Extraction of Single Spin Asymmetries for proton-Kaon pairs in the $e+p \rightarrow e'p'K+X$ reaction

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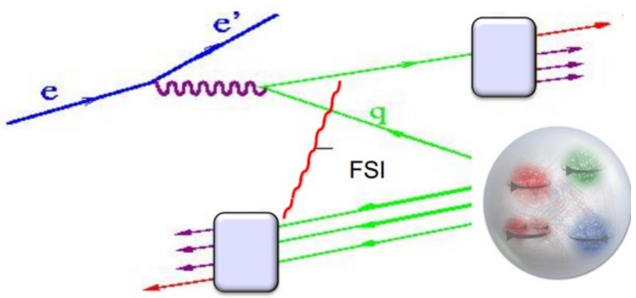
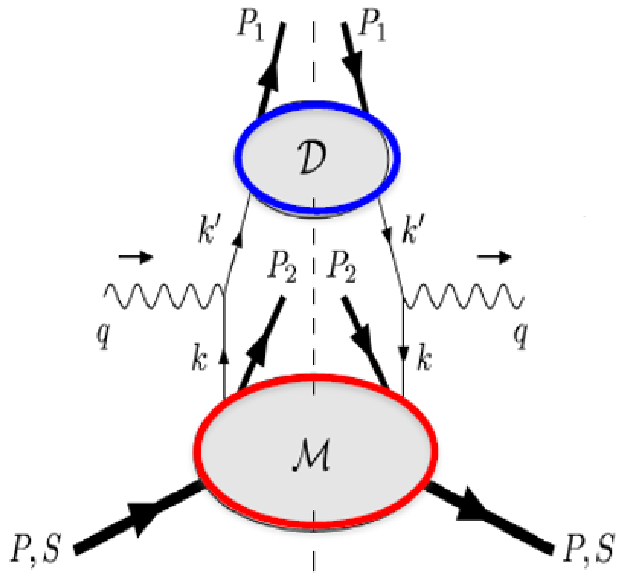
Back-to-back hadron (b2b) production in SIDIS

1 hadron from **current fragmentation region** and 1 from **target fragmentation region**





𝔉racture function: conditional probability to find a quark inside a nucleon fragmenting into a final hadron.

$$\mathcal{F}_{LU}^{\sin(\phi_1-\phi_2)} = \frac{|\mathbf{P}_{1\perp}||\mathbf{P}_{2\perp}|}{m_N m_2}\,\mathcal{C}\left[w_5\,\hat{l}_1^{\perp h} D_1\right],$$

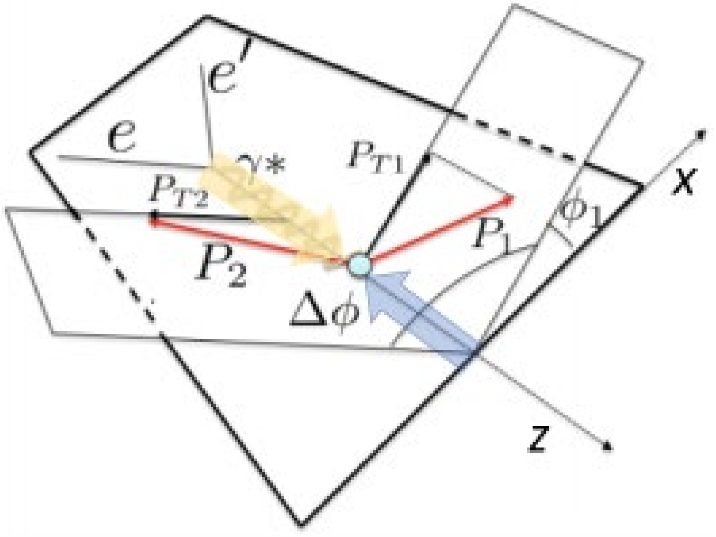
The beam–single -spin asymmetry appears at leading twist:

$$\mathcal{A}_{LU} = -\frac{y\left(1-\frac{y}{2}\right)}{\left(1-y+\frac{y^2}{2}\right)}\frac{\mathcal{F}_{LU}^{\sin\Delta\phi}}{\mathcal{F}_{UU}}\sin\Delta\phi$$

$\mathcal{F}$ carry a dependence on $P_{1\perp}$ $P_{2\perp}$
which introduces a dependence on $\cos\Delta\phi$
.

Leading Twist

	U	L	T
U	$\hat{u}_1$	$\hat{l}_1^{\perp h}$	$\hat{t}_1^h, \hat{t}_1^\perp$
L	$\hat{u}_{1L}^{\perp h}$	$\hat{l}_{1L}$	$\hat{t}_{1L}^h, \hat{t}_{1L}^\perp$
T	$\hat{u}_{1T}^h, \hat{u}_{1T}^\perp$	$\hat{l}_{1T}^h, \hat{l}_{1T}^\perp$	$\hat{t}_{1T}, \hat{t}_{1T}^{hh}, \hat{t}_{1T}^{\perp\perp}, \hat{t}_{1T}^{\perp h}$



$$A_{LU}(x,\zeta,\mathrm{k}^{\perp 2},\mathrm{p}_{\mathrm{P}}^{\perp 2},\Delta\phi) = A(x,\zeta,\mathrm{k}^{\perp 2},\mathrm{p}_{\mathrm{P}}^{\perp 2})\sin\Delta\phi + B(x,\zeta,\mathrm{k}^{\perp 2},\mathrm{p}_{\mathrm{P}}^{\perp 2})\sin(2\Delta\phi)$$

M. Anselmino, V. Barone and A. Kotzinian, Physics Letters B 713 (2012)

Data Set

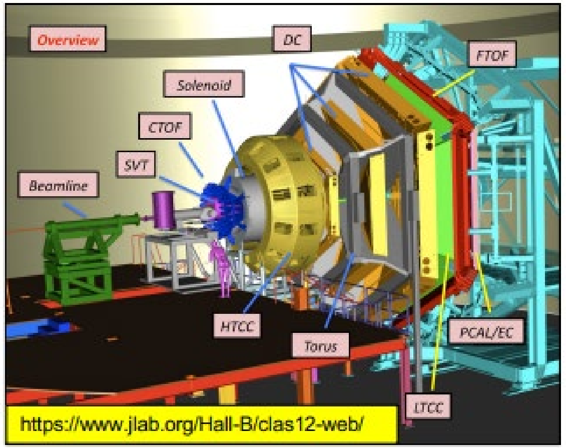
ep → e'p'K+X

- Data taken in the **Fall 2018** and **Spring 2019** with 10.6 (10.2) GeV longitudinally polarized electron beam and unpolarized LH_2 target. **RGA inbending data.**

- **Electron polarization** : 87% for 2018 and 85% for 2019

- Only **Forward detector** is used in this analysis.

- Only **Statistical** uncertainties are presented for these **Preliminary Results.**

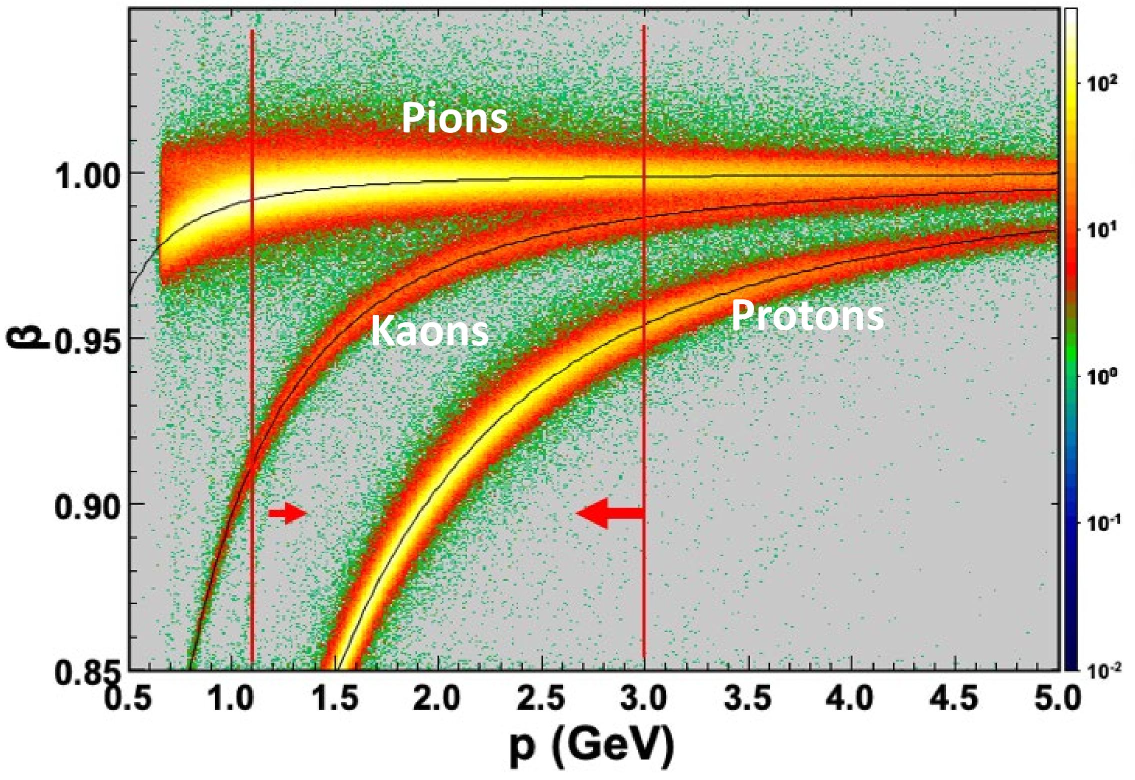


The data analysis procedure followed here is largely identical to that of several fully approved and published RGA first experiment SIDIS analyses (inclusive π+ and inclusive π+π− papers) . In addition to these we make specific use of the following analysis notes

- **RGA Common Analysis**: https://clas12-docdb.jlab.org/DocDB/0009/000949/001/RGA_Analysis_Overview_and_Procedures-08172020.pdf

- **Back-to-back" (b2b) π+-proton** recently fully approved final analysis note by T. Hayward, A. Kotzinian and H. Avakian: https://clas12-docdb.jlab.org/DocDB/0009/000935/014/102b2b_v4.pdf

One of the important aspects of this analysis: Hadron ID



Beta vs. hadron momentum studies

- 1.15 < Ph due to previous reconstruction inefficiencies and strong final state hadronic interactions that needed to be cut.
- P_h < 3 GeV
- chi2pid < 3
- Initial studies with RICH showed 20-30% pion-kaon misidentification in this range (see Gabe's talk, there is a chi2pi dependance).
- Correction that needs to be applied later-on. Considering one RICH.

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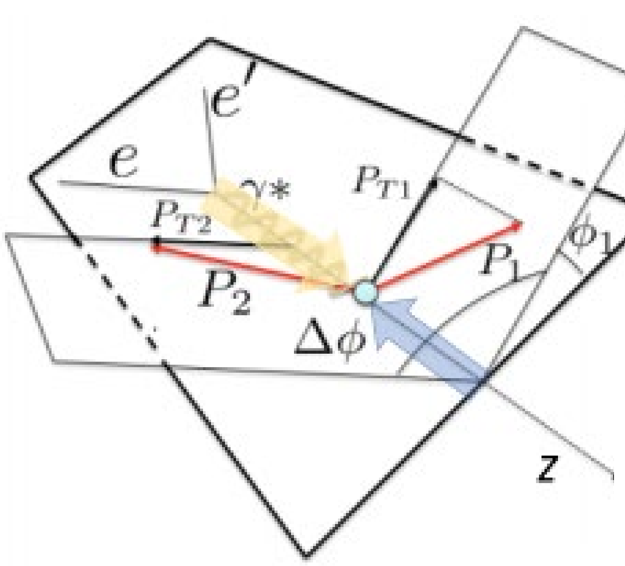
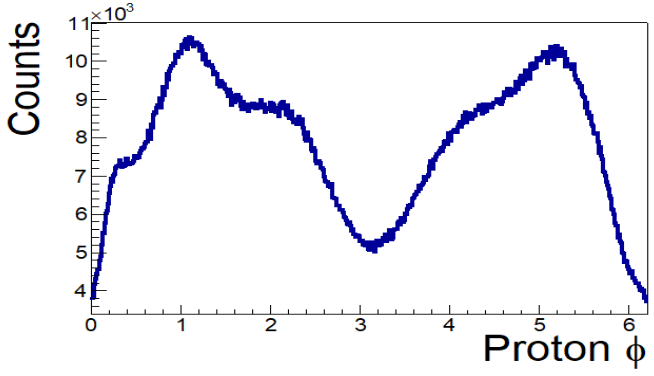
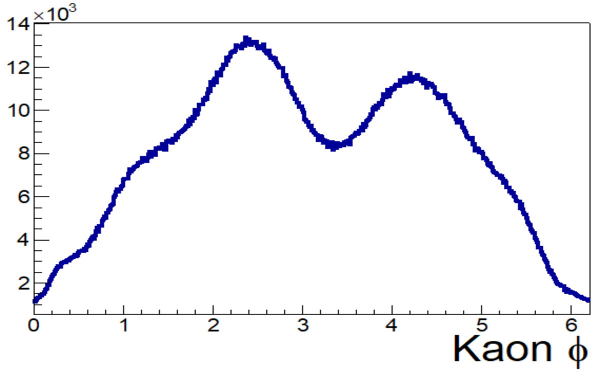
Key Variables: B2B Proton-Kaon pairs in the $e+p \rightarrow e'p'K+X$ reaction

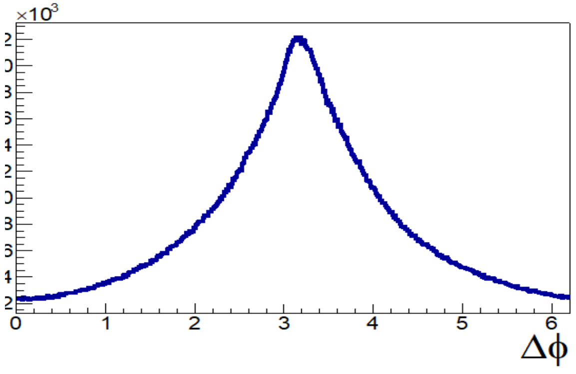


$$\mathcal{F}_{LU}^{\sin(\phi_1-\phi_2)} = \frac{|\mathbf{P}_{1\perp}||\mathbf{P}_{2\perp}|}{m_N m_2}\,\mathcal{C}\left[w_5\,\hat{l}_1^{\perp h} D_1\right],$$

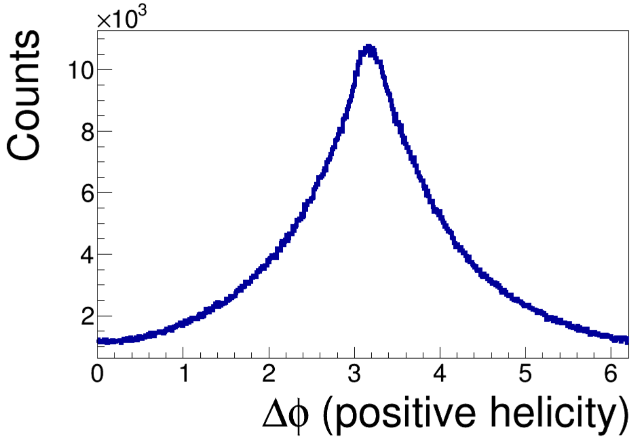
$$A_{LU}(x,\zeta,\mathrm{k}^{\perp 2},\mathrm{p}_{\mathrm{P}}^{\perp 2},\Delta\phi) = A(x,\zeta,\mathrm{k}^{\perp 2},\mathrm{p}_{\mathrm{P}}^{\perp 2})\sin\Delta\phi + B(x,\zeta,\mathrm{k}^{\perp 2},\mathrm{p}_{\mathrm{P}}^{\perp 2})\sin(2\Delta\phi)$$

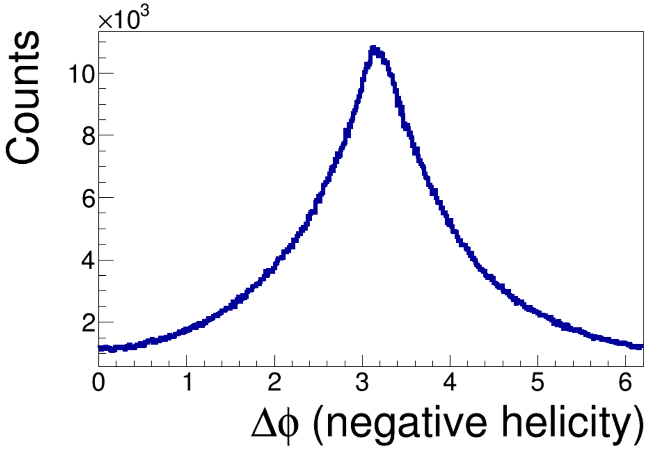


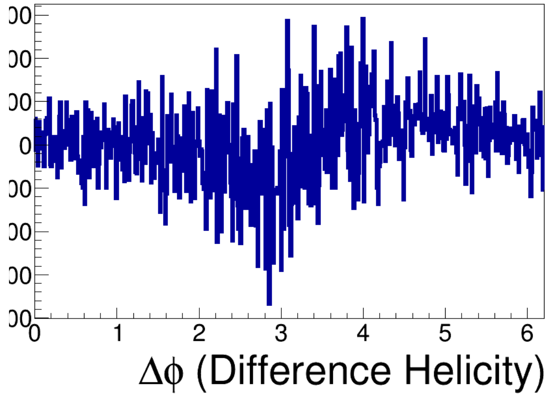




Technique: Hipos (RGA Fall 2018 and Spring 2019 SKIM4 inbending data) → Fiducial cuts, get a txt file, create a root Tree→ tighten some cuts, analyze with root.



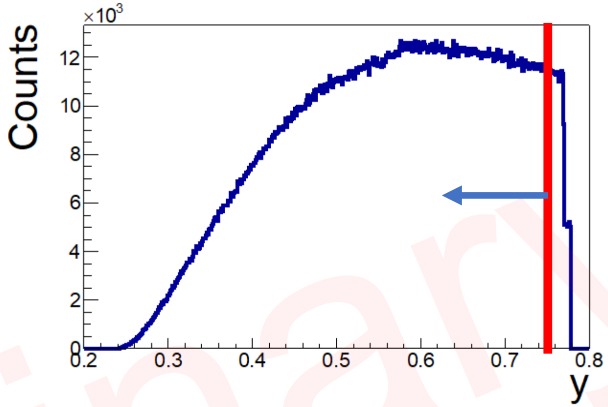


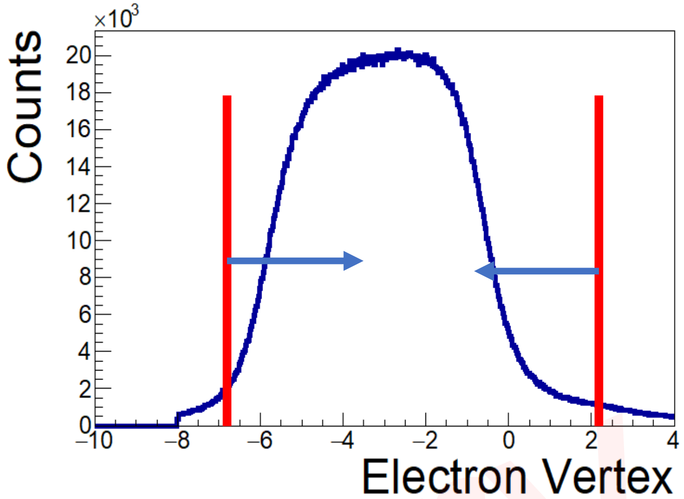


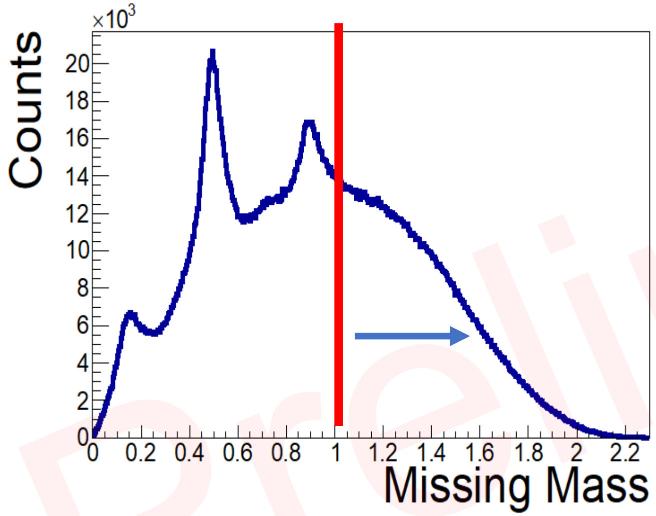
$$A(\phi)_{LU} = \frac{1}{p}\left(\frac{N^+ - N^-}{N^+ + N^-}\right)$$

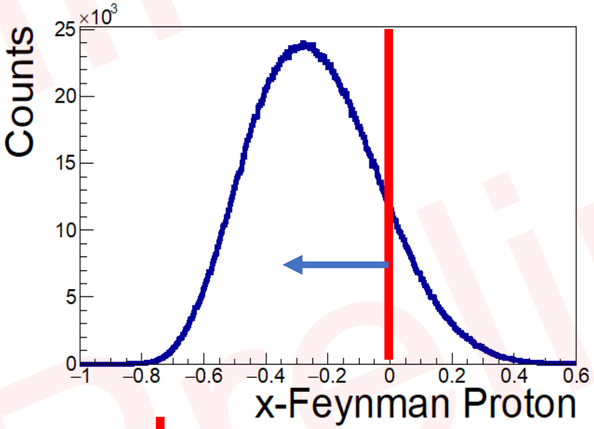
Event selection

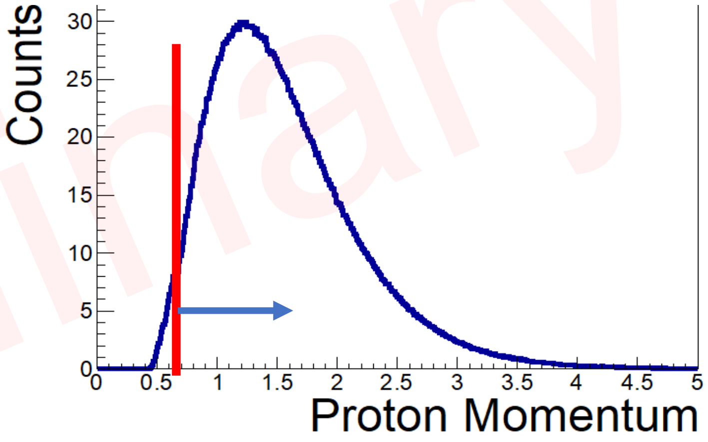
$e{+}p \rightarrow e'p'K{+}X$

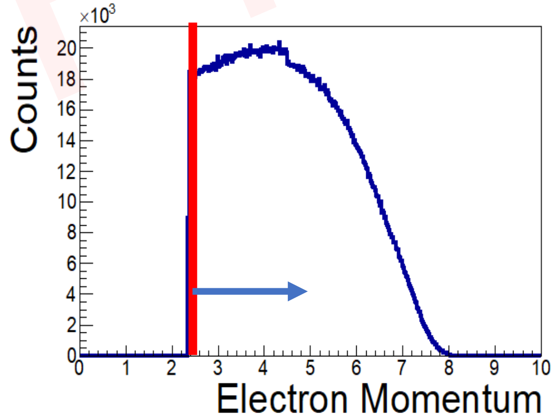


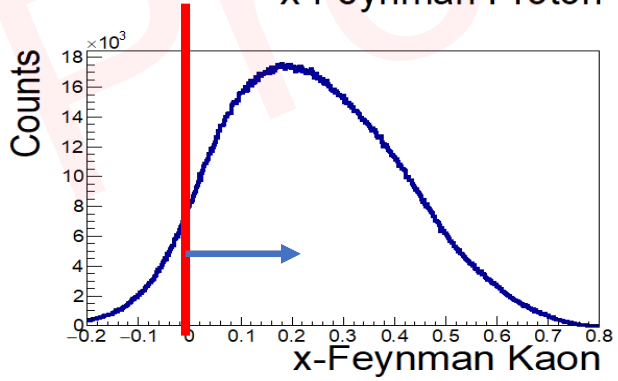


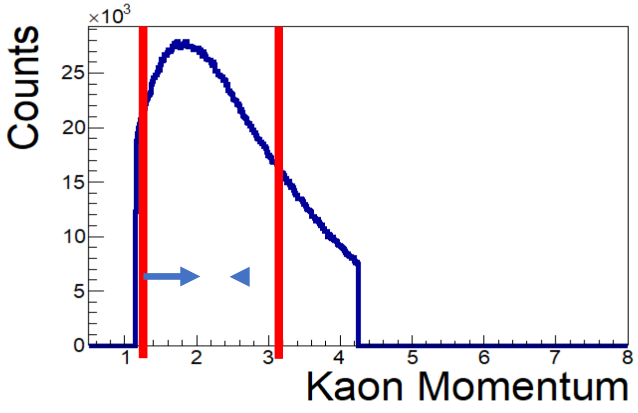




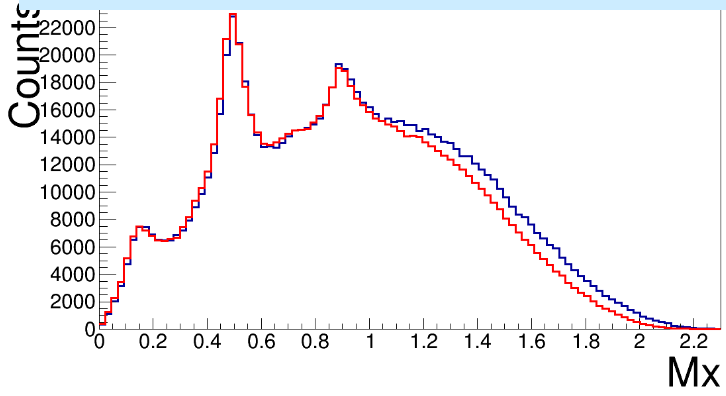


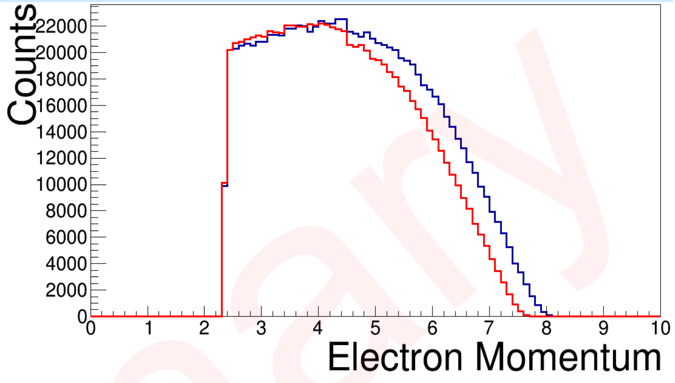


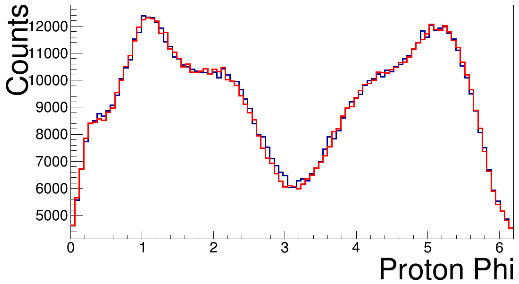


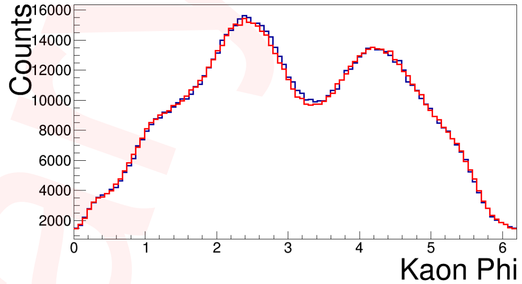


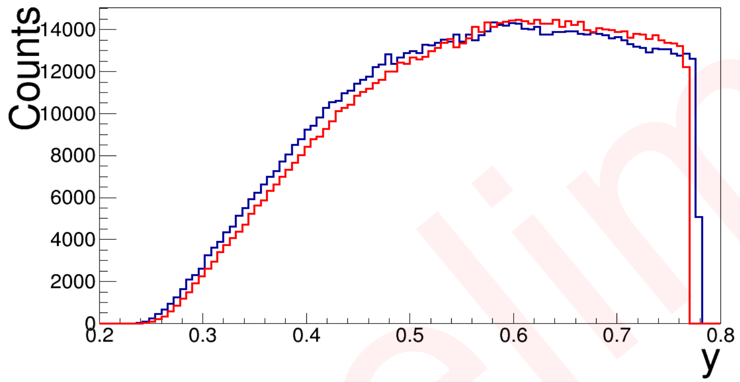
Fall2018–Spring2019 Comparison

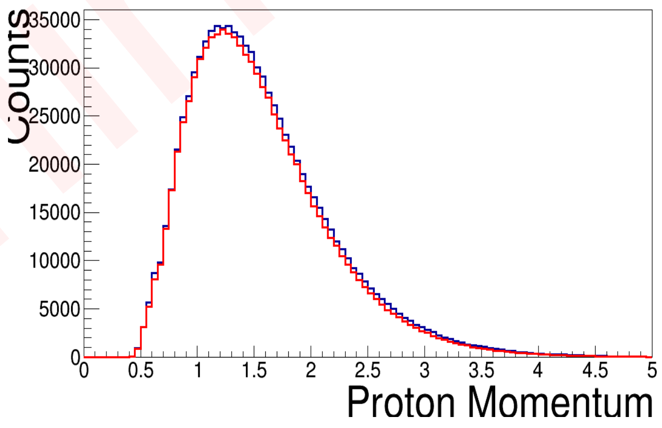


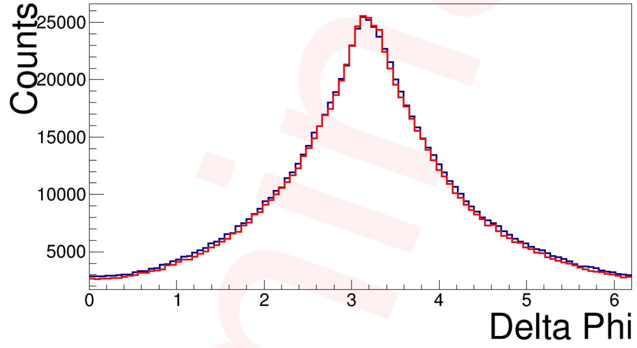


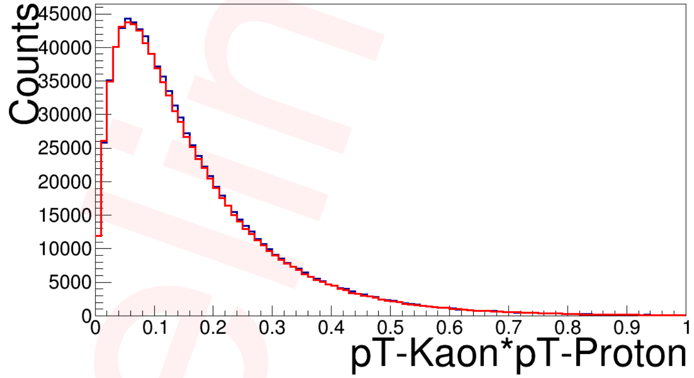


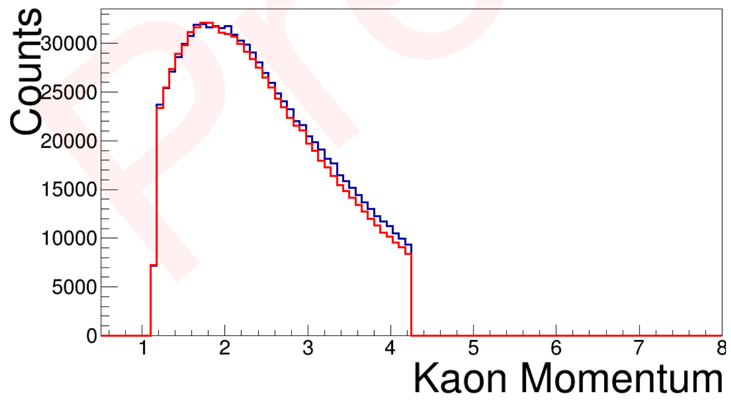


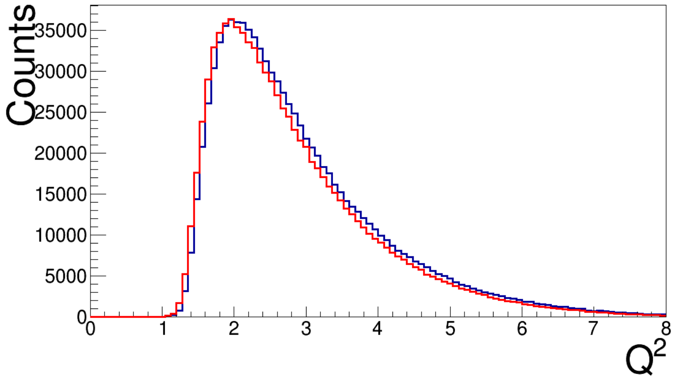


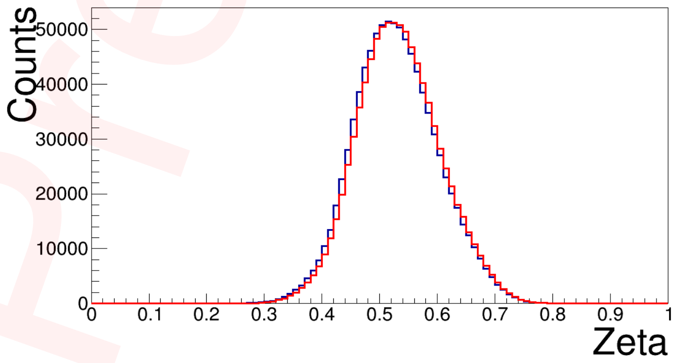




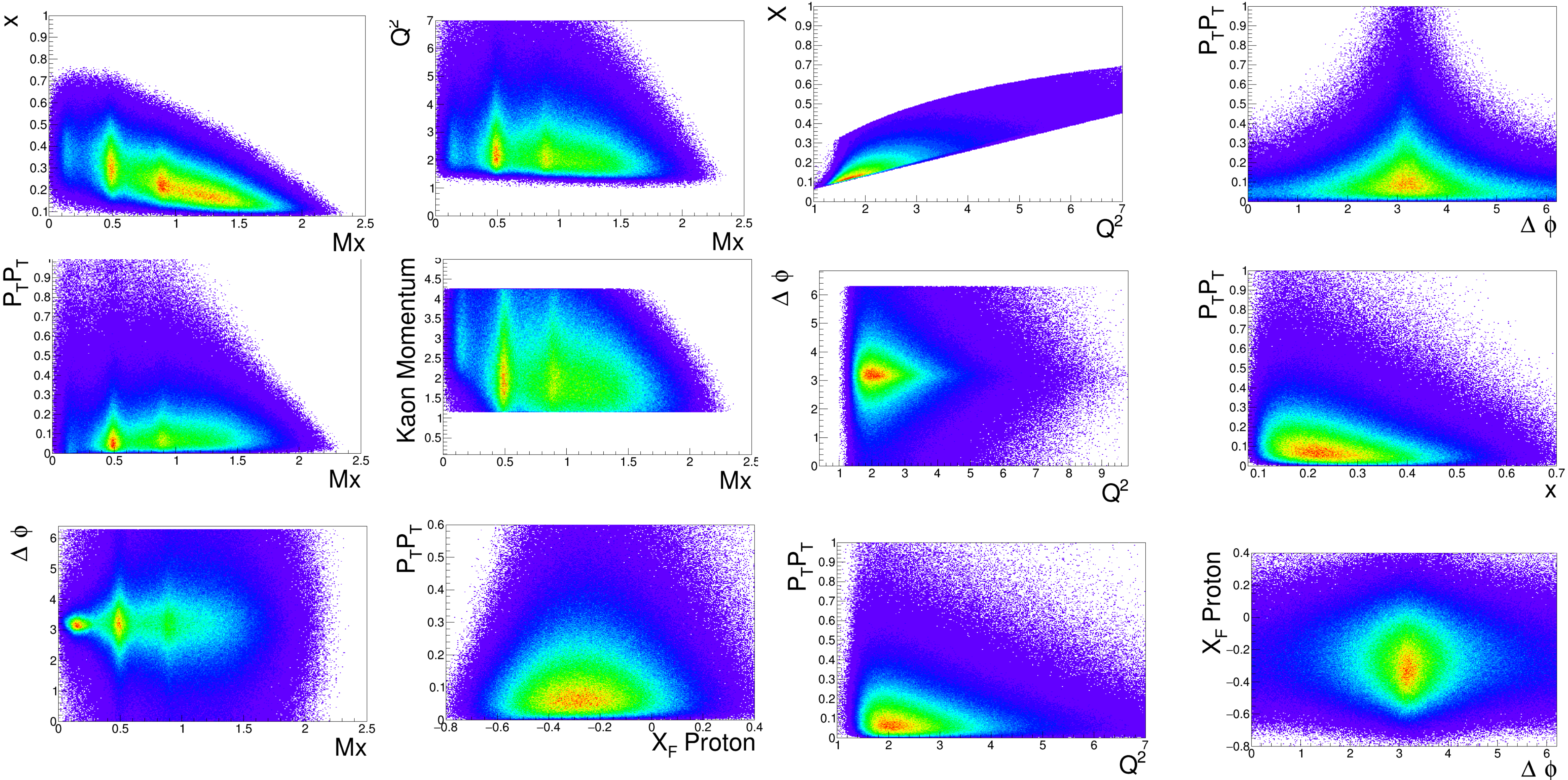








2D plots

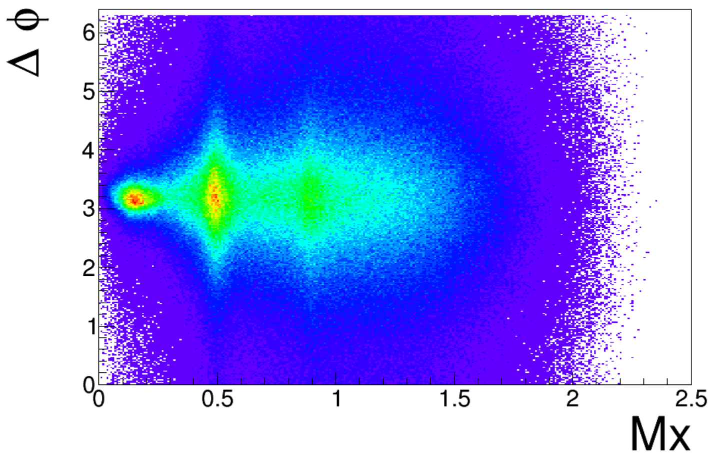


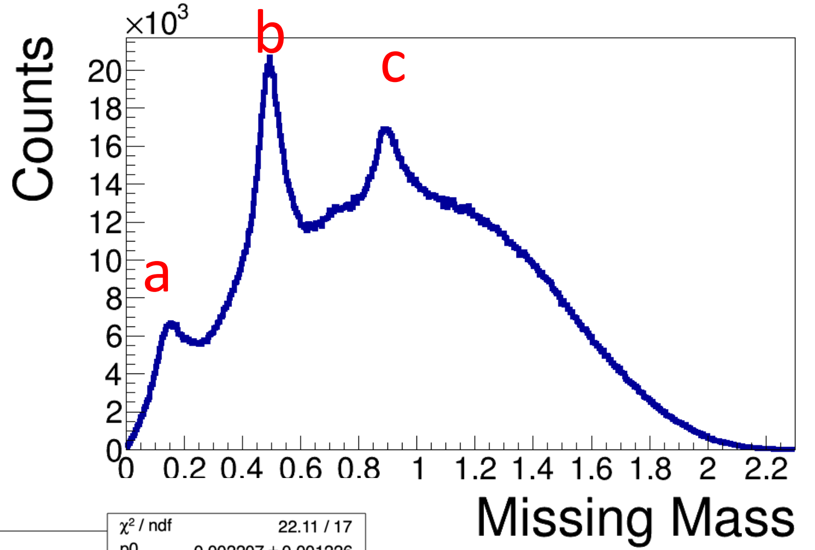
x
Mx
Q²
Mx
X
Q²
P_TP_T
Δ φ
P_TP_T
Mx
Kaon Momentum
Mx
Δ φ
Q²
P_TP_T
x
Δ φ
Mx
P_TP_T
X_F Proton
P_TP_T
Q²
X_F Proton
Δ φ

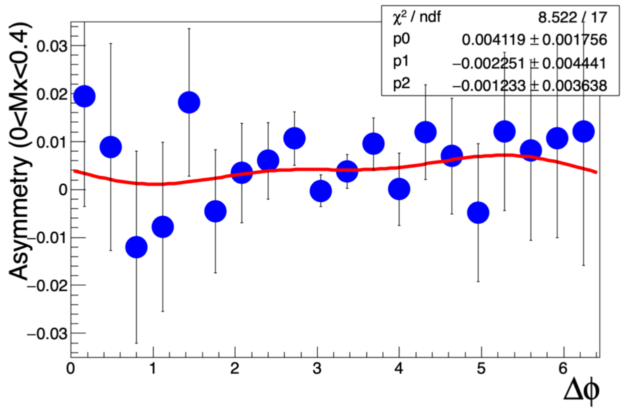
Channel selection, Study of Mx

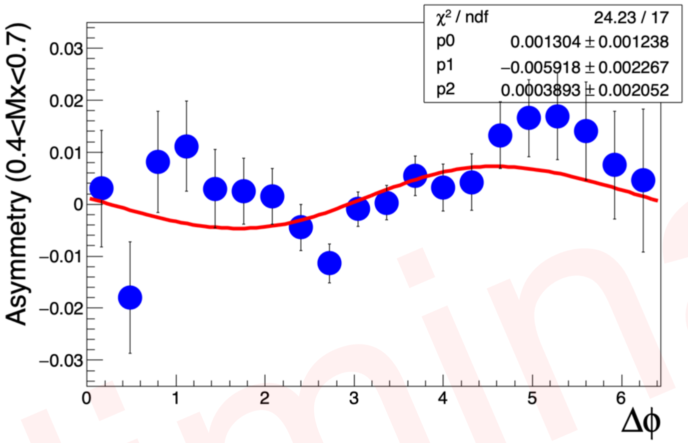
$$A(\phi)_{LU} = \frac{1}{p}\left(\frac{N^+ - N^-}{N^+ + N^-}\right)$$

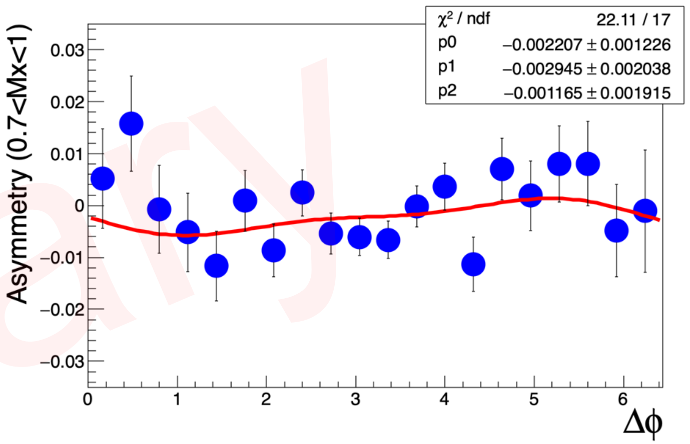
p0+p1 sin ϕ + p2 sin(2 ϕ)





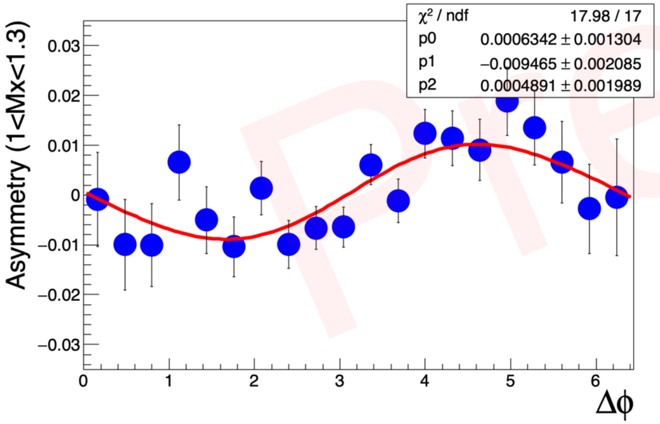


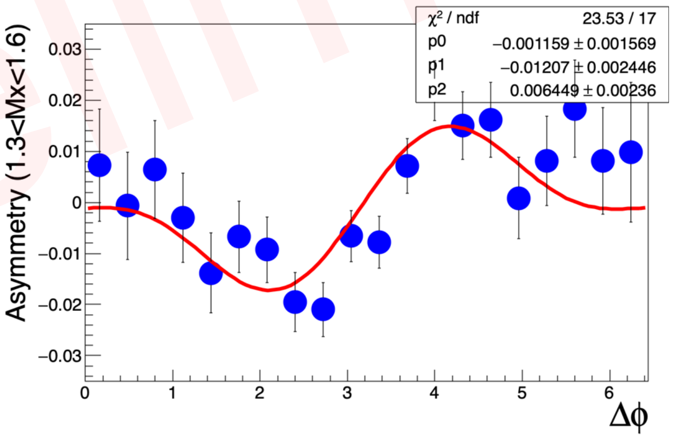


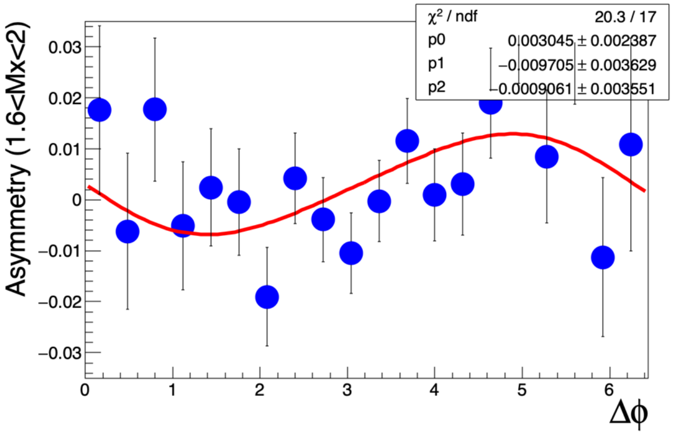


a) Λ→ pi- p
b) Generic excl. P:K+:K-
c) K* meson -> Kpi- pair

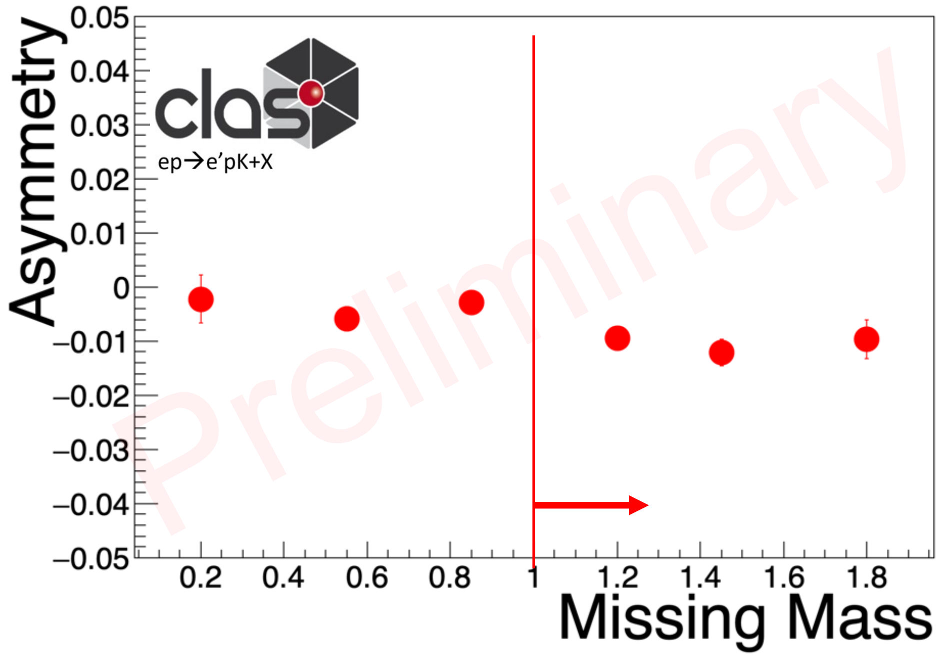
pi- (0.1396 GeV),
k- (0.4368 GeV) and
k*- (0.8917 GeV).

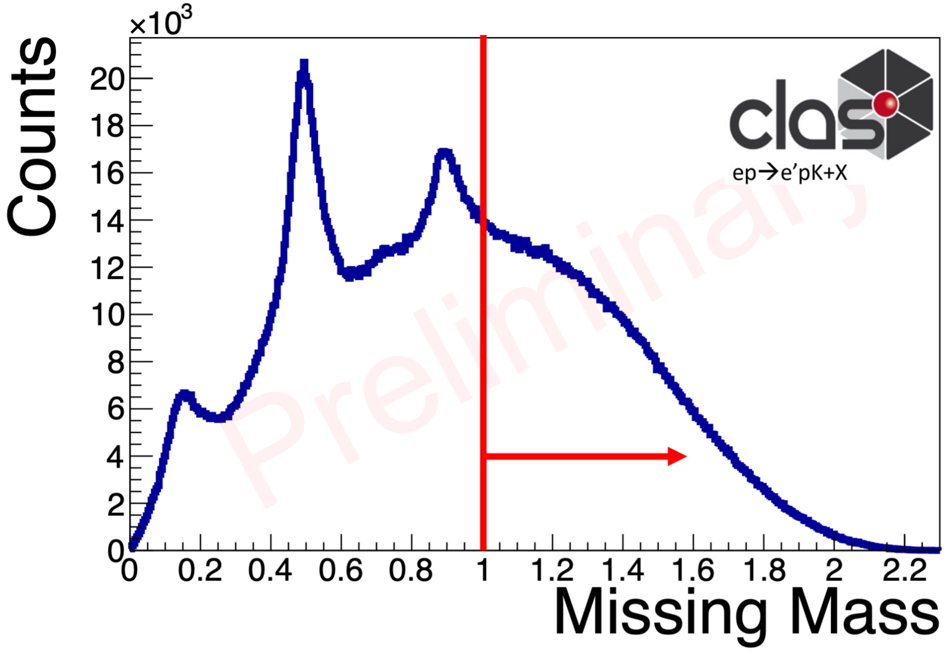






Asymmetry versus Mx Preliminary Results

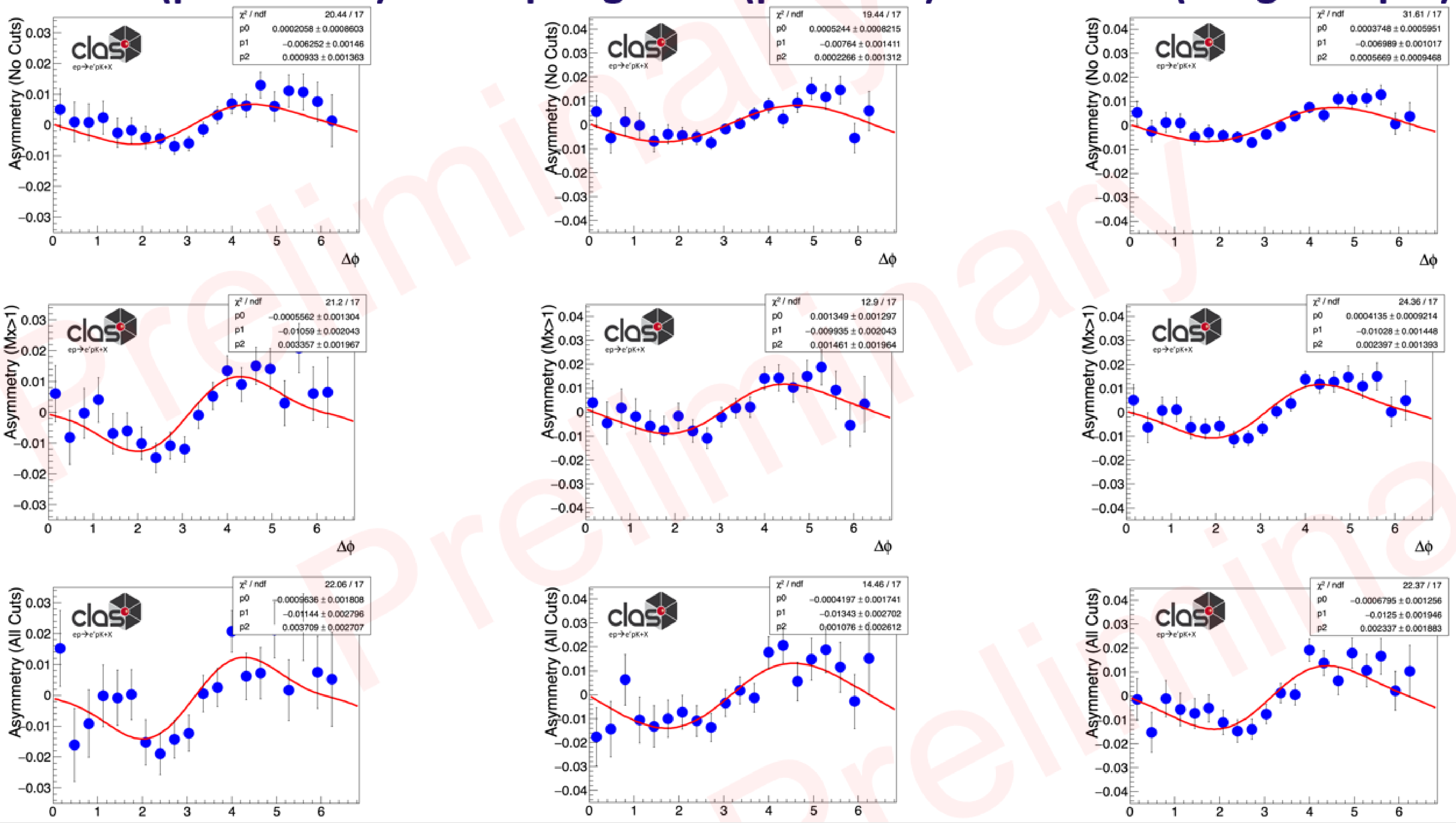




All the next studies are performed with Mx >1 GeV

Integrated Asymmetry Preliminary Results

Fall 2018 (pol= 0.869) | **Spring 2019 (pol=0.85)** | **Total (weighted pol)**

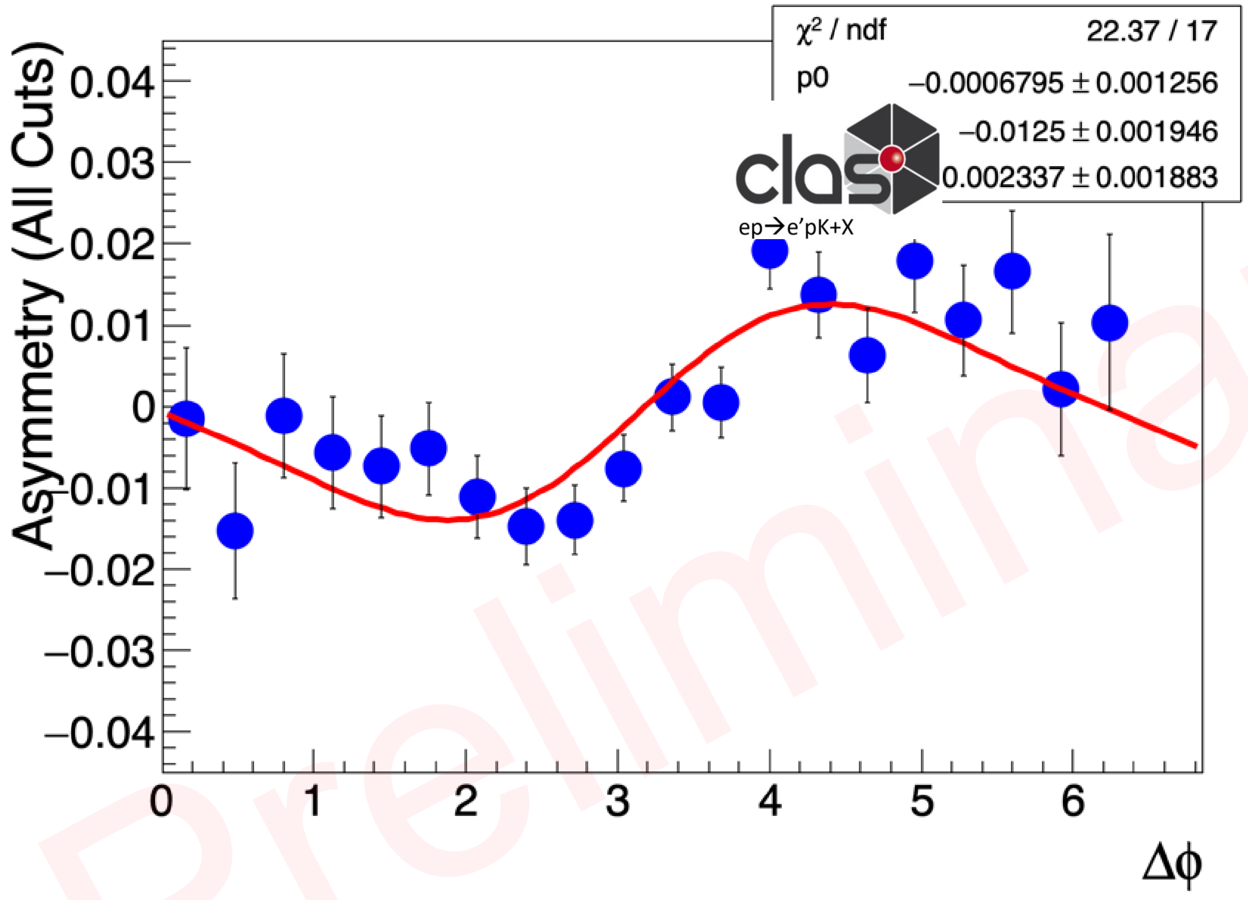


No cuts

Mx >1

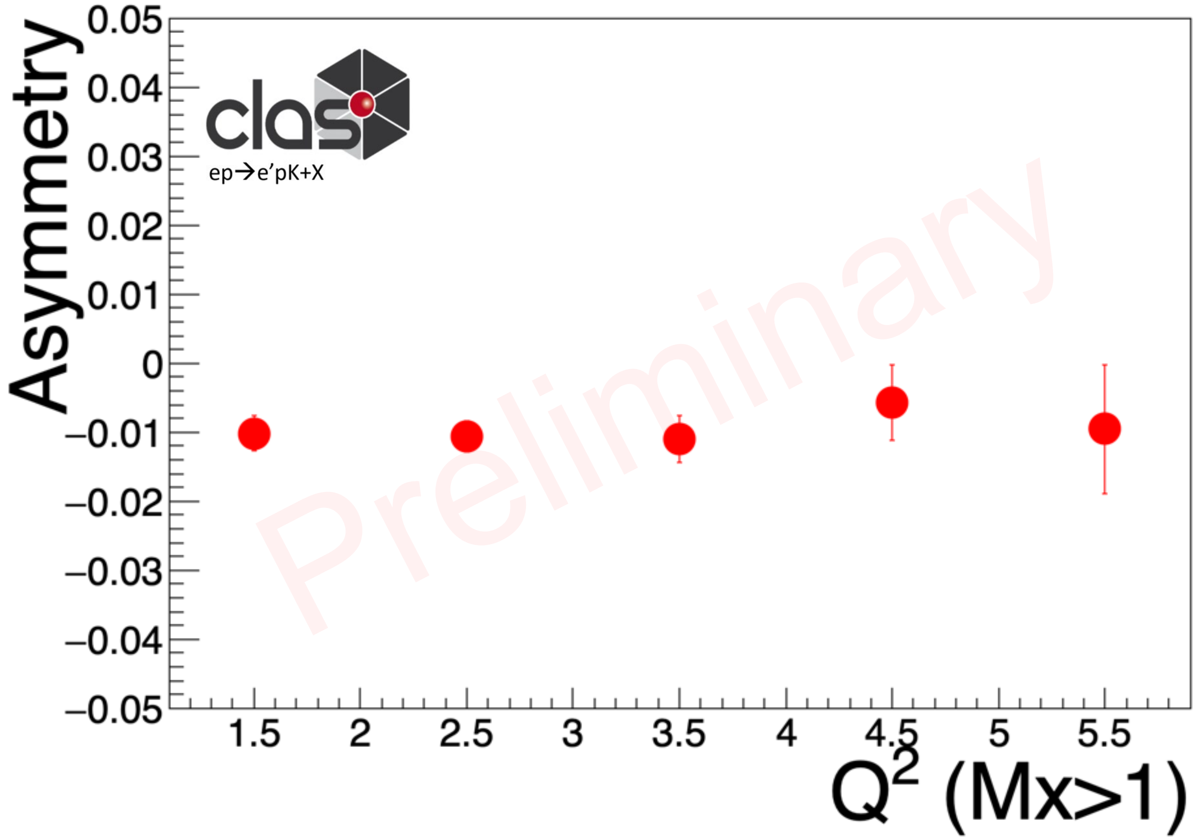
All Cuts

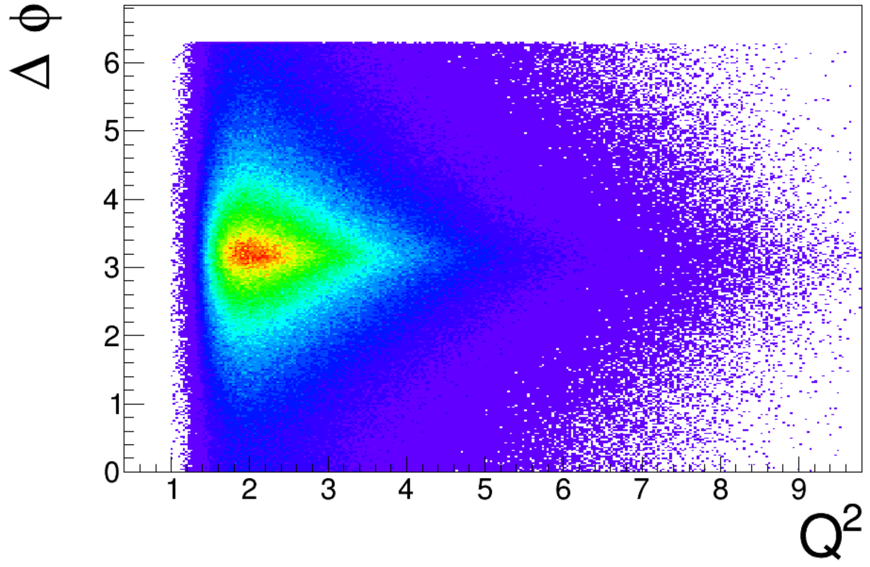
Integrated Asymmetry summary: Preliminary Single Spin Asymmetries for proton-Kaon pairs in the $e{+}p \rightarrow e'p'K{+}X$ reaction for RGA inbending data:

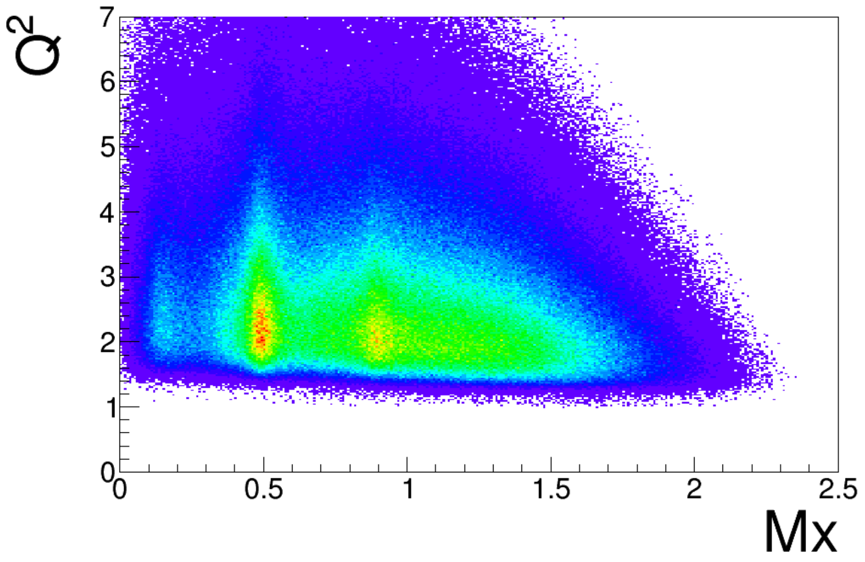


The question, is how much of these are pions?

Prel. Asymmetry versus Q^2

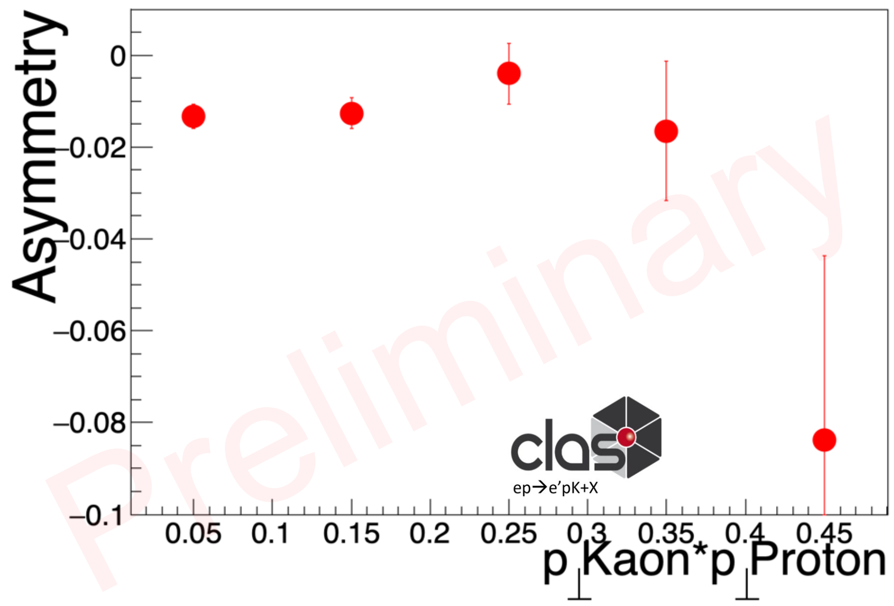


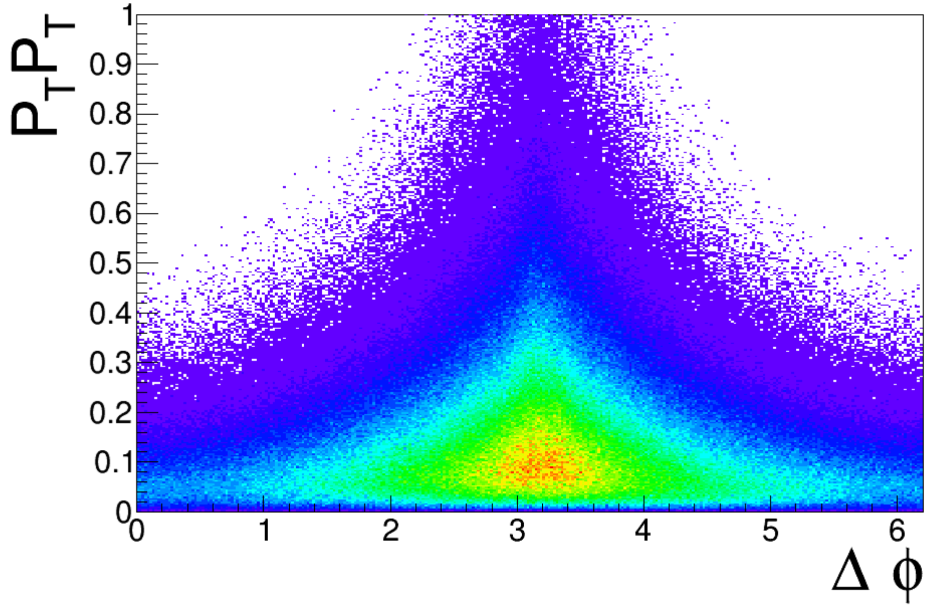


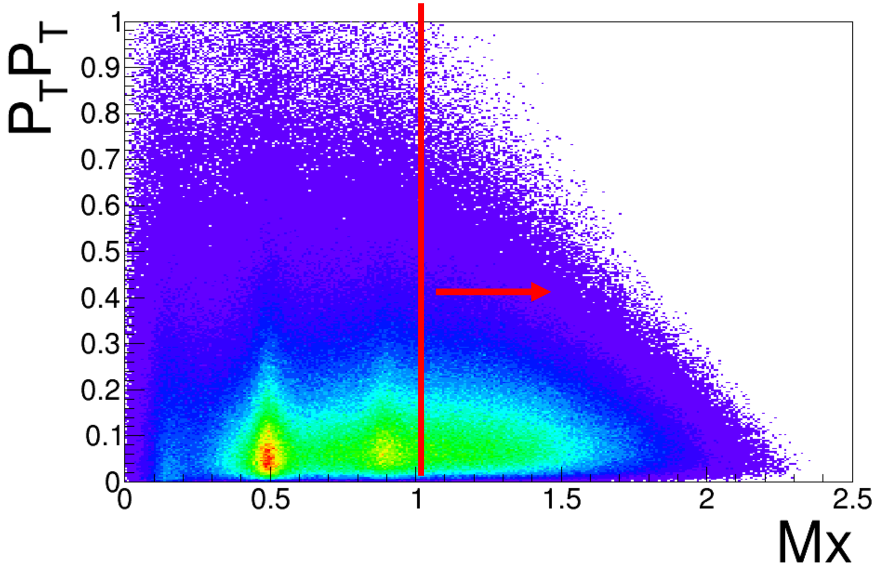


No significant dependence on Q^2

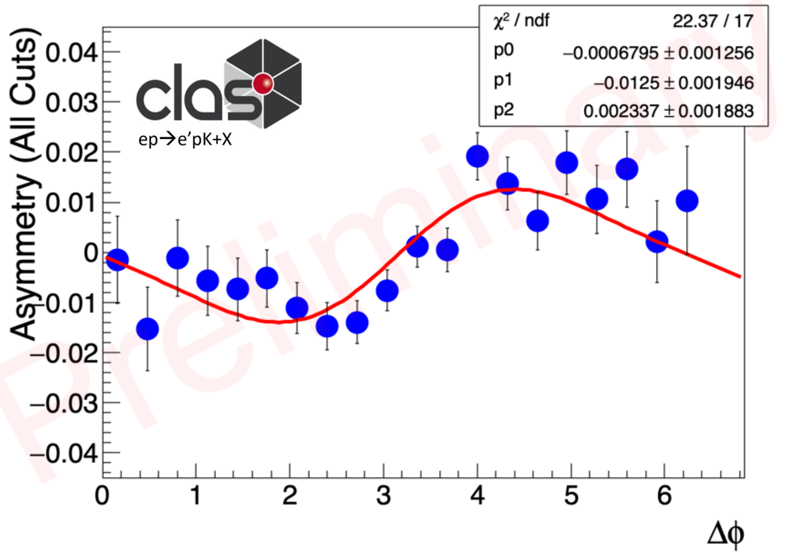
Prel. Asymmetry vs. $P_T P_T$







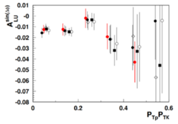
Non-zero Asymmetry is observed.
*Cross checks with H. Avakian underway.
Prel. Comparisons show agreements.



Conclusion and Outlook

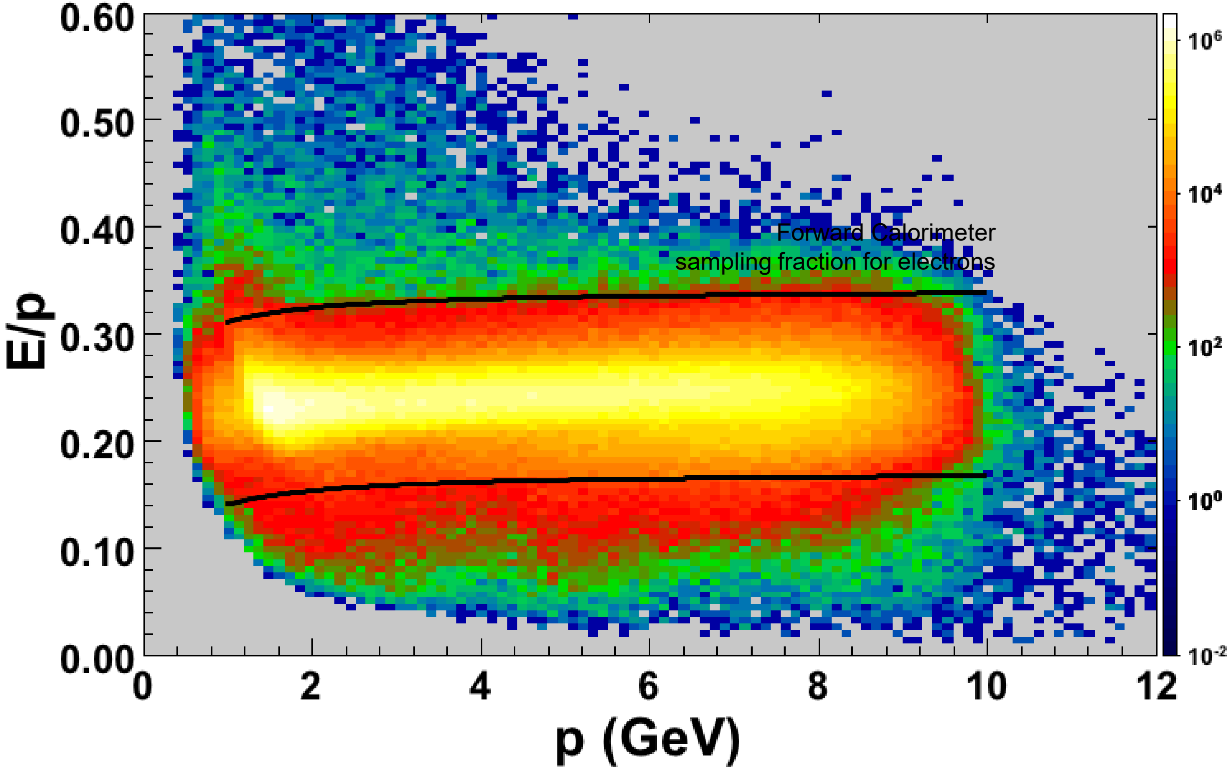
- Non-zero preliminary asymmetries have been measured for b2b proton-kaon channel for the first time.
- Next steps: Refine the study, include RICH, evaluate systematics, corrections…

Backup Slides



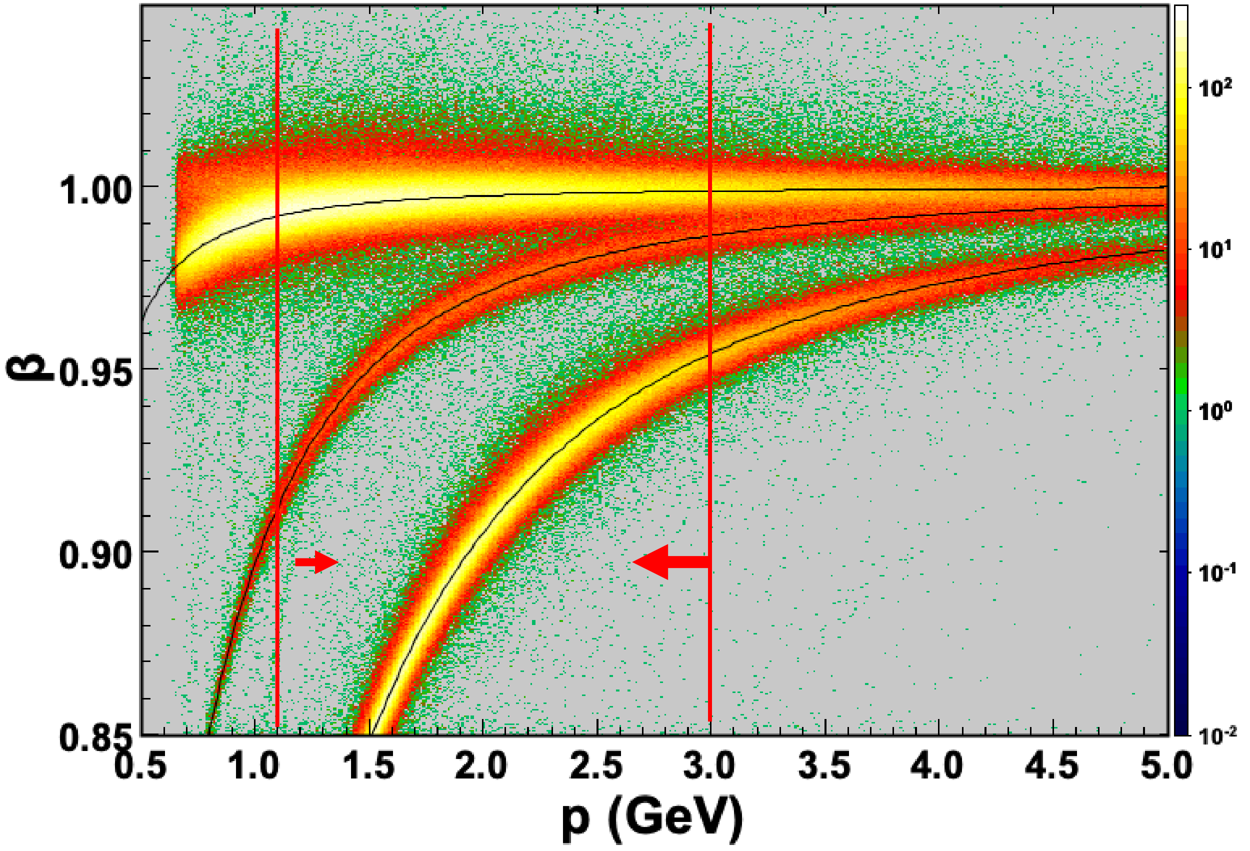
Particle ID

- Electron
  - Electromagnetic calorimeter.
  - Cherenkov detector.
  - Vertex and fiducial cuts.

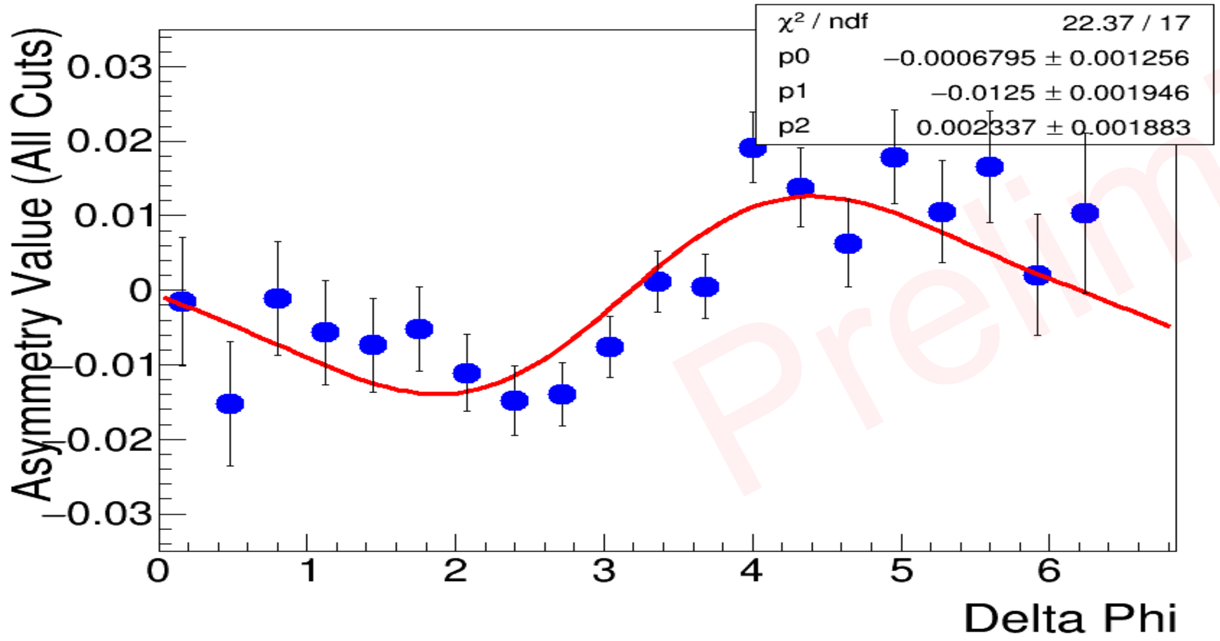


- Hadron
  - β vs p comparison between vertex timing and event start time.
  - Vertex and fiducial cuts.

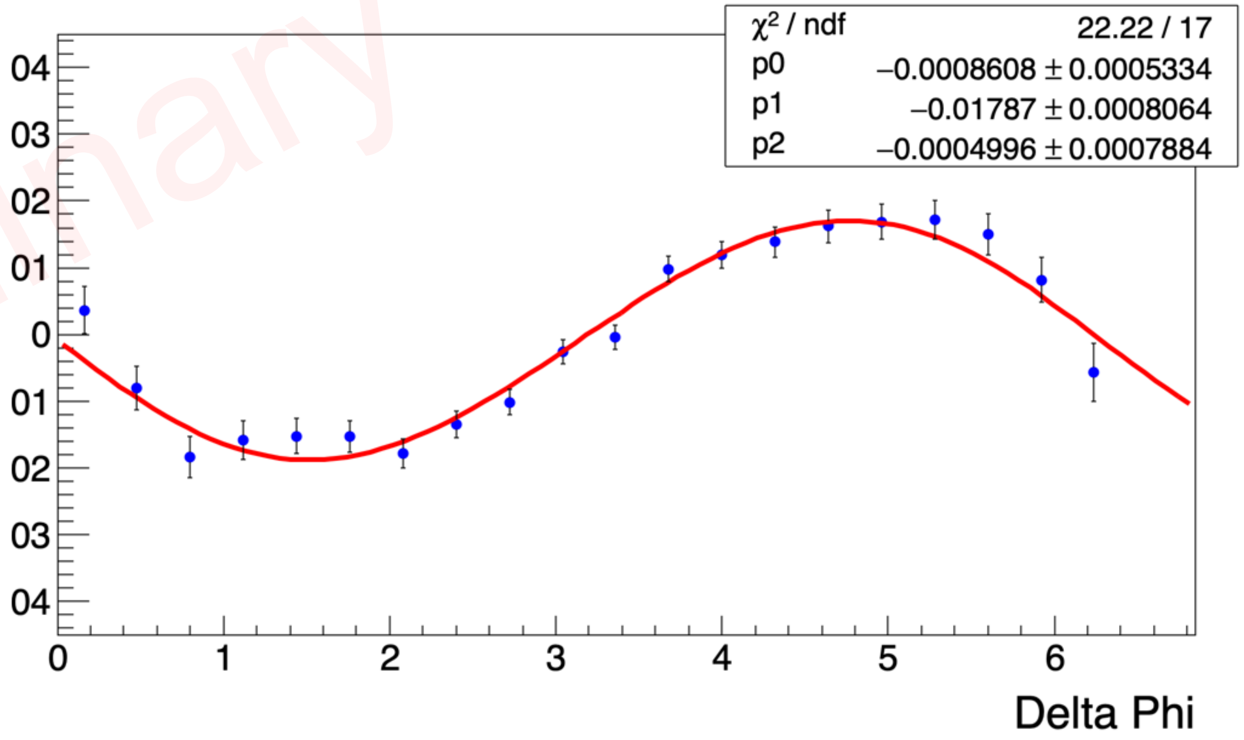
TOF particle identification



Kaons Total Asymmetry



Pion Total Asymmetry



Back-to-back hadron production in SIDIS would allow:

- study SSAs not accessible in SIDIS at leading twist
- measure fracture functions
- control the flavor content of the final state hadron in current fragmentation (detecting the target hadron)
- study entanglement in correlations in target vs current
- access quark short-range correlations and χSB (Schweitzer et al)
- ...