A 12 GeV Research Proposal to Jefferson Lab (PAC 38)

Studies of Dihadron Electroproduction in DIS with Unpolarized and Longitudinally Polarized Hydrogen and Deuterium Targets

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A CLAS collaboration proposal

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Collaborators' commitment to the 12 GeV upgrade of Jefferson Lab

- **Italian JLAB12 collaboration**

  The Italian JLAB12 collaboration (INFN Bari, INFN Catania, Laboratori Nazionali di Frascati, INFN Genova, INFN Roma I and Istituto Superiore di Sanita', INFN Roma Tor Vergata) is actively involved in this proposal. Among CLAS12 equipment, the group plans to contribute to the design, prototyping, construction and testing of the CLAS12 RICH detector and central calorimeter. Seven staff members and three post-docs will spend their time as needed on this project. Funding for the group is from the Italian research agency Istituto Nazionale di Fisica Nucleare (INFN). Additional funding are planned to be sought in the European Community.

Motivation

- The study of processes with two hadron production -- first in the current fragmentation region (CFR) and second in the target fragmentation region (TFR) -- of polarized SIDIS provide complementary information on the nucleon structure and hadronization dynamics. The leading order azimuthal asymmetries in particular provide access to polarized TMD Fracture Functions, which are conditional probabilities to produce a hadron ***h*** in TFR when hard scattering occurs on quark ***q*** from the target nucleon ***N***.

- Kinematical dependences of the ***sin ϕ*** moments for CFR and TFR regions will be studied to probe the underlying distribution and fragmentation functions.

- Studies with kaons, enabled by the CLAS12 RICH detector, which are complementary to measurements with pions, will provide additional information on the corresponding structure functions.

Goals

- study quark gluon correlations in semi-inclusive electroproduction of hadron pairs using the upgraded JLab 11 GeV polarized electron beam and the CLAS12 detector with unpolarized and longitudinally polarized proton and deuteron targets.

- the large acceptance of CLAS12 would allow simultaneous detection of the scattered electrons and hadrons from the hadronization of the struck quarks and target fragments, providing information on flavor and transverse momentum of underlying distribution functions.

- pairs of hadrons detected in current fragmentation region would allow studies of higher twist distribution functions describing quark-gluon correlations, and chiral-odd Dihadron Fragmentation Functions (DiFF) describing correlations between the transverse polarization of the fragmenting quark with certain flavor and the azimuthal orientation of the plain containing the momenta of the detected hadron pair.

Request

- We request 56 days of running on unpolarized hydrogen and deuterium and additional 30 days of running on NH_3 and 50 days of running on ND_3 (or possibly ^{6}Li D or HD), including about 20% overhead for target anneals, polarization reversal, and auxiliary measurements.

- The experiment will use the upgraded CLAS12 detector, 11 GeV highly polarized electron beam and unpolarized hydrogen and deuterium as well as longitudinally polarized solid ammonia targets (NH_3 and ND_3).

- This measurement will simultaneously run with already approved measurements using pion electroproduction.

$$
\frac{d\sigma}{dx_{_B}\,dy\,d\psi\,dz\,d\phi_{_R}\,dM_h^2\,d\cos\theta} =
$$

$$
\frac{\alpha^2}{x_{_B} y\, Q^2}\,\frac{y^2}{2\,(1-\varepsilon)}\left(1+\frac{\gamma^2}{2x_{_B}}\right)\Bigg\{ F_{UU,T} + \varepsilon\, F_{UU,L} + \sqrt{2\,\varepsilon(1+\varepsilon)}\,\cos\phi_{_R}\, F_{UU}^{\cos\phi_{_R}}
$$

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

$$
+ S_L\left[\sqrt{2\,\varepsilon(1+\varepsilon)}\,\sin\phi_{_R}\, F_{UL}^{\sin\phi_{_R}} + \varepsilon\sin(2\phi_{_R})\, F_{UL}^{\sin 2\phi_{_R}}\right]
$$

$$
+ S_L\lambda_e\left[\sqrt{1-\varepsilon^2}\, F_{LL} + \sqrt{2\,\varepsilon(1-\varepsilon)}\,\cos\phi_{_R}\, F_{LL}^{\cos\phi_{_R}}\right]
$$

$$
+ |\boldsymbol{S}_T|\left[\sin(\phi_{_R}-\phi_{_S})\left(F_{UT,T}^{\sin(\phi_{_R}-\phi_{_S})} + \varepsilon\, F_{UT,L}^{\sin(\phi_{_R}-\phi_{_S})}\right)\right.
$$

$$
+ \varepsilon\,\sin(\phi_{_R}+\phi_{_S})\, F_{UT}^{\sin(\phi_{_R}+\phi_{_S})} + \varepsilon\,\sin(3\phi_{_R}-\phi_{_S})\, F_{UT}^{\sin(3\phi_{_R}-\phi_{_S})}
$$

$$
\left. + \sqrt{2\,\varepsilon(1+\varepsilon)}\,\sin\phi_{_S}\, F_{UT}^{\sin\phi_{_S}} + \sqrt{2\,\varepsilon(1+\varepsilon)}\,\sin(2\phi_{_R}-\phi_{_S})\, F_{UT}^{\sin(2\phi_{_R}-\phi_{_S})}\right]
$$

$$
+ |\boldsymbol{S}_T|\lambda_e\left[\sqrt{1-\varepsilon^2}\,\cos(\phi_{_R}-\phi_{_S})\, F_{LT}^{\cos(\phi_{_R}-\phi_{_S})} + \sqrt{2\,\varepsilon(1-\varepsilon)}\,\cos\phi_{_S}\, F_{LT}^{\cos\phi_{_S}}\right.
$$

$$
\left. + \sqrt{2\,\varepsilon(1-\varepsilon)}\,\cos(2\phi_{_R}-\phi_{_S})\, F_{LT}^{\cos(2\phi_{_R}-\phi_{_S})}\right]\Bigg\},
$$

In the one-photon exchange approximation the cross section for two-particle inclusive DIS can be written as:

The relevant spin asymmetries can be built as ratios of structure functions. For the longitudinal polarization of the beam or of the target, alternatively, i.e. on the LU and UL combinations one can define the following asymmetries:

$$A_{LU}^{\sin\phi_R \sin\theta}(x,y,z,M_h,Q) = \frac{1}{\lambda_e}\frac{\frac{8}{\pi}\int d\phi_R\; d\cos\theta\;\; \sin\phi_R\,(d\sigma^+ - d\sigma^-)}{\int d\phi_R\; d\cos\theta\,(d\sigma^+ + d\sigma^-)} = \frac{\sqrt{2\,\varepsilon(1-\varepsilon)}\int d\cos\theta\, F_{LU}^{\sin\phi_R}}{\int d\cos\theta\;\,(F_{UU,T} + \epsilon F_{UU,L})}$$

$$A_{UL}^{\sin\phi_R \sin\theta}(x,y,z,M_h,Q) = \frac{1}{S_L}\frac{\frac{8}{\pi}\int d\phi_R\; d\cos\theta\;\; \sin\phi_R\,(d\sigma^+ - d\sigma^-)}{\int d\phi_R\; d\cos\theta\,(d\sigma^+ + d\sigma^-)} = \frac{\sqrt{2\,\varepsilon(1+\varepsilon)}\int d\cos\theta\, F_{UL}^{\sin\phi_R}}{\int d\cos\theta\;\,(F_{UU,T} + \epsilon F_{UU,L})}$$

In the bag model and assuming some approximations, the asymmetries become:

$$A_{LU}^{\sin\phi_R \sin\theta}(x,y,z,M_h,Q) = -\frac{W(y)}{A(y)}\,\frac{M}{Q}\,\frac{|\boldsymbol{R}|}{M_h}\,\frac{\left(4-\frac{1}{2}\right)\,xe^u(x)\,H_{1,sp}^{\sphericalangle,u}(z,M_h)}{\left(4+\frac{1}{2}\right)\,f_1^u(x)\,D_1^u(z,M_h)}$$

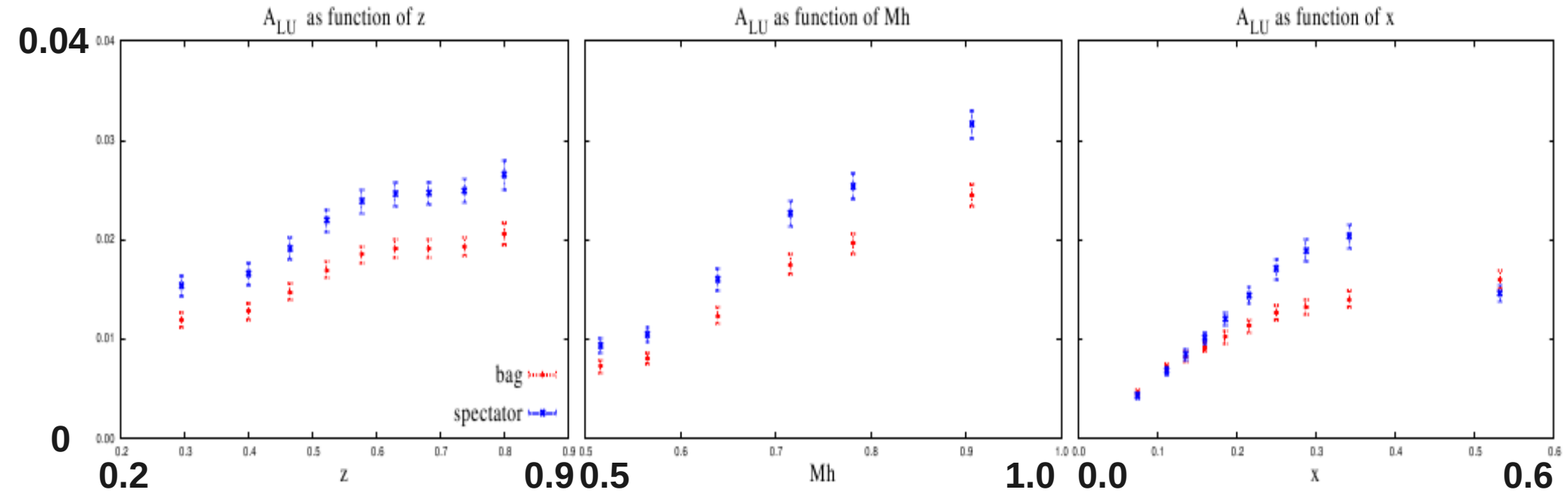
$$A_{UL}^{\sin\phi_R \sin\theta}(x,y,z,M_h,Q) = -\frac{V(y)}{A(y)}\,\frac{M}{Q}\,\frac{|\boldsymbol{R}|}{M_h}\,\frac{\left(4+\frac{1}{4}\right)\,xh_L^u(x)\,H_{1,sp}^{\sphericalangle,u}(z,M_h)}{\left(4+\frac{1}{2}\right)\,f_1^u(x)\,D_1^u(z,M_h)}$$

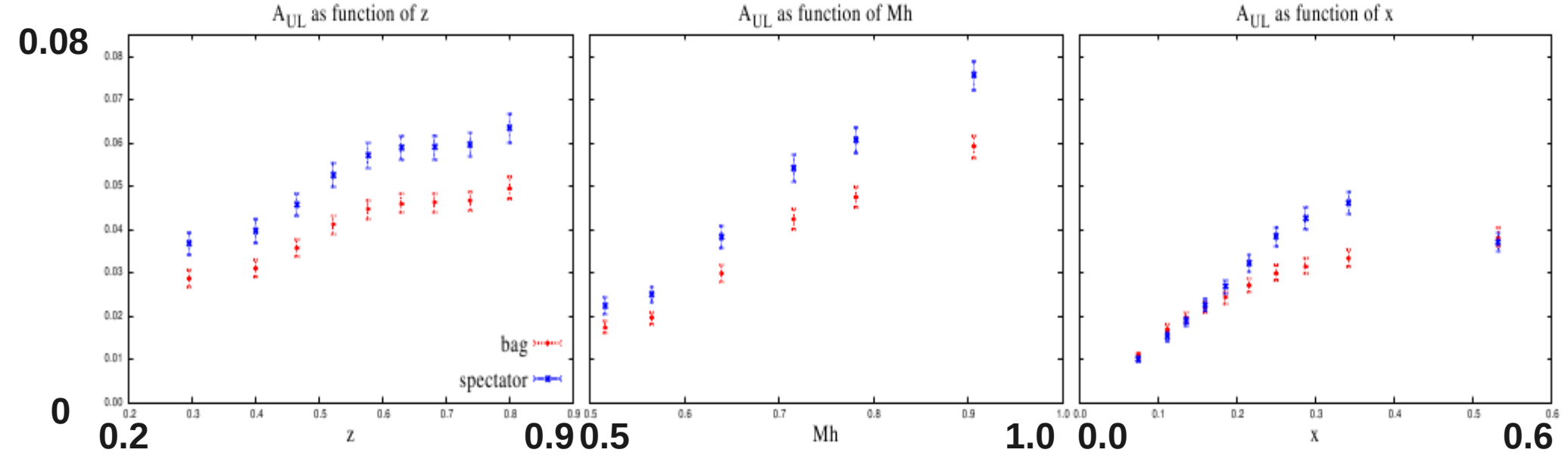
In the spectator model (same approximations), the asymmetries become:

$$A_{LU}^{\sin\phi_R \sin\theta}(x,y,z,M_h,Q) = -\frac{W(y)}{A(y)}\,\frac{M}{Q}\,\frac{|\boldsymbol{R}|}{M_h}\,\frac{x\left(4\,e^u(x)-e^d(x)\right)\,H_{1,sp}^{\sphericalangle,u}(z,M_h)}{\left(4\,f_1^u(x)+f_1^d(x)\right)\,D_1^u(z,M_h)}$$

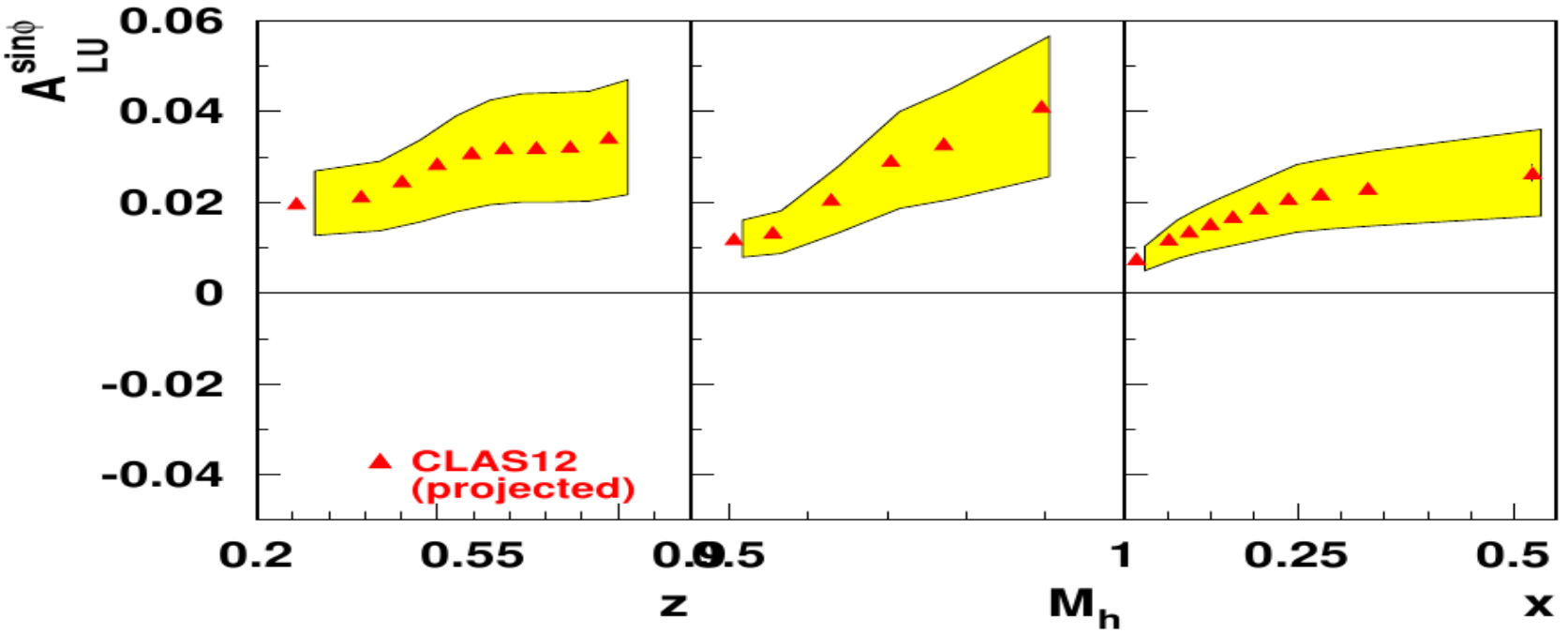
$$A_{UL}^{\sin\phi_R \sin\theta}(x,y,z,M_h,Q) = -\frac{V(y)}{A(y)}\,\frac{M}{Q}\,\frac{|\boldsymbol{R}|}{M_h}\,\frac{x\left(4\,h_L^u(x)-h_L^d(x)\right)\,H_{1,sp}^{\sphericalangle,u}(z,M_h)}{\left(4\,f_1^u(x)+f_1^d(x)\right)\,D_1^u(z,M_h)}$$

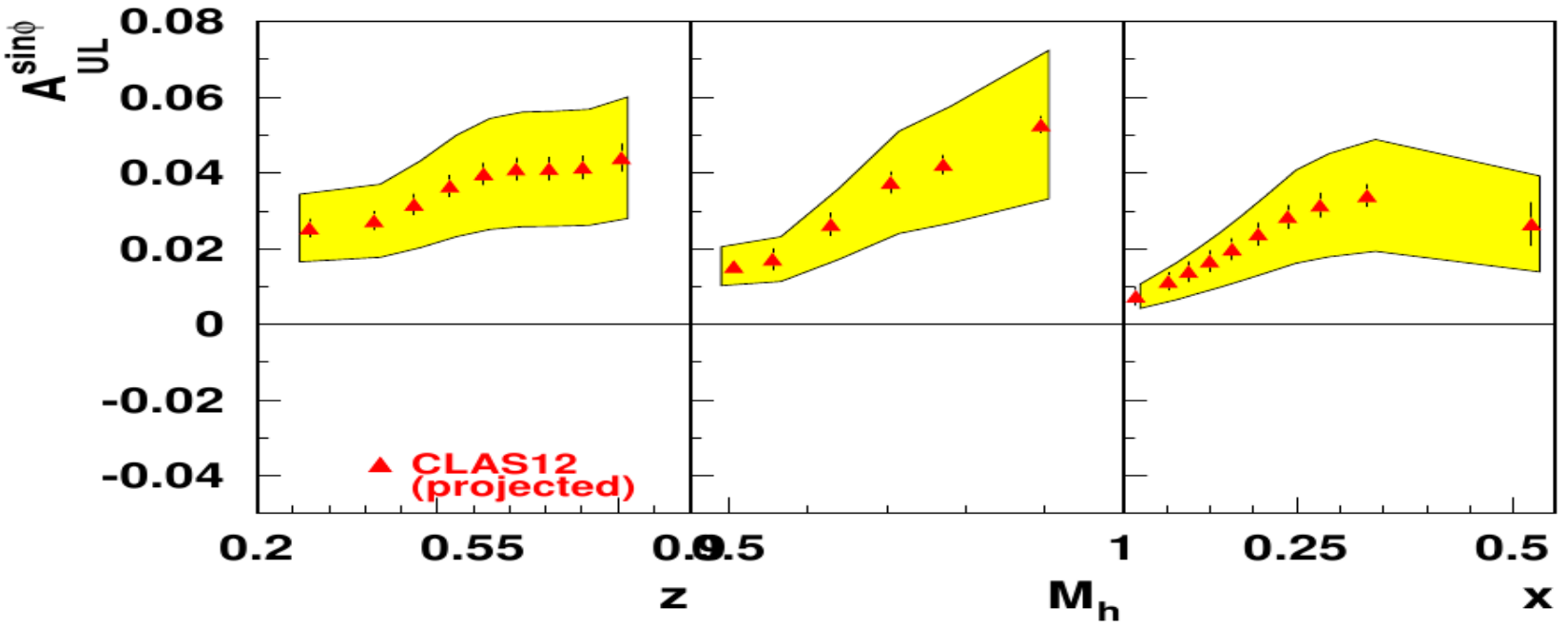
Calculated asymmetries



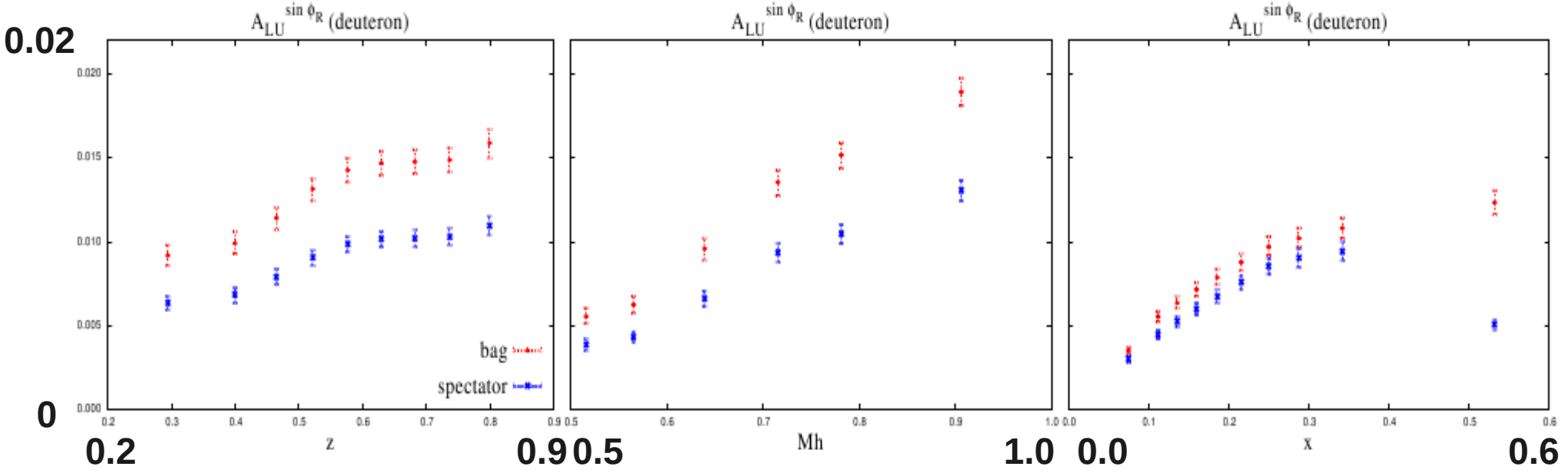


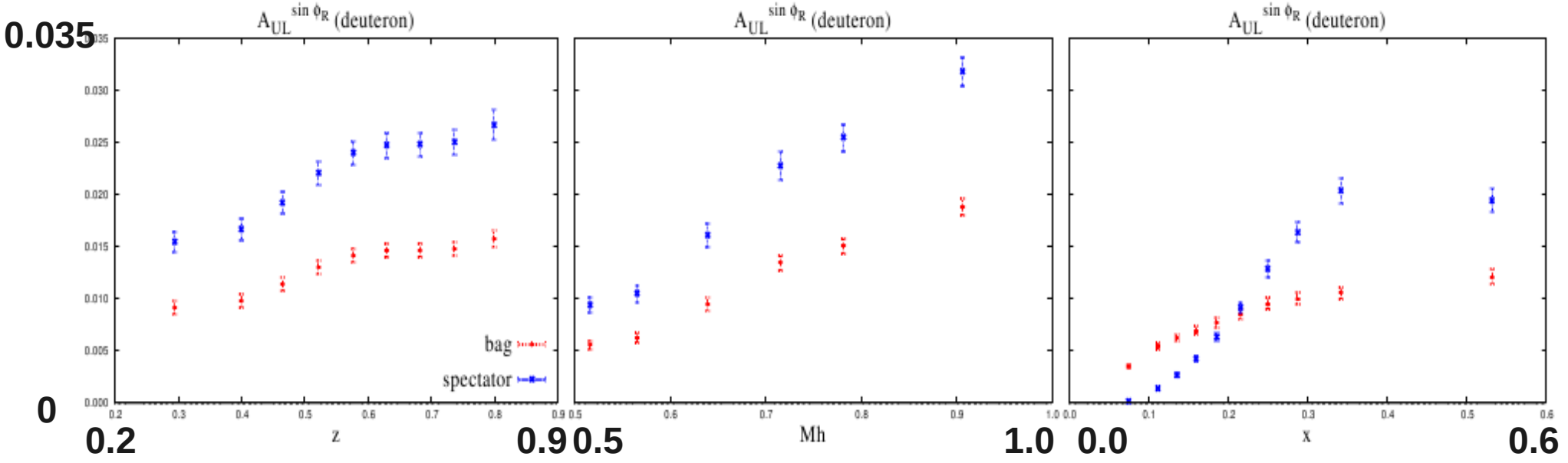
Projected asymmetries



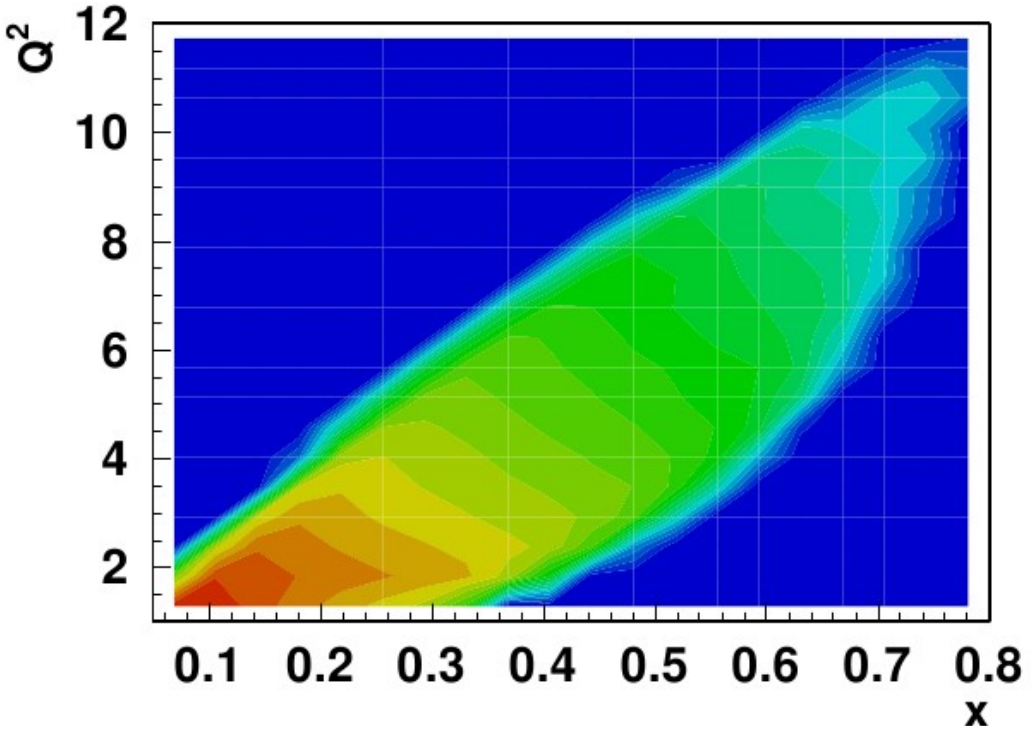


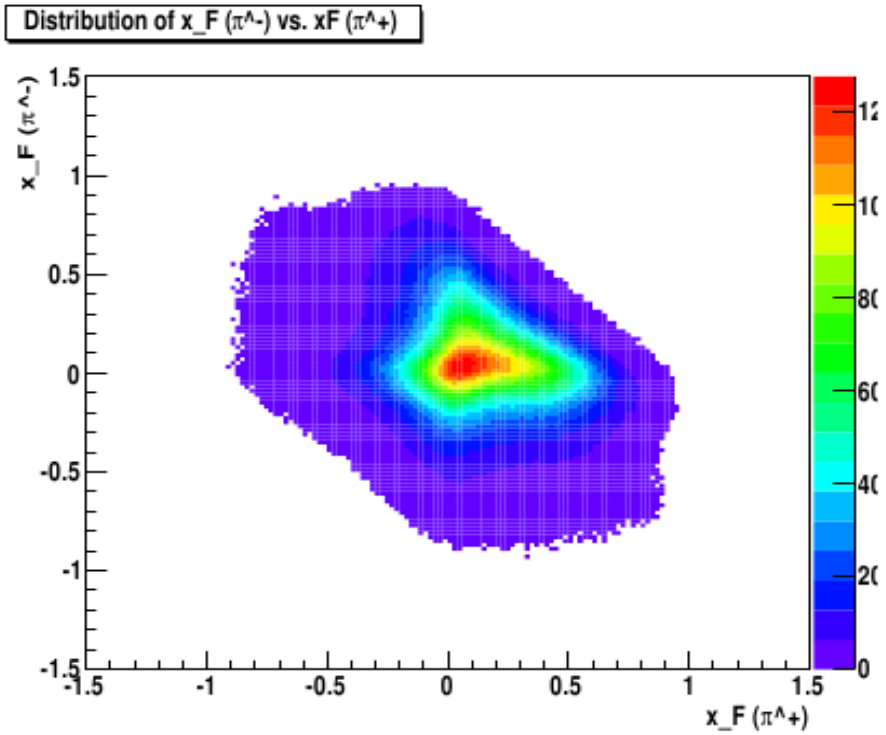
Calculated asymmetries

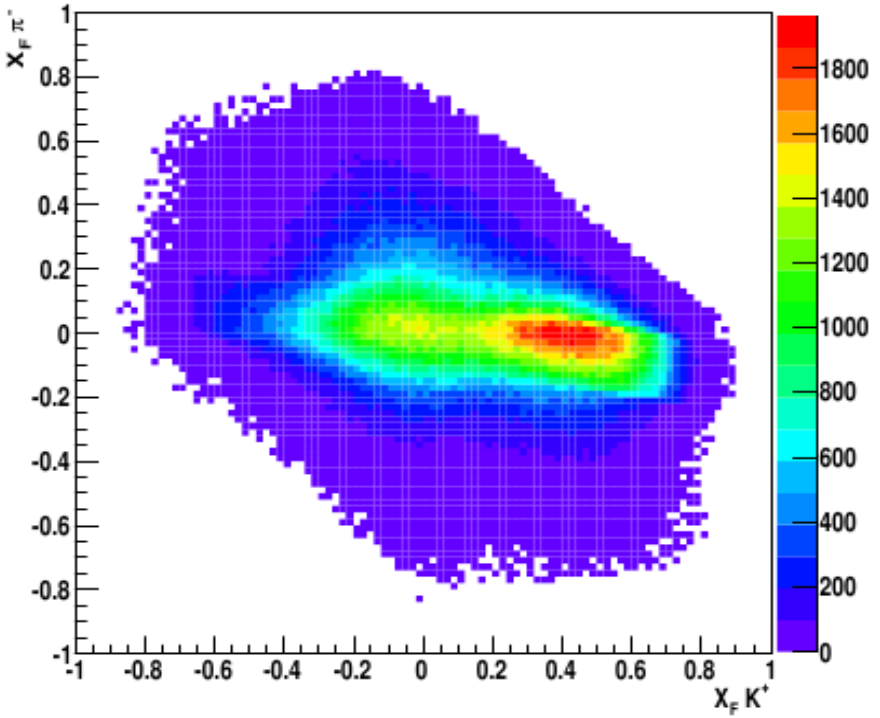


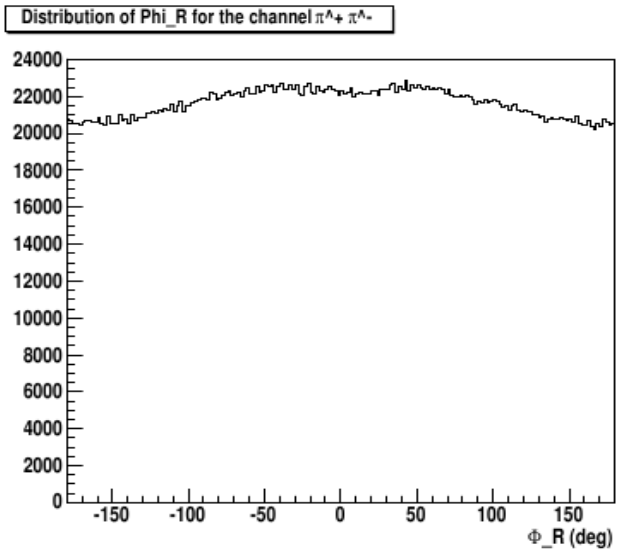


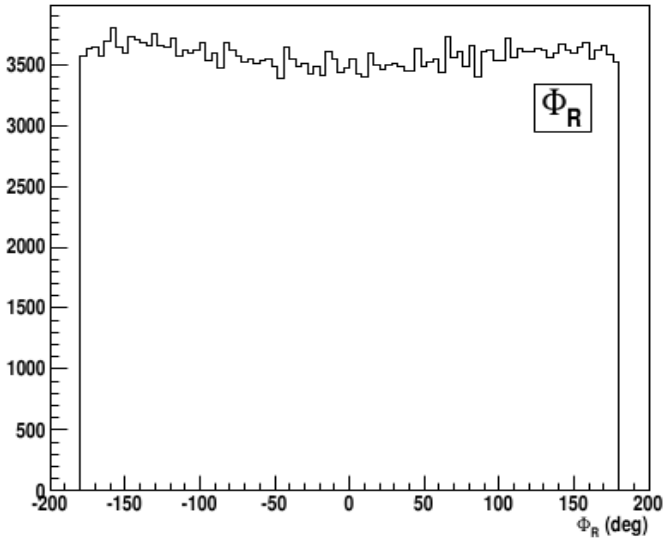
Some kinematics



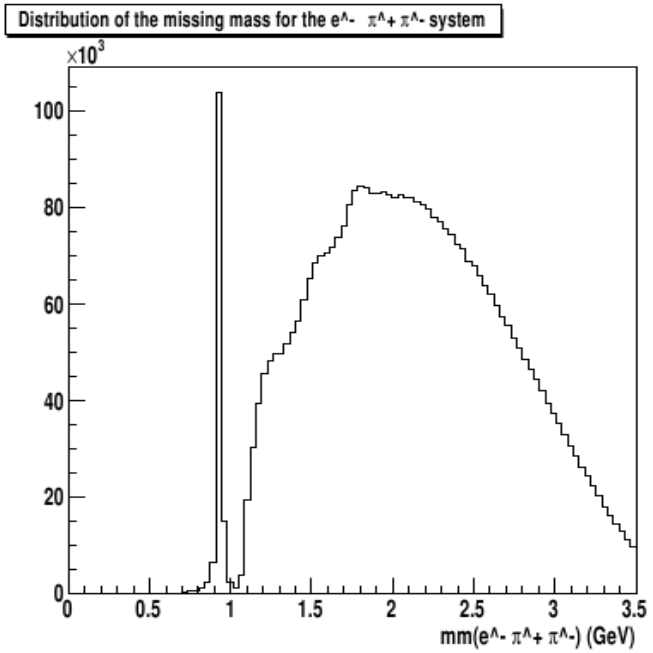


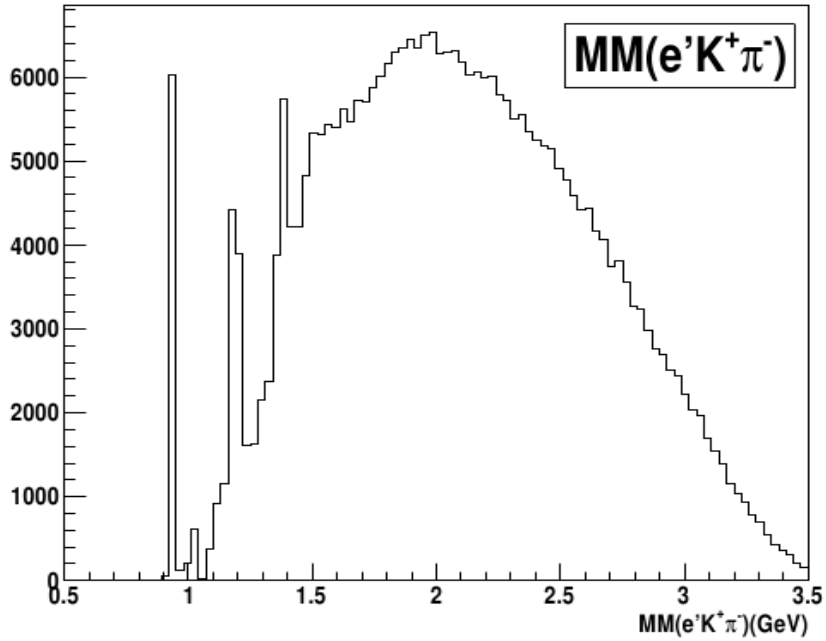




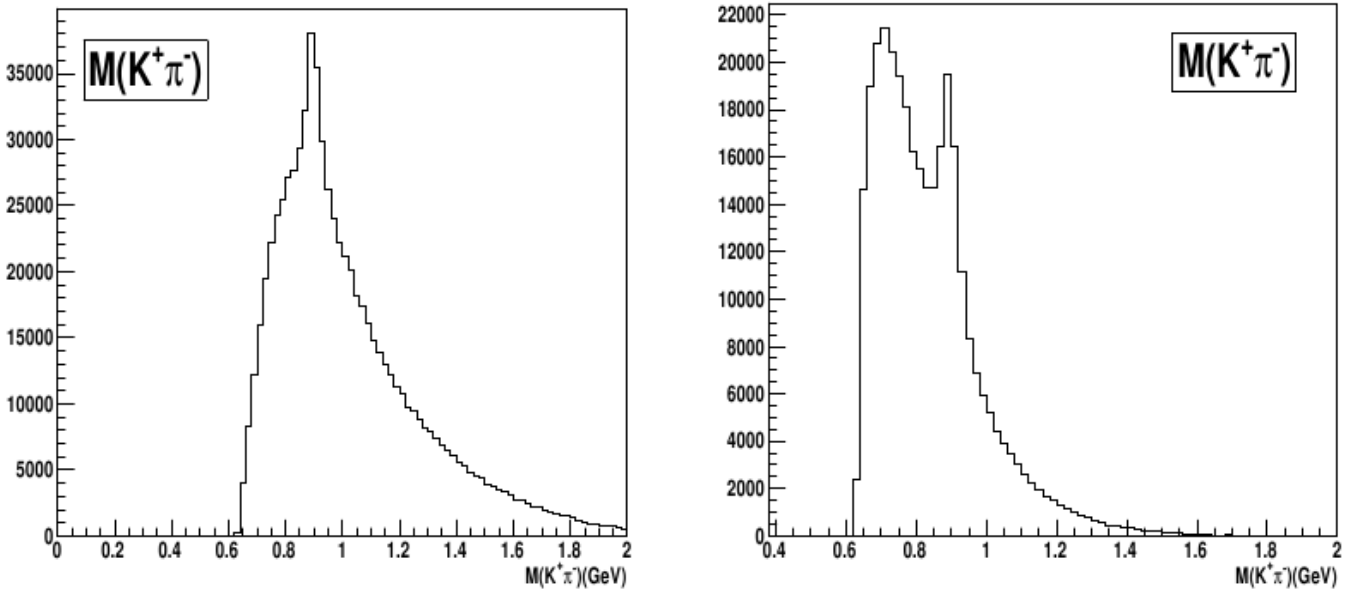


Distribution over ϕ_R for pion-pion and pion-kaon pairs from FASTMC





MM from PEPSI MC for ehhX events



Invariant masses for Kaon-pion pairs for tfr-cfr and cfr-cfr combinations

Table 3: Uncertainties for asymmetry measurements.

Item	$A_{LU}^{\sin\phi}$	$A_{UL}^{\sin\phi}$
beam polarization	3%	-
target polarization	-	3%
dilution factor	-	3%
radiative corrections	3%	3%
fitting procedure	4%	5%
transverse (to γ^*) spin effects	-	3%

The total uncertainty is expected to be less than 10% of the measured SSA.

Summary

- **The proposed set of measurements with unpolarized and longitudinally polarized proton and deuteron targets will yield a comprehensive set of azimuthal moments in spin-dependent and independent SIDIS providing access to corresponding distribution and fragmentation functions in a wide range of x, Q2 , z, and PT.**

- **Our data, combined with the data from HERMES, COMPASS, and BELLE, will provide independent (complementary to e + /e−) measurement of polarized and unpolarized pion and kaon DiFFs and will allow a complementary to pion SIDIS study of leading twist distributions.**