Beam-spin asymmetry on Kaon SIDIS using the RICH

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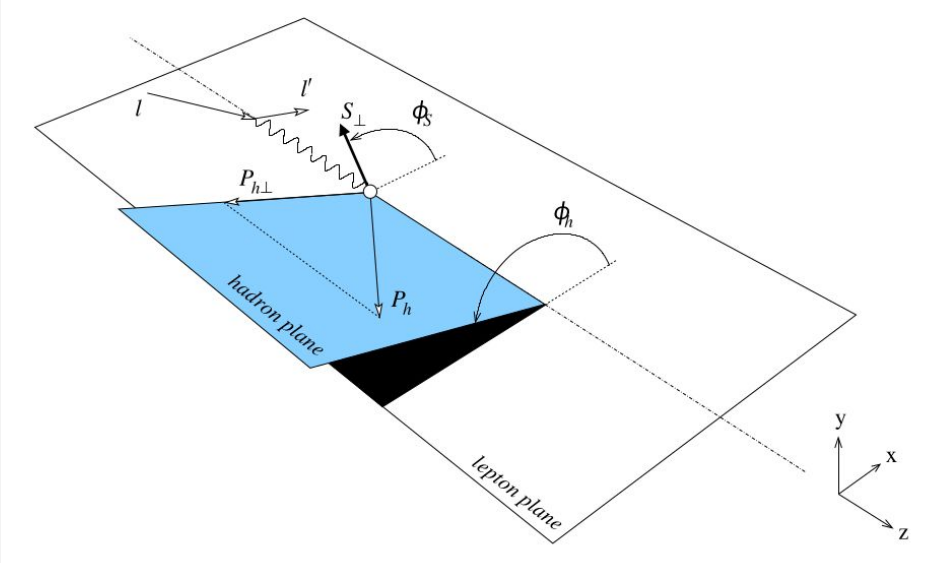
SIDIS

$l + N \to l' + H + X$



U = Unpolarized
L = Longitudinally polarized
T = Transversally polarized

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

$$
\begin{aligned}
\frac{d\sigma}{dx\,dy\,d\psi\,dz\,d\phi_h\,dP_{h\perp}^2} = {} & \\
\frac{\alpha^2}{xyQ^2}\frac{y^2}{2(1-\varepsilon)}\left(1+\frac{\gamma^2}{2x}\right)\Bigg\{ & F_{UU,T} + \varepsilon F_{UU,L} + \sqrt{2\,\varepsilon(1+\varepsilon)}\,\cos\phi_h\,F_{UU}^{\cos\phi_h} \\
& + \varepsilon\cos(2\phi_h)\,F_{UU}^{\cos 2\phi_h} + \boxed{\lambda_e\,\sqrt{2\,\varepsilon(1-\varepsilon)}\,\sin\phi_h\,F_{LU}^{\sin\phi_h}} \\
& + S_\parallel\left[\sqrt{2\,\varepsilon(1+\varepsilon)}\,\sin\phi_h\,F_{UL}^{\sin\phi_h} + \varepsilon\sin(2\phi_h)\,F_{UL}^{\sin 2\phi_h}\right] \\
& + S_\parallel\lambda_e\left[\sqrt{1-\varepsilon^2}\,F_{LL} + \sqrt{2\,\varepsilon(1-\varepsilon)}\,\cos\phi_h\,F_{LL}^{\cos\phi_h}\right] \\
& + |\boldsymbol{S}_\perp|\Bigg[\sin(\phi_h-\phi_S)\left(F_{UT,T}^{\sin(\phi_h-\phi_S)} + \varepsilon\,F_{UT,L}^{\sin(\phi_h-\phi_S)}\right) \\
& \quad + \varepsilon\,\sin(\phi_h+\phi_S)\,F_{UT}^{\sin(\phi_h+\phi_S)} + \varepsilon\,\sin(3\phi_h-\phi_S)\,F_{UT}^{\sin(3\phi_h-\phi_S)} \\
& \quad + \sqrt{2\,\varepsilon(1+\varepsilon)}\,\sin\phi_S\,F_{UT}^{\sin\phi_S} + \sqrt{2\,\varepsilon(1+\varepsilon)}\,\sin(2\phi_h-\phi_S)\,F_{UT}^{\sin(2\phi_h-\phi_S)}\Bigg] \\
& + |\boldsymbol{S}_\perp|\lambda_e\Bigg[\sqrt{1-\varepsilon^2}\,\cos(\phi_h-\phi_S)\,F_{LT}^{\cos(\phi_h-\phi_S)} + \sqrt{2\,\varepsilon(1-\varepsilon)}\,\cos\phi_S\,F_{LT}^{\cos\phi_S} \\
& \quad + \sqrt{2\,\varepsilon(1-\varepsilon)}\,\cos(2\phi_h-\phi_S)\,F_{LT}^{\cos(2\phi_h-\phi_S)}\Bigg]\Bigg\}
\end{aligned}
$$

Beam-Spin Asymmetry

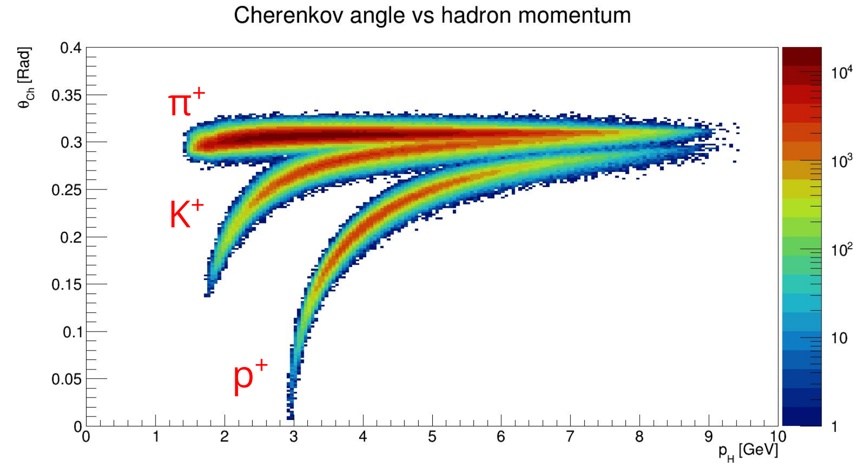
The RICH detector to improve the kaon identification at high momentum

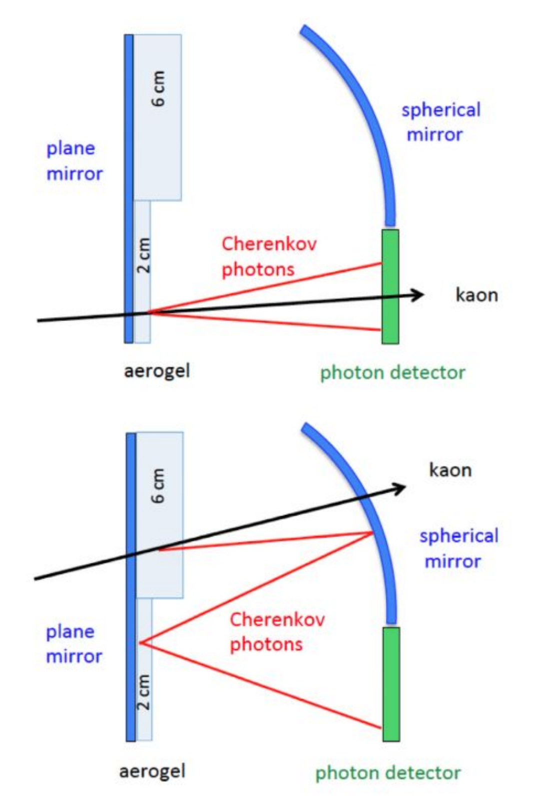
CLASS12 Ring Imaging Cherenkov

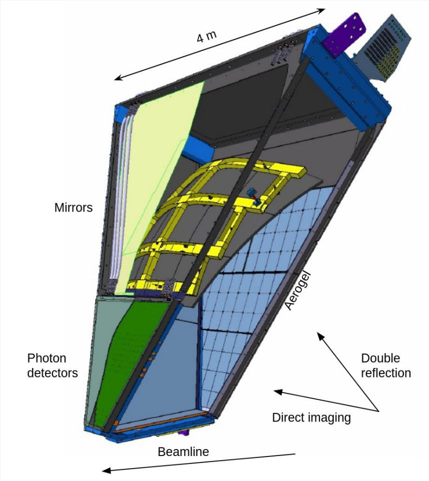
$$\cos\theta = \frac{1}{n\beta}$$

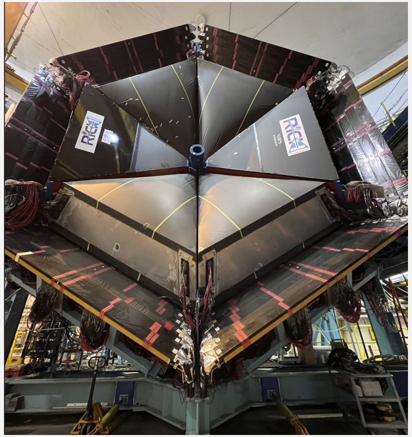
In 2016 one sector was equipped with a **RICH** detector **to improve the $\pi^{\pm}/K^{\pm}$ separation between 3 and 8 GeV/c**, the RICH is expected to provide separation with efficiency in better than 99%

Aerogel refractive index: n = 1.05.
Photon detector: Multi-Anode PMT







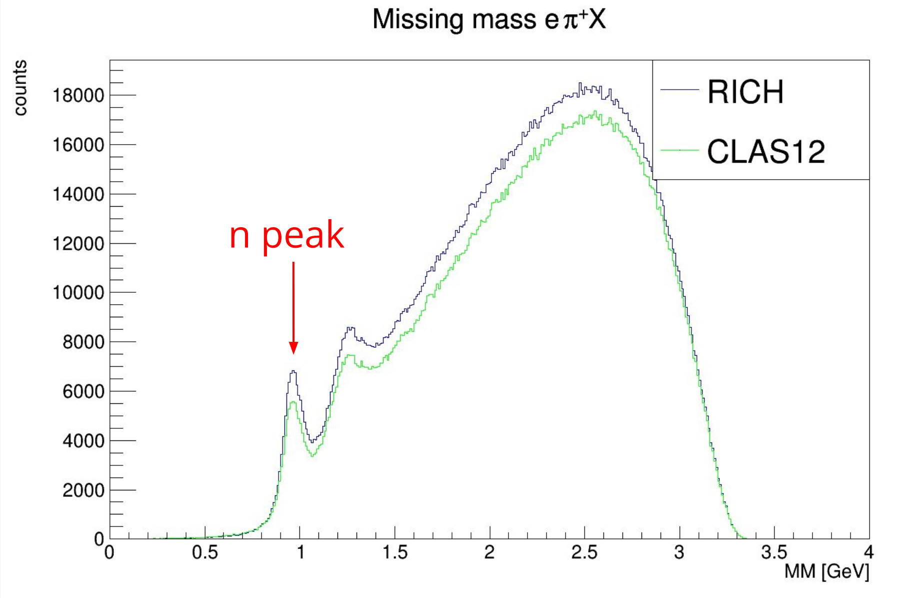


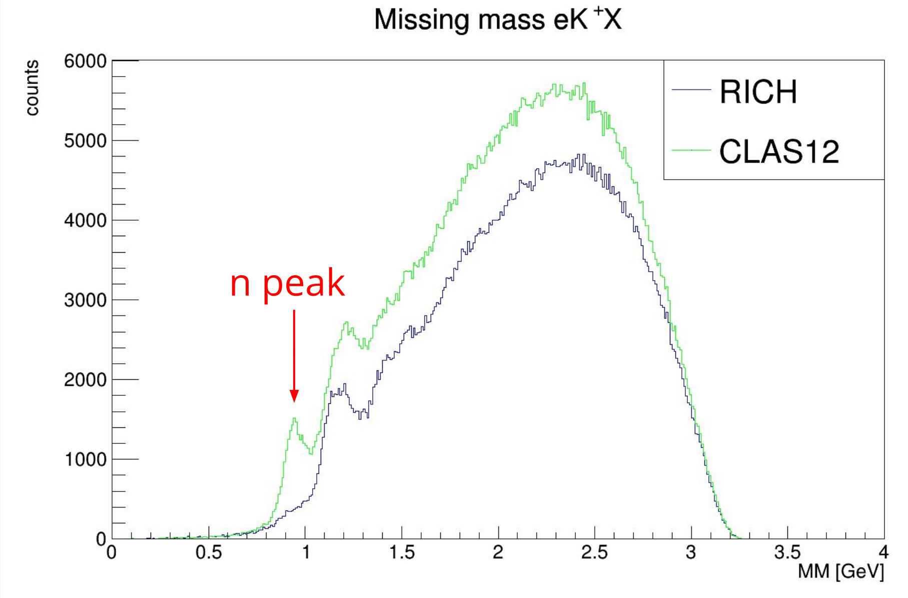
A second RICH was added in 2022

RICH efficiency study

Carried out analyzing the **missing mass of eH⁺X** final state, focus on the **neutron peak** at 0.94 GeV.
Allows to evaluate the percentage of:

- **Good identification of pion** = ratio between number of neutron in $e\pi^+X$ over ($e\pi^+X$ + eK^+X)
- **Misidentification of pion as kaon** = ratio between number of neutron in eK^+X over ($e\pi^+X$ + eK^+X)



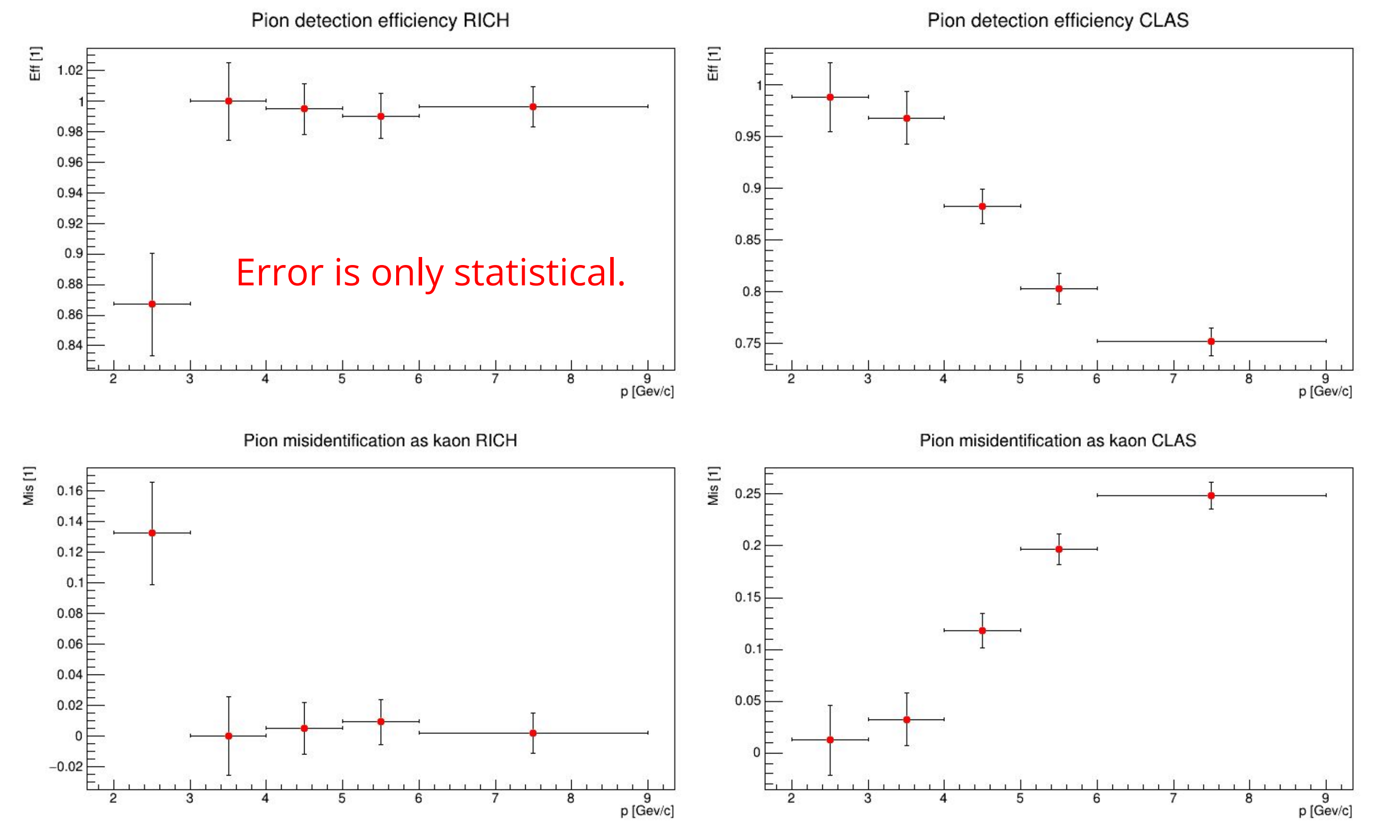


RICH efficiency preliminary results

The preliminary results on the efficiency as function of the hadron momentum show the expected behavior for RICH and CLAS12.

The RICH provides a cleaner sample of kaon, removing the not-negligible component of misidentified pions.

Kaon sample has lower statistic rather than the pion sample, then a unbinned maximum likelihood fit method has been studied.



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Validation of the analysis method: cross-check of $e\pi^+X$ BSA on RG-A data using the unbinned maximum likelihood fit.

Unbinned maximum likelihood fit

Single event probability density function

$$pdf(x_i, \alpha) = \sigma_{UU}[1 + A_i(\alpha)]$$

Likelihood function definition

$$\mathcal{L} = \prod_{i=1}^{N} pdf^{norm}(x_i, \alpha)$$

Minimization of the χ^2

$$\chi^2 \sim -2\log(\mathcal{L})$$

Probability density function for SIDIS

$$pdf(\phi_i, A_{LU}^{\sin\phi}) = 1 \pm P_b[A_{LU}^{\sin\phi}\sin(\phi_i)]$$

x_i = observables for event i

A_i = asymmetry term

α = set of parameter

P_b = beam polarization

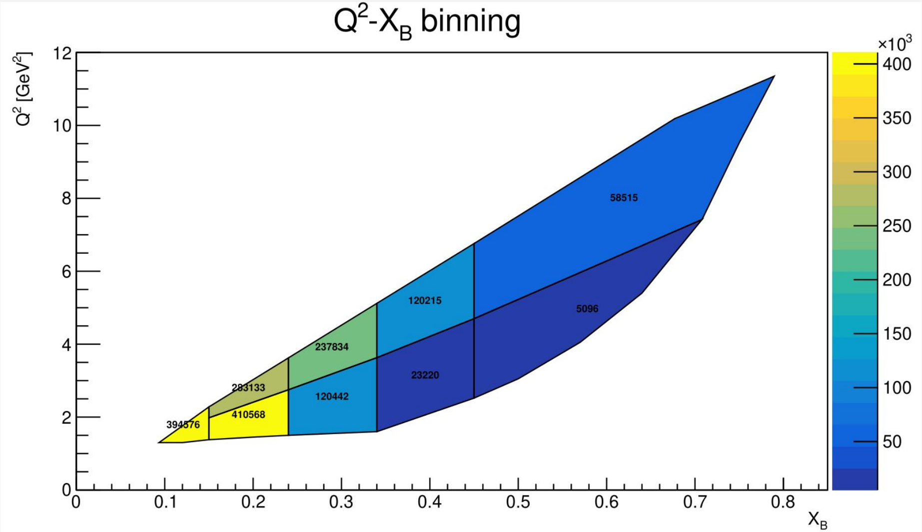
± ↔ beam helicity

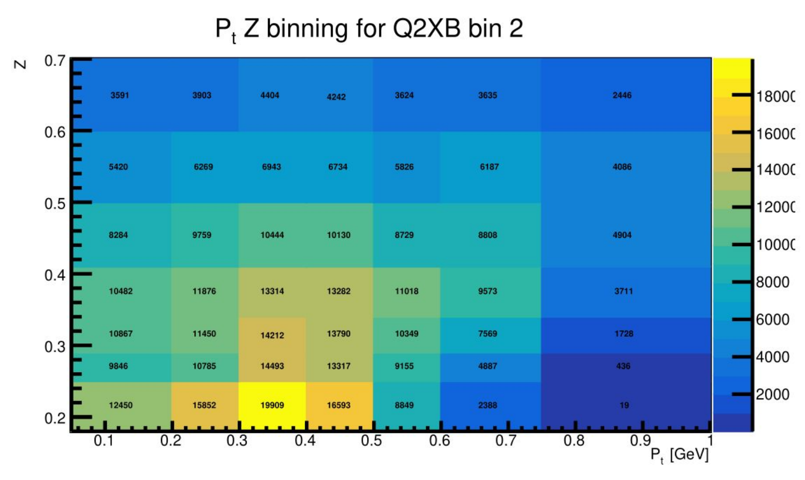
$$\frac{A_{LU}^{\sin\phi}}{\sqrt{2\epsilon(1-\epsilon)}} = \frac{F_{LU}^{\sin(\phi)}}{F_{UU}}$$

Analysis strategy: Validation of the unbinned fit by cross-checking the results obtained by S. Diehl on π^+ beam spin asymmetry [Ref], then apply it to the kaon case.

Kinematical cuts and binning for $e\pi^{+}X$

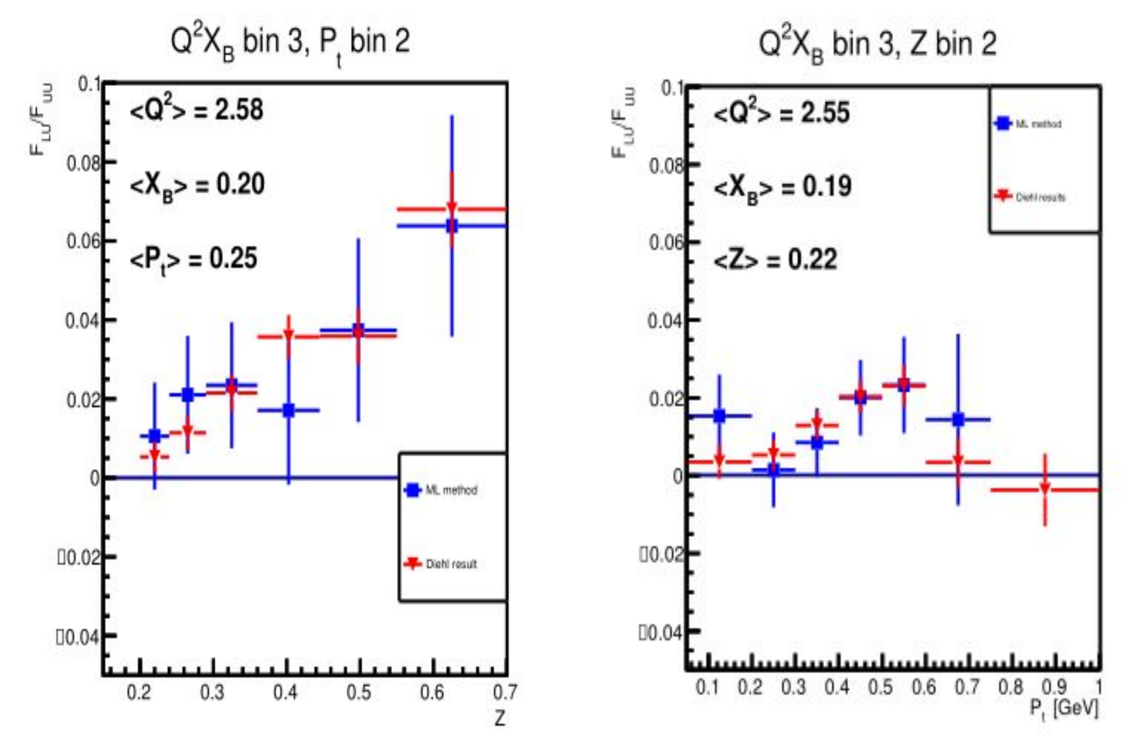
- $y < 0.75$
- $Q^2 > 1.0$ GeV^2
- $x_F > 0.0$
- $W > 2$;
- $z > 0.2$
- MM > 1.5 GeV





- 9 bin in Q^2-x_B
- Binning in z and p_T for each of the 9 bins
- Total of 344 4-dimensional bins (Q^2,x_B,z,p_T)

Comparison of unbinned fit results on $e\pi^+X$ with S. Diehl paper



BLUE: unbinned fit result. RED: S. Diehl result

The results are comparable.

- The analysis covers ~5% of the dataset of the inbending data
- The event builder has been used, without the RICH

To complete the validation, I will run the analysis over the full statistics

Preliminary results on kaon BSA on RG-B spring19 data “sidisdvcs” using RICH and pass-2

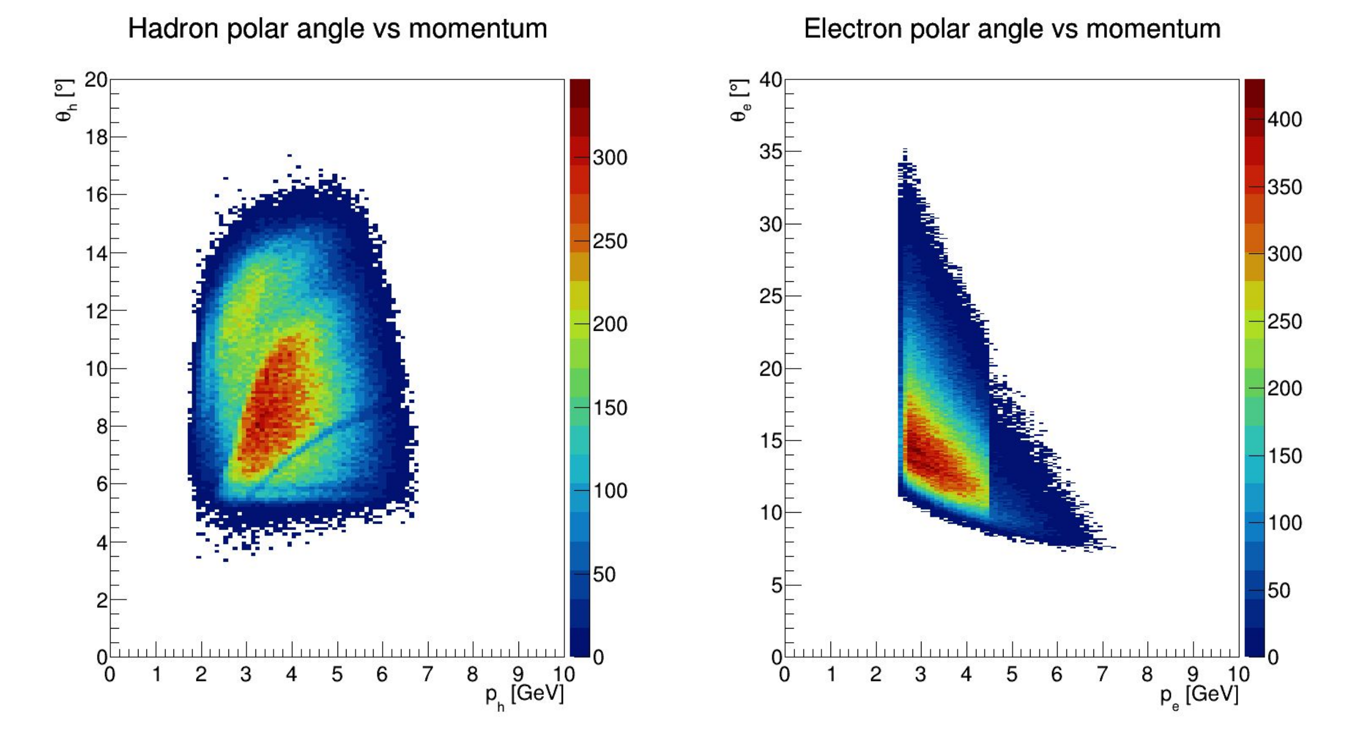
Kaon and electron selection

Kaon selection:

- Kaon identified by RICH (sector 4)
- RICH n_phe > 2
- DC fiducial cut
- -10 < z vertex < 2.5

Electron selection

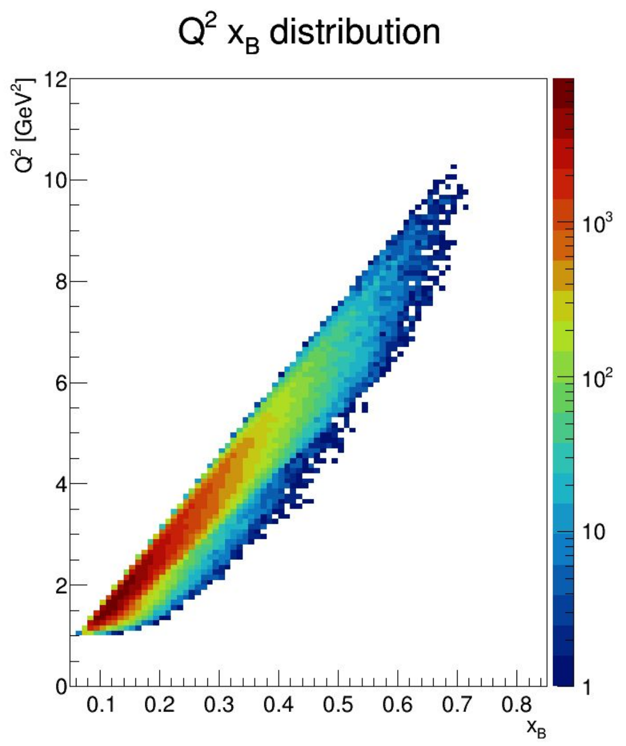
- Trigger electron
- e^- in Forward Detector
- HTTC n_phe > 2
- PCAL E > 0.07
- DC fiducial cut
- -8 < z_vertex < 3
- Diagonal cut at 4.5 GeV

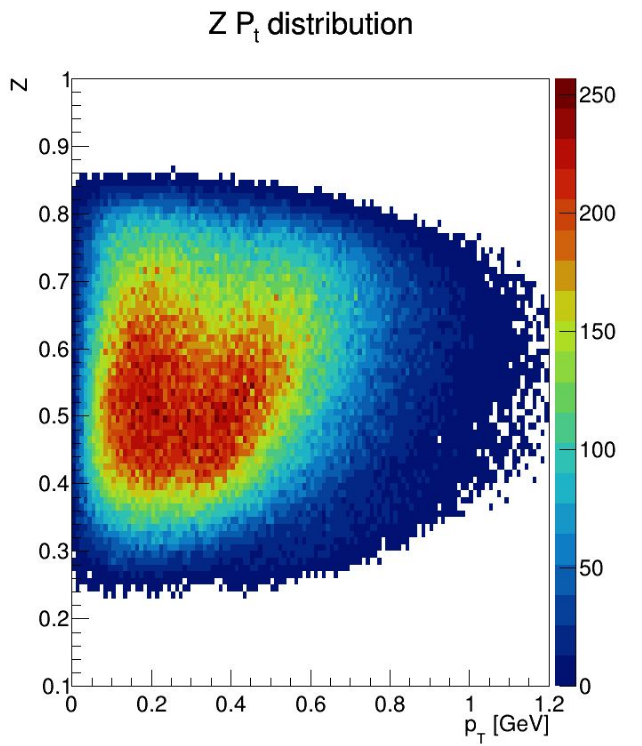


Kinematic cuts and binning

- $y < 0.75$
- $Q^2 > 1.0$ GeV^2
- $x_F > 0.0$
- $W > 2$;
- $z > 0.2$
- MM > 1.6 GeV

The 4-dimensional binning on Q^2, x_B, z, p_T is being defined and it is not yet applied.

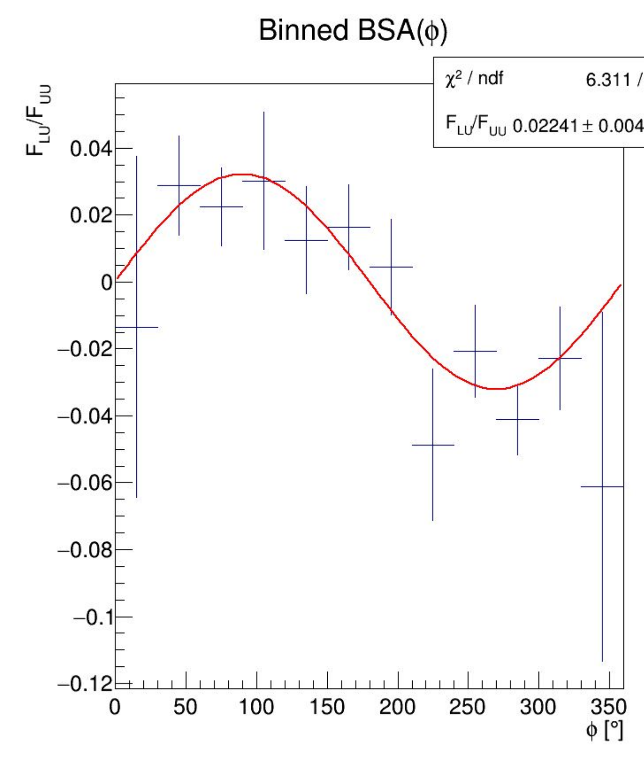


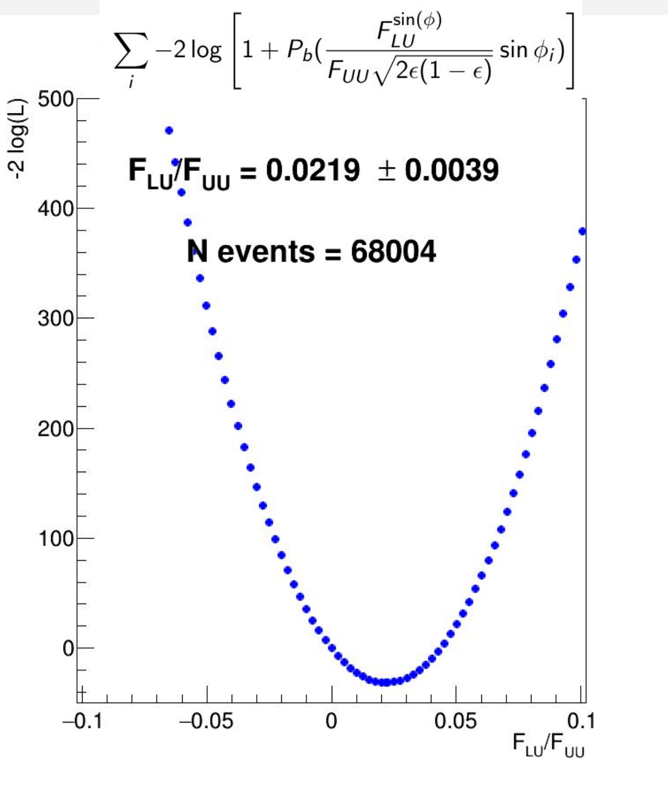


Comparison of unbinned and binned fit on eK^+X

Left: BSA as function of ϕ. The fit provides the value of F_{LU}/F_{UU}

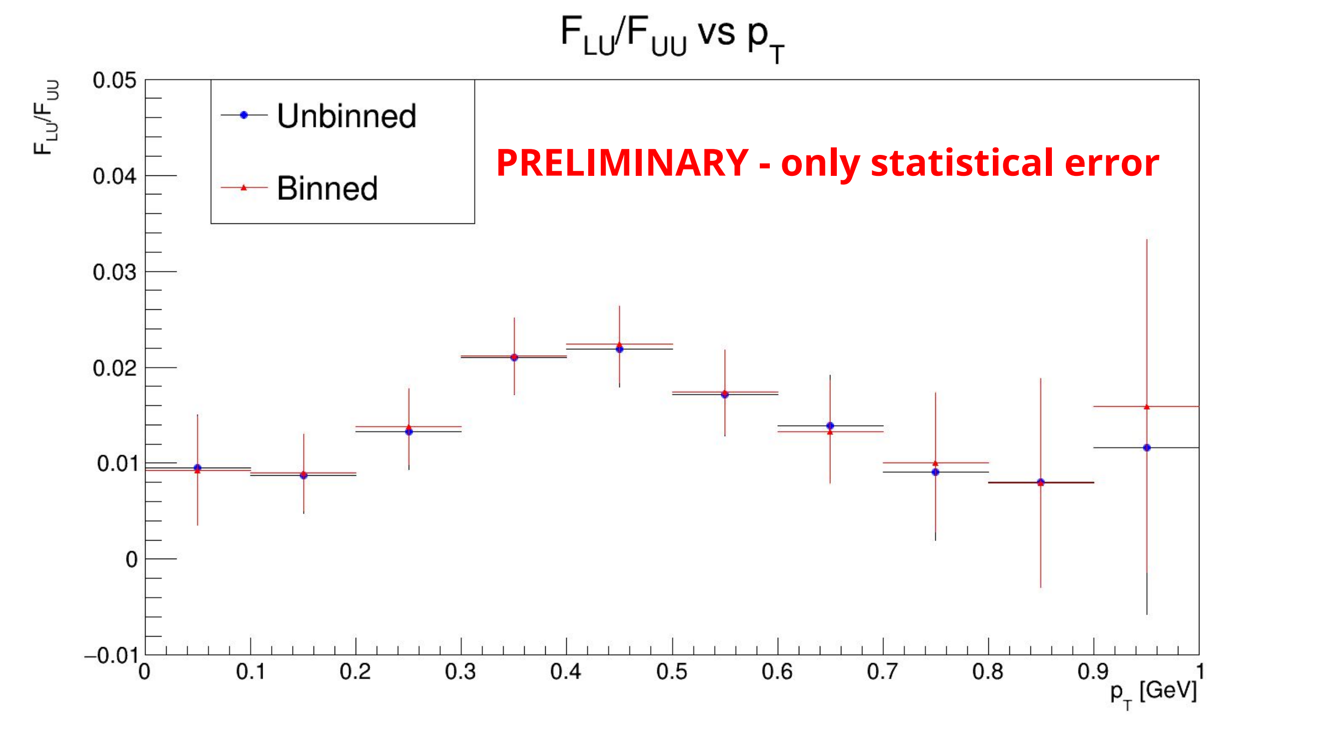
Right: -2 log (Likelihood) as function of the F_{LU}/F_{UU} , its value is located at the minimum of the function.



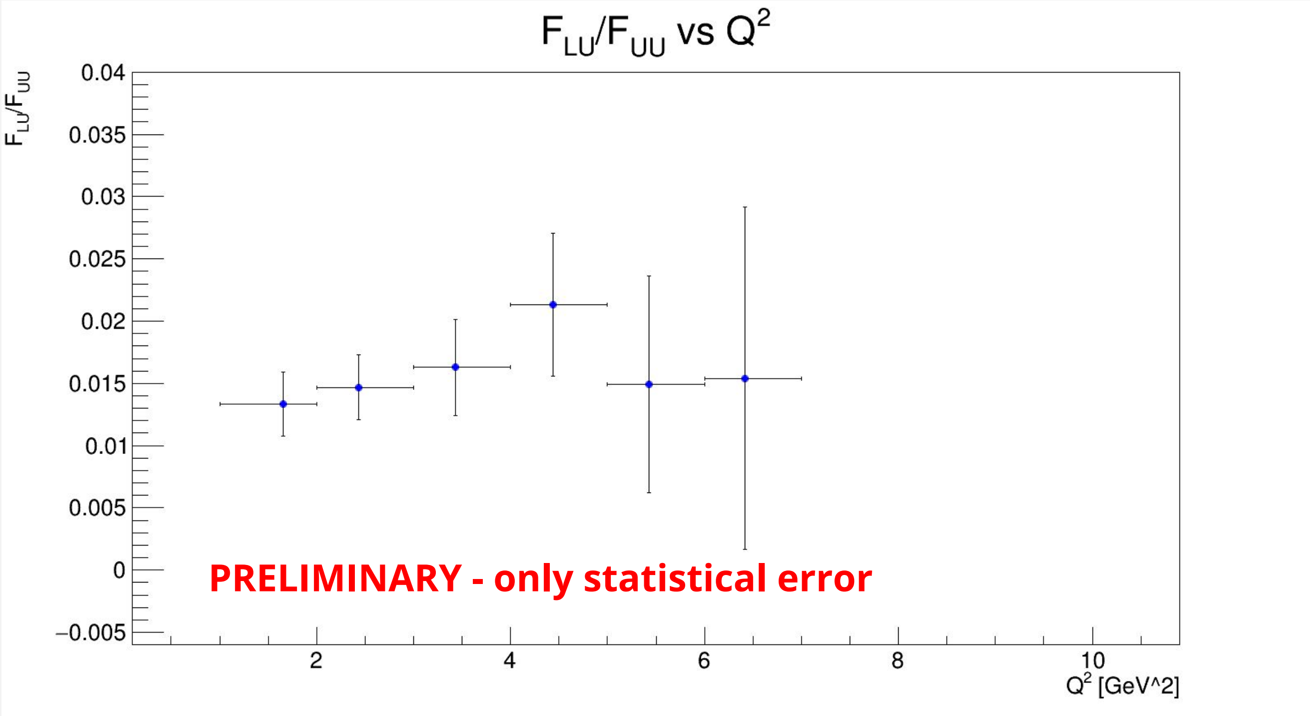


Comparison of unbinned and binned fit on eK^+X

Value of F_{LU}/F_{UU} as function of transverse momentum, applying standard binned fit (RED) and unbinned maximum likelihood fit (BLUE), for 1-dimensional analysis on p_T

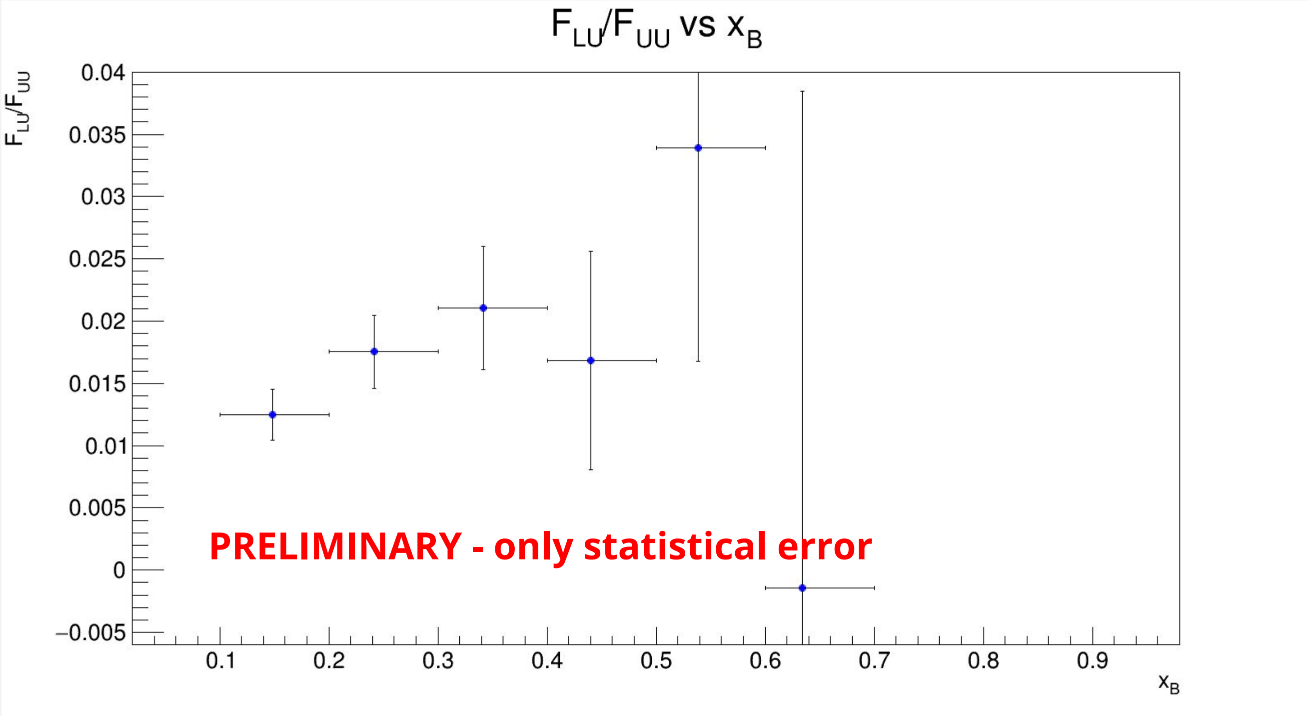


Preliminary one-dimensional BSA results on eK^+X.



- Preliminary results based on RG-B spring19 pass-2 data, using only events where K was identified by RICH (only one sector).
- Limited phase space using the RICH
- Only inbending data have been analyzed
- Studies on RICH data quality cuts are still missing

Preliminary one-dimensional BSA results on $eK^{+}X$.



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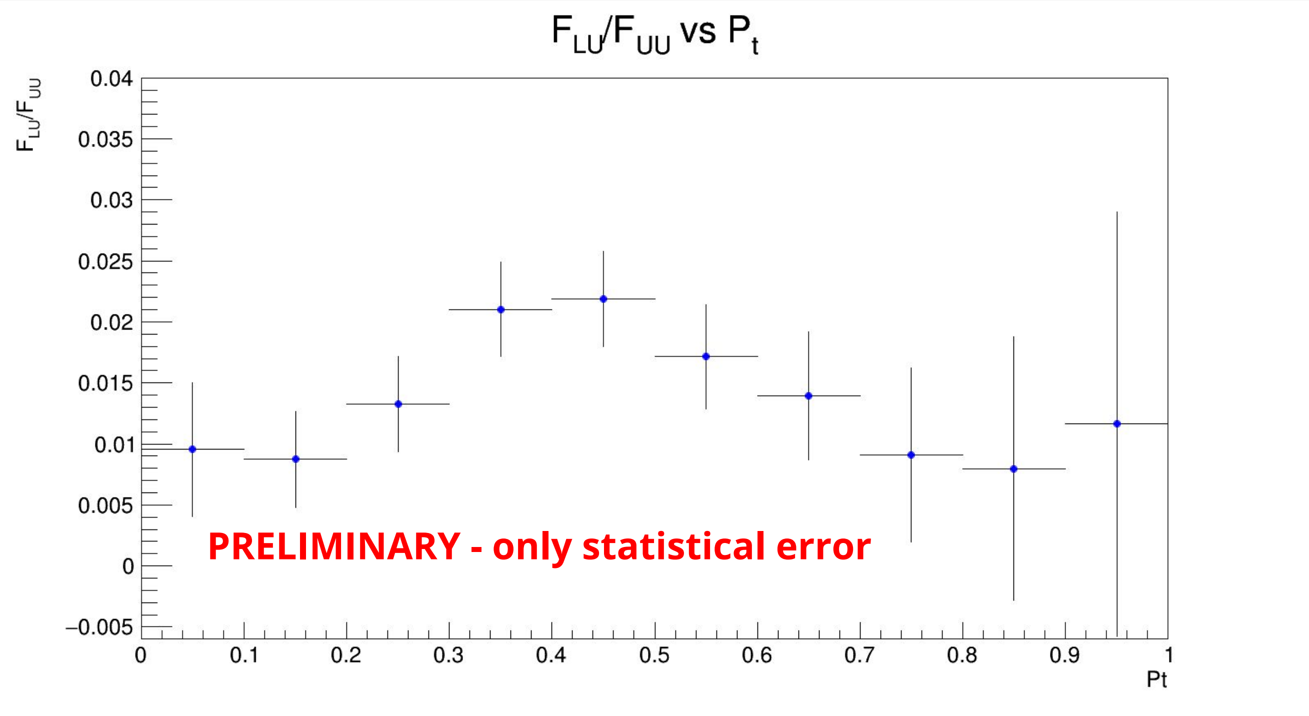

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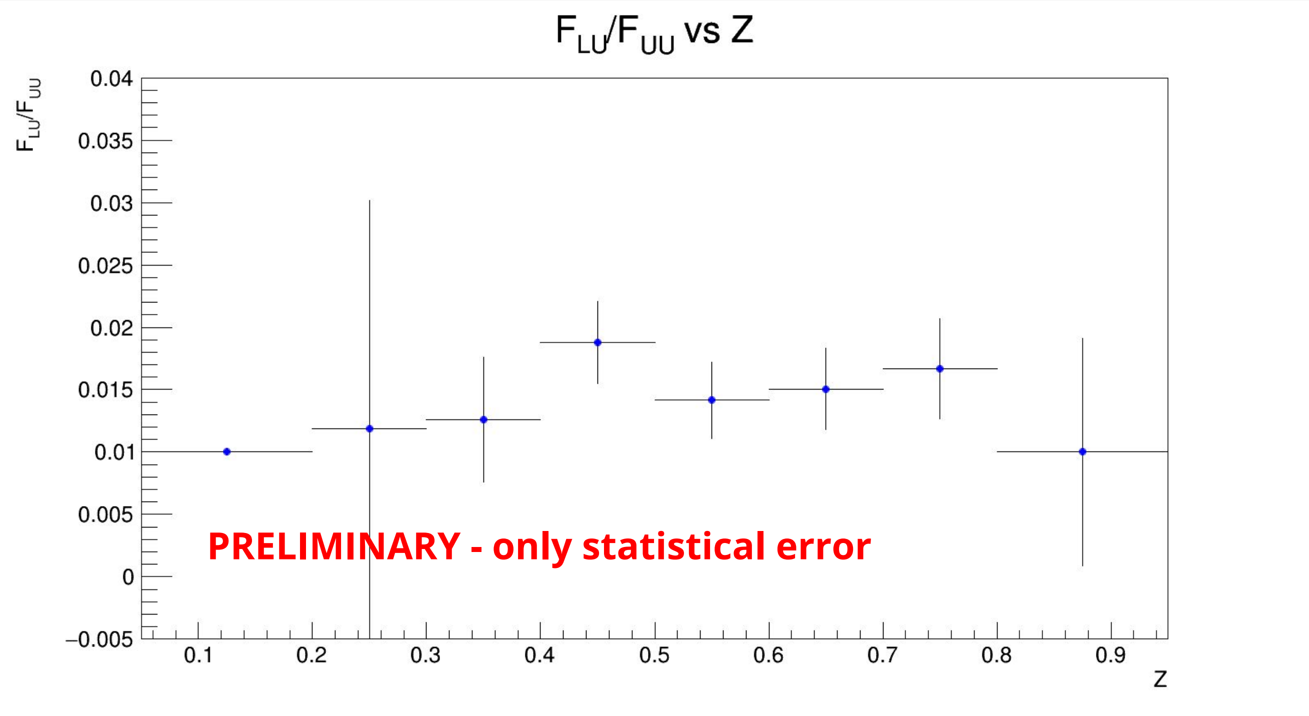

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Conclusion and outlook

- The RICH is effective in cleaning the kaon sample for the SIDIS studies.
- The unbinned maximum likelihood fit provides BSAs comparable with the results on the $e\pi^+X$.
- The unbinned maximum likelihood fit provides results comparable with the standard fit applied on the same sample of eK^+X.
- The firsts BSAs on eK^+X using the RICH on RG-B data have been obtained.

Future activities:

- Completion of the validation of the unbinned maximum likelihood fit.
- Study of the data quality cuts on RICH data and evaluation of the systematic error.
- Extraction of the BSA for eK^+X using a 4-dimensional binning using the full statistic and the last available version of RG-B pass2 data.

Thank you!