Future studies with eg1-dvcs data

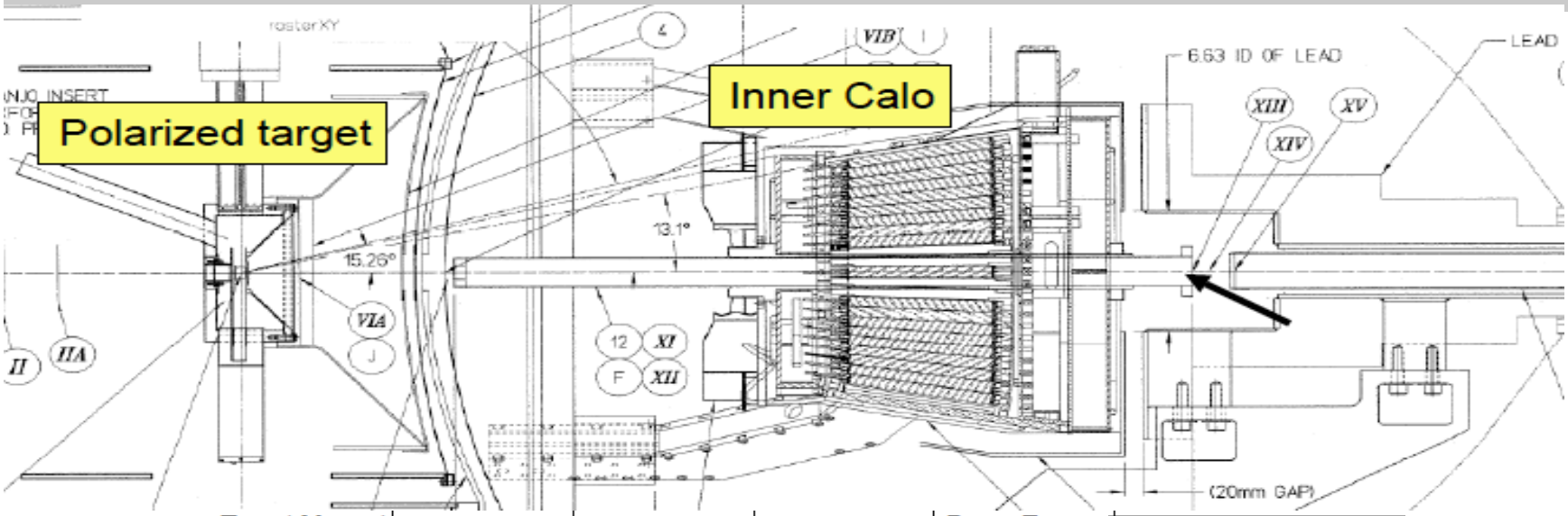
H.Avakian, S. Anefalos Pereira

Deep Processes Working group

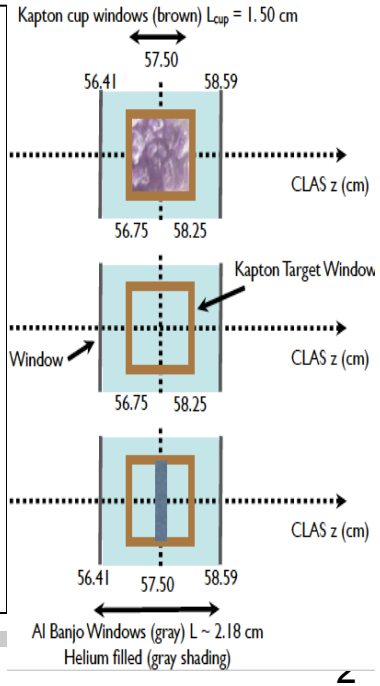
CLAS Collaboration Meeting, Feb 25

- eg1-dvcs experiment
- single pion production
- di-hadron production
- future studies
- summary

eg1-dvcs experiment



	Target Magnet Current	Target Position	Target Material	Torus Current	Beam Energy (ep elastic)	Charge/Triggers
Part A Feb 09'-Mar 09'	121.4A (5T)	-57.5cm	NH_3 Carbon Empty	2250A	5892 MeV 4735 MeV	6.9mC/ 5.6B
Part B Apr 09' – Jun 09'	121.4A (5T)	-67.5cm	NH_3 Carbon **12%** Empty **3.7%**	2250A -2200A	5967 MeV	15.4mC/14.1B
Part C Aug 09'-Sep 09'	-121.4A (5T)	-67.5cm	NH_3 ND_3 Carbon **15%** Empty **3.5%**	2250A -2250A 2271A	5764 MeV	7.7mC/7.5B



Name	Institution	Position	Topic	FTE
Harut Avagyan	JLab	Staff Scientist	A_{LL} for SIDIS, $A_{LL}(P_T)\pi^0$ for DVMP	??
Mher Aghasyan	ODU	Post-doc	SIDIS π^0 moments $A_{UL}^{\sin\phi}$	??
Ahmed El Alaoui	LPSC, Grenoble	Post-doc	DVCS backgrounds from π^0	0.8
Angela Biselli	Fairfield U.	Asst. Prof.	DVCS A_{LL}	??
Peter Bosted	JLab	Staff Scientist	$g_1^p(x,Q^2)$ and SIDIS $A_{LL}(x,z,p_T^2,\varphi)$ for π,κ,η	0.5
Keith Griffioen	W&M	Prof.	SIDIS transversity $A_{UL}^{\pi\pi}$	0.1
Sucheta Jawalkar	W&M	Grad-student	SIDIS asymmetries for π^-,π^0,π^+	1.0
Narbe Kalantarians	UVA	Post-doc	SIDIS κ / π,π^+ / π^- ratios and η spin asymmetries	??
Silvia Niccolai	Orsay	Staff Scientist	DVCS A_{LL}	??
Sergio Anefalos Pereira	LNF-INFN	Post-doc	ρ^+, ρ^0 asymmetries, π^+ background	0.8
Silvia Pisano	Orsay	Post-doc	DVCS A_{LL}	??
Yelena Prok	CNU	Asst. Prof.	Inclusive $A_1,g_1,\Gamma_1,\gamma_0$ and ρ production	0.2
Erin Seder	UConn	Grad-student	DVCS A_{LL}	1.0
Mauri Ungaro	UConn	Post-doc	DVMP A_{LL} for π^0 and η	0.5
Bo Zhao	W&M	Post-doc	DVMP A_{LL} for π^0 and η	0.5

A.Kim

eg1-dvcs single-pion SIDIS tables

tables with asymmetries ALU, AUL,ALL

(Suman's input tables)

Index Flav Q2Num Q2BinAvg XbNum XbBinAvg ZzNum ZzBinAvg PtNum PtBinAvg PhNum
PhBinAvg MxAvg YyAvg EeAvg DpAvg DiAvg Alu AluError
Aul AulError All AllError

63 0 0 1.14772 0 0.135591 0 0.349046 5 0.886265 2 77.6354 1.7382 0.763591 0.420486 0.842163
0.138502 -0.00956366 0.0328709
0.0450115 0.292196 0.23585 0.345479
64 0 0 1.14337 0 0.136228 0 0.347242 5 0.888113 3 104.958 1.71881 0.757405 0.430883 0.835993
0.138236 0.0494798 0.0269866
0.104973 0.24706 -0.0210623 0.291505
65 0 0 1.14175 0 0.135597 0 0.349518 5 0.887756 4 137.776 1.7291 0.759641 0.427246 0.838135
0.138388 0.00275549 0.0276319
0.380788 0.256311 -0.172219 0.302168

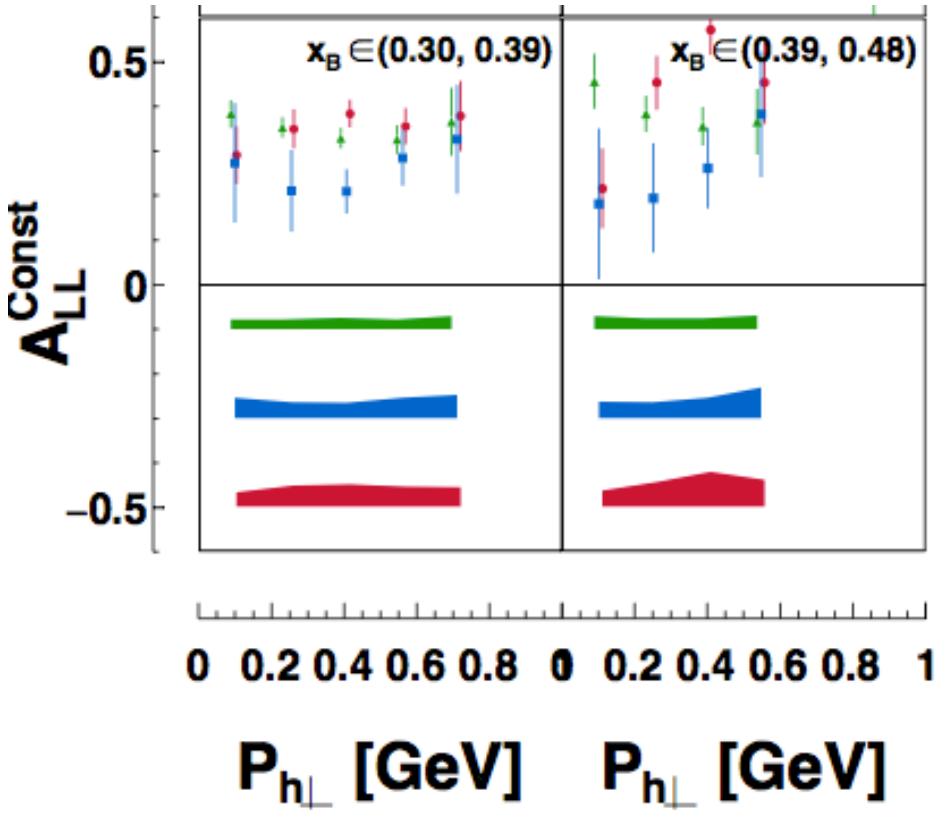
…… 20737 lines 6.5 Mb

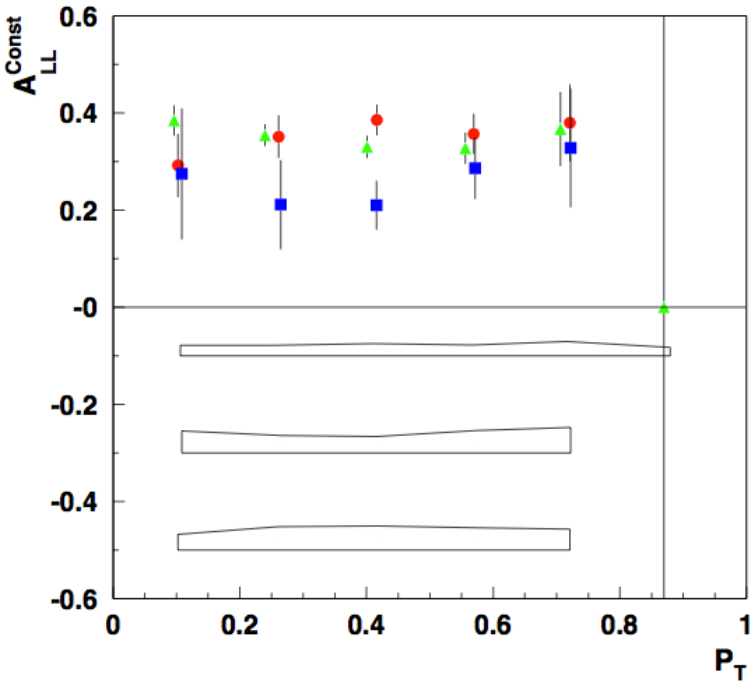
The analysis code, AnalysisPackageV0.C and the different tables are at:
/lustre/expphy/volatile/clas/claseg1dvcs/avakian/suman/AnalysisPackageV1/.
The directory also has the makefile and a readme.txt that explains the different columns of the data table.
The required table is: Sys00/RadCorrectedTextPart0And1.txt

Table storage of observables in multidimensional bin should allow:
- reproduce final asymmetries
- store the final numbers in the database

eg1-dvcs: single pion SIDIS

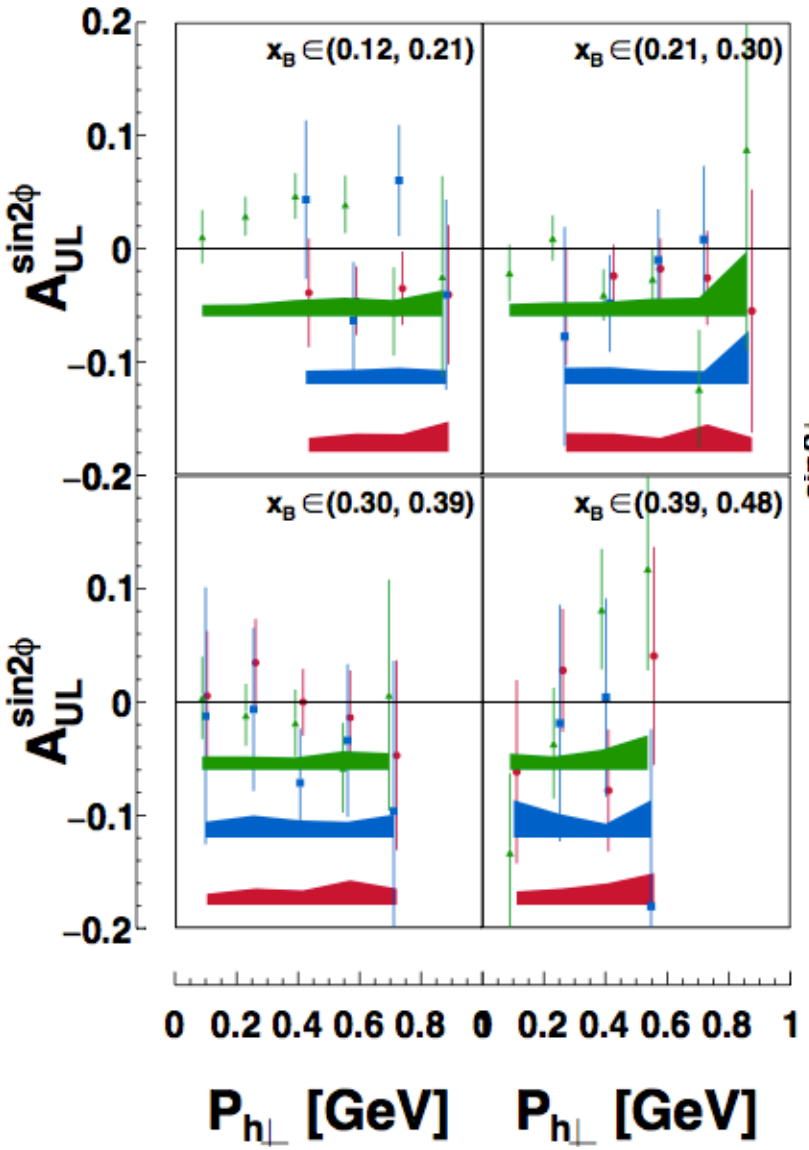
analysis package produces plots and stores final numbers





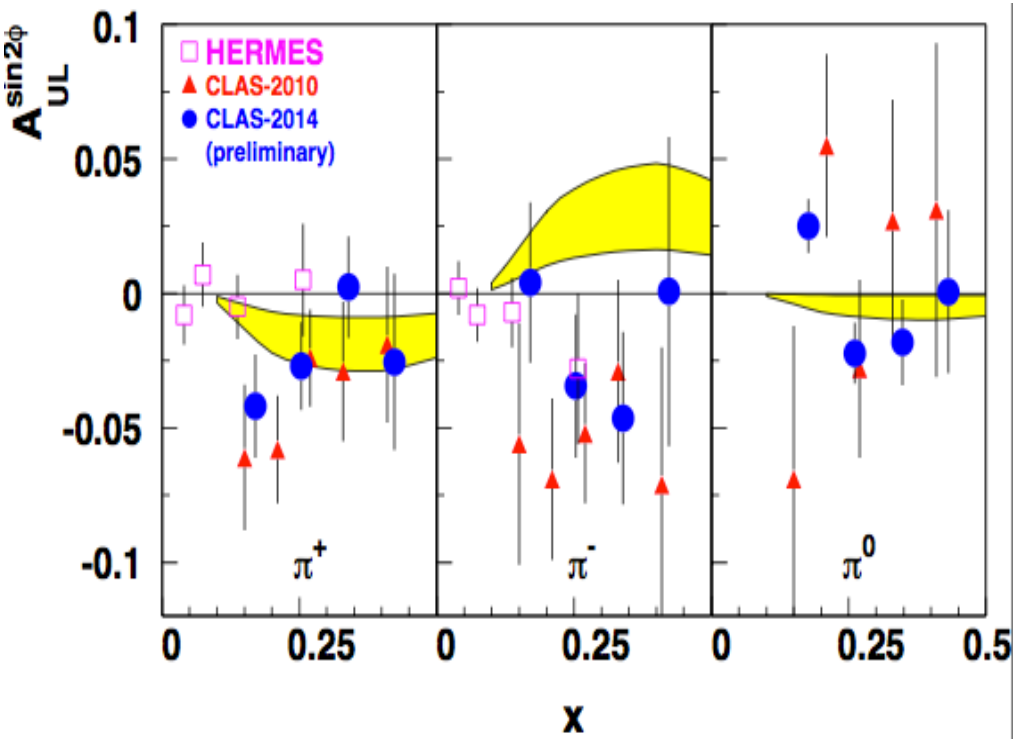
reproduced ALL (Silvia,Harut)

Comparing eg1dvcs with eg1

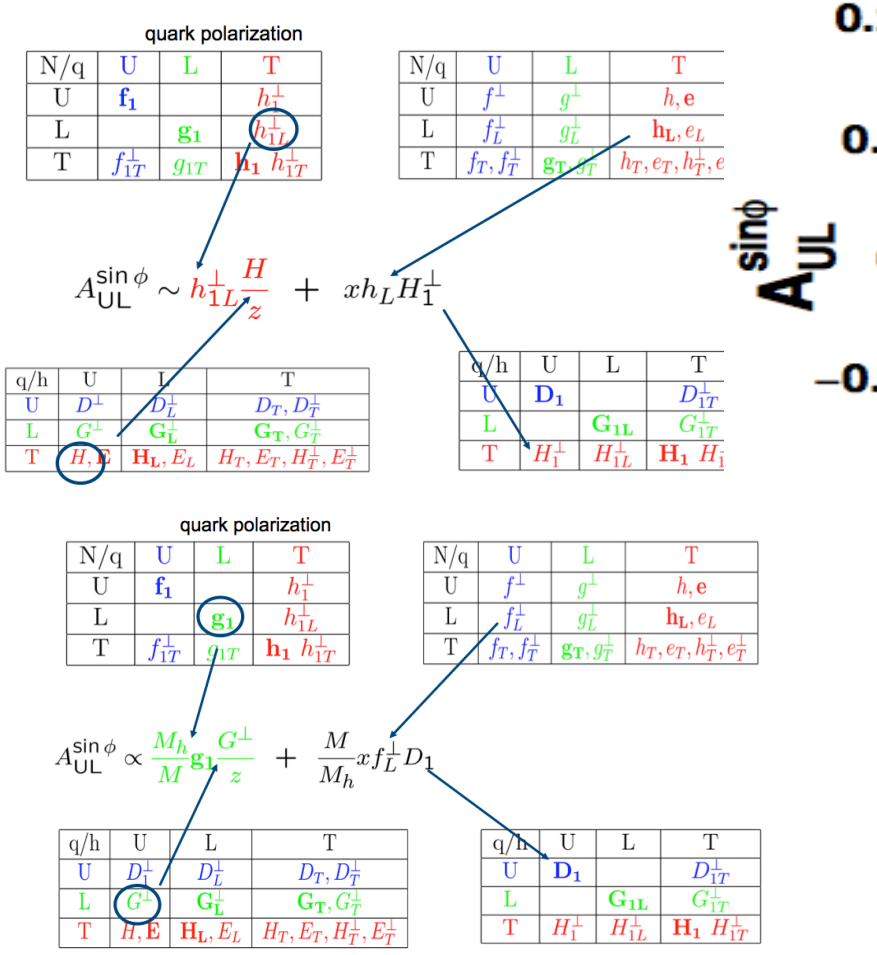


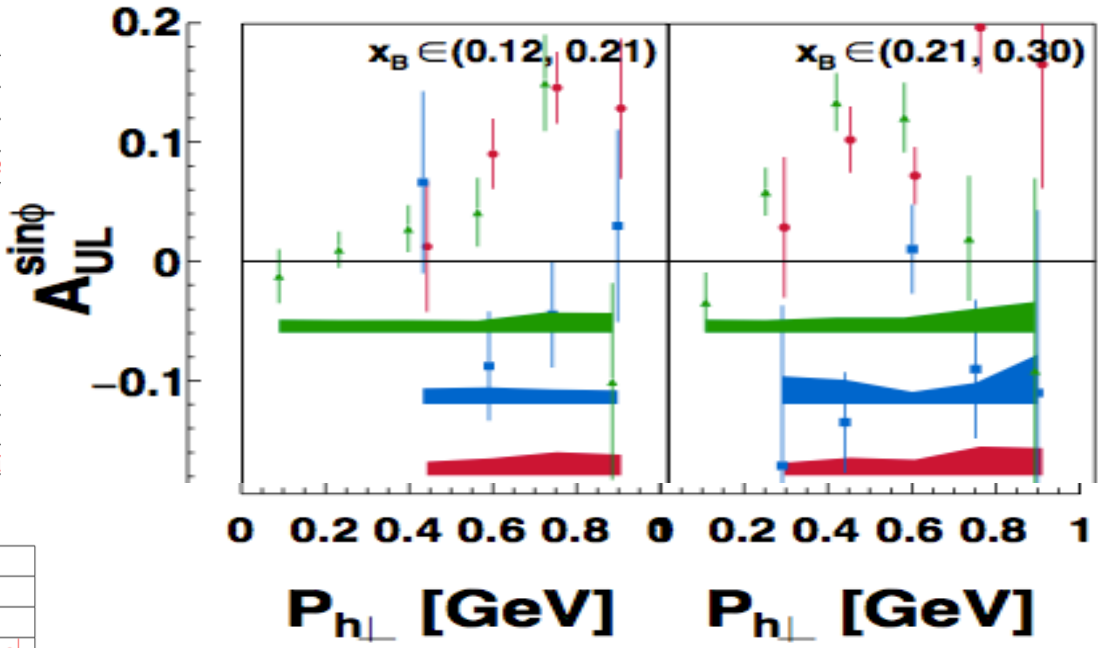
$$A_{UL}^{\sin 2\phi} \sim h_{1L}^{\perp} H_1^{\perp} \sin 2\phi$$

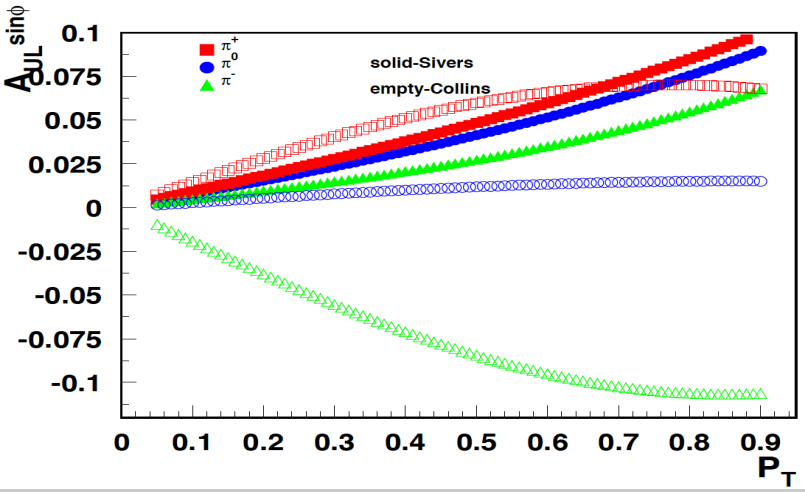
N \ q	U	L	T
U	f_1		$h_1^{\perp}$
L		g_1	$h_{1L}^{\perp}$
T	$f_{1T}^{\perp}$	g_{1T}	h_1 $h_{1T}^{\perp}$



$A_{UL}^{\sin\phi}$: From measurements to interpretation







Sivers contribution may dominate for π+ and π0, Collins for π-

$A_{LL}^{\cos\phi}$: From measurements to interpretation

quark polarization

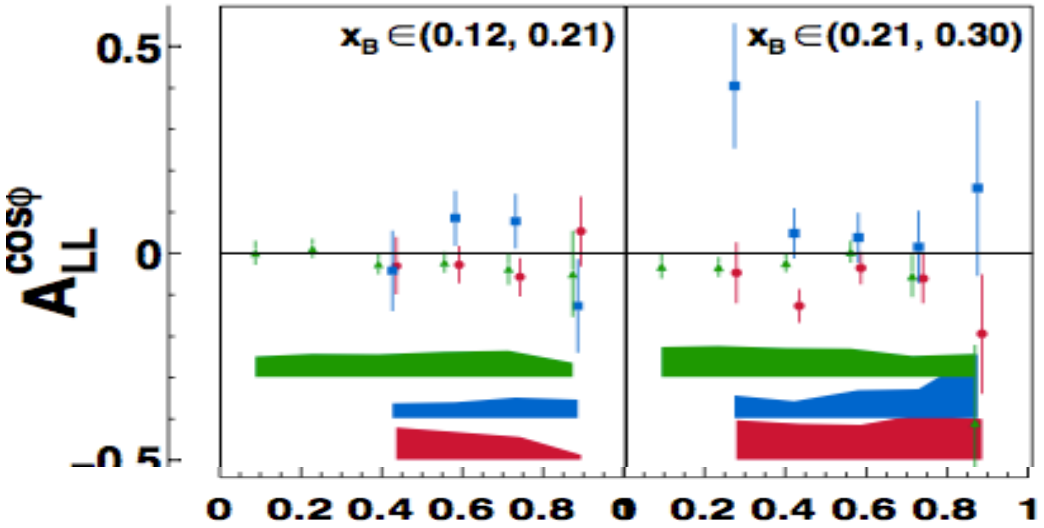
N/q	U	L	T
U	$\mathbf{f_1}$		$h_1^\perp$
L		$\mathbf{g_1}$	$h_{1L}^\perp$
T	$f_{1T}^\perp$	g_{1T}	$\mathbf{h_1}$ $h_{1T}^\perp$

N/q	U	L	T
U	$f^\perp$	$g^\perp$	$h, \mathbf{e}$
L	$f_L^\perp$	$g_L^\perp$	$\mathbf{h_L}, e_L$
T	$f_T, f_T^\perp$	$\mathbf{g_T}, g_T^\perp$	$h_T, e_T, h_T^\perp, e_T^\perp$

$$A_{LL}^{\cos\phi} \sim \frac{M_h}{M} g_{1L} \frac{D^\perp}{z} + x e_L H_1^\perp$$

q/h	U	L	T
U	$D^\perp$	$D_L^\perp$	$D_T, D_T^\perp$
L	$G^\perp$	$\mathbf{G_L^\perp}$	$\mathbf{G_T}, G_T^\perp$
T	$H, \mathbf{E}$	$\mathbf{H_L}, E_L$	$H_T, E_T, H_T^\perp, E_T^\perp$

q/h	U	L	T
U	$\mathbf{D_1}$		$D_{1T}^\perp$
L		$\mathbf{G_{1L}}$	$G_{1T}^\perp$
T	$H_1^\perp$	$H_{1L}^\perp$	$\mathbf{H_1}$ $H_{1T}^\perp$



quark polarization

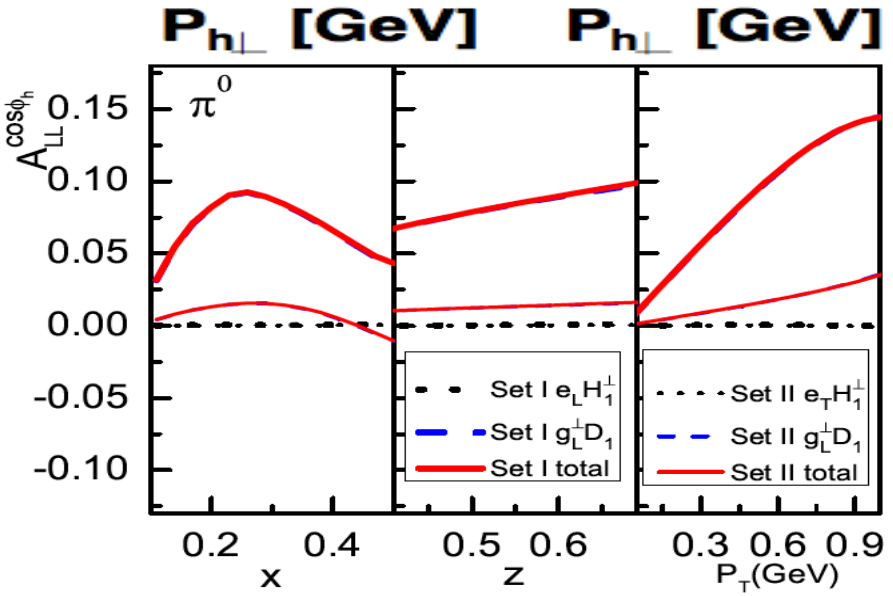
N/q	U	L	T
U	$\mathbf{f_1}$		$h_1^\perp$
L		$\mathbf{g_1}$	$h_{1L}^\perp$
T	$f_{1T}^\perp$	g_{1T}	$\mathbf{h_1}$ $h_{1T}^\perp$

N/q	U	L	T
U	$f^\perp$	$g^\perp$	$h, \mathbf{e}$
L	$f_L^\perp$	$g_L^\perp$	$\mathbf{h_L}, e_L$
T	$f_T, f_T^\perp$	$\mathbf{g_T}, g_T^\perp$	$h_T, e_T, h_T^\perp, e_T^\perp$

$$A_{LL}^{\cos\phi} \sim \frac{M_h}{M} h_{1L}^\perp \frac{E}{z} + x g_L^\perp D_1$$

q/h	U	L	T
U	$D^\perp$	$D_L^\perp$	$D_T, D_T^\perp$
L	$G^\perp$	$\mathbf{G_L^\perp}$	$\mathbf{G_T}, G_T^\perp$
T	$H, \mathbf{E}$	$\mathbf{H_L}, E_L$	$H_T, E_T, H_T^\perp, E_T^\perp$

q/h	U	L	T
U	$\mathbf{D_1}$		$D_{1T}^\perp$
L		$\mathbf{G_{1L}}$	$G_{1T}^\perp$
T	$H_1^\perp$	$H_{1L}^\perp$	$\mathbf{H_1}$ $H_{1T}^\perp$



SIDIS dihadron asymmetries from the eg1-dvcs experiment

Sergio Anefalos Pereira
(INFN – Frascati / University of São Paulo - USP)

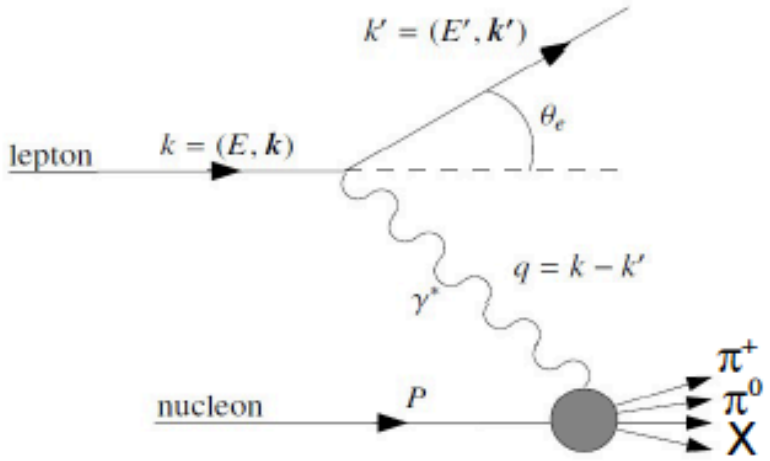
$e\,p \rightarrow e'\,\pi^+\,\pi^-\,X$

$$F_{LU}^{\sin\phi_R} = -x\frac{|\boldsymbol{R}|\sin\theta}{Q}\left[\frac{M}{M_h}\,x\,e^q(x)\,H_1^{\sphericalangle q}(z,\cos\theta,M_h) + \frac{1}{z}\,f_1^q(x)\,\tilde{G}^{\sphericalangle q}(z,\cos\theta,M_h)\right]$$

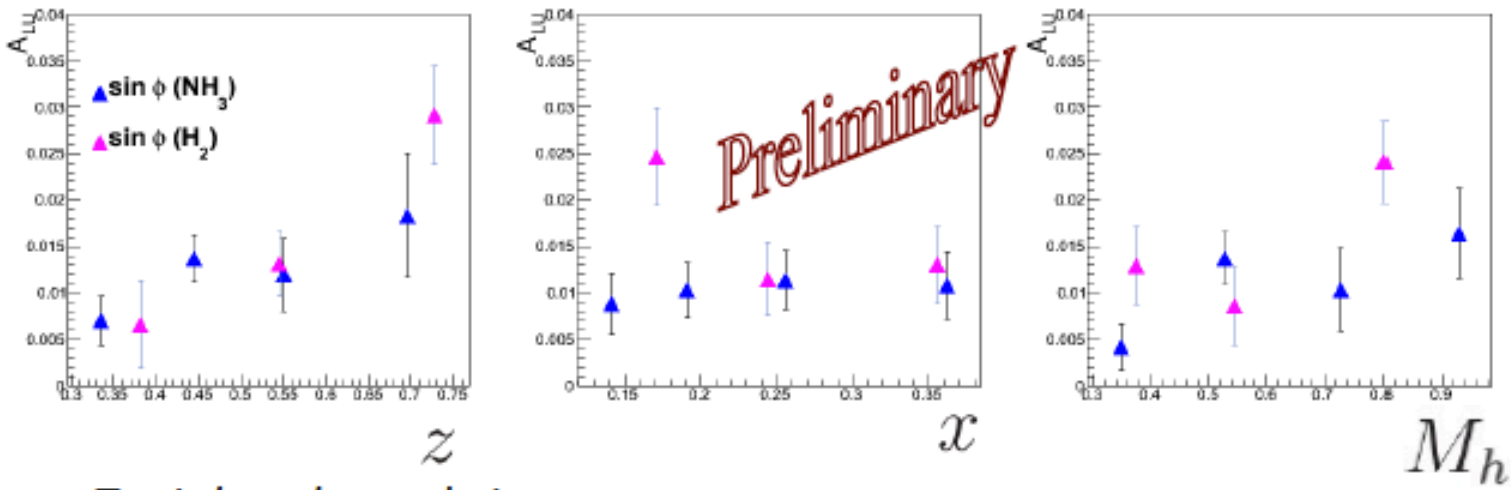
$$F_{UL}^{\sin\phi_R} = -x\frac{|\boldsymbol{R}|\sin\theta}{Q}\left[\frac{M}{M_h}\,x\,h_L^q(x)\,H_1^{\sphericalangle q}(z,\cos\theta,M_h) + \frac{1}{z}\,g_1^q(x)\,\tilde{G}^{\sphericalangle q}(z,\cos\theta,M_h)\right]$$

$$F_{LL} = x g_1^q(x)\,D_1^q(z,\cos\theta,M_h),$$

$$F_{LL}^{\cos\phi_R} = -x\frac{|\boldsymbol{R}|\sin\theta}{Q}\,\frac{1}{z}\,g_1^q(x)\,\tilde{D}^{\sphericalangle q}(z,\cos\theta,M_h).$$

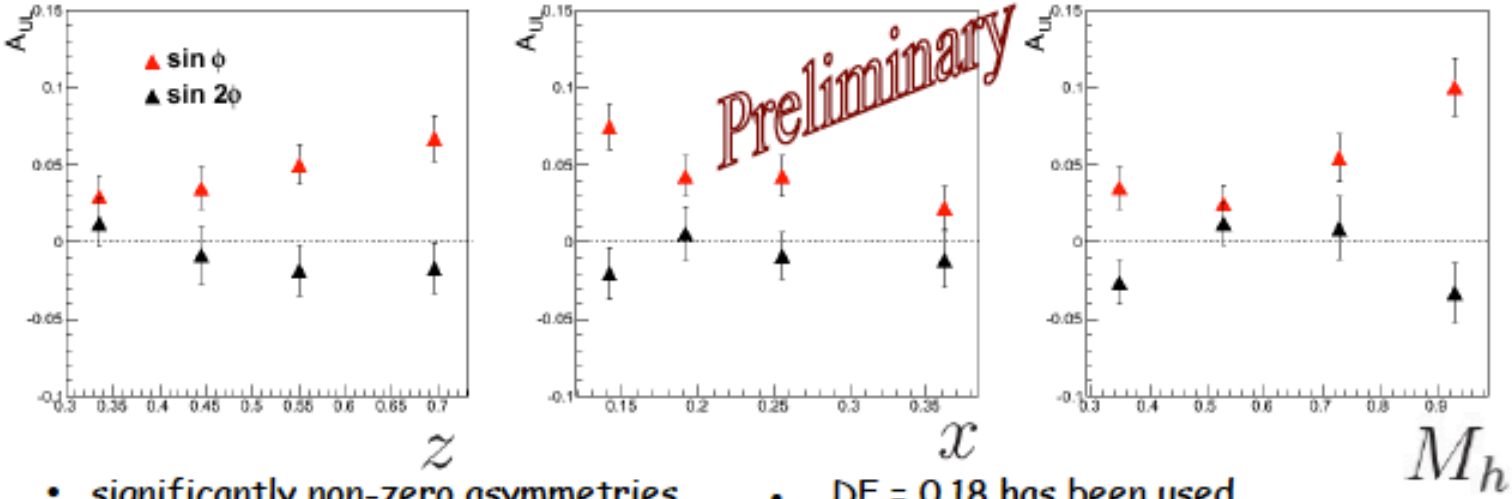


Beam-Spin Asymmetry (BSA) $A_{LU} \propto e(x) H_1^{\sphericalangle q}(z, \cos\theta, M_h)$



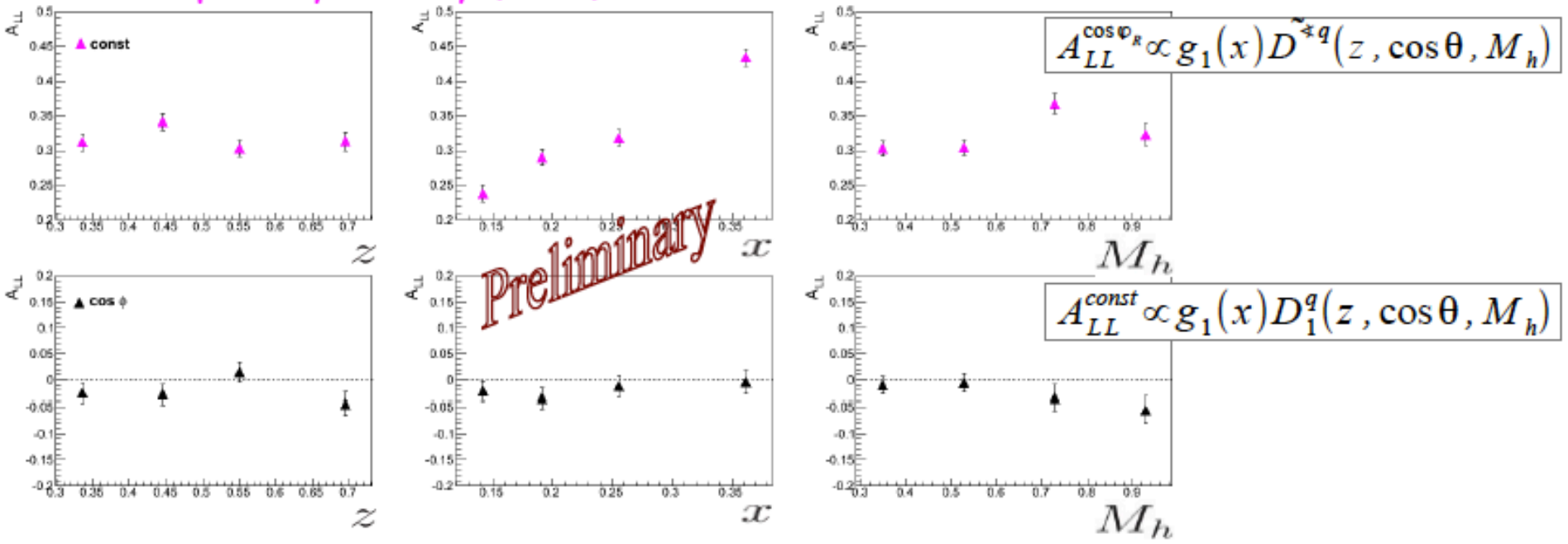
- Two independent analysis
- Two different experiments (unpolarized H_2 target (e1f) and longitudinally polarized NH_3 target (eg1-dvcs))
- Good agreement between the two analysis and no nuclear effects observed

Target-Spin Asymmetry (TSA) $A_{UL} \propto h_L(x) H_1^{\sphericalangle q}(z, \cos\theta, M_h)$



- significantly non-zero asymmetries
- sin 2f compatible with zero
- DF = 0.18 has been used
- gives access to the sub-leading twist PDF $h_L(x)$

Double-Spin Asymmetry (DSA)



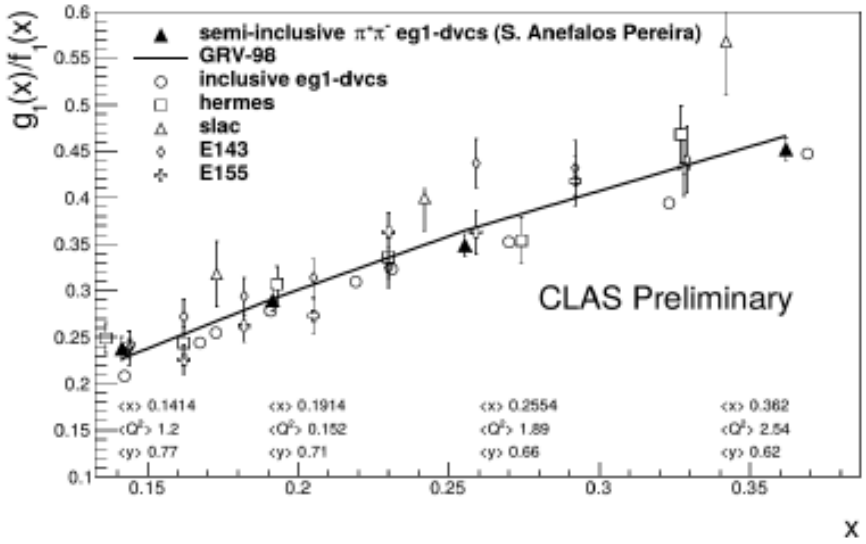
- Significantly non-zero A_{LL}^{const} asymmetries

- We measure

$$A_{LL}^{const} \approx \frac{F_{UU}}{F_{LL}}$$

$$\approx \frac{g_1^q(x)\,D_1^q(z,\cos\theta,M_h)}{f_1^q(x)\,D_1^q(z,\cos\theta,M_h)}$$

- This comparison shows that the present A_{LL}^{const} results are very consistent



Analysis status

- BSA , TSA and DSA were extracted for eg1-dvcs part B data set
- Hope to have first draft of the analysis note in a couple of months
- to finalize the analysis → systematic uncertainties (ongoing)

Summary

- these are the first simultaneous measurements of the dihadron A_{LU} , A_{UL} and A_{LL} asymmetries;
- dihadron SIDIS is a very powerful channel in order to access information about the collinear structure of the proton;
- preliminary results of a non-zero BSA, TSA and DSA for $\pi^+ \pi^-$ pairs have been shown;
- in the case of A_{LU} on both unpolarized H_2 and longitudinally-polarized NH_3 target indicates the absence of nuclear effects

novel observables

b2b hadron production with polarized target

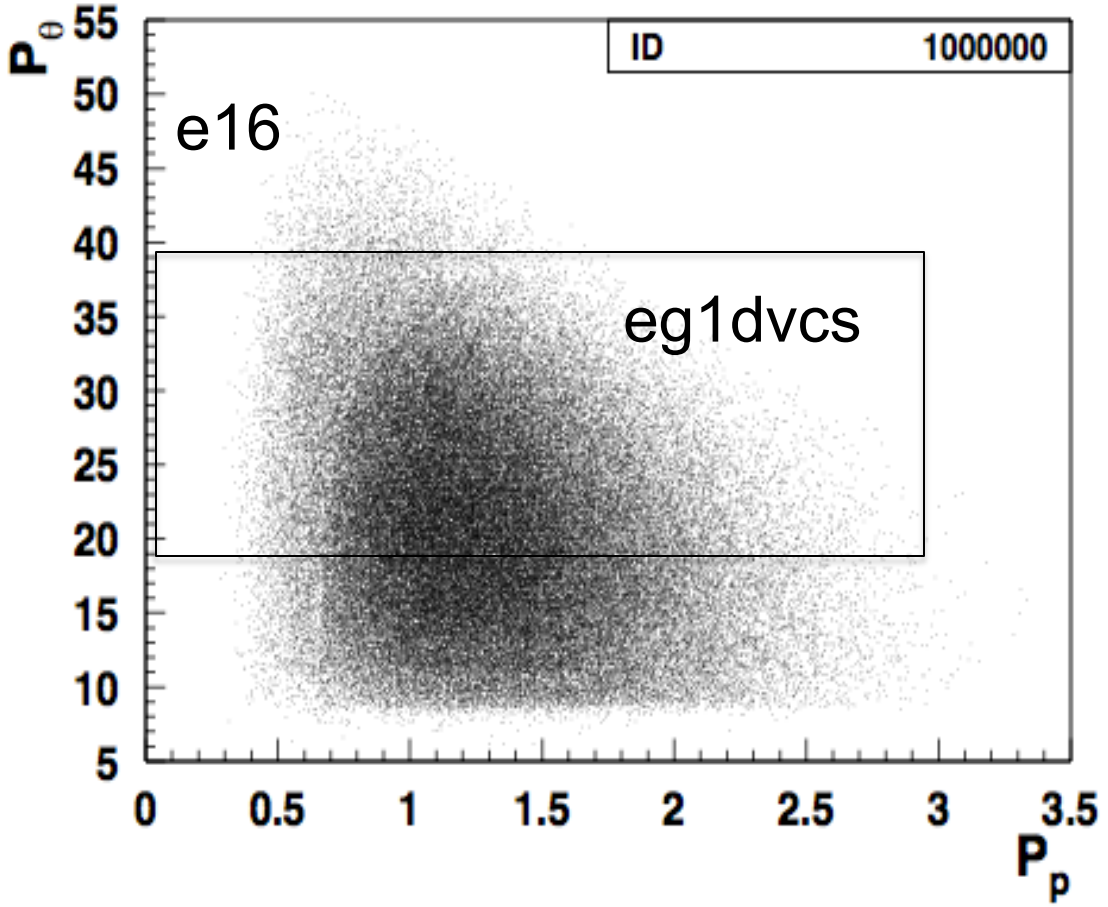
$$ep \rightarrow e'p\pi^+X$$

A_{LU}

Table 1. TABLE of Leading Twist FFs

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

A_{UL}

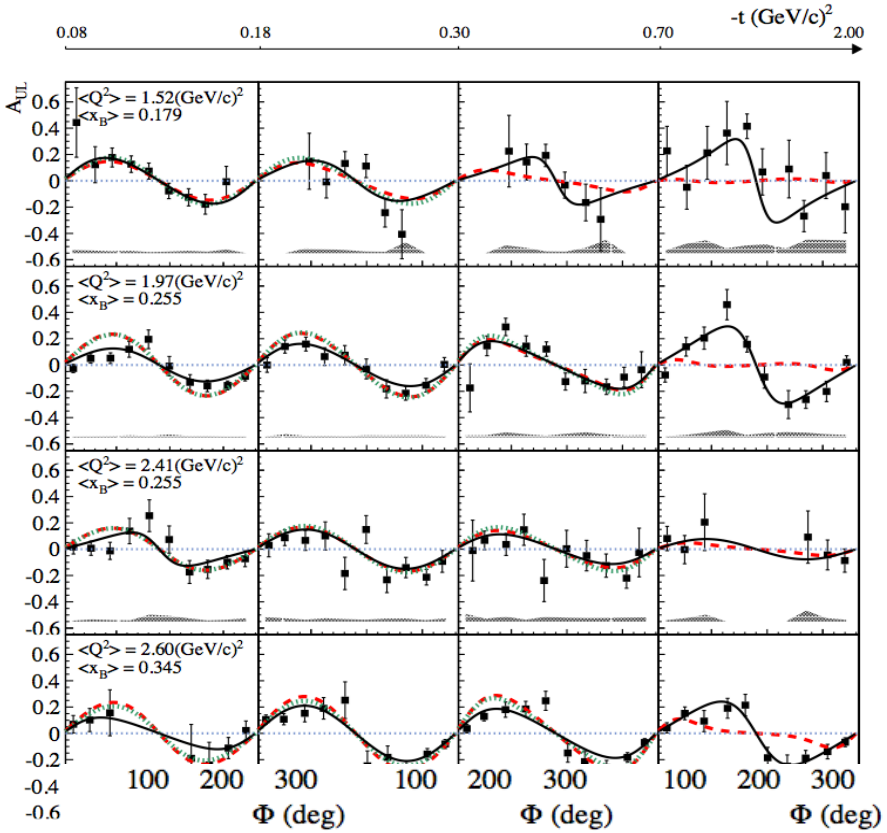


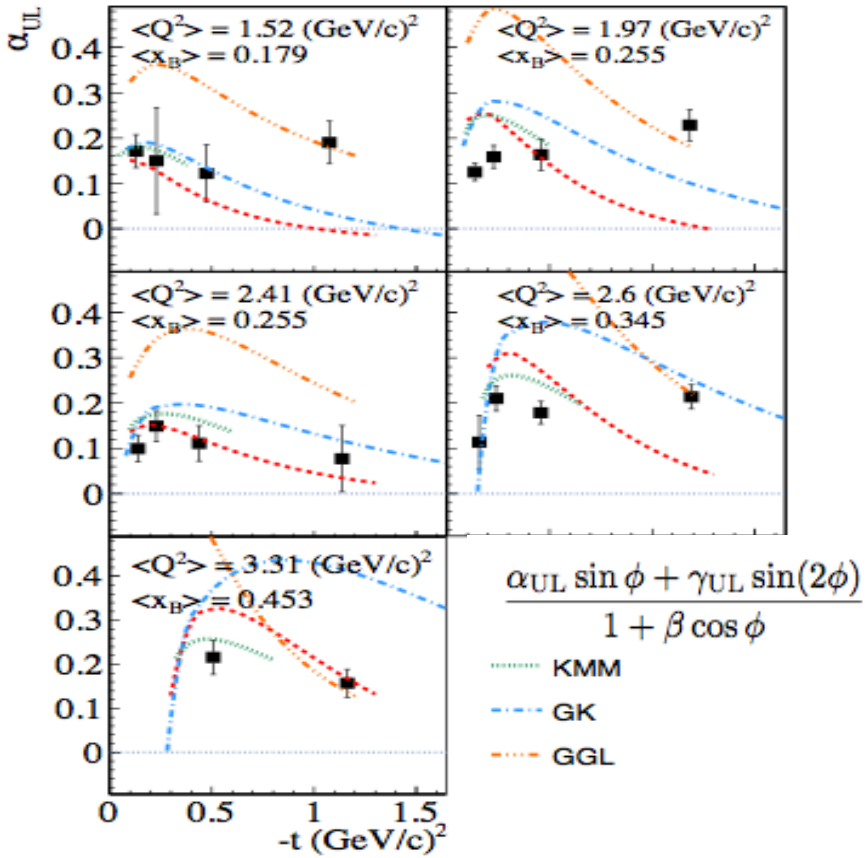
Proton (most critical for eg1dvcs) is in the acceptance allowing high precision measurements with polarized target (large effects expected)

separating the sin2ϕ in DVCS

Unpolarized beam, longitudinal target (TSA) :

$$\Delta\sigma_{UL} \sim \sin\phi\,\mathrm{Im}\{F_1\tilde{\mathcal{H}}+\xi(F_1+F_2)(\mathcal{H}+x_B/2\mathcal{E})-\xi k F_2\,\mathcal{E}+\ldots\}d\phi \;\Rightarrow\; Im\{\mathcal{H}_p, \tilde{\mathcal{H}}_p\}$$





at large t: disagreement with simple sinϕ (sin2ϕ may be important)

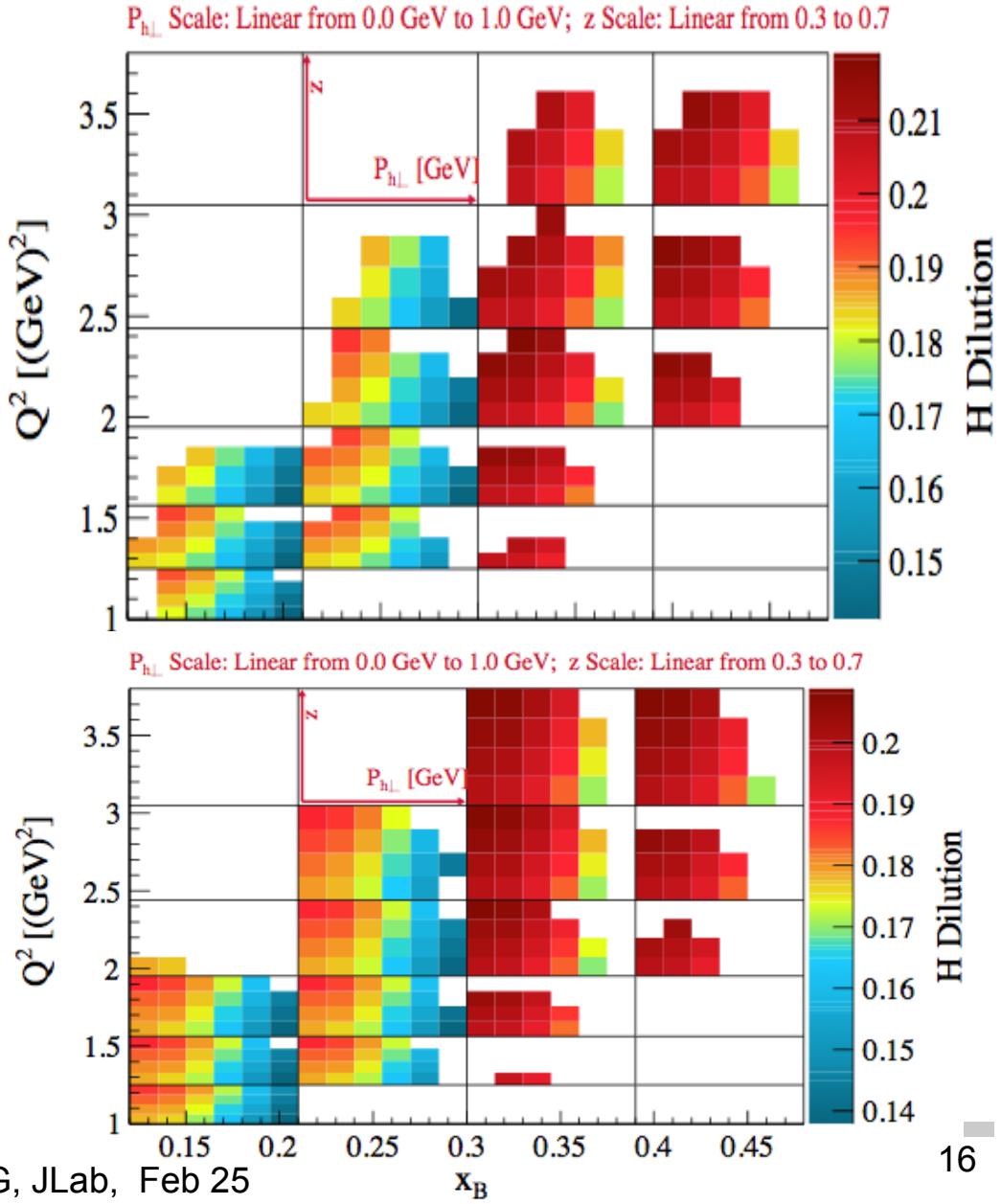
S. Liuti

x-section differences

$$f_{DF} = \frac{B_{NH_3}\sigma_p}{A_{NH_3}\sigma + B_{NH_3}\sigma_p}$$

$$\frac{n_{NH_3}}{n_C} = \frac{A_{NH_3}}{A_C} + \frac{B_{NH_3}}{A_C}\frac{\sigma_p}{\sigma}$$

Understanding the dilution factor is a major effort in precision multidimensional analysis, for multiparticle final states



Azimuthal moments in SIDIS

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

Experiment for a given target polarization measures all moments simultaneously

x-section sums/differences will provide an independent analysis with completely different systematics

SUMMARY

- Several papers published using eg1-dvcs data sets
- Most of the CAAs in progress (Bosted,Sergio)
- Final results available for SIDIS (Suman)
- New channels under study

TODO list

- export the eg1dvcs set to evio format enabling clas12 software tools for further data analysis (Kim)
- finalize the SIDIS paper, add theory curves
- study sin2ϕ in DVCS and SIDIS with different systematics, investigate the x-section differences