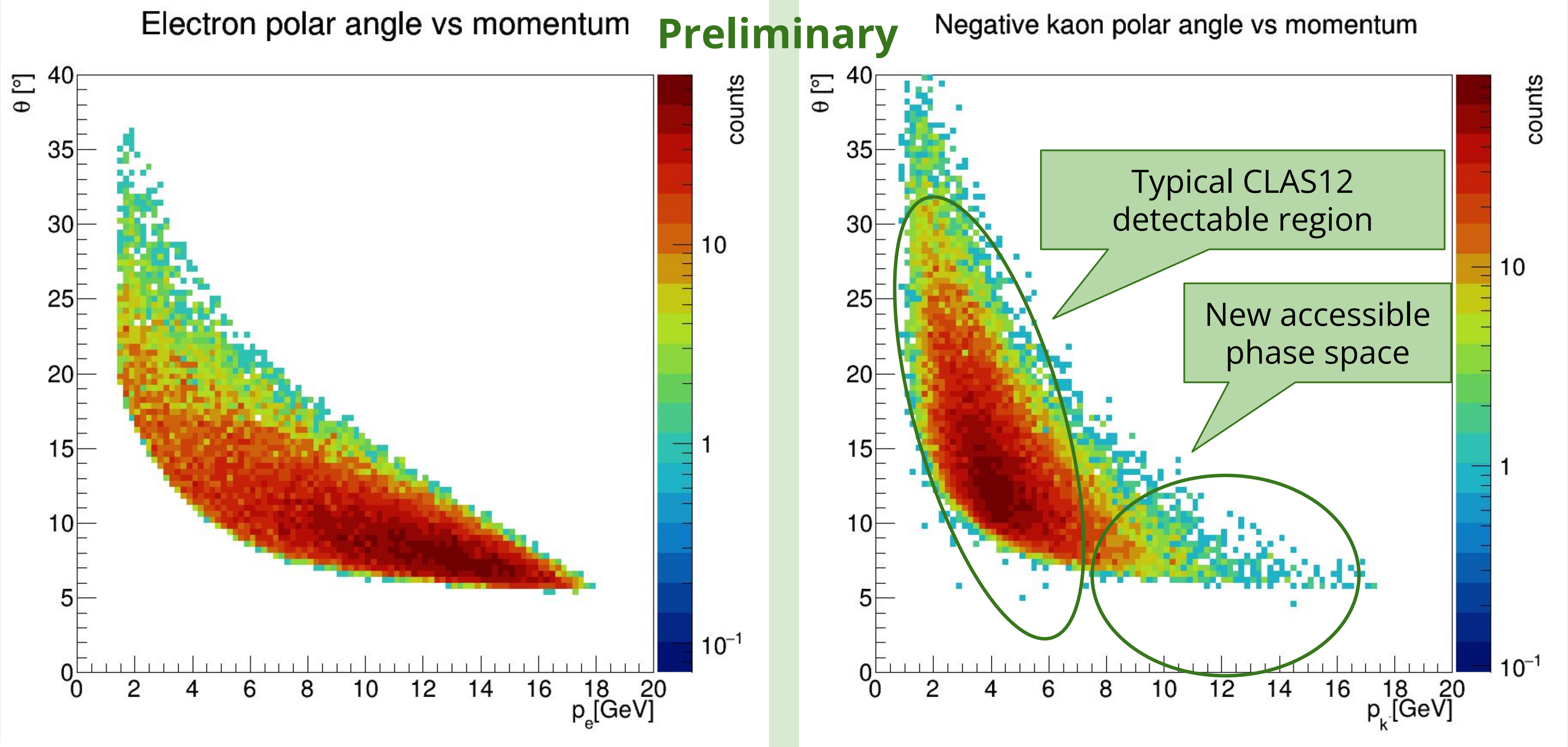
eK^+X phase space

Preliminary



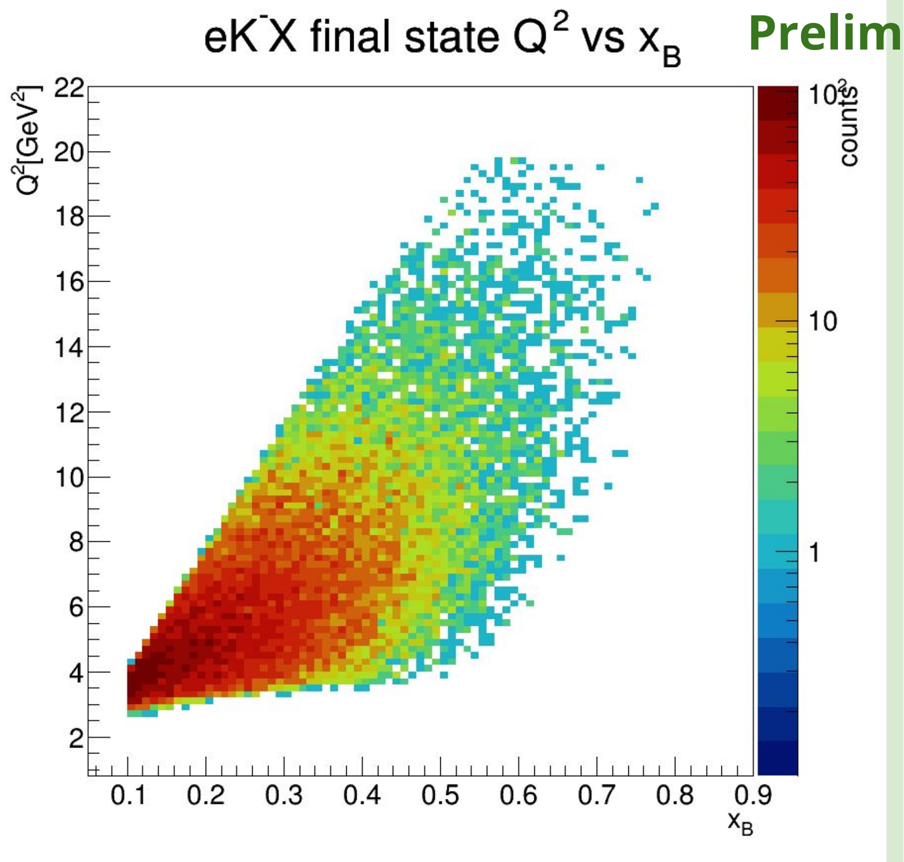


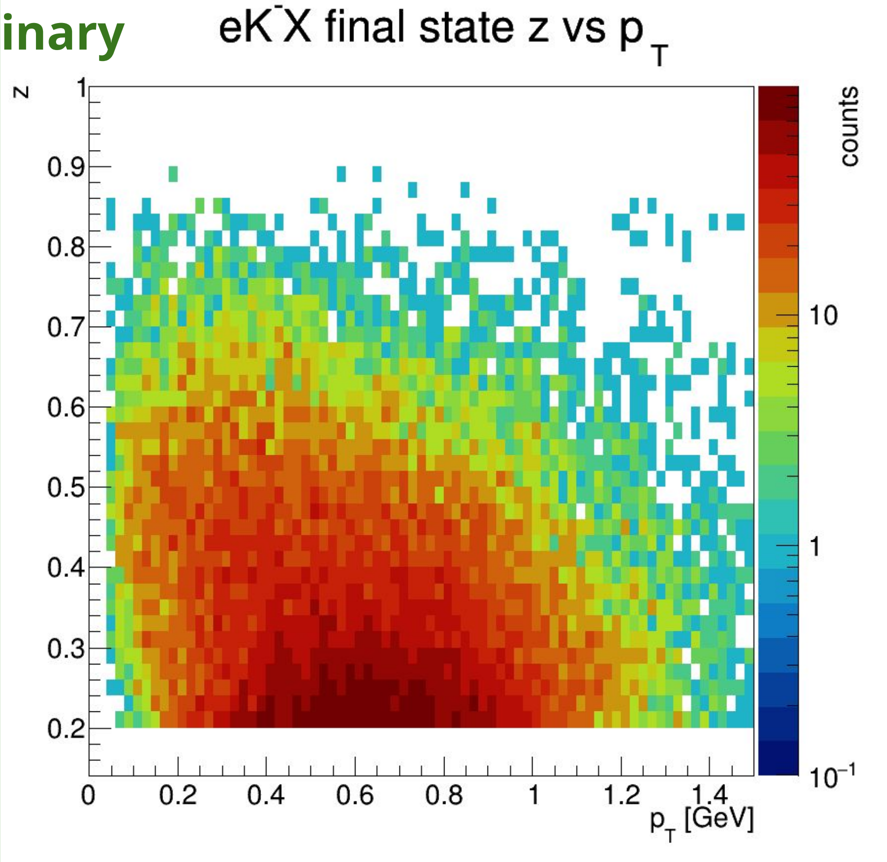
eK^-X phase space



eK^-X phase space

Preliminary

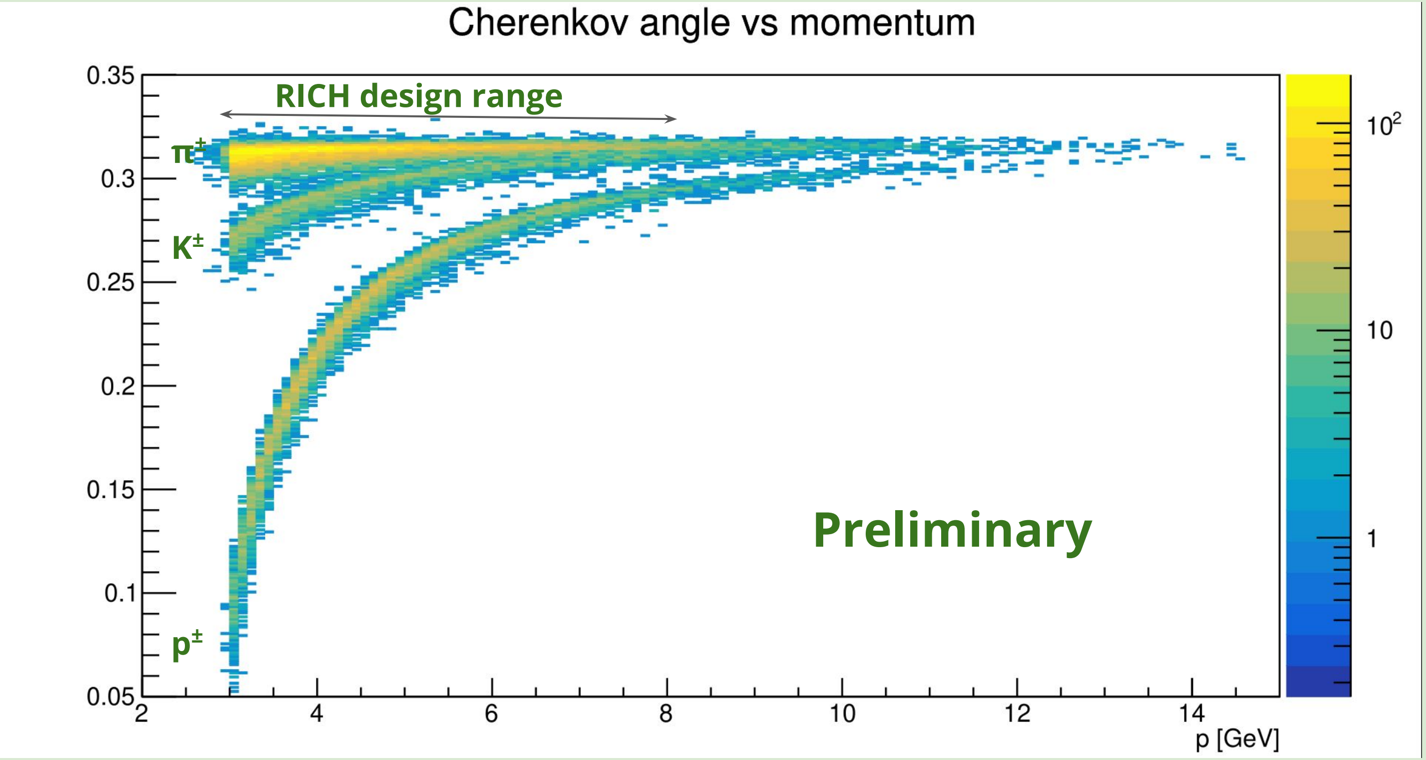




High momentum kaon identification

Courtesy of
Connor Pecar

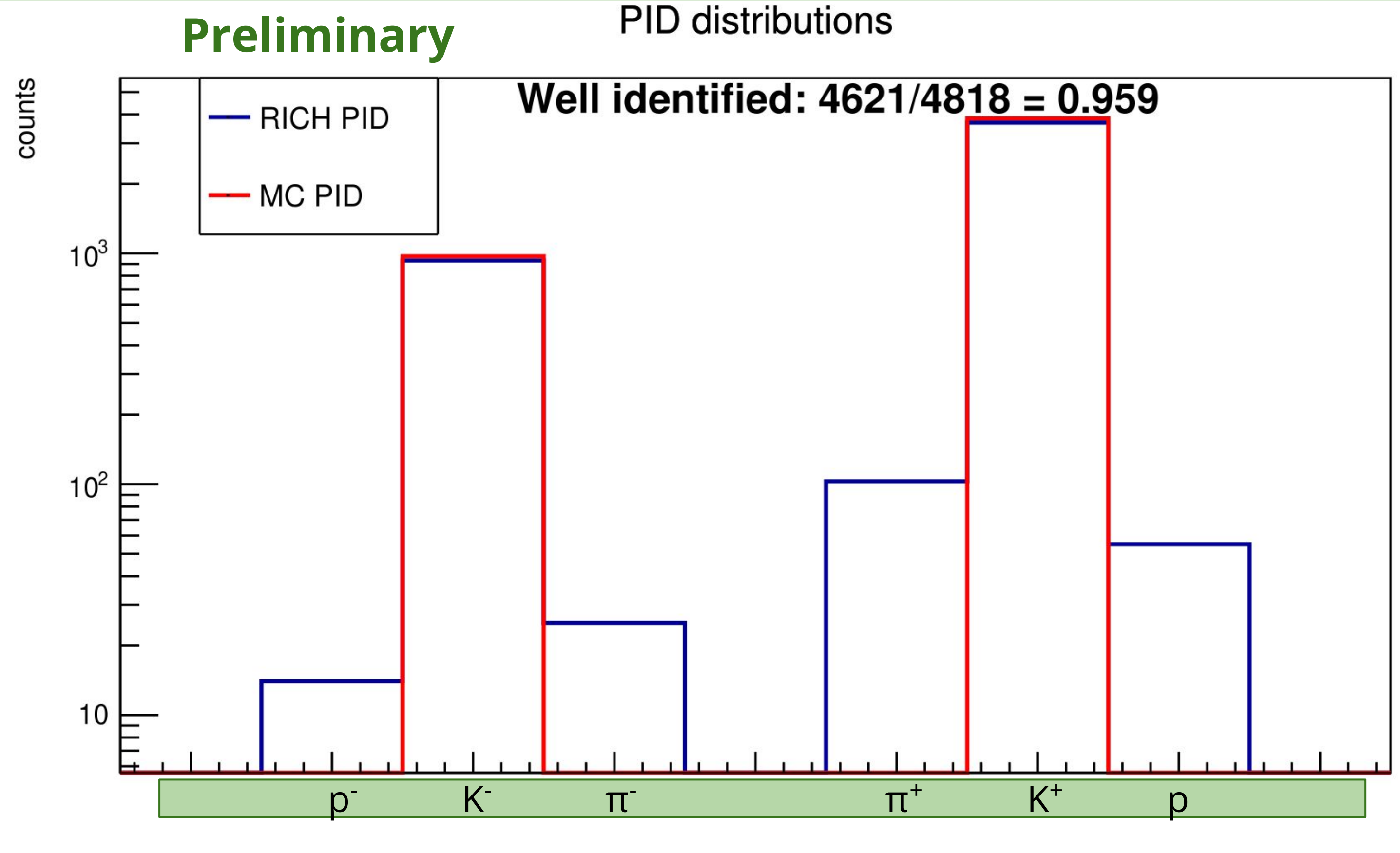
CLAS12 RICH performance at 22 GeV from simulation



Distribution of the Cherenkov angle as a function of the hadron momentum.

The population are clearly distinguished in the RICH design range (3-8 GeV).

CLAS12 RICH performance at 22 GeV from simulation

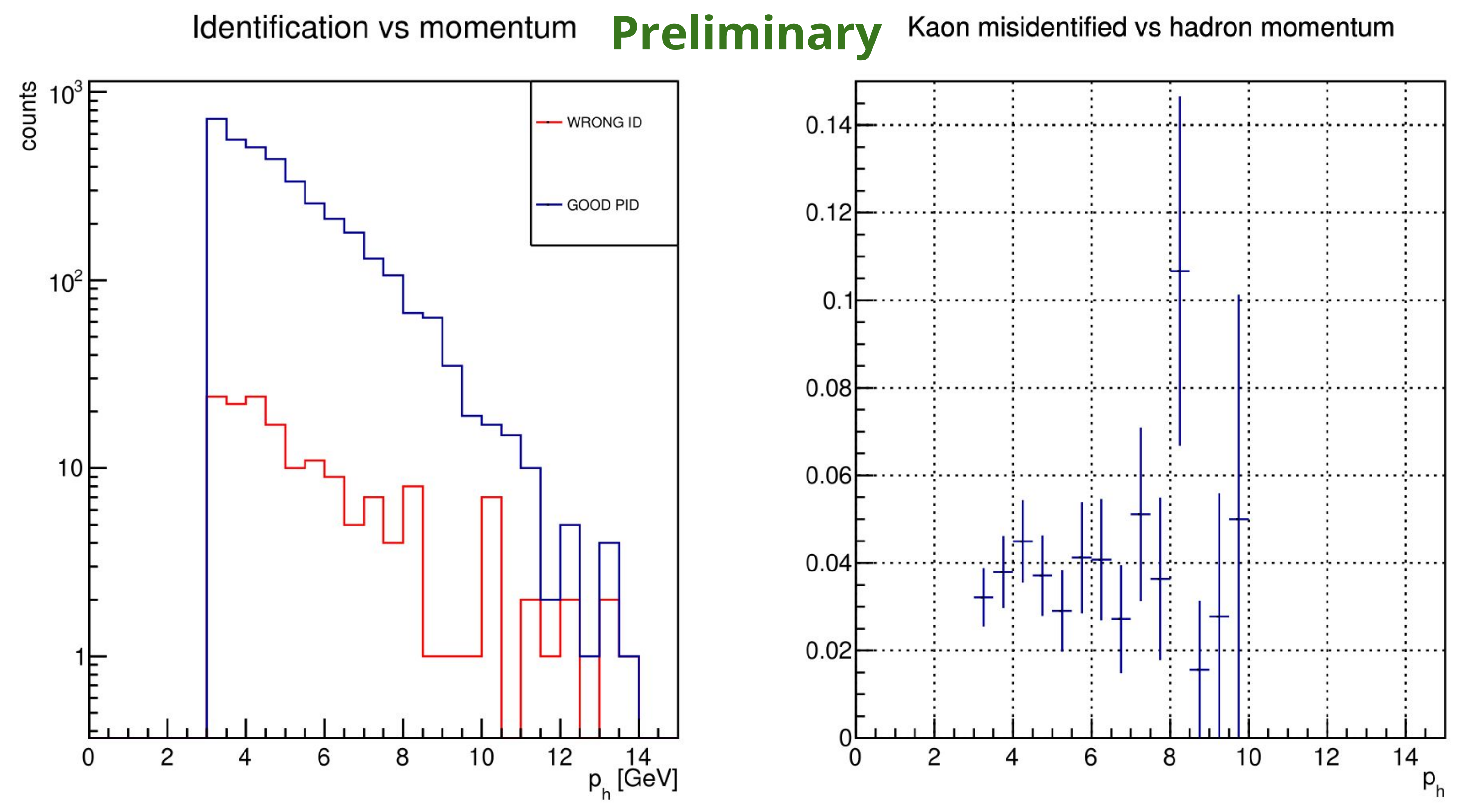


RED: True kaons selected from Monte Carlo variables.

BLUE: Identification provided by the RICH

No fiducial cuts were applied.

CLAS12 RICH performance at 22 GeV from simulation



The study suggests the CLAS12 RICH could be able to identify kaons in a range larger than the design 3-8 GeV.

A larger statistic and more tests on the simulation are needed to confirm thor preliminary result.

Outlook

- Semi-Inclusive Deep Inelastic Scattering (SIDIS) is a powerful tool for investigating nucleon structure, and increasingly precise measurements are essential to deepen our understanding of nature.
- The energy upgrade at Jefferson Lab will expand the accessible phase space and provide higher statistics for already covered kinematic regions.
- The preliminary studies suggest that the CLAS12 RICH detector will also be capable of identifying kaons with momenta exceeding 8 GeV/c with quite good efficiency.

The End

Backup slide

Measuring the structure function using Spin Asymmetry

$\phi^h \rightarrow \phi$

Definition of the Beam-Spin Asymmetry generated by the longitudinal polarization of beam

$$A_{LU} = \frac{d\sigma^+ - d\sigma^-}{d\sigma^+ + d\sigma^-} = \frac{A_{LU}^{\sin\phi^h} \sin\phi^h}{1 + A_{UU}^{\cos\phi^h} \cos\phi^h + A_{UU}^{\cos 2\phi^h} \cos 2\phi^h}$$

Experimental definition of BSA

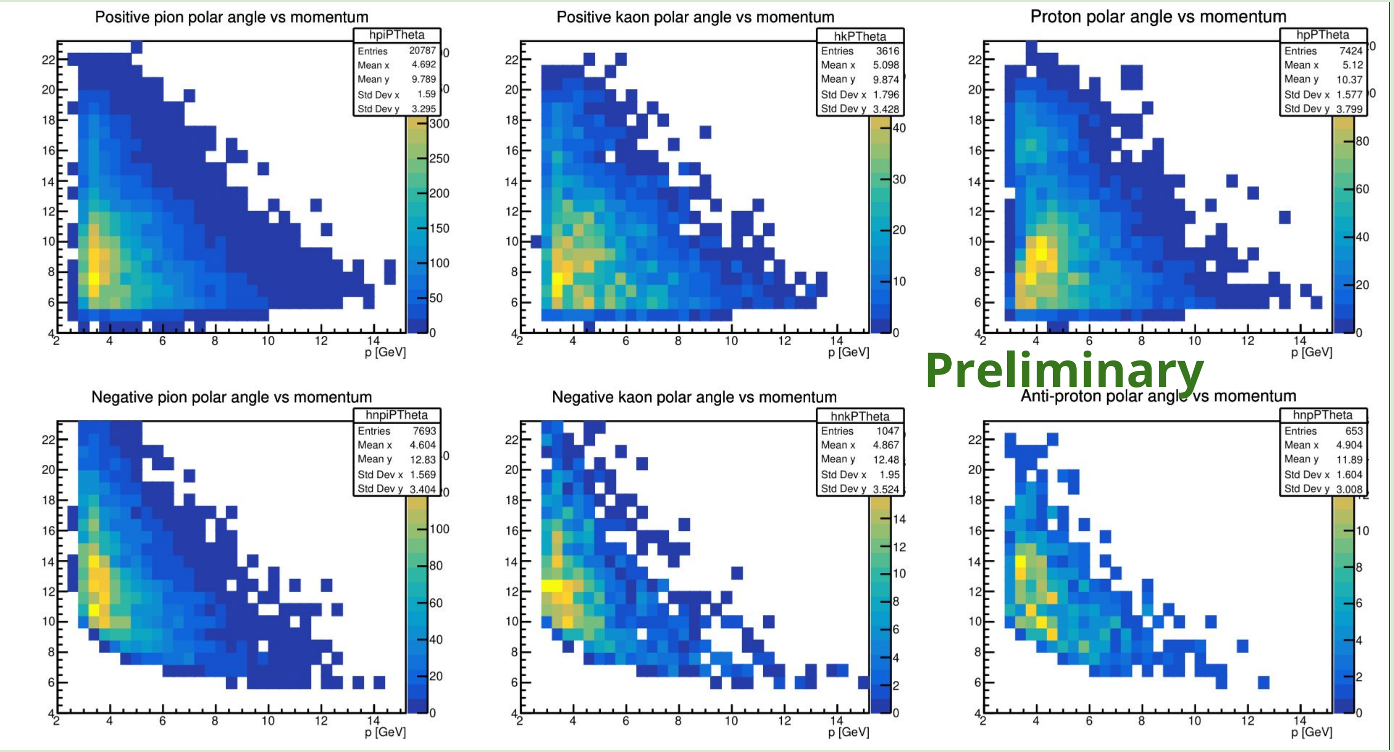
$$A_{LU}(\phi) = \frac{1}{P_b} \frac{N^+ - N^-}{N^+ + N^-}$$

$N^\pm$ indicates the number of events for beam with ± helicity; P_b is the beam polarization

$$A_{LU}^{\sin\phi} = \frac{\sqrt{2\varepsilon(1-\varepsilon)} F_{LU}^{\sin\phi}}{F_{UU}}$$

Relation between asymmetry term and structure-function

CLAS12 RICH performance at 22 GeV from simulation



Distribution of hadrons momentum and polar angle.