A_{LU} with π+K-, K+π-, and K+K- semi-inclusive dihadrons at CLAS12

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Workshop on Kaons at CLAS12

Research supported by:

U.S. DEPARTMENT OF ENERGY | Office of Science

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10.1103/PhysRevLett.126.152501:

Dihadron A_{LU} with CLAS12 rg-a

$$A_{\mathrm{LU}} = \frac{1}{P_{\mathrm{beam}}} \frac{N^+(\phi_h, \phi_{R_\perp}) - N^-(\phi_h, \phi_{R_\perp})}{N^+(\phi_h, \phi_{R_\perp}) + N^-(\phi_h, \phi_{R_\perp})} = A_{\mathrm{LU}}^{\sin(\phi_h - \phi_{R_\perp})} \sin(\phi_h - \phi_{R_\perp}) + A_{\mathrm{LU}}^{\sin(\phi_{R_\perp})} \sin(\phi_{R_\perp}) + \ldots, \quad (6)$$

arXiv:1408.5721:

$$d\sigma_{LU} = \frac{\alpha^2}{4\pi x y Q^2}\left(1 + \frac{\gamma^2}{2x}\right)\lambda_e \times \sum_{\ell=0}^{\ell_{\max}} \left\{ C(x,y) \sum_{m=1}^{\ell} \left[P_{\ell,m} \sin(m(\phi_h - \phi_{R_\perp}))\, 2 \left(F_{LU,T}^{P_{\ell,m}\cos(m(\phi_h - \phi_{R_\perp}))} + \epsilon F_{LU,L}^{P_{\ell,m}\cos(m(\phi_h - \phi_{R_\perp}))} \right) \right] + W(x,y) \sum_{m=-\ell}^{\ell} P_{\ell,m} \sin((1-m)\phi_h + m\phi_{R_\perp}) F_{LU}^{P_{\ell,m}\sin((1-m)\phi_h + m\phi_{R_\perp})} \right\}.$$

- Rg-a: longitudinally polarized electron beam, unpolarized target
  - Beam energy 10.6 GeV and 10.2 GeV
- A_{LU} already extracted for pi+/pi-
  - Higher statistics, full partial wave decomposition studied
- Extraction with dihadrons with kaons will provide information on same PDFs for strange sea in nucleon

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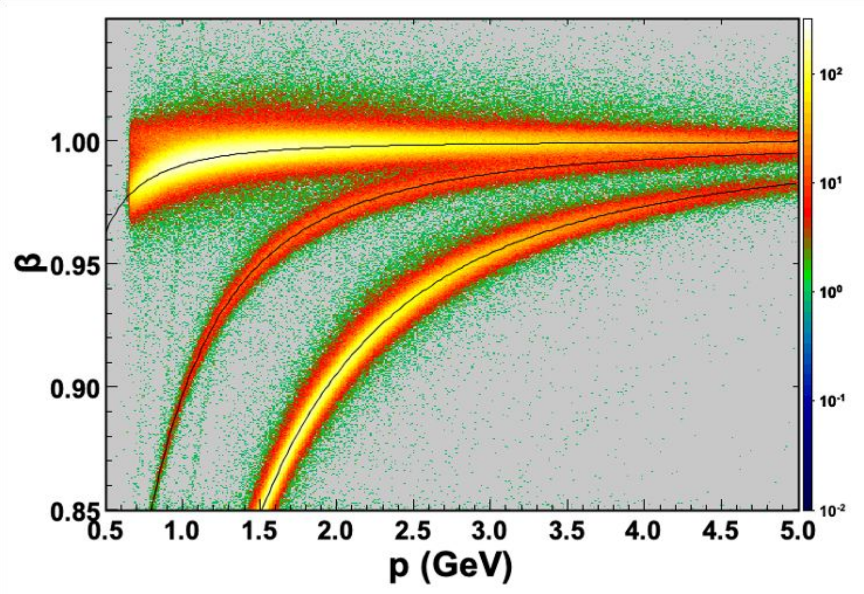
CLAS12 Kaon PID

- Low momentum: pi/K/p separated by with momentum + beta measurements
  - p > ~2.5GeV - 3GeV: significant overlap
- RICH detector in one sector
  - Only ⅙ of CLAS12 CD acceptance
  - Acceptance further limited by misalignments in RICH
  - Does provide a dataset of well-identified high momentum kaons, useful for verifying other ID approaches



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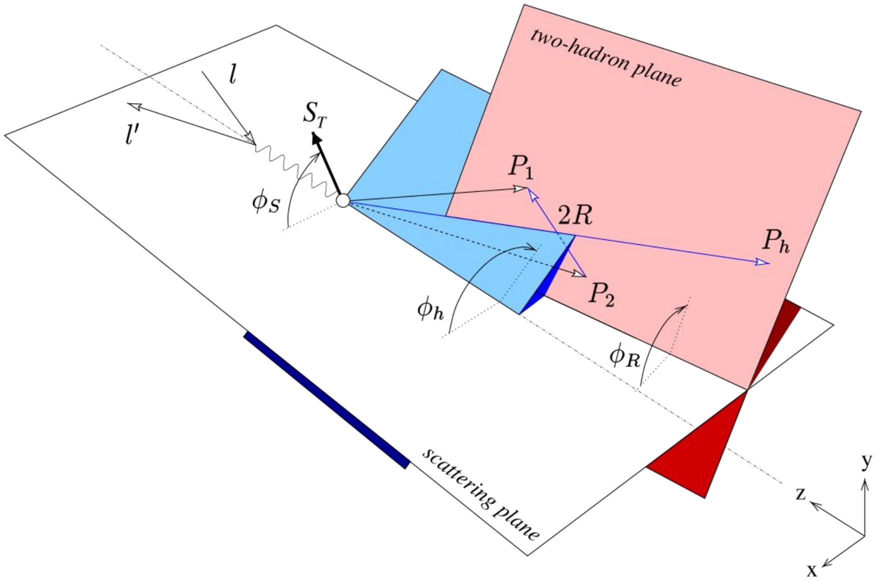
Semi-inclusive dihadrons

- $ep \to e'h_1h_2+X$
- SIDIS dihadron cross-section:
  - Not convolved over $p_{h,\perp}$, giving access to product of PDF and dihadron FF (DIFF)
    - Cleaner theoretical extraction
  - Dihadron FFs measured directly at e+/e- collisions
  - Access to twist-3 effects
  - Important test of theory, vector meson contributions



arXiv:hep-ph/0311173

NN for Kaon-pion discrimination

- Based on work by Áron Kripko, using machine learning to remove pion and proton contamination from CLAS12 Kaon sample
- Neural network classifier trained to classify individual hadrons as Kaon or non Kaon, then applied to selected dihadron events
- Training neural networks on particle information as well as detector level information for reconstructed hadrons with EBpid == 321
  - Momentum, beta
  - FTOF, ECAL, PCAL, HTCC
  - Timing information
- Using RICH identified particles as test sample instead of MC at higher momentum

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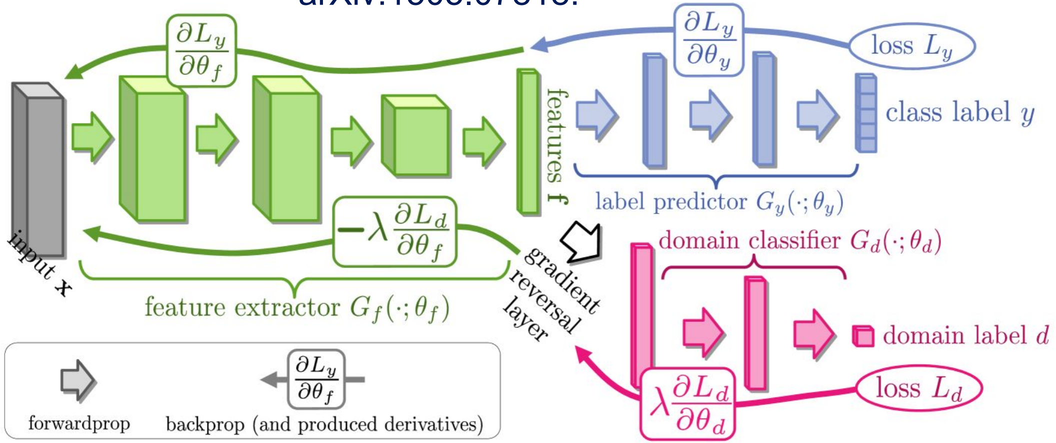
Domain-adversarial training of NN

- Domain-adversarial (DA) (arXiv:1505.07818) training of neural networks aims to improve performance when applying NN to a sample from a slightly different domain
  - Here, difference between data and CLAS12 Monte Carlo
  - Similar approach used at ALICE for PID (arXiv:2204.06900)

- Extracts features from data and MC from which it cannot distinguish between data and MC
  - Single hadron information from data and MC, equal number pions and kaons
- Model implemented in tensorflow
- 4 networks total trained:
  - Different networks for positive, negative hadrons
  - 1.25 GeV < p < 2.5 GeV, and 2.5 GeV < p < 5 GeV

arXiv:1505.07818:



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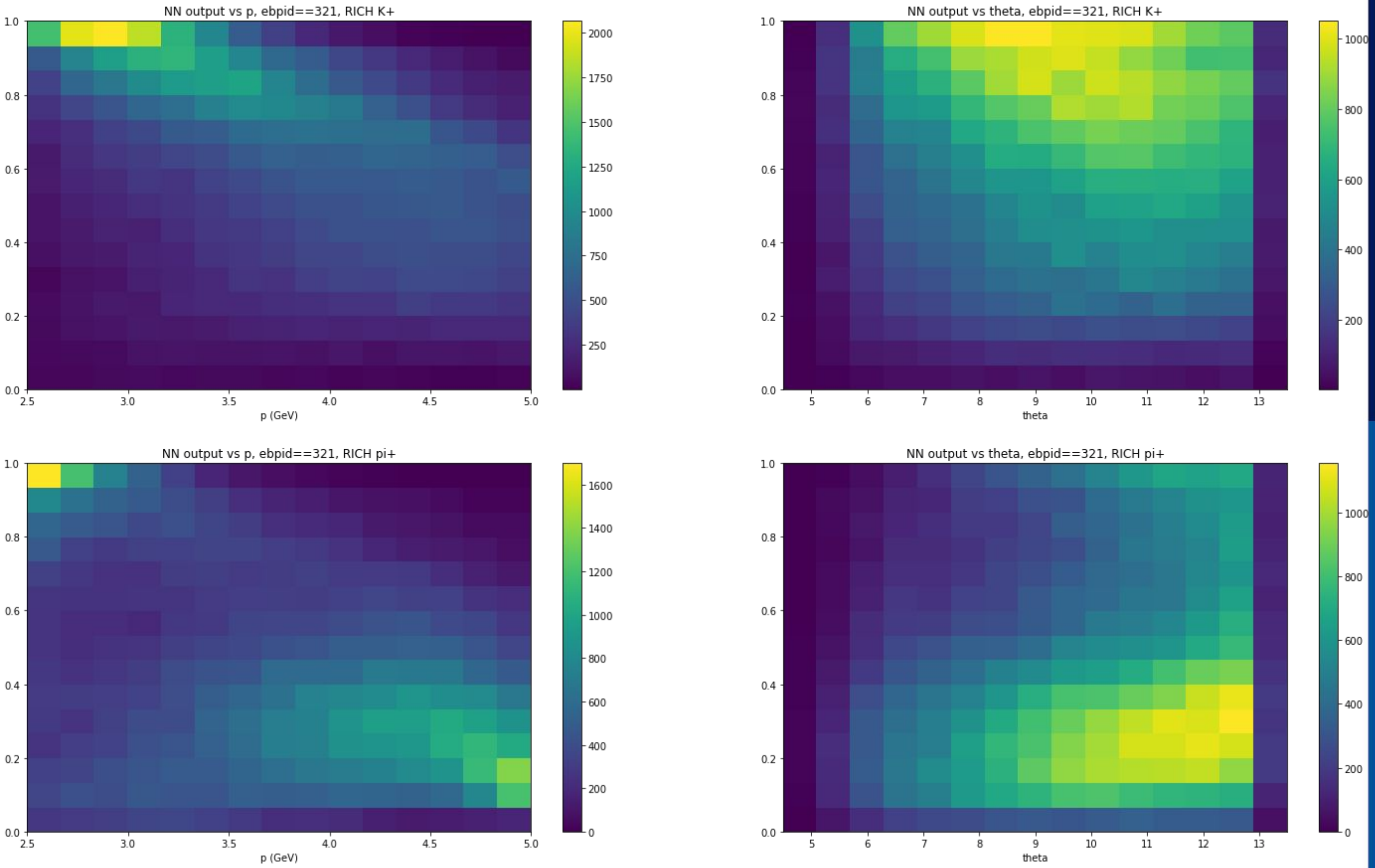
RICH K+ sample DANN output, λ=0.5

- Feature extractor output size: 10
- Domain classifier network maximally confused (outputs ~0.5 for all events)
- **λ -> factor for domain classifier loss, enforces domain invariance**

DANN output, lambda = 0.5



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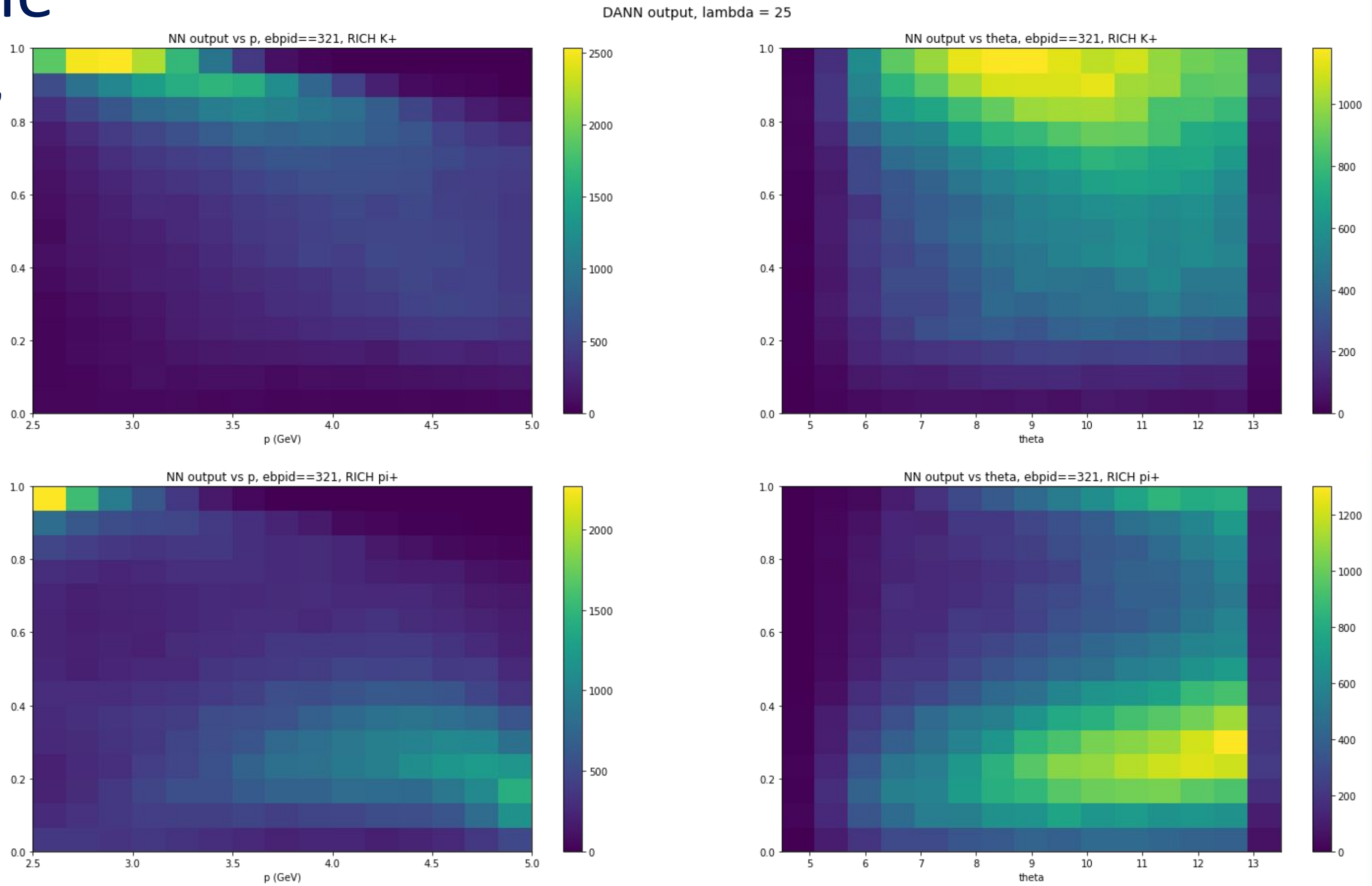
RICH K+ sample DANN output, λ=0.0

- **λ** = 0: network with no domain adversarial portion



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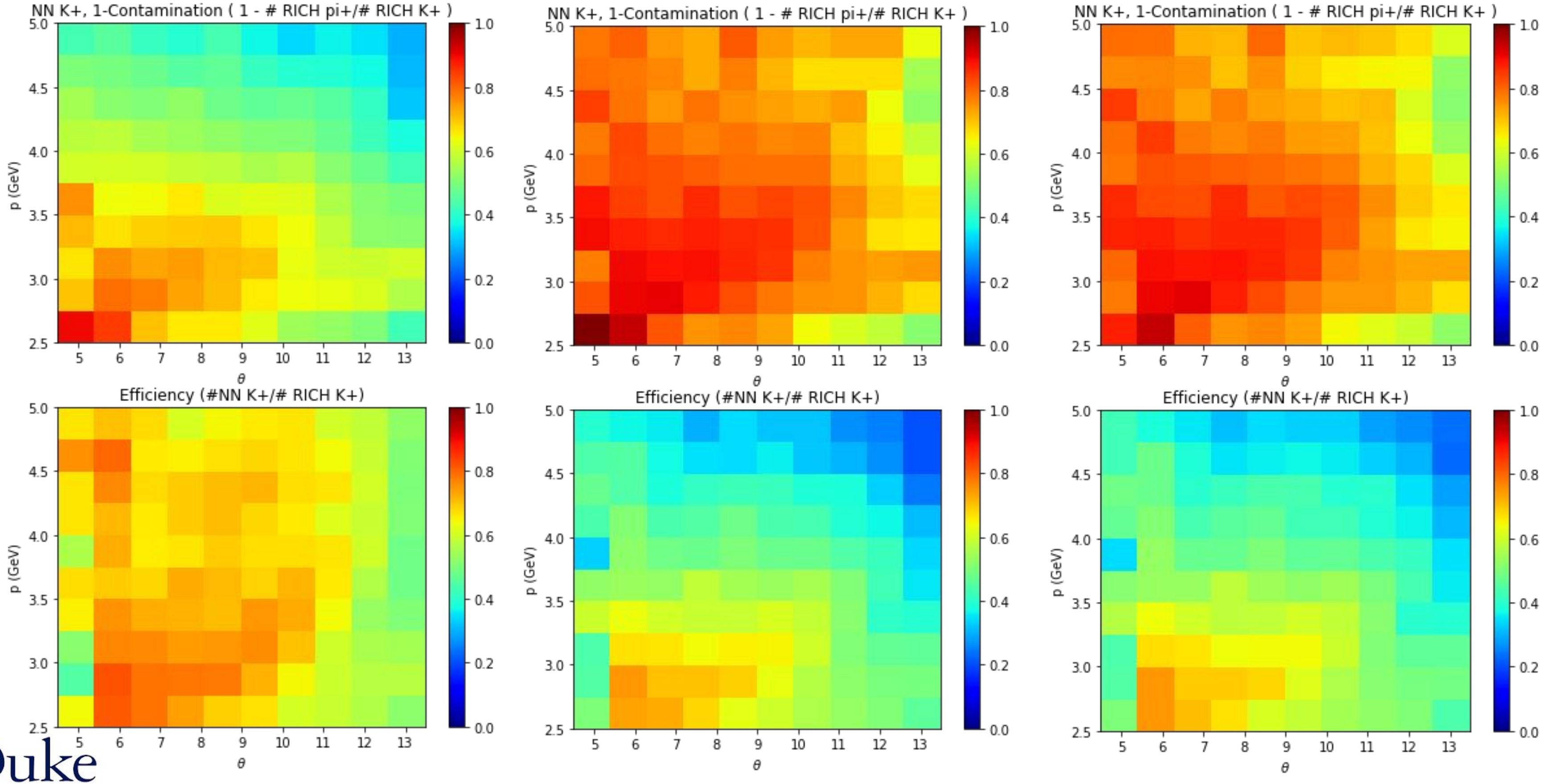
Contamination and efficiency, RICH K+ sample

chi2pid cut | **λ** = 0 | **λ** = 0.5

1 - Contamination

Efficiency



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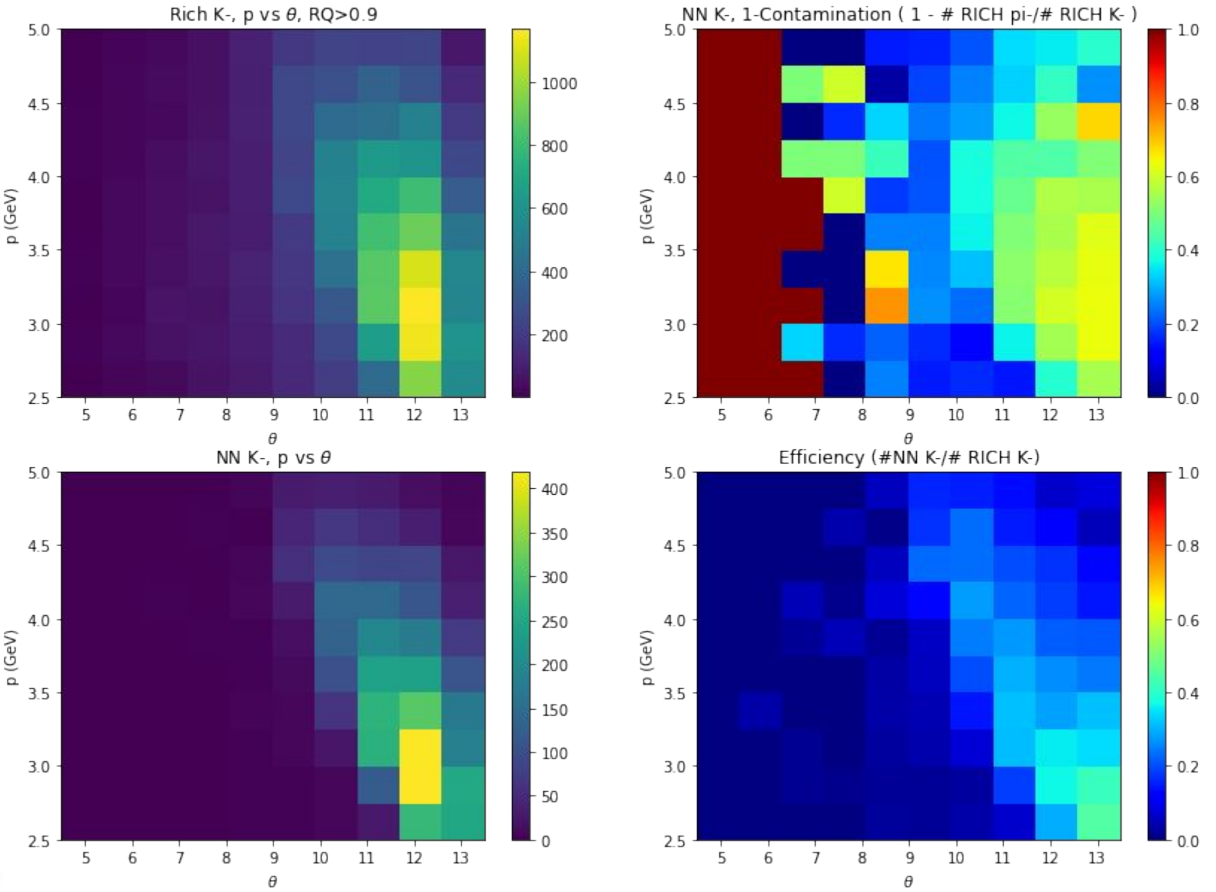
Contamination and efficiency, RICH K- sample



- Very poor performance for high momentum K- as of now, based on performance in RICH sample
  - Needs further investigation

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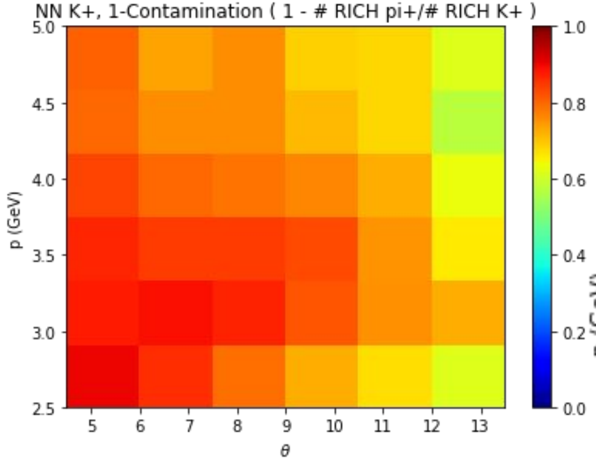
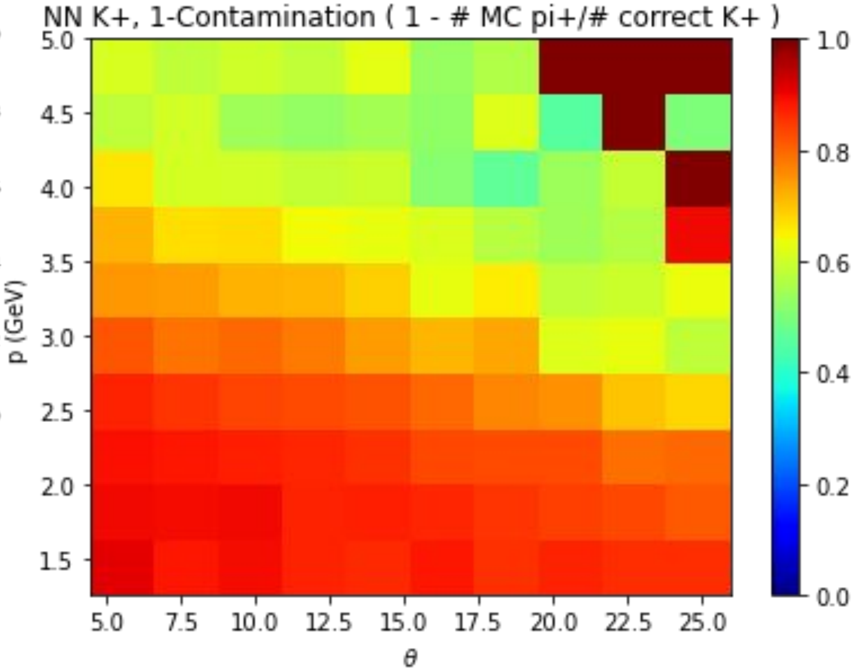
Contamination, p vs θ: MC (large) and RICH (small), DANN $\boldsymbol{\lambda}$ = 0.5

RICH K+



Monte Carlo K+



- Appears that performance is better on RICH ID'd particles than MC in higher momentum region

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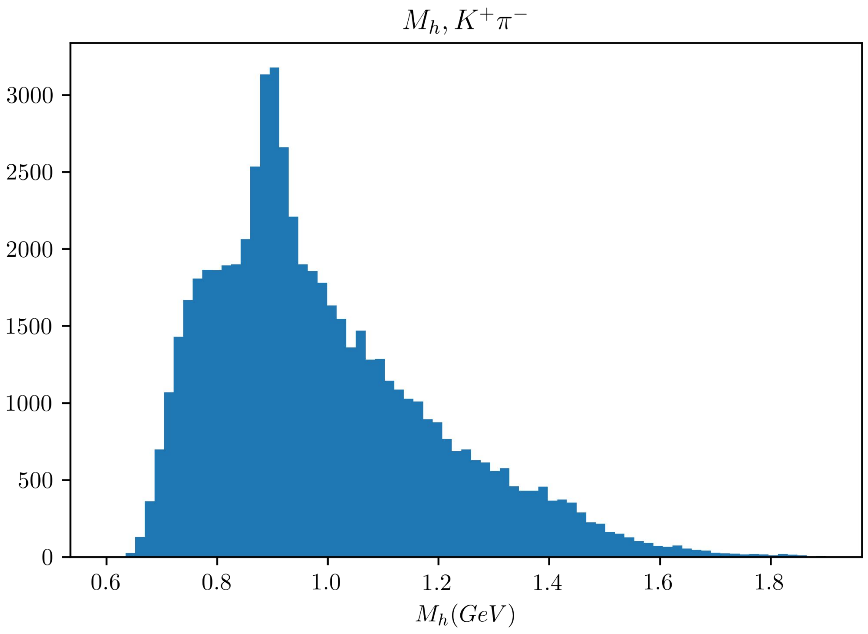
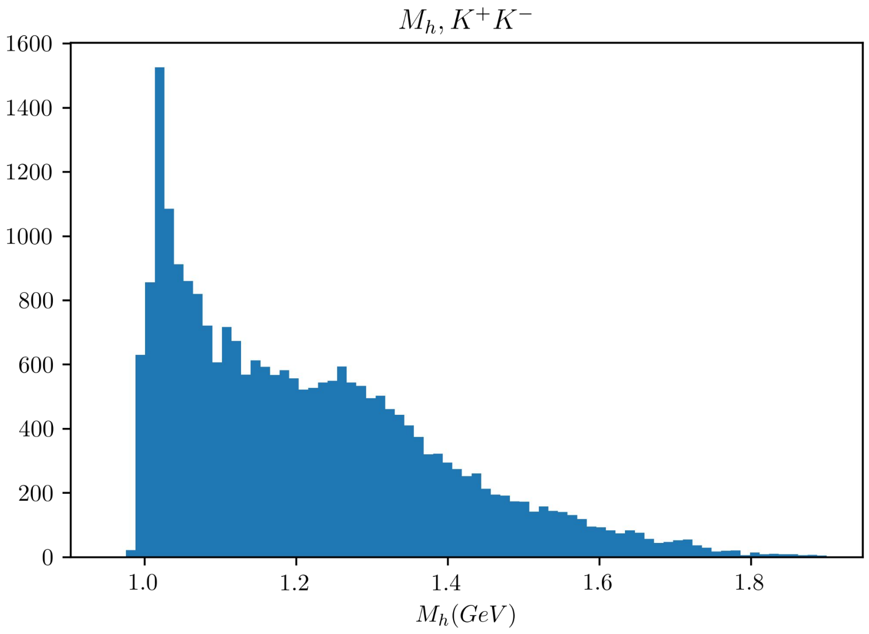
Invariant mass distributions





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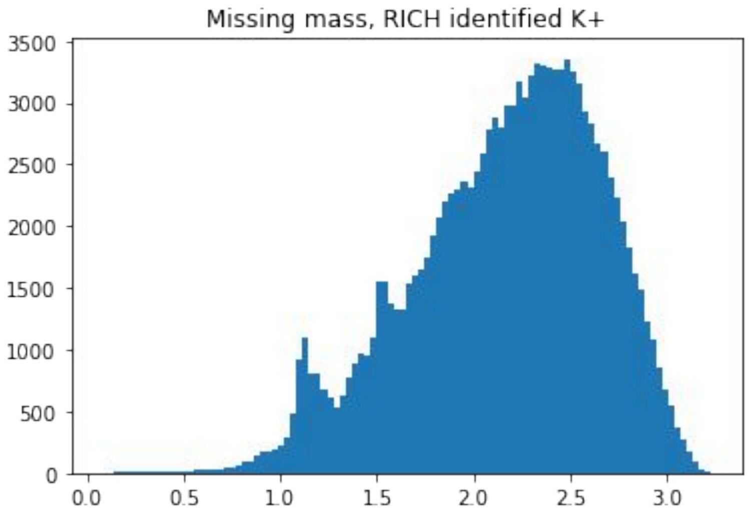
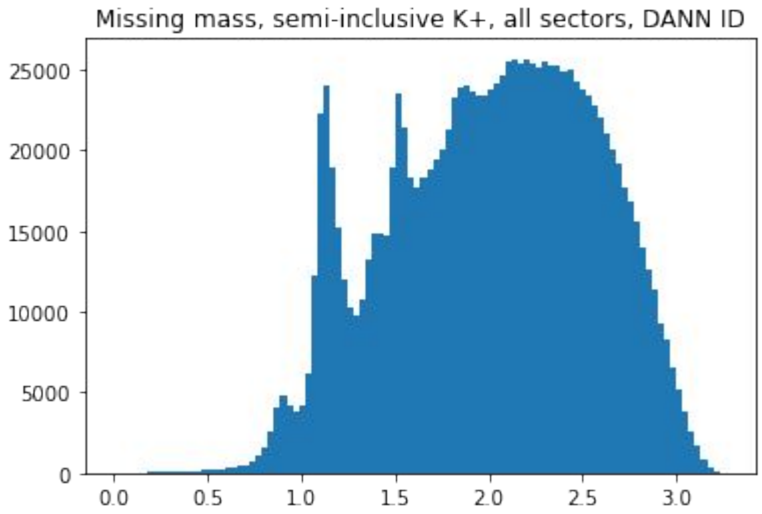
Missing mass distributions

Semi-inclusive K+, RICH identified, 2.5 GeV < p < 5 GeV



Semi-inclusive K+, identified by DANN, all sectors 2.5 GeV < p < 5 GeV



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SIDIS dihadron selection

- Hadrons required to have correct EB PID, abs(chi2pid) < 3,
- DANN($\boldsymbol{\lambda}$=0.5) output > 0.5 for kaons
- If hadron within RICH acceptance, use RICH (p > 2.5 GeV, theta < 13 degrees)
- 1.25 GeV < p < 5 GeV
- Cut on electron and hadron vertices
- SIDIS cuts:
  - $Q^2 > 1$ GeV^2, $y < 0.75$
  - xF1, xF2 > 0 (current fragmentation region)
  - W > 2 GeV
  - Missing mass > 1.3 GeV

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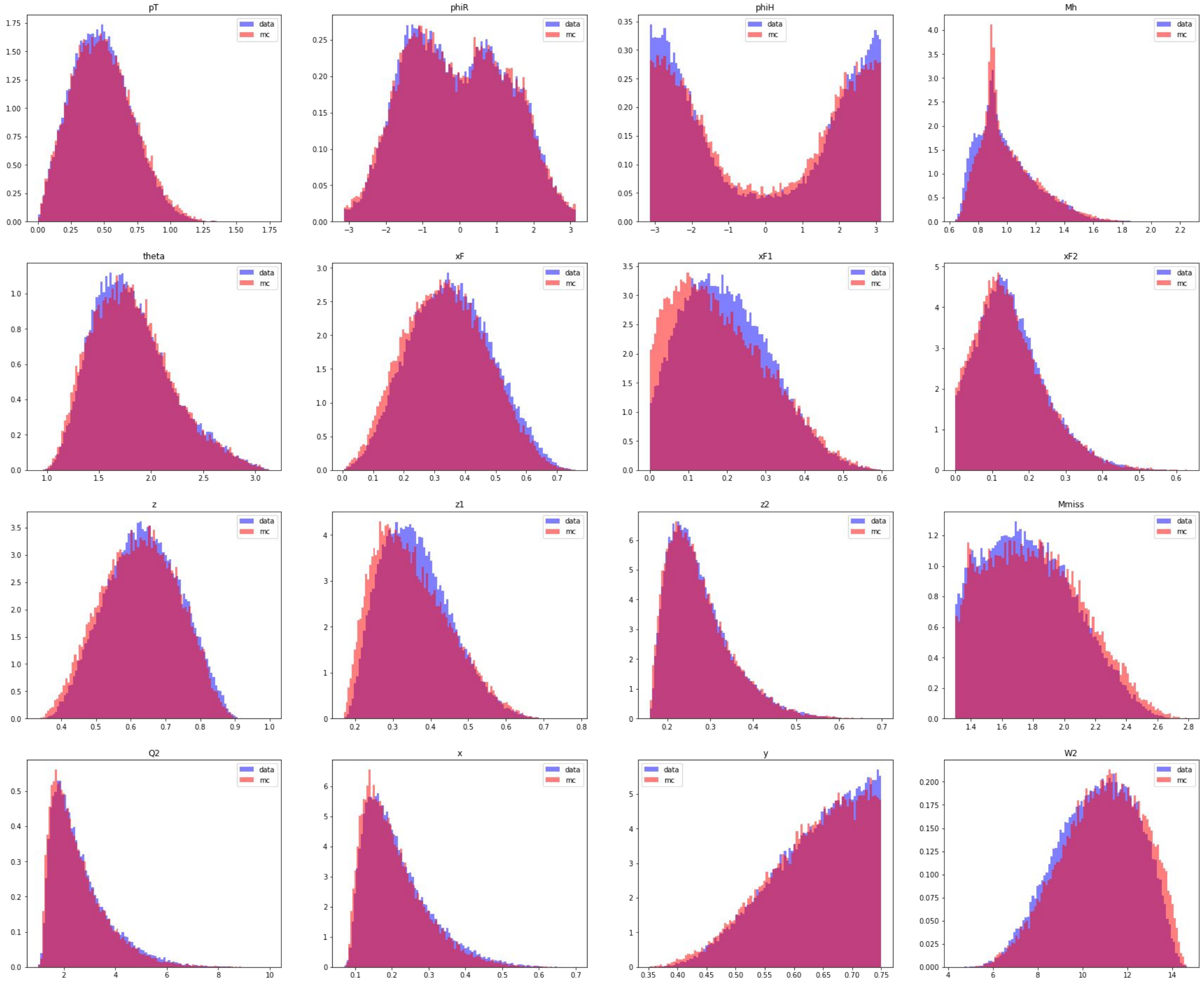
SIDIS dihadron kinematics, K+π-

- Significant differences in xF and invariant mass



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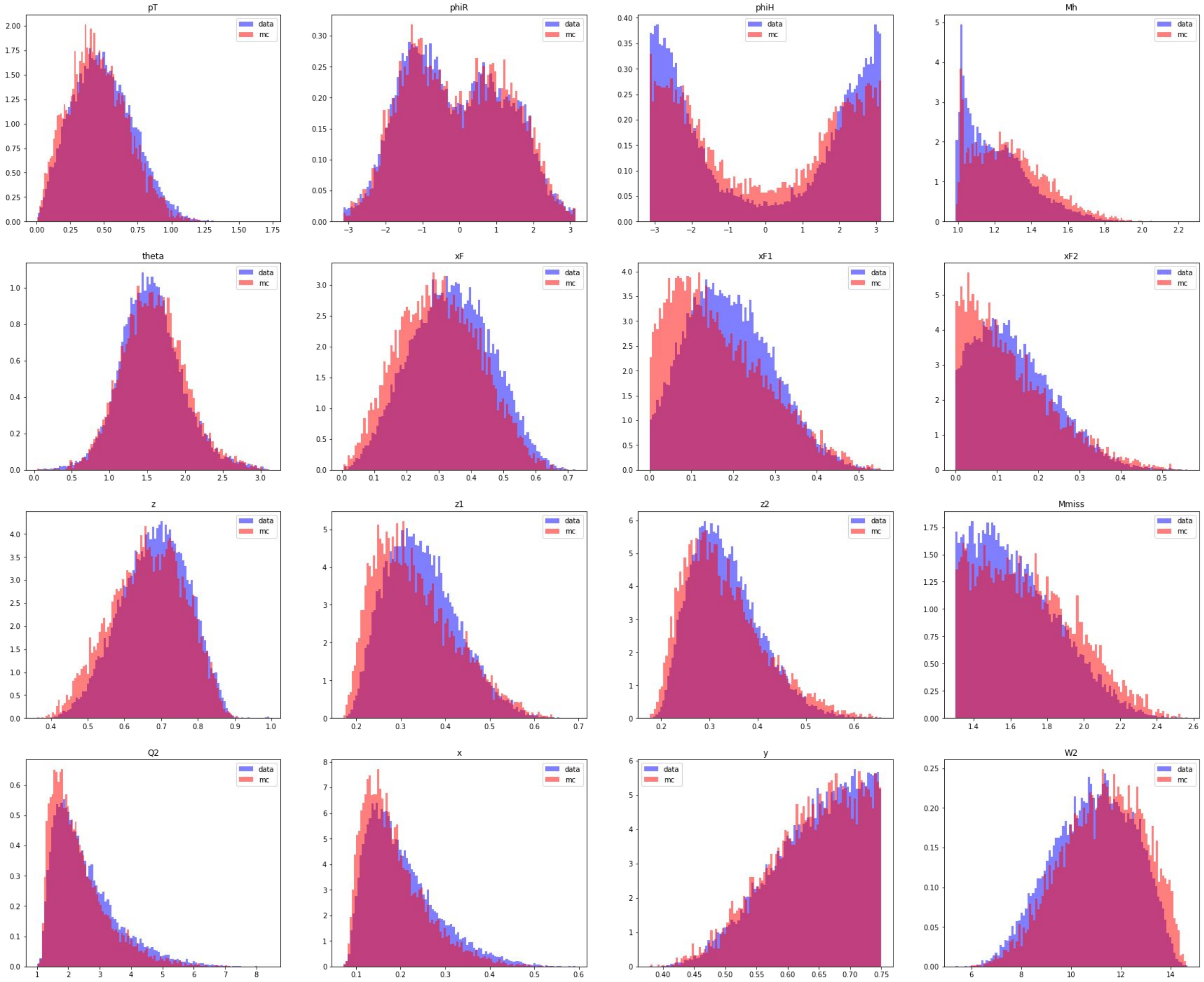
SIDIS dihadron kinematics, K+K-

- More significant changes in invariant mass spectrum



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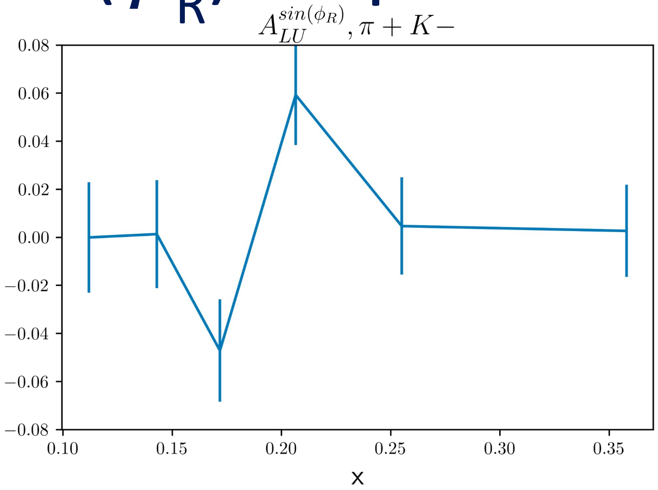
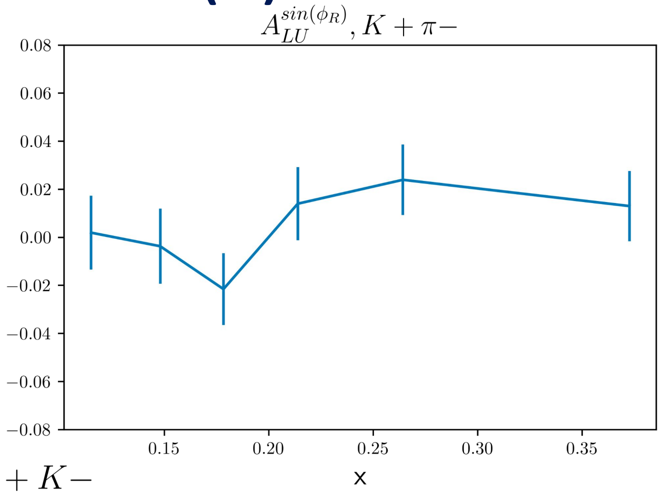
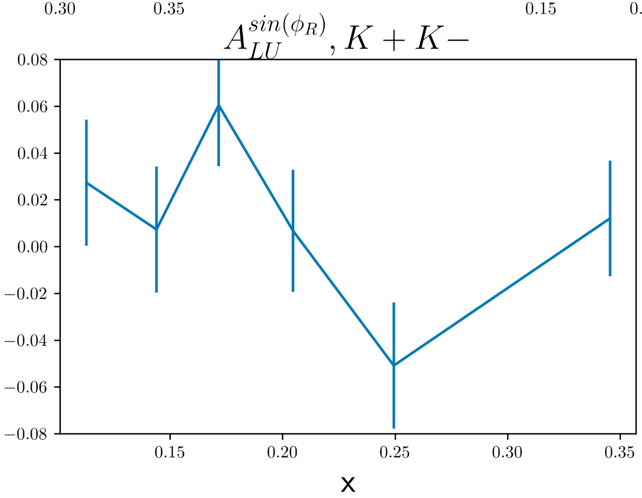
A_{LU} $\sin(\phi_R)$ amplitude $\propto$ DIFF e(x)





- All 7 modulations extracted with log likelihood fit
- Contaminated samples subtracted based on expected mis-ID probability from RICH where available and MC



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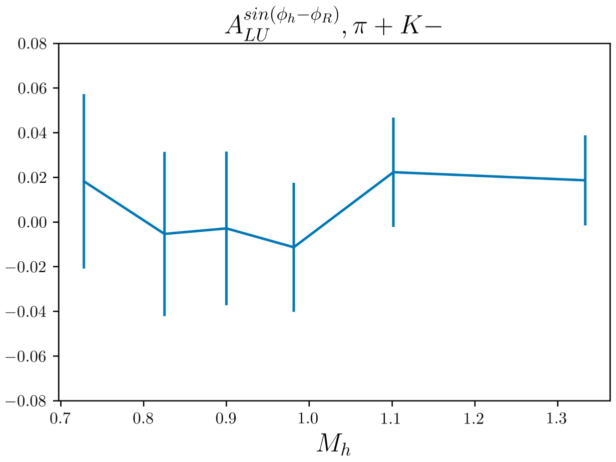
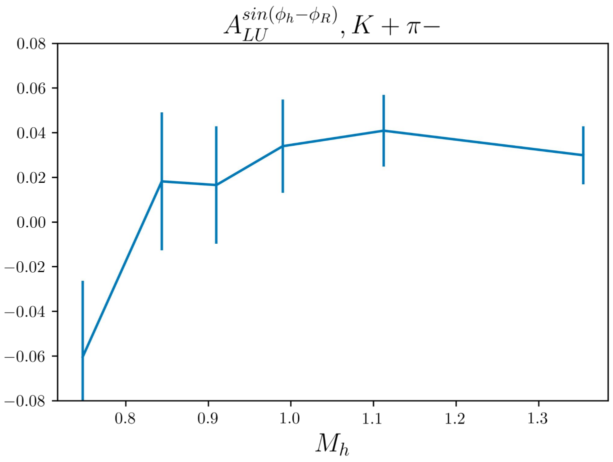
A_{LU} $\sin(\phi_h - \phi_R)$ amplitude $\propto$ DIFF $G_1^{\perp}$





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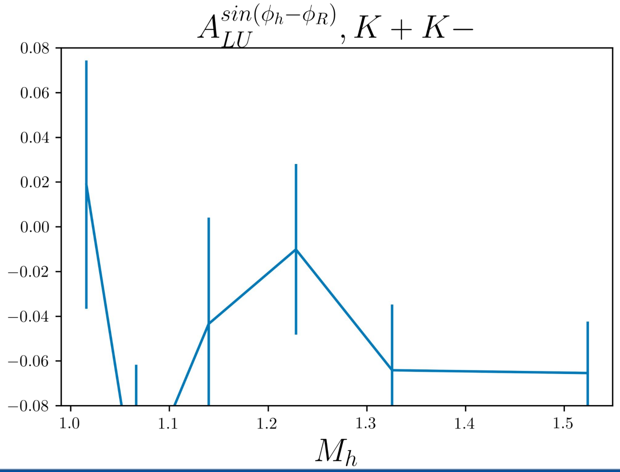

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Conclusions

- Initial extraction and background correction performed of A_{LU} for dihadrons with kaons
- Semi-inclusive K+π-, π+K-, K+K- observable uncertainties largely limited by statistics
  - Able to obtain a fairly pure kaon sample with machine learning particle ID
- Early studies conducted of domain-adversarial training of PID NN, with hopes that this can improve data-MC agreement
- Larger momentum DANN PID appears to perform well on RICH identified particles from rg-a

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